Study of fusion-fission dynamics of ^{32}S + ^{198}Pt reaction using neutron multiplicity as a probe

Shruti[1],* Amit[1], Chetan Sharma[1], Subodh[1], N. Saneesh[2], Kajol Chakraborty[3], D. Arora[2], Amninderjeet Kaur[1], Vikas[4], M. Kumar[2], K.S. Golda[2], A. Jhingan[2], H. Singh[4], S.Mandal[3], P. Sugathan[2], and B.R. Behera[1]
[1]*Department of Physics, Panjab University, Chandigarh, India*
[2]*Inter University Accelerator Center, New Delhi, India*
[3]*Department of Physics and Astrophysics, University of Delhi, Delhi, India and*
[4]*Department of Physics, Kurukshetra University, Kurukshetra, India*

Introduction

The intricate process involved in the collective re-arrangement of nuclear fission dynamics is still an unconfirmed topic. A few systematic studies are present in the literature related to neutron multiplicities where the experimental data covers wide range of mass and energy. Pre-scission neutrons are extensively studied to understand fusion-fission dynamics involved in the population of heavy and super-heavy nuclei. The main advantage of using this probe is the absence of coulomb barrier and also it serves as a clock for the measurement of time-scale of the reaction. Present study is based on the average neutron multiplicity measurements for ^{226,230}Pu (Z=94) compound nuclei populated by ^{32}S+ ^{194,198}Pt reactions. In the past few years similar kind of measurements were carried but with the lighter systems of ^{16,18}O +^{194,198}Pt→^{210,212,214,216}Rn [1], ^{19}F + ^{194,196,198}Pt→^{213,215,217}Fr [2] and ^{12}C + ^{194}Pt→^{206}Po [3] and they studied effect of N/Z, shell closure on nuclear dissipation and shell correction energies at saddle point using pre-scission neutron multiplicity. These experiments were focused on the study of dynamics of fusion-fission only. Presently performed experiment of ^{32}S+ ^{194,198}Pt→^{226,230}Pu*is a representative case of investigation of average neutron multiplicity at different lab energies ranging from 173-203 MeV. The motivation behind this work is to get deep insight of the dynamics of not only fusion-fission processes but also on the non-compound nuclear processes like quasi-fission (QF).

*Electronic address: shrutinarang.sn@gmail.com

Experimental details

The experiment was carried out using 15UD Pelletron + LINAC of IUAC, New Delhi where pulsed beam of ^{32}S in the lab energy range of 173-203 MeV was bombarded on ^{194,198}Pt targets resulting in the formation of the compound nuclei ^{226,230}Pu. Pt targets (thick rolled foils of ^{194}Pt and ^{198}Pt having thickness of 1.7 mg/cm^2 and 2.1 mg/cm^2 resp.) were mounted on the target ladder and kept at the center of the scattering chamber vertically to the beam axis. Neutrons emitted in coincidence with the fission fragments were detected using NAND detector array utilizing 50 organic liquid scintillator (BC501A). The detection of fission fragments was done using a pair of MWPC with active area (20×10) cm^2 and were placed at fission fragment folding angle of ±144°. They were operated at 4 mbar pressure of isobutane gas throughout the experiment. A SSBD kept at 12.5°was used for the normalization of beam flux. For the data acquisition VME based controller ROSE and NiasMARS software were used.

Data Analysis

The data analysis was done using ROOT software package. Neutrons were discriminated from gamma rays using pulse shape discrimination (PSD) based on zero-cross over technique and TOF method. Also the TOF spectra were calibrated using a precise time calibrator and the prompt γ peak as the time reference. TOF spectra was further gated with fission events so as to obtain neutrons corresponding to fission only. The calibrated and gated neutron TOF was then converted into neutron energy spectra. The neutron energy spectra thus obtained are then corrected with the experimentally obtained energy-dependent neutron detection efficiency using FLUKA values. Pre-and post-scission components of neutron multiplicity was extracted with moving source fit code (Watt's expression).

Results

Fig. 1 shows the fitted plots along with contributions from different neutron sources. The spectra are fitted for neutron energy ranging from 1 to 8 MeV. The data was fitted simultaneously for the 16 neutron detectors positioned in the reaction plane (7^{th} ring) and also M_{pre}, M_{post}, T_{pre} and T_{post} were treated as free parameters. It clearly shows that the shape-contributions for different sources vary dramatically with the relative angle between the neutron sources and the detectors. The variation is primarily because of kinematic focusing effects on the neutrons emitted from the rapidly moving fission fragments. The extracted values of average M_{pre}, M_{post}, T_{pre} and T_{post} after simultaneously fitting 16 energy spectra for the reaction plane neutron detectors using Watt's expression for ^{32}S+^{198}Pt at E^* = 81.9 MeV are 4.01±0.43, 2.22±0.18, 1.94±0.13 and 1.49±0.09 respectively. These measurements are also consistent with the values calculated using energy-balance equation. A detail analysis for calculation of average neutron multiplicities at different incident energies and their comparison with theoretical statistical model is in progress and will be presented during the conference.

Acknowledgments

The authors are thankful to Pelletron and LINAC crew of IUAC for providing stable beam of excellent quality throughout the experiment. The financial support by DST

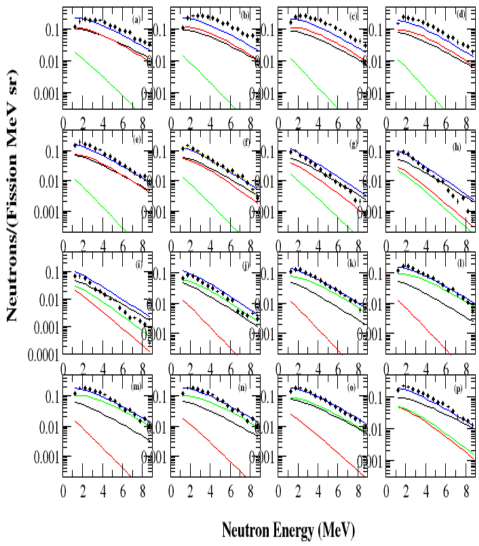

FIG. 1: Experimental double differential neutron multiplicity spectra (solid circles) for ^{32}S + ^{198}Pt reaction at E_{lab}=203 MeV for different neutron detectors of the reaction plane along with fitted values of pre-scission (black-line) and post-scission contribution from one fragment (red-lne) and that from other fragment (green line) are shown. The total contribution from all the three sources are given by blue line.

in the form of INSPIRE fellwoship is acknowledged by one of the author (Shruti). BRB acknowledges the Science and Engineering Research Board (SERB), Govt. of India, for support through Contract No. EMR/2017/004722.

References

[1] R.Sandal et al., PRC **87**,014604 (2013)
[2] Varinderjit et al., PRC **87**,064601 (2013)
[3] Golda at al., NPA **913** (2013) 157-169