Study Of Resistive Plate Chambers(RPC)

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My special thanks to Prof. N.K. Mondel and Dr. B. Satyanarayana for providing me the lab facilities and also for their extensive help, co-operation and devoting their precious time for me. I also thank to all those in the lab for helping me, making my visit enjoyable.

Introduction:

Resistive Plate Chambers(RPC) act as the active detector element for the INO experiment. These RPCs can measure the momenta and energies of different particles and can be used for their study. These gas detectors are based on the process called ionisation which is produced due to the passage of the charged particles under the uniform electric field applied on the resistive electrodes.

Principle of Operation of RPC:

Glass RPC is a parallel plate gas detector which utilises a constant and uniform electric field produced by two parallel electrode plates. One of which is made of a material with high bulk resistivity. These two electrodes are 2mm thick and are apart 2mm by means of spacers. When a suitable gas mixture is flown through the gap between the two electrodes, the gas is ionised by the charged particle. Then, the free charge carriers that are deposited in the gas gap trigger avalanche of electrons and produces a discharge. This discharge induces an electric signal on the two pickup strips and from these pickup strips the information is carried to the readout module. Also, in this process the Photons produced due to the recombination are absorbed by the ultra-violent absorbing gas present in the gas mixture.
The RPC can be operated in two modes, which depends on the voltages used for their operation and the gas composition. These are:

- Avalanche mode: In this mode, the primary ions produced by the charged particle under the electric field produces secondary ionizations on having collision with the gas molecules. The electric field produced by the ionized particle is opposed by the applied field and hence the multiplication process stops after some time. Then, the charges drift towards the electrodes and are collected. This mode operates at the low voltage and the pulses have their amplitude of the order of few mV. The gas composition in this mode is Freon(R134a):Isobutane:SF_6 as 95.15:4.51:0.34
- Streamer mode: In this mode, the secondary ionization continues until there is a breakdown of the gas and continuous discharge takes place. This is operated at high voltages and the pulses have their amplitude of the order of 100-200mV. The gas composition in this mode is Freon(R134a):Isobutane:SF_6 as 62:8:30

Work Done at TIFR:

Construction of 30cm ᚷ 30cm RPC:

Two ASII 30cm ᚷ 30cm glass, its four edges cut with the right dimension making 45^{o} angle, was taken. The glass was throughly cleaned with alcohol then labolene solution(soapy solution, can leave for 5 minutes before washing) and distilled water. Then, it is wiped with tissue paper and was kept for drying.

Spacers of equal size were cut and connected to four nozzles such that the glass sits in it. Before fixing everything, glass, spacers and button were cleaned with alcohol. Then, glue was applied to fix the button a the centre of the bottom glass and also applied to fix it with the glass at the top. Then, between the spacer and glass the glue was applied on the top and bottom side of glass and was kept for drying.

After gluing, uniform graphite coating was applied(with spray) on top-bottom surface of RPC, leaving 1 cm all sides from the corner and then its surface resistance was measured(should be of the order of ~1 MΩ). Its leakage test was also done successfully.

Gas Leakage Test:

Gas leakage test was performed for the 1m ᚷ 1m AB09 and AB08 RPC with the use of U-shaped manometer tube, which was filled with water. For this, the two diagonal sides(for gas inlet and outlet) of RPC were sealed. The other two sides were kept such that, from one of the side a continuous flow of pressurised(above the RPC the lead bars were put to pressurise the gas) Freon gas i.e. R134a was passed with the pressure of 0.5kg/cm^{2}. The other diagonal side of this was connected to the manometer with the tygon tube. Then, when the pressure of the gas was released the first reading of the manometer(the two lower meniscus level) was noted, along with this stopwatch was also started and noted the time also. So, the frequent readings were noted for the fall in the manometer reading. This experiment was performed for about one and half hour time. Precautions should be taken to avoid the fall in the manometer reading(gets affected with the increase in the pressure or sometimes the meniscus may be deformed due to the droplets

present already in the tube) as what we observed.
Along with RPC, this experiment was performed for the tygon tube and blocked tube also to check wethear these tubes were alright. The results for this experiment are here:

Leak test AB09 Ex-1

Time in sec	RHS (mm)	LHS (mm)	Difference R-L (mm)
0	15	0	15
120	12	2	10
360	9	4	5
1320	7	6	1

Leak test AB09 Ex-2

Time in sec	RHS (mm)	LHS (mm)	Difference R-L (mm)
0	41	24	17
120	36	26	10
300	34	27.5	6.5
660	31.4	29	2.4
3600	30.5	30	0.5

Leak test Ex-3 Only Tygon Tube

Time in sec	RHS (mm)	LHS (mm)	Difference R-L (mm)
0	47.5	19.5	28
840	46	19	27
1800	46	19	27

Leak test Ex-3 Tygon Tube + Blocker A

Time in sec	RHS (mm)	LHS (mm)	Difference R-L (mm)
0	37	25.5	11.5
360	35	27	8
900	33.5	28	5.5

1620	32.5	28.5	4

Leak test Ex-3 Tygon Tube + Blocker B

Time in sec	RHS (mm)	LHS (mm)	Difference R-L (mm)
0	46	18	28
195	44.5	20	24.5
387	43	21.5	21.5
1158	41	22.5	18.5

Due to the fall in the blocker B that tygon tube was replaced with blocker C.

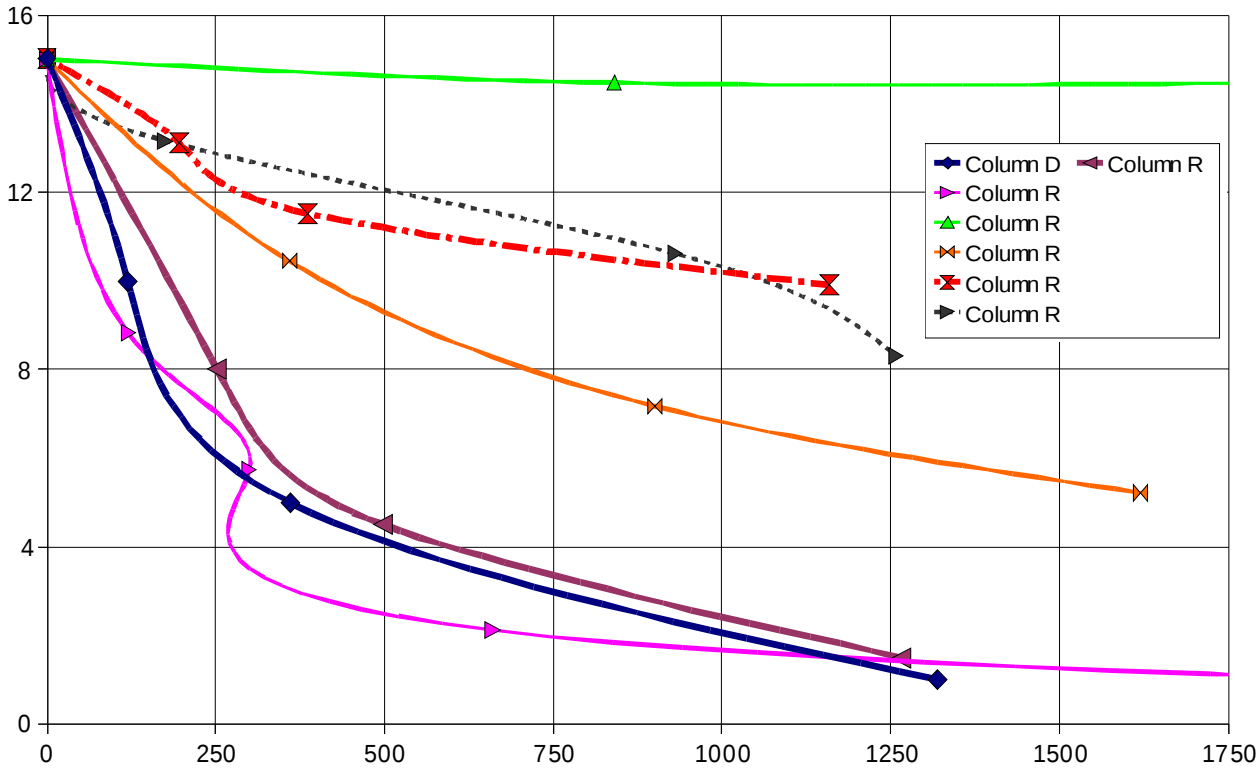
Leak test Ex-3 Tygon Tube + Blocker C

Time in sec	RHS (mm)	LHS (mm)	Difference R-L (mm)
0	49	16.5	32.5
175	46	17.5	28.5
930	43	20	23
1257	40	22	18

This fall of manometer reading may be due to the RPC which was used for this experiment.

Leak test AB09 Ex-3 Tygon Tube + Blocker C (with a difference of 20mm)

Time in sec	RHS (mm)	LHS (mm)	Difference R-L (mm)
0	38	23	15
252	34	26	8
498	32	27.5	4.5
1266	30	28.5	1.5



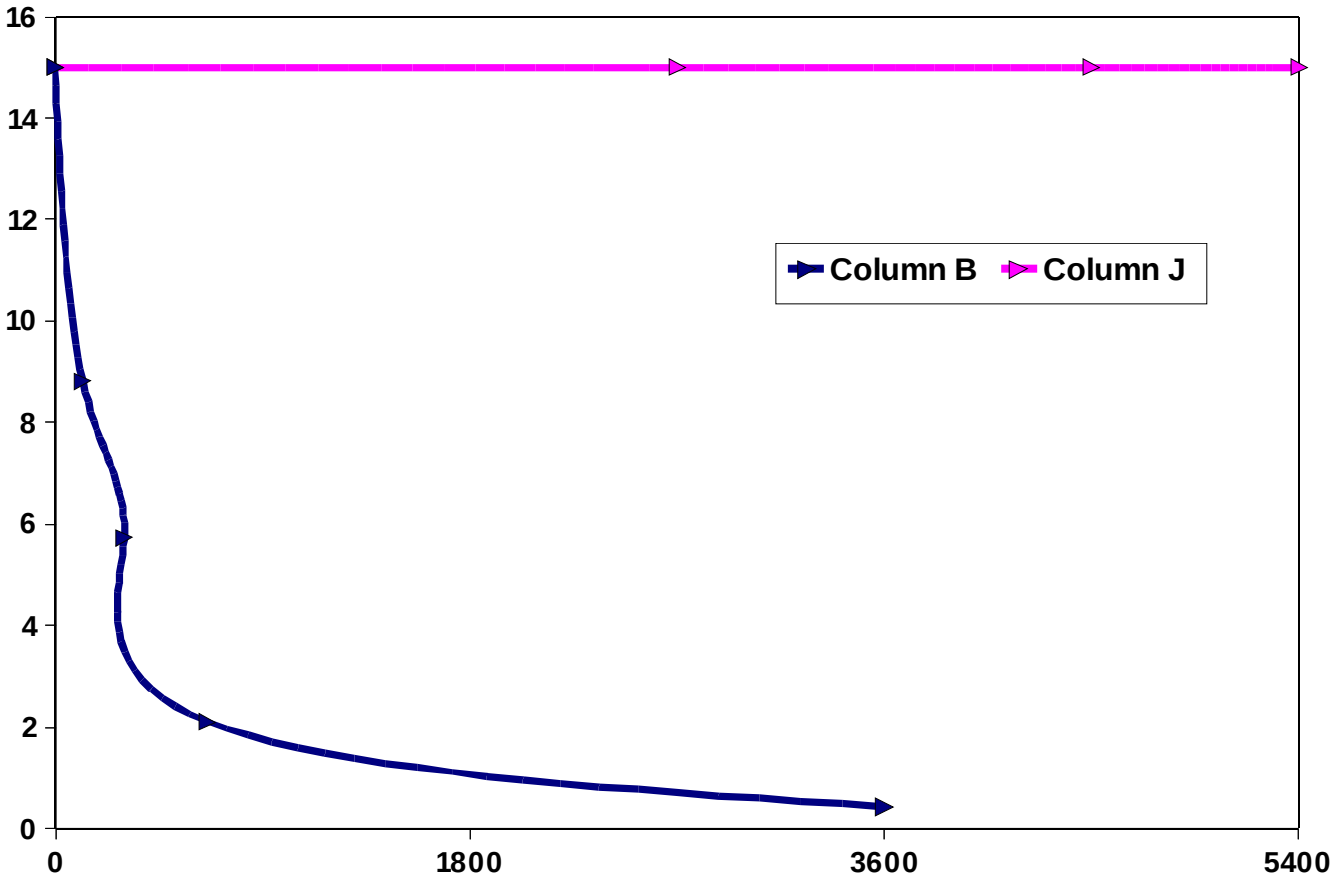
(where the different lines denotes, Blue-RPC test, Pink-RPC test(difference of 2mm), Green-Tygon tube, Orange-Tygon tube+ Blocker A, Red-Tygon tube+ Blocker B, Black-Tygon tube+Blocker C, Purple- Tygon tube+Blocker C(differernce of 2mm))

Leak Test for AB09 (after gluing)

Time in sec	Difference R-L (mm)
0	15
120	8.82
300	5.74
660	2.12
3600	0.44

Leak Test for AB09 (after re-gluing)

Time in sec	Difference R-L (mm)
0	15
2700	15
4500	15
5400	15

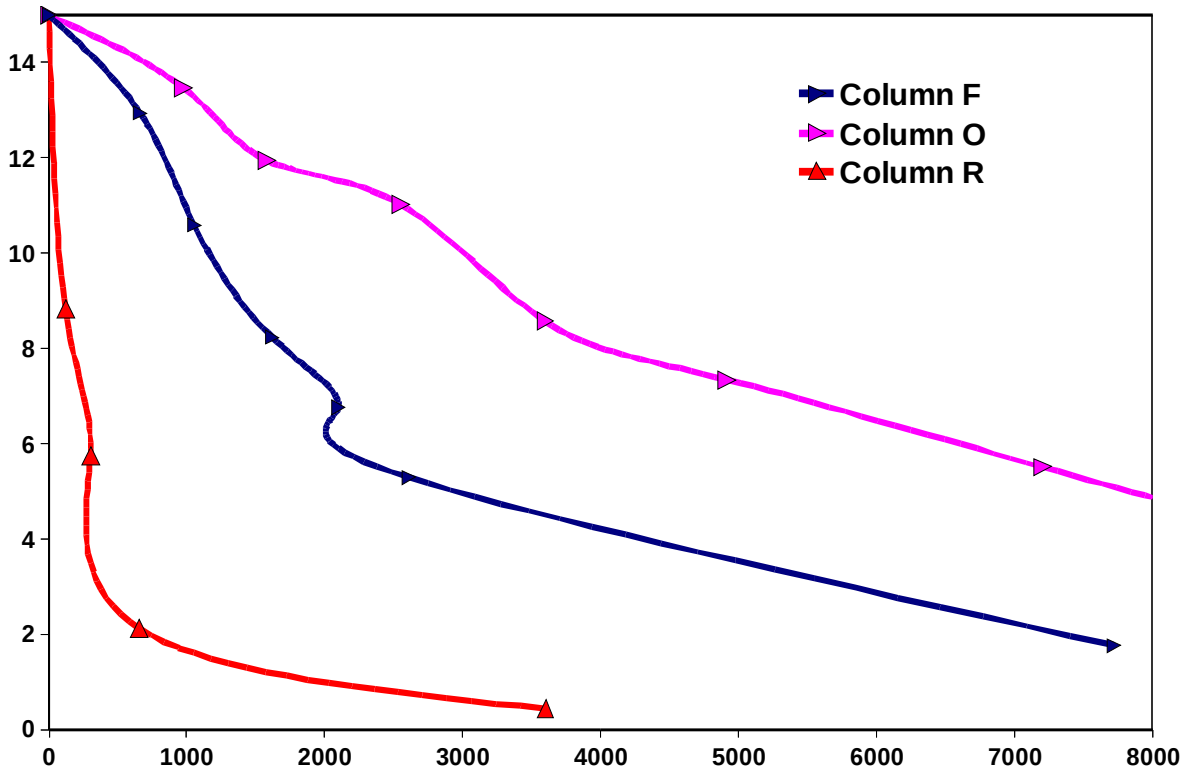


(Where, B-without gluing, J- after gluing. Their comparison was shown here.)

Leak Test for AB08 RPC

Time in sec	Difference R-L (mm)
0	15
662.55	12.94
1053.64	10.59
1618.64	8.24

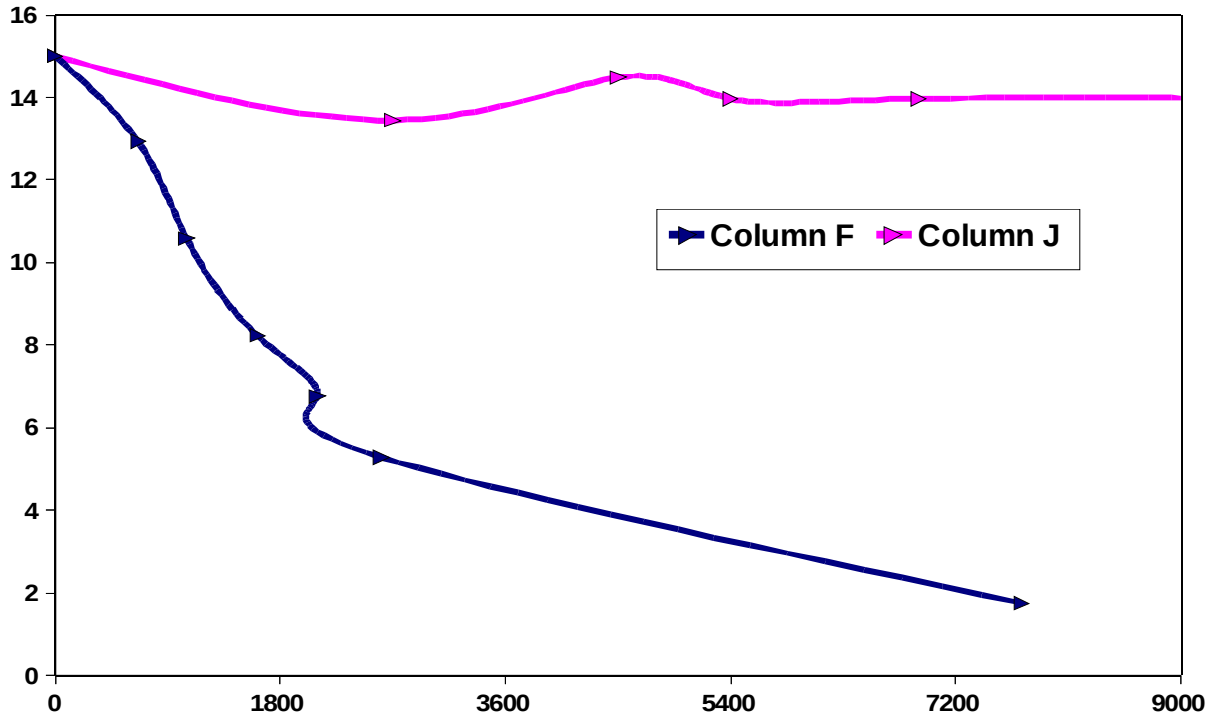
2098	6.76
2607	5.29
7723	1.76



(Where, F-AB08 without gluing, O-AB09 after gluing, R-AB09 without gluing, done for the comparison between the two RPC)

Leak Test for AB08 after gluing

Time in sec	Difference R-L (mm)
0	15
2700	13.45
4500	14.48
5400	13.97
6900	13.97
10200	13.97
13860	13.97



(Where, F-before gluing, J-after gluing, here shown the comparison between the two)

From the 1st and 3rd graph, it is concluded that there was a leakage in the AB09 and AB08 RPC. So, these were glued to avoid the leakage. But, before gluing the RPC we checked the leakage with the Gas Leak Checker to find those particular points in the RPC from which the gas was leaking. For this, gas was passed inside the RPC on one end and the other end was connected to a bulb with oil(non reacting with the gas) in it, so that when the gas was passed then the bubbles which appeared in the bulb were countable. The other two sides were blocked. The gas leak checker was kept at high scale for more senstivity. The gas leak checker have a suction pump at its tip which was used to check any leakage at the glued sides of RPC. Increase in the reading of the checker(making beep sound) showed that there was a leakage of the gas at some points and that point was marked for re-gluing. 2nd and 4th graph shows the comparison of the two RPCs before and after gluing.

Gluing of the RPC:

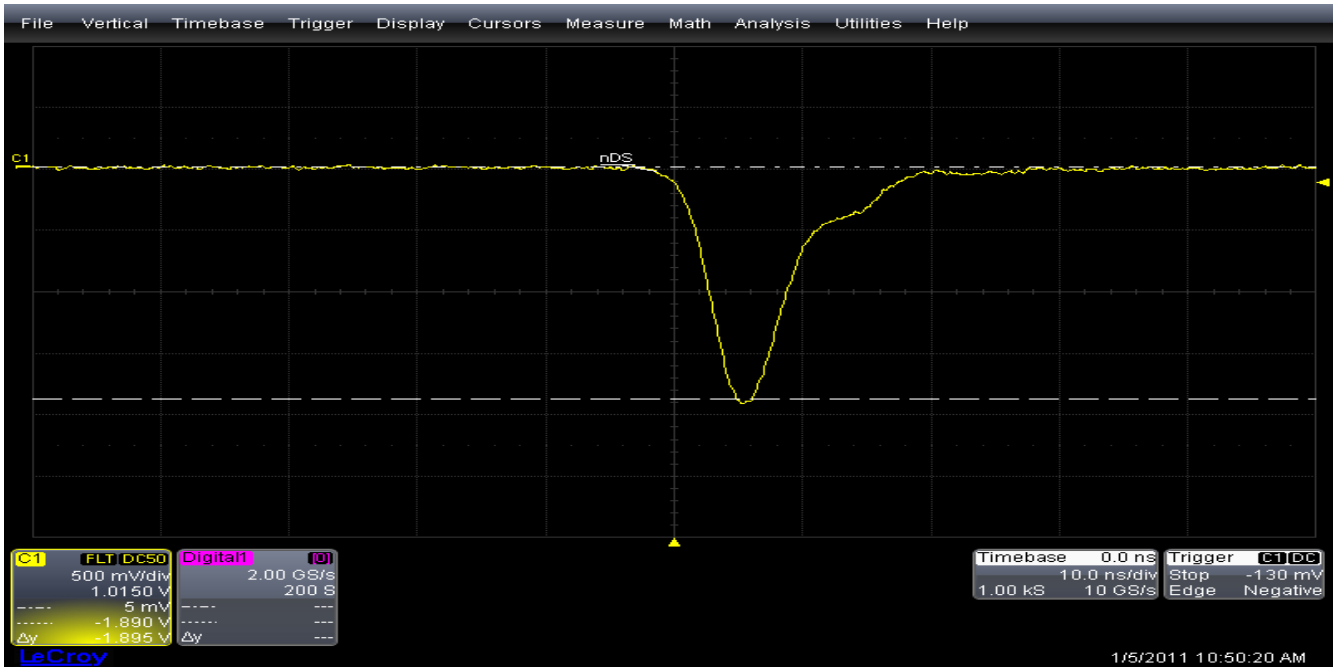
The glue used(non reacting with the gas and non-conducting) is an epoxy

adhesive, which is in a duo-pack cartridge. That glue was mixed with stirrer in the syringe and was then applied over the affected area of all sides(up-down) of the RPC with all outlets blocked. Whenever, a bubble appeared due to gluing then this was breaked with needle. This glue takes 6-8 hours for drying in the normal temperature conditions but, it took more than 8 hours for drying due to less temperature inside the lab.

Resistance measurement of Pick-up Panel:
Before packing the RPC, resistance of the pick-up panel was measured for the contacts and also for the two consecutive copper strips.

Packing of RPC:
After gluing the RPC, it was packed before putting into the stack of 12 layered 1m ⨯ 1m RPC. For this, two mylar sheets cleaned with alcohol were attached (with kepton tape) with the Pick-up panel which was put above the RPC. Again, two mylar sheets were attached with top surface of RPC. A Pick-up panel was placed above that surface. All the contacts of Pick-up panel were connected to the Pre-amplifiers. After packing it was moved to the 12 layered stack for 1m ⨯ 1m RPC. Gas was passed through RPC with its two diagonal sides blocked.
All the above procedure was done for the AB08 RPC also.

The RPC Pulse:
The AB09 RPC was connected to oscilloscope and with this the pulse shape, rise time, pulse height can be studied. The RPC pulse is:

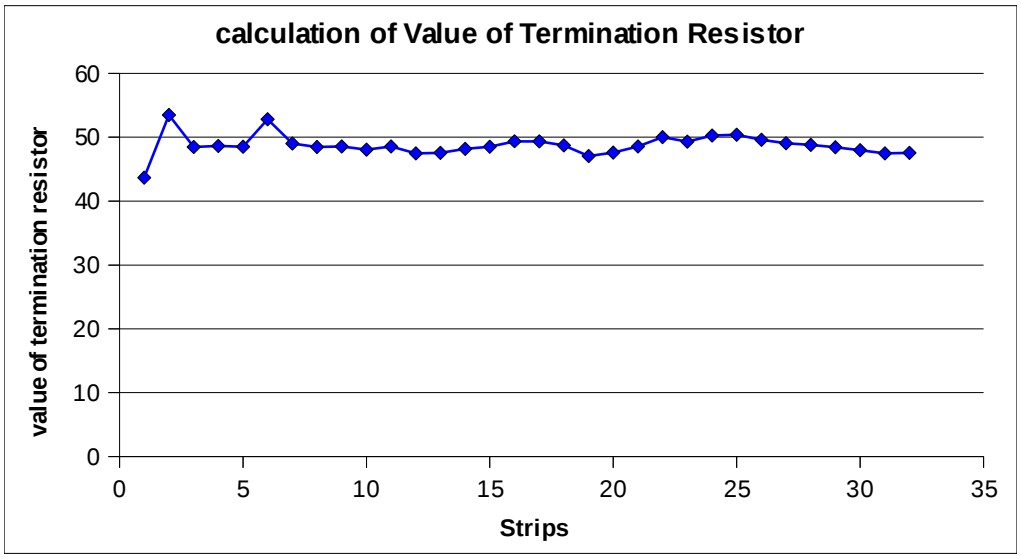


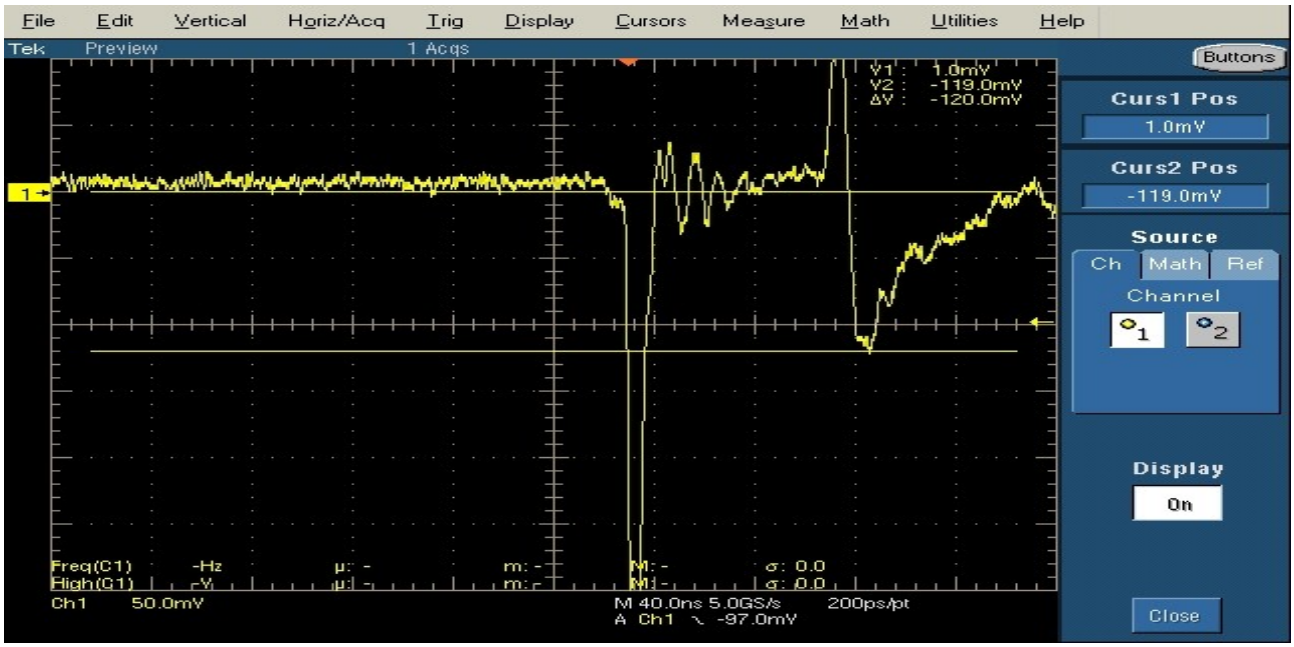
<u>Measurement of the Termination Resistance</u>:

To determine the termination resistance of the Pick-up panel, a set-up was used. In this set-up, a pulser that sends a pulse through a 50 ohms cable and that signal gets into the impedance matching circuit where it passes on to a 120 ohms cable without being distorted. The 120 ohms cable is about 10 m long and it was branched to an oscilloscope for study. The end of the 120 ohms cable was connected to the 32 strip Pick-up panel. For each strip, a pulse was sent, the pulse encountered a front-end reflection at the front of the panel and it also encountered a back end reflection at the back. The backend reflection interferes with the original signal and needs to be eliminated. For this, a terminating resistor of a value equal to impedance of the strip had to be connected to the other end of the panel. This was done by connecting a potentiometer and adjusted its resistance value until we get the flattened/terminated output on the display of the oscilloscope. The value of the terminating resistor(measured with multimeter) and the oscilloscope display were recorded for the further analysis. This procedure was carried out for every strip. The results obtained are:

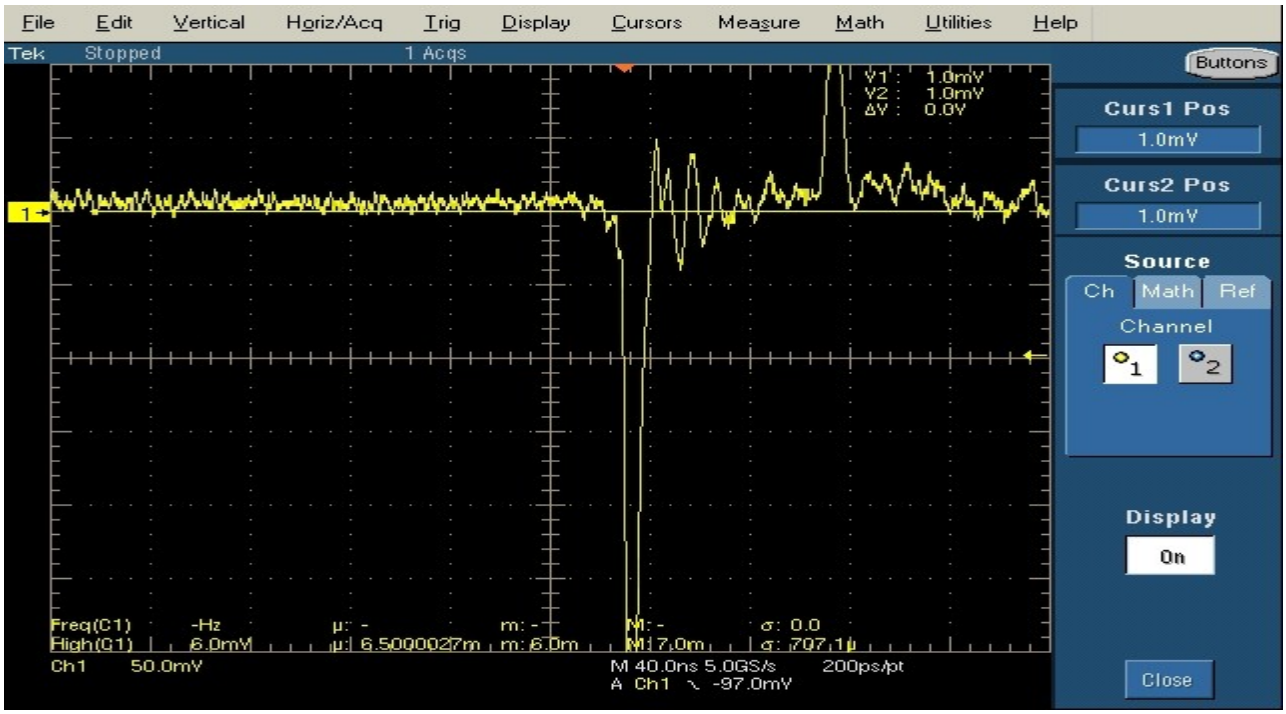
Results:

Input Signal=-440mV	
Strip No.	Termination Resistor
1	43.67
2	53.51
3	48.49
4	48.65
5	48.53
6	52.81
7	49.03
8	48.47
9	48.54
10	48.05
11	48.57
12	47.46
13	47.57
14	48.18
15	48.53
16	49.38
17	49.36
18	48.73
19	47.05
20	47.6
21	48.57
22	50.01
23	49.3
24	50.29
25	50.42
26	49.6
27	49.06
28	48.81
29	48.43
30	47.96
31	47.47
32	47.55





In the above image, first peak is of input signal and second peak is for the reflected wave.



The above image is for the flattened/terminated reflected wave.

Gain of +ve Pre-amplifier:

Pre-amplifiers, amplify the weak signals from a detector and drive the signals through the cable that connects the preamplifier with the rest of the equipment.

Three types of preamplifier exist:

a) Voltage senstive

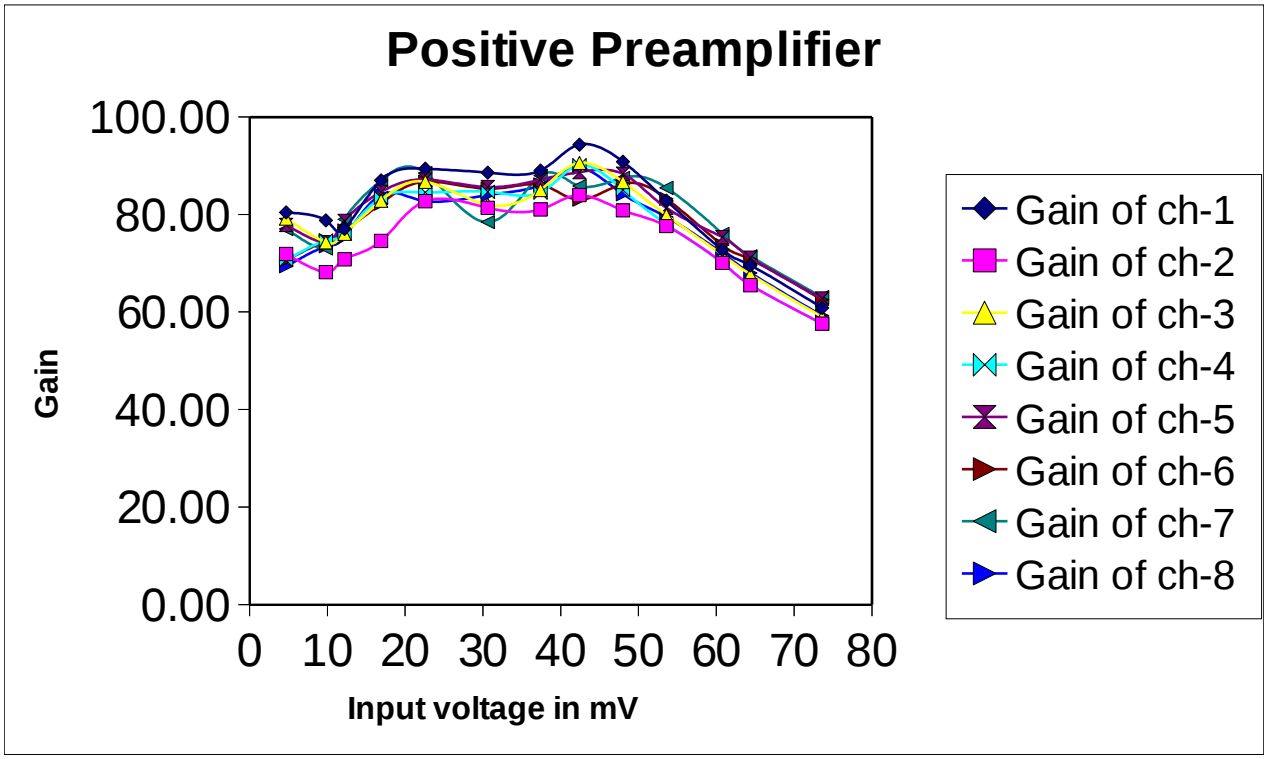
b) Current sensitive

c) Charge sensitive.

Out of the three types, voltage sensitive is the more conventional. It amplifies any voltage which appears at its input. Since, preamplifiers also reduces noise, thus to eliminate the noise, gain of the preamplifiers is necessary to view the performance of the preamplifier. Gain of preamplifier is ratio of output voltage to input voltage. We obtained the gain for the +ve voltage sensitive preamplifier - HMCPAP(ideally it should be 80-90). The results are here:

Input (mV)	Gain of ch 1	Gain of ch 2	Gain of ch 3	Gain of ch 4	Gain of ch 5	Gain of ch 6	Gain of ch 7	Gain of ch 8
4.7	80.43	71.91	79.15	70.64	77.87	70.64	77.02	69.36
9.8	78.78	68.16	74.29	74.69	74.29	74.69	73.06	73.47
12.2	77.05	70.82	76.07	76.07	78.69	76.72	79.02	75.41
16.9	86.98	74.56	83.43	83.43	84.62	82.25	86.98	84.02
22.6	89.38	82.74	84.51	84.51	87.17	86.73	88.50	82.74
30.6	88.56	81.37	84.64	84.64	85.62	85.29	78.43	83.99
37.4	89.04	81.02	84.49	84.49	87.17	86.10	87.97	86.10
42.4	94.34	83.96	90.09	90.09	88.68	83.02	85.85	89.62
48	90.83	80.83	85.00	85.00	88.33	86.25	87.50	84.17
53.6	82.84	77.61	77.99	77.99	81.34	83.21	85.45	79.48
60.8	72.70	70.07	70.07	70.07	75.33	73.68	75.99	72.04
64.4	69.57	65.53	65.53	65.53	71.12	70.81	71.43	68.01
73.6	60.87	57.61	57.61	57.61	62.77	62.50	63.04	59.24

(Where, Gain of preamplifier=output voltage/input voltage)



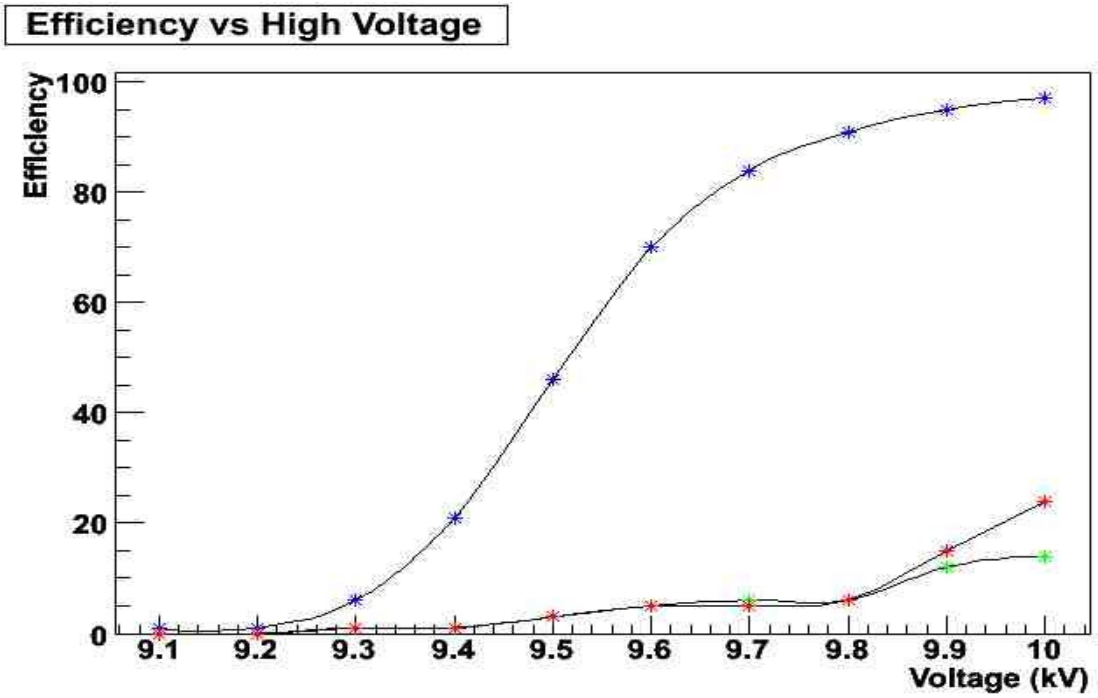
<u>Calculation of Efficiency</u>:

We have calculated efficiency of 2m ᵡ 2m AL06 RPC (in avalanche mode) at different values of the high voltage with 4-fold coincidence from a set of scintillator paddles. The scintillator pulses are fed into a PMT base. The requirement for the trigger is that all four paddles register a coincidence. The data was taken for the analysis. Thus, the efficiency is calculated as:
Efficiency = (No. of times RPC actually fires)/(No. Of times it should fire)

Results:

The efficiency is calculated for AL06 RPC against the different values of high voltage

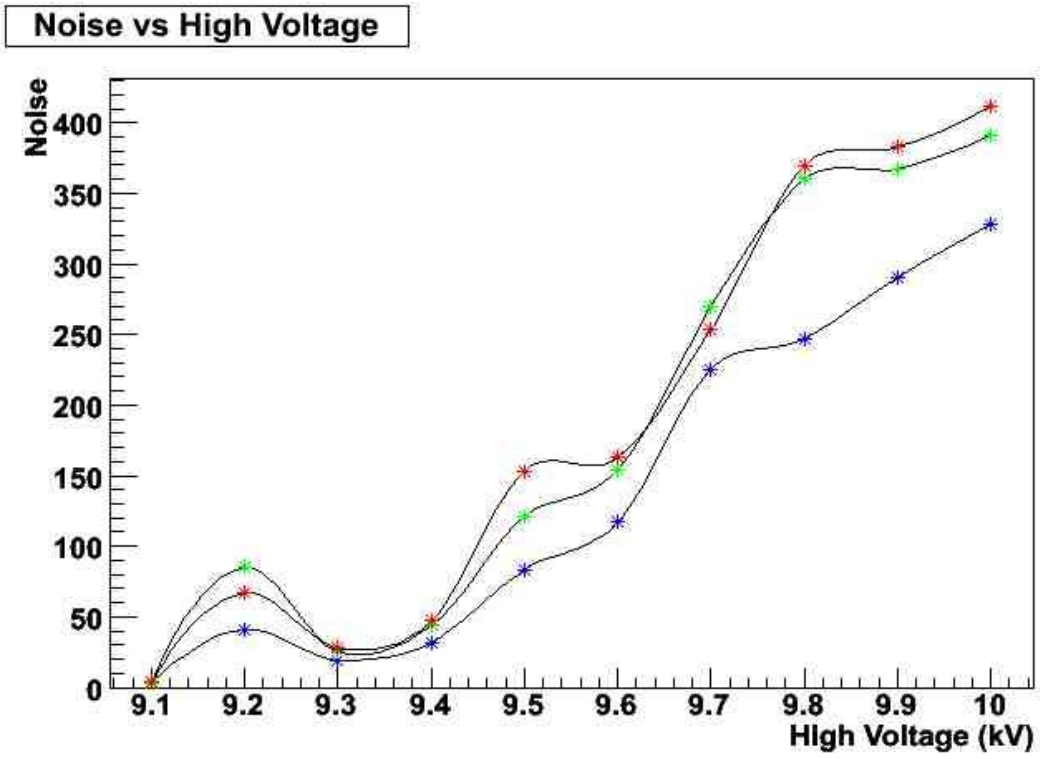
High Voltage(kV)	Main strip Efficiency(%)	X strip Efficiency(%)	Y strip Efficiency(%)
10	97	12	24
9.9	95	14	15
9.8	91	6	6
9.7	84	6	5
9.6	70	5	5
9.5	46	3	3
9.4	21	1	1
9.3	6	1	1
9.2	1	0	0
9.1	1	0	0



(Where lines denote, Blue- main strip, Green- X strip, Red- Y strip)

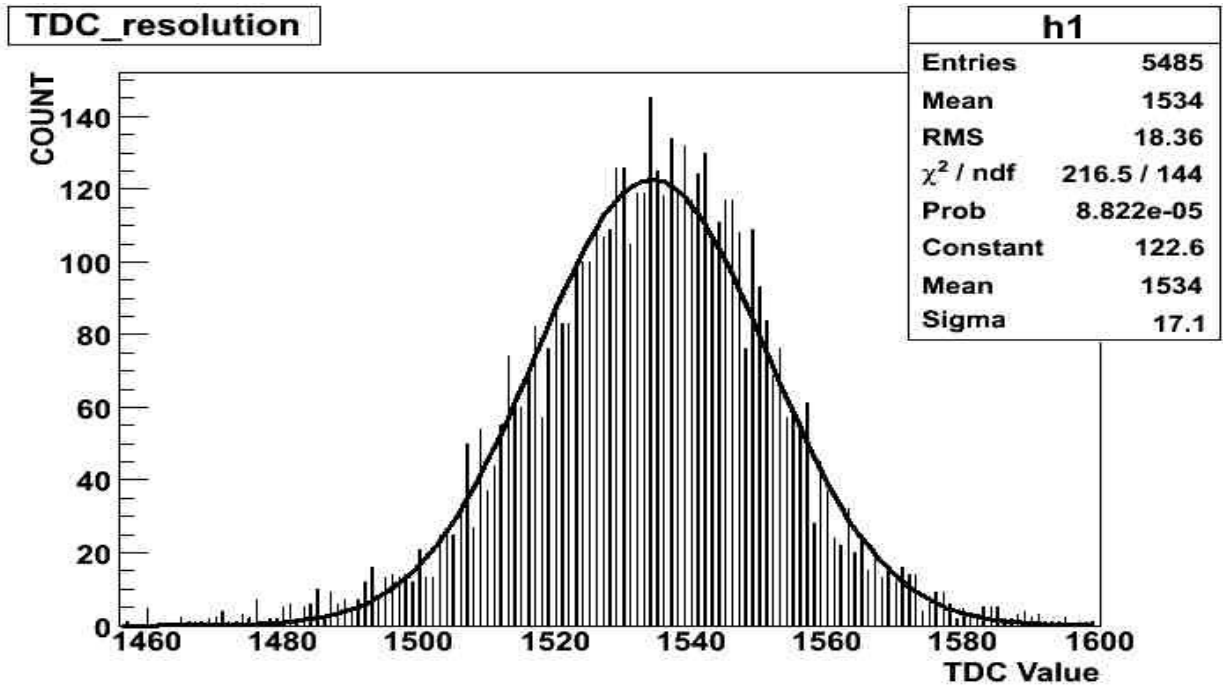
Noise vs High voltage is:

High Voltage(kV)	Main strip	X strip	Y strip
10	328.1	390.59	411.34
9.9	290.81	367.57	382.64
9.8	246.90	359.92	369.60
9.7	225.38	269.3	253.51
9.6	117.1	154.16	162.88
9.5	83.53	121.06	153.33
9.4	31.87	43.71	47.24
9.3	19.24	25.21	27.73
9.2	40.98	84.84	67.03
9.1	2.45	3.14	3.72



(Where the lines denote, Blue- main strip, Green- X strip, Red- Y strip.)

<u>TDC Resolution is:</u>

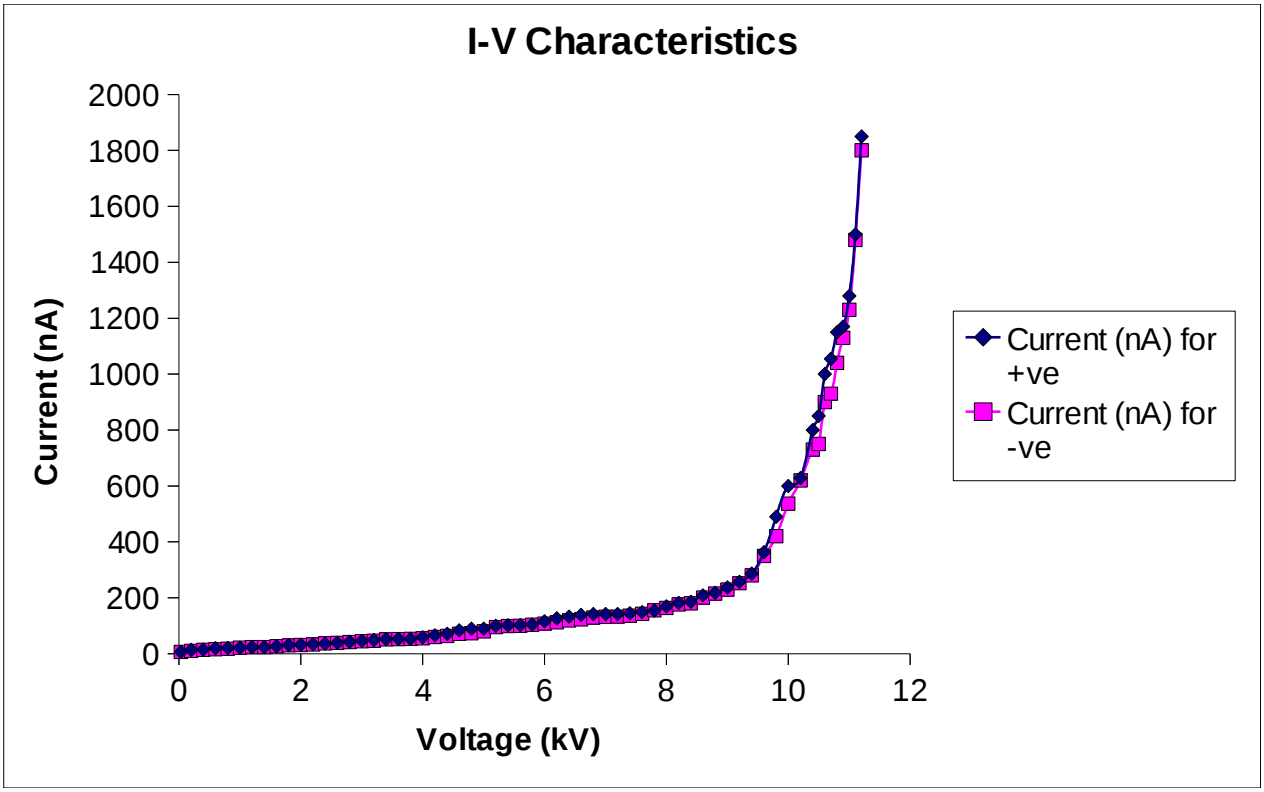


Results for I-V characteristics are:

Voltage (kV)	Current (IA) in nA	Current (IB) in nA
0.03	6	7
0.2	14	10
0.4	15	14
0.6	20	16
0.8	21	18
1	22	22
1.2	24	24
1.4	24	24
1.6	26	26
1.8	31	30
2	32	31
2.2	34	33
2.4	36	37
2.6	39	39
2.8	43	42

3	46	45
3.2	49	47
3.4	52	51
3.6	53	52
3.8	53	53
4	59	55
4.2	66	60
4.4	71	64
4.6	84	71
4.8	89	73
5	90	80
5.2	100	95
5.4	102	99
5.6	103	100
5.8	105	104
6	116	108
6.2	127	112
6.4	133	119
6.6	139	123
6.8	142	129
7	142	132
7.2	142	133
7.4	145	136
7.6	149	143
7.8	154	155
8	170	164
8.2	182	176
8.4	186	180
8.6	209	201
8.8	218	215
9	237	230
9.2	257	252
9.4	287	280
9.6	363	350
9.8	490	420

10	600	537
10.2	628	620
10.4	800	730
10.5	850	750
10.6	1000	900
10.7	1055	930
10.8	1150	1040
10.9	1170	1130
11	1280	1230
11.1	1500	1480
11.2	1850	1800



This plot shows that the breakdown voltage occurs at the high voltage ~10kV.

Summary of the work:

Resistive Plate Chambers serve as the active detector elements for the INO experiment. Making and maintaing its good performance is the most challenging task. I, during my visit at TIFR, tried to know more and more about RPC and the summary of my work is:

RPC of 30cm ⨯ 30cm was made and was tested for the gas leakage. Gas leakage test for different RPCs of 1m ⨯ 1m was done and were re-glued before their packing and then placed into the stack. For the pickup panel, its termination resistance was obtained. We obtained the gain of the +ve preamplifier. We obtained the efficiency of 2m ⨯ 2m RPC, its noise and tdc rate at high voltage were also obtained. I-V characteristics was also obtained for 2m ⨯ 2m with its voltage varying from 0-12 kV.