Identification of Low Energy Charged Particle with LiF-Si Hybrid Detectors

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INTRODUCTION

The nuclear physics at lower energies are subject to the production of protons, alpha particles and other light charged particles of lower energy at the exit channel. The detection and discrimination of these charged particles are important for the extraction of important physics from the experiment. The methods like nTOF for (n, p) and (n, α) reactions with light targets[1], (d, p) surrogate methods for neutron capture cross sections, Trojen-Horse methods for nuclear astrophysics etc are subjected to produce the low energy charged particles in the exit channel[2]. Further, the Boron neutron capture therapy(BNCT), which have a renewed interest in medical physics, is subject to produce low energy alpha particle on neutron capture. Hence the detection and discrimination of the low energy charged particle is significantly important.

However, the identification of these low energy charged particles including alpha and proton is an existing challenge in nuclear instrumentation. This is due to their shorter range and higher straggling as compared to the detector resolution. Si E-ΔE detectors are mostly used for the particle identification, which is unsuccessful for low energies as the charged particles are being stopped in ΔE detectors. Even though the ΔE detector is thin enough, the energy loss and straggling of particles in the dead layer of the telescope is also making a significant level of degradation in the particle resolution. Further the fairly thin detectors are not making any significant level of electronic signal, compared to the detector resolution. A combined effect of these makes the suppression of particle discrimination for low energy charged particles in Si Telescopes.

The other new generation detectors like CsI is also limited in producing the particle discrimination due to the shorter range of particles in CsI. Hence this is not sufficient to produce a particle range-energy dependent pulse shape information. Further it demands fairly a better detector resolution. As a solution to this, a noval detector geometry has been employed, having a hybrid detector configuration of LiF and Si. A 1.3 μm thick LiF crystal is grown on the Si detector. The LiF crystal is acting as a scintillation detector, having a stopping power which is one fifth that of Si. The LiF layer act as a thin ΔE detector and the silicon as thick E detector. However the signal is extracted as a single parameter.The construction and performance of the LiF-Si hybrid detector is given in the following sections.

MATERIALS AND METHODS

The hybrid detector is designed as per the methodology of pulse shape discrimination. The LiF layer act as a ΔE detector, which having a lower stopping power and higher light conversion efficiency. The particle interacts with the LiF detector initially, and deposit a part of its energy, depending on the mass and charge of the particle. This energy deposition produces scintillations, with a mean decay time of 50 ns. The particles leaving the LiF layer enters to Si, and deposits the rest of its energy. Due to the pulse rising time of 12 ns, the silicon detector signals emerges at first.Hence the E response in Si ends as the decay light of LiF falls on Si, producing an extra pulse.The ratio of rising and trailing pulses

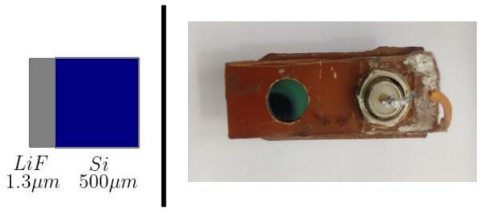

Figure 1: *Detector geometry*

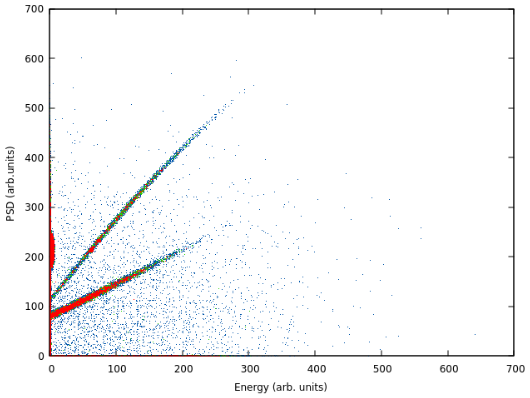

Figure 2: *ADC - PSD correlation showing proton and α bands.*

represents energy deposition in Si and LiF layers respectively.

The detector is fabricated by producing a crystalline LiF layer on the planar Si detector. A 1×1 cm^2 silicon surface barrier detector is used as the base of hybrid detector.A 1.3 μm LiF has been deposited on the top of silicon by thermal evaporation technique. Thermal evaporation is performed at a lower evaporation rate for getting LiF in crystalline form and for protecting Si from thermal damaging. In order to achieve the ohmic contacts, the set up is mounted on a PCB.

The fabricated hybrid LiF-Si detector is biased through Ortec IH-142 preamplifier to a voltage of 60V,to maintain a voltage of 6V across the detector. The energy output of the IH-142 is connected to CAEN DT-5743 digitizer. The pulse shape discrimination parameter is defined as the charge integrator ratio for short gate - long gate time base. The length of short and long gates are selected with the visual inspection of the signal.

A 20 μm thick mylar target is mounted in front of the detector and the set up is exposed to AmBe neutrons for generating protons. Similarly, a 20 µg/cm^2 Al target which is coated with a thin layer of boric acid is mounted across the detector and fired with neutrons. The alpha particle $^{27}Al(n,\alpha)$ produces a broader spectrum of alphas. The $^{10}B(n,\alpha)$ produces two discrete parts of energies 1.47 MeV and 1.94 MeV. A 2D histogram of total charge vs PSD has been made and banana gated for alpha colony and the banana gated colony is projected to energy axis for the calibrations.

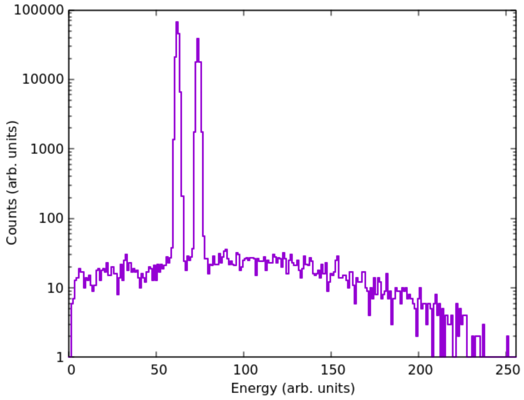

Figure 3: *The projection of α band on energy axis, showing $^{10}B(n,\alpha)$ peaks at 1.47 and 1.94 MeV*

RESULTS AND DISCUSSION

The ADC-PSD spectrum measured using LiF-Si hybrid detector configuration is illustrated in figure 2. The projection of the α band is shown in figure 3. The figure 2 shows a clear discrimination between α and protons, at lower energies. In the projected alpha spectrum, the alpha colonies from $^{10}B(n,\alpha)$ reactions corresponding to ground and excited states are well resolved. The set up provides 71 KeV energy resolution in FWHM units corresponding to 1.94 MeV alpha. The particle discrimination starts from 270 KeV for alpha and protons. As the detector meets the requirements of particle discrimination at lower energies, and achieves the energy resolution,it can be effectively used for detection and measuring of low energy charged particle with effective particle energy discrimination.

REFERENCES

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