Pulse height and timing characteristics of CsI(Tl)-Si(PIN) detector for fission fragments

Y. K. Gupta, D. C. Biswas, Pratap Roy, B. K. Nayak,
A. L. Inkar, R. P. Vind, B. John, and R. K. Choudhury
Nuclear Physics Division, Bhabha Atomic Research Centre, Trombay, Mumbai, 400085, India

Introduction

Light output response of the CsI(Tl) detector for the charged particles up to Z=36 has been studied earlier in detail in the intermediate energy region[1]. However, investigation of the light output response of CsI(Tl) detectors for fission fragments (FFs) is quite limited. The dE/dX behavior of FFs is quite different in comparison to charged particles ($2 \leq Z \leq 36$) because of the dependence of effective charge (Z_{eff}) of the FF on the fragment energy [2]. In order to explore the possibility of using CsI(Tl)-Si(PIN) detector for FFs measurement, in the present work we have investigated the light output response of the detector for fission fragments produced from a ^{252}Cf source. The energy dependence of the light output for FFs was studied by degrading the energies of the FFs in P-10 gas (90% Ar + 10% CH_4 mixture) at different pressures.

Details of detector setup

The CsI(Tl) crystal has entrance surface area of 25×25 mm^2 and thickness of 10.0 mm. Except the back surface, all other faces were covered with 1.2 μm thick reflecting foil of aluminized Mylar. A Si-PIN photodiode manufactured by Hamamatsu Photonics is coupled to the back surface via a $25 \times 25 \times 15$ mm^3 light guide. The photodiode type S3204-08 is 300 μm thick. The pulse height spectrum from a ^{252}Cf source has a strong peak due to α-particles of energy 6.11 MeV, that overlaps with FF pulse heights particularly when FF energy is degraded using absorbers. The separation of α-particles from FFs was achieved by employing time-of-flight (TOF) technique, where start signal was taken from a BaF_2 detector triggered by prompt γ-rays, and the stop signal was from CsI(Tl)-Si(PIN) detector. The CsI(Tl)-Si(PIN) detector and ^{252}Cf source were mounted in a vacuum chamber, whereas the BaF_2 detector was mounted outside but close to the chamber. Distances of the CsI(Tl)-Si(PIN) and BaF_2 detectors from ^{252}Cf source were 28.0 cm and 2.0 cm respectively. The P-10 gas was used as FF energy degrader in this experiment. The energies were degraded to 0.2 - 0.5 MeV/A for heavy FFs and 0.4 - 0.9 MeV/A for light FFs using P-10 gas at different pressure in the range of 5 to 50 mbar in steps of 5 mbar.

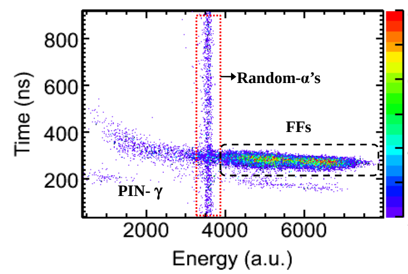

FIG. 1: Two dimensional plot of time versus energy of the γ-rays,α-particles and FFs from ^{252}Cf.

The FF and α-particles (6.11 MeV) were separated using TOF except for a small overlap region as shown in Fig.1. Other than α-particle and FF band in Fig.1, we also observe a 'PIN-γ' band corresponding to the γ-rays reaching directly to the photo diode. Because the start signal to the TAC is generated from γ-rays, α-particles are emitted randomly in the full range of the TAC. If we collect in singles, the ratio of α-particles to FFs is observed to be $\simeq$20, but because of TOF measurement, this ratio reduces to $\sim$0.2. The reduction in α-intensity helps in determining the mean energy of the most probable FF after passing through P-10 gas. The small overlap

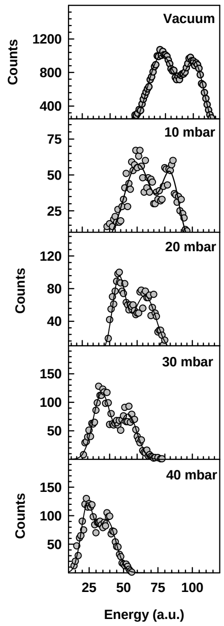

FIG. 2: Pulse height spectra of FFs(from ^{252}Cf) for different gas pressures.

of α-particles with FFs was subtracted appropriately at each gas pressure. The pulse height spectra of FFs after subtracting α-contribution are shown in Fig.2 for different gas pressures. The change in spectral shape with similar gas pressure is consistent with the earlier reported work [2], where energies of the FFs were measured using a gas ionization chamber. The light yield varies almost linearly as a function of energy, as shown in Fig.3. The light yield for heavy FF is more than light FF at a given energy. This difference in light yield is because heavier FFs have less dE/dX than lighter ones for the same fragment energy [2]. The light output response of the FFs in terms of dE/dX is consistent with the behavior previously observed for charged particles (2≤Z≤36) [1]. It may be noted that a constant differential scintillation efficiency (dL/dE) as a function of fragment energy is observed for FFs whereas in case of charged particles, the dL/dE increases with energy in a wide range of energy from 2.5 to 25.5 MeV/nucleon [1]. This is because the FFs studied in the present

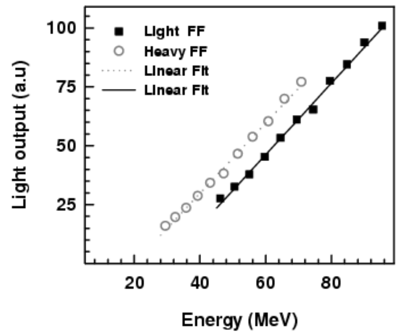

FIG. 3: Light output of the FFs as a function of energy deposited in CsI(Tl) crystal

work using ^{252}Cf source have a limited energy range of 0.5 to 1.3 MeV/nucleon.

Conclusion:

Pulse height response of CsI(Tl)-Si(PIN) detector has been investigated for fission fragments (FFs) produced in spontaneous fission of ^{252}Cf. The energy of light and heavy fragments was degraded using P-10 gas and scintillation pulse height (light yield) was determined as a function of energy deposited in the CsI(Tl) crystal. The scintillation light yield increases almost linearly as a function of energy for both the light and heavy FFs. At a given energy the light yield is observed to be more for heavy fission fragments in comparison to the light fragments. This difference in light yield is because the heavier FFs have lesser dE/dX than the lighter ones for the same fragment energy. This indicates that the scintillation light yield for fission fragments follow similar dependence on dE/dX as of charged particles (2≤Z≤36).

References

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