Mass-angle distributions: providing extensive insights into the dynamics and time scales of reactions forming heavy elements

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The formation of heavy elements is suppressed by fission occurring before a compact compound nucleus is formed, a process known as quasifission. A full understanding of the underlying physics of quasifission is crucial to map opportunities to form more superheavy nuclei. Quasifission is associated with the large Coulomb energy of two massive nuclei in contact, which inhibits fusion by quickly tearing the system apart. Thus a defining characteristic of quasifission is its shorter time scale. Reproducing experimental quasifission time scales is a key constraint to theoretical dynamical models. The direct time scale information carried in mass-angle distributions (MAD) is compared with new model calculations, and with times inferred from measurements of crystal blocking and pre-scission neutrons.

As well as the Coulomb energy, nuclear structure can significantly influence reaction outcomes. Recent detailed measurements of MAD at the ANU will be shown, demonstrating the role of entrance-channel static deformation alignment, spherical magic numbers, and N/Z asymmetry, as well as mass-asymmetry. As an example, for collisions of heavy projectiles, Fig.1 shows that experimental MAD and mass-widths for reactions having *several magic numbers* in the entrance channel have little mass-angle correlation and narrow mass distributions [1]. These correspond to longer sticking times, implying increased probability for fusion (as seen for ^{16}O+^{238}U). It is proposed that the effect is due to the reduced energy dissipation for spherical magic numbers [1]. However, it is only found for small N/Z asymmetry in the entrance channel. For ^{40}Ca+^{208}Pb, with a large N/Z asymmetry, quasi-fission is significant. TDHF calculations [1] show that N/Z equilibration early in the reaction changes the identities of the collision partners, thus suppressing the initial magicity during the slower fusion/quasifission competition.

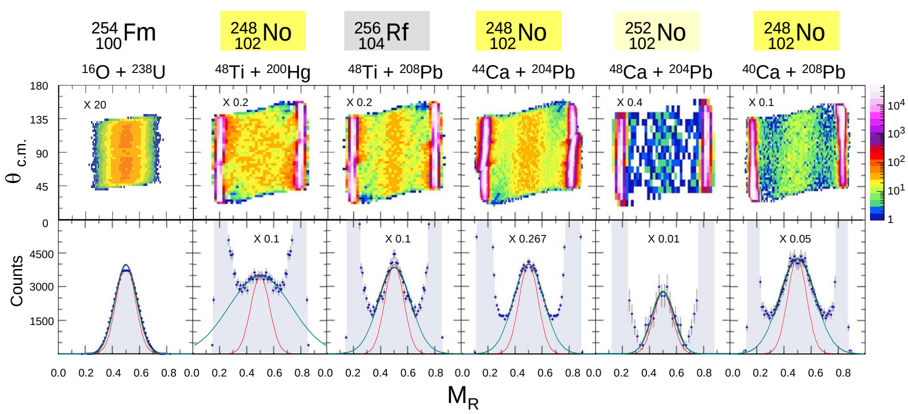

Figure 1: *Mass-ratio M_R vs. angle distributions (MAD) for reaction forming similar composite nuclei as indicated. The projected mass ratio spectra (lower panels) include Gaussian fits to the region around M_R=0.5 (turquoise lines), and Gaussian functions (red lines) with fixed $\sigma_{MR} = 0.07$ for reference [1].*

[1] C. Simenel *et al.* Phys. Lett. B **710** (2012) 607, and references therein.