Maxwell simulations

Cygno simulation meeting - 29/11/2021

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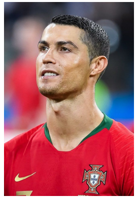
Who am I?

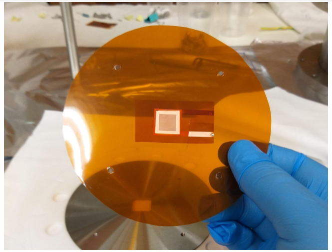
- David Marques

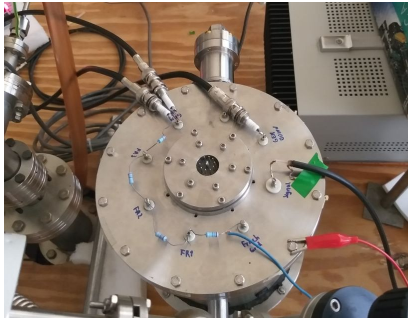
- New Ph.D. of Elisabetta at GSSI

- MSc: Negative ion mobility measurement in gases of interest for NITPCs

  https://eg.uc.pt/handle/10316/92234







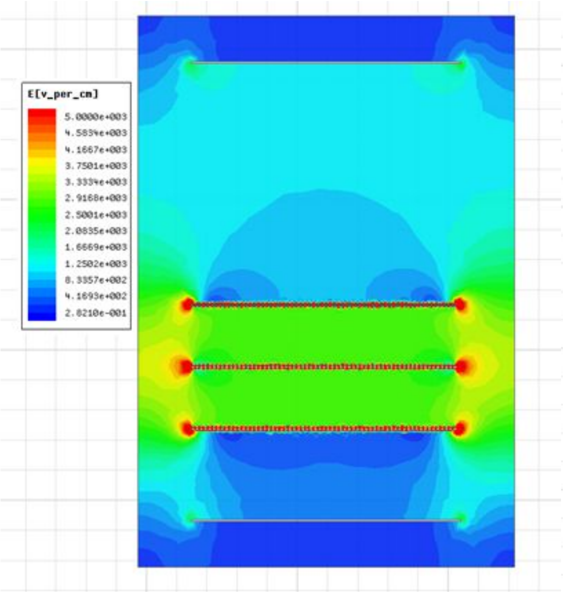
Objective

- ➔ Understand how the electric field around the GEM holes behaves.
  - Confirm the hypothesis of electroluminescence inside the MANGO.
  - Disprove the hypothesis of increase of charge amplification inside GEM due to increase of electroluminescence field ***<u>(Are we increasing the light or the charge?)</u>***

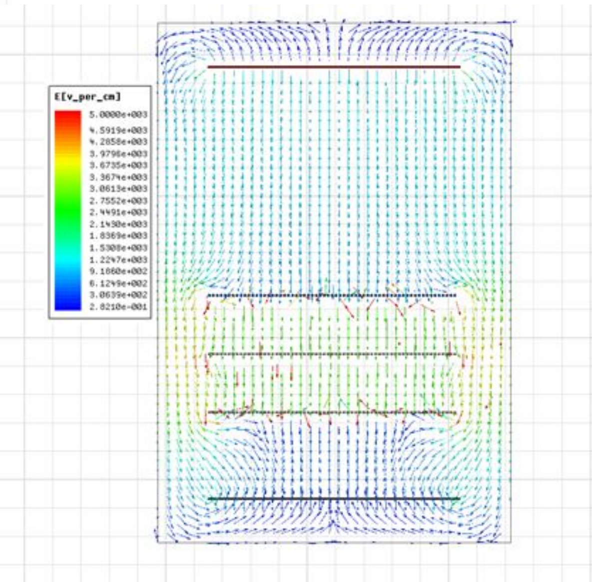
Maxwell - What for?

➔ Given a setup with **different materials** and **voltages** applied, Maxwell calculates the **electric field** within a defined region. The outputs can be:

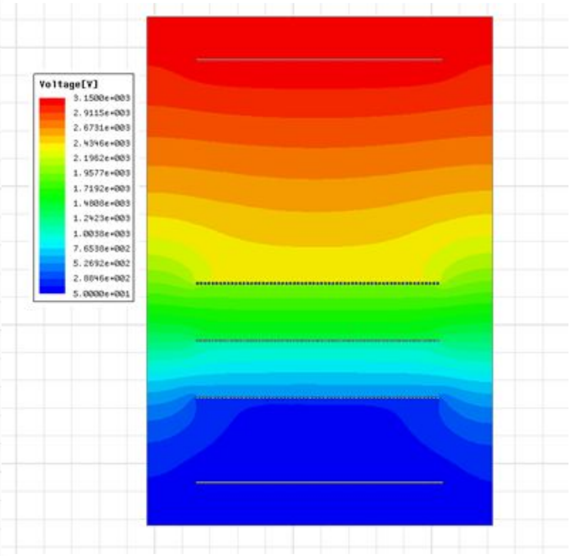
1. Electric **field** (V/cm)



2. Electric field **vector** (V/cm)



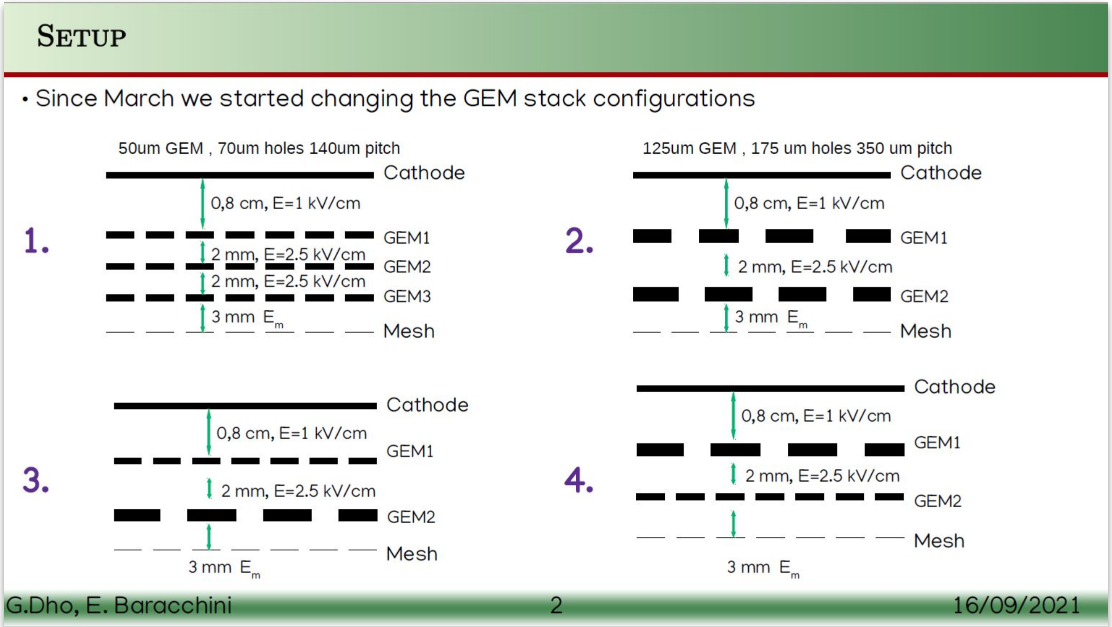
3. **Absolute** voltage (V)



Maxwell - Schematics to simulate

- ➔ Several configuration were tried with MANGO for data taking.
- ➔ These included thin (50 um) and thicker (125 um) GEMS.
- ➔ These are builded through etching.
- ➔ I have simulated schematics 1, 2 and 4.

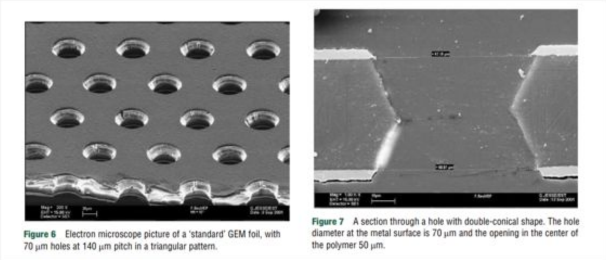
- ➔ Thick (400 um) GEM are builded differently. For details, see here: https://indico.cern.ch/event/25069/contributions/1575894/attachments/435000/603727/Breskin_THGEM_NIKHEF_Apr_08_.pdf



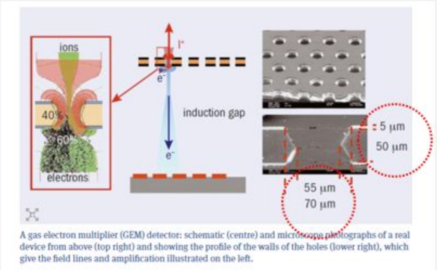
GEMs dimensions:

- 50 um:
  - 70 um holes
  - 140 um pitch
- 125 um:
  - 175 um holes
  - 350 um pitch
- 400 um:
  - 300 um holes
  - 500 um pitch

Source



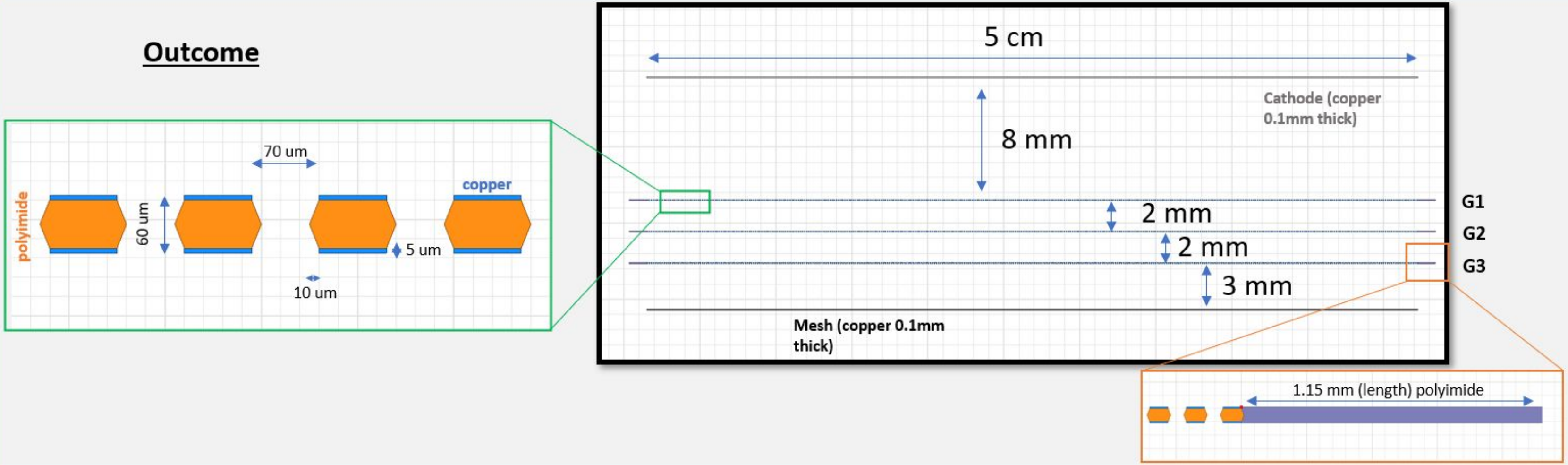
https://doi.org/10.1016/B978-0-444-53632-7.00625-0



https://cerncourier.com/a/the-continuing-rise-of-micropattern-detectors/

https://indico.cern.ch/event/346614/contributions/813299/attachments/683646/939073/GEM_at_CERN_seminar.pdf

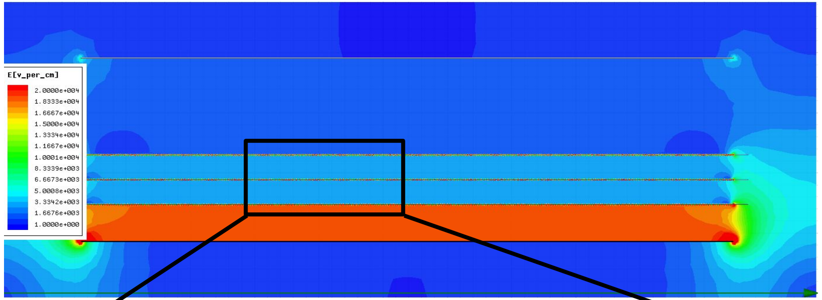
Outcome

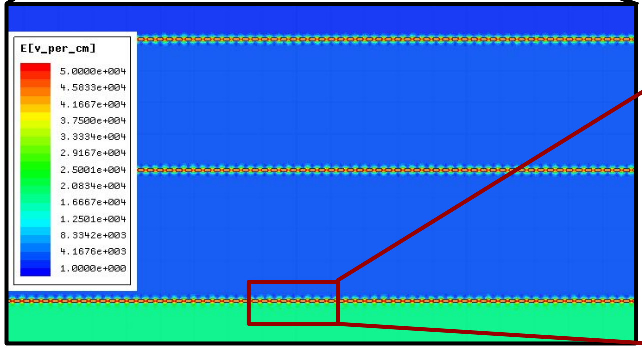


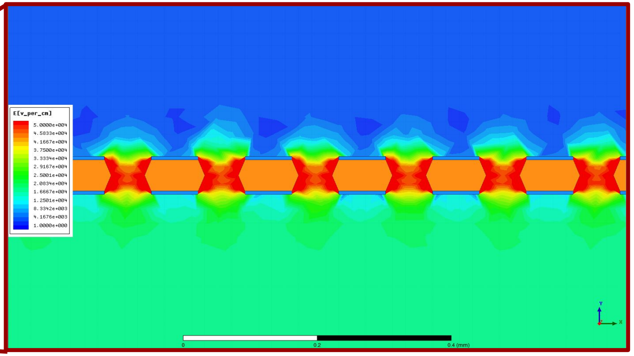
Example - Config 1

- This is an example of the calculated electric field in the t-t-t configuration.

- G3D : grounded
- Transfer Fields: 2.5 kV/cm, in 2 mm
- V_GEMs : 400V
- Drift Field: 1kV/cm, in 8mm
- **Induction field: 18.3 kV/cm, in 3 mm**





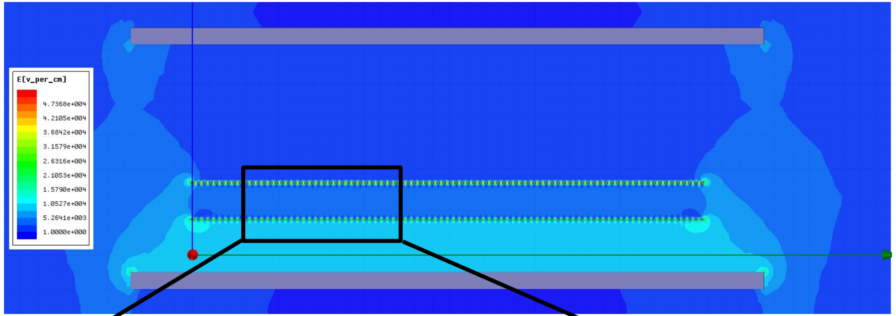


- → Border effects not so much significant.
- → Fields very constant (parallel plates)
- → Field on top/bottom of GEM is different in [+/- GEM thickness].

Example - Config 2

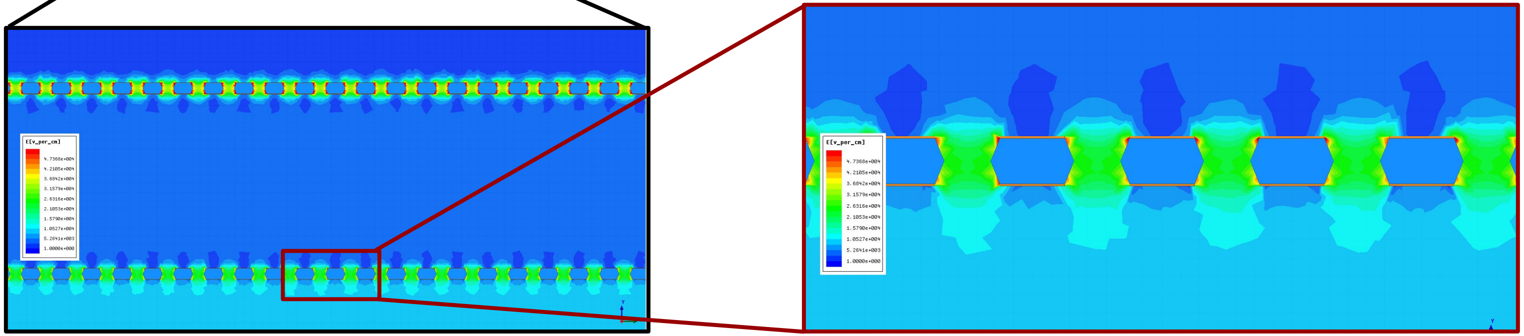
- This is an example of the calculated electric field in the T-T (125 um) configuration.

- G3D : grounded
- Drift Field: 1kV/cm, in 8mm
- Transfer Fields: 2.5 kV/cm, in 2 mm
- **Induction field: 10.0 kV/cm, in 3 mm**
- V_GEM 2: 500 V
- V_GEM 3: 700 V



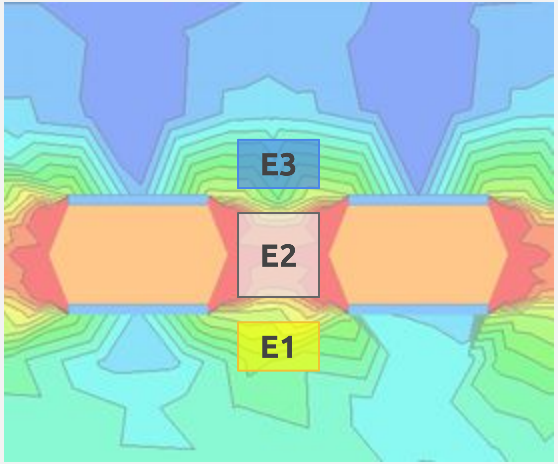
→ Field inside GEM not so intense, visually, around 20-30 kV/cm

→ Again, field on top/bottom of GEM is different in [+/- GEM thickness]



Simulation - *Model*

- Define three regions: below (E1), inside (E2) and above (E3) GEM.
- Obtain the electric field value in several points of these squares (1 um resolution)
- Average over all points
- Average over 10 holes



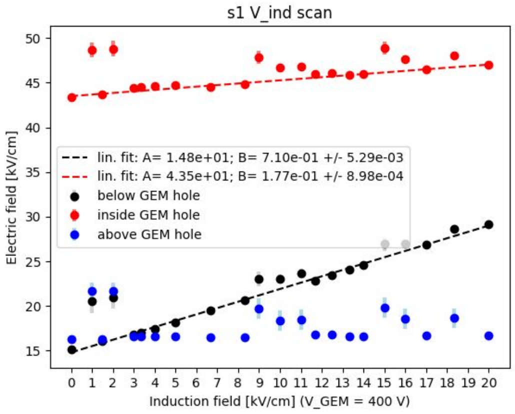
x 10 holes

Tests performed:

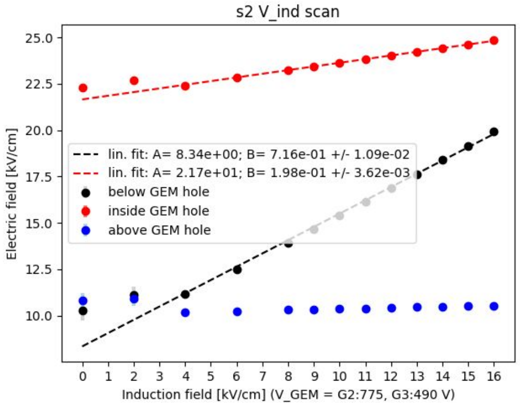
- Scan induction (luminescence) field, with fixed V_GEMs
- Scan on V_GEMs, with a fixed V_ind
- 3 different configurations:
  - t - t - t
  - T - T
  - T - t

Simulation - Results - E_induction scan

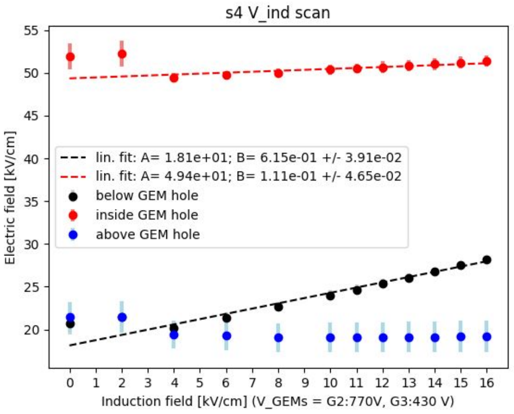
Conf. 1 (t-t-t)



Conf. 2 (T-T)



Conf. 4 (T-t)

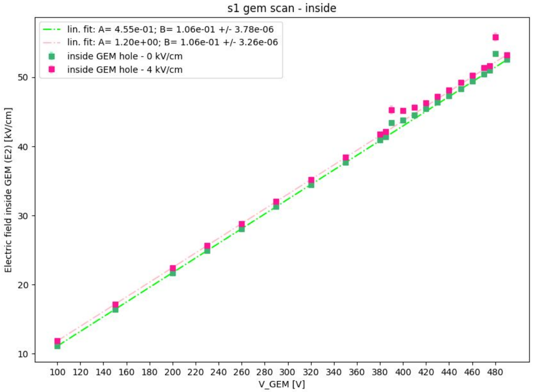


- ★ **Increase of E_ind** also slightly changes the field **inside the GEM [red]**
- ★ Grow below GEM **[black]** is ~**4-5x greater** than inside GEM **[red]**
- ★ In the **Thick** configuration the **below the GEM field** has a smaller baseline **(A)**

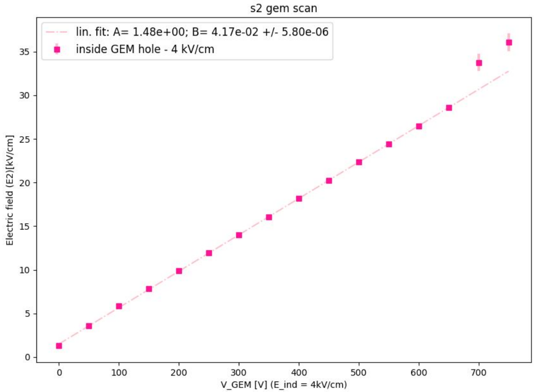
★ **Fit: A + Bx**

Simulation - Results - V_GEM scan

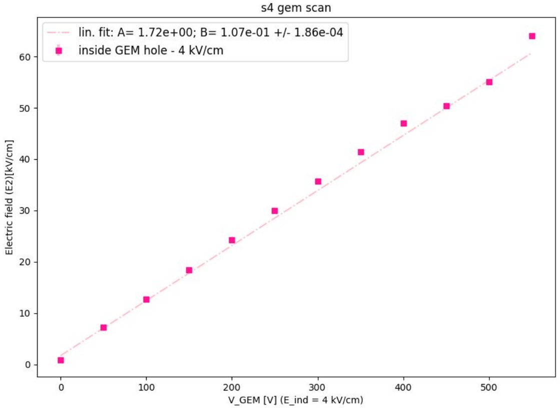
Conf. 1 (t-t-t)



Conf. 2 (T-T)



Conf. 4 (T-t)

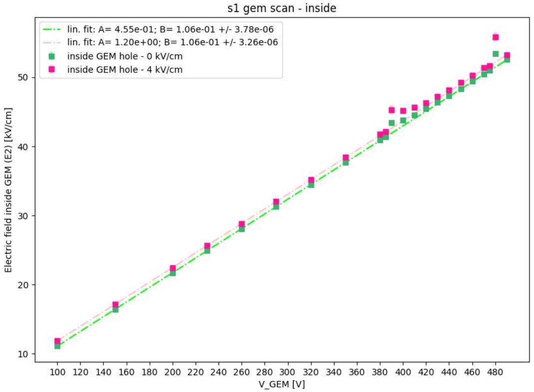


- Slope of elect. field increase on configurations 1 and 4 are equal (as expected).
  - The configuration above the last GEM doesn't induce any particular effect.
- Electric field growth **(B)** in config. 2 (125um GEM) is **smaller (2.5x)**
- In config. 1, the difference between having or not an E_ind doesn't change **slope** but only the **offset**, by **(2.5x)**
  - Confirmed in previous plots.

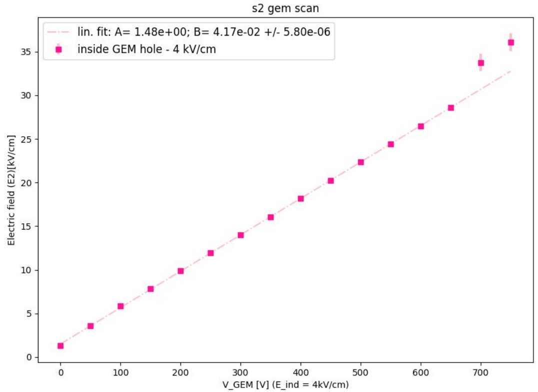
★ **Fit: A + Bx**

Simulation - Results - V_GEM scan - Continuation

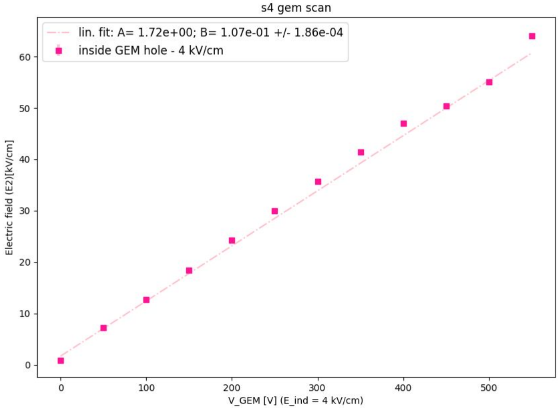
Conf. 1 (t-t-t)



Conf. 2 (T-T)



Conf. 4 (T-t)

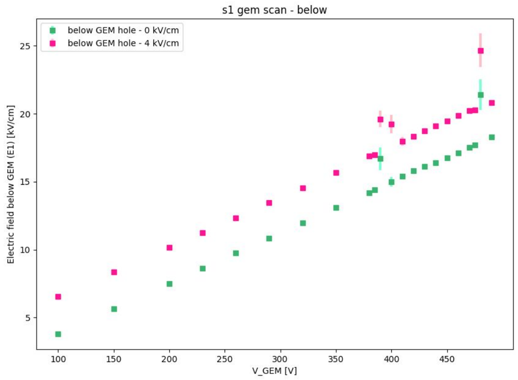


- ➔ The field found in configs 1 and 4 that produce gain (>400V) correspond to field of ~50 kV/cm.
  - ◆ **This value is also not reached below the GEM when scanning V_ind (no charge amplification)**
    - While increasing luminescence field also slightly increases field inside GEM, the light signal increase can't be justified with this. **Luminescence must be occurring!**

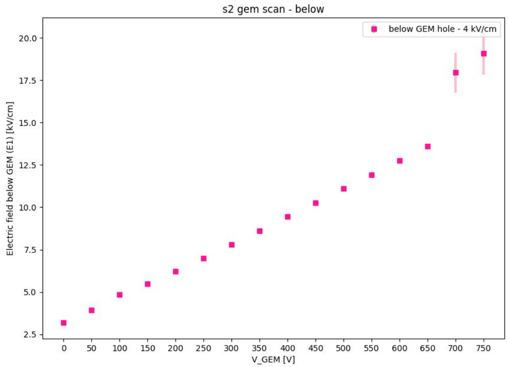
★ **Fit: A + Bx**

- What if the charge multiplication occurs on the exit of the GEM hole?
  - Let's plot the the **field below the GEM (E1) vs. V_GEM**

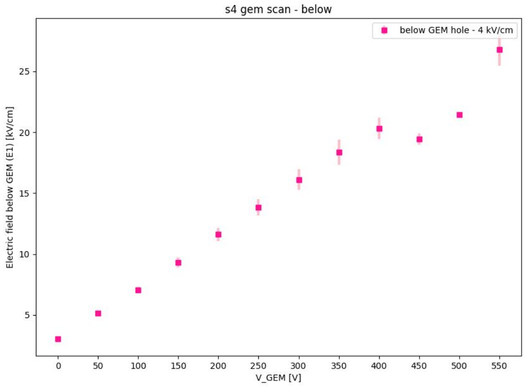
Conf. 1 (t-t-t)



Conf. 2 (T-T)



Conf. 4 (T-t)

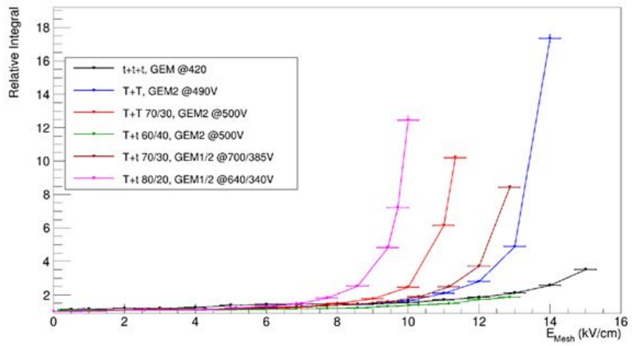


- The field below also increases, but increases slower and with a lower baseline.
- Most of the multiplication should occur inside the GEM.

Simulation - Work in progress

- Maybe increasing V_GEM increases the length where multiplication occurs?
- Which is the actual electric field and electron energy necessary to start an electron avalanche?
- How strongly does the shape of the GEM influentiate the this process? Is there a way to evaluate it?

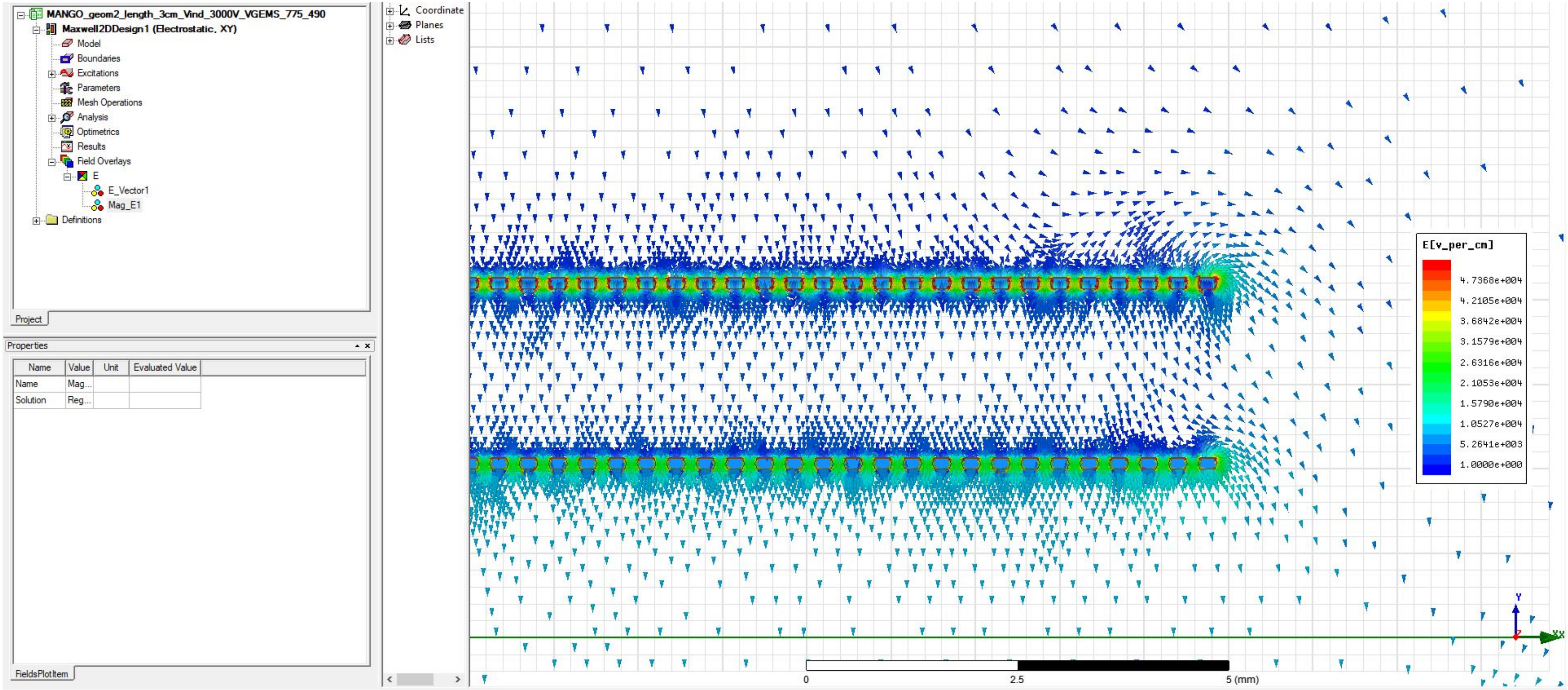
- Giorgio will continue the analysis of the data concerning the effects of electroluminescence field in the **charge and light output.**
- We can compare these results with this simulation to better understand this process.
- The PMT signal will also give us some insights on these effects since the signals' time window contain relevant information.
- Eventually **use this simulation** together with **Garfield++ and Magboltz** to characterize the electron multiplication process.



Conclusion

- I developed a method to **quantitatively** study the **electric fields** around the **GEM holes**.
- We concluded that **we are producing electroluminescence**, even though with some perhaps charge amplification, as also shown before by Giorgio.
- The **PMT signal** will give more information.
- Suggestions for future work?

Miscellaneous - Electric field vector: T - T



Miscellaneous - Electric field vector: + - + - +