Effect of Variation of Surface Resistivity of Graphite layer in RPC

Anil Kumar[1), 2), *], V. Kumar[1), 2)], J. Datta[1), 2)], S. Mukhopadhyay[1), 2)], S. Sarkar[1), 2)], N. Majumdar[1), 2)]

[1)] Saha Institute of Nuclear Physics, Bidhannager, Kolkata, India, [2)] Homi Bhabha National Institute, Trombay, Mumbai, India

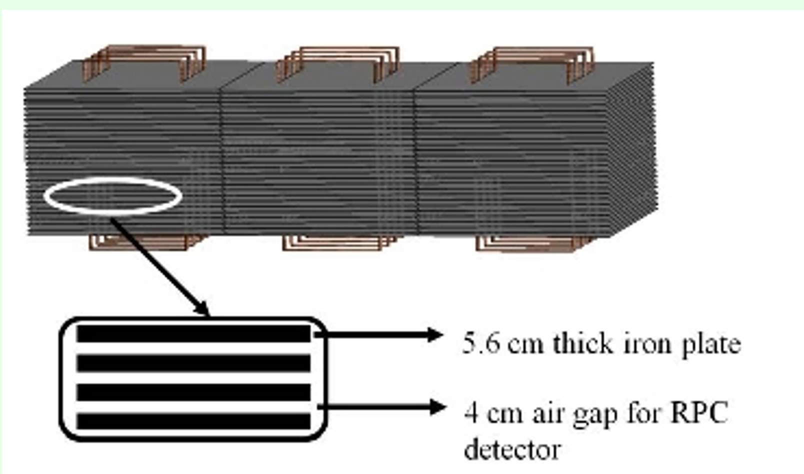
anilak41@gmail.com

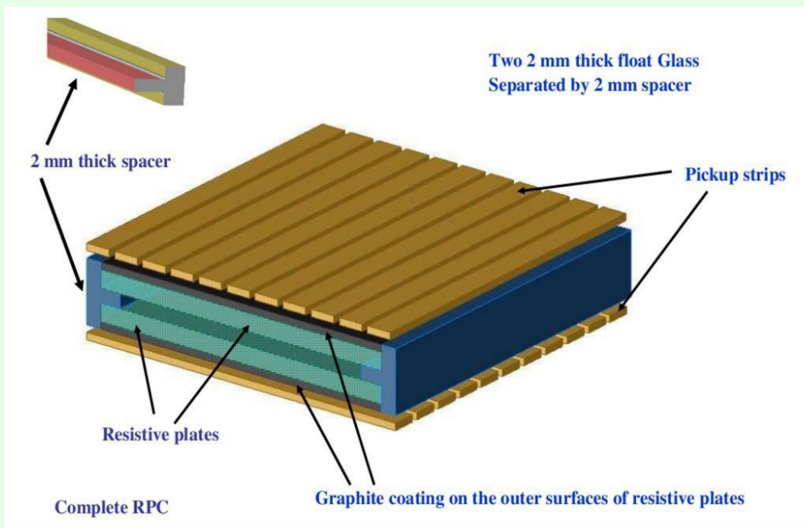
Introduction

I study the effect of resistivity variation of graphite layer on the working of Resistive Plate Chamber (RPC) which is an active detector in Iron CALorimeter (ICAL) detector at the India-based Neutrino Observatory (INO). INO Project is a multi-institutional effort aimed at building a world-class underground laboratory with a rock cover of approx. 1200 m for non-accelerator based high energy and nuclear physics research in India as explained in the Physics White Paper of the ICAL (INO) Collaboration [1].

Components of Project

- Construction of an underground laboratory and associated surface facilities at Pottipuram in Bodi West hills of Theni District of Tamil Nadu, India.
- Construction of an Iron Calorimeter (ICAL) detector consisting of 50000 tons of magnetized iron plates arranged in stacks.
- 29000 Resistive Plate Chambers (RPCs) of size 2 m×2 m would be inserted as active detectors in the gap between the iron layers.
- Resistive Plate Chamber is a gaseous detector where the gas is confined between the two parallel resistive plates made up of glass having a coating of graphite layer from outside for making electrical contact.



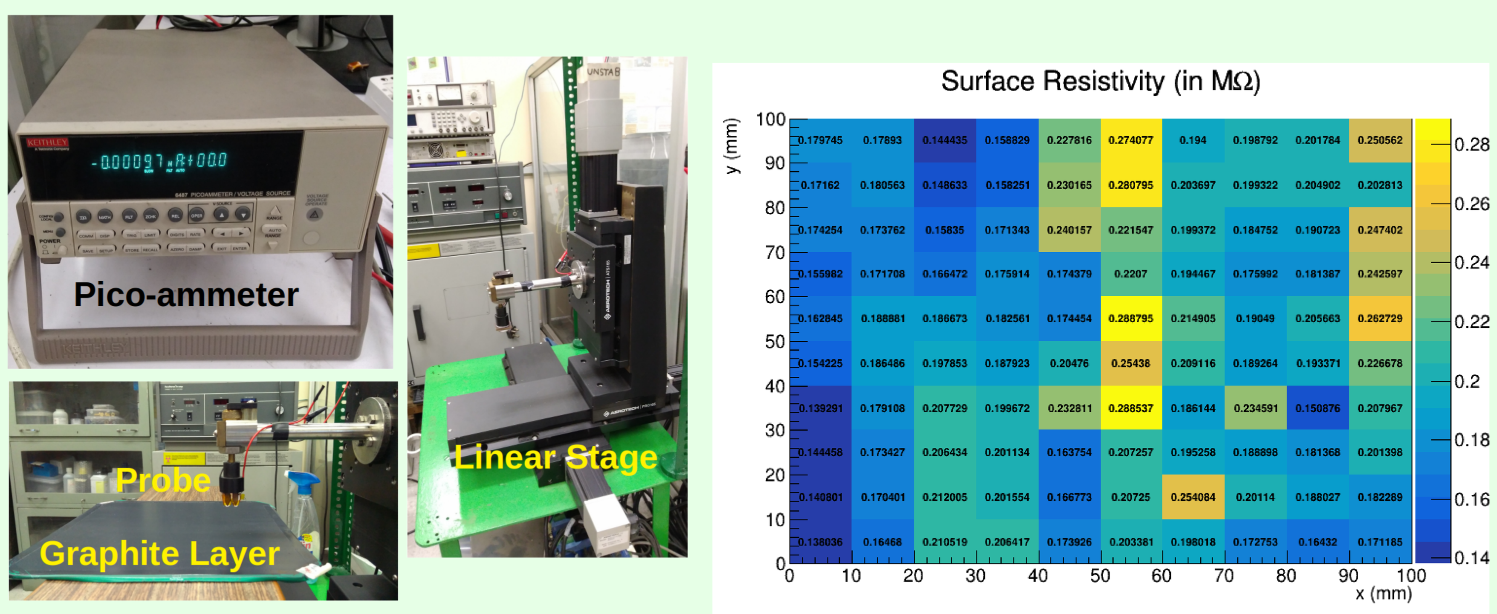


Motivation

We are investigating how resistivity of graphite layer in the RPCs modify the signals collected during the ICAL experiment and their analysis. The surface resistivity of the graphite layer is around 1 M$\Omega/\Box$. The non-uniform thickness of graphite layer leads to the variation in surface resistivity which may have an effect on the signal gain and dead time.

Experimentally measured Surface Resistivity

- The Aerotech linear stage (XYZ machine) is programmed in the BASIC programming language to traverse the surface of Graphite layer with an accuracy of 1 mm.
- The area of 10×10 cm^2 has been divided into 100 cells of size 1 cm^2 each.
- A square zig of size 1 cm^2 is used to measure the resistance which is equal to the resistivity of the square region.
- The Pico-ammeter is used to measure current when a constant voltage is applied across the probe and the data acquisition is done through Python program using GPIB interface.
- Both the programs have been synchronized to obtain the surface resistivity as the linear stage traverses the XY plane of the graphite layer.



(a) (b)

Figure 1: *(a) Experimental setup with square zig probe to measure surface resistivity. (b) Experimentally Measured Surface Resistivity of Graphite layer of size 10× 10 cm^2.*

Chani Code to Simulate Charge Transport

In Chani code [2], simulation of charge transport is carried out by the solution of the Poisson equation using "method of moments" through the surface of interest at each time step and calculation of the currents between small subcells of the surface.

$$\nabla^2 V = -\frac{\sigma}{\epsilon}\delta(z)$$

$$[l_{mn}][\sigma_n] = [V_m]$$

where,

$$l_{mn,m\neq n} = \frac{\Delta S_n}{4\pi\epsilon R_{mn}} \quad (1)$$

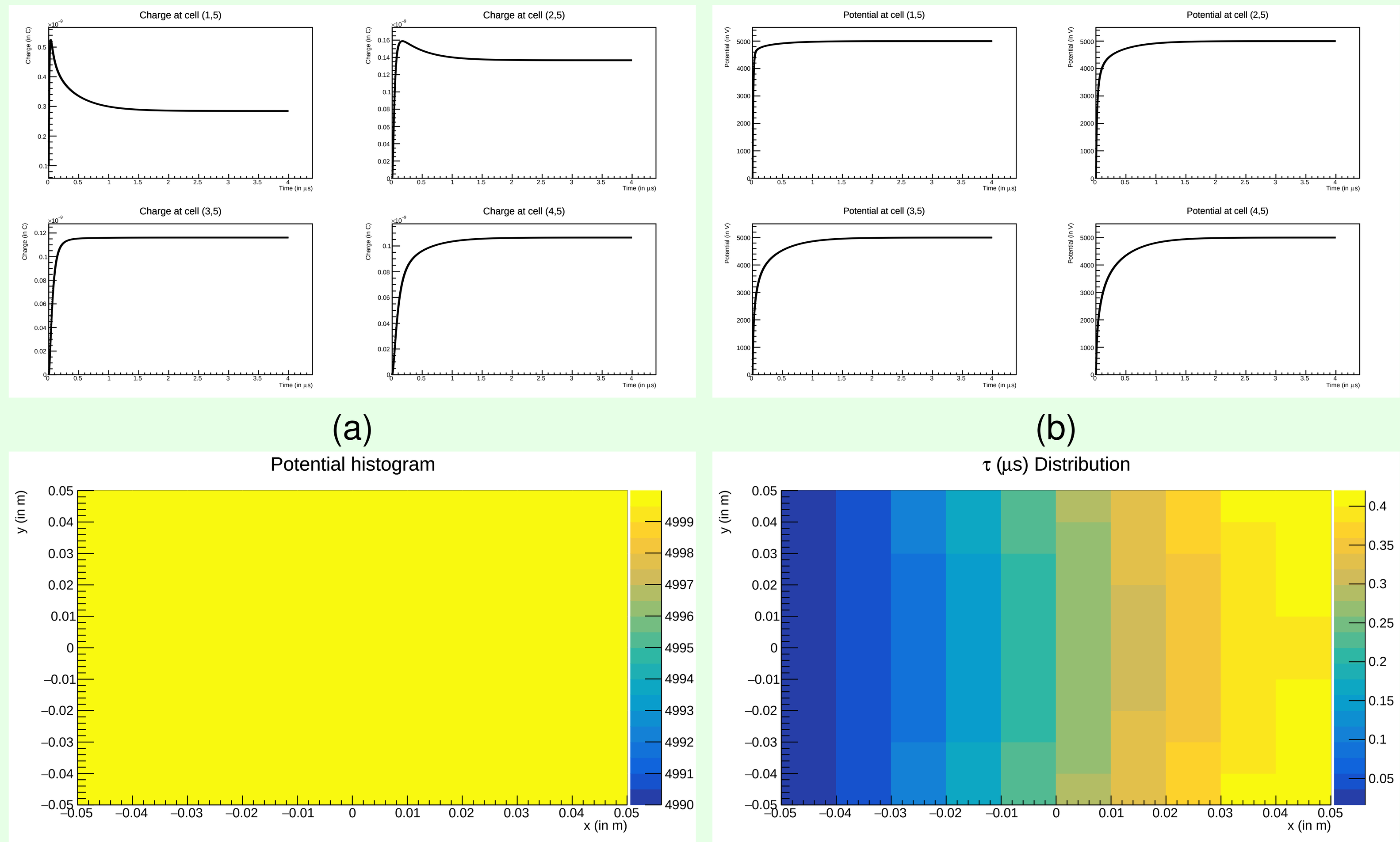
where ΔS_n is the area of n^{th} cell and the distance between m^{th} and n^{th} cells, R_{mn} is:

$$R_{mn} = \sqrt{(x_m - x_n)^2 + (y_m - y_n)^2} \quad (2)$$

$$l_{nn} = \frac{1}{4\pi\epsilon}\left[a_x \ln\left(\frac{\sqrt{a_x^2+a_y^2}+a_y}{\sqrt{a_x^2+a_y^2}-a_y}\right) + a_y \ln\left(\frac{\sqrt{a_x^2+a_y^2}+a_x}{\sqrt{a_x^2+a_y^2}-a_x}\right)\right] \quad (3)$$

where a_x and a_y are the size of the cell in x and y direction.

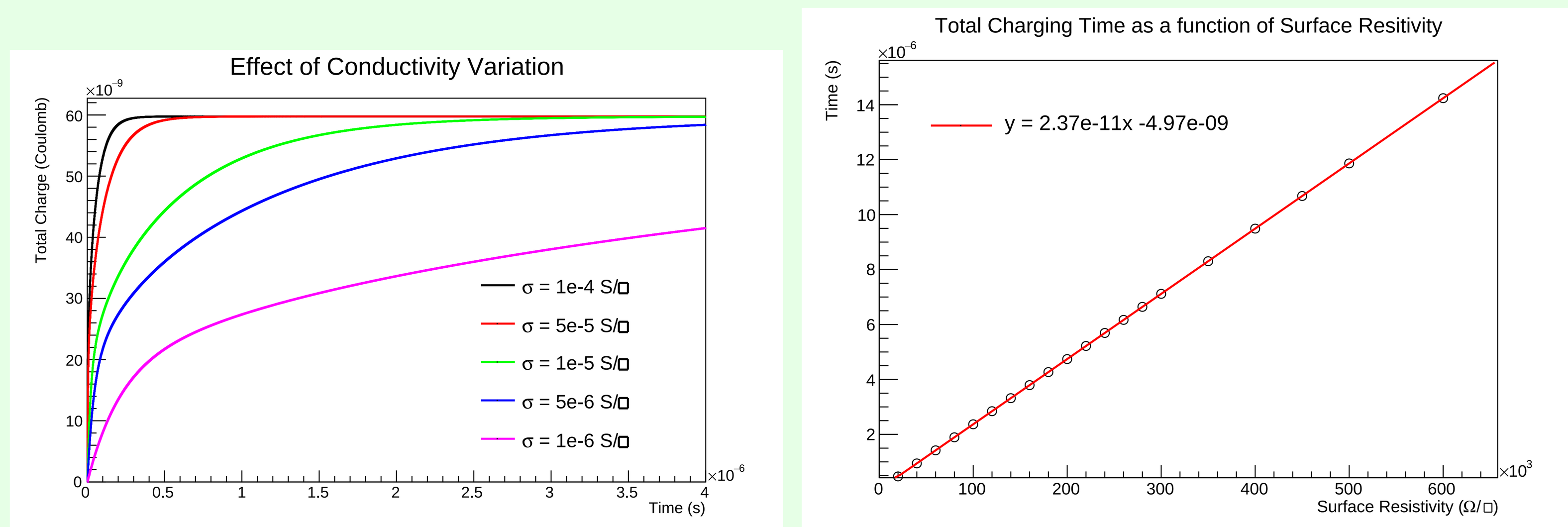
Simulation of Potential Buildup across Uniform Resistivity



(a) (b) (c) (d)

Figure 2: *The potential, V of 5000 V is applied at the left end of the resistive layer through a conducting contact. (a) Charge build up as a function of time in a cell (1,5) to (4,5). (b) Potential build up as a function of time in a cell (1,5) to (4,5). (c) Potential distribution for uniform resistivity after 4 μs. (d) Distribution of time required to reach a fixed voltage of $(1-1/e)\times 5000$ V for uniform resistivity.*

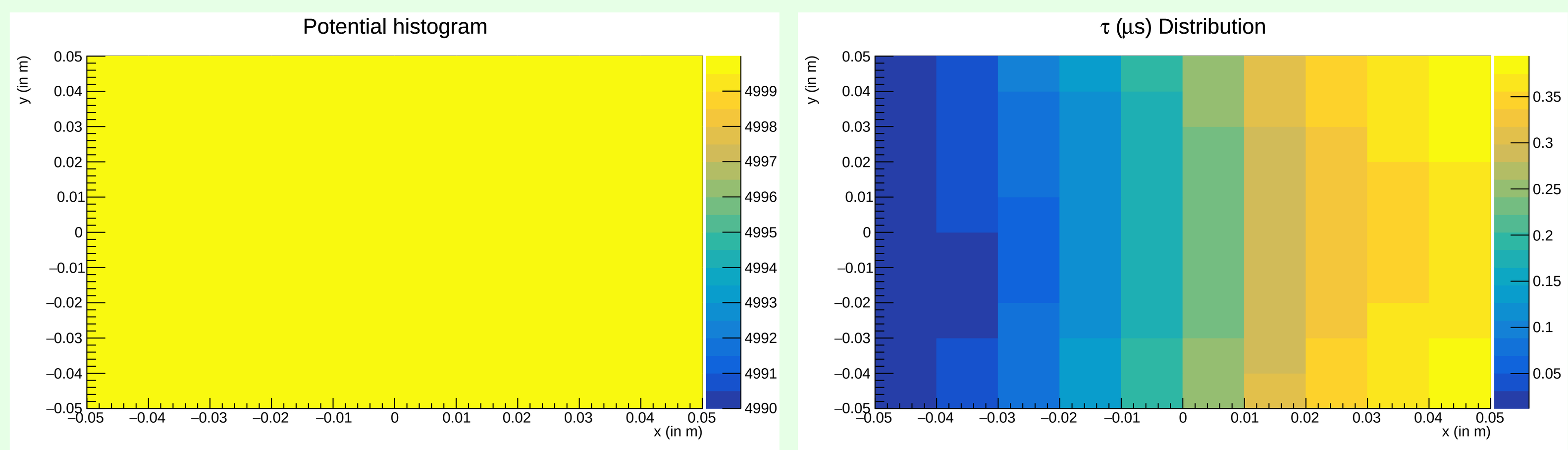
Variation of Charging Time as Function of Uniform Resistivity



(a) (b)

Figure 3: *(a) Comparison of charging behavior for various surface conductivities. (b) Total charging time as a function of surface resistivity variation.*

Potential Buildup across Non-uniform Resistivity



(a) (b)

Figure 4: *(a) Potential distribution for experimentally measured non-uniform resistivity after 4 μs. (b) Distribution of time required to reach a fixed voltage of $(1-1/e)\times 5000$ V for experimentally measured non-uniform resistivity.*

Summary

- The final potential does not depend on the non-uniformity of surface resistivity of graphite layer.
- The time required to reach the final potential depends on the resistivity and the distance from the point of the applied voltage.
- We will experimentally measure voltage distribution and charging behavior.
- We will include bakelite by modifying the code for 3-dimensional geometry which will require a different solver like neBEM.
- We are thankful to INO and SINP for providing research facility.

References

[1] S. Ahmed *et al.* [ICAL Collaboration], Pramana **88**, no. 5, 79 (2017) doi:10.1007/s12043-017-1373-4 [arXiv:1505.07380 [physics.ins-det]].

[2] N. B. Budanur, arXiv:1207.4585 [physics.comp-ph].

[3] R. Cardarelli, et al., Nucl. Phys. B (Proc. Suppl.) 158 (2006) 25-29

DAE-BRNS High Energy Physics (HEP) Symposium,10 - 14th December 2018, IIT Madras, Chennai 600036, Tamil Nadu, India