# Probing the fission dynamics of $^{208}$Rn using mass distribution and neutron multiplicity measurements

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## Introduction

Heavy ion induced nuclear reaction involves the fission of Compound Nucleus (CN) formed after the fusion of target and projectile nucleus. Formation and decay of CN involves many complex processes and have been under investigation for many decades through experimental as well as theoretical approaches. The evolving deformation of CN followed by the formation of Fission Fragments (FF) is a dynamical process and during this process, neutron emission is one of the dominant decay channel. FF mass-distribution and neutron multiplicity measurements have been used as effective probes to study the details of the dynamical evolution of the nuclear system [1]. Entrance channel mass asymmetry affects the evolution of Di-Nuclear System (DNS) by showing the changes in reaction dynamics across the Businaro-Gallone critical mass asymmetry ($\alpha_{BG}$). The non-equilibrium fission events also depends on the entrance channel of the reaction [2]. In the present study, the mass distribution and neutron multiplicities for the CN $^{208}$Rn, populated at same excitation energies through two different entrance channels, $^{30}$Si+$^{178}$Hf and $^{48}$Ti+$^{160}$Gd have been measured. These measurements were performed at Inter University Accelerator Centre (IUAC), New Delhi using the National Array of Neutron Detectors (NAND) facility.

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## Experimental Details

To populate the CN of $^{208}$Rn at same excitation energies of 50-85 MeV, through two different entrance channels, pulsed beams of $^{30}$Si and $^{48}$Ti with incident energies of 138-178 MeV and 211-249 MeV in steps of 5 MeV increment, respectively, were used. The repetition rate of both the beams was 250 ns with the beam width of ∼400-800 ps. For mass distribution measurements, thin carbon-

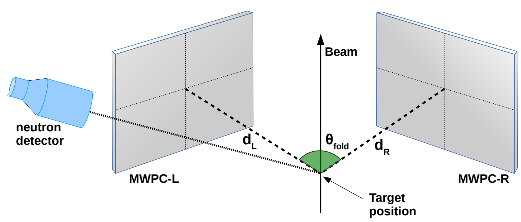


FIG. 1: Schematic diagram of setup used, consisting of two MWPCs and one of the neutron detectors of NAND-array is shown here.

backed sandwiched target of $^{178}$Hf (effective thickness of ∼150 $\mu$g/cm$^2$) and the self-supporting target of $^{160}$Gd (thickness ∼320 $\mu$g/cm$^2$) were used. For neutron multiplicity measurements, thick targets of $^{178}$Hf (thickness ∼350 $\mu$g/cm$^2$) and self supporting $^{160}$Gd (thickness ∼1.00 mg/cm$^2$) were used. To detect the fission fragments, two Multi-Wire Proportional Counters (MWPCs) with an active area of 11×16 cm$^2$ were symmetrically placed at the folding angles, at a distance of 16.5 cm from the center of the target. The neutrons were detected by NAND array consisting of organic liquid scintillator detectors (BC501A) of dimension 5"×5" mounted on geodesic dome structure. The flight path of neutrons from the target to detector is 175 cm [3]. For data collection, VME based data acquisition system coupled with Linux Advanced MultiParameter System (LAMPS) software has been used and data was collected in event mode.

## Data Analysis and Results

The mass distribution of FF was obtained through Relative Time method (RTM) [4], using kinematic coincident after determining the time of flight, position and velocities of FF. Time shift between RF and arrival of beam was determined by the position of $V_{||}/V_{c.m.}$ peak [FIG.2 (a)] and the electronic delay between two fragment was found out with the help of Mass ratio ($M_R$) peak [FIG. 2(b)]. Measured mass distribution at two excitation energies E*=60 & 65 MeV is shown in FIG.3. The broader mass peaks for $^{48}$Ti+$^{160}$Gd system indicates the presence of non-equilibrium fission processes. For neutron multiplicity measurement, the discrimination of neutron and gamma was done by using in-house developed Pulse Shape Discrimination (PSD) modules [5], based on zero-cross over and the time of flight (TOF) technique. To obtain the double differential neutron multiplicity (shown in the FIG.4), a PSD-TOF gate is applied on the calibrated neutron TOF spectra and neutron TOF was converted in to neutron energy spectra. Further, analyses to extract mass distribution, pre & post-scission neutron multiplicities ($\nu_{pre}$ & $\nu_{post}$) and required theoretical calculations are in progress and will be presented during the symposium.

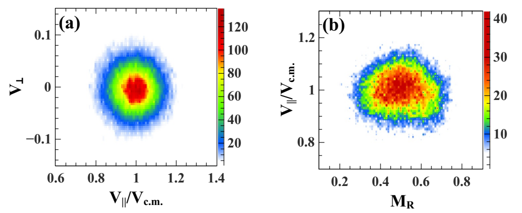


FIG. 2: Scatter plots of **(a)** $V_{||}/V_{c.m.}$ *vs* $V_\perp$ and **(b)** $M_R$ *vs* $V_{||}/V_{c.m.}$

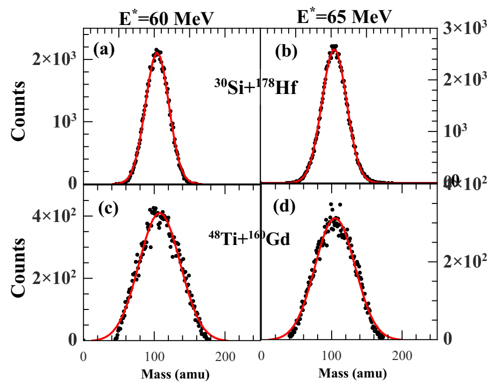


FIG. 3: Fission Fragment Mass distribution spectra

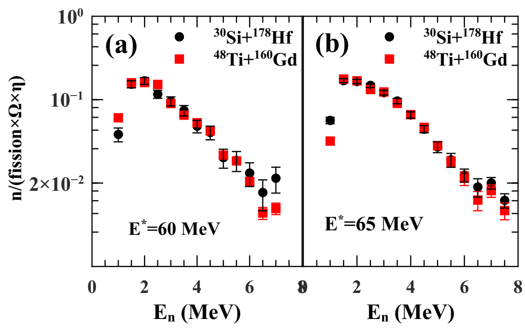


FIG. 4: Double differential neutron multiplicity spectra

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