Proceedings of ISINN-29, JINR, E3-2023-58, Dubna, 2023, p.147 –152

Determination of the Efficiency of Neutron Detectors in an Experiment of Inelastic Neutron Scattering on ^{12}C

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TANGRA

Project "TANGRA" (TAgged Neutrons & Gamma-RAys) [1] at JINR-FLNP (Dubna) is aimed at studying nuclear reactions caused by fast neutrons. As part of the TANGRA collaboration, an experiment is being conducted to study the reaction of inelastic neutron scattering on a carbon nucleus $^{12}C(n, n')^{12}C^*$ using the method of labeled neutrons. The 14.1 MeV neutrons are produced in fusion reaction

$$d + t \rightarrow \alpha + n + 17.59 \text{ MeV}$$

in VNIIA portable neutron generator ING-27 (Fig.1)[2]. The built-in ING-27 neutron tube 256-pixel a-detector allows to “tag” and count neutrons, because the both reaction products are emitted nearly collinear in opposite directions.

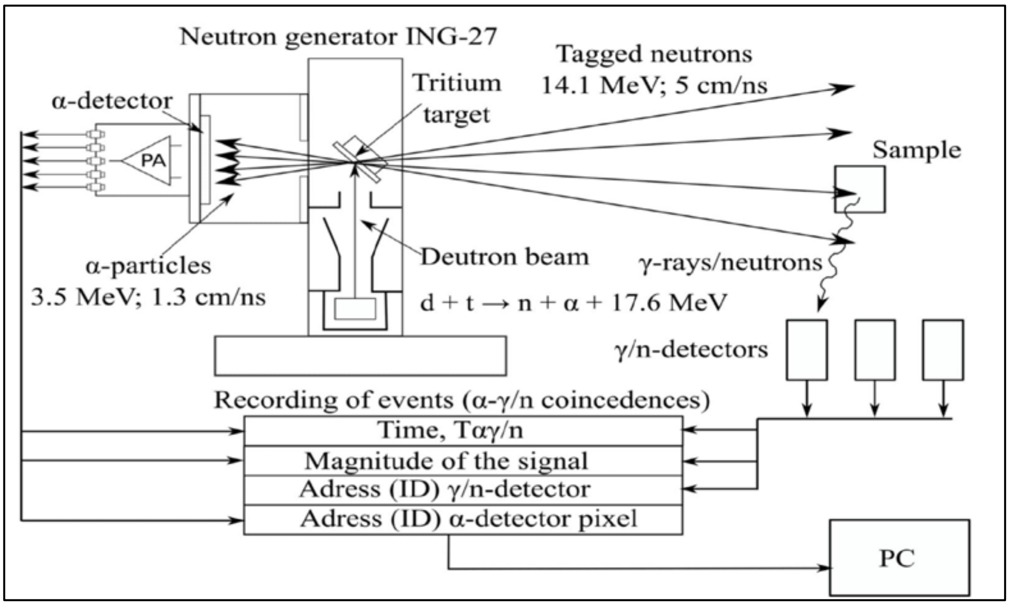

Fig.1. Schematic diagram of the experiment using of method of labeled neutrons.

Experimental installation

The installation is a neutron generator with a carbon ^{12}C screen located in front of it, surrounded by detectors at different angles with the increments of 15° (Fig.2). The angles 90, 180 and 270 are omitted due to the expected high neutron absorption in the target. 0 is omitted due to a direct neutron beam, which will spoil the statistics with a large number of high-energy events.

Plastic scintillation detectors

Plastic scintillation detectors are used in this experiment. Neutron falling into a plastic scintillator EJ-200 [3], knocks out the hydrogen in its composition, which, flying, increases the ionization of the medium and secondary gamma radiation. Secondary photons formed in the scintillator under the action of incident neutrons. They are registered in the PMT ETL 9821KFLB FEU [4].

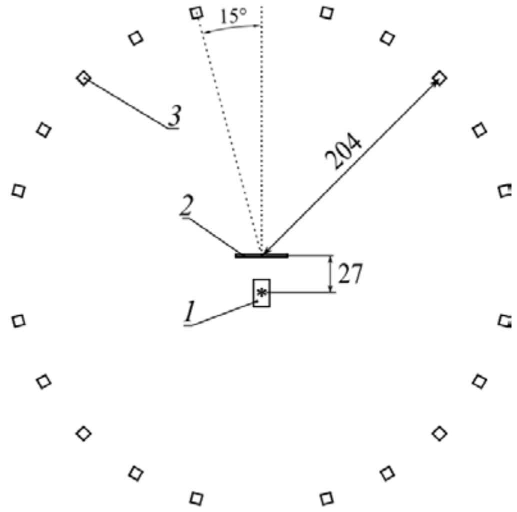

Fig.2. Scheme of the experimental installation. 1– ING-27 neutron generator, 2– carbon target, 3– n-detectors included in an array of 20 plastic scintillation detectors. All dimensions are given in cm.

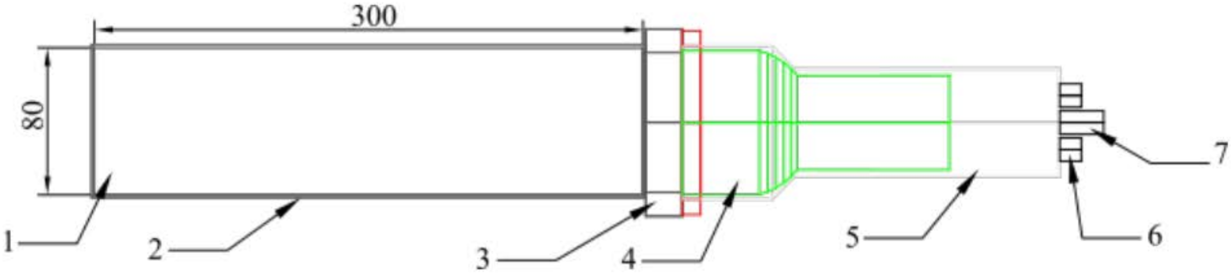

Fig.3. Detector based on a plastic scintillator. 1– plastic scintillator, 2– reflective winding, 3– aluminum holder, 4– PMT ETL9821KFLB, 5– magnetic shield, 6– BNC connectors (x2), 7– SHV connector. All dimensions are given in mm.

Method of determination efficiency

An important part of data analysis is to determine the efficiency of the detectors used in the experiment. This is important both for determining the sensitivity limits of measuring instruments and for estimating the total neutron flux for each detector. Efficiency estimates can be made using different methods, in particular, for a similar experiment, V. Valkovich's group used the following equations [5–6]:

$$(E_{thr}) = \frac{N_H\sigma_H}{N_H\sigma_H + N_C\sigma_C}\left(1 - e^{-d(N_H\sigma_H + N_C\sigma_C)}\right)\left(1 - \frac{E_{thr}}{E_{neutron}}\right),$$

where N_H is a density of hydrogen atoms, N_C is a density of carbon atoms, σ_H and σ_C – total cross sections for scattering of neutrons having energy $E_{n'}$ on H and C, d= 8cm. Thus, determination of efficiency of detectors requires energy calibration and determination of threshold energy of plastic detectors, used in experiment.

Energy calibration

Energy calibration begins with the processing of time-of-flight spectra. Red vertical lines indicate the kinematically predicted positions of peaks from incoming neutrons. After approximation by Gauss scattering, 1.5 sigma region is highlighted with black lines on both sides to isolate neutrons from desired regions.

Next step is a determination of incoming neutrons energy on amplitude spectra. The amplitude spectra consist of events belonging to the regions of neutron peaks of the previous step. The neutron energy is reduced in accordance with the cannel of edge of these spectra (the vertical line in Fig.4).

After this calibration line is constructed in order to determine the threshold energy (Fig.6).

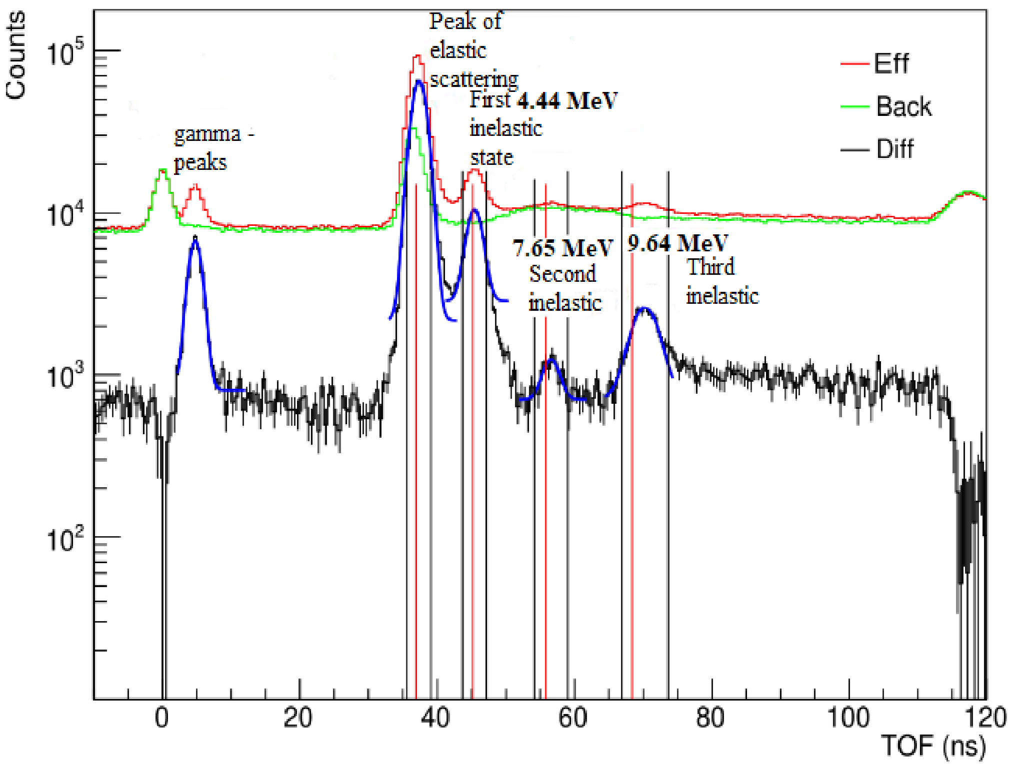

Fig.4. Processing of time-of-flight spectra.

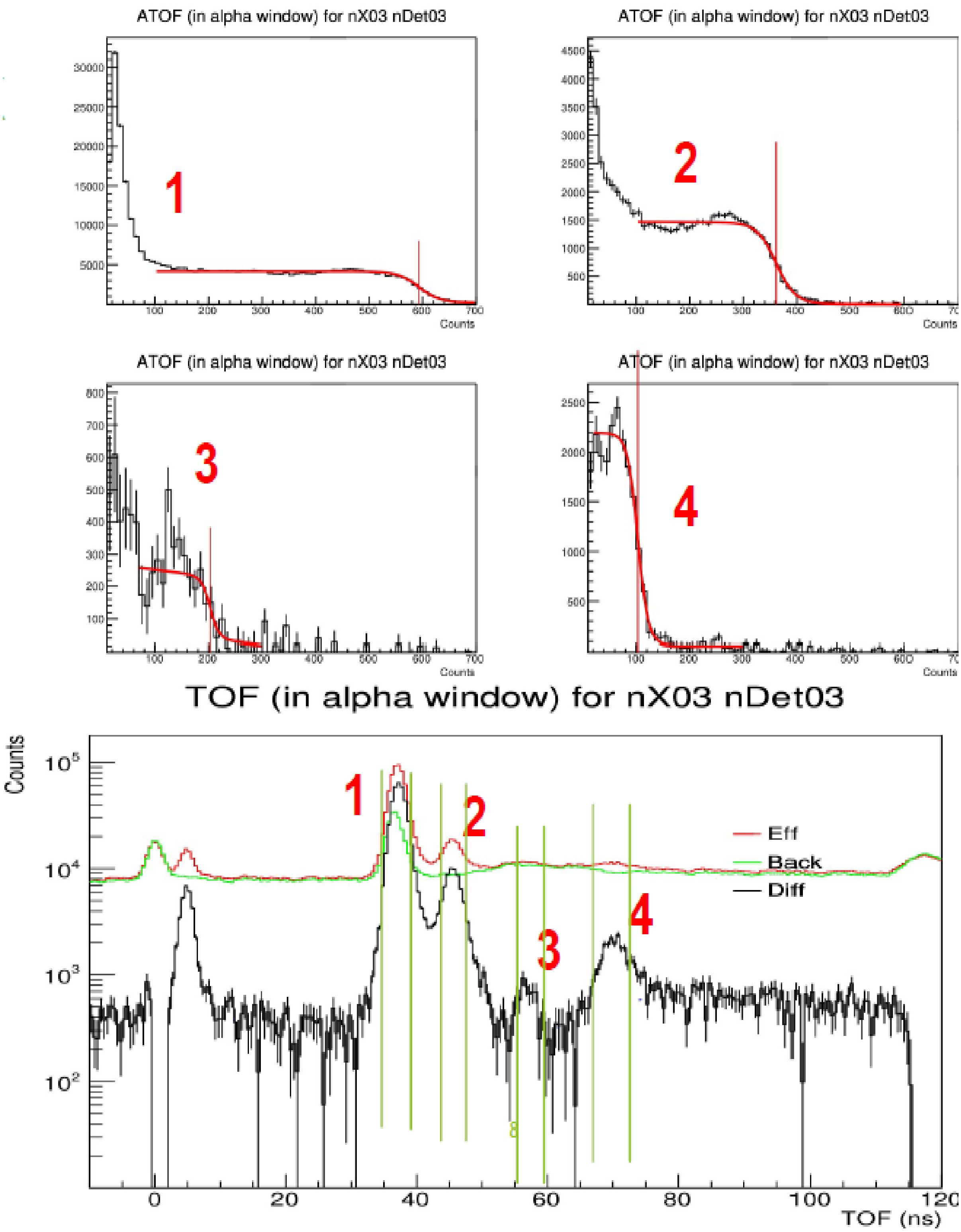

Fig.5. Processing of amplitude spectra.

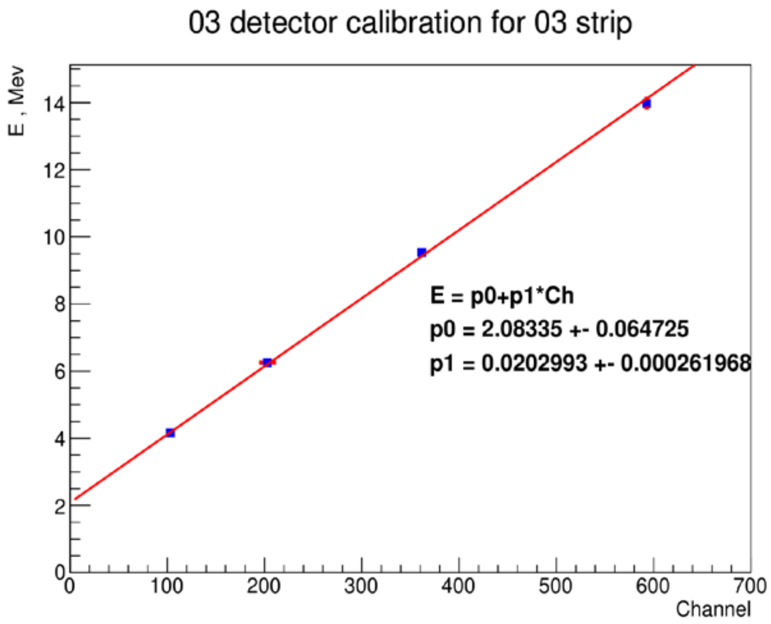

Fig.6. Calibration line for 3rd detector/3rd strip alpha detector.

Determine efficiency

Finally, using values of the threshold energy, dependence of the detector efficiency on the neutron energy are obtained, and the regions corresponding to energies of the incoming neutrons are identified.

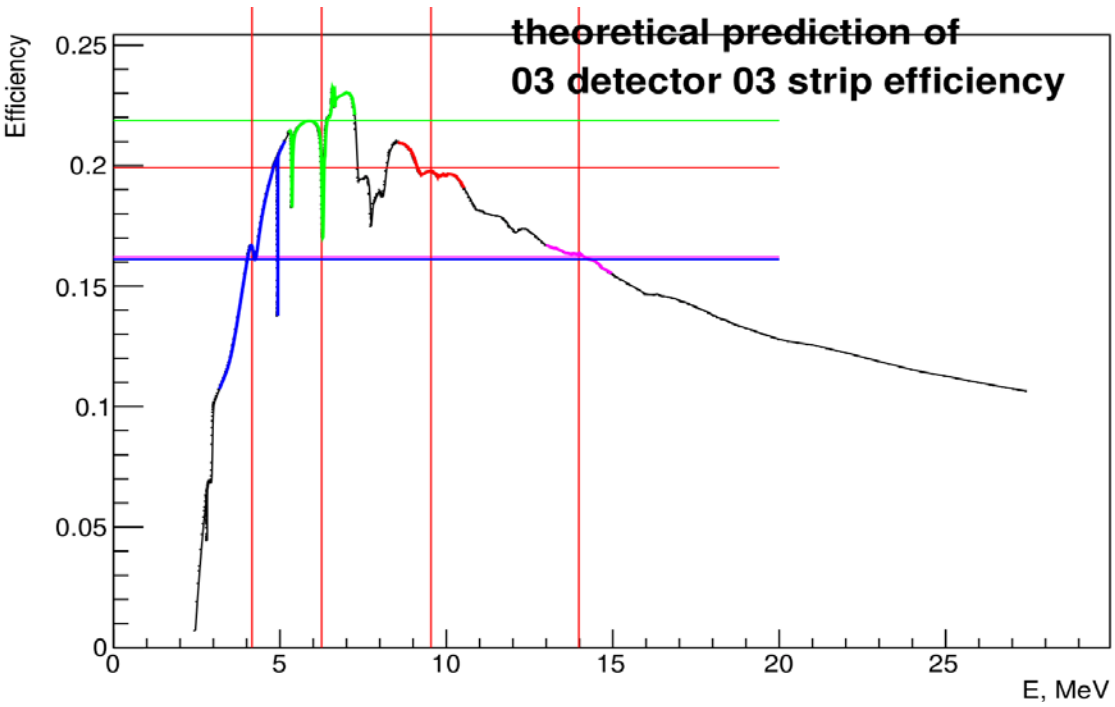

Fig.7. Dependence of the detector efficiency on the neutron energy.

Conclusion

In the course of this work, the dependences of the efficiency of detectors in their combination with the X-strips of the α-detector were constructed. The obtained values of the efficiencies of neutron detectors for various energies can later be used to determine the differential scattering cross-sections of neutrons with the energy of 14.1 MeV on carbon nuclei.

References

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