Exploring the fusion-fission dynamics via systematic study of light particle multiplicities using statistical model code JOANNE2

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Introduction

Exploring and understanding the dynamics of heavy ion induced fusion-fission reactions mechanism has always been of great interest. Extraction of fission time scales using different probes is of central importance for understanding the dynamics of fusion-fission process. The role played by nuclear dissipation or viscosity in fission process has been investigated for many reactions using different probes [1-3]. In order to extract fission time scales, extensive theoretical and experimental efforts have been made so far. Fission time scales obtained using different probes give insight of fission reaction mechanism [1]. More light particles are expected to be emitted during the fission process due to nuclear dissipation. 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) [3]. The understanding of these excess particles in terms of time scales is a complicated problem. However to elucidate fission mechanism, the total time scale is divided into two major components: Presaddle termed as transient time (τ_{tr}) and post saddle termed as saddle to scission time (τ_{ssc}). In addition to the slowing down of the system and converting some collective energy into internal energy, the two-body viscosity hinders the formation of neck [4].

The multiplicities of various particles (neutrons, protons, alphas etc.) emitted during the decay of excited nucleus provides the information about these time scales and hence, help in understanding the detailed fusion-fission dynamics. The particle multiplicities reported in coincidence with the fission fragments for variety of systems indicates the fission to be hindered. Charged particles faces coulomb barrier at the exit channel whereas neutron being neutral in nature is exempted from coulomb barrier. Deformation dependent particle binding energy plays an important role due to which emission of charged particles is suppressed and neutron is increased. This affect has been already incorporated in standard statistical model code JOANNE2 [1].

In the present work, our aim is to develop a systematic of alpha and neutron multiplicities reported by various groups for a number of nuclear reactions. Using JOANNE2 code the alpha and neutron multiplicities have been encapsulated from the data available in literature.

Standard statistical model code JOANNE2

JOANNE2 is a Monte-Carlo based code which models the fission process and is capable of calculating the residue cross sections and prescission light particles emission in fusion-fission mechanism. JOANNE2 inputs are the number of cascades in the simulations, the atomic and mass number of the target and projectile nucleus, laboratory projectile energy, level density parameter for the spherical system, and the shape parameter β_2 are needed for the calculations of fusion cross section and the fusion spin distribution. The pre-saddle particle decay widths were calculated using rotating finite range model (RFRM). Deformation and rotational energies were calculated using the liquid drop model (LDM) whereas the transmission coefficients were obtained using universal optical model. The statistical model fission width calculations were made using the RFRM fission barriers. In order to enable the determination of saddle to scission particle decay widths, a value of deformation lying in between the saddle to scission configurations is used. Factors affecting the particle decay widths as a function of deformation, such as shape and deformation energy, were determined using RLDM for axially symmetric nuclear shapes. The particle binding energy for the light particles as a function of deformation is taken as

$$B_{part} = M_{part} + M_d^s + D_d(\alpha_i) - M_p^s - D_p(\alpha_i)$$

Where M_{part} is the mass of the emitted particle, M_d^s and M_p^s are the masses of the spherical daughter and parent nuclei respectively.

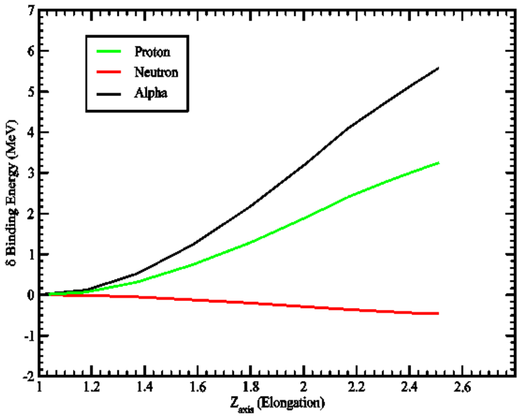

Fig 1- Change in particle binding energy as function of deformation for ^{212}Rn nucleus.

Calculations were performed for neutron and α-particle multiplicity for various systems. Change in binding energy as a function of deformation for one of the system is shown in Fig. 1. Calculations were done with and without considering the fission delays. Neutron multiplicity calculations are shown in Fig. 2 & 3 for ^{19}F+^{194,196,198}Pt and ^{16}O+^{194,196}Pt respectively, at various energies. Neutron multiplicity is seen to be reproduced by addition of delay ~(40-55 zs) (zs= 10^{-21}s). Detailed calculations for alpha and neutron multiplicities for various systems will be presented during the conference.

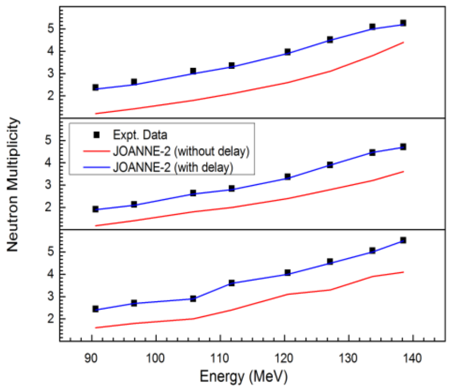

Fig. 2- Total Fission time deduced from JOANNE-2 by incorporating delay 42-55zs for ^{19}F+ ^{194,196,198}Pt reaction.

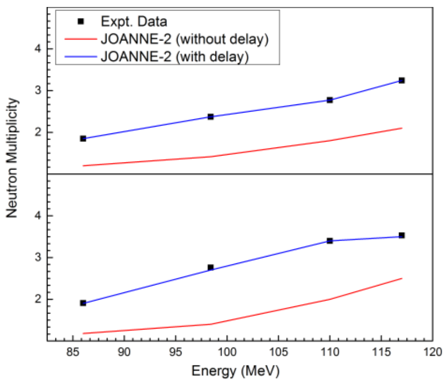

Fig. 3- Total Fission time deduced from JOANNE-2 by incorporating delay 40-52zs for ^{16}O+ ^{194,196}Pt reaction.

References

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