Studies on Electrostatic Field of a Resistive Plate Chamber

[1]A. Jash*, [1]N. Majumdar, [1]S. Mukhopadhyay, [2]S. Chattopadhyay
[1]Saha Institute of Nuclear Physics, Kolkata, West Bengal, India;
[2]Variable Energy Cyclotron Centre, Kolkata, West Bengal, India

Abstract: Resistive plate chambers[1] (RPC) (fig.1) are fast gaseous detectors, having a simple design and construction, good time resolution, high efficiency and low cost production. These are extensively used in high energy physics experiments. A large number of RPCs will be used as the main detector element for India's mega science project, namely India Based Neutrino Observatory[2] (INO). So, detailed study of this detector is very crucial for the scientific community. RPCs consist of two parallel plates made from very high resistivity material and separated by a gas volume; high voltage(±5kV) is applied on the plates using 20μm graphite (ε=12.0) coating (fig.2). COMSOL[3] has been used to generate the potential and field within a Glass (ε=5.0) RPC containing air and the effect of different detector components like spacers (mica, ε=5.4), frame on the field configuration is studied. The result obtained is compared with neBEM[4] (nearly exact Boundary Element Method) tool-kit developed at SINP, Kolkata.

Figure 1. Resistive Plate Chamber

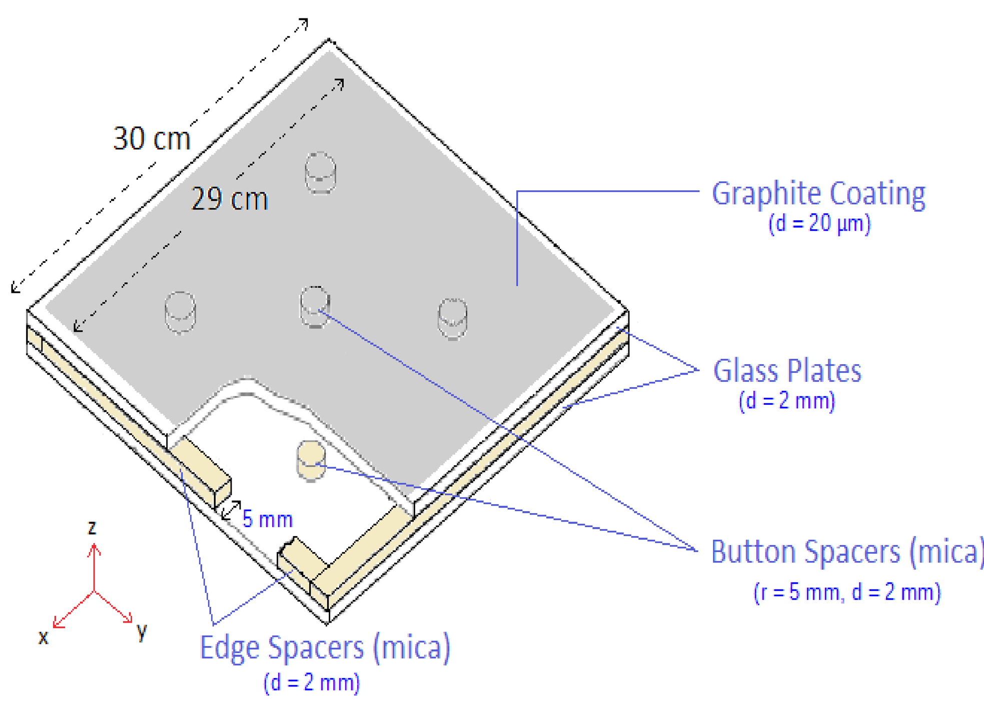

Figure 2. Schematic diagram of RPC

Comparative Study :

COMSOL

- Based on Finite Element Method.
- The complete 3D region of interest is discretized using nodes distributed throughout the volume.
- The governing equation is satisfied at the nodal points to solve for potential.
- The variation of potential from node to node is determined by a basis function, usually a low-order polynomial.
- Value of potential at an arbitrary point is obtained by interpolating values from the surrounding nodes.
- Field value is represented by lower order polynomial, so at a non-nodal point field value suffers a lot.

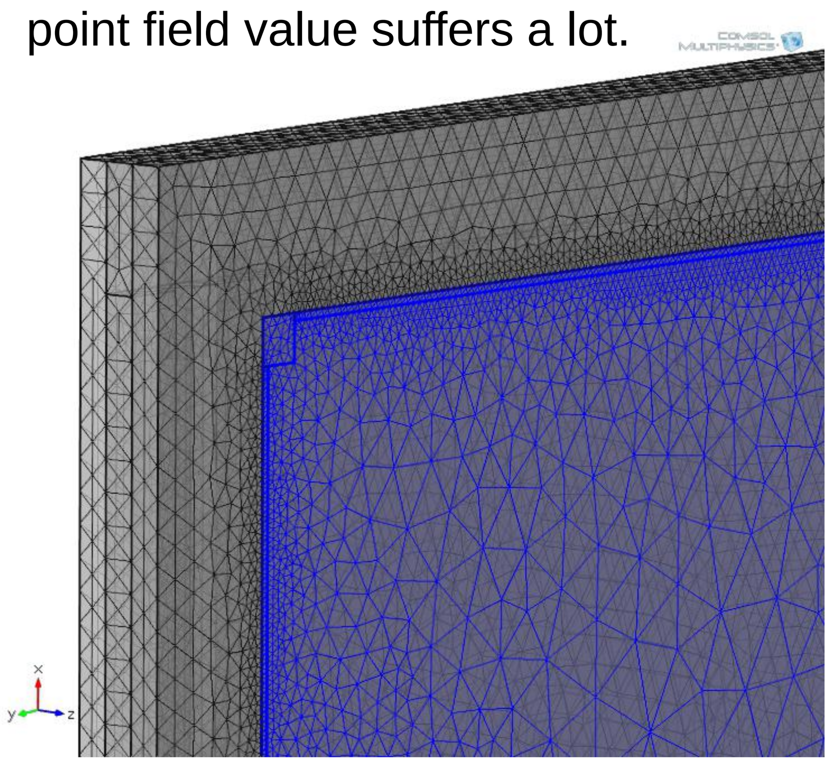

Figure 3. 3D meshing in COMSOL

- Triangular meshing on the outer surface of the coat, then sweep method used to mesh the volume of the coat. Tetrahedral meshing used for the rest of the geometry.
- Finer meshing used at the edges and corners of the coat.
- Complete mesh consists of about 21 lakh elements.
- D.O.F. Solved for : 4652766.
- System used : Windows PC (16GB RAM).

neBEM

- Based on Boundary Element method.
- It solves for charge density distribution on each of the boundary elements by adopting a Green function approach.
- Potential and field at any arbitrary point can be found using integral formulation of electrostatics: a mesh-less method.
- No interpolation and extrapolation is ever necessary.

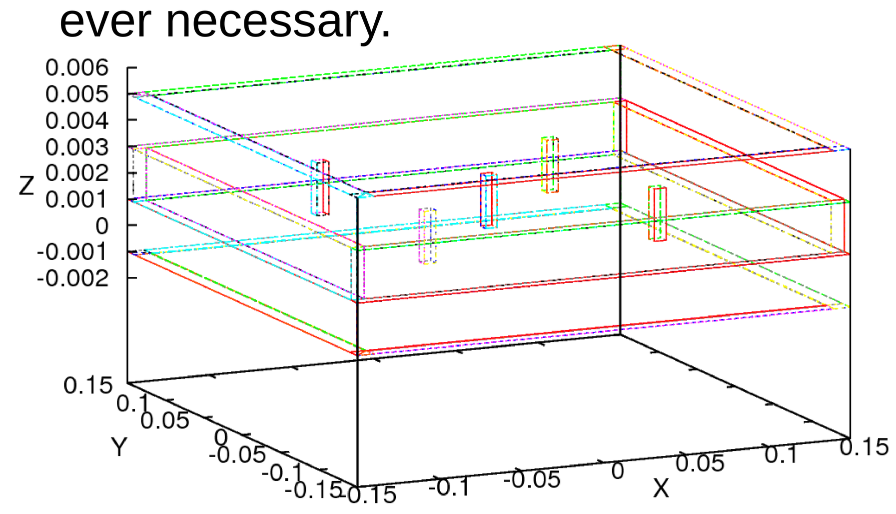

Figure 4.1. Primitives in neBEM

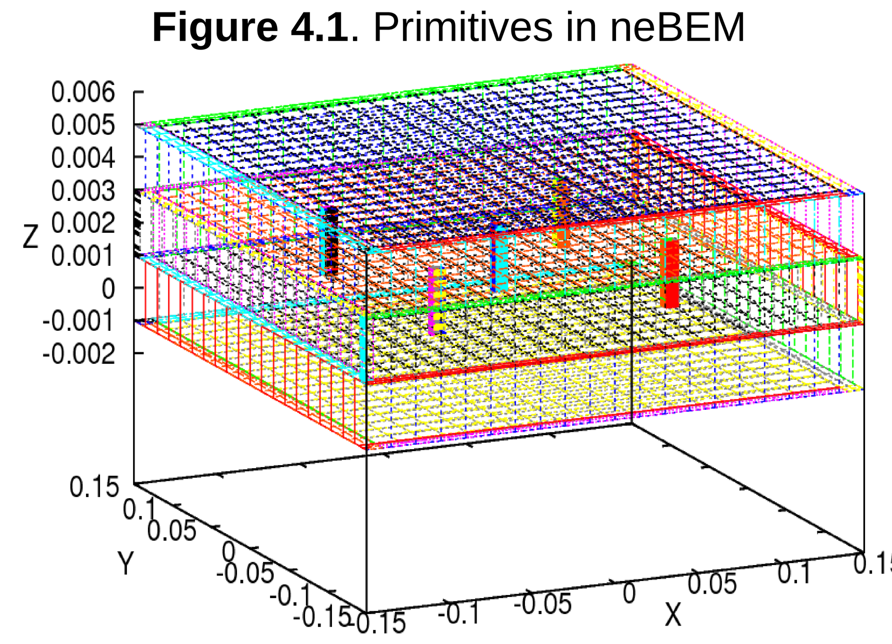

Figure 4.2. Discretization in neBEM

- Rectangular discretization for all the surfaces.
- Discretization of coat edge into 3 elements, Max no. of elements 20.
- No separate size of discretization used for the critical regions.
- Button spacers without top and bottom lid used (technical reason).
- Total no. of primitives = 82 and total no. of elements about 6000.
- System used : SL6 (8GB RAM).

Results:

Fig.5 shows the interesting points from where data has been taken.

1. COMSOL and neBEM solution at different locations of RPC :

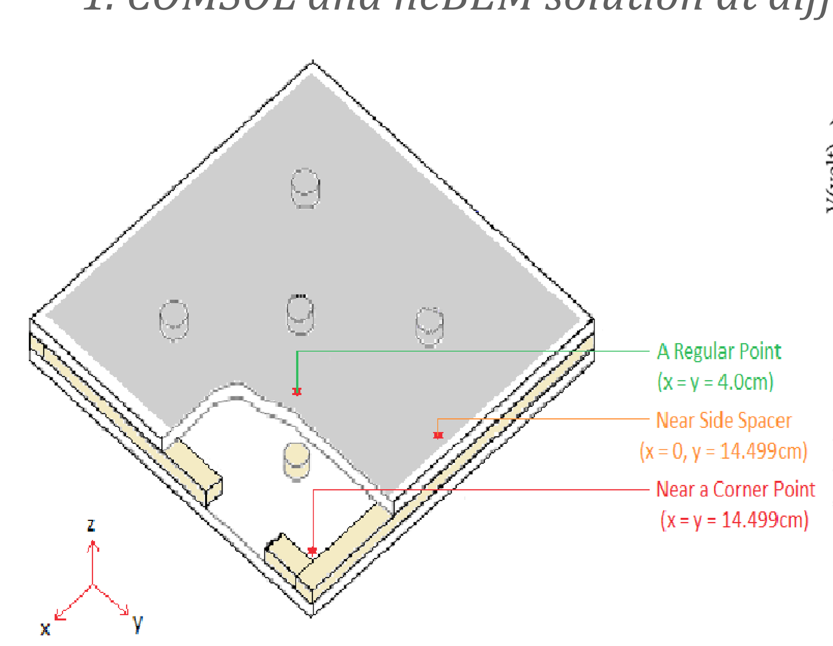

Figure 5. Points of interest

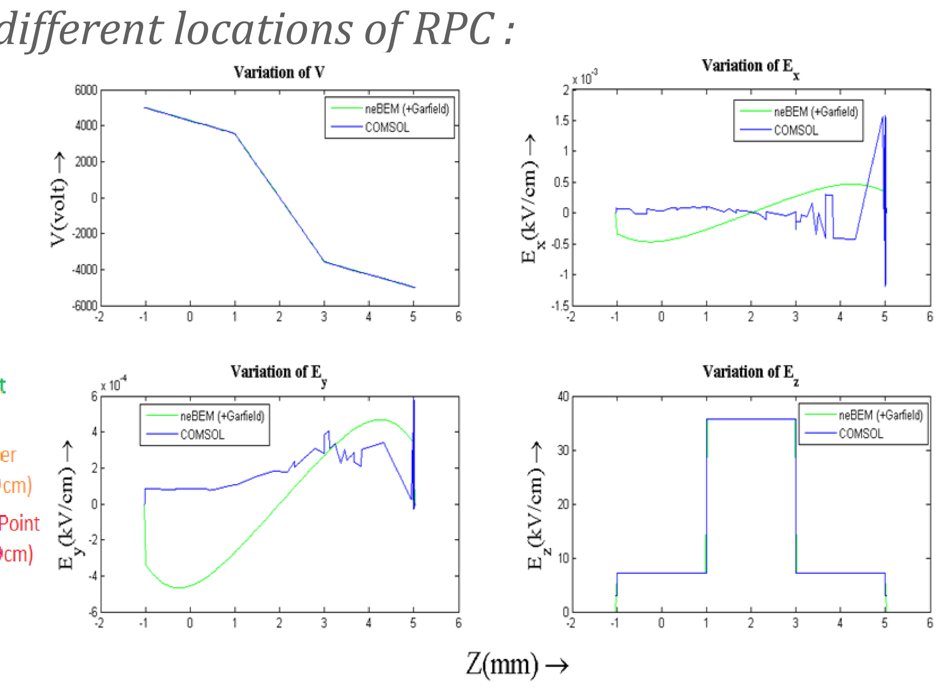

Figure 6.1. Comparison at a regular point

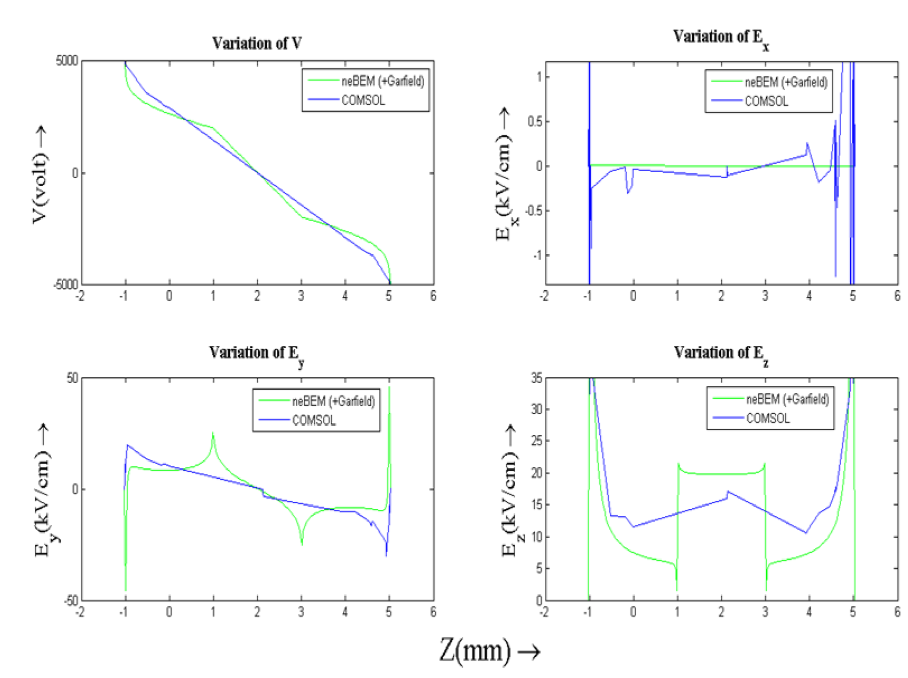

Figure 6.2. Comparison at a point near side spacer(10μm)

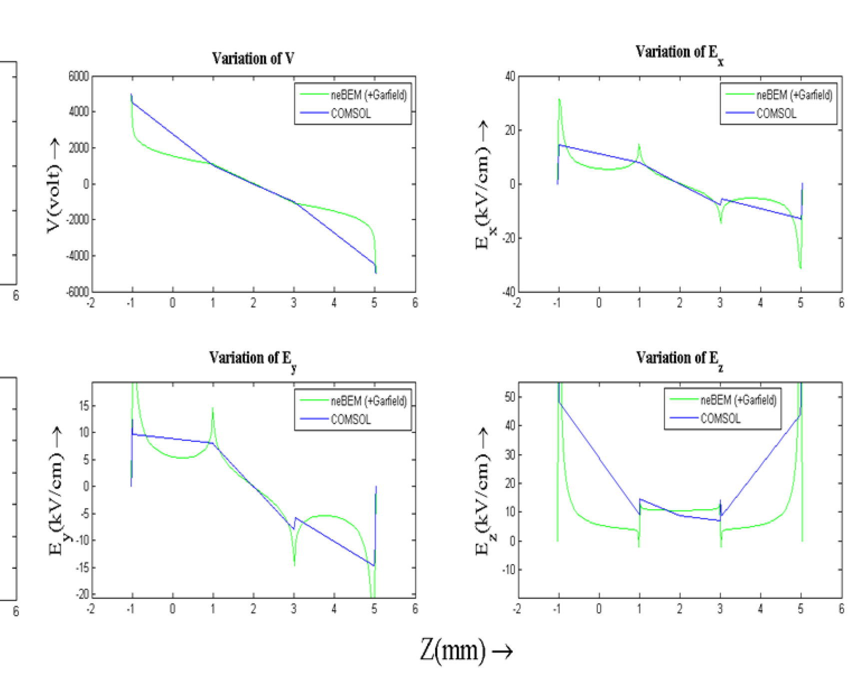

Figure 6.3. Comparison at a point near corner (10μm)

2. Effect of Spacers and frame :

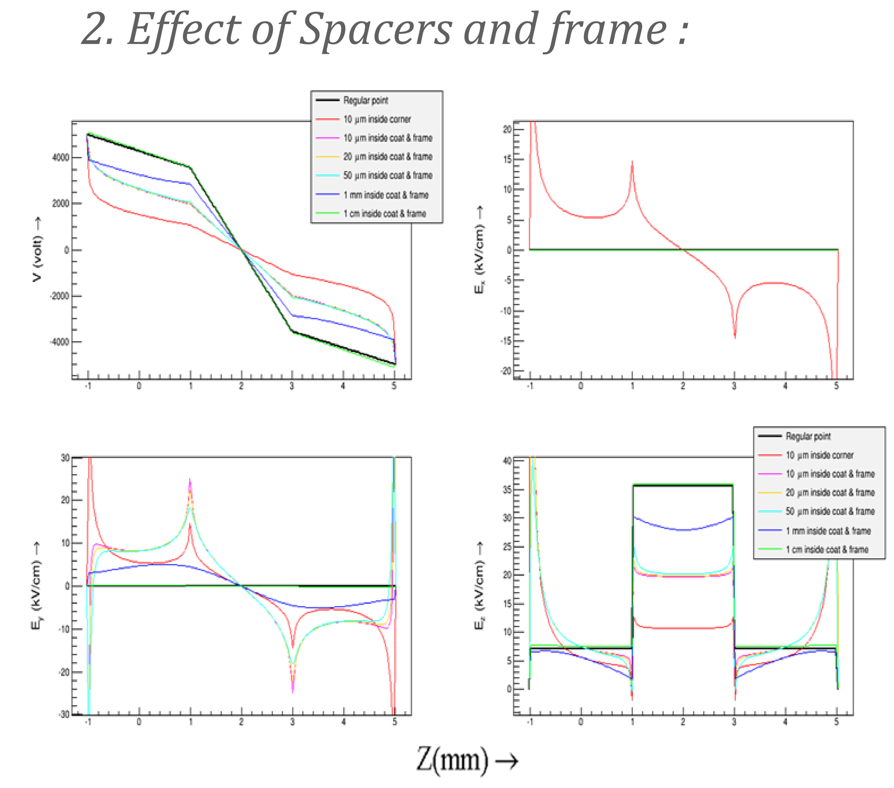

Figure 7.1. Result from neBEM

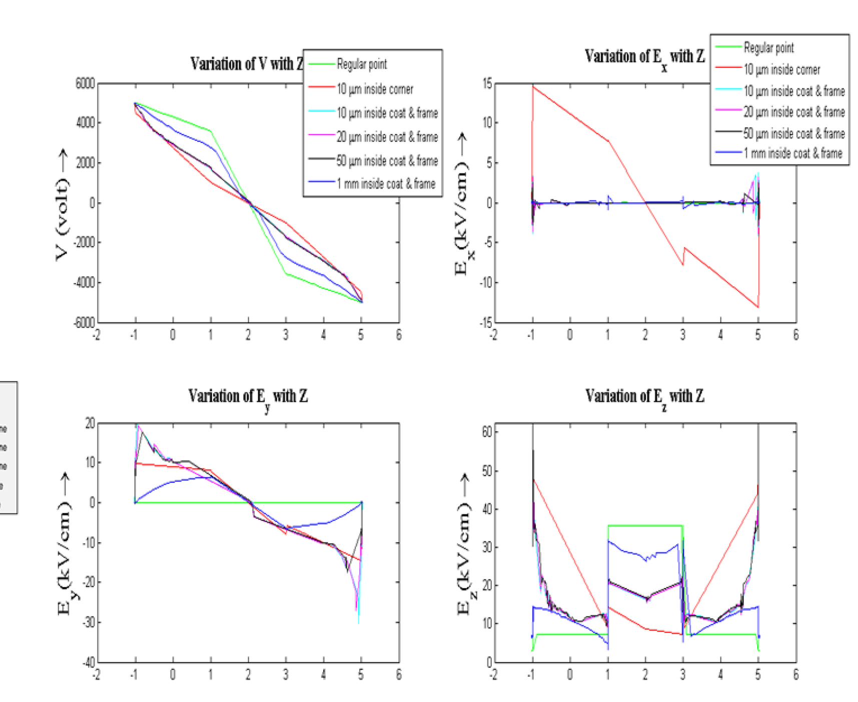

Figure 7.2. Result from COMSOL

Conclusions:

- COMSOL took about 8 mins (though figuring out the appropriate meshing took a long time) to solve the problem with an error less than 0.5X10-3 in 20 iterations (RAM used: about 8GB) whereas neBEM took about 25 minutes with maximum error 10^{-5} in an element near the corner region (RAM used: about 3.5 GB).
- The solution with neBEM is smoother(no interpolation or extrapolation for the nonnodal points).
- neBEM do not have a GUI.
- The solutions differ slightly at the critical regions.
- Both the solvers showed distortion of the field near the Side spacers and corner.
- The results from both the solvers will be compared with an standard method, may be an analytical result.
- The signal produced at the critical regions of RPC due to passing of charged particle will be generated using both the COMSOL and neBEM result and the comparison between the two methods will be done.
- The effect of uneven coat on the performance of the detector will also be seen.

References:

1. Saikat Biswas: Devlopment of high resolution gas filled detector for high energy physics experiments (PhD thesis, University of Calcutta, 2010).
2. http://www.ino.tifr.res.in/ino
3. http://www.comsol.co.in
4. http://neBEM.web.cern.ch/neBEM

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