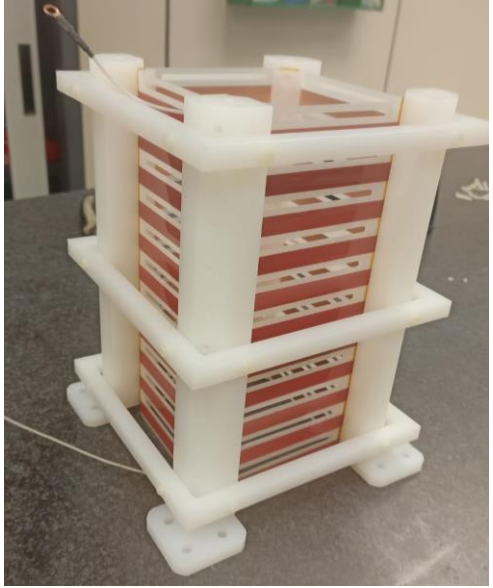
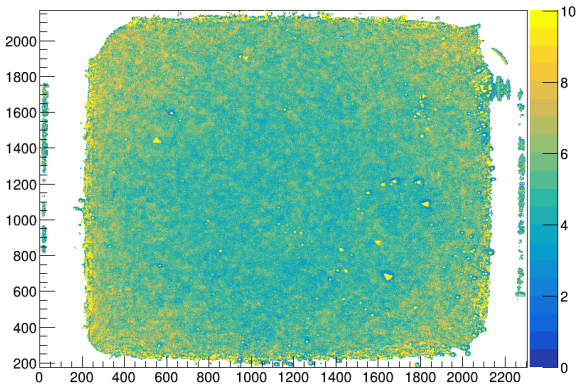


Update of GIN and GEM

Giorgio Dho

Istituto Nazionale di Fisica Nucleare (INFN-LNF), Frascati (RM), Italy



CYGNO Collaboration meeting

Summary

- Field Cage Studies
- Mozzarelle Studies on Field Cage Materials
- Radioactive Source Transparency
- Oxided GEM
- CYGNO-04 GEMs
- Extras

Summary

- Field Cage Studies
- Mozzarelle Studies on Field Cage Materials
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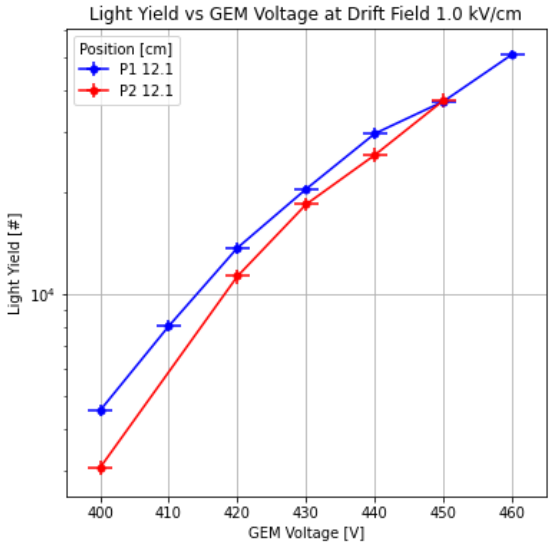
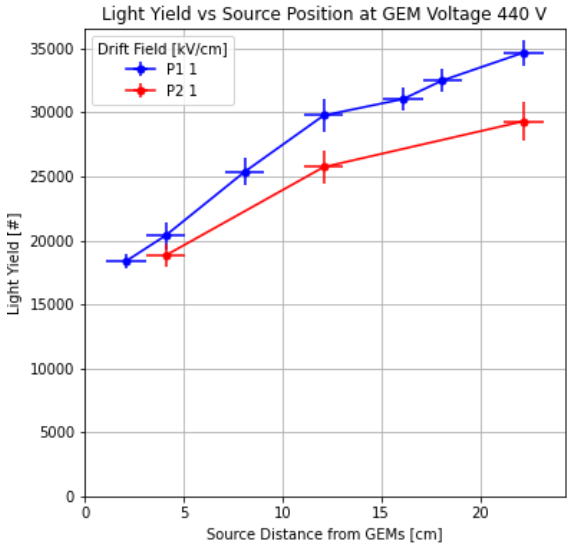
- Extras

Previously

- Among the field cages (FC) tried the ethereal looked the best and with the least material

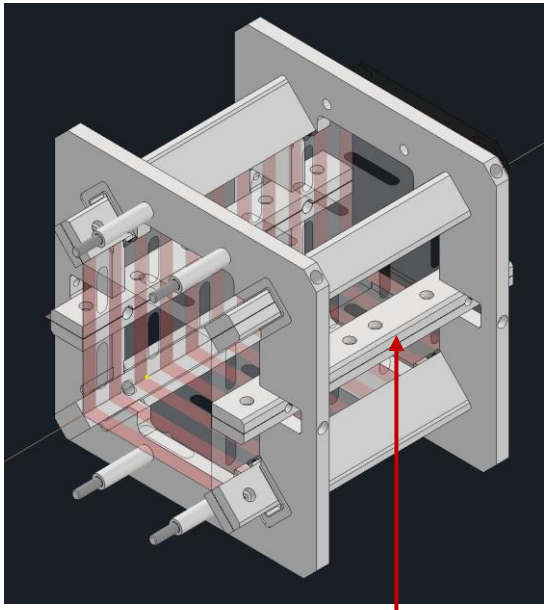
- Delrin pillars, copper and PET sheet field cage (P1 Cu cathode, P2 Al Mylar cathode)

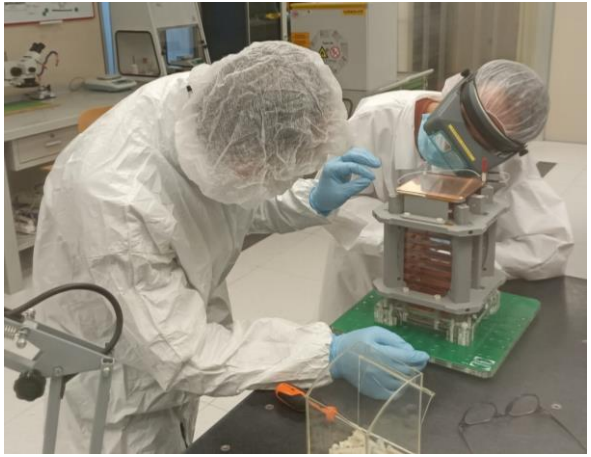


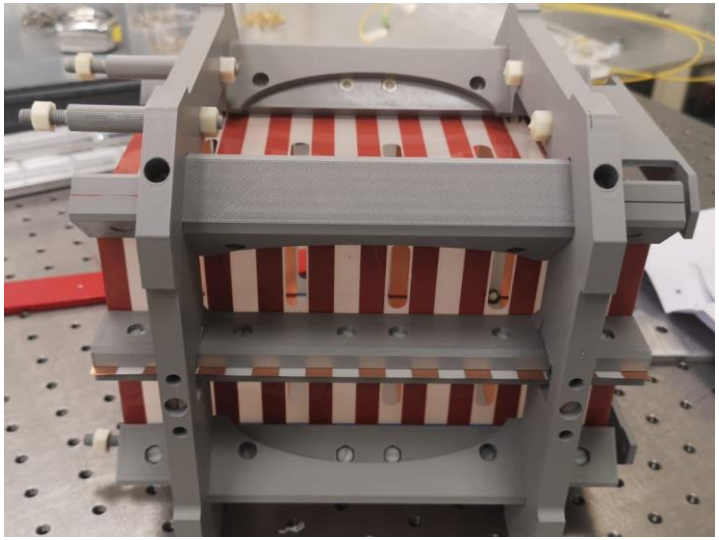


Field Cage V2_0

- Next version designed by Sandro with a structure dimension already capable of lift the CYGNO-04 field cage weight
- FC sheet clipped at the corners and SMD resistors soldered in the middle clip







Made of ABS plastic 3D printed

Turned out to be mildly conductive above 1 kV

Kapton tape to isolate FC sheet was not enough

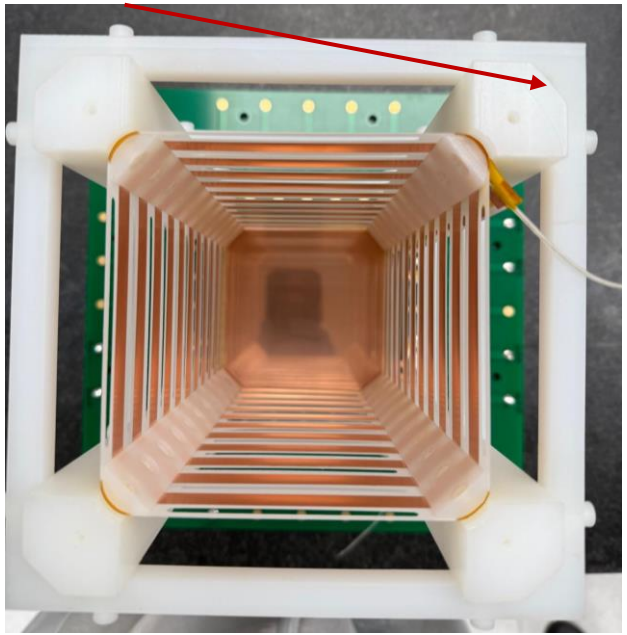
Could not be tested

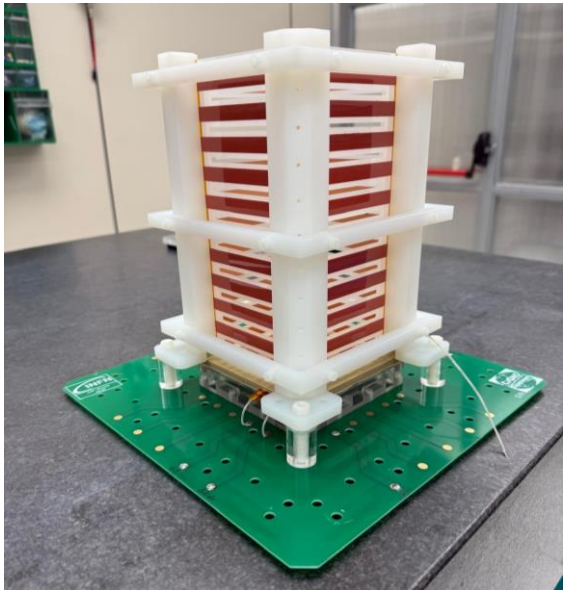
Field Cage V2_1

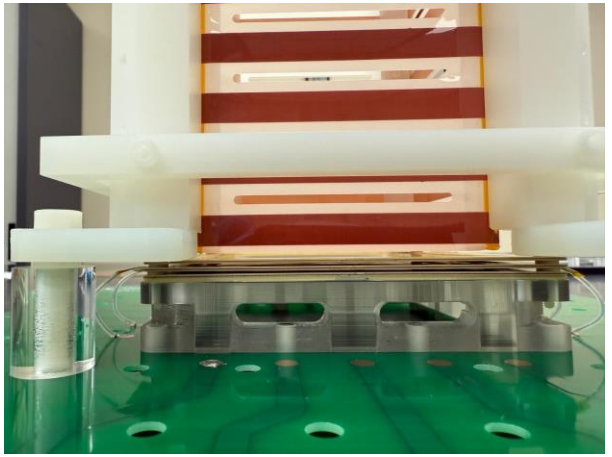
- Slightly different design by Daniele, more similar to ethereal concept.
- Considered able to sustain CYGNO-04 FC
- Made of nylon6 non-3D printed
- Distance copper first ring from GEM 0.5 mm (1 cm from the centre) and 2 cm from cathode to centre of copper strip:

Most uniform electric field configuration ever (from resistors and distances point of view)

Resistors







Field map

- No source and 8000 images per Drift field
- Regular triple thin GEM
- Tested fields: 0.15, 0.5, 1 kV/cm
- 2 different maps created. **Remember Up is Down in these maps**

GIN relevant parameters:

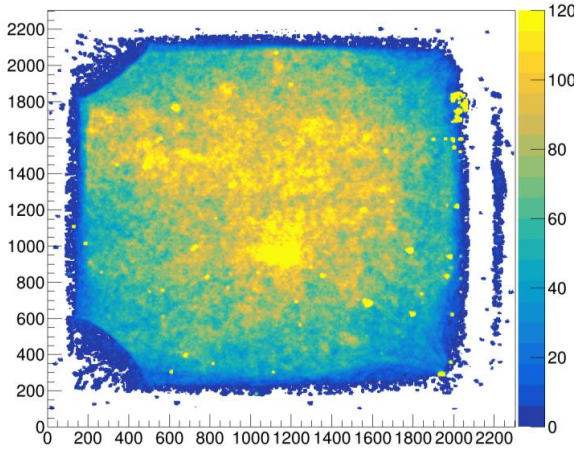
1 pixel = 50 um

Drift: *variable*

VGEM= 440 V

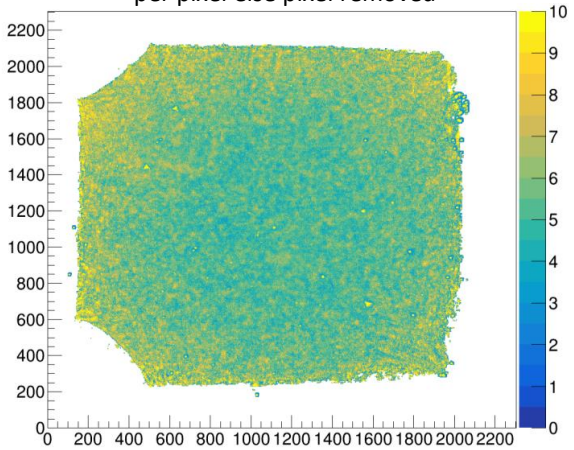
Occupancy

Map of the number of times each pixel was in a cluster



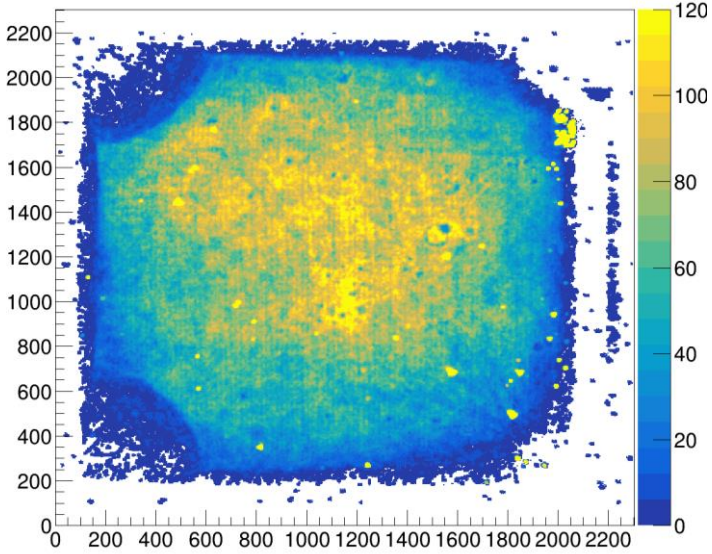
Intensity

Map of the light intensity of each pixel summing on all clusters and divided by the occupancy. More than 10 clusters required per pixel else pixel removed

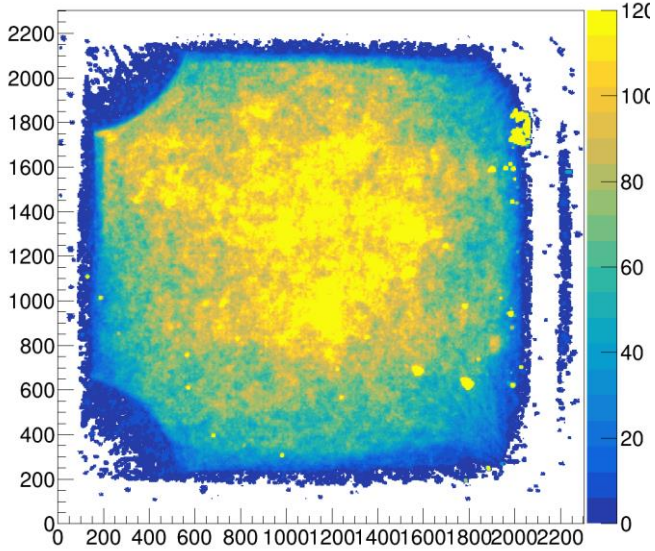


Field Map Occupancy

0.15 kV/cm



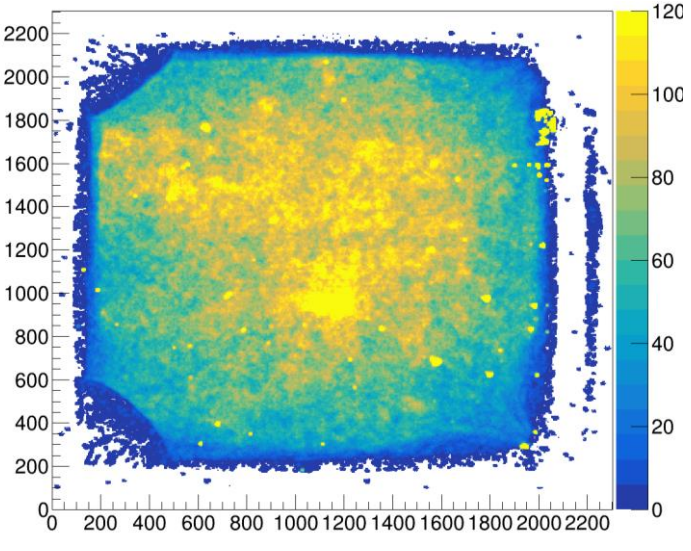
0.5 kV/cm



Clear improvement in field definition

Corner deformation

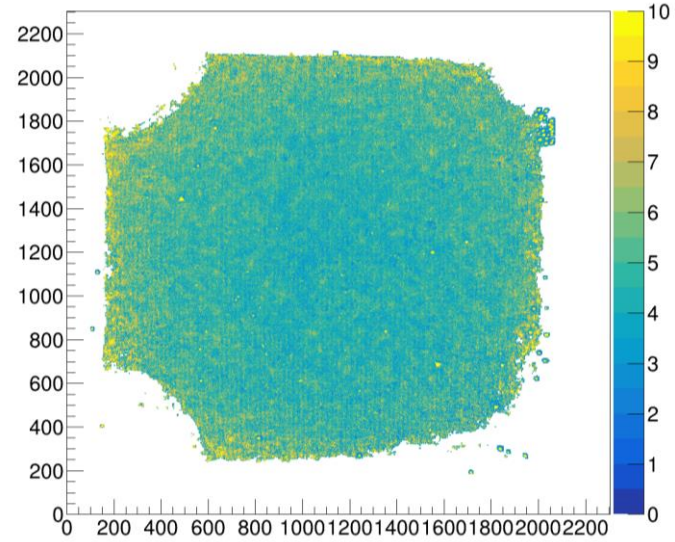
1 kV/cm



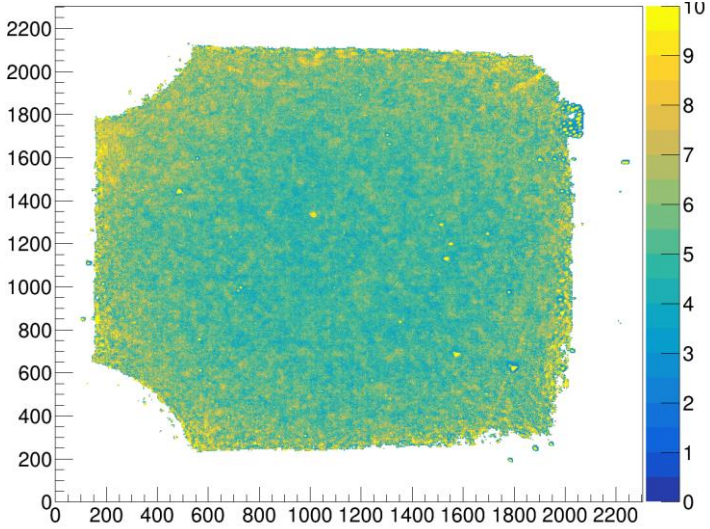
Intensity

- Intensity maps confirm previous hints about deformation

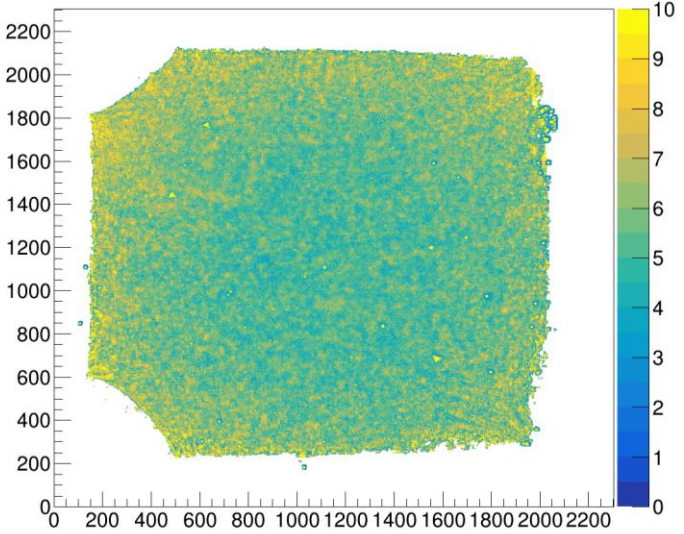
0.15 kV/cm



0.5 kV/cm



1 kV/cm

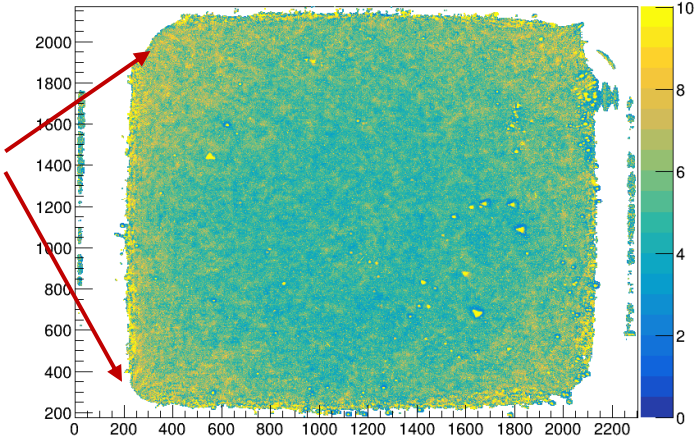


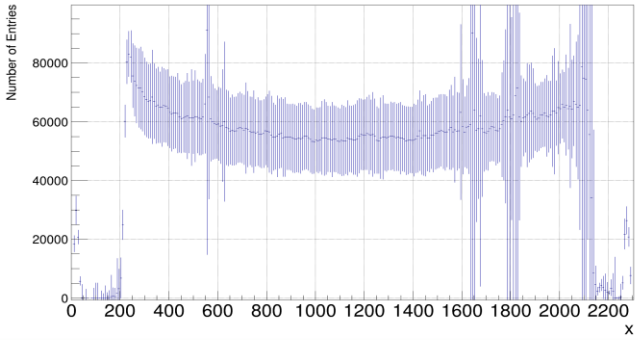
Intensity Projection

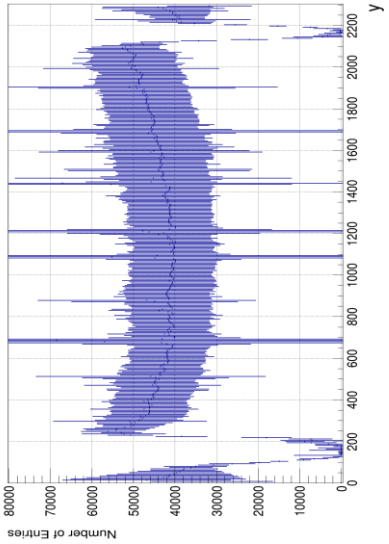
- To try to address the corner deformations, the Kapton tape was removed from the corners
- New test yielded better results
- 1 kV/cm map

Blind corners recovered

Pillow effect on all corners still present





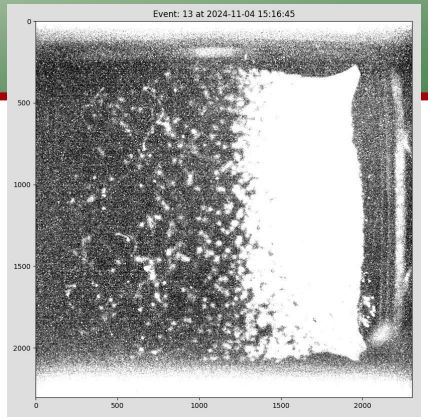


Corners avoided in the projections

Flat response of the field:

- ❑ Vignette used not calibrated on GIN (overcorrection)
- ❑ Underpopulation of the borders (overcorrection)
- ❑ Deviation from flat line below 15% (but within errors)
- ❑ **Asimmetry top-bottom < 5%**
- ❑ **Asymmetry left-right < 7%**

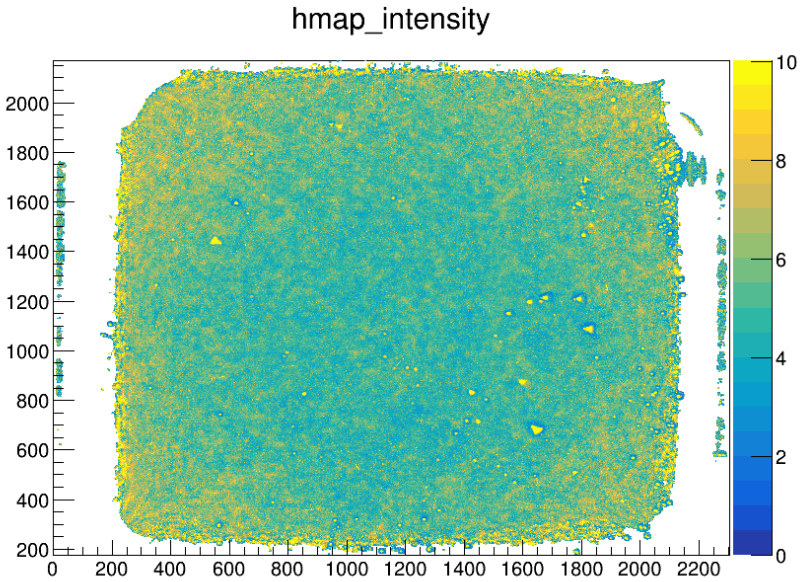
Distortion

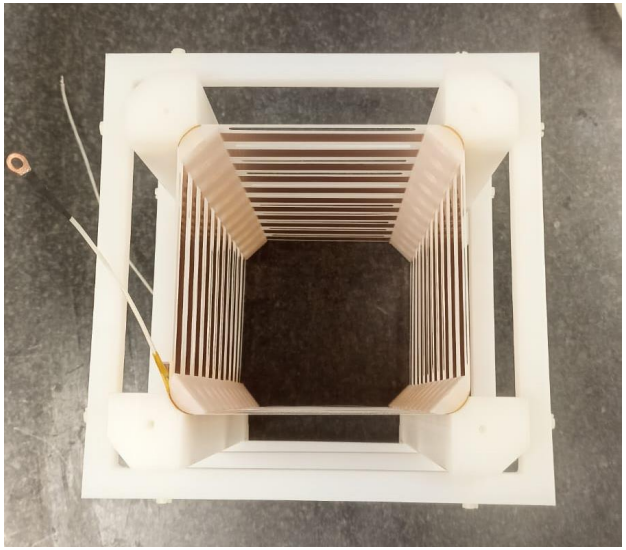


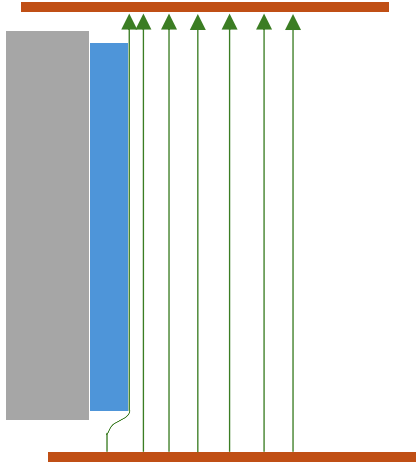
- The pillow effect ruins borders and distorts the tracks (iron looks oval)
- Idea:

  The presspillar is in the active area of the GEM and blocks electrons;

  But the electric field closes on the slightly wider GEM dragging electrons along
- This happens only when the field cage is inscripted in the GEM: at the corners

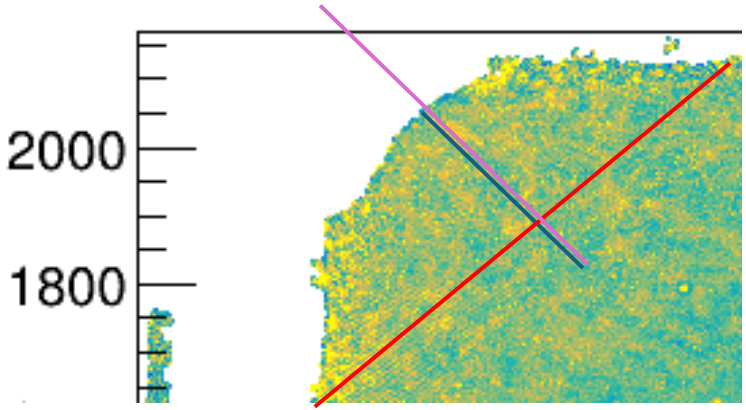




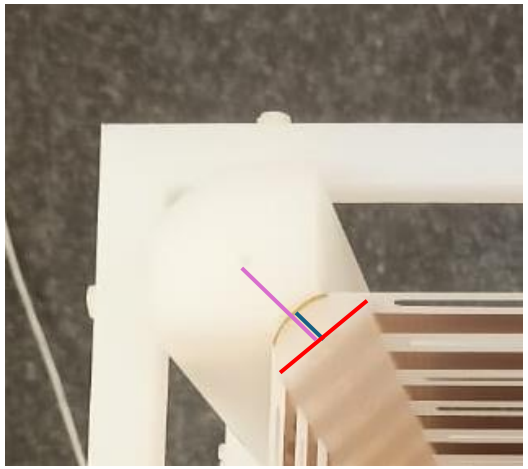


Distortion II

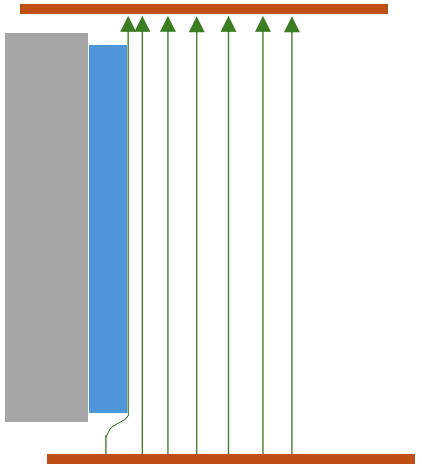
- Measurements suggest this is reasonable



Measured by camera



Measured by caliber



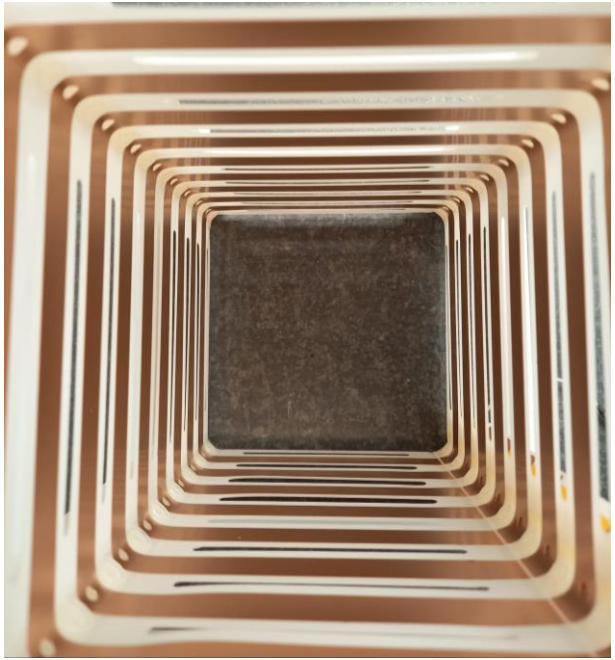
Blue line	5 mm	5 mm
Red Line	13 mm	16 mm
Purple line	13 mm	15 mm

- In GIN this effect riuns the field for 6% of the active area
- In CYGNO-04 the same pillar dimension will ruin the field for 0.1% of the area in the corners

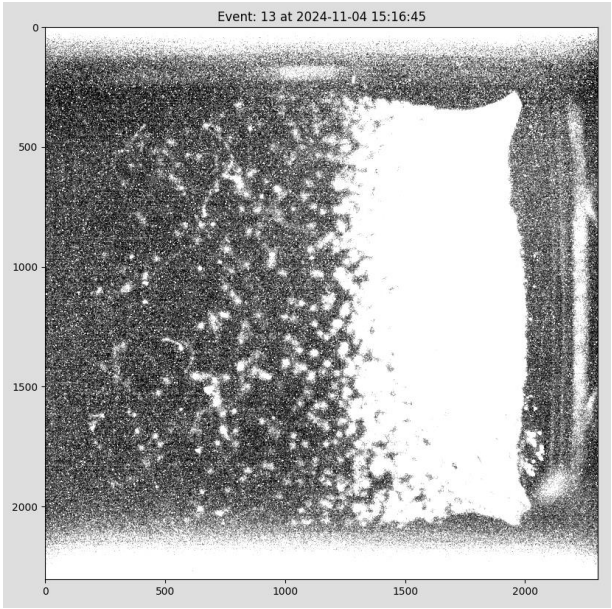
ACCEPTABLE

Distortion III

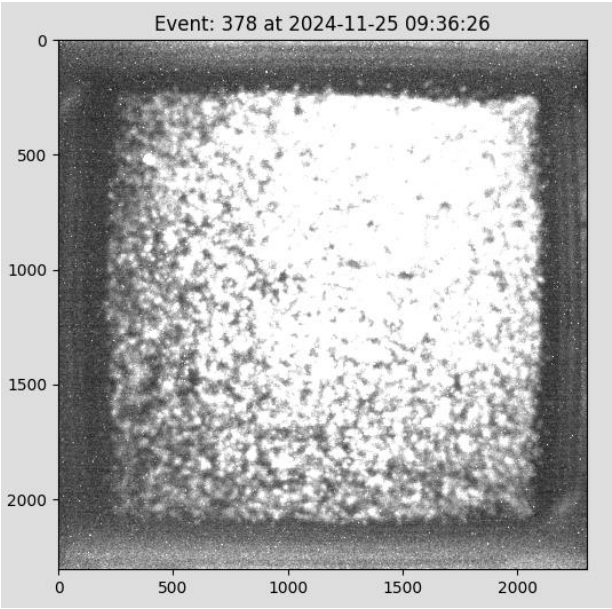
- To try and verify the presspillar idea, the FC was mounted without them (using only screws)



Before



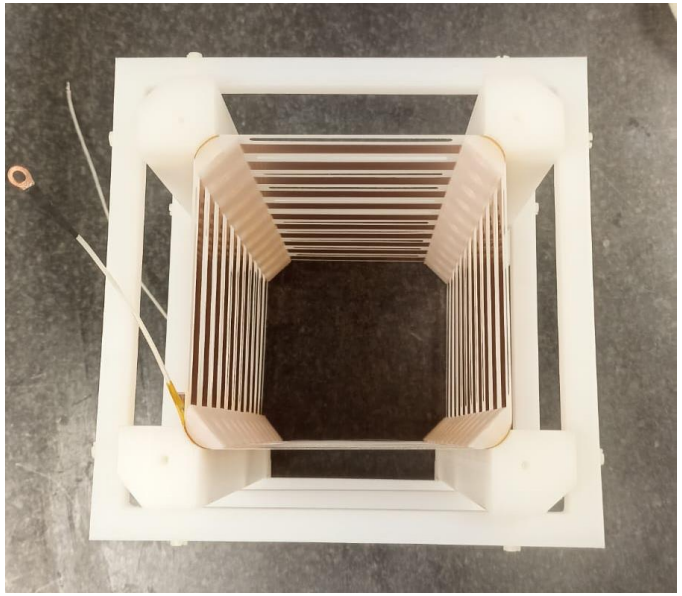
After

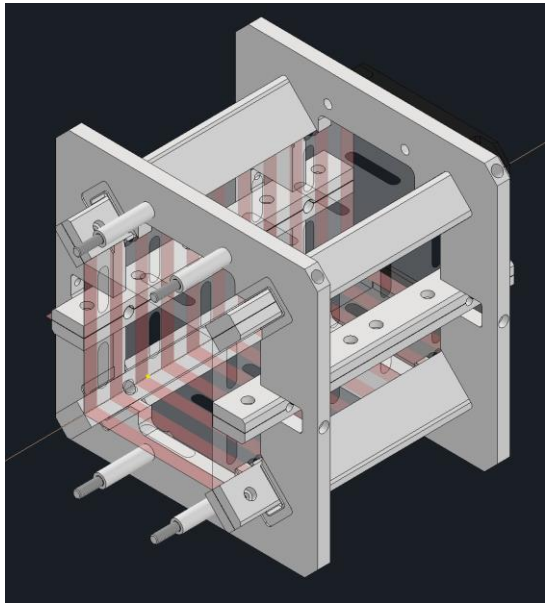


Hypothesis is consistent with data

Field Cage V3

- Next step is to try a hybrid between the two FC
- Using the material and resistor position of of the FC_V2_1, but the clipping angles of FC_V2_0 to try to guarantee better corners and solidify the hypothesis of the deformation





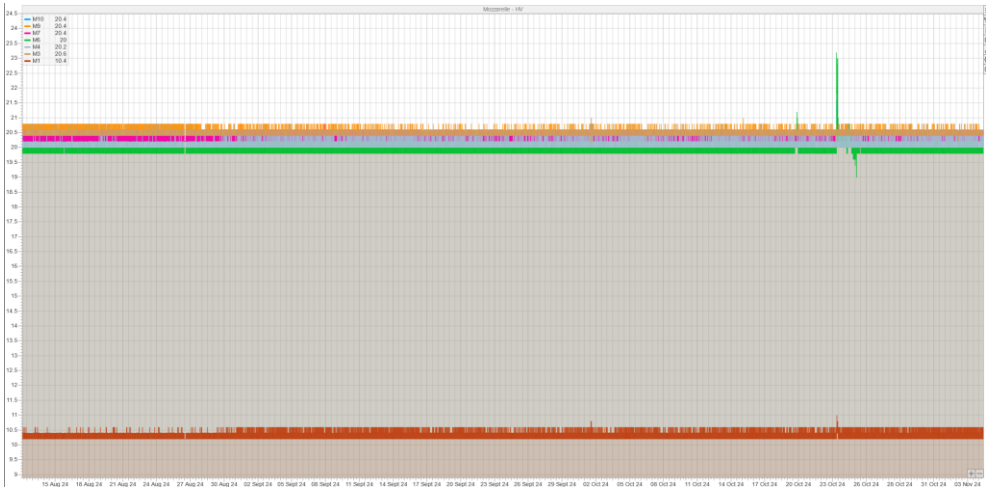
Summary

- Field Cage Studies
- **Mozzarelle Studies on Field Cage Materials**
- Radioactive Source Transparency
- Oxided GEM
- CYGNO-04 GEMs
- Extras

Mozzarelle Test

- Different samples of FC structure on different support materials were fluxed with He:CF_4 gas and powered to the equivalent of 1 kV/cm
- The test has being carried out since May to test any potential failure

- FC conductive material: copper stips 1 cm wide (35 um thick) separated by 1 cm and connected by resistor
- FC material: PET (75 um) or Kapton foil (50 um)
- Support: PVC, PMMA, nylon6



Current monitored to find failures

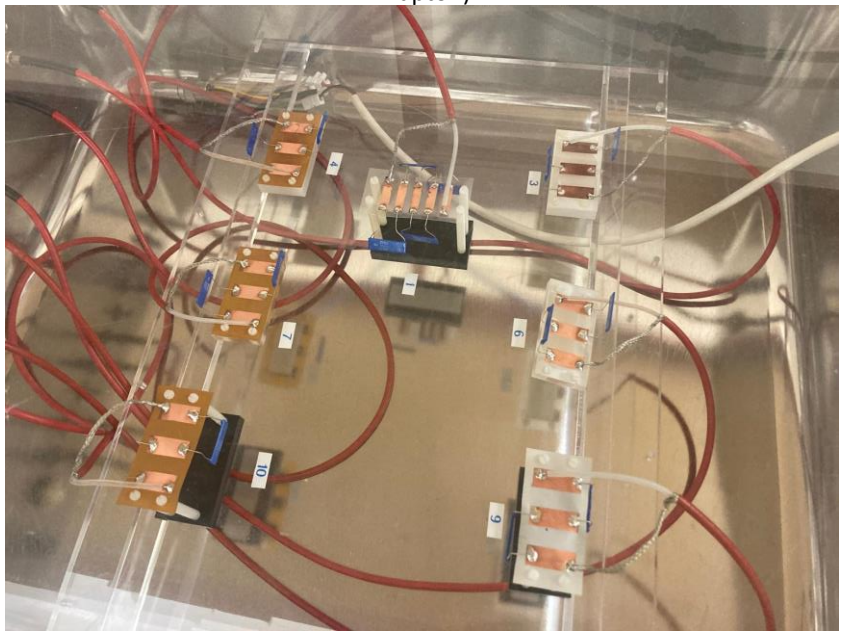
Mozzarelle Test

- No major degradation noticed

Kapton

Robertino extra (no PET nor kapton)

PET



Nylon6

PMMA

PVC

- M1: steady increase in the fluctuation of the current
- M6: had 2 sparks even though it recovered afterwards (PET on PMMA)
- All others have only fluctuations corresponsding to 1 bit of the ADC

No clear sign of strong degradation by any sample (apart from M1)

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Source Window Transparency

- CYGNO-04 foresees the use of 2 PET thin windows the calibration radioactive source needs to cross. How much does this attenuates the source?
- ^{55}Fe source in the centre of GIN with collimator with slit parallel to GEM plane (short brass with copper tape source far)
- Runs taken with regular setup: one window of 100-170 um of PET (?) like LIME
- Runs taken positioning a second layer of same thickness on top of the already existing window

GIN relevant parameters:

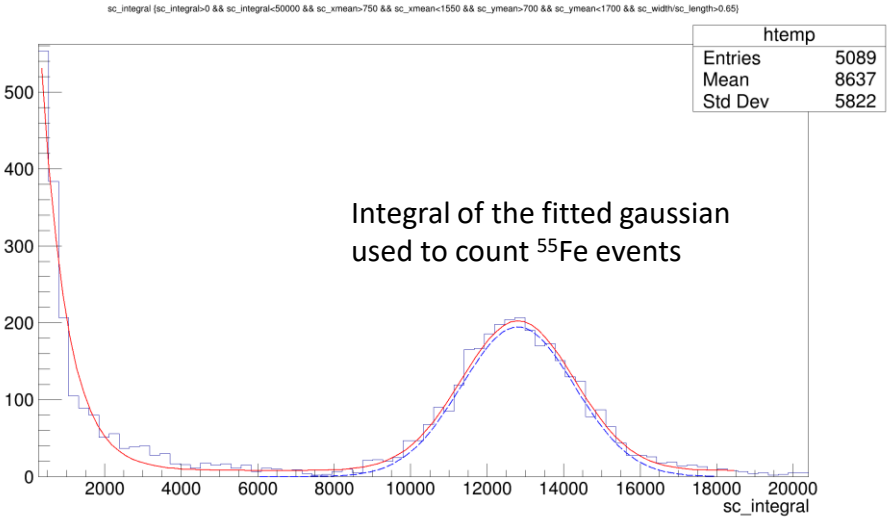
1 pixel = 50 um

Distance source to gas ~ 9 cm

Spread in z of source at 1.5 cm from field cage 1 cm (sigma)

Drift 1 kV/cm

VGEM 440 V



2 windows R_{2w}= 3030 ± 60

1 window R_w= 4060 ± 60

Ratio A= 0.75 ± 0.02

Absorption of a window measured as (25 ± 2)%

Summary

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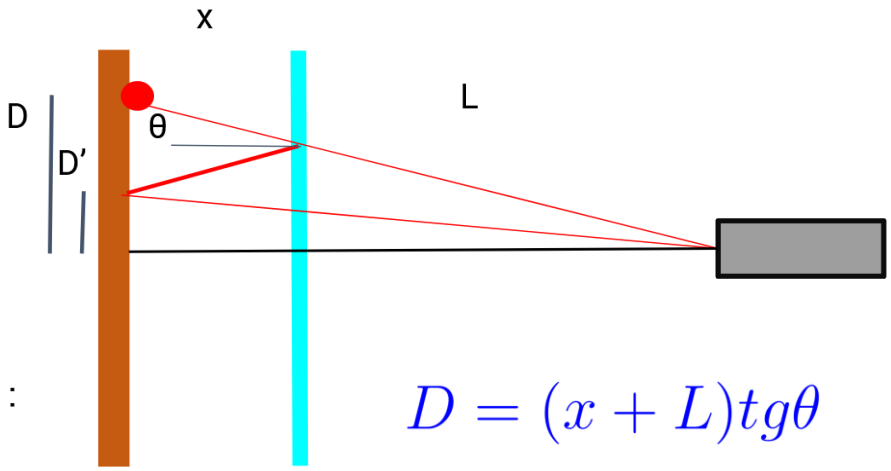
Reflection in LIME

Details: https://agenda.infn.it/event/43594/contributions/245432/attachments/126641/187022/Lenses%20reflection_update.pdf

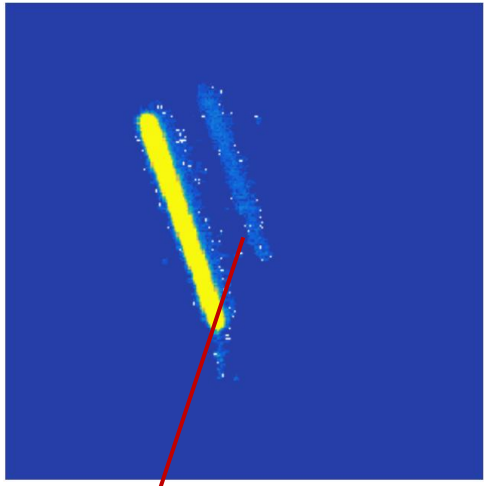
- The reflection issues found in LIME can spoil intense tracks energy and clusterization algorithm
- The reflection is caused by a combination of the reflectance of the PMMA optical window and of the GEMs, and of the geometry



$$D = (x + L)tg\theta$$

$$D - D' = 2xtg\theta$$

Distance of the shadow



Typical shadow features:

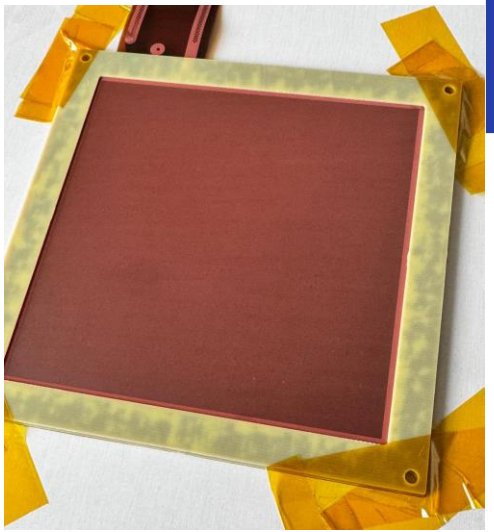
- Appears with very dense tracks (0,5-1 10^4 sc_integral/(pixel in length))
- About 4% of intensity

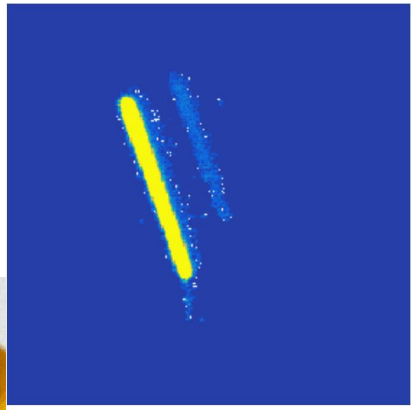
Theory and measurement agree (internal reflection inside PMMA do not)

Solutions: Oxided GEM?

- We could use optical windows with >99% reflection (too expensive and radiopure not found) **NO**
- Place the window 60 cm from the GEM to have the shadow way out of focus. Keeps the noise, complicates the design of PMMA box
- Use an oxided GEM:
  - Thin conductive layer of copper oxide to make it opaque
  - GEM washed for radiopurity after oxidation
  - Layer very thin (removable by the multimeter pin)

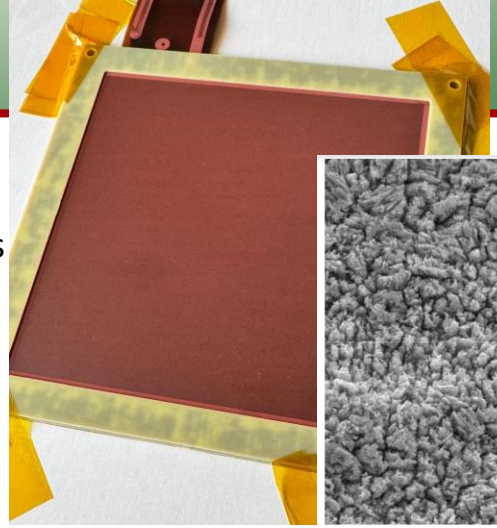
Or so we thought

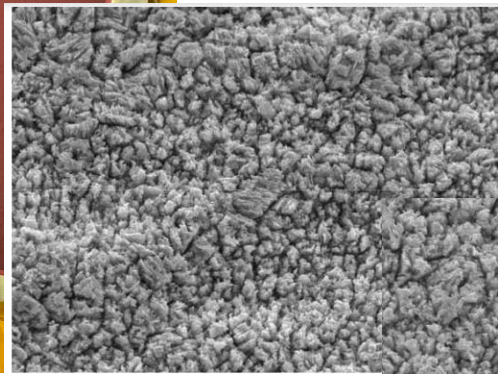




We Call it Oxided, It is V-Bond

- Actually, once the GEM is etched th V-Bond procedure is applied
- Bath of chemicals which etches non perfect Cu crystals generating small valleys
- Depth about 500 nm, width similar
- Generation of small film of 10 nm of
  - Rui says copper oxide
  - The company making Vbond writes organic copper film





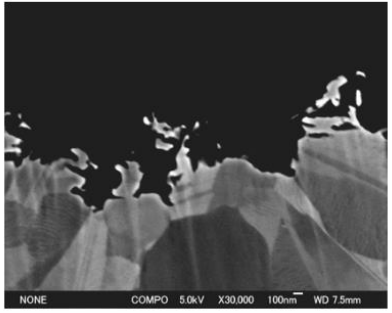
- Resistivite? Insulator? Very hard to test. Suggested test by Rui:

  Drop charge on a sample (he provided) center and connect the border to ground. If the center sparks, it is resistive
- Going through a second etching, the border of the GEM holes is likely to have been cleaned more, but maybe leaving th electrodes further away

Peaks and Valleys
=Physical Bonding

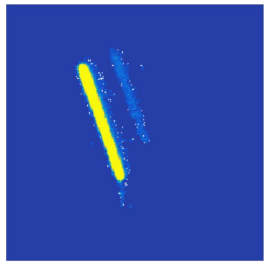
+

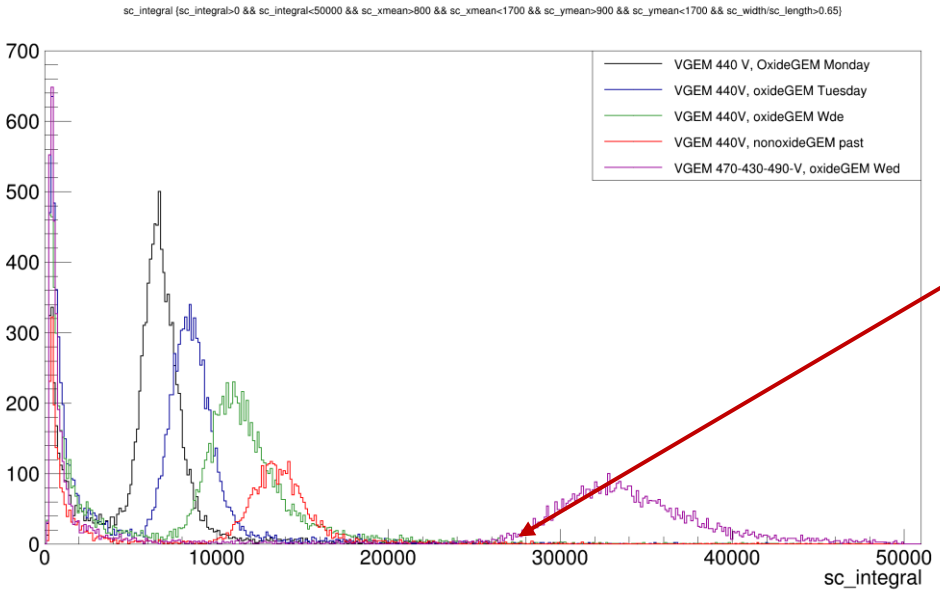
Organic Copper Film
=Chemical Bonding



Oxided GEM: alphas

- To test on GIN we need similar light yield
- With new GEMs we struggle a bit in light intensity (also without the oxided one)





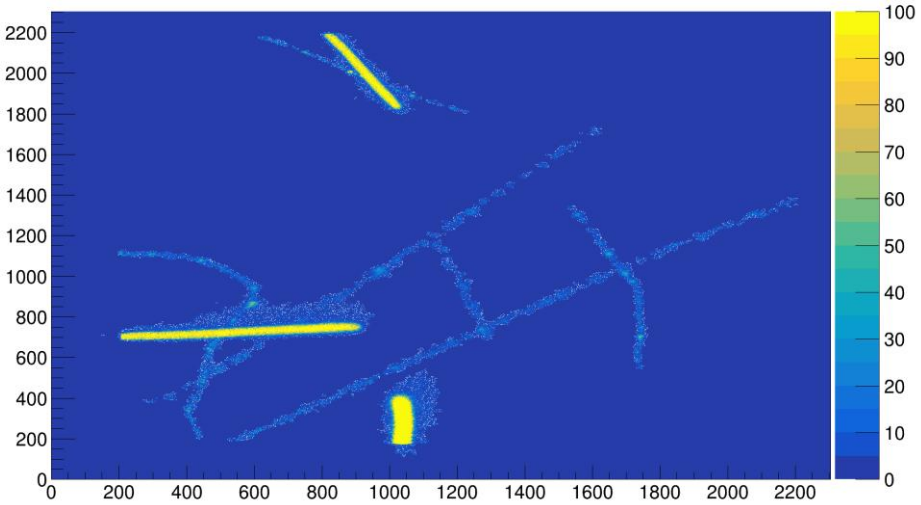
Typicallight with other GIN GEMs

Day by day the light and stability was improving

Non oxided GEM: alphas

- Some alphas

Old GIN light: alphas have 0,5-1 10^4 sc_integral/(pixel in length)

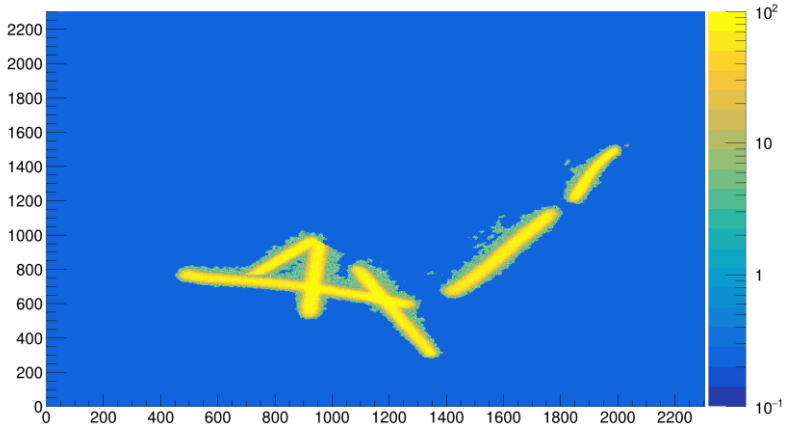


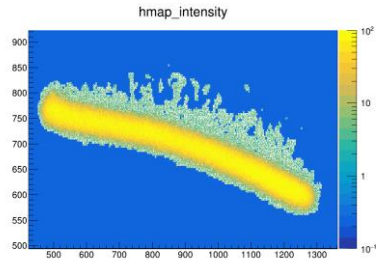
In GIN we have PET foil window

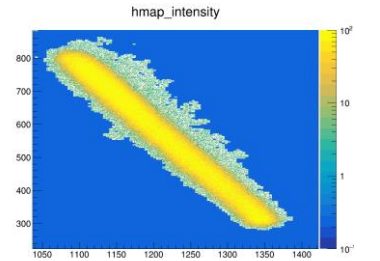
Different type of reflection: blur

New GIN light: alphas have 0.1-0.4 10^4

sc_integral/(pixel in length)



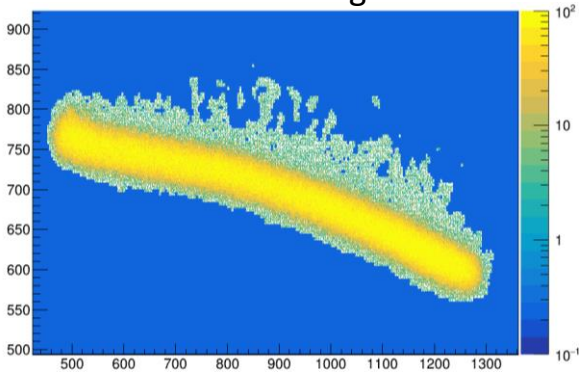




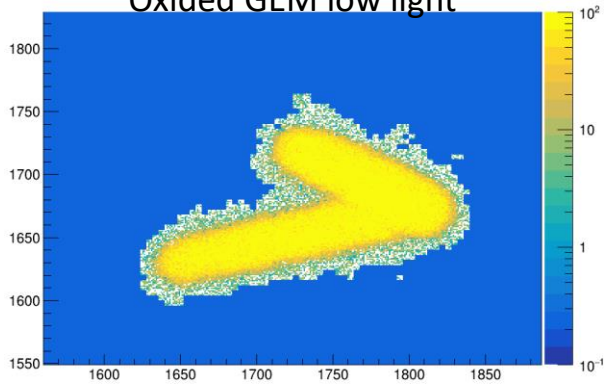
Shadow visible but fainter

Oxided GEM: alphas

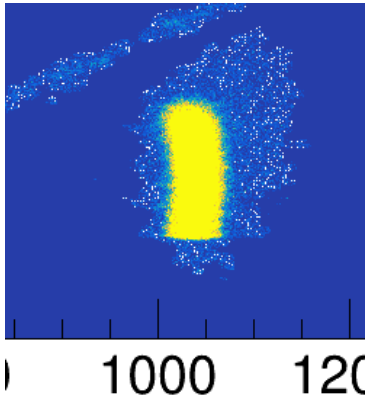
GEM low light

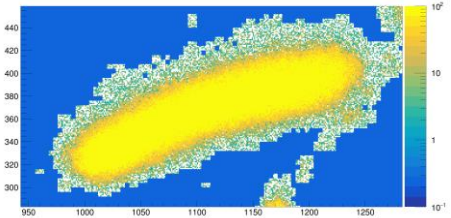


Oxided GEM low light

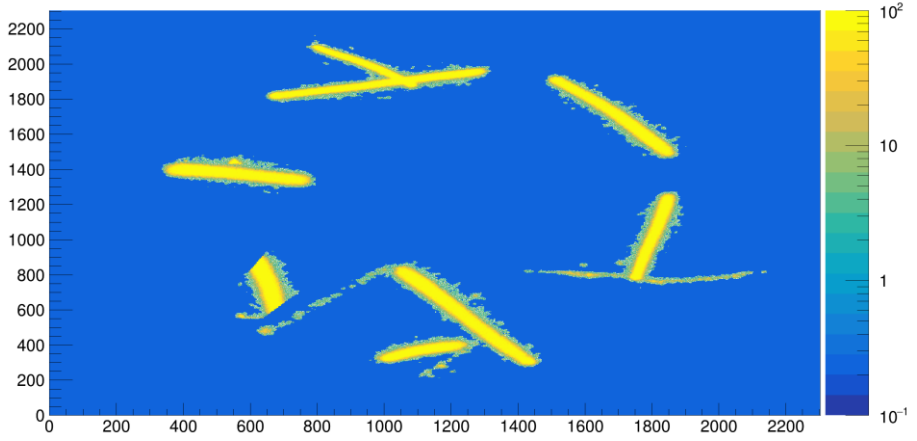


GEM large light





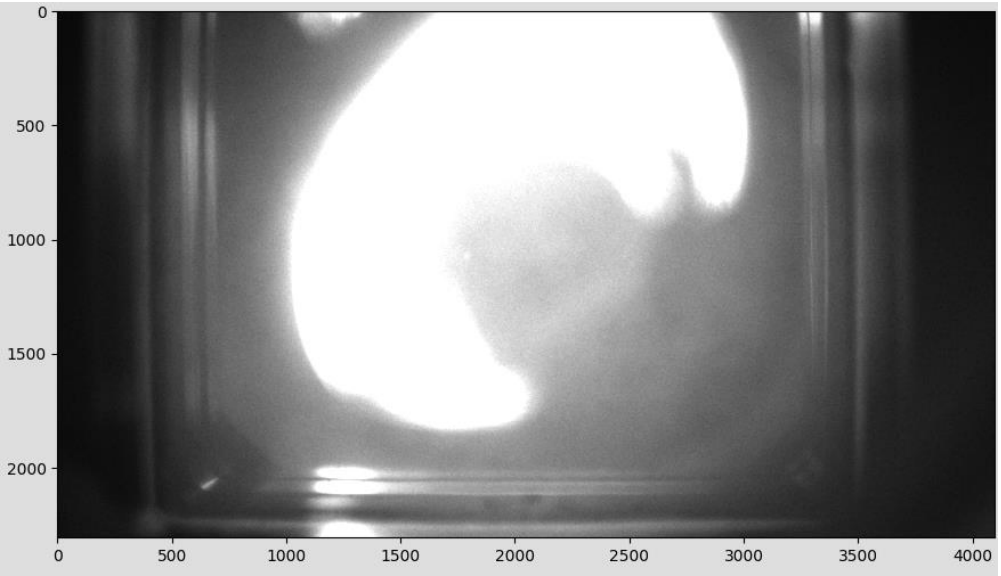
Oxided GEM large light



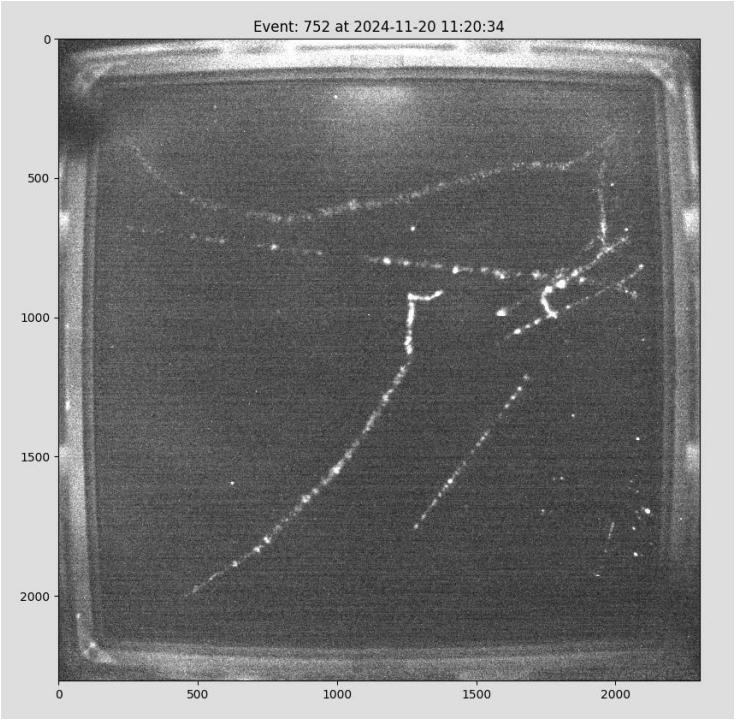
Oxided GEM: alphas

- Images with lots of photons entering the sensitive volume show oxided GEM do not have reflection

MANGO with regular GEM



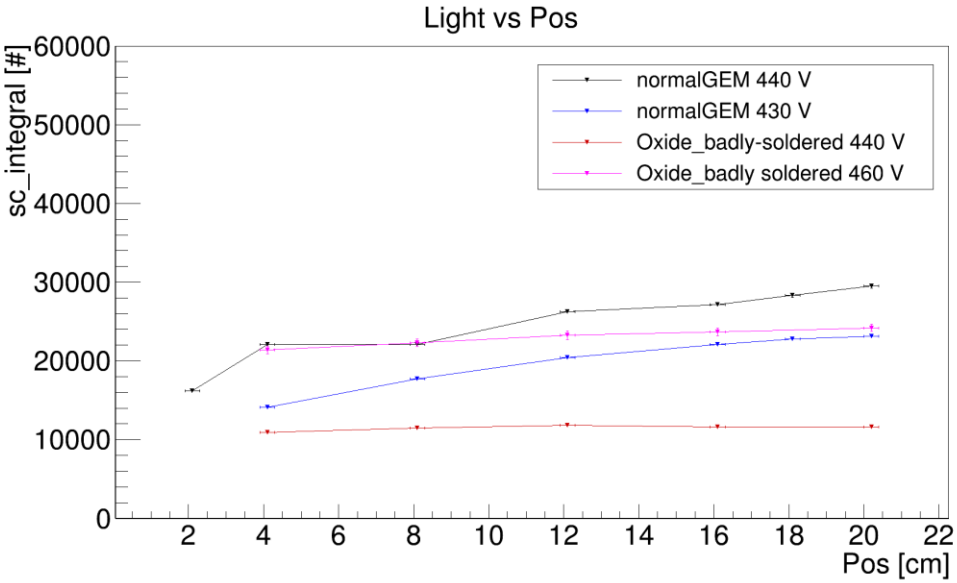
GIN with oxided GEM



Oxided GEMs do not have shadows

Oxided GEM: Round1

- Checking with regular GEM data we can crosscheck the saturation behaviour



Oxided_badly 460 V had GEM3 at 440V

Lower light yield wrt old GIN

Relevant things:

NormalGEM -> non oxided GEMs old GIN Schneider lens

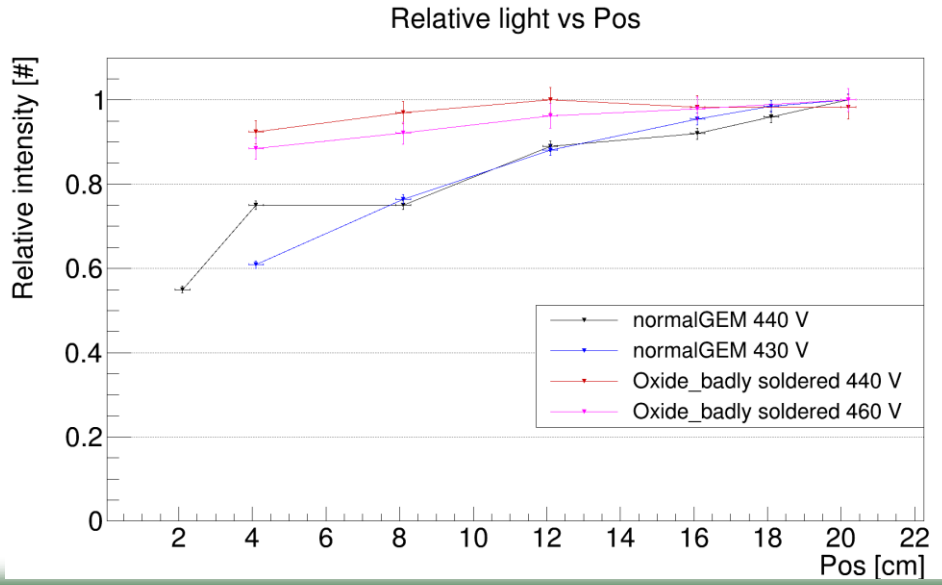
Oxide_badly -> badly soldered, GEM2 a bit burnt Schneider lens repaired (weird focus config)

Oxide -> New GEMs (GEM3 oxided), EHD lens

With same lights even less saturation

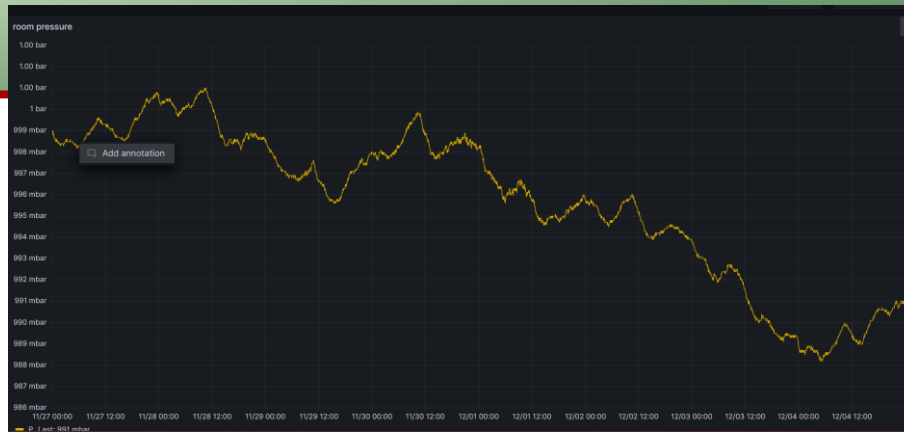
What is going on?

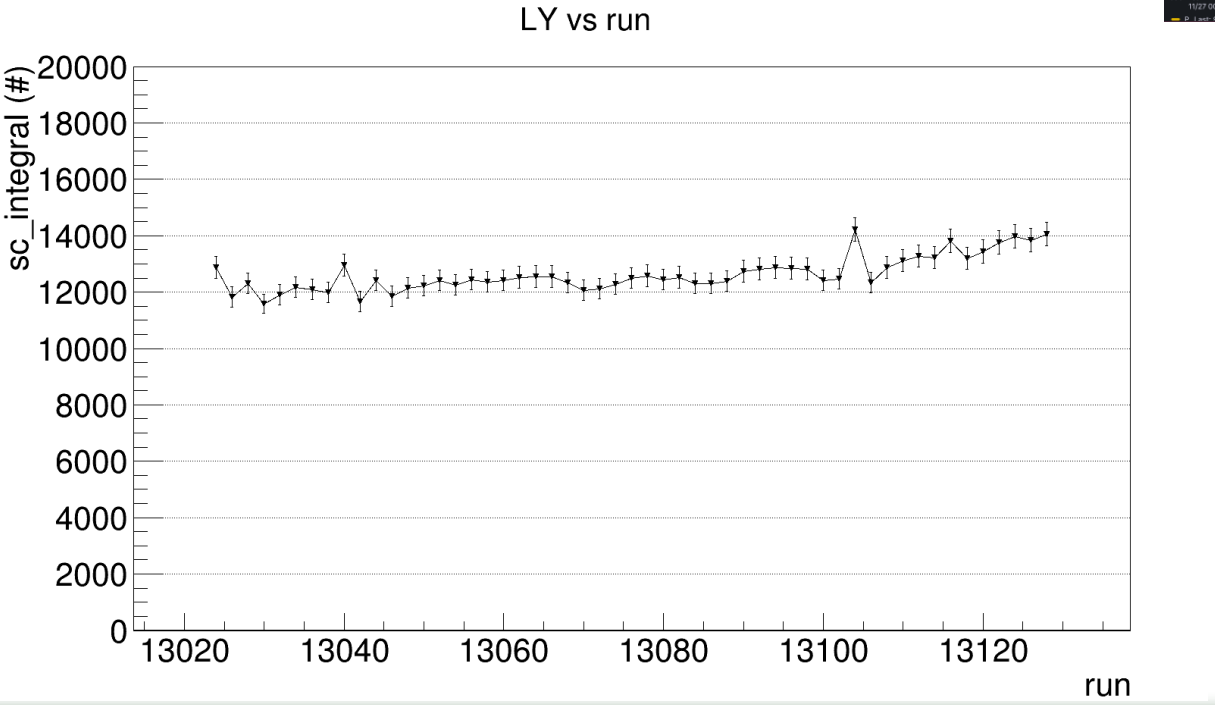
We discovered the redbox content



Oxided GEM: Stability

- Ok so we changed GEMs (all of them) still with GEM3 oxided
- We monitored for a week the light yield with ^{55}Fe source placed in about P8
- Data taken every 3 hours





Increase of 15%

Pressure difference measured should induce 6% increase (measured steady decrease of pressure with a difference of 10 mbar)

Charge-up of kapton and cleaning visible

Light reached with this GIN and with regular GEMs, but still much lower than in the past

Oxided GEM: New GEMs vs Old

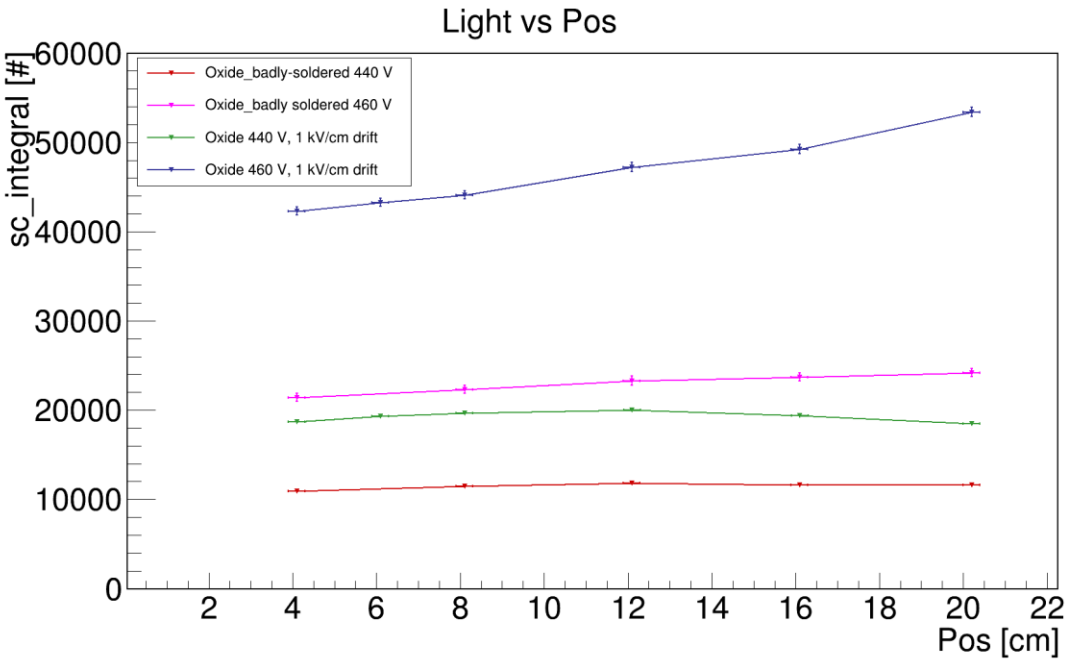
- Now we also changed the lens, placing the EHD (expect 25% more light than Schneider)
- New configuration is much more luminous than the badly soldered
- 25% increase due to lens is not enough to explain it

Relevant parameters:

NormalGEM -> non oxided GEMs old GIN Schneider lens

Oxide_badly -> badly soldered, GEM2 a bit burnt Schneider lens repaired (weird focus config)

Oxide -> New GEMs (GEM3 oxided), EHD lens



Oxided 460 V corresponds in

LY to 450 V old GIN

(accounting for the lens improvement)

Oxided 440 V corresponds in

LY to 420 V old GIN

Oxided GEM: Saturation and LY

- Checking with oldGIN we still have less saturation (not complaining)
- In particular below 10 cm saturation is clearly present in all sets
- At 440V of VGEM the absoption is visible while it wasn't in the past at 430V

Relevant parameters:

NormalGEM -> non oxided GEMs old GIN Schneider lens

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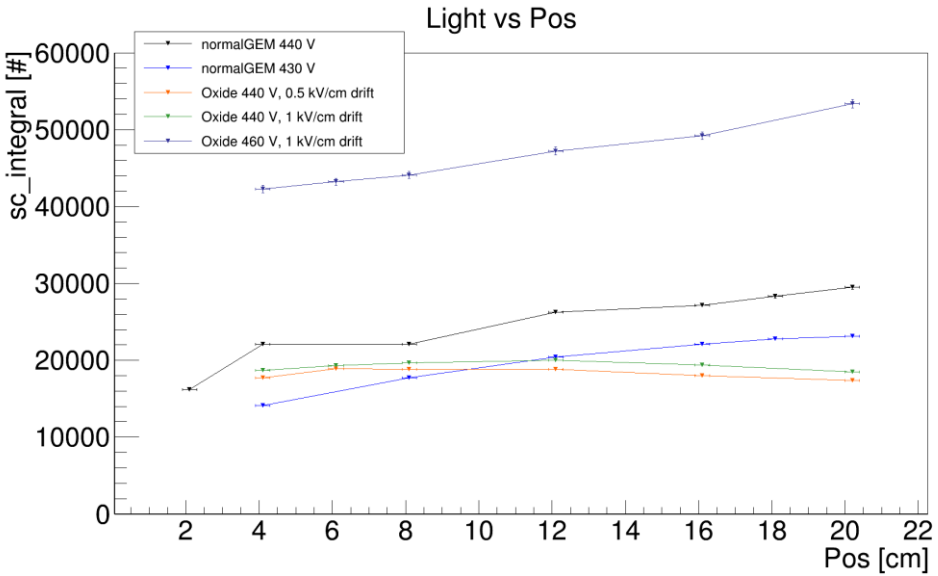
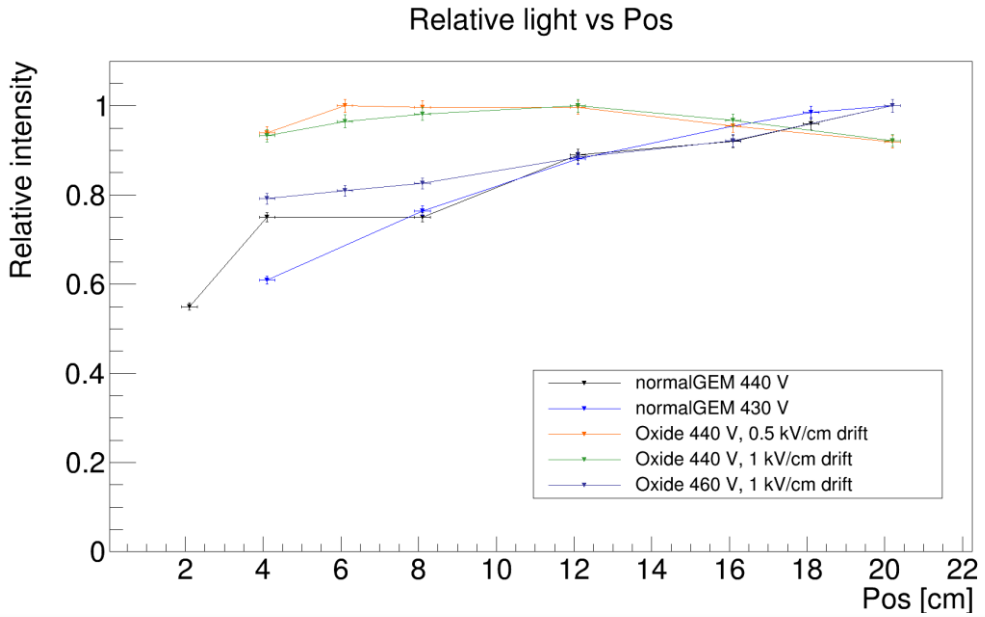
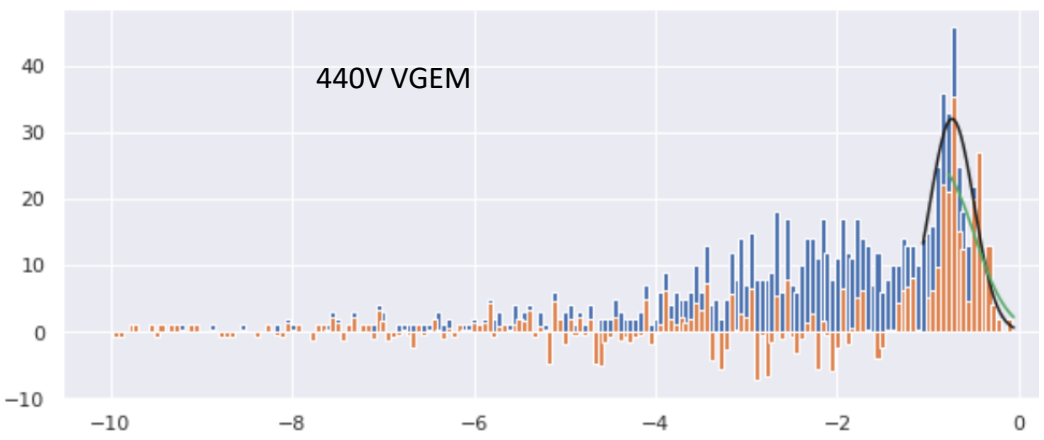
Oxide -> New GEMs (GEM3 oxided), EHD lens

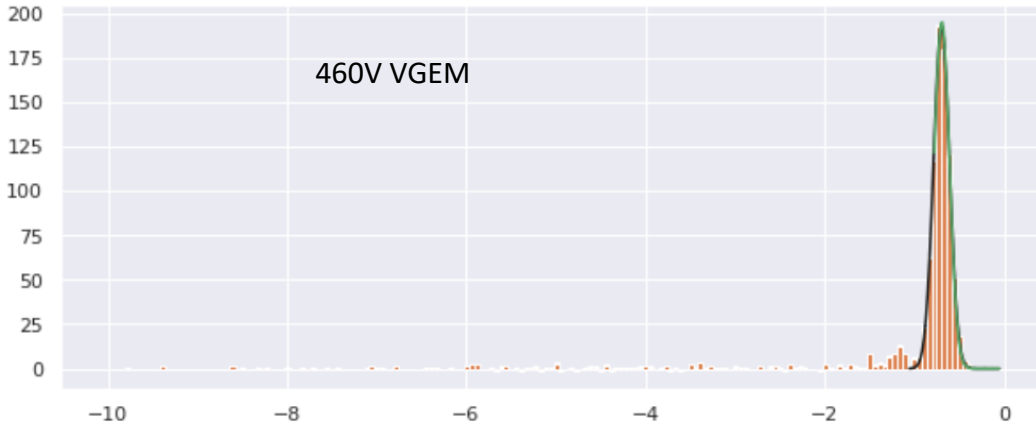




Oxided GEM: GEM vs LY

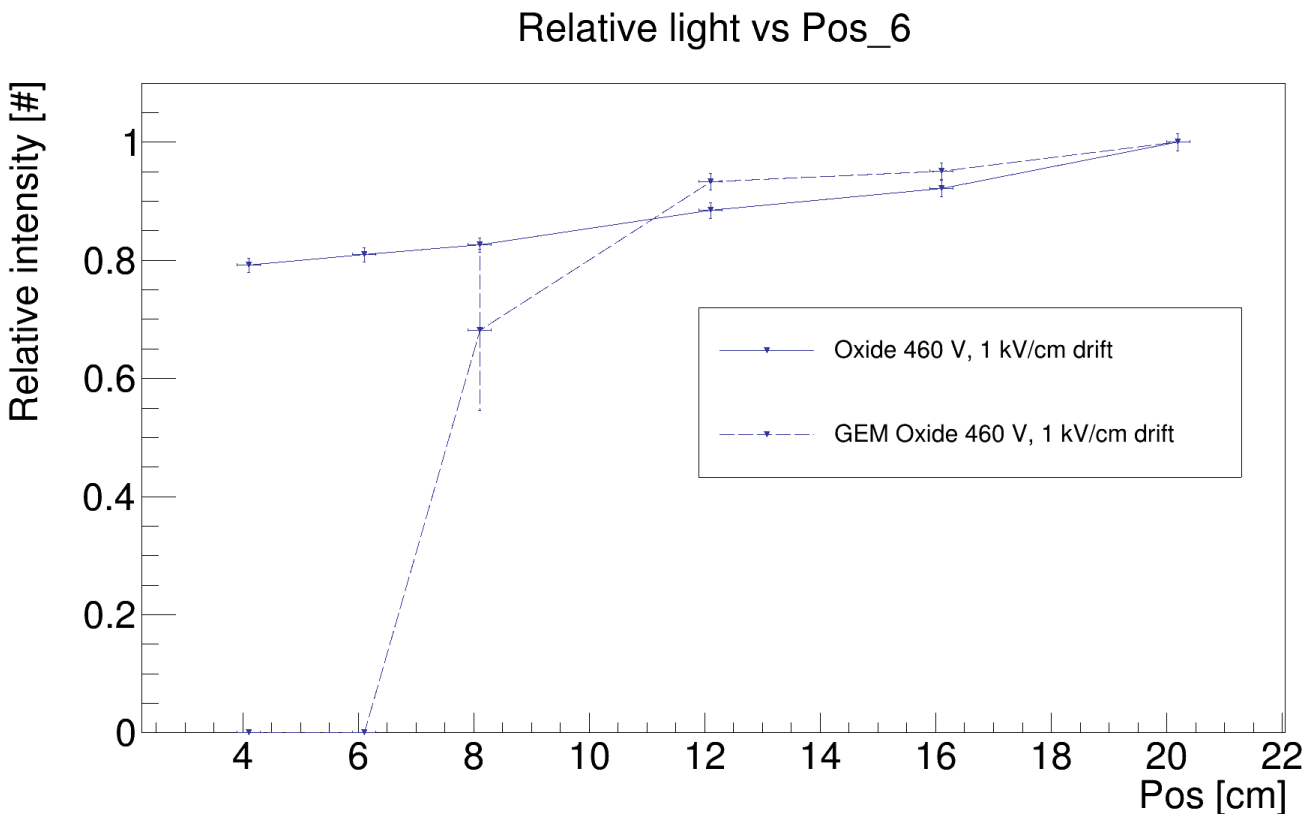
- Is saturation an effect on light due to the oxided GEM?
- GEM signal studied (Oscilloscope: 200 MHz low pass filter, 100MOhm coupling)
- Charge estimated as integral of the waveforms
- Background spectrum acquired, normalised to the signal data (in the range avove 2 pC where iron is not present) and subtracted
- Trigger put just above noise: Data at 440 V have no iron above noise. 460 V has until it gets too small





Oxided GEM: GEM vs LY

- Checking the saturation for LY and GEM



Relevant parameters:

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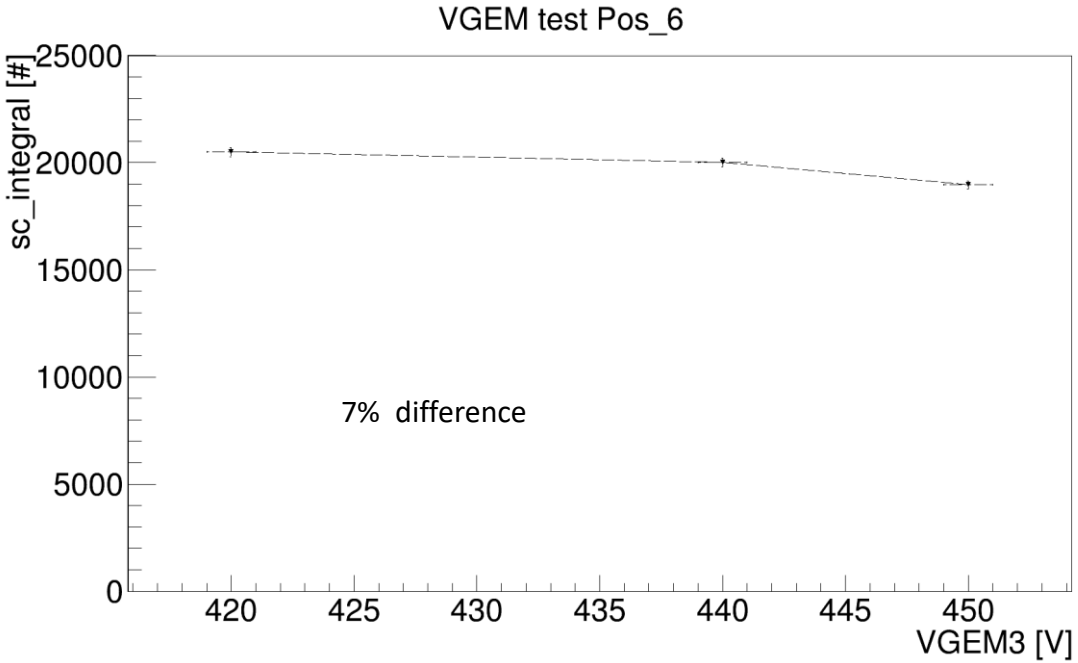
Oxide -> New GEMs (GEM3 oxided), EHD lens

Compatible!

New Test: VGEMtest

- At high gain, the LY will mostly depend on the sum of the voltages across the GEMs
- 3 configuration tested (fixed drift field and ^{55}Fe position)
- If oxided GEM behaves differently (poorly) when placed at 450 V with GEM2 at 420 V, the LY should be strongly less

GEM1	GEM2	GEM3
440	440	440
450	450	420
450	420	450



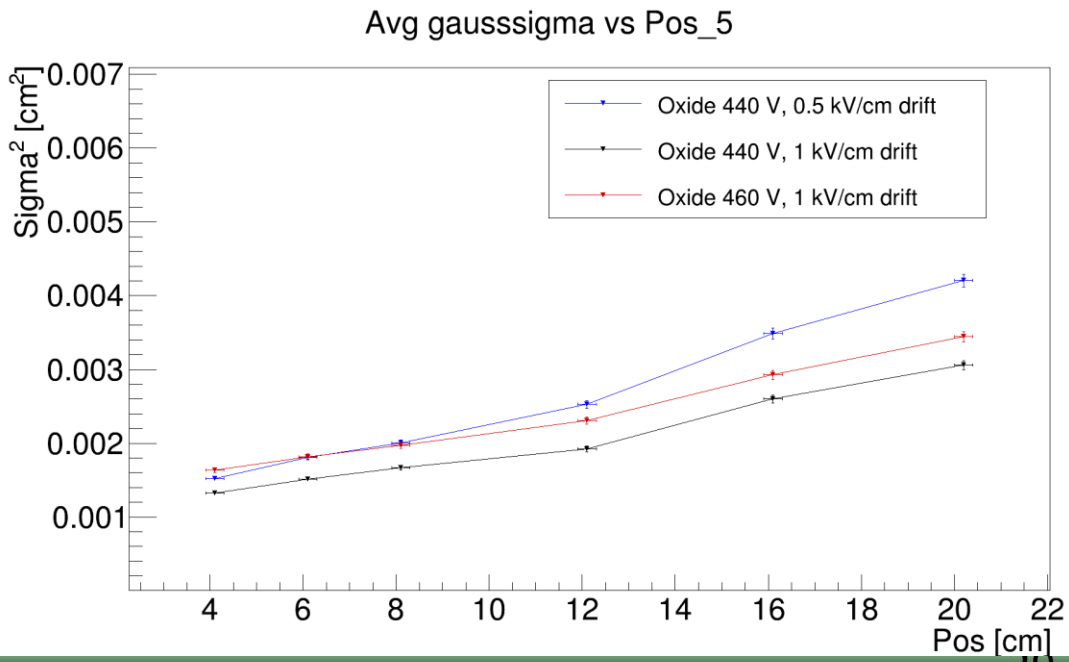
GEM test yields similar result

If it behaves worse it is of 7% -> little

Oxided GEM seems to be working as normal GEM (at least like GEM2)

Oxided GEM: Diffusion

- Is the light decrease fault of the drift field?
- Gaussian sigma squared vs source position measured
- Clear break where saturation matters a lot
- Sigma0 fitted with points < 10 cm
- Diffusion coeff fitted with data>10 cm



Sigma0:

Blue	(320 ± 15) um
Black	(310 ± 12) um
Red	(360 ± 12) um

Diff coeff

Blue	(145 ± 5) um/$\sqrt{cm}$
Black	(119 ± 4) um/$\sqrt{cm}$
Red	(118 ± 5) um/$\sqrt{cm}$

Expected from simulation

0.5 kV/cm	(142 ± 3) um/$\sqrt{cm}$
1 kV/cm	(113 ± 3) um/$\sqrt{cm}$

Diff coeff <10 cm

Blue	(110 ± 7) um/$\sqrt{cm}$
Black	(93± 6) um/$\sqrt{cm}$
Red	(91± 8) um/$\sqrt{cm}$

From MANGO (400V, remember lower pressure) expected about:

320 um for 440V

380 um for 440V

Diffusion coefficient consistent

No issues on the field

Why low light?

- Drift field not strong as we believe -> more capture?
    - Diffusion measurements state the field is fine
    - Increasing the field up to 1.7 kV/cm, no light increase noticed
    - With 0.5 kV/cm the absoption (see light vs Pos) does not worsen
- Pillars of nylon6 instead of delrin -> more dirty gas?
    - For more capture see last two bullets ago
    - Outgassing of material which absorbs light.. Boh
- Oxided GEM behaving weirdly
    - Test with VGEM configurations seems to disprove it
- They need time to fully clean
    - Possible

- Why different saturation behaviour? Simply Boh.. Luckily it is not worse

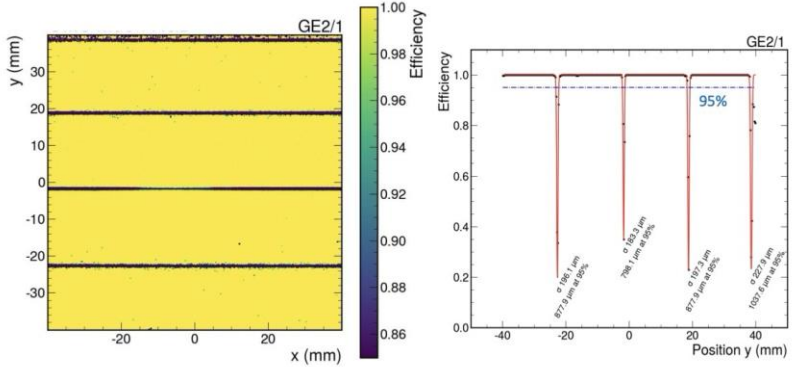
Summary

- Field Cage Studies
- Mozzarelle Studies on Field Cage Materials
- Radioactive Source Transparency
- Oxided GEM
- **CYGNO-04 GEMs**
- Extras

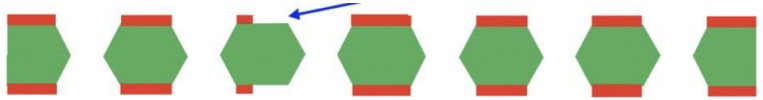
CYGNO-04 GEM

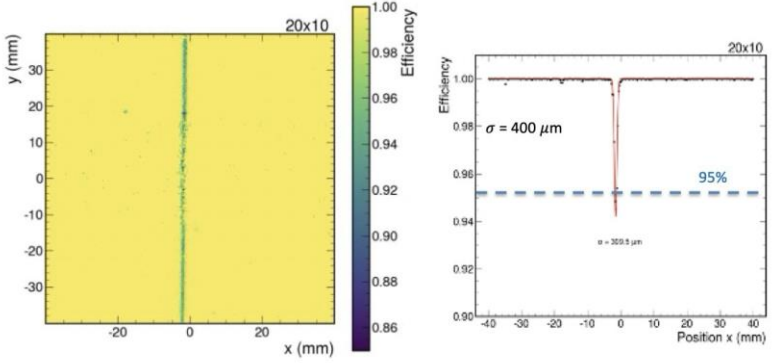
- We have ordered 8 GEM foils for CYGNO04 with 80x50 cm^2 active area

4 standard GEM foils (standard hole pattern) produced in2022



4 GEM foils with Random Segmented Pattern (RSP) to be produced November 2024



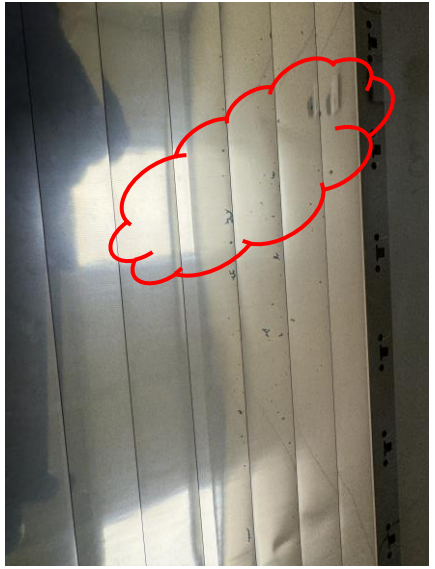


Ref. A. Pellecchia *et al* 2023 *JINST* **18** C07001

RSP provides much higher efficiency in the region go HV sectorization and smaller dead area

CYGNO-04 GEM

- In spring 2024 we tried to assembly the first GEM stack but we had issues with HV stability with three foils.
- Inspection of the foils shown defects on the active areas coming from production which prevented the operation of the GEM.
- The three GEMs have been sent back to MPGD lab@CERN for deeper inspection and retrofitting or newly produced.
- If as expected the option to use oxidated GEM3 is effective the plan is to have one standard GEM foils and one RSP GEM oxidated.

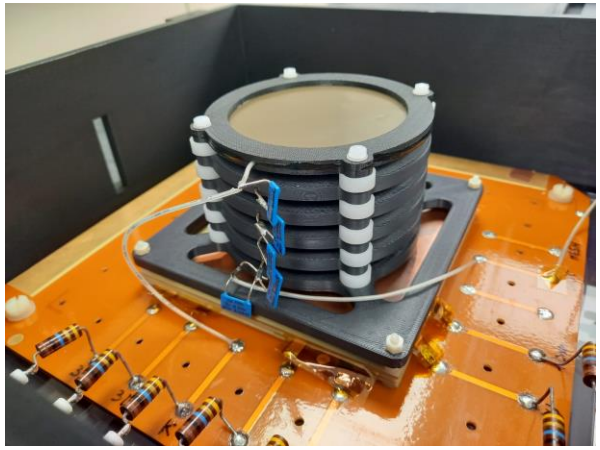


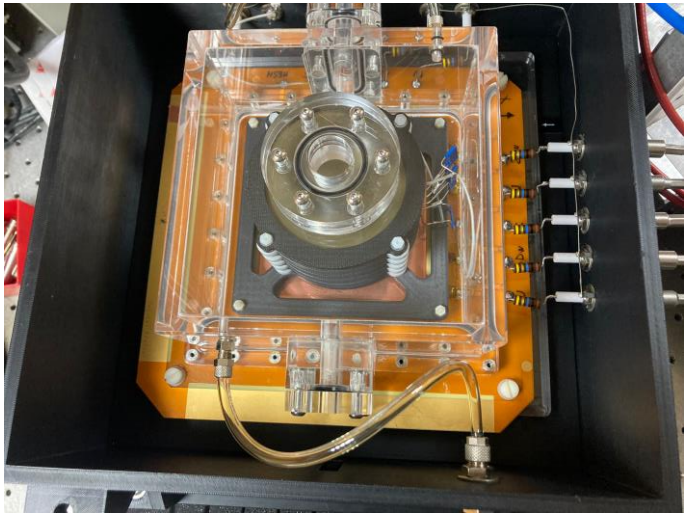
Summary

- Field Cage Studies
- Mozzarelle Studies on Field Cage Materials
- Radioactive Source Transparency
- Oxided GEM
- CYGNO-04 GEMs
- **Extras**

MetalMango

- As part of the requirements for the measurements of the polarized X-ray beam available at INAF, Mango digievolved again in *MetalMango*
- Aluminum structure to hold it vertical
- Hole in the plastic and PMMA vessel to allow X-rays to reach the sensitive area through the cathode side
- New plastic field cage holder and field cage adapter 3D printed





MetalMango

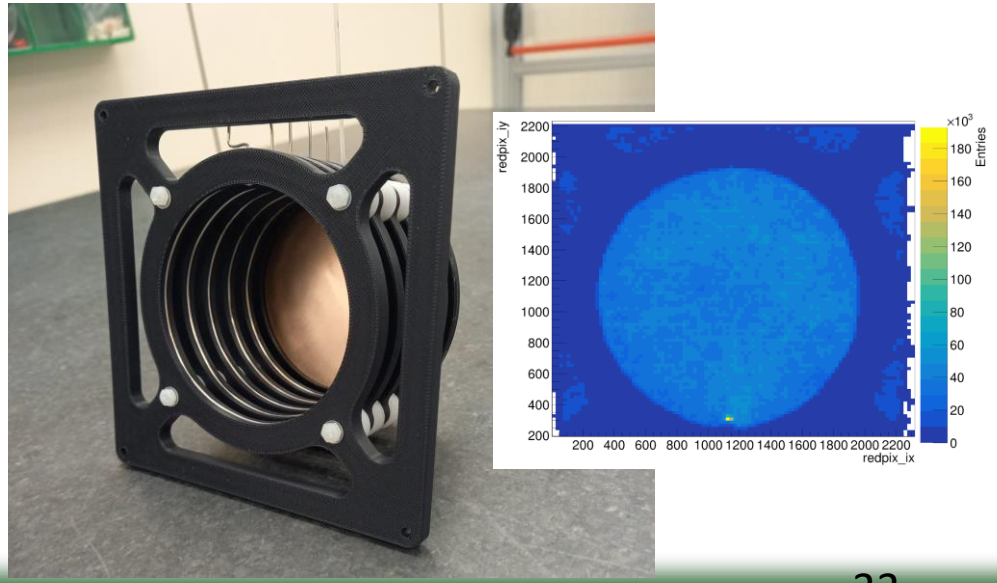
- 2 new cathodes to test
- They were required to be extremely thin to allow X-rays to pass

Kapton + Cu sheet (45+35 um) provided by ELTOS

Tested, works very nicely

Issues with the soldering required on the active

Cu part. Cause of coronas



Cu mesh with 50 um wires

To be tested

GIN 2 Brazil

- As part of the agreement with Brazilian group a copy of GIN was sent there

- Now Luigi and Robertino are installing it in Juiz de Fora (as soon as it passes customs)

Conclusions

- The development and test of the field cage for CYGNO-04 via GIN prototype showed promising results
- With the latest version a uniformity of the field at 1 kV/cm with below 7% asymmetries and a projected corner deformation of 0.1% of the redout area of CYGNO-04
- Stability tests of the support material for the field cage demonstrated no significant damaging of the materials for PET and kapton
- To solve the reflection issues, the oxided GEM under test demonstrating the removal of the shadow
- Longer stability tests of the GEM in operation in the gas will be undertaken
- Defects in some of the CYGNO-04 GEMs was found. They are already at CERN for repair
- Special thanks to

  Robertino, Emiliano, Luigi, Giovanni, Robertone, Daniele, Sandro, Alessandro, Filippo