Fission fragment angular distribution for ^{28}Si+^{175}Lu

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Study of non-compound nuclear fission (NCNF) processes is important as complete fusion between two massive nuclei is hindered by their presence. In NCNF, the di-nuclear system, formed after capture, reseparates before it is fully equilibriated in all degrees of freedom. In a recent work, Banerjee et al. [1] reported approximate boundaries for the onset of NCNF processes. Presence of NCNF in a system causes the *fusion probability*, $\langle P_{\rm CN}\rangle$, to deviate from unity. $\langle P_{\rm CN}\rangle < 1$ also signifies transition from the domain of statistical models to dynamical models. This transition occurs in the pre-actinide mass region. Significant deviation of the experimental fission fragment (FF) angular anisotropy from the prediction of the statistical saddle point model (SSPM) indicates presence of NCNF in a system. Evidences of NCNF or the signatures of fusion hindrance in reactions, leading to a pre-actinide composite system, were found experimentally through different probes (e.g. suppression in the evaporation residue (ER) cross section [2], anomalous FF angular anisotropy [3] and increase in FF mass ratio distribution width [4]). The systematics of Ref. [1] suggests that the system under investigation, namely, ^{28}Si+^{175}Lu might show signatures of NCNF. The motive of this work is to verify the presence of NCNF in this reaction, if any, by measuring FF angular distribution above the Coulomb barrier.

The experiment was performed in the general purpose scattering chamber (GPSC) facility of IUAC. A ^{28}Si beam was bombarded onto ^{175}Lu target of thickness 110 μg/cm^2 to populate the composite system ^{203}At. The target was fabricated at the target preparation laboratory of IUAC by resistive heating method, sandwiched between two thin $^{\rm nat}$C layers. Fission fragments were detected by nine hybrid telescope detectors [5] each consisting of a ΔE (gas) detector and E (silicon) detector. Out of these, six telescopes were mounted on the upper arm covering the backward angles (60°–170°) while the other three telescopes were mounted on the lower arm covering the forward angles (41°–70°). Pressure of isobutane gas in all the ΔE detectors was kept constant at 74 mbar. The experimental arrangement is shown in Fig 1.

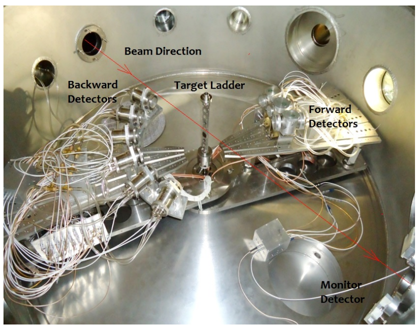

FIG. 1: The experimental set-up in the GPSC.

The trigger for the data acquisition system was generated using the OR of the timing signals from all E and ΔE detectors. Two monitor detectors were kept at 10° for positioning beam on the target and normalization of cross sections. Most of the fission fragments were stopped in ΔE detectors due to higher stopping power. All high energy beam-like particles passed through ΔE detectors and were

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stopped at E detectors.

The measured FF angular distributions (W(θ) or $\frac{d\sigma}{d\Omega}$) were transformed from the laboratory to the center of mass (c.m.) frame of reference using Viola systematics for symmetric fission [6]. The angular distributions (normalized to W(90°)) at three different projectile energies are shown in Fig. 2. The experimental anisotropies were obtained from the ratio $\frac{W(180°)}{W(90°)}$.

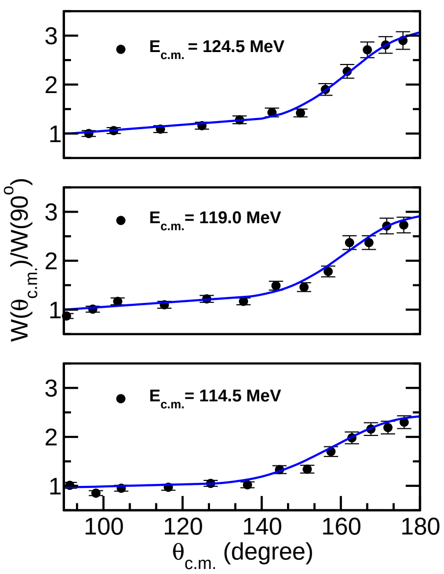

FIG. 2: Fission Fragment angular distribution for ^{28}Si+^{175}Lu. Filled circles are experimental points and solid lines are fit to the experimental data.

Ramachandran et al. [8] had reported measurement of prescission neutron, proton, and α-particle multiplicities for this system earlier. In order to explain observed multiplicities, fission barrier of 1.10 times the rotating finite range model [7] barrier was used in the statistical model calculation. In the present work, the same value of fission barrier was used for calculating anisotropies. The level density parameter was taken as $\frac{A}{11}$. Experimental anisotropies along with SSPM calculation are shown in Fig 3. Tripathi et al. [9] reported measurement of FF angular anisotropies for a neighbouring system, namely, ^{28}Si+^{176}Yb. Measured anisotropies

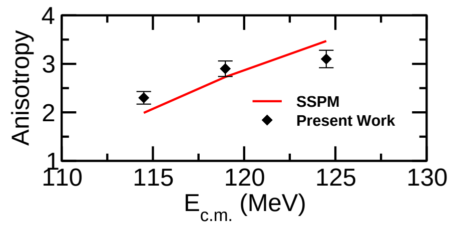

FIG. 3: Angular anisotropy of ^{28}Si+^{175}Lu reaction.

could be interpreted well with SSPM calculation indicating no major contribution from NCNF processes. We also observe (Fig. 3) that experimental anisotropies are approximately reproduced by calculation. Therefore, we conclude that the system ^{28}Si+ ^{175}Lu does not show significant contribution from NCNF processes. In other words, $\langle P_{\rm CN} \rangle$ is not expected to have a large deviation from unity for the present system.

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References

[1] Tathagata Banerjee, S. Nath, and Santanu Pal, Phys. Rev. C **91**, 034619 (2015).

[2] A. C. Berriman et al., Nature (London) **413**, 144 (2001).

[3] R. Yanez et al., Phys. Rev. C **88**, 014606 (2013).

[4] R. Rafiei et al., Phys. Rev. C **77**, 024606 (2008).

[5] A. Jhingan et al., Proc. DAE Symp. Nucl. Phys. **59**, 830 (2014).

[6] V. E. Viola et al., Phys Rev. C **31**, 1550 (1985).

[7] A. J. Sierk, Phys. Rev. C **33**, 2039 (1986).

[8] K. Ramachandran et al., Phys. Rev. C **73**, 064609 (2006).

[9] R. Tripathi et al., Phys. Rev. C **79**, 064607 (2009).