Contribution ID: **33** Type: **Invited Talk**

Colliding Heavy Nuclei Have Multiple Identities on the Path to Fusion

Thursday, 22 August 2024 16:40 (25 minutes)

Barrier passing models of fusion implement absorption (irreversible energy dissipation) through an incoming-wave boundary condition or imaginary potential located inside the barrier, ensuring separation between channel coupling effects and absorption. Couplings to few-nucleon transfer channels are found to be important in selected cases, otherwise nuclei fuse essentially unchanged.

Experiments show that this picture is too simple. Measured capture cross-sections for heavy-ion collisions at energies well above and well below the barrier are systematically smaller than model calculations. This may have a dynamical origin – exchange of nucleons and the loss of kinetic energy outside the barrier separation, prior to capture leading to reduced cross-sections.

Here, we seek to address the following question: is the state of the system at the barrier separation consistent with conventional models of fusion, that assume the nuclei are essentially unchanged prior to capture?

Measurements of reflected flux in reactions of ^{32}S,^{40}Ca + ^{208}Pb were performed at a series of below-barrier energies using the PRISMA spectrometer. The isotopically-identified reflected flux reveals that the onset of energy damping occurs *outside* the fusion barrier. By the time the barrier radius is reached, the reflected flux highly fragmented into many nuclide pairs with high excitation energies, lowering their energy with respect to the fusion barrier, and broadening the barrier distribution. This provides a pathway that explains the observed above-barrier fusion hindrance and is critically neglected in barrier passing models.

Funding Agency

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Session Classification: Nuclear Reactions II

Track Classification: Nuclear Reactions