The fabrication of Resistive Plate Chamber and the study of its different components

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Abstract

This report aims at discussing some important aspects of fabrication of single gap Resistive Plate Chamber (RPC) that we have come across during the making of small (30cm by 30cm) as well as large (1m by 1m) glass RPCs. The different components of the readout system and experimental procedure to study those are discussed. The temperature variation of efficiency and its plausible reason is also discussed.

1 Introduction

The India-based Neutrino observatory is supposed to use 2m by 2m glass RPCs to detect charged particles and to reconstruct their tracks. The time I joined this project was the transition to making bigger RPCs compared to the previously made smaller RPCs in TIFR. So I have come accross the problems and learned to tackle the problems of making bigger RPCs and tested the performance of RPCs, their noise levels, pulse profiles, efficiencies, variation of efficiencies with temperature and humidity, and various other things. These studies will certainly help to make and understand 2m by 2m RPCs which will be used in the real experiment.

2 Fabrication of RPC

Three 1m by 1m and two 30cm by 30cm RPCs were made and in this report they will be referred to by their names as described in the following table.

RPC name	Glass type	RPC dimension	Surface resistivity
JS04	Japanese	30cm by 30cm	550KΩ
JR05	Japanese	30cm by 30cm	500KΩ
JB01	Japanese	1m by 1m	200KΩ
JB00	Japanese	1m by 1m	150KΩ
IB01	Italian	1m by 1m	1500KΩ

The surface resistivity values of the graphite coating are average; they vary about 40% with respect to the given value not only for the different side but also from place to place on the same side. All RPCs have a gas gap of 2 mm. All the glass thickness is 2mm except for the Italian one which is 3mm. Button spacers having three holes in it and width $\sim$ 1.8 mm.

The glasses are cut by diamond cutter to the appropiate size and the four corner edges are chamfered by a jig of right dimension to make a correct 45° angle, as shown in fig.1. The glasses are thoroughly cleaned with alcohol and then labolene and distilled water. After that the edge spacers, corner spacers (which are connected to the gas nozzle), button spacers (used for bigger RPCs) are cleaned with alcohol. For smaller RPCs the glasses are glued and then coated with graphite and for the bigger ones it is the other way round. The glasses used for making IB01 are already painted. Graphite coating is done on both sides of the RPCs leaving about 2cm gap from all the edges so that leakage of HV can't take place through the edge spacers.

After cutting and cleaning the glasses one glass was put on a plastic sheet and on top of the glass the button spacers were glued in a square array of

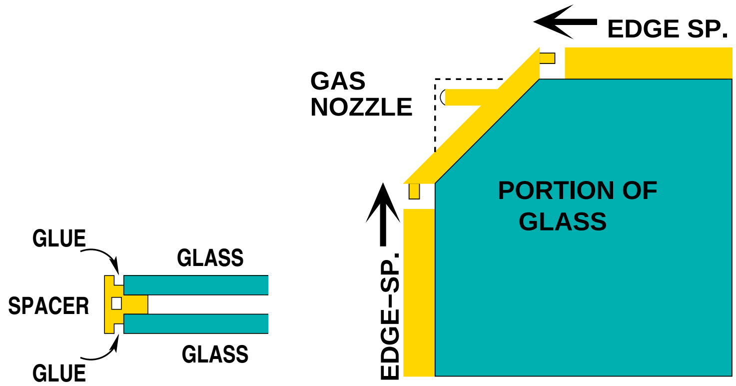

Figure 1: Left: Side view of a spacer, indicating the central gas gap and the position of the glass with respect to the spacers. Right: Top view of the corner piece of an edge spacer, with gas nozzle. The arrows indicate the manner in which the straight edges slot into corner piece. These type of spacers and nozzles are used in 1m by 1m RPCs.

side 12cm, the glue came out through the three holes of the spacers. Then the other glass plate was placed on those array of spacers. To put a uniform weight throughout the $1m^2$ area the whole set up was wrapped with the plastic sheets and the air inside the plastic sheets was sucked slowly to create partial vacuum and a pressure equivalent to 5cm of water column pressure. The set up was left for one day to be fixed with the spacers. Previously in case of making 30cm by 30cm RPCs lead blocks had been used to put the weight, but they couldn't put uniform pressure for $1m^2$ area.

The straight edge-spacers are also designed in "steps" so that the glass sits neatly within; ref Fig.1. There is a 1 mm gap where the glue can be poured (ref Fig.1). The central protrusion is 2 mm, thus supplying the required gap between glass plates. The central hole (shown in white in Fig.1) is where the wedge of the corner spacer fits. The glue was poured in the required gap and lead blocks were placed along the 4 sides to put pressure and the whole set-up was left for one day, on the next day the same procedure was follwed for the other side of the RPC. Now the RPC became ready to be tested to make sure that no gas leak occurs, especially at the glued joints. After passing the leak tests the base RPC is ready and it needs to be wired applying high voltage and picking up the signals as charged particles pass through. 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 a roughly equal and negative voltage to the other side, using a bi-polar high voltage DC supply, 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.

3 Study of different components of the RPC readout system

There are many differnt components of the RPC read-out system. For electrical insulation on the both graphite-coated sides of the RPCs two layers of 100 micron thick mylar is placed with pieces of kapton tape, which helps them to be fixed in place. Another mylar sheet is taped with kapton to the pick-up strip before it is laid on the RPC, there are three mylar sheets per side for insulstion.

3.1 Pick-up strips

The pick-up strips are made from foils of aluminium pasted on both sides of 5 mm thick foam, cut to the same dimensions as the RPC surface. This type of pick-up strip is used in JB01, for JB00 and IB01 another type of pick-up strip of 10mm thick foam is used. The foam with Aluminium acts as a transmission line. 30 strips of 3 cm each with a 2 mm gap between them are made on one side of the aluminium sheet whereas the aluminium sheet of the other side is left as it is. Twisted cables are soldered with on conducting copper tape and the tape is pasted on those grooves to pick up the signal as shown in Fig. 2. The grooved surface faces the RPC to pick up the signal and the ungrooved surface acts as the ground. The pick-up strips on two sides of the RPC are kept transverse to each other to provide the x- and y- position information from each RPC. At present, due to shortage of electronics only middle eight strips of one side of the pick-up strip are connected to the preamplifier and only one strip from each RPC is tested.

To measure [ref.1] the characteristic impedance of the pick-up the required circuit diagram is shown in Fig. 3. The Pulser/Wavetek sends a pulse through a 50 Ω cable and it gets into the terminating circuit where it passes on to a 110 Ω cable without been distorted. the 120 Ω twisted cable are then branched into two parts, one goes to the pick-up board and the other goes to the oscilloscope; ref. Fig. 3.

Fig. 4 shows a typical result without connecting any resistor at the end of the pick-up strip. For each strip, a pulse is sent, the pulse encounters a front-end reflection at the front of the pick-up strip and and it also encounters a back end reflection at the back. To get rid of the backend reflection as

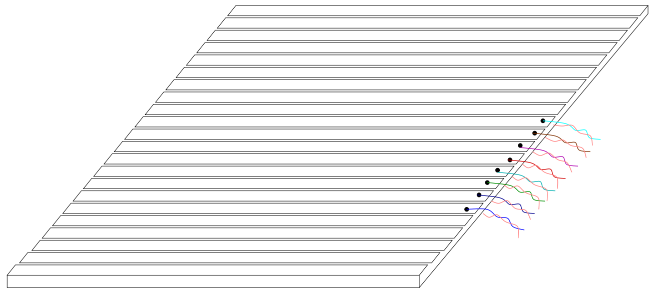

Figure 2: Pick-up strips of RPC

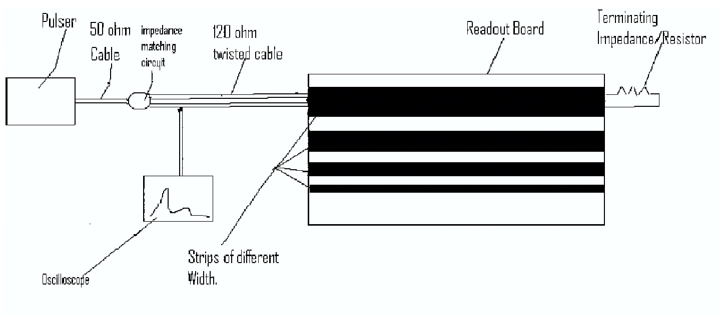

Figure 3: Experimental set up for measuring the characteristic impedance of the pick-up strips of RPC

much as possible, a terminating resistor of a value equal to the characteristic impedance of the pick-up strip is to be connected at the back end of the strip. To measure the characteristic impedance a turn-pot is connected at the back end of the strip and the the resistance of the turn pot is changed to observe the lowest back end reflection peak. When the back end reflection peak is minimised the resistance of the turn pot equals to the chracteristic impedance of the pick-up strip.

The amplitude of the input pulse taken from Wavetek is 1 V, rise time is of the order of 7 to 9 ns and FWHM is 9.8 ns.

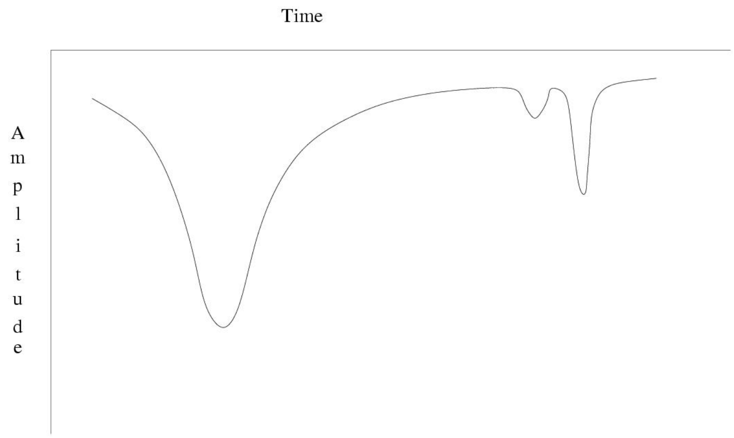

Figure 4: Pulse profile seen on the oscilloscope

New Pick-up Board (thickness = 6 mm):
Length of the pick-up strip = 40.2 cm
Variaion of Characteristic Impedance with frequency

Table I : Strip width 4.0 cm

$Pulseperiod\ (\mu s)$	$Frequency\ (kHz)$	Z_c (Ω)
250.0	4.0	91.33 / 91.33 / 89.93
500.0	2.0	95.35 / 95.35 / 95.43
750.0	1.33	91.43 / 91.2 / 90.17

Table II : Strip width 3.0 cm

$Pulseperiod\ (\mu s)$	$Frequency\ (kHz)$	Z_c (Ω)
250.0	4.0	117.13
500.0	2.0	114.64 / 126.0
750.0	1.33	$\sim$ 100

Table III : Strip width 2.0 cm

$Pulseperiod\ (\mu s)$	$Frequency\ (kHz)$	$Z_c\ (\Omega)$
250.0	4.0	118.05 / 114.54
500.0	2.0	119.7 / 126.76
750.0	1.33	123.97 / 126.7

Table IV : Strip width 1.0 cm

$Pulseperiod\ (\mu s)$	$Frequency\ (kHz)$	$Z_c\ (\Omega)$
250.0	4.0	123.87
500.0	2.0	125.40 / 128.42
750.0	1.33	124.36 / 124.36

The different values of Z_cs correspond to values obtained from different measurements.

The turn pot used for this test is 100 ohms, so anything greater than 100 ohms are measured with connecting a small resistance ($\sim 67\ \Omega$) in series with the turn pot.

Measurement of the capacitance of the pick-up strip: The capacitance of the pick-up strip was measured by using monoshot IC74123. When a monoshot is given to the IC74123 it gives an output monoshot whose time width is given by

$$t_w = 0.48 \times R_{ext} \times C_{ext} \tag{1}$$

where t_w is the time width of the output pulse in ns, R_{ext} is the variable external resistance in KΩ and C_{ext} is the capacitance of the pick-up strip in pF, which is the measurable quantity. The R_{ext} was varied to note down the width of the output square pulse on the oscilloscope and C_{ext} was measured in each case by eqn.1. They are given in the following table.

R_{ext} in KΩ	t_w in ns	C_{ext} in pF
10	283.6	59.1
20	550.0	57.3
30	817.2	56.7
40	1071.0	55.8
80	2162.0	56.0

3.2 Preamplifier

Two types of preamplifier are tested, firstly the discrete preamplifier of gain 10 and secondly the cascades one where there are two stages, the first stage is exactly same as the discrete version whereas the second stage is of hybrid variety. The discrete preamplifiers have a constant gain of 10, and for the cascaded ones gain can be varied by changing the coupling resistance between the two stages using the turn pot. The circuit diagram of the discrete pre amplifier is given in Fig.5.

The gain profiles of the "10-in-1 box" preamplifiers of which all are of discrete type were studied. Input signal was provided using a tail pulse generator. Plots are given in Fig.6 for amplifiers 1 through 5 and for amplifiers 6 through 10 separately. The range of input signal was varied from 5mV to 100mV. Signal below 5mV was too noisy to be measured with sufficient accuracy.

Tail pulse generator is used to provide the input signal for testing the cascaded preamplifier.The gain was characterised against input signal amplitude for five different gains by changing the coupling resistance between the two stages using the turn pot, the plots are shown in Fig.7. For lower voltages in case of discrete preamplifier the gain profile is not so smooth as compared to the cascaded ones which have a nice and smooth gain profile in betwwen 0 to 100 mV. The feed back circuit for the discrete preamplifier does not work properly for lower voltages.

4 Study of the performance of RPC with changing temperature

It was observed that the performance of RPCs depends very much on the surrounding temperature and humidity. Generally these parameters are kept fixed and vary little from time to time. In this project the temperature was increased by about 3 to 4 °C deliberately to study the difference of performance of the RPCs. Since there were no dehumidifier in the room, the humidity also changed by 3%. The current drawn by the RPCs increased with increasing temperature. The variation of efficiency and current drawn by the RPCs JB00 and JB01 are shown in the following graphs:

The performance in RPCs should not change drastically for such a fluctuation of temperature and humidity. This must be due to any leakage of HV which can occur in three different ways:

1. through the gas between two glass plates,

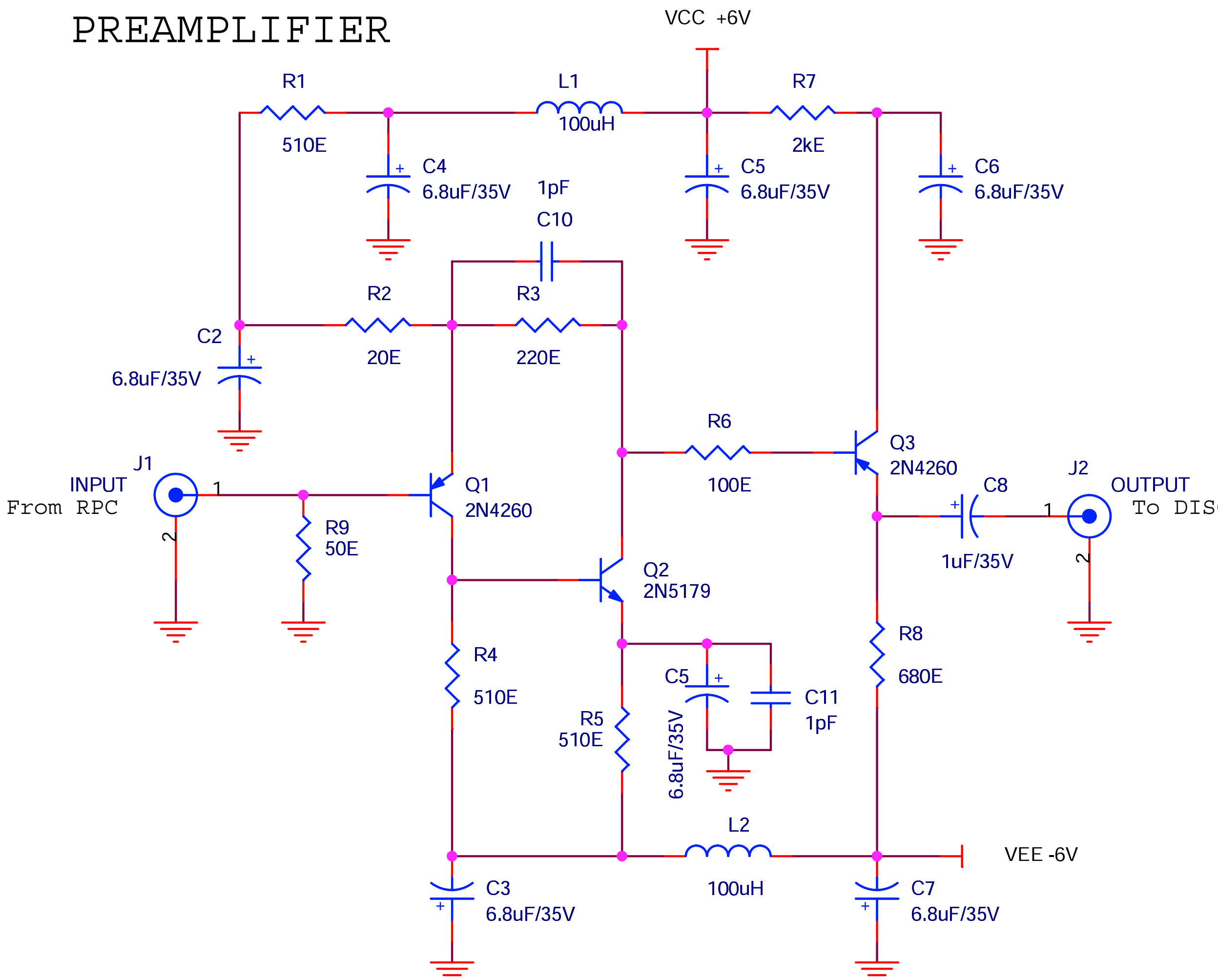

Figure 5: The circuit diagram of discrete preamplifier

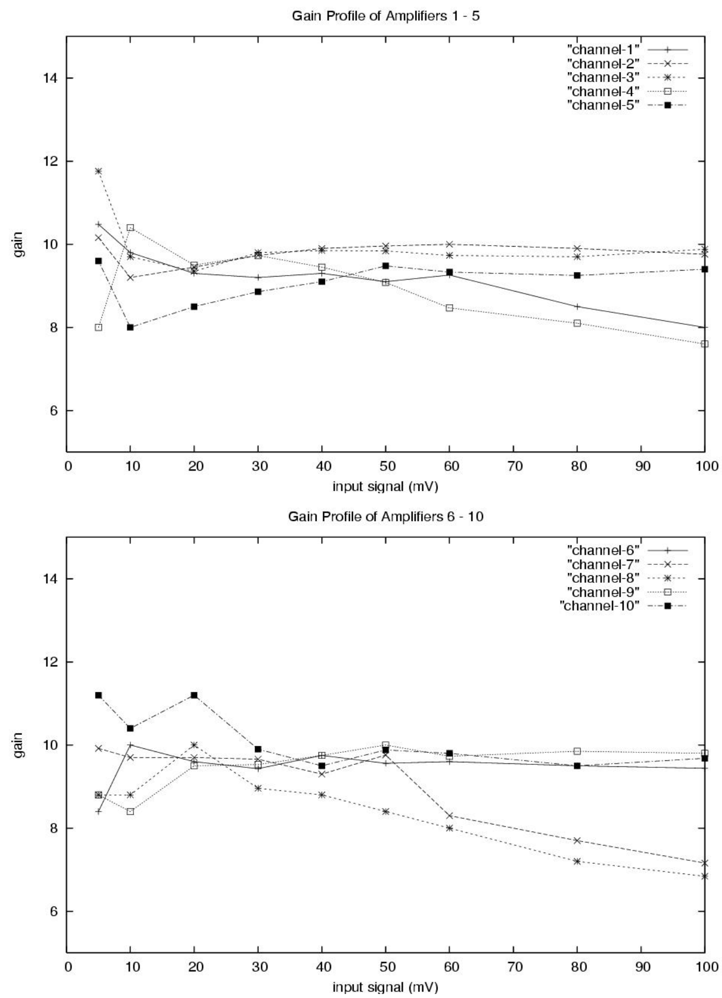

Figure 6: Gain profile of discrete preamplifier.Pulse rise time was 20ns and the fall time, 50ns. Output had an offset of 500 microvolts and a noise band of about 2mV.

2. through the edge spacers inside the gas volume,
3. through the edge spacers outside the gas volume,
4. water-vapour level in the gas can also affect leakage.

The fact that the RPC performance is quite sensitive to room temperature and room humidity suggests that there are some leakage through the edge spacers and corners outside or inside the gas volume. With increasing temperature there were some big pulses which could never have been

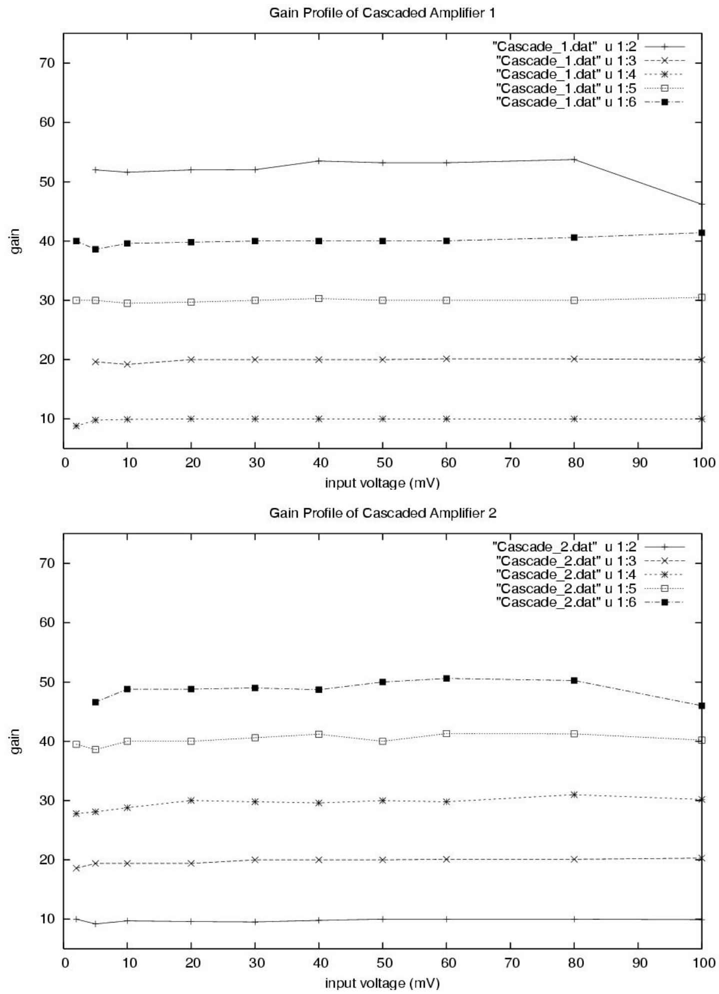

Figure 7: Gain profile of Cascaded Preamplifier. Baseline shift of the output for the first and the second cascaded preamplifier was 1.08mV and 0.88mV respectively.

streamer pulses, these were certainly the pulses due to leakage. Due to these big pulses the RPCs were frequently triggered and this may have caused the increase in efficiency with increasing temperature, especially for JB01, however this trend was not seen in case of JB00; its efficiency is more or less the same with the increasing temperature. This suggests that leakage is much larger in case of JB01.

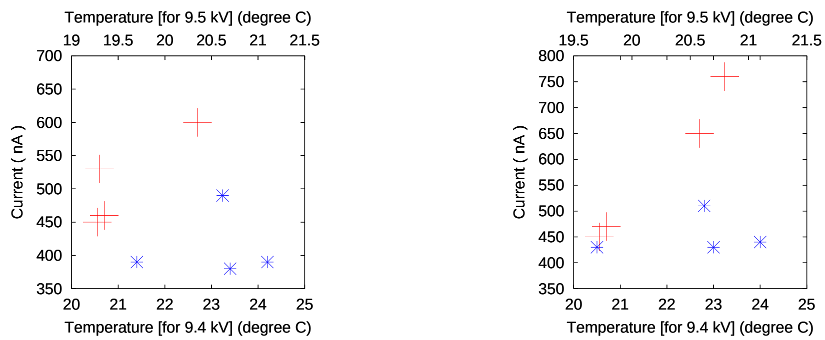

Figure 8: Variation of current drawn by JB00 (left) and JB01 (right) with temperature. The + signs corrrespond to efficiencies at 9.4 kV, the $*$ signs correspond to efficiencies at 9.5kV.

5 Conclusion

My time of the project was the research and development period for making the 2m by 2m RPCs which is supposed to be used in India-based Neutrino observatory experiment. At the end of the project the procedure for making 1m by 1m RPCs became almost stabilized after a lot of iteration. Now all components required for making and testing the RPCs are available. The most important challange to overcome is the problem of electronics, especially the preamplifiers to handle the fast signal of rise time of the order of 2 to 5 ns.

The other great problem was the noise which was eliminated by the refurbishment of the C-217 lab, especially the rewiring of the whole room to make the common ground. Now the noise problem is reduced to a great extent.

To study the variation of the performance of the RPCs with changing temperature and relative humidity is another important problem to address. Water-vapour level in the gas will affect the leakage. But that should not be so sensitive to small changes of room temperature and room humidity. To eliminate this possibility, one must monitor the water-vapour level of the flowing gas at the output rather than input because spacers as well as tubings can be the source of water-vapour getting into the RPC.

One can also raise the HV with air inside the gas volume. In that case streamer discharge through the gas will not happen, so one must surely see the only leakage pulses if any leakage occurs through the edge spacers. Then one have to think about the better insulation between the positive and neg-

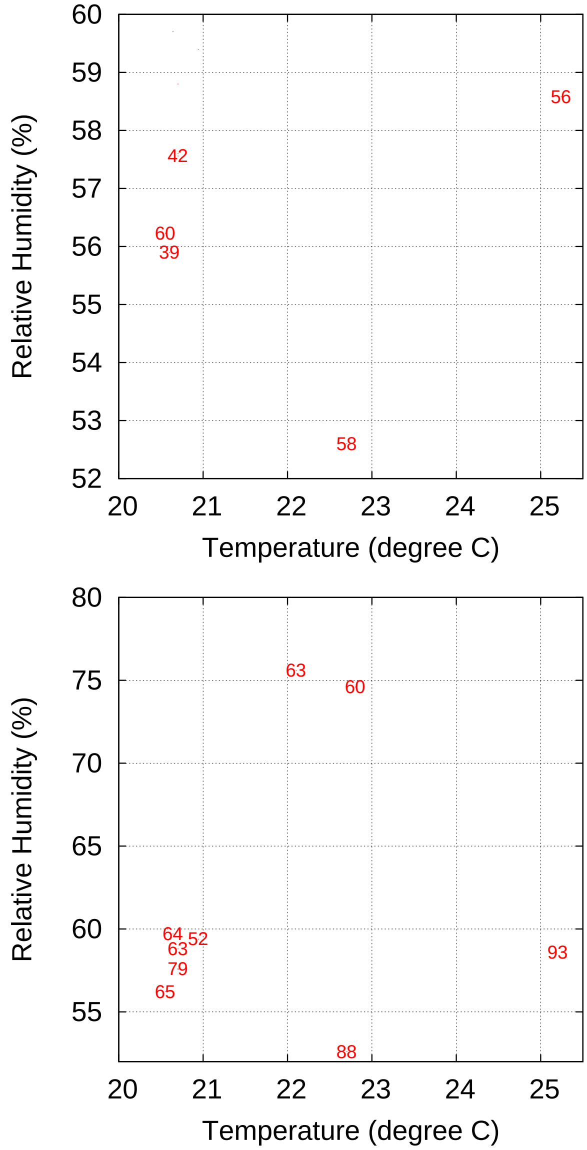

Figure 9: Variation of efficiency of JB00 (above) and JB01 (below) with temperature and humidity, both the data sets were taken at HV = 9.4kV using BARC HEX amplifier of gain 50.

ative plates of HV.

To conclude the conclusion I must say that the RPCs are working fine; raw RPC pulses are quite clean. moreover no aging problem is found in any of them in the time span of 3 to 4 months, but it is indeed true that for testing long term stability one has to run the RPCs for a longer period.

6 Acknowledgement

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7 References

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