Ratio of the *P*-odd asymmetry coefficients in the separation of fragments in double and triple fission of U-233 nuclei by polarized neutrons

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The coefficients of the *P*-odd asymmetry in the separation of light and heavy fragments during double and triple fission of U-233 nuclei by polarized neutrons have been measured simultaneously in an experiment in a polarized-neutron beam at the ILL high-flux reactor. The ratio of the coefficients for triple and double fission turns out to be 1.05 ± 0.10. This result is evidence that the fission channels for double and triple fission are approximately the same.

One particular consequence of the weak interaction between nucleons in a nucleus is that the angular distributions of the light fragments and, correspondingly, of the heavy fragments in the fission of nuclei by polarized s neutrons is asymmetric with respect to the neutron polarization direction:[1]

$$W(\theta) = \text{const}(1 + a\vec{\sigma}_n \cdot \vec{p}_L) = \text{const}(1 + a\vec{\sigma}_n \vec{p}_H),$$

where $\vec{\sigma}_n$ is a unit vector along the neutron polarization direction, $\vec{p}_L$ and $\vec{p}_H$ are unit vectors along the momenta of the light and heavy fragments, respectively, θ is the angle between the momentum of the light fragment and the neutron polarization direction, and a is the asymmetry coefficient.

According to the phenomenological model of Ref. 2, the asymmetry coefficient is proportional to the value of the quantum number K, which is the projection of the spin of the nucleus undergoing fission onto the deformation axis. This value characterizes the fission channel. We thus have a unique opportunity to solve an important problem in fission physics: Do the different fission modes go through the same channels or through different channels? In particular, we can compare fission into two fragments (double fission) with fission into two fragments, accompanied by emission of an α particle (triple fission).

In a previous letter[3] we described the experimental procedure in detail, and we

reported the result for Pu-239: The ratio of the P-odd asymmetry coefficients for triple and double fission turned out to be 1.12 ± 0.08. The accuracy here is obviously not good enough for an unambiguous conclusion, but improving the accuracy would require an unacceptable increase in measurement time. An alternative approach is to carry out measurements for another nucleus. In the present letter we are reporting the results of measurements of the P-odd asymmetry in the separation of fragments in the double and triple fission of U-233 nuclei by polarized neutrons.

The measurements were carried out in the polarized-neutron beam of the SN7 high-flux-beam reactor of the Laue–Langevin Institute. We used the same apparatus as described in Ref. 3, but with certain modifications. To reduce the relative number of random coincidences of the pulses from the fragment detectors and from the α detector, we sent the neutron beam not through the α detector (that approach would have put an unjustifiably high load on the α detector) but through the fragment detectors. The background load of these detectors was inconsequential, since the heights of the pulses produced by the fragments were many times the height of the pulses from background electrons. Correspondingly, the neutron beam was polarized longitudinally instead of transversely, and it was incident normally on the target. This target was an aluminum oxide film with a thickness of about 70 μg/cm^2. The tetrafluoride of U-233 was deposited on each side of the film, in a thickness of about 35 μg/cm^2. A double target was used in the first section of the chamber, and a single target in the second section. The overall count rate corresponding to double-fission fragments was $\sim 300\,000$ s^{-1}, and that corresponding to double fission was ~ 300 s^{-1}. Roughly 7% of the triple-fission events were random coincidences, which should exhibit the asymmetry of double-fission fragments, but in this case the background correction was negligible (2%). Also negligible was the correction (3.5%) for the difference between the mean cosines of the angles between the momentum of the fragment and the neutron polarization direction for the double and triple fissions. The degree of polarization of the neutron beam drops out of the ratio of coefficients, although it was fairly high (97%). The ratio of the P-odd asymmetry coefficients for the triple and double modes of the fission of U-233 by polarized neutrons turned out to be 1.05 ± 0.10.

This result for U-234 ($I = 2,3$)—for which the number of available fission channels is twice that for Pu-240 ($I = 0,1$)—along with the result for the latter (1.12 ± 0.08), is consistent with the conclusion that the effective values of the quantum number K for the double and triple fissions are essentially the same.

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