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

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 $\Delta E = E_{WO} - E_{W}$

- **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.

**Effect of space charge phenomena on gain for increasing GEM voltages**

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

**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.