IAEA
International Atomic Energy Agency

INDC(CCP)-0458
Distr. AD/G/IN/J/PF/RD/ST

INDC International Nuclear Data Committee

Precision measurements of ^{252}Cf, $^{233}U+n_{th}$, $^{235}U+n_{th}$ and $^{239}Pu+n_{th}$ prompt fission neutron spectra (PFNS) in the energy range 2 - 11 MeV

B.I. Starostov, V.N. Nefedov, A.A. Boytsov

V.I. Lenin Scientific Research Institute for Atomic Reactors (NIIAR)

Dimitrovgrad

(English translation of Proceedings of Neutron Physics Conference, Kiev, 1983, Vol. 2, p. 290; Russian Original distributed as INDC(CCP)-235 VOL II)

Translated by IAEA-NDS

July 2014

IAEA Nuclear Data Section
Vienna International Centre, P.O. Box 100, 1400 Vienna, Austria

Selected INDC documents may be downloaded in electronic form from
http://www-nds.iaea.org/publications
or sent as an e-mail attachment.
Requests for hardcopy or e-mail transmittal should be directed to
NDS.Contact-Point@iaea.org
or to:
Nuclear Data Section
International Atomic Energy Agency
Vienna International Centre
PO Box 100
1400 Vienna
Austria

Printed by the IAEA in Austria

July 2014

INDC(CCP)-0458
Distr. AD/G/IN/J/PF/RD/ST

Precision measurements of ^{252}Cf, ^{233}U+n$_{th}$, ^{235}U+n$_{th}$ and ^{239}Pu+n$_{th}$ prompt fission neutron spectra (PFNS) in the energy range 2 - 11 MeV

B.I. Starostov, V.N. Nefedov, A.A. Boytsov

V.I. Lenin Scientific Research Institute for Atomic Reactors (NIIAR)

Dimitrovgrad

ABSTRACT

The spectra were measured by the time-of-flight method at the flight distance of 6.1 m. It has been shown that for the neutron energies of 6.5 through 11 MeV the spectra intensity is essentially lower than that of calculated according to the Maxwell distribution.

July 2014

Precision measurements of ^{252}Cf, $^{233}U+n_{th}$, $^{235}U+n_{th}$ and $^{239}Pu+n_{th}$ prompt fission neutron spectra (PFNS) in the energy range 2-11 MeV

B.I. Starostov, V.N. Nefedov, A.A. Boytsov

(V.I. Lenin NIIAR)

Abstract

The spectra were measured by the time-of-flight method at the flight distance of 6.1 m. It has been shown that for the neutron energies of 6.5 through 11 MeV the spectra intensity is essentially lower than that of calculated according to the Maxwell distribution.

It is well known that PFNS for outgoing energies 1-6 MeV can be described by Maxwellian distribution $n(E) = C \sqrt{E} \exp(-E/T)$ within ±5%. However, at energies higher than 6 MeV the different measurements differ by 30% or more. Therefore, the question on whether Maxwellian distribution describes the PFNS data for outgoing energies 6-15 MeV is still open.

In the Refs. [1-3] it was stated that ^{252}Cf and $^{235}U+n_{th}$ PFNS can be described by Maxwellian distributions in the region 1-20 MeV. In other articles it was found that the spectra above 6 MeV is much lower than ones calculated by a Maxwellian distribution fitted to the data in the 1-6 MeV energy range. Analysing data Grundl and Eisenhauer [4] have shown that fission neutron spectra from ^{252}Cf and $^{235}U+n_{th}$ in the energy range 6.5 - 14 MeV are lower than the corresponding Maxwellian distributions. This interesting phenomena was, independently from [4], demonstrated in [5-7] for the case of ^{252}Cf, $^{235}U+n_{th}$ and $^{239}Pu+n_{th}$ fission neutron spectra. In the latest years the conclusions from the review paper [7] concerning the shape of the spectra above 6 MeV were confirmed by the works [8, 9]. In the present paper we describe the time-of-flight fission neutron spectrometer for high-precision measurements of neutron spectra for outgoing neutron energies 3 - 15 MeV and present the first results of our measurements.

The neutron spectrometer was installed on the horizontal channel of reactor SM-2. The experimental setup is shown in Fig. 1.

The fission fragment detector was set-up in the thermal neutron beam. The neutron beam was filtered (to supress fast neutrons and photons) by quartz glass (12 cm) and bismuth (8 cm). The beam was shaped by a steel collimator with a hole of dimensions 1.5x15 mm^2. To avoid detection of scattered fission neutrons, the experimental room was divided in two smaller rooms using a temporal wall of iron bricks of 50 cm thickness. Behind the wall in the second room a neutron detector was installed inside a water tank that served as a neutron shield. The detector was housed inside the shielding block made of water, boron carbide and lead. The detector was located at 6.1 m from the centre of fissile target. The neutron detector saw the fissile target through the flanges of the vacuum tube and hole in the wall and shield. For the further reduction of the neutron background from neutrons scattered in air, the vacuum tube was pumped to reach pressure of 10^{-3} Pa. An additional lead layer of 1 cm thickness was installed in the frontal face of the neutron detector to reduce the contribution of delayed-gamma.

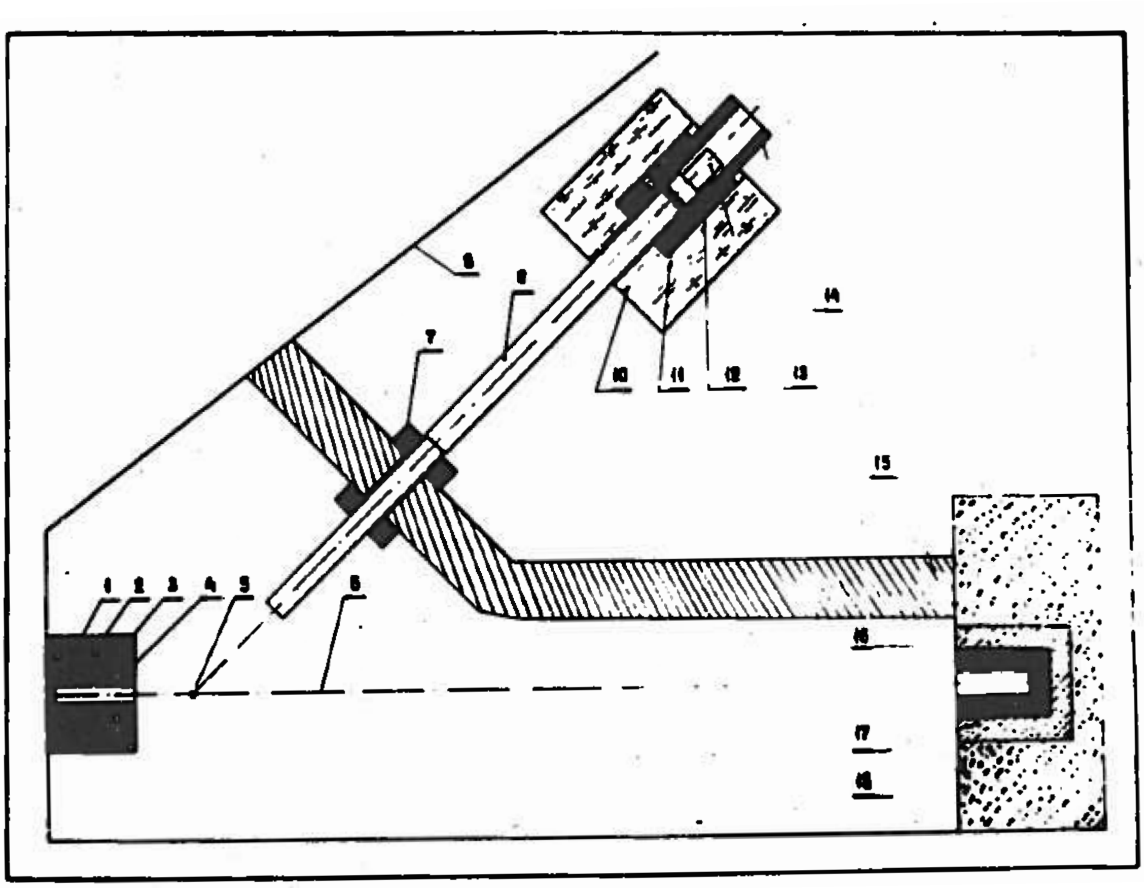

Figure 1. Geometry of experiment: 1 – collimator, 2 – paraffin with boron carbide; 3-4 – lead; 5 – ionization chamber; 6 - thermal neutron beam; 7 – lead; 8 – experimental room wall; 9 – vacuum tube; 10 – water tank; 11 - lead; 12 – boron carbide; 13 – neutron detector; 14 – lead; 15 – wall from iron bricks; 16 – neutron and photon beam dump made of lead; 17 – boron carbide; 18 – concrete.

Neutrons were detected by a plastic scintillator (200 mm diameter, 120 mm height) mounted on a FEU-63 photomultiplier.

Fission fragments (FF) were detected by four ionization chambers (IC). Every IC contained one of the studied nuclei ^{252}Cf, ^{235}U, ^{233}U, ^{239}Pu. Nuclide layers of 20 mm diameter were deposited on carefully electro-polished stainless steel plates (backing) of 25 mm diameter and 0.04 mm thickness. The FF count rate dependence on the discrimination level allowed to find that the total detection efficiency of the fragments which reached 98±2 (^{252}Cf), 97±2 (^{239}Pu), 95±2(^{235}U) and 92±2% (^{233}U). Some FF were not detected due to FF energy losses in the steel plate (backing) and in the fission layer itself. Count rate for each fissile target was 65000 fission/sec. The neutron detector was located at 45 degrees to the fissile target plane to neutralize the distortion of the measured spectra due to the anisotropy of the FF detection.

We have achieved the following characteristics of the neutron spectrometer: time resolution – 5 ns; energy threshold for neutrons - 2.1 MeV; counting rate 8000 pulses at E_n = 4 MeV and 70 pulses at E_n = 14 MeV during a 10 day experimental campaign; uncertainty of definition of the multi-channel analyser bin - 0.25%; uncertainty of the “zero” time – 0.3 ns; uncertainty of the distance target-detector - 2 mm; stability of discriminator level for the neutron detector – 0.05 keV in the electron energy scale.

In the Fig.2 are shown some of the undertaken measurements as a ratio of the ^{252}Cf spectrum counts to the ^{239}Pu+n_{th} spectrum counts. Both spectra are normalized to one fission event. The ratios of Maxwellian distributions calculated with T = 1.417 MeV and T = 1.367 MeV are also shown after normalization to $\overline{\nu}$ = 3.77 and 2.89 for spectra ^{252}Cf and ^{239}Pu, respectively. In the same figure we show the ratios of evaluated PFNS from ^{252}Cf [4] and ^{239}Pu+n_{th} [7]. It is seen that the measured ratios above 6 MeV do not agree with the ratios of Maxwellian distributions, but they are quite close to the ratios of evaluations [4] and [7]. If we consider that the evaluation [4] is true, then the intensity of the evaluated PFNS for ^{239}Pu+n_{th} [7] in the region 6.5 – 9.5 MeV should be reduced by 5%.

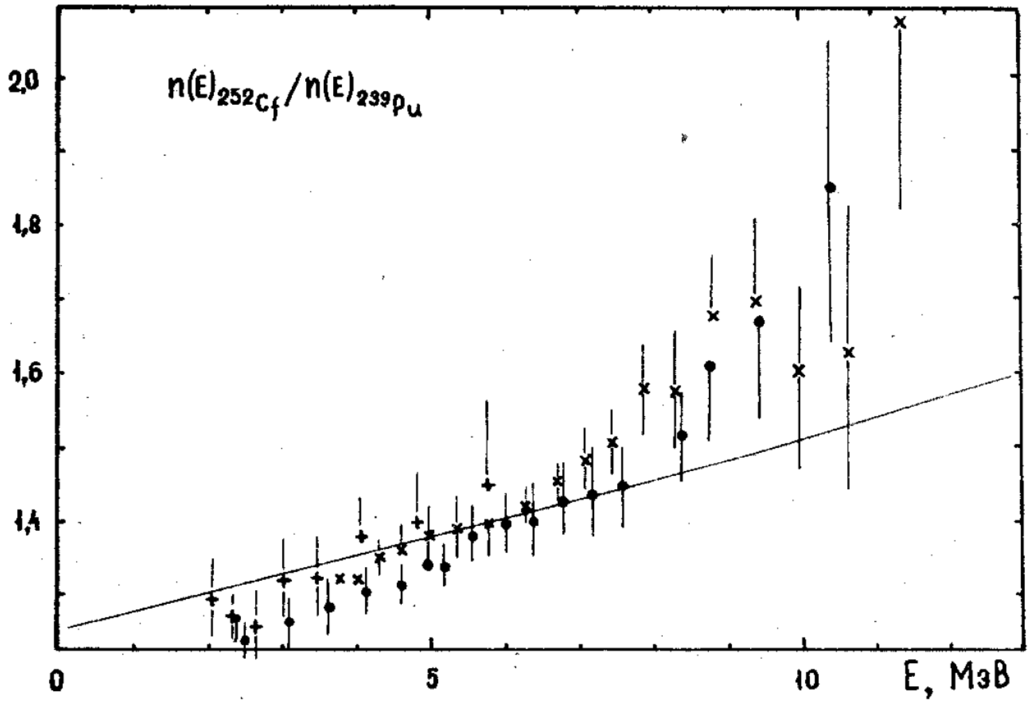

Fig.2. Ratios of ^{252}Cf fission neutron spectrum to ^{239}Pu+n_{th} fission neutron spectrum: — - ratio of Maxwellian distributions; + - ratio of spectra obtained with crystal anthracene; • - ratio of evaluated spectra from [4,7]; x – ratio of the spectra of present work.

References:

1. Boldemann J.W., Culley D., Cawley J.J., Trans. Amer. Nucl. Soc., 1979, 32, p. 733-735.
2. Johnson R.H., Wehring B.W., Dorning J.J. et al. Trans. Amer. Nucl. Soc., 1975, v. 22, p. 727-728.
3. Sherwood G.G., King J.S., Trans. Amer. Nucl. Soc., 1962, v. 10, p. 555.
4. Grundl J.A., Eisenhauer C.M., Nat. Bur. Stds. Pub, NBS-493, 1977, p. 198.
5. Starostov B.I, Semenov A.F., Nefedov V.N., NIIAR-13(347) (in Russian), Dimitrovgrad, 1978 (not available yet).
6. Starostov B.I, Semenov A.F., Nefedov V.N., NIIAR-1(360) (in Russian), Dimitrovgrad, 1979.
7. Starostov B.I, Semenov A.F., Nefedov V.N. Voprosy atomnoi nauki i techniki (Yadernye Konstanty), Moscow, Atomizdat 1980, vol. 37 (issue 2), p. 3-44 (in Russian) (available, will be translated by the IAEA).
8. Bottger R., Klein H., Chalupka A., Strohmaier B. – In: Proc. Int. Conf. on "Nuclear Data for Science and Technology", Antwerp, 6-10 Sept., 1982.
9. Bolshov V.I., Volodin K.E., Nesterov V.G., Turchin Yu.M., Voprosy atomnoi nauki i techniki (Yadernye Konstanty), Moscow, Atomizdat 1981, vol. 42 (issue 3), p. 43-46 (in Russian). Available online as INDC(CCP)-173.

Nuclear Data Section
International Atomic Energy Agency
Vienna International Centre, P.O. Box 100
A-1400 Vienna
Austria

e-mail: services@iaeand.iaea.org
fax: (43-1) 26007
telephone: (43-1) 2600-21710
Web: http://www-nds.iaea.org/