STUDY OF RESISTIVE PLATE CHAMBER (RPC) AND ITS EFFICIENCY

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Introduction:-

The Resistive plate chamber (RPC) is a gaseous detector with good spatial as well as timing resolution. RPCs are going to be used as the active detector element for the INO-ICAL experiment. . RPC's can also be used in the tracking (iron) calorimeter which can simultaneously measure the energy as well as the direction of the charged particle. RPCs are preferred over scintillator because it has 1) good detection efficiency (>90%) 2) Easy for construction 3) better time resolution (~1 ns) 4) long term stability.

Working Principle of RPC:-

RPC comprises of two parallel plates of glass and held together by spacers which maintain a gap between the glass plates through which gas flows. Two high resistive plates are acting as the two electrodes, where we have applied 5 kvolt to the each plate. An ionizing charged particle traversing the gap creates a charge pair in the gas volume. The charge produced in the gap drifts towards the electrodes and they induce charge in the pickup strips placed on the outer surface of the glass.

There are two modes of operation for RPC's

1) Avalanche mode:-

Any charged particles passing through the gaseous medium produce primary ionization. These ionized particles are accelerated by the electric field and produces secondary ionization by colliding with the other molecules. This internal field is finally opposed by the external electric filed, so the multiplication process stops after sometime. Charges are then drifting towards the electrodes from where they are collected. This mode operates at a lower voltage and the gain is low. Pulse amplitudes are of the order of few mV.

2) Streamer mode:-

In this mode secondary ionization continues until breakdown occurs in the gas. Then continuous discharge takes place. Discharge is localized to a small area of $0.1 cm^2$ due to the high resistivity of glass electrodes (10^{12} Ω/cm). Pulse amplitudes are of the order of 100-200 mV.

Circuit representation of of RPC is

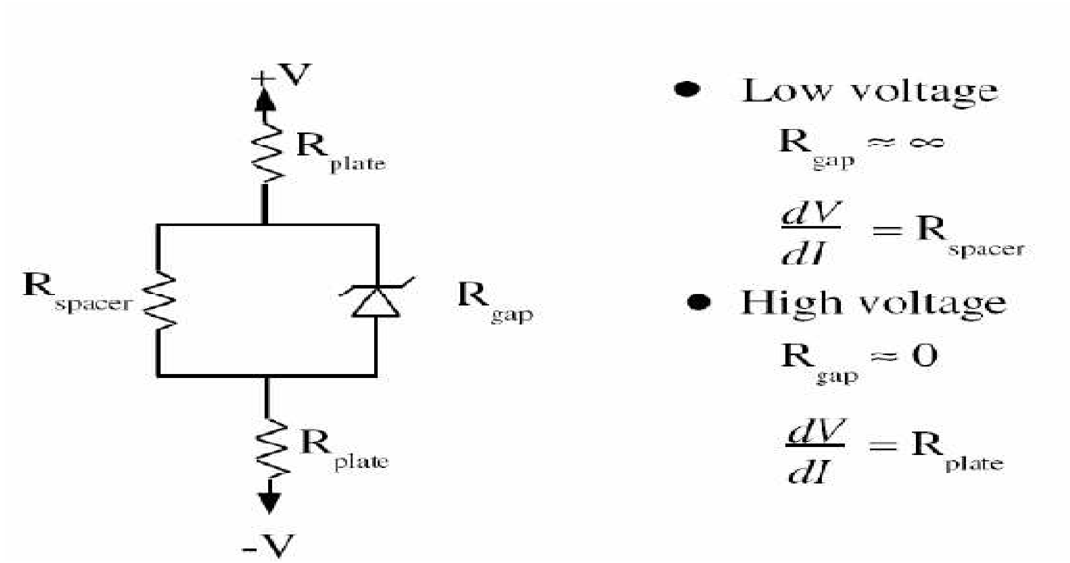


Fig 1- Equivalent circuit representation of RPC

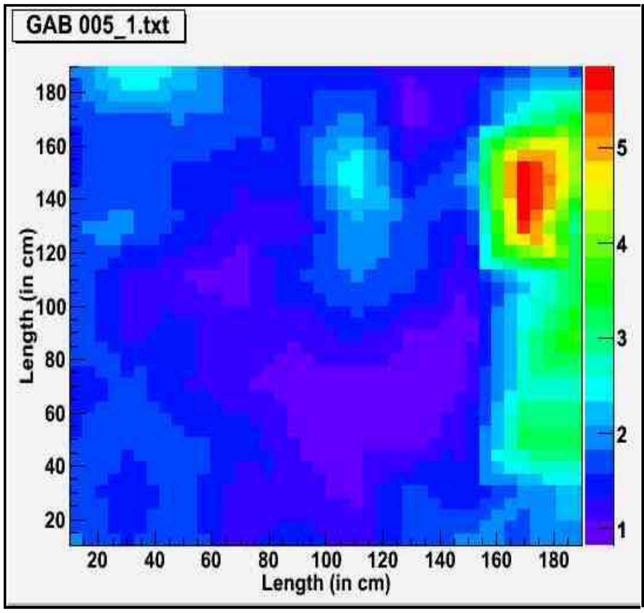
RPC Construction:-

We have made 2m x 2m RPC. Different stages of fabrication of RPC are

1. ***Glass cutting and cleaning*** *:-*
   Glass used for RPC is cut exactly in the dimension of 2m x 2m. Thickness of the glass is 3mm. The four edges are then cut off, just the right dimensions to make a correct 45^{Θ} angle. The glass is then thoroughly cleaned with alcohol (propan-2-ol) .
2. ***Conductive coating :-***
   Glass is coated in one side with a mixture of dry colloidal graphite. Then surface resistivity is measured by copper and brass square. This coating serves two purposes; it is conductive enough to act as anode/cathode and it is resistive enough to prevent itself from conducting signal away from the pickup planes.

   Surface resistance plot:-

   The surface resistance of five RPC's is measured and we get uniform resistance of two plates which are used for making RPC AL03. Change in resistance plot is due to the non uniform graphite coating. Surface resistance per unit area is 1 MΩ.



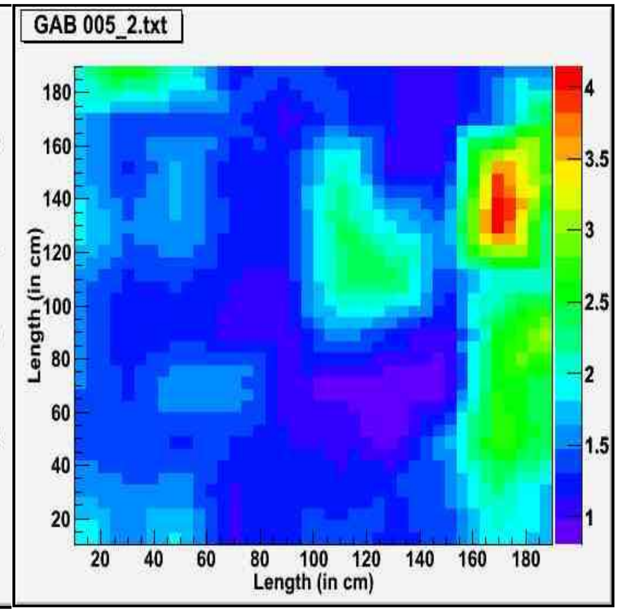
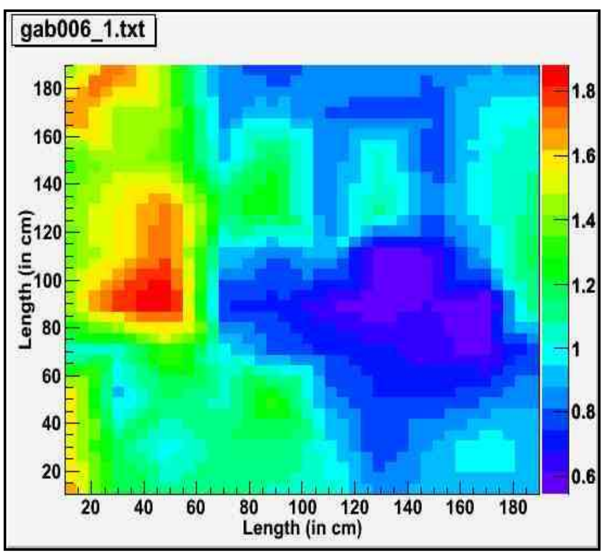


Fig 2- surface resistance along X axis

Fig3 – surface resistance along Y axis



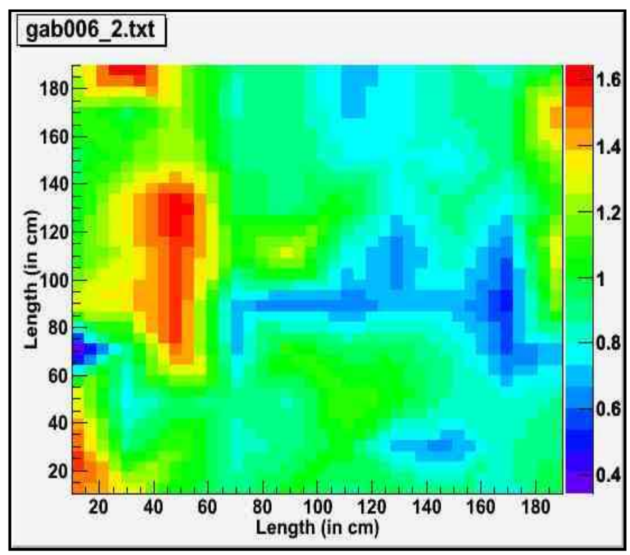


Fig 4- surface resistance along X axis

Fig 5 – surface resistance along Y axis

3. *Gluing of Glass :-*

One of the glasses is put on a plastic sheet, then button spacers (2mm) are placed on top that with glue. Then another glass is placed on top of it. Straight edge spacers are also attached with the help of glue. It also contains gas inlet/outlet pipes into which gas nozzle fits. It is shown in fig.

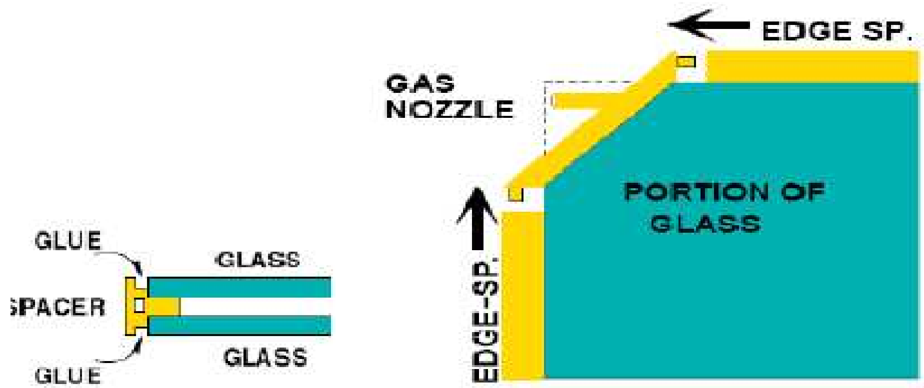


Fig 6: - view of spacers

4) ***Leak test :-***

   RPC now tested to make sure that there is no leak at the glued join. This is done by a gas sensor FLON GH-202F.

5) ***High Voltage Cables :-***

   High voltage is applied to the both plate of the RPC by bi-polar high voltage supply. So both the plates will see a common ground. This is done to avoid HV leak. Voltage is +5 kV (-5KV).

6) ***Pickup strips:-***

   Pickup panel consist of 64 strips copper foil. Each strip is 2.8 cm and gap between two strip is 0.2 cm. Each strip is terminated with 50Ω resistance to match with the characteristics impendence of preamplifier.

Gas flow system:-

The mode of operation of RPC depends upon the composition of Gas. Choice of the Gas is governed by several factors; low working voltage, high gain, good proportionality and high rate capability. We chose Nobel gases for getting minimum working voltage and also lowest electric field intensities for avalanche multiplication. The conditions which determine avalanche multiplication are

I. First ionization potential
II. First Townsend co-efficient
III. Electronegative attachment co-efficient

Gas Composition:-

It consist mainly three gases, Freon, Isobutene,SF_6 .Their compositions are

1) Freon → 95.2%
2) Isobutane →4.5%
3) SF_6 → 0.3%

Freon mainly produces ionization. Isobutane absorb ultraviolet photon which is produced in electron-ion recombination. For this reason isobutane is called “quenching Gas”. Function of SF_6 is that it controls excess number of electrons.

Components of Gas flow system:

1. **Purifier column-**
   It absorbs moisture content of the gas which passes through it. It consists of molecular sieve made of silica gel.
2. **Bellow valve –**
   From purifier column gas has to go to MFC through this valve which is activated using N_2 gas.
3. **Mass flow controller (MFC) –**
   Mass flow controller controls the flow of gas. It has 4 parts, Bypass, Sensor, an electronic circuit and regulating valve. Sensor mainly controls amount of
   flow of gas with the variation of temperature. Flow of gas is displayed in SCCM.

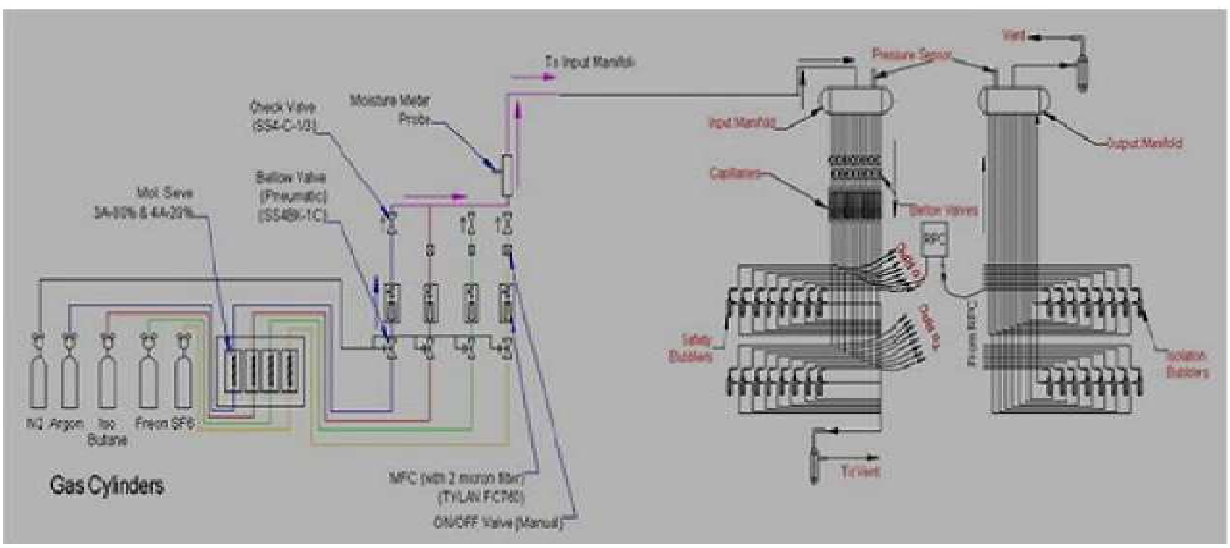


Fig 7- Block diagram of Gas flow system

4. **Capillaries –**
   Capillaries are used in order to maintain uniform flow of gas mixture through all RPC’s. Capillaries are of 2 m length and 200µ in diameter. These offers a resistance of 1/14 th of a bar to the gas flow when the flow is about 6 sccm.

5. **Bubblers –** There are two types of bubblers, safety bubblers and isolation bubblers. Safety bubblers take care of the back pressure exerted and protect RPCs from over

pressure. Isolation Bubblers prevents back diffusion of air into the RPC and also indicate flow of gas.

6. **Moisture meter –**

   It measures the moisture content of the gas mixture and dew point. Range of this meter is 0.5 to 1000 ppm moisture i,e 80ºc to 25ºc dew point.

7. **Exhaust manifold –**

   The gases to be vented are collected in this manifold. Output is provided to vent the used gas into the atmosphere. It has a pressure sensor which indicates the pressure with respect to the room pressure.

Trigger selection mechanism:-

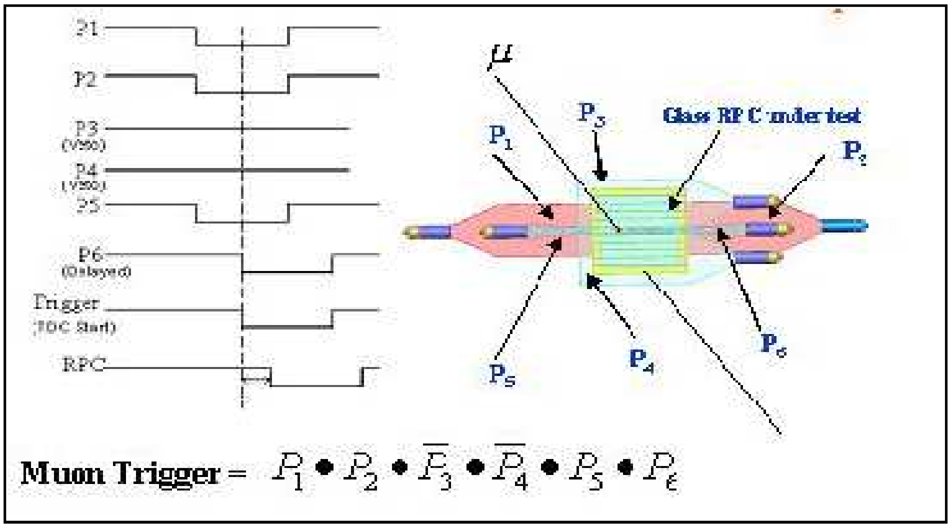


Figure 8. Schematic of the RPC test setup

Six scintillator paddles are used to set a coincident circuit for this purpose. The telescope consists of 4 cosmic ray muon trigger paddles P1, P2, P5, P6 and two veto paddles P3, P4. 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. Veto paddles are used to prevent generation of triggers when a muon passes through the rest of the area of RPC which is not under study. The event data from the RPC pickup strip is recorded whenever a cosmic muon generates a trigger signal through the logic $P_1 .P_2.\overline{P_3}.\overline{P_4} .P_5 .P_6$ 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.

Electronic setup for Data Acquisition System –

We need to record the event time, three dimensional interaction tracks in the detector . For entire signal processing setup is shown in the block diagram. Modules are described briefly here.

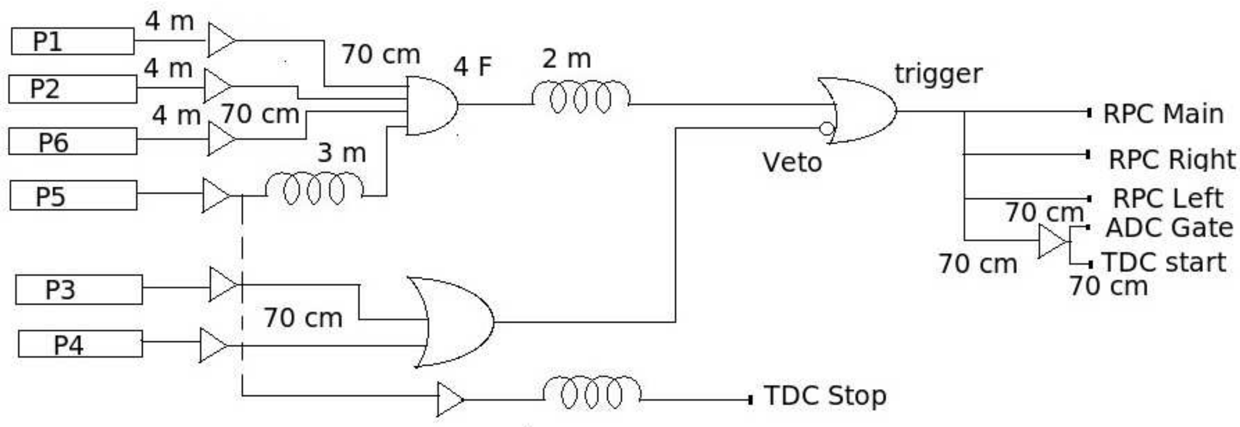


Fig 9 – Trigger Logic circuit

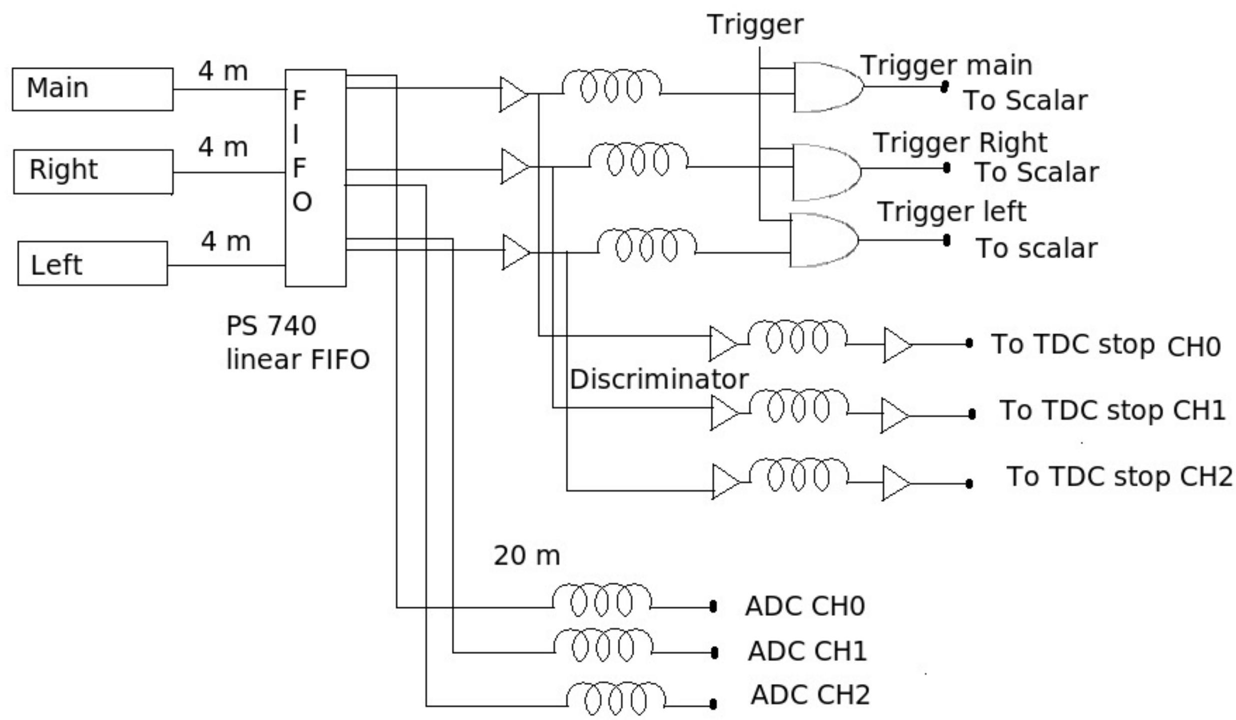


Fig 10 – Circuit Diagram for calculating efficiency

The entire signal processing and data acquisition system can be divided into the following modules:

- Front end electronics (16 channel analog front end and 32 channel digital front end).
- Trigger module.
- Signal routers (Trigger and TDC Router & Control and data Router).
- Back end DAQ system (Data and Monitor Control module & Data and Monitor Readout module).[5]

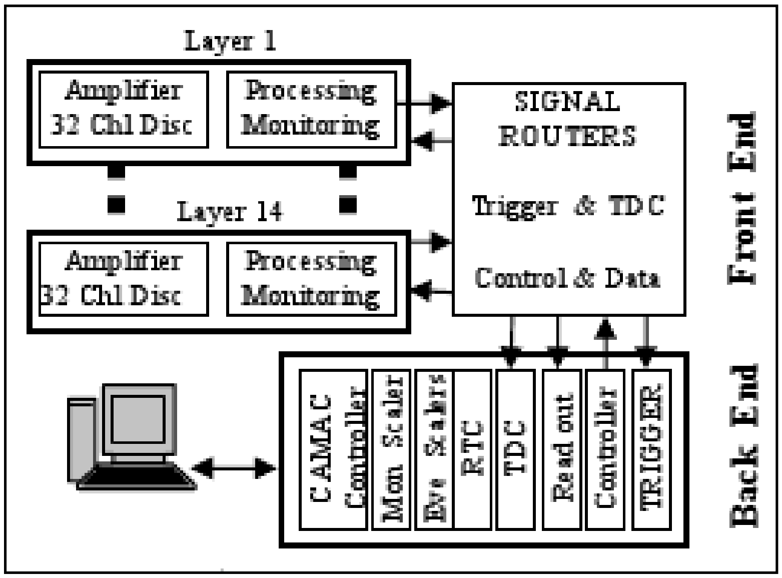


Fig 11 – Block diagram of Electronic circuit

Front End Electronics –

Charge collected in the pickup strip is passed through a -ve preamplifier (IC 1595) accepts –ve pulse and generate –ve pulse (x Plane) and similar for Y plane +ve preamp (IC1597) generates –ve signal. Then both are cascaded by second stage preamp (IC 1513). Gain of cascaded stage is about 80. Then the output is fed to two 32 channel discriminator modules. When the signal crosses the set threshold in the discriminator, we get a differential ECL output. These are called as Trigger 0 signal. The discriminator modules are connected to FEP modules which converts ECL to TTL, which generates trigger 1 signals.

- ***Trigger Logic*** –

Signals coming from the different strips are first converted in ECL logic. Then every 8th strip signal is ANDed to form trigger 0 signal. The basic principle of trigger logic is that (M x N) fold coincidence where M is the layer coincidence of M consecutive signals out of 64 pickup signals and N is the coincidence of M fold triggers from the consecutive N layers

[The M x N folds implemented are 1x5, 2x4, 3x3, 4x2.]

At first the shaped Discriminator pulses from every 8^{th} channel out of 64 channels in a X pick up plane of RPC are logically ORed to get 16 T0 signals.

These 16 T0 signals are logically ANDed to achieve the required M fold triggers (T1 signals – 1F, 2F, 3F, 4F) in the second stage. Due to loOse logic adopted in T0 logic, there may be unwanted triggers T1. Considering the low rate of pick up signals, the chance rate of unwanted triggers is almost negligible. But this logic helped in scaling down the circuit in second stage. The Trigger_1 logic is implemented in the Front End Processing module (FEP) using programmable device making it user configurable.

The M fold signals (T1) from X plane of RPC in all the layers are routed via Trigger and TDC Router module to the Final Trigger module in CAMAC crate. The MxN coincidence logic to obtain T2 trigger is implemented in this module using T1 signals. The T2 signals from X plane and Y plane are logically ORed to get a Final trigger signaling valid Event to be recorded.

This logic is applied where there is large number of RPC layer. But here we have applied scintillater paddle and the logic is $P_1 .P_2.\overline{P_3}.\overline{P_4} .P_5 .P_6$.

- ***Trigger and TDC Router: (TTR)***

The M fold signals (T1) from all the pick up planes are fed to this TTR module in LVDS form. They are grouped mainly as Trigger signals and TDC stops. The trigger signals (LVDS standard) are connected to Final Trigger module in the back end via twisted pair flat cable. The TDC stop signals (differential ECL standard) are connected to TDC modules in the CAMAC crate for recording relative time delay along line of interaction between the layers.

- ***Control and data Router :-***

It is basically buffers and establishes interface link to INO controller, daisy chains of FEP modules and INO Readout modules. All the input and output signals are of LVDS standard. It receives control signals from INO controller and fan outs them as 2 EveCom outputs and 8 Mon outputs. It receives serial data through 2 EveCom inputs and Monitoring signals through 8 Mon inputs and regroups them into a single connector to interface to INO Readout module.

- ## ***Data Acquisition system:***

Here PC based Data acquisition system is built using CAMAC standard modules in the back end and is connected to front end by a fast serial link. The modular approach has been adopted to achieve flexibility, scalability and fast implementation. The two main functions of DAQ System are event data recording and monitoring. Monitoring is controlled by a INO Controller module housed in a CAMAC crate at the back end. The front end modules (FEP) of X & Y planes of all the RPCs are daisy chained separately into two groups for event data recording. These FEP modules are daisy chained into 8 groups for monitoring purpose. The daisy chaining and grouping is very flexible as these modules are connected via detachable cables. The data is transferred bit serially via daisy chains to backend INO Readout module in the event process. The one pickup signal from each of 8 monitor daisy chains are linked to back end CAMAC based Sealers during the monitoring process.

Efficiency of RPC:-

Efficiency of main (S32) ,right (S33), left (S31) strips are calculated as a function of voltage. These are shown in fig.

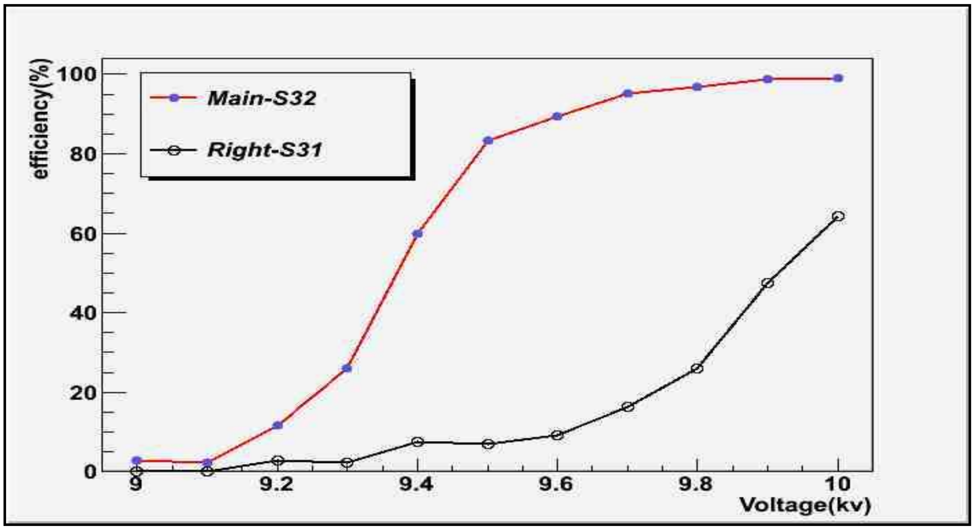


Fig 12: - Efficiency vs. Voltage.

Plateau region of RPC AL03 is obtained from 9.6kv. Efficiency is 95%, so the RPC AL03 is operated in 9.6kv. For left strip efficiency is flat at almost 5% efficiency, so it is not shown here.

- ***I-V Characteristics plot :-***

  I-V Characteristics for channel A shown in fig-

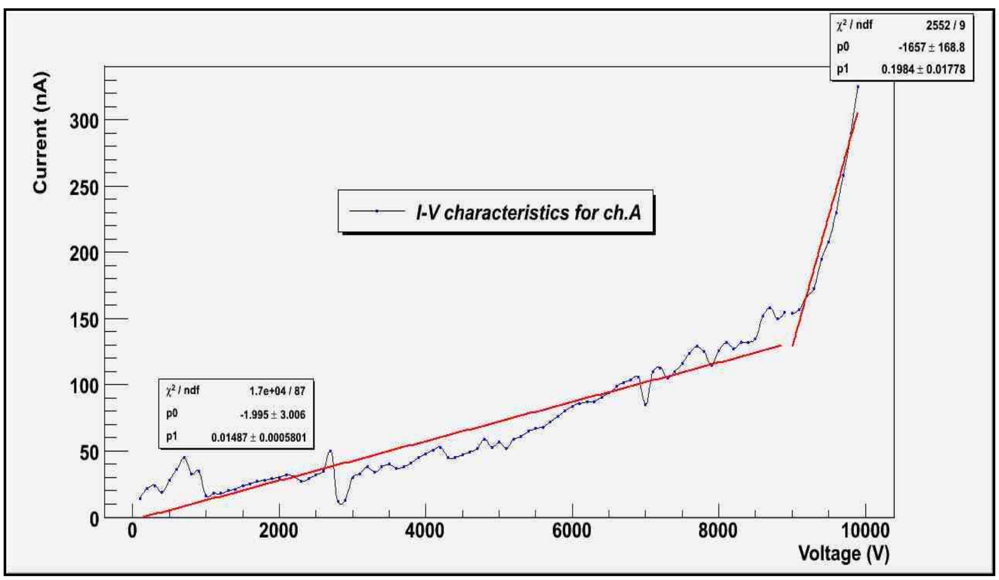


Fig 13 – current vs voltage for channel A.

For channel B i-v characteristics is shown in fig

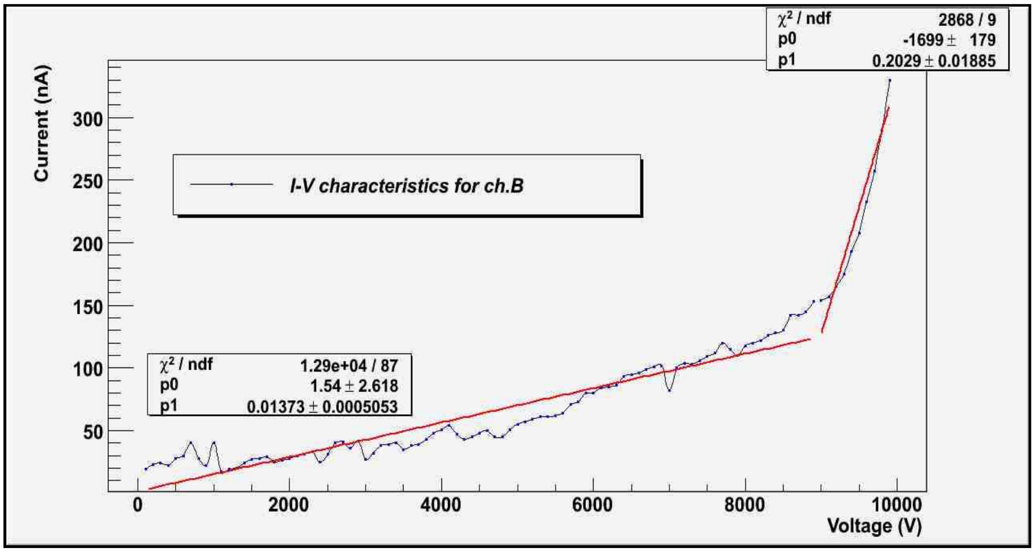


Fig 14 –current vs voltage for chB

Positive voltage is applied in ch A and Negative voltage is applied in ch B. Resistance for channel A is Gap resistance = 67.2598 GΩ, at low voltages Glass resistance= 5.04133 GΩ, at high voltages (above 9kV).

For channel B is
Gap resistance = 72.8188 GΩ, at low voltages
Glass resistance = 4.9283 GΩ, at high voltages (above 9kV)
Noise rate plot as a function of voltage is

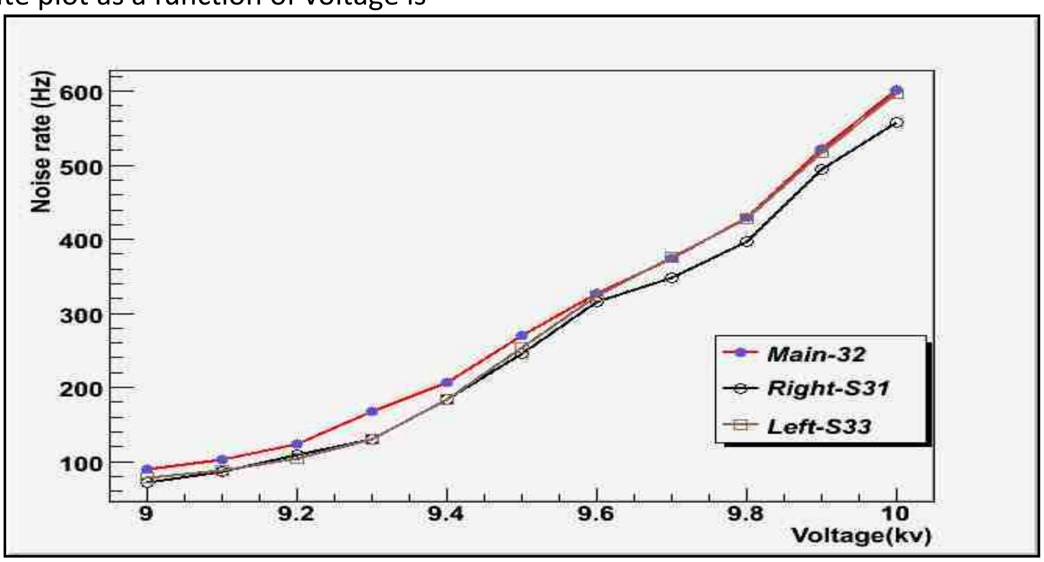
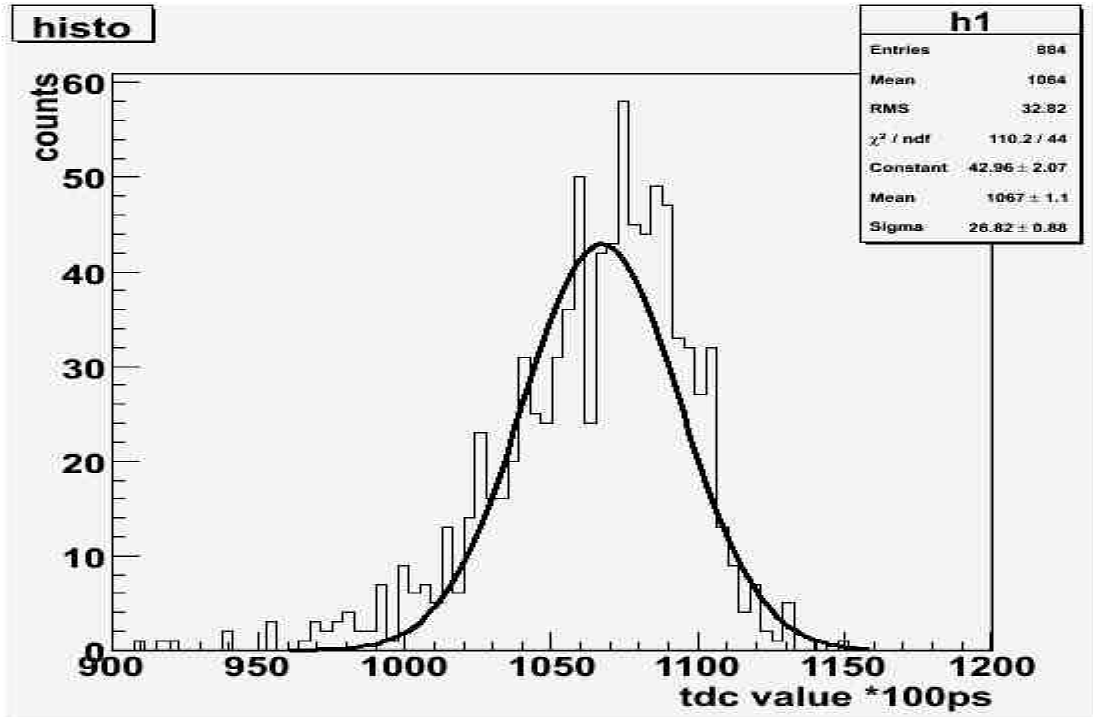


Fig 15 – Noise rate vs voltage

TDC Plot:-



Time Resolution of RPC main strip = Sigma x Least count of TDC

= (26.82x100) ps

=2.682 ns

Conclusion –

Construction of AL03 2mx2m is successfully done and it is operated in a voltage of 9.6 kv with an efficiency of 95%. Also noise rate and time resolution is calculated.

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References:-

1. V.M.Datar, S.Jena, S.D.Kalmani, N.K.Mondal, P.Nagaraj, L.V.Reddy, M.Saraf, B.Satyanarayana,R.R.Shinde, P.Verma, "Development of Glass Resistive Plate Chamber for INO experiment".
2. S.S.Upadhya, "Conceptual design of DAQ system for a prototype detector".
3. S.D.Kalmani, N.K.Mondal, B.Satyanarayana, P.Verma, "Online gas mixing and multi-channel distribution system".
4. . B.Satyanarayana, "ICAL electronics and DAQ schemes".
5. B.Satyanarayana, "Electronics for the INO ICAL detector".
6. B.Satyanarayana, "Commissioning of ICAL prototype detector electronics".
7. S.S.Upadhya, "Electronics and DAQ system for INO prototype detector".
8. D.Indumathi, IMSC "Report of work done at TIFR and BARC".

9. S.Biswas, "Resistive Plate Chambers for experiments at India -based Neutrino Observatory".