Studying Heavy-ion Reactions using the Mass- Angle Distribution (MAD) Technique

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Super-heavy elements [1] can only be formed by fusing two massive nuclei. These elements are predicted to be stabilised by nuclear shell effects associated with near-spherical shapes around new predicted neutron and proton magic numbers. Their cross section of formation is inhibited by several orders of magnitude by the premature breakup of the elongated di-nuclear system known as quasi-fission [2,3]; and by fission of the unstable compound nucleus after fusion.

The probability of fusion, and its complementary competitor quasi-fission, is determined by many variables, predominantly the mass-asymmetry of the two colliding nuclei, the charge of the heavy element being formed, deformation of the target nucleus [4,5] and, it is expected, the neutron and proton shell structure encountered during the fusion process.

The role of these variables is being investigated at the ANU through the measurement of the mass-angle distributions of the fission fragments. The mass-angle distribution technique used is sensitive to reactions on timescales of $<10^{-20}$s. Comprehensive measurements have been made for reactions of ^{40}Ca, ^{34}S, ^{28,30}Si, ^{24}Mg, ^{18}O and ^{12}C beams with targets of ^{238}U, ^{232}Th and ^{208}Pb. Different projectile and target combinations were used such that the same compound nucleus was formed via two reactions.; at bombarding energies around the Coulomb barrier.

I will present a summary of results from these experiments and highlight the salient features of our detector system. A typical set of MAD's is shown in fig. 1. The anisotropy of the angular distributions seen at the highest energies as a tilt in the MAD is a signature of quasi-fission.

[1] Yu. Ts. Oganessian *et al.*, Phys. Rev. C **74**, 044602 (2006).
[2] B. B. Back *et al.*, Phys. Rev. C **32**, 195 (1985).
[3] J. Toke *et al.*, Nucl. Phys. **A440**, 327 (1985).
[4] D. J. Hinde *et al.*, Phys. Rev. C **53**, 1290 (1996).
[5] D. J. Hinde *et al.*, Phys. Rev. Lett. **101**, 092710 (2008).

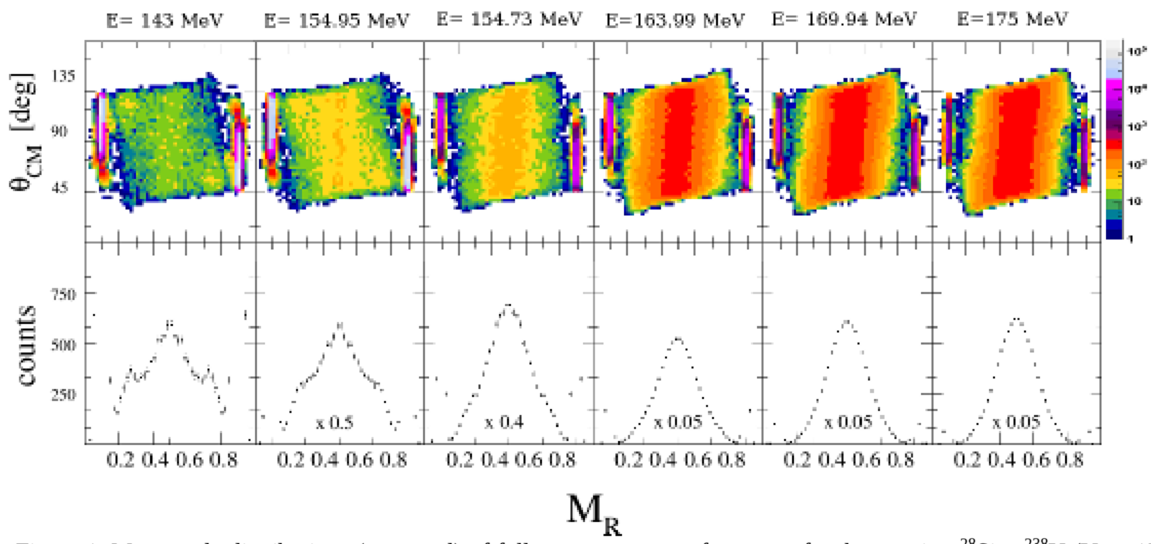

Figure 1. Mass-angle distributions (top panel) of full momentum transfer events for the reaction ^{28}Si + ^{238}U (V_B = 157 MeV). The projected mass ratios (bottom panel) show a distinct transition from significant mass-asymmetric fission at $E<V_B$, to mass-symmetric fission at $E>V_B$.