DETECTION OF TERNARY FISSION FRAGMENTS FROM ^{252}CF WITH A POSITION-SENSITIVE ΔE-E TELESCOPE

G.S. AHMADOV*[1,2,4], F.I. AHMADOV[2,4], Yu.N. KOPATCH[1], S.A. TELEZHNIKOV[1], C. GRANJA [3], A.A. GARIBOV[2,4], S. POSPISIL[3]

Joint Institute for Nuclear Research, Dubna, Russia[1]
Institute of Radiation Problems-ANAS, Baku, Azerbaijan[2]
Institute of Experimental and Applied Physics, Czech Technical University in Prague, Czech Republic[3]
National Nuclear Research Centre of Ministry of Communications and High Technologies, Baku, Azerbaijan[4]
**email:ahmadovgadir@gmail.com*

Using a thin silicon diode detector with thickness of 12 μm coupled with a Timepix detector (equipped with a 300 μm silicon sensor), a position-sensitive ΔE-E telescope has been constructed. The telescope provides information about position, energy, time and type of registered particles. The emission probabilities and the energy distributions of ternary particles (He, Li, Be) from ^{252}Cf spontaneous fission source were determined using a pair of these telescopes operated in coincidence and with synchronized readout. The response of Timepix detector to different particle species was tested by ternary particles.

Keywords: Ternary fission, ΔE-E method, Timepix pixel detector, PIN diode.
PACS: 25.85.Ca, 29.40.Gx, 29.40.Wk.

INTRODUCTION

Normally, fission is a binary process, in which the fissioning nucleus splits into two fission fragments. This is the case in general for both spontaneous and induced nuclear fission. Sometimes, however, instead of the standard "binary fission" a higher-multiplicity process with three or more charged particles emitted in the outgoing channels is observed. The accompanying particles are lighter compared to the main binary fragments. Therefore, they are called light charge particles (LCP). In ternary fission process, mostly H and He isotopes are emitted, although particles up to mass 36 have been observed [1, 2, 3]. Ternary fission process for different nuclei has already been extensively investigated with various detectors and methods. About 87% of ternary fission events are the ternary ^{4}He particles with mean energy around 16 MeV. These are often called Long Range Alpha (LRA) particles [4, 5].

1. A ΔE-E TELESCOPE

Each side of the de-e telescope consists of 12 μm thin silicon and 300 μm Timepix pixelated detector. The thin silicon detector is used for ΔE measurement and the Timepix detector for E measurement. A simplified electronic scheme of the set-up is presented in Fig. 1. All signals from the ΔE detector are first pre-amplified. Signals from a charge-sensitive preamplifier are split in two parts. One part of the signal is fed to a spectroscopic amplifier for energy measurements and the second to a fast timing filter amplifier, then to constant fraction discriminator for triggering the Timepix detector (E). A 250 MHz DT5720 CAEN digitizer is used for pulse height spectrum measurements for the ΔE detector [6]. Each telescope was placed at a distance of 8 mm from the source.

Main part of the telescope is the hybrid pixel detector Timepix. It is used as E detector. Timepix is equipped with a single discriminator per pixel and works either as a hit counter, as a timer relative to the detection of the particle, or as a time over threshold counter. In summary, each Timepix pixel is equipped with a counter operating in one of the three modes: Medipix mode (the counter counts incoming particles), Timepix mode (the counter works as a timer and measures time of the particle detection) and Time over threshold (TOT) mode. In this last mode of operation, the Timepix is analogous to a Wilkinson type ADC, allowing direct energy measurement in each pixel. From its time over threshold (TOT) mode of operation, the Timepix device can count the amount of charge being deposited by a particle in a given pixel element. Timepix consists of 256 x 256 square pixels with pitch of 55 μm [7]. The total energy of the particle is measured by summing over all pixels in the cluster of activated pixels. The measured charge distributions can be fitted to a Gaussian shape, permitting the determination of the point of interaction of the particle in the device with sub-pixel precision.Its spatial resolution can be achieved down to few μm [8]. Timepix detector is controlled with the special readout interface FITPix and plugged to PC via USB [9]. The interface can be controlled via Pixelman software [10].

2. MEASUREMENT

For the measurements it is used a thin (both sides) spontaneous fission source of ^{252}Cf with activity of about 100 Bq mounted on a 60 μg/cm^2 foil backing of Al_2O_3 and coated with a thin layer of gold (of less than 10 mg/cm^2). The source thickness is assumed to be uniform to within 20%. The source was round with outer diameter 18 mm and inner diameter 2.1 mm. The experiment was carried out in vacuum (<0.4 mbar) with two telescopes oppositely placed at 8 mm from the source. The count rate for ternary fission was 0.3/min on each telescope.

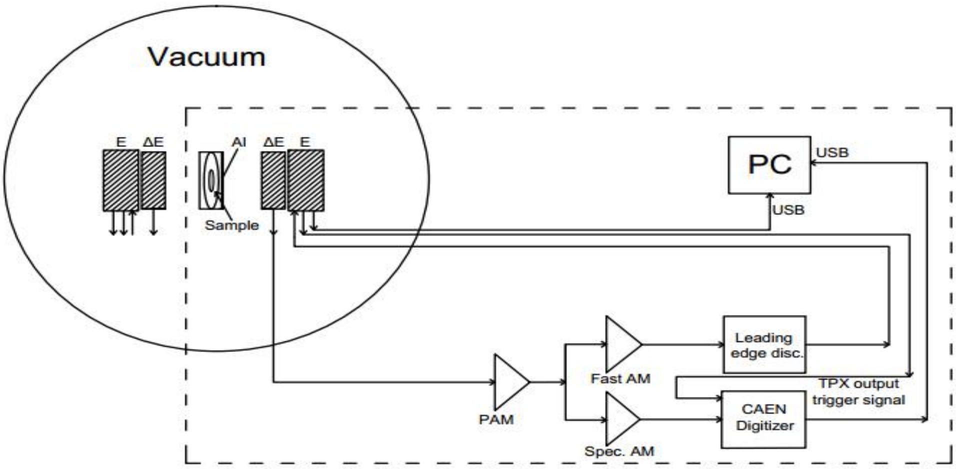

Fig.1. Schematic presentation of the detector configuration. One side of the set-up has a thin ΔE-detector (12 μm) and the hybrid pixel detector Timepix as E detector (300 μm).

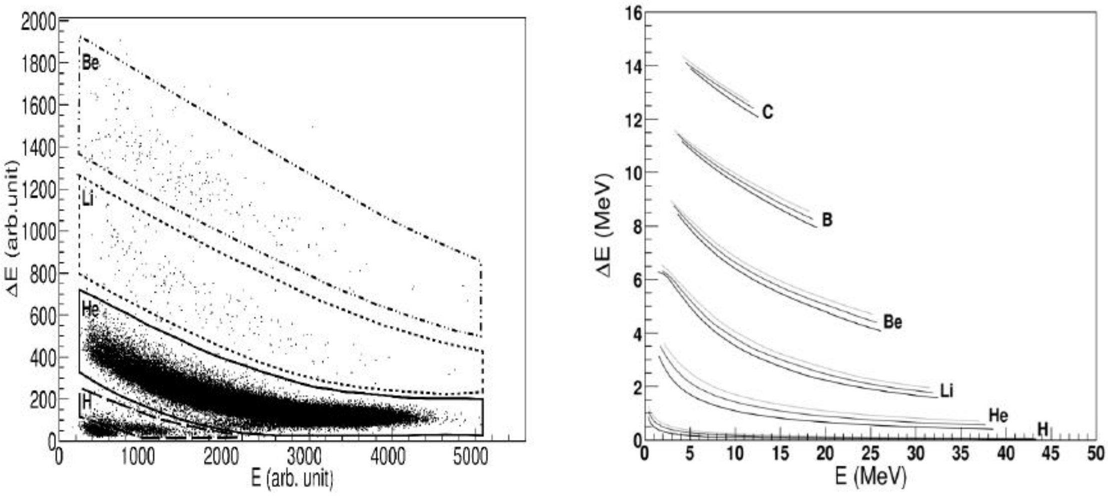

Fig. 2. The experimental (left) and simulated (right) ΔE-E patterns from ternary LCPs. The contour lines define the identification windows used for the analysis. 31 μm thick Al foil was used for protecting the telescopes from being hit by fission fragments and the 6.2 MeV background alpha particles.

3. TERNARY FISSION

A ΔE-E spectrum of LCPs measured (left) and simulated (right) with the telescopes is shown in Fig. 2. Data is created for simulation by SRIM program and simulated spectrum is plotted using ROOT. The contour lines define the identification windows used for the analysis of experimental data (fig.2 (left)). A 31 μm thick Al foil was placed in front of the detectors for stopping the background alpha particles from natural radioactivity of ^{252}Cf (6.2 MeV) in the experiment. The ternary particles from ^{3}H to Be were discriminated as shown in Fig.2 (left). Because of the energy threshold by the ΔE detector, isotopes lighter than ^{3}H are not well resolved in Fig.2 (left). Due to the 31 μm Al foil and 12 μm ΔE detector, the lowest energy (threshold) of α particles which can reach the E detector was about 7.5 MeV. Energy spectra were plotted for identified ternary particles using graphical cut-off method.

The LCP energy spectra obtained with the telescope on the ternary fission modes with He, Li and Be emission are displayed in Fig. 3. All spectra were corrected for energy loss in the absorber foil and the ΔE detector. For the heavier LCP species the accessible range of LCP energy was more seriously limited by the cutoff. This further imposed a strong distortion on the energy spectrum. Heavier LCP particles deposit only part of their energy in the telescopes and were, thus registered at higher energies. Li and Be LCPs emitted in ^{252}Cf ternary fission with kinetic energy over 16.5, 25.5 MeV, respectively, were identified and their relative yields and energy distribution parameters were estimated. A Gaussian fit to the ternary α data points above 12.5 MeV were performed to determine the average energy and sigma, as well as extrapolated counting rates. The results obtained for the various ternary particles are listed in Table. The estimated yields are in agreement with the experimental data from [5].

The highest yield was found for He ternary particles. The yield for Li was less than the yield for Be. It can be explained with stable nucleus.

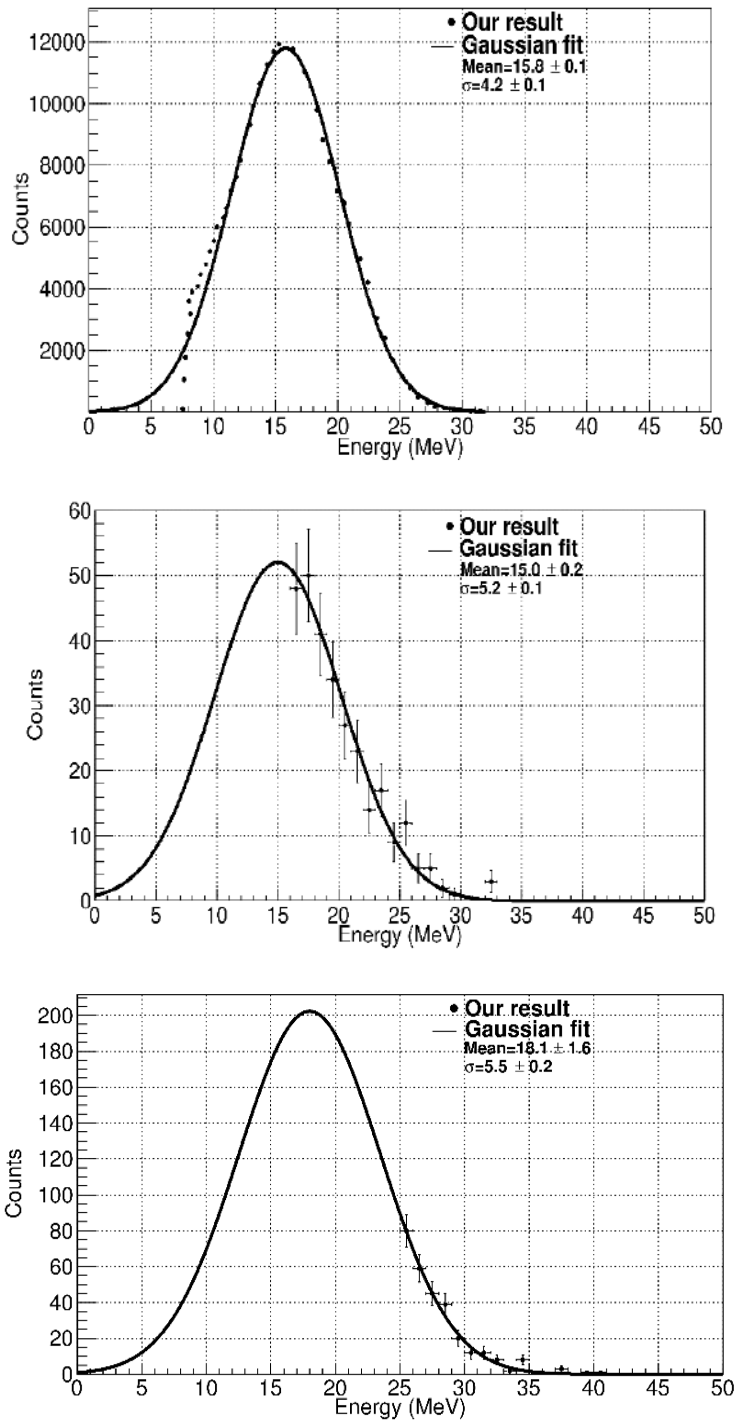

Fig. 3. Energy distribution for the ternary particles He (top), Li (middle) and Be (bottom) emitted in ^{252}Cf(SF), measured with the Al shielding foil. Correction was done for losses on the Al foil and ΔE detector.

Table

Relative emission probabilities of the various ternary particles and the energy distribution for the spontaneous fission of ^{252}Cf

Ternary particles	Events	Threshold energy (MeV)	Energy (MeV)	Sigma (MeV)	Yield per 10^4 α
He	10^5	7.5	15.8(0.1)	4.2(0.1)	10^4
Li	210	16.5	15.3(0.6)	5.2(0.4)	51(11)
Be	214	25.5	18.1(1.6)	5.5(0.2)	224(22)

SUMMARY AND CONCLUSIONS

Ternary particles from spontaneous fission source ^{252}Cf were studied in the experiment. Results obtained are in a good agreement with previous and other work.

In addition, ternary particles allowed us to test the response of Timepix detector to different particle species. Compared with other authors' results, the response of Timepix detector to He, Be and Li particles is the same.

[1] Proc. Seminar on Fission Pont d'Oye IV, Habay-la-Neuve, Belgium, 2000, p. 59.

[2] *S. Vermote, C. Wagemans, O. Serot, J. Heyse, J. Van Gils, T. Soldner, P. Geltenbort, I. AlMahamid, G. Tian, L. Rao.* Nucl. Phys. A, 837 (2010), p. 176.

[3] *Y. Ronen.* On the light particles in ternary fission. Phys. Scr. 86 (2012) 065203 (6pp).

[4] *Tishchenko V. G., Herbach C.M., Hilscher D., Jahnke U.* Study of ternary and quaternary spontaneous fission of ^{252}Cf with the NESSI detector. Report HMI-B 588, Nov. 2002.

[5] *C. Wagemans* The Nuclear Fission Process (1991).

[6] *G.S. Ahmadov, F.I. Ahmadov et. al.*, ISINN 21 Proceedings (2013).

[7] *X. Llopart et al.*, Nucl. Instr. Meth. Phys. Res. A 581 (2007) 485-494.

[8] *J. Jakubek, et al.*, Nucl. Instr. and Meth. in Phys. Res. A 600 (2009) 651-656.

[9] *V. Kraus, M. Holík, Jakubek et al.,* J. Instrum.6 (2011) C01079.

[10] *D. Turecek, T. Holy, J. Jakubek, S. Pospisil, et al.,* J. Instrum. 6 (2011) C01046.

Received: 24.11.2014