Fission dynamics of ^{214}At

D. Paul[1,2,*] T. K. Ghosh[1,2], A. Sen[1,2], Md. Moin Shaikh[1], K. Atreya[1,2], S. Kundu[1,2], C. Bhattacharya[1,2], D. C .Biswas[3], B. N. Joshi[3], N. Kumar[3], G. K. Projapati[3], Y. K. Gupta[1,3], K. Mahata [1,3], and K. Ramachandran[3]
[1] *Variable Energy Cyclotron Centre, 1/AF,Bidhan Nagar, Kolkata 700064, India*
[2] *Homi Bhabha National Institute, Training School Complex, Anushakti Nagar, Mumbai - 400094, India and*
[3] *Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai*

1. Introduction

The discovery of a new mode of asymmetric fission [1] in the proton rich nuclei ^{180}Hg has opened up multiple questions in the understanding of the dynamics of the fusion fission phenomena. It was experimentally observed that the mass distribution of ^{180}Hg was asymmetric at low excitation energy and maximum yield was observed near the mass number 70 and 110 . If the masses of the fission fragments are decided by the shell effects, mass distribution would have been symmetric about the mass number 90 (with N=50, Z=40). Therefore this observation could not be explained by either liquid drop model or shell model. Several theoretical models [2–4] have been developed for the explanation of the dynamics of fusion fission in the pre actinide region. These models probe the potential energy surface and predict the mass distributions that require immediate validation.

The macroscopic-microscopic model developed by Peter Moller *et al.* [2] using the Brownian shape motion along the potential energy surface, had successfully explained the asymmetric mass distribution of ^{180}Hg . However, if this model is indeed global, it should be capable of explaining mass distribution data for wide range of nuclei. This had predicted that the mass distribution of pre-actinide ^{213}At is asymmetric at excitation energy lower than 30 MeV. However no sign of asymmetric fission fragment mass distribution was observed in the fission of ^{213}At populated in the fusion of the strongly bound projectile ^{4}He with the target ^{209}Bi at the excitation energy 33 MeV. However the measurement of Sen *et al* [5] could not reach the excitation energy where asymmetry is predicted. In the present work, we report the fragment mass distribution in the fission of compound nucleus ^{214}At down to excitation energy 31 MeV to search for the asymmetric fission pathway as predicted. The nucleus ^{214}At was populated using weakly bound projectile ^{9}Be on ^{205}Tl target.

2. Experiment and analysis

The experiment was carried out at BARC-TIFR, PLF Mumbai. ^{205}Tl target of thickness $300\mu g/cm^2$ on ^{nat}C backing of thickness $20\mu g/cm^2$ was used.Two Multiwire Proportional Counters (MWPC) [6] of dimension 17.5 cm × 7 cm were used to detect the fission fragments by the time of flight technique. Forward and backward detectors were placed at an angle 54° and 120° respectively with respect to the beam axis and at a distance of 25.8 cm and 15.7 cm from the target. ^{205}Tl target was bombarded by ^{9}Be beam of 42, 43.5, 45 and 47 MeV energy.

3. Results and discussions

The fission fragment folding angle and mass distributions in the reaction ^{9}Be + ^{205}Tl have been measured at energies E_{lab} = 42, 43.5, 45 and 47 MeV. From the measured folding angle distribution, as shown in Fig 1, it is clearly seen that the admixture of fission followed by transfer reactions are minimal. Although ^{9}Be is a loosely bound nucleus (break up threshold for ^{4}He + ^{5}He is 1.66 MeV and for ^{8}Be + ^{1}n is 2.33 MeV), it is to be noted that the energy

*Electronic address: d.paul@vecc.gov.in

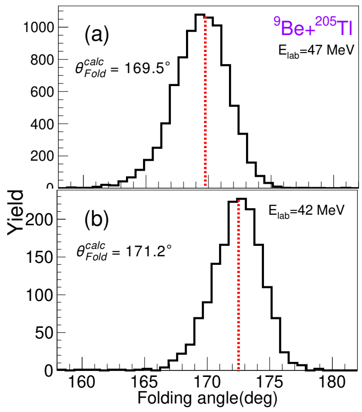

FIG. 1: Representative folding angle distributions for the system ^{9}Be + ^{205}Tl at energies E_{lab}= 47 and 42 MeV.

sharing of the break up fragments is typically half of the beam energy and if it fuses with the target, the compound nucleus will have lower fissility and much lower excitation energy for fission.

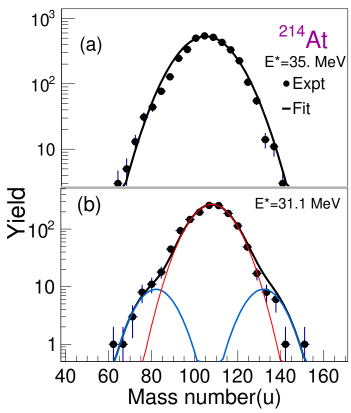

FIG. 2: Representative mass distributions of ^{214}At at excitation energies 35.9 and 31.1 MeV.

The measured fission fragment mass distributions are found to be symmetric at excitation energies E^{*} = 32.6, 34 and 35.9 MeV. However, at the lowest excitation energy, E^{*}= 31.1 MeV, the mass distribution is found to be asymmetric as predicted by the theory [2] for a simialr nucleus ^{213}At . In Fig 2, we show the representative mass distributions at E^{*} = 35.9 MeV and lowest excitation energy E^{*}= 31.1 MeV. Widths of the experimentally measured mass distributions have been compared with the theoretical value calculated from the recently developed code GEF. This is shown in Fig 3.

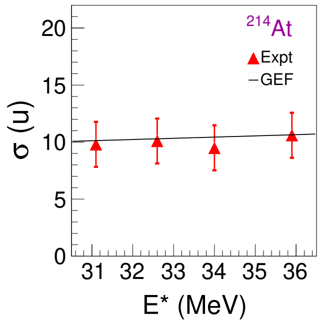

FIG. 3: Variation of variance of the mass distribution with the excitation energy of the compound nucleus. Black solid line denotes the theoretical calculation from GEF for the nucleus ^{214}At.

We conclude that slightly asymmetric mass distribution was observed at 31 MeV of excitation energy in the fission of ^{214}At, consistent with a recent macroscopic-microscopic calculation.

Acknowledgments

The authors thank BARC-TIFR, PLF staffs for providing high quality beam and J. K. Meena(VECC) for his help throughout the experiment.

References

[1] A. N. Andreyev *et al.*, Phys. Rev. Lett. **105**, 252502 (2010).
[2] P. Moller *et al.*, Phys. Rev. C **85**, 024306 (2012).
[3] A. V. Andreev *et al.*, Phys. Rev. C **86**, 044315 (2012).
[4] J. D. McDonnell*et al.*, Phys. Rev. C **90**, no. 2, 021302 (2014)
[5] A. Sen *et al.*, Phys. Rev. C **96**, no. 6, 064609 (2017).
[6] D. C. Biswas *et al.*, Nucl. Instrum. Methods Phys. Res. A **901**, 76 (2018).