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THE PROMPT NEUTRON SPECTRUM FROM THERMAL NEUTRON-INDUCED FISSION OF ^{235}U FOR THE ENERGY RANGE 30 keV TO 1 MeV

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ABSTRACT

Data are given for the prompt neutron spectrum from thermal neutron-induced fission of ^{235}U for the energy range 30 keV to 1.2 MeV. The relative method was used for performing the measurements and the prompt neutron spectrum from spontaneous fission of ^{252}Cf was taken as standard.

A precise value for the prompt neutron spectra from fission of nuclei is of great interest both for nuclear reactor calculation and for the development of ideas about the mechanism of fission neutron emission. At present there is a comparatively large amount of work being done on this question. However, the energy range $0 < E_n \lesssim 0.5$ MeV has hardly been studied for most nuclei. Exceptions to this are ^{252}Cf and ^{235}U. References [1-4] are devoted to research on the spectrum for californium in this region. The prompt neutron spectrum for fission of ^{235}U by thermal neutrons in the energy range 30 keV $< E_n <$ 1 MeV was studied in Refs [5-6].

The aim of our work was to measure the prompt neutron spectra from fission of ^{235}U, ^{233}U and ^{239}Pu by thermal neutrons in the low-energy range using lithium glasses and the time-of-flight technique. In the present paper the results relating to ^{235}U are presented.

Figures 1 and 2 show a block diagram of the experiment. The fragment detector was a gas scintillation chamber working on pure argon at atmospheric pressure. The inside of the chamber was scanned by a 56-UVP photo-multiplier.

The thermal neutron beam from a tangential channel of the WWR-S reactor at the Central Institute for Physics Research was formed with a special collimator. NE-912 lithium glass (45 mm diameter and 9.5 mm thickness) and a 56-AVP photomultiplier were used as a neutron detector. The detector was placed in special shielding to reduce the random coincidence background. In addition to the electronics and the measuring procedure, the designs of the fragment detector, the collimator and the neutron detector shield are described in detail in Ref. [6]. There was a difference in that, for measuring the background of delayed gamma rays, NE-913 lithium glass which is insensitive to neutrons was used in our work. The path length, the value for the analyser channel and the half-height width of the gamma peak were, in our work, 30 cm, 0.47 ns/channel and 2.5 ns respectively. Four series of measurements were carried out: ^{252}Cf - NE-912, ^{252}Cf - NE-913, ^{235}U - NE-913 and ^{235}U - NE-912. Special attention was paid to ensuring identical experimental geometry and identical operating conditions for the recording apparatus in the various series of measurements. For the time of building up of each energy spectrum the number of fission events recorded was $n = 9.82 \times 10^9$, 9.89×10^9, 1.53×10^{10} and 9.78×10^9, respectively.

The data were processed as follows. After normalizing the data to a particular number of fission events from the spectra measured with the NE-912 detector, the spectra obtained with the NE-913 were subtracted for californium and uranium, respectively. Then the background of random and systematic random coincidences was taken into account and the time spectra were converted to the energy scale. As a result, the spectra $N(E)_{Cf}$ and $N(E)_U$ were obtained for californium and uranium, respectively. It was then necessary to take the scattered neutron background into account. A correction for scatter was introduced in the approximation of a single energy dependence of the scattered neutron background for uranium and californium. Here it is easy to show that the uranium neutron spectrum can be found using the following equation:

$$\phi(E)_U = \phi(E)_{Cf} + \frac{N'(E)_U - N'(E)_{Cf}}{\varepsilon(E) \cdot \Omega \cdot \Delta E} \qquad (1)$$

Here, $\phi(E)$ is the prompt neutron spectrum in units of neutron/MeV steradian, referred to a single neutron fission event, $N'(E) = N(E) \cdot n^{-1} \cdot \bar{\nu}^{-1}$, $\varepsilon(E)$ is the efficiency of neutron recording, Ω is the solid angle of neutron recording and ΔE is the step on the energy scale. For $\phi(E)_{Cf}$ the following expression proposed in Ref. [7] was used:

$$\phi(E)_{Cf} = 0,5\pi^{-3/2}\ (0,98^{3/2} + 1,43^{3/2})^{-1}\ \sqrt{E}$$
$$\times[\exp(-E/0,98) + \exp(-E/1,43)]$$

$\bar{\nu}_{Cf}$ and $\bar{\nu}_U$ were taken to be equal to 3.74 and 2.40, respectively. For $\varepsilon(E)$ the data from Ref. [1] were used and were corrected for the difference in the relative ^{6}Li content in the NE-905 and NE-912 glasses. Here it should be pointed out that in the given method, as will be seen from Eq. (1), the uncertainty regarding efficiency shows itself in the results much less than in absolute measurements of the type found in Refs [1-4]. Figure 3 shows the curve of efficiency of the neutron detector and the energy dependence of the relative contribution of the scattered neutron background $\delta(E)$ to the spectra measured, determined according to the fomula:

$$\delta(E) = 100\ [N'(E)_{Cf} - \varepsilon(E)\cdot\Omega\cdot\Delta E\cdot\phi(E)_{Cf}]\cdot[N'(E)_{Cf}]^{-1}\ .$$

It will be noticed that the behaviour of the scattered neutron background is unusual and is reminiscent of a reverse efficiency dependence. This behaviour of $\delta(E)$ can be understood if one takes the passage of neutrons scattered on paraffin by the lithium-hydride casing of the neutron detector into account.

The ^{235}U fission neutron spectrum data obtained in our work are shown in Fig. 4. The results predicted by a Maxwellian distribution with the parameter T = 1.315 MeV (Ref. [8]) are shown by a solid line. It will be seen that points lie considerably higher. In this way it can be said that our data show that the prompt neutron spectrum from fission of ^{235}U by thermal neutrons is, as with spontaneous fission of californium, considerably softer than is predicted by extrapolation from the higher energy region using Maxwell's formula. This conclusion agrees with that reached in Ref. [5].

Figure 5 shows the energy dependence of the values for californium and uranium:

$$\beta = 100.\ [\phi(E) - 0,5\pi^{-3/2}T^{-3/2}\sqrt{E}\ \exp(-E/T)]\cdot[0,5\pi^{-3/2}T^{-3/2}\sqrt{E}\ \exp(-E/T)]^{-1}$$

Values for T in this expression were assumed to be equal to 1.43 and 1.315 MeV for californium and uranium, respectively. It will be seen that for uranium the spectrum is softened somewhat more than for californium. In Ref. [7], in an analysis of data on the prompt neutron spectrum for spontaneous fission of californium, it was suggested that one of the possible reasons for the divergences discussed could be the presence of an isotropic component of neutron fission. If this hypothesis is true and applicable to ^{235}U, the results obtained in our work can be interpreted as indicating that with fission of ^{235}U by thermal neutrons the contribution of the isotropic component should be rather greater than with fission of ^{252}Cf.

REFERENCES

[1] MEADOWS, J.W., Phys. Rev. 157 (1967) 1076.

[2] ZAMYATIN, Yu.S., KROSHKIN, N.I., MEL'NIKOV, A.N. and NEFEDOV, V.N., Nuclear Data for Reactors, IAEA, Vienna (1970) 183.

[3] JEKI, L., KLUGE, G., et al., Prompt Fission Spectra, IAEA, Vienna (1973) 81.

[4] BATENKOV, O.I., BLINOV, M.V., VITENKO, V.A., KRISYUK, I.T. and TUZ, V.T. Nejtronnaya Fizika [Neutron Physics], 5 Moscow (1976) 114 (in Russian).

[5] ANDREJCHUK, L.M., KOROSTYLEVA, V.A. et al., Nejtronnaya Fizika [Neutron Physics] 5 Moscow (1976) 120 (in Russian).

[6] LAJTAI, A., EKI, L. et al., Nejtronnaya Fizika [Neutron Physics] 5 Moscow (1976) 146 (in Russian).

[7] D'YACHENKO, P.P., SEREGINA, E.A. et al., At. Ehnerg. 42 (1977) 25 (in Russian; issued in English translation in "Soviet Atomic Energy").

[8] SEREGINA, E.A. and D'YACHENKO, P.P., in "Voprosy atomnoj nauki i tekhniki" [Questions of Atomic Science and Technology], Serija Yadernye Konstanty [Nuclear Constants Series] published by Atomizdat, 22 Moscow (1976) 9 (in Russian).

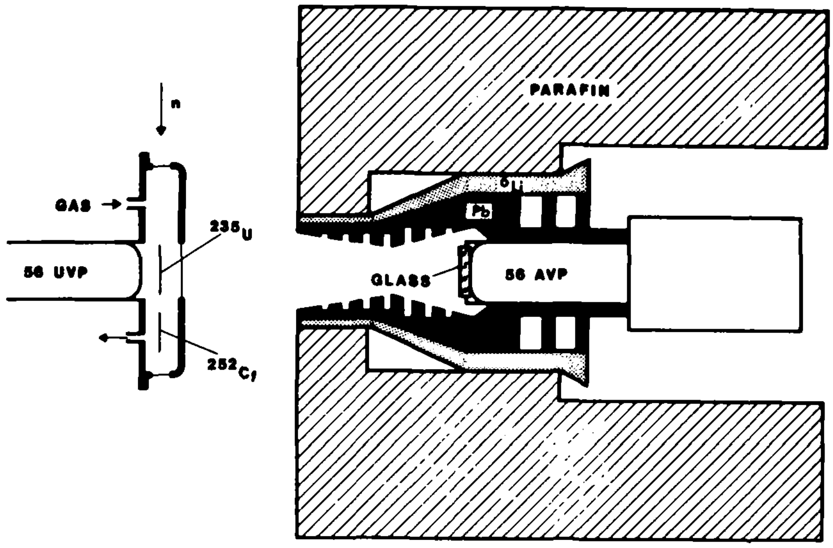


Fig. 1.

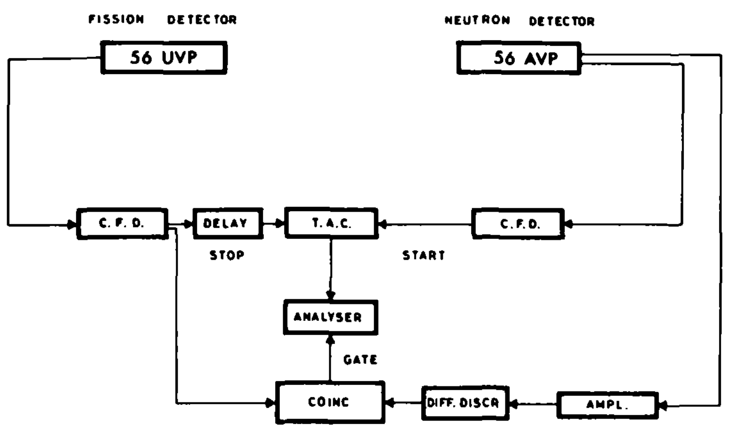


FIG 2

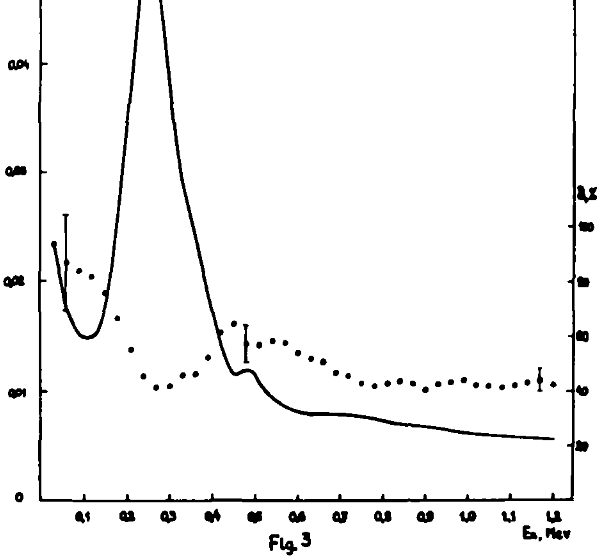


Fig. 3

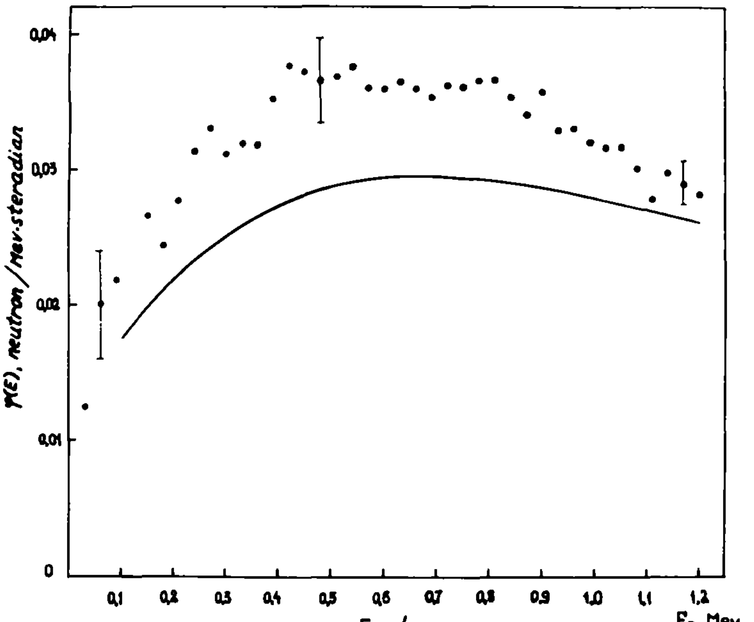
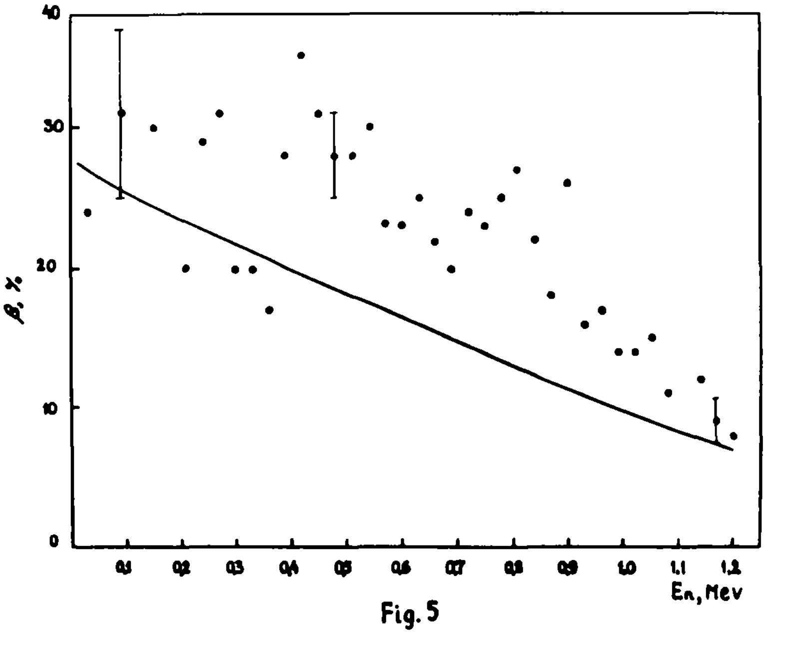

η(E), neutron/Mev·steradian
0,04
0,03
0,02
0,01
0
0,1
0,2
0,3
0,4
0,5
0,6
0,7
0,8
0,9
1,0
1,1
1,2
En, Mev

Fig. 4


β, %
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30
20
10
0
0,1
0,2
0,3
0,4
0,5
0,6
0,7
0,8
0,9
1,0
1,1
1,2
En, Mev

Fig. 5