Investigation of possible multi-modal fission modes in ^{235}U(n_{th},f) following fission fragment spectroscopy

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Introduction

In the actinide region, the nuclear fission reaction is the most dominating exit channel following the formation of a heavy compound nucleus. In this process, the excited compound nucleus splits into two smaller primary fission fragments (FFs) of intermediate masses. These FFs are produced by following the conservation of atomic number (Z_{CN}) of the compound nucleus, such that $Z_1 + Z_2 = Z_{CN}$, where $Z_{1,2}$ are the atomic numbers of the two correlated complementary fragment nuclei. Accordingly, a large number of fission fragment nuclei with varying yields and deformations are simultaneously produced in a typical fission reaction. One of the most peculiar aspect of these Fission Fragment Mass Distributions (FFMDs) is the simultaneous existence of different fission modes. The FFMDs of the low-energy fission of lighter actinides were initially interpreted on the basis of two different fission modes − (1) Asymmetric and (2) Symmetric [1]. However, an extensive theoretical model calculation based on the concept of multimodal fission process has shown that the various types of mass distributions originate due to the presence of multiple valleys and ridges into the potential energy surface of the fissioning system [2]. Subsequently, the fissioning system de-excites through any of these valleys, and thereby give rise to different fission modes. Till date, these fission modes have been primarily investigated using the Total Kinetic Energy (TKE) measurements. However, these modes can also be explored by performing an extensive study of the FFMDs [3].

Here, we report the newly obtained results from the multimodal analysis of the FFMD of the fissioning system, ^{235}U(n_{th},f). The FFMD of the fissioning nucleus, ^{236}U at an excitation energy (E$_{ex}$) of about 6.5 MeV has been extracted using the Fission Fragment Spectroscopy (FFS) technique following the prescription of Ref.[3]. Details of the relative isotopic yield measurement using the FFS technique by utilizing high statistics γ-γ and γ-γ-γ coincidence data, can be found in Ref.[4].

Results and discussion

The measured raw yields have been utilized to obtain the relative fission yield (in %) distributions of seven pairs of complemen-

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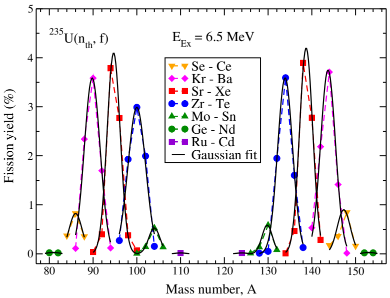

FIG. 1: The isotopic fission yield (in %) distribution for seven pairs of even-even FFs as obtained from the present work. The experimental data points have been fitted with Gaussian function.

tary fission fragments (See Fig.1). The extracted relative fission yields (in %) (following Fig.1) have further been utilized to construct the relative FFMD of the fissioning system, ^{235}U(n_{th},f) (See Fig.2). The total mass yield distribution thus obtained indicates a highly asymmetric distribution profile with peaks at A = 95 and 139, and covers a mass range from A = 82 to 152. The yields corresponding to 52 even-Z,even-N and 28 even-Z,odd-N correlated fragment nuclei have been unambiguously extracted. The experimental FFMD has been compared and found to be in good agreement with the (1) theoretical model calculation based on the GEF (GEneral description of Fission) simulation package [5], and (2) thermal neutron-induced fission yield data from nuclear data library of ENDF/B-VII.1 [6].

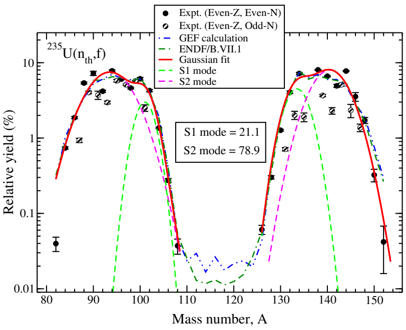

FIG. 2: Relative mass yield distribution (in %) of the even-Z FFs as obtained from the ^{235}U(n_{th},f) reaction. See text for details.

According to the Random Neck Rupture model (RNRM) [2], the asymmetric peaks in this reaction are due to the simultaneous existence of two different asymmetric fission modes, i.e. (1) standard-1 (ST-I) and (2) standard-2 (ST-II). These two fission modes occur due to the influence of shell structure effects. The extracted FFMD has been fitted with two Gaussian functions corresponding to the ST-I and ST-II fission modes. The peak positions corresponding to the ST-I and ST-II modes have been found to be around $A \sim 134$ and 142, respectively. The fittings have been utilized for extracting the yield (%) components corresponding to the two modes. A respective contribution of about 21.1% and 78.9% from the ST-I and ST-II fission modes have been found from the present investigation. The measured fission mode contributions are found to be in good agreement with the predicted result from the GEF model calculation (ST-I and ST-II are 19% and 81%, respectively) and experimentally measured values based on TKE measurements (ST-I and ST-II are 22% and 78%, respectively) from Ref.[7]. Detailed results and interpretations on all the aforesaid aspects will be presented during the symposium.

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