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AMPLITUDE ANALYSIS OF HIGHLY IONIZING PARTICLE SIGNALS REGISTERED WITH SILICON RADIATION DETECTOR. SOME REMARKS TO ANOMALIES

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Амплитудный анализ сильноионизирующих частиц,
регистрируемых кремниевым детектором.
Некоторые ремарки к аномалиям

Проведен анализ регистрируемых кремниевым детектором сигналов с существенным значением полного дефекта амплитуды ионизации (ДАИ), а именно для ядер отдачи и осколков деления, получаемых как редкие события в ядерных реакциях с тяжелыми ионами. Показана аномальность некоторых из ранее измеренных амплитуд.

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Tsyganov Yu. S. E13-2007-70
Amplitude Analysis of Highly Ionizing Particle Signals Registered
with Silicon Radiation Detector. Some Remarks to Anomalies

Analysis of the registered energy amplitudes measured with silicon radiation detector with the significant pulse height defect (PHD), namely for the evaporation residues (EVR) and fission fragments (FF), has been performed for rare events obtained in the heavy-ion induced nuclear reactions. It is shown, that in some cases those measured amplitudes are quite anomalous.

The investigation has been performed at the Flerov Laboratory of Nuclear Reactions, JINR.

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INTRODUCTION

Recently, at the Dubna Gas-Filled Recoil Separator (DGFRS) [1] more than 17 new nuclides with Z = 110–118 have been synthesized [2–6]. It should be noted that some of these experimental results were clearly confirmed by the independent experiments [7–9], involving studying of chemical properties of the synthesized atoms. To concentrate the reader's attention three major components of the success may be listed, namely:

• electromagnetic recoil separator design must provide not only acceptable value of the nuclide transportation efficiency (tens of percent), but also a significant suppression of background products;

• heavy-ion beam intensity should be high enough to provide nuclide under investigation formation;

• detection system must be not only quite informative to provide identification of the nuclide, but it should contribute to the process of deep suppression of backgrounds products [10–12].

Following the above points, the author formulated that an amplitude analysis, the goal of the present paper, is in fact can be considered as a supplement to the third point, although in an indirect mode.

1. REGISTERED AMPLITUDES OF SIGNALS OF EVAPORATED RESIDUES (EVR) IN HEAVY-ION INDUCED COMPLETE-FUSION NUCLEAR REACTIONS

Typically, when one studies decays of superheavy elements (SHE), detection system registers a multichain event consisting of recoil signal amplitude, alpha-decay signal amplitudes and, sometimes, amplitude of signal of one or two fission fragments (FF). Of course, the main part of every detected multichain event, are α-decays, according to the two reasons — it is possible to establish precisely energies of α-decays and then using this information to provide an indication to a nuclide's Z number [13]. Nevertheless, the registered amplitude of signals of recoils and SF, which have significant pulse height defect value (PHD) are also of interest in order to make the identification process more complete. It was F. P. Hessberger, who first recognized the importance of such an analysis and performed it in the form of Monte Carlo simulation of the SF decays of ^{256}Rf

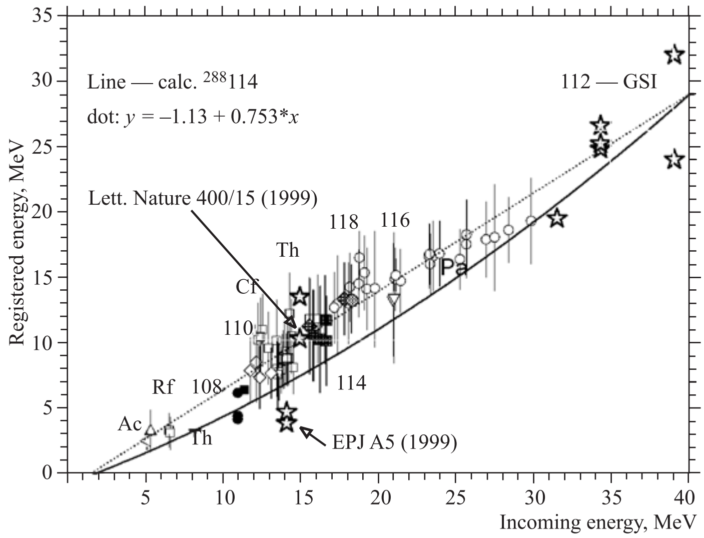

Fig. 1. Dependence of the registered recoil energy signal against incoming one. Calculation of [17] is shown by line. Dotted line is plotted to guide the eye — direct empirical calibration [18] measured for different heavy recoils at the DGFRS. Data of the SHIP and VASSILISSA are shown by stars

nuclei implanted into silicon radiation detector [15]. Method of simulating the EVRs spectra for the detection system of the DGFRS is reported in [16, 17] in detail as well as that for SF events in Refs. [18, 19]. As an illustration of fruitfulness and power of this simulation technique, one could mention an example from [14], where such an analysis has shown an anomalous signal amplitude of one of the three events of $Z = 112$ EVRs reported in [20].

The new nuclides with Z = 112 and 114 synthesized in the ^{238}U + ^{48}Ca $\rightarrow$ $\rightarrow$ 112* and ^{242}Pu + ^{48}Ca $\rightarrow$ 114* nuclear reactions now have got a strong support [8, 9].

In Fig. 1 the calculated dependence of the registered energy signal amplitude of the EVRs against the incoming one is shown for the DGFRS PIPS[1] detector. Six extra points (right upper corner)[2] for Z = 112 recoils from the GSI experiments obtained in ^{238}U + ^{48}Ca [8] and ^{68}Ni + ^{206}Pb [20] nuclear

[1] Produced by CANBERRA Semiconductors NV, Belgium. Both the SHIP and VASSILISSA detectors are from the same manufacturer.

[2] Left-down, marked by stars — measured at the VASSILISSA facility (four points) — Eur. Phys. J. A. 1999. V. 5 and Nature. 1999. V. 400. P. 15.

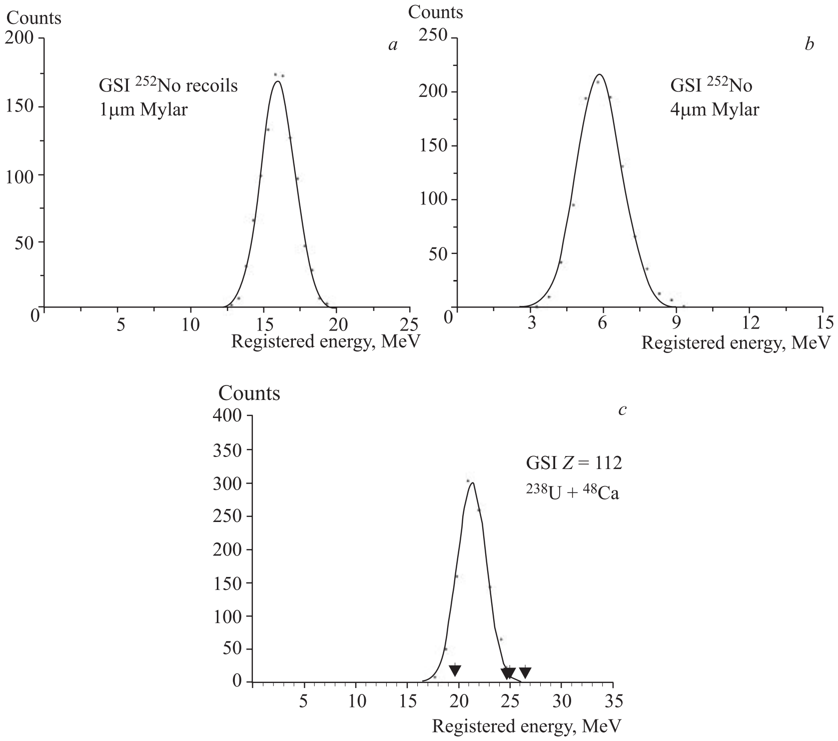

Fig. 2. Simulation of the registered energy spectra of EVRs of ^{252}No for experiment reported in [8]: *a*) with 1 μm Mylar; *b*) 4 μm Mylar degraders; *c*) simulation for Z = 112 recoils from ^{238}U + ^{48}Ca $\rightarrow$ 112 + 3n reaction

reactions show principal agreement with the calculations. Note, that the EVR amplitude, which had a significant deviation [14], was eliminated by the authors of [20] after careful reanalysis. In the next step, an attempt to reproduce ^{252}No recoil spectra measured in ^{206}Pb + ^{48}Ca$\rightarrow$^{252}No + $2n$ reaction has been performed using two different Mylar degraders (1 and 4 μm). The results shown in Fig. 2 *a, b*, as a whole, demonstrate an agreement with the measured ones, although with the small deviations of –1.75 MeV (11%) and 0.25 MeV (4.3%). Deviation of the mean value for four measured events of Z = 112 is about 2.7 MeV (11%).

As concerning the SF events, the spectrum which corresponds to that measured in [8] for one-micron Mylar degrader, the computer simulation has been performed with one variable parameter of the model, namely, the mean PHD value to put into agreement the calculated and measured mean values of summary

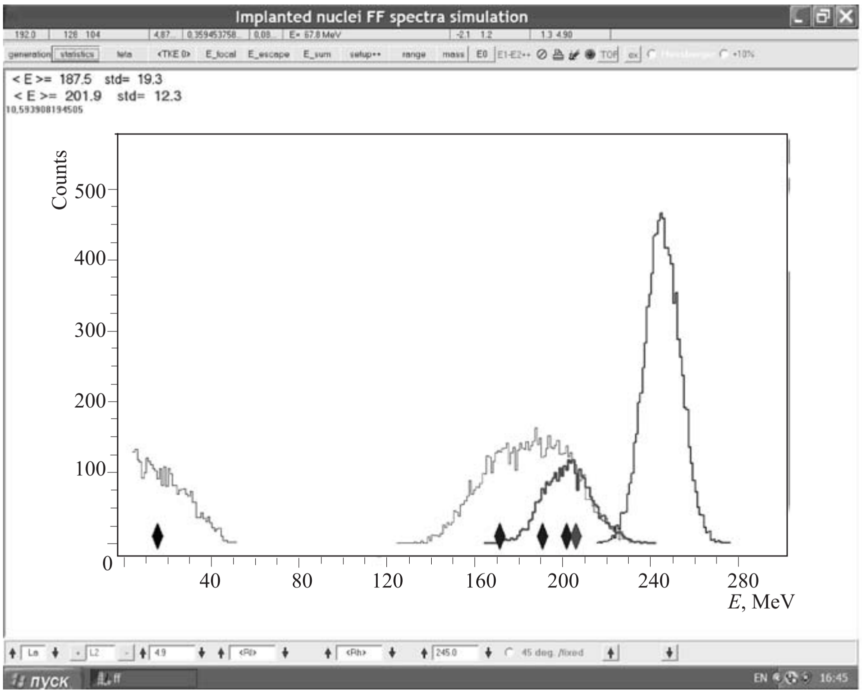

Fig. 3. Computer spectra simulation for ^{238}U + ^{48}Ca $\rightarrow$ 112 + 3n reaction. The measured GSI events are shown by rhombs

spectra. After this step, simulation for ^{238}U + ^{48}Ca reaction has been performed with a given value of mean PHD[1] and variable TKE[2] parameter.

2. RECOIL-FF SIGNAL AMPLITUDES MEASURED IN [21]

Note, that not for every experiment aimed at the SHE synthesis, the present analysis gives a satisfactory agreement with the measured values. For instance, the two events, attributed by the authors of [21] to the 114 element formation, do not agree with the present calculations. In Fig. 4 the experimental data obtained for an extended set of FF registered energy signals are shown.

It can be clearly seen that:

[1] PHD = 17%.

[2] Optimal $\langle$TKE$\rangle$ parameter is $\sim$240 MeV.

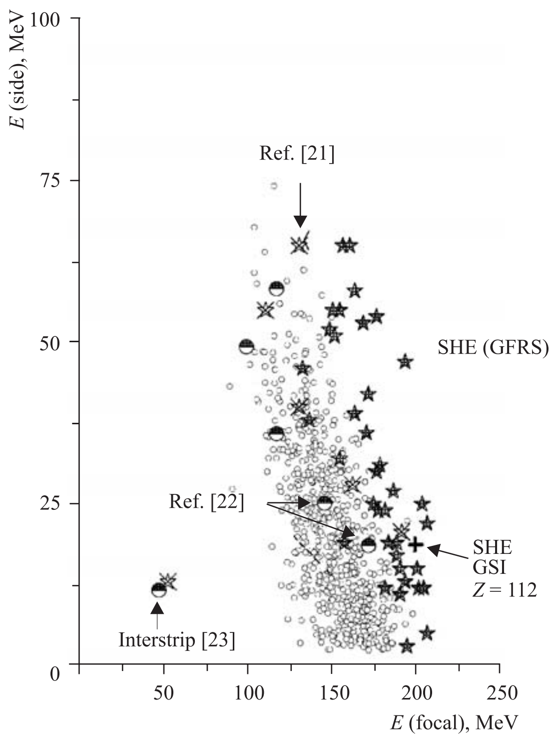

Fig. 4. Two-dimensional plot: energy registered in the main detector energy vs. that in the side detector. Open circles — ^{252}No; stars — SHE SF events measured at the DGFRS; semi-filled circles — measured at the VASSILISSA with reverse recalculation to «α-calibration» (star + cross — original data [21–23]); cross — Z = 112 (GSI)

1) those groups of events, which were attributed to SHE decays [2–7], are shifted strongly to the right upper side that demonstrates, as a whole, the greater TKEs relatively to the calibration with ^{252}No SF group;

2) measured signal amplitudes, reported in [21], are in fact in the left upper part, that, in the first approximation, indicates to a smaller TKE.

Of course, different measurements, made in the different conditions, may contain some systematic errors in the FF registered energy scale, and, therefore, can be systematically shifted with respect to each other. To this reason, let us consider some dimensionless value k equal to the ratio $E_{\rm esc}$ / ($E_{\rm esc}$ + $E_{\rm main}$), where «esc» and «main» subscripts denote detection by side and main detectors, respectively. It goes without saying, that such a ratio could be definitely diminishing the systematic shift of scales and can be introduced as a specific parameter for comparing the data.

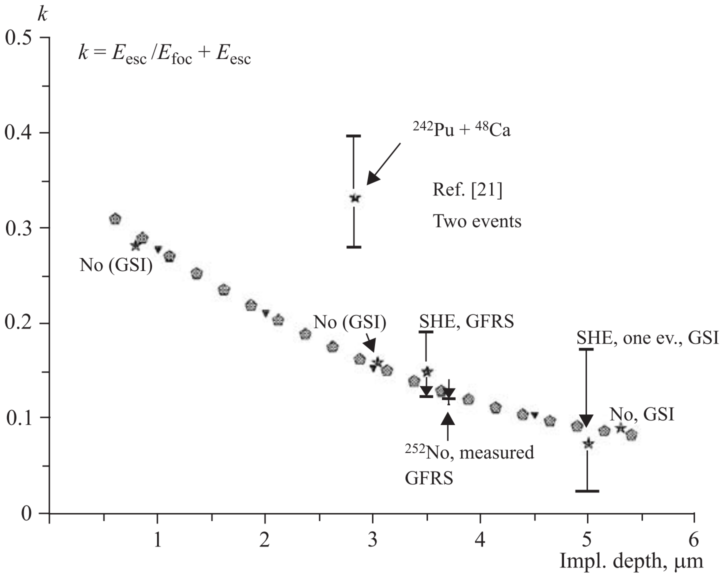

Fig. 5. The calculated dependence of k parameter against EVR implantation depth. Stars denote the values measured at different facilities

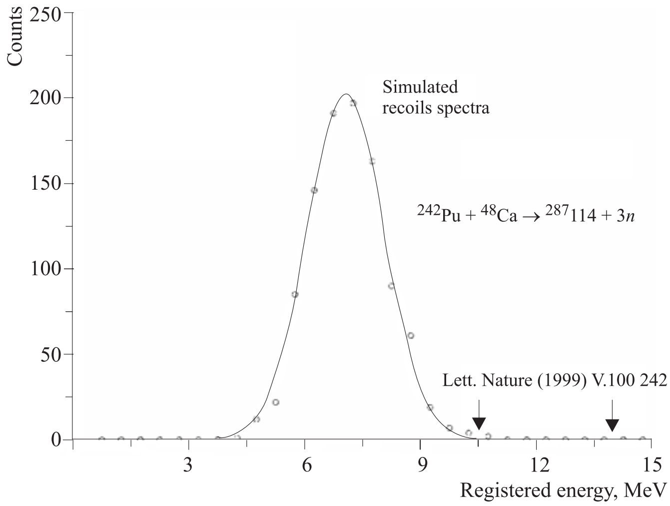

Fig. 6. Recoil spectrum simulation for recoil signal amplitudes reported in [21]. Measured (two events) deviate from calculations by $\sim$ 40 and 90%, respectively

Moreover, when one deals with complete-fusion reaction products, their implantation depth into the main silicon detector can be easily estimated and the $k$parameter should decrease with the increase of the implantation depth. In Figs. 5

and 6 such a behavior is shown both for calculations and some measured points. It is shown in this case the events measured in [21] are outside of the main trend for calculated and measured events.[1]

CONCLUSIONS

Method for analysis of registered energy signal amplitudes in heavy-ion induced nuclear reaction has been applied to compare results of different experiments with each other, as well as with the calculations. Reproducibility of calculated recoil spectra center of gravity with respect to measured ones of about $\sim$10% is achieved. Some criticism of the interpretation of the experimental results of [21] is presented. Moreover, if one considers EVR signal amplitudes measured in [21] to be true, the contradiction as to the k parameter becomes even greater. Note, that nuclear properties[2] of nuclei reported in [21] are beyond consideration of the present paper.

Of course, nearly the same criticism can be extended to the results reported in Ref. [24].

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[1] Nuclear properties reported in the same Ref. [21] are not supported anytime in any independent research.

[2] Half-life times, cross sections of nuclei formation, etc.

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