Total kinetic energy distribution of fission fragments in ^{6,7}Li +^{238}U reactions

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Introduction

The shape and width of fission-fragment (FF) mass and kinetic energy distribution provides a lot of information on the fission reaction mechanism and the structure of the compound nucleus (CN), the fragments as well as the interacting nuclei. The shape of the mass distribution of the fission fragments for the actinides induced by the proton or neutron is known to change with the incident energy. At low energies, it shows a double humped distribution which changes slowly to a single humped distribution as energy increases. However, for a reaction involving a weakly bound projectile (i.e., ^{6}Li + ^{232}Th), a sharp change in the shape of the mass distribution with energy was observed. The sharp increase in the peak to valley ratio (P:V) in the fission-fragment mass distribution in ^{6}Li + ^{232}Th reaction by Itkis et al. [1] and in ^{6,7}Li +^{238}U reactions by Santra et al. [2] was concluded to be due to the reduced energy transfer to the composite system caused by incomplete fusion (ICF) of alpha or deuteron/triton followed by fissions. Total Kinetic Energy (TKE) distribution of fission fragments is another important observable on which the effect of projectile breakup is not explored yet. In this contribution, the study of breakup/transfer effect on average TKE distribution for ^{6,7}Li +^{238}U reactions is presented.

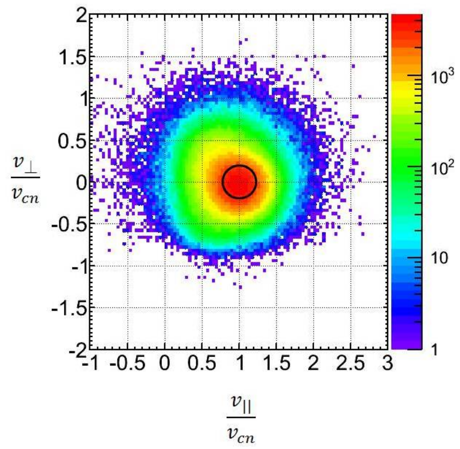

FIG. 1: Typical $\frac{v_{||}}{v_{cn}}$ vs. $\frac{v_\perp}{v_{cn}}$ plot at 50 MeV beam energy of ^{6}Li +^{238}U reaction. The events within the black circle correspond to CF-fission events.

Data analysis and Results

The experiment was performed using the ^{6,7}Li beam from the 15-UD pelletron facility in Inter University Accelerator Centre, New Delhi. The experimental details is same as in Ref. [2]. From the time of flight spectra of the fission fragments, velocities of the fragments have been obtained. The correction in the velocity due to the energy loss of the fission fragments in mylar windows of the gas detectors have been incorporated. Now applying the momentum conservation in centre-of-mass frame and assuming the sum of the masses of fission fragments equal to the mass of the compound nucleus, fragment masses have been extracted [2]. Knowing mass and velocities the TKE of the fragments have

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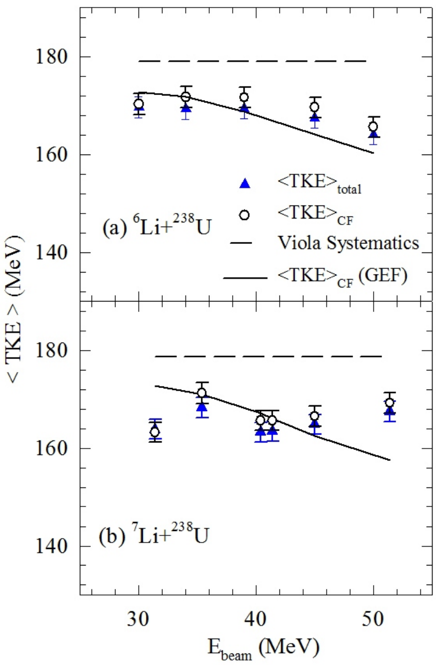

FIG. 2: <TKE> vs. beam energy spectra for (a)^{6}Li +^{238}U and (b)^{7}Li +^{238}U. Hollow circles represent the <TKE> of the fragments which are produced following complete fusion. Blue triangles represent <TKE> of total number of fission events. Black solid line is the <TKE> for CF-fission.

been derived. The parallel ($v_\parallel$) and perpendicular ($v_\perp$) components of the fragment velocities and compound nucleus velocity (v_{cn}) have been calculated following the expressions given in Ref.[2] and a plot of $\frac{v_\parallel}{v_{cn}}$ vs. $\frac{v_\perp}{v_{cn}}$ is shown in Fig. 1. For complete fusion (CF) fission $v_\parallel$ and $v_\perp$ should be equal to v_{cn} and zero respectively. The events with large deviation from above conditions are due to the contribution from breakup or transfer induced fissions. In the present measurement, it was very difficult to clearly differentiate the CF-fission and breakup or transfer induced (ICF) fission as the difference in mass number of the composite nuclei formed by CF and ICF is only by 2 to 4 units. However, selecting the intense peak of the plot which mainly follows the relation $\sqrt{(v_\parallel - v_{cn})^2 + v_\perp^2} < 0.2 v_{cn}$ as prescribed in Ref.[2] and shown by a circle in Fig. 1, one can get rid of ICF events and choose only the CF-fission events. As shown in Fig. 2, the average total kinetic energy (<TKE>) of the fission fragments has been obtained as a function of incident beam energy considering all fission events (triangles up) and CF-fission events (hollow circles) for ^{6}Li +^{238}U (Fig. 2:(a)) and ^{7}Li +^{238}U reaction (Fig. 2:(b)). It can be observed that the <TKE> for CF-fission events are ~2-3 MeV higher than that for total fission events. But this difference is very small and lies within the experimental uncertainty. The total kinetic energy is also calculated from Viola's systematics using the expression $\langle TKE \rangle = .1189 \frac{Z^2}{A^{\frac{1}{3}}} + 7.3$ (Z and A are charge and mass no. of the compound nucleus respectively) and shown as a dashed line Fig. 2 which is independent of beam energy. It is observed that, for both the reactions, the measured <TKE> is ~10 MeV less than <TKE> calculated from Viola's systematics. This difference may be attributed to the kinetic energy taken away by neutrons.

GEF Calculation

To have an idea about the energy dependence of <TKE>, more realistic calculations have been made using GEF code [3]. Required excitation energy has been obtained using the expression $E_x = E_{cm}+Q-B_f-E_{rot}-E_n$. Required RMS angular momentum has been calculated using CCFULL code. The absolute values of <TKE> for both the systems (solid line in Fig. 2) are pretty close to the experimental data (symbols), though the difference in the GEF calculation from the data has been found to be larger at high energies for both the reactions.

References

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