Measurement of α-particle yield in ^{212}Rn nucleus to understand the fission dynamics

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Introduction

Exploring the dynamics of fusion-fission reaction mechanism has always been of interest in heavy-ion-induced nuclear reaction. The extraction of fission time scales using different probes is of central importance for understanding fusion-fission process. In the past, extensive theoretical and experimental efforts have been made to understand the various aspects of the heavy ion induced fusion-fission reactions [1]. Compelling evidences have been obtained from the earlier studies that the fission decay of hot nuclei is protracted process i.e. slowed down relative to the expectations of the standard statistical model and more light particles are expected to be emitted during the fission process [2]. These particles are emitted from various stages of the reaction process i.e. from compound nucleus (CN) (prescission) and from fully accelerated fission fragments (postscission). The multiplicities of various particles (neutrons, protons, alphas etc.) emitted during the decay of excited nucleus provide the information about these time scales and hence, help in understanding the fusion-fission dynamics. Charge particles provides more information about the emitter in comparison to neutrons as charged particles faces coulomb barrier and are more sensitive probe for understanding the dynamics of fusion-fission reactions [3]. In the present work, we are reporting some of the preliminary results of charged particle multiplicity measurements.

Experimental Details

The experiment was performed at the 15 UD Pelletron facility at Inter University Accelerator Centre (IUAC), New Delhi, using General Purpose Scattering Chamber (GPSC). Enriched and self-supporting target of ^{196}Pt having thickness 1.8 mg/cm^2 was used in the experiment. Beam of ^{16}O with incident energy 98.4 MeV, was used to form ^{212}Rn. The charged particles (protons and alphas) were detected in coincidence with fission fragments, so as to extract the particle multiplicities for the reaction under study. In total, four detectors (16 crystals) of CsI(Tl) were used for the detection of protons and alpha particles. Two Multi-Wire Proportional Counters (MWPCs) were used for the detection of fission fragments. The MWPCs were kept at the folding angles to detect complimentary fission fragments. One MWPC detector was kept at an angle of 30^0 w.r.t beam whereas, the second was kept at an angle of 135^0 at a distance of 20.5 cm from the centre of target. Four CsI(Tl) detectors were kept at angles of 70^0, 90^0, 110^0 and 130^0 w.r.t the beam direction. All charged particle detectors, having four crystal each, were kept at a distance of 15.5 cm from the centre of the target covering a solid angle of 16.6 msr for each CsI(Tl) detector.

In order to obtain the energies of the detected charged particles, CsI(Tl) detectors were calibrated using both offline and online techniques. The offline calibration was done using ^{241}Am and ^{229}Th sources. The online calibration was done using two reactions ^{12}C + ^{12}C at 30 MeV and ^{7}Li + ^{12}C at 20 MeV. From ^{12}C + ^{12}C reaction, α energies are in the range of 1.63 MeV to 18.5 MeV. Similarly, from ^{7}Li + ^{12}C reaction, α energies are in the range of 5.27

MeV to 16.19 MeV. Schematic diagram of the experimental setup is shown in Fig 1.

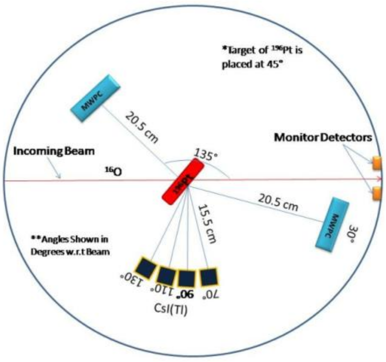

Fig 1. Schematic diagram for experimental setup.

Data Analysis and Results

Two dimensional view of α-particle band using pulse shape discrimination technique is shown in fig. 2. The particle identification (PID) plot was obtained by taking the difference between long decay time (τ_L) and short decay time (τ_S) divided by τ_S [4].

$$PID = \frac{\tau_L - \tau_S}{\tau_L},$$

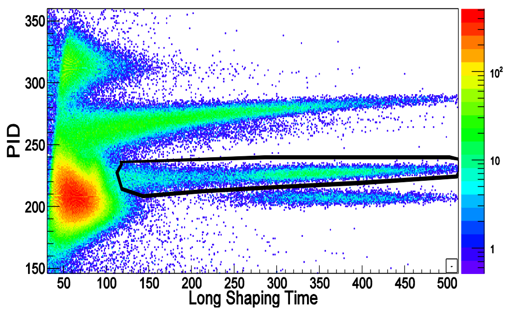

Fig 2- 2-D spectrum of CsI(Tl) for particle identification.

α-particles were gated with fission events recorded in MWPCs to obtain the fission coincidence α-particles spectra. Total α-particles yield spectra were fitted using the moving source technique [5] to get the pre-scission, post-scission and the near scission contributions. Values of the multiplicities obtained from the best fit for $^{16}O+^{196}Pt$ reaction at 106.0 MeV are α_{pre}= (1.86 ± 0.24) x10^{-2}, α_{post}= (0.63 ± 0.05) x10^{-2}, and α_{NSE} = (0.28 ± 0.06) x10^{-3}, ε_P= (20.7 ± 0.6) MeV, σ_ε= (2.5 ± 0.46) MeV, and σ_Θ= (11.5° ± 1.5°), T_{pre} and T_{post} were calculated as 1.58 MeV and 1.39 MeV respectively. The Coulomb barrier were kept fixed at V^B_{Pre} = 20.8 MeV and V^B_{Post} = 12.7 MeV and thus the minimum value of X^2/(degree of freedom) was obtained to be 5.9. Fitted spectra are shown in fig 3, representing various contributions.

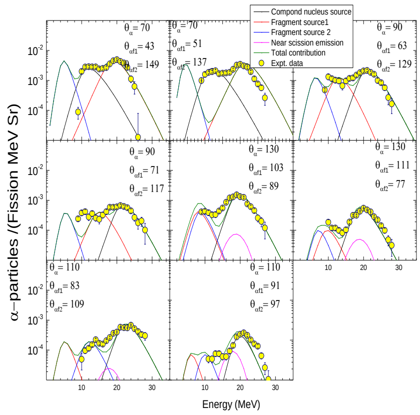

Fig 3 (color online)- Normalized α-particle multiplicity spectra at E_{lab}=106 MeV, Red and blue line represents the post-scission contribution, black line represents the compound nucleus contribution, neck contribution is shown by pink line. Total contribution is shown in green color.

Statistical model JOANNE2 calculations are in progress. Calculations will be done to get the fission timescales for $^{16}O+^{196}Pt$ at 106 MeV.

References

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