Breakup of proton halo nucleus ^{8}B at near-barrier energies†

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As recognized since the very first measurements in the mid-1980s,[1)] the most neutron-rich unstable isotope of lithium, ^{11}Li, was reported to present an unexpected halo-type structure. After this experimental discovery in ^{11}Li, several other nuclear systems with neutron halo structures were reported. On the proton-rich side, ^{8}B is one of the few cases whose ground state presents the proton halo.[2)] The large extent of the nuclear matter distribution and the very low threshold of the breakup channel strongly impact the reaction mechanism, particularly at energies around the Coulomb barrier, where couplings to the breakup continuums are expected to be particularly significant. Consequently, the detailed knowledge of the breakup mechanism is critical for an understanding of the reaction dynamics of halo nuclear systems.

The breakup mechanism of the proton halo nuclei is rather complicated. The dynamic Coulomb polarization effect[3)] may produce a hindrance to both the proton transfer and breakup processes,[4)] which results in the rather elusive character of proton halo systems. To obtain a comprehensive understanding of the breakup process, the coincident measurement of the breakup fragments is the inevitable course. However, it is a significant challenge for incident energies close to the Coulomb barrier, as it is not easy to carry out a coincidence measurement among the breakup fragments as was done at higher energies owing to the much reduced kinematic focusing. It becomes worse owing to the very low beam intensities of proton halo nuclei.

To address this long-standing challenge, we performed the complete kinematics measurement of ^{8}B + ^{120}Sn at two energies around the barrier.[5)] Owing to the highly efficient silicon detector array, the correlation of the breakup fragments, ^{7}Be and proton, is derived for the first time. As an example, the relative energy spectra ($E_{\rm rel}$) is presented in Fig. 1. The correlations can be explained by the state-of-the-art continuum discretized coupled channel calculations. The results indicate that ^{8}B presents distinctive reaction dynamics: the dominance of the elastic breakup. This breakup occurs primarily through short-lived continuum states and almost exhausts the ^{7}Be yield. The correlation reveals that the prompt breakup mechanism dominates, occurring predominantly on the outgoing trajectory. We also report that, as a large environment, the continuum of ^{8}B breakup may not significantly impact elastic scattering and complete fusion.

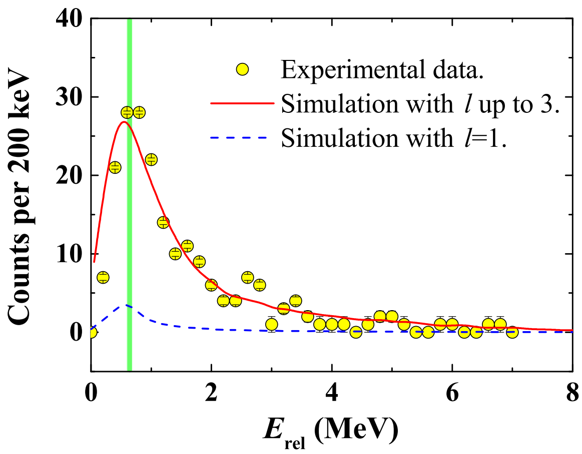

Fig. 1. Measured $E_{\rm rel}$ distribution (circles) for the breakup fragment at 38.7 MeV. The vertical line indicates the expected location of the peak from the first 1^+ resonance of ^{8}B. The solid and dashed curves denote the simulated distributions of $E_{\rm rel}$ with the orbital angular momentum up to $l = 3$ and the $l = 1$ (1^+) state, respectively.

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References
1) I. Tanihata *et al.*, Phys. Rev. Lett. **55**, 2676 (1985).
2) G. A. Korolev *et al.*, Phys. Lett. B **780**, 200 (2018).
3) M. Ito *et al.*, Nucl. Phys. A **787**, 267 (2007).
4) Y. Kucuk *et al.*, Phys. Rev. C **86**, 034601 (2012).
5) L. Yang *et al.*, Nat. Commun. **13**, 7193 (2022).