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Compositeness of near-threshold exotic hadrons in systems with Coulomb and short-range interactions

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Recent experiments have discovered various exotic hadrons near scattering thresholds, stimulating interest in their internal structure. For short-range s-wave interactions, the structure of near-threshold states has been clarified based on the low-energy universality: shallow bound states below threshold tend to be dominated by the hadronic molecular component [1], whereas narrow resonances slightly above threshold do not [2]. Near-threshold states also appear in systems with the Coulomb plus short-range interactions, such as two-baryon systems with heavy quarks studied in lattice QCD [3] and exotic nuclei [4]. For charged systems, the Coulomb interaction modifies the scattering amplitude even in the low-energy region, and the structure of near-threshold states cannot be understood by directly applying the pure short-range results.

In this work, we investigate near-threshold states in systems with Coulomb plus short-range interactions, describing the scattering amplitude using the Coulomb scattering length and the Coulomb effective range [5,6,7]. To quantify their internal structure, we evaluate the compositeness, which characterizes the molecular nature of the eigenstate [8]. We show that the behavior of the compositeness near the threshold is governed by the competition between the short-range and Coulomb interactions. In particular, when the Bohr radius is larger than the magnitude of the effective range, the compositeness increases in the near-threshold region as a remnant of the short-range low-energy universality, whereas this enhancement disappears when the Coulomb interaction becomes dominant with smaller Bohr radius [6,7]. Applying this framework to exotic hadrons and hypernuclei, we obtain results consistent with experimental observations, precise few-body calculations, and findings from the lattice QCD studies, and show that the molecular nature of near-threshold states can be understood as a common consequence of the remnant of the low-energy universality.

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Collaboration

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