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Nuclear Physics A ••• (••••) •••–•••

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Importance of the continuum-continuum couplings in the ^{6}Li elastic breakup on different target masses

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Received 28 April 2017; received in revised form 15 May 2017; accepted 15 May 2017

Abstract

A theoretical study of ^{6}Li breakup on target masses ranging from $A = 58$ to 208 is performed. It is obtained that when continuum-continuum couplings are included in the potential coupling matrix, they substantially reduce the total and nuclear breakup cross sections, while the Coulomb breakup cross sections for the medium and heavy target masses are increased. When these couplings are excluded, we show that the total and nuclear breakup cross sections depend linearly on $A_T^{1/3}$, namely they decrease linearly as the mass of the target increases. In the same case, the Coulomb breakup cross section depends linearly with the charge of the target Z_T (decreases as Z_T increases). We found that this linearity is destroyed when these couplings are included. However, in this case, it is the Coulomb-nuclear interference that also depends linearly with the target charge (increase with Z_T).

Keywords: Direct breakup; Continuum-continuum couplings; Coulomb-nuclear interference

1. Introduction

The importance of the continuum-continuum couplings (ccc) in direct breakup reactions involving loosely bound projectiles, has been a subject of great interest over the past decades [1–12]. The general conclusion is that once included in the coupling matrix element, these couplings largely reduce the breakup cross sections (see for example Fig. 4 of Ref. [1], Fig. 6 of

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http://dx.doi.org/10.1016/j.nuclphysa.2017.05.075
0375-9474/

Please cite this article in press as: B. Mukeru, M.L. Lekala, Importance of the continuum-continuum couplings in the ^{6}Li elastic breakup on different target masses, Nucl. Phys. A (2017), http://dx.doi.org/10.1016/j.nuclphysa.2017.05.075

Ref. [2], Fig. 3 of Ref. [4], Figs. 2–4 of Ref. [7]). In fact, the success of the CDCC (Continuum-Discretized Coupled Channels) method [13,14] (which is used in this work), over other methods such as semi-classical ones in describing reactions induced by loosely bound nuclei, is due to the fact that it accurately includes the ccc in the coupling matrix element. Also in this method, both the Coulomb and nuclear breakups are treating at the same footing. Despite the great success of this study, still there are important aspects so far not fully covered. For instance, the ccc dependence on the target mass and incident energies is not clearly established. Although the ccc effects have been shown to be more pronounced on the nuclear breakup cross section than on the Coulomb breakup cross section [1,2,7,8], these conclusions do not reveal much about how important are these couplings on the Coulomb-nuclear interference, which is regarded as one of the complex phenomena in the breakup process.

The results in the literature as far as the importance of the ccc is concerned, are mostly limited to halo nuclei, such as ^{8}B [1,2,4,7], ^{11}Be [5,9] and ^{15,19}C [7,8]. For loosely bound cluster nuclei such as ^{6,7}Li for example, few results are reported. It is not guaranteed that the conclusions obtained for halo nuclei can automatically be extended to loosely bound cluster nuclei, given on one hand, their different few-body structures and binding energies. The former are treated as a core plus one nucleon, while the latter are regarded as clusters of alpha particle plus deuteron (triton) nuclei. In fact, the results of [15] for the ^{7}Li + ^{144}Sm reaction, indicate that the inclusion of ccc in the coupling matrix element rather increases substantially the integrated breakup cross section. A further analysis of these results is needed, where for example, one can consider reactions involving ^{7}Li and halo projectiles on the same target, at the same incident energy to elucidate these differences. It is equally important to investigate whether similar conclusions can also be drawn for ^{6}Li nucleus.

In this paper we perform a theoretical analysis of the ccc importance on the total, Coulomb and nuclear breakup cross sections as well as on the Coulomb-nuclear interference, in the elastic breakup of ^{6}Li on the ^{58}Ni, ^{144}Sm and ^{208}Pb targets at $E_{\rm lab} = 35$ MeV incident energy. We mainly aim to study qualitatively and quantitatively the dependence of ccc effects on the mass of the target at a fixed incident energy. We analyze the ccc effects on the constructiveness and destructiveness of the Coulomb-nuclear interference. We carefully study the dependence of the Coulomb breakup cross section and Coulomb-nuclear interference on the target charge as well as the dependence of the total and nuclear breakup cross sections on the target mass. By so doing, we are mostly motivated by a search for linear scaling laws, which are already obtained in Refs. [16,17]. Although there are some ambiguities in separating the total breakup cross section into its Coulomb and nuclear components as shown in Ref. [18], in this paper, we obtain the Coulomb component by switching off the nuclear interaction potentials in the coupling matrix element. Likewise, to obtain the nuclear component, we switch off the Coulomb interaction potentials, keeping its diagonal part in the coupling matrix element. The choice of these reactions is generally motivated by a vast amount of literature available, for energies in the neighborhood of our incident energy, which in turn is chosen in accordance with the fact that it is well above the Coulomb barrier for the three reactions. For ^{6}Li + ^{144}Sm, elastic scattering data are available at this incident energy [19]. However, our study is purely theoretical, hence no data fitting is performed. The numerical calculations are carried out by means of FRESCO computer code [29].

The paper is organized as follows: in Section 2, we present and discuss the results, and the conclusions are summarized in Section 3.

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