Effect of projectile breakup on fission in ^{6,7}Li+^{238}U

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Introduction

Measurements by Freiesleben et al. show that the fission cross sections for ^{6}Li+^{238}U at energies around the Coulomb barrier is systematically higher than ^{7}Li+^{238}U. Although, this observation has been attributed to the higher probability of transfer induced fission for the former with respect to the latter, the detailed explanations was not provided. To understand this phenomenon, we have performed coincidence measurements to detect two fission fragments as well as projectile breakup fragments.

Measurements and analyses

The experiment was performed using ^{6,7}Li beam from the 15-UD pelletron facility in Inter University Accelerator Centre, New Delhi. The ^{238}U target of thickness $\sim$ 100 μg/cm^2 sandwiched between two layers of ^{12}C of thickness $\sim$ 15 μg/cm^2 was used. Two multi-wire proportional counter (MWPC) detectors were used to detect fission fragments. Both the MWPCs have an active area of 20x10 cm^2 and provide position signals in horizontal (X) and vertical (Y) planes, timing signal for time of flight measurements and energy signal giving the differential energy loss in the active volume. The start of the timing was taken from a small area (3.7 x 3.7 cm^2) transmission type fast timing multi-wire proportional counter and the stop was taken from the large area MWPCs. The combination of small MWPC and any one of the large MWPCs provide absolute timing of the fission fragments. Time of flight signal in combination with differential energy loss signal gives a clean separation of fission fragments from projectile and target like particles. Fig. 1 shows typical fission fragment folding angles distributions (FFFAD) in the reaction plane ($\theta_{c.m.}$) versus out of the plane ($\phi_{c.m.}$) for ^{6}Li at two energies and their respective projections on reaction plane.

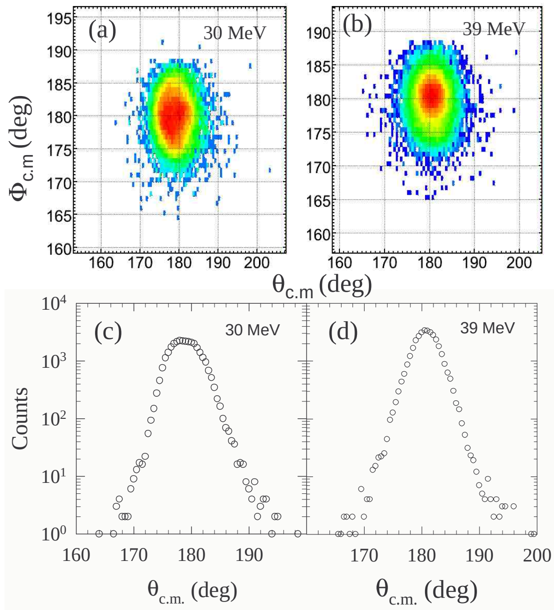

FIG. 1: Fission fragment folding angles distributions (FFFAD) in the reaction plane ($\theta_{c.m.}$) versus out of the plane ($\phi_{c.m.}$) for ^{6}Li beam energies of (a) 30 MeV and (b) 39 MeV. Respective projections on reaction plane are shown in (c) and (d) showing the difference in FWHM of the FFFAD.

In Fig. 2, full width at half maximum (FWHM) of FFFADs for ^{6,7}Li+^{238}U systems

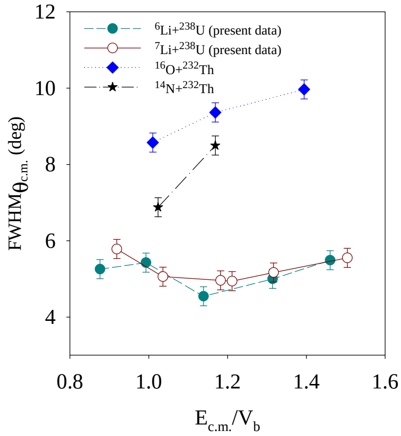

FIG. 2: Full width at half maximum (FWHM) of FFFAD as a function of energy normalized to Coulomb barrier ($E_{c.m.}/V_b$).

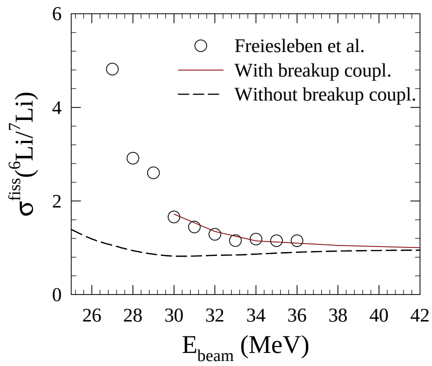

FIG. 3: Ratio of fusion excitation function data[1] of ^{6}Li+^{238}U to ^{7}Li+^{238}U. Results of FRESCO calculations for fusion cross sections are shown as a solid line (see text for details).

have been compared with the ones with tightly bound projectiles. It can be observed that the FHWM at energies above the Coulomb barrier for ^{16}O+^{232}Th[2] and ^{14}N+^{232}Th[3] systematically decreases with lowering the beam energy. But the energy dependence behaviour of the FWHM for present systems is quite different. It first decreases and then increases with energy. The increase in the FWHM at lower energies is possibly due to the large contribution of breakup fragment induced fission compared to complete fusion-fission.

Fusion/fission cross sections

Ratio of fusion excitation function data[1] of ^{6}Li+^{238}U to ^{7}Li+^{238}U at near barrier energies is shown as open circles in Fig. 3. It can be observed that the ratio increases with the decrease in energy, which can be understood in terms of low breakup threshold of ^{6}Li compared to ^{7}Li due to which the contribution from breakup fragments induced fusion/fission for the former is much higher than the latter. To estimate the total (=complete+incomplete) fusion for the above system, contnuum discretized coupled channels (CDCC) calculations are performed using cluster-folded potentials. Coupling scheme used in the calculations for breakup states is similar to Ref. [4] for ^{6}Li and Ref. [5] for ^{7}Li. Assuming the breakup to be the most dominant direct reaction channel, the cumulative absorption cross section due to long ranged imaginary potential calculated in the CDCC calculations equals to total fusion cross section. The ratio of the total fusion cross section thus calculated for ^{6}Li+^{238}U to ^{7}Li+^{238}U is shown as a solid line in Fig. 3, which shows similar trend in the observed energy dependence as the ratio of fission cross sections for the two systems. Dashed line represents the results without breakup coupling. This corroborates with our understanding that the increase in FWHM of the FFFADs at sub-barrier energies is due to the presence of breakup fusion that dominates over complete fusion.

References

[1] H. Freiesleben *et al.*, Phys. Rev. C **12** (1975) 42.
[2] R.K. Choudhury *et al.*, Phys. Rev. C **60** (1999) 054609.
[3] B.R. Behera *et al.*, Phys. Rev. C **69** (2004) 064603.
[4] S. Santra *et al.*, Phys. Lett. B **677** (2009) 139.
[5] V. V. Parkar *et al.*, Phys. Rev. C **78** (2008) 021601(R).