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C++ BUILDER 6.0 **CEDV** CODE FOR FILES PROCESSING

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Цыганов Ю. С. E10-2010-127
C++ Builder 6.0 программа CEDV для обработки файлов

Программа CEDV написана на RAD C++ Builder 6.0 в среде Windows XP для визуализации данных экспериментов на пучках тяжелых ионов для реакций полного слияния на циклотроне У-400. Основная цель программы — обработка данных экспериментов, направленных на изучение химических свойств сверхтяжелых элементов, а также файлов экспериментов на дубненском газонаполненном сепараторе (ГНС). Представлены подпрограммы для оценки статистических параметров экспериментов — они базируются на модифицированном BSC-подходе. Приводятся примеры для данных как химического эксперимента, так и экспериментов на ГНС.

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Tsyganov Yu. S. E10-2010-127
C++ Builder 6.0 CEDV Code for Files Processing

A RAD C++ Borland's Builder 6.0 code CEDV under Windows XP has been designed for visualizing data obtained from heavy-ion-induced complete fusion reactions at the main U-400 cyclotron of FLNR. The main purpose of the code is processing the data from the experiments aimed at studying chemical properties of SHE. Data from the Dubna Gas-Filled Recoil Separator could be processed too. Some subroutines for estimating statistical parameters are also presented; these are based on modified BSC (background signal combination) approaches. Examples of application both for chemistry experiments and the experiments performed at the Dubna Gas-Filled Recoil Separator are presented.

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

Communication of the Joint Institute for Nuclear Research. Dubna, 2010

INTRODUCTION

The experiments in low-energy physics are planned so that physically interesting effects mathematically are rare events, compared to others, whose probabilities are not small. Correspondingly, the purpose of the paper was the development of the formalism for the treatment of rare events, which definitely started for the recoil (ER) signal and after $\alpha(n)$ particle signals are finished by the FF (fission fragment) signal in the same strip and vertical position of the focal plane PIPS detector (see., e. g., [1–3]). Classical models (e. g., [4, 5]) usually deal with the single signal-imitator rate to calculate (estimate) random events value N_R. Schematically it is shown in Fig. 1. It is evident that to a some approximation one could consider not only regular single background signals to built some combination, but also pairs, triplets, etc., signals as primary backgrounds. Of course, it is assumed that this second-type background rate is much smaller than single signal rate and cannot be taken into account analytically — only via direct processing of experimental data. There are some physical reasons for those kinds

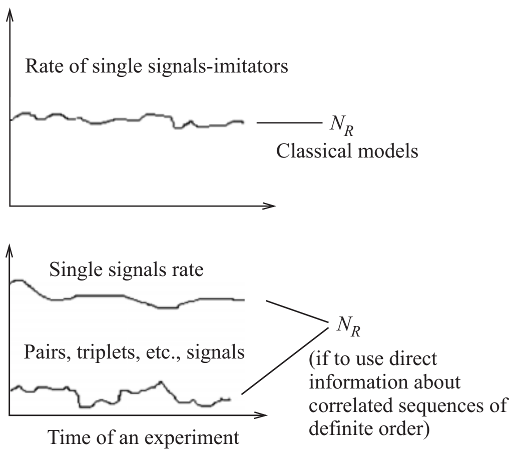

Fig. 1. Schematics of calculation of expectation number of random events in classical models and in the present approach

of signals. For instance, they are: all breakdown phenomena like Dee or even PIPS detector oxide rare breakdowns, as well as any RF pulse noises. Of course, in a real experiment the definite precautions should be taken, but sometimes their efficiency is not 100%.

In a sense, to some extent, background signals of this type may be considered as an intermediate stage from «thing-in-itself» (internal cause) to «thing-for-us» (obviously observed values).

1. BASIC MODELS TO CALCULATE THE RANDOM COINCIDENCE PROBABILITIES AND RANDOM EVENT EXPECTATION

It was K.-H. Schmidt who first recognized the entire significance of probabilities estimates for the multichain events detected with a PIPS detector located at the focal plane of SHIP velocity filter recoil separator [4]. It developed a very frequently used by the experimentalist LDSC (linked decay signal combination) model. Another principal (basis) approach by V. B. Zlokazov [5] considers background signal combination (BSC) and tests whether the signal sequence analyzed does fit in this concept or not.

At the same time, a trend of every experimentalist is to use parameters which can be extracted directly from the given experiment and not only the rates of the single signals which imitate the ER's, alpha particle and FF signals during the long-term experiment. Moreover, when one applies «active correlations» method one can separate different signal groups according to the elapsed time [6, 7]. Note, that according to the philosophy [4] there are some restrictions in application of the formulae from that paper. Namely, the background signal statistics should not be too extensive. That is, no signals from the definite energy range should be present except for the signals included into the links. Generally speaking, it is preferable to apply the formulae from [6] in the case if the resulting N_R is too small and much more less than 1. Otherwise, one can obtain more optimistic estimate, than realistic one. On the other hand, using the model [5] is quite questionable in the case if time interval from the end of alpha-group to the FF signal is much greater than the time duration from the recoil to finishing alpha particle signal. In part, this contradiction was solved in the modified model MBSC [5a].

In the case of signal combination $\alpha(n)$–FF is under experimentalists' interest, expectations to obtain together with this cluster starting $\alpha(n)$ signal-imitator for a time $t_{\alpha(n)-\mathrm{FF}}$ and finishing FF signal for a time $t_{\alpha(n)-\mathrm{FF}}$ can be written as

$$\bar{N}_R \approx N_{\mathrm{FF}} \cdot P_{\alpha(n)-\mathrm{FF}}. \tag{1}$$

Here, $P_{\alpha(n)-\mathrm{FF}}$ is the probability to «detect» group $\alpha(n)$ during a corresponding time interval before a FF signal for a time $t_{\alpha-\mathrm{FF}}$.

Having applied in the manner similar to [4, 5] Poisson-like statistics for the mentioned signal parameters, we obtain

$$\bar{N}_R \approx N_{\mathrm{FF}} \cdot (1 - \mathrm{e}^{-\lambda_{\alpha(n)} t_{\alpha-\mathrm{FF}}}). \tag{2}$$

In (2) parameter N_{FF} is the total number of FF signal for a given detector during the experiment.

2. FILE PROCESSOR CEDV CODE FOR CHEMICAL AND DGFRS EXPERIMENTS WITH ACTINIDE TARGETS

For file processing of the data, obtained from the heavy-ion reactions the CEDV (Chemistry Experiments Data Visualization) RAD C++ Builder under Windows XP code has been designed. It allows one to process files from the experiments performed at FLNR (JINR) in the field of superheavy elements [8]. One of the output results of its application is a list of α-α-α-FF correlations under

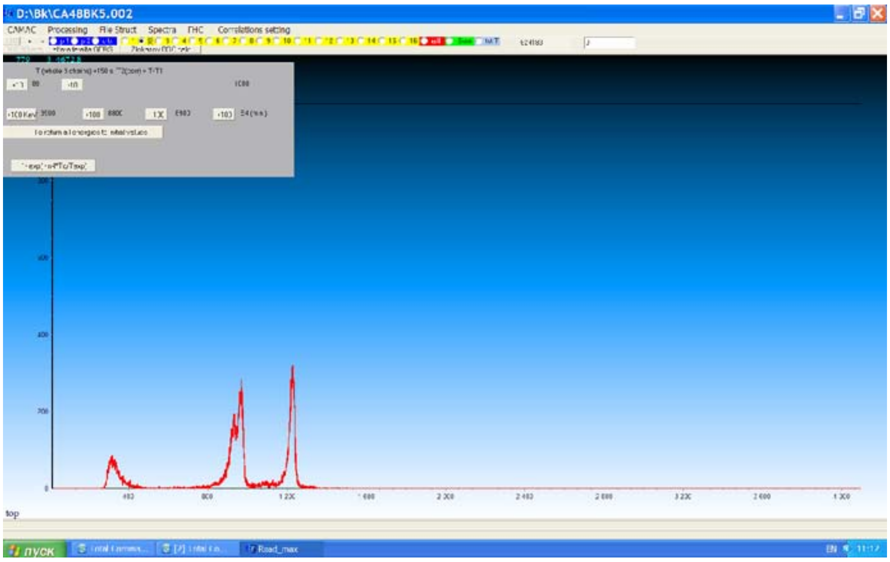

Fig. 2a. Spectrum obtained from the experimental file. Left upper corner — parameters for α-α-α and α-α-α-α correlations search (for a given detector) are shown. (For 16 pairs (top + bottom) with close to 4π geometry — 16 buttons in the upper panel). Bottom button in the panel is one to calculate N_R parameter after correlation search process is finished

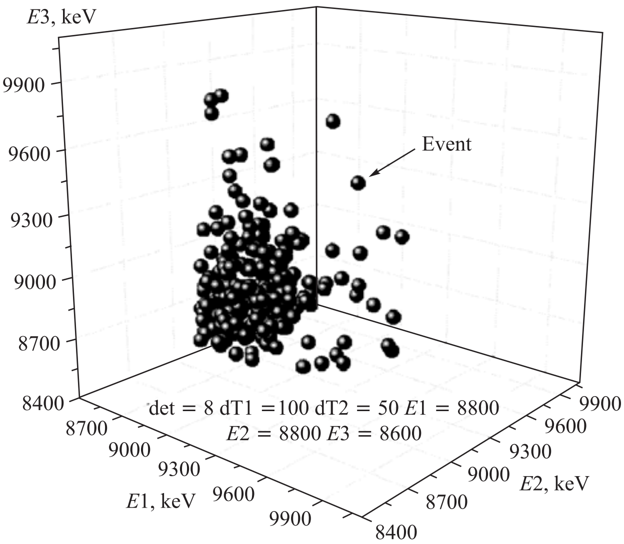

Fig. 2b. 3D picture of α-α-α group*. Detected event is indicated by the arrow. Left part — background signals

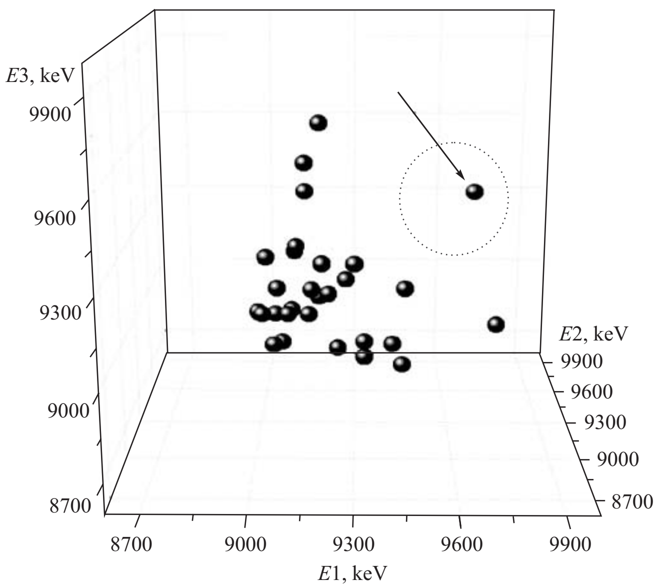

Fig. 2c. 3D picture of α-α-α group. Detected event is indicated by the arrow. Left part — background signals. *For chain*: ***9644 keV*** $\rightarrow$ ***8935*** $\rightarrow$ ***9549*** $\rightarrow$ ***8817*** *987671.312 64.812 6.562 815.625*

*An interactive mode. In principle, *on Timer* mode is possible easy for any on-line experiments.

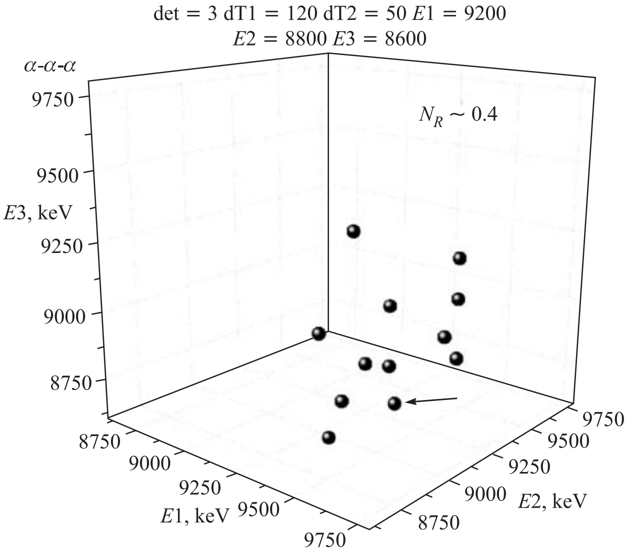

Fig. 2d. ...the same for another detector... (More worthier situation with N_R). Only three-alpha particles are taken into account

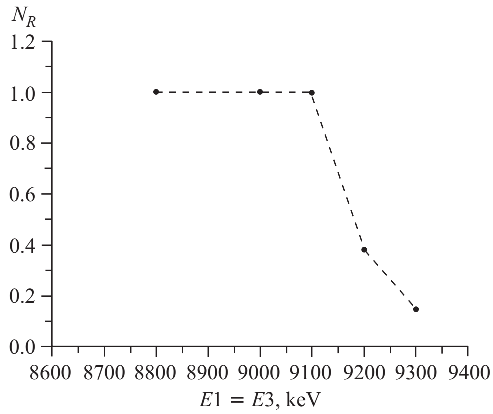

Fig. 2e. Dependence of N_R parameter on the lower limits $E1$ and $E3$ for the fixed value $E2 = 8800$ keV

definite time conditions. In Fig. 2 3D example is shown for three-alpha particle signal for a given detector*.

*Whereas, any 2D alpha-alpha picture has negligible statistical significance (Fig. 2g)!

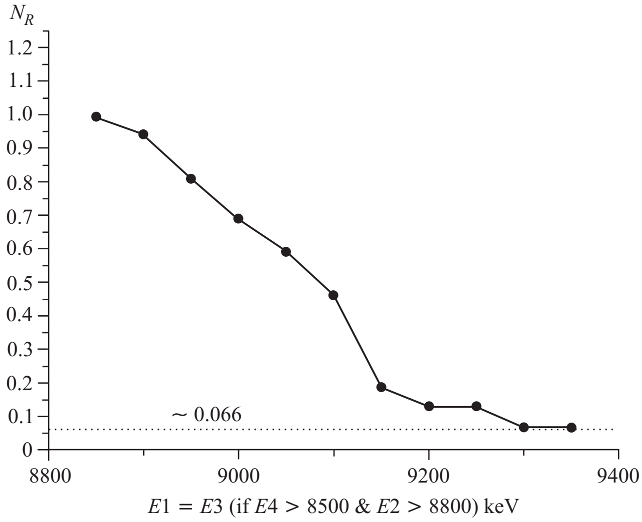

Fig. 2f. The same as Fig. 2e, but under additional condition $E4 > 8500$ keV. Asymptotic level of ~ 0.066 is shown by dotted line. (det. #8*)

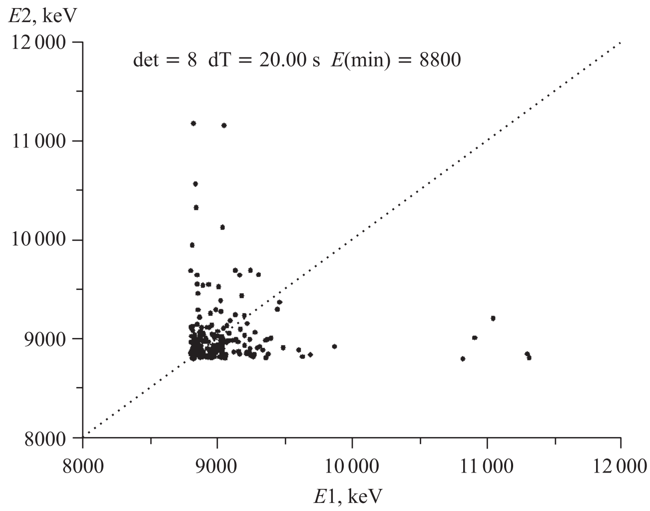

Fig. 2g. 2D picture for alpha-alpha correlated chains within 20 s time interval

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*Having considering neighbor left-right detectors and taking into account $\sim 85\%$ efficiency per pair and 92% full efficiency relatively 4π [8], N_R value will be slightly higher. Namely, it is equal approximately to 1.16. It means that $N_R \approx 0.066 \cdot 1.16 = 0.077$.

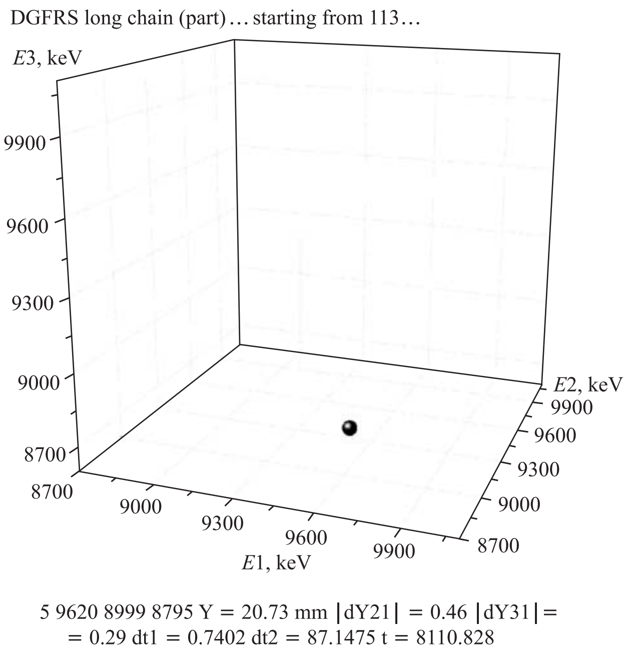

Fig. 3. One decay event from the DGFRS experiment [9] — demonstration of background-free conditions due to application of «active correlations» method

If one uses formula (2) for the given case the value of expectation of $N_R \approx 0.147$ for incoming parameters: 9300, 8800 and 9300 keV as low-energy limits and time intervals $\leqslant 100$ s for first-second alpha particle interval and $\leqslant 50$ s for second-third interval, respectively. In Fig. 2 low limit for $E1 = E3$ is considered as a parameter under condition of fixed parameter $E2 = 8800$ keV. For the sake of comparison, one can see in Fig. 3 the analogous picture from the DGFRS experiment, when the «active correlations» method to suppress the background signals is applied. Of course, vertical position signal is also taken into account.

3. ON THE ISSUE OF USING THE EDGE STABILITY OF STATISTICAL ESTIMATES

It is reasonable to consider some additional statistical criteria together with often used N_R parameter. It seems, to this aim consideration not only the mentioned parameter, but also first derivatives according to two basic variables, namely, time and energy, are useful.

For instance, in Fig. 4 the dependence $\dfrac{\partial N_R}{\partial E}$ on N_R is shown. Rapid growth of the parameter in the right zero vicinity, probably, manifests the statistical

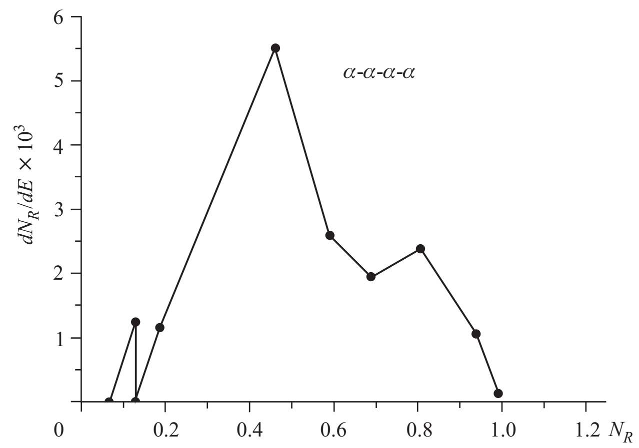

Fig. 4. Phase curve for α-α-α-α chain

parameter estimate nonstability region. To a first approximation it is proposed that simple relation $\left|\dfrac{\partial N_R}{\partial E} \cdot \Delta E\right| \ll N_R(E)$ and $\left|\dfrac{\partial N_R}{\partial t} \cdot \Delta t\right| \ll N_R(t)$ as a required condition to speak about parameter N_R as a stable estimation. At the same first step, one can also consider ΔE interval as one related to FWHM value of a detector and left edge energy as a critical point. Choice of Δt value, probably, should obey more branched scenario.

Another test (sufficient condition) for validity of statistical significance estimate was proposed in [10]. In fact, some re-norm factor is introduced. It relates to the given configuration of the detected event and the whole efficiency to detect a single-alpha particle. Stable estimate was defined as one corresponds to the case of the parameter of $N_R/P_{\rm conf} \ll 1$. Here $P_{\rm conf}$ is a probability of a definite configuration of an event.

SUMMARY

Approach to calculating random expectation value for heavy-ion-induced complete fusion reactions has been proposed. It is applicable if a number $N_{\alpha(n)}$ of $\alpha(n)$ combination signals can be directly extracted from the experimental data for the energy and time intervals of interest. Of course, it is assumed that $N_{\alpha(n)} \gg 1$, as an ideal case. And, of course, there are some uncertainties, when time interval between last alpha particle signal and FF signal is compared with that from the first to finishing alpha particle signal. But this is not the problem when only an order of magnitude estimate is of interest for the experimentalist. In this case, an effective time can be introduced into consideration by any way to overcome the mentioned problem. One can conclude that the chain shown in Fig. 2c is statistically significant, although with the remark, that the presented estimate may be unstable to some extent. In this case, it is essential whether the experimentalist considers the measured event as being known before the experiment or not. In the first case, the statement about statistical significance of the event will follow without doubt. In contrast, no definite conclusion can be drawn for the event shown in Fig. 2d. Additional thorough analysis is required, probably not just with statistical approach. As concerning the stability of the statistical estimates, it is the first time this point is introduced. Of course, the author welcomes anybody filling this definition with a new sense.

Since the major drawback of the described statistical estimate approach is an extension to a low level of background signals combinations, one should obtain not only the mean value of N_R, but also left and right confidence intervals for that estimate.

Additionally, three general conclusions can be drawn here, namely:

1. The event from ^{243}Am + ^{48}Ca reaction one can consider as a true event (Fig. 7, see below);

2. The second event from ^{249}Bk + ^{48}Ca reaction should be considered as background nature;

3. Under definite circumstances, especially with the additional positive analysis, nonrelated to a statistical one, the first event (Fig. 2c) can be considered as a candidate to the event.

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Supplement 1.

USING VMRIA CODE TO ESTIMATE PEAK CONTENT

To estimate content of any nuclide in the peak area, VMRIA code has been designed and described in [11]. To apply it in our case, CEDV code generates text-files in interactive mode, acceptable by VMRIA. In Fig. 5 an example of application is shown for heavy-ion-induced nuclear reaction ^{243}Am + ^{48}Ca $\rightarrow$ 115* (see [8] too). Authors (present paper & [11]) plan to improve VMRIA code to satisfy more exactly the experimental conditions of the chemical experiments.

Supplement 2.

SEARCH FOR SHORT ER-α (OR/AND α-α) CHAINS FOR DGFRS FILES

Sometimes a quick search of presence or absence of short correlated sequence is strongly required in the given file or group of files. To this aim in the CEDV code an appropriate menu button is designed for the DGFRS experiment file format. On pressing this menu item, short correlations like alpha-alpha can be extracted according to energy-time-position information.

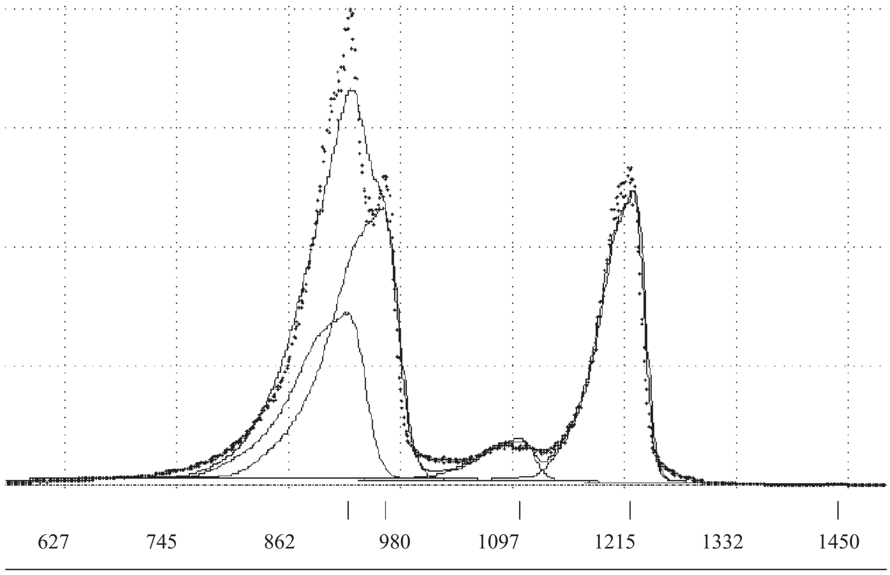


Fig. 5. Measured spectrum (dots) and different peaks (line) according to VMRIA processing from ^{243}Am + ^{48}Ca reaction

Very useful information corresponds to the case of ER-alpha chain for ^{217}Th nuclide obtained in the ^{nat}Yt + ^{48}Ca nuclear reaction* (Fig. 6a, b), due to namely this reaction nuclide is used for calibration purposes. Of course, it is assumed that all calibration parameters are ready for use. Below the figure a part of the resulting text buffer and meaning of the variables are presented. Of course, it is assumed that all calibration parameters are ready for application at that moment.

4	485	8338	9320	0	91207.640	dt = 399
8	491	7252	9279	0	91219.555	dt = 899
1	505	8725	9242	−3	91227.204	dt = 500
4	491	7670	9289	0	91231.470	dt = 399
1	491	7369	9263	−4	91235.651	dt = 299
2	480	9735	9282	−2	91238.907	dt = 1499

Here are:

1st column — strip number;

2nd column — TOF amplitude of ER in channels;

3rd column — ER energy signal amplitude;

*One from the DGFRS calibration complete fusion nuclear reactions.

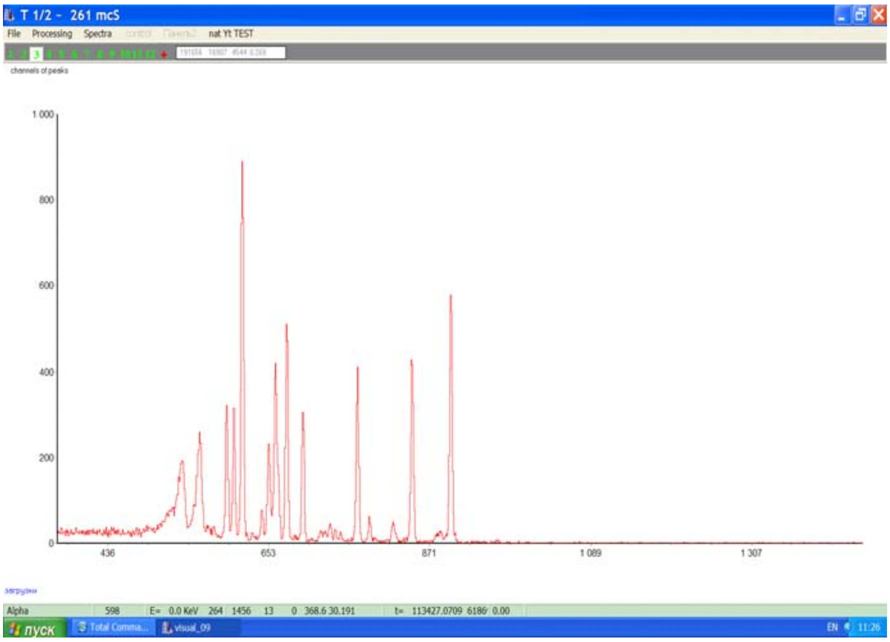


Fig. 6a. Spectrum from ${}^{\mathrm{nat}}\mathrm{Yt} + {}^{48}\mathrm{Ca} \rightarrow \mathrm{Th}^*$ reaction. Peak under interest is in the right-hand position in the spectrum (${}^{217}\mathrm{Th}$ isotope). Rough estimate value of T1/2 is in the Code form caption (left-upper)

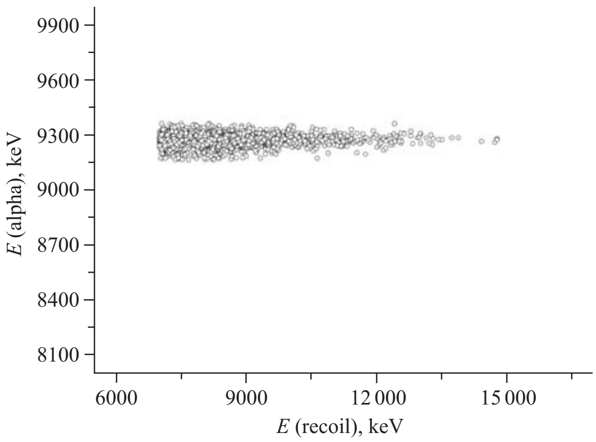


Fig. 6b. Correlation picture for extracted ER-α chains

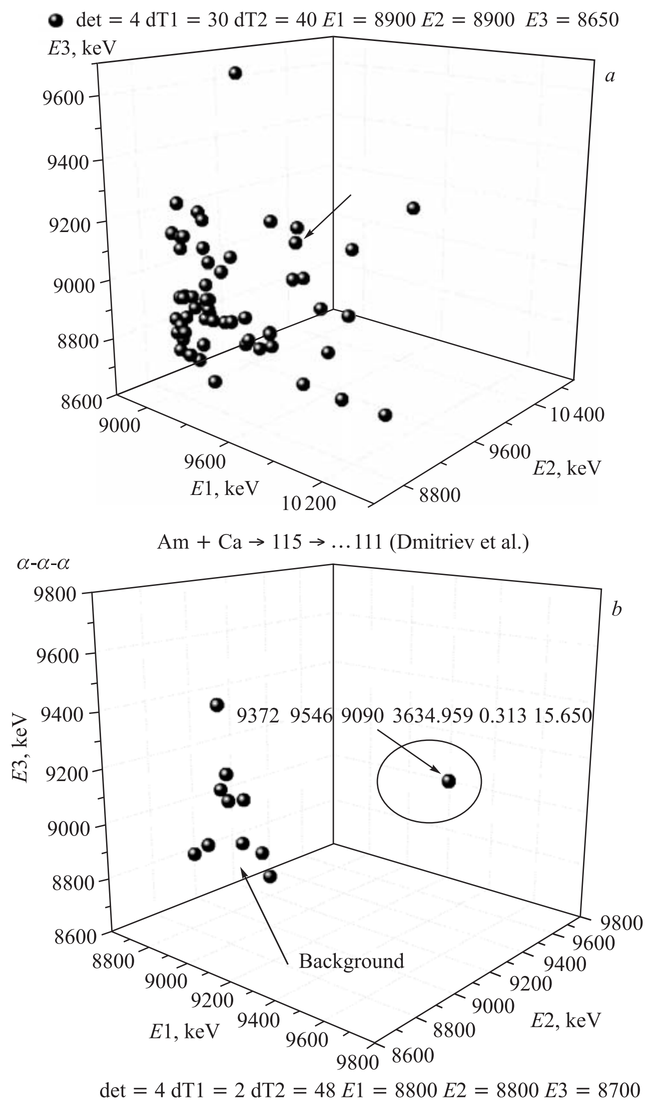
4th column — alpha particle energy signal amplitude;

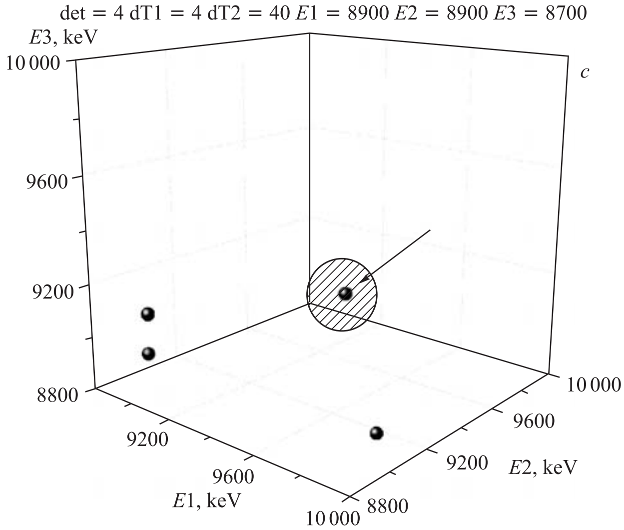
5th column — deviation in vertical position in pixels (one pixel $= 40/130$ mm);

6th column — elapsed time;
7th column — time difference ER-alpha.

Supplement 3.
REACTION Am + ^{48}Ca $\rightarrow$ 115... $\rightarrow$ 111...

The same (Fig. 2) picture was created by CEDV for Am + ^{48}Ca. It goes without saying, that background group is outside the event location area (Fig. 7).





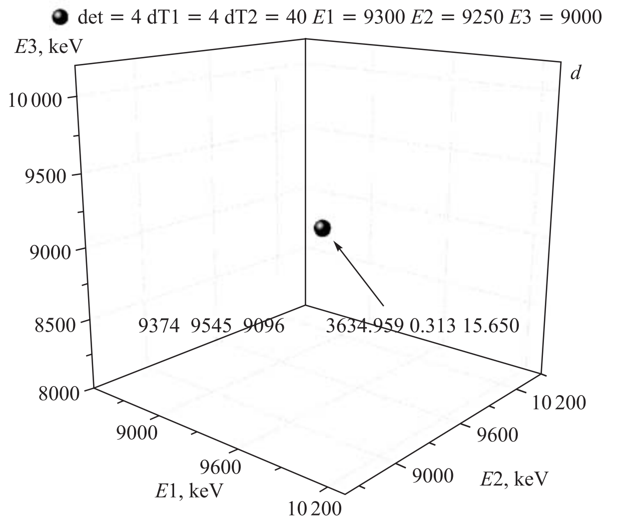


Fig. 7. 3D correlation pictures for ^{243}Am + ^{48}Ca reaction [8]. The event is shown by the arrow

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