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HIL Heavy Ion Laboratory

Application of the pulse-shape discrimination of the PiN type Si detectors in the neutron-rich nuclei investigation.

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Abstract

An identification and discrimination of fission fragments by means of time of-flight vs. energy and zero-crossing technique with reversed n-type Si detectors was undertaken. The several tests and calibrations with ^{252}Cf source were done before the fusion-evaporation reaction (e. g. ^{16}O + ^{208}Pb) will be investigated. A consequence of the rear-side injection mode is a strong variation of the charge-collection time with energy, charge, and mass number of the detected ion as it was noticed by G. Pausch et al. [1,2]. On the basis of results given in this papers the present measurements were initiated and are conducted with the aim to apply in the field of heavy-ion physics in conjunction with 4π EAGLE gamma-array.

Why do we want to identify fission fragments ?

Results of former experiments ^{16}O+ ^{208}Pb indicate a several delayed gamma-rays (Fig.1). In this reaction about fifty fission fragments were identified, most from the region of n-rich nuclei. Several lines (seen in red) are not ascribed to the proper mass, and the aim of this experiment is to solve this problem. In n-rich nuclei with A~80-130 a simultaneous existence of high and low j- orbitals, i. e. $2p_{1/2}$, $1g_{9/2}$ for protons and $1g_{7/2}$, $3s_{1/2}$, $2d_{3/2}$, $1h_{11/2}$ for neutrons, as well as collective structure favor possible isomerism. Examples of observed formerly gamma-rays half lives are shown in Table 1.

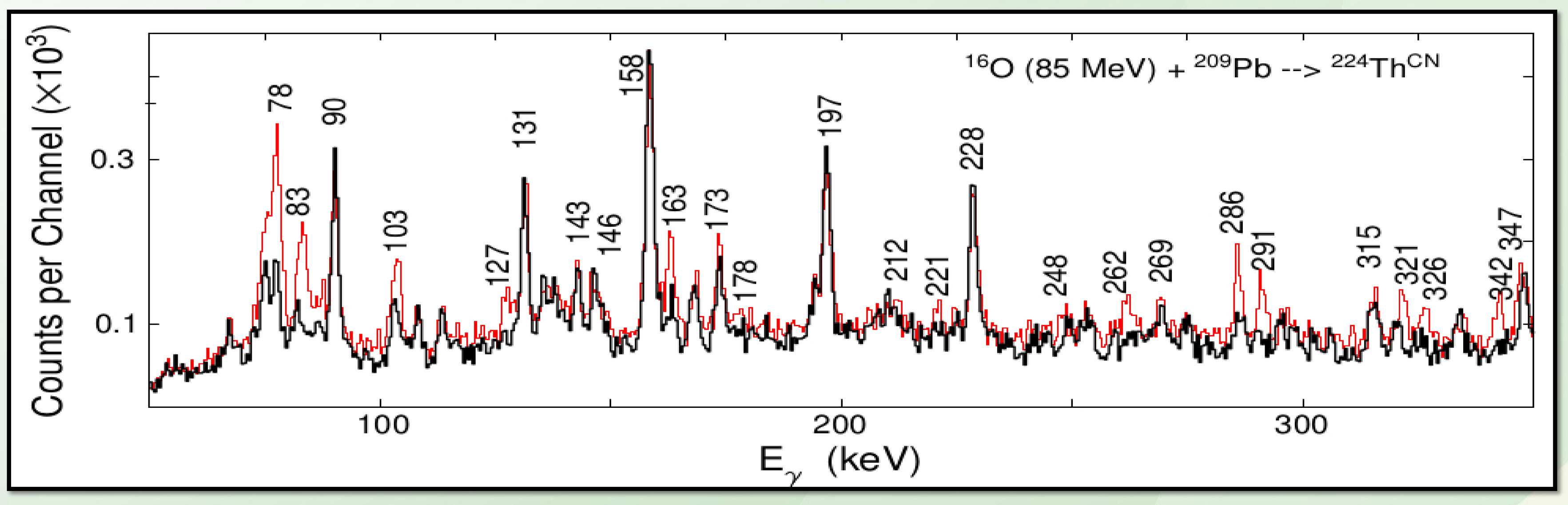

Fig.1 Example of partial two gamma-ray spectra collected for a time 300 microsec at the beginning (red line) and at the end (black line), 3.5 ms later, of the beam-off period

In order to identify isomeric states in fission fragments, it is planned to use fission fragment detectors to trigger the EAGLE array and isolate the delayed gamma-ray cascades, as well as to ascribe them to respective masses. Identification of fission fragment (FF) masses and energies has been, and still is a major concern in fission spectroscopic research. There are known several studies concerning the mass resolution like [3], where a mass of less then 1 amu for fission fragments is achievable, the other example is the ref. [4] (and the list of references there), which is showing determination of FF masses by measuring velocities and kinetic energies using specially adapted TOF detectors and ionization chambers or semiconductor detectors.

Table 1. List of few examples of gamma-rays suspected as being related to isomeric decays. The half-lives were estimated in the test experiment.

Eγ [keV]	$T_{1/2}$ [μsec]	Suspected isomers (not comfirmed)
82	79.4 ± 2.2	^{105}Te
248	42.4 ± 5.0	coincidence with 291 keV, ^{109}Pd
261	104.3 ± 2.5	^{125}Cd or ^{100}Tc
269	63.3 ± 1.2	^{106}Ru
286	89.5 ± 2.2	^{121}Sb or ^{76}Se
291	33.0 ± 3.0	coincidence with 248 keV, ^{109}Pd
342	112.4 ± 1.5	^{206}Pb or ^{216}Ra

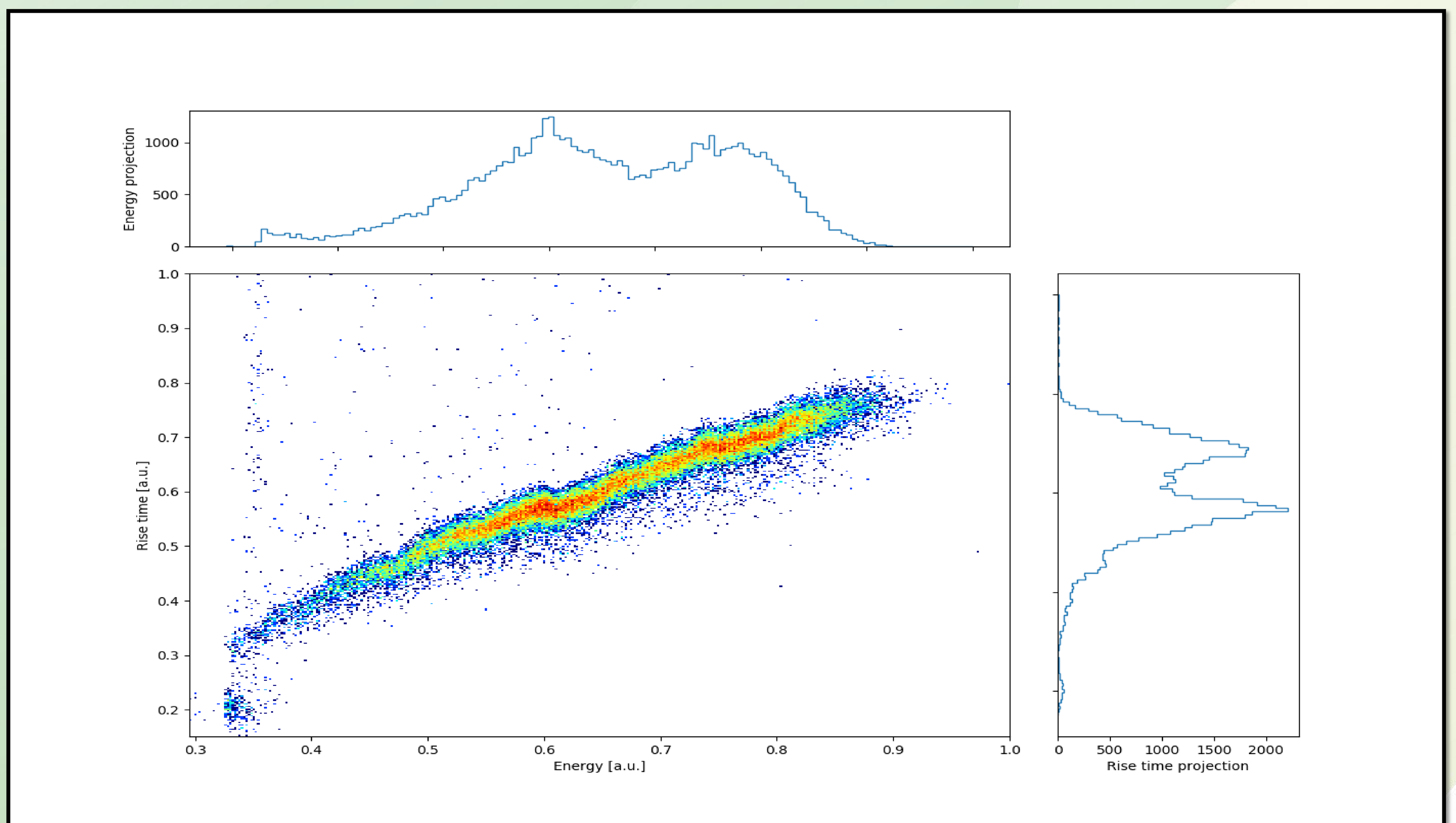

Fig.2 Rise time fraction vs energy 2D histogram obtained for the PIN Si detector and fission fragments from ^{252}Cf open source (center). Vertical axis (rise time fraction) projection (right). Horizontal axis (energy) projection (top).

In the Fig. 2 the 2D spectrum of the energy and rise time for the fission fragments from ^{252}Cf open source measured at NCBJ laboratory is presented. During the measurements a Si PIN diode detector of 300 μm thickness, charge preamplifier, high performance digital oscilloscope, dedicated software for the analysis was used. In the figure the spectrum segmentation for the rise time fraction and energy is shown

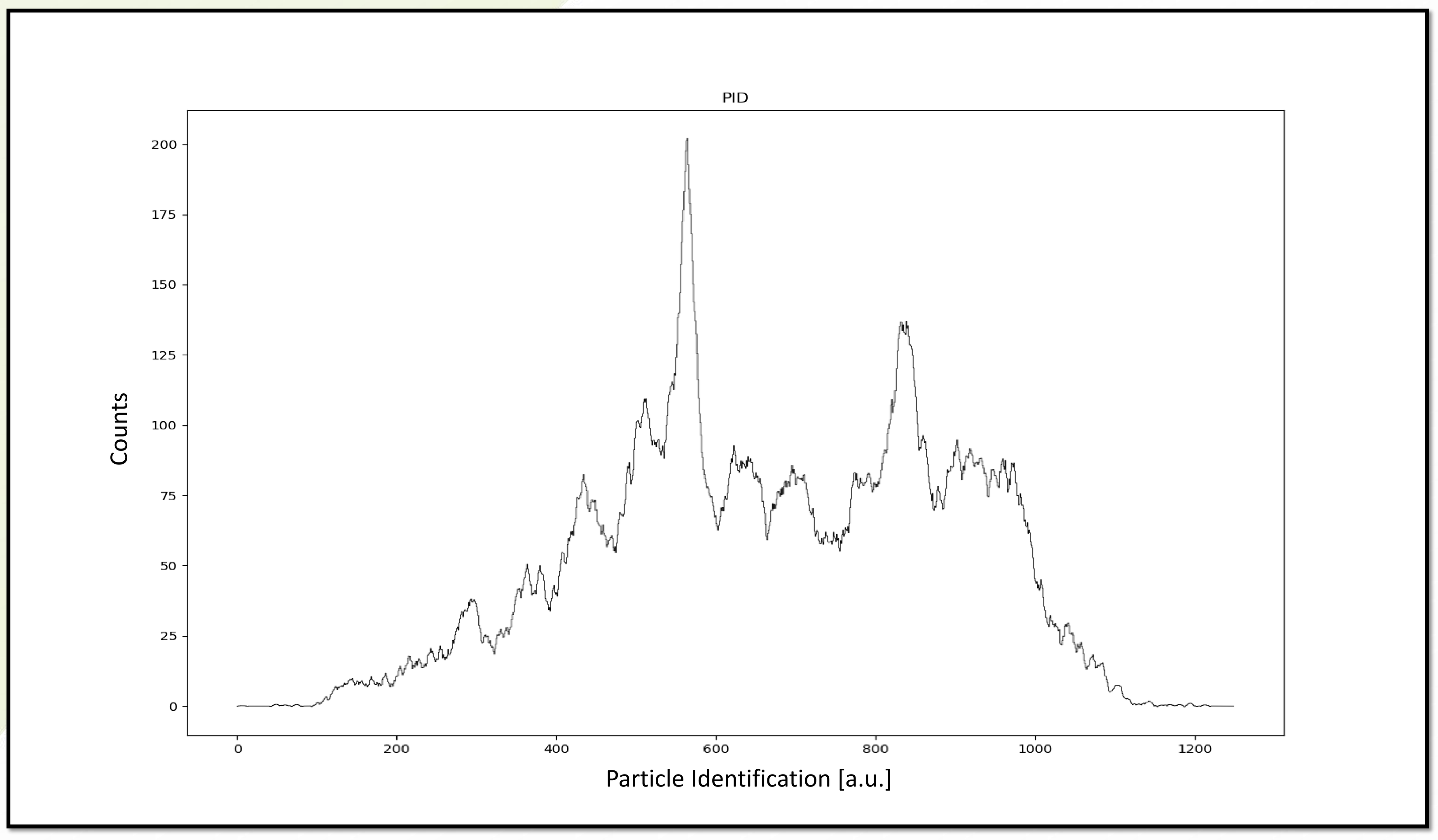

Fig.3 Particle identification (PID) histogram for the fission fragments from ^{252}Cf open source

In the Fig. 3 is presented the cross projection of the 2D histogram from the center of Fig. 2.

It is assumed that peaks on the PID figure represent Z-dependent fission fragments. Results on the above plot are very unique for the PIN type Si detectors, and the energy vs. rise time analysis.

Research project objectives

The shape of the pulse collection in a solid-state detectors following the the interaction of charged particles can be used for particle identification. The sensitivity of the pulse shape in the Si detectors depends on:

a) the plasma erosion time, and

b) the finite drift time of the charge carriers. As a result, the charge-collection time increases monotonously with charge and mass number of the detected ions . The heavy fragment generates a current signal of longer duration but smaller amplitude, which corresponds to a longer rise time of the charge signal, while the light fragment and elastically scattered ions have a shorter rise time signal allowing on the separation into different groups. Identification of fission fragment masses and energies has been, and still is a major concern in fission spectroscopic research.

Research project methodology

In order to identify isomeric states in fission fragments, it is planned to use fission fragment detectors, compact Si ball with surface barrier detector(s), e. g. PIN, Hamamatsu S3590, and/or mini Si ball with reversed planar n-type Si detectors to trigger the EAGLE Ge detectors array and isolate the delayed γ-ray cascades, as well as to ascribe them to respective masses. An optimal separation of FF masses was tested with ^{252}Cf source checking the time difference (T_{PSD}) between 90% and 10% of the charge signal Q(t).

Promising results obtained with ^{252}Cf source motivated us to carry out an identification of n-rich FF in heavy ions induced fission.

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