Fusion with exotic nuclei using microscopic methods

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Fusion reactions are affected by nuclear structure and many dynamical processes. Some effects of internal nuclear structure on reactions such as heavy-ion fusion can be seen by studying features of experimental fusion barrier distributions [1]. Until more recently, theoretical modelling of these reactions were largely of phenomenological nature. Whilst this approach is useful to start with and works very well for light stable systems, moving towards heavier and more exotic systems demands more powerful theory to be able to both describe processes observed experimentally and predict fusion cross sections for exotic nuclei. Upcoming exotic beam facilities at the ANU provide motivation to understand neutron rich systems theoretically.

Microscopic theory, in particular Hartree-Fock (HF) theory, is an insightful tool to study heavy-ion reactions including fusion. In addition to studying reactions, nuclear structure properties, both static and dynamic, can be calculated with microscopic theory. In this work (as seen in Ref. [3]) we use both static and time-dependent versions of the HF method to study the fusion reactions along the chain of systems $^{40-54}$Ca+^{116}Sn for even calcium isotopes. Fully microscopic theories such as HF theory have many advantages for studying structure and reactions. HF calculations were made for head on collisions between the calcium projectiles and the tin target to obtain fusion barrier heights. Referring to Fig 1, there are clear differences in the results between the two HF methods. Both trends exhibit discontinuities (kinks) in the barrier heights line whereas the phenomenological Akyüz–Winther potential [2], shown as a comparison, does not have this feature suggesting that macroscopic approaches like this lack vital information about internal nuclear structure.

Coupled-channels analysis reveals that much of the difference for these systems can be attributed to vibrational excitations. For the most neutron rich systems, however, there is still some difference which is unaccounted for by vibrations. We investigate the role transfer reactions may play in fusion barriers for these asymmetric, exotic systems.

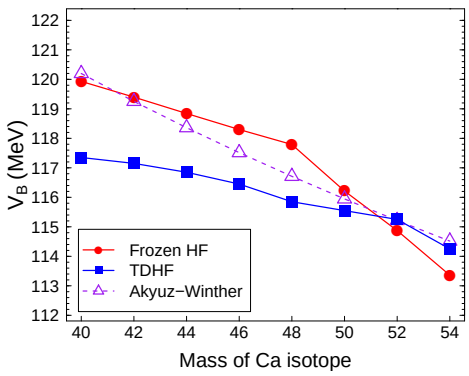

FIG. 1: Fusion barriers for ^{A}Ca+^{116}Sn systems

[1] M. Dasgupta *et al.*, Ann. Rev. Nucl. Part. Sci. **48**, 401 (1998)

[2] R. A. Broglia and A. Winther, *Heavy Ion Reaction Lecture Notes, Vol. I: Elastic and Inelastic Reactions* (Benjamin/Cummings, Reading, MA, 1981), p. 114

[3] K. Vo-Phuoc, C. Simenel and E. C. Simpson, PRC **94**, 024612 (2016)