Study of fission fragment angular anisotropies in ^{28}Si+ ^{197}Au, ^{209}Bi and ^{232}Th reactions

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I. Introduction

The fission fragment angular distributions from heavy-ion reactions are regarded as a rich source of information about the saddle point shapes of fissioning nuclei. The angular distribution is characterized by the anisotropy, defined as the ratio of yields at 180^o to that of 90^o with respect to the beam direction; W (180^o) / W (90^o) [1]. The angular anisotropies have been determined for a variety of target-projectile systems and observed values were anomalously different with respect to the standard statistical saddle point model (SSPM) [2] prediction. Understanding of these observed differences provides insight into the overall fission dynamics.

Non-compound-nucleus (NCN) fission is an important area in the field of heavy ion induced fission. In this process, the target and projectile come in contact forming a composite system, however, in which the system reseparates before reaching a compact compound nucleus (CN) due to onset of non-equilibrium phenomenon. The observed anomaly in the anisotropy values is thought to be due to the admixture of the NCN fission and the CN fission in the heavy ion induced reaction.

Measurement of the angular anisotropy is very useful probe to disentangle the different contribution of the compound nucleus and non compound nucleus (NCN) fission mechanism such as quasi fission, fast fission and pre equilibrium fission [3]. It has been observed that product of Z_pZ_t (Z_p and Z_t correspond to target and projectile, respectively) play an imported role in the formation of compound nucleus formation. Previously, it was predicted that quasi fission occur when Z_pZ_t >1600. But, recent results shows that onset of quasi fission start at Z_pZ_t value equal to nearly 1000 and plays a dominating role at higher value. Angular anisotropy data for a variety of target-projectiles systems are needed to understand the role of NCN fission to the total fission cross section.

In the present work, we report the results on fission fragment angular distributions for the ^{28}Si (179 MeV) + ^{197}Au, ^{209}Bi, ^{232}Th systems.

II. Experimental Setup

The measurement of fission fragment angular distribution was carried out using BARC-TIFR Linac booster at Mumbai. The ^{28}Si beam of 179 MeV energy was bombarded on targets ^{197}Au (400 μg/cm^2), ^{209}Bi (500 μg/cm^2) and ^{232}Th (1.3 mg/cm^2). Fission fragments were detected by using a Si-detector telescope, consisting of ΔE – E detectors (25 - 300 μm). This telescope was placed at a distance of 26 cm from the target on a rotating arm inside the scattering chamber. A collimator with 5 mm diameter was placed in front of this telescope. Most of the fission fragments were stopped in the ΔE detector while projectile like fragments and light charged particles reaching the E detector were well separated in a two dimensional ΔE versus E -plot. Another silicon detector with thickness of 300 μm was placed at an angle 15^o with respect to beam direction. This detector, with collimator of 2.0 mm was used to measure Rutherford scattering events and for normalization of the fission yields.

III. Results and Discussions

Measured fission fragment angular distributions are shown in Fig. 1 (solid circles).
The fission fragment angular anisotropies are extracted from least squares fit using Legendre polynomial expression up to fourth order to the measured data of fission fragment angular distributions as shown in the in Fig. 1 (solid lines). Measured anisotropies along with theoretical predictions of standard statistical saddle point model (SSPM) for the present work are shown in Table I. The beam energies after

correcting for energy loss within the target foil were used in SSPM calculations. According to SSPM model, fission fragment anisotropy is given by the relation

$$A = 1 + \frac{\langle l^2 \rangle}{4K_o^2}.$$

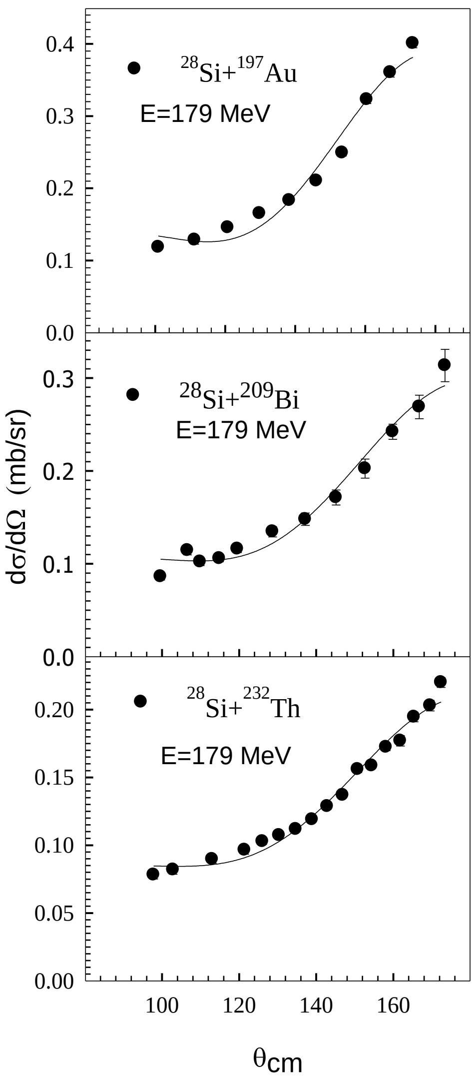

Fig.1. Measured fission fragment angular distributions for ^{28}Si+^{197}Au, ^{209}Bi and ^{232}Th systems at 179 MeV beam energy.

Where,

$$K_0^2 = TI_{eff} / h^2 ,$$

T, I_{eff} and $\langle l^2 \rangle$ are the temperature, the effective moment of inertia at the saddle point and the mean square angular momentum of the fissioning system respectively. The saddle point temperature is given by the following relation,

$$T = \sqrt{\frac{E^*}{a_f}}.$$

where E^* is the excitation energy of the fissioning system and a_f level density parameter at the saddle point. The E^* can be written as,

$$E^* = E_{cn}^* - B_f(l) - E_{rot}(l) - E_n.$$

where E_{cn}^* is the excitation energy of the compound nucleus, $B_f(l)$ and $E_{rot}(l)$ are the l dependent fission barrier and rotational energies, E_n is the evaporated neutron kinetic energy. The values of $B_f(l)$ and $E_{rot}(l)$ are calculated by using a rotating finite-range model [4]. E_n, is obtained from ref [5].

The present results may be considered as preliminary. The present data along with the data from the literature are being analysed to develop a systematic of fission fragment angular anisotropies of the compound system as a function of Z_pZ_t.

TABLE –I. Comparative study of anisotropy

Reaction	$E_{c.m.}$ (After correcting for loss in target)	W(180^o)/W(90^o)	
		Expt.	SSPM
^{28}Si+^{197}Au	156.23 MeV	2.81	3.26
^{28}Si+^{209}Bi	157.19 MeV	2.93	2.66
^{28}Si+^{232}Th	157.17 MeV	2.47	2.89

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