THE ABSOLUTE NEUTRON FLUX MEASURMENT AT THE VAN DE GRAAFF ACCELERATOR OF THE FRANK LABORATORY OF NEUTRON PHYSICS

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Abstract

We have measured the flux of fast neutrons at 4.6 MeV. The twin gridded ionization chamber and two ^{238}U samples in back-to-back geometry have been employed. Experiments were performed at the Van de Graaff accelerator of the Frank Laboratory of Neutron Physics, Joint Institute for Nuclear Research, Dubna, Russia. Fast neutrons were produced through the D(d,n)^{3}He reaction by using a deuterium gas. Cross section at E_n= 4.6 MeV of the ^{238}U(*n,f*) reaction was used as the standard for the absolute neutron flux determination. The abundance of the ^{238}U isotope in the sample is 99.999%. The working gas of the ionization chamber was Ar+3%CO_2.

1. Introduction

Monoenergetic neutron beams of known flux are needed in studies of nuclear structure and reaction mechanisms. In addition, this kind of neutron beam is in continuous demand for development of the technology of fission and fusion reactors, health physics and nuclear astrophysics. The D(d, n)^{3}He reaction is extensively used as a neutron source. We are using the standard cross section method for the determination of the absolute neutron flux.

2. Details of measurements

Experiments were performed at the Van de Graaff accelerator of FLNP, JINR. The experimental setup consists of three main parts: a double-section gridded ionization chamber (GIC) with a common cathode, neutron source, and neutron flux detectors. A deuterium gas target was used to produce the monoenergetic neutron through the ^{2}H(d,n)^{3}He reaction.

The diameter and the length of the cylindrical gas cell were 9 and 20 mm, respectively. The deuterium gas cell was separated from the beam-line vacuum tube by a molybdenum foil 6.0 µm in thickness. The deuterium gas pressure was 2 atm during the experiment.

In the present work, enriched ^{238}U foil samples were prepared. Data of the samples are listed in Table 1.

Table 1. Description of the samples. (^{a} Forward sample, ^{b}Backward sample)

Samples	**Material**	**Isotopic abundance (%)**	**Thickness (mg/cm^2)**	**Diameter (mm)**
$^{238}U^a$	$^{238}U_3O_8$	99.999	0.57	44.0
$^{238}U^b$	$^{238}U_3O_8$	99.999	0.54	44.0

The working gas of the ionization chamber was Ar + 3% CO_2 flowed through the volume at the pressure 1.0 atm. A sample changer was set in the common cathode of the ionization chamber with five sample positions and two back-to-back samples can be placed at each of them. A ^{238}U sample was placed in the GIC at the forward direction on the different positions of the sample changer to determine the absolute neutron flux by measuring the fission fragments.

The neutron flux monitor is a ^{3}He counter. The axis of the ^{3}He counter and the normal line of the electrodes of the ionization chamber were at 0° to the neutron beam line. Two-dimensional spectra of the cathode-anode coincidence signals for forward and backward directions were recorded separately, from which the number of fission-events from the measured (n,f) reactions can be obtained. The data-acquisition system (DAqS) can be found in Ref [1].

The experimental process in turn is as follows: 1) α source measurement for energy calibration of the DAqS, 2) foreground measurement for fission events, 3) background measurement with tantalum sheets.

We have measured neutron flux at E_n = 4.6 MeV, the ^{238}U(n,f) reaction were used as the standard to perform the measurement, the neutron flux can be calculated by the following equation:

$$\Phi_n = \frac{N_f}{N_{\text{samp}} * t * \sigma} \tag{1}$$

The σ is the standard ^{238}U(n,f) cross sections taken from ENDF/B-VIII library [2]. The N_f is the detected counts above the energy threshold from the ^{238}U(n,f) reaction (after background subtraction). The t is the time of our experiment. The N_{samp} is the numbers of ^{238}U nuclei in the samples.

3. Data processing, results

The number of nuclei in the sample determined by the alpha decay of ^{238}U.

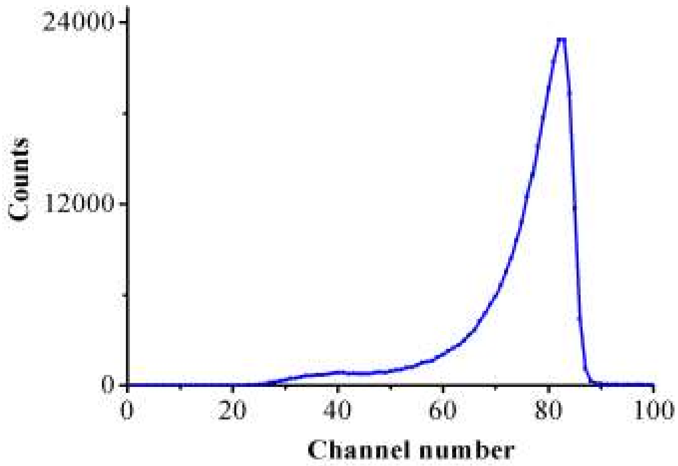

Fig. 1. Anode spectrum of the alpha decay of ^{238}U.

Fig. 1 shows the anode spectrum of α-events. The α counts above the threshold can be obtained from the anode spectrum. As it is shown in Fig. 1, the α counts above threshold, there are also α events below the threshold which cannot be detected. Therefore, threshold and self-absorption corrections are needed. The determination of the detection efficiency of α-particle, the anode spectra were simulated as shown in Figs. 2 and 4 with the red curves. First of all, we determined the detection efficiency of α-particle used the equation [3]:

$$\varepsilon = \frac{1}{2}\left[1 - \frac{\tau}{2(R_{\max} - R_{\text{threshold}})}\right] \tag{2}$$

The SRIM code [4] was used to get the stopping power of α-particles in the samples. The R_{max} is the maximum range at 4.6 MeV energy. The $R_{threshold}$ is the initial range at 1 MeV (we get the alpha spectra).

The detection efficiency for alpha-particle is about 97% for our twin grid ionization chamber. We also have done fitting calculations on the front part of the alpha and fission fragment spectrum using the program OriginPro8. It helps to calculate the number of alpha decay cut by the threshold and the number of fission events.

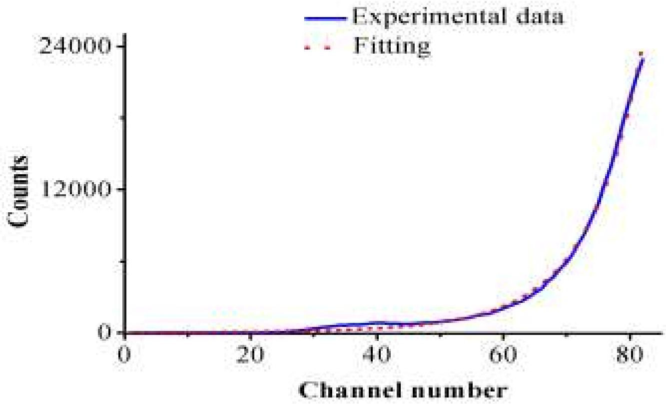

Fig. 2. Anode spectrum of the alpha decay of ^{238}U (fitted by Origin Pro8).

The events of fission fragments can be obtained from the anode spectrum of the fission fragments from the $^{238}U(n, f)$ reaction. The anode spectrum at E_n= 4.6 MeV is shown in Fig. 3. The correction of fission fragments' counts were made by Origin Pro8. Two-dimensional spectrum of the ^{238}U fission fragments is given in Fig.4.

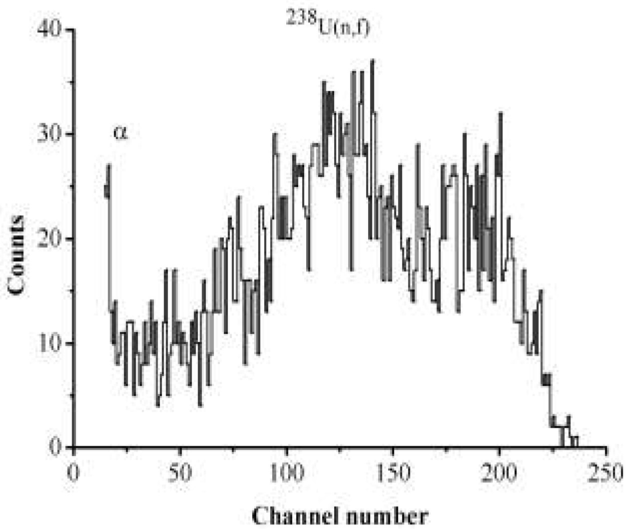

Fig. 3. Anode spectrum of ^{238}U fission fragments at E_n = 4.6 MeV.

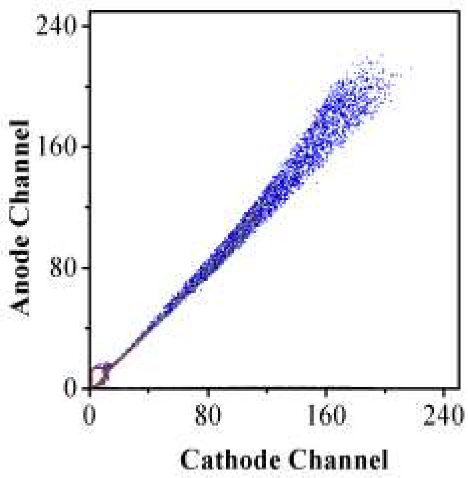

Fig. 4. Two-dimensional spectrum of the ^{238}U fission fragments.

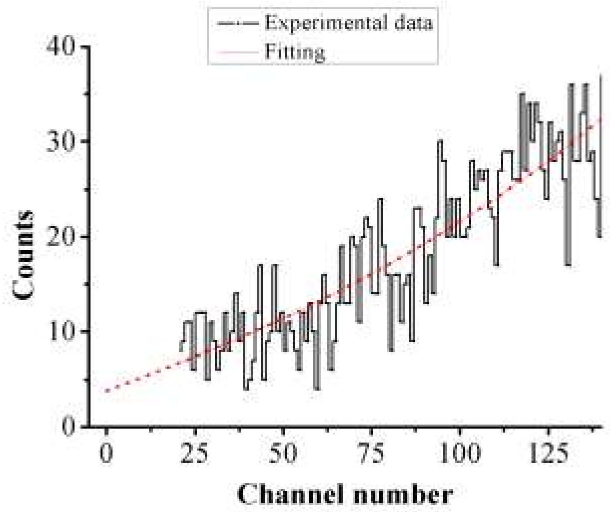

Fig. 5. Simulated anode spectrum of the ^{238}U fission fragments at E_n = 4.6 MeV.

The dotted curve in Fig. 5 shows the simulated result for the fission fragments with low energy.

Table 2. Thicknesses and neutron flux of the samples

Sample	**Thickness(mg/cm^2)**	**Neutron flux(10^5 n/cm^2*sec)**		
		Formula (1)	OriginPro	Energy Set Pro
$^{238}U^a$	0.57	1.13±0.05	1.15±0.06	1.72±0.23
$^{238}U^b$	0.54	1.1±0.04	1.13±0.05	1.72±0.23

4. Conclusion

In the present work, the ionization chamber with five pairs of exchangeable samples was used as a detector. The neutron flux measured for neutron energy E_n = 4.6 MeV. Our results are generally in agreement with simulation data. The neutron flux determined by the standard ^{238}U(n,f) cross sections and the Energy Set ver 3.1 [5].

5. References

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