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Fission fragment angular distributions in ^{16}O + ^{181}Ta

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Abstract. Time of flight and energy of fission fragments were measured using pulsed beam. Fission fragment mass and energy integrated angular distributions were extracted. Fission fragment anisotropy was explained in the framework of saddle point model.

Keywords. Fusion–fission; quasifission; saddle-point model.

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1. Introduction

Studies of HI induced fission angular distribution of fragments have shown a greater anisotropy than that expected on the basis of standard fission theory [1–2]. Wider mass distributions, forward backward asymmetry of mass distribution are also observed in some heavy systems [3]. These phenomena are attributed to many non-compound reaction process such as quasifission etc [3]. We have undertaken an experiment to understand reaction mechanism of fission through angular distribution and mass distribution measurements.

2. Experiment

The experiment was carried out at Nuclear Science Centre, New Delhi, using ^{16}O pulsed beam from 15UD pelletron. Beam of energy 92, 98 and 108 MeV was bombarded on tantalum target of thickness 205 μg/cm^2 and carbon backing 10 μg/cm^2 (thickness estimated by alpha transmission technique) in general purpose scattering chamber. Fission fragments were detected by number of 100 mm^2 partially depleted surface barrier detectors of thickness 200 to 300 micron operated in singles mode. Two additional detectors were kept at 10° on both side of beam axis inside the chamber to monitor Rutherford scattering for cross section normalization. For each event the detector measured energy and time of flight with respect to time structure of pulsed beam. The pulsed beam has repetition rate of 250 ns and width of 1.8 to 2 ns

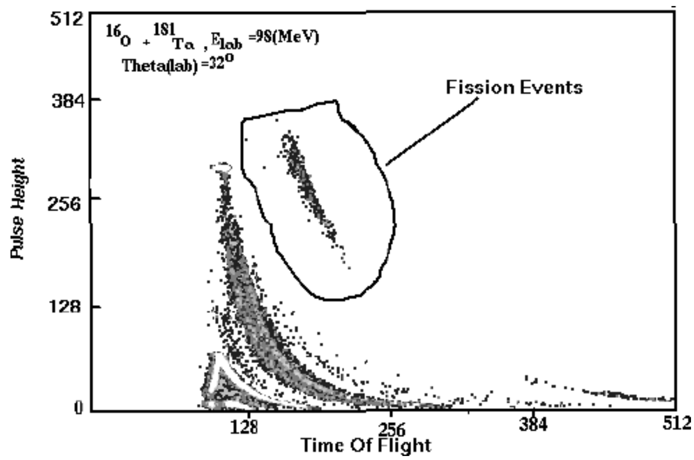

Figure 1. Two dimensional energy versus time of flight spectrum. Time of flight in arbitrary units.

(measured from width of elastic peak during the experiment). Start signal of the TAC was from detector and stop from RF of the accelerator. Absolute time scale of the events were determined from fast elastically scattered peak. The energy and time of flight signal were corrected for pulse height defect and plasma delay following the empirical formula of Ogihara [4]. Energy calibration of the detector was done from elastic scattering data at different energy and alpha and fission fragments emitted from ^{252}Cf source. Throughout the experiment there was good separation of fission events and other reaction products. For fission cross section calculation a gate was put on fission events at two dimensional scattered plot of energy versus time. At each angle cross section was normalized with yield of 10° monitor assuming it to be fully Rutherford. A typical two dimensional plot is shown in figure 1.

3. Results and discussion

The measured fission angular distributions were transformed from laboratory to center of mass frame by appropriate Jacobian obtained by using Viola systematics for symmetric fission [5]. The angular distributions in center of mass are fitted with sum of even order Legendre polynomials to extract the fission fragment anisotropy $W(180\,^\circ)/W(90^\circ)$. The angular distributions with fitting is shown in figure 2. Total fission cross sections are obtained by integrating the angular distribution data which is shown in figure 2. In the analysis of anisotropy saddle point model was used [6]. In the calculation of anisotropy by this model requires the value of the effective moment of inertia at the saddle point $J_{\rm eff}\,(l)$. The temperature T of the fissioning system at the transition state, and l distribution of the fissioning system. $J_{\rm eff}(l)$, the fission barrier $B_{\rm f}(l)$ and the ground state rotational energy $E_{\rm rot}(l)$ was calculated using the finite range model of Sierk [8]. The excitation energy at the saddle is calculated using the following equation:

$$E^* = E_{\rm cm} + Q - B_{\rm f}(l) - E_{\rm rot}(l) - E_n, \tag{1}$$

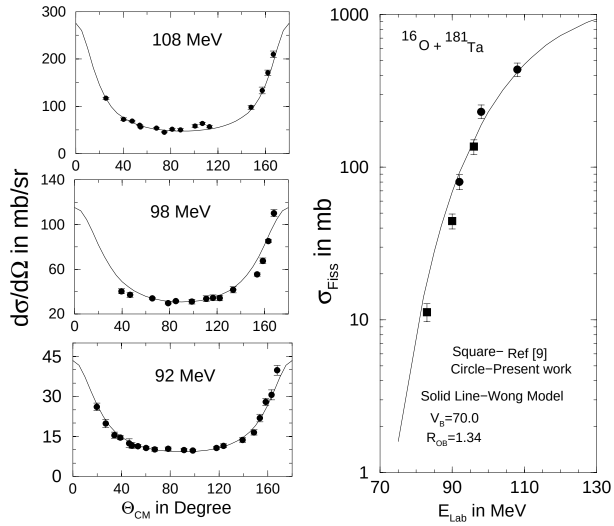

Figure 2. Left: Fission fragment angular distribution, solid lines are fit by even order legendre polynomials. Right: Fission excitation function.

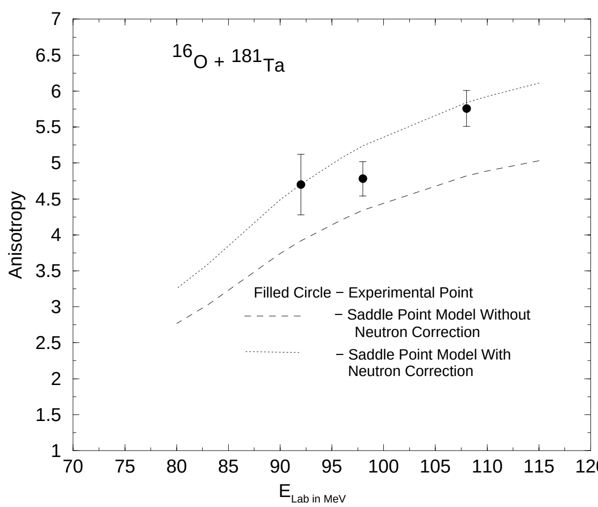

Figure 3. Fission fragment anisotropies for the system $^{16}O + {}^{181}Ta$.

where $E_{\rm cm}$ is the energy in the center of mass frame, Q is the Q value for forming the compound nucleus and E_n is the average energy removed by emission of the pre saddle neutrons. The saddle point temperature has been calculated using the relation $T = \sqrt{E^*/a}$, where a is the level density parameter. A value of $A/10$ MeV^{-1} was assumed for level density. In our system $\sigma_{\rm fission} < \sigma_{\rm fusion}$. The transmission coefficients $T(l)$ obtained from Wong model for fusion cross section [7] are multiplied by the fission probability $P_{\rm f}(l)$ to obtain the l distributions for fission. $P_{\rm f}(l)$ were obtained from statistical model code

Table 1. Summary of the results.

$E_{\rm beam}$ MeV	$\sigma_{\rm Fiss}$ (mb) expt.	$\sigma_{\rm Fiss}$ (mb) theory	A expt.	A (without neutron correction)	A (with neutron) correction)
108	437 ± 44	420	5.76±0.25	4.82	5.84
98	231 ± 41	189	4.78±0.24	4.34	5.22
92	80 ± 9	92	4.70±0.47	3.92	4.71

PACE2. We have used the values of prefission neutron multiplicity obtained from PACE2. The calculated anisotropies and measured anisotropies are shown in figure 3.

4. Conclusion

In the present paper analysis of fission fragment anisotropies and fission excitation function for the system ^{16}O + ^{181}Ta at energies above the barrier have been reported. The measured anisotropies are consistent with standard statistical model prediction. Mass distribution results will be reported elsewhere.

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