Multi-modal fission in ^{256}Fm*

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Introduction

The ^{254}Fm-^{258}Fm region is of interest to study multimodal fission, where the mass distribution drastically changes from asymmetric to symmetric one. This phenomenon has been recently explored theoretically using time-dependent generator-coordinate-method, and 3-D Langevin dynamics [1, 2]. Both the approaches predicts a gradual transition from asymmetric to symmetric fission, with asymmetric mode for ^{254}Fm, symmetric mode for ^{258}Fm and both mode in case of ^{256}Fm. The limited experimental data, on the other hand, indicates rather a sudden transition (asymmetric to symmetric from ^{256}Fm-^{258}Fm).

In this work, we report the fission fragment mass and charge distributions in ^{256}Fm from the re-analysis of the fission fragment spectroscopy data measured for ^{18}O+^{238}U reaction with improved background subtraction and updated level schemes. The fissioning nucleus, ^{256}Fm*, was populated by bombarding ^{18}O beam at energy E_{lab} = 100 MeV on a self-supporting ^{238}U target of thickness $\sim$ 15 mg/cm^2, and the γ-rays emitted by the fission fragments were detected using the Indian National Gamma Array (INGA) [3].

Results and discussion

The independent yield ($Y(Z, N)$) of $\approx$ 70 even-even fragments have been obtained from the reanalysis of the prompt γ-ray coincidence data. The fission fragment mass and charge distributions, have been determined from $Y(Z, N)$. A detail listing of the fragment independent yields and other fission observables viz. neutron-excess, isotopic, and isotonic distributions with their analysis will be published elsewhere.

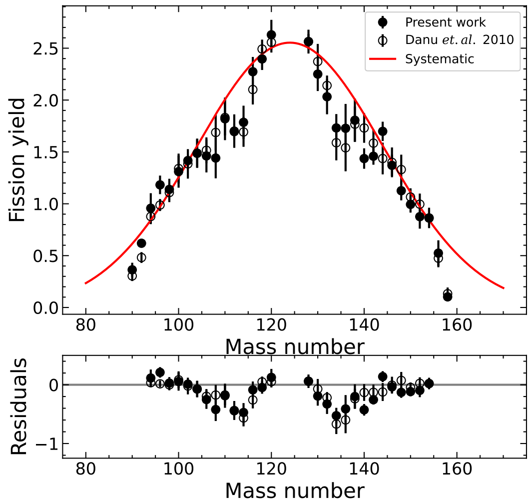

FIG. 1: Fission-fragment mass distribution obtained from the present work with improved background subtraction and updated level schemes (solid circles) and from Ref. [3] (hollow circles). The solid line represents the empirical distribution obtained from the mass-width systematic.

In Fig. 1, the fission-fragment mass distribution obtained from the present work has been compared with the empirical distribution estimated from the mass-width systematic [4] as well as with the data from Ref. [3]. Significant deviations from empirical distribution are observed where the experimental fragment yields are substantially smaller. This deviation occurs for fragments with N = 82 spherical shell closure and their complimentary partners. Fission fragment mass distributions of neutron deficient nuclei in A $\approx$ 180 region [5] and theoretical investigation by Scamps and

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Simenel [6] provide strong evidence for the reduced yield of spherical fragments in spite of their large shell correction energy.

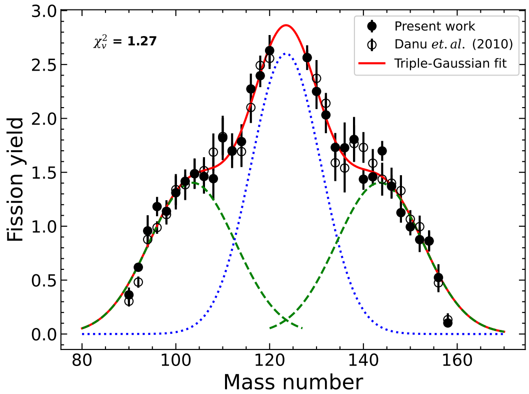

FIG. 2: Fission-fragment mass distributions in ^{256}Fm fitted with triple-Gaussian distribution. The mass-symmetric and the mass-asymmetric components of the fit are shown by the dotted and dashed lines respectively.

In Fig. 2, the experimental mass distributions are plotted along with fit to triple-Gaussian function. For the mass-asymmetric fission mode the fit results give the centroid of heavy fragment, $A_{asym} = 144 \pm 2$. This corresponds to the nuclei with nucleonic composition: Z ≈ 58 and N ≈ 86.

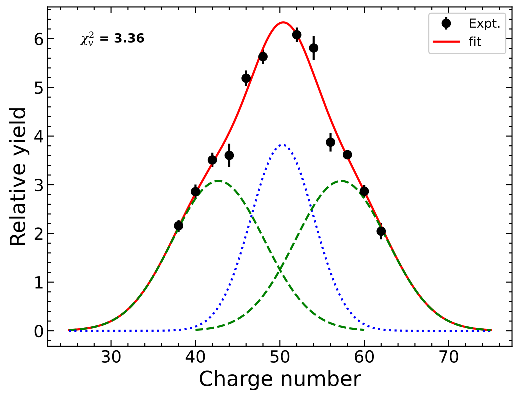

FIG. 3: Fission-fragment charge distribution in ^{256}Fm along with the triple-Gaussian fit.

The fragment charge distribution along with the fit is shown in Fig. 3. The centroid of mass-asymmetric heavy fragment charge is obtained as $Z = 57 \pm 3$.

Nuclear fission is described in terms of shape evolution in multi-dimensional deformation space. The macroscopic (liquid drop) parameters on one hand give minimum for symmetric split, the microscopic shell effects on the other hand favors shell stabilized fragments generally leading to asymmetric division. Their interplay results in different fission modes. The fragment yield measurements completely identified in Z and N are important to delineate the shell effects in fission. The present results on the fragment mass and charge distributions of ^{256}Fm fission clearly indicate the dominance of deformed shell closures over the spherical ones in determining the characteristics of multi-modal fission. The octupole deformation around Z ≈ 57 and N ≈ 86 of the fragments seems to play important role in the mass-asymmetric fission mode.

Summary

In summary, fission fragment mass and charge distributions in ^{256}Fm fission are presented. These distributions have been decomposed into symmetric and asymmetric components using triple Gaussian fit to study the characteristics of multi-modal fission. The present results indicate strong influence of deformed shell closure especially octupole deformation in fragments determining the asymmetric fission mode/s.

Acknowledgments

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