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Neutron-induced fission cross section of ^{242}Pu from 15 MeV to 20 MeV

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Abstract. Accurate nuclear-data needs in the fast-neutron-energy region have been recently addressed for the development of next generation nuclear power plants (GEN-IV) by the OECD Nuclear Energy Agency (NEA). This sensitivity study has shown that of particular interest is the ^{242}Pu(n,f) cross section for fast reactor systems. Measurements have been performed with quasi-monoenergetic neutrons in the energy range from 15 MeV to 20 MeV produced by the Van de Graaff accelerator of the JRC-Geel. A twin Frisch-grid ionization chamber has been used in a back-to-back configuration as fission fragment detector. The ^{242}Pu(n,f) cross section has been normalized to ^{238}U(n,f) cross section data. The results were compared with existing literature data and show acceptable agreement within 5%.

1. Introduction

Accurate cross section data for neutron induced nuclear reactions are required for many fields of science, particularly in the energy region up to about 20 MeV. In a sensitivity study of the OECD/NEA, the cross section for fission induced by fast neutrons has been identified as very important for the development of GEN-IV nuclear reactors in particular for specific nuclides, such as ^{242}Pu [1]. However, a search of the EXFOR international database of experiments shows that only one set of experimental data exists above 15 MeV and 5 single point measurements between 14 MeV and 15 MeV [2]. Based on this scarcity, in the present work the ^{242}Pu(n,f) cross section was measured at 6 incident neutron energies of 15.28 MeV, 16.16 MeV, 17.22 MeV, 18.02 MeV, 18.74 MeV and 19.81 MeV.

2. Measurements

The irradiations were done at the JRC-Geel Van de Graaff accelerator. For the production of the neutrons, the ^{3}H(d,n)^{4}He reaction was used. The neutron-production target was a Ti–^{3}H target of 2.293 mg cm^{-2}. The ^{3}H/Ti ratio was calculated to 1.4 at the start of the irradiation, based on activity and production data from the manufacturer. The target had not been used before and was water-cooled during the irradiation. Information about the used deuteron energy and the respective neutron energy are presented in Table 1. The neutron energies with uncertainty were calculated by means of the Monte-Carlo code TARGET [3]. The measurement was performed using a twin Frisch-grid ionization chamber in a back-to-back configuration (with a grid only on the ^{242}Pu sample side, see Figs. 1 and 2). This detector geometry gives advantage as there is no need for the determination of the neutron flux since it is considered the same for both samples. That means that the cross section of one sample can be determined relatively to the other sample. In this case the ^{238}U sample was used as a reference. The ionization chamber was filled with P10 gas (90% Ar + 10% CH4) at a constant flow rate of ca. 60 ml/min. The mass of the ^{242}Pu sample was 0.625 mg and that of the ^{238}U sample 0.861 mg. The anodes, the grids and the cathode were connected to charge sensitive preamplifiers. The signals from all preamplifiers were collected by a 12 bit, 100 MHz waveform digitizer [4]. The trigger was common for the two anodes (see Fig. 2) and it was also connected to the digitizer. A constant fraction discriminator was employed for setting of the electronic threshold for rejecting the signal from α particles.

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3. Data treatment

All data collected by the digital data acquisition system was analyzed offline with the help of a program written in C++, using the ROOT framework. It is described in detail in Ref. [4].

3.1. Digital-signal processing

The raw signals from the detector were first baseline corrected, then the ballistic deficit due to the decay time constant of the pre-amplifier was corrected and then the α particle background from the intrinsic activity of the sample was corrected. Then, via filtering the pulse height (PH) information from the detector signals were obtained.

3.2. Pulse height analysis

The PH was finally corrected for grid inefficiency, and alpha pile-up was rejected. To account for events below the electronic threshold an extrapolation to zero pulse height

Table 1. Neutron irradiation data. E_i: ion energy, E_n: neutron energy.

No.	E_i(MeV)	E_n(MeV)
1	3.300(11)	19.81(18)
2	2.500(11)	18.74(30)
3		
4	2.000(11)	18.02(20)
5		
6	1.500(11)	17.22(30)
7		
8	1.000(11)	16.16(20)
9		
10		
11	0.800(11)	15.28(30)

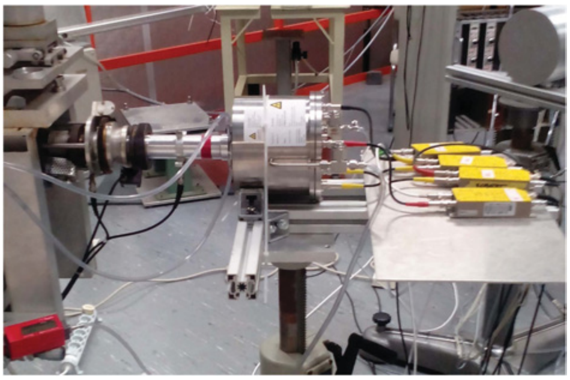

Figure 1. View on the end of the accelerator beam line(from the left) with the Ti-^{3}H target for neutron production and the ionization chamber placed in front of the target end-cap.

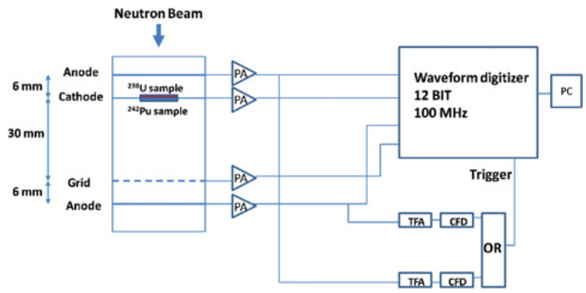

Figure 2. Schematic drawing of the experimental setup for the cross section measurement.

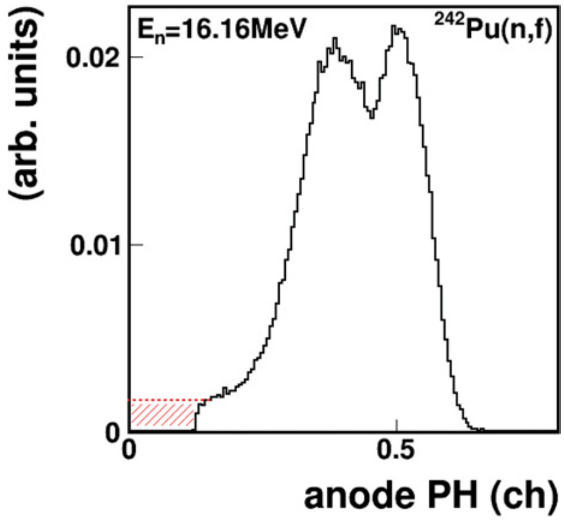

Figure 3. Anode pulse height (PH) distribution for ^{242}Pu(n,f) with the determination of the counts under the electronic threshold at E_n =16.16 MeV.

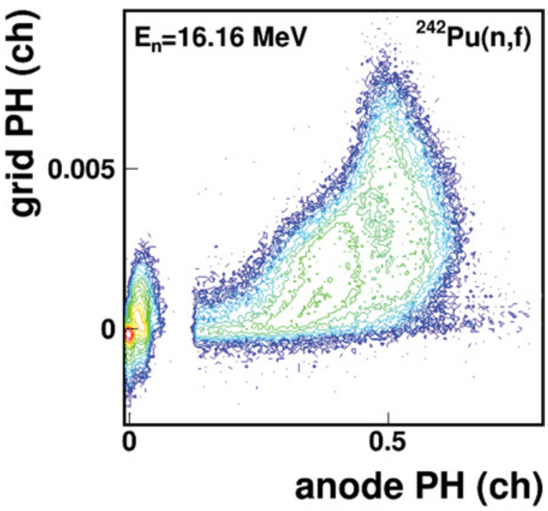

Figure 4. Grid PH versus anode PH data for ^{242}Pu(n,f) at E_n = 16.16 MeV.

was applied (see Fig. 3) [4]. An example of a Grid PH versus anode PH data obtained for ^{242}Pu(n,f) is shown in Fig. 4.

4. Results

The ^{242}Pu(n,f) cross section has been normalized to the ^{238}U(n,f) cross section data, based on the ENDF/B-VII.1 evaluation [5]:

$$\sigma_{Pu} = \frac{(N_{Pu} - N_{Pu\_sf})}{N_{U238}} \cdot \sigma_{U238} \cdot \frac{m_{U238} \cdot M_{Pu}}{m_{Pu} \cdot M_{U238}}, \qquad (1)$$

where N_{Pu}, N_{U238} and N_{Pu_sf} are the number of fission events of the ^{242}Pu, ^{238}U and the spontaneous fission of ^{242}Pu, respectively. M_{Pu}, M_{U238}, m_{U238} and m_{Pu} are the Molar mass and mass of the ^{238}U and ^{242}Pu targets, and σ_{U238} is the fission cross-section value of ^{238}U at a given neutron energy (from the ENDF/B-VII.1 data base). The values from different runs for the same neutron energy are averaged (see Table 1). The results in comparison with the existing data are shown in Fig. 5. The uncertainty budget includes both statistical and systematic uncertainties, such as mass uncertainty and efficiency. A more elaborate uncertainty budget will be made for a forthcoming publication.

It is clear from this figure that there is quite some spread in the different evaluated libraries shown with differently coloured lines. The present data are lower than the data of Tovesson [6] by about 5%. The data of Tovesson are shape data as they have been adjusted at 3 MeV. The TENDL-2014 [12] and WIND [13] libraries are in very good agreement with the present data points. The JEFF-3.2 library [14] shows higher values for the first three of our points but agrees well with the last three points.

5. Conclusion

In this work the cross section values for the neutron induced fission of ^{242}Pu in the energy range from 15

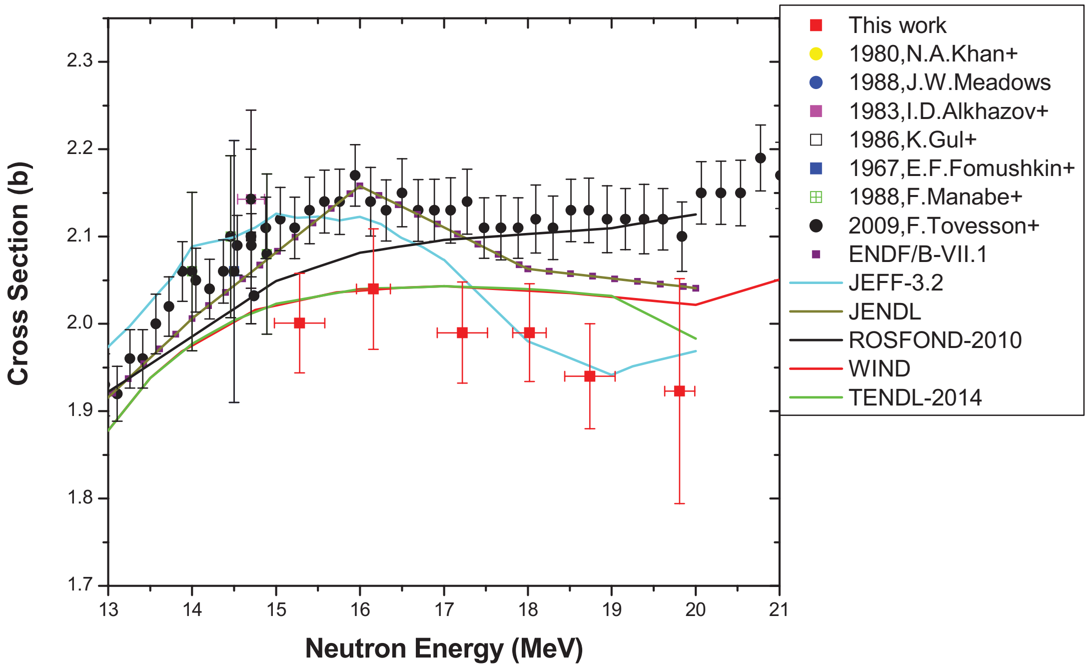

Figure 5. Neutron-induced fission cross section of ^{242}Pu(n,f) using ^{238}U(n,f) (ENDF/B-VII.1) as reference [2,5–14].

to 20 MeV have been measured at the JRC-Geel Van de Graaff accelerator. For this purpose, a twin Frisch-grid ionization chamber in a back-to-back configuration was employed. The ^{242}Pu(n,f) cross section has been determined relatively to the ^{238}U(n,f) cross section data.

The cross section values obtained in this study are lower than previous experimental data. The measurements at 18.74 MeV and 19.81 MeV neutron energies need further analysis.

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