Average Neutron Multiplicty Measurements from the Fission Process of ^{48}Ti+^{232}Th System

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Introduction

Understanding the concept of heavy-ion induced fusion-fission process is an important key to explore the mechanism of synthesis of superheavy elements (SHE). The study of fission dynamics in the actinide region has gained a lot of importance as it can be helpful in providing crucial information about the challenges en route to the formation of superheavy nuclei. The synthesis of SHE is being done in recent years both by using cold (where one of the reaction partners is spherical ^{208}Pb or ^{209}Bi) and hot (using ^{48}Ca induced actinide target) fusion reactions. Due to low rate of production, experiments on the synthesis of new elements need to last many months. Therefore, one of the main challenges is to search for the initial conditions that will favour the production of SHE. Alternatively, studies can be carried in detail about those processes that act against the CN formation,like, QF, and gain insight on their occurence and properties [1]. Recently measuremenents were made by M.Thakur [2] and S.Appanannababu et al. [3] to understand the fragmentation dynamics of near superheavy systems using a spherical target of ^{208}Pb. The present experiment is an attempt to study fission dynamics of a supeheavy system ^{280}Cn(Z=112) using a deformed target ^{232}Th.

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Experimental setup

The experiment was carried out using the 15UD Pelletron+LINAC accelerator and NAND facility at IUAC,New Delhi. Pulsed beam of ^{48}Ti having energy of 280 MeV was bombarded on deformed target of ^{232}Th (250μg/cm^2 and 80 μg/cm^2 flourine backing). Two MWPCs with active area of 10×20 cm^2 were used for the detection of fission fragments and they were placed at fission fragment folding angle of ± 66°. Neutrons emitted in coincidence with the fission fragments were detected using NAND detector array having 100 organic liquid scintillator (BC501A). Data acquisition was achieved using the upgraded indigenous VME controller ROSE and the NiasMARS software.

Data Analysis

The data analysis was performed using ROOT software package. Since neutron detectors are sensitive to both γ and neutrons, pulse shape discrimination (PSD) based on zero-cross over technique and time-of-flight (TOF) method was implemented. Neutrons were discriminated from gamma rays using this method and further TOF spectra were calibrated using a precise time calibrator and the prompt γ peak as the time reference. To distinguish the neutrons and the γ events a two-dimensional gate is applied on the caliberated n-TOF. Further it was gated with fission events in order to obtain neutrons corresponding to fission only. The calibrated and gated neutron TOF was then converted into neutron energy spectra and effeciency corrections were performed using the Monte Carlo simulated values from the FLUKA code. Moving source fitting method was used for the extraction of pre-and post-scission components of neutron multiplicities. The angular acceptance of neutron detectors as well as the fission detectors were taken into account while calculating the relative angle between the neutron and the source direction during the fitting procedure. The data was fit simultaneously for the 15 neutron detectors positioned in the reaction plane (7^{th} ring) and also M_{pre}, M_{FF1}, T_{pre} and T_{post} were treated as free parameters. Fig.1 shows the fits to the double differential neutron multiplicity spectra along with the contibution from different sources at different angles.

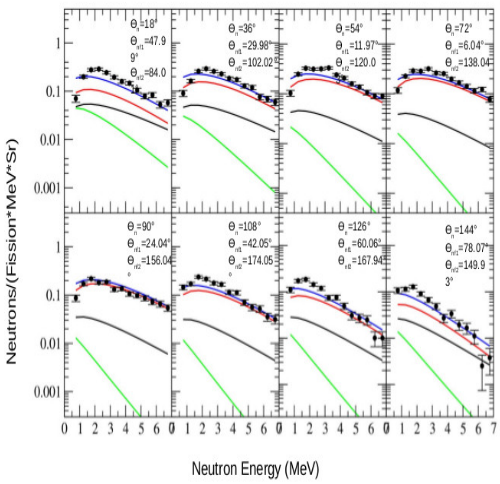

FIG. 1: Experimental double differential neutron multiplicity spectra (solid circles) for different neutron detectors of the reaction plane at along with fitted values of pre-scission (black-line) and post-scission contribution from one fragment (red-line) and that from other fragment (green line) are shown. The total contribution from all the three sources is given by blue line.

Results and Discussion

The obtained values of average M_{pre}, M_{FF1}, T_{pre} and T_{post} after simultaneously fitting energy spectra for the reaction plane neutron detectors using Watt's expression [4] for ^{48}Ti+^{232}Th at 280 MeV are 2.11±0.72, 3.11±0.31, 2.10±0.47 and 1.43±0.10 respectively. The fits for the spectra were done for neutron energy range of 0 to 7 MeV. From these values, it is clear that this dependence is predominately due to kinematic focusing of emitted neutrons in the direction of fully accelerated fission fragments. The experimentally observed neutron multiplicities were compared with the values predicted using the energy balance equation in order to check the consistency of the experimental data. Statistical model calculations were also performed for the above mentioned system at same value of E^* where the obtained value for pre-scission neutron multiplicty is found to be 0.58. The large discrepancy between the experimental and theoretical values can be due to the presence of quasi-fission processes in ^{48}Ti+^{232}Th system.

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References

[1] M.G. Itkis et al.,Nucl. Phys. A **944**, 204-237 (2015).
[2] Thakur et al., PRC **98**, 014606 (2018).
[3] Appannababu et al., PRC **94**, 044618 (2016).
[4] Hilscher et al., PRC **20** , 576 (1979).