Fusion dynamics in ^{40}Ca induced reactions

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Synthesis of superheavy elements (SHEs) and investigation of their properties are among the most challenging research topics in modern science. A non-compound nuclear process called quasifission is partly responsible for the very low production cross sections of SHEs. The formation and survival probabilities of the compound nucleus (CN) strongly depend on the competition between fusion and quasifission. A clear understanding of these processes and their dynamics is required to make reliable predictions of the best reactions to synthesise new SHEs. All elements beyond Nh are produced using hot fusion reactions and beams of ^{48}Ca were used in most of these experiments. In this context a series of fission measurements have been carried out at the Australian National University (ANU) using ^{40,48}Ca beams on various targets ranging from ^{142}Nd to ^{249}Cf. Some of the ^{40}Ca reactions will be discussed in this symposium.

Measurements were performed using the Heavy Ion Accelerator Facility of ANU. Pulsed ^{40}Ca beams from the Pelletron were further accelerated using the superconducting LINAC and were bombarded with targets of ^{142}Nd, ^{176}Yb, ^{178}Hf, ^{186}W, ^{192}Os and ^{238}U. The measurements were carried out at near and above Coulomb barrier energies in all cases. The reaction products were detected using the CUBE spectrometer [1]. The position and time-of-flight information from the CUBE were used to obtain the fragment velocities and center-of-mass angles assuming two-body kinematics [1–3]. This method allows us to obtain the mass ratio (M_R) of the binary fragments from the ratios of center-of-mass velocities. The mass-angle distributions (MAD) of the reaction products from the ^{40}Ca+^{192}Os reaction is shown in the top panels (a-f) of FIG. I, where M_R is plotted against center-of-mass angle. The experimental M_R distributions are shown in the bottom panels (g-l) along with theoretical predictions [4] (red line).

The MAD of the fragments from the ^{40}Ca+^{176}Yb, ^{178}Hf, ^{186}W and ^{192}Os reactions clearly show a strong mass-angle correlation which is an obvious signature of strong quasifission component. Presence of an angular momentum dependent mass-asymmetric component is also noticed in most of these reactions as indicated by the events inside the black ellipses in FIG. I (a-f). MAD of ^{40}Ca+^{238}U shows dominant mass-asymmetric quasifission which could be due to a very short sticking time of the projectile-target system after contact. No significant mass-angle correlation is observed in the ^{40}Ca+^{142}Nd reaction. However, the widths of the M_R distribution hints the presence of slow quasi fission in this reaction too.

The experimental M_R distributions are fitted using a Gaussian function and the standard deviation is taken as a measure of the M_R width. The M_R width for the CN fission events were calculated using GEF [4]. From these ratios, maximum fusion (or minimum quasifission) probablity is estimated for the reactions studied. These are plotted for the

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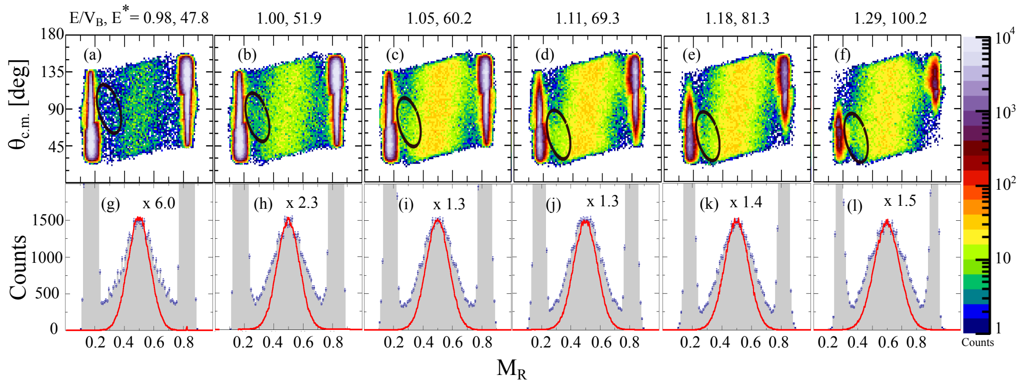

FIG. 1: MAD scatter plots for the ^{40}Ca+^{192}Os reaction at different beam energies. The mass-asymmetric quasifission components present in the MADs are shown inside the black ellipses in panels (a-f). The Gaussian distributions (red line) are the results of GEF calculations [4].

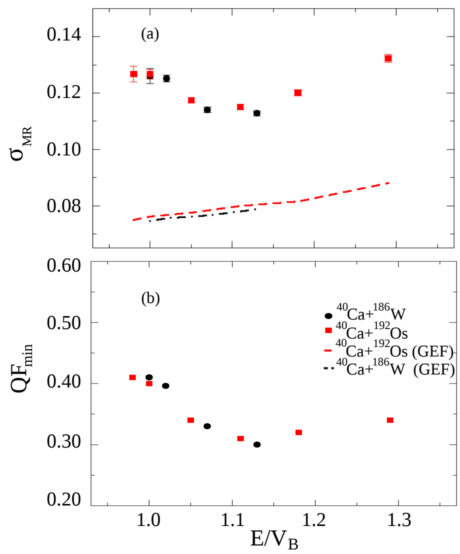

FIG. 2: (a) Experimental σ_{MR} values (solid points) and the σ_{MR} values for CN fission calculated (lines) using GEF model. (b) the minimum quasifission probability as a function of E/V_B.

^{40}Ca+^{186}W,^{192}Os reactions in FIG. 2. The maximum fusion probability ranges between 60-70% in these reactions. The angular distributions of the binary fragments were obtained from the experimental data and were used to calculate the fission cross sections. This is shown in FIG. 3. Coupled channels calcula-

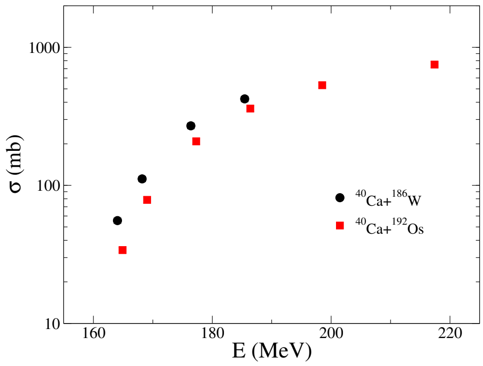

FIG. 3: Total capture cross sections for the ^{40}Ca+^{186}W and ^{40}Ca+^{192}Os reactions at different center-of-mass energies.

tions assuming standard Woods-Saxon parameters over predict the capture cross sections for these reactions indicating the dynamical effects of fusion at higher excitation energies.

References

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