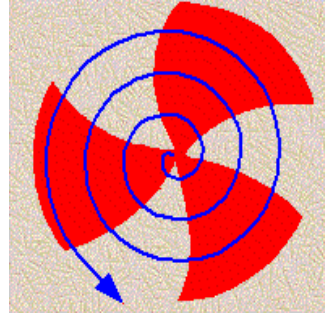


FABRICATION AND PERFORMANCE STUDIES OF LARGE SIZE OIL FREE BAKELITE RPC



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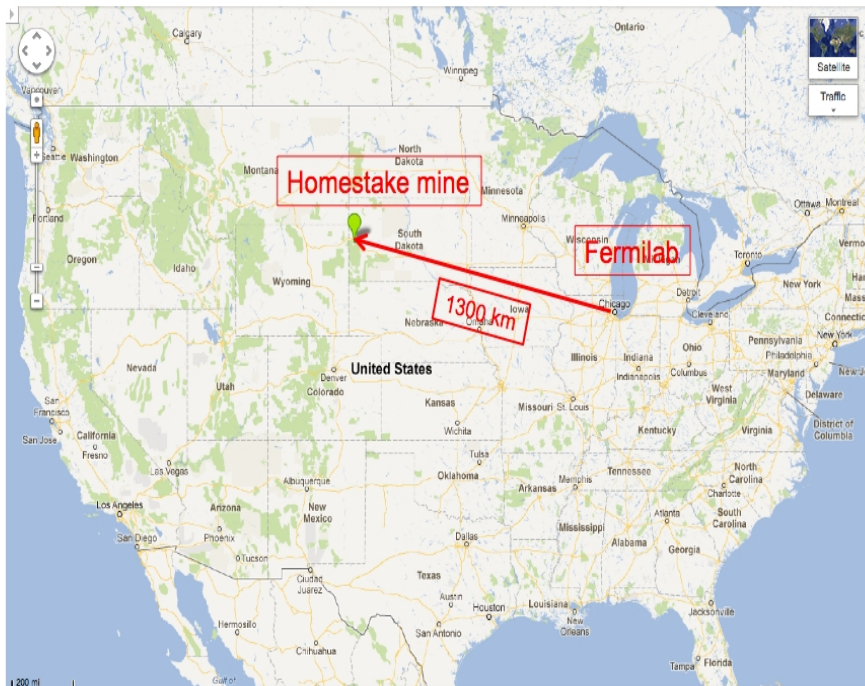
Outline:-

- **Motivation – RPCs for INO-ICAL and ND in DUNE.**
- **Electrical Properties of Bakelite Sample and Glue Samples.**
- **Fabrication of large RPC.**
- **Results.**
 - **Cosmic Ray Test Results.**
 - **Long Term Test Results.**
- **Conclusion and Outlook.**

Bakelite RPCs in DUNE (Deep Underground Neutrino Experiment)

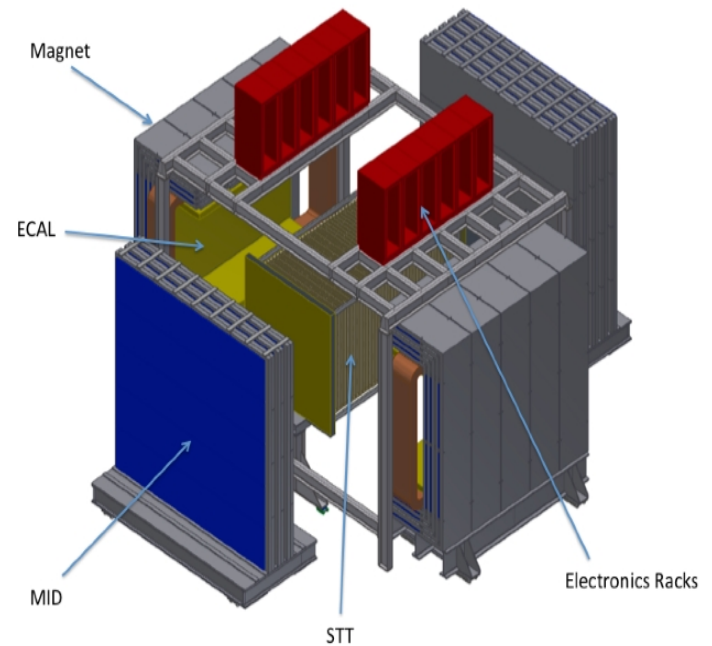
Aim:- To study neutrino oscillation details.

LBNE



Proposed RPC dimensions:-
a. (200 cm x 100 cm)

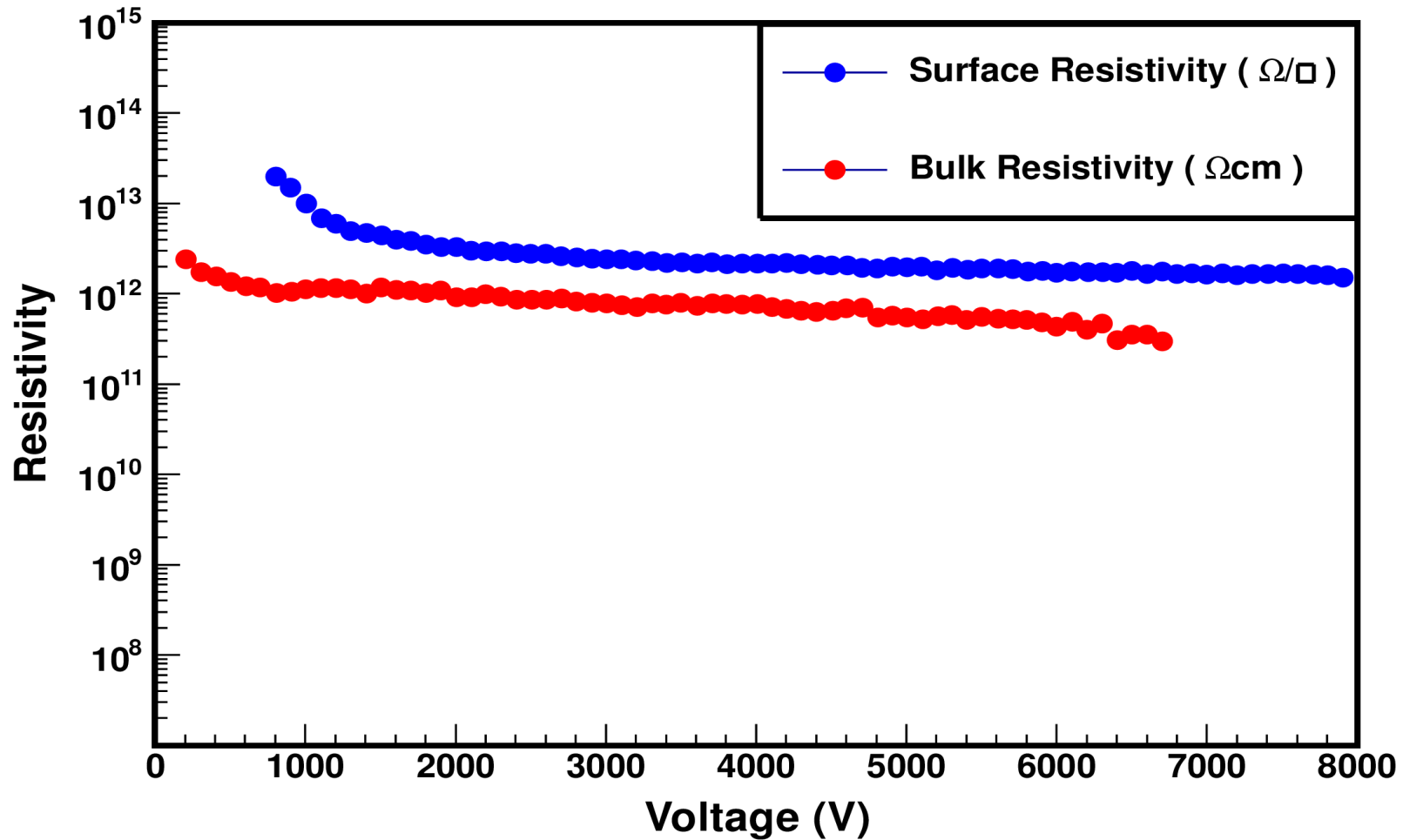
The neutrino detector



Muon detector: RPCs from VECC

arXiv : 1601.02984v1

Electrical properties of the bakelite sample



The average bulk resistivity $\rightarrow \sim 9 \times 10^{11} \Omega\text{cm}$.

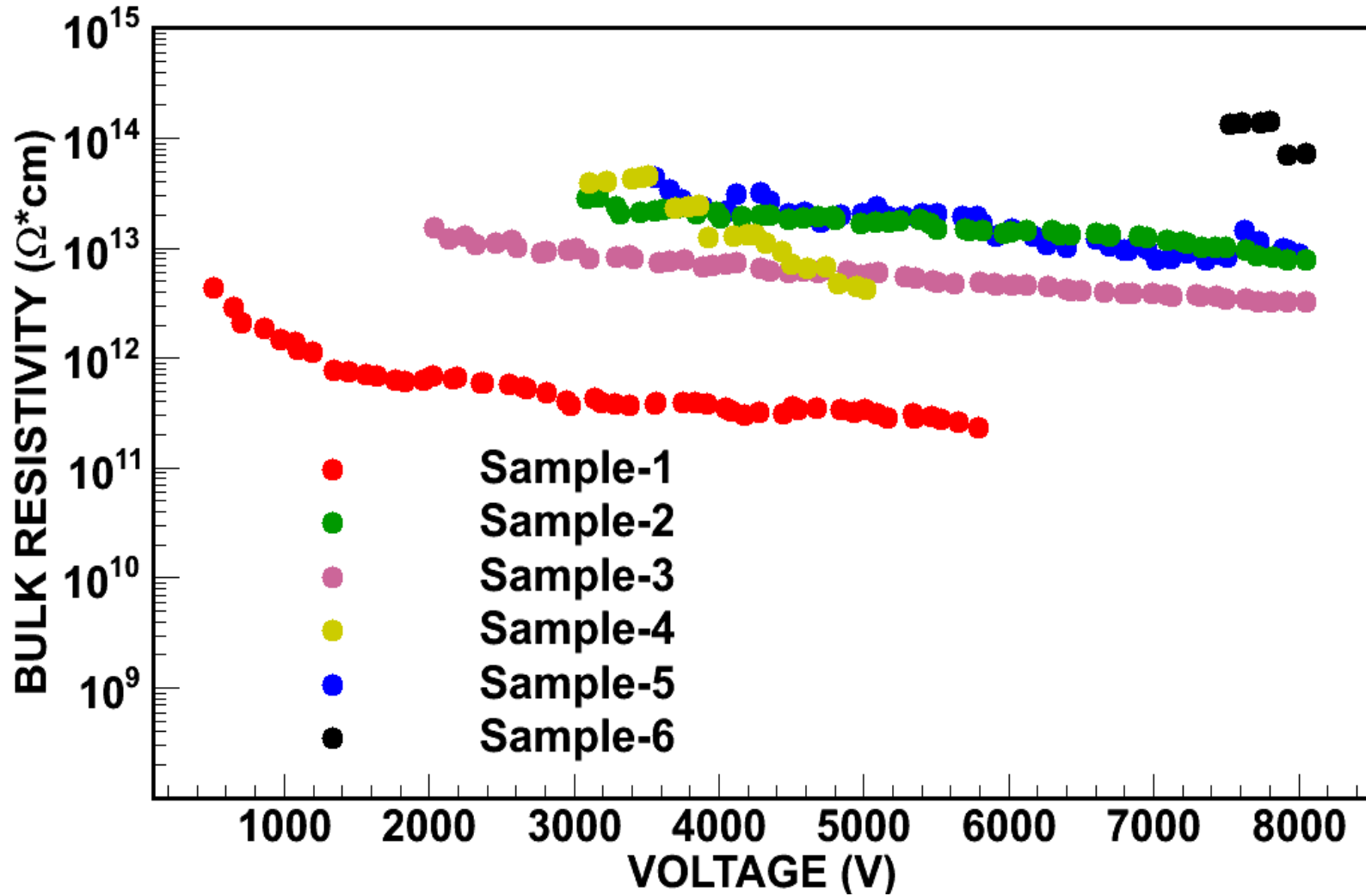
The average surface resistivity $\rightarrow \sim 3 \times 10^{12} \Omega / \blacksquare$.

Glue Test

6 different glue samples were made with the specifications as shown in the table.

| Glue Sample No. | Resin Specification | Hardner Specification | Resin:Hardner |
|-----------------|-----------------------------------|-----------------------|---------------|
| 1 | Dobekot 520F | Hardner 758 | 1.0 : 0.8 |
| 2 | Araldite | Araldite Hardner | 1.0 : 1.0 |
| 3 | Dobekot 520F | Hardner 758 | 11 : 1 |
| 4 | Dobekot 520F | Fevitite hardner | 21 : 2 |
| 5 | Bicron BC-600 | Hardner 758 | 1 : 1 |
| 6 | BC-600 : Araldite :: 1.0 : 1.0 | BC-600 Hardner | 4 : 1 |

Bulk Resistivity of Glue Samples



| Glue Sample No. | Bulk Resistivity (ρ) ($\Omega \cdot \text{cm}$) |
|------------------------|---|
| 1 | 6.773×10^{11} |
| 2 | 2.164×10^{13} |
| 3 | 8.376×10^{12} |
| 4 | 2.014×10^{13} |
| 5 | 6.620×10^{12} |
| 6 | 1.157×10^{14} |

Sample 6 was found suitable.

Flowchart of Fabrication of the RPC

Filing the bakelite edges for smoothening.

Cleaning the sheets using water and alcohol.

Painting the bakelite surfaces with black conducting paint by using hand spray.

Measuring the surface resistance over the entire painted surface.

Placing the bottom electrode on a specially made uniform platform.

Gluing the side spacers, gas nozzles and button spacers on the bottom electrode.

Giving time to settle (~ 1 day).

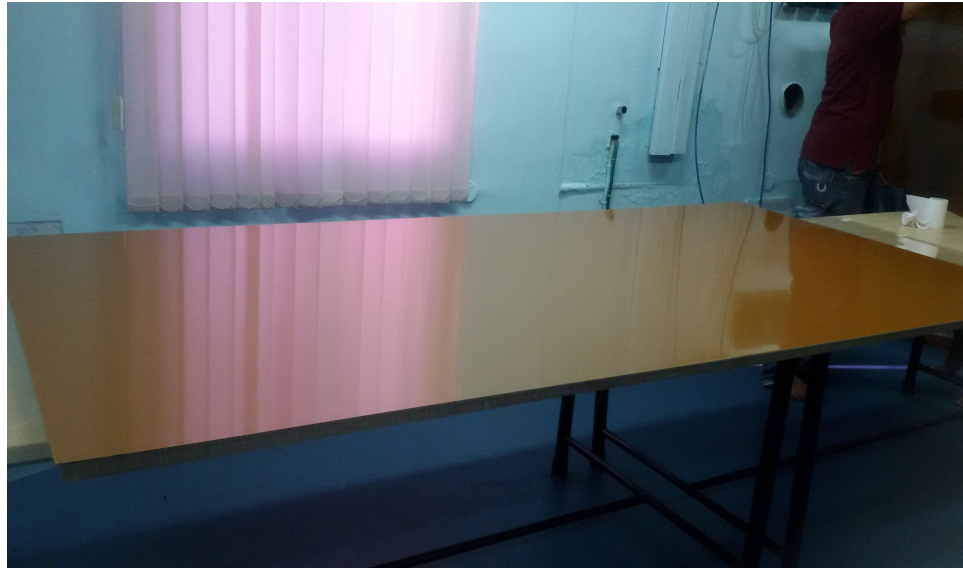
Applying glue on the top surface of all the spacers and then placing the top electrode.

Giving time to settle (~ 1 day).

Regluing the side spacers once again on both the sides, top and bottom.

Testing the RPC.

Fabrication of the RPC



Single large bakelite sheet.



Cleaning of bakelite sheet.

Paint used:-

**Black Conducting Paint
and
Special Dry Thinner,**

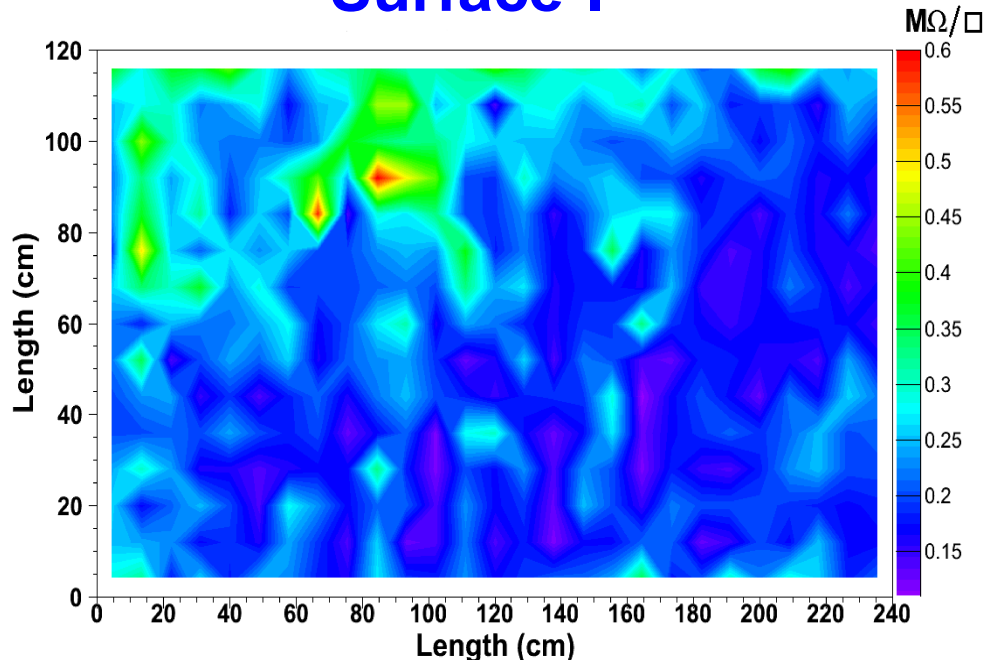
**both manufacturd by Kansai Nerolac,
mixed in the ratio 1:1 (by volume).**



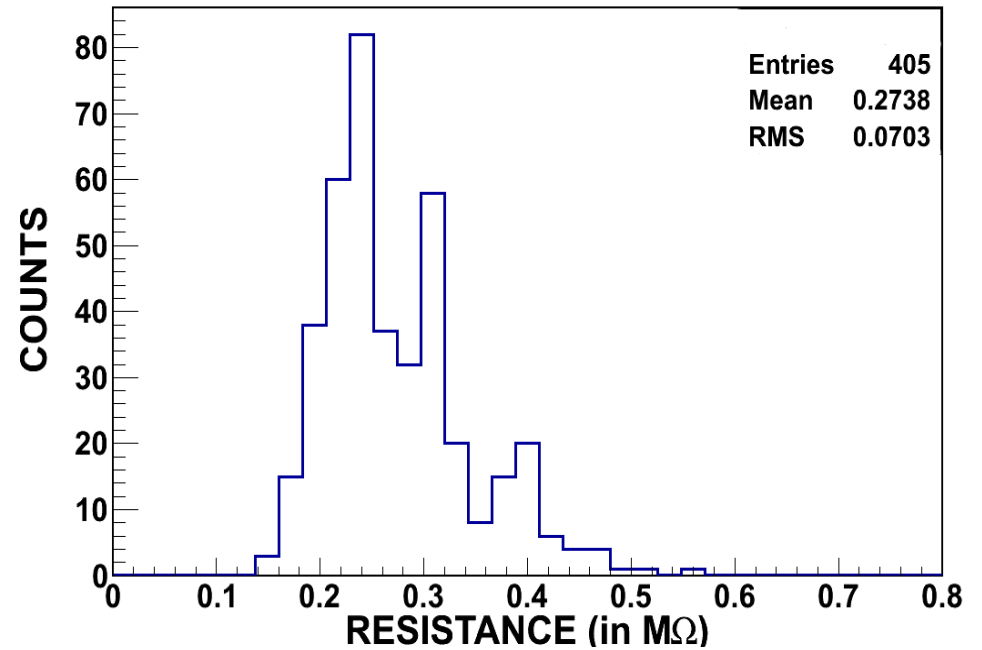
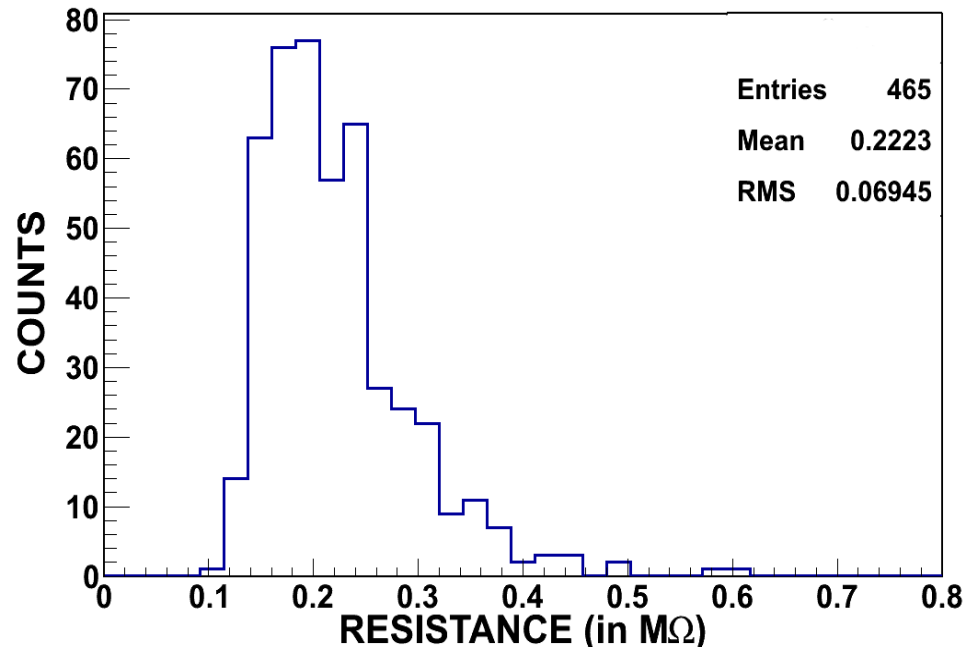
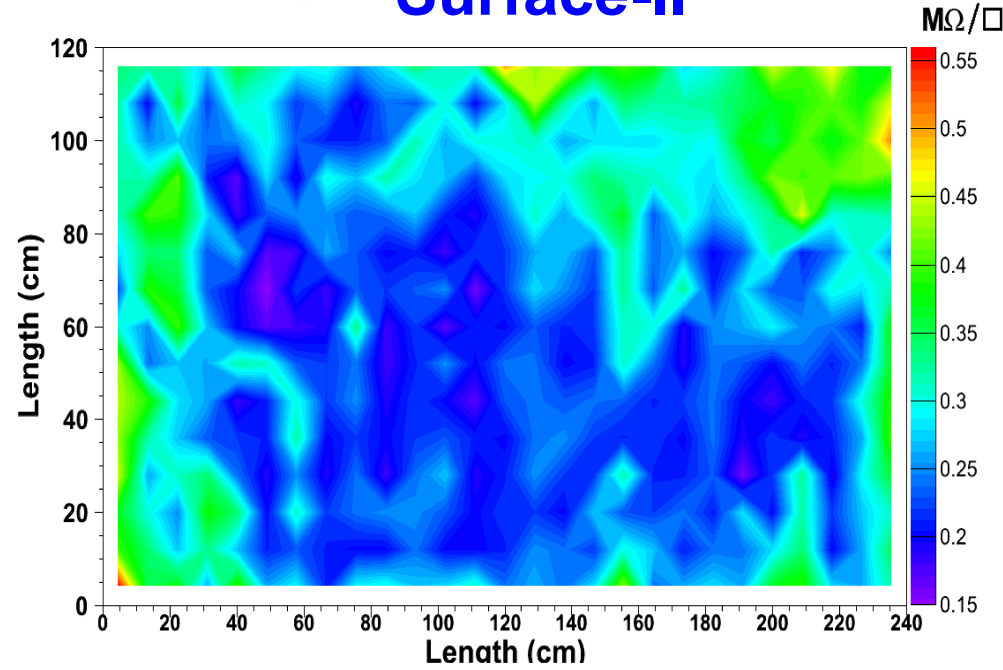
Painting of
bakelite
sheet.

Surface Resistance Profile

Surface-I

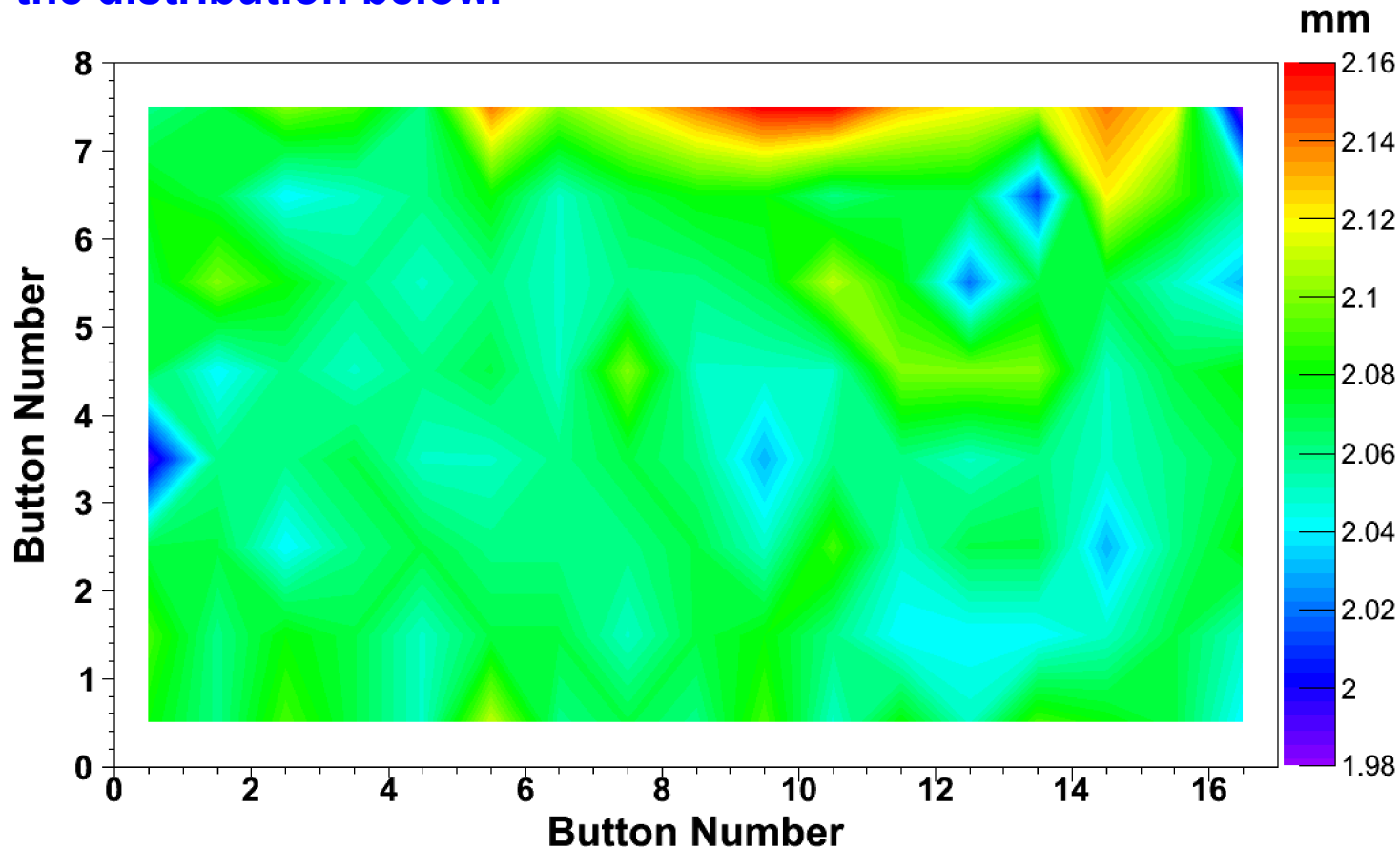


Surface-II

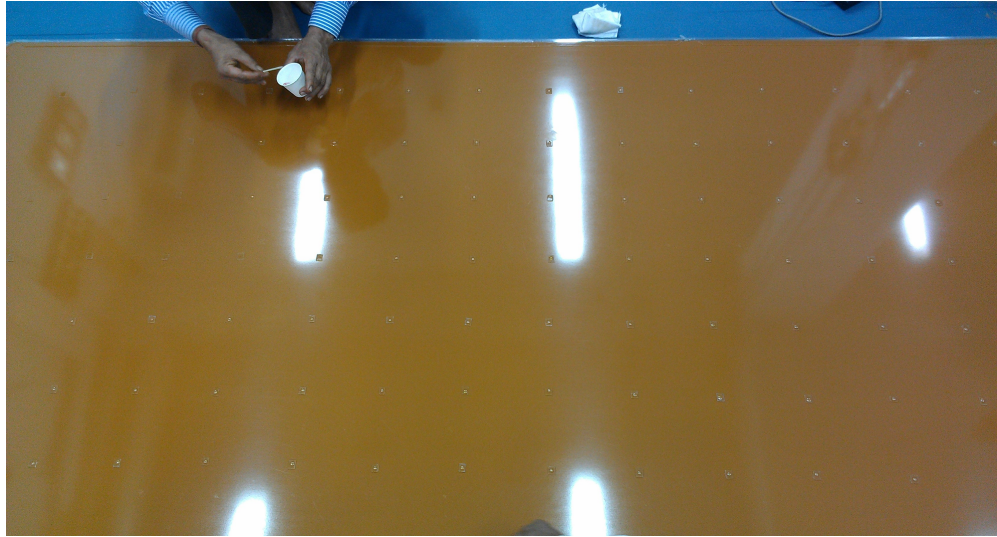


Levelling Measurement

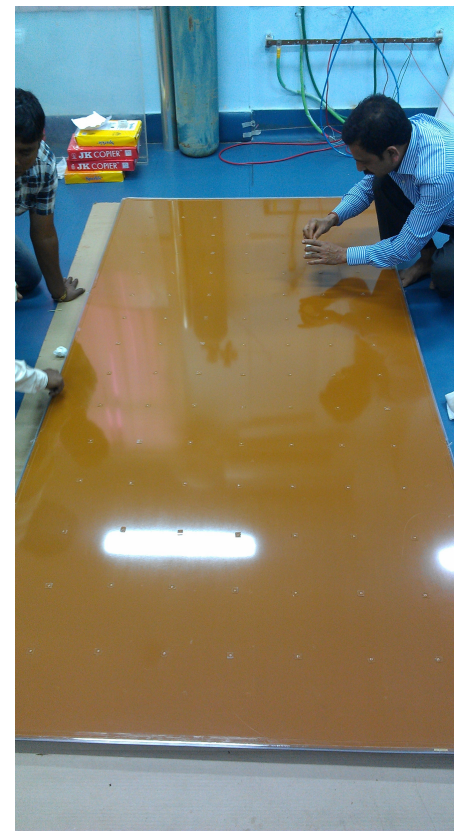
- A well levelled platform was made with cardboard sheets, 3 layers of ~1 cm thick foam and ~(240 cm X 120 cm X 2 cm) glass slab.
- The bottom electrode was placed on the platform.
- 128 locations were marked in (16 X 8) matrix fashion and the button spacers were glued on those locations.
- The local heights of the glued buttons pasted on the electrode were measured, as shown in the distribution below.



contd.



Gluing of side spacers and button scapers.



Closing the chamber.

Glue on a single button.



contd.

Paper bundles placed on the top bakelite sheet.



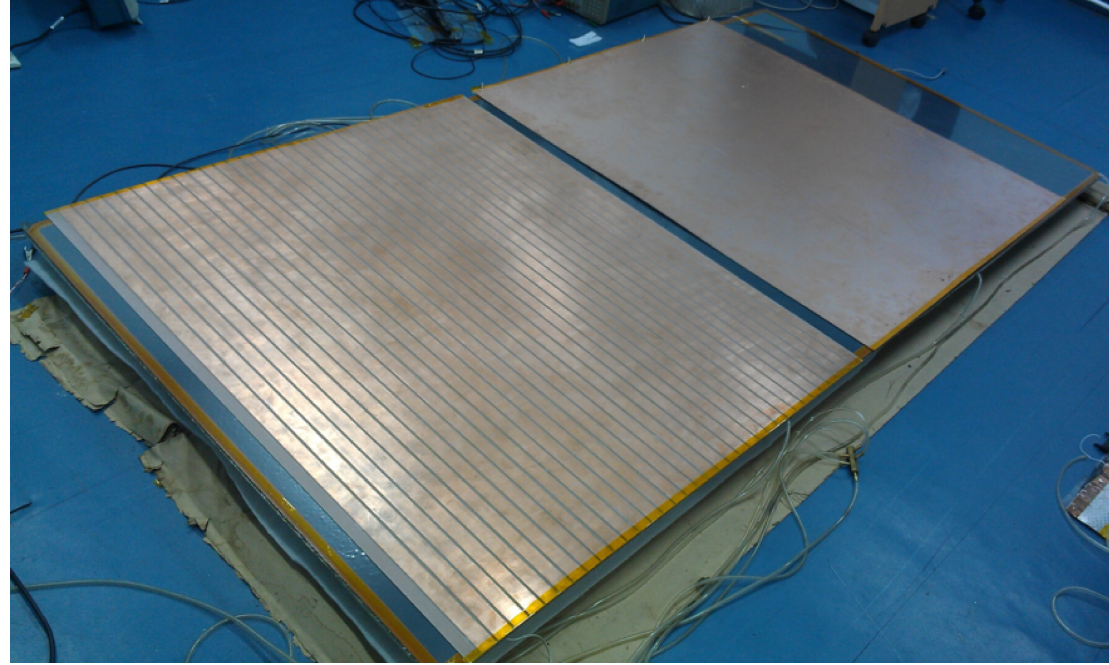
Plywood placed on the paper bundles.



Complete RPC

- With HV soldering
- 4 gas inputs
- 4 gas outputs

With pick up pannel.



Pick up pannel specifications:-

- Dimension – 122 cm X 107 cm X 0.16 cm.
- FR4 based material with 35 microns copper plated on both the surfaces.
- Each strip width is ~2.5 cm.
- Gap between two strips is ~5 mm.

Cosmic Ray Test Results

RPC tested with cosmic rays in a standard test set up with 3 scintillators:-

- **2 paddle scintillators (20 cm × 8.5 cm).**
- **1 finger scintillator (7cm × 1.5 cm).**

Electronics modules used:-

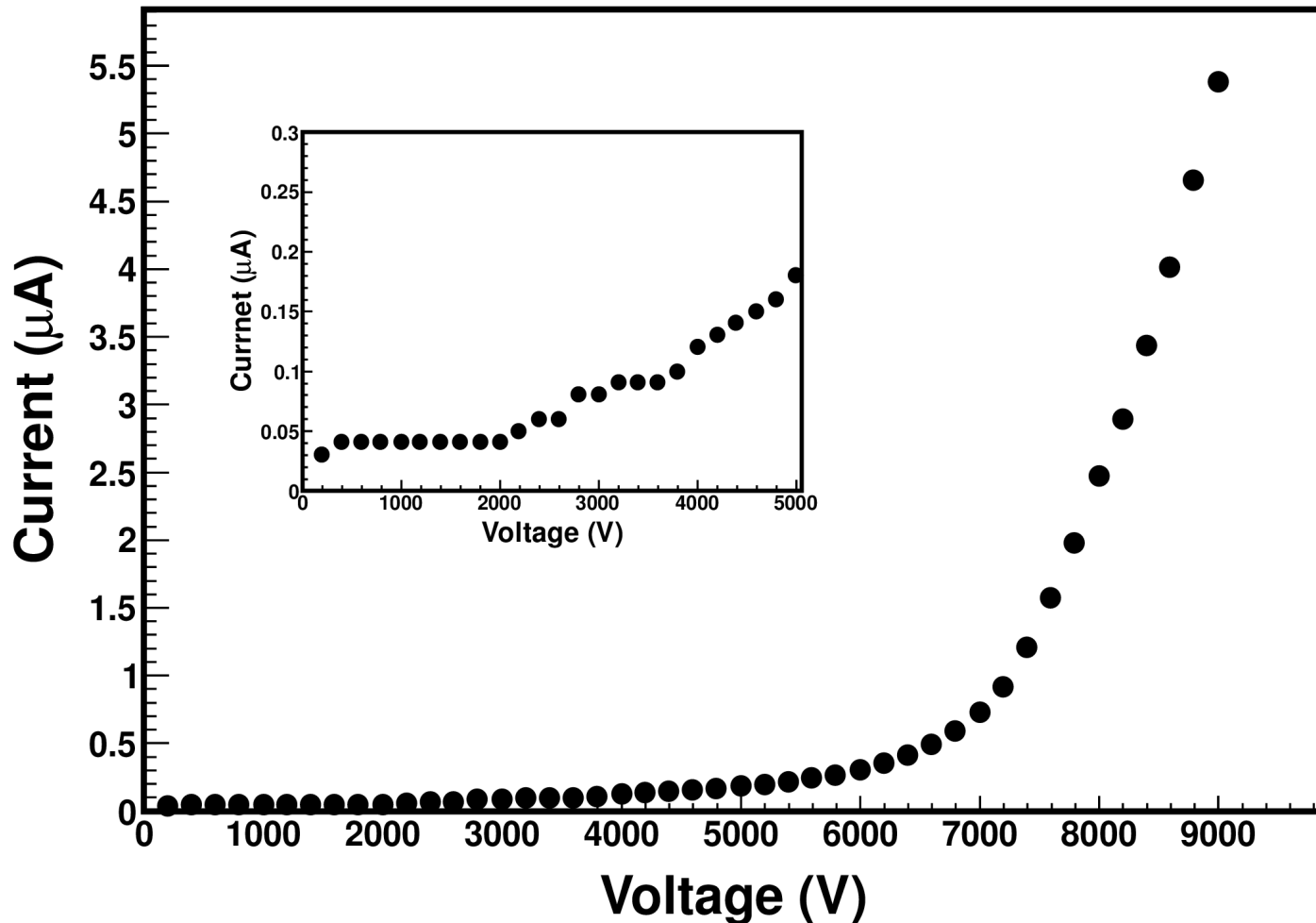
- **High Voltage → CAEN A1832PE and A1832NE.**
- **Discriminator → CANBERRA QUAD CFD 454.**
- **TDC → Philips Scientific 7186 16 Channel TDC.**

Gas Composition:- Ar : R134a : Iso-butane :: 34 : 57 : 9

Gas Flow Rate :- ~0.75 litre/hour

Master Trigger Rate:- ~ 0.008 Hz/cm².

V-I characteristics

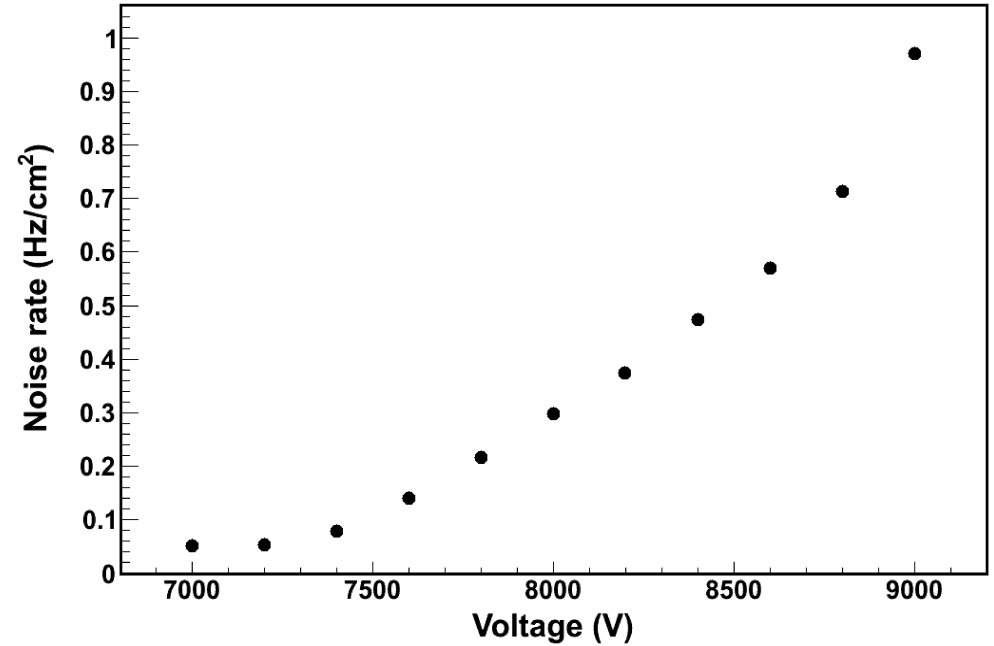
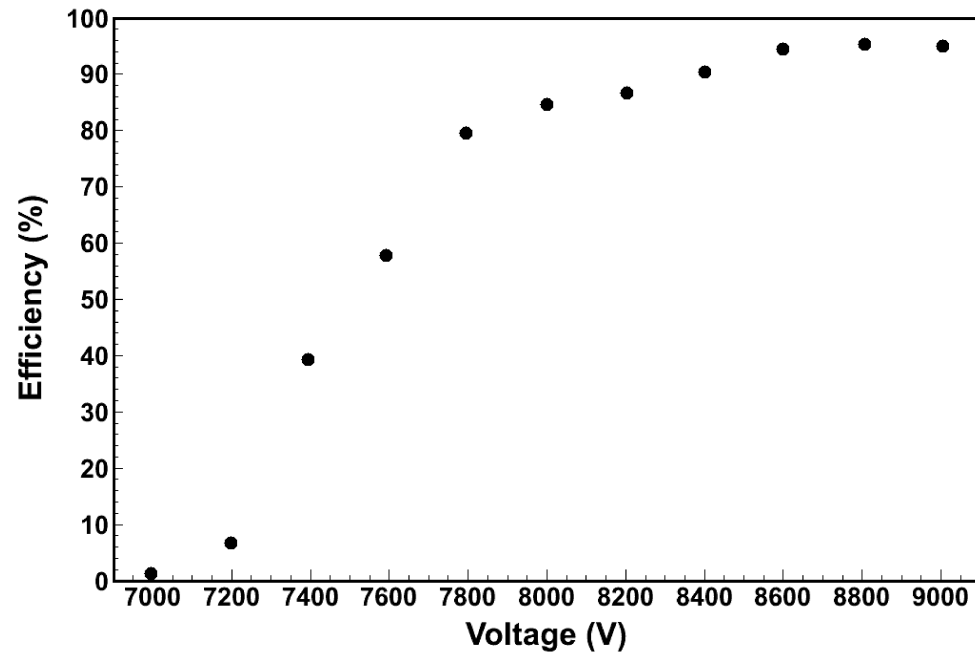


Picture in the inset shows the low voltage region.

The breakdown voltage was found to be **~7000 V**.

From the ohmic part, the calculated bulk resistivity of the chamber is **$\sim 1.72 \times 10^{13} \Omega\text{cm}$** .

Efficiency and noise rate



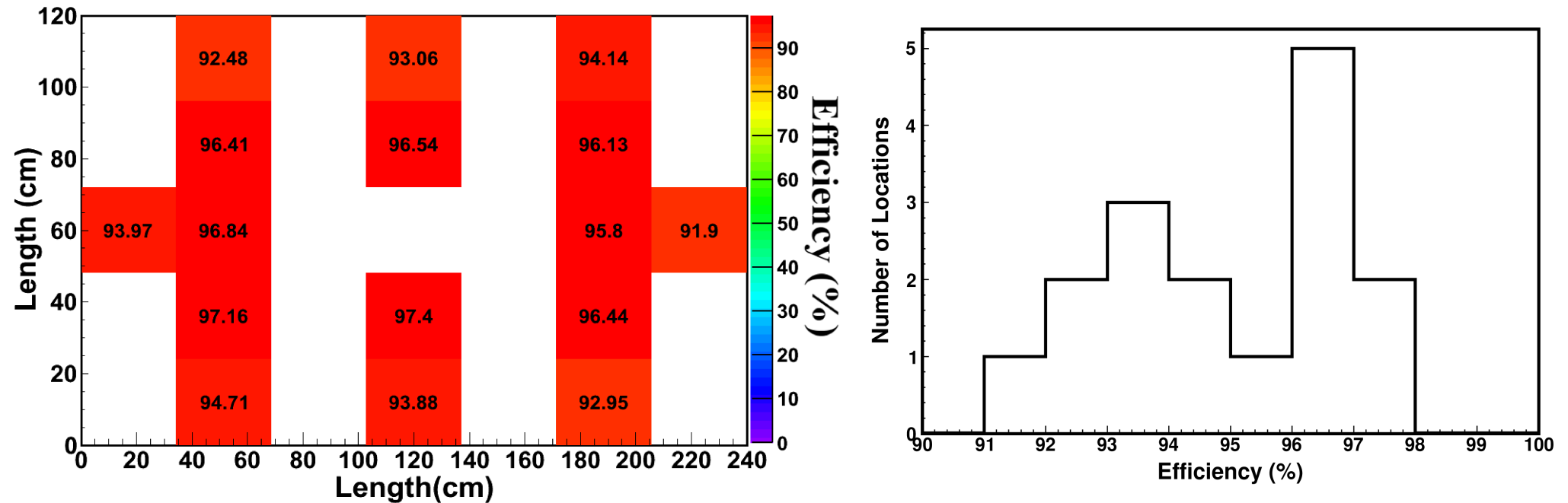
The plateau shows an efficiency $>95\%$ at voltage ≥ 8800 V.

RPC threshold \rightarrow - 20 mV.

Lab Temp. \rightarrow $\sim 20^{\circ}$ C.

Relative Humidity \rightarrow 50 % - 55 %.

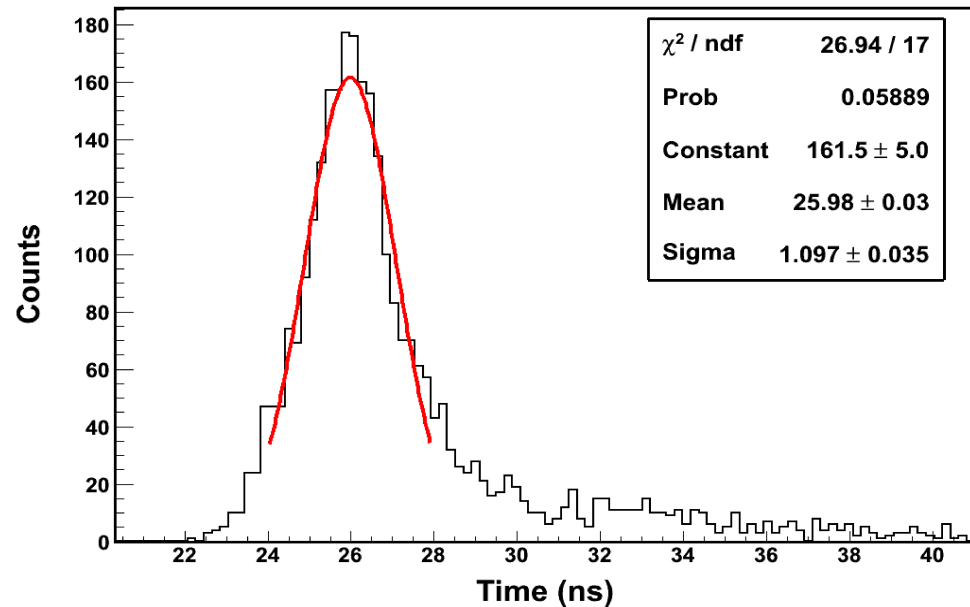
Efficiencies at Different Locations of the RPC



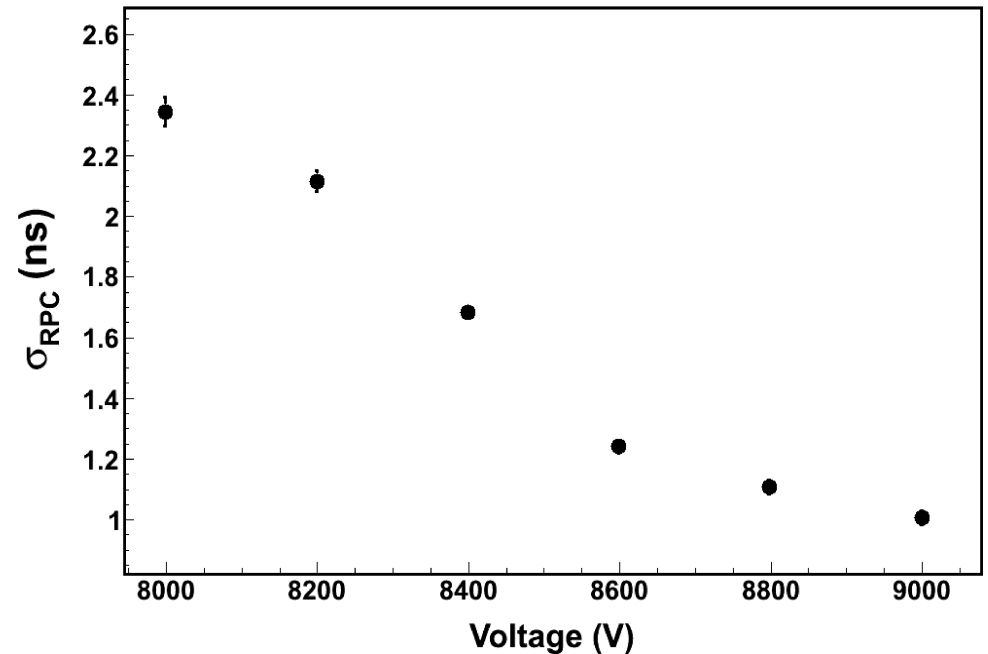
- The figure clearly shows two distinct groups.
- The edges of the RPC are relatively low efficient as the probability of distortion of the electric field and the non-uniformity of gas-flow are higher at these regions.
- The average efficiency is found to be $>95\%$.

Timing Measurement

TDC spectra @ 9000 V



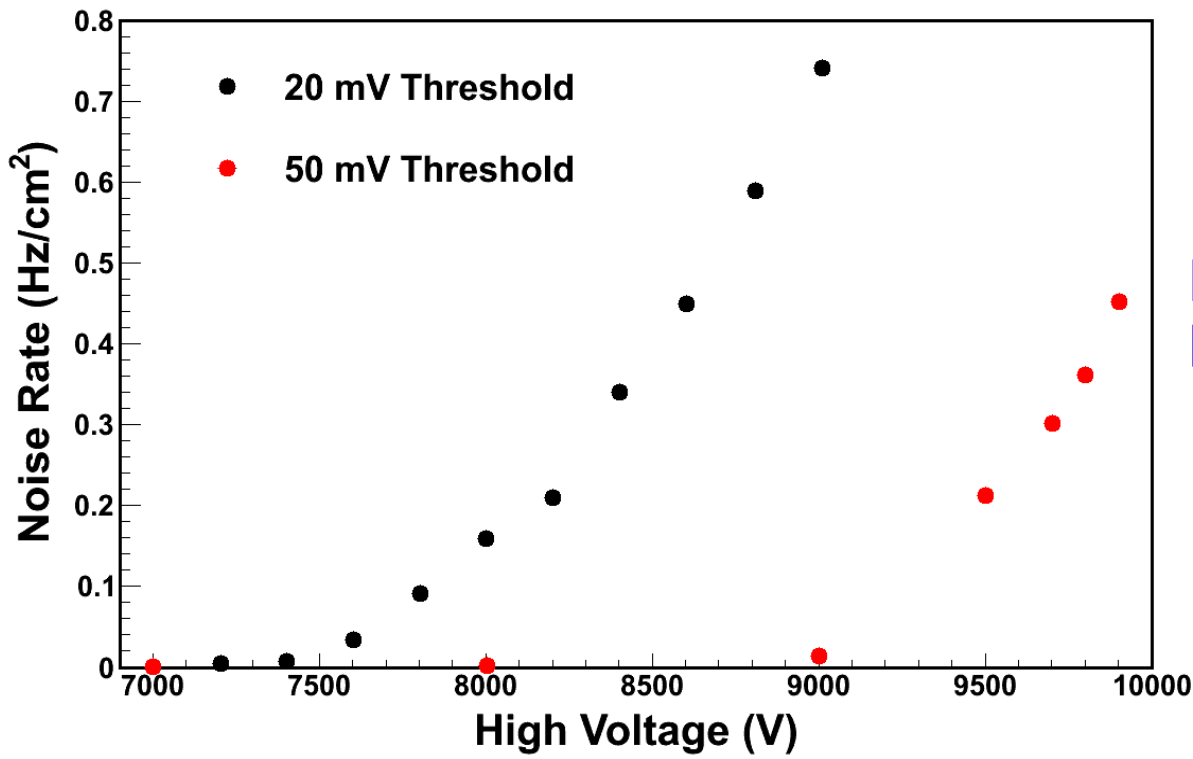
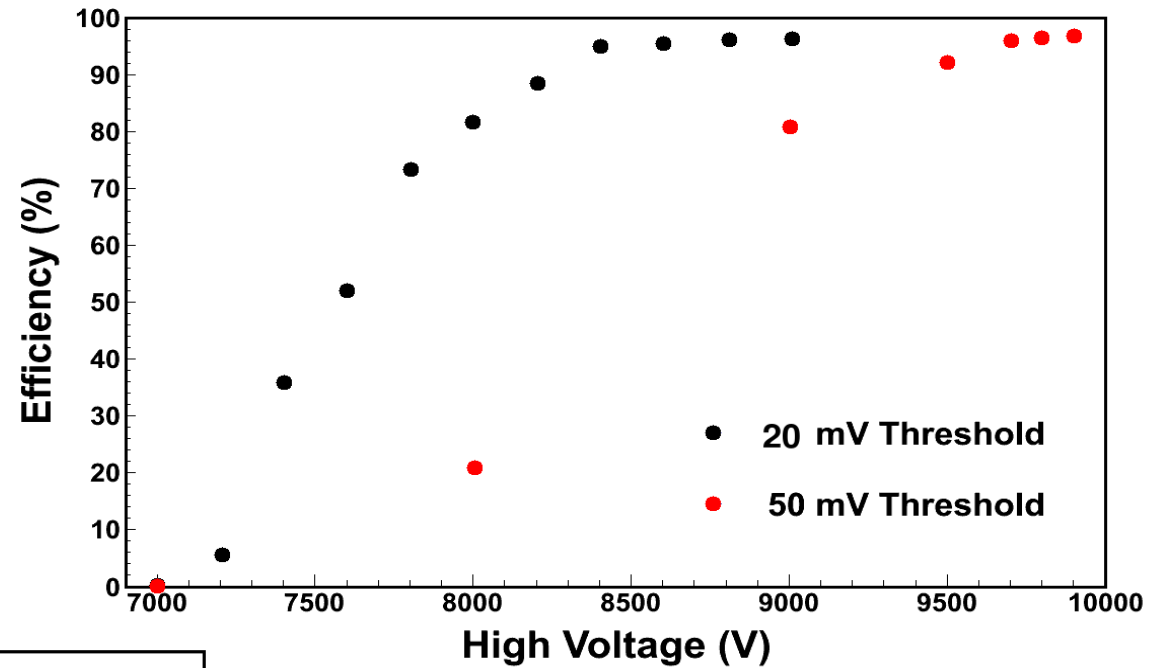
Variation of σ_{RPC} (corrected) with Voltage.



- The best value of the time resolution (σ_{RPC}) (corrected) has been found to be **~ 0.83 ns at 9000 V.**
- While correcting, we have only subtracted the contribution from the Scintillators.

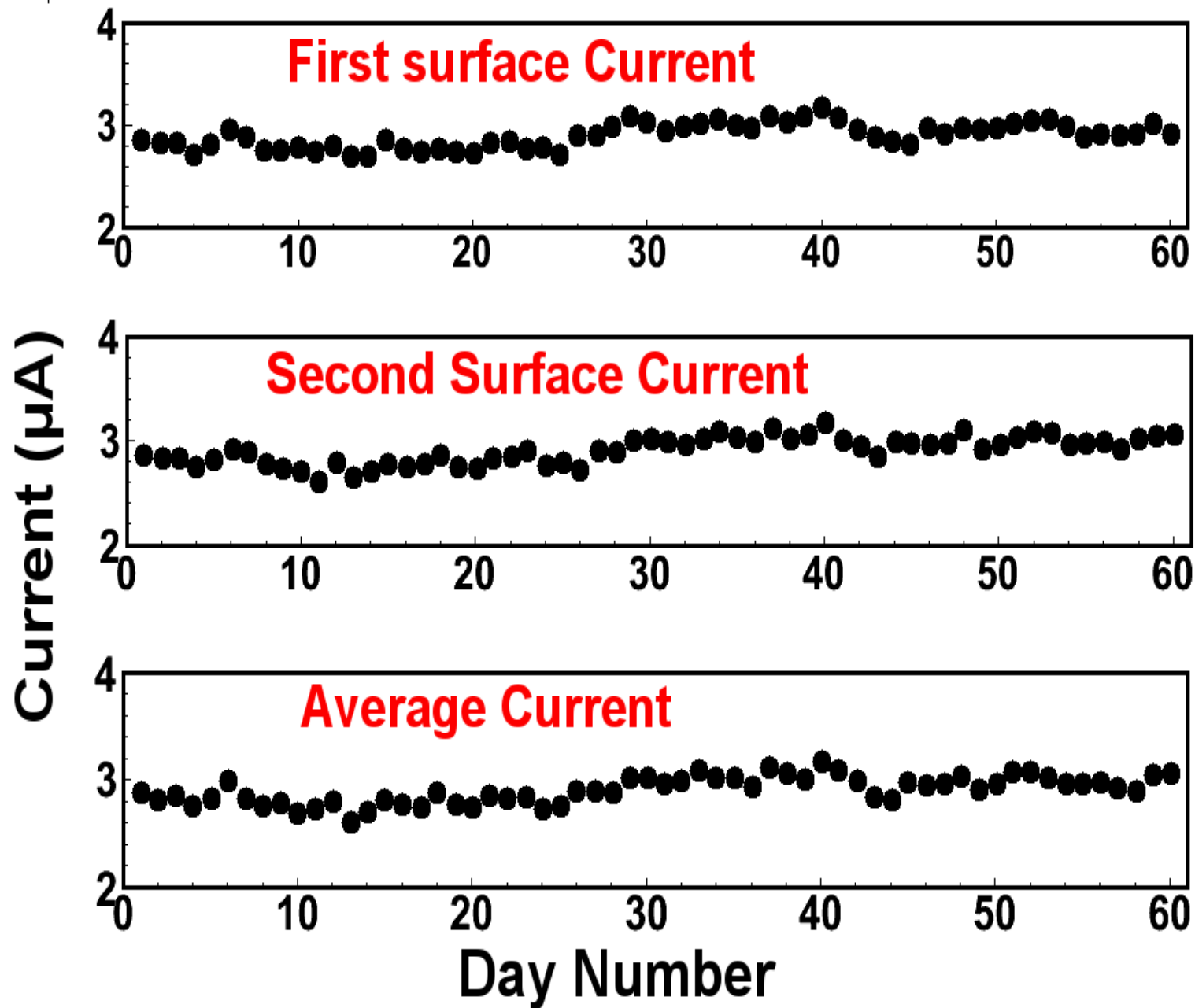
Efficiency and Noise Rate Curves at Different Thresholds

The curves show the average of the data taken at 3 different locations in the central region of the RPC.



Lab Temp. \rightarrow $\sim 10^0$ C.
Relative Humidity \rightarrow 35 % - 40 %.

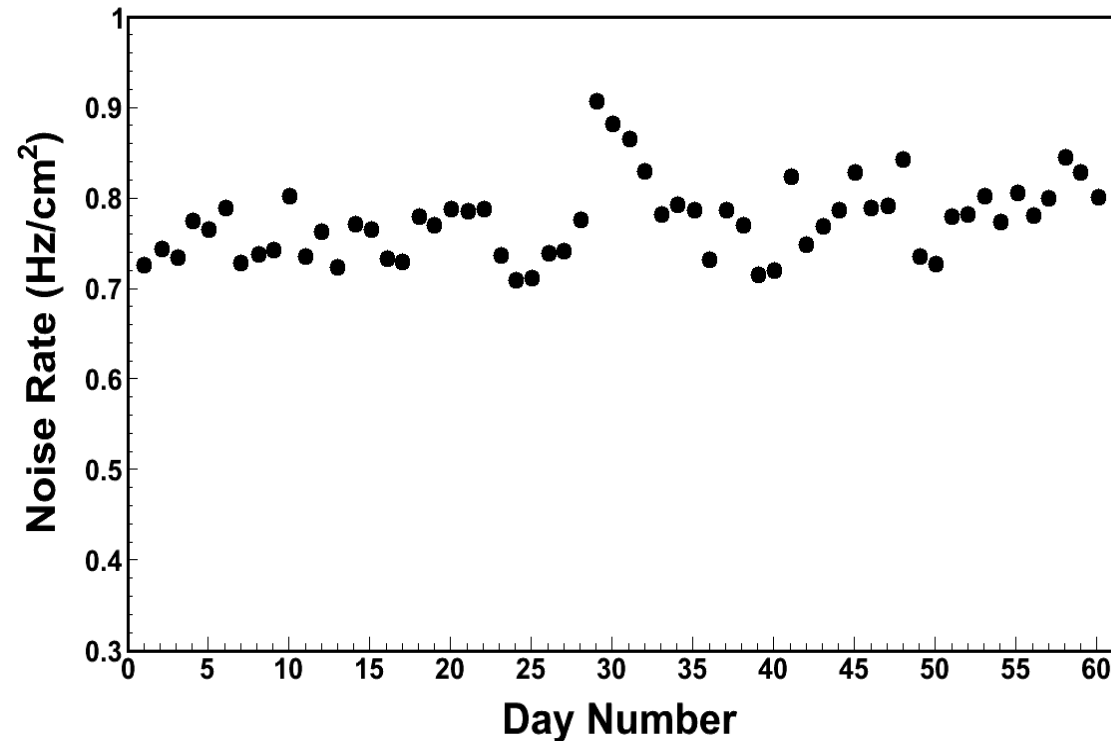
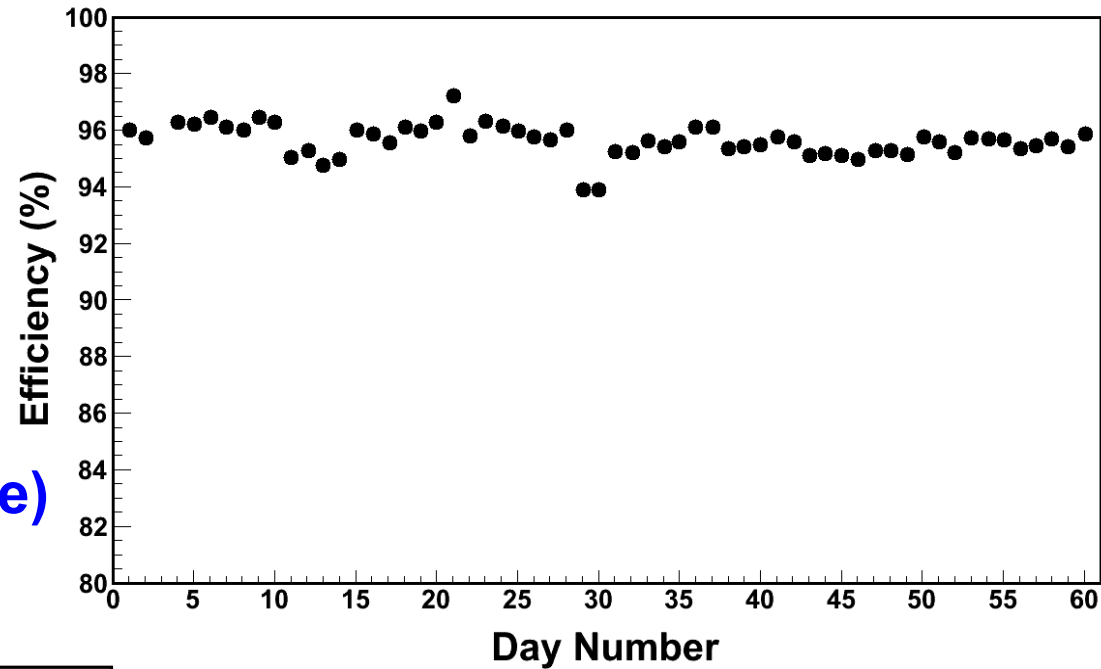
Current Stability @ 9000 V



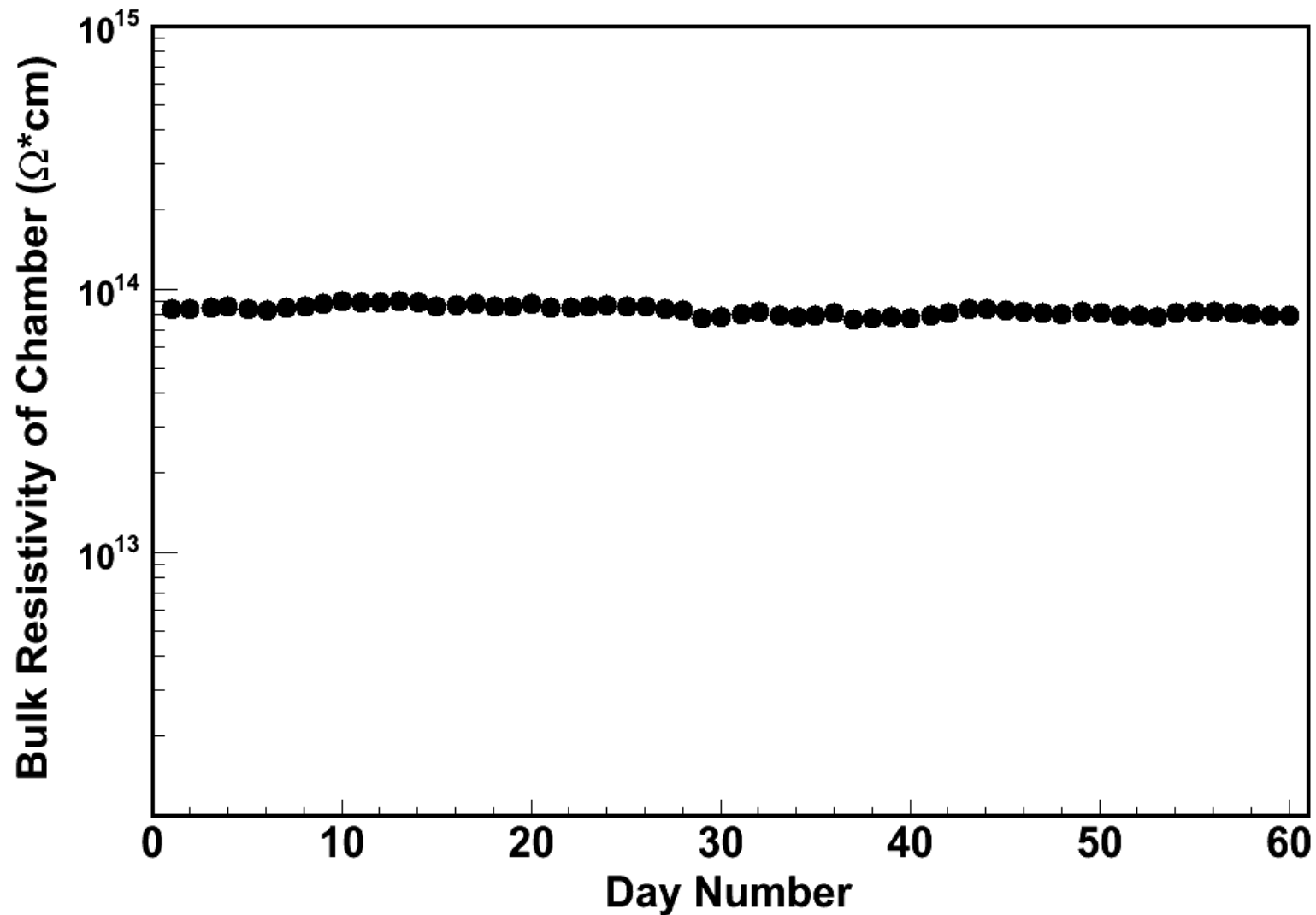
Long Term Efficiency and Noise Rate

Throughout the testing period:-

- Lab Temp. $\rightarrow \sim 10^{\circ} \text{C}$.
- Relative Humidity $\rightarrow 35\% - 40\%$.
- Efficiency $\rightarrow > 95\%$.
- Noise rate $\rightarrow \sim 0.75 \text{ Hz/cm}^2$ (average)

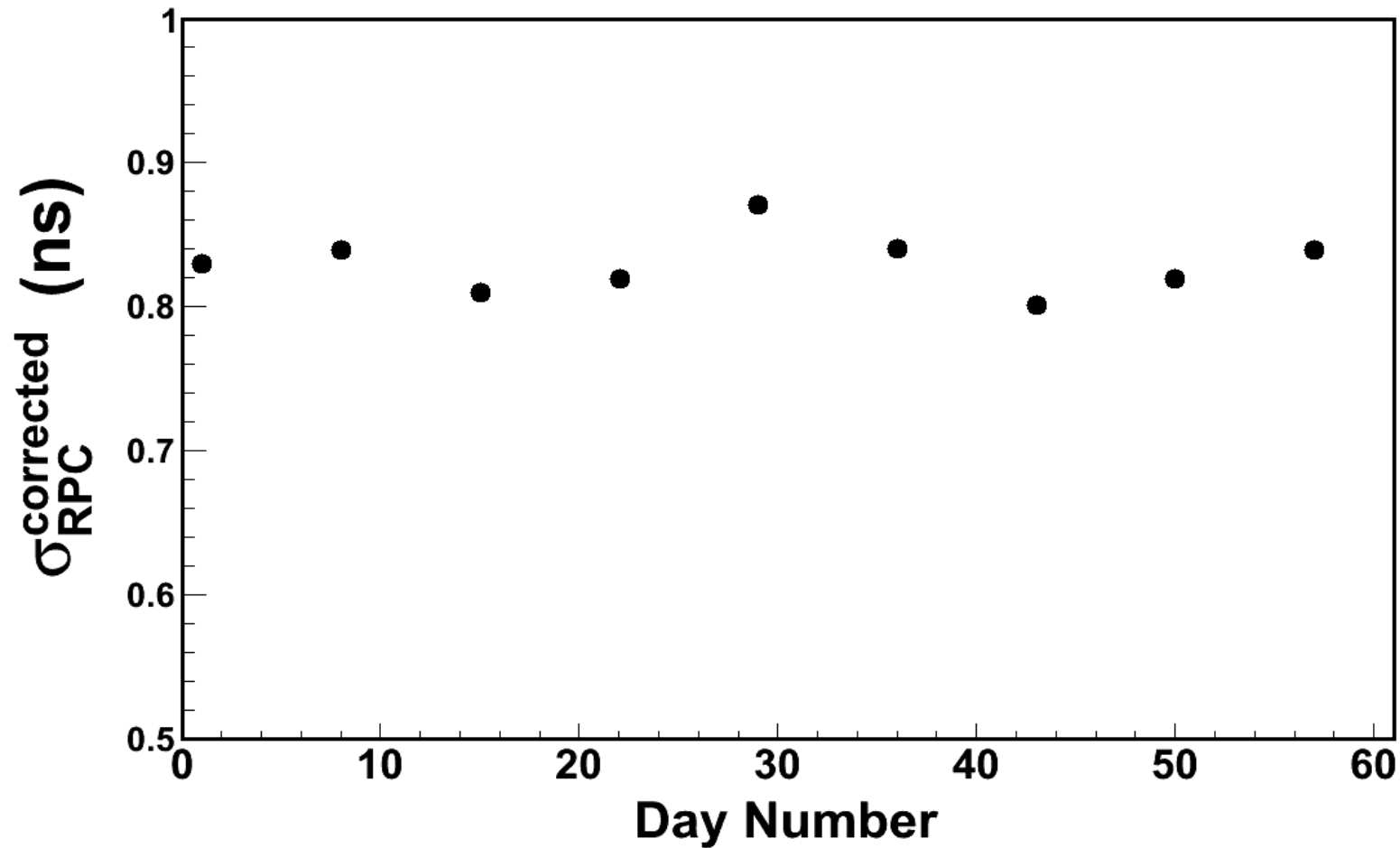


Bulk resistivity of The Chamber



The average bulk resistivity of the chamber is $\sim 8.8 \times 10^{13} \Omega cm$.

Long Term Time Resolution @ 9000 V



The average σ_{RPC} (corrected) of the chamber is **~ 0.83 ns.**

Summary

- The Bakelite sample was found suitable to build RPCs.
- We have successfully fabricated and tested a large oil-free bakelite RPC of (240 cm × 120 cm × 0.2 cm) size.
- The efficiency of the RPC was found to be >95% with a time resolution of ~0.83 ns at 9000V.
- The Efficiency, Current, Noise rate and Time resolution was found stable over a period of 60 days.

Outlook

- A stack of ~10nos. Of (240 cm × 120 cm × 0.2 cm) sized RPC will be made and cosmic muons will be studied.

Group Members:-

Mr. Rajesh Ganai, Mr. Arindam Roy, Mr. Kshitij Aggarwal, Mr. Subikash Choudhury, Mr. Mehul Kumar Shiroya, Mr. Ganesh Das, Mr. Jayant Kumar, Dr. Zubayer Ahammed, Dr. Subhasis Chattopadhyay.

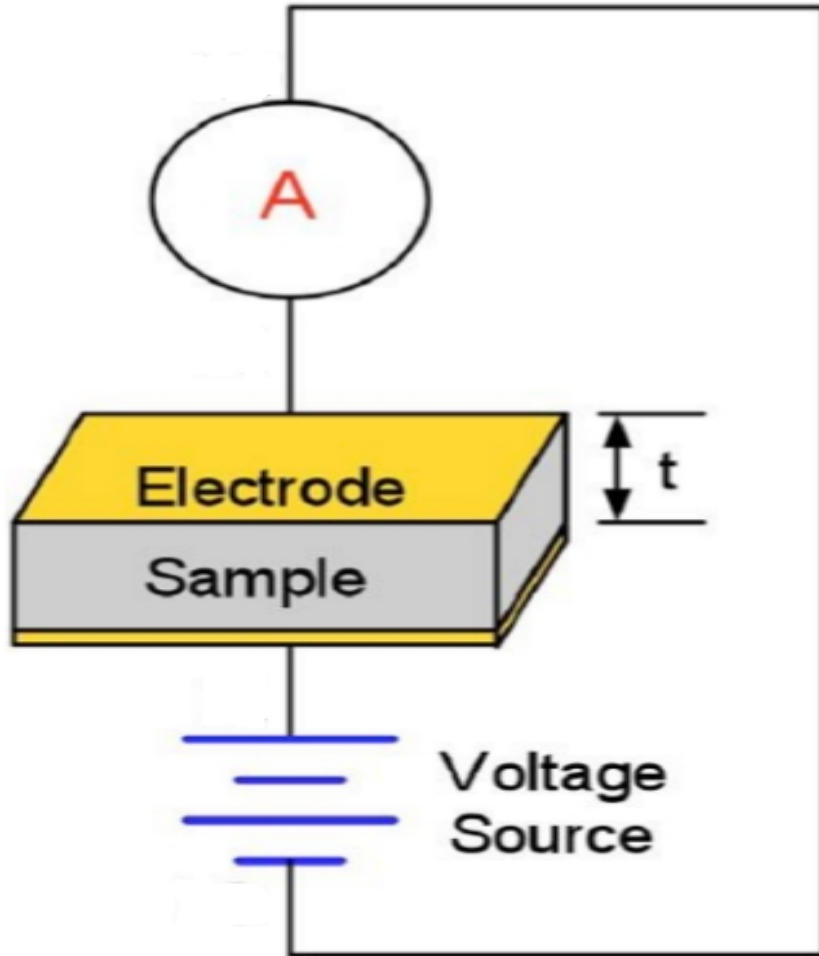


I am very thankful to INO collaboration.

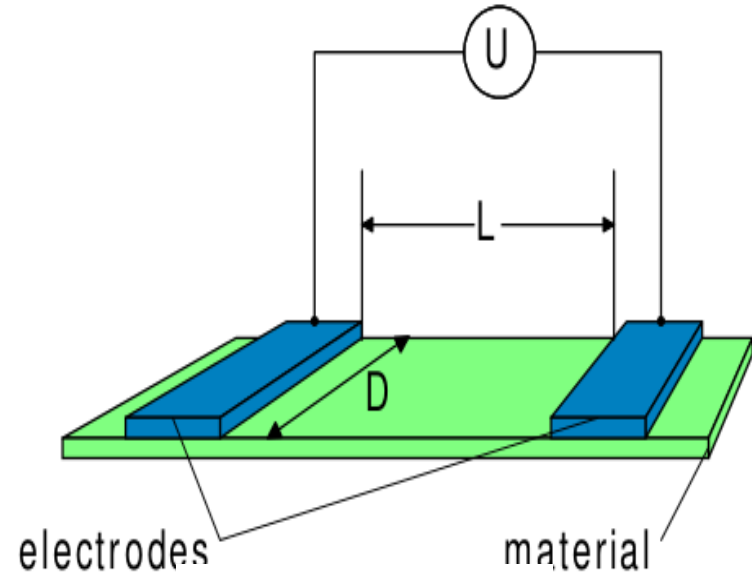
Any question(s) / comment(s) please.

BACK UP

Bulk resistivity measurement set up



Surface resistivity measurement set up



$$\rho_s = \frac{U}{\frac{L}{D} I_s}$$

U – Applied DC voltage.

L – Length between the Electrodes.

I_s – Surface current.

D – Length of the electrodes.

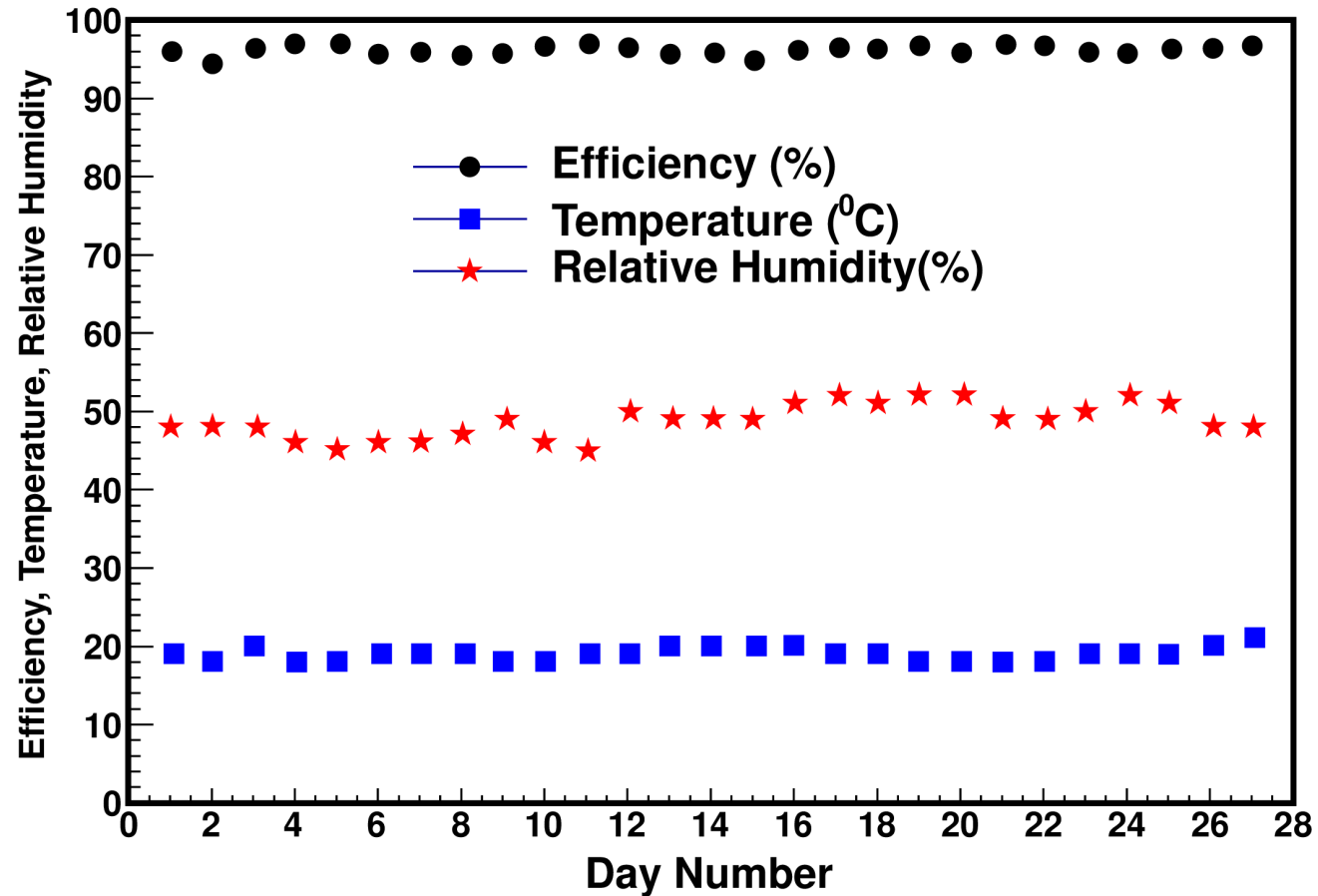
Time Resolution (σ) of Scintillators using CFD :

Paddle 1 : 0.367 ns

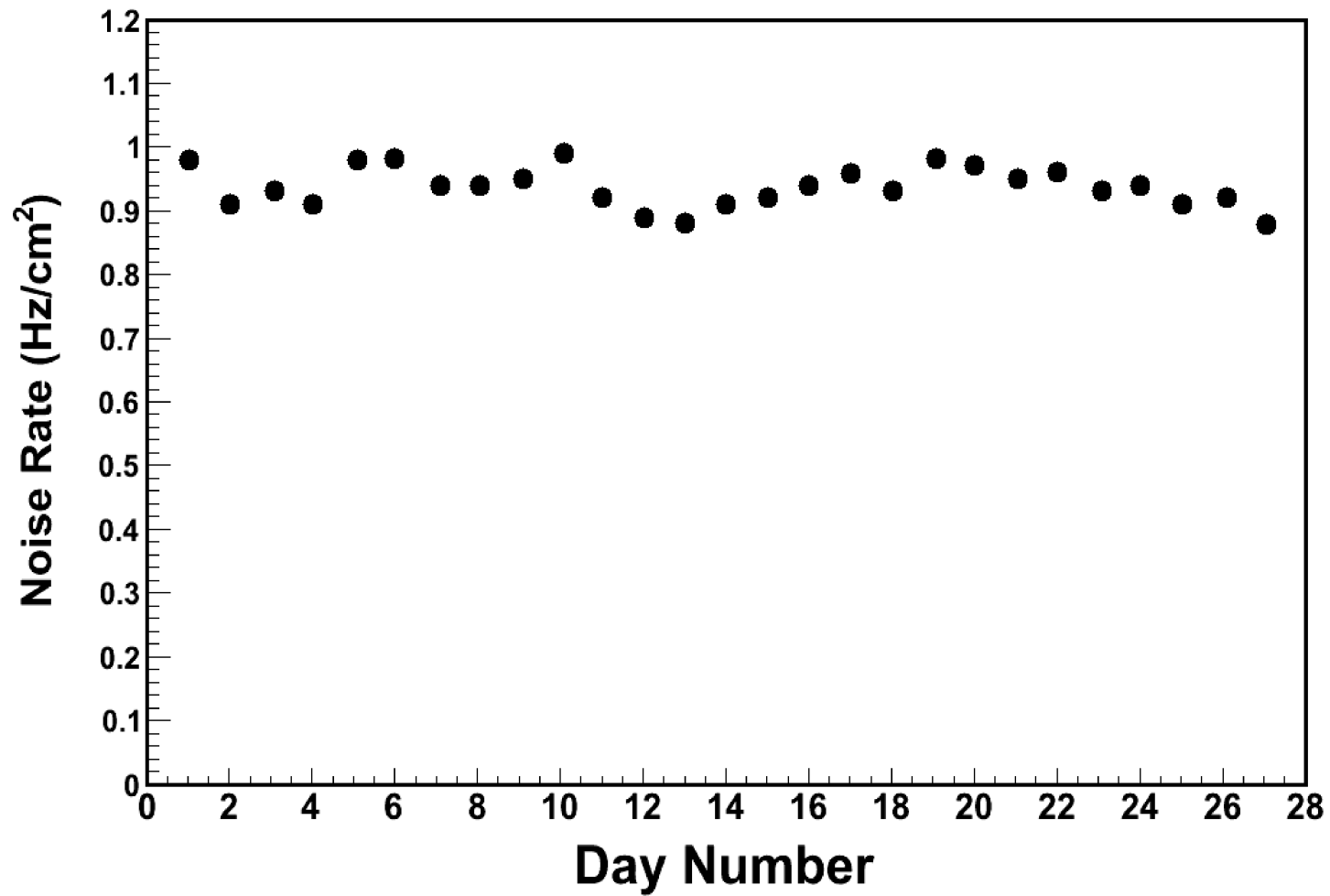
Paddle 2: 0.544 ns

Finger : 0.286 ns

Variation of Efficiency, Temperature and Humidity



Variation of Noise Rate



Variation of Bulk Resistivity of the Chamber

