Gas-CsI hybrid telescope for heavy ion detection

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Introduction

Hybrid telescope, having combination of gas (ΔE) and CsI – photo-diode (stopping), have been developed for heavy ion detection & particle identification in nuclear physics experiments with NAND/GPSC facility at IUAC. The detector telescope will be used for the detection of charged particles such protons, α-*particles* and other heavy fragments (*Li*, *C*, etc.) emitted during the heavy ion induced fission process. Ability of the detector system to identify lighter fragments can make them useful in ternary fission experiments. The detector system can also be used to identify projectile like fragments along with lighter charged particles in low energy experiments of astrophysical importance. As a standard practice either silicon telescopes with very thin (~10-40 μm) silicon detectors as ΔE and thick (100-300 μm) are used, or hybrid gas-silicon telescopes [1] have been used for such experiments. Silicon detectors are very prone to radiation damage. CsI–photo-diode detectors have been successfully used to study fission gated light charged particle multiplicity but these detector lack the ability to identify lighter fragments (*Li* onward) which is required to study ternary fission. Since probability of ternary fission is very small, detectors are required to be placed close to target (for increased solid angle and statistics) thus exposing them to high flux of elastics. Hybrid combination of gas and CsI – photo-diode detectors can be an ideal combination since they are not prone to radiation damage. We report the development of one such prototype detector.

Description of the detector

Fig.1 shows the schematic of the hybrid telescope. It consists of a gas ionization chamber, operating in axial field geometry mode, followed by a CsI – photo-diode. The ionization chamber (IC) is composed of three wire frames, a central anode sandwiched between two cathodes, of active diameter 25 *mm*. Inter-electrode separation is 10 *mm*. All wire frames are made from gold plated tungsten wires of 20 μm diameter stretched on a 1.6 *mm* thick printed circuit board. The wire pitch is 1 *mm*. The two cathodes are grounded whereas the anode operates in ionization region with a typical reduced field of about 0.5 – 1 $V\ cm^{-1}\ mbar^{-1}$. The IC is followed by a 20 x 20 mm^2 CsI crystal of thickness 3 *mm* coupled to a 10 x 10 mm^2 photo-diode [2].

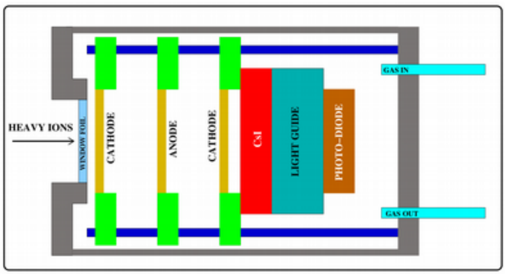

Fig.1: Schematic of hybrid detector

The electrodes are housed inside a cylindrical SS tube. The detector is operated with isobutane gas at pressures 50 – 100 *mbar*. Entrance window is made from 0.9 μm mylar. Fig.2 shows and assembled detector.

Fig.2: Assembled Gas-CsI detector

Signals of both IC and photo-diode are processed using in-house fabricated charge sensitive preamplifier with charge sensitivity of 90 *mV/MeV* (*Si equivalent*). For improved resolutions, the preamplifier were placed next to detector inside the vacuum chamber [1].

Performance

The detector was tested off-line with ^{232}Th a-particle and ^{252}Cf fission source. The detector was operated at 60 - 80 *mbar* gas pressure with a bias voltage of + 50 *V*.

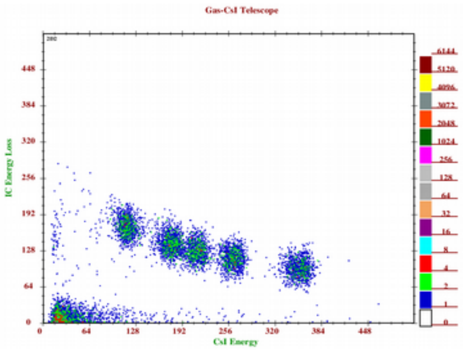

Fig.3: α-*particles* plot with ^{232}Th source. CsI energy is on the x-axis and IC energy on the y-axis.

A shaping time of 3 μs was applied on the spectroscopy amplifier for both IC and CsI detector. Fig. 3 shows the plot between energy loss in IC against energy deposited in CsI detector. Energy loss in CsI is about 3.5 % for 8.37 *MeV* α-particle. A detection efficiency of 100 % was observed for the IC with respect to CsI detector. In this case, gas pressure was 80 *mbar*.

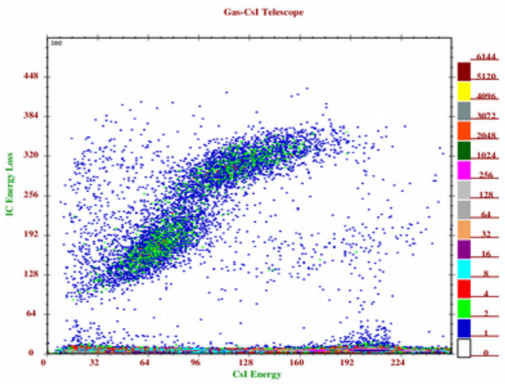

Fig.4: Fission fragment plot with ^{252}Cf source

Fig. 4 shows the plot between energy loss in IC against CsI detector for fission fragments emitted from ^{252}Cf source. In this case the detector was operated at 60 *mbar* gas pressure. Fission fragments are well separated from α-*particles*. Fig.5 is energy spectrum of CsI and IC displaying two resolved groups of fission fragments.

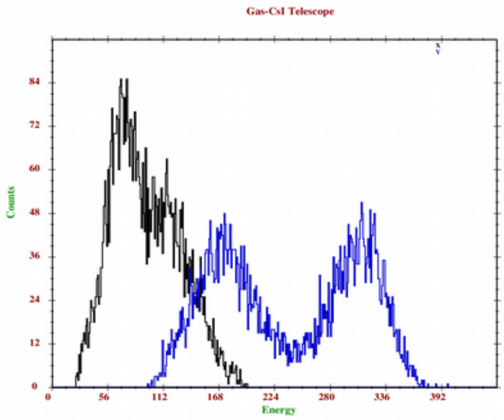

Fig.5: Energy spectrum with CsI (black) and IC (blue).

An important observation made is that for CsI detector, energy signals for a-particle and fission fragments tend to merge with each other, and for low energy fragments, signals are weaker than α-*particles*. This is due to the fact that, fission fragments, being much heavier, decays much faster and the light yield is much smaller as compared to α-*particles*. Pulse shape discrimination (PSD) techniques can provide separation but problems may be severe for low energy particles. In such cases differential energy loss measurements with gas IC is more useful and gives cleaner separation as shown in fig.4.

Future Perspective

In future we plan to have an array of such telescopes covering more angles simultaneously for angular distribution studies in nuclear astrophysics experiments with low energy high intensity beams from high current injector facility at IUAC. For ternary fission experiments, large area telescopes need to be fabricated by stacking more number of CsI detectors in 2 x 2 or 3 x 3 formation. PSD techniques will be incorporated for CsI detectors [2]. Custom made high density electronics is currently under development for the same.

References :

[1] A. Jhingan et al., Nucl. Inst. & Meth. Phys. Res. A 903 (2018) 326
[2] A. Jhingan et al., Nucl. Inst. & Meth. Phys. Res. A 786 (2015) 51.