SiPM based fast scintillation detector SciTil for PANDA: Simulation for photon arrival time distribution

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PANDA (acronym for Antiproton Annihilation at Darmstadt) is one of the major projects of the GSI future international facility FAIR (Facility for Antiproton & Ion Research) at Darmstadt, Germany. The aim of PANDA project is study of strong interaction in non-perturbative regime. Phase space cooled antiproton beams in the momentum range 1 – 15 GeV/c from the HESR (High Energy Storage Ring) will be made to collide on fixed target (Liquid hydrogen/ deuterium) and the reaction products will be detected by a composite detector PANDA. Nuclear targets will also be used for hyper-nuclear physics studies.

The proposed work in India[1] consists of several parts: (i) development of SiPM based scintillation tile hodoscope (SciTil) for PANDA that will be used as trigger for PANDA and also form start signal for TOF information, (ii) development of a luminosity detector (silicon micro strip detector), and (iii) simulation studies of these detectors design as well as physics case studies. In the present paper we report simulation studies on the SciTil detector that is being carried out at the Nuclear Physics Division (NPD), BARC, Mumbai.

A new concept [2] was proposed to design a scintillation tile hodoscope (SciTil) as a general purpose timing detector and will be mounted in front of the Electromagnetic Calorimeter (EMC). The SciTil will be made of 3 x 3 x 0.5 cm^3 scintillator tiles matching the front face of the EMC crystals, and will be read out by 3 x 3 mm^2 Silicon Photo Multipliers (SiPMs) – also known as Geiger APDs (G-APDs) - works in the Geiger mode and a gain comparable to the conventional PMTs can be achieved. The presence of large magnetic field due a solenoid magnet prohibits the use of PMTs. The scintillator will be made of plastic providing a good light output and fast time response. Because of the reduced thickness of the "SciTil", it is advantageous over a TOF detector made of thick scintillator bars that cause deterioration of the response of the EMC calorimeter due to photon conversions in the materials of the bars.

The one of the aims is to achieve a very fast timing ~ 100 ps. In this connection an R&D work has been initiated at NPD, BARC for detailed simulation studies and hardware development of such a fast counter with plastic scintillator coupled to SiPM. The simulations are being carried out using a ROOT based general purpose Monte Carlo simulation program "SLitrani". In an earlier study[1] we have reported photon "detection efficiency" at different positions of the SiPM. In the present paper, a "time analysis" has been performed for three different types of commercially available plastic scintillator sheets, viz., BC408, BC420 and BC422, in order to understand how long it takes before the photons generated by the charged crossing particles at t=0 reach the detector. This time will strongly be dependent on the position of the tiles at which photons are generated either for those going directly to the G-APD and for those which are reflected, nevertheless it will provide useful information for timing resolution.

In our simulation work we have performed time analysis for two sets of threshold for SiPM. In the first case the threshold is set as single photon, while in the second situation, the SiPM will generate a signal with the number of incident photons three or more. The properties/data used for different scintillators are shown in Table 1, and the scintillation tile - SiPM geometry used in the present simulation is shown in the Fig.1. Kaon beam of momentum 1 GeV/c was taken as the incident particle and the photons were generated as a result of interaction of these kaons with the scintillator tile.

Fig. 2 shows the arrival time of at least one photon at the detector while Fig. 3 shows the same for at least three photons at the detector for different scintillators.

Scintillators	BC408	BC420	BC422
Light o/p (%Anthracene)	64	64	55
Rise time (ns)	0.9	0.5	0.35
Decay time(ns)	2.1	1.5	1.6
Max. emission (λ nm)	425	391	370
Bulk attenuation Length (cm)	380	110	8

Table 1: Some of the properties of three different scintillators (taken from Ref.[3]) used as inputs to the SLitrani calculations.

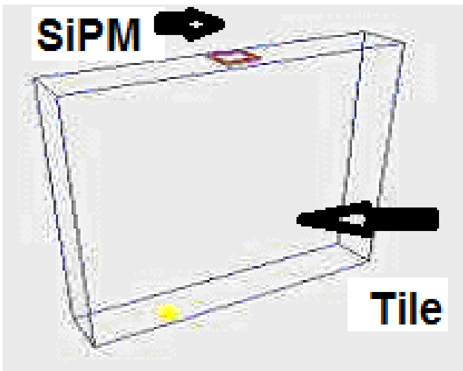

Fig.1: Geometry used for the present simulation for time of arrival analysis.

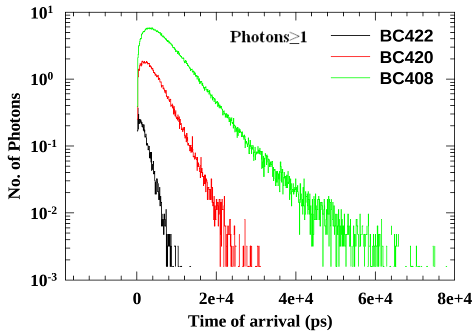

Fig.2: Plot showing the time of arrival of at least one photon at the detector for a single-particle run (for even with of one kaon of momentum 1 GeV/c).

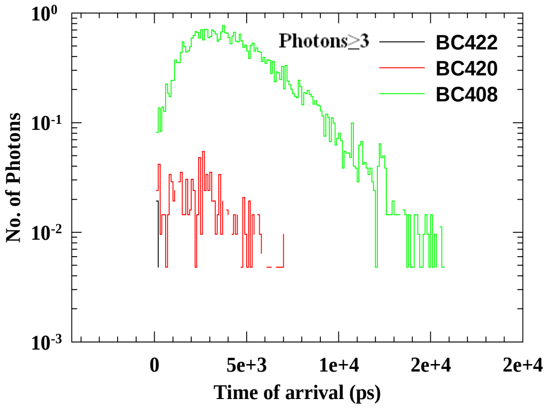

Fig.3: Plot showing time of arrival of at least three photons at the detector for a single-particle run (for even with of one kaon of momentum 1 GeV/c).

Simulation studies are in progress in order to understand the effect of this timing information on the timing resolution measurement. In parallel, we are also developing this detector and a detailed R&D work is being carried out at NPD, BARC.

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[3] Saint Gobain Crystals: www.detectors.saint-gobain.com