Minimizing distortion with segmented GEM electrodes. Single hole GEM studies

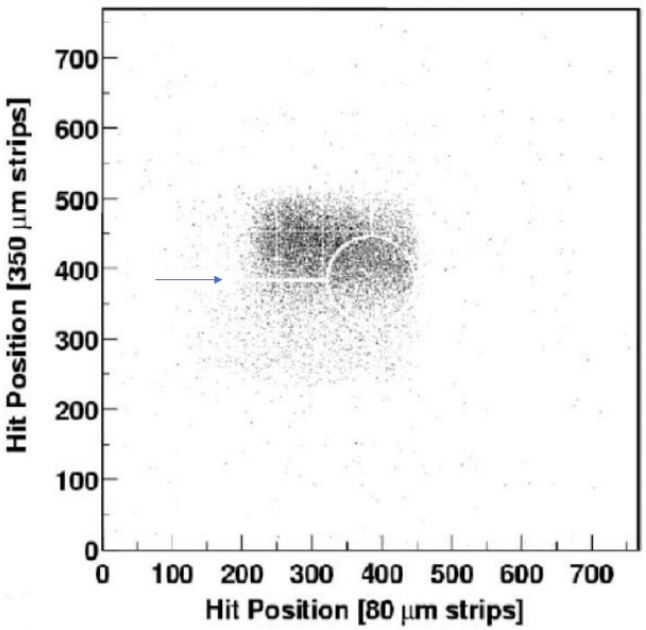
CERN Summer Project

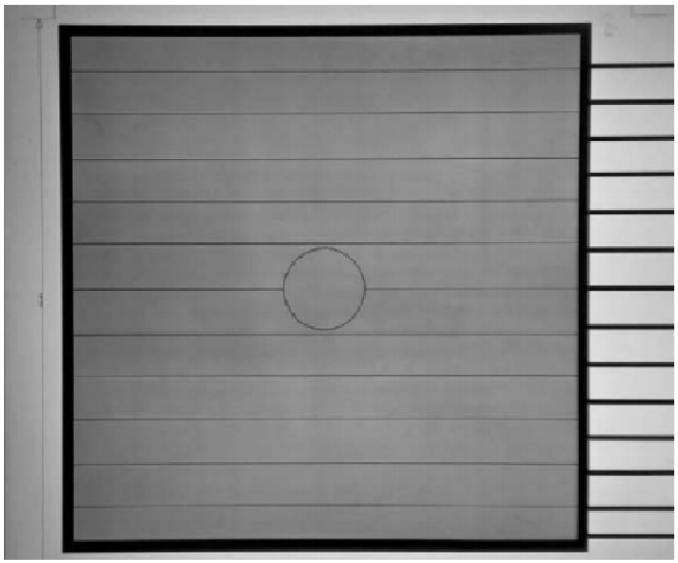
Afonso Marques

About me

- Taking a master's degree in Engineering Physics at University of Coimbra, Portugal.
- 2 summer internships (2017, 2018) at LIP (Laboratory of Instrumentation and Experimental Particles Physics) in Gaseous Detectors Group with Prof. Filipa Borges and Dr. André Cortez working on ion mobility studies in several gaseous mixtures.
- 1 summer internship (2019) at CERN working on the Gas Detectors Development Group with Fabio Sauli, Florian Brunbauer, Eraldo Oliveri...
- Next year will begin my thesis in NEXT (Neutrino Experiment with Xenon) group at the Instituto de Física Corpuscular (IFIC) in Valencia, Spain (collaboration to search for the neutrinoless double beta decay of the Xe-136 isotope).

Distortion at sector borders of large-area GEM detectors

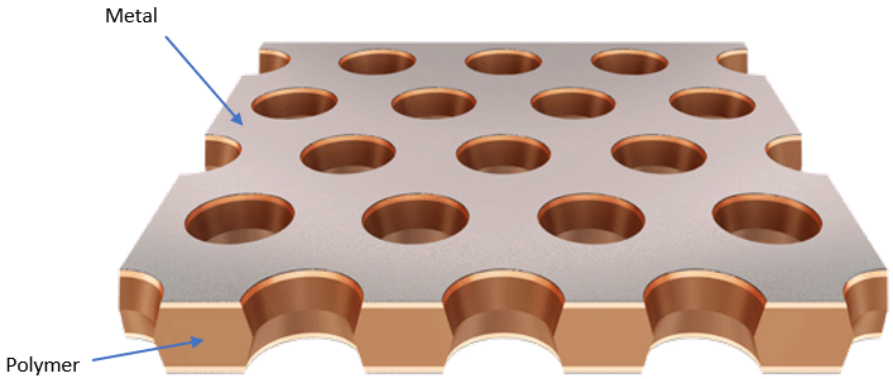




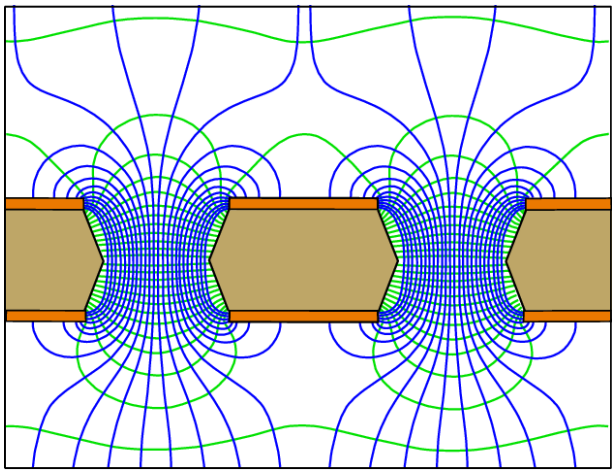
Sector border effect of triple-GEM tracking detector for COMPASS[1]

[1] Nucleon spin structure and hadron spectroscopy in Super Proton Synchrotron (SPS)

GEM



GEM model



Electric field lines in the holes

GEM operation

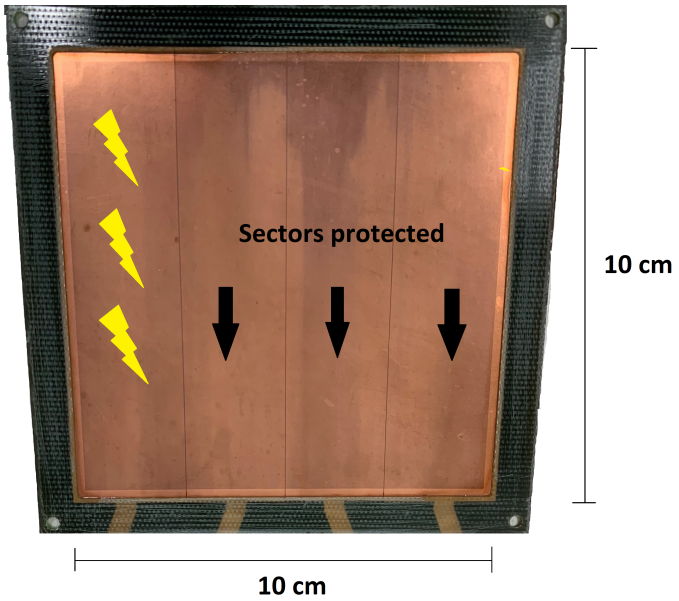
- The electrons released due to the ionization of a gas will drift in the direction of the GEM under an electric field
- Due to a large electric field in the holes, the electrons will start the avalanche process (G up to $10^2 - 10^3$/GEM)
- Use of molecular gases mixtures (enables inelastic collisions due to more degrees of freedom) with noble gases like Ar/CF_4
- Gain depends mainly on hole size and geometry and the gas mixture

GEM characteristics

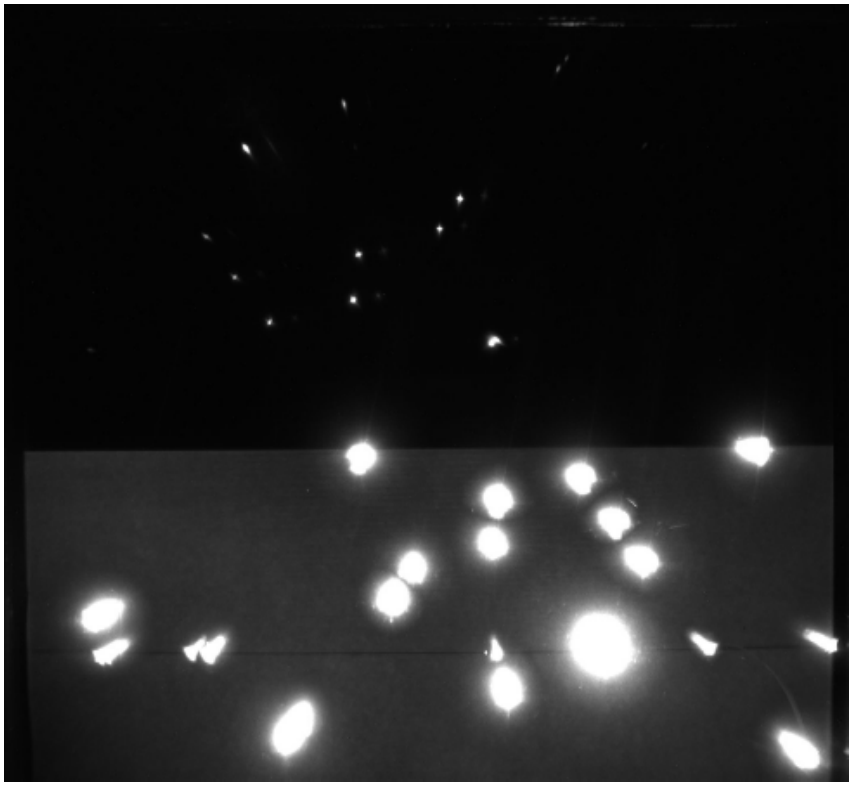
- High gain, reasonably cheap, high robustness, reliable, high time and space resolutions
- Used in:
  - High energy physics experiments for position detection of ionizing radiation such as charged particles, photons, X-rays and neutrons
  - Medical imaging
  - Radiation therapy dosimetry
  - Astronomy
  - Astrophysics
  - Material analysis

Purpose of sectorization

- Protects the sectors from the effect of a discharge on other sectors by reducing the energy of each discharge, but implies signal distortion
- Creates some resistance between sectors ($\sim$ MΩ)
- The capacitance effect is quite important on large area GEMs

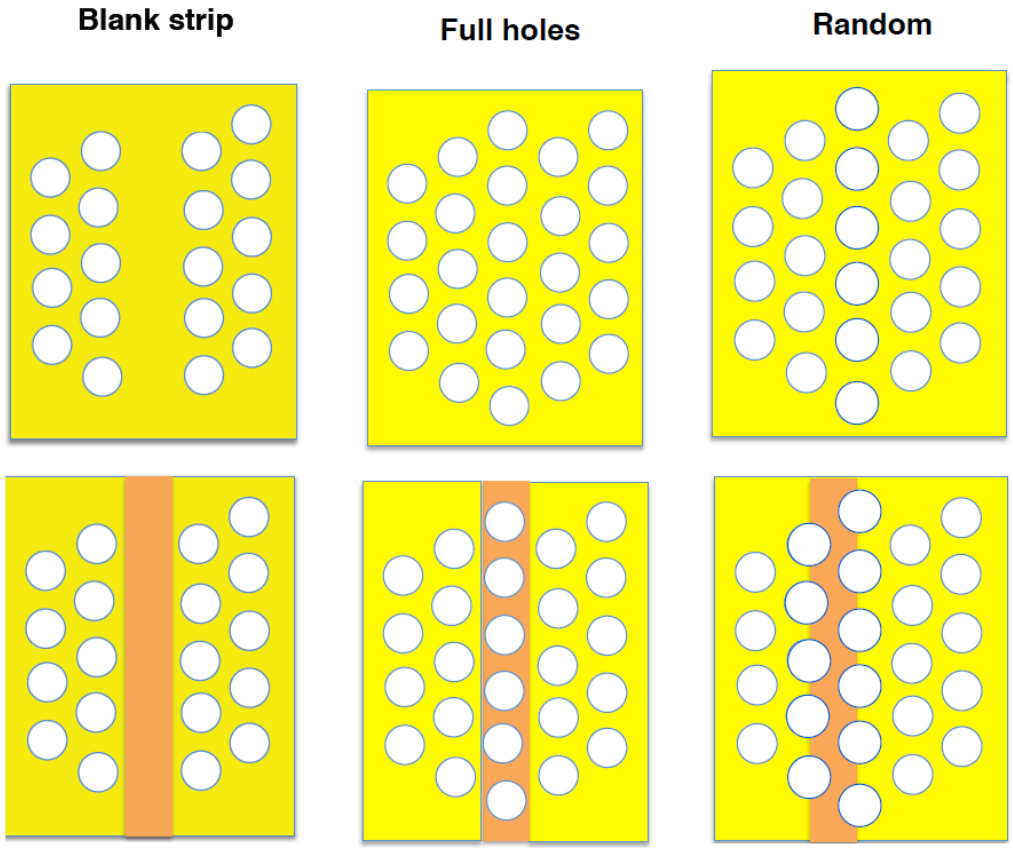


Discharge protection



Discharges in a sectorized GEM

Sectorization patterns

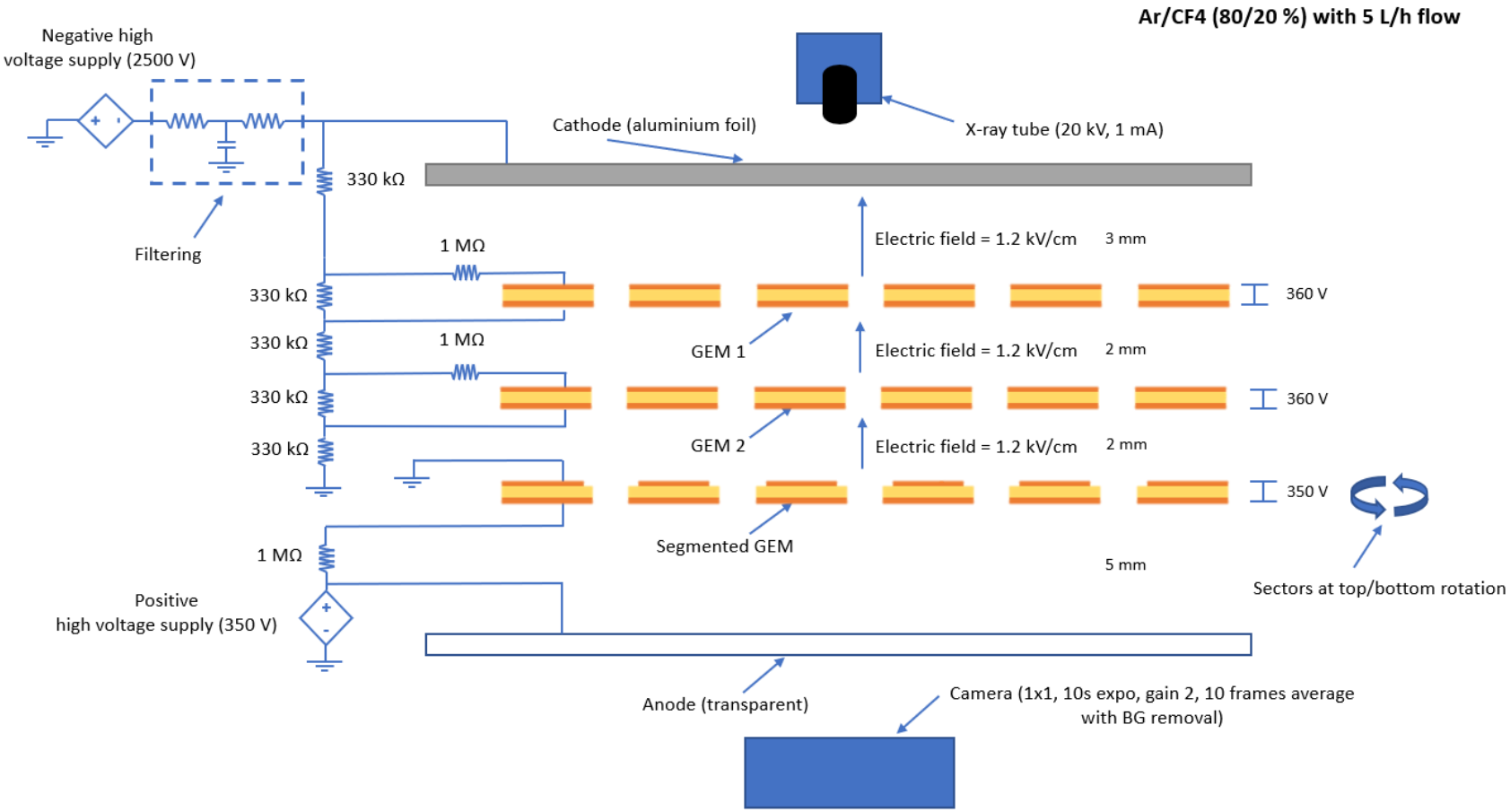


Adapted from Sauli, Fabio

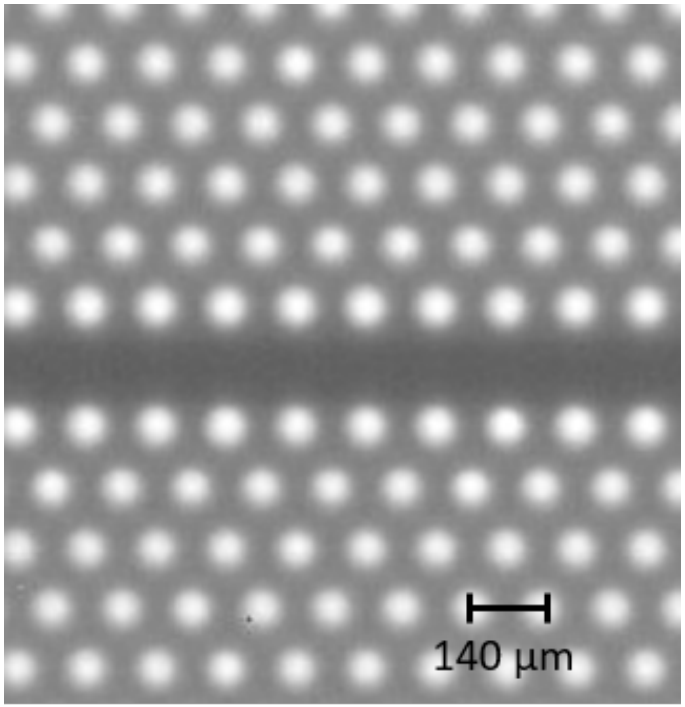
Sectorization implications

- Increases the signal distortion in the sectorized area
- For some imaging applications may be very limiting

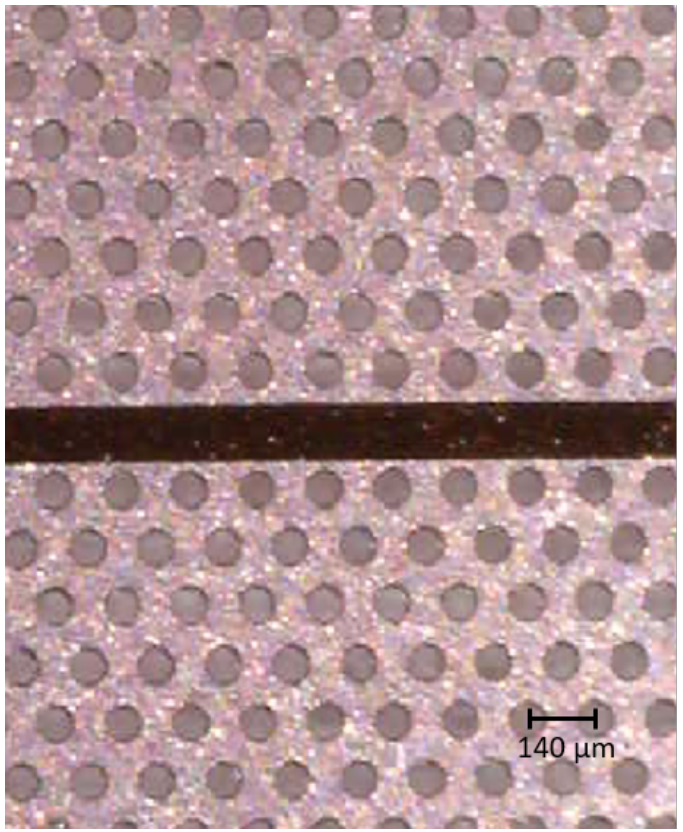
Blank strip triple-GEM stack



Blank strip GEM

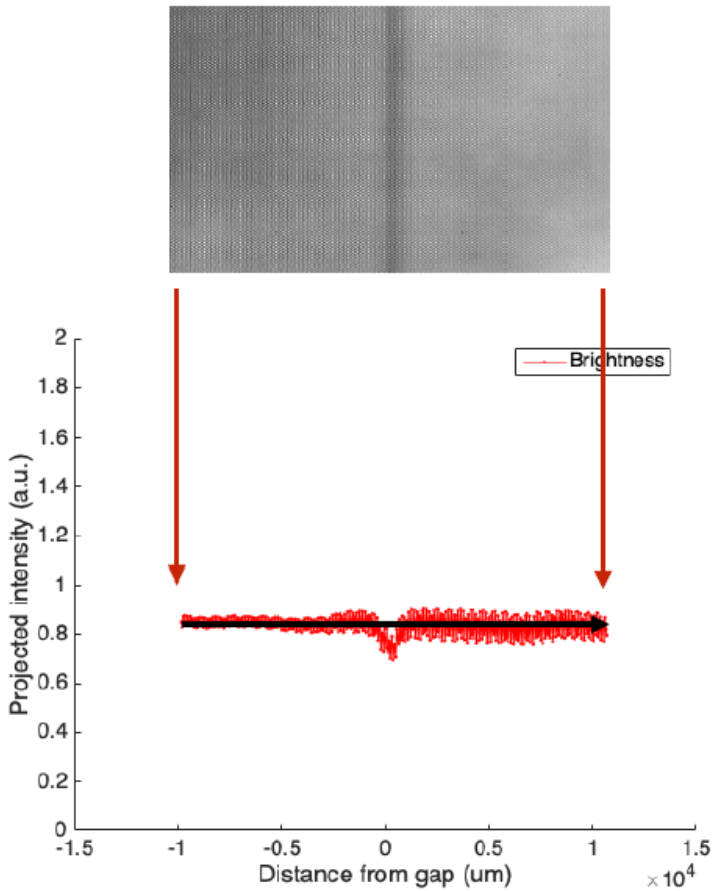


Optical picture

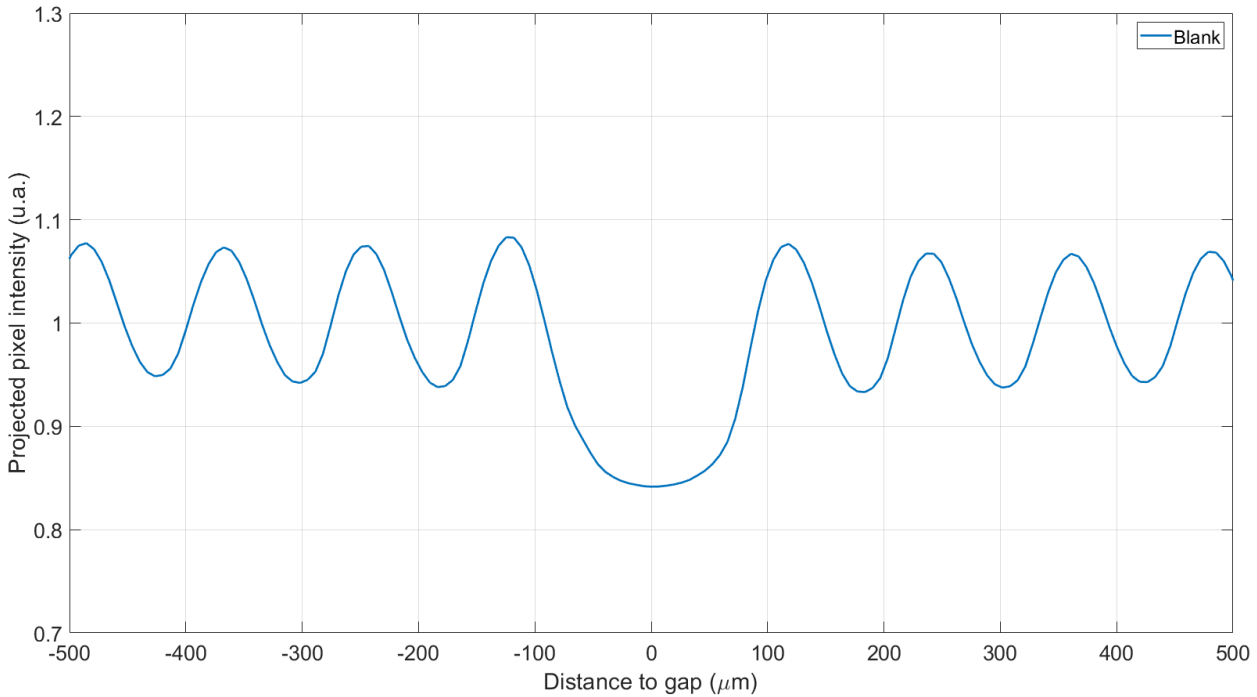


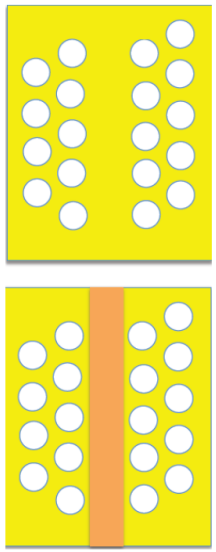
Microscopic picture

1D projection of pixel intensity

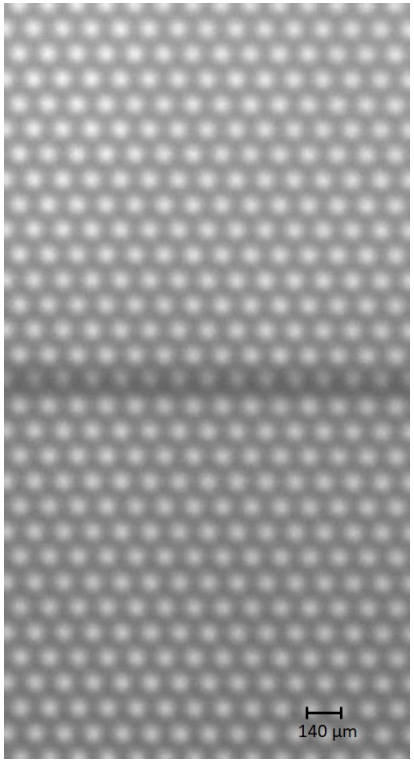


1D projection: blank strip GEM

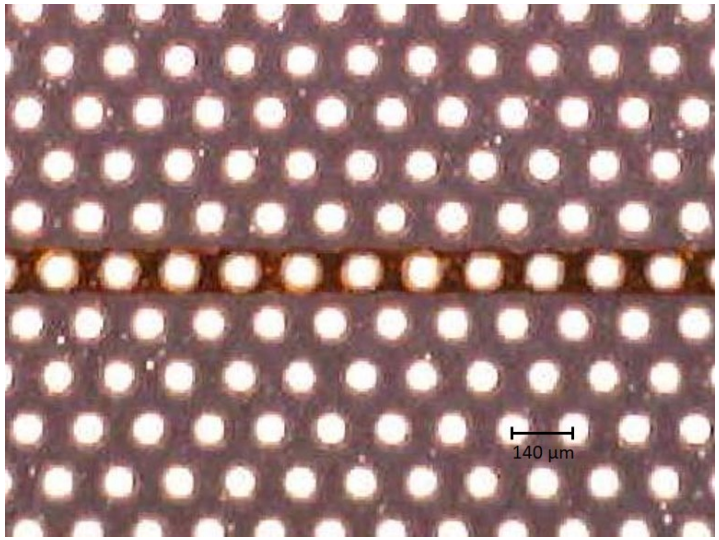




Full holes non-DLC GEM

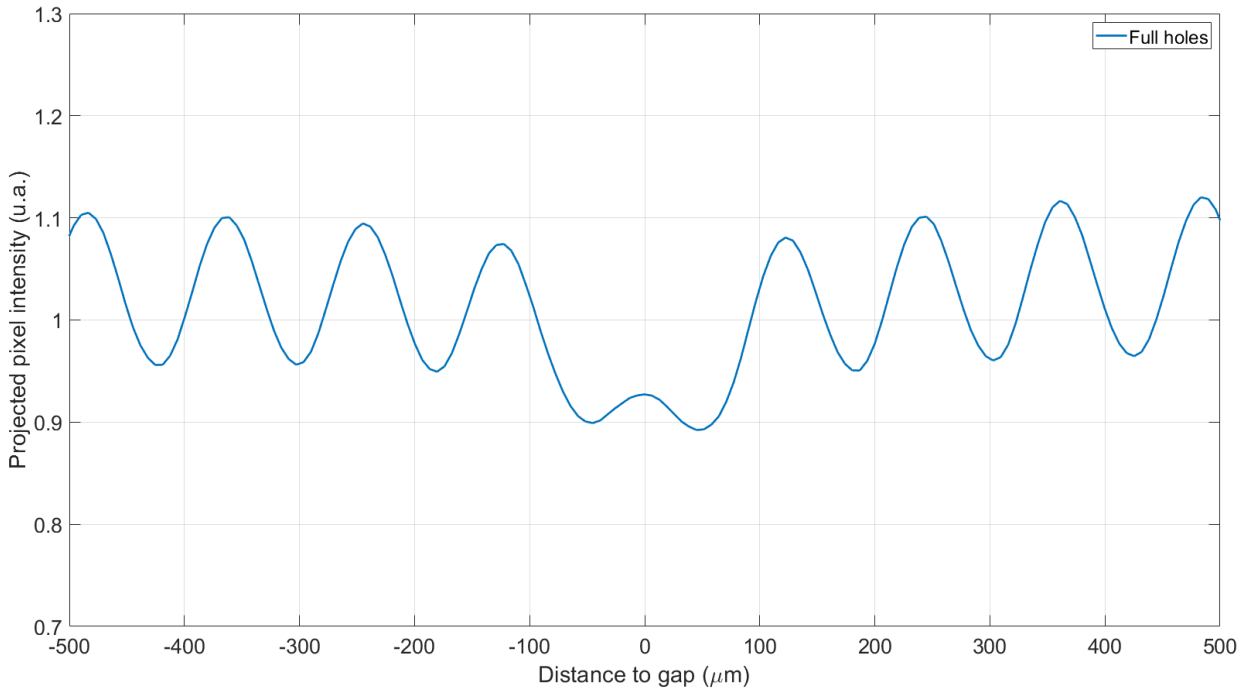


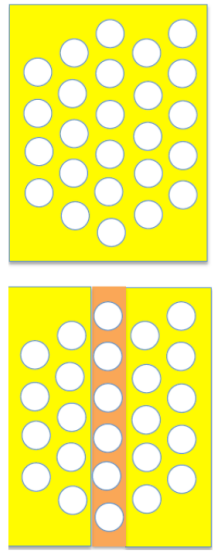
Optical image



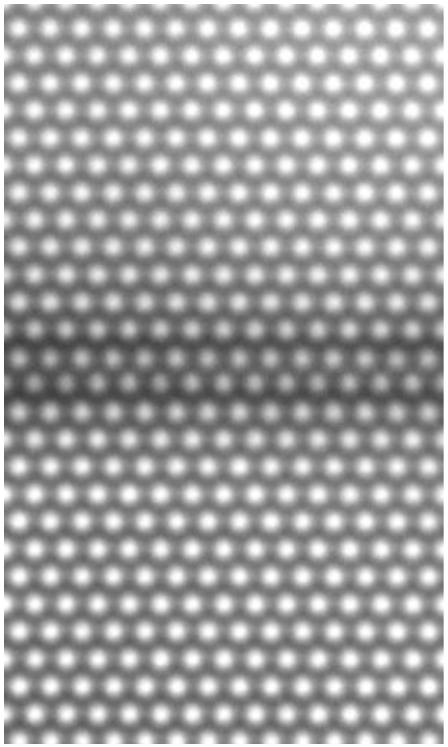
Microscopic picture

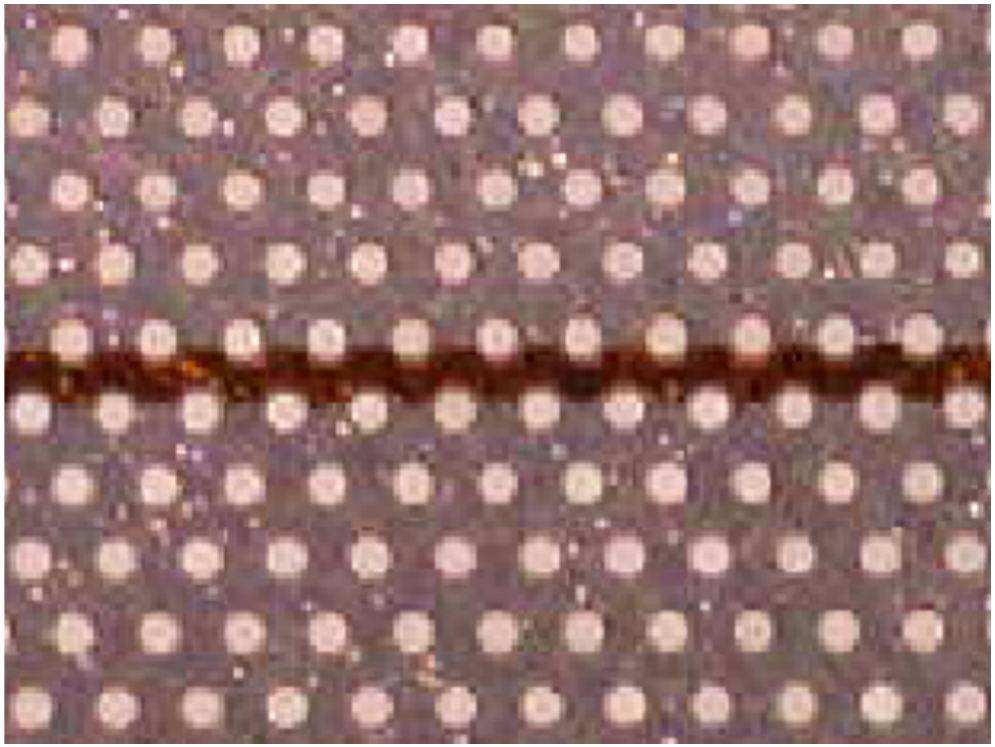
1D projection: full holes non-DLC GEM



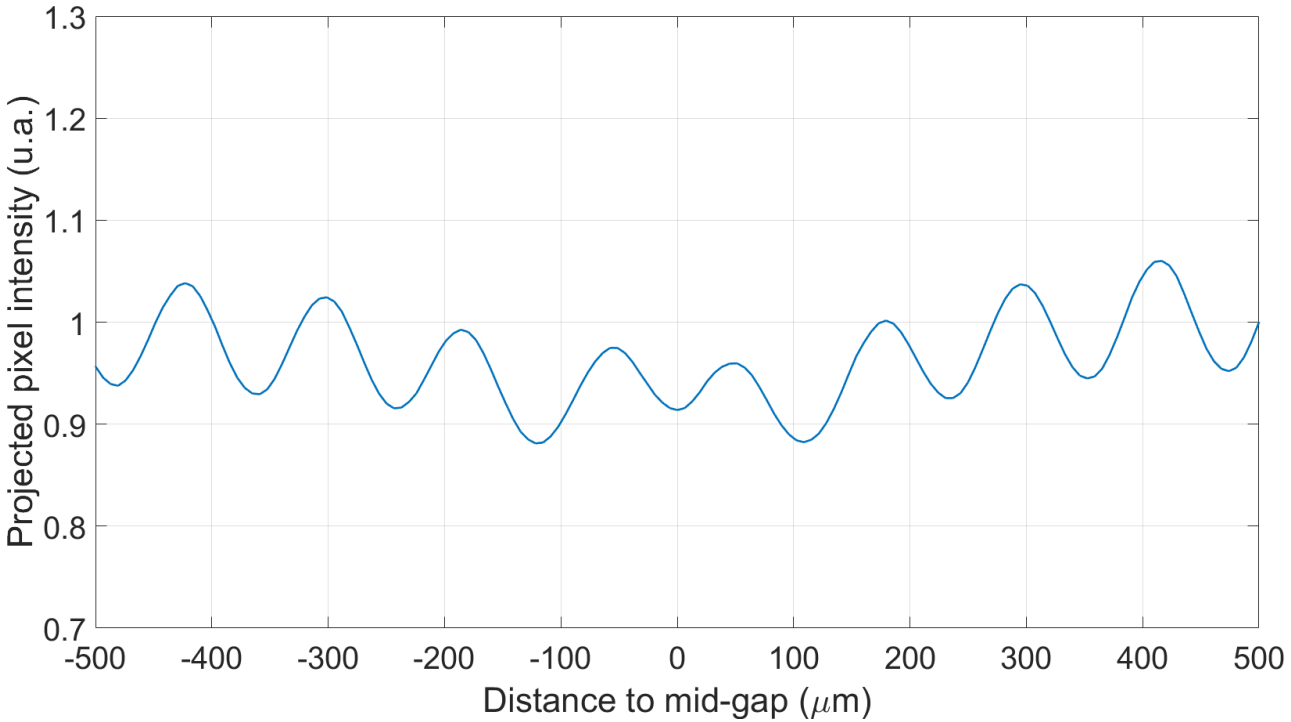


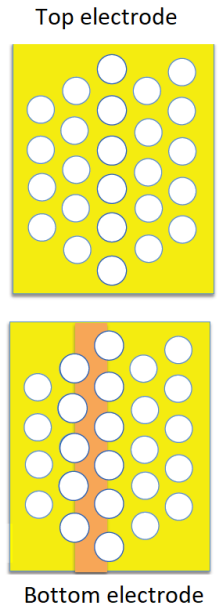
Random alignment non-DLC GEM





1D projection: random alignment



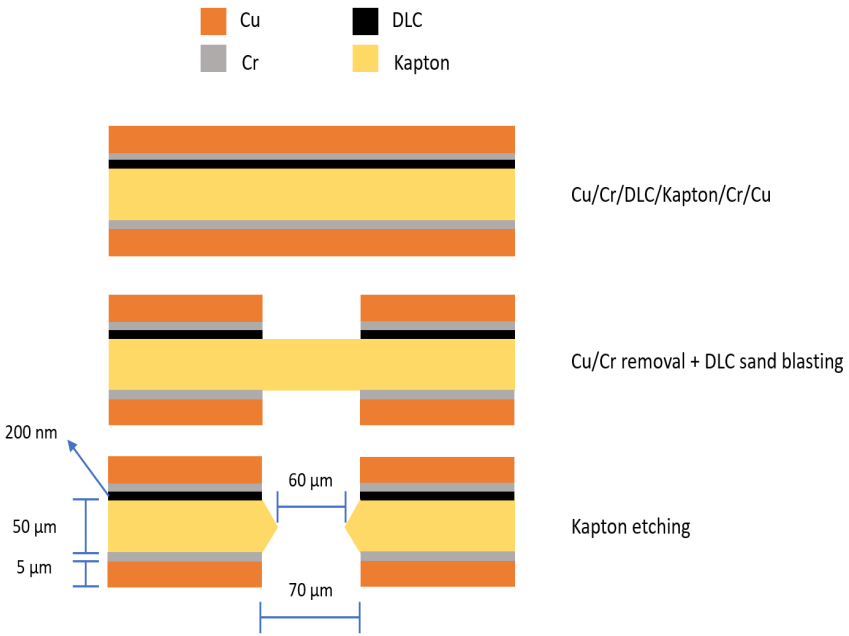


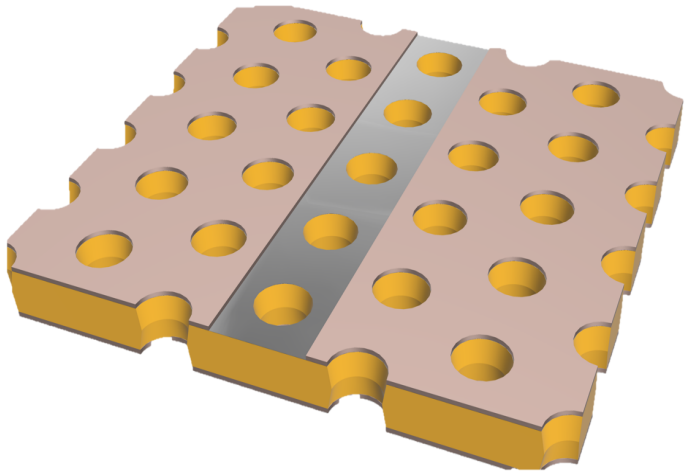
Purpose of the DLC

- Discharges can melt copper that may create leakage paths between the GEM shorting the sides
- In a triple-stack GEM setup, a discharge in one GEM can propagate to others GEMs

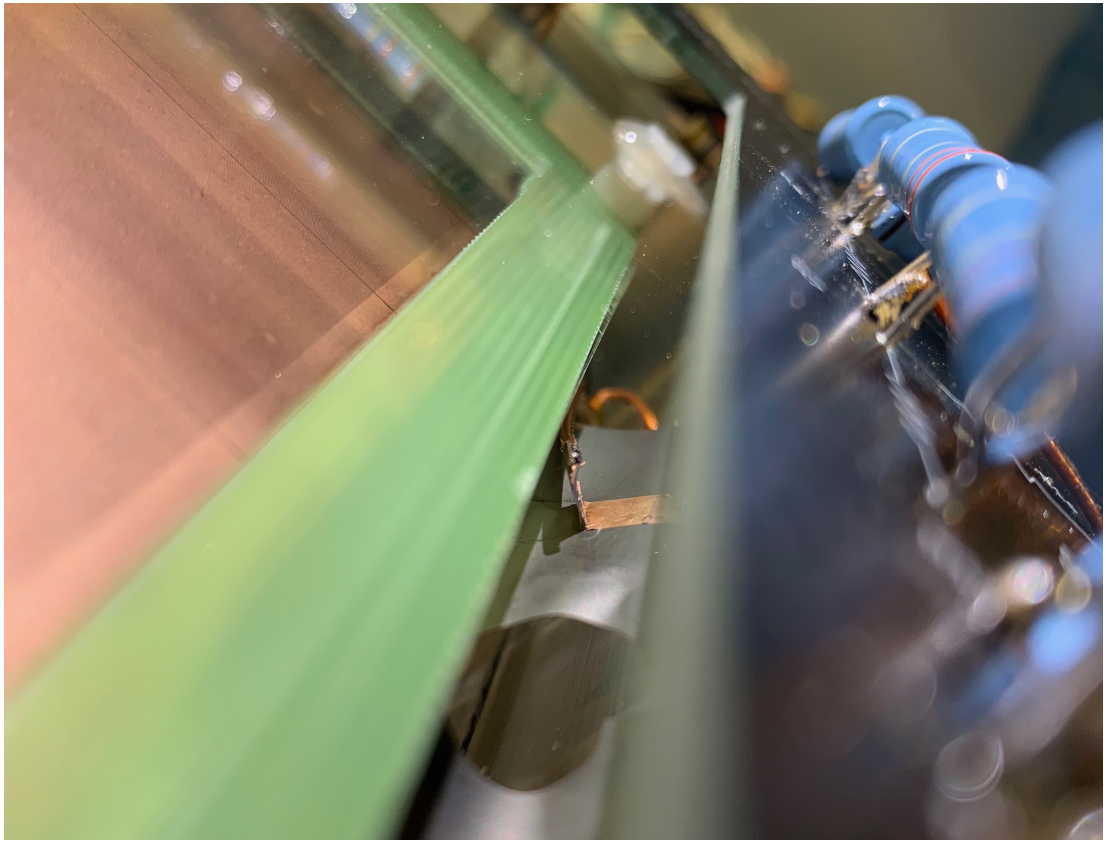
DLC (diamond-like carbon) acts as a resistive material that keeps the same potential through out the GEM. The desired effect is to direct the electrons through the holes to reduce the signal distortion.

DLC GEM


Cu
DLC
Cr
Kapton
Cu/Cr/DLC/Kapton/Cr/Cu
Cu/Cr removal + DLC sand blasting
Kapton etching
200 nm
50 µm
5 µm
60 µm
70 µm

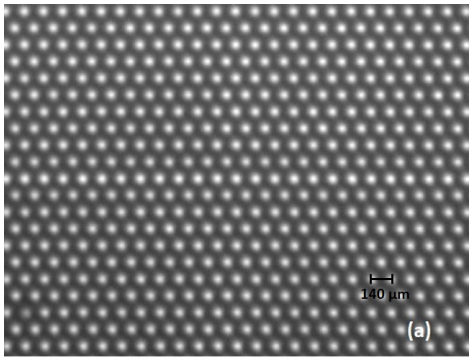


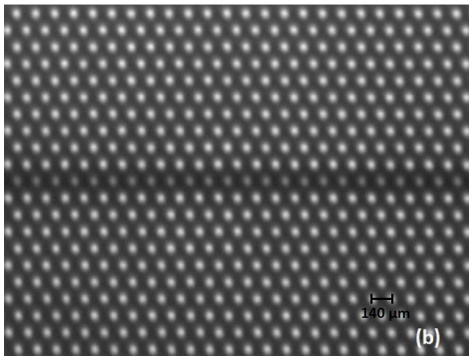
DLC problems



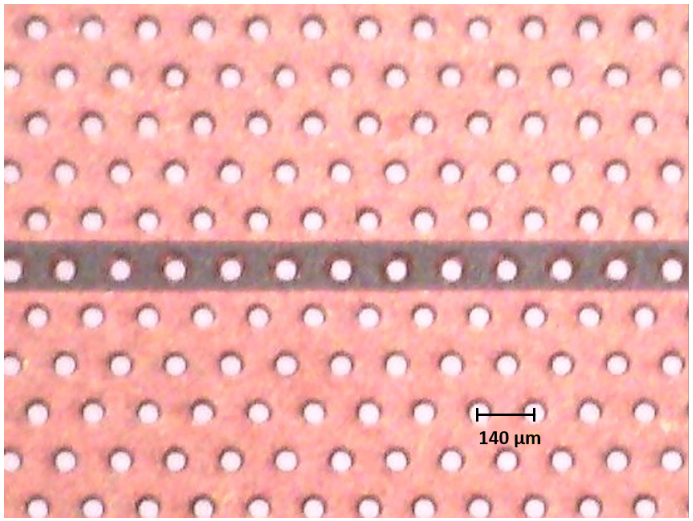
Cu trace ripping of from DLC

Full holes DLC GEM



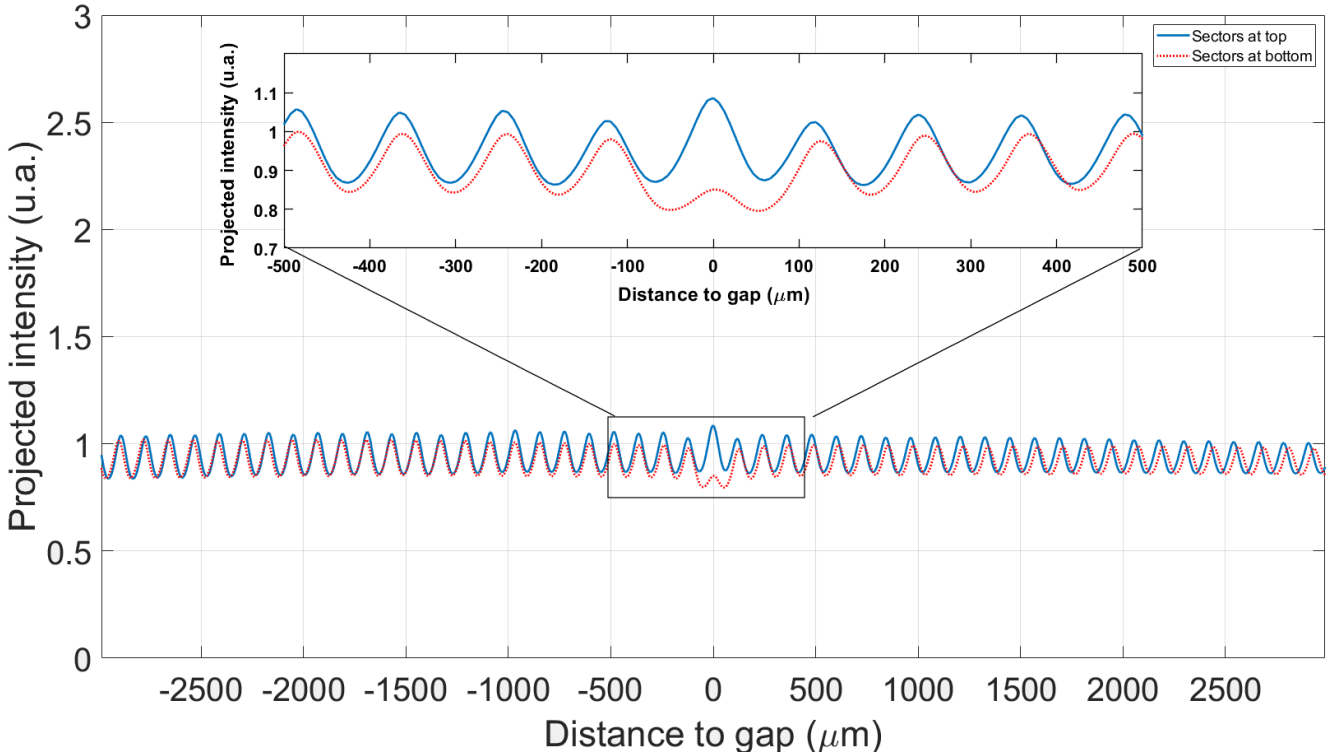


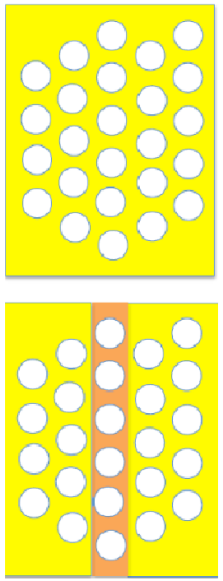
Sectors: (a) at top; (b) at bottom



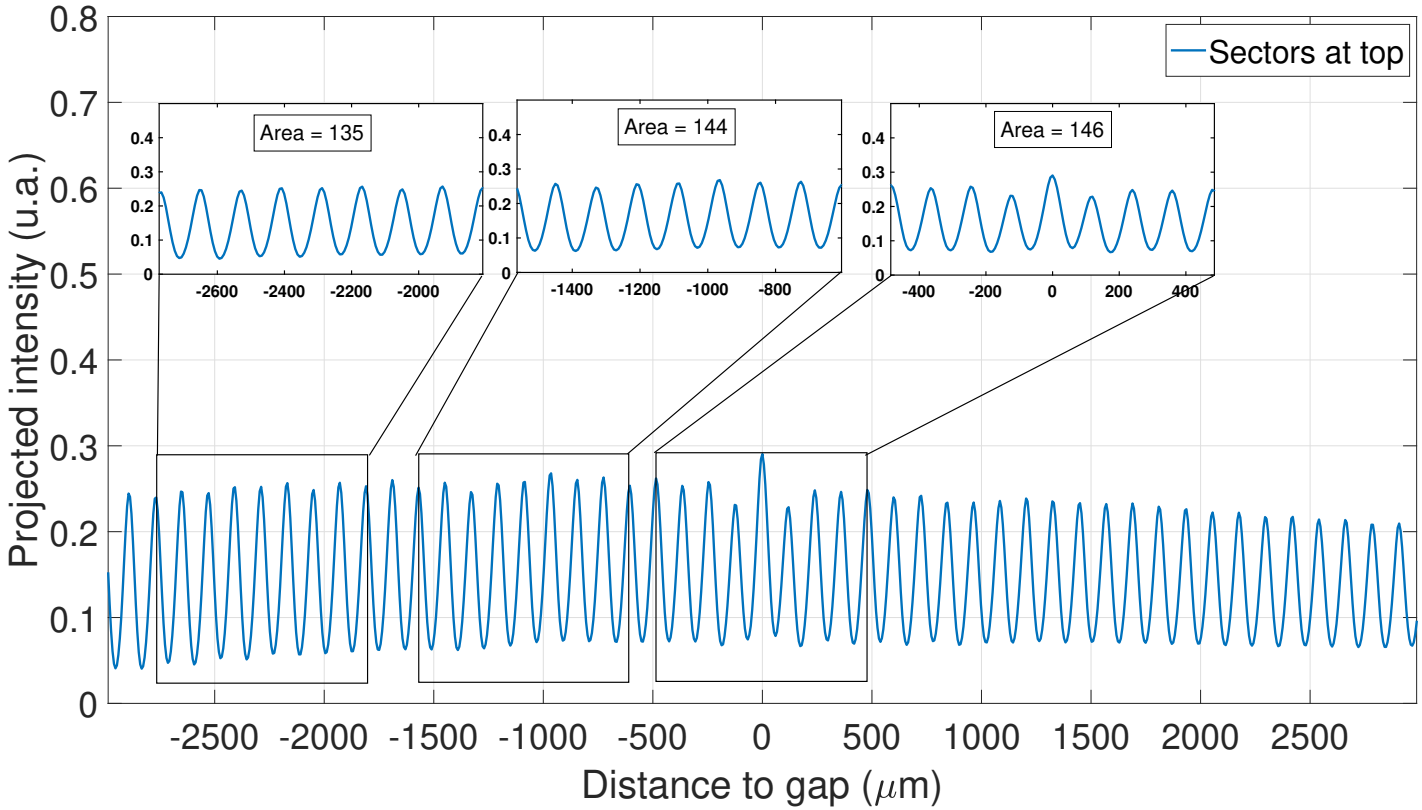
Microscopic picture

1D projection: full holes DLC GEM

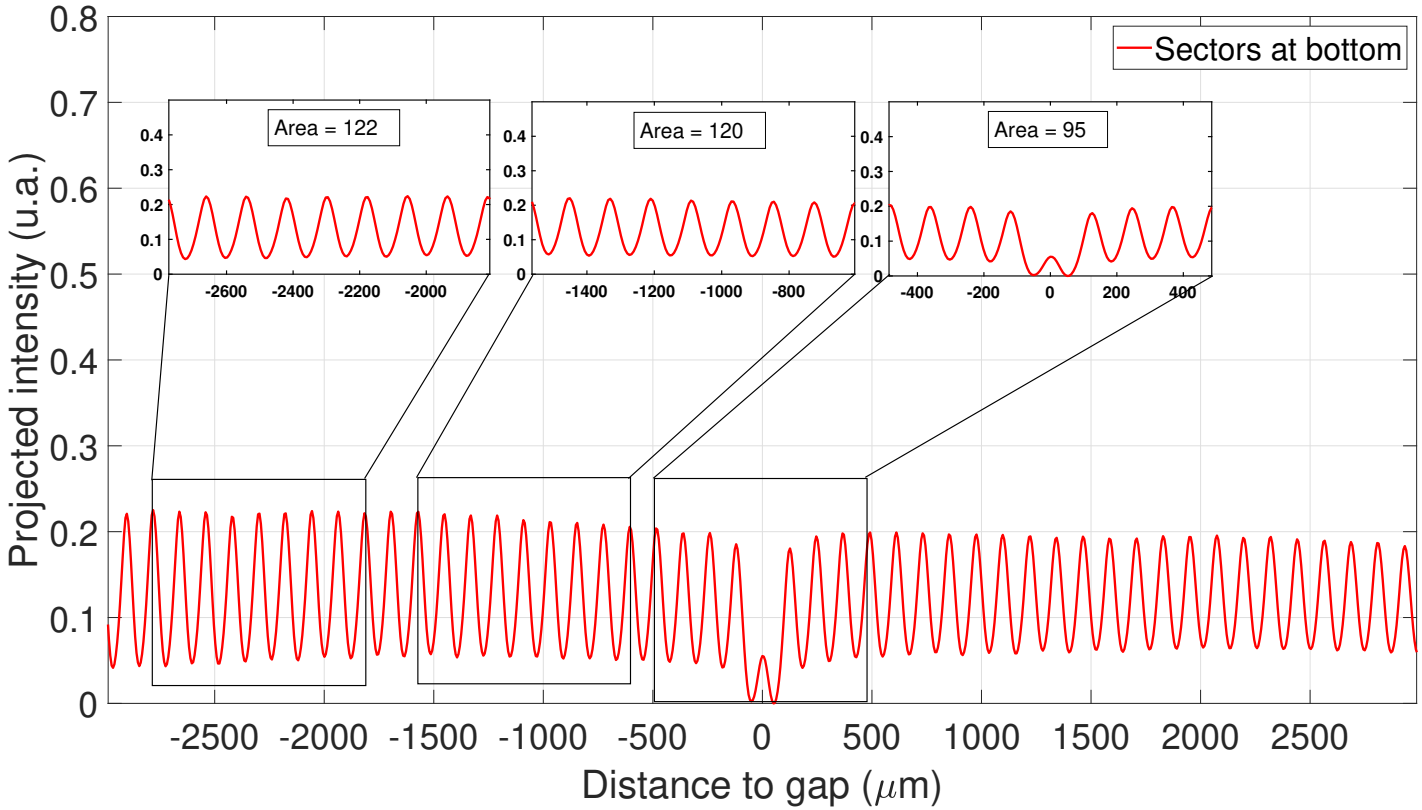




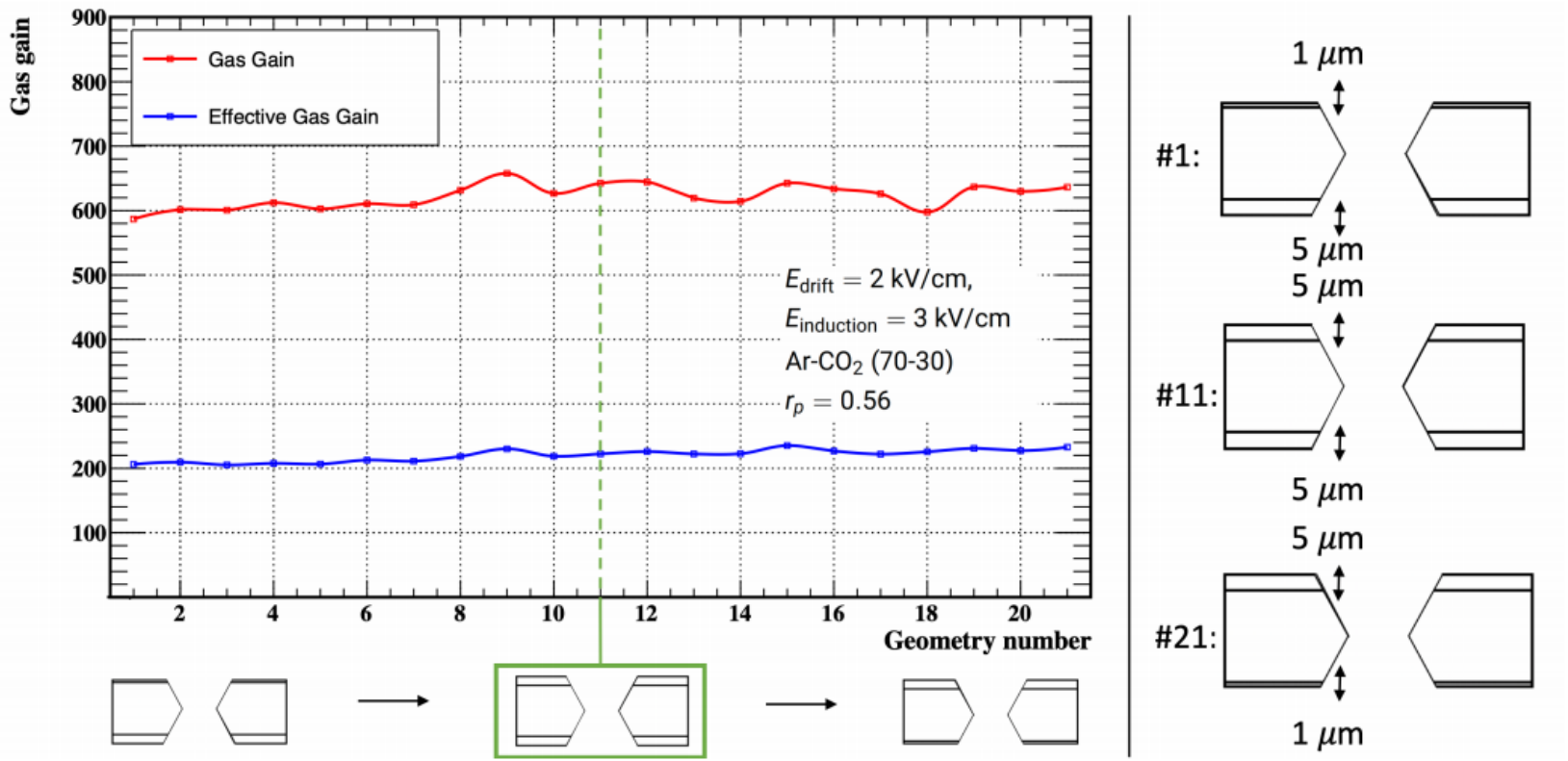
1D projection: full holes DLC GEM (top)



1D projection: full holes DLC GEM (bottom)



Influence of copper width in gas gain



Simulated by Djunes J.

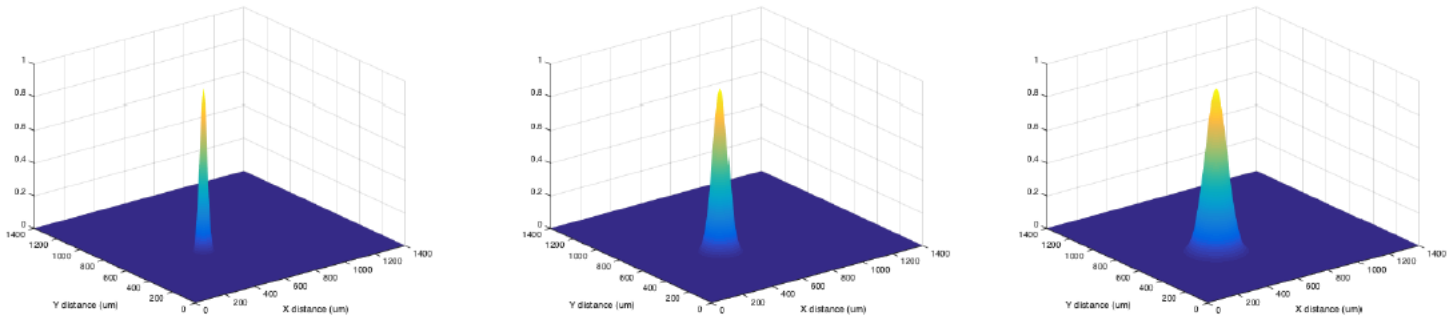
Conclusions

- No signal loss for sectors at top orientation (although the integration test is not conclusive)
- The DLC coated GEM seems to reduce signal distortion, specially for the sectors at top orientation
- Random alignment with DLC may achieve even better results

Single hole GEM

The first objective is to determine the width of the emission profile in each hole and see if there's any significant overlap of emission from adjacent holes:

20μm sigma **40μm sigma** **60μm sigma**

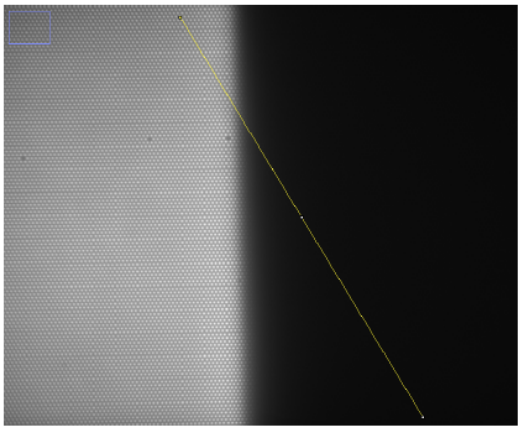


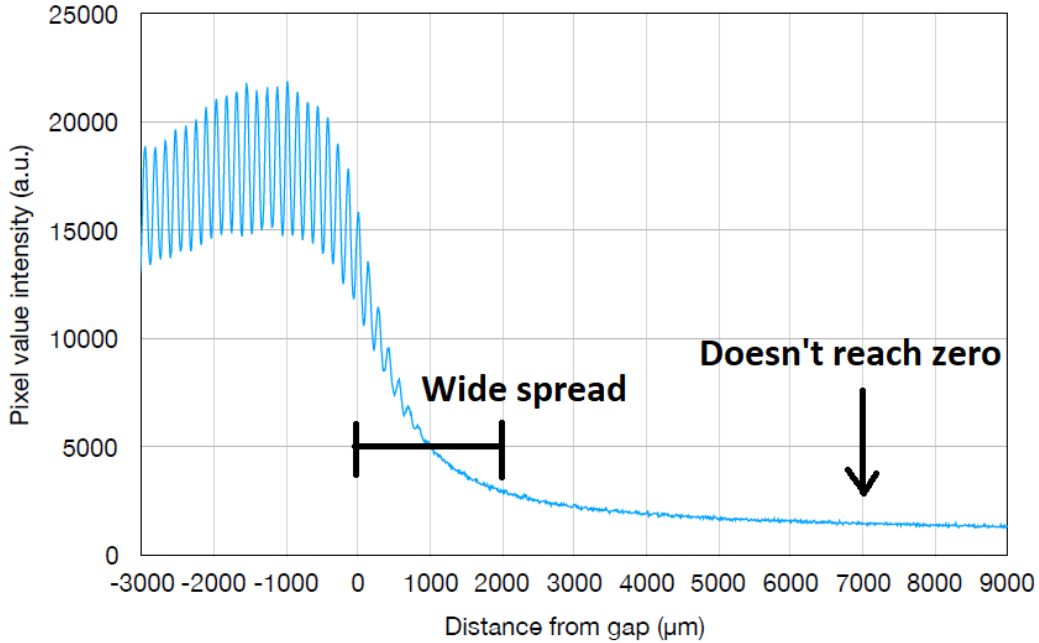
$$z(x,y) = A + B \cdot \exp\left(-\frac{(x-x_0)^2}{2{\sigma_x}^2} - \frac{(y-y_0)^2}{2{\sigma_y}^2}\right) \quad \Big\} \text{ Gaussian model}$$

Covered strips

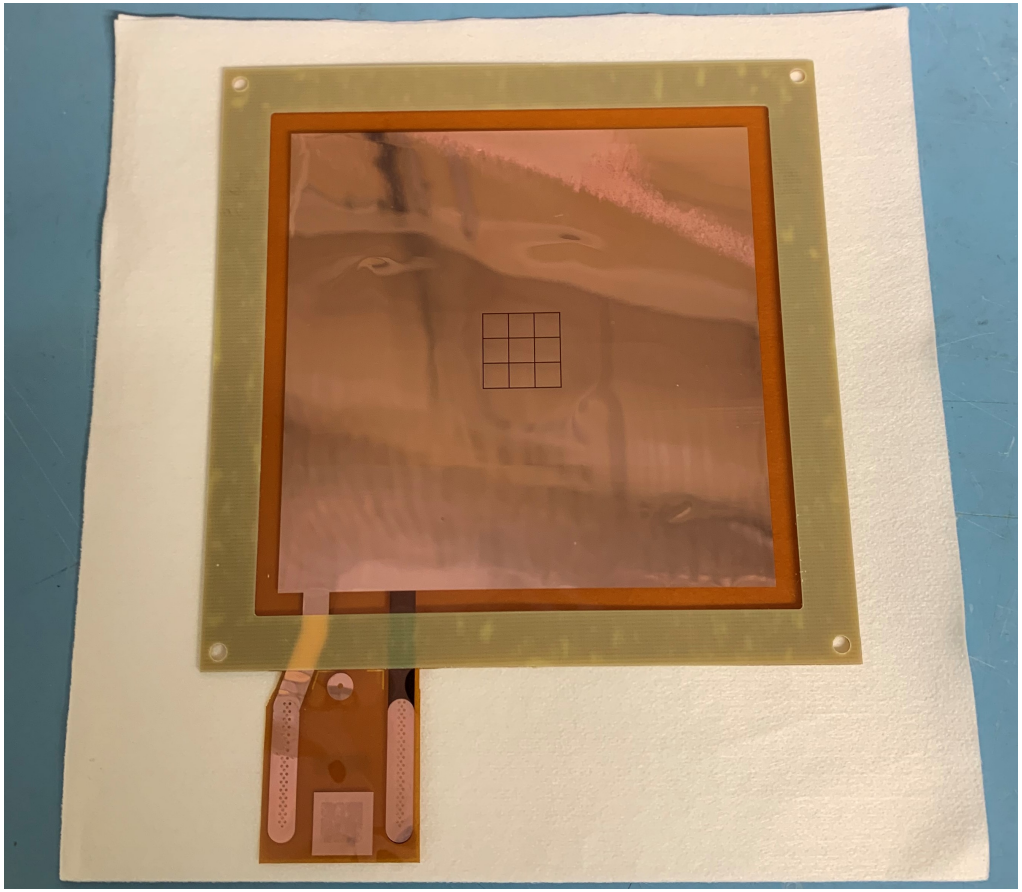
Then, related to the first objective, we want to figure why we have such a wide spread in light profile when we cover the GEM while doing the Line profile across border of Kapton covered region, with full holes and sectors at bottom. The GEM3 contribution is subtracted remaining the residual contribution of GEMs 1+2 and an anti-reflective window is used.

Covered strips

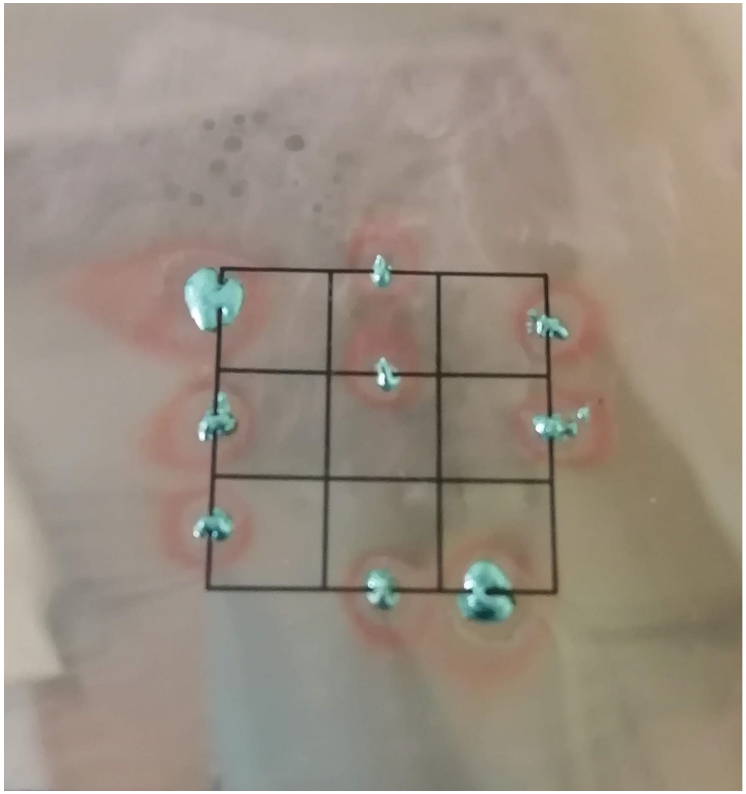


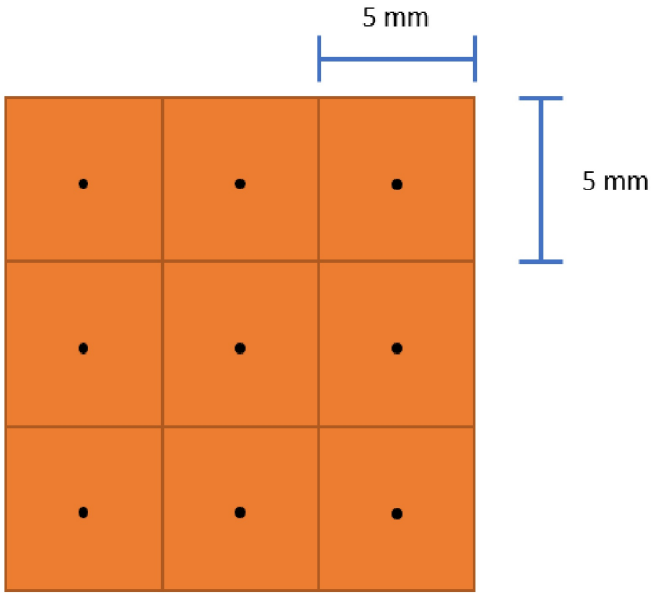


Single hole GEM photo

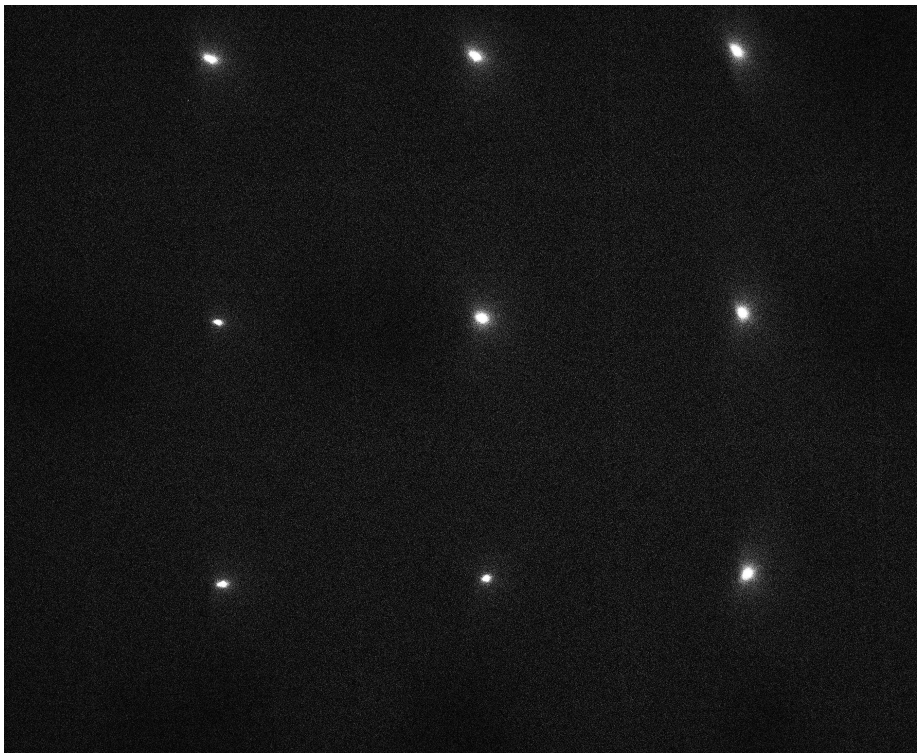


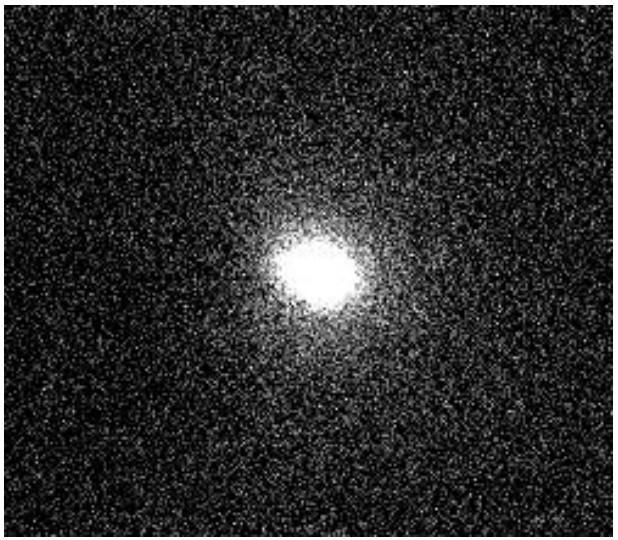
Microscopic picture





Optical profile



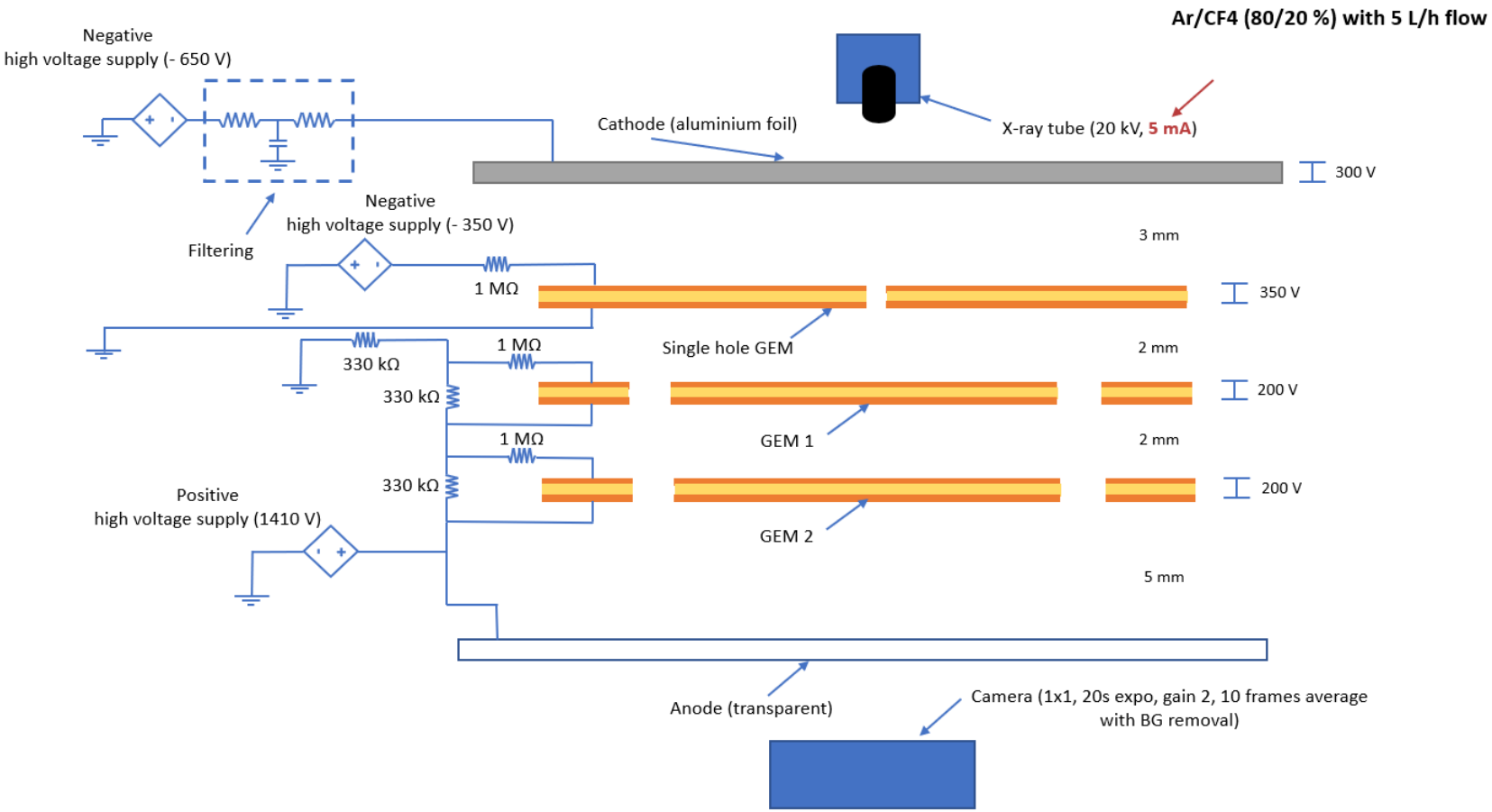


Single hole GEM studies

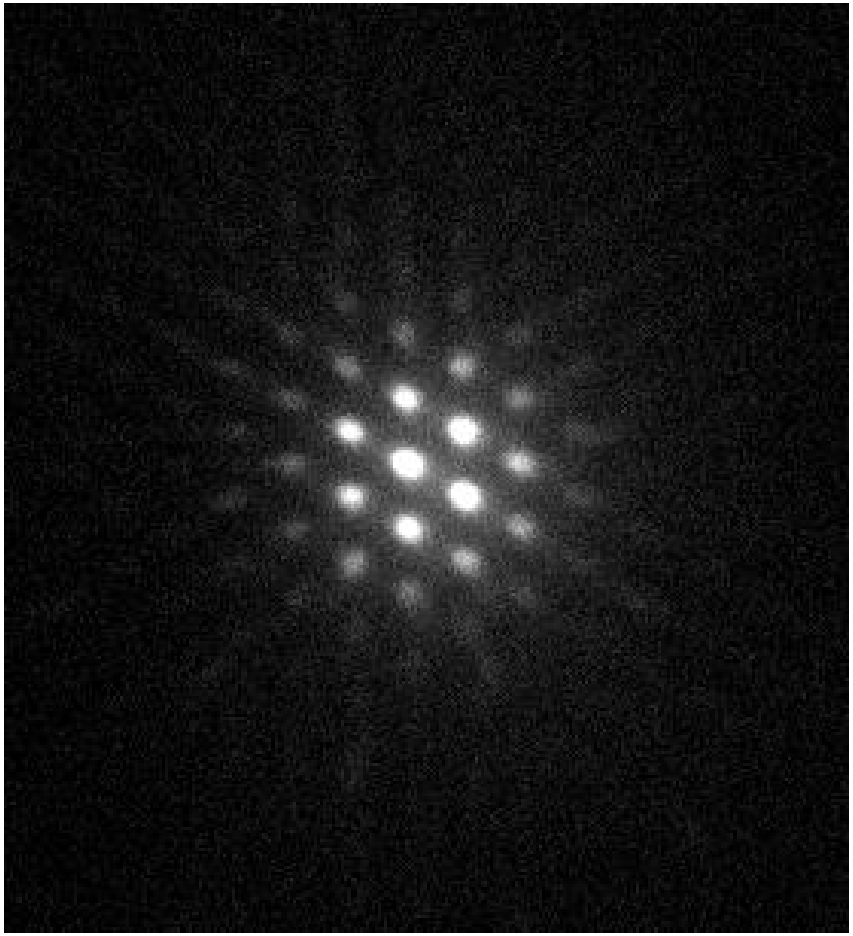
- Changing the electric field in the induction field from 0 to 3000 V/cm and the drift field from 500 to 2000 V/cm, there's no significant effect on the width

$$\sigma_x = 25 \pm 1 \ \mu\text{m}$$
$$\sigma_y = 27 \pm 1 \ \mu\text{m}$$

Single Hole GEM + 2 x Normal GEM



Single Hole GEM + 2 x Normal GEM



Calculating the width

We cannot simply try to fit a gaussian function to the images before because we have several holes:

Hence, what I did is a **radial projection**.

Radial projection

Imagine having this data points, where the blank value is the center value:

...	...	...	...	...	...	...	...	...	...	...
...	3	4	8	6	3	7	2	4	4	...
...	10	20	7	4	5	2	10	17	10	...
...	5	13	45	78	18	20	20	17	6	...
...	8	10	32	87	30	14	23	18	1	...
...	8	19	19	45	208	65	24	18	10	...
...	7	7	26	45	32	23	23	1	3	...
...	6	2	25	24	30	18	25	4	3	...
...	8	15	6	5	3	2	6	3	9	...
...	4	9	1	2	7	10	3	8	8	...
...	...	...	...	...	...	...	...	...	...	...

Radial projection

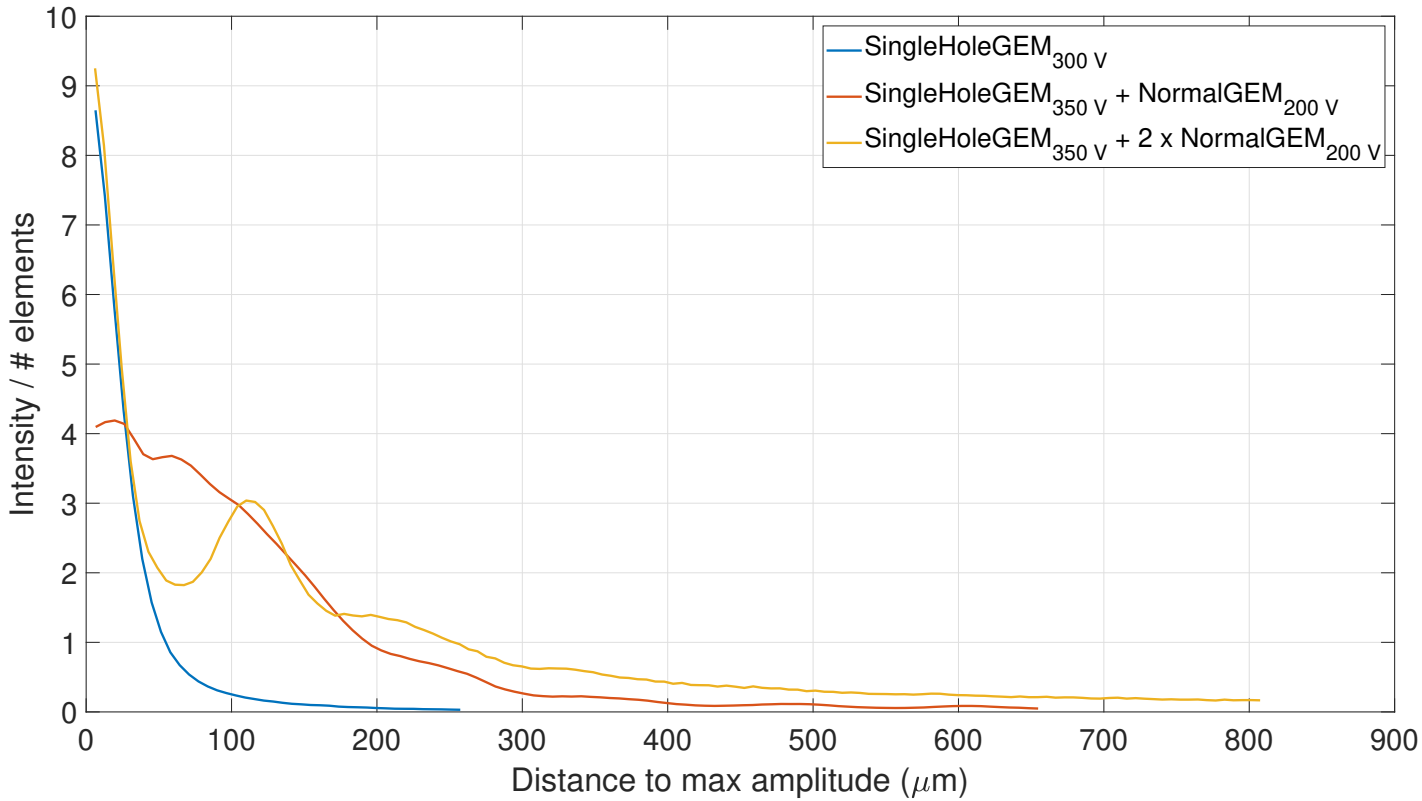
Now, for an integer "distance" d from the center value, we sum all the points at that "distance" and then divide by the number of elements at the same "distance" d:

elements around the center value at an integer "distance" d is $8 \cdot d$

...	...	...	...	...	...	...	...	...	...	...
...	3	4	8	6	3	7	2	4	4	...
...	10	20	7	4	5	2	10	17	10	...
...	5	13	45	78	18	20	20	17	6	...
...	8	10	32	87	30	14	23	18	1	...
...	8	19	19	45	208	65	24	18	10	...
...	7	7	26	45	32	23	23	1	3	...
...	6	2	25	24	30	18	25	4	3	...
...	8	15	6	5	3	2	6	3	9	...
...	4	9	1	2	7	10	3	8	8	...
...	...	...	...	...	...	...	...	...	...	...

Distance	# elements	Sum	Sum/# elements
1	8	341	43
2	16	450	28
3	24	214	9
4	32	187	6
...	...	...	...

Single Hole GEM + (1,2) x Normal GEM

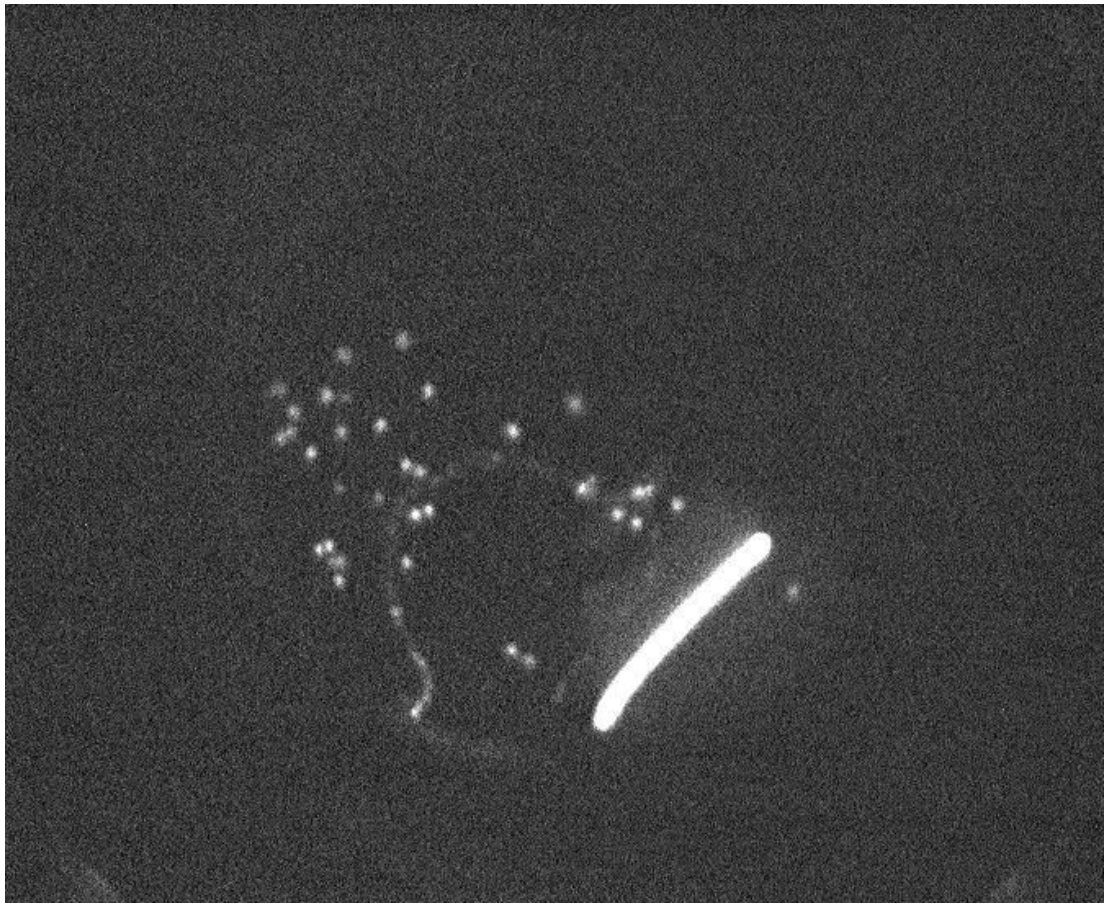


Other work

- High speed camera test (7.4 fps for 1280 x 800 and 7Gpx/second of transmission) with α-particles and X-rays to determine if it had enough sensitivity for X-ray fluorescence tests

Phantom VEO 710

One of the images



α-particles, x-rays and an electron from a cosmic event

Developed skills in my internship

- Physics, electronics and computational
- English
- Social ("desembaraço")
- Endurance (specially while trying to focus the camera)

What CERN offered me

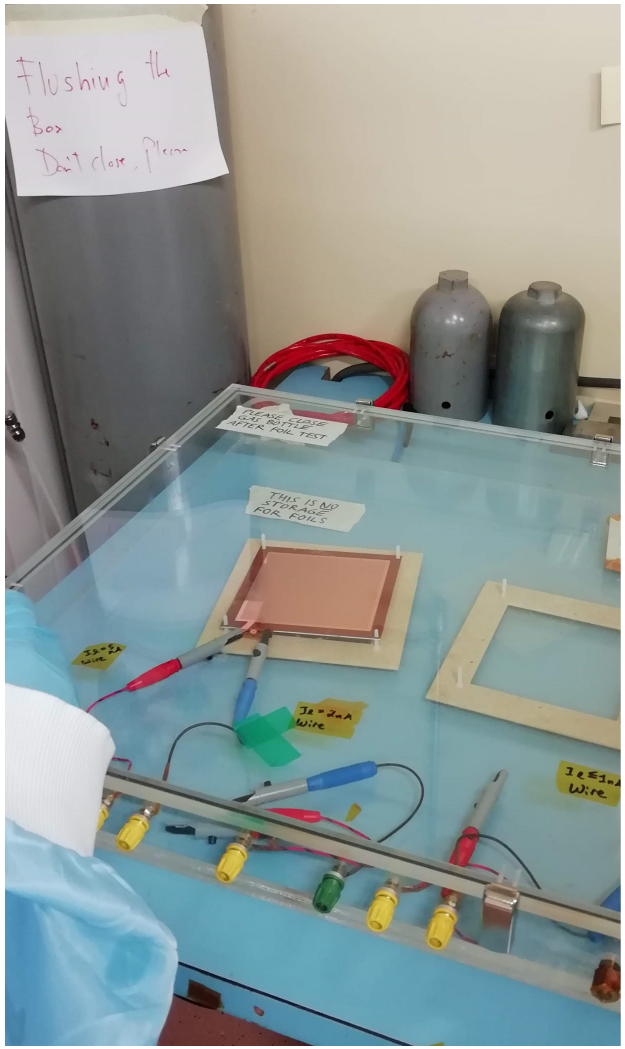
- 90 CHF daily allowance
- Travel expenses (250 CHF)
- Health insurance
- A paper is coming...

What I will not forget

- 10h30, 13h30 and 16h00 are coffee-break times
- "Só quem não trabalha é que não parte coisas"
- 12h00 $\pm$ 00h15 is the perfect time to have lunch
- "Next wednesday" does not mean the immediate wednesday, but next week's wednesday
- Portuguese food is the best in the world
- There are no "Dr.s" at CERN: I had lunch side by side with the General Director Fabiola Gianotti, with John Ellis

Photos

Photos

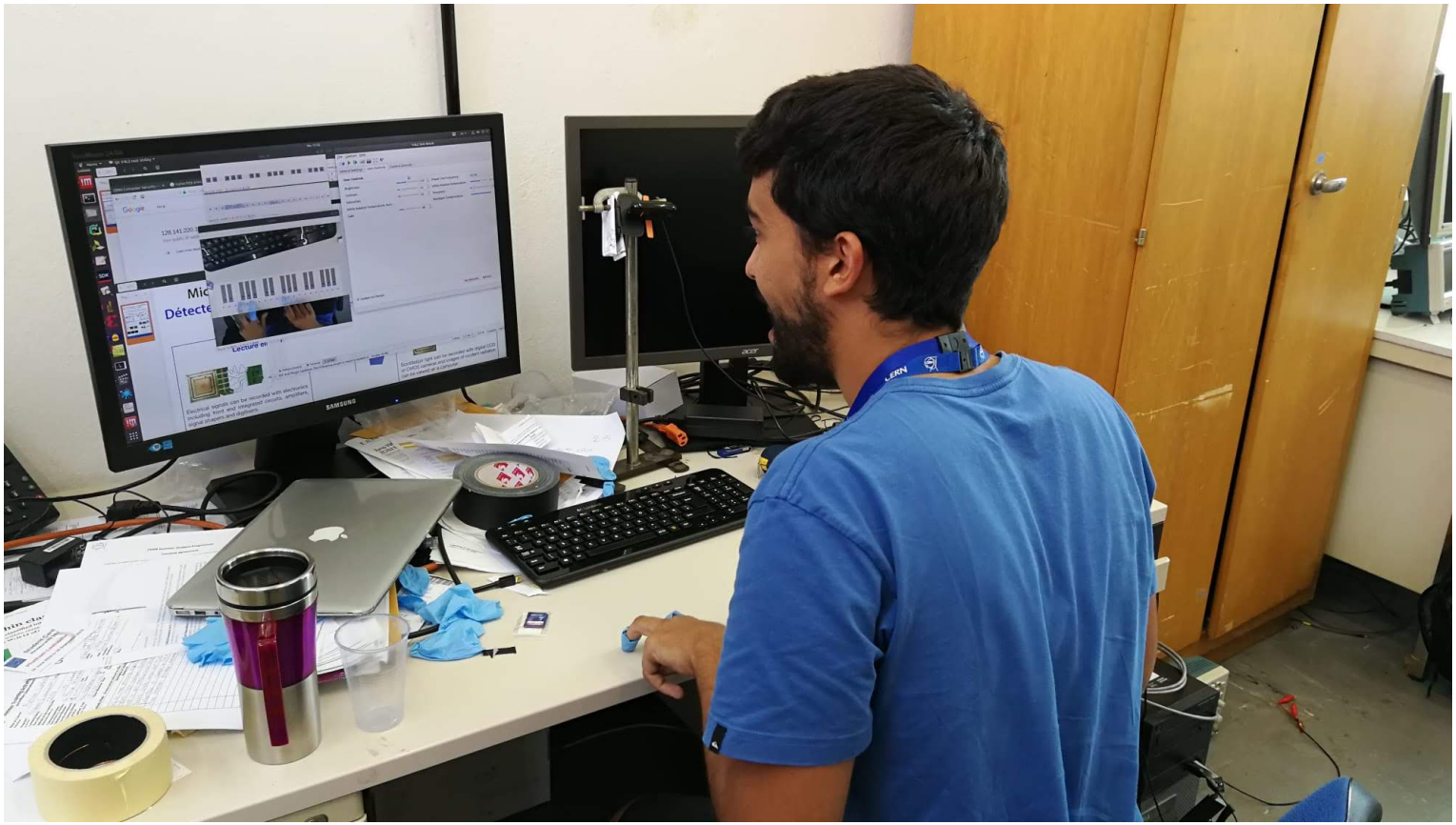

Flushing th
Box
Don't close, Plea
PLEASE CLOSE THIS BOX AFTER FOIL TEST
THIS IS NO STORAGE FOR FOILS

Photos

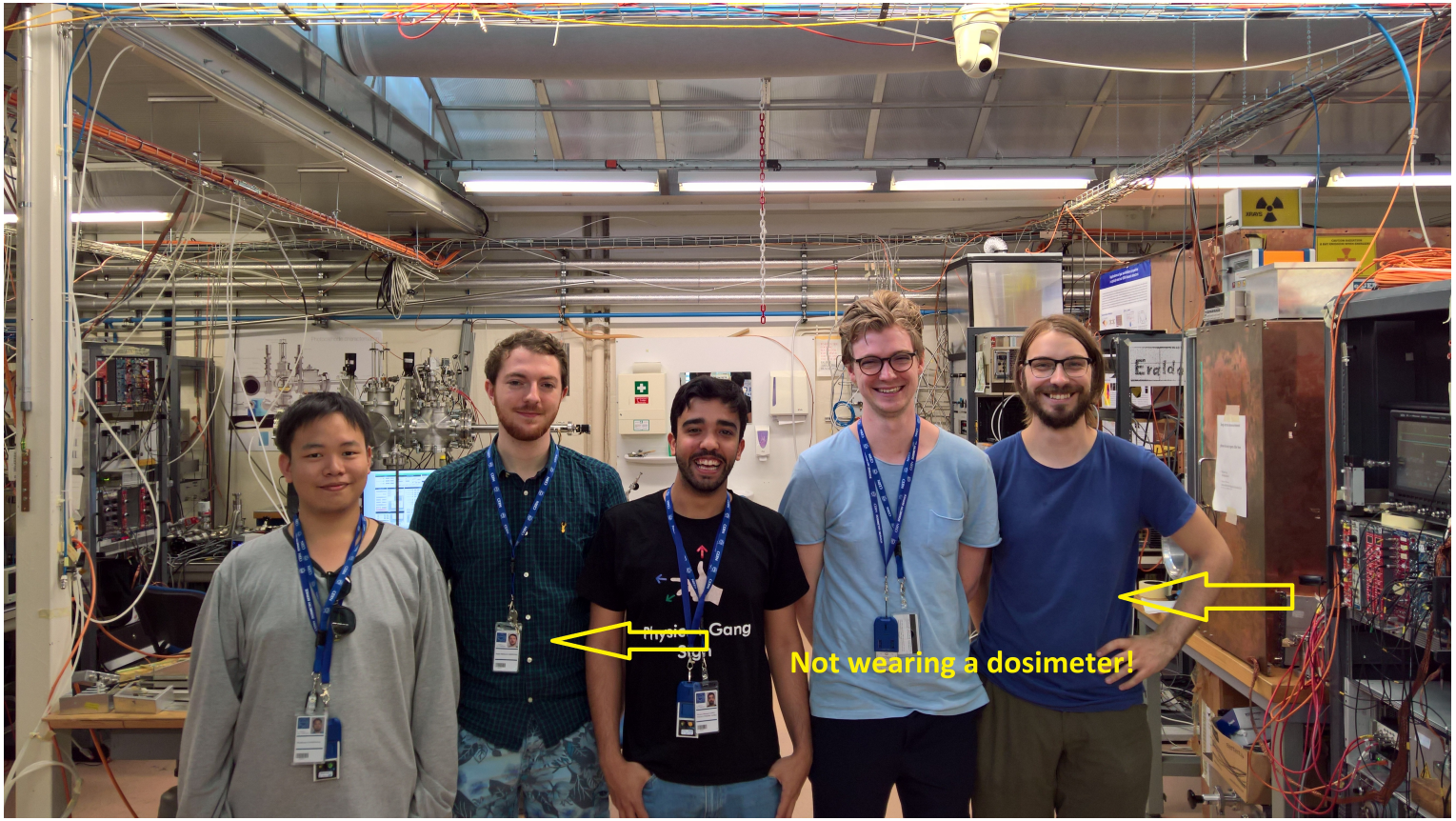
Photos

"Físicos serão físicos"

Photos



Photos



Photos

Thank you

http://cds.cern.ch/record/2690697/files/Summer_Student_Project_Report.pdf?version=1&fbclid=IwAR0kc5cD7h91i4n7SFRG9Q4a0Ea2M3NEyI71QQLwbruGqZraZveySDC8bj0