Fragment mass distributions in fusion fission of ^{213}At

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Introduction

The evolution of nuclear shell effect with excitation energy and its manifestations in various nuclear reaction processes have recently become a subject of special interest, particularly in pre-actinide region. The discovery of the symmetric fission of ^{180}Hg at low excitation energy revealed that the mass split in fission are determined by the shell effects between saddle and scission; unlike in actinides where shell effects in the nascent fragments plays the dominant role to determine the mass distribution. Recently, Moller *et al.* [2], using Brownian shape motion model, calculated the mass distributions of ^{180}Hg and the neighbouring nuclei which is considered as a bench mark for newer advanced theories in the pre actinide region. Several other models based on density functional theory [4] that uses a self-consistent study considering the thermal effects on the fission pathway explored the excitation-energy dependence of fission yields in the pre-actinide region. These models that describe the asymmetric fission of ^{180}Hg, also predicts the mass distributions of the pre-actinide nuclei. In general, whereas at E* = 0 MeV, the dominant fission pathway favours a slight mass asymmetry for the pre-actinides, at E* more than 40 MeV, the fission fragment mass distribution becomes purely symmetric in nature. To test the universality of the theoretical models, measurements of mass distribution for several pre-actinide nuclei are required.

Here, we report the results of our new measurement of the mass distributions of the pre-actinide nuclei 213At produced in alpha induced reaction. Measurement with alpha induced reactions reduces complication of the effect of entrance channel fusion dynamics (e.g; mixture of transfer induced or non-compound nuclear fission).

Experiment

Alpha beam of energy 37-55 MeV, from the K-130 Room Temperature Cyclotron at VECC, Kolkata was bombarded on a self-supporting target of enriched ^{209}Bi of thickness 440 μgm/cm^2. Two indigenously developed MWPC detectors of active area 20 X 6 cm^2 were used to detect the complementary fission fragments. The detectors were placed at an angle of 60^0 and 114^0 inside the scattering chamber, the angles being decided on the basis of symmetric fission fragments following Viola's systematics. The detectors covered an angular area of 60^0 and 72^0 respectively. The detectors were operated in low pressure (3 torr) of iso-butane gas, so that they were transparent to elastic and quasi elastic particles. The time of flight of the fission fragments, position of impact of the fission fragments with the detector and the energy loss of the particles in the gas volume were recorded in a VME based DAQ system.

Results and discussions

The mass of the fission fragments was calculated from the difference between the time of flight, polar and azimuthal angles and the momentum transferred and the recoil velocities. The folding angle distributions were generated and a gate of $\pm4^0$ was used around the theoretically calculated folding angle following complete transfer of momentum from the projectile to the target.

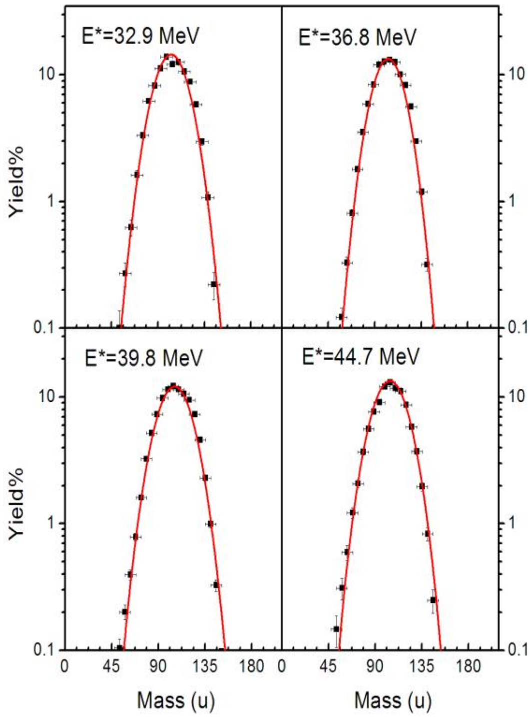

Fig 1: The fission fragment mass distributions for ^{213}At at various excitation energies.

This ensured complete rejection of all transfer induced fission events while constructing the mass distributions. Fig 1 shows the fission fragment mass distributions, corrected for the energy loss in the target, for various excitation energies. The red line shows the single Gaussian fit to the mass distribution. The mass distributions have been plotted in log scale so that any weak fine structure, which may be a signature of shell effect in the mass distribution of fission fragments, can be visualized. Peter Moller *et al.*, had predicted a slight asymmetric mass distribution for this nuclei at a lower excitation energy of 25.69 MeV, which could not be measured by us due to very low fission cross section.

From this plot we find that even at a low excitation energy of E^*=32.9 MeV, there seems to be no signature of any fine structure or deviation from the single Gaussian fit. Since the width of the mass distribution is also sensitive to the presence or absence of shell effects, the normalized widths of the distributions have been compared with those of other known nearby systems in Fig2.

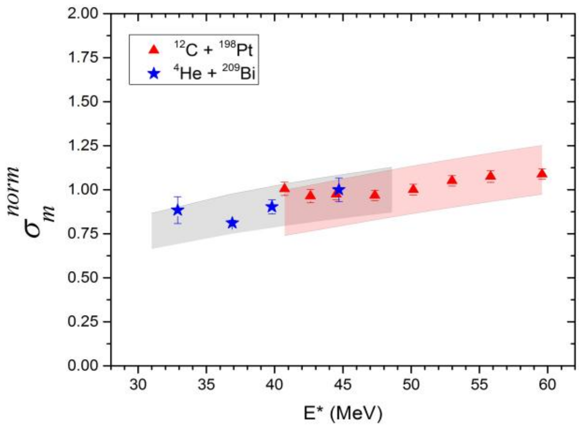

Fig 2: The width of the mass distributions of ^{213}At compared with ^{210}Po.

It is found that the widths of the mass distributions show no anomalous deviation and increases monotonically. The shaded region has been generated using the phenomenological equation $\sigma_m=\sqrt{(\alpha T+\beta\langle l^2\rangle)}$, with the width of the region accounting for the uncertainties in the values of α and β. The experimental widths are well within these limits.

From the present study it can only be inferred that the shell effect in ^{213}At is not prominent above E* ~ 32 MeV. Measurement at lower excitation energy ~ 25 MeV is needed to verify if shell effect persists at that energy as predicted by theory.

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