Emission of conversion muons in radiative fission of uranium nuclei by muons

G. E. Belovitskiĭ, Yu. A. Batusov,[1)] and L. V. Sukhov

Nuclear Research Institute, USSR Academy of Sciences
(Submitted 21 April 1978)
Pis'ma Zh. Eksp. Teor. Fiz. **27**, No. 11, 662–664 (5 June 1978)

Direct experimental proof of the existence of muon conversion in nonradiative fission of uranium nuclei is obtained. Some of the quantitative characteristics of this fission are estimated.

PACS numbers: 25.85.Ge

The possibility of fission of heavy nuclei by muons, via the energy released in nonradiative mesic-atom transitions, was considered in[1]. In this method of fission ("prompt fission") the muons remain on one of the fission fragments and are subsequently either absorbed by the fragments or dumped via internal conversion into the continuum.

An experimental observation of conversion muons was undertaken in[2]. A total of 738 fissions of ^{238}U was observed in an emulsion filled with uranium nuclei and bombarded by slow muons. None of these fissions revealed muon conversion, whereas according to[1] about 8 conversion events should have been observed. This result indicated only that the conversion probability was overestimated in[1]. The question of the existence of the muon-conversion process remained open.

In recent years more intense muon beams were obtained at JINR. This has made it advisable to repeat the experiments on the direct observation of the muon-conversion process. We present below the preliminary results of these experiments.

NIKFI-K emulsions of 200 μm thickness, filled with uranium nuclei, were exposed for 4 hours to a beam of slow muons at the Nuclear-Problems Laboratory of JINR (the π^- contamination of the muon beam was $\sim 1\%$).

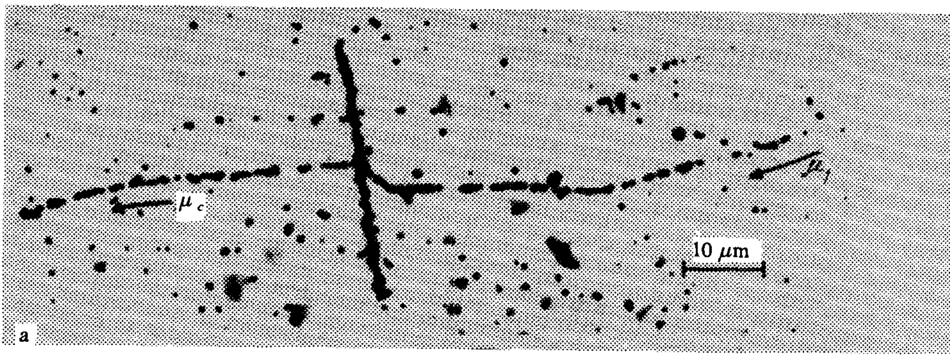
The emulsions were scanned under a microscope with a total magnification $900\times$ ($60\times$ $1.5\times$ $10\times$). Muon-induced fission accompanied by emission of a third triply charged particle, with a range larger than 5 μm, was investigated. The conversion-muon tracks were selected by measuring the ionization and the scattering, as well as by using the kinematics of the elastic collisions.

The detection of conversion muons with energy larger than 1.5 MeV was made complicated by pion-induced fission accompanied by fast-proton emission,[3] and the detection of muons with energy less than 0.4 MeV was made complicated by the recoil nuclei, (H,C,N,O) produced in the course of motion of the fragment in the emulsion.

In view of the limited accuracy of the angle and range measurements, tracks of length smaller than 5 μm (muon energy less than 0.2 MeV) were not analyzed.

Among the $\sim 10^4$ fissions of the uranium nuclei by muons, we identified 16 fission events accompanied by emission of conversion muons (12 reliable and 4 probable).

 0021-3640/78/2711-0625$00.60



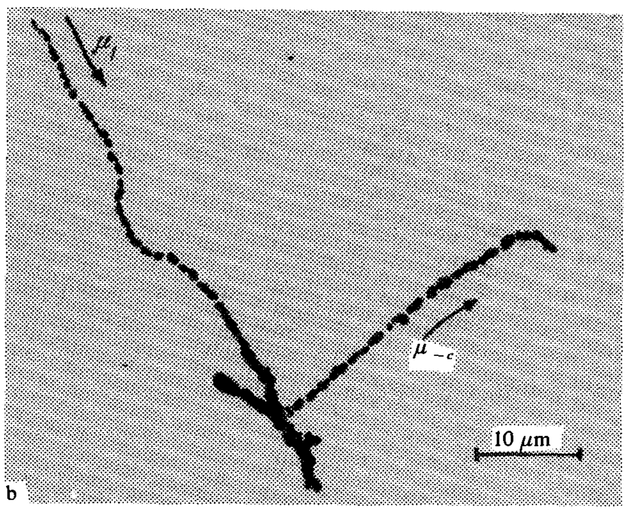


FIG. 1. Micrograms of fission of uranium nuclei by slow muons (M_1), accompanied by emission of conversion muons (M_2).

Micrograms of two reliable events are shown in Fig. 1. These conversion muons are emitted from the fission point (within a time less than 10^{-13} sec) and are stopped in the emulsion. These ranges are 29 and 35 μm, and the l.s. energies are 0.73 and 0.80 MeV, respectively. The energies of the remaining conversion muons emitted from the fission point lies in the interval 0.30–2.0 MeV. The energy of 6 muons emitted from moving fragments is smaller and lies in the interval 0.2–0.4 MeV. All but one of these muons are emitted from the light fragment within a time $(0.7–7.0)\times 10^{-13}$ sec.

A rough estimate (accurate to a factor of three) of the conversion-muon emission probability W_c yields a value ~ 0.02 per nonradiative fission event.

The conversion probabilities were calculated in[4] under the assumption that muon capture by light and heavy fragments is equally probable. In this case $W_c = 0.09$ (for $E1$ transitions), which differs noticeably from our estimate. If it is assumed that the muon is captured in $\sim 90\%$ of the cases by the heavy fragment, then $W_c = 0.023$.

This value agrees better with our estimate and points to predominant capture of the muon by the heavy fragment.[5] Muon conversion was directly observed earlier[6,7] by another procedure that made it possible to determine only the order of magnitude of the conversion probability.

For a complete study of the fate of the muon after nonradiative fission it is necessary to increase substantially the statistics of the muon-conversion events.

This will uncover a possibility of obtaining both new qualitative and quantitative characteristics of the muon-conversion process.

The authors are grateful to I.Ya. Barit and I.M. Frank for collaboration, to V.S. Roganov and V.M. Sidorov for help in exposing the photographic plates, and to L.N. Kolesnikova for help with the measurements.

[1)]Nuclear Problems Laboratory, JINR.

[1]D.F. Zaretskiĭ, Proc. of Second Intern. Conf. on Peaceful Uses of Atomic Energy, Papers of Soviet Scientists [in Russian] **1**, 462 (1969).
[2]G.E. Belovitskiĭ, N.T. Kasukeev, A. Mikhul, M.G. Petrashku, T.A. Romanova, and F.A. Tikhomirov, Zh. Eksp. Teor. Fiz. **38**, 404 (1960) [Sov. Phys. JETP **11**, 296 (1960)].
[3]G.E. Belovitskiĭ, T.A. Romanova, L.V. Sukhov, and I.M. Frank, Zh. Eksp. Teor. Fiz. **28**, 729 (1955) [Sov. Phys. JETP **1**, 581 (1955)]; **29**, 537 (1955) [**2**, 493 (1956)].
[4]I.Ya. Barit, G.E. Belovitskiĭ, and D.G. Zaretskiĭ, Preprint IYaI, No. 0058, 1977.
[5]F.F. Karpeshin, M. Listengarten, I.M. Band, and L.A. Sliv, Izv. Akad. Nauk SSSR Ser. Fiz. **40**, 1164 (1976).
[6]Gz. Ganzorig, T. Kragulski, W.D. Kuznetsov, S.M. Polikanov, and B.M. Sabirov, JINR E-15, 9365, 1976.
[7]Gz. Ganzorig, P. Hansen, T. Yohansson, B. Yonson, Y. Konig, T. Kragulski, W.D. Kuznetsov, L. Westgaart, S.M. Polikanov, and G. Tibell, CERN/SEE 77-22-1977.