Near-barrier fusion and breakup of weakly bound and exotic halo nuclei

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In reactions with weakly bound nuclei, the influence on the fusion process of coupling both to collective degrees of freedom and to break-up/transfer channels is a key point for the understanding of N-body systems in quantum dynamics [1,2]. Due to the very weak binding energies of halo nuclei, such as $^6$He, a diffuse cloud of neutrons of halo nuclei would lead higher fusion cross sections at sub-barrier energies as compared to predictions of one-dimensional barrier penetration model [1]. This was understood in terms of the dynamical processes arising from strong couplings to collective inelastic excitations of the target and projectile [3]. However, in the case of reactions where at least one of the colliding nuclei has a sufficiently low binding energy for breakup to become a competitive process, conflicting model predictions and experimental results were reported [1,2,4]. Recent experimental results with $^6,^8$He beams show that the halo of $^6$He does not enhance the fusion probability, confirming the prominent role of one- and two-neutron transfers in $^6$He induced fusion reactions [1,2]. The effect of non-conventional transfer/stripping processes appears to be less significant for stable weakly bound projectiles [4].

Several experiments involving tightly bound projectiles such as $^9$Be, $^7$Li, and $^6$Li projectiles on targets ranging from $^{12}$C to $^{209}$Bi have been investigated [2]. In this talk, excitation functions for sub- and near-barrier total (complete + incomplete) fusion cross sections measured using γ-ray techniques for the $^6,^7$Li+$^{59}$Co reactions [3,4] are presented. The comparison with Continuum-Discretized Coupled-Channel (CDCC) calculations [5] indicates only a small enhancement of total fusion for the more weakly bound $^6$Li below the Coulomb barrier, with similar cross sections for both reactions at and above the barrier. This result is consistent with rather low breakup cross sections measured for the $^6$Li+$^{59}$Co reaction even at incident energies larger than the Coulomb barrier [4].

The investigation of the breakup process in the $^6,^7$Li + $^{59}$Co,$^{115}$In reactions with particle techniques is also presented to discuss the interplay of fusion and breakup processes including the role of elastic scattering [4]. Coincidence data compared to three-body kinematics calculations reveal a way how to disentangle the contributions of breakup, incomplete fusion and/or transfer-reemission process.

As far as exotic halo projectiles are concerned we have initiated a systematic study of $^{4,6}$He induced fusion reactions [4] with an improved three-body CDCC method [5] using a dineutron model for $^6$He ($\alpha-2n$). Some of the preliminary results will be presented. However a full understanding of the reaction dynamics involving couplings to the breakup and neutron-transfer channels will need high-intensity radioactive ion beams and precise measurements of elastic scattering and yields leading to the breakup itself. The application of four-body (required for an accurate $\alpha$-n-n description of $^6$He) CDCC models under current development [6,7] will then be highly desirable.