Role of entrance channel magicity in fusion fission dynamics

A. Sen[1,2*], T.K.Ghosh[1,2], C Bhattacharya[1], S. Bhattacharya,[1,#] , T.K. Rana[1]
D.C. Biswas [3], K. Mahata [3], K. Ramachandran[3], A. Shrivastava [3] , S. Gupta[2,3] , J. K. Meena[1] , G. Mukherjee[1,2], S. Kundu[1], S. Manna[1,2], R. Pandey[1,2], Pratap Roy[1,2]
[1]*Variable Energy Cyclotron Centre, 1/AF, Bidhan nagar, Kolkata-700064, INDIA.*
[2]*HBNI, Training School Complex, Anushaktinagar, Mumbai-400094, INDIA.*
[3]*Nuclear Physics Division, BARC, Mumbai 400085, INDIA.*
** email: a.sen@vecc.gov.in*
[#]Raja Ramanna Fellow.

Introduction

One of the major aspects of contemporary nuclear physics research is synthesizing heavy and super heavy elements (SHE) through fusion of a target and a projectile. The best entrance channel configuration (target/projectile mass, charge, deformation, nuclear structure effect etc.) requires to be identified for the maximum production of SHE in the laboratory.

Systematic analysis for the formation cross section of the heavy element Th by different target projectile combinations was studied by Hinde, *et al*. [5] from the evaporation residue cross section data which revealed that fusion probabilities are somewhat enhanced with two magic numbers in the entrance channel. In an another study of fission fragment mass distributions in ^{40,44,48}Ca induced reactions on ^{204,208}Pb targets, it was reported that the width of the fission fragment mass distributions (sigma_MR) was higher in reactions with less entrance channel magicity. For example, measured sigma_MR in ^{48}Ca+^{208}Pb reaction (entrance channel magicity= 4 as the neutron and proton numbers for both the target and projectles are magic) was found to be 25 % lower compared to ^{44}Ca+^{204}Pb reaction (entrance channel magicity =2). From the time dependent Hartree–Fock calculations, the increased mass width was interpreted as due to the presence of quasi fission [1]. However, it was difficult to disentangle whether quasi-fission or entrance channel magicity is the cause for the observed increase in the mass width, as the Ca induced reactions have ZpZt value that may drive the system to the quasi-fission path. Measurement of fission fragment mass distributions forming the same compound nucleus Th with different entrance channel magicity will be helpful to throw light on this as the system has less ZpZt and quasi fission is not expected.

In our present study, we intend to delve deeper into the aspect of the influence of magicity on the dynamics of fusion fission through a series of experiments with lighter ion beams with $Z_PZ_T < 800$, populating the same compound nucleus of ^{224}Th and studying its fission fragment mass distribution, which has already been established as a sensitive probe for fusion fission dynamics. In the present communication, we report our findings from our experiment ^{16}O + ^{208}Pb → ^{224}Th, where both target and the projectile are doubly shell closed.

Experiment

^{16}O beam of energy 77-88 MeV was extracted from the pelletron accelerator at TIFR and bombarded on a target of isotopic enriched ^{208}Pb of thickness 500 µgm/cm^2. Indigenously developed MWPC detectors, one of active area 20 X 6 cm^2 and the other of active area 15 X 4 cm^2, were used for the detection of fission fragments. The detectors were placed at angles of 50^0 and 110^0, with angular coverage of 37^0 and 43^0 respectively. The detector angles were so chosen corresponding to Viola's systematics [2] of folding angle corresponding to symmetric fission following complete transfer of momentum from the projectile to the target. The detectors were operated with isobutane gas at a pressure of 3.0 torr, such that the detector is transparent to elastically scattered projectile like particles. The time of arrival of the fission fragments, the position of impact of the fission fragment and the energy loss of the fission fragment was recorded in a VME based DAQ using LAMPS.

Results and discussions

The time of flight difference method [3] was used to calculate the mass of the fission fragments using the difference between the time of arrival of the fission fragments, the azimuthal and the polar angles of the point of impact of the fragment on the detector. The folding angle distribution was constructed and a gate of $\pm 4^0$ around the peak of the distribution following complete momentum transfer was used. This ensured the any events arising from transfer induced reactions would not contaminate the data.

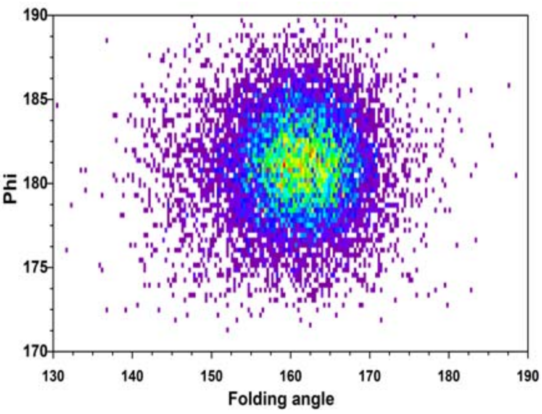

Fig 1: A typical folding angle-phi distribution at 88 MeV for the reaction.

Fig 1 shows the folding angle distribution for the reaction. The mass distribution at various excitation energies are shown in fig 2. The distributions are all symmetric in nature and perfectly fit a single Gaussian distribution, which is shown by a red line in the figures. The width of the mass distribution increase systematically with increase in excitation energy. As the mass distributions are purely symmetric even for the lower excitation energy ~ 28 MeV, the role of any shell effects in the exit channel dynamics may be discounted [4]. Further study of this nucleus by populating the same nucleus through the reaction channel ^{19}F + ^{205}Tl (none of the projectile target combination is shell closed) and ^{18}O + ^{206}Pb (proton numbers of both projectile and target are shell closed) at similar excitation energies and comparing their mass distributions will throw more light into the dynamics of fusion fission at play.

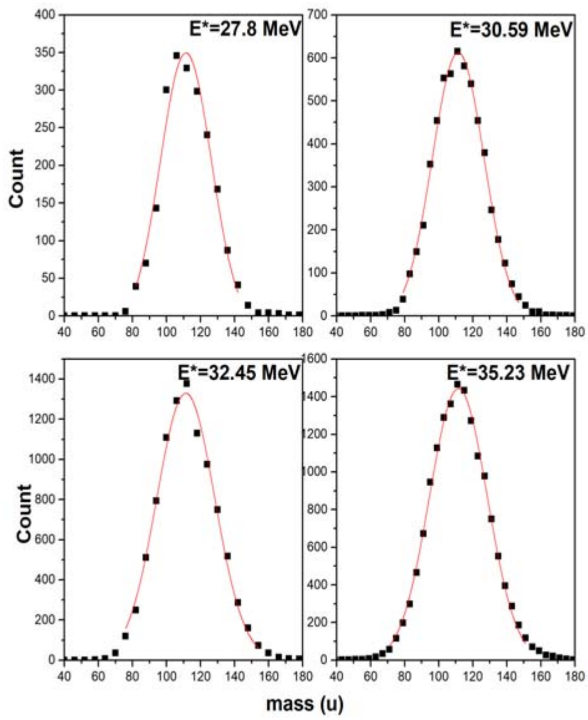

Fig 2: Fission fragment mass distribution of ^{224}Th at various excitation energies.

References

[1] C. Siemenel, *et al.*,Phys. Lett. B 710, 607, (2012).
[2] V.E. Viola, *et al.*, Phys. Rev. C 31, 1550 (1985).
[3] T.K. Ghosh, *et al.*, Nucl. Instrum. Phys. Res. A 540, 285 (2005).
[4] A. Sen, *et al.*, Phys. Rev. C 96, 064609 (2017)
[5] D.J. Hinde , *et al.* , Phys. Lett. B 622, 23 (2005).