Elastic Scattering of the halo nucleus ^{11}Li and its core ^{9}Li on ^{208}Pb at energies around the Coulomb barrier

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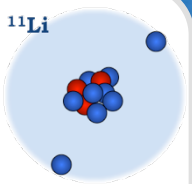
Introduction

The halo structure affects the reaction properties at near Coulomb barrier energies. As for the very loosely bound system the model space should include the coupling between the bound states and the continuum.

The ^{11}Li is the archetype of halo nucleus formed by a ^{9}Li core and two loosely bound neutrons (S_{2n}=369.15 (65) keV [1]). Due to the loosely bound structure, the neutron halo should be easily polarizable in the strong electric field of a heavy target. So at energies below the Coulomb barrier the elastic scattering will depart from Rutherford scattering. This deviation can shed light on the structure of the ^{11}Li nucleus and it can give a hint on how the scattering process depends on the coupling to the continuum.

In order to disentangle the contribution of the loosely bound structure of ^{11}Li to the reaction process, one should know the behaviour of the core, ^{9}Li, in the same conditions. No data exists for the scattering of ^{11}Li near the Coulomb barrier and for the scattering of ^{9}Li the data are scarce.

To study these effects we have performed an experiment in ISAC II (Isotope Separator and Accelerator) at TRIUMF laboratory in Vancouver, Canada, to measure the elastic and breakup cross-sections of ^{11}Li on ^{208}Pb at energies below and around the Coulomb barrier. And the core ^{9}Li at the same centre of mass (CM) energy.



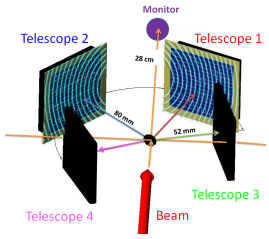
Reaction mechanism and Nuclear effects of halo nuclei need to be understood

Experimental Set-up

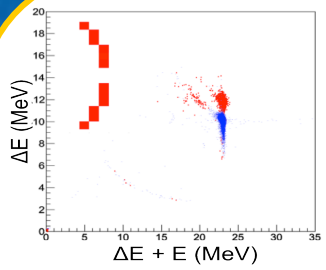
We used a set of four telescopes with angular coverage from 10º to 140º. The forward telescopes, T1 and T2, consisted of 40 µm DSSSD detector in front with a 500 µm Silicon PAD in the back. The backward telescopes had a very thin 20 µm SSSD detector in front and 60 µm DSSSD detector behind to be able to separate in energy and mass the contribution for the elastic ^{11}Li scattering and the breakup product, ^{9}Li nuclei. In total 1024 micro-detectors were analysed. The angular coverage per pixel was 2-3º for T1 and T2 and for the telescopes T3 and T4 between 3-4º.

This configuration gave rise to large angular coverage with high resolution.

We selected the double magic nucleus, ^{208}Pb, as target due to its structural stability. The target thickness chosen were 1.45 and 1.9 mg·cm^{-2} as compromise between sufficient statistics and extra broadening due to the straggling. The ^{11}Li beam was up to 6000 Hz, with an average of 4000 ion/s.



Data Analysis



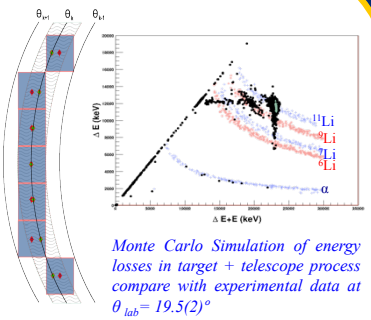
The ^{9}Li (in blue) and the ^{11}Li +^{208}Pb (in red) scattered data at the same CM energy of 23.0 MeV.

The cross section of a ^{11}Li beam on a 1.45 mg/cm^2 thick ^{208}Pb target was measured for first time in this work at energies around the Coulomb barrier, at 24.2 and 29.7 MeV. To characterize the behaviour of the core, the ^{9}Li + ^{208}Pb scattering was measured with the same setup and at the same CM energies of 23.0 and 28.2 MeV.

The events were selected in the following way. Individual thresholds were chosen for each strip. A time condition selected by the TDC was applied. When two neighbour strips were fired the event was disregarded to avoid charge sharing.

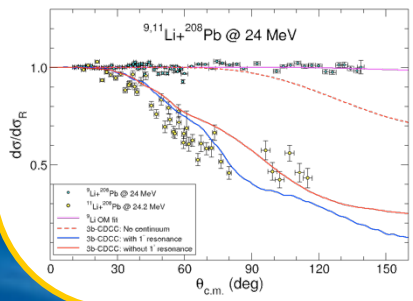
Due to the close geometry of the setup, the geometrical determination of the angle subtended by each pixel for telescopes T1 and T2 was further refined using the fact that the elastic scattering of ^{9}Li on ^{208}Pb at energies below the barrier should follow the Rutherford behaviour at forward angles.

Elastic events were selected in the two-dimensional plot of ΔE versus ΔE + E energy spectra for each pixel. A clear identification of the elastic peaks and fragments, both in the ^{9}Li and in the ^{11}Li scattering data was achieved.



Monte Carlo Simulation of energy losses in target + telescope process compare with experimental data at θ_{lab}= 19.5(2)°

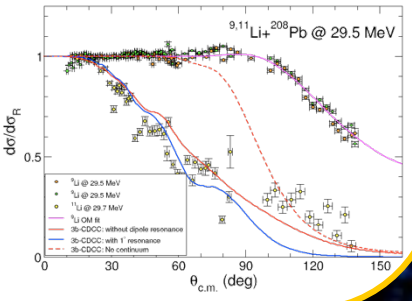
Differential elastic cross section of ^{9}Li & ^{11}Li on ^{208}Pb



Results and Discussion

- The experimental data for the elastic scattering of ^{11}Li + ^{208}Pb display a strong reduction with respect to Rutherford, over the whole angular range, at both energies. In contrast to the behaviour of the data for ^{9}Li, which behaves as a *normal* nucleus.
- The special behaviour of ^{11}Li is associated to the effect of Coulomb Dipole Polarizability [2]. The weakly bound ^{11}Li, in the strong Coulomb field of the target, gets distorted and eventually breaks up
- These data have been compared with CDCC calculations assuming a two-body model for ^{11}Li (^{9}Li+2n) and using for the ^{9}Li+^{208}Pb interaction the potential deduced from ^{9}Li data [3,4,5]. The inclusion of a 1$^-$ resonance in ^{11}Li has been considered and improves greatly the agreement with the data.

Differential elastic cross section of ^{9}Li (^{9}Li) & ^{11}Li on ^{208}Pb



Summary and Outlook

- We present here the first measurement of the elastic scattering of the halo nucleus ^{11}Li and its core ^{9}Li on ^{208}Pb at energies below and around the Coulomb barrier .
- The ^{9}Li + ^{208}Pb scattering data behave with the angle as expected.
- The strong reduction of the ^{11}Li + ^{208}Pb elastic cross section observed both below and around the Coulomb barrier, along with the increase in the break-up cross section, depends strongly on the Coulomb dipole coupling of the ground state to low energy continuum states in ^{11}Li. The inclusion of the low resonance 1$^-$ state in ^{11}Li improves the agreement with the data considerably.
- A consistent analysis of the elastic and the break-up differential cross sections is currently in progress.

References

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