

Total reaction cross sections of neutron-rich light nuclei measured by the COMBAS fragment-separator

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Preliminary results of measurements of the total reaction cross sections σ_R for nuclei ^4He , ^6He , ^8He , ^7Li , ^8Li , ^9Li , ^{11}Li , ^7Be , ^9Be , ^{10}Be , ^{11}Be , ^{12}Be , ^8B , ^{10}B , ^{11}B and ^{12}B nuclei at energy range (10-50) AMeV with ^{28}Si target is presented. The secondary beams of light nuclei were produced by bombardment of the ^{15}N (50 AMeV) primary beam on Be target and separated by COMBAS fragment-separator. In dispersive focal plane a horizontal slit defined the momentum acceptance as 1% and a wedge degrader of 600 μm Al was installed. The B_p of the second section of the fragment-separator was adjusted for measurements in energy range (10-45) AMeV. The strong absorption model reproduces the A-dependence of σ_R , but not the detailed structure. We are comparing our experimental data with predictions of microscopic (dashed line) and strong absorption model, Glauber multiple scattering theory and preliminary results are obtained.

Keywords: total reaction cross sections, transmission method.

Introduction

Nowadays one of the major goals of nuclear science is to learn about the behavior of isotopes with exotic neutron to proton number ratios. The production of radioactive ion beams of light nuclides from the 1980s onwards has contributed towards a substantial increase of information on the properties of nuclei far away from the beta stability line, mainly on new aspects of their nuclear structure such as skins, haloes shells and others, in such a way that heavy-ion reaction cross-section measurements can be considered today as an essential tool to investigate the nuclear structure of exotic nuclei. Measurements of the total reaction cross-section, σ_R , defined as the total, σ_T , minus the elastic, σ_{el} , cross-sections for two colliding nuclei ($\sigma_R = \sigma_T - \sigma_{el}$) are important for the evaluation of the nuclear matter radius, thus providing information about the size of nuclei.

We report σ_R measurements ^4He , ^6He , ^8He , ^7Li , ^8Li , ^9Li , ^{11}Li , ^7Be , ^9Be , ^{10}Be , ^{11}Be , ^{12}Be , ^8B , ^{10}B , ^{11}B and ^{12}B nuclei at energy range (10-50) AMeV with ^{28}Si target is. Most of these nuclei are neutron and proton-rich; some are on the proton drip line, and therefore may be proton-halo candidates. The measurements were made by aiming these projectiles at a stack of thin Si elements which served as both targets and detectors.

We interpret our data using phenomenological strong absorption models, as well as more elaborate models such as the optical limit of Glauber multiple-scattering theory.

In our experiment, a primary ^{15}N beam was accelerated to around 50 AMeV by the U-400M cyclotron of the Flerov Laboratory of Nuclear Reactions, JINR, and sent to a ^9Be target of 89 mg/cm^2 thickness. A secondary beam cocktail consisting of particles He, Li, Be and B isotopes was produced and transported by the COMBAS fragment separator system [1] to the detector system (Figure 1). The secondary beams were partially purified by $600\text{ }\mu\text{m}$ Al wedge. The energy dispersion was limited to less than 1% FWHM by analyzing slits. COMBAS separator a magneto-optic configuration is realized on the rigid focusing principle. Three parameters are important for particle separation and trajectory analysis by COMBAS setup: magnetic rigidity ($B\rho$), energy loss difference in the degrader ($\Delta E/\Delta x$) and time of flight (TOF).

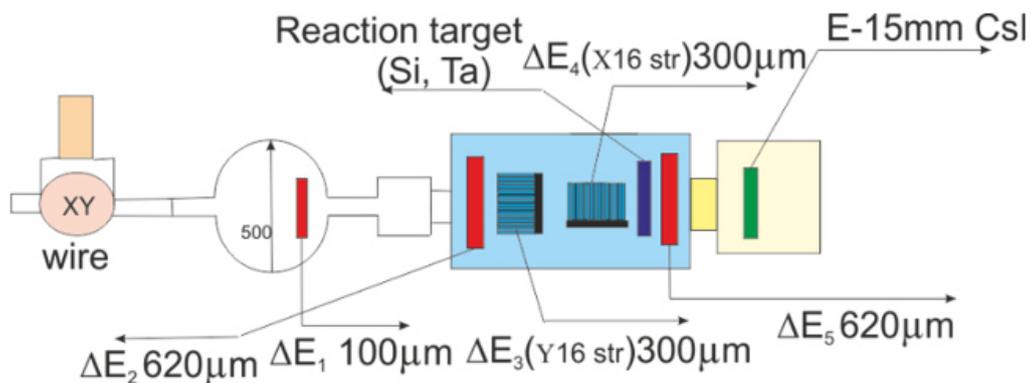


Figure 1. Experimental schematic view of detection set-up

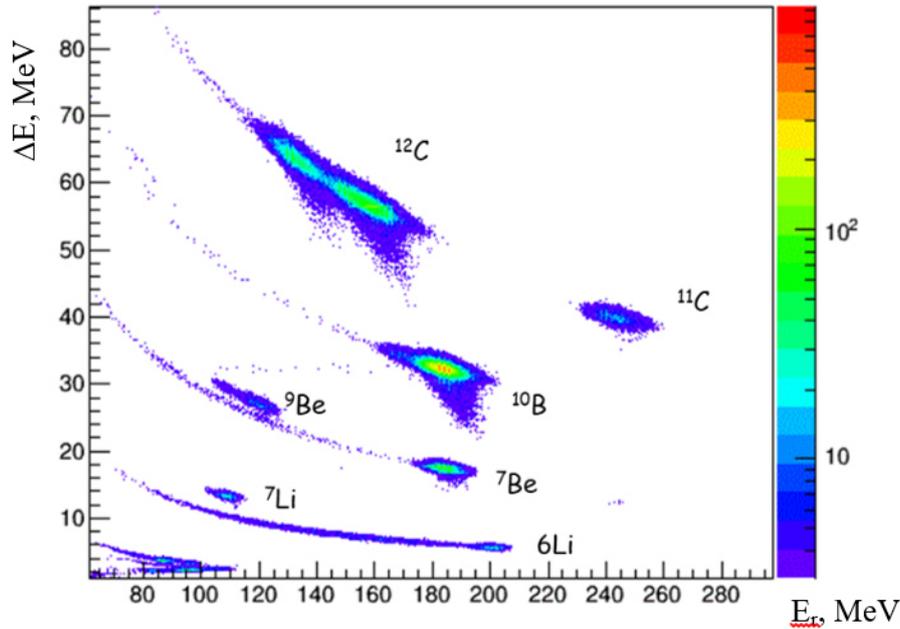


Figure 2. The scatter plot illustrates our secondary beam composition, by energy loss measurement ΔE versus the remain energy deposited in one of the CsI-detector, as the total energy in the telescope.

The first Si ΔE_1 double-sided strip detector (100 μm thickness, was used to obtain ΔE information and space x-y distribution of incoming secondary beam. Behind this detector, there was a ΔE_2 detector (620 μm thickness, $50 \times 50 \text{ mm}^2$) and two other detectors with 16 horizontal X strips and 16 vertical Y strips in rear side of ΔE_3 (300 μm thickness, $55 \times 55 \text{ mm}^2$) and ΔE_4 (300 μm thickness, $55 \times 55 \text{ mm}^2$), respectively. These detectors were designed for both precise measurement of spectra of the secondary beams and control of divergence by the x-y coordinate distribution. The silicon ΔE_5 (620 μm thickness, $50 \times 50 \text{ mm}^2$) detector was acquiring additional ΔE information and performing identification of fragments. In order to measure the remaining energy of particles (E_r) a CsI(Tl) (see Figure 2) detector with 15-mm thickness was used and mounted at the end of the telescope.

Total reaction cross section measurement

To obtain σ_R , we applied the transmission method (1), where is based on one simply counting of the number of beam particles incident on the target N_{inc} , and the corresponding number of outgoing particles, which have not undergone a reaction in the target N_{el} . The difference between these two numbers N_{inc} and N_{el} represents the number of reactions N_{reac} , which occurred in the target for N_{inc} incident particles:

$$\sigma_R = \frac{N_{inc} - N_{el}}{N_{inc}} \cdot \frac{A}{dN_A} \quad (1)$$

where A is mass number, d is target thickness (reaction target), N_A is Avogadro's number.

Then we compared our measured data's with the A dependence lines of the Kox formula [3]. The Kox formula gives excellent results for stable nuclei when the

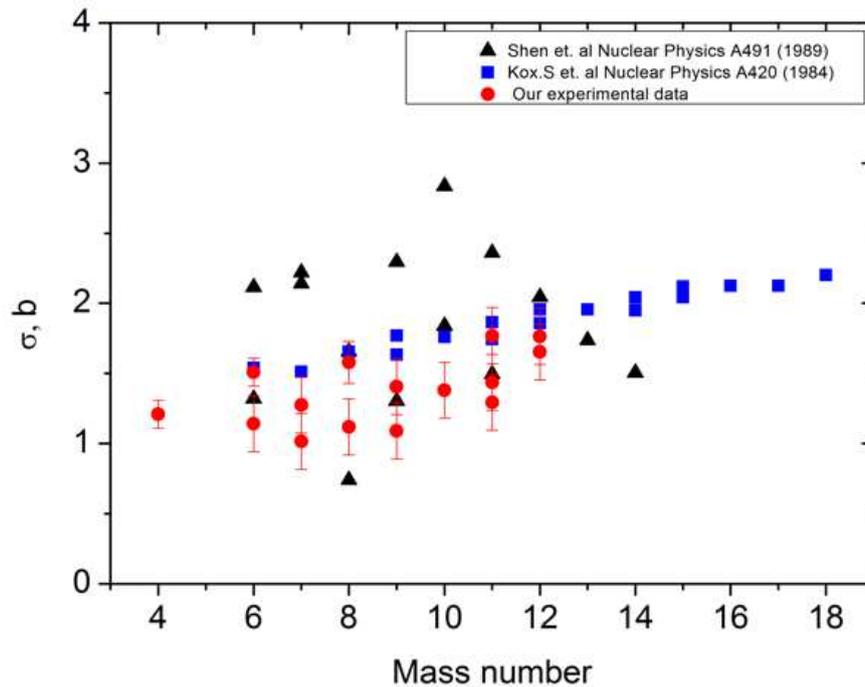


Figure 3. Compared our measured data's with the A dependence lines of the Kox formula (when the reduced strong absorption radius $r_0 = 1.1$ blue points and other group's experimental data [5]).

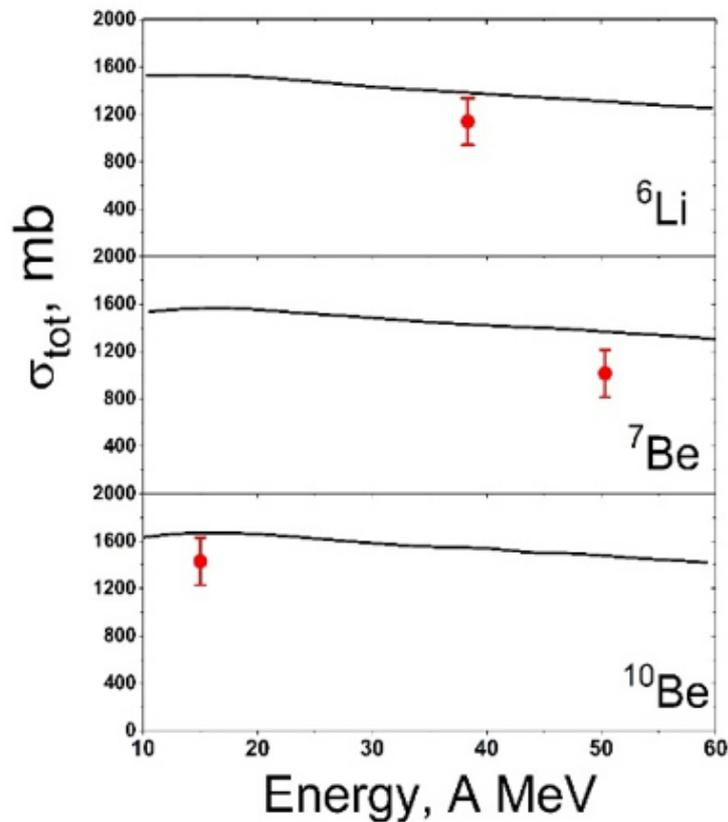


Figure 4. Experimental reaction cross sections points for ${}^6\text{Li}$, ${}^7\text{Be}$, ${}^{10}\text{Be}$ compared with calculation preliminary results of optical limit of the Glauber model (continues lines).

reduced strong absorption radius r_0 is fixed at 1.1 fm, and therefore any significant departure from its predictions may disclose a halo structure. The smooth A

dependence of the predictions reproduces the data on average, but is unable to explain the scatter of the reaction cross sections observed in the experiment (see Figure 3). This observation suggests that a more sophisticated theory is needed to explain these data. We are comparing our experimental data with Glauber multiple scattering calculation [4] and preliminary results are obtained (see Figure 4).

Conclusion

We have measured total reaction cross sections (σ_r) for Li and Be, He, B in Si with energies of (10-50) AMeV on ^{28}Si targets. The success of the method shows that Si telescope measurements of σ_r for other solid targets are also feasible.

The measured total reaction cross-sections σ_r are compared the calculations by reduced strong absorption and optical limited of the Glauber models.

References

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