Measurement of Mass Gated Neutron Multiplicity for ^{48}Ti+^{232}Th System

Shruti[1],* H. Arora[1], Chetan Sharma[1], Amit[1], Subodh[1], N. Saneesh[2], Kajol Chakraborty[3], D. Arora[2], Amninderjeet Kaur[1], Raghav[1], M. Kumar[2], K.S. Golda[2], A. Jhingan[2], H. Singh[4], S.Mandal[3], H.J. Wollersheim[5], J. Gerl[5], 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*
[4]*Department of Physics, Kurukshetra University, Kurukshetra, India and*
[5]*GSI, Darmstatd, Germany*

Introduction

The formation of super-heavy elements by bombarding a heavy projectile on to a heavy target is a prominent topic in nuclear physics in the recent years. The studies related to the measurement of MD, MED and MAD are helpful in understanding the reaction dynamics of SHE. Additionally, neutron multiplicity measurements are extremely favourable to understand the formation of SH mass region because it acts as a sort of clock, offering a means to determine the timeframes of processes such as Quasi-Fission (QF) and Fusion-Fission (FF) individually. Pre-scission neutron multiplicity emerges as a favourable avenue for analyzing the reaction mechanism of the systems for which MD, MAD and MED fail to distinguish the QF and FF processes. Both the processes of FF and QF follow different trajectories during the evolution of a dinuclear system and thus consequently leads to different travelling timescales of these processes from the contact point to the scission point.

In recent years, researchers have investigated the relationship between mass and neutron multiplicities to gain insights into the dynamics of systems involving ^{50}Ti + ^{208}Pb [1] and ^{48}Ti + ^{208}Pb [2]. These studies utilized a spherical ^{208}Pb nucleus as the target. Expanding upon this research, it would be intriguing to conduct a similar investigation using deformed nuclei as the target. With this goal in mind, we conducted measurements involving mass gated neutron multiplicity for the reaction ^{48}Ti + ^{232}Th, which leads to the formation of the super-heavy nucleus ^{280}Cn at an excitation energy of 63.5 MeV. This experiment was conducted utilizing the specialized facility known as the National Array of Neutron Detectors (NAND) at IUAC, New Delhi. Detailed information about the experimental procedure and analysis of average neutron multiplicity can be found elsewhere [3].

*Electronic address: shrutinarang.sn@gmail.com

Data analysis and Results

The experimental data was analyzed event-by-event, and mass distribution was obtained using a kinematic coincidence method. FIG.1 illustrates the mass-energy correlation of the fission fragments extracted from the studied reaction. It is clear that in the intermediate region, a significant number of events corresponding to QF and FF are present between A=70–210. Fusion-fission is primarily expected to take place in the symmetric mass split region of A=140±20($A_{CN}/2$). As shown in FIG.2, the mass distribution of the studied reaction has typical wide double hump shape with the maximum at the mass numbers A=80 and A=200 which is caused by the yield of the asymmetric QF fragments.

To distinguish the QF events from the true FF events, neutron multiplicity measurements were carried out in correlation with the fis-

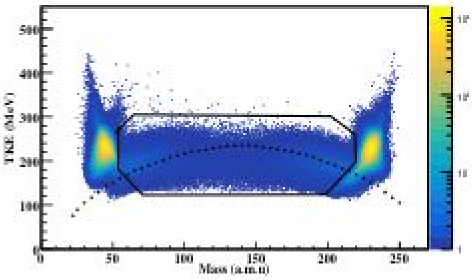

FIG. 1: (Color online) Mass-TKE correlation for ^{48}Ti +^{232}Th at E*=63.5 MeV. The dotted points shows <TKE> calculated from the Viola systematics.

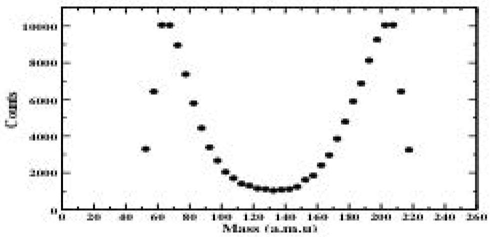

FIG. 2: The mass distribution corresponding to the intermediate gated region as depicted in FIG.1.

sion fragments masses, and by adopting moving source fitting procedure (Watt's expression) [3]. To achieve this objective, the MED of the fission fragments corresponding to ($A = 140 \pm 20(A_{CN}/2)$) region was considered. The extracted values for neutron multiplicities after simultaneous fitting the data for all the neutron detectors are given in TABLE I and these values are consistent with the energy balance equation. We also extracted the temperature values both before neutron emission (i.e., Tpre = 2.18 ±0.34) and after neutron emission (i.e., T$post$ = 1.58 ± 0.17) through simultaneous fitting. The double-differential neutron energy spectra for four typical reaction plane detectors and corresponding to symmetric mass split are shown in FIG.3. The figure indicates that source contributions vary significantly with the fission fragment-neutron detector angle. These extracted values primarily show the kinematic focusing of emitted neutrons towards the fully accelerated fission fragments. Statistical model calculations, however, failed to reproduce the experimental multiplicities which suggests that NCN processes like QF might have a significant impact on such heavy systems. Consequently, much higher β value or τ_{delay} must be required to reproduce the experimental value.

TABLE I: Neutron multiplicity values for symmetric mass cut ($120 < A_{CN} < 160$) for ^{48}Ti +^{232}Th reaction

Symmetric cut	$120 < A_{CN} < 160$
M_n^{pre}	3.22 ± 0.29
M_n^{post}	6.34 ± 0.38
M_n^{total}	9.56 ± 0.47

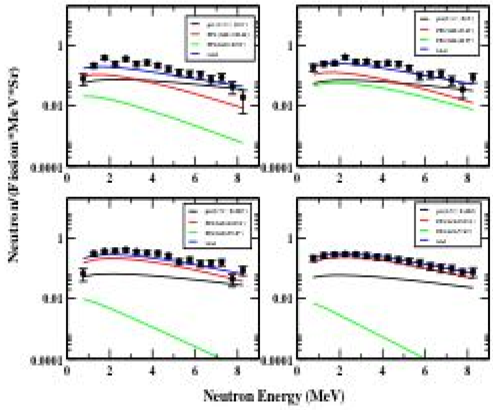

FIG. 3: Experimental double-differential n-energy spectra (solid circles), fitted for the reaction plane neutron detectors. The pre-scission contribution is shown by the black line whereas the red line and green line represents the post-scission contribution from the complementary fragments respectively. The total contribution from all the three sources is depicted by blue line.

References

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