P-odd asymmetry in the fission of ^{239}Pu by polarized thermal neutrons

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We measured the P-odd asymmetry of the emission of a light (and, correspondingly, heavy) fragment in a direction parallel and antiparallel to the spin of the fissioning nucleus ^{240}Pu produced when a polarized thermal neutron is captured by ^{239}Pu. The asymmetry coefficient turned out to equal $a = (-4.8 \pm 0.7) \times 10^{-4}$.

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We have previously reported[1] an investigation of the P-odd angular correlation $W(\theta) = \mathrm{const}(1 + a\sigma \mathbf{p})$, where σ is a unit vector in the direction of the nuclear spin, p is a unit vector in the direction of the momentum of the light fragment, and θ is the angle between them, in the case of ^{235}U fission by polarized thermal neutrons. The asymmetry coefficient for the fissioning ^{236}U nucelus turned out to be $a = (1.37 \pm 0.35) \times 10^{-4}$. The positive sign of the asymmetry means in this case that the light fragment is emitted predominantly along the spin of the captured neutron.

We present below the results of analogous measurements for the fission of ^{239}Pu by polarized thermal neutrons. A beam of polarized thermal neutrons with cross section 5×100 mm, flux density 3×10^{6} neut/cm^2 sec, and polarization 0.84 passed through a thin Mylar window into an evacuated fission chamber and was incident on the target. The target consisted of five aluminum disks of 25 mm diameter and 0.15 mm thickness, placed in the plane of the beam, and coated on each side with a layer of plutonium hydroxide 100 μg/cm^2 thick. On each side of each individual disk, 13 mm away from it, were located two surface-barrier silicon detectors of 16 mm diameter, displaced ± 11 mm relative to the plane defined by the beam axis and the disk axis. A fragment collimator bounding a definite solid angle was placed between the target and the detector. Groups of five detectors, shifted relative to the disks in the same direction, were connected in parallel. The pulses from the resultant four groups of detectors were amplified and fed to discriminators that separated, respectively the pulses due to the heavy and light fragments. The pulses proceeded from the discriminators to a distributing unit, which directed them to different groups of scalar circuits, depending on the neutron-beam polarization direction at the instant of arrival of the pulse.

The polarization direction could be registered every second, but the regularity of this process was violated by a pulse with a random distribution in time. The reconnection of the electron registration channels after the measurement cycle was effected in the same random manner.

The measurements with the polarized beam alternated with measurements made with a "depolarized" beam (residual polarization $\sim 8\%$) each 16 minutes. During this time, approximately 600 reversals of the polarization took place.

The information from the scalar circuits was analyzed with a computer operating on line with the experimental setup. After each measurement cycle, the asymmetry of the counts of the light and heavy fragments was calculated for each group of detectors.

Prior to the measurements of the P-odd asymmetry in the fission of ^{239}Pu, control measurements were made of the asymmetry in the fission of ^{235}U. The asymmetry coefficient, corrected for the degree of polarization of the neutrons and the finite solid angle, turned out to be $a(^{236}U) = (2.2 + 1.0) \times 10^{-4}$, which agrees within the limits of the measurement errors with the results obtained by us earlier using a fission chamber with a different geometry.[1] We measured also the instrumental asymmetry of the count of the number of α particles from a plutonium target. The instrumental asymmetry averaged over many measurement runs turned out to be $\bar{a}_{instr} = (1.5 \pm 2.9) \times 10^{-5}$. The averaged value of the count asymmetry of the light (or, respectively heavy) fragment in the fission of ^{239}Pu by polarized thermal neutrons turned out to be $\bar{a}' = (-3.4 \pm 0.3) \times 10^{-4}$. The measurements with the "depolarized" beam yielded $\bar{a}'' = (-0.6 \pm 0.3) \times 10^{-4}$. Taking into account the residual polarization of the neutrons in the "depolarized" beam, we obtain

$$\bar{a} = (-3.1 + 0.4) \times 10^{-4} \quad \text{and} \quad \bar{a}_{instr} = (-0.3 \pm 0.3) \times 10^{-4}.$$

The last value does not contradict the results obtained in the registration of α particles. After correcting the obtained asymmetry for the finite solid angle ($\overline{\cos\theta} = 0.76$) and for the degree of polarization of the neutrons ($p_n = 0.84$) we obtain ultimately

$$a(^{240}Pu) = (-4.8 \pm 0.7) \times 10^{-4}.$$

The values of the asymmetry for individual detector groups have shown that the observed asymmetry is not connected with the possible asymmetry of the installation. Moreover, for an additional monitoring of this effect, the fission chamber was rotated regularly during the course of the experiment as a unit through $\pm 180°$ relative to the beam and the measurement results were independent of the chamber orientation. It is also obvious that the observed effect cannot be due to any methodological factors, for otherwise the interchange of the targets (^{235}U and ^{239}Pu) could not lead to a change in the sign of the asymmetry. Consequently, the observed asymmetry is the result of parity nonconservation in the nuclear fission process.

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[1]G. V. Danilyan, V. P. Dronyaev, B. A. Vodennikov, V. V. Novitskiĭ, V. S. Pavlov, and S. P. Borovlev, Preprint ITEF-4, 1977.