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# SEARCH FOR RETARDED NEUTRONS FROM SPONTANEOUS FISSION OF $^{252}Cf$

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## ABSTRACT

Search for retarded neutrons from spontaneous fission of $^{252}Cf$ is reported. No evidence of their existence has been obtained.

## РЕЗЮМЕ

Нами был исследован вклад задержанных нейтронов при спонтанном делении $^{252}Cf$. На основе результатов настоящего эксперимента их существование не подтвердилось.

## KIVONAT

Méréseket végeztünk a $^{252}Cf$ spontán hasadásánál keletkező un. retardált neutronok kimutatására. Eredményeink alapján ezek létezése nem látszik bizonyitottnak.

Results of some recent experiments [1-3] have been interpreted as evidence of the existence of retarded neutrons emitted from fission fragments at times from $10^{-7}$ to $10^{-9}$ sec after the act of fission. V.N. Nefedov and his coworkers [3] used time-of-flight and delayed coincidence methods to measure the energies, emission times and yields of the retarded neutrons. The energies of the different retarded groups were evaluated as 0.4 to 3.3 MeV, with emission times from 2.3 to 100 nsec and yields varying between 0.2 and 2.7 per cent of the total number of neutrons per fission. Some of these measurements have been critically revised by L. Jéki and his coworkers [4] and it has been shown that the conclusions drawn from these experiments concerning the origin and properties of retarded neutrons are questionable.

We searched for these neutrons by utilizing the characteristic of the angular distribution of fission neutrons. The stopping time of fission fragments in a material can be much less than the observed life-times of the so-called retarded neutrons. For tungsten the stopping time is not more than $10^{-11}$ sec, thus the retarded neutrons emitted from the stopped fragments are expected to increase the isotropic contribution to the angular distribution of fission neutrons.

The scheme of the measuring arrangement is shown in Fig.1. A $^{252}Cf$ source, about 7 mm in diameter and approximately $10^5$ fission/sec was mounted at the centre of a vacuum chamber. It was prepared by selftransfer method with a thin aluminium oxide film backing, 30 μg/cm$^2$ in thickness. The front-side of the source was covered by a similar film to prevent self--dispersion of californium in the chamber made of 0.4 mm thick stainless steel. To determine the direction of the flight of the fission fragments, a silicon surface-barrier detector, 2 cm in diameter, was placed at 6.5 cm from source. The neutrons were recorded in coincidence with the fragments by a 22x34 mm stylbene crystal placed at an angle of 90$^o$ relative to the fragment direction. By electronic n-gamma discrimination [5] the gamma counts were reduced by a factor of 50 at neutron energies at the 400 keV threshold energy of the neutron detector and even more at higher neutron energies. The threshold energy of the neutron detector was measured by Van-de-Graaf accelerator. The neutron spectra for spontaneous fission of $^{252}Cf$ were measured in an energy range from 400 keV to 6 MeV. The dependence of the detection efficiency on neutron energy is shown in Fig. 2. In this experimental arrangement the angular anisotropy of the fission neutrons i.e. the ratio of the neutron counts at 0$^o$ to those at 90$^o$ relative to the direction of fragment motion was found to be 4.5. A tungsten foil of 25 μm thickness was used to stop the fission fragments. It was placed periodically at a distance of 5 mm from the source to stop the fragments flying in the direction opposite to that of the fragment detector without changing any of the other experimental conditions.

The fragment-neutron coincident counts $N_2$ were recorded simultaneously with the fragment counts $N_1$ and neutron counts $N_3$. The dead time of the coincidence unit was 0.5 μsec. Four series of measurement were performed with using one or two stopping foils at both positions of the neutron detector.

Each series consisted of ten runs, each of them comprising ten distinct successive measurements of ten minutes either with or without foil to preclude the effect of any instrumental instability.

The results of the measurements are summarised in the table. The primed values have been measured with, the others without the stopping foil. It can be seen that the value $A = (N_2' - N_2)/N_2'$ , expressing the contribution from retarded neutrons, does not exceed the range of the experimental error.

It is important to evaluate the sensitivity of the present experimental method. If retarded neutrons existed the value of A would be given for the present experiment by

$$A = \frac{N_2' - N_2}{N_2'} \approx \frac{1}{2} \cdot \frac{\bar{\nu}}{4\pi} \cdot \frac{\sum_i \varepsilon(E_n)\alpha_i\,(1-I)}{\int_{E_n} \varepsilon(E_n)\,N(E_n)\,dE_n}$$

$$I = \begin{cases} \left[\left(E_n^i - E_f\right)/E_n^i\right]^{1/2} & \text{for} \quad E_f < E_n^i \\ 0 & \text{for} \quad E_n^i \le E_f \end{cases} ,$$

where $\bar{\nu}$ is the average number of prompt neutrons per fission, $\varepsilon(E_n)$ is the neutron detection efficiency, $\alpha_i$ , $E_n^i$ are the yield and energy of the $i^{th}$-group of retarded neutrons, respectively, $E_f$ is the fragment kinetic energy per nucleon and $N(E_n)$ is the prompt fission neutron spectrum at angle $90^o$ relative to the direction of the fragment motion. The factor 1/2 arises from the fact that only one of two fragments was stopped in our experiment. It can be seen that the sensitivity of the present experimental method depends on the energy of the retarded neutrons. The calculation using the $N(E_n)$ data of Bowman et al. [6] for the energy points with the lowest sensitivity shows the values of A should be approximately 1.8 and 0.4 % for neutron groups with energies $E_n^i = 0.5$ MeV and $E_n^i = 3$ MeV, respectively taking $\alpha_i$ to be 3% in both cases. Since the energies of the retarded neutrons measured by V.N.Nefedov et al. [3] lie in an energy interval where the sensitivity of the present method is even higher, a value of A above our experimental error should have been observed.

It is instructive to compare the values of $A = (N_2'-N_2)/N_2'$ to those of $B = (N_3'-N_3)/N_3'$ obtained under different experimental conditions. The similar behaviour of these values suggests that the fluctuations in A observed within the experimental error are probably due to the scattering of prompt neutrons by the stopping foil.

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## FIGURE CAPTIONS

Fig. 1 Scheme of the experimental arrangement.

Fig. 2 Detection efficiency $\varepsilon$ as function of neutron energy.

Table

| Position of the neutron detector | Number of foils | Total number of counts | | | | | Coincidences $A = (N'_2 - N_2)/N'_2$, [%] | Neutrons $B = (N'_3 - N_3)/N'_3$, [%] |
|---|---|---|---|---|---|---|---|---|
| | | Fragments $N_1$ | With foil | | Without foil | | | |
| | | | Coinciden-ces $N'_2$ | Neutrons $N'_3$ | Coinciden-ces $N_2$ | Neutrons $N_3$ | | |
| I | 2 | 44840000 | 118606 | 18757447 | 118268 | 18368883 | 0,28 ± 0,32* | 2,07 ± 0,12* |
| | 1 | 44840000 | 118707 | 18796319 | 117715 | 18455699 | 0,33 ± 0,46 | 1,81 ± 0,18 |
| II | 1 | 44840000 | 102681 | 15833042 | 102899 | 15916493 | -0,21 ± 0,43 | -0,53 ± 0,09 |
| | 2 | 44840000 | 104255 | 16054092 | 104663 | 16277129 | -0,39 ± 0,49 | -1,39 ± 0,20 |

* The errors are calculated from the dispersion of the runs

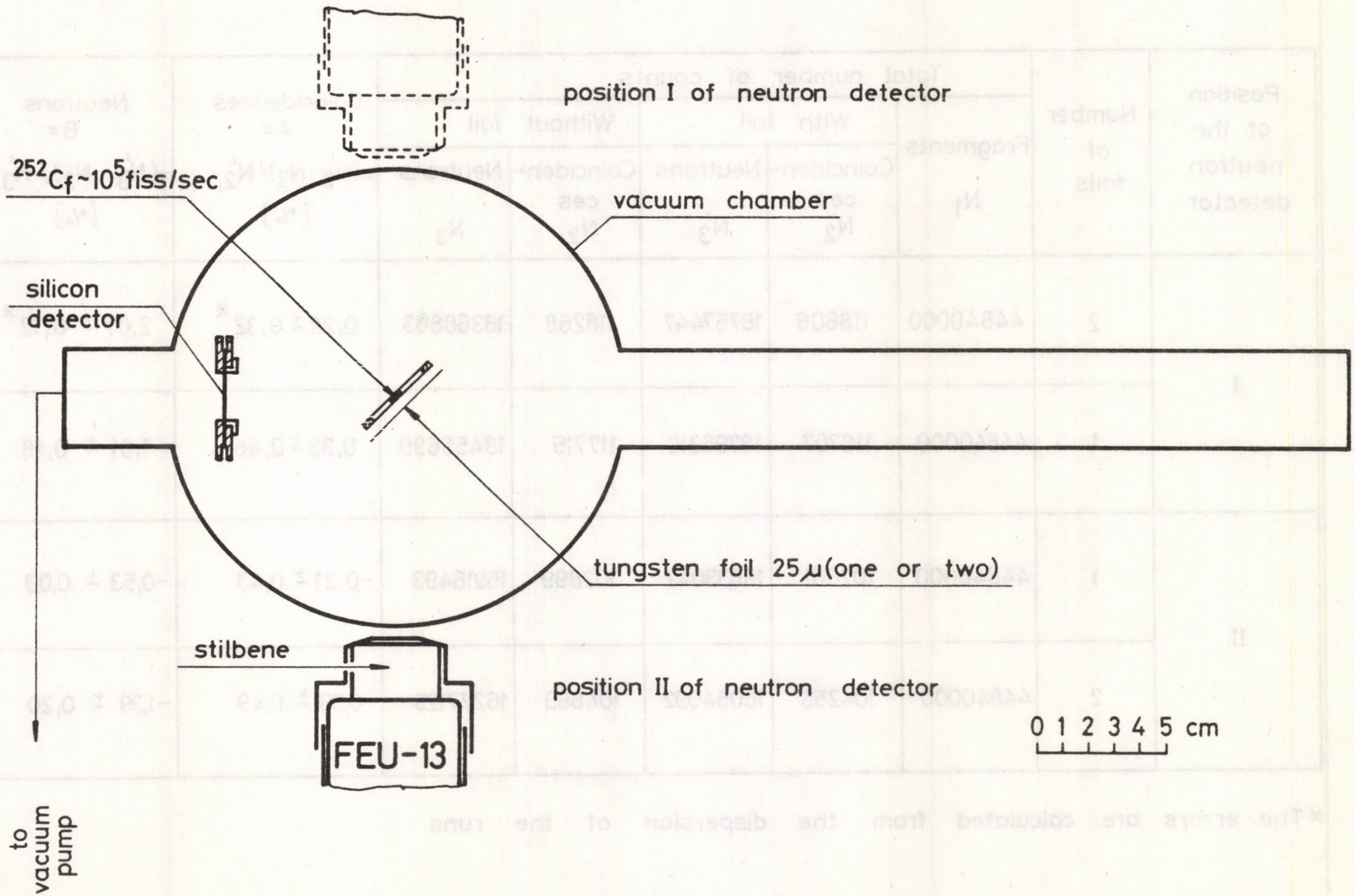
position I of neutron detector
$^{252}Cf \sim 10^5$ fiss/sec
vacuum chamber
silicon detector
tungsten foil 25 μ (one or two)
stilbene
position II of neutron detector
FEU-13
0 1 2 3 4 5 cm
to vacuum pump

Fig.1

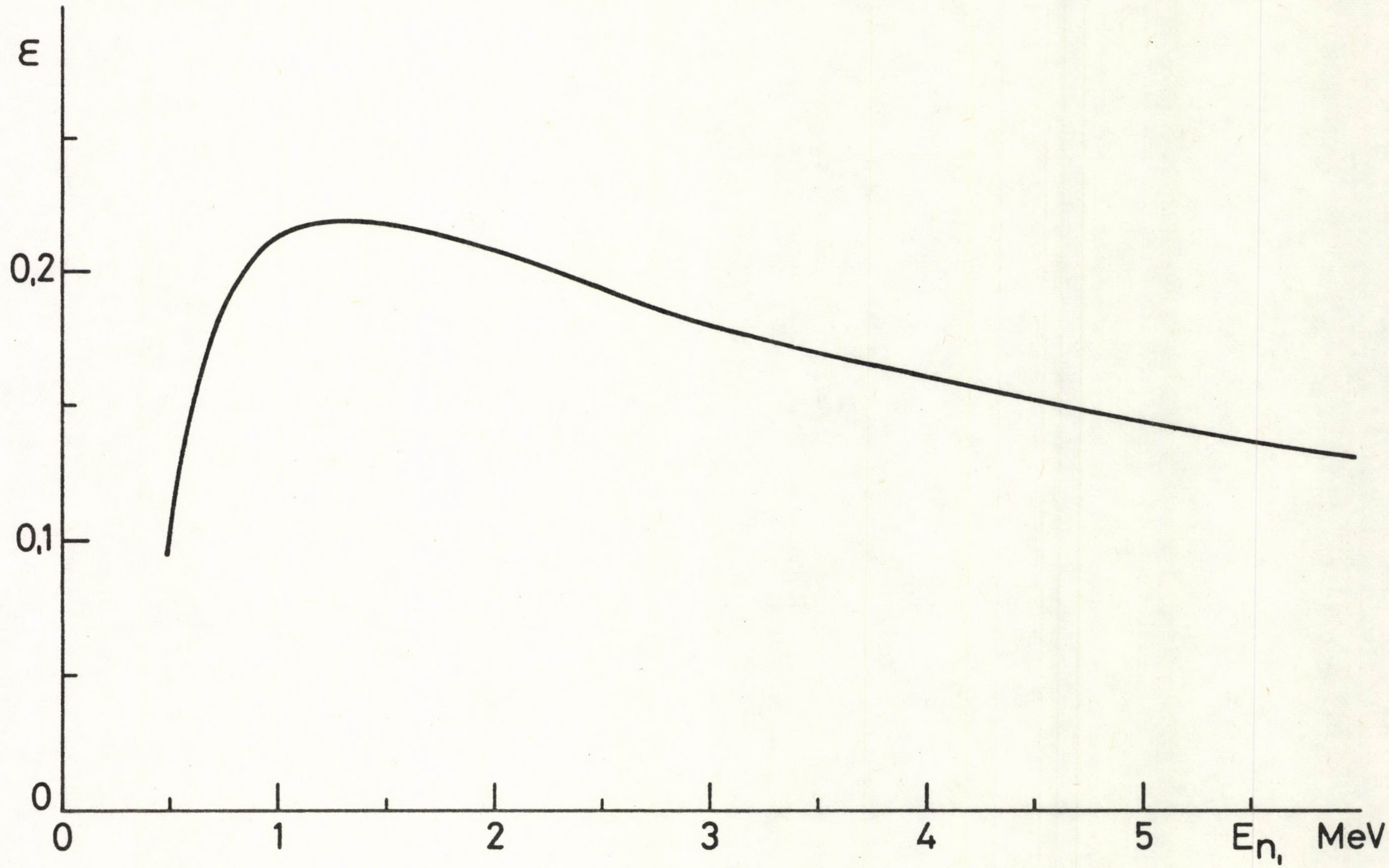


Fig. 2

62.033

Kiadja a Központi Fizikai Kutató Intézet
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