Understanding complete and incomplete fusion-fission reactions induced by weakly bound nuclei ^{6,7}Li

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Introduction

Recent measurements by Parihari *et al.* [1] show that the fission cross sections for ^{6}Li+^{235,238}U systems at energies around and the Coulomb barrier is systematically higher than ^{7}Li+^{235,238}U. This difference has been attributed to the higher probability of breakup or transfer induced fission for the former with respect to the latter. Coupled channels calculations including breakup channels show that $<\ell^2>$ gets enhanced at sub-barrier energies which in turn partially explain the observed enhancement in fission fragment (FF) anisotropy for the above systems. To investigate the effect of breakup and its threshold energy on other fission observables, here we report on the measurements of the FF mass and folding angle distributions for ^{6,7}Li+^{238}U reactions. The identification and study of pure complete fusion-fission (CF-F) from total fusion-fission (TF-F) has also been reported.

Analysis and Results

FF mass and folding angle distributions for ^{6,7}Li+^{238}U reactions are measured by time-of-flight technique using two MWPC detectors [2]. The ratios of peak to valley of FF mass distributions are obtained as a function of compound nucleus (CN) excitation energy and shown in Fig. 1 as filled squares (upper panel) and circles (lower panel) respectively and compared with the literature data for p induced reactions forming similar compound nuclei [3, 4]. The P/V values obtained from the mass distributions calculated using GEF code [5] (dotted line) are found to be consistent with the available data for p+^{244}Pu reaction (that forms the same CN as in ^{7}Li+^{238}U reaction). However, it is interesting to observe that the P/V ratios for ^{6,7}Li+^{238}U are systematically higher than the GEF predictions over the measured excitation energy range. Similar observations are also made by Itkis *et al.*[6] in ^{6}Li+^{232}Th reaction which was concluded to be due to a reduced energy transfer to the composite system caused by incomplete fusion (ICF) of alpha or deuteron followed by fissions.

The increase in the P/V ratio for ^{6}Li+^{238}U at sub-barrier energies is sharper than that for ^{7}Li+^{238}U. The smaller deviation in the measured P/V ratio from the predictions observed for ^{7}Li+^{238}U (compared to ^{6}Li+^{238}U) is due to larger breakup threshold for ^{7}Li and hence less ICF contribution.

For the above plots, the events due to ICF fission have not been separated. So, the behavior observed are due to CF-F+ICF-F. In order to disentangle the behavior of CF-F from TF-F, a scatter plot of velocity components of the composite nuclei is made using the formalism by Hinde *et al.*[7] from which only the intense central events with velocity components similar to that of a CN are selected as in Fig. 2. The P/V ratio of these pure CF-F events are shown as hollow squares(upper panel) and hollow circles (lower panel) in Fig. 1 for ^{6,7}Li+^{238}U reactions respectively. Interestingly these values are very close to the GEF calculations. So, the addi-

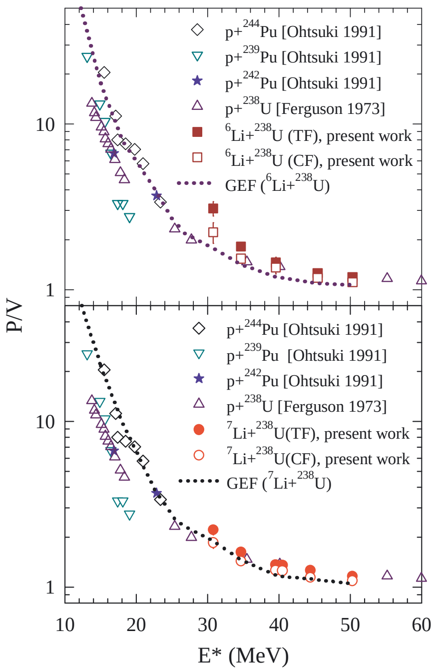

FIG. 1: Ratio of peak to valley of measured FF mass distribution for ^{6}Li(^{7}Li)+^{238}U are shown as filled squares(circles) in upper(lower) panel, along with literature data for p+^{239,242,244}Pu (Ohtsuki 1991: [4]) and p+^{238}U (Ferguson 1973: [3]) and GEF calculations (dotted line). P/V ratio derived only for present CF events are shown as hollow squares and circles respectively.

tional contributions towards P/V ratios obtained earlier are certainly due to ICF events.

In Fig. 3, the FWHM of FF folding angle distributions are also obtained for only the above-mentioned selected CF-F events. They are found to increase linearly with energy, similar to the reactions induced by tightly bound projectiles, but different from TF-F.

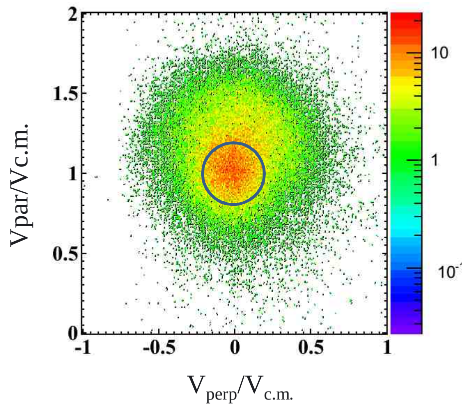

FIG. 2: Typical scatter plot of the parallel velocity component ($v_{\rm par}$) versus perpendicular velocity component ($v_{\rm perp}$) of the fissioning nuclei normalized to its center-of-mass velocity ($v_{\rm c.m.}$) for ^{7}Li+^{238}U reaction at $E_{\rm lab}$=31.4 MeV. A circular cut with radius $[(v_{\rm par}-1)^2+v_{\rm perp}^2]^{1/2} \leq 0.2 v_{\rm c.m.}$ corresponds to pure CF events.

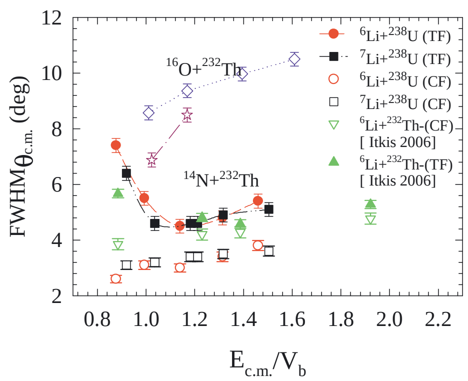

FIG. 3: FWHM of FF folding angle distributions versus $E_{\rm c.m.}/V_b$. Filled circles (squares) correspond to total fusion and hollow circles (squares) correspond to complete fusion events for presently measured ^{6}Li(^{7}Li)+^{238}U reaction.

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