Characterization and Testing of
Glass Resistive Plate Chamber

Submitted by

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Introduction

Resistive plate chambers (RPC) are the active detectors used in ICAL (Iron Calorimeter) for India based Neutrino Observatory. RPCs are widely used to detect high energy cosmic ray muons. RPCs are preferred due to their high gain, good spatial resolution, low cost and simple design compared to other particle detectors.

Modes of Operation

There are two modes of operation for RPCs, i) Avalanche Mode and ii) Streamer mode.

1.) Avalanche Mode

Charged particles passing through the gaseous medium produce primary ionization. Ionized particles are accelerated by electric field which produces secondary ionization by colliding with the other molecules. This avalanche stops as the external field opposes the internal field due to ionization and the charged particles get collected on the respective electrodes. The pulse produces in this mode will be small in the order of few mill volts and amplifiers are required in the signal readout system.

2.) Streamer Mode

In this mode of operation, the electric field inside the gap is kept intense enough to generate limited discharges localized near the crossing point of the ionizing particle. Signal generated will be large in the order few hundreds of milli volt.

Before ,

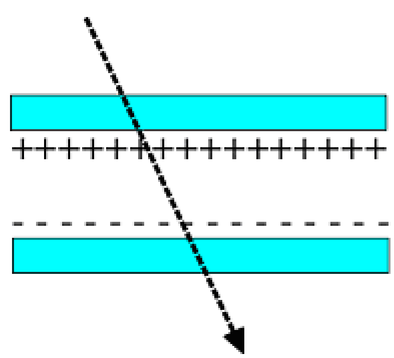


Fig.1.1a

After ,

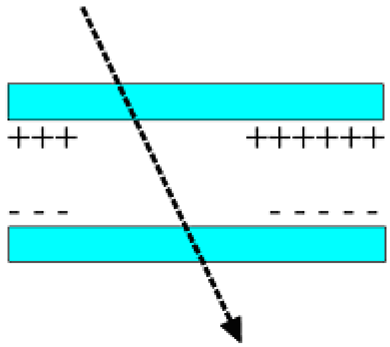
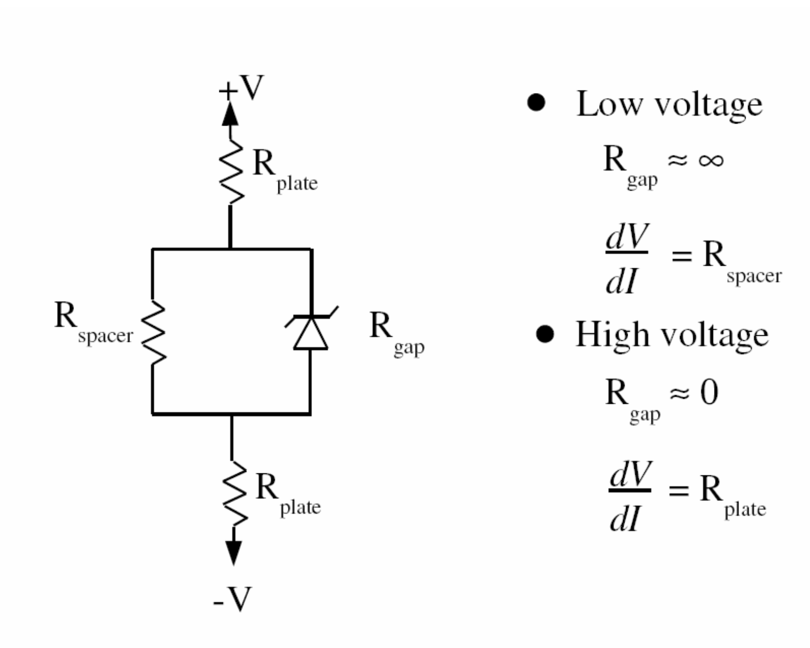


Fig.1.1b

The discharge is localized to a small area of 0.1 cm^2 due to the high resistivity of glass electrodes ($10^{12}\Omega$ cm). The discharge leads to a signal on both X and Y pick up strips generated by induction. Recovery time is about 2 seconds. Even though, the 0.1 cm^2 area of RPC is locally dead for 2 seconds, the other area of the detector is active to give signal.

Electrical Representation of RPC



Fabrication of 1m X 1m RPC

Various stages involved in the fabrication of RPC are,

1.) Glass Cutting And Cleaning
2.) Conductive (graphite) coating.
3.) Gluing of glass.
4.) Surface resistance Measurement.
5.) Gas leak test.
6.) Connecting High Voltage cables.

7.) Packing with pick up panels.
8.) Connecting pre-amplifier boards.

Gas Mixture

The gas volume is a mixture of three gases. Their composition and functioning are described below,

1.) Freon (R134A) is an eco-friendly gas. 95.2% of the mixture is Freon.
2.) 4.5% of the gas mixture is isobutene.
3.) 0.3% of the gas mixture is SF_6.

In Avalanche mode, we use the highly electronegative gas, Freon which reduces the avalanche electron number. Isobutene is the ‘photon quenching gas’. It absorbs the ultraviolet photons produced in the electron-ion recombination.SF_6 (Sulphur hexafluoride) used control the extra produced electrons.

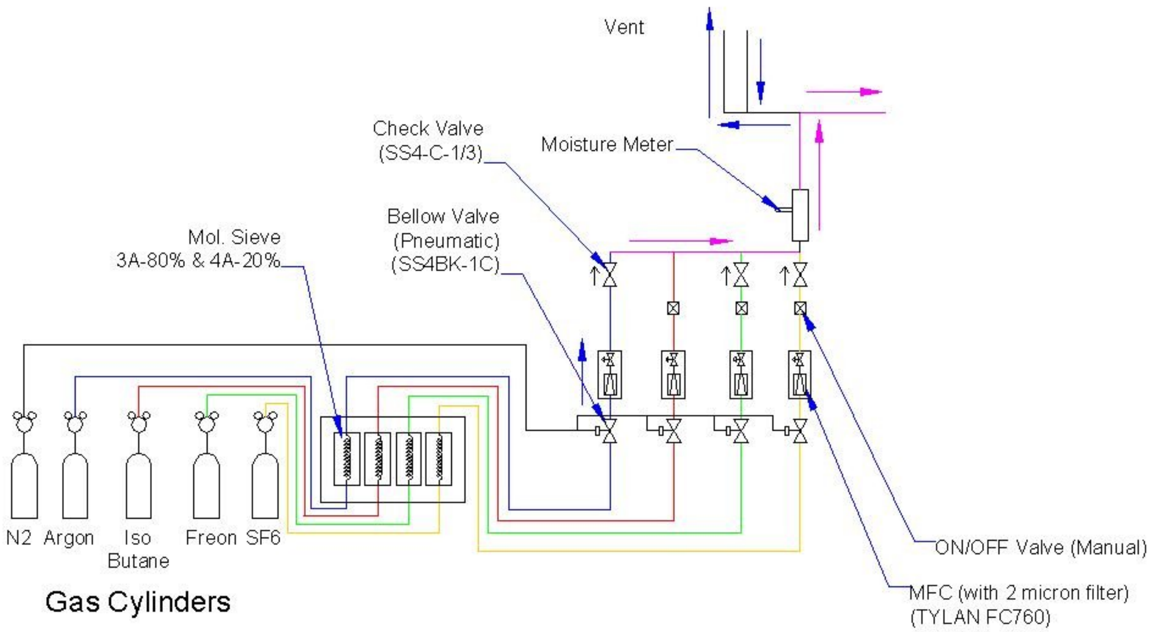
Gas Flow System

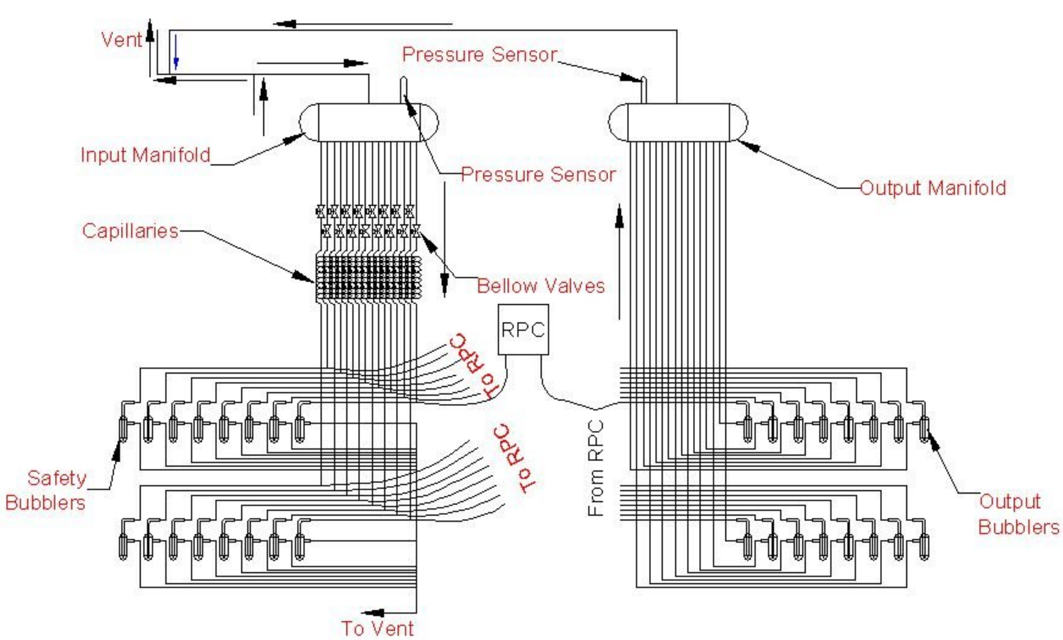
The system is designed for mixing four gases. Argon, Freon (134A), Isobutene and SF_6 gases by volumetric method. The gas flow system consists of the following components,

1.) Purifier Column
It contains molecular sieve used to absorb moisture and purify it.
2.) Mixing Unit
Mixing unit is based on MFCs (Mass Flow Controllers) and the flow of gas is displayed in SCCM (Standard Cubic Centimeter per Minute).
3.) Distribution Panel
In this Panel RPCs can be connected in parallel, which is achieved by “Flow Resistor”.
4.) Safety Bubblers
Safety bubblers take care of the back pressure exerted and protect RPCs from over pressurizing.
5.) Isolation Bubblers
It prevents back diffusion of air in to the RPC and also indicate the flow of gas.
6.) Exhaust Manifold
All the gas to be vented is collected in this manifold and a single is provided to vent the used gas in to the atmosphere. This manifold has a pressure sensor to indicate the pressure with respect to room temperature.

7.) Moisture meter

Block Diagram of Gas Flow System


Vent
Check Valve
(SS4-C-1/3)
Moisture Meter
Bellow Valve
(Pneumatic)
(SS4BK-1C)
Mol. Sieve
3A-80% & 4A-20%
N2
Argon
Iso
Butane
Freon
SF6
Gas Cylinders
ON/OFF Valve (Manual)
MFC (with 2 micron filter)
(TYLAN FC760)


Vent
Pressure Sensor
Input Manifold
Pressure Sensor
Output Manifold
Capillaries
Bellow Valves
RPC
To RPC
To RPC
From RPC
Safety
Bubblers
Output
Bubblers
To Vent

Assignment .1

Aim

To calculate Tracking efficiencies of 12 RPCs in the C217 stack.

Procedure

1. For Trigger Condition : Keep alternate RPCs (AB08, AB04,AB01,IB02,AB11,AB07) in coincidence to form trigger and the other alternate layer(AB12,AB03,AB02,AB09,AB10,AB06) for Plateauing.

2. Vary high voltage from 8.8 KV to 10KV and calculate efficiency for each voltage.

3. Do the same for both X-plane and Y-plane of the RPC.
4. Plot efficiency versus high voltage and calculate the operating voltage.
5. Change Trigger condition by keeping platued RPCs (AB12,AB03,AB02,AB09,AB10,AB06) for triggering and the other alternate layers (AB08, AB04,AB01,IB02,AB11,AB07) for Plateauing.
6. Repeat step number 2 to 4.

Results

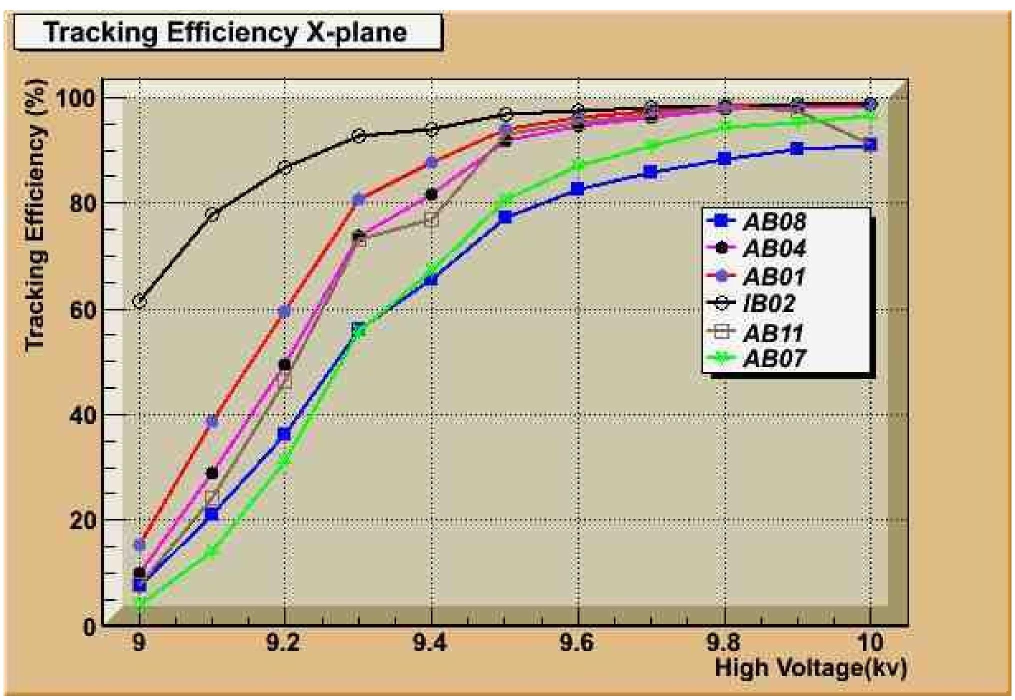


Fig.1.a

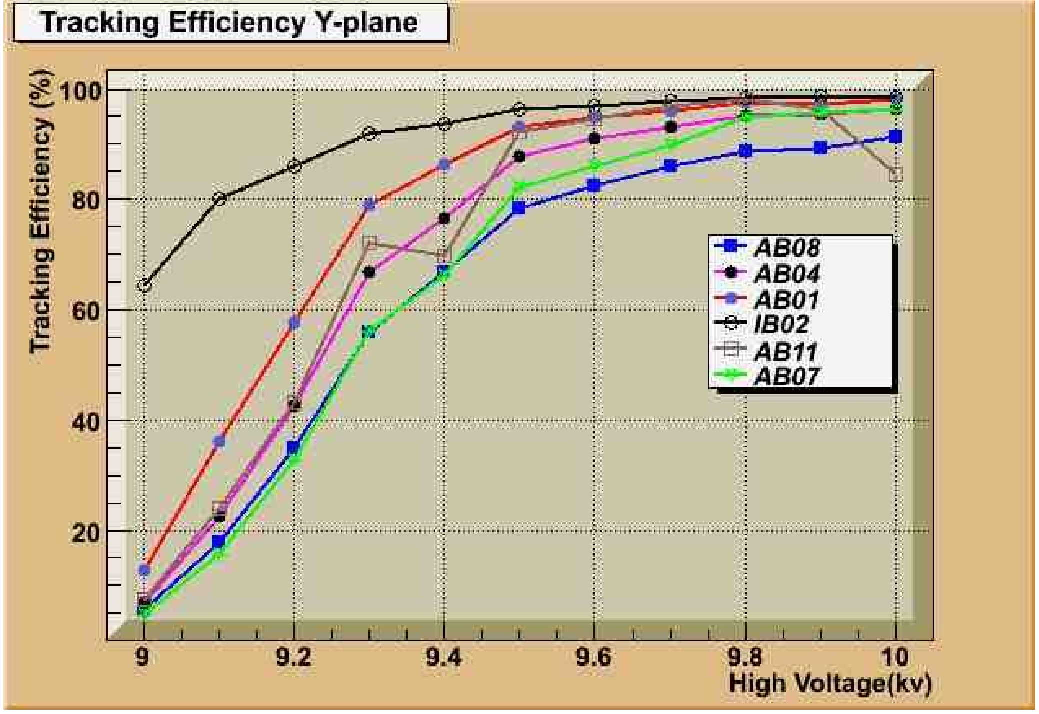

Tracking Efficiency Y-plane
Tracking Efficiency (%)
100
80
60
40
20
9
9.2
9.4
9.6
9.8
10
High Voltage(kv)
AB08
AB04
AB01
IB02
AB11
AB07

Fig.1.b

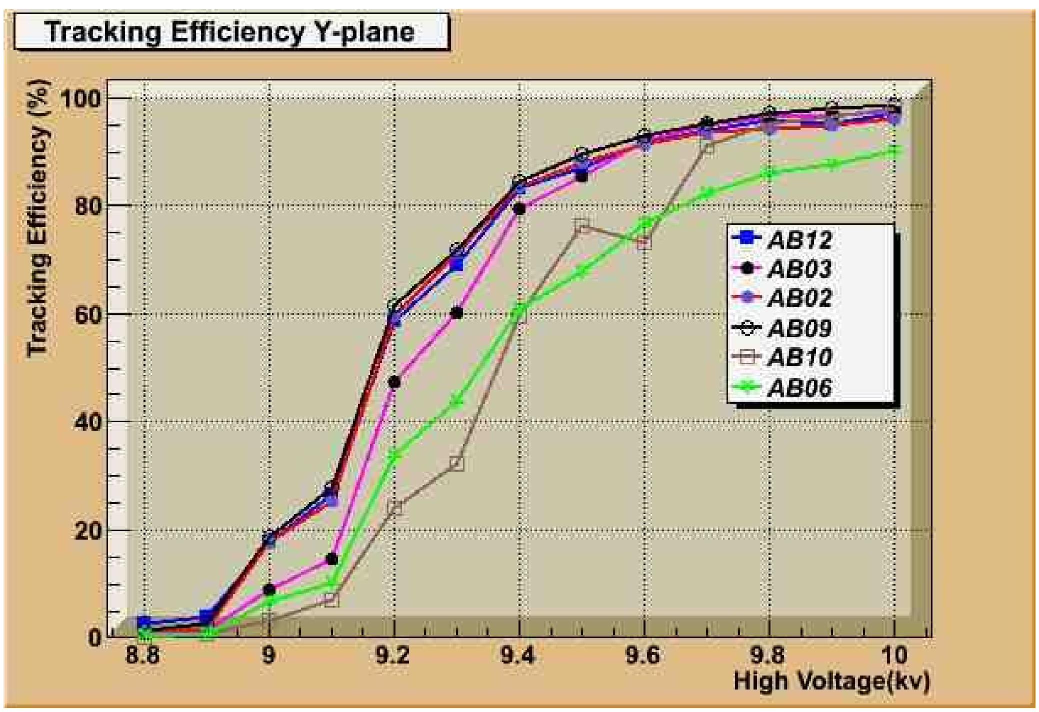

Tracking Efficiency Y-plane
Tracking Efficiency (%)
100
80
60
40
20
0
8.8
9
9.2
9.4
9.6
9.8
10
High Voltage(kv)
AB12
AB03
AB02
AB09
AB10
AB06

Fig.2.a.

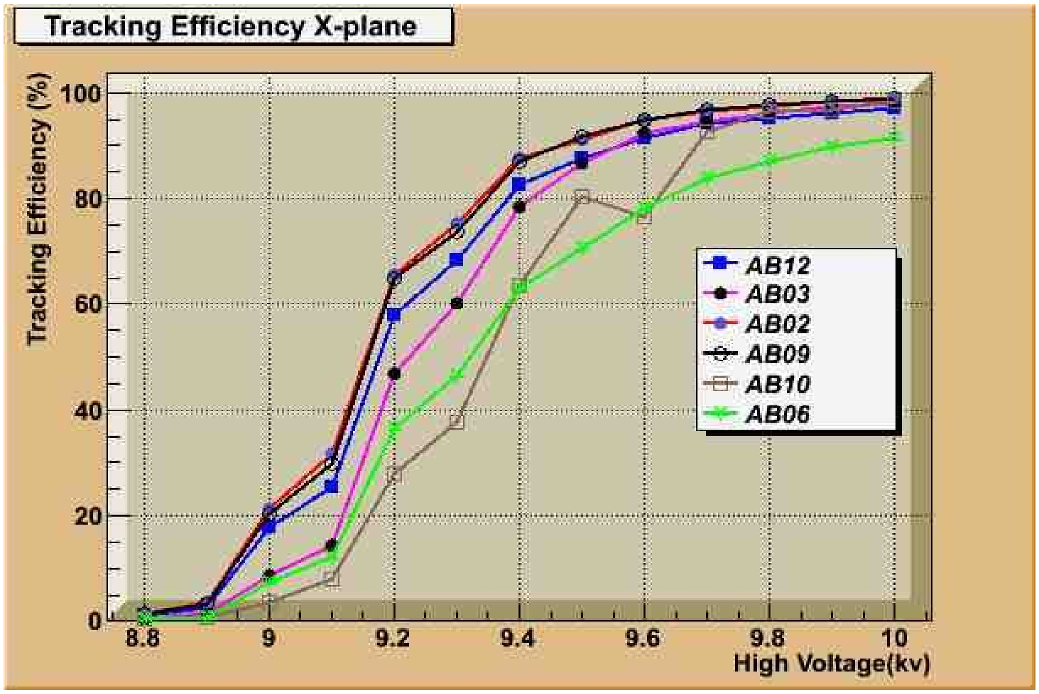


Fig.2.b.

Most of the RPCs in the platue region show efficiency above 90%. From Fig.1a. And Fig.1b. It is clear that both X-plane and Y-plane of IB02 shows more efficiency and is almost flat from 9.4KV to 10KV. It can be operated in this range. Top most RPC in the stack AB08 and bottom most RPC in the AB06 show less efficiency.

Assignment 2

Aim

Characterization of 1m X 1m RPC.

Procedure

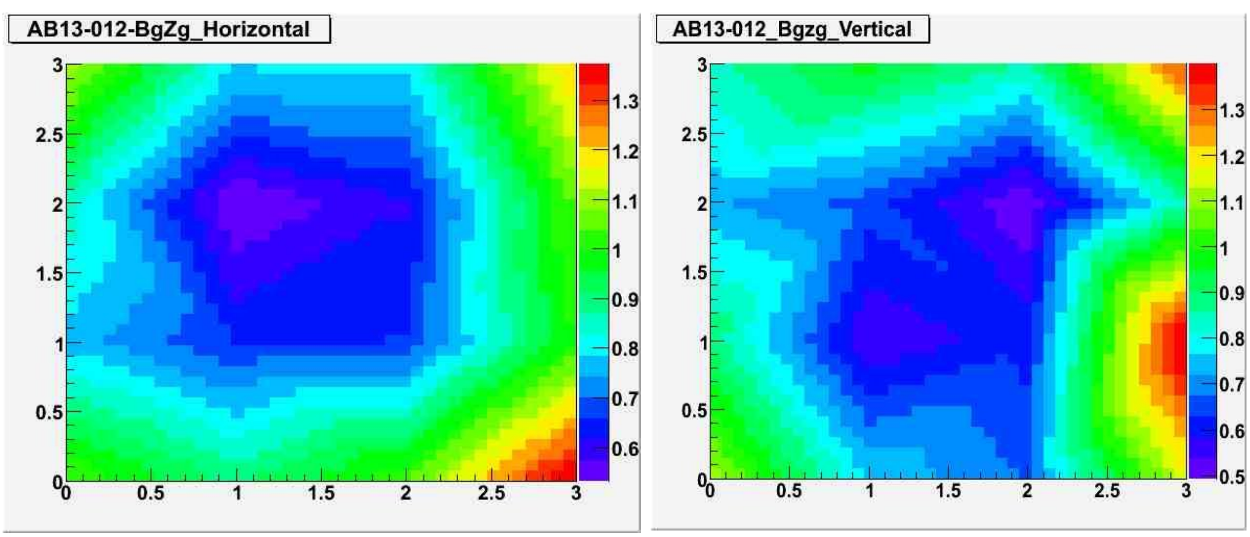
1. Measure the surface resistance of both surfaces of the RPC.
   Strip width measurement.
2. Cutting Mylar sheets.
3. Pack up the RPC.
4. Connect preamplifier boards for both X-strips and Y-strips.
5. Allow gas flow inside RPC at least 8 hours.
6. Vary high voltage and note down current to plot VI characteristics.
7. Calculate efficiency using paddle triggering.

Results

Surface Resistance Measurement

Surface resistance of graphite layer coated on glass surface is measured using big jig is shown in the following contour plots.

Fig.2.1.1a. Surface resistance of glass ID 012 measured using Big jig.



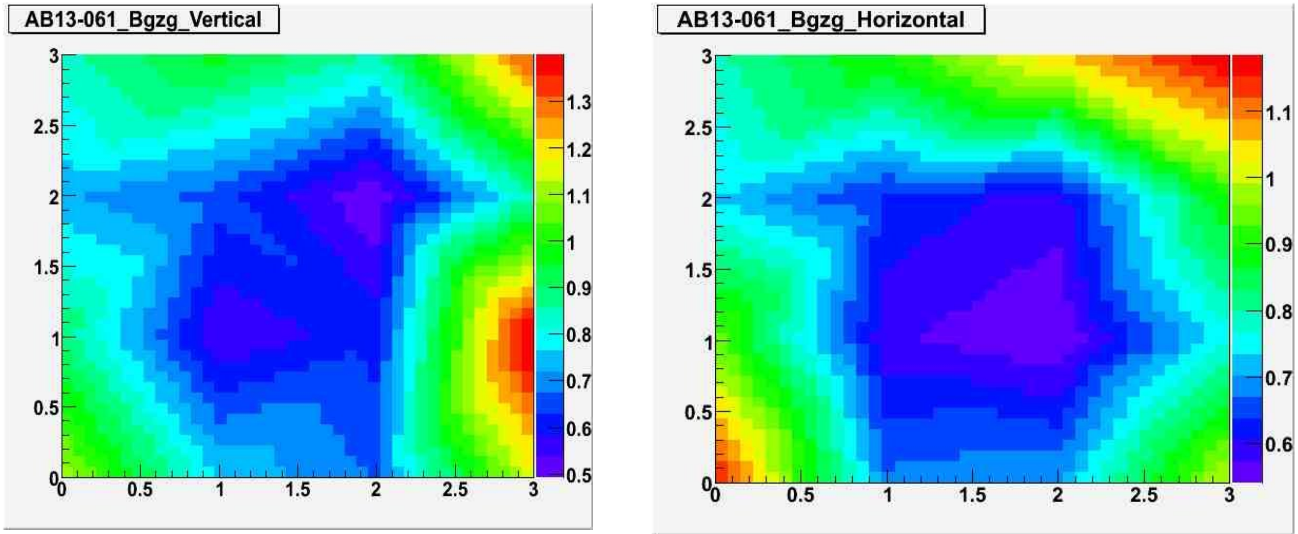


Fig.2.1.1b. Surface resistance of glass ID 061 measured using Big jig.

Uniform surface resistance of 1 MΩ is expected. But there is a variation on the surface from 0.4 to 1.4 MΩ. The variation is due to the variation in the deposition of conductive pigment on the glass surface.

VI Characteristics of AB13 (1m X 1m)

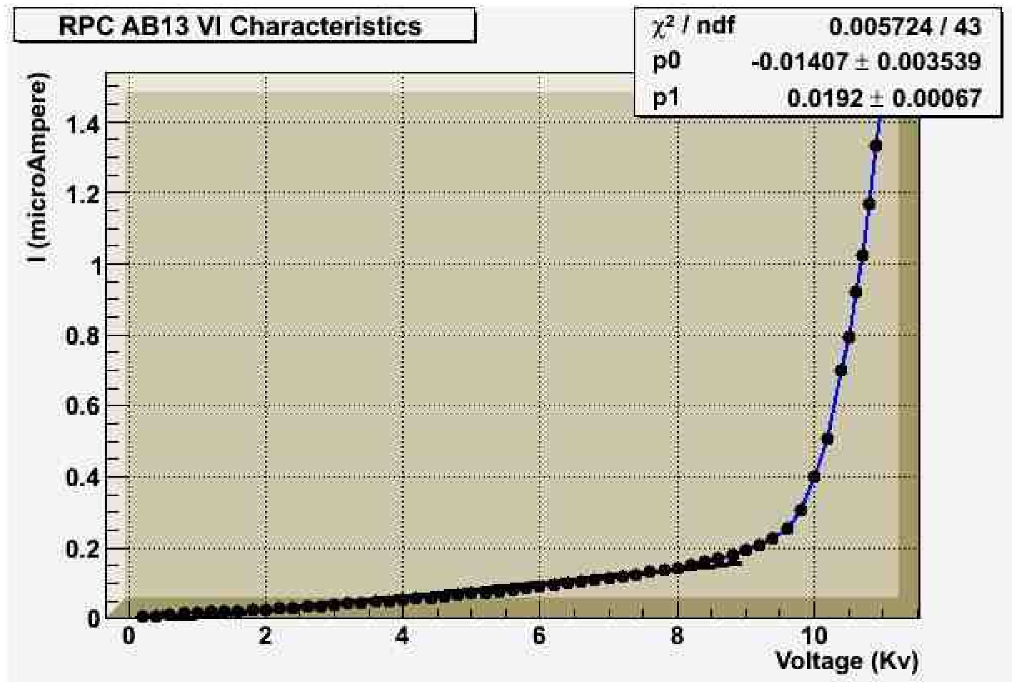
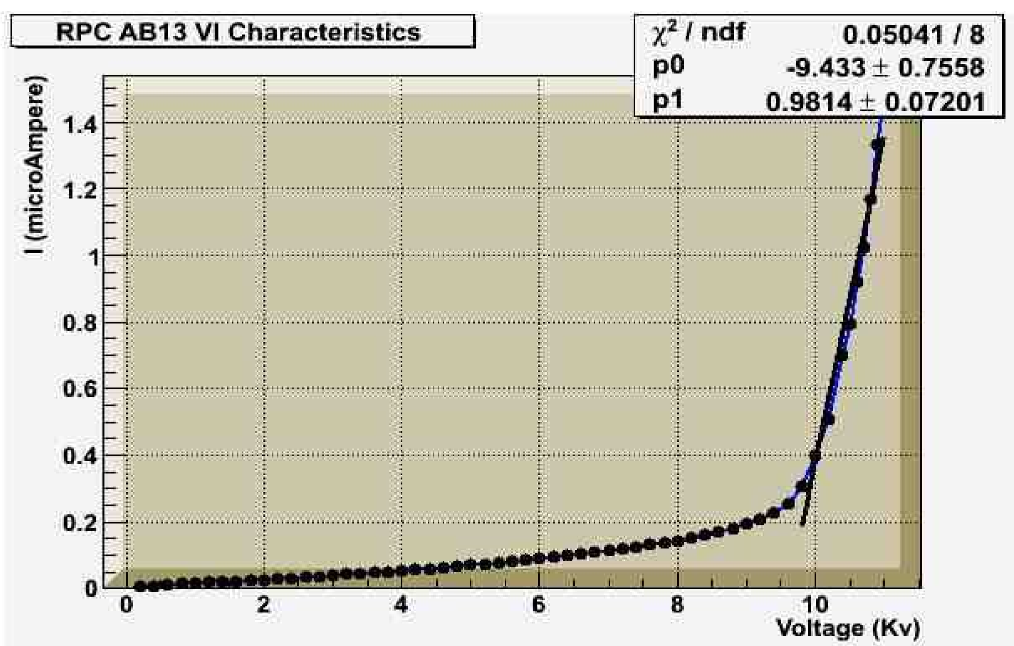
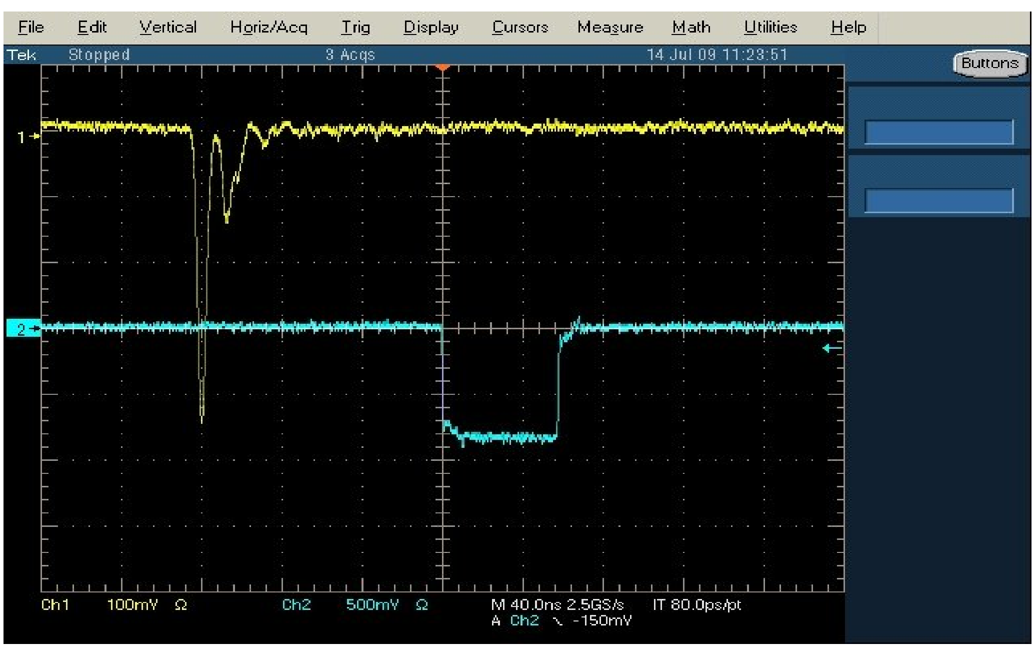


Fig.3.a

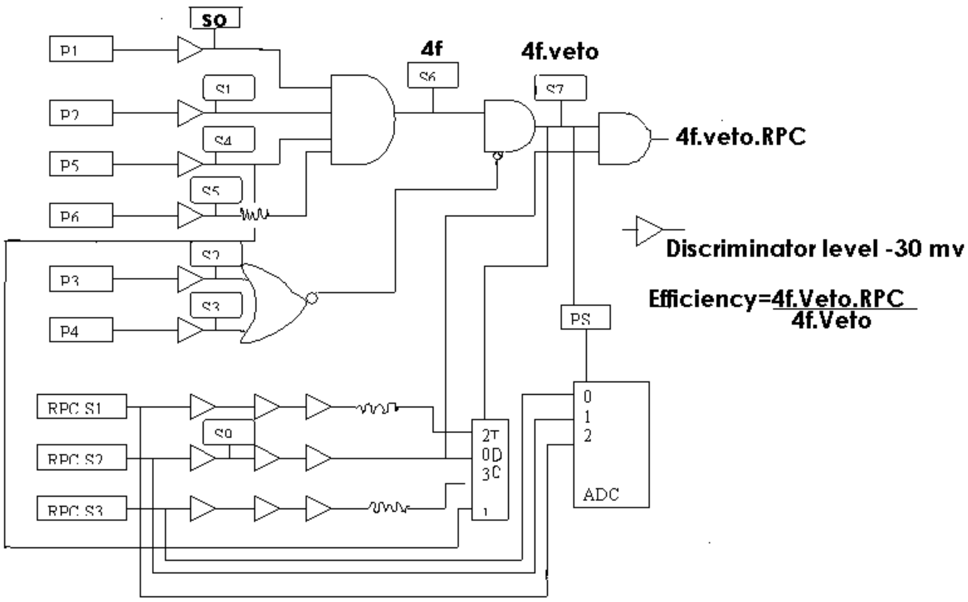


Testing of RPC

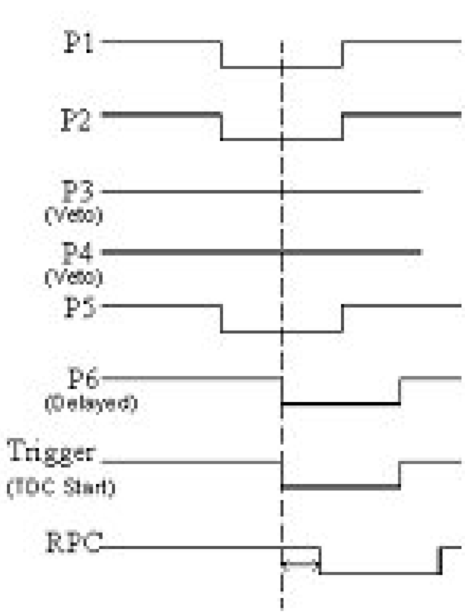
RPC can be tested using a scintillation paddle based cosmic ray muon telescope. The telescope consists of 4 cosmic ray muon trigger paddles P_1, P_2, P_5, P_6 and two veto paddles P_3, P_4. The area of these scintillation paddles are 60×20, 60×20, 30×3, 30×2, 40×20, 40×20cm^2 respectively. The scintillation paddle gives out a signal when a cosmic ray muon or other charged particle passes through it. The geometry of the telescope using these paddles has been setup such that we define a window of about 30×2cm, for the cosmic ray muons to pass through the telescope as well as through one of the pickup strips of the RPC under test. Narrow paddles are used to define the telescope geometry precisely and veto paddles to prevent generation of triggers when a muon passes through the rest of the area of RPC which is not under study.
The data from the RPC pickup strip is recorded whenever a cosmic muon generates a trigger signal through the logic $P_1.P_2\overline{P_3}\,\overline{P_4}P_5P_6$ i.e., a trigger is formed when a muon passes through the paddles P_1, P_2, P_5 and P_6 and does not pass through the veto paddles P_3 and P_4.
Following figure shows the trigger signal and the RPC event signal thus generated. The trigger signal is generated with respect to the delayed P_6 signal which is done to take care of the jitter from the scintillation paddles which arises due to its finite time resolution.
The recorded data of the RPC is used for its characterization by finding its efficiency, time resolution and other parameters.

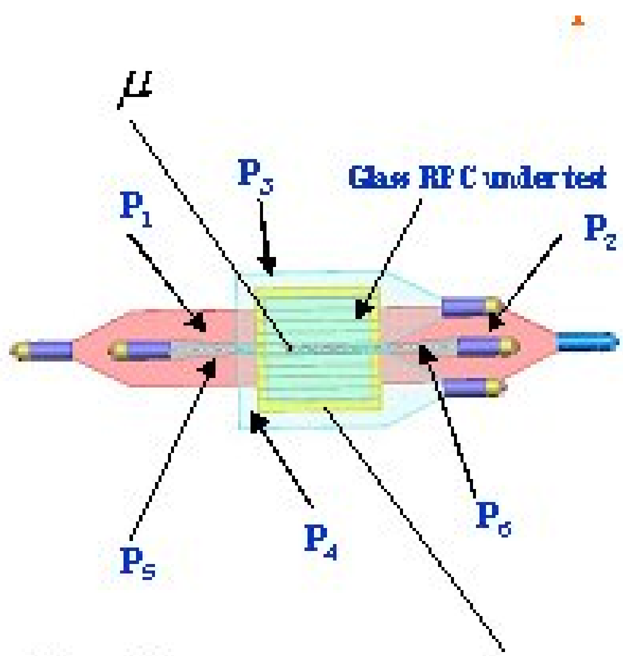


Basic circuit



Block diagram of lab set up

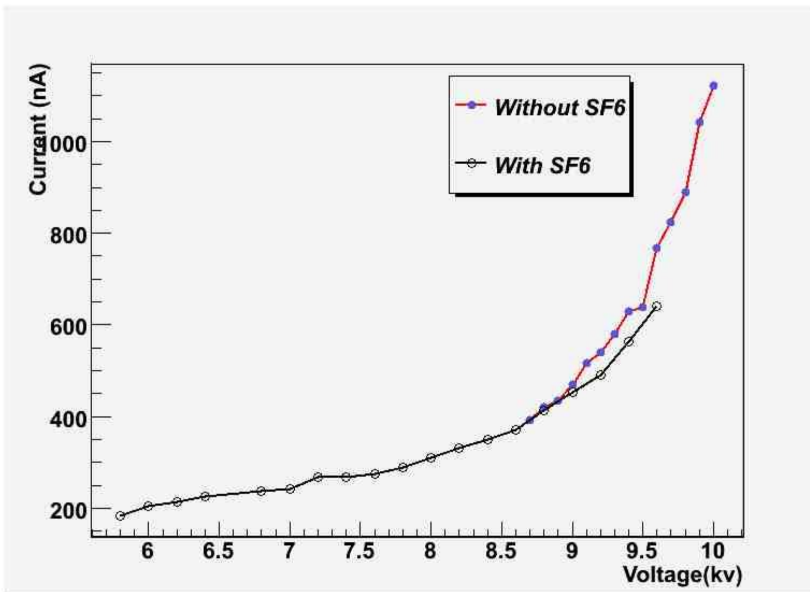




$$\text{Muon Trigger} = P_1 \bullet P_2 \bullet \overline{P_3} \bullet \overline{P_4} \bullet P_5 \bullet P_6$$

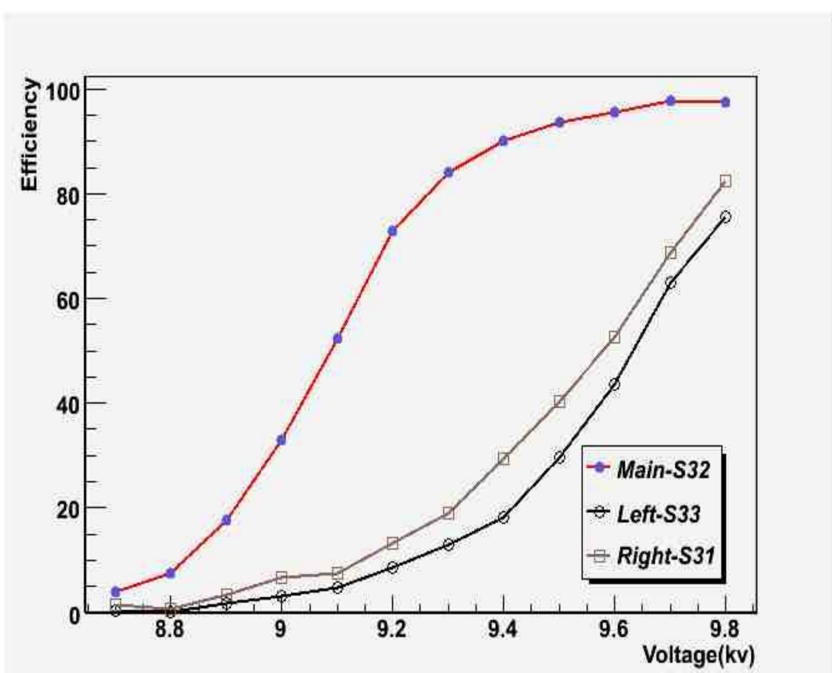
Results from 2m X2m RPC

VI Characteristics



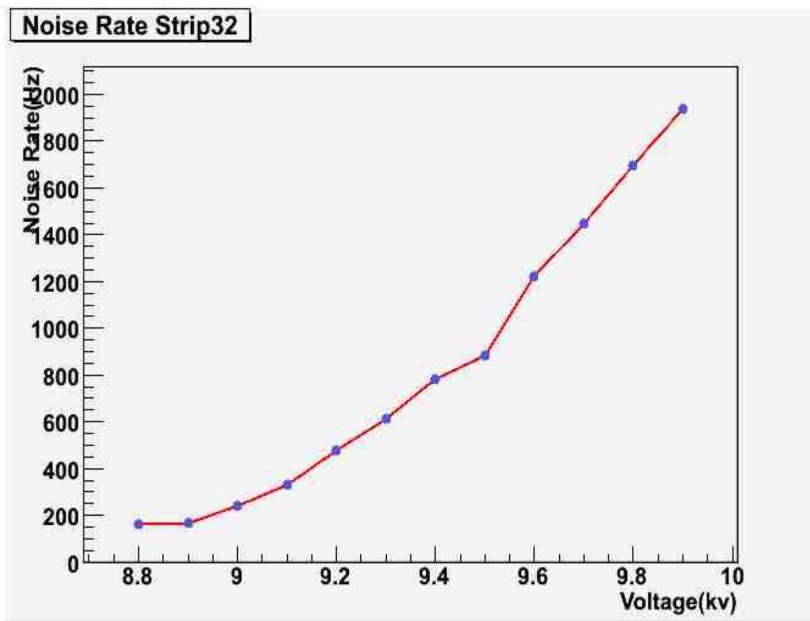
The above plot shows the VI characteristics of 2m X 2m RPC with and without SF6 From the plot it is clear that after adding SF6 current comes down.

Efficiency

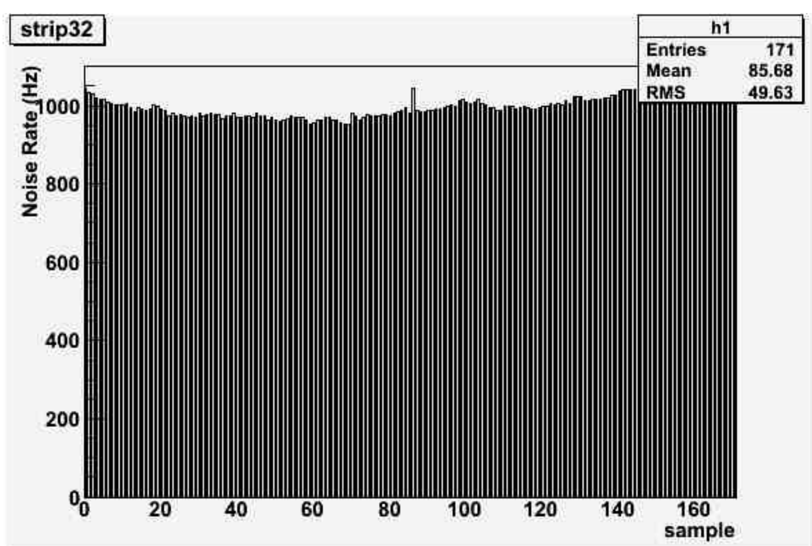


Efficiency of main strip and the adjacent left and right strips are shown in the above plot. We can also see adjacent left and right strips also showing some efficiency. This is due to the cross talk between strips. From the above plateau operating voltage is selected as 9.6 kV.

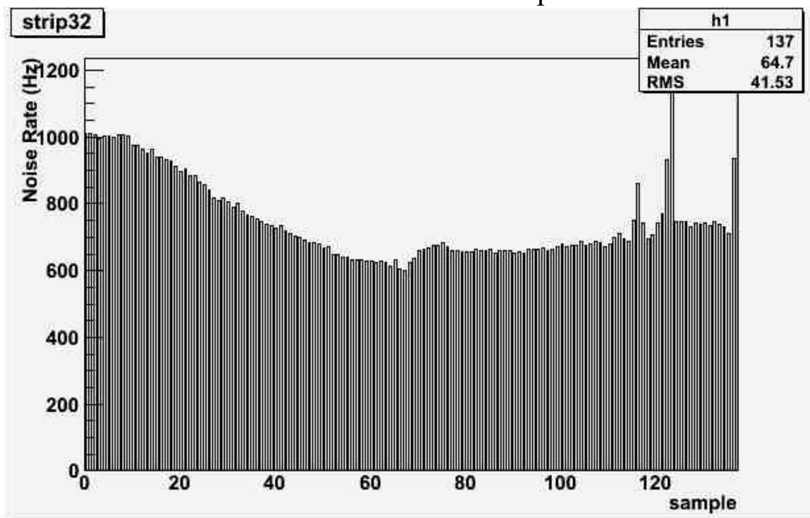
Noise Rate



Noise rate of the center strip at various voltages is shown in this plot.



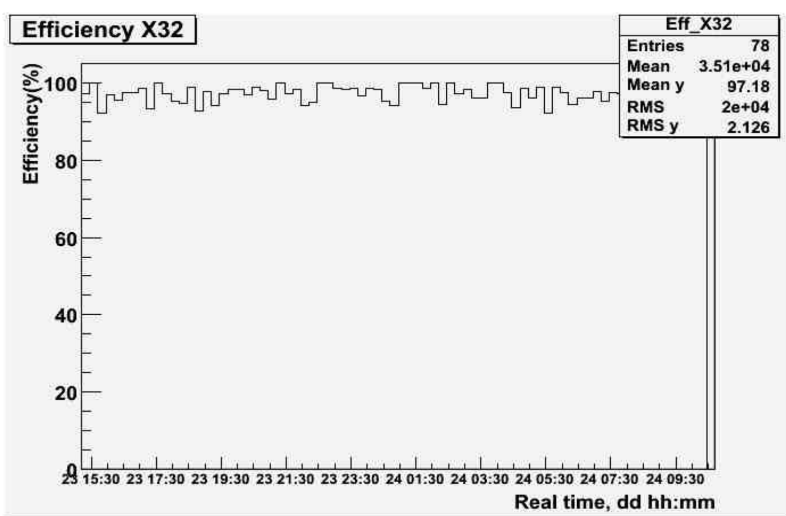
Noise rate of all the 64 channels in the X-plane is shown here.



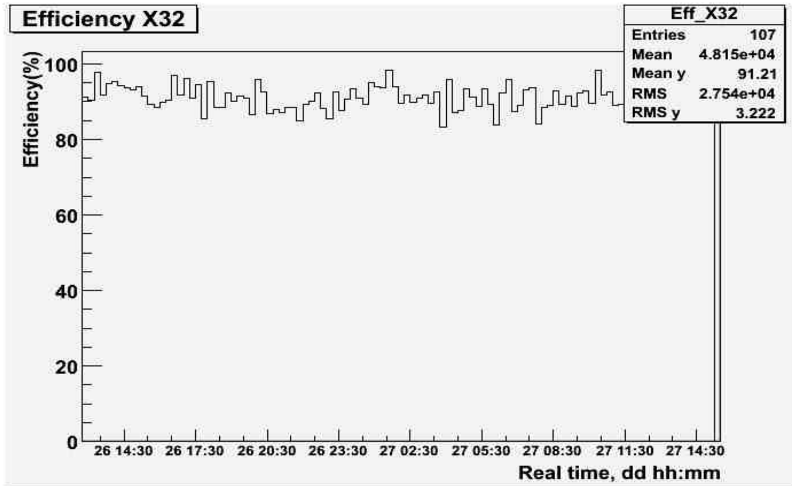
Noise rate of all the 64 channels in the X-plane after adding SF6 is shown in the plot.

It is clear from the two noise rate plot that after adding SF6 noise rate is decreasing and after few hours it is becoming stable.

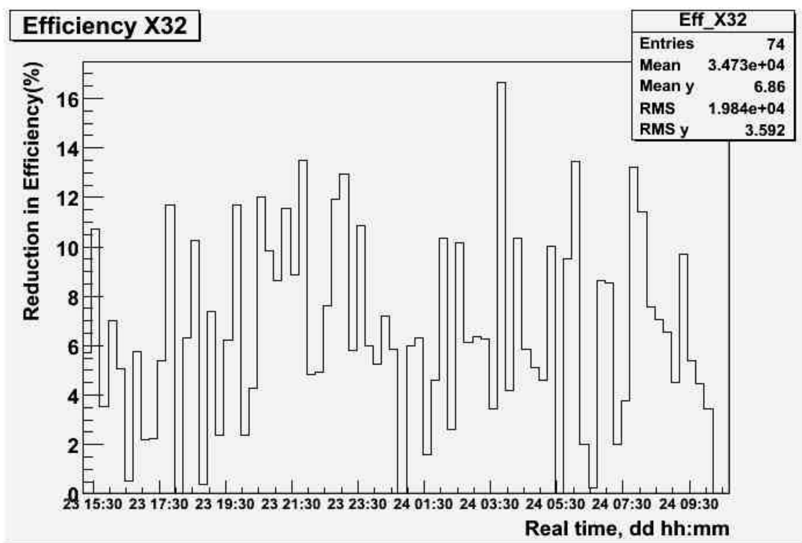
Efficiency Plots for two different concentrations of SF_6



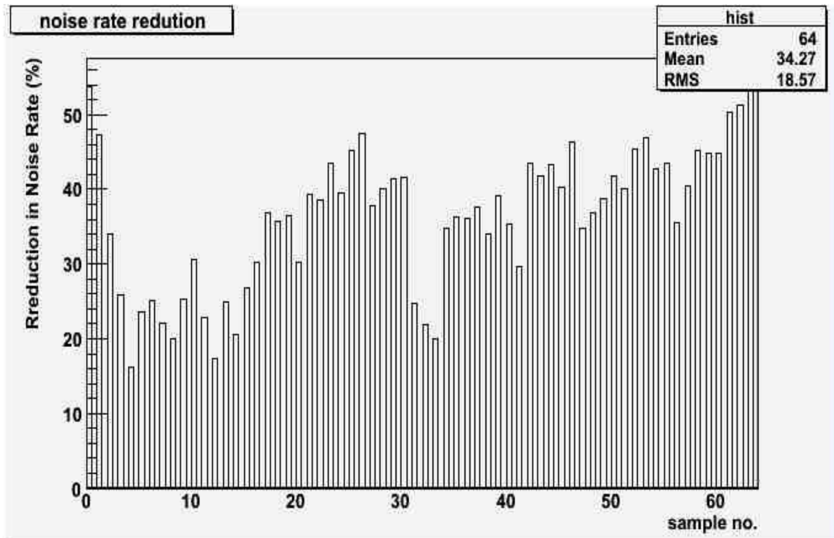
Efficiency plot with 0.32% SF_6



Efficiency plot with 0.3% SF_6



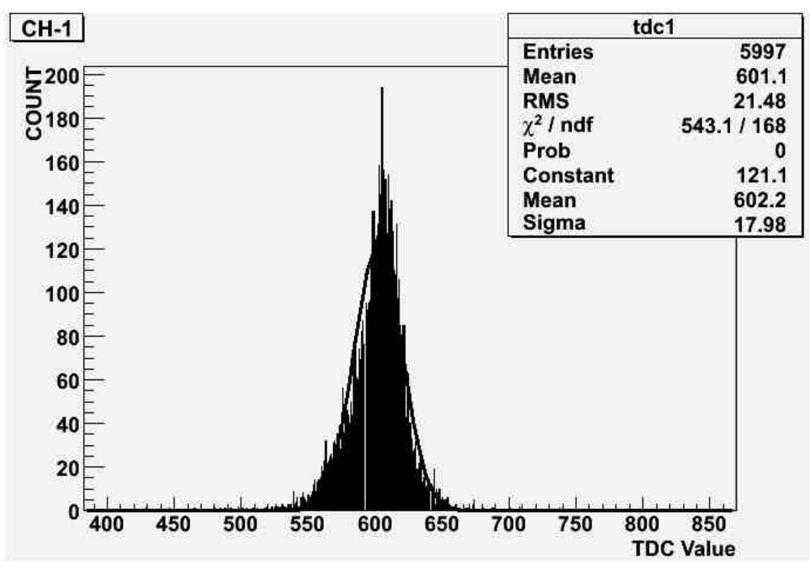
Percentage Reduction in Efficiency while increasing the concentration of SF_6 to 0.32%



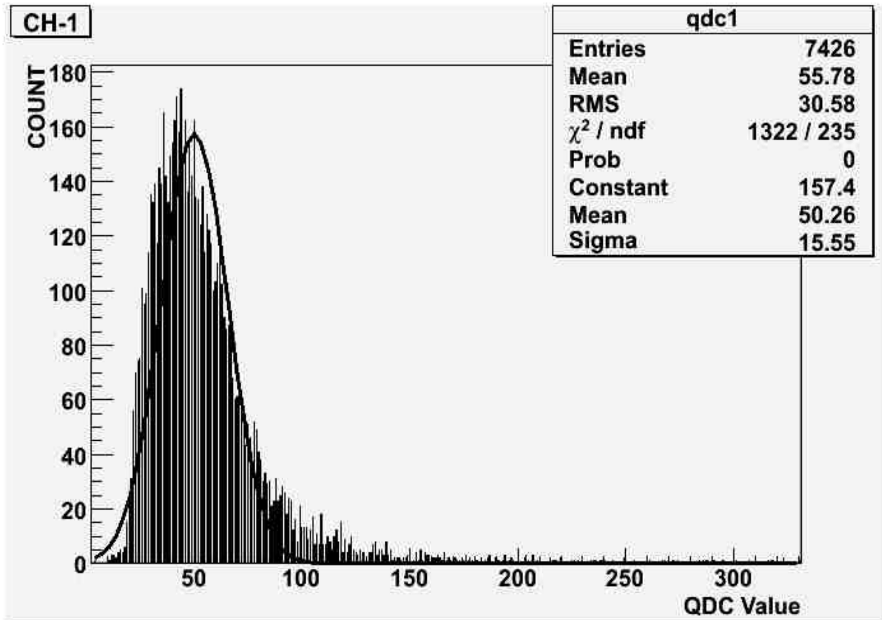
Percentage Reduction in Noise rate while increasing the concentration of SF_6 to 0.32%

SF_6 acts as an "electron quenching gas". It controls the excess number of electrons. It enhances the avalanche mode and decreases the cross-talk. The behavior of SF_6 is clear from the above plots. Noise rate is reduced by 50% when we increase the concentration by 0.02%. Also efficiency is reduced by 6%.

TDC and QDC Plots



Time Resolution of RPC main strip = sigma X Least Count of TDC
= 17.98 X 100 ps
= 1.798 ns



Charge collected from the main strip = Mean X 0.25pC
= 50.26 X 0.25pC
=12.565pC

Conclusion

Studied the characteristics of 2mX2m RPC by analyzing the data from the X-plane (64 strips) of 2m X 2m RPC.

Acknowledgment

I sincerely thank Prof. N.K. Mondal and B.satyanarayana.for providing me the lab facilities in INO lab for completing my project work. I would like to acknowledge all the lab members, especially Mr.R.R Shinde, Mr.Manas ,Mr.Shekhar,Mr. Mandar and my collegue Mr. Waheed for their help throught my project work