A Dissertation On

FABRICATION OF RPC DETECTOR AND ITS FRONT-END ELECTRONICS USING NINO ASIC CHIP FOR INO-ICAL PROJECT

Submitted in the partial fulfillment of the requirements of the degree of

MASTER OF TECHNOLOGY

In

NUCLEAR SCIENCE & ENGINEERING

By

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CERTIFICATE

This is to certify that the Major project (AP-811) report entitled " **FABRICATION OF RPC DETECTOR AND ITS FRONT-END ELECTRONICS USING NINO ASIC CHIP FOR INO-ICAL PROJECT** *" is a bonafide work carried out by* **Mr. RIZWAN AHMAD** *bearing Roll No.* **2K14/NSE/22**, *a student of Delhi Technological University, in partial fulfilment of the requirements for the award of Degree in* **Master of Technology** *in* "**Nuclear Science & Engineering**". *As per declaration given by the student this work has not been submitted to any other university/institute for the award of any degree or diploma.*

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DECLARATION

I declare that this written submission represents my ideas in my own words and where others' ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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Rizwan Ahmad

Abstract

INO is an Indian-based Neutrino Observatory project which is a multi-Institutional Collaboration for setting up a magnetized Iron Calorimeter **(ICAL)** detector to detect atmospheric neutrino and study their properties. It is a world class underground laboratory for high energy experimental and nuclear physics research in India. The primary goal of INO is to study Neutrino because they are the fundamental particles having little mass but were expected to be massless in standard of particle physics. Today, determination of neutrino masses and mixing parameters is one the most challenging open problem in physics. So, ICAL detector is going to be designed to address this key open problem in a unique way.

The Resistive Plate Chamber (RPC) detectors (with a single gas gap) have been chosen as the active detector elements for the magnetized iron calorimeter (ICAL) detector at INO, due to their excellent efficiency, position (mm) & timing (ns) characteristics and suitability for large detector coverage. I have done the fabrication and preliminary characterization including efficiency, counting rate, leakage current and time resolution of RPC detectors (dimension 30 cm × 30 cm). I took two glasses of 2 mm thickness coated with a conductive layer of graphite, are used as the external electrodes. The pickup panel consists of honeycomb panels with copper strips of width 2 cm. The gas gaps are sealed by gluing side spacers between the outermost electrodes. The RPCs are being tested in avalanche mode with a gas mixture of Freon (R134a-95.15%), Isobutane (C_4H_{10}-4.51%), SF_6(0.34%) with a flow rate of 5 SCCM. Three scintillator paddles of width 2 cm in coincidence mode has been used for the trigger. The signals from the pickup strips are amplified with the NINO ASIC chip and then taken with coincidence with the trigger. An ultra-fast front-end preamplifier-discriminator chip NINO has been developed for use in the ALICE Time-Of-Flight detector. The chip has 8 channels and each channel is designed with an amplifier with less than 1 ns peaking time, a discriminator with a minimum detection threshold of 10fC and an output stage. The output pulse has minimum time jitter (less than 25ps) on the front edge, and the pulse width is dependent of the input signal charge. Each channel in NINO chip takes the differential signal from the pickup strips as input, and amplifies them in a four stage cascade amplifier. The study on the detector performance with varying HV and at different concentrations of the gas mixture components will be presented in detail.

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ABBREVIATIONS

- **INO-** Indian-based Neutrino Observatory
- **ICAL-** Iron Calorimeter
- **R&D-** Research and Development
- **RPC**- Resistive Plate Chamber
- **DC-** Direct Current
- **MFC-** Mass Flow Controller
- **PC**- Personnel Computer
- **NIM-** Numerical Instrument Method
- **HEP-** High Energy Physics
- **TDC-** Time to Digital Converter
- **DAQ-** Data Acquisition
- **ADC-** Analog to Digital Converter
- **DAC**- Digital to Analog Converter
- **CERN-** European Organization for Nuclear Research
- **ALICE-** A Large Ion Collider Experiment
- **TOF-** Time-of-Flight
- **MRPC-** Multigap Resistive Plate Chamber
- **ASIC-** Application Specific Integrated Circuit
- **PID-** Particle Identification
- **CMOS-** Complementary metal-oxide Semiconductor
- **LVDS-** Low Voltage Differential Signal
- **NMOS**- N-type metal-oxide Semiconductor
- **DSO-** Digital Storage Oscilloscope
- **Op-Amp**- Operational Amplifier
- **TTL**- Transistor-Transistor Logic
- **ECL-** Emitter Coupled Logic
- **IC's-** Integrated Circuits

CHAPTER 1

INTRODUCTION

INO is an Indian-based Neutrino Observatory project which is a multi-Institutional Collaboration for setting up a magnetized **ICAL** detector to detect atmospheric neutrino and study their properties. It is a world-class underground laboratory for high energy experimental and nuclear physics research in India.

1.1 INO Project Includes:

- Design and development of an ICAL detector to study Neutrinos, which consist of 50 kt of magnetized iron plates to produce very high magnetic field as 1.5 Tesla. These plates are arranged in stacks with a gap in between where Resistive Plate Chamber (RPCs) would be inserted as an active detector to detect Muon coming from neutrino interaction with ICAL.
- Set up a High Energy Physics Experiment Centre at National level.

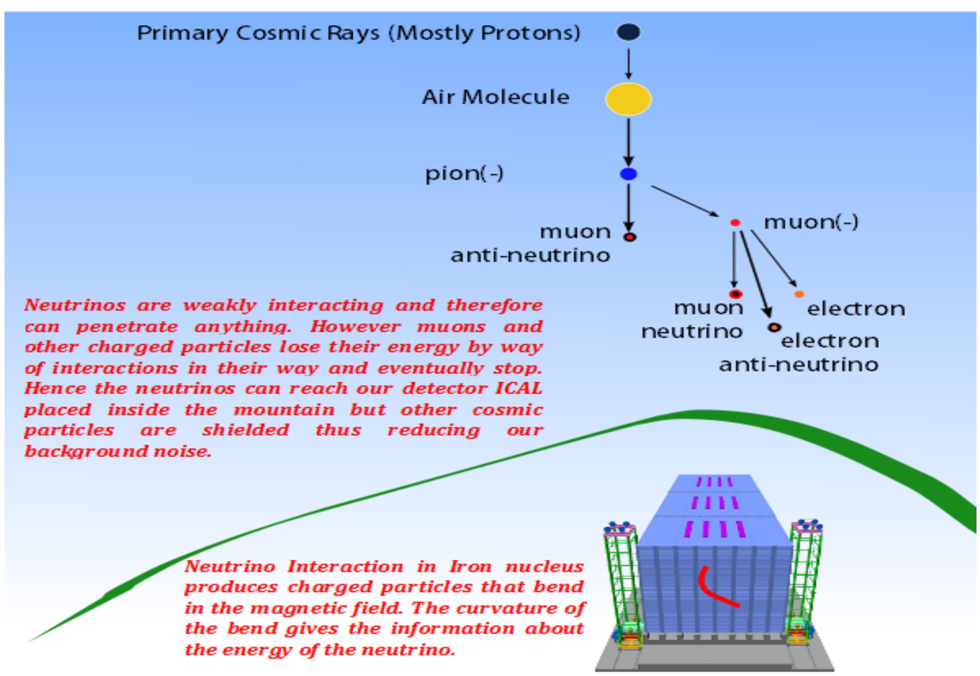


Fig 1.1 ICAL Detector for INO

The primary goal of INO is to study neutrino because they are the fundamental particles having little mass but were expected to be massless in standard of particle physics. Today, determination of neutrino masses and mixing parameters is one the most challenging open problem in physics. So, ICAL detector is going to be designed to address this open key problem in a unique way.

1.1.1 This Project can achieve many physics goal such as:

- More precise determination of neutrino Oscillation and their mixing parameters using Atmospheric neutrinos.
- Study of matter effects.
- Study of charge conjugation and parity violation in the lepton family as well as possible charge conjugation, parity, time reversal violation studies.
- Study of possible identification of very-high-energy neutrinos and multi-muon events.

Therefore, the detector R&D, magnet design, electronics, and control, as well as High Energy Physics Studies and Numerical Simulation, are being done in a house.

1.1.2 ICAL detector:

The proposed Iron Calorimeter is a large modular structure having a total size of 48m×16m×12m. It consists of a stack of 151 horizontal layers of ~6 cm thick magnetized iron plates which will produce above ~1.5 Tesla magnetic field, interleaved with 2.5cm gaps to house the RPCs layers.

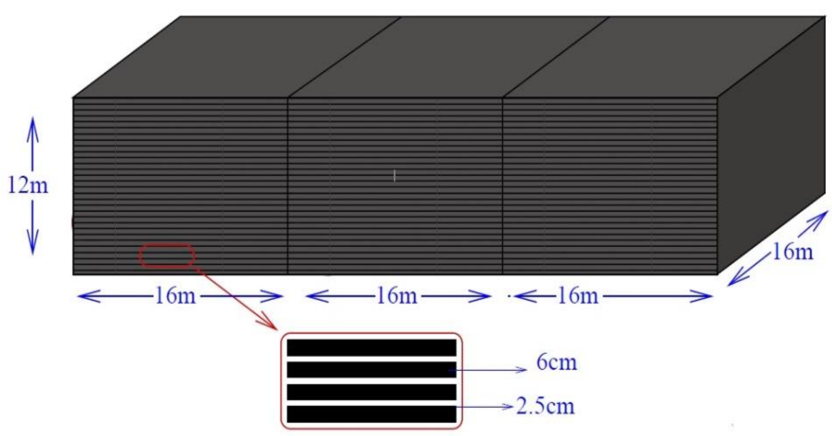


Fig 1.2 Schematic of ICAL Detector

1.1.3 RPC detector:

Resistive Plate Chambers is going to be used as the active detector element for the INO-ICAL experiment in the tracking of iron calorimeter which can simultaneously measure the energy as well as the direction of the charged particle. The detector working concepts are based on gaseous ionization produced by charged particles through the active area of the detector, under a strong uniform electric field applied by resistive electrodes. RPCs are preferred to scintillators because of several reasons:

- Good position resolution and detection efficiency (>90%).
- Minimal cost.
- Easy to Fabricate and simple read-out electronics.
- Show better time resolution ($\sim 1ns$) and long-term stability.

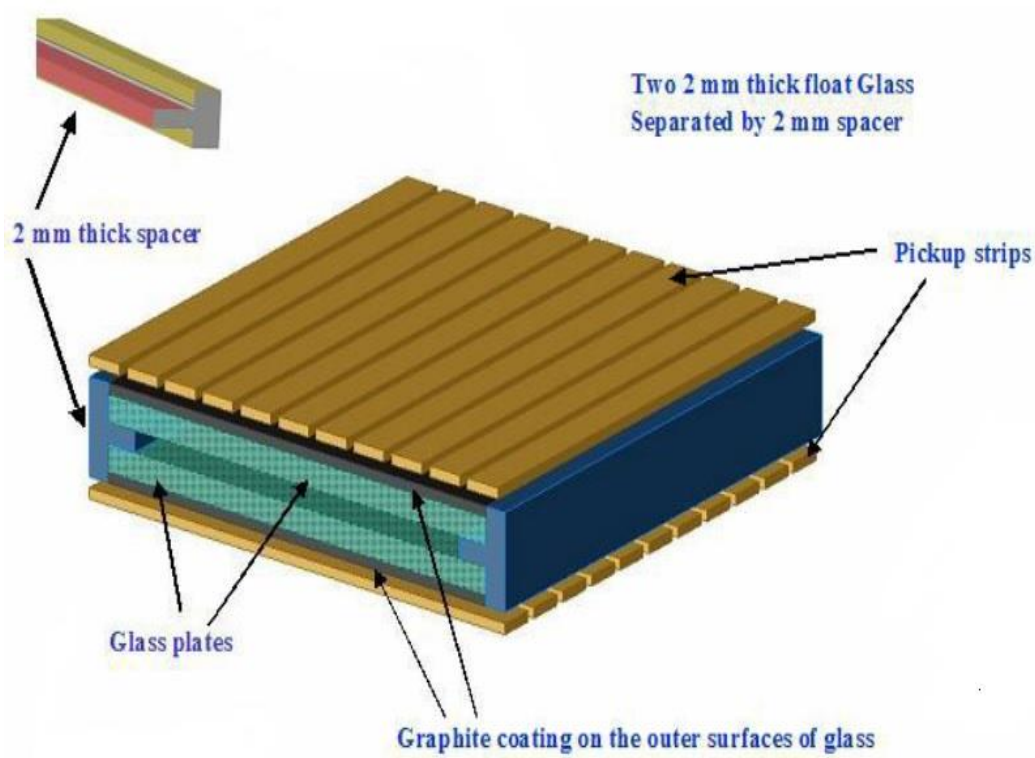


Fig 1.3 Prototype of RPC Detector

1.1.4 Specification of the ICAL and RPCs detector in INO:

Table 1.1

ICAL	
Number of Modules	3
Dimension of Module	16m×12m×12m
Dimension of Detector	48m×16m×12m
Number of Layers	151
Thickness of Iron Plate	~6cm
Gap between RPCs trays	2.5
Setup Magnetic Field	~1.5 Tesla
RPCs	
Unit Dimension of RPC	2m×2m
Width of Readout strip	3
No. of RPC units/Layer/Road	8
No. of Roads/Module/Layer	8
No. of RPC units/Layer	192
Total No. of RPCs Units	~2900
No. of Readout Channel	3.6×10^{6}

1.2 Neutrino Physics:

Neutrinos are elementary Particles belonging to lepton family. They are found in three flavors, associated with an electron, muon, and tau. According to Standard Model of particle physics neutrinos are massless, but recent discoveries indicate that these are a neutral fundamental particle, have finite but small mass which is unknown. So the determination of neutron oscillation and their mixing parameters is one of the open challenging problems today.

1.2.1 Brief History:

- Firstly Wolfgang Pauli postulated the neutrino in December 1930.
- In 1933 Francis Perrin and Enrico Fermi concluded that neutrino is a massless particle.
- In 1946 Neutrinos could be detected through the reaction by Pontecorvo as below:

$$\bar{\nu}_e + {}^{37}_{17}\mathrm{Cl} \rightarrow e^- + {}^{37}_{18}\mathrm{Ar}$$

- In 1957 Clyde L.Cowan discovered the electron antineutrino via inverseβ-decay weak interaction process and got Nobel Prize.

$$\bar{\nu}_e + p \rightarrow e^+ + n$$

- In 1957 Neutrino oscillations were discovered by Bruno Pontecorvo.
- In 1962 The Muon Neutrino was detected by M. Schwartz, L.M Lederman, and J. Steinberger and they got Nobel Prize.
- In July 2000 the Tau Neutrino was observed in Fermilab.

In Neutrino Physics many exciting discoveries have been observed in last few decades. One of them Neutron Oscillation is most important discovery which proves that neutrino is not massless since it requires the neutrino Eigenstates to have different masses.

1.2.2 Sources of Neutrinos:

Neutrinos are the second most abundant particle after Photon and play a very important role in many objects and events in astrophysics and cosmology.

- Cosmological Neutrinos
- Supernovae
- Natural Radioactivity Neutrinos
- Astrophysical Neutrinos
- Reactors and Accelerators Neutrinos
- Atmospheric Neutrinos (are produced by the collision of cosmic rays with the earth's upper atmosphere)

$$\pi \rightarrow \mu\bar{\nu}_\mu; \qquad \mu \rightarrow e\bar{\nu}_e\nu_\mu \, .$$

1.2.3 Detectors for Neutrino:

As we know that neutrino is changeless and weakly interacting fundamental particle so it requires some special type of detector. The event rates for atmospheric neutrino are the order of ~0.5 events and to have appreciable rates, one needs very massive detectors.Hence detector for atmospheric neutrino has been constructed using essentially two techniques as below:

- Iron Calorimeter detectors with a segmentation of order 1cm.
- Water Cherenkov Detectors

1.3 Muon Physics:

Carl. D Andersen discovered Muon in 1936, during the study of cosmic radiation but J. C Street and E. C. Stevenson's cloud chamber experiment confirmed the existence of muon in 1937. It is an elementary charged particle belonging to lepton family having an electric charge of -1e and a spin of the half with a much greater mass. It is an unstable subatomic particle with a mean lifetime of 2.2μs. Hence it interacts with the matter via the weak and electromagnetic forces. Its decay always produces three particles which must contain an electron of the same charge as the muon and two neutrinos of different types.

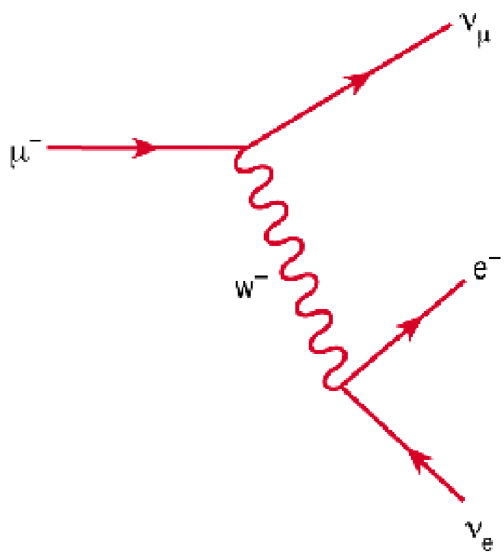


Fig 1.4 Muon Interactions

1.3.1 Sources of Muon:

The primary cosmic rays collide with the nuclei of air molecules and produce a shower of particles that includes neutron, proton, pions, positron, photons, electrons and kaons. These secondary particles then undergo nuclear and electromagnetic interaction to produce additional particles in a cascading process, and some of these will interact via the strong forces with air molecule nuclei, but others will spontaneously decay via the weak forces into a muon plus a neutrino or antineutrino.

$$\pi^{+} \rightarrow \mu^{+} v_{\mu}$$

$$\pi^{-} \rightarrow \mu^{-} \bar{v}_{\mu}$$

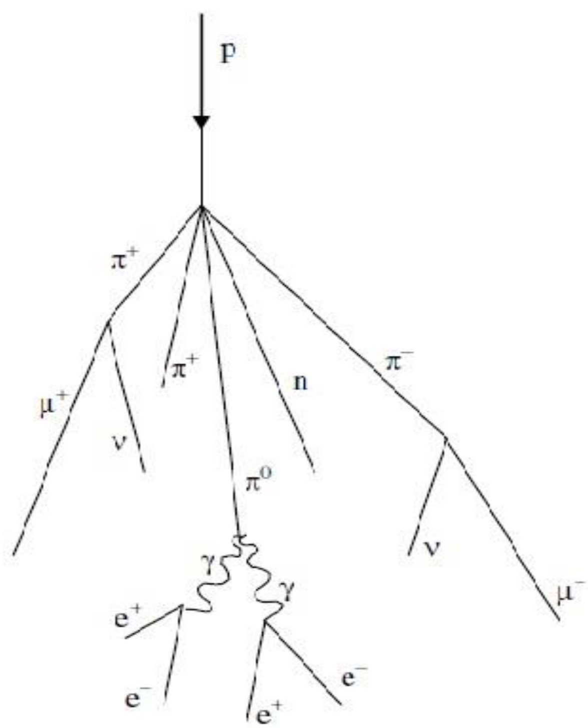


Fig 1.5 Muon Productions

CHAPTER 2

RESISTIVE PLATE CHAMBER AND ITS CHARACTERISTICS

2.1 Principle Operation of RPC:

RPC is a gaseous-based detector which is composed of two parallel electrodes with float glass with a volume resistivity of about $10^9 - 10^{12}\Omega$-cm. These two electrodes are 2mm thick and are mounted 2mm apart using highly insulated spacers (Polycarbonate). A suitable gas mixture (Freon, Isobutane and SF_6) is flown at the atmospheric pressure through the gap with an appropriate electric field applied across the glass electrodes through a graphite coating on their outer surfaces to ensure uniform electric field. Whenever a charged particle traversing the gap, initiates an Avalanche/Streamer in the gas volume due to which a local discharge produces. This discharge is limited to a very small area of about 0.1cm^2 due to the high resistivity of the glass electrodes. This discharge induces an electrical signal on external pickup strips (orthogonal to each other) on both sides, which can be used to readout electronics for record the location and time of ionization.

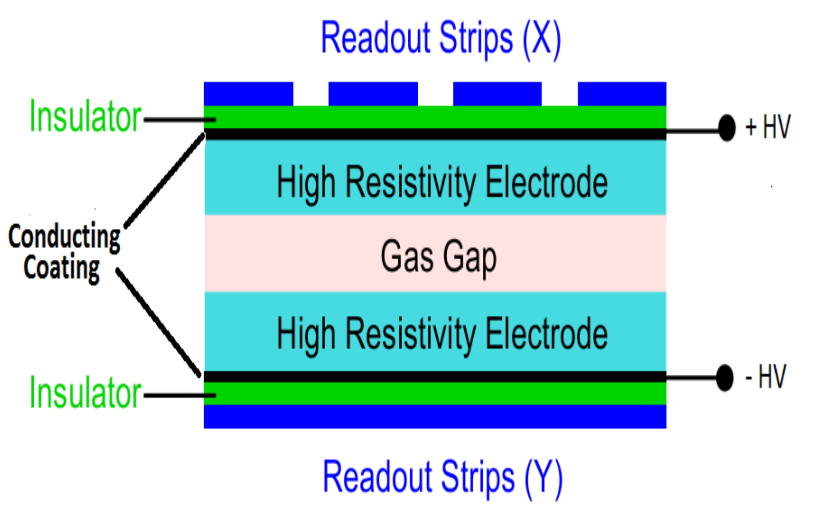


Fig 2.1 RPC Electrodes

2.2 Mode Operation of RPC:

RPC can be operated in two different modes depending on the voltage operation and gas composition used.

- **Avalanche Mode:** In this, the primary ions produced by the charged particle under the electric field which produces secondary ionizations due to collision with the gas molecules. The ionized particle produces an electric field which is opposed by the applied field and after some time the multiplication process stops. Then, the charges drift towards the electrodes are collected. This mode operates at the lower voltage, and the pulse has amplitude of the order of few mV. The gas composition in this mode is Freon (R134a): Isobutene: SF_6 as 95.15:4.51:0.34(in %).

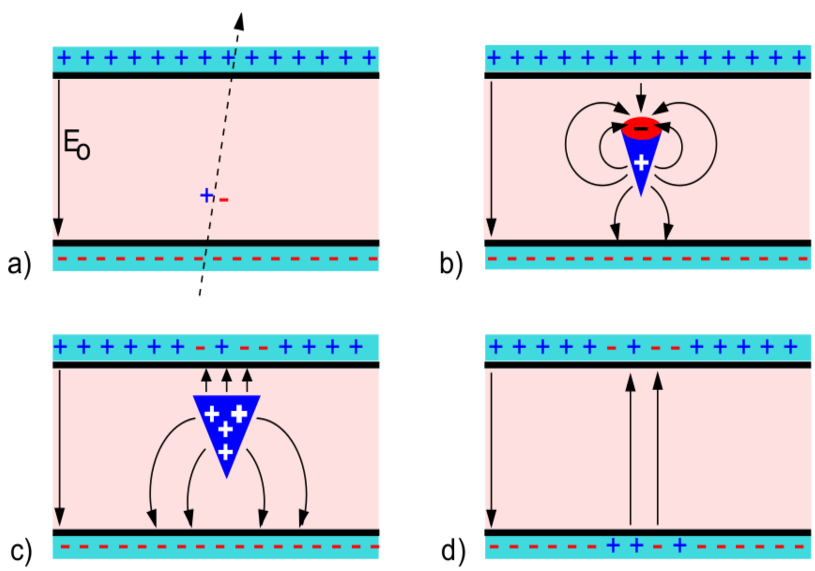


Fig 2.2 Avalanche Mode

- **Streamer Mode:** In this, the secondary ionization persists until there is a breakdown of the gas and continuous discharge takes place. This mode is operated at high voltages, and the pulse has an amplitude of the order of 100-200mV. In this mode, gas composition is used Freon (R134a): Isobutane: SF_6 as 62:8:30 (in %).

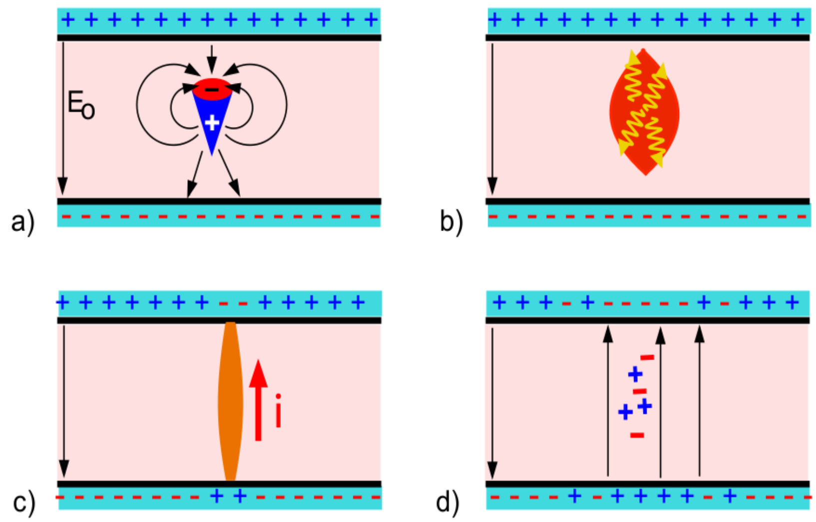


Fig 2.3 Streamer Mode

2.3 Circuit Diagram for RPC:

In the low voltage region, spacer resistance comes into play while in high voltage region the glass resistance dominates.

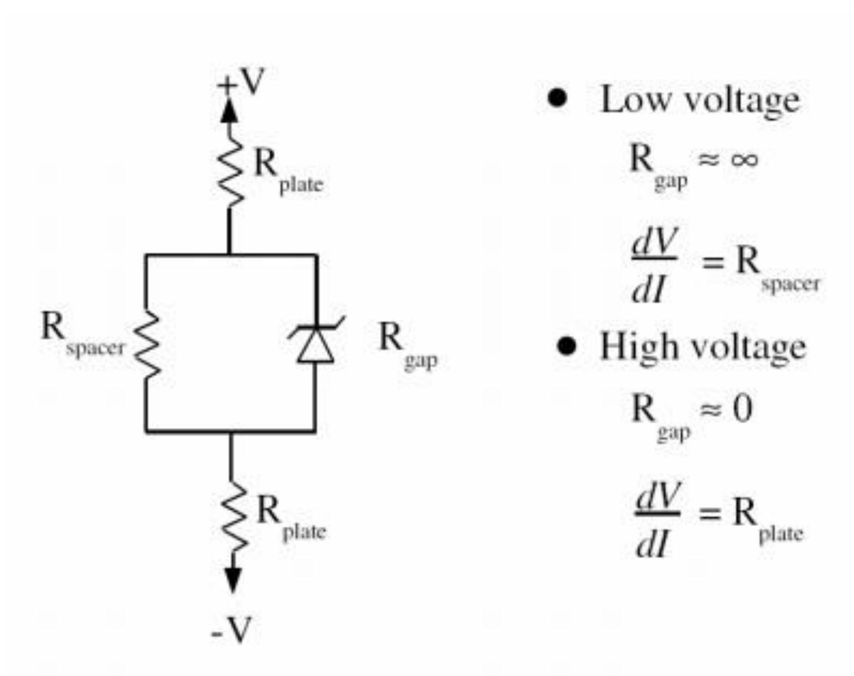


Fig 2.4 Electrical Representation of RPC

2.4 Fabrication of 30cm×30cm RPC:

I have developed 30cm×30cm RPC with resistivity electrodes plates made of float Saint Gobain glass having resistivity of the order of $10^{12}\Omega$cm and thickness of 2mm. There are different steps have been taken as below:

- **Glass Cutting and Cleaning:** Take two saints Gobain glass which is cut by diamond cutter to the appropriate size with four corner edges making correct 45^0 angle. The glasses are thoroughly cleaned with alcohol Labolene solution and then leave for 5 minutes before washing. Then, it is wiped with tissue papers and kept for drying. After that, the corner spacers connected to the gas nozzle and cleaned with alcohol. Then glass edges are taped over 2cm with masking tape to prevent the conductive coating painted right up to the edge of the glass.

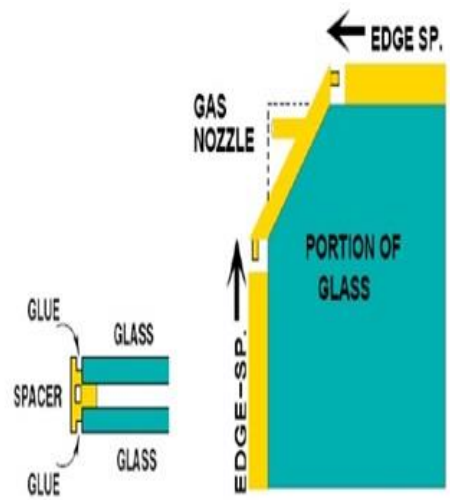


Fig 2.5 Glass cutting

Fig 2.6 Corner cutting

Fig 2.7 Taping **Fig 2.8** Cleaning

- **Conductive Coating:** Uniform graphite coating is done one of the sides of two glasses using a spray gun to increase the conductivity of the glass. This is done to make two electrodes as anode and cathode for the application of high voltage to the RPC for their operation.

- **Gluing of Glasses:** The glue which I used is 3M scotch-weld epoxy adhesive in the duo-pack cartridge. Taking both glasses, keeping overlap to each other with maintaining proper 2mm gap between them and put on a plastic sheet and are glued in a square array. To put a uniform weight throughout and then the whole set up is wrapped with a plastic sheet. Slowly sucked the air inside plastic sheet to create a partial vacuum and left complete set up for one day.

- **Gas Leak Test:** This test is done due to make sure that, no gas leakage occurs at the glued joints. This is performed by flowing Freon gas at atmospheric pressure and checked gas leakage. In this test, I use U-shaped manometer tube, filled with water. One of the diagonal sides of RPC sealed and other kept such that, from one of the sides continues the flow of Freon gas (R134A) passed. The other side is connected to the manometer with

Tygon tube. Then take a reading of the manometer, when the pressure of the gas releases along with stop watch to note down time. Hence this experiment is performed for about one and half hour time.

- **High Voltage Cables:** Now RPC is wired to apply high voltage and picking up the signals as a charged particles passing through it. This is done to the graphite layer by sticking copper tape and lead to it with proper soldering to make positive voltage is applied to one side and equal and negative voltage to other side using a bi-polar high voltage DC supply with a common ground.

- **Signals Pickup Strips:** Now RPC is sandwiched between two honeycomb pickup panels which are placed orthogonal to each other and then packed in an aluminum case. The pickup panel contains 10-12 copper strips foil on one side of a layer of 5mm of foam and aluminum on another side. The width of each strip is 2cm with a gap of 0.2cm in between two adjacent strips. Each strip is terminated with a 50Ω impedance to match the pre-amplifier impedance characteristic. Then a layer of Mylar sheet of thickness 100µm is placed between the graphite layer and pickup panel to provide insulation.

Fig 2.9 Connection of Pickup Strips

2.5 Gas Flow System:

The requirement of filling gasses for RPC is governed by several factors as below:

- Low working voltage
- High gain
- Good proportionality
- High rate capability

As we know that, the primarily function of RPC depends on the ionizing gas within the detector volume. The properties of gasses in mixture decide the working mode of RPC, namely Streamer mode or Avalanche mode. Therefore in both modes of operation, the proper and efficient functioning of the detector depends on the appropriate and accurate mixing of gasses. So here for prototype detector, I used and MFC based on-line gas mixing unit which can take four gasses as input and distribute the mixture to 16 different output channels.Here the RPC is operating in avalanche mode in which three gasses are used as composition below:

Table 2.1

Gas Constituents	Percentage
Freon	95.15
Isobutane	4.51
SF_6	0.34

- **Freon (R134a):** This is an eco-friendly electronegative gas with high enough primary ionization production but with a small free path for electron capture. It absorbs the charged particles to avoid any further avalanche production.

- **Isobutane:** This is an organic gas having higher absorption probability for an ultra violet photon which produced in electron-ion recombination. Means, it limits the formation of secondary avalanche from primary ionization.

- **SF_6(Sulphur-hexafluride):** This acts as quenching gas and is used to trap the excess energetic electrons from the gas volume before they can initiate a new avalanche.

2.5.1 Overview of Gas System:

Broadly, the gas mixing system comprises the following components as below:

- Gas purifier column
- Gas mixing unit
- Distribution panel
- Safety and isolation bubbles
- Exhaust manifold
- Mass flow controllers
- Control and monitoring
- Calibration of MFCs

Fig 2.10 Front Panel of Gas Mixing Unit

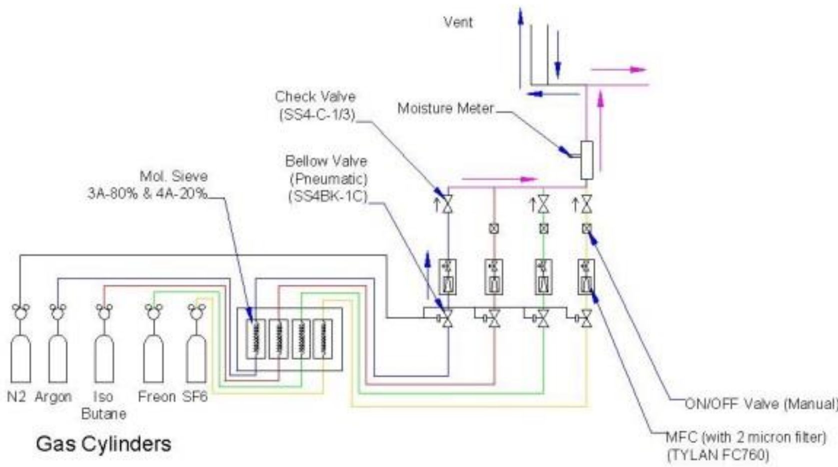


Fig 2.11 Schematic of Gas Mixing Unit

- **Purifier column:** These are made of stainless steel and having two built-in heaters of 500 watts each, connected in series. Each column is charged with 300 grams of molecular sieve adsorbents of type $3A^0$ (80%) and type $4A^0$ (20%).Due to long transit time and storage, moisture and other impurities may have diffused through valves and other accessories, so it needs to purify the gases being used.

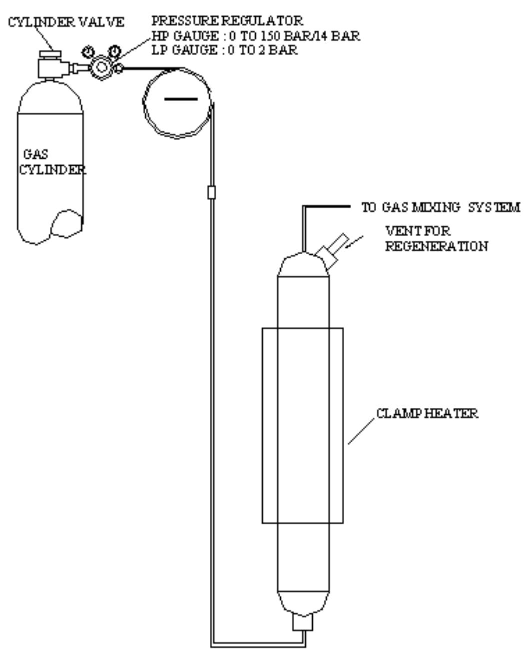


Fig 2.11 Purifier Column

- **Mixing Unit:** The output from purifiers enters the mixing unit which contains mass flow controller, mixing line, pneumatic valves, bellow sealed valves, probe for moisture measurement, check valves and nitrogen gas. A microprocessor based capacitive type commercial sensor with dew point display is used to measure the moisture content in the mixed gas.

- **Mass flow controller:** MFCs are used to measure and control the flow of gasses. These are designed and calibrated to control a specific type of gas a particular range of flow rates.

Fig 2.12 Mass Flow Controller

➢ **Distribution system:** It is a flow resistor-based distribution system which consists of a manifold and pressure transducer. Manifold mixes the gas mixture further in a small cylinder which provides high cross-section and residence time and the pressure transducer is used to indicate the pressure at which the gas mixture is being dispensed. The flow rate through capillary is calculated using poisoullie's equation given by

$$F = \frac{R^4 P}{8.\eta.L}$$

Where, F is the gas flow rate, R is the capillary radius, P is the differential pressure, η is the viscosity of gas, L is the length of the capillary tube.

➢ **Safety bubblers:** These are made of borosilicate glass, connected to a stainless Tygon tube. They are mounted on individual output lines to take care of the back pressure and protect the RPCs from a possible damage due to over pressure.

➢ **Isolation bubblers:** These are used to prevent back diffusion of air into the RPC and these are also similar to safety bubbler.

Fig 2.13 Safety and Isolation Bubbler unit

- **Control and monitoring:** The unit requires a flow rate of individual gasses in the system which can be set and monitored locally as a PC interface.

- **Calibration of MFCs:** As we know that MFCs used to regulate the rate of flow of each gas. Here MFC used Nippon Dylan made of model FC-760 in which all MFCs is recalibrated using this simple technique.

  The gas coming out through the MFC is flown through a graduate tube in which at the inlet, we insert a droplet of a viscous liquid. The liquid drop flows along the tube as a result of the pressure exerted by the incoming gas using a stopwatch to measure the time taken by the liquid drop through a fixed length of the tube. Gas flow rate is calculated by the given equation.

$$\text{Flux} = \frac{\text{Change in volume}}{\Delta t}$$

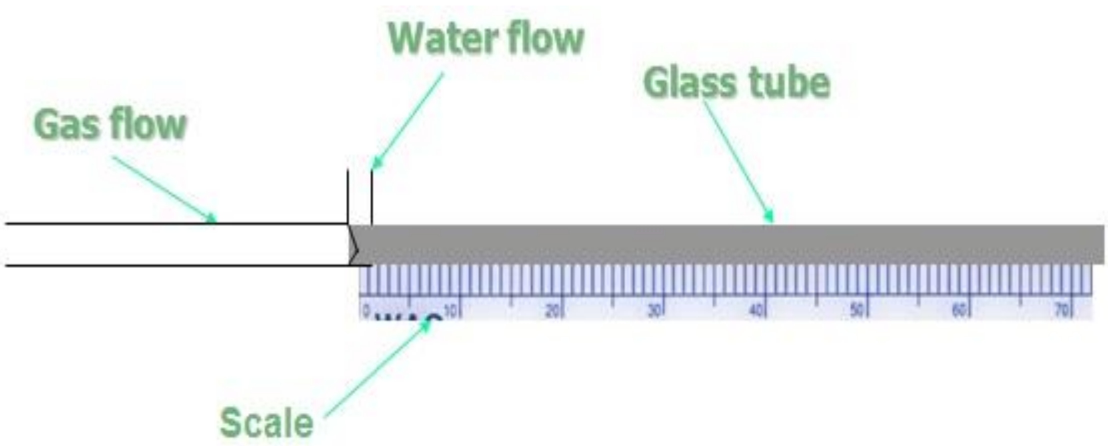
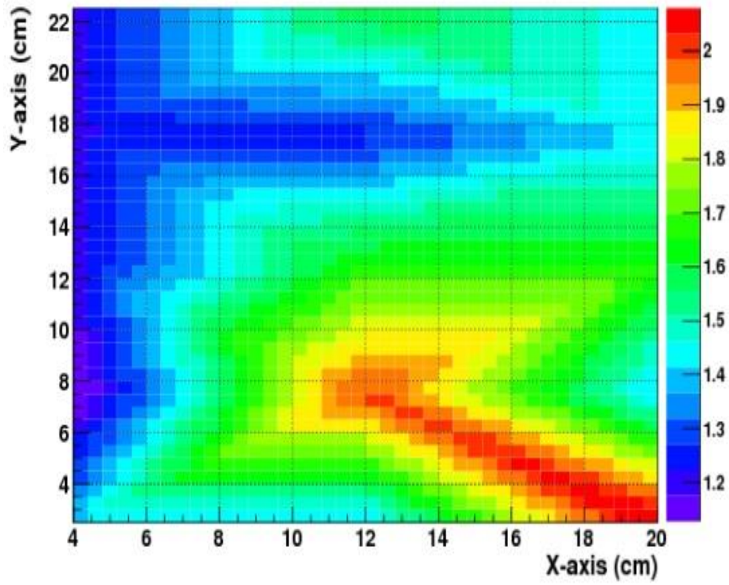


Fig 2.14 Recalibration of MFCs

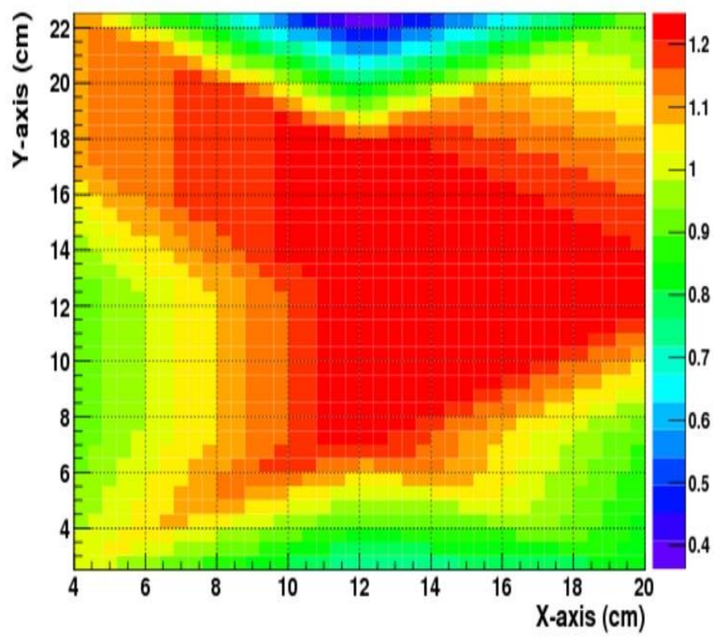
2.6 Characterization of RPC:

There are some tests are performed on RPC to calculate its characteristic as below:

- **Surface Resistivity Test:** Surface resistivity of graphite layer coated on the glass surface is measured using a jig placing in horizontal and vertical direction.



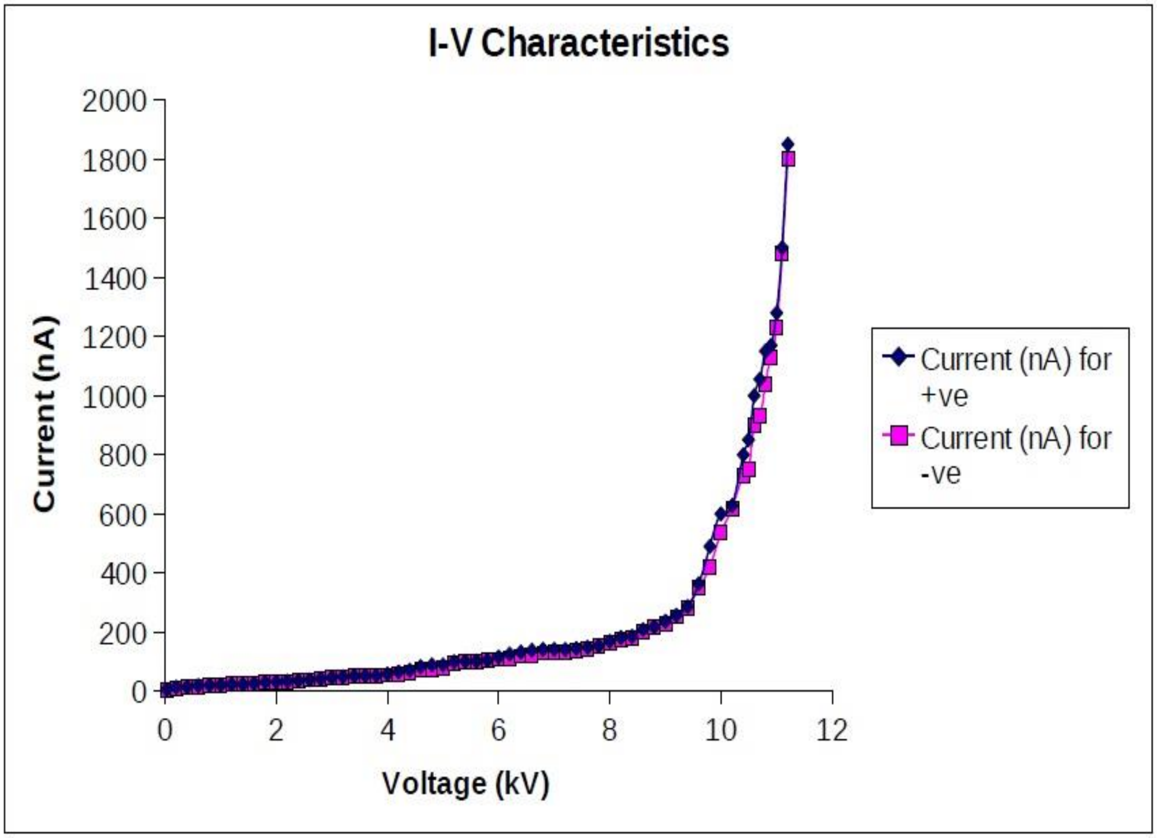
Graph 2.1 One Side of Glass 1



Graph 2.2 One Side of Glass 2

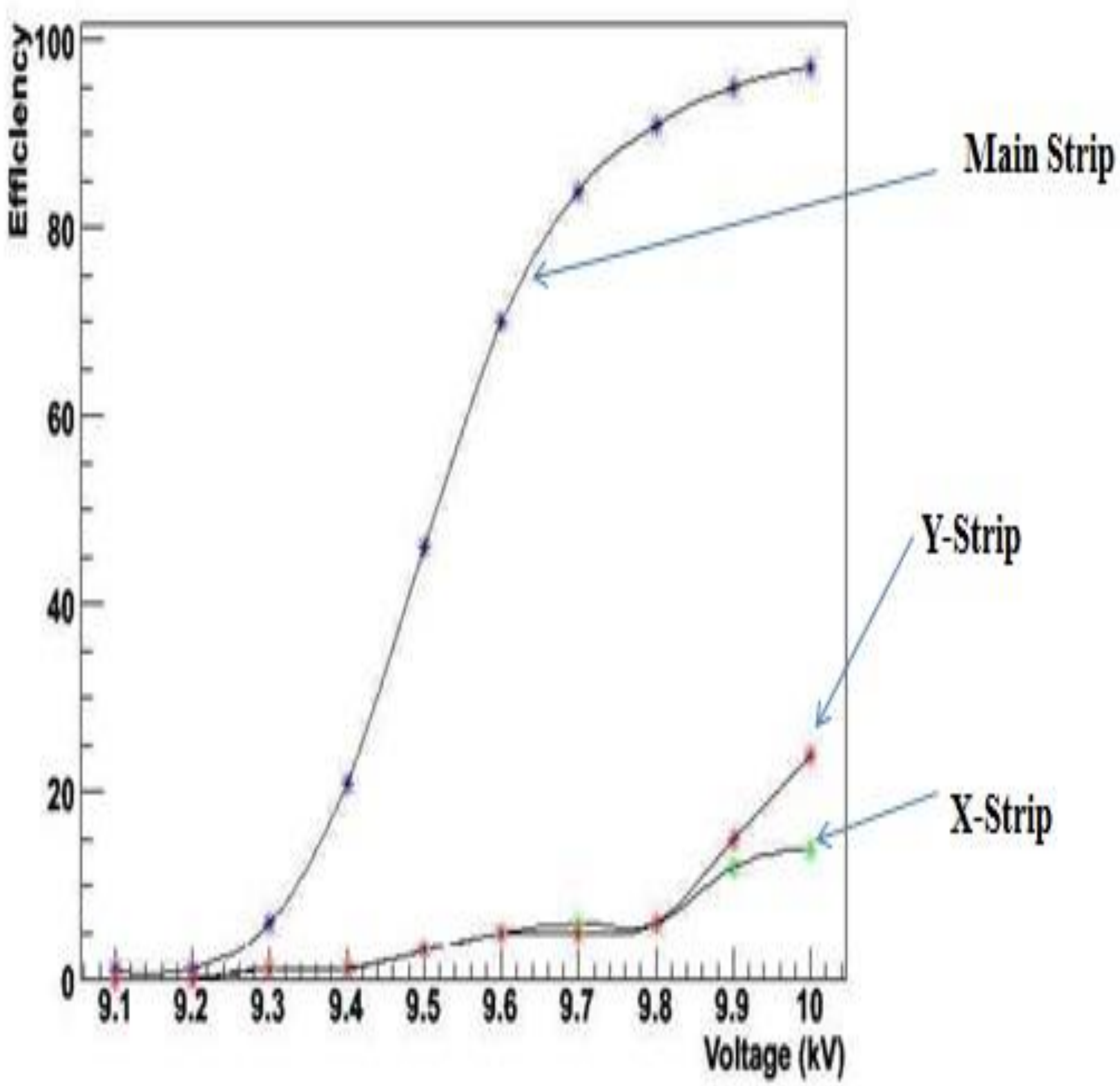
The X and Y axes are the length and breadth of centimeters of the glass plates whose surface resistivity was measured. The intensity of the colors indicates the value of the surface resistivity in $10^{11}\Omega$cm and the variation in colors represents the variation in the surface resistivity at different points across the glass plate.

- **I-V Characteristic:** This test is done to know about
    - Leakage Current
    - Breakdown voltage: This is a minimum voltage that cause of an insulator to become electrically conductive. Here this occurs at approximately 10 KV.



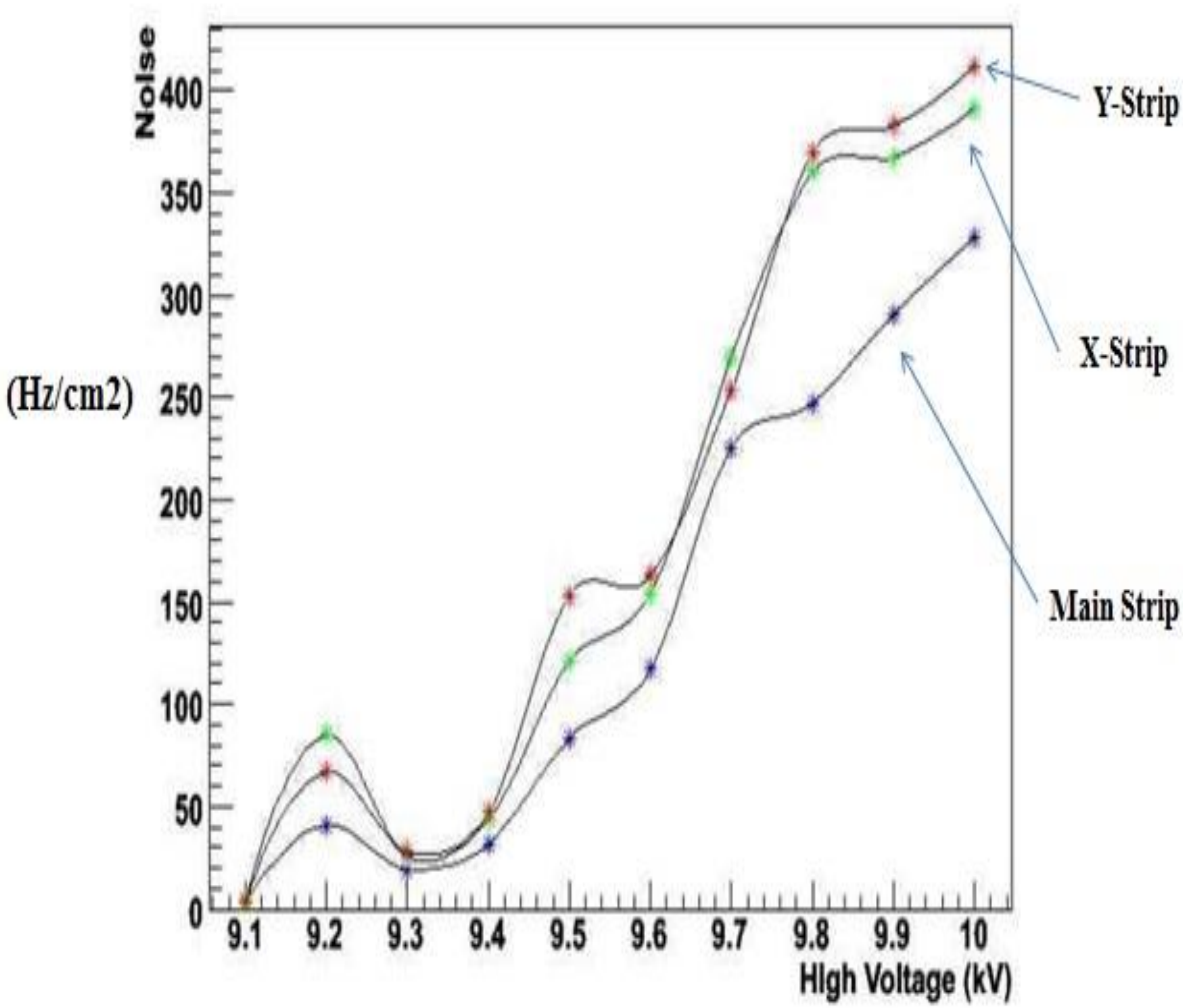
Graph 2.3 V-I Characteristic

- **Efficiency vs. Applied voltage:** This test is done to know about the Plateau Region for the optimization of RPF. In this region efficiency will remain constant if we increase the voltage after certain voltage this occurs at approximately 9.8 KV.



Graph 2.4 Plateau Region for Efficiency

➢ **Noise Rate vs. Applied Voltage:** This is done to know Noise rate which is also a function of applied voltage.



Graph 2.5 Noise Rate

2.7 Calculation of Efficiency:

The efficiency of RPC is calculated with respect to the scintillator paddles as reference. Three paddles are used in order to provide a three-fold coincidence (3F). A trigger would be produced when a muon would pass through three the paddles and the signal from each scintillator is sent to a discriminator (with a threshold of -30 mV) to convert the analog pulse into a NIM pulse. The outputs from one of the discriminators with delayed by 150 ns to avoid for jitters. The three outputs are then passed through an AND gate to get a trigger pulse. The outputs of the RPC strips is passed through pre-amplifiers and then through discriminators (threshold of -22mV) to get a NIM pulse. Then these pulses are directly passed to scalars to count the pulses to measure the noise rate. The NIM pulses from the RPC strips along with the trigger pulses from the scintillator are given to an AND gate to get the four-fold (4F) coincidence. Now the efficiency is calculated by given the formula:

$$\text{Efficiency} = \frac{4\text{F}}{3\text{F}} \times 100$$

2.7.1 Setup for calculating Efficiency and Noise rate:

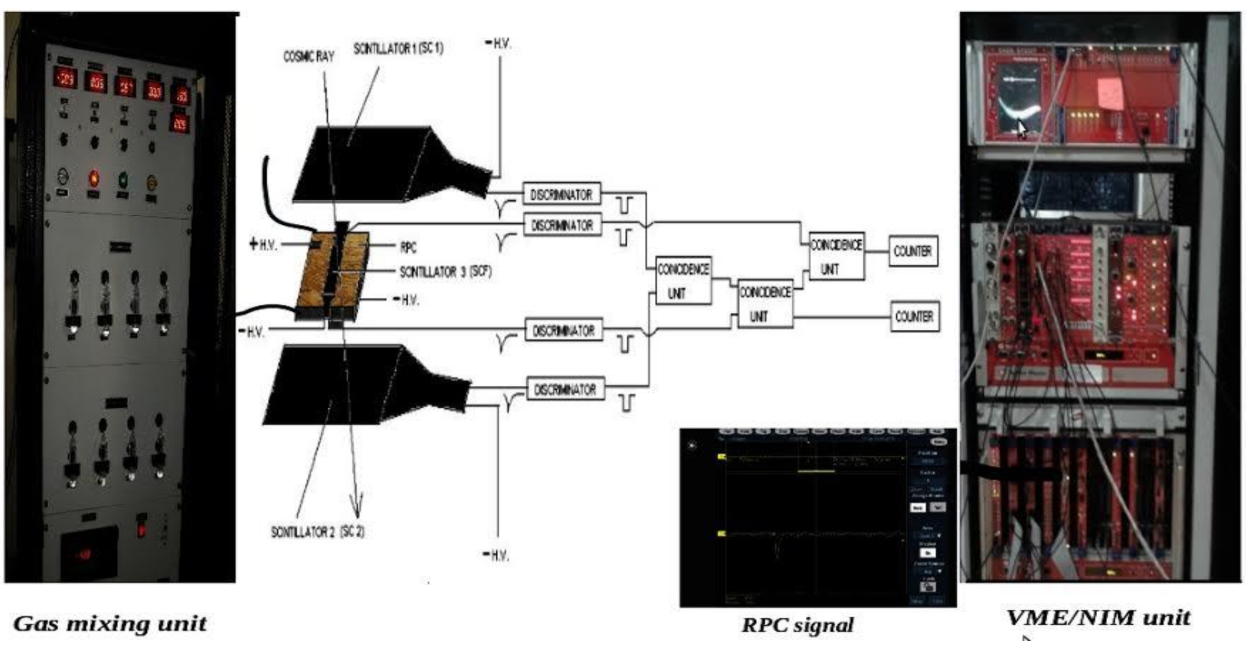


Fig 2.15 Setup for Efficiency Calculation

CHAPTER 3

FRONT-END ELECTRONICS OF RPC DETECTOR USING NINO BOARD

3.1 Basic Functions of Front-End Electronics of Detectors:

In High Energy Physics requires constant improvement of radiation detectors time-resolution (now in the range of tens of picoseconds). The most precise time requirements are met for detectors measuring the transit time of relativistic particles to identify the particles momentum and energy.

The entire signal processing and data acquisition system can be divided into the following modules:

- Front-end electronics
- Trigger module.
- Signal routers (Trigger and TDC Router & Control and data Router).
- Back end DAQ system (Data and Monitor Control module & Data and Monitor Readout module).

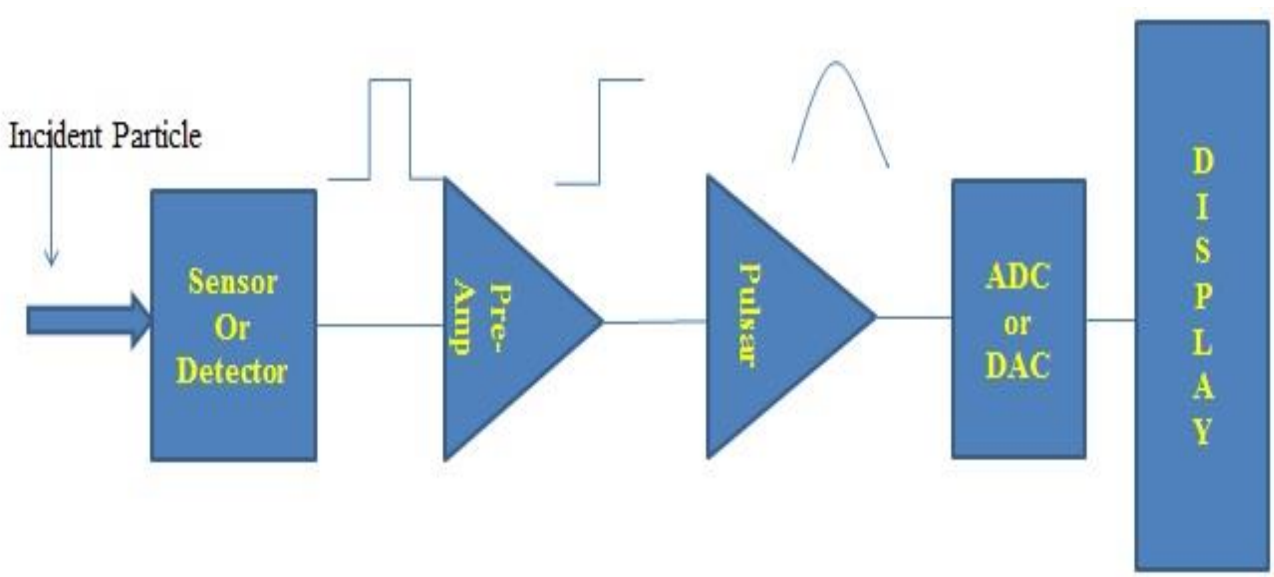


Fig 3.1 Pulse Processing

3.2 Need for front-end Electronic for Detector:

- Acquire Electrical signal from detector typically a short current pulse
- Tailor the time response (Means shape output pulse) of the system to optimize for
  - Minimum detectable signal
  - Magnitude of signal
  - Event rate and time of arrival
  - Transits time of the relativistic particle to identify the particle momentum and energy.

3.2.1 For RPC detector:

- RPC pulses become too low amplitude of the order of 2-5mv
- The typical rise time of RPC pulses is the order of 1ns. Means pulses become extremely narrow viz. 5-10 ns.

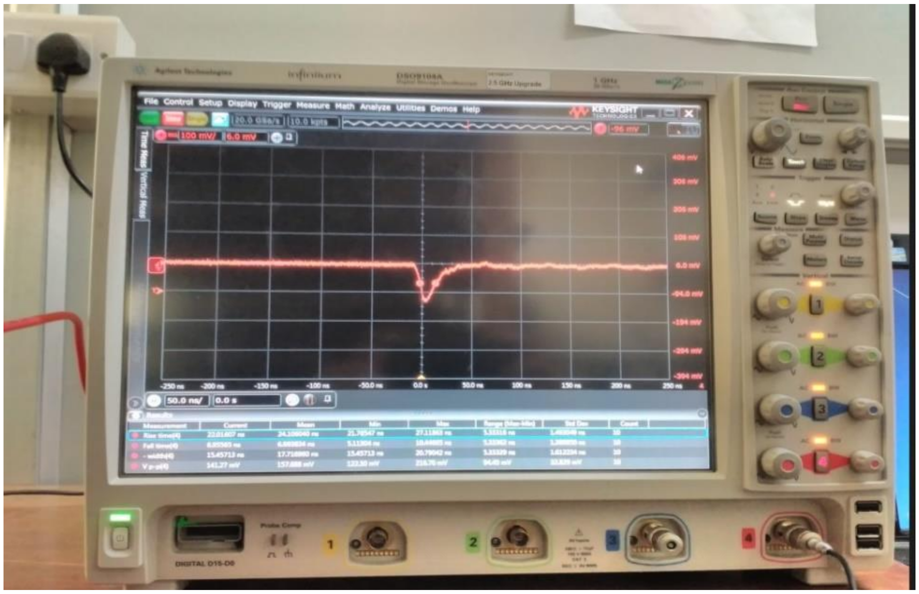


Fig3.1 Low Amplitude Negative RPC pulse

3.2.2 So it needs to:

- To minimize signal reflection and cross talk
- To boost the signal amplitude, an appropriate front-end amplifier is used.

3.3 NINO: an ultra-fast and low-power front-end amplifier/discriminator ASIC:

Firstly the NINO ASIC was purposely designed as the front-end amplifier/discriminator for the MRPCs used for the TOF array of the ALICE experiment at CERN. The Time-of-flight detector is the major system for performing particle identification in the ALICE experiment. So For the full exploitation of the excellent timing properties of the MRPCs, frontend electronics with special characteristics are needed. These are

- Differential input, to profit from the differential signal from the MRPC
- A fast amplifier with less than 1 ns peaking time
- Input charge measurement by Time- Over-Threshold for slewing correction.

Hence 8-channel amplifier and discriminator chip have been developed to match these above requirements. This is the NINO ASIC, which is fabricated with 0.25 mm CMOS technology.

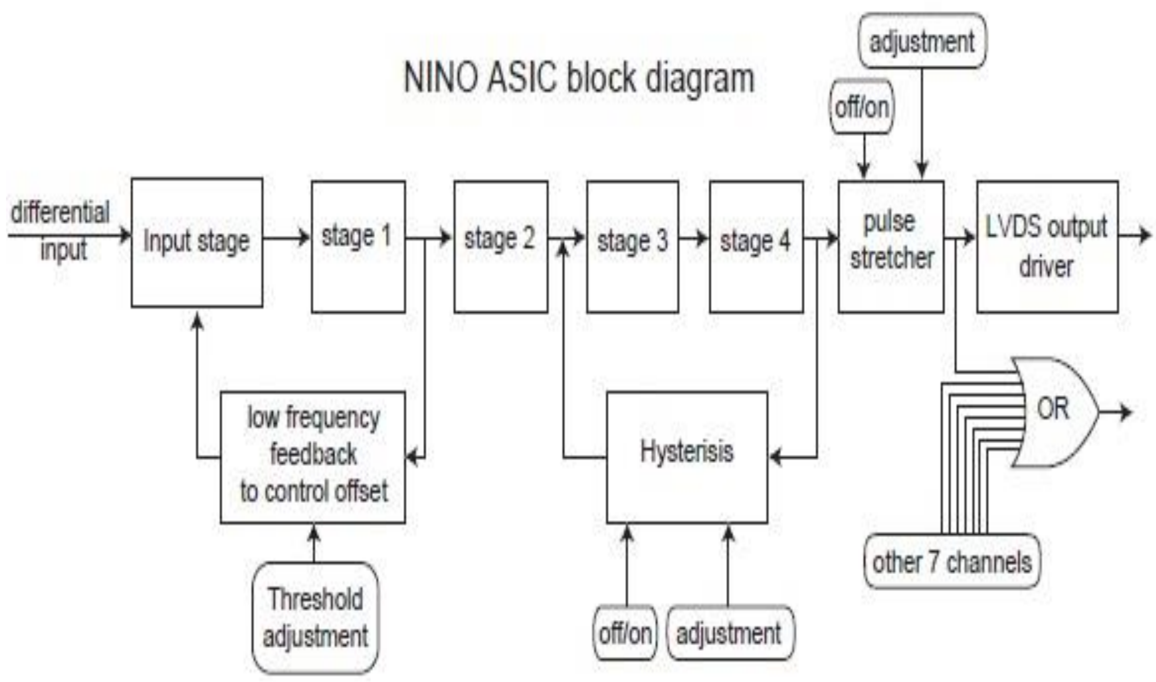


Fig 3.2 Block Diagram of NINO ASIC Chip

3.3.1NINO ASIC chip Specification:

Table 3.1

Parameter	**Value**
Peaking time	1ns
Signal range	100fC-2pC
Noise (with Detector)	$< 5000\ e\ rms$
Front-edge time jitter	$< 25\ ps\ rms$
Power consumption	$30\mathrm{mW/channel}$
Discriminator threshold	10Fc-100Fc
Differential input impedance	$40\Omega < \mathrm{Z_{in}} < 75\Omega$
Output interface	LVDS

3.3.2NINO ASIC Chip:

- NINO is an ultrafast front-end Preamplifier/Discriminator chip developed for use in the ALICE TOF detector.
- It has eight channels per chip with $30\mathrm{mW/channel}$ power consumption.
- Time resolution is <5ps RMS and Delay time are 1ns.
- Every amplifier per channel with less than 1ns peaking time, and a discriminator with a detection threshold of 10fC to 100fC and an output stage.
- Fully differential structure from input to output. Gain is obtained by 4 consecutive stages, High bandwidth low gain stages (G=6, BW=500 MHz).

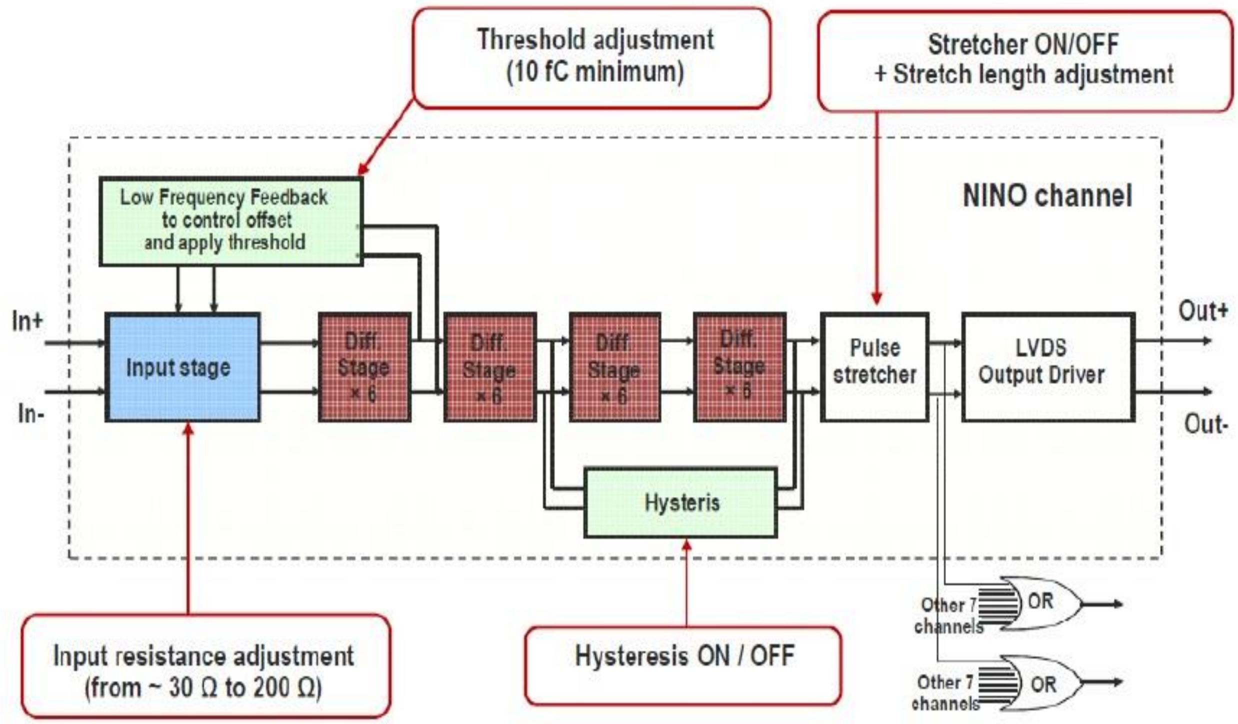


Fig 3.3 Functional Block Diagram of NINO chip

3.4 Components of NINO ASIC Chip:

The NINO ASIC satisfies the following requirement as below:

- Differential input
- Optimized to operate with 30Pf input capacitance
- LVDS output
- Output pulse width dependence on the charge of the input signal
- Fast amplifier to minimize time jitter
- Adjustable discriminator threshold in the range of 10-100fC
- Eight channel per ASIC

➢ Input Stage of NINO ASIC Chip:

With a short transmission line, the detector is connected to the input of the NINO ASIC to match the input impedance of the transmission line. First, the input current pulse is fed into the source of the NMOS (M1) transistor and emerges from the drain and is again fed into the source of the second NMOS (M2) transistor. The current pulse will then emerge from the drain of M2, but the impedance at this point is very different (much larger) than at the input. This current charges the capacitance (which is the unavoidable stray capacitance associated with the transistor) on the drain; the rise time of this signal is governed by the characteristics of the transistor itself while the fall time is given by the time the capacitance C takes to be recharged (i.e. RC). The input impedance is $(1/g_m)$ M1 and therefore the biasing and geometry of M1 is chosen to keep this impedance low to match the transmission line carrying the input signal. The output voltage is defined by the parasitic capacitance C and thus M2 is designed to minimize this capacitance.

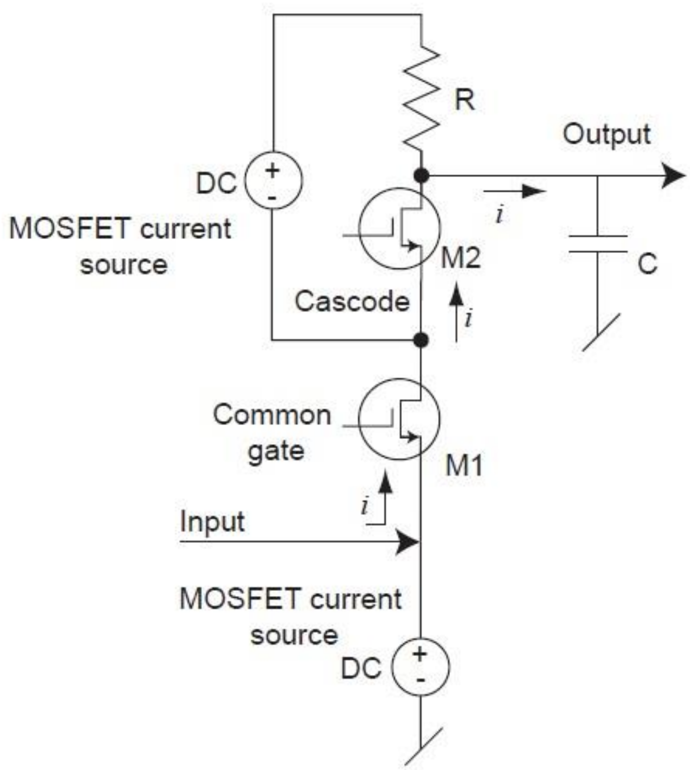


Fig 3.4 Schematic Input Stage of NINO ASIC

➢ Biasing Circuit:

A common biasing circuit is used to provide biasing current and voltage to channel in the NINO chip to match input impedance to an external resistance used as a reference as shown in given fig. Therefore two branches are biased with identical currentsI_0. The ratio of $W1/W2$ of transistor M1 and M2 and reference resistance $R_p$which is inserted at the source of M1. The expression for current I_0 is given by.

$$I_0 = \frac{1}{K_n \frac{W2}{L}} \times \frac{1}{R_p^2}(1 - \frac{1}{M})$$

Where, $= \sqrt{\frac{W1}{W2}}$, If $\frac{W1}{W2} = 4$,the source impedance of transistor M2 is expressed as

$$1 \Big/ gmsb_{M2} = \frac{1}{2\sqrt{K_n \frac{W2}{L} I_0}} = R_p$$

The above equations are established for circuit operation in strong inversion whereas transistor M1 and M2 are operating in moderate inversion.

The two input devices of the differential input stage are biased as the transistor M2. Thus impedance of the input device is matched to the value of the reference resistance R_p.

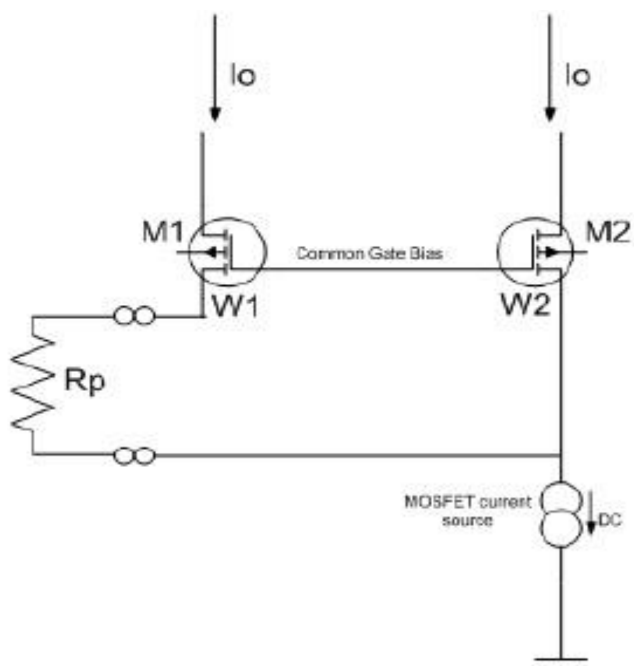


Fig 3.5 Schematic of Biasing Circuit

- **Cascaded voltage stage gain:**

  After the input stage voltage gain amplification is provided with four cascaded identical high bandwidth differential pair amplifiers. Each amplifier has a voltage gain of 6 with –3dB bandwidth of 500MHz.

3.5 Advantage of differential signaling:

In differential signaling, the transmitter translates the single input signal into a pair of outputs that are driven 180° out of phase. This transmission scheme provides the kind of large common-mode rejection and noise immunity to a data transmission system.

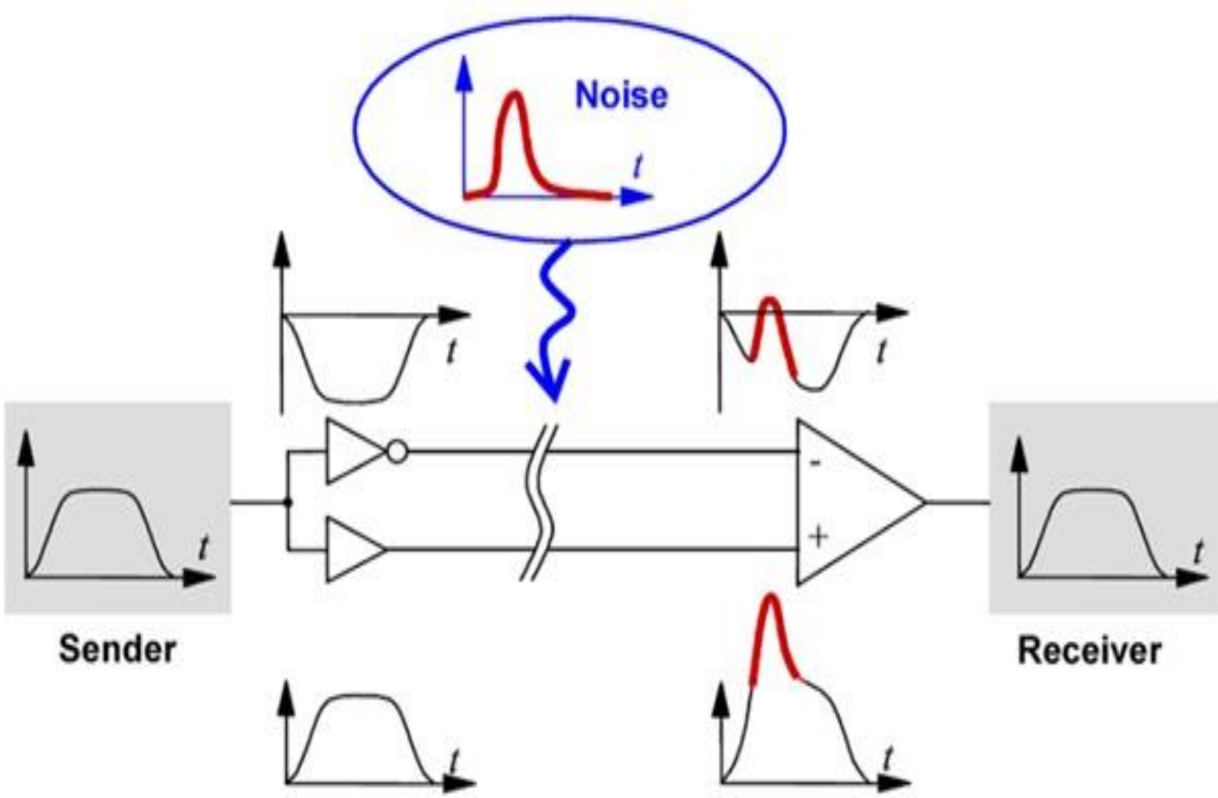


Fig 3.6 Differential Signaling

3.6 Setup for testing of NINO Board:

In this setup I used a function generator to make a low amplitude pulse similar to RPC pulse and then fed to the NINO board for testing purpose with their required instruments and connection wires and got result on display device DSO.

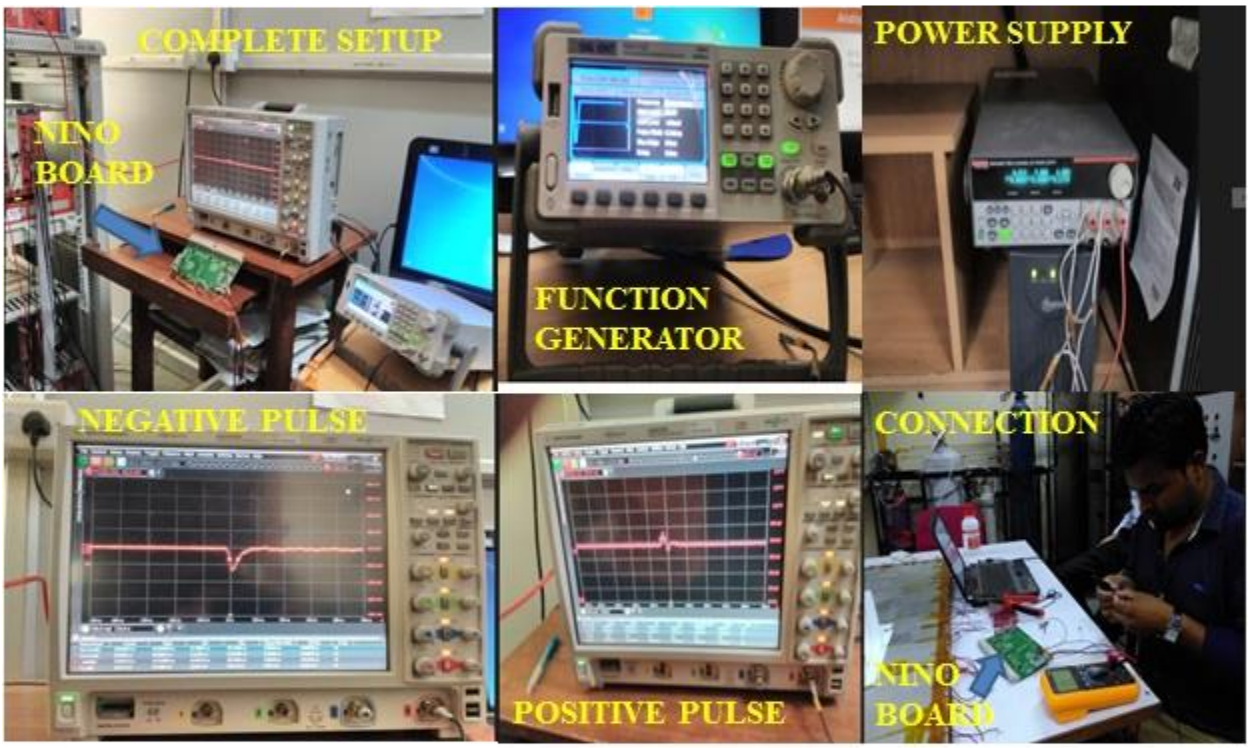


Fig 3.7 Setup for NINO test

CHAPTER 4

FUTURE PLANING OF WORK WITH NINO BOARD

4.1 Interfacing of NINO Board to single gap RPC:

RPC induces single ended signals on pick-up strips but NINO requires differential input, so to interface NINO with RPC, single ended signal needs to be converted to differential signal. This conversion can be done in three ways:

- Rearrangement of signal pickup strips panel
- Using passive circuit (e.g. RC circuit)
- Using active circuit (e.g. OP-AMP)
  - No attenuation occurs
  - Desired gain cab be obtained
  - Common mode voltage cab be matched

4.1.1Rearrangement of Signal Pickup Strips Panel: Normally signal pickup strips become orthogonal to each other for getting the particle position in both (X-axis and Y-axis) direction. In this position of panel, RPC induces single ended signal on pickup strips. So it needs to be rearranging to make a differential signal. This is done by doing pickup panel placed in parallel to each other. We get similar positive and negative signal and fed to the NINO board and get RPC pulse on display device DSO with their supporting instruments.

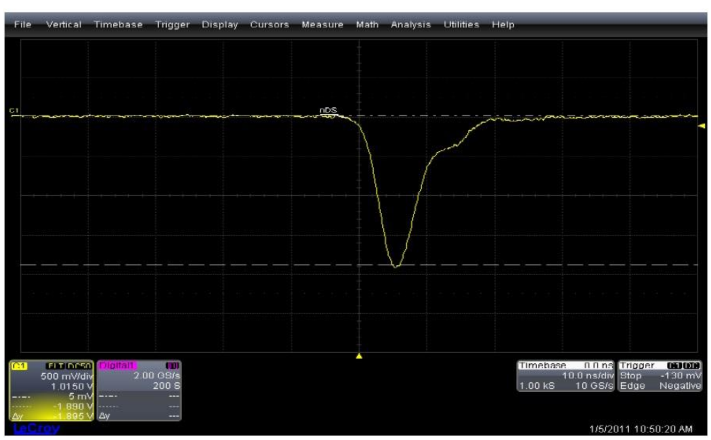


Fig 4.1 Low Amplitude RPC pulse

4.1.2 Using Active Circuit:

Here I am using THS4520 Op-Amp, which is a single-channel wideband, a fully differential operational amplifier having features as below.

- Minimum Gain of 1 V/V (0 dB)
- Centered Input Common-mode Range
- Bandwidth: 620 MHz
- Output Common-Mode Control
- Voltage: 3.3 V (±1.65V) to 5 V (±2.5V)
- Current: 10 mA

Fig 4.2 Fabricated THS4520 Op-Amp

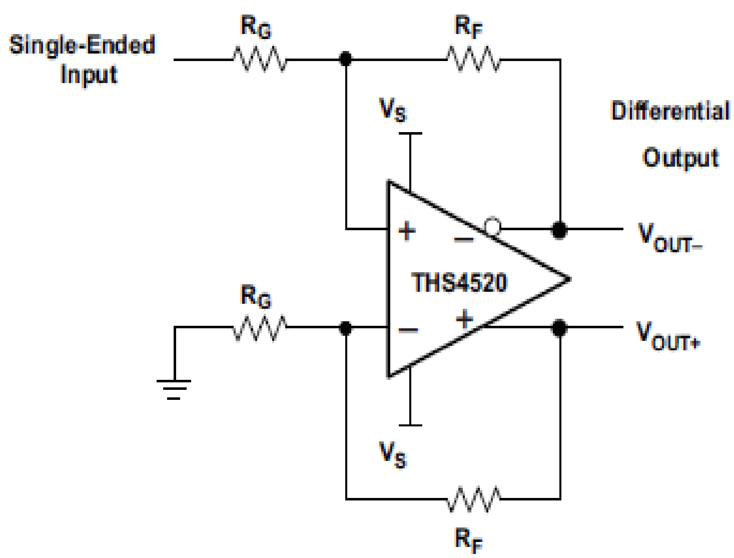


Fig 4.3 Functional Block Diagram

4.2 Designing of LVDS to NIM/ECL translator:

The LVDS–ECL translator is designed by using two IC's and interfacing to each other on Bread Board for desired output.

- **DS90C032B (LVDS- TTL converter):**
- >155.5 Mbps switching rates
- Accepts small swing (350mV) Differential signal
- Ultra low power dissipation
- 600ps maximum differential skew

Fig 4.4 IC's LVDS- TTL converter

- **MC10H124 (TTL-ECL converter)**
- Propagation delay 15ns typical
- Improved noise margin 150mV
- Voltage compensated

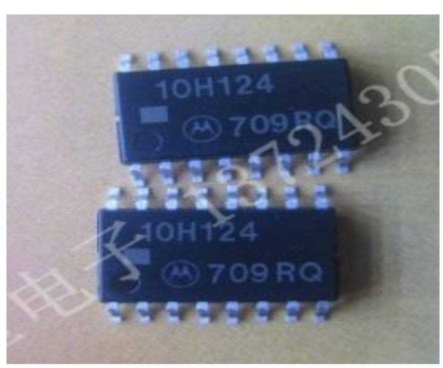


Fig 4.5 IC's for TTL-ECL converter

4.3 Next Proposed Setup for NINO Board with their Interfacing: This setup will be used for calculating efficiency comparing with scintillators paddle as trigger.

$$\text{Efficiency} = \left[\frac{\text{Trigger} \times \text{RPC}}{\text{Trigger}}\right] \times 100$$

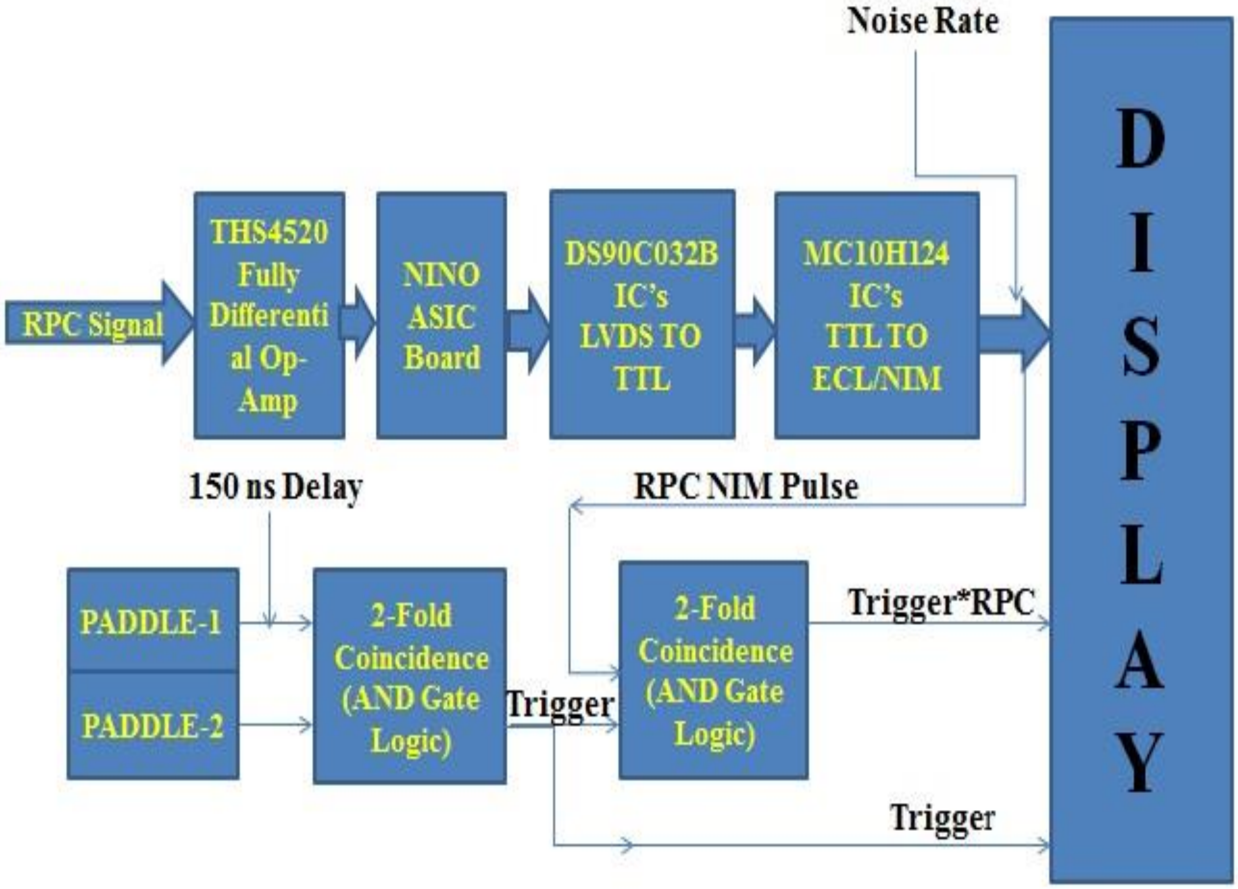


Fig 4.6 Setup for NINO Board with their Interfacing

CONCLUSION AND SUMMARY

During this dissertation project, I worked with RPC detector to detect muon for the study of atmospheric neutrinos and their mixing parameters for INO-ICAL Project.

I developed 30cm×30cm glass electrodes using highly resistive Saint Gobain glass and its gas flow system. Then I studied its characteristics- variation of current, efficiency, noise rate as a function of applied voltage.

I also studied its front-end electronics using NINO ASIC board which is ultra-fast amplifier/discriminator for the calibration of RPC detector signal.

Next, I will work with the interfacing of NINO board for calibration of RPC detector.

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