Di-neutron cluster model for near-barrier fusion induced by halo nuclei

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In reactions induced by light weakly bound nuclei, the influence on the fusion process of couplings to collective degrees of freedom and to breakup and transfer channels is a key point for a deeper understanding of few-body systems in quantum dynamics [1-6]. Due to the very weak binding energies of halo nuclei, such as ^{6}He, a diffuse cloud of neutrons should lead to enhanced tunneling probabilities below the Coulomb barrier as compared to predictions of one-dimensional barrier penetration model [5]. This was understood in terms of the dynamical processes arising from strong couplings to collective inelastic excitations of the target and projectile [5]. 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 [5]. Recent experimental results with ^{6,8}He beams illustrate the preponderant role of one- and two-neutron transfers in ^{6}He induced reactions [5]. The effect of non-conventional transfer/stripping processes as well as the specific role of breakup have still to be determined for stable weakly bound projectiles [5].

Several experiments involving weakly bound projectiles such as ^{9}Be, ^{7}Li, and ^{6}Li projectiles on targets ranging from ^{12}C to ^{209}Bi have been investigated [5]. In this contribution, excitation functions for sub- and near-barrier total (complete + incomplete) fusion cross sections of ^{6,7}Li+^{59}Co [1] are analyzed. The comparison with Continuum-Discretized Coupled-Channel (CDCC) calculations [2] 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 [1-5]. The investigation of the breakup process in ^{6,7}Li+^{59}Co and its interplay with fusion was done with the analysis of the corresponding elastic scattering data [3,4]. The real and imaginary parts of the optical model potentials did not allow us to draw any concrete conclusions concerning the occurence or not of the threshold anomaly phenomenon in these systems [4].

As far as exotic halo projectiles are concerned we have initiated a systematic study of ^{6}He induced fusion reaction with medium-mass [3-5] with an improved three-body CDCC method [2] using a di-neutron cluster model for the three-body "Borromean" nucleus ^{6}He (approximated as being a α-^{2}n system). Sub-barrier fusion cross sections calculated by CDCC for ^{6}He+^{59}Co are much larger than the total fusion yields measured for ^{6}Li+^{59}Co [1] and ^{4}He+^{59}Co [4]. Similar conclusions are drawn for ^{63,75}Cu and ^{64}Zn targets [4]. The relative importance of breakup and bound-state structure effects on fusion will be presented. However, a full understanding of the reaction dynamics involving couplings to the breakup and neutron-transfer channels (1-n and 2-n) will need high-intensity radioactive ion beams and very exclusive experiments to determine very precisely the spatial (angular and energy) correlations of the individual neutrons. The application of four-body (required for an accurate α-n-n description of ^{6}He) CDCC models under current development [6] will then be highly desirable.

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