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Sub-barrier Fusion Excitation Functions of Heavy-Ion Systems

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One of the yet unsettled problems in heavy-ion fusion near and below the barrier is the relative influence of nucleon transfer channels and couplings to collective modes on the cross sections. We recall two relevant papers [1] where that influence, and the moments of fusion-barrier distributions were investigated.

In this contribution, we present a new analysis of several systems, based on the combined observation of the energy-weighted excitation functions Eσ in relation to their first energy derivatives d(Eσ)/dE (slopes). That derivative is proportional to the s-wave transmission coefficient and to the square of the barrier radius. This representation helps our understanding of the situation.

The two-dimensional plot of d(Eσ)/dE vs Eσ for 48Ca,36S + 48Ca, obtained from Refs. [2, 3] is interesting. In this type of plot trivial Coulomb barrier differences between the two systems are eliminated to a large extent. The colliding nuclei are closed-shell or magic, and, at sub-barrier energies, the two data sets are completely overlapping. Indeed the Wong formula [4] implies that the slope and the excitation function are proportional to each other for all cross sections in that energy range. The proportionality constant is $2\pi/\hbar\omega$, i.e. inversely proportional to the second radial derivative of the barrier approximated by a parabola. In the cited example the overlap of the two data sets implies that the two barriers have approximately the same width.

Other cases behave differently, like 40Ca + 96Zr [5] and 58Ni + 64Ni [6], where neutron transfer couplings are dominant, compared to 40Ca + 90Zr [7] and 64Ni + 64Ni [8], respectively. In either case, the system where transfer couplings are dominant, lies below the other case, meaning that the effective one-dimensional barrier is thinner. This mimics a wider barrier distribution produced by couplings, extending to lower energies and leading to a cross section enhancement vs energy, as observed. A full systematics will be shown in the talk, with more detailed and quantitative considerations for the various
cases.

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