14.2 MeV NEUTRON INDUCED U-235 FISSION CROSS SECTION MEASUREMENT

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ABSTRACT

The cross section of U-235 fission induced by 14.2 MeV neutrons was measured by the time correlated associated particle method. The result obtained is (2.078±0.040) barn. Comparision with other author's is also given.

Introduction

The fission cross section of 14 MeV neutron induced U-235 is one of the standard reference data. The accuracy of 1% is required. We have measured the fission cross section of U-235 at 14.2 MeV neutron energy by means of the time correlated associated particle (TCAP) technique using T(d,n)He-4 reaction neutrons. In this method the neutron flux was precisely determined by counting the associated alpha particles, and the background of fission events coming from scattered and thermal neutrons could be minimized. So the uncertainty of the measured fission cross section may be reduced to about 1%.

The experimental method is similar to the previous work (1), which is schematically shown in Fig.1. From the number of He-4 particles counted within the cone $\Delta\Omega ap$ the neutron number in the cone $\Delta\Omega n$ was precisely determined. When the size of the fission foil is large enough to cover the cross section of the neutron cone. The coincidence counts between He-4 and fission pulses is due to the fission events induced by the neutron which were produced in the $\Delta\Omega n$ cone. So the fission cross section can be obtained by:

$$\sigma_f = Nc/n*N$$

where Nc: number of coincidence events,
n: areal density of fission nuclei in sample,
N: number of associated He-4 particles.

The advantange of TCAP method is as follows:

1) The fission cross section is independent of the efficiency of the alpha particle detector.
2) No geometry factor correction is needed.
3) The background fission events can be greatly reduced.
4) The systematical errors of the experimental data are relatively small.

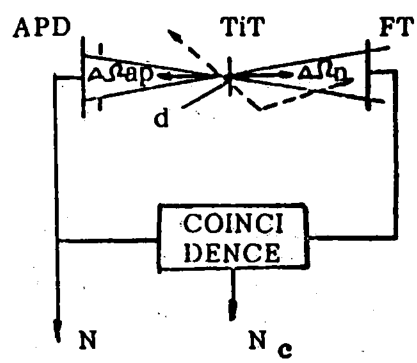

Fig.1 Scheme of the TCAPM

So the uncertainty of the measurement is mainly coming from the areal density of fission sample and the statistical error.

Experimental arrangment

The experimental arrangment is shown in Fig.2.

Neutron source: 14.2 MeV neutron were obtained from T(d,n)He-4 reaction at neutron generator of the Institute of Atomic Energy, Beijing. The thickness of T-Ti target is 0.6 to 1mg/cm^2 Ti deposite on a 0.2mm thick Mo backing. The deuteron energy is 220 keV and the angle between deuteron and the detected He-4 particle is 90 deg.

Fission chamber: The fission chamber used in this measurement is a parallel plate type one. The chamber has an oblate cylinder shape 10cm in diameter and 5cm in length, and was filled with pure methane gas of one atomsphere. The incident direction of the correlated neutron beam goes along the normal of the sample plate. The fission pulses with a rise time 10ns, width 100ns were obtained after going through preamplifier , fast amplifier and fast discriminator. The fission ionization chamber is made of stainless steel with a 0.3mm thick neutron window. In order to reduce neutron background, a 0.3mm cadmium foil was used to cover the fission chamber.

Fission sample: The samples of uranium with 26mm were electrodeposited on 40 μm platinum backing. Three methods were used to determine the quantity of uranium in the sample: direct weighing; α-counting in a low solid angle equipment and titration (1). The uniformety of the deposite layer was tested by scanning with a samll diaphgram. The nonuniformity was determined as about 1%.

Alpha detector: The alpha detector consists of a 1 μm aluminium foil, a 100 μm plastic scintillator and a 56DVP/03A photomultiplier. About 1ns of the time resolution for the alpha pulses was obtained.

The diagram of the electronics is shown in Fig.2.

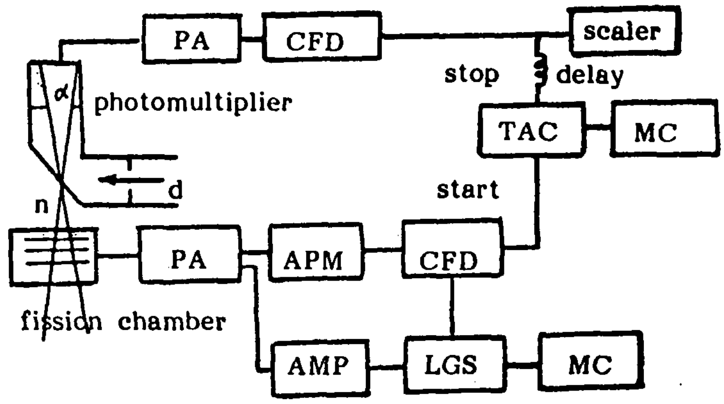

Fig.2 Schematic diagram of experimental arrangment and electronics

Experimental procedure

In order to determine the correct position of the neutron beam correlated with the 90 deg alpha particles we have used a small plastic scintillator as a neutron detector scanning along the horizontal and vertical directions to measure the coincidence rate with alpha particles.

The fission cross section was deduced from the following formula

$$\sigma_f = \frac{Nc-Nb}{N*n*\varepsilon*(1-K)*(1-B)} - C$$

where Nc: counts of the coincidence events between alpha and fission fragment,
Nb: random coincidence counts,
n: nuclear areal density of fission sample,
ε: detected efficiency of fission chamber,
B: neutron attenuation factor,
K: factor accounting for the effects of incident neutron momentum, self-absorbtion of fragment in sample and anisotropy of fission fragments,
C: term accounting for the fission events coming from other isotopes except U-235.

The K factor is calculated with

$$K= \left(\frac{t}{2R} \pm \left(\frac{En*Mn}{Ef*(Mf+Mn)}\right)^{\frac{1}{2}}\right) * \frac{3}{2+A}$$

The first term is self absorbtion correction. The second term is neutron momentum correction whose sign is decided according to whether the sample is faced to '+' or backed to '-' neutron beam.

R: mean range of fission fragment,
t: thickness of fission sample layer,
En: kinetic energy of incident neutron,
Mn: neutron mass,
Ef: average kinetic energy of fragment,
Mf: mass of the uranium target nucleus,
A: value of the anisotropy in fission fragment angular distribution.

Besides, some additional factors were taken into account too:

1) The uncertainty of n is increased by 0.3% due to spread of neutron cone;

2) The background in alpha counts come from neutron induced charged particle emission in the plastic scintillator. This factor was obtained by counting pulses when the scintillation counter is shielded with a 30 μm aluminim foil and a neutron detector was used as monitor;

3) The neutron radiation capture effects in the material which surround the target. This factor was obtained by counting rate via time after cutting down the deuteron beam.

4) Background induced by Ti(d,p) and C(d,alpha) reaction. These effects were obtained by bombarding the pure Ti target with deutron beam as shown in Fig.3.

These correction values and errors of the measurements are shown in Table 1.

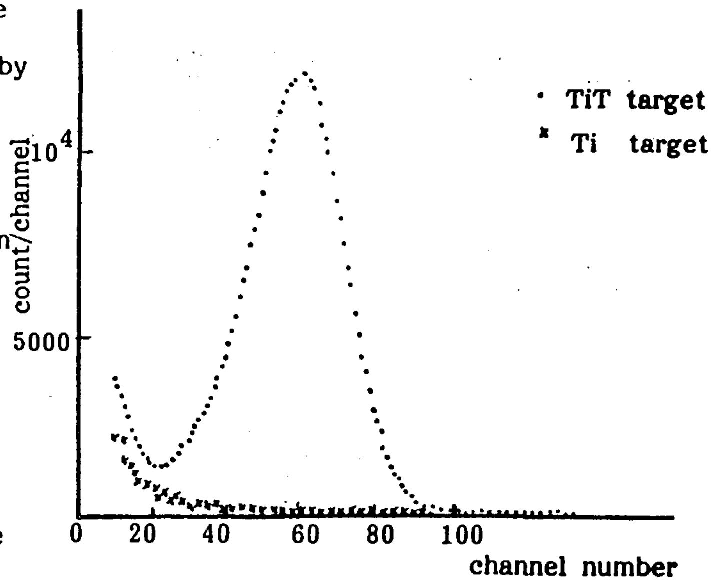

Fig.3 alpha particle spectrum

Table 1: Correction values and errors

item	correction value (%)	error induced by correction (%)	error for result (%)
n			1.0
ε	1-2	20	0.40
statistical error			0.80
K			0.30
nonuniformity of sample			1.0
attenuation of neutron	2.68	10	0.27
fission events of non-U-235	6.33	10	0.63
spread of neutron cone			0.3
(n,γ) effect	0.5	20	0.1
charged particle effect	0.9	20	0.20
TOTAL ERROR			1.90

.Result

From the above metioned TCAP experiment we obtained the value of fission cross section for U-235 at 14.2 MeV $\sigma f = (2.078 \pm 0.040)$ barn.
Fig.4 shows the comparision with other author's results at 14 MeV neutron regions. From Fig.4 we see that σf increases slowly with neutron energy.

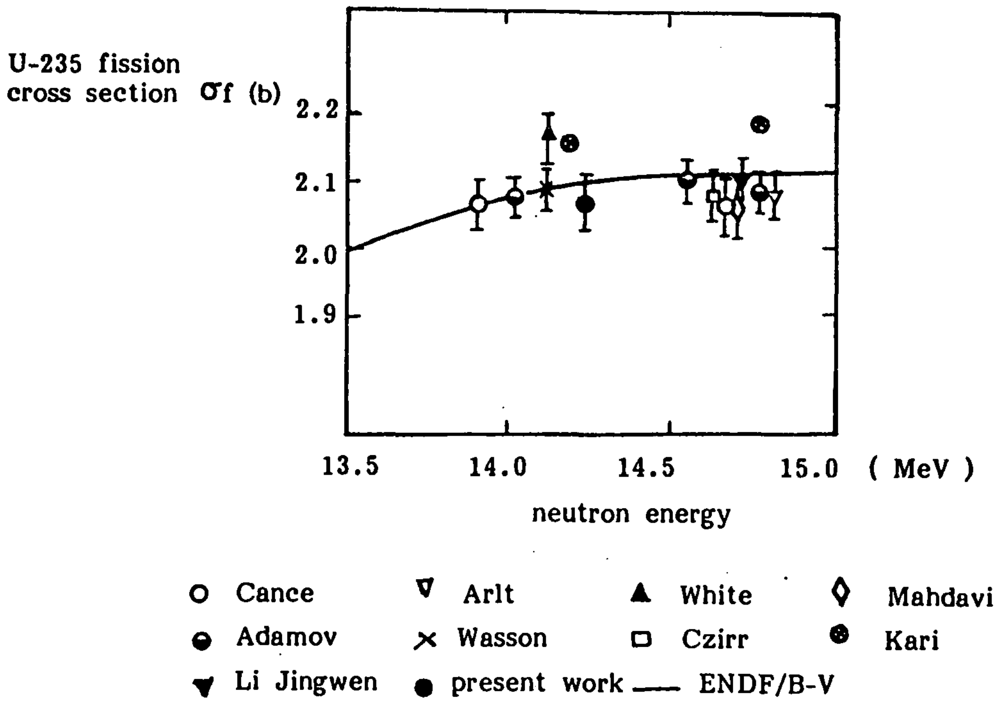

Fig.4 Comparison of the result of the present experiment with other measurements

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