Design & Development of Laboratory

FOR

PRODUCTION OF RESISTIVE PLATE CHAMBERS

FOR

CMS EXPERIMENT AT CERN GENEVA

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The Experimental High Energy Physics group at Panjab University, Chandigarh is going to produce 40 numbers of large Area Resistive Plate Chambers (RPC) for end-cap region of CMS, in collaboration with BARC Mumbai. These detectors shall be assembled in Physics Department with the imported gas gaps, mechanics and front end electronics. The RPC's after assembly shall be tested for their performance and sent to CERN for integrating them into the CMS detector main frame. Here are some pictures of the established laboratory for undertaking various jobs for assembly and testing of RPC's. The entire infrastructure consists of a dust free lab, air conditioning, gas handling and mixing system, high voltage power supply, cosmic stand, data acquisition system and associated electronics, efficiency measurement of RPC.

RPC Lab View at Panjab University

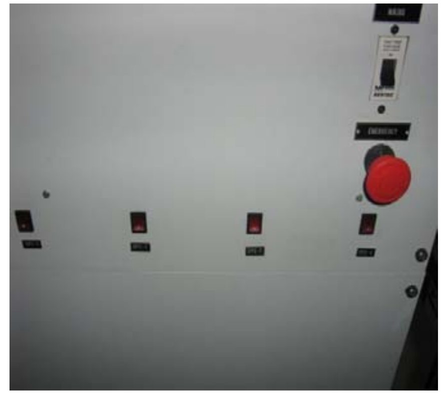
- **The Air Conditioned lab is equipped with Set of Gas Cylinders, Gas Mixing Unit, Cosmic Ray Test Stand using Scintillator Paddles and Data Acquisition System Using NIM & CAMAC Standard Electronics.**

Gas Mixing System for RPC

- **The photographs shows the Gas Mixing controll pannel in RPC Lab at Panjab University.**
- **For proper and efficient working of RPCs, it is required to premix individual gases in appropriate proportion and also control the flow in the detector.**
- **This is done with the help of gas mixing and distribution system we have designed and developed with the help of local industry.**
- **A gas mixing unit capable of mixing four individual gas components and control the mixing gas flow through the 4 RPC Gas Detector**

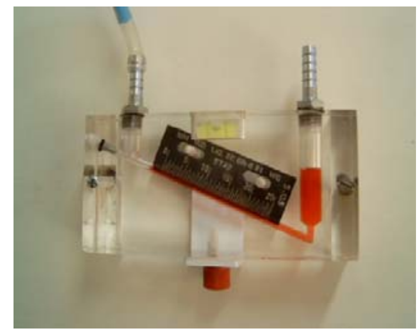
Gas Mixing System for RPC











- **The gas mixing system comprises of gas purifier column, a gas mixing unit, distribution panel, safety bubblers, an exhaust manifold, controls for monitoring and set of gas cylinders together with manual pneumatic valves.**
- **For optimum pressure each cylinder is provided with pressure regulators.**
- **Steel tubing is used to for individual gas supply from gas cylinders to the mixing unit as well as from gas mixing unit to the RPC test stand.**
- **Flow rate of individual gases calibrated in SCCM are settable and are displayed on the front panel.**
- **Safety bubblers serve to prevent back diffusion of air into the RPC**
- **The mixed gas can be flown into four RPC's with the help of selectable switches provided on the front panel.**

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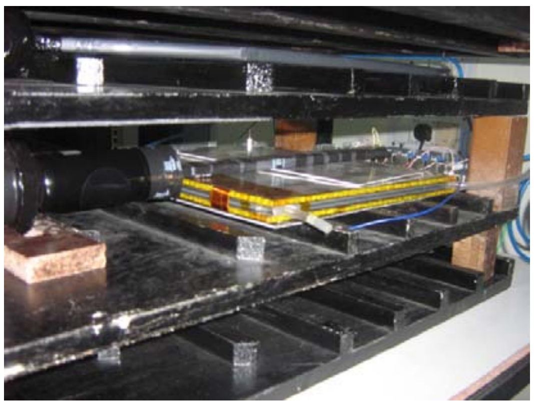
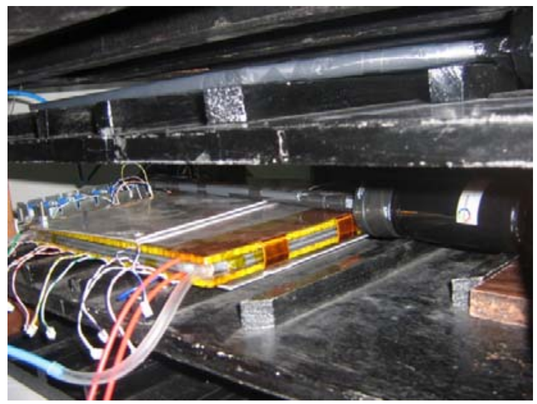
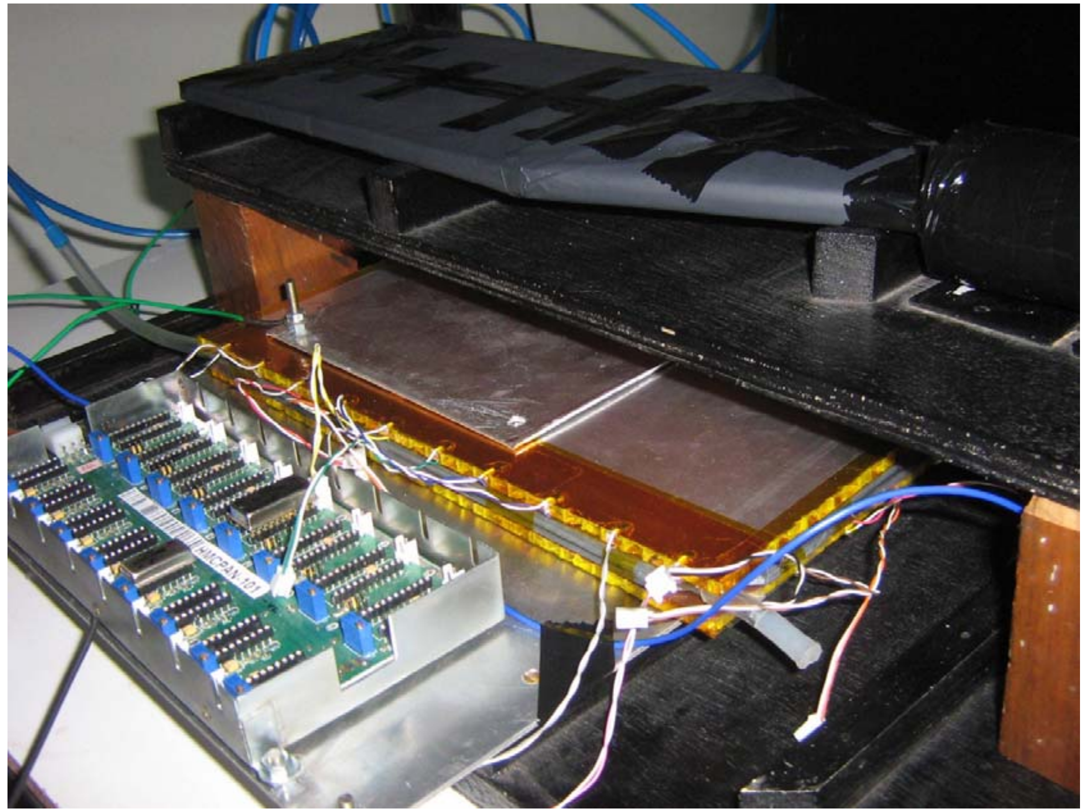
Cosmic Ray Set-Up for Efficiency Measurement of RPC



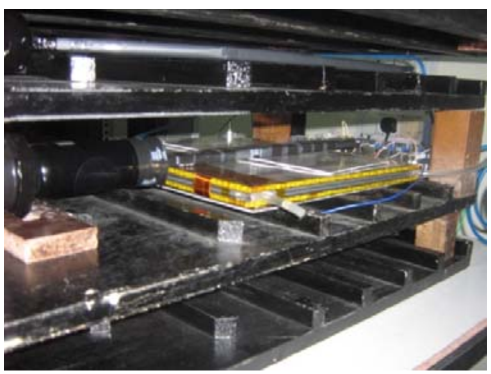

- **The photographs above show the Cosmic Ray Set-Up complete with Data Acquisition and Gas Mixing System. The set-up in lab eables us to test RPC for efficiency, time resolution and other parameters.**
- **A Scintillator paddle based *cosmic ray muon telescope* is made for this purpose which is found to exhibit excellent stability. This telescopic arrangement is set-up in our test stand.**

Cosmic Ray Set-Up for Efficiency Measurement of RPC



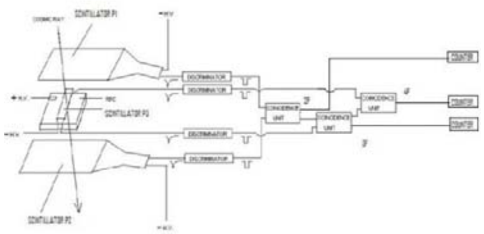
- **The Test Stand forTelescopic Arrangement of Scintillator Paddles for testing of the protype RPC. HV cable connections and signal cable connections can be seen here.**
- **Gas pipes are seen through which mixture of gases is circulated into the RPC. Signal wires are connected to the pre-amplifier board and output of the preamplifier is taken using co-oxial cable and is connected to DAQ.**

Cosmic Ray Set-Up for Efficiency Measurement of RPC



- **We measure the efficiency of RPC by making the experimental setup in such a way to ensure that the trigger pulse is solely due to atmospheric muons.**
- **Here we use 3 Scintillator Paddles P1 to P3. Area of P1 and P2 is 20cmX35cm where as the area of the third paddle in taken as the area of the prototype RPC strip i.e. 3cmX30cm (Finger Paddle).**
- **We keep peddle P3 along the strip and peddle P1 and P2 above and below the RPC respectively.**
- **All paddles are made up of Scintillator material of 1cm thickness. These Scintillator Paddles are optically coupled to photomultiplier (PMT) for converting scintillation light into electrical signal.**
- **When PMT is operated with high voltage (HV), the paddle gives a signal indicating the passage of a cosmic ray muon.**
- **The geometry of the three Paddles is arranged in such a way that we define a window of about 30cmX3cm for the cosmic muon to pass through peddles P1, P2, P3 and one of the pickup strips of RPC under test. Finger Paddle P3 is used to define the geometry precisely.**
- **This ensures us that muon trigger is generated when we have three paddles in coincidence.**
- **To find out the efficiency of the RPC we monitor individual count rates of paddles as well as various coincidence logic signals rates. This is achieved by a dedicated Data Acquisition Systems being setup in the lab.**

Cosmic Ray Set-Up for Efficiency Measurement of RPC



- **We have designed and developed a Data Acquisition System (DAQ) for testing of RPC using NIM and CAMAC Standard Electronics. Block diagram and photographic View is shown in Figure.**
- **The Scintillator Paddle signals (analog pulses) are converted to NIM level Logic signals (Digital Pulses) by feeding them into discriminator modules operating with threshold of -30 mV and producing a pulse of 50 ns width. The cosmic ray trigger signal is formed by using NIM logic circuits.**
- **A 2F Coincidence consists of 2-input AND of P1 and P2. The Output of this first stage are ANDed again to generate the final trigger (3F).**
- **Scalars are added in every stage to monitor counting rates of these signals.**
- **Pickup strips of RPC are connected to preamplifiers by twisted pair cables and to discriminators by coaxial cables and then to different channels of TDC with some delay. Analog signals are also fed in as inputs to CAMAC Charge ADC module. The NIM Logic-output of RPC is again fed in as input to a CAMAC TDC module.**
- **The Efficiency of the RPC is determined by the ratio of its coincidence with the triggers (4F) and triggers themselves (3F) both of which are counted simultaneously with the help of Scalar module.**

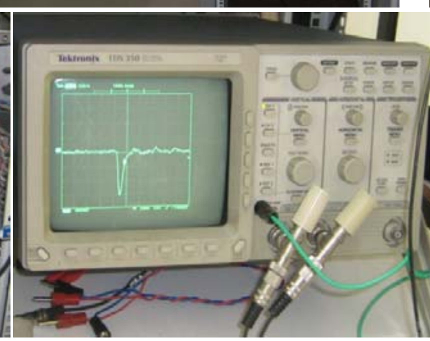
$$\text{Efficiency} = \frac{\textbf{RPC Count with Signal in coincidence with trigger (4F)}}{\textbf{Trigger count (3F)}}$$

Data Acquisition System





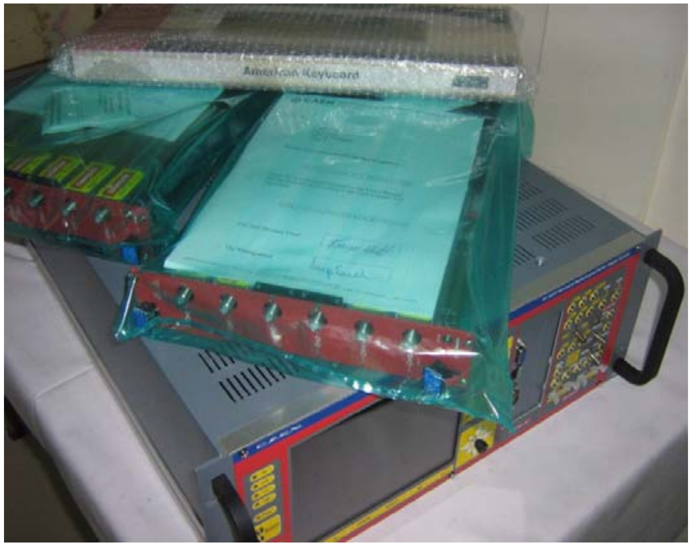





- **The photographs show the Data Acquistion System (DAQ) designed and developed for testing of RPC using NIM and CAMAC Standard Electronics. DAQ data is controlled and stored by a dedicated PC attached to it**
- **Various Modules in use here are: Discriminators, Coincidence Logic Units, Fan-In and Fan-Out, Scalar, ADC, TDC and HV modules. We are using 200 MHz Oscilloscope for studying various signals formed by Scintillators & RPC**

Power Supply System for RPC



Power Supply and Monitor System

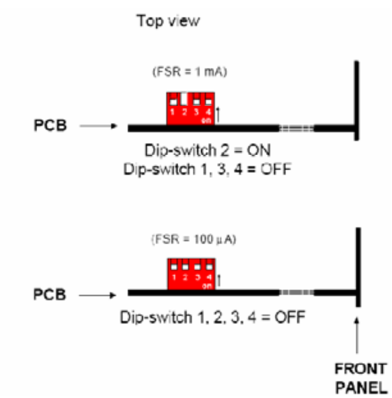
- For RPC we need to setup an electric field across the electrodes by applying differential high voltage of ±4.9KV.
- The base RPC is wired for applying high voltage and picking up the signals as charged particles pass through.
- The voltage is applied to the graphite layer by sticking on a copper tape and leads are then soldered on to the copper.
- Positive voltage is applied to one side and roughly equal and negative voltage to the other side, The essential features of the high voltage power supply need to be a multichannel monitoring of output voltage and load currents.
- We also need DC power supply like ±6 Volts and ±8 Volts for the front-end electronics comprising of preamplifiers, analog and digital frontend systems.
- Fine control of supply at the load input and monitoring of the supply voltages and load currents is the essential requirement of low voltage power supply system.
- We have designed the power supply system using commercially available components from CAEN shown in figure.

Operation of HV Power Supply CAEN 2527 Control

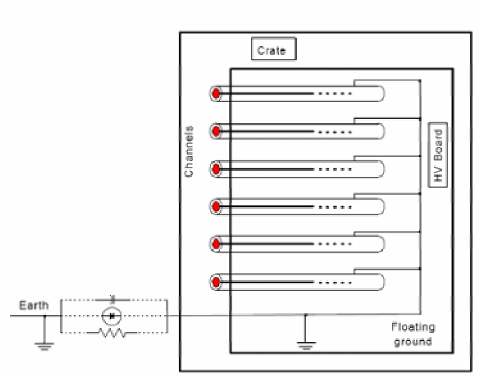
1. Plug in the supply to mains
2. Turn the main switch on back of the power supply on (Switch on I)
3. Turn the key on the front to the position **Local**
4. The switches are to be **local enabled**
5. Connect a standard PC keyboard to the power supply (socket **KBD** on the front)
6. Press any key, then login as admin (password admin)
7. Go to **Setup** menu, select the submenu **Communications** and choose **TCP/IP settings**
8. Enter 192.168.0.90 for **IP address** and 255.255.255.0 for **IP NetMask** and gate way 192.168.0.1
9. Select **Ok** to confirm the settings.
10. Use the arrow keys to navigate, the **Tab** key to change back to main menu and **Enter** key to select something.
11. In the main menu you will find the **channels** submenu, where you can set voltages and current limits and see the status.
12. After you have changed the value confirm it with **Enter or Space Key**
13. To toggle between yes/no or on/off, use **Space**.
14. When a channel is turned "on" the LED **CH-ON** on the top right corner of power supply is on.
15. Make sure that the trip time **Trip** is set to 0.0s and software maximum voltage **SVMax** is set to 1560V (or another value slightly above your used maximum)
16. Usually **V0SET** and **I0SET** are used to values (Indicated by **V0 I0** in the status line at the bottom of the window).
17. Use **Tab** to go back to the menu and on the main menu select **Logout**

Some Important Comments on HV 1526P or 1526N Boards

High Voltage Boards which are inserted into the Main Frame need to be set as per our requirements i.e to 1mA or 100µA maximum current. This is done as described below. Also the board need to be enabled to get the channels on. Once the board is enabled we get the channels selected from the front panel. This is indicated by the LED's on the 1526 HV System

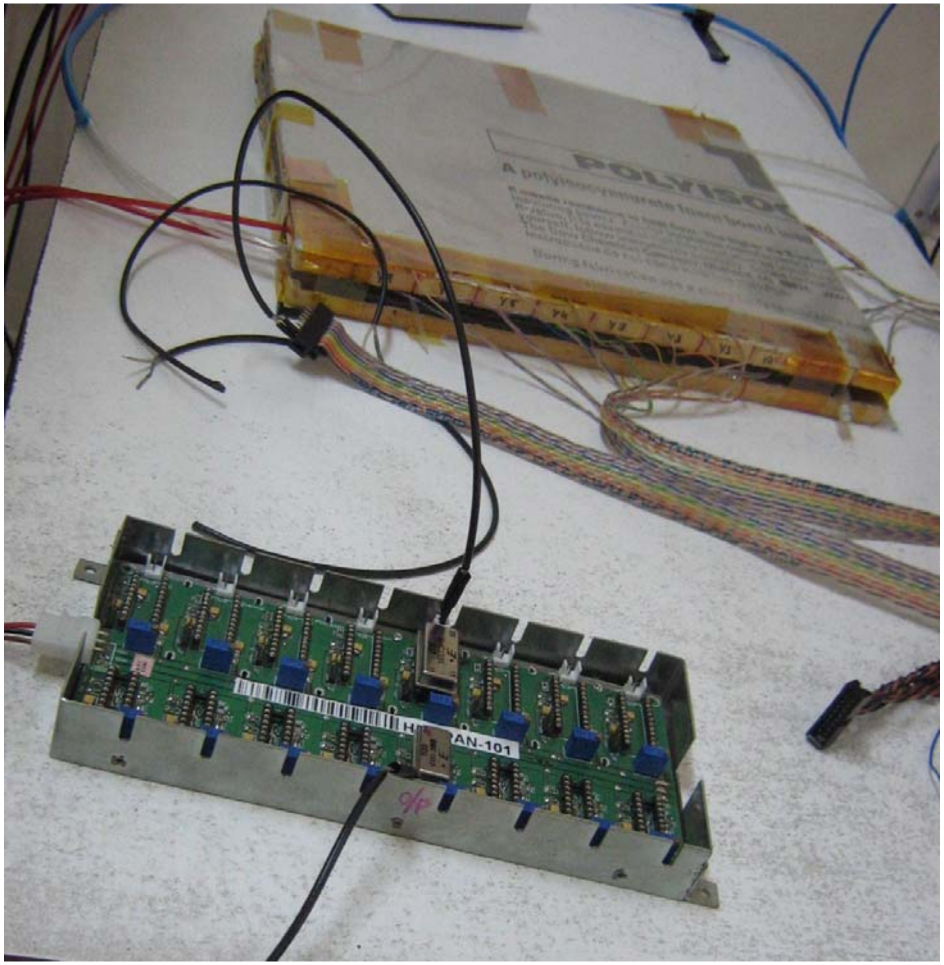


- **To change or manipulate boards, shut everything down. Log out, put the key on *OFF* position, put the main switch (on the back of the PS) in O position.**
- **On the back of the board, on the *HVEN* (HV Enable) Lemo Connector, must be a 50Ohm Resistor. (50 Ohm Lemo Terminator).**
- **To switch between 100uA (All Dip-switch OFF) and 1mA (Dip-switch 2 = ON) maximum current, pull out the board (make sure the PS is turned off and disconnected) and change the Dip-switch #2 on the switch.**



- **The HV Module board 1526 channels share a common floating ground, which does not coincide with the crate ground, which is available as earth connector on the front panel of the board. This feature allows on detector grounding, thus avoiding loops which may increase noise level. Floating ground and earth may be coupled in several ways as shown.**

Prototype RPC



- The 30 cm X 30 cm prototype RPC is made of 2mm thick float Glass.
- Special type of PVT material is used for the insulator spacers for maintaining precise and electrically isolated gap between the two electrode plates.
- Also T-shaped frames are used for supporting the electrodes and for forming an enclosed gas volume.
- The gas plates, spacers, frames, gas inlet and outlet nozzles are assembled using special 3M Scotch-Weld 2216 or DP-190 epoxy.
- A semi-resistive coating is applied to establish electrodes for applying high voltage. A mixed graphite powder (of grade 40019) and industrial lacquer in ratio 1:8 is sprayed uniformly on glass surface using paint spray gun.
- The signal pick-up panels are made up of poly-isocyanurate foam board with reinforced poly-aluminum foil facers on both sides. While on side of this material, strips of required pitch were milled, the other side is used as the ground reference for pickup signal.
- Mylar sheet is placed between the RPC electrodes surfaces for achieving the necessary isolation between RPC electrodes and pickup strip. Special nozzles are implemented as gas inlet and outlet for the RPC.

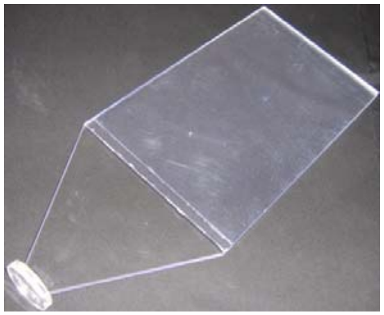
HV Cables & Connectors for Prototype RPC

- **HV Cable used for connecting the Prototype RPC to one of the channels of 1526 HV Power Supply System**
- **Positive HV cable from RPC is connected to the red connector and negative HV to black**
- **With this we establish an electric field across the two graphite coated electrodes of RPC**

Scintillator Master Paddel

(Assembled with Acrylic Light guide and Cookie)

Size of Scintillator: 20cmX35cm







- **All paddles are made up of Scintillator material of 1cm thickness, Light guide, Cookie, PMT and Housing for voltage divider. Photographs shows various assembly parts of the Scintillator Master Paddles.**
- **These Scintillator paddles are optically coupled to photomultiplier using light guide made of Acrylic material.**
- **Paddels are wrapped with two layers of papers, first with Tyveck paper (White) and then with Teddler (Black).**
- **Aluminum housing is used to assemble voltage divider. Plastic coupling is used to mount Photo Multiplier Tube connector on one side of the housing and aluminum coupling for HV & Signal Connectors**

Narrow Scintillator Finger Paddel

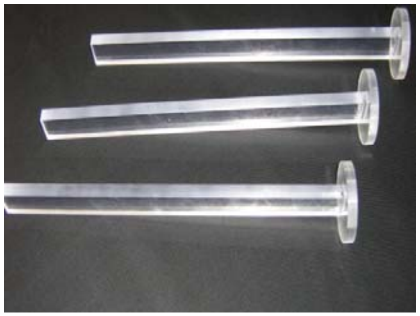







- **All paddles are made up of Scintillator material of 1cm thickness, Cookie, PMT and Housing for voltage divider. Photographs shows various assembly parts of the Narrow Scintillator Finger Paddles.**
- **These Scintillator Paddles are optically coupled to photomultiplier using cookie made of Acrylic material.**
- **Paddles are wrapped with two layers of papers, first with Tyveck paper (White) and then with Teddler (Black).**
- **Aluminum housing is used to assemble voltage divider. Plastic coupling is used to mount Photo Multiplier Tube Connector on one side of the housing and aluminum coupling for HV & Signal Connectors.**

Parts of Narrow Scintillator Finger Paddle



1: Narrow Scintillator with Cookie

2: Housing for PMT Voltage Devider

3: Plate for mounting HV & Signal Connectors

4: Platic support for PMT Connector

5: Voltage Devider Assembly

6: Photo Multiplier (PMT)

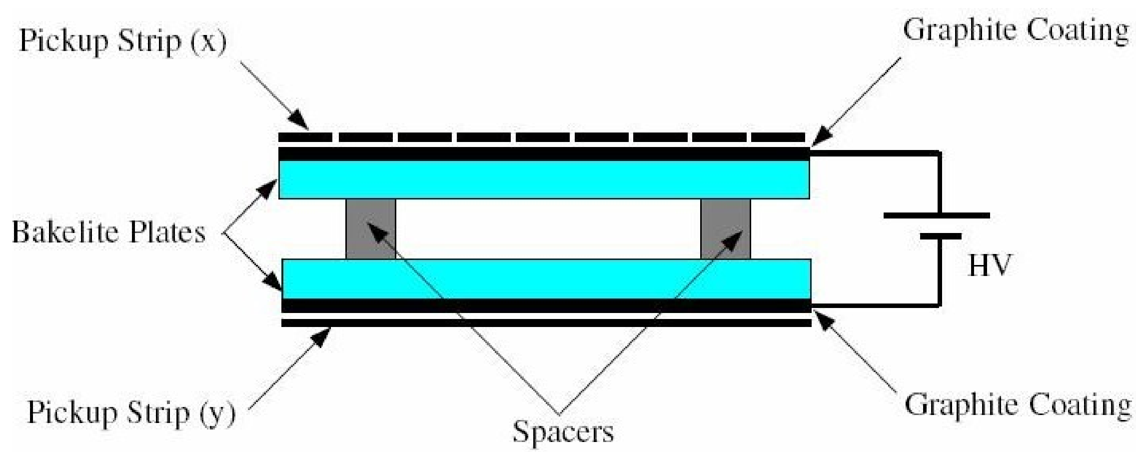
7: Assembled PMT with Voltage Devider

8: The complete Narrow Finger Paddle

Assembled Scintillator Finger Paddel

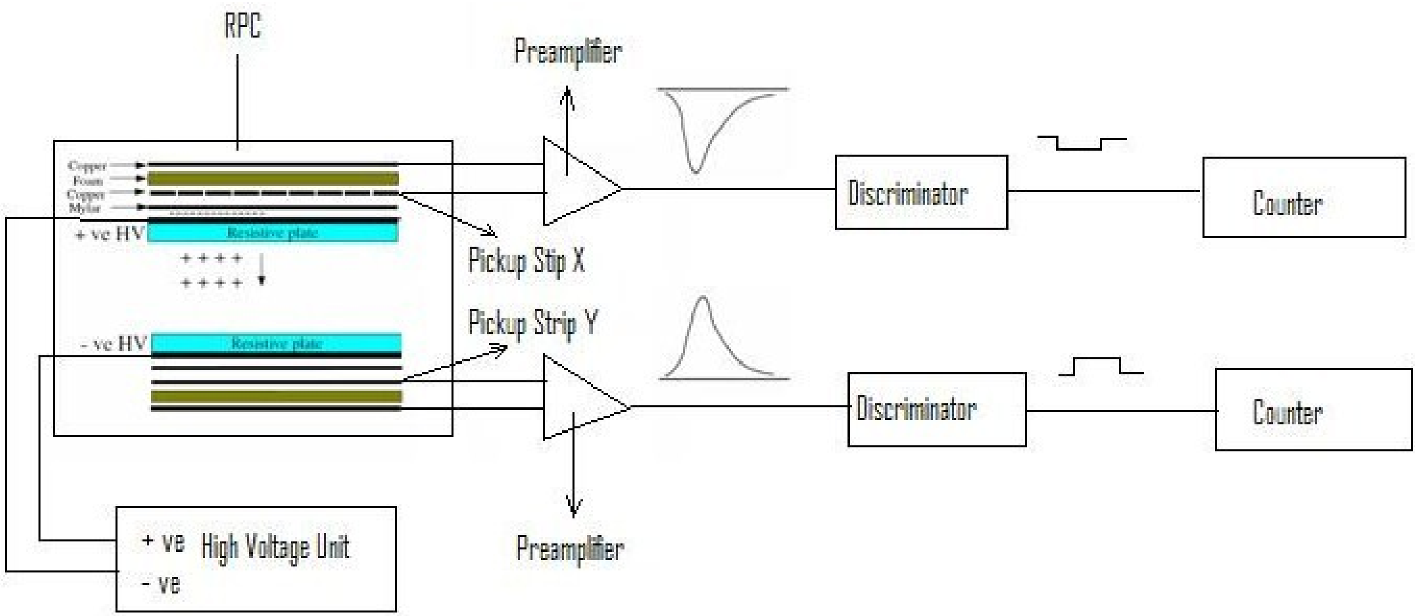
Fully Assembled Narrow Scintilator Finger Paddle coupled to Photomultiplier Tube.

Basic Design of a RPC

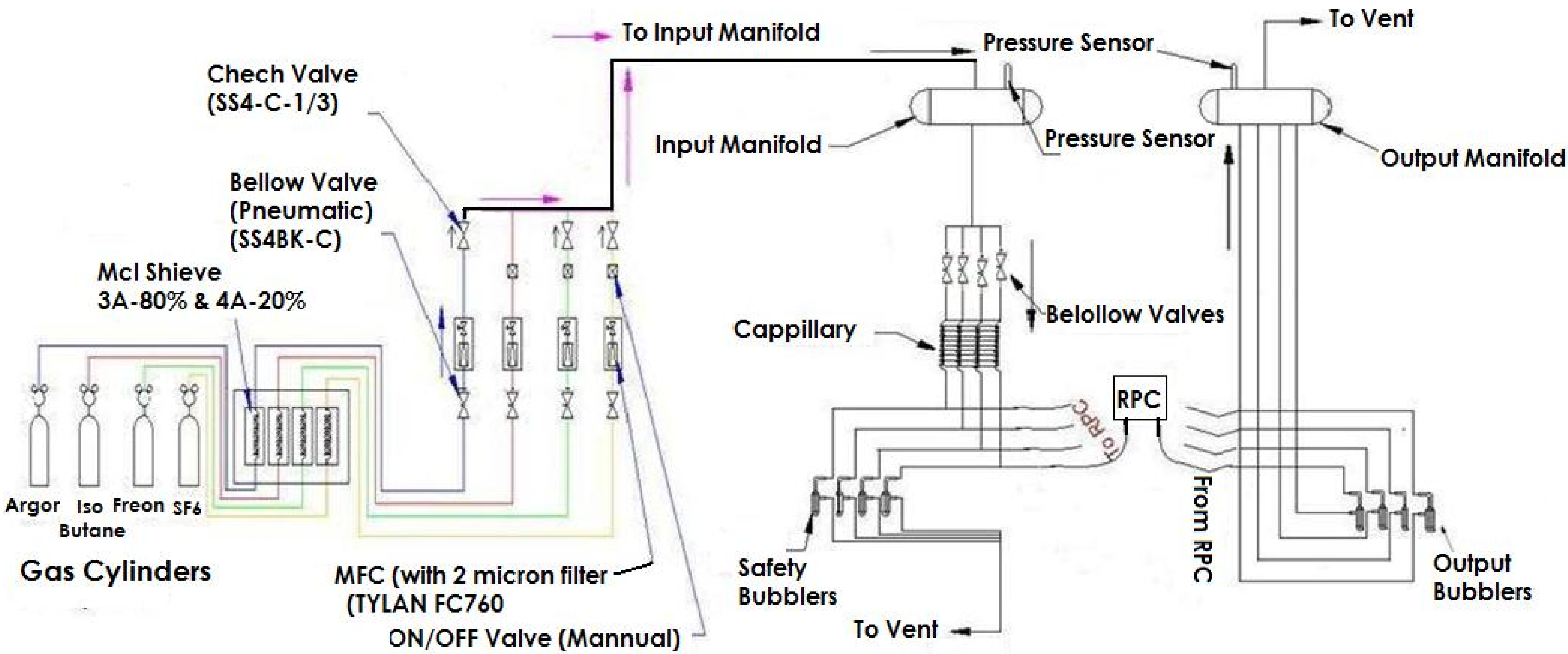


- It consists of two parallel resistive plates such as glass or Bakelite (phenol-formaldehyde polymers) about 2mm thick, separated by a gas gap whose width is maintained by spacers.
- The gas is kept at atmospheric pressure and DC voltage is applied to the plates via a layer of graphite paint on their external surface.
- The graphite electrodes are covered with insulating layer on which is etched a thin layers of copper which acts as a pickup pad to detect any movement of charge within the chamber

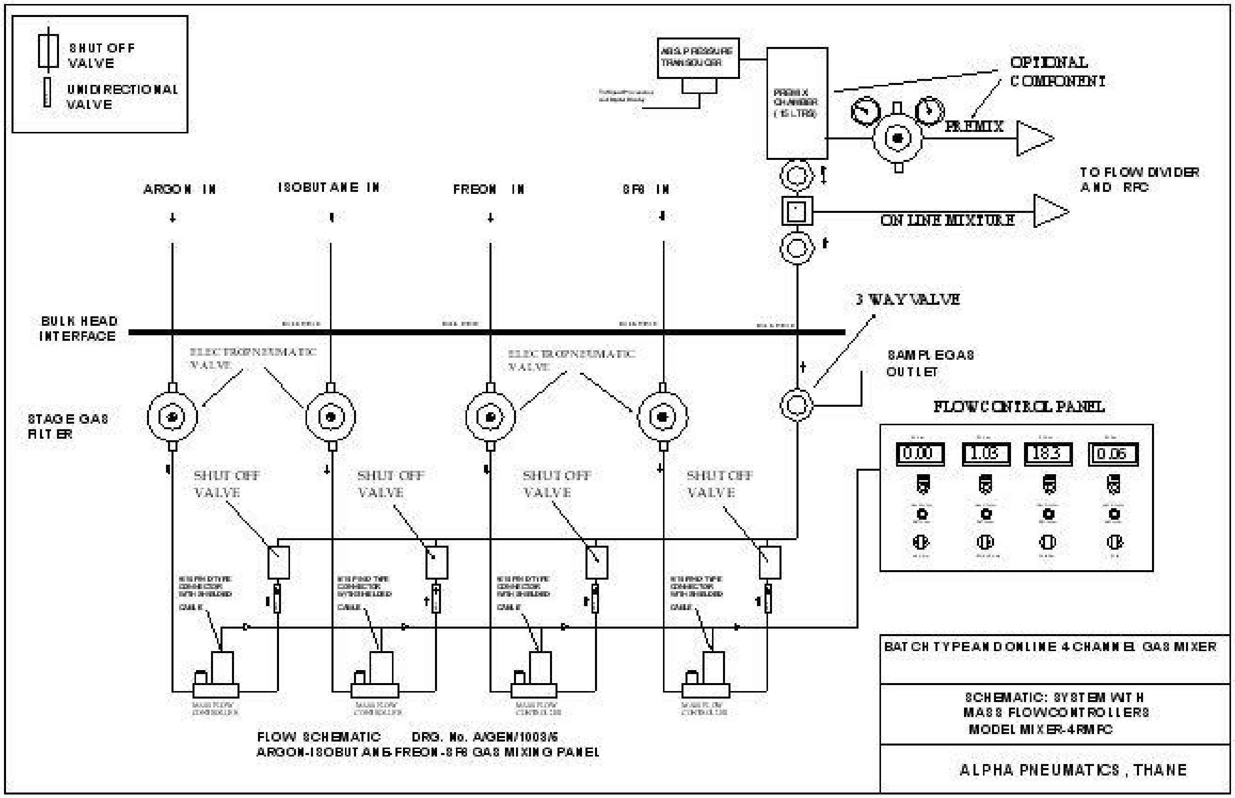
BLOCK DIAGRAM FOR RPC SIGNAL TESTING



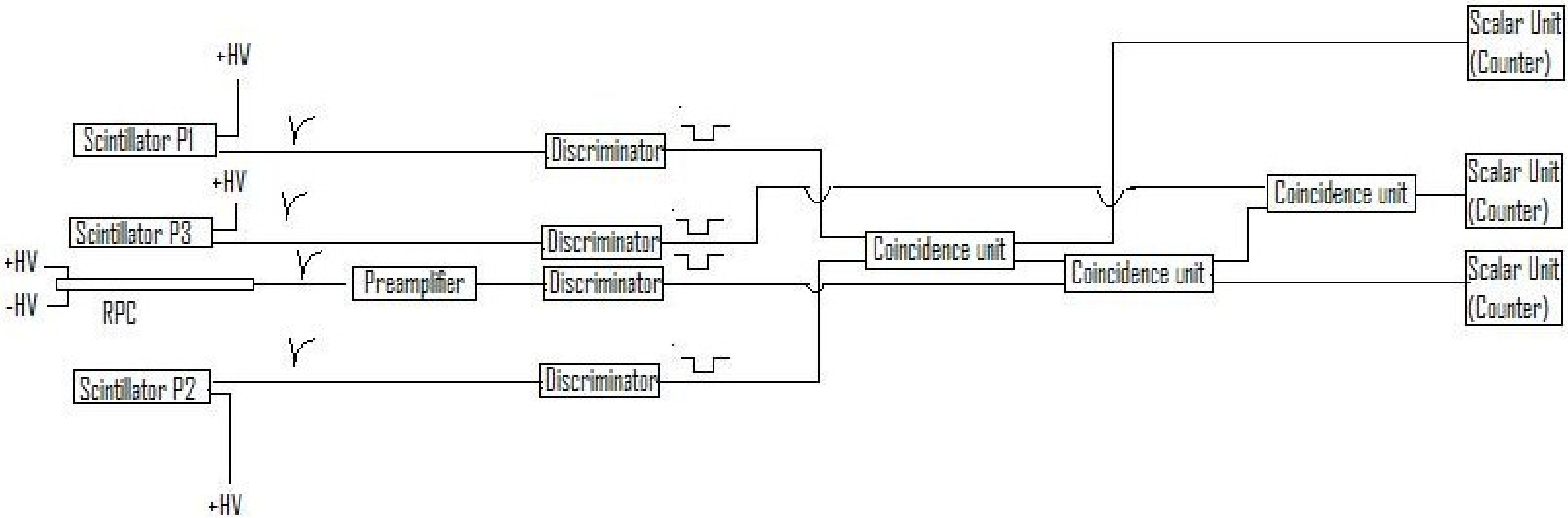
BLOCK DIAGRAM OF GAS MIXING UNIT



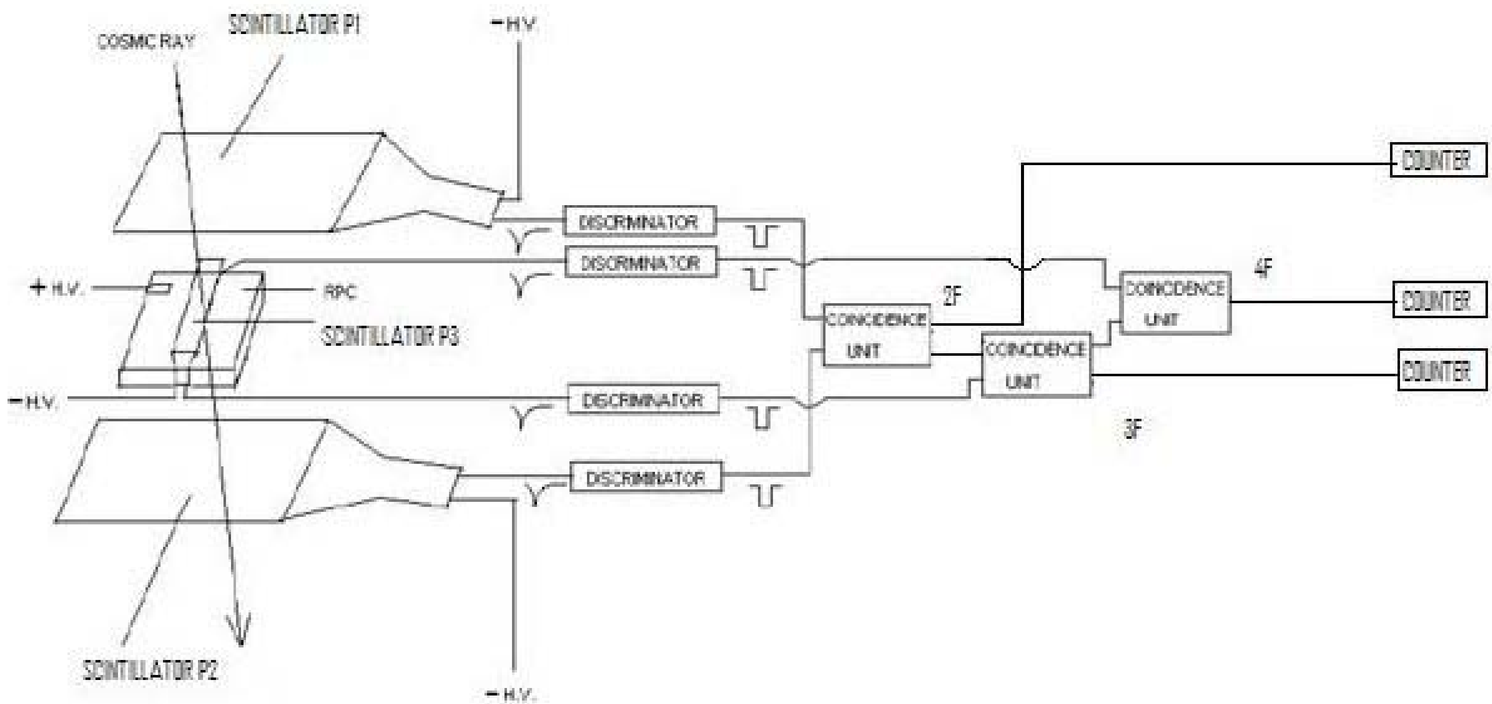
Schematic of Gas Mixing Console



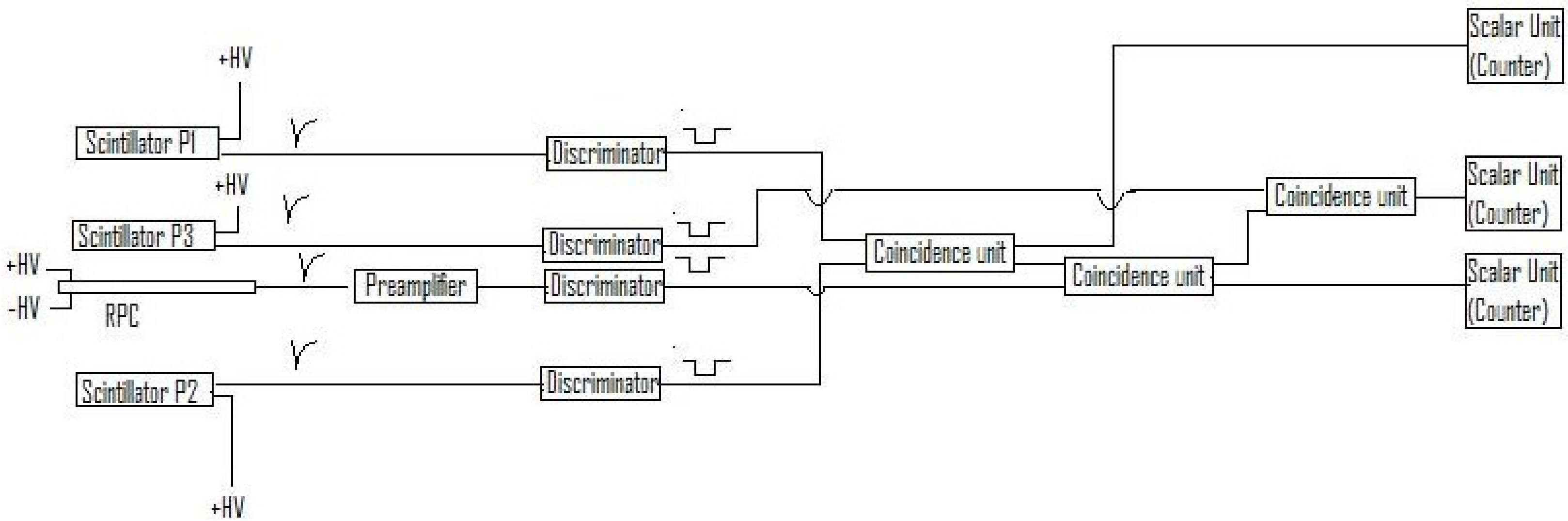
Block Diagram for Efficiency Testing of RPC



Cosmic Ray Setup for RPC Efficiency

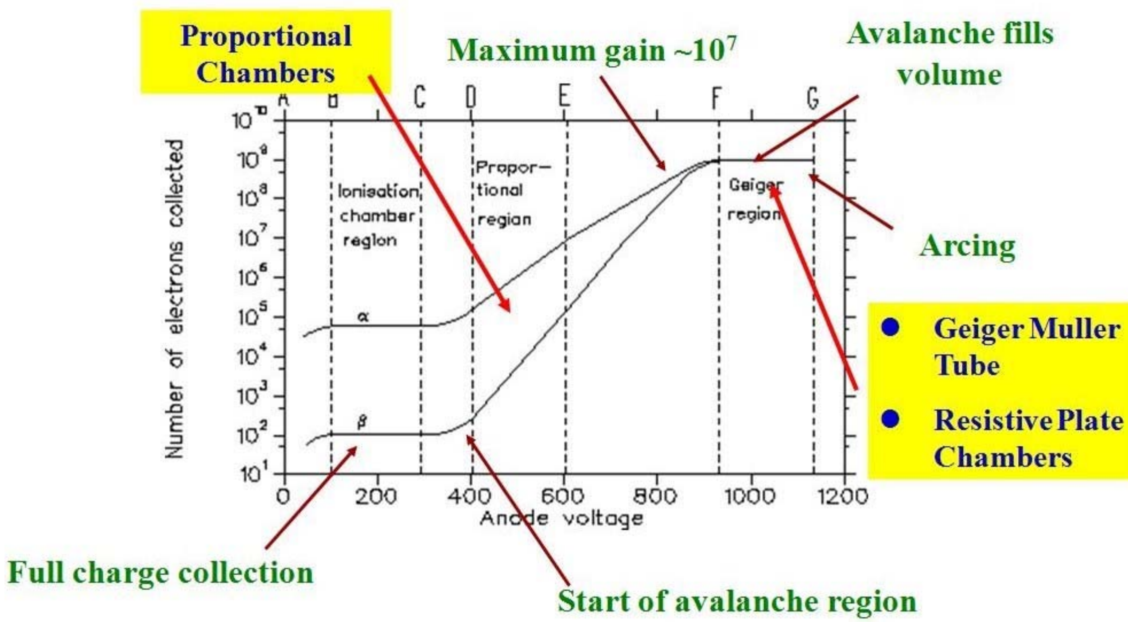


Cosmic Ray Setup for RPC Efficiency

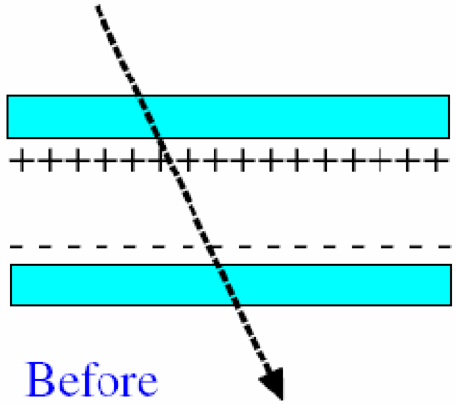


$$\text{Efficiency} = \frac{\text{RPC Count with Signal in coincidence with trigger (4F)}}{\text{Trigger count (3F)}}$$

Modes Of Operation In Gases

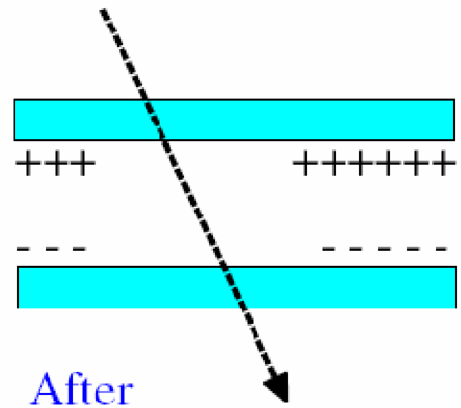


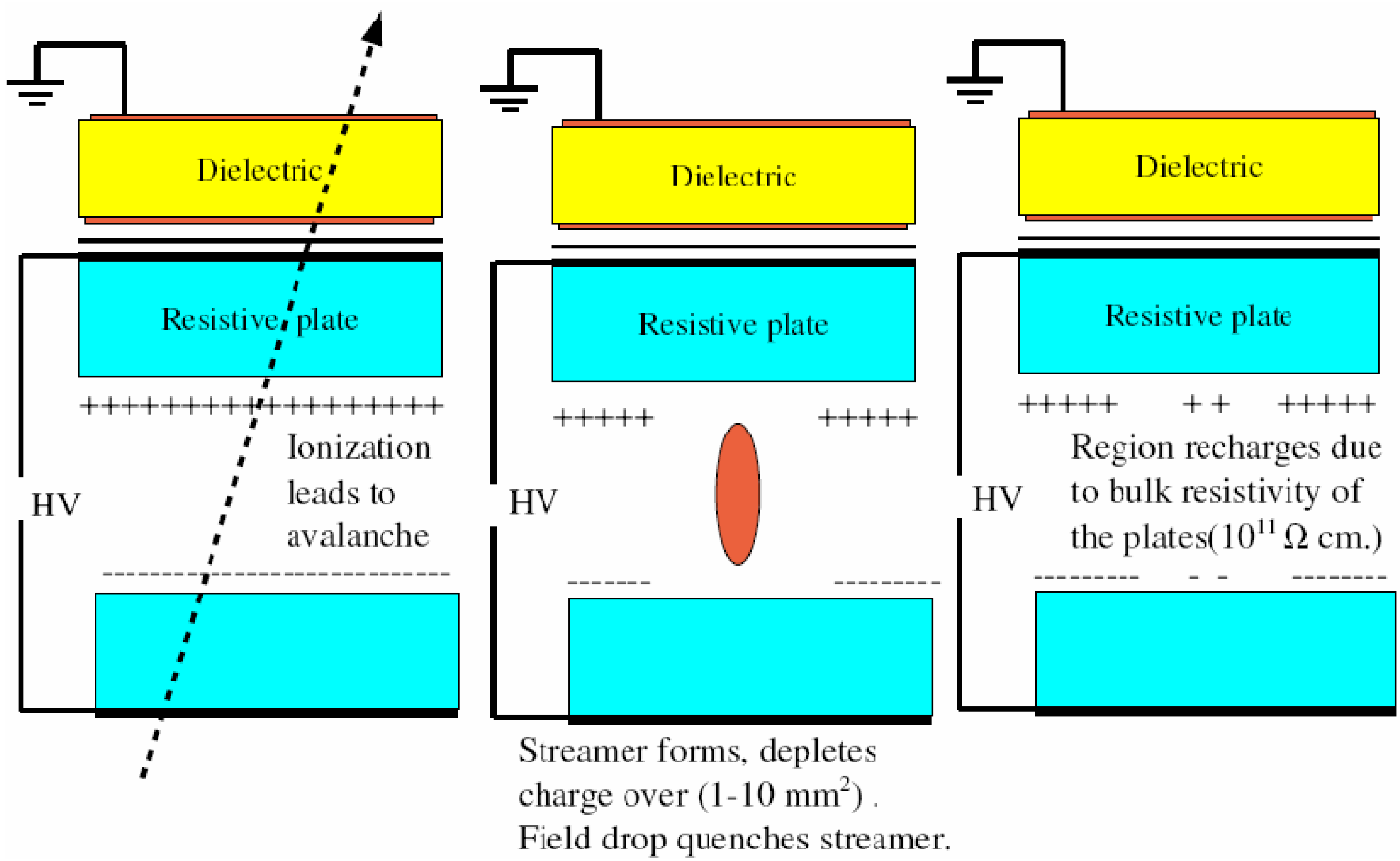
Principle of Operation



A passing charged particle induces an avalanche, which develops into a spark. The discharge is quenched when all of the locally ($r \approx 0.1\ cm^2$) available charge is consumed.

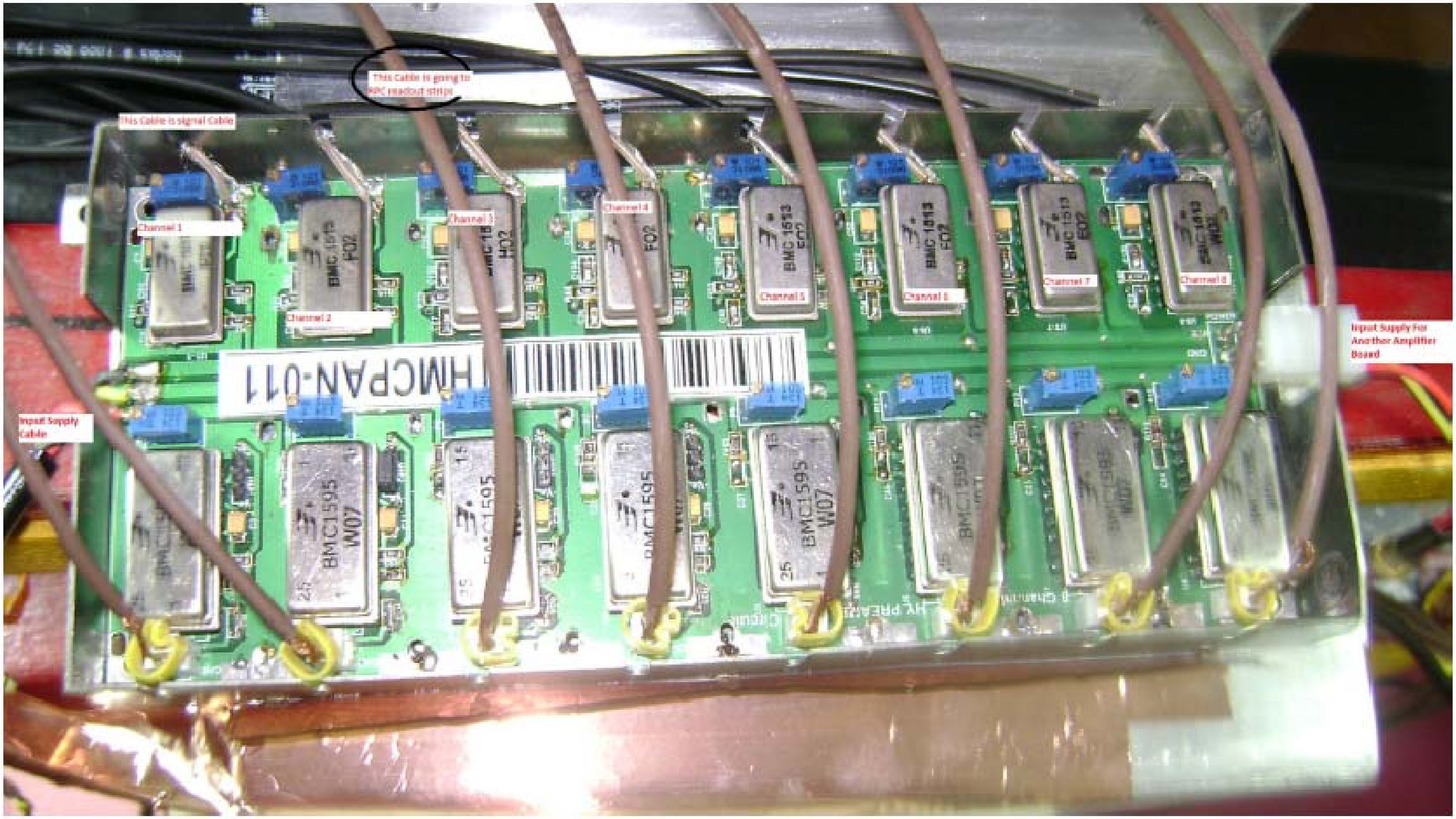
The electric field drops only around the streamer location, for a time proportional to the electrode resistivity. The discharged area recharges slowly through the high-resistivity bakelite plates.



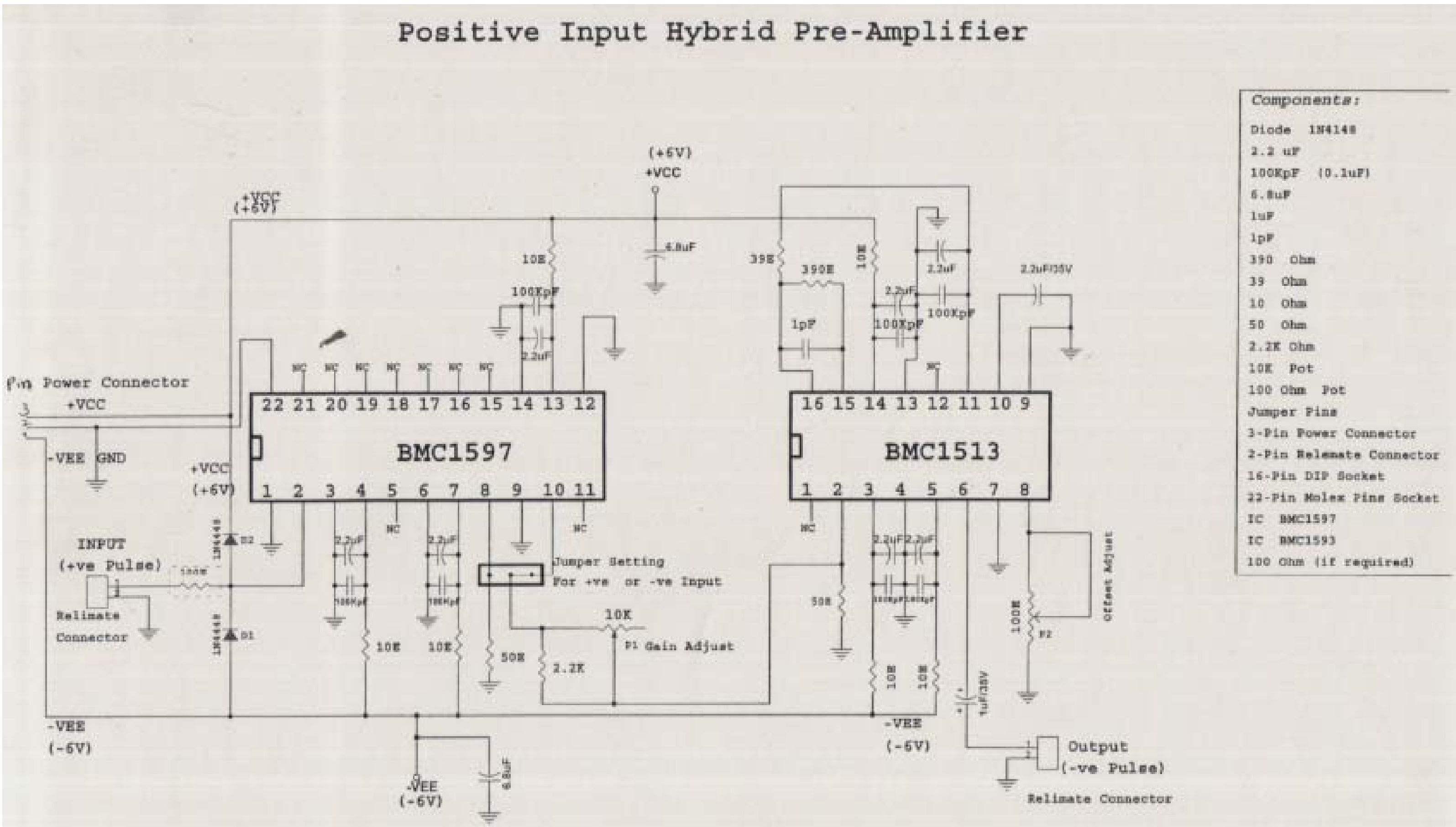


Dielectric
Resistive plate
++++++++++++++++++
Ionization leads to avalanche
HV
Dielectric
Resistive plate
+++++ +++++
HV
Streamer forms, depletes charge over (1-10 mm^2) .
Field drop quenches streamer.
Dielectric
Resistive plate
+++++ ++ +++++
Region recharges due to bulk resistivity of the plates(10^{11} Ω cm.)
HV

Preamplifier for RPC -Signal -Amplification



Preamplifier Circuit for Prototype RPC



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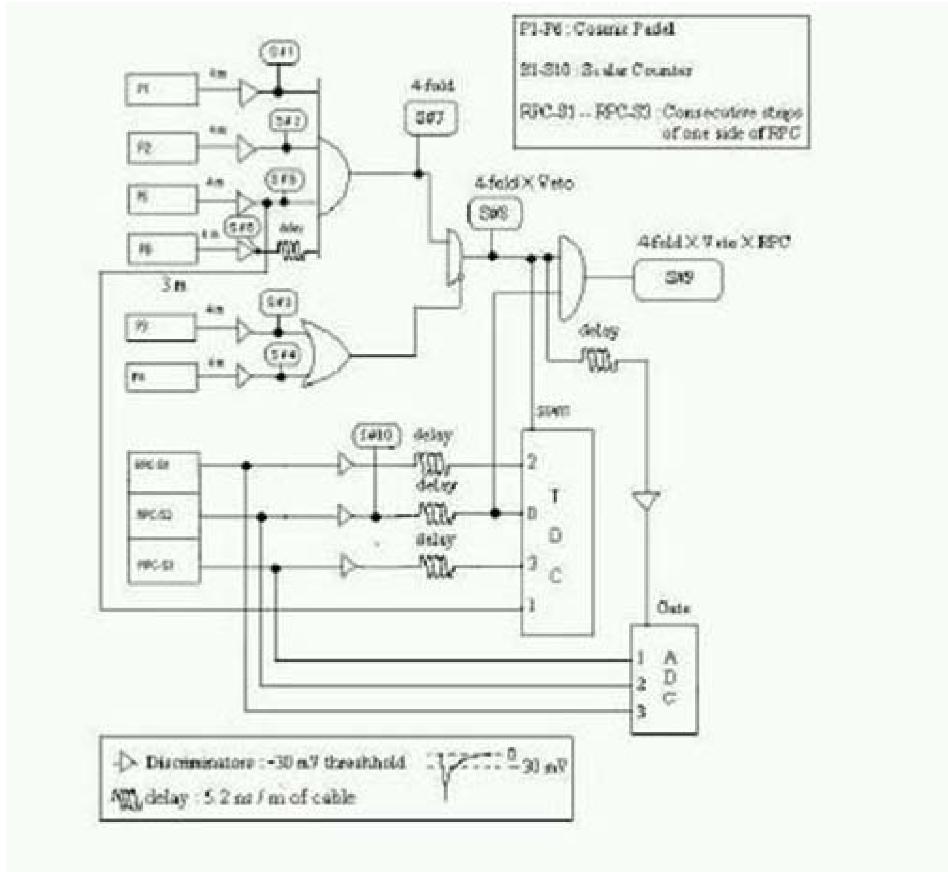
Cosmic Ray Setup & DAQ for RPC Efficiency



$$\text{Efficiency of RPC} = \frac{(4\text{-fold} \times \text{Veto} \times \text{RPC})}{(4\text{-fold} \times \text{Veto})}$$