Performance of CsI(Tl) detector array for digital INGA

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Introduction

The high spin states of neutron deficient and stable isotopes remain a topic of significant interest in nuclear structure research. Heavy-ion fusion evaporation reactions are used to populate the high-spin states of these nuclei. Different exotic nuclei with quite low cross-sections can be populated in the charged particle emission channel. Large array of Compton suppressed High-Purity Germanium (HPGe) clover detectors coupled to a 4π-charged particle detector array will be an efficient tool to study isotopes produced with low cross-sections through charged particle emission channels [1]. In addition, large segmentation of the 4π-charged particle detector array will improve the resolution of the gamma rays from the thin target experiments through better estimate of the momentum of the recoils [2]. The thallium-activated cesium iodide (CsI(Tl)) crystal coupled with a light guide and photodiode is one of the compact size detector system being used in various 4π charged particle detector arrays (CPDA) [2, 3]. This detector is capable of discriminating various particles based on the rise-time of pre-amplifier pulse shapes. A 4π charged particle array containing around eighty CsI(Tl) detectors is being planned to be coupled with the Indian National Gamma Array (INGA).

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The particle identification (PID) is one of the most important parameters in these kind of experiments. The rise time of this processed signal will be different for different particles and hence can be used for particle identification. Digital pulse shape analysis of CsI(Tl) detectors has been used to discriminate between the signals obtained from γ, α, p and other charged particle channels. This will help in the optimization of the DSP algorithm for the CPDA. In the present report, we will describe the performance of a CsI(Tl) array as an ancillary detector for gamma spectroscopic study.

Experimental Details and Results

The present in-beam experiment was performed at the BARC-TIFR 14UD pelletron accelerator facility at Mumbai, using heavy ion fusion-evaporation reaction with ^{82}Se target and ^{13}C beam at E_{lab}=60 MeV and an array of 11 Compton-suppressed CLOVER HPGe detectors arranged in spherical geometry. Apart from CS-CLOVER HPGe, an array of 24 CsI(Tl) detectors arranged in rhombicuboctahedron geometry and 4 $LaBr_3$(Ce) detectors have been coupled to the present digital INGA setup and used in this experiment. Three HPGe detectors were arranged in 90°, three in 140° i.e(-40°), three in 157° and two at 115°, with respect to the beam direction. Four CsI(Tl) detectors were in 142°(i.e-38°), four in 127°, four in 97°, four in 7°, four in 53° and four in 38°. To reduce the Compton continuum each clover is shielded by BGO detector. The target used was a 1 mg/cm^2 enriched ^{82}Se, on 4.26 mg/cm^2 gold backing. The projectile energy of 60 MeV was chosen on the basis of a statistical model calculation [7] using PACE4 code. The pre-amplifier signal of all detectors directly fed into the channels of the 100 MHz Pixie-16 system [5]. The reaction produces different nuclei in different channels such as in neutron channel ^{90}Zr and ^{91}Zr, in proton/neutron channel ^{90}Y and in α/neutron channel ^{88}Sr and ^{87}Sr. The elastically scattered ^{13}C beam was stopped using suitably calculated Ta foils. The pulse shapes were analyzed in the digitizer with trace length of 16 μsec. ROOT version of the MARCOS program has been used to sort the coincidence data of the clovers and CsI(Tl) detectors. The baseline of the pre-amplifier signal is first brought to zero level. Area under the pulse for a short as well as long gates were calculated to generate the PID. A typical PID plot has been shown in Fig. 1 depicting the protons and alphas. Fig. 2 shows the proton and alpha gated spectra (in the insets) along with the total projection. Enhancements of 1464 and 1564 keV transitions of ^{88}Sr and ^{87}Sr have been observed in the alpha gated spectrum compared to the total projection. Similarly, proton gated spectrum shows the enhancement of the transitions of ^{90}Y.

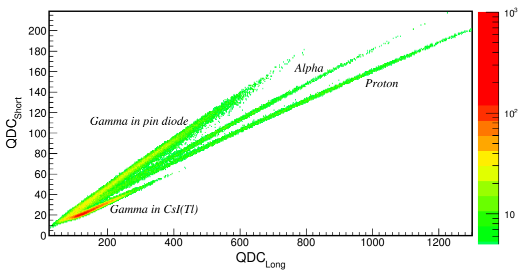

FIG. 1: PID curve showing α, proton and gamma observed in the experiment.

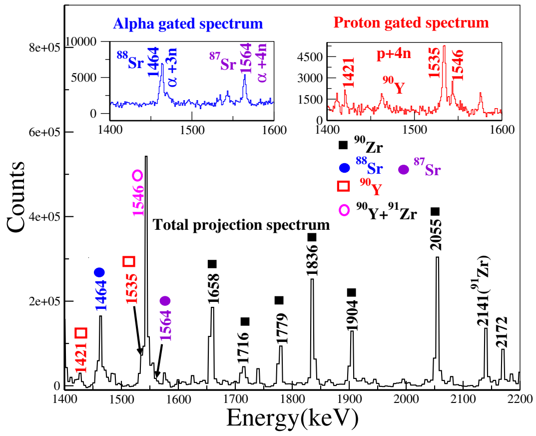

FIG. 2: Total projection, α and proton gated spectrum deduced from the present experiment.

Summary and Conclusion

The digital signal processing technique has been successfully utilized for the proton-alpha-gamma discrimination in CsI(Tl) detectors. The performance of the CsI(Tl) array coupled to INGA during the in-beam experiment has been reported. The implementation of low power pre-amplifiers [6] is in progress which is essential to complete the 4π-coverage of the CPDA.

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