ELASTIC SCATTERING OF ^{8}He + ^{208}Pb AT 22 MeV*

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The dynamics of ^{8}He around the Coulomb barrier is investigated by measuring the energy and angular distribution of the elastic ^{8}He and the ^{6}He and ^{4}He fragment yields in the collision process with a ^{208}Pb target. The experiment was carried out at SPIRAL/GANIL in October 2010. The experimental results will provide information about the relevant reaction mechanisms and the validity of the optical model (OM) when applied to exotic nuclei. In this paper, details of the experimental setup and preliminary results on the elastic scattering for the collision at 22 MeV are presented.

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1. Introduction

The particular features of ^{8}He have made its scattering with heavy targets attractive for the scientific community. ^{8}He is the lightest skin nucleus and it has the largest neutron-to-proton ratio of the particle-stable nucleus. Only a few scattering data sets at barrier energies are presently available [1, 2] and there is still a lack of information concerning collective aspects as characteristic nuclear excitations, coupling between different reaction channels and neutron-core correlations.

Compared with ^{6}He, previously studied by the collaboration [3–5], ^{8}He has more neutrons of valence but more tightly bound and its binding energies for $1n$ and $2n$ systems are similar whereas in the ^{6}He the two-neutron breakup is energetically favored. The differences between both helium isotopes are expected to be reflected in the elastic and reaction cross sections for collisions with heavy targets at Coulomb barrier energies.

This work is focused in the experimental results for the elastic scattering, up to 95°, of ^{8}He+^{208}Pb at 22 MeV, and its comparison with those obtained for ^{6}He with the same target at the same energy.

2. Experimental setup

The experiment was performed in the G21 line at the SPIRAL/GANIL facility in Caen (France), where high quality beams of exotic ^{8}He were produced at 18 and 22 MeV. The experimental setup consisted of a portable reaction chamber were the silicon array was mounted, with a dedicated set of collimators and a beam diagnostics system for driving the radioactive beam through the detection system. The target, a self-supported foil of ^{208}Pb with a thickness of 1 mg/cm^2, was introduced inside the silicon array tilted 30° in order to avoid the shadowing of the detectors and allowing the detection of particles around 90° (detailed description can be found in Ref. [6]).

The detection system, called GLORIA (GLObal ReactIon Array), has been developed at the University of Huelva with the aim of studying the structure and dynamics of light exotic nuclei using nuclear reactions. GLORIA consists of 12 DSSSD detectors arranged in 6 particle telescopes, each of them made of a first 40 μm stage (ΔE detector) and a second 1 mm stage (E detector). It has been designed in such a way that it ensures the measurements in a continuous angular range between 15° and 165°, with no gaps, covering an overall solid angle of 26.1% of 4π.

3. Experimental results

The experimental results obtained for the elastic scattering of ^{8}He on a ^{208}Pb target at 22 MeV are shown in Fig. 1 in black/red filled squares. The depicted points correspond to the three first telescopes of the GLORIA array (the two forward ones and the top one) thus convering up to 95°. The data set has been normalized to the corresponding Rutherford cross section. For comparison, the ^{6}He+^{208}Pb [3, 4] scattering system at the same energy is plotted in gray/green circles.

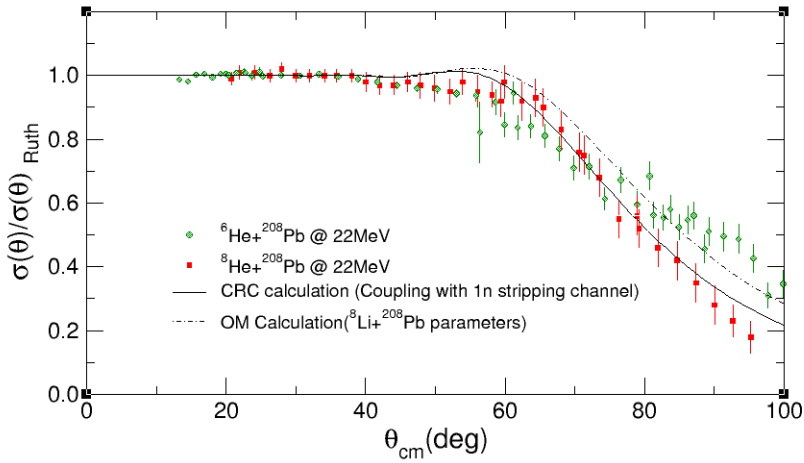

Fig. 1. Angular distribution of the elastic cross section for the systems ^{8}He+^{208}Pb and ^{6}He+^{208}Pb, both at $E_{\rm lab} = 22$ MeV. See the text for details.

For ^{6}He, the elastic cross section decreases in a smooth way, losing the characteristic Coulomb-nuclear rainbow of the Fresnel type interference pattern of light stable nuclei at this energy regime.

In order to obtain the angular distribution of the elastically scattered ^{8}He, a strong effort has been made to properly assign the scattering angles and to calculate the solid angle subtended by each pixel of every telescope. Regarding this distribution, the elastic scattering of ^{8}He follows the trend of ^{6}He up to about 70°, being evident that the Coulomb-nuclear rainbow again disappears. At more backward angles, the absorption is even stronger for ^{8}He than for ^{6}He. The distribution of elastic ^{8}He has been compared with two calculations. For the one shown in the figure with a dot-dashed line, an OM calculation, the entrance and exit channel optical potentials used the ^{8}Li+^{208}Pb parameters of [7] for $E_{\rm cm} = 33$ MeV, a similar energy with respect to the Coulomb barrier as for the current ^{8}He+^{208}Pb data. Moreover, a coupled reaction channels (CRC) calculation (solid line), has been

performed by means of the FRESCO code [8]. It was used as a first approach a bare interaction consisting of the former ^{8}Li+^{208}Pb optical potential plus the couplings to the ^{208}Pb(^{8}He,^{7}He)^{209}Pb single neutron stripping, where the $\langle ^{8}\mathrm{He}|^{7}\mathrm{He}+n\rangle$ and $\langle ^{209}\mathrm{Pb}|^{208}\mathrm{Pb}+n\rangle$ overlap form factors were taken from [9] and [10], respectively. The comparison of these calculations reveals the importance of the coupling with the $1n$ stripping channel for ^{8}He, producing a reduction on the elastic cross section as compared with the results of a simple OM calculation using the previous ^{8}Li+^{208}Pb optical potential.

4. Summary and conclusions

The elastic scattering of ^{8}He+^{208}Pb has been measured at 22 MeV at SPIRAL, GANIL (Caen, France) using GLORIA, a new detector array which consists of six particle telescopes (40μm ΔE, 1mm E) and has demonstrated an excellent performance separating clearly the elastic ^{8}He as well as the ^{6,4}He production channels.

The angular distribution of the elastic channel follows the trend found for the ^{6}He+^{208}Pb system, losing the Coulomb-nuclear rainbow, up to the grazing angle, where the absorption becomes greater. The comparison of the experimental data with the presented calculations shows the importance of the coupling with the $1n$ stripping channel which produces a reduction in the elastic cross section.

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