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^{8}B + ^{208}Pb Elastic Scattering at Coulomb Barrier Energies

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Abstract. The scattering process of weakly-bound nuclei at Coulomb barrier energies provides deep insights on the reaction dynamics induced by exotic nuclei. Within this framework, we measured for the first time the scattering process of the short-lived Radioactive Ion Beam (RIB) ^{8}B (S_p = 0.1375 MeV) from a ^{208}Pb target at 50 MeV beam energy. The ^{8}B RIB was produced by means of the in-flight facility CRIB (RIKEN, Japan) with an average intensity on target of 10 kHz and a purity about 25%. Elastically scattering ions were detected in the angular range $\theta_{c.m.}$ = 10°-160° by means of the detector array EXPADES. A preliminary optical model analysis indicates a total reaction cross section of about 1 b, a value, once reduced, 2-3 times larger than those obtained for the reactions induced by the stable weakly-bound projectiles ^{6,7}Li on a ^{208}Pb target in the energy range around the Coulomb barrier.

1 Introduction

Nuclei far from $\beta-$stability valley, as ^{6}He, ^{11}Be, ^{8}B, are very interesting because of their peculiarities as far as their structure and their way to interact with other nuclei are concerned, indeed during the last decades many theoretical and experimental efforts have been devoting to the investigation of halo nuclei in order to shed light on their unusual and intriguing features [1]. Nuclear collisions involving stable and unstable weakly-bound nuclei have attracted great interest nowadays. However, despite great efforts in experiments and theories over the past decades, the precise description on the influence of breakup channel on fusions is still elusive, due to the limited knowledge on the breakup process, especially for the unstable reaction systems. More knowledge in this framework can be obtained starting from the investigation of simple processes, as elastic scattering. It is well accepted by the nuclear physicists community that the presence of a proton (neutron) halo or skin may heavily influence the behavior of an exotic nucleus in terms of nuclear reaction mechanism as well as can strongly influence its structure [1] [2]. Elastic scattering, a simple process, is a very appropriate probe to study the size and surface diffuseness of exotic nuclei by comparing similarities and differences in reactions induced by weakly bound and tightly bound nuclei. Anyway, elastic scattering data for proton-halo isotopes around the Coulomb barrier are still not enough to fully understand the dynamics of this process. ^{8}B is a proton-drip-line $\beta-$decaying isotope, conveying pretty much interest because of the role it plays in the production of high-energy neutrinos in the sun and its quite unusual structure, being considered by now a one-proton halo nucleus [3]. It is a very interesting isotope since it has a very low proton separation energy, S_p = 0.1375 MeV, which makes it a very lightly bound nucleus being an ideal candidate for nuclear-reaction mechanism investigations with exotic nuclei. Furthermore, the studies on ^{8}B reaction-mechanism processes are rather exiguous due to the difficulty of producing the ^{8}B beam, being it produced only in very few facilities and anyhow with low intensities [4] [5] [6]. In

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this paper we report new experimental data for the elastic scattering of ^{8}B on a ^{208}Pb-target, at 50 MeV, which means just on the Coulomb barrier, showing very preliminary data results.

2 Experimental setup and data analysis

The radioactive beam ^{8}B at 50 MeV (6,25 A MeV) has been produced via the reaction ^{3}He(^{6}Li,^{8}B)n (Q_{value} = −1.97 MeV) at the facility CRIB [7], situated at the RIKEN laboratory in Japan. The primary beam of ^{6}Li had an intensity of 3eμA, and a cryogenic ^{3}He−target with pressure of 1 bar and a typical temperature of 90 K was used. The secondary beam had an intensity (on target) of 10^{4} pps and a purity of 20% consistent with the expected one, being the main contaminants ^{7}Be and ^{3}He, besides the ^{6}Li scattered beam. Anyhow all the contaminants had different times of flight through the separator and then it was possible to separate events coming from the various components of the beams by using proper gates in the ToF spectra. Charged products arising from the reaction of the ^{8}B beam impinging on a 2.2 mg/cm^{2} ^{208}Pb target (evaporated on a 1.5 μm thick mylar backing foil) were detected with the detector array EXPADES [8] utilized in a configuration consisting of 6 $\Delta E - E_{res}$ double-sided silicon-strip detectors, placed at 113 mm from the center of the ^{208}Pb target in a slightly asymmetric configuration such to ensure the whole angular-coverage ranging from 16° till 164° in the laboratory frame. In Fig.1 a very preliminary evaluation of the angular distribution for the elastic scattering process in the system ^{8}B+^{208}Pb is shown, where each of the four plotted points corresponds to the angular-range mean placement of the EXPADES detectors. The

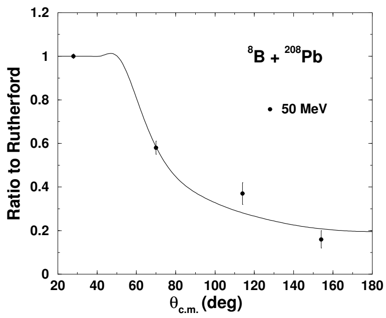

Figure 1. Preliminary elastic scattering angular distribution for the system ^{8}B+^{208}Pb at 50 MeV beam energy. The continuous line is the result of the optical model analysis of the collected data

experimental data have been normalized with a Monte-Carlo simulation accounting for the detector-geometry and the elastic-scattering of the process, whereas the simulated events have been generated according to a pure Rutherford cross-section. The continuous line represents the result of an optical model best-fit analysis (FRESCO code). In this way we could extract a −preliminary− evaluation of the reaction cross-section for the system ^{8}B+^{208}Pb at 50 MeV beam energy.

In Fig.2 the reaction X-sections for the systems ^{6,7}Li, ^{7}Be and ^{8}B +^{208}Pb in the energy range around the Coulomb barrier are shown [10], [11] and [12]. The data for the different systems have been reduced as reported in ref. [8] and multiplied by a normalization factor of the ^{7}Be+^{208}Pb reaction, in order to be comparable with each other. It seems, even if the data analysis is in the first stages of its route, that the reaction induced by the one-proton halo nucleus ^{8}B (S_p =0.1375 MeV) on the ^{208}Pb target has a total reaction X-section much larger than those measured for reactions induced by other weakly-bound isotopes on the same target.

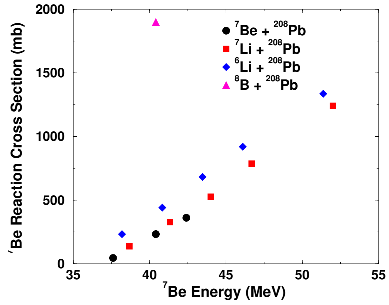

Figure 2. Reaction X-sections for the systems ^{6,7}Li, ^{7}Be and ^{8}B +^{208}Pb (see [10], [11] and [12]). The data were reduced according to the procedure recommended in [8] and then normalized to the system ^{7}Be +^{208}Pb

3 Discussion and outlook

This is to some extent consistent with the outcome for reactions induced by the same projectiles on ^{58}Ni [3]. If this will be confirmed, the data analysis will hopefully allow us to disentangle which mechanism, direct processes (such as break-up and/or transfer) or fusion, is responsible for accounting such large X-section value.

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