Large scale SiPM testing for the Cosmic Muon Veto detector

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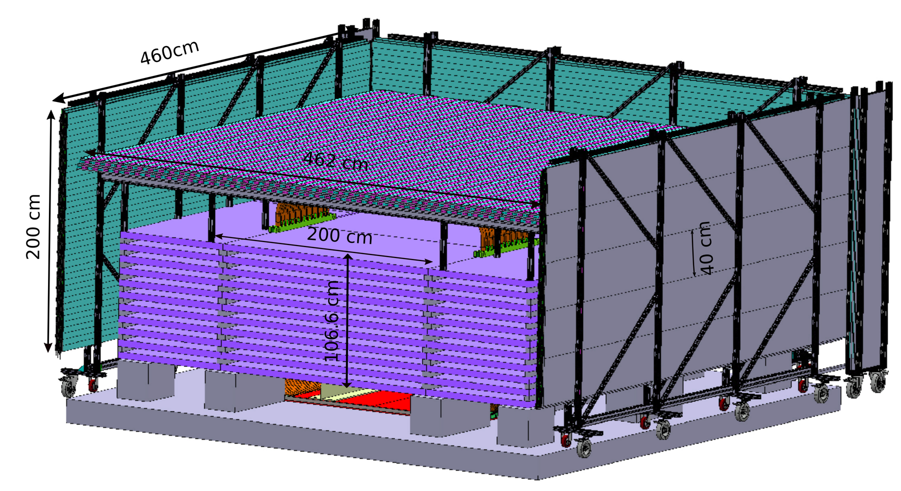
Abstract

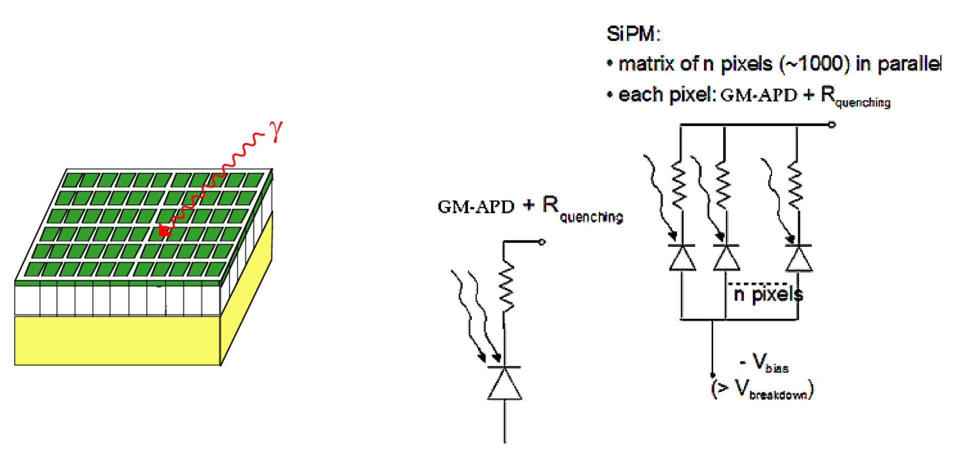
A Cosmic Muon Veto (CMV) detector using extruded plastic scintillators is being built around the mini-Iron Calorimeter (mini-ICAL) detector at the transit campus of the India based Neutrino Observatory, Madurai. The extruded plastic scintillators will be embedded with wave-length shifting (WLS) fibres to absorb scintillating photons and propgate the re-emitted photons to the silicon-photomultipliers for the electronic signals. The CMV detector will require 736 scintillators to shield the mini-ICAL detector, and will require 2912 SiPMs for the readout. The design goal for the cosmic muon veto efficiency of the CMV is >99.99% and fake veto rate less than 10^{-5}. Hence, every SiPM used in the detector needs to be characterised to satisfy the design goal of the CMV. A large-scale testing system was developed, using an LED driver, to measure the gain and noise rate of each SiPM, and thus determine its breakdown voltage (V_{br}) and optimum operating over voltage (V_{ov}).

CMV detector on top of Mini-ICAL

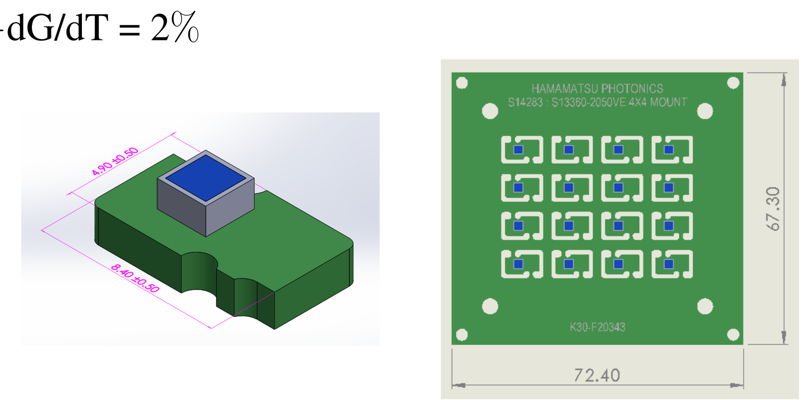


- 10 layers of RPC sandwiched between 11 layers of iron with an 85 ton magnet.
- Muon veto walls of extruded plastic scintillator.

Silicon Photo-multiplier

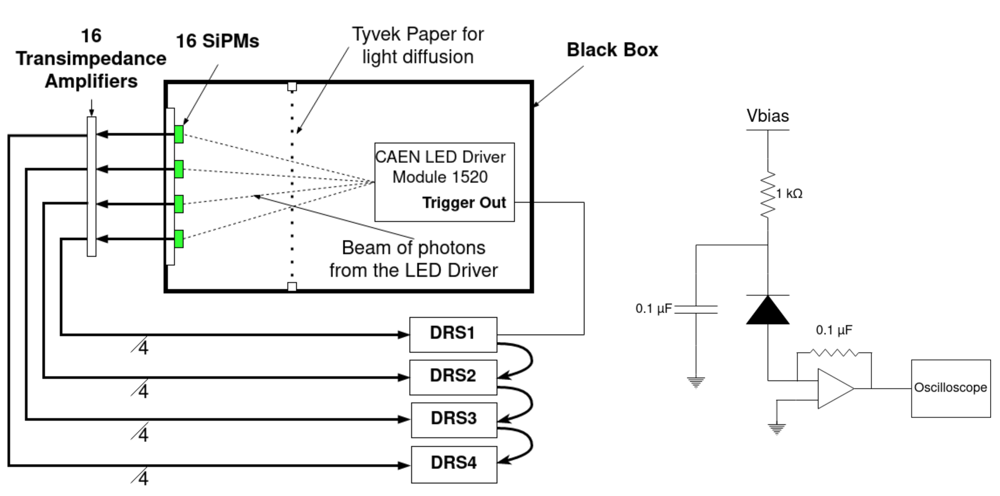


- S13360-2050VE Hammamatsu, total size of 2 mm × 2 mm with 1584 pixels
- Breakdown voltage : (53 ± 5) V + overvoltage of 3 V
- −dG/dT = 2%



One SiPM panel has 16 SiPMs. A total of 219 such panels were tested.

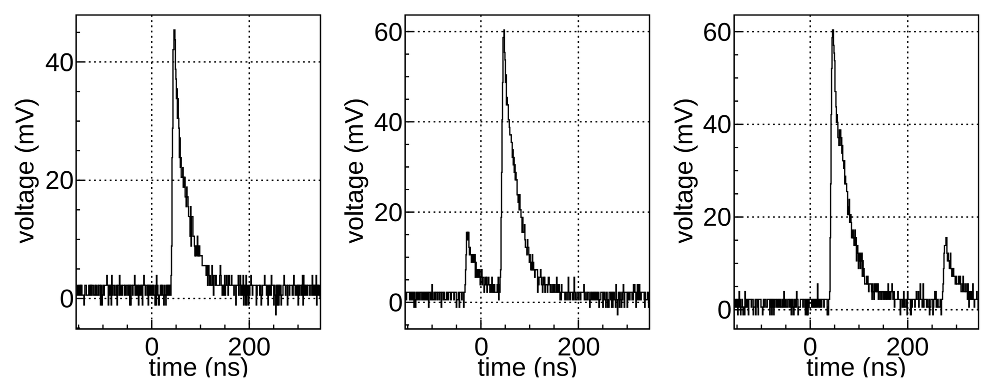
Experimental setup for LED testing



The SiPM panel under test was kept inside a light proof black box. An ultrafast LED driver is used to flash light on the SiPMs. The SiPMs signals were amplified using a trans-impedance amplifier (gain 1.25 kΩ). The data collection was done using 4 DRS boards connected to a computer system.

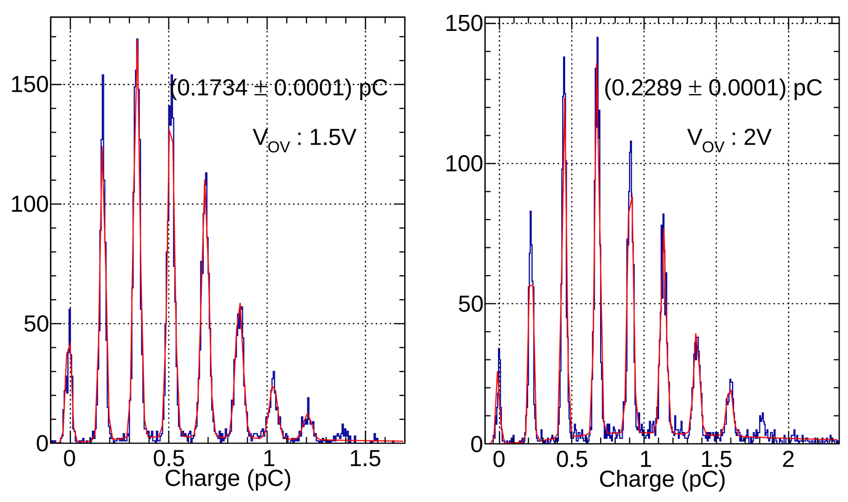
Calibration using LED

Few examples of raw signals from the setup :



The integrated charge is calculated using the equation :

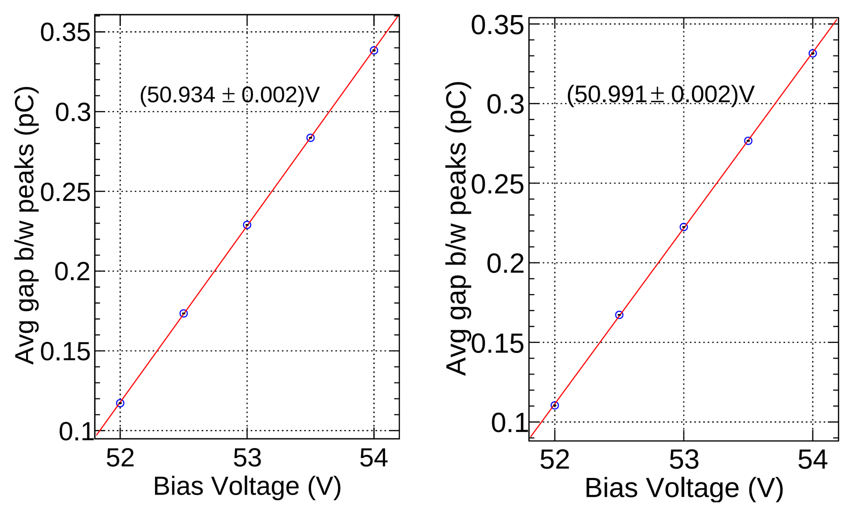
$$Q_{tot} = \frac{1}{R}\int_{t_0}^{t_1} V(t)dt$$



The total collected charge is fitted with a function [1]:

$$f(y) = Landau(y) + \sum_{a=0}^{N-1} R_a \times e^{-\frac{(y-a\mu)^2}{2\sigma^2}}$$

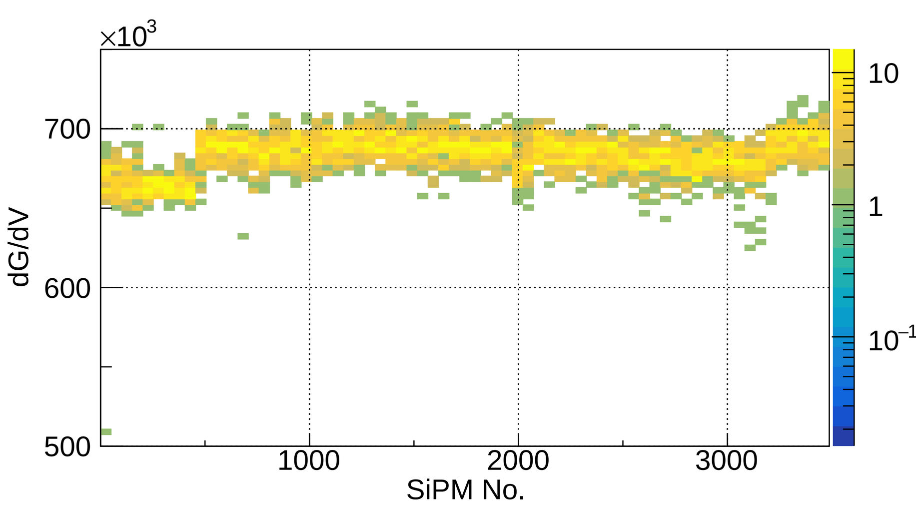
where N is the number of photoelectron (p.e.) peaks, R_a is the peak height, μ is the gain of SiPM and σ is the gaussian width of p.e. peak.



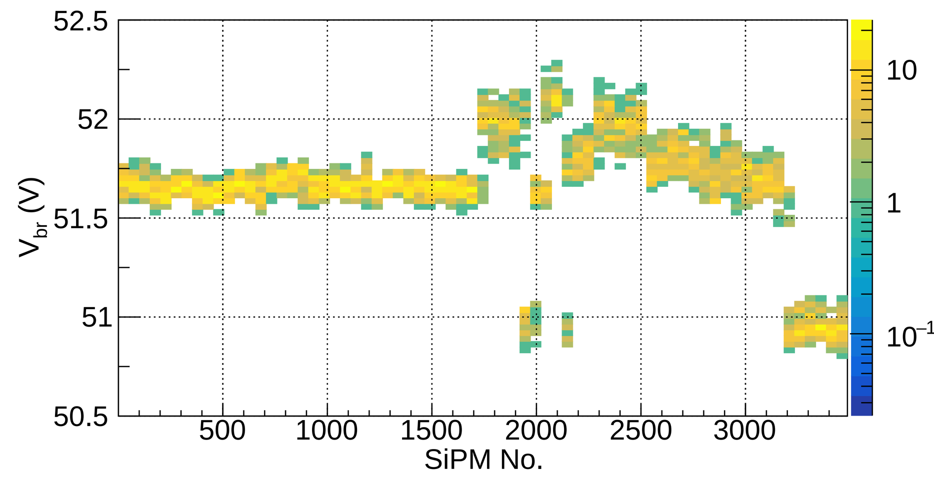
The average gap between the consecutive peaks increases linearly with V_{ov}.

Test Results from LED setup

From the linear fit, the breakdown point (V_{br}) and dG/dV is measured for each SiPM.



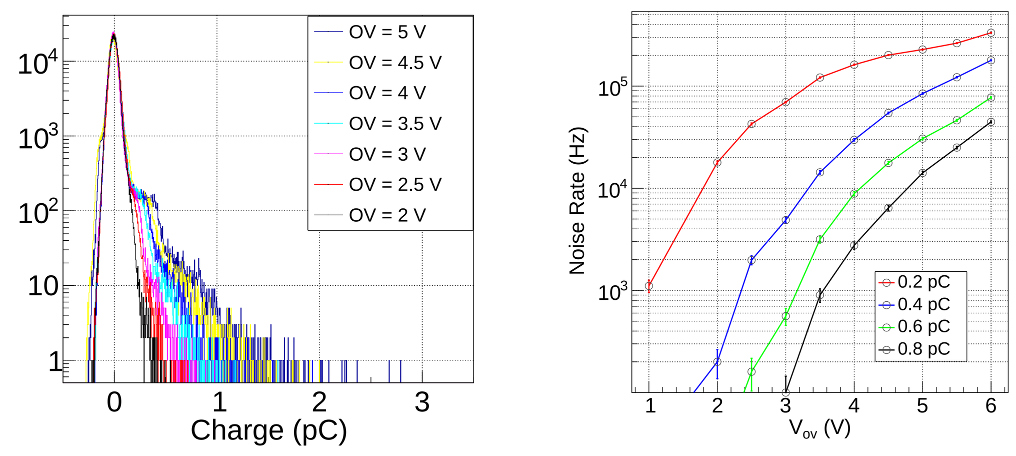
A summarised plot of dG/dV values for all SiPMs. One SiPM is found to be bad and one SiPM has low gain.

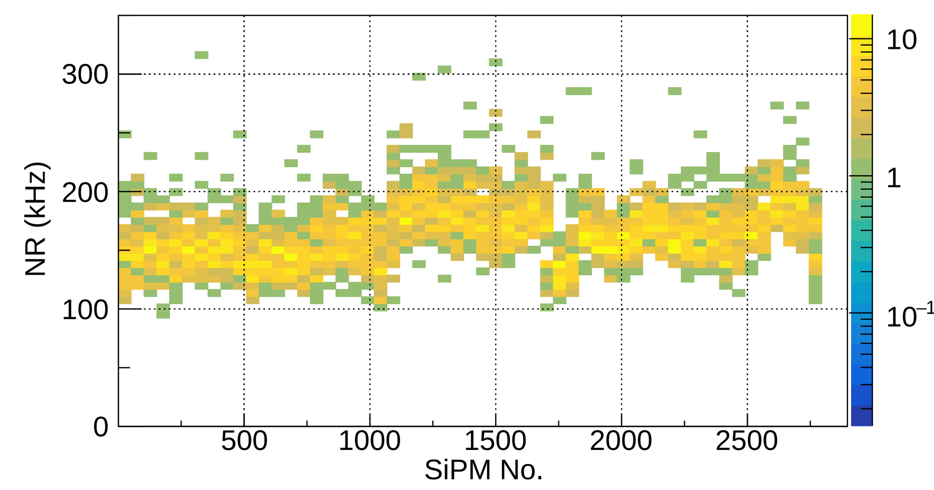


The measurement of V_{br} value for each SiPM. A total of three bands are observed for V_{br} values.

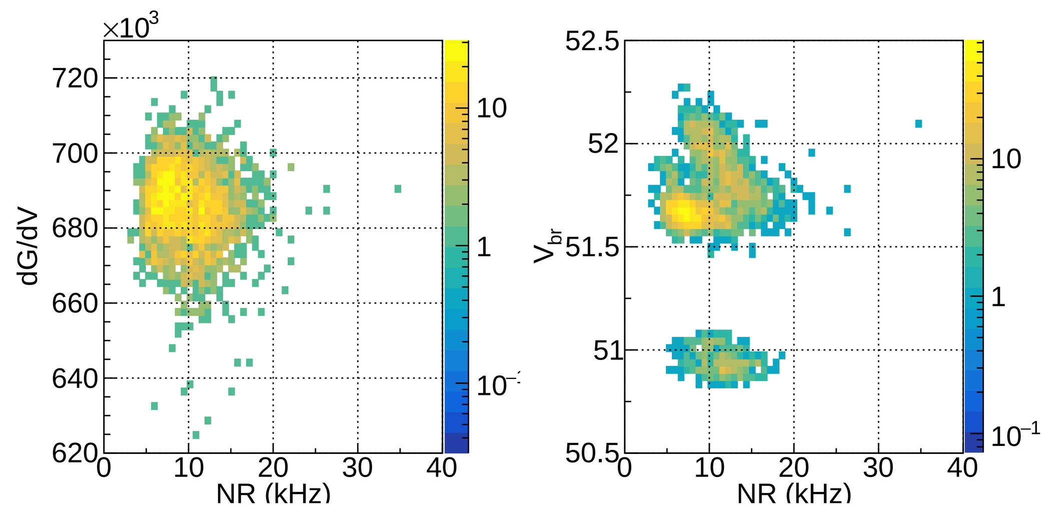
Noise rate measurement for SiPMs

The same light proof box is used without any LED signal.





The noise rate of each SiPM at a threshold of 0.5 photoelectron.



There are no correlation of noise rate with gain/V_{br}.

Conclusion

- Out of total 3488 SiPMs, all SiPMs are suitable for CMVD purposes except one.
- A total of 3 sets of values are obtained for the breakdown point of the SiPM.
- Noise rate of all tested SiPMs are within tolerable range.

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.

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