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 influence of nucleon transfer couplings (with respect to couplings to collective modes) on the cross sections. We recall two relevant papers [1, 2] 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 $E\sigma$ in relation to their first energy derivatives $d(E\sigma)/dE$ (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.

We show in the figure (left) the two-dimensional plot of $d(E\sigma)/dE$ vs $E\sigma$ for ^{48}Ca,^{36}S + ^{48}Ca, obtained from Refs. [3, 4]. 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 we see that, at sub-barrier energies, the two data sets are well overlapping. Indeed the Wong formula [5] 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 figure (left), the two data sets essentially coincide (i.e. the two barriers have approximately the same width).

This is not the case for the two other systems (and further ones) reported in the center and on the right of the figure. For ^{40}Ca + ^{96}Zr [6] and ^{58}Ni + ^{64}Ni [7] neutron transfer couplings are dominant, and this is reflected in the different behaviour with respect to ^{40}Ca + ^{90}Zr [8] and ^{64}Ni + ^{64}Ni [9], 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, leading to a cross section enhancement as a function of energy, as observed. A full systematics will be shown in the talk, with more detailed and quantitative considerations for the various cases.

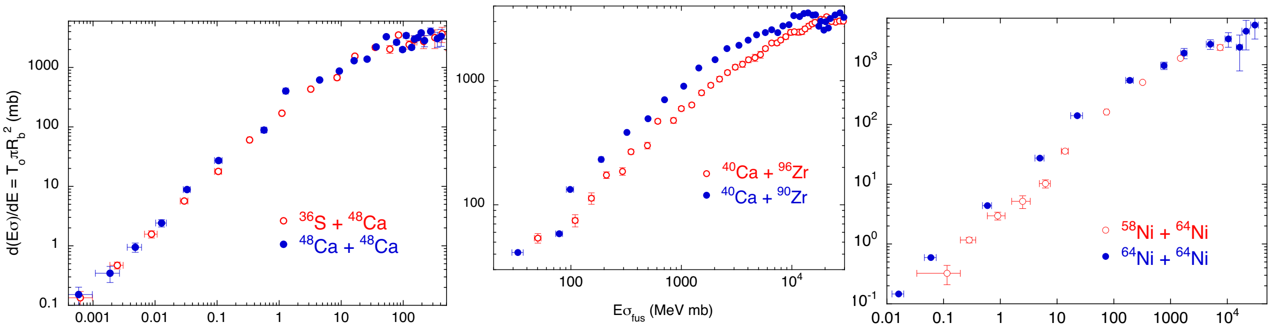

FIG. 1: Experimental plots of $d(E\sigma)/dE$ vs $E\sigma$ for the three pairs of systems ^{48}Ca,^{36}S + ^{48}Ca (left), ^{40}Ca + ^{90,96}Zr (center), and ^{58,64}Ni + ^{64}Ni (right) discussed in the text. To be noted that the ordinate is proportional to the s-wave transmission coefficient and to the square of the barrier radius.

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