Measurement of neutron multiplicity to investigate the nature of nuclear dissipation

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Introduction

Heavy-ion induced fusion-fission reactions involve many complex processes, which are understood through experimental as well theoretical approach. It is well known fact that in a collision between two heavy nuclei there is a considerable contribution from quasi-fusion processes along with the fusion-fission processes. To investigate these processes, a number of attempts like mass distribution, mass-angle correlations, and mass-gated neutron multiplicity measurements have been done. In the recent years, nuclear dissipation has emerged as a topic of considerable interest involved in the fusion-fission process. Nuclear dissipation causes the delay in the fission process with respect to the statistical picture of compound nucleus (CN) decay. The deep understanding of the nuclear dissipation is still a matter of detail study because of the complexities involved in the process.

The measurement of neutron multiplicity has been done to investigate the details of the dynamical evolution of the nuclear system [1]. To understand the nuclear dissipation, neutron emission is one of the preferable probe. It helps in measuring the time-scales of these processes and in understanding the mechanism of energy dissipation in heavy ion reactions. In the literature, some measurements have been reported to investigate the effect of entrance channel mass asymmetry, neutron shell closure, N/Z, etc. in the fission process [2-4]. In the present study, we have measured the neutron multiplicity for the reaction $^{18}O+^{186}W$ populating the compound nucleus ^{204}Pb to understand the dissipation fission dynamics.

Experimental Details

The experiment was performed using the National Array of Neutron Detectors (NAND) facility of IUAC, New Delhi. The pulsed beam of ^{18}O with a repetition rate of 250 ns delivered from 15UD Pelletron accelerator was bombarded on ^{186}W target of thickness 637 μg/cm^2 with carbon backing of 40 μg/cm^2. Neutron multiplicity measurements were performed at three energies E_{lab} = 97 MeV, 102 MeV, 107 MeV. The neutrons were detected in coincidence with the fission fragments using 50 organic liquid scintillators (BC 501) of 5” x 5” dimensions kept at a distance of 175 cm from the center of the target. Two Multi-Wire Proportional Counters (MWPCs) of the active area 11×16 cm^2 were symmetrically placed at the folding angles, at a distance of 26 cm (35^0) and 21 cm (126^0) to detect the fission fragments. MWPCs were operated with the isobutene gas pressure of 4 mbar. Two Silicon Surface Barrier Detectors (SSBD) were also placed inside the chamber at $\pm 12.5^0$ with respect to the beam directions to monitor the beam. The data collection was done using the VME based data acquisition system coupled with Linux Advanced Multi-Parameter System (LAMPS) software in the event mode data. The fast time signals of the MWPCs were used to obtain the time of flight of the fission fragments. The acquisition was set according to the trigger logic generated by coincidence between RF of the beam pulse and the fission detectors.

Data Analysis

Neutron detectors are sensitive to detect neutrons as well as gamma-rays. The discrimination between neutrons and gamma was done using the time of flight (TOF) technique as well as pulse shape discrimination (PSD) based on zero – cross over method. The PSD-TOF spectrum of one of the neutron detector is shown in Fig. 1.

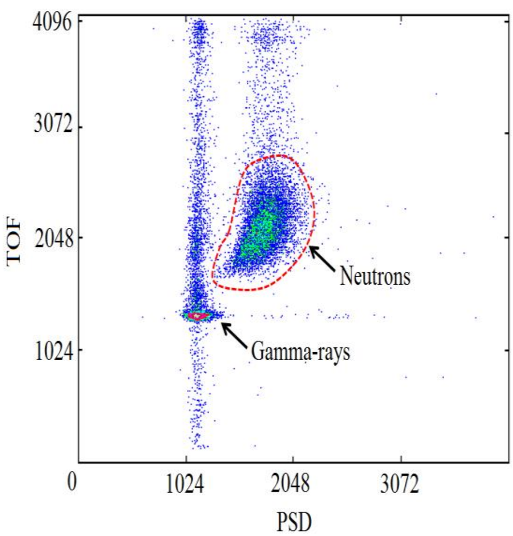

Fig. 1: Two dimensional plot of PSD-TOF spectrum for reaction $^{18}O+^{186}W$ at the excitation energy $E^*=79.38$ MeV.

To identify the neutron and gamma event, a two-dimensional gate was applied to the neutron spectra, which is shown as dotted closed-loop in Fig. 1. The neutron TOF spectra were converted into energy spectra by considering the gamma peak as a reference line. Neutron energy spectra were gated with TOF spectra of fission fragments to ensure that neutrons are only emitted from the fusion-fission process. Double differential neutron multiplicity spectra are shown in Fig. 2 for the reaction $^{18}O+^{186}W$ at the excitation energy 79.38 MeV, 74.82 MeV, and 70.26 MeV for the detector placed at the lab angle 36^0 w.r.t the beam direction.

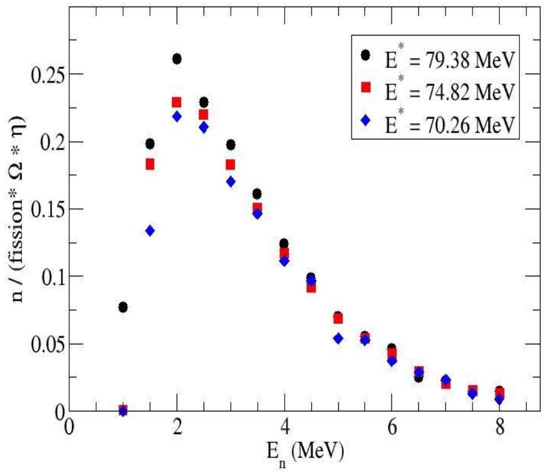

Fig. 2: Double differential neutron multiplicity spectra for the reaction $^{18}O+^{186}W$.

Data analysis is in progress, the value of pre and post-scission neutron multiplicity and temperature (M_{pre}, M_{post}, T_{pre}, and T_{post}) and their theoretical calculations will be presented during the symposium.

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