Preliminary Scintillator and Solid-State Photomultiplier Direct Coupling Tests

Gerald C. Blazey

Northern Illinois University – Northern Illinois Center for Accelerator and Detector Development
Department of Physics, DeKalb, Illinois – USA

Initial cosmic ray measurements show strong minimum ionizing particle response for scintillator directly coupled to solid-state photomultipliers. Source scans show strong dependence on scintillator thickness.

1 Introduction

An excellent candidate for the highly segmented calorimeters required for particle flow algorithms (PFA) appears to be a scintillator based detector with solid-state photomultipliers directly coupled to scintillator pads and both mounted on a multi-layer printed circuit board (PCB). Calorimeter prototypes utilizing the scintillator and solid-state photomultiplier combination have recently been built and beam tests show the technology suitable for precision calorimetry. These prototypes coupled the scintillator cells to the photomultipliers with wave-length shifting fiber. Direct coupling of the cells with solid-state sensors represents an attractive alternative for construction and assembly of the highly segmented mega-channel detectors required for PFAs. We describe direct coupling measurements with green emitting scintillator. Tests were performed with sensors from different vendors and with different cell geometries. Uniformity across the scintillating cell was measured with a radioactive source. Minimum ionizing particles were used as a source of cosmic rays.

2 Source Scans

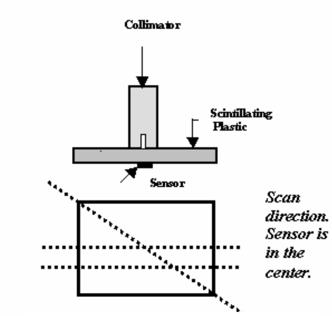

Figure 1: Scan apparatus

As illustrated in Fig. 1 we performed scan measurements with a Sr90 radioactive source collimated to 0.8mm. A Hamamatsu sensor (MPPC S10362-11-025C) [1] was placed at the center of the scintillating cell and current from the sensor recorded. The source was moved along the cell surface. All cells had the same coating and the edges were unpolished and painted white. Two layers of Tyvek on the top and the bottom of the scintillator served as a reflective material. The sensor opening in the reflective coating was 3x3 mm². Positioning was accurate within ±0.5 mm. The maximum signal to background ratio was ~150. The measurements were reproducible to within ~3 %. We performed three different scans with four different thicknesses of scintillator. Scans were performed through the center of the scintillating cell, across the scintillator with a 10mm offset with respect to the center, and from corner-to-corner. As shown in Fig. 2, the uniformity improves with thickness and the non-uniformity is greatest at cell edge. For 6mm thick scintillator, the edge response (normalized to the central position) was 54% for the scan through the center and 52% for the diagonal scan (at a distance of 15mm from the center).

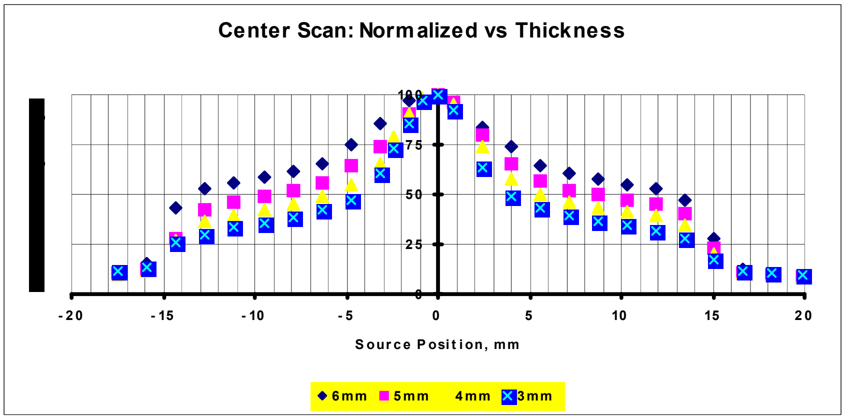

Figure 2: Scan measurements through the center for different thicknesses.

3 Cosmic Ray Measurements

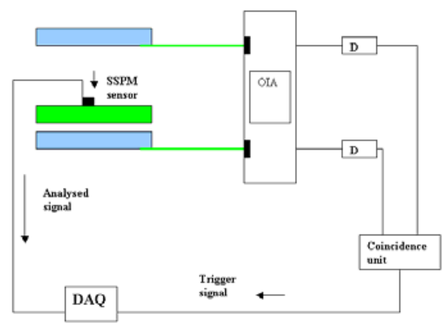

Figure 3: Cosmic ray apparatus

The experimental apparatus used to measure the response to cosmic muons is illustrated in Fig. 3. The trigger utilized two 3x3 cm² scintillating cells with sigma type grooves and glued Y-11 WLS fibers 1 mm in diameter. The optical signal from the trigger scintillating pads was amplified with an Optical Interface Amplifier (OIA) made by CPTA [2]. The OIA includes solid-state photomultipliers with bias circuits, amplifiers, and shapers. The CPTA photomultiplier detection efficiency was about 35% at 450nm. The discriminator transforms the analog signal into NIM signals and a coincidence unit finalizes the trigger. The threshold for each trigger counter was set at five photoelectrons. The random coincidence rate was approximately one event per 30 minutes. The 3x3 cm² scintillating test cell was made of EJ-260 green emitting plastic scintillator [3] and located between the two trigger counters which were positioned 10 cm from one another. The scintillator thickness was 6 mm. The photo-sensor was placed directly on the scintillator and coupled with optical grease. The cell was wrapped with VM2000 film. For each measurement a 3x3 mm² opening was made in the film and a solid-state photomultiplier placed at the center of the opening. The signal was read out with a data acquisition system developed by the CALICE collaboration, running on a PC controlling a VME DAQ board [4].

The response to cosmic rays was measured for the three different likely sensor positions (Fig. 4). A CPTA sensor distribution for the central position in ADC units is shown in Fig. 5. The pedestal can be distinguished from the most probable value. We used the most probable value to evaluate the difference in the light output for the three different sensor positions; these are shown in Table I normalized to the central position. The uncertainty is estimated at 15% and includes statistical uncertainties and photomultiplier gain variations due to temperature changes. As shown in Table I, we performed a second set of calibrated measurements with a Hamamatsu photomultiplier (MPPC S10362-11-100C) [1]. Although not shown, the signal is far from the pedestal, suggesting high registration efficiency. We measured a 10.8+/-1.5 PE response without optical grease at the central position, implying opportunity to optimize the coupling.

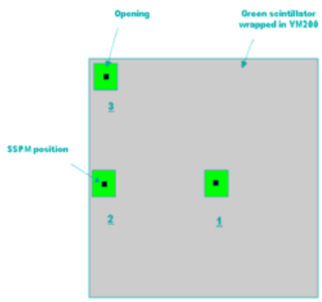

Fig.4: Measurement positions

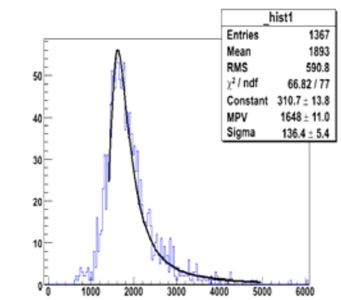

Fig 5: Response at center position

TABLE I: Sensor Response at Various Locations (with optical grease)

Position	CPTA (Normalized to Center Position)	Hamamatsu (PE)
Center	100%	16.8 +/- 2.5
Edge	92%	19.3+/- 3.0
Corner	71%	Not measured

4 Conclusions

Detailed source scans show that uniformity improves with scintillator thickness. Cosmic ray measurements are encouraging, both CPTA and Hamamatsu sensors generate strong MIP signals which indicates that highly efficient directly coupled detectors are feasible. R&D continues with different scintillator, surface treatments, and sensors. An integrated PCB board with scintillator and SiPMs both mounted on the surface is in preparation for beam tests this year. Slides can be found at Reference [5].

5 References

[1] Catalog N KAPD0002E01, Jan. 2007, DN Hamamatsu Photonics K.K.
[2] D. Beznosko, et al., NIM A545 727 (2005).
[3] Eljen Technology 2010 E. Broadway, Sweetwater, Texas 79556, United States.
[4] CALICE Collaboration, http://www.hep.ph.ic.ac.uk/calice/elecProduction/electronics.html
[5] Slides:
http://ilcagenda.linearcollider.org/contributionDisplay.py?contribId=383&sessionId=108&confId=1296