Angular distributions of photofission fragments of ^{238}U in the region of the isomer shelf

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(Submitted June 17, 1976)
Pis'ma Zh. Eksp. Teor. Fiz. **24**, No. 5, 309–311 (5 September 1976)

It is established experimentally that the photofission of ^{238}U in the region of the isomer shelf is isotropic. This proves that the shelf in the cross section of the ^{238}U photofission is due to spontaneous fission of the shape isomer, which corresponds to the ground state of the second well.

PACS numbers: 27.90.+b, 24.80.+y

A new phenomenon, called the isomer shelf, was observed recently in the cross section for photofission deep below the barrier.[1,2] It consists of a sharp change in the slope of the fission cross section curve σ_f with decreasing photon energy. Its origin is attributed to the double-hump structure of the fission barrier.

In the course of the deformation, a nucleus falling in the second well cannot only be "promptly" fissioned, but can drop by radiative deexcitation to the bottom—to the shape isomer state. The subsequent fate of the isomer depends on the ratio of the probabilities for spontaneous fission (delayed fission) or of returning to the first well. The cross section σ_{pf} of the prompt fission is determined by the penetrability of the entire barrier, and the cross section σ_{df} of the delayed fission is determined by the penetrability of only the internal hump A. Owing to the sharp exponential dependence of the humps, the hump curve $\sigma_f(E) = \sigma_{pf}(E) + \sigma_{df}(E)$ has a break at $\sigma_{pf} \approx \sigma_{df}$, with $\sigma_f \approx \sigma_{pf}$ above this "point" and $\sigma_f \approx \sigma_{df}$ below.

According to this interpretation, on going from prompt fission to delayed fission, the angular anisotropy of the fragments should be decreased by the disorientation of the angular momentum when γ quanta are emitted in the second well. This should serve as a critical check on the nature of the isomer shelf. The present paper is devoted to an experimental verification of this prediction.

The experiment was performed with the bremsstrahlung beam of the microtron of our Institute. The most favorable for the investigation of the effect are even-even nuclei, for which the angular distribution $W(\theta)$ of the photofission fragments is strongly anisotropic. We chose the most thoroughly investigated even-even nucleus ^{238}U. The quantum characteristics of the lowest state in the second well are 0^+, 0, so that the angular distribution following fission from the isomeric state should be fully isotropic. Our latest measurements[3] of the angular distributions of ^{238}U made it possible to advance to the end-point energy $E_{max} = 4.6$ MeV of the bremsstrahlung spectrum of the γ quanta. To advance by another 0.5 MeV and enter the region of the shelf, it was necessary to raise the sensitivity of the procedure by approximately two orders of magnitude. This

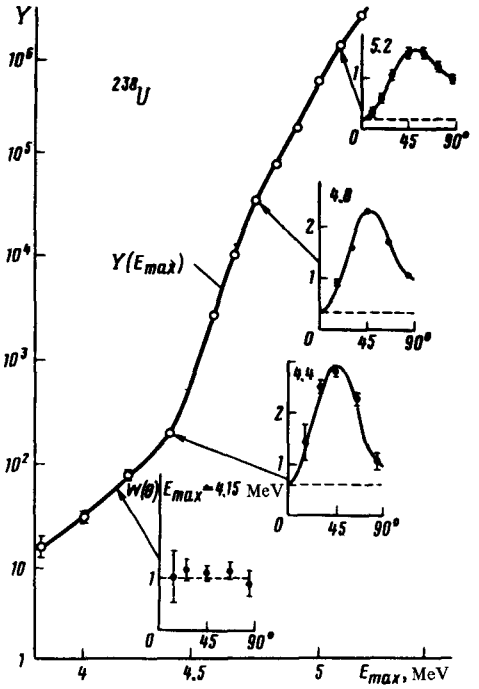

FIG. 1. Dependence of the yield and of the angular distribution of the fragments (in the insert) of the photofission of ^{238}U on the end-point energy of the bremsstrahlung spectrum.

was accomplished by increasing the intensity of the microtron beam to 100 μA, that is, by a factor of two, by increasing the solid angle of the recorded fragments by seven times, and by decreasing the distance from the fissioning target to the source by two times. In all other respects the experimental conditions were the same as in[3].

The results of the undertaken experiment together with the data of[3] are shown in the figure. Attention is called to the gradually accelerating increase of the contribution of the isotropic component of $W(\theta)$ with decreasing E_{max}; this growth becomes predominant on going directly into the shelf region.

The spectrum of the energy of excitation of the ^{238}U nucleus in the second well at E_{max}=4.15 MeV extends from 0 to 1.6 MeV[4] and is connected mainly with the collective states inside the energy gap. Since the quadrupole component predominates in the angular distribution of the prompt-fission fragments, it can be concluded that the decisive role in all the processes that occur at low energies is assumed by the states $J^\pi = 2^+$. Their radiative decay via emission of photons with multipolarity $E2$, which predominate at low energies, ensures a transition to the ground state 0^+ either directly or via the states of the rotational band 2^+ and 4^+. Thus, the observed isotropy offers direct evidence that the fission of ^{238}U in the region of the isomer shelf proceeds from the ground state in the second well.

The authors thank P. L. Kapitsa and S. P. Kapitsa for support of the research, V. M. Strutinskiĭ for interest in the work and useful discussions, and A. A. Kolosov for technical help.

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