Elastic scattering of ^{9}Li on ^{208}Pb at energies around the Coulomb barrier

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Abstract. We have studied the dynamical effects of the halo structure of ^{11}Li on the scattering on heavy targets at energies around the Coulomb barrier. This experiment was performed at ISAC-II at TRIUMF with a world record in production of the post-accelerated ^{11}Li beam. As part of this study we report here on the first measurement of the elastic cross section of the core nucleus, i.e. ^{9}Li on ^{208}Pb, at energies around the Coulomb barrier. A preliminary optical model analysis has been performed in order to extract a global optical potential to describe the measured angular distributions.

Keywords: Elastic scattering, large angular coverage, halo nuclei, DSSSD detectors
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The availability of unstable radioactive beams accelerated at different energy regimes have open up new physics opportunities based on the interplay of nuclear structure and reaction dynamic effects. In particular the discovery of the halo nuclei has brought renewed interest in the modeling of nuclear reactions since for the very loosely bound systems the reaction model should include the coupling between the bound states and the continuum. The fact that the system is loosely bound gives rise to an increase in the breakup cross section, proportional to the reduction of binding energy, but also changes in other observables including elastic scattering due to the distortion (dipole polarizability) of the loosely bound projectile in the presence of the strong electric field of a heavy target.

The purpose of our work was to study the reaction of halo nuclei on the strong Coulomb field of the target at energies around the Coulomb barrier to assess the relevant reaction mechanisms. A ^{208}Pb target was chosen due to its double magic character and its high Z number (Z=82). The large Z guarantees that ^{11}Li - lead scattering would be

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dominated by Rutherford scattering if ^{11}Li was a normal compact nucleus. The fact that it is a halo nucleus results in departures from Rutherford scattering and this deviation can shed light on the nuclear halo. To isolate the halo effect it is crucial to determine the dynamic behaviour of the core, ^{9}Li, in the same conditions. The energies were chosen such that the absolute energy of the ^{9}Li fragments and the ^{11}Li fragments were the same.

We report here on the elastic scattering of ^{9}Li on ^{208}Pb at energies below (24.0 MeV), around (29.4 MeV) and above (33.0 MeV) the Coulomb barrier. An optical model analysis has been performed with the aim of extracting an overall optical potential for the three measured energies. Although similar studies have been done for ^{6}He (see [1] and references therein) and for ^{9}Li on ^{208}Pb well above the Coulomb barrier [2], this is the first measurement of the scattering of the two-neutron halo nucleus ^{11}Li and its core, ^{9}Li, around the Coulomb barrier.

Experimental Set-up, Analysis Method and Results

The experiment was performed at TRIUMF. The radioactive beams of ^{9}Li and ^{11}Li produced in a Ta target were transported to the ISAC-II facility for post acceleration. The detection system contained 4 particle telescopes around the scattering target covering the following angles: T1: 10°- 40°, T2: 30°- 60°, T3: 50°-100° and T4: 90°- 140°. The choice of the angles covered by the telescopes was determined by the behaviour expected for the differential cross section for elastic scattering of the halo nucleus ^{11}Li according to a coupled-channels calculation which includes both nuclear and Coulomb couplings to the continuum. The target thickness was 1.45 mg/cm^2 for 2.67 and 3.27 MeV/u ^{9}Li beam energies and 1.9 mg/cm^2 for 3.27 and 3.67 MeV/u ^{9}Li beam energies. The target was tilted 75° with respect to the beam axis.

Elastic events were selected in the two-dimensional plot, the ΔE versus E mass spectra. A clear identification of the elastic peak, both in the ^{9}Li and in the ^{11}Li scattering data is achieved. Data were analyzed first assuming that the detectors T1 and T2 were at the position determined by the geometrical measurements and the beam centered in the Pb target. This allowed for an assignment of the scattering angle for each pixel of the DSSSD detectors. Due to the close geometry of the setup final tuning of the geometry was needed to assure a flat behaviour of the elastic cross section dividied by Rutherford at forward angles.

The extracted differential elastic cross sections shown in Fig. 1 have been compared with optical model (OM) calculations in which the projectile-target interaction has been parametrized with a standard Woods-Saxon shape, with real and imaginary parts. Due to the lack of previous experimental data for ^{9}Li scattering on heavy targets in this energy regime, we considered initially the potential reported in Ref [3], which reproduces the elastic scattering data for the ^{7}Li+^{208}Pb reaction at 33 MeV. This parametrization uses a common geometry for the real and imaginary parts, with radius r_0=r_i=1.3 fm and diffuseness a_0=a_i=0.65 fm (labeled “set 1” in Fig. 1). This geometry was found to be inadequate to describe the present data, so we have performed a χ^2 best–fit analysis in which the potential parameters were allowed to vary in order to minimize the χ^2 for the data at 3.27 and 3.67 MeV/u data, for which we expect a larger sensitivity with respect to

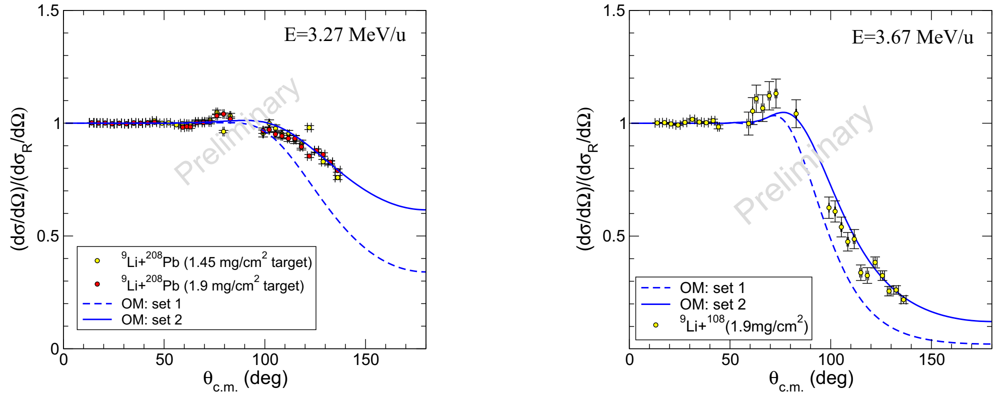

FIGURE 1. Measured differential elastic cross sections for the ^{9}Li+^{208}Pb reaction at E_{lab}=3.27 MeV/u (left panel) and 3.67 MeV/u (right panel). The solid and dashed lines are the optical model calculations described in the text.The large Fresnel interference shown by the data at the highest energy (3.67 MeV/u) requires further investigation.

the nuclear potential. As a result of this analysis, we obtained the values: V_0=15.1 MeV, r_0=1.15 fm, a_0=0.95 fm, W=58.7 MeV, r_i=1.19 fm, and a_i=0.51 fm (labeled "set 2" in Fig. 1). This analysis should be consider preliminary, since both the experimental and theoretical analyses are in progress. A more detailed analysis will be presented elsewhere.

SUMMARY AND OUTLOOK

The elastic scattering of a exotic ^{9}Li beam on a ^{208}Pb target has been measured at three different energies, 2.67, 3.27 and 3.67 MeV/u. For the lowest energy, which is below the nominal Coulomb barrier, the extracted cross section is consistent with an almost pure Rutherford scattering. For the two other energies, the measured angular distribution follows the Rutherford formula for scattering angles up to 45°. The data for these two energies have been compared with optical model calculations. Initially, we considered the optical model potential derived in Ref. [3] from the analysis of the elastic scattering of ^{7}Li by ^{208}Pb at Coulomb barrier energies. This potential proved to be inadequate to describe the present data. With the idea of extracting a global optical potential for the measured energies, we performed a best–fit analysis of the data starting from the above mentioned potential, but allowing the depth and geometry to vary. The resulting potential provides a reasonably good overall agreement of the three angular distributions. Although a more refined analysis is still to be done, this kind of potentials will be an essential ingredient for the few-body calculations that will be eventually performed for the ^{11}Li+^{208}Pb elastic and breakup data measured in the same experiment.

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