Energy dependence of the continuum-continuum couplings in the breakup of ^{6}Li on ^{144}Sm target

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Abstract. The energy dependence of the continuum-continuum couplings is studied for the ^{6}Li + ^{144}Sm breakup reaction. We show that for energies well below the Coulomb barrier ($\gamma = E_{\rm cm}/V_B \leq 0.7$), continuum-continuum couplings enhance the breakup cross sections. However, for $\gamma \geq 0.8$, the breakup cross sections are suppressed, owing to these couplings. It is shown that the suppression factor increases with the incident energy.

1. Introduction

In the recent past, dynamic effects of the continuum-continuum couplings (ccc) in breakup reactions induced by loosely bound nuclei have been intensively investigated [1, 2, 3, 4, 5, 6, 7, 8, 9]. It is generally agreed that, once such couplings are included in the coupling matrix element, they result in a substantial suppression of the breakup cross section at energies above the Coulomb barrier. Not only has the attention been focused on energies above the barrier, but also most of the results in the literature are based on halo nuclei, like ^{8}B, ^{11}Be, ^{15}C etc. Not much has been done in this direction as far as cluster nuclei like ^{6,7}Li are concerned. However, analysing the ^{7}Li + ^{144}Sm reaction in Ref. [10], it was shown that for energies below and around the barrier, the breakup cross sections are rather enhanced, owing to the ccc. It is unclear whether such conclusion could be extend to the ^{6}Li nucleus, given on one hand, their different ground state energies upon which the breakup cross section are strongly dependent. Moreover, in any case, the energy dependence of the ccc effects is yet to be fully established. In order to understand clearly the importance of the ccc in the breakup process, it is interesting to investigate their energy dependence. A detailed analysis of the ccc effects in breakup reactions could shed more light in similarities and differences in the breakup of halo and loosely bound cluster nuclei.

In this paper, we study the energy dependence of the ccc in the ^{6}Li + ^{144}Sm breakup reaction. To this end, we consider incident energy below, around and above the Coulomb barrier ($0.6 \leq E_{\rm cm}/V_B \leq 2$, where $V_B = 23.8\,$MeV is the barrier height [11]). The different breakup cross sections are obtained by means of the CDCC (Continuum Discretized Coupled-Channels) method [12], after the resulting coupled differential equations are numerically solved using FRESCO [13]. This reaction has been intensively investigated, especially for fusion cross, for example [14]. The paper is organized as follows: in Section 2, we present and discuss the results, while the conclusions are reported in Section 3.

2. Results and Discussion

The ^{6}Li prompt breakup is well modelled as ^{6}Li $\rightarrow \alpha$+d. The parameters of the $V_{\alpha d}$ potential used to generate the ground state and bin wave functions are taken from Ref. [15]. The $V_{\alpha t}$ and V_{dt} potential parameters are the same as those used in Ref. [16], together with the different CDCC breakup model parameters. In what follows, $\sigma_{\rm ccc}$ denotes the breakup cross section in the presence of ccc and $\sigma_{\rm nccc}$ the breakup cross section in the absence of ccc.
In Fig. 1, we summarize the differential angular distributions breakup cross sections for energies below, around and above the barrier ($0.6 \leq \gamma \leq 2$, where $\gamma = E_{\rm cm}/V_B$). Looking at this figure, one observes that for $\gamma = 0.6$, the breakup cross section $\sigma_{\rm ccc}$ is largely enhanced, owing to the ccc, since it is clear that $\sigma_{\rm ccc} \gg \sigma_{\rm nccc}$ for the whole angular range displayed. For $\gamma = 0.7$, we observe that the cross section is still enhanced at $\theta \leq 140^\circ$, while beyond this angle, $\sigma_{\rm ccc}$ is suppressed due to these couplings ($\sigma_{\rm ccc} < \sigma_{\rm nccc}$). However, for $\gamma \geq 0.8$, we observe that at forward angles, the breakup cross sections $\sigma_{\rm ccc}$ are relatively enhanced. At backward angles, on the other hand, we notice a substantial suppression of these cross sections, because $\sigma_{\rm ccc} \ll \sigma_{\rm nccc}$. One also notices that the large extension of the $\sigma_{\rm nccc}$ breakup cross sections towards larger angles is continuously washed away as the incident energy increases.

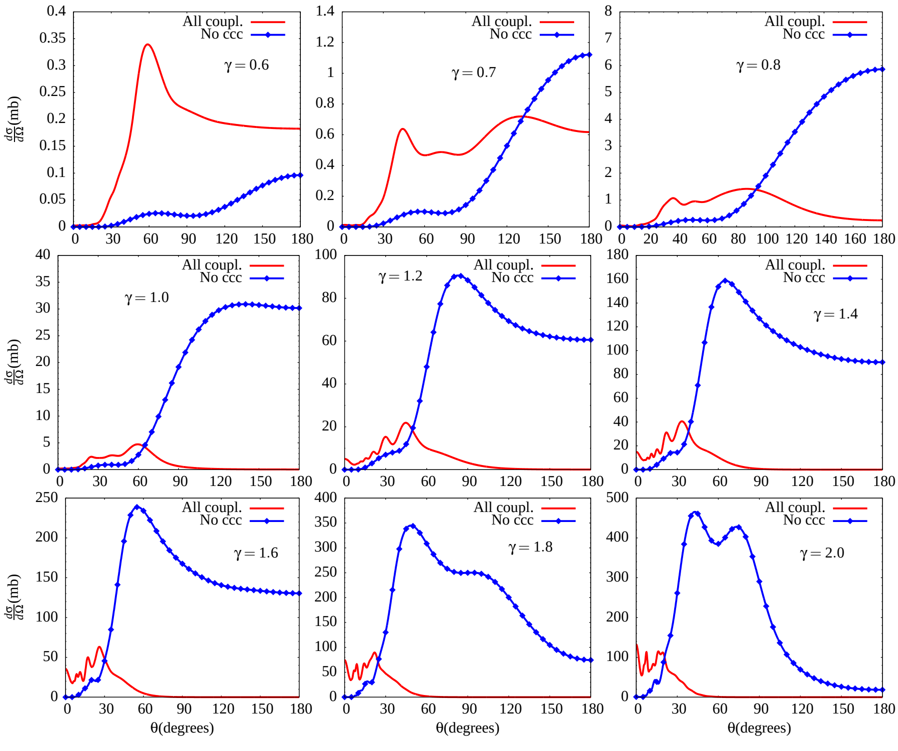

Figure 1. Differential breakup cross sections for energies below and above the Coulomb barrier.

In Fig. 2, we plot the breakup cross sections $\sigma_{\rm ccc}$ and $\sigma_{\rm nccc}$ as functions γ, and show that the suppression of $\sigma_{\rm ccc}$ due to the ccc above the barrier increases with γ. We performed a numerical integration of the differential breakup cross sections and show that for $\gamma = 0.6$ the integrated breakup cross sections are $\sigma_{\rm ccc} = 2.542$ mb and $\sigma_{\rm nccc} = 0.389$ mb, giving an enhancement factor of 0.85. For $\gamma = 0.7$, $\sigma_{\rm ccc} = 6.743$ mb and $\sigma_{\rm nccc} = 4.033$ mb, corresponding to an enhancement factor of 0.40. However, for $\gamma = 0.8$ for example, $\sigma_{\rm ccc} = 11.50$ mb while $\sigma_{\rm nccc} = 24.35$ mb, resulting in a suppression factor of 0.53.

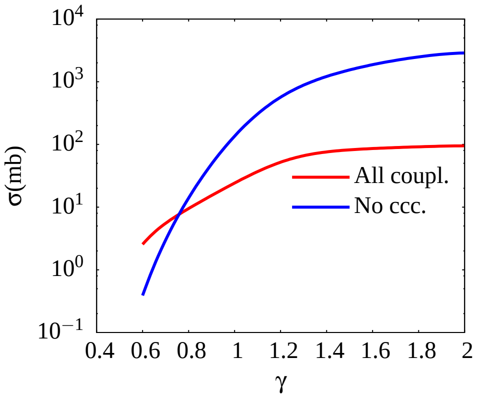

Figure 2. Integrated σ_{ccc} and σ_{nccc} breakup cross sections as functions of γ.

3. Conclusions

In this paper, we have studied the energy dependence of the ccc in the ^{6}Li + ^{144}Sm breakup reaction. We show that for energies below the Coulomb barrier ($E_{\text{cm}}/V_B \leq 0.7$), the breakup cross sections are enhanced due to these couplings. However, for $E_{\text{cm}}/V_B \geq 0.8$, a suppression of the breakup cross section is rather observed. It is shown that the suppression factor increases with the incident energy.

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