Evaporation residue excitation function for ^{30}Si + ^{180}Hf

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Introduction

Understanding the dynamics of the nuclear reaction as well as the factors that determine the reaction outcomes are challenging in the superheavy mass region [1]. The quasifission (QF) process [2], in which the system reseparates before reaching a compact compound nucleus (CN), is a major hurdle in forming heavy and superheavy evaporation residues (ERs) in heavy-ion induced reactions. Conclusive evidence of QF can be inferred from anomalous fission fragment angular anisotropies, broadened fission fragment mass distributions, mass-angle correlations and strong reduction in ER cross-section [3].

We have previously studied the fission fragment mass ratio distribution for the reaction ^{30}Si + ^{180}Hf populating the CN ^{210}Rn. The system shows (FIG. 1) larger mass ratio widths when compared with a very asymmetric reaction ^{16}O+ ^{194}Pt, forming the same CN [4]. The result indicates the onset of QF in the ^{30}Si + ^{180}Hf reaction and hints the entrance channel dependence of QF despite the relatively lower values of Z_PZ_T in these reactions. Here, we report the study of the ER measurements for the reaction ^{30}Si + ^{180}Hf. The results are compared with that of ^{16}O+^{194}Pt reaction, populating the same CN [5].

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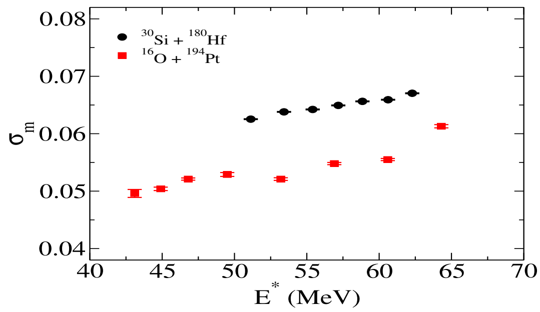

FIG. 1: Experimental mass ratio widths of the fragments from the ^{16}O + ^{194}Pt and ^{30}Si + ^{180}Hf reactions at similar compound nuclear excitation energies [4].

Experimental Details

The ER excitation function measurement was performed at the 15UD Pelletron + LINAC accelerator facility of IUAC. Pulsed ^{30}Si beam with 2 μs pulse separation was used to bombard the isotopically enriched ^{180}Hf target of thickness 150 μg/cm^2 on 40 μg/cm^2 thick carbon backing at laboratory energies in the range of 130 to 172 MeV. ERs were separated from the intense beam background using HYbrid Recoil mass Analyzer (HYRA) [6]. Two silicon detectors were used inside the target chamber, placed at $\theta = \pm 25°$, to detect the Rutherford scattered beam-like particles for absolute normalization of ER cross sections. These detectors were also used for positioning the beam at the center of the target.

The ERs reaching the focal plane were detected using a position sensitive multiwire proportional counter (MWPC) of active area 6 inch × 2 inch followed by a silicon strip detector of active area 2.4 inch × 2.4 inch. A time-of-flight (TOF) spectrum was generated with the timing pulse from the MWPC anode as start and the radio frequency (RF) signal, delayed suitably, as stop. The energy loss (ΔE) vs TOF spectrum helped in unambiguous identification of ERs from the beam-like and the target-like contaminations. FIG. 2 shows the two-dimensional plot of ΔE versus TOF at 147.4 MeV beam energy.

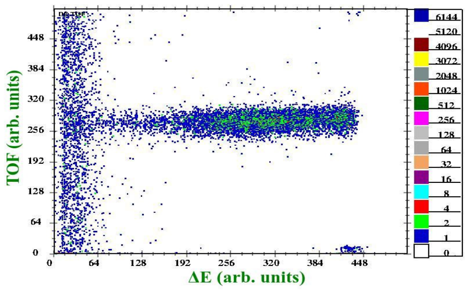

FIG. 2: Two-dimensional plot of ΔE vs TOF for the reaction ^{30}Si + ^{180}Hf at 147.4 MeV beam energy.

Data analysis and results

Total ER cross sections (σ_{ER}) were calculated using the relation

$$\sigma_{ER} = \frac{Y_{ER}}{Y_{mon}} \left(\frac{d\sigma}{d\Omega}\right)_R \Omega_M \frac{1}{\varepsilon_{HYRA}} \qquad (1)$$

where Y_{ER} is ER yield at the focal plane, Y_{mon} is the yield of elastically scattered projectiles registered by the monitor detector, $(\frac{d\sigma}{d\Omega})_R$ is the differential Rutherford scattering cross section, Ω_M is the solid angle subtended by the monitor detector, and ε_{HYRA} is the transmission efficiency of the HYRA.

We calculated ε_{HYRA} for the ^{30}Si + ^{180}Hf reaction by using the ^{30}Si + ^{186}W reaction [7] as the calibration system following the method described in Ref. [5]. The ER angular distribution for the two reactions were simulated using TERS [8] and were compared within the angular acceptance of HYRA. The efficiency obtained for ^{30}Si + ^{186}W reaction is hence normalized to get the transmission efficiency for ^{30}Si + ^{180}Hf reaction.

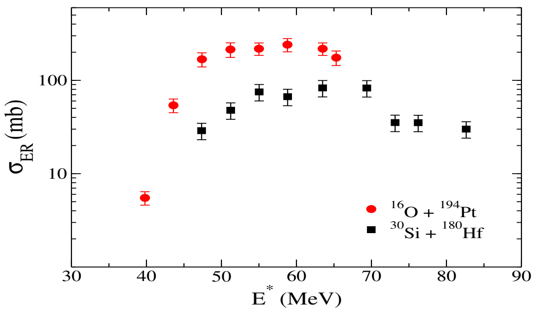

FIG. 3: The experimental ER cross section for the ^{30}Si + ^{180}Hf reaction compared with the ^{16}O + ^{194}Pt reaction.

Experimental ER cross sections for the ^{30}Si + ^{180}Hf reaction is compared with that of the ^{16}O + ^{194}Pt reaction in FIG. 3. Significant reduction in ER cross section in ^{30}Si + ^{180}Hf has been observed, confirming the presence of QF in the reaction. Present results are in very good agreement with our previous observations in fission fragment mass ratio distribution in these reactions.

Acknowledgments

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