FABRICATION OF 1m X 1m AND CHARACTERIZATION OF 2m X 2m GLASS RESISTIVE PLATE CHAMBER (RPC)

ANUJ CHANDRA
PROJECT ASSISTANT-II
INO
ALIGARH MUSLIM UNIVERSITY
&
TATA INSTITUTE OF FUNDAMENTAL RESEARCH

UNDER THE GUIDANCE
OF
Dr. SATYANARAYANA BHEESETTE

CONTENTS.

Abstract

Resistive Plate Chamber is a closed gaseous chamber which can be accessed as a charged particle detector. This kind of detector is made up of two parallel bulk resistivity material plates, those are kept at high voltages. RPC works on the principle of energy loss due to ionization and the filled gas works as an active medium for energy loss of incoming ionizing particle through ionization. Minimum ionized particles move toward and penetrate their respective polarity plates and captured by the pickup channels and produced an weak electric signal, which we have to make it strong enough to get information from it, therefore, we are needed a sophisticated electronics. RPC provides good position and timing resolution in charged particle detection because of this it has been found applications in many particle physics experiments. The detector elements in the INO ICAL detector are the RPCs. The INO ICAL detector will contain approximately about 30,000 of these 2m x 2m RPCs.

In this report, I tried to discuss characterization and fabrication of RPC and some its characteristic parameters such as leak rate of RPC, V-I characteristic, surface resistivity and efficiency of the RPC.

Chapter-1

Resistive Plate Chamber

1.1 ***INTRODUCTION***

Resistive Plate Chambers are the recent member of their ancestors generation in particle detection based on ionization.

Let us have a brief idea on ancient generation of particle detectors:

Birth of radioactivity and X-Ray in 1980s acquired the participation of particle detectors in Experimental High Energy Physics. H. Becquerel's photosensitive paper, which was blackened by the radiation released by Uranium salt was possibly the first documented particle detectors. Then E. Rutherford and E. Marsden developed a scintillating screen to detect scattered alpha particle. For capturing the particles track people discovered some more advanced detectors such as emulsion, spark-, cloud-, streamer- and bubbler chambers. By the time, improved technology has been converted optical methods into electrical methods of particle detection.

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. But the geometry of such kind of detector can provide us a good spatial resolution but we have to compromise with time resolution because of fluctuation in the drift time of the primary electrons. The first gas detector taking advantage of the improved time resolution in strong uniform electric fields was the Keuffel Spark Counter, a gaseous avalanche detector with parallel plate geometry, that was introduced as early as 1948.

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 electrodes has timing resolution of 1 ns over wired gas chamber with 100ns resolution, But in conducting electrodes, the increasing avalanche leads shorting of the two electrodes. So the detector needs to be switched off thus increasing the dead time and decreasing the detection rate.

Then a new type of parallel plate spark chamber was introduced which had high resistivity plates ($\sim 10^9 \ \Omega - cm$) electrodes and special gas mixture for photon absorption in 1971. Because of high resistivity value further discharge can not develop across the plate by primary ionization hence it is limited to an area around the primary avalanche and therefore the remaining counter area is still sensitive to charged particle. Moreover.

Localization of voltage drop around the primary avalanche can be prevented by putting some percentage of organic gases with high ultra violet absorption capability and by using resistive electrodes high voltage switching off circuits are no longer necessary and consequently a higher detection rate can be achieved. **Planer Spark Chamber(PSC)** built by Pestov was the first detector containing resistive electrodes.

Parallel Plate Avalanche Chamber (PPAC) is a single gap gaseous detector very similar to the Spark Counter. Operated in avalanche mode; streamers and discharge are unwanted side effects in this type of detector. Its advantages include a fast response and an increased rate capability of up to 10 MHz/ cm^2. Time resolution is 100 to 250 ps. Gain depends on the gas mixture used inside the chamber with a very low discharge probability.

Resistive Plate Chamber (RPC) was introduced in 1981 by R. Santonico and R.Cardarelli. An RPC is a particle detector which utilizes a uniform electric field produced by two parallel electrode plates, at least one of which is made of a material with high bulk resistivity. A gas mixture with a high absorption coefficient for ultraviolet light is flown through the gap between the electrodes. High resistivity does not allow the spreading of avalanche except in the minute space near the primary avalanche hence remaining space is still sensitive to the incoming ionizing particles and the ultra-violet absorbing components in the filled gas absorbs the unwanted photons those can cause further avalanches. RPCs exhibit much better time resolution than wire chambers because the uniformity in field provides it to low time fluctuation while drifting of ions which does not happen in wire detectors at all because of 1/r dependance.

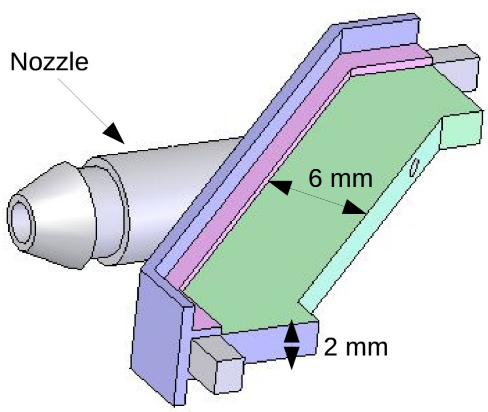
1.2 ROLE OF RPC IN INO-ICAL

ICAL termed as Iron CALorimeter. The main focus of ICAL at INO is to study interactions involving atmospheric muon neutrinos and anti-neutrinos. This requires the construction of a detector that is sensible to the energy, direction and sign of the electric charge of muons, produced by charged-current interactions of neutrinos with the detector material. RPC will work as an active part of the the detector which will help us to monitor the track of the charged particle from the Iron plates. Layers of RPC will be laid after every 5.6 cm of iron layer. The estimated weight of detector for the physics requirements is 100 kt. To begin with we are proposing a detector of about 50 kt, which may be enlarged to its final size of 100 kt in stages.

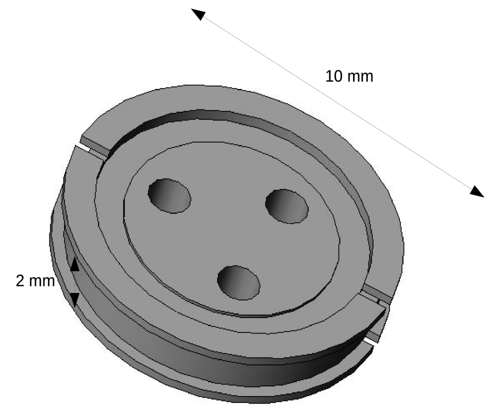
1.3 CONSTITUENTS OF RPC

The RPCs those are being used in INO-RPC Lab. At TIFR made up of glass plates. Its several constituents are as follows:

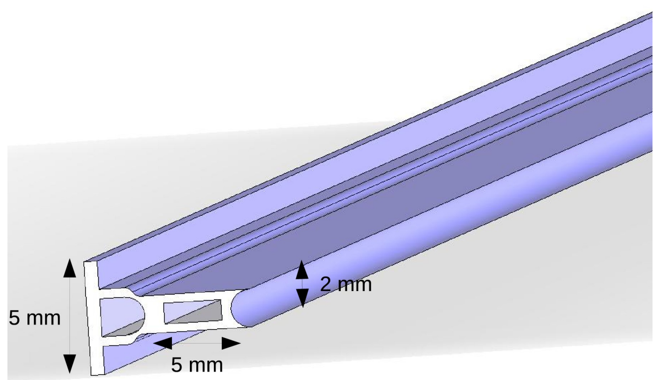
- Two Planer electrodes made up of 2m x 2m glass of 3mm thickness for each, separated by a width of 2mm. Glass with bulk resistivity of 10^{10}-10^{12} Ω . Electrodes kept at high voltage
  5 KV /mm in gas gap. Glass is externally coated with graphite to increase the surface resistivity, which helps setting of uniform electrical field. I made the chamber of the dimension of 1m x 1m Italian glass plates coated with Italian paint provided by the Italian company.
- Two plates are separated using polycarbonate buttons shaped spacer, with bulk resistivity greater than 10^{13} $\Omega - cm$. Side spacer and corner spacer used to seal RPC from all 4 side edges.



Corner Spacer



Button Spacer



Side Spacer

Fig. 1 Spacers with their dimensions

- Gas mixture to be filled
  Argon: Target for ionizing particles.
  Freon (R134a is eco-friendly substitute of freon): is an electronegative gas and absorbs free charge particles in the gas before any further avalanche is produced.
  Isobutane: being an organic gas, helps to absorb the photons from recombination processes thus limiting the formation of secondary avalanches far from the primary ones.
  SF6: works as a quencher agent.
  The suitable ratio of Freon: Isobutane: SF6 for running the RPC in avalanche mode should be 95.50: 3.90:0.60. For running the RPC is avalanche mode.

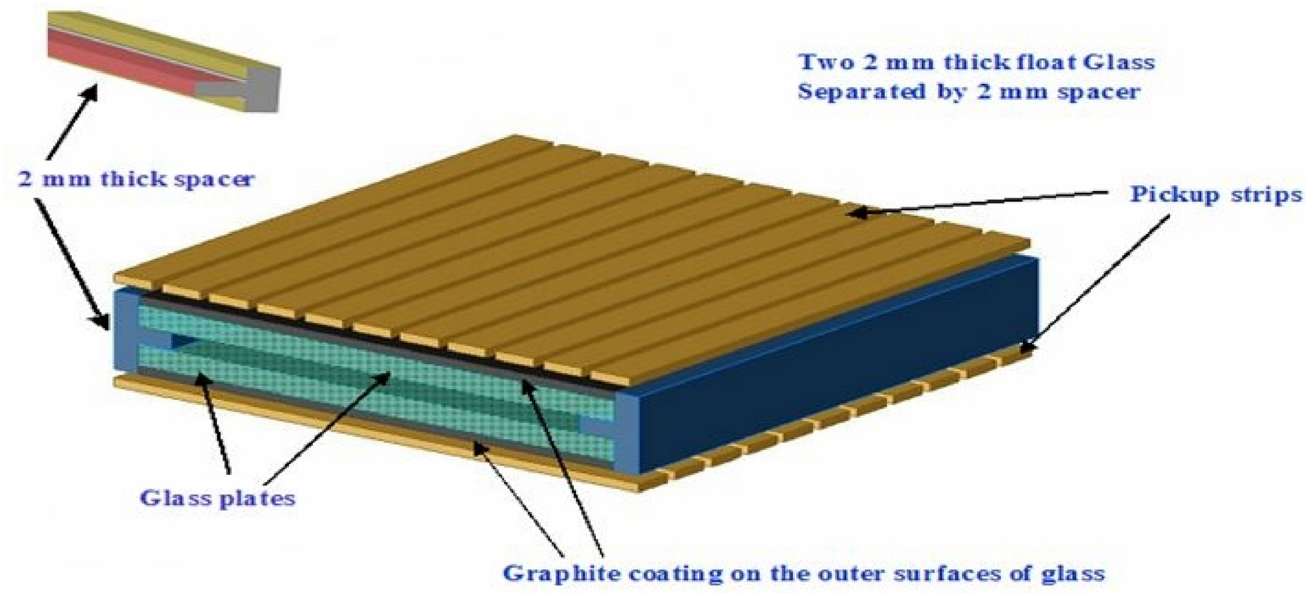


Fig. 2 Schematic diagram of the RPC

- Pickup strips: are being used as the swift transmission lines of electrical pulses produced by drift of charges , just after the outer surface of RPC separated by the thin layer of mylar insulator. Therefore, strips with typical characteristic impedance of about 50 Ω . 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 to wire which connects to electronics. RPC with panels are packed with Aluminium casing.

1.4 OPERATING PRINCIPLE

The task of a detector system in general is to identify and to measure the momenta and/or energies of different particles, which leave their signatures in the detectors. Ionization is the basic physical process which occurs in most of the detectors. The passage of a charged particle through a gas volume gives rise to the production of electron-ion pairs. The drift velocity of electrons is much higher compared to that of ions. If an intense enough electric field is applied throughout the gas volume then the primary electrons produce further ionizations. This multiplication mechanism results in a distribution of free charge in the gas which has the characteristic shape of an avalanche. Recombination process usually take place during the avalanche development. Photons are produced in such recombination and they can in turn start the development of secondary avalanches. The regime in which several secondary avalanches are produced causing large amounts of free charge in the gas is called streamer regime. Moreover, if the ion-electron plasma is so large as to connect the two electrodes, then so called spark is created. High resistive electrodes prevents high voltage supply from providing the electric charge that would be necessary to maintain the discharge between the electrodes. Therefore the electric field drastically in the region of the discharge causing it to extinguish. This behavior can be understood by observing that the typical discharge time (10 ns) and the electrodes recharge time ($\tau \sim 1.8$ s) is independent of the detector surface dimensions(resistivity*dielectric constant). The large difference between these two times ensures that electrodes behave like insulators during the discharge. A dynamical calculation for electric field,electron's sensitivity for the field and proper percentage for ionizing, quenching densities makes the suitable mode of operation for the RPCs.

1.5 MODES OF OPERATION

Operation of a detector strongly depends on the gain factor (M) of the detector.

$$M = n/n_0$$

Where $n=n_0 * \exp(\eta x)$ are the number of electrons that reach the anode.

n_0 are the number of electrons of a given cluster are accelerated by the electric field.

$\eta=\alpha-\beta$, α is the first Townsend coefficient, i,e, the number of ionizations per unit length and β represents the attachment coefficient, i.e. the number of electrons that are captured by the gas per unit length and x is the distance between point of ionization and anode.

Basically there are two modes for operating RPC:

a) **Avalanche Mode($M<10^8$),** the release of the primary charge by the incoming ionizing radiation is followed by the propagation and multiplication of the electrons corresponding to the Townsend avalanche. Avalanche propagates and multiplication occurs by the influence of electric field in the gas gap. High rate applications and detector aging issues demand the avalanche mode by reducing the produced charge in the gas gap. This mode can also be facilitated by the development of new highly quenching $C_2F_4H_2$-based gas mixtures or with addition of small fraction of SF_6 to the gas mixture.

b) **Streamer mode($M>10^8$)**, when the gas gain is increased further by the avalanche mode, photons start to contribute to the propagation of the avalanche and streamer appear. As the streamer signal are quite large(between 50 pc and a few nc), no amplification is needed and the signal can be discriminated against the detection threshold directly. Thus the read out of streamer mode RPC is quite simple. Efficiency about 99%, good timing resolution and low rate capability.

Chapter-2

FABRICATION OF RPC

2.1 MAKING

We used the float Italian glass dimensions of 1m x 1m produced and painted by an Italian company with surface resistance 1MΩ ±¿ 200KΩ. While making of a RPC we followed some steps:

- We selected two glass plates of dimensions 1m x 1m, put one glass plate on the table of suitable dimensions then we remove the plastic layer which sticks to the protected surface for the RPC which was being used and did the same thing with the second plate.
- Now clean both the plates one by one with Iso-propyl alcohol and now be cautious that no extra dirt should deposit on the protected surface of the plates.
- Take a template which is used to give exact position to buttons on the plate. We used total 25 buttons, i.e. spacing between two consecutive button is 20 cm. Put the glue(**DP 125 TRANSLUCENT**) at the respective positions (circles) of the template. Alignment of template should be as such that the separation for circles adjacent to opposite sides are same.
- Put the buttons as soon as you put a drop of glue and press it a little and again put drops of glue on above the button spacers, remove the template now, hold the second plate put it on above the glue and careful that the misalignment should not occur in button spacers.
- Cover the whole assembly with a polyethylene sheet with edge sealed on the working table with masking tapes. Start the suction pump and adjust the suitable suction pressure. Close the suction pump after five hours. This step we did for giving uniform separation to RPC so it can sustain uniform field inside it.
- Now the RPC is ready for gluing across its sides, i.e. for the closed chamber. Select four side spacers of appropriate dimensions with respect to the glass plates edge dimensions and four nozzles. Clean all the nozzles and spacers with alcohol and insert the spacers inside the RPC along the side ways now interconnect the all four spacers with four nozzles.
- We are ready now to make a close chamber, therefore, we allowed the glue **3M Scotch-Weld Epoxy Adhesive DP-125 TRANSLUCENT** into the blank spaces between glass plate and spacers along the edges of either side with extra care if some how this glue comes in contact with the conductive layer of the plate this causes resistance increment at that place which can cause the electric discharge in

excess and there should not be any air gap (bubble) left behind after gluing. Leave the surface as such until the applied glue gets dry it took more than eight hours in drying the glue. Next day we overturn the glass plates and did the same job as for the opposite plate and waited for the time until it got dry.

2.2 LEAK TEST

Next day RPC was ready for the leak test. In leak test we allowed a freon gas to flow inside the prepared chamber, we closed two diagonally opposite nozzles by using blockers and one of the two remaining nozzle we connected with freon gas inlet and the remaining last we connected to the manometer which gives the indication of leak by lowering in the water column. If sudden change occurs in the level that means leak is there, then check the leak by using hand-held Freon gas leak checker of model RIKEN GH-202F sniffer across the circumference of prepared chamber. If this sniffer shows rise in the indicators very fast or up to 10ppm that means leak is at that place then you have to do re glue at that point again and make sure yourself that there should not be any leak further at that spot. After checking with the sniffer again go to the leak test for checking leak in the re glue. One more method is there for leak checking named as flow check in which a continuous flow of freon is allowed to RPC and connect diagonally nozzle to the bubbler and exhaust pump. Uniform flow through the detector without any leak shows train of bubbles, else lumpy flow of bubbles indicating leak. If leak is not there then RPC is ready for packing.

2.3 RPC PACKING

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 are placed in between pickup panel and graphite coating and over the pickup panel for insulation. All this is packed in an aluminium casing.

Chapter-3

GAS SYSTEM

3.1 GAS MIXING AND DISTRIBUTION SYSTEM

Proper and efficient functioning of the RPC detector demands premixing or on-line mixing of individual gases, in an appropriate proportion, together with a controlled flow of mixed gases through the detector. We have designed and developed two generations of gas mixing and distribution systems. The first one feature is a single output channel and employs rota-meters to mix the input gas in the required proportion. The mixed gas is stored in the reservoir cylinder and subsequently allowed to flow through the output channel. The input gases are controlled through two-stage gas regulators mounted on the cylinders. The gases are then passed through silica dryer cartridges installed on the steel gas line, where contaminants such as water vapor, oil traces etc. are removed. The gases then enter the rota-meters, which are used to control the gas flow rate through the line precisely. Individual solenoid valves mounted after the rota meters are used to allow the individual gases enter the mixed gas flow on-line into the detector under test or to fill up the pre-mixed gas cylinder for later use. Another three way valve further down stream allows either the pre-mixed gas stored in the cylinder through the detector or let the cylinder be evacuated. Either the bulkhead interface or the pre-mix gas cylinder can be evacuated using the vacuum pump. The utility of the first generation system was limited to gas flow in only one detector chamber. Parallel connection of RPCs on the single output channel of the system did not result in uniform flow through the chambers as their individual resistances to the gas flow are different. Therefore we use a rota-meter based six channel distribution system as an add-on unit to the gas mixing system. An additional alumina filter is mounted on the gas system's output line. The alumina is reactivated from time to time using the built in electric heating element. Mass Flow Controller (MFC) is capable of mixing four input gases (Argon, Freon, Isobutane and SF_6) on-line by the volumetric method, and distributing it simultaneously to sixteen individually controlled output channels. Equal gas flow rate in each of output channels is maintained by using capillary tubes which serve as flow resistors. The return gas from the chambers is controlled in a common manifold and is vented out to the atmosphere.

3.2 WORKING OF THE COMPONENTS OF GAS SYSTEM

A brief description of the design and functioning of each of the components in the gas system is provided below.

1. Input gases: Four gases are used in RPC operation, Freon (R134a), Isobutane gases

are in liquid form for which low pressure input regulators are used of range 0 – 50 Kg/cm^2, while 200 Kg/cm^2 pressure regulators are used for Argon and SF_6 . Depending on the mode of RPC operation, appropriate gases at optimum pressure are allowed to flow into the purifier column.

2. Gas purifier columns: Initially the gases from every specific gas cylinder are 99.9% pure, but some amount of unwanted moisture, oil traces comes into picture due to long transit time, storage and some impurities in the transmission line. We need a purifiers those can prevent gases from these traces. Four in-situ rechargeable molecular sieve based column (one for each input gas) are mounted on the input gas lines in order to absorb moisture, oil traces and other contaminants from the gases.. these columns are made of stainless steel and have built-in heaters of 500 watts each. Each column charged with 300 grams of molecular sieve absorbent of Type 3Å (80%) and Type 4Å (20%); the Argon column has a 13X type absorbent in addition to these.

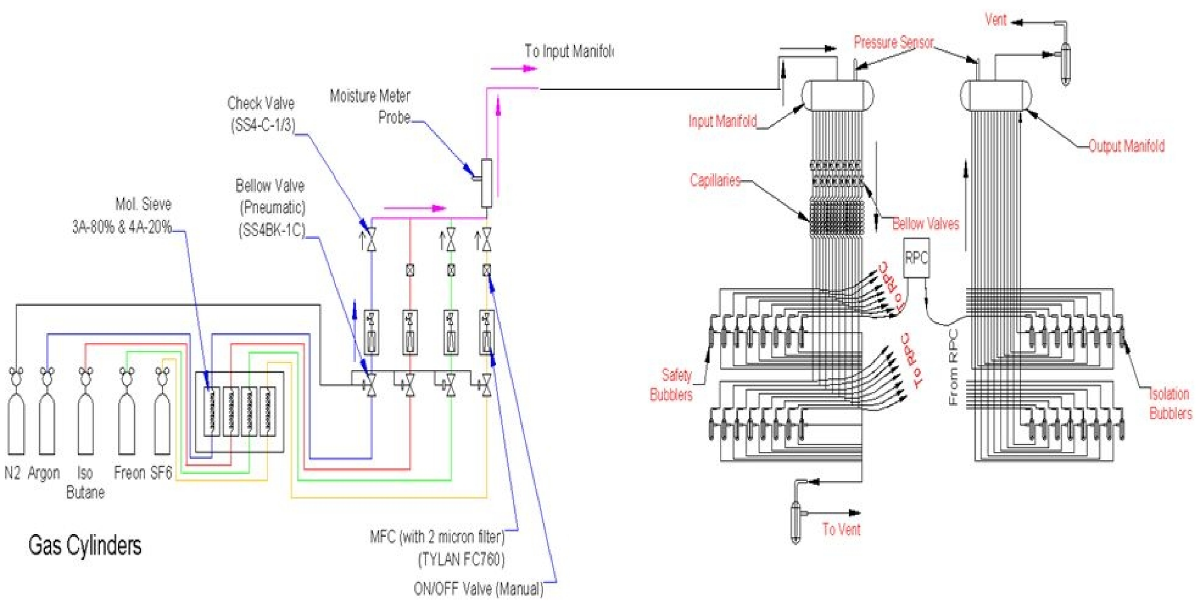


Fig. 3 Gas distribution system

3. Mixing unit: The output from purifiers enter the mixing unit, which consists of pneumatic valves, mass flow controllers, mixing line, check valves, bellow-sealed valves and a probe for moisture measurement. The pneumatically controlled bellow-sealed valves are activated by a pressure of about 4 bar. A dry nitrogen gas or an air compressor is used for maintaining this pressure. All the valves used in the system are normally-closed type.

4. Mass flow controllers: are used to measure and control the flow of gases. They are designed and calibrated to control a specific type of gas at a particular range of flow rates. Each of these MFC has a built-in 2 μm dust filters. The control input to MFCs and the output from the same are both DC voltages (0-5 volts) which are linearly proportional to the mass flow. They are displayed as SCCM (Standard Cubic Centimeters per Minute) units. A ten turn potentiometer is used for adjusting the mass flow, and the set valve is displayed by an LED on the front panel of the system.

5. Distribution system: consists of a manifold and pressure transducers. Gas mixture entering the manifold is mixed further in a small cylinder which provides higher cross section and residence time. A transducer-gauge of range 0-1 kg/cm^2 is mounted here to indicate the pressure at which the gas mixture is being dispensed. Gas is supplied to 16 selectable channels, isolated by pneumatically activated valves, with control switches at the bottom front panel. Almost equal flow of gas mixture is maintained by 16 flow resistor, which are two meter long stainless steel capillaries having an inner diameter of 300 μm. One end of the capillaries is connected to one pneumatically controlled valve after the mixing cylinder and other end is connected in parallel to the RPC and safety bubbler. A fine particle filter is mounted before the inlet of RPC for allowing the pure mixed gas into the RPCs.

6. Safety bubblers: Every bubbler is made of borosilicate glass and is connected to a stainless steel tube by a flexible Tygon tube. Every bubbler has a 25 mm column of silicon diffusion pump oil. Safety bubblers prevent RPCs from possible damage due to over pressurization of RPC that might occur due to the blockages in the flow path, by relieving the excess gas to bubbl through safety bubblers. The outlets of all these are connected to a common vent.

7. Isolation bubblers: Similar to a safety bubblers in dimensions and serve to prevent back diffusion of air into the RPC. There are 16 such bubblers in the system. The gas mixture flowing out of each RPC flows through one isolation bubbler. The absence of bubbling in these bubblers implies the presence of leak in the RPC. The output from all bubblers is fed into a output/ exhaust manifold and then vented out.

8. Exhaust manifold: All the gas to be vented is collected in this manifold and a single output is provided to vent the used gas into the atmosphere. This manifold has a pressure sensor to indicate the pressure with respect to the room pressure.

9. Remote control and monitoring: The required flow rates of individual gases in the system can be set and monitored through a PC interface. Other important system parameters such as pressures at various stages of the unit can also be monitored using this interface.

3.3 CALIBRATION OF MFC

MFCs are designed and calibrated to control a specific type of gas at a particular range of flow rates. Normally, the rating on MFCs is the one that corresponds to the flow of Nitrogen gas, and hence, calibrating the MFCs for different gases being flown through them is a prerequisite. All the MFCs employed in our gas mixing system are calibrated by water downward displacement method and cross-calibrated by linear gas flow method.

Chapter-4

PROCESSING AND MONITORING ACCESSORIES

4.1 DATA ACQUISITION AND TRIGGER SYSTEM

The RPCs prepared then tested for their performance by using cosmic ray muons. When a muon passed through the gas filled RPC, it causes ionization in the mixture of gas these ionized particles will give a signal which we have to develop for the information of ionizing muon. This signal, we pick up by using sophisticated electronics. Signal inside the RPC is picked up by the copper strips aligned orthogonally just after the both opposite conducting surfaces of the RPC separated by a thin Mylar film. This signal is transmitted through strips acting as transmission line to the electronics. It is further amplified by using 2-stage PreAmplifiers. 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.

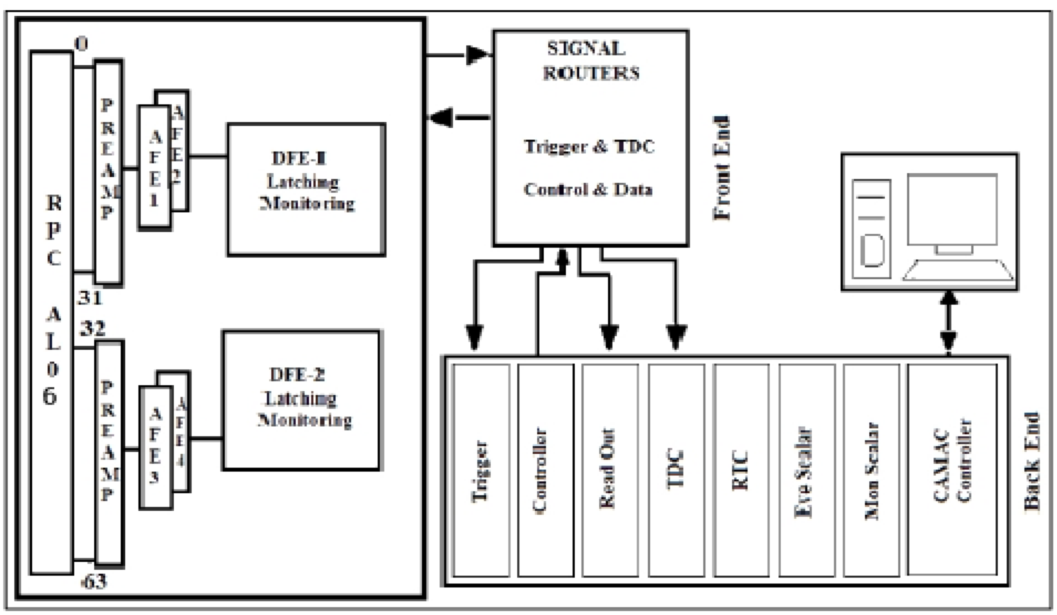


Fig. 4 Block diagram of DAQ.

4.2 FAST PREAMPLIFIERS

The signal range captured by strips across of a 50Ω load is 0.5-2 mV and rise time of about 1 ns, there is a need for a high speed, low noise preamplification for the RPC strip signals before it can be further processed by the front-end electronics. These signals are proceeded to the front end electronics through a 50Ω resistor line by using two stage Hybrid Micro Circuits (HMC) based high speed high gain preamplifiers. Two types (BMC 1595 and BMC 1597) of first stage HMCs-one of each for positive and negative polarity strip signals, were designed to provide a nominal gain of 10 and a negative polarity output signal. The second stage HMC (BMC 1513) offers another factor of 10 gain to these signal that is all 100 gain provided to the signal, but this provides up to 90 gain.

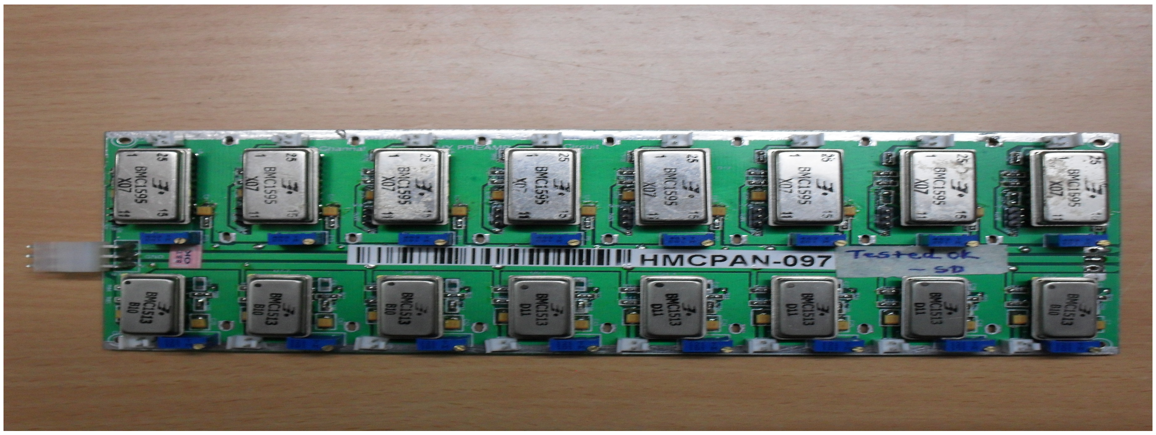
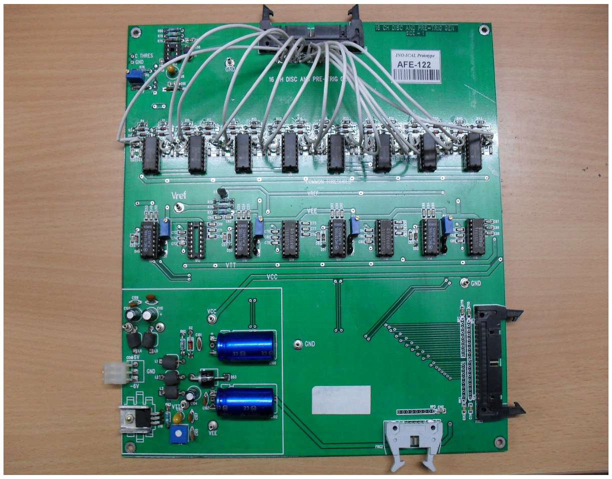


Fig.5 Preamplifier

4.3 ANALOG AND DIGITAL FRONT END

The preamplified RPC strip signals are fed to AFE boards. One of the main feature of the AFE board is to convert these amplified analog RPC pulses into logic signals by using low threshold discriminator circuits. The AFE boards also incorporate a primitive trigger logic on board, where discriminator outputs of four channels are shaped to 50 ns pulses and logically ORed to generate level-0 trigger signals. The discriminator signals from the AFE boards are further processed by a DFE, which mainly consists of three sections – event data readout, monitoring and level-1 trigger generation. The shaped logic strip signals are registered in a latch which is timed by the final trigger signal. The latched information is then flushed out serially to the back-end along with the board identification code.



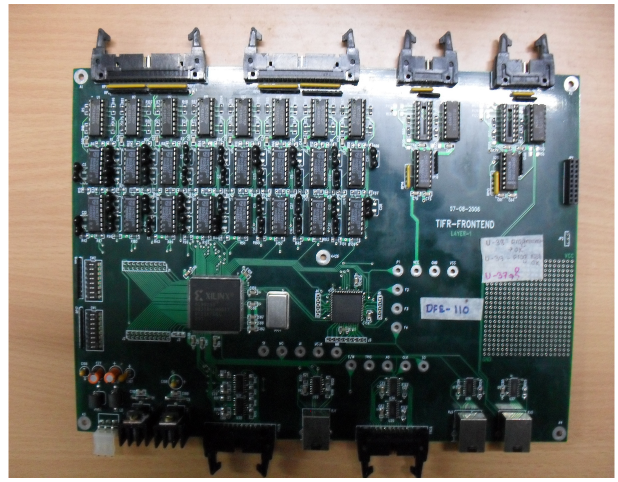


Fig.6 AFE (Left) and DFE (Right) boards respectively

In monitor mode, the counting rates of all the strip signals as well as a few fixed frequency calibration signals are monitored sequentially. While, the sequence of signals is initialized by the the back-end, the subsequent channels are selected locally in the front-end module itself. This helps reducing communication over-head between the front-and back-ends. Only the multiplexing of these signals is done on the DFEs, while the actual counting is performed by scalers located in the back-end. Both event and monitor data from a DFE are identified by their board identification codes preset by static switches. These two sub-sections are implemented in a CPLD chip (Xilinx XC95288 HQ208 AEM0049). Finally the level-0 trigger signals from the AFE are logically ANDed to achieve the required M-fold triggers, where M is the layer coincidence of M consecutive signals out of 32 pickup signals. The level-1 trigger logic is implemented using another CPLD chip(Xilinx XC95536 PC44 AEM0217), thus making it user configurable.

4.4 BACK-END CONTROL AND DAQ SYSTEM

The back-end control and DAQ system is implemented on the CAMAC modular instrumentation standard. This layer completes all the requirements of the data acquisition system, taking inputs from the providing interface services to the front-end, using fast serial links. On the other hand, this layer is interfaced to a PC based host via an intelligent stand alone Ethernet port based CAMAC controller, for providing the DAQ, data storage and user interface function. Apart from the controller, the following modules from the CAMAC back-end system. Functions such as final trigger generation (based on the lower level front-end trigger signals), trigger signal fanout, pre-trigger signal scalers, trigger identification latch etc. are implemented using a FPGA (Altera Flex EPF 10K 50EQC240-2) based Final Trigger Module (FTM). The Readout Module (RM) supports two serial connections for event data recording and 8 channels for monitoring. During the event process, the serial data from front-end modules are converted to 16-bit parallel data. This data are written into Fan-In-Fan-Out (FIFO) memory buffers of 4K words in size. The data from both FIFOs are read via the CAMAC bus in the program. The event data size is normally much smaller than the buffer size. The FIFO overflow can be read from the status port and it also blocks further writing to the FIFO. Generation of all the control lines required for the data readout and monitoring of various status lines as well as fanning out the global trigger signal to all the DAQ subsystem are accomplished by the control module (CM). Scaler modules used for monitoring strip signals and TDC modules used for monitoring strip signals and TDC modules used for timing measurement are also part of the back-end system. While the CAMAC controller and TDC were commercial modules, the rest of t he modules were developed by Electronics Division of Tata Institute of Fundamental Research and Bhabha Atomic Research Centre (BARC), Mumbai.

4.5 TRIGGER GENERATION

To measure the efficiency of the RPC, firstly we ensure that the trigger pulse generated is solely due to the atmospheric muons. Four scintillator paddles are used to set a coincident circuit for this purpose, i.e. a cosmic ray telescope with these scintillator. The telescope consists of 4-cosmic ray muon trigger paddles P1, P2, P3, P4. The area of these scintillation paddles are 40x20, 40x20, 40x2, 40x3 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 30cm x 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. We did not use veto paddles for measuring efficiency of neighbor strips of main strip due to cross talk among them. The data from the RPC strip is recorded whenever a cosmic muon generates a trigger signal through the logic P1.P2.P3.P4 i.e. a trigger is formed when a muon passes through the paddles P1, P2, P3, P4. The recorded data of the RPC is used for its characterization by finding its efficiency, time resolution and other parameters.

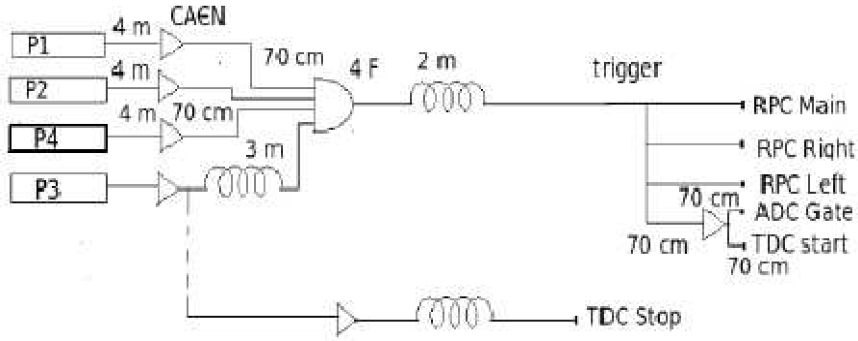


Fig.7 Circuit of the trigger logic

The analog pulses that come from the PMTs are converted to digital pulses through discriminators kept at a threshold of -20 mV. P1, P2, P3 and P4 are ANDed. scalers are added in every stage to monitor counting rates of these paddles which arises due to its finite time resolution. The pick-up strips of the RPC are connected to preamplifiers by the twisted pair cables and to discriminators by coaxial cables and then output are taken to different channels of TDC with some delay. Trigger is taken from the middle strip (under test) of RPC and ANDed with 4-fold. Finally, 4-fold X trigger is recorded.

Chapter-5

RPC Characteristics

There are so many characteristics of RPC detectors but i have gone with few of them such as, surface resistivity curve, V-I characteristic curve, RPC pick-up strip efficiency, noise rate and TDC curve.

5.1 SURFACE RESISTIVITY CURVE

We measured surface resistivity of a 1m x 1m RPC (Chamber ID is IB 017) by using 15cm long copper bar jig. We used a geometrical trick for measuring the resistance of surface we took two alignment at the same place and went along the ordinate (abscissa) by keeping abscissa (ordinate) fixed.

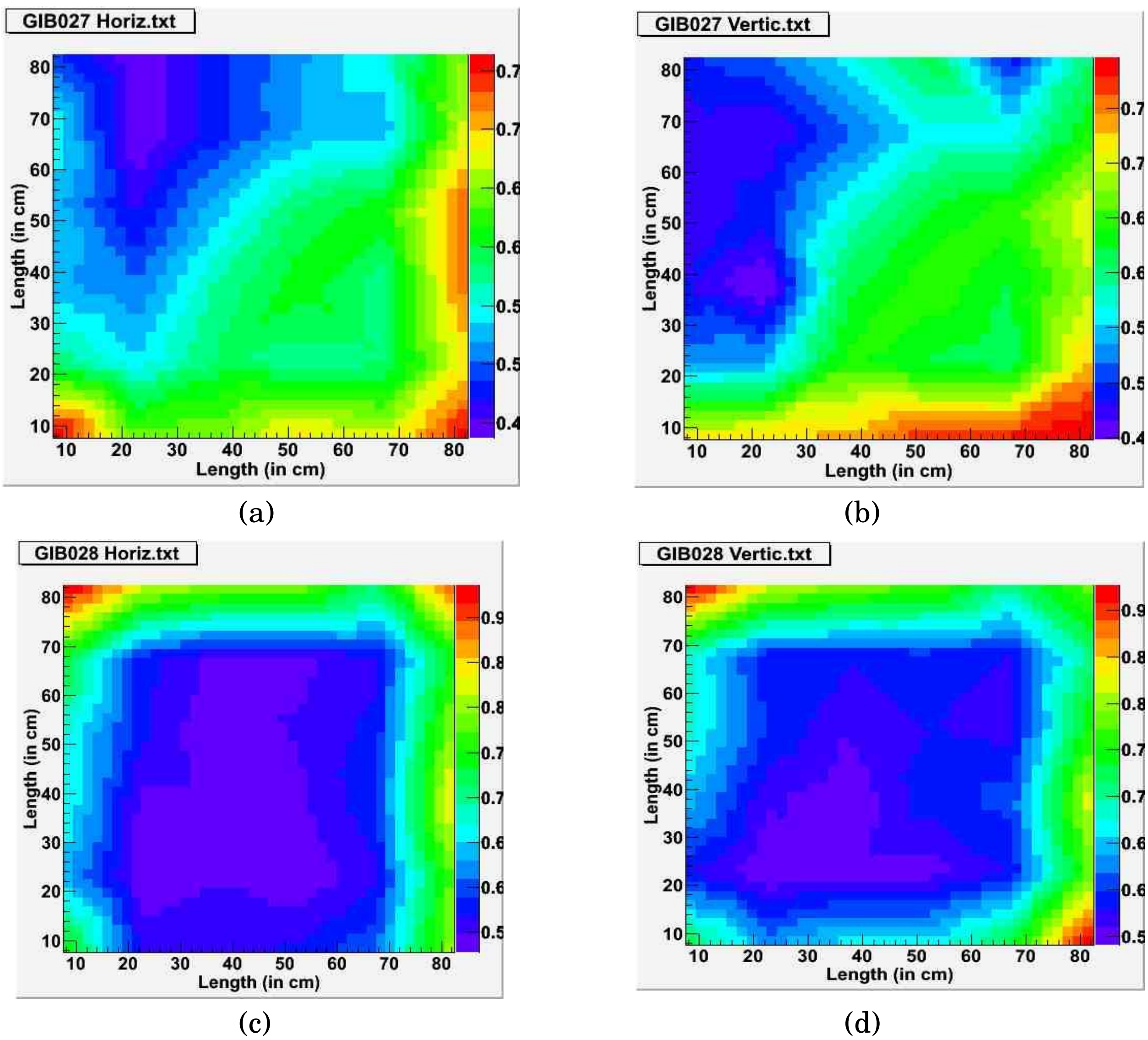
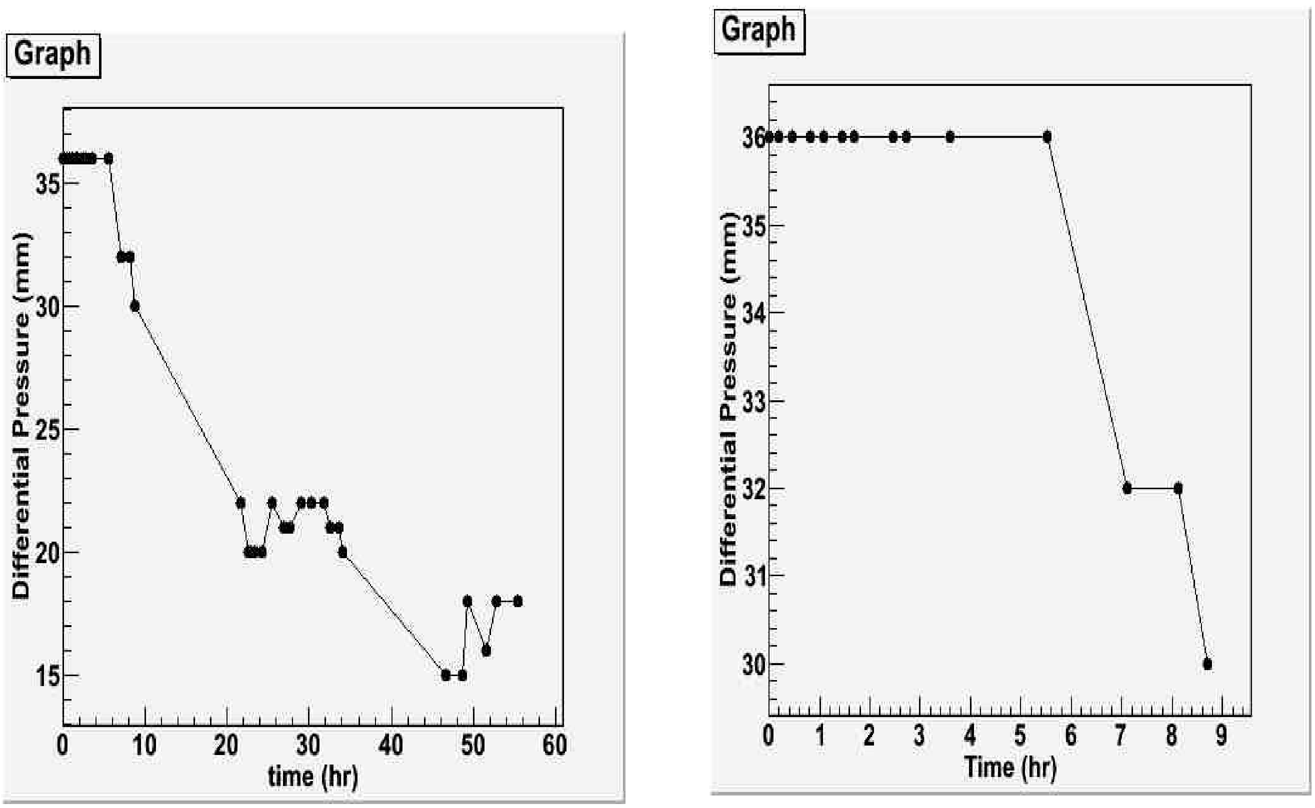


Fig.8 Surface resistivity curves with respective alignment and glass ID.

Hence, we have 36 measurements by one surface. The value of surface resistance should come 1 MΩ . But from my measurements the average resistance came less than 1 MΩ but greater than 500Ω. As we can see from above plots that most of the region is covering the range in between 0.6 and 0.5 MΩ . The resistance near the boundaries is approximate 0.8 MΩ. The reduction of resistance in centre of the plate may be caused development of electric discharge near lower resistance area and hence can affect on the efficiency and age of the RPC. We made the RPC chamber ID IB 017 by these two glass plates.

5.2 LEAK BEHAVIOR

We used manometer for measuring the leak in the RPC. We kept the water level in tubes 36mm of water. We monitored the water level for three days continuously and found the RPC was leak proof.



(a) (b)

Fig.9 (a) shows long run and (b) shows short term run.

We can see from above figures that for initial six hours there is no any measurable change in water column, which signify no leak in RPC. As we can see plot for the long run then we will find a huge measurable pressure difference in a random way which could be happened because of variation in ambient pressure inside the Lab. The main causes of change in ambient pressure are random presence of persons, run of air condition, humidity and etc. The overall leak rate we found from our measurements **0.33 mm/hr**. The adhesive we used for making this RPC was **DP-125 Adhesive TRANSLUCENT** manufactured by **3M Scotch-Weld company**. It contains epoxy resin, aliphatic polymer diamine; sulfonic acid salt.

5.3 V-I CHARACTERISTIC

We did measurements for 2m x 2m RPC AL04 in avalanche mode. We can think the RPC gas gap is represented by a parallel combination of spacer (Ohmic) resistance and gas ionization volume of the gap (represented by a Zener diode).

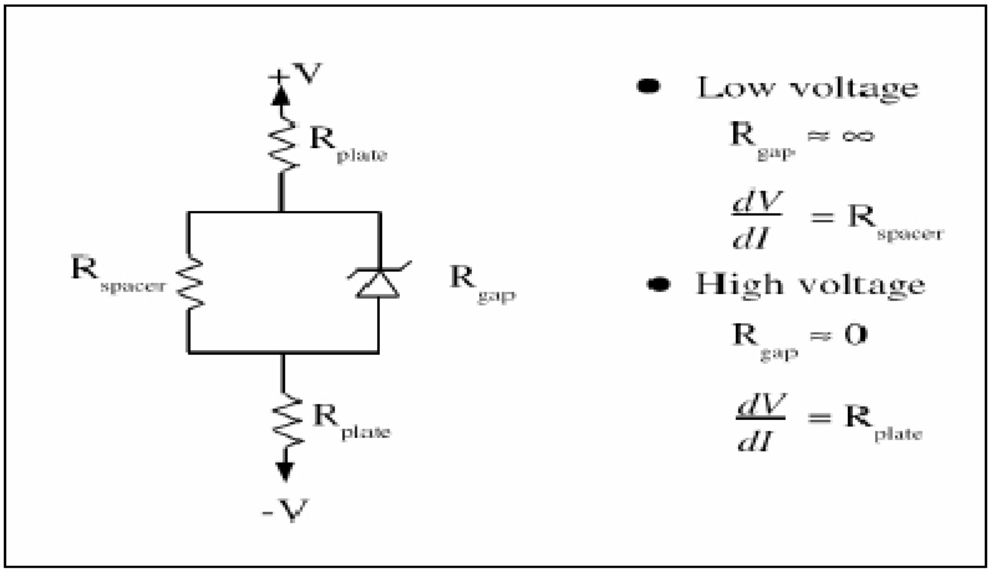
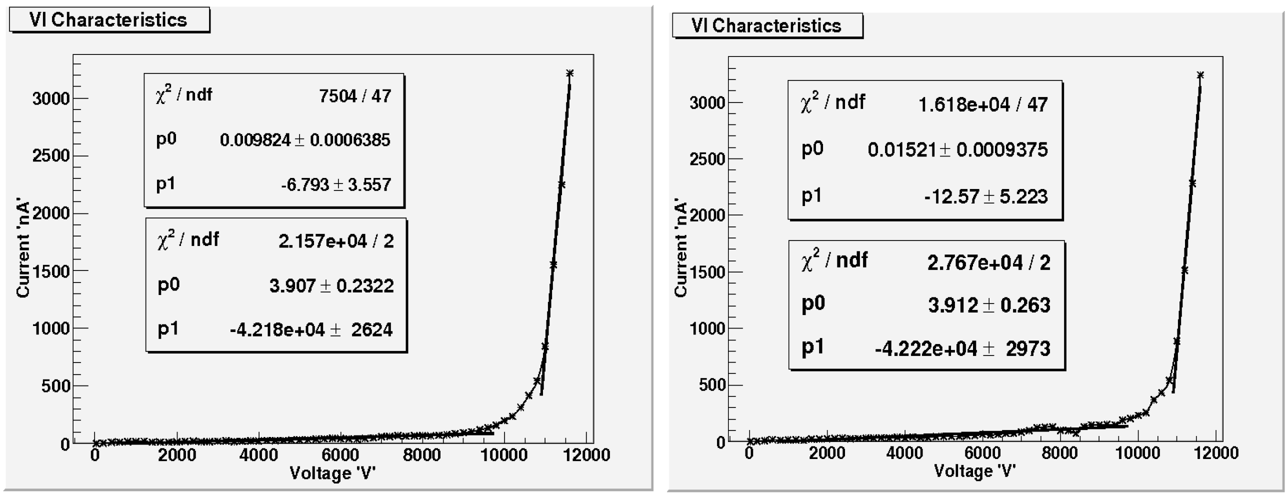


Fig.10 Equivalent electrical circuit for RPC gap

At lower applied voltages, the primary ionization in the gas gap do not lead to development of avalanches. Therefore, the gas gap offers infinite resistance. The current flowing through the chamber then is entirely determined by the spacer resistance. Starting from the chamber's turn- on point, the slope of the curve changes drastically as the ionization volume almost seizes to offer any ohmic resistance. The current flowing through the chamber in this case is determined by the glass resistance. We have measured V-I data for AL04 RPC and draw the characteristic curve for the same RPC.

Channel A corresponds to positive voltage and channel B to negative voltage side.
For channel A (Left)
Spacer Resistance = 101.80 GΩ (low voltage region)
Gap Resistance = 0.26 GΩ (high voltage region)
For channel B (Right):
Spacer Resistance = 65.75 GΩ (low voltage region)
Gap Resistance = 0.26 GΩ (high voltage region).



(a) (b)

Fig.11 V-I characteristics for channel A (left) and channel B (right).

5.4 NOISE RATE AND EFFICIENCY

Noise rate is the total counting rate of all its signals above a certain discriminator threshold. These signals can be produced by the cosmic ray charged particles of all energies, due to the surrounding stray radioactivity as well as due to the dark current of the chamber. This rate per unit cross-sectional area of a particular RPC should be consistent when averaged over a reasonable period of 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 aging side-effects of RPC and the dark current.

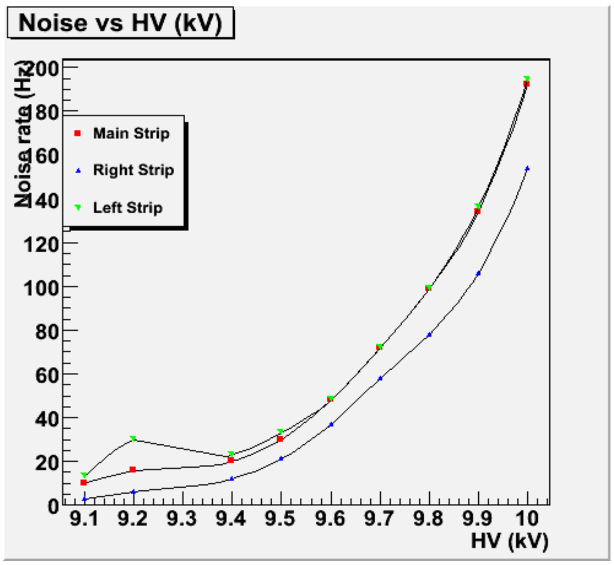
When we get a trigger from cosmic ray telescope, we also expect the RPC strip aligned with window set by this cosmic ray telescope to pick up the signal. Some time the signal is picked up by adjacent strips. This is called Crosstalk. Crosstalk can be due to misalignment of strip or due to inadequate 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.

From fig. (b) we can easily see the efficiencies for main and adjacent left and right strips due to cross talk. There we can find operating voltage more than 9.8 kV.

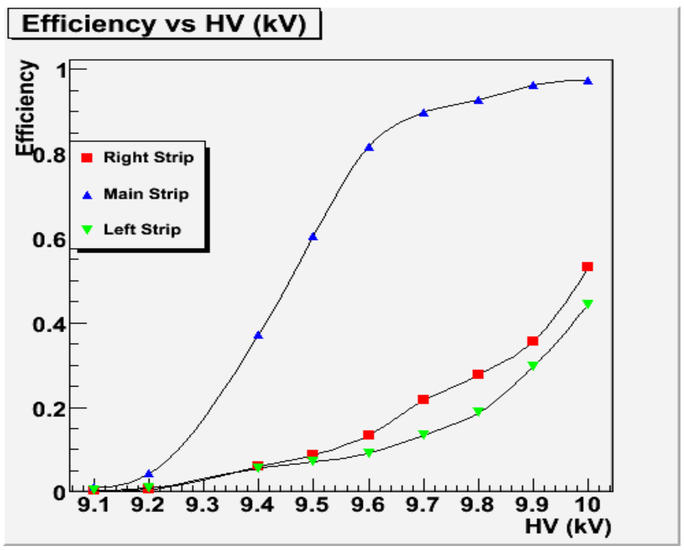
Efficiency of the RPC is the measure of how efficiently the RPC responds to the signal.

Efficiency (strip) = (No. Of hits on the strips)/Total no. of trigger.

In above plot, we chose main strip as 20th strip, 19th strip (right) and 21st strip (left) of AL04 obtained at different voltages. Efficiency of right and left strips should come low as desirable. 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%.



(a)



(b)

Fig.12 (a) Noise rate vs high voltage for main and its adjacent two strips. 12(b) Efficiency against voltage for main and adjacent right and left strips.

5.5 TDC DISTRIBUTION

Timing response of detector depends on the high voltage applied to the detector in such a way by increasing the voltage, gain of the chamber also increases for the same amount of primary ionization, the mean rise time improves exponentially. Smaller the temporal spread to a charged particle gives the more accurate direction of incoming particle. 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 with respect to the trigger. Following plot shows a histogram of the TDC value, the sigma of the fit fives timing resolution.

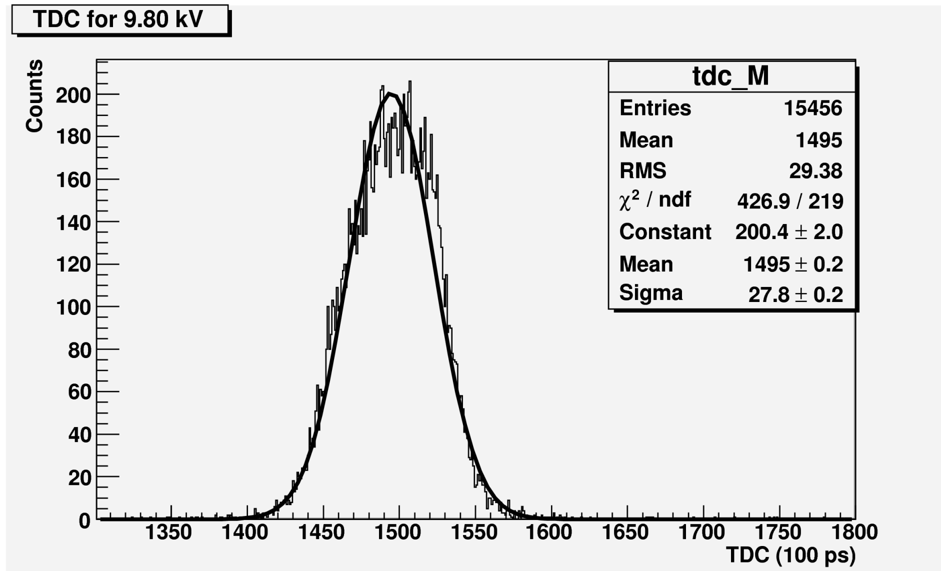


Fig.13 TDC Histogram for 9.8 KV.

Timing resolution was 2.78 ns at operating voltage 9.8 KV.

CONCLUSIONS

We did fabrication part on 1m x 1m RPC glass sheets, were provided by the Italian company. We glued two RPCs with identified as IB016 and IB017 with different glue 3M Scotch-weld Adhesive DP-190 GRAY and DP-125 TRANSLUCENT respectively. We found the performance of DP-125 was good while gluing and leak testing. We also did some characterization also. We measured surface resistivity of RPC glued by DP-125 TRANSLUCENT, came out of the order of 0.6 MΩ. We also looked for V-I Characteristics which can show us the Spacer Resistance = 101.80 GΩ and Gap resistance = 0.26 GΩ. Efficiency came out more than 90% for main strip (20) of AL04 on more than 9.8 KV. Noise rate and TDC curve we can calculate easily.

ACKNOWLEDGEMENTS

I am really very thankful to GOD who chose me for doing work in such a great institute. Now I am thankful to Prof. Naba K. Mondal who allowed me to do work on RPC in INO Lab. I am also thankful to Dr. B Satyanarayana for his valuable time and proper guidance without which i could not be able to learn advancement in my learning. I thank to Mr. R.R.Shinde for arranging the practical set-up according to my convince and without his help I was not able to complete my work. I also thank to S.D.Kalmani Scientific Officer, S.S Chavan, Manas Bhuyan, Vishaal Asgolkar and every lab member. I am lucky that I got very co-operative colleagues – Varchaswi Kashyap, Rajesh Ganai, Raveendrababu Karnam, I thank them for their consistent discussion and help which was really helpful for enhancing my skills here. I am thankful to all who were cause of my inspirations.

REFERENCES

1. Design and Characterisation Studies of Resistive Plate Chamber by Satyanarayana Bheesette.
2. Technique for nuclear and particle physics experiment. W.R. Leo.
3. Radiation and detection and measurement, Glenn F. Knoll.
4. Personal Website of Satyanarayana Bheesete: http://www.hecr.tifr.res.in/~bsn/ino.html