Measurements of Elastic Scattering Cross Sections of Carbon, Iron and Lead for 75 MeV Neutrons

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Abstract

We have performed the measurements of elastic scattering cross sections of carbon, iron and lead for 75 MeV neutrons using a $^{7}Li(p,n)$ quasi-monoenergetic neutron source. Elastically scattered neutrons were measured with a time of flight method (TOF) using five liquid scintillation detectors. The data were obtained at 25 laboratory angles between 2.6° and 53.0°. The experimental data were compared with the neutron cross section libraries, systematics used in cascade/transport codes and optical model calculations.

1.Introduction

The neutron emission cross sections for neutron incident reactions are very important for the shielding design of the high-energy accelerator facilities. In particular, the importance of the elastic scattering cross sections was pointed out by the analysis of shielding experiments using the 40 and 65 MeV quasi-monoenergetic neutrons at TIARA facility [1]. Experimental data is very scanty and poor above 40 MeV. Experimental data reported in the past were restricted to only forward angles. Recently, two measurements were reported from U.C.Davis group [2][3]. These data were measured by using the neutron spectrometer consisting of a multi wire chamber and a recoil proton telescope, with source neutrons produced by the $^{7}Li(p,n)$ reaction ($E_n=65MeV$) and by the spallation reaction ($E_n=50\sim250MeV$). The data by spallation source were available only for forward angle (~23°) and has relatively large systematic errors.

In this study, we have performed measurements of elastic scattering cross sections of carbon, iron and lead for 75 MeV neutrons. The data were obtained by using the $^{7}Li(p,n)$ quasi-monoenergetic neutron source and the time-of-flight (TOF) method for scattering angle between 2.6° and 56°. Experimental results were compared with the cross section libraries, systematics used in cascade/transport code and optical model calculations.

2.Experiment

Experiment was carries out at TIARA AVF cyclotron facility [4]. Source neutron were produced via the $^{7}Li(p,n)$ reaction. Figure.1 shows the source neutron spectrum. The peak around 75 MeV is due to the $^{7}Li(p,n_{0,1})$ process and continuum component is attributed to multi-body breakup process. Figure 2 shows a setup of the elastic scattering measurement. The scattering samples, carbon (5cmϕ×8cm), iron (4cmϕ×6cm) and lead (3cmϕ×6cm), were placed at 10 m from the Li neutron production target. Elastically scattered neutrons were measured by a time of flight method (TOF) using five liquid scintillation detectors (12.7cmϕ×12.7cm, four NE-213 and a BC501A detectors) concurrently. We employ a CAMAC system for data acquisition. The detector anode signals were fed into QDC (charge-to-digital converter) and integrated by two types of the integration gate for n-γ discrimination, one is for total component and the other for slow component. The TOF is obtained by measuring the time difference between the anode signals and the RF signal of the cyclotron by using TDC (time-to-digital converter). A set of three data for pulse-height (total and slow components) and TOF is acquired event by event for each detector.

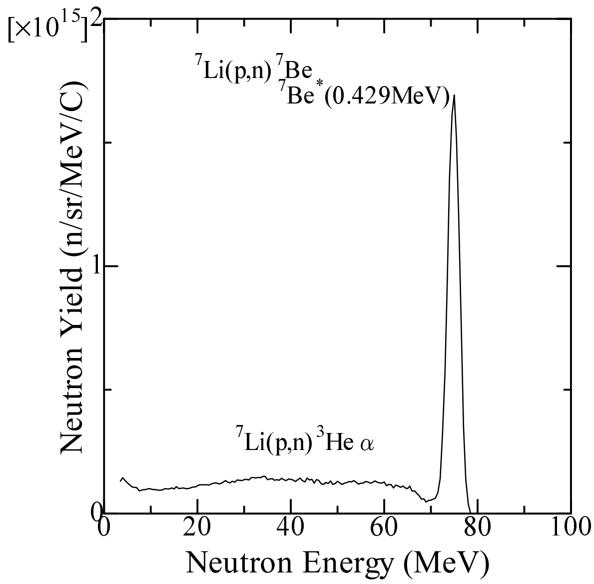

Fig.1 Source neutron spectrum

The TOF spectra were obtained at 25 points between 2.6° and 56° in laboratory scattering angle. In addition to sample measurements, background runs with no sample were done for removing the sample independent background. Scattering angle were changed by rotating the detector array. The flight paths were around 5m for forward angles and 2m for backward angles. Fission chambers (^{238}U and ^{232}Th) located near by the Li target were used as neutron monitor for normalization between foreground and background run. Thin plastic scintillator, which was set at collimator exit, monitored source neutron TOF spectrum. The absolute elastic scattering cross sections were determined relative to the incident neutron flux measured by the scintillation detectors, which were identical with ones for scattering measurements.

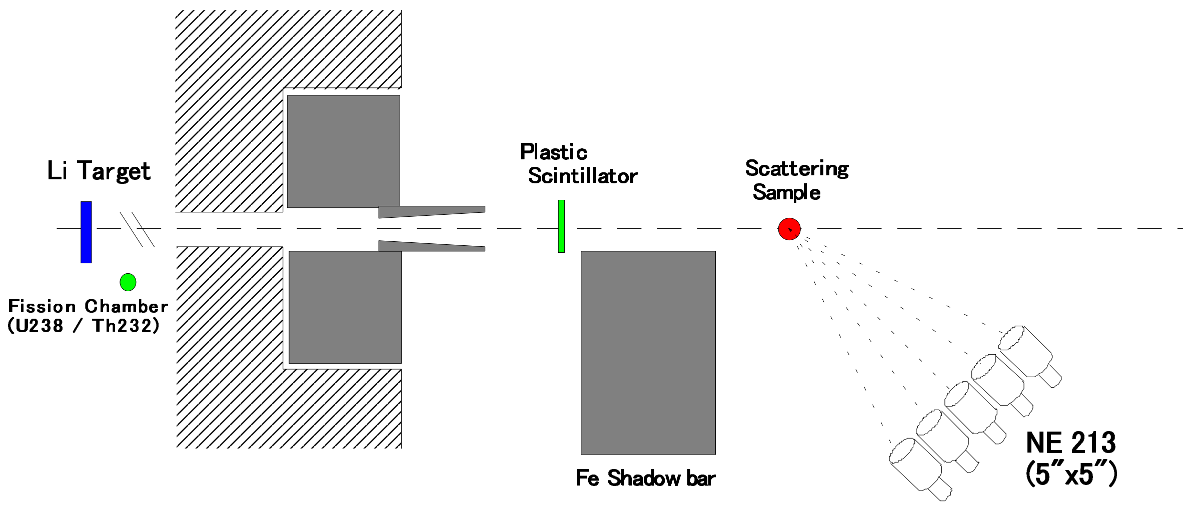

Fig.2 Experimental setup

3.Data reduction and correction

Figure 3 shows the TOF spectra for foreground and background in the Fe run. The peak area subtracted with a background was converted to cross sections. The elastic scattering cross sections deduced were further corrected for the effects of the inelastic scattering and the finite sample-size, i.e. the effect of flux attenuation and multiple scattering, by Monte Carlo calculation [5]. Corrections for the effects of inelastic scattering were to remove inelastically scattered neutrons included in the "elastic" peak because of limited energy resolution, and done by calculating the ratio of the inelastically scattered neutrons to the total (elastic and inelastic) ones considering experimental energy resolution. In this calculation, we used the LANL 150 MeV library [6] as input data for the neutron-sample nuclide interaction. In fig.4, the cross, triangle and circle indicate the raw data, sample size corrected data and inelastic neutron corrected data of Fe, respectively. Because of strong forward peaking of the elastic scattering angular distribution, inelastically scattered neutrons do not affect the results at forward angles, but the correction factors vary from 20% around 30° to 40% around 50°.

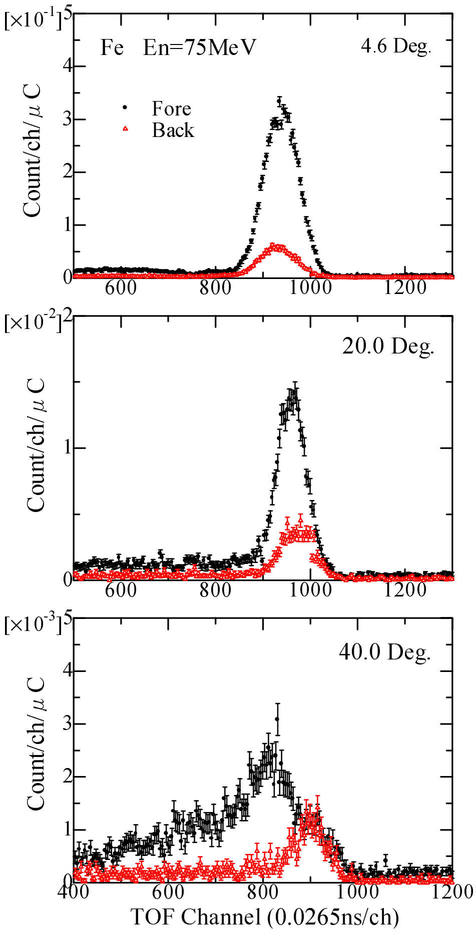

Fig.3 TOF spectra of Fe

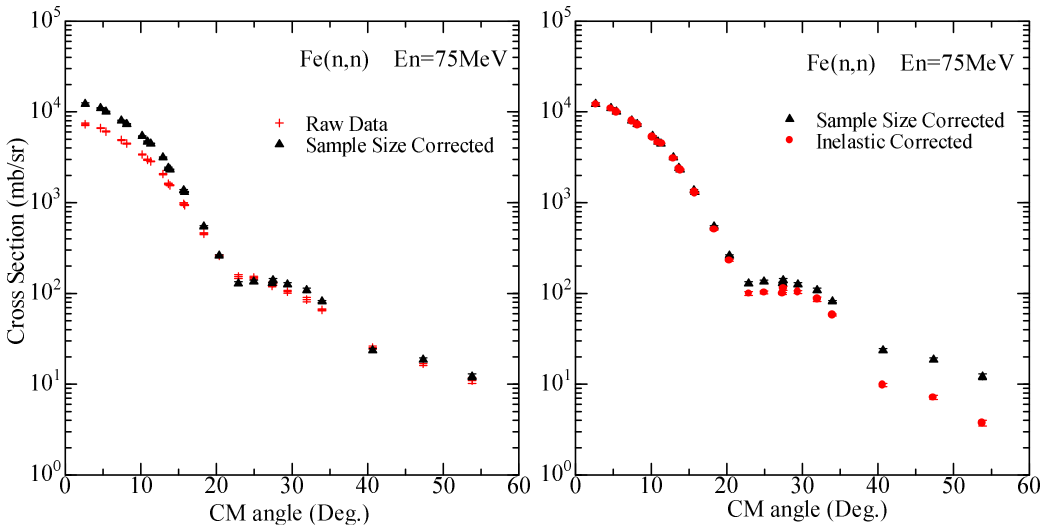

Fig.4 Correction for the effects of the sample size and the inelastic scattering neutrons

4.Results

Figure 5 shows the present results together with LANL 150 MeV library [6] and the experimental data at WNR/LAMPF [3]. Agreement between our experimental data and evaluation is good except for forward angle of carbon, but WNR/LAMPF data are milder forward peaking than our data and evaluation.

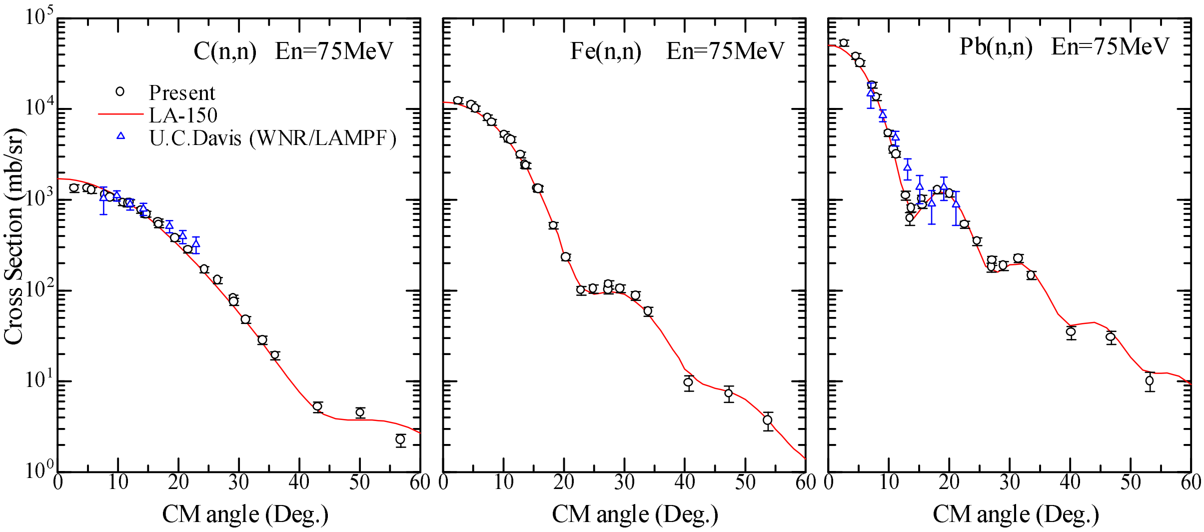

Fig.5 Comparison of the present data with the U.C.Davis data [3] and the LANL 150 MeV library [6]

Figure 6 shows comparison with the DLC119/HILO86 multi-group library [7] and the systematics used in the cascade/transport code [8]. These data were normalized to the experimental data at 0°. Both of the data show large discrepancy because DLC119 library applies P5 Legendre expansion and the systematics ignores scattering to backward angles.

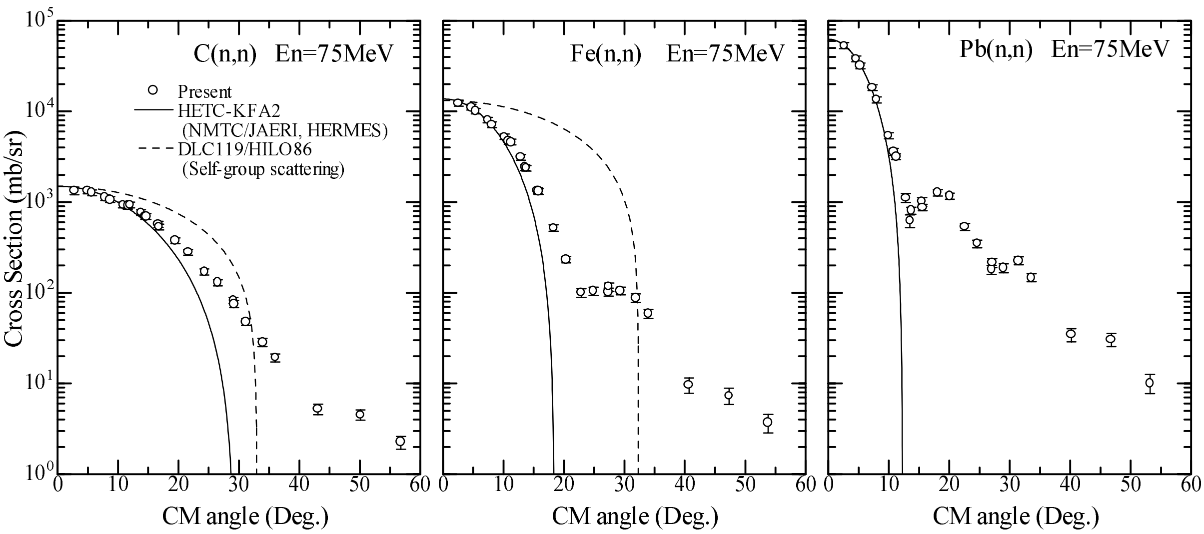

Fig.6 Comparison of the present data with the DLC119 Library [7] and the systematics [8]

Figure 7 shows comparison with the optical model calculations with the global potentials proposed by Madland [9] and JLM (Jeukene, Lejeune and Mahaux) [10]. The calculation results by JLM potential underestimates the experimental data with 10~20% at forward angles for carbon, iron and lead. The results by Madland potential agree with the experimental data for iron very well but differ largely for lead at backward angles.

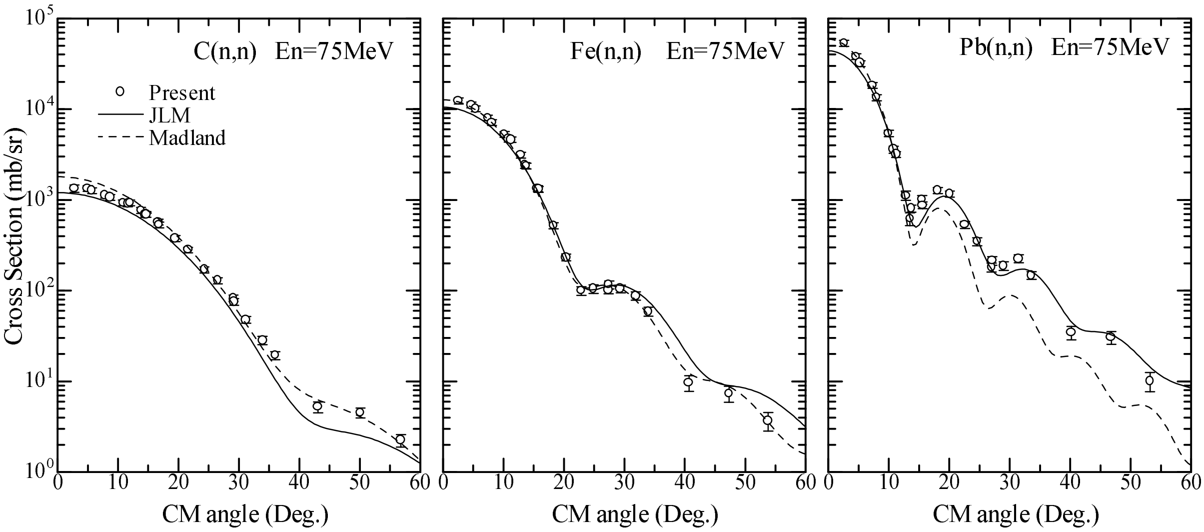

Fig.7 Comparison of the present data with the optical model calculations [9][10]

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75MeV 中性子に対する炭素、鉄、鉛の弾性散乱断面積の測定

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