# Probing the cluster structure of $^{10}$B through coupled channel calculations

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The structure of light nuclei has been a subject of extensive investigation, largely driven by the role of clustering phenomena in shaping their nuclear properties. In particular, experimental measurements of elastic scattering and breakup observables in reactions involving these nuclei demonstrate that the scattering and breakup probabilities are strongly affected by their underlying cluster configurations. The nuclei of $^{6}$Li, $^{7}$Li, $^{7}$Be, and $^{9}$Be exhibit well-established cluster structures, which are essential for understanding their nuclear behavior and the mechanisms governing their reactions. Specifically, $^{6}$Li is typically described as an $\alpha + d$ cluster, while $^{7}$Li and $^{7}$Be exhibit $\alpha + t$ and $\alpha + {}^{3}$He configurations, respectively. Similarly, $^{9}$Be is characterized by an $\alpha + \alpha + n$ cluster arrangement. These cluster models provide critical insights into the resonant states and reaction pathways of these light nuclei [1, 2].

In the case of $^{10}$B, clustering phenomena reveal several significant configurations, including $\alpha + {}^{6}$Li, $^{9}$Be + $p$, and $^{8}$Be + $d$. Among these, the breakup channel $^{10}\text{B} \rightarrow {}^{6}\text{Li} + \alpha$ (Q =-4.461 MeV) is particularly important due to its low energy threshold, making it the most energetically favorable mode. This channel plays a crucial role in elastic scattering and reaction mechanisms, highlighting the need for including couplings to continuum states in accurate modeling. The $\alpha + {}^{6}$Li cluster is especially noteworthy for its role in $\alpha$-induced reactions and its significance in nuclear astrophysics and fusion processes. Characterized by the weak binding of $^{6}$Li, this configuration is essential for understanding the breakup dynamics of $^{10}$B. In contrast, the breakup channels $^{10}\text{B} \rightarrow {}^{9}\text{Be} + p$ and $^{10}\text{B} \rightarrow {}^{8}\text{Be} + d$, with thresholds exceeding 6 MeV, are expected to have a lesser impact on elastic scattering distributions due to their higher binding energies compared to the $\alpha + {}^{6}$Li breakup channel.

The study by N. Curtis *et al.* [3] investigated the decay of $^{10}$B through reactions such as $^{12}$C($^{7}$Li, $^{10}$B$^{*}$)$^{9}$Be and $^{16}$O($^{7}$Li, $^{10}$B$^{*}$)$^{13}$C at 58 MeV. Their analysis indicated that the $\alpha$-decay channels dominate in excited states of $^{10}$B. However, cross-sectional information for the decay channels, including $\alpha$+$^{6}$Li, $d$+$^{8}$Be, and $p$+$^{9}$Be, is not available. M. A. G. Alvarez *et al.* [4] also emphasized the importance of the cluster structure in $^{10}$B for understanding its reaction dynamics. Since cross-sectional information for the decay channels, including $\alpha + {}^{6}$Li, $d + {}^{8}$Be, and $p + {}^{9}$Be, is not available, coupled channel calculations are necessary to extract quantitative insights into the cluster structure of $^{10}$B.

The present work is dedicated to the analysis of $^{10}$B+$^{120}$Sn reaction through the application of Continuum Discretized Coupled Channel (CDCC) calculations. This approach is particularly suited for studying the cluster structure of $^{10}$B, as CDCC allows for the explicit treatment of couplings between the elastic scattering and breakup channels. By discretizing the continuum states, it becomes possible to accurately model the influence of various cluster configurations, such as $\alpha$+$^{6}$Li, on the reaction dynamics. Through this analysis, we aim to gain deeper insight into how the underlying cluster structure of $^{10}$B affects its interaction with $^{120}$Sn, providing quantitative information on the breakup probabilities

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and other reaction observables.

Continuum Discretized Coupled Channels (CDCC) calculations were performed in three stages using the code FRESCO [5]. In the first stage, $^{10}$B was modeled as a cluster of $\alpha$ + $^{6}$Li, considering both its bound and continuum states. The breakup of the projectile into $\alpha$ and $^{6}$Li fragments is attributed to inelastic excitations into different partial waves within the continuum, driven by the interactions between the projectile fragments and the target through both Coulomb and nuclear forces. Couplings to the $3^+$ ($E_x$ = 4.97 MeV), $3^+$ ($E_x$ = 7.10 MeV), and $2^+$ ($E_x$ = 8.05 MeV) resonant states, as well as the non-resonant continuum, were included. The continuum, extending up to 10.03 MeV of excitation energy, covered $\alpha$-$^{6}$Li relative momentum states with $L = 0, 1,$ and 2. The s- and p-wave continua were discretized into 16 momentum bins. For the d-wave continuum, which includes resonant states, the discretization was adjusted to avoid double counting. Three resonant states, with widths of 0.0020 MeV, 0.196 MeV, and 1.6 MeV, were also treated as momentum bins with finer resolution. In the subsequent stages, the calculations were extended to include the $^{9}$Be + $p$ and $^{8}$Be + $d$ cluster configurations.

To investigate the effect of different cluster configurations on elastic scattering, the elastic scattering data of M. A. G. Alvarez *et al.* [4] were compared with Continuum Discretized Coupled Channels (CDCC) calculations obtained using the FRESCO code. The $\alpha$+$^{6}$Li configuration, due to its weak binding, significantly enhances the contribution of breakup channels, modifying the elastic scattering at backward angles. In contrast, the effect of the $^{9}$Be+$p$ and $^{8}$Be+$d$ configurations was relatively small. The inclusion of resonant and non-resonant states within the clusters improved the agreement with experimental data, demonstrating that the cluster structure, particularly $\alpha$+$^{6}$Li, plays a crucial role in describing elastic scattering dynamics.

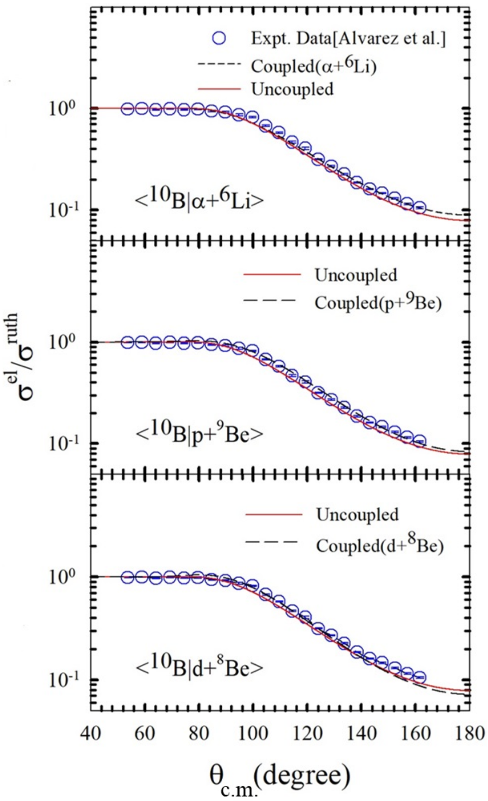


FIG. 1: Comparison of elastic scattering data at $E_{\mathrm{LAB}}$ = 37.5 MeV with CDCC calculations performed using the FRESCO code for different cluster configurations.

## References

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