2021

JOINT INSTITUTE FOR NUCLEAR RESEARCH

Joint Institute for Nuclear Research

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JINR MEMBER STATES

Republic of Armenia
Republic of Azerbaijan
Republic of Belarus
Republic of Bulgaria
Republic of Cuba
Czech Republic
Georgia
Republic of Kazakhstan
Democratic People's Republic of Korea
Republic of Moldova
Mongolia
Republic of Poland
Romania
Russian Federation
Slovak Republic
Ukraine
Republic of Uzbekistan
Socialist Republic of Vietnam

AGREEMENTS ON GOVERNMENTAL LEVEL ARE SIGNED WITH THE FOLLOWING STATES:

Arab Republic of Egypt
Federal Republic of Germany
Republic of Hungary
Italian Republic
Republic of Serbia
Republic of South Africa

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INTRODUCTION

In the year of the 65th jubilee of JINR, at the March session of the Committee of Plenipotentiaries of the JINR Member States, the CP approved and adopted the JINR Long-Term Development Strategic Plan up to 2030 and Beyond which is aimed at sustainable development of the Institute as a leading international intergovernmental organization and high impact scientific research that is to the benefit of the JINR Member States.

The year 2021 became a historical one: the community of the JINR Member States accepted a new country — the Arab Republic of Egypt. The Institute took an active part in the programme of the Year of Science and Technology in the Russian Federation — the country of its location. The jubilee of the Institute and its bright scientific achievements are a good reason, on behalf of the international community, to express gratitude to all Member States, Associate Members and JINR partners for their omnifaceted support of JINR activities.

Despite strict limitations in connection with the COVID-19 pandemic, the Institute functioned to the full extent and reacted immediately to arising challenges. The last year allowed many our colleagues to establish new partner ties, present brave scientific initiatives, and showed unprecedented importance of science and ever-lasting value of true international scientific dialogue.

The year 2021 was rich in events. Theoreticians of the Institute managed to find the most general formula that allows simplifying multiloop calculations and using renormgroup equations in spontaneous generalization of the Standard Model without labourious and large calculations. As an application, four-loop beta functions were derived from all gauge couplings in the Standard Model and its generalization with several Higgs doublets. The calculations are based on the renormgroup of N. Bogoliubov and D. Shirkov that became classical in theoretical physics.

A key result of 2021 in implementation of the NICA megascience project was the technical launch of the Booster–Nuclotron channel — in September, a beam of Fe ions, extracted from the Booster of the NICA complex and accelerated to the project parameters of the Nuclotron (about 600 MeV/nucleon), was successfully transferred through the channel. On 28 December, the first superconducting magnet was installed in the tunnel of the NICA collider. It is a very important event that demonstrated the start of the collider assembling and preparation of the accelerator complex to be put into operation.

The experiments at the Factory of Superheavy Elements allowed us to double statistics of obtaining isotopes of moscovium and flerovium. Hundreds of events obtained at the Factory allow studies of the properties of superheavy elements and achievement of the synthesis of elements 119 and 120. The scientific infrastructure of the SHE Factory is gradually improving: the U-400 and U-400M accelerators are developed, a new facility DC-140 is established for applied research in track membranes and materials science. Three series of experiments were conducted in 2021 at the new GSN-2 gas-filled separator. Fusion reactions of isotopes ^{243}Am, ^{242}Pu, and ^{238}U with accelerated ^{48}Ca ions at the DC-280 cyclotron were used for determination of parameters of this new separator and opportunities to continue research of superheavy nuclei at the higher level of sensitivity.

At the beginning of March, the official commissioning of the Baikal-GVD detector with eight clusters took place. It became a part of the global net of research infrastructure of neutrino astrophysics. The Baikal neutrino telescope is constructed and accumulates data due to the international collaboration, with the leading role of the Institute for Nuclear Research of RAS, the founder of this experiment and “neutrino astronomy” in the world, and the Joint Institute for Nuclear Research. In total, about 70 scientists and engineers from scientific centres of Russia, Germany, Poland, the Czech Republic, Slovakia, and Kazakhstan take part in it. A wonderful present from the Universe in the late 2021 was without exaggeration a unique event — in December, for the first time two world-largest neutrino telescopes — IceCube in the South Hemisphere and Baikal-GVD in the North —

discovered and registered two neutrino signals from one possible source — a flushed radioblazar.

The number of applications for experiments grew within the framework of the IBR-2 User Programme. Work was continued on the ambitious project to create at JINR a new neutron source in the second half of the 2030s, which should become the record holder in terms of intensity in the world. In 2021, JINR joined the international programme GNeuS (Global Neutron Scientist) aimed at the support and development of research using neutron scattering methods.

High quality of scientific infrastructure of the Institute was marked by the recommendation to include its projects — the NICA complex, the Baikal-GVD neutrino telescope, the SHE factory, and the IBR-2 reactor — into the EUROLABS net and the ESFRI Roadmap 2021.

Much work was done using different nuclear physical methods to solve tasks in ecology, materials science, archeology, study of art, medicine, studies of objects of extraterrestrial origin, etc. JINR specialists used the following methods: X-ray fluorescent spectrometry, infrared spectroscopy, stratigraphy and optical microscopy, chemical microanalysis. JINR scientists managed to achieve breakthrough results in a new direction — in research of biohybrid nanocomplexes aimed at development of pharmaceuticals of a new generation to fight against microorganisms rigid to antibiotics or those that have a high potential against localized cancerous tumours. Using the neutron activation analysis method, successful studies of objects of cultural heritage and archeological finds were conducted.

In the field of information technologies, in 2021 JINR specialists concentrated their efforts on the development of the DIRAC platform which includes grid-technologies, cloud storages, the "Govorun" supercomputer, and robotic systems of data storage. The Institute aims at advanced development of IT-infrastructure of the Multifuctional Information and Computing Complex. Our supercomputer cluster is in the top-500 leading systems in the world that process data faster and more efficiently. A bright initiative of Dubna scientists in this field is an interlaboratory international project of MLIT, FLNR, and BLTP, together with colleagues from Germany, Israel, and the USA to establish a quantum algorithm for calculating the limits of nuclear stability and limits of the Mendeleev Table. It is a very sophisticated algorithm for calculating interactions of several hundred bodies — protons, neutrons, and electrons that are linked by electromagnetic and nuclear interactions.

Radiobiologists of the Institute presented intermediate results in development of composite materials to protect the shell of the spacecraft and spacesuits of spacemen against space radiation. Besides, a unique variant of the radiation field simulator inside the accommodation module of the spacecraft in conditions of deep space was developed. This variant of the simulator shows in the right ratio all components of the radiation field of the spacecraft averaged according to solar activity.

There should be mentioned the growing scientific importance and more active participation of staff members and research groups of JINR in the physical analysis of data from ALICE, CMS, ATLAS, NA61 and NA64 experiments at the LHC at CERN. In 2021, specialists of the Institute made a significant contribution to the programme of the ATLAS detector upgrade, in particular, to the production and assembling of all thirty two Micromegas big quadruplets for small muon rings. Successful participation of JINR physicists in maintenance of the ATLAS detector and development of software was continued.

Based on the full Run-2 140 fb^{-1} statistics in the CMS experiment, JINR scientists established upper limits of the ratio — $(\sigma \cdot B)z'/(\sigma \cdot B)z^0$ — multiplications of the cross section of production and probability of decay in dilepton channel of the new resonance with its own width up to 10% to the channel of Z^0 boson of SM with probability of 95%. Within the framework of upgrading of the CMS detector for HL-LHC, the group from JINR continued to take part in the development of the high-granularity calorimeter (HGCal) and in upgrading of the ME1/1 front muon station.

Success was achieved in implementation of the project of the International Innovation Centre of JINR. In late December, the first stage of the ARIADNA project — an infrastructure for applied studies at NICA that overlaps channels of ion beams transport — started. The equipment of the station SOCHI (Station Of Chip Irradiation) started to be used. It is an important component of the programme of applied research and innovations at NICA meant for irradiation of microschemes with ion beams extracted from HILAC. In December, a carbon beam with energy of 3.2 MeV/nucleon was transported through the channel SOCHI and reached the target. The project to develop a medical superconducting cyclotron MSC-230 was approved that will provide the use of the most modern methods of proton therapy, including the "pencil" beam and flash-therapy.

The number of scientific publications and defended theses at the Institute reached the level of that before the pandemic: 17 candidate theses and 6 doctoral theses were defended.

The University Centre of JINR conducted many practical courses and training sessions. Realization of new ideas and approaches in the development of the educational trend at JINR brings good results. Students from all over the world take part in the online programme INTEREST organized by the UC for students and postgraduates of scientific-technical specialties — INTErnational REmote Student Training at JINR. In 2021, 136 students and postgraduates from 25 countries participated in three stages of the online programme INTEREST. Fruitful and promising cooperation was started with educational centre "Sirius" (Sochi).

In September, on the initiative of JINR, the Physics and Mathematics Lyceum named after Academician V. G. Kadyshevsky was opened in Dubna. The best teachers not only from Dubna, but also from other cities of the Russian Federation became part of the pedagogical community of this lyceum. Among its students are children from the JINR Member States. A comfortable educational atmosphere will undoubtedly contribute to harmonious development of young members of our society and the discovery of their talents.

Another ambitious initiative was the decision of organizing in Dubna, with the support of JINR, a branch of the Lomonosov Moscow State University on the basis of the already existing branch of SINP MSU.

At the November session of the Committee of Plenipotentiaries of the JINR Member States in Bulgaria, the resolutions on the JINR flag and associate membership to the Institute — the documents worked out by the CP Working Group on Strategic Issues — were adopted as a new efficient instrument to implement the Strategy of the Institute regarding the development of international cooperation.

One of the key results of the November CP session in Bulgaria was the signing of the Sofia declaration greeted by the President of the Republic of Bulgaria, representatives of the diplomatic core of the Member States and Associate Members of JINR, the CP members, high guests of the event. The document appeals to the interested states and organizations to join the multifaceted scientific cooperation realized at JINR.

The cooperation with the Republic of Serbia became more active and close. In this connection, together with the representatives of the government and the specialized ministry of this country, the plan of actions to change the status of Serbia at the Joint Institute from the associate to the full membership was worked out. The interaction with universities is expanded, a net of JINR Information Centres is developing in the JINR Member States which not only work independently, but also start cooperating and exchanging experience with each other.

The JEMS training courses for administrative scientific personnel of research and educational organizations of the Member States, Associate Members and partners of JINR are another important part of JINR international activities bringing good practical results. In total, in 2021 the JINR partner network for the first time exceeded one thousand of scientific and scientific-educational organizations.

The Joint Institute for Nuclear Research is one of the organizers of the International Year of Basic Sciences for Sustainable Development (IYBSSD 2022) proclaimed on 2 December at the UN General Assembly, and is a member of its steering committee.

At the beginning of 2021, a reorganization of the JINR management structure was started where departments and services were formed. The Innovations and Intellectual Property Department in the service of the Chief Engineer was organized. The digitalization of JINR is actively developing.

Among the priority directions of our Institute's development is the creation of a comfortable and attractive social environment in Dubna. In 2021, a full-scale renovation and modernization of the room stock and dormitory of building 3 of the Dubna Hotel was completed, the ceremonial commissioning of which was timed to coincide with the 65th anniversary of the Institute and took place in the presence of the Plenipotentiaries of the Republic of Poland, the Slovak Republic, and the Czech Republic to RF. The Joliot-Curie Garden Square was overhauled. The decisions on its major overhaul were based on the concern about preserving the current historical appearance of the centre of the JINR part of Dubna.

On 23 July, within the framework of the events dedicated to the 65th anniversary of JINR and Dubna, the solemn opening of the panel "Mendeleev's Periodic Table", which reflects the outstanding contribution of Dubna scientists to the discovery of new chemical elements, took place. It is 284 square metres large making it the biggest in Europe.

On 15 November, the presentation of the UNESCO–Russia Mendeleev International Prize in the Basic Sciences to Academician Yu. Oganessian, the Scientific Leader of the Flerov Laboratory of Nuclear Reactions of JINR, and to Professor V. Balzani (the University of Bologna, Italy) took place at the UNESCO Headquarters in Paris. The award was presented in recognition of breakthrough discoveries that had expanded the boundaries of the Periodic Table, as well as of a significant contribution to promoting the development of fundamental sciences on a global scale.

Much attention was paid to saving the health of employees. Last year, we achieved negative dynamics for COVID-19. At the Institute, the number of people protected from this virus amounted to 4 300 people that is 80% of employees. Together with the FMBA of Russia, a Roadmap for the modernization of the Medical Unit No. 9 was signed, and the implementation of ambitious plans for the radical transformation of the medical unit into an advanced medical institution was launched.

In October, a preparation for a new Seven-Year Plan for the Development of JINR for 2024–2030 began. Without changing the scientific directions of its activities, the Institute takes the focus on the search for new tasks in the field of elementary particle physics, nuclear and condensed matter physics, relying on international global initiatives in solving the problems of sustainable human development. Now it undoubtedly applies to research in the field of climate change and ecology, new energy, big data, biomedicine, and everything related to life sciences. We are aimed at forming a modern, international, ambitious scientific programme.

Our main value is the human capital, the intelligence of scientists, engineers and specialists of our multinational team: from young to mature leaders and honored veterans of the Institute. Our immutable mission implies attracting talented and professional personnel to the Institute, flexible personnel policy, expanding the geography of the JINR Member States and partner countries. There is no doubt that the close-knit international team of the Institute is ready to face any challenges.

Academician G. TRUBNIKOV
Director
Joint Institute for Nuclear Research

2021

GOVERNING AND ADVISORY BODIES OF JINR

ACTIVITIES OF JINR GOVERNING AND ADVISORY BODIES

SESSIONS OF THE JINR COMMITTEE OF PLENIPOTENTIARIES

A regular session of the Committee of Plenipotentiaries of the Governments of the JINR Member States was held on 25 March by videoconference under the chairmanship of the representative of Romania F.-D. Buzatu.

Having heard and discussed the report presented by JINR Director G. Trubnikov, the Committee of Plenipotentiaries took note of the information presented by the JINR Directorate on the recommendations of the 129th session of the JINR Scientific Council, the proposal for updates to the Seven-Year Plan for the Development of JINR for 2017–2023, the JINR management activities for realizing the long-term strategy of the Institute, the Member States' contribution to the total performance of the large-scale projects of the Institute, the recent research-and-engineering achievements, and the most important events of JINR.

The CP approved the JINR Long-Term Development Strategic Plan up to 2030 and Beyond endorsed by the Scientific Council and commissioned the JINR Directorate to pursue the work on the Seven-Year Plan for the Development of JINR for 2024–2030. The CP supported the JINR Directorate's initiative to form a Strategic Development Committee (SDC) reporting to the CP Chair and recommended that the Plenipotentiaries of the JINR Member States submit their appointees prior to 1 May 2021.

The CP endorsed the JINR Directorate's activities for implementing the JINR Long-Term Development Strategic Plan inasmuch as improving the JINR management's performance, organization restructuring of the JINR central management and developing a complex monitoring system of KPIs for the long-term strategy.

The CP approved the presented amendments to the Seven-Year Plan for the Development of JINR for 2017–2023 based on the long-term strategy of JINR, the recommendations made by the JINR Finance Committee, and the general directions for the updates endorsed at the previous CP session in November 2020.

The CP took note of the substantial research-and-engineering, intellectual and human resources contributed by the JINR Member States to the realization of the large-scale projects of the Institute, in particular, the extensive involvement of researchers and specialists in the MPD, BM@N and SPD collaborations around the NICA project, the signing of the Memorandum of Understanding on the Baikal-GVD project, and research in neutrino astrophysics of high energies, neutrino astronomy and neutrino physics in cooperation with a number of partner institutions and organizations from the JINR Member States, the Member States' contribution to the creation and commissioning of the SHE Factory, the establishment of the IBR-2 International User Committee with substantial representation of the JINR Member States, as well as an increase in the number of the "Govorun" supercomputer users from the Member States and the start of the activities for connecting new cloud components of the JINR Member States to Distributed Information and Computing Environment based on the resources of JINR and its Member States.

The CP congratulated the JINR Directorate on having one of the basic blocks of the NICA complex — the superconducting booster synchrotron (the Booster) commissioned on 20 November 2020 in the presence of Prime-Minister of the Russian Federation M. Mishustin as a special guest and took note with satisfaction that generating of a sustainable circulation of the beam of monovalent helium ions injected in the Booster was achieved in strict compliance with its scheduled date on 19 December 2020.

The CP highly appreciated the Directorate's and Baikal-GVD team's activities for having launched the largest deep-water neutrino telescope in the Northern Hemisphere, the commissioning ceremony of which took place on 13 March 2021 with the participation of the Plenipotentiary of the Govern-

ment of the Russian Federation, Minister of Science and Higher Education of the Russian Federation, V. Falkov, — which became a highlight of the Year of Science and Technology in Russia.

The CP took note with satisfaction that the first experiments in synthesizing moscovium isotopes in the $^{48}Ca + {}^{243}Am$ reaction carried out at the SHE Factory in November 2020 and January 2021 resulted in fifty-five decay events observed for moscovium-288 in the $^{48}Ca + {}^{243}Am$ reaction and six events observed for moscovium-289 (that is almost twice as many as the number of such isotopes previously synthesized at the U-400 accelerator in the period of 2003–2012), as well as tentative detection of α decay of dubnium-268 that first-ever evidenced a new lawrencium-264 isotope discovery.

The CP greeted the opening of the JINR Information Centre at the Academy of Scientific Research and Technology (ASRT) of the Arab Republic of Egypt held on 23 December 2020 attended by representatives of the Government of the Arab Republic of Egypt, the JINR management, ASRT and the North Ossetian State University, as well as by some honourable guests from the Member States and partners of JINR.

The CP endorsed the JINR Directorate's activities for executing the agendas for the 65th anniversary of JINR and the Year of Bulgaria at JINR, as well as for setting out the scope of JINR's participation in the agenda for the Year of Science and Technology in Russia. Along with the launch of the Baikal-GVD deep-water neutrino telescope, the first full-cycle acceleration run with extracted beam at the NICA complex scheduled for December 2021 was added high on the agenda for the Year of Science and Technology in Russia for 2021.

The CP welcomed the information on having held the first meeting of the Joint Coordination Committee for Vietnam–JINR Cooperation as a vehicle for Vietnam's growing participation in JINR. In this regard, the CP noted the JINR Directorate's support for the implementation of the resolution made at the CP session of November 2019 to develop a plan of cooperation between the Vietnam Academy of Science and Technology, VINATOM and JINR for the execution of the project of a new research reactor in Vietnam.

The CP endorsed the JINR Directorate's activities for developing a design concept for the Innovation Centre for Nuclear Physics Research, its international research programme and project management plan.

Having heard and discussed the report "Execution of the JINR budget for 2020 and draft of the revised budget of JINR for 2021" presented by Head of Digital Services Development Department M. Vasilyev, the Committee of Plenipotentiaries approved the consolidated final adjustment of the income and expenditure of the JINR budget for the year 2020, the revised JINR budget of US$ 265 825.2 thousand.

In order to minimize the volatility of the lower limits for contributions of the JINR Member States, the CP updated the method of calculating the lower limits with the amendment that the amount of the direct costs for personnel assigned by the Plenipotentiary to JINR is calculated as the arithmetic average of the direct personnel costs accrued in the three years preceding the year in which the contributions of the Member States are calculated.

The CP adjusted the amounts of the contributions of the JINR Member States for the year 2021, as well as the provisional contributions of the Member States for 2022–2024, taking into account the updated lower limits for contributions and the contributions in arrears to be paid by the Member States to the JINR budget for the year 2021.

Having heard and discussed the report "Results of the meeting of the JINR Finance Committee held on 22 March 2021" presented by Plenipotentiary of the Government of Georgia A. Khvedelidze, the Committee of Plenipotentiaries approved the minutes of the Finance Committee meeting held on 22 March 2021.

With reference to the fact that the coronavirus pandemic of 2020 resulted in an international cooperation surplus on the budget, the CP commissioned the JINR Directorate to consider an issue of equivalent increase of this expenditure item when budgeting for the years 2022 and 2023.

The CP took note of the information about the selection of a company to contract for special purpose reporting on the audit of the JINR financial results of 2020 presented by the JINR Directorate, and about the selection of FinExpertiza as the auditor of JINR for the year 2020 and authorized the company to audit the JINR financial results of the said period.

Having heard and discussed the proposal for "Endorsement of appointments of Vice-Directors, Chief Scientific Secretary and Chief Engineer of JINR" submitted by JINR Director G. Trubnikov, the Committee of Plenipotentiaries, following the voting results, approved in office: Vice-Directors of JINR — S. Dmitriev, V. Kekelidze, L. Kostov; Chief Scientific Secretary of JINR — S. Nedelko; Chief Engineer of JINR — B. Gikal, — whose term of office will expire together with the elected Director in office, i.e., on 1 January 2026.

The CP expressed gratitude to R. Lednický, B. Sharkov, A. Sorin for their continuous performance as Directorate members, their huge contribution to the Institute's achievements and the development of international research cooperation.

Having heard and discussed the proposal for "Naming the Laboratory of Information Technologies after M. Meshcheryakov" presented by JINR Director G. Trubnikov and Director of the Laboratory of Information Technologies V. Korenkov, the Committee of Plenipotentiaries named the Laboratory of Information Technologies after M. Meshcheryakov for his outstanding contribution to the creation, evolvement and development of the network infrastructure

and IT complex of the Laboratory, the Institute and its Member States.

Having heard and discussed the information presented by Plenipotentiary of the Government of the Republic of Bulgaria to JINR T. Bachiyski on the agenda for the Year of Bulgaria at JINR and arrangements for the CP session to be held in Bulgaria and scheduled for November 2021, the Committee of Plenipotentiaries took note of and approved the agenda for the Year of Bulgaria at JINR as reported including the arrangements for the CP session to be held in Bulgaria and scheduled for November 2021, and commissioned the JINR Directorate to massively contribute to the execution of the agenda with due regard for the epidemiological situation.

A regular session of the Committee of Plenipotentiaries of the Governments of the JINR Member States was held on 22–23 November in Bansko and Sofia (Bulgaria) under the chairmanship of the Plenipotentiary of Romania, F.-D. Buzatu.

Having heard and discussed the report made by the JINR Director, G. Trubnikov, the Committee of Plenipotentiaries took note of the information provided by the JINR Directorate on the Recommendations of the 130th session of the JINR Scientific Council, on the implementation of the current Seven-Year Plan for the Development of JINR, on the contribution of the Member States to the implementation of large-scale projects of the Institute, on the new R&D deliverables and the most important events related to research, scientific, academic and international cooperation activities of JINR. The CP noted with appreciation the management actions and high pace of work taken by the Institute to achieve the objectives of the JINR Long-Term Development Strategic Plan up to 2030 and Beyond.

The CP took note of the information on the election of S. Kilin as Co-Chair of the Scientific Council and the change in the JINR Scientific Council: F. Šimkovic as the Plenipotentiary of the Government of the Slovak Republic appointed B. Tomášik (Matej Bel University, Banská Bystrica) to the JINR Scientific Council replacing M. Hnatič starting November 1st, 2021.

The CP positively noted the successful work on the implementation of the NICA project: first of all, its next scheduled stage — the acceleration of the ion beam in the Booster as high as the projected capacity, the launch of the beam transportation channel from the Booster to the Nuclotron, and the successful extraction of a Fe^{14+} ion beam from the Booster to the Nuclotron via this channel, as well as the completion of the extensive work of commissioning the electric-power substations, preparing the cryogenic hub, installing equipment in the new compressor building and commissioning new main buildings. Taking into account the recommendations of the international Machine Advisory Committee of the NICA Complex project (MAC), the decision of the international Cost and Schedule Review Committee of the NICA Complex project (CSRC), as well as the decision of the Supervisory Board for the NICA Complex project on the need to extend the deadline for completing the project, the CP agreed to reset the deadline for constructing the main facilities of the NICA Complex (its basic configuration) in order to start the research programme by the end of 2023.

The CP noted the significant progress in the creation of the Baikal neutrino telescope for observing natural neutrino fluxes: the installation and commissioning of one more cluster of optical modules in the period from February to April 2021, which increased the effective volume of the deep-water detector up to 0.4 km^3, — and also encouraged intensifying the work of analysing the data collected in 2018–2020.

The CP noted a significant contribution to the research, technical, managerial and intellectual capital made by the JINR Member States to develop the MPD, SPD and BM@N collaborations at the NICA Complex and to widen the international cooperation within the Baikal-GVD collaboration.

The CP noted the significant advance of the SHE Factory experiments, including the experiments at DGFRS-II (Dubna Gas-Filled Recoil Separator-II), in which the target showed resistance to irradiation with high-intensity beams of up to 3 μA and more than 100 events of ^{286}Fl and ^{287}Fl isotope production were detected tripling the number of such events previously observed worldwide.

The CP took into account the information on the status of work for creating the new neutron source NEPTUNE — the intense high-flux reactor (IBR-3) with neptunium nitride fuel: there were received design specifications for the reactor, the R&D for neptunium nitride fuel is underway. The CP decided in favour of getting to the next stage of work for developing reference design, conceptual design, feasibility assessment of the facility and scheduling resolution on its construction for the year 2023.

The CP noted with satisfaction the active work of the Meshcheryakov Laboratory of Information Technologies for developing research in the field of quantum computing algorithms in the software environment containing a set of quantum simulators using the “Govorun” supercomputer.

The CP upheld the intensive development of fundamental and applied research in life sciences and condensed matter physics by evolving the Interlaboratory Research Programme on the basis of the Laboratory of Radiation Biology and the International Innovation Centre for Nuclear Physics Research that is in the process of being established by JINR.

The CP upheld the initiative of the JINR Directorate to assess the performance of the JINR Long-Term Development Strategic Plan up to 2030 and Beyond in order to define it and, if necessary, to adjust the long-term planning priorities for the development of the JINR large-scale research infrastructure and research avenues required for drafting the next Seven-Year Plan for the Development of

GOVERNING AND ADVISORY BODIES OF THE JOINT INSTITUTE FOR NUCLEAR RESEARCH

COMMITTEE OF PLENIPOTENTIARIES OF THE GOVERNMENTS OF THE JINR MEMBER STATES

Republic of Armenia	– S. Hayotsyan
Republic of Azerbaijan	– A. M. oglu Gashimov
Republic of Belarus	– A. Shumilin
Republic of Bulgaria	– T. Bachiyski
Republic of Cuba	– A. Diaz García
Czech Republic	– M. Vyšinka
Georgia	– A. Khvedelidze
Republic of Kazakhstan	– B. Karakozov
Democratic People's Republic of Korea	– Li Je Sen
Republic of Moldova	– V. Ursachi
Mongolia	– S. Davaa
Republic of Poland	– M. Waligórski
Romania	– F.-D. Buzatu
Russian Federation	– V. Falkov
Slovak Republic	– F. Šimkovic
Ukraine	– B. Grynyov
Republic of Uzbekistan	– B. Yuldashev
Socialist Republic of Vietnam	– Le Hong Khiem

Finance Committee

One representative of each JINR Member State

SCIENTIFIC COUNCIL

Chairman: G. V. Trubnikov
Co-Chairman: S. Kilin (Belarus)
Scientific Secretary: S. Nedelko

A. Aprahamian	– United States of America
F. Azaiez	– Republic of South Africa
Ts. Baatar	– Mongolia
U. Bassler	– Switzerland
C. Borcea	– Romania
M. Budzyński	– Republic of Poland
Bum-Hoon Lee	– Republic of Korea
L. Cifarelli	– Italian Republic
A. Dubničková	– Slovak Republic
A.-I. Etienvre	– French Republic
P. Fré	– Italian Republic
S. Galès	– French Republic
P. Giubellino	– Federal Republic of Germany
B. Grynyov	– Ukraine
M. Jeżabek	– Republic of Poland
Jiangang Li	– People's Republic of China
G. Khuukhenkhuu	– Mongolia
S. Kilin	– Republic of Belarus
M. Kovalchuk	– Russian Federation
G. Lavrelashvili	– Georgia
P. Logatchov	– Russian Federation
S. Maksimenko	– Republic of Belarus
S. Maskevich	– Republic of Belarus
V. Matveev	– Russian Federation
J. Mnich	– Switzerland
Sh. Nagiyev	– Republic of Azerbaijan
D. L. Nagy	– Republic of Hungary
A. Nersessian	– Republic of Armenia
N. Nešković	– Republic of Serbia
I. Padrón Díaz	– Republic of Cuba
S. Pospišil	– Czech Republic
I. Povar	– Republic of Moldova
E. Rabinovici	– State of Israel
V. Rubakov	– Russian Federation
K. Rusek	– Republic of Poland
V. Sadovnichy	– Russian Federation
A. Sergeev	– Russian Federation
M. Spiro	– French Republic
H. Stöcker	– Federal Republic of Germany
Ch. Stoyanov	– Republic of Bulgaria
Gh. Stratan	– Romania
B. Tomášik	– Slovak Republic
Trần Đức Thiệp	– Socialist Republic of Vietnam
G. Trubnikov	– Russian Federation
R. Tsenov	– Republic of Bulgaria
M. Waligórski	– Republic of Poland
I. Wilhelm	– Czech Republic
B. Yuldashev	– Republic of Uzbekistan
M. Zdorovets	– Republic of Kazakhstan
G. Zinovjev	– Ukraine

Programme Advisory Committee for Particle Physics

Chairperson: I. Tserruya (Israel)
Scientific Secretary: A. Cheplakov

Programme Advisory Committee for Nuclear Physics

Chairperson: M. Lewitowicz (France)
Scientific Secretary: N. Skobelev

Programme Advisory Committee for Condensed Matter Physics

Chairperson: D. L. Nagy (Hungary)
Scientific Secretary: O. Belov

INTERNAL ORGANIZATION OF THE JOINT INSTITUTE FOR NUCLEAR RESEARCH

DIRECTORATE

Director G. Trubnikov
Vice-Director S. Dmitriev
Vice-Director V. Kekelidze
Vice-Director L. Kostov
Chief Scientific Secretary S. Nedelko
Chief Engineer B. Gikal

Bogoliubov Laboratory of Theoretical Physics

Director D. Kazakov

Research in
– symmetry properties of elementary particles
– field theory structures
– interactions of elementary particles
– theory of atomic nuclei
– theory of condensed matter

Frank Laboratory of Neutron Physics

Director V. Shvetsov

Research in
– nuclei by neutron spectroscopy methods
– fundamental properties of neutrons
– atomic structure and dynamics of solids and liquids
– high-temperature superconductivity
– reactions on light nuclei
– materials by neutron scattering, neutron activation analysis and neutron radiography methods
– dynamic characteristics of the pulsed reactor IBR-2

Veksler and Baldin Laboratory of High Energy Physics

Director R. Lednický

Research in
– structure of nucleons
– strong interactions of particles
– resonance phenomena in particle interactions
– electromagnetic interactions
– relativistic nuclear physics
– particle acceleration techniques
– interactions of multicharged ions in a wide energy range

Meshcheryakov Laboratory of Information Technologies

Director V. Korenkov

Research in
– provision of operation and development of the JINR computing and networking infrastructure
– optimal usage of international computer networks and information systems
– modern methods of computer physics, development of standard software

Dzhelepov Laboratory of Nuclear Problems

Director V. Bednyakov

Research in
– strong, weak and electromagnetic interactions of particles, particle structure
– nuclear structure
– nuclear spectroscopy
– mesoatomic and mesomolecular processes
– particle acceleration techniques
– radiobiology

Laboratory of Radiation Biology

Director A. Bugay

Research in
– radiation genetics and radiobiology
– photo radiobiology
– astrobiology
– radiation protection physics
– mathematical simulation of radiation-induced effects

Flerov Laboratory of Nuclear Reactions

Director S. Sidorchuk

Research in
– properties of heavy elements, fusion and fission of complex nuclei, cluster radioactivity, reactions on an isomer hafnium target
– reactions with beams of radioactive nuclei, structure of neutron-rich light nuclei, nonequilibrium processes
– interactions of heavy ions with condensed matter
– particle acceleration techniques

University Centre

Director S. Pakuliak

Directions of activities:
– education programme for senior students
– preparation of qualification papers by students and postgraduates
– holding international student practice courses and schools
– popularization of achievements in modern science
– advanced training of the Institute personnel

Central Services

– central scientific and information departments
– administrative and economic units
– manufacturing units

JINR for 2024–2030. The international Working Group was supposed to report on the implementation and adjustment of the scientific strategy for the JINR development up to 2030 and beyond at the session of the Committee of Plenipotentiaries scheduled for March 2022.

The CP demanded that the JINR Directorate submit the concept of the Seven-Year Plan for the development of JINR for 2024–2030 at the session of the Committee of Plenipotentiaries scheduled for March 2022. The concept should accommodate the adjustments made to the JINR long-term scientific strategy, optimization of the Topical Plan for JINR Research and International Cooperation, financing and staffing of research projects. It worked out a proposal for calculating the Member States' contributions in dynamics providing implementation of the Seven-Year Plan for the Development of JINR for 2024–2030, taking into account the current world inflation statistics and forecasts.

The CP highly recommended the JINR Directorate and the Working Group on Strategic Issues under the CP Chair analyse the relevance of the regulations applied to the cooperation programmes for research and education and grants of Plenipotentiaries, analyse the practice of spending within the programmes and grants, and, based on the analysis, submit a proposal for better regulation of cooperation programmes and grants. On the basis of the analysis, the CP expects proposals on updating the normative regulation of cooperation programmes and grants, taking into account the updated structure of contributions of the JINR Member States.

The CP congratulated the Scientific Leader of the Flerov Laboratory of Nuclear Reactions, Academician Yu. Oganessian, on being awarded the UNESCO–Russia Mendeleev International Prize in the Basic Sciences, expressing the deepest appreciation for his contribution to world science and the development of JINR.

The CP commended the JINR Directorate's work carried out for the restructurization and optimization of the general administration of JINR, for the execution of miscellaneous managerial re-arrangements to improve the performance of the JINR administration and research management, and for the development of the comprehensive KPI monitoring system for the JINR long-term strategy in accordance with the JINR Long-Term Development Strategic Plan up to 2030 and Beyond. It supported more active engagement of candidates from the Member States in sending Plenipotentiaries and recommended involvement of the Working Group on Strategic Issues under the CP Chair for methodological support.

The CP assented to the JINR Directorate's proposal for JINR's financial participation in the development and support of healthcare, social and educational institutions located within the town of Dubna in order to improve the JINR employees' living conditions and quality of life, and endorsed the actions of the JINR Directorate for enhancing the strategic cooperation with the Federal Medical-Biological Agency (FMBA) of the Russian Federation aimed at improving the quality of healthcare for the JINR employees.

The CP supported the initiative of the JINR Directorate for the social care payments to the former JINR employees.

The CP took note of the information presented by the Directorate on the amended Procurement Policy of JINR and the continuation of the work for improving the procurement activities of the Institute.

The CP supported the organization of the JINR Directorate's comprehensive work for developing a network of JINR information centres, conducting JEMS, and miscellaneous ways of cooperation with research and academic institutions and JINR-relevant government bodies of the JINR Member States, as well as for developing new instruments in the field of scientific interactions and scientific diplomacy.

The CP encouraged the Directorate's activity for expanding the list of the JINR Members and Associate Member States.

The CP endorsed the Recommendations of the 129th and 130th sessions of the JINR Scientific Council, as well as the Topical Plan for JINR Research and International Cooperation for the year 2022.

Having heard and discussed the report "The Arab Republic of Egypt joining JINR as its Member State" made by JINR Director G. Trubnikov, the Committee of Plenipotentiaries of the Governments of the Member States of the Joint Institute for Nuclear Research, in compliance with articles 7 and 17 of the JINR Charter, with reference to the Letter of Application for JINR membership received from the Arab Republic of Egypt to participate in JINR as its full member presuming the applier's consent with the JINR Charter and all that it implies, based on consensus opinion, admitted the Arab Republic of Egypt to the JINR Member States starting from the moment of signing these minutes.

Having heard and discussed the report "JINR budget proposed for 2022; JINR Member States' provisional contributions for 2023, 2024, 2025" made by Head of the Budget and Economic Policy Department N. Kalinin, the Committee of Plenipotentiaries approved the JINR budget for the year 2022 with the total income and expenditure amounting to US$ 274 304.1 thousand.

The CP authorized the Director of the Institute to make adjustments to the JINR budget for the year 2022, including adjustments to the expenditure items "Salaries" and "International Cooperation", within the approved budget in compliance with the Regulations for the Introduction of Adjustments to the Budget of JINR.

The CP agreed on including the contribution of the Democratic People's Republic of Korea, the membership of which was decided to suspend, in the JINR budget for the year 2022 to maintain the established proportion of the contributions of the JINR Member

States and decided to compensate the deficit of the budget in 2022 ocurred as a result of suspension of the DPRK membership to JINR, at the expense of other incomes and receipts to the JINR budget.

The CP determined the provisional amounts of the JINR budget in income and expenditure as US$ 223.0 million for the year 2023, US$ 228.6 million for the year 2024, and US$ 234.6 million for the year 2025, as well as the provisional amounts of contributions of the JINR Member States for the years 2023, 2024, and 2025.

The CP charged the JINR Working Group on Financial Issues and the JINR Directorate to elaborate a proposal for increasing the Member States' contribution amounts starting with the next Seven-Year Plan for the Development of JINR for 2024–2030, taking into account actual and forecast inflations.

The CP approved the allocations of the special-purpose funds in the total amount of 2 571 292.5 thousand roubles received under the Agreement between the Government of the Russian Federation and JINR on the construction and operation of the NICA complex of superconducting rings for heavy-ion colliding beams as budgeted for the year 2022.

The CP granted permission to the JINR Director to introduce the salary indexation within the manoeuvrable part of the JINR budget for the year 2022 and according to the JINR Collective Bargaining Agreement for 2020–2023, and granted permission to the JINR Directorate to annually budget expenses for JINR's participation in developing and supporting healthcare, social and educational institutions located within the town of Dubna in order to improve the JINR employees' living conditions and quality of life.

The CP charged the JINR Directorate with developing prior to the end of February 2022 and submitting for consideration by the Working Group on Financial Issues a detailed procedure for accounting the personal income tax (PIT) for foreign employees — citizens of the JINR Member States.

The CP heard and discussed the report "Amount of the contribution to the JINR budget from the Republic of Azerbaijan" made by the Plenipotentiary of the Government of the Republic of Azerbaijan, A. Gashimov, with request to take measures to pay out the full contribution of the Republic of Azerbaijan to the JINR budget for the year 2021.

Having heard and discussed the report "Readout of the meeting of the JINR Finance Committee held on 19 November 2021" made by Chair of the JINR Finance Committee A. Khvedelidze, the Committee of Plenipotentiaries endorsed the Minutes of the meeting, accepted the application of the Arab Republic of Egypt for a gradual entry into the contribution payments to the JINR budget provided that the Arab Republic of Egypt gets paying its full-amount contribution estimated by the new method for calculating the scale of the Member States' contributions no later than 2028. Therewith, the membership contributions that shall be paid to the JINR budget by the Arab Republic of Egypt through 2028 are not below the total sum of direct costs of the personnel assigned to JINR by the Plenipotentiary, amounts funded for grants of the Plenipotentiary and cooperation programmes, and expense allowance for infrastructure. The CP decided to budget contribution of the Arab Republic of Egypt as additional to the estimated total of the contributions of the JINR Member States and instructed the JINR Directorate to make adjustments to the JINR budget for the year 2022 including the Arab Republic of Egypt's contribution.

The CP charged the JINR Directorate with the work aimed at investigation of the receivables from the countries participating in JINR under their bilateral cooperation agreements on R&D with the Institute.

The CP approved the Audit Report on the JINR financial results of 2020, took into account the information on the JINR Directorate's implementation of the Corrective Action Plan following the results of the audit of JINR's financial activities in 2019, and approved the Accounting Report of the Joint Institute for Nuclear Research of 2020.

The CP took note of the Corrective Action Plan following the results of the audit of the JINR financial activities of 2020 drawn up by the JINR Directorate.

Having heard and discussed the report "Project of the JINR Innovation Centre for Nuclear Physics Research" made by Vice-Director S. Dmitriev, the Committee of Plenipotentiaries approved the JINR Directorate's activities in developing the project of the JINR Innovation Centre for Nuclear Physics Research and continuation of the work for establishing the centre as well as active engagement of project partners from the JINR Member States.

The CP took note of the successful start of the projects of creating the DC-140 cyclotron for developing technologies of radiation materials science, testing electronic components, and manufacturing track membranes, as well as of creating a superconducting proton accelerator (230 MeV) for promoting new methods of hadron-beam therapy and developing radiobiological research.

The CP took a positive note of the international Round Table, the participants of which supported the guidelines for developing the applied innovation research at the NICA Complex; and supported the first-priority steps to establishing a broad international collaboration for the implementation of the research.

The CP took note of the JINR Directorate's decision to buy out the equipment for NanoLab (FLNR, JINR) leased from the Fund for Infrastructure and Educational Programs, to withdraw from the shareholders of JSC "International Innovative Nanotechnological Centre" and from the Investment Agreement of 31 August 2010, made between the Joint Institute for Nuclear Research, the State Russian Corporation of Nanotechnology, JSC Concern "Radiotechnical and Information Systems", JSC "IT. Information Tech-

nologies", JSC "Special Economic Zones", having the JINR Directorate submit to the Member States the materials on purchasing the equipment for NanoLab (FLNR, JINR) and on withdrawing from the Investment Agreement of 31 August 2010.

Having heard and discussed the report "Readout of the meeting of the Working Group on Strategic Issues under the CP Chair held on 22 July 2021" made by the Chair of the Working Group on Strategic Issues under the CP, I. Štekl, the Committee of Plenipotentiaries welcomed the new instrument of intersessional work set up under the Committee of Plenipotentiaries, i.e., the Working Group on Strategic Issues (hereinafter referred to as WGSI), and its entering upon the office, endorsed the JINR Directorate's efforts ensuring effective work of WGSI, in particular, the creation of the WGSI Secretariat (under the JINR Directorate) chaired by Vice-Director L. Kostov, and named this working group as the Working Group on Strategic Issues under the CP.

Having heard and discussed the report "Draft of the Regulations for the JINR Associate Membership" made by the Chair of the Working Group on Strategic Issues under the CP, I. Štekl, the Committee of Plenipotentiaries approved the Regulations for the JINR Associate Membership, taking into account the comments of the Plenipotentiaries made at the session, extended the Regulations for the JINR Associate Membership to cover the agreements on participation in the JINR programmes concluded by JINR with some states unless their terms are contrary to the Regulations, inviting, if necessary, the states that have entered into such agreements to amend those agreements so that to bring their terms in line with the Regulations for the JINR Associate Membership.

The CP welcomed the application of these Regulations as a basis for resuming negotiations on status formalization with a wide range of the JINR partner countries and ordered that the JINR Directorate should annually report to the JINR Member States on the implementation of the Associate Membership agreements with JINR.

Having heard and discussed the report "Draft of the JINR Flag Code" made by the Chair of the Working Group on Strategic Issues under the CP, I. Štekl, the Committee of Plenipotentiaries approved the JINR Flag Code and released flagging in accordance with the JINR Flag Code.

Having heard and discussed the report "Sofia declaration on the value of international integration in science and technology" (further — Declaration) made by JINR Director G. Trubnikov, the Committee of Plenipotentiaries accepted the Sofia declaration taking into account the suggestions in preparation and discussion to bring the Declaration to the notice of the Member States' governments.

Following the Declaration and according to the JINR Long-Term Development Strategic Plan up to 2030 and Beyond, the CP instructed the JINR Directorate to intensify the systematic work to attract new partners to JINR, to explore new frontiers for further enlargement of the community of the Member States, Associate Members and partner-countries, and to develop an appropriate action plan.

Having heard the report "Bulgarian Academy of Sciences — Traditions and horizons" made by the President of the Bulgarian Academy of Sciences, Academician J. Revalski, the Committee of Plenipotentiaries expressed its gratitude to the speaker for his interesting and informative report.

The Committee of Plenipotentiaries took note of the information on the pre-accession actions undertaken by the Republic of Serbia to enter JINR as its full member and welcomed the signing the respective action plan.

The Committee of Plenipotentiaries enclosed gratitude to the host party and the Plenipotentiary of the Government of the Republic of Bulgaria for a high level of organization and holding of the Committee session.

SESSIONS OF THE JINR SCIENTIFIC COUNCIL

The 129th session of the JINR Scientific Council took place by videoconference on 18–19 February. It was chaired by JINR Director G. Trubnikov and Professor C. Borcea of the H. Hulubei National Institute of Physics and Nuclear Engineering (Bucharest, Romania).

G. Trubnikov delivered a comprehensive report covering information about decisions of the latest session of the JINR Committee of Plenipotentiaries held by videoconference (November 2020), results and achievements of JINR as well as recent events in the field of JINR's international cooperation.

The Scientific Council took into account information on the progress of the NICA project presented in the report by V. Kekelidze, and on the first experiments at the SHE Factory presented in the report by Yu. Oganessian. The report on the programme of the Centre for Radiobiological Studies of JINR, presented by A. Bugay, was heard, as well as the report by A. Sorin on the draft amendments to the Seven-Year Plan for the Development of JINR for 2017–2023.

The Scientific Council heard the scientific report "Implementation of the SKIF project at the Budker Institute of Nuclear Physics (Novosibirsk)" made by P. Logatchov and took into account the presentation "The recent SEM and ENAA investigations of carbonaceous meteorites obtained in collaboration with

JINR and PIN (RAS) and their potential relevance to astrobiology and the origin and distribution of biospheres" by R. Hoover (USA).

The recommendations of the Programme Advisory Committees were reported by I. Tserruya (PAC for Particle Physics), M. Lewitowicz (PAC for Nuclear Physics), I. Tserruya and M. Lewitowicz (joint meeting of the PAC for Particle Physics and the PAC for Nuclear Physics to evaluate JINR projects in the field of neutrino physics), D. Nagy (PAC for Condensed Matter Physics).

The Scientific Council approved the Jury's recommendation on the award of the title of "Honorary Doctor of JINR", as well as on the award of the B. Pontecorvo Prize and on the award of the JINR annual prizes for best papers in the fields of scientific research, instruments and methods, and applied research.

JINR Director G. Trubnikov and Director of LIT V. Korenkov came forward with a proposal for naming the Laboratory of Information Technologies after M. Meshcheryakov.

At the session, new elections of the Director of VBLHEP were announced.

General Considerations of the Resolution. The Scientific Council warmly thanked V. Matveev for his outstanding contribution to the development and success of JINR during his mandate at the head of the Institute and congratulated G. Trubnikov on his election as Director of JINR.

The Scientific Council was pleased to hear about the in-person and remote meetings and conferences in the Member States dedicated to the 65th anniversary of JINR. These meetings are useful instruments for raising the worldwide visibility of the Institute. The Scientific Council wished to recognize the initiative welcomed by the Committee of Plenipotentiaries to declare 2021 the Year of Bulgaria at JINR.

The Scientific Council supported JINR's participation in the programme of events for 2021 declared as the Year of Science and Technology in the Russian Federation and recommended that the JINR Directorate take measures to widely advertise key achievements of JINR in the Russian mass media and beyond.

The Scientific Council welcomed the endorsement by the JINR Committee of Plenipotentiaries of the programme of JINR development presented by G. Trubnikov. The Scientific Council also fully endorsed the JINR Long-Term Development Strategic Plan up to 2030 and Beyond.

The Scientific Council recognized the recent scientific results and technology achievements obtained within the development of the large-scale research infrastructures of JINR.

In particular, the Scientific Council strongly appreciated the recent success obtained during the commissioning of the Booster of the NICA complex, illustrated by the first accelerated Booster beam. The Scientific Council also welcomed the progress in constructing the NICA collider systems and MPD, as well as the high-quality results of the scientific collaborations around NICA and the plans in this direction for the year 2021.

The Scientific Council was impressed by the result of the first experiment on synthesizing moscovium isotopes performed at the Factory of Superheavy Elements (SHE) and processing the first data taken with the new DGFRS-2 separator. The potential of discovery opened by the new SHE Factory and its new equipment is clearly on its way. The Scientific Council noted the progress in the development of the DRIBs-III accelerator complex in the field of nuclei far from stability.

The Scientific Council appreciated the installation of two new clusters of the Baikal Neutrino Telescope, whose deep-water detector had reached an effective volume of 0.35 km^3, thus making Baikal-GVD the largest telescope in terms of effective area and volume in the Northern Hemisphere.

The Scientific Council noted the progress of implementation of the User Programme with the IBR-2 spectrometers and supported the activity performed for developing the concept of the new neutron source for FLNP at JINR.

The Scientific Council approved the contribution of the JINR Tier-1 centre to the CMS experimental data processing in 2020, noting that, in terms of performance, the JINR Tier-1 is ranked the second among the world Tier-1 centres for the CMS experiment. The Scientific Council also welcomed the publication of the scientific results achieved using the "Govorun" supercomputer resources.

The Scientific Council noted the extension of the applied research scope of JINR, in particular, in order to contribute to the COVID-19-related research made in cooperation with partner institutions. The Scientific Council also welcomed the Committee of Plenipotentiaries' approval of the initiative to establish an Interlaboratory Innovation Centre of JINR whose development programme should be further defined.

The Scientific Council highly appreciated the reported new steps in strengthening the cooperation with non-Member States in proliferation of shared interests in research and technology, as well as in training and information exchange activities.

Progress of the NICA Project. The Scientific Council heard the progress report concerning the NICA project presented by the Acting Vice-Director and VBLHEP Director, V. Kekelidze, and recognized the recent impressive achievements in its implementation, in particular, first of all, the successful launch of the superconducting booster synchrotron, which confirmed the high quality of all preparatory work.

The Scientific Council commended the efficiency of the regular meetings of the Cost and Schedule Review Committee of the NICA project. The infrastructure development and production of collider elements are progressing at a good pace. The development of

research collaborations on the two main experimental facilities (MPD and BM@N) continues. The third collaboration is being formed to prepare the SPD experiment.

The resources requested for the NICA project within the updates of the Seven-Year Plan for the Development of JINR for 2017–2023 are in line with the construction of the basic configuration of the Complex and the implementation of the planned scientific programme. The Scientific Council agreed that, if the proposed funding profile is met, the launch of the basic configuration of the Complex in 2022–2023 is realistic. At the same time, the Scientific Council admitted possible shifts in the plans during 2021–2023 due to the pandemic, which has been going on for about a year.

First Experiments at the SHE Factory. The Scientific Council listened with great interest to the report of the FLNR Scientific Leader Academician Yu. Oganessian. The Scientific Council noted with satisfaction the successful implementation of the first experiments on the synthesis of element 115 (moscovium) in the $^{48}Ca + {}^{243}Am$ reaction. The Scientific Council congratulated the Laboratory team on the successful start of the work and recommended a high priority for the programme of experimental research at the SHE Factory over the short- and mid-term horizons.

Programme of the JINR Centre of Radiobiology Research. The Scientific Council heard the report concerning the research programme in radiation biology presented by LRB Director A. Bugay. The Scientific Council highly appreciated the scientific goals and strategy of the innovative research in radiation neuroscience and clinical radiobiology. The Scientific Council welcomed the extension of scientific cooperation between the JINR Member States in socially relevant applied research directions. The Scientific Council recommended preparing a more precise project proposal with specific milestones to consider it at the next meetings of the JINR PAC.

Proposals for Updates to the Seven-Year Plan for the Development of JINR for 2017–2023. The Scientific Council took into account the report "Proposal for updates to the Seven-Year Plan for the Development of JINR for 2017–2023" presented by Chief Scientific Secretary A. Sorin. The Scientific Council highly appreciated the complex efforts taken by the JINR Directorate to define key performance indicators and analyze the execution of the current Seven-Year Plan.

The Scientific Council supported in general the directions proposed for updating the Seven-Year Plan for the Development of JINR concerning, in particular, the implementation of the NICA megascience project, the development of DRIBs-III accelerator complex, the elaboration of a new neutron source of JINR, JINR's participation in the construction of the SOLCRYS Laboratory at the SOLARIS National Synchrotron Radiation Centre of the Jagiellonian University (Poland), the construction of the Baikal-GVD neutrino telescope, the performance of the advanced experiments with reactor neutrinos within the DANSS and GEMMA/νGeN projects, the development of the JINR Multifunctional Information and Computing Complex including the "Govorun" supercomputer.

The Scientific Council supported the initiative of the JINR Directorate to establish an interlaboratory international Innovation Centre for Nuclear Physics Research (Innovation Centre), its main task being the development of technologies and methods in the field of nuclear and radiation medicine, radiation materials science, and IT, as well as the advanced training of professionals from the JINR Member States. The Scientific Council took note of the plans for developing a new DC-140 cyclotron for these purposes in 2021–2023.

Recommendations in Connection with the PACs. The Scientific Council took note of the recommendations made by the PACs at their meetings in January 2021, as reported at this session by I. Tserruya, Chair of the PAC for Particle Physics, M. Lewitowicz, Chair of the PAC for Nuclear Physics, and D. L. Nagy, Chair of the PAC for Condensed Matter Physics, and requested the JINR Directorate to consider these recommendations while preparing the JINR Topical Plan of Research and International Cooperation for the year 2022.

The Scientific Council acknowledged the measures being taken by the JINR Directorate to consolidate the JINR scientific programme on the main tasks of the current Seven-Year Plan. In particular, the Scientific Council welcomed the mandate given by the JINR Directorate to all three PACs to propose an approach for prioritization of JINR projects, — which would allow concentrating financial, human and intellectual resources on major scientific ventures of high impact potential.

The Scientific Council highly valued rather nontrivial and delicate work of the PACs on prioritization of the projects within the JINR Topical Plan, as exemplified by the prioritization presented in the field of neutrino physics by the joint work of the PACs for Particle Physics and for Nuclear Physics. This process is extremely important for the implementation of the JINR Long-Term Development Strategic Plan up to 2030 and Beyond.

The Scientific Council welcomed the intention of the JINR Directorate to follow the priority recommendations of the PACs based on JINR impact while maintaining existing international obligations. The Scientific Council advised the JINR Directorate to act together with the leadership of the JINR Laboratories towards applying the PACs' recommendations where possible for consolidation of the available intellectual and material resources.

Particle Physics. Concerning the NICA project, the Scientific Council seconded the PAC for Particle Physics in congratulating the Booster team on the smooth and successful first beam circulation in the Booster, confirming the high quality of all the preoperational works. Despite problems caused by the pandemic, all areas of the VBLHEP infrastructure development were advancing at the necessary pace. The Scientific Council was pleased to note the progress achieved in constructing and commissioning the new compressor station of the cryogenic complex, in developing the beam transport channels with corresponding magnetic optics, in the serial production of the collider cryomagnetic system, and other NICA elements. The Scientific Council supported the PAC's recommendation to extend the Nuclotron–NICA project until the end of 2023.

The Scientific Council congratulated the MPD team on reaching the important milestones: the completion of the magnet yoke assembly, the delivery of the solenoidal magnet and the start of the installation of MPD elements at their places inside the MPD hall aiming at their commissioning in 2021–2022.

The Scientific Council appreciated the progress towards the realization of the BM@N project, including preparation of detectors, simulations and development of data analysis methods for the forthcoming runs of the BM@N detector with ion beams in 2021. The Scientific Council congratulated the Collaboration on the first publication of short-range correlation results in journal "Nature Physics".

The Scientific Council recognized the long-lasting collaboration between JINR and GSI as well as the large synergies between the NICA and FAIR research programmes. The experience obtained by the JINR physicists in the CBM experiment at FAIR is valuable for the MPD, SPD and BM@N experiments at NICA. The Council endorsed the PAC's recommendation on the continuation of JINR's participation in the CBM project until the end of 2025.

The Scientific Council noted the large similarity between the muon systems of PANDA and of the JINR flagship SPD experiment and appreciated the strong cooperation between the FAIR and NICA research programmes. The Scientific Council endorsed the PAC's recommendation on the participation of JINR in the PANDA project until the end of 2024. It also shared the PAC's concern about the high average age of the JINR team and the large fraction of participants with very low FTE contribution (0.3 or less). The Scientific Council concurred with the PAC's advice to adapt the team's commitments to the available resources. The Scientific Council joined the PAC in thanking the SPD team for the preparation of a comprehensive Conceptual Design Report (CDR) of a universal 4π detector for registration and identification of secondary particles at high luminosity.

The Scientific Council supported the PAC's suggestion to the NICA management to appoint an appropriate Detector Advisory Committee for a thorough review of the CDR and its subsequent evolution into a Technical Design Report (TDR). It also encouraged the SPD team to pursue every effort to form an international collaboration, find adequate resources and attract students and young scientists.

Nuclear Physics. The Scientific Council congratulated the FLNR team on the successful start of the Superheavy Element (SHE) Factory experimental programme. The first experiment was aimed at the synthesis of isotopes of element 115 (moscovium) in the $^{48}Ca + {}^{243}Am$ reaction, which became possible thanks to the new selection and rejection capabilities of the new DGFRS-2 separator put into operation at the end of 2020. During the five-week experiment more than fifty decay events of ^{288}Mc and ^{289}Mc isotopes were obtained, which nearly doubled the statistics on these isotopes collected in previous experiments using the U-400 accelerator complex during the period from 2003 to 2012. The high background suppression was achieved in the focal plane of the DGFRS-2 separator, which is of great importance for registering decay events of long lifetimes.

The next round of experiments at the SHE Factory will take advantage of the increased intensity of ^{48}Ca beams on targets (up to 3.0–5.0 pμA), the construction of a new differential pumping system and the implementation of larger targets. The programme includes experiments for the synthesis of flerovium isotopes (Fl) via the $^{242}Pu + {}^{48}Ca$ reaction and the development of a high intensity ^{50}Ti beam to prepare experiments for the synthesis of elements 119 and 120. The Scientific Council supported the ongoing scientific programme at the SHE Factory and the proposed experiments for the synthesis of superheavy elements.

The Scientific Council recognized the scientific interest of the research performed at ACCULINNA-2 fragment separator related to the study of properties of light exotic nuclei at the drip line. The first experiments at the ACCULINNA-2 fragment separator were carried out using the $^{2}H(^{8}He, ^{3}He)^{7}H$ reaction to reach nuclear structure information on the extremely neutron-rich ^{7}H nucleus in which ground and excited states were clearly observed. In other reactions, excited states in exotic nuclei ^{7}He, ^{9}He, and ^{10}Li were investigated.

The Scientific Council supported the PAC's recommendation on opening in 2022 a project for modernization of the EG-5 accelerator under the theme "Investigations of neutron–nuclei interactions and properties of the neutron" for one year. Funding of the project for the year 2022 was agreed to be provided within the budget allocated to FLNP according to the update of the Seven-Year Plan for the Development of JINR for 2017–2023 approved by the Committee of Plenipotentiaries on 23 November 2020.

The theme "Non-accelerator neutrino physics and astrophysics" is devoted to studying rare phenomena associated with weak interactions by the meth-

ods of modern nuclear spectroscopy. The Scientific Council supported the general direction of such a topical development, when participation in highly prestigious international projects provides an access to know-how for the development of home-based neutrino experiments at the two facilities located at Kalinin NPP and Lake Baikal.

The Scientific Council recognized the importance of the Baikal-GVD large-scale project and particularly noted the vital contribution of JINR to the construction of the deep-water detector of this facility.

The Scientific Council endorsed the PAC's recommendation on continuation of the scientific programme under the theme "Non-accelerator neutrino physics and astrophysics" until the end of 2024 with the highest priority.

Neutrino Physics. The Scientific Council congratulated the PAC for Particle Physics and the PAC for Nuclear Physics for the careful evaluation, in the joint session of the two PACs, of the five neutrino projects under the theme "Non-accelerator neutrino physics and astrophysics". Following the guidelines outlined by JINR Director G. Trubnikov, the ultimate aim was to classify projects, using the scheme adopted in the previous joint session in January 2019, based primarily on the scientific merit of the project, and the performance, impact and visibility of the JINR group:

— category A: excellent projects, to be fully funded with adequate resources and encouraged to continue and expand their impact;

— category B: very good projects, but with some weaknesses, to be funded together with a strong recommendation on where improvements are needed;

— category C: projects with relatively low performance and impact, not prioritized for funding.

The project leaders were requested to answer a short common questionnaire prepared by representatives of the two PACs. Each project was reviewed by one referee from the PAC for Particle Physics and one from the PAC for Nuclear Physics. The questionnaire itself, the answers to the questionnaire and the referees' reports were uploaded to the Indico webpage of the PACs' joint session. The final evaluation of each project was made taking into account the opinions of the two relevant referees and the subsequent discussion of the project at the joint session of the two PACs.

The evaluation resulted in specific recommendations for each project, emphasizing their strengths and weaknesses as outlined in the recommendations of the joint session. The projects were ranked as follows:

— category A: DANSS, EDELWEISS-RICOCHET, GERDA (LEGEND);

— category B: GEMMA, SuperNEMO.

Condensed Matter Physics. The Scientific Council appreciated the close attention paid by the PAC for Condensed Matter Physics to the development of the concept for a new neutron source at FLNP and supported further monitoring and review of the progress in this direction. The Scientific Council shared the PAC's recommendations on construction of the SOLCRYS Laboratory at the SOLARIS National Synchrotron Radiation Centre. Together with the PAC, the Scientific Council welcomed the progress in constructing the SOLCRYS Laboratory and recommended paying closer attention to the construction schedule and design details of the Laboratory. Meanwhile, the Scientific Council shared some PAC's concerns about a slight delay in the planned schedule of the Laboratory construction occurred in 2020 due to the COVID-19 pandemic. However, it concurred with the PAC that this delay appeared to be manageable within the timeframe of the entire project. The Scientific Council also welcomed regular meetings of the Working Group for the construction of the SOLCRYS Laboratory as well as discussions on the basic elements of the facility under development.

The Scientific Council noted with satisfaction the results of the PAC's assessment of the plans for the IBR-2 instrumentation development for 2021–2025. In particular, the Scientific Council welcomed the status of the RTD neutron diffractometer (real-time diffraction) and a new small-angle neutron scattering and imaging options, which will meet the high demands of the user community for small-angle scattering experiments.

The Scientific Council agreed with the PAC that the development of the new inelastic neutron scattering spectrometer in inverse geometry is essential for extending the capacities of experiments in studying the dynamics and vibrational properties of condensed matter. The Scientific Council concurred with the PAC that the activities focused on the development and modernization of other instruments are important for providing competitive research opportunities compared to other leading neutron centres, as well as for the successful realization of the FLNP User Programme and the extension of the research scope of the IBR-2 facility. Following the PAC, the Scientific Council supported further modernization of IBR-2 instruments and the suggested measures for improving their performance.

The Scientific Council was pleased with the statistics of the FLNP User Programme at the IBR-2 spectrometers and the implementation of the new web-based application intended for collecting and evaluating research proposals. Together with the PAC, the Scientific Council noted that the IBR-2 facility has been operating according to the User Programme even in the pandemic period. The Scientific Council supported further development of the FLNP User Programme and recommended its extension.

Membership of the PACs. Following the proposal of the JINR Directorate presented by JINR Director G. Trubnikov, the Scientific Council appointed W. Dominik (Institute of Experimental Physics, University of Warsaw, Poland) and A. Ivanov (Institut

Laue-Langevin, Grenoble, France) as new members of the PACs for Particle Physics and for Condensed Matter Physics, respectively, for a term of three years.

The Scientific Council thanked J. Pluta and J. Mnich for their dedicated work in the PAC for Particle Physics.

Scientific Reports. The Scientific Council thanked Academician P. Logatchov for his scientific report "Implementation of the SKIF project at the Budker Institute of Nuclear Physics (Novosibirsk)" and Professor R. Hoover (USA) for his excellent presentation "The recent SEM and ENAA investigations of carbonaceous meteorites obtained in collaboration with JINR and PIN (RAS) and their potential relevance to astrobiology and the origin and distribution of biospheres".

Awards and Prizes. The Scientific Council approved the proposal of JINR Director G. Trubnikov to award the title "Honorary Doctor of JINR" to Professor L. Cifarelli, Professor M. Waligórski, and Professor S. Dubnička, in recognition of their outstanding contribution to the advancement of science and education of young scientists.

The Scientific Council approved the Jury's recommendations presented by JINR Acting Vice-Director V. Kekelidze on the award of JINR annual prizes for the best papers in the fields of scientific research, methodology, research and technology, and applied research.

The Scientific Council approved the Jury's recommendations presented by JINR Director G. Trubnikov and by Jury Chair A. Olshevskiy of awarding the Bruno Pontecorvo prize for 2020 to Professor K. Niwa (Nagoya University, Japan) for the development of the high-resolution nuclear emulsion technique, which led to identification of the tau neutrino and direct observation of tau-neutrino oscillations.

Naming of the Laboratory of Information Technologies after M. Meshcheryakov. The Scientific Council supported the proposal of the JINR Directorate presented by JINR Director G. Trubnikov and LIT Director V. Korenkov for naming the Laboratory of Information Technologies after M. Meshcheryakov.

Announcement of New Elections of VBLHEP Director. The Scientific Council announced a vacancy for the position of VBLHEP Director. The elections were to be held at the 131st session of the Scientific Council in February 2022.

On 23–24 September, the 130th session of the JINR Scientific Council was held under the chair of JINR Director G. Trubnikov and Professor of the Belarusian State University S. Kilin.

G. Trubnikov delivered a comprehensive report covering information about decisions of the latest session of the JINR Committee of Plenipotentiaries (March 2021), results and achievements of JINR, as well as recent events in the field of JINR's international cooperation.

The recommendations of the Programme Advisory Committees were reported by I. Tserruya (PAC for Particle Physics), M. Lewitowicz (PAC for Nuclear Physics), D. Nagy (PAC for Condensed Matter Physics).

The Scientific Council heard the scientific report "Four pillars of BLTP" presented by D. Kazakov and the reports of young scientists recommended by the PAC.

The award of the Bruno Pontecorvo Prize and the award of JINR annual prizes for the best papers in the fields of scientific research, methodology, and applied research were presented.

At the session, new elections of the Director of BLTP were announced.

General Considerations of the Resolution. The Scientific Council thanked C. Borcea, on the completion of his tenure as Co-Chair of the Scientific Council, for his impeccable work as Co-Chair of the Scientific Council, for his tactful moderation of debates and meticulous attention to every opinion.

Having considered the JINR Director's proposal, the Scientific Council elected S. Kilin Co-Chair of the Scientific Council for the period of three years starting from this session.

The Scientific Council took note of the comprehensive report by JINR Director G. Trubnikov. The Scientific Council appreciated the progress in the implementation of the current Seven-Year Plan, especially as to the flagship projects. The Scientific Council acknowledged the increased activity and outcomes of the international cooperation development made by the Institute through this year. The Council supported JINR's development as an international intergovernmental research organization and the extension of its partnership.

Recommendations in Connection with the PACs. The Scientific Council took note of the recommendations made by the PACs at their meetings in June 2021. All three PACs followed the new evaluation scheme as proposed by the JINR Directorate aiming at classifying projects into three categories (A, B, and C) primarily based on their scientific merit, and the performance, impact and visibility of JINR groups. Following the directive of the JINR Directorate, the projects were approved till the end of the current Seven-Year Plan (the end of 2023), with the understanding that for those projects that will be included in the next Seven-Year Plan the approval will automatically be extended till the end of the requested period.

Particle Physics. The Scientific Council acknowledged the progress in realization of the NICA project, in particular, in commissioning of power substations, preparations of the central cryogenic plant, installation of equipment in the new compressor building, and commissioning of the main

new buildings. The Scientific Council welcomed the completion of the installation of the beam transport channel from the Booster to the Nuclotron and the plans for the second Booster run in 2021. The Scientific Council congratulated the accelerator team on the commissioning of the Booster–Nuclotron channel and on the successful transfer of the beam of iron ions from the Booster to the Nuclotron through this channel. The growth of the MPD collaboration and the preparation of the MPD detector for the first physics measurements at the start of NICA operations were also appreciated.

The Scientific Council seconded the PAC's recommendation to approve the JINR's participation in the T2K-II phase II experiment till the end of 2023 with ranking B and with a progress report in one year. The Scientific Council recommended that the JINR management, when defining the next JINR Seven-Year Plan, should take into account that a possible JINR's participation in the future large-scale Hyper-Kamiokande experiment should be decoupled from the one in T2K-II.

The Scientific Council recognized the importance of JINR's obligations in the upgrade of the CMS detector and endorsed the PAC's recommendation to approve the JINR's participation in the second phase of the CMS detector upgrade till the end of 2023 with ranking A.

The Scientific Council shared the PAC's concern about the lack of personnel for the data analysis and simulations in the BM@N experiment. The Council acknowledged the high importance of the BM@N detector successful operation in the first run of the accelerator complex including the Booster and supported the PAC's recommendation for continuation of the BM@N project till the end of 2023 with ranking A.

The Scientific Council recognized the important role of the JINR group in the development and construction of the main subdetector systems of the COMET setup, together with JINR's visible participation in the research coordination and management of the international collaboration. The Council endorsed the PAC's recommendation for continuation of the project until the end of 2023 with ranking A and with a progress report in one year.

The Scientific Council appreciated the significant contribution of the JINR team to the design, construction, operation and maintenance of the NA62 spectrometer, as well as the results of the 2016–2018 datasets analysis that led to the observation of twenty candidate events of the rare kaon decay $K^+ \to \pi^+\nu\nu$. The Council supported the PAC's recommendation to approve JINR's participation in the NA62 experiment till the end of 2023 with ranking B.

The Scientific Council congratulated the ALPOM-2 team for having successfully finalized the data analysis and for publishing the results of the analysing power measurements which are of particular relevance to the JLab experiments. The Council supported the PAC's recommendation for continuation of the ALPOM-2 experiment till the end of 2023 with ranking A.

The Scientific Council noted that JINR has been participating in the STAR experiment since its inception and has contributed to the construction and maintenance of the detector, to the software development and data analysis. The Scientific Council noted that the limited impact and visibility of the JINR team over the past three years is disproportionate to the group of thirty-three members (FTE 21). As the experience gained by the team has application in the NICA project, the Scientific Council concurred with the PAC that the team should gradually shift its focus to the NICA experiment and endorsed the PAC's recommendation for continuation of the JINR's participation in the STAR experiment till the end of 2023 with ranking B.

The Scientific Council supported the JINR team's plan to upgrade the proton polarimeter of the DSS experiment for measurements with polarized deuterons and protons at the Nuclotron and endorsed the PAC's recommendation for continuation of the DSS experiment till the end of 2023 with ranking B.

The Scientific Council supported the JINR group's plans to participate in the HADES upgrade programme and in the physics analysis of $p + p$ data. The Council noted the relatively small size of the JINR team, the relevance of HADES and CBM to the MPD and BM@N physics programme and a possible synergy between these experiments. The Scientific Council seconded the PAC's support for the plans of merging the JINR groups participating in HADES and CBM into one focusing on the research programme of the CBM experiment, as well as the recommendation for continuation of JINR's participation in the HADES experiment till the end of 2023 with ranking B.

The Scientific Council noted the new results obtained from the energy scan programme of the NA61 experiment and the involvement of the JINR group in the upgrade of the NA61 setup. The Council recognized the relevance of NA61 to the NICA project and a possible benefit of having young researchers trained in the framework of the NA61 experiment for the NICA project, so the Council supported the PAC's recommendation for continuation of JINR's participation in the NA61 experiment till the end of 2023 with ranking B.

The Scientific Council appreciated the progress in the realization of the project "Precision laser metrology for accelerators and detector complexes". The use of Precision Laser Inclinometer (PLI) is growing: four PLIs have been installed in the LHC tunnel and two more PLIs are already used for the VIRGO detector. The Scientific Council supported the group involvement in the registration of the angular microseismic tilts of the earth's surface for the NICA, LHC and FCC colliders, as well as the use of compact PLIs for the "Einstein Telescope" project. The Council endorsed the PAC's recommendation for

continuation of the project till the end of 2023 with ranking A.

The Scientific Council noted with satisfaction the important scientific results obtained by the JINR teams participating in the ALICE, ATLAS and CMS experiments at LHC.

Nuclear Physics. The Scientific Council noted that the start of experiments at the Superheavy Element (SHE) Factory at FLNR, with the DC-280 cyclotron as the key element, had been an important event for JINR. The Scientific Council also noted that the commissioning of the SHE Factory, the upgrade of the U-400M cyclotron, as well as the creation of new-generation experimental setups for operation at the FLNR accelerators scale up JINR's capacities for carrying out fundamental nuclear physics and applied research to the highest level in wide collaboration with scientific centres of the JINR Member States and other countries interested in conducting research in Dubna.

The Scientific Council particularly highlighted the results of the first experiments at the SHE Factory in production of Fl (flerovium) and Mc (moscovium) isotopes in fusion reactions $^{48}Ca + {}^{242}Pu$ and $^{48}Ca + {}^{243}Am$, respectively, and supported the programme for a detailed study of radioactive properties of isotopes from Lr (lawrencium) to Mc in 2022–2023.

The Scientific Council also supported the continuation of the experiments with α-, β- and γ-spectroscopy of isotopes of transfermium elements using the SHELS and DGFRS-2 separators, which are to obtain data about their nuclear levels. The study of chemical properties of the new elements and relativistic effects associated with them is another purpose of the experiments carried out at FLNR, for which a new gas-filled separator DGFRS-3 has already been installed in the experiment hall of DC-280.

The Scientific Council noted that the experiments studying mass-energy distribution of composite systems with Z from 114 to 120 formed in reactions with $^{52,54}Cr$, ^{48}Ti, ^{86}Kr, and ^{68}Zn beams make it possible to assess the contribution of quasi-fission to the capture cross sections. Carrying out such experiments is extremely important for the synthesis of new superheavy elements with $Z = 119$ and 120.

The further development of the FLNR accelerator complex and research setups includes modernizing and developing the FLNR cyclotron complex and creating new physics facilities. The main stages of the theme are aimed at increasing the stability of accelerators, increasing the intensity and improving the quality of the ion beams of both stable and radioactive nuclides in the energy range from 5 to 60 MeV/nucleon, while reducing their energy consumption. The main purpose of the work within the theme is to significantly increase the efficiency of experiments for synthesizing superheavy elements and studying their properties, as well as for producing light nuclei at the drip lines.

The Scientific Council endorsed the PAC's recommendations for extending the themes "Synthesis and properties of superheavy elements, the structure of nuclei at the limits of nucleon stability" and "Development of the FLNR accelerator complex and experimental setups (DRIBs-III)" for 2022–2023 with the first priority.

The Scientific Council endorsed the PAC's recommendation for launching "Investigation of prompt fission neutron emission in fission (ENGRIN)" in 2022 as B-ranked project for one-year period and considering its possible further extension.

The Scientific Council endorsed the PAC's recommendation for extending the B-ranked project "Study of deep subcritical electronuclear systems and feasibility of their application for energy production and radioactive waste transmutation (E&T&RM)" until the end of 2023.

Condensed Matter Physics. The Scientific Council noted with satisfaction the extraordinary meeting of the PAC for Condensed Matter Physics held on 29 April 2021 and aimed at prioritization of JINR projects into three categories. The Council also thanked the PAC for continuing this activity at its regular 54th meeting held on 28 June 2021 and for completing the priority list of the JINR projects in Condensed Matter Physics following their detailed reviewing.

The Scientific Council welcomed the ongoing progress of the new neutron source of JINR — NEPTUNE. In particular, the Scientific Council noted that, following the previous PAC's recommendations, FLNP had updated the roadmap for the development of the new neutron source for approval of the JINR management and Rosatom State Atomic Energy Corporation. The approval of the roadmap will enable R&D activities of developing fuel elements with neptunium-nitride-based fuel and of preparing technical specifications for a conceptual design of the NEPTUNE reactor. The Scientific Council agreed with the PAC that a detailed report on the R&D activities of developing fuel elements and preparing a conceptual design of the NEPTUNE reactor should be presented at the next PAC meeting. The Scientific Council also shared the expectation of the PAC to hear a report on principal points of the design of cold moderators, primary neutron optics and shielding as an integral part of the neutron source.

Together with the PAC, the Scientific Council supported further development of the small-angle neutron scattering method at the pulsed neutron source of JINR. In particular, the Scientific Council recommended continuing the upgrade of the YuMO diffractometer and welcomed the PAC's intention to consider its detailed upgrade programme at the next meeting.

The Scientific Council agreed with the PAC's recommendations for extending the theme "Radiation physics, radiochemistry, and nanotechnology investigations using beams of accelerated heavy ions" for 2022–2023.

The Scientific Council welcomed the PAC's suggestion to additionally discuss the approach for assigning reviewers to projects at the next meeting of the PAC.

The Scientific Council thanked the PAC for holding the young scientists' poster session in videoconference format and suggested that the other PACs should have this practice.

The Scientific Report. The Scientific Council thanked BLTP Director D. Kazakov for the report on the work of the Bogoliubov Laboratory of Theoretical Physics. The report detailed the success in all the main areas of research carried out at BLTP: high-energy physics, nuclear physics, theory of condensed matter, mathematical physics, as well as in scientific-organizational and scientific-educational work.

The Scientific Council recognized the high level of the achieved scientific results most of which are world-leading. The Council recognized that BLTP is on the top of the world scientific agenda in many areas. The cooperation of BLTP with other JINR research Laboratories remains extremely important, within the flagship projects in particular. The Scientific Council supported BLTP's activity in organizing scientific conferences and schools for young scientists, maintaining BLTP's status as one of the world-leading centres of theoretical physics. The personnel capacity of BLTP keeps growing as BLTP attracts not only the young, but also a number of outstanding scientists who make a strong addition to the scientific team of the Laboratory.

Progress of Implementation of the NICA Project. The Scientific Council took note of the progress report on the NICA project presented by VBLHEP Director R. Lednický and of the achievements in implementation of the project, despite the problems caused by the pandemic. In particular, the Scientific Council noted the progress in creating the beam extraction and transport channel for heavy ions accelerated in the superconducting booster synchrotron to the Nuclotron; the successful results of the channel test proving the high quality of the preparatory work; the success in the infrastructure development and a good pace in the production of collider elements; the strengthening cooperation on the two main experimental facilities (MPD and BM@N), as well as the formation of a collaboration and corresponding Detector Advisory Committee to prepare the third big facility (SPD); the significant progress in creating the MPD setup: the superconducting solenoid magnet had been integrated with its yoke; the preparing activities for the autumn run of the BM@N experiment within the physical programme for short-range correlations and for the spring run with heavy ion beams scheduled for 2022 do continue. The Scientific Council left open the possibility of shifts in the NICA project implementation schedule forced by the longsome pandemic.

JINR Long-Term Development Strategic Plan. The Scientific Council followed with interest the report of JINR Director G. Trubnikov presented by S. Nedelko on the implementation of the JINR long-term development strategy.

The Council took a positive note that, following the Long-Term Development Strategic Plan, JINR gets intensively acting for developing innovations: the Institute proceeded to create its own Innovation Centre and it got started the NICA Applied Research and Innovation Committee, as well as the Working Group on Strategic Issues established by the decision of the Committee of Plenipotentiaries. There had also been launched a new web-resource for monitoring strategy implementation. The Directorate payed due attention to improving the performance of the Topical Plan realization and administrative management. The Council also noted that the development of the new setups and modernization of the existing ones are being well executed.

The Scientific Council recommended that a concept of the Long-Term Development Strategic Plan for 2024–2030 should be presented at the next session.

Reports by Young Scientists Recommended by the PACs. The Scientific Council appreciated the report "Effect of charged lipids on β-amyloid peptide interactions with a phospholipid membrane" made by D. Badreeva and selected by the PAC for Condensed Matter Physics for presentation at this session. The Scientific Council emphasized that young scientists' reports are most welcome.

Awards and Prizes. The Scientific Council congratulated Professor K. Niwa (Nagoya University, Japan) on winning the Bruno Pontecorvo prize for 2020. The Council highly appreciated Professor Niwa's report prepared for this session and presented by A. Olshevskiy.

The Scientific Council approved the proposal of JINR Director G. Trubnikov to award the title "Honorary Doctor of JINR" to Professor M. Kovalchuk, President of the National Research Centre "Kurchatov Institute".

The Scientific Council congratulated the winners of the JINR annual prizes for the best papers in the fields of scientific research, methodology, research and technology, and applied research.

MEETINGS OF THE JINR FINANCE COMMITTEE

A meeting of the Finance Committee was held on 22 March in a videoconference format, under the chairmanship of the representative of Georgia A. Khvedelidze.

The Finance Committee heard the report by Director of the Institute G. Trubnikov and recommended that the CP approve the measures in improving the system of administrative management of JINR to implement the issues of the JINR Long-Term Development Strategic Plan up to 2030 and Beyond, as well as enact the correction of the Seven-Year Plan for the Development of JINR for 2017–2023, including the financial grounding of the proposed changes and scheduled distribution of means for 2021–2023.

The Finance Committee greeted the news about the launch of one of the main blocks of the megaproject "NICA Complex" — the superconducting booster synchrotron (the Booster) — that occurred on 20 November 2020 with participation of Chairman of the RF Government M. Mishustin, and the information on the launch of the largest in the Northern Hemisphere deep-water neutrino telescope Baikal-GVD that was held on 13 March 2021 in the presence of the Minister of Science and Higher Education of the Russian Federation, Plenipotentiary of the RF Government to JINR V. Falkov.

The Finance Committee highly evaluated the results of the first experiments at the Factory of Superheavy Elements in November 2020 and January 2021 on the synthesis of moscovium isotopes in the $^{48}Ca + {}^{243}Am$ reaction, where 55 chains of the moscovium-288 nucleus decay and 6 chains of moscovium-289 were registered, that is practically two times higher than the number of isotopes synthesized earlier at the U-400 accelerator in the period of 2003–2012, and greeted preliminary results of the experiments that indicate first evidence of alpha decay of dubnium-268 and lead to the discovery of a new isotope of lowrencium-264.

The Finance Committee marked strengthening of ties with scientific, scientific-technical and educational organizations of the JINR Member States in extending the partner network, signing of new documents on cooperation on different levels, development of jointly established collaborations and committees and creation of JINR Information Centres on the basis of organizations of cooperating states.

The Finance Committee endorsed the JINR Directorate's activities for executing the agendas for the 65th anniversary of JINR and the Year of Bulgaria at JINR, as well as for setting out the scope of JINR's participation in the agenda for the Year of Science and Technology in Russia.

Having heard and discussed the report "Execution of the JINR budget for 2020 and draft of the revised budget of JINR for 2021" presented by Head of the Digital Services Development Department M. Vasilyev, the Finance Committee recommended that the CP take note of the information on the budget, approve the consolidated final adjustment of the income and expenditure of the JINR budget for the year 2020 and the revised JINR budget of US$ 265 825.2 thousand for 2021.

With reference to the fact that the coronavirus pandemic of 2020 resulted in an international cooperation budget surplus, the Finance Committee recommended that the CP commission the JINR Directorate to consider an issue of equivalent increase of this expenditure item when budgeting for the years 2022 and 2023.

In order to minimize the volatility of the lower limits for contributions of the JINR Member States, the Finance Committee recommended that the CP update the method of calculating the lower limits with the amendment that the amount of the direct costs for personnel assigned by the Plenipotentiary to JINR is calculated as the arithmetic average of the direct personnel costs accrued in the three years preceding the year in which the contributions of the Member States are calculated.

The Finance Committee recommended that the CP adjust the amounts of the contributions of the JINR Member States for the year 2021, as well as the provisional contributions of the Member States for 2022–2024, taking into account the updated lower limits for contributions and the contributions in arrears to be paid by the Member States to the JINR budget for the year 2021.

On the report of JINR Vice-Director R. Lednický "About the choice of the audit organization to check the financial activities of JINR in 2020", the Finance Committee recommended that the CP approve the plan of audit checking of the JINR financial activities in 2020 reported by the JINR Directorate and select FinExpertiza as the auditor of JINR for the year 2020 and authorize the company to audit the JINR financial results of the said period and analysis of implementation by the JINR Directorate of the plan of activities on the results of the audit check of JINR financial activities in 2019.

A meeting of the Finance Committee was held on 19 November under the chairmanship of the representative of Georgia A. Khvedelidze.

The Finance Committee heard the report by the Director of the Institute G. Trubnikov and recommended the following to the Committee of Plenipotentiaries:

— to take note of the information on the recommendations of the 130th session of the JINR Scientific Council, on the implementation of the current Seven-Year Plan for the Development of JINR, on the contributions of the JINR Member States to the realization of the major projects of the Institute, on

the new scientific and R&D deliverables, and on the most important events related to the academic and international cooperation activities of JINR;

— to uphold the JINR Directorate's initiative to assess the performance of the JINR Long-Term Development Strategic Plan up to 2030 and Beyond in order to define it and to adjust the long-term planning priorities for the development of the JINR large-scale research infrastructure and research avenues required for drafting the next Seven-Year Plan for the Development of JINR for 2024–2030;

— to commend the JINR Directorate's work carried out for the restructurization and optimization of the general administration of JINR, for the execution of miscellaneous managerial re-arrangements to improve the performance of the JINR administration and research management, and for the development of the comprehensive KPI monitoring system for the JINR long-term strategy in accordance with the JINR Long-Term Development Strategic Plan up to 2030 and Beyond;

— to assent to the JINR Directorate's proposal for and the expediency of JINR's financial participation in the development and support of healthcare, social and educational institutions located on the territory of Dubna in order to improve the quality of life and create favorable living conditions of the JINR employees;

— to support the initiative of the JINR Directorate for the social care payments to former JINR employees.

As to the report of "JINR budget proposed for 2022; JINR Member States' provisional contributions for 2023, 2024, 2025" made by the Head of the Budget and Economic Policy Department of JINR, N. Kalinin, the Finance Committee encouraged the Committee of Plenipotentiaries to approve the JINR budget for the year 2022 of US$ 274 304.1 thousand for income and expenditure total; to approve the amounts and the scale of contributions of the JINR Member States for the year 2022; to approve the amounts of the contributions in arrears to be paid by the JINR Member States to the JINR budget for the year 2022; to authorize the Director of the Institute to make adjustments to the JINR budget for the year 2022 including adjustments to expenditure items of salaries and international cooperation and within the approved budget in compliance with the Regulations for the Introduction of Adjustments to the Budget of JINR; to agree on including the contribution of the Democratic People's Republic of Korea, the membership of which was decided to suspend, in the JINR budget for the year 2022 to maintain the established proportion of the contributions of the JINR Member States; to offset the deficit of the JINR budget for the year 2022 that resulted from the suspended membership of the Democratic People's Republic of Korea in JINR with other income and receivables of the JINR budget.

The Finance Committee recommended that the Committee of Plenipotentiaries set the provisional amount of the JINR budget for income and expenditure as US$ 223.0 million for the year 2023, US$ 228.6 million for the year 2024, and US$ 234.6 million for the year 2025, as well as the provisional contributions of the JINR Member States for 2023, 2024, and 2025.

The Finance Committee recommended that the Committee of Plenipotentiaries charge the JINR Working Group on Financial Issues and the JINR Directorate with elaborating the proposal for increasing the Member States' contribution amounts starting with the next Seven-Year Plan for the Development of JINR for 2024–2030 and taking into account actual and forecast inflations.

The Finance Committee recommended that the Committee of Plenipotentiaries approve the allocations of the special-purpose funds in the total amount of 2 571 292.5 thousand roubles received under the Agreement between the Government of the Russian Federation and JINR on the construction and operation of the NICA complex of superconducting rings for heavy-ion colliding beams as budgeted for the year 2022.

The Finance Committee recommended that the Committee of Plenipotentiaries grant permission to the JINR Director to introduce the salary indexation within the manoeuvrable part of the JINR budget for the year 2022 and according to the JINR Collective Bargaining Agreement for 2020–2023.

The Finance Committee recommended that the Committee of Plenipotentiaries instruct the JINR Directorate with developing prior to the end of February 2022 and submitting for consideration by the Working Group on Financial Issues a detailed procedure for accounting the personal income tax (PIT) for foreign employees — citizens of the JINR Member States.

As to the report of "Notice of Intent of the Arab Republic of Egypt to enter JINR as a Member State. Contribution amount to the JINR budget to be made by the Arab Republic of Egypt" made by the representative of Georgia A. Khvedelidze, the Chair of the Finance Committee, the Finance Committee recommended that the Committee of Plenipotentiaries, in case of a positive decision on the admission of the Arab Republic of Egypt to the JINR Member States, accept the Arab Republic of Egypt's application for a gradual increase in the contribution payments to the JINR budget provided that the Arab Republic of Egypt gets paying its full-amount contribution estimated by the new method for calculating the scale of the Member States' contributions no later than 2028. Therewith, the membership contributions that shall be paid to the JINR budget by the Arab Republic of Egypt through 2028 are not below the total sum of direct costs of the personnel assigned to JINR by the Plenipotentiary, amounts funded for grants of the Plenipotentiary and cooperation programmes and expense allowance for infrastructure. The Finance Committee recommended that the Committee of Plenipotentiaries bud-

get the Arab Republic of Egypt's contribution as additional to the estimated total of the contributions of the JINR Member States.

The Finance Committee recommended that the Committee of Plenipotentiaries charge the JINR Directorate with the work aimed at investigation of the receivables from the countries participating in JINR under their bilateral cooperation agreements on R&D with the Institute.

As to the "Readout of the meeting of the Working Group on Strategic Issues under the CP Chair held on 22 July 2021" made by the Chair of the Working Group on Strategic Issues under the CP Chair, I. Štekl, the Finance Committee welcomed the start of the Working Group on Strategic Issues and further development of intersessional activity instruments.

As to the "Audit report on the JINR financial results of 2020 and analysis of the JINR Directorate's execution of the Corrective Action Plan following the audit of the JINR financial results of 2019" made by the Audit Engagement Partner of the FinExpertiza audit company, I. Krasilnikov, the Finance Committee recommended that the Committee of Plenipotentiaries approve the Audit Report on the JINR financial results of 2020.

The Finance Committee appreciated the interesting and comprehensive report of "Neutron research in life science" made by Director of the Frank Laboratory of Neutron Physics V. Shvetsov.

MEETINGS OF THE JINR PROGRAMME ADVISORY COMMITTEES

The 54th meeting of the Programme Advisory Committee for Particle Physics took place on 18 January via videoconference. It was chaired by Professor I. Tserruya.

The Chair of the PAC presented an overview of the implementation of the recommendations taken at the previous meeting and highlighted the Resolution of the 128th session of the JINR Scientific Council relevant to the PAC for Particle Physics.

The PAC took note of the report on the infrastructure developments at VBLHEP presented by N. Agapov. The Committee acknowledged the progress on reconstruction of power supply lines, commissioning of power substations, equipment assembly in the compressor station, and civil construction.

The PAC heard with interest the report on the realization of the MPD project presented by A. Kisiel. The production of all components of the MPD first-stage detector configuration was progressing, their commissioning was planned for 2021–2022. The PAC congratulated the team on reaching the important milestones: the completion of the magnet yoke assembly, the delivery of the solenoidal magnet, and the start of the installation of MPD elements at their place inside the MPD hall.

The PAC appreciated the progress towards the realization of the BM@N project presented by M. Kapishin. The team was focused on the preparation for the forthcoming runs of the BM@N detector with ion beams in 2021. The PAC congratulated the BM@N Collaboration on the first publication of short-range correlation results in the journal "Nature Physics".

The PAC welcomed the progress in realization of the Nuclotron–NICA project presented by A. Sidorin. The PAC congratulated the Booster team for the smooth and successful first beam circulation in the Booster, confirming the high quality of all the preoperational works. The PAC was pleased to note the progress achieved by JINR in construction and commissioning of the new compressor station of the cryogenic complex, in developing the beam transport channels with corresponding magnetic optics, in the serial production of the Collider cryomagnetic system, beam pipe and other NICA elements. The PAC recommended continuation of the Nuclotron–NICA project till the end of 2023.

The PAC took note of the report on the Compressed Baryonic Matter (CBM) project presented by V. Ladygin. The CBM experiment at the future FAIR accelerator (Germany) concentrates on investigating hadronic matter at the highest baryon densities and moderate temperatures, including the deconfinement and chiral symmetry restoration phase transitions. The experience obtained by JINR physicists in the development of silicon detectors and reconstruction software in FAIR/CBM is valuable for the MPD, SPD and BM@N experiments at NICA. The PAC recommended continuation of the JINR group's participation in the CBM project until the end of 2025.

The PAC took note of the report on JINR's participation in the PANDA experiment presented by G. Alexeev. The PANDA experiment is planned at the FAIR High Energy Storage Ring (HESR). The team plans to contribute to various hardware projects and suggested several studies for PANDA, namely, measuring proton structure functions in a new kinematical region, and measuring elastic and deep inelastic antiproton–nuclei processes. The PAC recommended JINR's participation in the PANDA project for the period of 2022–2024. However, the PAC was concerned about the high average age of the JINR team and the large fraction of participants of low FTE (0.3 or less). The PAC advised the team to adapt the team's commitments to the available resources.

The PAC heard with interest the presentation of the Conceptual Design Report (CDR) for the SPD experiment made by A. Guskov. The main goal of the experiment is to study the polarized gluon structure of proton and deuteron in the production of charmonium, open charm and direct photons. The PAC thanked the SPD (proto-)collaboration for the preparation of the comprehensive CDR and recommended that the NICA management appoint an appropriate Detector Advisory Committee (DAC) for a thorough review of the CDR and its subsequent evolution into an SPD TDR (Technical Design Report). The PAC encouraged the team to pursue every effort to form an international collaboration, find adequate resources and attract students and young scientists.

The PAC took note of the results obtained by the JINR groups in the LHC experiments presented by V. Pozdnyakov (ALICE), E. Khramov (ATLAS), and I. Gorbunov (CMS). The PAC acknowledged the importance of the scientific results as well as the significant contribution made by the groups for the detectors upgrade programme.

Joint Session of the PAC for Particle Physics and the PAC for Nuclear Physics for the assessment of JINR neutrino projects took place on 21 January.

The PAC for Particle Physics and the PAC for Nuclear Physics held a joint session for the evaluation of five neutrino projects under the theme "Non-Accelerator Neutrino Physics and Astrophysics" aimed at classifying the various projects into three categories, based primarily on the scientific merit of the project, and the performance, impact and visibility of the JINR group. The final evaluation of each project was made taking into account the opinions of the two relevant referees and the subsequent discussion of the project at the joint session of the two PACs.

The PAC heard the report by K. Gusev on the GERDA (LEGEND) project dedicated to searching for the neutrinoless double-beta decay of ^{76}Ge with open Ge-detectors directly immersed in liquid argon. The GERDA project is carried out at Gran Sasso in Italy by a large international collaboration. The analysis of the full GERDA data set of 127.2 kg $\cdot$ y collected in Phase I and Phase II enabled setting a new world-best half-life limit on the neutrinoless double-beta decay of $^{76}\mathrm{Ge} > 1.8 \cdot 10^{26}$ y. The full-scale project with 1 t of ^{76}Ge aims for a sensitivity of 10^{28} y by reducing the background by a factor of 10 and then for a potential answer to the question about neutrino mass hierarchy.

The PAC heard the report by V. Tretyak on the SuperNEMO project at LSM (Modane, France), dedicated to the search for neutrinoless double-beta decay ($0\nu2\beta$) employing tracker-calorimeter techniques with a design capability of measuring of the order of 100 kg of various isotopes, for maximum sensitivity of the ultimate detector to half-lives $T_{1/2}(0\nu2\beta) \geqslant 10^{26}$ y. The JINR group participates in the construction of the passive shielding, the VETO system, the calorimeter, software and data handling, and in the development of radiochemical purification methods. It was noted that the present generation of the project features several years of delay, that anyhow hamper the potential impact of the experiment within the harsh international competition. Nevertheless, the tracking-calorimeter capability, as well as the free selectivity for any of the candidate isotopes, could make SuperNEMO contributing to the assessment of a possible $0\nu2\beta$ signal once found by other searches. To make it possible, the PAC encouraged the proponents to set up a focused and timely productive group for the exploitation of the SuperNEMO Demonstrator detector.

The PAC heard the report by Yu. Shitov on the DANSS reactor neutrino project at the Kalinin NPP dedicated to the search for sterile neutrinos. DANSS safely installed a compact neutrino spectrometer near the reactor and in five years of operation during 2016–2020 registered world-record statistics of four million reactor antineutrinos. This allowed DANSS to obtain world-class results by showing the lack of significant effect of oscillations of reactor antineutrinos into sterile neutrinos after analyzing most of the collected statistics and by demonstrating ability to monitor the reactor power with a statistical error of $\sim 1.5\%$ in two days of measurements, and to determine the composition of the nuclear fuel. It is planned to continue working on the development of a mini-spectrometer S3 (S-cube) (~ 64 L), which will register ~ 300–400 neutrinos per day, and on the upgrade of the DANSS-2 spectrometer with a factor of two better energy resolution, which will allow expanding significantly the tested phase space region in the search of sterile neutrino.

The PAC heard the report by A. Lubashevskiy on the proposal for the extension of the νGeN (GEMMA) project performed by the JINR group at the Kalinin NPP. The measurements are focused on studying reactor neutrino properties such as the search for neutrino magnetic moment and the coherent elastic neutrino–nucleus scattering. The experiment makes use of high-purity, low-threshold germanium detectors (200 eV) with a low background of 1 cts/(keV $\cdot$ kg $\cdot$ d), up to a total mass of about 5.5 kg, placed at a short distance from the reactor centre, under a flux larger than $5 \cdot 10^{13}$ antineutrinos/(cm^2 $\cdot$ s). The 50 m w.e. overburden and the movable spectrometer, which allows varying the antineutrino flux, are qualifying features of the project. Despite delays in the realization of the project and a consequent reduced scientific production, the PAC acknowledged the strong commitment of the JINR group and their capability to conduct the research autonomously, as well as within the strong international competition, in particular, concerning the observation of neutrino coherent scattering.

The PAC heard the report by E. Yakushev on the latest results of the EDELWEISS experiment and on the continuation of its research programme with

new cryogenic HPGe detectors-bolometers, that will be expanded to include coherent elastic neutrino–nucleus scattering studies. The PAC noted the successful development of bolometer detectors, which will enable EDELWEISS-RICOCHET to carry out high precision spectrometric measurements down to very low energies (with an energy threshold below 100 eV). The first phase of the RICOCHET programme, with a large (kg scale) experiment, will be carried out at the ILL research reactor (Grenoble, France). At the same time, the newest detectors will continue to be used at EDELWEISS for the direct search of Dark Matter particles from the galactic halo in the low-mass WIMP region (1 GeV/c^2 and below). The PAC was pleased to note that EDELWEISS-RICOCHET has produced the world-leading results and maintains strong competitive capabilities.

The evaluation made at the joint session of the two PACs resulted in the following classification:

— category A: DANSS, EDELWEISS-RICOCHET, GERDA (LEGEND);

— category B: GEMMA, SuperNEMO.

The 53rd meeting of the Programme Advisory Committee for Nuclear Physics was held on 22 January. It was chaired by Professor M. Lewitowicz.

The Chairman of the PAC presented an overview of the implementation of the recommendations taken at the previous meeting. JINR Vice-Director S. Dmitriev informed the PAC about the Resolution of the 128th session of the Scientific Council (September 2020) and about the decisions of the Committee of Plenipotentiaries (November 2020).

The PAC heard the report by V. Utyonkov on the first experiment at the Factory of Superheavy Elements (SHE) at FLNR JINR, which was conducted with the DGFRS-2 separator and aimed at synthesis of isotopes of element 115 (moscovium) in the $^{48}Ca + {}^{243}Am$ reaction. Over 30 decay events of ^{288}Mc and ^{289}Mc isotopes were observed during the three-week experiment, which nearly doubled the statistics for these isotopes gathered at the U-400 accelerator complex for the period from 2003 to 2012. As a result, a high background suppression was achieved in the focal plane of the separator, which is of great importance for registering decay events of long lifetimes. The above-mentioned resulted in the first-ever recording of ^{268}Db alpha decay subsequently transiting to a new spontaneous fission ^{264}Lr isotope.

The further programme for experiments at the SHE Factory provides for the increased intensity of ^{48}Ca beams on targets to 3.0–5.0 pμA (completion of works on creation differential pumping and transition to larger targets). It also includes experiments on the synthesis of Fl isotopes in the $^{242}Pu + {}^{48}Ca$ reaction, as well as the development of acceleration of ^{50}Ti ions to prepare the experiments for the synthesis of elements 119 and 120.

The PAC congratulated the FLNR team on the successful launch of the implementation of the SHE Factory experimental programme and recommended that the work on the development of the differential pumping system at the DGFRS-2 separator and the higher dimension target wheel be finished, making experiments with extremely high-intensity beams possible.

The PAC heard with great interest a report by V. Chudoba on the results of the first experiments at the ACCULINNA-2 fragment separator aimed at studying extremely neutron-rich ^{7}H nucleus in the $^{2}H(^{8}He, ^{3}He)^{7}H$ reaction. The cross sections and statistics for this reaction are not high, however, the ACCULINNA-2 experimental group put measures in place to address some of these problems in the most efficient way. The analysis allowed the authors to conclude the observation of the ground and excited states of ^{7}H, and other excited states in exotic nuclei like ^{7}He, ^{9}He, ^{10}Li. Data analysis is processing, and the new results were announced to be presented at the next meetings. The PAC ranked the ACCULINNA-2 experimental programme in category A.

The PAC heard a proposal by A. Doroshkevich to open a new project "Modernization of the EG-5 accelerator and development of its experimental infrastructure" and noted the exceptional importance of EG-5 for JINR as one of the most important installations of its class. The PAC recommended opening in 2022 the new project for modernization of the EG-5 accelerator and its experimental infrastructure under the theme "Investigations of neutron nuclear interactions and properties of the neutron" for one year. The project can be continued for two more years depending on the available funding. The PAC ranked the project in category B.

The PAC heard a report by P. Zarubin on the BECQUEREL project aimed at studying the dissociation of relativistic nuclei by means of nuclear track emulsion (NTE). The fragmentation of nuclei into stable and radioactive isotopes was studied in the experiment at the Nuclotron. The finalized data analysis allowed several young researchers to defend their PhD theses. The realization of the plans for data processing automation is expected to result in a significant increase in the statistics. The PAC recognized the uniqueness of the NTE technique for the measurements of charged particles at relativistic energies that, however, in comparison with other techniques, is seen to be less competitive. Therefore, the BECQUEREL project was ranked by the Committee in category C.

The PAC heard a report by S. Tuituinnikov and E. Levterova on the project "Research of deeply subcritical accelerator-driven systems and features of their application for energy production and transmutation of the waste nuclear fuel (E&T&RM)". The project is dedicated to the study of reactions in the uranium target exposed to beams of deuterons and protons at the Phasotron. Interesting results on ob-

servation of high-energy and high-intensity neutron emission from the surface of the nuclear assembly were obtained and could be used for the transmutation of spent nuclear fuel (SNF). The project is aimed at an experimental facility equipped with the "quasi-infinite" target. A broad range of nuclear data necessary to determine the optimal parameters for the innovative neutron source is anticipated. The PAC recommended continuing the "E&T&RM" project through the year 2021 and ranked it in category B.

The PAC heard a report by E. Yakushev on the implementation of the theme "Non-Accelerator Neutrino Physics and Astrophysics" and proposal for its extension. The theme consists of seven projects which are devoted to the studies of rare phenomena associated with the weak interaction by methods of modern nuclear spectroscopy. Implementation of the projects is related to common approaches and resources. In addition to the scientific staff involved in the theme, the following resources are available to carry out the scientific programme: the laboratory for the production and repair of semiconductor detectors; the laboratory for creation and production of scintillation materials for detectors; the radiochemical sector, mechanical workshops, a group of computer support, a group of mass separators, and others. The PAC noted the international recognition of the team with a highly visible contribution to hardware, simulation and analysis and its capabilities to lead or to participate in world-class experiments. The PAC supported the general direction in which the theme is developing, when the participation in highly prestigious international projects provides an access to know-how for developing home-based neutrino experiments at the two basic facilities — the laboratories located at the Kalinin NPP and Lake Baikal. The PAC recognized the importance of the Baikal-GVD as one of the JINR flagship projects and recommended extending the theme "Non-Accelerator Neutrino Physics and Astrophysics" until the end of 2024 and supported the experiments within the framework of this theme with the highest priority.

The 53rd meeting of the Programme Advisory Committee for Condensed Matter Physics was held on 25 January in the videoconference mode. It was chaired by Professor D. L. Nagy.

The Chair of the PAC, D. L. Nagy, presented an overview of the implementation of the recommendations concerning JINR research in the areas of condensed matter physics taken at the previous PAC meeting. JINR Vice-Director B. Sharkov informed the PAC about the Resolution of the 128th session of the JINR Scientific Council (September 2020) and the decisions of the JINR Committee of Plenipotentiaries (November 2020).

The PAC took note of the progress report on the development of a new neutron source at FLNP presented by V. Shvetsov. The PAC welcomed the planned organization of a dedicated IBR-3 unit, feeling that the extent of the work demanded to achieve milestones and deliverables according to the project plan requires an acceleration of this process.

Accepting the report on the progress of the SOLCRYS Laboratory construction presented by N. Kučerka, the PAC noted a slight delay in the planned schedule occurred due to the unforeseen pandemic, which, however, appears to be manageable within the timeframe of the entire project schedule. The PAC also took note of the results of the regular meetings of the Working Group for the construction of the SOLCRYS Laboratory held in remote mode during the year 2020. The base elements discussed at the meetings were the superconducting wiggler and the construction project for extension of the experiment hall. Close attention was paid to the versions of the beamlines, the final specifications of which were to be proposed in 2021. Appreciating the progress in constructing the SOLCRYS Laboratory, the PAC recommended paying closer attention to the construction schedule and design details of the Laboratory. The PAC looked forward to receiving regular progress reports.

The PAC took note of the plans for the IBR-2 instrumentation development for 2021–2025 presented by D. Kozlenko and of the status of the RTD neutron diffractometer (real-time diffraction) at beamline 6A of the IBR-2 facility, presented by V. Turchenko. In particular, the PAC noted that the construction of the new small-angle neutron scattering and imaging option at beamline 10A of IBR-2 equipped with the cryogenic moderator is to complement the YuMO spectrometer and to meet high demands of the user community for small-angle scattering experiments. The development of the new inelastic neutron scattering spectrometer in inverse geometry at beamline 2 of IBR-2 is essential for extending the capacities of experiments in studying the dynamics and vibrational properties of condensed matter. The activities focused on the development and modernization of other instruments are important for providing competitive research opportunities compared to other leading neutron centres, for the successful realization of the FLNP scientific programme and User Programme, as well as for the extension of the research scope at the facility. The PAC supported the reported modernization and the suggested measures planned for improving the performance of the instruments by increasing the signal-to-background ratio.

The PAC took note of the report on the statistics of the FLNP User Programme at the IBR-2 spectrometers and implementation of the new web application intended for collecting and evaluating research proposals. The PAC was pleased to note that the IBR-2 facility has been operating according to the User Programme even in the pandemic period. The PAC supported further development of the FLNP User Programme and recommended its extension. The PAC also appreciated the implementation of the new web application.

The PAC heard with interest the scientific report "Experimental studies and multiscale modelling of latent tracks in radiation-resistant insulators" presented by V. Skuratov and thanked the speaker for his excellent presentation.

The PAC took note of the information about the International Conference "Condensed Matter Research at the IBR-2" (12–16 October 2020, Dubna) presented by T. Ivankina. The PAC recognized the significant attention of the international scientific community to the recent research results in condensed matter physics obtained at the IBR-2 facility and recommended that the practice of holding similar international conferences be continued in future.

Following the discussion at the meeting with members of the JINR Directorate, the PAC expressed its intension to proceed with the ranked assessment of all the JINR research themes and projects within the competence of the PAC for Condensed Matter Physics based on the scientific merit of the project or theme and the performance of the JINR group involved.

The 55th meeting of the Programme Advisory Committee for Particle Physics took place on 21–22 June via videoconference. It was chaired by Professor I. Tserruya.

At the opening of the meeting, JINR Director G. Trubnikov and Chair of the PAC for Particle Physics I. Tserruya payed tribute to the memory of Prof. Jean Cleymans, member of the PAC since 2010, who passed away in a tragic accident on 22 February 2021. A minute of silence was observed by all meeting participants.

The Chair of the PAC presented an overview of the recommendations taken at the previous meeting and highlighted the Resolution of the 129th session of the JINR Scientific Council relevant to the PAC for Particle Physics.

The PAC heard with interest the report presented by JINR Vice-Director V. Kekelidze on the ongoing activities in the Institute, the Resolution of the Scientific Council, the decisions of the Committee of Plenipotentiaries, and the development of new managerial structures aimed at the consolidation of intellectual, material and human resources in accordance with the priorities of the current Seven-Year Plan.

The progress report on the realization of the Nuclotron–NICA project was presented by A. Sidorin. The PAC noted with satisfaction the confirmation of the completion of the installation of the beam transport channel from the Booster to the Nuclotron and the plans for the second Booster run in 2021. The PAC was pleased to note that, in spite of the delay in completing the civil work in the collider building 17, the target time for launching the NICA collider was unaffected.

N. Agapov made the progress report on the infrastructure developments at VBLHEP, including the Nuclotron facility. The PAC acknowledged with satisfaction the significant progress achieved in commissioning of power substations, preparations of the central cryogenic plant, installation of equipment in the new compressor building, and commissioning of the main new buildings.

The PAC appreciated the report on the realization of the MPD project presented by A. Kisiel. The PAC noted with satisfaction the growth of the MPD collaboration with the recent affiliation of three new institutions. The PAC underlined the importance of further simulation work aimed at optimization of the detector performance, the analysis methodology and the readiness for the first physics measurements at the start of NICA operations.

The evaluation of new projects, as well as those seeking continuation, was conducted aiming at classifying the projects into three categories (A, B, and C), using the scheme adopted at the previous joint sessions with the PAC for Nuclear Physics in 2019 and in 2021. The ranking is primarily based on the scientific merit of the project, and the performance, impact and visibility of the JINR group. Following the directives of the JINR Directorate, the projects were approved till the end of the current Seven-Year Plan, i.e., till the end of 2023, with the understanding that for those projects that will be included in the next Seven-Year Plan, the approval will automatically be extended till the end of the requested period.

The PAC took note of the report on JINR's participation in the T2K-II and Hyper-Kamiokande experiments presented by V. Glagolev. The PAC recognized the team's plan to potentially contribute to the upgrade of the T2K-II near detector. However, the role, the strategy and the perspectives of the group present elements of qualitative and quantitative concern. Therefore, the PAC recommended JINR's participation in T2K phase-II till the end of 2023 with ranking B and requested a progress report in one year. The possible participation in the future large-scale Hyper-Kamiokande experiment should be considered by the JINR management when defining the next JINR Seven-Year Plan.

V. Karjavine presented the new project "Upgrade of the CMS detector". The goal of the project is to prepare the CMS detector for effective operation at the HL-LHC conditions. JINR team will participate in the design and construction of the high granularity calorimeter HGCal and the upgrade of the forward muon station ME1/1. The PAC recommended approval of the JINR's participation in the second phase of the CMS detector upgrade till the end of 2023 with ranking A.

The PAC appreciated the progress towards realization of the BM@N project presented by M. Kapishin. The team is focused on the preparation of detectors, further development of the data analysis methods and simulation for the forthcoming runs of the BM@N detector with ion beams starting in 2022. The PAC reiterated its concern about the lack of sufficient manpower for the data analysis and

simulations. The PAC acknowledged the high importance of the BM@N detector successful operation in the first run of the accelerator complex including the Booster and recommended continuation of the BM@N project till the end of 2023 with ranking A.

The PAC took note of the report on JINR's participation in the COMET project at J-PARC presented by Z. Tsamalaidze. The experiment aims at searching for a possible charged-lepton flavour violation through the neutrinoless process of muon-to-electron transition, as a probe into physics beyond the Standard Model. The PAC noted with satisfaction that the JINR group is playing an important role in the development and construction of the main subdetector systems of the COMET setup. The PAC recommended continuation of the project till the end of 2023 with ranking A and requested a progress report in one year.

The report on JINR's participation in the NA62 experiment at the CERN SPS was presented by D. Madigozhin. The experiment aims at measuring the very rare kaon decay $K^+ \to \pi^+\nu\nu$. NA62 is planning a test of the Standard Model (SM) by means of a 10%-precision measurement of the Cabibbo–Kobayashi–Maskawa (CKM) matrix element V_{td}. The PAC appreciated the results of the 2016–2018 datasets analysis that led to the observation of 20 candidate events of the rare decay and recommended continuation of JINR's participation in the NA62 experiment till the end of 2023 with ranking B.

The PAC heard the progress report on the realization of the in-house ALPOM-2 project presented by N. Piskunov. The main goal of the project is to extend the measurements of analyzing power for the reactions of polarized nucleon scattering on different targets at the Nuclotron. The PAC noted the particular relevance of these measurements to the JLab experiments. The PAC supported the group's plan to pursue this experiment as it will secure JINR's leadership in polarimetry and recommended continuation of the ALPOM-2 experiment till the end of 2023 with ranking A.

Yu. Panebrattsev presented the report on JINR's participation in the STAR experiment at RHIC. The JINR group contributed to the construction and maintenance of the endcap and cylindric calorimeters, to the preparation of the new reaction plane detector, to the software development and data analysis. The PAC noted that, over the past three years, the impact and visibility of the JINR team in terms of leadership positions within the collaboration, papers published with major JINR contribution and talks at conferences, had not been commensurate with the very large size of the group of 33 members (21 FTE). Noting that the experience gained by the team is relevant to the NICA project, the PAC encouraged the team to gradually shift its focus to the NICA experiment and recommended continuation of JINR's participation in the STAR experiment till the end of 2023 with ranking B.

The progress report on the realization of the DSS project was presented by M. Janek. The experiment is focused on the study of the spin structure of $2N$ and $3N$ short-range correlations via measurements of polarization observables in deuteron induced reactions at the Nuclotron. The JINR team made significant contributions to hardware, software development and data analysis. The PAC supported the plans of the JINR team in upgrading of the DSS setup and recommended continuation of the DSS experiment till the end of 2023 with ranking B.

The PAC took note of the report on JINR's participation in the HADES experiment at GSI presented by V. Ladygin. The HADES spectrometer is devoted to the study of low-mass dilepton production and in-medium modification of light vector mesons in the warm and dense matter created in heavy-ion collisions at the SIS-18 accelerator at GSI. JINR contributions were to hardware, software development and data analysis. The PAC noted the relevance of HADES and CBM to the MPD and BM@N physics programmes and the possible synergy between these experiments. The PAC recommended continuation of JINR's participation in the HADES experiment till the end of 2023 with ranking B.

A. Dmitriev presented the report on JINR's participation in the NA61 experiment at the SPS. The PAC noted the new results obtained from the energy scan programme of the NA61 experiment and the involvement of the JINR group in the upgrade of the NA61 apparatus. The PAC recommended continuation of JINR's participation in the NA61 experiment till the end of 2023 with ranking B.

M. Lyablin reported about the progress in realization of the project "Precision laser metrology for accelerators and detector complexes". The project aims at developing precision instruments for registration of microseismic phenomena. Four precision laser inclinometers (PLIs) are already installed in the LHC tunnel and two more PLIs are used for the VIRGO detector. The PAC recommended continuation of the project till the end of 2023 with ranking A.

The PAC took note of the reports on the scientific results obtained by the JINR groups in the experiments at the LHC presented by B. Batyunya (ALICE), V. Lyubushkin (ATLAS), and M. Savina (CMS). The PAC acknowledged interesting results obtained in ultra-peripheral Pb–Pb collisions, in searches for manifestations of physics beyond the Standard Model and progress in the upgrade of the detectors.

The 54th meeting of the Programme Advisory Committee for Nuclear Physics was held on 23 June. It was chaired by Professor M. Lewitowicz.

The Chairman of the PAC presented an overview of the implementation of the recommendations taken at the previous meeting. JINR Vice-Director S. Dmitriev informed the PAC about the Resolution of the 129th session of the Scientific Council (February

2021) and about the decisions of the Committee of Plenipotentiaries (March 2021).

The PAC heard the report "SHE at FLNR: Research and development" presented by Yu. Oganessian. The report gave an overview on the work performed during the last four years. The most significant event was certainly the start of the operation of the new cyclotron DC-280 in 2019. The PAC noted that the commissioning of SHE, the upgrade of the U-400M cyclotron and construction of next-generation experimental setups considerably expand the possibilities for carrying out fundamental and applied research in nuclear physics at JINR at the highest level.

The PAC highly appreciated the results of the first experiments at the SHE Factory on the synthesis of Mc and Fl isotopes in the $^{48}Ca + {}^{243}Am$ and $^{48}Ca + {}^{242}Pu$ fusion reactions, respectively. Sixty-one events of production of $^{288,\ 289}Mc$ isotopes (compared to 35 chains detected previously) and 99 $^{286,\ 287}Fl$ decay chains (to 25 chains for all previous years) have been registered. Owing to the high efficiency of the conducted experiments and sufficient background suppression, an alpha decay of ^{268}Db was registered for the first time, making the discovery of the new ^{264}Lr isotope possible. A series of experiments were performed that aimed at studying mass-energy distributions of binary products formed in reactions with $^{52,54}Cr$, ^{48}Ti, ^{86}Kr, and ^{68}Zn beams, leading to a composite system with $Z = 114$ to 120. The experiments allow the evaluation of quasifission contribution to the capture cross section, which is of great importance to the planned experiments for the synthesis of new superheavy elements with $Z = 119$ and 120.

The new gas-filled separator, DGFRS-III, for the study of the chemical behaviour of the new elements and related topics, has already been mounted in the experimental hall at DC-280.

The PAC heard a report on the implementation of the theme "Development of the FLNR accelerator complex and experimental setups (DRIBs-III)" for 2017–2021 presented by G. Gulbekyan and noted that within this period a wide variety of scientific and applied investigations in heavy-ion physics were conducted using FLNR cyclotrons (DC-280, U-400, U-400M, and IC-100). The PAC noted that the programme of experimental investigations at the FLNR accelerator complex U-400 was implemented under the work schedule. A major part of experimental efforts at U-400 was devoted to research with ^{48}Ca (DGFRS and SHELS) and ^{50}Ti beams (SHELS) and applied work (Roscosmos).

The U-400M cyclotron upgrade was started in July 2020, its commissioning being scheduled for the middle of 2022. Before the upgrade was initiated, the U-400M cyclotron had ensured the implementation of the programme of experimental investigations with ^{11}B, ^{15}N, ^{32}S (ACCULINNA-1 and ACCULINNA-2 separators), ^{18}O, ^{22}Ne (COMBAS setup), and ^{40}Ar, ^{48}Ca beams (MASHA mass spectrometer).

The PAC acknowledged the importance of the reconstruction of the U-400 accelerator (into U-400R) and the construction of the new experimental hall and highly appreciated the work on preparing the project of the new experimental hall for the U-400R accelerator which was approved by Glavgosexpertiza of Russia. The scheduled period for the construction of the new experimental hall is 2.5 years (2022–2024).

The PAC noted that much attention is paid to the construction and development of new experimental facilities at FLNR. The new gas-filled recoil separator DGFRS-2 was commissioned. Moreover, the new expanded system of detectors was manufactured and tested. The system is located in the focal plane of DGFRS-2 allowing for an increase in reaction product collection by a factor of 1.5. This is of paramount importance to the long-run experiments for SHE synthesis. The PAC noted that ACCULINNA-2 separator was developed and commissioned within the theme. A series of methodological works to prepare experiments with ^{6}He, ^{8}He, ^{9}Li, ^{10}Be, ^{27}S, etc., beams were undertaken in 2017–2021.

The PAC heard a proposal for prolongation of the themes "Development of the FLNR accelerator complex and experimental setups (DRIBs-III)" and "Synthesis and properties of superheavy elements, the structure of nuclei at the limits of nucleon stability" for 2022–2023 presented by S. Sidorchuk.

Further implementation of the theme "Development of the FLNR accelerator complex and experimental setups (DRIBs-III)" includes: the upgrade and development of the FLNR cyclotron complex, the expansion of the experimental infrastructure of the laboratory (constructing new physics instruments), and the development of accelerator systems. The milestones of the theme are the increased stability of the accelerators and the increased intensity and improved quality of ion beams of both stable and radioactive nuclides in the energy range from 5 to 60 MeV/nucleon with simultaneous reduction of power consumption. The theme objective is to significantly improve the efficiency of experiments for the synthesis of superheavy elements and light nuclei at the limits of nuclear stability and study of their properties.

As to the theme "Synthesis and properties of superheavy elements, the structure of nuclei at the limits of nucleon stability" in 2022–2023, the experiments for the synthesis of isotopes of elements 114 (Fl) and 115 (Mc) in reactions of ^{48}Ca ions beam with ^{242}Pu and ^{243}Am targets will be continued at the SHE Factory to study radioactive properties of Lr to Mc isotopes. Furthermore, a series of experiments aimed at measuring production cross sections for SHE isotopes in reactions of actinides with ^{50}Ti and ^{54}Cr will be conducted allowing researchers to determine the prospects of synthesizing

new elements 119 and 120 and to launch the first dedicated experiments.

The experiments on α-, β-, and γ-spectroscopy of the isotopes of transfermium elements, which enable physicists to obtain data on the structures of nuclear levels, will be continued using SHELS and DGFRS-3 separators and GABRIELA and SFiNX detecting systems. The first experiments on the spectroscopy of moscovium nuclei are planned.

After launching the U-400M cyclotron in 2022, an evaluation of experimental capabilities will be carried on at the ACCULINNA-2 separator to improve the efficiency of experiments aimed at investigating the ^{7}H structure and other neutron-rich nuclei — ^{10}He, ^{11,13}Li, ^{16}Be, ^{18,19}C, and ^{26}O.

The PAC recommended that the themes "Development of the FLNR accelerator complex and experimental setups (DRIBs-III)" and "Synthesis and properties of superheavy elements, the structure of nuclei at the limits of nucleon stability" be extended to 2022–2023 with the highest priority.

The PAC heard a proposal to open a new project "Investigation of prompt fission neutron emission in fission" (project ENGRIN) presented by Sh. Zeynalov. The experiments to be carried out with the use of resonance neutrons assume studying the correlation between the multiplicity and angular distributions obtained for the prompt fission neutrons and the data obtained for the fragment energy and mass spectra. Such challenging experiments are promising for receiving information needed for estimation of the dimension and shape acquired by the nucleus just before the neck rupture. The PAC classified the reviewed project in category B and recommended opening this project for a year starting from 2022 with its possible subsequent extension.

The PAC heard a report on the status of the project "Measurement of ordinary muon capture for testing nuclear matrix elements of 2β decays" (project MONUMENT) presented by M. Shirchenko. The task of the project is to carry out experimental measurements of muon capture at several daughter candidates for $0\nu\beta\beta$-decay nuclei. Its obtained results would be crucial for verifying the accuracy of theoretical calculations of the nuclear matrix elements. The JINR group was to carry out measurements at the meson factory of the Paul Scherrer Institute (PSI) in Switzerland. The start of measurements themselves was to be in October 2021. The PAC ranked the project in category A and recommended that this project be continued till the end of 2023.

The PAC heard a report on the project "Study of deep subcritical electronuclear systems and possibilities of their application for energy production, transmutation of radioactive waste and research in the field of radiation materials science (E&T&RM)" presented by A. Baldin. The project is dedicated to the development of a new concept of Accelerator-Driven Systems (ADS) based on a high-current accelerator of light nuclei. The prospect of ADS is due to the possibility of creating a closed fuel cycle and the transmutation of radioactive waste. The project includes both theoretical studies and experiments on beams of protons, deuterons, and light nuclei of the JINR accelerator complexes including Phasotron and NICA. The special-purpose nuclear power technology station being created at the NICA accelerator complex extends the frontiers of experimental research on extracted beams of protons and light nuclei.

The PAC recommended extending project E&T&RM until the end of 2023. Furthermore, the PAC considered the two additional branches: SINET (Station for Investigation of Nuclear Energy Technologies) and Development and Construction of the Prototype of a Complex for Radiotherapy and Applied Research with Heavy-Ion Beams at the Nuclotron-M, to be of extreme interest and recommended that the current status and, if possible, a detailed plan including budget, man-power and institution involvement be presented at the next PAC meetings. The PAC ranked the E&T&RM project in category B.

The 54th meeting of the Programme Advisory Committee for Condensed Matter Physics was held on 28 June in the videoconference format. It was chaired by Professor D. L. Nagy.

The Chair of the PAC, D. L. Nagy, presented an overview of the implementation of the recommendations concerning JINR research in the areas of condensed matter physics taken at the previous regular and extraordinary PAC meetings. JINR Vice-Directors L. Kostov and S. Dmitriev informed the PAC about the Resolution of the 129th session of the JINR Scientific Council and the decisions of the JINR Committee of Plenipotentiaries.

The PAC took note of the report on the status of the new NEPTUNE neutron source of JINR presented by M. Bulavin. Following the previous recommendations of the PAC, FLNP has updated the roadmap for the development of the new neutron source for approval by the JINR management and Rosatom State Atomic Energy Corporation. The approval of the roadmap will enable the R&D activities on the development of fuel elements with neptunium-nitride-based fuel and on the preparation of technical specifications for a conceptual design of the NEPTUNE reactor. The PAC recommended presenting a detailed report on the R&D activities. The PAC also expressed its wish to hear a report on the principal points of the design of cold moderators, primary neutron optics and shielding as an integral part of the neutron source.

The PAC considered the report on the status of the YuMO small-angle neutron scattering diffractometer at beamline 4 of the IBR-2 reactor presented by O. Ivankov. The PAC recognized the high demand for the diffractometer and the importance of the research results obtained with it and published in high-ranked journals. The PAC supported further development of the small-angle neutron scattering

method at present and future pulsed neutron sources of JINR. The PAC recommended continuing the upgrade of the YuMO diffractometer and preparing a detailed upgrade programme to be presented at the next meeting.

The PAC took note of the report presented by P. Apel on the expiring theme "Radiation physics, radiochemistry, and nanotechnology investigations using beams of accelerated heavy ions". The PAC appreciated the wide range of the R&D studies that had been realized and the high quality of the obtained results. The proposal for the extension of the theme allows synchronizing the activity within the framework of the theme with the current Seven-Year Plan for the Development of JINR. The PAC found the presented proposal well-formulated and recommended extending the theme for 2022–2023.

One of the important outcomes of the PAC meeting was the completion of the prioritization of the JINR projects within the competence of the PAC for Condensed Matter Physics. The updated reports were reviewed on projects in relation to which critical comments were made at the extraordinary PAC meeting in April 2021. The PAC noted that the remarks indicated earlier had been taken into account and ranked the projects "Construction of a complex of cryogenic moderators at the IBR-2 facility", "New semiconductor detectors for fundamental and applied research", and "Development of experimental techniques and applied research with slow monochromatic positron beams" as category A.

The PAC discussed the additional reviews requested at the extraordinary PAC meeting on 29 April 2021 concerning the projects "Research on the biological effects of heavy charged particles with different energies", "Research on cosmic matter on Earth and in nearby space; research on the biological and geochemical specifics of the early Earth", "RADIOGENE: Molecular genetics of radiation-induced changes at the gene, genome and transcriptome level in *Drosophila melanogaster*", and "Study of the radioprotective properties of the Damage suppressor (Dsup) protein on a model organism *D. melanogaster* and human cell culture HEK293", and finally also recommended assigning these projects to category A.

The PAC heard with interest the scientific reports "Magnetic fluids and elastomers: Structural studies for innovative applications" presented by M. Balasoiu and "Investigating model lipid membranes complementarily by neutron and Raman scattering" presented by D. Soloviov and Y. Arynbek. The PAC thanked the speakers for their excellent presentations.

The PAC reviewed 12 virtual poster presentations made by young scientists in the field of condensed matter theory and information technology. The presentation "Effect of charged lipids on β-amyloid peptide interactions with a phospholipid membrane" made by D. Badreeva was selected the best presentation of the session. The PAC noted two other high-quality virtual poster presentations: "Distributed information and computing infrastructure of the JINR Member State organizations" by Ye. Mazhitova and "Information system for analyzing behavioral and morphological changes in the central nervous system in the study of the effects of ionizing radiation and other factors (joint project of MLIT and LRB JINR)" by I. Kolesnikova.

PRIZES AND GRANTS

PRIZES AND GRANTS

The Bruno Pontecorvo Prize for 2021 was awarded to Professor Thomas K. Gaisser (Bartol Research Institute, University of Delaware, USA) for his significant contributions to neutrino, astroparticle and high-energy cosmic ray physics, in particular to the atmospheric neutrino flux calculation from its early-stage development.

JINR PRIZES FOR 2021

I. Theoretical Physics Research

First Prizes

1. "Calculation of critical exponents and representative physical parameters of scaling behavior of stochastic systems by quantum field theory methods".

Authors: L. Adzhemyan, N. Antonov, M. Hnatič, J. Honkonen, P. Kakin, G. Kalagov, M. Kompaniets, T. Lučivjansky, L. Mižišin, M. Nalimov.

2. "A new era of RG calculations at BLTP: Modern methods, tools, and recent achievements".

Authors: A. Bednyakov, A. Pikelner.

II. Experimental Physics Research

First Prize

"Neutrino studies in the OPERA experiment".

Authors: S. Vasina, Yu. Gornushkin, S. Dmitrievsky, Z. Krumstein, D. Naumov, A. Olshevsky, A. Sadovsky, A. Sotnikov, A. Chukanov, A. Sheshukov.

Second Prizes

1. "New structural, magnetic and physical phenomena in geometrically frustrated functional magnetic materials at changes of thermodynamic parameters".

Authors: D. Kozlenko, N. Golosova, S. Kichanov, E. Lukin, A. Rutkauskas, B. Savenko, O. Lis, N. Belozerova, Dang Ngoc Toan, Le Hong Khiem.

2. "α-, γ-spectroscopy and decay properties of ^{249,252,254,256}No and ^{253,254,257}Rf".

Authors: A. Svirikhin, A. Yeremin, A. Popeko, O. Malyshev, Yu. Popov, A. Isaev, M. Tezekbaeva, R. Mukhin, A. Lopez-Martens, K. Hauschild.

III. Physics Instruments and Methods

First Prize

"Creation of the NICA Booster".

Authors: A. Butenko, V. Volkov, A. Galimov, V. Karpinsky, S. Kostromin, I. Meshkov, V. Mikhailov, A. Sidorin, G. Trubnikov, H. Khodzhibagiyan.

Second Prizes

1. "Positron annihilation spectroscopy studies of defects induced by surface mechanical treatments".

Authors: K. Siemek, P. Horodek, J. Dryzek, M. Eseev, M. Wróbel.

2. "Development and implementation of a unified access to the heterogeneous distributed resources of JINR and its Member States on the DIRAC platform".

Authors: V. Korenkov, N. Kutovskiy, V. Mitsyn, A. Moshkin, I. Pelevanyuk, D. Podgainy, O. Rogachevskiy, V. Trofimov, A. Tsaregorodtsev.

IV. Applied Physics Research

First Prize

"Calculation and modeling of the radiation field inside a spacecraft beyond Earth's magnetosphere".

Authors: G. Timoshenko, I. Gordeev.

Second Prizes

1. "Atmospheric deposits of heavy metals — assessment based on analysis of moss-biomonitors: Results of the 2015/2016 moss survey".

Authors: M. Frontasyeva, Yu. Aleksiayenak, K. Vergel, I. Zinicovscaia, P. Nekhoroshkov, A. Svozilikova-Krakovská, G. Hristozova, O. Chaligava, Trinh Thi Thu My, N. Yushin.

2. "Development of ion-selective track membranes for nanosensors and electrodialysis".

Authors: P. Apel, I. Blonskaya, O. Ivanov, O. Kristavchuk, N. Lizunov, A. Nechaev, K. Olejniczak, O. Orelovitch, O. Polezhaeva, Yu. Yamauchi.

V. Encouraging Prizes

1. "The method of the separable approximation for Skyrme force and effects of complex configurations in the structure of exotic nuclei".

Authors: N. Arsenyev, V. Voronov, Giai Nguyen Van, N. Pietralla, A. Severyukhin, Ch. Stoyanov.

2. "The Higgs boson properties study in $b\bar{b}$ pair decay channel and search for new physics with the ATLAS detector at the Large Hadron Collider".

Authors: F. Ahmadov, E. Khramov, E. Cherepanova.

3. "Test of the Standard Model and search for new physics in the Dimuon Final State with the CMS experiment at the LHC".

Authors: I. Golutvin, A. Zarubin, V. Zykunov, V. Karjavin, V. Korenkov, A. Lanyov, V. Matveev, V. Palchik, M. Savina, S. Shmatov.

GRANTS

In 2021, for the implementation of a number of scientific projects, the staff members of the Joint Institute for Nuclear Research received financial support of the Russian Foundation for Basic Research (RFBR), the Russian Scientific Foundation (RSF), the Ministry of Science and Higher Education of RF.

RFBR financed JINR projects in the framework of the following competitions: "Competition of Projects of Fundamental Scientific Research" (8 projects); "Competition of the Best Projects in the Topic "Fundamental Properties and Phase Transformations of Hadron and Quark–Gluon Matter: Facility of the Megascience Class "Complex NICA" (Megascience – NICA)" (10 projects); "Competition of the Best Projects of Interdisciplinary Fundamental Research" (2 projects).

RFBR financed a number of JINR scientific projects in the framework of international contests: together with the State Committee of Science of the Ministry of Education and Science of the Republic of Armenia (1 project); together with the Belarusian Republican Foundation for Basic Research (2 projects); together with the Vietnam Academy of Science and Technology (1 project); together with the Department of Science and Technology of the Government of India (2 projects); together with the State Foundation of Natural Sciences of China (1 project); together with the Ministry of Science, Technology and Environment of the Republic of Cuba (1 project); together with the Ministry of Education, Culture, Science and Sport of Mongolia (1 project); together with the German Scientific-Research Community (2 projects); together with the National Centre of Scientific Research of France (1 project).

RSF rendered financial support to scientific projects of JINR in the framework of the competitions "Holding of Fundamental Scientific Research and Scientific Research in Separate Scientific Groups" (5 projects), "Holding of Fundamental Scientific Research and Scientific Research by International Scientific Communities" (3 projects), "Holding of Initiative Research by Young Scientists" (2 projects), "Holding of Research by Scientific Groups under the Guidance of Young Scientists" (1 project), "Holding of Research on the Basis of Existing Scientific Infrastructure of the World Level" (4 projects).

The RF Ministry of Science and Higher Education financed two projects: "Superheavy nuclei and atoms: Limits of nuclear mass and boundaries of the Periodic Table" and "Development and creation of elements of experimental stations based on pulsed and permanent neutron source".

2021

INTERNATIONAL RELATIONS AND SCIENTIFIC COLLABORATION

COLLABORATION IN SCIENCE AND TECHNOLOGY

The main results of the international cooperation in science and technology of the Joint Institute for Nuclear Research in 2021 reflected the following data:

— joint research was conducted with scientific centres in the Member States, as well as international and national organizations in other countries, on 42 topics of first priority and one topic of second priority;

— to solve cooperation issues and questions of participation in scientific meetings and conferences, the Joint Institute sent 959 specialists;

— for joint work and consultations, as well as for participation in meetings, conferences, and schools held at JINR, 323 specialists were received;

— 29 international scientific conferences and schools, 20 workshops, and 14 meetings were organized and held.

The international cooperation of JINR is presented in agreements and treaties. Its development comprises joint experiments at basic facilities of physics centres, the acquisition of research data, the preparation of joint publications of the joint research results, the supply of equipment and techniques for the interested sides, etc.

On 11 January, Special Representative of the President of the Russian Federation on Digital and Technological Development D. Peskov visited the Joint Institute for Nuclear Research.

At the meeting with JINR Director Academician G. Trubnikov, the guest was acquainted with unique experience of JINR as an international intergovernmental scientific research organization. D. Peskov congratulated G. Trubnikov on his taking the office in the position of JINR Director, had an excursion to VBLHEP where he visited, in particular, the site of the NICA megaproject, to FLNR where he visited the Factory of Superheavy Elements on the basis of the new accelerator DC-280 and the Nanocentre, to LIT where he visited the "Govorun" supercomputer, as well as met with the leaders and staff members of these Laboratories.

On 15 January, the third meeting of the Cost and Schedule Review Committee (CSRC) of the "NICA Complex" project, formed by the decision of the Committee of Plenipotentiaries of JINR and the Supervisory Board of the "NICA Complex", was held, aimed at consulting on the issues related to the evaluation of costs and efficiency of work on the project.

The meeting of the Committee was held by F. Ferroni (INFN, Italy) via videoconference and was attended by all its members.

The Committee heard and discussed the report of the NICA project Leader V. Kekelidze on the project status and the implementation of the recommendations made at the previous CSRC meeting. The Committee noted the outstanding progress of the NICA project commissioning in the ongoing difficult situation of the COVID-19 global pandemic, in particular, the commissioning of the Booster, the installation of MPD magnet elements, the construction of a complex of power substations, and progress in the construction of a new cryogenic compressor station.

The Committee invited the management of the NICA project to prepare in the near future an updated project implementation schedule indicating the stages and their deadlines in order to be able to track the progress with a frequency of three months. It strongly recommended that a document should be prepared with a risk analysis for the most important elements of the project, to draw up a detailed list of the needs for qualified specialists with a description of the requirements to them.

On 19 January, a bilateral meeting took place in a videoconference format, participants of which discussed the results of joint work done in the framework of the Memorandum of Understanding between JINR and the Botswana International University of Science and Technology (BIUST). JINR Vice-Director B. Sharkov headed the JINR party. The BIUST side was headed by Vice-Chancellor of the University O. Totolo.

The sides highly evaluated the development of contacts that began in 2015 and the successful

work of young BIUST specialists at JINR Laboratories. G. Hillhouse, Head of BIUST Department of Physics and Astronomy, presented the prospects for the development of the scientific infrastructure and research of the University and plans for further strengthening of cooperation with JINR.

The sides agreed on the participation of students of the Botswana International University of Science and Technology in the online project of the JINR University Centre INTEREST, as well as on the extension of thematic fields for selection of young Botswana students for participation in scientific work of research groups of the JINR Laboratories as soon as it becomes possible in terms of the epidemiological situation.

On 20 January, JINR Director G.Trubnikov had a videoconference meeting with President of the European Physical Society (EPS) L. Berge.

During the meeting, they discussed prospects of interactions and a number of joint initiatives. In particular, they focused on the idea of the joint organization of conferences, schools for young scientists and promotion of contacts of EPS in Russia. They also discussed opportunities of extending representation of JINR in departments and groups of EPS and participation of EPS in the Scientific Council of JINR. Consultations between EPS and JINR will be continued as the work proceeds.

On 28 January, a meeting "Opportunities for Chile–JINR Cooperation" between representatives of the Chilean scientific community and heads of the Institute was held in a videoconference format. The goal of the meeting was to discuss possible ways for extending access of Chilean research organizations and universities to the Institute's research infrastructure and participation in its studies.

A. Orellana, Vice-Rector of Andrés Bello National University (UNAB), organized the event. 29 participants from 8 organizations represented the Chilean side, and 11 participants were from the JINR side. Vice-Director B. Sharkov and Chief Scientific Secretary A. Sorin represented the JINR Directorate.

A number of reports on the basic facilities of JINR, the User Programme of the IBR-2 research reactor, the training programmes, the current state and development plans of international cooperation were presented to the Chilean side.

A wide range of issues were discussed. At the end of the meeting, the sides agreed to find out possible contact points and the membership of the proposed council from both sides, as well as decide on the priority fields of studies for new cooperation lines.

On 4 February, the first visit to the Joint Institute for Nuclear Research of Chairman of the Executive Board of RUSNANO Group S. Kulikov was held. JINR Director Academician G. Trubnikov welcomed the RUSNANO LLC delegation. The sides discussed issues of cooperation. During the meeting, the delegation of RUSNANO visited the sites of JINR scientific infrastructure and got acquainted with its flagship projects.

On 11 February, JINR Vice-Director R. Lednický had a videoconference meeting with State Secretary of the Ministry of Education, Science and Technological Development of the Republic of Serbia M. Dukić-Mijatović. Moderators of the event were coordinators of Serbia–JINR cooperation — Member of the Governing Council of the Vinča Institute of Nuclear Sciences L. Hadžievski and Head of the JINR International Cooperation Department (ICD) D. Kamanin. The Serbian side at the meeting was represented by Assistant Minister A. Jović, Member of the National Council for Scientific and Technological Development and Member of the JINR Scientific Council N. Nešković, Head of the Department of Development and Research Programmes Z. Dukić, and Senior Assistant Minister S. Bogdanović.

The sides discussed the current state and prospects of cooperation. The results of the implementation of the Roadmap of cooperation development signed in October 2019 were considered, in particular, the participants discussed the issues of training and attracting young staff members from Serbia to JINR, prospects for opening a JINR Information Centre in Novi Sad, and also the opportunities of Serbia's participation in the MPD and SPD detectors of the NICA collider. Deputy Director of FLNP O. Culicov, Director of the JINR UC S. Pakuliak participated in the discussion. In general, the parties confirmed their mutual commitment to continue further strengthening of ties.

On 16 February, the 31st meeting of the Joint Committee for Collaboration of the National Institute of Nuclear and Particle Physics (IN2P3) and the Joint Institute for Nuclear Research took place by a videoconference. The sides discussed plans for scientific exchange, results achieved during the year, as well as prospects for cooperation enhancement.

JINR Director G. Trubnikov headed the side of the Joint Institute at the meeting. Scientific Leader V. Matveev, Vice-Directors B. Sharkov, S. Dmitriev, and V. Kekelidze, Chief Scientific Secretary A. Sorin, and Heads of the JINR scientific Laboratories and the International Cooperation Department represented the Institute at the event. IN2P3 Director R. Pain, Deputy Director B. Giebels, Scientific Directors F. Farget, V. Poireau, L. Vacavant, J. L. Biarrotte, and S. Crepe-Renaudin, as well as Head of IN2P3 International Office T. Palychata, took part in the event on behalf of IN2P3.

Overview reports were presented on the current status of major projects and the latest results of activities of the Institutes. The representatives of the French side noted with appreciation the high level of the JINR cooperation with scientific organizations of France, as well as the impressive progress in the NICA collider construction. G. Trubnikov in his

turn highlighted that the IN2P3 bright programme in the fields of accelerator physics together with the IN2P3 research field on heavy ion physics and, in particular, on radioactive beams, is of scientific interest to JINR.

During the discussion, the parties approved 20 joint projects in the fields of nuclear physics, astrophysics, particle physics, accelerator technologies, and computing. This list also included two new projects on the search for dark neutron decay and physics of electron cyclotron resonance (ECR).

The parties congratulated each other on upcoming jubilees of the organizations, namely the 65th anniversary of JINR and the 50th anniversary of IN2P3. They discussed the possibility of cross-participation of delegations in upcoming jubilee events.

On 18 February, a specialized cryogenic transport tank for liquid helium was delivered to VBLHEP JINR. This unique equipment is one of the main elements of the NICA accelerator infrastructure and was delivered under the contract between JINR and the R&D company "Geliymash".

The arrived tank container is designed for the storage and transportation of liquid helium and has a volume of 40 m^3. It will be possible to use such containers to provide medical and scientific centres with helium.

It should be noted that the cooperation of JINR with JSC "R&D Geliymash" dates back to the early 1970s of the 20th century. The result of this cooperation at that time was the development of the first Russian stock helium and cryogenic facilities KGU-250 and KGU-1600. In 1993, at the suggestion of JSC "Geliymash", the liquefaction of helium and refueling of transport containers for import were carried out at JINR. This allowed creating a financial base for the construction of the Nuclotron, the first superconducting synchrotron in Europe.

Nowadays, the organizations support close contacts working in the field of cryogenic equipment, including joint research, the development of large-scale cryogenic complexes, and commissioning. Moreover, JSC "R&D Geliymash" created a steam-liquid turbine specially for JINR, which had a rotation speed of up to five thousand revolutions per second, operated in a two-phase helium medium. This device allowed increasing the cooling capacity of facilities by 50%.

On 24 February, a meeting of JINR representatives with representatives of the German Physical Research Centre DESY and the project "X-Ray Free-Electron Laser" (European XFEL) was held as a videoconference. Director of the Institute G. Trubnikov headed the JINR delegation. Chairman of the DESY Board of Directors H. Dosch and Chairman of the Management Board of European XFEL R. Feidenhans´l headed the German party. Representatives of management of scientific laboratories and departments of JINR, DESY and European XFEL also took part in the event.

The meeting was organized to exchange current information of the parties on the scientific results and progress within major research fields, developed in accordance with the framework agreement between JINR and DESY signed in 2019, as well as with the implementation of large-scale infrastructure projects, such as NICA, PETRA IV, and others. The parties also discussed cooperation areas for upcoming years in the fields of digitalization and scientific computing, particle physics, astroparticle physics, and accelerator research.

Both JINR and the German party made reports on each of the realms. Outside of a review of scientific work on the topic, practical proposals for joint work in the future were worded. An active discussion took place on such areas of mutual interest as machine learning in the field of accelerator management and detector control, during which the participants of the SPD project also put forward proposals for joint work.

The German party noted its interest in JINR educational capabilities for young scientists, and their particular interest was focused on the new summer school DD (Dubna – Darmstadt), which is a joint initiative of JINR and our partners from FAIR/GSI with the support of the BMBF.

During the meeting, a large number of exciting projects were planned. Participants selected coordinators of joint subprogrammes from the speakers. Moreover, it was decided to hold such meetings regularly.

On 24 February, the first meeting of the User Committee of the IBR-2 neutron source, organized by FLNP, took place via videoconference.

The User Committee of the IBR-2 neutron source has been established to increase the users' activity related to the interactions with FLNP, giving support to both specific and general users' questions, and with the aim to provide a discussion forum for the benefit of the users.

Representatives of the FLNP Directorate and delegates from Armenia, Bulgaria, Hungary, Poland, and Spain took part in this meeting. A fruitful discussion on further steps of the development of the IBR-2 instruments and infrastructure, ways to improve users' satisfaction and to achieve a general success of neutron science at IBR-2 was held.

On 4 March, the first in this year meeting of the JINR Science and Technology Council (STC) was held. Along with other issues, the agenda contained structural changes at the Institute. JINR Scientific Leader V. Matveev opened the meeting with his report on the results of the PACs and the session of the Scientific Council.

VBLHEP Director V. Kekelidze informed the STC members on the status of the NICA collider construction: the successful completion of the first run on the Booster and the accomplishment of development of all basic systems of the NICA accelerator complex according to the plan. The next stage

must be integration of the Booster into the general system with the Nuclotron. As V. Kekelidze said, the assembling of magnetic blocks in the collider channel must be started in 2021 and finished in 2022.

At the meeting, Diplomas of the Candidates of Physical-Mathematical Sciences were handed to young scientists of the Institute who recently defended their theses in dissertation councils of JINR Laboratories. Diplomas on conferring a scientific title were handed to A. Sapozhnikov (MLIT), A. Terekhin (VBLHEP), and A. Airyan (MLIT).

JINR Director G. Trubnikov spoke about changes in the structure of the JINR Administration. To increase the efficiency of management of the Institute activities, five new departments were organized: Human Resources and Records Management Department (Head — E. Kolganova); International Cooperation Department (Head — D. Kamanin); Development of Digital Services Department (Head — M. Vasiliev); Budget and Economic Policy Department (Head — N. Kalinin); Property Complex Development Department (Head — A. Brun).

Until 31 December 2021, Acting Chief Accountant of JINR was E. Kuteinikova, Acting Head of the Internal Audit Service of JINR was O. Kapuskina, Acting Chief of the Personnel Department was S. Bobrov, Acting Chief of the Legal Department was A. Kharevich, Head of Procurement and Logistics Service — V. Ivanov. S. Dotsenko was appointed JINR Director Assistant on Financial Issues. The leader of the JINR Director Protocol Department I. Suleimanov coordinated the work of departments taking part in the protocol activities, information service of the Institute and communication with mass media.

On 13 March, the ceremonial launch of the largest in the Northern Hemisphere deep underwater neutrino telescope Baikal-GVD was held in Lake Baikal and it became one of the key events of the Year of Science and Technology in Russia. The unique neutrino telescope Baikal-GVD will help detect sources of high-energy neutrinos, study the evolution of galaxies and the Universe, as well as solve the key task of forming the world's neutrino network. The telescope is the result of intense work of an international team of scientists from Russia, the Czech Republic, Slovakia, Germany, and Poland with the leading role of the Joint Institute for Nuclear Research, and the Institutes of the Russian Academy of Sciences.

Minister of Science and Higher Education of the Russian Federation V. Falkov together with JINR Director RAS Academician G. Trubnikov, Director of INR RAS M. Libanov, and ISU Rector A. Schmidt launched the facility. Governor of the Irkutsk Region I. Kobzev also took part in the ceremony.

The same day, on the ice of the Baikal deep underwater neutrino telescope camp, the Ministry of Science and Higher Education of Russia and the Joint Institute for Nuclear Research signed a Memorandum of Understanding for the development of the Baikal deep underwater neutrino telescope Baikal-GVD. The Memorandum focuses on the further development of the Baikal-GVD project, as well as experimental studies in the fields of neutrino high-energy astrophysics, neutrino astronomy, and neutrino physics and provides every possible assistance of the parties to the implementation of the project "Baikal deep underwater neutrino telescope Baikal-GVD", increase in the effective volume of Baikal-GVD up to a cubic kilometer.

On 13 March, Chairman of the RF Government M. Mishustin signed an order of the plan of the main activities in the framework of the Year of Science and Technology in Russia.

By the decision of the RF Government among the most important federal events of the year were two events of JINR: the launch of the neutrino telescope Baikal-GVD in Lake Baikal and the first run of the full cycle of acceleration at extracted beams of the NICA complex (the BM@N experimental programme).

On 16 March, the 10th regular session of the Joint Committee on JINR–ARE Cooperation was held via a videoconference. Vice-Director R. Lednický, Director of the University Centre S. Pakuliak, Head of the International Cooperation Department D. Kamanin, Director of the Frank Laboratory of Neutron Physics V. Shvetsov, and Head of the national group of Egypt at JINR W. Badawy took part in the event on behalf of JINR. The Egyptian side was represented by Vice-President of the Academy of Scientific Research and Technology G. El-Feky and Professor of the Faculty of Pharmacy of Helwan University S. Surur.

Participants noted that despite the pandemic the Roadmap for JINR–Egyptian cooperation development is being implemented according to the plan. Prospects of the resumption of practical communication and the restoration of full cooperation with the exchange of visits, organization of student internships, and long-term business trips for specialists were discussed.

The Egyptian side highlighted the interest in the possibilities of the JINR Innovative Centre being created. The parties also agreed to start work of the JINR Information Centre in the Academy of Scientific Research and Technology and to prepare its inauguration.

On 17 March, the first meeting of the Joint Coordination Committee (JCC) on Vietnam–JINR Cooperation was held via a videoconference.

Vice-Director B. Sharkov headed the JINR delegation. Plenipotentiary of the Government of Vietnam Le Hong Khiem headed the Vietnamese delegation. President of the Vietnam Atomic Energy Institute (VINATOM) Tran Thi Thanh and representatives of the industry structures included in the VINATOM system also took part in the meeting.

Chief Designer of scientific and research reactors at Rosatom NIKIET I. Tretyakov took part in the event as an invited expert.

The meeting confirmed the key fields of JCC's work aimed at deepening Vietnam's participation in JINR, in particular, support and expansion of the joint scientific programme, participation of Vietnam in the JINR programmes of personnel training, active involvement of new partners from Southeast Asia into joint projects, etc. Participants expressed the intention to draft a strategic action plan for the next meeting on the issues discussed.

On 18 March, a meeting in the videoconference mode was held of the JINR Directorate and the new Plenipotentiary of the Government of the Republic of Azerbaijan to JINR A. Gashimov and his deputy A. Rustamov. Azerbaijani NAS Academician-Secretary, Chairman of the Board on Ties of AR with JINR at AR NAS A. Garibov took part in the meeting. JINR was represented by Director G. Trubnikov, JINR Scientific Leader V. Matveev, JINR Vice-Director S. Dmitriev, Chief Scientific Secretary A. Sorin, and Head of ICD D. Kamanin.

The sides marked the existing close and fruitful cooperation of JINR and Azerbaijan and agreed on its further extending. They paid special attention to opportunities to develop cooperation within the NICA megascience project and in nuclear physics, radiation materials science, information technologies and radiobiology. They also stressed the important role of JINR in training high-quality scientific staff.

JINR Directorate was ready to support the initiative of the Azerbaijani side to hold a seminar of Azerbaijani staff members of JINR. JINR Director G.Trubnikov invited the Azerbaijani representatives to take part in the festive events on the 65th anniversary of JINR scheduled for July 2021.

On 18 March, a meeting was held as a videoconference of the JINR Directorate with the new Plenipotentiary of the Government of the Republic of Armenia to JINR, Chairman of the State Committee on Science of the RA Ministry of Education, Science, Culture and Sport S. Hayotsyan and his deputy A. Movsisyan.

JINR was represented at the meeting by Scientific Leader of the Institute V. Matveev, Vice-Directors S. Dmitriev and B. Sharkov, Advisor to JINR Director M. Itkis, Head of ICD D. Kamanin, Senior Researcher of DLNP G. Torosyan.

The sides discussed urgent issues of cooperation of JINR with scientific centres of Armenia, marked the high level of cooperation and the potential of its further development, and considered some formal items, in particular, planning the contribution of Armenia to the JINR budget.

The Armenian colleagues stressed the expediency of continuation of work to locate a net of precision laser inclinometers (PLIs) in Armenia developed at JINR and informed JINR on the status of preparation of places to install PLIs in the RA territory by the Institute of Geophysics and Engineer Seismology of RA NAS and the Service of Seismic Protection of the RA Ministry of Emergency Situations. S. Hayotsyan marked high interest of colleagues from the Institute of Mechanics of RA NAS in obtaining and analyzing of data from the PLI net to study mechanisms of generation of earthquakes and their early prevention.

The sides also marked with satisfaction the results of joint efforts in testing crystals of the calorimeter for the Mu2e experiment at the electron beams of LUE-75 of the Yerevan Physics Institute in the mode of the lowest intensities necessary for the experiment, and expressed their hope to continue cooperation in this direction.

There was also a discussion of plans to hold in October the 5th International Conference "Modern Problems in Genetics, Radiobiology, Radioecology, and Evolution" dedicated to N. W. Timofeev-Ressovsky and his scientific school in Armenia, in the context of celebration of the 65th anniversary of JINR.

On 24 March, Extraordinary and Plenipotentiary Ambassador of the Czech Republic to RF V. Pivoňka and accompanying persons visited JINR.

The Czech diplomats took part in the festive ceremony of opening the hotel "Dubna" (Moskovskaya street, 2), that was repaired by the Czech building company ASARKO on the order of JINR, and visited the multimedia exhibition on the 65th anniversary of the Institute. The delegation had an excursion to VBLHEP to become acquainted with the status of implementation of the scientific flagship of JINR — the megascience project NICA. During the visit, an informal meeting of V. Pivoňka with representatives of the Czech national group at JINR was held, where the work of Czech staff members at JINR was highly evaluated.

At the JINR Directorate the delegation was received by JINR Director Academician G. Trubnikov, JINR Scientific Leader Academician V. Matveev, JINR Vice-Director R. Lednický and Head of ICD D. Kamanin. The meeting was also participated by the Deputy Plenipotentiary of the Government of the Czech Republic to JINR I.Štekl and Head of the national group of the Czech Republic at JINR V. Chudoba.

G. Trubnikov marked the active and fruitful participation of Czech scientists in scientific and organizational activities of JINR, and considerable contribution of high-tech Czech enterprises to the development of scientific infrastructure of the Institute. The sides especially stressed the importance of intensification of work to attract young people to science and training high quality staff, and discussed the organization of Days of the Czech Republic at JINR scheduled for October. On behalf of the Ministry of Foreign Affairs and the Ministry of Education of the Czech Republic, V. Pivoňka invited G. Trubnikov to visit the Czech Republic as soon as the epidemiological conditions allow it.

Extraordinary and Plenipotentiary Ambassador of the Czech Republic to RF V. Pivoňka congratulated the Joint Institute on its 65th jubilee. The visit of the Ambassador of the Czech Republic was covered by Czech tele- and radio companies. JINR Director G. Trubnikov also gave them an interview.

On 22–26 March, a working visit to JINR was held of the General Director of the Institute of Nuclear Physics (INP) of the Ministry of Energy of the Republic of Kazakhstan, Plenipotentiary of the Government of RK to JINR B. Karakozov and Director of the Department of INP in Astana M. Zdorovets.

On 23 March, a meeting was held at the JINR Directorate with participation of JINR Director G. Trubnikov, JINR Scientific Leader V. Matveev, Vice-Directors R. Lednický and S. Dmitriev, JINR Director Advisor M. Itkis, and Head of ICD D. Kamanin. The RK national group at JINR was represented by its leader A. Isadykov, his deputy D. Aznabaev and INP Vice-General Director on Science D. Dzhanseitov.

During the meeting, the sides marked the high level of cooperation and active participation of young scientists of the Republic of Kazakhstan in scientific projects of JINR, discussed opportunities to extend cooperation, in particular, the joint development of the INP accelerator complex. JINR leaders liked the initiative of the Kazakh colleagues to hold one of the next conferences of JINR young scientists and specialists in Almaty. B. Karakozov invited JINR representatives to take part in the International Scientific Forum "Nuclear Science and Technology" in September 2021.

The guests visited VBLHEP where they were acquainted with the NICA complex under construction and the factory of superconducting magnets. At FLNR the delegation visited the Factory of Superheavy Elements on the basis of the new DC-280 accelerator and the Nanocentre, had a meeting with FLNR Director S. Sidorchuk and discussed with him directions of cooperation. During the visit to FLNP, in addition to an excursion to the research reactor IBR-2, the guests had a meeting with the leaders of the Laboratory and discussed the present status and development of cooperation, in particular, in the construction of the multifunctional diffractometer at INP.

On 24 March, a meeting was organized of the guests with the national group of the Republic of Kazakhstan in the format of a seminar of Kazakh staff members of JINR.

On 25 March, Plenipotentiary of the Government of the Republic of Kazakhstan B. Karakozov took part in the JINR CP session and festive events on the 65th anniversary of JINR.

On 26 March, Ambassador Extraordinary and Plenipotentiary of the Federal Republic of Germany to the Russian Federation G. A. von Geyr and accompanying persons visited the Joint Institute for Nuclear Research. JINR Director Academician G. Trubnikov, Scientific Leader of the Institute Academician V. Matveev, and representatives of the JINR management welcomed the important guest at the JINR Directorate.

The parties discussed prospects for the enhancement of German participation in JINR, as well as capabilities of the Joint Institute for the staff training. In particular, participants of the event discussed the first international DD School (Dubna–Darmstadt) scheduled for spring 2022 and organized jointly by JINR and FAIR/GSI. The parties also discussed the prospects for the integration of science, culture, and arts. Thus, a good opportunity for the popularization of joint scientific projects was a summer festival in Germany organized by the German party in the framework of the Year of Germany in Russia 2021.

As a part of the visit to JINR, the German delegation was acquainted with the objects of the JINR scientific infrastructure. German Ambassador visited the Veksler and Baldin Laboratory of High Energy Physics where JINR Vice-Director V. Kekelidze acquainted him with the progress of the NICA megascience project and the factory of superconducting magnets. At the Flerov Laboratory of Nuclear Reactions, FLNR Director S. Sidorchuk welcomed the distinguished guest. In addition, H. E. Ambassador visited a multimedia exhibition at the JINR Cultural Centre "Mir" dedicated to the jubilee of the Joint Institute, its history, and research fields.

On 9 April, a delegation of the International Bank for Economic Cooperation (IBEC) headed by Chairman of the IBEC Board D. Ivanov visited JINR. During the visit, the IBEC representatives had a meeting with JINR leaders, as well as visited VBLHEP where they were acquainted with the implementation of the JINR flagship project "NICA Complex".

IBEC is an international financial organization with the headquarters in Moscow. It was established in 1963; its charter is registered in the UN. Members of IBEC are Bulgaria, the Czech Republic, Mongolia, Poland, Romania, Russia, Slovakia, and Vietnam.

JINR Director G. Trubnikov headed the JINR party at the meeting with the IBEC delegation. The JINR party was also represented by Vice-Director V. Kekelidze, Chief Engineer B. Gikal, heads of JINR offices and services. The parties noted successful cooperation between JINR and IBEC, which began in 2019 and in the framework of which the Bank ensured the interaction of the Institute with the Frako-Term Sp. z o.o. Polish company and the Vacuum Praha Czech company both supplying equipment for the NICA project.

Participants of the meeting considered IBEC proposals in the fields of lending, investment of funds, settlement and cash services, and investment financing of projects. The parties discussed opportunities for IBEC participation in the financial side of

the implementation of the Institute's projects in the Member States and JINR partner countries.

On 19 April, the 16th international training programme for decision-makers in science and international scientific cooperation JEMS — "JINR Expertise for Member States and Partner Countries" (JEMS-16) started at JINR. This training programme gathered representatives of Belarus, Bulgaria, and Russia.

The basic part of the JEMS-16 programme was grouped into the scientific blocks scheduled for separate days of the training programme: "Heavy Ion Physics and Accelerator Technologies", "Neutron Applications and Nanoworld", "Neutrino, Theory, Information, Education", "Life Sciences on the Earth and in Space", and "Neutrino and Particle Physics". The participants were acquainted in detail with the Institute, had lectures, meetings with leaders and specialists of the Laboratories. The guests visited the objects of the research infrastructure and attended the traditional round table with the Institute's Directorate.

On 21 April, JINR Vice-Director L. Kostov greeted the participants of the round-table discussion. The participants discussed the concept and aims of Information Centres of JINR. It was suggested that JINR Information Centres' sites should be used for joint work in modernization of the educational process as a whole and improvement of virtual educational programmes of UC JINR.

On 22 April, JINR Director Academician G. Trubnikov and Director General of the Special Economic Zone "Dubna" A. Afanasiev signed an agreement to develop the technological cooperation of the Joint Institute for Nuclear Research with production resident partners of the Special Economic Zone "Dubna". The signing ceremony took place at a festive event organized in honour of the 15th anniversary of the SEZ "Dubna". The agreement included the introduction of applied scientific research of the Institute in industrial, medical, and other technical developments, mutual scientific and technical help, and the use of the infrastructure and human resources of the parties to increase the efficiency of innovation activities.

The programme of the event also included the presentation of Awards for the best scientific and technical projects for students, postgraduates, and schoolchildren. This joint JINR–SEZ "Dubna" scientific and educational project started in 2021.

On 22 April, a meeting of representatives of the JINR leadership headed by JINR Director G. Trubnikov with a delegation of the Irkutsk State University (ISU) was held. The ISU delegation was represented by Rector of the University A. Schmidt, Dean of Faculty of Physics N. Budnev, and Director of the Research Institute of Applied Physics A. Tanaev. The delegation arrived at JINR to take part in the international training JEMS-16.

At the meeting in the JINR Directorate, the parties discussed opportunities for the cooperation development and mutual strengthening of its potentials by the launch of new joint scientific and educational projects. In particular, participants discussed in detail the organization of a joint JINR–ISU astrophysical laboratory to conduct experimental and theoretical studies in the field of particle astrophysics on the basis of the Baikal-GVD and TAIGA projects.

On 12 May, Ambassador Extraordinary and Plenipotentiary of the Republic of Cuba to the Russian Federation J. A. Garmendia Peña visited JINR. He visited the Institute's Laboratories and the interactive exhibition dedicated to the 65th anniversary of JINR, as well as had a meeting with JINR Director G. Trubnikov.

Participants of the meeting discussed the issues of expanding the range of joint research, in particular, in the fields of radiobiology and life sciences. It was noted that JINR facilities provide great opportunities for radiation and medical studies: the use of radiosensibilizers, flash therapies, studies of radiopharmaceuticals. Besides the use of JINR scientific infrastructure by Cuban scientists, the parties confirmed their intention to revive internships for Cuban students coming to JINR, as well as to organize trainings for university and school teachers at JINR.

The Cuban delegation visited the NICA complex, the factory of superconducting magnets, the Superheavy Element Factory, and the Nanocentre. In addition, the delegation met with JINR employees sent to work from the Republic of Cuba.

On 13 May, a delegation of the Vitus Bering Kamchatka State University (KamSU) represented by Acting Rector E. Merkulov and Vice-Rector for Science, Innovation, and International Affairs V. Efimenko visited JINR. The aim of the delegation's visit was the acquaintance with JINR and discussion of areas for the cooperation development.

The guests got acquainted with a number of objects of the Institute's scientific infrastructure: they visited the NICA complex under construction and the factory of superconducting magnets at VBLHEP, the Superheavy Element Factory and the Nanocentre at FLNR, the Radiochemical Laboratory and the Precision Laser Metrology Laboratory of DLNP, as well as the spectrometer complex of the IBR-2 fast pulsed reactor at FLNP. The delegation also visited the interactive exhibition dedicated to the 65th anniversary of JINR.

Scientific Leader of the Institute Academician V. Matveev welcomed the KamSU delegation. JINR Chief Scientific Secretary S. Nedelko, Head of the International Cooperation Department D. Kamanin, and Director of the University Centre S. Pakuliak also took part in the event. They discussed the practical content of the framework cooperation agreement signed in 2018, the participation of professors and students of KamSU in JINR internships, including in

the online programme INTEREST focused on practical research work. The participants considered the training of personnel within the framework of joint projects both for the development of the Kamchatka territory and for future work in the JINR projects.

On 18 May, the online conference "Perspective of Collaboration Development between JINR and IN2P3 in the Next Decades" was held. The event was organized on the occasion of the joint anniversaries: the 65th for JINR and the 50th for the French National Institute of Nuclear and Particle Physics (IN2P3).

The aim of the conference, which gathered over 60 participants, was discussion of results of long-standing cooperation between two Institutes and prospects for new joint projects.

The talks were thematically divided into six sections: nuclear physics, SPD physics, computing, neutrinos, radiobiology, and accelerators. The parties discussed common interest in the experiments on the synthesis of superheavy elements and the study of their properties. In this regard, a field for cooperation development in the framework of research conducted at the Superheavy Element Factory of FLNR JINR and at the S3 spectrometer of the GANIL French National Centre was defined. Participants noted prospects for joint studies in the fields of nucleon structure and the generalized parton distribution in them at the Electron-Ion Collider (EIC) in the USA and at the SPD detector of the NICA complex. Participants presented research on neutrino physics carried out in the Baikal-GVD, KM3NeT, and RICOCHET projects that provide wide opportunities for the exchange of technologies and data processing methods. Regarding radiobiological studies, the parties paid special attention to research on damages in the central nervous system under radiation and the mechanisms of DNA repair, which is of interest for space programmes. Participants also highlighted opportunities for joint research at the cellular level with the use of the U-400 cyclotron at FLNR.

The sides confirmed mutual interest in further cooperation enhancement and noted that a wide range of common interests indicates the necessity to hold one more such conference to present projects in other areas of research. Representatives of the Joint Institute also reminded about an opportunity of preparing PhD at JINR and invited French researchers to Dubna for participation in experimental programmes.

On 3 June, a regular meeting of the JINR STC was held where presentations of all members of the new Directorate were delivered with information on activities in the trends and tasks for 2021.

JINR Director G. Trubnikov noted a technological run with an ion beam in the Linac–Booster–Nuclotron chain at VBLHEP JINR in June and the adjustment of the Booster–Nuclotron beam channel for the autumn run. At the Superheavy Element Factory (FLNR), a 27-day run on the synthesis of Fl in the reaction $^{48}Ca + {}^{242}Pu$ resulted in 43 decay chains of $^{286,287}Fl$ (earlier 25 chains in all decays). In late May, at the IBR-2 reactor (FLNP), the fifth cycle of the reactor power operation was completed, in which colleagues from Serbia and Egypt participated. In addition, irradiation of samples sent by mail from centres of the JINR Member States was performed. In April, data collection at eight clusters of deep underwater neutrino telescope Baikal-GVD was started. The programme of one of the largest neutrino conferences "Very Large Volume Neutrino Telescope" (VLVnT 2021), which took place in May, included 20 reports on this topic. G. Trubnikov highly evaluated the operation of MLIT Multifunctional Information and Computing Complex (MICC). He also remarked that in 2021, 14 degree-seekers defended their theses at JINR Dissertation Councils.

The JINR Director informed the STC members on the distribution of responsibilities in the new Directorate, the establishment of departments, and the gradual restructuring of the Institute management system. He paid special attention to the broadening of forms of international cooperation and the visibility of JINR research activities at all possible levels. G. Trubnikov also spoke about JINR's participation in preparation for opening the Lyceum named after Academician V. Kadyshevsky and repair of hotel "Dubna" in Moskovskaya Street. In his report, he also touched upon the establishment of the International Innovation Centre for Nuclear Physics Research. Director G. Trubnikov reported the revised action plan for 2021 on the implementation of decisions and commissions of JINR CP (March 2021, November 2020), and spoke about measures to prevent coronavirus infection.

JINR Vice-Director S. Dmitriev reported on the establishment of new departments of budget and economic policy, personnel and documentation, and development of property complex, and indicated the main stages of the project of the International Innovation Centre for Nuclear Physics Research. The milestones of the project will be applied innovative research under the project of a complex of superconducting rings at colliding heavy-ion beams at NICA; establishment of the DC-140 cyclotron at FLNR JINR for the development of technologies for radiation materials science, testing of radioresistence of electronic components, enhancement of technology and production of track membranes, and etc. (2021–2023); state-of-the-art radiochemical complex with a Class-I radiochemical laboratory for the development of methods of radioisotope production in photonuclear reactions for nuclear medicine at industrial electron accelerator (2022–2026); radiation biology: expanding research infrastructure of LRB, development of omics technologies, radiation neuroscience research, development of approaches of increasing beam therapy efficiency based on radiomodifiers (pharmaceuticals and transgene systems), search for new methods of targeted delivery (molecular vectors) of radiomodifiers and radionuclides to tumor cells; establishment of R&D centre on radiation ther-

apy for studies on the proton flash-therapy, new treatment planning; pencil beam methods, producing a superconducting p-cyclotron (230 MeV) as a pilot element for the future medical centre (2021–2024). To realize the main stages of the project on the Innovation Centre establishment, a roadmap had to be formulated (November 2021).

JINR Vice-Director V. Kekelidze spoke about the establishment of the Development of Digital Services Department, which is under his supervision in the Directorate. It comprises the Procurement and Logistics Service, the Division of Maintenance and Development of Information Systems, and the Group of Information-Technology Support.

JINR Vice-Director L. Kostov spoke about the establishment of an expert-analytical group, a working body to the JINR Director. It will prepare forward-looking decisions, as mandated by the JINR Director, jointly with a working group of experts under the CP Chair.

JINR Scientific Leader Academician V. Matveev acquainted participants of the meeting with the plan of action on preparing the new Seven-Year Plan for the Development of JINR for 2024–2030.

JINR Chief Scientific Secretary S. Nedelko introduced the structure of the Science Organization Department, and spoke about starting regular meetings with scientific secretaries of the Laboratories on the whole range of strategic and current tasks of scientific-technical work.

JINR Chief Engineer B. Gikal acquainted participants with the relevant JINR services and noted their main tasks.

LRB Director A. Bugay took the floor with the report "On the Project of the JINR Scientific Programme on Natural Sciences" where he spoke about the application of nuclear physical methods of JINR in natural sciences that cause growing interest.

On 8–12 June, General Director of the Institute of Nuclear Physics (INP) of the Ministry of Energy of the Republic of Kazakhstan, Plenipotentiary of the Government of the Republic of Kazakhstan to JINR B. Karakozov visited JINR. The programme included a visit to the Flerov Laboratory of Nuclear Reactions where a number of working meetings with the management and leading Laboratory's scientists were organized. Moreover, B. Karakozov met with the national group of Kazakhstan at JINR. He listened to the reports on the group's work, met responsible employees in the Laboratories of the Institute, as well as discussed a grant programme of the Plenipotentiary of the Government of the Republic of Kazakhstan.

On 10 June, a meeting was held with JINR Director Academician G. Trubnikov. At the meeting, the sides highly evaluated the cooperation between JINR and the Republic of Kazakhstan. They discussed in detail the issues of reconstruction of the accelerator complex on the basis of U-150M at the Institute of Nuclear Physics and noted the necessity to work out the physics programme at the facility. The sides also discussed the establishment of JINR department on the INP basis, development of cooperation in theoretical and experimental physics of particles and heavy ions, in particular, as part of possible participation of INP in the ATLAS and CMS experiments at the LHC at CERN. They also discussed prospects of joint programmes of research in hydrogen energetics.

The Joint Institute for Nuclear Research and the National Research Centre "Kurchatov Institute" agreed on joint implementation of socio-humanitarian projects. The agreement was signed **on 11 June** at a meeting of the Scientific Council of the NRC "Kurchatov Institute".

The agreement signed at the meeting of the Scientific Council concerns the joint implementation of educational projects and programmes, festivals, and other events. Moreover, the NRC "Kurchatov Institute" and JINR enhance scientific interaction. One more cooperation area will be the formation of the scientific personnel reserve. At the meeting, Scientific Leader of the Flerov Laboratory of Nuclear Reactions of JINR RAS Academician Yu. Oganessian was awarded the title of Honorary Doctor of the NRC "Kurchatov Institute".

On 13 June – 13 July, a regular Internship for young scientists from the CIS countries was held in Dubna. The Internship was held by the International Innovative Nanotechnology Centre of the CIS countries (InINCIS) with the support of the Intergovernmental Foundation for Educational, Scientific and Cultural Cooperation and the Joint Institute for Nuclear Research.

Young scientists and specialists from the CIS countries, who conduct research, development, or project work individually or as part of a team, were invited to participate in the event. The selection of participants was carried out on a competitive basis.

Participants of the Internship got acquainted with the JINR activities in detail, its scientific and educational programmes, objects of the scientific and research infrastructure, as well as the Special Economic Zone "Dubna".

On 17 June, a new Laboratory of Electronics and Microprocessor Technologies was officially opened on the basis of the International Engineering School of Dubna State University. The Laboratory was established with the support of the Joint Institute for Nuclear Research and with the active participation of specialists of the Accelerator Department of VBLHEP. The opening ceremony was attended by Vice-Director of the Joint Institute V. Kekelidze, UC Director S. Pakuliak and Rector of Dubna University D. Fursaev.

The Laboratory is provided with state-of-the-art test equipment and computers with professional software, including an assembly workshop. The involvement of experienced teachers (leading develop-

ment engineers of VBLHEP JINR) in the Laboratory, combined with modern tools for development, diagnostics, measurement and testing of electronic means, will raise the process of educating students in engineering and technology areas at Dubna University to a higher level and facilitate the entry of young professionals into the work on practical challenges arising at the NICA accelerator complex and other basic facilities of JINR.

On 18 June, an online meeting was held of the leaders of JINR and the European Physical Society (EPS) where the sides agreed on participation of EPS students in the student programmes of JINR.

Participants of the event discussed issues of the cooperation of scientists within scientific groups of the two organizations, as well as identified areas of common interest for their further development. The EPS representatives highlighted theoretical physics, particle physics, nuclear physics, and high-performance computing as promising realms for co-organizing schools and conferences. Moreover, the parties outlined the prospects for cooperation in terms of internships and programmes organized by the JINR University Centre and the Association of Young Scientists and Specialists of JINR (AYSS).

On 6 July, a leadership delegation of the Peoples' Friendship University of Russia (RUDN University) visited JINR. During the visit, bilateral agreement was signed on joint training of staff in the fields of physics, mathematics, IT, and life sciences, as well as on cooperation in the realm of research activities with the use of JINR's unique equipment. JINR Director G. Trubnikov and RUDN Rector O. Yastrebov signed the agreement in the presence of JINR Scientific Leader V. Matveev and RUDN President V. Filippov.

The Joint Institute for Nuclear Research and the RUDN University agreed to conduct regular joint basic and applied studies, as well as integrate scientific-educational and scientific-research programmes, thus improving personnel training in the following scientific areas: particle physics and nuclear physics, condensed matter physics, theoretical and mathematical physics, mathematical modelling and computing physics, networks, computer technologies, life sciences.

The RUDN delegation visited VBLHEP, where the RUDN representatives learned about the progress in the implementation of the NICA megaproject and the factory of superconducting magnets, visited the FLNR Nanocentre and MLIT.

On 16 July, Ambassador Extraordinary and Plenipotentiary of Romania to RF C. Istrate visited JINR. He met with Romanian scientists who work at JINR and visited the interactive exhibition at the Culture Centre "Mir" dedicated to the 65th anniversary of JINR.

At the JINR Directorate, participants of the meeting in Dubna discussed Days of Romania at JINR within the framework of which it was planned to organize an exhibition of Romanian technological enterprises for the development of technical cooperation between the countries.

Opening the meeting, JINR Director G. Trubnikov highlighted that Romania is one of the active participants of the Institute's scientific life. Staff members of leading Romanian scientific centres take part in the JINR flagship project NICA and other projects. Romanian scientists work with Dubna colleagues in CERN projects, as well as in studies of dense baryonic matter at the GSI accelerator complex (Darmstadt).

On 19 July, Plenipotentiary of the Government of the Slovak Republic to JINR F. Šimkovic met with the JINR Directorate. At the meeting, participants discussed strategic aims of the interaction development, in particular, the increase in the presence of young Slovak scientists at JINR, including students and postgraduates, as well as the increase in participation of high-tech enterprises of Slovakia in the JINR projects.

F. Šimkovic arrived at JINR with a one-week visit, the programme of which included some meetings. It included, in particular, participation in the first meeting of the Working Group on Strategic Issues established by the Committee of Plenipotentiaries, holding an online round table with high-tech companies of Slovakia, working discussions with leaders of the JINR Laboratories and management offices of the Institute, and a meeting with the national group of Slovakia at the Institute.

On 21 July, Ambassador Extraordinary and Plenipotentiary of Bulgaria to the Russian Federation A. Krastin visited JINR. The Ambassador arrived in Dubna accompanied by Director of the Bulgarian Cultural Institute in Moscow V. Boichev. At the meeting with JINR leaders, ways to enhance cooperation were discussed and, in particular, preparation for the coming CP session in Bulgaria, including suggestions to hold meetings and high-level events within the framework of the CP. Among the key events of 2021, which was declared the Year of Bulgaria at JINR, the parties discussed the opening of Information Centre of JINR in September in Sofia University.

At the end of the meeting, Mr Ambassador and members of the Bulgarian party together with JINR leaders took part in the opening ceremony of the exposition "Natural and Cultural Heritage of Bulgaria" in the dormitory at Moscovskaya str., 2. The programme of the visit included a tour around the Flerov Laboratory of Nuclear Reactions of JINR, where the Bulgarian representatives got acquainted with the Superheavy Element Factory. The high guests also visited the multimedia exhibition dedicated to the 65th anniversary of JINR at the Cultural Centre "Mir".

On 22 July, the first meeting of the Working Group on Strategic Issues (WGSI) was held in a

mixed format. The Group was established by the decision of the Committee of Plenipotentiaries of JINR in March 2021. Experts and specialists from 15 JINR Member States appointed to its membership by decisions of Plenipotentiaries, the President of the Vietnam Atomic Energy Institute (VINATOM), as well as Plenipotentiaries of the Governments of the Czech Republic, Cuba, Georgia, Poland, Slovakia, and Vietnam took part in the event. Participants of the meeting decided to elect the representative of the Czech Republic I. Štekl as the WGSI Chairman.

JINR Vice-Director L. Kostov spoke about the WGSI organizational basics and expressed confidence that this Working Group would be a reliable tool contributing to closer participation of the Member States in the JINR activities, and increasing the spread of information and the degree of elaboration of issues for discussion by Plenipotentiaries at CP meetings.

JINR Director G. Trubnikov presented a brief overview of major results and events in the life of the Institute over several months since the new JINR Directorate took up the duties.

Participants of the event considered the draft of regulations on associate membership in JINR presented by JINR Special Representative to Russian and International Organizations B. Sharkov. Adviser to the JINR Directorate M. Tumanova presented the draft regulations on the JINR flag. At the end of the discussion, the WGSI members made the proposal on submitting the drafts of these documents for discussion by Plenipotentiaries at the November CP session in Sofia with a view of the comments made. A general discussion and signing of the final protocol concluded the meeting.

On 23 July, JINR Director G. Trubnikov met with the leadership of the Academy of Scientific Research and Technology of Egypt (ASRT) — President M. Sakr and Vice-President G. El-Feky. Ambassador Extraordinary and Plenipotentiary of the Arab Republic of Egypt to the Russian Federation I. Nasr took part in the meeting accompanied by the first Advisor of the Embassy M. Elvi. Head of the national group of Egypt at JINR W. Badawy represented Egyptian employees.

The central topic of the meeting was the discussion of the possibility of participation of Egypt in JINR up to the full membership. To work on this issue and set particular tasks in fundamental science, innovations, staff training, and information work, the parties agreed to establish a joint expert group and organize a number of workshops. Among the promising areas of cooperation with JINR, representatives of the ARE also noted the experience and rich connections of the Institute with universities of the Russian Federation.

The visit of the ASRT delegation also included acquaintance with the JINR scientific infrastructure. The guests visited LRB, MLIT, the multimedia exhibition dedicated to the 65th anniversary of JINR and met with leaders of the JINR University Centre.

The ASRT delegation took part in the ceremonial meeting on the occasion of the 65th anniversary of JINR and the city of Dubna and in the festive opening of the panel "Mendeleev's Periodic Table" on the Volga embankment.

On 6–10 September, a workshop "Ukraine–JINR Collaboration Prospect", timed to the 65th anniversary of the Joint Institute for Nuclear Research, was held at institutes of the National Academy of Sciences of Ukraine as a hybrid event. The meeting was opened by Plenipotentiary of the Government of Ukraine to JINR B. Grinev. JINR Vice-Director L. Kostov spoke about the key directions of the Institute's development.

The JINR delegation included Ukrainian staff members who presented the results of their scientific research carried out at the JINR basic facilities. The participants were particularly interested in reports on such an urgent area of scientific research as the development of new types of scintillation materials for the production of detectors of high-energy particles. Examples of the efficient use of such detectors produced at the Institute for Scintillation Materials of the National Academy of Sciences of Ukraine in various experiments at CERN were given. The parties discussed the possibility of applying such devices in the MPD and SPD experiments of the NICA collider at JINR. Workshop participants expressed their keen interest in the User Programme implemented at the IBR-2 reactor at FLNP. As a result of discussions, joint studies of nanomaterials based on silicon and vanadium oxide were planned using the capabilities of neutron scattering methods at the spectrometers of the IBR-2 reactor.

As part of the meeting, an excursion to the new nuclear research facility at the National Science Centre "Kharkiv Institute of Physics and Technology" took place. After the excursion, a round table was held with the participation of representatives of the JINR Directorate and heads of the JINR Laboratories via a videoconference. At the round table, the opportunities for cooperation development between Ukraine and JINR on the production and operation of neutron spectrometers based on the created neutron source were discussed.

On 9 September, JINR Vice-Director L. Kostov met with President of the Republic of Bulgaria R. Radev in his residence in Sofia. The parties discussed the prospects for the development of the partnership between Bulgaria and JINR in the field of fundamental and applied scientific research. Participants of the meeting noted a considerable contribution made by Bulgaria to scientific studies of the Institute throughout the JINR history. Annually, about 100 Bulgarian researchers have working visits to JINR.

The year 2021 was declared the Year of Bulgaria at the Joint Institute for Nuclear Research. At the

meeting, R. Radev accepted the invitation extended by L. Kostov to become an official guest at the festive session of the Committee of Plenipotentiaries of JINR dedicated to the 65th anniversary of JINR. The session was planned to be held in Sofia in November 2021.

On 13–14 September, a JINR delegation headed by JINR Director Academician G. Trubnikov paid an official visit to Cairo (ARE). The delegation took part in the event "Arab Republic of Egypt (ARE)–Joint Institute for Nuclear Research (JINR): Today and Tomorrow", organized under the guidance of the Academy of Scientific Research and Technology of Egypt (ASRT). The agenda also included a meeting of the JINR Directorate with the ASRT President, the Minister of Higher Education and Scientific Research of Egypt, representatives of the Embassies of the JINR Member States, and leaders of higher educational institutions and research institutes of ARE.

The first event of a scientific workshop was the plenary session "Strategic Opportunities for Advancing Global Collaborative Perspectives towards Achieving 2030 Main Research Goals". JINR Director G. Trubnikov, who acquainted the audience with JINR's research areas, basic facilities and educational opportunities, as well as development strategy of the Institute, opened the session.

The participants of the ceremonial opening of the event were welcomed by Chairman of the Egyptian Atomic Energy Agency (EAEA) A. El-Hag Ali, President of ASRT M. Sakr, and Minister of Higher Education and Scientific Research of Egypt H. Abdel-Ghaffar. The welcome addresses on behalf of the JINR Member States were delivered by: Ambassador of the Russian Federation to Egypt G. Borisenko — on the part of the JINR's country of residence; Ambassador of Romania to Egypt M. Stuparu — on the part of the country chairing the JINR Committee of Plenipotentiaries in 2021; Ambassador of Bulgaria to Egypt D. Angelov — on the part of Bulgaria and in honour of the Year of Bulgaria declared in JINR. Among the participants of the meeting, there were the Ambassador of the Czech Republic, representatives of the Embassies of Kazakhstan, Hungary, and Slovakia.

Topical parallel sessions were held with the participation of representatives of JINR Laboratories, as well as Egyptian universities and research centres.

On 14 September, a full-time opening of the JINR Information Centre, which was opened in an online format in December 2020, took place at the headquarters of ASRT.

On 15–16 September, the International Round Table on Applied Research and Innovations at NICA was held at JINR. The session was focused on the informing the general scientific community about new capabilities of the NICA complex for applied research in biology and medicine, the study of radiation hardness of semiconductor devices, radiation materials science, and development of advanced nuclear power technologies.

Over two active days, about 300 scientists from Australia, Belarus, Belgium, Brasil, Bulgaria, China, the Czech Republic, Germany, Italy, Japan, Moldova, Romania, Russia, South Africa, the USA, Uzbekistan, as well as from international organizations — the European Animal Research Association (EARA), the European Space Agency (ESA), CERN, JINR, research institutes, research and production companies, educational institutions and the media, took part in the Round Table. The session of the Round Table was held in a format combining remote participation with the full-time presence of JINR employees and a number of Russian organizations.

The Round Table was opened by JINR Director Academician G. Trubnikov, who accented its opportune holding to discuss the policy of using beams for applied research and determining the interest of the scientific community in organizing an international programme of users of the NICA complex in terms of applied research.

Leader of the NICA project, JINR Vice-Director V. Kekelidze, spoke about its current status. He noted that along with gaining new knowledge in the field of fundamental science, research in the fields of power industry, microelectronics, radiobiology and much more is of great importance. The prospects of launching full-scale applied research at the NICA complex were noted as a factor for expanding the scope of activities of young scientists, developing JINR tools for staff training and education.

On the first day, during the Round Table sessions, along with a widely presented range of JINR applied research, reports were made by leading scientists from the European Space Agency, CERN, as well as specialists from research centres in Australia, the Czech Republic, Germany, Italy, Japan, Russia, South Africa, and the USA. M. Durante (GSI, Germany), A. Sorin (JINR), T. Hei (Columbia University, USA), and O. Belov (JINR) moderated the sessions of the first day. At the end of the first day, the participants had a hybrid (in-person/virtual) excursion to the NICA complex.

On the second day of the event, Ch. Trautmann (GSI, Germany), P. Apel (JINR), H. Sakurai (RIKEN, Japan), M. Paraipan (JINR), and I. Rudnev (NRNU MEPhI, Russia) moderated the session. Scientists discussed the development of nano- and microstructured materials at the new collider, testing the radiation effect on electronic devices, simulating experiments on nuclear planetology, and applied work on the development of new nuclear power technologies.

Following the results of the sessions of the second day, a Memorandum was signed in which the participants of the event noted the significant interest of the scientific community in the organization of applied research at the NICA complex and expressed their opinion on a number of strategic issues on the further development of the work.

The participants of the Round Table approved the proposed name of the infrastructure for applied research at the NICA complex, combining the created channels, — ARIADNA (Applied Research Infrastructure for Advanced Developments at NICA fAcility) and the corresponding logo.

An Advisory Committee on Applied Research and Innovations on ARIADNA channels was formed to further develop the project of the identified strategic initiatives by the NICA project leadership. The first meeting of the Advisory Committee took place immediately after the end of the open part of the Round Table.

On 16 September, on the sidelines of the International Round Table on Applied Research and Innovations at NICA, the JINR Directorate had a meeting with representatives of the RAS Institute of Biomedical Problems (IBMP RAS) headed by Director of IBMP, Academician O. Orlov.

The main subject of the meeting was the discussion of new prospects for the implementation of research using ion beams of the NICA complex related to practical safety issues of manned space flight, and as well as fundamental issues of space biology and medicine, which could open a new page in the history of interaction between the two institutes.

The issues of integration of IBMP RAS into the NICA megascience project collaboration were raised, as well as attracting experienced personnel from specialized scientific institutes with a broad analytical base for obtaining and processing results. The issues of joint participation of the two institutes in various international programmes were discussed based on the experience of IBMP RAS in cooperation with partner organizations of different countries in the field of space and related research. In the terms of specific requirements for irradiation parameters at the NICA complex, it was suggested to work in the "multi-ion" beam mode, which implies a quick change of the ion type and energy.

On 15–18 September, JINR delegation headed by Vice-Directors L. Kostov and V. Kekelidze visited Sofia as part of a series of events dedicated to the 65th anniversary of the Institute and the Year of Bulgaria at JINR, organized by the Institute jointly with the Bulgarian Nuclear Regulatory Agency (BNRA).

The Bulgarian side was represented at the events by the Plenipotentiary of the Government of Bulgaria to JINR, Chairman of BNRA Ts. Bachiyski, employees of the Ministry of Education and Science of the Republic of Bulgaria and the Bulgarian Academy of Sciences, as well as the staff of research centres involved in joint projects with JINR.

The programme of the visit started on 15 September in Sofia South Park, where a new recreation area was arranged with the assistance of JINR, BNRA, and Kozloduy NNP. This "green initiative" has not only improved territory of one of the largest parks, but will also help attract the attention of the Bulgarian community to the activity of JINR.

On 16 September, the first in the European Union JINR Information Centre based on the Faculty of Physics of Sofia University "St. Kliment Ohridski" was solemnly opened. Within the framework of IC opening, agreements aimed at widening cooperation between JINR and Sofia University in scientific-research and innovation activities, staff training and popularization of natural science were signed.

On 17 September, a festive scientific session "65 Years of Bulgaria–JINR Cooperation" took place at the Central Military Club. Reports on the contribution of Bulgarian scientists to the JINR development and participation of Bulgaria in the JINR–CERN cooperation were included in the agenda of the meeting. The topics of JINR research areas, including particle physics, neutron physics, heavy-ion physics and computing were considered. Besides, the JINR Long-Term Development Strategy up to 2030 and beyond was presented.

Within the framework of JINR anniversary year and the Year of Bulgaria at JINR, the Bulgarian Nuclear Regulatory Agency supported publication of the book "65 Years of Bulgaria in JINR". The book covers the history of JINR starting from its foundation up to the present, tells about the Laboratories of the Institute and participation of Bulgarian researchers in each of them, as well as major events within cooperation — meetings, workshops, schools, etc.

On 24 September, as part of the celebration of the 65th anniversary of JINR, Ambassadors Extraordinary and Plenipotentiary of the Czech Republic, the Republic of Poland, and the Slovak Republic to the Russian Federation arrived in Dubna.

A round-table meeting with the JINR Directorate in the large hall of the JINR Scientists' Club gave start to the visit. JINR Director G. Trubnikov in his welcoming speech highlighted that the Czech Republic, Poland, and Slovakia — as founding states of JINR — have been taking an active part in the formation of the JINR scientific programme since the very beginning of the Institute's history.

The Ambassadors took part in the 130th session of the JINR Scientific Council, greeting and congratulating the JINR scientific community, the team and partners of the Institute on the 65th JINR anniversary.

Within the framework of the programme, the guests visited the interactive exhibition dedicated to the 65th anniversary of JINR where they left their notes in the visitors' book. The Ambassadors together with their accompanying delegations visited the MPD experimental hall and the factory of superconducting magnets at VBLHEP, met with the national groups of the Czech Republic, Poland, and Slovakia at JINR.

A festive start of work of the room stock in the dormitory at Moscovskaya str., 2 was timed to coincide with the visit of the honorary guests. An exposition was opened decorated with photographs of notable places of the Czech Republic kindly provided

by the Czech tourism development agency "Czech-Tourism". A short time before, in the Year of Bulgaria at JINR, a photo exhibition dedicated to the nature and culture of Bulgaria had been already opened in the hotel. An opening ceremony of a commemorative plaque continued the programme. The plaque was installed with the participation of JINR Vice-Director L. Kostov and the distinguished guests, on the completion of the overhaul of the hotel for the 65th anniversary of JINR. Ambassadors from the Czech Republic, Poland, and Slovakia became the first guests of the newly opened hotel and left positive reviews.

On 24 September, an agreement was signed in St. Petersburg on uniting three supercomputers, including the object of the scientific infrastructure of the JINR Member States — the "Govorun" supercomputer — into a single network. Its aim is to develop the National Research Computer Network of Russia (NIKS). Rector of St. Petersburg Polytechnic University (SPbPU) A. Rudskoi, Director of the Joint Supercomputer Centre of the Russian Academy of Sciences (JSC RAS) B. Shabanov, and Director of MLIT JINR V. Korenkov signed the document in the presence of Deputy Prime Minister of the Russian Federation D. Chernyshenko.

Nowadays, NIKS, created in 2019 on the assignment of the Ministry of Science and Higher Education of the Russian Federation, provides services to more than 150 institutions of higher education and science from 34 regions. The total number of users of the network exceeds three million people, thus making it not only the largest research and educational network of the country, but also one of the largest computer networks in the world. In the near future, it is planned to connect 40% of the total number of leading organizations and all 10 supercomputer centres of the country. Researchers and developers will be provided with global access to services of machine learning, big data analysis, supercomputer resources.

On 28–29 September, JINR delegation headed by JINR Director Academician G. Trubnikov and JINR Scientific Leader V. Matveev took part in the International Scientific and Practical Conference "30 Years of the Commonwealth of Independent States: Results, Prospects", which was held in Minsk. The Conference gathered more than 300 representatives of state bodies, bodies of the CIS, leading scientists and specialists, heads of the largest scientific and educational institutions from some countries, representatives of the diplomatic corps, and other participants.

As part of the working visit, on the first day of the Conference, JINR representatives took part in a meeting of the Council of the International Association of the Academies of Sciences (IAAS) at which JINR Director G. Trubnikov was unanimously elected a full member of IAAS. JINR Scientific Leader V. Matveev received the badge "IAAS Academician" in commemoration of his election as a full IAAS member in September 2020. JINR delegation took part in a meeting of the IAAS Council of Young Scientists.

On 7 October, JINR Vice-Director L. Kostov met with Vice-Rector for Science, Innovation, and International Affairs of the Vitus Bering Kamchatka State University (KamSU) V. Efimenko at the Directorate of the Joint Institute for Nuclear Research. During the meeting, the parties signed an agreement on the opening of the JINR Information Centre at KamSU. The signing was preceded by a discussion of the work of the future centre, aims and tasks of the activities and nearest efforts of its development. In the discussion, in particular, the successful experience was marked of the joint holding of the Kamchatka School on Elementary Particle Physics, and the start of cooperation in the use of the muon radiography method in volcano observation. Widening of interactions of scientific organizations of the region was discussed in the plans of the work of the new information centre.

On 18 October, a delegation of the Plekhanov Russian University of Economics (PRUE) headed by the Rector of the University, I. Lobanov, visited JINR to discuss prospects for expanding cooperation both in science and in the field of personnel training.

In a conversation with the JINR Directorate, the guests noted the existing cooperation: the Laboratory "Cloud Technologies and Big Data Analytics" headed by MLIT Director V. Korenkov was established on the basis of the University several years ago. Moreover, the University has been using the capacities of the Institute's big data processing hardware to process economic data. Participants of the meeting expressed a general desire to continue and extend mutually beneficial cooperation in this field.

The delegation members noted that, based on the successful experience of the Data Science Group and the Foresight Higher School being implemented by MLIT JINR, it was decided to create a separate faculty for training Bachelor and Master students in the field of big data analytics, as well as a Master course in supercomputer technologies. The parties also considered possibilities of participation of PRUE students in the JINR Student Practice, as well as in the INTEREST online programme in IT-related projects.

During the visit to JINR, the guests learned about the NICA megascience project and the factory of superconducting magnets at the VBLHEP site, as well as visited MLIT.

On 25 October, a meeting was held between the representatives of general contractor of the NICA project STRABAG and leaders of JINR. At the meeting, the parties considered the status of the object, as well as the status of the so-called MEP complex, i.e., mechanical, electrical, and plumbing systems. They also discussed possible increase in the pace of work

and improvement of efficiency of further contacts. STRABAG representatives visited the construction site of the complex and evaluated the progress in the creation of the NICA collider.

On 27 October, an agreement was signed in Dubna between JINR and the Leader of the International Research Centre (IRC) MBIR Consortium, JSC on cooperation in the field of basic scientific and applied research at the multipurpose fast neutron research reactor (MBIR). JINR Vice-Director L. Kostov and Director-General of the IRC MBIR Consortium K. Vergazov signed the document.

Rosatom State Corporation is constructing a unique research facility MBIR within the complex programme "Development of equipment, technologies, and scientific research in the area of nuclear energy use in the Russian Federation". Rosatom is building the reactor in Dimitrovgrad, Ulyanovsk Region, on the basis of the Joint Stock Company "State Scientific Centre — Research Institute of Atomic Reactors" (SSC RIAR JSC).

The agreement aims to promote the creation of the IRC MBIR for conducting scientific and technological research in nuclear physics, high energy physics and plasma, radiation materials science, and other promising scientific realms. One of the key areas of cooperation within the framework of the signed agreement will be the development and further coordination of the user policy of the project, as well as the formation of a research programme.

During the visit to JINR, a delegation of Rosatom representatives visited VBLHEP, where they got acquainted with the implementation of the NICA megascience project.

On 29 October, EU Ambassador to the Russian Federation M. Ederer accompanied by Plenipotentiary Minister, Head of Science and Technology of the EU Delegation to the Russian Federation L. Bochereau visited JINR.

At the meeting with JINR leaders, the guests discussed prospects of development of interactions of JINR and the European Union, including partnership in such programmes as CREMLINplus, ESRFI, as well as in events of the International Year of Basic Sciences for Sustainable Development 2022, whose co-organizer is JINR together with UNESCO. It was noted that the important aspect of cooperation is the strategic support by EU of the projects of fundamental research and projects of development of large-scale research infrastructure of the international centre in Dubna. The sides discussed opportunities to attract young talents from the countries of the European Union for research at the NICA Complex and participation in other JINR projects, holding meetings of attaché of science from the JINR Member States for discussion of instruments of scientific diplomacy, as well as the idea of organization of the exhibition "JINR: Science Bringing Nations Together", dedicated to bright scientific projects and results of the Institute, in the office of the European Union in Brussels.

The guests visited the NICA collider under construction and the factory of superconducting magnets. The high-level delegation also visited the Superheavy Element Factory based on the new DC-280 accelerator and the Nanocentre at the Flerov Laboratory of Nuclear Reactions. Moreover, the guests had a tour of the interactive exhibition "JINR Basic Facilities" dedicated to the 65th anniversary of JINR at the Cultural Centre "Mir".

From 8 to 12 November, the Joint Institute for Nuclear Research held the 19th International training programme "JINR Expertise for Member States and Partner Countries" (JEMS-19). Heads and specialists of research and educational institutions of Bulgaria and Serbia took part in this training programme. On the first day of the internship, heads of the diplomatic missions of both countries in the Russian Federation also joined the event — Extraordinary and Plenipotentiary Ambassador of Bulgaria to RF A. Krastin and Charge d'Affaires a.i. of the Republic of Serbia to RF S. Carić.

The year 2021 was announced the Year of Bulgaria at JINR. The visit of the representative delegation of Bulgaria for a detailed acquaintance with JINR was one of the events of the Year and was also a preparatory event for the session of the Committee of Plenipotentiaries of the Governments of the JINR Member States scheduled for November in Bulgaria. The visit of the Serbian delegation is connected with the Serbian side's elaboration of the accelerated fulfillment of the Roadmap of Cooperation and, consequently, planned considerable enhancement of Serbian participation in JINR.

A. Krastin and S. Carić, together with JEMS participants, got acquainted with the construction of the NICA superconducting complex. The participants continued learning about the Laboratories and facilities of JINR. Leading experts of the Institute delivered lectures on the current research fields. In addition, the guests were introduced to the international and educational activities of the Institute, and organization of the social infrastructure of the Institute.

On 9 November, a delegation of the Embassy of the United Mexican States to the Russian Federation headed by Ambassador N. B. Pensado Moreno visited JINR. At the meeting with representatives of the JINR Directorate headed by JINR Vice-Directors V. Kekelidze and L. Kostov, the existing experience of cooperation between the Joint Institute and Mexico, high potential of Mexican scientists, in particular, in theoretical physics, and their mutual interest in further strengthening of contacts were noted. The Mexican delegation took part in the work of JEMS-19, visited VBLHEP and FLNR and the interactive exhibition of JINR.

On 10 November, a ceremony of presenting regional awards to JINR staff members for fruitful

scientific and practical activities was held at the Flerov Laboratory of Nuclear Reactions during the visit of Governor of the Moscow Region A. Vorobiev to Dubna. The event was devoted to the World Science Day.

FLNR Scientific Leader Academician Yu. Oganessian was conferred the title of the Honorary Citizen of the Moscow Region — the highest regional award — for his outstanding contribution to the development of basic science and strengthening of international scientific-technical cooperation.

The Badge "For Merit to the Moscow Region" II degree was presented to Director of the Joint Institute for Nuclear Research Academician G. Trubnikov. JINR Vice-Director Professor S. Dmitriev received the Badge "For Merit to the Moscow Region" III degree. The Badge "For Merit to the Moscow Region" III degree was also presented to Deputy Scientific Leader of the JINR Flerov Laboratory of Nuclear Reactions Professor M. Itkis. Head of the FLNR Sector of Synthesis and Properties of Superheavy Nuclei V. Utenkov was conferred the Honorary Title "Honored Scientist of the Moscow Region". The Badge of St. Sergius of Radonezh was presented to FLNR Chief Technical Expert G. Gulbekian and to Head of the FLNR Accelerator Department V. Semin.

On 15 November, in the UNESCO Headquarters in Paris, in the framework of the 41st session of the UNESCO General Conference, the presenting of the UNESCO–Russia Mendeleev International Prize in the Basic Sciences was held. The laureates of the Prize Yu. Oganessian and V. Balzani (University of Bologna, Italy) received gold medals with the portrait of D. I. Mendeleev and honorary diplomas. The festive ceremony was conducted by Sh. Nair-Bedouelle, UNESCO Assistant Director-General for Natural Sciences. UNESCO Director-General O. Azule spoke at the ceremony. Head of the Prize jury Professor J.-P. Sauvage, the Nobel Prize Winner in Chemistry, addressed the laureates with congratulations.

On the Prize presentation day, President of Russia V. Putin sent a congratulatory telegram to Yu. Oganessian: "Dear Yuri Tsolakovich! I cordially congratulate you on the award of the UNESCO–Russia Mendeleev International Prize. The multifaceted activity you devoted your life to fully corresponds to the high mission of the Prize. The Prize, which is established on the initiative of Russia and named after a great Russian scientist Dmitry Ivanovich Mendeleev, aims to promote the development of international humanitarian cooperation, popularization of advanced scientific achievements. Of course, this prestigious award reflects a worthy evaluation of the results of your fundamental works, acknowledgement of outstanding, indisputable merits in the pedagogical, mentoring fields. I wish you further success, good health, and all the best. V. Putin."

On 15 November, the first webinar of JINR Information Centres "Along the Meridian: From the White Sea to Southern Africa" took place. A series of such meetings should promote communication of infocentres of the Institute. The webinar included about 100 participants.

JINR Scientific Leader Academician V. Matveev welcomed participants of the webinar. DLNP Deputy Director D. Naumov made a report "The Universe through the Baikal Neutrino Telescope (Baikal-GVD)".

Coordinators of the JINR Information Centres made welcoming remarks, starting with Director of the JINR IC in the South of Russia N. Pukhaeva, who noted a wide geographical coverage of the first IC: about a dozen scientific and educational institutions in the North Caucasus have already been involved into the orbit of the IC for three years of operation. Thanks to the Inforcentre, 4 out of 15 faculties of the North Ossetian State University cooperate with JINR.

M. Aish, Director of JINR IC in Cairo, noted in his welcoming speech that "fruitful cooperation between JINR and all the Information Centres will be achieved only by focusing on achieving the goals of these centres." Director of the new IC in Bulgaria D. Mladenov in his turn expressed the wish that webinars of this format would be a traditional site for communication of IC representatives.

Special guests of the webinar from iThemba LABS — Deputy Director R. Nchodu and Head of the Communications Group G. Arendse — noted the long-standing cooperation with JINR and plans of iThemba LABS on extending the network of cooperating institutions not only in Africa but also in the world scientific community.

The welcoming speech before the lecture was given by Head of the Scientific Documentation Department of the Arab Atomic Energy Agency (AAEA) N. Nasr. On behalf of AAEA Director-General S. Hamdi, she expressed gratitude to JINR for the support of the Agency provided within the Memorandum of Understanding, as well as for the support of plans on opening the IC and the virtual laboratory in Tunis in the AAEA Headquarters in summer 2022.

On 22 November, at the visiting session of the Committee of Plenipotentiaries of the Governments of the JINR Member States in Bulgaria, members of the Committee unanimously decided to raise the status of the Arab Republic of Egypt in JINR up to a full-fledged JINR Member State.

According to the Charter of JINR, participants of the CP session considered the application of the Arab Republic of Egypt on its wish to become a JINR Member State signed by Minister of Higher Education and Scientific Research of Egypt Kh. Abdel Ghaffar. Within the subsequent vote, all the JINR Member States unconditionally supported the proposal to make Egypt a JINR Member State.

According to the general opinion expressed by Plenipotentiaries, the accession of Egypt to the JINR

Member States will significantly contribute to the development of the Institute, will allow expanding its scientific programme and launching new interesting and ambitious projects.

President of the Academy of Scientific Research and Technology of Egypt (ASRT) M. Sakr expressed gratitude to the Committee of Plenipotentiaries of JINR and the JINR Directorate for the support provided. "As a guide to the scientific communities in the countries of North African, Middle Eastern, and Arab regions, Egypt will contribute to establishing partner contacts with JINR," M. Sakr highlighted.

On the Egyptian side, Director-General of the Arab Atomic Energy Agency (AAEA) S. Hamdi, Vice-President of ASRT G. El-Feky, and Head of the national group of Egypt at JINR W. Badawy also took part in the CP session.

The decision to proclaim 2022 the Year of Basic Sciences was taken **on 2 December** by the UN General Assembly. The Joint Institute for Nuclear Research is one of the organizers of the International Year of Basic Sciences for Sustainable Development (IYBSSD) and is a member of the IYBSSD 2022 Steering Committee.

Together with JINR, the organizers of the event are such leading international scientific centres and communities as CERN, the International Union of Pure and Applied Physics (IUPAP), the International Union of Pure and Applied Chemistry (IUPAC), the National Institute for Nuclear Physics (INFN, Italy), and others.

The proposal for the Year was made at the 41st General Conference of UNESCO. It was developed by IUPAP, under the leadership of M. Spiro, IUPAP President. The Year would help highlight the crucial role of basic sciences for sustainable development and emphasize the achievement of 17 Sustainable Development Goals (SDGs) adopted by the UN for all countries of the world for the period of 2016–2030.

The IYBSSD 2022 is supposed to increase awareness of the critical function of basic sciences amongst policy-makers, business and industry, international organizations, philanthropic foundations, universities, teachers and students, media, and broad public.

On 2 December, under the auspices of the Delegation of the European Union to the Russian Federation, a meeting of Scientific Advisors from the Embassies of the EU Member States to Russia was held via videoconference, which was attended by JINR leaders.

It was the 44th meeting and it was held in the Ministry of Science and Higher Education of the Russian Federation. The central topics of discussions were the status of experiments at CERN and participation of the Russian side in them. One of new elements of the joint agenda was the discussion of the RF programme "Prioritet 2030" and growing involvement of Russian universities in CERN programmes.

CERN Director-General F. Ganotti headed the delegation of CERN. The Russian side was represented by Russian companies and scientific educational organizations, including RF Deputy Minister of Science and Higher Education N. Bocharova.

The reports by CERN representatives were devoted to the status of experiments CMS, ATLAS, LHCb, and ALICE. Wide involvement of Russian physicists was marked in the CERN experiment NA-64 on search of physics beyond SM, where the Joint Institute takes an active part. JINR Scientific Leader V. Matveev stressed it in his speech. In the discussion of the GRID digitalization for CERN experiments, MLIT Director V. Korenkov spoke about the status of the development of the centre of the Tier-1 level and the centre of the Tier-2 level for other virtual organizations at the LHC, and about active work at JINR on the EOS data storage system for all experiments.

By order of Minister of Science and Higher Education V. Falkov, JINR Director G. Trubnikov headed the Russian part of the Committee "5+5 CERN–RF". He presented a long-standing strategy of JINR development, principles of activitites of the Institute, key trends and flagship projects. Speaking about international cooperation of the Institute, G. Trubnikov noted the growing joint publication activity of JINR with European countries. Besides, educational programmes were presented that caused interest among the participants of the meeting. In conclusion, JINR Director invited the participants to visit the scientific centre in Dubna.

A special webinar was organized **on 16 December** to present JINR current activities and projects to an extended audience of the Mexican scientific community, as well as to discuss opportunities for further enhancement of joint Mexico–JINR research activities.

The JINR team was headed by JINR Vice-Directors V. Kekelidze and L. Kostov, as well as A. Kisiel, VBLHEP JINR Deputy Director. Over 30 representatives of Mexican research centres and universities, as well as officials from the Mexican Science Funding Agency (CONACYT) and the Mexican Embassy in the Russian Federation, participated in the event. The webinar was chaired by Prof. A. Ayala from the Institute for Nuclear Sciences of the National University of Mexico, who is also the MPD IB Chair and main Liaison Officer in Mexico to promote cooperation between Mexico and JINR.

The webinar programme featured two reports: an overview of JINR activities presented by D. Kamanin, Head of the International Cooperation Department, and a dedicated talk on the NICA collider project, a JINR flagship project, presented by JINR Vice-Director V. Kekelidze. International programmes for students, implemented by JINR, proved to be a topic of special interest with the Mexican colleagues, who were keen to receive details on the terms and conditions for participation.

On 23 December, a joint meeting of the JINR Science and Technology Council (STC) and the Institute Directorate was held where results of the year were analyzed and plans and tasks of JINR, including long-term ones, were discussed.

JINR Director Academician G. Trubnikov spoke about the brightest scientific results of 2021 obtained at Laboratories of the Institute and discussed the results of the reorganization of the Management of the Institute and some reforms. The speaker gave actual data on vaccination of staff members against COVID-19 and plans to basically reorganize the Medical Unit No. 9. One more ambitious initiative was the decision on establishing a branch of the Lomonosov MSU on the basis of the existing branch of SINP MSU.

Speaking about the results of the November session of JINR CP in Bulgaria, G. Trubnikov marked the entry of Egypt into JINR as a full member as the brightest event that was the result of 12 years of constant work in cooperation development.

Head of the International Cooperation Department D. Kamanin continued the discussion of international contacts. A Working Group on Strategic Issues under the CP was established which, in particular, worked out a number of documents — the regulations on JINR flag and on associate membership to JINR — that were adopted at the November CP session in Bulgaria.

As an important part of international activities at JINR that give practical results, the speaker mentioned training courses JEMS. Contacts with universities were greatly expanded; in the JINR Member States a whole net of information centres is developing that not only work on their own but also collaborate and exchange experience.

D. Kamanin said that the partner net of JINR in 2021 for the first time included more than a thousand organizations and, with priorities and instruments in the Strategic Plan of JINR development, it is possible to expect its further growth.

STC members supported the nomination of Senior Researcher Candidate of Physics and Mathematics A. Pikelner (BLTP) with the paper "Multi-Loop Calculations and Their Applications to Different Models of Quantum Field Theory" for RAS medal competition of 2021 with prizes for young Russian scientists for the best scientific papers in the nomination "Nuclear Physics".

The meeting concluded with ceremonial handing of awards in connection with the 65th anniversary of JINR. Thirty JINR staff members received awards of the RF Ministry of Science and Higher Education, Governor of the Moscow Region, the Rosatom State Corporation and Honorary Commemorative Medals of JINR.

CONFERENCES AND MEETINGS HELD BY JINR

Seventeen conferences were the largest among the scientific conferences and workshops held at JINR in 2021.

On 19–23 April, the 4th International Summer School and Workshop ***"Complex and Magnetic Soft Matter Systems: Physico-Mechanical Properties and Structure" (CMSMS'21)*** was held in the online format in Timişoara (Romania). The first meeting of this series took place in 2012 in Alushta, the next in 2014 and 2017 in Dubna.

The meeting was organized by JINR, the West University of Timişoara, the Institute of Continuous Media Mechanics of the Ural Branch of the Russian Academy of Sciences (Perm), the UNESCO Chair of the Belarusian National Technical University, the Horia Hulubei National Institute of Physics and Nuclear Engineering (Bucharest), and the Romanian Physical Society.

The purpose of CMSMS is to unite both the outstanding scientists and students working in a wide range of scientific fields related to the research of complex and magnetic systems of soft matter.

The programme of the meeting included invited reports, oral and poster presentations. Their topics covered theory, simulations, and experimental research in physical, mechanical, structural, chemical and biological aspects of soft complex matter with special emphasis on soft magnetic matter (magnetic liquids and elastomers, ferrogels, ferroliquid crystals, associations of nanoparticles with biomolecules and cells, etc.), as well as applied research at large-scale research facilities IBR-2, SOLARIS, etc.

The meeting made it possible to discuss the latest achievements in this area. It gathered more than 120 participants who heard the reports of 23 invited speakers, 23 oral and 36 poster presentations were made, 17 young scientists prepared short oral presentations. The participants of the meeting were researchers from Azerbaijan, Austria, Belarus, France, Germany, Great Britain, Ireland, Poland, Romania, Russia, Slovakia, and Ukraine.

On 19–20 April, ***the Collaboration Meeting on the BM@N Experiment at the NICA Facility*** was held in a mixed format. Thirteen reports were made at the plenary meetings and 25 presentations at three parallel sessions on detectors, data analysis and software of the experiment.

The readiness status of the BM@N detectors and the system of accelerators Booster–Nuclotron were discussed for the runs in the beams of medium and

heavy ions that are planned for 2022. The preparation to the run on the study of short-lived nucleon correlations that was planned for the late 2021 was considered in detail.

Results of the BM@N experimental data analysis were presented at the meeting on production of Λ hyperons, charged π and K mesons and nuclear fragments in interactions of carbon ion beams and argon beams with targets nuclei.

On 21–23 April, ***the 7th Collaboration Meeting on the MPD Experiment at the NICA Facility*** was held in a mixed format. Over 190 leading scientists, students and engineers from all over the world — from China to Mexico — took part in it. Almost 50 reports were made during three days of plenary meetings.

The Collaboration status, as well as a summary of the preparation of the main detector components, were presented and put in perspective in comparison to the timeline of the completion of the NICA accelerator complex. The recent milestone of the successful launch and the start of the commissioning of the Booster accelerator was highly appreciated. The readiness of the software and computing infrastructure was also discussed.

Five Physics Working Groups of MPD showed the recent performance studies using the massive productions of Monte Carlo simulated events. These results were shown recently at large international scientific conferences. In addition, special talks focusing on specific studies were given, including by young members of the Collaboration.

During the session of the MPD Institutional Board, new members of the Executive Committee were elected. Three institutions — from Serbia, Poland and Mexico — were accepted as new members of the MPD Collaboration.

As part of drawing up the JINR Strategic Development Programme, the Laboratory of Radiation Biology (LRB) hosted a workshop entitled ***"Nuclear Physics Methods in Life Sciences: Neuroradiobiological Research and New Approaches to Radiation Therapy of Tumors"***. The meeting was held in a mixed format on 27–28 April at the JINR House of Scientists. It was attended by more than 100 representatives of various institutes from 11 JINR Member States.

The scientific part of the meeting was opened by LRB Director A. Bugay. In his report "Neuroradiobiological research at JINR", he spoke in detail about the plans and prospects of research carried out at the Laboratory in brain sciences. The main tasks are the assessment of radiation risks for astronauts during deep space flights, the study of side effects arising from radiation therapy of brain tumors, and the use of radiation in the study of the mechanisms of neurodegenerative diseases. A detailed review was made of neuroradiobiological research on radiation-induced disorders in the central nervous system at the molecular, cellular, and systemic levels.

In her report "Integrative physiology. Opportunities for cooperation", Director of the Pavlov Institute of Physiology L. Filaretova, RAS Academician, spoke in detail about the laboratories of the institute and the areas of their activities. The institute is the initiator and coordinator of the International Consortium for Integrative Physiology. Integrative physiology studies the functioning of the organism as a whole.

Great interest from the audience was aroused by the report of A. Latanov, Head of the Department of Higher Nervous Activity, Faculty of Biology, Lomonosov Moscow State University, entitled "The effect of ionizing radiation on the visual-motor behavior of monkeys". The speaker emphasized that radiation exposure of the human body is the main limiting factor as regards deep space flights.

E. Moskaleva, Head of a Laboratory at the Kurchatov Institute, presented a report "Mechanisms of neuroinflammation development in the long-term period after brain irradiation and the search for ways to reduce it". She noted that neurodegenerative diseases and ionizing radiation exposure cause similar damage, which can be associated with the development of neuroinflammation due to the activation of microglia cells. Possible methods of treating neurodegenerative diseases using microglia proliferation inhibitors were proposed.

LRB Scientific Leader E. Krasavin, RAS Corresponding Member, spoke in his report "Radiobiological aspects of increasing the therapeutic effectiveness of ionizing radiation" about research prospects in medical radiobiology. The main goal here is to develop new breakthrough approaches in order to increase the effectiveness of radiation and radionuclide therapy. These approaches are based on increasing the radiosensitivity of tumor cells by interfering with the functioning of genetic regulatory networks using various radiomodifiers. It was also proposed to focus research on finding modular nanotransporters for the delivery of agents and radionuclides to tumor cells.

I. Zamulaeva, Head of the Department of Radiation Biochemistry, Tsyb Medical Radiological Research Centre, presented a report entitled "Tumor stem cell resistance to sparsely ionizing radiation is one of the key problems of radiation oncology". These cells are resistant to radiation and chemical agents and can persist for many years in the patient's body, causing cancer recurrence.

Professor M. Falk of the Institute of Biophysics, the Czech Academy of Sciences, focused in his report "Superresolution microscopy in research of IRIF nanoarchitecture and biological effects of high-LET ions" on studying the molecular mechanisms of radiation damage repair in the cell genetic apparatus.

FLNP Director V. Shvetsov presented in his report "Promising technologies of neutron capture therapy of oncological diseases" a joint project of JINR, Moscow State University, and the Institute of Theoretical and Experimental Physics on the development of breakthrough technologies for boron

neutron capture therapy. The project includes the creation of a compact cost-effective facility based on a high-current proton accelerator, as well as the development of mechanisms for the selective delivery of boron-containing drugs to tumor cells and enhancing the latter's sensitivity to radiation resulting from the capture of a thermal neutron by the ^{10}B nucleus.

During the general discussion, RAS Academicians L. Filaretova and A. Lisitsa drew attention to the fact that a global problem of modern biology was raised at this meeting: the absence of a link connecting the physiological and molecular biology data, and, as a consequence, the absence of a systemic molecular model explaining the functioning of cells and organs.

Based on the results of the meeting, recommendations for the further development of the JINR Strategic Programme of Radiobiological Research were prepared. It was proposed to establish an international collaboration, where LRB would be the central element and unifying link. It is assumed that the collaboration will form an international programme advisory expert council that would coordinate activities in life sciences and determine the range of tasks and resources necessary for their successful solution for the benefit of all equal participants using the infrastructure and capabilities of JINR Member States' institutes.

The regular annual ***28th International Seminar on Interaction of Neutrons with Nuclei (ISINN-28)*** was supposed to be held in May 2020 in Beijing, but the outbreak of a pandemic canceled these plans. After discussions with the Chinese co-organizers, ISINN-28 was postponed and, as a result, it was held online on 24–28 May 2021. The seminar was organized by the Frank Laboratory of Neutron Physics of JINR together with the colleagues from Chinese institutes and universities.

The seminar programme traditionally covered a wide range of issues on neutron physics: from promising neutron sources, fundamental properties of the neutron and fundamental interactions in reactions with neutrons, nuclear fission, ultracold neutrons to analytical methods in archeology, materials science, ecology and life sciences. The seminar brought together over 150 participants from the physics centres of Albania, Azerbaijan, Belarus, Bulgaria, China, the Czech Republic, Egypt, France, India, Iran, Kazakhstan, Moldova, Romania, Serbia, Spain, Sweden, USA, and Vietnam, as well as from the Institute of Physics and Power Engineering and the National Medical Research Radiological Centre (Obninsk), the Moscow National Research Centre "Kurchatov Institute" (NRC KI) and the NRC KI of the Institute for Theoretical and Experimental Physics, NRC KI of the St. Petersburg Nuclear Physics Institute (Gatchina), NRC KI of the Institute for Nuclear Research RAS (Troitsk), employees of the Frank Laboratory of Neutron Physics and the Flerov Laboratory of Nuclear Reactions of JINR. Seventy-eight oral and 51 poster presentations were made (for more details, see the website http://isinn.jinr.ru/past-isinns/isinn-28/program.html).

On 8–10 June, ***the 1st Meeting of the International Collaboration of the Spin Physics Detector (SPD) at the NICA Collider*** (JINR) was held in a videoconference mode.

The main purpose of the SPD experiment at NICA is the study of the spin structure of nucleons in collisions of polarized protons and deuterons and other phenomena connected with spin at total energy of colliding beams up to 27 GeV and luminosity up to $10^{32}\ \mathrm{cm}^{-2} \cdot \mathrm{s}^{-1}$.

JINR Vice-Director V. Kekelidze opened the meeting with greeting words. Chairperson of the Working Group E. Tomasi-Gustafsson (Nuclear Research Centre in Saclay, France) spoke in detail about the process of establishing the Collaboration.

The status of the construction project of the SPD detector was given in detail by Head of the Collaboration, Head of the Experimental Department of Colliding Beams of DLNP A. Guskov. Deputy Head of the VBLHEP Accelerator Department of High Energy Physics A. Sidorin acquainted the members of the Collaboration with the status of activities in the construction of the NICA accelerator complex. The leading researcher of the Department of Hadron Physics of VBLHEP A. Korzenev presented the technical design of the project of the SPD detector. Deputy Head of the Experimental Department of Colliding Beams of DLNP A. Zhemchugov described the software for data processing from the detector.

The next two days of the meeting were devoted to discussion of parameters of each part of the future SPD detector.

A Conference of Young Scientists and Specialists of JINR was held on 8–15 June in Alushta in Resort Hotel "Dubna". Forty-seven young scientists from eight countries presented their reports on their scientific research and listened to the lectures on modern achievements at JINR Laboratories. This year the Conference was dedicated to the 65th anniversary of JINR.

In the framework of the Conference, a contest for the best report was held, and after the voting the winners were: A. Torosyan (MLIT), R. Kozhina (LRB), E. Mardyban (BLTP), A. Trifonov (DLNP), M. Zakharov (FLNP), D. Pugachev (FLNR), Yu. Stepanenko (DLNP), M. Korobitsina (VBLHEP).

At the round-table discussion with JINR Directorate, young scientists and specialists from Azerbaijan, Belarus, Kazakhstan, Moldova, Mongolia, Romania, Russia, and Vietnam discussed a wide range of issues important for young people of the Institute. JINR Director G. Trubnikov, Scientific Leader V. Matveev, JINR Director Assistant G. Shirkov, JINR Chief Engineer B. Gikal and Head of the International Cooperation Department D. Kamanin answered questions about the development of the

Institute infrastructure, postgraduates, participation of JINR in new international scientific collaborations, and others.

In the course of the Conference, a meeting was held by videolink with young scientists of SPbSU and the Mendeleev RCTU on the topic "Scientific communication". D. Kamanin gave a lecture about the history of international cooperation at JINR.

From 30 June to 2 July, an international meeting ***"Superheavy Elements"*** was held at JINR within the framework of the meeting of the RAS Council on Heavy Ion Physics. It gathered about 200 participants from Russian and foreign scientific centres, including from Germany, Israel, Switzerland, and the USA. RAS President A. Sergeev took part in the meeting and made a report "Vacuum Ionization in Superstrong Laser Fields". RAS Vice-President S. Lyulin also represented the Russian Academy of Sciences. The RAS delegation visited the Factory of Superheavy Elements, the construction site of the NICA collider and the factory of superconducting magnets.

The main aim of the meeting was a complex discussion of the scientific programme of SHE research and development of modern infrastructure to implement it. Leading scientists and heads of scientific centres connected with the research programme under discussion took part in the meeting.

JINR Director Academician G. Trubnikov and FLNR Scientific Leader Yu. Oganessian opened the meeting. The participants discussed the status of research in the synthesis of superheavy elements and tasks in applied science related to this topic. These are new generations of calculation algorithms, materials science, spheres of applied science related to SHF devices of a new frequency range and new capacities, new generations of ion sources.

On 5–9 July, the 9th International Conference ***"Distributed Computing and Grid Technologies in Science and Education" (GRID'2021)*** was held at the Meshcheryakov Laboratory of Information Technologies in a mixed format. The GRID Conference, which takes place every two years, was dedicated to the 65th anniversary of JINR and the 55th anniversary of the foundation of LCTA (now MLIT).

More than 270 scientists (103 — in person, over 170 — remotely) from research centres of Armenia, Belarus, Bulgaria, China, the Czech Republic, Egypt, France, Georgia, Germany, Iran, Italy, Moldova, New Zealand, Poland, Romania, Slovakia, Sweden, and Switzerland took part in the Conference. Russia was represented by participants from 28 universities and research centres. The Conference was organized in 10 sessions, where issues associated with the development of distributed computing technologies, cloud technologies, heterogeneous computing, volunteer computing and Big Data analytics, machine learning and quantum information processing were discussed. Twenty-three plenary and 140 sessional talks were delivered.

JINR Director G. Trubnikov opened the Conference with a report on JINR's Long-Term Development Strategy up to 2030 and beyond. He underlined that information technology (IT) is a dynamically developing area, and the MLIT Multifunctional Information and Computing Complex (MICC) is the basic facility of JINR. MLIT Director V. Korenkov continued the strategic topic with a report on the prospects and plans for IT development at the Institute. He highlighted that MLIT would proceed to provide high-quality services and support to scientists participating in projects of JINR both on the territory of Dubna and beyond, keeping on developing telecommunication technologies, data storages, computing systems, algorithms and software, data processing and analysis technologies, as well as information security.

The talk "Prospects for the development of system programming and cybersecurity" by RAS Academician A. Avetisyan, a leading Russian specialist in system programming, evoked great interest among the audience.

One of the developers of the distributed computing system for the experiments at the LHC at CERN O. Smirnova (Lund University, Sweden) gave an overview of distributed computing in science. S. Campana (CERN) spoke about how the worldwide distributed system for processing data from the LHC experiments was changing under conditions of increasing the accelerator's luminosity and data flow. The current state of the distributed computing monitoring and accounting infrastructure in the ATLAS experiment was presented by A. Alekseev (ISP RAS). T. Mkrtchyan (DESY, Germany) delivered a report on the development of data storage systems based on the dCache file system.

A. Tsaregorodtsev (Centre for Particle Physics of Marseille, France) devoted his talk to the development of the DIRAC project, which serves as the basis for building distributed computing systems. At present, the MICC computing resources and storage systems, as well as the NICA computing cluster and that of the National Autonomous University of Mexico (UNAM), have been integrated using DIRAC.

A separate plenary session was dedicated to quantum computing. Recognized world expert in this field C. Calude (New Zealand) presented a report explaining the superiority of quantum computing over traditional computing methods. Leading Russian specialist in this field A. Fedorov (Quantum IT Group Leader, Skolkovo) spoke about quantum computing from its origins to the present day, its status in Russia and worldwide.

V. Velikhov (NRC "Kurchatov Institute") delivered a plenary talk on the concept and development prospects of a new segment of the Russian consortium RDIG (Russian Data Intensive Grid) named RDIG-M, i.e., RDIG for megascience projects.

A review of the state and development prospects of the MICC was given by T. Strizh (MLIT JINR).

It is noteworthy that the Tier-1 grid site at MLIT is well functioning and ranks second in the world in terms of data processing for the CMS experiment; the Tier-2 site is the most productive in the Russian consortium RDIG; the cloud infrastructure and the HybriLIT heterogeneous platform, including the "Govorun" supercomputer, are successfully developing.

M. Zuev (MLIT JINR) devoted his report to the development of heterogeneous computing at JINR based on the "Govorun" supercomputer, which is a unique computing hyperconverged system with a software-defined architecture. The supercomputer is equipped with an ultrafast data processing and storage system and ranks first among Russian supercomputers in terms of the information acquisition and processing rate.

At the Conference there were plenary talks on the concept of computing for the SPD experiment at NICA (A. Zhemchugov, DLNP JINR); on the IT development strategy at the Institute of High Energy Physics in China (Q. Huang, IHEP CAS, China); on the status of the PIK computing centre, the major task of which is to store and process data from experiments at the PIK nuclear reactor (A. Kiryanov, PNPI NRC "Kurchatov Institute").

The report of P. Lula (Cracow University of Economics, Poland) on clustering methods in the ontology-based exploratory analysis of scientific productivity and the report of V. Lakhno (IMPB RAS, Pushchino) on the prospects of nanobioelectronics and the creation of DNA-based electronic devices aroused great interest.

Round tables organized within the Conference were dedicated to the use of IT in education; to the Russian segment of WLCG (Worldwide LHC Computing Grid), i.e., RDIG; to supercomputer technologies. At one of the round tables, Intel presented its new product — the DAOS high-speed file system.

A number of plenary talks at the Conference were made by representatives of the IT industry, who were sponsors of the Conference. Among them were IBS Platformix, IT Cost, Niagara Computers, Dell EMC, RSC Group, Intel, Softline.

The 27th Russian Particle Accelerator Conference (RuPAC-2021) took place in the "Dubna" Resort Hotel in Alushta from 26 September to 2 October. The Conference was organized by the RAS Scientific Council on Charged Particle Accelerators and the Joint Institute for Nuclear Research. The year of the Conference was of special importance to JINR as it celebrated the 65th anniversary of its founding.

The aim of the Conference was to share information and discuss a range of topics of modern accelerator science and technology, as well as to present new projects of accelerators and accelerator complexes. Among the latter, new projects under construction aroused increased interest: NICA (Nuclotron-based Ion Colider fAclity, JINR), SKIF (Siberian Ring Photon Source, Boreskov Insitute of Catalysis and Budker Institute of Nuclear Physics of the Siberian branch of RAS), HIAF (High Intensity Heavy Ion Accelerator Facility, China), Kurchatov Synchrotron Radiation Source (NRC "Kurchatov Institute", Moscow), Powerful Long-Pulse THz-Band Bragg FEL Based on Linear Induction Accelerator (IAP RAS, Nizhny Novgorod).

A large number of the papers were dedicated to accelerator science and technology, new ideas and proposals for their development. Proposals for the use of accelerators in technology and medicine were presented in seven oral reports at the final session of the Conference, as well as in many poster presentations.

A special session was dedicated to the memory of outstanding accelerator physicist Evgeny Denisovich Donets who past away in 2021.

A group of participants of the Conference (Prof. S. Polozov (MEPhI) and others) initiated a session to discuss problems of teaching physics and mathematics in universities, which aroused great interest. Based on the proceedings of the session, a letter with suggestions for the Russian Ministry of Science and Higher Education was planned to be developed.

In total, 147 participants attended RuPAC-2021 (including 12 online speakers) from 25 institutions, both Russian (21) and foreign (4). Among the presented papers, there were nine invited ones (including three online), 49 oral reports (nine of them online) and 133 poster presentations.

On one of the Conference days D. Kamanin delivered a lecture devoted to the 65th anniversary of JINR, which the audience met with great interest. In addition, a lecture "2021 — the Year of Science and Technology in Russia" by M. Itkis served as a bright culmination on the last day of the Conference.

Traditionally, the Organizing Committee of the Conference held a competition of scientific papers presented by young scientists (for authors under the age of 35 inclusive). An ad hoc jury formed out of the leading representatives of Russian accelerator laboratories and chaired by Professor V. Telnov (Budker Institute of Nuclear Physics of the Siberian branch of RAS) selected the laureates. The jury took a decision to award four diplomas in 2021, one of them being a group diploma. Its owners became scientists from VBLHEP JINR, who presented a series of papers on the development of a unique technology and production of superconducting magnets for the NICA accelerator complex and SIS-100 synchrotron (FAIR project, Germany): A. Bortsova, D. Zolotykh, S. Korovkin, D. Nikiforov, T. Parfilo, M. Shandov, A. Shemchuk, Yu. Bespalov, I. Donguzov, E. Zolotykh, B. Kondratyev, I. Nikolaychuk, M. Petrov, and D. Khramov.

Personal awards were won by K. Gikal for the technology of heavy ion beam generation on the DC-280 cyclotron (FLNR JINR), I. Gorelyshev (VBLHEP JINR) for the design of a stochastic cool-

ing system for the NICA collider, and Yu. Osina (Efremov Scientific Research Institute of Electrophysical Apparatus, St. Petersburg) for the design of a multicharged ion cyclotron. All the laureates received the 1st degree prizes.

Traditionally, all the RuPAC papers (as well as of other conferences on accelerator physics) are published on the JACoW web-site (www.jacow.org).

On 3–8 October, ***the 8th Collaboration Meeting on the BM@N Experiment at the NICA Facility*** was held in a mixed format at VBLHEP. The event gathered about 100 participants from world-leading scientific centres.

The focus of the meeting was on the completion of the experimental setup for the future heavy-ion physics programme. The participants discussed the plans for the next BM@N experimental runs, as well as the status of data analysis of strange particle and nucleus fragment production in carbon and argon beams. At a separate IB Meeting on 4 October, the organizational issues of the BM@N Collaboration were worked out.

On 5–9 October, the International Conference ***"Modern Problems of Genetics, Radiobiology, Radioecology, and Evolution"*** dedicated to N. W. Timofeev-Ressovsky and his scientific school was held in a mixed format at the Nor-Amberd mountain space station, Armenia.

The main organizers of the Conference were JINR and the A. I. Alikhanyan National Science Laboratory (AANL) of YerPhI, the sponsors were the GSI Helmholtz Centre in Berlin-Buch and Darmstadt, as well as the Institute of Industrial Ecology of the Ural Branch of RAS. V. Matveev (JINR), A. Aprahamyan and A. Chilingaryan (AANL) headed the Organizing Committee and participated in the Conference.

The Conference programme included plenary, oral and poster presentations. Despite the active scientific discussions, a friendly atmosphere prevailed. Lectures on biology and physics for students and young scientists were organized at the Yerevan State University. V. Matveev spoke about research at JINR, and V. Nikitin — about elementary particles. Lectures were broadcast to universities and institutes of different countries. Students and young scientists from different countries made their presentations at the Conference, their short articles will be published in JINR.

The Organizing Committee and Rossotrudnichestvo in Armenia organized scientific excursions to the Aragats upper space station (AANL) and the Laboratory of the Armenian NPP in Metsamor on radiation protection of the environment. Excursions to Matenadaran and Lake Sevan were also organized for Conference participants.

The International Conference ***"Advances in Quantum Field Theory" (AdQFT'21)*** was held in Dubna from 10 to 14 October. It was organized by the Bogoliubov Laboratory of Theoretical Physics of the Joint Institute for Nuclear Research and turned out to be one of the few scientific events not postponed due to the coronavirus pandemic.

The Conference was dedicated to the 70th anniversary of seven famous theorists: V. Belokurov (MSU), K. Chetyrkin (INR RAS), D. Kazakov (JINR), N. Krasnikov (INR RAS, JINR), A. Radyushkin (ODU, JLab), V. Smirnov (MSU), and A. Vladimirov (JINR) — who together graduated from the Faculty of Physics of the Moscow State University in 1974. The topics of the Conference were determined by the broad scientific interests of the anniversaries and covered a number of important problems of modern theoretical physics. In particular, such themes as the renormalization group, multiloop calculations, scattering amplitudes, effective theories, physics beyond the Standard Model, dark matter and cosmology were discussed.

More than 200 participants from Armenia, Australia, Bulgaria, Canada, the Czech Republic, France, Germany, Greece, Italy, Poland, Russia, Slovakia, Spain, Sweden, Switzerland, UK, and the USA took part in the Conference. JINR Scientific Leader V. Matveev opened the event and congratulated the anniversaries, emphasizing the significant role of each of them in the development of quantum theory.

Within four days, leading experts in elementary particle theory, supersymmetry, gravitation and cosmology gave 63 reports. Among them were V. Rubakov (Moscow), E. Boos (Moscow), M. Shaposhnikov (Lausanne), E. Ivanov (Dubna), G. Arutyunov (Hamburg), G. Korchemsky (Saclay), J. Buchbinder (Novosibirsk), P. Vanhove (Saclay), D. Gorbunov (Moscow), V. Zakharov (Moscow), I. Aref'eva (Moscow), A. Dolgov (Novosibirsk), A. Mironov (Moscow), M. Vasiliev (Moscow), M. Shifman (Minnesota), L. Dixon (Stanford), D. Broadhurst (Milton Keynes), and others. Three of the anniversaries also presented their results: V. Smirnov spoke about five-loop propagators, N. Krasnikov gave a brief review on the search for light dark matter and the NA64 experiment, and V. Belokurov discussed path integrals in quantum gravity.

Comprehensive and interesting talks on modern topics stimulated numerous discussions, the exchange of ideas and the establishment of scientific contacts. The participants noted the high level of organization, as well as the warm and friendly atmosphere, created by the Organizing Committee chaired by BLTP JINR Director D. Kazakov.

More detailed information, talk slides and video recordings of the sessions can be found on the Conference website https://indico.jinr.ru/e/qft.

On 11–15 October, ***the 25th International Conference of Young Scientists and Specialists of JINR (AYSS-2021)***, dedicated to the 30th anniversary of Independence of the Republic of Kazakhstan, was held in a mixed format at the Institute of Nuclear Physics (INP) of the Ministry of Energy of the

Republic of Kazakhstan. The annual Conference gathers students, young scientists and specialists from scientific centres from all over the world.

INP Director B. Karakozov and JINR Director Assistant G. Shirkov made speeches at the solemn opening of the Conference.

Within the framework of the Conference, leading scientists gave lectures on recent theoretical, experimental, and applied investigations conducted all around the world with the emphasis on the major results obtained at JINR. The following topics were discussed during the Conference: theoretical physics, mathematical modeling and computational physics, high energy physics, particle accelerators and nuclear reactors, experimental nuclear physics, information technology, condensed matter physics, applied research, life science.

JINR Director G. Trubnikov and FLNP JINR Director V. Shvetsov spoke about the youth policy of the Institute, international cooperation and research on neutron sources of JINR. Speaking about international cooperation, the JINR Director noted the close cooperation with the participating countries, in particular, with the Republic of Kazakhstan, which became the first visiting site of the AYSS Conference outside Dubna.

On 12–14 October, ***the Collaboration Meeting on the MPD Experiment at the NICA Complex*** was held in a mixed format at VBLHEP, which gathered more than 170 online and offline participants from 13 countries.

Participants of the meeting discussed recent results of the detector assembly in the MPD Hall. Reports on the readiness of components of all the main subsystems of the facility, on the status of their installation, commissioning and calibration schedule were considered. The schedule fulfilment of the NICA complex construction and its commissioning, as well as plans for the first beams, were presented. The participants got acquainted with new developments in the performance studies for physics observables carried out within the MPD Physics Working Groups, including publication plans. In addition to the physical programme of the experiment, special attention at the meeting was paid to the discussion of computing and software infrastructure.

On 12–15 October, ***the 8th Congress on Radiation Research (Radiobiology, Radioecology, Radiation Safety)***, a traditional congress of the Radiobiological Society under the Russian Academy of Sciences (RAS), was held in Moscow. The Congress was organized by RAS (RAS Department of Physiological Sciences, RAS Department of Biological Sciences, RAS Scientific Council on Radiobiology, and RAS Radiobiological Society), the Joint Institute for Nuclear Research (the Laboratory of Radiation Biology), and Russian Federal Biomedical Agency (FMBA) (Burnazyan Federal Medical Biophysical Centre (FMBC)).

The Congress was attended by more than 400 radiobiologists, radioecologists, physicians, and scientists of related specialties from Russia, Belarus, and Azerbaijan. They represented scientific centres, research institutes, laboratories of RAS and National Academies of Sciences, JINR, FMBA scientific institutions, the RF Ministry of Health, the RF Ministry of Defense, the RF Ministry of Emergency Situations, universities, and other scientific and educational institutions, as well as research and production corporations and enterprises.

The programme of the Congress included a discussion of the results of research on the most important problems of radiation biology, radioecology, and radiation safety. The Organizing Committee received 372 abstracts of reports and applications for participation in the Congress. By the beginning of the Congress, a book of abstracts had been published (Dubna: JINR, 2021, 444 p.). During the Congress, nine plenary and more than 144 section reports were heard; 45 posters were presented.

At the plenary session, reports were made by leading Russian scientists and specialists in the main areas of radiobiology, radiology, and radioecology. The current state of research in the main areas of radiobiology was reviewed in the report "Charged particles in radiation biology: Problems and prospects" by LRB JINR Scientific Leader E. Krasavin.

On 17 December, a festive ***Seminar Dedicated to the 80th Anniversary of JINR Scientific Leader Academician V. A. Matveev*** was held in the Conference Hall of the Bogoliubov Laboratory of Theoretical Physics of JINR. On behalf of the multinational community of the Institute, JINR Director Academician G. Trubnikov congratulated V. Matveev with an address signed by representatives of 19 Member States.

RAS President A. Sergeev congratulated V. Matveev as a member of the Presidium of RAS. He pointed out that Viktor Anatolievich headed the RAS Department of Physical Sciences for several years, which was always a flagship structure in the Academy.

Bright and interesting scientific reports were given at the seminar. Colleagues and pupils of Viktor Anatolievich Matveev — theoreticians and experimenters, spoke about an outstanding contribution of V. Matveev to science, showing an unusual side of his scientific interests, which are very wide.

Chief Scientific Researcher of the RAS Institute of Nuclear Research Academician V. Rubakov stressed that the results of joint efforts achieved in the late 1980s found unexpected development — in particular, in connection with experiments at the NICA collider.

Chief Scientific Researcher of INR RAS N. Krasnikov spoke in his report about his work with V. Matveev on the analysis of potential capabilities of the Large Hadron Collider at CERN from the point of view of search for new physics of fundamental

interactions beyond the Standard Model that brought about wide resonance in scientific circles.

BLTP JINR Director RAS Corresponding Member D. Kazakov marked a great role of V. Matveev in the position of the Director of the Joint Institute — as an outstanding scientist, science organizer, a teacher for the young generation who possesses great human qualities and as a many-sided personality.

A documentary devoted to events of scientific life of Academician V. Matveev was shown for the participants of the seminar. It was prepared by the Scientific Information Department of JINR specially for his jubilee.

PARTICIPATION OF JINR IN INTERNATIONAL CONFERENCES

In 2021, scientists and specialists of the Joint Institute for Nuclear Research took part in 229 international conferences and meetings.

The largest delegations representing JINR attended the following events: 28th International School "Mathematics. Computer. Education" (online) (Moscow, Russia); 35th Scientific Conference "Novgorod and Novgorod Land. History and Archaelogy" (Velikiy Novgorod, Russia); IUCr High-Pressure Workshop 2021 (Novosibirsk, Russia); 33rd COMET Collaboration Meeting (online) (Tokai, Japan); 5th EOS Workshop (online) (Geneva, Switzerland); 25th International Symposium "Nanophysics and Nanoelectronics" (Nizhniy Novgorod, Russia); 7th European Joint Theoretical/Experimental Meeting on Membranes (EJTEMM 2021; online) (Graz, Austria); International Scientific Conference of Students, Postgraduates and Young Scientists "Lomonosov 2021" (Moscow, Russia); 15th All-Russian Youth Scientific and Innovation School "Mathematics and Mathematical Modeling" (Sarov, Russia); 1st International School-Conference "Atom. Science. Technologies" (online) (Almaty, Kazakhstan); All-Russian Conference "Physical and Analytical Chemistry of Natural and Technological Systems" (Dubna, Russia); 11th All-Russian Conference "Information and Telecommunication Technologies and Mathematical Modeling of High-Tech Systems" (ITTMM 2021; online) (Moscow, Russia); 10th Inter-Institute Scientific Conference "Physics of Elementary Particles and Cosmology" (Moscow, Russia); Annual Conference "Polynomial Computer Algebra" (PCA 2021; hybrid format) (St. Petersburg, Russia); 10th International Conference "Abalkin Readings" (to the 90th anniversary of the birth of Academician L. I. Abalkin) (hybrid format) (Moscow, Russia); NuBall2 Online Scientific Meeting (online) (Orsay, France); Very Large Volume Neutrino Telescope Workshop (VLVnT 2021; online) (Valencia, Spain); 12th International Particle Accelerator Conference (IPAC'21; online) (Campinas, Brazil); 50th Tulinov International Conference on Physics of Charged Particles Interactions with Crystals (online) (Moscow, Russia); 2nd Conference "Condensed Matter Physics" (to the 90th anniversary of the birth of Academician Yu. A. Osipyan) (online) (Chernogolovka, Russia); Quarks Online Workshops 2021: "Quantum Gravity and Cosmology" (to the centenary of the birth of A. D. Sakharov) (Moscow, Russia); Workshop "Neutron Diffraction 2021" (Gatchina, Russia); Quarks Online Workshops 2021: "Modification of Gravity: Theories and Observations" (to the centenary of the birth of A. D. Sakharov) (Moscow, Russia); 57th Karpacz School of Theoretical Physics and Training School on Equation of State of Dense Matter and Multimessenger Astronomy (Karpacz, Poland); RAD 2021 — International Conference on Radiation in Various Fields of Research (hybrid format) (Herceg Novi, Montenegro); Scientific and Technical Conference "Nuclear and Electrophysical Facilities — Sources of Powerful Ionizing Radiation" (Snezhinsk, Russia); 15th International Conference "Advanced Carbon Nanostructures" (ACNS'2021; online) (St. Petersburg, Russia); 34th COMET Collaboration Meeting (online) (Tokai, Japan); 37th International Cosmic Ray Conference (ICRC 2021; online) (Berlin, Germany); International Symposium on Symbolic and Algebraic Computation (ISSAC 2021) (St. Petersburg, Russia); 29th Annual International Laser Physics Workshop (LPHYS'21; online) (Moscow, Russia); 13th European Biophysics Conference (EBSA 2021; online) (Vienna, Austria); 38th International Symposium on Lattice Field Theory (online) (Cambridge, USA); Virtual Tribute to Quark Confinement and the Hadron Spectrum 2021 (Stavanger, Norway); 20th Lomonosov Conference on Physics of Elementary Particles (Moscow, Russia); 10th International Conference on New Frontiers in Physics (ICNFP 2021; hybrid format) (Kolimbari, Greece); 25th International Conference "Ion-Surface Interactions" (ISI 2021; hybrid format) (Yaroslavl, Russia); 22nd Particle and Nuclei International Conference (PANIC2021; online) (Lisbon, Portugal); Scientific Conference "Scientific Information and Scientific Resources under Conditions of Lockdown 2020–2021" (Kaliningrad, Russia); 23rd International Conference "Computer Algebra in Scientific Computing" (CASC 2021) (Sochi, Russia); 3rd International Conference on Solar Technologies and Hybrid Mini Grids to Improve Energy Access (Palma de Mallorca, Spain); International Workshop "Shapes and Dynamics of Atomic Nuclei: Contemporary Aspects" (SDANCA-21) (Sofia, Bulgaria); EMMI Workshop "New Avenues for the Low-Energy NUSTAR Program at GSI-FAIR" (online) (Darm-

stadt, Germany); 3rd International Scientific Forum "Nuclear Science and Technology" (hybrid format) (Almaty, Kazakhstan); International Conference on Nuclear Physics "Nucleus-2021. Nuclear Physics and Elementary Particle Physics. Nuclear Physics Technologies" (online) (St. Petersburg, Russia); 14th International Conference "Interaction of Radiation with Solids" (Minsk, Belarus); Super-FRS Experiment Workshop (online) (Darmstadt, Germany); 4th International Youth Conference "Modern Problems of Radiobiology, Radioecology and Agroecology" (Obninsk, Russia); 6th All-Russian Symposium "Separation and Concentration in Analytical Chemistry and Radiochemistry" (Olginka, Russia); International Scientific and Practical Conference "30 Years of the Commowealth of Independent States: The Results and Perspectives" (Minsk, Belarus); Conference on the Use of Neutron Scattering in Condensed Matter Research (online) (Yekaterinburg, Russia); Scientific Conference "Supercomputer Days in Russia" (online) (Moscow, Russia); 22nd GANIL Colloquium (Autrans-Méaudre-en-Vercors, France); NUSTAR Week (Darmstadt, Germany); International Conference on Precision Physics and Fundamental Physical Constants 2021 (FFK-2021) (Stara Lesna, Slovak Republic); International Seminar "Neutrons and Synchrotron Radiation in Investigations of Condensed Matter" (online) (Poznan, Poland); ECOpole'21 Conference (online) (Cracow, Poland); 9th All-Russian Conference "Mass Spectrometry and Its Applied Problems" (Moscow, Russia); School and Workshop "Aspects of Symmetry" (online) (Tbilisi, Georgia); 33rd International Workshop on High Energy Physics "Hard Problems of Hadron Physics: Non-Perturbative QCD and Related Topics" (Protvino, Russia); TIM 20–21 Physics Conference (online) (Timişoara, Romania); Workshop on Future Super c-tau Factories 2021 (Novosibirsk, Russia); Scientific Conference of the Mongolian Physical Society (to the 60th anniversary of the Institute of Physics and Technology of the Mongolian Academy of Sciences) (online) (Ulaanbaatar, Mongolia); 22nd Inter-Institute Youth Scientific School-Conference named after B. S. Ishkhanov "Concentrated Fluxes of Energy in Cosmic Technique, Electronics, Ecology and Medicine" (online) (Moscow, Russia); International Conference "Modern Problems of Nuclear Energy and Nuclear Technologies" (to the 65th anniversary of the Nuclear Physics Institute of Uzbekistan) (Tashkent, Uzbekistan); 8th All-Russian Scientific-Practical Conference of X-Ray Equipment Manufacturers (St. Petersburg, Russia); 20th International Workshop on Advanced Computing and Analysis Techniques in Physics Research (ACAT 2021; online) (Daejeon, Republic of Korea); 35th COMET Collaboration Meeting (online) (Tokai, Japan); All-Russian Scientific-Practical Conference "Tasks and Methods of Neutron Investigations of Condensed Matter" (Dubna, Russia); MLZ User Meeting 2021 (online) (Garching, Germany); Congress of Young Scientists (Sochi, Russia); Virtual SHE Seminars of the National Centre for Nuclear Research (NCBJ) of Poland (Warsaw, Poland).

DEVELOPMENT OF THE JINR INTERNATIONAL COLLABORATION AND RELATIONS OF THE YEAR 2021

1.	Number of short-term visits to JINR by specialists from the Member States (not counting Russian specialists)	222
2.	Number of visits of specialists from other countries,	101
	including visits of specialists from the Associate Members	46
3.	Number of visits by JINR specialists to the Member States (not counting missions within Russia)	652
4.	Number of visits by JINR specialists to other countries,	307
	including visits of specialists to the Associate Members	79
5.	Number of conferences, schools, and meetings held by JINR	60
6.	New cooperation agreements (memoranda of understanding), addenda to existing ones	40

LIST OF CONFERENCES, SCHOOLS, AND MEETINGS HELD BY JINR IN 2021 *

No.	Name	Place	Date	Number of participants
1.	54th Meeting of the Programme Advisory Committee for Particle Physics (online)	Dubna	18 January	63
2.	Joint Meeting of the Programme Advisory Committee for Particle Physics and the Programme Advisory Committee for Nuclear Physics (online)	Dubna	21 January	140
3.	53rd Meeting of the Programme Advisory Committee for Nuclear Physics (online)	Dubna	22 January	31
4.	53rd Meeting of the Programme Advisory Committee for Condensed Matter Physics (online)	Dubna	25–26 January	67
5.	Meeting "Opportunities for the JINR–Chile Cooperation" (online)	Dubna	28 January	40
6.	16th BLTP JINR Winter School "Actual Cosmology" (online)	Dubna	1–7 February	75
7.	31st Meeting of the Joint Committee on the IN2P3–JINR Collaboration (online)	Dubna	16 February	20
8.	129th Session of the JINR Scientific Council (hybrid format)	Dubna	18–19 February	79
9.	Meeting of JINR, DESY and XFEL Representatives (online)	Dubna	24 February	41
10.	1st Meeting of the Joint Coordination Committee Vietnam–JINR (online)	Dubna–Hanoi	17 March	15
11.	Meeting of the JINR Finance Committee (hybrid format)	Dubna	22–23 March	71
12.	Session of the Committee of Plenipotentiaries of the Goverments of the JINR Member States	Dubna	25–26 March	102
13.	Workshop "Distributed Computing and Data Science"	Vladikavkaz, Russia	31 March – 3 April	50
14.	4th International School and Workshop "Complex and Magnetic Soft Matter Systems: Physico-Mechanical Properties and Structure" (online)	Timişoara, Romania	19–23 April	125
15.	16th JINR Training Course "JINR Expertise for Member States and Partner Countries" (JEMS-16)	Dubna	19–23 April	25
16.	7th Collaboration Meeting on the BM@N Experiment at the NICA Facility (hybrid event)	Dubna	19–20 April	127
17.	7th Collaboration Meeting on the MPD Experiment at the NICA Facility (hybrid event)	Dubna	21–23 April	193
18.	Extraordinary Session of the Programme Advisory Committee for Condensed Matter Physics (online)	Dubna	29 April	54
19.	Workshop on Perspectives of Collaboration Development between JINR and IN2P3 (online)	Dubna	18 May	51
20.	28th International Seminar on Interaction of Neutrons with Nuclei (ISINN-28; online)	Dubna	24–28 May	218
21.	22nd Workshop on Computer Algebra (hybrid format)	Dubna	24–25 May	74
22.	17th JINR Training Course "JINR Expertise for Member States and Partner Countries" (JEMS-17)	Dubna	24–28 May	25
23.	Workshop "Discussion of the Project of the Federal Program of Neutrino and Particle Astrophysics Research" (hybrid format)	Dubna	26 May	40

* A number of conferences were held jointly with other organizations.

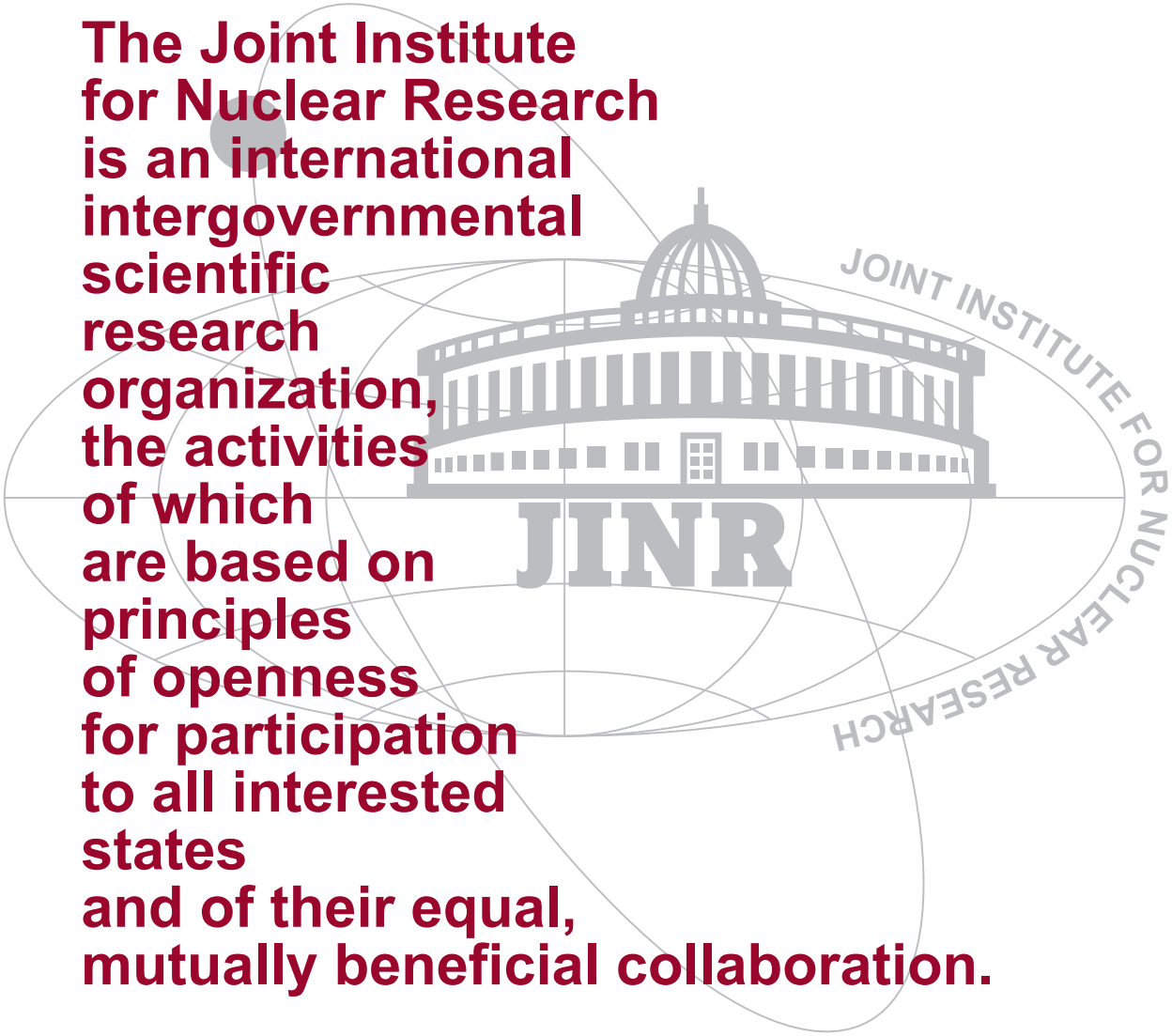
No.	Name	Place	Date	Number of participants
24.	6th Meeting of the Joint Coordination Committee Serbia–JINR (online)	Dubna–Belgrade–Novi Sad	27 May	10
25.	School of Young Scientists "Modern IT-Technologies for Solving Scientific Problems"	Vladikavkaz, Russia	31 May – 1 June	60
26.	SPD Collaboration Meeting	Dubna	8–10 June	119
27.	10th Scientific Conference of JINR Young Scientists and Specialists (Alushta-2021)	Resort Hotel "Dubna", Alushta, Russia	8–15 June	105
28.	School of Young Scientists "Collider NICA, MPD Experiment and Its Main Tasks"	Vladikavkaz, Russia	10–12 June	35
29.	55th Meeting of the Programme Advisory Committee for Particle Physics (online)	Dubna	21–22 June	67
30.	54th Meeting of the Programme Advisory Committee for Nuclear Physics (online)	Dubna	23–24 June	27
31.	54th Meeting of the Programme Advisory Committee for Condensed Matter Physics (online)	Dubna	28–29 June	70
32.	Workshop "Superheavy Elements" (hybrid format)	Dubna	30 June – 2 July	200
33.	18th JINR Training Course "JINR Expertise for Member States and Partner Countries" (JEMS-18)	Dubna	5–9 July	23
34.	9th International Conference "Distributed Computing and Grid Technologies in Science and Education" (GRID 2021; hybrid format)	Dubna	5–9 July	301
35.	25th JINR Summer School of Young Scientists and Specialists "Lipnya-2021"	Dubna	16–18 July	60
36.	International Workshop "Geometry, Integrability and Supersymmetry" (GIS21)	Yerevan, Armenia	22–27 August	35
37.	Workshop "Prospects of Cooperation of Ukraine with JINR" (hybrid format)	Kharkov, Ukraine	5–6 September	30
38.	Science School for Students of the School University of the Egyptian Academy of Scientific Research and Technology	Dubna	6–11 September	23
39.	Workshop for Employees of Regional Scientific and Technical Museums "Mediation: The Practice of Interaction with the Visitor, Scientific Communication"	Dubna	14–17 September	52
40.	International Round Table on Applied Research and Innovations @ NICA (hybrid format)	Dubna	15–16 September	301
41.	Workshop on Numerical and Symbolic Scientific Computing	Sofia, Bulgaria	20–24 September	30
42.	130th Session of the JINR Scientific Council (hybrid format)	Dubna	23–24 September	86
43.	27th Russian Particle Accelerator Conference (RuPAC 2021)	Resort Hotel "Dubna", Alushta, Russia	26 September – 2 October	145
44.	8th Collaboration Meeting on the BM@N Experiment at the NICA Facility	Dubna	3–8 October	105
45.	5th International Conference "Modern Problems of Genetics, Radiobiology, Radioecology, and Evolution" dedicated to N. W. Timofeev-Ressovsky (GRRE2021; hybrid format)	Nor Amberd, Armenia	5–9 October	152

No.	Name	Place	Date	Number of participants
46.	International Conference “Advances of Quantum Field Theory” (hybrid format)	Dubna	11–14 October	122
47.	25th International Scientific Conference of Young Scientists and Specialists (AYSS-2021)	Almaty, Kazakhstan	11–15 October	133
48.	8th Collaboration Meeting on the MPD Experiment at the NICA Facility (hybrid format)	Dubna	12–14 October	175
49.	Online Conference “Neutrons and Synchrotron Radiation in Investigations of Condensed Matter”	Dubna	12–13 October	100
50.	8th Congress on Radiation Research (Radiobiology, Radioecology, Radiation Safety) (hybrid format)	Moscow	12–15 October	400
51.	2nd Workshop “Use of Nuclear Physics Methods for Cultural Heritage Research”	Kazan, Russia	15–20 October	102
52.	Meeting “ITMO University–JINR: Prospects for Cooperation”	Dubna	19–20 October	20
53.	Workshop on the Development of the Joint JINR–Poland Collaborations in the Field of Heavy Ion Physics	Warsaw, Poland	20 October	12
54.	27th Nuclear Physics Workshop	Lublin, Poland	21–23 October	59
55.	Conference “New Trends in Nuclear Physics Detectors” (NTNPD-2021)	Warsaw, Poland	25–27 October	75
56.	19th JINR Training Course “JINR Expertise for Member States and Partner Countries” (JEMS-19)	Dubna	8–12 November	27
57.	Meeting of the JINR Finance Committee	Bansko, Bulgaria	19 November	72
58.	Session of the Committee of Plenipotentiaries of the Goverments of the JINR Member States	Bansko, Sofia, Bulgaria	22–23 November	103
59.	JINR Contact Points Meeting	Dubna	1–3 December	16
60.	International Symposium “Science. Phylosophy. Religion”	Dubna	10 December	52
61.	Workshop on the Application of the Tagged Neutron Method in Ecology (hybrid format)	Dubna	16 December	60
62.	Seminar dedicated to the 80th anniversary of Academician V. A. Matveev (hybrid format)	Dubna	17 December	220

Six meetings of the JINR Science and Technology Council were also held, as well as a regular open robotic tournament (the 10th in the series; CyberDubna 2021), a training course for young scientists of the CIS countries, student program, Physics Days 2021.

Besides, JINR was one of the organizers of the 20th Lomonosov Conference on Physics of Elementary Particles, the International Conference “Nucleus-2021. Nuclear Physics and Elementary Particle Physics. Nuclear Physics Technologies”, the 28th International Seminar “Nonlinear Phenomena in Complex Systems” in the memory of V. I. Kuvshinov, the 3rd International Scientific Forum “Nuclear Science and Technology”, the International Conference on Precision Physics and Fundamental Physical Constants, and other events.

The Joint Institute for Nuclear Research is an international intergovernmental scientific research organization, the activities of which are based on principles of openness for participation to all interested states and of their equal, mutually beneficial collaboration.



A ceremonial opening of the panel "Mendeleev's Periodic Table" on the wall of the JINR "Archimedes" Swimming Pool

Dubna, 26 March.
The ceremonial meeting on the occasion of the JINR Establishment Day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Sofia, 22–23 November. A visiting session of the JINR CP

Dubna, 23 June. The 54th meeting of the PAC for Nuclear Physics

Dubna, 25 March. Opening of the multimedia exhibition dedicated to the 65th anniversary of the JINR establishment

Dubna, 23–24 September. The 130th session of the JINR Scientific Council

Dubna, 3 March. The solemn meeting of the JINR Directorate with representatives of the national group of Bulgaria on the occasion of celebration of the Day of Bulgaria's Liberation from the Ottoman yoke

Dubna, 24 March. Ambassador Extraordinary and Plenipotentiary of the Czech Republic to RF V. Pivoňka (right) at the opening of the JINR hotel in Moskovskaya street, 2 after the repair work done by the Czech building company ASARKO

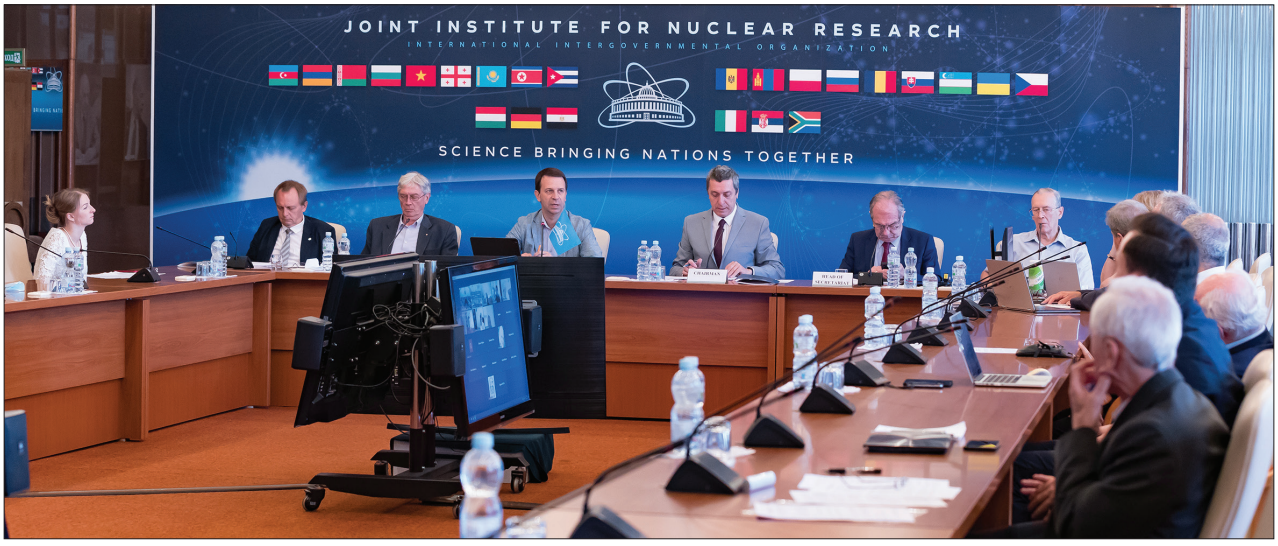
Dubna, 18 March. Participants of the videoconference with the new Plenipotentiary of the Government of the Republic of Armenia to JINR, Chairman of the State Committee on Science of the RA Ministry of Education, Science, Culture and Sport S. Hayotsyan and his deputy A. Movsisyan

Dubna, 19 April. Participants of the round-table discussion in the framework of the 16th international training programme JEMS

Dubna, 22 April. JINR Director G. Trubnikov and SEZ “Dubna” Director General A. Afanasiev after signing an agreement on development of technological cooperation of JINR with industrial resident partners of the SEZ “Dubna”

Moscow, 11 June. Signing of the agreement between JINR and the Kurchatov Institute on joint implementation of projects in socio-humanitarian sphere

Dubna, 22 July. The first meeting of the Working Group on Strategic Issues of JINR



Dubna, 16 July. Meeting of Ambassador Extraordinary and Plenipotentiary of Romania to the Russian Federation C. Istrate (second from left in the first row) with Romanian scientists working at the Institute

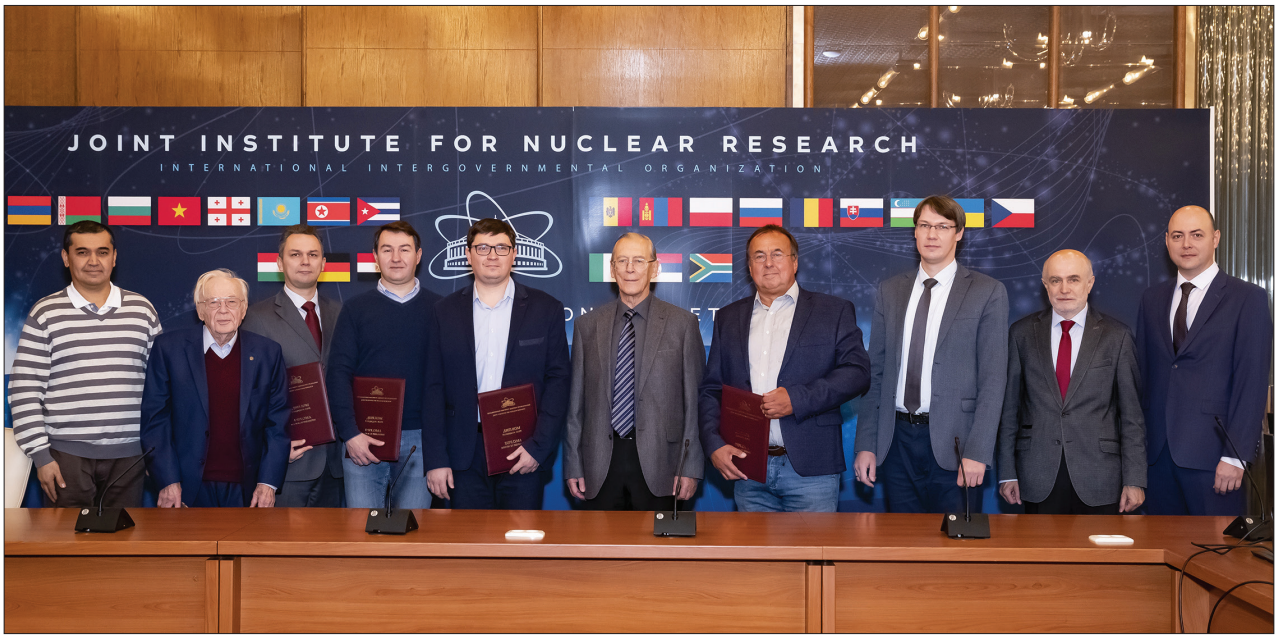
Dubna, 8–12 June. General Director of the Institute of Nuclear Physics of the Ministry of Energy of the Republic of Kazakhstan, Plenipotentiary of the Government of RK to JINR B. Karakozov meets the national group of JINR staff members from Kazakhstan

Dubna, 19 July. Meeting of Plenipotentiary of the Government of the Slovak Republic to JINR F. Šimkovic (in the centre) with the JINR Directorate

Sofia (Bulgaria), 16 September. Opening of the JINR Information Centre at Sofia University "St. Kliment Ohridski" as part of a series of events dedicated to the 65th anniversary of the Institute and the Year of Bulgaria at JINR. From left to right: JINR Vice-Director L. Kostov and Rector of Sofia University Professor A. Gerdjikov

Dubna, 7 October. JINR Vice-Director L. Kostov and Vice-Rector for Science, Innovation, and International Affairs of KamSU V. Efimenko signed an agreement on the opening of the JINR Information Centre in the Vitus Bering KamSU

Dubna, 20 October. A festive awarding ceremony of diplomas on conferring academic degrees

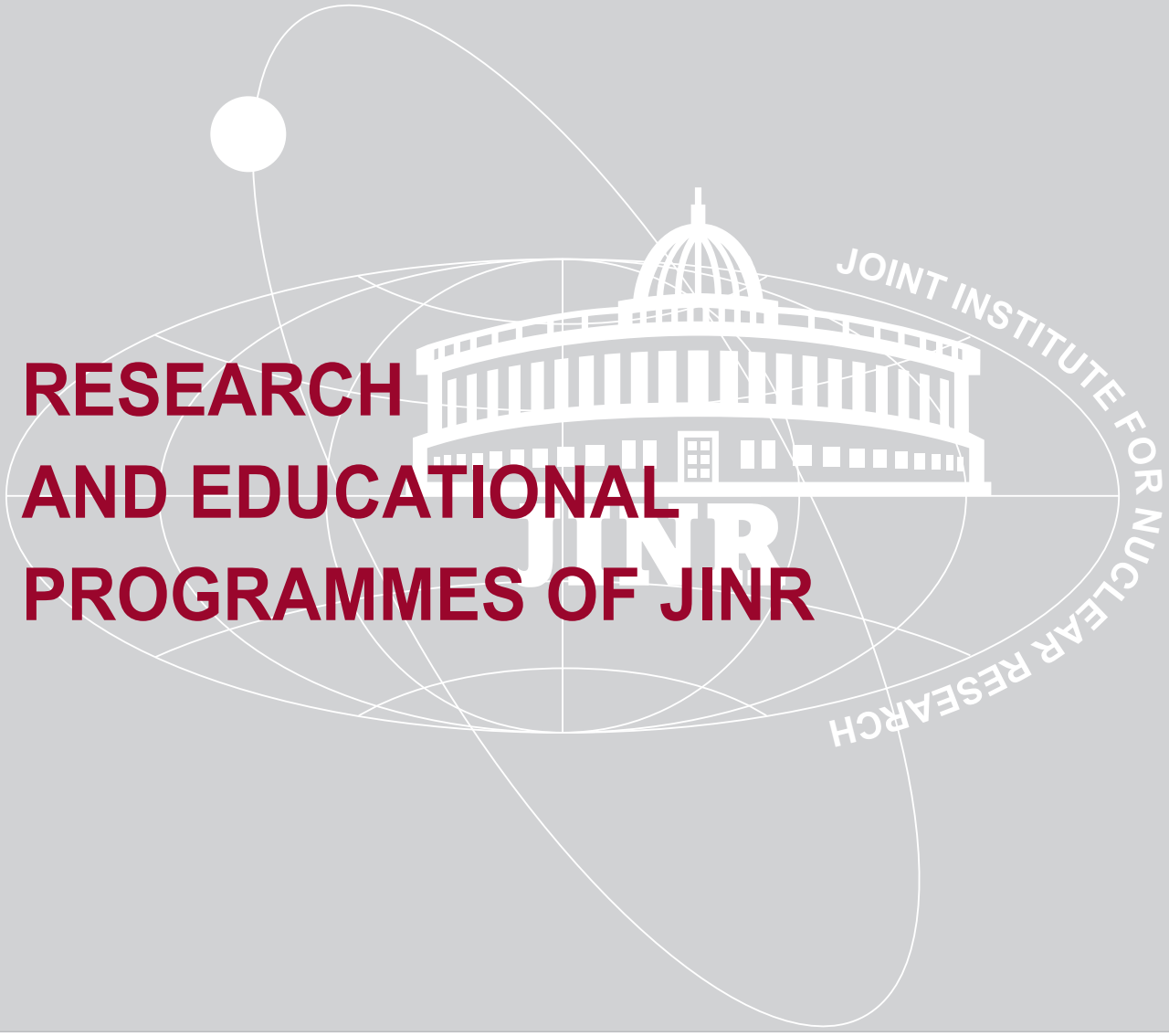


Minsk (Belarus), 28 September. Participants of the meeting of the International Association of the Academies of Sciences awarded the badge “IAAS Academician” (*photo of the newspaper “Navuka”*)

Dubna, 1 September.
Solemn opening of the new Physics and Mathematics Lyceum named after V. G. Kadyshevsky

2021

RESEARCH AND EDUCATIONAL PROGRAMMES OF JINR



BOGOLIUBOV LABORATORY OF THEORETICAL PHYSICS

In 2021, at the Bogoliubov Laboratory of Theoretical Physics (BLTP), studies were carried out on the following four themes: Fundamental Interactions of Fields and Particles; Theory of Nuclear Systems; Theory of Complex Systems and Advanced Materials; Modern Mathematical Physics: Gravity, Supersymmetry and Strings. In the theme "Theory of Complex Systems and Advanced Materials", a new sector "Methods of Quantum Field Theory in Complex Systems" was formed. An important component of the BLTP activities is theoretical support of experimental research to be carried out within major international projects with the participation of JINR as well as Dubna-based experimental programmes of JINR Laboratories. The research resulted in about 380 publications in peer-reviewed journals and proceedings of international conferences. Most of the results were obtained in cooperation with scientists from the JINR Member States, Brazil, China, Egypt, France, Germany, India, Italy, South Africa, and other countries. Every year BLTP is a venue for scientific events of the highest level. Despite the restrictions due to the pandemic of the new coronavirus, three conferensces and workshops and one school for students and young scientists were organized by BLTP in 2021. These events were held in a mixed format (in person/remote). In addition to them, on 17 December, BLTP hosted a scientific seminar dedicated to the 80th anniversary of JINR Scientific Leader V. A. Matveev. At the same time, BLTP researchers gave over 170 talks at more than 120 conferences and workshops, both in person and at events held online. International collaboration was supported by grants of the Plenipotentiaries of the Governments of Azerbaijan, Belarus, Bulgaria, the Czech Republic, Kazakhstan, Poland, Romania, the Slovak Republic, and the JINR Directorate. Collaboration with German theorists was based on the Heisenberg–Landau Programme; with Polish theorists, on the Bogoliubov–Infeld Programme; with Czech theorists, on the Blokhintsev–Votruba Programme; and with Romanian theorists, on the Titeica–Markov Programme. For support of the collaboration with colleagues from Slovakia, a new programme was organized called the Bilenky–Ilkovic Programme. In the framework of agreements, the collaboration was carried out with scientists from Egypt, France (JINR–IN2P3), Italy (JINR–INFN), Serbia, and South Africa. The Bogoliubov Laboratory has collaboration agreements with APCTP (South Korea) and ITP CAS (Beijing) as well as active cooperation with theorists from CERN. Six research projects were supported by the RFBR grants; three research projects, by the RSF. Traditionally, much attention was paid to recruiting young researchers, students, and post-graduate students to the Laboratory within the research and education project "Dubna International Advanced School of Theoretical Physics (DIAS-TH)"; however, due to the coronavirus pandemic, the programme of work with foreign young scientists was significantly reduced. The Laboratory serves as a training center for young scientists and students from many countries. Currently, about one third of the BLTP scientific staff are young scientists and PhD students. Several young researchers from non-Member States: India, Iran, and Japan, have been working at BLTP on a long-term basis.

SCIENTIFIC RESEARCH

Fundamental Interactions of Fields and Particles

Theoretical investigations in 2021 were carried out in the framework of the following projects:

- Quantum field theory and physics beyond the Standard Model;
- QCD and spin/3D hadron structure;
- Strong interaction phenomenology and precision physics;
- Theory of hadronic matter under extreme conditions;
- Theory of electroweak interactions and neutrino physics.

Combining traditional methods and new ideas, expressions for the renormalization group (RG) functions in the most general quantum field theory in four dimensions were found. This allows one to carry out RG analysis of arbitrary renormalizable Beyond-the-SM models without the need for tedious diagrammatic calculations. For the first time, general beta functions were computed for the gauge and Yukawa constants in the four- and three-loop approximations, respectively. Moreover, in the framework of general scalar theories φ^4 six-loop evolution equations for all the parameters of the Lagrangian were derived [1].

A new method was developed that allows one to find solutions for a wide class of elliptic Feynman integrals in terms of iterated integrals with algebraic kernels. This method was tested on the example of a two-loop elliptic integral of the sunset type, as well as on the example of a three-loop elliptic integral of the banana type. It was shown that the obtained results can be successfully used to calculate more complex integrals of the "kite" type [2].

Two-loop sunrise integrals with two different internal masses at pseudo-threshold kinematics were studied and solved in terms of elliptic polylogarithms to all orders of the dimensional regulator [3].

At large distances, the Universe has a honeycomb structure: galaxies and clusters of galaxies are located on the walls, while the space inside — voids, gigantic regions, look almost empty. The exact formula for the central density of the void was derived. The density in the void center is determined exclusively by the amplitude of the initial perturbation and does not depend on its shape. The results show that computer simulations somewhat overestimate void voidness. The central region of the void behaves like a part of Friedman's open "universe", and its evolution is fundamentally different from the evolution of our Universe: there is a long stage when the "universe" is dominated by the contribution of curvature, which suppresses the formation of massive galaxies and galaxy clusters within the voids. It is also shown that dark energy suppresses the growth of voids by increasing the density of matter [4].

The dominant radiative transitions of the charmonium S- and P-wave states were studied within the covariant confined quark model. The basic model parameters were kept (the constituent c-quark mass m_c, the global infrared cutoff λ) and only one common adjustable parameter $\rho > 0$ was introduced additionally to describe the quark distribution inside the hadron. The renormalized couplings and fractional one-photon decay widths for $\eta_c, J/\Psi, \chi_{c0}, \chi_{c1}, h_c, \chi_{c2}$ were calculated. The estimated results are in good agreement with the latest experimental data. The "theoretical full width" $\Gamma_{\rm theor}(h_c) = (0.57 \pm 0.12)$ MeV was also predicted which may be compared with the latest data $\Gamma_{\rm PDG}(h_c) = (0.7 \pm 0.4)$ MeV. It was shown that the obtained results do not change with the global cutoff parameter value $\lambda < 0.181$ GeV up to the "deconfinement" limit [5].

A method was proposed for testing lepton universality in semileptonic decays of heavy mesons and baryons, which is based on the factorization of the dependence on lepton masses in the expression for the convexity parameter in the angular distribution. Experimental measurements of the thus optimized partial width for each lepton decay mode will make it possible to judge the lepton universality regardless of the type of form factors used in the calculation [6].

New results on precision spectroscopy of HD^+ were obtained. Two new independent experiments in Düsseldorf and Amsterdam achieved a relative precision of 10^{-11}–10^{-12}. Comparison of these experiments with theoretical calculations unambiguously indicated that the proton charge radius should be determined from the muonic hydrogen experiment, and the Rydberg constant from the $1S$–$2S$ transition in the ordinary hydrogen atom. Only in this case, the experiment and theory in HD^+ are reasonably consistent with each other. A new value for the proton-to-electron mass ratio was obtained with a relative uncertainty of $1.5 \cdot 10^{-11}$, which allows calculating the atomic mass of an electron with a two-fold improved precision relative to the value recommended by the CODATA group in 2018 [7].

The possibility was studied that the so-called reactor antineutrino anomaly, that is, the deficit of antineutrino event rates in reactor experiments in comparison with theoretical expectations, can be at least in part explained within a quantum field-theoretical approach to neutrino oscillations that in particular predicts a small deviation from the classical inverse-square law at short (but still macroscopic) distances between the (anti)neutrino source and detector. Extensive statistical analysis of the current reactor data on the integrated antineutrino event rates vs. baseline was performed to examine this speculation. The obtained results were applied to study another long-standing puzzle — gallium neutrino anomaly, which is a missing neutrino flux from Ar-37 and Cr-51 electron-capture decays as measured by the Ga–Ge solar neutrino detectors GALLEX and SAGE [8].

Two-neutrino double beta decay provides a complementary probe of physics beyond the Standard Model. It was investigated how the presence of a sterile neutrino, coupled to the Standard Model either via a left-handed or right-handed current, affects the energy distribution and angular correlation of outgoing electrons in two-neutrino double beta decay. The results complement the corresponding studies on sterile neutrinos from single beta decay measurements in the heavy neutrino mass range: 0.1–10 MeV [9].

The q-derivatives of the Srivastava and Daoust basic multivariable hypergeometric function with respect to the parameters were considered. These functions embody an entire number of various q-hypergeometric series of one and several variables.

Explicit equations were given for the general case of summation indices with positive real coefficients. As an example, the derivatives of the q-analog of the non-confluent Horn type hypergeometric function H_3 were presented [10].

The gluon anomaly contribution to the transition form factors of η, η', and π^0 mesons was investigated. The estimations were carried out using the ASR for the isovector, octet and singlet components of axial current. The space-like and time-like regions were analyzed and a universal description of the transition form factors was obtained. Contrary to the case of real photons ($Q^2 = 0$), where the non-Abelian anomaly contribution is suppressed, at higher values of Q^2 the non-Abelian anomaly contribution becomes significant [11].

It was shown that using renormalization-group summation to generate QCD radiative corrections to the $\pi-\gamma$ transition form factor, calculated with the light-cone sum rules (LCSR), renders the strong coupling free of Landau singularities while preserving the QCD form-factor asymptotics. This enables reliable applicability of the LCSR method to momenta well below 1 GeV^2. This way, one can use the new preliminary BESIII data with unprecedented accuracy below 1.5 GeV^2 to fine tune the prefactor of the twist-six contribution. Using a combined fit to all available data below 3.1 GeV^2, it is possible to determine all nonperturbative scale parameters and a few Gegenbauer coefficients entering the calculation of the form factor. By employing these ingredients, a pion distribution amplitude was determined with the conformal coefficients (b_2, b_4) that agree at the 1σ level with the data for $Q^2 \leqslant 3.1$ GeV^2 and fulfill at the same time the lattice constraints on b_2 at N3LO together with the constraints from QCD sum rules with nonlocal condensates. The form-factor prediction calculated herewith reproduces the data below 1 GeV^2 significantly better than analogous predictions based on a fixed-order power-series expansion in the strong coupling constant [12].

The analytical results were presented for massless correlators of two vector, tensor, and scalar composite vertices with the Bjorken fractions x and y of an order $\beta_0\alpha_s^2$ of QCD. The structure of these correlators $\Pi^{V,T,S}(x, y; p^2)$ and properties of their main elements were discussed in detail. Special attention was paid to verifying the results and comparing them with known particular cases. The correlators were applied to evaluate radiative corrections to the distribution amplitudes of light mesons within the QCD sum rules [13].

A solution to the problem with a factor of 2 in the chiral vortical effect (CVE) for photons was found. It was shown that the prediction for the temperature contribution to CVE, based on considering an auxiliary rotating black hole and the gravitational anomaly on its horizon, comes in agreement with a statistical calculation based on the Kubo formula if in both cases low mass infrared regularization is used [14].

The full analytical results for angular phase space integrals for 2 into 3 scattering processes were obtained. The case of two massive propagators which was not considered earlier in the literature was also calculated. Moreover, the method of reducing the product of two or more massive propagators makes it possible to express this product in terms of a sum of massless and massive propagators with fewer massive propagators in each term. The obtained expression can be used for calculation of large process classes. In particular, such results will be used to analyze the Drell–Yan process in the second order of strong coupling at a small transverse momentum of a vector boson that will decay into a lepton pair [15].

The role of the $1/N_C$ corrections in the description of the processes $\rho \to \pi\pi$ ($g_\rho = 6.0$), $\rho \to l^+l^-$ ($g_\rho = 5.0$) and $\omega \to l^+l^-$ ($g_\rho = 5.7$), where $l = e$, μ was investigated. It was shown that the emission of a photon by charged meson loops in the ρ, ω, $\varphi \to \gamma$ transitions is the key process for describing the above vector meson decays into two leptons with a single value $g_\rho = 6.0$. The obtained result supports Sakurai's idea about universality of neutral vector mesons and clarifies the role of accounting of $1/N_C$ corrections to its fulfillment [16].

The total cross section of electron–positron annihilation into a proton–antiproton pair in the energy range close to the mass of charmonium $\psi(3770)$ was calculated. It was shown that the main contribution to this cross section is made by a three-gluon mechanism that generates a large phase relative to the contribution of the continuum. This phase provides a characteristic dip behavior of the cross section (in contrast to the usual Breit–Wigner peak), which was observed in the BES experiment. The mechanism with the D-meson loop was also considered, which gives a relatively small contribution to the cross section and phase [17].

A systematic investigation for the possible locations of the special point (SP), a unique feature of hybrid neutron stars in the mass–radius diagram, was presented within the two-phase approach where the high-density (quark matter) phase is described by the constant-sound-speed (CSS) equation of state (EoS) and the nuclear matter phase around saturation density is varied from very soft (APR) to stiff (DD2 with excluded nucleon volume). It was demonstrated for the first time that the SP is invariant not only when the nuclear matter EoS changes, but also when the schemes for constructing a phase transition are varied: Maxwell construction, mixed phase construction, and parabolic interpolation. Since the SP serves as a proxy for the maximum mass and accessible radii of massive hybrid stars, conclusions are drawn for the limiting masses and radii of hybrid neutron stars [18].

Predictions were made for the global polarization of Λ hyperons in Au + Au collisions at moderately relativistic collision energies 2.4–11 GeV. They

were based on the thermodynamic approach to the global polarization incorporated into the model of the three-fluid dynamics. Centrality dependence of the polarization was studied. It was predicted that the polarization reaches a maximum or a plateau (depending on the equation of state and centrality) at $\sqrt{s_{NN}} \approx 3$ GeV. It was found that the global polarization increases with the width of the rapidity window around the midrapidity [19].

The effect of rotation on the confinement/deconfinement phase transition in $SU(3)$ gluodynamics was studied within lattice simulation in the rotating reference frame, where rotation is specified by an external gravitational field. To analyze the confinement/deconfinement phase transition, the Polyakov loop and its susceptibility were calculated for various temperatures and angular velocities. The results obtained indicated that the critical temperature of the confinement/deconfinement phase transition in $SU(3)$ gluodynamics increases with angular velocity. The results obtained are qualitatively independent of the choice of boundary conditions in directions orthogonal to the axis of rotation [20].

One-loop QCD correction of QCD (contributions of pure gluodynamics and massless quarks) to free energy of Abelian (anti-)self-dual field inside finite-size ball was evaluated. It was shown that quasi-zero modes (modes that become zero in the limit of infinite volume) necessitate treatment beyond one loop which induces effective mass for these modes. This may lead to a minimum of the free energy density with respect to both the background field strength and size of the ball. The minimum determines the mean value of the scalar gluon condensate and the size of homogeneity in the model of QCD vacuum represented by an ensemble of almost everywhere homogeneous (anti-)self-dual fields [21].

It was shown that the elliptic flow in heavy-ion collisions is weakly dependent on event-by-event fluctuations everywhere except for very central collisions 0–2%, whereas the triangular flow is mostly determined by fluctuations [22].

Theory of Nuclear Systems

In 2021, investigations were carried out in accordance with four projects:

- Microscopic models for exotic nuclei and nuclear astrophysics;
- Low-energy nuclear dynamics and properties of nuclear systems;
- Quantum few-body systems;
- Relativistic nuclear dynamics and nonlinear quantum processes.

The self-consistent approach based on the quasiparticle random-phase approximation implemented with Skyrme interaction and taking into account coupling to complex configurations was generalized for describing the process of double γ decay in an even–even nucleus. For the first time, the $\gamma\gamma$ decay of the first quadrupole state of the doubly magic nucleus ^{48}Ca was studied which could proceed in competition with a single γ decay. It was shown that the $\gamma\gamma$-decay width is sensitive to the mixing of simple and complex configurations in the giant dipole resonance region. The obtained estimate of the $\gamma\gamma$-decay probability, $3 \cdot 10^{-8}$, can be tested experimentally [23].

Based on the collective nuclear Hamiltonian and the microscopic approach to the description of the structure of low-lying states of nuclei, the relationship between excitation energy and the probability of the $E2$ transition to the first 2^+ state was theoretically derived. This ratio was established on the basis of the analysis of experimental data back in 1962, but its theoretical derivation was absent [24].

For future experiments, the production cross sections of superheavy nuclei with charge numbers 114–117 were predicted in the $(5-9)n$ evaporation channels of the ^{48}Ca-induced complete fusion reactions [25].

Based on the energy density functional, the nucleus ^{288}Fl was predicted as the next double magic nucleus after ^{208}Pb, and 304–120 was identified as the most likely candidate for next-to-next double magic nucleus [26].

It was found that the account of the nondiagonal matrix elements of the coupling matrix, traditionally neglected in the conventional coupled-channels approaches, allows one to explain the difficulties arising in various models in the interpretation of experimental data for the S factor of the fusion reaction of two colliding heavy nuclei [27].

The model was developed for the description of the dipole decay widths, in which the energy-dependent shift of the one-phonon states arising due to the coupling of the one-phonon states with complex configurations can be estimated analytically. The obtained results are in good agreement with the results of the microscopic calculations for nuclei around ^{208}Pb [28].

A family of analytically solvable potential models for the one- and two-channel problems was considered within the Jost matrix approach. The migration of the S-matrix poles on the Riemann surface of the energy caused by variations of the potential strength was studied. It was demonstrated that the long-range ($\sim 1/r^2$) tails and Coulomb potential ($1/r$) cause unusual behaviour of the S-matrix poles. The Coulomb tail not only changes the topology of the Riemann surface but also breaks down the so-called mirror symmetry of the poles in both the single-channel and two-channel problems [29].

A new efficient method was proposed for sympathetic cooling of ions: the use for this purpose of cold buffer atoms in the region of atom–ion confinement-induced resonances (CIRs). It was shown that the destructive effect of ion micromotion on its sympathetic cooling can be suppressed in the vicinity of the atom–ion CIR. The effect of sympathetic cooling around CIRs in atom–ion and atom–atom confined collisions was investigated within the quantum-quasiclassical approach using the Li–Yb$^+$ and Li–Yb

confined systems as an example. The region was found near the atom–ion CIR where the sympathetic cooling of the ion by cold atoms is possible in a hybrid atom–ion trap. It was shown that it is possible to improve the efficiency of sympathetic cooling in atomic traps by using atomic CIRs [30].

The two-dimensional scattering of a quantum particle was studied in the field of a central long-range potential decaying in the limit of a large distance r as a power-law function $r^{-\beta}$ with the exponent $\beta > 2$. The explicit low-energy forms of all partial scattering phases were found for such a particle [31].

Based on the folding optical potential and also on the Kisslinger potential, calculations were performed of the π-meson interaction with nuclei at the 33-resonance energies. It was established that the pion interaction with the nucleon bounded in a nuclear matter is too weak as compared to the pion interaction with a free nucleon [32].

The theory of nonlinear quantum processes in strong electromagnetic fields was developed. For the first time, the developed methods were used for prediction of the production probabilities of hard Compton photons and electron–positron pairs in interaction of ultra-relativistic electrons with intense laser pulses in a wide range of electron energies and laser beam intensities at the largest European laser project (XFEL, DESY), which is now under construction [33].

In the framework of the kinetic models of the Monte Carlo type — Quark-Gluon-String Model (QGSM) and Parton-Hadron-String Dynamics (PHSD), the transverse and global polarization of Λ hyperons in interactions of heavy ions in the energy range of the NICA collider was studied. The analysis of the spatial structure of the transverse and diagonal vorticity components relative to the reaction plane was carried out; the spatial separation of hydrodynamic helicity was revealed. The results of theoretical calculations show satisfactory agreement with the experimental results of the STAR collaboration. In the MPD experiment performed using Monte Carlo simulations, the transverse polarization of Λ hyperons was studied to analyze the detector's sensitivity to this observable [34].

The effect of temperature on the bound states of quark–antiquark pairs was studied. The presence of a phase transition was shown, and estimates of the temperature of this transition were given [35].

Theory of Complex Systems and Advanced Materials

Theoretical investigations in 2021 were carried out in the framework of the following projects:

- Complex materials;
- Nanostructures and nanomaterials;
- Mathematical models of statistical physics of complex systems.

In cold atoms, Tan's theorem relates the long-range momentum distribution to the derivative of the energy with respect to the scattering length. It is widely used to describe the thermodynamics of systems in experiments with atomic traps. This theorem was generalized for interactions of an arbitrary shape, and its simple physical interpretation was suggested [36].

A method of self-similar factor approximants was developed allowing for effective summation of asymptotic series. The method was used for solving several problems in statistical physics and quantum field theory [37].

Characteristics of the structural and associated magnetic phase transitions in metallic terbium measured under high external pressure by the group of D. P. Kozlenko (FLNP, JINR) were quantitatively explained using the methods of density functional theory [38].

The electronic spectrum and superconductivity were investigated within the extended $t{-}J{-}V$ model where the electron–phonon and intersite Coulomb interactions were taken into account. The Fermi surface in the form of arcs was explained. It was shown that the electron–phonon and intersite Coulomb interactions give a small contribution to the superconducting temperature for the d-wave pairing [39].

A method was proposed to extract the main structural parameters of surfaces/interfaces from experimental data based on the small-angle scattering technique. It involves the analysis of scattering intensities and the corresponding pair distance distribution functions. This allows the extraction of information with respect to the overall size, fractal dimension, Hurst and spectral exponents. The method was applied to several classes of fractional Brownian surfaces, and it was shown that the obtained numerical values of the structural parameters are in very good agreement with theoretical ones [40].

The $O(1)$ dense loop model and related critical percolation model are paradigmatic models of statistical physics being a laboratory for studying critical phenomena. Exact densities of contractible and non-contractible loops were obtained in the $O(1)$ model on a strip of the square lattice rolled into an infinite cylinder of finite even circumference $L = 2N$. They are also equal to the densities of critical percolation clusters on forty-five-degree-rotated square lattice rolled into a cylinder, which do not or do wrap around the cylinder, respectively. The results were presented as explicit rational functions of N taking rational values for any N. Their asymptotic expansions in the large N limit have irrational coefficients reproducing the earlier results in the leading orders. The result obtained gives a unique example of exact calculation of an observable in a confined system that approaches a critical state in the infinite size limit [41].

The model of the totally asymmetric exclusion process with the generalized update rules was studied, which, unlike the usual totally asymmetric exclusion process, has an additional parameter enhancing clustering of particles. The exact multiparticle

distributions of distances travelled by particles on the infinite lattice were derived for two types of initial conditions: step and alternating ones. Two different scaling limits of the exact formulas were studied. Under the first scaling associated with the Kardar–Parisi–Zhang (KPZ) universality class, the convergence of joint distributions of the scaled particle positions to finite-dimensional distributions of the universal Airy2 and Airy1 processes was proven. Under the second scaling, the convergence of the same position distributions to finite-dimensional distributions of two new random processes, which describe the transition between the KPZ regime and the deterministic aggregation regime, in which the particles stick together into a single giant cluster moving as one particle, was proven [42].

The theory and applications of self-similar potentials in quantum mechanics were considered. These potentials are described by solutions of q-deformed Painleve-IV and Painleve-V equations and their analogues of the higher order. As special cases, they contain finite-gap potentials related to the Riemann theta functions of arbitrary genus. New coherent states of the harmonic oscillator were described that are related to a new automorphism of the Heisenberg–Weyl algebra and the Fourier transformation. They have the form of a special superposition of canonical coherent states and emerge as solutions of integro-differential equation associated with a new realization of the Heisenberg–Weyl algebra generators [43].

The influence of the transverse size of a magnetic tunnel nanojunction on the magnitude of the magnetoresistance was studied. During modeling, the size of the right contact was fixed, while the size of the left one gradually changed until they coincided. A sharp drop in the tunneling magnetoresistance (TMR) in nanocontacts with the mismatched cross section was found. This can be explained by the peculiarities of the spatial distribution of the electron density, which is different for majority- and minority-spin states. The discovered effect must be taken into account in the design of TMR-based nanodevices [44].

The phase dynamics, IV characteristics, and magnetization dynamics of the φ_0 Josephson junction at small values of spin–orbit interaction, ratio of the Josephson junction to magnetic energy, and Gilbert damping were studied. It was shown that the coupled Landau–Lifshitz–Gilbert–Josephson dynamics is reduced to a scalar nonlinear Duffing oscillator. The resulting Duffing equation incorporates the Gilbert damping in a special way across the dissipative term and the restoring force. An anomalous shift of the ferromagnetic resonance frequency with decreasing Gilbert damping was found. It was demonstrated that there is a critical damping value at which nonlinearity comes into play, and it changes the damping dependence of the ferromagnetic resonance [45].

The dynamical critical exponent z for 2d and 3d Ising universality classes was calculated by means of minimally subtracted five-loop ε expansion obtained for the one-component model A. This breakthrough turns out to be possible through the successful adaptation of the Sector Decomposition technique to the problems of critical dynamics. The obtained fifth perturbative order accompanied by the use of advanced resummation techniques for asymptotic series allowed one to find highly accurate numerical estimates of z: for two- and three-dimensional cases 2.14(2) and 2.0235(8), respectively. The numbers found are in good agreement with the recent results obtained using different approaches [46].

Modern Mathematical Physics: Gravity, Supersymmetry and Strings

The topics of main focus in the theme in 2021 were:

- Quantum groups and integrable systems;
- Supersymmetry;
- Quantum gravity, cosmology and strings.

In the framework of the AdS/CFT correspondence, the 5-dimensional Kerr–AdS black hole was considered as a gravity dual for a rotating quark–gluon plasma. It was shown that the rotation decreases the temperature of the Hawking–Page transition corresponding to the first-order phase transition in the dual thermal ensemble of $N = 4$ SYM on $R \times S^3$. The energy loss of a heavy quark in the rotating quark–gluon plasma was investigated. Following the holographic prescription, the heavy quark was associated with a string endpoint fixed on the boundary of the Kerr–AdS_5, while the string hangs down to the horizon. The thermal mass of a static quark was calculated, the contribution from the rotation was found. For the cases of one nonzero and two equal rotational parameters, the components of the drag force acting on a heavy quark were computed. It was shown that for the case of one nonzero rotational parameter, the results are in good agreement with the prediction from the 4d case (Kerr–AdS_4), which was obtained earlier in arXiv:1012.3800. For two equal rotational parameters, it turned out that the drag force vanishes, it matches the calculations from the hydrodynamical approach on the 4-dimensional cylinder $R \times S^3$ [47].

A construction due to Mironov, who presented some time ago new examples of minimal and Hamiltonian minimal Lagrangian submanifolds in C^n and CP^n, was generalized. His construction was based on the considerations of a noncomplete toric action of T^k, where $k < n$, on subspaces that are invariant with respect to the action of a natural antiholomorphic involution. This situation takes place for a rather broad class of algebraic varieties: complex quadrics, Grassmannians, flag varieties and so on, which makes it possible to construct many new examples of Lagrangian submanifolds in these algebraic varieties [48].

It was shown by explicitly constructing the fully nonlinear solutions of the Einstein–Klein–Gordon theory that static boson stars, composed of a single complex scalar field, Φ can have a non-trivial multipolar structure yielding the same morphologies for their energy density as those that elementary hydrogen atomic orbitals have for their probability density. In the gravitational theory, multipolar boson stars can be interpreted as individual bosonic lumps in equilibrium [49].

The $6D$, $N = (1,1)$ supersymmetric Yang–Mills theory was studied in the $N = (1,0)$ harmonic superspace formulation. It was explicitly demonstrated that among four two-loop background-field dependent supergraphs contributing to the effective action, only one diverges off shell. It was also shown that the divergences are proportional to the superfield classical equations of motion and hence vanish on shell [50].

Massless infinite spin irreducible representations of the six-dimensional Poincare group were constructed in the space of fields depending on twistor variables. It was shown that the massless infinite spin representation is realized on the two-twistor fields. A full set of equations of motion for two-twistor fields represented by the totally symmetric rank $2s$ two-twistor spin-tensor was presented, and it was shown that they carry massless infinite spin representations. A field twistor transform was constructed and infinite spin fields were found in the space-time formulation with an additional spinor coordinate [51].

Quantum properties of $SU(2|1)$ supersymmetric extension of the superintegrable Smorodinsky–Winternitz system on the complex Euclidean space C^N were studied. It was shown that $SU(2|1)$ supersymmetry implies the bosonic and fermionic states to belong to separate energy levels, thus exhibiting the "even–odd" splitting of the spectra. An equivalent description of the same system in terms of superconformal $SU(2|1,\ 1)$ quantum mechanics was considered [52].

The complete off-shell $4D$, $N = 2$ superfield actions for any free massless integer spin $s \geqslant 2$ fields were presented using the $N = 2$ harmonic superspace approach. On shell, the standard spin content $(s, s-1/2, s-1/2, s-1)$ was restored. For $s = 2$ the action describes the linearized version of "minimal" $N = 2$ Einstein supergravity [53].

It was shown that a wide class of scalar-tensor gravity models universally generates beyond Horndeski interactions at the one-loop level. An explicit form of interaction terms was calculated at the leading order within perturbation theory. The existence of such interactions may be crucial for physics of the early Universe. It was shown that a simple dimensional reasoning proves that in the contemporary Universe the discussed interactions are strongly suppressed and negligible. On the contrary, at the characteristic scales of the early Universe the discussed interactions are no longer suppressed and their existence cannot be neglected [54].

The approach to the decay of a false vacuum in the 4-dimensional scalar field theory, developed by Coleman, was generalized. A wide class of unbounded potentials for which the Coleman instantons do not exist was constructed. For such potentials, the decay of the false vacuum is provided by the proposed new instantons. Universal formulas were obtained for basic physical quantities related to the problem of the decay of a false vacuum. For space of any number of dimensions the potentials were constructed for which the instanton equations are exactly solvable [55].

The vacuum energy of a scalar field in the space-time of two nonparallel cosmic strings was considered. To this end, metrics for orthogonal straight cosmic strings and for slightly nonparallel strings was obtained. In the first case, the separation-dependent part of the vacuum energy was derived in the leading order of string tension. The dependence of the vacuum energy on separation differs from that known for parallel strings. For two strings inclined at a small angle to each other, the approximation used simply reproduces the result for parallel strings, since the angle dependence enters the next-to-leading order. The results were compared with the Casimir interaction between two inclined cylinders [56].

DUBNA INTERNATIONAL ADVANCED SCHOOL OF THEORETICAL PHYSICS (DIAS-TH)

The educational programme of the DIAS-TH in 2021 was cut due to the coronavirus pandemic, and it was not possible to organize all the planned schools for students and young scientists. XVI Winter School in Theoretical Physics "Actual Cosmology" was held on-line. Regular seminars for students and postgraduates were organized, computer processing of video records of lectures was continued, web-site of DIAS-TH was supported.

Preparations for the Winter School in Theoretical Physics "Supersymmetry and Integrability" scheduled for February 2022 were carried out.

CONFERENCES AND MEETINGS

Three conferences and workshops, one seminar, and one school for students and young scientists were organized in 2021:

• XVI Winter School on Theoretical Physics "Actual Cosmology", 1–7 February, Dubna;

• International conference "Low Dimensional Materials: Theory, Modelling and Experiment", 12–17 July, Dubna;

• International workshop "Geometry, Integrability and Supersymmetry", 22–27 August, Yerevan;

• International conference "Advances of Quantum Field Theory", 11–14 October, Dubna;

• International scientific seminar dedicated to the 80th anniversary of JINR Scientific Leader V. A. Matveev, 17 December, Dubna.

COMPUTER FACILITIES

In 2021, two PC-servers, each equipped with 8-core 11th generation Intel CPU and 128 GBytes of RAM, were brought into operation. To upgrade computers at workplaces, 10 PCs were purchased. Extensions of technical support were purchased and fresh versions were installed for Mathematica, Maple, Origin Pro. New development software Intel OneAPI replaced the former Parallel Studio. Two enterprise class laser printers replaced older printers in the computer hall KRAST. Additional audio-video equipment was installed in two main lecture halls to support events with on-line participantion.

REFERENCES

1. *Bednyakov A., Pikelner A.* // Phys. Rev. Lett. 2021. V. 127, No. 4. P. 041801; JHEP. 2021. V. 04. P. 233.
2. *Bezuglov M. A., Onishchenko A. I., Veretin O. L.* // Nucl. Phys. B. 2021. V. 963. P. 115302; *Bezuglov M. A.* // Phys. Rev. D. 2021. V. 104, No. 7. P. 076017.
3. *Campert L. G. J., Moriello F., Kotikov A.* // JHEP. 2021. V. 09.
4. *Baushev A. N.* // Monthly Not. Roy. Astron. Soc. Lett. 2021. V. 504, No. 1. P. 56–60.
5. *Ganbold G., Gutsche Th., Ivanov M. A., Lyubovitskij V. E.* // Phys. Rev. D. 2021. V. 104. P. 094048.
6. *Groote S., Ivanov M. A., Korner J. G., Lyubovitskij V. E., Santorelli P., Tran C. T.* // Phys. Rev. D. 2021. V. 103. P. 093001.
7. *Korobov V. I., Karr J.-Ph.* // Phys. Rev. A. 2021. V. 104. P. 032806.
8. *Naumov V. A., Shkirmanov D. S.* // Universe. 2021. V. 7. P. 246.
9. *Bolton P. D., Deppisch F. F., Gráf L., Šimkovic F.* // Phys. Rev. D. 2021. V. 103. P. 055019.
10. *Bytev V., Pengming Zhang* // Phys. Part. Nucl. Lett. 2021. V. 18, No. 3. P. 284.
11. *Klebtsov S., Klopot Y., Oganesian A., Teryaev O.* // Phys. Rev. D. 2021. V. 104. P. 016011.
12. *Mikhailov S. V., Pimikov A. V., Stefanis N. G.* // Phys. Rev. D. 2021. V. 103. P. 096003.
13. *Mikhailov S. V., Volchanskiy N.* // JHEP. 2021. V. 02. P. 197.
14. *Prokhorov G. Yu., Teryaev O. V., Zakharov V. I.* // Phys. Rev. D. 2021. V. 103. P. 085003.
15. *Lyubovitskij V. E., Wunder F., Zhevlakov A. S.* // JHEP. 2021. V. 06. P. 066.
16. *Volkov M. K., Osipov A. A., Pivovarov A. A., Nurlan K.* // Phys. Rev. D. 2021. V. 104. P. 034021.
17. *Bystritskiy Yu. M.* // Phys. Rev. D. 2021. V. 103. P. 116029.
18. *Cierniak M., Blaschke D.* // Astron. Nachr. 2021. V. 342. P. 819.
19. *Ivanov Yu. B.* // Phys. Rev. C. 2021. V. 103. P. 031903.
20. *Braguta V. V., Kotov A. Y., Kuznedelev D. D., Roenko A. A.* // Phys. Rev. D. 2021. V. 103. P. 094515; *Astrakhantsev N. Y., Braguta V. V., Kolomoyets N. V. et al.* // Phys. Part. Nucl. 2021. V. 52. P. 536.
21. *Nedelko S. N., Voronin V. E.* // Phys. Rev. D. 2021. V. 103. P. 114021.
22. *Eyyubova G. Kh., Korotkikh V. L., Snigirev A. M., Zabrodin E. E.* // J. Phys. G. 2021. V. 48. P. 095101.
23. *Severyukhin A. P., Arsenyev N. N., Pietralla N.* // Phys. Rev. C. 2021. V. 104. P. 024310.
24. *Jolos R. V., Kolganova E. A.* // Phys. Lett. B. 2021. V. 820. P. 136581.
25. *Hong J., Adamian G. G., Antonenko N. V., Jachimowicz P., Kowal M.* // Phys. Rev. C. 2021. V. 103. P. L041601.
26. *Malov L. A., Adamian G. G., Antonenko N. V., Lenske H.* // Phys. Rev. C. 2021. V. 104. P. L011304; P. 064303.
27. *Wen P. W., Lin C. J., Nazmitdinov R. G., Vinitsky S. I., Chuluunbaatar O., Gusev A. A., Nasirov A. K., Jia H. M., Góźdź A.* // Phys. Rev. C. 2021. V. 103. P. 054601.
28. *Severyukhin A. P., Aberg S., Arsenyev N. N., Nazmitdinov R. G.* // Phys. Rev. C. 2021. V. 104. P. 044327.
29. *Ershov S. N., Rakityansky S. A.* // Phys. Rev. C. 2021. V. 103. P. 024612.

30. *Melezhik V. S.* // Phys. Rev. A. 2021. V. 103. P. 053109.
31. *Pupyshev V. V.* // Theor. Math. Phys. 2021. V. 207. P. 459.
32. *Lukyanov V. K., Zemlyanaya E. V., Lukyanov K. V., Abdul-Magead I.* // Nucl. Phys. A. 2021. V. 1010. P. 122190.
33. *Kampfer B., Titov A. I.* // Phys. Rev. A. 2021. V. 103. P. 033101;
Hernandez Acosta U., Titov A. I., Kampfer B. // New J. Phys. 2021. V. 23. P. 095008.
34. *Nazarova E., Akhat R., Baznat M., Teryaev O., Zinchenko A.* // Phys. Part. Nucl. Lett. 2021. V. 18, No. 3. P. 429.
35. *Dorkin S. M., Kaptari L. P., Kaempfer B.* // Few Body Syst. 2019. V. 60. P. 20.
36. *Cherny A. Yu.* // Phys. Rev. A. 2021. V. 104. P. 043304.
37. *Yukalov V. I., Yukalova E. P.* // Phys. Rev. D. 2021. V. 103. P. 076019.
38. *Kozlenko D. P., Yushankhai V. Yu., Hayn R., Richter M., Golosova N. O., Kichanov S. E., Lukin E. V., Savenko B. N.* // Phys. Rev. Mater. 2021. V. 5. P. 034402.
39. *Tung N. D., Vladimirov A. A., Plakida N. M.* // Physica C. 2021. V. 587. P. 1353900.
40. *Anitas E. M.* // Symmetry. 2021. V. 13. P. 2042.
41. *Povolotsky A. M.* // J. Phys. A. 2021. V. 54. P. 22LT01.
42. *Derbyshev A. E., Povolotsky A. M.* // J. Stat. Phys. 2021. V. 185. P. 16.
43. *Spiridonov V. P.* // Phys. Part. Nucl. 2021. V. 52. P. 274.
44. *Katkov V. L., Osipov V. A.* // J. Magn. Magn. Mater. 2021. V. 15. P. 168103.
45. *Shukrinov Yu. M., Rahmonov I. R., Janalizadeh A., Kolahchi M. R.* // Phys. Rev. B. 2021. V. 104. P. 224511.
46. *Adzhemyan L. Ts., Evdokimov D. A., Hnatič M., Ivanova E. V., Kompaniets M. V., Kudlis A., Zakharov D. V.* // Phys. Lett. A. 2022. V. 425. P. 127870.
47. *Aref'eva I. Ya., Golubtsova A. A., Gourgoulhon E.* // JHEP. 2021. V. 04. P. 169.
48. *Tyurin N. A.* // Sb. Math. 2021. V. 212. P. 389.
49. *Herdeiro C. A. R., Kunz J., Perapechka I., Radu E., Shnir Ya.* // Phys. Lett. B. 2021. V. 812. P. 136027.
50. *Buchbinder I. L., Ivanov E. A., Merzlikin B. S., Stepanyantz K. V.* // Phys. Lett. B. 2021. V. 820. P. 136516.
51. *Buchbinder I. L., Fedoruk S. A., Isaev A. P.* // Nucl. Phys. B. 2021. V. 973. P. 115576.
52. *Ivanov E., Nersessian A., Sidorov S.* // JHEP. 2021. V. 01. P. 015.
53. *Buchbinder I., Ivanov E., Zaigraev N.* // JHEP. 2021. V. 12. P. 016.
54. *Latosh B. N.* // Mod. Phys. Lett. A. 2021. V. 36. P. 2150258.
55. *Mukhanov V. F., Rabinovici E., Sorin A. S.* // Fortsch. Phys. 2021. V. 69, No. 2. P. 2000100; P. 2000101;
Mukhanov V. F., Sorin A. S. // JCAP. 2021. V. 10. P. 066; P. 049.
56. *Pirozhenko I. G.* // Universe. 2021. V. 7. P. 217.

VEKSLER AND BALDIN LABORATORY OF HIGH ENERGY PHYSICS

In 2021, the activity of the Veksler and Baldin Laboratory of High Energy Physics was aimed at construction, development and commissioning of various units of the accelerator complex "Nuclotron–NICA" and MPD, BM@N and SPD experimental facilities. Experiments were also continued at external accelerators.

MOST IMPORTANT RESULTS IN THE DEVELOPMENT OF THE NICA COMPLEX

Nuclotron/NICA Project

Booster and Beam Transport Channels. The systems of the Booster synchrotron — one of the key units of the heavy-ion accelerator complex NICA — were brought to the design parameters in September 2021. During the run, for the first time the iron ion beam in the Booster ring was accelerated to the design energy of 578 MeV/nucleon (Fig. 1) [1]. The equipment of the Booster electron cooling system was fully launched and, for the first time in Russia, the electron cooling of the heavy-ion beam was obtained. The beam cooling experiment was performed with $^{56}Fe^{14+}$ ions circulating at the injection energy of 3.2 MeV/nucleon.

The significant outcome of the run was the successful completion of joint work between specialists from JINR and the INR SB RAS on constructing the systems of extracting the beam from the Booster and the beam transport channel to the Nuclotron. The tuning of the channel magnet system and the testing of the equipment control system were finished. After that, a unique pulsed magnetic kicker for extracting the beam from the Booster with a record level of the magnetic field of 2 kG was commissioned. A group of specialists launched a "bump" system, i.e., a system of local displacement of the closed orbit, which was also required to ensure the fast extraction of the beam from the Booster. The extraction of two types

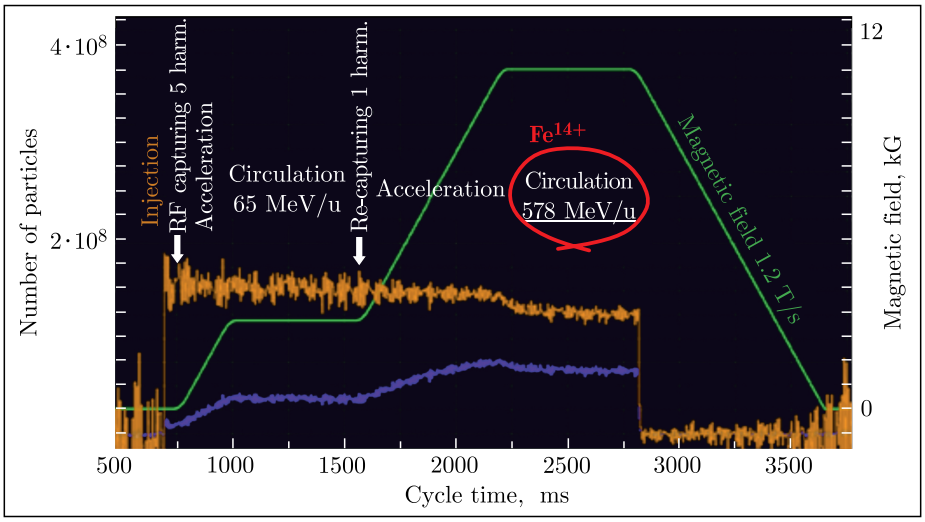


Fig. 1. A signal from the beam current sensor in the Booster

of ions, helium and iron, was obtained at an energy of 240 MeV/nucleon with their further transportation through the channel. At the final section of the channel, beam current and position sensors detected the beams, and the screenshots of the beam profiles from the phosphor screen were obtained (Fig. 2).

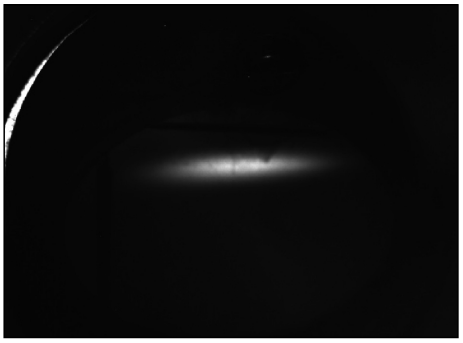


Fig. 2. A beam of $^{56}Fe^{14+}$ ions on the phosphor screen at the end section of the Booster–Nuclotron transport channel

The installation of a new system of injection of a beam into the Nuclotron has been completed, as well as the construction of a chain of magnets for the acceleration of heavy ions, which will be the basis for operating the NICA collider and the BM@N facility. The first run at the NICA complex with a full acceleration cycle is planned for January 2022.

The infrastructure for conducting applied and radiobiological studies within the framework of the ARIADNA (Applied Research Infrastructure for Advance Development at NICA fAcility) collaboration is being actively developed. The ion beam transport channel from HILac to the Station Of CHip Irradiation (SOCHI), which is designed for irradiating microchips, has already been constructed. In December 2021, the first cycle of commissioning to tune the channel magnetic system was carried out. The beam was transported to the SOCHI station, where it was registered by several detectors. The plan is to complete the installation of equipment of three stations for applied research and their testing in 2022.

Collider. The NICA collider is located in building 17. The readiness of the building by the end of 2021 is as follows: 100% of works on piles, concrete structures, load-bearing floors, metal structure installation, earth works and temporary roads, brick and foam block partition walls, the wall drainage system, and the displacement of water supply networks are completed; the works on the roofs (93%), facades installation (94%), finishing works (84%), engineering systems (28%), installation of household and storm sewer (92%), installation of individual heating units (75%), inside doors (40%) and landscaping (82%) are in their final stage.

The change of deadlines for completing the civil works is primarily due to a significant (50%) increase in construction volume at the stage of the project implementation. The coronavirus pandemic has also affected meeting the contract deadlines.

In 2021, the production and testing of equipment for the collider subsystems continued. 100% of the collider's dipole and 65% of the quadrupole magnets have already been produced and tested on the high-technology line for assembling and testing superconducting magnets.

Work on the reconstruction of power lines continued. A permit was obtained to operate eleven 6 kV upgraded substations with a total power of up to 33.6 MW.

Cryogenic Complex. New cryogenic equipment was installed at the central compressor station in building 1B: a helium liquefier with a capacity of more than 1000 l/h, a helium refrigerator for cooling the Booster at 2000 W at a temperature of 4.5 K, four purification units of compressed helium, a 1300 kg/h nitrogen liquefier and a recondenser of nitrogen vapors from the Booster shield with a capacity of 500 kg/h.

Large-scale cryogenic equipment, which is located outside the buildings, is completely ready for operation: a 40 m^3 tank container for liquid helium, 1000 m^3 gasholder tanks for gaseous helium and nitrogen.

In general, the volume of work performed to construct the design configuration of the Nuclotron–NICA complex is about 85% by the end of 2021.

MPD Project

The formation of the MPD collaboration was completed in 2020. Now, the collaboration numbers 42 institutes from 12 countries and more than 500 members. Eight collaboration meetings were held, at which the implementation of the project was discussed and coordinated. The installation of incoming equipment and engineering systems was started in a special hall of the main building 17 of the NICA complex, where the MPD detector will be located.

MPD Superconducting Solenoid. At the end of December 2020, the magnetic circuit was fully assembled in the MPD hall. The control measurements showed a high-quality, accurate assembly, which is necessary for obtaining a uniform magnetic field in the detector. The deviations of most of the measured geometric dimensions and parameters were within 0–200 μm with a magnetic circuit length of 8970 mm and a diameter of 6670 mm. The solenoid was installed into the yoke in July 2021. Measurements of the position of the yoke and the solenoid after the installation showed that the axis displacements did not exceed the expected 2 mm.

The simulation of the magnetic field by ASG specialists based on the actual position of the magnet demonstrated satisfactory performance without the need for further adjustment of the solenoid relative to the yoke. Now, the magnetic circuit is assembled to 13 plates. Further assembly of the yoke involves

the installation of support rings and assembly up to the last 28th plate.

The first cycle of leakage tests of the solenoid was successfully carried out in September 2021. Due to this, it was concluded that there was no leakage at a pressure of 10 bar for nitrogen and 25 bar for helium. At present, the solenoid is ready for vacuum tests. Most of the MPD cryogenic infrastructure equipment has already been ordered.

Time Projection Chamber (TPC). TPC is the main tracking detector of the MPD experiment for reconstructing the tracks of charged particles and their identifying by dE/dx for high-multiplicity events. It consists of four cylinders (C1–C4) produced by the Russian industry from composite materials. This ensures sufficient longitudinal strength of the cylinders (deflection at the centre is less than 100 μm) and a small amount of material budget on the beam line — 0.4 g/cm^2. All four cylinders are interconnected by two aluminum flanges.

Readout Chambers (ROC) for the initial version of MPD are based on MWPC with pad readout. The total number of readout pads for TPC is 95 232. All of 24 serial ROC chambers are produced and tested.

Gas System was developed based on the experience of constructing the STAR and PHENIX gas systems at BNL, USA. The system consists of two circulation loops, outer and inner, and operates as a closed-loop system with recirculation of the working gas mixture through the TPC through an inner loop containing a purification system.

Cooling System is used for stabilization of the gas temperature inside the TPC volume within 0.5°C. The system uses 180 Pt1000 sensors placed on the detector surface and providing temperature measurement with an accuracy of 0.1°C. Thermal screens for the TPC thermal stabilization system were supplied to JINR. The electronics for the TPC cooling system are produced and being tested.

Front-End Electronics (FEE) and TPC Data Readout System are based on specialized ASIC, FPGA and chips for high-speed datalink. Each of the 62 cards (FEC) has 64 registration channels and a separate bidirectional communication interface with its controller (2.5 Gbit/s). FECs work in parallel, providing a full bandwidth of up to 100 Gbit/s. Each FEC has two specialized ASIC SAMPA chips (1488 in total), developed by the USP Brazil group of electronic engineers together with CERN to upgrade the ALICE experiment and made using radiation-resistant technology (TID $\sim$ 100 krad). The use of SAMPA chips on FEC cards made it possible to significantly reduce their geometric size and radiation length ($X/X_0 \sim 3\%$). FPGA Altera Cyclon-5, used to read out data from two SAMPA chips, is a commercial chip. Taking into account the radiation vulnerability of FPGA of this class to SEE (Single Event Error), MEPhI is developing a radiation-resistant ASIC (65 nm CMOS process) to replace it in the future. The total ionization dose stated by the developer will be $\sim$100 Mrad. The FPGA prototype was put into production (Europractice) in November 2020.

TPC Assembly and Infrastructure. At the beginning of 2022, it is planned to complete the series production of readout electronics, install ROC cameras into TPC and test TPC with cosmic rays. In March 2022, TPC will be transported to the MPD experimental hall. After that, it will be installed into MPD and adjusted. The MPD facility is planned to be tested with cosmic rays, starting in August 2022.

Time-of-Flight System (TOF). TOF is the basic identification system for charged hadrons in MPD. In the initial configuration, TOF will be presented as a cylinder about 6 m long and 3 m in diameter, assembled from 28 modules. In addition to these modules, each having 10 subdetectors based on Multi-gap Resistive Plate Chambers (MRPC), TOF also includes service subsystems. The TOF system should be put into operation at the beginning of 2022.

Multi-Gap Resistive Plate Chambers (MRPC). Each TOF module consists of 10 identical MRPCs with 24 readout channels. The final version of the MRPC is made of commercial float glass, 280 μm thick. It has 15 gas gaps 200 μm wide and provides a time resolution of 50 ps. The production of 280 MRPCs will be completed in June, and 28 TOF modules will be ready by December 2022. TOF modules have been tested since the beginning of 2020 at a special cosmic stand.

Readout and DAQ System for MPD TOF and FFD systems is developed on the basis of the time-to-digital converter VME64x VXS TDC72VHLv4 with an HPTDC chip. It is used to digitize LVDS signals with a sampling time of 24.4 ps. TDC72VHLv4 provides the possibility of accurate time synchronization with other devices using White Rabbit technology. The total number of TDC required for MPD TOF is 196 (14 modules for each of 14 VME crates). All VME crates were purchased and delivered to JINR. The required number of TDC72VHLv4 modules was produced, and testing and calibration of the readout electronics was performed.

Electromagnetic Calorimeter (ECal). ECal is designed to identify particles, measure the flow of photons and reconstruct some decays involving photons. A large-sized (6 m long and 4.5 m in diameter) cylindrical electromagnetic calorimeter covers the central region of the pseudorapidity $|\eta| < 1.2$ and has a projective geometry in which the axis of each tower is directed to the beam intersection point. The layout of the towers in such a calorimeter is shown in Fig. 3.

At present, the companies OOO Polipak in Dubna and OOO Uniplast in Vladimir produced 10 million scintillation plates, which is 100% of the total ECal. The production of calorimeter modules was established at PAO TENZOR in Dubna and IHEP in Protvino. The first order, amounting to 40% of the

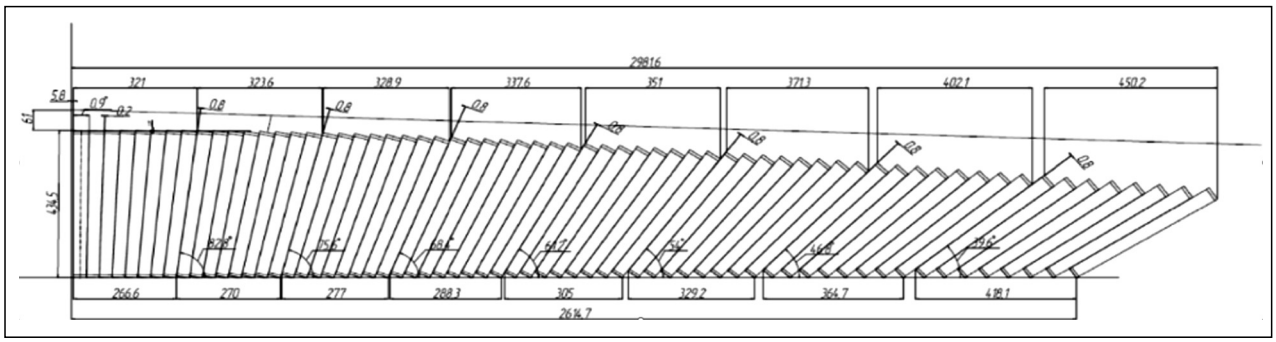


Fig. 3. Layout of the towers in the half-sector of the electromagnetic calorimeter with a projective geometry

JINR quota and 15% of the total number of calorimeter modules, was placed in 2020 at these enterprises. The second part of the order is being produced. A total of 800 modules will be produced until the end of 2022. This will make it possible to assemble 8 (out of 25) complete sectors of the calorimeter.

The production of modules for 8 more sectors was started in China. The most essential part of the materials is supplied from JINR. The assembly is being performed in four institutes. The first prototypes of the calorimeter modules were produced, and their testing is underway. By the last quarter of 2022, the production of 800 modules in China is expected to be completed.

In geometrical terms, ECal consists of 25 sectors or 50 half-sectors. Each half-sector (Fig. 4) has 48 modules of 8 different types, which are glued into a fiberglass container (basket), as well as the corresponding readout and control electronics, and it weighs about 1.5 t. Calculations show that the deformation of the half-sector under its own weight will not exceed 0.5 mm for all possible spatial orientation. According to the signed contract, all 52 baskets are planned to be received by June 2022.

The readout and control electronics were developed at JINR. Their mass production was completed in November 2021. Now, the ECal group is making every effort to develop an innovative system for installing and replacing the calorimeter electronics without dismantling the calorimeter itself.

To control the quality of the modules produced and perform the initial calibration of the detectors, a special stand was developed that allows simultaneous testing of 12 ECal modules with cosmic muons. Eight such stands were put into operation (for 8 different types of modules) with a total capacity of 96 modules (or 2 half-sectors) for every 2 weeks. This will allow testing all ECal modules within a year.

BM@N Experiment

The BM@N collaboration includes 230 physicists and engineers from 19 institutes and 10 countries. The experiment is aimed at studying the dynamics of reactions and the properties of hadrons in dense nuclear matter in the interactions of extracted Nuclotron beams with fixed targets [2, 3]. Within the framework of the project, the structure of nuclei at small inter-nucleon distances is also studied [4]. The development and production of detectors for the full configuration of BM@N are underway [5] (Fig. 5). The status of the construction of the main components for the heavy-ion programme is as follows:

• Silicon Beam Tracker detectors and beam profile meters were constructed; their installation and commissioning is scheduled for the spring of 2022;

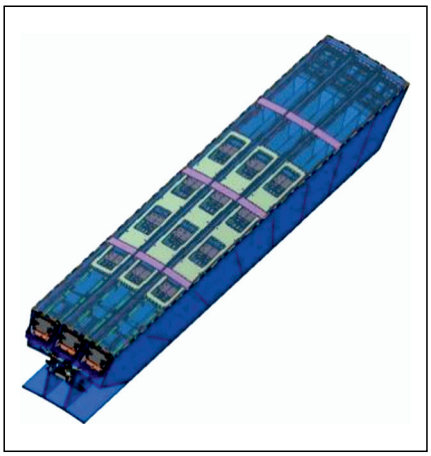


Fig. 4. ECal basket with electronics

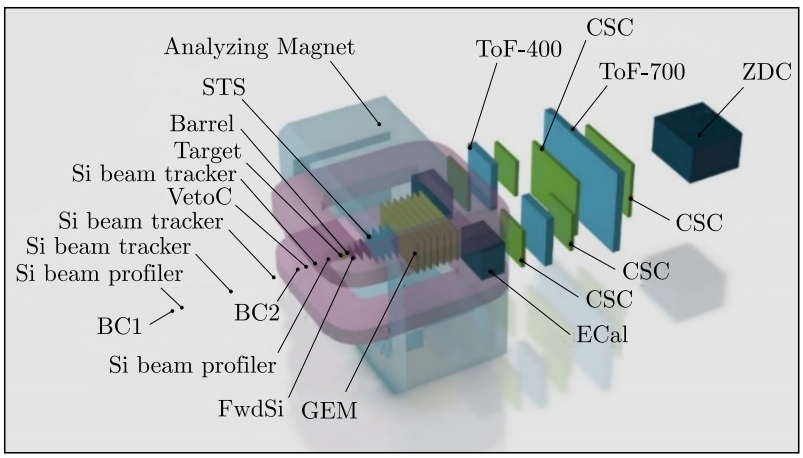


Fig. 5. Complete configuration of the BM@N detectors for studying heavy nucleus interactions

• Forward Silicon detectors (FwdSi) for the Central Tracker were constructed; the detectors have already been operated in the C, Ar, Kr runs. Their installation and commissioning is scheduled for the spring of 2022;

• Large-aperture Silicon Tracking System (STS) for the Central Tracker is being jointly developed by Russia (JINR, MSU) and Germany (GSI/FAIR, Tübingen). Two STS pilot stations (out of four) are planned to be developed and installed for the BM@N physics run in 2023;

• Full STS configuration is planned to be commissioned after 2023.

• GEM detectors for the Central Tracker, produced in CERN together with the BM@N specialists, were tested. Their installation and commissioning is scheduled for the spring of 2022. A contract for fast FEE (VMM3a chips) production (contribution from Germany) is being fulfilled;

• Trigger and T0 detectors will be ready by the spring of 2022 — by the start of installation and commissioning;

• CSC chambers for track matching with ToF-400 are ready; one big CSC chamber for track matching with ToF-700 is planned to be constructed in the spring of 2022, and another one — at the end of 2022;

• Carbon fibre beam pipe inside BM@N and the target station will be constructed and tested by the spring of 2022;

• Beam pipe in front of the target and the detector boxes are ready;

• New forward hadron calorimeter (ZDC) was installed into BM@N; the hodoscope in front of the calorimeter is planned to be installed in the spring of 2022.

Implementation of the BM@N physics programme in heavy-ion beams is foreseen to start in the spring of 2022 (April–May 2022) with the Xe ion beam of up to 3.9A GeV kinetic energy. Statistics of around $2 \cdot 10^9$ interactions with the CsI target for the period of 800 h are planned to be collected. In the spring of 2023, the implementation of the physics programme with heavier ions will be continued to collect statistics up to $2 \cdot 10^9$ interactions (Au + Au or Bi + Bi).

SPD Project

The Conceptual Design Report (CDR) of the SPD experiment was presented at the meeting of the PAC for Particle Physics in January 2021. Later, SPD Detector Advisory Committee was formed, which conducted a thorough review of the project to develop the SPD TDR (Technical Design Report). A considerable progress was achieved in forming the international collaboration. More than 300 scientists from 32 institutes became interested in joining it. Such collaboration bodies as the Executive Board, Technical Board, etc., were formed and started their work. The SPD Collaboration Board adopted the Constitution of the Collaboration. Memoranda of Understanding are being prepared. Two collaboration meetings were held. The physics programme of the future experiment is being actively developed [6–9].

The first version of the technical design of the detector was prepared (Fig. 6), in which two options of the SPD solenoid magnetic system were considered based on technologies developed at JINR VBLHEP and INP (Novosibirsk).

A prototype of the muon system for Nuclotron test beams is being developed: about 100 MDT detectors were produced, analog electronics were prepared, and new digital electronics were developed and produced. The total number of electronic channels in a fully equipped prototype is 1300.

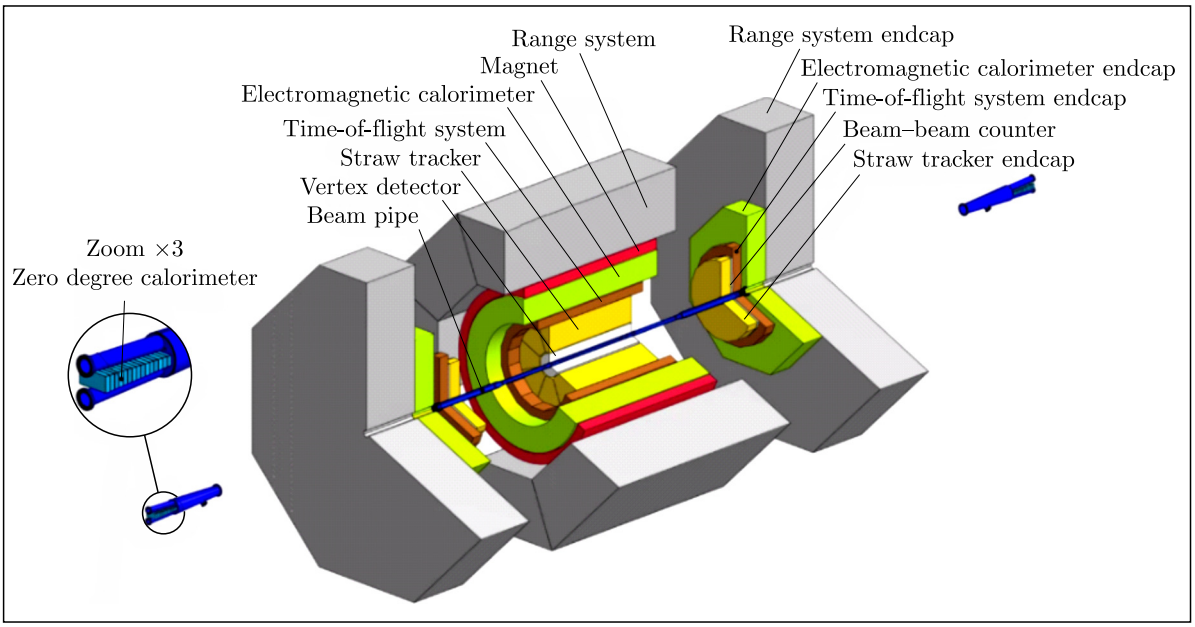


Fig. 6. Upgraded configuration of the SPD detector

The design of the electromagnetic calorimeter was finalized taking into account changes in the SPD magnetic system. A new prototype of the calorimeter module was constructed and tested at the cosmic ray test bench. A prototype of the DSSD sensor was produced for a vertex detector using 6″ FZ-Si wafers with a sensitive area of 93×63 mm. It is planned to conduct a series of tests using it.

As part of R&D for developing a track system, coordinate straw detectors, as well as electronics, were prepared and tested in the SPD test zone. Negotiations are underway with a group from Saclay (France) on their participation in the construction of Micromegas chambers, which are designed for the vertex detector for the second stage of the experiment.

In 2021, together with ITEP, prototypes of scintillating detectors for SPD BBC (beam–beam counter) with two types of electronics were tested: one with the TOT function and one developed for the DANSS experiment.

While constructing the SPD test zone, two target stations were developed and produced to place targets and detectors in the common vacuum volume of the extracted beam channel. Two control rooms were constructed. Work is underway to construct detecting and metrological equipment for low-energy and high-energy channels.

A new concept of triggerless/streaming DAQ is being developed. The possibility of developing dedicated electronics based on FPGA/ASIC and implementing commercially available industrial network solutions is under consideration.

The development of online filtering of events, algorithms for fast online event reconstruction, simulation and offline data processing was carried out in 2021 — both at the design stage of the facility and during the experiment.

Study of Polarization Phenomena and Spin Effects at JINR Nuclotron-M

As part of the work on the development of the infrastructure for spin physics studies at the Nuclotron and other complexes, a contract with STL Zaryad (Novosibirsk) was signed and fulfilled on the development of a proton polarization control system for the NICA collider, operating in two configurations of the spin transparency mode. An agreement with MIPT (Dolgoprudny) was also signed on performing an experiment to search for the electric dipole moment (EDM) of protons at the NICA collider in the spin transparency mode. The magnetic structure of the solenoids and the collider was coordinated, the resonator power was calculated, a proton polarization control system [10] and error compensation was developed, and the spin dynamics of protons was numerically simulated.

The concept of a superconducting solenoid with a static magnetic field of up to 6 T and a length of 1 m continues to be developed. It will allow the collider to operate with a polarized proton beam with an energy of up to 1.6 GeV. In 2022, together with STL Zaryad and MIPT, it is planned to develop a spin navigator to control the polarization of protons in the entire energy range of the collider at integer spin resonances, taking into account the synchrotron energy simulation [11]. Work will be carried out to optimize the parameters of the optics of the NICA collider for maximum amplification of the EDM signal, and the development of a 3D navigator based on existing correcting magnetic elements of the collider will start.

In the **ALPOM-2** project, the data previously collected on a polarized neutron beam were analyzed on the charge exchange reaction $dp \to (pp)n$ at $1.75A\,\mathrm{GeV}/c$ at the spectrometer STRELA [12]. The group's plan to continue the experiment was supported by the PAC for Particle Physics. It will ensure the leadership of JINR in the field of polarimetric equipment and research. Work is being completed to equip the ALPOM-2 setup with new drift chambers and a wide-aperture hadron calorimeter.

A proposal was prepared for a new project "Search for Polarized Phenomena at Nuclotron (**SPPN**)", based on the previously obtained results on the search for high-momentum asymptotic of spin observables of a bound np pair and the results of studying a free L-polarized np pair in the measurements of $\Delta\sigma_{L,T}(np)$. This programme also offers new up-to-date studies of the spin structure of np interactions. The implementation of the SPPN project will require equipping a polarized proton target with a cryostat and HTSP magnets to rotate the proton spins of the target from a horizontal state (L) to a vertical state (T), and constructing a vertex detector.

In the framework of the **DSS** project, the data were obtained [7, 13] on the angular dependences of the deuteron analyzing powers A_y, A_{yy} and A_{xx} of elastic deuteron–proton scattering at deuteron energies of 400–1300 MeV at the internal target. The experimental data on the angular dependences of the analyzing power A_y of the quasi-elastic proton–proton scattering reaction at energies of 200–650 MeV/nucleon were also collected.

The upgrade and adjustment of the **HyperNIS** spectrometer for searching for hypernuclei (${}^{6}_{\Lambda}\mathrm{H}$) is being completed. Work is advancing towards the development of a more efficient software programme for tracking and determining the momentum of particles. In a joint project with the Short Range Correlations (SRC) experiment, calculations and the search for optimal technical solutions for the placement of appropriate detectors are being performed.

Experiments at the Large Hadron Collider

ALICE. The main efforts of the JINR group in the data analysis and the physics simulation were focused on the study of femtoscopic correlations and the production of light vector mesons in Pb–Pb ultra-peripheral collisions (UPC) [14, 15]. In addition, the JINR group continued to participate in the maintenance and development of the GRID–ALICE analysis at JINR.

During the 1D and 3D femtoscopic correlation analyses of identical charged kaons for Pb–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV, the source radii versus particle multiplicity and transverse pair momentum were studied. It is shown for the first time (Fig. 7) that kaon emission time decreases three-fold in the peripheral interactions compared to the central ones.

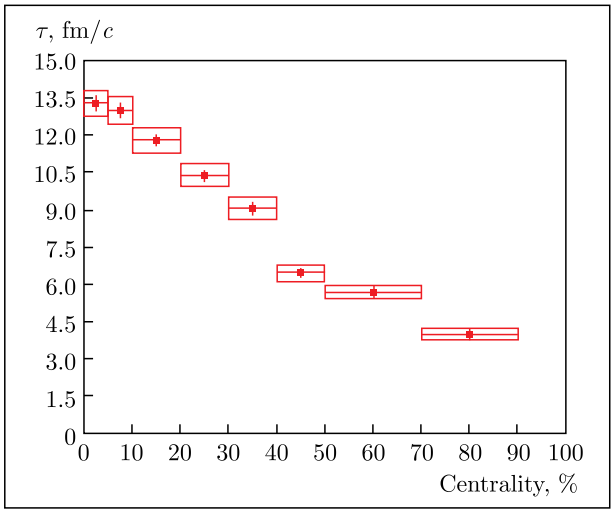


Fig. 7. Kaon emission time at different centrality

The analysis of only four pions ($\pi^+\pi^+\pi^-\pi^-$) coherent photo-production in the Pb–Pb UPC at an energy of 5.02 TeV continued. The preliminary results show that the best description of the four-pion invariant mass distribution has been obtained using two Breit–Wigner functions and interference between them. At the same time, the resonance states have masses close to the tabular ones — $\rho(1450)$ and $\rho(1700)$.

The results were published for the description by the three-component model of the transverse momentum spectra and the ratios of the hadrons produced in pp and Pb–Pb collisions at the LHC energies [16].

ATLAS. After completing the analysis of the full Run-2 dataset to search for and measure the properties of the Higgs boson decaying into a pair of b quarks and produced in association with an electroweak vector boson V (W or Z), a combined analysis was started. It integrates the $VH(\to b\bar{b})$ process, when the Higgs decay products are reconstructed as two distinct jets or as one large-radius jet, and the $VH(\to c\bar{c})$ process with the Higgs boson decaying into a pair of c quarks.

The parameters of the Monte Carlo event generator MadGraph were adjusted for $t\bar{t}$ samples with $0, 1, 2$ jets at next-to-leading order precision in QCD using the MadGraph5_aMC@NLO + Pythia8 generators and the FxFx merging scheme for $\sqrt{s} = 13$ TeV: merging scale μ_Q, strong coupling constant α_S. In addition, for parton shower setups, the effect from varying some parameters of the default A14 tune was estimated. The results obtained are consistent with the unfolded ATLAS and CMS data and the Powheg + Pythia8 generator.

CMS. Based on the full Run-2 LHC statistics in 140 fb^{-1}, the JINR group searched for the signatures beyond the Standard Model (SM) and tested its predictions [17–21]. As a result, the most stringent lower limits to date were obtained on the masses and other parameters for scenario beyond the Standard Model. Thus, upper limits are set on the ratio of the production cross section in a dilepton channel of a various spin-1 and spin-2 new resonance to that of the SM Z^0 boson at 95% confidence level. The limits are interpreted in the context of a sequential SM (SSM) and a superstring-inspired model that predict spin-1 resonances. Lower mass limits of 5.15 (4.56) TeV/c^2 are set in the $Z'_{\rm SSM}$ (Z'_ψ) models (Fig. 8). The observed upper limit on narrow spin-1 resonances is translated into the limits on generalized couplings of Z' to up and down quarks in several classes of new physics models. For spin-2 graviton resonances in the Randall–Sundrum model of extra dimensions, lower limits on the graviton mass of 2.47–4.78 TeV/c^2 are set for values of the coupling parameter $k/M_{\rm Pl}$ between 0.01 and 0.1.

For spin-1 resonances that act as a mediator between SM particles and dark matter (DM), exclusion limits are set in the mass plane of the mediator and DM particles. For large values of $m_{\rm DM}$, mediator masses below 1.92 (4.64) TeV/c^2 are excluded in a model where the mediator is a vector (axial vector) with small (large) coupling to leptons. For $m_{\rm DM} = 0$, these limits are reduced to 1.04 and 3.41 TeV/c^2, respectively.

The JINR group participated in CSC studies at the GIF++ test beam at CERN in 2021. The tests were carried out at H4 muon SPS beam line with GIF++ 12 TBq ^{137}Cs gamma source. The chamber operation in the high background conditions and with gas mixtures with different CF_4 contamination was studied. The project "Upgrade of the CMS Detector" was prepared and approved for operation in the HL-LHC configuration. The main goal of the project is the contribution to the construction of the High Granularity Calorimeter (HGCal) and the upgrade of the Forward Muon Station ME1/1. It is planned to

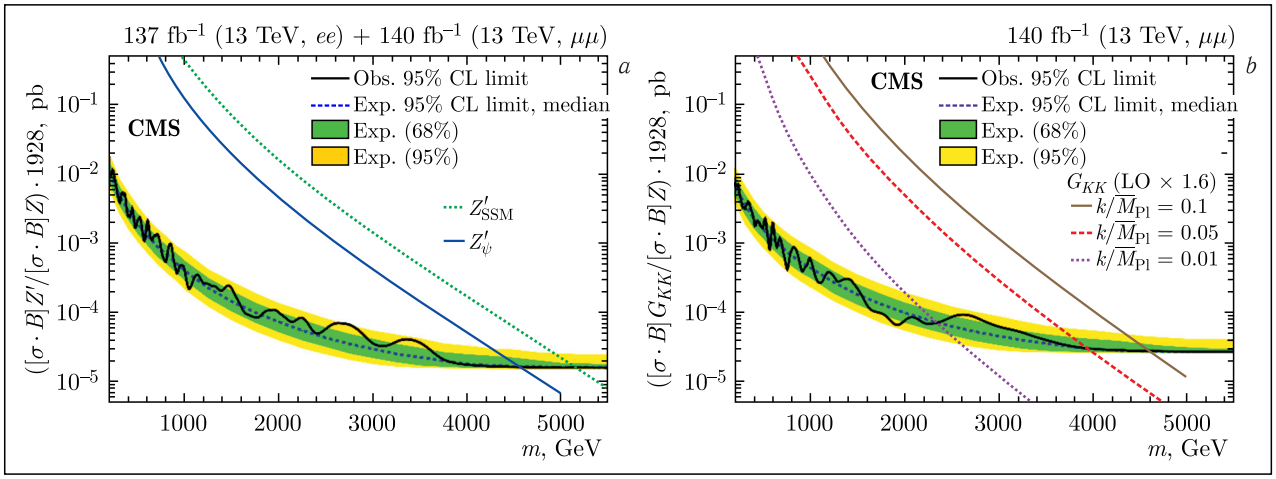


Fig. 8. The upper model-independent limits at 95% CL on the production cross section for a spin-1 (*a*) and spin-2 (*b*) resonances, relative to the product of the production cross section and the branching fraction of a Z^0 boson, multiplied by the theoretical value of 1928 pb. Simulated predictions for the spin-1 Z'_{SSM} and Z'_{ψ} resonances, as well as for the spin-2 resonances for coupling parameters k/M_{Pl} of 0.01, 0.05, and 0.10, respectively, are shown for comparison

continue the construction of the system for testing HGCal active elements in 2022. The production of the HGCal cooling panels was started.

Experiments at the CERN Super Proton Synchrotron

COMPASS. The JINR group made a significant contribution to the preparation of the setup and data taking for measurements of semi-inclusive processes using a polarized deuterium target and a 190 GeV muon beam, including support of the hadron calorimeter, the coordinate detector systems, and DAQ.

When analyzing the data, the study of transversity was performed by measuring the polarization of Λ hyperons produced in SIDIS off transversely polarized protons [22]. Within the experimental uncertainties, no significant deviation from zero was observed. When studying the spin-exotic $J^{\mathrm{PC}} = 1^{-+}$ amplitude in single-diffractive dissociation of 190 GeV/c pions into $\pi^-\pi^-\pi^+$ using a hydrogen target [23], the $\pi_1(1600) \to \rho(770)$ amplitude was confirmed, which interferes with a nonresonant 1^{-+} amplitude. The results obtained are consistent with the basic assumptions for the isobar model for $J^{\mathrm{PC}} = 1^{-+}$ amplitudes.

NA61/SHINE. Measurements of double-differential spectra and mean multiplicities of $\Xi(1530)^0$ and anti-$\Xi(1530)^0$ resonances produced in inelastic $p + p$ interactions were performed at NA61/SHINE [24]. The results were obtained from a sample of $2.6 \cdot 10^7$ minimum-bias events at the CERN SPS using a proton beam of 158 GeV/c momentum ($\sqrt{s_{NN}} = 17.3$ GeV). The $\Xi(1530)^0$/anti-$\Xi(1530)^0$ ratio at mid-rapidity was found to be $0.54 \pm 0.07 \pm 0.08$. Theoretical calculations within EPOS show similar values, but there are discrepancies when compared with the predictions of URQMD and the hadron-resonance gas model in the canonical formulation.

The JINR group is responsible for the upgrade of the time-of-flight (TOF) system based on a Multigap Resistive Plate Chambers (MRPC) with analog reading developed at VBLHEP. The mass production of MRPC was completed in 2021 [25]. Together with colleagues from the RAS Lebedev Physical Institute, tests of the developed MRPC with analog reading were carried out, which demonstrated stable operation and a time resolution of (51.0 ± 0.9) ps, which meets the requirements of the experiment.

NA62 (NA48/2). The NA62 experiment at CERN is dedicated to the study of a very rare kaon decay into a charged pion, neutrino and antineutrino. As part of this experiment, JINR and CERN groups are jointly responsible for the operation of the NA62 Magnetic Spectrometer and for the development of all software.

Searches for the lepton number violating decay $K^+ \to \pi^-\mu^+e^+$, and the lepton flavor violating $K^+ \to \pi^+\mu^-e^+$ and $\pi^0 \to \mu^-e^+$ decays were performed [26] using the data taken by the NA62 experiment at CERN in 2017–2018. The upper limits of the branching ratios at 90% confidence level were obtained: $\mathrm{Br}(K^+ \to \pi^-\mu^+e^+) < 4.2 \cdot 10^{-11}$, $\mathrm{Br}(K^+ \to \pi^+\mu^-e^+) < 6.6 \cdot 10^{-11}$ and $\mathrm{Br}(\pi^0 \to$ $\to \mu^-e^+) < 3.2 \cdot 10^{-10}$. These results are improved by an order of magnitude over previous results for these decay modes.

Preliminary results of the $K^+ \to \pi^0e^+\nu\gamma$ decay analysis based on the NA62 data were presented at the conference [27]. The paper is being prepared for the publication.

The analysis of the experimental data taken in 2014–2021 is planned to be performed in 2021 for studying the following decays: $K^+ \to \pi^+\pi^-\mu^+\nu$, $K^+ \to \mu^+\mu^-\mu^+\nu$, $K^+ \to e^+e^-\mu^+\nu$, $K^+ \to$ $\to \mu^+\mu^-e^+\nu$, $K^+ \to e^+e^-e^+\nu$, $K^+ \to \pi^+e^-e^+\gamma$. Work will be carried out to search for the light sgoldstio signatures. The JINR group will maintain the NA62 spectrometer straw detector during the

next NA62 experimental run. The slow control system will be further improved. Software for straw modules and complete detector calibration, the DAQ system, as well as the simulation and analysis of experimental data will be developed in the future.

NA64. The JINR group taking part in the NA64 experiment is responsible for the development, construction and commissioning of coordinate detectors based on thin-walled straw tubes. It participates in the development of the software system for their online monitoring, simulation and reconstruction, and takes part in the reconstruction and analysis of data aimed at searching for the dark photon. By the start of the run in 2021, the setup had been significantly upgraded, supported by the RF earmarked grant and JINR. Straw detectors with an operating area of 20×20 cm, one of the key elements of the tracking system, were equipped with new electronics. This allowed for significantly reducing the background level, setting lower thresholds and increasing the efficiency. For the operation on the muon beam, JINR produced seven new 60×120 cm straw chambers.

During two runs performed in 2021, $\sim 7 \cdot 10^{10}$ events were collected in search of the dark A' production in the invisible mode at the electron beam energy of 100 GeV [28] and $6 \cdot 10^9$ events in search of the dark Z' boson to study the muon $(g-2)$ anomaly [29]. At present, the data collected in both runs are being analyzed. The JINR group commissioned two new large straw detector stations operating together with hadron calorimeters.

Experiments at RHIC

The participation of the JINR group in the STAR project is aimed at studying the properties of nuclear matter at extreme densities and temperatures, and phase transitions during collisions of heavy ions in a wide range of energies at the Relativistic Heavy Ion Collider (RHIC). The research programme also includes the study of the structure functions of quarks and gluons in collisions of longitudinally and transversely polarized protons.

The final run of the BES II programme in the range of 3–200 GeV was carried out in 2021. This makes it possible to study the phase diagram of nuclear matter in a wide temperature range $T_{\rm ch} = 60-160$ MeV and baryon densities $\mu_B = 25-720$ MeV. In central Au + Au collisions, a non-monotonic change in the magnitude of the product of the kurtosis coefficient and the dispersion of the distribution of the number of net-protons was detected with a change in the collision energy with a significance of 3.1σ [30].

The polarization of Ξ and Ω hyperons measured for the first time in central Au + Au collisions at $\sqrt{s_{NN}} = 200$ GeV [31] is in reasonable agreement with a multiphase transport (AMPT) model. Studies of spin effects and structure functions of partons (PDF) continued. Although PDFs became more precise, there are still kinematic regions where more data are needed: measuring the ratio of the production cross sections of vector bosons W^+/W^-, the limits were set on PDF for sea quarks d^-/u^- [32].

EVENTS

On 15 January, the third meeting of the Cost and Schedule Review Committee of the NICA Complex Project, formed at JINR by the decision of the Committee of Plenipotentiaries of the Governments of the JINR Member States, was held. The Committee noted the outstanding progress on the NICA Project implementation in the ongoing difficult situation of the COVID-19 global pandemic. In particular, the Committee highlighted the commissioning of the Booster, the installation of MPD magnet elements, the construction of a complex of power substations, and progress in the construction of a new cryogenic compressor station.

On 19–20 April, the 7th BM@N Collaboration Meeting was held in Dubna. More than 40 reports were presented. The participants discussed the progress in the construction of detectors and plans for upgrading the facility.

On 21–23 April, the 7th Collaboration Meeting on the MPD Experiment was held in a mixed format. More than 190 senior scientists, students and engineers from all over the world — from China to Mexico — took part in the meeting. During the three days of plenary sessions, almost 50 reports were presented on the construction of MPD detector systems and physics analyses.

On 15–16 September, an International Round Table on Applied Research and Innovations at NICA was held at VBLHEP. It gathered around 300 participants from 19 countries. A Memorandum of the Round Table was adopted. The document reflects a considerable interest of the scientific community in the issues of organization of applied research at the NICA complex and the opinion of participants about a number of strategic issues on the further development of works. For further elaboration of the outlined initiatives, the NICA Project management formed an Expert Committee on Applied Research and Innovation at ARIADNA (Applied Research Infrastructure for Advanced Developments at NICA fAcility) channels.

On 3–8 October, the 8th BM@N Collaboration Meeting was held in Dubna. The meeting brought together about 100 participants from leading scientific centres, who presented 40 reports.

On 12–14 October, the 8th MPD Collaboration Meeting was held via videoconference. More than 150 participants from 15 countries attended the meeting online and in person.

On 16–17 November, the 4th meeting of the Cost and Schedule Review Committee of the NICA Complex project was held. The Committee highlighted significant advances in the launch of the Booster, the completion of civil works and the construction of cryogenic systems. The Committee also revised the deadlines and proposed to postpone the launch of the basic configuration of the complex to the end of 2023.

On 19 November, new deadlines for the implementation of the project were agreed at the 7th meeting of the Supervisory Board of the NICA Complex project.

REFERENCES

1. *Butenko A. et al.* The NICA Complex Injection Facility // Proc. of the 27th Russ. Particle Accel. Conf. RuPAC2021, Alushta, Russia, 2021; JACoW Publ.
2. *Guber F. for the BM@N Collab.* Measurements of Centrality in Nucleus–Nucleus Collisions at the BM@N Experiment // Phys. Part. Nucl. 2021. V. 52, No. 4. P. 571–577.
3. *Kapishin M. et al.* Production of Hyperons, Strange Mesons and Search for Hypernuclei in Interactions of Carbon, Argon and Krypton Beams in the BM@N Experiment (Contribution to RFBR Grants for NICA) // Phys. Part. Nucl. 2021. V. 52, No. 4. P. 710–719.
4. *Patsyuk M. et al. (BM@N Collab.).* Unperturbed Inverse Kinematics Nucleon Knockout Measurements with a 48 GeV/c Carbon Beam // Nature Phys. 2021. V. 17. P. 693–699; 2102.02626 [nucl-ex].
5. *Zinchenko A. et al.* Performance Evaluation of the Upgraded BM@N Setup for Strangeness Production Studies // Phys. Part. Nucl. 2021. V. 52, No. 4. P. 725–729.
6. *Arbuzov A. et al.* On the Physics Potential to Study the Gluon Content of Proton and Deuteron at NICA SPD // Prog. Part. Nucl. Phys. 2021. V. 119. P. 103858; [hep-ex/201115005].
7. *Abramov V. et al.* Possible Studies at the First Stage of the NICA Collider Operation with Polarized and Unpolarized Proton and Deuteron Beams // Phys. Part. Nucl. 2021. V. 52, No. 6. P. 1044–1119; [hep-ex/210208477]
8. *Alexakhin V. et al.* On the Study of Antiprotons Yield in Hadronic Collisions at NICA SPD // Phys. Part. Nucl. Lett. 2021. V. 18. P. 196–201.
9. *Guskov A. for the SPD Collab.* Spin Physics Detector Project at JINR // PANIC21 Proc.; [hep-ex/2110.08930].
10. *Filatov Yu. N., Kondratenko A. M., Kondratenko M. A., Derbenev Y. S., Morozov V. S., Butenko A. V., Syresin E. M., Tsyplakov E. D.* Polarization Control in Spin-Transparent Hadron Colliders by Weak-Field Navigators Involving Lattice Enhancement Effect // Eur. Phys. J. C. 2021. V. 81, No. 11. P. 986.
11. *Filatov Yu. N., Kondratenko A. M., Kondratenko M. A., Vorobyov V. V., Vinogradov S. V., Tsyplakov E. D., Kovalenko A. D., Butenko A. V., Derbenev Ya. S., Morozov V. S.* Hadron Polarization Control at Integer Spin Resonances in Synchrotrons Using a Spin Navigator // Phys. Rev. Accel. Beams. 2021. V. 24, No. 6. P. 061001.
12. *Basilev S. N. et al.* Charge Exchange $dp \to (pp)n$ Reaction Study at $1.75A$ GeV/c by the STRELA Spectrometer // Eur. Phys. J. A. 2021. V. 57, No. 4. P. 133.
13. *Volkov I. S. et al.* Analyzing Power in Quasi-Elastic Proton–Proton Scattering at 500 and 650 MeV/nucleon // Proc. of the XXIV Intern. Sci. Conf. of Young Scientists and Specialists (AYSS-2020), Dubna, Nov. 9–13, 2020. AIP Conf. Proc. 2021. V. 2377. P. 030020.
14. *ALICE Collab.* Coherent ρ^0 Photoproduction in Ultra-Peripheral Xe–Xe Collisions at $\sqrt{s_{NN}} = 5.44$ TeV; arXiv:2101.02581. 2021.
15. *ALICE Collab.* Kaon–Proton Strong Interaction at Low Relative Momentum via Femtoscopy in Pb–Pb Collisions at the LHC // Phys. Lett. B. 2021. V. 822. P. 136708.
16. *Grigoryan S.* A Three Component Model for Hadron p_T-Spectra in pp and Pb–Pb Collisions at the LHC. arXiv:2109.07888. 2021
17. *CMS Collab.* Search for Resonant and Nonresonant New Phenomena in High Mass Dilepton Final States at 13 TeV // JHEP. 2021. V. 07. P. 208.
18. *Zhizhin I. A., Lanyov A. V., Shmatov S. V.* Search for Heavy Neutral Gauge Bosons in the Dilepton Channel in the CMS Experiment at the LHC // Phys. At. Nucl. 2021. V. 84, No. 10. P. 1–5.
19. *Zhizhin I. A., Lanyov A. V., Shmatov S. V.* Searches for New Physics in the Dilepton Channel with the CMS Detector at the Large Hadron Collider // Phys. At. Nucl. 2021. V. 84, No. 2. P. 184–189 (Yad. Fiz. 2021. V. 84, No. 2. P. 143–148).
20. *Lanyov A. V., Shmatov S. V., Zhizhin I. A.* Search for a High-Mass Dark Matter Mediator Decaying to Dilepton Final State in the CMS Experiment at the LHC // AIP Conf. Proc. 2021. V. 2377. P. 030009.
21. *Savina M. V., Seitova D.* Program of Searches with the CMS Detector for Signals from Multidimensional Low-Energy Gravity at the Large Hadron Collider // Phys. At. Nucl. 2021. V. 84, No. 2. P. 190–196 (Yad. Fiz. 2021. V. 84, No. 2. P. 149–155).
22. *COMPASS Collab.* Probing Transversity by Measuring Λ Polarization in SIDIS. CERN-EP/2021-072; hep-ex/2104/13585.
23. *COMPASS Collab.* The Exotic Meson $\pi_1(1600)$ with $J^{\mathrm{PC}} = 1^{-+}$ and Its Decay into $\rho(770)\pi^-$. CERN-EP-2021-162; hep-ex/2108.01744.

24. *Acharya A. et al.* Measurements of $\Xi(1530)^0$ and Anti-$\Xi(1530)^0$ Production in Proton–Proton Interactions at $\sqrt{s_{NN}} = 17.3$ GeV in the NA61/SHINE Experiment // Eur. Phys. J. C. 2021. V. 81, No. 10. P. 911.
25. *Tefelski D. et al.* NA61/SHINE Detector Upgrade // Acta Phys. Polon. Suppl. 2021. V. 4, No. 3. P. 579–582.
26. *NA62 Collab.* Search for Lepton Number and Flavor Violation in K^+ and π^0 Decays // Phys. Rev. Lett. 2021. V. 127, No. 13. P. 131802.
27. *Madigozhin D.* New Measurement of Radiative Decays at the NA62 Experiment at CERN // The XXVIII Intern. Conf. on Supersymmetry and Unification of Fundamental Interactions (SUSY 2021), Shanghai, China, Aug. 23–28, 2021 (virtual).
28. *Andreev Yu. M. et al.* Improved Exclusion Limit for Light Dark Matter from e^+e^- Annihilation in NA64 // Phys. Rev. D. 2021. V. 104, No. 9. P. L091701; 2108.04195 [hep-ex].
29. *Cazzdniga C. et al.* Probing the Explanation of the Muon $(g-2)$ Anomaly and Thermal Light Dark Matter with the Semi-Visible Dark Photon Channel. 2107.02021 [hep-ex].
30. *STAR Collab.* Net-Proton Number Fluctuations and the QCD Critical Point // Phys. Rev. Lett. 2021. V. 126. P. 92301.
31. *STAR Collab.* Global Polarization of X, Ξ and Ω Hyperons in $\mathrm{Au}+\mathrm{Au}$ Collisions at $\sqrt{s_{NN}} = 200$ GeV // Phys. Rev. Lett. 2021. V. 126, No. 16. P. 162301.
32. *STAR Collab.* Measurements of W and Z/γ^* Cross Sections and Their Ratios in $p+p$ Collisions at RHIC // Phys. Rev. D. 2021. V. 103. P. 012001.

DZHELEPOV LABORATORY OF NUCLEAR PROBLEMS

NEUTRINO PHYSICS AND RARE PHENOMENA, ASTROPHYSICS

During the visit of the Minister of Science and Higher Education of the Russian Federation, V. N. Falkov, at the beginning of March 2021, the official commissioning of the **Baikal-GVD** detector with eight clusters and 2304 photosensitive optical modules took place. The efficient detector volume for neutrinos with energies above 100 TeV has reached 0.4 km^3, which makes it the largest neutrino telescope in the North Hemisphere. The first ten events were selected as astrophysical neutrino candidates after the analysis of the 2018–2020 data (Fig. 1). The data were analysed, and the first results of the search for events from neutrinos on the Baikal-GVD detector associated with the alerts of the Antarctic IceCube detector were published [1, 2].

Within the **Daya Bay** experiment, the final dataset containing the whole statistics acquired in 2011–2021 was frozen. The final oscillation analysis is underway to be ready by the beginning of the Neutrino 2022 conference. The group from DLNP is one of the groups taking part in the data analysis. In 2021 the group was assigned to prepare data preservation, which includes development of the data format, data preparation, and development of a public code to read the data and perform the analysis. Part of this work was done in 2021.

Within the **JUNO** experiment, the group from DLNP made a major contribution to the vertex and energy reconstruction using the machine learning methods [3]. The analysis of the JUNO sensitivity to the neutrino mass ordering based on the atmospheric neutrino data and the combined JUNO and NOvA sensitivity to the neutrino mass ordering were initiated. The Top Tracker assembly and installation procedure is under development, the DAQ software is under testing.

In 2021, the **NOvA** neutrino beam experiment continued data collection. The DLNP and other Russian groups participated in the NOvA experiment from the Remote Operation Centre, ROC-Dubna. The 3-flavour oscillation analysis based on $13.6 \cdot 10^{20}$ POT (protons on target) with the neu-

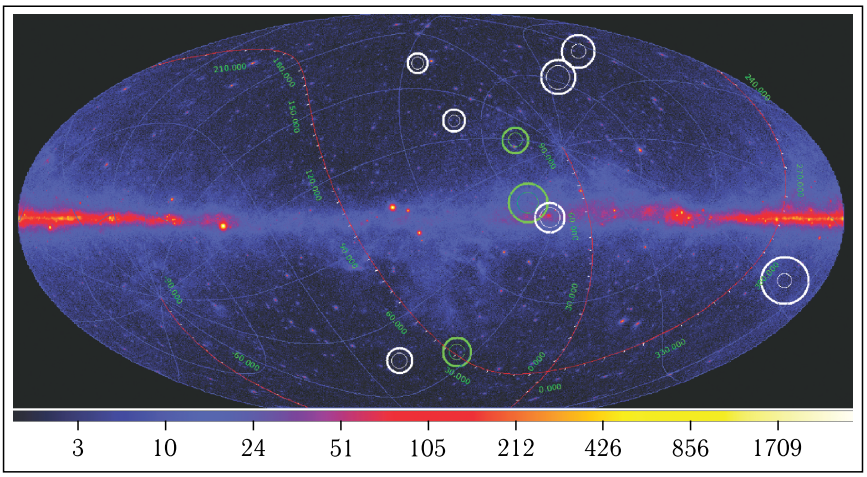


Fig. 1. Position of the first ten candidates for astrophysical neutrino events in Baikal-GVD on a celestial map with Fermi-LAT sources in the galactic coordinate system. The inner and outer circles around the events correspond to the 50% and 90% detection probability

trino beam and $12.5 \cdot 10^{20}$ POT with the antineutrino beam was prepared [4] and submitted to "Phys. Rev. D". The analysis of the data on the search for slow magnetic monopole based on the 95-day exposure in 2015 was published [5], a new analysis with higher statistics and sensitivity continues, and a new trigger was upgraded for the future data taking. A test bench was made to measure the contribution of Cherenkov light to the light output of the NOvA scintillator.

A search for conversion of solar neutrinos into antineutrinos in the solar magnetic field was performed using **Borexino** data. The limits on the conversion probability were set at $7.2 \cdot 10^{-5}$ and $8.7 \cdot 10^{-5}$ at 90% C.L. using high and low metallicity solar models, respectively [6]. A preliminary estimate of the Borexino sensitivity to the effective solar neutrino magnetic moment was performed, and the result ($2 \cdot 10^{-11} \mu_B$ at 90% C.L.) was close to the values necessary to explain the anomaly in the XENON1T data. The method for simultaneous analysis of the data from multiple Borexino phases aimed at improving the limit due to the higher statistics and lower backgrounds in later data is under testing. A corresponding paper is planned for the year 2022. The Borexino collaboration was awarded a prestigious Giuseppe and Vanna Cocconi Prize of the European Physical Society in astrophysics and cosmology for breakthrough studies of solar neutrinos providing the only and exhaustive evidence of nuclear fusion reactions in the Sun in the *pp*-chain and in the CNO cycle.

The **EDELWEISS** project is now searching for new physics in three directions: direct search for dark matter, precision studies of coherent elastic neutrino–nucleus scattering (CEνNS, Ricochet) [7], and search for $2\beta0\nu$ decay of ^{100}Mo with Li_2MoO_4 scintillation crystals in the EDELWEISS cryostat (CUPID-MO) [8]. In 2021, an intensive preparation of the Ricochet phase of the project in the ILL (Grenoble, France) was continued with a thorough study of the background conditions at the selected experimental site near the research reactor. JINR participates in the building of a cryogenic low-background setup (^{3}He–^{4}He dilution cryostat), selection of low-background materials, background measurements, and creation of an active veto system. Creation and testing of novel bolometer detectors (Fig. 2) continues under the EDELWEISS cryostat conditions (low-background environment in the deep underground LSM laboratory) with simultaneous search for light DM. It is planned to obtain first CEνNS measurement results in 2024.

Within the **DANSS** experiment, 5.5 million reactor antineutrinos were accumulated in five years of measurements; this is the world record statistics. A significant effect of oscillations to sterile neutrinos is not observed in the largest part of the phase space compared to competitors (parameters $\sin^2(2\theta_{14})$, Δm^2_{14}), including the points of the best fit of the reactor antineutrino anomaly and the BEST experiment excluded at a level of more than 5σ. In the autumn of 2021, the spectrometer electronics were repaired and updated, which will allow data collection to continue in 2022 [9]. Also in 2021, the work to create a new DANSS-2 spectrometer and R&D to optimize the configuration of the DANSS-2 spectrometer were underway [10].

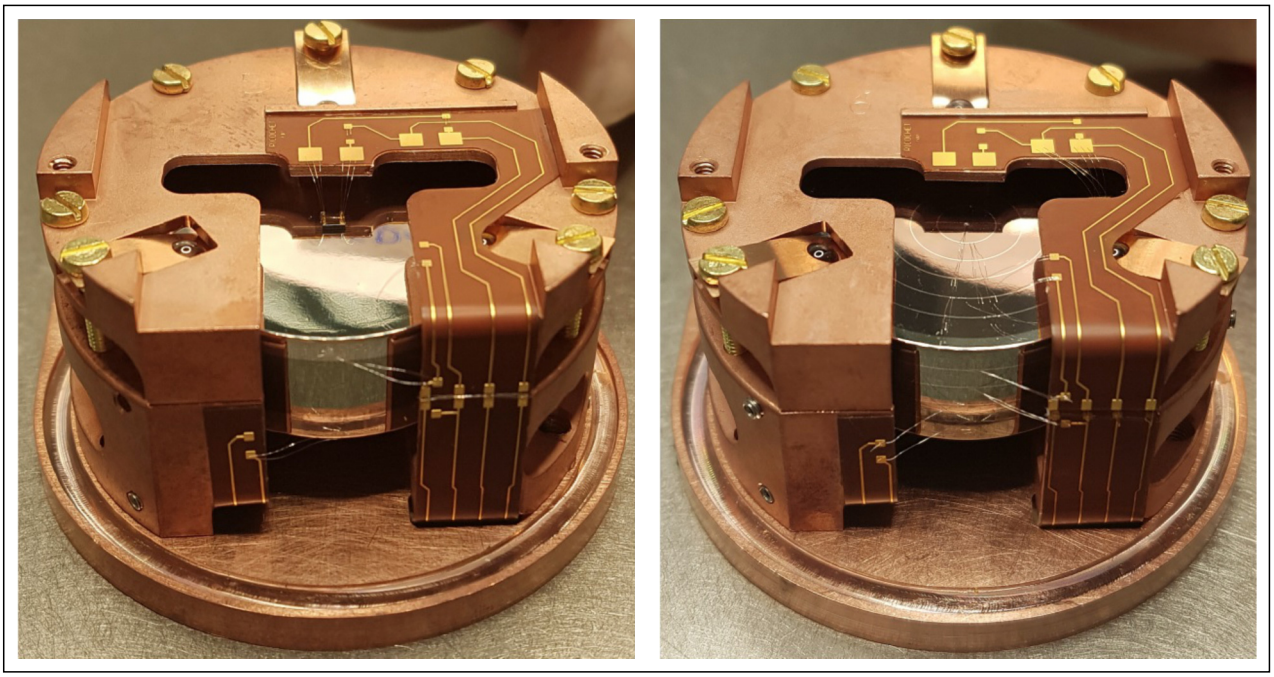


Fig. 2. Photos of a planar (left) and an FID (right) detector prototype made by EDELWEISS/Ricochet for Dark Matter search and precision study of CEνNS

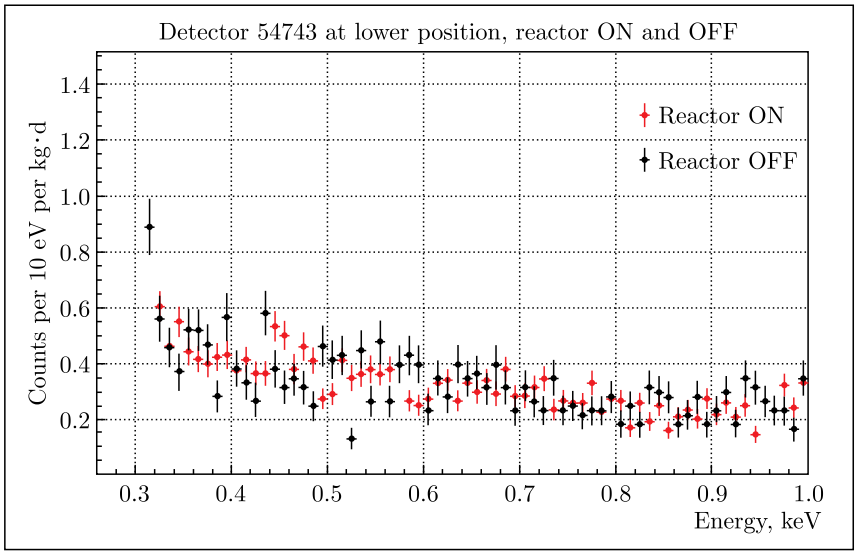


Fig. 3. Comparison of spectra taken with the reactor ON and OFF

The **νGeN** experiment is aimed at the precise investigation of the electroweak sector and search for new physics from coherent elastic neutrino nucleus scattering (CEνNS) detection in the full coherency regime and search for the neutrino magnetic moment down to the level of $(5{-}9)\cdot 10^{-12}\ \mu_B$. Low-threshold high-purity germanium detectors were specially produced. In 2021, the possibility of detecting events with an energy above 250 eV with an efficiency of 80% was demonstrated. A comparison of the spectra taken with the reactor ON and OFF showed identical background levels and shapes (Fig. 3).

Preliminary statistical analysis of the difference spectrum showed that in the energy region of [0.32…0.36] keV less than 0.47 count/(kg · d) should be expected from CEνNS (90% C.L.). The expected number of events from CEνNS (with the Lindhard parameter $k = 0.18$) is 0.46 count/(kg · d). The data taking and analysis continue, and new results are expected soon. The obtained results were presented at the TAUP 2021 [11] and Magnificent CEνNS 2021 [12] conferences.

In 2021, the analysis of the data collected in the **GERDA** experiment was continued [13, 14]. Within the framework of the GERDA/LEGEND collaboration, preparations for LEGEND-200 went on. The following important milestones were achieved: installation of the lock system and successful transfer into the cryostat, maintenance and modifications of the water Cherenkov system, completion of filling of the liquid-argon cryostat with purified argon, and installation, tests and commissioning of the new liquid-argon veto system (designed and produced by the joint TUM + JINR team).

Results were obtained of methodological studies carried out within the **SuperNEMO** project to measure the distribution of ^{207}Bi deposition on calibration sources [15]. The results of a search for periodic modulations of the ^{100}Mo double beta decay rate obtained by analyzing the data of the NEMO-3 experiment were published [16]. The results of studying the double beta decay of ^{150}Nd to excited levels of ^{150}Sm were reported at the international conference NUCLEUS-2021. For the first time, a signal from the $2\nu\beta\beta$ transition to the 0_1^+ level was measured with a significance exceeding 5σ. The corresponding half-life is measured to be $T_{1/2}2\nu\beta\beta(0_1^+) = = \left[1.11^{+0.19}_{-0.14}\,(\text{stat.})^{+0.17}_{-0.15}\,(\text{syst.})\right]\cdot 10^{20}$ y.

The aim of the **MONUMENT** project is experimental measurements of muon capture on several daughter candidates for neutrinoless 2β decay. The results would be drastically important for checking the accuracy of theoretical calculations of the nuclear matrix elements. On the basis of JINR, a frame for HPGe detectors and a muon trigger system with a target were created. During October–November 2021, muon capture measurements with isotopically enriched ^{136}Ba and ^{76}Se isotopes were carried out at the meson factory of the Paul Scherrer Institute (PSI) in Switzerland. A paper on the results of test measurements of the solid and gas targets in 2019 was prepared and accepted [17]. The analysis of the data obtained in the 2021 measurement campaign with the solid ^{136}Ba and ^{76}Se targets began. The next measurement stage with the isotopically enriched ^{100}Mo and ^{96}Mo targets is planned for June 2022.

Within the **T2K** project, the technical design of the base and assembly platform for the SuperFGD target was performed. Seismic resistance calculations were carried out. A prototype of a NIM electronic board with 12 channels for controlling the calibration LEDs was created for the SuperFGD detector calibration system. Studies were carried out to evaluate systematic uncertainties arising in calculations of the muon and proton momentum from the muon and protons range in different subdetectors of the ND280 detector. The “range-based momentum” considered here is calculated from the track length and the energy loss within a certain particle hypothe-

sis. The range-based momentum was compared with the momentum found from the track curvature in the TPC, and consistency of the experimental data and the MC simulation was verified. The results are published in T2K technical note (T2K-TN-433) for being used to define systematics in analyses that exploit the range-based momentum for tracks with no reliable TPC information, e.g., analyses using the ND280 samples with muons going backward or at high angle with respect to the neutrino beam direction.

ELEMENTARY PARTICLE PHYSICS

Within the **ATLAS** project, a very significant achievement was the start of participation in production of the high-tech detectors based on the MicroMegas (MM) technology for the New Small Wheel (NSW) ATLAS upgrade project. In 2017, a workshop was constructed for production of MicroMegas chambers and assembly of quadruplets at JINR. By now, all 32 quadruplets have been assembled and delivered to CERN, and thus JINR has successfully fulfilled its obligations to the ATLAS collaboration despite the pandemic situation. Also, construction of a full-cycle MicroMegas production workshop is underway.

Scientists from DLNP participated in the search for long-lived particles stopped in the ATLAS detector during periods in the LHC bunch structure when collisions were absent. The subsequent decays of these long-lived particles can produce high-momentum jets resulting in large out-of-time energy deposits in the ATLAS calorimeters. The analysed dataset is composed of events from proton–proton collisions produced by the LHC at $\sqrt{s} = 13$ TeV in 2017–2018. Lower limits were imposed on the mass of gluino R-hadrons with masses of up to 1.4 TeV at gluino lifetimes of 10^{-5} to 10^{3} s, assuming the branching fraction $\mathrm{Br}(\mathrm{gluino} \to qq\chi_1^0) = 100\%$ [18].

Also, DLNP participates in investigations of the Standard Model Higgs boson decaying into a b–anti-b pair and produced in association with a W or Z boson decaying into leptons, which are conducted using the pp collision data collected in 2015–2018 at the LHC at $\sqrt{s} = 13$ TeV and corresponding to an integrated luminosity of 139 fb^{-1}. The production of a Higgs boson in association with a W or Z boson was established with the observed (expected) significances of 4.0(4.1) and 5.3(5.1)σ, respectively. Cross sections were also measured as a function of the gauge boson transverse momentum. The cross section measurements were all consistent with the Standard Model expectations [19].

Within the **BESIII**, the observation of the $Z_{\mathrm{cs}}(3985)$ structure in the $e^+e^- \to K^+(D_s^- D^{*0} + + D_s^{*-} D^0)$ process with the beam collision energy of 4.68 GeV was done [20]. This state was observed in the decays to $D_s^- D^{*0}$ and $D_s^{*-} D^0$, and has a mass of about 3.98 GeV. This is the first candidate for a charged hidden-charm tetraquark with strangeness decaying into $D_s^- D^{*0}$ and $D_s^{*-} D^0$, which might be the $SU(3)$ partner of $Z_c(3900)$.

The Born cross section of electron–positron annihilation reactions into a neutron and antineutron pair and the neutron's effective form factor were measured. The data were recorded with the BESIII experiment at center-of-mass energies between 2.00 and 3.08 GeV using an integrated luminosity of 647.9 pb^{-1} [21]. The effective form factor of the neutron shows a periodic behavior, similar to earlier observations of the proton form factor. The nature of this behavior is still obscure.

The absolute branching fraction of the decay $\mathrm{D}_s^+ \to \tau^+\nu_\tau$ was measured [22]. On the basis of the data sets with an integrated luminosity of 6.32 fb^{-1} collected at centre-of-mass energies between 4178 and 4226 MeV, it was found that $\mathrm{Br}(D_s^+ \to \tau^+\nu_\tau) = (5.27 \pm 0.10 \pm 0.12) \cdot 10^{-2}$. The precision is improved by a factor of 2 compared to the previous best measurement. This significantly constrains the product of the decay constant $f_{D_s^+}$ and the absolute value of the CKM matrix element V_{cs}.

As part of the work on the preparation of the **Mu2e-II** project, radiation hardness of BaF_2 crystals, both pure and doped with the rare earth element yttrium (Y) in a proportion of 1 at.% Y, 3 at.% Y, 5 at.% Y, was studied. Crystal samples were irradiated with neutrons at the IBR-2M reactor with a total fluence of about $2.3 \cdot 10^{14}$ cm^{-2}. It was found that after irradiation the light output of pure BaF_2 decreased by about 8%, while the light output loss of the yttrium-doped samples was twice as high. It was found that the fast component in the yttrium-doped samples had a light output loss 2–3% higher than the slow component. This should be taken into account when using the fast emission component of yttrium-doped BaF_2 crystals in a high radiation environment [23].

Within the **COMET** project, new test benches were developed for quality control of straw tubes and study of their properties. Testing of the 5-mm-diameter straw tubes with a length of 0.7 m for the 64-channel prototype continued in 2021. At the COMET calorimeter prototype made of long LYSO:Ce crystals, the non-uniformity of the detector response along the crystal length and at the angles

of cosmic muon incidence of 9° and 19° relative to the crystal end plane was measured. An estimate of the energy resolution of the COMET calorimeter was obtained.

The following results were obtained: the light yield non-uniformity along the length measured using the source and cosmic muons had the same distribution pattern; energy resolution of the calorimeter prototype at an angle of 19° was ∼6%. The measurements showed that non-uniformity of scintillator responses should be taken into account when creating a calorimeter with the required resolution based on LYSO crystals for the COMET experiment [24–26]. At present, a comparative analysis of the measured data is being carried out to determine the calorimeter calibration procedure.

In 2021, the design of the SCRV system and the design for the central region of the SCRV system were proposed and approved by the COMET collaboration. The study of CRV module efficiency (both experimental and by simulation) showed that, by using the standard production process for strips with the light-reflecting surface made by etching, it is very difficult to achieve the required efficiency of 99.99% at a distance of 2.5 m from the photodetector. One of the ways to increase efficiency is to reduce the distance between the working volumes of the adjacent strips. Changing the strip production by replacing the side etching with mylar cover will reduce the gap between adjacent strips from 500 to 130 μm. The GEANT4 simulations to select the optimal thickness of aluminium plates showed that the basement layer should be at least 10 mm thick, and the intermediate layers should be 5 mm thick each. Also, an additional shield is necessary to reduce the electron flux.

Within the **GDH&SPASCHARM** project, the photon asymmetry Σ on a neutron was measured for the first time in the region of $\Delta(1232)$ and $N(1440)$ resonances [27]. Accurate measurement of differential cross sections and the linearly polarized photon beam asymmetry $\Sigma 3$ for the proton Compton scattering made it possible to obtain the proton electric and magnetic polarizabilities with unprecedented precision [28].

Within the **Ariel** project, development of the Monte Carlo event generator ReneSANCe and the integrator MCSANCee for modelling processes at electron–positron colliders better than at the one-loop level was continued. An interface of NLO electroweak radiation corrections with PYTHIA was created. A standard calculation procedure for helicity approach $2 \to 3$ and $2 \to 4$ was developed [29]. Updates were made to the DIZET and Zfitter software products. The DIZET release notes are sent to "CERN Yellow Rep. Monogr.".

APPLIED RESEARCH AND ACCELERATOR PHYSICS

Within the project **"Precision Laser Metrology for Accelerators and Detector Complex"**, in March–May 2021, a network of five precision laser inclinometers (PLIs) was installed for the first time at the LHC: two PLIs near the ALICE, two PLIs in the bypass tunnel of the CMS, and one PLI in Transport Tunnel No. 1. The network is designed to register microseismic vibrations for determining their impact on the collider beams.

In 2021, development of the sixth-generation PLI, a Compact Precision Laser Inclinometer, was completed. On the basis of daily monitoring of the angular microseismic activity of the Earth's surface in DLNP region, the main characteristics of the inclinometer were measured. Its sensitivity was $6 \cdot 10^{-11}$ rad/Hz$^{1/2}$ in the frequency range of 10^{-3}–15 Hz. The instrumental accuracy was found online to be $5.0 \cdot 10^{-10}$ rad. The measurement results make it possible to use the MPLI as the main tool in stabilizing colliders, Interferometric Gravitational Antennas against the action of angular microseismic vibrations of the Earth's surface and also for predicting earthquakes.

Within the **R&D of new semiconductor detectors**, the mechano-electronic stage of the development of a laboratory version of the tomograph in the protective case Kalan-4 has been completed. All main units — X-ray tube, sample attachment unit and X-ray camera based on Medipix3RX, Widepix MPX3 1×15 microcircuits with CdTe sensors 1 mm thick, and computer-controlled devices for moving all these units — were mounted and launched. The first X-ray images were obtained from a Widepix MPX3 1×15 camera consisting of 983 040 separate X-ray-sensitive pixels 55 × 55 μm in size. The alignment and adjustment of the tomograph continue [30].

In 2021, on the basis of the **Medico-Technical Complex (MTC)**, a statistical analysis of clinical data for different nosologies treated at the MTC was continued. The results are very close to those of proton therapy centres abroad. The cytotoxic and cytogenetic effects of gold nanoparticles on tumour cells of human lung carcinoma A549 under the influence of radiation with different values of LET (photons, protons) were studied.

Work was conducted to establish patterns of responses of the central nervous system to the effects of ionizing radiation of different quality. Induction and modulation of emotional, motivational behavior and cognitive functions of laboratory an-

imals were studied using neurochemical evaluation of the metabolism of excitatory neurotransmitters represented in morphological structures of the brain. The neurochemical data were compared with the behavioral changes induced by radiation [31, 32].

To conduct radiobiological research in the field of FLASH radiotherapy, a proton beam with the necessary parameters was shaped in Laboratory 4 of the Phasotron building of DLNP. Since the beam extracted from the accelerator has insufficient transverse dimensions for the given task, a lead scatterer of variable thickness was calculated and manufactured to form a homogeneous dose field on biological objects, which made it possible to deliver a beam with a homogeneous dose area of about 47 mm in diameter (at 90% level), while the dose rate was $\sim$70 Gy/s. Such beam parameters make it possible to conduct radiobiological studies both on cell cultures and on living biological objects (laboratory mice). Together with colleagues from the Institute of Theoretical and Experimental Biophysics of RAS (Pushchino), experiments were conducted with a proton beam in the FLASH radiotherapy mode. In the course of these studies, 100 laboratory mice and some cell cultures were irradiated. The purpose of this experiment was to study the nature of manifestation of the FLASH effect as a result of exposure of biological objects to ultrahigh-dose-rate ionizing radiation. The results of the experiments are being processed.

Joint experiments of the **DLNP Sector of Molecular Genetics of the Cell** and INR RAS were carried out to study the effect of low radiation background on model biological objects. For the first time, all *D. melanogaster* genes that changed their expression in the low-background laboratory conditions were identified using RNA sequencing. Analysis of the data indicates that a decrease in the radiation background does not affect a complex model organism. This result raises the question of the applicability of the linear non-threshold model in the low-dose region [33].

Also, experiments on assessment of the increase in the radioresistance of *D. melanogaster* and the human cell culture using the tardigrade protein Dsup (Damage suppressor) have been completed. The data indicate a significant increase in radioresistance of the model organisms.

In 2021, the project **"Development of Experimental Techniques and Applied Research with Slow Monochromatic Positron Beams"** focused on applied research in solid state physics and materials and surface engineering using the method of positron annihilation spectroscopy. A novel complementary method was proposed for studying the surface defect in nanoparticles [34]. The defect structure was interrelated with the magnetic properties of $BaTiO_3$ nanoparticles. The next topic was to study the evolution of defects arising in the process of cavitation [35]. The results may help counteract the destructive nature of cavitation. Two cavitation erosion stages were studied: incubation period and maximal erosion rate stage. Each stage has a specific dominant type of defect and differs in the depth of its occurrence. Apart from the performed material studies, improvement of the positron beam into the ordered beam is also continued. The measurements have shown that about 30% of the positron beam annihilates on the grids of the acceleration gap of the RF system. The accelerator gap was modified, and the cavities were re-installed in the positron channel.

The activities on **development of methods for the separation of elements (radiochemistry and mass separation)** are aimed at working out new separation and purification strategies to produce radionuclides for medical purposes and for spectrometric researches [36]. The conditioning is important among the radionuclide isolation stages, since the quality and chemical form suitable for the synthesis of a radiopharmaceutical depend on it. The study of the sorption of some elements on ion-exchange resins in an acetic acid medium has shown that the cation-exchange resin–acetic acid system can be used at the final stage of purification of group III and IV elements [37]. In addition, the research is carried out to study the possibility of using this chemical system to obtain an α-emitting medical radionuclide ^{223}Ra (11.4 d) via a radionuclide generator $^{227}\mathrm{Ac} \rightarrow {}^{227}\mathrm{Th} \rightarrow {}^{223}\mathrm{Ra}$.

REFERENCES

1. *Allakhverdyan V. A. et al.* Neutrino Telescope in Lake Baikal: Present and Nearest Future // PoS ICRC2021. 2021. P. 002; doi: 10.22323/1.395.0002.
2. *Avrorin A. V. et al.* Deep Water Cherenkov Detector in Lake Baikal // ZhETF. 2021. V. 161, No. 4 (in press).
3. *Qian Z. et al.* Vertex and Energy Reconstruction in JUNO with Machine Learning Methods // Nucl. Instr. Meth. A. 2021. V. 1010. P. 165527.
4. *Acero M. et al.* An Improved Measurement of Neutrino Oscillation Parameters by the NOvA Experiment. 2108.08219 [hep-ex].
5. *Acero M. et al.* Search for Slow Magnetic Monopoles with the NOvA Detector on the Surface // Phys. Rev. D. 2021. V. 103. P. 012007.
6. *Agostini M. et al.* Search for Low-Energy Neutrinos from Astrophysical Sources with Borexino // Astropart. Phys. 2021. V. 125. P. 102509.

7. *Ricochet Collab.* Ricochet Progress and Status // Proc. for the 19th Intern. Workshop on Low Temperature Detectors (LTD19). arXiv:2111.06745. 2021.
8. *Armengaud E. et al. (CUPID-MO Collab.).* A New Limit for Neutrinoless Double-Beta Decay of Mo from the CUPID-Mo Experiment // Phys. Rev. Lett. 2021. V. 126. P. 181802.
9. *Alekseev I. et al.* Observation of the Temperature and Barometric Effects on the Cosmic Muon Flux by the DANSS Detector. arXiv:2112.03702 [physics.ins-det].
10. *Alekseev I. et al.* Optimized Scintillation Strip Design for the DANSS Upgrade. arXiv:2112.04973 [physics.ins-det].
11. *Lubashevsky A.* First Results of νGeN Experiment at Kalinin Nuclear Power Plant on Coherent Elastic Neutrino–Nucleus Scattering. https:// indico.ific.uv.es/event/6178/contributions/15547/.
12. *Lubashevsky A.* First Results of the νGeN Experiment. https://indico.cern.ch/event/1075677/contributions/4556660/.
13. *Agostini M. et al.* Characterization of Inverted Coaxial Ge-76 Detectors in GERDA for Future Double-β Decay Experiments // Eur. Phys. J. C. 2021. V. 81, No. 6. P. 505.
14. *Agostini M. et al.* Calibration of the GERDA Experiment // Eur. Phys. J. C. 2021. V. 81, No. 8. P. 682.
15. *Arnold R. et al.* Measurement of the Distribution of ^{207}Bi Depositions on Calibration Sources for SuperNEMO // J. Instrum. 2021. V. 16. P. T07012.
16. *Arnold R. et al.* Search for Periodic Modulations of the Rate of Double-Beta Decay of ^{100}Mo in the NEMO-3 Detector // Phys. Rev. C. 2021. V. 104. P. L061601.
17. *Belov V. V.* Total Capture Rates of Negative Muons in ^{24}Mg // Part. Nucl., Lett. 2022. V. 19, No. 3.
18. *Aad G. et al.* A Search for the Decays of Stopped Long-Lived Particles at $\sqrt{s} = 13$ TeV with the ATLAS Detector // JHEP. 2021. V. 07. P. 173.
19. *ATLAS Collab.* Measurements of WH and ZH Production in the $H \to bb$ and Decay Channel in pp Collisions at 13 TeV with the ATLAS Detector // Eur. Phys. J. C. 2021. V. 81. P. 178.
20. *Ablikim M. et al. (BESIII Collab.).* Observation of a Near-Threshold Structure in the K^+ Recoil-Mass Spectra in $e^+e^- \to K^+(D_s^- D^{*0} + D_s^{*-} D^0)$ // Phys. Rev. Lett. 2021. V. 126. P. 102001.
21. *BESIII Collab.* Oscillating Features in the Electromagnetic Structure of the Neutron // Nature Phys. 2021. V. 17. P. 11.
22. *Ablikim M. et al. (BESIII Collab.).* Measurement of the Absolute Branching Fraction of $D_s^+ \to \tau^+\nu_\tau$ via $\tau^+ \to e^+\nu_e\nu_\tau$ // Phys. Rev. Lett. 2021. V. 127, No. 17. P. 171801.
23. *Atanov N. et al.* Development, Construction and Tests of the Mu2e Electromagnetic Calorimeter Mechanical Structures. FERMILAB-CONF-21-468-V; J. Instrum. (in press).
24. *Volkov A. et al.* Properties of Straw Tubes for Tracking Detector of the COMET Experiment // Nucl. Instr. Meth. A. 2021. V. 1004. P. 165242
25. *Volkov A. D. et al.* Test Bench for Study of Straw Characteristics // Usp. Prikl. Fiz. 2019. V. 7, No. 1. P. 76–83.
26. *Kalinnikov V. et al.* Comparison of the Scintillation Properties of Long LYSO:Ce Crystals from Different Manufacturers // Phys. Part. Nucl. Lett. 2021. V. 18, No. 4. P. 457–468.
27. *Mullen C. et al. (A2 at MAMI Collab.).* Single π^0 Production off Neutrons Bound in Deuteron with Linearly Polarized Photons // Eur. Phys. J. A. 2021. V. 57, No. 6. P. 205.
28. *Mornacchi E. et al. (A2 at MAMI Collab.).* Measurement of Compton Scattering at MAMI for the Extraction of the Electric and Magnetic Polarizabilities of the Proton. arXiv: 2110.15691 [nucl-ex]. 2021; Phys. Rev. Lett. (submitted).
29. *Boyko I. et al.* Two-Photon Physics at Future Electron–Positron Colliders. https://arxiv.org/abs/2110. 01426; Chin. Phys. (submitted).
30. *Boyko I. et al.* Measurement of the Radiation Environment of the ATLAS Cavern in 2017–2018 with ATLAS-GaAsPix Detectors // J. Instrum. 2021. V. 16. P. P01031; doi:10.1088/1748-0221/16/01/P01031.
31. *Borowicz D. M. et al.* Ultra-Hypofractionated Proton Therapy in Localized Prostate Cancer: Passive Scattering versus Intensity-Modulated Proton Therapy // J. Personal. Medicine. 2021. V. 11, No. 12. P. 1311; https://doi.org/10.3390/jpm11121311.
32. *Agapov A. V., Mytsin G. V.* A Dynamic Irradiation Method for Proton Radiotherapy // Biomed. Engin. 2021. V. 55, No. 2. P. 139–144; doi:10.1007/s10527-021-10088-w.
33. *Zarubin M. et al.* First Transcriptome Profiling of *D. melanogaster* after Development in a Deep Underground Low Radiation Background Laboratory // PLoS ONE. 2021. V. 16, No. 8. P. e0255066; https://journals.plos.org/plosone/article/authors?id= 10.1371/ journal.pone.0255066.
34. *Siemek K. et al.* Investigation of Surface Defects in $BaTiO_3$ Nanopowders Studied by XPS and Positron Annihilation Lifetime Spectroscopy // Appl. Surf. Sci. 2022. V. 578. P. 151807; https:// doi.org/10.1016/j.apsusc.2021.151807.
35. *Siemek K. et al.* Defects Studies of Nickel Aluminum Bronze Subjected to Cavitation // Appl. Surf. Sci. 2021. V. 546. P. 14910; https:// doi.org/10.1016/j.apsusc.2021.149107.
36. *Radchenko V. et al.* Radiochemical Aspects in Modern Radiopharmaceutical Trends: A Practical Guide // Solv. Extr. Ion Exch. 2021. V. 39, No. 7. P. 714–744; doi:10.1080/07366299.2021.1874099.
37. *Dadakhanov J. et al.* Sorption of Various Elements on Ion-Exchange Resins in Acetic Media // J. Radioanal. Nucl. Chem. 2021. V. 327, No. 3. P. 1191–1199; doi:10.1007/s10967-021-07600-7.

FLEROV LABORATORY OF NUCLEAR REACTIONS

OPERATION AND DEVELOPMENT OF FLNR ACCELERATOR COMPLEX (DRIBs-III)

Under the theme on the development of the FLNR cyclotron complex (DRIBs-III project) in 2021, work was carried out on the construction of new and on the upgrade and optimization of existing accelerating set-ups with a view to improving the intensity and the quality of ion beams of both stable and radioactive nuclides in the energy range from 5 to 60 MeV/nucleon. The project also aimed at improving the efficiency of experiments on the synthesis of new superheavy elements and study of their properties as well as at expanding the programme of experiments on the synthesis of rare exotic nuclei and study of reactions with beams of radioactive nuclides.

According to the JINR Topical Plan for 2021, the following results were achieved.

DC-280. The basic facility of the Superheavy Element Factory — DC-280 cyclotron — provided 5095 h of beamtime for research in 2021. During this period, the novel gas-filled separator GFS-2 was employed for conducting experiments on the synthesis of element 114 (flerovium) in the $^{242}Pu + {}^{48}Ca$ reaction, element 115 (moscovium) in the $^{243}Am + {}^{48}Ca$ reaction, and element 112 (copernicium) in the $^{238}U + {}^{48}Ca$ reaction. The experiment on the synthesis of Mc lasted for 1820 h; Fl, for 410 h; and Cn, for 810 h. The energy of ions extracted from the cyclotron could be smoothly varied, which was of particular importance for experiments conducted at the SHE Factory. Thus, the intensity of the beams of ^{48}Ca ions in experiments varied from 0.05 up to 6.5 pμA. It should be noted that the intensity of the ^{48}Ca beam reached 10 pμA at the extraction radius, providing an intensity of 7.1 pμA in the beam transport channel [1, 2].

Work on adjusting the acceleration modes for the $^{52,54}Cr$ and ^{48}Ti ions continued. The intensity of the accelerated ^{52}Cr beam reached 2.4 pμA, and the intensities of the beams of ^{54}Cr and ^{48}Ti ions were 2.2 and 1 pμA, respectively. In addition, preparations were complete for experiments at a new physics set-up GFS-3.

U-400M. As part of the U-400M cyclotron upgrade project, the main magnet coils were replaced with a new set in collaboration with the OOO NPO GKMP, Bryansk [3]. The novel components were connected to the power supply and cooling system; a magnetic field measuring system was installed. Another major enhancement involved an upgrade of operational elements and manufacturing of novel components for the vacuum system and for the cooling and control systems of the U-400M cyclotron. The start-up of U-400M is planned for the end of 2022.

U-400. A wide variety of scientific and applied investigations in heavy-ion physics were conducted using the U-400 cyclotron. In 2021, the cyclotron provided 6085 h of beamtime. Most of the operation time was devoted to the implementation of the programme focused on studying the beams of ^{22}N ions (SHELS set-up), ^{46}Ti ions (chemical set-up, SHELS), ^{48}Ca ions (CORSET, SHELS, MAVR), and ^{56}Fe ions (MAVR). In addition, experiments on accelerating ^{238}U ions were carried out. Applied studies (NIIKP) were also conducted employing the U-400 cyclotron.

IC-100. The upgraded IC-100 cyclic implanter is used for the implementation of the applied research programme. Ions ranging from C to W accelerated up to 1.0–1.2 MeV/nucleon at IC-100 were used for irradiation of graphene samples, Si_3N_4, TiNZrN/Zr, AlNTiN, ZnO, ODS steels, high-temperature superconductors, and titanium-based alloys (under the collaboration programme with the South Africa, Poland, Serbia, Belarus, Kazakhstan, and the Czech Republic).

DC-140. Work on the creation of a new DC-140 cyclotron for applied research has begun [4]. Sent into retirement, the U-200 cyclotron was dismantled and will be replaced with a new accelerating set-up. The foundation and the building were carefully examined. Civil engineering work is proceeding for the building that will host the new cyclotron. In parallel, the systems of the successor are designed and manufactured. The construction of the control and engineering systems is in full swing.

SYNTHESIS AND PROPERTIES OF NUCLEI AT STABILITY LIMITS

Experiment at Gas-Filled Separator (GFS-2). In 2021, three series of experiments were conducted at the new gas-filled separator GFS-2 of the Factory of Superheavy Elements at FLNR JINR. The fusion reactions of a beam of ^{48}Ca ions that impinged on target nuclei of ^{243}Am, ^{242}Pu, and ^{238}U were used to determine the operational characteristics of the new separator, analyze the prospects for future investigations of superheavy nuclei using higher sensitivity (transmission, background conditions, target stability, etc.), and to thoroughly study the properties of the isotopes of Mc, Fl, Cn and their daughter nuclei. The results showed that the transmission of GFS-2 was twice as efficient as that of GFS-1 at U-400.

The ^{243}Am + ^{48}Ca reaction was studied at five projectile energies and an intensity of up to 1.3 pμA. Six new decay chains of ^{289}Mc (product of the $2n$ channel), 58 chains of ^{288}Mc (produced in the $3n$ channel), and two chains of ^{287}Mc (produced in the $4n$ channel) were synthesized, thereby making it possible to produce a novel isotope ^{286}Mc ($5n$ channel). It should be noted that in earlier experiments the isotope ^{287}Mc was observed only in three chains, and the decay products of ^{286}Mc were detected in two chains. An α decay of ^{268}Db was detected for the first time, allowing the measurements of the α-decay branch and the half-life; moreover, a new isotope ^{264}Lr was produced. Spontaneous fission of the isotope ^{279}Rg was for the first time registered. The cross section for the $3n$ evaporation channel was shown to be twice as high as that previously measured.

In the experiment with ^{242}Pu, the intensity of ^{48}Ca ions reached 3 pμA. At two ^{48}Ca energies, 25

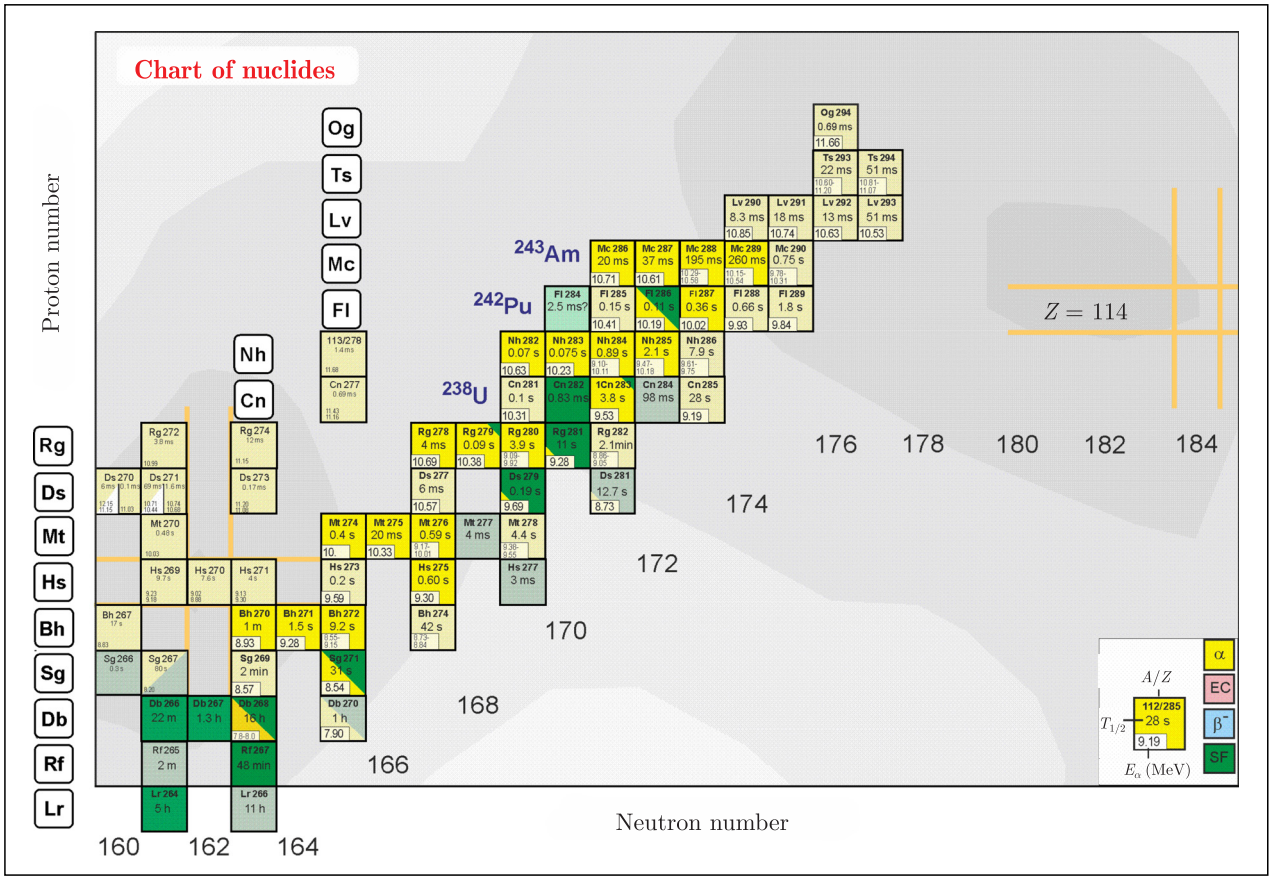


Fig. 1. Chart of nuclides. The isotopes produced in the reactions under investigation in 2021 are marked in bright yellow (α decay) and in green (spontaneous fission)

decay chains of ^{286}Fl and 69 decay chains of ^{287}Fl were registered, respectively. The cross sections were also twice as high as those measured earlier, which could be attributed to statistics that had increased manyfold. Indications were found for the existence of two decay branches of ^{287}Fl, ^{283}Cn, and ^{279}Ds, which differed in the correlation between the partial probabilities of α decay and the spontaneous fission of ^{279}Ds. This can present evidence for the population of the low-energy levels of ^{287}Fl and/or ^{283}Cn. The specific features of the ^{286}Fl and ^{282}Cn decays can also be ascribed to the decay of isomeric levels.

The intensity of the ^{48}Ca beam irradiating the ^{238}U target was 6.5 pμA. During the experimental run, sixteen ^{283}Cn decay chains were observed. In the course of a series of experiments, both the cross sections for the reactions under investigation at various projectile energies and the decay properties of about 30 isotopes of elements Rf through Mc (in Fig. 1 they are marked in bright yellow) were measured. The charges of the Mc, Fl, and Cn ions were measured in rarefied hydrogen. The reliability of the charge systematics obtained at GFS-1 was confirmed, which is crucial for the synthesis of new elements 119 and 120. The results of experiments are presented in [5–8].

Spectroscopy of Heavy and Superheavy Nuclei. The radioactive decay properties of the ^{253}Rf nucleus synthesized in the complete fusion reaction of ^{50}Ti ions with target nuclei of ^{204}Pb, followed by an emission of one neutron, were investigated. Spontaneous fission of ^{253}Rf was confirmed as a dominating decay mode. ^{253}Rf underwent an α decay registered for the first time, leading to an earlier produced isotope ^{249}No ($b_\alpha = (17 \pm 6)\%$) [9]. In addition, two low-lying short-lived spontaneous fission states for ^{253}Rf with drastically different half-lives were observed. One of these states with a half-life of 0.66 ms was detected for the first time and could be referred to a high-spin K isomeric state in ^{253}Rf. The results were submitted to *Phys. Rev. B* [10].

In May 2021, a new detecting system SFiNX was commissioned. This physics instrument comprises 116 neutron counters (^{3}He) surrounding a focal position-sensitive DSSSD detector 100×100 mm in size. The SFiNX system is highly efficient in registering neutrons (55%) and is dedicated to studying the properties of spontaneously fissioning short-lived nuclei produced in experiments at the SHELS separator [11]. The new system enabled measurements of neutron yields for the short-lived isotope ^{252}No with the record precision (an average number of neutrons emitted per fission was $\overline{\nu} = 4.25 \pm 0.09$).

During the summer shutdown, the ion-optical system of the SHELS separator was upgraded. The first triplet of ageing quadrupole lenses was replaced by a new set manufactured by Sigma Phi in France. The new triplet aperture is 50% larger, allowing, in turn, a better capture of reaction products flying out from a target. An improved configuration of the vacuum chamber of the new triplet enables a considerable reduction of the background from scattered ions. Conducted in October 2021, a short test run employing the upgraded SHELS separator showed a significant improvement of the characteristics of the ion-optical system and a background reduction in the detector.

Throughout 2021, the FLNR group worked on the assembly and start-up of the new GFS-3 separator installed on the fourth beam line of the DC-280 cyclotron of the SHE Factory. The start-up of the machine is scheduled for the beginning of 2022.

Chemistry of Transactinides. Research in 2021 aimed at studying the stopping of reaction products in the recoil chamber after their separation in the gas-filled recoil separator and further transport in inert gases to the cryodetector. These investigations are necessary to conduct a first chemical experiment at the SHE Factory scheduled for 2022. The research was done in cooperation with a superheavy element group from the Paul Scherrer Institute (PSI), Switzerland. The behavior of mercury, a light homologue of copernicium, was studied online employing the U-400 accelerator. Reaction products were first separated in the kinematic separator SHELS. The time of flushing mercury out of the chamber by a gas flow into a quartz tube and the transport time through a Teflon capillary into the cryodetector were measured using two short-lived α-emitting products ^{179,180}Hg formed in the ^{136}Ce(^{48}Ti, xn)$^{184-x}$Hg reaction. The experimental technique consisted of using a trigger, which turned on a beam for 500 ms and subsequently switched it off for 10 s. In this time interval, α radiation was continuously measured by the cryodetector operating in a given mode for argon with a flow of 1 and 3 $\mathrm{l \cdot min^{-1}}$. The mercury detection time after a short beam-on interval was 0.5 s, which was in good agreement with the results obtained with a model of the chamber (COMSOL software) simulating mercury yield and Ar flow.

By using the SHELS separator, the examining of the conditions for the formation of volatile compounds of the superheavy element nihonium continued. Experiments in 2021 mainly concentrated on studying the effect of oxygen and water vapor on the formation of various compounds of Tl — a light Nh homologue — on a quartz surface. The chemistry of single atoms of thallium produced in the ^{141}Pr (^{48}Ti, xn)$^{189-x}$Tl reactions at U-400 was studied by isothermal adsorption chromatography. A tantalum getter with a furnace temperature of 1000°C was placed in front of a quartz column to ensure the elemental state of thallium compounds formed by stopping their atoms in the recoil chamber. The admixtures of oxygen and water vapor to the carrier gas Ar were used after passing through the getter. Isothermal adsorption chromatography on the quartz surface was performed at temperatures ranging from 100 to 850°C. Thallium yield was mea-

sured online by gamma spectrometry. The obtained integral chromatograms revealed two chemical forms of thallium characterized by different adsorption behavior. Data are currently being processed with a view to determining the enthalpy of adsorption and identifying the detected thallium compounds.

Dynamics of Heavy-Ion Interaction, Fission of Heavy and Superheavy Nuclei. The synthesis of nuclei with $Z > 118$ and study of their properties are of particular interest in investigating the "island of stability" due to the shell effect at $N = 184$ and $Z = 114$ and/or $Z = 120$–126. To advance into the region of nuclei with $Z > 118$ using complete fusion reactions, projectiles heavier than ^{48}Ca should be used. In passing to heavier incident ions, however, the Coulomb repulsion between interacting nuclei strengthens, thereby leading to an increase in the contribution of quasi-fission and deep inelastic scattering, suppressing the formation of a compound nucleus. That is why the experimental studies of competition between fusion and quasi-fission in reactions with the beams of titanium and chromium are of paramount importance in planning experiments on the synthesis of as-yet-undiscovered superheavy elements. Mass and energy distributions of binary fragments formed in the $^{54}\mathrm{Cr} + {}^{232}\mathrm{Th}, {}^{238}\mathrm{U}$ reaction at energies in the vicinity of the Coulomb barrier were measured. Experimental data are processed.

Mass and energy distributions of the fission fragments of ^{178}Pt, ^{180,182,183,190}Hg, and ^{184,192,202}Pb formed in reactions with ^{36}Ar and ^{40,48}Ca ions over a wide energy range of 35–70 MeV were measured with a view to studying the fission properties of excited pre-actinide nuclei. The fission properties were shown by analysis to be governed by the proton numbers $Z \approx 36$ in a light fragment, $Z \approx 46$ in a heavy fragment, and $Z = 28$ and/or 50 in both light and heavy fragments. With regard to the fission mode ascribed to the proton number $Z \approx 36$, a fissioning nucleus has a prolate shape, as opposed to that predicted by the liquid-drop model, and is more compact than that peculiar to the mode caused by the influence of $Z \approx 46$ [12, 13].

In studying the $^{68}\mathrm{Zn} + {}^{112}\mathrm{Sn}$ reaction, it was found that mass and energy distributions of fragments differed widely from those formed in the $^{36}\mathrm{Ar} + {}^{144}\mathrm{Sm}$ reaction leading to the formation of the very same ^{180}Hg composite system at similar excitation energies of about 50 MeV. The fragment mass distribution for the reaction involving ^{68}Zn is broad and double-humped, with maximum yields of light and heavy fragments of 70 and 110 amu, in contrast to 80 and 100 amu during the fission of ^{180}Hg formed in the $^{36}\mathrm{Ar} + {}^{144}\mathrm{Sm}$ reaction. Such a considerable difference in mass–energy distributions is due to a greater contribution (over 70%) from quasi-fission in the reaction with ^{68}Zn ions [14]. The research on the fission properties of pre-actinide nuclei was supported by the RFBR grant No.19-52-45023_инд_а (jointly with RFBR and the Department of Science and Technology of the Government of India).

In 2021, significant efforts were also focused on studying fast fission. Mass and energy distributions of fragments formed in the $^{40}\mathrm{Ca} + {}^{144}\mathrm{Sm}, {}^{208}\mathrm{Pb}$ reactions at energies above the Coulomb barrier were measured. Angular momenta at these energies are high, so the fission barrier vanishes. The fission barrier for ^{184}Pb ($^{40}\mathrm{Ca} + {}^{144}\mathrm{Sm}$) is mainly determined by the macroscopic properties of the potential, whereas the nucleus stability for ^{248}No ($^{40}\mathrm{Ca} + {}^{208}\mathrm{Pb}$) is governed by the shell correction.

The studies showed that mass distributions of fast fission fragments were almost unaffected by increased interaction energies for the reactions under investigation and were characterized by a negligible mass asymmetry $\eta = (A_H - A_L)/(A_H + A_L) = 0.17$ for ^{184}Pb and 0.21 for ^{248}No. Mass and energy distributions of quasi-fission fragments formed in the $^{40}\mathrm{Ca} + {}^{208}\mathrm{Pb}$ reaction differed significantly from those of fast fission fragments. The shape of the mass distribution of quasi-fission fragments was broad and two-humped, with the light fragment of mass about 77 amu ($\eta \approx 0.38$), which is ascribed to a strong effect of the closed proton ($Z = 28$) and neutron ($N = 50$) shells. A paper reporting these results was submitted to *Phys. Rev. C*. The studies of the effect of the angular momentum on the formation of the compound nucleus were supported by the RFBR grant No.19-42-02014 (jointly with RFBR and the Department of Science and Technology of the Government of India).

Structure of Exotic Nuclei. In 2021, the generated data were analyzed on the experiment with a high-quality ^{8}He beam ($I \sim 10^5$ s^{-1}, $P \sim 95\%$, $E = 26$ MeV/nucleon) in the $^{8}\mathrm{He}(d, {}^{4}\mathrm{He})^{6}\mathrm{H}$ and $^{8}\mathrm{He}(d, {}^{3}\mathrm{He})^{7}\mathrm{H}$ reactions conducted at the ACCULINNA-2 fragment separator [15]. In nuclear energy levels, there were indications of the population of the ground state at 2.2(5) MeV and several excited states at ~ 5.5, ~ 7.5, and ~ 11 MeV. The ^{7}H energy spectrum was defined by a missing mass method with the resolution $\Delta E \sim 1$ MeV by measuring the energies and the emission angles of ^{3}He recoils in coincidence with tritons from the decay $^{7}\mathrm{H} \to t + 4n$. The experimental technique enabled simultaneous investigations of the ^{6}H system energy spectrum populated in the $^{8}\mathrm{He}(d, {}^{4}\mathrm{He})^{6}\mathrm{H}$ reaction. The data analysis is underway.

Studies continued of the low-lying states for the isotopes ^{7}He, ^{9}He, and ^{10}Li populated in the $^{6}\mathrm{He}(d,p)^{7}\mathrm{He}$, $^{8}\mathrm{He}(d,p)^{9}\mathrm{He}$, and $^{9}\mathrm{Li}(d,p)^{10}\mathrm{Li}$ reactions, respectively. For analyzing and interpreting experimental data, theoretical approaches were developed with due regard for the specific features of one-nucleon transfer reactions at a beam energy of 25–30 MeV/nucleon. The data on the spectrum of ^{7}He energy levels, particularly the interference between states of different parities in the energy range of 1–7 MeV, are being thoroughly analyzed

and getting ready for publication. Note also that a high energy resolution of ~ 150 keV (full width at half maximum — FWHM) for the ^{7}He ground state $3/2^{-}$ at $E = 0.445$ MeV attained in registering triple p–^{6}He–n coincidences was consistent with the best results of the world's foremost research centres. Taking into account the preliminary analysis of data on ^{10}Li, a wealth of statistics (around 400 triple p–^{9}Li–n coincidences), and a high energy resolution of 230 keV (FWHM), new data on low-lying ^{10}Li states at energies ranging from 0.5 to 4 MeV are expected.

The modifications and upgrade of the research instruments of the ACCULINNA-2 set-up continued into 2021 and involved: (a) construction of a tritium target complex; (b) adjustment of a new tracking system of the secondary beam based on two low-pressure avalanche counters (PPAC detectors); (c) adjustment of the velocity filter based on a high-frequency resonator (RF kicker). Updates on the current status of the ACCULINNA-2 complex are available at http://aculina.jinr.ru.

Reactions with Beams of Light Stable and Radioactive Nuclei. In 2021, two experiments were conducted at the U-400 cyclotron employing the high-resolution magnet analyzer MAVR. In experiments with the beams of ^{48}Ca and ^{56}Fe ions accelerated to 10 MeV/nucleon and directed to the Be, Au, Ta, and ^{238}U targets, the differential cross sections for the emission of alphas and other light charged particles at an angle of 0° with respect to their energy were measured with high sensitivity [16]. The resulting spectra were found to contain fast alpha particles of the energy corresponding to the kinematic limit for a three-body exit channel (Fig. 2).

The experimental data were analyzed using a moving source model. The analysis revealed several sources of non-equilibrium particles with extreme energies. The formation of non-equilibrium alphas could be attributed to their emission from a heavier target nucleus upon complete or incomplete fusion of nuclei. Details of a technique for registering coincidences of light particles with the fission fragments of a residual nucleus were also worked out.

Further analysis of experimental data related to the effect of the structure of weakly bound nuclei ^{6,8}He, ^{9}Be, ^{9,11}Li, and ^{8}B on total cross sections was continued.

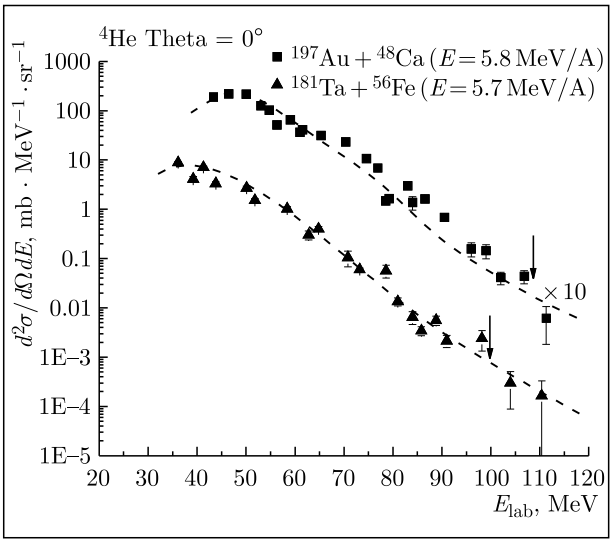


Fig. 2. Energy spectra of alphas measured at an angle of 0°. The arrows indicate the kinematic limits of two-body reaction channels

CONSTRUCTION OF NEW AND DEVELOPMENT OF EXISTING EXPERIMENTAL SET-UPS

Construction of a Separator Based on Resonance Laser Ionization (GaLS Set-Up). The GALS set-up under construction is intended for separation and study of the products of multi-nucleon transfer reactions. The following main results were achieved in 2021 [17]:

1. The reference chamber of the GALS set-up designed to search for and study the optimal levels of atomic transitions in multi-stage resonance laser ionization was upgraded. The upgrade began after the parameters of the evaporative laser had been verified. The laser energy density per pulse will be increased up to the level required for atomizing an Os sample. The scanning laser system is currently being modified and adjusted to allow offline work with a reference cell.

2. In cooperation with the Sofia University (Bulgaria), a detecting system of GALS was developed. A key element of the system is a detector component of the BEDO set-up (Orsay, France). The decision on the optimal choice of detectors and the geometry of scintillators is being currently finalized. Designed in collaboration with iThemba LABS (South Africa), the tape station was launched into manufacture.

3. The calculations of the parameters of the electrostatic ion guide system were performed. The distributed power supply systems feeding the beam line electrodes were developed. They are currently being assembled and tested together with the electrical and radio frequency power systems.

Ion Gas Catcher. The construction of the cryogenic gas ion catcher, a new set-up for the SHE Factory and other accelerator FLNR complexes, continued into 2021. A hall was prepared for the assembly and adjustment of the set-up. The apparatus

comprises a cryogenic gas catcher and a multiple-reflection time-of-flight mass spectrometer (room 203, bld. 101). A "warm" component of the chamber of the cryogenic catcher was assembled and vented to 10^{-5} mbar. A multi-electrode system for transporting the beam to the supersonic nozzle is under assembly; components are fabricated for the copper sheath of the cold chamber; and the instrumentation is ready for soldering and welding of the cooling pipe coil for helium fed into the cryogenic catcher.

The multiple-reflection time-of-flight mass spectrometer is designed by the Institute for Analytical Instrumentation of RAS (Saint Petersburg) and supported by a grant from the Ministry of Higher Education and Science of the Russian Federation No. 075-10-2020-117 ("Superheavy nuclei and atoms: Mass limits of nuclei and the borders of the Mendeleev Periodic Table"). This research instrument is intended for precision measurements of the masses of heavy isotopes and superheavy nuclei. In 2021, the design and main ingredients of the set-up underwent conformity assessment, and ion-optical calculations were performed. The feasibility study of a three-dimensional model is ongoing.

RADIATION EFFECTS AND PHYSICAL BASES OF NANOTECHNOLOGY, RADIOANALYTICAL AND RADIOISOTOPE INVESTIGATIONS AT FLNR ACCELERATORS

Comparative Analysis of Radiation Resistance of Nanoparticles Y–Ti(Al)–O in Metallic Matrices and Bulk Y–Ti(Al) Oxides against the Impact of Heavy Ions of Fission Fragment Energy. The tracks of xenon and bismuth ions in the $Y_4Al_2O_9$ and $Y_2Ti_2O_7$ nanoparticles were studied using the high-resolution transmission electron microscopy (HRTEM). It was found that ion track radii depended on specific ionizing energy losses. Amorphous latent tracks in $Y_2Ti_2O_7$ were found to form both in isolated particles and in those embedded into metallic matrices, whilst tracks in $Y_4Al_2O_9$ were registered only in isolated nano-oxides [18].

Study of Residual Stress Profiles in Nitrides (AlN, Si_3N_4) and Carbides (SiC) Irradiated with High-Energy Ions. A depth-resolved Raman spectroscopy technique was used to study the residual stress profiles in polycrystalline silicon and aluminum nitrides irradiated with high-energy bismuth ions at fluences ranging from 10^{12} to 10^{13} cm^{-2}. There was experimental evidence of both compressive and tensile stress fields being formed in the irradiated Si_3N_4 sample, whereas the residual stress in AlN was registered only at the Bi ion fluence of 10^{13} cm^{-2} [19].

Transmission Electron Microscopy (TEM) Study of Gas Swelling Behavior of Ferritic Steels, Varying with the Structure and Conditions of Their Doping with Inert Gases by Homogeneous Ion Implantation. Using the TEM technique, the regularities in the development of gas porosity were investigated in three samples of ferritic steels: conventional ferritic steel AISI410S and two experimental dispersion strengthened ferritic alloys Cr16-ODS and EP450-ODS. The samples were uniformly doped with helium ions up to the doses of 0.2 and 1 at % and annealed in a vacuum at a temperature of 10^{23} K. A technique was developed for uniform ion doping of material samples intended for structural studies by TEM. On the basis of theoretical calculations for ion implantation profiles in moving targets, a device with a rotating target was designed and manufactured. The target drive control programme enables the plotting of a resulting ion implantation profile in real time.

Development and Study of Ion-Selective Track Membranes. The detailed studies were conducted on the processes occurring during the irradiation of polyethylene terephthalate films with accelerated heavy ions, their subsequent exposure to ultraviolet radiation and liquid extraction. Such treatment leads to the formation of an ion-conducting cation-selective structure (selective to cations of different charges, too). The ion permeability and selectivity were found to depend on a number of factors, including mutual intersections of tracks, external and internal stresses in the polymer, and electric voltage. A phenomenological model of a resulting structure was proposed whose properties largely corresponded to the heterogeneous ion-exchange membrane [20, 21].

Hydrophobization of Polyethylene Terephthalate Track Membranes by Electron-Beam and Magnetron Sputter Deposition of Polymers onto Their Surfaces with a View to Producing Composite Membranes for Membrane Distillation. Techniques were developed for forming hydrophobic coatings on the surface of the polyethylene terephthalate track membrane by polymerization of organic compounds. The morphology and chemical structure of hydrophobic nanoscale coatings formed by magnetron sputtering of ultra-high-molecular-weight polyethylene and polytetrafluoroethylene in vacuum were also studied. In addition, the FLNR team investigated the physical and chemical properties of nanocoatings formed by electron beam dispersion of

polyvinyl chloride in vacuum. A possibility was also investigated of using track membranes with hydrophobized selective layers in seawater desalination by membrane distillation [22, 23].

Characterization and Production of Biodegradable Polymer Nanofibers by Electroforming on the Surface of Metallized Track Membranes for Medical Applications. A wound dressing was developed. The covering represents a perforated polyethylene terephthalate film modified with chitosan nanofibers by electrospinning. Impermeable to water and gas, the new wound dressing has a high tensile strength and elasticity, providing for efficient cell proliferation due to an extracellular matrix-mimicking structure. The composite material is non-toxic and could become a basis for the next generation of wound dressings used in combustiology [24, 25].

Development of Methodological Approaches to the Creation of a Technology for Producing Sterilizing Track Membranes. Approaches were developed to produce a prototype of sterilizing track membranes by creating two arrays of pores in a film whose thickness exceeded the length of the ion path. The prototype is based on a sieving mechanism of separation and sorption of filtered bacterial suspensions. The structural and strength characteristics of experimental and pilot samples of membranes comply with the international norms required for sterilizing membranes. The pilot samples produced by the roll technology were challenged with 10^7 colony forming units (cfu) of *Brevundimonas diminuta* (ATCC 19146) per cm^2 and demonstrated by testing to produce a sterile filtrate, thus establishing the bacteria retention capability.

X-ray Fluorescence Method and Gamma Activation Analysis Used in the Environmental Impact Assessment of Operational Industrial Facilities, in Particular Coal-Fired Heat and Power Plants (Collaboration with Mongolia). An environmental impact assessment associated with Ulaanbaatar Thermal Power Plant No. 4 was conducted. The concentration of heavy metals and radionuclides in the samples of coal, ash, slag, soil, and plants was estimated using the X-ray fluorescence method, gamma activation and gamma-spectrometer analyses. In addition, the level of heavy metal contamination in soils with regard to the maximum permissible concentration and background content was assessed and the radiation effects on human habitation and the surrounding environment were evaluated [26].

Expansion of the Fleet of Equipment and Introduction of New Physical and Chemical Investigation Methods (Transmission Electron Microscopy, Thermogravimetry, Measurements of Thermostimulated Currents in Dielectrics). A new Talos F200i transmission electron microscope was launched and used for studying various materials subjected to bombardment with accelerated heavy ions. A differential scanning calorimetry method, a thermally stimulated current technique, and mechanical testing of polymer films were introduced. A set-up for producing nanofibers was launched, and a number of experiments on creating hybrid track membranes and track-membrane-based composites were conducted. Some of the results of novel experimental methods have already been published, and the remainder was prepared for publication.

REFERENCES

1. *Semin V. A. et al.* DC-280 Cyclotron for Factory of Super Heavy Elements, Experimental Results // Proc. of the 12th Intern. Particle Accel. Conf. (IPAC'21), Campinas, Brazil, May 2021. P. 4126–4129; doi:10.18429/JACoW-IPAC2021-THPAB182.
2. *Gikal K. B., Bogomolov S. L., Ivanenko I. A., Kazarinov N. Yu., Pugachev D. K., Semin V. A., Lisov V. I., Protasov A. A.* Peculiarities of Producing ^{48}Ca, ^{48}Ti, ^{52}Cr Beams at the DC-280 Cyclotron // Proc. of the 27th Russ. Particle Accel. Conf. (RuPAC2021), Alushta, Russia, Sept. 2021. P. 95–98; doi:10.18429/JACoW-RuPAC2021-FRA01.
3. *Ivanenko I. A., Gulbekyan G. G., Kalagin I. V., Kazarinov N. Yu., Osipov N. F., Semin V. A.* Reconstruction of U400M Cyclotron: Upgrade of U400M Cyclotron Magnetic Structure // Proc. of the 12th Intern. Particle Accel. Conf. (IPAC'21), Campinas, Brazil, May 2021. P. 1838–1840; doi:10.18429/JACoW-IPAC2021-TUPAB187.
4. *Mitrofanov V. et al.* FLNR JINR Accelerator Complex for Applied Physics Researches: State-of-the-Art and Future // Proc. of the 22nd Conf. on Cycl. and Their Appl., Cape Town, South Africa, Sept. 2019. P. 358–360; doi:10.18429/JACoW-CYCLOTRONS2019-FRB02.
5. *Tsyganov Yu. S., Ibadullayev D., Polyakov A. N., Voinov A. A., Subbotin V. G., Schlattauer L., Kuznetsov D. A., Shubin V.* New Analog Spectrometer of the DGFRS-2 Setup for Real-Time Searching of ER-α and α–α Correlated Sequences in Heavy-Ion Induced Complete Fusion Nuclear Reactions // Acta Phys. Polon. B. Proc. Suppl. 2021. V. 14, No. 4. P. 767.
6. *Ibadullayev D., Tsyganov Yu. S., Solovyov D. I., Shumeiko M. V.* Yda C++ Program Package for Operating with a New Analog Spectrometer of DGFRS-II Setup // Acta Phys. Polon. B. Proc. Suppl. 2021. V. 14, No. 4. P. 873.
7. *Sagaidak R. N.* Effects of Beam Wobbling and Target Rotation on the Target Temperature in Experiments with Intense Heavy Ion Beams // Phys. Rev. Accel. Beams. 2021. V. 24. P. 083001.
8. *Sagaidak R. N.* Empirical Relations for Heavy-Ion Equilibrated Charges and Charge-Changing Cross

Sections in Diluted H_2 with Application // Eur. Phys. J. D. 2021. V. 75. P. 220.

9. *Svirikhin A. I., Yeremin A. V., Zamyatin N. I., Izosimov I. N., Isaev A. V., Kuznetsova A. A., Malyshev O. N., Mukhin R. S., Popeko A. G., Popov Y. A., Sokol E. A., Sailaubekov B., Tezekbayeva M. S., Chelnokov M. L., Chepigin V. I., Andel B., Antalic S., Bronis A., Mosat P., Gall B., Dorvaux O., Lopez-Martens A., Hauschild K.* The New ^{249}No Isotope // Phys. Part. Nucl. Lett. 2021. V. 18, No. 4. P. 445–448.
10. *Lopez-Martens A., Hauschild K., Svirikhin A. I., Asfari Z., Chelnokov M. L., Chepigin V. I., Dorvaux O., Forge M., Gall B. J. P., Isaev A. V., Izosimov I. N., Kessaci K., Kuznetsova A. A., Malyshev O. N., Mukhin R. S., Popeko A. G., Popov Yu. A., Sailaubekov B., Sokol E. A., Tezekbayeva M. S., Yeremin A. V.* Fission Properties of ^{253}Rf and the Stability of Neutron-Deficient Rf Isotopes // Phys. Rev. C. 2022. V. 105. P. L021306.
11. *Isaev A. V., Yeremin A. V., Zamyatin N. I., Izosimov I. N., Kuznetsova A. A., Malyshev O. N., Mukhin R. S., Popeko A. G., Popov Yu. A., Sailaubekov B., Svirikhin A. I., Sokol E. A., Tezekbayeva M. S., Testov D. A., Chelnokov M. L., Chepigin V. I., Antalic S., Mosat P., Brionnet P., Gall B., Dorvaux O., Kessaci K., Sellam A., Lopez-Martens A., Hauschild K.* Study of Spontaneous Fission Using the SFiNX System // Acta Phys. Polon. B. Proc. Suppl. 2021. V. 14, No. 4. P. 835.
12. *Bogachev A. A. et al.* // Phys. Rev. 2021. V. 104. P. 024623.
13. *Kozulin E. M. et al.* // Phys. Rev. C (submitted).
14. *Kozulin E. M. et al.* // Phys. Lett. B. 2021. V. 819. P. 136442.
15. *Muzalevskii I. A., Bezbakh A. A., Nikolskii E. Yu., Chudoba V., Krupko S. A., Belogurov S. G., Biare D., Fomichev A. S., Gazeeva E. M., Gorshkov A. V., Grigorenko L. V., Kaminski G., Kiselev O., Kostyleva D. A., Kozlov M. Yu., Mauyey B., Mukha I., Parfenova Yu. L., Piatek W., Quynh A. M., Schetinin V. N., Serikov A., Sidorchuk S. I., Sharov P. G., Shulgina N. B., Slepnev R. S., Stepantsov S. V., Swiercz A., Szymkiewicz P., Ter-Akopian G. M., Wolski R., Zalewski B., Zhukov M. V.* Resonant States in ^{7}7H. Experimental Studies in the ^{2}He(^{8}He, ^{3}He) Reaction // Phys. Rev. C. 2021. V. 103. P. 044313; arXiv: 2010.09655.
16. *Penionzhkevich Yu. E., Samarin V. V., Maslov V. A., Lukyanov S. M., Aznabayev D., Borcea K., Butusov I. V., Issatayev T., Mendibayev K., Skobelev N.K., Stukalov S. S., Shakhov A. V.* Energy Spectra of Alpha Particles in the Interaction of ^{56}Fe Nuclei with Tantalum and Uranium Nuclei at an Energy of 320 MeV // Phys. At. Nucl. 2021. V. 84. P. 115.
17. *Zemlyanoy S. G., Zagrebaev V. I., Avvakumov K. A., Zuzaan B., Tserensambuu T., Myshinsky G. V., Zhemenik V. I., Kudryavtsev Yu., Fedosseev V., Bark R., Janas Z., Kabytayeva R. K.* GALS — Setup for Production and Study of Heavy Neutron Rich Nuclei at JINR. Status Report // IGLIS-NET Newslett. 2021. No. 9.
18. *Korneeva E. A., Ibrayeva A., Janse van Vuuren A., Kurpaska L., Clozel M., Mulewska K., Kirilkin N. S., Skuratov V. A., Neethling J., Zdorovets M.* Nanoindentation Testing of Si_3N_4 Irradiated with Swift Heavy Ions // J. Nucl. Mater. 2021. V. 555. P. 153120; https://doi.org/10.1016/j.jnucmat.2021.153120.
19. *Zhumazhanova A., Mutali A., Ibrayeva A., Skuratov V., Dauletbekova A., Korneeva E., Akilbekov A., Zdorovets M.* Raman Study of Polycrystalline Si_3N_4 Irradiated with Swift Heavy Ions // Crystals. 2021. V. 11. P. 1313; https://doi.org/10.3390/cryst11111313.
20. *Blonskaya I. V., Lizunov N. E., Olejniczak K., Orelovich O. L., Yamauchi Y., Toimil-Molares M. E., Trautmann C., Apel P. Yu.* Elucidating the Roles of Diffusion and Osmotic Flow in Controlling the Geometry of Nanochannels in Asymmetric Track-Etched Membranes // J. Membr. Sci. 2021. V. 618. P. 118657; https://doi.org/10.1016/j.memsci.2020.118657.
21. *Blonskaya I. V., Kristavchuk O. V., Nechaev A. N., Orelovich O. L., Polezhaeva O. A., Apel P. Yu.* Observation of Latent Ion Tracks in Semicrystalline Polymers by Scanning Electron Microscopy // J. Appl. Polym. Sci. 2021. V. 83, No. 8. P. 49869; https://doi.org/10.1002/app.49869.
22. *Kravets L. I., Altynov V. A., Gainutdinov R. V., Satulu V., Mitu B., Dinescu G.* Hydrophobization of Poly(ethylene Terephthalate) Track-Etched Membrane by Magnetron Sputter Deposition of Polymers onto Its Surface // Nanoindustry. 2021. V. 14, No. 6. P. 32–43.
23. *Kravets L. I., Yarmolenko M. A., Rogachev A. A., Gainutdinov R. V., Gilman A. B., Altynov V. A., Lizunov N. E.* Formation of Hydrophobic Coatings onto the Surface of Track-Etched Membranes by Electron-Beam Deposition of Polyvinyl Chloride in a Vacuum // Nanoindustry. 2021. V. 14, No. 6. P. 44–54.
24. *Pereao O., Uche C., Bublikov P. S., Bode-Aluko C., Rossouw A., Vinogradov I. I., Nechaev A. N., Opeolu B., Petrik L.* Chitosan/PEO Nanofibers Electrospun on Metallized Track-Etched Membranes: Fabrication and Characterization // Mater. Today Chem. 2021. V. 20. P. 100416; https://doi.org/10.1016/j.mtchem.2020.100416.
25. *Vinogradov I. I., Petrik L., Serpionov G. V., Nechaev A. N.* Composite Membrane Based on Track-Etched Membrane and Chitosan Nanoscaffold // Membr. Membr. Technol. 2021. V. 3, No. 6, P. 400–410; doi: 10.1134/S2517751621060093.
26. *Gustova M. V., Kaplina S. P., Gustova N. S., Baljinnyam N., Badamgarav Ch.* The Assessment of the Risk of the Radioecological Pollution near the Coal-Fired TPP. JINR Preprint P18-2021-43. Dubna, 2021.

FRANK LABORATORY OF NEUTRON PHYSICS

In 2021, the scientific programme of the Frank Laboratory of Neutron Physics was aimed at obtaining new results within the framework of seven research themes of the JINR Plan for Scientific Research and International Scientific and Technical Cooperation: in condensed matter physics ("Investigations of functional materials and nanosystems using neutron scattering", 04-4-1142-2021/2025, leaders — D. P. Kozlenko, V. L. Aksenov and A. M. Balagurov; "Modern trends and developments in Raman microspectroscopy and photoluminescence for condensed matter studies", 04-4-1133-2018/2023, leaders — G. M. Arzumanyan and N. Kucerka); in neutron nuclear physics ("Investigations in the field of nuclear physics with neutrons", 03-4-1128-2017/2022, leader — E. V. Lychagin); in the development of the FLNP basic facilities ("Development of the IBR-2 facility with a complex of cryogenic neutron moderators", 04-4-1105-2011/2022, leaders — A. V. Belushkin, A. V. Vinogradov and A. V. Dolgikh); in the development of the IBR-2 spectrometers and computation complex ("Scientific and methodological research and developments for condensed matter investigations with IBR-2 neutron beams", 04-4-1143-2021/2025, leaders — V. I. Bodnarchuk and V. I. Prikhodko); in the development of the design of a new neutron source ("Development of the conceptual design of a new advanced neutron source at JINR", 04-4-1140-2020/2022, leaders — V. N. Shvetsov and M. V. Bulavin); in the development of the SOLCRYS structural research laboratory in Poland ("Development of the SOLCRYS Structural Research Laboratory at the SOLARIS National Synchrotron Radiation Centre", 04-4-1141-2020/2022, leader — N. Kucerka).

CONDENSED MATTER PHYSICS

In 2021, the IBR-2 reactor operated for physical experiments within the user programme for 60 days. From November to the end of the year, the programme was implemented completely without the direct participation of users. Two hundred and ninety-seven applications for experiments were received: 35% of them were aimed at solving problems of materials science, 23% were devoted to physical problems, and the remaining 42% covered research in the field of chemistry, geological sciences, biology and applied problems. Two hundred and forty submitted applications were accepted for realization.

Structure Investigations of Novel Oxide, Intermetallic and Nanostructured Materials. Layered van der Waals magnetic compounds CrX_3 (X = Cl, Br, I) are a promising class of layered materials — analogues of graphene, in which magnetic atoms form quasi-2D weakly interacting layers with hexagonal unit cells. Recent studies of two-dimensional forms of van der Waals magnets have shown that they retain magnetic order at sufficiently high temperatures even for a single atomic layer. In addition, a wide variety of new physical phenomena have been discovered in these materials with changing thermodynamic parameters (temperature and pressure), including superconductivity, topological spin excitations, skyrmion states, dielectric-metal transition, and spin crossover.

Using neutron diffraction (DN-6 diffractometer) and a complementary method of Raman spectroscopy, the structural, magnetic and vibrational properties of a model representative of the family of CrX_3 van der Waals magnetic compounds — $CrBr_3$, were studied [1]. The magnetic moments of Cr ions forming a graphene-like magnetic lattice in Br–Cr–Br layers are ordered ferromagnetically at a temperature $T_C = 37$ K. Anomalous behavior of structural characteristics, including crystal lattice parameters, interatomic distances and angles, was found in the vicinity of the ferromagnetic ordering

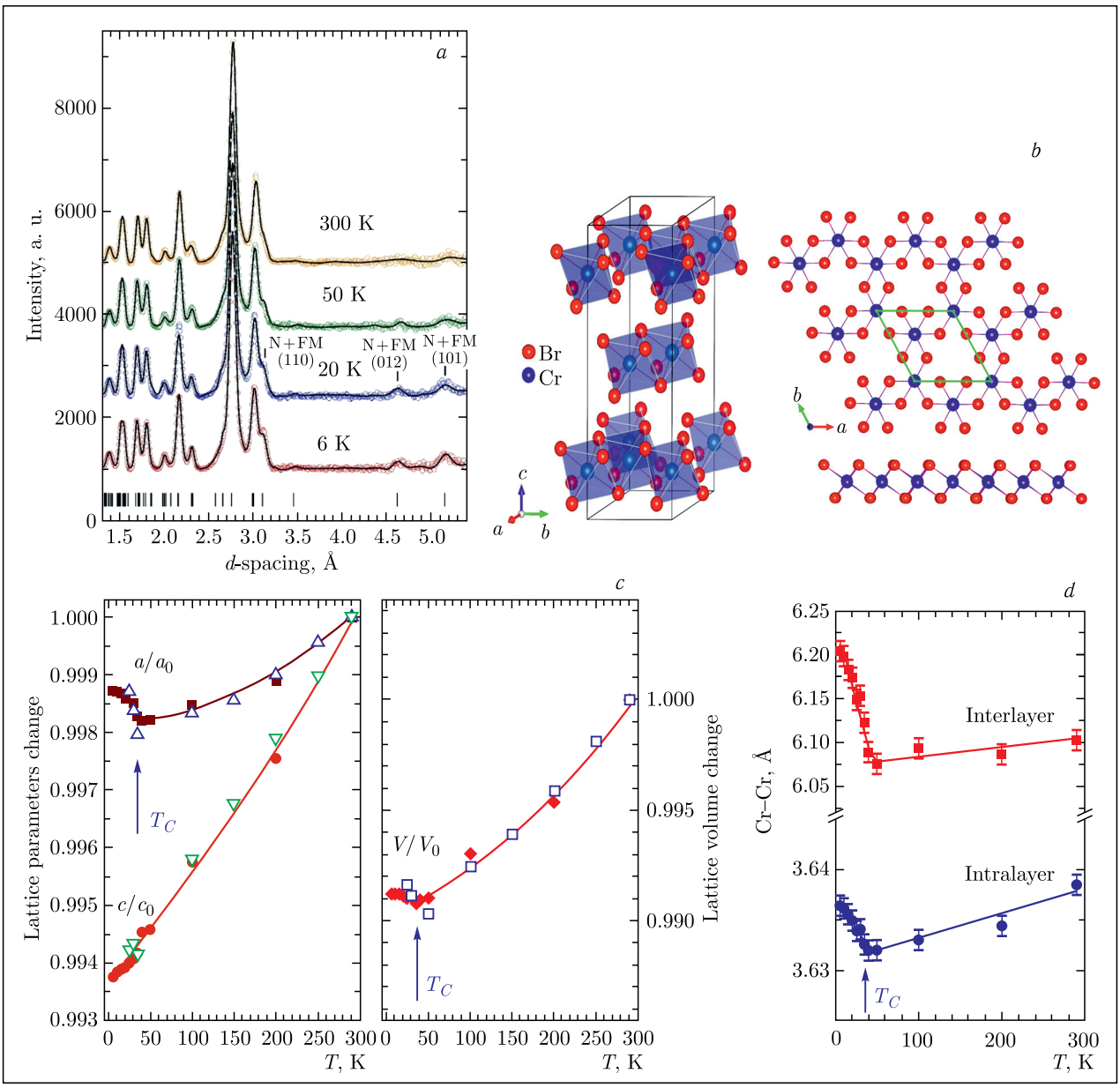


Fig. 1. *a*) Neutron diffraction patterns of $CrBr_3$ measured at various temperatures, and calculated profiles refined by the Rietveld method. *b*) Rhombohedral crystal structure of $CrBr_3$ of $R\bar{3}$ symmetry. *c*) Temperature dependences of the parameters and unit cell volume of the $CrBr_3$ crystal lattice, normalized to the corresponding values at room temperature. *d*) Temperature dependences of the distances between magnetic Cr ions inside van der Waals layers (intralayer) and between layers (interlayer).

temperature T_C (Fig. 1). In addition, below this temperature, in $CrBr_3$, a change in the character of thermal expansion from positive to negative was observed both for the entire crystal lattice volume and for quasi-2D van der Waals layers. It should be pointed out that negative thermal expansion is a relatively rare physical effect found only in a few classes of materials. Furthermore, graphene also exhibits negative thermal expansion, and the coefficient of linear thermal expansion of atomic layers in $CrBr_3$ for $T < T_C$, $\alpha_l = -1.6 \cdot 10^{-5}$ K^{-1}, turned out to be close to the corresponding value for graphene at low temperatures. The obtained result demonstrates a good compatibility of materials such as CrX_3 and graphene from the viewpoint of the prospects for producing heterostructures on their basis for practical application. In the vicinity of the magnetic ordering temperature, pronounced spin–phonon coupling effects were observed as well, which manifested themselves in a significant increase in the frequencies of vibrational modes.

Using high-intensity and high-resolution neutron diffraction (HRFD diffractometer), for Fe–xAl and Fe–xGa alloys, coherent cluster ordering effects were analyzed in dependence on the Al or Ga content and during order–disorder phase transitions upon a

change in temperature [2]. It was found that the formation of an ordered structure leads to a decrease in the unit-cell parameter with a "jump" of the order of $\Delta a/a \approx 0.001$. It follows from the neutron diffraction data that in a certain range of Al or Ga content in the alloy, a specific type of microstructure can be formed, which combines mesoscopic clusters of an ordered phase dispersedly incorporated into a disordered or partially ordered matrix. The characteristic sizes of coherently scattering areas inside the clusters are several hundred Å and increase during annealing. The unit-cell parameters of the matrix and clusters have a high degree of coherence, which manifests itself in their coincidence with a high degree of accuracy ($\Delta a/a \leqslant 0.0001$). Distortions and, moreover, splitting of the diffraction peak profiles are not observed. The splitting of the peaks detected in the surface layers of alloys or in thin films by X-ray or electron diffraction methods is related to the formation of incoherent two-phase states. The differences in the parameters of the crystal lattices of these phases correspond to the expected values and exceed the differences in the parameters of the phases forming the cluster microstructure by tens of times. This means that the two-phase states (A2 + B2, A2 + D03, B2 + D03) observed in the surface layer (X-ray or electron diffraction) and in bulk (neutron diffraction) of Fe–Al and Fe–Ga alloys have completely different nature and causes. Therefore, the assumptions about a possible relationship between the increased magnetostriction of Fe–Al and Fe–Ga alloys and the two-phase states observed in X-ray or electron diffraction experiments are not confirmed.

Comprehensive studies of solid solutions of strontium hexaferrites $SrFe_{12-x}In_xO_{19}$ ($x = 0.1$, 0.6, and 1.2) were continued [3]. Their structural features were studied by neutron diffraction in the temperature range from 1.5 to 300 K. Comparison of the crystal structure of strontium hexaferrites within the centrosymmetric ($P6_3/mmc$) and noncentrosymmetric ($P6_3mc$) space groups indicates a different degree of distortion ($S_{(FeO_6)}$) of neighboring oxygen polyhedra. The presence of an anomalously low thermal expansion of the unit cell parameters in the temperature range from 1.5 to 300 K was found, which may be due to a change in the regime of mutual rotations and tilts of oxygen polyhedra, by analogy with complex perovskite-like oxides. In $SrFe_{12-x}In_xO_{19}$ ($x = 0.1$, 0.6, and 1.2) samples, the appearance of spontaneous polarization was detected, which contradicts the description of its crystal structure within the framework of the generally accepted centrosymmetric $P6_3/mmc$ (No 194) space group. The mechanism of the occurrence of spontaneous polarization is explained by the incommensurate distortion of neighboring oxygen polyhedra due to the violation of the inversion symmetry of the crystal structure of strontium hexaferrites.

Investigation of Magnetic Fluids and Nanoparticles. The structural organization of magnetic textiles, a nanocomposite material developed for biocatalysis, was investigated using small-angle neutron and X-ray scattering (Fig. 2). Iron oxide nanoparticles exhibit enzymatic activity and are studied as a basis for artificial enzymes. In particular, their incorporation into various artificial tissues seems very promising. So, for this purpose, the deposition of magnetic nanoparticles on cotton products from magnetic fluids, controlled by an external magnetic field, is used. For the purpose of complex characterization, magnetite nanoparticles and their aggregates bound on woven cotton textiles employing two simple modification procedures were considered [4]. One modification was based on the treatment of textiles with perchloric-acid stabilized magnetic fluid diluted with methanol followed by drying. The second procedure was based on the microwave-assisted conversion of ferrous sulfate at high pH followed by drying. The structure and functional properties of these modified textiles were analyzed in detail. On the basis of the obtained results from small-angle X-ray and neutron scattering measurements, a conclusion was made about different structural organization of nanoparticles in the two kinds of textile samples. The catalytic properties of magnetic textiles were determined by the peroxidase-like activity in the decolorization of a standard solution of crystal violet with a substrate (sulfate salt N) in the presence of hydrogen peroxide.

Investigations of Biological Nanosystems, Lipid Membranes and Lipid Complexes. Morphological changes in model lipid membranes caused by the incorporation of amyloid-beta peptide were studied using small-angle scattering [5]. It was shown that the incorporation of amyloid-beta peptide affects both the structure of aggregates and the internal structure of the membrane in general and its thickness in particular. Figure 3 shows changes in the thickness of the membrane and the size of aggregates for the systems based on dimyristoylphosphatidylcholine (DMPC) and dipalmitoylphosphatidylcholine (DPPC) lipids. These lipids differ in the so-called main phase transition temperature. Changes in the thickness of the membrane and the size of the aggregates are presented as a function of the temperature shift relative to the temperature of the main phase transition. The obtained dependences are indicative of the common character of the interaction of the peptide with the membrane and confirmed by transmission electron microscopy.

Two-component systems (TCS) are responsible for the communication of microorganisms with the environment; they are present in almost all domains of life and are the most abundant signaling systems in nature. TCS receptors are generally transmembrane proteins. Despite the wide interest of the scientific community in the study of TCS, currently high-resolution structures of only fragments of these

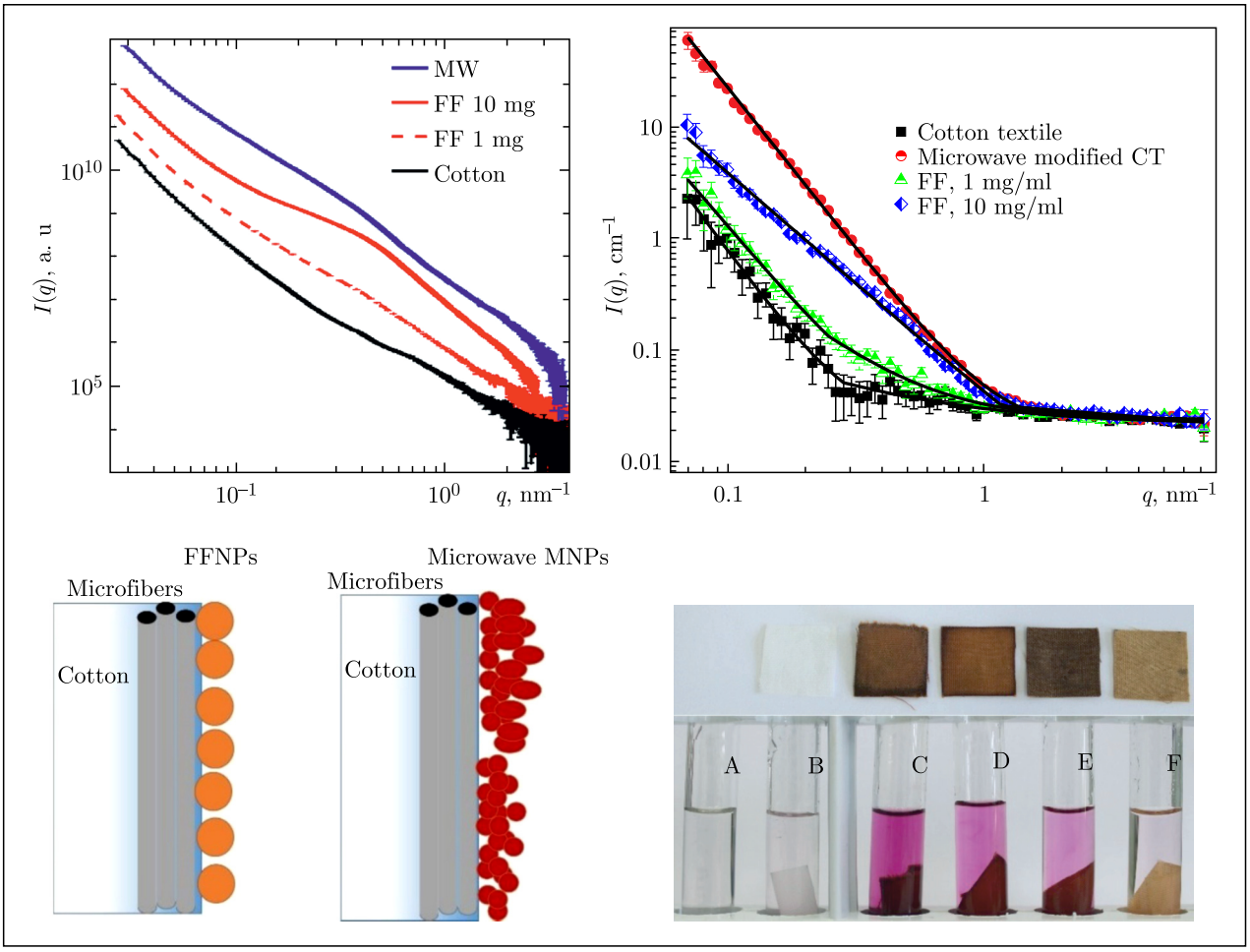


Fig. 2. Experimental SAXS (left) and SANS (right) curves for the native and nanocomposite textiles modified with magnetic nanoparticles with direct deposition of magnetite from magnetic fluid and drying (ferrofluid (FF)-treated textiles) and with microwave irradiation during the synthesis of nanoparticles in the presence of cotton fabric (microwave (MW)-treated textiles). A schematic drawing of the structural organization in the modified nanotextile for two deposition methods is shown. The peroxidase-like activity of magnetic textiles is demonstrated depending on the magnetite content

proteins are described in the literature. Difficulties in studying the structure of full-size TCS receptors are related to the large size and high dynamics of the water-soluble part of transmembrane TCS receptors. Using small-angle neutron scattering, the structure of the TCS sensor — a full-length photoreceptor complex of sensory rhodopsin with its cognate transducer from the extremophilic archaeon *Natronomonas pharaonis*, was studied on the YuMO spectrometer (IBR-2, JINR, Dubna) [6, 7]. Light-activated sensory rhodopsin II (*Np*SRII) induces structural and/or dynamic changes in the transducer (*Np*HtrII), which are converted by two HAMP domains and conveyed along the 200-Å-long cytoplasmic kinase module to the tip region of the cytoplasmic part of *Np*HtrII. The transducer-activated histidine kinase CheA (bound to the adapter protein CheW) undergoes autophosphorylation and further transfers the phosphate group to the response regulators CheY or CheB. CheY affects the rotational bias of the flagellar motor, while the methylesterase CheB, along with the methyltransferase CheR, controls the adaptation mechanism. The general scheme of the molecular mechanism of signal transduction involves successive dynamic changes in cytoplasmic domains. Both chemoreceptors and sensory rhodopsin transducers demonstrate different dynamics in adjoining modules, which correlates with the signal transfer along the cytoplasmic rod. Homodimers of chemoreceptors (or rhodopsin–transducer complexes) in the cell membrane form trimers that constitute the functional units. The trimers of dimers form the structural and functional unit in the formation of two-dimensional signaling arrays — compact membrane supercomplexes responsible for amplifying the incoming stimulus. The presented molecular model of a hexamer (trimer of dimers) was constructed using the combination of small-angle scattering data and molecular modeling. It was shown that the dimers of *Np*SRII/*Np*HtrII in the hexamer associate solely through contacts between their cytoplasmic regions, whereas the transmembrane regions

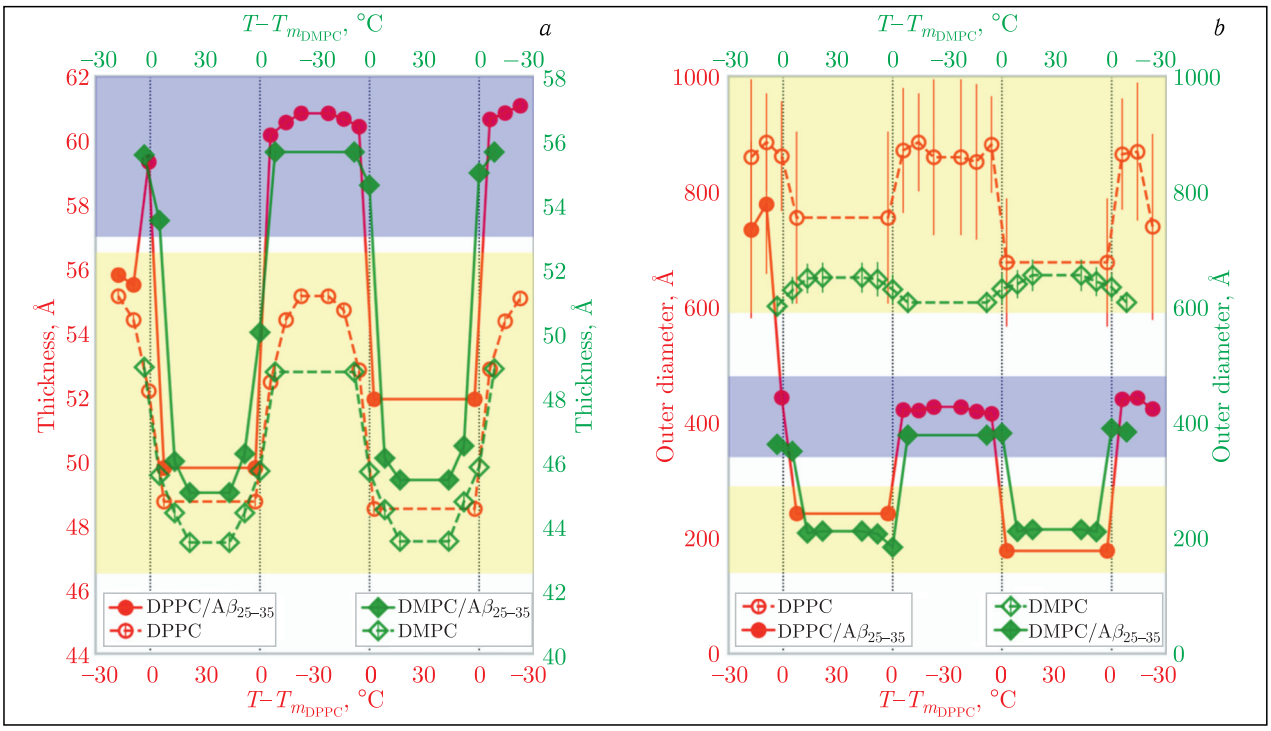


Fig. 3. Changes in the thickness of the model membrane (*a*) and sizes of aggregates (*b*) as a function of the temperature shift relative to the main phase transition temperature for DMPC (green diamonds) and DPPC (red circles) with and without the addition of amyloid-beta peptide

of the dimers remain unconnected; i.e., this is a "tripod"-shaped model, which differs from the "O"- and "Y"-shaped models proposed earlier in the literature.

The effect of melatonin and/or cholesterol on the structural properties of a model lipid bilayer prepared from 1,2-dioleoyl-sn-glycero-3-phosphocholine was investigated [8]. Neutron reflectometry experiments performed with single supported membranes revealed changes in lipid bilayer thickness upon the introduction of additional components. While the presence of cholesterol led to an increase in membrane thickness, the opposite effect was observed in the case of melatonin. The results obtained are in good agreement with molecular dynamics simulations, which provided further information on the organization of components within the systems under study, indicating a mechanism underlying the membranes' thickness changes due to cholesterol and melatonin that had been observed experimentally. Cholesterol and melatonin preferentially accumulate in different membrane regions, presumably affecting the conformation of lipid hydrophobic moieties differently, and in turn having distinct impacts on the structure of the entire membrane.

The antibiotic resistance of pathogenic microorganisms is one of the key problems in global public health care. Existing antibiotics turn out to be ineffective against new bacterial strains, the emergence of new drugs is too slow and humanity has come close to the threshold beyond which is a return to the "pre-antibiotic era", the transformation of seemingly defeated infections into deadly threats. A team of scientists from Russia, Romania, Serbia, Poland and the Czech Republic carried out a study on antimicrobial properties of new biocompatible nanocomplexes consisting of soy lecithin liposomes, chitosan and silver/silver chloride nanoparticles (NPs) [9, 10]. It is important to note that in order to reduce the toxicity of nanoparticles, "green" synthesis was used in the study — the production of NPs from plant extracts. Morphological (AFM, SEM) and structural (SAXS, SANS) methods of analysis confirmed the nanoscale size of components of the produced biocomposites. The presence of hybrid Ag/AgCl nanoparticles synthesized from turmeric rhizomes or grape and nettle leaves was determined by XRD and EDS methods. The formation of stable biohybrid nanocomplexes was confirmed by optical spectroscopy (UV–Vis absorption and FTIR) and zeta potential measurements. All of the above studies were aimed at developing highly effective biocompatible complexes with a wide potential for application in various fields of medicine. It is interesting to note that the synthesized and investigated materials also exhibit pronounced activity against cancer cells, which is confirmed in this study in *in vitro* experiments with HT-29 and HepG2 cells. At the same time, high efficiency (and the absence of hemolytic activity) was demonstrated only by composites containing biosimilar lipid bilayers.

Research of Polymeric Materials. The effect of a water-soluble monomer (acrylamide) on the structure and rheological properties of giant worm-like

micelles of anionic surfactant potassium oleate was studied at different salt contents. SANS measurements using YuMO (IBR-2) in combination with complementary methods (rheometry, fluorescence and NMR spectroscopy, tensiometry) made it possible to track the nature of the change/preservation of the structure of micelles. It was shown that at a low salt content, when worm-like micelles are linear, acrylamide induces their shortening and transformation into spherical micelles as a result of its incorporation into the micellar corona, which leads to a drop in viscosity. At a high salt content, which provides for the formation of branched worm-like micelles, the monomer first triggers their transition to long linear chains, which enhances viscoelasticity, and then to rods. Thus, the effect of the monomer on rheological properties differs significantly for linear and branched micelles [11]. The application of branched micelles allows preserving large worm-like micelles at a high water-soluble monomer content, which is favorable for their use as nanoreactors for the synthesis of copolymers with a high degree of blockiness, giving mechanically tough polymer gels.

Applied Research. Aluminum alloys of the 2xxx series are widely used in many industries, especially in aerospace, due to their high mechanical strength and light weight. However, at temperatures above 200°C, their mechanical characteristics deteriorate due to the acceleration of the processes of precipitation of secondary phases (precipitates). Of particular interest is the creep of aluminum and its alloys at different temperatures, as well as the distribution of residual stresses in materials after heat treatment. A detailed study of the stress state of cylindrical samples of 5083Al and 2014Al aluminum alloys produced by extrusion and subjected to quenching and subsequent slow cooling was conducted [12]. Texture measurements were carried out at CENIM (Madrid, Spain) with a Bruker AXS D8 X-ray diffractometer; residual stresses in the 5083Al alloy samples were studied with the FSD neutron Fourier stress diffractometer at FLNP JINR, and in the 2014Al alloy specimens by using synchrotron radiation diffraction data obtained with the EDDI diffractometer at the BESSY synchrotron radiation source (Berlin, Germany). From the results of texture measurements, it was found that as a result of extrusion, an axial texture is formed in the 5083Al alloy with ⟨111⟩ and ⟨100⟩ components along the extrusion axis, which smoothly fall from the center of the sample to its edge. All the main diffraction peaks for the 5083Al alloy in the neutron diffraction spectra were indexed to a face-centered cubic crystal structure (space group $Fm3m$) with a lattice parameter $a_0 \approx 4.07$ Å. It is assumed that noticeable microstresses develop during heat treatment. The calculations based on a genetic algorithm for the hardened cylindrical 5083Al sample showed that microscopic residual stresses can vary significantly from -263 to 301 MPa. In addition, in the case of slow cooling, the d_{hkl} profiles are not flat, which suggests the presence of small macroscopic residual stresses that do not completely relax as a result of heat treatment. Similar parabolic profiles are also observed for the 2014Al alloy. Errors in determining stresses do not exceed ± 20 MPa. It can be seen that in both quenched samples, the residual stress profile as a function of the distance to the sample center is parabolic. And the maximum value of the residual stress (axial component) in the quenched 2014Al sample is almost two times lower than in the 5083Al alloy. This difference is fully consistent with the results of recent studies, in which, based on FEM calculations, it was found that the level of macroscopic residual stresses depends not only on the thermal and mechanical properties of alloys, but also on the parameters of quenching of the material and the sizes (diameters) of cylindrical samples. It was shown that the difference in residual stresses between the inner and outer regions increases with an increase in the distance traveled by the quenching front (i.e., sample diameter) and decrease of the yield strength. The samples subjected to slow cooling demonstrate a non-zero level of macroscopic residual stresses, which are due to their incomplete relaxation as a result of heat treatment: 68 MPa for the 5083Al alloy and 12 MPa for the 2014Al alloy. This is an unexpected result, since heat treatment should have led to full relaxation of macroscopic residual stresses, which requires further study and analysis. Taking into account the texture gradient leads to a rather significant increase in the axial residual stresses in the 5083Al alloy after quenching (about 24 MPa) and practically does not change them after slow cooling (the difference is about 3 MPa). For the 2014Al alloy, the situation is reversed: there are no changes after quenching (the difference is about 5 MPa), after slow cooling, the difference is noticeable and is about 18 MPa. In addition, calculations of residual stresses for the 5083Al alloy were performed on the basis of the results from the Rietveld analysis under the assumption of a uniform texture. In this case, the stress distribution also had a parabolic profile, and the obtained residual stress values were in good agreement with the results from the individual peak analysis. After slow cooling, almost full relaxation of residual stresses within ± 10 MPa was observed.

The effect of the elemental content of shells of bivalve mollusks (*Mytilus galloprovincialis*) inhabiting the Saldanha Bay area (South Africa) on their crystallographic texture was studied. The content of 23 elements in the shells of these mollusks was determined using neutron activation analysis. The shells of mussels from three different stations were analyzed. As was found from the neutron activation analysis data, wild mussels from the Danger Bay, which is open to ocean waters, live in stressful natural conditions and contain a greater amount of most elements compared to mussels grown in closed water areas (Langebaan Yacht Club and the Small Bay) with anthropogenic loads. The measurements

of complete pole figures were carried out using the time-of-flight neutron diffraction method at the SKAT instrument. For the study, valve sizes of at least 30 mm in length and a mass of at least 10 g were selected. Three-four valves were connected using a two-component adhesive. The shells consist of two mineral phases, calcite and aragonite. The most intense diffraction reflections corresponding to crystallographic planes with Miller indices (0006) and (10–14) for calcite and (012)/(121) and (102)/(200) for aragonite were analyzed. Even though significant differences between concentrations of elements among the stations were found, the crystallographic textures of mussel shells from the studied bays showed insignificant dissimilarities. The observed differences in the maximum values in the pole figures lay within the range of variability identified for the genus *Mytilus*. Nevertheless, they appeared to correlate with the concentrations of Br, Mg, and Sr [13].

The chemical composition and spatial distribution of phase components of ancient Greek copper coins from the "Volna-1" large necropolis and known as Charon's obols were studied in detail using neutron diffraction and tomography methods [14]. It was these coins that accompanied a dead person after burial as a payment to Charon, the ferryman who conveyed souls across the river Styx that divided the world of the living from the world of the dead. The high penetrating power and the character of the interaction of neutrons with matter made it possible to determine the phase composition of the coins, as well as to separate the metal alloy of the coins from the patina material. The obtained neutron tomography data made it possible to partially restore the elements of the minting patterns of these coins. The relative concentration of tin in the bronze alloy of the coins was determined by neutron diffraction. The obtained neutron data allow one to draw some conclusions about the origin of the found coins, as well as about the historical period of their monetary circulation in the ancient Greek colonies.

Instrument Development. As part of the ongoing instrumentation development project, a number of instrument upgrades and improvements have been made on the FSD diffractometer. A new Fourier chopper manufactured by Airbus Defence and Space company was fully integrated into the SONIX experiment control system; a vacuum valve for the Airbus Fourier chopper was installed, and vacuum sensors for the Fourier chopper and neutron guide were mounted and connected. An additional XY positioning stage 8MT200XY (Standa) was installed to expand the possibilities for sample positioning with high precision.

A significant modernization of the FSS Fourier diffractometer was carried out. The old chopper previously employed on the FSS diffractometer was replaced with an upgraded Fourier chopper from the FSD diffractometer with a new automated positioning stage. The maximum rotation speed of the old Fourier chopper was limited by design to $\Omega_{\max} = 2000$ rpm. Its replacement with an upgraded Fourier chopper with a much higher maximum rotation speed $\Omega_{\max} = 6000$ rpm made it possible to significantly increase the resolution of the instrument. The installed chopper was mounted on a high-precision positioning stage, which allows one to remotely move the chopper into the beam and remove it if necessary, as well as quickly switch between TOF (high intensity) and RTOF (high resolution) modes. The results of test diffraction experiments with a standard iron sample showed that after replacing the Fourier chopper, the resolution of the FSS improved significantly due to a decrease in the time component of the resolution function. And with an increase in the maximum speed of the chopper from 2000 to 6000 rpm, the gain factor for the full resolution function of the FSS reaches 2.6 at $d_{hkl} = 0.5$ Å and 1.19 at $d_{hkl} = 2.5$ Å. If necessary, radial collimators with a focal length $F = 230$ mm and a spatial resolution of 1 or 2 mm can be installed in front of the Ost and West detectors, which ensure the possibility to shape a small gauge volume within the sample under study. Radial collimators are installed on positioning stages that allow them to be remotely moved into and removed from the scattered beam, which makes it possible to shape a beam of scattered neutrons in the experiment in the required way. Remote control over the motion of both collimators via SONIX scripts was implemented.

MULTIMODAL PLATFORM FOR RAMAN AND NONLINEAR OPTICAL MICROSCOPY AND MICROSPECTROSCOPY FOR CONDENSED MATTER STUDIES

The project "Biophotonics" comprises fundamental and applied parts. As for the basic research, the activities are aimed at identifying and understanding the mechanisms of anomalous ratio of intensities of the anti-Stokes/Stokes components in the spectrum of surface-enhanced Raman scattering (SERS). This will allow formulating the conditions for obtaining reproducible SERS spectra during the development of biosensors. Applied tasks are related to (i) spectroscopic studies of NETosis, in particular, to search for Raman markers of this phenomenon, as well as to determine the mechanisms for triggering the sterile activation of NETosis under the influence of UV radiation, and (ii) lipid–protein interaction in membrane mimetics liposomes/lipodiscs.

The aim of the study is to specify and quantify the role of the mechanisms responsible for the observed discrepancy of the aS/S ratios from those defined by the Boltzmann relation for thermal equilibrium populations of the upper and lower vibrational

levels, corresponding to the Raman-active transitions being excited.

The power density dependences of the line strength ratio for three respective pairs of vibrational lines of a thiolate of 2-nitrobenzoic acid (TNB) in SERS spectra were derived. By using the data, the contributions were specified and quantified which are responsible for the discrepancy between this ratio and that defined by the thermal equilibrium populations of the upper and lower vibrational levels corresponding to the Raman-active transitions. These contributions are the following: (i) the spectral profile of an LSPR contour, (ii) local heating of the reporter molecule/AgP conjugates by the 785-nm radiation, and (iii) optical (Raman) pumping of the upper vibrational levels of the transitions involved.

The formation of AgPs on the por-Si samples was carried out by immersion deposition in 3 mM $AgNO_3$ aqueous-alcohol solution. The Ag-coated por-Si was selected as SERS substrate. Hence, even at the highest excitation intensity, the strongest Raman-resonant TNB peaks can be simultaneously registered in both Stokes and anti-Stokes ranges not in all the spatial points of the mapping area.

In the case of the AgP/por-Si SERS-active surface under study, the reproducibility range corresponded to excitation intensities $I_L \leqslant 105\ \mu W/\mu m^2$. In this range of intensities, all the variations of the SERS spectra were fully reversible, and neither spectral shifts of the strongest Raman lines nor any significant relative changes of their strengths were observed.

Synthesis of Lipodiscs/Lipodiscs with Embedded Proteins and the Study of Their Chemical Structure and Morphology by Raman Spectroscopy. One of the modern methods for isolating membrane proteins is the use of a styrene-maleic acid (SMA) copolymer. This amphipathic copolymer can integrate into biological membranes and easily destroy them. As a result, discoid membrane fragments with a size of 10–40 nm are formed, surrounded by a copolymer belt. Such particles are known as SMALPs (SMA lipid particles) or lipodiscs. The polymer has no affinity to any specific lipids, and, in SMALPs, the ratio of lipids remains the same as it was in the original membrane.

MS confirmed that the lipids were present in the lipodiscs, and Raman spectroscopy detected several specific spectral peaks, which could be attributed to lipids. The Raman spectroscopy study of lipodiscs will be continued.

Study of Conformational Changes in Model Lipid Membranes Embedded with Various Additives by Raman Spectroscopy. It is well known that addition of various molecules to the membrane can change its physical properties and alter its structure, which in turn may affect its functionality. Thus, it is crucial to know the origin of these changes and understand the intermolecular interactions responsible for embedding various additives to the membrane.

A steep increase in the ratio of trans/gauche conformers upon the addition of cholesterol to the DPPC bilayers with no melatonin clearly suggests its rigidifying effect on the membrane. The effect of the cholesterol addition to the DPPC bilayers is modulated clearly by the additional presence of melatonin. This can be seen in the declining steepness of the trans/gauche ratio changes as a function of cholesterol concentration in the case of DPPC bilayers loaded with increasing amount of melatonin. Thus, the vibrational dynamics of lipid hydrocarbon chains is affected proportionally by both additives.

UVA-Induced NETosis: Raman and Immunofluorescent Microscopy Analysis. The research activities in 2021 were devoted to the application of Raman spectroscopy and immunofluorescent microscopy analysis of neutrophils transformed during NETosis and the quantitative determination of the level of their transformation based on the analysis of the neutrophil Raman spectra.

Kinetic analysis with highly sensitive vibrational spectroscopy applied for this study revealed in the low-frequency range of the neutrophil cells Raman spectrum the evolution (growth) of the citrulline peak within 30–40 min after the beginning of the inflammatory process, which can be classified as an early diagnosis of NETosis. Because the peak with the Raman shift of $\sim 170\ cm^{-1}$ is practically absent in inactivated neutrophils and increases significantly after activation, one can assume that it is associated with the accumulation of citrulline in the cell, the spectrum of which also has a characteristic peak around $170\ cm^{-1}$. Normally, citrulline is practically absent in human cells. However, it is known that during NETosis, citrulline could be produced, first of all, by transformation of histones, the most important structural chromosomal proteins inside neutrophil nuclei.

It was revealed that UV-induced activation undoubtedly leads to the formation of NETotic cells in the form of cloud-like spread in the observed immunofluorescence imaging. Nevertheless, in contrast to NETosis activation with the calcium ionophore A23, the citrulline peak in Raman spectra is not observed. Preliminarily, it is an evidence of the NOX-depended signaling pathway of NETosis under the UV radiation applied. This research is in progress, including the study of low-frequency range of Raman spectra of DNA for NETotic cells.

Investigations of Reactions with Fast Neutrons. At the EG-5 accelerator (FLNP JINR), the cross section measurements for $^{14}N(n,\alpha)^{11}B$, $^{35}Cl(n,\alpha)^{32}P$, and $^{91}Zr(n,\alpha)^{88}Sr$ reactions were performed in the neutron energy range of 3–5.5 MeV.

The systematic high-precision cross section measurements for the $^{35}Cl(n,\alpha)^{32}P$ reaction were carried out at neutron energies of 3.3, 3.9, 4.3, 4.8, 5.0, 5.1, and 5.3 MeV. The obtained cross sections in the neutron energy range of 3.9–4.3 MeV are consistent with the estimates of ENDF/B-VIII.0, FENDL-3.1c, JEFF-3.3 and BROND 3.1, and for 4.8–5.3 MeV the experimental results are lower than those indicated in the nuclear data libraries. The total and partial cross sections of the (n,α) reaction are satisfactorily described by TALIS-1.9 calculations with improved parameters of the optical model. The alpha-cluster preformation factor for the $^{35}Cl(n,\alpha)^{32}P$ reaction was determined within the framework of the direct reaction mechanism using a knock-on model.

Interaction of a Wave Packet with Potential Structures Moving with Acceleration. In experiments with ultracold neutrons (UCN), FLNP researchers observed a change in the energy and velocity of a particle after passing through a refracting sample that oscillates in space and moves with a sign-variable acceleration; the results agree quite satisfactorily with the theory. Further development of ideas about this optical phenomenon, called the Accelerating Matter Effect, led to the emergence of a hypothesis about the existence of a very general Acceleration Effect. In relation to the physics of the microcosm, the essence of this effect can be formulated as follows: the result of the interaction of a particle with any object moving with acceleration should be a change in its energy and frequency, determined by the relation $\Delta\omega = ka\tau$, where k is the wave number, a is the acceleration of the object, τ is the time of interaction.

A numerical study of the problem of interaction of a wave packet with potential structures moving with constant acceleration was carried out (Figs. 4, *a, b* and 5, *a–d*). Both the cases of reflection of neutrons passing through a potential barrier and well, allowing a simple analysis based on the classical approach, and the cases of tunneling through accelerating potential structures were investigated. The case of total neutron reflection from a double potential step moving with acceleration was also considered; the group delay time for reflection from such a structure significantly exceeds the reflection time from a conventional potential step.

In all cases, the result of the interaction was a change in the velocity spectrum. The results are fully consistent with the idea of the universality of the acceleration effect, which consists in a change in the frequency of a wave when scattered by an object moving with acceleration, and the magnitude of the shift in the spectrum in the first approximation is determined by the product of the acceleration and the group delay time.

Nanotoxicology. In cooperation with the Vladimirskiy Moscow Regional Research and Clinical Institute, studies were continued to assess the effect of metal nanoparticles on the offspring of mice after their administration to the female mice during pregnancy and lactation. The level of cognitive functions in young animals exposed to gold nanoparticles was compared with that in control ones. The gold content in various organs (blood, liver, lungs, kidneys and brain) of female mice and their offspring was determined by the neutron activation analysis method. According to the obtained data for female mice, the highest gold concentration was determined

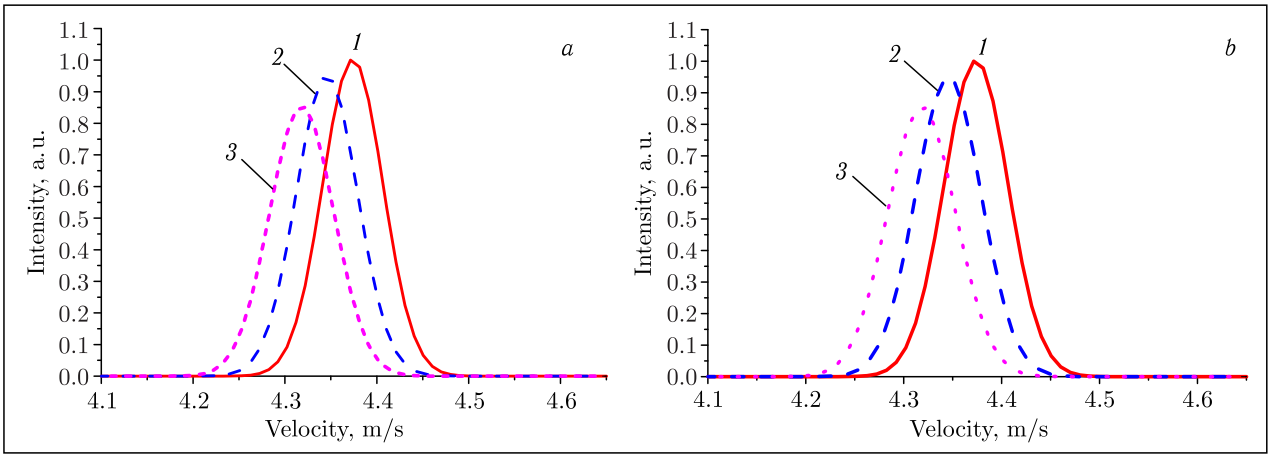


Fig. 4. *a*) Velocity spectra of UCN that passed over an accelerating potential barrier as a function of the barrier height: *1* — initial spectrum; *2* — $U = 50$ neV; *3* — $U = 75$ neV; *b*) velocity spectra of UCN that passed over an accelerating potential well: *1* — initial spectrum; *2* — well depth 50 neV; *3* — well depth 75 neV

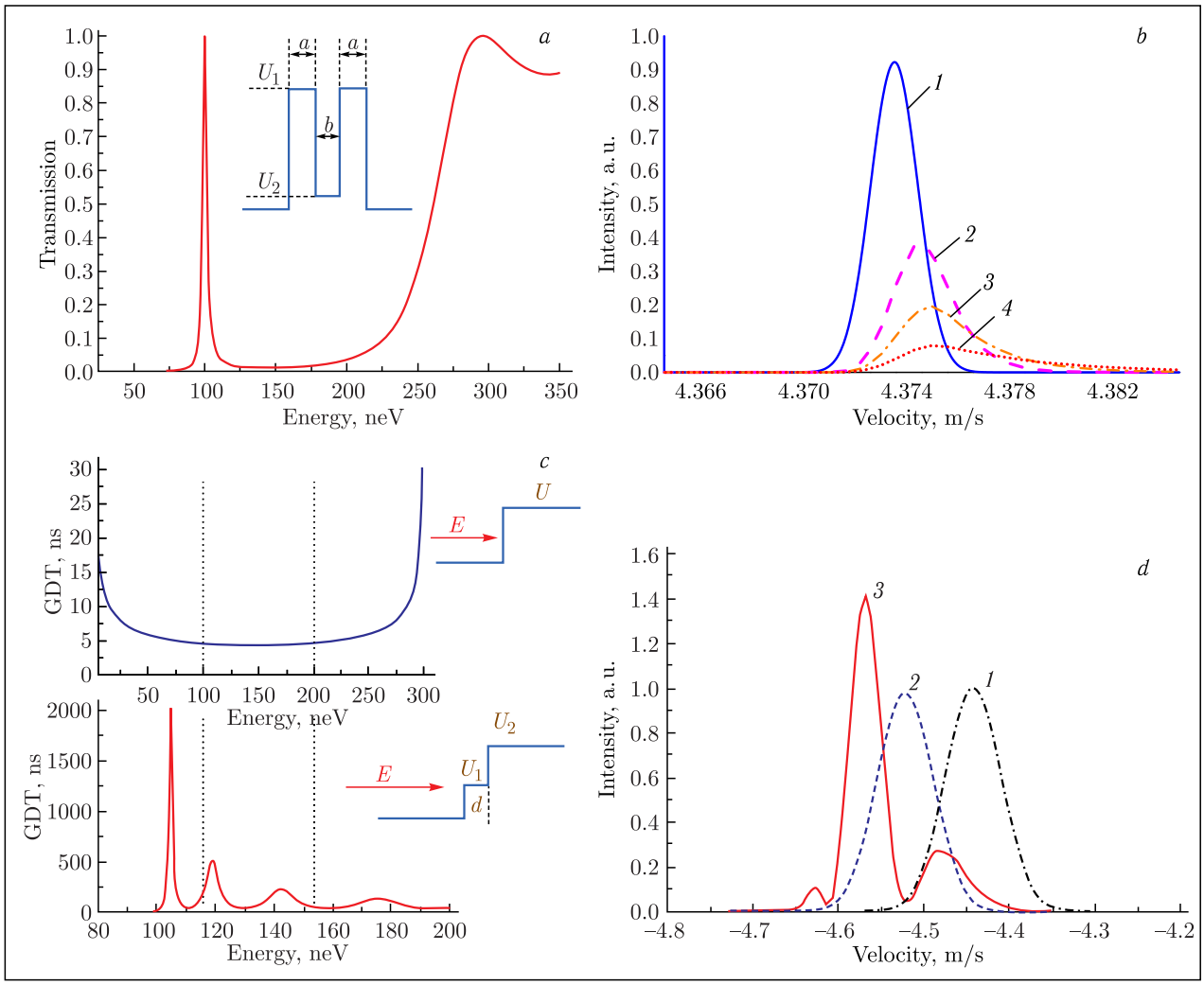


Fig. 5. *a*) The potential structure of the filter and its transmission line; *b*) the velocity spectrum of a neutron that passed through the filter moving with an acceleration directed along the neutron velocity (curve *1* is the spectrum of the initial state; the other curves are the transmitted spectra for different acceleration of the interference filter: *2* — 5000 m/s^2, *3* — 10 000 m/s^2, *4* — 20 000 m/s^2); *c*) group delay time during reflection from a conventional potential barrier and from a double potential step; *d*) velocity spectra after reflection from a moving double potential step (curve *1* is the velocity spectrum upon reflection from a stationary potential step; curve *2* is the velocity spectrum of a wave packet reflected from a double potential step moving towards the packet at a small constant velocity; curve *3* is the evolution of a wave packet after reflection from a double potential step moving with acceleration $a = 5 \cdot 10^4$ m/s^2 directed against the neutron velocity)

in kidneys, followed by liver, lungs, brain and blood. In the offspring, the accumulation of gold in organs changed in the same order. The average mass content of gold in the brain was (0.25 ± 0.10) ng (for female mice) and (0.08 ± 0.03) ng (for offspring). No significant differences in spatial orientation and memory were found between the experimental and control offspring according to the results of the Morris water maze test, but experimental mice showed increased levels of anxiety in the elevated plus maze test. Thus, the studies revealed the effect of gold nanoparticles on the emotional state of mice exposed to nanoparticles during prenatal and early postnatal development, but not on their cognitive abilities. The obtained data are important for assessing the toxic effect of nanomaterials on the human reproductive system.

A new series of studies on the effect of unmodified (AgNPs) and functionalized *Spirulina platensis* biomass silver nanoparticles (AgNPs-Spirulina) on rats was started. The silver content in different organs was determined using neutron activation analysis. In animals administered with the unmodified nanoparticles, the highest silver content was determined in the brain and kidneys, whereas in animals administered with AgNPs-Spirulina, silver was mainly accumulated in the brain and testicles (Fig. 6). After its elimination half-life, silver was rapidly eliminated from the spleen and kidneys; however, its clearance from the brain was very poor and slow, regardless of the type of nanoparticles.

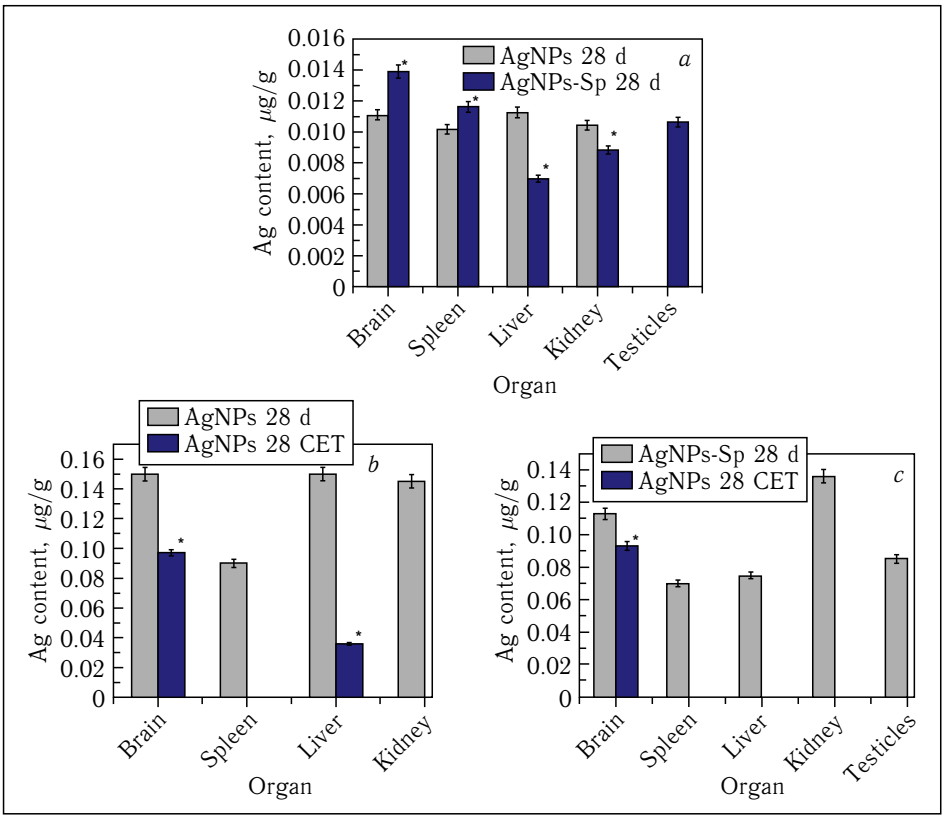


Fig. 6. Silver content in the organs of the rats: *a*) animals administrated with AgNPs and AgNPs-Spirulina for 28 days, measured immediately after the end of the experiment; *b*) animals administrated with AgNPs for 28 days with measurements after the elimination half-life; *c*) animals administrated with AgNPs-Spirulina for 28 days after the elimination half-life [15]

Hematological and biochemical tests were performed to determine the effect of nanoparticles on rats. A significant difference was found in the content of eosinophils in the experimental and control groups. The hematological indices of the rats did not change significantly under the action of the silver nanoparticles except for the content of reticulocytes and eosinophils, which increased significantly. Changes in the biochemical parameters did not exceed the limits of normal values [15].

The effect of copper oxide nanoparticles on bioactive compounds, possible ultrastructural modifications, and the content of elements in wheat was studied. The use of nanoparticles led to a decrease in the content of chlorophylls and carotenoids and an increase in the content of polyphenols and antioxidant capacity. The addition of copper nanoparticles to the soil completely inhibited the accumulation of seventeen elements in wheat, while their application caused the accumulation of K, Br, Al, and Zn and the decrease of Cl, Na, Ba, and Sr in wheat samples, regardless of the type of nanoparticles being applied. The application of chemically obtained nanoparticles completely blocked the accumulation of Fe, Mo, As, Sb and Sm in wheat and contributed to a much greater accumulation of Br than biogenic nanoparticles.

FLNP BASIC FACILITIES

IBR-2 Pulsed Reactor. In 2021, the IBR-2 research nuclear facility was operated in a nominal mode under Rostekhnadzor license valid until 30.09.2022. Statistical data on the IBR-2 operation are presented in the table.

Due to the need to repair the air heat exchanger, cycles 8 and 9 were cancelled.

IREN Facility. In 2021, despite the difficult epidemiological situation and the associated quarantine restrictions, the IREN facility operated for experiments for 1700 h, including 104 h at a frequency of 50 Hz.

New Equipment for the Suite of Spectrometers at the IBR-2 Reactor. In 2021, the regular operation of the CM-201 cryogenic moderator for physics experiments continued. The moderator operated failure free for five IBR-2 reactor operation cycles.

The spectra were obtained at IBR-2 beamlines No. 4, 5, 6, 9. The measurement results showed

Cycle number	Period	Power, MW	Reactor operation for physics experiments, h
1	25.01–06.02	1.65	288
2	15.02–26.02	1.65	264
3	15.03–03.04.	1.55	161
4	12.04–24.04	1.55	285
5	14.05–26.05	1.5	285
6	20.09–02.10	1.3	61
7	11.10–30.10	1.3	109
8	15.11–26.11	Cancelled	
9	06.12–17.12	Cancelled	
		Σ	1453

that the gain in the intensity of cold neutrons compared to a moderator in the thermal mode based on room-temperature water (20°C) reaches up to 12 times, depending on the neutron wavelength.

Work was carried out to install a horizontal-vertical cryostat with a superconducting magnet (developed under the PTH project within the framework of theme 1122 (2015/2020)) at the sample position on the DN-12 diffractometer. The cryostat was successfully tested in its working position. The maximum declared field of 5 T (at a current of 300 A) was obtained. It was found that the operating temperature of the magnet at a rated field of 4 T is 17.5 K, while the minimum temperature of the high-pressure chamber is 4.55 K. This is slightly higher than the helium temperature (4.2 K) and is determined by the residual thermal coupling of the chamber and the magnet. Obtaining a lower temperature can be achieved by additional isolation, which, however, would reduce the solid angle visible to the detector.

NEW NEUTRON SOURCE

In the course of studying the problems of stability and reliability of the operation of the NEPTUNE reactor, a new possible physical cause affecting reactivity was revealed — fuel rod bending. Based on the calculations, a noticeable temperature gradient was observed in the fuel rod column and its steel cladding towards an increase in the neutron flux. The temperature gradient causes the column and the cladding to bend. The performed calculations of the deformation of individual fuel rods with different fixation methods showed that the bending value has a maximum of about 0.1–0.5 mm, which causes reactivity effects at the level of 10^{-4} k_{eff}. It was found that bending can lead to both negative and positive contributions to reactivity, in contrast to axial expansion, where the contribution to reactivity is strictly negative.

Detailed calculations for an individual fuel rod showed that it is possible to account fairly accurately for the effect of bending on the reactivity and dynamics of the reactor, and fix fuel rods in such a way as to exclude such an influence or limit it to safe limits. In addition to static bending, the effect of “dynamic” bending was also taken into account.

Calculations for a system of fuel rods were performed, taking into account their mutual influence on each other as a result of impacts. Calculations of the dynamics of a pulsed reactor in the form of a system of 300 oscillators showed that the spread in the amplitude of power fluctuations directly depends only on the limitation of the movement of individual oscillators. For stable operation of the reactor, this parameter should be minimized and not exceed tenths of a millimeter. Thus, on the basis of this analysis, it was concluded that the preferred option for the core arrangement is a variant with rigid fixation of one of the ends of the fuel rods not assembled in the fuel assembly, and with a limited small transverse displacement of the other.

In addition, a method for reducing power pulse energy fluctuations by adding enriched uranium to nitride nuclear fuel was proposed and substantiated by calculation. Calculations were performed to justify the previously proposed fundamental changes in the design of the titanium hydride reactivity modulator in order to reduce the neutron background between power pulses while maintaining the duration of the neutron pulse.

EVENTS

1. The 28th International Seminar on Interaction of Neutrons with Nuclei (ISINN-28, 24–28 May 2021; http://isinn.jinr.ru/).

2. The international seminar “Neutrons and Synchrotron Radiation in Investigations of Condensed Matter” (12–13 October 2021; https://indico.jinr.ru/event/2439/).

3. The 2nd international workshop “Application of Nuclear-Physical Methods for Research of Cultural Heritage Objects” (16–20 October 2021;

https://kpfu.ru/imoiv/struktura/otdeleniya/vysshaya-shkola-istoricheskih-nauk-i-vsemirnogo/39primenenie-yaderno-fizicheskih-metodov-dlya).

4. The Conference of Young Scientists and Specialists of FLNP (30 November – 2 December 2021; https://indico.jinr.ru/event/2672/).

REFERENCES

1. *Kozlenko D. P., Lis O. N., Kichanov S. E., Lukin E. V., Belozerova N. M., Savenko B. N.* Spin Induced Negative Thermal Expansion and Spin–Phonon Coupling in van der Waals Material $CrBr_3$ // Quantum Mater. 2021. V. 6. P. 19.
2. *Balagurov A. M., Bobrikov I. A., Sumnikov S. V., Golovin I. S.* Coherent Cluster Ordering in Fe–xAl and Fe–xGa Alloys // J. Alloys Compounds. 2021. V. 895. P. 162540.
3. *Turchenko V. A., Trukhanov S. V., Kostishin V. G., Damay F., Porcher F., Klygach D. S., Vakhitov M. G., Lyakhov D., Michels D., Bozzo B., Fina I., Almessiere M. A.* Features of Structure, Magnetic State and Electrodynamic Performance of $SrFe_{12-x}In_xO_{19}$ // Sci. Rep. 2021. V. 11, No. 1. P. 18342(1–14).
4. *Safarik I., Prochazkova J., Schroer M. A., Garamus V. M., Kopcansky P., Timko M., Rajnak M., Karpets M., Ivankov O. I., Avdeev M. V., Petrenko V. I., Bulavin L., Pospiskova K.* Cotton Textile/Iron Oxide Nanozyme Composites with Peroxidase-Like Activity: Preparation, Characterization, and Application // ACS Appl. Mater. Interfaces. 2021. V. 13. P. 23627–23637.
5. *Ivankov O. I., Murugova T. N., Ermakova E. V., Kondela T., Badreeva D., Hrubovčák P., Soloviov D. V., Tsarenko A., Rogachev A. V., Kuklin A. I., Kučerka N.* Amyloid-Beta Peptide (25–35) Triggers a Reorganization of Lipid Membranes Driven by Temperature Changes // Sci. Rep. 2021. V. 11. P. 21990.
6. *Ryzhykau Yu. L., Orekhov P. S., Rulev M. I. et al.* Molecular Model of a Sensor of Two-Component Signaling System // Sci. Rep. 2021. V. 11. P. 10774.
7. *Ryzhykau Yu. L., Vlasov A. V., Orekhov P. S., Rulev M. I., Rogachev A. V., Vlasova A. D., Kazantsev A. S., Verteletskiy D. P., Skoi V. V., Brennich M. E., Pernot P., Murugova T. N., Gordeliy V. I., Kuklin A. I.* Ambiguities in and Completeness of SAS Data Analysis of Membrane Proteins: The Case of the Sensory Rhodopsin II – Transducer Complex // Acta Cryst. D. 2021. V. 77. P. 1386–1400.
8. *Hrubovčák P., Dushanov E., Kondela T., Tomchuk O., Kholmurodov K., Kučerka N.* Reflectometry and Molecular Dynamics Study of the Impact of Cholesterol and Melatonin on Model Lipid Membranes // Eur. Biophys. J. 2021. V. 50. P. 1025–1035.
9. *Barbinta-Patrascu M.-E., Gorshkova Yu., Ungureanu C., Badea N., Bokuchava G., Lazea-Stoyanova A., Bacalum M., Zhigunov A., Petrovič S.* Characterization and Antitumoral Activity of Biohybrids Based on Turmeric and Silver/Silver Chloride Nanoparticles // Materials. 2021. V. 14. P. 4726.
10. *Gorshkova Yu., Barbinta-Patrascu M.-E., Bokuchava G., Badea N., Ungureanu C., Lazea-Stoyanova A., Răileanu M., Bacalum M., Turchenko V., Zhigunov A. et al.* Biological Performances of Plasmonic Biohybrids Based on Phyto-Silver/Silver Chloride Nanoparticles // Nanomaterials. 2021. V. 11. P. 1811.
11. *Ospennikov A. S., Gavrilov A. A., Artykulnyi O. P., Kuklin A. I., Novikov V. V., Shibaev A. V., Philippova O. E.* Transformations of Wormlike Surfactant Micelles Induced by a Water-Soluble Monomer // J. Col. Interface Sci. 2021. V. 602. P. 590–601.
12. *Millán L., Bokuchava G., Fernández R., Papushkin I., González-Doncel G.* Further Insights on the Stress Equilibrium Method to Investigate Macroscopic Residual Stress Fields: Case of Aluminum Alloys Cylinders // J. Alloys Compounds. 2021. V. 861. P. 158506.
13. *Nekhoroshkov P., Zinicovscaia I., Nikolayev D., Lychagina T., Pakhnevich A., Yushin N., Bezuidenhout J.* Effect of the Elemental Content of Shells of the Bivalve Mollusks (*Mytilus galloprovincialis*) from Saldanha Bay (South Africa) on Their Crystallographic Texture // Biology. 2021. V. 10, No. 11. P. 1093.
14. *Bakirov B., Saprykina I., Kichanov S., Mimokhod R., Sudarev N., Kozlenko D.* Phase Composition and Its Spatial Distribution in Antique Copper Coins: Neutron Tomography and Diffraction Studies // J. Imaging. 2021. V. 7. P. 129.
15. *Zinicovscaia I., Hramco C., Chaligava O., Yushin N., Grozdov D., Vergel K., Duca Gh.* Accumulation of Potentially Toxic Elements in Mosses Collected in the Republic of Moldova // Plants. 2021. V. 10. P. 471; https://doi.org/10.3390/plants10030471).

MESHCHERYAKOV LABORATORY OF INFORMATION TECHNOLOGIES

An important component of the Laboratory's activity in 2021 was to ensure the reliable functioning and growth of the JINR network, information and computing infrastructure, as well as to develop mathematical support and software for the research and production activities of the Institute and its Member States on the basis of the JINR Multifunctional Information and Computing Complex (MICC). The research was carried out within two topics: "Information and Computing Infrastructure of JINR" and "Methods, Algorithms and Software for Modeling Physical Systems, Mathematical Processing and Analysis of Experimental Data".

In 2021, the staff of the Meshcheryakov Laboratory of Information Technologies (MLIT) published over 200 scientific papers and presented more than 150 reports at international and Russian conferences.

INFORMATION AND COMPUTING INFRASTRUCTURE OF JINR

The major information and computing resources of JINR are concentrated in the MICC [1], which can be considered as JINR's unique basic facility that plays a key role in studies asking for modern computing power and data storage systems. The uniqueness of the MICC is ensured by a combination of all state-of-the-art information technologies, namely, a network infrastructure with a bandwidth of 4×100 Gbit/s, distributed computing and data storage systems based on grid technologies and cloud computing, a hyperconvergent high-performance computing infrastructure with liquid cooling for supercomputer applications. The MICC is characterized by multifunctionality, high reliability and availability for calculations in 24/7 mode, scalability and high performance, a reliable data storage system, information security and an advanced software environment. The JINR computing infrastructure comprises an IT ecosystem for the experiments of the NICA megaproject (BM@N, MPD, SPD), which, thanks to grid technologies (DIRAC Interware), brings together the dedicated computing resources of all the MICC components: the Tier-1 grid site for the CMS experiment at the LHC; the Tier-2 grid site, which provides data processing for the experiments at the LHC, NICA, FAIR and other large-scale experiments, as well as support for users from the JINR Laboratories and Member States; the integrated cloud environment of the Member States devoted to support of users and experiments (NICA, ALICE, BESIII, NOvA, Baikal-GVD, JUNO, etc.); the HybriLIT platform, which includes the basic resource for high-performance computing, the "Govorun" supercomputer, and the training and testing polygon.

JINR Network Infrastructure. The network infrastructure is a fundamental component of the IT infrastructure of JINR and of the MICC. It provides access to the Internet, the computing resources and the data storage systems, as well as enables experimental data processing and computing. It is necessary to ensure the reliable and fault-tolerant operation of all the components of the network infrastructure: the external telecommunication channels, the JINR backbone network with a multi-node cluster structure and the MICC local area network.

In 2021, the reliable functioning of the following JINR telecommunication channels was ensured: the Moscow–JINR backup channel with a bandwidth of 3×100 Gbit/s, the 100 Gbit/s JINR–CERN direct channel together with its 100 Gbit/s backup channel, which passes through Moscow and Amsterdam and ensures the operation of the LHCOPN network for the connection between Tier-0 (CERN) and Tier-1 (JINR) and of the LHCONE external

overlay network allocated to the JINR Tier-2 centre for communication with the RUHEP collaboration and the networks of the National Research Computer Network of Russia and RetN using RU-VRF technology. IPv6 routing was implemented for the Tier-1 and Tier-2 sites. In 2021, the Nortel DWDM equipment on the RSCC fiber-optic links route (Dubna, Radishchevo, Moscow) was replaced with the Infinera new equipment, which made it possible to broaden the bandwidth of all Dubna–Moscow channels.

The distribution of the incoming and outgoing traffics by the JINR subdivisions in 2021 (exceeding 25 TB by the incoming traffic) is shown in Table 1.

Table 1

Subdivision	Incoming traffic, TB	Outgoing traffic, TB
DLNP	941.9	158.27
MLIT	325.56	449.63
VBLHEP	280.18	160.98
Hotel and Restaurant Complex	171.74	33.52
Dubna State University	129.73	41.08
FLNR	108.59	48.07
FLNP	106.46	69.34
Remote Access Node	77.75	10.44
JINR Directorate	76.42	76.51
University Centre	29.83	6.35
BLTP	26.22	21.64

The overall incoming traffic of JINR, including the general-purpose servers, Tier-1, Tier-2, the computing complex, the "Govorun" supercomputer and cloud computing, amounted to 33.23 PB in 2021 (29.91 PB in 2020), while the overall outgoing traffic reached 35.86 PB (36.94 PB in 2020). The traffic with the scientific and educational networks, accounting for 97% of the total, is overwhelming.

The local area network (LAN) is based on the JINR backbone network with a bandwidth of 2×100 Gbit/s and the distributed multi-node cluster network between the DLNP and VBLHEP sites (4×100 Gbit/s). In 2021, the hardware and software of the Cisco C9500 routers of the JINR Laboratories (with 100 Gbit/s interfaces) were upgraded up to the latest version recommended by the vendor.

The MICC internal network has a Tier-1 segment built at the Brocade factory with a bandwidth of 80 Gbit/s. The network segments of the EOS data storage system, Tier-2, cloud computing and the "Govorun" supercomputer are built on Dell and Cisco hardware. The 10 Gbit/s and 100 Gbit/s ports are used to connect server components to the switches of the MICC network core built on Cisco Nexus 9504 and Nexus 9336C switches with an $N \times 100$ Gbit/s port bandwidth.

The internal network of the "Govorun" supercomputer consists of three main parts, namely, a communication and transport network, a control and monitoring network, and a task management network. The communication and transport network uses Intel OmniPath 100 Gbit/s technology. The network is built on a "thick tree" topology based on 48-port Intel OmniPath Edge 100 Series switches with full liquid cooling. The control and monitoring network enables the unification of all compute nodes and the control node into a single Fast Ethernet network. This network is built using Fast Ethernet HP 2530-48 switches. The task management network connects all compute nodes and the control node into a single Gigabit Ethernet network. The network is built using HPE Aruba 2530 48G switches.

In 2021, the central network virtual cluster of the JINR network service (NOC), which is built on top of the Proxmox VE (Virtual Environment) open source software under the GNU license, was modernized. This approach made it possible to use the NOC central cluster in 24/7 mode. It is noteworthy that the virtual machines operating in the central cluster serve all essential elements of the JINR network.

New software (Proxmox Mail Gateway) was introduced on the @jinr.ru email cluster; it significantly reduced the number of spams by training the system in spam filtering mechanisms.

Continuous availability monitoring and logging of logins to network sessions were added to the SSO system. The ability to edit LDAP entries for working in external services and the ability to register non-JINR staff members were added. The coverage of the eduroam WiFi network on the JINR territory was extended.

The JINR LAN comprises 8768 network elements and 17 602 IP addresses, 6377 network users, 6377 users of mail.jinr.ru, 1419 users of electronic libraries and 504 users of the remote access service.

MICC Engineering Infrastructure. In 2021, the work on the replacement and enhancement of the MICC engineering infrastructure, designed to ensure the reliable, uninterrupted and fault-tolerant operation of the information and computing systems and the data storage resources, was in progress.

The MICC computing facilities are hosted in one computing hall of 800 m^2 of floor space at the 2nd floor of the MLIT building. It currently consists of eight separate IT equipment modules (Fig. 1) with 2 MW power:

- Module 1 and Module 2: 22.55 m^2 of floor space each, 33 server racks and 20 kW per rack;
- Module Tier-1: 29.33 m^2 of floor space, 16 server racks and 35 kW per rack;
- Tape library space: 13 m^2 of floor space, two robotic tape libraries IBM TS3500 and IBM TS4500 with a total capacity of 50.6 PB;
- "Govorun" supercomputer: 1.97 m^2 of floor space, 4 racks and 100 kW per rack;

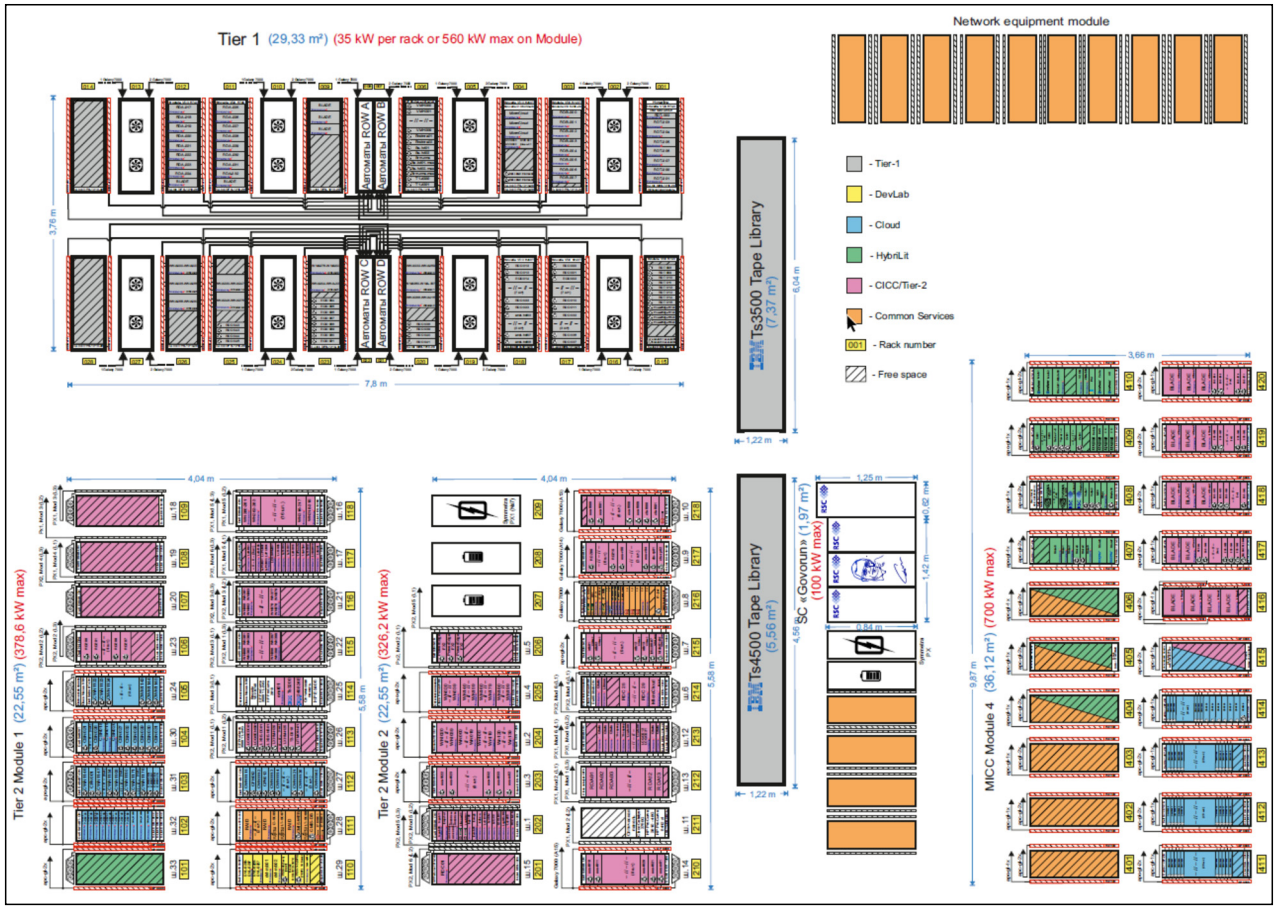


Fig. 1. Location of equipment in the MICC server hall

• Module that hosts critical services of the standard business computing type (administrative systems and databases, etc.);

• Module 4: 36.12 m^2 of floor space, 20 server racks and 35 kW per rack;

• Network equipment module that hosts the main network services for the MICC, JINR local and wide area networks.

All racks are UPS backed up with an autonomy of 10–15 min. Racks are equipped with intelligent (switched and metered) power distribution units, which enable the fine-grained monitoring of power consumption. In addition, there are two diesel generator backups for critical services.

Module Tier-1 and Module 4 are air-cooled with in-row racks arranged between server racks. Modules 1 and 2 are air-cooled, and the cold air is blown through large ducts underneath the false floor, where it diffuses into cold aisles through perforated floor tiles. The "Govorun" supercomputer is fully "hot" water-cooled, which allows for a power density of 100 kW per rack and PUE = 1.06.

All engineering equipment that provides both the guaranteed energy supply to the MICC and the cooling system is located at the first and basement floors of the building. Only chillers, dry coolers and diesel generators are located on the territory adjacent to the MLIT building.

The DCIM (Data Centre Infrastructure Management) system was put into operation for controlling and accounting the equipment of the MICC hall.

JINR Grid Environment (Tier-1 and Tier-2 Sites). The JINR grid infrastructure is represented by the Tier-1 centre for the CMS experiment at the LHC and the Tier-2 centre for processing data from the ALICE, ATLAS, CMS, LHCb, BES, BIOMED, MPD, NOvA, STAR, ILC experiments and others. Both JINR grid sites ensure on average 100% availability and reliability of services.

Since 2021, the Tier-1 resource centre has also been used to perform simulations for the MPD experiment of the NICA project. At present, there are 16 096 cores with a total performance of 253 135.18 HEP-SPEC06. The software and compilers used are CentOS Scientific Linux release 7.9, gcc (GCC) 4.4.7, C++ (g++ (GCC) 4.4.7), GNU Fortran (GCC) 4.4.7, dCache-5.2 for data storage, Enstore 6.3 for tape libraries and FTS. FairSoft, FairRoot and MPDRoot were installed to support the experiments of the NICA megaproject. The total usable capacity of disk servers is 14 PB, and that of tape libraries is 50.6 PB. The long-term data storage system based on the IBM TS4500 library is focused on servicing the NICA and CMS experiments.

In 2021, all resources of the JINR grid sites were migrated from CREAM-CE and Torgue-Maui to the Advanced Resource Connector Compute Element

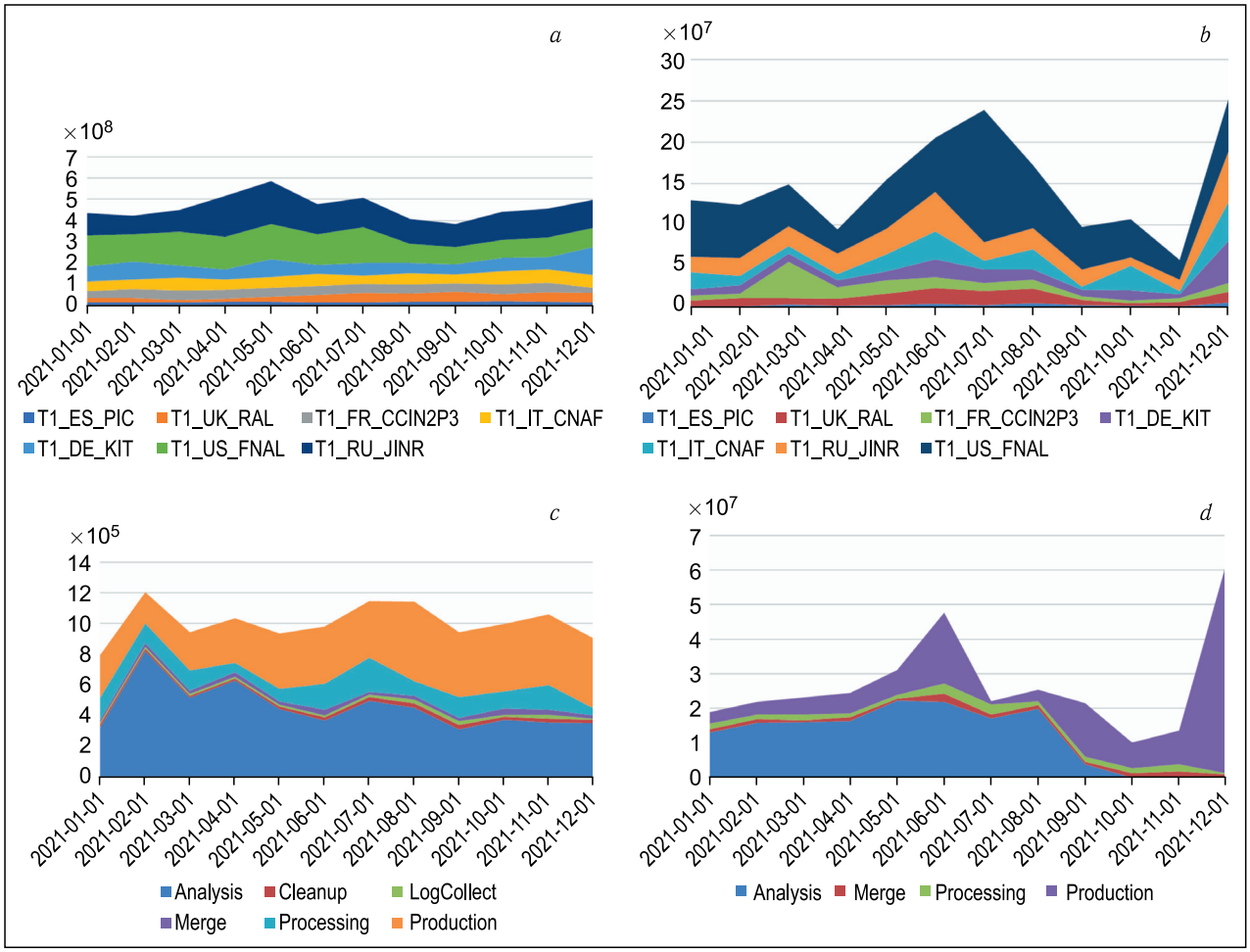


Fig. 2. Contribution of the world Tier-1 centres to CMS experimental data processing in 2021: *a*) distribution by the normalized CPU time in HEP-SPEC06 hours; *b*) number of processed events. Statistics on the use of the JINR Tier-1 centre by the CMS experiment by different types of data stream processing in 2021: *c*) distribution of jobs; *d*) distribution of events by the type of processing

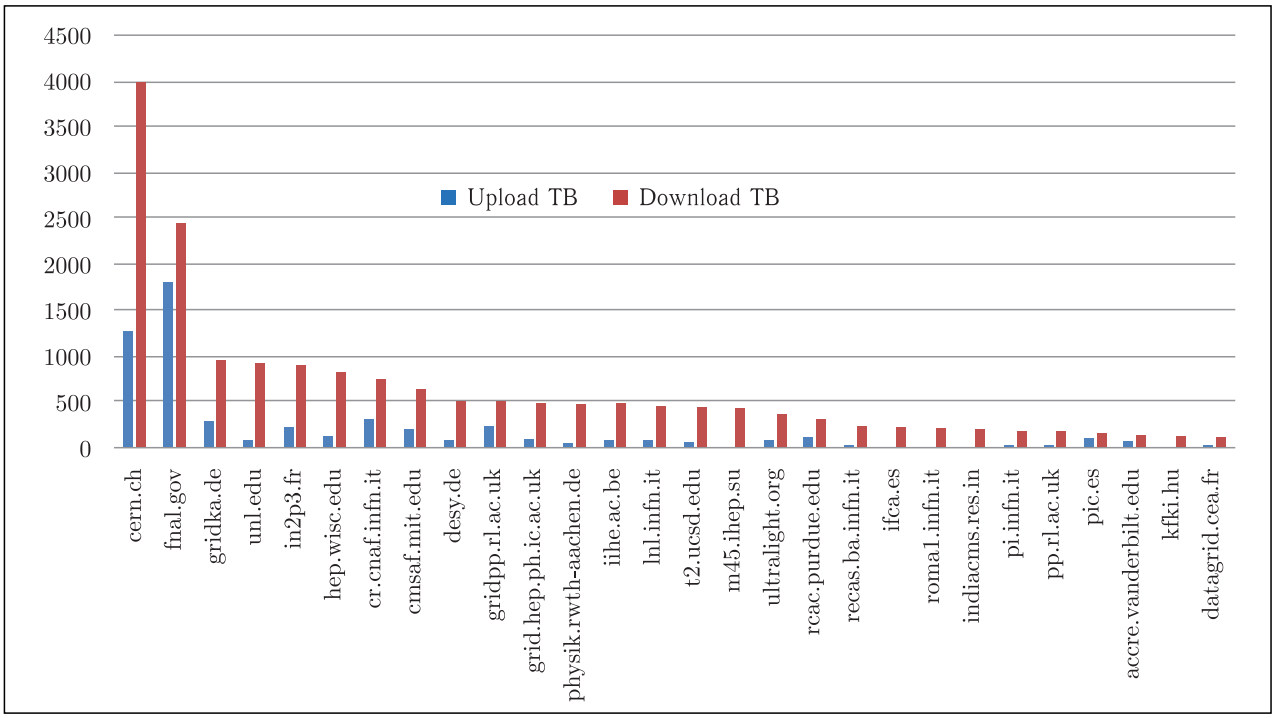


Fig. 3. Statistics on JINR Tier-1 data exchange with the world data processing centres of the WLCG infrastructure via the dCache-based data storage system

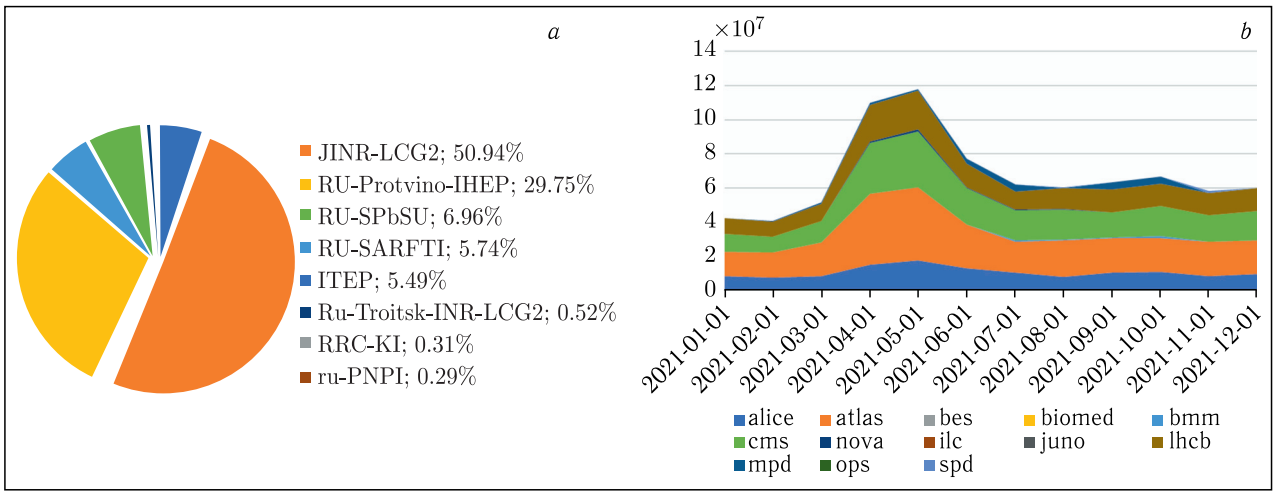


Fig. 4. Statistics of the JINR Tier-2 operation: *a*) distribution of the number of jobs by the web sites of the organizations being part of the Russian Consortium RDIG; *b*) use of the JINR Tier-2 site by virtual organizations of the global grid infrastructure (by the normalized CPU time in HEP-SPEC06 hours)

(ARC-CE) and the SLURM resource manager (adapted to kerberos and AFS), which is also used on the "Govorun" supercomputer.

In terms of performance, Tier-1 (T1_RU_JINR) is ranked first among the Tier-1 world centres for the CMS experiment (Fig. 2, *a*). In 2021, more than 321 million events were processed, which accounts for 18% of the total number of processed events (Fig. 2, *b*) and 29% of the total CPU load of all Tier-1 centres for the CMS experiment.

Figure 2, *c*, *d* shows the number of jobs and events processed at the JINR CMS Tier-1 centre in 2021 by different types of data stream processing (reconstruction, modeling, reprocessing, analysis, etc.).

The main functions of Tier-1 are to provide data exchange with all world sites operating for the CMS experiment and storage of raw experimental and simulated data. In 2021, the overall volume of data exchange between the 210 sites of the WLCG global network for processing data of the experiments at the LHC with the dCache-based storage system at JINR amounted to more than 30.5 PB, of which 24 PB of data were read and 6.5 PB of new files were written. Figure 3 illustrates the statistics of data exchange of JINR Tier-1 with other grid centres with a volume of over 100 TB for the outgoing traffic.

The JINR Tier-2 output is the highest in the Russian Consortium RDIG (Russian Data Intensive Grid). Over 83% of the total CPU time in the RDIG used for computing is provided by JINR Tier-2. In 2021, the computing resources of the Tier-2 centre were expanded to 9272 cores, which currently provides a performance of 149 938.7 HEP-SPEC06. The total usable capacity of disk servers is 4763 TB for ATLAS, CMS and ALICE and 140 TB for other virtual organizations.

Figure 4, *a* presents the distribution of jobs performed on the RDIG grid sites. The data on utilizing the JINR Tier-2 site (JINR–LCG2) by virtual organizations within grid projects in 2021 are shown in Figure 4, *b*.

The MICC allows users to perform calculations outside the grid environment. This is necessary for some experiments and local users of the JINR Laboratories. JINR and grid users have access to all the computing power via a single batch processing system.

In 2021, the EOS-based data storage system was extended to 16.7 PB. Figure 5 demonstrates the statistics on the use of the EOS system.

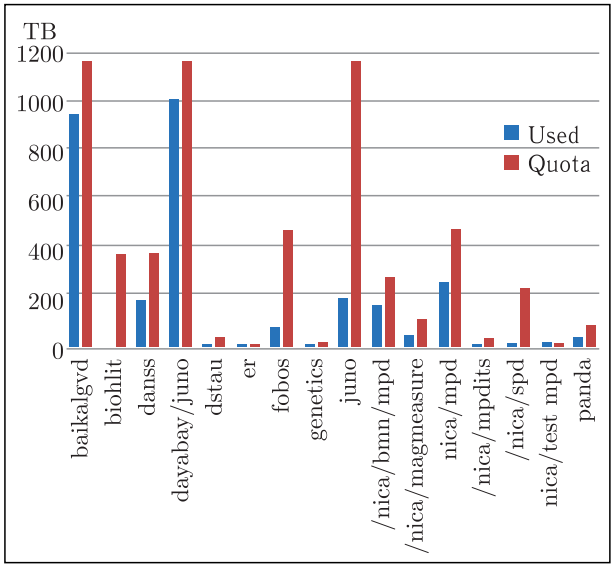


Fig. 5. Use of storage resources in the EOS system by user groups and JINR's experiments

To ensure the guaranteed and stable operation of the infrastructure under constant load conditions, centralized and timely software maintenance and the rapid introduction of new compute nodes are required. As a solution to this problem, the Lifecycle Management Service (LMS) was created; its purpose is to automate the process related to software maintenance and the commissioning of new computing resources [2].

Cloud Environment. 2021 was mainly devoted to the optimization of JINR cloud computing. Besides the general-purpose ceph-based storage with a total raw capacity of 1.1 PB, two new storage elements were deployed: the first is devoted to NOvA experiment needs only, and the second is an SSD-based ceph storage for a set of production services and users with high demands in terms of disk I/O. The main parameters of all these cloud storage systems are listed in Table 2.

A fairly wide set of software was used for JINR cloud servers and for the monitoring of some of its services (Nagios, InfluxDB time series database (TSDB), Prometheus TSDB, etc.). node_exporters were deployed on all cloud servers to provide Prometheus with servers state data. Alerting is implemented at the Prometheus level. Grafana is used for data visualization.

JINR cloud management is done along the "Infrastructure-as-a-Code" (IaC) approach, where host

Table 2. Characteristics of the cloud storage elements

Storage element	Disk type	Consumers	Ceph version	Raw capacity, PB	Replication	Connectivity
Regular cloud storage	HDD	All	14.2.21	1.1	3 ×	2 × 10 GBase-T
NOvA storage	HDD	NOvA	15.2.11	1.5	3 ×	2 × 10 GBase-T
Fast cloud storage	SSD	High disk I/O demands	15.2.13	0.419	3 ×	4 × 10 GBase-T + 2 × 100 Gbps –

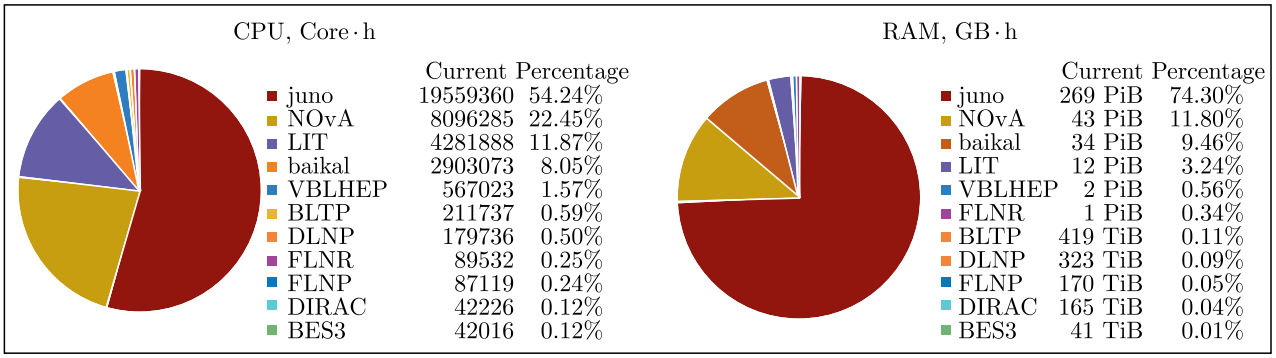


Fig. 6. Use of cloud computing by JINR's experiments and subdivisions

provisioning and management are performed via configuration files. The Foreman and Puppet software are used for this purpose.

Figure 6 provides information on the use of the cloud infrastructure resources in 2021.

The JINR cloud is part of the distributed information and computing environment (DICE) based on the resources of JINR and its Member States' organizations [3, 4]. The amount of JINR cloud resources contributed to the DICE varies depending on its load.

In 2021, the cloud of the Egyptian National STI Network of the Academy of Scientific Research and Technology was put into operation and integrated into the DICE. At present, the Plekhanov Russian University of Economics (Russia), the North Ossetian State University (Russia), the Astana branch of the Institute of Nuclear Physics (Kazakhstan), the Institute of Physics of the National Academy of Sciences of Azerbaijan, the Egyptian National STI Network of the Academy of Scientific Research and Technology, the Institute for Nuclear Research and Nuclear Energy (Bulgaria), Sofia University "St. Kliment Ohridski", the Scientific Research Institute for Nuclear Problems of the Belarusian State University are fully integrated into the DICE, and the Institute of Nuclear Physics (Uzbekistan) and the Georgian Technical University are in the progress of integration.

The total number of jobs performed by the most active JINR DICE clouds is shown in Fig. 7.

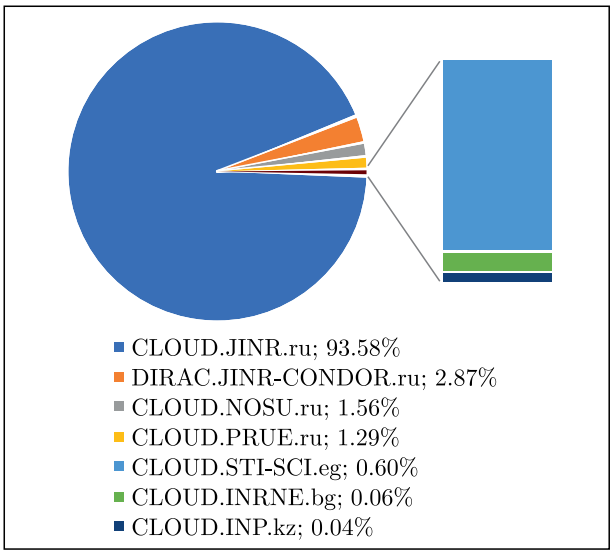


Fig. 7. Distribution of jobs completed in the JINR DICE in 2021

Similar to the previous year, idle resources of the JINR DICE were involved in research on the SARS-CoV-2 virus within the Folding@Home platform. Figure 8 illustrates the contribution of each of the DICE resource centres to this undertaking.

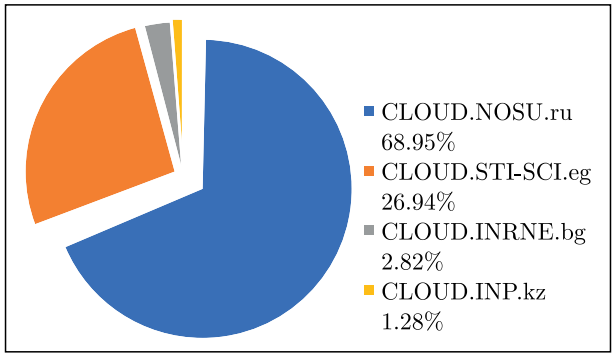


Fig. 8. Distribution of contributions of the DICE participants to the study of the SARS-CoV-2 virus via the Folding@Home platform

Heterogeneous Infrastructure. The JINR MICC heterogeneous infrastructure is represented by the HybriLIT platform, which involves the education and testing polygon and the "Govorun" supercomputer, driven by a common software and information environment. In 2021, an Information and Computing System (ICS) was developed on the platform at a very rapid rate to solve tasks related to the calculations of electron shells of superheavy elements. The ICS encompasses the computing resources of the "Govorun" supercomputer and a set of IT solutions and software required for modeling electron shells. The created system enables the solution of tasks of different types, with distinct requirements for both the amount of computing resources and the amount of data and the requested speed of access to them. The ICS itself is based on the on-demand computing system created on the "Govorun" supercomputer, which contains 288 physical cores (576 logical cores) and a 7 TB file storage managed by the NFS file system. Intensive computing using the AMS and DIRAC software was carried out on this system to calculate the electronic properties of superheavy elements.

Another important direction associated with the ICS enhancement is the development of quantum algorithms implemented on quantum computing simulators. For this purpose, a number of quantum simulators, capable of working on different computing architectures, were implemented in the ICS.

To work with Big Data, including for the NICA megaproject, a hierarchical data processing and storage system with a software-defined architecture was developed and implemented on the "Govorun" supercomputer [5]. According to the speed of accessing data, the system is divided into layers that are available for the user's choice. The fastest layer of the hierarchical system is based on the latest DAOS (Distributed Asynchronous Object Storage) technology. DAOS was deployed on eight nodes of the "Govorun" supercomputer and demonstrated a high read/write speed, ranking 16th in the "10 node challenge" nomination in the current edition of the IO500 list (https://io500.org/list/isc21/ten). Great prospects for the use of this technology are associated with its application to the NICA project at all stages of its work, from experimental data acquisition to final physics analysis (Fig. 9).

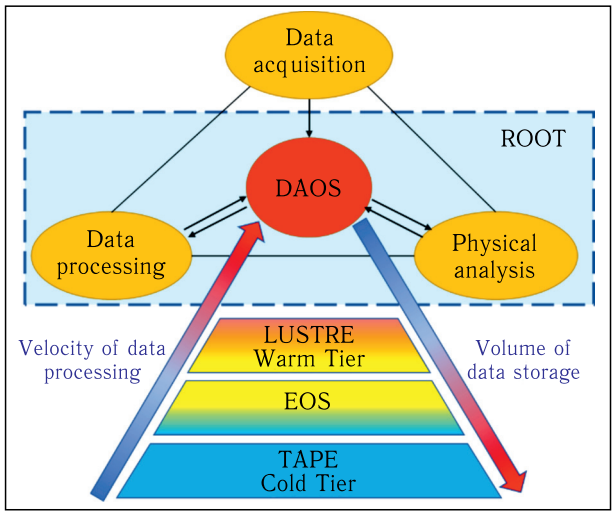


Fig. 9. Planned use of DAOS technology for the NICA project

The use of DAOS for the NICA project will enable the storage and read of multidimensional data structures of TB size in a single address space. Moreover, the DAOS technology looks promising in applications to other types of tasks related to Big Data. These are primarily ML/DL tasks and quantum computing [6, 7].

In 2021, latest versions of more than 20 software packages, in particular, Quantum Espresso (BLTP); JAM, current versions of FairSoft and FairRoot with add-ons for BmnRoot and MPDRoot (NICA); AMS, FLUKA, FLAIR (FLNR); ORCA (DLNP); MAGMA, ViennaCL, Tesseract (MLIT), etc., were implemented in the HybriLIT environment and supported at the request of user groups.

The total number of registered users of the "Govorun" supercomputer is currently 517, of which 322 are JINR staff members and 195 are from the Member States.

In 2021, the overall usage of the resources of the "Govorun" supercomputer amounted to 551 016 jobs, which corresponds to 40 million core hours, and to 56 763 jobs on the GPU component, which corresponds to 18 158 GPU hours. The average load of the CPU component was 96.1%, while the GPU load was 92.3%.

In 2021, HybriLIT platform users published 38 papers, 11 of them in Q1 and 4 in Q2, including an article published by the BM@N collaboration in *Nature Physics* (*BM@N Collab.* Unperturbed Inverse Kinematics Nucleon Knockout Measurements

with a 48 GeV/c Carbon Beam // Nature Phys. 2021. V. 17. P. 693–699).

Integration of Computing Resources. A significant feature of the created infrastructure is the integration of the distributed computing resources. For three years now, the integration of the heterogeneous distributed computing resources on the basis of the DIRAC Interware platform has been functioning at JINR. The DIRAC Interware is a product for combining heterogeneous computing and storage resources into a single platform; it is based on the use of standard data access protocols (xRootD, GridFTP, etc.) and pilot jobs. By the end of 2021, all the MICC components, the clouds of the JINR Member States, the NICA cluster, as well as the cluster of the National Autonomous University of Mexico (NAUM, within the cooperation on the MPD project), were integrated into DIRAC. During the reporting year, new clouds of the Member States were added. Figure 10 displays the contribution of all the organizations integrated on the DIRAC platform to data processing.

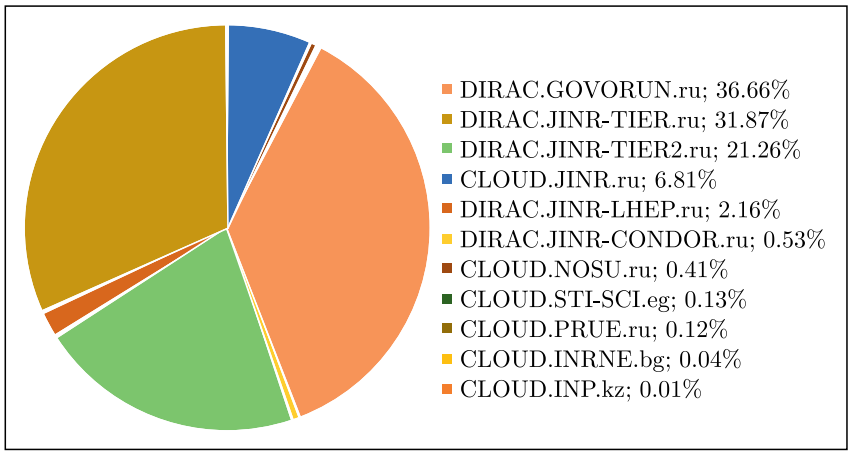


Fig. 10. Contribution of all the organizations integrated on the DIRAC platform to data processing

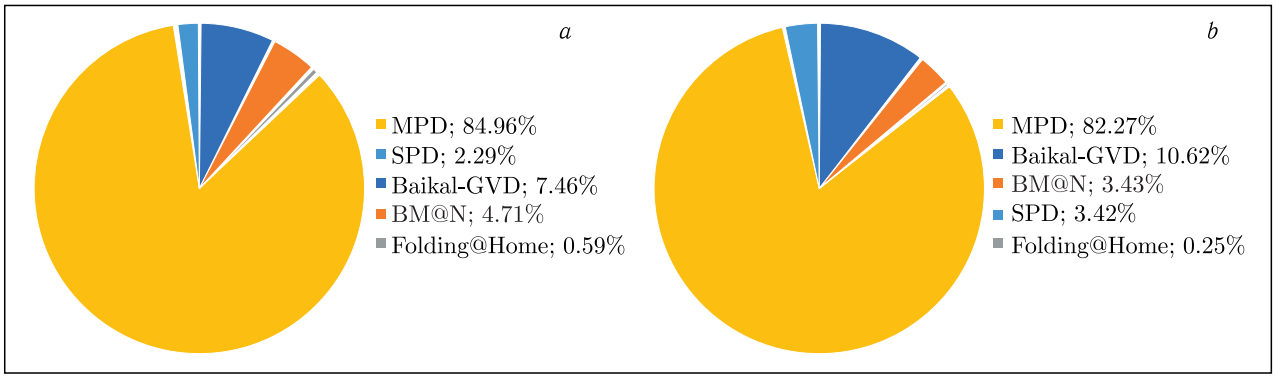


Fig. 11. Use of resources integrated into DIRAC by main users: *a*) consumed computing resources in HEP-SPEC06 hours; *b*) by the number of jobs

A total of 614 000 jobs (+30% compared to 2020) was completed during the year under review. The average time of job completion amounted to 7.6 h. The overall amount of consumed computing resources was 86 million HEP-SPEC06 hours (+65% compared to 2020). The first physics jobs of the BM@N and SPD experiments were launched. For the time being, the distributed infrastructure is used by the following experiments: MPD, Baikal-GVD, BM@N, and SPD (Fig. 11).

Thanks to the integration via DIRAC, it became possible to use the largest amount of computing resources for centralized data generation by the Monte Carlo method for the MPD experiment. The "Govorun" supercomputer, the Tier-1/Tier-2 clusters and the NICA cluster participated in computing. Over 505 000 jobs were successfully completed. All data are registered in the DIRAC file directory and stored in the EOS system.

To simplify the access of MPD collaboration members to the computing resources, a special application was developed; it enables the description of the data generation job in physical terms, i.e., collision energy, type of the generator used, target and beam material [8]. The developed application was integrated into the web interface of the DIRAC platform at JINR and can be accessed by all MPD users.

Monitoring System. The developed integrated monitoring system of the MICC allows receiving

information from different components of the computing complex: the engineering infrastructure, the network, the compute nodes, the job launch systems, the data storage elements, the grid services, which guarantees a high level of MICC reliability. In 2021, a new accounting system [9] was introduced to the Litmon monitoring system; it allows the collection of statistical data on the use of resources by user jobs (for any time interval), namely, the astronomical job execution time and CPU time in HEP-SPEC06 hours, the number of jobs and efficiency of using the computing cluster. The system enables accounting for resources and their use within the distributed data processing system.

Information Services. In 2021, the Electronic Document System (EDS) "Advance Reports" was developed and put into operation; it is designed for electronic recording in the JINR Accounting Department to receive prepayment and report on business trips and household expenses. The system enables preliminary loading of the required data to accelerate the work of the Accounting Department and generates a number of financial reports.

A number of works on the development and current maintenance of the "Dubna" EDS were completed. In particular, new documents "Instruction" and "Request" with the possibility of automatic control of deadlines, the document "Strabag (KS-2, KS-3, invoice)", "SEDNPSS archive" for storing the technical documentation of the Scientific and Engineering Department of Nuclotron Power Supply Systems of VBLHEP were introduced. A number of works on the adaptation of the "Dubna" EDS to accommodate the changes in the organization of the procurement procedures at JINR were carried out.

The ongoing maintenance and on-demand development of the APT EVM information systems for NICA, CERNDB, ISSC, HR LHEP, ADB2, PIN, ISS, Document Base and Electronic Photo Archive were performed.

In 2021, the work on enhancing and applying the WALT (Web Application Lego Toolkit) platform, which is a template-oriented platform designed for developing web applications of different complexity, was in progress. In contrast to many other platforms that are "magic black boxes", the WALT underlying idea is to provide transparent, extensible and modifiable tools to solve specific tasks arising in the development of web applications. The WALT platform is used to develop JINR's corporate web applications such as ADB2, PIN, NICA EVM, EDS, etc. [10].

In 2021, to improve the quality of accounting the publication activity of JINR staff members, the work on the development and introduction into trial operation of the information system of the institutional repository of scientific publications based on the JOIN2 software platform (JINR Document Server — publications.jinr.ru) was in progress. To achieve this goal, the work to organize a single subsystem for entering bibliographic metadata into the JINR Document Server and JINR Personal INformation (PIN) systems is underway.

METHODS, ALGORITHMS AND SOFTWARE FOR MODELING PHYSICAL SYSTEMS, MATHEMATICAL PROCESSING AND ANALYSIS OF EXPERIMENTAL DATA

One of the main activities of MLIT is to provide mathematical, algorithmic and software support for experimental and theoretical research underway at JINR. A summary of prominent results is presented below.

In 2021, within the optimization of the characteristics of the superconducting magnets of the NICA project, the three-dimensional modeling of the collider's quadrupole magnet, the vertical output dipole magnet and the final focus lens was performed. The forces acting on the superconducting winding of the solenoid for the SPD experiment, as well as the level of the magnetic field in the detector area of the BM@N facility, were investigated.

A comparative analysis of the efficiency of numerical calculations of magnetostatic fields was carried out by the finite element method (FEM) in the COMSOL Multiphysics® environment in terms of magnetic vector and total scalar potentials for modeling accelerator magnets [11]. Computations were illustrated by the model of a dipole magnet designed to form a magnetic field in the SC200 isochronous cyclotron. The numerical effectiveness of both methods was analyzed in terms of the relevant FEM parameters, accounting for the cost of computing resources. In particular, it was shown that the use of the scalar potential as compared to its vector counterpart substantially reduced the number of degrees of freedom, the use of computer memory and the computational time for a similar relative error.

Modeling in the drift chambers of the BM@N experiment was fine-tuned for all types of data acquired during runs in 2018 to more accurately identify the resulting particles. It was shown that the modeling completely agreed with the experimental data. Reconstruction efficiencies were obtained for all types of data and particles [12].

The geometric and software models of the tracking detectors (GEM, Forward Silicon and CSC) of the BM@N experiment were developed [13]. Algorithms for realistic Monte Carlo simulation and the reconstruction of the spatial coordinates of the points

for passing charged particles through the detectors' planes were implemented.

The studies on the development of algorithms based on Deep Neural Networks for the reconstruction of elementary particle tracks in the BM@N, SPD and BESIII experiments were in progress. Algorithms of local tracking TrackNETv2 and of global tracking RDGraphNet and LOOT were enhanced [14–16]. All developed models of Deep Neural Networks were successfully implemented in the Ariadne library, i.e., a library for particle tracking using deep learning methods, being developed by the authors.

An event metadata system [17] was developed for the experiments of the NICA project; it represents a database that contains summary data on particle collision events and links to their storage location in a distributed storage, providing a quick search and selection of the required set of events according to the stored metadata for their further processing and physics analysis. It comprises an event metadata base, a web service for viewing metadata and selecting events, a software interface for automated recording of new metadata during event processing and a required events query according to specified criteria for physics analysis in the experiment software. The event metadata system was integrated with the condition database, which is also being developed by MLIT specialists.

Modeling that describes the structure of hadrons within the strongly correlated quark model was performed. It was shown how the properties of mesons and baryons could be modified in a dense nuclear medium, namely, nucleons were converted into delta isobars, hyperons and their excitations, and mesons were produced predominantly via vector resonances. Moreover, the properties of vector mesons, consisting of light quarks, changed drastically. The decay width increased, and the mass value decreased [18]. In-medium modifications, especially in the energy range of the NICA megascience project, can result in such observed effects as the enhancement of strangeness, "horn-effect", and enhancement of dilepton invariant mass spectra at 0.2–0.7 GeV.

The previously developed method for constructing a phase transition in nuclear matter under extreme conditions, which are formed in the nuclei of neutron stars, was systematically studied and applied [19]. The construction enabled one to model the equations of the state of nuclear matter, which admits a phase transition, even in cases when there is no phase equilibrium point in a physically justified region of densities. The applicability of this construction and its restrictions were demonstrated.

An algorithm for delimiting overlapping signals from two charged particles in the CSC (Cathode Strip Chambers) detector of the CMS experiment was developed. The reconstruction for the CSC chambers of special geometry ME1/1, developed and assembled at JINR, was tuned for problem areas [20]. The developed algorithms resulted in a more accurate and high-quality reconstruction of hits and segments in the CMS muon system and in the ME1/1 chambers, in particular. The authors' code was implemented into the official CMS software and will be used by default starting from Run 3 data taking.

As part of the software development for Run 3 of the ATLAS experiment, the Resource Manager component was upgraded in accordance with new security rules [21]. A new EventPicking service was developed for the ATLAS EventIndex project; it automates the procedure for finding event location using EventIndex and sending jobs to PANDA to receive the requested events [22]. The service was used for the second stage of the analysis of $\gamma\gamma \to WW$ events. The work on converting data from the old format to CREST and improving the corresponding tools was in progress.

Jointly with physicists of FLNR JINR, a computer model of the fine structure found on the basis of experiments with the transuranium element, californium, was developed [23]. To test the hypothesis that the found structure objectively exists and is not a noise artifact, a deep convolutional neural network was applied as a binary classifier. The preliminary results of using the developed neuroclassifier underlined the prospects of the proposed approach.

Air pollution dispersion modeling on the basis of the Land Use Regression (LUR) model was performed. Testing was carried out in the Tritia region. Two sets of air pollution factors, i.e., emission data and dispersion model results, were considered. Neural network-based regression was compared with linear regression. Neural network-based regression demonstrated significantly better results. It proved to have a positive impact on the quality of LUR models, since it better reflects the overall non-linear behavior of pollution dispersion [24].

A triplet loss function was successfully used to significantly improve the accuracy of vegetation recognition tasks [25]. The first task was plant disease detection on 20 classes of five crops (grape, cotton, wheat, cucumbers, corn). The second task was the identification of moss species (5 classes). In both tasks, self-collected image databases were used. A Siamese network with a triplet loss function and MobileNetV2 as a base network showed an accuracy of 97.8% for plant disease detection and 97.6% for moss species classification.

In 2021, the JINRLIB library was replenished with a program developed by MLIT specialists: RK4-MPI, a parallel implementation of the numeral solution of the Cauchy problem by the fourth-order Runge–Kutta method using MPI technology (http://wwwinfo.jinr.ru/programs/jinrlib/rk4-mpi/indexe.html).

In cooperation with FLNP, using the separated form factor method, an analysis of Small-Angle Neutron Scattering (SANS) spectra, measured on the YuMO small-angle spectrometer on polydisperse populations of single-layer vesicles of the phospho-

lipid transport nanosystem and the Indolip nanodrug in heavy water at three concentrations, was carried out. The basic structural parameters of these vesicular systems, obtained by the computer analysis of the SANS spectra, generally agreed with the corresponding results of Small-Angle X-Ray Scattering (SAXS) data processing. At the same time, the SANS method turned out to be less sensitive in comparison with SAXS in terms of the detailed account of the structural features of the bilayer of the vesicle envelope [26].

The molecular dynamics method was used to study samples of copper, iron and nickel with the structure of real crystals with specified defects such as pores, irradiated by copper nanoclusters with an energy of 1–100 eV/atom [27]. Modeling and testing were carried out using a modified LAMMPS package installed on the HybriLIT cluster. The effect of shock waves on the defective structures of the pore type in the target was investigated within numerical modeling. Threshold irradiation energies of copper nanoclusters, which changed the structure of the defect in the targets, were obtained. The results showed a greater resistance of pore-type defects in an iron target to the impact of a shock wave in comparison with the samples of copper and nickel.

New efficient algorithms for calculating the normalized Mott scattering differential cross section of relativistic electrons by the Coulomb potential, as well as for calculating the total Mott–Bloch correction to the Bethe formula for heavy-ion ionization energy losses based on the proposed representation of the Mott exact cross section in terms of Mott partial amplitudes, were developed and implemented numerically [28]. The inapplicability of the known approximate methods for calculating the cross section of heavy elements and the advantage of the developed method for calculating the normalized Mott cross section in the region of high and medium electron energies were demonstrated.

The relativistic ground state energies of two-centre problems for the Dirac equation were calculated with an accuracy of 8–9 digits at an internuclear distance of $2/Z$ up to $Z = 121$ [29]. Slater-type orbitals (up to the orbital $g_{9/2}$, the maximum number of basis functions is 62) and the minimax method were used in the calculations. The major advantage of the minimax method is that the kinetic balance conditions are not necessary to exclude the false solutions, thereby significantly increasing the convergence rate in the number of basis functions.

A method that enables the extrapolation of asymptotic series to finite values of the coupling parameters, and even to their infinite limits, was proposed [30]. The method is based on the use of self-similar factor approximants, which allow for the extrapolation of function values to arbitrary values of the coupling parameters, knowing only the expansions of these functions in small coupling parameters. The efficiency of the method was illustrated with several problems of quantum field theory.

The spectrum of vibrational-rotational bound, metastable states and scattering states of the beryllium dimer in the ground $X^1\Sigma_g^+$ state was calculated [31]. The problem was solved using the authors' KANTBP 5M software package, which implements Newton's method and the high-accuracy finite element method. The spectrum of rotational-vibrational metastable states of the beryllium dimer with complex energy eigenvalues was obtained for the first time. The presented approach, implemented in the form of a software package, provides a useful tool for studying weakly bound states with eigenenergies close to the dissociation threshold and processes of the near-surface diffusion of diatomic molecules.

The studies on the analysis of the quantum information resource of a finite-dimensional quantum system using the method of quasidistributions in the phase space were in progress [32]. Measures of quantumness were introduced; they made it possible to quantitatively describe the degree of difference between quantum states and the corresponding classical analog. Based on the property of negativity of the corresponding Wigner quasidistribution, an indicator of quantumness of basic functions, qubits, and qutrits was calculated for different metrics (Hilbert–Schmidt, Bures and Bogoliubov–Kubo–Mori) given on the space of quantum states.

APPLIED RESEARCH

Based on the integration of the supercomputers of JINR, of the Interdepartmental Supercomputer Centre of the Russian Academy of Sciences and of Peter the Great St. Petersburg Polytechnic University, a scalable research infrastructure of a new level was created. Such an infrastructure is in demand for the tasks of the NICA megascience project; to date, 3000 event generation and reconstruction tasks were launched on it for the MPD experiment. As a result, about 3 million events were generated and reconstructed. The obtained data were transferred to Dubna for further processing and physics analysis.

A prototype of the "MLIT Information and Analytical System for Maintaining Licenses" (IAL, http://soft-lit.jinr.ru) was developed. The IAL main task is the automation of the management, purchase, maintenance and use of licensed software products (LSP), asked by the need to both plan and optimize the purchase of licensed software and the necessity of controlling the compliance with the rules of the licensing policy. The system database contains all the information on the purchased licenses, on the basis of which the user's personal account (PA) is formed. The PA stores data about licenses owned by

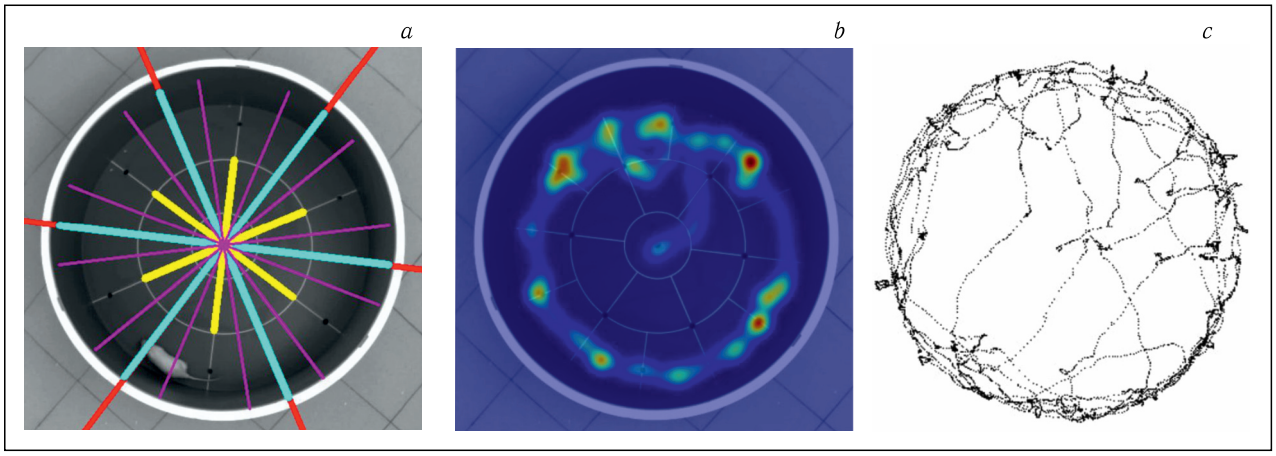


Fig. 12. *a*) Automated marking and refinement of the sector centres of the experimental setup "Open Field"; *b*) heat map of the movements of a laboratory animal in the experimental setup; *c*) frame-by-frame trajectory of the animal's movements

the user. The Administrator/Auditor PA is designed for LSP management and monitoring. Login to the IAL is made through the SSO-JINR user authentication system. The web interface is implemented in the WALT development environment.

Within the joint project of MLIT and LRB, new achievements in the development of the BIO-HLIT Information System (IS) for the tasks of radiation biology (https://bio.jinr.ru/) were obtained. The algorithmic block of the IS is based on the methods of machine and deep learning, as well as of computer vision. In 2021, algorithms for the automated marking and tracking of the behavior of a laboratory animal with the construction of a high-quality movement trajectory and accurate marking of the experimental setup were developed (Fig. 12). Components for visualizing the results of data analysis were elaborated [33].

INTERNATIONAL COOPERATION

In collaboration with BLTP and Cairo University, the cross sections for elastic scattering of charged π mesons by ^{28}Si, ^{40}Ca, ^{58}Ni, ^{208}Pb nuclei in the energy range from 130 to 290 MeV were calculated [34]. The calculations were carried out within two models of microscopic optical potential (OP), namely, the folding model and the local modified Kisslinger type OP. The cross sections of pion–nucleon scattering were obtained by the numerical solution of the Klein–Gordon equation. For both OP models, good agreement with the experimental data was obtained. By fitting the elementary $\pi^{\pm}N$ amplitude parameters in the folding OP to the $\pi^{\pm}A$ scattering experimental data, the effect of the nuclear medium on the mechanism of pion–nucleon scattering was investigated.

The successful cooperation involving MLIT, BLTP, and China Institute of Atomic Energy resulted in a new theoretical approach to the coupled channel method, stable computational schemes, algorithms, and a new modified programme KANTBP 3.1, which implements the finite element method of high-order accuracy [35]. The upgraded version of the programme was used to calculate the fusion cross sections of heavy ions $^{12}C + {}^{12}C$, $^{64}Ni + {}^{64}Ni$, $^{64}Ni + {}^{100}Mo$, $^{28}Si + {}^{64}Ni$, $^{36}S + {}^{48}Ca$. The results of calculating the fusion cross sections of heavy ions and the astrophysical S factor are in good agreement with the available experimental data.

Within a joint grant between JINR and Romania, a prototype of the IFA Database system for managing research programmes was developed. The system will be a major tool for the organization of competitive funding for studies in Romania. The prototype of the IFA Database system is implemented on top of the WALT platform, being developed by MLIT specialists, and currently comprises the following modules: registration and login of different users, grant application, administrator panel, registration and validation of organizations in the system.

EDUCATIONAL PROGRAMME ON THE EDUCATION AND TESTING POLYGON

In 2021, training courses and practical classes on "High-Performance Computing and Supercomputer Technologies" and "Machine Learning and Data Mining" were held on the HybriLIT platform. 780 students of Dubna State University and more than 300 students and postgraduates from other universities and JINR's Member States are registered on the training and testing polygon. In 2021, nine

master's and bachelor's theses were prepared using the resources of the HybriLIT platform.

The programme of the International School of Information Technologies "Data Science", whose students are engaged in real scientific projects of JINR, is underway. The results of graduates are presented in a collection of scientific and project activity reports: http://itschool.jinr.ru/discipline.html#science-project.

In 2021, the workshop "Distributed Computing and Data Science", within which students attended the training course "Distributed Computing, Machine and Deep Learning for Solving Applied Tasks", and the 3rd IT School for Young Scientists "Modern IT Technologies for Solving Scientific Tasks", in which over 60 students and teachers from universities of the South of Russia (North Ossetia, Kabardino-Balkaria, Chechnya) and from the Tibilov South Ossetian State University participated, were held at the North Ossetian State University. Lectures on JINR's scientific projects, on information technologies and solutions for scientific tasks being developed at JINR were delivered; master classes and training courses on distributed computing, virtualization and cloud technologies, machine and deep learning algorithms for analyzing data of a complex structure were conducted.

REFERENCES

1. *Baginyan A. et al.* // CEUR Workshop Proc. 2021. V. 3041. P. 1–6.
2. *Baranov A. et al.* // CEUR Workshop Proc. 2021. V. 3041. P. 429–433.
3. *Balashov N. et al.* // CEUR Workshop Proc. 2021. V. 3041. P. 280–284.
4. *Kutovskiy N., Pelevanyuk I., Zaborov D.* // CEUR Workshop Proc. 2021. V. 3041. P. 196–201.
5. *Podgainy D. et al.* // CEUR Workshop Proc. 2021. V. 3041. P. 612–618.
6. *Moshkin A. A. et al.* // Russian Supercomputing Days: Proc. of the Intern. Conf., Sept. 27–28, 2021, Moscow. P. 4–11.
7. *Kudryavtsev A. O., Podgainy D. V., Moskovsky A. A.* // ISC High Performance, Hamburg, Germany, May 29 – June 2, 2021; https://www.isc-hpc.com/;
   Moskovsky A. A., Brekhov A. T., Podgainy D. V., Kudryavtsev A. O. // Sixth Intern. Parallel Data Systems Workshop, Nov. 15, 2021; https://sc21.supercomputing.org/session/?sess=sess332;
   Val'a M., Podgainy D., Lavrenko P., Brekhov A. // Fifth Annual DAOS User Group Meeting, Nov. 19, 2021; https://daosio.atlassian.net/wiki/spaces/DC/pages/11015454821/DUG21.
8. *Moshkin A., Pelevanyuk I., Rogachevskiy O.* // CEUR Workshop Proc. 2021. V. 3041. P. 321–325.
9. *Kashunin I., Mitsyn V., Strizh T.* // CEUR Workshop Proc. 2021. V. 3041. P. 285–290.
10. *Korenkov V., Kuniaev S., Semashko S., Sokolov I.* // CEUR Workshop Proc. 2021. V. 3041. P. 387–392.
11. *Chervyakov A.* // Intern. J. Engin. Systems. 2021. V. 4. P. 1–17.
12. *Palichik V., Voytishin N.* // Phys. Part. Nucl. Lett. (in press).
13. *Baranov D.* // AIP Conf. Proc. 2021. V. 2377. P. 060002.
14. *Shchavelev E. et al.* // CEUR Workshop Proc. 2021. V. 3041. P. 218–222.
15. *Nikolskaya A. et al.* // CEUR Workshop Proc. 2021. V. 3041. P. 332–337.
16. *Rezvaya E. et al.* // CEUR Workshop Proc. 2021. V. 3041. P. 138–142.
17. *Alexandrov E. et al.* // CEUR Workshop Proc. 2021. V. 3041. P. 439–444.
18. *Musulmanbekov G.* // Phys. Part. Nucl. Lett. 2021. V. 18, No. 5. P. 548–558.
19. *Ayriyan A. et al.* // Eur. Phys. J. A. 2021. V. 57, No. 318. P. 2102.13485.
20. *Palichik V., Voytishin N.* // Programme Advisory Committee for Particle Physics, Jan. 24, 2022.
21. *Kazarov A. et al.* // Eur. Phys. J. Web Conf. 2021. V. 251. P. 04019.
22. *Alexandrov E. et al.* // CEUR Workshop Proc. 2021. V. 3041. P. 223–228.
23. *Ososkov G. A., Pyatkov Yu. V., Rudenko M. O.* // Part. Nucl., Lett. 2021. V. 18, No. 5(237). P. 430–447 (in Russian).
24. *Bitta J., Svozilík V., Svozilíková Krakovská A.* // Atmosphere. 2021. V. 12, No. 4. P. 452.
25. *Uzhinskiy A. V. et al.* // Comput. Optics. 2021. V. 45, No. 4. P. 608–614.
26. *Kiselev M. A. et al.* JINR Preprint P3-2021-49. Dubna, 2021; J. Surf. Invest.: X-ray, Synchrotron Neutron Tech. (in Russian) (in press).
27. *Sharipov Z. A. et al.* // J. Surf. Invest.: X-ray, Synchrotron Neutron Tech. (in Russian) (in press).
28. *Kats P. B., Halenka K. V., Voskresenskaya O. O.* // Phys. Part. Nucl. Lett. 2021. V. 18, No. 3. P. 277–283.
29. *Chuluunbaatar O. et al.* // Chem. Phys. Lett. 2021. V. 784. P. 139099-1–139099-9.
30. *Yukalov V. I., Yukalova E. P.* // Phys. Rev. D. 2021. V. 103. P. 076019.
31. *Derbov V. L. et al.* // J. Quant. Spectrosc. Radiat. Transf. 2021. V. 262. P. 107529.
32. *Abgaryan V., Khvedelidze A., Torosyan A.* // Phys. Lett. A. 2021. V. 412, No. 7. P. 127591.
33. *Stadnik A. et al.* // CEUR Workshop Proc. 2021. V. 3041. P. 348–352.
34. *Lukyanov V. K. et al.* // Nucl. Phys. A. 2021. V. 1010. P. 122190.
35. *Wen P. W. et al.* // Phys. Rev. C. 2021. V. 103. P. 054601.

LABORATORY OF RADIATION BIOLOGY

In 2021, the Laboratory of Radiation Biology (LRB) continued research under Themes 04-9-1077-2009/2023 "Research on the Biological Effect of Heavy Charged Particles of Different Energies" and 04-9-1112-2013/2022 "Research on Cosmic Matter on Earth and in Nearby Space; Research on the Biological and Geochemical Specifics of the Early Earth."

At the 129th Session of the JINR Scientific Council, LRB Director A. N. Bugay presented the Programme of Radiobiological Research at JINR and the LRB Development Strategy. The Programme had preliminarily been discussed at the LRB Biophysical Seminar, which was attended by JINR Director Academician of the Russian Academy of Sciences (RAS) G. V. Trubnikov, JINR Scientific Director RAS Academician V. A. Matveev, and representatives of JINR Laboratories. Also, the LRB Programme of Heavy Ion Beam-Based Radiobiological Research was discussed at the International Round Table on Applied Research and Innovations at the NICA complex.

At the end of 2021, the stock of the LRB's facilities was supplemented with two X-ray sources for radiation biology applications. A compact CellRad irradiator manufactured by Precision X-ray Inc. (the US) is intended for work with cell cultures. Installation began of the SARRP (Small Animal Radiation Research Platform) multifunctional research complex manufactured by Xstrahl Ltd. (the UK) for radiobiological research on small laboratory animals. The instrument can perform X-ray tomography and provide highly conformal irradiation.

RADIATION GENETICS AND MOLECULAR RADIOBIOLOGY

Research on the Molecular Mechanisms of Action of DNA Repair Inhibitors. Research has continued on the modifying effect of the DNA synthesis inhibitor cytosine arabinoside (AraC) on the formation of DNA double-strand breaks (DSBs) in normal (fibroblasts) and tumor (U87 glioblastoma) human cells after Bragg peak proton and accelerated nitrogen ion exposure (Fig. 1). It has been found that in the presence of the inhibitor, DNA DSB repair effectiveness is suppressed both in normal and tumor cells (Fig. 1, *a* and *b*, respectively) after accelerated nitrogen ion exposure. The most pronounced modifying effect of AraC is observed after proton exposure.

The modifying effect has been studied of AraC and the DNA ligase IV inhibitor SCR7 on DNA DSB formation and repair in human fibroblasts after Bragg peak proton exposure. With the combined use of these modifiers, an increase in the number of DNA DSBs and a decrease in the effectiveness of their repair are observed (Fig. 2).

A DNA comet assay was used to study DNA DSB induction and repair in mouse B16 melanoma cells after accelerated proton exposure *in vitro* under normal conditions and in the presence of AraC and SCR7. It has been found that DNA DSBs form more efficiently in the presence of AraC than in the control samples and in the presence of SCR7 only. A similar trend was observed in mouse hippocampal cells after γ-ray exposure *in vivo* under normal conditions and in the presence of AraC and hydroxyurea.

An analysis was made of formation and elimination kinetics and structure of clustered DNA damage with modified bases in human fibroblast cells after accelerated proton and nitrogen ion and γ-ray exposure. It has been shown that repair systems eliminate clustered damage as a single complex [1].

Research on Radiation-Induced Structural Mutations in Mammalian and Human Cells. A series of experiments were conducted to study radiation-induced mutagenesis in V79 Chinese hamster cells after irradiation with ^{60}Co γ rays and accelerated ions of different LET (50, 116, 138, and 153 keV/μm) [2]. A PCR assay of structural disorders in the *hprt* gene in spontaneous and radiation-in-

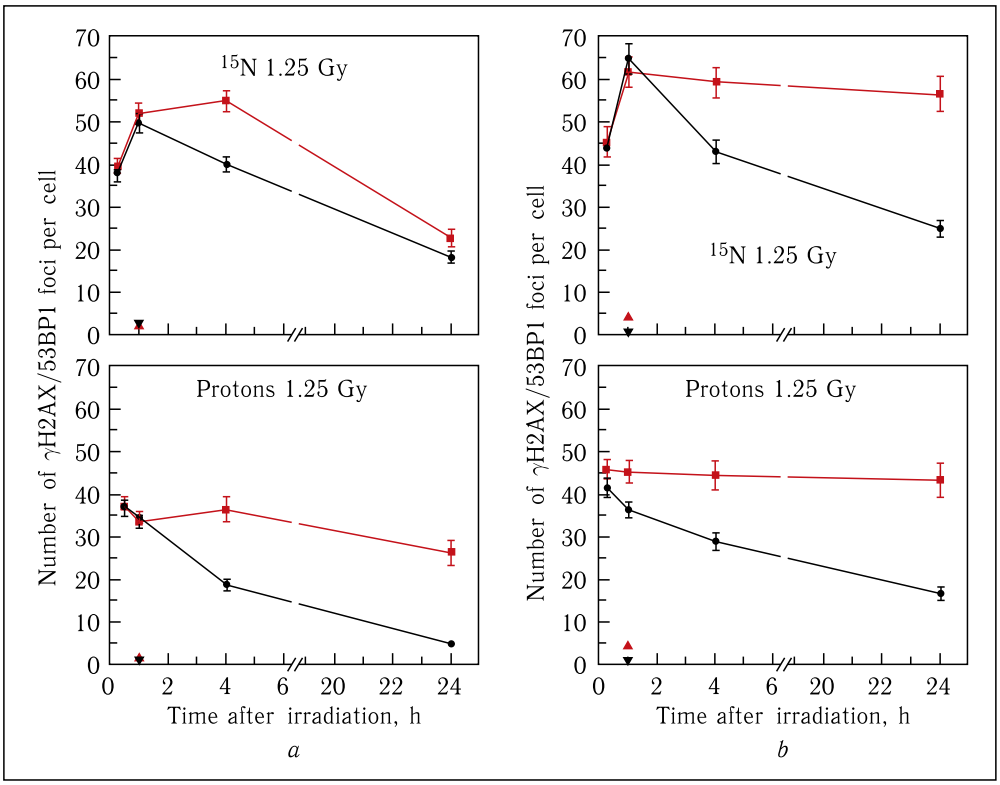


Fig. 1. Formation and repair kinetics of radiation-induced γH2AX/53BP1 foci in human fibroblasts (*a*) and tumor cells (*b*) after accelerated nitrogen ion and proton exposure — in the presence (red) and absence (black) of the modifier

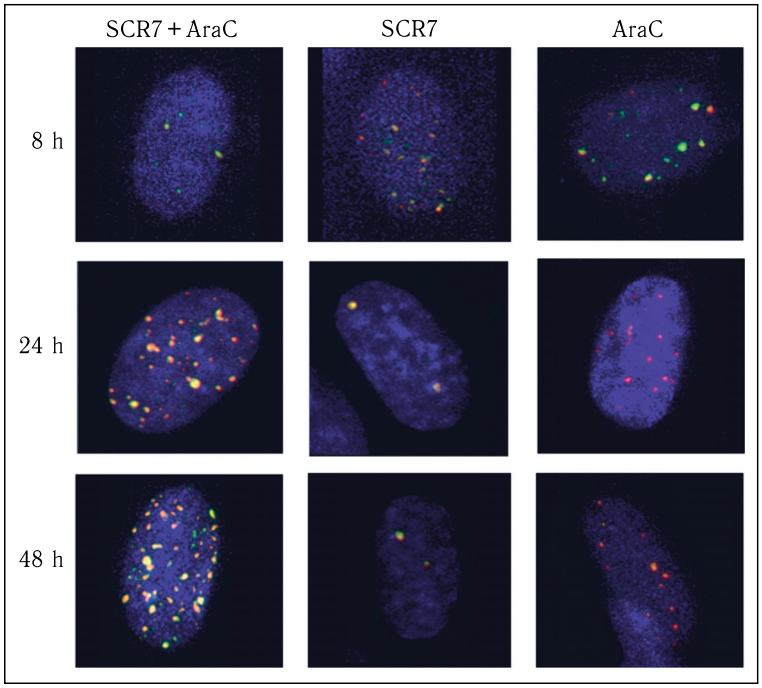


Fig. 2. Radiation-induced foci of DNA DSB repair proteins γH2AX (green signals) and 53BP1 (red signals) in nuclei of normal human fibroblasts after irradiation with Bragg peak protons at a dose of 1.25 Gy in the presence of AraC and SCR7

duced mutant subclones has shown an increase in the frequency of mutants with deletions of different types (partial and complete). All radiation-induced mutants had a greater number of large deletions than spontaneous mutants (SM). There was a trend towards an increase in the proportion of deletions in the *hprt* gene with increasing LET (Fig. 3).

Cytogenetic analysis has continued of chromosomal aberrations in *Macaca mulatta* monkey blood lymphocytes after a complex exposure simulating the

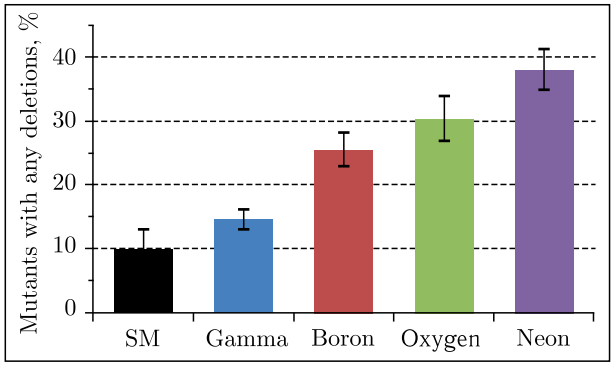


Fig. 3. Distribution of deletions in the *hprt* gene for all samples (the average of all analyzed doses and time points)

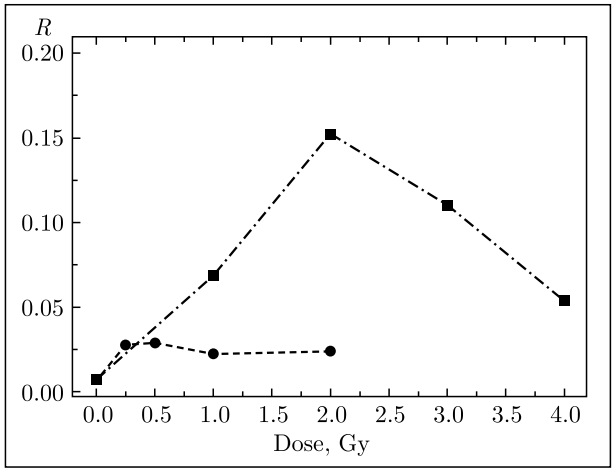


Fig. 4. Dose dependence of cytogenetic risk R, i. e., the probability for an aberrant cell with stable aberrations to undergo mitosis after exposure to X rays (squares) and α particles (circles)

space flight conditions (antiorthostatic hypokinesia, long-term ^{137}Cs γ irradiation, and irradiation of monkeys' heads with ^{12}C ions at a dose of 1 Gy) [3]. Within 1.3 years after irradiation, the total number of chromosomal aberrations was three times higher than the control level.

In collaboration with the GSI Biophysics Group (Darmstadt, Germany), the relative biological effectiveness of α particles was evaluated by the induction of various types of chromosomal aberrations in human blood lymphocytes irradiated *ex vivo* [4]. Analysis of the kinetics of cells reaching the first and subsequent post-irradiation mitoses and mFISH (multicolor fluorescent *in situ* hybridization) analysis of chromosomal aberrations were used to assess the cytogenetic risk, i. e., the probability of maintaining stable inherited aberrations in surviving lymphocytes. It has been shown that the cytogenetic risk of α radiation is lower than that of X rays (Fig. 4). Similar results in terms of the frequency of chromosomal aberrations and the proportion of complex aberrations were obtained after radon exposure [5].

Radiation Genetics of Unicellular Eukaryotes. Research has continued on the induction of point mutations and gene rearrangements in yeast after exposure to accelerated heavy charged particles of different energies. The molecular nature of these mutations has been analyzed [6]. Genetic indicators of the effect of accelerated protons (150 MeV, 0.54 keV/μm) on various yeast strains have been studied. The strains' mutability has been evaluated by the frequency of fungicide resistance mutation. Higher radioresistance and lower mutability of probiotic *S. boulardii* yeast strains have been observed compared with laboratory *S. cerevisiae*.

RADIATION PHYSIOLOGY AND NEUROCHEMISTRY

Research on Behavioral Reaction Disorders and Pathomorphological Changes in Irradiated Animals. A study was performed of morphological changes in the central nervous system (CNS) and specific physiological parameters of mice (aged seven months) on the 30th day after irradiation with ^{60}Co γ rays at a dose of 2 Gy. There have been statistically significant differences in the behavior of irradiated rodents in the open field test compared with the control group. In irradiated animals, a statistically significant decrease in the number of leukocytes, an increase in the number of neurons with destructive changes, a decrease in the amount of total glia, and foci of cellular depletion have been observed.

The radiation protective effect has been studied of the nootropic drug Piracetam on behavioral reactions and morphological changes in the brain of laboratory rats after whole-body irradiation with γ rays at a total dose of 5 Gy fractionated into 0.5 Gy exposures. Animals treated with Piracetam after irradiation showed normalization of passive defensive behavior, preservation of the morphometric parameters of the granular layer of the dentate gyrus at the level of intact animals, and a reduction of neurodegenerative changes in the CNS [7].

To study modification of the disorders of the CNS higher integrative functions by pharmacochemical protection after whole-body irradiation with accelerated protons, the nootropic drug Cerebrolysin was used. An experiment was performed on male rats, which underwent whole-body irradiation with 170 MeV protons at a dose of 4 Gy at the medical beam of the JINR Phasotron. It was found in behavioral tests that Cerebrolysin significantly restores the value of motor activity indicators and has a positive effect on the working memory of irradiated animals.

Research on the Neuroinflammatory Response and Destruction of the Myelin Sheath of Axons (Demyelination). To study these radiation-induced pathological processes, the secretion of inflammatory cytokines and the level of the myelin basic protein MBP1 in mouse brain homogenates were evaluated using enzyme immunoassay after irradiation with γ rays and after irradiation with Bragg peak protons at doses up to 5 Gy. A preliminary analysis of experimental data revealed neither a pronounced neuroinflammatory response nor a drop in myelin levels in the early stages (a week) after γ irradiation; however, in the long term (two months) after proton irradiation, demyelination was observed.

MATHEMATICAL MODELING OF RADIATION-INDUCED EFFECTS

Radiation Damage to CNS Cells. By Monte Carlo simulation of the stochastic structure of heavy charged particle tracks using the Geant4-DNA software toolkit, the induction of primary DNA damage of various types in nerve cells has been calculated (Fig. 5, *a*): base damage, single-strand breaks, clustered single-strand breaks, double-strand breaks, and clustered double-strand breaks [8]. Based on data on DNA damage, the survival of radiosensitive neural progenitor cells in the subgranular zone of the hippocampus after radiation exposure has been modeled (Fig. 5, *b*). The calculated survival data are in good agreement with the experimental results reported in the literature.

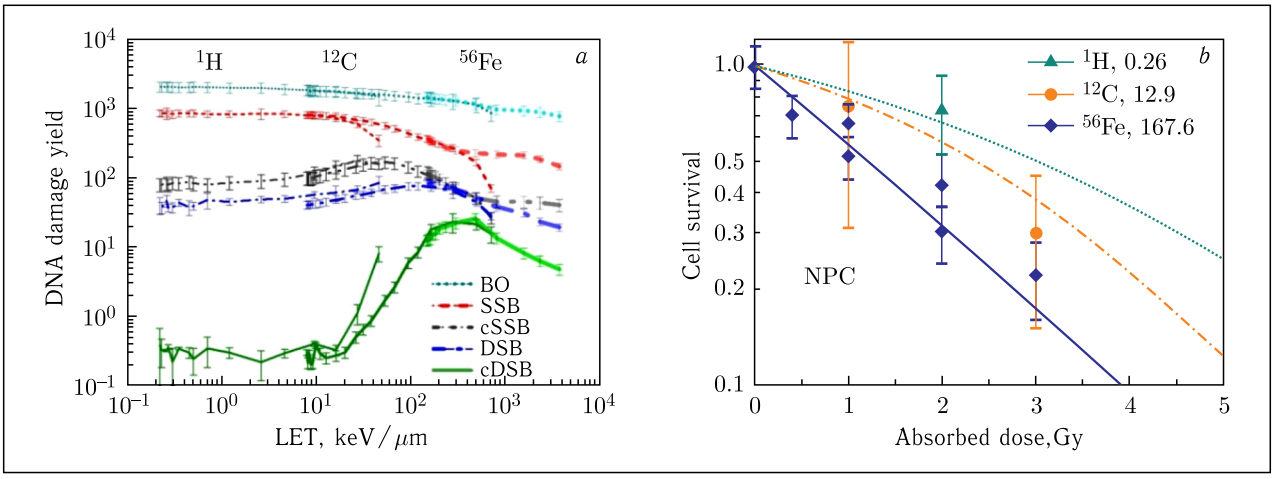


Fig. 5. Calculated radiation damage to the CNS. *a*) The yield of primary DNA damage of different types in the nuclei of hippocampal nerve cells per unit absorbed dose depending on the LET of different particles. The damage types considered include base damage (BD), single-strand breaks (SSB), clustered single-strand breaks (cSSB), double-strand breaks (DSB), and clustered double-strand breaks (cDSB). *b*) Survival curves of neural progenitor cells in the subgranular zone of the hippocampus after exposure to ^{1}H (1000 MeV), ^{12}C (300 MeV/nucleon), and ^{56}Fe (600 MeV/nucleon) with the corresponding LET values, keV/μm

Modeling Neuro- and Gliogenesis in the Hippocampus. A mathematical model of neurogenesis has been developed based on the scheme of asymmetric division of nerve stem cells in the dentate gyrus of the mouse hippocampus [9]. The model reproduces experimental data on age-related changes in the number of neural stem cells amplifying neural progenitors, neuroblasts, immature neurons, and, for the first time, mature neurons, astrocytes, and oligodendrocytes. Proportions have been calculated of mature neurons, astrocytes, and oligodendrocytes surviving in the long-term period after X-ray exposure.

Modeling Neural Network Functioning. The properties have been studied of synaptic NMDA receptors with mutations in the GluN2B subunits and with different composition of the GluN1, GluN2A, and GluN2B subunits, and their influence on the functioning of the hippocampal neural networks and EEG brain rhythms has been evaluated [10]. In particular, it has been found that when the GluN2B subunit is replaced by GluN2A during brain aging, the receptor's properties deteriorate, low-frequency rhythms decrease, and high-frequency rhythms increase. It is assumed that this mechanism may be associated with age-related disorders of attention and memory.

ASTROBIOLOGY

In collaboration with the LRB's colleagues from Italy, research has continued on the formation of prebiotic compounds under accelerated heavy charged particle exposure. Proton irradiation at 170 MeV was performed of diglycosylated adenines in a mixture with formamide and NWA 1456 meteorite material. The results show that after accelerated proton exposure these adenines act as glycosyl donors in the intermolecular trans-glycosylation of pyrimidine nucleic bases. Formamide and meteorite material increased the yield and selectivity of the reaction. The data obtained indicate a possible role of intermolecular trans-glycosylation in the prebiotic formation of nucleosides without additional synthetic pathways [11].

Micropaleontological studies of Murchison, Aguas Zarkas, Sutter's Mill, Tagish Lake, NWA 7184, and other carbonaceous chondrite meteorite material (more than 30 samples) were carried out using a Tescan Vega 3 scanning electron microscope with an X-ray microanalyzer. New finds of microfossils have been made in meteorite samples (Fig. 6), represented by remains of both prokaryotic and eukaryotic microorganisms [12].

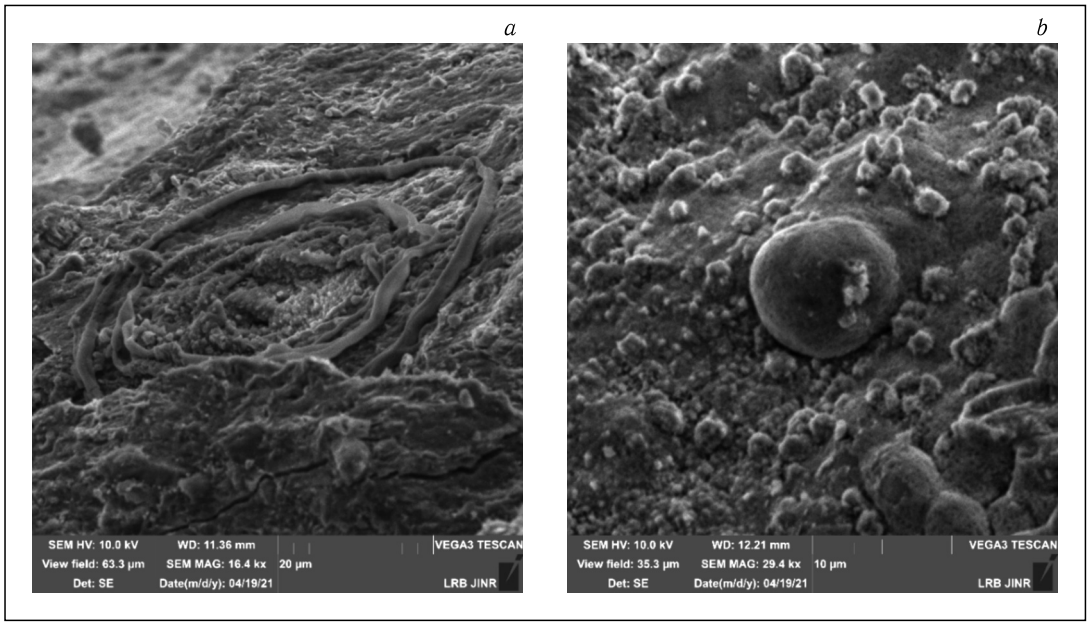


Fig. 6. Images of fossilized microorganisms in meteorites: *a*) Sutter's Mill (filamentous shape); *b*) NWA 7184 (spherical shape)

RADIATION PROTECTION PHYSICS AND RADIATION RESEARCH

A series of studies have been conducted to assess the radiation risk to cosmonauts during interplanetary flights [13, 14]. Detailed calculations have been performed of the spectra of all components of the radiation field inside the inhabited module of a spacecraft associated with galactic cosmic rays (GCR) for minimum and maximum solar activity. The calculations were verified with the only available experimental data from the RAD and Liulin-MO instruments, which showed good agreement between the calculations and experiment (Fig. 7). Corrected fluence-to-effective dose conversion factors have been calculated for all components of the radiation field inside a spacecraft.

Within the framework of cooperation with the RAS Institute of Space Research on the development of instruments for nuclear planetary science, sessions have been continued at the proton beam of the DLNP Phasotron to refine the tagged proton technique [15].

With the aim of advancing experimental methods of evaluating space radiation risk under terrestrial conditions, a unique simulator has been proposed of the radiation field inside the habitable module of a spacecraft in deep space [16]. The simulator (Fig. 8) would provide the correct ratio of all components of the spacecraft's internal radiation field averaged over solar activity. It can be installed at the 1 GeV/nucleon ^{56}Fe nuclei beam of the Nuclotron's radiobiological channel, which is being created as part of the Programme of Applied Innovative Research at the NICA complex. A patent for the invention has been obtained [17].

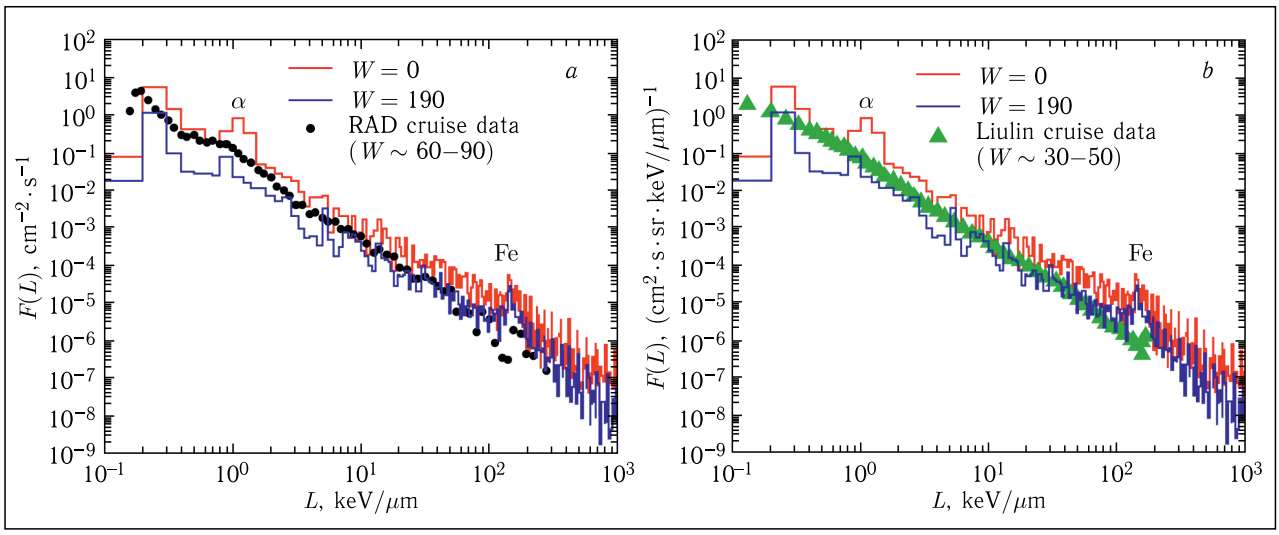


Fig. 7. A comparison of the calculated LET spectra inside a spacecraft and experimental data from RAD (*a*) and Liulin-MO (*b*)

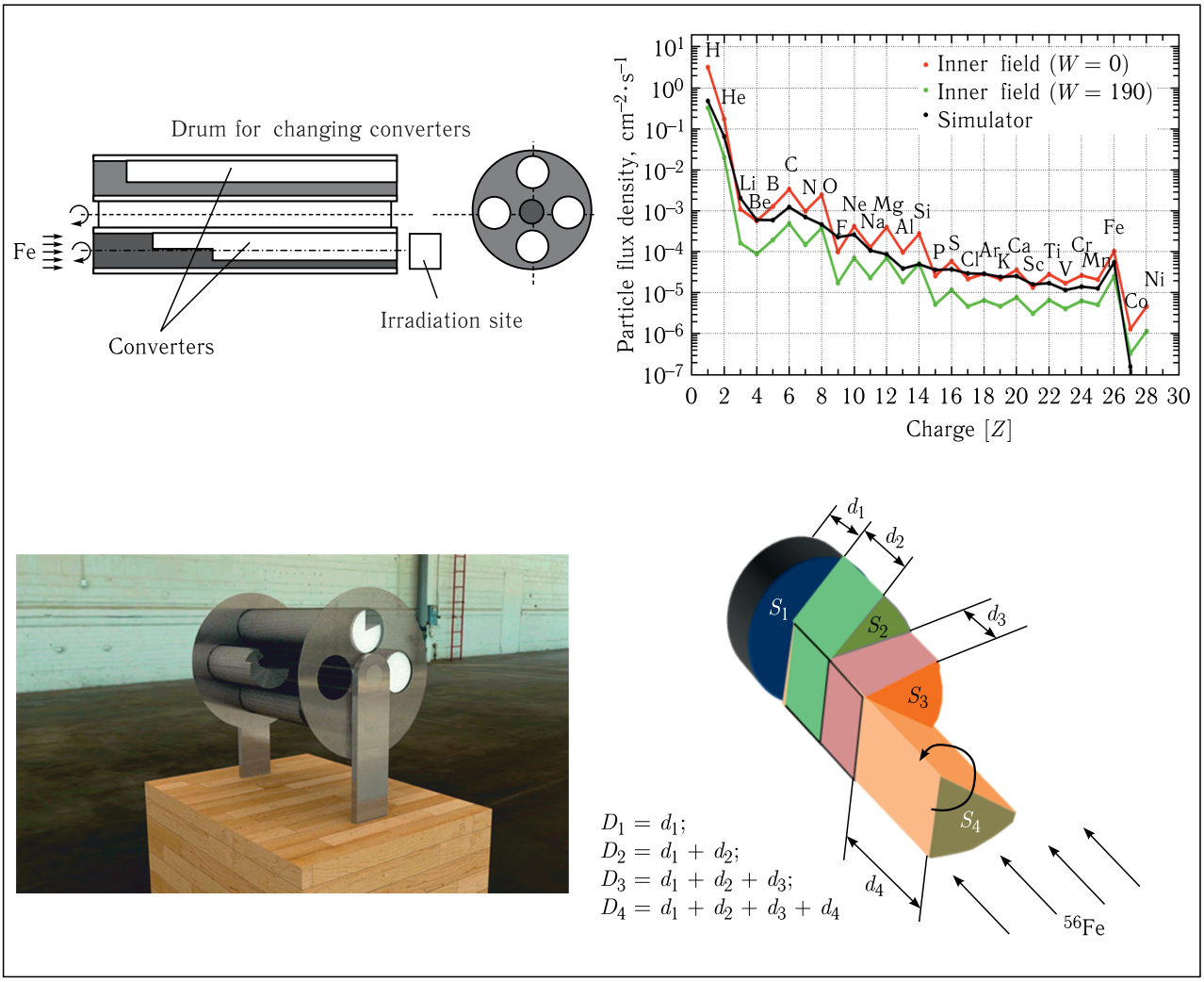


Fig. 8. An illustration of the concept of a new GCR simulator: a schematic of a drum for changing converters, a graph of the produced integral value of the particle fluence at the irradiation site, and a 3D schematic of a separate converter

CONFERENCES AND EDUCATION

In 2021, LRB staff took part in 29 scientific conferences held in a mixed online and offline format.

On 27–28 April, the international workshop "Nuclear Physics Methods in Life Sciences: Neuroradiobiological Research and New Approaches to Radiation Therapy of Tumors" was held in a mixed format. It was attended by specialists from JINR, Armenia, the Czech Republic, Georgia, Poland, and Russia. At the end of the meeting, a decision was made at the round table to form an international collaboration on the basis of JINR's LRB.

On 12–15 October, with support from JINR's LRB, the 8th Congress on Radiation Research (Radiobiology, Radioecology, Radiation Safety), a traditional congress of the RAS Radiobiological Society, was held in Moscow. The Congress was attended by more than 400 radiobiologists, radioecologists, doctors, and scientists of related specialties from Azerbaijan, Belarus, and Russia.

The educational process has continued at the Department of Biophysics, Dubna University. The Department's total enrolment is 36 students and 7 postgraduates. Four students successfully completed their programmes and received a master's degree in physics.

REFERENCES

1. *Shamina D. D., Boreyko A. V., Zadneprianetc M. G., Hramco T. S., Krupnova M. E., Kulikova E. A., Pavlova A. S., Smirnova E. V., Filatova A. S.* The Complexity of Clustered DNA DSBs in Human Fibroblasts under the Action of Low- and High-LET Radiation // AIP Conf. Proc. 2021. V. 2377. P. 050005.
2. *Blaha P., Koshlan I. V., Koshlan N. A., Bogdanova Y. V., Petrova D. V., Govorun R. D., Mucka V., Krasavin E. A.* Structural Changes in HPRT Gene of V79 Cells after Irradiation with Heavy Ions — Immediate and Delayed Effects // Frontiers Phys. 2021. V. 8. P. 584326.
3. *Belyaeva A. G., Kudrin V. S., Koshlan I. V., Koshlan N. A., Isakova M. D., Bogdanova Y. V., Krasavin E. A., Timoshenko G. N., Blokhina T. M., Yashkina E. I., Osipov A. N., Nosovsky A. N., Perevezentsev A. A., Stemberg A. S.* Effects of Combined Exposure to Modeled Radiation and Gravitation Factors of the Interplanetary Flight: Monkeys' Cognitive Functions and the Content of Monoamines and Their Metabolites; Cytogenetic Changes in Peripheral Blood Lymphocytes // Life Sci. Space Res. 2021. V. 30. P. 45–54.
4. *Hartel C., Nasonova E., Ritter S., Friedrich T.* Alpha-Particle Exposure Induces Mainly Unstable Complex Chromosome Aberrations Which Do Not Contribute to Radiation-Associated Cytogenetic Risk // Radiat. Res. 2021. V. 196. P. 561–573.
5. *Paz N., Hartel C., Nasonova E., Donaubauer A., Frey B., Ritter S.* Chromosome Aberrations in Lymphocytes of Patients Undergoing Radon Spa Therapy: An Explorative mFISH Study // Intern. J. Environ. Res. Public Health. 2021. V. 18. P. 10757.
6. *Koltovaya N., Zhuchkina N., Shvaneva N.* Mutation Induction by Heavy-Ion Beams with Different LET in Yeast *Saccharomyces cerevisiae*. JINR Preprint E19-2021-19. Dubna, 2021.
7. *Severyukhin Yu. S., Lalkovičová M., Kolesnikova I. A., Utina D. M., Lyakhova K. N., Gaevsky V. N.* The Effect of Piracetam on Behavioral Reactions of Adult Rats and Morphological Changes in the Brain after Whole Body Fractionated Gamma Irradiation — An Exploratory Study // Radiat. Environ. Biophys. 2021. V. 60. P. 73–86.
8. *Batmunkh M., Bayarchimeg L., Bugay A. N., Lkhagva O.* Computer Simulation of Radiation Damage Mechanisms in the Structure of Brain Cells // AIP Conf. Proc. 2021. V. 2377. P. 050001.
9. *Glebov A. A., Kolesnikova E. A., Bugay A. N.* Modeling Neurogenesis Disruption in Mice after Acute X-ray Exposure // Russ. J. Biol. Phys. Chem. 2021. V. 6, No. 2. P. 280–284 (in Russian).
10. *Aksenova S. V., Batova A. S., Bugay A. N., Dushanov E. B.* Modeling the Main Hippocampal Rhythms with Different NMDA Receptor Types // Russ. J. Biol. Phys. Chem. 2021. V. 6, No. 2. P. 55–56 (in Russian).
11. *Bizzarri B. M., Fanelli A., Kapralov M., Krasavin E., Saladino R.,* Meteorite-Catalyzed Intermolecular Trans-Glycosylation Produces Nucleosides under Proton Beam Irradiation // RSC Adv. 2021. V.11, No. 31. P. 19258–19264.
12. *Rozanov A. Yu., Hoover R., Ryumin A. K., Saprykin E. A., Kapralov M. I., Afanasyeva A. N.* New Finds of Microfossils in the Orgueil Meteorite // Paleontol. J. 2021. No. 1. P. 1–3 (in Russian).
13. *Timoshenko G. N., Gordeev I. S.* Computation of Linear Energy Transfer of Space Radiation in Biological Tissue Analog // Planet. Space Sci. 2021. V. 199. P. 105190.
14. *Timoshenko G. N., Gordeev I. S.* Reference Radiation Field for GCR Chronic Exposure Simulation // Phys. Part. Nucl. Lett. 2021. V. 18, No. 7. P. 781–787.
15. *Mitrofanov I., Sanin A., Anikin A., Mokrousov M., Golovin D., Nikiforov S., Timoshenko G., Shvetsov V.* Laboratory Demonstration of Space Experiment for Spectrometry of Planetary Gamma-Rays with Tags of Galactic Cosmic Rays Producing Them // Nucl. Instr. Meth. A. 2021. V. 1003. P. 165286.
16. *Timoshenko G. N., Gordeev I. S.* A New Type of Ground-Based Simulator of Radiation Field inside a Spacecraft in Deep Space // Life Sci. Space Res. 2021. V. 30. P. 66–71.
17. A Device for Modeling Mixed Radiation Fields at High-Energy Heavy Ion Beams for Experimental Radiobiological Research / Timoshenko G. N., Gordeev I. S. Patent RU 2761376 C1. Russia's Federal Service for Intellectual Property (Rospatent). Published 7 Dec. 2021. Bull. No. 34 (in Russian).

UNIVERSITY CENTRE

In 2021, the JINR University Centre celebrated its 30th anniversary — in January 1991, the USSR State Committee for Public Education and the USSR Ministry of Atomic Energy and Industry issued a joint Order on specialised JINR-based training of highly qualified personnel.

JINR-Based Training Process. In 2021, all training of students at the JINR-based departments of MSU, MIPT, MEPhI, Dubna University, and Member States Universities was organised in a mixed format — both online and offline — depending on the anti-COVID19 measures in effect on the territory of the Russian Federation.

In 2021, 20 degree-seekers were attached to JINR in order to prepare their PhD theses without completing the academic programme of the PhD course. Six students out of 20 chose the specialty "Physics of charged particle beams and accelerator technology", 3 students — "High energy physics", 3 — "Instruments and methods of experimental physics", 3 — "Physics of the atomic nucleus and elementary particles". The degree-seekers were distributed by the laboratories as follows: VBLHEP — 10 people, FLNP — 3, BLTP — 2, DLNP — 2, FLNR — 2, LIT — 1. The first three thesis defenses of the JINR-attached degree-seekers were held for the staff members of FLNP and MLIT.

Online INTEREST Programme. INTEREST — INTErnational REmote Student Training — is an all-year-round online programme by the JINR University Centre for students and postgraduates specialising in science, engineering, and IT. One hundred and thirty-six students and postgraduates from Azerbaijan, Belarus, Bosnia and Herzegovina, Botswana, Bulgaria, Cuba, Czech Republic, Egypt, Greece, India, Indonesia, Italy, Japan, Mexico, Mongolia, Poland, Romania, Russia, Serbia, Spain, South Africa, Turkey, Ukraine, and Uzbekistan took part in the three Waves of INTEREST held in 2021. Since its launch, INTEREST has been attended by 180 representatives of 29 countries of the world. The Programme allows its participants to get acquainted with the main areas of research conducted at the Institute and to find a thesis supervisor. It also increases the chances to get selected for full-time offline internships in the laboratories of JINR. Each Wave of the Programme lasts for 4–6 weeks dedicated to remote work on the projects, as well as to lectures and online excursions. In 2021, 53 projects were developed by JINR experts for the Programme.

During an online meeting, the representatives of the European Physical Society (EPS) and JINR came to an agreement that students from the European universities that are members of the EPS would be encouraged to participate in the JINR training programme, in particular, online programme INTEREST. The participation of students in the INTEREST programme was also discussed at meetings with representatives of the Botswana International University of Science and Technology (BIUST), Plekhanov Russian University of Economics, and Kamchatka State University named after V. Bering (KamSU).

Events. The JINR UC Social Communications Group participated in the organisation of JINR representation at various outreach events:

- Science and Technology Festival "Geek-Picnic" in Moscow and recording of video lectures by JINR scientists followed by their uploading on YouTube (21 August). The videos attracted over 16000 views;
- Festival "TECHNOSREDA" at VDNKh (25–26 September). The JINR exhibition stand was attended by over 5000 visitors;
- All-Russian Science Festival "NAUKA 0+" in Mosow, Expocentre and MSU (8–10 October);
- International Drawing Competition dedicated to the 65th anniversary of JINR attended by 145 participants from different countries, who submitted 105 works;
- 4th Workshop Project "Museum Connections" on the topic "Mediation: The Practice of Interaction with the Visitor, Scientific Communication" (15–16 September);
- Open Day at MEPhI (LaPlas Institute) (17 January);

• Open Day at MEPhI (Institute of Nuclear Physics and Engineering) (31 January);

• Career Forum at MIPT (offline) (11 June);

• Marathon "Start of a Career: Autumn 2021" at NRNU MEPhI (22–26 November);

• Online event for MIPT students: discussion of career prospects in science "I would become a scientist…" (17 December).

19th International Training Programme "JINR Expertise for Member States and Partner Countries". On 8–12 November, the 19th international training programme "JINR Expertise for Member States and Partner Countries" (JEMS-19) was held at JINR. The participants in the event were heads and specialists of research and educational organisations in Bulgaria and Serbia, as well as heads of diplomatic missions of these countries in the Russian Federation. The participants got acquainted with JINR laboratories and basic facilities, directions of current scientific research, and educational activities at the Institute.

Interschool Physics and Mathematics Open Classroom. On 31 January, the 60th off-site MIPT Olympiad in Physics and Mathematics was held at Bogolyubov Gymnasium No. 8. This Olympiad was one of the qualifying rounds of the Phystech Olympiad 2021. Traditionally, the off-site Olympiad was supervised by MIPT students — ex-students of Dubna schools. Seventy-eight school students (grades 8–11) took part in the event.

On 23 and 25 January, the regional stage of the All-Russian Olympiad in Physics for school students (grades 9–11) and the J. C. Maxwell Olympiad (grades 7–8) took place. The winners and prize-winners in the regional stage were students of the Interschool Physics and Mathematics Open Classroom (grades 6, 8, and 10).

In May and September, the Dubna Interschool Physics and Mathematics Open Classroom ran the XXIX and XXX Open Olympiads in Physics and Mathematics.

School students of grades 10–11 attended the organised classes in Experimental Physics and preparation for the State Exam in Physics held in the Kadyshevsky Lyceum.

33rd International Computer School. On 1–13 August, the JINR Library hosted the 33rd International Computer School. Under the guidance of mentors, 23 participants from Dubna and other cities carried out projects in Physics, Mathematics, and Informatics.

First Graduation from Yandex.Lyceum in Dubna. On 26 June, 21 Dubna school students were awarded certificates of successful completion of a two-year Yandex.Lyceum programme. Classes at Yandex.Lyceum in Dubna are held as additional training and supported by JINR. The first-year study group 2021–2022 was formed according to the results of an open competition that started in August among students of grades 8–9.

Science School for Students of the School University of Egypt. On 6 September, the Science School for Students of the School University of the Egyptian Academy of Scientific Research and Technology (ASRT) began its work. Fourteen students of the ASRT School University aged 13–16 arrived in Dubna to participate in the event.

The programme of the School included the attendance of the interactive exhibition dedicated to the 65th anniversary of the Institute and visits to FLNR, VBLHEP, and LRB. The staff members of the Institute introduced the participants to the stages of the nuclear physics experiment and demonstrated how the most important equipment for detecting, collecting, and processing information works in practice.

Lectorium. Within the framework of the JINR UC Lectorium, lectures by JINR scientists were organised for schoolchildren and undergraduate students. Lectures for schoolchildren "S'COOL science" were held both offline and online. Offline, 9 lectures were read to 320 schoolchildren and students at different sites in Dubna. As part of the Virtual Science Camp, online lectures were delivered for 100 students from 4 educational institutions of Russia and 122 students from 27 countries (Austria, Azerbaijan, Belgium, Bulgaria, Czech Republic, France, Germany, Great Britain, Greece, India, Iran, Ireland, Italy, Jordan, Luxembourg, Mexico, North Macedonia, Portugal, Romania, Russia, Singapore, Slovakia, Spain, Sri Lanka, Switzerland, Turkey, USA).

As part of the Marathon "JINR Visiting Schools in Dubna", JINR specialists visited 14 educational institutions of the city and demonstrated experiments, gave lectures and video tours for 4883 students representing 70% of Dubna schoolchildren.

In June, at the Sirius Educational Centre, a live stream of lectures by JINR scientists and Q&A sessions with the listeners were organised. The streams of the lectures are available on social networks in JINR groups on VKontakte and Facebook.

New Knowledge Festival STEAM FEST. In 2021, the Festival of New Knowledge STEAM FEST for schoolchildren was held online. For two weeks in February, participants were immersed in science, technology, engineering, art, and mathematics. The main participants of the STEAM FEST 2021 were representatives of Nizhnevartovsk, Muravlenko, Blagoveshchensk (Republic of Bashkortostan). In three thematic blocks of the Festival, JINR representatives introduced schoolchildren to the NICA project, data analysis system and held a master class on electronics development.

JINR and the Project "Bolshaya Peremena". FLNR, FLNP, and MLIT staff members delivered online lectures for Russian school students as part

of the project “Bolshaya Peremena” (a project of the presidential platform “Russia — the Country of Opportunities”), thus having opened a thematic week dedicated to nuclear technologies. The lecture programme of JINR speakers covered areas of ecology, IT technologies, and the limits of the Periodic Table. In the first days after streaming, each lecture got more than 8 thousand views, and this number keeps growing. The video streams of the lectures are available in the Bolshaya Peremena community: https://vk.com/bpcontest.

JINR as a Participant of the All-Russian Marathon. JINR took part in the national Marathon “Science Is Near”, which started on 11 June all over the country as part of the Year of Science and Technology. The programme included lectures and excursions to the laboratories of the leading universities and scientific centres of the country. The main goal of the All-Russian Marathon is to introduce the wide audience to scientists and their work recognised in Russia and abroad. The organisers of the Marathon were ANO “National Priorities”, the Russian Society “Znanie”, the All-Russian Science Festival “Nauka 0+”, ANO “Bolshaya Peremena”, and the Coordination Council for Youth Affairs in the Sphere of Science and Education under the Presidential Council for Science and Education. On 11 June, the University Centre organised a live-streamed excursion to the accelerator complex of the NICA megascience project for the Marathon participants.

Visits. In 2021, introductory visits were organised for students of grades 12–13 of the non-state educational private institution “British International School” (Moscow), as well as for participants of the project “Hello, Russia!” and participants of the physics forum that took place at MIPT as part of the All-Russian Student Olympiad “I Am a Professional”.

Training of Specialists and Skill Improvement. To improve the certification procedures for employees of organisations supervised by Rostekhnadzor, the Federal Environmental, Industrial and Nuclear Supervision Service developed a Central Testing Portal in industrial safety, safety of hydraulic structures, and safety in the electric power industry. According to the new requirements, testing of personnel responsible for the operability and safety of equipment was organised in the University Centre computer class.

Two hundred and forty-two JINR employees, including executives, engineers and technicians, attended the advanced training courses and were certified by the Central Attestation Commission of the Institute for regulatory legal acts and regulatory technical documents that establish industrial safety requirements in various branches of supervision, and by the Territorial Attestation Commission of the Central Department of Rostekhnadzor. For 49 JINR workers, training courses for personnel maintaining facilities subordinate to Rostekhnadzor were organised. Eighty-five employees were trained in the basics of fire safety. Internships at JINR were organised for 36 students of colleges and technical schools.

Sixty JINR staff members were enrolled in the English language course. Specialists of the DLNP Design Department continued their studies of English. English classes were organised for the staff members of the Legal Department and the Accounting Department of JINR.

JINR UC in Social Networks. The UC communities created on social networks in 2019 are regularly updated with the latest information on the upcoming events. In 2021, all UC channels on VKontakte, Facebook, Instagram, YouTube were renamed from “Dubnium” to “jinr_uc”.

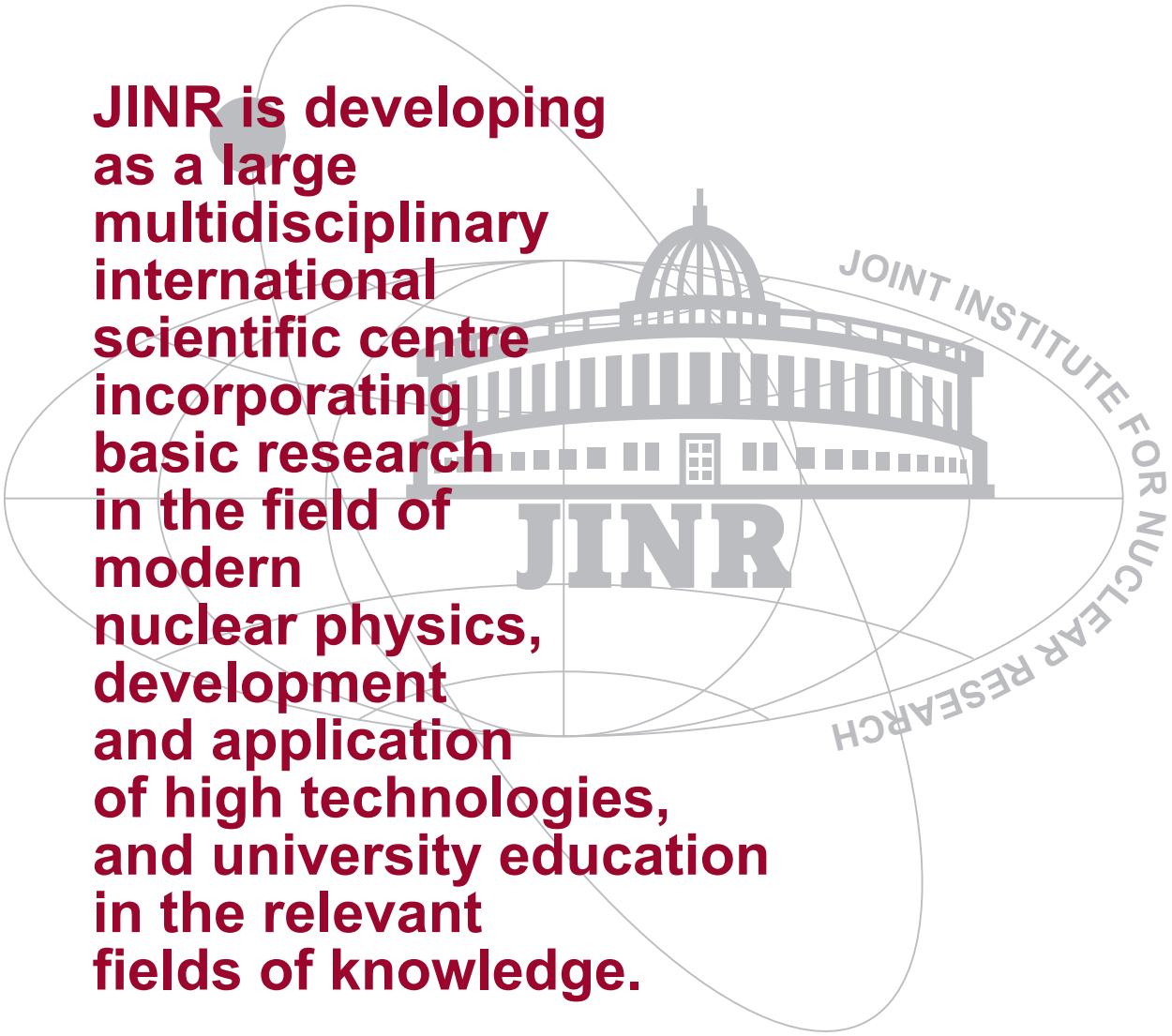
JINR Information Materials and Promotional Merchandise. The Social Communications Group develops design and content for the production of information materials, brochures, and souvenirs. All promotional products are distributed at the UC events, in the JINR information centres, among schoolchildren and students.

Video Materials. To update the video content of the outdoor digital billboard located at the JINR Scientists’ Club, the staff members of the UC Social Communications Group (SCG) made and uploaded 44 videos about JINR and Dubna. Information kiosks — “Infoguides” — are being updated with 104 previously filmed and edited videos. Many events run by the SCG are covered in videos. Nineteen videos were made on request.

JINR Textbooks. The JINR Publishing Department issued two new textbooks for undergraduate and postgraduate students specialising in nuclear physics:

- “Physics of Heavy Ions and Its Applications” by Yu. Ts. Oganessian, Yu. E. Penionzhkevich and V. A. Grigoriev;
- “Relativistic Nuclear Physics” by A. I. Malakhov.

JINR is developing as a large multidisciplinary international scientific centre incorporating basic research in the field of modern nuclear physics, development and application of high technologies, and university education in the relevant fields of knowledge.



The building of the Bogoliubov Laboratory of Theoretical Physics
that celebrated in 2021 the 65th anniversary of its foundation

Dubna, 27 March.
The ceremonial inauguration
of the memorial plaque
on the occasion of renaming one of Dubna
streets in memory of Academician D. Shirkov

The Bogoliubov Laboratory of Theoretical Physics, 11–14 October. International Conference “Advances in Quantum Field Theory”

The Bogoliubov Laboratory of Theoretical Physics, 12–17 July. The International Conference "Low-Dimensional Materials: Theory, Modeling, Experiment" (LDM2021)

The Bogoliubov Laboratory of Theoretical Physics, 17 December.
A festive seminar dedicated to the 80th anniversary of JINR Scientific Leader Academician V. Matveev

The Veksler and Baldin Laboratory of High Energy Physics, 23 March.
A part of the solenoid magnet's transport container was removed in the pavilion of the MPD experiment

The Veksler and Baldin Laboratory of High Energy Physics, 19–20 April.
Participants of the 7th Collaboration Meeting on the BM@N Experiment at the NICA Facility

The Veksler and Baldin Laboratory of High Energy Physics, 21–23 April.
The 7th Collaboration Meeting on the MPD Experiment at the NICA Facility

Dubna, 26 March. Ambassador Extraordinary and Plenipotentiary of the Federal Republic of Germany to the Russian Federation G. A. von Geyr (centre) and accompanying persons on an excursion at VBLHEP

The Veksler and Baldin Laboratory of High Energy Physics, 29 July. Superconducting solenoid of the MPD detector of the NICA accelerator complex was installed in the standard position

Dubna, 17 June. Presentation of the Laboratory of Electronics and Microprocessor Technologies established under JINR support and with active participation of specialists of the VBLHEP Accelerator Department on the basis of the International Engineering School of Dubna State University

The Veksler and Baldin Laboratory of High Energy Physics, 10 August.
A group of JINR young scientists and specialists who have received housing certificates of social mortgage

Dubna, 15–16 September. The International Round Table on Applied Research and Innovations at NICA

Alushta (Crimea), 26 September – 2 October. The 27th Russian Particle Accelerator Conference (RuPAC-2021)

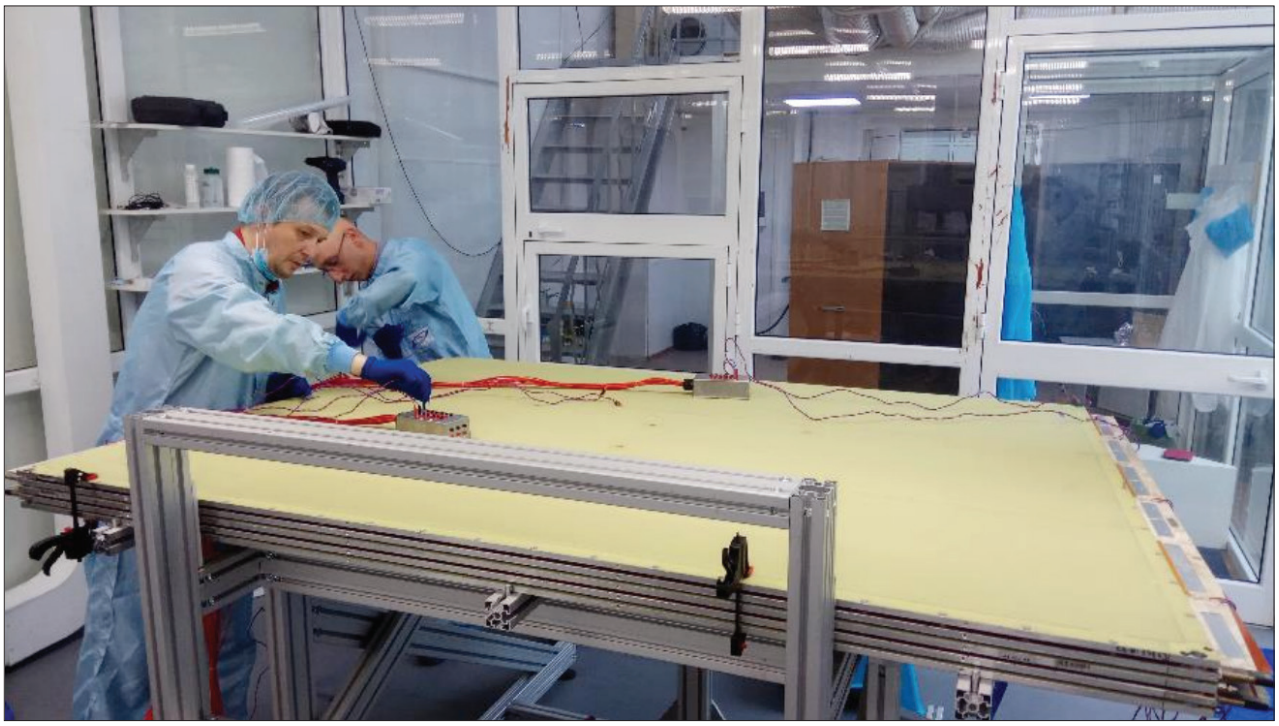
The Veksler and Baldin Laboratory of High Energy Physics, 25 October.
A meeting of the representatives of the general contractor of the NICA project STRABAG
and the leaders of JINR

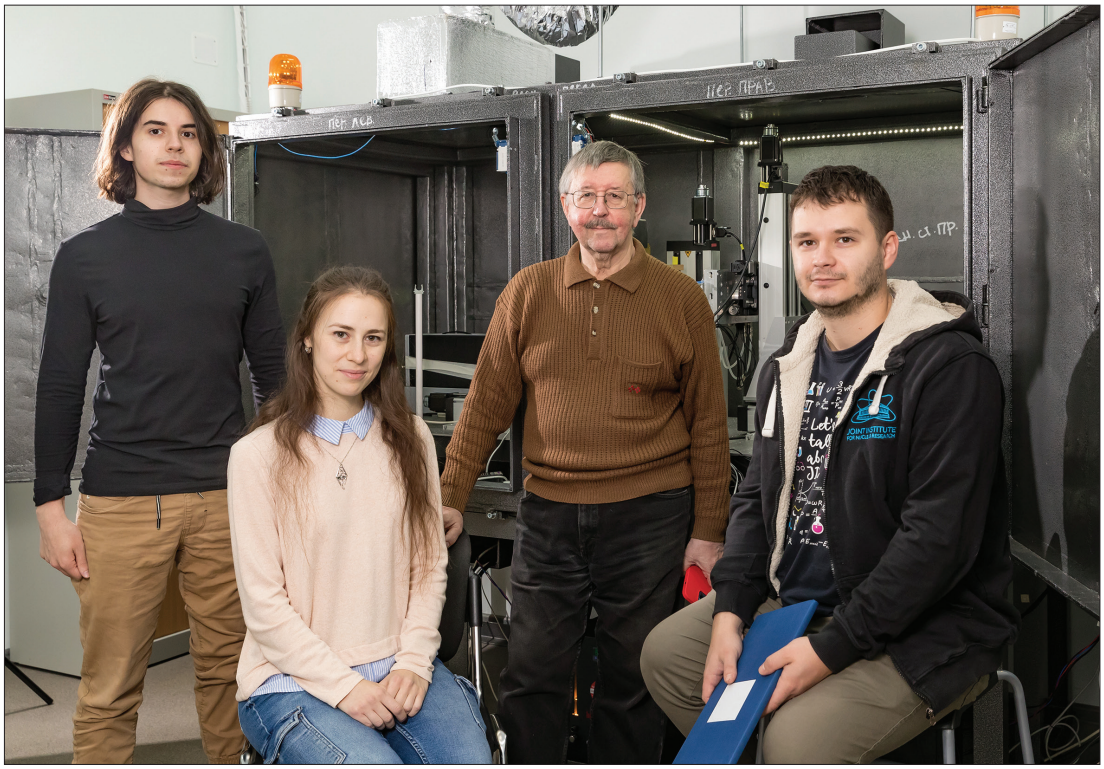
The Veksler and Baldin Laboratory of High Energy Physics, 28 December.
The first superconducting magnet was installed in the tunnel of the NICA collider

The Baikal, 13 March. The ceremonial launch of the largest in the Northern Hemisphere deep underwater neutrino telescope Baikal-GVD and signing of the Memorandum of Understanding by the RF Ministry of Science and Higher Education and JINR on the development of the Baikal deep underwater neutrino telescope (*photo by B.Shaibonov*)

The Dzhelepov Laboratory of Nuclear Problems. The muon group at the production site

The Dzhelepov Laboratory of Nuclear Problems.
Assembly of detectors based on the MicroMegas technology for the ATLAS New Small Wheel upgrade project





The authors of the patent for the invention “A Method for Measuring the Intensity of Radiation of Unidentified Composition” are employees of DLNP: D. Rastorguev, E. Cherepanova, G. Shelkov, V. Rozhkov

Head of the Laboratory of Low-Background Research of BNO INR RAS A. Gangapshev and SMGC DLNP researchers M. Zarubin, K. Tarasov, E. Kravchenko in the cross passage at a distance of 4200 m away from the entrance (*photo by M. Zarubin*)

Moscow, 11 June. The title of Honorary Doctor of the NRC "Kurchatov Institute" is conferred on Scientific Leader of FLNR Academician Yu. Oganessian at a meeting of the NRC KI Scientific Council

Paris, 15 November. Presentation of the UNESCO–Russia Mendeleev International Prize in the Basic Sciences to Academician Yu. Oganessian


JOINT INSTITUTE FOR NUCLEAR RESEARCH
INTERNATIONAL INTERGOVERNMENTAL ORGANIZATION
SCIENCE BRINGING NATIONS TOGETHER
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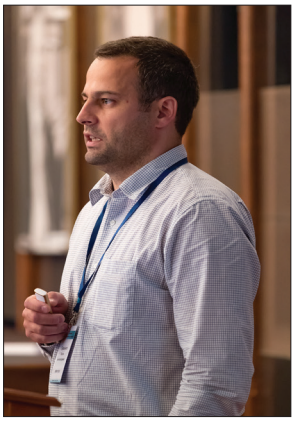
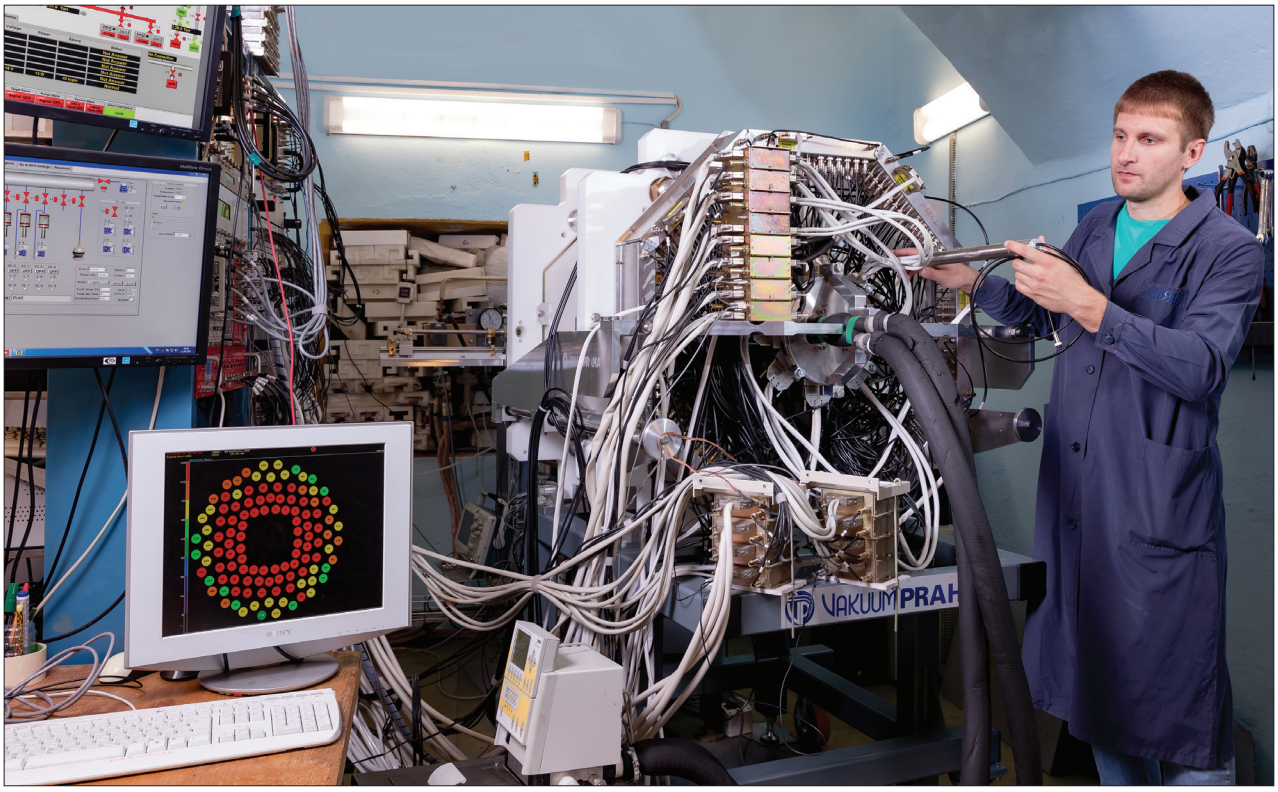
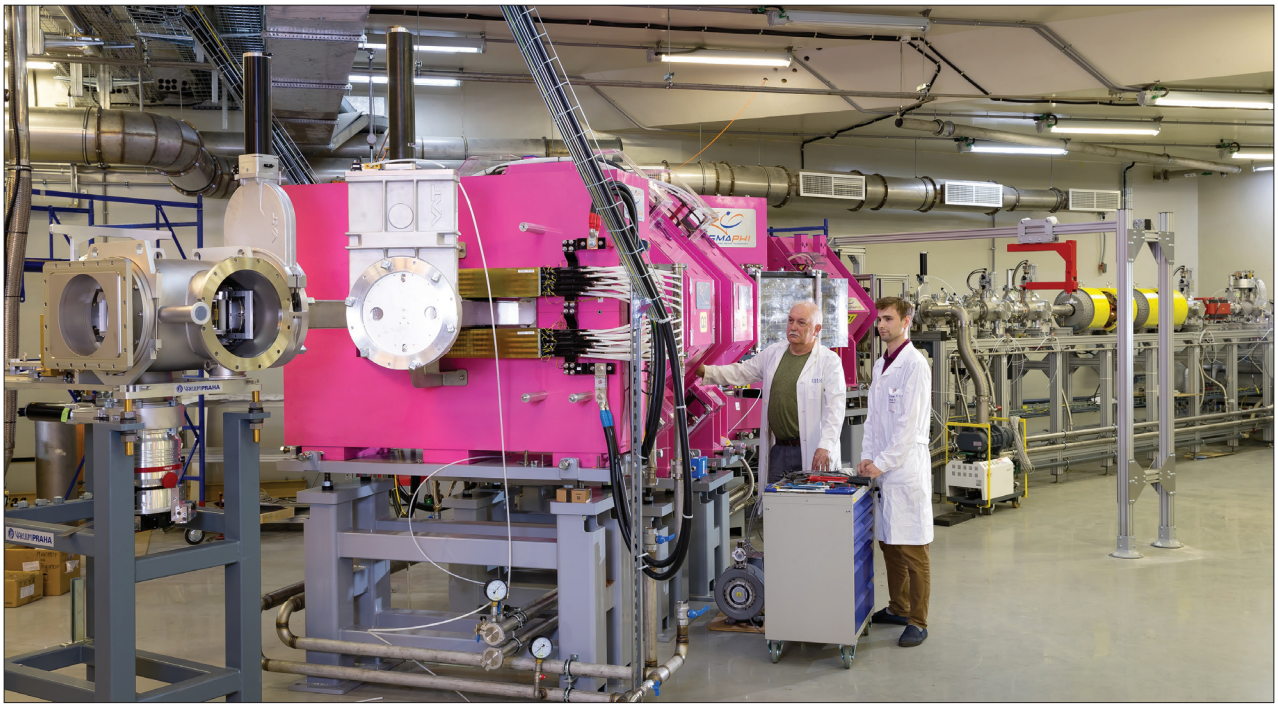


Dubna, 30 June – 2 July. The international meeting “Superheavy Elements” as part of the meeting of the RAS Council on Heavy Ion Physics



The Flerov Laboratory of Nuclear Reactions. The SFiNX detector system of the SHELS separator for studies of the properties of the spontaneously splitting short-lived nuclei obtained in reactions with heavy ions

The Flerov Laboratory of Nuclear Reactions.
The final adjusting of the setup DGFRS-3 at the Factory of Superheavy Elements

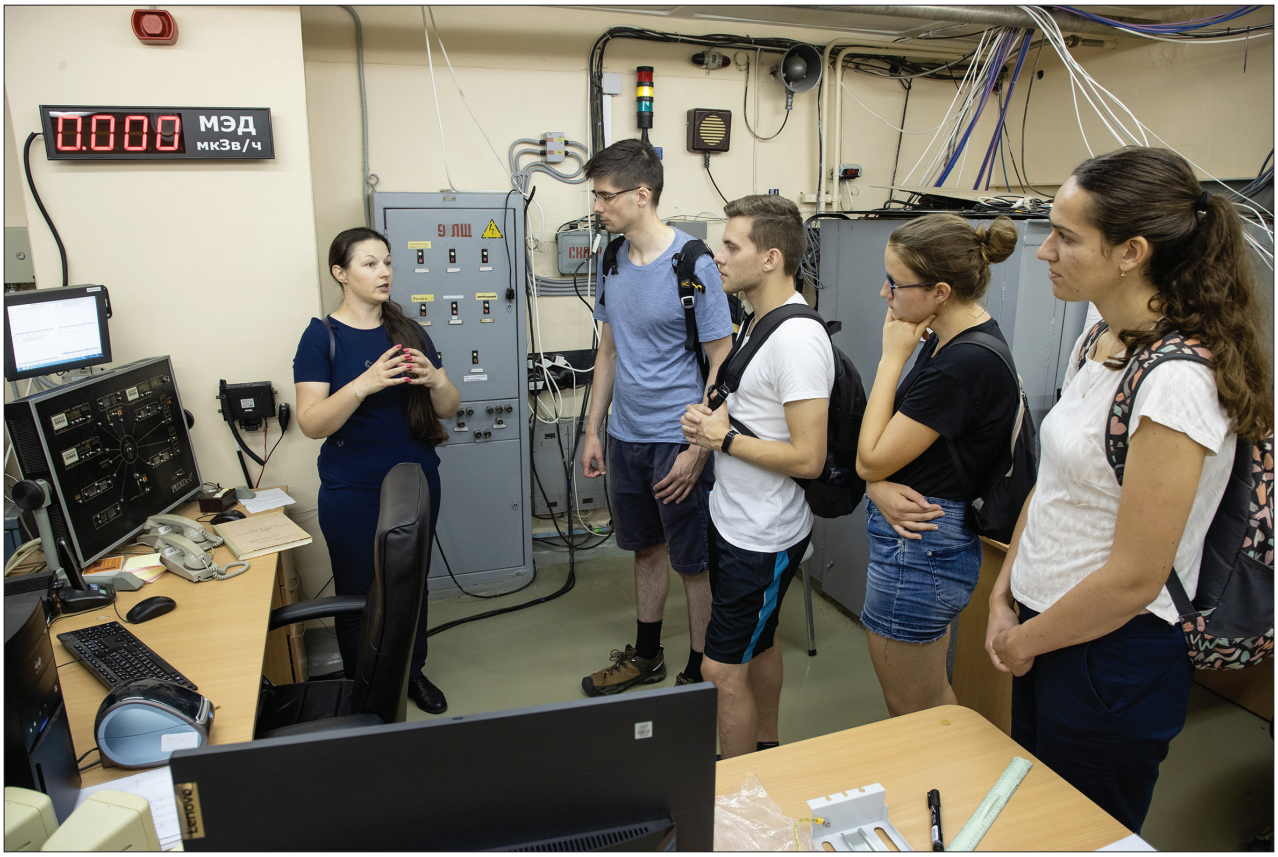


The Flerov Laboratory of Nuclear Reactions, 29 October. EU Ambassador to the Russian Federation M. Ederer (3rd from left) accompanied by Plenipotentiary Minister, Head of Science and Technology of the EU Delegation to the Russian Federation L. Bochereau (2nd from right) on an excursion at JINR

The Flerov Laboratory of Nuclear Reactions, 9 November. A visit to JINR of a delegation of the Embassy of the United Mexican States in the Russian Federation headed by Ambassador N. B. Pensado Moreno (centre)

Dubna, 22 September. Solemn opening of the monument to I. M. Frank and F. L. Shapiro near the building of the Frank Laboratory of Neutron Physics

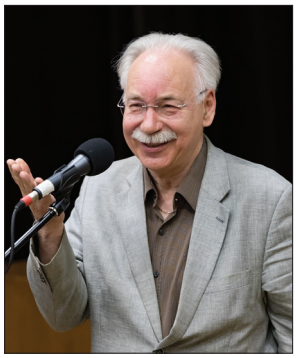
Yekaterinburg, 27 September – 1 October.
Participants of the Conference “Neutron Scattering in Condensed Matter Research” (RNIKS-2021)

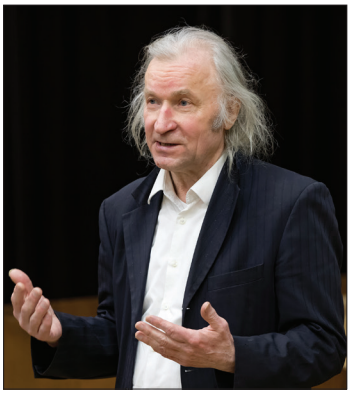


The Frank Laboratory of Neutron Physics, August. Participants of the summer student practice are acquainted with the operation of the pneumatic REGATA setup at the IBR-2 reactor

The Frank Laboratory of Neutron Physics, 10 November.
RAS Vice-President, Director of the Institute of Archaeology of RAS N. Makarov on an excursion at JINR

The Frank Laboratory of Neutron Physics. Equipment examination of the EG-5 accelerator





The Meshcheryakov Laboratory of Information Technologies, 24–25 May. Workshop on Computer Algebra

The Meshcheryakov Laboratory of Information Technologies, 5–9 July. The 9th International Conference "Distributed Computing and Grid Technologies in Science and Education" (GRID'2021)

St. Petersburg, 24 September. Signing of the agreement on uniting three supercomputers, including the "Govorun" supercomputer, into the single National Research Computer Network of Russia

Dubna, 23 July. Meeting of President of the Academy of Scientific Research and Technology of Egypt M. Sakr (foreground, right) and Vice-President G. El-Feky with the leadership of the Meshcheryakov Laboratory of Information Technologies

LRB Director A. Bugay presents the Strategic Programme of Innovative Radiobiological Research at JINR

The Laboratory of Radiation Biology. Analysis of chromosome aberrations in human lymphocytes with mFISH method

The Laboratory of Radiation Biology. Staff members of LRB conduct an experiment at the X-ray irradiator of cell cultures CellRad

Publications issued by the JINR Publishing Department in 2021

2021

CENTRAL SERVICES

PUBLISHING DEPARTMENT

In 2021, the Publishing Department issued 56 titles of publications and 91 titles of official documents.

The Proceedings of the XXVIII International Seminar on Interaction of Neutrons with Nuclei (ISINN-28), the abstracts of papers of the VIII Congress on Radiation Research, the Book of Abstracts of the Fifth International Conference dedicated to N. W. Timofeeff-Ressovsky and his scientific school "Modern Problems of Genetics, Radiobiology, Radioecology, and Evolution" were published.

On the occasion of the jubilee of JINR Scientific Leader V. A. Matveev, the book "Viktor Anatolievich Matveev: On His 80th Birthday" was issued.

In the series "Educational and Methodical Manuals of the JINR University Centre", the following publications were issued: "Heavy Ion Physics and Its Applications" by Yu. Ts. Oganessian, Yu. E. Penionzhkevich, V. A. Grigoriev, "Relativistic Nuclear Physics" by A. I. Malakhov, "Introduction to Experimental Nuclear Physics and Nuclear Electronics", volume 1 (in English) by I. Vankov, D. Kamanin, and Yu. Panebrattsev.

The JINR Annual Report for 2020 (Russian and English versions) and the JINR Long-Term Development Strategic Plan up to 2030 and beyond (in Russian and English) were published.

In 2021, six issues of the journal "Physics of Elementary Particles and Atomic Nuclei" (brief name "Particles and Nuclei") that included 89 papers came out. Issue 2 comprises the Proceedings of the seminar "Search for Beauty: From Condensed Matter to Integrable Systems" dedicated to the memory of V. B. Priezzhev (Dubna, 10 September 2019). Issue 4 contains materials of the Conference "RFBR Grants for NICA" (Dubna, 20–23 October 2020). Seven issues of the journal "Physics of Elementary Particles and Atomic Nuclei, Letters" (brief name "Particles and Nuclei, Letters") that included 94 papers were published.

The information bulletin "JINR News" was continued to be published in Russian and English.

Fifty issues of the JINR weekly newspaper "Dubna: Science, Cooperation, Progress" were published in 2021. In the series "Library of Weekly Newspaper 'Dubna'", two booklets were issued: "Stories" by G. Levin and "Conversations with Scientists: About Physics, about Life and about Themselves".

In the framework of exchange of scientific publications, the organizations in over 40 countries of the world that cooperate with JINR received the following JINR publications: JINR preprints and communications, the information bulletin "JINR News", JINR Annual Reports, the journals "Particles and Nuclei" and "Particles and Nuclei, Letters".

The Publishing Department forwarded 73 papers and reports on the results of research conducted by JINR scientists to the editorial boards of journals, to various conferences, symposia, meetings and schools held both in the JINR Member States and in other countries. Papers by JINR staff members were submitted to the journals "Nuclear Physics", "Bulletin of the Russian Academy of Sciences: Physics", "Instruments and Experimental Techniques", "Nuclear Physics and Engineering", "Crystallography", "Journal of Surface Investigation. X-ray, Synchrotron and Neutron Techniques", and other periodicals.

To keep readers of the Science and Technology Library (STL) timely informed about new publications received, express bulletins of STL are issued by the Publishing Department. "The Bibliographic Index of Papers Published by JINR Staff Members in 2020" was issued. Publication of express bulletins of the Licensing and Intellectual Property Department was continued.

The Publishing Department continued uploading the periodical and nonperiodical publications issued at JINR in the database of the Russian Science Citation Index (RSCI) on the platform of Scientific Electronic Library.

The Publishing Department fulfilled numerous orders to produce photo posters and poster presentations of the Institute's staff members for submission to conferences and workshops.

At the request of the laboratories and other departments of JINR, the Publishing Department performed binding services and photocopying of scientific-technical and engineering-design documentation. Over 130 thousand various forms were printed.

The following new equipment for bookbinding and for poster printing was purchased: a machine for cutting metal springs and an archival bookbinding system, as well as a new large-format printer.

SCIENCE AND TECHNOLOGY LIBRARY

In 2021, the JINR Science and Technology Library (STL) rendered services to 2000 readers. An electronic loan system has been implemented. 2484 copies of publications were given out. As of 1 January 2022, the library stock amounted to 431 927 copies, 195 197 of them being in foreign languages. 179 publications ordered by readers were received via the interlibrary loan system. 54 requests from other libraries were completed. On the whole, the library received 1721 copies of books, periodicals, preprints and theses from all acquisition sources, including 559 publications in foreign languages. All the new publications were registered in the central catalogues, branch catalogues and in the information system "Absotheque".

142 issues of the express bulletins "Books", "Articles", "Preprints" were published including 6496 titles. Electronic versions of the bulletins are available on the page "New Acquisitions" of the JINR STL website and are distributed among 100 addresses via e-mail. Subscription is available via the Scientific Library website in the section "Services" http://lib.jinr.ru/ntb_mail/newslist.html. The exhibitions of new acquisitions of books, preprints, periodicals and theses were arranged regularly, where 1311 publications were displayed. Eight topical exhibitions were organized.

The electronic catalogues of books, journals, articles, preprints and theses are accessible in Internet at the address: http://lib.jinr.ru:80http://lib.jinr.ru:8080/OpacUnicode/80/OpacUnicode. The total number of requests to the electronic catalogues was 15 500. In the electronic catalogue in the personal account the readers can order requested literature and look through their reader's register forms.

"The Bibliographic Index of Papers Published by JINR Staff Members in 2020" (1459 titles) was prepared by the JINR STL and published by the JINR Publishing Department. The Index is available on the Library website in the section "Services" http://lib.jinr.ru/buk/2020/bibl_uk.php. One biobibliographic index has been prepared. The database of papers of JINR scientists is Internet accessible.

3414 JINR preprints and communications have been scanned and added to the electronic catalogue.

The STL received 100 titles of periodicals. Due to the Library subscription to the foreign journals, JINR scientists have access to full-text electronic versions of these journals.

Scientific Electronic Library is used by our readers very actively. The total number of requests to the electronic journal versions through Scientific Electronic Library and sites of foreign publishing houses was 150 000. Due to the national electronic subscription of the RFBR, JINR scientists are provided with the electronic access to the full-text versions of journals of the following publishing houses: Elsevier, Springer, American Physical Society, American Institute of Physics, Wiley, IEEE Digital Library, as well as journals "Nature", "Science" and information retrieval databases Web of Science and Scopus.

Within the framework of the project "History of JINR and Dubna in Books, Journals and Central Newspapers", 91 new bibliographic records have been introduced. The information system "Literature about JINR Scientists" (994 records) was put into service which is available on the page of the site of JINR STL "Publications about JINR" http://who-is-who.jinr.ru/catalog3/main.html.

In 2021, in exchange for JINR publications printed by the JINR Publishing Department, the Library received 287 publications from 10 countries. Among them 19 issues were from Russia, 10 from Romania, 5 from Ukraine, 206 from Germany, 3 from France, 10 from Japan, and 10 from CERN.

In 2021, within the framework of the information system "Absotheque", the input of documents to electronic catalogue was for: books — 514 titles, journals — 1647 numbers, preprints — 2536 titles, theses and author's abstracts — 130 titles, book articles — 248 titles, and journal articles — 6360 titles.

As of 1 January 2022, the total number of records in the information system "Absotheque" was 329 941.

On requirements of the JINR Directorate, briefing notes and statistics of indicators of publications activity of JINR scientists and their coauthors from

other countries and organizations with the usage of Web of Science, Scopus, RSCI have been prepared.

Bibliometric Factors of Publication Activity of JINR Staff Members (by Web of Science Database on 27.01.2022)

JINR publication statistics in 2020 was as follows:

- Total number of publications: 1 108;
- Total number of citations: 1 201;
- Excluding self-citations: 979;
- Average citations per article: 1.08;
- h-index: 12.

Joint publications of JINR authors and authors from different countries are presented in Tables 1–3.

Table 1. Joint publications with authors from JINR Member States

State *	Number of publications
Armenia	147
Azerbaijan	122
Belarus	192
Bulgaria	152
Cuba	34
Czech Republic	289
Egypt	105
Georgia	150
Kazakhstan	51
Moldova	15
Mongolia	71
Poland	312
Romania	202
Slovakia	152
Ukraine	167
Uzbekistan	39
Vietnam	19

* In alphabetical order.

Table 2. Joint publications with authors from JINR Associate Members

State *	Number of publications
Germany	421
Hungary	205
Italy	326
Serbia	161
South Africa	124

* In alphabetical order.

Table 3. Joint publications with authors from other states and regions

State / Region *	Number of publications	State / Region *	Number of publications
USA	368	Latvia	74
China	331	Slovenia	73
France	298	Lithuania	72
England	296	Ireland	71
Turkey	253	Morocco	71
Switzerland	236	Cyprus	70
India	228	Ecuador	70
Brazil	221	Estonia	70
Austria	190	New Zealand	69
Sweden	190	Malaysia	68
Spain	188	Qatar	67
Greece	185	Montenegro	54
Netherlands	181	Sri Lanka	52
Taiwan	169	Kuwait	40
Pakistan	168	Palestine	40
Japan	164	Indonesia	32
Portugal	161	Peru	32
Thailand	154	UAE	31
Australia	150	Philippines	21
Colombia	145	Saudi Arabia	21
Croatia	126	Lebanon	3
South Korea	124	Uruguay	3
Finland	123	Venezuela	3
Norway	122	Algeria	2
Mexico	117	Iraq	2
Denmark	110	Tajikistan	2
Chile	106	Wales	2
Canada	104	Iceland	1
Belgium	98	Madagascar	1
Scotland	92	North Ireland	1
Israel	83	North Macedonia	1
Iran	76	Oman	1
Argentina	74	Sudan	1

* In order of decreasing number of publications.

LICENSING AND INTELLECTUAL PROPERTY DEPARTMENT

In 2021, the activities of the Licensing and Intellectual Property Department (LIPD) were conducted in the following areas.

Industrial Intellectual Property Protection. In this area, in cooperation with the Federal Institute of Industrial Property (FIIP) of the Federal Service of the Russian Federation for Intellectual Property (Rospatent), work was done on applications for JINR patents that had undergone the formal FIIP expertise of Rospatent in 2020–2021. Arrangements were done; changes, alterations and clarifications were agreed upon and included into the application documents according to the comments rendered by FIIP experts. Expert evaluation was conducted of a number of project elaborations of JINR staff members for the purpose of patentability that included objects of legal protection and their classification according to the International Patent Classification (IPC); analogues and prototypes were searched.

For eleven elaborations, in collaboration with the authors, packages of submission documents were prepared and forwarded to RF Rospatent for patents on inventions:

— "Laser inclinometer for long-term recording of earth surface angles" by Yu. Budagov, M. Lyablin;

— "Method for determining the presence of a genetic predisposition to longevity" by A. Ivanova, E. Kravchenko;

— "Method for analyzing atomic composition of dispersed powder materials" by V. Shalyapin, S. Tyutyunnikov, V. Artyukh;

— "Mechanical neutron beam filter with the time focusing" by V. Sadilov, V. Bodnarchuk;

— "Laser inclinometer" by Yu. Budagov, M. Lyablin;

— "Method for measuring intensity of radiation of unknown composition" by G. Shelkov, D. Rastorguev, V. Rozhkov, E. Cherepanova;

— "Frame for superconducting solenoid" by M. Novikov, G. Khodzhibagiyan, M. Zaslavsky;

— "The device for forming a sawtooth voltage on capacitor" by S. Dolya, V. Smirnov;

— "Method for measuring the probability of absorption of neutrons during their sub-barrier reflection from a surface and a structure for its implementation" by Yu. Nikitenko;

— "Device for modelling mixed radiation fields at high-energy heavy-ion beams for experimental radiobiology fields" by G. Timoshenko, I. Gordeev;

— "Scintillation detector" by S. Afanasiev, A. Boyarintsev, A. Golunov, I. Golutvin, N. Gorbunov, B. Grinev, Yu. Ershov, A. Malakhov, E. Sukhov, V. Smirnov, V. Ustinov.

In 2021, 12 sets of application documents for obtaining new patents for inventions were prepared and sent to the FIIP for formal examination.

As of 1 January 2022, JINR is the copyright holder of 83 RF patents for invention in force.

Eight computer programs were registered in Rospatent: "Dosimetric control system at IBR-2 reactor" by S. Murashkevich; "Program for collection, analysis, and visualization of experimental data Romana" by Yu. Kopach; "Programme for controlling the parameters of the proton beam Beam Control" by G. Mitsyn, K. Shipulin, A. Molokanov; "Program for experimental data processing QA tools" by K. Shipulin; "Program for controlling bolus verification device Bolus Verification" by K. Shipulin; "Program for automatic verification of the position of the patient in radiotherapy Verify Treat" by K. Shipulin; "Program for proton irradiation simulation in heterogeneous tissues" by K. Shipulin, G. Mitsyn; "Program for organizing and storing photos. JINR Electronic Photo Archive" by V. Borisovsky, B. Starchenko, O. Belov, N. Bogoliubova, E. Goryachkin, A. Gushchin, A. Zorin, L. Kuchugurnaya, R. Titov, T. Tyupikova, O. Tyapkina, I. Shcherbakova, D. Usov.

The database "JINR Digital Photo Archive" by B. Starchenko, V. Borisovsky, O. Belov, N. Bogoliubova, E. Goryachkin, A. Gushchin, A. Zorin, L. Kuchugurnaya, R. Titov, T. Tyupikova, O. Tyapkina, I. Shcherbakova, D. Usov is registered in Rospatent.

As of 1 January 2022, JINR is the copyright holder of 19 registered programs and databases.

Patents and Information. In 2021, 36 issues of the Rospatent bulletin "Inventions. Utility Models" were received in electronic form at JINR. The information published in the bulletin was processed according to JINR topics. The processing results were presented in 12 issues of the LIPD bulletins "Patents", which were sent to subscribers of the Institute both in electronic and paper format. The electronic database of LIPD bulletins is also available on the department website (https://oliis.jinr.ru/).

Information lists of LIPD are produced on obtaining new patents by the Institute and state registration of objects of industrial intellectual property. This information is regularly included in the chapter "Patents" on the JINR website (http://www.jinr.ru/posts/category/patents-ru/). Full information about JINR patents and programs is available on the website of the department (https://oliis.jinr.ru/index.php/patentovanie-2/patenty-programmy-otkrytiya). The LIPD page on the JINR website is updated (https://oliis.jinr.ru/).

Standardization. Standard library was supplemented: 12 new intergovernmental and state RF standard documents (GOSTs), 3 GOST directories and 12 standard information directories (SID) for 2021; technical conditions, guidelines, recommendations and regulations issued in 2021. The newly adopted technical regulations of the Russian Federation have been purchased in the quantity necessary for the work of the divisions. More than 40 alterations were introduced into relevant documents of the standard library files and subscribers' copies. Fourteen GOST official copies were distributed in departments for permanent use.

The database and automatic search for norm documents (NDs), which is in the collection of the LIPD library, was updated. The access is supported to the database of the standards library that contains about 11 000 positions on the LIPD internet page.

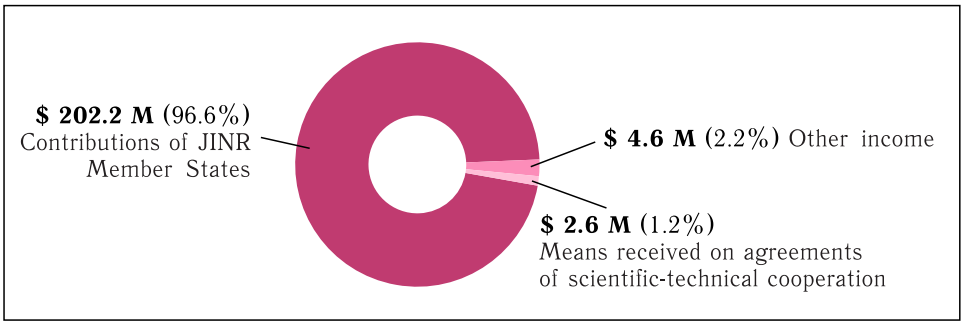
Information on technical regulations in force in Russia, intergovernmental standard documents (GOST), Russian National Standard (GOST R) and other regulatory and technical documentation in force at the Joint Institute for Nuclear Research were updated.

2021

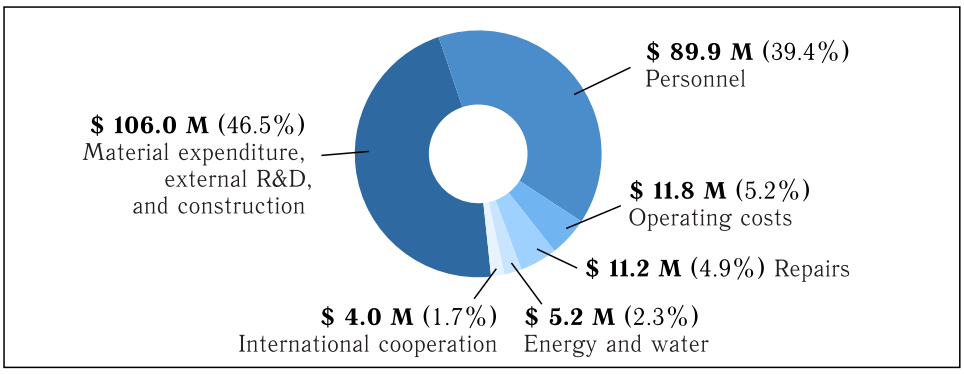
ADMINISTRATIVE ACTIVITIES

FINANCIAL ACTIVITIES

Execution of the JINR budget in 2021 in incomings in total **209.4 million US dollars:**



Execution of the JINR budget in 2021 in expenditure in total **228.1 million US dollars:**



Scale (in %) of contributions of JINR Member States in 2021

State	%	State	%
Republic of Armenia	0.12	Republic of Moldova	0.09
Republic of Azerbaijan	0.36	Mongolia	0.10
Republic of Belarus	0.73	Republic of Poland	5.08
Republic of Bulgaria	0.73	Romania	1.87
Republic of Cuba	0.72	Russian Federation	80.86
Czech Republic	2.57	Slovak Republic	1.36
Georgia	0.16	Ukraine	1.59
Republic of Kazakhstan	1.52	Republic of Uzbekistan	0.52
Democratic People's Republic of Korea	0.21	Socialist Republic of Vietnam	1.41
		Total:	100.00

STAFF

As of 1 January 2022, the total number of the staff members at the Joint Institute for Nuclear Research was 5203 (without temporary staff members).

Working at JINR are: RAS Academicians V. Matveev, I. Meshkov, Yu. Oganessian, M. Ostrovsky, G. Trubnikov, B. Sharkov; RAS Corresponding Members V. Aksenov, L. Grigorenko, D. Kazakov, V. Kekelidze, E. Krasavin, A. Starobinsky, G. Shirkov; Members of other state Academies of Sciences B. Yuldashev, O. Chuluunbaatar; 45 Professors, 28 Assistant Professors, 235 Doctors of Science, and 625 Candidates of Science.

In 2021, 447 people were employed and 459 people were discharged because of engagement period expiry and for other reasons.

AWARDS

For the services for JINR, international cooperation and in connection with the 65th anniversary of JINR, awards of the Moscow Region were presented to 31 staff members; awards of the RF Ministry of Science and Higher Education were presented to 42 staff members; awards of the State Atomic Energy Corporation ROSATOM were presented to 37 staff members; the Honorary Diploma of the Mayor of the Dubna city was awarded to 70 staff members; the JINR Honorary Certificate was awarded to 907 staff members. In total, 1098 JINR staff members were awarded.

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2022-9

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