RPC CHARACTERIZATION AND TESTING

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Introduction:

RPC are the Resistive Plate Chamber which consists of gas mixture in the gap between two glass plates (coated with pigment paint). RPC are the active detectors which will be used in INO-ICAL experiment in order to the study the atmospheric neutrino and its oscillation. In our lab we are making 2mx2m prototype RPC, by which we are detecting the muons. As the R & D lab of RPC is in ground (not underground) we cannot detect neutrino due to the cosmic ray muon, which act as a background.

RPC are generally preferred over scintillator as it can cover large area, high spatial resolution, and long term stability.

Operating mode of RPC:

Generally RPC can be operated in 2-mode namely streamer and avalanche mode. The mode of operation depends upon the gas composition we use and the voltage we apply.

Avalanche Mode:

When the charged particle passes through the gas mixture, it will ionize the gas molecule (primary ionization), the so produced ions will further ionize the neighbor molecule, results in the secondary ionization. As the external applied opposes the internal field produced by ionization, this avalanche stops. The pulse so produced will be small of the order of few millivolts and hence it require amplifiers to readout its signal.

Streamer mode:

In order to operate RPC in this mode, Argon, SF_6, Isobutane and Freon gases are used. In this mode, continuous ionization of gas mixture will take place until there is a breakdown. The signal produced in this mode will be of the few hundreds of millivolts, hence can be readout directly without seeking the help of amplifiers.

Though streamer mode reduce the cost as it does not require pre-amplifiers, the life time of RPC will be reduced in this mode. So right now RPC are working in avalanche mode.

Electrical Analogy of RPC:

Electrically RPC is represented as

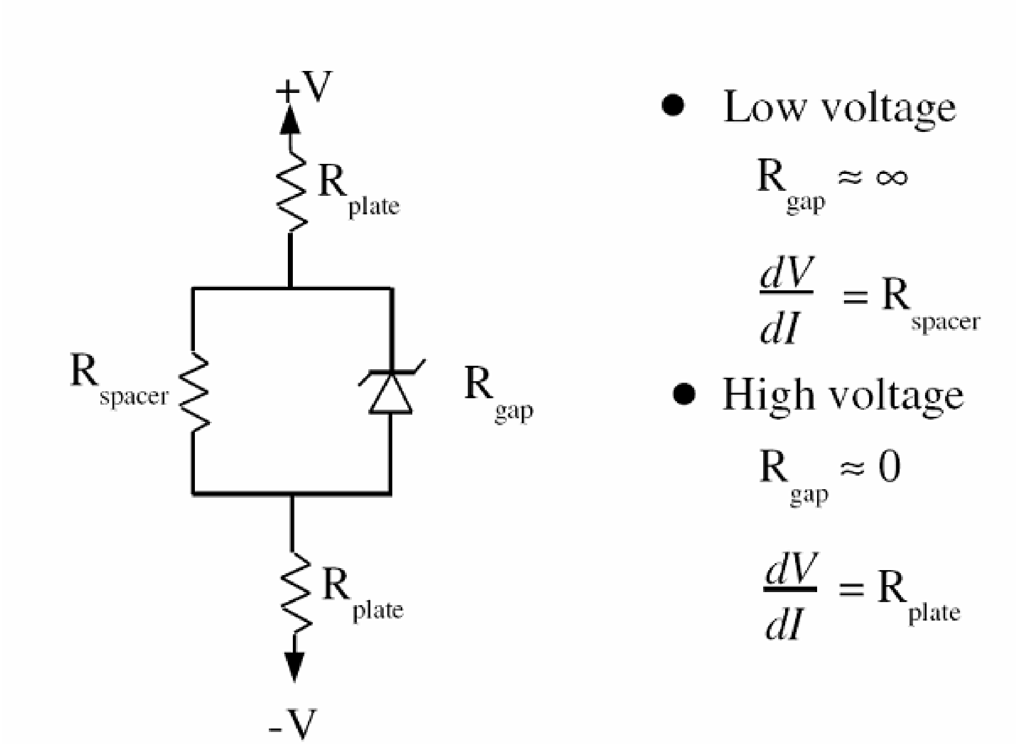


Fig 1. Electrical Representation of RPC

The spacer sandwiched between plates as a resistance, whereas gap(through which gas flow) act as zener diode.

Fabrication of RPC:

RPC gap was fabricated in the following method. First we had taken 2 glass plates, cleaned them with various liquid in the following order.

1) Alcohol,
2) Distilled water
3) Labolene (wait for 5 min.)
4) Distilled water
5) Alcohol.

Then the glass plates were taken to paint. One side of both the glass plate were coated with conductive pigment paint. Then it was allowed to dry.

When the paint got dried, surface resistance of both RPC plates were measured using Brass Resistive Measurement Jig and the plots were plotted.

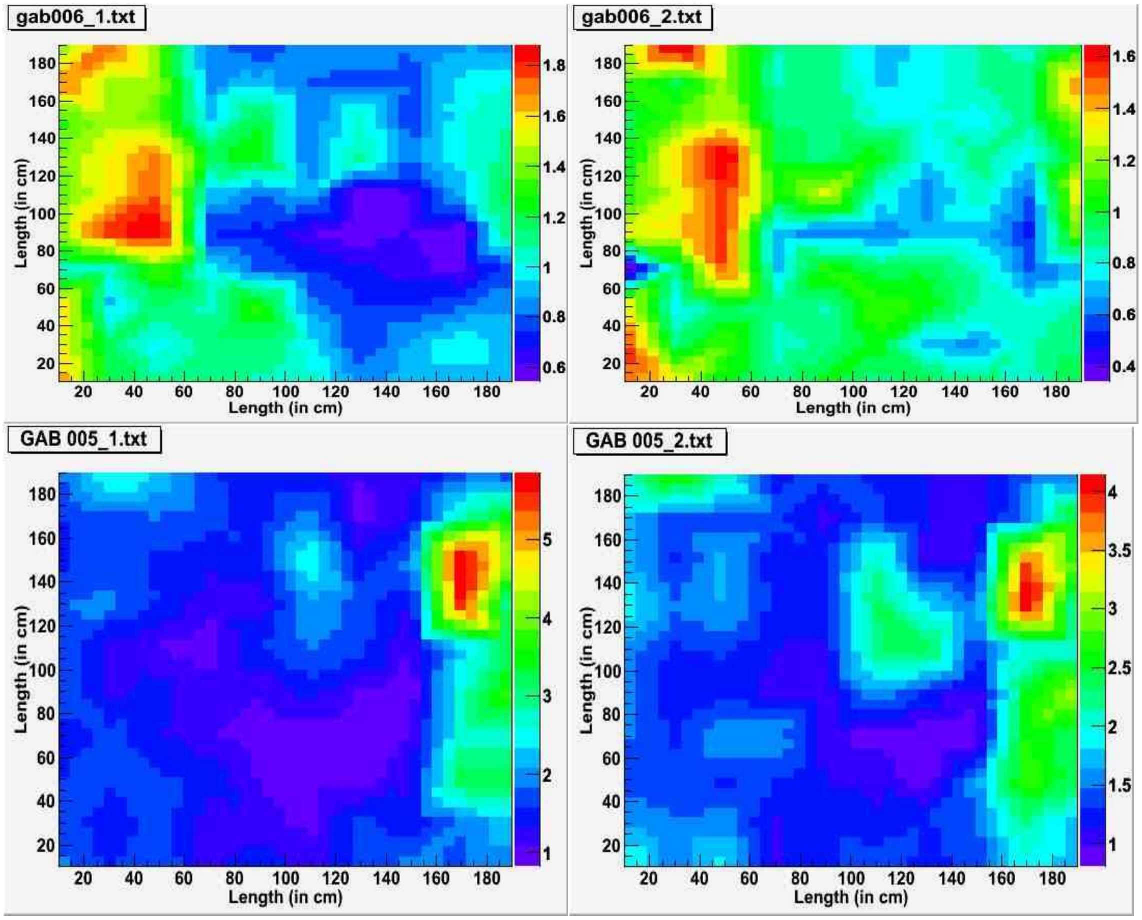


Fig 2. Surface resistance of glass plates GAB 005 & GAB 006

The surface resistance were measured both horizontal and vertical vice and hence for 2 plates 4 plots were there.

After surface resistance measurement, RPC gap was made. This was made by placing spacers (say disc of 1cm diameter and thickness of 2mm), in between 2 glass plates such that the uncoated side face each other. Then side spacer and gas nozzle are placed and then glued. We were sure that no air bubbles formed while gluing. After gluing, uniform pressure was applied over the RPC by downward displacement of water.

Now in order to check, whether any leak was there in the glued portion, Freon gas was passed through gas nozzles. Diagonal corner act as inlet and outlet for the gas flow. With the help of leak detector (RIKEN KEIKI, GH-202F) which was calibrated for Freon, leak was checked.

Finally RPC were made. First x-plane pick up strip (plastic honey combs sandwiched between Al bottom and Cu strips), followed by Mylar sheet for insulation, then RPC gap, again Mylar sheet and finally y-plane pick up strip. Both x and y strip have to be orthogonal to each other. After this arrangement RPC testing was done, which will be discussed later in this report.

Gas flow system:

Though the system is designed in such a way to mix 4 gases, currently we are using only 3 gases as the system is operated at avalanche mode.

Gases Used:

In order to operate RPC in avalanche mode we need 3 gases, such as Freon R134A, SF_6 and Isobutane.

Freon (95.42%, 17.9sccm) to produce electrons.

Isobutane (4.21%, 0.79sccm) act as a photon quenching gas as it absorbs uv photon produced during electron ion recombination.

SF_6 (0.37%, 0.07sccm) used to controls background electrons.

Freon and Isobutane are in liquid form (within container) and SF_6 is in gaseous form whose pressure is monitored by two stage pressure regulator connected to the outlet of the cylinder. (0-5 kg/cm^2 for Freon and for SF_6 order of 25kg/cm^2)

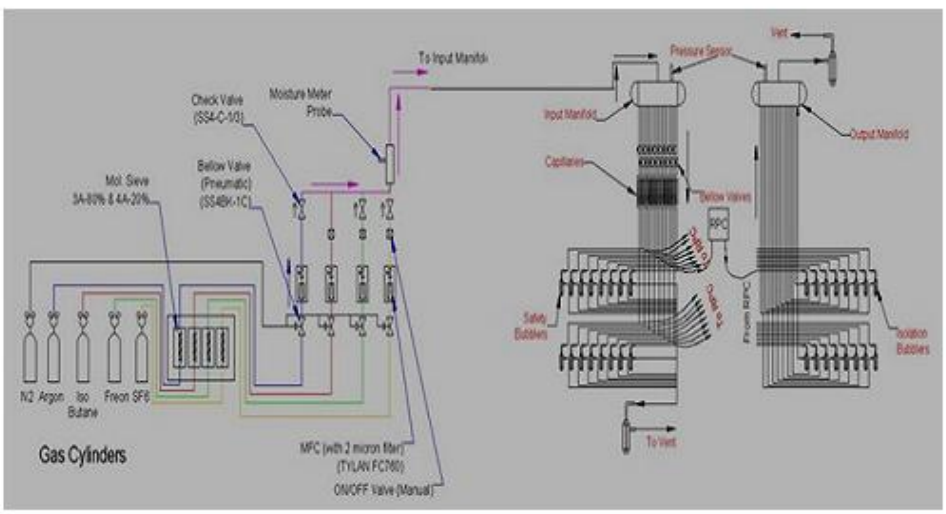


Fig 3. Block diagram of gas flow system

Gas flow system consists of various components such as:

1) Purifier column:

These gases has to pass through separate purifier column, which will absorb the moisture content of the gas which passes through it as it consists of molecular sieve made of silica gel. This is surrounded by SS tube, which is connected to heaters at the time of regeneration.

During regeneration two heaters of 500 Watts are connected in series and dry nitrogen gas is allowed to flow through the sieve. Even after heater is switched off the dry gas will continuously flow till purifier column attain the surrounding temperature.

Generally regeneration is done once in a year for Freon and once in 2 years for Isobutane and SF_6.

2) Bellow Valve:

From purifier column the gas has to go to MFC through pneumatic bellow valves which are activated using compressed air as it needs 5 bar pressure to operate.

3) Mass Flow Controller:

In this part the flow of the gas is regulated and accurately measured. Each gas channel is connected to separate MFC.

MFC consists of 4 main components such as Bypass, sensor, an electronic board and a regulating valve.

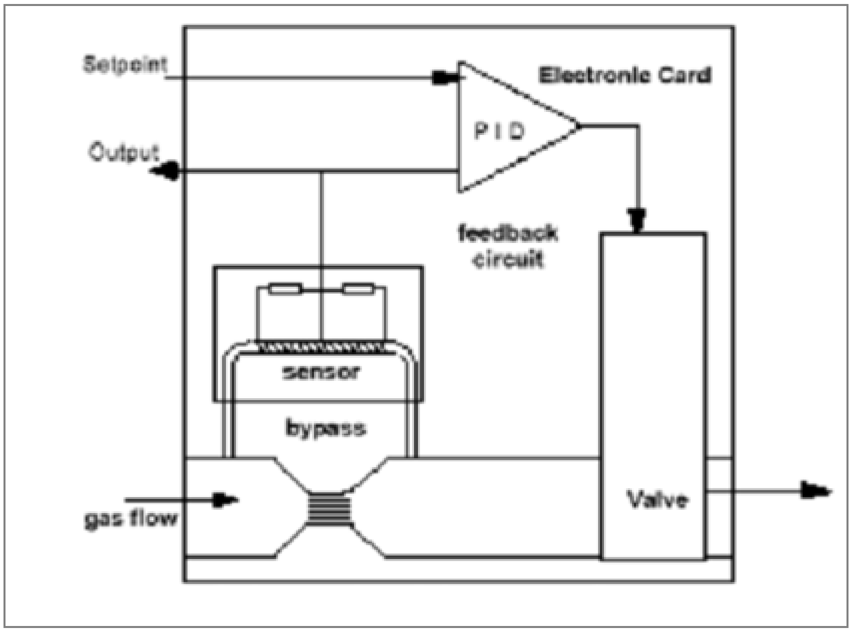


Fig 4. Schematic diagram of MFC

The gas flow is divided into heated sensing tube and a bypass, where most of the gas mixture will flow. The gas flow through sensor is always proportional to the flow through bypass.

The sensor response is linear up to 5sccm gas flow and hence for maximum flow the bypass is used. The electronic board in MFC will amplify the sensor signal. The signal will be of 0-5V. 0V indicates no flow and 5V indicates maximum flow.

In this MFC there is a set point, in which the necessary flow rate can be set up manually. There is a comparator which will compare this set valve and the amplified sensor signal and accordingly operate the control valve.

4) Moisture meter:

All three gases has to flow through a common moisture meter. This will measure the moisture content of the gas mixture, will also gives reading in dew pt. Its sensitive range is 0.5 to 1000 ppm moisture i.e., 80 ˚C to 25 ˚C due point. For a typical dry gas this meter have to read 1-2 ppm moisture.

5) Input Manifold:

The gas after passing through moisture meter will get collected in input manifold, from where the gas is distributed to various RPC through 16 capillaries, isolated by pneumatically activated valves.

6) Capillaries:

These 16 capillaries are of 2m length and 200μ in diameter. These offers a resistance of 1/14th of a bar to the gas flow when the flow is about 6sccm. Each capillary is connected to different RPC. These capillaries are used in order to maintain the uniform flow of gas mixture through all RPC's.

7) Bubblers:

There are two types of bubblers used in this gas system. Though functioning, dimensions are same for both the bubbler; they differ by the place where we use them.

Safety bubblers are connected in parallel with RPC but it is connected so as to bubble only when there is a block in RPC.

Isolation bubblers or output bubblers are used to monitor the flow of gas mixture through RPC and also to prevent back diffusion of air into RPC. The gas mixture after flowing through RPC it thrown to output manifold through isolation bubblers.

Electronics and DAQ for INO-ICAL:

The electronics for the prototype have to be designed in such a way that it should record the time in which the event occurred, 3-dimensional tracking of the particle, along with the direction of the particle.

Thus for above described purpose the electronics set-up includes processing of signal, Trigger logic, DAQS. The block diagram of the electronic setup was shown below.

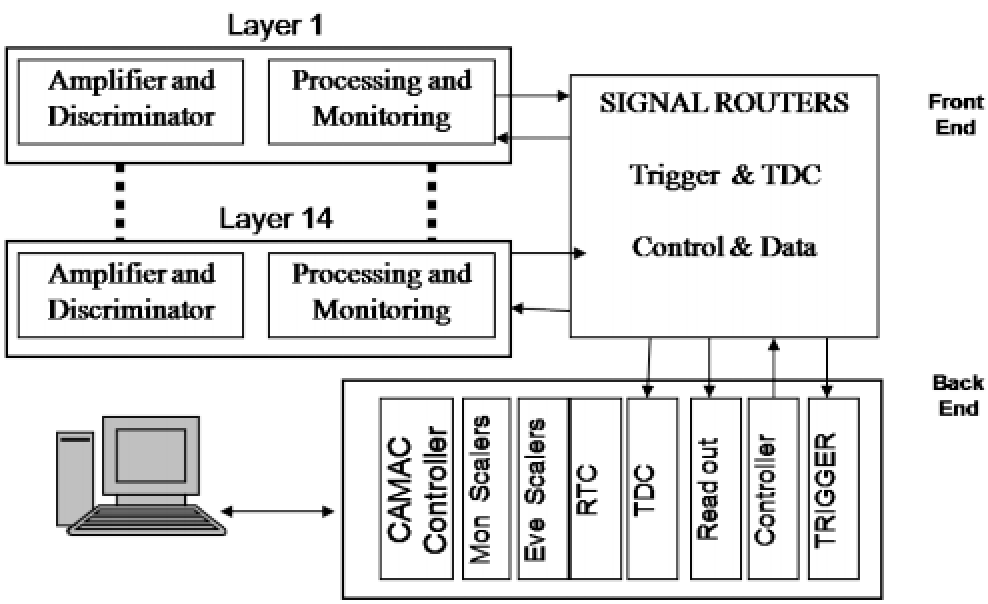


Fig 5. Block diagram of electronic setup

Processing of Signal:

As soon as the charged particle pass through the detector, the pick up panel picks up the signal and this signal have to pass through a pre-amplifier and this output is fed to 16-channel discriminator modules. Whenever the signal is above -20mV, threshold voltage of the discriminator, an ECL output is generated, which is then converted to TTL output by 32 channel Front End Processing.

Trigger Logic:

The events to be recorded are picked up the trigger logic. The basic principle of trigger generations is,

M X N fold coincidence.

M – no. of consecutive strips that pick up signal (out of 32),

N – no. of consecutive layers that picked up M layer signals

When M X N fold satisfies 1x5, 2x4, 3x3, 4x2 then the signal will be recorded.

Trigger is implemented in three stages. In first stage, ie., trigger_0 logic, shaped discriminator pulse from every 8^{th} channel of 32 channel in X-plane are logically ORed and the signal is taken out as T_0 signal, similar signal was taken for Y-plane.

These eight T_0 signal are logically ANDed to achieve the required M-fold triggers (T_1 – 1F,2F,3F,4F) in each layer. The trigger_1 logic is implemented in the Front End Processing (FEP) module using CPLDs.

The M-fold signals (T1) from X-plane of all RPC layers are routed via Trigger and TDC Router module to the Final Trigger module in the CAMAC crate. The M×N coincidence logic (T2 trigger) is implemented in this module using T1 signals. T2 signals from X-plane and Y-plane are logically ORed to get the final trigger output which indicates the valid event to be recorded. The trigger generation rate is monitored with in-built scalers. All the triggers are maskable.

Signal Routers:

Trigger and TDC router receives the M-fold T1 signals and TDC signals from the FEP modules and routes them to the Final Trigger module and TDC module respectively. Control and Data Router receives control signals from the INO. Controller module and routes them towards the FEP modules. It also receives data and feds the same to the Readout module.

DAQ:

DAQ is built based on PC, using CAMAC standard modules in the back end and is connected to front end by a fast serial link. Event data recording and monitoring are the two main functions of DAQ and is controlled by INO controller module housed in the CAMAC crate at the back end. The FEP modules of X and Y planes of all the RPCs are daisy chained into two groups for event data recording. The so acquired data is transferred bit serially through daisy chain to backend INO Readout module in the event process. These 28 FEP modules are daisy chained into 8 groups for monitoring purpose. One pickup signal from each of eight monitor daisy chain are linked to CAMAC based monitoring scalers during the monitoring process.

Testing RPC using veto paddles:

As soon as the particle pass through paddles, trigger is produced in the discriminator. The signal from P1, P2, P5, P6 are ANDed to get 4F signal and that from P3, P4 are logically ORed to get veto signal. These signals namely 4F and veto are together ORed and given as start pulse. The electronic circuit for recording trigger from veto paddles is shown in Fig.6.

The signal from RPC is given as the stop pulse for TDC. We had chosen S-32 strip as the main strip, the signal from this strip as well as that from adjacent strip also taken into account. The electrical circuit for this process is shown in Fig.7.

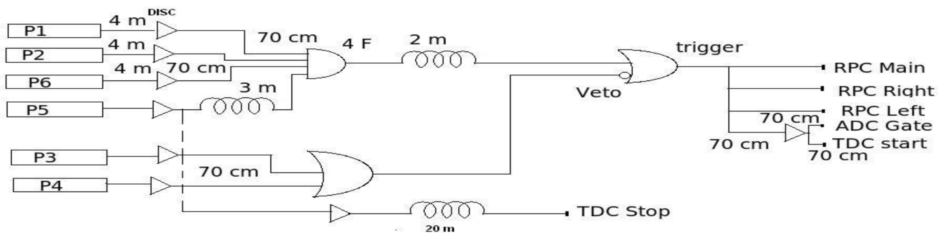


Fig 6. Electrical circuit for veto paddles

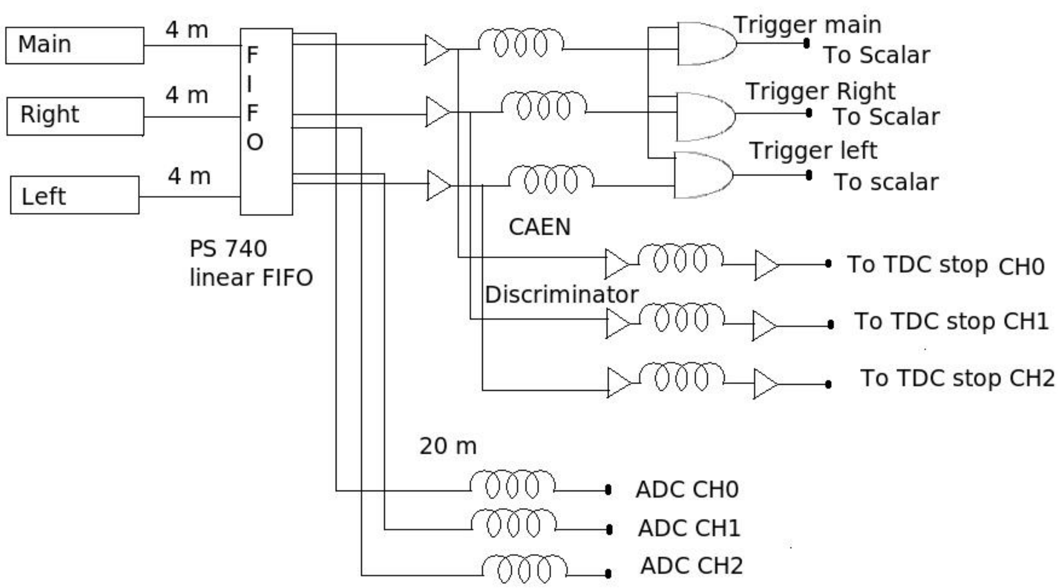
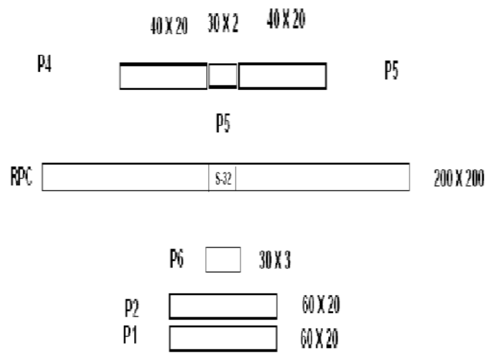


Fig 7. Electrical circuit to record RPC signal

In order to test working condition of RPC veto paddles were used, say P1, P2, P3, P4, P5, P6. They were placed above and below the RPC, such that the centre strip for finger paddles will be 32(under test). This arrangement is shown below (dimensions are in cm).



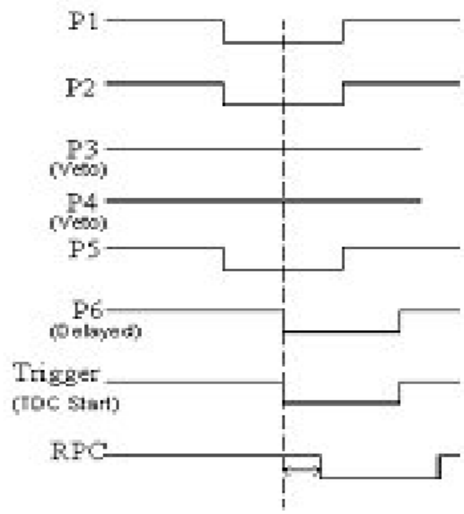


Fig 8. Veto paddles arrangement, **Fig 9. Pulse description of signal**

From the figure it is clear that we are interested in strip 32. Thus when cosmic muon pass through P1,P2,P5,P6 and not through P3,P4 a signal was produced and this was given as TPC start pulse, whereas RPC response was given as stop pulse. The time between start and stop pulse cannot record any other particle. After this RPC test, we studied its various characteristic such as efficiency, VI characteristic, noise rate, TDC.

Characteristic Study Of RPC:

VI characteristics:

The voltage was ramped from 0 to 10 kV using bipolar high voltage scheme and the corresponding current was noted for both A & B channel separately (channel represent the plate). Thus plotted graph will look like,

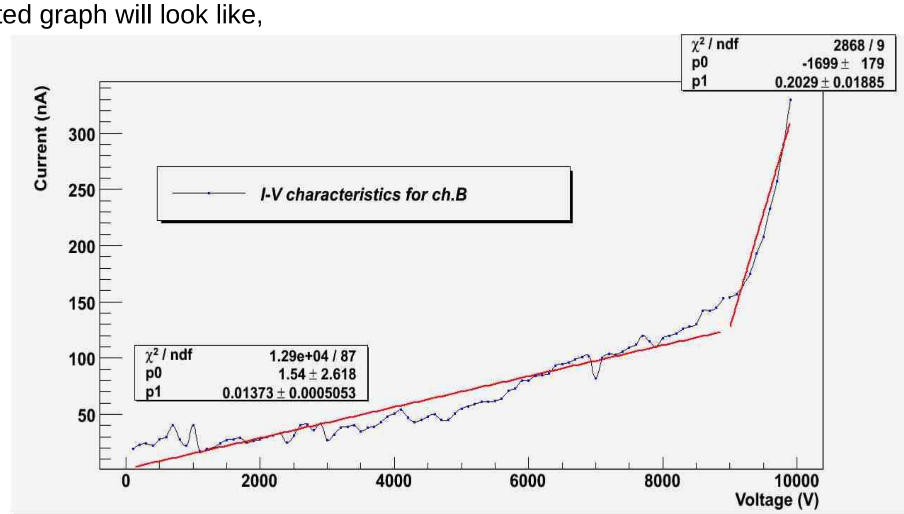


Fig 10. V-I Characteristics of Channel B

Positive voltage is applied to Channel B. It's
Gap resistance = 72.8188 GΩ, at low voltages
Glass resistance = 4.9283 GΩ, at high voltages (above 9kV).

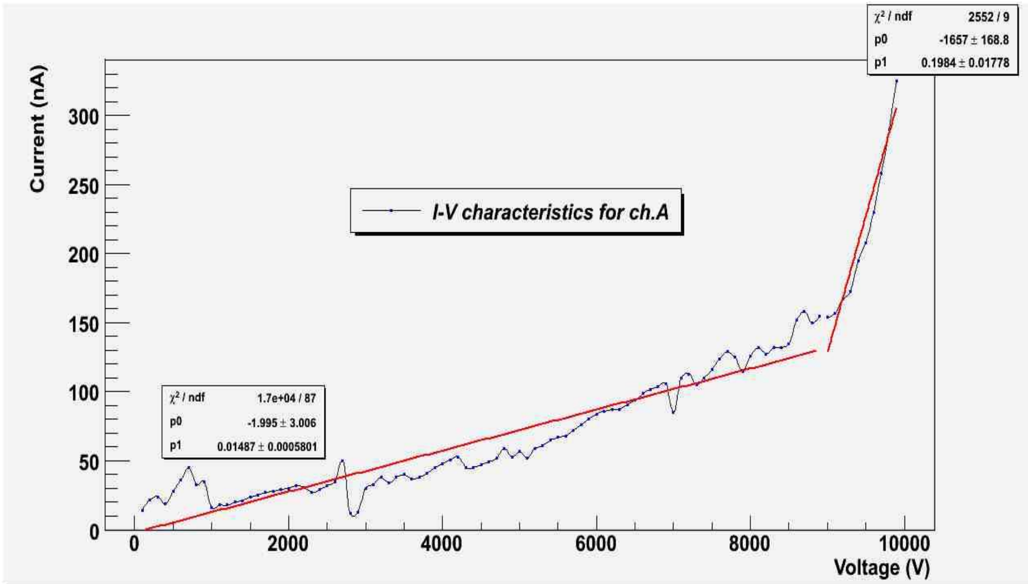


Fig 11. V-I Characteristics of Channel A

Negative is applied to Channel A. It's
Gap resistance = 67.2598 GΩ, at low voltages,
Glass resistance = 5.04133 GΩ, at high voltages

Efficiency:

The efficiency for the chosen strip S-32 and the strip right to it are drawn in fig. 12

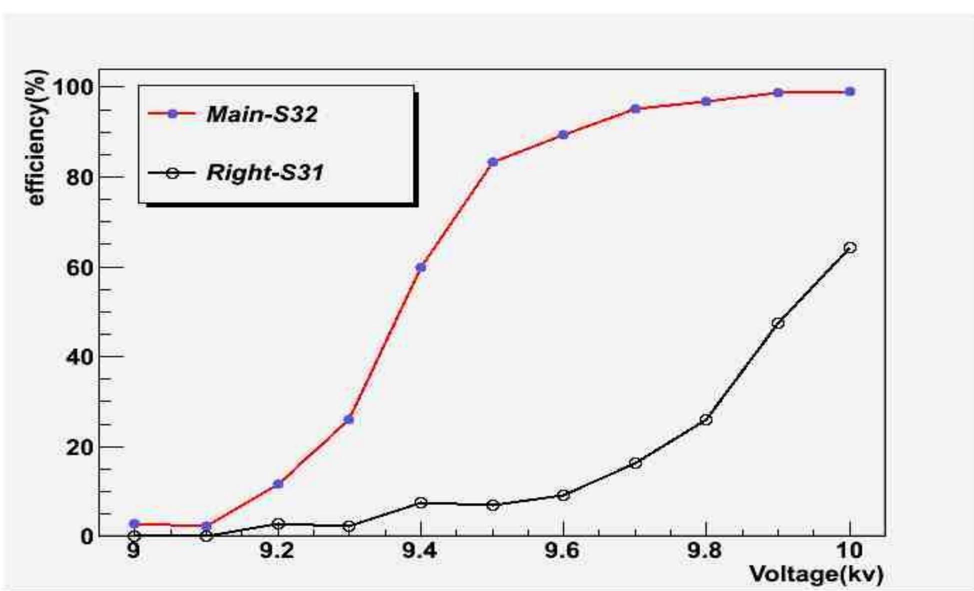


Fig 12. Efficiency plot for Main S-32 and Right S-31 strip

From the figure the plot we can easily figure it out that from 9.6V the plateau region started and hence the operating voltage was chosen as 9.6V. Efficiency came around 89% at this voltage.

We also calculated manually the efficiency at 9.6V. For this we kept the threshold voltage as -20mV. Whenever the signal amplitude was above the threshold it was taken as signal, and whenever below the threshold it was considered as no signal.

Noise rate:

Noise rate of main as well as two adjacent strips was shown below.

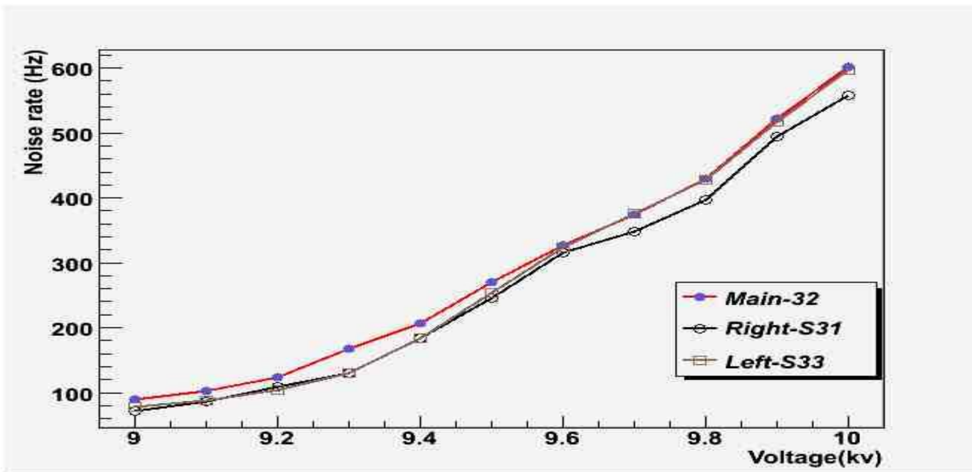


Fig 13. Noise rate for Main S-32, Right S-31 and Left S-33

From the figure, it was clear that noise rate increases with voltage.

TDC Plot:

TDC stands for Time to Digital Converter. This device will convert the time difference between the trigger produced and RPC response, into digital value. The data obtained using TDC is plotted and shown in Fig.14.

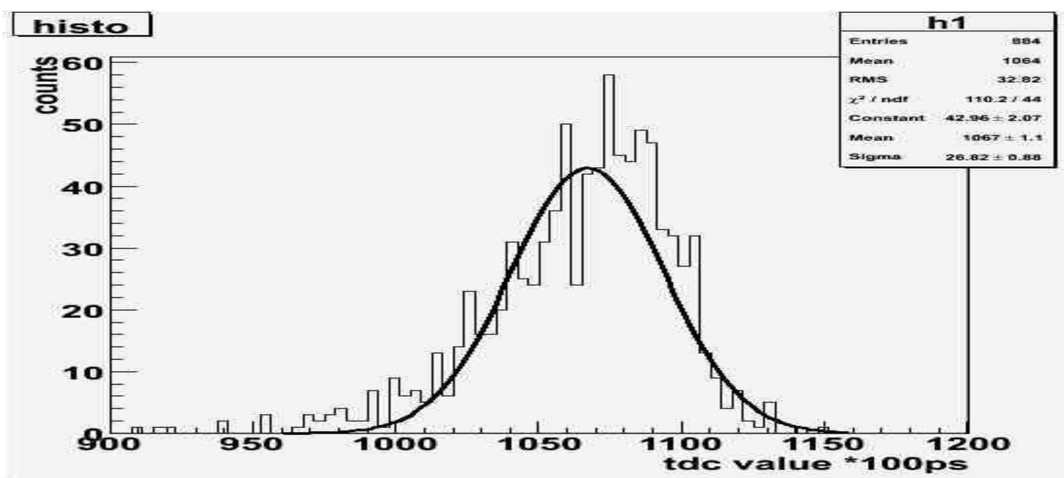


Fig 14. TDC plot for the chosen main strip S-32

Time response of RPC main strip = 2.68 ns.

Conclusion:

Thus 2m x 2m RPC was made. Tested its working condition and finally we studied its various characteristics of the same.

Reference:

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