Development of a Fast Timing Counter Based on Plastic Scintillator with SiPM as Photon Detector

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The plastic scintillator detectors are undoubtedly the most often and widely used particle detection devices in nuclear and particle physics experiments. The fast timing response of these scintillators makes this device a popular choice for measurements where timing information is needed i.e., the time difference between two events to be obtained with greater accuracy. These scintillators can be coupled to silicon photomultipliers (SiPM) - the new generation photo sensors - to develop a very fast timing detector that can be used as a triggering device as well as a start detector for TOF measurement in many nuclear physics experiments. SiPMs are new generation photon counting devices that show great promise to be used as detection device in combination with plastic scintillators / Cherenkov radiators / hadron calorimeter. SiPM, also known as Geiger APD / Multipixel Photon Counter(MPPC), is essentially an avalanche photo-diode operated in limited Geiger mode capable of low light level detection. The device can detect single photon like a conventional PMT, hence the name silicon photo-multiplier. The SiPM is an opto-semiconductor device with excellent photon counting capability and possesses great advantages over the conventional PMTs because of low voltage operation, compact in size and insensitivity to magnetic fields. SiPM operating in Geiger mode a very large gain (~10^6), magnitude of which is determined by the internal diode capacitance and applied over-bias voltage, comparable to that of PMTs can be achieved. The potential use of SiPM includes medical diagnosis eg., simultaneous PET/MR studies due to their insensitivity to magnetic field and high photon detection efficiency.

The primary motive of the present work is to develop a fast timing detector array based on plastic scintillator tiles with SiPM. The dimension of each tiles is chosen sufficiently small so that the granularity of scintillation tile can provide additional information on position (spatial resolution) when a large array of a scintillation hodoscope is constructed using these devices. The advantages of these detectors are very fast timing, compactness in size and can be operated in high magnetic field where the use of PMTs is prohibited.

The present communication reports the timing measurements for such a device.

I-V characteristic, optical response and time resolution study:

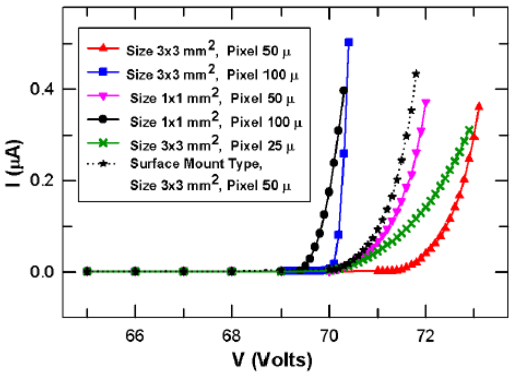

Fig. 1: The I-V characteristic curve of different types of MPPC as indicated in the figure. The line through the data points is to guide the eye.

The I-V characteristic and optical response[1] of SiPM have been studied. In Fig.1 we plot current vs applied voltage to the sensor in reverse bias condition. The breakdown voltage is observed to be ~ 70 Volts depending on the type of sensors. Optical response of SiPMs is studied with β-source ($^{90}Sr/^{90}Y$). The source was placed on top of the scintillator tile (Fig. 2) and the scintillation photons generated in the scintillator were seen by the photo sensors connected to the tile.

For time resolution measurement, we have coupled two MPPCs at two opposite sides of the

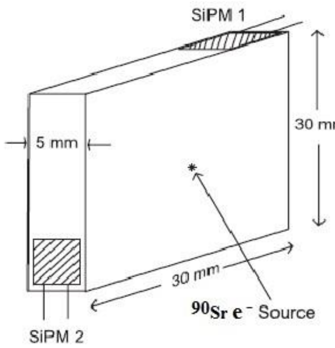

Fig.2 Setup(schematic) used for time resolution measurement. A plastic scintillation tile (30 X 30 X 5 mm^3) coupled to two photo sensors at the side. Beta source was placed at the centre.

tile. The tile was covered with aluminium reflecting foil. Time difference between the photons arriving at the two photon counters is measured. A time coincidence setup was employed(Fig.3) and data were collected on LAMPS based VME DAQ system.

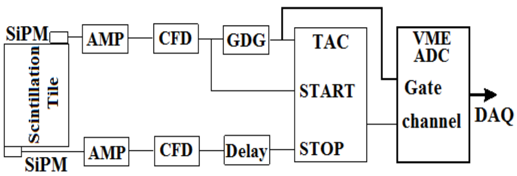

Figure 3: Coincidence circuit used for time resolution measurement: CFD- constant fraction discriminator; GDG- gate & delay generator; TAC- time to amplitude converter.

The time calibration is done by introducing known time delay between the start and stop signals of TAC. Measurements are performed with different types of plastic scintillators and SiPMs. The best time resolution achieved, as shown in Fig.4, is σ = 233 pico-second with scintillation tile BC422 and SiPMs having dimension of 3x3mm^2, pixel size 25μ and 50μ.

The study of variation of timing resolution with sensor bias voltage has been performed. Fig. 5 shows the results of these measurements as a function of the over-bias voltage. Our preliminary studies indicate improvement of resolution with increasing bias voltage up to a

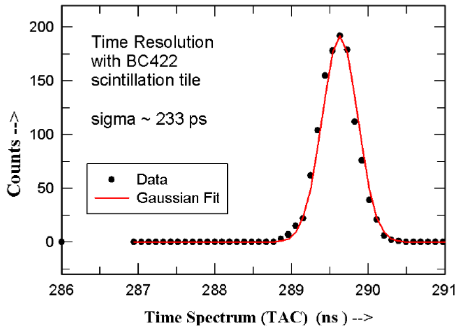

Fig. 4: Time spectrum obtained in the time resolution study. A Gaussian fit to the data yielded time resolution of 233 pico-seconds.

certain voltage after which it more-or-less saturates. Further measurements are in progress. All measurements reported here have been carried out at room temperature. Measurements at low temperature are being planned as cooling of SiPM expected to improve resolution due to reduction in thermal noise.

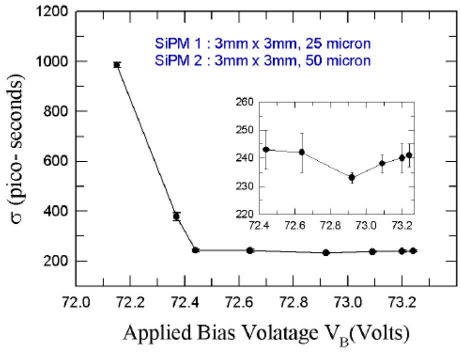

Fig.5 Detector timing resolution as a function of applied over bias voltage. Solid line is drawn through the data points to guide the eye.

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References:

[1] B. J. Roy et al, SiPM as photon counter for Cherenkov det., Proc. Int. Symp.Nucl.Phys.54(09)666