DRD1
Gaseous Detector Technologies

CERN

Field-Assisted Transparent Gaseous Electroluminescence Multipliers (FAT GEM) - Updates

USC UNIVERSIDADE DE SANTIAGO DE COMPOSTELA

D. Rodas Rodríguez

ASTROCENT
NICOLAUS COPERNICUS ASTRONOMICAL CENTER OF THE POLISH ACADEMY OF SCIENCES

NATIONAL SCIENCE CENTRE POLAND

Funded by the European Union

European Funds Smart Growth

Republic of Poland

FNP Foundation for Polish Science

European Union European Regional Development Fund

Outline

DRD1 Gaseous Detector Technologies

CERN

1. Dark Matter detection challenges
2. Brief FAT-GEM history
3. New production @AstroCeNT
4. Experimental campaign
5. Results
6. Ongoing work
7. Conclusions

National Science Centre Poland

Funded by the European Union

European Funds Smart Growth

Republic of Poland

FNP Foundation for Polish Science

European Union European Regional Development Fund

Dark Matter detection challenges

Dual-phase detectors are a preferred choice in **Dark Matter searches** (XENON, LZ, DarkSide)**.** Detection rely on **electroluminescence** mechanism in the gas phase.

Improving sensitivity:

- **Improving the background rejections**
- **Lower detection threshold**
- Larger exposure (mass x time)

Improve light collection efficiency:

- Ar based detectors → VUV emission → need of WLS
- Meshes and wires widely use as amplification stage:
  - Loss of tension with time
  - Difficult to scale up to large areas
  - Lack of modularity
  - No option of direct coupling to solid WLS
  - Difficulties at extracting e- from the liquid-gas interface

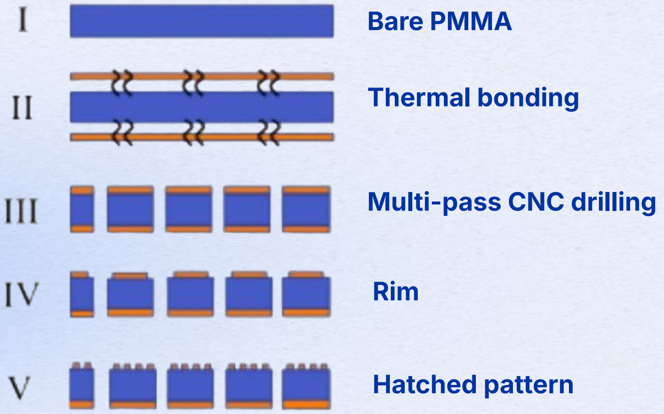
Field Assisted Transparent Gaseous Electroluminescence Multiplier (FAT GEMs)

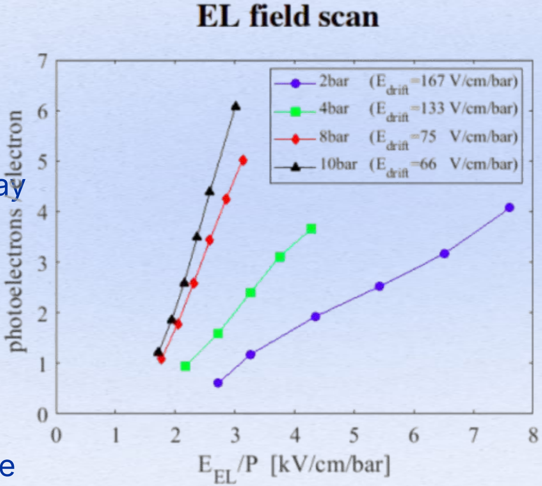
- Integration with **WLS coatings**
- Modular, **tileable**, and **radiopure**
- Robust mechanical design

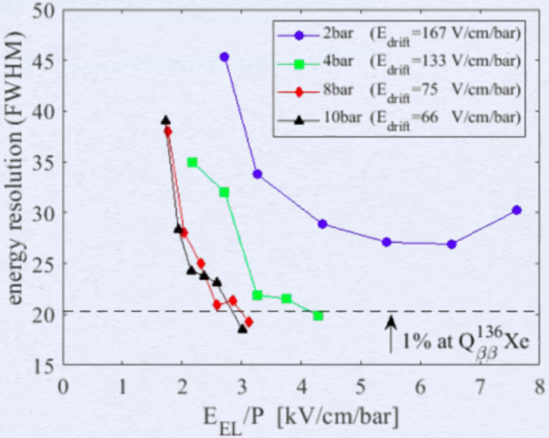
Brief FAT-GEM history (I)

FAT GEMs introduced in **2020**. Originally developed for neutrino-less double beta decay in HP-Xenon

- Intrinsically **radiopure** (based on PMMA and Cu)
- Flexibility to tune optical properties (solid WLS, reflectivity and transmission)
- **Proof-of-principle**: (D. González-Díaz et al., J. Phys. Conf. Ser., 1498 (2020) 012019.)
- Structure inherently **stable** up to 3kV/cm/bar at 10bar (about x2.5 higher voltage than NEXT-NEW)





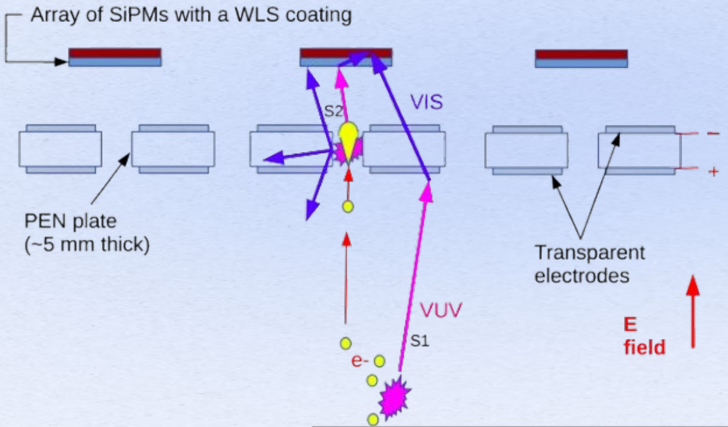


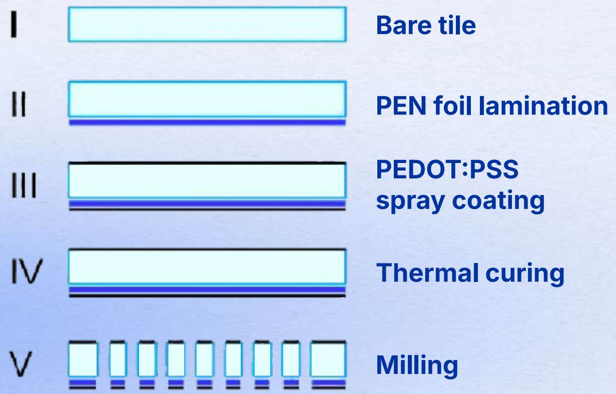
Brief FAT-GEM history (II)

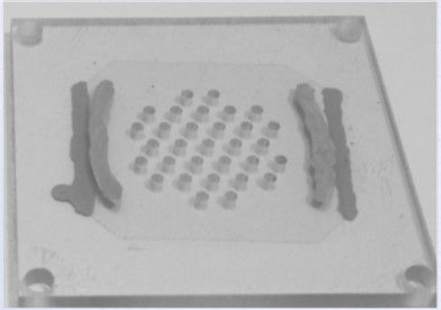
WLS implementation

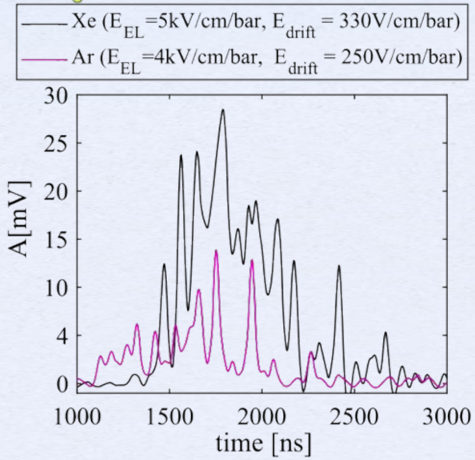
(M. Kuźniak et al., Eur. Phys. J. C, 81 (2021) 609.)

- Use transparent bulk material (PEN) as solid WLS.
- Demonstrated **first operation in Ar with conventional (Ar-blind) photosensors.**





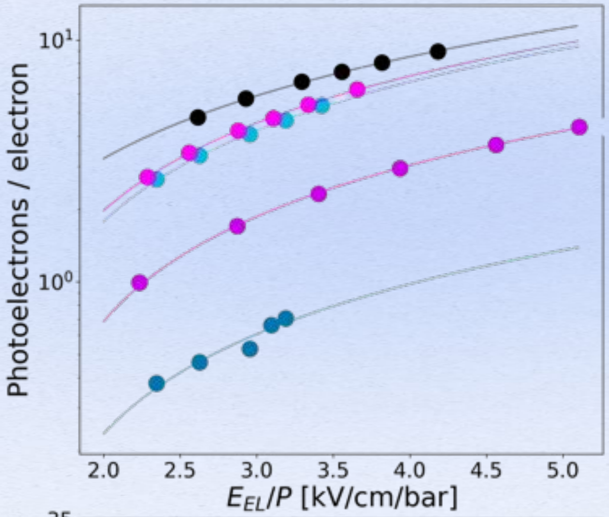


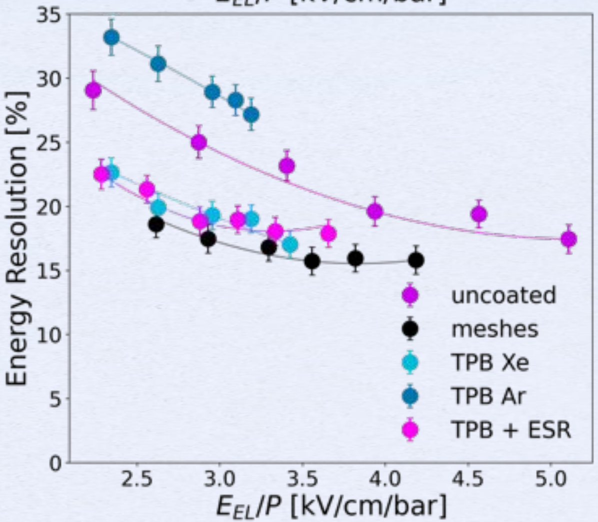


Brief FAT-GEM history (III)

Introduce new procedures: (S. Leardini et al., Sci. Technol. 2 (2024) 1373235.)

- Incorporates reflective (ESR) and transparent ITO films to the structure to enhance light collection.
- New method to evaporate TPB into the holes' walls.
- Demonstrated **performance comparable** to that obtained under **parallel meshes**.

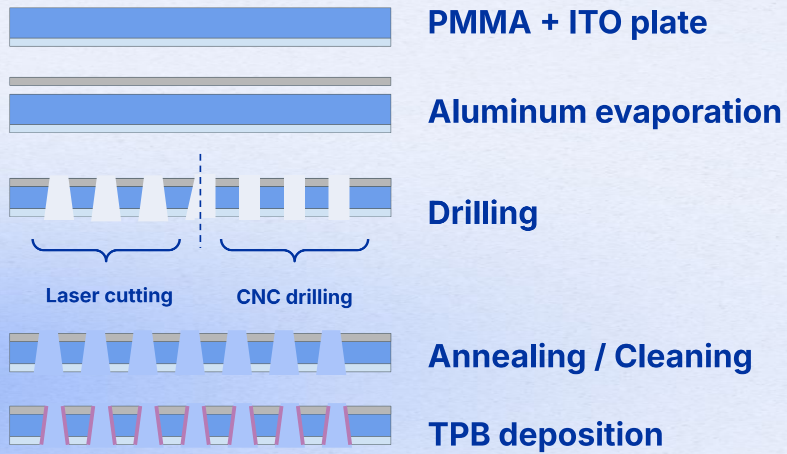




New production @AstroCeNT

Limitations encountered:

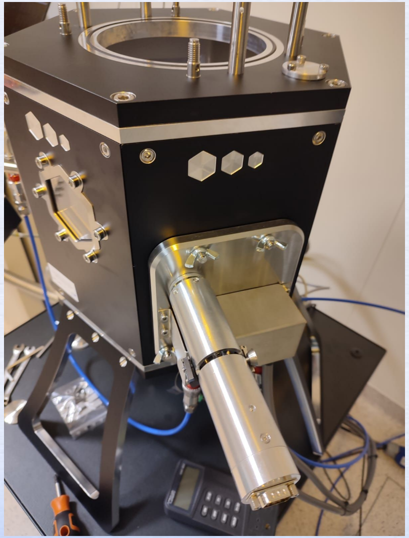
- ESR producing **charging up** of the structure.
- ITO and ESR as an **adhesive film**
- ITO transparency: 80%

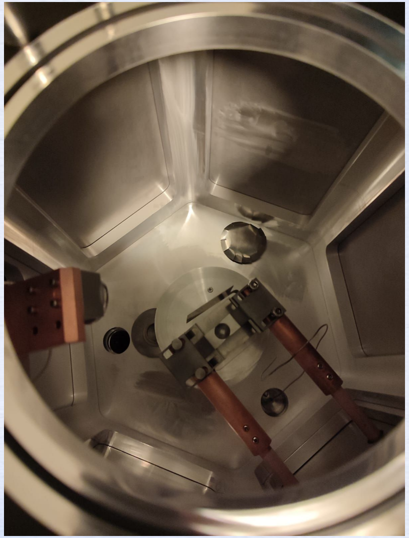


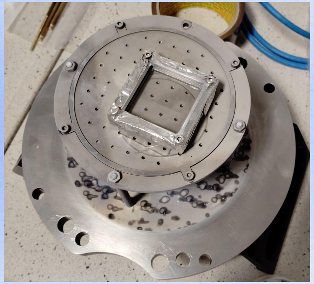
Upgrades from last production:

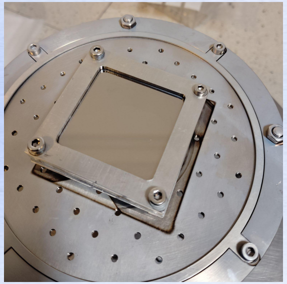
- Replacing ESR for **Aluminum electrode**, removes charging up keeping reflectivity at similar values.
- Adhesive ITO replaced for **magnetron sputtered ITO.**
  - Higher transparency (from 80% to 90%)
- **Laser drilling** instead of CNC drilling.
  - Explore the impact of different hole geometries

Aluminum evaporation



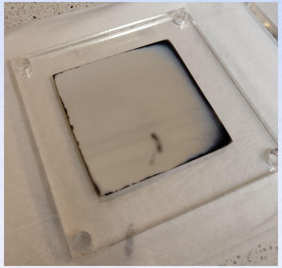


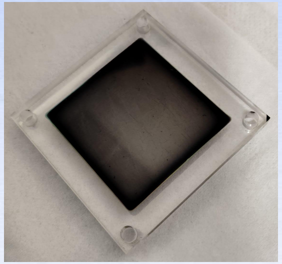




Problems faced:

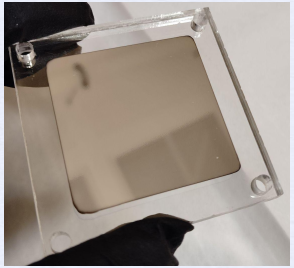
- Dark spots
- Completely black electrode – non reflective





Optimization of evaporator parameters:

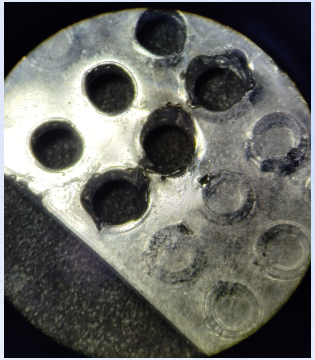
- Vacuum
- Temperature
- **Rate** and thickness
- **Frames**



Laser drilling

Main **advantages**:
- Fully autonomous production
- Easy and fast production
- Try different geometries

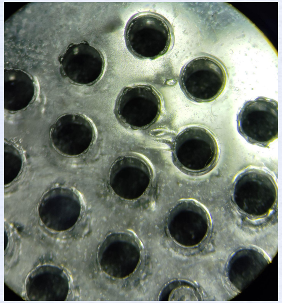
Problems faced:



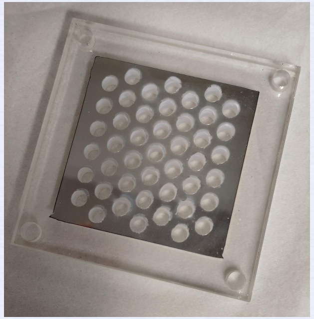
Grid reflections

White spots

Fixed:
Adding a spacer



Fixed:
Laser power and time between holes

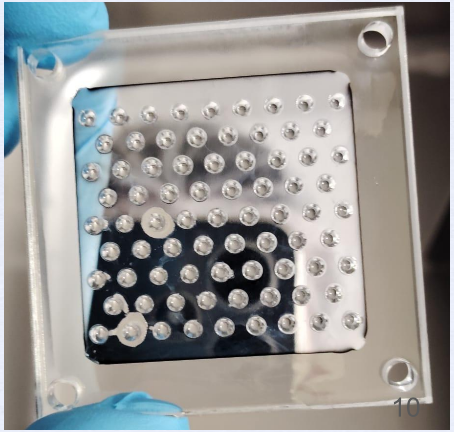


Annealing / Cleaning + TPB deposition

- **Laser drilling** exposes the bulk material to localized high temperatures that produces stress in it. **Annealing** is needed to reduce the stress and recover material properties.

- **CNC drilling** might leave residual oils or other materials in the holes. A cleaning process is needed to reduce impurities.
    - Ultrasonic bath is very aggressive and might end up removing the Aluminum layer.
    - Specific soap and brushes were used.

- **TPB** was deposited in the holes of the structures. However, there might be some uniformities in them.



Experimental Campaign

A batch of structures with different configurations was produced and shipped to **IGFAE**, Spain where it was tested during summer.

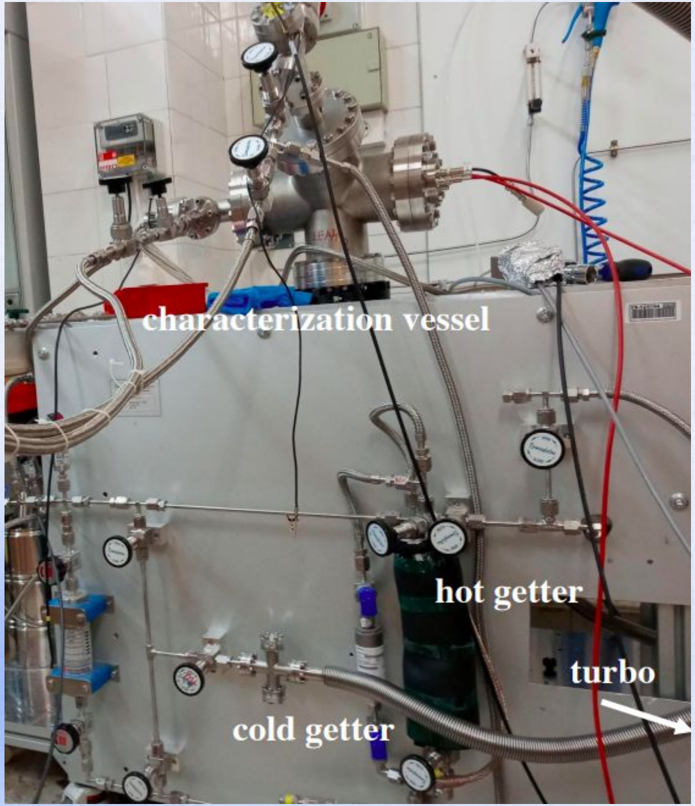
Structure	Size (cm^2)	Hole diameter (mm)	Pitch (mm)
A	5x5	2	4
B	5x5	3	5
C	7x7	2	4

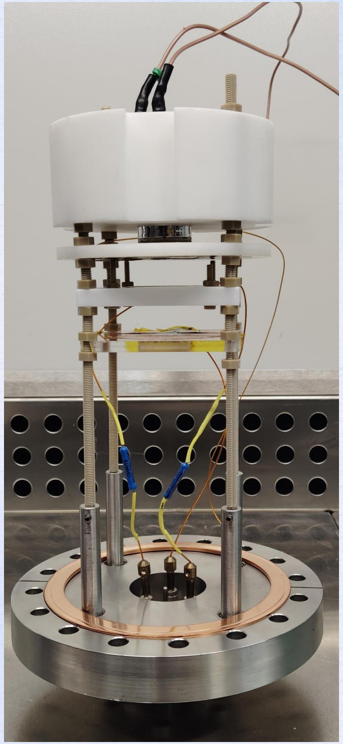
- First step, characterizarin of these structures before cryogenic tests.

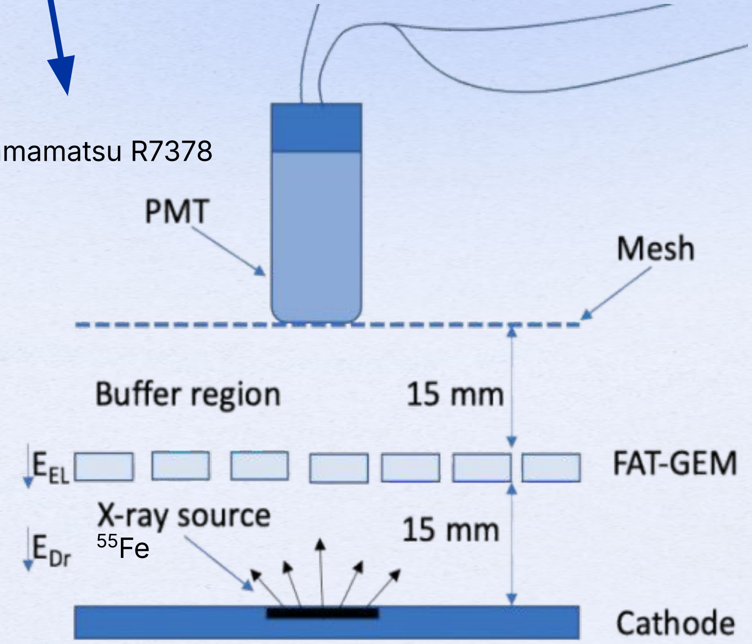
Setup

BLIND TO AR LIGHT

@IGFAE, Spain

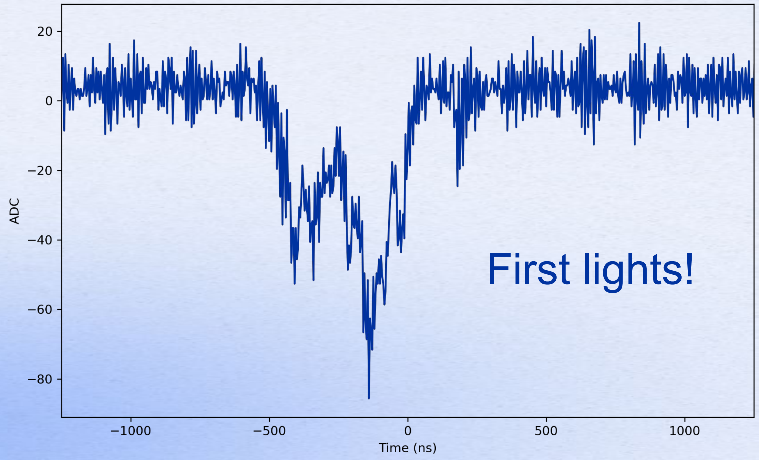




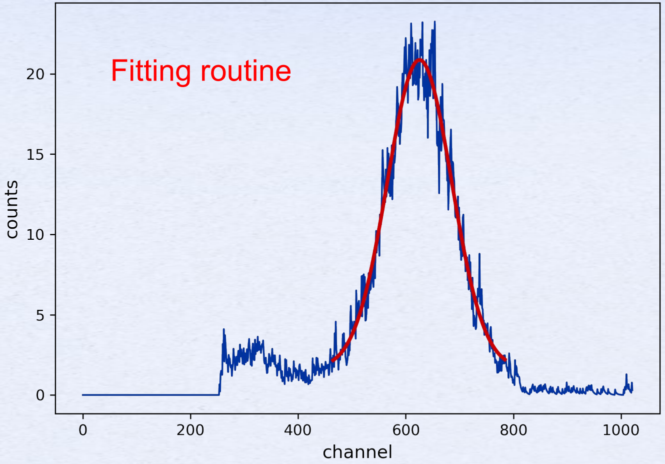


Results

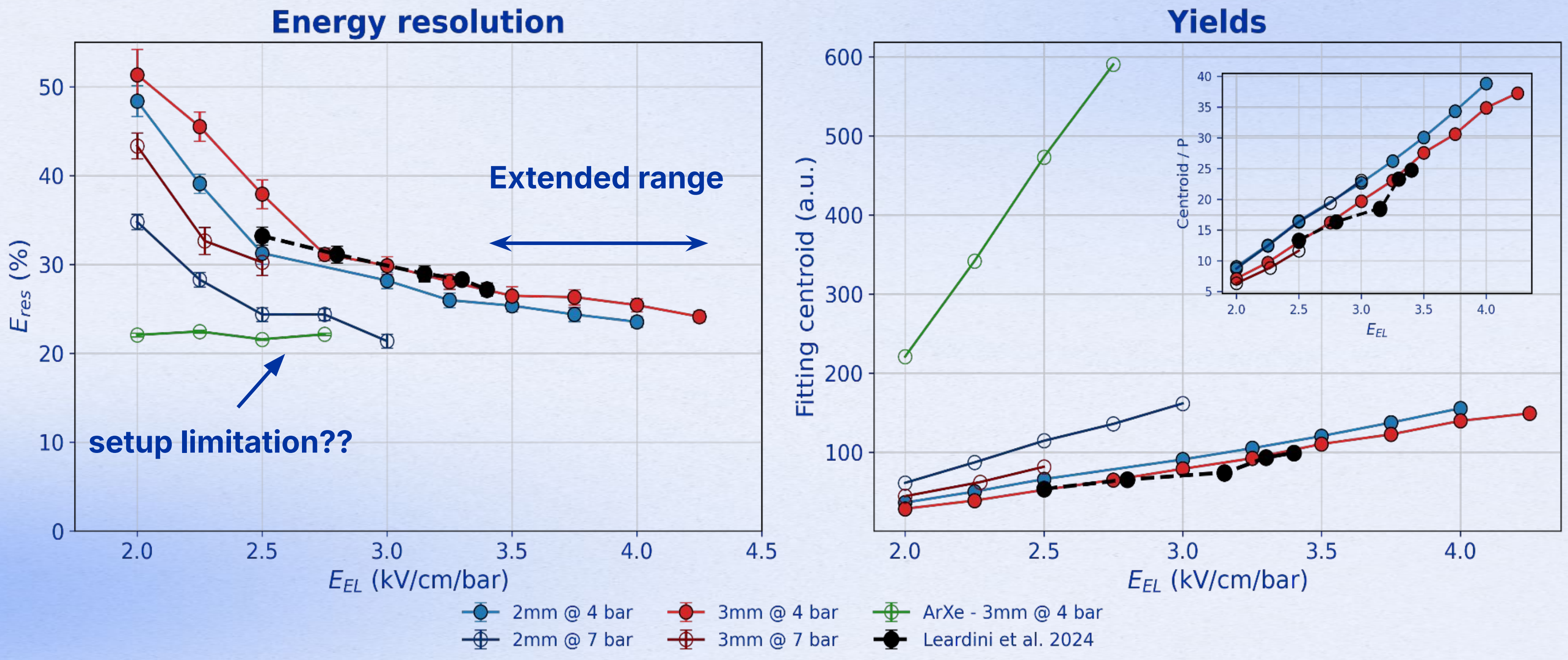
- **Ar** at **4 bar and 293 K** → **equivalent density to cryogenic operation** (1 bar, 87.5 K)
  - Initial commissioning was done in Ar/Xe (99/1) at 4 bar.
  - Cold getter used to purify Ar



Pre-amplifier
+
Amplifier
+
MCA



Results


Energy resolution
Extended range
setup limitation??
E_{res} (%)
E_{EL} (kV/cm/bar)
Yields
Fitting centroid (a.u.)
Centroid / P
E_{EL}
E_{EL} (kV/cm/bar)
2mm @ 4 bar
2mm @ 7 bar
3mm @ 4 bar
3mm @ 7 bar
ArXe - 3mm @ 4 bar
Leardini et al. 2024

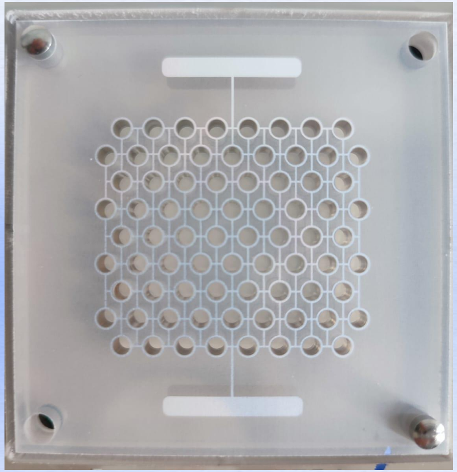
A B

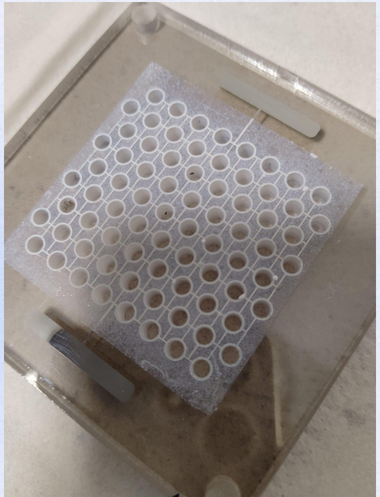
Ongoing Work

Batch of structures produced ar CERN Workshop are being tested right now at IGFAE

- **Semi-transparent electrode** allowing for S1 detection
- First tests with 5.5 MeV alpha source
- **Smooth operation**, no strong indication of charging-up from TPB at the FAT-GEM cathode

S1 !!





Ongoing Work

- Batch of structures produced ar CERN Workshop are being tested right now at IGFAE
  - **Semi-transparent electrode** allowing for S1 detection

- New batch of structures produced at AstroCeNT to be tested in Warsaw in **cryogenic conditions** as a first approach to dual-phase applications.

- **Simulations**:
  - Optimize optical response (WLSE and light collection)
  - Understand effects of hole size variations and shapes in detector response.

ArGset @CEZAMAT

Conclusions

- A revision of the fabrication process of FAT GEMs was undertaken at AstroCeNT facilities:
    - ITO adhesive film replaced by magnetron sputtered ITO (improved transparency from 80% to 90%).
    - Replacing ESR adhesive film for evaporated Aluminum (eliminates charging up keeping similar reflectivity).
    - Replacing CNC for laser drilling.

- FAT GEM performance improves over previous structures with room for improvement (optimization of TPB evaporation - WLS eff 40-50% from simulation).

- A second production batch at CERN made with a semitransparent cathode.

Thank you!

D. Rodas Rodríguez[1,2], A. F. V. Cortez[1], M. Kuźniak[1], A. Gnat[1], G. Nieradka[1], T. Sworobowicz[1], P. Amedo[2], D. González-Díaz[2], C.D.R. Azevedo[3], K.F. Floethner[4], P. Gasik[5,6], C.M.B. Monteiro[7], R. Oliveira[4], V. Peskov[4], J.M.F. dos Santos[7],J.Llerena[2], D.Tenreiro[2], E. Alario[2], A. Pallas[2]

[1]Astrocent, Nicolaus Copernicus Astronomical Center of the Polish Academy of Sciences, Warsaw, Poland.
[2] Universidade de Santiago de Compostela (USC), Santiago de Compostela, Spain.
[3]Institute of Nanostructures, Nanomodelling and Nanofabrication (i3N), Universidade de Aveiro, Aveiro, Portugal.
[4]CERN, Esplanade des Particules 1, Meyrin, Switzerland.
[5]GSI Helmholtzzentrum für Schwerionenforschung GmbH (GSI), Darmstadt, Germany.
[6]Facility for Antiproton and Ion Research in Europe GmbH (FAIR), Darmstadt, Germany.
[7]LIBPhys-UC, Department of Physics, University of Coimbra, Portugal.

NATIONAL SCIENCE CENTRE POLAND

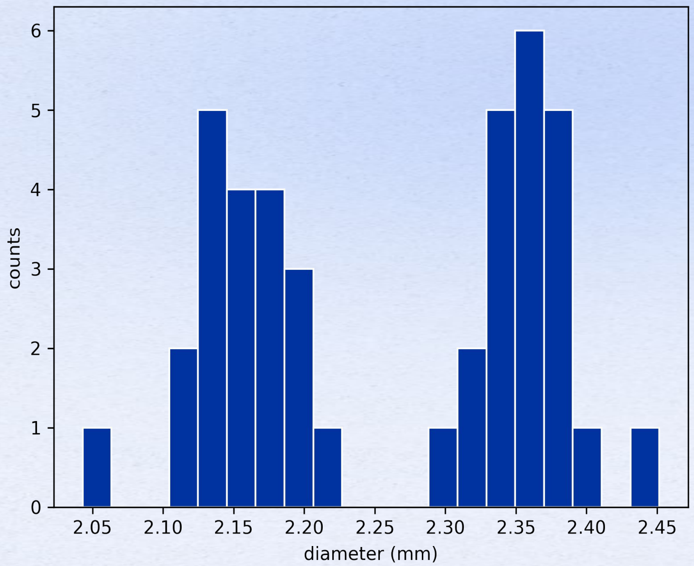
Funded by the European Union | European Funds Smart Growth | Republic of Poland | FNP Foundation for Polish Science | European Union European Regional Development Fund

Laser drilling

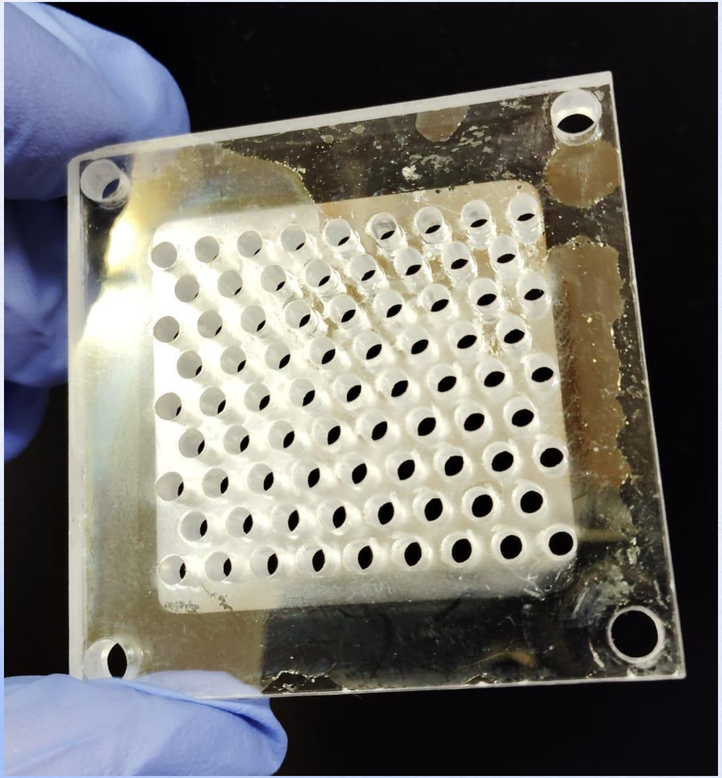
Main **advantages**:

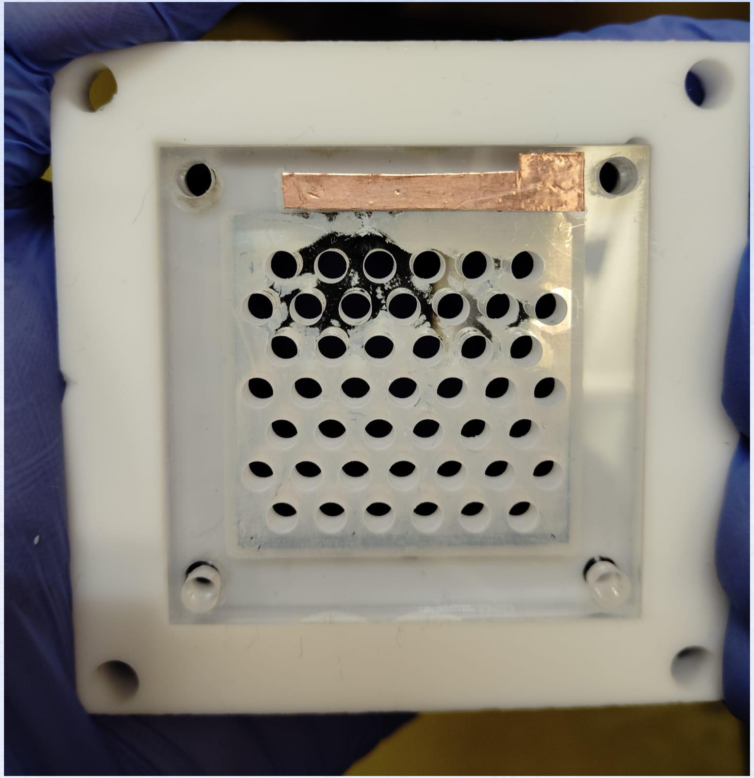
- Fully autonomous production
- Easy and fast production
- Conical holes (?)

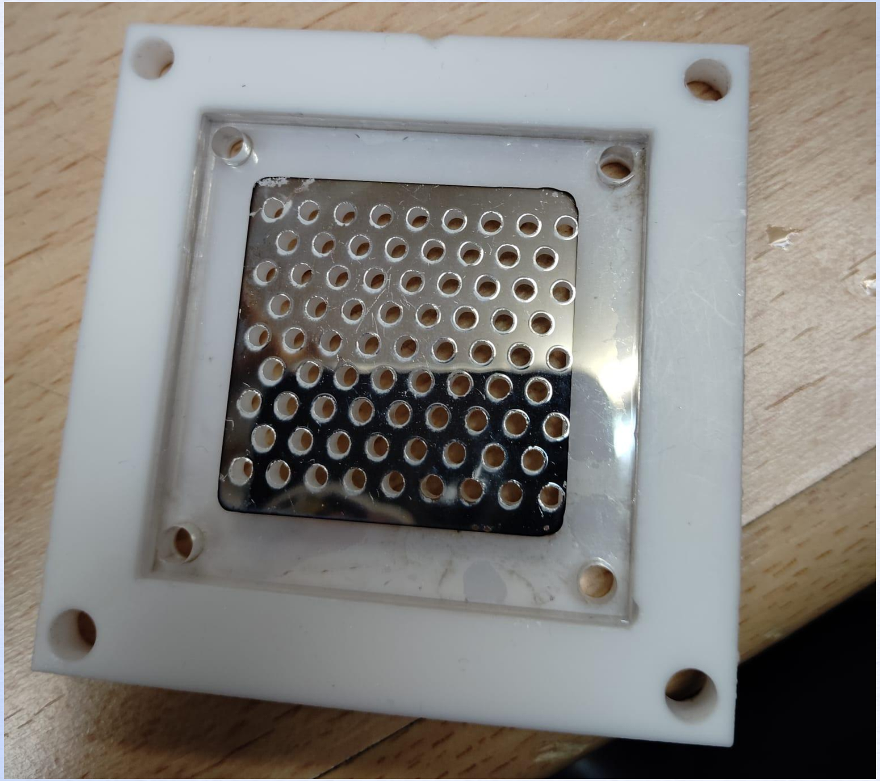
Hole size characterization

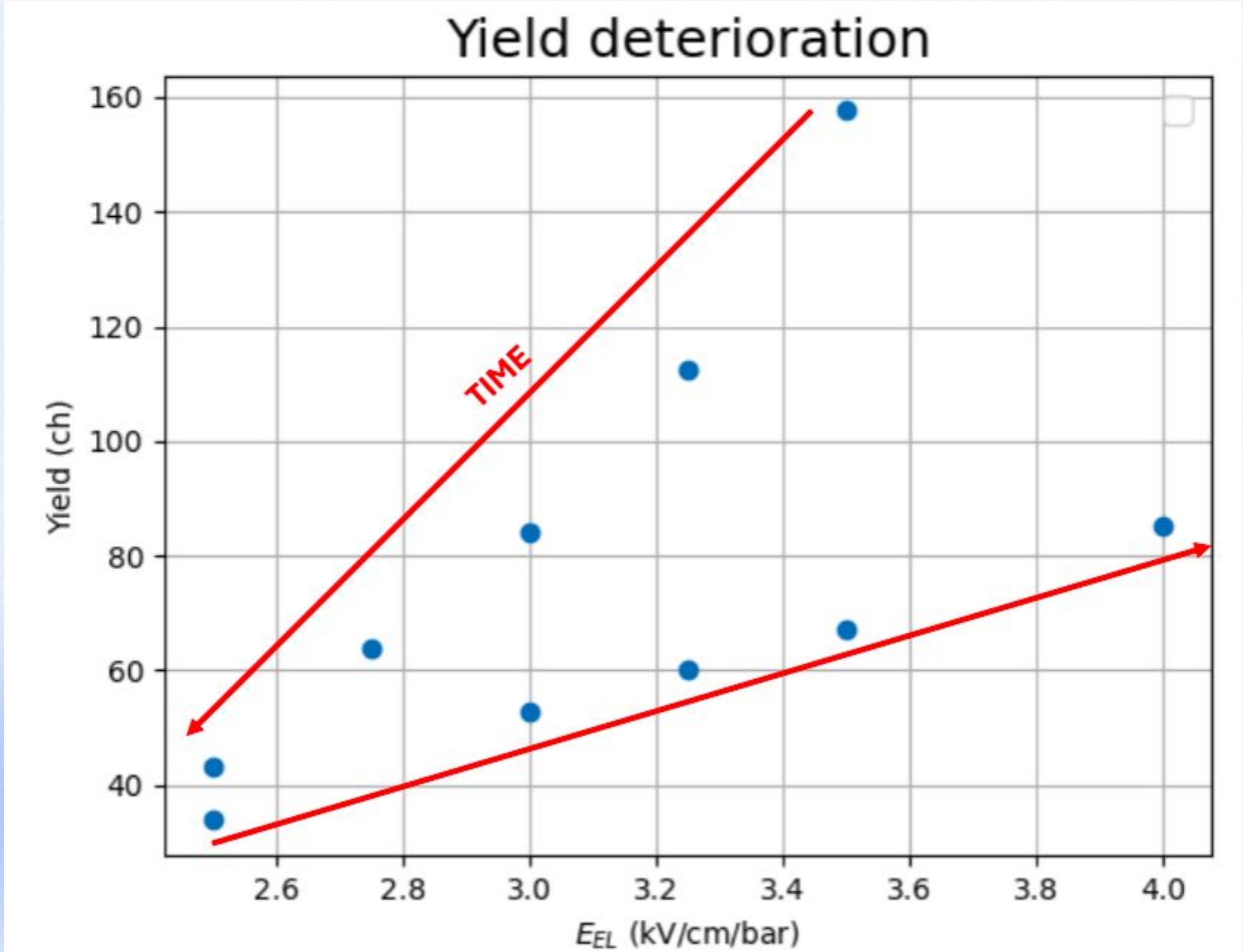


- **Side down**: 2.157 ± 0.034 (mm)
- **Side up**: 2.358 ± 0.026 (mm)









Yield deterioration
Yield (ch)
160
140
120
100
80
60
40
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0
E_{EL} (kV/cm/bar)
TIME