Investigation project: studying of fission fragment's brake-up while passing through solid state foils, using Timepix3 detector

D.V. Kaminin 1, S. Pospisil 2, Yu.V. Pyatkov 1,3, O.V. Strelkovsky 1,4, Z.I. Goryainova 1

1 Joint Institute for Nuclear Research, 141980 Dubna, Russia
2 Institute of Experimental and Applied Physics, Czech Technical University in Prague, Husova 240/5, 110 00 Praha 1, Czech Republic
3 National Nuclear Research University "MEPhI", 115409 Moscow, Russia
4 Dubna State University, 141980 Dubna, Russia

Timepix3 hybrid pixel detectors. The Timepix3 device consists of a semiconductor detector chip (300 μm thick silicon) bump-bonded to a readout chip. The detector chip is equipped with a single common backside electrode and a front side matrix of electrodes (256 x 256 square pixels of pitch of 55 μm) of 1.6x1.4 cm² total active area. For Timepix3, timing accuracy is 1 ns. Each element of the matrix (pixel) is connected to its respective preamplifier, discriminator and digital counter integrated on the readout chip (Fig. 7). Timepix detectors make measurement of both energy deposition and time of particles’ arrival, which make it possible for position and energy-sensitive detection of hitting particles.

Methods for calculating energy of a hitting particle with Timepix:
1. Direct calculation of the total charge by summation of all the fractional charges (in each pixel in the cluster). Under conventional detector settings, the pixel electronic signal deviates at ~ 1 MeV/pixel and higher – Volcano effect: calcrap like hollowing out of the measured energy deposition in the center of a cluster [1]. As a result, total measured energy of the particle is substantially lower than the one theoretically expected (Fig. 8).

This effect can be suppressed, and the pixel ToT range expanded up to at least 100 MeV, by suitably fine tuning the Si- detector baseline and threshold levels together with applying the sensor bias voltage optimally low (Fig. 9).

2. From cluster area (number of pixels) which determined by the kinetic energy and hitting power of the particle. Using the appropriate calibration, it is possible, for instance, to obtain energy distribution of FF from 253Cf(α) (Fig.10).

Fig. 6. Kinematics of the CCT process by an example of Sn-NiCa partition (Fig. 6). Ni-Ca clusters form due to the brake-up of the Cf fragment from binary fission when it passes through the source backing. Knocked-out ion from the backing - the brake-up spectator.

Goal of the Experiment
Using Timepix3, in events with a reliably identified spectator-ion, register two clusters, significantly different from each other in the number of pixels, since the energies of the fragments that form them differ by an order of magnitude. The expected angle between the fragments is in the range of 0.3°-2°.

For reliable identification of the spectator-ion, we plan to measure its mass by time of flight. The start signal is given by the fragment registered in the PIN diode (1) (Fig.11), the stop signal and information about the particle energy are taken from one of the PIN diodes (5). Delayed coincidence between the PIN (1) and PIN (5) signals form a trigger signal for a multichannel flash-ADC (Amplitude to Digital Converter) digitizer CAEN DTS74 which provides digitization of the signals [4]. The criteria for a trigger signal are such that the background from alpha particles (natural radioactivity, conventional ternary fission and polar emission) is reliably suppressed. If the ring (5) has a radius R = 10 cm, the flight times for the least energetic alpha particles of 238U natural radioactivity and four 5 MeV Al ions knocked out of the foil differ by 10 ns. The distance from foil (4) to the Timepix3 (2) (15 cm) has been chosen so that the clusters of pixels (so-called blob) from Ni and Ca ions would not overlap even if the angle between these fragments was 0.3°. In order to improve the angle resolution, at the next stage of the experiment, the PIN (1) will be replaced with a Timepix device, in order to measure the coordinates of the points at which the fission fragments cross the FOV source with an active pixel radius of 5 mm.

The experimental setup (Fig. 11) includes miscellaneous detectors operating with different readout systems. Information from PIN diodes is obtained using the CAEN DTS74 digitizer as digital images of the signals, which are further processed by a special complex of programs off-line. Data from Timepix3 are obtained and transferred using the read-out interface LKatherine (Fig. 7). Synchronization of the read-out systems is required to form a single event. A similar problem was solved in [5].

A schematic view of the data acquisition system of the experimental setup, including two ΔE-Te telescopes is shown in Fig. 12. The specially designed HITPix COMBO device acquires a signal from the backside electrode and the pixel part of Timepix. SPECTrix device (a modified version of HITPix COMBO), however, is used for the acquisition of signal from ΔE detector. The timestamp jitter obtained for the single telescope is 11 ns (σ), while timestamp jitter between both telescopes is 13.8 ns (σ). Synchronization of miscellaneous detectors with such a time spread is quite acceptable for the implementation in the experiment we are planning (Fig. 11).