"NEUTRON BELT" FOR COMETA SETUP

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Abstract. Forthcoming experiments aimed at studying the mechanism of collinear cluster tripartition are planning to be performed with the new facility. Charged products will be registered with the double arm time-of-flight spectrometer composed of mosaics of PIN-diodes and MCP (micro channel plates) based timing detectors. Several tens of ^{3}He-filled counters will be gathered round the ^{252}Cf source. In order to choose an optimal configuration of the neutron detector and other parameters of the experiment special modeling has performed using both "neutron barrel" and known MCNP code. The first test run of the new facility is in progress also its "neutron skin" in under construction.

INTRODUCTION

Some years ago in the framework of the program of studying of a new type of nuclear transformation called by us as collinear cluster tripartition (CCT) the experiment aimed at measuring of neutrons correlated with unusual decay channel was performed [1, 2]. We expected one of the CCT modes to be an isotropic neutron source of high multiplicity. A special designed neutron detector based on ^{3}He counters was used in order to reveal this mode. 140 neutron counters were located as a belt surrounded ^{252}Cf source in the plane (fig. 1) orthogonal to the mean fission axis. Six modules of FOBOS spectrometer in each arm were used for measuring of fission fragments (FF) masses.

Probability distribution for number of detected neutrons in a time gate started by fission event is compared with the model [2] one is shown in fig. 2a. As can be referred from the figure the model gives an adequate description of the experimental curve up to number of detected neutrons amounts to five. The yields at higher multiplicities forming a "tail" in the distribution are underestimated by the model, which accounts only "conventional" neutrons originated likely from binary fission. Thus some unusual neutron source to be investigated could give rise to the "tail" observed.

We have examined some alternative hypothesis concerning the parameters of the neutron source being able to reproduce the "tail" [3] and came to the conclusion that the neutron source in question should be at rest and should be collimated in the plane perpendicular to the fission axis. It could be a "hot spot" between two fragments right after scission. Evidently, we deal in this case with ternary decay and the effect of "hot spot" could be due to collapsing of the neck of unusual shape [4]. Configuration of the system after scission which we mean was discussed in past in connection with polar emission of light charged particles (fig. 3).

It should be stressed, that presumable existence of the decay mode accompanied by the emitting of ~ 12 neutrons does not seem to be something absolutely exceptional. Really, there are well known data [5, 6] which demonstrate neutron multiplicities at least up to ten (fig. 4).

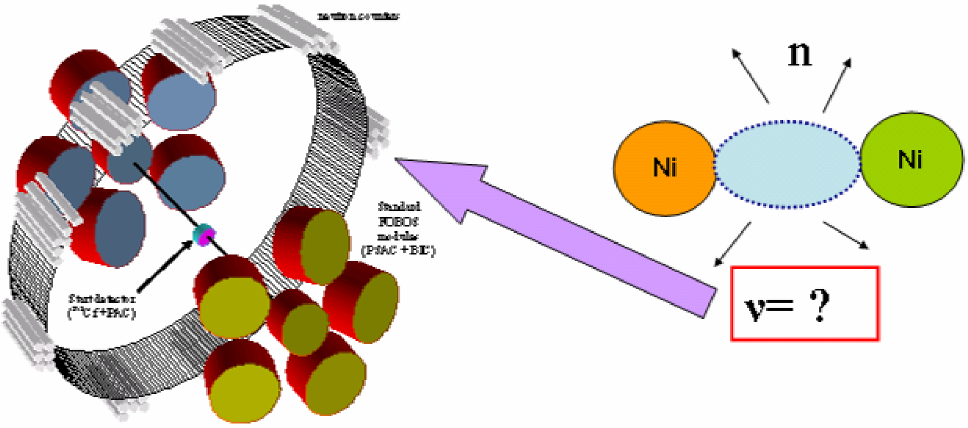


FIGURE 1. Sketch of the experimental setup used for registration of neutrons emitted in the CCT channel in coincidence with fission fragments.

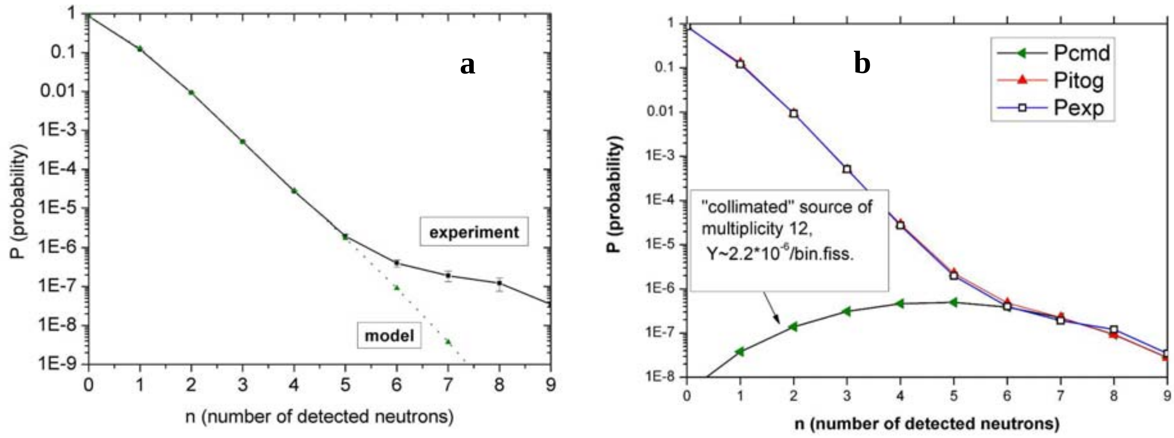


Figure 2. Experimental probability of detecting of fixed number of neutrons emitted in a single fission event (a). Possible parameters of the neutron source to be decisive for the "tail" (b).

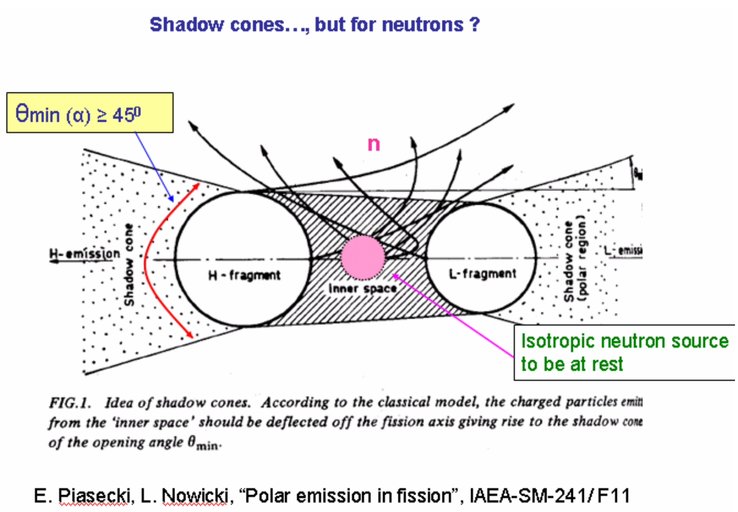


FIGURE 3. Possible mechanism of "focusing" of the neutrons emitted by the "hot spot" located in between two fragments right after scission. Original picture was drawn for treating of polar emission of light charged particles (see reference in the bottom of the figure).

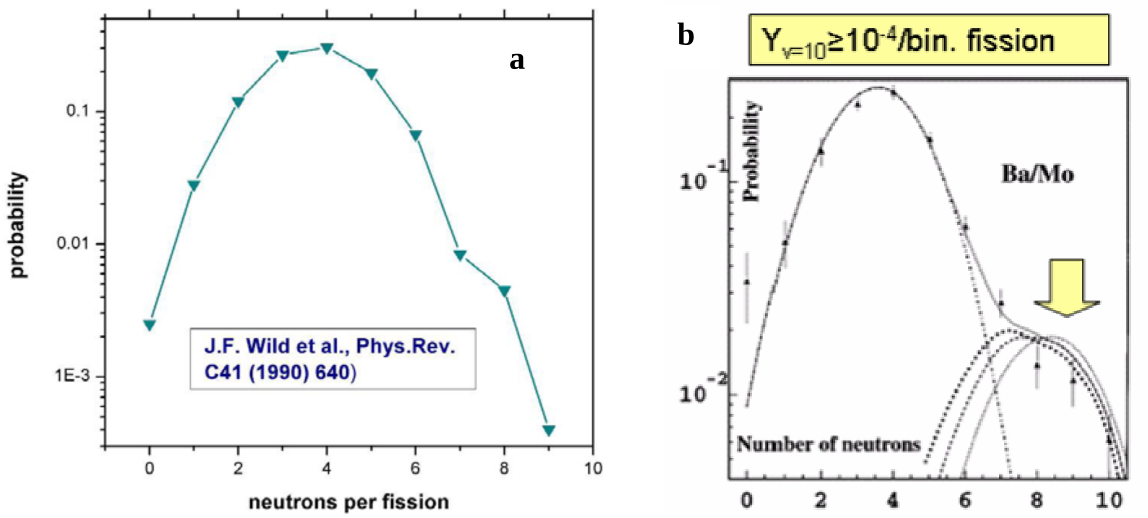


FIGURE 4. Number of neutrons emitted per fission in ^{252}Cf (sf) (a). Neutron multiplicities for the partitions Ba/Mo in the same system [5] (b).

MOTIVATION

There are some reasons to continue the investigations devoted to studying the CCT channel using neutrons for selection of the corresponding events.

1. Unfortunately, for the moment there is no information about the masses of the fission fragments (FF) from the events which gave rise to the "tail" in fig. 2a.

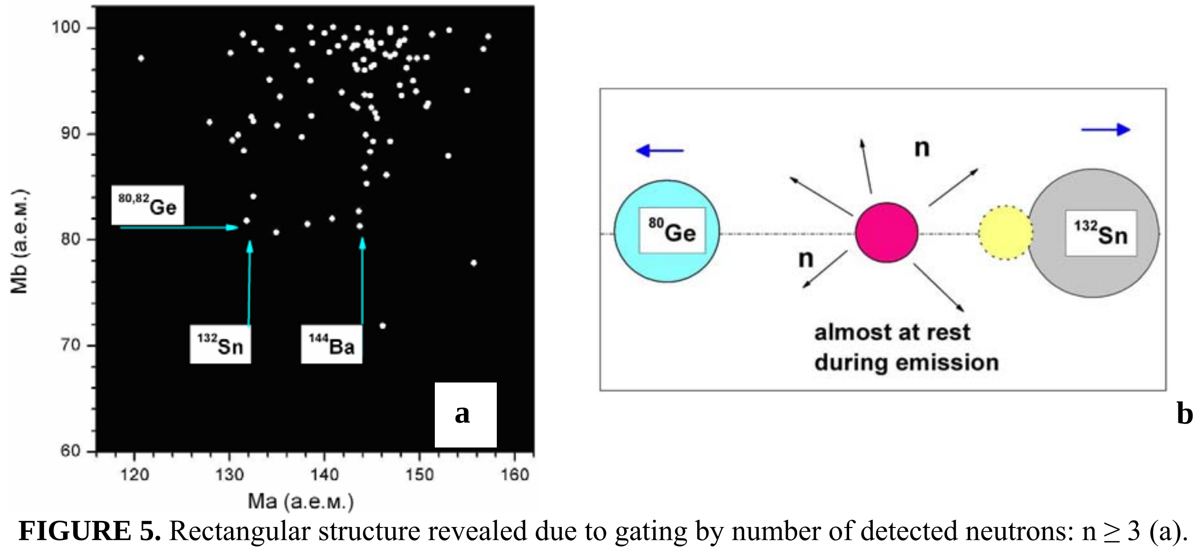


FIGURE 5. Rectangular structure revealed due to gating by number of detected neutrons: n ≥ 3 (a). Presumable scenario of the neutron emission along the trajectory Mb = const (the bottom side of the rectangle) (b).

2. Due to selection of fission events triggered by increased number of neutrons (n) we have revealed specific structures in the FF mass-mass distribution. Corresponding plot for n ≥ 3 is shown in fig. 5a. The structure looks like rectangle bounded by the magic nuclei. Similar but more populated plot was obtained using n ≥ 2 selection condition. The modes at hand manifest themselves as an isotropic neutron source of multiplicity four (fig. 5b) [3]. The

original experiment was performed in the frame of the “missing mass” method of identification of the CCT events. We need in direct detection of all the decay partners in order to elaborate the decay scenario.

Thus, summing up, new time-of-flight spectrometer for solving the problems formulated above must be based on mosaics of detectors which can provide simultaneously energy and timing signals being fired by the FF and includes neutron counters triggered by the FF.

MODELING OF NEUTRON SKIN

We have succeeded in revealing the unusual decay modes due to special arrangement of the neutron counters (fig. 1). A key parameter was the ratio of the probability to detect neutron emitted by an isotropic source (to be at rest) to that linked with the neutrons emitted from the moving fragment P_iso/P_mov. We estimated this ratio experimentally with the help of the “neutron barrel” used in the experiments devoted to the chemical properties of the superheavy elements. It consists of 54 ^{3}He filled neutron counters in the moderator (fig. 6a) [7]. Special assembling consists from two PIN-diodes placed face to face to each other and the Cf source in between was used to define a fission axis. Coincident signals delivered by the PINs opened the gate for detecting of neutrons. The positions of the assembling relative to the “barrel” are shown in fig. 6b. The results obtained are presented in Table 1.

TABLE 1.

Position of the source	P_iso %	P_mov%	P_iso/P_mov
1	13.4	27.4	0.49
2	3.1	3.4	0.91
3	1.4	1.4	1
4	3.4	8.1	0.42

As can be referred from the table the best value of the P_iso/P_mov ratio did not exceed unity thus one would fails to pick out isotropic neutron source with such geometry of the detecting system.

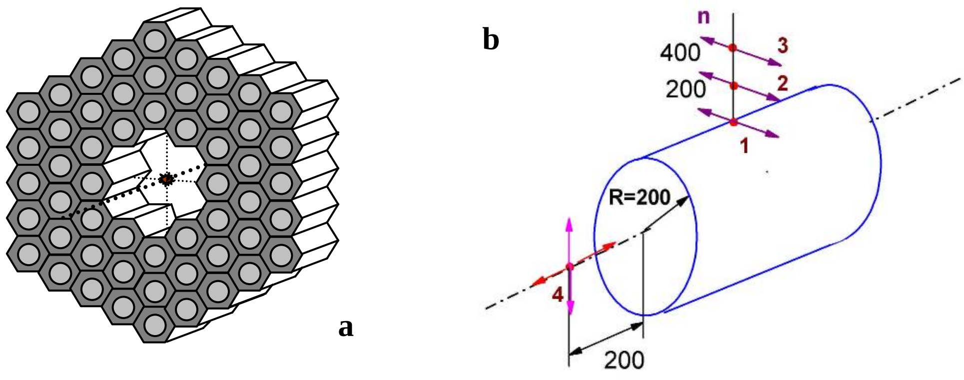


FIGURE 6. Arrangement of the 3He filled neutron counters in the “neutron barrel” (a). Positions of the PIN-diodes assembling around the “barrel” (b).

The modeling let came to some important conclusions regarding parameters of the neutron detector. Revealing “the tail” of high neutron multiplicities (fig. 2) is one of the goals of forthcoming experiments. In order to estimate the contribution of both the background of the experimental hall and the random coincidences neutrons were also registered in the time gates opened by an external generator.

Resultant experimental spectrum of the multiplicities of the detected neutrons (fig. 2a) is equal to convoluted distribution of the total background and real events linked with fission. It should be emphasized that one can not used Poisson distribution for predicting both the spectrum of total background and effect from fission. Comparison of the results obtained using generator and prediction according Poisson law is presented in fig. 7a. Distribution of time intervals “start signal from fission – detecting of the first neutron in the gate” (fig. 7b) is also far from being unique exponential function as it must be in the Poisson stream. Thus, only special statistical model of the neutron detection channel is capable to reproduce experimental data. It was worked out by us earlier [2]. In the frame of this model an optimal efficiency for registration of neutrons emitted from the accelerated FF can be chosen. Corresponding results are presented in fig. 8.

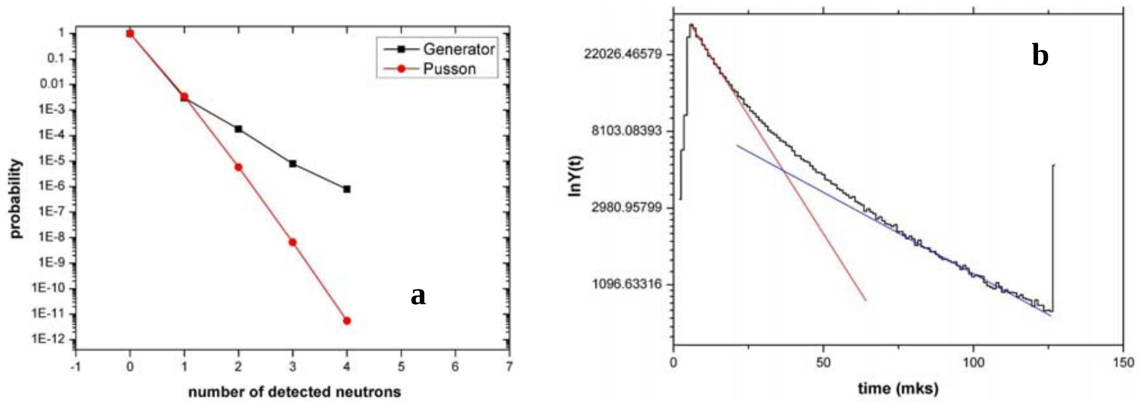


FIGURE 7. Number of detected neutrons per gate opened by the generator in comparison with the prediction using Poisson distribution (a). Spectrum of the time intervals “start signal from fission - detecting of the first neutron in the gate” (b).

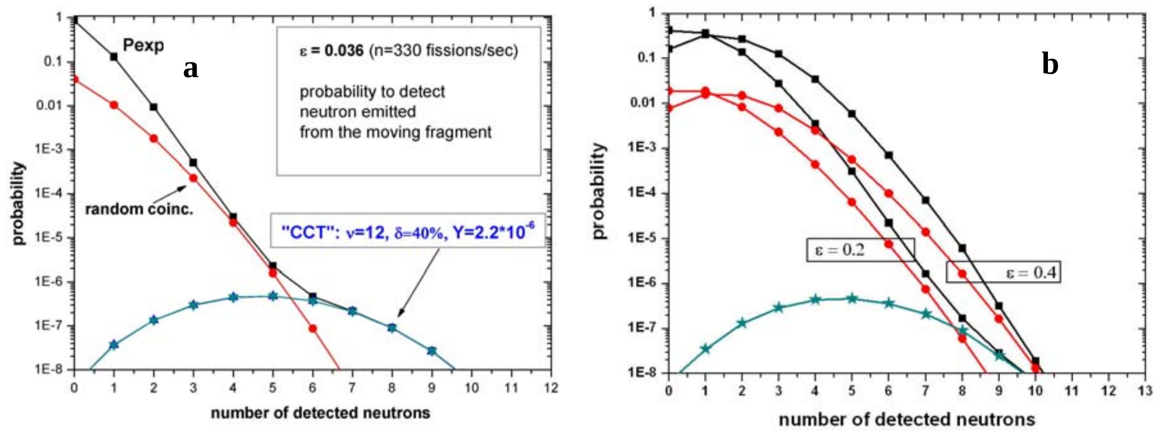


FIGURE 8. Spectra of the neutron multiplicities from three sources namely random coincidences (red points), decay mode to be identified (green points) and resultant spectrum being the sum of two listed sources and neutrons from conventional binary fission (black points) . Parameters of the model are shown in the panels.

It is seen that the mode to be identified becomes invisible due to the random coincidences at the registration probability in the vicinity of 0.4 (fig. 8b).

Layout of the spectrometer under construction is shown in fig. 9. The symmetry axis of each neutron counter is oriented transversely to the symmetry axis of the spectrometer.

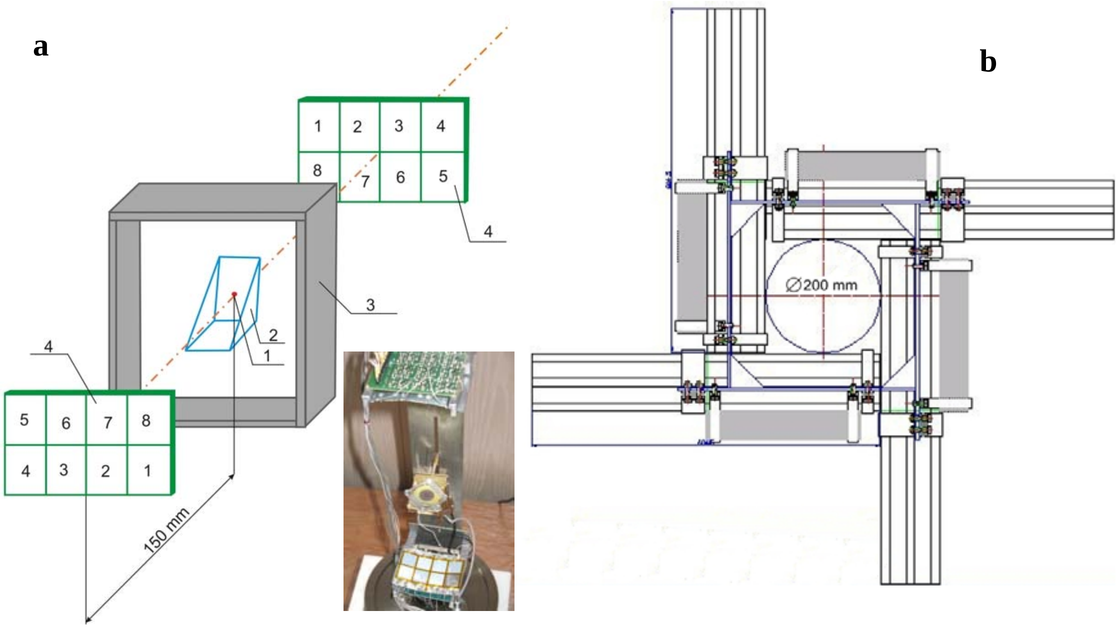
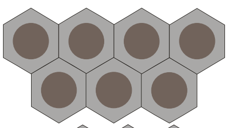
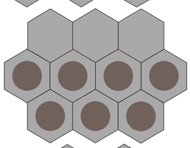
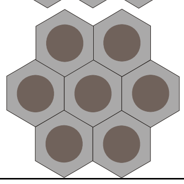
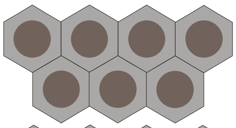
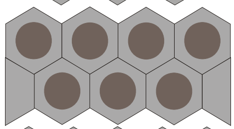
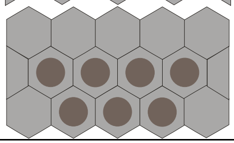


FIGURE 9. Scheme of the setup (a): Cf source – 1, micro-channel based start detector – 2, belt of neutron counters – 3, mosaic of PIN-diodes – 4. Front view of the neutron belt (b). View of the spectrometer is illustrated by the photo at the left. The fragment part is under operation while neutron part is under assembling.

Different ways to arrange the neutron counters in the belt were examined applying the MCNP code. The results of modeling are presented in Table 2 for two distances R between the neutron source (fig. 9b) and the internal raw of counters within a moderator shield.

TABLE 2.

Configuration	P_iso	P_mov	P_iso/P_mov
		R = 15 cm	
	6.4 %	2.6 %	2.46
	8.37 %	3.45 %	2.43
	5 %	1.9 %	2.6

Configuration	P_iso	P_mov	P_iso/P_mov
		R = 10 cm	
	11.89 %	5.23 %	2.27
	16.17 %	7.77 %	2.08
	25 %	13 %	1.9

CONCLUSIONS

Basing both on experimental modeling and calculations we have chosen an optimal configuration of the setup aimed at studying isotropic component of neutrons linked presumably with multbody decay channel. The array of the neutron counters should be located in the plane perpendicular to the symmetry axis of the spectrometer and looks like rectangle (fig. 9) constructed from the modules shown in the second raw of Table 2.

ACKNOWLEDGMENTS

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