# Search for $P$-odd asymmetry of prompt neutrons emission in $^{235}$U fission induced by cold polarized neutrons

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The preliminary result of the $P$-odd asymmetry of prompt neutron emission in $^{235}$U fission induced by polarized cold neutrons is $a = (2.7 \pm 0.8) \cdot 10^{-5}$. Only the scission neutrons can show such asymmetry, whereas neutrons emitted by excited fragments are the unavoidable background, which suppress the sought asymmetry. The P-odd asymmetry of light fragment emission for $^{235}$U is equal to $(8.4 \pm 0.6) \cdot 10^{-4}$. Assuming that last figure defines the parity mixture of fissile nucleus then the suppression factor is equal approximately to 3.

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The problem of scission neutrons existence is one of the unsolved problems in fission physics yet. Scission neutrons are the neutrons emitted by fissile nucleus before or during its rupture into two fragments. Angular distribution of these neutrons must differ from one for neutrons emitted from completely accelerated by Coulomb force excited fragments. Last one must be elongated with the fission axis due to velocities summation. Common technique to search for scission neutrons is the fitting of angular and energy distributions of prompt fission neutrons by two components. The first one is the contribution of fragment's neutrons. Angular distribution of the second component is assumed to be approximately isotropic (scission neutrons). This technique gives very contradictory results. The fraction of the second component varies from 1% to 35% depending on the experiment and the assumptions made [1]. Thus it's necessary to work out the alternative method to search for the scission neutrons.

We suppose that the specific angular correlations like as left-right asymmetry of prompt fission neutron emission:

$$W = \mathrm{const}(1 + b\mathbf{n}_{\mathrm{pfn}}[\mathbf{n}_{\mathrm{lf}}, \mathbf{S}]) \qquad (1)$$

or $P$-odd asymmetry of scission neutron emission:

$$W = \mathrm{const}(1 + a\mathbf{n}_{\mathrm{pfn}}, \mathbf{S}), \qquad (2)$$

where $b$ and $a$ is the asymmetry coefficients, $\mathbf{n}_{\mathrm{pfn}}$ and $\mathbf{n}_{\mathrm{lf}}$ are the unit vectors in the direction of prompt fission neutron and light fragment momenta respectively, $\mathbf{S}$ is the unit vector in the captured neutron spin direction, can be considered as the evidence of the scission neutrons existence, because the same asymmetries for neutrons evaporated from fragments must be washed out due to summation of asymmetry coefficients over a huge number of final states in fission process. Of course, the neutrons emitted by fragments can show the $P$-odd asymmetry reflecting the $P$-odd asymmetry in fragments, since light fragments emit 30% more neutrons than heavy ones. But the geometry of the experiment can be chosen to suppress this "kinematic" effect very much.

It's obvious that this method is free of arbitrary assumptions.

Some time ago we have measured the left-right asymmetry of prompt neutron emission in fission of $^{235}$U by polarized thermal neutrons, i.e., the correlation (1). This asymmetry is the result of $s$- and $p$-waves interference in entrance channel of the reaction. The magnitude of the left-right asymmetry coefficient for fission fragments is about $3 \cdot 10^{-4}$. The same coefficient for prompt neutrons measured at the angle $\theta = 90°$ between the detected neutron momentum and the fission axis was found to be equal $b = (-5.8 \pm 1.4) \cdot 10^{-5}$ [2]. The difference must be caused by the asymmetry suppression due to the large background of fragment's neutrons. It's easy to show that the factor of suppression is equal to:

$$\eta = 1 + N_{\mathrm{fr}}(\theta)/N_{\mathrm{sc}}. \qquad (3)$$

This is the negative feature of the background in asymmetry measurements. But there is the positive one too. As was already pointed out the angular distribution of fragment's neutrons is elongated with the fission axis. Thus the background and therefore the factor of asymmetry suppression depends on the angle between the mo-

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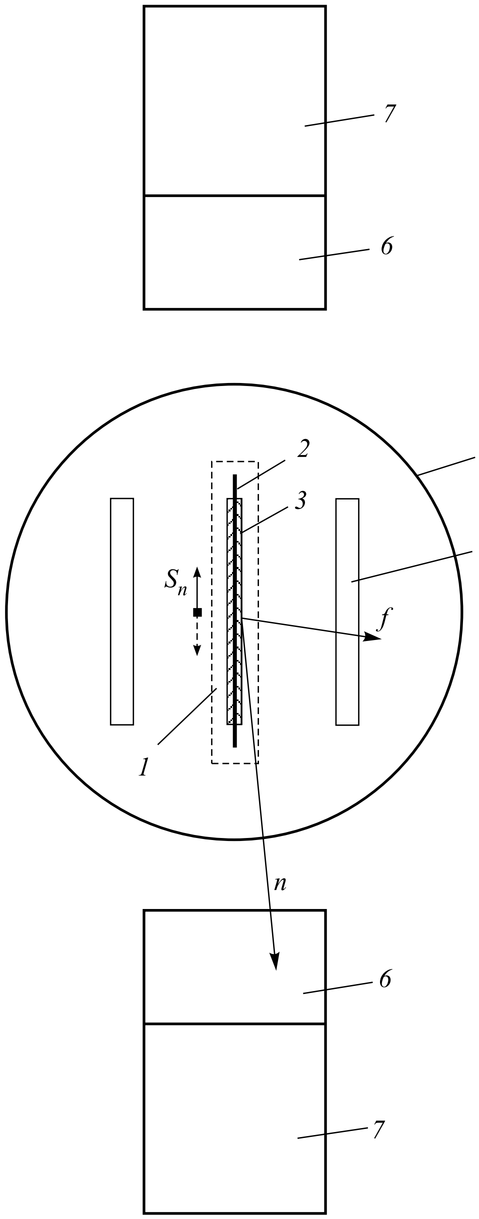


Fig.1. Experimental setup: *1* – cross-section of $n$-beam, *2* – Zr plate, *3* – $U_3O_8$ layers, *4* – fission chamber, *5* – fission fragments' detectors, *6* – scintillators, *7* – photomultipliers

mentum of detected prompt neutron and fission axis. The background is minimal at the angle 90° and it is maximal at 0°. So the measurement at two angles (for example at 90° and 45°) can give $\eta$'s and therefore it's possible to evaluate the fraction of scission neutrons. The experiment [2] have been performed on the polarized thermal neutron beam of the MEPhI small reactor and the low intensity of neutron beam does not permit us to measure with high accuracy the correlation (1) at the angle 45° to find the magnitude of $\eta$.

Nevertheless to solve the problem we've performed the measurements of correlation (2) on the polarized cold neutron beam of the reactor BER-II of BENSC HMI. For the first step we searched for the $P$-odd asymmetry of prompt neutron emission in $^{235}U$ fission. The geometry of experiment is shown in Fig.1.

The setup consists of the fission chamber, including target and fragment detectors, neutron detectors, electronic modules (CAMAC) and the computer. The target's size is $20 \times 100$ mm. It contains 24 mg of $^{235}U_3O_8$ plotted to the both sides of the thick Zr plate. Two multiwire lowpressure proportional counters were situated on both sides of the target to detect fission fragments. They do not distinguish between light and heavy fragments. The neutron beam was polarized in the plane of target, perpendicularly to the direction of beam and to the average direction of momentum of fission fragments. The polarization of the neutron beam was about 85%. The target and fragment detectors were enclosed into aluminum chamber. The chamber is filled by isobutane up to pressure 10 torr. Two neutron detectors were placed outside the chamber in orthogonal geometry to the beam direction and to the fission axis at the distance 25 cm from the center of target. These detectors consist of plastic scintillator and photomultiplier FEU-63. To distinguish between prompt fission neutrons and prompt fission $\gamma$-quanta, the time- of-flight technique was used. The pulses from the fragment detectors were triggers of the fission events and were used as start signals for the time-to-amplitude converters (TAC). The stop signals were the pulses from neutron detectors. The TAC signals were led to the inputs of ADC computer card. The 4 scalers were used in parallel to the TAC-ADC

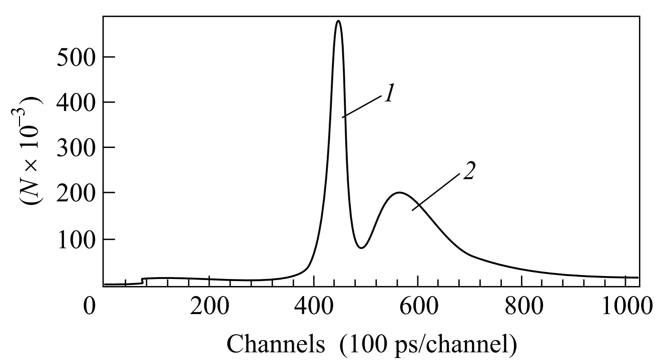


Fig.2. *1* – $\gamma$-peak, *2* –prompt fission neutrons' peak

system. The polarization of neutron beam is reversed by the signal from the experiment control module once per second. The data acquisition program collects spectra of the delayed coincidences and data from scalers for the both directions of neutron beam polarization. It also shows the on-line results. The numbers of detected fission fragments and pulses from photomultipliers were monitored too. All runs were divided into 15-minutes expositions. We measured the value:

$$A_n^* = (N^+ - N^-)/(N^+ + N^-). \quad (4)$$

Here $N^+$ and $N^-$ are sum of the events under the neutron peak in delayed coincidence spectrum (Fig.2) for opposite directions of neutron beam polarization. The same value for the asymmetry of the coincidence under the gamma peak was also measured. Last one used for checking of the apparatus asymmetry. We have also reversed the direction of guiding magnetic field in the second half of the measurements. No apparatus asymmetry was found. The results for both neutron detectors are shown in table.

The value of asymmetry measured at 90° relative to fission axis lies in the interval

$$1.4 \cdot 10^{-5} \leq A^* \leq 4.0 \cdot 10^{-5} \quad \text{at } 90\% \text{ c.l.}$$

The experiment will be continued to measure the asymmetry at two angles (90° and 45°) with accuracy better than $4 \cdot 10^{-6}$.

**Experimental results**

| | $A_n^* \cdot 10^5$ | $A_\gamma^* \cdot 10^5$ |
|---|---|---|
| Detector 1 | $+3.5 \pm 1.1$ | $+0.7 \pm 0.9$ |
| Detector 2 | $+1.9 \pm 1.1$ | $-0.9 \pm 0.9$ |
| Average | $+2.7 \pm 0.8$ | $-0.1 \pm 0.6$ |

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