Development of 6-gap Bakelite Multigap Resistive Plate Chamber

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On behalf of

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Outline

- **Motivation**
- **Multi-Gap Resistive Plate Chamber (MRPC)**
- **Electrical properties of the Bakelite samples**
- **Development of a six gap Bakelite MRPC**
- **Characterisation of the developed MRPC**
- **Summary and Outlook**

Thank you, the organisers of RPC – 2018

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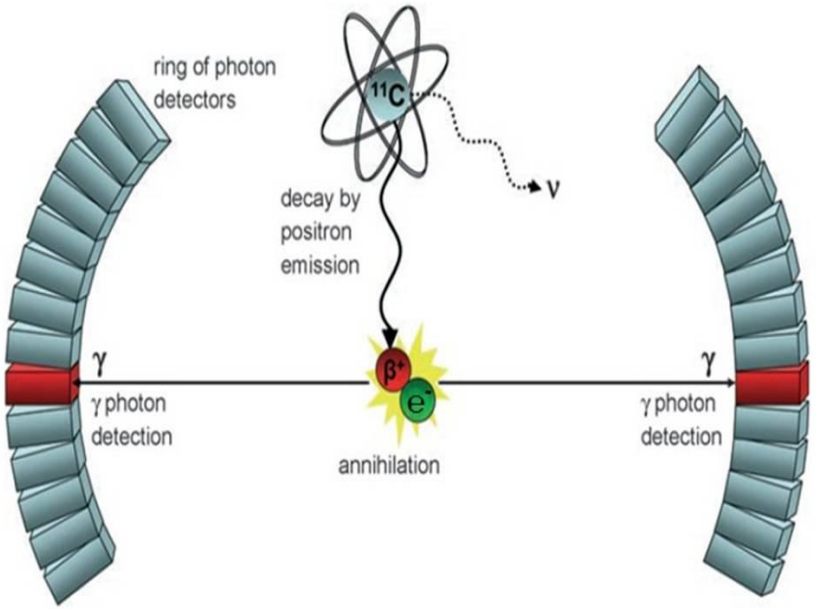
Time of Flight Positron Emission Tomography (ToF-PET)



Positron Emission Tomography (PET) is a nuclear medicinal imaging technique that is used to observe metabolic processes in the body by the basic principle of detecting a pair of back to back photons created by the annihilation of e^+ and e^-.

The drug used is Fluorodeoxyglucose (FDG) (common name).

IUPAC name : 2-Deoxy-2-[^{18}F]fluoroglucose

We have developed two nearly identical 5-gap glass MRPCs to establish the basic working principle of PET imaging. (preseneted in DAE BRNS HEP 2016 symposium *, India.)

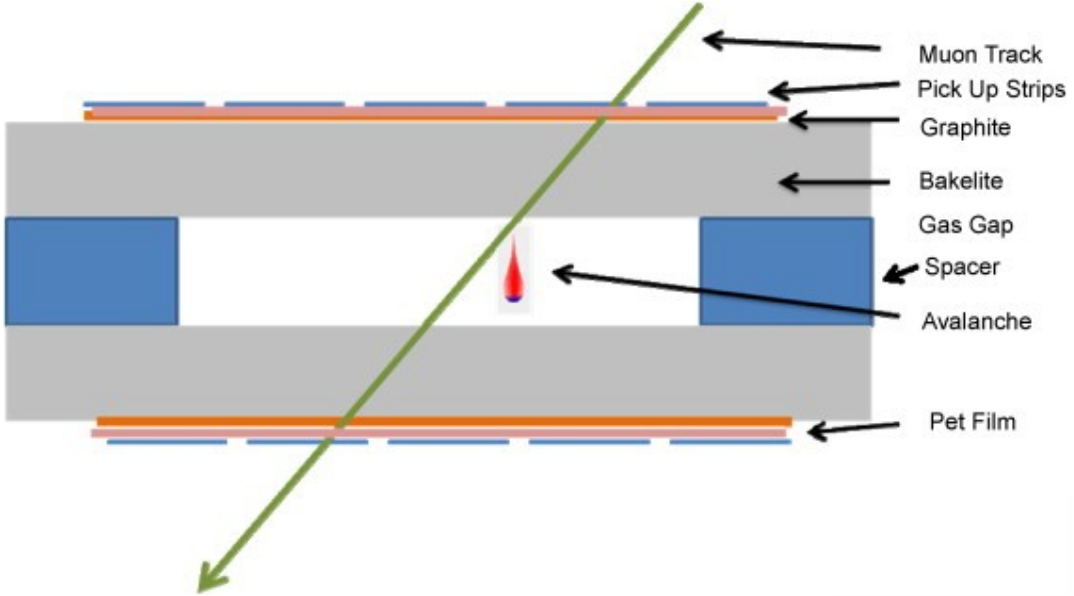
Why MRPCs ?

1. They are low cost and easy to fabricate.
2. They have good time resolution (~10 ps). (Of course it depends on the number of gas gaps.)
3. They can easily be fabricated over a large area.

Main disadvantage is that they have very poor photon detection efficiency.

* manuscript already submitted to Springer Proceedings in Physics.

Multi-gap Resistive Plate Chamber



Picture taken from :-

Archana Sharma, Summary of RPC 2007 the IX International Workshop, Nucl. Instr. And Meth. 602 (2009) 854.

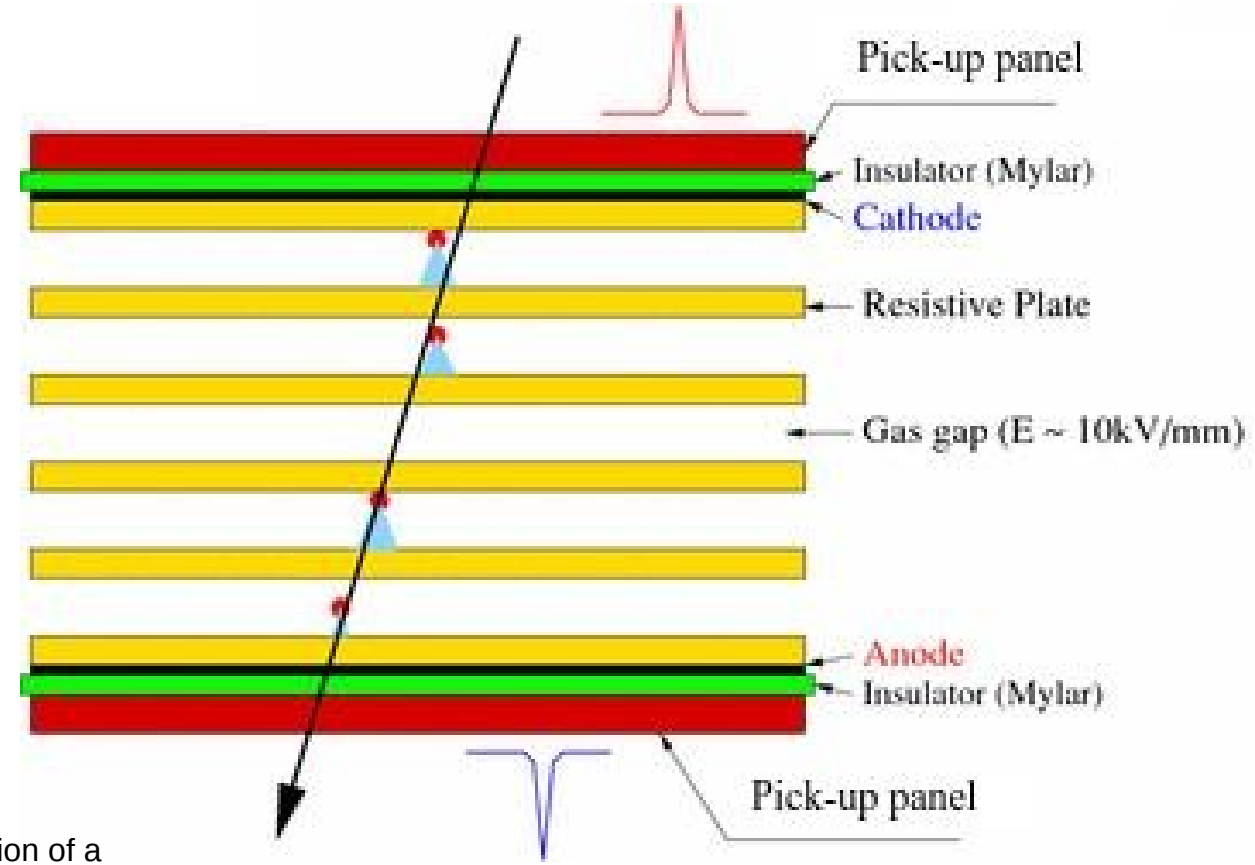
Detection efficiency : > 95 %

Time resolution : ~ 1 ns

Detection efficiency : > 95 %

Time resolution : ~ 10's ps
(depends on number of gaps)

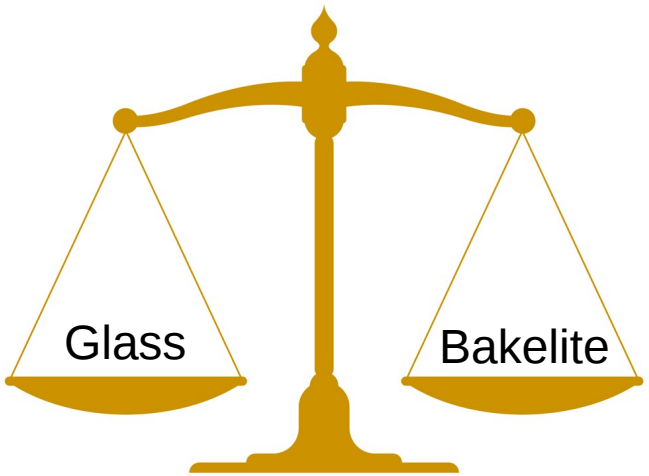
For a fixed gas gap, the time resolution of the chamber improves with increasing the number of sub-gas gaps.



Picture taken from :-

E. Cerron Zeballos et. al., Simulation study on the operation of a multi-gap resistive plate chamber, Measurement Science and Technology 17, (2006), Number 1.

Why bakelite ?



Advantages :-

1. Unlike glass, bakelite sheets do not break easily.

2. Testing, handling and shifting of bakelite based modules are much more easier than the glass modules.

3. Bakelite RPCs can be easily operated in “streamer mode" unlike glass RPCs reducing the number of electronics channels used and hence the overall cost in an experiment.

Disadvantages :-

1. The surface morphological structure of glass is smoother than bakelite.

2. Bakelite electrodes may sag when stacked one on the other in a MRPC leading to non-uniformity in gas gap and hence the electric field.

Answers :-

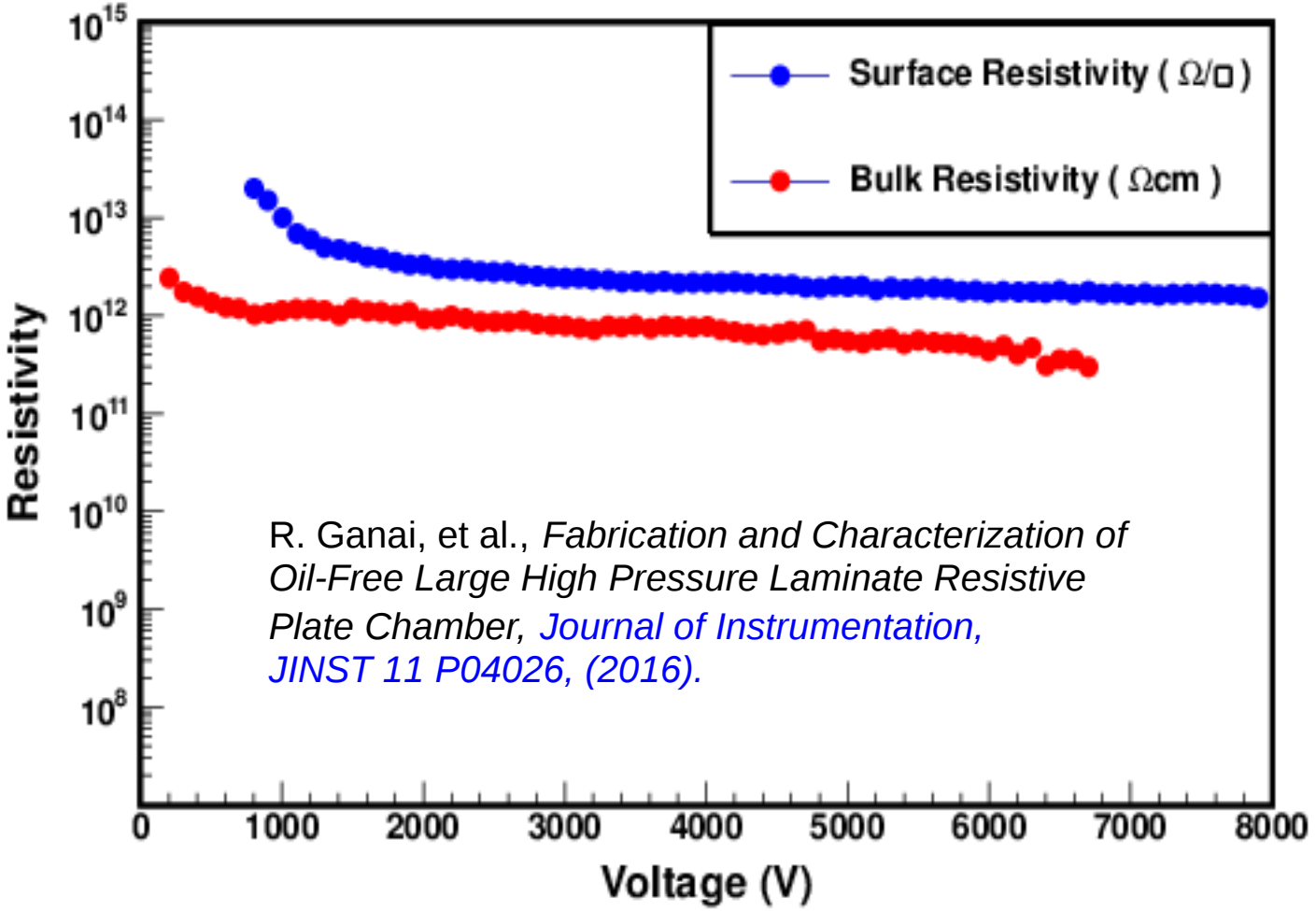
1. The bakelite sample which we used have good surface finishing and **did not** require any kind of oil treatment. The RPC developed with this sample had shown stable performance over a long period of time. (*R. Ganai, et al., Long term performance studies of large oil-free bakelite resistive plate chamber, Journal of Instrumentation, JINST 11 C09010, (2016).*)

2. Placing the button spacers at proper positions may solve the “sagging” problem.

3. Use of thinner “inner electrodes” will help to increase the number of gas gaps within a particular “overall gas gap” which may lead to even better time resolution.

4

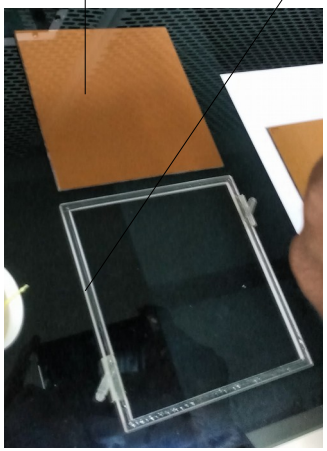
Electrical Properties of the Bakelite Sample



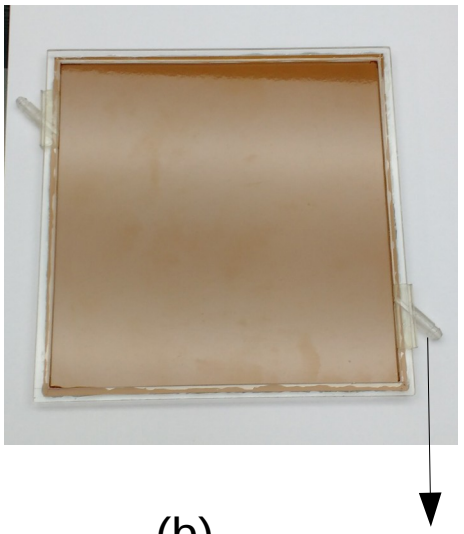
R. Ganai, et al., *Fabrication and Characterization of Oil-Free Large High Pressure Laminate Resistive Plate Chamber,* *Journal of Instrumentation, JINST 11 P04026, (2016).*

The average bulk resistivity	~ 9×10^{11} Ω cm
The average surface resistivity	~ 3×10^{12} Ω / ■

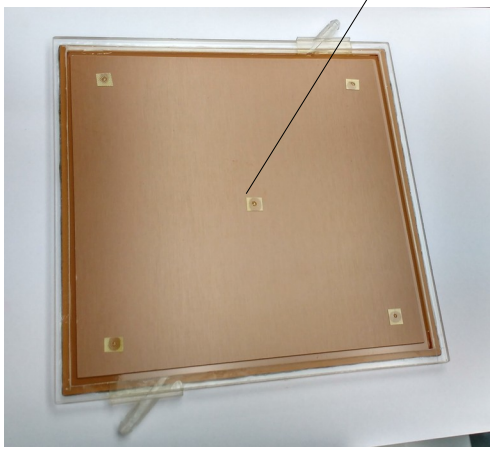
Development of Bakelite MRPC



(a)

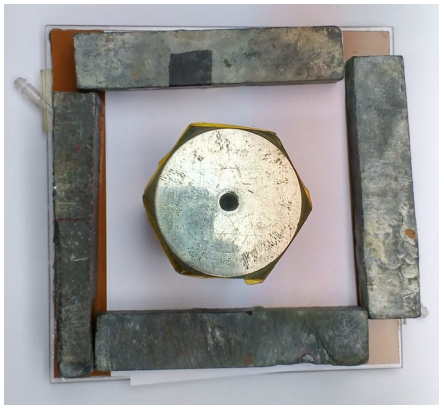


(b)



(c)

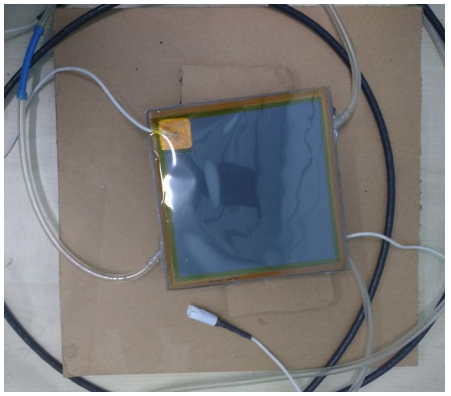
(d)



(e)

Painted MRPC

(f)



MRPC with gas &
electrical connections

(g)

Cosmic ray test set up

(h)

Detector Specifications

1. Total area of the detector : ~ 15 cm x 15 cm

2. Active area of the MRPC : ~ 14 cm x 14 cm

3. Dimensions of outer electrodes : ~ 15 cm x 15 cm x 0.30 cm

4. Dimensions of inner electrodes : ~ 14 cm x 14 cm x 0.050 cm

5. Thickness of button spacers : ~ 0.024 cm

6. Total gas gap thickness : ~ 0.15 cm

7. Paint Used: Black conducting paint : Special dry thinner :: 1:1 (by volume)

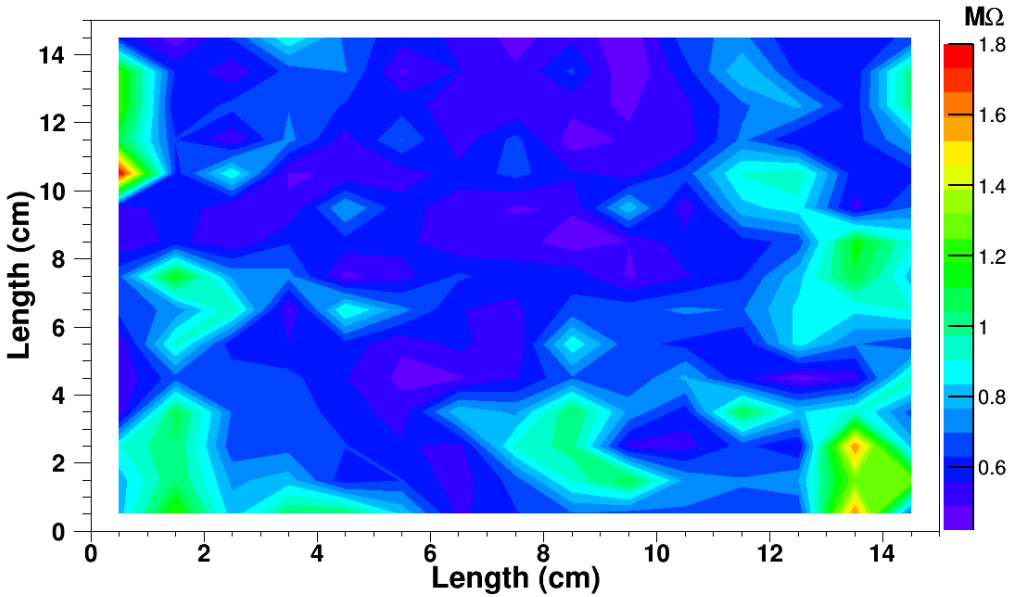
8. Pick up panel used : ~(15 cm × 15 cm × 0.15 cm) FR4 sheet sandwiched between ~(15 cm × 15 cm × 0.0035 cm) copper Sheets.

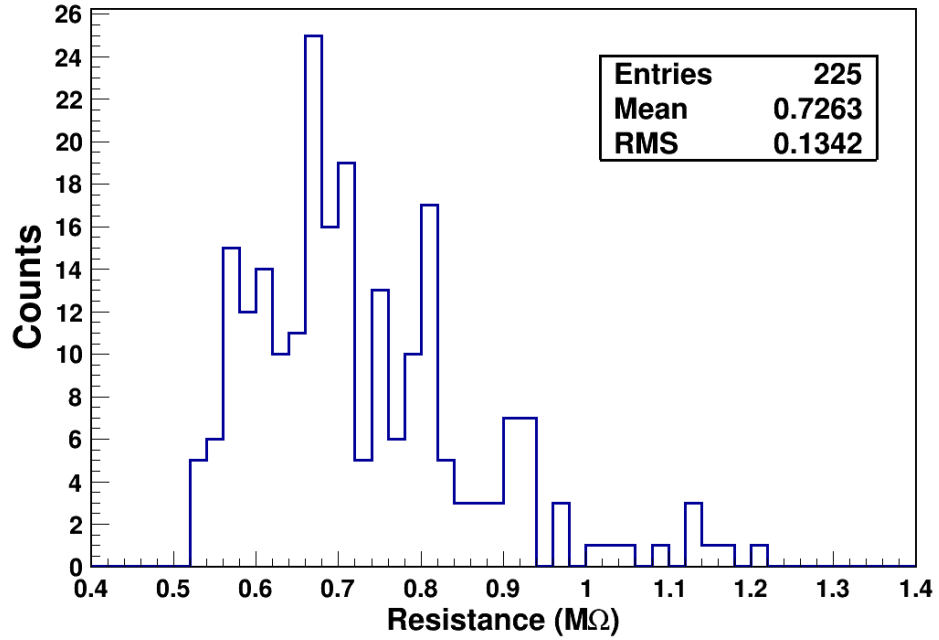
9. Strip size : ~15 cm x 2.5 cm

10. Overall gap between the outer electrodes : 0.4 cm

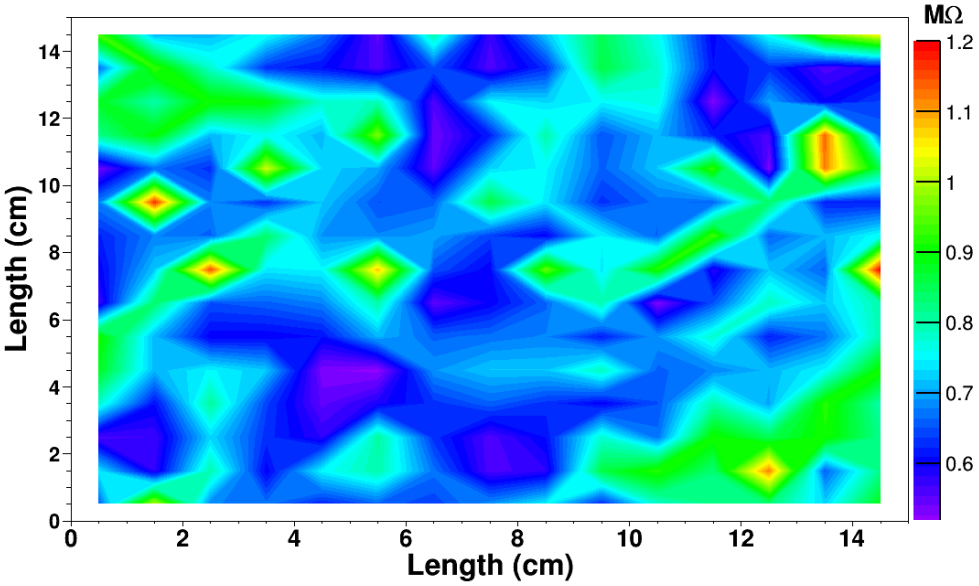
Surface Resistance Profile of Painted Surface

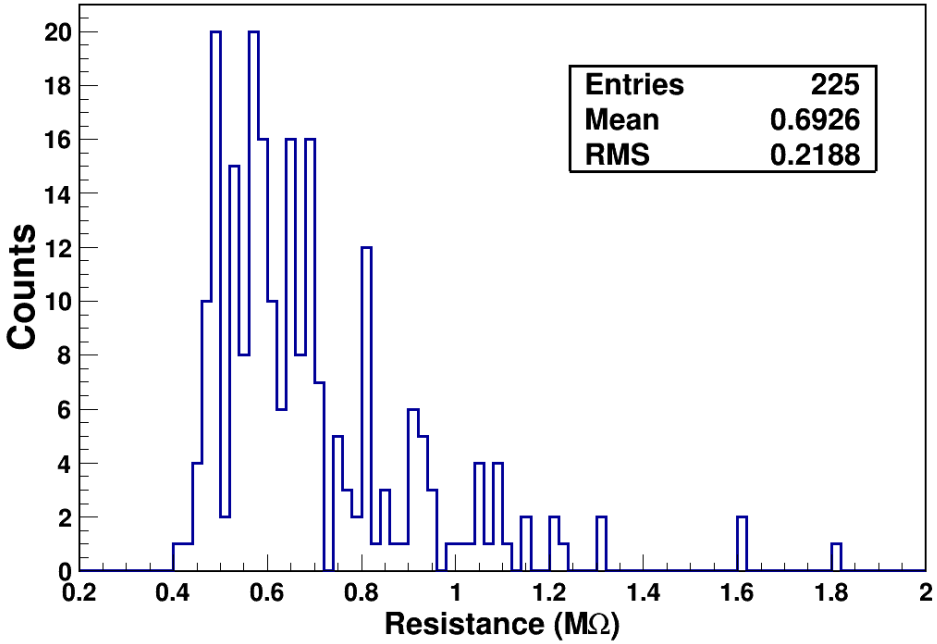
First surface





Second surface





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:-

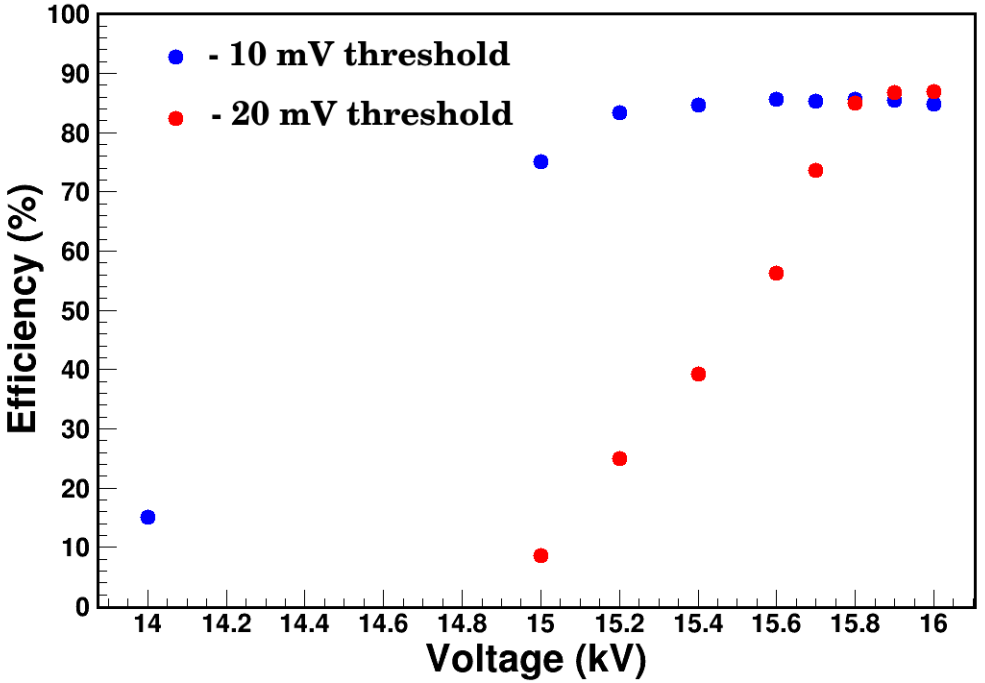
- **High Voltage → CAEN N471A.**
- **Discriminator → CANBERRA QUAD CFD 454.**
- **TDC → Philiphs Scientific 7186 16 Channel TDC.**

Gas Composition:- **R134a : Iso-butane :: 85 : 15**

Gas Flow Rate :- **~0.21 litre/hour**

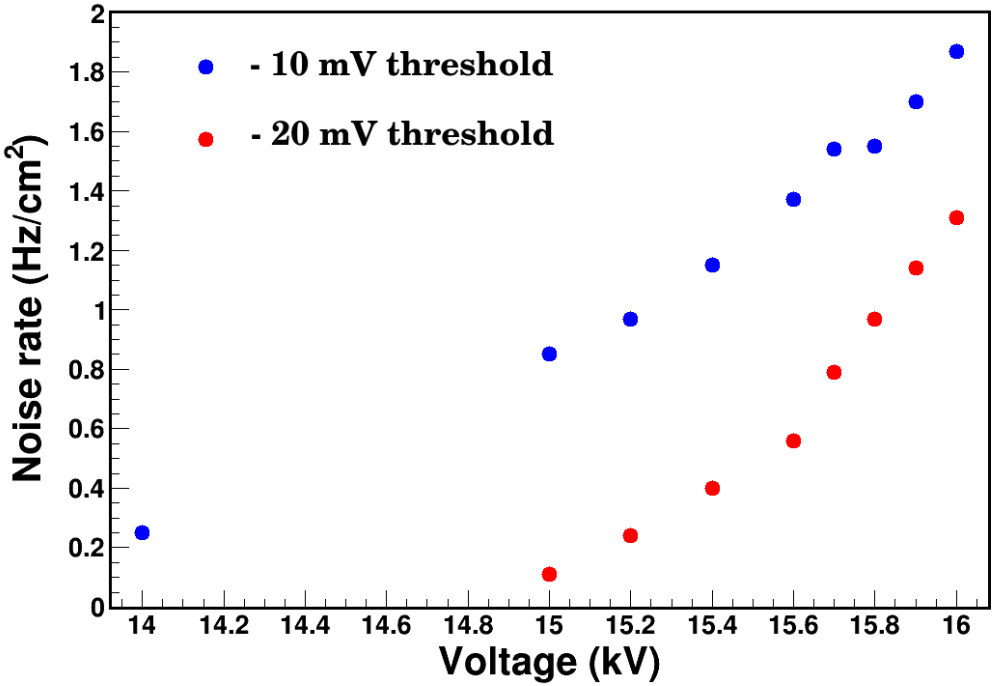
Master Trigger Rate:- **~ 0.008 Hz/cm^2.**

Efficiency and Noise Rate Measurements



Efficiency Plateau obtained beyond 15.2 kV

The plateau shows an efficiency ~ 85%



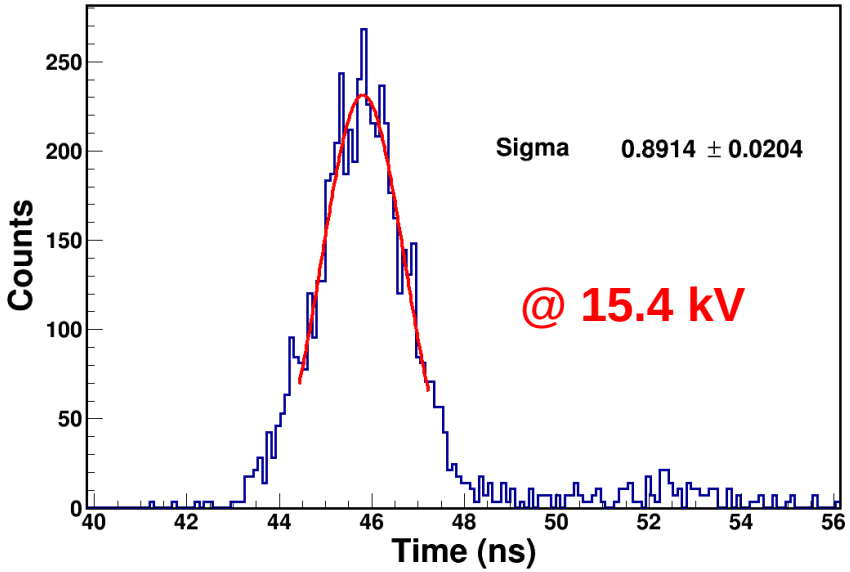
Maximum Noise rate

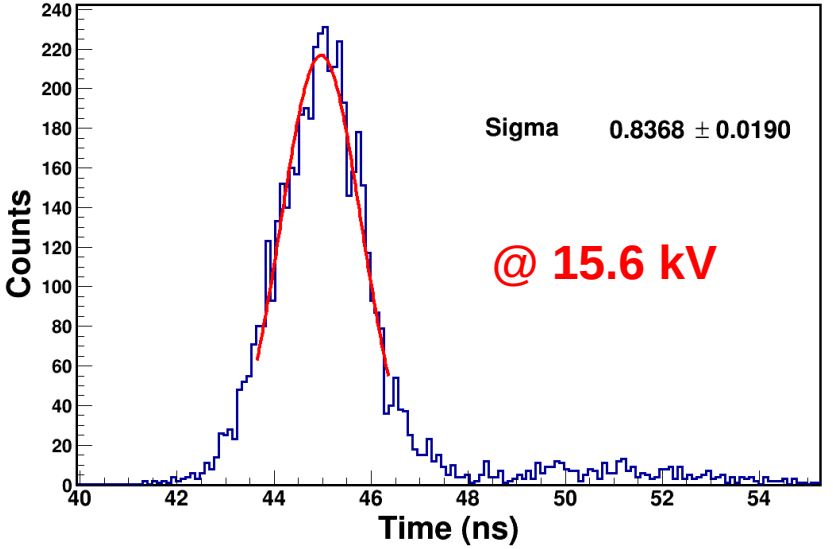
~1.87 Hz/cm^2 @ 16 kV @ -10 mV threshold

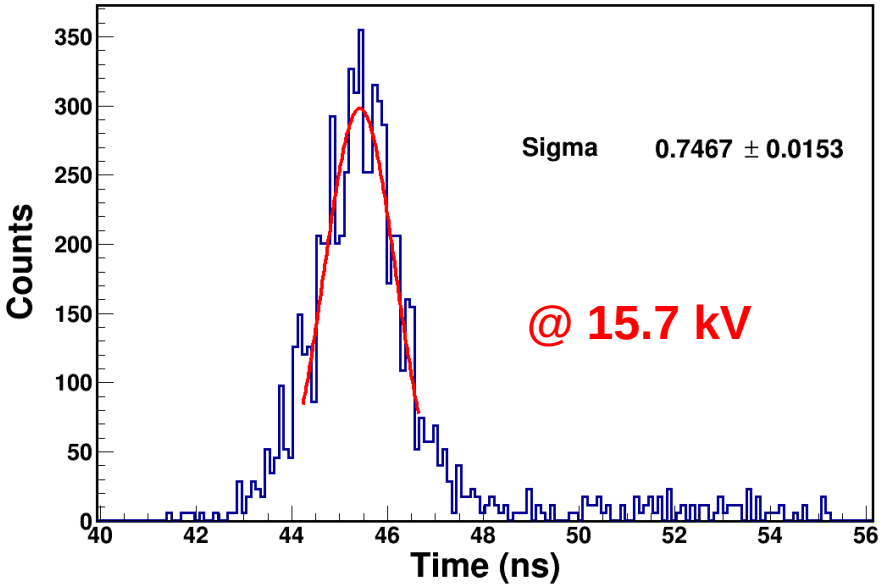
~1.3 Hz/cm^2 @ 16 kV @ -20 mV threshold

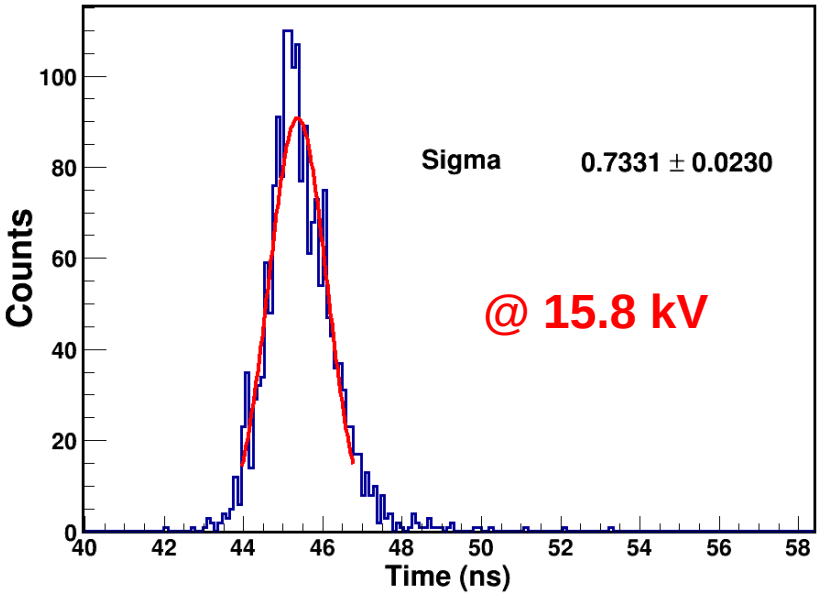
Time Resolution Measurements

Time resolutions were measured in standard cosmic ray test set up with three scintillators at a threshold of -10 mV

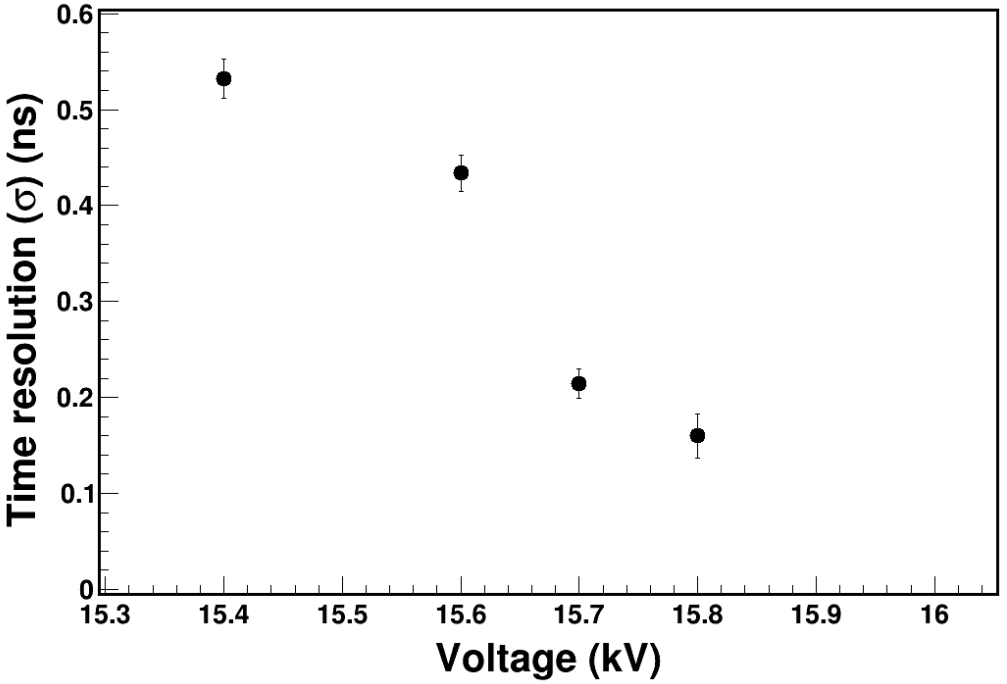








Time Resolution Measurements



The time resolution improves with increasing applied high voltage.

The best time resolution :
~ 160 ps @ 15.8 kV

The measurements have been corrected for scintillators according to :-

$$\sigma^2_{observed} = \sigma^2_{sc\,1} + \sigma^2_{sc\,2} + \sigma^2_{sc\,3} + \sigma^2_{MRPC}$$

Summary

1. A six gap bakelite MRPC has been successfully developed.

2. The MRPC was operated in with gas mixtures of

   R134a : iso-butane :: 85 : 15. → **Efficiency ~ 85%**

3. The best time resolution obtained is ~ 160 ps @ 15.8 kV

4. We have developed 3 more such modules. The characterisation of these modules are in progress.

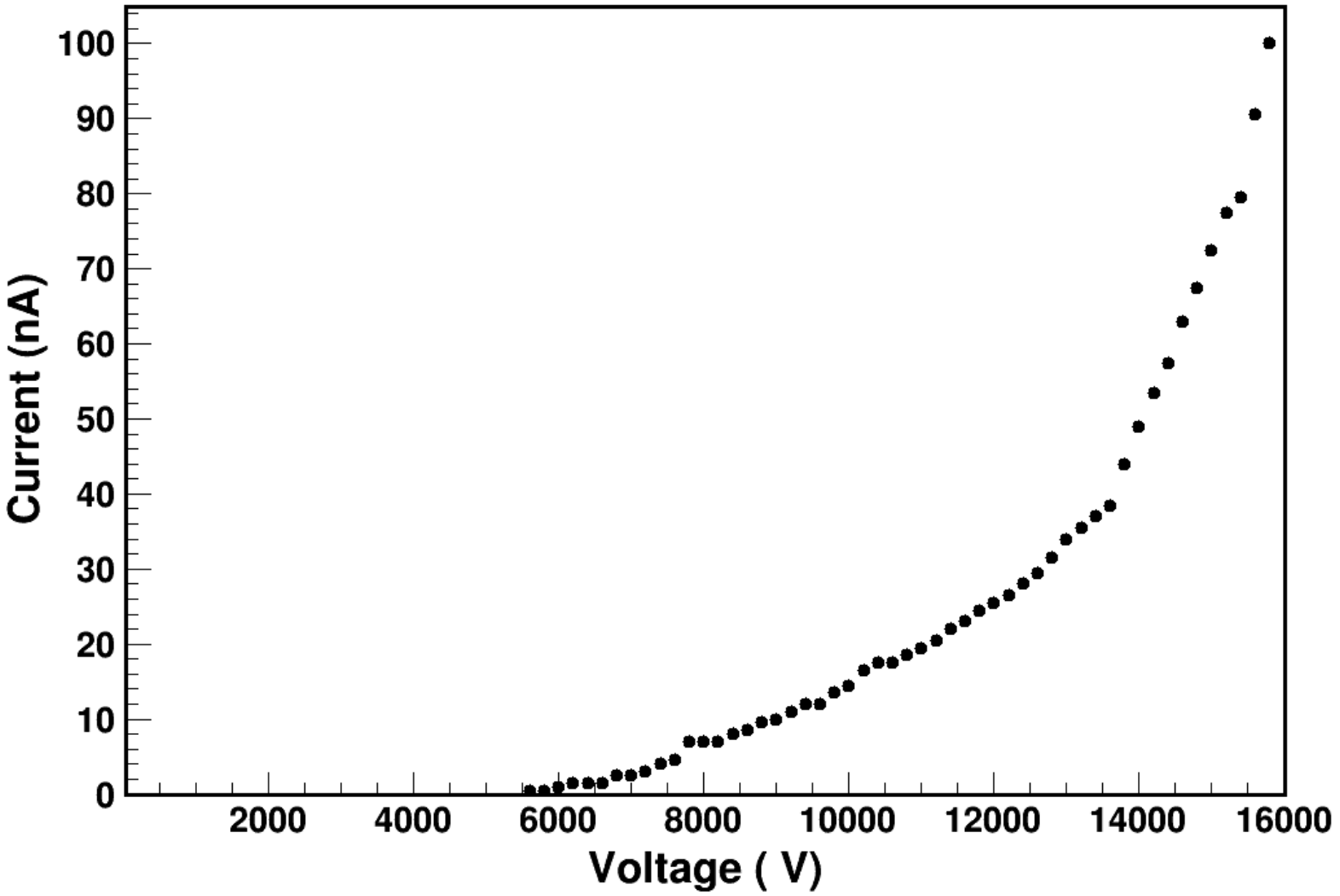
5. We are waiting for **0.4 mm** thick bakelite sheets from the company.

Outlook

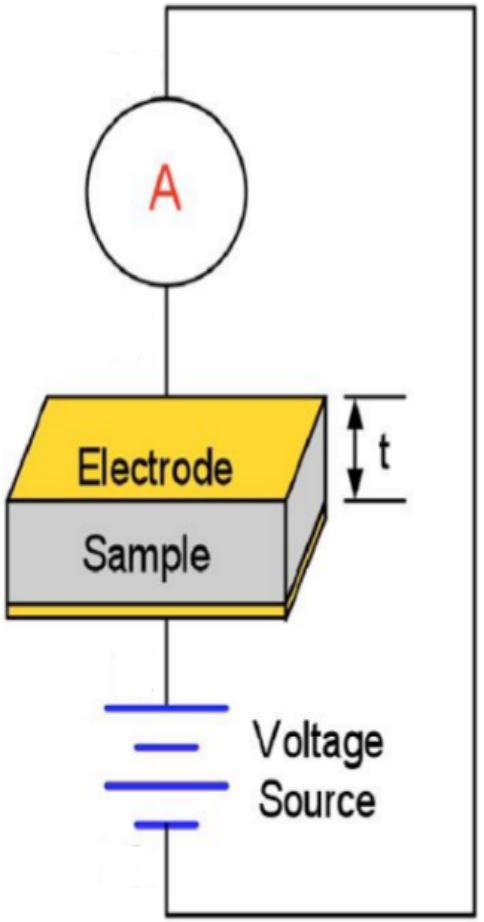
- To improve the time resolution.
- To test the detector with several other gas mixtures.
- To test the performance stability of the detector over a long peroid of time.
- To test the detector for photon detection efficiency.

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

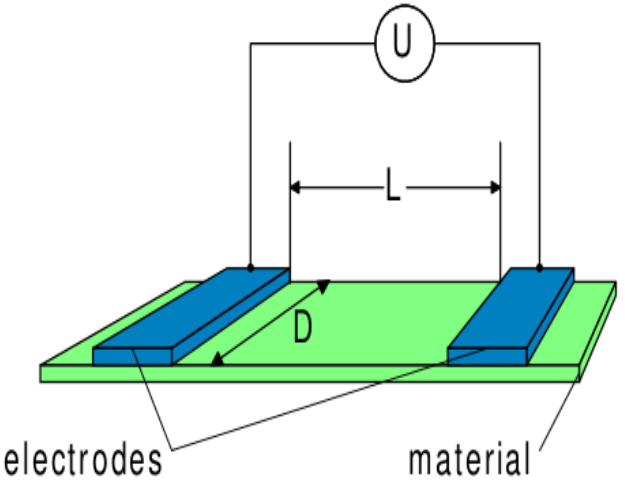
IV


Current (nA)
100
90
80
70
60
50
40
30
20
10
0
2000
4000
6000
8000
10000
12000
14000
16000
Voltage (V)

Bulk resistivity measurement set up



Surface resistivity measurement set up



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

U – Applied DC voltage.
L – Length between the Electrodes.
I_s – Surface current.
D – Length of the electrodes.

Pick up panel