Total reaction cross sections for ^{6,8}He and ^{8,9}Li nuclei at energies of (25-45) A MeV on ^{nat}Al and ^{nat}Pb

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FLNR JINR, theme 03-5-1094-2010/2016

I. Introduction

The total nuclear reaction cross sections (σ_R) measurements have long been of interest since they tell us about the radii and transparency of these nuclei and give clues to understanding of their structure. For studies of unstable nuclei, in particular the physical properties of halo nuclei and the neutron skin thickness, it is valuable to know not only the root-mean-square radii (rms) but it is important to know the details of nucleus-nucleus potentials. Our goal was to study total reaction cross sections (σ_R) by a direct measurement technique (the so-called beam attenuation or transmission method) which allows to extract model independent information. The interaction radii for ^{6}He, ^{8,9}Li were extracted, which are in agreement with the previous measurement at the similar energies (about a few tens of AMeV)

II. Experimental setup

Extraordinary variety of nuclear reactions with heavy ions and numerous possible combinations "ion–target nucleus" open up favorable prospects both for obtaining and forming secondary beams of accelerated radioactive nuclei with anomalous neutrons-to-protons ratio and for studying the structure of exotic nuclei. Reactions with heavy ions are very efficient in synthesis with unknown isotopes at the nuclear dripline or even beyond it. Mainly in-flight separators have been used today to obtain and separate secondary beams of radioactive nuclei with predetermined values of mass number A and atomic number Z. Nevertheless, using the in-flight separation techniques, it is impossible to obtain intense monoisotopic beams of secondary radioactive nuclei without significant losses of their intensity. It is known that ions—nuclear reaction products—obtained in exchange and fragmentation reactions have wide momentum distributions and different charge states Q. As a result, monoisotopic separation of nuclear reaction products cannot be ensured solely by magnetic rigidity Bρ, since magnetic rigidity Bρ of the separator is a function of a few parameters of analyzed particles, namely: $B\rho \sim P/Q = Av/(Z - n)$, where B [T m] is the magnetic field of the separator; ρ [m] is the radius of the central track of the separated particle; P is the particle momentum; $Q = (Z - n)$ is the charge state of an ion, which is equal to the difference of nuclear charge Z and number n of captured electrons; and v [m/s] is the velocity of transported particles. Therefore, a multiparameter detection system must be used for unambiguous identification by A and Z of nuclear reaction products, including their charge states Q. For this reason, the detection system of the COMBAS fragment separator is formed from a cascade of drift X- and Y-coordinate detectors with different thicknesses, which measure the ionization losses of particles ΔE with simultaneous signal generation for the TOF system and detector of residual energy absorption Er,

$$\Delta E \sim (Z/V)^2,$$

$$\Delta E + E_r \sim (A/V^2)/2 \ \text{and TOF} \sim (1/V) \ (2)$$

In combination with magnetic analysis, this variant of the detection system allows one to simultaneously measure the whole spectrum of transported particles both for light long-range products (within the limits of the E-detector thickness) and for short-range high-Z heavily ionizing particles (only a few forward ΔE-detectors are used). Analysis shows that a set of parameters Bρ, ΔE, Er, and TOF is sufficient for unambiguous identification by A and Z of reaction products, including charged states of their ions Q. The aim of this work is to develop a set of detecting modules (ΔE1, ΔE2, Er), which could provide a sufficient spatial angle of detection, a high angular resolution, and unambiguous identification of the whole spectrum of reaction products transported toward the output focal plane of the COMBAS separator. Each module is a compact telescopic combination of two 32-strip coordinate (X, Y) silicon E-detectors and a scintillation CsI(Tl) E-detector composed of a 3 × 3 array of CsI(Tl) crystals, which provides a means for obtaining the timing signals from the strip detectors for TOF measurements. Special charge-sensitive preamplifiers were developed for servicing the hybrid

Si + CsI(Tl) telescope.

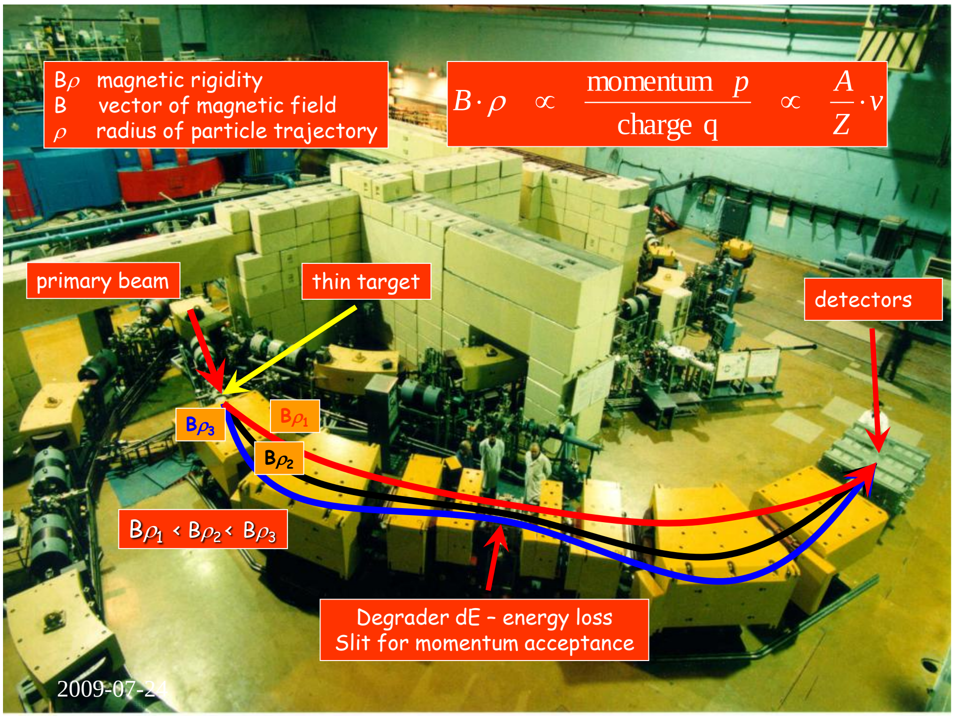

Fig.1 General view of the COMBAS fragment separator installed in the experimental hall of the U-400M cyclotron of the FLNR at the JINR.

III. Practical works

1.To acquainted fragment separators (the COMBAS separator).

2. To acquainted detectors at the COMBAS separator; semiconductor detectors (Si), scintillation detectors strip detectors.

3. Identification of the fragments generated in heavy ion collisions in the reactions performed at COMBAS separator.

4. Simulation of ΔE-E, E-TOF spectra in LISE++ code and comparison with the experimental spectra

5. To determine the interaction radii for ^{6}He, ^{8,9}Li previous measurement

The main goal of the practice is to make the students to introduce the detection techniques of charged particles at Fermi energy . During the practice students will work with detectors used at the COMBAS separator and identification spectra.

Requirements:

Basic knowledge in nuclear physics and heavy ion detection techniques. C++ programming is well seen

IV. Recommended literature

1. Artukh A.G. et al, Wide aperture kinematic separator COMBAS realized on the strong focusing principle, *Nucl. Instr. and Meth*, *A**426*** (*1999*) *605*
2. R. E. Warner et al, Total reaction and neutron-removal cross sections of (30–60)AMeV He and Li isotopes on Pb, *Phys. Rev. C* **62**, 024608.
3. M.G. Saint-Laurent et al, Total Cross Sections of Reactions Induced by Neutron-Rich Light Nuclei, Z. *Phys. A Atomic Nuclei* **332**, 457-465 (1989)