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Challenges in Describing Near-Barrier Fusion: Pinning Down the Interplay of Breakup, Transfer and Fusion

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Understanding the interactions of weakly bound nuclei, and their reaction outcomes, is a key challenge in nuclear reactions research. Apart from the well-known channel coupling effects, reaction dynamics involving weakly-bound nuclei has added complexity due the presence of low-lying particle unbound states, not just in the interacting nuclei but also in neighboring nuclei that are populated following nucleon transfer. Currently there is no theoretical model to describe all the modes of breakup (particularly transfer-triggered breakup) and their effect on fusion. Thus, experimental observations play a crucial role in formulating theoretical models of near-barrier reaction dynamics.

The findings of suppression of above barrier complete fusion, first observed using weakly bound stable beams, and later for light radioactive beams, led to idea that the suppression is caused by breakup of the projectile before reaching the fusion barrier. This idea was tested recently using a large angular acceptance detector array to measure coincident charged fragments following breakup of weakly bound stable beams on a wide range of targets. A recently developed classical model was combined with new experimental observables to separate breakup that occurs in the incoming trajectory from that in the outgoing trajectory. This separation proved crucial as it shows that breakup prior to reaching the barrier is insufficient to explain the observed suppression of complete fusion. Thus some other mechanism must also be contributing to suppression of complete fusion.

These new measurements will be presented and possible mechanisms that can cause reduction in fusion will be discussed. The latter will draw on similarities observed in experiments with well-bound nuclei where transfer to highly excited states is being investigated as a possible doorway to energy dissipation that can reduce complete fusion cross sections. These emerging ideas built on recent experiments serve as pointers to the development of new models.

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