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

EXPERIMENTAL REPORT SUBMITTED TO INO FOR THE PARTIAL FULFILMENT OF COURSE WORK FOR THE “INO GRADUATE SCHOOL”

BY

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CHAPTER- 1: <u>RPC</u>

1.1) INTRODUCTION:-

The Resistive Plate Chamber (RPC), introduced in 1981 by R. Santonico and R. Cardarelli, is a gaseous particle detector based on the principle of "Spark Chamber", utilising a constant and uniform electric field produced by two parallel electrode plates which are made up of a material with high bulk resistivity. Its working concepts are based on the detection of gaseous ionization produced by charged particles traversing the active area of the detector, under a strong uniform electric field applied by resistive electrodes. A gas mixture namely Freon which is ionised by charged particles traversing the detector, is flown through the gap between the electrodes. The electrodes which we are using in INO RPC lab are glass electrodes, coated with a layer of graphite on one side. The RPC's are preferred over scintillators because of the following reasons:-

1) They give a good position resolution and give good detection efficiency.

2) They can be made to have a large area but at a minimal material cost.

3) These are easy to assemble and they possess simple read-out electronics.

4) They exhibit better time resolutions than scintillators and long-term stability.

The glass RPC's have been proposed as the active element in the iron calorimeter detector for the India-based Neutrino Observatory. Single and double gap RPCs have found application in cosmic ray experiments, in high energy experiments as well as in astroparticle physics.

1.2) PRINCIPLE OF OPERATION OF GLASS RPC:-

The basic principle of working of a RPC is based on the principle of Spark Chamber i.e. "ionisation". Spark chambers consist of metal plates placed in a sealed box filled with a gas such as helium, neon or a mixture of the two. As a charged particle travels through the detector, it will ionize the gas between the plates. A trigger system is used to apply high voltage to the plates to create an electric field immediately after the particle goes through the chamber, producing sparks on its exact trajectory.

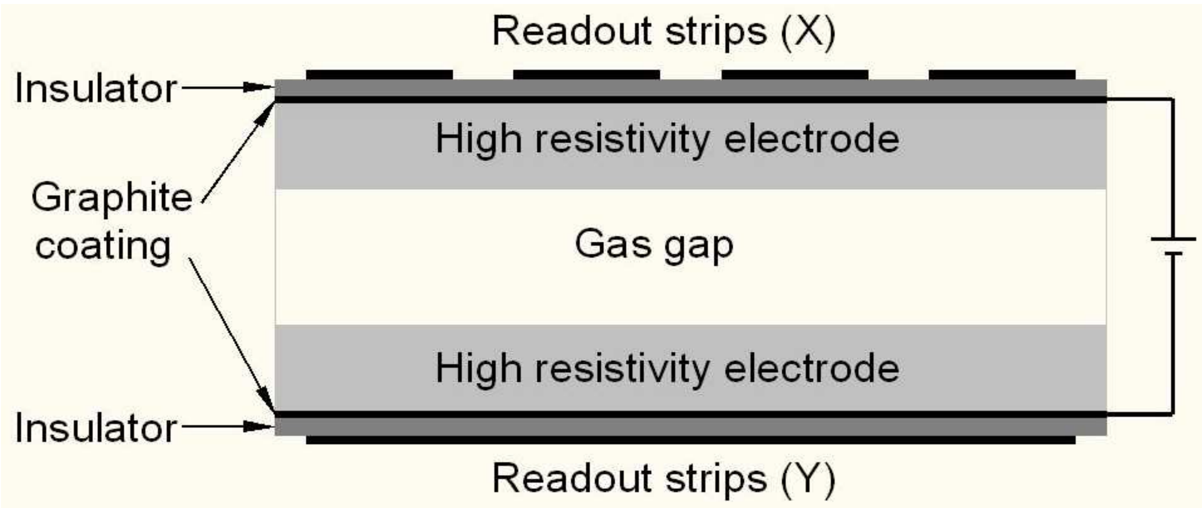

Fig. 1:- This is how a typical glass RPC looks like from side.

The glass RPC is consists of two parallel electrodes made up of float glass with a volume resistivity of about 10^{12} Ω-cm. The two electrodes, 2mm thick, are mounted 2mm apart by means of highly insulated spacers. A suitable gas mixture is flown at the atmospheric pressure through the gap while an appropriate electric field is applied across the glass electrodes through a resistive coating on their outer surfaces. An ionizing charged particle traversing the gap initiates a streamer in the gas volume that results in a local discharge of the electrodes. This discharge is limited to a tiny area of about $0.1 cm^2$ due to the high resistivity of the glass electrodes and the quenching characteristics of the gas. The discharge induces an electrical signal on external pickup strips on both sides orthogonal to each other, which can be used to record the location and time of ionization. The discharge area recharges slowly through the high resistivity glass plates and the recovery time is about 2secs. The duration of discharge is typically ~ ns. This discharge is quenched by the following mechanisms:

1) Prompt switching off of the field around the discharge point, due to the large electrode resistivity.
2.) UV photon absorption by the quencher preventing secondary discharges from gas photo ionisation.
3) Capture of outer electrons of the discharge due to the gas with high electron affinity, which reduces the size of the discharge and possibly its transversal dimensions.

Because of the large difference between the duration of discharge and recovery time, the electrode plates behave like insulators so that only a limited area of ~$0.1cm^2$ around the discharge point remains inactive for the dead time of the detector. The discharge induces an electrical pulse which is picked up by the pick-up panels, made up of copper strips, through graphite painted high voltage electrodes. The copper strips are insulated against the high voltage by thin mylar sheets. The electric signal is then properly picked up by the "read-out electronics" and analysed.

Before,

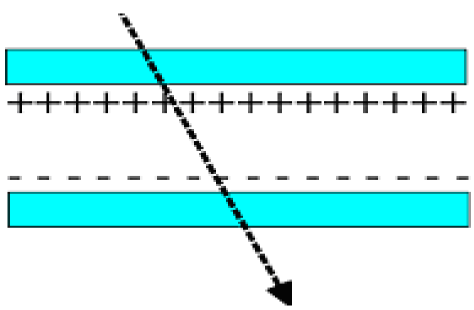

Fig. 2:- A passing charged particle induces an avalanche, which develops into a spark. The discharge is quenched when all of the locally (r~0.1cm2) available charge is consumed.

After,

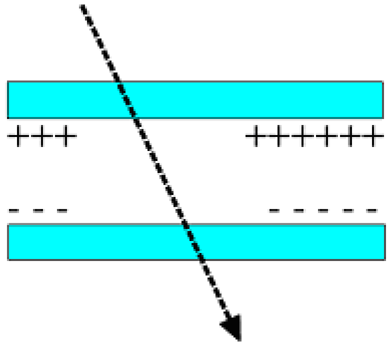

Fig. 3:- The electric field drops only around the streamer location, for a time proportional to the electrode resistivity. The discharged area recharges slowly through the high-resistivity glass plates.

1.3) <u>MODES OF OPERATION</u>:-

Based on the applied electric potential and the ionisation phenomenon, the modes of operation of a RPC are classified as follows:-

a) Avalanche mode.
b) Streamer mode.

a)<u>Avalanche mode</u>:-

A charged particle passing through the gaseous medium produces primary ions. These ions, being accelerated by the electric field, collide with the gas molecule to produce secondary ionization. The external field opposes the electric field of the ionising particles and the multiplication process stops after sometime. Then the charges drift towards the electrodes and are collected there.

The electric field across the gap (and consequently the gas amplification) is reduced and a robust signal amplification is applied at the front end electronic level. The substantial reduction of the charge produced in the gap improves the rate capability by more than an order of magnitude, allowing application of RPCs to high rate experiments.

This mode corresponds to the generation of a Townsend avalanche followed by the release of primary charge by the ionizing radiation .It operates at a lower voltage and the gain is less. Typical pulse amplitudes are of the order of a few mV.

b)<u>Streamer mode</u>:-

In this mode the avalanche generated is followed by a streamer discharge. The secondary ionization continues until there is a breakdown of the gas and a continuous discharge takes place. This mode operates at a higher voltage and also results in high gain. Typical pulse amplitudes are of the order of 100-200 mV. The electric field inside the gap is kept intense enough to generate limited discharge localized near the crossing of the ionizing particle. Due to the relatively long relaxation time of the resistive electrode, this mode is adequate for cosmic ray and low-rate accelerator experiments.

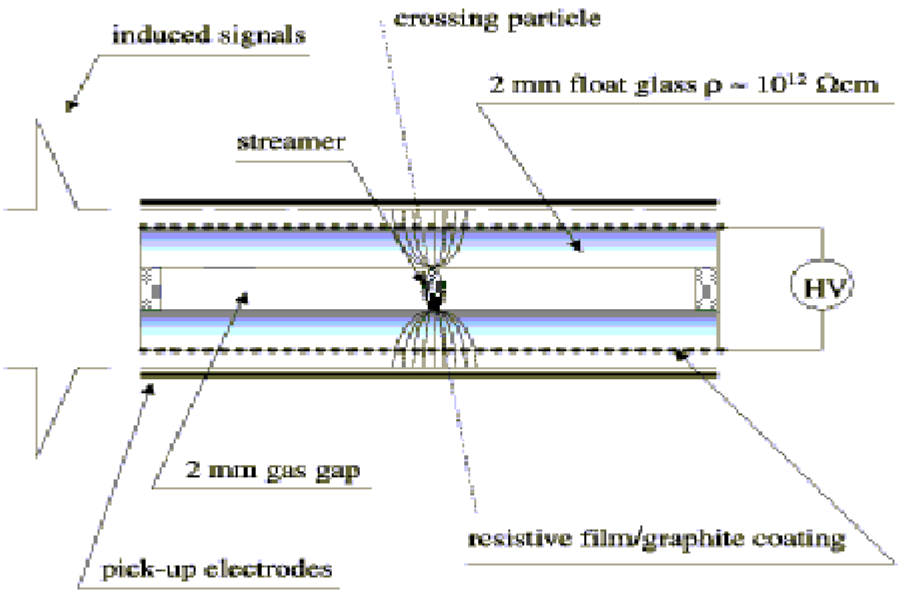

Fig. 4:- Schematic of a RPC in operation in streamer mode

OUR MODE OF OPERATION IS "<u>AVALANCHE MODE</u>".

1.4) <u>EQUIVALENT CIRCUIT OF RPC</u>:-

At low voltage: R_{gap} is very high and the conduction is done by R_{spacer}.
At high voltage: R_{gap} becomes very low.

(For diagram, please see next page)

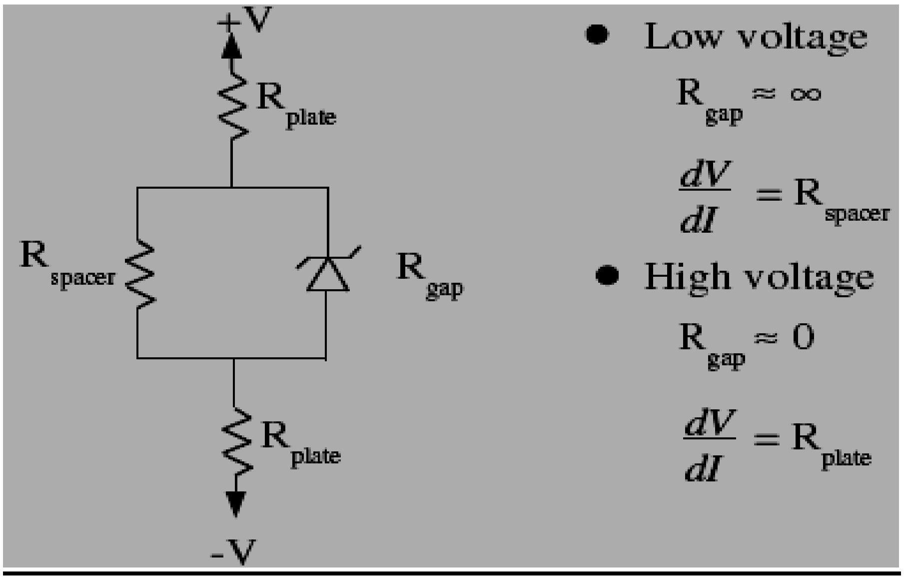

Fig. 5:- Equivalent circuit of a RPC.

CHAPTER- 2:- <u>Fabrication and set –up.</u>

We constructed a 1mx1m, single layer RPC in our INO RPC lab. The following steps are involved in the fabrication of a RPC:-

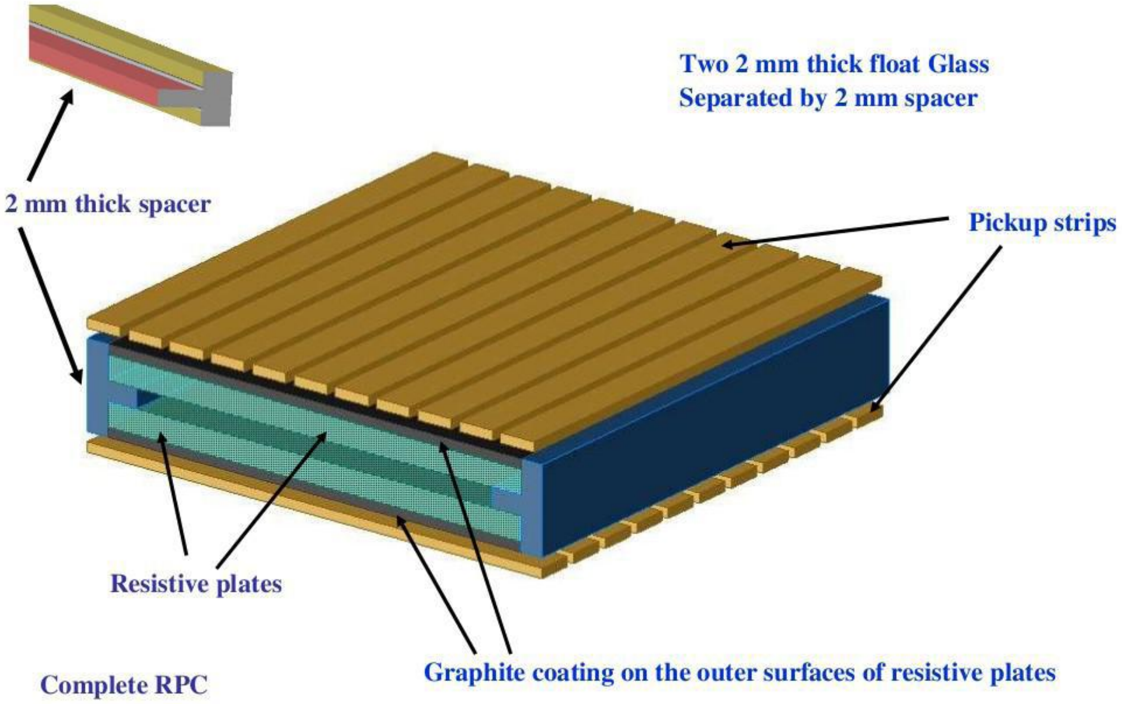

Fig. 6:- This is how a standard single layer RPC looks like.

2.1) <u>Glass Cutting and Cleaning</u>:- The Asahi float glasses (each 3mm thick) procured by local vendors are cut by diamond cutter to the appropriate size and the four corner edges are chamfered by a jig of right dimension to make a correct 450 angle. The glasses are thoroughly cleaned with alcohol followed by labolene and distilled water. After that the edge spacers, corner spacers (which are connected to the gas nozzle) and polycarbonate button spacers are also cleaned with alcohol. The glass edges are taped over with masking tape with 1 cm being masked or taped off on each side so as to prevent the conductive coating to be painted right up to the edge of the glass so that leakage of high voltage does not take place through the edge spacers

2.2) <u>Conductive Coating</u>:- Conductivity of the glass is increased by coating one side of it with a mixture of dry colloidal graphite and Industrial lacquer in a ratio of 1:8 using a spray gun. Once the surface is coated the masking tape is removed and the resistivity of both surfaces is measured using a resistance measurement jig (a copper and brass square about 17.5 x 17.5 cm2). This layer serves two purposes: it is conductive enough to act as anode/cathode and it is resistive enough to prevent itself from conducting away signal to the pickup strips so as to minimise the lateral spread.

2.3) <u>Gluing of Glass</u>:-

The glue used is 3M Scotch-weld epoxy adhesive (DP 190) in a duo-pack cartridge. The button spacers (width ~1.8mm) are glued in a square array on top of the glass surface without the graphite coating. The glue comes out through the three holes of the spacers, and glue is again applied on top of the buttons. Then the other glass plate is placed on this array of spacers thus obtaining a gas gap of 2mm. To put a uniform weight throughout the 4m2 area the whole set up is wrapped with plastic sheets and the air inside the plastic sheets is sucked slowly to create partial vacuum and a pressure equivalent to 5cm of water column pressure. The set-up is left for six hours to fix the spacers.

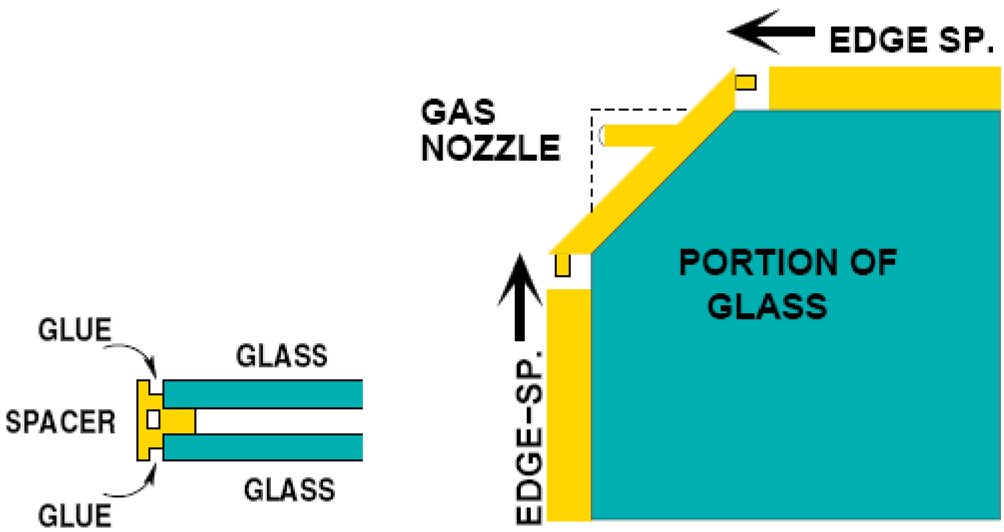

Fig. 7:- Side view and top view of spacers.

The straight edge-spacers are also designed such that the glass sits neatly within. There is a 1mm gap where the glue can be poured. The central protrusion is 2mm, thus supplying the required gap between glass plates. The corner spacers (gas nozzles) contain the gas inlet/outlet pipes. The glue is poured in the required gap and lead blocks are placed along the 4 sides to put the pressure and whole setup is left for one day, on the next day the same procedure is followed for the other side of the RPC.

2.4) <u>Gas Leak Test</u>:- To ensure against the gas leak (especially at the glued joints), a test is done by flowing Freon gas at slightly above atmospheric pressure and using a gas leak checker RIKEN GH-202F.Re-gluing is done on the edge spacers wherever a gas leak is detected.

2.5) <u>High Voltage supply</u>: - The high 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 an equal and negative voltage to the other side, using a bi-polar high voltage DC supply (N471A), so that both see a common ground. The bi-polar connection is better than the unipolar since each glass surface sees only half the total voltage, thus decreasing the chances of HV leaks. Also it minimises the maximum absolute rating of the resources used e.g. HV modules and HV carrying cables.

2.6) <u>Pickup Strips</u>:- The RPC is now sandwiched between two honeycomb pickup panels placed orthogonal to each other and then packed in an aluminium case. The pickup panel consists of 64 copper strips on one side and a layer of 5mm of plastic and aluminium (serving as a ground) on the other side. Each strip is machined to a width 2.8 cm and the gap between two adjacent strips is 0.2cm. Honeycomb panels are lightweight and provide adequate mechanical strength. Each strip is terminated with a 50Ω impedance to match the characteristic impedance of the strip. A layer of mylar of thickness 100μ is placed between the graphite layer and the pickup panel to provide insulation.

2.7) <u>Alignment of RPC in the laboratory</u>:- To measure the efficiency of the RPC, firstly we ensure that the trigger pulse generated is solely due to the atmospheric muons. Four scintillator paddles are used to set a coincident circuit for this purpose, .i.e., a cosmic ray telescope with these scintillators. The telescope consists of 4 cosmic ray muon trigger paddles P1, P2, P3, P4. The area of these scintillation paddles are 40×20, 40×20, 30×2, 30×3 respectively. The scintillation paddle gives out a signal when a cosmic ray muon or other charged particle passes through it. The geometry of the telescope using these paddles has been setup such that we define a window of about 30×2cm^2, for the cosmic ray muons to pass through the telescope as well as through one of the pickup strips of the RPC under test. Narrow paddles are used to define the telescope geometry precisely and veto paddles to prevent generation of triggers when a muon passes through the rest of the area of RPC which is not under study. The data from the RPC pickup strip is recorded whenever a cosmic muon generates a trigger signal through the logic P1 .P2.P3.*P*4 i.e., a trigger is formed when a muon passes through the paddles P1, P2, P3 and P4. The recorded data of the RPC is used for its characterization by finding its efficiency, time resolution and other parameters.

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

Efficiency of RPC is defined as:

$$E = \frac{4\,fold\ \times rpc}{rpc}$$

The RPC pulses are connected to ADC before digitising and the 4fold x veto is given to the ADC gate to ensure that when TDC gives a START the ADC gate is also open at the same time.

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2.8) <u>Electronic Data Acquisition System</u>: The entire signal processing and data acquisition system can be divided into the following modules:

- Front end electronics (16 channel analog front end and 32 channel digital front end).
- 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).[5]

1. <u>Front End Electronics</u>: - The signal from a pickup strip is passed through a pre-amplifier (gain70-80) and the output is fed to four 16 channel discriminator modules (Analog Front End). For channel-A, IC's 1597-1513 and for channel-B IC's 1595-1513 are used respectively. The signal crossing the set threshold in the discriminator generates differential ECL output. At present, the threshold is kept at -20mV. This section also generates the primitive trigger_0 logic. The discriminator modules are connected to two 32 channel Front End Processing (FEP) module (Digital Front End) which converts the ECL i/p to TTL o/p and also generates trigger_1 signals. Both the DFE's work independently.

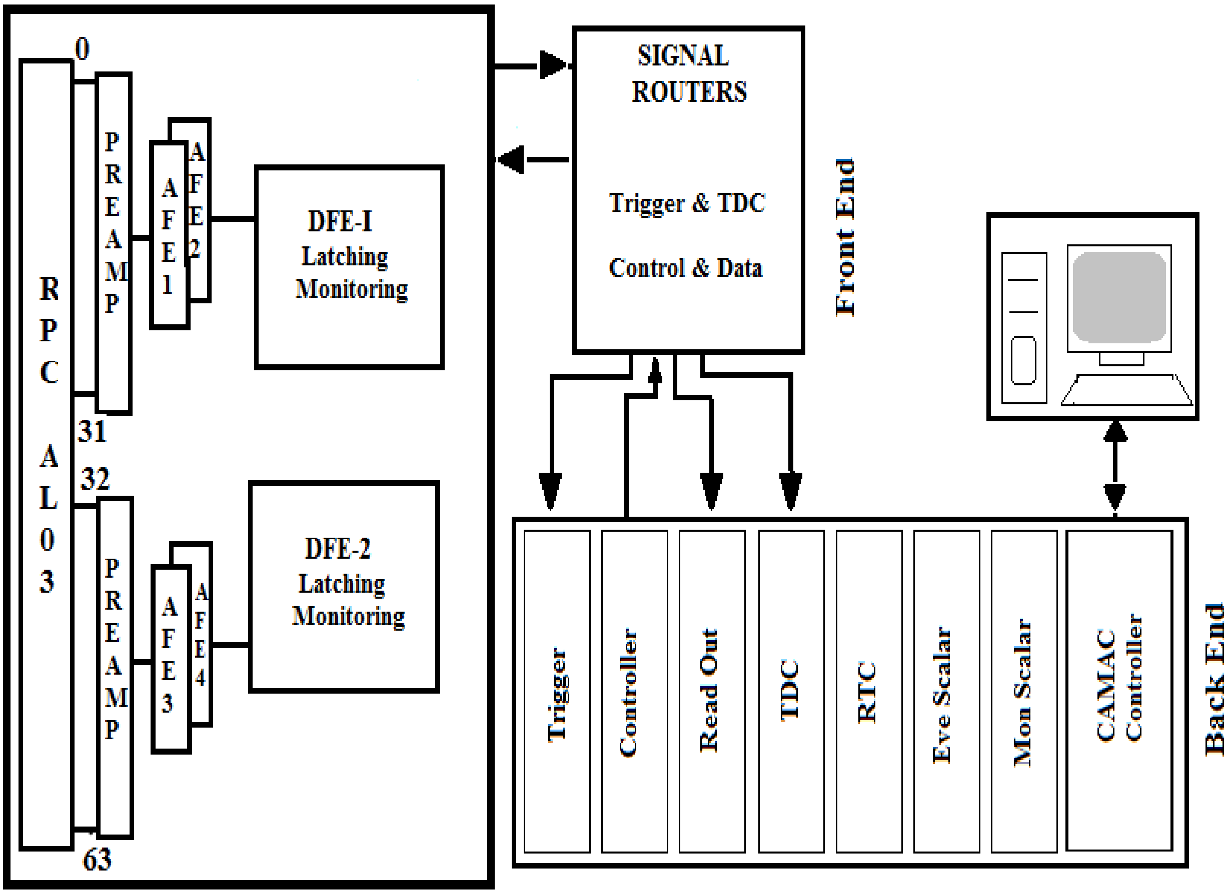

Fig. 8:- Block diagram or electronics set up for X-plane of RPC.

2. Trigger logic:- The trigger logic picks up the event to be recorded. The basic principle of trigger generation is M × N fold coincidence where M is the layer coincidence of M consecutive signals out of 32 pickup signals and N is the no. of consecutive layers satisfying M fold layer coincidence. The M×N folds implemented are 1×5, 2×4, 3×3, and 4×2. Trigger is implemented in three stages. In the first stage i.e. trigger_0 logic, the shaped discriminator pulses from every 8th channel of 32 channels in the X-plane of RPC are logically ORed to get eight T0 signals. Similar signals are obtained for the Y-plane of each RPC. These eight T0 signals are logically ANDed to achieve the required Mfold triggers (T1 signals – 1F, 2F, 3F, 4F) in each layer. The trigger_1 logic is implemented in the Front End Processing (FEP) module using CPLDs. The M-fold signals (T1) from X-plane of all RPC layers are routed via Trigger and TDC Router module to the Final Trigger module in the CAMAC crate. The M×N coincidence logic (T2 trigger) is implemented in this module using T1 signals. T2 signals from X-plane and Y-plane are logically ORed to get the final trigger output which indicates the valid event to be recorded. The trigger generation rate is monitored with in-built scalars. All the triggers are maskable.

3. <u>Signal Routers</u>:- Trigger and TDC router receives the M-fold T1 signals and TDC signals from the FEP modules and routes them to the Final Trigger module and TDC module respectively. Control and Data Router receives control signals from the INO Controller module and routes them towards the FEP modules. It also receives data and feds the same to the Readout module.

4. Data Acquisition:- A PC based data acquisition system is built using CAMAC standard modules in the back end which is connected to the front end with a fast serial link. The two main functions of the DAQ system i.e. Event Data Recording and Monitoring is controlled by the INO Controller module housed in the CAMAC crate. The Front End processing module of X and Y planes of all the RPCs are daisy chained into two groups for event data recording. At present no daisy chains are used for monitoring purpose and hence all the RPCs can be monitored simultaneously. On a final trigger, CAMAC controller invokes an interrupt handler routine where INO controller initiates data transfer from front end modules in a bit serial mode via daisy chain and data is buffered in the Readout module for further CAMAC readout. A set of 40 signals are selected in each monitoring cycle by the INO controller, which invokes interrupt handler at pre-defined monitoring period (10sec) where rates of the selected signals are recorded and the next set of signals are selected for monitoring. The set of signals monitored in each cycle consist of 32 pickup signals of one RPC, 4 fixed frequency signals and 4 M-fold trigger_1 (1F, 2F, 3F, 4F) signals. The next 32 pickup signals of the same RPC are monitored simultaneously through the second DFE. The need is to record the event time, three dimensional interaction tracks and its direction in the detector. The event initiated by the final trigger records the Boolean status information of all pickup channels contributing to the track information. The relative time of interaction of track at each layer is recorded in the TDC which gives the directional information.

CHAPTER- 3:- <u>RESULTS</u>

3.1) EFFICIENCY PLOT:-

The efficiency of the right (Strip no.21), main (strip no. 20) and left (Strip no. 19) strips is calculated and plotted as a function of voltage applied. The main strip will show the maximum efficiency as the 2cm paddle was along the main strip.

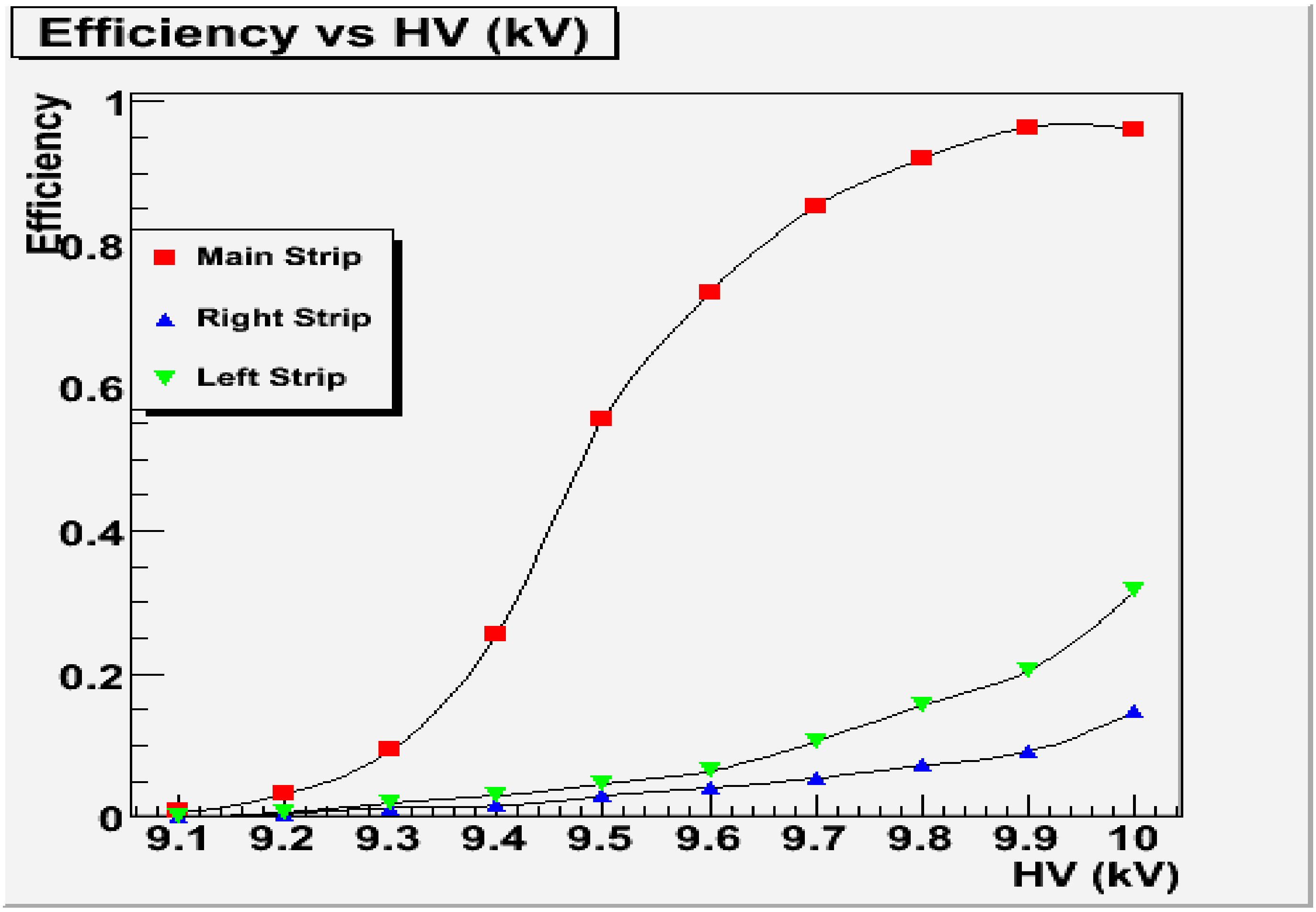

Fig. 9:- Efficiency plot.

3.2) I-V PLOT FOR BOTH THE GLASS PLATES OF RPC AL06.

A) FOR CHANNEL A (+ve HIGH VOLTAGE):-

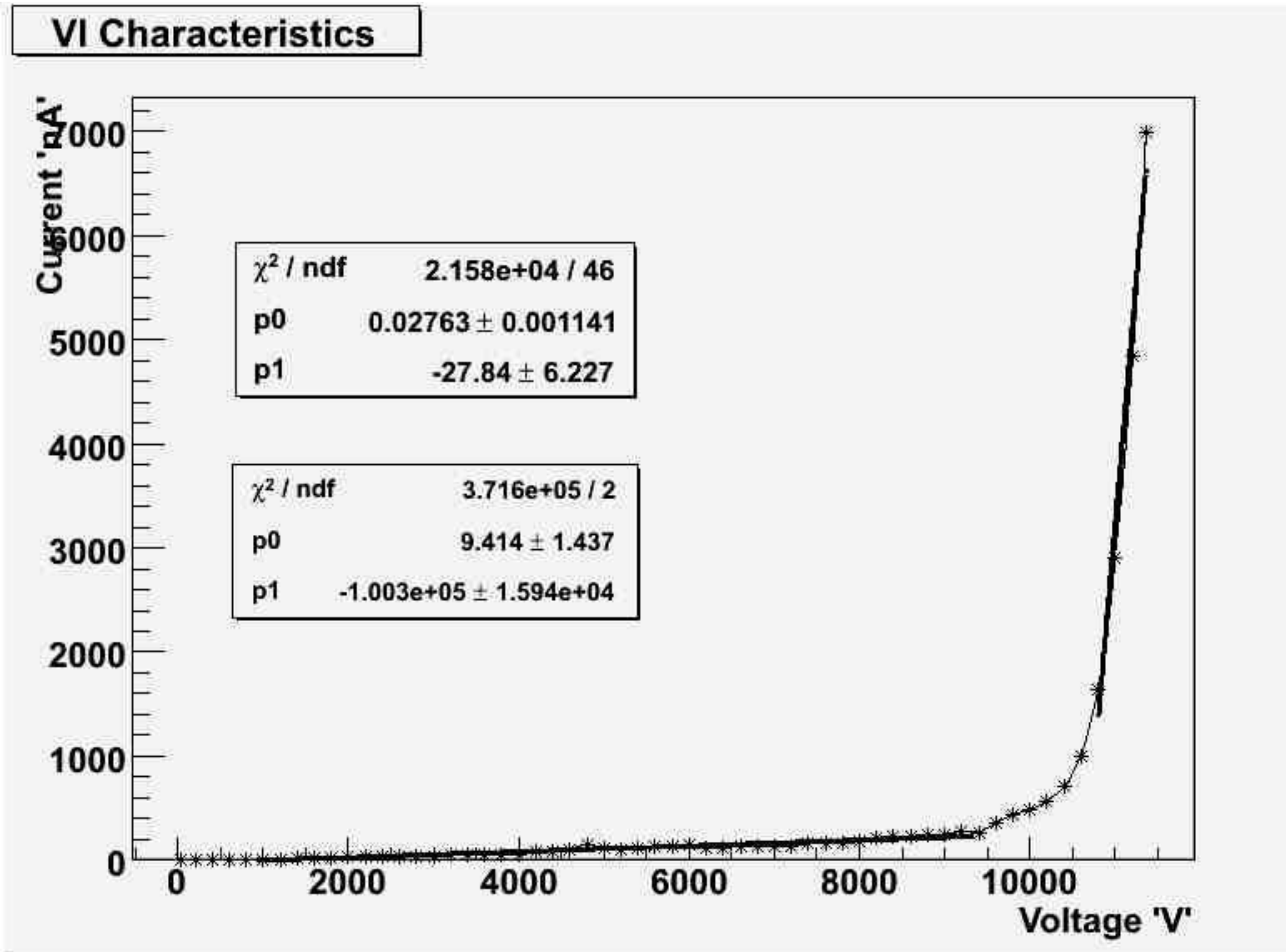

Fig. 10:- V-I characteristics for channel A, i.e +ve high voltage.

B) FOR CHANNEL B (-ve HIGH VOLTAGE):-

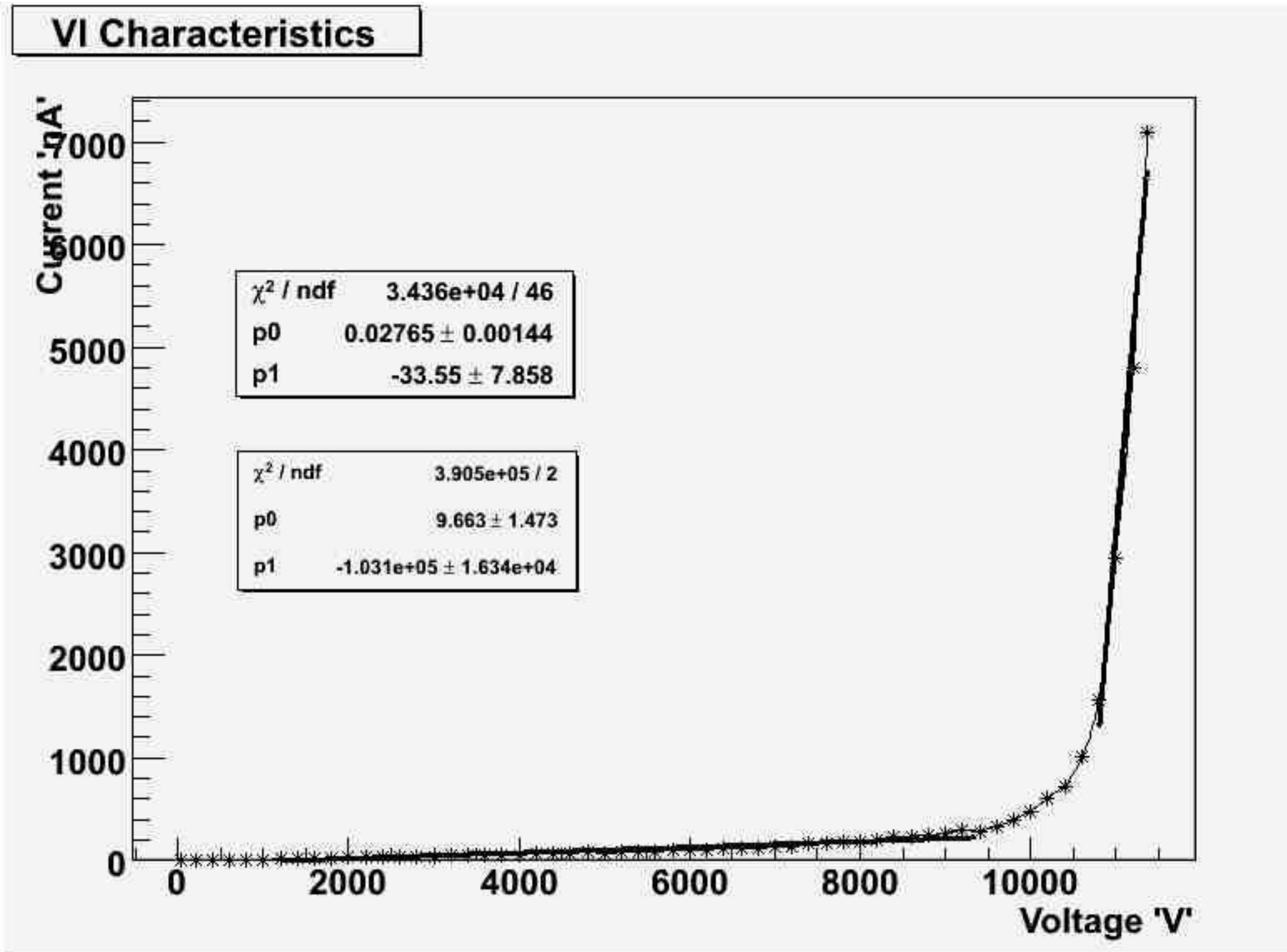

Fig. 11:- V-I characteristics for channel B, i.e -ve high voltage.

3.3) NOISE PLOT:-

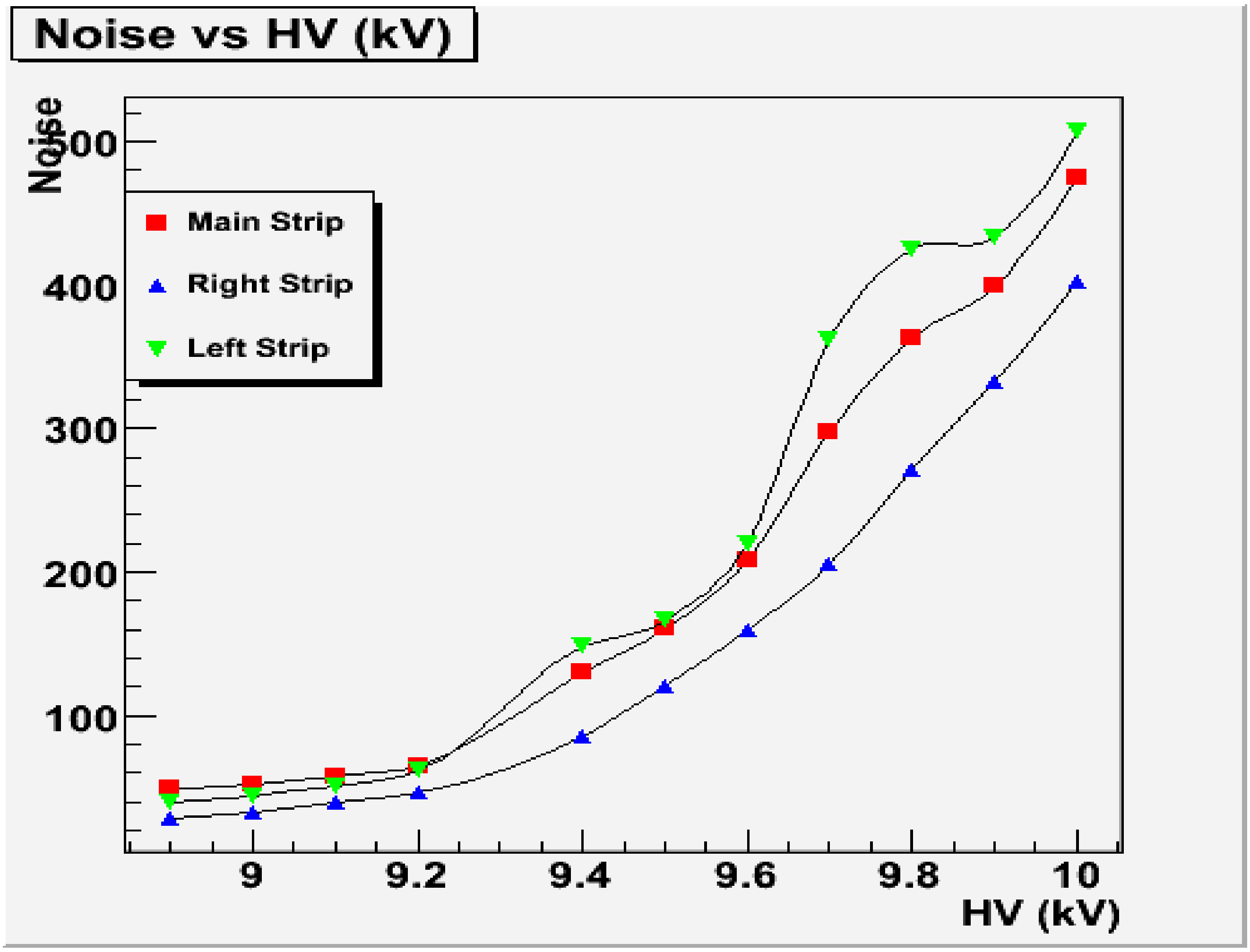

Fig. 12:- Noise rate v/s voltage plot.

3.4) TDC PLOT:-

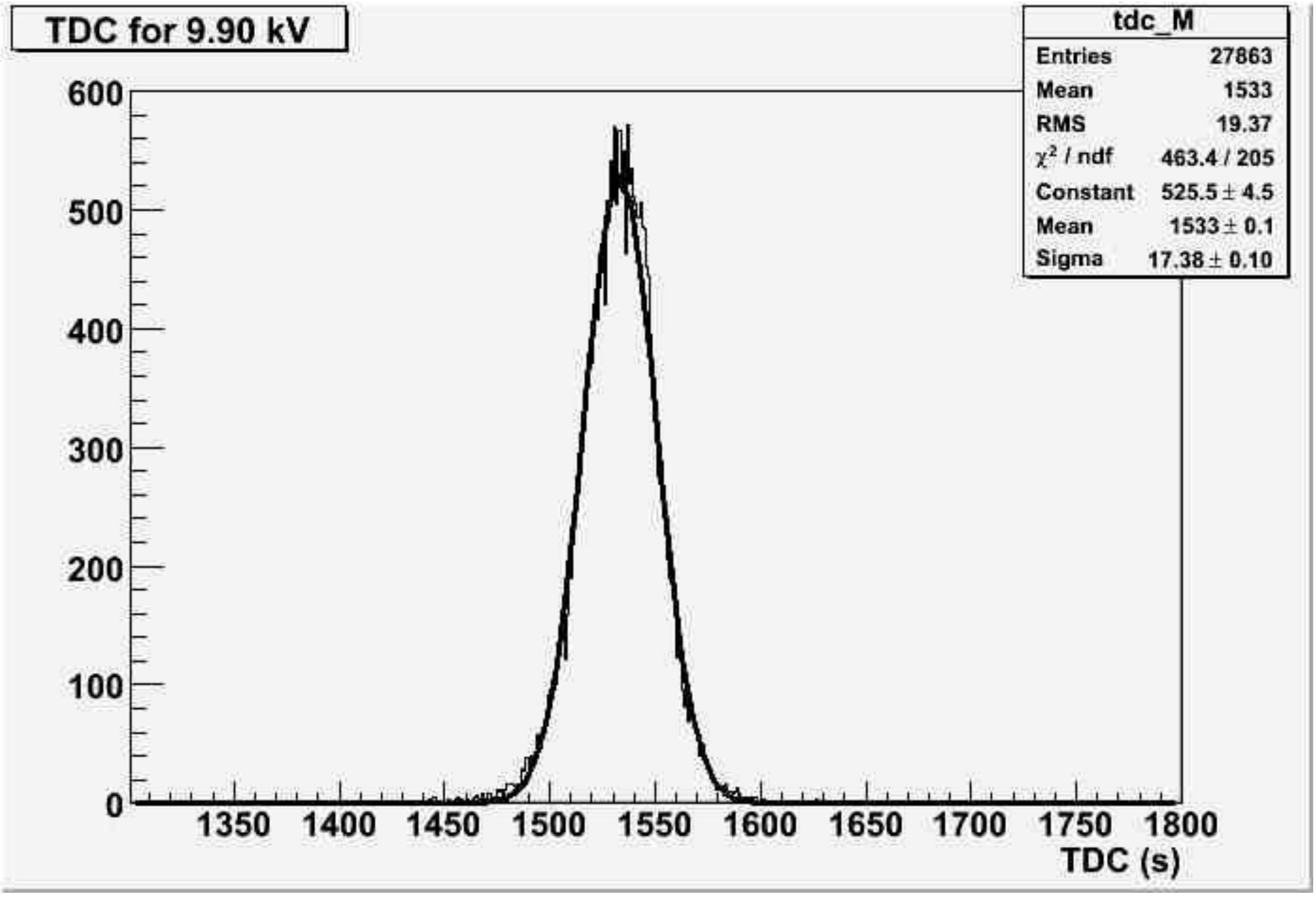

Fig. 13:- TDC plot at 9.9 kV.

3.5) RESULTS:-

1) From the efficiency plot (fig.9), the plateau region for the main strip was achieved at 9.9 kV with an efficiency of ~95%.
2) From the V-I plot for channel A, we get,
    a) Gap resistance = 36.1925Ω at voltage ≤ 9 kV.
    b) Gap resistance = 0.10622Ω at voltages above 10kV.

3) From the V-I plot for channel A, we get,
    a) Gap resistance = 36.16637Ω at voltage ≤ 9kV.
    b) Gap resistance = 0.10349Ω at voltage above 10 kV.
4) From the TDC plot (fig. 13), the time resolution of the RPC was found to be 17.38ns (~18 ns).

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