Measurement the $^{13}C(\alpha,n_0)^{16}O$ reaction cross-section in the energy range of 2-6.2 MeV

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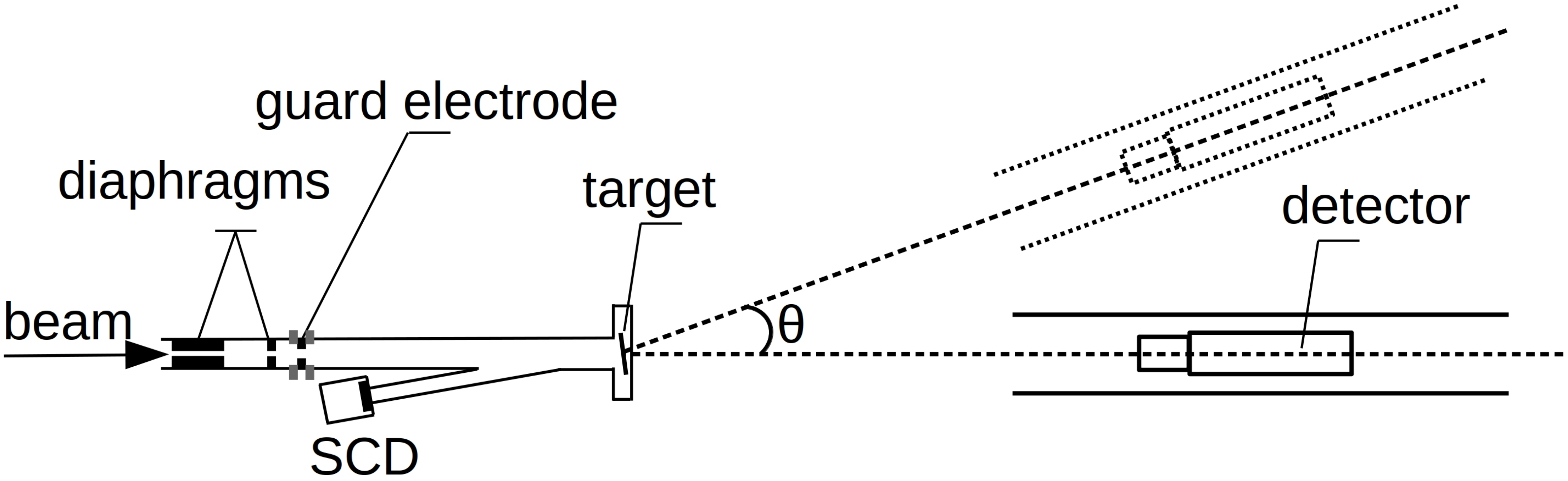
Motivation

- The $^{13}C(\alpha,n)^{16}O$ reaction is of interest as the potential background source at the geo-neutrino measurements and as the neutron source for s-process in nuclear astrophysics
- The inverse $^{16}O(n,\alpha)^{13}C$ reaction data are of great importance to nuclear power
- The existing evaluations and experimental data differ significantly (20-80%)

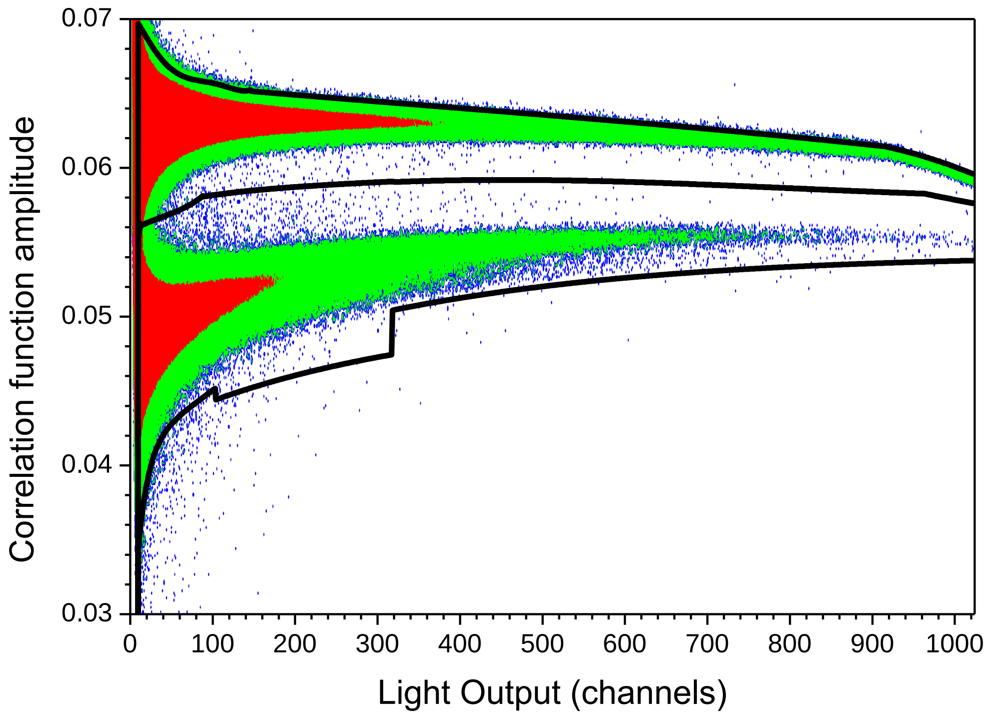
New experimental data are needed to clarify the reasons for the discrepancy between various authors and obtaining more accurate evaluations of the $^{13}C(\alpha,n)^{16}O$ и $^{16}O(n,\alpha)^{13}C$ reactions cross section.

Experimental method

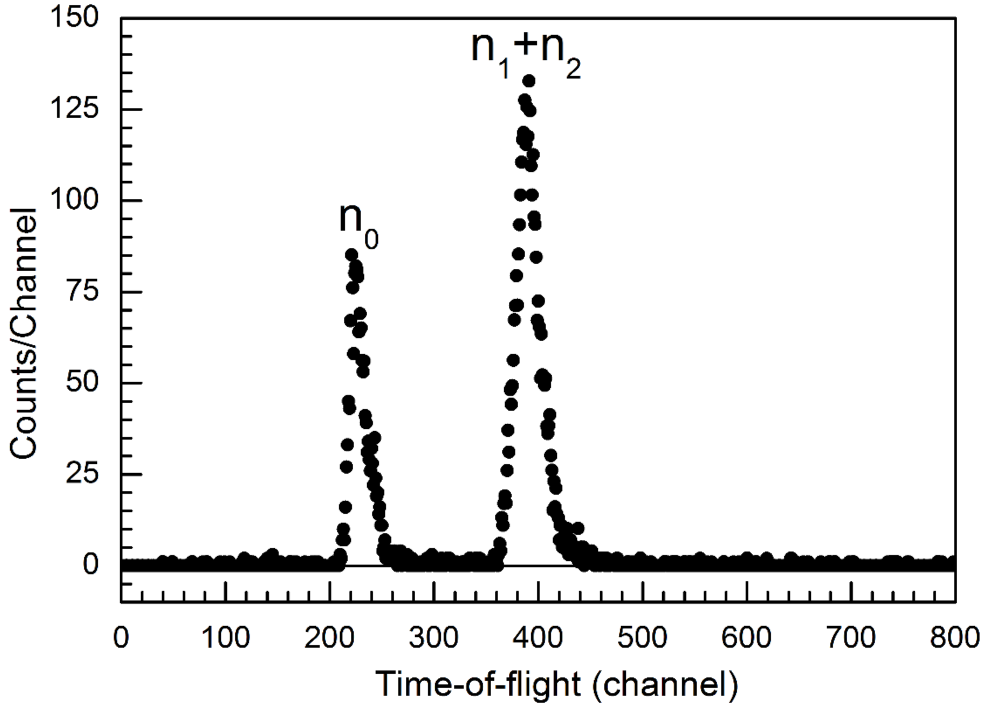


- The differential cross-sections of $^{13}C(\alpha,n_0)^{16}O$ reaction were measured in the angle range of 0-150 degrees
- The time-of-flight method was used for the measurement
- The semiconductor detector (SCD) was used as the independent beam current monitor
- Amorphous carbon-13 48 ug/cm2 layer deposited on gold backing was used as a target
- The 40x40 mm p-terphenyl crystal was used as the neutron detector
- Signals from the neutron detector and the accelerator chopper-buncher system were digitized and saved on a computer hard disk

Digital signal processing

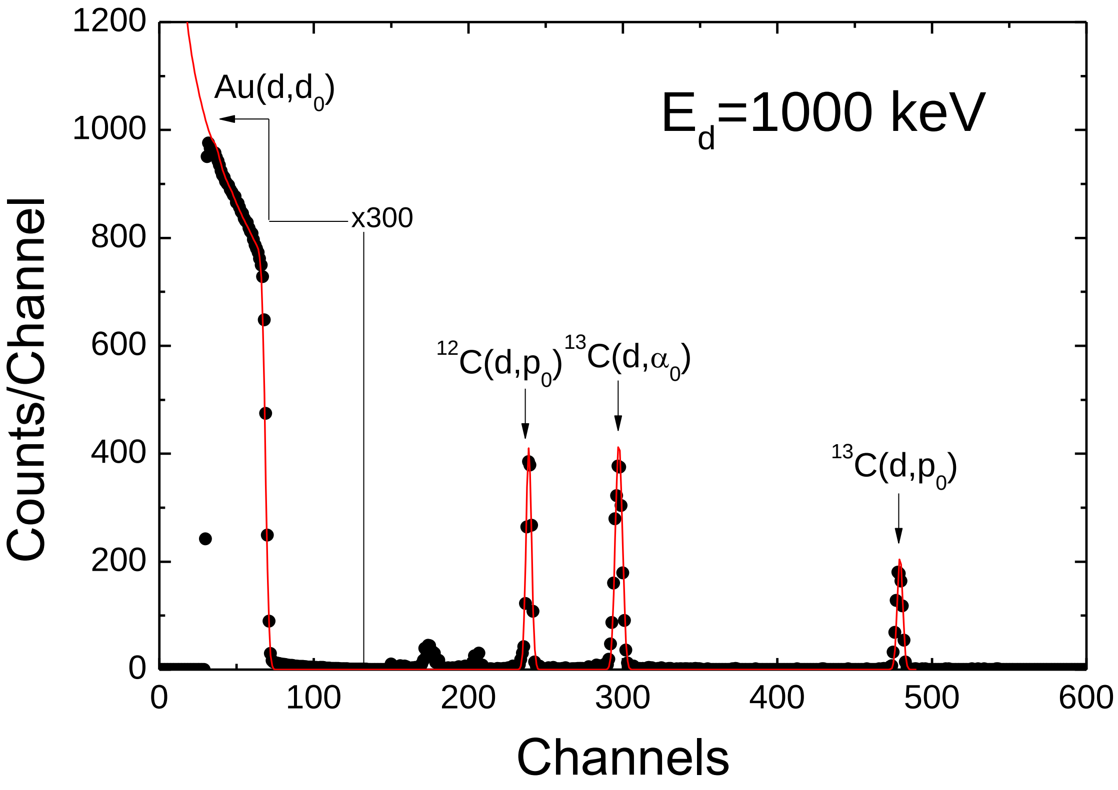


Separation parameter distribution for the signals from neutron detector



The example of neutron time-of-flight spectrum

The target thickness measurement

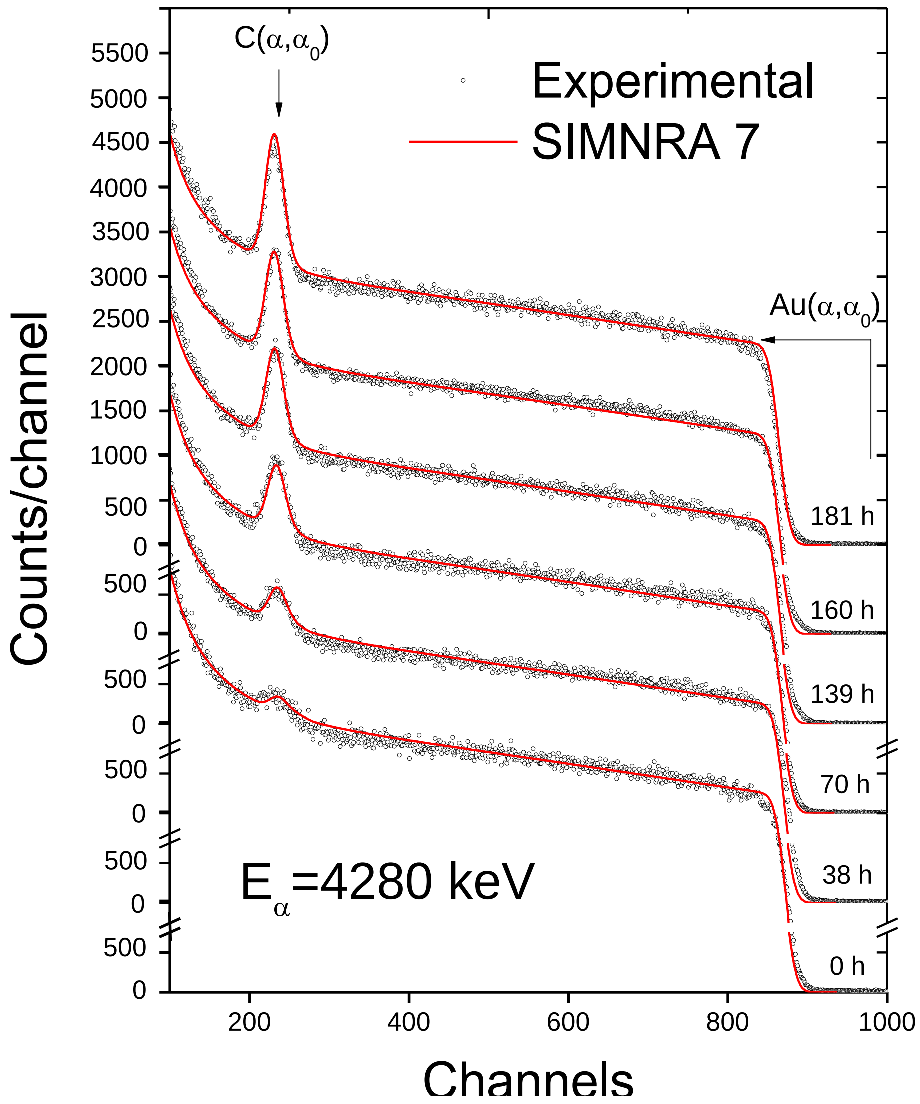


•The part of spectrum measured on the ^{13}C target.

•Dots – experimental data, the red line – simulation using SIMNRA 7

- The surface density of ^{13}C atoms in the target was measured by NRA method using the reactions ^{13}C(d,p_0)^{14}C and ^{13}C(d,α_0)^{11}B.
- The reaction cross sections given by J.L. Colaux (Nucl. Instrum. Methods in Physics Res. B, 254 (2007) 25) were used to simulate the NRA spectra
- The surface density of ^{13}C atoms in the target, obtained by fitting the spectra by the SIMNRA7 program, was $2.2\cdot10^{18}\pm1\cdot10^{17}$ atoms/cm^2
- Uncertainties: uncertainty of the cross-section in Colaux's work ≈4%, statistical uncertainty ≈3%
- The scattering of deuterons on a gold backing was used as an internal monitor for the beam current and solid angle.

The target parameters control

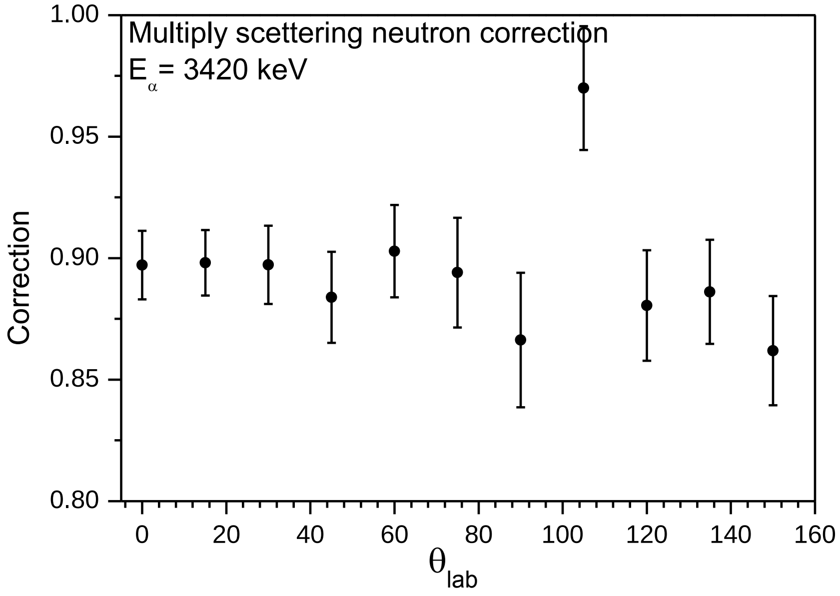


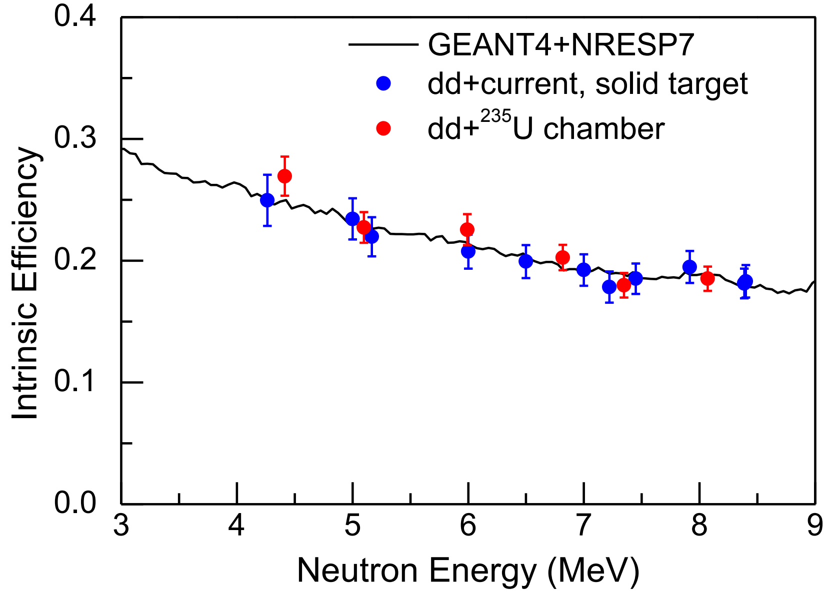
The semiconductor detector was used as an independent monitor of the beam current and ^{12}C carbon deposits during measurements.

The ^{12}C deposit was monitored periodically by measuring the backscattering spectra at an α-particle energy of 4280 keV.

The beam current was monitored for each measurement with a neutron detector by measuring the backscattering spectra of α-particles on gold.

Neutron distribution analysis





Differential cross-section of $^{13}C(\alpha,n_0)^{16}O$ reaction:

$$\frac{d\sigma}{d\Omega}(\theta) = \frac{S_n(\theta)\gamma(\theta)}{N_\alpha \eta \varepsilon \Omega} 10^{24} \text{ (barns)}$$

$S_n(\theta)$ – neutron peak area,

$\gamma(\theta)$ – multiply scattering correction,

N_α – full number of α-particle,

η – surface density of ^{13}C atoms,

ε – neutron detector efficiency,

Ω – solid angle obtained from the geometrical parameters of the experimental setup

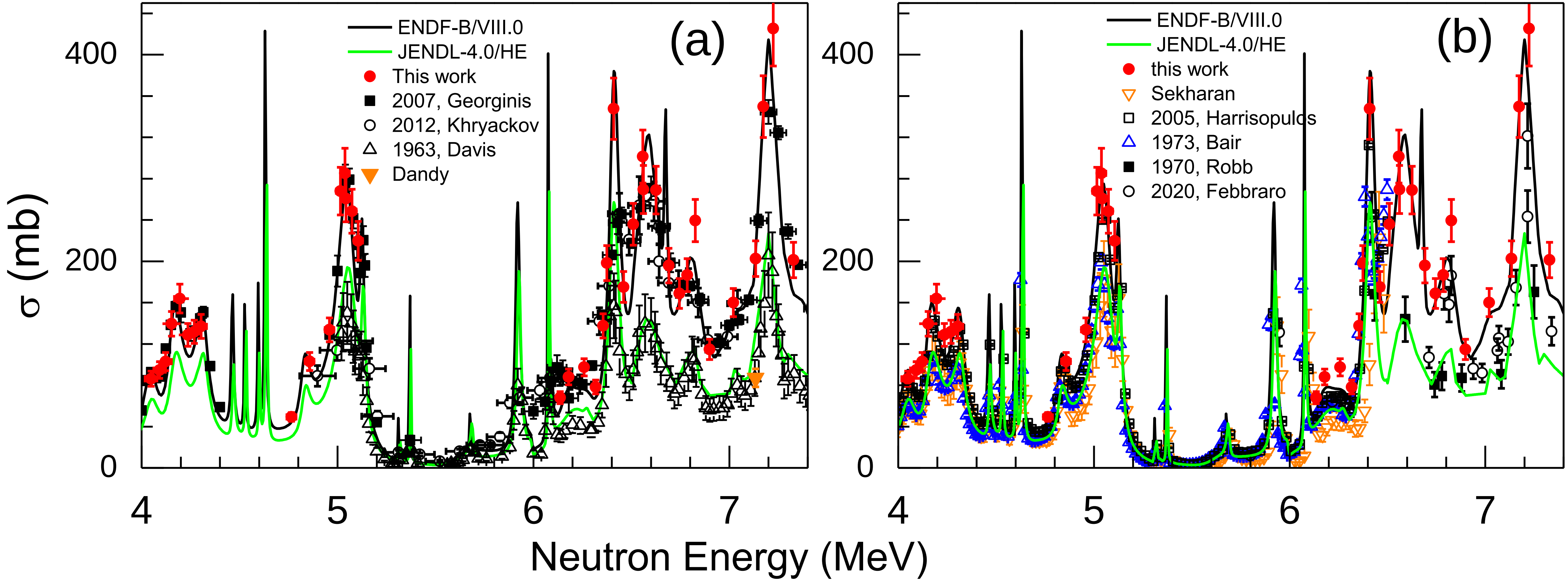
The obtained angular distributions of the differential cross sections were fitted by Legendre polynomials of 4-6 degrees to calculate the total reaction cross section.

The resulting cross sections were converted to the cross sections for the $^{16}O(n,\alpha_0)^{13}C$ reaction using the reciprocity theorem.

Uncertainties budget

Uncertainty Source	Contribution, %
Statistical	0.5-1.5
Target Thickness	4
Detector Efficiency	4
Beam Current	2
Solid Angle	2.5
Multiply Scattering Correction	2
Total	6.8-7

Results



Comparison of the data obtained in the work with the estimates and data of other authors.

(a) – data obtained from $^{16}O(n,\alpha_0)^{13}C$ reaction measurements

(b) – data obtained from $^{13}C(\alpha,n_0)^{16}O$ reaction measurements

Conclusions

- Differential cross sections for the reaction $^{13}C(\alpha,n_0)^{16}O$ were measured in the energy range 2-6.2 MeV

- The time-of-flight method was used to suppress the contribution of neutrons from excited states of the residual nucleus

- The cross section for the reaction $^{16}O(n,\alpha_0)^{13}C$ was calculated using the reciprocity theorem

- The results obtained are in agreement with the ENDF-B / VIII.0 evaluation.

Thanks for your attention!