Reinvestigating the role of nuclear dissipation in fission of ^{220,222,224}Th nuclei

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Introduction

One of the major challenges of modern day nuclear physics is to understand the fission dynamics of excited compound nuclei formed in heavy-ion induced fusion reactions. Further, exploring the role of excitation energy, microscopic shell structure, nuclear dissipation and shape (deformation) on fission dynamics is of utmost interest. There are various probes available for such investigations, measurement of pre-scission particle emission (protons, neutrons, alphas and GDR-γ rays) being the most reliable. Neutron emission is one of the most dominant decay channels in fission reactions. The pre-scission yield of neutrons has proven to be an efficient probe to explore the fusion–fission dynamics of a Compound Nucleus (CN). The enhancement in the pre-scission neutron multiplicity immediately points to a slowing down of the fission process compared to the statistical model fission rate as given by Bohr and Wheeler [1]. Fission of hot nuclear systems is strongly hindered owing to the effect of nuclear dissipation on the fission process.

A systematic exploration of the fission hindrance for the ^{16}O+^{204,206,208}Pb systems has been done through neutron multipliicty measurements over a wide range of beam energies above the Coulomb barrier. The experiment has been performed at Inter University Accelerator Centre (IUAC) using the old National Array of Neutron Detectors. The details of the experimental set-up are given elsewhere [3]. While comparing the experimental multiplicity values with the reported values, a noticeable disagreement was observed between our values and the well established values reported by Rossner *et al.* for the ^{16}O+^{208}Pb system [2]. Further, the pre-scission (Mpre) as well as total neutron multiplicity (Mtot) values for all three nuclei i.e. ^{220,222,224}Th were compared with the statistical model predictions. Details of the same are reported elsewhere [4]. The pre-scission multiplicities for all the systems could not be explained within the stastical model framework. In the present work, the data of this experiment has been reanalysed to revalidate the multiplicity values and further implore the nature and strength of nuclear dissipation in the fisson of ^{220,222,224}Th nuclei.

The data was reanalysed using the software framework of ROOT. Neutron multiplicity per fission is considered to have components mainly from the (i) CN, (ii) fission fragment and the (iii) complementary fission fragment. It was assumed that the prescission neutrons are emitted from the CN and post-scission ones from the two fully accelerated fission fragments. To extract the pre- and post-scission neutron multiplicity, the observed TOF spectra of the neutrons were calibrated using TDC calibration and the prompt position of γ as a reference time. Since neutron detector is sensitive to both neutron and γ, the calibrated TOF spectra were cleaned using a 2D gate between PSD and TOF as shown in Fig. 1. To eliminate all the transfer and quasi-elastic processes, the TOF spectra were cleaned using a 2D gate between the timing signals of both the MWPCs with an angular bin of 10^0 in position signals. The TOF spectra were then converted to energy spectra and corrected for the energy-dependent neutron detection efficiency using the FLUKA code. The energy spectra of all the 16 de-

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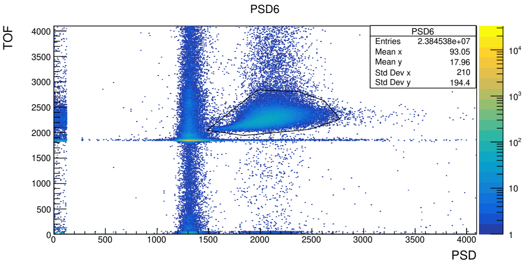

FIG. 1: 2D plot of TOF vs PSD used to separate the neutrons from the γs. The neutron lobe is outlined using a solid line.

tectors in the reaction plane thus obtained, were fitted simultaneously to extract the pre- and post-scission components by carrying out moving source least square fitting at various angles using the Watt expression [5].

Results and Discussions

The same multiplicity values have been reiterated from the current analysis with an uncertainity of less than 20% between the two values. To further confirm the experimentally obtained pre-scission neutron multiplicities, an exclusive moving source fitting was carried out by considering the data only from the neutron detectors perpendicular to the fission direction, where contribution from post-scission component is expected to be small. The pre-scission multiplicity value thus obtained match with that determined after including all the detectors within the fitting uncertainties. Similar results have been observed while comparing the data with that of Rossner *et al.* for the ^{16}O+^{208}Pb system [2]. The experimentally obtained Mpre is higher compared to Mpre obtained by Rossner, but Rossners Mtot is higher compared to the present Mtot as shown in Fig. 2. Additionally, to check the consistency of the experimental data, the experimental values of Mtot were compared with the number expected from the energy balance equation following the procedure suggested by Hinde *et al.* [6]. Fig. 3 shows that the value of the experimental multiplicities are consistent with the excitation energy of the compound nuclei. This ascertains the need to include the effect of higher order terms of dissipation and shape dependent dissipation in theoretical interpretation of the data.

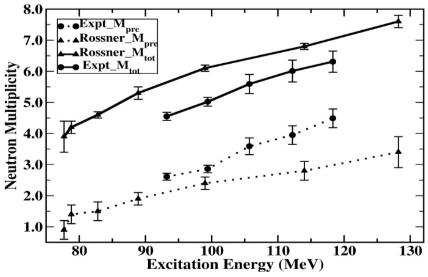

FIG. 2: Comparison of Rossners Mpre and Mtot with the experimentally obtained Mpre and Mtot for ^{16}O+^{208}Pb system.

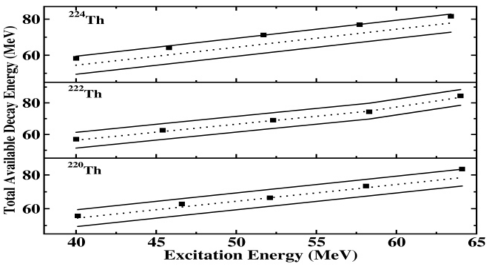

FIG. 3: Total available decay energy vs excitation energy of CN calculated using experimental Mtot (solid squares) and the total available decay energy using the excitation energy (dotted line) and solid line represents a spread of 5 MeV.

References

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