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YDA C++ PROGRAM PACKAGE FOR OPERATING WITH A NEW ANALOG SPECTROMETER OF DGFRS-II SETUP*

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YDA (Yury and DAstan) Builder C++ PC-based code has been developed. It allows to provide data acquisition using 48×128 DSSSD (Double Side Silicon Strip Detector) and multiwire pentane filled low-pressure gaseous detector. The main feature of the developed program package is to use flexible real-time algorithms to provide in-fact background-free conditions for ultra-rare alpha decays registration. Three scenarios of these algorithms are under consideration. Two of them deal with the relatively low rate of beam stops, whereas the third one corresponds to a high beam stop rate. First results of YDA code application are presented. The example of an iteration process to obtain an optimizing recoil-alpha time interval value is presented too. Part of visualization programs are written in Python.

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1. Introduction

The most interesting information about the properties of nuclei arises when studying their extreme states. An example of such nuclei are superheavy nuclei. Superheavy nuclei consist of a large number of protons; the Coulomb repulsive forces are so high that only shell effects prevent from spontaneous fission. However, various nuclear models can predict the existence of the so-called "island of stability" [1] — a region of nuclei around $_{114}$Fl, whose lifetime will be much longer compared to nuclei far from this region. The last known superheavy nuclei were discovered in experiments on a Dubna gas-filled recoil separator (DGFRS) at the FLNR JINR [2, 3]. ^{48}Ca beams were used in all these experiments.

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For further research, the SuperHeavy Element Factory (SHEF) was put into operation on the basis of the new DC-280 cyclotron, where the intensity of the ^{48}Ca ion beam is approximately 10 times greater than the intensity achieved at the previous U-400 cyclotron [4]. The first experimental installation of the SHEF is a new gas-filled separator DGFRS-II. The DGFRS-II is intended for separating heavy nuclei — the products of fusion–evaporation reactions — from a beam of heavy ions bombarding a target and other background particles. The main feature of this installation is the high efficiency of collecting synthesized superheavy nuclei, which is estimated to be about 60% for targets with a thickness of 0.5 mg/cm^2 [5]. The DGFRS-II separator consists of 5 magnetic elements: 2 dipole magnets designed to separate the products of the complete fusion reaction from background particles, and 3 quadrupole lenses that focus the reaction products in the focal plane of the separator, where the detecting system is located.

2. The detection system

The recoil atoms that have passed through the separator and the time-of-flight measurement system are implanted into a semiconductor detector consisting of separate vertical and horizontal strips (Fig. 1). This combination makes it possible to determine the location of the implanted recoil, the energy of an alpha particle or a fragment of spontaneous fission. During alpha decay, there is a possibility that the alpha particle will fly out of the core in the direction of the separator. Side detectors are in use to register particles moving in the opposite direction with respect to the beam.

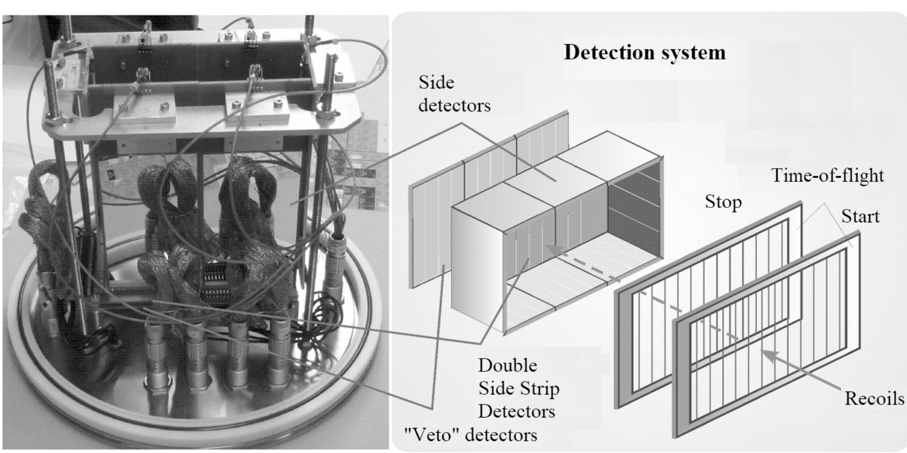

Fig. 1. Schematic view of the detection module. DSSSD detector, side detectors and two multiwire low pressure proportional chambers are shown.

3. A program for processing the results of experiments on DGFRS-II

This program is necessary for processing the results of experiments on the synthesis of superheavy nuclei at DGFRS-II. The visualization program allows to visually show the spectra of alpha events, fusion–evaporation residues and fission fragments from the side, front and back strips. We can view the spectra on each strip separately. We can also observe the spectra of events from the time-of-flight camera. Another feature of this program is the search for correlation events and events out of the beam, which makes it possible to find decay chains of superheavy nuclei. In Fig. 2, we can see the view of the visualization program main interface.

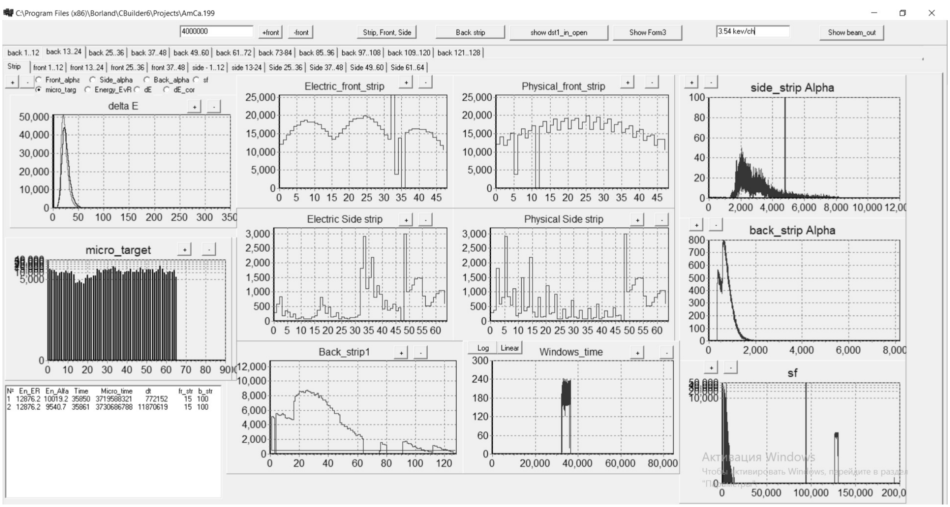

Fig. 2. Main interface view of Dastan No. 1 C++ program.

4. Flowchart of the main process

In Fig. 3, the flowchart of the main data acquisition process is shown schematically. These routines, marked in grey are responsible for a search of ER-α correlated sequence in a real-time mode [6–8]. The YDA C++ program starts the acquisition process when the status register is greater than null in the first 7 bits position. Three bits correspond to 48 strips of the focal plane , whereas another four bits correspond to 64 strips of the side detector. When data taking process takes place, each event specifies by 16 words of 16 bits. Thresholds of each ADP-16 CAMAC 1M unit are established by the NAF function in the program booting stage. All CAMAC routines are located within one Thread of Builder C++ except for one

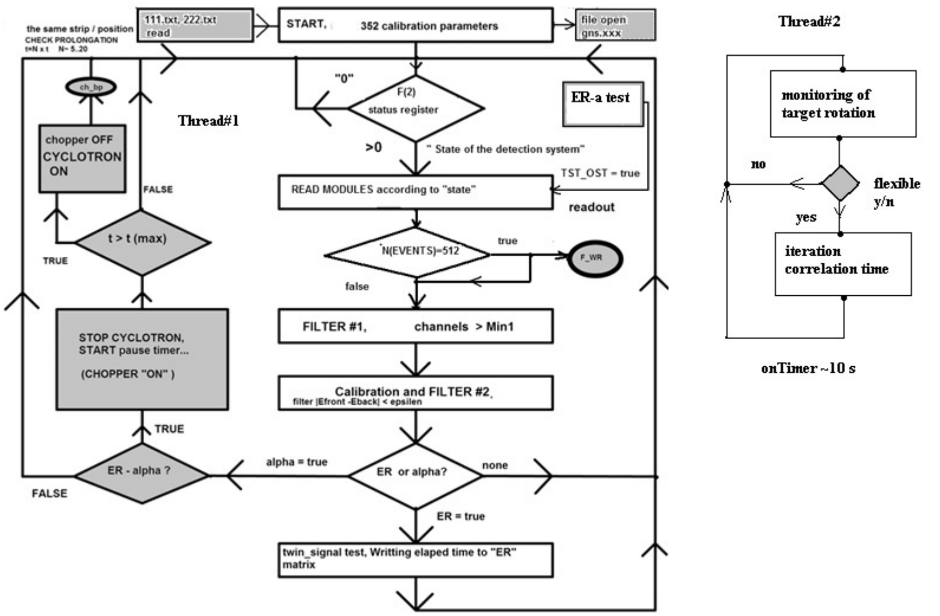

Fig. 3. Flowchart of YDA program main process.

(another Thread, operation: once per 10 s) working with monitoring of the target rotation speed parameter. Note that the detection system is described in detail in [9]. A flexible scenario for real-time detection of ER-α sequence is described in [10]. For more detailed visualization, a MAXSHU program has been developed in Python [11]. This program creates 1472 histograms in an on-line process. Some programs of file processing are written under Linux media. It is important that the MAXSHU program looks for a whole correlation multichain event for a few minutes delay (not only ER-α). In Fig. 4, examples of YDA C++ code application in heavy-ion induced complete fusion reactions ^{242}Pu+^{48}Ca$\rightarrow^{287}$Fl+3n and ^{243}Am+^{48}Ca$\rightarrow^{288}$Mc+3n are shown. Note that shadows denote that a beam stop was created by the YDA C++ program for a short time in a real-time mode.

Additionally, the "flexible" algorithm to search for ER-α correlated sequence in a real-time mode has been tested too. It means that the initial value for the recoil-alpha time interval was changed during YDA code execution. The optimizing parameter of $N_{\rm b}$ was in fact a number of beam stops due to random correlations. In Fig. 5, the pre-setting parameter of $N_{\rm b}$ was equal to 4 and correlated time was 20 s in a first approximation. Background signals distributions which imitate "ER" or "α" signals are considered as Poison-like ones.

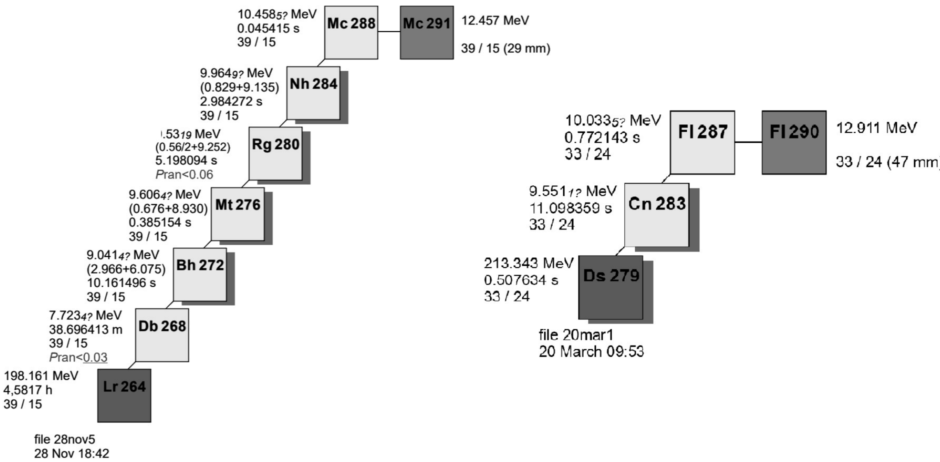

Fig. 4. Examples of YDA C++ code application in ^{48}Ca-induced complete fusion nuclear reactions.

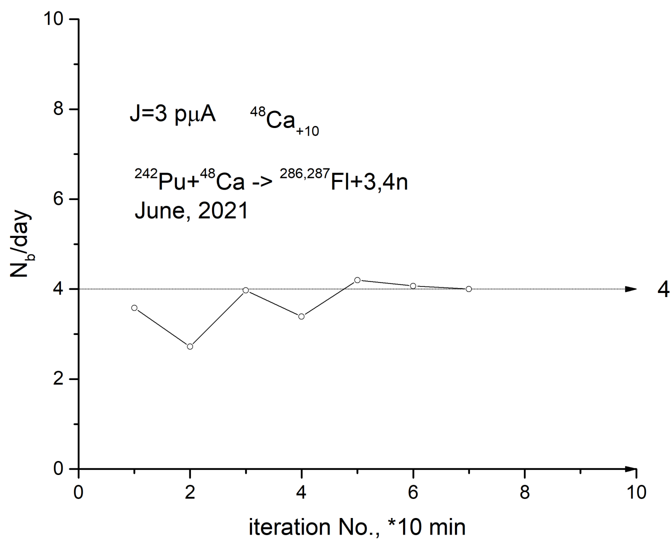

Fig. 5. Test of "flexible" algorithm. Pre-setting parameter of N_{b} is equal to 4. Final ER-α time interval is about 40 s.

5. Summary

The YDA C++ program package for new analog spectrometer of DGFRS-II setup has been designed and successfully tested in ^{242}Pu+^{48}Ca$\rightarrow^{*}$Fl and ^{243}Am+^{48}Ca$\rightarrow^{*}$Mc complete fusion nuclear reactions. The complimentary visualization program MAXSHU (Python) for files processing has been tested too.

It is the first time a flexible algorithm for an active correlation method has been applied in a test mode. ^{238}U+^{54}Ca experiment is now in progress. We plan to apply this software in the nearest future for ^{238}U+^{54}Cr$\rightarrow$*Lv experiment.

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