ELASTIC SCATTERING FOR THE ^{11}Be+^{64}Zn SYSTEM CLOSE TO THE COULOMB BARRIER*

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The quasi-elastic scattering angular distribution of the collision ^{11}Be + ^{64}Zn was measured and compared with the elastic scattering angular distribution for its core, the ^{10}Be nucleus on the same target. Optical model and continuum-discretized coupled-channel calculations of the ^{11}Be+^{64}Zn reaction were performed in order to interpret the effect of coupling with the break-up channels on the measured cross-sections.

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1. Introduction

Elastic scattering and direct reactions around the barrier, in collisions induced by halo nuclei, has been the object of many publications in the last years, see *e.g.* [1–3]. Elastic scattering, being a peripheral process, allows one to investigate the surface properties of the halo nuclei. The various experiments performed using the halo ^{6}He nucleus on several targets at low bombarding energy have shown that coupling to the continuum strongly affects the elastic cross-section, especially on heavy targets, with dramatic changes in the elastic cross section from the expected behavior (*e.g.* Refs. [4, 5]) and with an overall increase in the total reaction cross section in favor of direct reaction channels. Taking advantage of the availability of a post-accelerated ^{11}Be beam at REX-ISOLDE we have measured a high quality quasi-elastic scattering angular distribution (a.d.) for $1n$-halo ^{11}Be nucleus [6, 7]. Here we report the results on the quasi-elastic a.d. for ^{11}Be on ^{64}Zn along with a comparison of the elastic scattering a.d. of its core the ^{10}Be nucleus. The theoretical analysis performed on the data will be also discussed.

2. Results and discussion

The experiment was performed using the post-accelerated ^{10,11}Be radioactive beams of REX-ISOLDE at CERN. The energy of the ^{10}Be beam was chosen in order to have the same center of mass energy of the ^{11}Be + ^{64}Zn system. The apparatus, used to detect the light charged particles produced in the reactions, consists of an array of 6 two stage Si-detector telescopes. The ΔE stage consists of a 40 μm, 50×50 mm^2 DSSSD detector and the E stage consists of a Si Single Pad detector. In Fig. 1 (a), a comparison of the extracted elastic scattering a.d. for ^{10}Be+^{64}Zn and the quasi-elastic scattering a.d. of ^{11}Be+^{64}Zn is shown. As one can see from Fig. 1 (a), the ^{10}Be a.d. shows a classical diffraction behavior. On the contrary, the ^{11}Be scattering data show a very different pattern. The quasi elastic cross-section is suppressed at all measured angles. In particular, the main feature that one can observe is the strong suppression of the elastic cross-section starting at small scattering angles. In order to understand the origin of such absorption, we have performed an analysis of the data using the Optical Model (OM) framework. For ^{10}Be a Woods–Saxon (WS) form of the real and imaginary potential was used. In the ^{11}Be case two types of OM analysis have been performed. In the first calculation, the volume part of the OM potential, responsible for the core-target interaction, was taken from the OM fit of the elastic-scattering of the core ^{10}Be on ^{64}Zn. In order to account for the presence of long-range couplings, we have considered in addition to the imaginary volume potential a phenomenological surface potential having the shape of a WS derivative. The effect of such term, as one

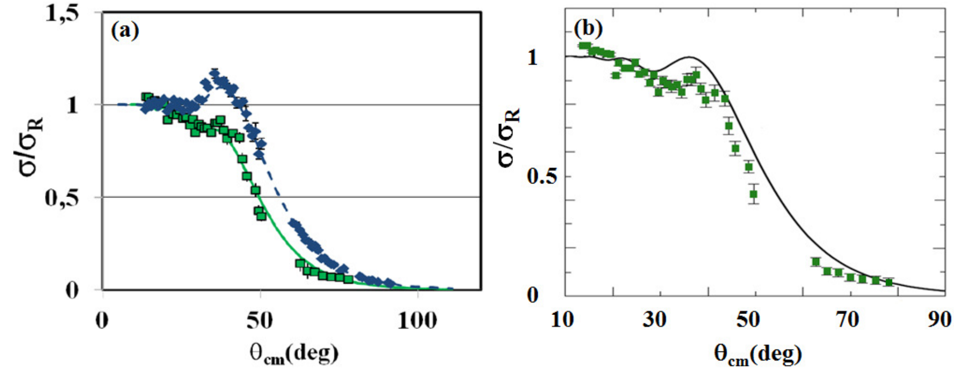

Fig. 1. (a) Quasi-elastic scattering a.d. for the ^{11}Be+^{64}Zn system (squares) and elastic scattering a.d. for ^{10}Be+^{64}Zn (diamonds). The solid lines represent the results of the OM analysis. (b) ^{11}Be+^{64}Zn quasi-elastic scattering a.d. (symbols). The curve represents the result of the OM calculation (see the text for details).

can see in Fig. 1 (a), where the results of the calculations are shown together with the experimental data, is to reduce the scattering cross-section at all measured angles and, in particular, in order to reproduce the behavior of the elastic cross-section at forward angles a very large surface diffuseness, 3.5 fm, is needed. This large diffuseness confirms the presence of long range absorption mechanisms in the case of the halo nucleus. The second type of OM analysis was done considering in addition to the ^{10}Be+^{64}Zn volume potential, in place of the phenomenological surface term, an analytic potential that takes into account the coupling to the excited states of the projectile arising from the dipole part of the Coulomb interaction [8]. The result of this calculation is shown by the solid line in Fig. 1 (b). As one can see, adding the dipole Coulomb couplings to the bare potential produces a strong reduction in the elastic cross section. However, the magnitude of this reduction is not sufficient to reproduce the measured data. This result suggests that long-range nuclear couplings must also contribute to the further reduction in the elastic cross section at large distances.

In order to explicitly take into account the excitations of the ^{11}Be nucleus to its continuum states, we have performed Continuum Discretized Coupled Channel (CDCC) calculations. In Fig. 2, we compare the measured quasi-elastic a.d with the calculations. The solid line represents the full CDCC calculation. The dotted line is the calculation omitting the coupling to the continuum states and including only the ground state and the first excited state of ^{11}Be. The inclusion of the coupling to the break-up channels, as one can see from the comparison, has a considerable influence and produces an important reduction in the elastic cross-section at small angles. This result confirms that the large coupling effect seen in the measured a.d. is due to the coupling to the continuum. In order to disentangle the relative contribution of the Coulomb and nuclear couplings to the elastic cross section, we have also performed two additional CDCC calculations, including only either nuclear or Coulomb break-up. The results of these calculations are depicted in Fig. 2 by the dashed and dotted-dashed lines. As one can see, the Coulomb coupling only is not sufficient to explain the behavior of the measured angular distribution and the nuclear coupling is fundamental to reproduce the damping of the elastic cross-section at small angles, thus confirming our previous finding with the OM calculations.

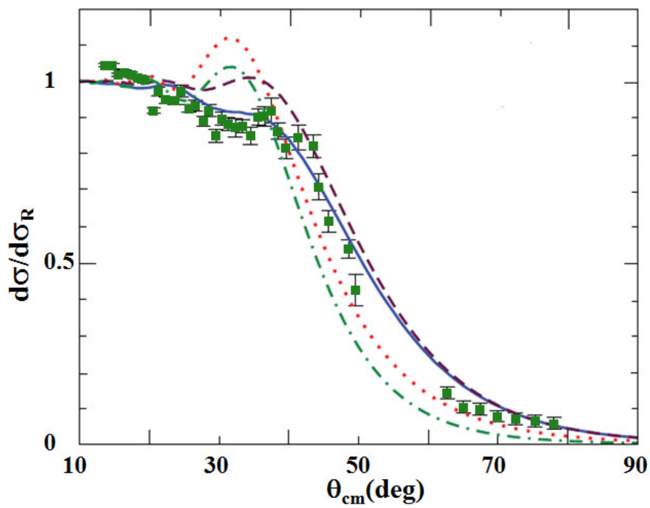

Fig. 2. Quasi-elastic a.d. measured in the present experiment (symbols) and CDCC calculations. See the text for details.

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