Testing of the extruded plastic scintillators on a large-scale for the CMVD

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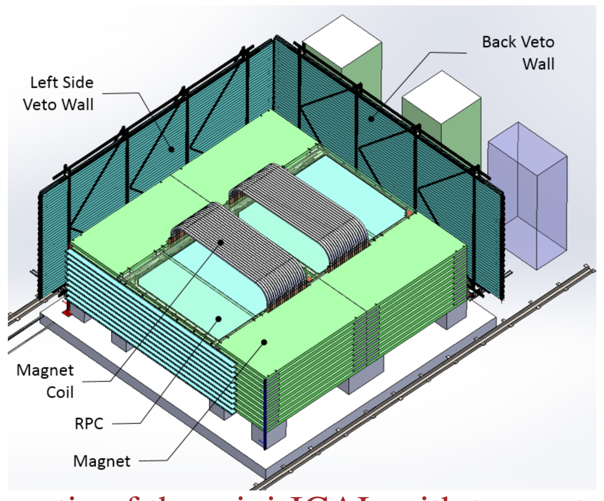
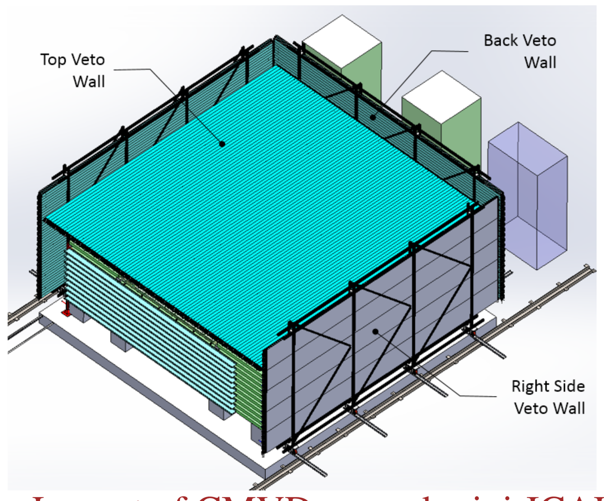
Abstract

The construction of a cosmic muon veto detector (CMVD) is in progress to cover the mini-Iron Calorimeter detector at IICHEP, Madurai. The goal of the CMVD is to study the feasibility of a shallow depth (100 m) neutrino experiment. The estimated reduction in cosmic muon flux will be 10^6 at a depth of 1 km. The same order of reduction in cosmic muon flux at a shallow depth (100 m) will be possible, only if the cosmic muon veto detetor will have veto efficiency of more than 99.99% and fake rate of less than 10^{-5}. The CMVD will consist of $\sim$ 4.5 m long extruded plastic scintillators (EPSes), WLS fibre to collect the scintillation photons and the silicon-photomultipliers (SiPMs) for the readout. A total of 760 EPSes will be required in making of the CMVD. Two EPSes will be glued together to make one unit called di-counter. It is essential to test all the components (i.e. di-counters, SiPMs and the readout electronics) of the CMVD before installation to achieve the required veto efficiency goal. To test the di-counters, a cosmic muon coincidence setup is made to generate a trigger of cosmic muon trajectory. DRS modules are used to collect muon signals of the test di-counters.

CMV detector on top of Mini-ICAL



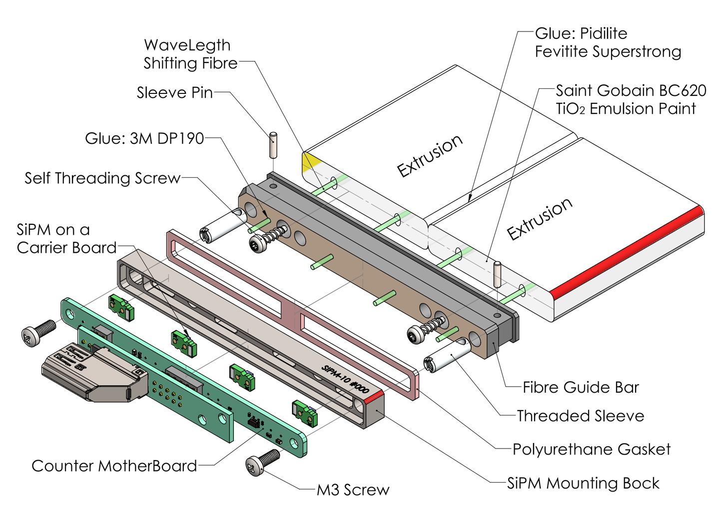
Schematic of the mini-ICAL with two veto walls.



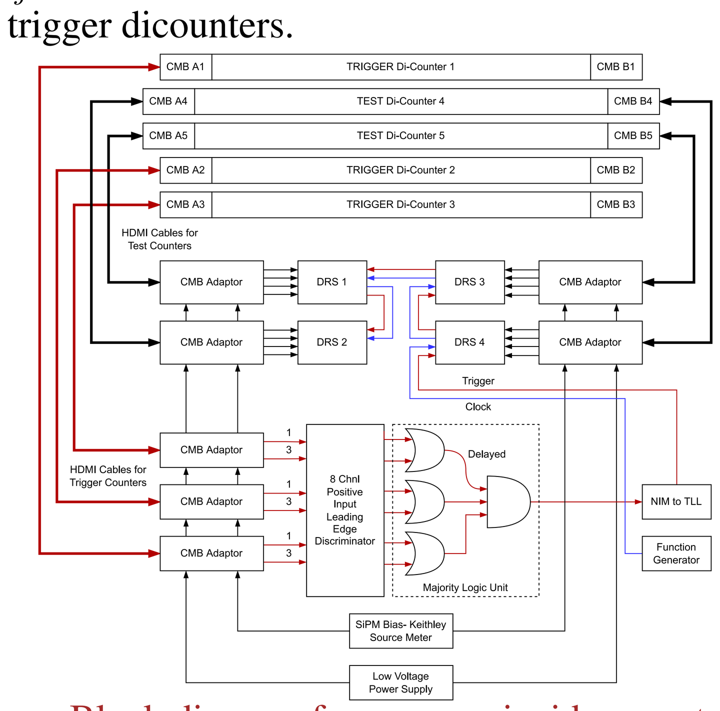
Layout of CMVD around mini-ICAL.

Exploded view of the dicounter and the experimental setup

A three fold cosmic muon coincidence trigger was generated using the dicounters itself. To test both the EPSes of the dicounter in a single run, the trigger was generated using an AND(OR(A_{1i},A_{1j}), OR(A_{2i},A_{2j}), OR(A_{3i},A_{3j})) logic where A_{1i} and A_{1j} are SiPM channels belongs to different EPSes of the first dicounter and same goes for the other two trigger dicounters.

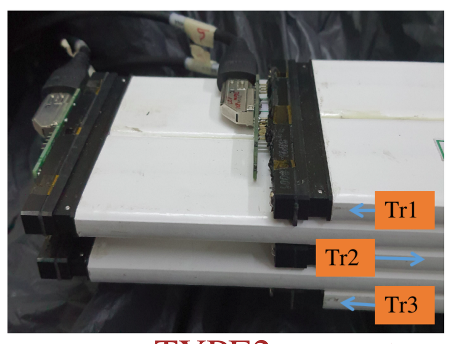


Dicounter assembly made by joining two EPSes.

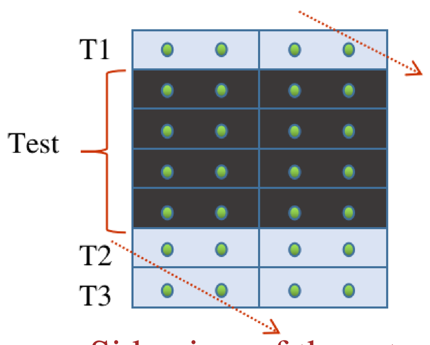


Block diagram for muon coincidence setup.

TYPE1 geometry.



TYPE2 geometry.

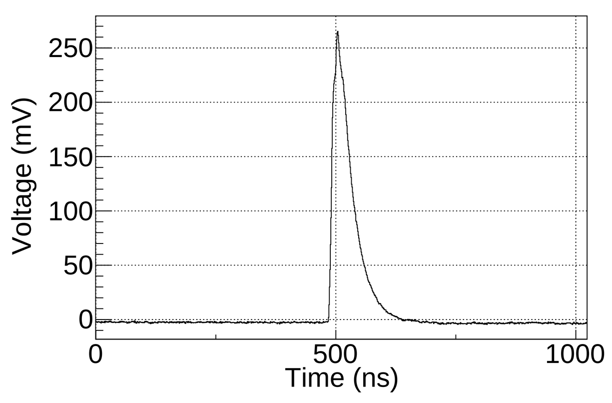


Side view of the setup.

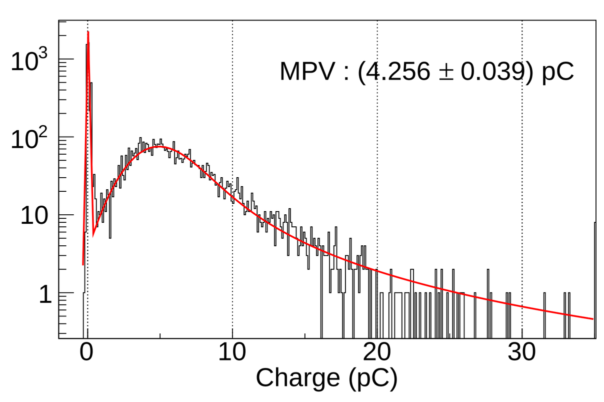
All the dicounters are tested using TYPE1 geometry to reduce the physical work. Only two dicounters were tesetd at once due to the limitation on the number of DRS boards available.

Test results

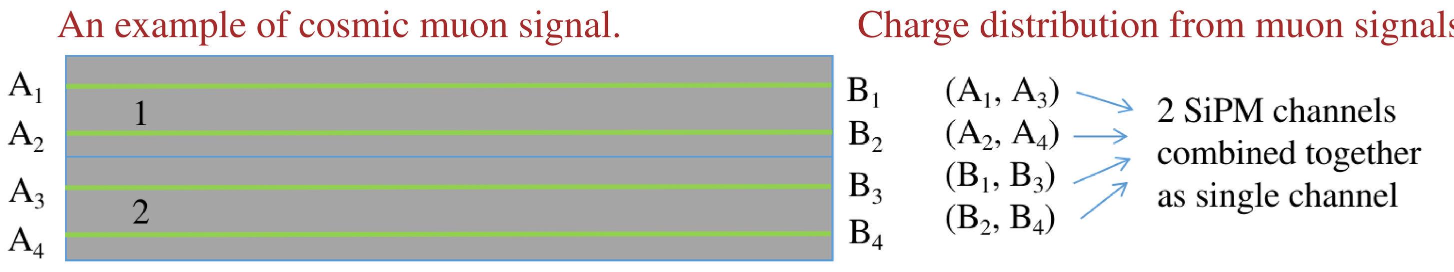
A total of 10,000 events were collected for each of the dicounter under test on trigger. The signal was integrated within a 100 ns window and pedestal was subtracted to reduce the effect of the baseline fluctuations. The integrated charge distribution is fitted with a Gaussian convoluted Landau function.



An example of cosmic muon signal.

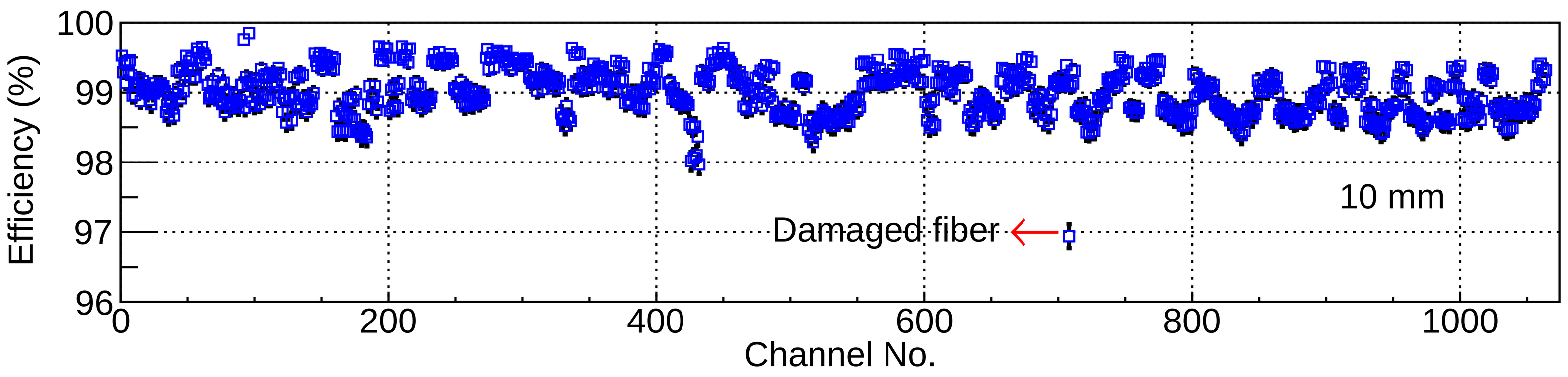


Charge distribution from muon signals.

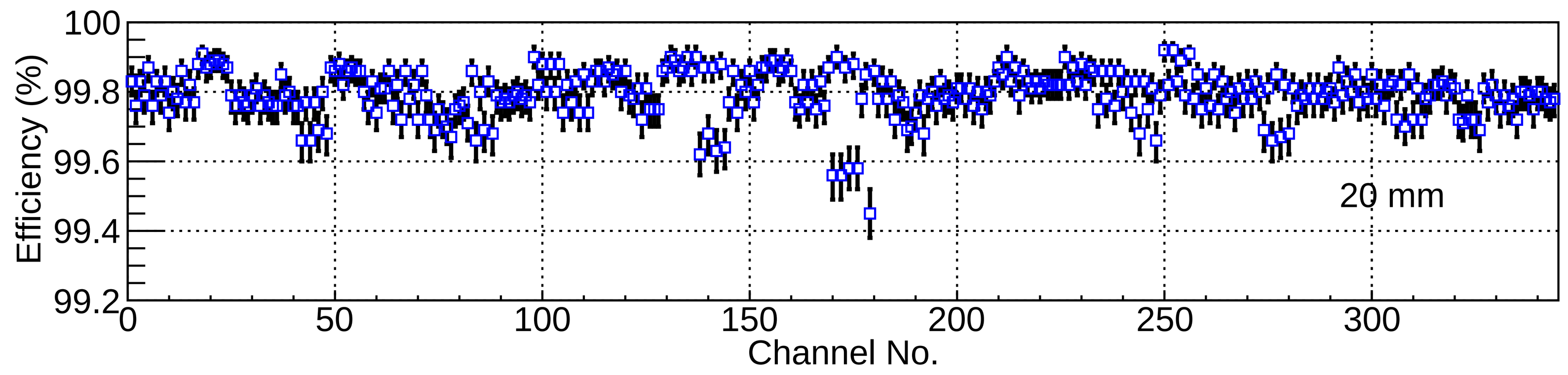


Schematic of the convention used for estimating cosmic muon efficiencies.

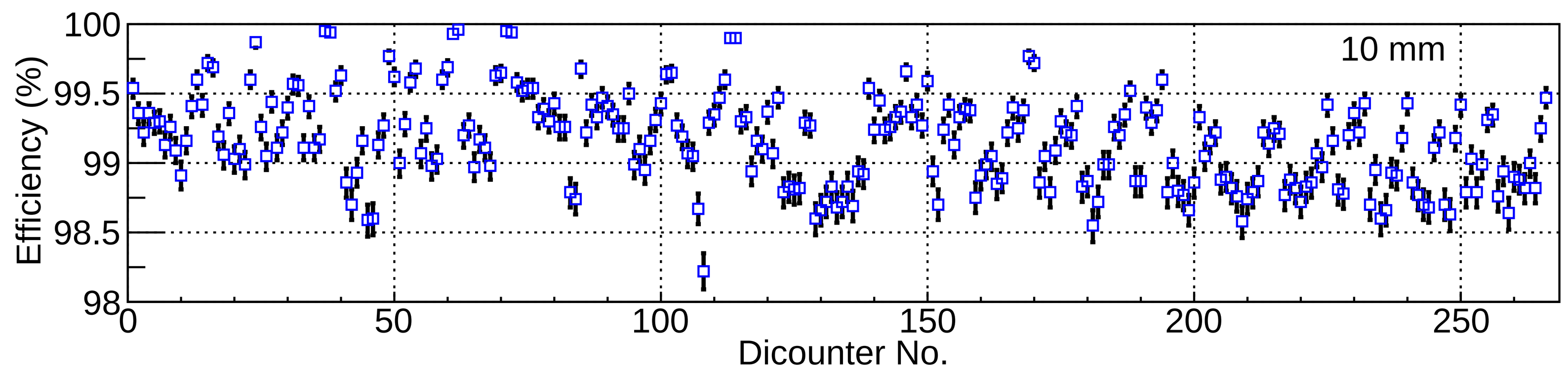
As per the trigger condition, there will be a signal in only one EPS at a time and hence the channels are combined together (one from each strip) for the Cosmic muon detection efficiency measurements as shown in the above schematic.

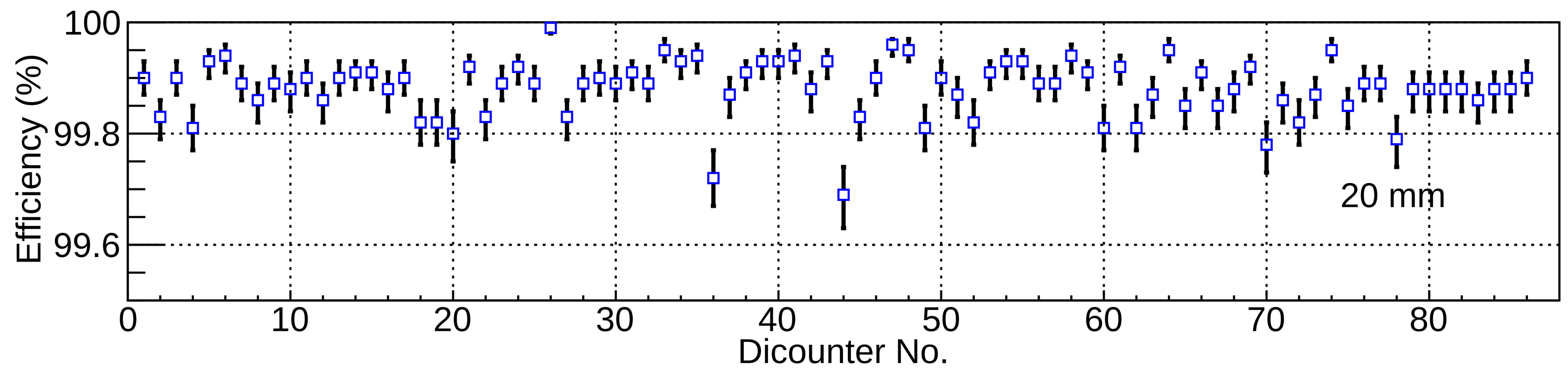


Cosmic muon detection efficiencies of SiPM channels using TYPE1 geometry.



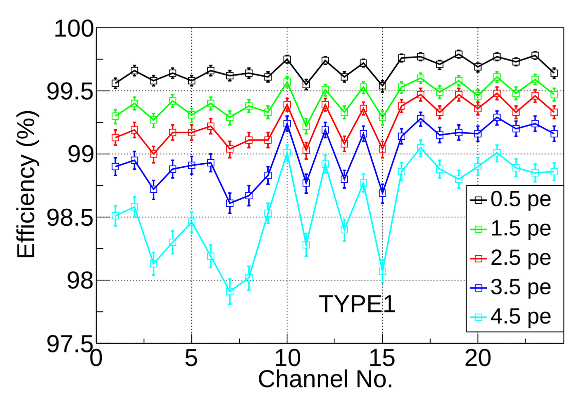
Cosmic muon detection efficiencies of SiPM channels using TYPE1 geometry.

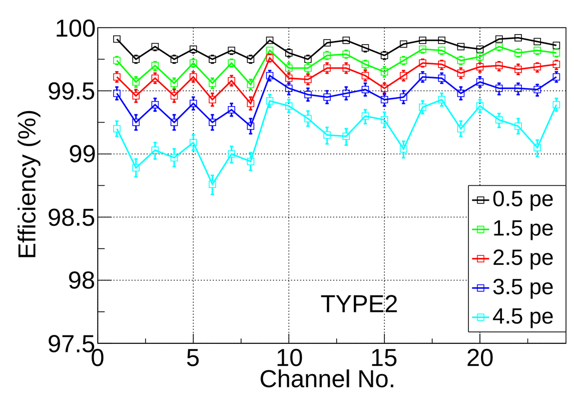




Cosmic muon detection efficiencies of a scintillator when two out of four SiPMs in a scintllator will have signal above 2.5 pe threhsold using TYPE1 geometry.

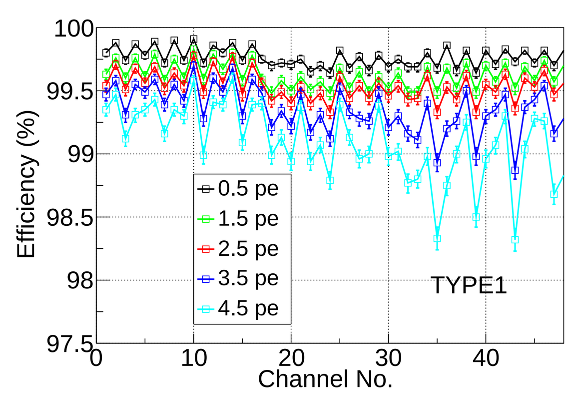
To achieve CMVD veto efficiency better than 99.99%, the scintillator efficiency should be at least 99% [1]. The scintillator efficiency for 20 mm dicounters satisfies the efficiency requirement. But most of the 10 mm dicounters failed to satisfy the minimum efficiency requirement, one of the sources is the false trigger in the setup geomtery. As per TYPE1 geometry, it may happen that one muon passes through the top trigger dicounter only and another muon passes through the two bottom trigger dicounters only as shown in side view of the setup (on left) and this way it forms a FALSE trigger leading to the inefficiency. To confirm the same, data is taken for six 10 mm dicounters in TYPE2 geometry.

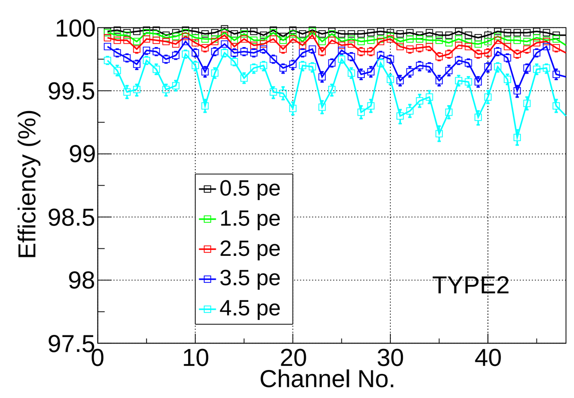




Cosmic muon detection efficiencies of SiPM channles for 10 mm dicounters.

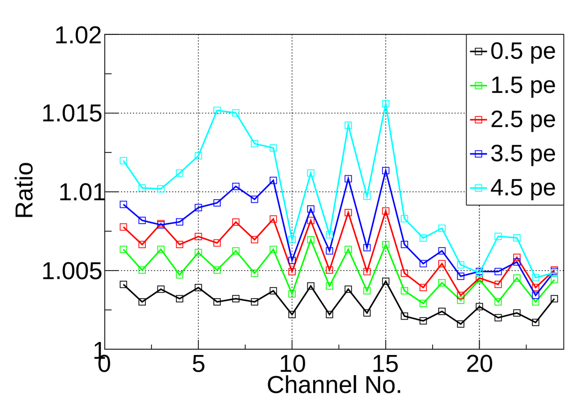
Clearly, there is an improvement in the efficiency measurements done using TYPE2 geometry.

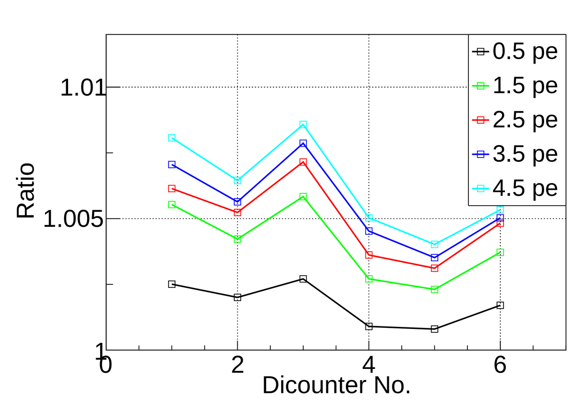




Cosmic muon detection efficiencies of SiPM channles for 10 mm dicounters when trigger was generated on a single strip of the dicounter.

The trigger on the single strip of the dicounter at a time would have been an ideal way to test these dicounters and the plots above shows the same and further improvement in the efficiency can be observed.





The ratio of cosmic muon efficiency measurement from TYPE2 geometry with single strip trigger to TYPE1 geometry with trigger on the dicounter for SiPM channel (on left) and for a scintillator (on right) to estimate the efficiency correction factor due to the FALSE triggers in the geometry.

The average efficiency correction factor at 2.5 pe threshold is found to be 1.01198 for individual SiPM and 1.00807 for a scintillator when two out of four SiPM in a scintillator will have signal. Implementing the correction factor, the 10 mm dicounters also satisfies the minimum scintillator efficiency requirement i.e. 99%.

Conclusion

The dicounters to be used for the construction of the CMVD are tested and it was observed that all the dicounters satisfies the minimum efficiency requirment to achieve the CMVD veto efficiency to be better than 99.99%. The damaged dicouters were repaired and reused for a shorter length dicounter.

References

[1] Mamta Jangra et al., Characterization of Silicon-Photomultipliers for a Cosmic Muon Veto detector, Journal of Instrumentation, 10.1088/1748-0221/16/11/P11029 **16** (2021) P11029.

Acknowledgements

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