Coupled-Channels Density-Matrix Approach to Reaction Dynamics

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Coupled-channels approaches have been very successful in explaining several collision observables. However, problem remain. Foremost is the inability to describe elastic scattering and fusion measurements simultaneously and, related, the more recent failure to describe in a physically consistent way the below-barrier quantum tunneling and above-barrier fusion yields [1].

These problems may be caused by the neglect of important physical processes (e.g., deep-inelastic) which cannot be treated within (standard) coupled-channels models. Measurements [2] have shown that deep-inelastic processes occur even at sub-barrier incident energies, in competition with the process of quantum tunneling, and thus fusion. The understanding of this complex interplay, at near- and below barrier energies, requires a dynamical model which can describe coupling assisted tunneling with dissipation.

I will present a novel coupled-channels density-matrix approach [3] that overcomes these difficulties. The coupled-channels description is formulated with the Lindblad equation for a reduced density matrix. It describes the time evolution of the reduced system (comprising the relative motion of the nuclei plus selected, intrinsic collective excitations) that irreversibly interacts with an “environment” of complex excitations.

The development provides a significant step towards an improved theoretical understanding of low-energy collision dynamics, as model calculations exhibit both quantum decoherence and energy dissipation. These cannot be treated within standard coupled-channels approaches [4]. Effects of decoherence and dissipation on reaction dynamics can be manifested outside the fusion barrier radius, changing the quantum tunneling probability (fusion) and scattering observables.

[1] M. Dasgupta *et al.*, Phys. Rev. Lett. **99**, 192701 (2007), and references therein.
[2] D.J. Hinde *et al*., Nucl. Phys. **A834**, 117c (2010).
[3] A. Diaz-Torres *et al.*, Phys. Rev. **C78**, 064604 (2008).
[4] A. Diaz-Torres, Phys. Rev. **C81**, 041603(R) (2010).