^{8}Li+ resonant elastic scattering: a tool to study cluster states in ^{12}B

^{8}Li+α resonant elastic scattering: a tool to study cluster states in ^{12}B

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Abstract. The ^{8}Li+^{4}He elastic scattering excitation function was measured by using the inverse kinematic thick target method. The ^{8}Li beam was provided by the LNS radioactive facility EXCYT at an energy of 30 MeV and it was delivered into a large scattering chamber filled with ^{4}He gas. The detection system was made by three silicon telescopes and one MCP. This last detector was used to measure the number of incident particles as well as the time of flight allowing for the discrimination between elastic and inelastic scattering. The setup and the experimental technique will be described in details and the results, as well as the comparison of the data with an R-matrix calculation, will be shown and discussed.

1. Introduction

One of the interesting topics that can be explored by radioactive beams is the exotic clustering. In this type of clustering nuclei are described as formed by two or more clusters where, at least one of them, is an exotic nucleus itself.

Studying the structure of neutron rich nuclei, Kanada En'yo and collaborators [1] performed calculations in the Antisymmetrized Molecular Dynamics (AMD) framework in order to describe the structure of odd Boron isotopes. Calculations show how the cluster structure becomes more evident and more exotic with the increasing of neutron number in the case of boron isotopes. For instance, the structure of the ^{19}B ground state can be described with a very exotic dinuclear configuration ^{11}Li-^{8}He, while the less neutron rich ^{13}B shows a single particle behavior. Analogous predictions concern also the even isotope ^{12}B. A calculation using the Generator Coordinate Method (GCM) has been performed by Descouvemont [2]. In this study the presence of a positive parity band with a large reduced width for α-decay, located just above the α-decay threshold, supports the picture of a α-^{8}Li cluster configuration for ^{12}B.

In this paper it will be described an experiment aimed to the study of the resonant elastic scattering of a ^{8}Li beam on a ^{4}He target by using the Thick Target Inverse Kinematic elastic

scattering method (TTIK) [3, 4, 5].

2. The technique

The TTIK method has been used in order to investigate the α-^{8}Li structure of ^{12}B in the excitation energy range between 13.5 MeV and 19.6 MeV. In this technique the thick ^{4}He gas target has a threefold role. It acts at the same time as a degrader, as a target and as a shield for the detector that can be placed along the beam direction. Passing through the ^{4}He gas, the beam decreases its energy down to zero, hence the elastic scattering is induced in a continuous range of energies between the initial beam energy (30.6 MeV) and zero. While the heavier ^{8}Li beam is stopped inside the target the recoiling α particles, owing to their lower stopping power, reach the detectors placed at forward angles (backward angles in center of mass (CM) system).
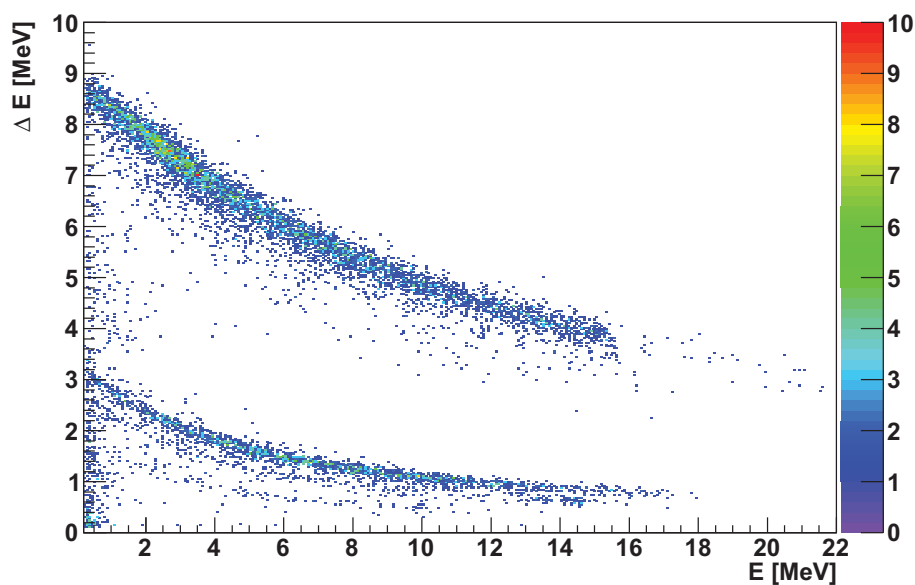

Figure 1. E versus ΔE plot for the telescope at $0°$ showing the separation of α-particles from hydrogen isotopes.

The ^{8}Li beam delivered at an energy of 30.6 MeV was produced by the radioactive beam facility EXCYT of INFN-LNS [6]. EXCYT uses the ISOL technique taking advantage of a K-800 superconducting cyclotron as a driver, and of a 13 MV Tandem for post-acceleration of the radioactive beams. Before entering the scattering chamber, the beam passes-through the aluminized Mylar foil (0.8 μm thick) of a Micro Channel Plate (MCP) detector. This last provides a reference signal for time measurements and, at the same time, allows for counting the beam particles ($\sim$5·10^4 pps). After the MCP detector, the ^{8}Li beam passes through a kapton foil (13μm thick) that separates the beam line from the CT2000 scattering chamber filled with ^{4}He enriched gas at a pressure P$\sim$700 mbar and temperature T$\sim$294 K. The recoiling α particles are detected by an array of three Silicon ΔE-E telescope detectors that are placed at forward angles θ=-5°, 0°, +5° with respect to the center of the chamber, $\sim$180 cm far from the entrance of the chamber. The first stage of the telescope is made by four-quadrant-Silicon-Pad detectors (50-60 μm thick) while the second stage is made by Double-Sided-Silicon-Strip-Detectors (DSSSD) 500-1000 μm thick. An experimental limitation of the TTIK method is represented by the

contribution of other possible reaction mechanisms to the detected α spectrum. For example inelastic scattering if the center-of-mass energy is high enough to open the inelastic channel. Two α-particles can be detected with the same energy if one comes from an elastic event occurred in a given position of the chamber whilst the second one comes from an inelastic event occurred in a different position of the chamber. Thus, it is not possible to disentangle α coming from elastic and inelastic scattering, looking just at the detected energy of the α-particle.

This difficulty was overcome with by improving the technique with the time of flight measurement. The time elapsed between the ^{8}Li passing through the foil of the MCP and the detection of α particles was measured. In this case α-particles detected with the same energy but originated from different processes have different time of flight (ToF). Thus, in this way it is possible to discriminate elastic from inelastic events.

3. Analysis
In the following the results obtained from the most forward telescope ΔE-E, placed at $\theta_{lab}=0°$ with respect to the beam direction will be described. For this telescope, the ΔE nominal thickness is 47 μm. The ΔE-E plot is shown in Fig. 1. In this plot it is possible to notice that the α-particles are well separated from hydrogen isotopes. We can also see the presence of a large yield of tritons, coming most probably from the break-up channel ^{8}Li $\rightarrow$ ^{4}He+t+n+4.5 MeV.
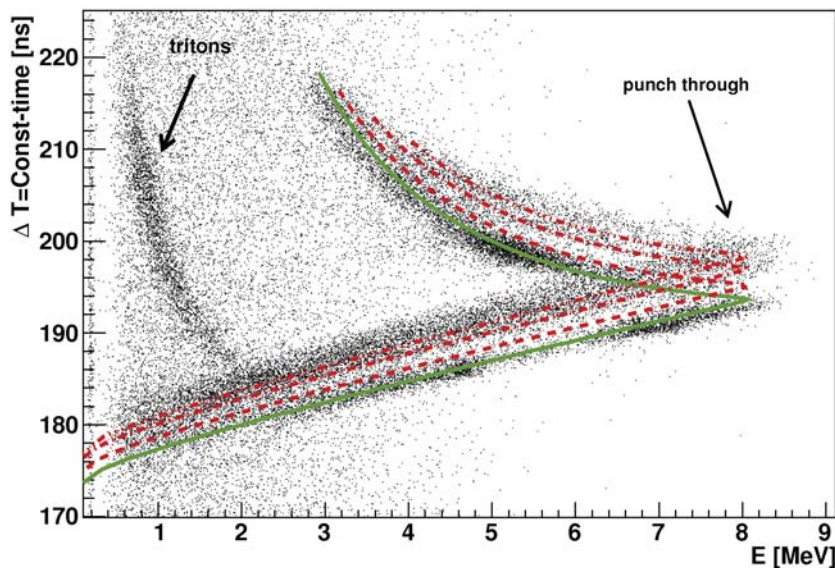

Figure 2. ToF versus ΔE plot for the detector at 0°. Continuous line is a calculation for the elastically scattered α-particles. Dotted lines correspond from bottom to the top respectively to the inelastic scattering for the three first excited states of ^{8}Li.

In Fig. 2, the ToF is shown as a function of the energy deposited in the ΔE detector. The lines are calculations of the ToF as a function of the detected energy both for the elastic and inelastic scattering corresponding to ^{8}Li first three excited levels. The calculation includes the kinematics, energy losses of ^{8}Li and α-particles in ^{4}He gas and energy losses of α-particles in the entrance dead layer of the detector. It can be seen that the calculated locus of the elastic

events is in agreement with the data. As regards the inelastic events, we can notice that the inelastic scattering corresponding to the first excited state of ^{8}Li is scarcely populated. As one can observe, the elastic events are clearly distinguished from inelastic events.

A source of background comes from the ^{8}Li decay in two α (^{8}Li$(\beta^-) \to$ ^{8}Be$^* \to 2\alpha$). The life time of ^{8}Li is 838 msec, for this reason the α particles are uncorrelated in time and hits the detectors at random time. The background of uncorrelated in time α-particles that ranges up to 5 MeV was taken into account and subtracted from the elastically scattered α particles.

For the events which stop in the ΔE detector the elastically scattered α-particles have been selected by a graphical cut on the plot ToF-ΔE. While for particle stopping in the E stage of the telescope it is possible to make a selection of the α particle locus from the ΔE-E plot and then select the elastically scattered α-particles from the ToF-E plot.

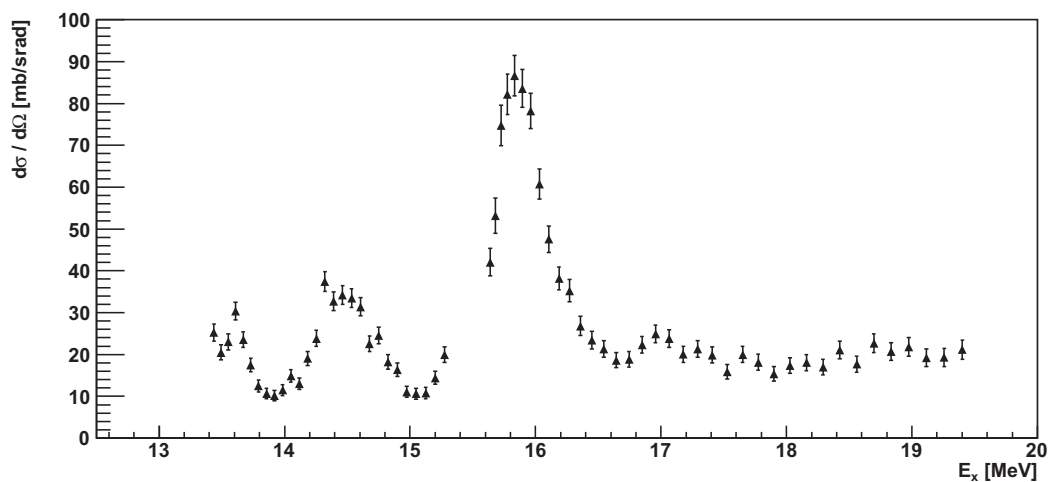**Figure 3.** Elastic scattering differential cross section for most forward angles ($\sim 180°$).

In order to reconstruct the elastic scattering excitation function from the spectrum of the detected α-particles it is required a precise knowledge of the stopping power of ^{4}He for ^{8}Li and α. For this reason during the same experiment a measurement of the stopping power was also performed.

The elastic scattering excitation function extracted for the telescope placed at $0°$ degree is shown in Fig. 3 and it manifests different structures. The analysis of the excitation functions was performed using an R-matrix approach. In order to simplify the problem the approximation of spin zero for ^{8}Li was considered. In this case, the spin of each level J is equal to the relative angular momentum l. In order to fit the data seven resonances were used. An additional background resonance at higher energy was introduced to fit the long tail in the high energy region. For the data fitting, the R-matrix calculation was convoluted with the experimental resolution function. The ^{8}Li$+\alpha$ excitation function is reproduced rather well by the R-matrix calculations as shown in Fig. 4. Some of the resonances was previously known [7, 8].

The reduced α-widths of the seven resonances used to perform the fit were calculate and their low values (less than 5%) indicate that there is no clear evidence of α-cluster configurations associated to the observed resonances.
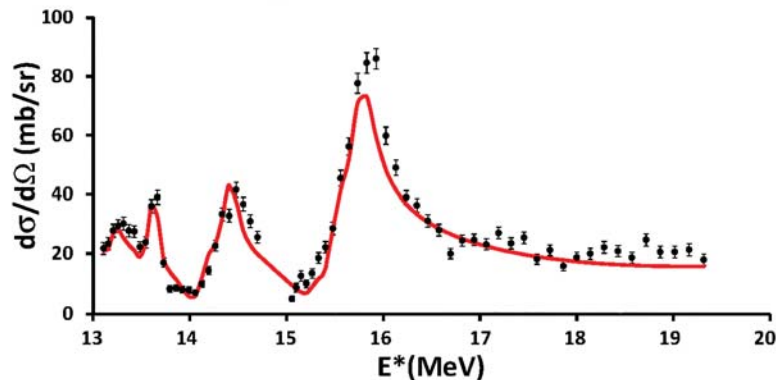
Figure 4. The elastic scattering cross section experimental data are shown as full circles, the solid red line is the R-matrix fit.

4. Conclusions

We have reported the measurements of the ^{8}Li-α elastic scattering excitation function by using the TTIK method. The technique included a time of flight measurement that allows the discrimination of elastic scattering from other reaction mechanisms. The excitation function was measured for excitation energy in the range of 13.5 and 19.5 MeV and it was analyzed using an R-matrix approach. The R-matrix calculation, that reproduces rather well the experimental data, includes seven resonances plus a background term. The reduced α-widths do not show evidence of strong α cluster configurations

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