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SMALL ANGLE SCATTERING CROSS SECTIONS OF 14.7 MeV NEUTRONS FOR ^{238}U

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Abstract: A position sensitive neutron detector was used to measure the scattering cross sections of 14.7 MeV neutron from ^{238}U between 2.5° and 15°. The angular distribution are calculated with coupled channels code ECIS79 using different parameters. The measured and calculated results are compared and disscussed.

(small angle scattering, ^{238}U, 14.7 MeV neutron)

Introduction

The fusion-fission hybrid reactors are being investigated recently. The ~14 MeV neutrons produced in the D-T fusion plasma of the reactors interact with ^{238}U in the blanket will produce ^{239}Pu. So the cross sections of neutron scattering from ^{238}U are important. Several measurements/1-5/ of neutrons scattering cross section of ^{238}U near 14 MeV have been made. Some of them are at small angles. But the data differences between the different labs are bigger than the error they gave.

There is a forward peak in the angular distribution of the ~14 MeV neutron scattering from ^{238}U. So the accurate values of the small angle scattering cross sections are very important.

In present work, the differential scattering cross sections from 2.2° to 14.6° for ^{238}U at 14.7 MeV were measured. The results were compared with others and analysed with couple-channels Optical Model.

Experimental Method and Arrangements

The experimental arrangements are shown schematically in Fig 1. The 120-175 KeV collimated beam of deuterons from Cockroff Walton accelerator is used to generate neutrons from T(d,n)^{4}He reaction. Neutron beam is collimated in ~±0.5° by a square truncated cone collimator located in a shield which is 70 cm in thickness of iron, 60 cm in thickness of paraffin and 10 cm lead. All round the neutron-producing target was shielded perfectly by iron, lead and paraffin. It is different from the previous measurements /6/. There is no shielding water wall for the present apparatus as the neutron hall is much bigger than that of the previous.

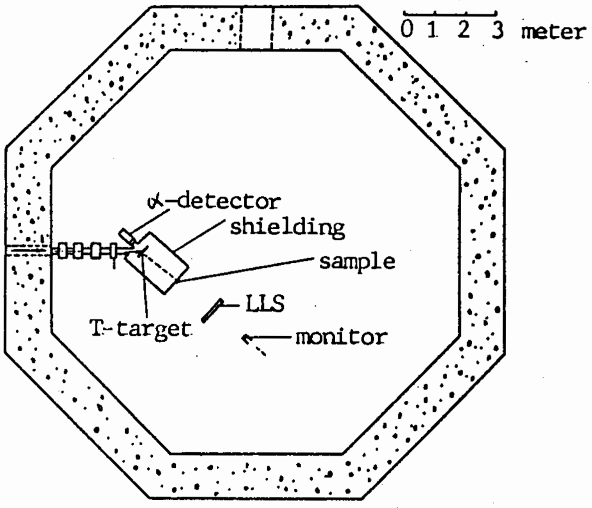

Fig 1. Schematic diagram of experimental arrangement

The main detector is a position sensitive neutron detector which consists of a long cylindic liquid scintillation tube (LLS) and two photomultipliers at both ends of the tube. The position of the incident neutrons is determined by the time difference between the output signals of the two photomultipliers. The detailed design of the detection system has been described elsewhere/7/. The metallic depleted uranium scattering sample, 6 cm in diameter, 0.8 cm in thickness, oriented with its axis parallel to the collimated neutron beam. The distance from the neutron-producing target to the scattering sample and that from the scattering sample to LLS are both 1.5 meter.

The collimated neutron beam was monitored by a liquid scintillator, 10 cm in diameter, 10 cm in thickness. The solid angle subtent by the liquid scintillator at the neutron source just equal to the solid angle of the collimated incident neutron beam.

The differential scattering cross section is obtained from following formula

$$\sigma(\theta) = \frac{N(\theta)\ k}{N_o \mathcal{E}(\theta)\ nt\ d\Omega(\theta)}$$

where $N(\theta)$ is the net counts of the scattering neutrons at the angle θ in the element $A(\theta)$ of LLS. No is the net counts of perpendicular incident neutrons in the element B in the middle of the LLS. Both $N(\theta)$ and No are normalized to the counts of the neutron monitor, or to α-counting rate produced by $T(d,n)^4He$ reaction. $\mathcal{E}(\theta)$ is the intrinsic efficency ratio of the element $A(\theta)$ to the element B. k is the ratio of the solid angle subtend by the element B at the neutron source to that by the scattering sample at the neutron source. $d\Omega(0)$ is the solid angle subtend by the element $A(\theta)$ at the scattering sample. n is the number of nuclei in a unit volume of the sample. t is the thickness of the sample.

The simplified block diagram of the measurement system is shown in Fig 2. Where LS: liquid scintillator, PM: photo multiplier, CFD: Constant Fraction Discriminator, PSD: Pulse Shape Discriminator, SCA: Single Channel Amplitude Analyser, MCA: Multi Channel Amplitude Analyser, MT: Meantimer, ADD: added circuit, TAC: Time to Amplitude Converter, COIN: Fast/slow coincident circuit.

TOF technique and n,γ discrimination were used to reduce background. The MT: meantimer was used to cancel the time uncertainty from the different position of the incident neutron. The added circuit

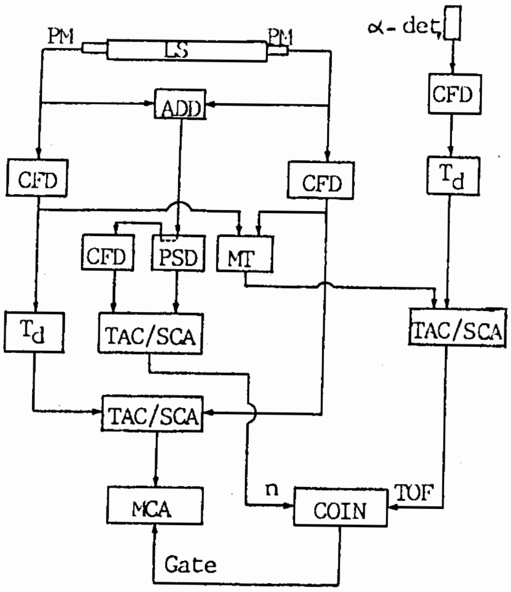

Fig 2. The simplified block diagram of the electronic system.

was used to improve the n,γ discrimination property. The TOF technique and n,γ discrimination were used in the monitor as well. They are not shown in Fig 2 for simplicity.

Experimental Results and Discussion

The measurements were made at 14.7 MeV incident neutron energy. Several runs of the measurement have been done. In each run we measured the position spectra according to the following order: incident neutrons — scattering neutrons — incident neutrons — background — incident neutrons. The energy resolution of the measurement system was about 1 MeV. It could not separate the neutrons scattered elastically and the neutrons scattered inelastically from low-lying excited levels. So the results of present measurement include the contribution of such inelastic neutrons.

The data of differential cross sections were corrected for multiple scattering and finite geometry by Monte Carlo Method.

The angular distribution of present work* and others are shown in Fig 3. The error bars are standared errors of the average data of six runs which are 3% to 5% and the statistical uncertainties are less than 3%. As shown in Fig 3, our data are in agreement with the data measured in the seventies and eighties. The curves represent the differential cross sections of elestically scattering added with inelastically scattering from the three low-lying excited levels. They are calculated with coupled channel (CC) code ECIS79 using different parameters/8-11/ which fit the data of the large angle region of ^{238}U for about 14 MeV neutron quite well, but as shown in Fig 3 at small angle the discrepancy are quite large. It is probably because of the parameters being obtained from the data not including small angle region.

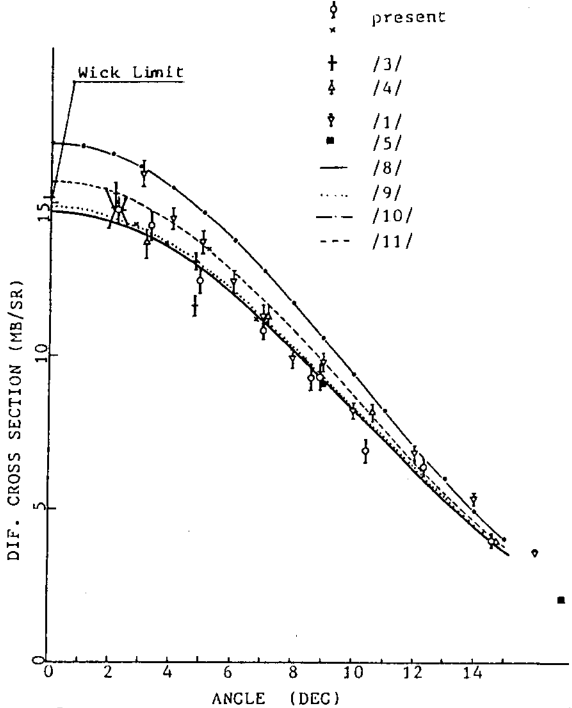

Fig 3. Comparison of the measured differential scattering cross sections with cc calculation at small angular region.

The best parameters were obtained to fit the present data and the large angles data of Hansen/5/. These parameters are listed below:

Real potential

V=43.2985 r_0=1.243 a_0=0.6501

Surface imaginary potential

W=9.3933 r_s=1.1588 a_s=0.6667

Spin-orbit potential

V_{so}=9.3617 r_{so}=1.256 a_{so}=0.626

The comparison of the measured differential scattering cross sections with cc calculations using the best parameters in the full angular region are shown in Fig 4.

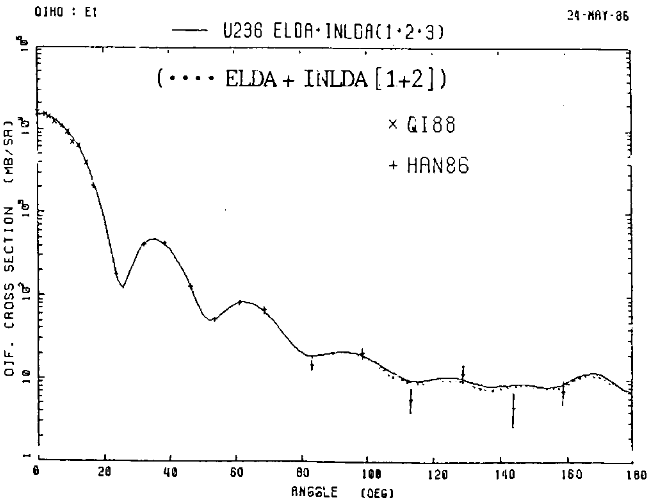

Fig 4. Comparison of the measured differential scattering cross sections with cc calculations using the best parameters.

In this comparison of the measurements with the calculations, the 6^+ level was not included in the sum since its excitation energy is 309 KeV compared with the 250 KeV resolution of the measurements. As shown in Fig 4, good fits to the experimental data were obtained for both small angle and large angle. So in our opinion, the earlier views on the existence of "anomaly" are unreasonable.

* There are two cases in the present work, in one case, the angle between the deuteron beam and α-particle is 135°, in another that is 170°. The data were represented by ϕ and x respectively.

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