Neutron multiplicity measurements for ^{192,202}Po compound nuclei

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Introduction

The prevalent reaction mechanism for nuclear reactions induced between heavy ions is not only fusion-fission (FF), but a fast, out of equilibrium process called quasi-fission (QF) [1]. It is well established that the pre-scission neutron multiplicity is one of the most proficient probes to study the dynamics of heavy-ion induced FF and QF reactions [2]. This is because FF and QF reactions have their own characteristic reaction times, implying that each reaction process is associated with the different pre-scission neutron multiplicity. Therefore, measurement of pre-scission neutron multiplicities from an isotopic chain will be a suitable tool to disentangle FF and QF processes. Several experimental as well as theoretical approaches have been adopted to understand the dynamics of FF and QF processes in heavy nuclei. With this motivation, we have measured pre-scission neutron multiplicities from two compound nuclei, namely ^{192,202}Po populated by ^{48}Ti+^{144,154}Sm systems at 260 MeV and 230 MeV of laboratory energy using National Array of Neutron Detectors (NAND) facility at IUAC, New Delhi. For systems with heavier projectile, sizeable contribution from QF process is expected. Also, ^{144}Sm is nearly spherical (β_2 = 0.088) and ^{154}Sm is deformed (β_2 = 0.27). The experiment was performed using 15 UD Pelletron + LINAC facility of IUAC. For more details on the experimental set up reader is referred to Ref. [3]. In the present paper, we are reporting results of this experiment.

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Data Analysis and Results

The fission fragments were identified by TOF technique using MWPCs. The calibrated and gated TOF spectra are converted into the neutron energy (E_n) spectra. The efficiency correction for neutron detector was performed using FLUKA simulation code [4]. Neutrons detected in coincidence with fission fragments were fitted with three moving sources namely compound nucleus evaporation and two fission fragments. The compound nucleus contribution (pre-scission) and contribution from fission fragments (post-scission) were assumed to be isotropic in their respective frames. The pre- and post-scission components of neutron multiplicities (M_{pre} and M_{post}) are obtained from the measured neutron energy spectra by using a multiple source least-square fitting procedure, using the Watt expression [5] keeping M_{pre}, M_{post}, T_{pre} and T_{post} as free parameters. Neutron multiplicities obtained from fitting for decay of ^{192,202}Po are given in TABLE 1. Fig. 1 shows double differential neutron multiplicity spectra of four detectors placed at θ_n=54°, θ_n=72°, θ_n=18° and θ_n=90° for ^{48}Ti+^{144,154}Sm respectively.

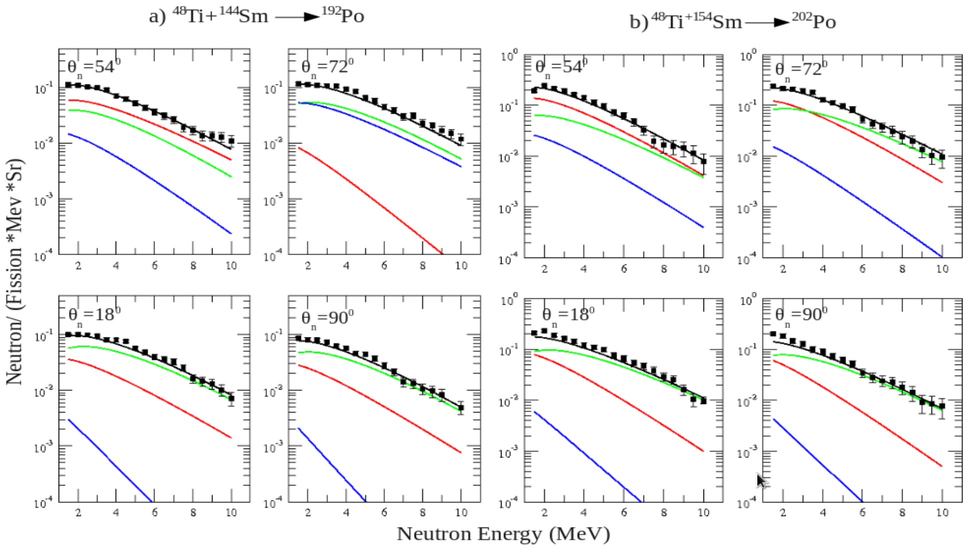

FIG. 1: Neutron multiplicity spectrum for a)^{48}Ti+^{144}Sm and b)^{48}Ti+^{154}Sm systems at 70 MeV of excitation energy for four of the neutron detectors. The fits for the pre-scission (red line) and post-scission contribution from one fragment (green line) and that from the other (blue line) are shown. The solid black line represents the sum of the different contributions.

TABLE I: Fitted values of M_{pre}, M_{post}, T_{pre}, T_{post} and Chisquare/NDF for ^{192,202}Po, respectively.

CN	M_{pre}	$2M_{post}$	T_{pre}	T_{post}	Chisquare/NDF
^{192}Po	1.91±0.11	2.80±0.12	1.93±0.15	1.45±0.07	1.7
^{202}Po	2.90±0.20	3.28±0.08	1.78±0.097	1.12±0.04	2.1

Theoretical Calculations

Statistical model calculations were performed for these systems using fission widths from both the transition-state model (Bohr-Wheeler) as well as the Kramers formalism [6] where fission damping due to dissipation is included. Both the models, even after including a strong damping in the Kramers fission width substantially underestimates the pre-scission neutron multiplicities. Earlier, we have also performed statistical model calculations for ^{16,18}O+^{192}Os→^{208,210}Po systems [7]. The comparison of calculated pre-scission neutron multiplicities with the experimental values clearly shows that the predictions using Bohr-Wheeler fission width considerably underestimate the pre-scission neutron multiplicity at all the energies. However, the experimental data was well reproduced by including dissipation strength (β=1.0-3.0). In earlier case, reaction is induced by lighter projectile and for present case projectile is heavier. So, there may be the presence of non-compound nucleus processes such as QF and fast-fission.

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