METHODICAL BASE OF EXPERIMENTAL STUDIES OF COLLINEAR MULTIBODY DECAYS

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Our recent experiments dedicated to study of the CCT of ^{252}Cf (sf) were carried out at the COMETA setup based on the mosaics of PIN diodes and special array of ^{3}He filled neutron counters. Principal peculiarity of the experiment consists in measuring of the heavy ions masses in the frame of the TOF-E (time-of-flight vs. energy) method in the wide range of masses and energies and almost collinear recession of the decay partners. The methodical questions of such experiment are under discussion here.

1. Introduction

In our previous experiments [1-4] we have observed multiple manifestations of new ternary decay of low and middle excited heavy nuclei called “collinear cluster tri-partition” (CCT) due to the features of the process observed. The main results were obtained at the modified FOBOS and mini-FOBOS setups based on the gas filled detectors of the FOBOS spectrometer [5]

in the frame of the "missing mass" method. It means that only two fragments were actually detected in each fission event (in opposite detectors, at 180^0) and their total mass Ms was served as a sign of a multibody decay, if it is significantly smaller than the mass of the initial system. In order to increase reliability of selecting of the CCT events by means of direct detection of all the CCT partners new COMETA (Correlation Mosaic E–T Array) spectrometer was put into operation in the Flerov Laboratory of the JINR. A simpler prototype of this spectrometer we have successfully used earlier for searching for the CCT channel in the reaction ^{232}Th + *d* (10 MeV) [6].

Peculiarity of the experiment: measuring of the heavy ions masses in the frame of the TOF-E (time-of-flight vs. energy) method in the wide range of masses and energies.

2. Detectors

COMETA is a double arm time-of-flight spectrometer which includes micro-channel plate (MCP) based "start" detector with the ^{252}Cf source inside, two mosaics of eight PIN diodes each and a "neutron belt" comprises 28 ^{3}He filled neutron counters.

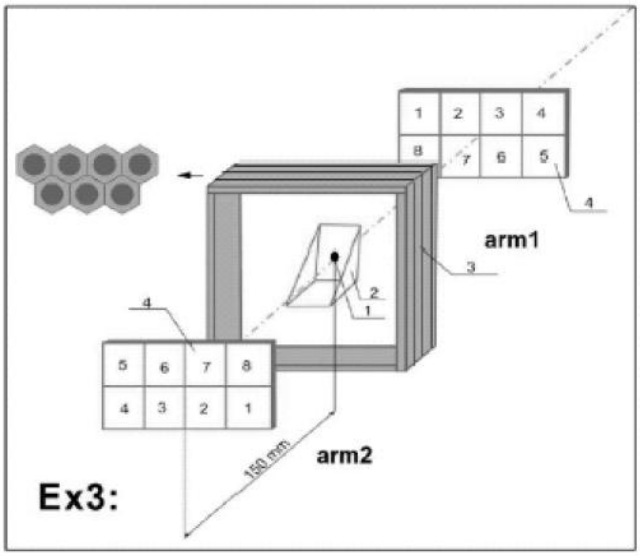

Figure 1. Scheme of the COMETA setup which consists of two mosaics of eight PIN diodes each (4), MCP based start detector (2) with the ^{252}Cf source inside (1) and a "neutron bel"" (3) consisting of 28 ^{3}He-filled neutron counters in a moderator. The section of the belt is marked by the arrow.

Each PIN diode (2x2 cm of surface area) provides both energy and timing signals. The neutron belt is located in the plane perpendicular to the symmetry axis of the setup. According to modeling and previous experiments, the detection efficiency is estimated to be ~5% and ~12% for the neutrons emitted in binary fission and from an isotropic source, respectively.

Thus, the geometry of the neutron belt provides preferential detection of the neutrons emitted isotropically.

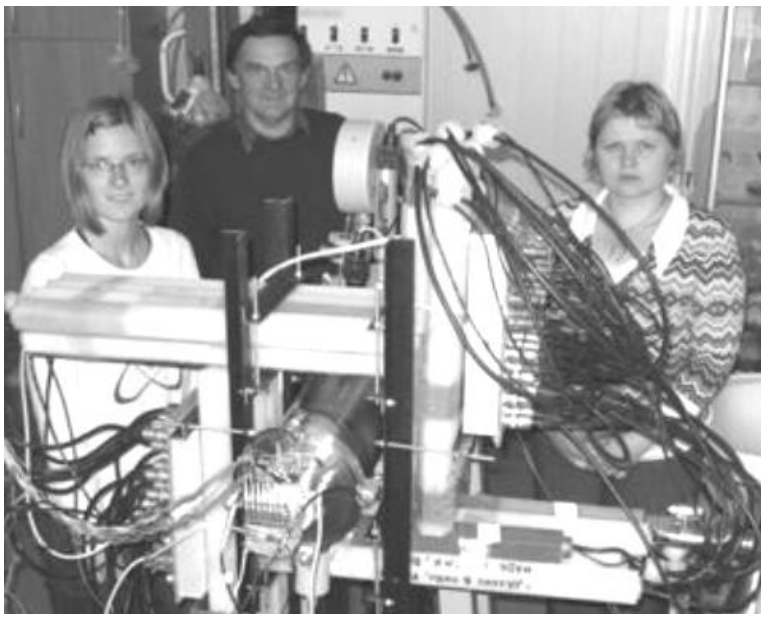

Figure 2 Overall view of the spectrometer.

3. Electronics

The scheme of the electronics used is shown in Figure 3.

Specificity of the electronic scheme, namely, using of TDC for measuring of the fission fragments (FF) time-of-flight and applying of QDC for measuring of the FF energy is resulted in relatively low price of a TOF/E channel at acceptable spectrometric parameters.

Energy and time resolution achieved for the alpha-particles does not exceed 151 KeV and 330ps respectively. Mass resolution for the FF was estimated using specific structure linked with the CCT.

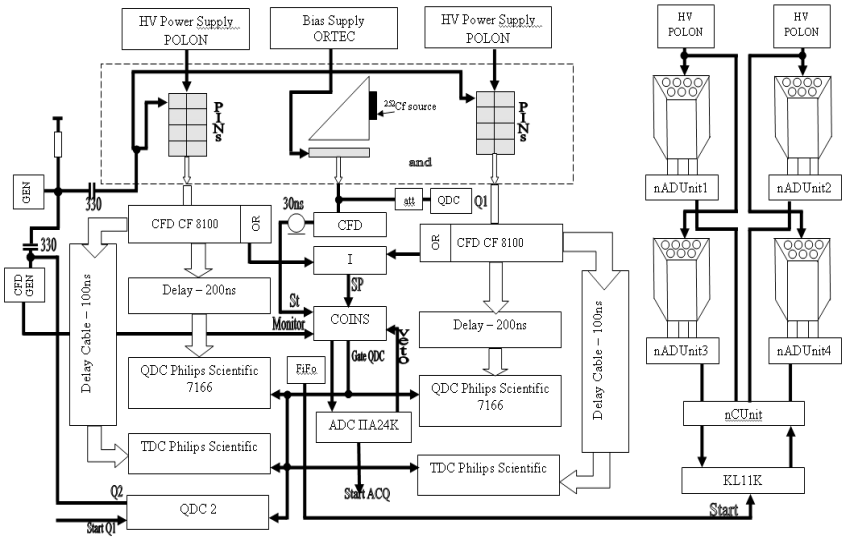

Figure 3. Schematic diagram of the electronics of the COMETA setup.

Mass resolution estimated by the line M2 = const = 68 amu does not exceed 1.5amu (fwhm)[4].

4. Data acquisition system

Data acquisition system (DACS) for the COMETA setup is based on those used earlier at FOBOS spectrometer. The entire system is organized on the basis of several PCs with the x86 processors under the operational systems family Win32 (beginning from the Windows XP up to Windows 7). Using of these OS and x86 family gave us very simple possibility to scale up the computational power of the DACS. The main features of our DACS are the possibilities of the online accumulating experimental data presorting and visualization of the data without reduction of the speed of data acquisition, also we have the possibility to analyze offline the data from our experiment.

The DACS lets us on-line graphical representation of the experimental variables in physical units (MeV, amu, cm/ns).

5. Calibration of E & T channels, calculation of the TOF-E FF masses

The use of the Si-semiconductor detectors in TOF-E spectrometry of heavy ions (or FFs) is known to have delicate methodological problems due to the "amplitude (pulse-height) defect" and "plasma delay" effects in the *E* and TOF channels, respectively. The first effect involves nonlinearity in the dependence of the "deposited energy versus electrical charge measured", while the latter distorts the TOF used in the calculation of the heavy ion masses. Correct accounting for both effects needs rather complicated procedure of the FF mass reconstruction.

Actually we use three-step approach in the reconstruction of the TOF-E FF masses. At the first stage a simplified approach is used ("first approximation" calibration) as follows. Two coefficients of the linear time calibration are calculated using the velocity spectrum of the known FFs from the literature. The energy calibration dependence is presented as a parabolic curve passing via three points, namely through the known centers of the energy peaks for the light and heavy fragments, and the energy of the alphas of natural radioactivity of ^{252}Cf nucleus. In the frame of this simple approach we have on-line estimation of the current status of the experiment. At the same time both specific distorting effects mentioned above are taken into account rather roughly.

At the second step much more complicated procedure based on the parameterization of the pulse-height defect (PHD) proposed by S. Mulgin and coauthors ("true calibration") is used. It lets to reconstruct the FF kinetic energy and mass taking into account PHD as a function of these parameters in the frame of certain iterative procedure.

At the last step TOF is corrected on plasma delay while PHD is also taken into account.

6. Conclusions

The COMETA setup presented here proved to be an adequate instrument for study of very specific multibody decay channel of heavy nuclei called collinear cluster tri-partition (CCT). Forthcoming upgrade of the spectrometer involves essential increase of its aperture for fragments from multibody decays.

References

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