Understanding nuclear structure in heavy-ion reactions with Hartree–Fock methods

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Nuclear structure plays a major role in nuclear reactions. 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]. It is useful to know what properties of the nucleus contribute to the prevention or enhancement of nuclei undergoing fusion reactions. Upcoming exotic beam facilities at the ANU provide motivation to understand neutron rich systems theoretically.

In this work the self-consistent mean-field Hartree–Fock (HF) theory, both static and time-dependent (TDHF) versions, was employed to study static and dynamic properties of ^{116}Sn and calcium isotopes (of even atomic mass number ranging from 40 to 54 inclusive) and the reactions between them. 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. The effects of the nuclear properties on the HF fusion barriers for these systems are discussed.

Static properties are uncovered from the single particle shell structure as calculated by the static HF method. Since the calcium isotopes range from an equal N/Z ratio to a very neutron rich one, the neutron skin increases with each isotope of increasing mass. The filling of these neutron single particle shells essentially characterise the static HF fusion barrier trend. Dynamic properties of the nuclei, including low-lying vibrational modes, are calculated with TDHF and selectively used in coupled-channels calculations to see which modes have the most effect on the TDHF fusion barrier. It turns out there is more to characterising the TDHF fusion barriers than just the vibrational modes (for near spherical nuclei), so other possible effects like transfer channels must also be considered.

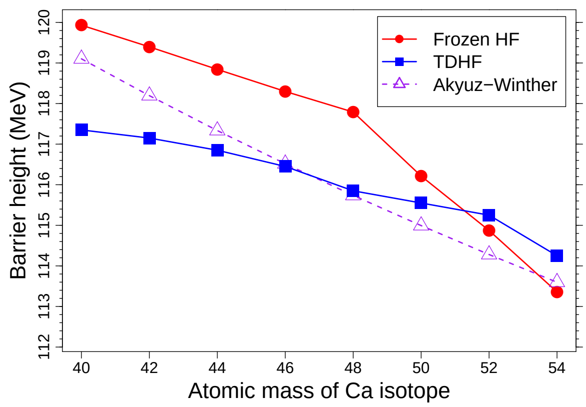

FIG. 1: Fusion barriers for ^{A}Ca+^{116}Sn systems

[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