Nuclear Data for Science and Technology (1988 MITO), 131- 132, Copyright © 1988 JAERI.

INVESTIGATION OF THE SHAPE OF THE $^{235}U(n,f)$ CROSS-SECTION WITH VERY COLD NEUTRONS

C. Wagemans*, A.J. Deruytter, R. Barthélémy

Commission of the European Communities,
Joint Research Centre - Geel-Establishment,
Central Bureau for Nuclear Measurements, 2440 Geel, Belgium.

W. Mampe, P. Ageron, A. Michaudon

Institut Laue-Langevin, 156X, F-38042 Grenoble, France

Abstract: At the Very Cold Neutron Source of the Institut Laue-Langevin at Grenoble, the shape of the $^{235}U(n,f)$ cross-section has been measured in the μeV-neutron energy region. For this purpose, a slow chopper has been installed at the end of the very cold neutron guide. Very thin $^{235}UF_4$ and ^{6}LiF samples and PIPS-detectors were used for the detection of the $^{235}U(n,f)$ fragments and for the determination of the neutron flux via the $^{6}Li(n,\alpha)t$ reaction. Within the experimental accuracy, the present results do not show a significant deviation of the $^{235}U(n,f)$ cross-section from a 1/v-shape.

(^{235}U, fission cross-section shape, neutron energy 6-60 μeV)

Introduction

Recently, reactor physicists showed a renewed interest in the reaction cross-sections induced in ^{235}U and ^{238}U by low-energy neutrons[1]. One of the quantities concerned was the shape of the $^{235}U(n,f)$ cross-section in the subthermal neutron energy region, which was postulated to go faster to a 1/v-shape than indicated by the ENDF-B5 data file[2]. In another paper at this conference[3] we demonstrated that this trend is observed in the neutron energy region from 2 to 10 meV.

For the calculation of the Westcott g_f-factor on the other hand, the measured data points - which generally stop at a few meV - need to be extrapolated down to zero neutron energy. For this purpose often a 1/v-extrapolation of $\sigma_f(E)$ has been applied.

Moreover, the postulated[1] negative energy resonance(s) might influence the fission cross-section shape at very low energies.

In view of all these arguments and since σ_f has never been measured before with μeV neutrons, a series of measurements has been performed at the ILL (Grenoble) taking benefit of the intense Very Cold Neutron Source available at this Institute.

Experimental conditions

The vertical Very Cold Neutron Source originates from a 25°K liquid D_2 moderator[4] and covers neutron wave lengths between 20 and 600 Å with a peak around ~ 80 Å. Via a set of vertical and curved neutron guides with excellent reflectivity, the neutrons are brought to the experimental area. The integrated neutron flux at the exit of the neutron guide is about 1.2×10^9 neutrons/cm^2.s.

In order to determine the neutron energies, a slow chopper (operated at 300 or at 600 rotations per min.) has been installed at the end of the neutron guide. A ^{6}LiF layer (for the neutron flux determination) and a $^{235}UF_4$ layer were mounted back-to-back in a vacuum chamber at a distance of 581 mm from the chopper. Both layers were homogeneously evaporated on a thin aluminum backing, and their thickness (3 μg $^{6}LiF/cm^2$ and 11 μg $^{235}U/cm^2$) was chosen in such a way as to avoid significant absorption and self-absorption effects.

* NFWO, University of Ghent and SCK/CEN, Mol, Belgium

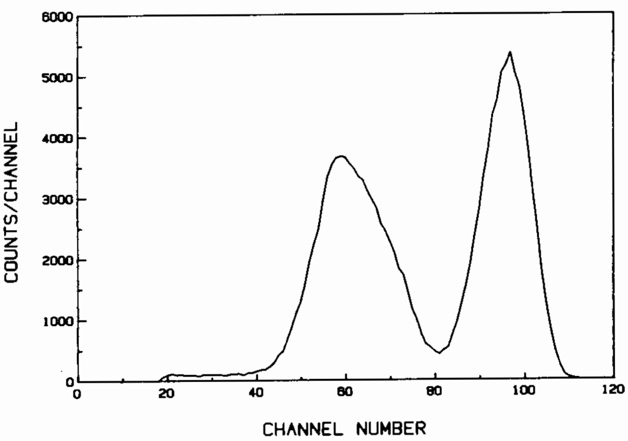

Fig. 1 $^{235}U(n,f)$ pulse-height spectrum.

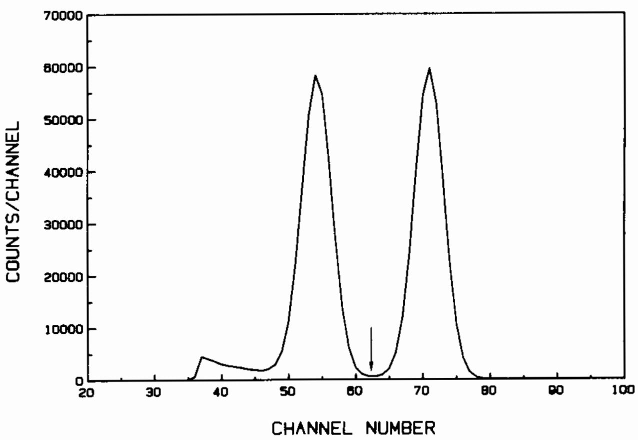

Fig. 2 $^{6}Li(n,\alpha)t$ pulse height spectrum. The arrow indicates the discriminator setting used.

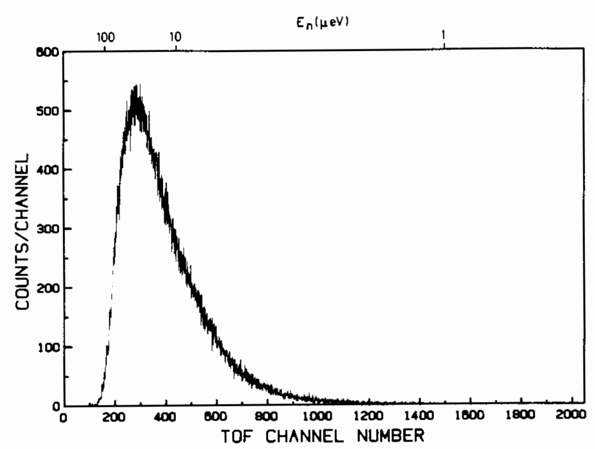

Fig. 3 $^{235}U(n,f)$ time-of-flight spectrum.

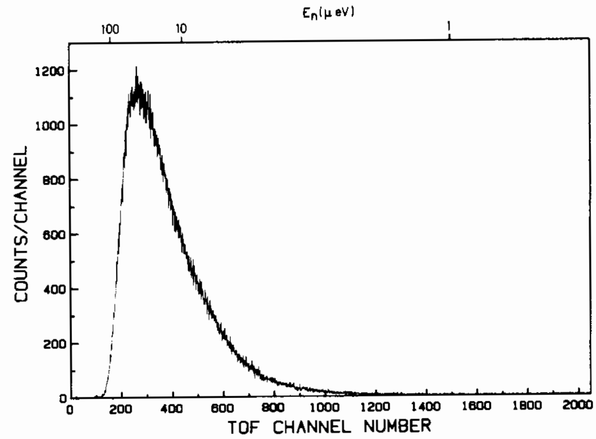

Fig. 4 Time-of-flight spectrum for the tritons emitted in the $^6Li(n,\alpha)t$ reaction.

The $^{235}U(n,f)$-fragments and the $^6Li(n,\alpha)t$ particles were detected in a low geometry with 30 cm^2 large PIPS (passivated implanted planar silicon) detectors. After amplification, the detector signals were split and sent to an ADC (Ortec 800) and (via a Timing Single Channel Analyser) to a time-coder with a channel width of 28.8 µs. For the $^{235}U(n,f)$ as well as for the $^6Li(n,\alpha)t$ reactions, bi-dimensional pulse-height versus t.o.f. spectra were recorded with a HP 1000 A700 data acquisition system. The corresponding integrated pulse-height spectra are shown in Figs. 1 and 2.

Results

The $^{235}U(n,f)$ time-of-flight spectrum obtained with a chopper velocity of 300 rot./min. is shown in Fig.3. The excellent background conditions are illustrated by the absence of counts in the first 100 and in the last 500 t.o.f. channels, which also proves that the counting contribution from possible overlap neutrons is negligible.Fig.4 shows a similar t.o.f. spectrum for the tritons. Although also here the background is very small, the data are corrected for it. By dividing the counting-rates of the corresponding $^{235}U(n,f)$ and $^6Li(n,\alpha)t$ t.o.f. channels and assuming a 1/v-shape for the $^6Li(n,\alpha)t$ cross-section, $k\sigma_f(E)\sqrt{E}$ is obtained. The condensed $k\sigma_f(E)\sqrt{E}$ data are represented by the dots in Fig. 5. Within the accuracy of the data, these results do not show a significant deviation from a 1/v-shape.

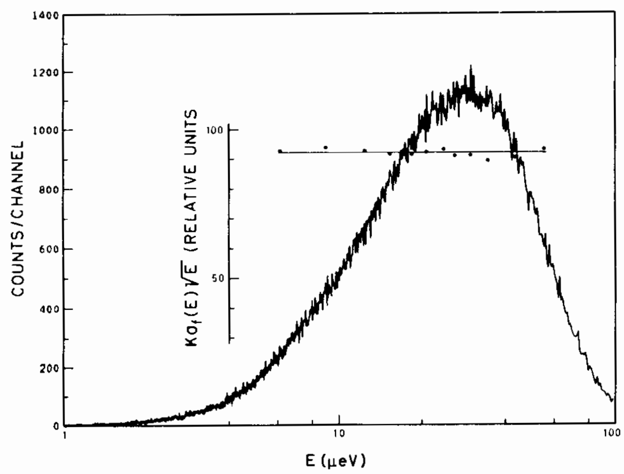

Fig. 5 Measured neutron flux distribution at the Very Cold Neutron Source (ILL). Dots give the values of $k\sigma_f(E)\sqrt{E}$ for ^{235}U in relative units.

This is consistent with the trend observed in the meV-region by Wagemans et al.[3]. It contradicts however the earlier extrapolated shape as shown in ref.5.

Conclusion

The present measurements give the first experimental evidence that the shape of the $^{235}U(n,f)$ cross-section in the neutron energy region from 6 to 60 µeV is compatible with a 1/v-behaviour. No resonances have been observed in the energy region considered and the influence of possible negative energy resonances turns out to be very small.

References

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