Near scission emission peak energies of α particles in heavy-ion fission reactions

Y. K. Gupta[1,2],* G. K. Prajapati[1], B. V. John[1,2], B. N. Joshi[2], N. Kumar[1], L. S. Danu[1], S. Mukhopadhyay[1], S. Dubey[3], K. Mahata[1,2], K. Ramachandran[1], A. Jhingan[4], M. Kumar[4], N. Deshmukh[5], A. S. Pradeep[6], and B. K. Nayak[1,2]
[1] *Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai - 400085, INDIA*
[2] *Homi Bhabha National Institute, Mumbai-400094, INDIA*
[3] *Tata Institute of Fundamental Research, Mumbai -400005, INDIA*
[4] *Inter-University Accelerator Centre, Aruna Asaf Ali Marg, New Delhi, 110067, INDIA*
[5] *Saha Institute of Nuclear Physics, Kolkata, W.B. - 700064, INDIA and*
[6] *IIIT-AP, RGUKT, RK Valley, Kadapa, Andhra Pradesh 516329 . INDIA*

Introduction

Particle emission is a quite useful probe to gain insights about the complex fission dynamics [1]. During the heavy-ion fission, neutron and charged-particle (mainly proton and α-particle) emission takes place from various stages namely from the fissioning compound nucleus (pre-scission) and from the accelerated fission fragments (post-scission) [1, 2]. Pre-scission neutron and charged particle emission spectra and multiplicities provide important information on the statistical and dynamical aspects of heavy-ion induced fusion-fission reactions [3]. In case of α-particle emission, it is also observed that a part of pre-scission α-particles is emitted very near the neck region in the fission process just before scission, akin to the ternary fission events in low energy fission [3]. This part of pre-scission α-particles emitted near the neck region is termed as near scission emission (NSE).

Recently, a systematic study has been carried out for pre- and near-scission α-particle multiplicities ($\alpha_{\rm pre}$ and $\alpha_{\rm nse}$) as a function of Z^2/A and the excitation energy of the compound nuclei (E_{CN}) for various target-projectile combinations [3]. It is shown that $\alpha_{\rm pre}$ values when normalized to $E_{CN}^{2.3\pm0.1}$ show a systematic linearly increasing trend with the α-particle emission Q-value (Q_α). Also, it has been established that the fraction of $\alpha_{\rm nse}$ remains nearly the same at around 10% of the total pre-scission multiplicity for a variety of heavy-ion reaction partners, populating compound nuclei of different excitation energies. These features of $\alpha_{\rm nse}$ in heavy-ion fission indicate that α-particles emitted from the neck region near the scission point are due to the statistical emission process. This is in contrary to the low energy fission where it is a pure dynamical process. It seems that as the available excitation energy increases, statistical emission dominates over dynamical emission near the scission point as well. It has been inferred that the nuclear collective motion exhibits a change over from superfluid to viscous nature as the excitation energy is increased [3].

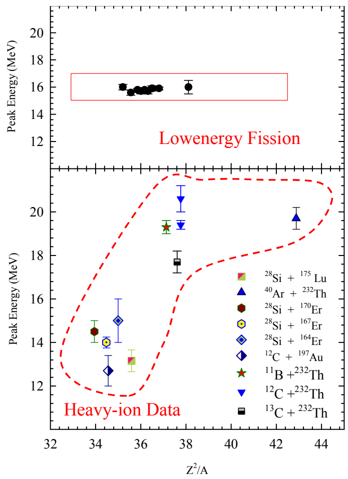

FIG. 1: The peak energies of NSE α-particles as a function of Z^2/A from low energy fission (top panel) and heavy-ion fission (bottom panel) taken from Refs. [3–5]

One of the very important observables of the near scission emission, is the peak energy (ϵ_p) of the Gaussian energy distribution of the α particles. In the low-energy fission (spontaneous, photo-, neutron-induced fission) it is almost constant around 15.5 MeV irrespective of Z^2/A of the fissioning nuclei [6] as shown in Fig. 1 (top panel). Though, the near-scission multiplicity in heavy-ion fission has

*Electronic address: ykgupta@barc.gov.in

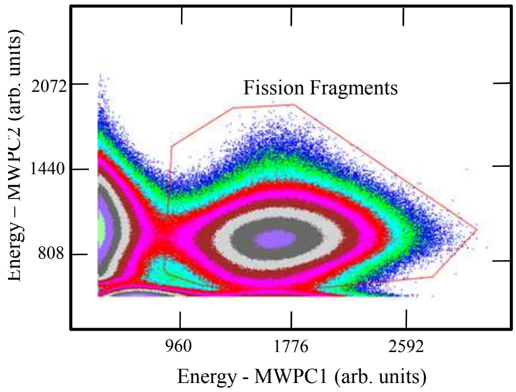

FIG. 2: Fission fragment energy correlations between the two MWPCs.

been understood systematically, but, its peak energy is very much scattered and not understood clearly as revealed in the Fig. 1 (bottom panel). It seems from available data that NSE peak energy depends on both, the fissility and the excitation energy of the fissioning nucleus. A clear understanding of the NSE peak energy would provide a crucial insight on the scission configuration and nuclear viscosity. In this context it is utmost important to measure the NSE peak energy in the two dimensional space of fissility and the excitation energy. In this paper we present our measurements of α-particle multiplicity spectra in ^{16}O + ^{232}Th reaction at various relative angles with respect to beam and the fission fragment direction.

Experimental Details and Results

96-MeV ^{16}O beam was obtained from 14-MV BARC-TIFR Pelletron facility, Mumbai. A self-supporting metallic foil of ^{232}Th ($\sim$1.6 mg/cm^2) was used as the target. The FFs from reaction were detected using two large area Multi-Wire Proportional Counters (MWPCs), placed in folding angle configuration. The MWPCs were placed at 60° and 100° with angular openings of $\pm$15° and $\pm$25°, respectively. Both the MWPCs were operated at 2.0 mbar gas pressure (iso-butane). Fission events were clearly separated from other reaction products by plotting cathode pulse height from one MWPC against the other as shown in the Fig. 2. Angle calibration for both the MWPCs was achieved by detecting the fission events from ^{252}Cf source. The α particles emitted in the reaction were detected by twelve collimated CsI(Tl)-Si(PIN) detectors, covering a wide range of relative angles. Zero Crossover Time (ZCT) as well as Ballistic Deficit (BD) were used for the particle identification in CsI(Tl) detectors. Triple coincidence between the two MWPCs and ORed timing of all the CsI(Tl) detectors were recorded using a TAC. All the CsI(Tl) detectors were energy calibrated periodically at every 24 hours during the experiment using ^{229}Th source. Detailed data analysis and results will be presented.

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