Development of Resistive Plate Chamber for charge Particle Detection

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Abstract

This project report discusses basically how to design and characterize a prototype glass RPC (Resistive Plate Chamber)detector.Larger version of this detector will be used for muon detection in the proposed INO experiment.RPC works on the principles of ionization of gas molecules to detect tracks of charge particles.Its main advantages over other gas detectors are easy fabrication and operation,good timing capability and low cost.Therefore excellent up-down discrimination of muons is possible using this detector.

1 Introduction

Particle physics is the study of smallest particles of matter in the universe (called quarks and leptons)and the forces between them.It is carried out using huge machines and accelerate particles to choose to the speed of light before smashing them together.By studying the debries from large number of such collision physicist can learn about the particles and forces.So to study various particle interactions and searching for new particles physicist use various types of detector.

Dc operated gaseous detectors of ionizing particles such as wire or drift

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chambers are indeed not competitive with the scintillators as far as time resolution is concerned. This is due to the fluctuation of the time needed by the electrons liberated in the gas by an ionizing particle to drift up to the multiplication region very close to the wire where avalanches and eventually streamers are produced .

So a higher time resolution can be achievable if a uniform and intense electric field is used instead of that produced by a charged wire.In this case indeed the sequence of transition as free electron-avalanche-streamer can occur in a very short time and with minimal fluctuations.

The RPC which we designed here have been chosen as an active element in the muon detector as the triggering device.Now a days for scintillators the time resolution can be achievable up to 1-2 ns but in this case it can be achievable up to the order of ps by varying the gap between two electrode.This form of detector prototype is suitable to choose for its easy manufacturing and its simple readout electronics.

2 RPC theory and Operation

The basic components of RPC are a cuboid container with parallel electrodes, a mixture of gases.The cuboid container is designed in such a way to provide the right volume for a gas mixture and the same time provide the right geometry for attachment of an anode and cathode as shown in fig.1.

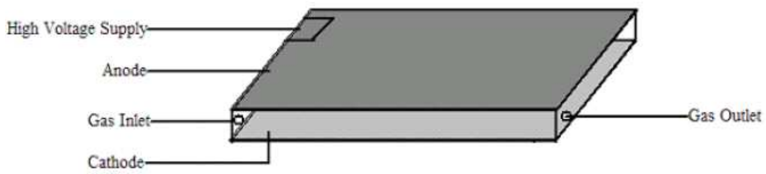
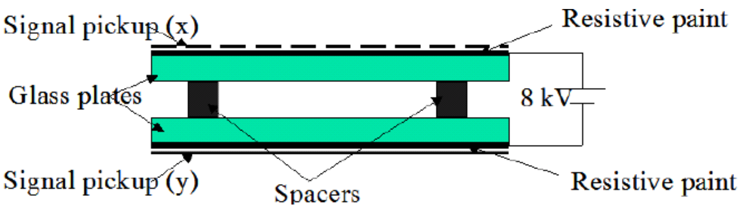


fig.1 Diagram of basic RPC.

fig.2 Finished RPC frame.

High voltage is used to supply an electric field in the direction from the anode end to the cathode .In some construction a spacer is used to ensure the distance d as shown in fig.4 which is constant between the anode and cathode.This in turn will provide a uniform electric field E=$\frac{V}{d}$ over the entire volume.



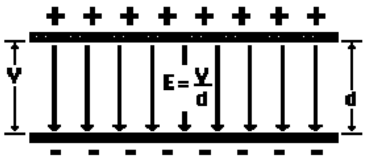


fig.3 Glass RPC layout.
fig.4 Diagram depicting electric field line movement.

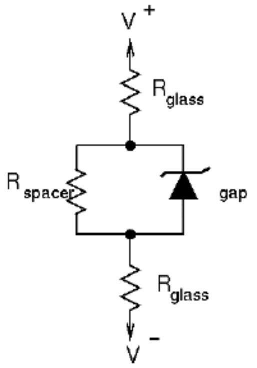
The two parallel electrodes are made up of float glass with volume resistivity of 10^{12} Ω cm at room temp.The two electrodes 2 mm thick are kept 2 mm apart by means of suitable NORYL spacers.These spacer sustain both electrodes ensuring a gap tolerance at the level of a few microns for uniform working condition in a such large apparatus .The gap between two electrodes defines the gas volume where the particle detection occurs.

The use of highly resistive material as electrodes ensures that the spark discharged just a limited area around the spark location.The time to recover the electric field depending on the electrode resistivity as ($\tau \approx \rho\epsilon$ where ρ the glass volume resistivity and ϵ its dielectric constant avoids self sustaining sparking.

The read out of the detector is performed with external pickup aluminium strips which pickup the induced pulses allowing a bi-dimensional localization of the crossing particles together with time information.

The two glass plates are joined by gluing with spacer and we have to make sure that the possible variation of gas pressure does not change the distance between the electrodes .The high voltage is applied to the electrodes by means of resistive coating of graphite.Here we use glass electrodes for its high mechanical stiffness and surface quality.

The resistive layer is applied directly on the outer side of both glass plates.Here the resistive paint used serves two functions :it is conductive enough to serve as the anode and cathode and it is resistive enough to prevent itself from conducting away signals from the signal pickup configuration.At low voltage the gas mixture is insulating so the current passes through spacer.At high voltage the gas mixture is shorted out because of the discharge and this make the gas mixture to act effectively as a conductor .As a results of the effective voltage is applied on the glass electrodes as shown in fig.5, which results in a high current.



Low voltage

$$R_{gap} \approx \infty$$

$$\frac{dV}{dI} = R_{spacer}$$

High voltage

$$R_{gap} \approx 0$$

$$\frac{dV}{dI} = R_{glass}$$

fig.5 Electrical circuit representation of Glass RPC.

The gas mixture we used basically a mixture of Ar,Butane and Freon which is nonflammable and non-ozone depleting in character.The butane prevents a secondary streamer by absorbing efficiently UV photons which are radiated from a de-excited Ar molecule.Where the excited Ar is mainly formed through a collision of Ar^+ ion and Ar molecule with electron in the primary streamer .

Freon has high electron affinity and reduces the streamer size from spreading transversely due to electron capture.

For a minimum working voltage noble gases are usually chosen since they require the lowest electric field intensities for avalanche formation. Because of its higher specific ionization and lower cost argon is usually preferred.

Under particular gas mixture(30% Ar,8% isobutane, 62% Freon) and electric field configuration, the detector is operated in streamer mode.
Where along the path of the charge particle ion electron pairs are formed due to interaction with gas molecules.The ion pairs formation is more likely a stochastic processes.There is also a chance of secondary ionization caused by a photon emitted by excited molecule which travel to other part of the container to cause further ionizion.Which are so large that the space charge created distorts the electric field eventually causing a discharge in detector gas .

A quencher gas is added to the original detector gas to control and localize this discharge in the form of streamline.The streamers are picked up by the external strips.In this case the streamer choose low resistance path for flowing.The side strips are also capable of picking the streamer but it should be less than main strips.

Typical signal amplitudes of the order of 100-200 mv/50Ω are observed corresponding to a charge of about 100-200 pc (depending on the intensity of the applied field).

3 RPC Fabrication

- A pair of float glass are first washed and dried to make them free of streaks and other potential contaminants.The glass plates are then glued to each side of four edgers.

- A spacer is glued between the glass plates to give a precise distance of 2mm required for the uniform electric field between the glass plates.The spacer in between the glass plates should be slightly smaller than edgers in order to keep the gas uniformity inside the chamber.

- The spacer are created on one of the four edgers for fixation of two gas nozzles.

- The presence of any substance inside the chamber can effect the system, so before joining the two glass plates we have to check it.

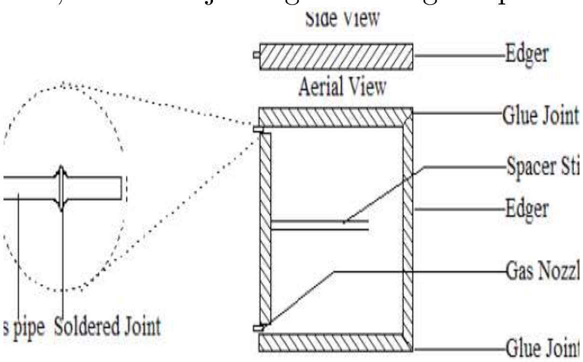


fig.6 Gas Nozzle,RPC framme.

- After making the glass chamber,it is coated with graphite uniformly on both sides. After graphite coating the resistance of the whole electrodes should be 200 kΩ to 1 MΩ /sq.

- After all the chamber is further glued on four edges in order to avoid any gas leakage.

4 Laboratory Test setup

Cosmic particles basically muons are freely available in the atmosphere so they provide a good source for signal events required for the test.The coincidence logic for testing the rpc are shown below.

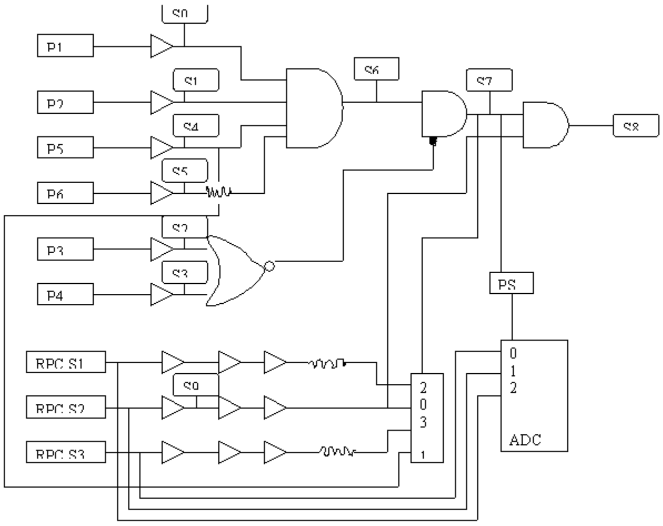


fig.7 Basic circuit for testing RPC.

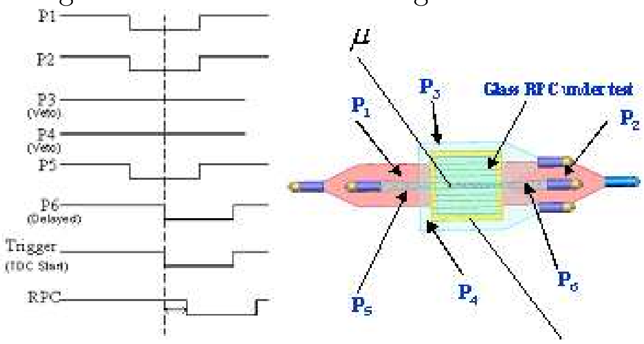


fig.8 Coincidence logic.

The trigger in this case was decided by 6 scintillators.They are assembled in such a way(Which are shown in fig) that they define the confined area of the RPC.In our present case the prototype RPC have volume of 30 cmx30 cm .The net overlapping region of various paddles gives 14 cmx2 cm and one

of strip of RPC have 30x3 cm in our present case.. when ever the charge particle enters through p1 p2 p5 p6 and not through p3 or p4 that events gives the wanted signal satisfying the basic logic equation $muon\ trigger = p1 * p2 * \bar{p3} * \bar{p4} * p5 * p6$.
Between graphite coating and the pickup strips we use mylar sheets as an insulator.Which avoid the high field profile at pickup strips.
The gas bubbler is used to give the information about the continuous gas flow.

4.1 Readout Electronics

In the first stage of readout system, the pickup strips give signal to the discriminator module.A module that gives out a standard logic signal when the pulse height of the signal is greater than a certain threshold value.Here the out put of both pickup strips and photomultiplier tube are connected to discriminator.The value of the threshold is adjustable in our case at -30 mV to avoid the noise.

We are using NIM logic having level(0 -0 mA, 1 -20 mA).The logic unit acts as an equivalent of an boolean circuit for the standard pulses it receive.It performs the AND operation on the pulses.So it performs a fourfold AND operation on the pulses from the scintillators.This is done to ensure that events are being read only from the defined area of RPCs.So the logic unit decide the main signal that we are looking for.

To measure the time interval between two successive events which generates two electrical signal provided by the discriminator we use TDC module.Where a capacitor is charged up by a constant source initiated by the START pulse and end up by the STOP pulse. The total charge delivered by the capacitor is then an analog representation of time interval is to be measured.During this stage the charged is removed from the capacitor at a constant rate during which time pulses from an oscillator are gated into a scalar.The final current is thus proportional to the time interval measured.

To determine the total charge collected due to single collision we use ADC module.
How many times the main strips gives a streamer pulse with comparison to the trigger pulse determine the efficiency of the detector.The % Efficiency =

$\frac{4f.veto.RPC}{4f.veto}$ x 100 as shown in fig.7
In our experiment DAQ system we adjust the set up such that the signal transmission occurs on 50 Ω resistance path due to impedance matching.

The second stage includes all the modules that we describe above are inserted in CAMAC crate.Look at Me Module (LAM) informs the computer to start taking data from the ADC.A particular software is installed in computer for taking data.

5 Results

From the experiment We found the time resolution,efficiency and ADC distribution for the prototype RPC.

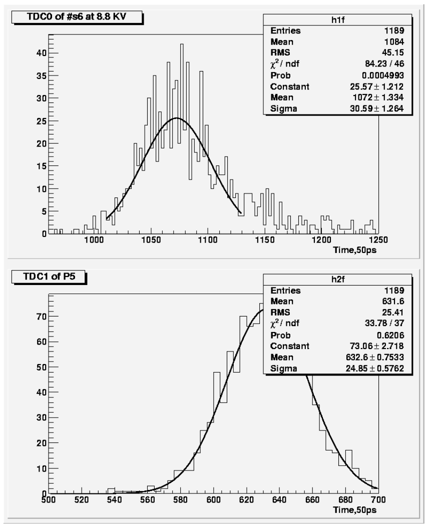


fig.8 Typical timing distribution at 8.8 kv.

This is a typical time distribution curve at 8.8 kv.The below curve represents the timing distribution for one of the scintillator paddles.From the graph we found σ the FWHM for RPC as 30.59.So the time resolution σ x 50ps(the bin size)is of the order 1.5 ns.Which was expected.

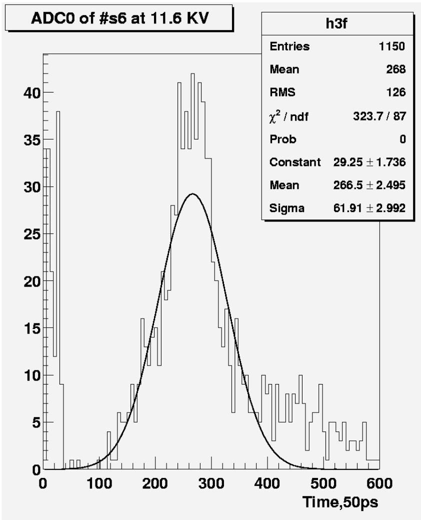


fig.10 ADC distribution at 11.6 kv.

This is a typical charge distribution curve at 11.6 kv.For this case we have to select the whole range of the distribution,where the area represents the total charge collected.we found σ=61 which gives the average charge collected by the strips is of the order of pc which was expected. which gives an indirect signature of average energy loss of the charge particle.

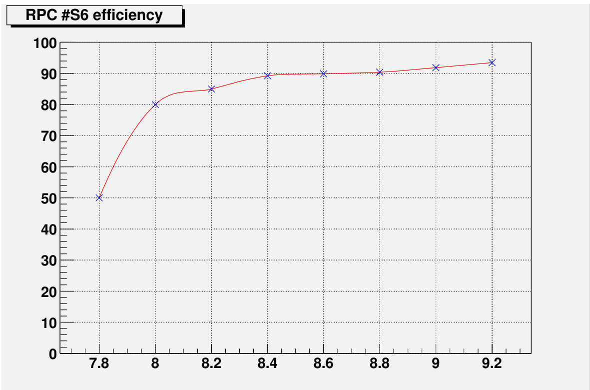


fig.11 % Efficiency at various voltages in kv.

It shows how the efficiency of the RPC changes with increasing voltages.At

8.4 kv on wards it saturates with an efficiency of 91% .Which was expected.Also it can be improved by reducing further the gap between the electrodes.

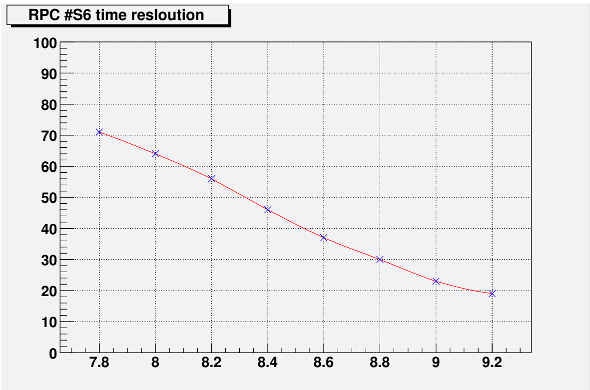


fig.12 Time resolution at various voltages in kv.

It gives an idea about how the time resolution changes with applied voltages.it improve with voltages because of with high voltage the jitter reduces.

6 Acknowledgment

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