Characteristics of CsI(Tl) crystal coupled with PIN photodiode for γ-rays and charged particles

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Introduction

In recent years, there have been considerable interest in using CsI(Tl) scintillators coupled to PIN photodiode for light charged particle-detectors in nuclear experiments because of their large stopping power and identifying capability [1]. Moreover, these detectors are cheaper, rugged, and easy to operate with low power dissipation. The shapes of the electronic signal generated from these detectors depend on the ionizing power as well as the interaction process of the radiation falling on the detector [2]. In this paper we report particle identification capability for light charged particles and luminance response for γ-rays and light charged particles, of CsI(Tl)-PIN detector. These detectors have been procured for their use in the charged particle detector array, Pelletron/Linac-facility, Mumbai.

Detector setup details:

The CsI(Tl)–PIN detectors has been supplied by, M/S SCIONIX, Holland. CsI(Tl) crystal had entrance surface area of 25×25mm^2 and of thickness 10.0 mm. Except the back surface, all other faces were covered with 1.5 μm reflecting foil of aluminized Mylar. A Si-PIN photodiode manufactured by Hamamatsu Photonics was coupled to the back surface via a 25×25×15 mm^3 light guide. The photodiode, type S3204-08, was 300 μm thick with an active area of 18×18 mm^2. A rectangular collimator of opening area 22×22 mm^2 was kept at the front surface of the crystal to avoid the edge effects. The signal readout was achieved by a charge sensitive pre-amplifier, attached to the photodiode. The low power dissipation ~120 mW of the preamplifier allows it to operate in vacuum without cooling. Signals from preamplifier had a dc off-set of 2-3V, which was eliminated by using a capacitor of 6μF. The required +12V to the preamplifier was supplied using a battery which improves the signal to noise ratio in comparison to NIM module. Gain of the preamplifier was 6mV/MeV for alpha particles with output impedance of 50Ω. Preamplifier signals were amplified and shaped using a spectroscopy amplifier (CEAN N968). The leakage current at bias voltage +35V was about 5nA.

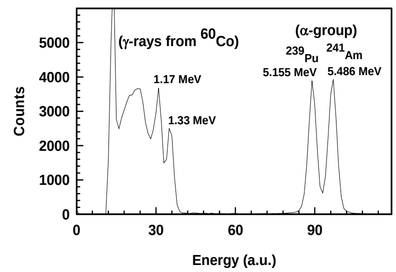
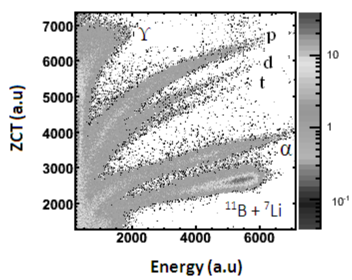


Fig.1 Energy spectrum of α-particles (^{241}Am-^{239}Pu) and ϒ-rays (^{60}Co).

The detector has been tested with α-particles from ^{241}Am-^{239}Pu sources as well as ϒ-rays from ^{60}Co. The energy spectrum for these sources is shown in Fig 1. The enery resolution (FWHM) for ~5 MeV α-particles is ~180 keV, and ~190 keV for ~1 MeV ϒ-rays at shaping time 3.0μs and bias voltage to the photodiode +35V.

Particle identification: To test performance characteristics, the CsI(Tl) detector has been used in an in-beam experiment in ^{11}B+^{232}Th reaction at 62 MeV. The pulse shape discrimination (PSD) technique has been employed to separate various charged particles and Υ-rays produced in this reaction. The rise time for different particles was extracted from the zero cross over time (ZCT) of the bipolar pulses produced from the spectroscopic amplifier. It was observed that the particle discrimination is better for shaping time 2 μs. Fig.2 shows a two dimensional spectrum of ZCT vs energy of various particles. It is clearly seen that the LCPs (p,d,t, and α), Υ-rays are well separated from projectile-like particles (PLFs). The threshold energy for p-α discrimination was ~5 MeV.

Fig. 2 2D plot of ZCT versus energy of the particles.



Light output response:

The non-linearity of the light output of the scintillation crystal in the energy region from 5 MeV to 25 MeV has been investigated for protons and α-particles. The alpha particles in this energy range were used from ^{228,229}Th source and Pelletron accelerator. Discrete α-particle peaks corresponding to $^{20}Ne^{*}$ states were obtained from the reaction ^{12}C (^{12}C, α) ^{20}Ne* at ^{12}C-beam energies of 25 and 40 MeV. The protons in this energy range were obtained from elastic scattering of 20MeV-protons with ^{12}C,^{197}Au, and ^{232}Th targets. Apart from this recoil protons from bombardment of ^{12}C beam on Mylar film were detected at three different beam energies. Light yield as a function of energy is shown in Fig. 3 for protons as well as α-particles. In Fig.3 three band are for three CsI(Tl) detectors having different gain settings. The light yield for both the particles is fitted with the simple expression, $L(Z,E)=aZ^{b}E^{c}+d$, where constant *a* and *d* are related to electronics setting, while *b* and *c* depend on particle type and their response within the crystal, respectively. The value of *c* obtained for alpha particle is 1.3 and for proton it is 1.0, irrespective of value of *b*, which is consistent

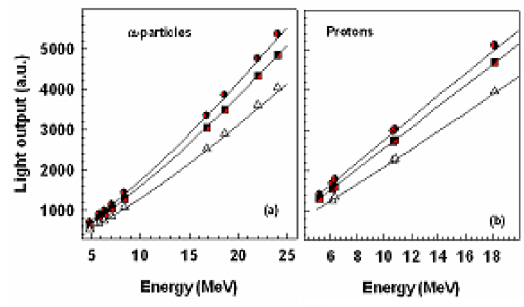


Fig. 3. Light output as a function of particle energy for protons and alpha particles.

with the earlier reported values [1]. In Fig.3 solid lines show the fit to the light output. It is observed that there is a non-linearity in the light yield for α-particles in the energy range of 5-25 MeV, whereas for protons it is linear in the same energy range.

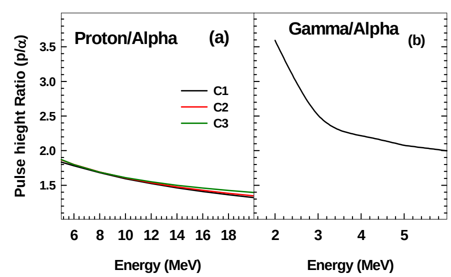


Fig. 4. Pulse height ratio for p to α and Υ to α, as a function of energy.

The ratio of light out puts for proton to alpha was plotted as a function of their energy, as shown in Fig. 4(a). The light output for Υ-rays from ^{60}Co and α-particles from ^{241}Am-^{239}Pu source was also studied. In Fig. 4(b) ratio of light outputs for Υ-rays to α-particles has been plotted as a function of their energies. It is observed that the light output ratio for p to α as well as Υ to α decreases as a function of particle energy.

References

[1] S. Aiello *et. al*. Nucl. Instrum. Meth. A **369**, 50(1996).

[2] C.J.W. Twenhofel *et. al*. Nucl. Instrum. Meth. B **51**, 58(1990).