ОБЪЕДИНЕННЫЙ
ИНСТИТУТ
ЯДЕРНЫХ
ИССЛЕДОВАНИЙ

ДУБНА

14/IV-75

E15 - 8628

B.M.Aleksandrov, G.V.Buklanov, W.D.Fromm,
Dz.Ganzorig, A.S.Krivokhatski, T.Krogulski,
S.M.Polikanov, B.M.Sabirov

MUON-INDUCED FISSION OF ^{237}Np, ^{242}Pu, AND ^{239}Pu

1975

E15 - 8628

B.M.Aleksandrov, G.V.Buklanov, W.D.Fromm,
Dz.Ganzorig, A.S.Krivokhatski, T.Krogulski,
S.M.Polikanov, B.M.Sabirov

MUON-INDUCED FISSION OF ^{237}Np, ^{242}Pu, AND ^{239}Pu

Submitted to "Physics Letters B"

A muon captured by a heavy atom can induce fission of the nucleus excited due to radiationless muonic transitions and to the absorption process $(Z,N) + \mu^- \to (Z-1,N+1)$. Both kinds of fission have been observed in a number of works [1-4] for several nuclei. However, as far the relative yields of prompt and delayed fission were measured. It is only recently that the absolute yields of prompt and delayed fission per μ^- capture for ^{232}Th, ^{238}U, and ^{235}U were published [5]. In the present work we continue to build up the systematics of the absolute yields for three additional isotopes, two of which ^{237}Np and ^{242}Pu, have not yet been studied.

The experimental set-up, the order of measurements and analysis were identical as in ref. [5]. The measurements were made using the μ^- and π^- separate beams of the Dubna 680 MeV synchrocyclotron. The fission events were registered in the fast many-plate methane filled ionization chamber. The μ^- stop events were registered by a counter telescope consisting of four plastic scintillators operating in the usual $123\bar{4}$ coincidence mode.

The widths of the prompt fission events distribution was 2.5 ns and 5.8 ns for a moderate (about 10^6 α/sec) and high (about 10^8 α/sec) alpha-activity background in the chamber, respectively.

The chamber contained (111±6) mg of ^{237}Np, (7.70±0.85) mg of ^{242}Pu and 125 mg of ^{239}Pu.

The detection efficiency was (95-100)% in measurements with ^{237}Np and ^{242}Pu, and $(52 \pm 5)\%$ in the case of ^{239}Pu *.

The time distributions of the fission events with regard to the μ^- stop moment have been measured simultaneously for the following pairs of isotopes: ^{237}Np and ^{238}U, ^{239}Pu and ^{235}U, ^{242}Pu and ^{239}Pu. In this way by measuring the relative yields of fission events we could obtain the absolute yields using the appropriate values for ^{238}U and ^{235}U published in paper /5/. The fission induced by π^- produces only the prompt events, and measurements with the π^- beam enables us to control characteristics of the timing system

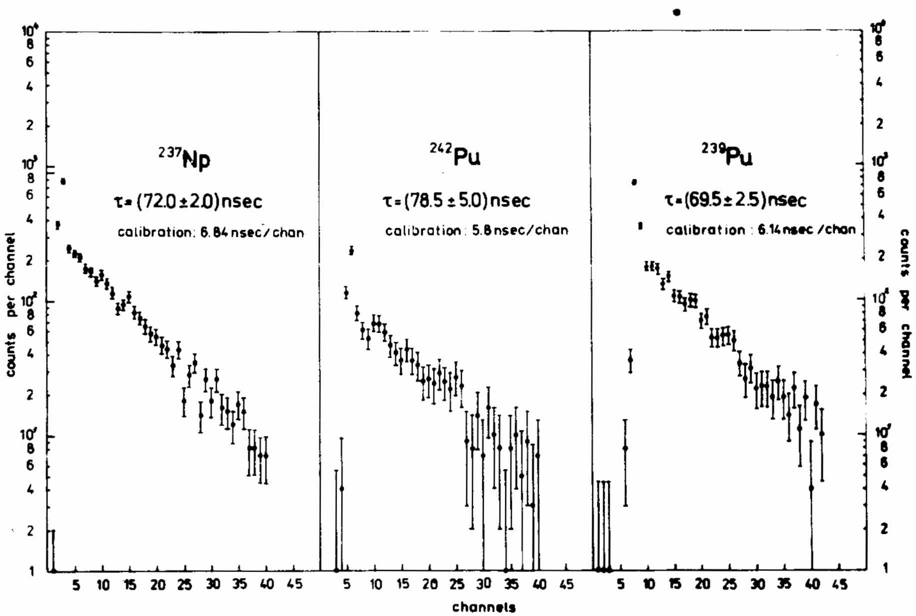

Fig. 1. Time distribution of the fission events in ^{237}Np, ^{242}Pu, *and* ^{239}Pu *induced by* μ^- *(the background has been subtracted).*

---

*In the case of ^{239}Pu the efficiency was defined only for the measurements of the fission yields in ^{239}Pu relatively to the fission yield in (125 ± 2) mg of ^{235}U, contained in the second half of the chamber.

and analyse the response curve of prompt coincidence for every run independently.

The measured spectra summed over every 16 channels are presented in fig. 1. The mean time of the exponential decay was found by the least squares method with a confidence level of 0.05.

The primary spectra were fitted with the sum distributions: (1) the prompt coincidence curve defined in the measurements with π^-, (2) its convolution with the exponentially decaying curve, and (3) the constant background.

Having as the result of the procedure the relative yields of both kinds of fission and the relations of the fission probabilities of the nuclei under study, normalization to the values quoted in ref. /5/ was made and the absolute yields per μ^- capture were found. In this analysis the assumption was made that the energy spectra of fragments are the same for prompt and delayed fission. The results are shown in fig. 2 together with the photofission probability for the photon energy corresponding to the energy of the $2p \to 1s$ muonic transition in those nuclei. The yields of prompt fission normalized to the radiationless transition probabilities taken from /6/ are shown in fig. 3. Two facts are quite evident here. Primarily, the yield of prompt fission is much lower than the photofission probability and shows a pronounced variation with the fissility parameter x. These trends can hardly be compensated by taking into account different radiationless transition probabilities as shown in fig. 3.

Secondly, as it is seen in fig. 2, the probabilities of fission induced by the captured muon (delayed fission) are several times lower than it could be predicted from the Γ_n / Γ_f systematics for the 15-20 MeV nuclear excitation characteristic of μ-capture. For uranium isotopes the fission probability should be about 0.3 for the first chance fission and 0.5 for the first plus second chance fission. For neptunium isotopes these values are 0.5 and 0.8, respectively /7,8/. Therefore, the evident decrease of the delayed fission probability for ^{239}Pu

can hardly be discussed in terms of the decay of the compound nucleus, viz, in Γ_n / Γ_f terms.

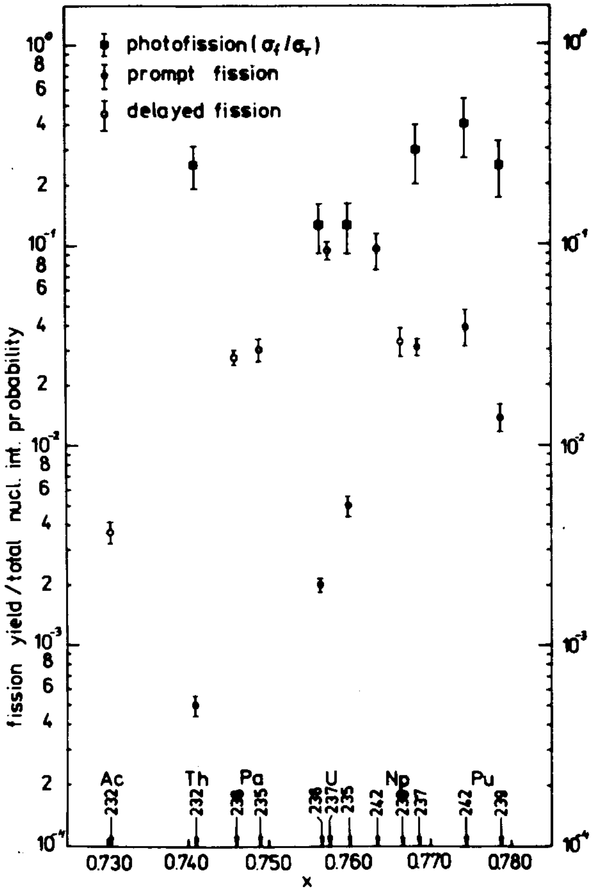

Fig. 2. The absolute yield of prompt and delayed fissions induced by μ^- capture as a function of the fissility parameter x /9/ . The probability of photofission for the photon energy corresponding to K_a transitions is also given (the cross sections $\sigma_f(\gamma)$ are taken from refs. /10 , 11/) and $\sigma_T(\gamma)$ from ref. /12/ . The errors, except for photofission probability values, represent uncertainty in the relative yields only and do not provide for the 25% uncertainty of the scale on the axis of ordinates.

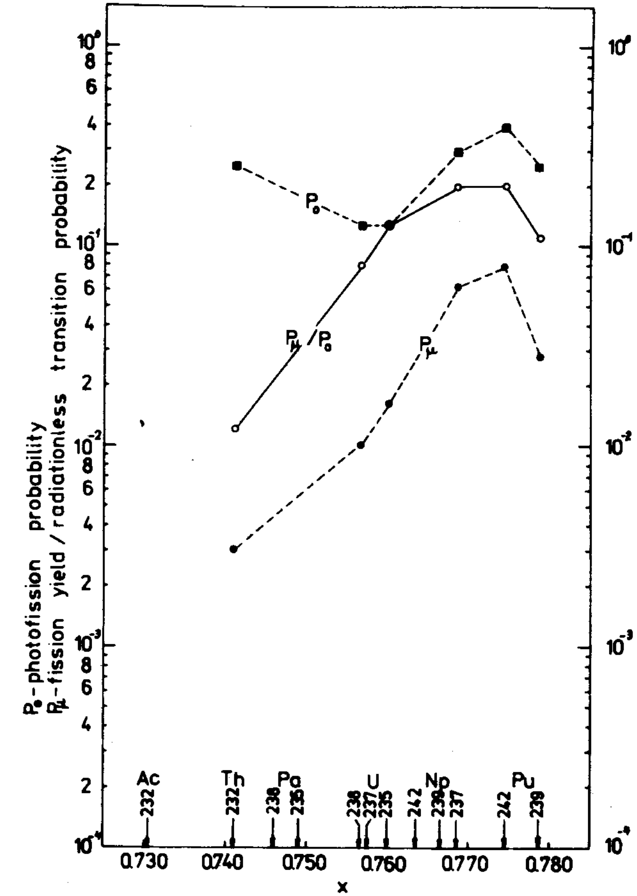

Fig. 3. Comparison of the photofission and radiationless-transition fission probabilities. The radiationless transition probabilities were taken as 0.15 for ^{232}Th , , 0.20 and 0.30 for uranium isotopes, and 0.50 for neptunium and plutonium isotopes according to ref. /6/ where the values for ^{232}Th , ^{235,238}U and ^{239}Pu are given.

The decrease of the prompt fission probability of ^{239}Pu seems to be quite natural in view of the difference in the fission barrier heights. According to ref. /13/ the first fission barrier for ^{239}Pu is about 1 MeV higher than that for ^{242}Pu and ^{237}Np . As the excitation energy in the radiationless transition $2p \rightarrow 1s$ is about 6.5 MeV for these isotopes, it means that the influence of the muon binding energy in the $1s$ orbit on the fission barrier penetrability is much more pronounced in the case of ^{239}Pu. Besides, the effects connected with the channel structure of the fission barrier may cause additional fluctuations in the prompt fission probabilities, as it has been discussed in ref. /5/.

Acknowledgements

The authors gratefully acknowledge the help and support in the course of the work on the part of Professors V.P.Dzhelepov, L.I.Lapidus and K.Ya.Gromov.

We thank Doctors K.Andert and A.I.Kalinin and G.N.Zorin for their assistance in setting up the electronic circuitry.

References

1. *J.A.Diaz et al. Nucl.Phys., 40, 54 (1963).*
2. *B.Budick et al. Phys.Rev.Lett., 24, 604 (1970).*
3. *V.Cojocaru et al. Phys.Lett., 20, 53 (1966).*
4. *A.Buta et al. Revue Roumaine de Physique, 16, 215 (1971).*
5. *D.Chultem et al. JINR, E15-8134, Dubna, 1974.*
6. *M.Ya.Balats et al. JETP, 38, 1715 (1960); JETP, 39, 1165 (1960); JETP, 49, 7 (1965).*
7. *C.J.Bishop et al. Nucl.Phys., A198, 161 (1972).*
8. *R.Vandenbosch, J.R.Huizenga. Nuclear Fission, Academic Press 1973, pp. 219-227.*
9. *W.D.Meyers,W.J.Swiatecki. Report UCRL-11980.*
10. *A.M.Khan, J.W.Knowles. Nucl.Phys., A170, 333 (1972).*
11. *A.V.Ignatyuk et al. JETP, 61, 1284 (1971).*
    A.S.Soldatov et al. Yad.Fiz., 11, 992 (1970).
    N.S.Robotnov et al. Yad.Fiz., 11, 508 (1970).
12. *J.R.Huizenga et al. Nucl.Phys., 34, 439 (1962).*
13. *B.Back et al. Physics and Chemistry of Fission, 1973 Rochester, vol. 1, p.3.*

Received by Publishing Department on February 20, 1975.