Neutron multiplicity measurements for the ^{30}Si+^{182,184,186}W reactions populating ^{212,214,216}Ra

M. Shareef[1],* E. Prasad[1], P. Sugathan[2], N. Saneesh[2], A. Jhingan[2], K. S. Golda[2], Mohit Kumar[2], A. M. Vinodkumar[2], A. Shamlath[1], P. V. Laveen[1], A. C. Visakh[1], M. M. Hosamani[5], DVGRKS. Kumar[4], P. Sandya Devi[4], G. N. Jyothi[4], A. Tejaswi[4], P. N. Patil[5], and A. Chatterjee[2]

[1]*Department of Physics, School of Physical Sciences, Central University of Kerala, Kasaragod 671314, India*
[2]*Inter-University Accelerator Centre, Aruna Asaf Ali Marg, New Delhi 110067, India*
[3]*Department of Physics, University of Calicut, Calicut 673635, India*
[4]*Department of Nuclear Physics, Andhra University, Visakhapatnam 530003, India and*
[5]*Department of Physics, Karnatak University, Dharwad 580003, India*

Introduction

The complex process involved in the collective re-arrangement of nuclear matter in fission is still a debatable topic. A major challenge is to understand the influence of various parameters such as entrance channel mass asymmetry, shell effect, N/Z dependence etc., in fission phenomena. Different experimental observables and theoretical interpretations reveal different manifestation of the involvement of fundemental nuclear properties in the fission dynamics. Among many probes, pre-scission neutron multiplicity (ν_{pre}) is one of the best probes to understand the evolution of the compound system from ground state configuration to scission configuration. Observation of excess emission of ν_{pre} than standard statistical model (SSM) [1] predictions suggest that nuclear fission is a dynamical process [2]. Statistical model analysis of ν_{pre} data for 26 systems incorporating delay in fission width shows a larger fission delay for symmetric sytem than asymmetric cases indicating strong entrance channel dependence of fission [3]. In another model [4], dissipative nature of fission account for the excess emission of neutrons than SSM predictions.

Few measurements have been reported to investigate the effect of neutron shell closure, N/Z etc in the fission process. Considering dissipative dynamics for fission, it has been reported that dissipation is relatively weaker for a shell closed nucleus in comparison to adjacent nuclei away from shell closure [5]. In another measurement it is reported that simultaneous fitting of ν_{pre} and fission cross section requires considerable amount of shell correction at the saddle point [6]. However dynamical calculations for the same systems [7] based on four dimensional Langevin equations neglecting saddle point shell correction were able to reproduce the ν_{pre} values and other fission observables. To ensure the robustness of the models interpreting heavy ion fission, more experimental evidence have to be made available.

Guided by the above open problems, we report here our measurements on neutron multiplicity for the ^{30}Si+^{182,184,186}W reactions populating ^{212,214,216}Ra compound nuclei. Of these compound nuclei, ^{214}Ra has neutron shell closure (N=126) and other two are two neutrons away from the shell closure. The measurements were performed in the excitation energy range between 45 MeV to 95 MeV.

Experimental Setup

The experiments were performed at the National Array of Neutron Detectors (NAND) [8] facility of IUAC, New Delhi. Pulsed beam of ^{30}Si with a repetition rate of 250 ns delivered from 15 UD Pelletron + LINAC accelerator system were used in the experiment to bombard on ^{182,184,186}W targets of thickness 405 μg/cm^2, 450 μg/cm^2 and 331 μg/cm^2 respectively, with carbon backing of 25 μg/cm^2. Neutron multiplicity measurements were performed at nine energy points between E_{lab}=140 to 193 MeV. Emitted neutrons from the fusion-fission reactions were detected in coincidence with the complementary fission fragments using 50 organic liquid scintillators (BC 501) of 5" x 5" dimensions kept at a distance of 175 cm from the centre of the target. Fission fragments were detected using two large area, position sensitive MWPCs kept at the fission fragment folding

*Electronic address: shareef.m.cuk@gmail.com

angle with respect to the beam direction and at a distance of 16.5 cm from the target centre.

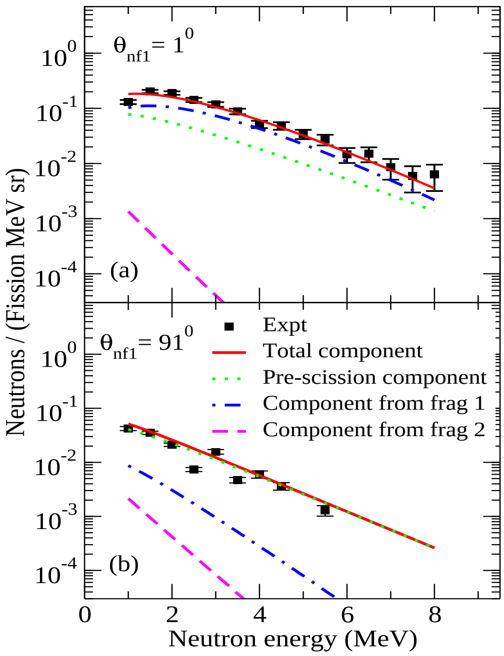

FIG. 1: Double differential neutron multiplicity spectra for ^{30}Si+^{186}W reaction at an excitation energy of 49.46 MeV (E_{lab}=139 MeV) along with fit and components.

MWPCs were operated with isobutane gas pressure of 3.5 mbar with a cathode bias of 435 V. The fast timing signals from the MWPCs were used to obtain the time of flight of the fission fragments and other reactions products. The logical OR of the two fission fragments AND-gated with RF of the beam was used as the trigger of the data acquisition system.

Data Analysis

Discrimination between neutron and gamma was made using time of flight (TOF) technique as well as pulse shape discrimination based on zero crossing method [9]. The TOF spectra was converted into neutron energy by considering prompt gamma peak as the referance line. Neutron energy spectra were gated with fission fragment TOF spectra to ensure that the neutrons were emitted only from respective fusion-fission process. MWPC position spectra was further sliced and gated with the neutron energy spectra inorder to minimise the angular uncertainty account of the large area of MWPCs. The pre- and post-scission components of neutron multiplicities and temperature were obtained from measured neutron energy spectra using least square fitting of the Watt expression given as.

$$\frac{d^2M}{dE_n d\Omega_n} = \sum_{i=1}^{3} \frac{M_i\sqrt{E_n}}{2(\pi T_i)^{3/2}} \times$$

$$exp[-\frac{E_n - 2\sqrt{E_n E_i/A_i}cos\theta_i + E_i/A_i}{T_i}] \qquad (1)$$

Where E_n is the laboratory energy of the neutron and A_i, E_i, T_i and M_i are the mass, energy, temperature and multiplicity of each neutron emitting source i. θ_i is the neutron emission angle with respect to the neutron emitting source. Three sources of neutrons, the moving compound nucleus and two fully accelerated fission fragments were considered in the fitting. Emission of neutrons were assumed to be isotropic in the rest frame and fission is considered to be symmetric. The kinetic energy of the fission fragments were calculated using Viola systematics [10]. Fig. 1 shows the fits to the double differential neutron multiplicity spectra of two of the neutron detectors placed at 1 degree and 91 degree with respect to the fission axis for the ^{30}Si+^{186}W reaction at 139 MeV of beam energy.

Extracted pre-scission, post-scission neutron multiplicities and temperature for the three reactions for all the measured energy points and its theoretical analysis will be presented.

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