THE DEPENDENCE OF SPATIAL LOCATION AND SIZE OF NEUTRON FLUX ON THE MAXIMUM NEUTRON ENERGY

Meshkov I.V.[1,*], Potashev S.I.[1,2], Karaevsky S.Kh.[2], Burmistrov Yu.M.[2], Ponomarev V.N.[2], Solodukhov G.V.[2], Drachev A.I.[2]

1 - P.N. Lebedev Physical Institute, Russian Academy of Sciences
2 - Institute for Nuclear Research, Russian Academy of Sciences

1. Introduction

It becomes necessary to control the direction and distribution of the fast neutron flux when preparing and performing neutron-physical experiments. Usually, for this purpose, activation, as well as ionization or scintillation detectors using the recoil proton method are used [1, 2]. The time-of-flight method allows the determination the neutron energy, but this requires the removal of the detector over a long distance and the requirement of a minimal jitter of the accelerator pulse. In addition to the neutron flux from the source channel all these detectors also detect the scattered neutron background. Scintillation detectors are also very sensitive to gamma and X-ray radiation and can be overloaded if the intensity is high making measurement impossible.

2. Position-sensitive neutron detector on the base of ^{10}B and proportional chamber

A position-sensitive neutron detector based on a ^{10}B layer and an ionization chamber demonstrated in the experiment directional sensitivity to fast neutrons which incident approximately perpendicular to the detector plane [3 - *I. V. Meshkov* // Bull.of RAS: Phys. 84, 382 (2020)]. This detector has the property of directional detection also for thermal neutrons, just like the recently proposed detector system of ^{3}He counters [4 – *R. Bedogni* // NIMA, 983, 164595 (2020)]. The proportionality of the amplitude signals of the ionization energy makes it possible to indirectly judge the secondary nucleus energy and consequently the neutron energy at above 1 MeV. It was shown that using pulse heights from the detector it is possible to determine the maximum neutron energy in the flux [5 - *S. Potashev* // EPJ Web of Conf. 231, 05010 (2020)]. Also, the detector has an extremely low sensitivity to gamma and X-ray quanta due to the absence of competing reactions of the photon with the ^{10}B nucleus.

3. Experimental setup

In the experimental setup shown in Fig. 1 the neutron source based on an LUE-8 linear electron accelerator was used. The incident beam *1* with fixed energies of 5, 6, and 7 MeV produced in the tungsten target *2* a bremsstrahlung spectrum of photons with the same boundary energies. These gamma quanta on beryllium target *3* generated the neutron flux with the intensity up to 107 $cm^{-1}s^{-1}$ due to the $^{9}Be(\gamma,n)^{8}Be$ reaction. Most of the neutrons were thermalized down in moderator *4*. The fast neutron residual flux through collimator *5* with a diameter of 3 cm and a length of 45 cm and a cadmium filter *6* were directed to position-sensitive detector *7* based on layer ^{10}B and a proportional chamber. The ^{3}He-counter *8* served as a monitor controlling the slow neutron residual flux.

3. Experimental setup

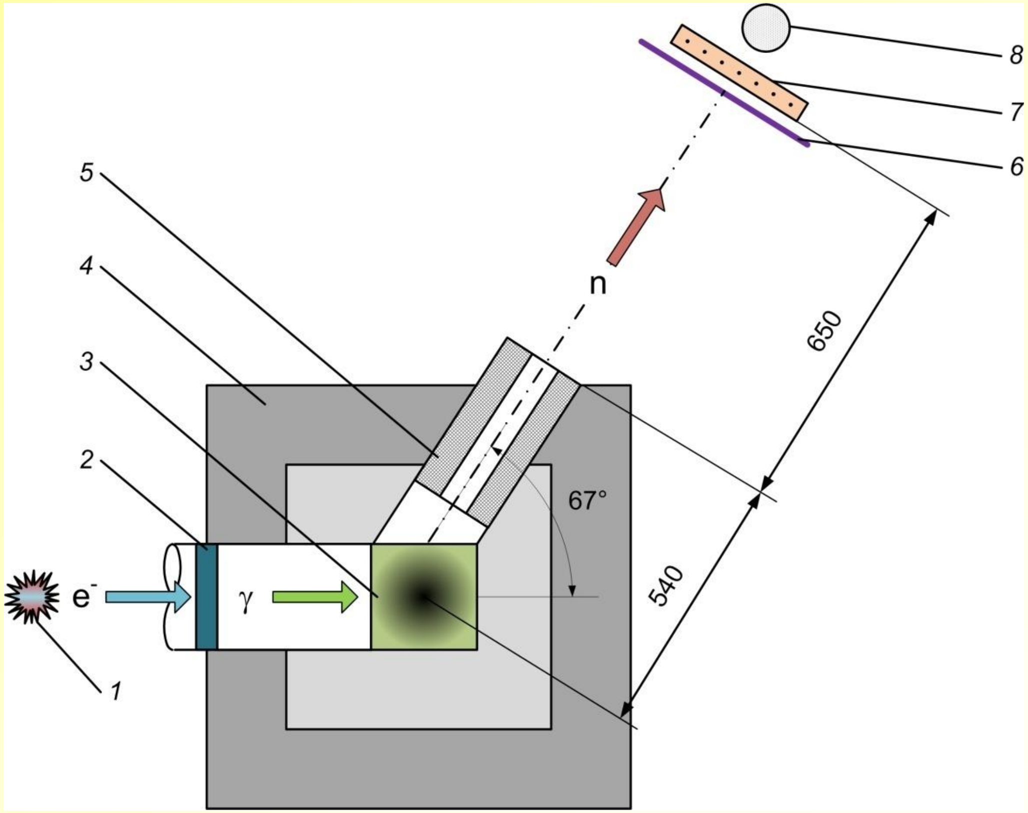

Fig. 1. Schema of the experimental setup. *1* - electron beam; *2* – W-target; *3* – Be-target; *4* - Moderator; *5* - Collimator; *6* – Cd-filter; *7* - position-sensitive neutron detector based on ^{10}B; *8* - ^{3}He-counter.

4. Dependence of the maximum energy in the neutron flux on the electron energy

The kinematics simulation of the $^{9}Be(\gamma, n)^{8}Be$ reaction showed that an increase in the boundary γ-ray energy by 1 MeV in the studied energy range at an angle of 67° to the collimator axis leads to an increase in the maximum neutron energy in the flux by 0,9 MeV. Taking into account the threshold of this reaction of 1,67 MeV the maximum neutron energy in three experiments at energies E_e = 5, 6 and 7 MeV will be E_n^{max} = 3,3, 4,2, and 5,1 MeV, correspondingly. In spite of the 5 mm thick cadmium filter limits the neutron energy to about 0,55 eV the lower limit of detected neutrons is determined by the settled threshold for detecting the secondary nucleus in the 2-nd sensitive gap of the detector. It was ranged from 0,1 to 0,2 MeV. This means that the energy of the ^{4}He or ^{7}Li nucleus with taking into account the loss in the 1st gap, was no less than 0,5 MeV (as it was found the loss of the ^{4}He nucleus for thermal neutrons was 0,43 MeV [6].

5. Experimental results

The coordinates of the neutron detection point were calculated by the charge division method from the signal amplitudes which had described in [7 – Karaevsky // Bull. Russ. Acad. Sci.: Phys. 82, 748 (2018); 8 – Karaevsky // Phys. Atom. Nuclei 82, 1686 (2019)]. Two-dimensional distributions of the neutron flux emitted from the source channel for three values of the maximum neutron energy: 3,3, 4,2, and 5,1 MeV are shown in fig. 3 (a), (b) and (c). It can be seen that the position of the maximum with an increase in the maximum energy for every 0,9 MeV moves backward relative to the electron beamline by about 2 cm along the horizontal X axis. In this case, the full width at half-height of the distribution changes from 4,5 to 6 cm with an increase in the maximum neutron energy from 3,3 to 5,1 MeV. Last fact can be explained by an increase in the range of energies of detected neutrons. At the same time, the position of the distribution maximum along the vertical Y axis and its full width at half maximum does not change.

5. Experimental results

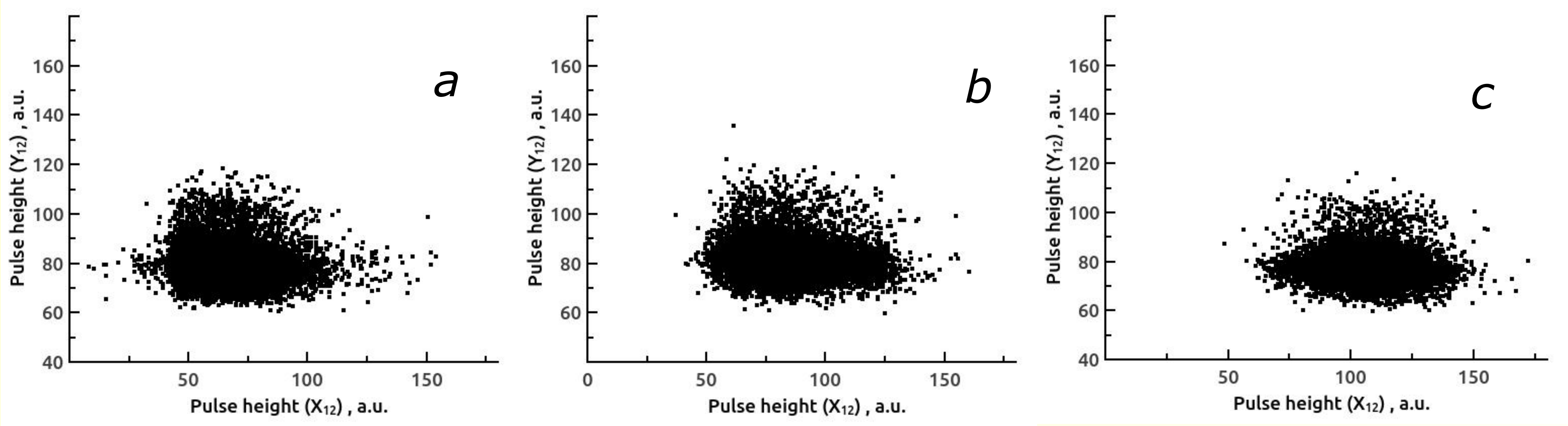

Fig. 2 Correlation between of pulse heights from 1-st and 2-nd detector gaps for neutrons in the flux with the maximum energy: a) 3,3 MeV; b) 4,2 MeV and c) 5,1 MeV.

5. Experimental results

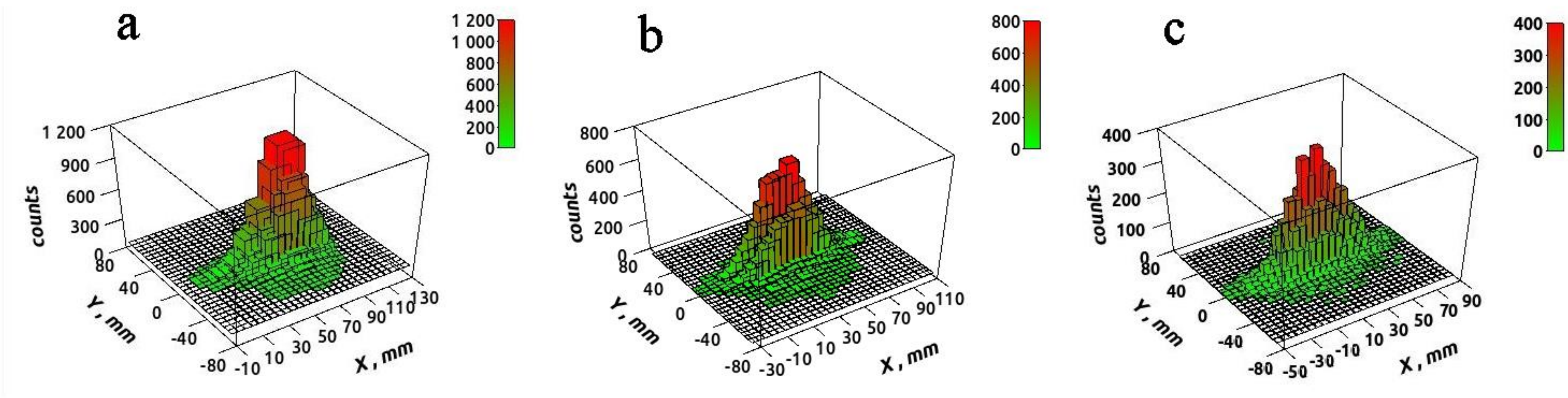

Fig. 3 Distribution of neutrons in the flux with the maximum energy: a) 3,3 MeV; b) 4,2 MeV and c) 5,1 MeV.

6. Conclusions

The spatial distribution of fast neutrons with the maximum energies from 3.3 to 5.3 MeV was investigated using a two-coordinate ^{10}B-detector.

The increase in maximum neutron energy by 0.9 MeV corresponded approximately 2-cm shift of maximum position in experimental spatial fast neutron distribution on distance 120 cm from Be-target center.

Changing the position of the maximum in the horizontal coordinate distribution of neutrons with an increase in the maximum energy makes it possible to determine and control this energy in run time.

7. List of publication

1. *Dreyzin V. T. et al.* Real Time Multidetectors Neutron spectrometer // Journal of Applied Spectroscopy. V.83 (2016) No 3. P. 454.

2. *Thomas D. J. et al.* Bonner sphere spectrometers – a critical re view // Nuclear Instruments and Methods in Physics Research. A 476 (2002). P. 12.

3. *I. V. Meshkov et al.* Studying the spatial distribution of a neutron flux using detectors based on helium-3 and boron-10 // Bulletin of the Russian Academy of Sciences: Physics. V.84 (2020). P. 382.

4. *R. Bedogni et al.* Design of an ultra-sensitive single-moderator directional neutron spectrometer based on ^{3}He detectors. // NIMA, 983, 164595 (2020).

5. *S. Potashev et al.* Hybrid boron10 gaseous detector for slow and fast neutron simultaneous detction // EPJ Web of Conferences V. 231, 05010 (2020).

6. *S. Potashev et al.* A Possibility of Detecting Fast Neutrons in a ^{10}B Solid-gas Detector // KnE Energy. The 3rd International Conference on Particle Physics and Astrophysics (ICCPA). P.115.

7. *Karaevsky S. Kh. et al.* Accuracy of Determining Coordinates by Means of Charge Division in a Position-Sensitive Thermal Neutron Detector Based on Boron-10 // Bull. Russ. Acad. Sci.: Phys. 2018. V. 82. P. 748.

8. *Karaevsky S. Kh. et al.* Data Correction Method for Improving the Spatial Resolution of a Position-Sensitive ^{10}B Neutron Detector // *Phys. Atom. Nuclei* 82, 1686 (2019).

Thank you!