Uniformity study of large size glass RPC detector using an alternative front-end electronics for INO-ICAL Experiment

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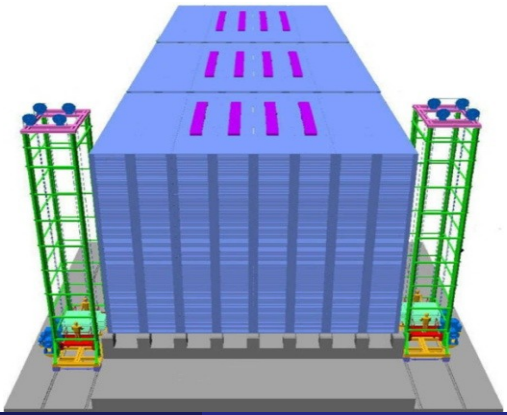
Overview

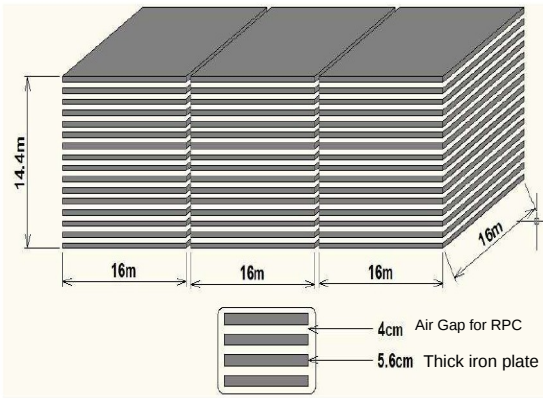
Introduction

The proposed 51 kton magnetized Iron-CALorimeter (ICAL) detector at India-based Neutrino Observatory (INO) aims to study the atmospheric neutrinos and antineutrinos in an underground lab.

The complete detector require approx 29,000 Resistive Plate Chambers (RPCs) for detecting charged particles, which in turn requires 3.7 million electronic channels to be read out.

Such a large number of channels require an efficient, compact, low power consumption and cost-effective readout system.





Uniformity

RPC will be used as tracker in ICAL, therefore, uniformity across the detector is important to build tracks efficiently and also for global threshold setting.

Significant variation in performance across the detector can affect data quality and related information which will ultimately affect the physics outcome.

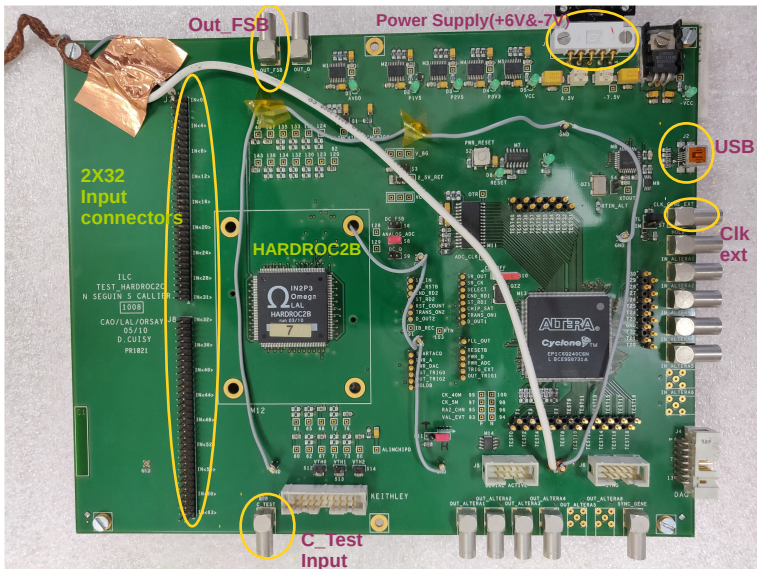
The ICAL RPC will be 2m X 2m in size. To begin our In our study we performed uniformity study on 1m X 1m RPC with 32 strips.

Testboard

The University of Delhi group tested and commissioned multichannel system HARDROC as an readout option for the ICAL RPCs.

HARDROC (Hadronic Rpc Detector ReadOut Chip) is a 64-channel front end ASIC designed primarily for the readout of gaseous detector like RPCs.

There are three versions of HARDROC, we used version 2 versions called HARDROC2B for our study.

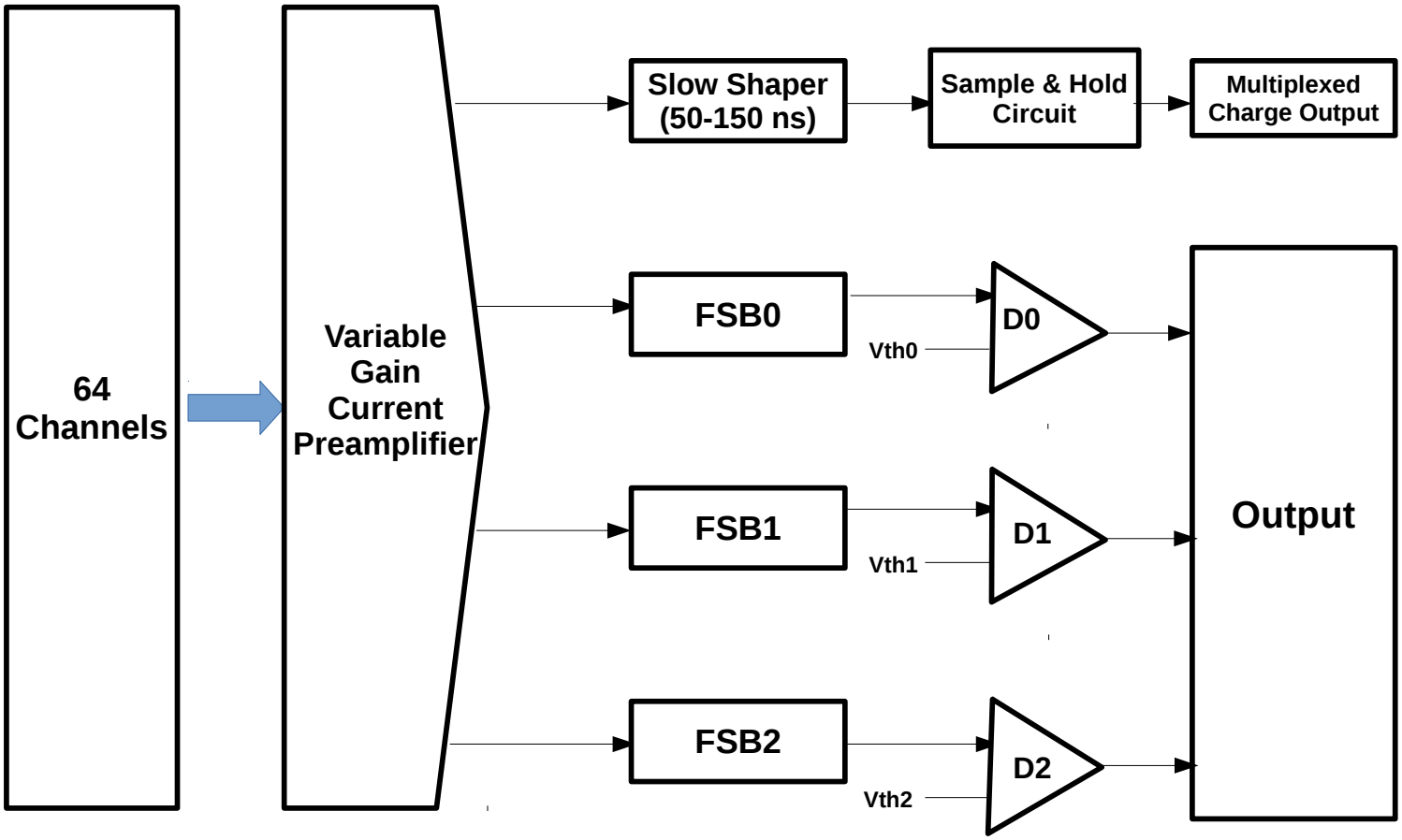


Characteristics of HARDROC

The 64 channels of the HARDROC2 are made of:

- A fast low impedance current preamplifier with 8-bit variable gain (analog G=0 to 2)
- A variable slow shaper (50-150ns) followed by a Track and Hold buffer to provide a multiplexed analog charge output up to 10pC
- 3 variable gain CR-RC fast shapers (peaking time 20-25 ns)
  FSB0 is dedicated for input charges from 10fC up to 100fC
  FSB1 for input charges from 100fC up to 1pC
  FSB2 for input charges from 1pC up to 10pC
- 3 low offset discriminators
  3 internal 10 bit- DACs to set the thresholds
  3 discriminators are sent to a 3 input to 2 output encoder.

Synoptic layout of HARDROC2 chip

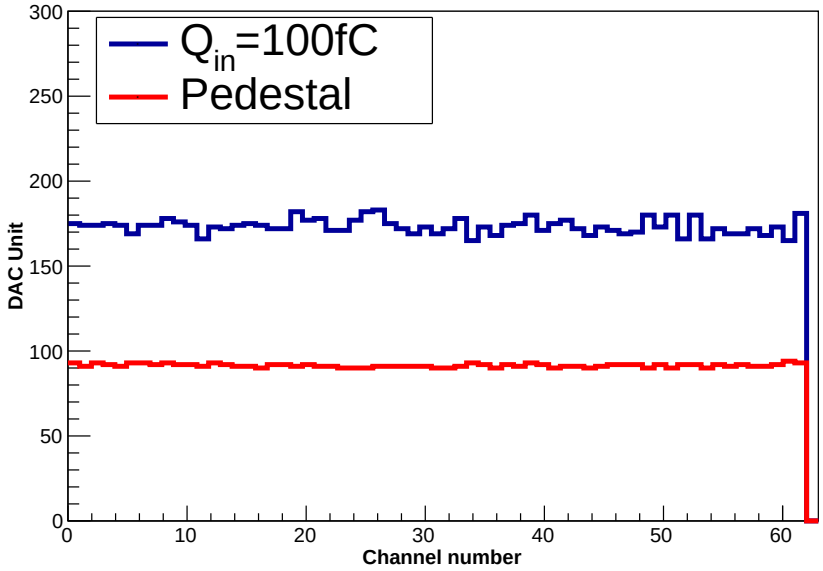


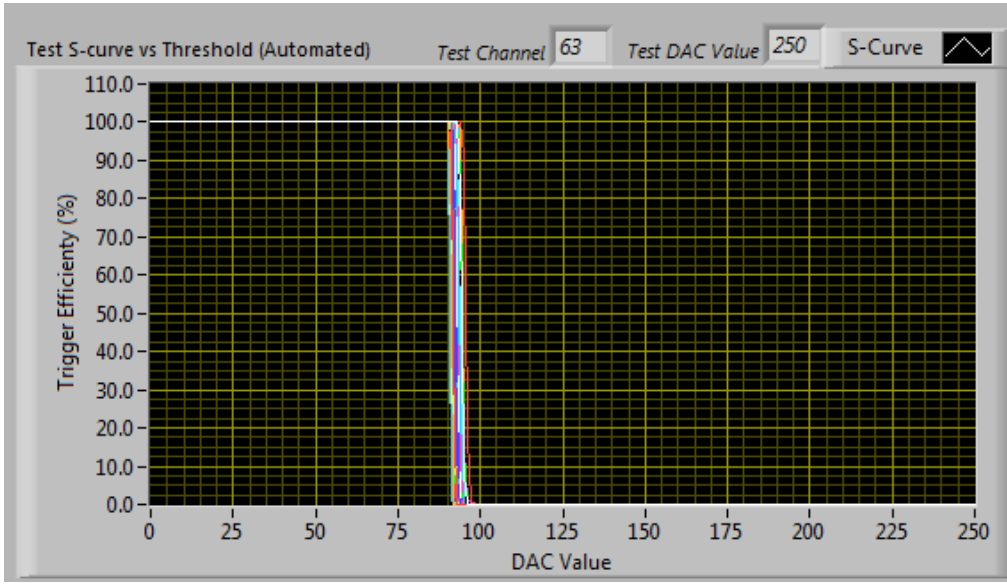
FSB: Bipolar Fast Shaper
D0,D1,D2: Discriminators

S-Curve

The gain of each of the 64 channels of the HARDROC is varied to have a uniform response to given charge.

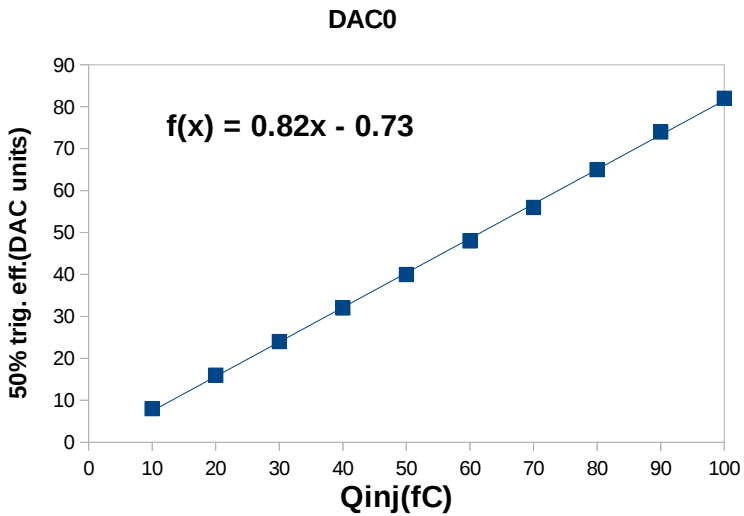
S-curve: dispersion of 64 pedestals
Threshold value in DAC units corresponding to 50% efficiency of the curve.

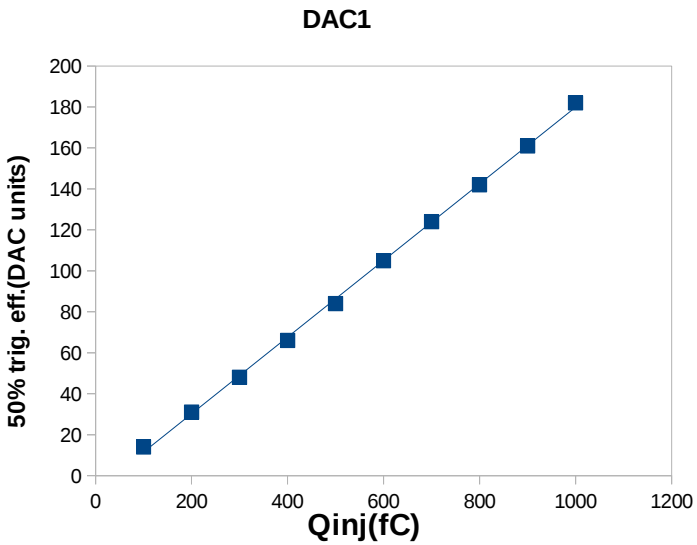


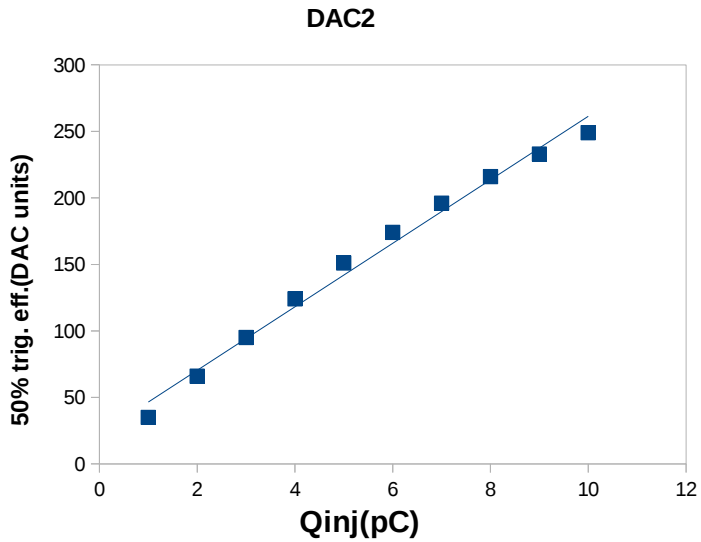


Shaper Linearity

The equation is obtained after subtracting the pedestals





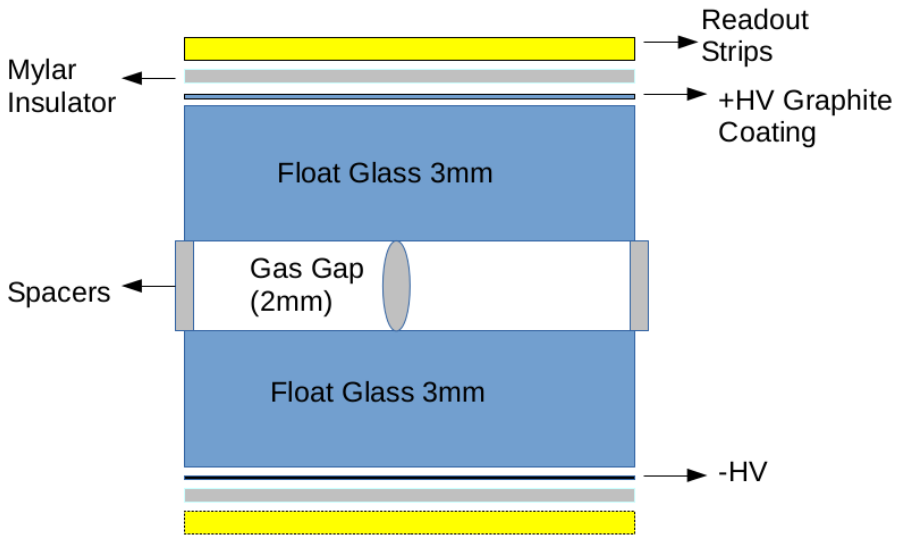


Resistive Plate Chamber Detector

- Resistive Plate Chambers(RPCs) are gaseous parallel plate particle detectors utilising a constant and uniform electric field produced by two parallel resistive electrode plates, a gas mixture with a high absorption coefficient for ultraviolet light is flown through the gap between the electrodes.
- Advantage: RPCs are simple to construct and operate, low cost per unit area of coverage, good homogeneity of the sensitive medium, excellent sub-nanosecond time resolutions and good position resolution. This makes them excellent timing and triggering detectors, especially in muon systems for general purpose detector experiments.
- Working Principle: The passage of charged particle through the gas gap produce primary ionization cluster which under the effect of electric field develop avalanches in the gas. This exponential avalanche growth induces signal on the external readout electrodes.

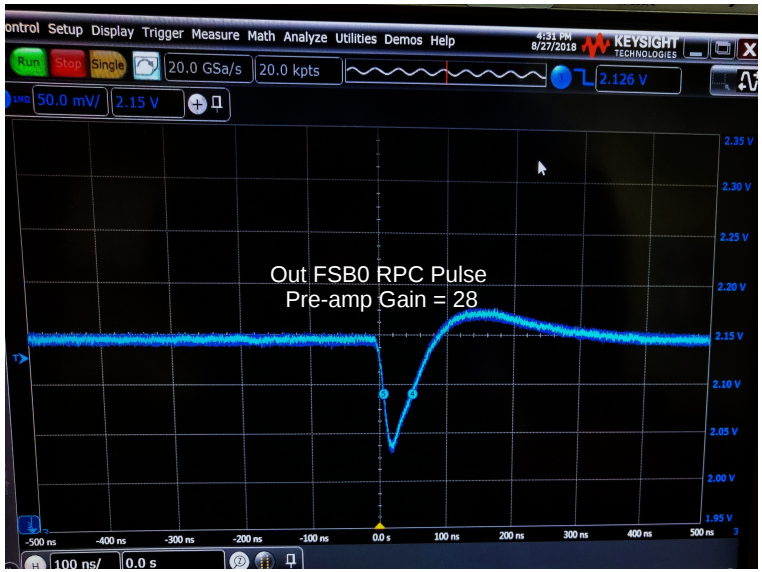
Structure of an RPC

- Two parallel high resistive electrodes: Glass 10^{12} - 10^{13} Ω-cm
- Graphite coating to distribute the high voltage
- Spacers to ensure uniform gap thickness (2mm)
- Copper readout strips (strip pitch 30mm) on both read-out planes
- Gases: R134a (94.5%), isobutane (5%), SF_6 (0.5%)

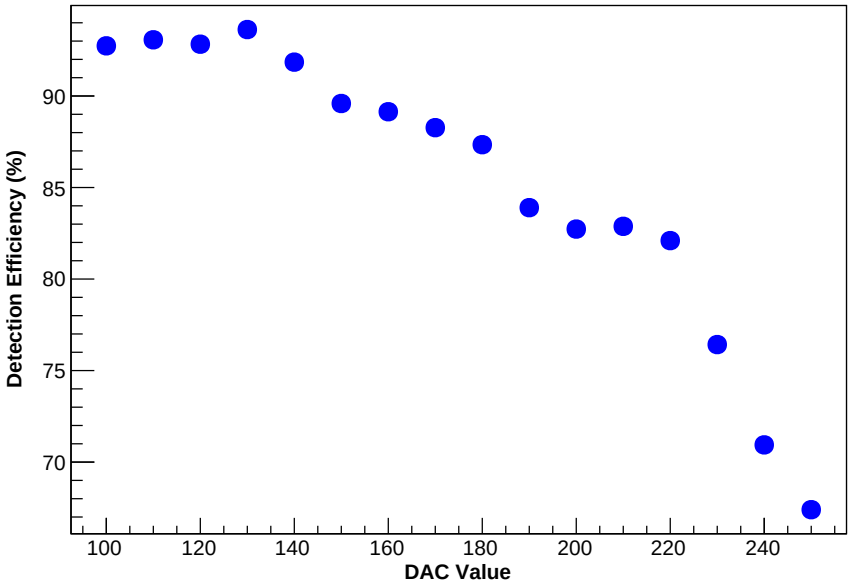


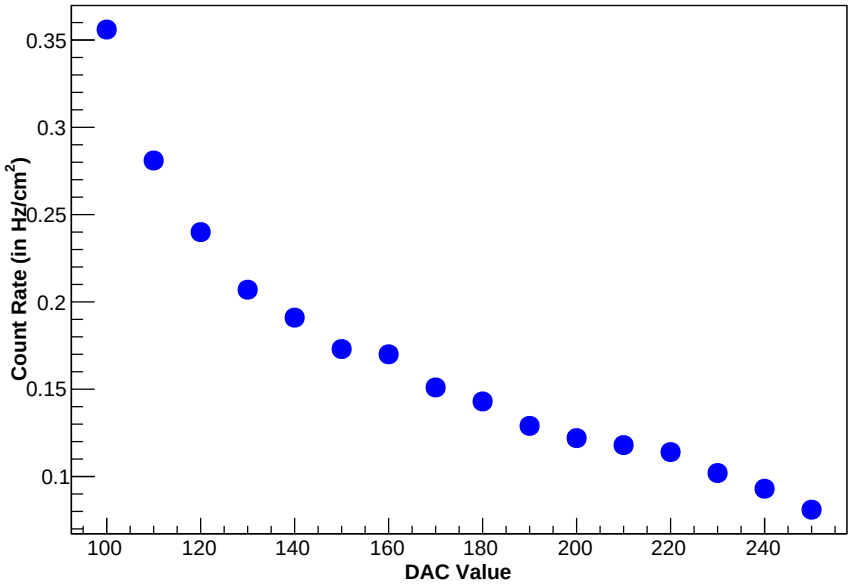
RPC/HARDROC pulse

Detector Read-out	RPC
No of Channels	64
Polarity	Negative
Dynamic Range	10fC-10pC
Power Consumption	10μW/channel
Input	64 current input
Peaking Time	20 ns



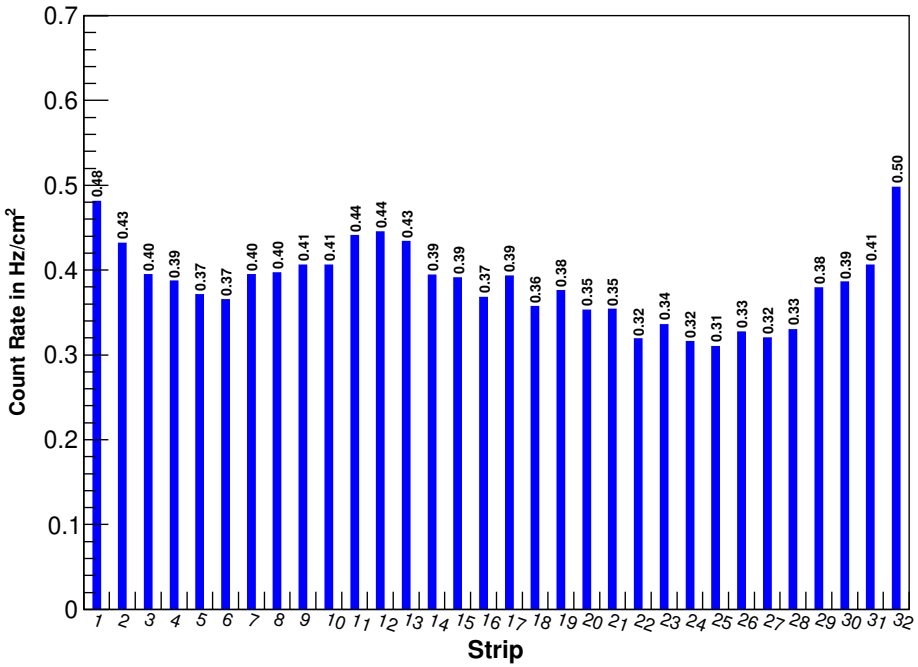
Threshold Scan





1. Efficiency decreasing down to 70% at 240 DAC value.
2. Count rate moving as expected $\Rightarrow$ lowering as threshold increases

Count Rate

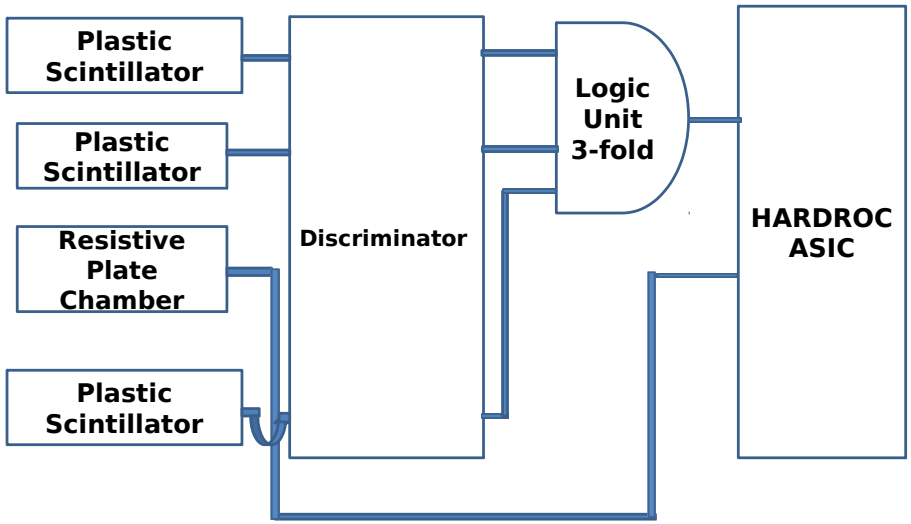


The count rate is determined independently for each strips by counting the number of hits that are above the discrimination threshold per unit area of the strip.

Higher count rate at the edges are observed.

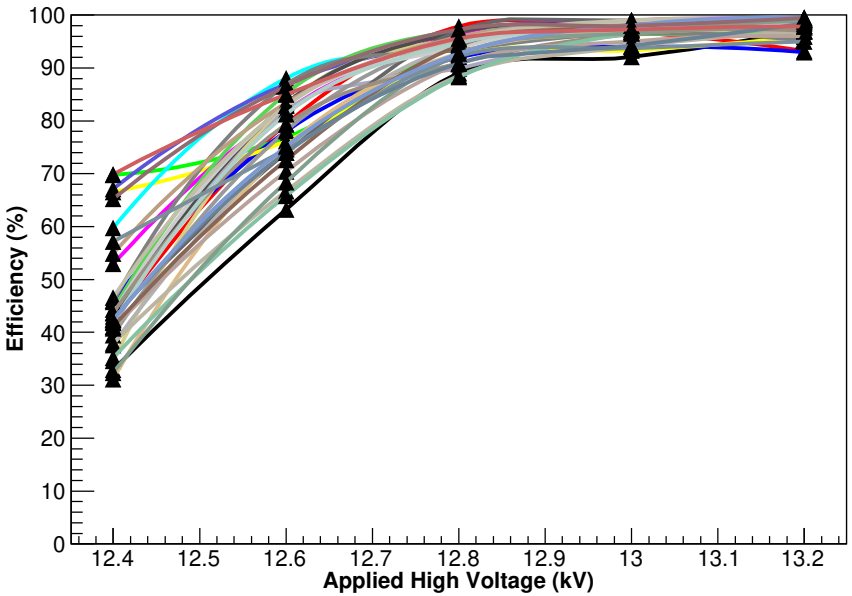
Experimental Set-up

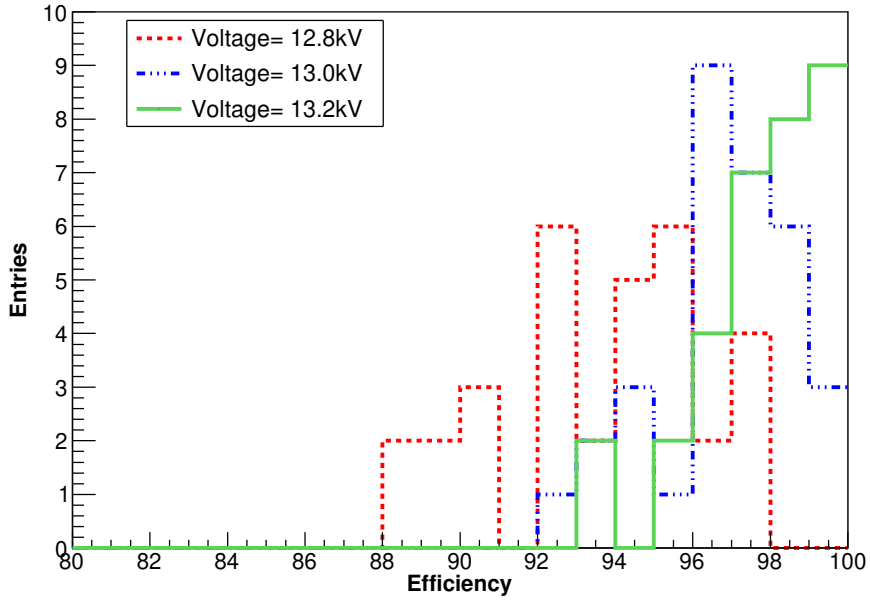
The trigger system is made of three scintillators each couples to a PMT. The detector performance and characterization were carried out by using cosmic ray muons. The efficiency is obtained by evaluating the ratio between the number of events in which RPC strip under consideration has fired to the total number of triggered events in the time window of 200 ns.



HARDROC Set-up

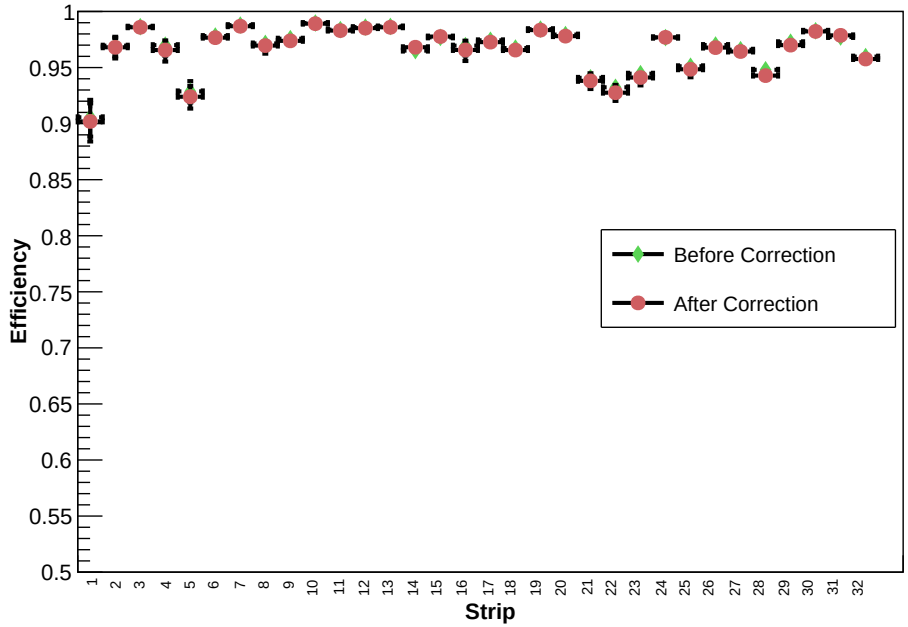
Efficiency Distribution for all the Strips





Scan of efficiency at equidistant high voltage points.
Efficiency is above 90% from 12.8 kV voltage onwards.
The spread of efficiency for all the strips is less than 5% from mean value for applied high voltage of 13 kV and 13.2 kV.

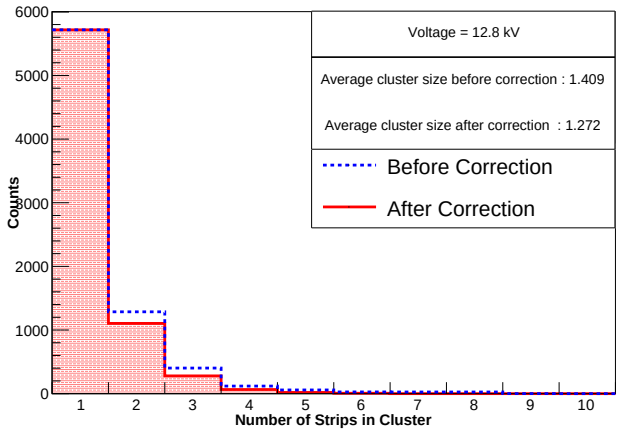
RPC Plateau Efficiency

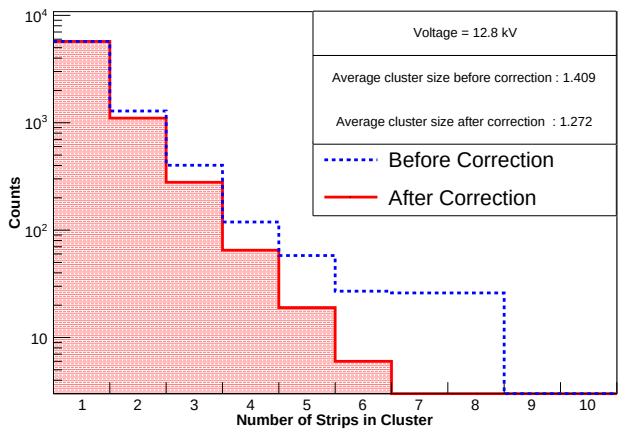


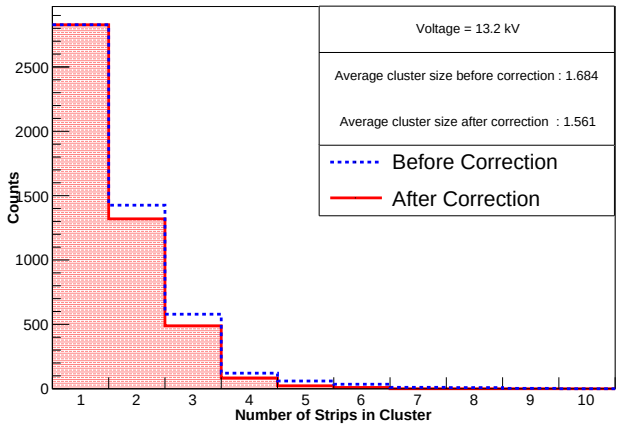
RPC plateau efficiency distribution at 13 kV for all the strips.
No significant reduction in efficiency has been observed after neglecting the events which show noisy events or multiple cluster hit in the detector within fixed interval.

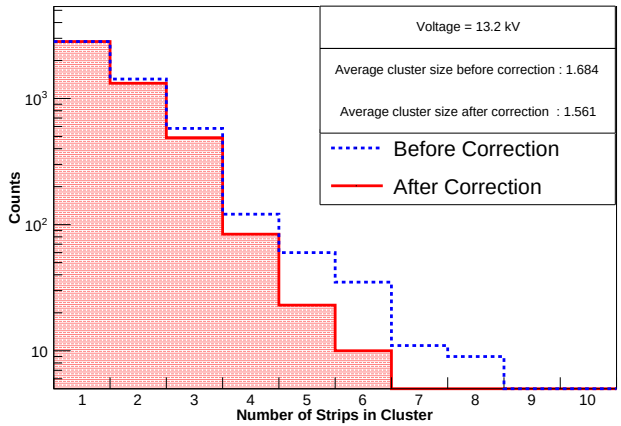
Hit Multiplicity

A correction in the number of fired strips is done by considering only the consecutive set of strips i.e. clustering of strips to be adjacent.



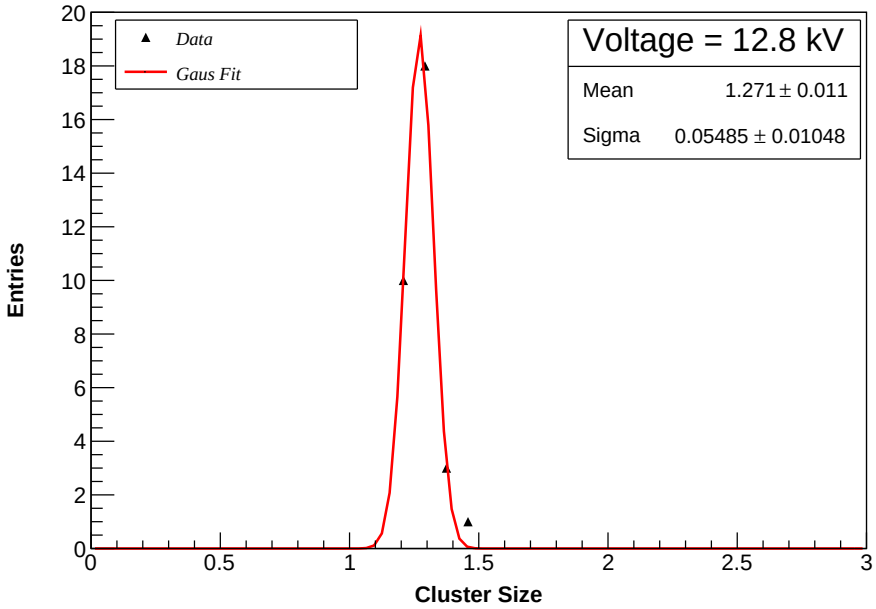


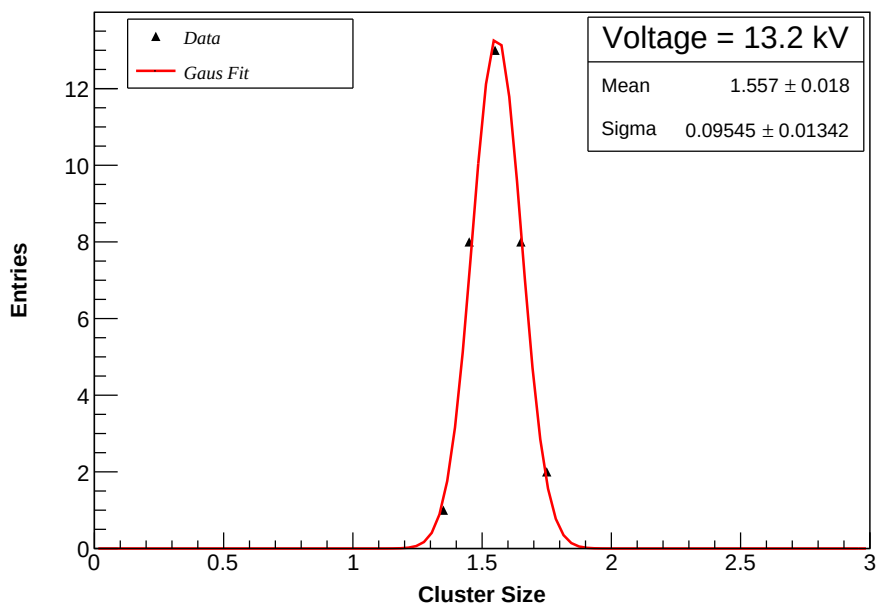




Distribution of the Cluster Size

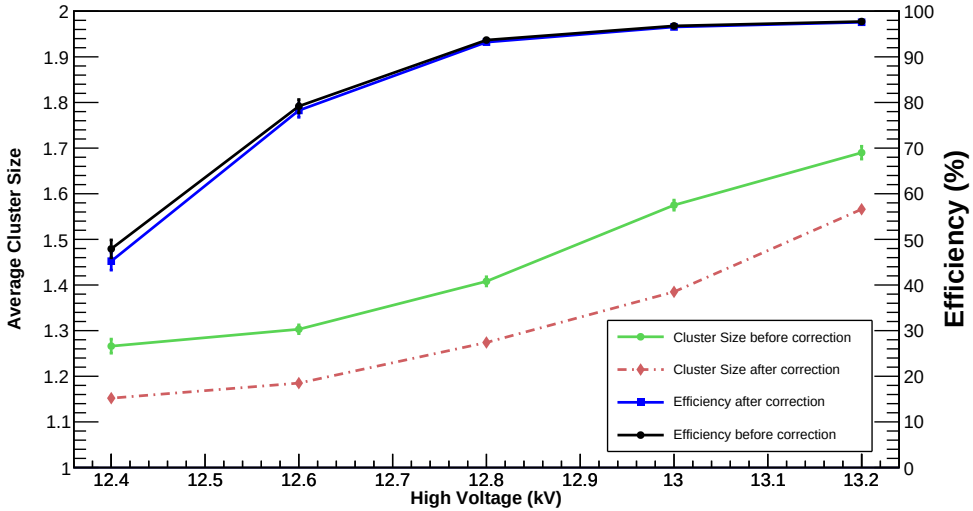
Cluster size is defined as the number of adjacent strips fired above the threshold once a charged particle pass through the detector.
The cluster size response for all the strips at two different applied voltages are shown in Fig





As the high voltage is increased in the plateau of the detector, the consecutive neighbour strips also gets fired.

Mean Cluster Size and Efficiency of the chamber



More than 95% efficiency is achieved at the operating voltage of 13.0 kV while the cluster size remains less than 1.4 after applying the corrections. No visible reduction in the efficiency has been observed after correction, whereas the cluster size reduces after correction

Uniformity in Cluster Size for the 4 sectors of the RPC

The variation of cluster size in four different regions of the detector, with each sector divided in 8 readout strips, which corresponds to 25 cm region.

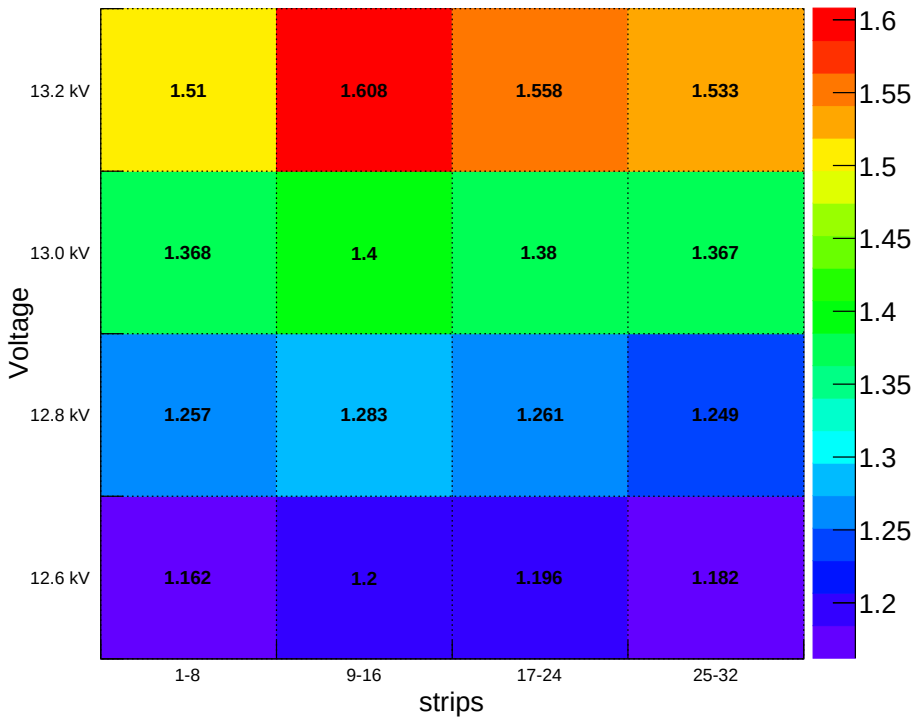


Figure shows that the uniformity in the cluster size amongst all the regions is within 5% from the mean values in the plateau region.

Summary

Test Study

The calibration and testing of The HARDROC ASIC has been performed.

DAC Threshold

The correlation between the DAC values and charge of FSB0 is used to set the proper threshold.

Performance

Count rate for most of the strips are within 15% of the mean value $0.38 Hz/cm^2$.
The average cluster size of the detector at plateau voltage 13 kV is 1.4 strips with all the strips having efficiency above 90%.
The detector has been found to be uniform within 5% for cluster size as well as efficiency over 32 strips.
This uniformity in response seems reasonable for the application in INO-ICAL experiment.

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