SiPM based Scintillation Detector for sub-nanosecond Timing Measurements

B. J. Roy[1,*], A. Parmar[2], V. Jha[1], H. Kumawat[1], S.Kailas[1],

1: *Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai-400085*
2: *Sardar Patel University,Vallabh Vidyanagar, Anand, Gujrat- 388120*
* Corresponding author: bjroy@barc.gov.in

The Silicon Photomultiplier (SiPM) based fast scintillation detector, known as SciTil [1], is designed to be a large barrel shaped and will be positioned[2] in between the barrel DIRC (Cherenkov detector) and Electromagnetic Calorimeter (EMC) of the PANDA detector at FAIR. The detector will serve for precision time measurement and will be used as a trigger and determination of time-of-flight information for charged particles. In addition, a good spatial resolution due to its granularity can be obtained. The SciTil hodoscope will also provide information on charged-neutral discrimination and will be an useful information for the EMC detector. The timing detector concept is based on about 5700 small plastic scintillation tiles, each tile having a dimension of about 3 x 3 x 0.5 cm^3 (matching the front face of crystals of the EMC detector). As the SciTil detector will be housed inside a large solenoid magnet, the magnetic field (~ 2.5 Tesla) and the compactness of the detector prohibit the use of photo-multiplier tube (PMT). This brings the concept of use of SiPM - a new generation silicon photo detector (also known as Geiger APD) that has several advantageous over the conventional PMTs.

The BARC, Mumbai group in this collaboration [2] is involved in the R&D studies and development of this SiPM based fast scintillation counter. We have developed a test set-up facility at NPD, BARC and have recently achieved a time resolution of ~ 500 pico-second. The present paper reports on this time resolution measurement.
The SiPMs having pixel density typically between 100 and 10000 / mm^2 with each pixel acting as a digital device where output signal is independent of the number of photons absorbed. By connecting pixels in parallel, the detector can be made an analog device thereby allowing the number of incident photons to be counted.

At present we are using SiPMs -also known as MPPC (Multi Pixel Photon Counter)- having sensor area of 3 x 3 mm^2 and different pixel size and density. The I-V characteristic and dark current have been studied (Fig.1).

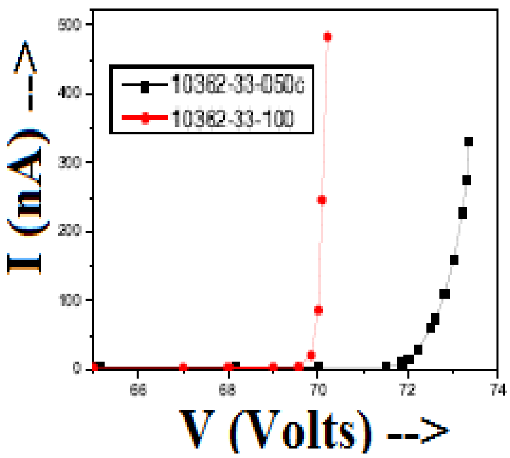

Fig.1 The I-V characteristic curve of two different types of MPPC as indicated in the figure.

For optical response of SiPMs, the photo-diodes are coupled to a plastic scintillator tile (3cm x 3cm, thickness = 5mm) (fig.2). An α- source was used to generate scintillation photons in the scintillator which were then readout by the photo sensors. The measurements were performed inside a light tight black box.

Two types of pre-amplifiers with different timing and gain, make Photonique SA, were used. Fig.3 shows a typical SiPM signal obtained with a fast pre-amp but low gain.

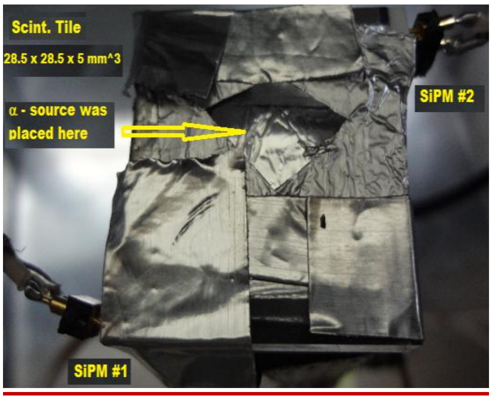

Fig.2 The scintillator tile with SiPMs coupled at two sides.

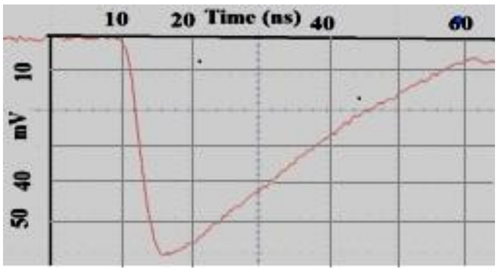

Fig.3 MPPC signal with a fast pre-amplifier as detailed in the text. Rise time ~ 6 ns is obtained.

For time resolution measurement, we have coupled two SiPMs at two sides of the tile and the alpha source was positioned around the middle of the tile as is shown in the Fig.2. The time differences between scintillation photons reaching two SiPMs were measured. A standard coincidence circuit was employed and a VME based data acquisition system was used.

Different time resolution was obtained using various types of plastic scintillators obtained from different manufacturers (Fig.4 and 5). The best result was obtained using an ultra fast scintillator equivalent to BC-422 and a time resolution of 500 pico-seconds (Fig.5) has been achieved in the present set-up.

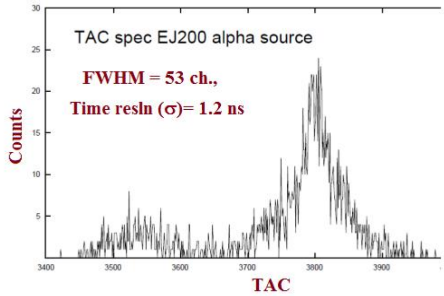

Fig.4 Timing spectrum with scintillator EJ200.

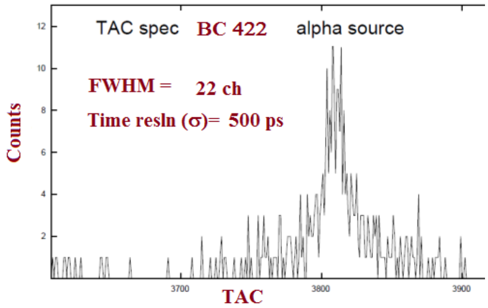

Fig.5 Timing spectrum with BC422.

There are several factors that affect the timing resolution and are being taken care to further improve the resolution to ~ 200 pico-seconds, the goal of this study.

It is to mention that as a part of this collaboration study, efforts are being made by the Micro Electronics & MEMS Centre, Electronics Division, BARC for development of ASIC electronics for SiPM readout.

Acknowledgments:

The authors would like to thank A.Chatterjee, V.M.Datar and A.K.Mohanty for their support and interest in this work. We would also like to thank D.Dutta and U.K.Pal for their interest in this project. One of the authors (BJR) acknowledges the financial support received from the DAE-BRNS via sanction no. 2011/38/02-BRNS with PRF, dated 03/Feb/12 to carry out R&D activity of this project.

References

[1] B.J.Roy et al, DAE symp NP **56,** (2011)
[2] S.Kailas, et al, Current Sci., **100,** 690 (2011)
[3] B.J.Roy et al, DAE symp. NP, **54**, 666 (2009)