SiPM characterisation for cosmic muon veto detector of mini-ICAL.

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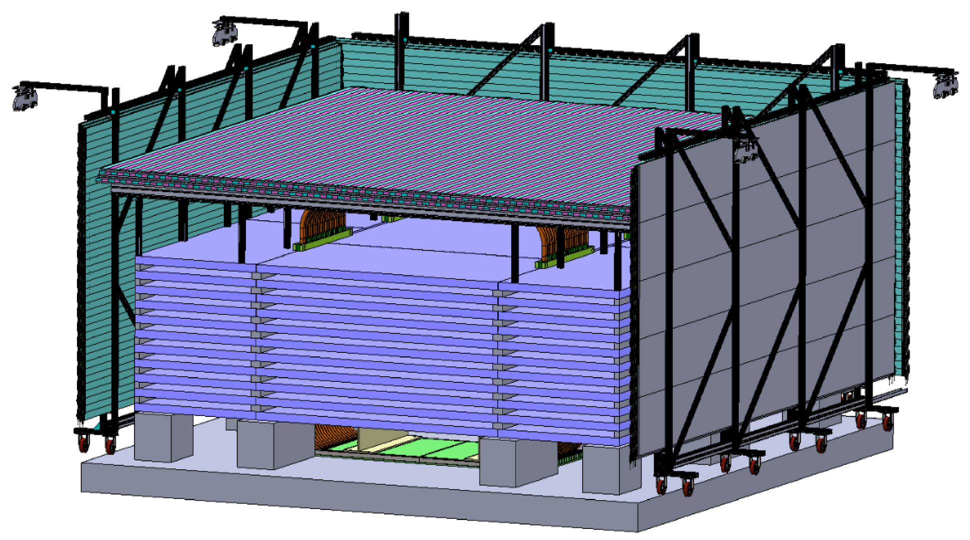
Abstract

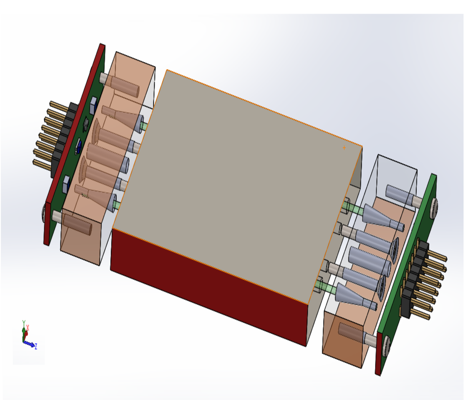
The prototype detector of Iron CALorimeter (ICAL) experiment at the India-based Neutrino Observatory i.e., mini-ICAL is currently running at IICHEP Madurai, India. An active cosmic muon veto (CMV) detector is going to house the mini-ICAL from top and sides except the front side. CMV consists of 5cm wide extruded plastic scintillators with embedded two WLS fibers to propagate scintillation light and SiPM at both ends of fibres as photosensors for detecting photons. The SiPM will be calibrated using an LED ultrafast driver. A small experimental setup is built to characterise the SiPM along with an extruded scintillator strip to optimise the operating over voltage, threshold of SiPM signals and the veto criteria by observing muon signals and the noise rates in the SiPM. These optimisations along with other characteristics of SiPM, e.g. cross-talk, after pulse, recovery time etc are presented in this poster.

CMV detector on top of Mini-ICAL

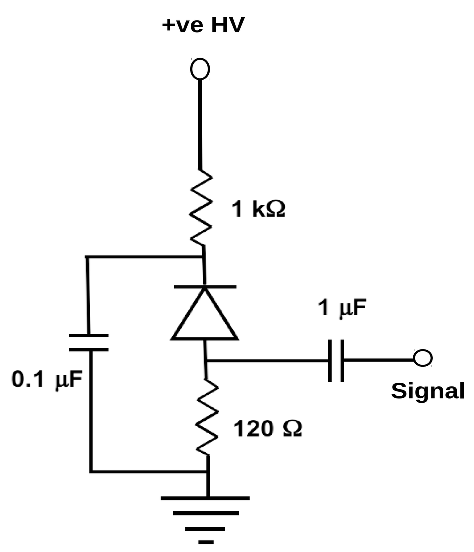


- 10 layers of RPC sandwitched between 11 layers of iron with 85 ton magnet.
- Muon veto walls of extruded plastic scintillator.

Signal readout and SiPM electronic



Scintillator counter schematic.



SiPM circuit diagram.

SiPM calibration using LED

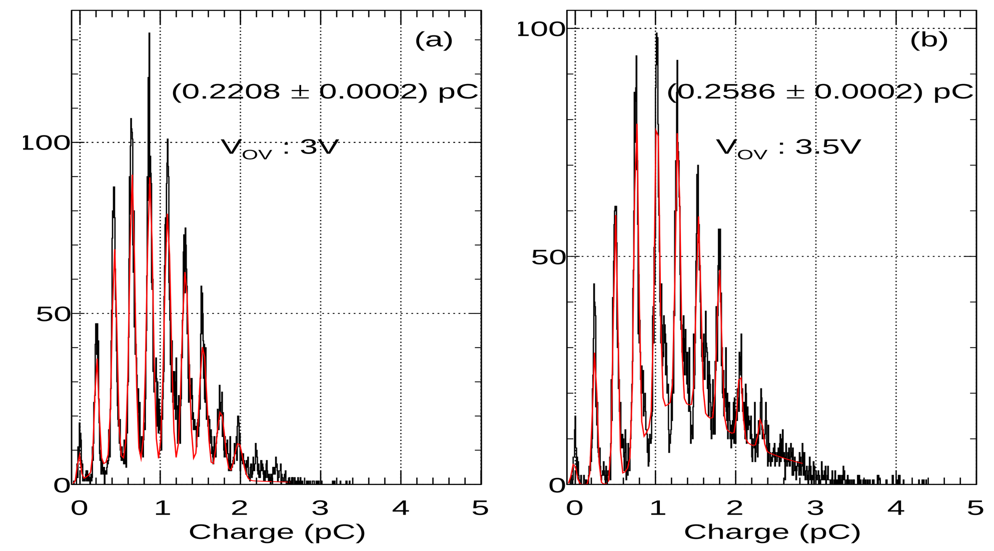
The integrated charge is calculated using the equation :

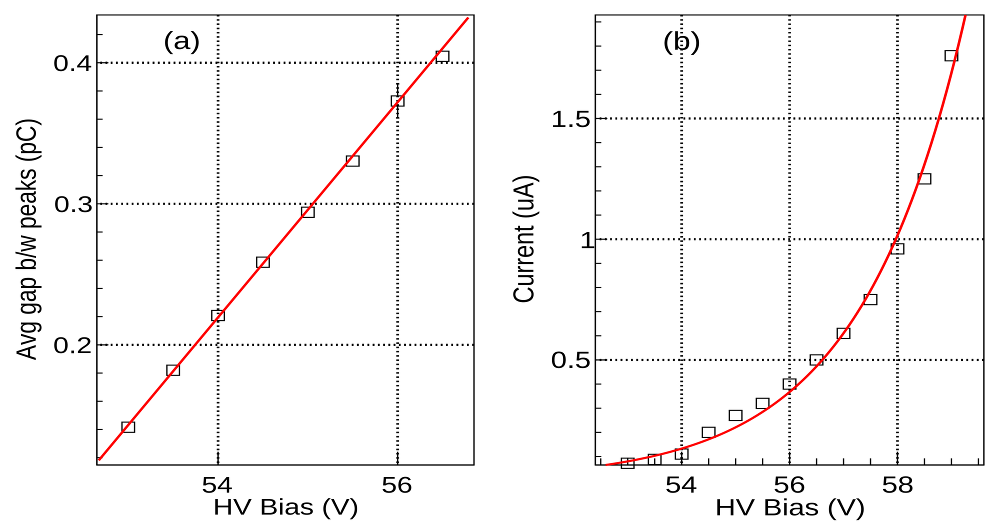
$$Q_{tot} = \frac{1}{R}\int_{t_0}^{t_1} V(t)dt \quad (1)$$

Total collected charge is fitted with a function:

$$f(q) = Landau(q) + \sum_{n=0}^{N-1} R_n \times exp\left(-\frac{(q-n\cdot\mu)^2}{2\sigma^2}\right) \quad (2)$$

where N is the number of photolectron (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.

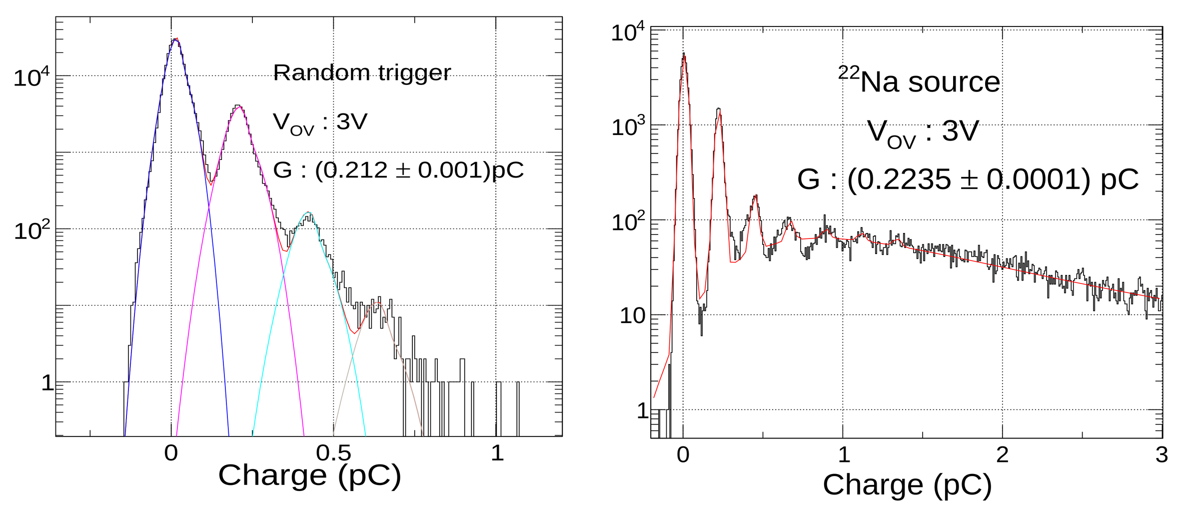




Good linearity of gain with V_{ov}. Dark current increases exponentially with V_{ov}, where V_{br} = 51.0 V.

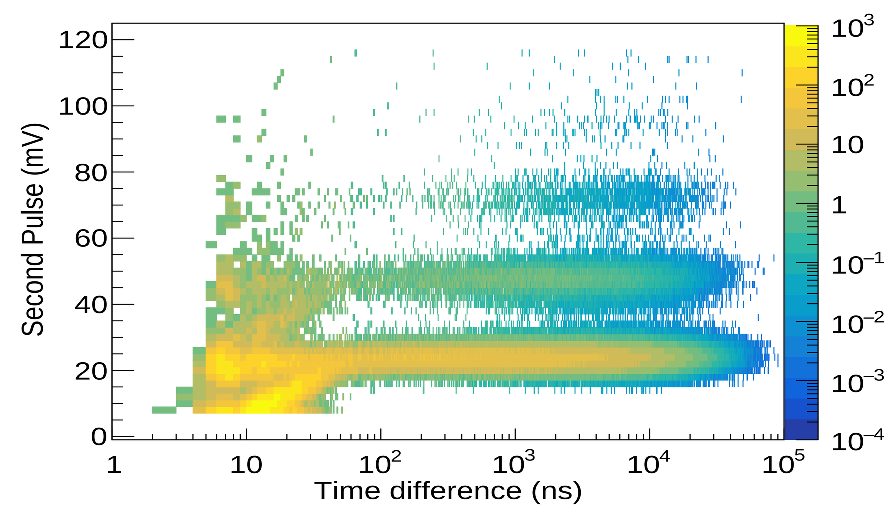
Calibration using random trigger and radio-active source data

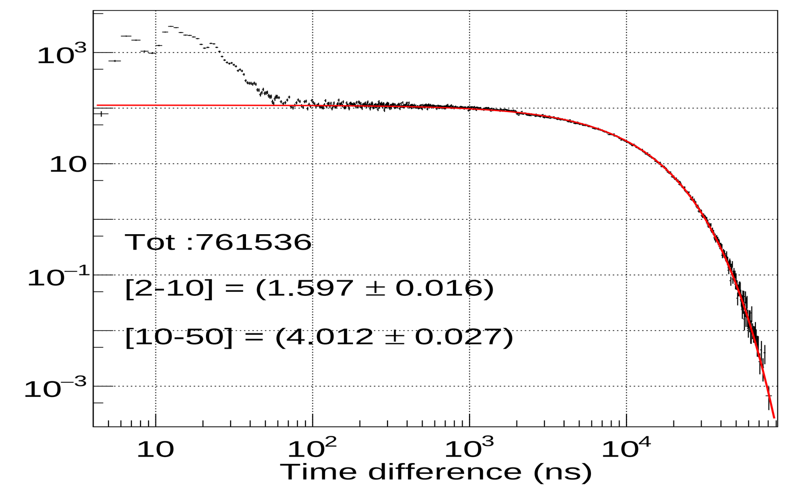
In all these calibration methods, single p.e. value is calculated by measuring the average gap between consecutive peaks from the fit.



Study of correlated noise

Correlated noise e.g., crosstalk and afterpulse along with primary Dark Count Rate (DCR) can deteriorate the SiPM performance. The most common method to measure DCR and correlated noise rate is to study the output pulses from SiPM at controlled temperature in a dark environment. [1, 2].

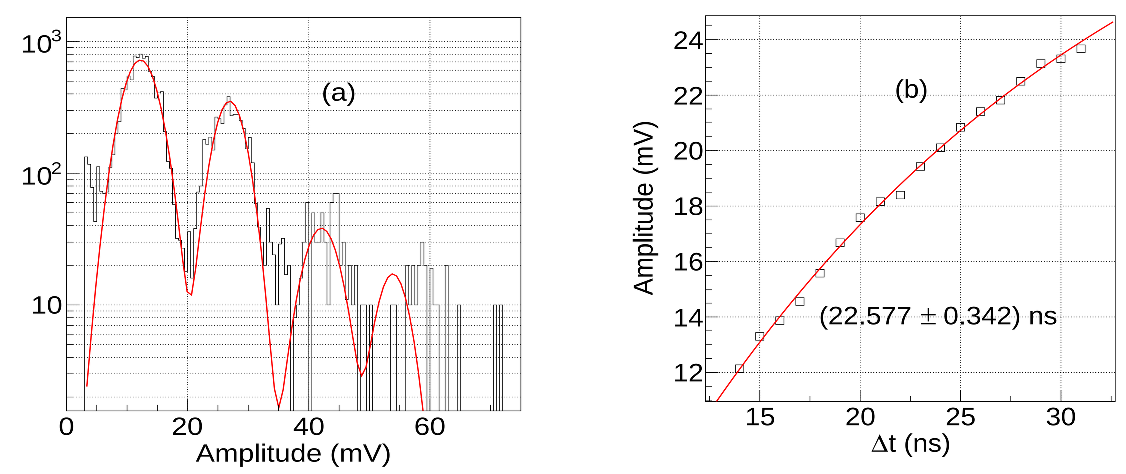




Events due to afterpulse and crosstalk can be seen clearly. Rates have been calculated by taking the difference between the actual values and the fit values by extrapolation.

Recovery time of SiPM

Fit of the position of after pulse for various time differences.



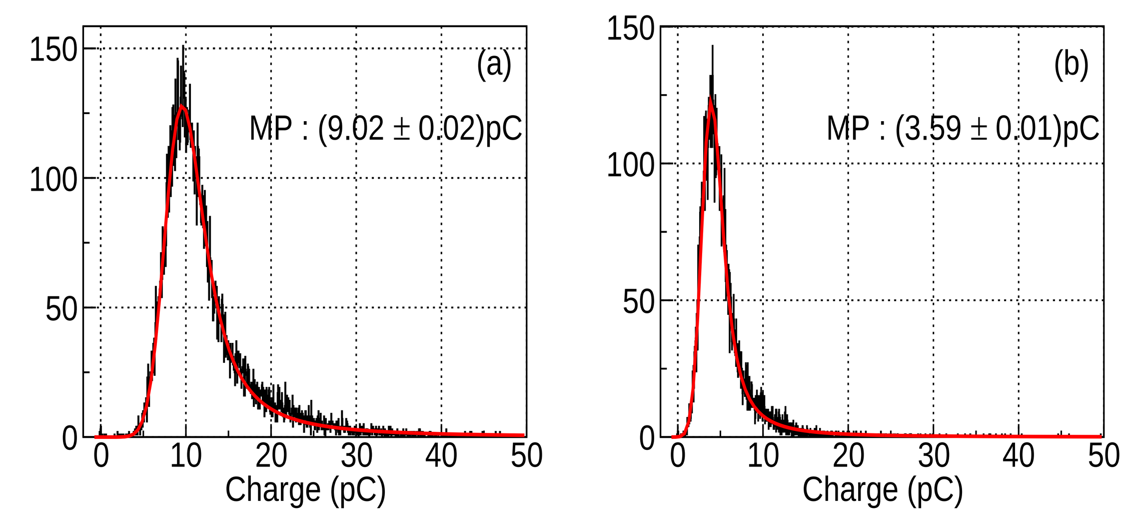
The distribution (a) is fitted with individual four Gaussian functions, 2nd and fourth are for the peak of after pulse and the distribution (b) is fitted with :

$$f(\Delta t) = p_0 \times \left[1 - exp\left(-\frac{(\Delta t - t_0)}{\lambda}\right)\right] \quad (3)$$

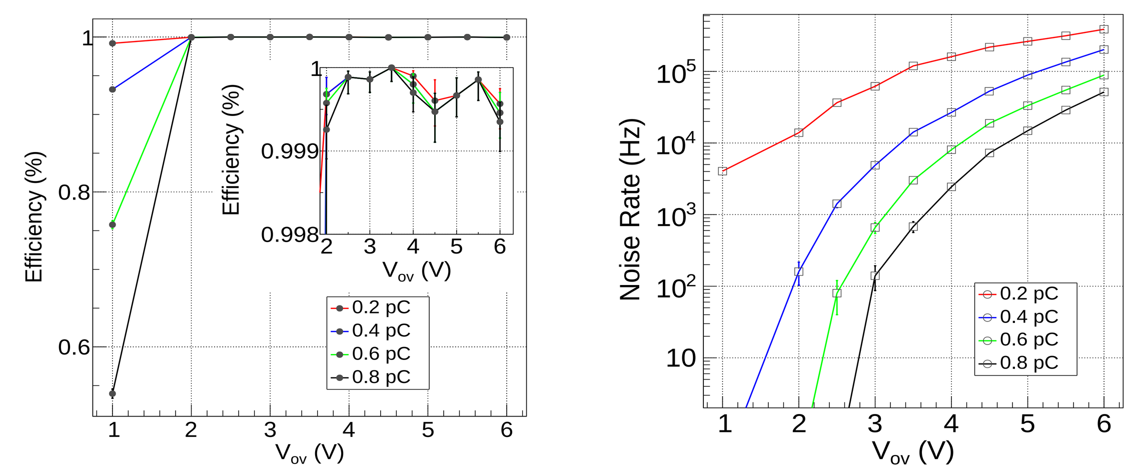
where λ is the decay constant. Recovery time is found to be vary from (10 - 35) ns for different V_{ov}.

Optimisation of signal efficiency vs noise rate

Cosmic muon signal for the WLS fibre length 26 cm and 4.25 m.



Efficiency of a scintillator detector bar is defined as at least two out of four SiPMs having signals within 100 ns time window with integrated charge more than the threshold value. Muon selection efficiency requires at least two overlapping trigger scintillator bars. Muon detection efficiency and noise rate for various V_{ov} and threshold on integrated charge.



Conclusion

- Correlated noise is observed to be (5 - 6)% of the total noise.
- Optimised value of V_{ov} is decided to be (2 - 3) V.
- Noise Rate at $V_{ov} = 3V$ is of order of tens of kHz at a threshold of one photoelectron.

References

[1] Claudio Piemonte, Alberto Gola, Overview on the main parameters and technology of modern Silicon Photomultipliers, Nuclear Inst. and Methods in Physics Research, A 926 (2019) 2-15.

[2] Robert Klanner, Characterisation of SiPM's, Nuclear Inst. and Methods in Physics Research, A 926 (2019) 36-56.

Acknowledgements

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