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FISSION CROSS SECTION MEASUREMENTS AROUND 14 MeV

Institute of Atomic Energy
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14.2 MeV Neutron Induced U-235 Fission Cross Section Measurement

14.7 MeV Neutron Induced Fission Cross Section Ratio of U-238 to U-235

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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.

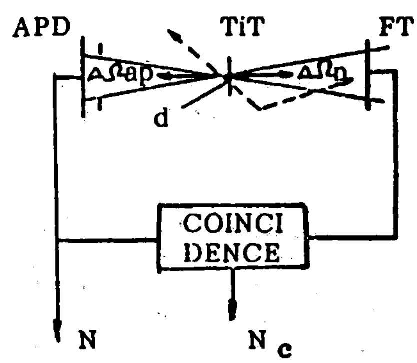

Fig.1 Scheme of the TCAPM

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.

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 40μm 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 1μm 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.

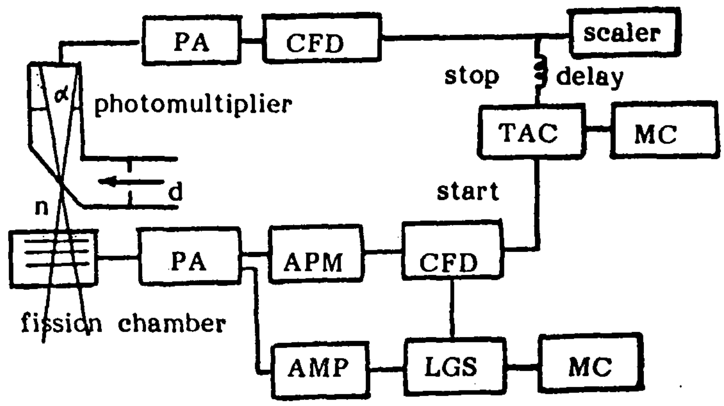

Fig.2 Schematic diagram of experimental arrangment and electronics

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.

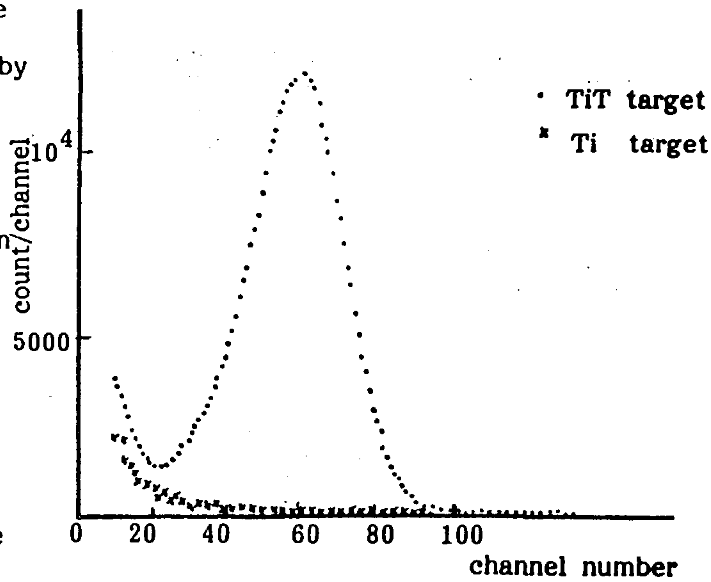

Fig.3 alpha particle spectrum

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.

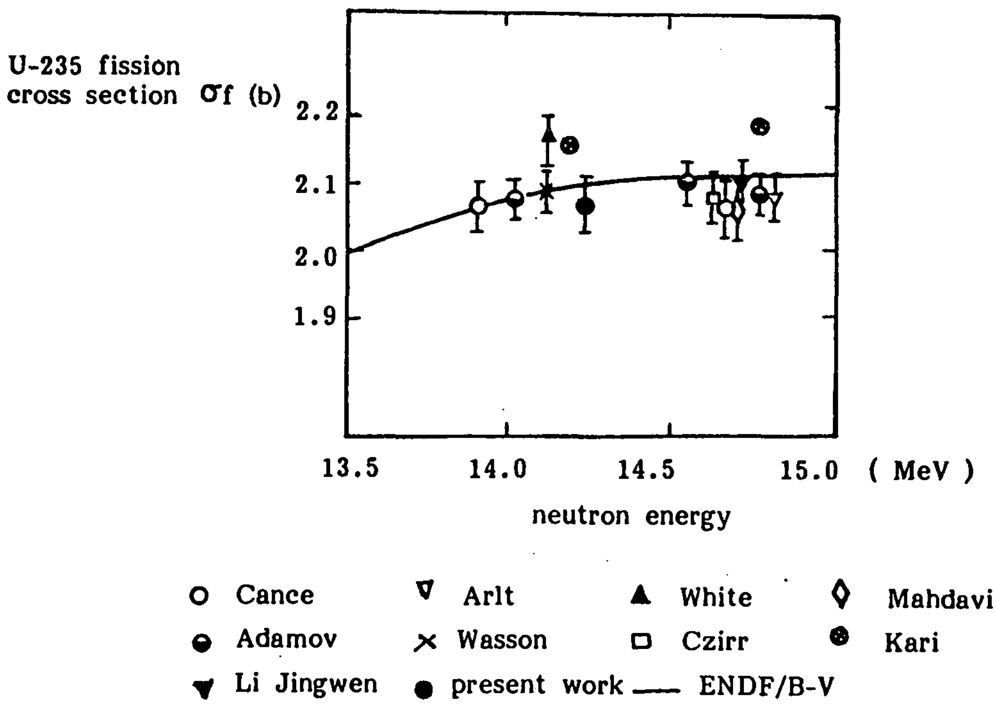

Fig.4 Comparison of the result of the present experiment with other measurements

REFERENCE

1) Yan Wuguang et al., Chin. Jour. Sci. and Techn., 1975, No.1, 19
2) Li Jingwen et al., Nucl.Data for Sci and Techn. (Antwerp) 1982,55
3) M. Cance et al., Nucl. Sci. Eng., 68, 197 (1978)
4) V. M. Adamov et al., Proc. Int. Conf. Nuclear Cross Sections for Techn., (NBS) 1980 p.995
5) R. Arlt et al., Ibid., p.990
6) O.A. Wasson et al., Nucl. Sci. Eng., 80,282 (1982)
7) M. Mahdovi et al., Nucl. Data for Sci and Techn.(Antwerp) 1982 p.58
8) J.B. Czirr et al., Nucl. Sci. Eng., 57, 18 (1975)
9) P.H. White, J.Nucl. Energy, A/B 19, 325 (1965)
10) K.Kari et al., KFK-2673 (1978)

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14.7 MeV NEUTRON INDUCED FISSION CROSS SECTION RATIO OF U-238 TO U-235

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14 MeV neutron induced uranium fission cross section values are important standard reference data. In recent years, the σ_f value for U-235 measured in different laboratories agreed well with each other within a uncertainty close to 1%, but for U-238 there still exists large discrepancy.

We have measured the fission cross section ratio of U-238 to U-235 using time correlated associated particle (TCAP) technique.

The experimental schematic diagram is shown in Fig.1. The neutron were produced from T(d,n)He-4 reaction at neutron generator of Institute of Atomic Energy, Beijing. The angle between deuteron beam and associated particle is 135 degree with En=14.7 MeV.The scintillation counter consists of a 100 μm plastic scintillator, a 1 μm aluminium foil and a XP-2020 photomultiplier. An 8mm diameter diaphragm and an anti-scattering diaphragm of 15mm were placed in front of the scintillator.

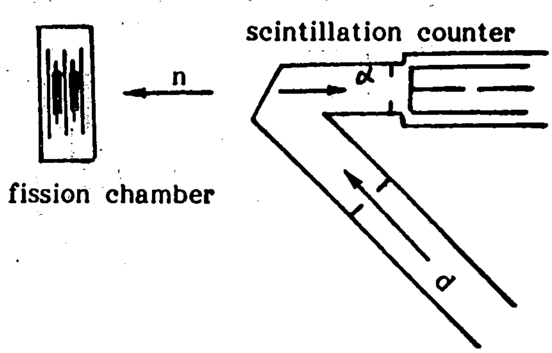

Fig.1 Experimental arrangment sketch

The fission chamber was located in the correlated neutron beam at a distance of about 22cm from the T-Ti target. We adopted the geometry in which the cross section of correlated neutron cone is larger than area of fission sample.

Two U-238 foils and two U-235 foils have been set in a back to back way as shown in Fig.1. The distance between electrodes is 2.5mm. The fission chamber was filled with 1.3 ATM pure methane. The characteristics of U-235 foils are the same as before (1). The U-238 samples are made of depleted uranium with U-238 isotope abundance 99.997% and the quantity was determined by weighing and α-counting.

The diagram of the electronic circuits used in the experiment is shown in Fig.2. The pulses from U-235 and U-238 fission chambers were preamplified by 142A. The T output signal after through type 579 Fast Filter Amp and type 583 CFD, was sent to 467 Time to Pulse Height Converter as the start pulse. The E output signals through 474 Timing Filter Amp, 427 Delay Amplifir and 542 Linear Gate Strecher gated by the pulse from 583 CFD, were sent to S-88 multichannel analyzer (MCA).

The pulse coming from the anode of photomultiplier, after through 583 CFD and 100 ns delay, was sent to 467 as the stop signal. The output signal from 467 was analysed by S-88 multichannel analyzer too. The pulse coming from D-9 of photomultiplier was used for neutron monitoring.

The time spectra and the energy spectra of fission-fragments for U-238 and U-235 were analyzed by S-88 MCA respectively. A typical set of these spectra was shown in Fig.3.

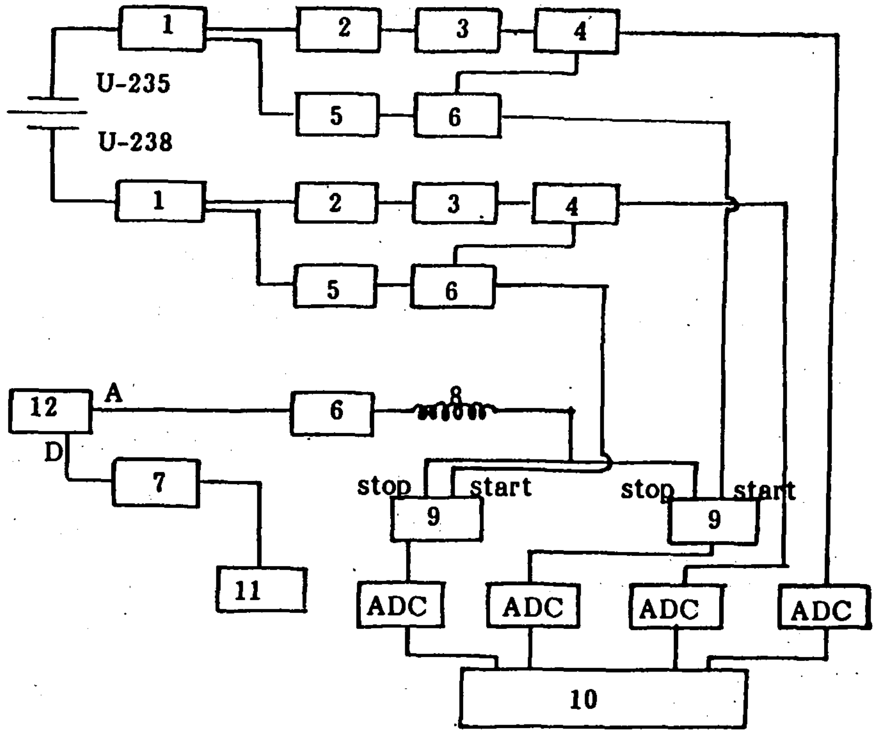

Fig.2 The electronic diagram

1. 142A preamplifier
2. 474 timing filter Amp
3. 427A delay amplifier
4. 542 liner gate strecher
5. 579 fast filter Amp
6. 583 CFD
7. follower
8. 100ns delay
9. 467 TAC
10. S-88 MC
11. monitor
12. photomultiplier

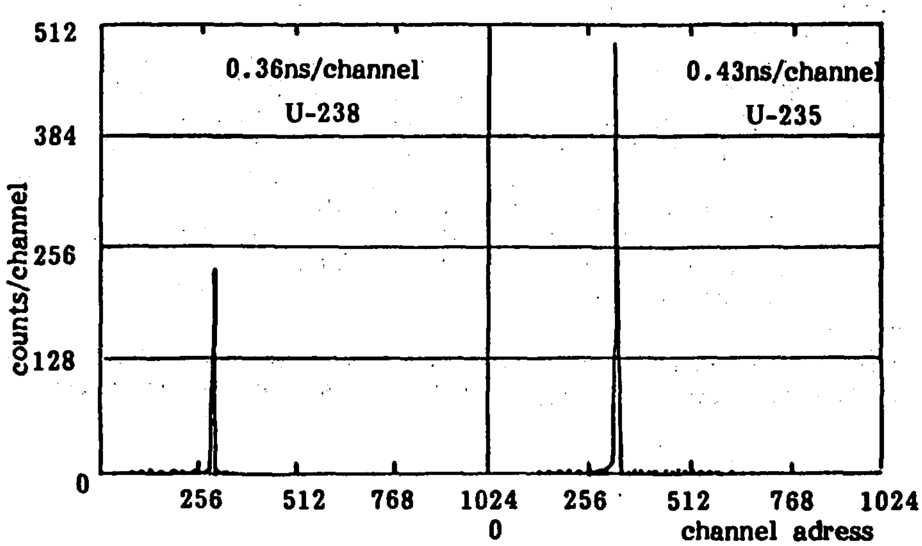

Fig.(a) Typical time distribution of fission pulses

The time resolution is about 2 ns . In the fission fragment pulse height spectrum the alpha background has been discriminated and the discrimination threshold level was set at a level slightly lower than the highest alpha pulses. In such case the efficiency of the fission chamber is increased and the increase of the background in the time spectrum is not important, so the accuracy could be inceased.

The fission rates of the two deposite were determined simultaneously. The measurements were carried out twice for each set of foils, once with the U-238 foil and once with the U-235 foil facing the neutron source, in order to eliminate effect due to the momentum carried by the incoming neutrons.

The following correction items were considered:

1) The random coincidence backgroud: this term can be calculated from the counts of the both sides far from time peak ;

2) Fission events from other isotope contents in the sampls ;

3) Fission foil self-absorbtion ;

4) Extrapolating the fission discrimination level to zero point ;

5) Neutron momentum effect ;

6) Anisotropy of fission fragment angular distribution .

These correction values , errors induced by correction and errors of the measurements are summarized in Table 1.

Table 1. Correction values and errors

item	correction value (%)	error for result (%)
statistical		1.0
other isotopes of U-235 sample	5.08	0.4
the quantity of U-235 sample		1.0
the quantity of U-238 sample		1.0
nonuniformity of U-235 sample		1.0
nonuniformity of U-238 sample		1.0
U-235 isotopic composition of U-235 sample		0.8
extrapolation to zero pulse height of U-235	1.4-4.4	0.8
extrapolation to zero pulse height of U-238	0.1-1.6	0.2
neutron flux correction	1.0-8.0	0.4
sulf-absorbtion of U-235	2.1-3.2	0.2
sulf-absorbtion of U-238	1.6-1.8	0.1
TOTAL ERROR		2.53

Our final result of σ_f(U-238)/ σ_f(U-235) at 14.7 MeV is 0.565±0.014. Comparision with other author's was shown in Fig.4.

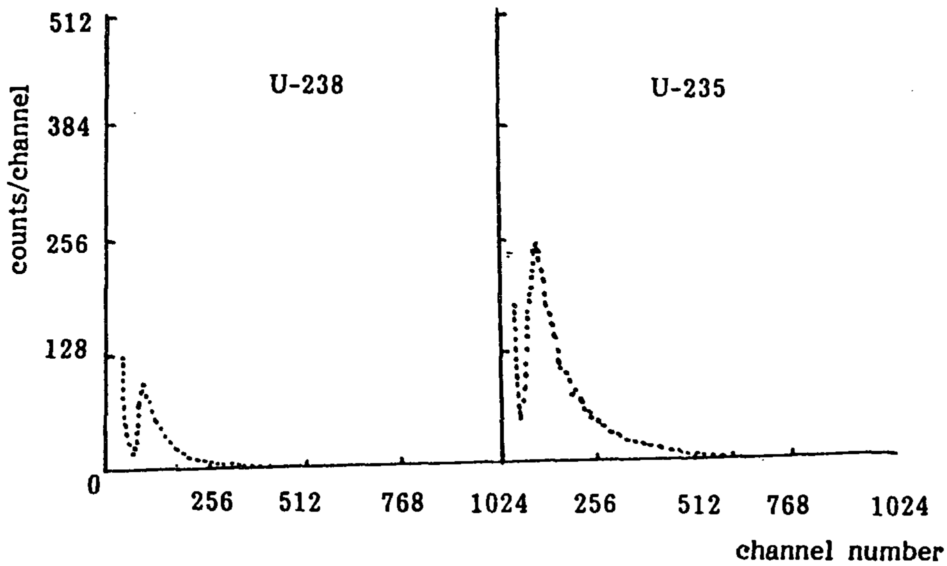

Fig.3(b) Fission fragment pulse height spectrum

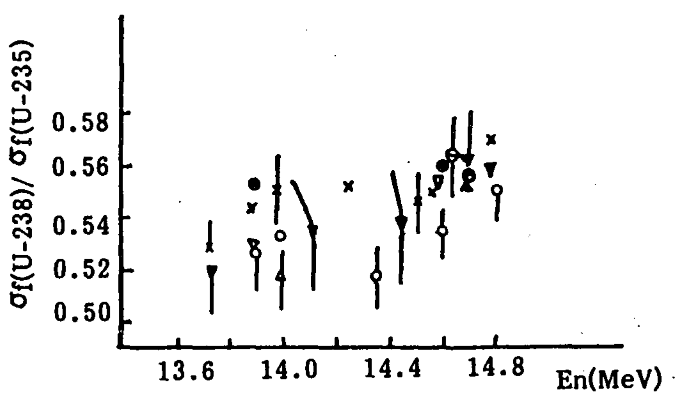

Fig.4 Some experimental results of f(U-238)/ f(U-235) near 14 MeV

- ▲ Arlt
- ▼ Varnagy
- ● Cance
- × Cierjacks
- ● Adamov
- o Coates
- ▼ Adams
- ▲ Uttley
- ⊖ present work

Refference

1) Li jingwen et al., Nucl. Data for Sci and Techn., (Antwerp) 1982 p. 55
2) M.Cance et al., Nucl. Sci. Eng., 68, 197 (1978)
3) V.M.Adamov et al., Proc. of the Int. Conf. on Nuclear Cross Section for Technology. Knoxxille, 1979, NBS Spec. Publ. 594, p. 995. 1980
4) R.Arlt et al., Kernenergie, 24, 48 (1981)
5) S.Cierjacks et al., ANL-76-90, 94 (1976)
6) M.S.Coates et al., NEANDC (UK) 116 AL (1976)
7) B.Adams et al., J. Nucl. Energy, 14, 85 (1961)
8) M.Varnagy et al., Nucl. Instr and Methods. 196, 465 (1982)
9) C.A. Uttley et al., AERE NP/R 1996 (1956)

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