Observation of asymmetric fission in mass distribution of ^{222}Th Compound nucleus

S. K. Duggi[1],* P. V. Madhusudhana Rao[1], P. Sandya Devi[1], G. Naga Jyothi[1], A. Tejaswi[1], M. Ratna Raju[6], S. Appannababu[1], V. Vishnu Jyothi[1], N. Saneesh[2], A. Jhingan[2], K. S. Golda[2], C. Yadav[2], Mohit Kumar[2], Divya Arora[2], P. Sugathan[2], Meenu Thakur[3], M. Shareef[4], A. Shamlath[4], P. V. Laveen[4], Gurpreet Kaur[2], and B. K. Nayak[5]

[1]*Swami Jnanananda Laboratories for Nuclear Research, Department of Nuclear Physics, Andhra University, Visakhapatnam - 530003, INDIA*
[2]*Inter University Accelerator Centre, Aruna Asaf Ali Marg, New Delhi - 110067, INDIA*
[3]*Department of Physics, Panjab University, Chandigarh - 160014, INDIA*
[4]*Department of Physics, Central University of Kerala, Kasaragod - 671316, INDIA*
[5]*Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai - 400085, INDIA and*
[6]*Department of Physics, M. R. College (A), Vizianagaram - 535002, INDIA*

Introduction

At low excitation energies fission mechanism is strongly influenced by the nuclear structure of the fissioning nucleus. The shell stabilisation in the fragments results in either asymmetric mass-division [1, 2] or symmetric mass-division [3]. The strongest shell effects are expected to appear in the doubly magic spherical nuclei, such as ^{132}Sn. But, the measurements of electromagnetic induced fission in actinide nuclei [4] show that the mean charge of the heavy fragments is distributed around 52-56. This indicates that the asymmetric fission of actinides is not only due to the spherical shell closure (Z=50 and N=82). These Shell effects depend on the excitation energy and mass number of the fissioning nuclide. Thus nuclear fission allows to study the interplay of macroscopic (collective) and microscopic (single particle) degrees-of-freedom in both the fissioning nuclide and the fission fragments (FF) in transition of the nuclei. It is also observed that the increase in nucleon number of the fissioning heavy nucleus has shown a transition from symmetric to asymmetric fission modes in Ra-Th region [4] which may be attributed to the excess neutrons.

*Electronic address: sivakumar.duggi@yahoo.com

As part of the systematic study of mass distribution of the neutron deficient Thorium nuclei, we present the results on the fission fragment mass distribution (FFMD) for ^{222}Th nucleus measured at moderate excitation energies. The ^{222}Th compound nucleus (CN) is populated through the fusion reaction of ^{18}O+^{204}Pb.

The experiment was performed using ^{18}O beam provided by the Pelletron-LINAC booster accelerator facility at Inter University Accelerator Centre, New Delhi.The large spherical scattering chamber of NAND facility is used for the present experiment and the details are discussed earlier [5].

Data Analysis and Results

Multi-parameter data collected in list-mode online during the experiments is later anlysed offline using ROOT package [6]. Conventional two body kinematics [7] was adopted to extract the mass distribution. In the present work ν_{pre} (pre-scission neutron multiplicity) is estimated by using Baba systematics [8], which is used in the fragment mass calculations. From the experimentally measured time-of-flights fragment masses, velocities, kinetic energies (KE) of the fragments were extracted. Further, the extracted KE of fragments were corrected for the energy losses of the fragments in the target foil and the Mylar foil of the Multi Wire Proportional Counters.

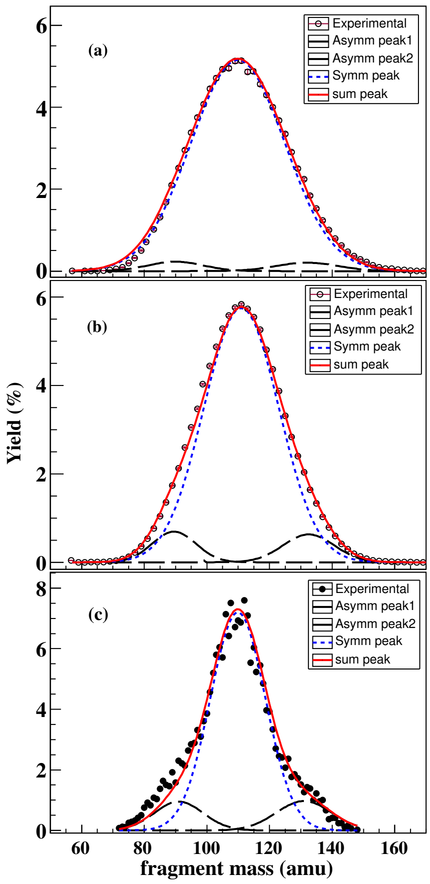

FIG. 1: FFMD of ^{222}Th CN with three peak fit (a) E^*_{CN}=98 MeV, (b) E^*_{CN}=44 MeV (error bars are within the data points) and (c) the experimental data obtained [11].

The energy loss corrections were made using library of range which calculates the stopping powers of charged particles in different materials [9]. The experimentally deduced average total kinetic energy is 166.6 MeV for this nucleus at E*=29 MeV and it is in good agreement with the viola systematics [10] for the symmetric fission.

A multiple peak fitting analysis was performed in order to investigate the multimodal nature of fission of this nucleus.

From the multimodal fit in Fig. 1, it is observed that different components of fission appear in the FFMD yields, which can be attributed to different modes of fission. One can also clearly observe a transition of fission from asymmetric to symmetric mode with increasing excitation energy. It is also observed that the asymmetric mode of fission is persistant at $E^*_{CN} \approx 98$ MeV which is ≈ 5.3 %. The present results were compared with the recent measurements of electromagnetic induced fission [11] at $E^* \approx 12$ MeV. The present results indicate that the asymmetric mode is may be due to either the proton deformed shell closures of Z $\sim$ 52-56 and/or neutron deformed shell closures of N $\sim$ 84-88 in the heavy fragment.

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