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

C. Beck[1], A. Sànchez i Zafra[1], A. Diaz-Torres[2], I.J. Thompson[3], N. Keeley[4]

[1] *Institut Pluridisciplinaire Hubert Curtien, UMR7178, CNRS-IN2P3 et Université Louis Pasteur Strasbourg, B.P. 28, F-67037 Strasbourg Cedex 2, France*
[2] *The Australian National University, Canberra ACT 0200, Australia*
[3] *Department of Physics, University of Surrey, Guildford GU2 7XH, U.K.*
[4] *DAPNIA/SPhN Saclay, F-91190 Gif-sur-Yette, France*

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 (α-^{2}n). 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 α-n-n description of ^{6}He) CDCC models under current development [6,7] will then be highly desirable.

[1] J.F. Liang and C. Signorini, Int. Jour. of Mod. Phys. E **14**, 1121 (2006).
[2] L.F. Canto, P.R.S. Gomes, R. Donangelo, and M.S. Hussein, Phys. Rep. **424**, 1 (2006).
[3] C. Beck *et al.*, Phys. Rev. C **67**, 054602 (2003).
[4] C. Beck *et al.*, arXiv:nucl-ex/**0411002** (2004).
[5] A. Diaz-Torres, I.J. Thompson, and C. Beck, Phys. Rev. C **68**, 044607 (2003).
[6] T. Matsumoto *et al.*, Phys. Rev. C **70**, 061601(R) (2004).
[7] M. Rodriguez-Gallardo *et al.*, Phys. Rev. C **72**, 034007 (2005).