Testing and characterization of a fast scintillator detector

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Introduction

In the field of experimental nuclear physics, measurement of life-time of excited state of nuclei can provide crucial information about the structure of a nucleus. There are several well established techniques of undertaking such measurements such as, Doppler Shift Attenuation Method (DSAM), Plunger method and fast timing method; the use of either of these modes depends on the range of the life-time of the nucleonic state in consideration.

In this paper, we report, in part, the designing and fabrication of a multi-detector system suitable for investigating the lifetime of a nucleonic state using a particle-gamma correlation setup at the University of Delhi's Nuclear Physics laboratory. Our aim is to identify the beta decay of the mother nucleus to tag that daughter nucleus, which we are interested to study for lifetime measurements. Then fast timing detectors would be used to measure the lifetime of the tagged nucleonic state. Generally we are interested to study nuclei with lifetime in the nanosecond ranges. For gamma-decay measurements, fast timing detectors such as BaF_2, $LaBr_3$(Ce) are used, accompanied by electronic timing methods. At our lab, we have recently procured $CeBr_3$ [1] crystals and are in the process of designing a composite particle-gamma correlation detector setup. Our laboratory has the facility to populate desired nucleonic states by neutron activation technique.

We have tested the performance of a fast plastic scintillator detector combined with a photo multiplier tube (PMT), which would be used to study the beta decay which forms the first step of our measurement setup. Our primary aim has been to characterize and test this new plastic scintillator to gauge its performance and judge its applicability in our setup, regarding its timing properties.

In addition, we have also very recently procured an SiPM [2-3] mounted carrier board. In order to carry out the life-time measurements, besides the beta tagging stage, we would design, fabricate and study the performance of a $CeBr_3$ crystal coupled to the SiPM. To address the front-end electronics for the SiPM (which has a fast output besides a standard output), we would be using the preamplifier AMP0604, supplied by Advatech UK Ltd. [4].

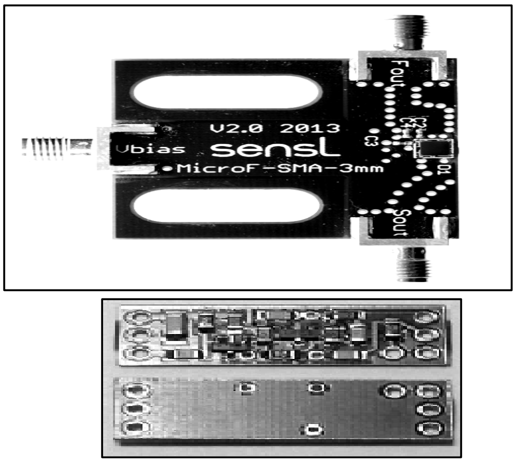

Fig. 1 Advanced SiPM-Preamplifier combination for detector testing

Experimental Details

We have, in this paper, provided the test results of the particle detection ability of a plastic scintillator detector coupled to a PMT. The plastic scintillator tested is the Eljen Techology EJ-228 Plastic Scintillator [5]; coupled to it is the Hamamatsu PMT R6094 [6].

EJ-228 is around 10cm in length and has a decent light output (67% Anthracene). The plastic material emits scintillation photons at a maximum wavelength of close to 391nm. It displays a rise time of 0.5ns and a decay time of 1.4ns.

R6094 is a Hamamatsu PMT of 2.8cm diameter, 11-stage dynode, bialkali photocathode material. The wavelength of maximum response peaks at around 420nm, with an overall spectral response lying between 300 to 650nm. As a part of our testing parameters, we varied the supply bias voltage from +700 V to +1000V and optimized our detector at a supply of +925V (for anode). Then we set the amplifier gain at 50 and to accommodate the fast decaying pulse, we used various shaping times, ranging from 0.5μs to 2μs at the mentioned bias supply. We also tested our scintillators' sensitivity for high energy cosmic muon detection. Calculations to estimate the precise efficiency of the plastic scintillator are being undertaken presently after taking into account, the activity of ^{90}Sr source on the day of experiment (N_s), and thus also the number of beta particles emitted.

Results

The spectrum obtained as a result of setting the shaping time as 0.5μs has been displayed in the figure below (Fig.2).

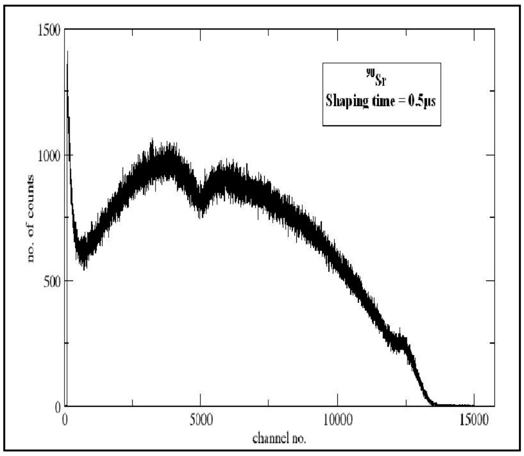

Fig. 2 Beta ray spectrum of ^{90}Sr source (at shaping time 0.5μs)

It was observed, as per previously known physics, that the plastic scintillator was virtually transparent to the incident gamma rays. However, it showed fine detection properties when beta particles were incident on it (^{90}Sr source) and we obtained pulses with fast decay times. Also, cosmic muons were successfully detected by the scintillator; muons striking the detector gave rise to expected pulse shape on the oscilloscope. We conclude that the Eljen Ej-228 plastic scintillators, coupled with Hamamatsu R6094 PMT can be particularly useful when high counting rates are meant to be tackled. Thus these plastic scintillators can be of good use in our setup's first stage to tag beta decays.

Acknowledgment

The authors would like to express gratitude towards Akhil Jhingan for providing constant guidance regarding SiPM-preamplifier coupling.

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