Modelling effects of halo breakup on fusion

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The effect of breakup of weakly bound halo projectiles on fusion has been extensively investigated in recent years by many groups both experimentally and theoretically, but there is not yet a definitive conclusion. The theoretical challenge is to calculate the effects of breakup channels on the effective barrier and the effective depletion rates for the elastic channel, while at the same time also including fusion that might follow after breakup from the projectile ground state.

The coupled channels discretised continuum (CDCC) method offers what is probably the most comprehensive solution for the three-body wavefunction of the projectile fragments during the reaction, including the effects of both real and virtual breakup. The fusion cross section is then taken as a function of this three-body wave function, for example the integral of a short-ranged 'imaginary fusion potential'.

Several ambiguities remain in this CDCC procedure, however, stemming from the different ways of including imaginary optical potentials during the dynamical calculation. We report on two possibilities, and the effects therein of continuum-continuum couplings. The dynamical model may have an imaginary potential as a short-ranged function of the distance from the projectile centre of mass to the target, justified by the assumption that if this distance is small then the projectile should have fused with the target. Alternatively, the dynamical imaginary potentials may be those of the fragment-target optical potentials, justified by the observation that the model then calculates that part of the total wave function in which the target and the projectile fragments themselves remain in their ground states.

Further ambiguities remain concerning the measurements and modelling of the two independent fusion processes that can be distinguished, namely complete fusion and incomplete or partial fusion. The total fusion is the sum of these processes (complete + incomplete). A clear definition of complete and incomplete fusion is necessary to compare theoretical predictions to experimental data, as definitions in the literature are not always consistent. From a strict theoretical point of view, complete fusion refers to the capture of all the projectile fragments (from bound and breakup states) by the target, whereas the incomplete fusion is related to the capture of only some of those fragments. Experimentalists tend to define complete and incomplete fusion as absorption of all the charge of the projectile and of a part of that charge, respectively. These definitions are only equivalent to the strictly theoretical ones if all the projectile fragments are charged. We therefore compare calculations of ^{11}Be fusion with those of ^{6,7}Li fusion, where the effects of the different treatments of the imaginary optical potentials may be manifested.