Observation of asymmetric fission in ^{193}Tl at intermediate excitation energies

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Introduction

During nuclear fission, a heavy nucleus splits into two fragments, releasing a significant amount of energy. While the basic features of the fission process can be explained by the simplistic liquid-drop (LD) model, this macroscopic approach predicts symmetric fragment distribution and fails to account for the observed asymmetric mass splits in actinides. Asymmetric fission in preactinides near the beta-stability line was first observed in the 1980s, but the discovery of dominant asymmetric fission in the neutron-deficient ^{180}Hg isotope at ISOLDE [1] rekindled theoretical and experimental interest in the fission of neutron-deficient nuclei in the preactinide region. In the fission of ^{180}Hg, the production of ^{90}Zr fragments, which have a magic neutron number of N = 50, would be expected to be energetically favorable. However, it was observed that fragments with masses of 80 and 100 u were most probable. This contrasts with the fission of heavy actinides, where strong shell effects in the heavy fragments have been found to dominate [2]. The attempts to explain the new type of asymmetric fission include shell effects in prescission configurations associated with dinuclear structures or quadrupole deformed neutron shells in the fragments and fissioning nucleus [3].

A recent analysis [4] of the available experimental data on low energy asymmetric fission of neutron-deficient nuclei around Pb concludes a leading role played by the light-fragment proton configuration, which is in contrast to the dominance of neutron shells predicted earlier. In this work, we present the measurement of fission fragment mass distributions of ^{193}Tl populated in ^{34}S+^{159}Tb reaction. The measured fission fragment mass distribution is compared with the predictions of the semiempirical GEF model [5] and the measured FF mass distribution for ^{192}Pb from Ref. [6].

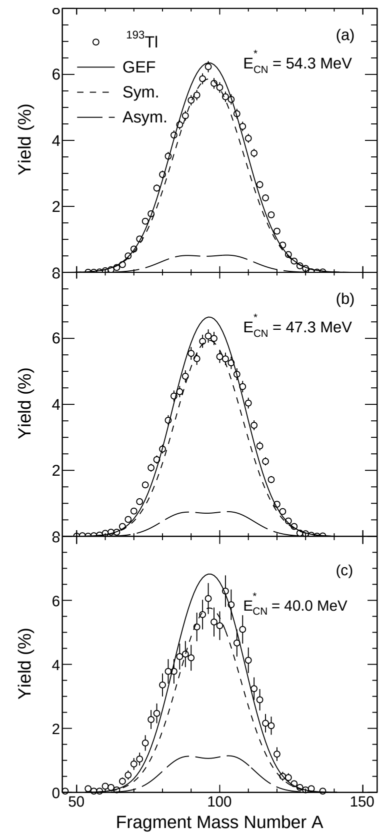

FIG. 1: The measured fission fragment mass distribution for ^{193}Tl in the ^{34}S + ^{159}Tb reaction at E^*_{CN} = 54.3 MeV (a), E^*_{CN} = 47.3 MeV (b) and E^*_{CN} = 40.0 MeV (c). The measured fission fragment mass distributions are compared with the predictions of the semiempirical GEF model [5].

Experiment and data analysis details

A 200 μg/cm^2 thick ^{159}Tb target on $\approx$ 250 μg/cm^2 thick Al backing was mounted inside the 1.5 meter diameter scattering chamber at the BARC-TIFR Pelletron-LINAC facility, Mumbai. The target was mounted such that the incoming beam was first faced by the backing to minimize

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the FF energy loss inside the target. The bunched beam of ^{34}S was bombarded on the target at energies 156.7, 148.3 and 139.6 MeV. Two large area (12.8×8.0 cm^2 and 19.3×11.2 cm^2) multiwire proportional counters (MWPCs) were placed in a scattering chamber at distance of 25.3 cm at ±66.5° for the coincident detection of the fission fragments [7]. The larger MWPC, with an area of 19.3×11.2 cm^2, was developed at NPD, BARC. Its X-plane consists of 150 gold-plated tungsten wires, each with a diameter of 20 μm, while the Y-plane is composed of 30 copper strips. The time of flight (TOF) with respect to the arrival of the beam pulse, position (x, y), and the energy loss information of both the fragments in the detectors were recorded event by event. The velocity vectors of the fragments were extracted using the position and TOF information. Fragment masses were finally determined using the kinematic coincidence method. Small corrections in the fragment mass due to their energy loss in the target were obtained on an event-by-event basis in an iterative manner for all the possible fragments.

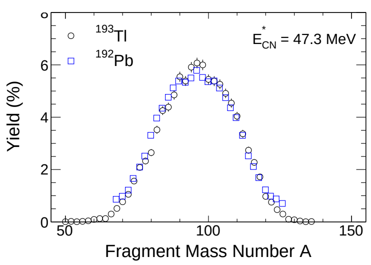

FIG. 2: The measured fission fragment mass distribution for ^{193}Tl in the ^{34}S + ^{159}Tb reaction at E^*_{CN} = 47.3 MeV. The fission fragment mass distributions is compared with those for ^{192}Pb in ^{48}Ca + ^{144}Sm reaction at E^*_{CN} = 48.4 MeV from Ref. [6].

Results and discussion

Figure 1 shows the measured Fission fragment mass distribution for ^{193}Tl in the ^{34}S + ^{159}Tb reaction at (a) E^*_{CN} = 54.3 MeV, (b) E^*_{CN} = 47.3 MeV and (c) E^*_{CN} = 40.0 MeV. The predictions of the GEF model [5], folded with the experimental mass resolution ($\sigma \sim$ 5u), are compared with the measured fission fragment mass distributions. The GEF model provides a reasonable qualitative description of the measured data, although the measured distributions are slightly broader than the GEF predictions. This disagreement is likely due to the presence of quasi-fission, which is expected for reactions involving heavy projectiles [8]. Further analysis of the data will be conducted to test this hypothesis. The GEF model also predicts substantial asymmetric contribution at all three energies and a gradual reduction of the asymmetric component. Figure 2 shows the measured fission fragment mass distribution for ^{193}Tl in the ^{34}S + ^{159}Tb reaction at E^*_{CN} = 47.3 MeV. The measured fission fragment mass distributions is compared with those for ^{192}Pb measured in ^{48}Ca + ^{144}Sm reaction at E^*_{CN} = 48.4 MeV from Ref. [6]. The measured fission fragment mass distributions for ^{193}Tl is in good agreement with the ^{192}Pb validating the performance of MWPC developed at NPD BARC.

Summary

The measurement of fission fragment mass distributions of ^{193}Tl populated in ^{34}S + ^{159}Tb reaction is presented. The measured distributions show good agreement with measured FF mass distribution for ^{192}Pb from Ref. [6]. The measured distributions are slightly broader than the GEF predictions likely due to the presence of quasi-fission. The further analysis of FF mass distributions for ^{193}Tl will be conducted to test this hypothesis and the detailed results will be presented in the symposium.

Acknowledgments

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