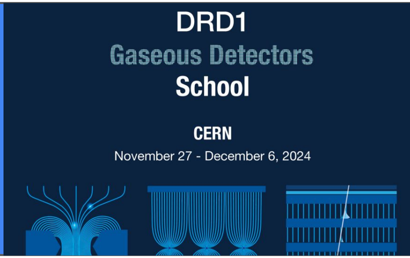

Characterization of THGEM Detector: A Member of the MPGD Family

DRD1 school 2024 - CERN

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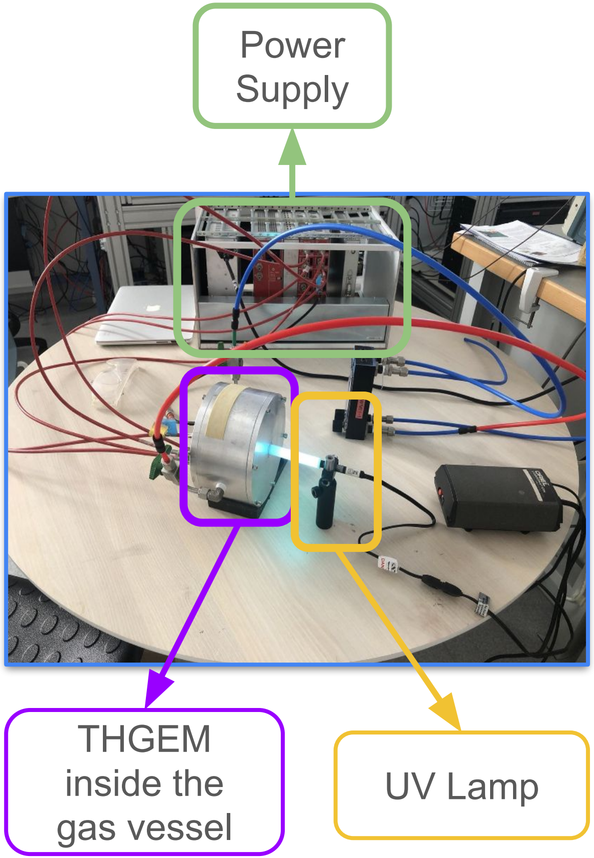
WG8 collaboration meeting 13 December 2024

Outline

- Experimental setup
- Gain measurement and results
  - HV scan of the gem field with drift and induction field = 0
    - Gain Scan
  - scan of induction field with fixed gem field and drift field = 0
    - Best collection
  - scan of the drift field with fixed gem field and induction field = 0
    - Best Extraction
  - scan of the gem field with fixed drift (maximum extraction) and induction field (maximum collection at anode)
    - Optimal operation

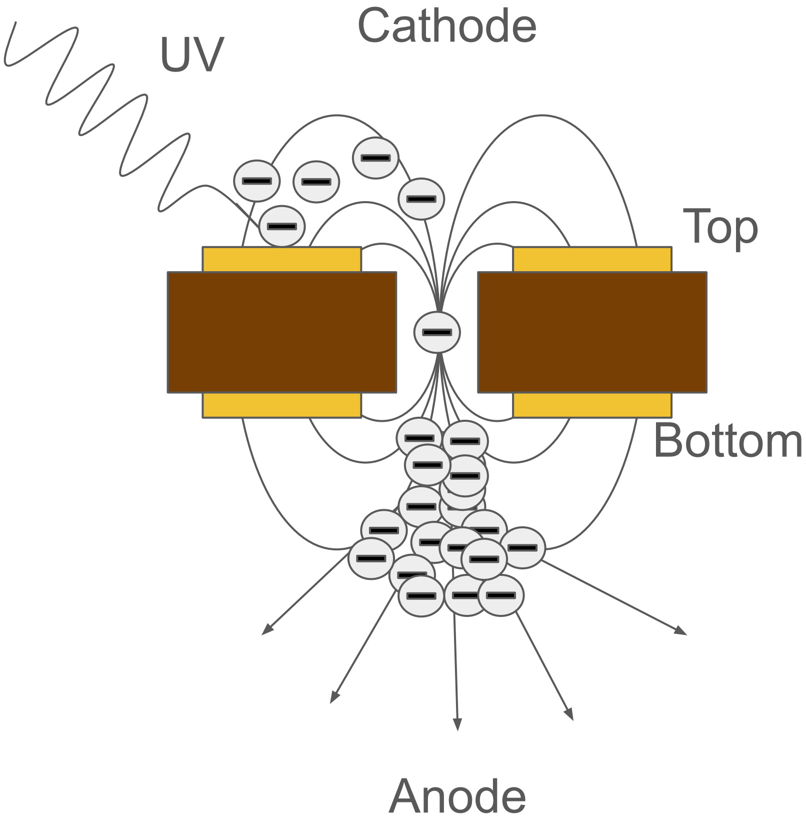
Experimental Setup

- Drift region ~ 5 mm
- Insulator ~ 0.8 mm
    a. 1 mm pitch hexagonal pattern of 0.5 mm diameter holes (obtained by drilling and etching)
- Induction region ~ 1 mm
- 10 x 10 cm2 Thick GEM
- Gas Mixture: $Ar/CO_2/iC_4H_{10}$ (93:5:2%) flushing
- Sources: UV lamp (Hg) with lines in 200 to 600 nm range
- Keithely 6517A (1pA resolution)
- HV power supply : 4 ch. CAEN HV Module
- A computer for HV control and automated measurements (Labview interface)



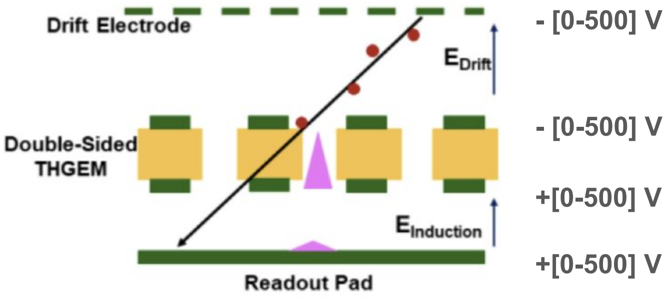
Experimental Setup - Photoelectric effect in GEM foils

- Photons from the UV lamp
  - λ ~ 200 to 600 nm
- Electrons extracted from the copper surface
  - work function ~ 4.5 to 5.1 eV
- The drift lines extracts the electrons and then the multiplication lines drags the electrons into the hole
- The electric currents generated in the cathode, top GEM, bottom GEM and anode are monitored to understand the phenomena



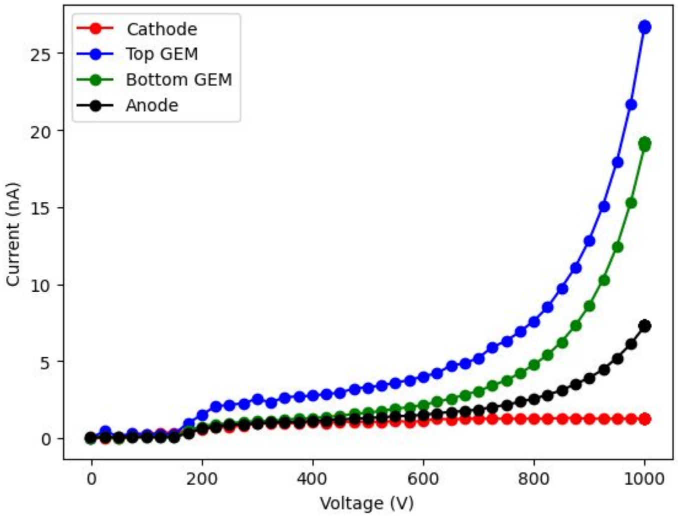
1) HV scan of the gem field

- ΔV(drift) = ΔV(induction) = 0V
- V(GEM) scanned from 0 to 1000V
  → ΔV GEM scanned from 0V to 1000V
  → opposite polarity tested



ΔV scan from 0 to 500 V → electric field ↓

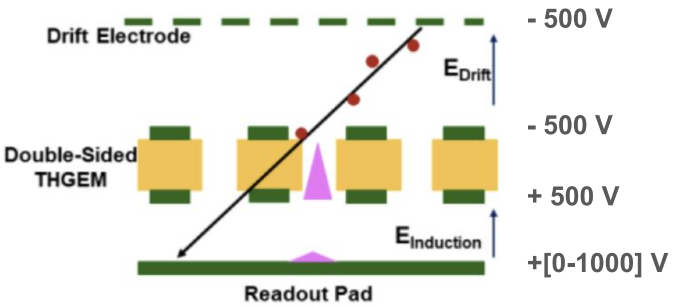
- electrons from the avalanche are pushed towards the bottom electrode of the gem: all the electrons are collected at the bottom electrode of the gem
- most of the ions are collected at the top electrode of the gem
  - cathode and anode currents ~ 0

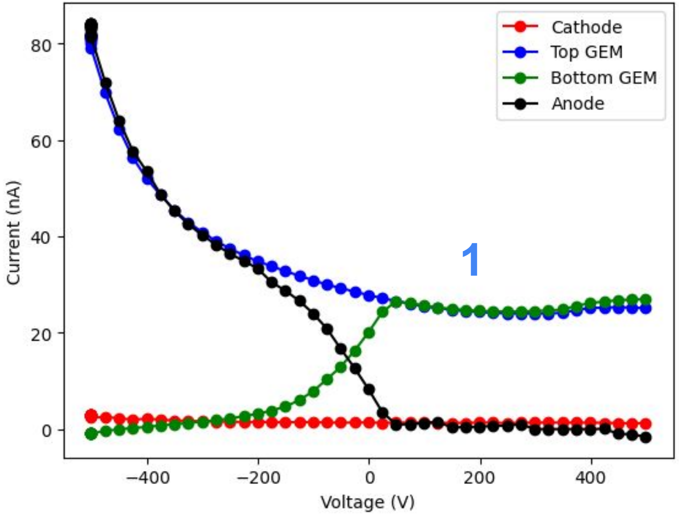


2) Scan of the induction field

- ΔV(drift) = 0V, ΔV(gem) = 1000V
- V(anode) scanned from 0 to 1000V
  → ΔV anode scanned from -500V to 500V
  → opposite polarity tested

1) ΔV scan from 0 to 500 V → electric field ↓
   - electrons from the avalanche are pushed towards the bottom electrode of the gem: all the electrons are collected at the bottom electrode of the gem
   - most of the ions are collected at the top electrode of the gem
     - cathode and anode currents ~ 0

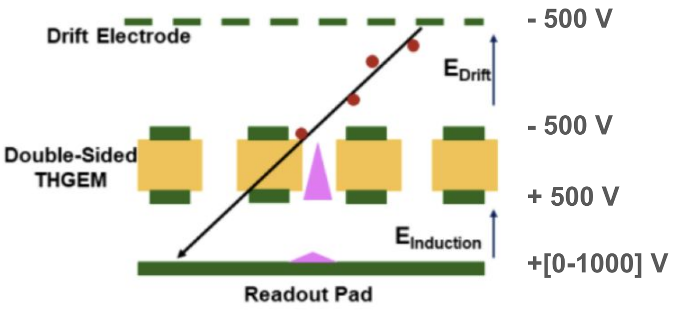


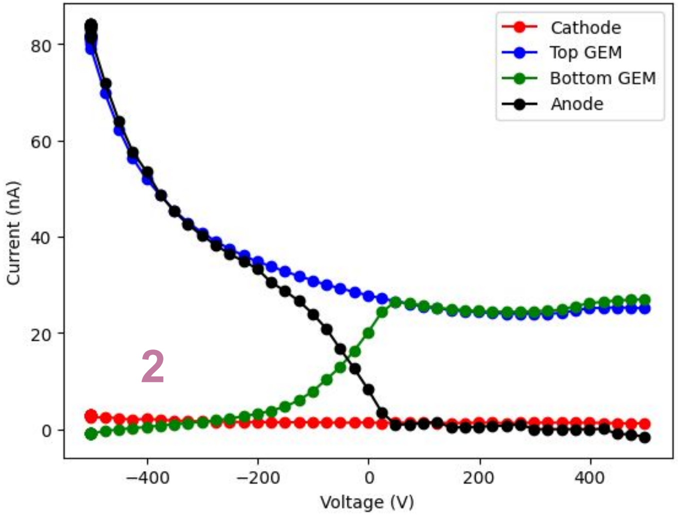


2) Scan of the induction field

- $\Delta V(drift) = 0V$, $\Delta V(gem) = 1000V$
- V(anode) scanned from 0 to 1000V
  → ΔV anode scanned from -500V to 500V
  → opposite polarity tested

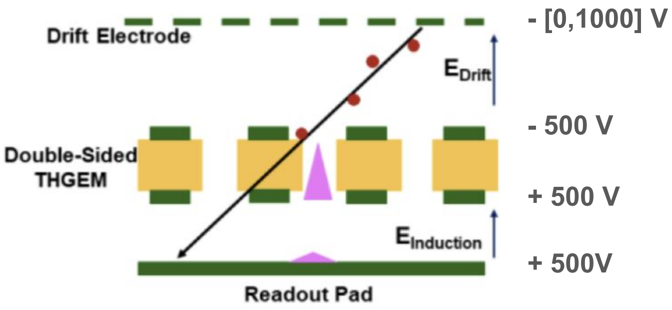
2) ΔV scan from 0 to -500 V → electric field ↑ nominal direction of the electric field
- as the electric field increases the electrons from the avalanche are directed towards the anode → the anode current increases and the gem bottom current decreases
  - from ~-200 V all the electrons are collected at the anode
  - from ~-350 V we start to observe the multiplication process in the induction gap



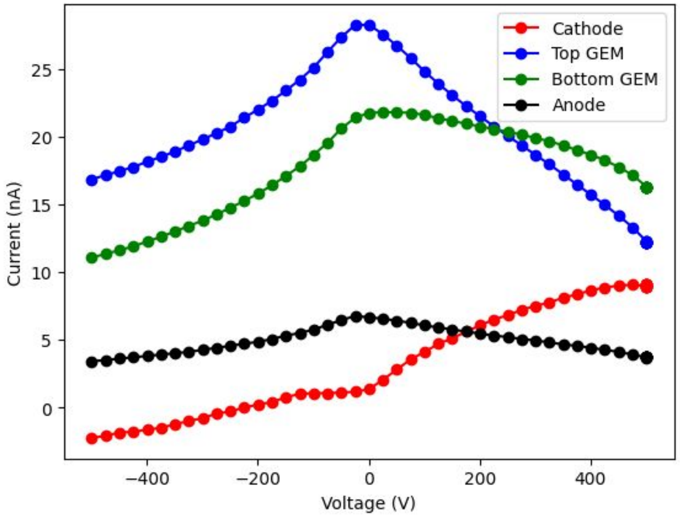


3) Scan of the drift field

- ΔV(induction) = 0V, ΔV(gem) = 1000V
- V(cathode) scanned from 0 to -1000V
  → ΔV cathode scanned from -500V to 500V
  → nominal and opposite polarity tested



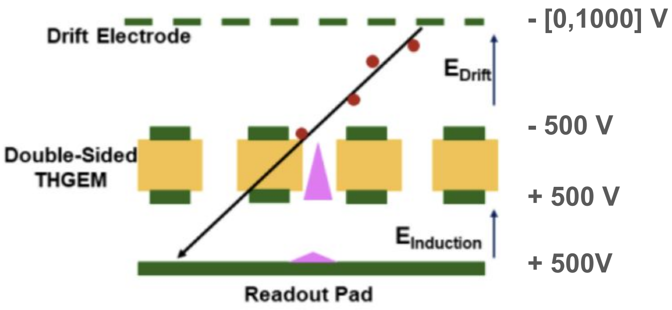
1) ΔV scan from 0 to 500 V → electric field ↓
   - some of the electrons extracted from the top gem are drifted towards the cathode → the cathode current increases with ΔV
   - less electrons start an avalanche → less ions and secondary electrons produced
     → top and bottom gem currents and anode current decrease with ΔV

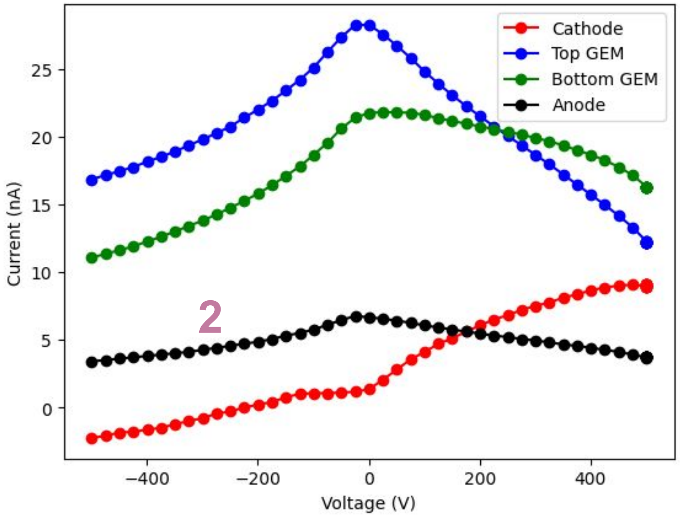


3) Scan of the drift field

- ΔV(induction) = 0V, ΔV(gem) = 1000V
- V(cathode) scanned from 0 to -1000V
  → ΔV cathode scanned from -500V to 500V
  → nominal and opposite polarity tested

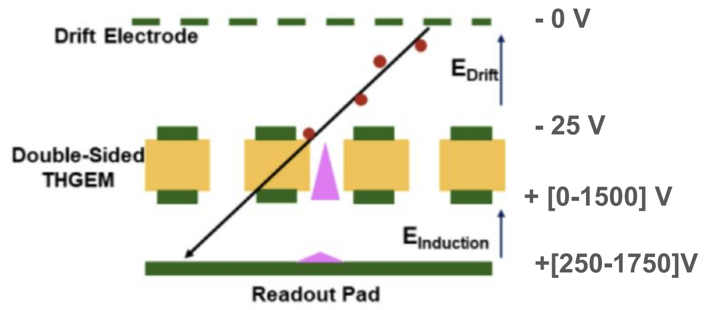
2) ΔV scan from 0 to - 500 V → electric field ↑
   - the electrons extracted are pushed towards the top gem electrode and some of the ions towards the cathode → small negative cathode current
   - the drift field reduces the number of electrons extracted from the top gem → less electrons start avalanches → top and bottom gem currents and anode current decrease with ΔV





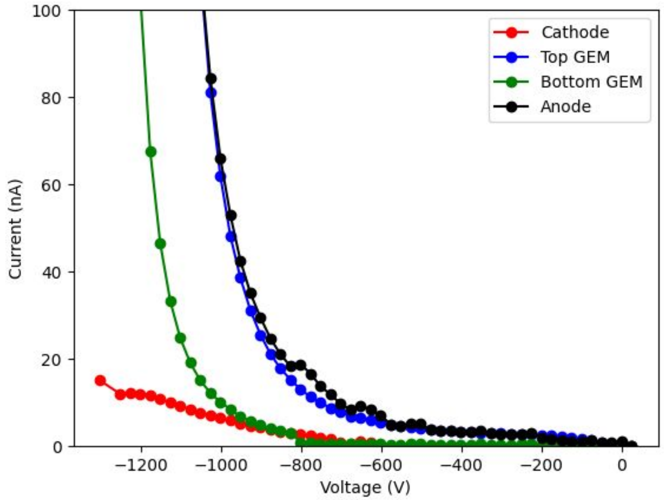
4) Gain in maximum extraction and induction

- ΔV(drift) = -25V
- ΔV(GEM) scanned from 0 to -1500V
- ΔV(Induction) scanned from
  → ΔV cathode scanned from -500V to 500V
  → nominal and opposite polarity tested



ΔV scan from 0 to +1500 V → gain ↑ (around 10^2)

- the electrons extracted are dragged by the electric field inside the hole where multiplication takes place
- the current in the top gem and the anode are very similar and much higher than the current in the bottom and the cathode
- Could not reach a maximum gain due to overcurrent



Conclusion

- Multiplication:
    - Almost no multiplication in ΔV below - 600V
    - Exponential growth in the gain in ΔV above - 600V
- Inverted Polarity:
    - Reversed induction field: higher current measured in the bottom
    - Matching induction field: higher current measured in the anode
    - top GEM measured the same current as the bottom/anode
- Voltage setup:
    - application of a GEM-based detector for photoelectric effect
    - optimal operation: best extraction and best collection of the electrons
    - Could reach higher gains

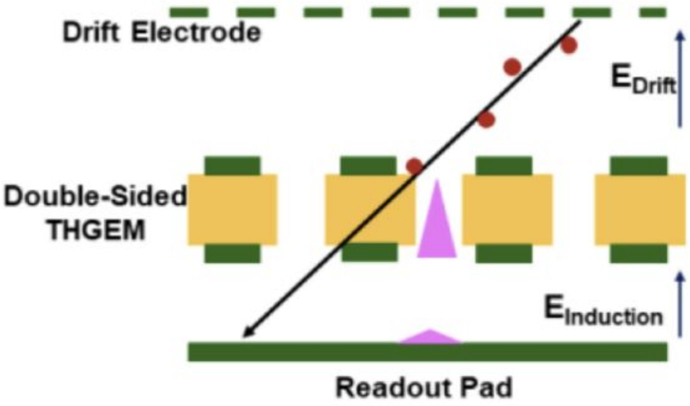
THGEM: Overview and experimental parameters

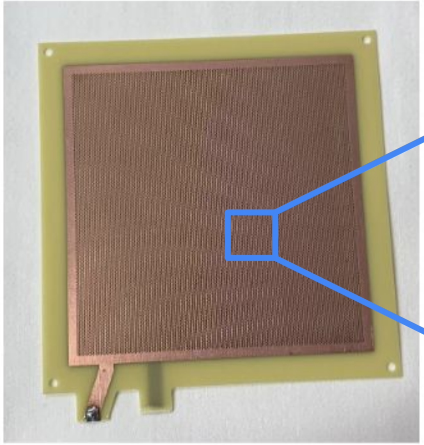
1) Large holes larger than e- diffusion
   a) full electron collection efficiency from conversion gap, photocathodes
   b) good energy resolution
   c) optimal geometry
      i) easier manufacturing
2) Large multiplication factor in most gases (incl. noble gases
   a) Single THGEM gain around 10^4 to 10^5
3) Rate capability ~ 10^4 Hz/mm^2
4) High resistance to radiation damage

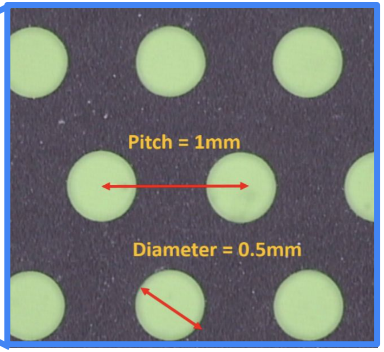
- 10 x 10 cm2 Thick GEM
- Gas Mixture: Ar/CO2/iC4H10 (93:5:2%) flushing
- Sources: UV lamp (Hg) with lines in 200 to 600 nm range
- Keithely 6517 A (1pA resolution)
- HV power supply : 4 ch. CAEN HV Module
- A computer for HV control and automated measurements (Labview interface)

Thick Gas Electron Multiplier (THGEM)

- drift region ~ 5 mm
- insulator ~ 0.8 mm
    - 1 mm pitch hexagonal pattern of 0.5 mm diameter holes (obtained by drilling and etching)
- induction region ~ 1 mm







- Large holes larger than e- diffusion
- Good energy resolution
- Easy manufacturing
- High Gains
    - around 10^4 to 10^5
- Rate capability ~ 10^4 Hz/mm^2
- High Resistance to radiation damage

THGEM: overview

1) Large holes larger than e- diffusion

- full electron collection efficiency from conversion gap, photocathodes
- good energy resolution with ionizing radiation
- efficient electron transfer effective cascading of electrodes
- optimal geometry: hole diameter = thickness

2) Large multiplication factors in most gases incl. noble gases

- single electrons - Single THGEM Gain 10^4 - 10^5

3) Rate capability:~10^4 MHz/mm2

4) Fast response

Experimental Parameters

- 10 x 10 cm^2 Thick GEM
- Gas Mixture: $Ar/CO_2/iC_4H_{10}$ (93:5:2%) flushing
- Sources: UV lamp (Hg) with lines in 200 to 600 nm range
- Keithely 6517 A (1pA resolution)
- HV power supply : 4 ch. CEAN HV Module
- A computer for HV control and automated measurements (Labview interface)

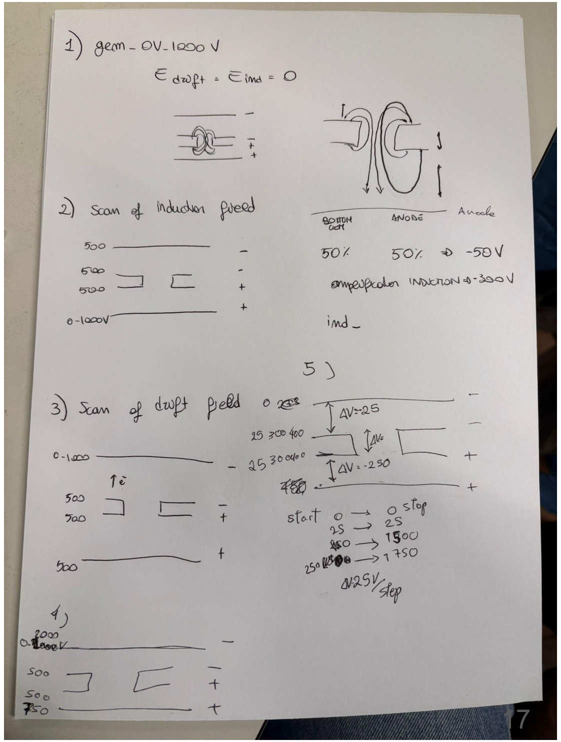
Thick Copper THGEM

- Use a thicker copper (400μm) on bottom electrode → converter directly on the GEM
- Geometrical Parameters
  – Thickness=0.8mm
  – HoleDiameter=0.5mm
  – Pitch=1mm
  – Top Copper Thickness=0.035mm

  – BottomCopperThickness=0.4mm
- Square Pattern
- This THGEM should have a very high real gain but a unitary effective gain

Methodology

- Scanning of different configurations of the electric fields inside the three regions
- we set a fixed voltage for 2 regions then we did a scan using the software between 0-1000V in the other electrode -> discussed the effects with this change
-



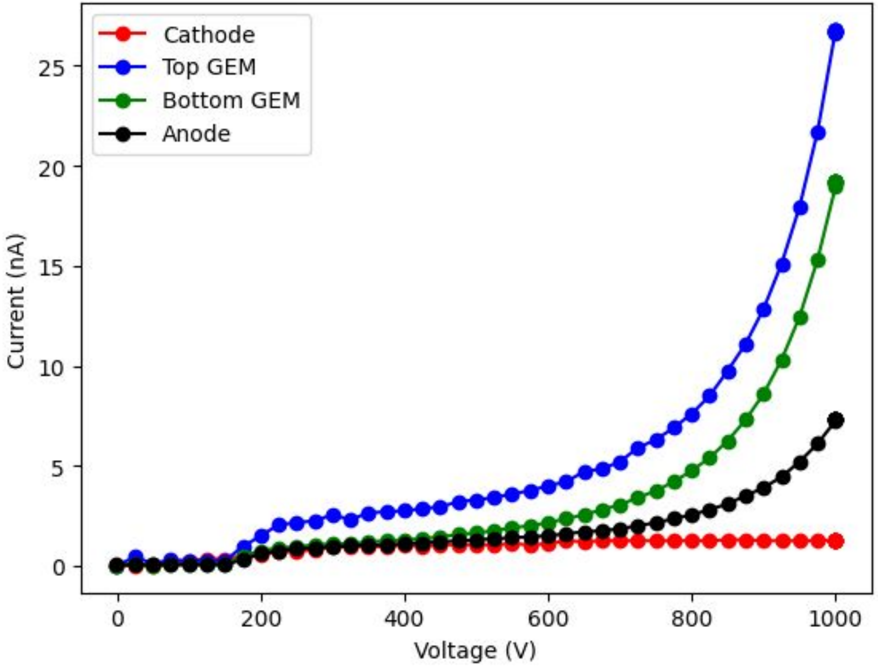
Conclusions and Future Plans

- Every voltage setup should be chosen for a specific application
    - In this experiment, we wanted to extract the maximum current and collect it in the anode
- Scanning regions allows to identify

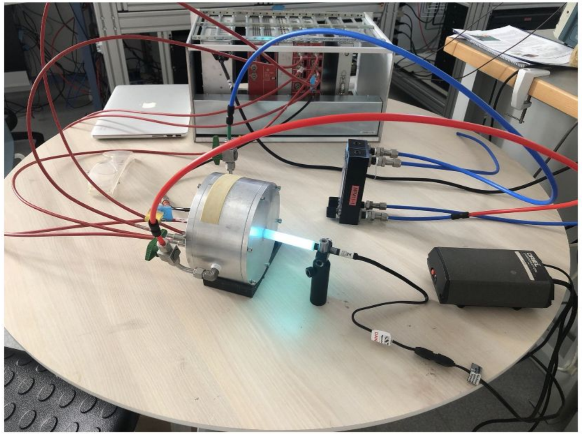
1) HV scan of the gem field with drift and induction field = 0

- high current in top and bottom of gem
- low current in anode and cathode
- we had more current in top gem than in the bottom
    - because we had photoelectric + ions coming due to avalanche than in the bottom that were just the electrons from multiplication

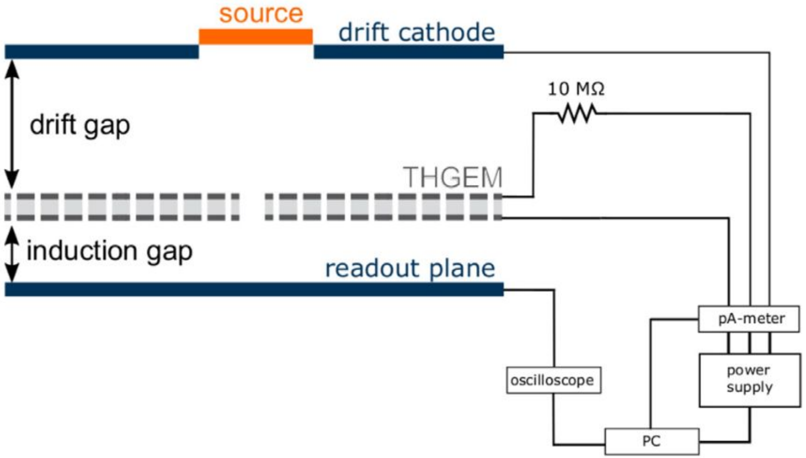
(make new graphs with python)



Experimental Setup (Subir)



Detector setup with vessel, UV lamp and power supply.



Schematic of double THGEM detector for UV detection.