Mass distribution of fission fragments arising from excited ^{190}Pt

R. Kumar[1*,†] M. Maiti[1,‡] A. Pal[2,3], S. Santra[2,3], P. Kaur[1], H. Sharma[1], Y. Arafat[1], P. C. Rout[2,3], A. Baishya[2,3], P. Taya[2], M. Meher[2,3], and T. Singh[2,3]
[1] *Department of Physics, Indian Institute of Technology Roorkee, Roorkee-247667, India*
[2] *Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai- 400085, India and*
[3] *Homi Bhabha National Institute, Anushaktinagar, Mumbai - 400094, India*

Introduction

The fission in neutron-deficient lead region has witnessed significant advancements, both experimentally and theoretically in recent times. The discovery of asymmetric splitting in β-delayed fission of ^{180}Tl [1] followed by subsequent heavy-ion experiments on the fission of neutron-deficient mercury isotopes have contributed to a deeper qualitative understanding of the complex fission process in sub-lead nuclei [2, 3]. The inability of contemporary theoretical calculations to explain fission properties of A≤200 nuclei let to improved microscopic calculations that revealed the role of p/n deformed shell gaps in driving multiple fission modes in these nuclei. However, how these shell gaps impact the fission process in preactinides and their response to the temperature of fissioning nuclei remains an open question in the current nuclear fission research.

More focused measurements on fission dynamics of Hg and Pb nuclei have left the isotopes of Pt the least explored in A≤200 region. Carrying up on this, we have made mass and total kinetic energy distribution measurement of ^{190}Pt nuclei using ^{30}Si + ^{160}Gd reaction at projectile energies 134.4 and 147.8 MeV to examine the region for observed anomalies.

Experimental details

^{190}Pt* compound nucleus was populated with ^{30}Si + ^{160}Gd reaction, performed at 14-UD BARC-TIFR Pelletron- Linac facility, Mumbai using a pulsed beam of ^{30}Si at lab energies 134.4 and 147.8 MeV. A thin ^{160}Gd target ($\approx$ 50 $\mu g/\text{cm}^2$ backed by $\approx 20\mu g/\text{cm}^2$ ^{12}C layer) was used in the experiment. Coincident fission fragments were detected by placing two position sensitive multi-wire proportional counter (MWPC) having dimensions of 12.5 cm × 7.5 cm at folding angles for symmetric fission. After time and position calibration of the MWPC detectors, the timing correlation spectra of the two fission fragments was employed to segregate pure fission events from quasi-elastic events. θ and ϕ information were extracted from hit positions in the MWPC X and Y wire frame for each event. Using time of flight and θ/ϕ information, fragment velocities were obtained [2] and a typical $v_{\parallel}$-v_{cn} vs

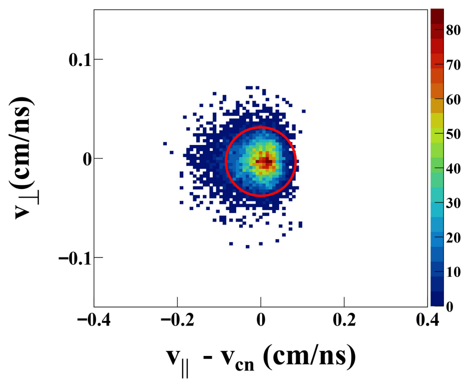

FIG. 1: Correlation between the two velocity components $v_{\parallel}$-v_{cn} vs $v_{\perp}$ ($v_{\parallel}$ = parallel component and v_{per} = perpendicular component) of ^{30}Si + ^{160}Gd reaction at E_{beam} = 147.8 MeV. The area inside the red contour represent FMT events used for mass and TKE distribution analysis.

*Present address: Inter-university Accelerator Centre, New Delhi - 110067, India
†Electronic address: rkumar4@ph.iitr.ac.in
‡Electronic address: moumita.maiti@ph.iitr.ac.in

$v_\perp$ plot obtained at 147.8 MeV beam energy is displayed in Fig. 1, which shows the full momentum (mainly complete fusion-fission) events. The events shown inside the red circle (to filter out the contaminated events) in Fig. 1 were further analyzed by applying the time difference method to obtain the fission fragment mass distribution (FFMD) for the projectile energies, 134.4 and 147.8 MeV. A FFMD obtained for 147.8 MeV beam energy (E^*_{CN} = 69.5 MeV) is shown in Fig. 2.

Results and discussion

It can be clearly observed from Fig. 2 that the mass distribution for ^{190}Pt* fissioning nucleus is single peaked, a trivial feature known for symmetric fission. The, single Gaussian (red curve in Fig. 2a) fits well ($\chi^2 = 0.026$) the mass distribution confirming that the dominating fission channel at such high excitation energies is symmetric in nature. The mass distribution is peaked at A = 95 u and the experimental TKE is observed to be 133.5 MeV, which is in consonance with Viola estimates (TKE_{Viola} = 133.1 MeV). Residuals obtained by difference between the observed and Gaussian fit yield at different masses are shown in Fig. 2b. It can be noted carefully that two finite peaks around $A_{CN}/2$, which indicate towards presence of an asymmetric mode in the fission of ^{190}Pt*. The two peaks correspond to masses, $A_L \approx 80$ u and $A_H \approx 110$ u. $A_L \approx 80$ u has also been observed in asymmetric fission of ^{180}Hg [1] and ^{178}Pt [4].

Dhuri *et al.* have showed recently a symmetric fission for ^{187}Ir compound nucleus which has a similar N/Z $\sim$ 1.43 [3] whereas Kumar *et al.* put forth identical mass distribution for ^{192}Hg* at such excitation energies. Although the single Gaussian fit the mass distribution well, a slight deviation at the tail can be observed which could be due to the interference of quasi-fission process which has been suggested as a contributing process in these nuclei [5].

Conclusion

Fission fragment mass distribution of ^{190}Pt* was found to be single peaked in nature indicating towards dominating symmetric fission.

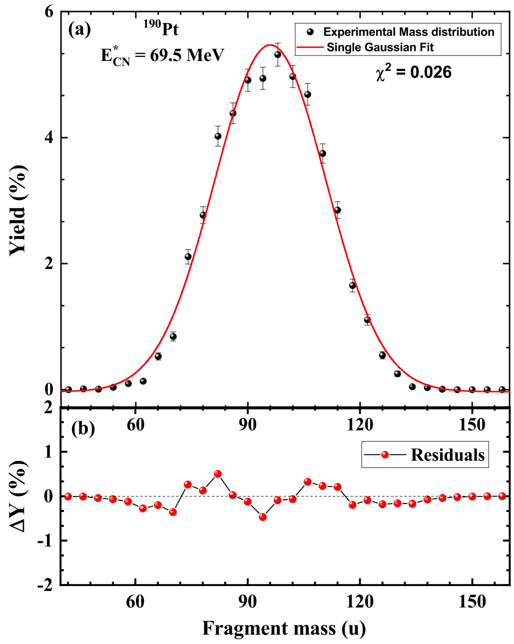

FIG. 2: **(a)** Mass distribution obtained for ^{190}Pt* populated via ^{30}Si + ^{160}Gd reaction at E_{beam} = 147.8 MeV (black filled circles). FFMD fitted with single Gaussian along with the corresponding χ^2. **(b)** Residuals from the single Gaussian fitting showing the need to include an asymmetric fission mode around $A_L \sim$ 80.

The mass distribution was found to fit well with a single Gaussian centered at A = 95 u. The finite residuals around $A_{CN}/2$ hint towards relatively weak contributions from asymmetric fission too.

Research fellowships from INSPIRE(DST), MHRD, and UGC, Government of India, are gratefully acknowledged.

References

[1] A. N. Andreyev *et al.*, Phys. Rev. Lett. **105**, 252502 (2010).
[2] R. Kumar *et al.*,Phys. Rev. C **107**, 034614 (2023).
[3] S. Dhuri *et al.*, Phy. Rev. C **106**, 014616 (2022).
[4] I. Tsekhanovich *et al.*, Phys. Lett. B **790**, 583 (2019).
[5] Kavita *et al.*, Phys. Rev. C **100**, 024626 (2019).