COMIMAC - MANGO Integration

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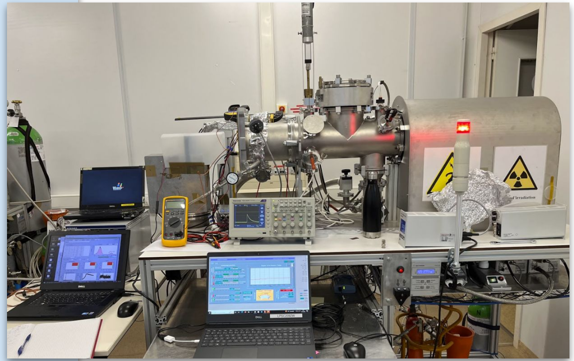
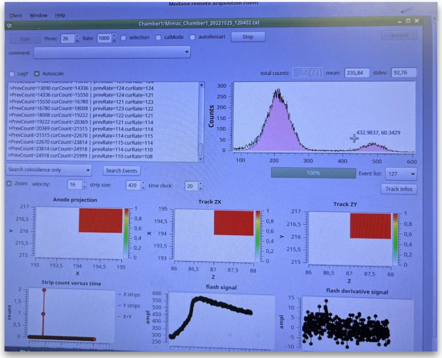
F. di Giambattista

COMIMAC simulation - Interest

→ Grenoble measurements in a nutshell:

- Many questions regarding the experimental setup accuracy.
- Some more serious inconsistencies between data
- Quenching factor (QF) roughly measured
  - **Dependency of QF with drift field hypothesized**
    - We didn't have time to properly make this measurement
- Many questions regarding the dependency of QF with the overall experimental setup
  - Best way to test it → ***Bring MANGO to Grenoble*** and couple it with their setup
    - Mechanical questions:
      - Can we get a couplable detector vessel? → Yes, Elisabetta and Cesidio working on it.
      - Do we need a field cage? → ***Maxwell simulation can help!***

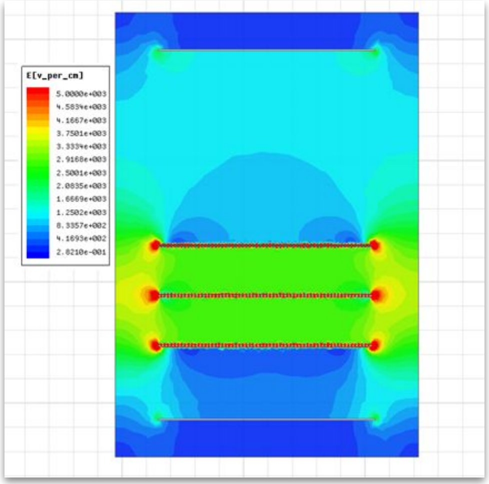




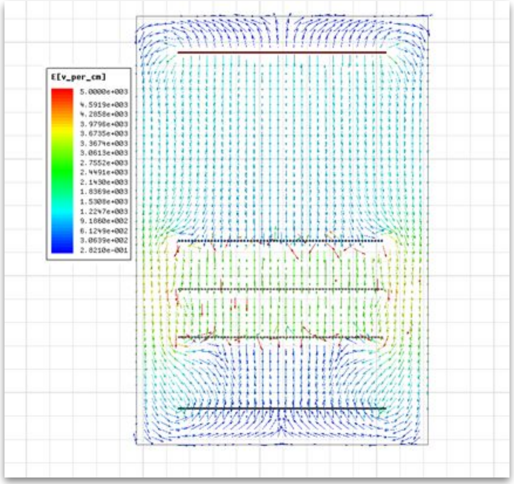
Maxwell - What for?

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

Electric **field** (V/cm)



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



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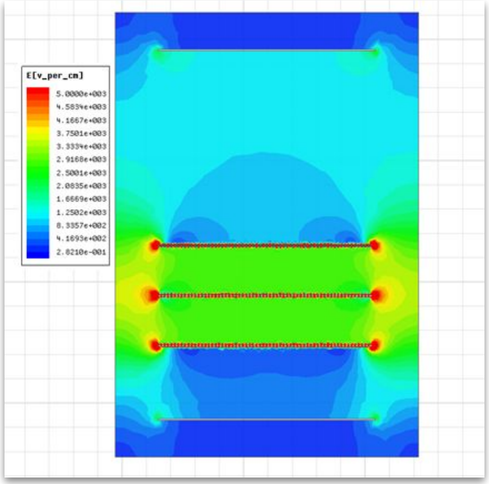

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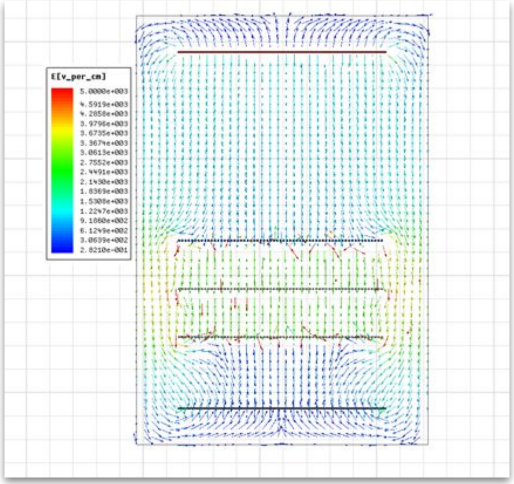
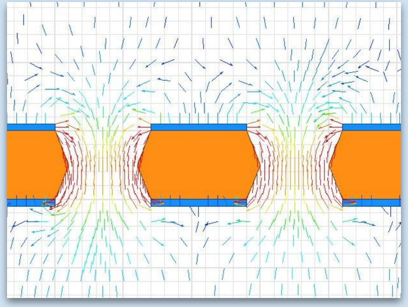
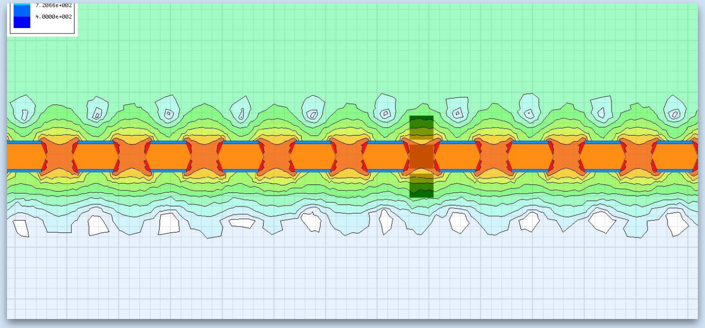


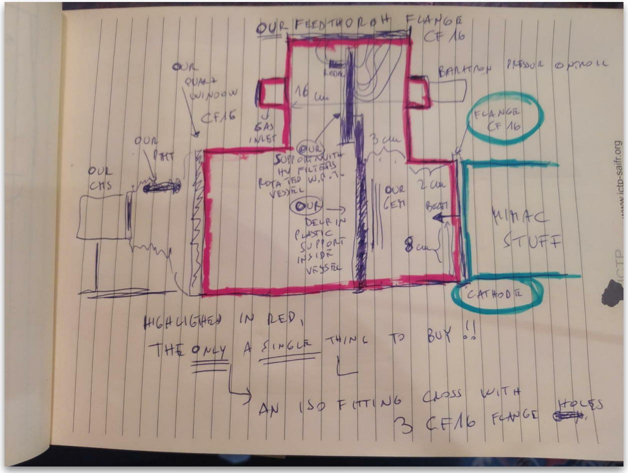


Interesting to study the GEM fields, etc.

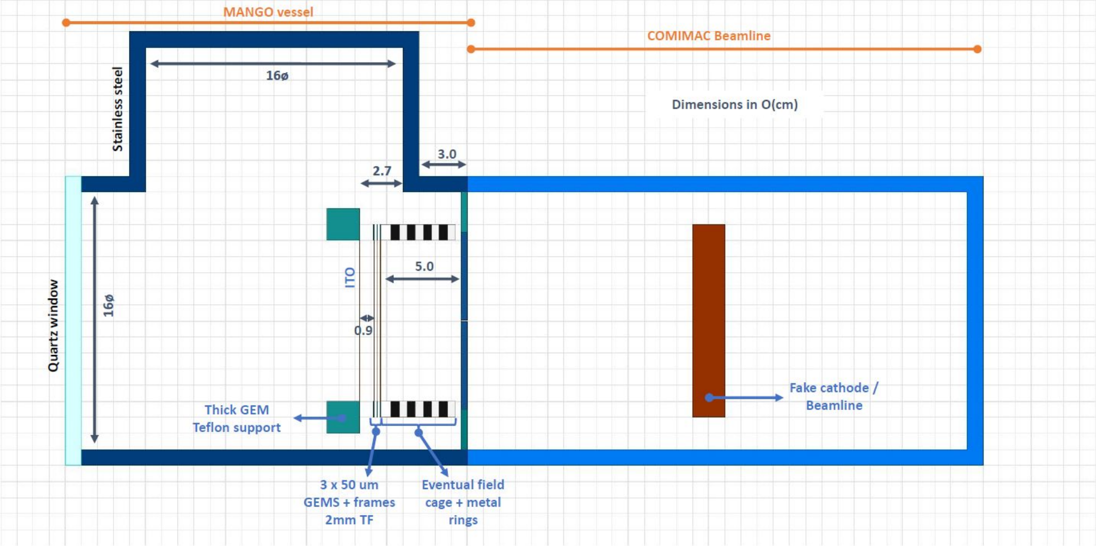


COMIMAC simulation - Rational

- From Elisabetta's schematic and Grenoble's people designs, I made a schematic of the COMIMAC-MANGO integration in Maxwell.
- The simulation consisted in studying **different drift fields** **with** and **without** field cage



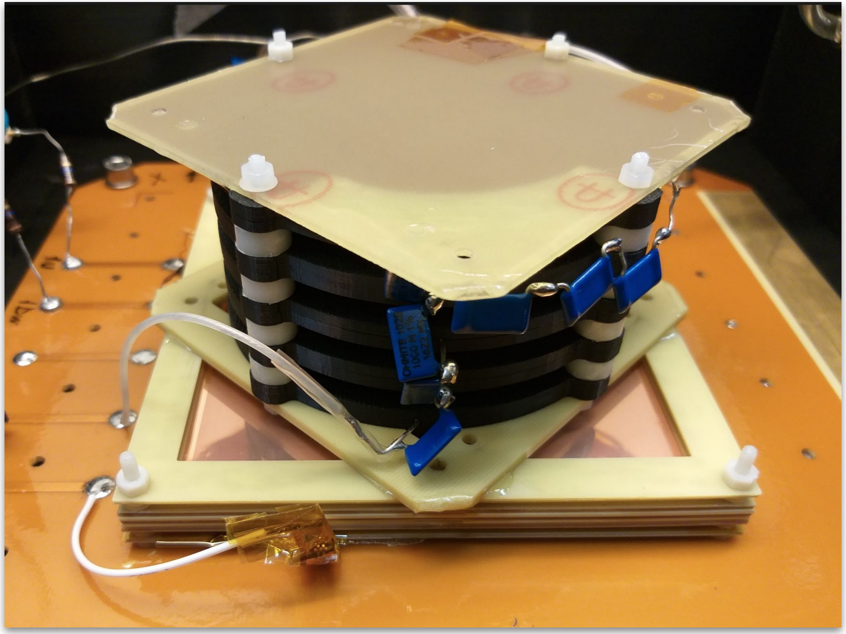
Source



Outcome

COMIMAC simulation - Rational

- For the field cage, I mimicked our setup.



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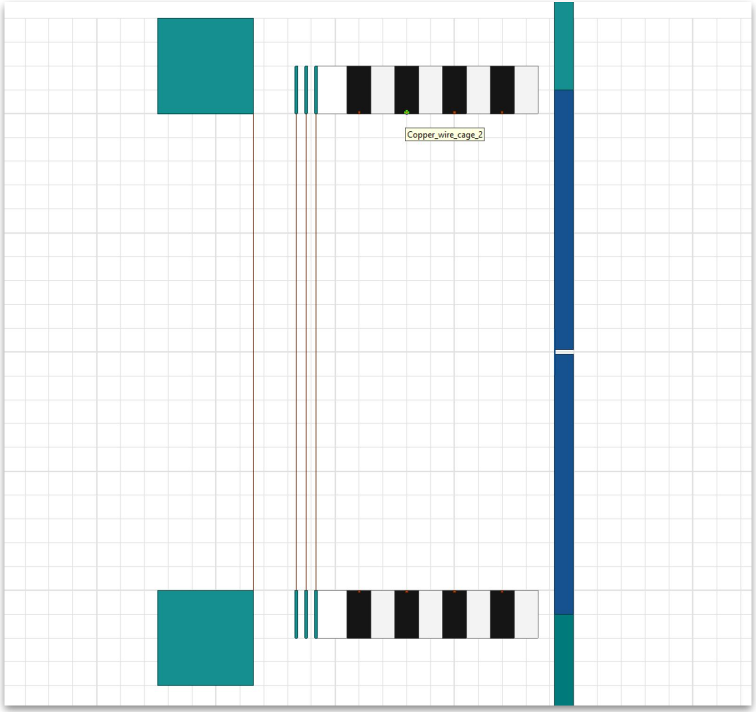
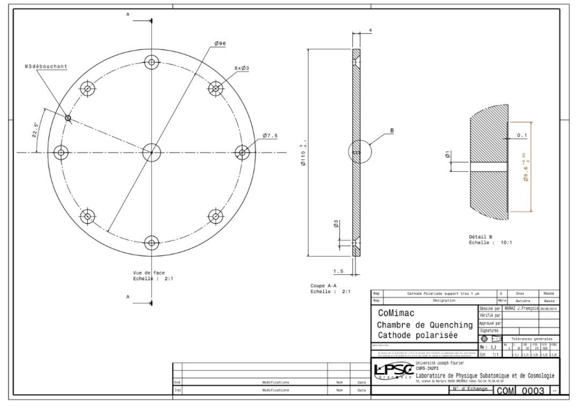
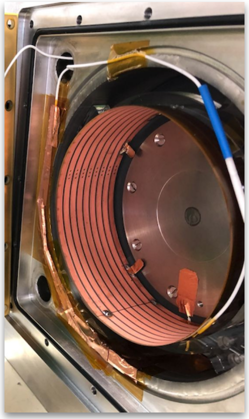


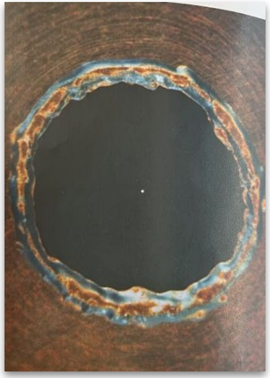
Outcome

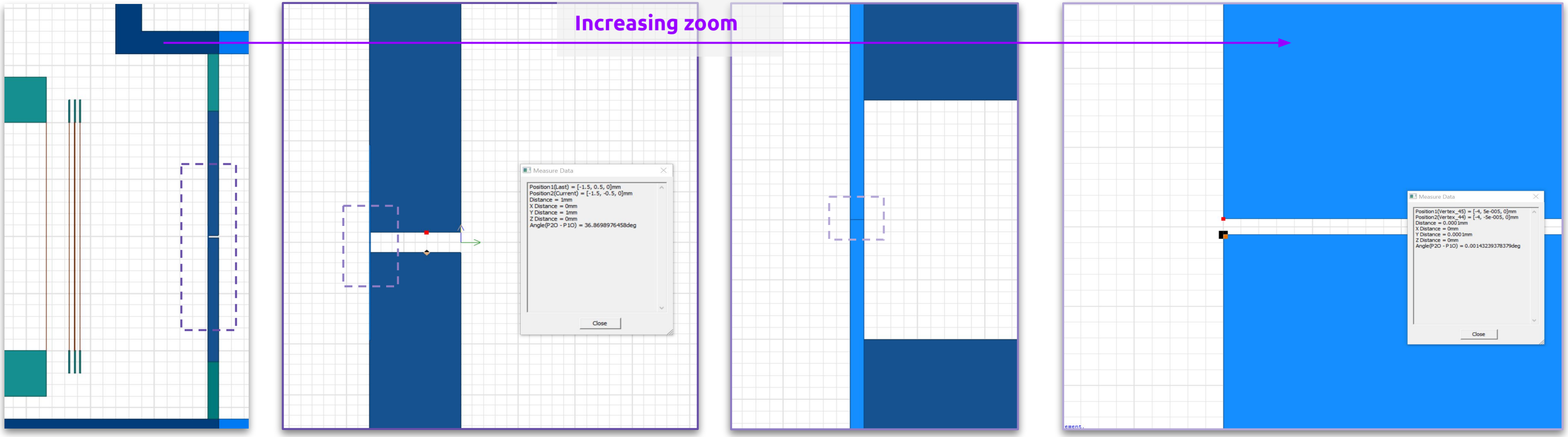
COMIMAC simulation - *Simplifications*

1. **Cathode**
   a. It is not super clear the whole design around the cathode part: It's a **O(10) um sheet*** with a **1 um hole** in the middle that separates gas from vacuum.





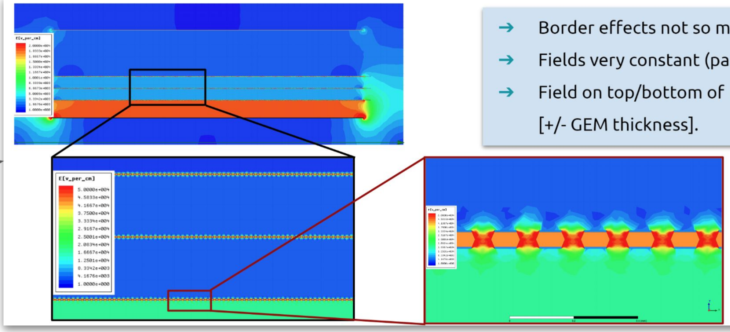




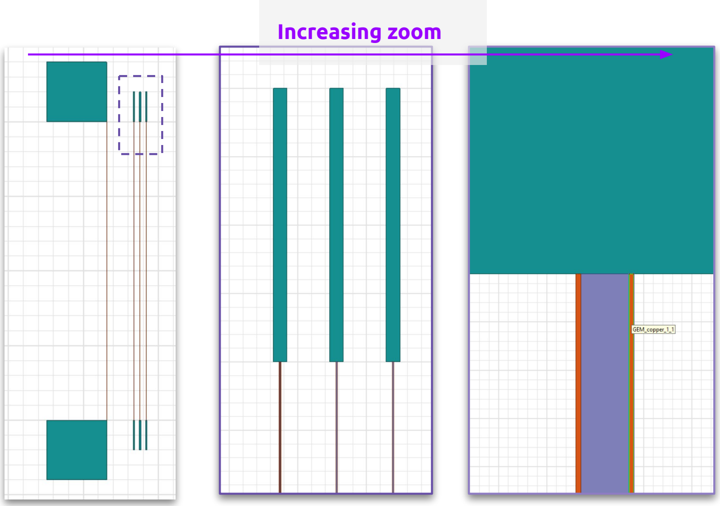
***Thanks Flaminia for the discussion**

COMIMAC simulation - *Simplifications*

1. **GEM**
    a. It was observed during the previous simulations that the O(100) um holes **do not** affect the **macroscopic** properties of the electric field.
    b. But simulating O(10^3) holes increases a lot the computing time.
    c. I **simplified the GEMs** to two flat copper surfaces separated by kapton.

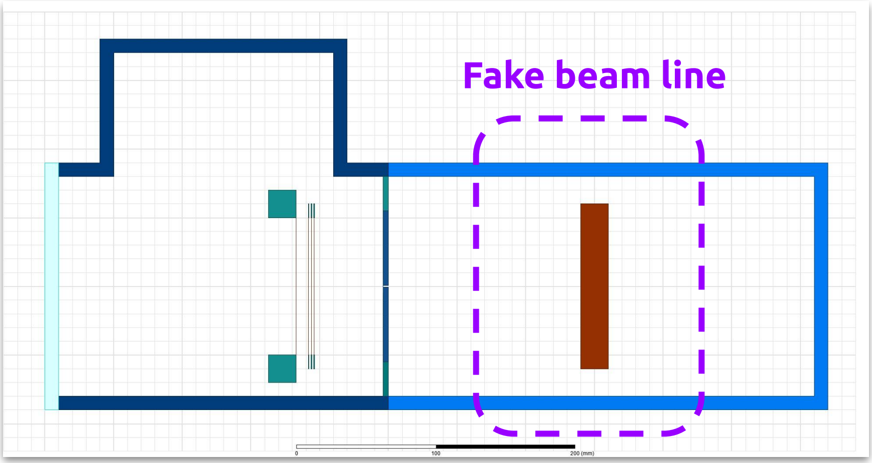


- → Border effects not so much significant.
- → Fields very constant (parallel plates)
- → Field on top/bottom of GEM is different in [+/- GEM thickness].



COMIMAC simulation - Simplifications

1. **Beamline**
   a. Since we are **not very interested in the MIMAC part**, I just designed a **huge HV** to help [closing the field lines].
   b. Also the electric field in that region is “irrelevant” as we’re just interested in the [particle beam itself].
   c. If necessary, *I can also design more in detail the beam* line electric fields (I would require more details from the Grenoble people though).

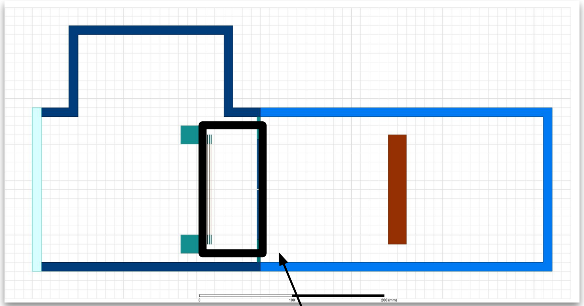


Results

& Conclusions

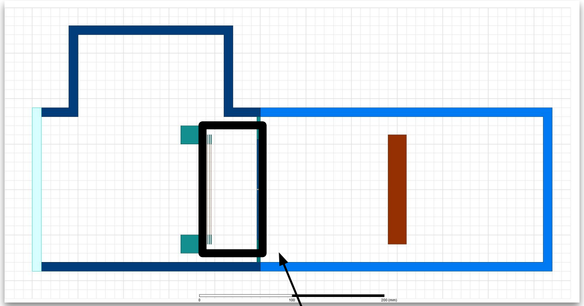
COMIMAC simulation - Results

No field cage



ROI (drift region)

COMIMAC simulation - Results



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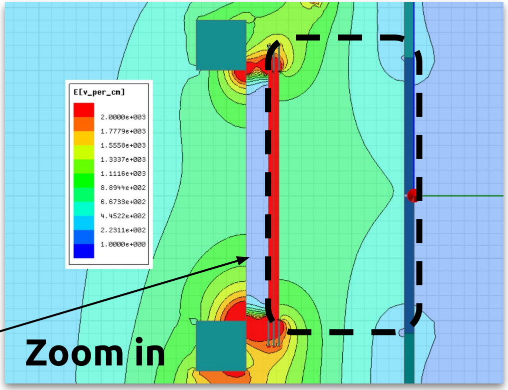

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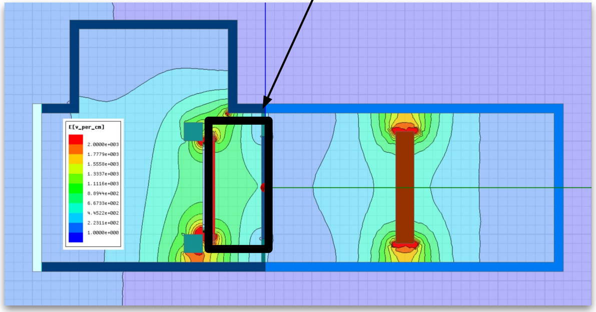
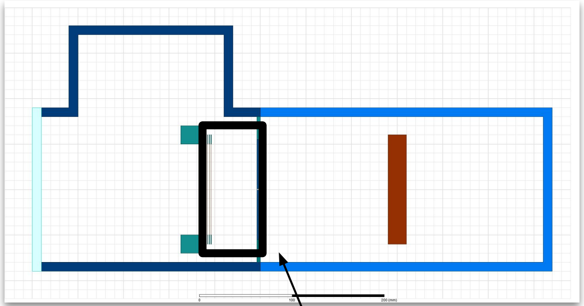


- Drift field: **700 V/cm**
- GEMs: 420 V
- Transfer Fields: 2.5 kV/cm, in 2 mm
- Induction field: 120 V in 9 mm → 133 V/cm

COMIMAC simulation - Results



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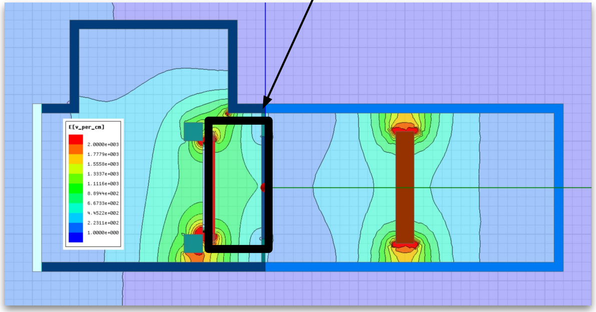

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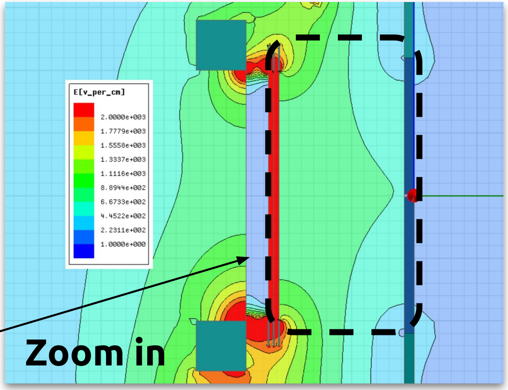

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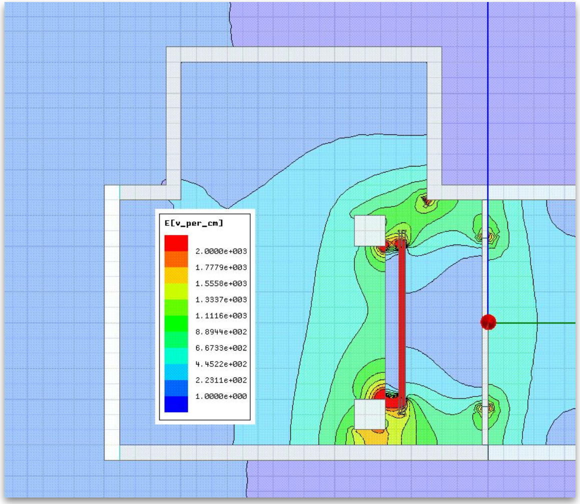
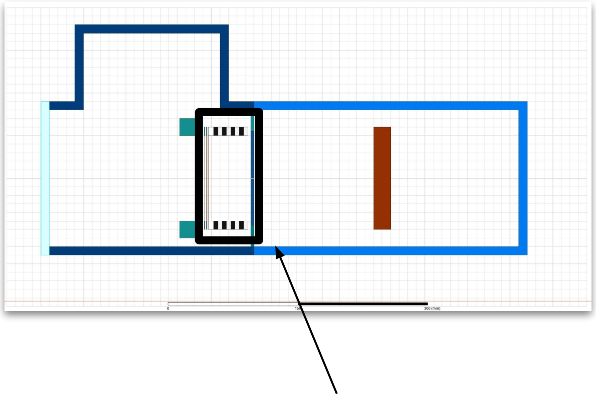


- **Drift field scan:** 150, 300, 500, 700, 1000 V/cm
- (full images at the end)

COMIMAC simulation - Results

YES field cage



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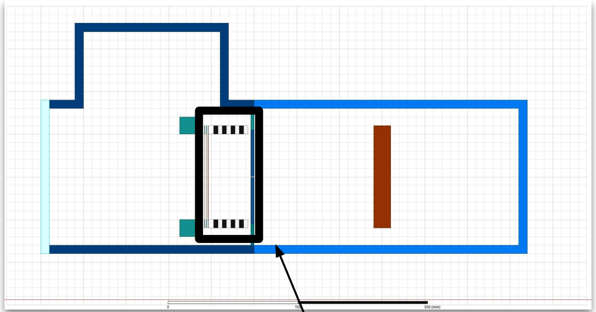

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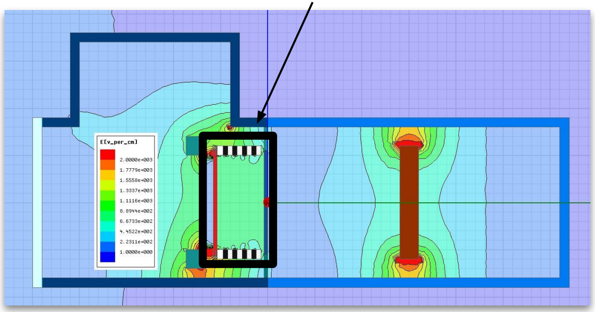

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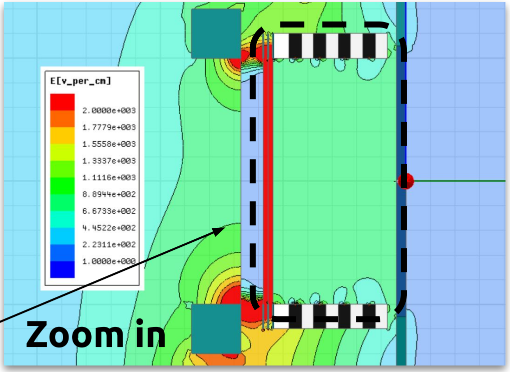

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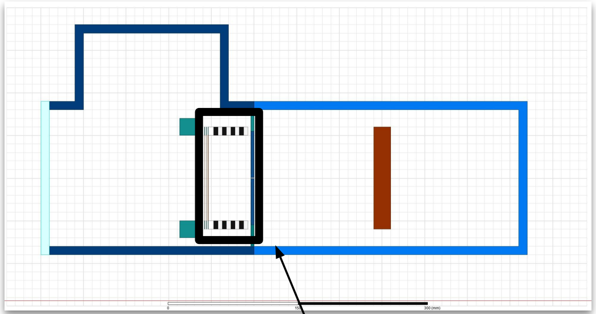

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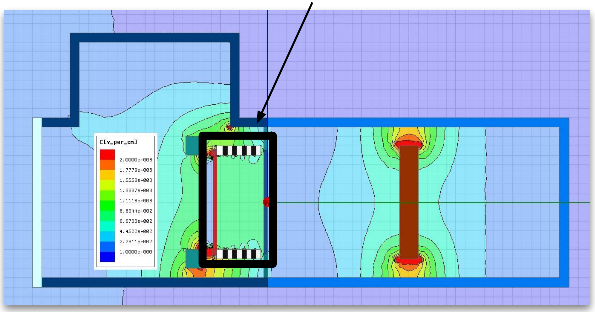

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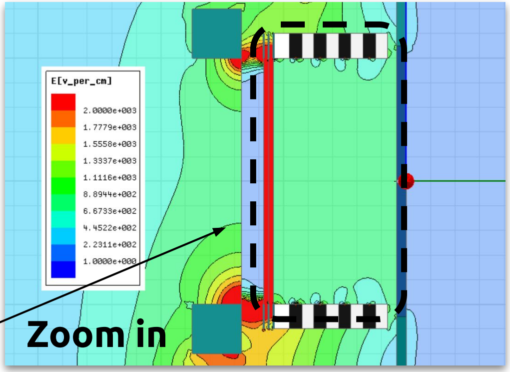

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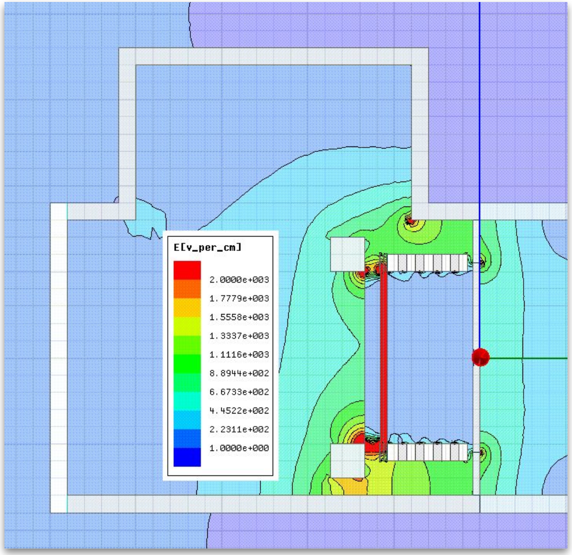

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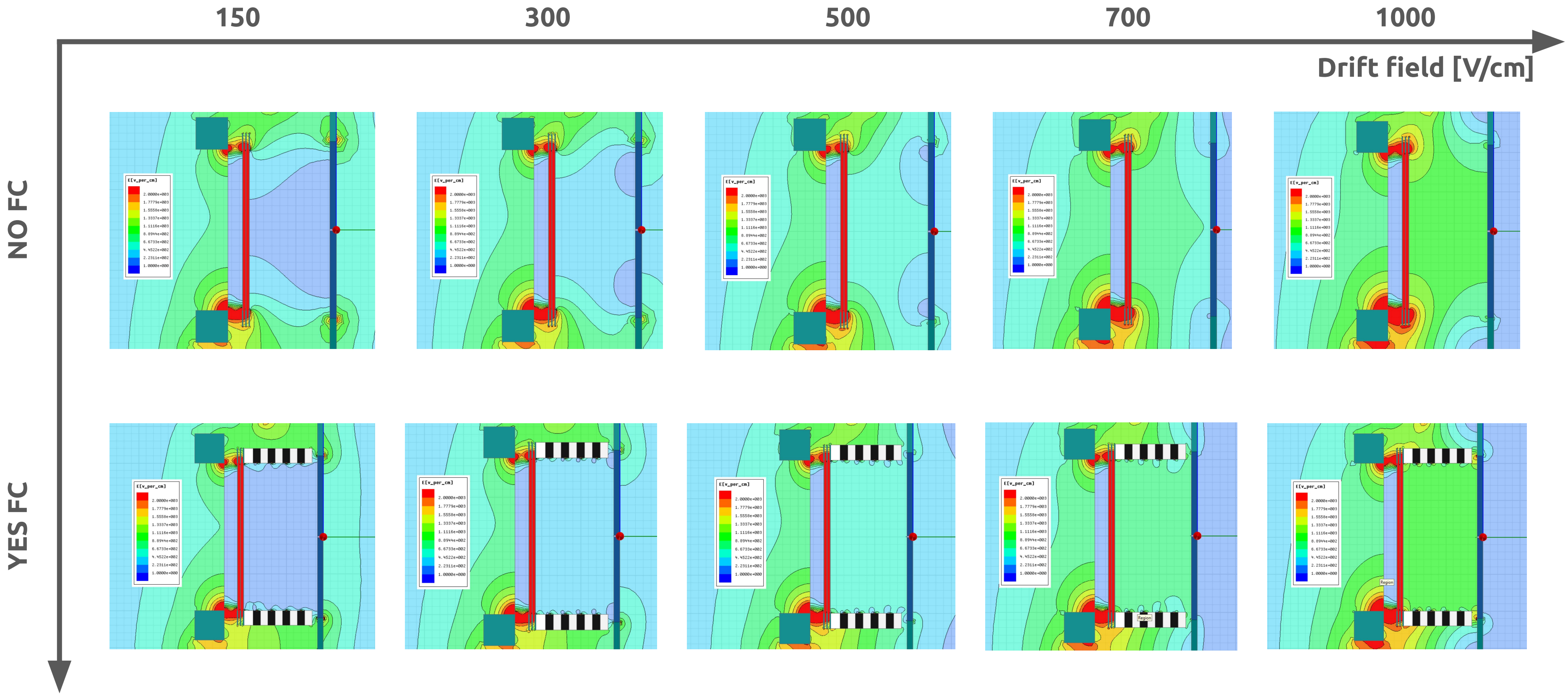
COMIMAC simulation - *Comparison*



COMIMAC simulation - Conclusion

- **Qualitative** verification of the need of a field cage performed using a **Maxwell simulation**.
  - *Something more quantitative could be performed if necessary.*
- In my *opinion*, a **field cage is necessary**. Reasons:
  - There are already some **uncertainties on their experimental setup**. Introducing another source of uncertainty could **negatively impact** even more the final measurement.
  - Thinking in the **hardware**, I think that the inclusion of a field cage (FC) it's not hard:
    - We just need to use the **old small MANGO FC**. (or remove the elongation of the FC put by Roberto to go from 5 to 15 cm drift) and **unmount our cathode** since they already have it.
    - ***If we cannot connect the last FC ring*** to the cathode to make the *voltage divider*, we can also (probably) **directly connect it to one of the feedthroughs.**

COMIMAC simulation - A few questions

→ Considering the **voltages used previously**, will we be able to reach a cathode voltage for this?

- We remember that the **cathode could only reach 3kV**(?)
- I used **420V on the GEMs** because this would be required at least for the **electron calibration at energies O(1) keV**.
- If we lower the voltages to **350 V** (enough the see the He ions), we reach a total of 1kV. Summing the transfer fields, we are at 2kV. If the maximum voltage of the cathode is 3kV, **we have available 1kV for 5 cm drift**, leaving to a **maximum drift field of ~200 V/cm**

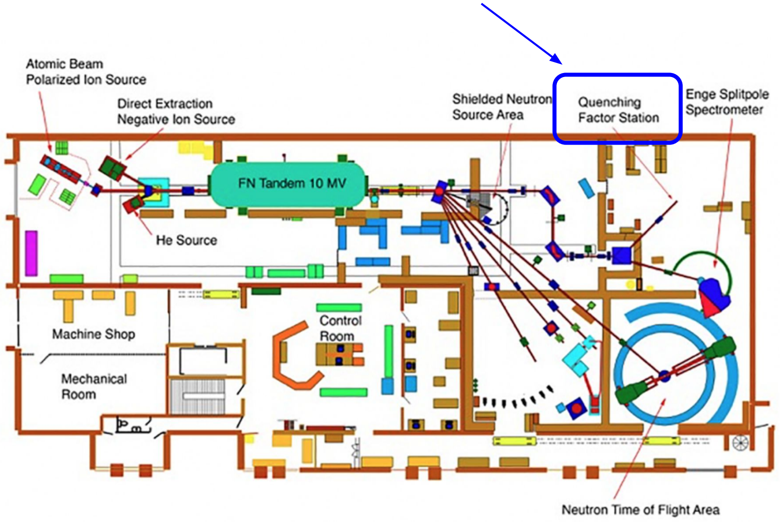
- To be discussed…

Higher drift field run

Helium in source								
Run number	Hour	Beam energy (keV)	Cathode voltage (kV)	Ion effective energy (keV)*	Focalization voltage (kV)	Peaks (ADC counts)		comments
	16h58	27.19	2.81	30	0	593	-	
	17h0X	Junk	Junk	Junk	Junk	Junk	Junk	
	17h05	22.19	2.81	25	0	488	-	
	17h08	17.19	2.81	20	0	374	-	
	17h12	12.19	2.81	15	0	258	-	Evertyhing using 810/810/2810, ie, E = (2810-810)/5 = 400 V/cm
	17h15	7.19	2.81	10	0	144	-	
	17h17	5.19	2.81	8	0	101	-	
	17h22	3.19	2.81	6	0	59	-	

...A new and recent idea...

TUNL facilities - Neutron beam



[Facilities | Triangle Universities Nuclear Laboratory]

Calendar:
https://calendar.google.com/calendar/u/0/embed?src=2esueavoe9rp28f784qvutulu8@group.calendar.google.com&ctz=America/New_York
Free from March…

- Is there **another place** where a **similar measurement** could be performed?
- What about **TUNL**?
- Let's discuss…

TUNL facilities - Neutron beam

➔ Recently, a **different location** was thought to be a possibility: the **TUNL facilities** in North Carolina State University, Duke. *In a few words:*

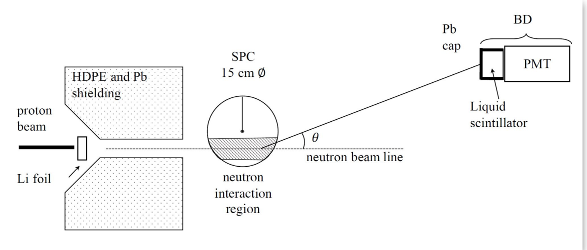
- **Neutron beam**
  - Neutron scatter -> Nuclear recoil -> QF measurement
  - Other sensitivity studies with very low (10^{-1} - 10^{0} keV_{nr}) nuclear recoils
- TUNL provided detector characteristics: *(from private communication from Philippe Gros, NEWS-G collab.)*
  - **Neutron tagging** with *backing detectors*
    - Closed kinematics -> Precise measurements
  - **Trustworthy beam**
- **Trigger** system
- **Experience** with this type of measurements (NEWS_G – SpherePC – QF measurement)
- **No money** required -> Only **co-authorship** in resulting paper.

https://arxiv.org/pdf/2109.01055.pdf

I studied the NEWS-G paper to understand if it possible to bring "MANGO" to their facilities

TUNL facilities - CYGNO/MANGO feasibility

- **Hardware:**
  - A priori, **easy to couple** with MANGO (it's a beam line).
  - **Backing detectors** to measure scattered neutron's **energy** and **angle** -> Closed kinematics -> **nuclear recoil energy deposited.**
    - They worked with $\mathbf{E_{nr}}$ **= [0.74 - 6.8] keV$_{\mathbf{nr}}$**
      - *Enough for us? Need of different target or more beam power?*
  - They have **data acquisition system.**
  - Monitor interaction between proton and target ("t_0").
  - Neutron beam energy measured *in situ* with ToF between **n** and γ (PSD discrimination).
  - Neutron energy in range [40-700] keV (target dependent). *Not sure of beam's maximum energy…*
  - Target and beamline shielded to reduce background.



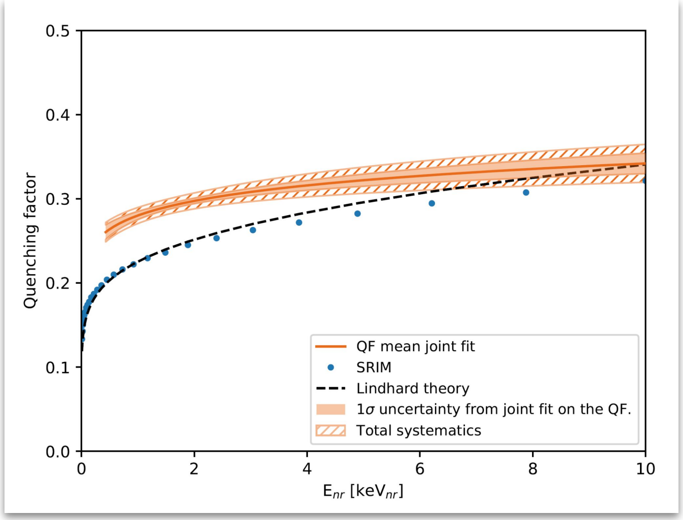
Proton interact with LI target generation neutron beam. Scattering angle measured with BD.

$$p + {}^7\mathrm{Li} \longrightarrow n + {}^7\mathrm{Be} + \gamma$$

$$E_{nr}(\theta_s, E_n) = 2E_n \frac{M_n^2}{(M_n + M_T)^2} \times \left(\frac{M_T}{M_n} + \sin^2\theta_s - \cos\theta_s \sqrt{\left(\frac{M_T}{M_n}\right)^2 - \sin^2\theta_s} \right)$$

TUNL facilities - CYGNO/MANGO feasibility

- **Software:**
  - **Trigger on BDs** -> *Camera free running mode?*
  - ToF between target interaction and BD -> **reject background.**
  - **Runs take O(10) hours.**
    - Long **stability** required.
    - NEWS-G performed **continuous gain monitor** with ^{55}Fe.
  - **NEWS-G thorough analysis** can help us identifying signals and calculating QF. *(Ph.D. thesis available to full details)*
  - Good for us to **test our nr. vs. er. capabilities.**
  - Beam characteristics well defined.
  - ***Caveat:***
    - We cannot choose recoiling nucleus (**He, C and F signals mixed**).
      - ***Interaction rates** simulated with Geant4 could be of interest for better analysis.*



NEWS-G final results.

(To give an idea of achievable accuracy)

Thank you for your attention!

The CYGNO Project counts with the collaboration of several international researchers coming from:

Backup

& more details

COMIMAC simulation - Details

- Continuing on the feedthroughs topic, they use this very good FC, which is the sort of the whole "tube" itself.
  - *"About field cage, it's a Kapton pipe with copper printed conductor and a resistor chain. The diameter is about 120 mm and the cage is centered in the pipe by a transparent ring made of PMMA" - Grenoble people*
  - If removable, could be eventually placed in our vessel… *to be confirmed*
- If not, I propose we use the old setup with the new support and without the cathode.