# Nonconservation of space parity in the fission of heavy nuclei by polarized neutrons

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The *P*-odd asymmetry in the escape of light (heavy) $U^{233}$ fission fragments by neutrons relative to the direction of their polarization is investigated. The asymmetry coefficient for the group of light fission fragments is $a = (4.83 \pm 0.38) \times 10^{-4}$. In first approximation the asymmetry is independent of the mass of the fission fragments.

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The *P*-odd angular correlation $W(\theta) = 1 + a\boldsymbol{\sigma}\mathbf{p}$ in the fission of heavy nuclei by polarized neutrons, where $\boldsymbol{\sigma}$ is the unit polarization vector and $\mathbf{p}$ is the unit vector in the direction of the momentum of the light (heavy) fission fragment, was investigated in Refs. 1–3.

The existence of this effect was first indicated in Refs. 4 and 5, where it was thought that this effect can be greatly strengthened due to the dependence of the fission barriers on parity[4] and on the resonance transmission of the double-humped fission barrier.[5]

Because of the importance of the experiments on nonconservation of parity and systematics of nuclear fission, we focused attention on the following problems: 1) verification of the results of Refs. 1–3 for the case of $U^{233}$ fission under other experimental conditions and using another experimental technique and 2) investigation of the dependence of the asymmetry on the properties of the fission products for the purpose of understanding at which stage of the fission process the effect is intensified.

The main procedural differences between our experiment and those of Refs. 1–3 were as follows: both fission fragments were recorded simultaneously, thin sources of fissionable material were used, the "light' and "heavy" fragments were separated according to the mass distribution, monitoring was based on the total number of recorded fission events, and the differential effect was studied in addition to the integral effect. Such experimental setup leaves much less room for assumptions about the systematic nature of the asymmetry effect observed in Refs. 1–3.

The experiment is shown schematically in Fig. 1. The polarized neutrons with a flux density of $2 \times 10^7$ neutrons/cm$^2$·sec were obtained in the horizontal channel of the VVR-M reactor by using a polarizing neutron guide for an average wavelength of 2.2 Å.

The targets of fissionable material in the form of uranium fluoride were deposited by vacuum sputtering onto a thin, self-supporting titanium substrate ($\sim$ 50 $\mu$g/cm$^2$) with an active spot radius of $\sim$20 mm and a thickness of $\sim$150 $\mu$g/cm$^2$. The fission fragments were recorded by two circular semiconductor detectors 44 mm in diameter,

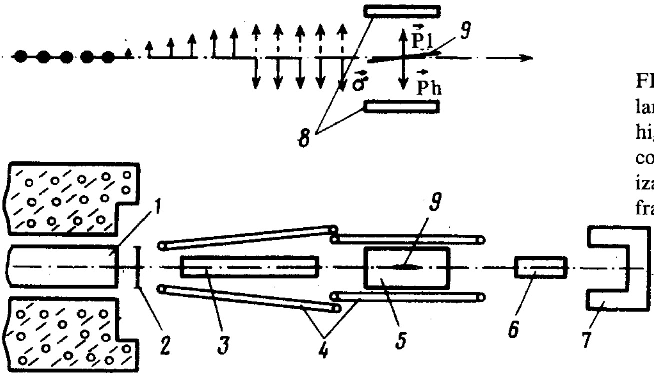

FIG. 1. Experimental set-up: 1—polarizing neutron guide; 2—shim; 3—high-frequency flipper; 4—Helmholtz coils; 5—vacuum chamber; 6—polarization analyzer; 7—beam trap; 8—fragment detectors; 9—target.

which were cooled down to a temperature of −100 °C in order to decrease noise and increase radiation stability.

The electronic part of the setup, together with the Elektronika-100 computer, carried out the amplification, discrimination, summation, and division of the signals, and the overall control of the experiment.

As a result of each series of measurements of about 18-hour duration, we obtained distributions of the energy ratios $E_1/(E_1 + E_2)$, which are approximately proportional to the fission fragment masses, and of the kinetic energies $(E_1 + E_2)$ for two neutron polarizations in the opposite direction. The polarization direction was changed every two seconds by using a high-frequency flipper ($\sim$ 150 kHz); the initial direction of polarization, which was established by a system of guiding fields, could be reversed manually or automatically by changing the polarity of the feed voltage of the Helmholtz coils. The neutron-beam polarization, which was checked several times during the measurment cycle, was 90% on the average.

The instrumental asymmetry was measured by two different methods. One of them involved standard measurements of the neutron beam that was depolarized by an iron plate. In this case the measurements of the effect were alternated with measurements of the depolarized beam. The other method consisted of measuring the effect with opposite initial directions of the neutron polarization. Assuming that the instrumental asymmetry is independent of the direction of the initial polarization, this method allowed us to measure simultaneously the effect and the instrumental asymmetry, since the latter could be checked by summing the results and a pure double effect could be obtained by subtracting them. This method allowed us to speed up the collection of the statistics and to reduce the equipment-induced distortions of the differential effect due to the influence of the high-frequency flipper. The results of the measurements of the instrumental asymmetry by both methods agreed within the limits of statistical error; they were, respectively,

$$a_1^{(o)} = -(0{,}54 \pm 0.39)\cdot 10^{-4}, \qquad a_2^{(o)} = -(0.30 \pm 0{,}28)\cdot 10^{-4}.$$

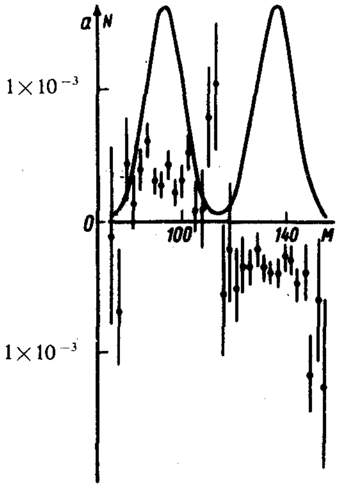

FIG. 2. Dependence of the asymmetry on the mass (experimental points) and the mass distribution of fragments (solid curve) obtained after a 10-day measurement.

The asymmetry for the *i*-th mass interval was calculated from the equation

$$a_i = \frac{C_i(\downarrow) - C_i(\uparrow)}{C_i(\downarrow) + C_i(\uparrow)}, \text{ where } C_i(\downarrow) = \frac{N_i(\downarrow)}{\sum_1^{32} N_i(\downarrow)} .$$

Figure 2 shows the result of the measurements of the dependence of asymmetry on the mass, together with the mass distribution of fission fragments. It can be seen that in the first approximation a dependence of the asymmetry on the mass was not observed. (The mass resolution is ~8 mass units.) The integral asymmetry for the group of light fission fragments turned out to be similar in the experiment.

$$a_{\text{exp}} = (3.48 \pm 0.28) \cdot 10^{-4}.$$

After introducing the corrections for the solid angle of recording ($\overline{\cos\theta} = 0.8$) the neutron polarization (0.9), the asymmetry is

$$U^{233}: \qquad a = (4.83 \pm 0.38) \cdot 10^{-4}.$$

The maximum systematic error after the introduction of all the corrections is estimated to be 20%. To determine whether a larger *P*-even effect can exist, e.g., due to interference of *s* and *p* neutron resonances, we performed measurements when the axis for recording the fission fragments was perpendicular to that of the neutron polarization. The result of the measurements $a_\perp = (0.63 \pm 1.1) \times 10^{-4}$ allowed us to eliminate the *P*-effect as a possible cause of asymmetry.

Thus, we have no doubt that the *P*-odd asymmetry effect, which was observed in Refs. 1–3 for the first time, exists.

The discrepancies in the asymmetry values (a value of $a = (2.73 \pm 0.33) \times 10^{-4}$ was obtained in Ref. 2) could be attributed to the difference in the techniques of separating the fission fragments into "light" and "heavy" groups.

However, the present level of theoretical understanding of nonconservation of $P$ parity in the fission of heavy nuclei is such that the existing discrepancies in the absolute value of the asymmetry are a secondary factor.

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