RESISTIVE PLATE CHAMBER: A MUON DETECTOR
STUDY OF IT'S FABRICATION AND CHARACTERISTICS

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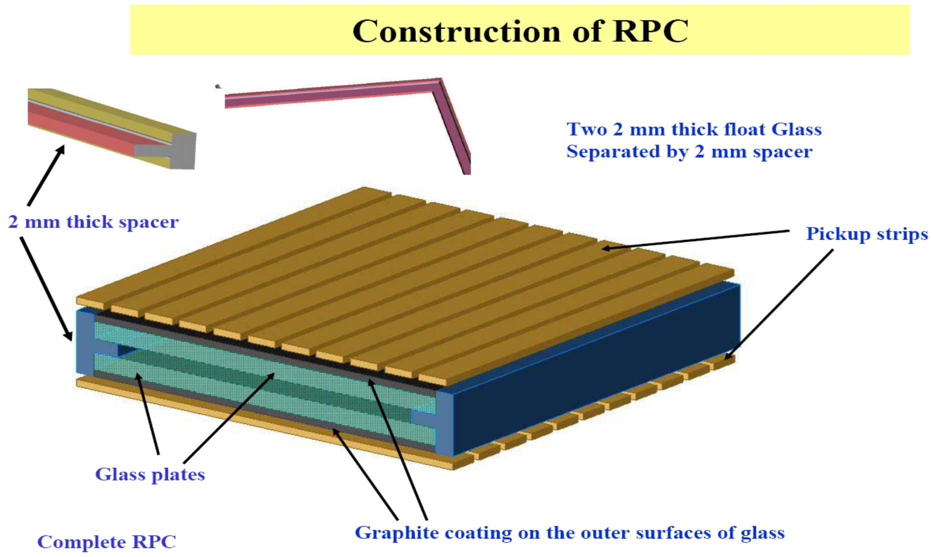
Submitted on 10 th February,2010

INTRODUCTION: Resistive Plate Chambers (RPC's) are used as detectors in High Energy physics and Astrophysics experiments.They will be used in ICAL (Iron Calorimeter) for India based Neutrino Observatory to detect high energy cosmic ray muons. RPCs find use as the active elements in the tracking (iron) calorimeter which can simultaneously measure the energy as well as the direction of the charged particle . They are preferred over other detectors because of:

1. High gain.
2. Good spatial and time resolution alongith reasonably good detection efficiency(>90%)
3. Simple design and capability of covering large area at the same time.
4. Low cost of these detectors.

STRUCTURE OF A SINGLE LAYER STANDARD RPC:



Glass RPC is a gaseous detector composed of two parallel electrodes made up of float glass with a volume resistivity of about 10^{12} Ω-cm. The two electrodes, 2mm thick, are mounted 2mm apart by means of highly insulated spacers. A suitable gas mixture is flown at the atmospheric pressure through the gap while an appropriate electric field is applied across the glass electrodes through a resistive coating of Graffite on their outer surfaces. Two glass plates are separated by button spacers and the chamber between them is sealed in the sides by edge-spacers.

PRINCIPLE OF OPERATION:

The detector working concepts are based on the detection of gaseous ionization produced by charged particles traversing the active area of the detector, under a strong uniform electric field applied by resistive electrodes . The chamber is filled with a proper gas which gets ionized when a sufficiently energetic radiation penetrates the chamber thereby resulting in the formation of electron ion- pairs. Owing to the high resistivity of the electrodes, the electric charge quickly dies off in a very limited area (typically 0.1 sq.cm) around the points where the discharge occurs .The discharge produces signals which are counted and analyzed by appropriate read out electronics.

- Modes of Operation

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

1.) <u>Avalanche Mode</u> :Ionized particles,createdby primary ionisation of gas through charged particles are accelerated by the electric field and in their way to the electrodes they ionise the gas again to set in an Avalanche process,.However this process stops as the internal opposite fiekld is balanced by the external field and the charges are collected in the respective electrodes.the pulse hight in this mode is of the order of few millivolts and amplifiers are required in this mode of operation.This mode is also called proportional mode.

2.) <u>Streamer Mode</u>: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.The avalanche is followed by a streamer discharge and signal generated will be large in the order few hundreds of milli volt. Hence no amplifiers will be needed.

- **Signal Induction and Readout**

The charge signal drifting in the gas gap generates a current induced on the electrically isolated metallic pick up strips. The electron and ion currents are absorbed through resistive electrodes by high power supply. Positive voltage is applied on one side and the negative voltage is applied on the other side, using a bi-polar high voltage ~10KV. The bi-polar connection is better than the uni-polar because of decreasing the chance of HV leaks.The main advantage for their high resistivity, the drop in the applied tension during the discharge in the gas is specially localized. The dead time for the detector is due to the time necessary to restore the voltage tension at the gas gap, but will concern only on a small area of the detector surface. Then the signal followes further electronic read out system.

- **Gas System**

The choice of filling the gas for resistive plate chambers is governed by several factors: low working voltage, high gain, good proportionality and high rate capability. For a minimum working voltage , noble gases are generally used having high first ionization potential as compared to the other elements and they require the lowest electric field intensities for avalanche formation.

To work in Avalanche mode the main components could be an electronegative gas, with high primary ionization but with small free path for electron capture. The high electronegative attachment co-efficient limits avalanche electron number. Tetrafluorehtane(known as Freon), which is widely used, has shown some these specifies. But here we use R134A (as Freon) which is eco-friendly.

One more component is constituted by polyatomic gases, often Hydrocarbons**,** which have absorption probability for ultra violet photons, produced in electron-ion recombination. This gas is known as quenching gas as it limits the lateral charge spread. In our gas system we have used Iso-Butane as quenching gas.

Finally we use SF_6 (sulfur-hexafluoride) to control the excess number of electrons. A small quantity of SF_6 in a few per mill fraction of the standard gas mixture could enlarge the pure avalanche mode operating voltage range up to 1 KV streamer free plateau. Three gases are mixed in the following proportion

R134A (as Freon)	95.20%
Iso-Butane	4.50%
SF_6 (sulfur-hexafluoride)	0.30%

STUDY OF FABRICATION OF RPC:

The following steps are followed for the fabrication of a 1m x 1m RPC .

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.

I was involved in the steps of Glueing of glass,Gas leak test,Connecting high voltage cables and fabricating pre-amplifier boards,their testing of gain and finaly connecting them to the RPC.

I-V CHARACTERISTIC STUDY OF RPC:

For further study of RPC characteristics we applied high voltage to the Rpc from 0 volts to very high voltage upto 10 kV and noted the curent at different voltage to plot the current-voltage relationship of the RPC.

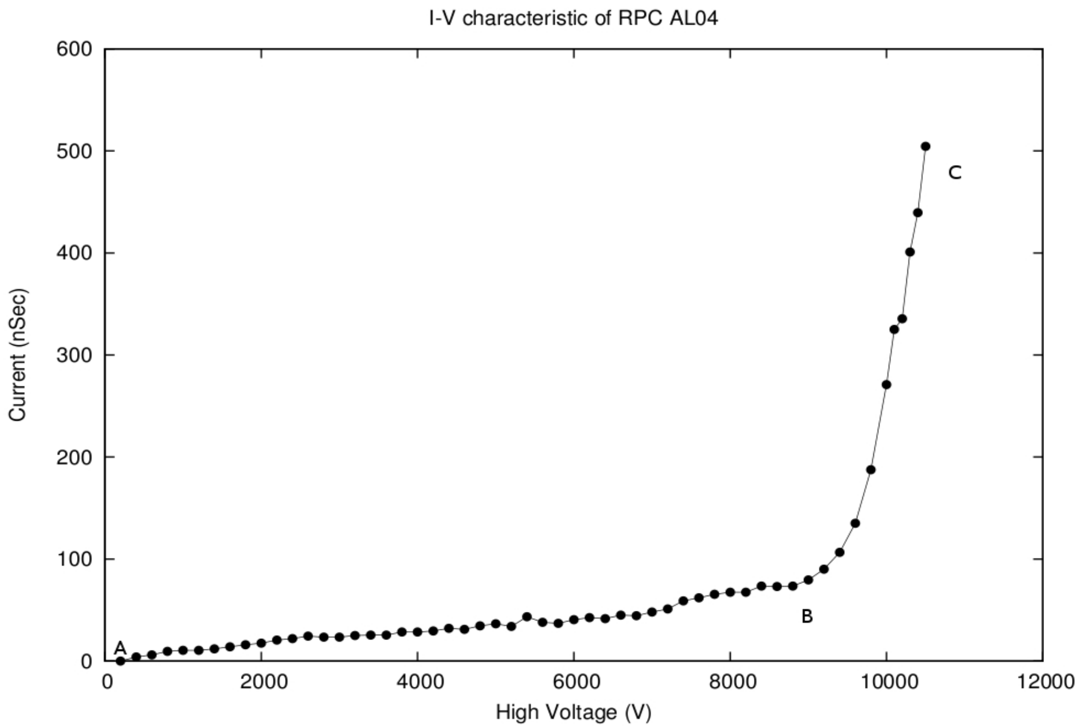


Illustration 1: I-V PLOT

The AB part is simply due to a ohmic resistance and the sudden rise at B points to the behavior of a Zener diode.Hence the equivalent electrical circuit of the RPC is shown beside.So in low operating voltages RPC acts as like a resistance due to the spacer and at high voltages resistance falls down drastically to imitate the behavior of a zener diode.

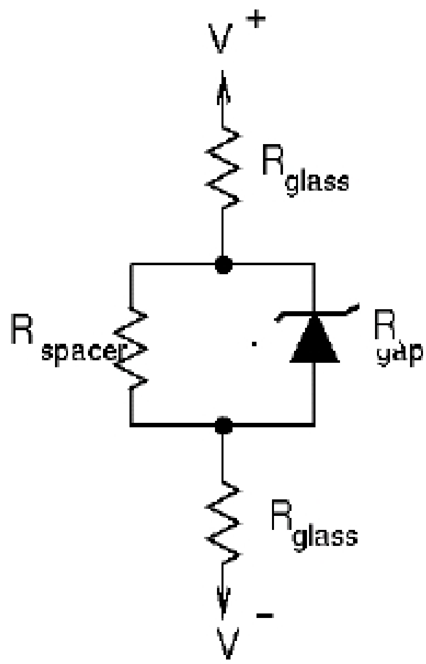


Illustration 2: CIRCUIT REPRESENTATION

RPC AS COSMIC RAY TELESCOPE:

To make sure that our RPC detects only muons we set up our experiment in such a way as to ensure that trigger pulse is generated by atmospheric muons. So to do this, we have to exclude all other cosmic ray which forms the background noise. For this we use six scintillator paddles. Thus we make a cosmic ray telescope with these scintillators applying a coincidence logic. We named them $P_1 .... P_6$. We have set the Discriminator threshold to be -20 mV for removing noises from the RPC signal.

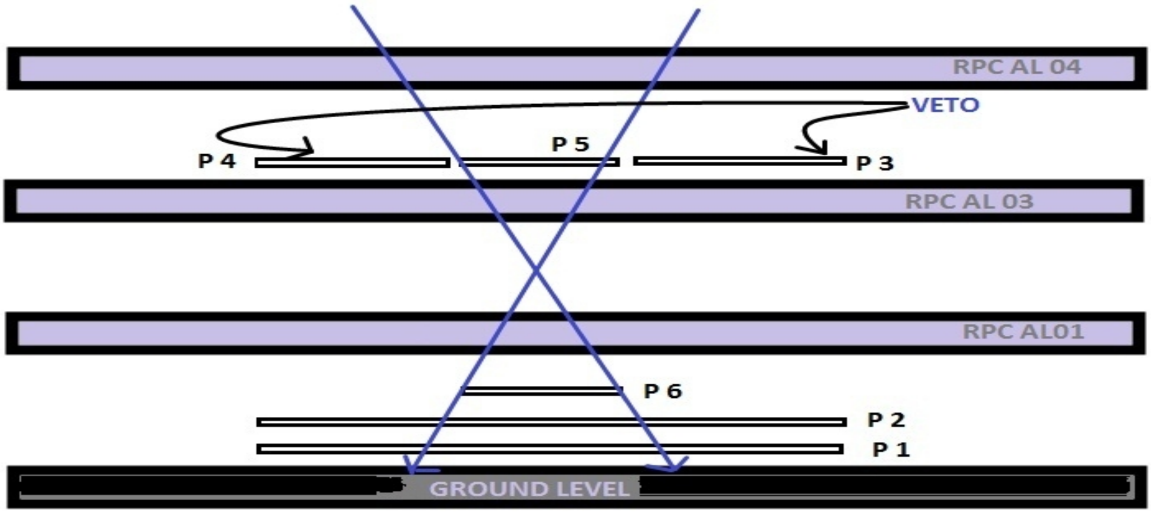


Illustration 3: ALLIGNMENT GEOMETRY

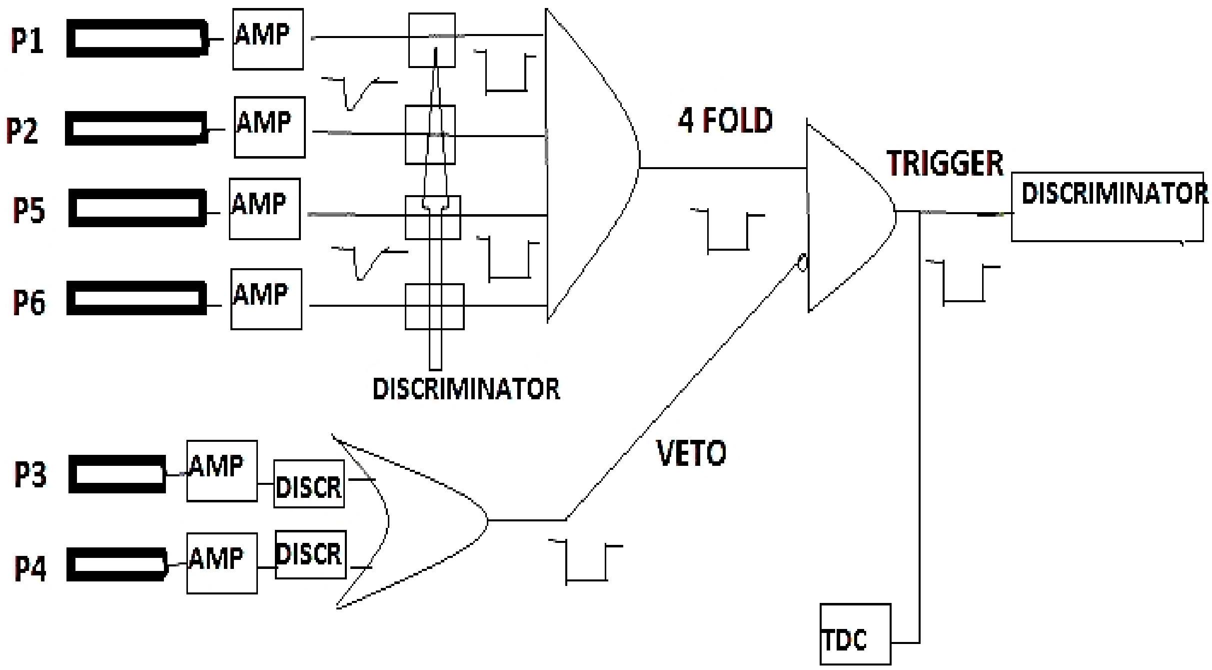
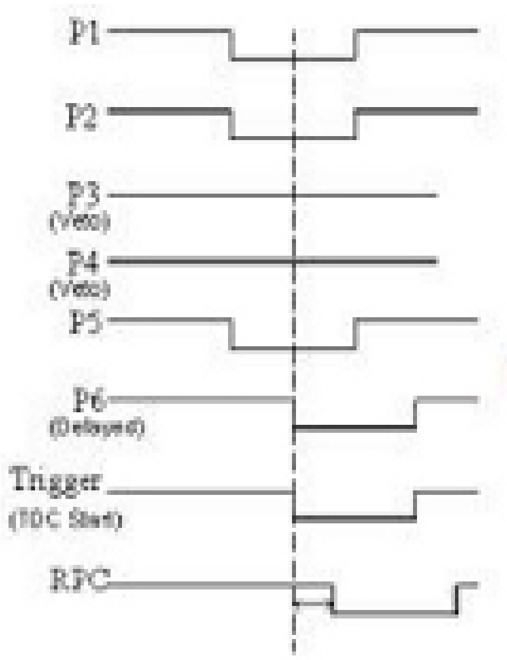


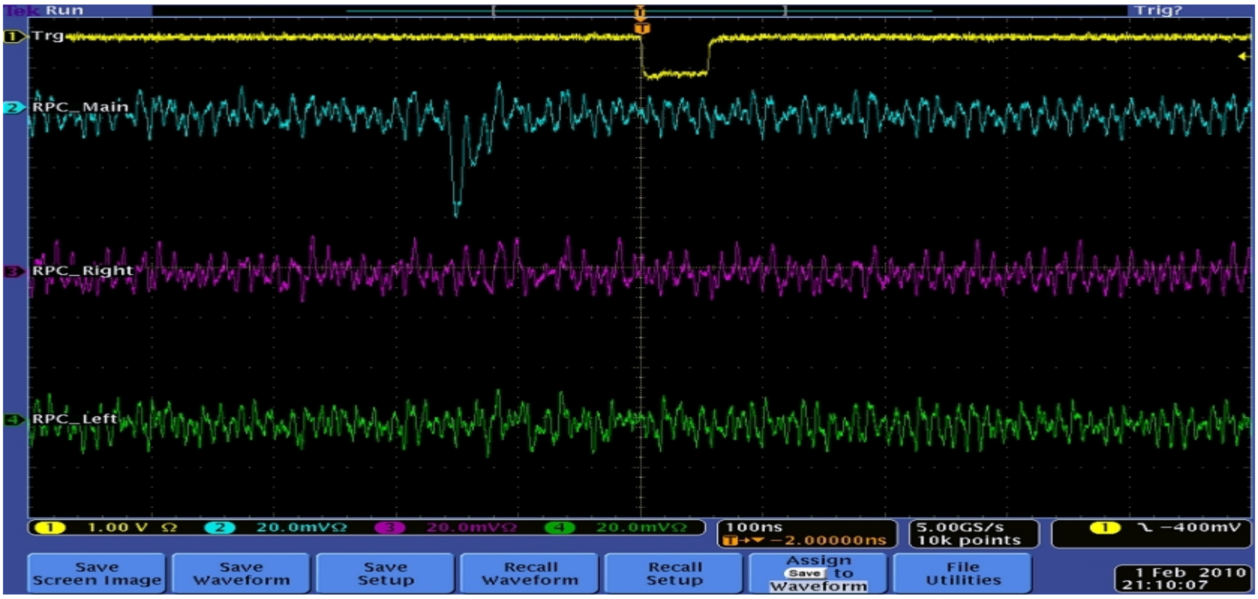
Illustration 4: SCHEMATIC SET UP



With those scintillator paddles we generate our trigger as, Muon trigger = $P_1 . P_2 . \overline{P_3} . \overline{P_4} . P_5 . P_6$. This ensures that muon trigger is generated when we have three paddles are in coincidence and (P_3 and P_4) are in anti coincidence. Hence the paddles P_3 and P_4 are called VETO paddles.

Thus the trigger being formed we have already created a coincidence window.Then make the allignment geometry such that the 20th strip (starting from 0) of RPC AL04 lies exactly coincidental with that window. This named as "MAIN STRIP" and 19th and 21st strip becomes respectively the "RIGHT" and "LEFT" strips.

Now i show a typical pulse from the RPC along with trigger signal as recorded in oscilloscope.

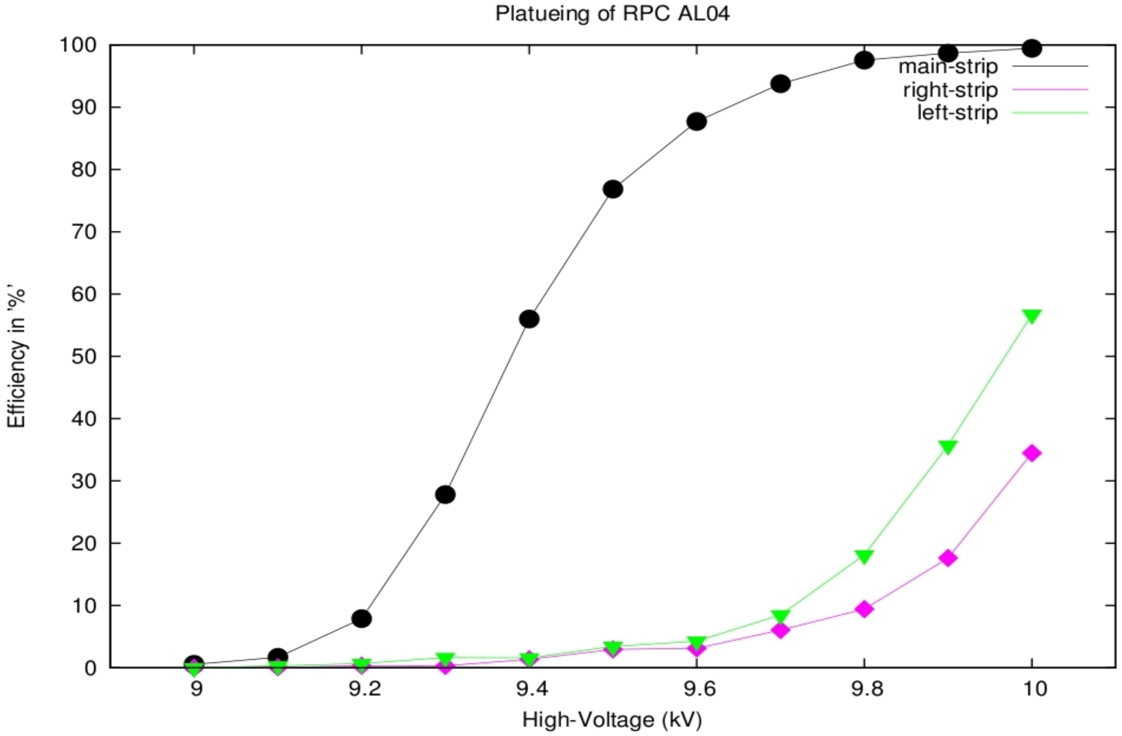


As it is obvious from the picture that RPC_Main pulse is coming before the trigger pulse,we have to add ∼130 nS delay through NIM COAXIAL cables (5 nS delay per metre) for proper synchronizaton.

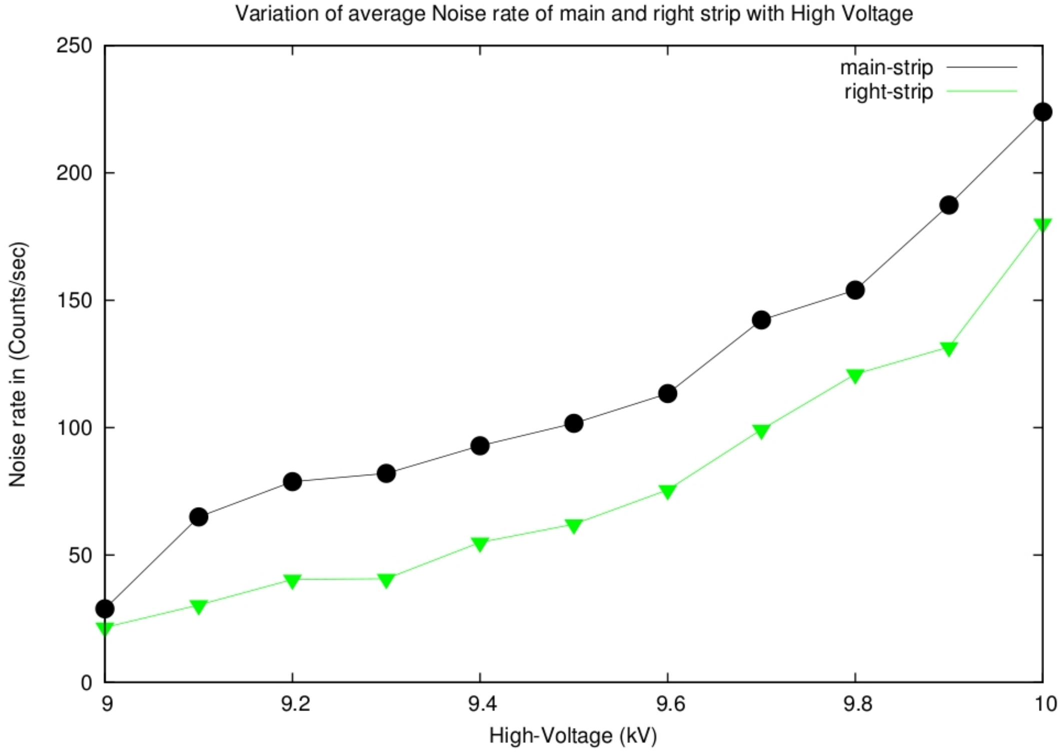
CALCULATING RPC EFFICIENCY:

As it may sometimes happen that we have got a trigger but the RPC signal is absent,so we were interested in the efficiency of the main strip,that is to take into account how efficiently RPC can detect a muon when there is already a trigger,that means the scintillator paddles have detected the muon already.therefore defining the efficiency of RPC $= \dfrac{RPC\ count}{Trigger\ count}$

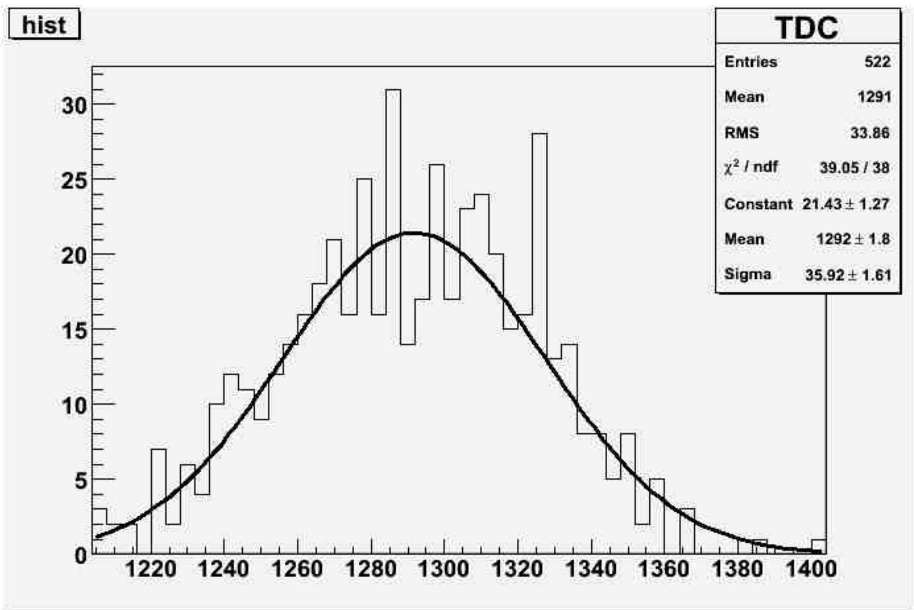
Here I am giving the effficiency plot of the main strip along with right and left strip for CROSS_TALK.



As ideally when main strip is giving a pulse ,right and left strip should remain silent,but often depending on the amount of charge deposited being high or the muon hit being at the edge of the main strip, we can see that right and left strip pick up signal due to induction and that tendency grows with the high voltage being ramped up.But most significantly the efficiency of the main strip remains above 90% for a sufficiently large range of the high voltage.
One most important thing is to notice that the noise rate of any strip increases with high voltage.the figure shows clearly that.

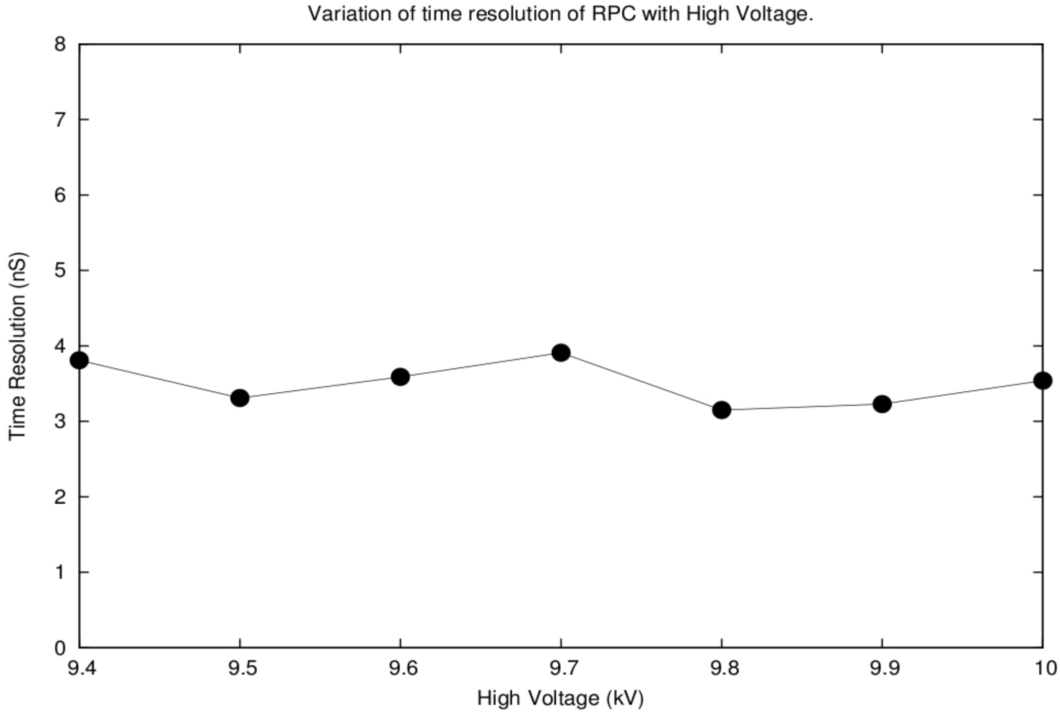


TDC MEASUREMENTS AND CALCULATING TIME RESOLUTION:

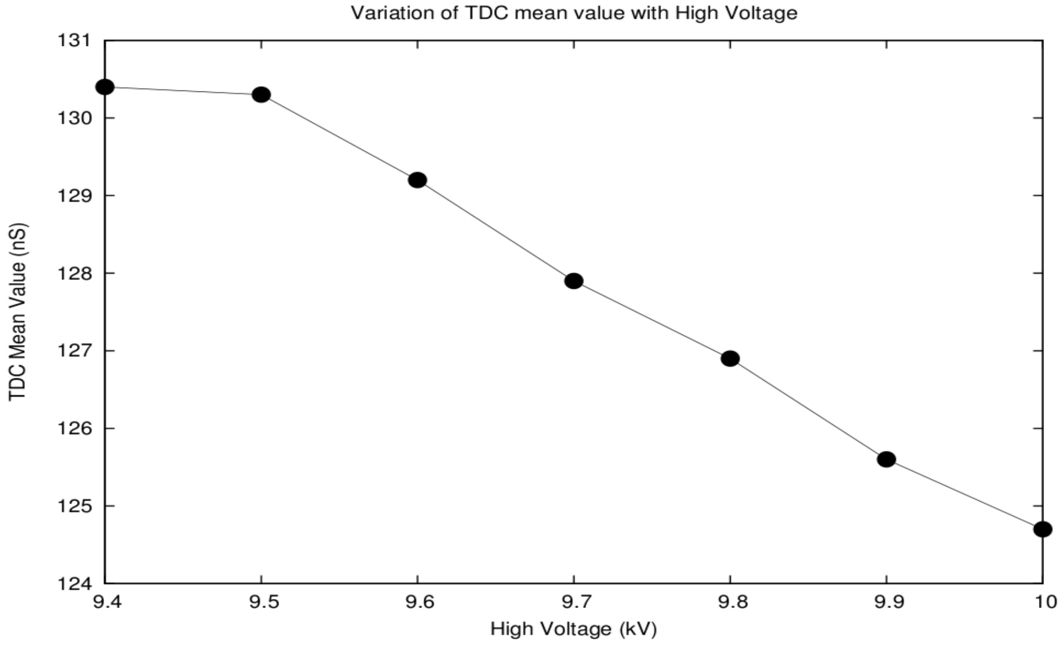


In TDC (Time to Digital Converter) a reference signal is set,in our case we gave the trigger pulse as reference to act like TDC start.then the RPC signal from main,left,right strips (Digital signal from discriminator) were given to the TDC.And that way in every run of 3 hours it took the samples in every 2 minutes and recorded the time lagging of a RPC pulse after the Trigger pulse.

Tdc resolution is 0.1 nS. From there we fit a Gaussian curve to the TDC values and calculated the Sigma of the distribution and reffered it as RPC Time resolution. The figure in the previous page is one such TDC histogram plot fitted with Gausssian curve.
One another plot i am giving that shows the RPC time resolution remains almost constant over the range of high voltage from 9.4 kV to 10 kV.



I am also giving the plot of the variation of tdc mean value of the main strip with high voltage

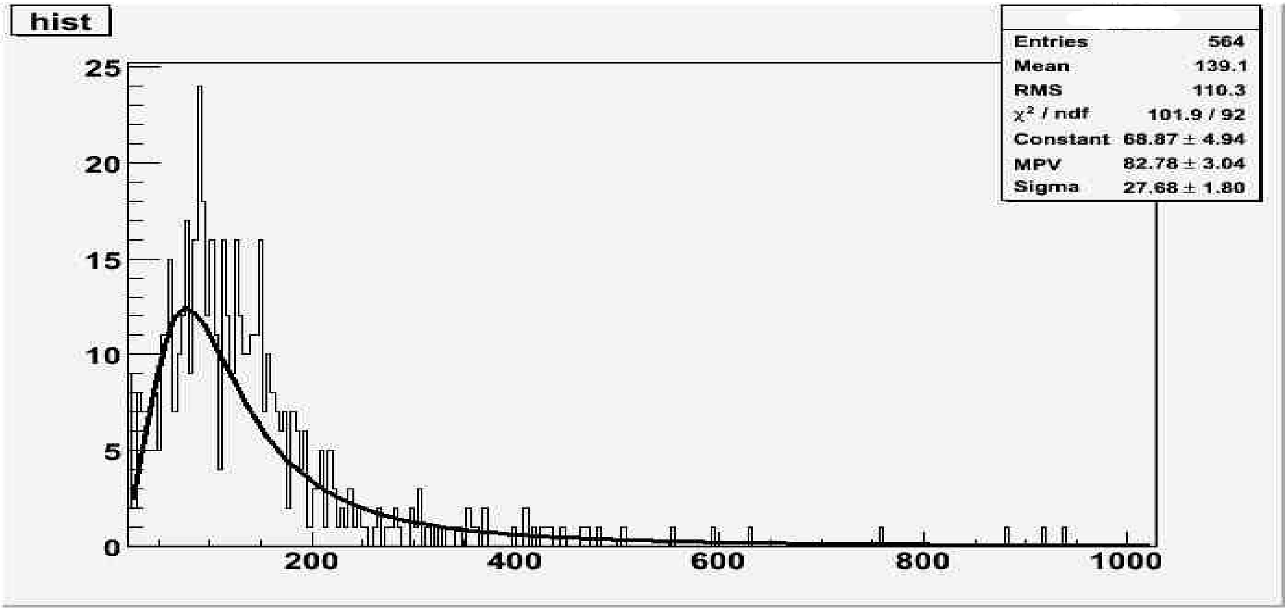


This plot helps us to conceive that at high voltages time delay between trigger and RPC pulse decreases and thus time resolution is bettered.

QDC MEASUREMENT AND CHARGE RESOLUTION:

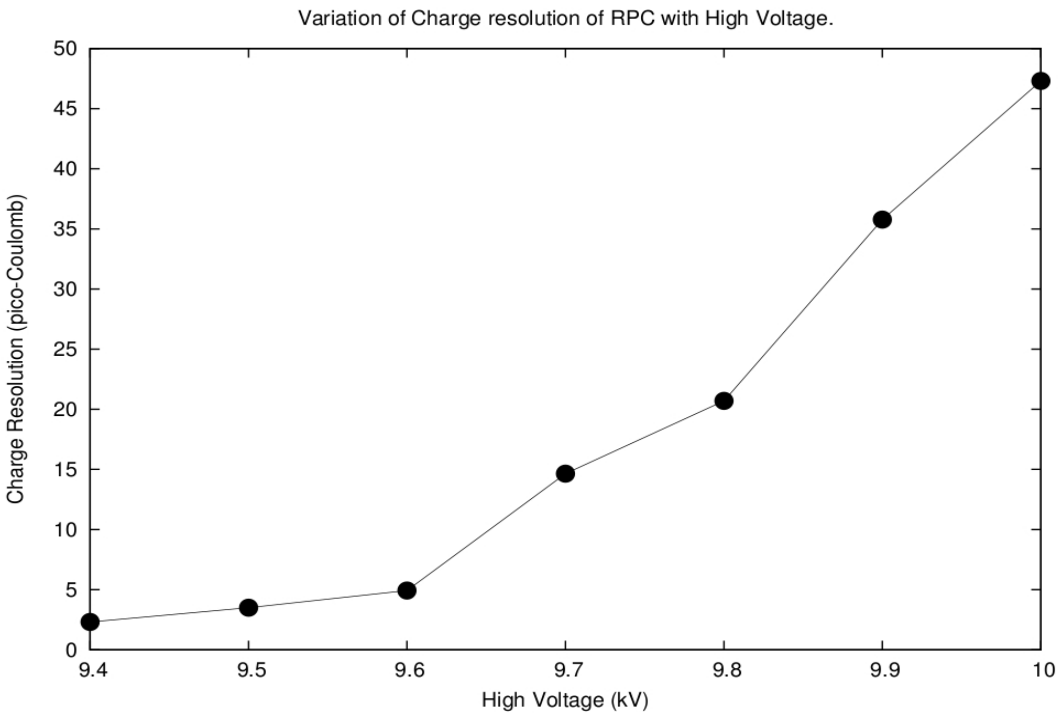
Similarly for measuring charge resolution we used an ADC where the analog pulse from the RPC strips were given alongwith the trigger pulse as the common GATE.We call it a QDC (Charge to Digital Converter). As it measures the resolution of the chrge detected by the RPC.It has a resolution(Calibration) of 0.25 pico-Ccoulomb.

We fitted a Landau curve to the histogram plot of the data samples.Here the plot is at 9.8 kVolt for main strip.



From this plot for each high voltage data we noted the most probable value of the fitted plot and that will correspond to the charge resolution of the RPC.

Now the Variation of the charge resolution with high voltege is shown below,which clearly shows with increasing high voltage charge resolution also increases.



SUMMARY:

Studying the characteristics of the 2m x 2m RPC it may be conclusively said that the working voltage of the RPC should be chosen such that its efficiency is large,cross talks are less, time resolution is less and charge resolution is large at the same time.

ACKNOWLEDGMENT:

REFERENCE: