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THE CROSS-SECTIONS FOR THE BINARY AND TERNARY FISSION OF URANIUM AND LEAD INDUCED BY 14 GeV PROTONS

Ž. TODOROVIĆ, R. ANTANASIJEVIĆ and M. JURIĆ

Institute of Physics, Beograd

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Abstract: The cross-sections for the binary and ternary fission of uranium and lead induced by 14 GeV protons have been computed. A solid-state plastic detector (macrofol) was used as the detector of fission fragments.

1. Introduction

The binary and ternary fission induced by high-energy particles is defined as a decay of the nucleus into two resp. three fragments of approximately equal masses[1]. In late years these processes have mainly been investigated using solid-state track detectors.

Data on the binary and ternary fissions of uranium and lead induced by high-energy protons were obtained mainly using macrofol [2,3,4] and mica [5,6] as the detectors of fission fragments.

In order to get a more complete picture of the dependence of the cross-sections on proton energy, in the present work the cross-sections have been calculated for the binary and ternary fissions of U and Pb induced by 14 GeV protons. A polycarbonate (macrofol) sensitive to fragments with mass number $Z \geqslant 8$ was used for detection of fission fragments.

2. *Experimental method*

The polycarbonate detector was made of two foils of a size of $(3 \cdot 4 \cdot 0.02)$ cm^3. Targets of natural uranium and lead were vacuum evaporated onto one of the foils. The targets were about 500 Å thick. The errors in determination of the target thicknesses were less than 10%. The foils were packed in such a way that they formed a sandwich with the target placed between them. The sandwiches were pressed and fixed by glueing together two opposite edges with methylene chloride.

The sandwiches prepared in such a way were exposed to 14 GeV protons at CERN. The proton flux was normal to the surface of the detector. Taking into account the characteristics of the proton flux and the position of the detector, the error in determination of the flux did not exceed 20%.

After exposure the uranium and lead targets were dissolved in HNO_3 and HCl respectively. The sandwiches were etched in 20% NaOH for 40 min at a temperature of 60°C.

The scanning and measurement of the events recorded in the detector were carried out with an optical microscope at a magnification by factors of 500 and 1000.

The events recorded in the detector were established to be of the three types: single events, two-prong events and three-prong events. Events with two tracks and a solid angle between them larger than 90°, and events with three tracks having length greater than $3 \mu m$ and originating from the same point of the target were considered to be binary and ternary fission respectively.

The density of events in the detector was about 3000 events per cm^2, hence the coincidence of two single tracks and of a single event with a binary event was neglected. The loss of events due to the dissolution of the surface layer of the detector in the course of chemical treatment was about 2%.

3. *Results and discussion*

The binary fission cross-sections of uranium and lead were calculated using the relation $\sigma_B = F/NP$, where F is the number of binary fission events per cm^2, N is the number of target nuclei per cm^2, and P is the number of incident protons per cm^2.

Figs. 1 and 2 give the corrected calculated values of the binary fission cross--sections of uranium and lead respectively. The same figures also give the values of the cross-sections at different proton energies obtained in other experiments using solid-state track detectors. In both cases the binary fission cross-section at energies above 3 GeV decreases with increasing proton energy, and then more rapidly in the case of uranium.

The ternary fission cross-section was calculated from the relation $\sigma_T=(T/B)\sigma_B$, where T/B is the ratio of ternary to binary events. The calculated T/B ratios for uranium and lead for a proton energy of 14 GeV are $(1.5 \pm 0.4)\%$ and $(3.12 \pm \pm 0.8)\%$ respectively.

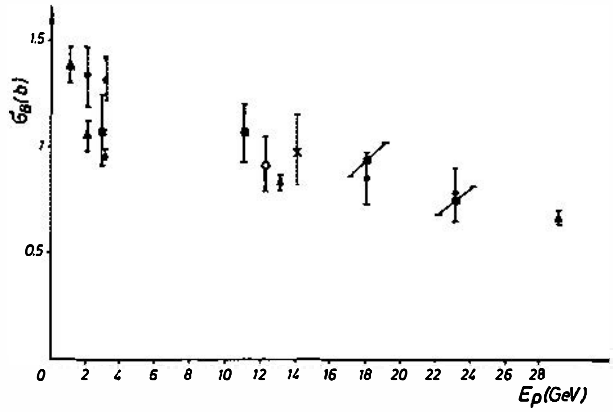

Fig. 1. The binary fission cross-sections of uranium as a function of incident proton energy: ● , ○ polycarbonate detectors (Refs.[2, 3]); × the present work; ▲, ■ mica (Refs.[5) 6)])

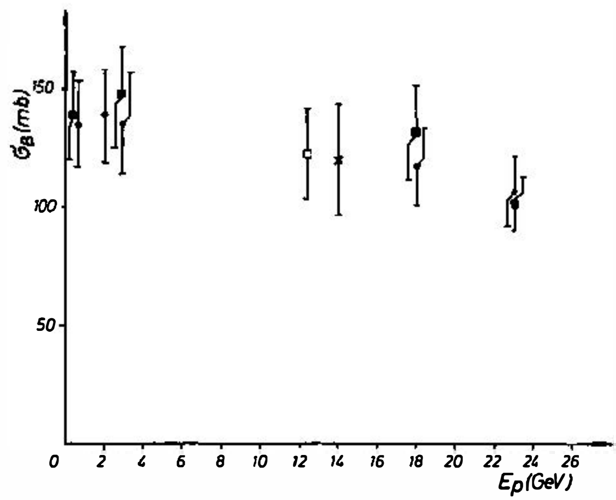

Fig. 2. The binary fission cross-sections of lead as a function of incident proton energy: ●, □ polycarbonate detectors (Refs.[2, 4]), × the present work; ■ mica (Ref.[6]).

The corrected calculated values of the ternary fission cross sections of uranium and lead are given in Figs. 3 and 4 respectively. The same figures also present the cross-section values obtained in other experiments using solid-state track detectors. The ternary fission cross-sections of lead and uranium strongly depend on proton energy. The dependance of the cross-section σ_T on incident proton energy for uranium is similar to that for lead, but the values of the cross-sections of uranium are larger ($\sigma_{T_U}/\sigma_{T_{Pb}} \simeq 4$).

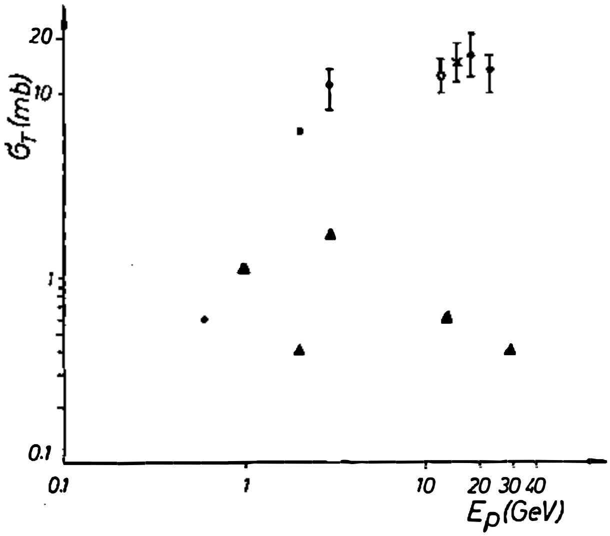

Fig. 3. The ternary fission cross-sections of uranium as a function of incident proton energy. The notation is the same as in Fig. 1.

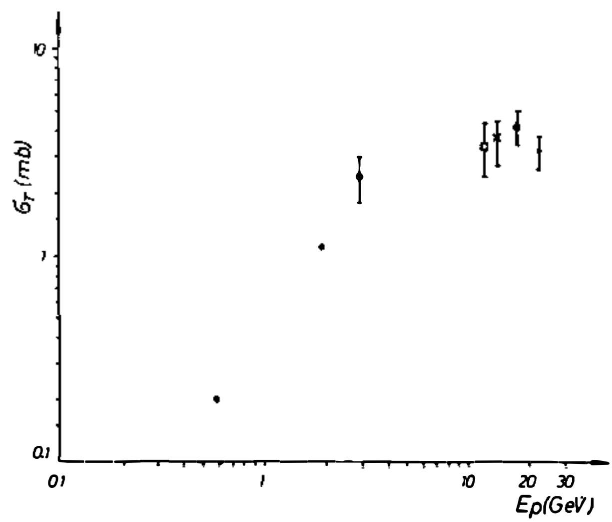

Fig. 4. The ternary fission cross-sections of lead as a function of incident proton energy. The notation is the same as in Fig. 2.

The errors of the calculated binary and ternary fission cross-sections are due to the statistical errors, the error in measurement of the target thickness and the uncertainty in determination of the proton flux.

4. Conclusion

The calculated values of the cross-section for the binary fission of uranium and lead induced by 14 GeV protons are (980 ± 190) mb and (120 ± 24) mb respectively, while those for the ternary fission at the same proton energy are (14.7 ± 3.7) mb and (3.7 ± 0.8) mb respectively.

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PRESECI ZA BINARNU I TERNARNU FISIJU URANA I OLOVA IZAZVANU PROTONIMA OD 14 GeV

Ž. TODOROVIĆ, R. ANTANASIJEVIĆ i M. JURIĆ

Institut za fiziku, Beograd

Sadržaj

U ovom radu su izračunati preseci za binarnu i ternarnu fisiju urana i olova izazvanu protonima od 14 GeV. Za detekciju fisionih fragmenata korišćen je čvrsti plastični detektor (makrofol), koji je osetljiv na fragmente sa masenim brojem $A \geqq 16$.