E9-2003-55

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MATHEMATICAL MODEL OF THE ELECTRONUCLEAR SET-UP ON THE BEAM OF THE JINR SYNCHROTRON

Submitted to «Nuclear Instruments and Methods
in Physics Research, B»

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Introduction

An experimental electro-nuclear set-up SAD containing 354 kg Pu-U fuel MOX and producing several kW of heat on the 660 MeV proton beam of the JINR's phasotron is designed presently in Dubna (some preliminary variants of this set-up are described, for example, in [1]-[3]). The set-up will be ready for experiments in 2 - 3 years. Another, deep-subcritical, assembly "Energy –Transmutation" with a similar central Lead target and about 3081 kg of natural Uranium in the proton beam of JINR accelerator NUCLOTRON with energy of several GeV is already ready in part and is used in experiments [4]. (For brevity this installation will be referred as "DSAD" – Deep-Subcritical Assembly in Dubna which corresponds more exactly to the properties of the set-up). This set-up can be considered as a first step in the planned ADS experiments in Dubna. The International Science and Technology Center has supported these investigations providing 1.5 millions of USA$.

The set-up DSAD provides, in particular, a possibility to measure distributions of heat and intensities of neutron and charge particle fluxes along the leaden target which is important in order to check our calculations of ionization losses and modelling of internuclear cascades. Several codes are used now for such calculations, however, their precision is investigated not enough. The measuring of low- and high-energy neutron spectra also helps to improve the cascade-evaporation model. For cascade calculations it is important to know the total neutron yield in the set-up and the neutrons spectra inside the Uranium blanket at various radii and distances along the primary beam direction. The physicists studying the internuclear cascade theory and the designers of the more powerful ADS SAD need the total energy and spectrum of produced γ-rays. Designers of ADSs are interested also in the dependence of heat and neutron production on the deepness of the gap where the primary proton beam hits the target. Estimations suggest that such a dependence must be rather strong.

The set-up DSAD consists of several identical sections of 10.4 cm length, so the measurements accompanied by theoretical calculations can be done for set-ups with a different number of sections at various proton energies. Since in more powerful ADSs the Lead target, perhaps, will be replaced by a temperature-steady Tungsten target, one must perform the measurements for W target, too.

Finally, the theoretical estimations prompt that neutron yield and ADS heat power increase significantly if a deuteron beam is used instead of a proton one [5, 6]. Preliminary experiments of K.D.Tolstov's group suggested that the neutron yield also increases for high-energy ($E > 1$ GeV/amu) very heavy ions due to a large cross-section of practically total decay of the colliding nuclei into nucleons and light fragments [7, 8]. It would be interesting to test this suggestion using the deuterium and more heavy ion beams of JINR accelerators. We see that one may propose an interesting researh program with ADS DSAD.

On the basis of the CASCADE code [9, 10], developed at JINR, a Monte Carlo model is created for mathematical experiments with various modifications of the set-up DSAD taking into account both the changes of its details (a number of sections and distances between them, inclusion of an additional reflectors and moderators, and so on) and the possible variations of surrounding: changes of dimensions and radiation shielding of the box where the set-up is placed, set-up support etc. The high-energy cross-section are taken from [11, 12], for low-energy - from [13][1]. We trace π^+-mesons up to energy E=2 MeV, protons – up to E=10 MeV. At the lower energies these particles are considered as stopped ones. Low-energy π^--mesons are captured by nuclei and create intranuclear cascades. Neutrons are traced up to $E=2.5 \cdot 10^{-8}$ MeV. However, in media containing hydrogen, as we will see below, much slower neutron must be taken into account. For all discussed below simulations, not less than 10000 internuclear cascades, have been sampled.

In the next chapter the proton irradiation of the Lead target, with and without moderator, is considered as a first stage of the planned experiments, After that we considered second part of the experimental program — the proton irradiation of the two- and nine-section assembly with Uranium blanket. In most cases we consider some middle proton energy E=1 GeV which is used in the first experiments, recalcu-

[1]We are thankful to V. P. Filinova for the help in preparing files of the low-energy data.

lation for a lower or a higher energy can be done by PC Pentium during several hours. The considered parameters of the set-up can be somewhat changed in future experiments (for details see also [4], [14, 15]).

Modelling of experiments for research on the DSAD neutron spallation source

Experiments will be done with a cylindrical lead target of 20 cm length and 4 cm radius [2]. The primary proton beam is injected into the center of the target forwardface. We suppose that it is of needle-shape form (Fig. 1). Table I presents the calculated energy dependence of the neutron yield for the Lead target and for the target covered along all the sides by a 6 cm paraffin or graphite moderator. The contribution of neutron leakage and capture in (n, γ)-reactions is shown. As the set-up weight is not too large, one may use a thin support which is not taken into account in our calculations.

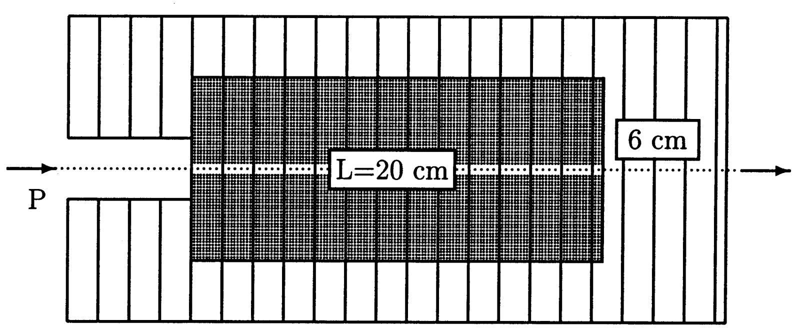

Fig. 1.*Neutron spallation source with moderator.*
By calculations of particle spectra the cylindrical surface has been divided into layers. The proton beam is injected throw a channel into the hutt-end of the Lead slab.

[2]Part of measurements at the energy 1 GeV was already carried out in December 2002 and their results are under studying now. We are thank to prof. I. A. Shelaev for the discussion of the plans of the current and future experiments.

The numbers of neutrons generated in the Lead target and in the targets covered by the moderator increase approximately proportional to proton energy E. At the same time, the specific energy E/N spent for generation of one neutron has a broad minimum around E=1.5 GeV. The calculated values agree with the previously calculated [16]-[19] and measured values (see Table II) for Lead target [3]. However, at E=1 GeV all these values are significantly smaller the value $N_{tot} = 55.9$ calculated in [15]. It seems like, that this value is strongly overestimated.

One should note that in the target with a paraffin moderator the main part (about 70 - 80%) of neutrons are "supercold" with energies smaller 10^{-8} MeV. Such neutrons appear due to multiple collisions with hydrogen and are absent in the considered graphite moderator.

Table I

Neutron yield in the Lead set-ups with and without moderator (neutrons per primary proton with the energy E)

E, GeV:	0.66	1	2	4
Escaped neutrons				
Lead	11.7	16.8	27.1	45.9
Paraff. moderator	10.8	16.1	26.1	43.1
Graphite moderator	12.3	19.0	31.3	51.3
Captured neutrons				
Lead	0.003	0.01	0.019	0.03
Paraff. moderator	0.44	0.64	1.01	1.61
Graphite moderator	0.01	0.01	0.03	0.05
Total yield				
Lead	11.7	16.8	27.2	45.9
Paraff. moderator	11.2	16.7	27.1	44.7
Graphite moderator	12.3	19.0	31.3	51.3

[3]The presented data can be changed somewhat due to influence of the laboratory surrounding, however, Monte Carlo estimations have shown that the charge is at the level of several percent.

Table II
Comparison of the measured and calculated neutron yield in the Lead targets with radius R and length L irradiated by protons with energy E (per primary proton)

R=5.1 cm,	L=61 cm		R=10.2 cm,	L=61 cm
E,GeV	Exper [20, 21]	Theor	Exper [19]	Theor
0.47	8 ± 0.4	6.4	8.7 ± 0.4	6.6
"	6.4 ± 0.3			
0.72	11.8 ± 0.6	12.5	13.9 ± 0.7	13.7
"	11.7 ± 0.4			
0.96	16.6 ± 0.8	18.4	20.3 ± 1.1	20.0
1.47	26.4 ± 1.3	27.4	34.5 ± 1.6	30.0
"	27.5 ± 0.6			

In the limits of statistical errors ($\approx$ 1%) the neutron yield in the targets with a 6 cm graphite moderator is practically the same as in the Lead slab and slowly increases, as one can see in Tables III, with increasing the moderator thickness ΔR: six-time increase of ΔR, from 6 up to 30 cm, passes only about 20% inecreasing of neutron leakage and yield.

Table IV gives the average particle energies and heat produced in the set-ups. We see that the moderator decreases significantly the escaped particle energies, nevertheless, the energies, especially for protons, remain large enough. Paraffin due to the presence of hydrogen nuclei is a better moderator than graphite. The summary energy balance is positive due to (n, γ)-reactions and high-energy fission. At E= 1 GeV the latter gives 30, at E=2 GeV – 50 MeV.

The sources of γ-quanta are (n, γ)-reactions, deexcitation of residual nuclei and decay of π^o-mesons. The latter gives the main contribution. For example, in the Lead set-up this contribution makes up about 60% of the summary energy at E=1 GeV and almost 90% at E=4 GeV. The "nuclear" γ-rays have energies within region of several MeV and lower, but meson decays produce γ-quanta with energy more than 70 MeV and this demands a rather thick radiation shielding.

Table III
Neutron yield in the set-ups graphite moderator
of various thickness
(per primary proton with energy 1 GeV)

ΔR, cm:	10	15	20	30
Escaped neutrons	18.8	19.5	19.8	20.4
Captured neutrons	0.03	0.05	0.07	0.10
Total yield	18.8	19.5	19.9	20.5

Tables V and VI show how the yield and the average energies of the escaped neutrons are distributed along the outer cylindrical surfaces of the Lead set-up and the neutron source with moderator. Since the most detectors have a threshold much higher the energy of "supercold" neutrons, $E < 0.025$ eV, these neutrons are not included in Tables. By calculations the Lead set-up has been divided into 13 layers of 1.5 cm width and the last, the 14-th, layer of 0.5 cm, keeping in mind the width of threshold detectors, which are used for measurements. In the case of the set-up with the moderator the surface has 20 layers of 1.5 cm. Tables also present data for the neutrons escaping the forward, and the backward surfaces.

The Lead set-up empties mainly the particles with energy $E >$0.1 MeV, fluxes of low-energy particles is rather weak. At the same time, as it was mentioned above, a very large share of the neutrons escaping paraffin moderator consists of the low-energy "supercold" particles. Such a part of spectrum is absent in Lead and graphite. However, if the graphite layer is more than 30 – 70 cm, a remarkable number of neutrons with E< 10^{-8} MeV are created, too.

Both particle spectra have maximum of particle intensity, displaced with respect to the other one on ΔZ=6 cm. Energies of the emitted particles increase smoothly to the end of the target because, colliding with target nuclei, the slow cascade particles are scattered, on average, at the large angles than the fast ones.

In the Lead set-up (Table V) almost 20% of all neutrons are emitted from the target hutt-ends, and a half of these particles having the average energy of 59 MeV escape the small central area of forward face with R=0 - 0.5 cm. The most part of protons emitted from the target forward face also escape through this area. Their average energy is about 0.7 GeV. Qualitatively, a similar picture is also observed in the set-ups with a moderator, however, in this case protons have somewhat smaller energies and the "supercold" neutrons are emitted more isotropically.

Table IV
Energy (MeV) of particles generated in the Lead set-ups with and without moderator (per primary proton with energy E)

E,GeV:	0.66	1	2	4
Energy of escaped neutrons				
Lead	117	203	421	839
Paraff. moderator	97	161	340	675
Graphite moderator	120	220	447	879
Energy of escaped charge particles				
Lead	134	288	765	1640
Paraff. moderator	116	261	721	1642
Graphite moderator	94	213	631	1511
Summary energy of γ-rays				
Lead	14	33	98	358
Paraff. moderator	14	34	115	347
Graphite moderator	17	42	139	379

Neutron spectra plotted in Fig. 2 concerns the surface layer at $\Delta Z = 4.5 - 6$ cm where emitted neutron intensity is maximal. The moderators, especially paraffin, increase essentially the low-energy part of spectrum. In this case spectrum has a long, practically constant "tail" with a smooth hump at $10^{-7} - 10^{-8}$ MeV. In this region the difference of intensities in the set-up with paraffin and others is of several orders of magnitude. While increasing the thickness of graphite ΔR, one can observe a gradual transition of neutrons from high to low energies and fast growth of the hump in the left part of their spectrum for $\Delta R > 30$ cm.

Table V
Yield N_n and energy E_n (MeV)
of neutrons escaping the Lead surface
(per primary proton with energy E=1 GeV)

Z,cm	N_n	E_n
0 - 1.5	0.832	6.90
1.5 - 3.0	1.144	7.78
3.0 - 4.5	1.327	9.00
4.5 - 6.0	1.372	9.71
6.0 - 7.5	1.353	10.41
7.5 - 9.0	1.314	11.16
9.0 - 10.5	1.231	11.73
10.5 - 12	1.152	11.88
12 - 13.5	1.068	12.94
13.5 - 15	0.973	12.44
15 - 16.5	0.844	13.34
16.5 - 18.0	0.717	14.13
18.0 - 19.5	0.556	15.87
19.5 - 20.0	0.141	19.12
Backward		
R=0 -4 cm.	1.08	35.03
Forward		
R=0 -4 cm.	1.72	5.63

Table VI

Yield N_n and energy E_n (MeV)
of neutrons escaping the paraffin surface
(per primary proton at E=1 GeV)

Z,cm	N_n	E_n
-6.0- -4.5	0.260	26.42
-4.5- -3.0	0.392	25.06
-3.0- -1.5	0.504	24.07
- 1.5- -0.0	0.664	26.54
0.0-1.5	0.806	27.04
1.5-3.0	0.101	27.96
3.0-4.5	0.119	31.22
4.5-6.0	0.132	32.10
6.0-7.5	0.142	37.27
7.5-9.0	0.146	40.16
9.0-10.5	0.145	42.91
10.5-12.0	0.145	48.02
12.0-13.5	0.141	51.77
13.5-15.0	0.128	53.72
15.0-16.5	0.124	58.86
16.5-18.0	0.107	64.16
18.0-19.5	0.102	65.95
19.5-21.0	0.854	75.25
21.0-22.5	0.745	84.01
22.5-24.0	0.637	86.84
24.0-25.5	0.510	103.35
25.5-26.0	0.144	101.58
Forward		
R=0-10cm.	0.373	143.6
Backward		
R=0-10cm.	0.876	6.24

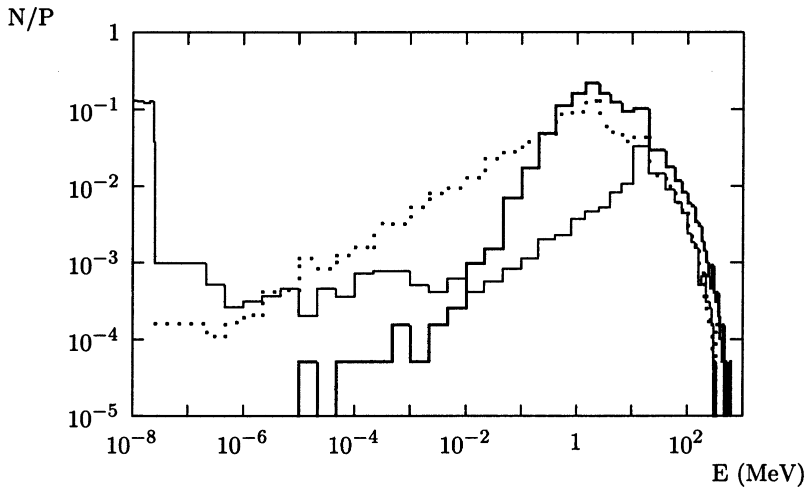

Fig. 2. *Neutron spectra on the cylindrical set-up surface (per primary proton with E=1 GeV). Points – data for the set-up with a graphite moderator, boldfaced and thin histograms – data for the Lead spallation source and for the set-up with paraffin moderator. All data for the layer with DeltaZ* $= 4.5 - 6$ *cm.*

Modelling of Uranium assemblies

In its complete form the assembly DSAD includes nine identical sections of 10.4 cm length each divided by $\Delta Z \simeq 0.1$ cm intervals for thin detectors. Every section includes 210 cylindrical fuel rods of 1.66 cm radius with 1.63 kg of natural Uranium covered by 0.165 cm Aluminum. The average blanket density is 16.84 g/cm^3. The sections have a hexagonal cross-section with a 13.9 cm inscribed circle radius and of 16.05 cm side. Each section has an outer 0.1 cm iron cover (Fig.3). Total weight of Uranium in the assembly is 342.3 kg $\times 9 = 3081$ kg.

The assembly is centered inside a chamber of the outer dimensions $\Delta X \times \Delta Y \times \Delta Z = 100 \times 110 \times 110$ cm^3 with thick (of several tens cm) polyethylene and thin (1 mm) Cadmium radiation shielding.

In contrast to the neutron sources considered in the preceding chapter, heavy Uranium set-up has a thick support: the layers of 3 cm textolite, 8 cm wood and 1 cm steel. More detailed data of geometrical dimensions and nuclear composition of DSAD one can find in [4, 14].

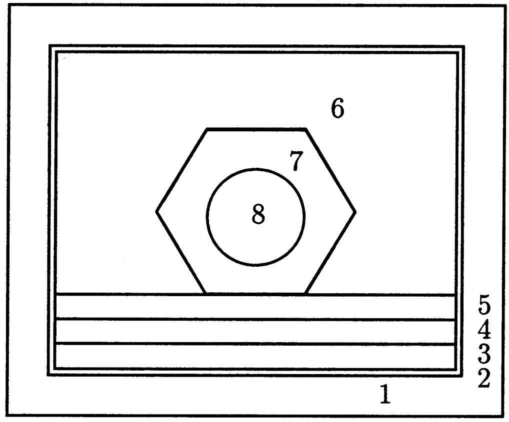

Fig. 3.*Cross-section of the ADS DSAD and its surrounding. 1 – polyethylene shielding, 2 – Cadmium layer, 3 – textolite, 4 – wood set-up support, 5 – iron set-up foundation, 6 – blanket cover, 7 – Uranium blanket, 8 – Lead target.*

As in preceding chapter, we assume that the proton beam is of needle-shape form and is injected into the center of the target hutt-end.

It is planned, as a first step, to use in experiments a truncated assembly only with two sections , so we have performed modelling of two set-ups – with two and nine sections. In Table VII the calculated neutron yield for the "naked " assemblies, without support and shielding, are shown. In order to estimate the influence of the support and shielding, the respective values are presented in brackets for neutrons outside the box. The main share of the difference is due to the shielding, the influence of DSAD support is remarkably less. For example, taking it into account for two-section set-up increase (n,γ)-capture from 2.5 up to 2,7 and the summary neutron yield from 11 to 22.3.

In both "naked" feudalists a large leakage of neutrons takes place . The loss can be diminished, if primary proton will be injected through a gap of several cm length. Number of the escaped protons is much smaller – about 0.4 and 0.01 particles per one primary proton in the two- and nine-section set-ups. The most charge particles are stopped inside the set-ups due the ionization losses.

The number of the escaped neutrons outside the box is practically the same as for the "naked" set-ups. In polyethylene very slow neutrons are created due to collisions with hydrogen nuclei and their escapinng is not prevented by the Cadmium layer if it placed, as it was proposed in [4], under polyethylene. Instead to be shielding polyethylene plays part of a source of slow neutron. In order to exclude these neutron some absorbents have to be used. In [4] it is proposed to use admixture of Boron carbonate however, this problem demands a more detailed consideration.

Table VII

Neutron yield in the set-ups with Uranium blanket (per one primary proton with energy 1 GeV)

Number of sections:	2	9
Escaped neutrons		
with $E_n > 2.5 \cdot 1o^{-8}$ MeV	19 (4)	28.8 (8.1)
with $E_n < 2.5 \cdot 1o^{-8}$ MeV	0 (13.9)	. 0 (17.9)
Captured in n, γ-		
reactions	2.5 (3.6)	6.4 (9.8)
Total neutron yield	22 (23.5)	35.6 (35.8)

One must pay also attention on rather small, approximately only twice increasing of the neutron yield when the two-section set-up is replaced by the nine-section one. Heat production increases also not significantly – only about of 1.5 times. Essentially, of two order of value due to the ionization losses in the additional sections, only the escaping proton energy is changed, however, in comparison to others this quantity is not very interesting. From this point of view the more expensive the nine-section set-up with much more amount of Uranium has small advantage in comparison to the two-section one.

Table VIII shows the values of particle energies and summary produced energy. These quantities are practically the same for "naked" set-ups and outside the box. Remarkable difference is observed only for the escaped neutrons. (In particular, if we take into account only the set-up support without radiation shielding the energy of these neutrons decreases on 10%.) At the same time, as we see below, the support changes remarkably the shape of spectra.

Summary energy E_{tot} generated in set-up exceeds significantly the primary proton energy E, so the energy gain

$$G = 100 * (E_{tot} - E)/E$$

is about 60% in the two- and twice more in the nine-section set-up.

Table VIII

Energy (MeV) generated in the set-ups with Uranium blanket (per one primary proton with energy 1 GeV)

N_s:	2	9
Energy generated by fission	440 (441)	844 (899)
Summary energy of γ-rays	70) (80)	130 (140)
Energy of high-energy γ-rays (from π^o-decays)	29 (30)	35 (35)
Energy of escaping neutrons	141 (94)	116 (69)
Energy of escaped charge particles	270 (254)	3.6 (2.5)
Summary produced energy	1600 (1610)	2130 (2190)

For the primary proton beam energy 1 GeV and intensity of NUCLOTRON $N \approx 5 \cdot 10^9$ heat power of set-ups

$$W = (E_{tot} - E_{out}) * N$$

is about of 0.1 - 0.2 wT.

A remarkable share of the generated energy ($\approx$ 12%) is taken off by γ-rays. In contrast to the considered above Lead set-ups the large part of this share is due to the contribution of low-energy γ-rays emitted in (n, γ)-reaction and by the relaxation of excited residual nuclei. However, spectra of γ-rays there is again a hump at $E > 70$ MeV connector with π^o-meson.

Fig. 4 shows the rather strong dependence of neutron yield on the thickness of Lead target – 25% increase by the pass from R=4 to R=1 cm. It is due to the small dimension of Uranium blanket when even a little variations of its radius influence the set-up properties. In big assemblies the dependence on target is much weaker [23]. The cross-section of proton beam from JINR synchrotron 1.5×1.5 cm^2 prevents the use of too thin targets.

Distributions of escaping neutron numbers and energy along the central part of the top blanket surface (Fig. 5) in the two- and nine-section DSADs are presented in Tables IX and X. These data take into account the contribution of support. The contribution of neutrons rescattered back by shielding is insignificant. Tables do not include "supercold" neutrons with E <0.025 eV. The most part of these neutrons is absorbed by Cadmium layer.

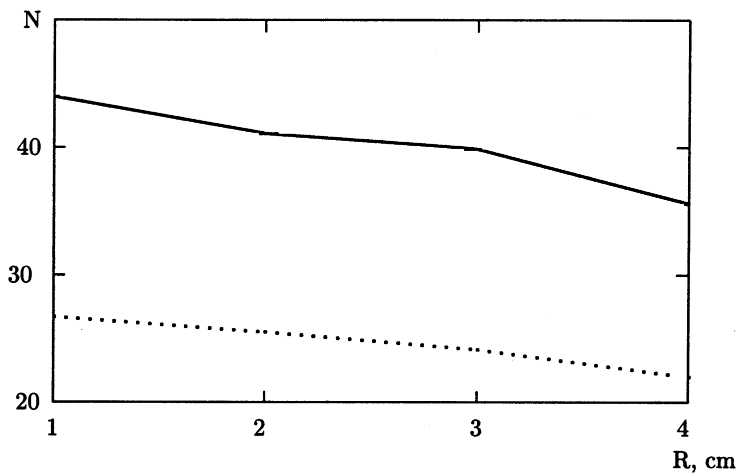

Fig. 4. *Neutron yield in "naked" two-section DSAD with constant dimensions and density of Uranium blanket at various radii of Lead target R. Data per one primary proton with energy 1 GeV.*

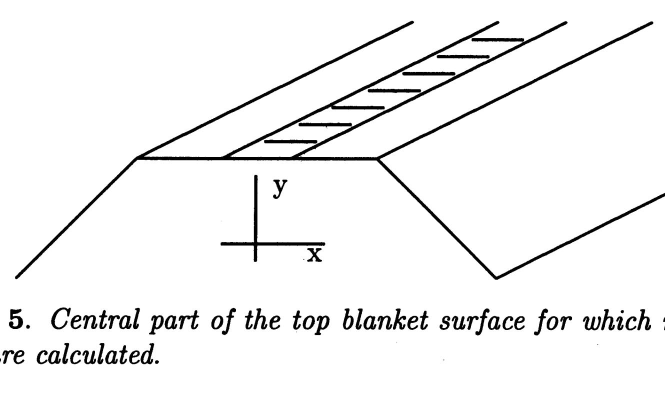

Fig. 5. *Central part of the top blanket surface for which neutron spectra are calculated.*

Table IX

Number and average energy of neutrons in the squares $1.5 \times 1.5 cm^2$ along the surface of two-section DSAD (per one primary proton with E=1 GeV)

Z, cm	N_n	E_n	Z, cm	N_n	E_n
44.6 - 46.1	0.0828	3.34	55.1 -56.6	0.0977	3.45
44.6 - 46.1	0.0836	3.44	56.6 -58.1	0.0984	4.37
47.6 - 49.1	0.0870	3.49	58.1 -59.6	0.0966	3.31
49.1 - 50.6	0.0920	3.04	59.6 -61.1	0.0954	4.77
50.6 - 52.1	0.0994	3.57	61.1 -62.6	0.0927	4.91
52.1 - 53.6	0.0949	2.78	62.6 -64.1	0.0851	5.40
53.6 - 55.1	0.0978	2.86	64.1 -65.6	0.0705	4.91

Table X

Number and energy of neutrons in the squares $3 \times 3 cm^2$ along the top surface of nine-section DSAD (per one primary proton with E=1 GeV)

Z, cm	N_n	E_n	Z, cm	N_n	E_n
7 - 10	0.214	2.6177	55 - 58	0.126	6.9384
10 -13	0.245	2.8852	58 - 61	0.101	7.1213
13 -16	0.279	2.7408	61 - 64	0.090	6.4401
16 - 19	0.303	2.9232	64 - 67	0.072	6.1904
19 - 22	0.327	2.9509	67 - 70	0.060	8.7227
22 - 25	0.331	3.2206	70 - 73	0.051	8.4289
25 - 28	0.334	3.1314	73 - 76	0.041	6.4770
28 - 31	0.322	3.3080	76 - 79	0.036	7.9043
31 - 34	0.311	4.3086	79 - 82	0.026	1.1790
34 - 37	0.286	3.4171	82 - 85	0.023	7.1938
37 - 40	0.269	3.8096	85 - 88	0.017	1.2349
40- 43	0.239	4.2456	88 - 91	0.015	9.6653
43 - 46	0.215	4.2409	91 - 94	0.012	1.1541
46 -49	0.187	3.8983	94 - 97	0.010	1.3146
49 - 52	0.166	4.8753	97 - 100	0.008	8.5898
52 -55	0.140	7.2941	100 - 103	0.001	10.401

In both set-ups neutron yield has maximum at somewhat large distances from the forward face than in the Lead target [4]. In the nine-section assembly neutron energy also has maximum — close to its end. Number of protons on the blanket surface is small and data for these particles are not presented.

In Fig. 6 energy spectra are plotted for the neutrons emitted by the same surface squares as in Tables IX and X in the intervals ΔZ close to the neutron yield maxima. These spectra concern the "naked" set-ups. Fig. 7 shows how these spectra are deformed by the set-ups supports. The low-energy part of spectra increase essentially. The low-energy neutron created in collisions with hydrogen nuclei of polyethylene are captured by Cadmium and are not inside the box. Shape of the spectra in two- and nine-section set-ups are similar, that convinces again in small advantage of the nine-section set-up.

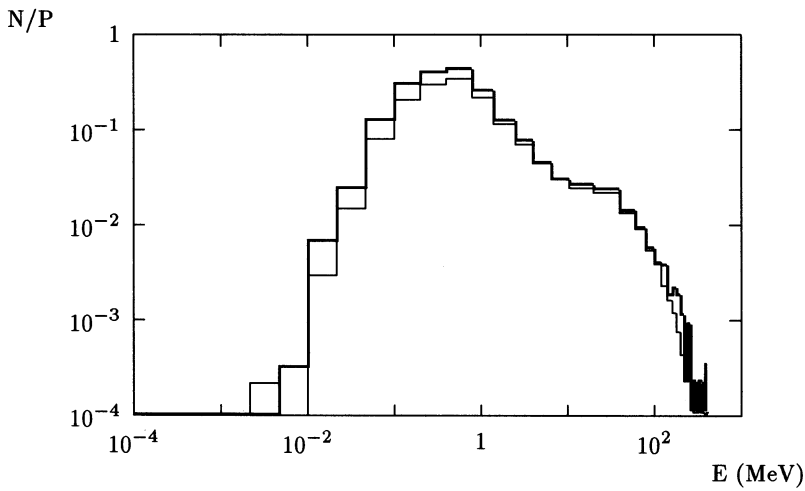

Fig. 6. *Energy spectra of neutrons crossing the squares* 1.5×1.5 cm^2 *(two-section DSAD, thin histogram) and* $1.5 \times 1.5 cm^2$ *(nine-section DSAD, boldfaced histogram) on the top of Uranium blanket of the"naked" set-ups.*

[4]Since the set-ups are centered in the box, their forward faces are placed at Z=44.6 and 7 cm.

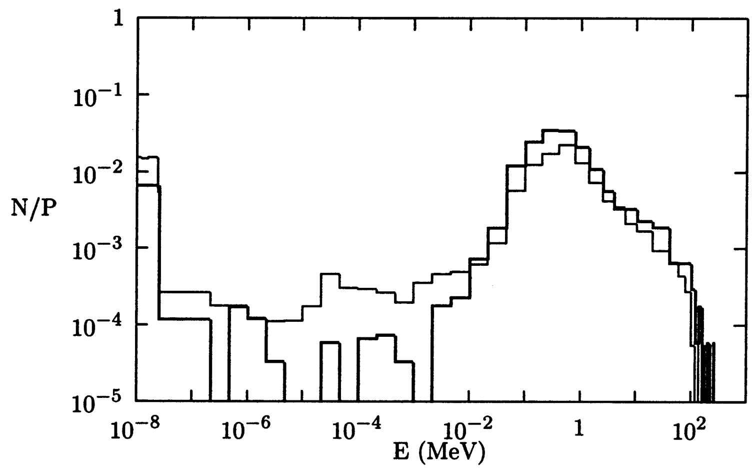

Fig. 7. *Energy spectra of neutrons emitted by the top surface squares taking into account the set-up supports. All designations are the same as in Fig. 6.*

Conclusion

Mathematical experiments with various modifications of DSAD and their target part show that neutron yield increases, roughly speaking, proportional to the energy of bombarding protons, however, the specific energy spent for the production of one neutron has a broad minimum close to 1.5 GeV. Properties of Lead set-ups with graphite and paraffin [24, 25] moderators allowing one to investigate the behavior of target in more complicate ADSs not strongly differ one from another. Surrounding of DSAD weekly influence the neutron yield, however, changes the neutron spectra, especially their low-energy part. Since the polyethylene layers produce a lot of slow neutrons one must consider absorbing admixtures in detail .

Properties of particles generated in two- and nine-section Uranium assemblies are also close one to other. From this viewpoint nine-section set-up has no significant advantages in comparison to two-section one.

JINR is an international organization, so DSAD is opened for physicists from various Institutes and countries.

Acknowledgements

One of authors (VSB) is thankful to International Science and Technology Center (project 1372) for financial support. Another author (HK) is thankful to Homi Baba Research center for financial support.

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Received on April 4, 2003.

Барашенков В. С. и др. E9-2003-55

Математическая модель электроядерной установки на пучке синхротрона ОИЯИ

На основе разработанного в ОИЯИ монте-карловского программного комплекса CASCADE создана математическая модель глубокоподкритической сборки с урановым бланкетом, с которой выполняются эксперименты на пучке протонов с энергией 0,6–4 ГэВ ускорителя ЛВЭ ОИЯИ. Данную модель можно рассматривать в качестве первого шага к экспериментам на проектируемой в ОИЯИ уран-плутониевой электроядерной установке SAD с тепловой мощностью в несколько десятков кВт. Рассчитаны выходы и энергии генерируемых частиц и спектры нейтронов. Сопоставляются свойства нескольких модификаций моделируемой установки и ее мишенной части. Рассмотрено влияние парафинового и графитового замедлителей на свойства рождающихся в свинцовой мишени частиц.

Работа выполнена в Лаборатории информационных технологий ОИЯИ.

Препринт Объединенного института ядерных исследований. Дубна, 2003

Barashenkov V. S. et al. E9-2003-55

Mathematical Model of the Electronuclear Set-Up on the Beam of the JINR Synchrotron

On the base of the Monte Carlo code CASCADE, developed at JINR, a mathematical model of the deep-subcritical set-up with uranium blanket used in experiments underway at JINR using a 0.6–4 GeV proton beam, is created. The neutron spectra, yields and energies of generated particles are calculated and compared for several modifications of the set-up. The influence of paraffin and graphite moderators on the characteristics of particles escaping lead target is studied. The modelled set-up can be considered as a first step to experiments with the designed at JINR U–Pu ADS SAD with heat power of several tens of kW.

The investigation has been performed at the Laboratory of Information Technologies, JINR.

Preprint of the Joint Institute for Nuclear Research. Dubna, 2003

Макет *Т. Е. Попеко*

Подписано в печать 14.05.2003.
Формат 60 × 90/16. Бумага офсетная. Печать офсетная.
Усл. печ. л. 1,43. Уч.-изд. л. 1,56. Тираж 280 экз. Заказ № 53884.

Издательский отдел Объединенного института ядерных исследований
141980, г. Дубна, Московская обл., ул. Жолио-Кюри, 6.
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