Reaction Dynamics Study of ^{20}Ne + ^{238}U at E* = 82.5 MeV

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Introduction

Despite extensive research over several decades, a comprehensive understanding of the nuclear fission process, particularly its complex dynamics, remains elusive. The study of quasi-fission and fast-fission dynamics is pivotal in unraveling the complexities of superheavy element (SHE) formation, as these phenomena often pose significant barriers to the synthesis of such elements. Measurements at higher energy and high angular momentum is particularly important for proper understanding of the processes intermediate between deep in-elastic and fusion fission.

Fission fragment folding angle and mass distributions are valuable tools for understanding fission reaction mechanisms. The folding angle distribution reveals information about the linear momentum and energy transfer involved. Since the folding angle of the fission fragments depends on the recoil velocity of the fissioning nuclei, reactions with different momentum transfers (such as compound nuclear fission and transfer fission) can be distinguished based on their distinct recoil velocities. At energies close to the barrier, transfer reactions are the most significant among direct reaction channels. Consequently, the fission fragment folding angle distribution technique has been effectively used to differentiate transfer fission from pure fusion fission [1, 2]. Fission fragment mass distributions, on the other hand, can provide information if the target projectile system follows fusion-fission path or non-compound nuclear fission (e.g; quasi-fission, fast fission etc) path. It is now well established that the width of the fission fragment mass distributions are wider in case of quasi-fission or fast fission.

Fission fragment mass distributions for heavy ion-induced reactions on actinides targets near the Coulomb barrier is well studied in last few decades, however has received limited attention well above the Coulomb barrier due to the lack of data. An extensive study at high excitation energy is particularly useful as it bridges our understanding of the mechanism of fission and noncompound nuclear reactions. In the present work, we report the fission fragment folding angle distribution and mass distributions for the reaction ^{20}Ne +^{238}U at high excitation energy E* = 82.5 MeV.

Experimental details

The experiment was performed at VECC, Kolkata, India, using a ^{20}Ne beam at 145 MeV to bombard a ^{238}U target with a thickness of 300 μg/cm^2 mounted at a 45° angle. Two large-area position-sensitive multiwire [3] proportional counters (MWPCs) were placed on movable arms in the scattering chamber to detect fission fragments at calculated angles based on Viola's systematics [4]. The MWPCs operated with isobutane gas at 3.0 Torr, and data on time of flight, X and Y coordinates, and energy loss were collected using a VME-based DAQ system.

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Results and discussions

Figure 1 shows the folding angle distributions for the reaction ^{20}Ne +^{238}U at E* = 82.5 MeV. The peak of the folding angle distribution was found to be consistent with the calculated values from the Viola's systematics. The distribution suggests majority of the events originates from the full momentum transfer events at this excitation energy. We put a narrow gate to isolate potential complete fusion events. It was confirmed that narrowing the gate further reduces the statistics but has no effect on the mass distribution width.

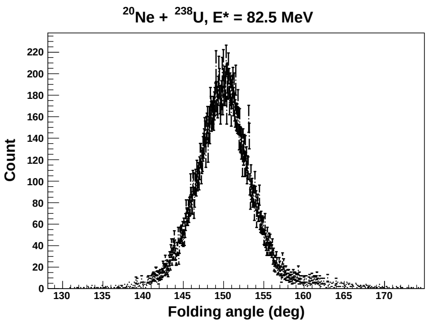

FIG. 1: The measured folding angle distributions at E* = 82.5 MeV for the reaction ^{20}Ne + ^{238}U.

The experimental mass distribution as shown in Figure 2, were obtained using the TOF difference technique. The peak of the mass distribution is around the half of the composite system mass ($A_{cn}/2$). An analysis, following the method proposed by Itkis et al. [5–8], utilized the transitional-state approach with shell correction to characterize the mass distribution. It was observed that the experimental mass distribution broadens compared to the LDM calculation, indicating significant influence from transfer-induced fission or non-compound fission for the reaction system.

It may be mentioned here that the previous analysis of folding angle distributions [1] suggests that the admixture of transfer induced fission (TF) and fusion fission (FF) may not be solely possible with a narrow gate in folding angle distribution in reactions with actinides targets. This is because there is a significant overlap of TF and FF events in folding an-

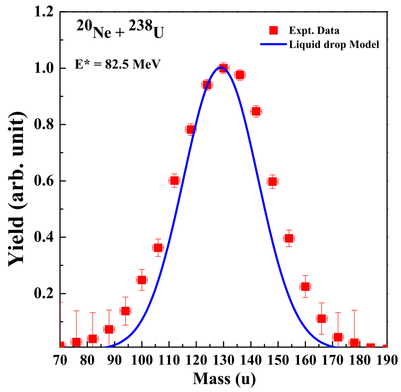

FIG. 2: The measured mass distributions at E* = 82.5 MeV for the reaction ^{20}Ne + ^{238}U. Solid bullets represent the experimental data points and LDM calculation of compound nuclear shown by blue solid line.

gle distribution. This puts a significant question regarding the origin (e.g; quasi/fast fission or transfer induced fission) of the broadening of the mass distribution as shown in Figure 2. Preliminary results for both the mass and folding angle distributions are presented here. Further analysis is ongoing, and the detailed findings will be presented at the symposium.

References

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