An alternative technique to do the position calibration of large area plastic scinitillators

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Introduction

This paper present a study to use thick plastic scintillators (PS) bars of 'ISMRAN (Indian Scintillator Matrix for Reactor Anti-Neutrinos)' [1] scintillator matrix, to reconstruct the cosmic muon hit points on the scintillator planes, for the applications like Muon Tomography [2]. An alternative technique for position calibration of thick PS using cosmic muon as a probe, is presented. The results of hit positions obtained from the cosmic muons based calibration method is compared with the traditional calibration method using the radioactive source. Finally the muon hit map observed using different calibration technique on one scintillator plane is presented.

Experimental Setup

The experimental setup consists of a matrix of 90 PS bars. Each PS bar is coupled to a 3" Photo Multiplier Tube (PMT) at both ends, which are used to record the timing and integrated charge. The 90 PS bars are arranged in the staggered configuration, where the successive layer is placed orthogonal to the next one. The staggered arrangement confines the region (defined by the formed pixel size), for the particle to pass through . Figure 1(a) and 1(b) shows the 3D schematic and experimental setup respectively. The Data Acquisition (DAQ) system consist of 12 CAEN V1730 [3], 16 channel waveform digitizers, with a 14-bit flash ADC with the sampling frequency of 500 MS/s.

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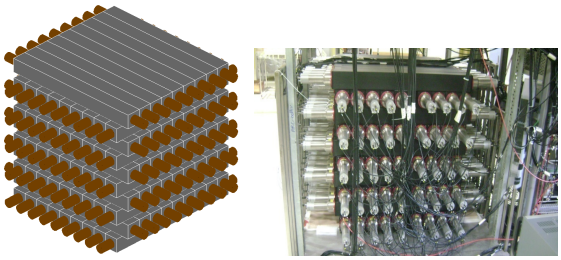


(a) (b)

FIG. 1: Staggered geometry configuration of 90 PS bars (a) 3D schematic (b) Experimental setup.

Position calibration with ^{137}Cs

Position calibration of the PS is required to map the measured parameters to the position of interaction. Position calibration is done by placing ^{137}Cs source at 9 different positions (from -40 cm to +40 cm with the step size of 10 cm) along the length of scintillator, with the center of PS bar at 0 cm. The difference of timestamp recorded by left and right PMT (ΔT^{Cs}_{LR}) is used to find a parameterization, by fitting a 2nd order polynomial between the mean values of ΔT^{Cs}_{LR} distribution and the corresponding physical positions of the radioactive source, as shown in Fig. 2(a). The parameterization can be later used to map the ΔT^{Cs}_{LR} to the hit positions as shown in Fig. 2(b).

Position calibration with cosmic muons

The advantage of using cosmic muons as the probe, is the collimated nature of indi-

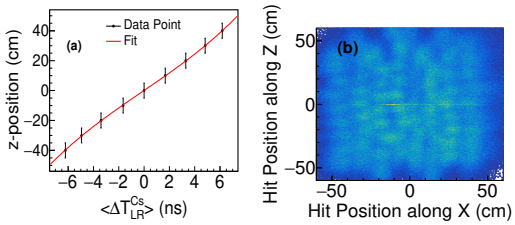


FIG. 2: (a) Parameterization to map ΔT^{Cs}_{LR} to hit position. (b) Obtained hit position map.

vidual high energy cosmic muons. To do the position calibration, these muons need to be confined. In the experimental setup, these are confined by the staggered geometrical arrangement of the scintillator layers as shown in Fig. 1. This arrangement gives the pixels of 10 cm × 10 cm. For position calibration only the vertically going muons are chosen, i.e. those muons which pass through the same pixel in each layer. Now using the same procedure as done for ^{137}Cs source, parameterizations are obtained using the difference of timestamp recorded and using the ratio of integrated charge as shown in Fig. 3(a) and 3(b) respectively.

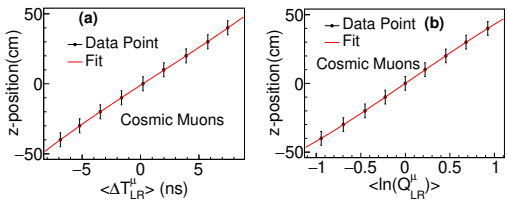
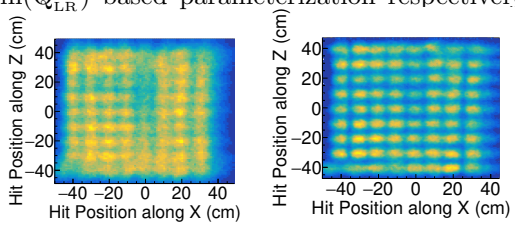


FIG. 3: Parameterization to map (a) ΔT^{μ}_{LR} to hit position. (b) $\ln(Q^{\mu}_{LR})$ to hit position, along the 100 cm length of scintillator bar.

Results

Parameterization obtained with cosmic muons is used to obtain the hit points on a complete plane of scintillator. Results are presented using vertically going muons. Figure 4(a) and 4(b) shows the distribution of hit position on the scintillator plane using ΔT^{μ}_{LR} and $\ln(Q^{\mu}_{LR})$ based parameterization respectively.



(a) Using ΔT^{μ}_{LR} based parameterization (b) Using $\ln(Q^{\mu}_{LR})$ based parameterization

FIG. 4: Hit position map on one complete layer using vertically going muons.

It is evident that using muon based parameterization results in visualization of all the pixels formed due to staggered geometric arrangement of the PS bars. The variation in the counts in some of the pixels is due to the noise in a few PS bars. The generated hit point map is much clear as compared to hit point map generated using ^{137}Cs based parameterization.

Conclusion

An alternative method for calibration of large-area plastic scintillator using cosmic muons is presented. The presented method is particularly useful for the application like Muon Tomography, that critically depends on the quality of the reconstructed muon tracks. Using cosmic muons based parameterization, all the pixels are clearly visible and also their locations are matching well with the geometry of the experimental setup.

References

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