Electron and Ion Transport in GEM detectors - an update

Aritra Bal[1], Anand Dubey[2]

[1]Undergraduate Student, Department of Physics,
Indian Institute of Technology Kharagpur
[2]Variable Energy Cyclotron Centre (VECC), Kolkata

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Outlook

1. Repeat our electron avalanche and ion transport simulation for a more realistic voltage, instead of $\Delta V_{GEM} = 500V$ previously.

2. Understand the discharge phenomena in GEM detectors.

3. Study the time variation of the avalanche as a follow-up to the animation presented at the February mini-week. The goal is to get a dynamic picture of the charge sharing between the holes of the middle and bottom GEMs.

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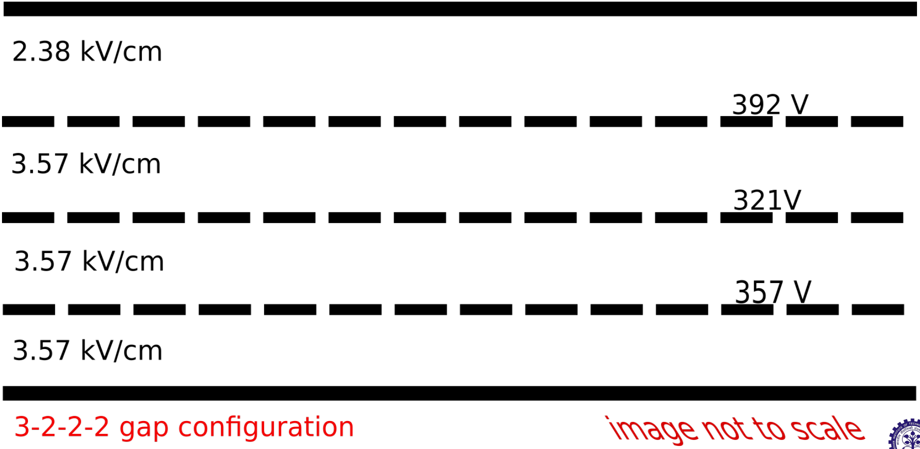
Methodology - I

A schematic of the GEM detector is shown below.



Methodology - II

1. More than 300 events were simulated.
2. Single electron was released - $70\mu m$ above the top GEM, in drift gap.
3. No size limit on the avalanche was imposed.
4. We used Ar-CO_2 mixture in 70-30 (for a range of pressures) and 80-20 ratio.

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Conventions

1. **Solid Red**: Histogram of all charges resulting from avalanches in only the central hole (at $x \sim 121\mu m$) of the concerned GEM layer. We take a buffer along the Z axis and project all the charges onto the X direction.

2. **Hollow Blue**: Histogram of all charges resulting from all avalanches in the entire GEM layer of concern. This histogram is larger as the avalanche products of multiple holes (except top GEM) are included.

Electron Avalanche - I

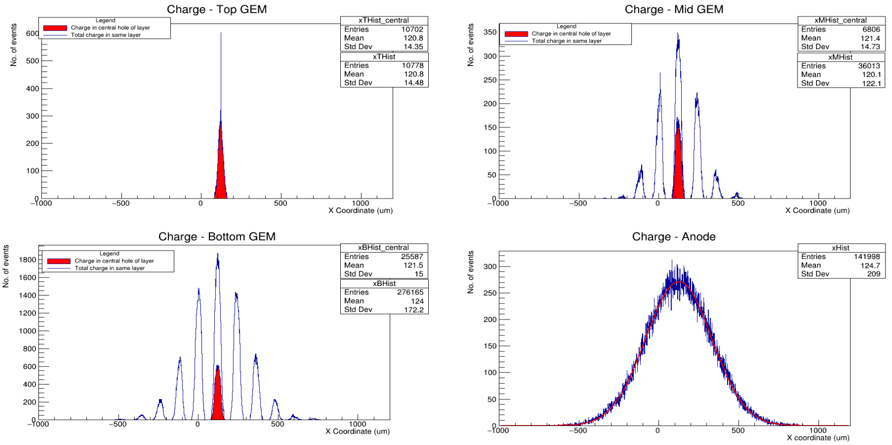

Figure: 70-30 gas mixture, pressure = 760 torr

Electron Avalanche - II

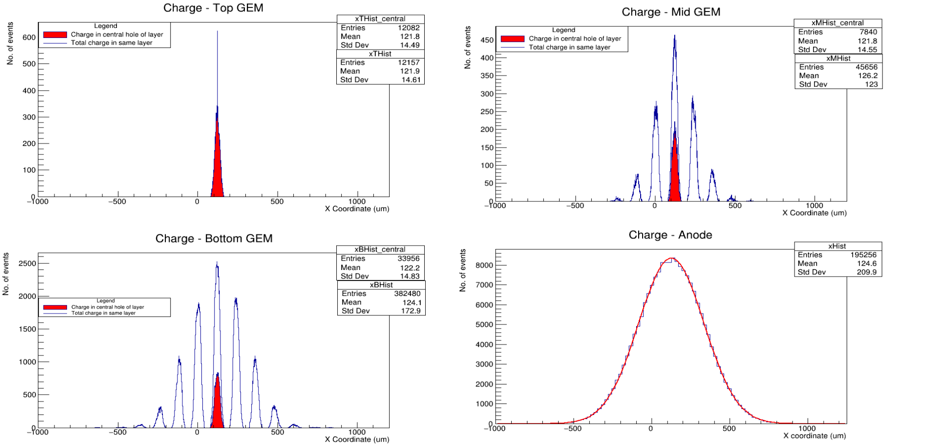

FIGURE: 70-30 gas mixture, pressure = 740 torr

Electron Avalanche - III

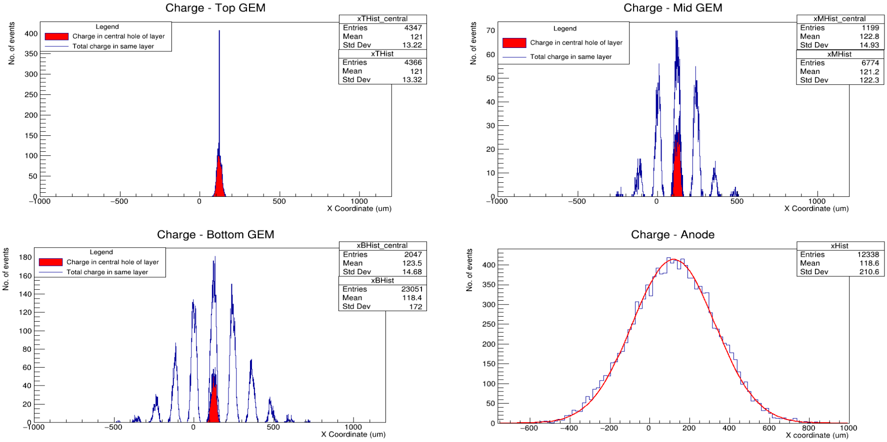

Figure: 70-30 gas mixture, pressure = 740 torr, Penning Effect not considered

Electron Avalanche - IV

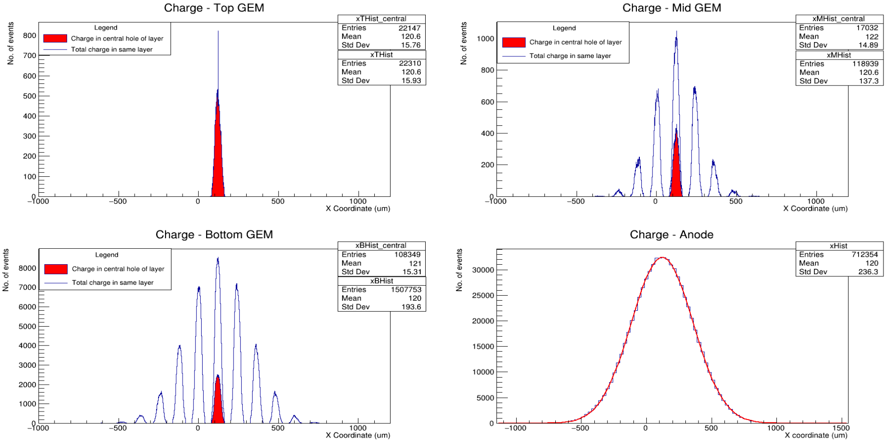

Figure: 80-20 gas mixture, pressure = 740 torr

Electron Avalanche - V

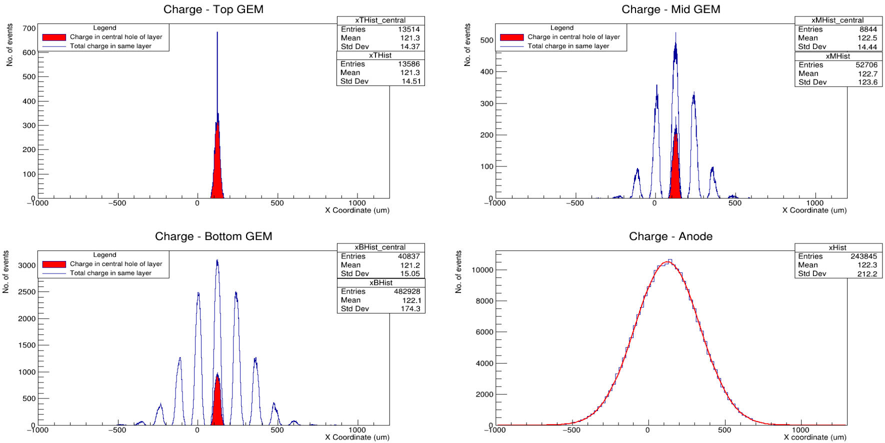

Figure: 70-30 gas mixture, pressure = 720 torr

Some Observations

1. We observed the gain to increase with decreasing pressure, as expected.
2. Decreasing the amount of quench gas to get a 80-20 gas mixture led to a sharp increase in gain.
3. The value of σ at the anode does not vary appreciably with the pressure. It increases by about 12% when the Ar fraction is increased to 80%.

A point worth mentioning

As mentioned in an earlier talk, charge sharing within a layer can be estimated from the following term (as suggested by Dr F.Sauli).

$$C.R = \frac{\text{Total charge in layer}}{\text{Charge in central hole of layer}}$$

It is obvious that this is primarily driven by diffusion. More the diffusion, greater the C.R value, which tends to decrease the discharge probability.

At 740 torr, for a 70-30 gas mixture, we obtain σ for GEM2 and GEM3 to be $123\mu m$ and $173\mu m$. At the anode, this value was $210\mu m$, which matches well the prediction from known diffusion coefficients.

What do we do with this?

At 740 torr, for a 70-30 gas mixture, we obtained $C.R$ to be around $\sim 1:6:11$ for GEM1, GEM2 and GEM3.

By releasing the primary just above the top GEM, we ensured charge does not spill over into any other hole for GEM1.

But does this $\langle C.R \rangle$ address the question of discharges?

Maybe not.

How about looking at its dynamic variation instead?

At some arbitrary point of time, C.R could be **much** higher or lower!

A movie!

At the miniweek, we presented a movie of the triple GEM avalanche progression, which can be seen at the example pages of Garfield++. It is clear that all the avalanches in GEM2 and GEM3 do not take place at the same time.

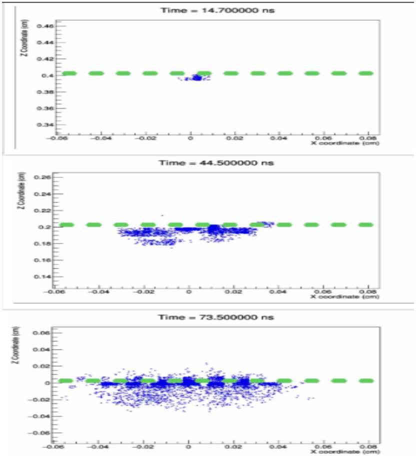

FIGURE: Progression of avalanche

Another movie?

Using a similar idea, it is possible to track the dynamic variation of C.R.

This allows us to visualise the evolution of the charge sharing phenomenon.

Click to play histogram animation.

Evolution of C.R

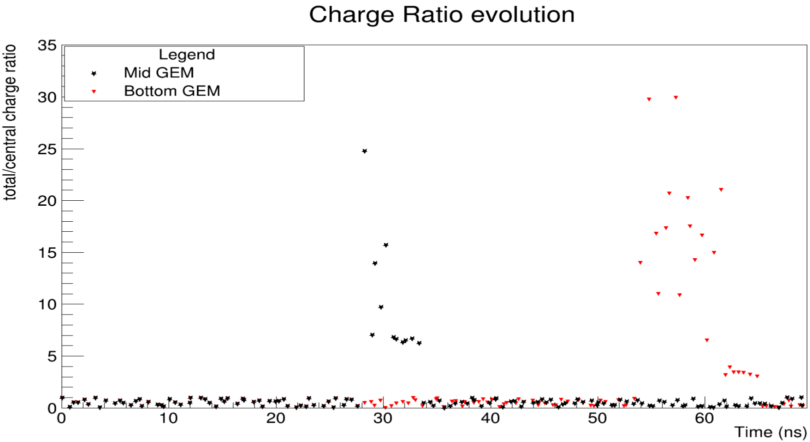

Figure: Evolution of C.R with time for mid and bottom GEM

What do we conclude from this?

1. The charge sharing effect between holes, quantified by C.R is greater than what our initial values suggested, by taking the total produced charges over all time.
2. Momentarily, C.R was observed to be as high as 25 for the mid GEM and 30 for the bottom GEM.
3. The mean values still come out to be what we obtained by taking the total charges.

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Further Plans

1. Our time evolution of the charge sharing was done with a 0.5ns timestep. We need to refine it further to get more accurate plots.
2. The dynamic evolution needs to be studied over several events for a better statistical estimate.
3. We plan to study the ion diffusion problem. The data we are using now is insufficient and does not account for several factors such as reactions.

THANK YOU!