Investigating multi-chance fission via mass gated pre-scission neutron multiplicty measurement of ^{250}Cf

Divya Arora[1],* N. Saneesh[1], N. Kumar[1],† A. Parihari[2], M. Kumar[1], I. Ahmed[1], S. Kumar[1], C. Kumar[1], K.S. Golda[1], A. Jhingan[1], J. Gerl[3], Hans J.Wollersheim[3], and P. Sugathan[1]

[1]*Inter University Accelerator Centre, Aruna Asaf Ali Marg, New Delhi - 110067, INDIA*
[2]*Department of Physics and Astrophysics, Delhi University, Delhi-110007, India. and*
[3]*GSI, Planckstrasse 1, D-64291 Darmstadt, Germany.*

Introduction

Heavy-ion induced fusion-fission reactions are a useful tool for investigating the macroscopic and microscopic features of nuclear fission at moderate to high excitation energies and angular momentum. Extensive theoretical and experimental efforts [1, 2] have been employed to understand the influence of multi-chance fission (MCF), particularly at high energies. The dynamical competition between cascade of neutron emission and fission determines the fate of the decaying nucleus. The effect of multi-chance fission has been exhaustively studied with various probes such as mass distribution (FFMD) [2], average total kineatic energies [3] and angular anisotropy of fission-fragments[4]. However, a simultaneous study of mass distribution and mass gated pre-scission neutron multiplicity (MGN) corresponding to symmetric and asymmetric mass division and their correlation with MCF is quite scarce in the existing literature.

Experimental details and analysis

The experiment was performed at the 15UD Pelletron accelerator facility of Inter University Accelerator Centre (IUAC), New Delhi. A pulsed beam ^{12}C of width ∼1 ns was bombarded on ^{238}U targets of areal thickness 290 μg/cm^2 with lab energies 67 MeV, 85 MeV and 94 MeV. Neutrons were detected using 80 organic scintillator detectors of NAND array [5]. These detectors are placed at different polar and azimuthal angles in a geodesic dome structure at distance of 175 cm from the target. Fission fragments were detected using two large area (20x10 cm^2) position sensitive multi-wire proportional counters (MWPCs).

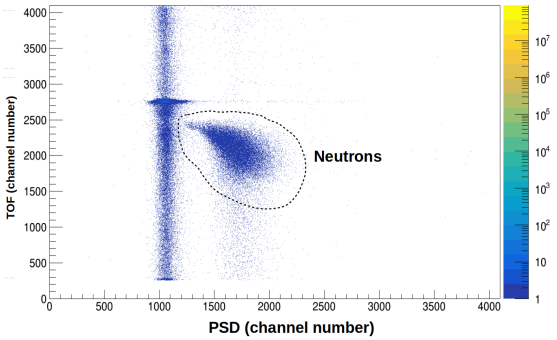

FIG. 1: Neutron-gamma ray discrimination from PSD and TOF correlation plot. Marked region shows neutron events.

The data analysis has been performed with CERN ROOT package. The fission events were separated from elastically scattered events by an appropriate software gate in 2D Time of flight (TOF) signals of MWPCs. The mass distribution data analysis has been carried out following the velocity reconstruction method of Hinde *et al.*[6]. The polar angles (θ,ϕ) and velocity components ($V_{parallel}$ ($V_\parallel$)and $V_{perpendicular}$ ($V_\perp$)) on to the beam axis were determined and corrected for energy loss of fragments in the target in an event-by-

*Electronic address: indivyaarora@gmail.com
†Presently at Grand Accélérateur National d'Ions Lourds (GANIL), CEA/DRF-CNRS/IN2P3, B.P. 55027, 14076 Caen, cedex 5, France

event mode. Fission events originating from complete fusion-fission were selected from the 2D velocity correlation spectra. A software gate was applied around ($V_{||}$-$V_{c.m.}$,$V_{\perp}$)=(0,0) to identify full momentum transfer (FMT) events. The mass ratio was calculated following the kinematic coincidence method [7].
Pulse shape discrimination (PSD) and TOF techniques were employed for discrimination between neutrons and gamma-rays. Fig 1 shows clear identification of neutrons and gamma-rays obtained from PSD and TOF correlation plot. The neutron energy spectra was derived from TOF spectra after calibration taking prompt gamma-ray peak as time reference. Further, Double differential neutron multiplicity (DDNM) spectra were extracted and corrected with detector efficiency, solid angle and energy per bin. These spectra were simultaneously fitted with Watts expression [8] with three moving source least-square fitting method followed by chi-square minimization procedure.
Guided by three Gaussian fitting of mass distribution, three mass cuts corresponding to symmetric and two asymmetric fragments were selected for gating average pre-scission neutron multiplicities. The mass gated neutron multiplicities for each mass slice were determined at three measured excitation energies (E^*).

Results and discussion

The mass distribution and MGN of ^{250}Cf at 67 MeV lab energy (E^*=40 MeV) are displayed in Fig 2. For this lowest excitation energy studied in our work, the measured mass distribution uni-vocally deviates from a normal distribution and is rather a flat topped distribution. Similar features were also observed for ^{247}Cf formed via ^{12}C on ^{235}U for E^*= 32.6 and 38.4 MeV [9]. Interestingly, MGN associated with asymmetric mass fragments is found to be higher than the symmetric counterpart. This is attributed as a manifestation of fragment shells contributing from the higher chances of multi-chance fission. A detailed experimental analysis of the three studied energies and assimilation of these results within theoretical framework is in progress.

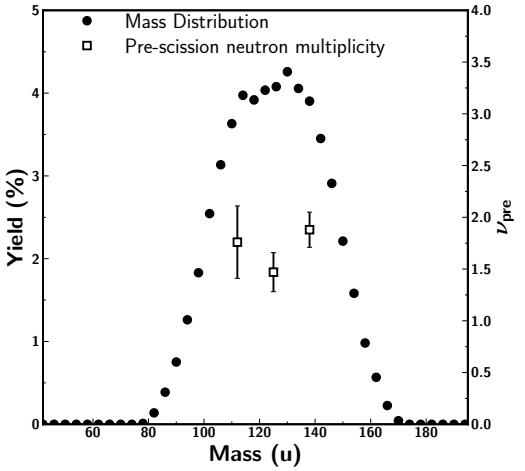

FIG. 2: Fission fragment mass distribution and mass gated pre-scission neutron multiplicity measured for reaction ^{12}C+^{238}U at 67 MeV beam energy.

Acknowledgments

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