Fission Fragment Spectroscopic Studies in and around near-spherical and deformed nuclei

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The present thesis work is based on the use of Fission Fragment Spectroscopy (FFS) technique for understanding the different aspects of nuclear fission dynamics. Within a very short interval of time, the fission process gives rise to a large scale collective rearrangement of nucleonic matter, and subsequently produces several fission fragment nuclei in and around near-spherical and deformed regions. This complex process provides an ideal ground for exploring the influence of both classical (macroscopic) and quantum (microscopic) world simultaneously on a physical system.

In the present thesis work, an attempt has been made to study the various aspects of fission dynamics by measuring the fission yields for the fissioning compound nucleus, ^{236}U* that have been produced in two different experiments at different excitation energies (E$_{ex}$) via direct and surrogate reaction mechanism. It is worthwhile mentioning that the yields of the fission fragment nuclei of a particular fissioning system can be measured either by directly detecting the fission fragments or indirectly by detecting the de-exciting γ-rays from the fragments. In the present thesis work, the indirect way of the measurement of fragment yields through Fission Fragment Spectroscopy (FFS) has been used. The yields of the fission fragments produced from the reactions, ^{235}U(n_{th},f) [1] and ^{232}Th(α,f) [2] have been extracted.

In the first experiment, a target (∼600 μg/cm^2) of ^{235}U was bombarded with thermal neutrons from the high-flux reactor facility at the Institut Laue-Langevin (ILL), Grenoble, France. In the second experiment, a thick target (∼25 mg/cm^2) of ^{232}Th was bombarded with the accelerated 30 MeV α particles from the K130 cyclotron at the Variable Energy Cyclotron Centre (VECC), Kolkata. The de-exciting γ-rays from the Fission Fragments (FF)s were recorded using the EXILL array (EXOGAM@ILL), and Indian National Gamma Array (INGA) spectrometers during the first and second set of experiments, respectively. In both the experiments, the obtained high-statistics multifold coincidence data have been analyzed offline using the RADWARE and Tv software packages.

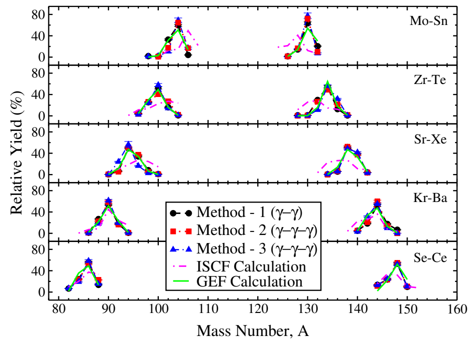

FIG. 1: Comparison of relative yield distributions for the complementary even-even fission fragment pairs extracted from the analysis of Methods 1, 2, and 3. Details have been discussed in Ref.[1].

The relative isotopic yield distribution profiles of several complementary even-Z, even-N fission fragments have been extracted for the fissioning system, ^{235}U(n_{th},f) at E$_{ex}$ ∼ 6.5 MeV utilizing different analysis procedures. The fragment yields obtained from the different analysis methods have been corrected for the contributions due to side-feedings from discrete yrast and non-yrast states, and also corrected for the several accompanying ex-

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perimental biases. An optimum yield measurement methodology has been devised by utilizing multifold γ-ray coincidence data [1]. The extracted results have been compared with two theoretical calculations based on (1) GEneral description of Fission (GEF) and (2) ISospin Conservation Formalism (ISCF) (see Fig.1). The extent of purity of the isospin quantum number in the neutron-rich fission fragments has been explored in the regime of low-energy fission of the concerned fissioning system.

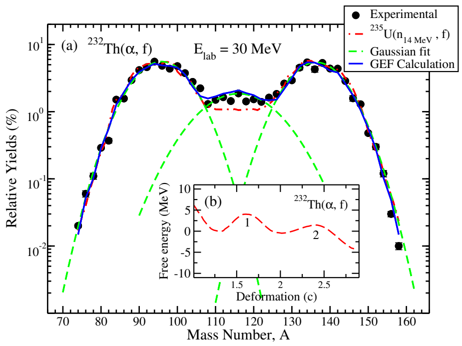

FIG. 2: (a) Even-Z,N mass yield distribution profile obtained from the reaction, ^{232}Th(α,f). (b) Calculated free energy profile as a function of deformation parameter of the system. Details have been discussed in Ref.[2].

The optimized yield measurement technique based on FFS has further been utilized for measuring the relative isotopic yield distributions corresponding to eighty nine even-even FFs. Subsequently the measured fission yields have been utilized to deduce the relative charge and mass yield distribution profiles of the fissioning system, ^{232}Th(α,f) at E$_{ex}$ $\sim$ 21.5 MeV. The extracted yield distribution profiles have been interpreted on the basis of simultaneous existence of both shell effect and multichance fission. The observed distinct triple hump structure structure of the yield distributions (see Fig.2) has been interpreted on the basis of Random Neck Rupture Model (RNRM). The results provide experimental evidence for the presence of two distinct compound nucleus fission modes for ^{236}U*. The respective contributions from the superlong symmetric mode (SL) along with the two asymmetric modes of standard I (ST I) and standard II (ST II) are measured. The impact of excitation energy (E$_{ex}$) and angular momentum (L) on a specific fissioning system has been investigated. A slight enhancement in the yield for the symmetric mode of fission has been found in the case of the surrogate reaction, ^{232}Th(α,f) when compared to that of the direct reaction, ^{235}U(n_{14MeV},f). An average neutron multiplicity value of 4.60 (9) has been extracted for the fissioning system, ^{232}Th(α,f) at the given E$_{ex}$ [2]. The experimental results have been further utilized for the estimation of several valuable fission observables [3].

The present thesis work brings out the fact that although it is very challenging to make an unambiguous analysis of the complicated γ spectra of the fission fragments, a careful analysis of in-beam γ-spectroscopic data can bring out an overall picture of the underlying fission dynamics.

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