FABRICATION AND CHARACTERISATION OF RESISTIVE PLATE CHAMBER.

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UNDER THE GUIDANCE OF

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Abstract :

Resistive Plate Chamber is a detector meant for detecting ionizing particles. RPC is a gas filled detector with gas enclosed between two parallel plates of large bulk resistivity kept at high voltage. Minimum ionizing particle passing through the detector ionizes the gas atoms inside. Ions thus formed drift through the field to give signals.

RPC with its good position and timing resolution has found application in many particle physics experiments. RPCs stacked one on other make a good tracking device. At INO RPC will be used as active detector to track the secondary particle produced on neutrino interaction with Fe.

This report presents the work we did as a part of our Experimental Course, which involved construction of RPC, its study and characterization.

Content

REISISTIVE PLATE CHAMBER

Introduction:

Particle detectors have evolved all the way from photographic plates which accidently detected X rays, through scintillation detector, gas wired detector and stages of improvement and up-gradation taking them to present state of art.

Resistive Plate Chamber followed in the hierarchy of Gas detectors.

Gas chambers are based on the principle of ionization. The ions produced drift through electric field applied. The electrons on reaching the anode wire pass through a resistor producing voltage signal proportional to the charge picked up. These detectors made it possible to record both charge and timing of the signal. E.g Ionization chamber, Proportional counter, Geiger Muller counter etc.

Parallel plates then replaced the cylindrical wire detector, as in the uniform field set up by parallel plates all the primary ionized cluster immediately produce next avalanche giving good timing resolution. Spark chamber made from parallel plate electrode has timing resolution of 1ns over wired gas chamber with 100 ns resolution. But in conducting electrodes, the increasing avalanche leads to shorting of the two electrodes. So the detector needs to be switched off thus increasing the dead time and decreasing the detection rate.

Resistive Plates were then introduced**.** Main advantage with resistive plates was, switching off of electrodes to avoid shorting of electrodes by discharge was no more required. Large electrodes can now be used as energy deposited is small. Resistive plates along with good organic gasses with high ultraviolet absorption capabilities are used then charge diffusion in the gas will localize the discharge area. This improves position resolution.

All these improvements lead to the development of Parallel Plate Avalanche chamber

(PPAC) with

- Fast response
- Increased rate capabilities up to 10MHz/cm^2.
- gain of 10^3 to 10^4
- low discharge probability 10^{-5}

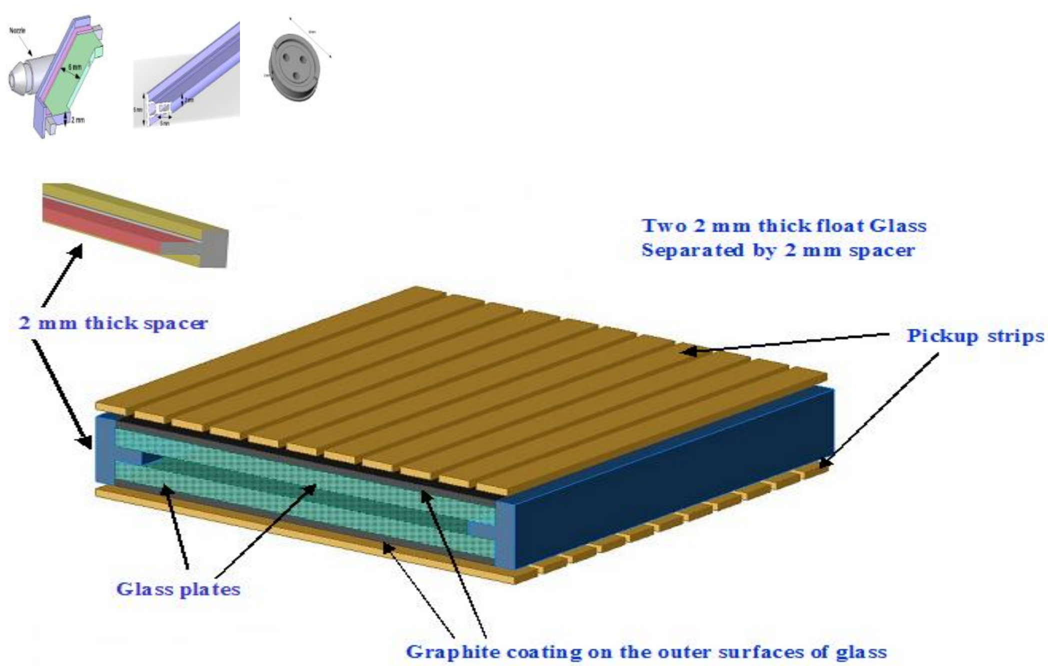
Resistive Plate chamber, a successor of PPAC, was later introduced by R. Santanico and R. Cardarelli in 1981. Thus Resistive Plate Chamber, usually called RPC is a *gas detector* based on the principle of ionization, made *from parallel plate electrode* of *high bulk resistivity* kept at high voltage producing uniform electric field.

Over the years with its good timing and position resolution, fast response rate along with low cost makes RPC find application in Particle Physics, Astrophysics and medical imaging.

Specifications for Glass RPC used in INO-ICAL

INO-ICAL is a neutrino detector, which will indirectly detect neutrino from the observation of the secondary particles emitted on its interaction with Iron. RPC because of its good timing and position resolution will be used as an active detector to track these secondary particles as they pass through the detector. Layers of RPC will be laid after every 5.6 cm. of iron layer.

Schematic of RPC detector



Components of RPC.

- Two Planer electrodes made up of 2m X 2m glass of 3mm thickens each, separated by a width of 2mm.
  Glass with bulk resistivity of 10^{10}-10^{12} Ω
  Electrodes kept at high voltage 5 KV/mm in gas gap. Glass is externally coated with graphite to increase the surface resistivity, which helps setting of uniform electric field.
- Two plates are separated using polycarbonate buttons shaped spacer, with bulk resistivity greater than 10^{13} Ω cm. Side spacer and corner spacer used to seal RPC from all 4 side edges.
- Fill Gas mixture:
  Argon: Target for ionizing particle.
  Freon (R134a is eco-friendly substitute of freon): absorbs free charge particles in the gas before any further avalanche is produced.
  Isobutane: organic gas to absorb photons from recombination process, limiting the formation of secondary avalanche from primary.
  SF6: quenching gas.
  For running the RPC is avalanche mode Freon: Isobutane: SF6 is used in a ratio of 95.5: 3.9: 0.60.
- The pick-up panel composed of a plastic honeycomb core 5mm thick, with 50 micron aluminium sheet on one side for grounding and copper strips on other side. Two pick up panels are place on the either side of RPC, oriented orthogonally to each other each having 64 readout strips, soldered to wire which connects to electronics.

- Pickup panel and RPC are separated by insulating mylar sheath.
- RPC with pickup panels are packed in Aluminium casing.

Working of RPC

When a minimum ionizing particle passes through RPC detector it ionizes the gas. The ions thus produced drift in the electric field producing further ionization if the field is strong enough. Further multiplication leads to free charge which recombines to give photons which inturn produce avalanche. As the time to recharge the electrode ($\tau \sim 1.8$ s, τ = dielectric constant * resistivity) is larger than the discharge time (1ns), field drops in the region of discharge thus reducing further multiplication known as space charge effect. High resistivity also ensures localization of charges and remains active for time.

Modes of operation

Gain factor of the detector is defined as

$$M = n / n_0, \quad n = n_0 \exp(\alpha - \beta)x$$

where α = first townsend co.effecient. i.e. number of ionization/length.
β = attachment co-efficient /length.
x = distance of point of ionization and the anode.

$M < 10^8$ is avalanche mode. No secondary avalanche.

- Higher rate capability.
- Aging effect not seen.

$M > 10^8$ is streamer mode. Recombination photon leads to avalanche.

- Higher efficiency – 99 %
- Good timing resolution 1 ns.
- Low rate capability.

FABRICATION:

We used the Float Glass of 3mm thickness of make Asahi, corners chamfered at 45 degree. Cleaned and painted as per the standard procedure. Glass is spray painted on one side by Nerolac conduction paint (Paint the thinner ratio 1:1.) with surface resistance of the order of 1MΩ +/- 200kΩ .

We followed the standard protocol for making RPC. (refer. elog)

i. Select two glasses of similar resistance.
ii. Remove thermocal protection from glasses.
iii. Clean the protected surface (surface without paint) with Iso-propyl alcohol. Also, clean button spacers with alcohol.
iv. Put one glass with painted surface facing below on a flat assembly table.
v. Put the top unpainted surface, put a drop of glue (DP 190 grey) at ever 200mm spacing.
vi. Put a button spacer on the top of each glue drop an press lightly.
vii. Again put a drop of glue on the top of the button spacer.
viii. Place the second glass with unpainted down on top of the button spacer taking precaution that both top and bottom glass edges should be aligned properly.
ix. Cover this assembly with a polyethelene sheet with edge sealed on the working table with masking tapes. (Polythelene sheet should be big enough so as to cover the suction port on assembly table.)
x. Start the suction pump and adjust the suction pressure.

xi. Close the suction pump after 4 hours.
xii. Cut the edges to proper size.
xiii. Clean the edge spacer and gas nozzle with alchol.
xiv. Put the edge spacer and gas nozzle along the sides of RPC and interlock them.
xv. Put glue between the edge spacers and gas nozzle & glass edge. Glue should be enough to seal the edge gap but not overflow on the spacer or glass. Allow the glue to harden for 12 hours.
xvi. Overturn the RPC and again apply glue between the spacers and glass edge on the other side. Allow the glue to harden.
xvii. Flow the Freon gas through the RPC and detect the leaks.
xviii. If leak I found then reapply the glue to the leaking areas and recheck for leak after glue hardens.
xix. If no leak is found RPC is ready for packing.

Leak testing.

- Flow test: Freon gas is filled in RPC from one corner of the detector with two adjacent corners sealed. The glass that flows out through the diagonally opposite nozzle is passes through a bubbler to test the flow patter of the gas. Uniform flow through the detector without any leak is indicated by train of bubbles, else lumpy flow of bubbles indicating leak.

- Pressure test: Freon gas was filled detector through a nozzle and the adjacent nozzle is connected to manometer with other to corner nozzle sealed with a stopper. Gas is filled in the detector to obtain differential pressure of around 27mm. And the inlet is then sealed using constrictor. The detector is left for 2 hours. Leak in the detector will be indicated by reduction in pressure of the filled gas.

Only if the detector passes this leak test that it is ready to use. If leak is detected the leak position is identified by Freon sniffer RIKEN GH-202, re-gluing done where ever necessary and leak test is repeated..

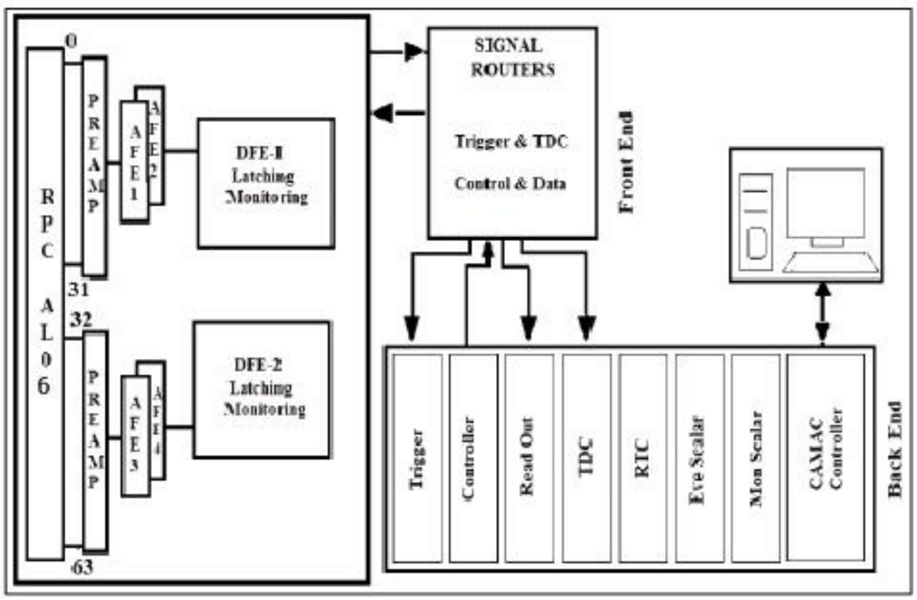
Packing of RPC

Leak tested RPC is then packed, with panel pickup strip on either side. Small copper strip is pasted on the graphite and high voltage cables are soldered. Positive voltage is applied to upper plate while negative voltage is applied to the lower plate. Mylar sheets ate placed in between pickup panel and graphite coating and over the pickup panel for insulation. All this is packed in an aluminum casing.

DAQ and TRIGGER SETUP.

The RPC made are then tested for their performance using cosmic ray muon. When a muon pass through RPC the signal generated in RPC is picked up by copper strips on both the pick-up panel close to the ionization. This signal is transmitted through strips acting as transmission line to the electronic. It is further amplified: *PreAmplifier*. Processes by the Front-End electronics: *AFE, DFE, Signal Router*. If a trigger signal is received indicating passage of a muon track, the processed signals are latched and recorded by the NIM and CAMAC based Back-End electronics: *Control module and Readout Module*. All these modules are is interfaced to a PC through CAMAC controller which regulated the synchronous functioning of all CAMAC modules.

Following figure shows Block diagram for the Data Acquisition System.



Block Diagram of Data Acquisition system.

Trigger logic:

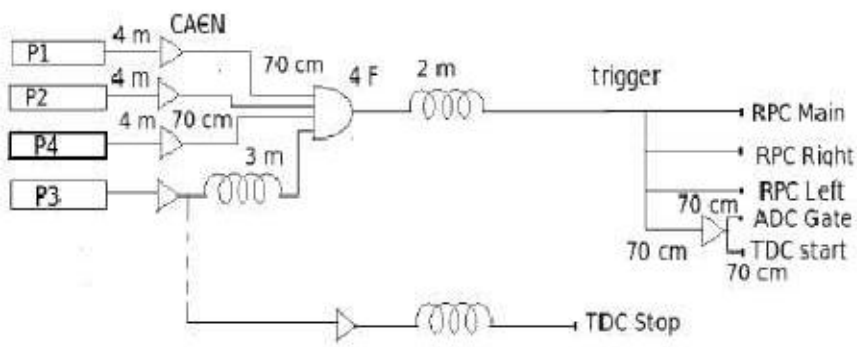
In order to study the efficiency of the Detector, a cosmic ray telescope is build using four panels of Plastic scintillation with following dimensions,

P1 (30 x 3 sq cm), P2 (30 x 2 sq cm),

P3 (40 x 20 sq cm) , P4 (40 x 20 sq cm).

Four Panels were placed one above the other separated by about 16 cm, such that it makes a window of 20 cm x 2 cm, which was aligned with strip number 20, we will call it Main strip. RPC was placed after P2. This will ensure that when the muon passes through all the

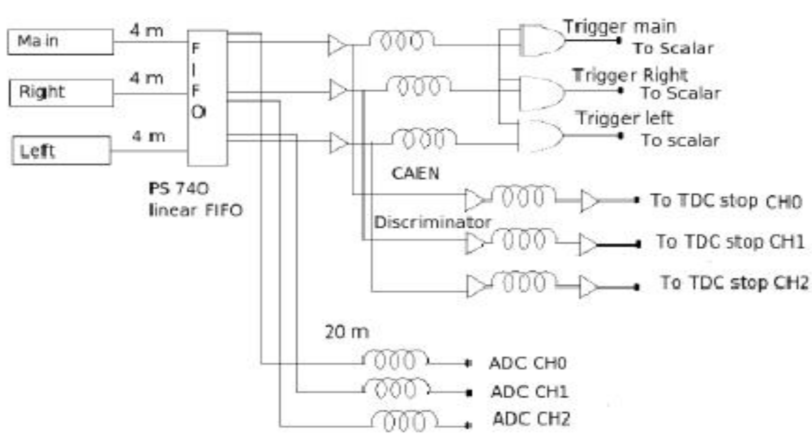
four panels of the telescope it has passes through the RPC also.
Signal from all four panels are passes through a discriminator with threshold voltage of 20 mV and ANDed together to give P1.P2.P3.P4 four fold signal. P3 is delayed by extra 3m to account for gitter in the rising edge of the signal from each panel. The ANDed signal is the trigger pulse, if 1 it indicated the passage of muon through the set window in the detector. This trigger signal is then ANDed with signal from Main strip of RPC which is aligned to the telescope and also with the signals from adjacent Right strip and left strip. This Trigger also sends a start pulse to TDC and ADC Gate.



TRIGGER SCHEME CIRCUIT DIAGRAM.

Signals from main strip and the adjacent right and left strips are sent to discriminator and delayed the before being ANDed with Trigger signal. Only when the 4Fold trigger is 1 and the respective RPC strip signal is 1 that the Scalar counter of respective strip will increment its count by one. The number of time the condition is satisfied out of the total trigger signal gives the efficiency of the detector.

Signal from the strips also go as Stop pulse to respective TDC corresponding to that strip and the respective ADC.



Circuit for Efficiency study.

Data read out.

Scalar for Trigger x Main - No. of times the main strip gave signal above threshold on trigger.

Scalar for Trigger x Right - No. of times the right strip gave signal above threshold on trigger.

Scalar for Trigger x Left - No. of times the left strip gave signal above threshold on trigger.

TDC of Main - Time between trigger pulse and RPC pulse from main strip.

TDC of Right - Time between trigger pulse and RPC pulse from right strip.

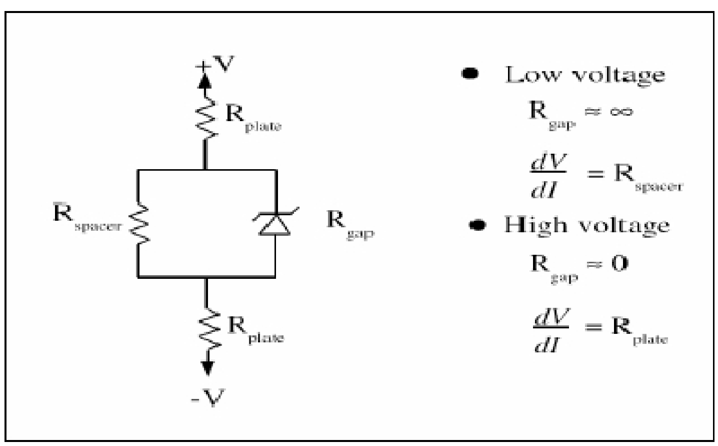
TDC of Left - Time between trigger pulse and RPC pulse from left strip.

STUDY OF RPC CHARACTERISTIC

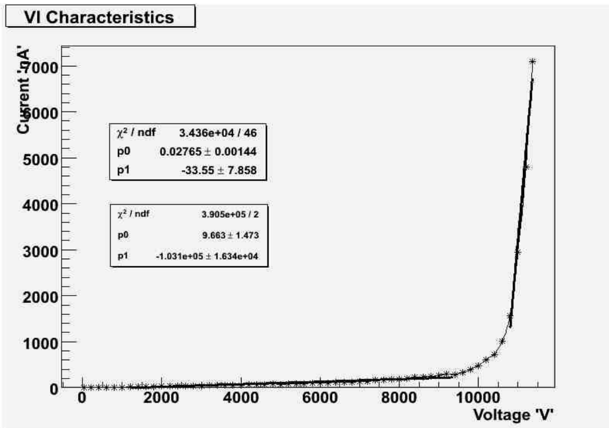
V–I Characterization:

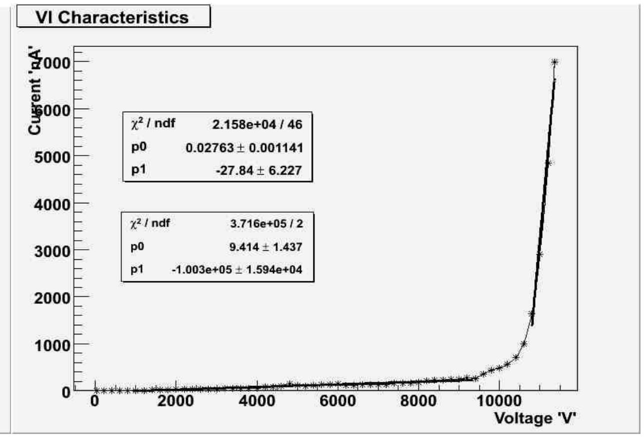
To see the V-I characteristic of RPC, varying voltage applied across RPC current was noted. Plots for V-I characteristic for both positive and negative channel are given below. The seen in the plot the V-I plot can be divided in two regime of voltages. At low voltage the primary ionization does not produce avalanche. Hence the gas gap impedance is infinite and the current through the RPC is proportional to resistance provided by spacer which is certainly less than gap resistance. While at higher voltages when avalanche are produced the gas resistance drops down and the current obtained sees resistance due to Glass plates.

Equivalent circuit is as given below



RPC Equivalent circuit





V-I FOR NEGATIVE VOLTAGE V-I FOR POSITIVE VOLTAGE

PLOT SHOWS V-I CHARACTERISTIC OF POSITIVE VOLTAGE (CHANNEL A) AND NEGATIVE VOLTAGE (CHANNEL B)

For Channel A:

Gas Resistance: 36.1925 GΩ (low voltage region.)

Glass Resistance: 0.1062 GΩ (high voltage region.)

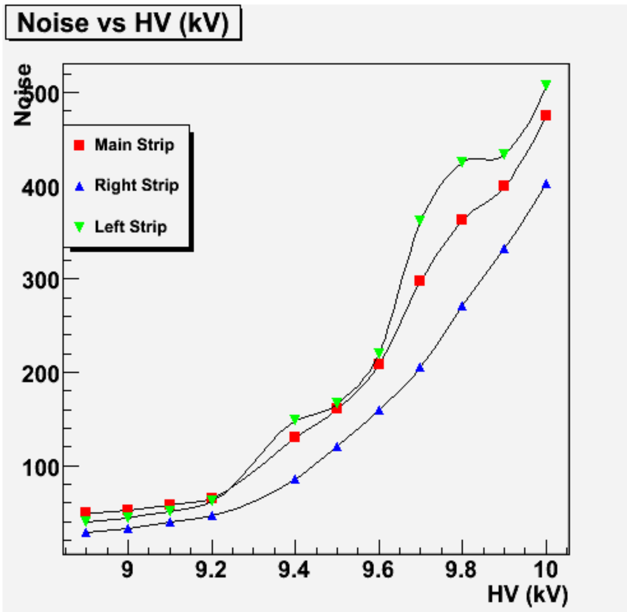
For Channel B:

Gas Resistance: 36.1663 GΩ (low voltage region.)

Glass Resistance: 0.1034 GΩ (high voltage region.).

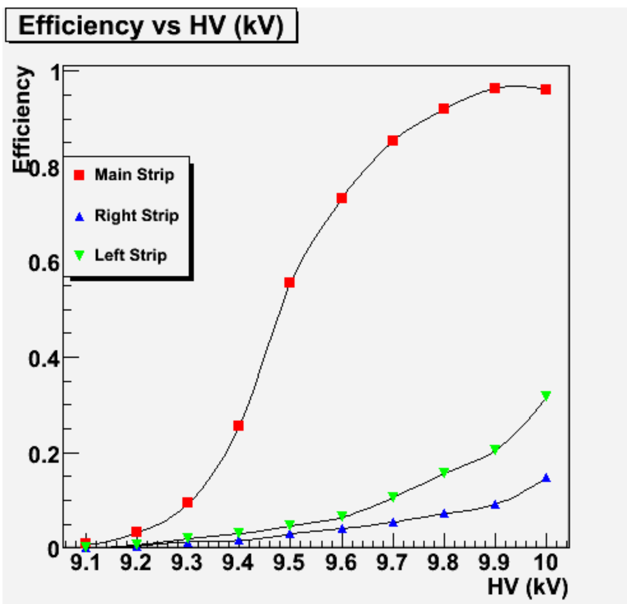
Noise Rate of the strip:

Noise rate is the rate at which random noise signal hits the strip. These signals can be due cosmic ray particles, stray radioactivity and dark current in chamber. This rate per unit area is fairly constant for an RPC when averaged over sufficiently large time. As the voltage increases even low energy particle are able to produce signal above threshold, leading to increase in noise. Noise gives a measure of health of RPC, its long term stability and the dark current.



Noise rate at different voltage for main strip and two adjacent strips.

Efficiency and Crosstalk:



Efficiency at different voltages for main strip and the adjacent right and left side strip.

When we get a trigger from cosmic ray telescope, we also expect the RPC strip aligned with window set by this cosmic ray telescope to pick up the signal. Some time the signal is picked up by adjacent strips. This is called Crosstalk. Crosstalk can be due to misalignment of strip or due to inadequate amount of quenching gas used which result in spread of discharge. Crosstalk is undesirable effect and effort take to reduce it, in order to improve the spatial resolution of the detector.

Efficiency of the RPC is the measure of how efficiently the RPC responds to the signal.

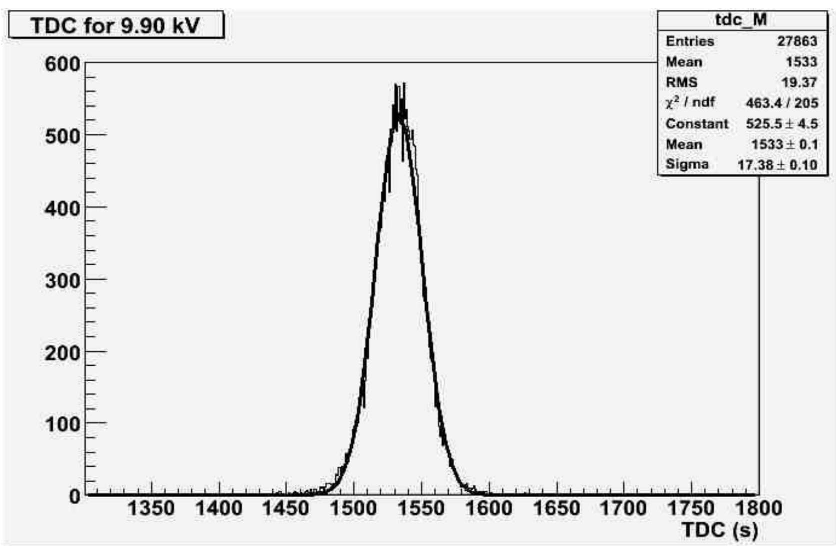
Efficiency (strip) = (No. of strip hits & Trigger) / Total no. trigger.

In above plot, Main strip efficiency is the efficiency of RPC AL06 obtained at different voltages. And Right and left strip efficiency is the cross talk efficiency which is as desired low.

Efficiency of the detector is seen to increase with voltage and reach a plateau at higher voltage. The operating voltage of the RPC is fixed at the point where RPC efficiency is greater than 90%.

Time Resolution:

In a tracking device it is desirable to know the timing of RPC signal to get the direction of the incoming muon. Time-to-Digital-Converter measures the timing of RPC signal w. r. t the trigger. Following plot shows a histogram of the TDC value, the sigma of the fit gives timing resolution.



TDC Histogram for 9.9 kVvalue in 10ns.

Timing resolution was 1.738 ns at operating voltage of 9.9kV.

CONCLUSION:

Two 1m by 1m RPCs were fabricated successfully. As these RPCs we meant VECC lab, we performed the RPC characterization study on RPC AL06 which is 2m by 2m RPC. Efficiency, Noise rate and V-I characteristic shows desired behavior.

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References:

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