Fission like fragments from the reaction ^{16}O + ^{124}Sn at E/A ≈ 22.7 MeV/A

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Introduction

Soon after the discovery of nuclear fission, one of the greatest challenges was to understand the observation of asymmetric mass distribution for actinides. Even for last few decades it was believed that mass distributions for pre-actinides are symmetric. Discovery of asymmetric fission of Hg in the pre-actinde region and mapping of the mass distribution of pre-actinides and actinides with seminal work by Karl Heinz Schmidt at GSI brings many surprises in nuclear fission research. These studies ignited flurry of theoretical and experimental work in recent times . One of the unexplored area of research is the fission of mid mass region (A ≈ 150). While, heavy elements (HE) and super heavy elements (SHE) easily undergoes fission due to a smaller fission barrier, medium mass nuclei (A ≈ 140-150 u) have a very large fission barrier (B_f ≈ 40-50 MeV) which prevents the fission channel. The fission barrier itself is a function of the temperature and the angular momentum of the nucleus, decreasing as both the temperature and the angular momentum increases. Thus high energy heavy ion beams, now available at the K 500 Super Conducting Cyclotron (SCC) at VECC, Kolkata, offers to carry such studies for the first time in India. However, with increase in energy of the beam, multiple reaction channels open up, which complicates the understanding of the data under examination, with beyond the mean field phenomena entering into the reaction mechanisms [1]. The composite populated by ^{16}O + ^{124}Sn is ^{140}Ce, which has a fission barrier about 47 MeV in the ground state. With a heavy ion beam of ^{16}O, the composite reaches a sufficient temperature and angular momentum, at which fission like phenomena has been observed.

Experimental details

The K-500 Super Conducting Cyclotron (SCC) at VECC is currently delivering the most energetic heavy ion beams in the country. This provides us an opportunity to study fission like phenomena in medium mass nuclei. A ^{16}O beam of energy 363 MeV was bombarded on a isotopic enriched target of ^{124}Sn of thickness around 200 μgm/cm^2. For the detection of fission like fragments, multi wire proportional counters (MWPC) were used which are transparent to beam like particles. Two MWPC detectors of dimensions 20 cm X 6 cm are placed at an angle of 60^0 with respect to the beam axis, corresponding to the folding angle, with an angular coverage of around 40^0 each. This ensures that all fragments arising from binary fragments are detected in co-incidence in the two detectors. The detectors were operated with 3 torr of isobutane gas for the most efficient detection of fission like fragments. The time of arrival of the fragments, the X and Y position of the point of impact of the event and the energy loss of the fragment in the gas volume were recorded event by event basis. The timing correlation spectra from the two MWPC detectors has been presented in Fig 1.

Result

As shown in fig 1, the fragments detected in the two MWPC detectors from the reaction ^{16}O + ^{124}Sn were found to be correlated, suggesting that they arise from binary fragmentation mechanism. The energy loss spectra also clearly separated the quasi elastic projectile like fragments

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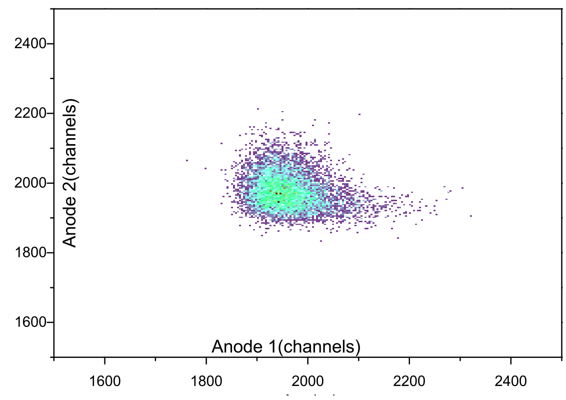

FIG. 1: The timing correlation spectra from the experiment from the anodes of the two MWPC detectors.

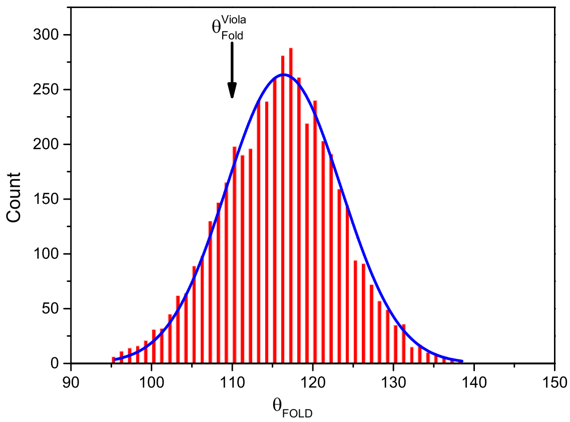

FIG. 2: The folding angle distribution from the reaction. The black arrow points to the folding angle corresponding to Viola's systematic. The blue line corresponds to a Gaussian distribution, best fitting the data.

from the fission like fragments. In order to elucidate the mechanisms giving rise to these binary fission like fragments, the folding angle distribution, i.e., the angle subtended between the fragments in the laboratory frame, has been presented in Fig 2. The distribution is Gaussian in nature, with some deviations, clearly indicating that there are multiple reaction mechanisms at play [2]. It is noteworthy that the peak of this distribution is also shifted from the peak predicted by Viola's systematic for binary fragmentation following the complete momentum transfer from the projectile to the target (marked with a black arrow in Fig 2). This is indicative of the incomplete transfer of linear momentum phenomena, which had been observed earlier in such high energies in heavier target projectile systems [3]. It is worth noting from Fig 2, that the reaction mechanism seems to compete with complete linear momentum transfer events. In order to examine this, the

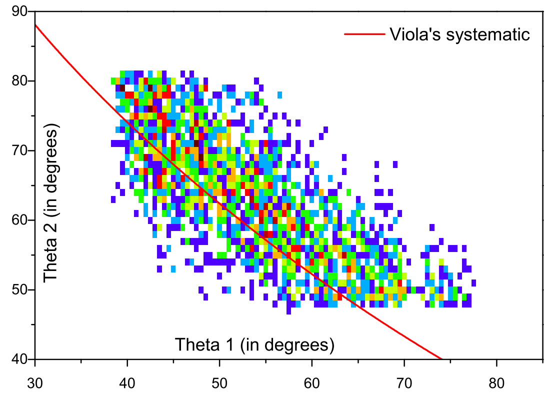

FIG. 3: The angular correlation between the fission fragments. The red line corresponds to angular correlation following Viola's systematic following full linear momentum transfer.

angular correlation between the two fission fragments have been examined in Fig 3. It can be inferred that there are some correlated events arising from full linear momentum transfer. These events may correspond from fusion-fission, fast fission, etc., which are mean field phenomena.

Summary

We report the first fission measurement at the K500 Superconducting Cyclotron facility. Fission like fragments from the reaction ^{16}O + ^{124}Sn, which populates a composite of mass $\approx$ 140 u. The folding angle distribution and the angular correlation between the fragments points to a competition between full linear momentum transfer events and incomplete momentum transfer events. The full momentum transfer events may arise from mean field phenomena like fusion fission, etc, which will be presented in the symposium.
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