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YEREVAN PHYSICS INSTITUTE

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MEASUREMENT OF THE CROSS SECTION OF PHOTO AND ELECTROFISSION OF ^{235}U and ^{238}U IN THE ENERGY RANGE 1.33-4.32 GeV

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^{235}Ա ԵՎ ^{238}Ա ՄԻՋՈՒԿՆԵՐԻ ՃԵՂՔՄԱՆ ԿՏՐՎԱԾՔՆԵՐԻ ՉԱՓՈՒՄԸ ՖՈՏՈՆՆԵՐԻ ԵՎ ԷԼԵԿՏՐՈՆՆԵՐԻ ԱԶԴԵՑՈՒԹՅԱՆ ՏԱԿ, 1,33-4,32 ԳԷՎ ԷՆԵՐԳԻԱՆԵՐԻ ՏԻՐՈՒՅԹՈՒՄ

Բերված են ^{235}Ա և ^{238}Ա միջուկների էլեկտրաճեղքման կտրվածքների և ֆոտոճեղքման ելքերի չափման արդյունքները 1-5 ԳԷՎ էներգիների տիրույթում, էլեկտրոնների էներգիայի /նաև ֆոտոնների առավելագույն էներգիների/ չորս արժեքների համար՝ ստացված ցածր ծնշման բազմալար համեմատական խցիկների կիրառմամբ միջուկների ճեղքման բեկորների զբոսանցման համար:

Երևանի Ֆիզիկայի ինստիտուտ

Երևան 1988

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MEASUREMENT OF THE CROSS SECTION OF PHOTO AND ELECTROFISSION OF ^{235}U and ^{238}U IN THE ENERGY RANGE 1.33-4.32 GeV

The results of the electrofission cross section and the photofission yield measurements using low-pressure multiwire proportional chambers to detect the fission fragments of the nuclei ^{235}U and ^{238}U are presented in the energy range 1-5 GeV of electrons and the bremsstrahlung beam.

Yerevan Physics Institute
Yerevan 1988

Препринт ЕФИ-1104(67)-88

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ИЗМЕРЕНИЕ СЕЧЕНИЙ ДЕЛЕНИЯ ЯДЕР ^{235}U И ^{238}U ПОД ДЕЙСТВИЕМ ФОТОНОВ И ЭЛЕКТРОНОВ С ЭНЕРГИЕЙ 1,33 - 4,32 ГЭВ

В работе приведены результаты измерений сечения электроделения и выхода фотоделения на ядрах ^{235}U и ^{238}U для четырех значений энергии электронов (и максимальной энергии фотонов) в области энергии 1-5 ГэВ, полученные в экспериментах с использованием многопроволочной пропорциональной камеры низкого давления (КНД) для регистрации осколков деления ядер.

Ереванский физический институт

Ереван 1988

Introduction

The measurement of the cross section of the heavy nuclei fission by photons and electrons is of great interest. First, the absolute values of these cross sections will allow to judge about the mechanism of interaction of real and virtual photons with nuclei. Second, the energy dependence of these cross sections gives information about that of the total cross section of the photon absorption by heavy nuclei (see ref.1) These measurements are especially interesting for the nuclei with $Z > 90$, for which the photoabsorption and photofission cross sections are equal, as with the increasing energy of the gamma-quanta the fissionability of such nuclei approaches unity.

The works on the measurement of the cross section of electrofission in the energy range up to 1 GeV [2,4] suggest, that the interactions of real and virtual photons with nuclei are of alike character. In this aspect it is interesting to continue the studying of the electrofission on heavy nuclei in the region of higher energies, where the problem of virtual photon shadowing remains open and there are no experimental data.

The cross section measurements of the photofission of ^{235}U and ^{238}U in a wide energy range will allow to determine the

relative fissionability of these nuclei at high energies, this being of practical interest in connection with the use of photofission to determine the total cross section of the hadron photoabsorption.

The results of measurements of the electrofission cross section and the photofission yield for four values of the electron energy (and the maximum photon energy) within 1-5 GeV are presented in this paper. These results are obtained in the experiments using low-pressure multiwire proportional chambers (LPC) to detect the fission fragments.

Measurement Procedure

The measurements were carried out on the external beam of the Yerevan synchrotron. A schematic diagram of the set-up is shown in Fig.1. The electron beam, passing through the collimators C1 and C2, was formed by the doublets of lenses L1L2 and L3L4, the deflecting magnets M1 and M2 and hit the LPC detector of fission fragments. The proportional chamber (PC) was to measure the beam profile and the quantameter Q - to monitor the electron and photon beams. The radiator R was to obtain bremsstrahlung photons and was removed when measuring the electrofission cross section.

The LPC is a multiwire proportional chamber filled with heptane vapours under 14 torr. The target is glued on the high-voltage electrode of the chamber [5]. Uranium targets (^{235}U, ^{238}U) electrochemically deposited on aluminium supporters of $\sim 20\,\mu m$ thickness were used. Their specifications are

given in Table 1.

Table 1

Target	Area cm^2	Weight mg	Number of nuclei per cm^2 of area
^{235}U	33.9	33.1	$2.5 \cdot 10^{18}$
^{238}U	30.8	30.2	$2.48 \cdot 10^{18}$

The mode of LPC operation is chosen such to detect only the heavy fission fragments, not involving the significant contribution of α-particles produced in the decay of the uranium isotopes.

A pure electron beam with no admixture of bremsstrahlung photons is required in the measuremnt of the uranium electrofission cross section. The electron beam is cleared by two-stage bending of the electron path and by the beam's passing through a vacuum line (see Fig.1). But there is an 50 cm air gap between the vacuum tube and the vacuum chamber, which is a source of bremsstrahlung photons. This is the reason why in the electrofission cross section measured there is a certain share of photofission the value of which is determined experimentally. To do that, the magnet M3 is connected up to deflect the electron beam from the track. The LPC target would hit only the bremsstrahlung photons produced when the electron beam passes through the air gap. Then the LPC responses will coincide with the events of photofission of the uranium nucleus by the bremsstrahlung photons produced in the air gap and with the α-particle background.

To measure the uranium photofission yield a continuous spectrum of bremsstrahlung photons obtained on an aluminium radiator of 0.034 X_o thickness mounted under the electron beam before the magnet, is used. The maximum energy of the bremsstrahlung spectrum corresponds to that of the extracted electron beam.

Results of Measurements and Discussion

The results of the measurements of the electrofission cross section and the photofission yields of the ^{235}U and ^{238}U nuclei for four values of the energy of incident electrons are presented in Table 2. Statistical errors are only given. There are also ~5% of systematic errors connected with the electron and photon beams monitoring.

Fig.2 shows the our measured electrofission cross sections together with the analogous data from refs. 2-4 . As is seen from the figure, our results are in good agreement with those available in the region of lower energies.

Fig.3 shows the energy dependence of the yield of photofission of the nuclei ^{235}U and ^{238}U. The results of ref. 6 are also presented for comparison. It is seen that all the results are in quite good agreement with each other.

Fig.4 shows the energy dependence of the ratio of the cross section of ^{235}U to that of ^{238}U for the processes of photo and electrofission. Data in the region up to 1 GeV are taken from ref. 7 . As is seen from the figure, the ratio decreases with increasing energy, this indicating to equal fissionability of these nuclei at high energies. Note that these results of

the cross section ratio $^{235}U/^{238}U$ are devoid of systematic errors due to beam monitoring, since the measurements on both of the nuclei are carried out simultaneously, under quite identical conditions.

In Fig.5 the energy dependence of the ratio of the our obtained results of the photofission yield and the electrofission cross section for the nuclei ^{235}U and ^{238}U are shown together with the analogous data from refs. 4,6 . Full curve is the dependence taken from ref. 1 :

$$\frac{\sigma_{\gamma f}}{\sigma_{ef}} = \frac{\pi}{2\alpha \ln E_e/m_e},$$

where $\alpha = 1/137$, m_e and E_e are the mass and the energy of electron. As is seen from the figure, the experimental results are in good agreement with the theoretical dependence between the electrofission cross section and the photofission yield.

Thus, using a LPC as a fission-fragments detector situated under electron and photon beams will allow to measure the heavy nuclear fission cross sections with good accuracy.

Table 2

Energy	Cross section	^{235}U	^{238}U
1.33	Electrofission	13.54±0.2	7.56±0.1
	Photofission	378±4.6	243±3.7
2.26	Electrofission	17.57±0.6	9.77±0.37
	Photofission	370.7±6	260±5
3.33	Electrofission	18.95±0.13	11.82±0.1
	Photofission	435.3±7.9	307.7±5.6
4.32	Electrofission	19.68±0.2	12.34±0.12
	Photofission	480.07±8.3	306.8±7.5

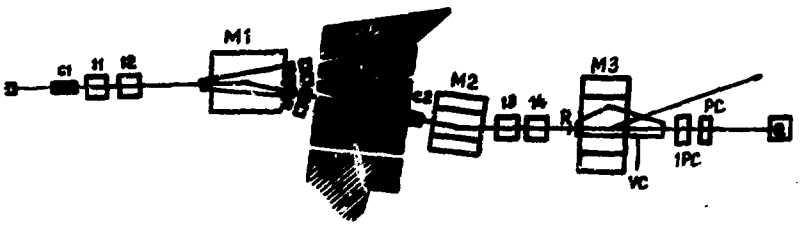


Fig.1

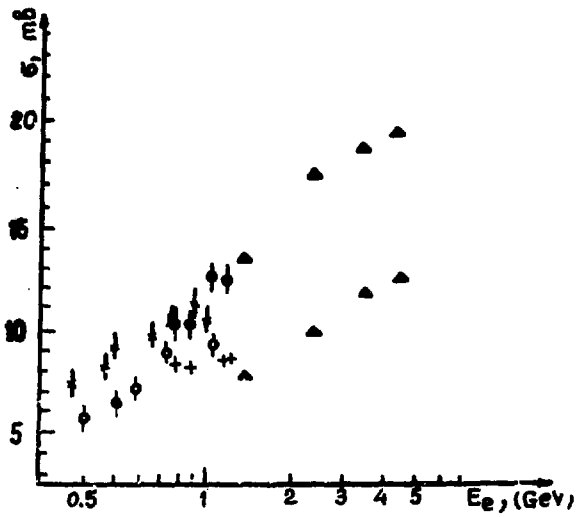


Fig.2

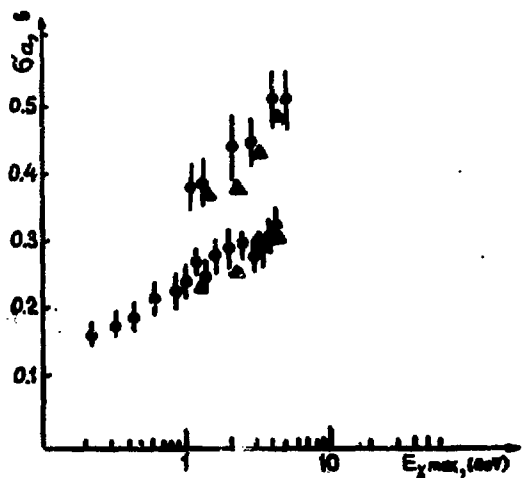


Fig.3

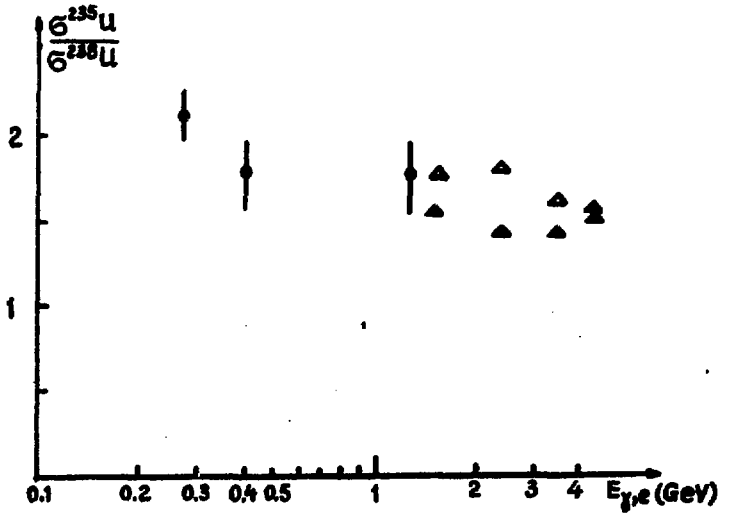

$\frac{\sigma^{235}U}{\sigma^{238}U}$
2
1
0.1
0.2
0.3
0.4
0.5
1
2
3
4
$E_{\gamma,e}$ (GeV)

Fig.4

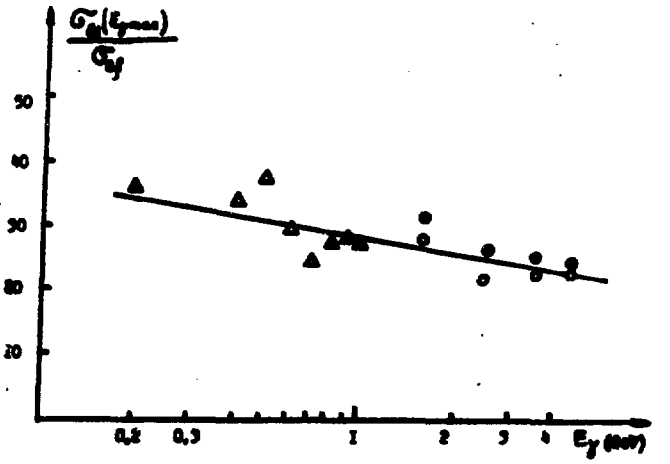

$\frac{\sigma_{\gamma n}(E_{\gamma max})}{\sigma_{\gamma f}}$
50
40
30
20
0,2
0,3
1
2
3
4
E_γ (GeV)

Fig.5

Figure Captions

Fig.1 Schematic diagram of the experimental set-up.

C1C2 - collimators; LPC - low-pressure chamber;
M1,M2,M3 - magnets; PC - proportional chamber;
L1-L4 - lenses; R - radiator;
VC - vacuum chamber; Q - quantameter.

Fig.2 The energy dependence of the cross section of electrofission of the nuclei ^{235}U and ^{238}U.

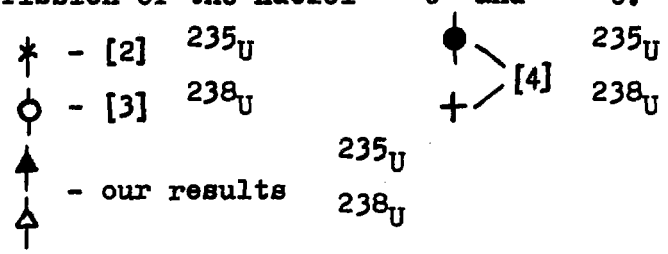


Fig.3 The energy dependence of the photofission yield of the nuclei ^{235}U and ^{238}U.

Fig.4 The energy dependence of the ratio of the cross section of fission of ^{235}U to that of ^{238}U.

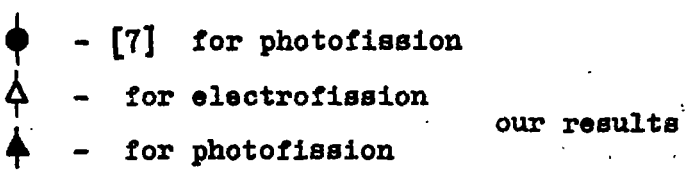
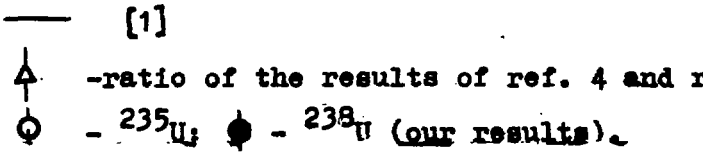


Fig.5 The energy dependence of the ratio of the photofission yield to the electrofission cross section.



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ИЗМЕРЕНИЕ СЕЧЕНИЙ ДЕЛЕНИЯ ЯДЕР ^{235}U И ^{238}U ПОД ДЕЙСТВИЕМ ФОТОНОВ И ЭЛЕКТРОНОВ С ЭНЕРГИЕЙ 1,38 - 4,32 ГЭВ

(на английском языке, перевод Папяна Г.А.)

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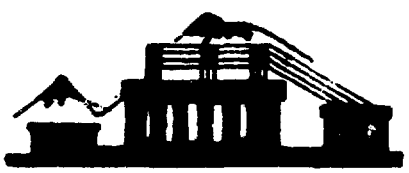

ЕРЕВАНСКИЙ ФИЗИЧЕСКИЙ ИНСТИТУТ