Study of space charge phenomena in GEM based detectors

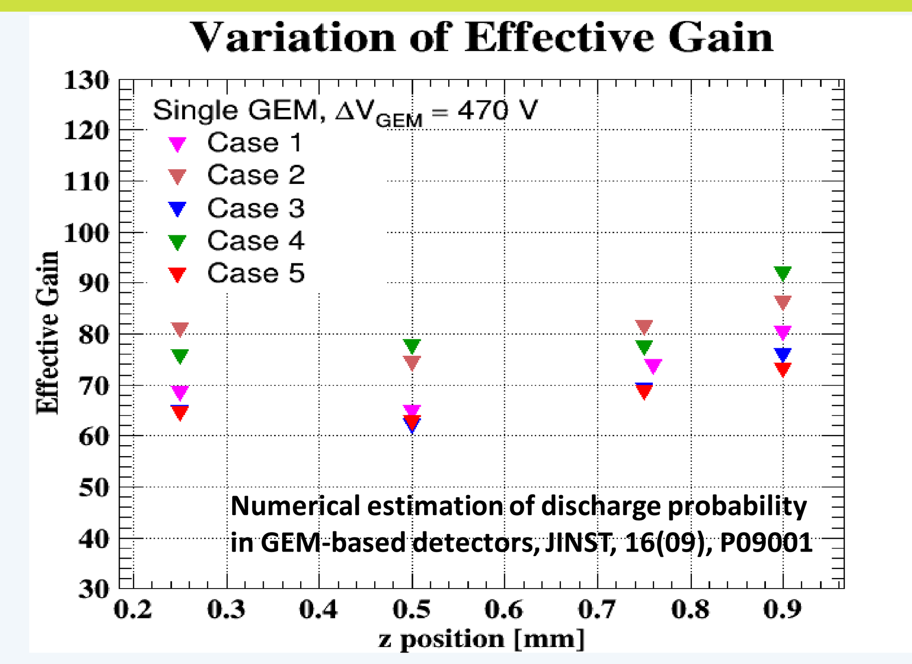
Promita Roy [1], Prasant Kumar Rout [2], Jaydeep Datta [3], Purba Bhattacharya [4], Supratik Mukhopadhyay [1], Nayana Majumdar [1] and Sandip Sarkar[1]*

[1] Saha Institute of Nuclear Physics, Kolkata - 700064, a CI of the Homi Bhabha National Institute, Mumbai - 400094, India, [2] National Central University, Taiwan, [3] Université libre de Bruxelles, Av. Franklin Roosevelt 50, 1050 Bruxelles, Belgium, [4] School of basic and applied sciences, Adamas University, Kolkata-700126

*Retired Professor

Poster id - 283

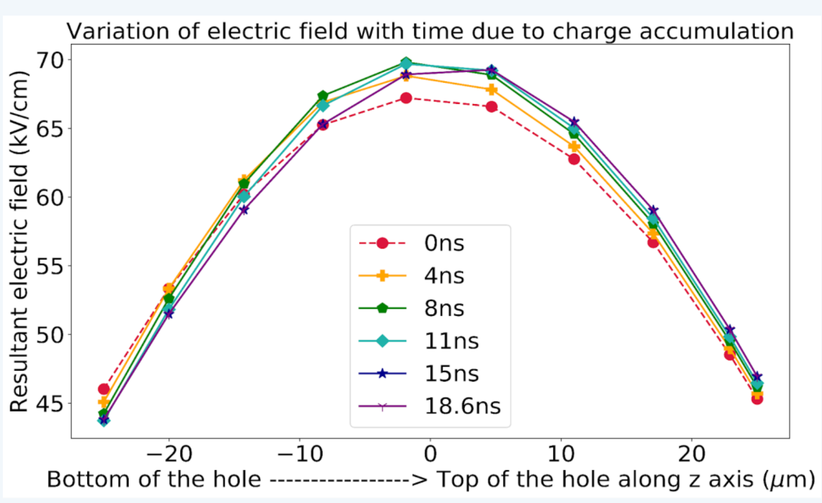
Motivation: Space charge accumulation within GEM holes is one of the vital phenomena which affects many of the key working parameters of these detectors through its direct influence on the resulting electric field in and around the holes. This accumulation is found to be significantly affected by the initial primary charge configurations and operating parameters of the detector since they determine charge sharing and the subsequent evolution of detector response. A recent numerical study[1] on the possible effect of charge sharing on space charge accumulation in GEM holes has motivated us to investigate the phenomenon in greater detail. **It has been observed that charge sharing among a larger number of holes allows higher gain since the space charge accumulation effect gets shared among these holes.**

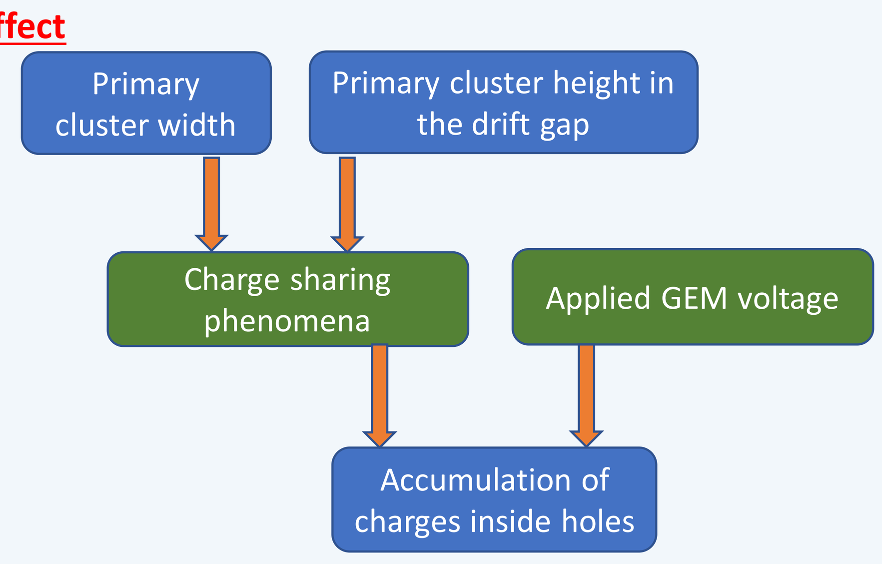


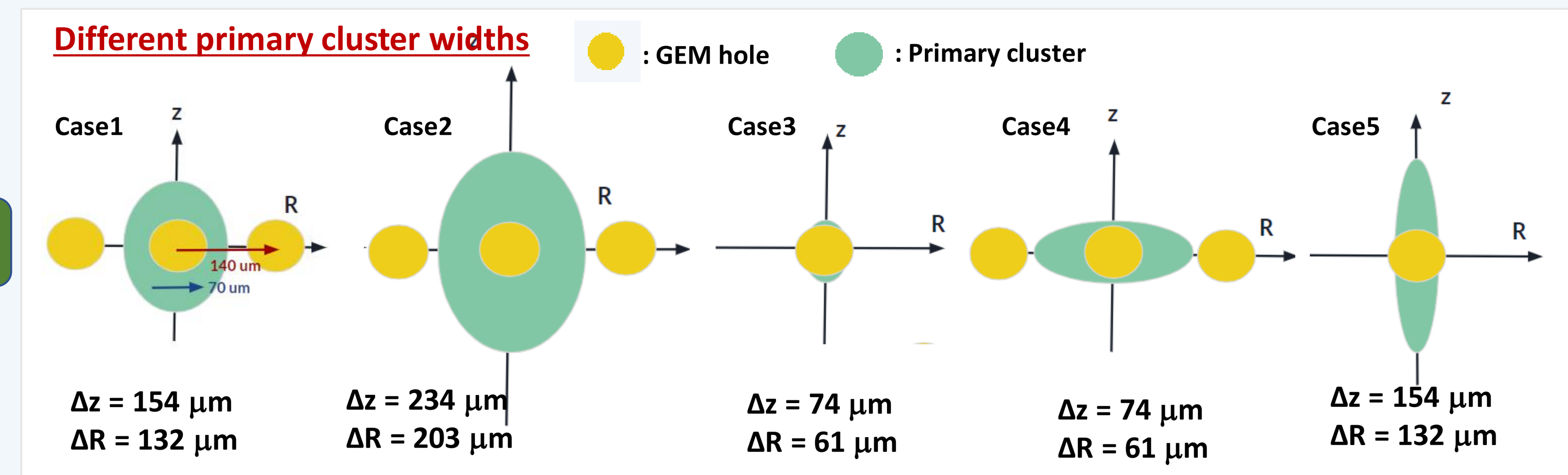
Space charge effect and numerical model:

Accumulation of charges inside the holes results in the modification of the electric field within the GEM foil which in turn can modify the effective gain. A hybrid numerical model based on 2D-axisymmetric capable of simulating avalanches and discharges has been adopted to numerically study the space charge effects in GEM detector. This model has important contributions from particle model and geant4 simulation framework.

Variation of electric field within the hole due to space charge effect





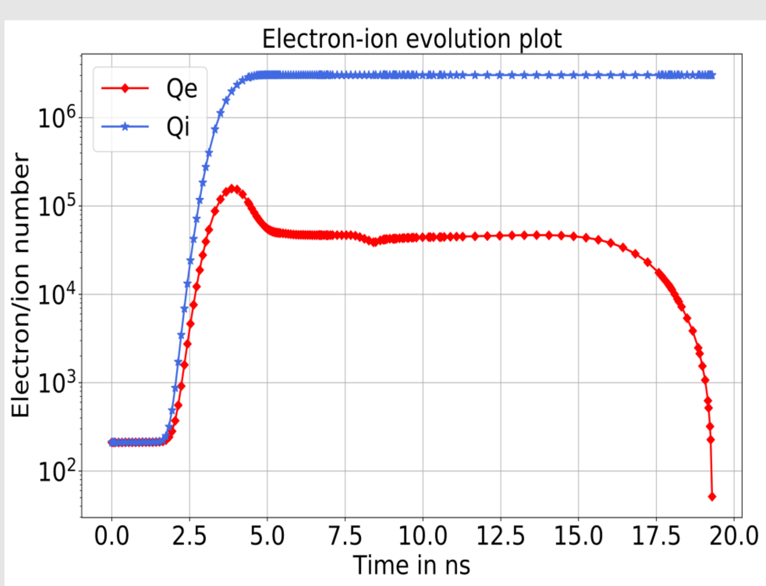


Space charge effect and detector gain

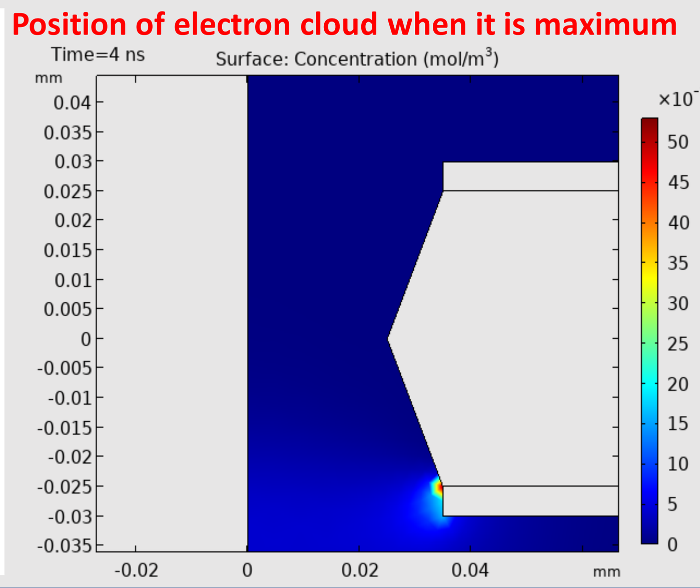
Gain depends on applied GEM voltage or multiplication inside holes.

Space charge effect is likely to be maximum when electron or ion number is maximum

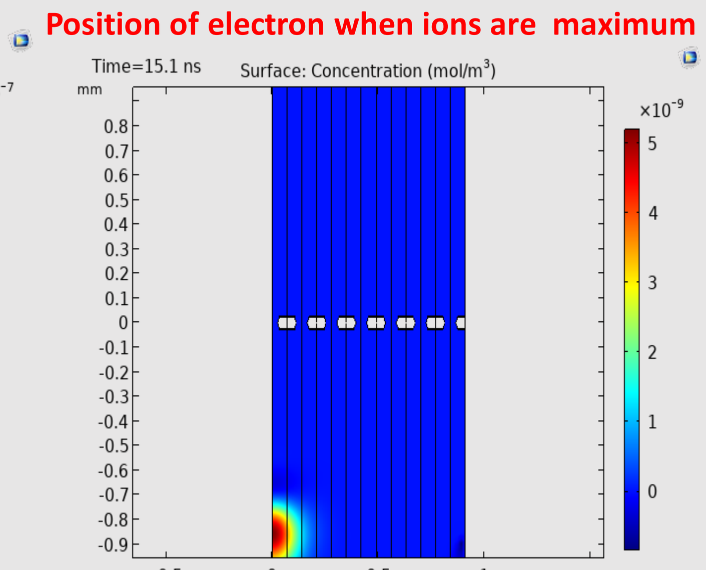
- **Electron number is maximum -- electrons are at the vicinity of the GEM hole bottom**
- **Ion number is maximum -- electrons are either halfway through the induction gap or collected at the anode**



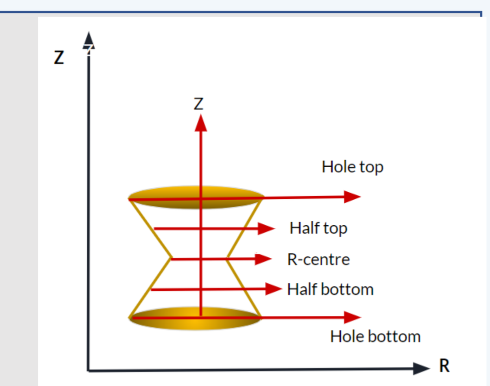
Position of electron cloud when it is maximum



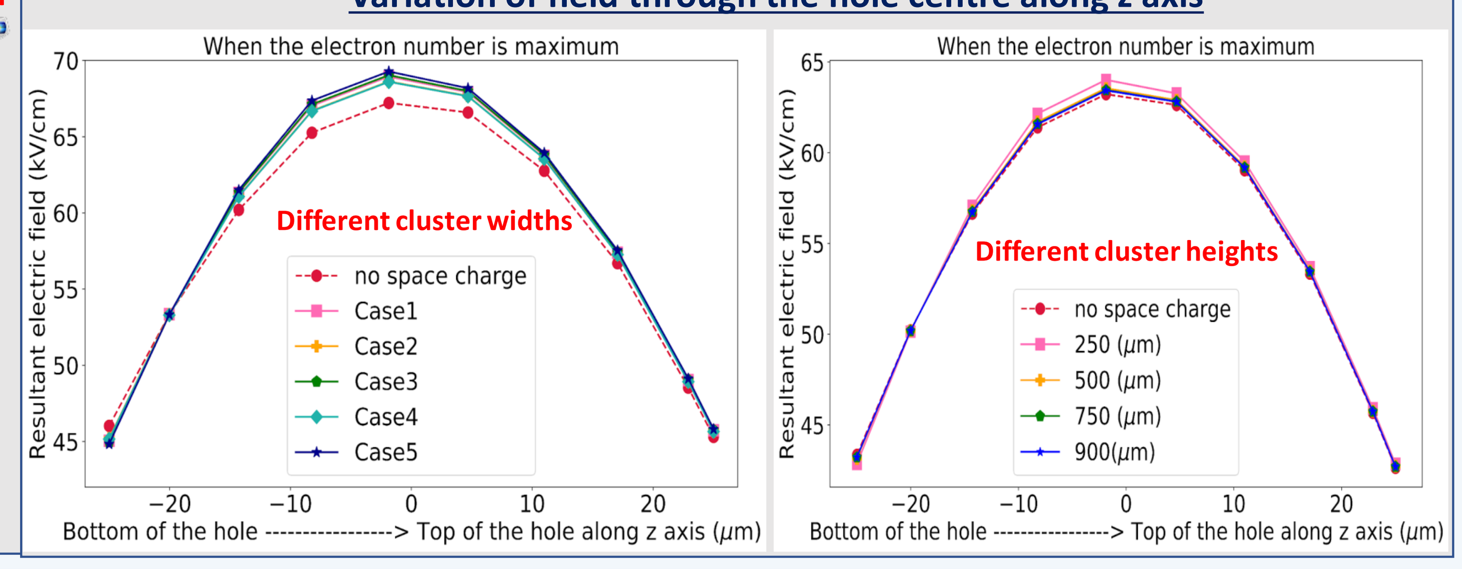
Position of electron when ions are maximum



- **To see the effect of space charge phenomena on gain, the time at which the electron number is maximum has been used and changes in electric field have been noted.**
- **Five lines along the radial direction mapping the height the hole have been considered to study the space charge effect.**



Variation of field through the hole centre along z axis

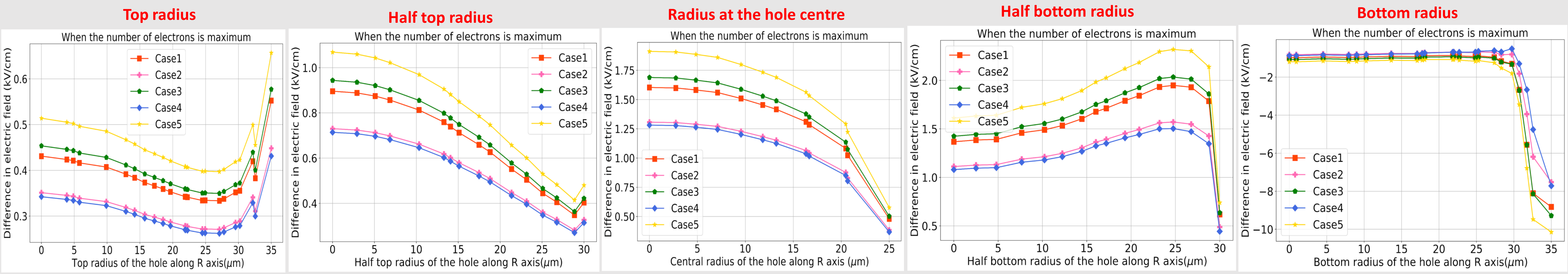


Variation of space charge effect with primary cluster widths

Changes in resultant electric field inside the holes due to space charge have been plotted along various lines.

If E_{WO} = Electric field without space charge effect and E_W = Electric field with space charge effect, then the difference in electric field is $\Delta E = E_W - E_{WO}$

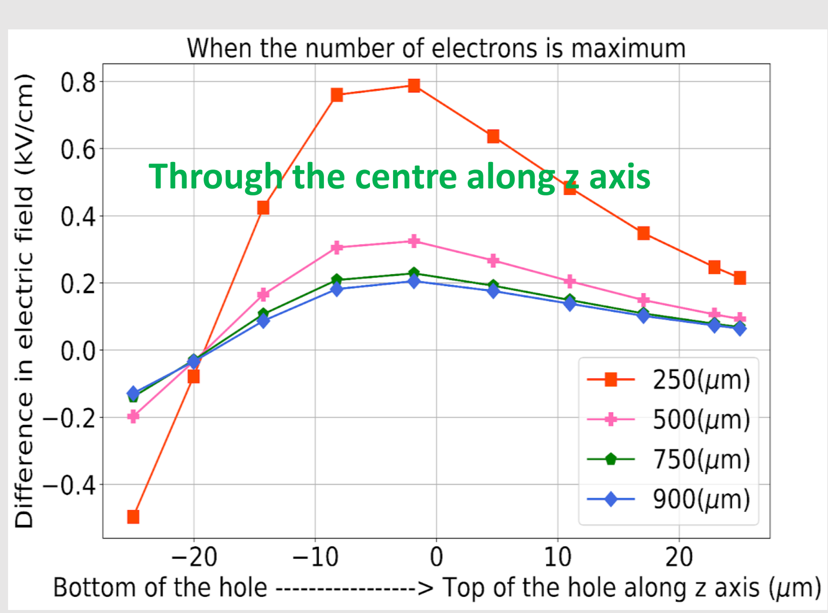
Variation of ΔE due to space charge effect along various lines

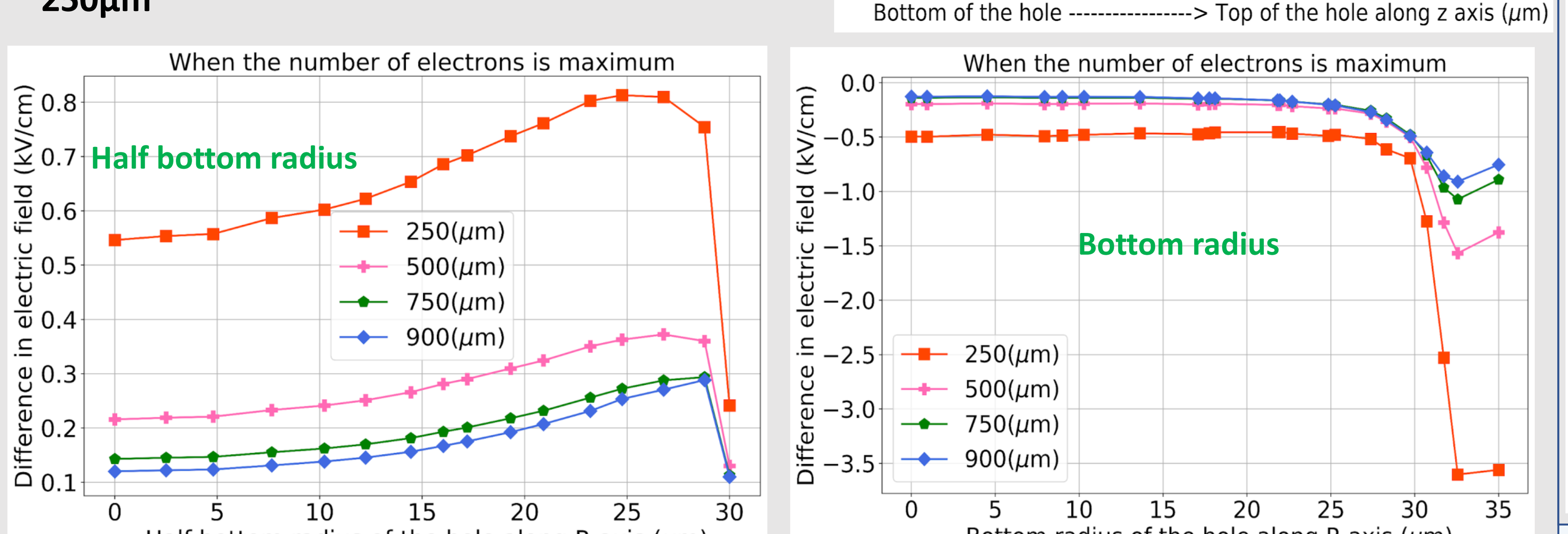


- **Space charge effect increases the field for all the primary cluster cases along the lines top, half-top, centre and half-bottom, whereas the field decreases along the bottom line.**
- **The cases 2 and 4 which are radially elongated (have the highest radial spread); exhibit more charge sharing and are found to have higher fields around the hole bottom.**
- **The cases 3 and 5 which are radially shrunk (have the least radial spread) have higher field values towards the hole top but have lesser field value towards the hole bottom.**
- **Since most of the electron multiplication takes place around the hole bottom, cases 2 and 4 have higher gain values.**

Variation of space charge effect with the height of the primary cluster in the drift gap

- **With increase in the height of the primary cluster, ΔE due to space charge effect decreases.**
- **Along the half bottom line space charge effect increases the field and it is maximum for 250μm**
- **Along the bottom line, space charge effect decreases the field and the field is minimum for 250μm**

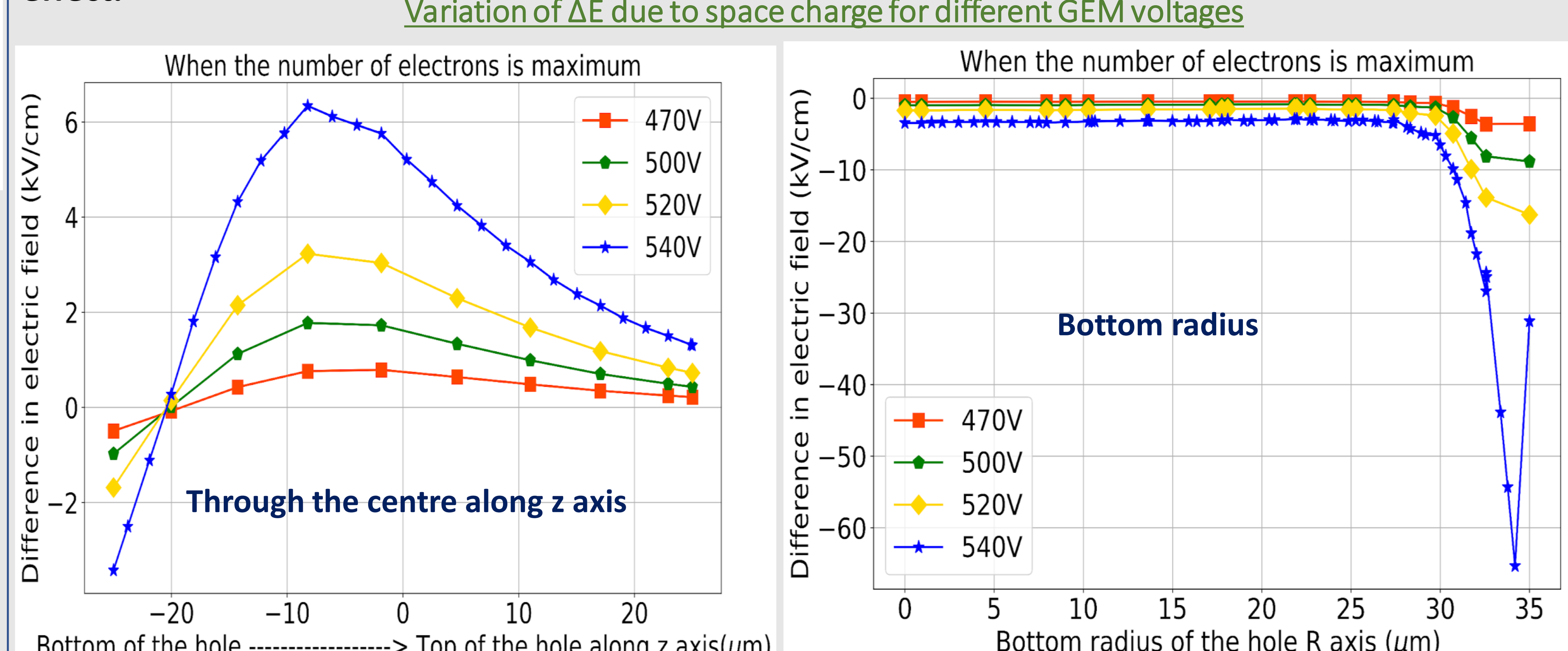




Effect of space charge phenomena on gain for increasing GEM voltages

With increase in GEM voltage ΔE increases i.e. effect of space charge phenomena increases. Towards the hole top $E_W > E_{WO}$ whereas towards the bottom of the hole $E_W < E_{WO}$. Since, most of the multiplication takes place in the vicinity of the hole bottom, space charge effect towards the bottom of the hole dominates and as a result, gain decreases due to space charge effect.

Variation of ΔE due to space charge for different GEM voltages



Future Work:

- Use 3D-hydrodynamic model to simulate the space charge effect more realistically.
- Study space charge phenomena and its effect on detector gain and stability for multi-GEM structures.
- Study the effect of hole geometry on space charge phenomena.

Conclusion:

- **Primary cluster cases which are radially elongated exhibit more charge sharing and yield higher gain values. Sharing of charges among larger number of holes allows sharing of space charge effect. As a result, reduction of gain due to space charge effect is compensated by charge sharing in radially elongated clusters.**
- **Space charge effect is maximum when the height of the primary cluster is minimum.**
- **Space charge effect increases with increasing GEM voltage. It reduces the field in the vicinity of the hole bottom and thus gain due to space charge becomes less than gain without space charge.**

Acknowledgement:

Authors would like to thank their respective institutes for the necessary support and funding to carry out this work. Authors would also like to acknowledge RD51 collaboration members for their suggestions and showing keen interest in this work.

Reference:

[1] Numerical estimation of discharge probability in GEM-based detectors, JINST, 16(09), P09001