Neutron emission from near super-heavy nuclei ^{256}Rf

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Introduction

For last few decades, topic of synthesis of super-heavy elements (SHE) is of great concern in nuclear physics. A fair understanding of fusion-evaporation and fusion-fission (FF) dynamics is necessary as it helps in exploring the different combinations of target and projectile to maximize the formation probability of super-heavy nuclei. It is a well established fact that for these heavy elements, there is a significant contribution from quasi-fission (QF) processes along with FF processes [1]. Presence of QF hinders the fusion of heavy nuclei and reduces the fusion cross-sections to pico-barn levels. To disentangle these processes, a large number of reaction probes such as fission fragment angular distribution, mass distribution (MD), mass-energy distribution (MED) and mass-gated neutron multiplicity have been used. As we go for heavier and heavier mass region, MD and MED are not sufficient to distinguish the above two components in the fission path of heavy elements as mass symmetric region may be populated by both FF and QF processes [2]. Neutron emission is one of the useful probes for measurements of the time-scales of these processes and it also helps in understanding the mechanism of energy dissipation in heavy-ion reactions. Recently, it was shown that the neutron multiplicity is lower for the QF processes as compared to the neutron multiplicity for the FF processes [3].

Present work aims to measure mass-gated neutron multiplicity for the system ^{48}Ti + ^{208}Pb populating near super-heavy compound nucleus (CN) ^{256}Rf (Z=104). The choice of this system with relatively smaller Z gives the advantage to make use of already existing fusion probability and evaporation residue cross-section for CN with Z=104, populated through the reaction ^{50}Ti+^{208}Pb [4, 5], where the CN formation is assured. Very recently, similar measurement for ^{258}Rf was also performed at LNL, Italy [6]. In the present work, we are reporting some of the results from our recently performed experiment for the system ^{48}Ti + ^{208}Pb using the dedicated facility National Array of Neutron Detectors (NAND) [7] at Inter University Accelerator Centre (IUAC), New Delhi.

Experimental Setup

The experiment was carried out using a pulsed beam of ^{48}Ti obtained from the 15UD Pelletron + LINAC accelerator facility at IUAC. ^{48}Ti beam (current = 0.7 pnA and repetition rate = 250 ns) with the laboratory energy of 275 MeV was bombarded on ^{208}Pb target of thickness 250 μg/cm^2 with carbon backing of thickness 20 μg/cm^2. The target ladder was tilted to an angle of 40° with respect to the beam axis in order to minimize the shadowing to position-sensitive multiwire proportional counters (MWPC). Neutrons were detected using NAND facility which consists of 100 organic liquid scintillators (BC501 A) of 5” × 5” dimension, placed on a geodesic dome

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structure outside the scattering chamber at a distance of 175 cm from the target. For fission fragment detection, two large area (5" × 3") MWPCs were used. MWPCs were placed at distance of 25 cm from the target on movable arms on either sides of the beam axis at angle of 73° and 54° respectively. Along with this, two silicon surface barrier detectors (SSBD) kept at ±13.5° with respect to the beam direction were used to monitor the beam flux. The fission fragment detected in any of the MWPC in coincidence with RF is used as trigger for list mode data collection with LAMPS as the acquisition software.

Data Analysis

Pulse shape discrimination (PSD) based on the zero-cross over technique and TOF method were used to discriminate neutrons and γs. Considering prompt γ peak in TOF spectrum as time reference, the neutron TOF was converted into neutron energy. Further, neutron energy spectra were gated with neutron lobe (in 2D plot of TOF vs. PSD) and fission fragments. As MWPC has large effective area, to minimize the angular uncertainty we have extracted neutron energy corresponding to only its middle slice of size 3.0 cm × 3.0 cm and we will also be doing a similar analysis for other slices. Efficiency correction for the neutron detectors was performed using FLUKA [8] code. Double differential neutron multiplicity spectrum for one of the neutron detectors placed at 0° with respect to the fission axis is shown in Fig. 1. Also, fission fragment mass-energy correlation for ^{48}Ti + ^{208}Pb system has been extracted as shown in Fig. 2.

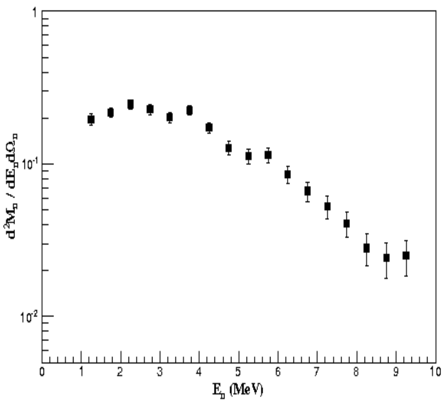

FIG. 1: Double differential neutron multiplicity spectrum from neutron detectors placed at 0° with respect to the fission axis.

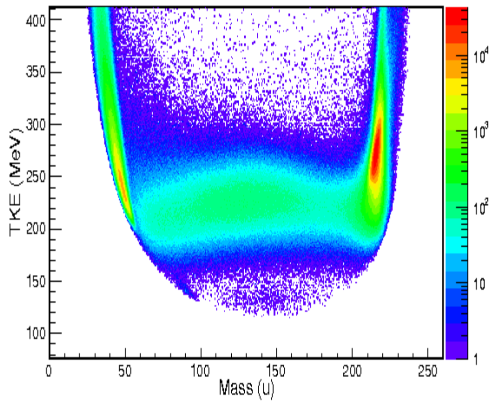

FIG. 2: Mass-energy correlation for ^{48}Ti + ^{208}Pb system.

We will consider different mass regions of fission fragments to extract mass-gated neutron multiplicity. To extract the pre and post scission neutron multiplicities (ν_{pre} and ν_{post}), moving source analysis involving fitting of the fission neutron angular correlations is in progress.

References

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