Study of continuum excitation by light weakly bound projectiles on proton target

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Abstract. Elastic scattering and breakup angular distribution measurements for the systems ^{6,7}Li + p were performed at the MAGNEX facility of the **I**stituto **N**azionale di **F**isica **N**ucleare-**L**aboratori **N**azionali del **S**ud (INFN-LNS) in Catania, in the energy range of (2.3-5.4)AMeV. The breakup channel was identified and quantified adopting the algorithm MULTIP. Within this algorithm which is a Monte Carlo simulation code, the history of the breakup fragments can be tagged from the rest frame of the decay nucleus itself to the laboratory frame. Angular distribution data of both elastic scattering and breakup were analyzed under the same theoretical model and the influence of continuum on the elastic channel was investigated.

1 Introduction

Weakly bound nuclei are characterized by relatively small binding energies and thus, during a nuclear collision with a target nucleus, they can easily break into their cluster constituents. Therefore, breakup may be used as a tool to assess coupling effects on the elastic channel, when weakly bound nuclei are involved. The most widespread theoretical model which was developed to describe the effect of couplings of the breakup channel on elastic scattering is the **C**ontinuum **D**iscetized **C**oupled **C**hannels (CDCC) model. From the experimental point of view, is not always an easy task to obtain a clear signature of the breakup mechanism by studying energy spectra in singles, since due to their continuous shape they may interfere with events originating from different sources of background or with events triggered by a different reaction mechanism. Therefore, we have performed elastic scattering and exclusive breakup measurements with the weakly bound nuclei ^{6,7}Li on a proton target. Both data are considered into a CDCC framework. The goal is twofold: first to test the realism behind the discretization of the continuum phase space by comparing experimental and simulated energy spectra. In this respect the CDCC reaction model is coupled to a recently developed simulation algorithm, named MULTIP [1]. The second task is to probe coupling channels effects of the breakup on elastic channel in a CDCC approach.

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2 Experimental Setup

The two experiments were performed at the MAGNEX facility [2, 3] of the INFN-LNS. The ^{6}Li and ^{7}Li beams were delivered by the TANDEM accelerator and impinged on a thin CH_2 target. For the elastic scattering measurement [4–6], the ^{6}Li (^{7}Li) ejectiles were detected by the MAGNEX spectrometer while, for the breakup measurement [6–8] the α-particles were measured in MAGNEX in coincidence with ^{2}H (^{3}H) measured in a silicon detector, appropriately masked by a tantalum foil to avoid elastic scattering deterioration. The angular range covered by MAGNEX was $0^o \leq \theta_{lab} \leq 10^o$, while for the silicon detector was $4^o \leq \theta_{lab} \leq 6^o$.

3 Identification of the breakup channel

The Monte Carlo simulation algorithm, MULTIP [1] was employed in order to identify the kinematical loci of the breakup channel and to determine the detection efficiency of our experimental setup. Bellow are presented the main steps, adopted in the algorithm for the simulation of the energy spectra corresponding to the breakup of ^{6}Li. The same philosophy is also adopted in case of the ^{7}Li breakup.

In the first step of the simulation, the momentum vector of ^{6}Li excited nucleus in the laboratory reference frame is determined, by treating the continuum excitation as a 2-body like reaction ^{6}Li+p $\Rightarrow$ ^{6}Li*+p, using for each continuum bin the excitation energies and the reaction probabilities predicted by the CDCC calculation.

Then, the breakup of the ^{6}Li* in its rest frame is considered. The ^{6}Li nucleus acquires randomly an excitation energy inside the energy bin as specified in the CDCC framework and breaks into two fragments, an ^{4}He and a ^{2}H. It is assumed arbitrarily that the ^{4}He is emitted randomly with a specific energy and momentum, while the energy and momentum of the deuteron is determined by applying the conservation laws in the rest frame of ^{6}Li*.

In the last step, having determined the momentum vector of the excited ^{6}Li nucleus (P,θ), the momentum vectors of the breakup fragments are transformed from the ^{6}Li* rest frame to the laboratory one, by imposing a Galilean transformation followed by the appropriate rotation [1, 9]. A comparison between the experimental and simulated coincidence spectra is presented in Figure 1. The simulated data denoted with the magenta and orange points correspond to the simulation of the resonant and non-resonant breakup respectively. It is seen that the simulations are in very good agreement with the experimental data, validating the philosophy of the discretization of the continuum phase space behind the CDCC approach.

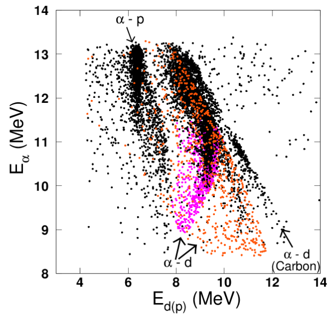

Figure 1. E_α-$E_{d(p)}$ correlation plot for the α-particles detected in MAGNEX in coincidence with deuterons (protons) detected in the detector mounted at θ_{lab} ~5^o at the beam energy of 25 MeV (See text for details). Data are also reported in Ref.[6, 7].

4 Results and Discussion

Having determined the efficiency of our detection system via code MULTIP, the angular distributions for the breakup of ^{6,7}Li on a proton target were deduced. The resulted breakup data together with the elastic scattering ones were analyzed within the CDCC framework following the prescription described in Refs.[10, 11]. As an example, elastic scattering and breakup data for ^{6}Li + p system at the energy of 25 MeV are presented in Figure 2. Results for the rest of the energies may be found in [7]. As it is seen, coupling to resonant breakup is the dominant one, while coupling to the non-resonant (direct) breakup has a minor effect on the reproduction of the elastic scattering data. The same conclusion remains valid even at the lower energy of 16 MeV where although the resonant breakup is alsmost zero, its coupling influence on elastic channel is the strongest one. The analysis of the ^{7}Li+p reaction at 38 MeV [8] yielded the same results, where strong coupling to the 7/2$^-$ resonance of ^{7}Li is inferred althought the resonance is barely excited. This systematic behavior for both ^{6,7}Li + p systems, suggests that the strength of the coupling to the continuum excitation is not always correlated with the magnitude of the breakup cross section.

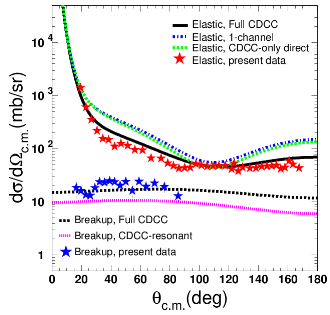

Figure 2. Experimental and theoretical angular distributions for the elastic scattering and breakup of ^{6}Li+p system at the energy of 25 MeV. Data and calculations from Ref.[6, 7].

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