Study of Fission Dynamics using Neutron Multiplicity & Mass Distribution Measurements and through Dynamical Model Calculations

Neeraj Kumar*
Department of Physics &Astrophysics,
University of Delhi, Delhi-110007, INDIA

Introduction

Study on heavy ion nuclear reactions is an unique approach to understand the behavior of dynamical features of nuclear matter. Nuclear fusion-fission dynamics involve many complex processes and have been under investigation for many decades through experimen- tal as well as theoretical approaches. The deep understanding of such processes is still a matter of detailed studies, because of the complexities in- volved. Pre-scission particle multiplicity and fission fragment mass distribution measurement has been used as one of the most effective tool to study various features of nuclear fusion-fission processes [1-5]. In the present work, a detailed and systematic study of fusion-fission dynamics of excited CN formed in heavy-ion induced nuclear reaction is presented through both theoretical and experimental approaches. The theoretical work addresses the investigation of the role of dynamical deformation on pre-scission neutron multiplicity. The experimental part of the present work is focused on the entrance channel effect and the influence of Quasi Fission on fusion-fission dynamics. z

Theoretical calculations

In the theoretical work, one dimensional Langevin dynamical model is used to calculate the pre-scission neutron multiplicity for both spherical and evolving deformed shapes of the CN ^{224}Th as shown in the FIG. 1. After observing the influence of dynamical deformation on neutron emission for higher angular momentum (ℓ) states the study is extended to heavier mass regions. The calculation is performed for ^{19}F + ^{232}Th, ^{27}Al + ^{224}Rn, and ^{40}Ar + ^{211}Tl systems, populating the same CN ^{251}Es, but at different ℓ values. To understand the saddle to scission evolution, the neutron multiplicity contribution from this phase is also calculated for various systems. In addition to the above

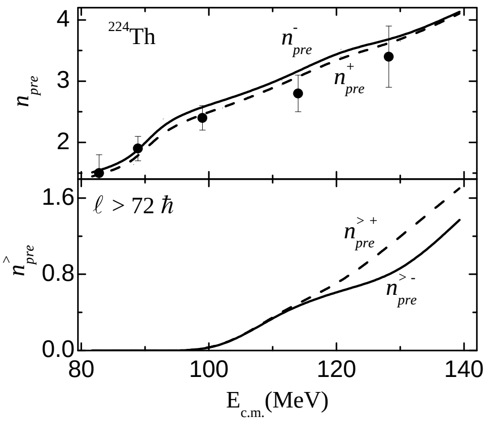

FIG. 1: n^-_{pre} (solid line) and n^+_{pre} (dashed line) calculated with deformation independent $\Gamma_n(\ell, c = 1)$ and deformation dependent $\Gamma_n(\ell, c)$, respectively. Experimental values (solid circles) of n_{pre} is taken from Ref. [1]

theoretical investigations, the dissipation strength (β) is extracted for ^{251}Es using the deformation dependent pre-scission neutron multiplicity.

Experimental Work

In the experimental work, two experiments have been performed with the National Array of Neutron Detectors (NAND) facility [6,7] at Inter University Accelerator Centre (IUAC), New Delhi,

*Electronic address: `neerajkumar.phys@gmail.com`

using the pulsed beams from the 15UD pelletron accelerator and the superconducting LINAC facility. In these measurements, pre-scission neutron multiplicities and fission fragment mass distributions have been measured for a CN ^{208}Rn populated by two different entrance channels ^{30}Si + ^{178}Hf and ^{48}Ti + ^{160}Gd at similar excitation energies. In neutron multiplicity measurements, the emitted neutrons are detected in coincidence with the fission fragments. To extract the value of pre-scission and post-scission components of neutron multiplicity, a fitting of experimental double differential neutron multiplicity spectra are performed using the moving source model using Watt expression. The measured pre-scission neutron multiplicities are analysed within the framework of Langevin dynamical model calculations. The value of β relevant for the present measurements is optimised from the existing data for CN ^{210}Rn populated by ^{16}O + ^{194}Pt reaction. Using this

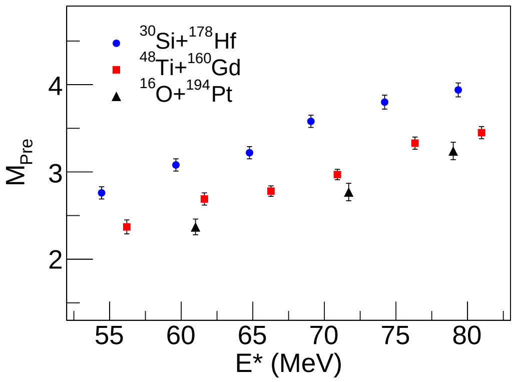

FIG. 2: Measured values of pre-scission neutron multiplicity at various excitation energies.

value of β, the values of neutron multiplicity for the decay of equilibrated CN ^{208}Rn are calculated. The result shows that for both the systems, the value of M_{pre} increases monotonically with excitation energy as shown in the FIG. 2. The values for ^{30}Si + ^{178}Hf are higher than for ^{48}Ti + ^{160}Gd system. The capture cross-section, fusion probabilities and effective fusion time are also calculated for the present measurements. Further, the fission fragment mass distribution measurements for the CN ^{208}Rn is also performed in the present work by adopting the time difference method. The widths of the normalised mass ratio distributions for fission fragments are also extracted for both the measured systems and a comparison is carried out with existing data for ^{16}O + ^{194}Pt system.

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