Ratio of *P* odd asymmetry of separation of fission fragments in binary and ternary fission of Pu-239 by polarized neutrons

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The *P* odd asymmetry of separation of fission fragments has been measured simultaneously for the binary fission and ternary fission (with the emission of an α particle) of Pu-239 by polarized thermal neutrons. The ratio of the asymmetries is $A_{\text{tern}}/A_{\text{bin}} = 1.12 \pm 0.08$.

The discovery of parity violation in the fission of heavy nuclei[1] gave physicists a new tool not only to study the nature of weak interaction but also to investigate the fission process itself.

According to the existing phenomenological model,[2] the *P* odd asymmetry of the separation of fission fragments is proportional to the quantum number of the *K* projection of the nuclear spin onto the deformation axis, which characterizes the fission channel. It would therefore be of considerable interest to compare these asymmetries for the ordinary fission and various rare fission modes such as "cold fission,"[3] "hot fission,"[4] and ternary fission (in which α particles are emitted), all of which could, in principle, proceed through different channels.

The relative probability of a ternary fission is $\sim 2\times 10^{-3}$. The *P* odd asymmetry is $\sim 10^{-4}$. The principal problems of the given experiment are therefore the collection of a sufficient statistical base on the ternary fission and identification of events corresponding to the ternary fission, against the background of binary fission. As the detectors of fission fragments we used multiwire low-pressure proportional chambers (MLPPC) and to detect particles from ternary fission we developed and built a cylindrical avalanche counter (CAC). We thus were able to construct an apparatus which was capable of efficiently detecting the fission fragments and α particles, and which had a good count rate and was insensitive to radiation damage. A good time resolution makes it possible to reliably identify the light and heavy fission fragments by the time-of-flight difference method and to decrease the random coincidence background.

The experimental setup built by us consists of two independent sections with an equal number of detectors and electronic measurement equipment. Each section (Fig. 1) consists of a CAC (1), inside of which there are four targets containing fissionable material (2). A Pu-239 oxide layer was vacuum-deposited on aluminum oxide substrates 60 μg/cm^2 thick. The active layer is 24 mm in diameter and 100 μg/cm^2 thick. This detector is terminated with MLPPC at each end (3). The measurements were carried out on a high-flux-beam reactor of the Laue-Langevin Institute in Grenoble. A polarized neutron beam [the neutron density in the beam was 2×10^8 n/(cm^2.s), and the degree of polarization was $P = 96\%$] was transmitted through an alpha detector

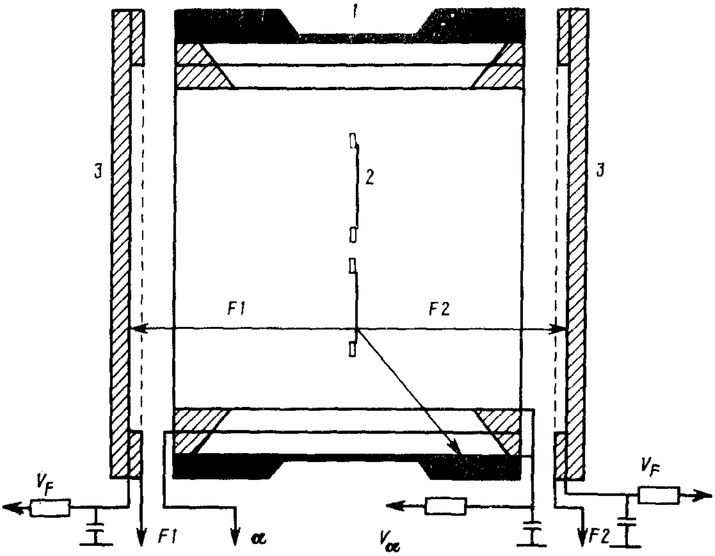

FIG. 1. Schematic diagram of a section of the experimental setup.

parallel to the fissionable-material targets. The polarization direction was reversed at a frequency of 1 Hz. The two sections were placed in tandem in the direction of the neutron beam in the same gas volume. Isobutane in a concentration of 1–2 vol/h was pumped through the gas volume at a pressure of 7 Torr. The fission-fragment detectors are made from fiberglass-reinforced plastic plates covered with an aluminum foil, above which gold-plated tungsten wires 20 μm in diameter and spaced 1 mm apart are stretched at a height of 3 mm. The foil is held at a negative voltage and the signal is recorded from the wires. The sensitive surface of the detector is 130×130 mm. The α-particle detector (CAC) consists of three concentrically arranged cylindrical electrodes whose diameters are 120, 130, and 140 mm, respectively. We thus have two cylindrical capacitors with a common plate and with a 5-mm spacing between the plates. The two interior plates are made from an aluminum foil 25 μm thick, while the third plate is an inner wall of an aluminum tube which doubles as the detector housing. The foils are stretched and attached to the detector casing by means of Kapralon rings. The casing has 5-mm-thick walls at the edges. At the center the wall thickness is reduced to 1 mm in order to decrease the neutron scattering during the passage of the beam through the detector. The detector casing is 140 mm long and the length of the sensitive region is 110 mm. The external plates are held at a negative voltage and the signal is recorded from the middle foil. The thickness of the foil closest to the targets was chosen on condition that it could absorb α particles of the Pu-239 natural radioactivity. The α particle of the ternary fission, which has a much higher energy (on the order of 16 MeV), passes through both foils, losing part of its energy. As the α particle slows down, the ionization density increases along its track, and the signal amplitude, which for CAC is proportional to the ionization density, increases. The time resolution of the fission-fragment detector is 350 ± 50 ps and that of the α-particle detector is 1.5 ± 0.3 ns.

The experimental setup had to satisfy three conditions: it had to simultaneously measure the asymmetry in the binary and ternary fissions; it had to have two separate electronic circuits, and, finally, it had to have two independent sections. These measures made it possible, in our view, to maximally reduce the systematic errors in determining the asymmetry and to constantly monitor the experiment. The electronic circuit of one section of the experimental setup is shown in Fig. 2. The signal from the detectors is transmitted through fast time preamplifiers (TPA) to the input of the shapers with the next threshold (SNT). The signals are then branched out and sent to two separate circuits that record the events. The first circuit is used to collect the spectra of the time-of-flight difference of the fission fragments in the binary and ternary fissions by means of a time-to-amplitude converter (TAC) and a pulse height-to-digital converter (PDC). The time-to-amplitude converter was gated by means of two coincidence circuits, CC1 and CC2, which single out respectively the events associated with the binary and ternary fissions. To reduce the dead time of the PDC, we introduced into the binary-fission channel a scaling circuit which resolved the detection of each 16th binary-fission event only. The circuit of the shaper (S) shapes the gating

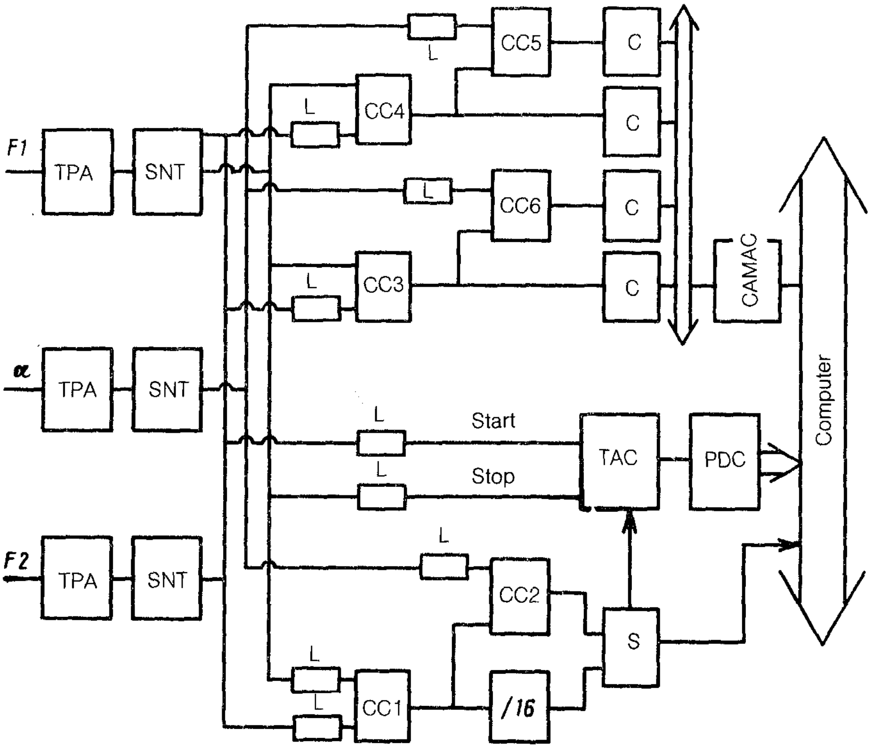

FIG. 2. Schematic of the electronic circuit.

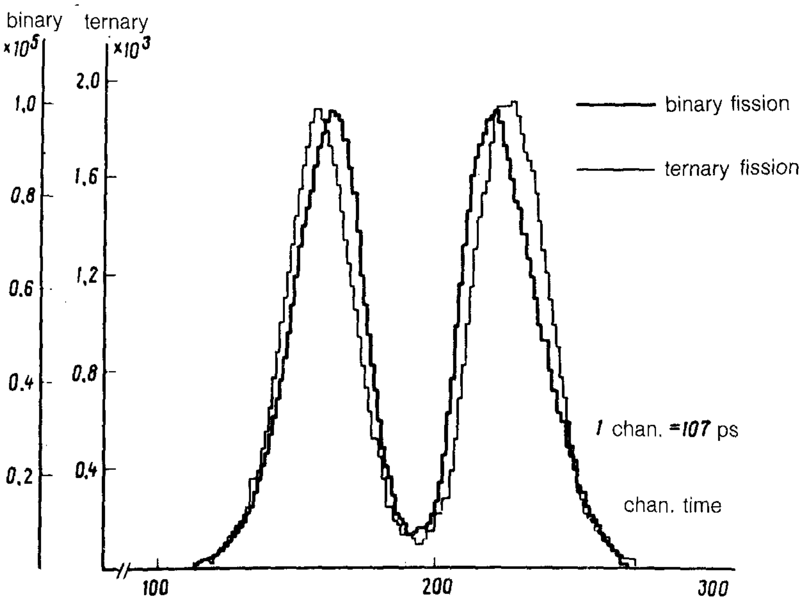

FIG. 3. Spectra of the time-of-flight difference of the fission fragments of binary and ternary fissions.

pulse which sets the TAC outputs to 50 ns and simultaneoulsy sends to computer a signal which indicates whether a binary or ternary fission is detected. The spectrum for the time-of-flight difference of fission fragments for the binary and ternary fissions is shown in Fig. 3. In the second circuit the fission fragments were divided into two groups, corresponding to the two peaks of the time-of-flight spectrum, by means of two coincidence circuits (CC3 and CC4) for the binary fission and by CC5 and CC6 for the ternary fission. The signals from all four coincidence circuits were sent to the counters (C), whose readout was sent through a CAMAC to the computer.

For binary and ternary fissions the P odd asymmetry is given by

$$A_{\rm exp} = \frac{\overrightarrow{N_i} - \overleftarrow{N_i}}{\overrightarrow{N_i} + \overleftarrow{N_i}}$$

where $\overrightarrow{N_i}$ is the number of fission events of a particular group ($i = 1$—light fission fragments, $i = 2$—heavy fragments) for two opposite directions of polarization of the neutron beam. The asymmetry measured experimentally is related to the physical asymmetry A by the relation

$$A_{\rm exp} = AP\overline{\cos\theta} \ ,$$

where P is the degree of polarization of the neutron beam and $\overline{\cos\theta}$ is the average fragment detection cosine relative to the direction of polarization. The average detection cosines of the fission fragments in the binary and ternary fissions were calculated by the Monte Carlo method. To eliminate the instrumental asymmetries, we have changed the direction of the guiding field once a day, which caused the sign of the P odd asymmetry to change, while leaving the instrumental asymmetry constant. After the introduction of corrections, the ratio of the physical asymmetries for the ternary and binary fissions will be

$$A_{\text{term}} / A_{\text{bin}} = 1{,}12 \pm 0.08.$$

In other words, this ratio lies, within 99% certainty, in the range 0.91–1.33. This accuracy clearly is not high enough to determine unambiguously whether the asymmetries of the binary and ternary fissions are equal. It would therefore be of considerable interest to develop these experiments in three directions: improve the statistical accuracy for Pu-239, measure this ratio for nuclei with other asymmetries, and measure the asymmetries of other rare fission modes.

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[1] G. V. Danilyan *et al*, Yad. Fiz. **27**, 42 (1978) [Sov. J. Nucl. Phys. **27**, 25 (1978)].
[2] A. P. Sushkov and V. V. Flambaum, Yad. Fiz. **33**, 59 (1981) [Sov. J. Nucl. Phys. **33**, 31 (1981)].
[3] H. G. Clerc *et al.*, Nucl. Phys. A **52**, 277 (1986).
[4] P. Koczon *et al.*, Phys. Lett. B **191**, 249 (1987).
[5] A. V. Belozerov *et al.*, Prib. Tekh. Eksp. **3**, 65 (1989).

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