CHAPTER 3

EXPERIMENTAL WORKS
Chapter 3

Experimental Works

In this chapter, we describe the design and development of RPCs along with their performance tests carried out. Prime motivation of this work is to develop a low cost particle detector of predictable performance to work as substitute for scintillation detector in the mini array. The mini array method (Appendix A) is pursued in the GU Cosmic Ray Research laboratory to detect Ultra High Energy Cosmic Rays. The requirements of the detector for this experiment are (i) large size i.e. 50 cm x 50 cm, (ii) good timing characteristics of the order of few nS, (iii) low cost (iv) easy availability of materials, and ease of fabrication with minimum resources of a small laboratory. Due to their inherent advantage, we chose RPCs as the reasonable substitutes for the costly scintillation detectors used in the above experiment. In this pursuit we have put in considerable efforts to design, develop and experiment with a variety of small, medium and large RPCs and various components required for production of RPCs. We have also designed and developed front end fast electronics instrumentation necessary to test and operate the RPCs.

3.1. Experiment Part I

At the beginning we designed and fabricated small and medium size RPCs with different resistive materials with gas gap of 1mm and 2mm. Four different types of resistive materials were used. The materials were

(i) Bakelite,
(ii) Window glass,
(iii) Mirror glass,
(iv) Paper phenolic printed circuit boards.

The later two were tried because they are already coated with conductive layer.
3.1.1 Small and medium size RPCs

At first we built and operated several RPCs of 10 cm x 10 cm in size of two different gas gaps, 2mm and 3mm. We have used a number of materials which are locally available. A schematic diagram of small and medium size RPCs fabricated is shown in Figure 3.1.

These RPCs were made with four different types of resistive material as mentioned above. For the glass RPCs, coating methods used for applying conductive coating on one side of the electrodes was necessary. This is discussed later. We have chosen the mirror glass due to its excellent surface uniformity achieved without the surface treatment, resulting in better field uniformity. The insulator spacers were used for maintaining precise and electrically isolated gap between the glass electrodes and square shaped frames are used for supporting the electrodes. For forming an enclosed gas volume, a gas chamber was made with a rectangular frame made with microscope glass slides of thickness 1mm The glass plates, spacers, frames, gas inlet and outlet nozzles are all assembled using two component epoxy adhesive e.g. araldite. This adhesive has very good peel off strength and is also found to be non reactive to most of the detector gases.

(49)
We fabricated more than two dozens small area RPCs of dimension 10 cm x 10 cm and 15 cm x 15 cm. We also extended the size up to an area of 30 cm x 30 cm. The design of small and medium area RPCs was identical.

3.1.2. Anode coating method

The resistive coating of the outer surfaces of the electrodes plays a very crucial role in the operation of the RPC detector. While the surface resistivity of this coating should be small enough so that the bias voltage that is required for the RPC operation can be applied on these coats, it should be high enough to render it transparent to electric pulses generated by the charge displacement in the gas gap. This way, the charges produced inside the gas gap on passage of a particle, can induce electric signals on the external metallic pickup strips, which are capacitively coupled to the gas gap. There is another important consideration of this electrode coat on the performance of the RPC. Every charge particle passing through the RPC produces a tiny charge spot of about 1 cm² in area. This area is too small to result in any noticeable cross talk between two adjacent pick up strips on which signals are induced. However if the surface resistivity of the graphite coat is too small, the induced charge is less localized and spread laterally across the graphite coat, producing the large crosstalk between the pick up strips and thus severally affecting the position resolution of the detector.

Several types of materials and variety of application methods for obtaining this coating can be found out. A silk screen printing method can also be used by which the coat can be controlled precisely. Other technique such as metal oxide paints, anti static paints, graphite varnishes, adhesive graphite foils, special inks and commercial automobile paints are also used.

In the case of our initial designs of glass and bakelite RPC with size up to 30 cm x 30 cm the following coating methods were tried.

3.1.2.1 Coating with graphite powder

This method is used for coating the window glass and bakelite. Graphite powder of -300 mesh fineness was prepared from commercial graphite powder. For this, the coarse graphite powder was ball milled in a pulverizer (Model Pulverisettee-7, FRITSH,
and sieved. The powder was then mixed thoroughly with epoxy resin to make a paste (adhesive: hardener ratio 2:3). The best ratio for epoxy to graphite was found to be 1:3. A thin coat of the mixture is then applied on one side of the resistive plate and allowed to cure for 24 hours. In this method, first hardener and resin is mixed in the ratio of 2:3 and is glued. Then graphite powder mixed with 1:3 of araldite and graphite. When it mixed very nicely, it is rubbed on the window glass sheet or Bakelite sheet to form a very thin and fine layer, using a small glass strip. The sheet is then cured for 24 hours before use. The average resistivity of this coating is measured and found to be 700 kilo ohm/sq.

To obtain more uniform results spray deposition of graphite conductive coating was used in case of large RPCs which is described later.

3.1.2.2. Vapour deposition method

In this method aluminium conductive coating was developed on a glass sheet by vapour deposition method (Vacuum Coater, Model No. VC112, Vacuum Instrument Company, New Delhi). At first window glass sheet was cut to required size and then properly cleaned. The cleaning procedure involved cleaning the plates in chromic acid followed by rinsing in distilled water. Later the plates are dried and cleaned with alcohol. The clean plates were placed in the chamber of the vacuum coater (Model No. VC112, Vacuum Instrument Company, New Delhi. At temperature above boiling point of Al and pressure ($10^{-6}$ torr), Al vapour is formed which produced a fine coating of aluminium on exposed surface of the plates. However, in this case the size was limited to 15 cm x 15 cm due to the limited size of the coating chamber.

The normal Ag coating on mirror glass and electro deposited Cu coating on phenolic materials such as printed circuit boards were also used as to act as conducive electrode. The resistive materials in these cases were either glass (in case of mirror) or phenolic (in case of PCB).

3.1.3. Design of signal pick up strip

Signal from the RPC is obtained from pick up strips placed over the anode with proper insulation. Whereas pick up electrodes can be placed on both sides, in all the
RPCs developed by us pick up from only one side is used. The main criteria for selecting size of the strips are their characteristic impedance, cross talk and detector size. The pick up strips are laid on the pick up electrode plate. The strips are 3 cm wide with lengths covering the RPC active area. The separation between the strips is kept at 2mm. These sizes are arrived at by observing the best pulse shape by trial and error. In case of small and medium size RPCs the strips are made by etching the pattern on a single sided glass epoxy printed circuit board. Figure 3.2 shows a photograph of a pick up electrode plate.

![Photograph of a pick up electrode plate](image)

**Figure 3.2: Photograph of a signal pick up strip of (15 cm x 15 cm) RPC.**

3.1.4. RPC gas chamber design

One of the most crucial aspects of fabricating the RPC gas gap is to mount the two electrodes parallel to each other. This ensures a uniform field across the entire area of the chamber when high voltage is applied to the gas assembly. As mentioned in the section 3.1, the insulating glass insulators are used to maintain the precise gap between the electrodes. It is important that the insulating glasses are arranged perfectly on each side of the assembly so that they will provide rigidity and mechanical strength required for the assembly to overcome the pressure exerted by the gas flowing through the whole chamber.
3.1.5. Development of large area RPC

Having learnt the art and the science of RPC design through the fabrication and study of small and medium size prototype chambers, as well as having developed the design, fabrication and testing infrastructure needed for detector R & D, we have taken the next logical step to develop larger area RPCs of 50 cm x 50 cm in size. These were glass RPCs with gap 2mm and active area of 48 cm x 48 cm. A schematic of this RPC is shown in Figure 3.4. The entire procedure described below was developed based on our experience and also that of others and is followed rigorously to ensure expected results.

![Schematic of the large area RPC](image)

Figure 3.4: Schematic of the large area RPC.
3.1.6. Cleaning of glass plates and spacers

The glass plates of size 50 cm x 50 cm and thickness 3 mm (Asahi float glass procured from local market) were first thoroughly cleaned with household detergent. Next, the glass plates were subjected to mild acid (chromic/acetic acid) and mild alkali wash. After completing each washing the plates were rinsed thoroughly with distilled water. The plates were then left to dry in ambient condition in a dust free polythene cabinet designed and fabricated for that purpose. The plates are then packed in clean wrap transparent film to protect it from dust. The 2mm thick window glass strips used for spacers are also cleaned with the same procedure.

3.1.7. Gluing the gas chamber and the glass plates

The following actions were performed in a laminar flow cabinet system available in clean room in the biotechnology department of G.U.

Before assembly, all the glass parts are finally cleaned with alcohol and rubbed clean with lint free cloth. Glass strips 1.25 cm wide and 2mm thick are used to make the gas chamber frame and spacers. Spacers were 1.25 cm x 1.25 cm placed at the center. We have assembled RPCs with and without spacers as spacers produce dead space in the detector. The gas chamber frame which also works as the spacers and extra spacers are glued to one side of a plate with superglue. The frame gets stuck in a few minutes. Requisite gaps to hold two pairs of 1.8mm nylon tubing for gas inlet and outlet are left on opposite sides. These tubes are put in position and the other glass plate is attached to it by applying two component epoxy resin applied through a plastic syringe without attaching the needle. All sides are glued as evenly as possible allowing the glue to flow into the gap left by the spacer in between the plates. The whole assembly is then left there under pressure for 24 hours.

3.1.8. Coating outer sides to form the conductive layers

Coating of the plates is done by spray painting method. The liquid conductive suspension is made by mixing carbon black with paint lacquer. Thinner is used to bring the viscosity to the optimum level. The best proportion is 1:4:4 carbon: lacquer: thinner. The plates are then held in a suitable stand and spray painted with the help of compressed
air and spray gun used in automobile paint shops. The paint cures within a couple of minutes. The paint thickness is adjusted to produce a surface resistivity of ohm 700kΩ/□. Margins at the edges are left by covering these with adhesive tape.

### 3.1.9. Signal pick up strip

Pick up electrodes of size 3cm wide covering the detector effective area was made of thin aluminium foil. Strips were cut and pasted carefully on a mylar insulating sheet with a spacing 3mm wide. This sheet was laid on top of the anode coating with two more sheets of same size to provide requisite insulation. The top of the signal pickup strips is covered with a glass sheet 2mm thick. Other side of this glass plate is pasted with aluminium foil to make ground contact. Gold plated fingers were used to make contact with the strip to take out the pulse signal. A glass epoxy printed circuit board (PCB) is used to hold these fingers in place. On the other end another PCB with similar contact connects the termination resistances from pick up strips to ground. This is necessary to properly match the signal lines.

![Figure 3.5: Photograph of a signal pick up strip of (50 cm x 50 cm) RPC.](image)
3.1.10. Final assembly

As the glass plates are fragile a frame made of plywood (bottom) and plexiglass (top) is used to hold the detector assembly without stress. The top and bottom sides are covered with half inch foam (PUF) sheets to reduce shock further. Figure 3.6 and 3.7 shows two stages in assembly of the RPC while Figure 3.8 is a photograph of fully assembled detector.

Figure 3.6 An assembled RPC in the laminar flow system.

Figure 3.7: RPC after conductive coating applied

Figure 3.8: A fully assembled large area RPC

3.1.11. Gas mixing & distribution

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. This is usually achieved either by using gas mixing and distribution systems of gas recovery systems.

We have designed and developed gas distribution and mixing systems. According to this system the gases are stored in individual cylinders fitted with regulators. The input gases are controlled through two stage gas regulators mounted on cylinders. The gases are then allowed to flow through copper connector to the gas distribution panel. The copper gas lines are fitted by nut and ferule and these are tightened by Teflon tape for making leak proof joint. This gas distribution panel consists of three input channel and one output channel.

Photograph of the complete gas distribution system is shown in Figure 3.9. Three different gases can be mixed and distributed to the RPC (Detector) with this panel. Gas mixture ratio can be controlled by controlling the flow of gas in each channel by independent pressure regulators.

![Figure 3.9: Photograph of the gas distribution panel](image-url)
3.1.12. Chromatopak moisture trap

The Presence of water vapour in the gas effects the operation of the RPC. Traces of moisture can be removed by passing the gas through a bed of inert moisture absorbing material. Initially we designed moisture trap in our lab. But because of poor performance it is replaced by two channel moisture trap with pressure indicator manufactured by Chromatopak. It is placed in the inlet of the gas mixture that is connected to the detector.

![Figure 3.10 Gas flow system of the Chromatopak moisture trap.](image)

3.1.13. Bubble type gas flow meter

A simple bubble type gas flow meter is designed as shown in the Figure 3.11. It is made out of a borosil test tube in which the outcoming gas stream is allowed escape through water. The escaping gas produces bubbles. The bubbles are counted manually to estimate the gas flow rate through the detector at the time of operating the detector. The flow rate is adjusted at the gas mixing chamber. The level of water is maintained from time to time.
3.2. Experiments Part II

3.2.1. Testing of the RPCs

The block diagram complete electronic pulse recording system with HV bias supply is shown in Figure 3.12. For recording of the detector pulses and determine their characteristics i.e. rise time, pulse width and pulse height a Digital Storage Oscilloscope (DSO), (Tektronix, TDS 520A, 500MHz, 500 sample/S) is connected and pulses are

![Block diagram of experimental setup.](59)
C1=P10 Gas (90% Ar+10% CH4) Pre Mixed.
C2=Freon (Freon 134a)
C3= Optional
S1=S2=S3=Manual Switch

Figure 3.13: Gas Flow Arrangement for RPC

recorded via GPIB interface. For count rate measurement, pulses are applied as input to
the discriminator described in section 3.2.4. and counting of the shaped discriminator
output pulses is done manually using digital counter timer (Model, ECIL-5104).

We test the RPC in two different gas mixtures P-10 and Freon-134A at slightly
lower than the atmospheric pressure. P-10 gas provides efficient gas amplification and
Freon 134A has been used as “quench gas” to control charge and physical size of
streamers. Gas mixtures have been taken in four different ratios P-10 and Freon. These
ratios of P-10 and Freon are 50:50, 40:60, 60:40 and 30:70.

3.2.2. Measurement of rise time and fall time and RPC pulse height spectrum

The pulse heights, rise time and fall time of the detector pulses are measured for a
definite interval using the DSO. For recording all these parameters separate GPIB
software program is developed to acquire heights of each pulse, its rise time and fall time which are then stored in computer memory. At the end of predetermined period of time the data are stored in hard disk. Separate software analyzes the recorded pulse height data and plots the pulse height spectrum. These results are compared with simulation results obtained for 30 cm x 30 cm size RPCs both for 1 mm as well as 2 mm gas gap which is presented in chapter 4.

3.2.3. High voltage circuit design

To run a detector like the RPC, HV bias that can generate electric field of the order of 30-40 kV per cm is required. Commercial reasonably priced models available indigenously can give maximum 3 kV. Those above are very expensive. As the current requirement is of the order of few micro amperes, a H.V. Power supply was designed and fabricated with available components.

This is a DC to DC converter, a low voltage DC to high voltage DC converter that can supply voltage up to 7.8 kV and current 0.5 mA. The circuit diagram for the high voltage section and the filter section of the power supply is shown in the Figure 3.14 and Figure 3.15. The output of high voltage power supply is tested using high voltage probe MOTWANE Digital Meter (Model-DM352, 080206, & High voltage probe, Model No. HV 40). The high voltage output is 7.8 kV.
To operate the scintillation detector separate standard modular H.V. power supplies have been used. These HV modules were imported and we assembled complete power supply with locally available component and a PCB designed for the same. These
are adjustable 15 KV power supplies which were tested by using high voltage probe MOTWANE Digital Meter (Model-DM352, 080206, & High voltage probe, Model No. HV 40).

3.2.4. Discriminator circuit

To discriminate the pulses from the detector output pulses discriminator circuits have to be used. We used separate discriminator circuit for scintillation detector and RPC.

3.2.4. (i) Discriminator circuit design for PMT

A modified eight channel discriminator board is designed and fabricated using high speed voltage comparators for the present experimental setup. The unit produces the logic pulse as the incoming pulse crosses the discriminator bias (set at 50mV). The circuit diagram of one channel of the discriminator with pulse shaper is shown in Figure 3.16. Scintillation detector pulses are fed into the inverting terminal of the high speed comparator IC1 (LM361) and the bias is set by the preset (Trim pot) P0. As the incoming pulse crosses the discriminator bias in the comparator input, i.e. discriminator output unit produces the logic pulse of 600nS or 10nS width adjusted by R7 & C4 connected to U3.

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**Figure 3.16: Circuit diagram of discriminator for PMT**
3.2.4. (ii) Discriminator circuit design for RPC

To acquire the fast pulse type signal from the RPCs a separate discriminator was designed and developed. The RPC pulses were first brought into the ultra fast comparator IC MAX 9691(U2). This device has a very wide bandwidth and low propagation delay. However, the outputs are in the ECL level. Hence, an ECL to TTL converter is needed to convert the pulses so that they can be fed to the existing pulse processing electronics. This is done using another comparator i.e. IC LM 361(U3). The discriminator threshold voltage is set by the potentiometer P1 which is buffered by IC LM358 (U1).

Figure 3.17: Circuit diagram of discriminator for RPC

Figure 3.18: Photograph of a discriminator circuit board (PMT).
3.2.4.1. Calibration of the discriminator

For the calibration of the discriminator circuit boards, a standard pulse generator and a timer counter was used. The individual channels of the discriminator boards are tested with the help of standard pulse and timer counter. This test pulses are fed to the discriminator input. The bias of the discriminator channel is adjusted to produce a definite count rate. This rate is measured over a long period of time and doesn’t show any appreciable change. It is found that the drift is also negligible.

Figure 3.19: Snapshot of discriminator input and output wave forms.

3.3. Experiments Part III.

3.3.1. Measurement of bulk Resistivity

The arrangement for the measurement of resistivity of a resistive material is shown in Figure 3.20. We measure the bulk resistivity by I-V method. For this, a setup as shown in Figure 3.20 is used. The material to be tested is placed in between two polished copper plates and held tight between them. As we were dealing with phenolic material, the alignment of the plates was not a problem due to semi transparent nature of the resistive sheet. Current values for different voltages were measured using micro ammeter (TESTRONIX-8, Digital Micro Volt / Ammeter) and used to find the resistivity.
3.3.2. Detector cathode current measurement:

The arrangement shown in Figure 3.21 is used for the measurement of the detector cathode current. RPC anode is connected to the positive terminal of the HV supply and cathode is connected to a precision resistor whose other end is connected to negative HV supply which is at ground potential. A Digital Micro-voltmeter
3.3.3. Measurement of cross talk

Cross talk between adjacent signal paths in an electronic system is a common problem. As the pick up strips of the RPC run parallel adjacent to each other in a common plane, signal in one strip induce low level signals in a number of other strips. In RPCs cross talk is also produced due to the spread in the size of the discharge spot if the conductive layer on the electrode is low. The cross talk has been measured by others and is found to be related to electrical characteristics of the pickup, its thickness, surface resistivity of the electrodes, and composition of gas used.

As there are no standard methods for measuring cross talk we have used the following method for its measurement. In this method, one of the strips is fed with artificial pulse and both the pulses, the pulse induced in the adjacent and the original pulse is recorded in an oscilloscope (Digital Storage Oscilloscope (DSO, (Tektronix, TDS 520A, 500MHz, 500 sample/S). Their heights are compared at a number of different levels of input pulse. Another test is carried out during actual operation of the detector. Here, pulses from two adjacent strips are discriminated and fed into 2-fold coincidence. The output of the coincidence is counted to find the amount of cross talk.

3.3.4. Detector efficiency test

Figure 3.22. shows schematic representation of the experimental setup the measuring efficiency. RPC module is sandwiched between the two scintillators (SC1 and SC2) each of dimension of 50 cm × 50 cm × 5 cm. To obtain the RPC efficiency in a region within one pickup strip, the trigger setup is further zoomed into a region of Finger scintillator (SCF) of dimension 5 cm × 5 cm x 5 cm and place above the pickup strip. The trigger signal is obtained as SC1 AND SC2 AND SCF indicating passage of a cosmic ray muon. We therefore obtain the efficiency in a region of 3 cm ×5 cm within a pickup strip. Coincidence between RPC count and the trigger count is taken as final count. Therefore, efficiency is obtained from the following formulae.
\[
\% \text{Efficiency} = \frac{\text{RPC count with the signal in coincidence with trigger}}{\text{Trigger Count}} \times 100
\]

Parameters which have been varied in efficiency test are (a) Gas Mixture (b) detector bias voltage.

The muon trigger rate and the RPC coincident count rate are measured as follows. The pulses from the 3 scintillation detectors and the RPC pulses are brought into their individual discriminators. The shaped pulses from the discriminators are fed to the fast coincidence circuit. Stretched pulses at the output of the coincidence unit corresponding to the trigger and RPC coincident with trigger are counted separately.

The muon trigger rate is determined with counter timer (ECIL 5104). For counting the RPC coincident pulses the DSO with GPIB interface is used (otherwise two numbers of counter/timers are required). Whenever a trigger occurs at the scope for RPC coincident pulse the oscilloscope increments a counter set up to record the trigger. This action is continued automatically for a pre-determined period. Separate software is written for the scope handles this.

The high voltage to the scintillator is supplied from ECIL, HV 4800D HV power supply and the RPC is biased from the HV supply discussed earlier.

Figure 3.22: Experimental setup for efficiency test for RPC
3.3.4.1. Fast scintillation detectors

Two scintillator detectors SCI & SC2 are of identical design. The third scintillation detector is different and much smaller in dimension compared to the others. SCI and SC2 are made of 50 cm x 50 cm x 5 cm plastic scintillators (BICRON BC-400) viewed by XP 2050 PMT fitted inside a light tight enclosure. The PMT dynode chain and anode is supplied with HV voltage (1400V) from HV power supply (ECIL HV 4800E) and from the designed high voltage power supply. The anode signal coupled to RG57 HF cable through HS preamplifier and emitter follower circuit detailed later. SCF is made of 5 cm x 5 cm x 5 cm of similar scintillator viewed by EMI 9807B fast PMT in a small light tight enclosure. Dynode chain and anode HV (1800V) supply is given from NIM HV power supply (ECIL HV 216A). The anode pulses are amplified by compact fast preamplifier and fed to the HF output cable (Type RG58A/U).

![Figure 3.23: Photograph of Experimental setup of efficiency test for RPC](image-url)
3.3.4.2: High speed preamplifier circuit

The anode pulse from the PMT is low. So for further processing a preamplifier circuit is required. The following two circuit diagrams are used for SCF (Figure 3.24) and SC1, SC2 (Figure 3.25). Wide band (200MHz) differential amplifier is used in these amplifiers. The gain of the amplifiers is set at 100. SC1 and SC2, which are designed as particle detectors for the rooftop miniarray need emitter follower to drive the H.F. cables. These pulses are brought to the individual discriminators. The discriminator thresholds are adjusted below the single particle pulse height level obtained from omni directional pulse height distribution measured for the individual detectors using cosmic ray muons.

![High Speed Preamplifier for PMT](image)

**Figure 3.24: High speed preamplifier circuit schematic for SCF**
We test the RPC in two different gas mixtures P-10 & Freon-134A at slightly lower than the atmospheric pressure. P-10 gas provides efficient gas amplification and Freon-134A has been used as "quench gas" to control charge and physical size of streamers. Gas mixtures have been taken in four different ratios P-10 and Freon. According to percentage this P-10 and Freon are 50:50, 40:60 and 30:70 and measured efficiency has been found to increase the HV and change of gas ratios.

The rise time of the RPC pulse was 3.2 ns. In testing, the threshold value of the discriminator of the RPC is generally set at 50mV.

3.3.5. Digital Pulse stretcher circuit

The output of the fast coincidence unit is a pulse that may vary up to a maximum of 10 nano second. To count these pulses a separate pulse stretching circuit is required to increase the width of these pulses, which are fed to slow speed counters. This new pulse stretcher circuit designed is capable of stretching input pulses of few nanoseconds to several micro seconds. The RPCs produce characteristic pulse having rise time 8.6 ns and width 48.44 ns. The output of the fast discriminator which was applied to the input of the pulse stretcher is shown in Figure 3.26. The corresponding stretched pulse width adjusted to 29.56µS. This shows the successful operation of the circuit. We have been using this circuit for studying RPC count rates and detection efficiency.
Figure 3.26: Digital Pulse Stretcher Circuit Schematic

Figure 3.27: Photograph of digital pulse stretcher circuit
3.3.5.1 Circuit description

Circuit diagram of the pulse stretcher is shown in Figure 3.27. The circuit basically can be divided into two stages. The first stage generates an output pulse of fixed width of 20ns. Whenever an input pulse is present, the Q output (Pin 5) of Fast TTL IC 1 (74F74, dual F/F), which is initially set HIGH, is set LOW with its CLK pin 3, which is fed with the pulses from discriminator. The Q output passes through the series connected six inverters of fast TTL IC 2 (74F04 HEX Inverter) producing an output that is delayed by six gate delays of 30nS. This output is branched into two, one going to the reset pin 1 of IC 1 and another going to the input of the next stage, which is a mono stable multivibrator, based on timer LM 555 (Pin 2). In the monostable mode, the discharge and threshold pins of the timer IC 3 (LM 555) are connected together. Whenever a pulse of sufficient width from pin 8 of IC 2 is applied to the trigger pin, the output goes high and remains at that level till the capacitor C is recharged. The output goes low when the capacitor is charged up to a voltage, which is 2/3rd VCC. This time depends on the values of R2 and C4. By making R2 variable this is made adjustable so that a pulse of variable width can be generated.

3.3.6. Coincidence circuit

Each detector pulses first shaped into our desired pulse width 2 microsecond (i.e. 2 to 3 microsecond) then it fed to the AND circuit and measure the coincidence of pulse. The discriminated signals of two large scintillators are coincided and with this output the discriminated signals of the smallest scintillators are coincided QUAD CINICIDENCE LOGIC UNIT (Figure 3.28)
Figure 3.28: 4- Fold coincidence unit circuit schematic

Figure 3.29: Photograph of coincidence circuit
This triple coincidence circuit has been used as a trigger. The three-fold coincidence output have been coincided with the RPC signal by the same coincidence logic unit. Three fold coincidence output count rate are taken by the counter timer (ECIL-5104) and four fold coincidence counts are taken by Computer through GPIB (IEEE-488) interface bus.

In chapter 4 the simulation work on RPC pulse height distribution is presented.