Fission Fragment mass distribution for neutron deficient nuclei in A∼200 region

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Introduction

A renewed interest in heavy-ion fusion-fission studies has emerged after the observation of asymmetric mass-distribution of the fragments, originating from fission of ^{180}Hg, at low excitation energies [1]. The mass-asymmetric fission observed for low-energy fission of actinide nuclei is well understood in terms of the effects of shell structure in the nascent fragments [2]. The models that explain actinide fission predicted a symmetric mass split for ^{180}Hg, resulting in semi-magic nascent fragments ^{90}Zr. However in contrast to the anticipation of symmetric split, recent experiments for the systems forming nuclei around Hg-Fr showed a pronounced mass-asymmetric fission, suggesting that shell structures other than those of the fragments may play a vital role in shaping fission outcomes [1–5]. Different theoretical models proposed to explain these results give contradictory interpretations [6, 7]. More measurements to study the evolution of the fission-fragment mass distributions with the N/Z and excitation energy E* of the fissioning nucleus, spanning region between actinides and pre-actinides are required to understand the origin of shell effect and discriminate between various models. We have started a program to study mass distribution of fission fragment for systems forming neutron deficient compound nucleus near A∼ 200 region. Calculations predict presence of both symmetric and asymmetric contribution at very low excitation energies where fission cross-section is of the order of microbarns [8]. As the fissility of the nuclei in the mass region of 180-200 is lower, the quasi-elastics dominates the count rate in the detector, hence measurement of mass distribution at very low energies is challenging specifically with high Z impurities in the target. The present work being exploratory in nature is aimed to get an idea on the lowest possible energy that can be studied for shell effects in the experimental set up available.

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Experimental Details

The experiment was performed at the Pelletron-Linac Facility, Mumbai, using ^{28}Si beam of energies 142, 132 and 125 MeV on a self supporting target of ^{175}Lu (97.41% enriched, 1.5 mg/cm^2 thick). Fission fragments were detected using two large area multiwire proportional counters (MWPCs) placed inside the scattering chamber for a coincidence measurement of the fission fragments. The distance between the target and the center of the cathodes was 23 cm. The detectors were located symmetrically around the beam axis at θ_1 = 70° for MWPC1 and θ_2 = -70° for MWPC2. Each of the detector covered angular range of ±15° around the detector center. The active area of each MWPC was 12.5× 7.5 cm^2. The detectors were operated with isobutane gas at a pressure of about 5 mbar. The signals of MWPCs were recorded using time-to-digital converter triggered with the rf signal filtered with fission.

A plot of time of flight spectrum (TOF_1

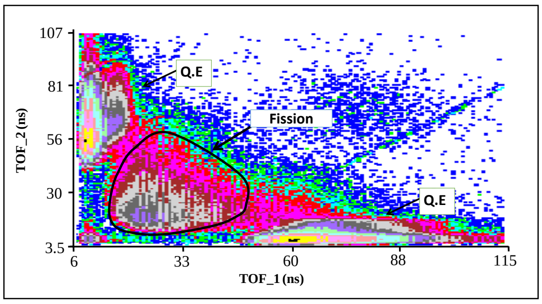

FIG. 1: Timing spectrum from the cathode of two MWPCs plotted against each other at E_{beam} = 142 MeV. Events corresponding to fission and quasi-elastic scattering are marked.

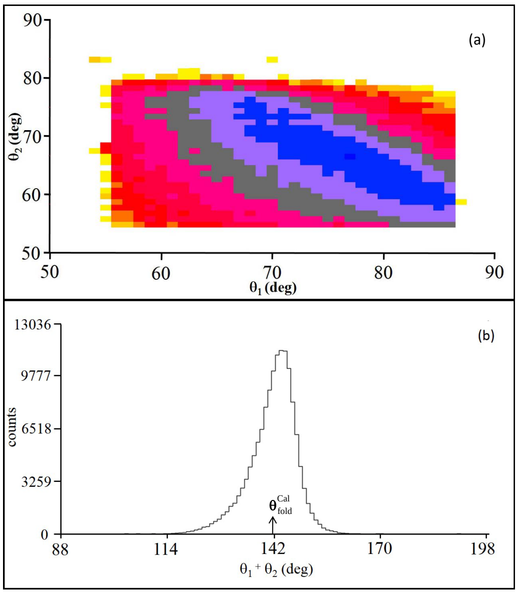

FIG. 2: (a) Plot of θ_1 vs θ_2 of fission fragments detected in MWPC1 and MWPC2 respectively (b) Folding angle distribution of the fission fragments (θ_1 + θ_2) at E_{beam} = 142 MeV. Arrow indicates folding angle calculated for symmetric fission.

vs TOF_2; 1 and 2 refer to the fragments detected in detector 1, 2 respectively) for the ^{28}Si + ^{175}Lu reaction at E_{beam} = 142 MeV is shown in Fig. 1(a). A clear separation between the fission (fragment-fragment coincidence) and quasi-elastic scattering (projectile like - target like coincidence) events is obtained.

Analysis and Summary

The calibrated positions and the time of flight information from the MWPCs were used to obtain the fragment emission angles and velocities assuming two-body kinematics. A correlation plot of the angle of fission fragments detected in both the detectors is shown in Fig. 2(a). The fission events were selected by putting a two dimensional gate in the timing spectrum shown in Fig. 1. The folding angle distribution is plotted by adding the emission angle for each event, that peaks around 142 degrees at E_{beam} = 142 MeV. The fission cross-section at 132 MeV relative to that at 142 MeV is smaller by a factor of ∼10, while at 125 MeV it is smaller by a factor of ∼600. At the lowest energy the event rate corresponding to the quasi-elastic scattering is many order of magnitude larger than that of fission. At all the three measured energies, fission cross section and mass distribution deduced from the above data will be presented. In future we plan to perform measurement with thin target to improve the resolution of the mass distribution at a low energy estimated based on the cross-sections extracted from the present measurement.

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