Rugged and radiopure amplification structures for large-area xenon chambers read out through electroluminescence

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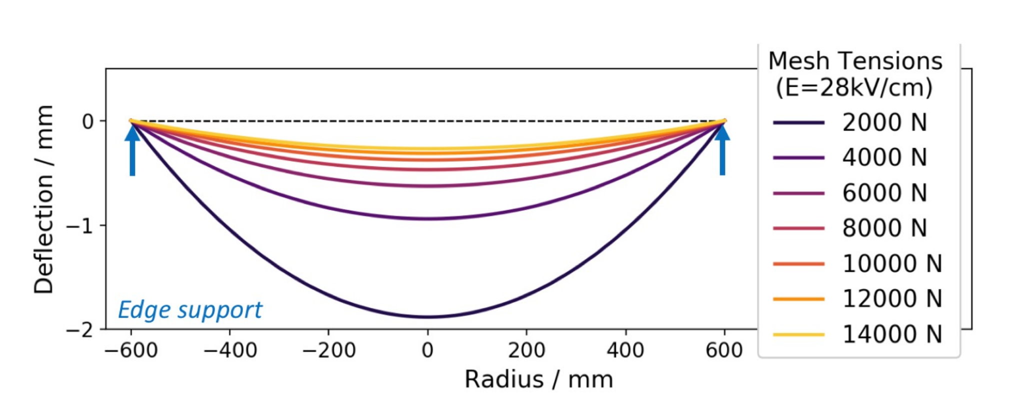
IGFAE Instituto Galego de Física de Altas Enerxías
European Union
ASTROCENT

State – of – art

- Meshes (woven, calendered, electroformed, or set as an array of wires) are widely used as secondary scintillation structures in the field of rare event searches
- Excellent energy resolution and ability to detect single-electrons
- Difficult scalability



Rogers et al., 2018 *JINST* **13** P10002

Loss of tension

mesh-stretching on large areas is complicated

vulnerability to weak points

lack of modularity complicates testing

State – of – art

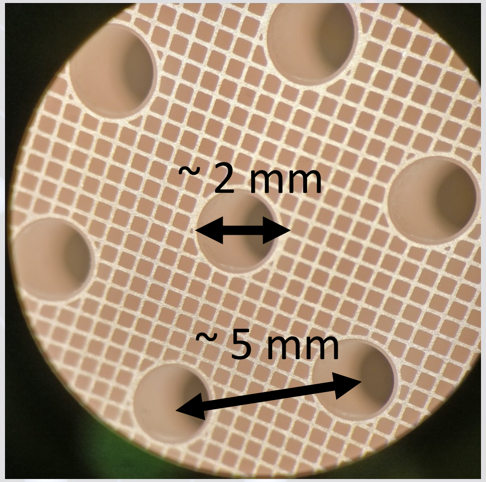
IDEA -> FATGEMs
(Field-Assisted Transparent Gaseous Electroluminescence Multiplier)

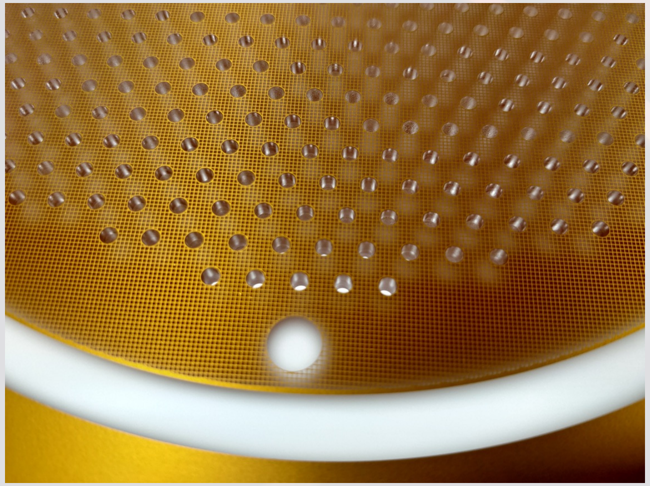
- Scalability
- Radiopurity
- Transparent to scintillation

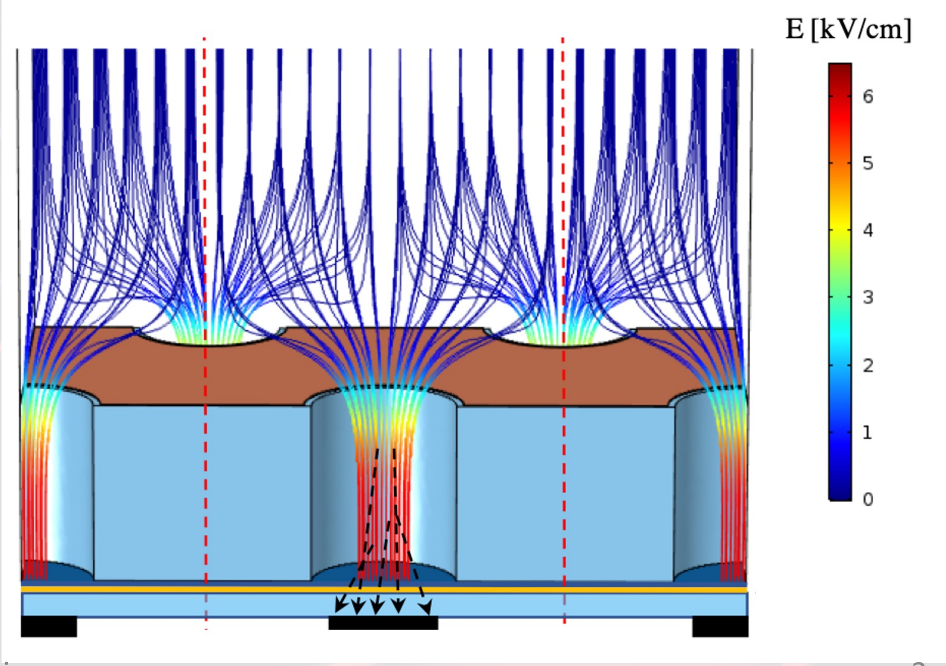
- Similar version but with opaque (Teflon) substrate developed in:

https://www.sciencedirect.com/science/article/pii/S0168900217309828?via%3Dihub

AXEL (talk tomorrow)



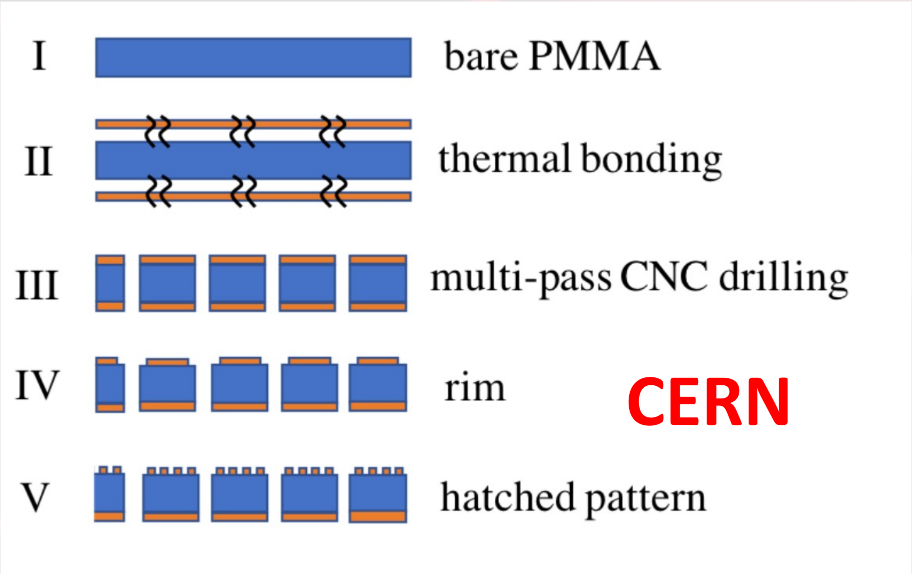




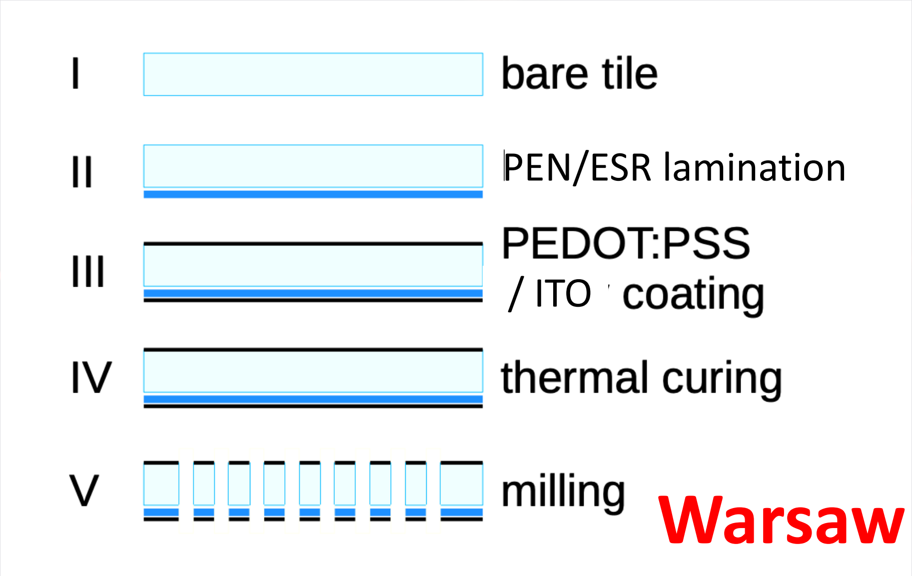
Saa et al., JOURNAL OF SYNCHROTRON RADIATION, 2021, Volume 28, Part 5

How it’s made

- Machined at CERN
  and at AstroCeNT/CAMK PAN (Poland)
- Bulk made of PMMA (Polymethyl methacrylate) or PEN (polyethylene naphtalate)
- Thermally bonded electrodes / Pedot or ITO coating
- Area up to 50 cm x 50 cm at least (easily tiled)
- Thickness = 5 mm (!)
  (important for high electroluminescence yields)



D. González-Díaz et al 2020 J. Phys.: Conf. Ser. 1498 012019



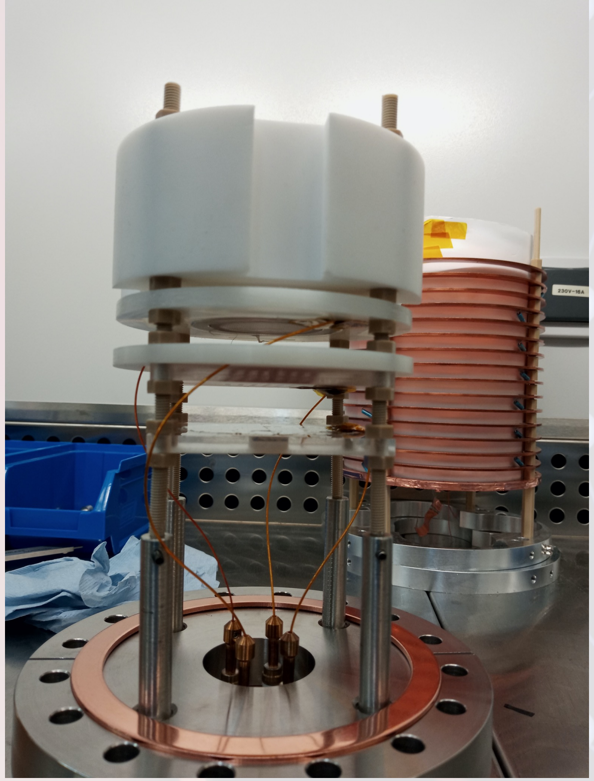
Kuzniak et al., The European Physical Journal C volume 81, Article number: 609 (2021)

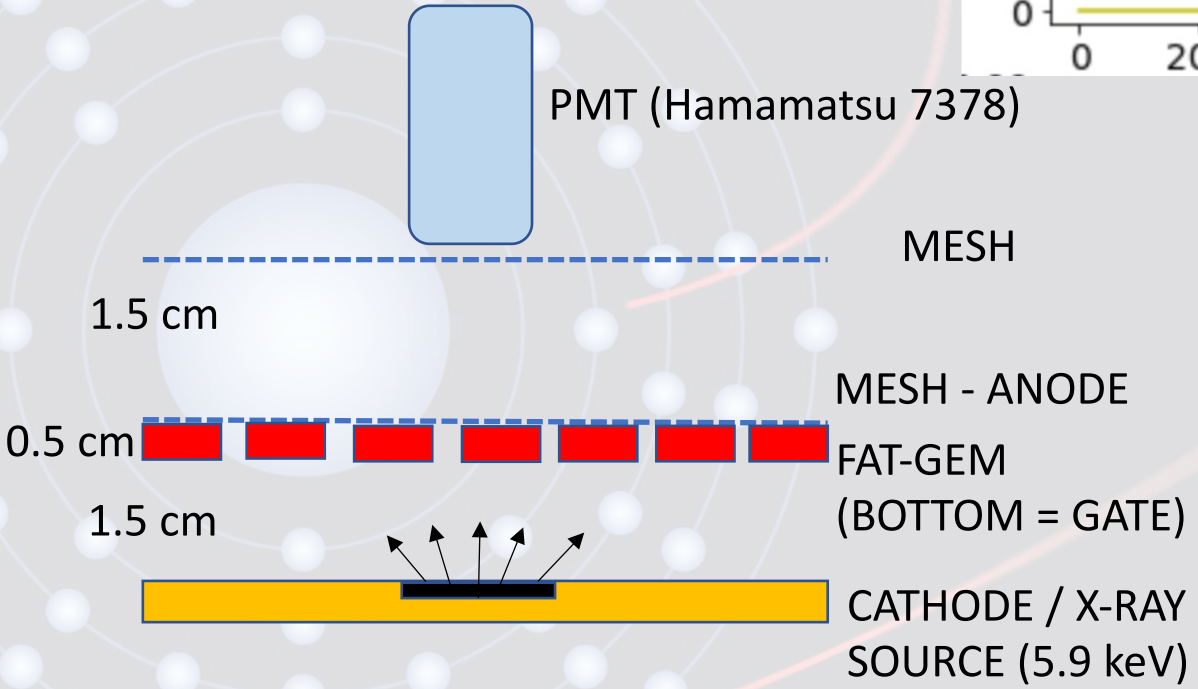
Radiopurity

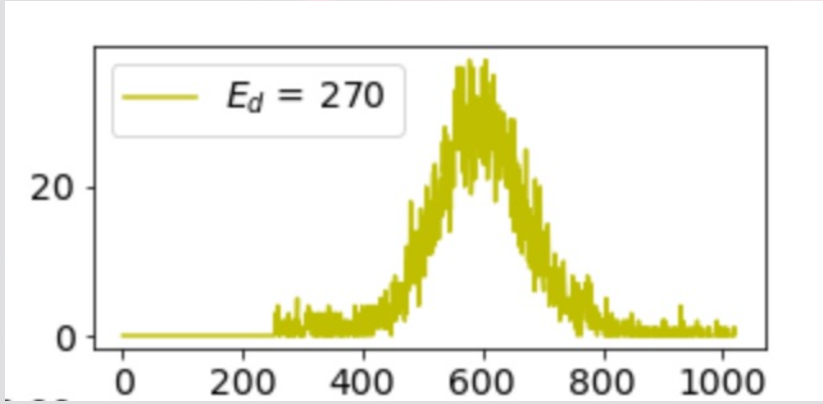
- Radiopurity of FAT-GEM studied at Canfranc Underground Laboratory (thanks to I. Catalin Bandac and S. Cebrián)
- No isotope was detected in 47.7 days!

	Acrylic (mBq/kg)	FAT GEM (mBq/cm^2)
U-238/Pa-234m	<340	<0.741
U-238/Pb-214	<2.8	<0.006
U-238/Bi-214	<2.3	<0.007
Th-232/Ac-228	<8.8	<0.021
Th-232/Pb-212	<2.9	<0.007
Th-232/Tl-208	<6.3	<0.014
U-235/U-235	<1.9	<0.006
K-40	<17	<0.036
Co-60	<0.74	<0.002
Cs-137	<1.1	<0.002

Setup - detail

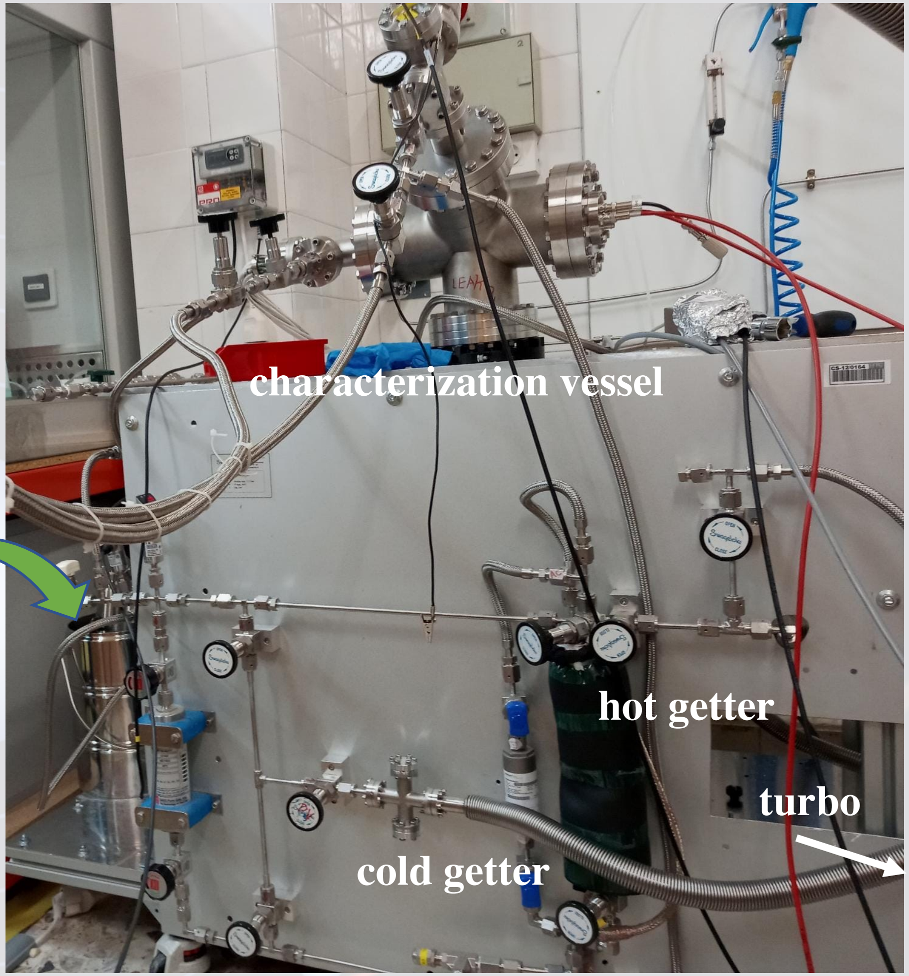






Signal sent to pre-amplifier (ORTEC 142) + amplifier (ORTEC 572A) chain and recorded through an MCA (Amptek 8000D)

Setup- overview



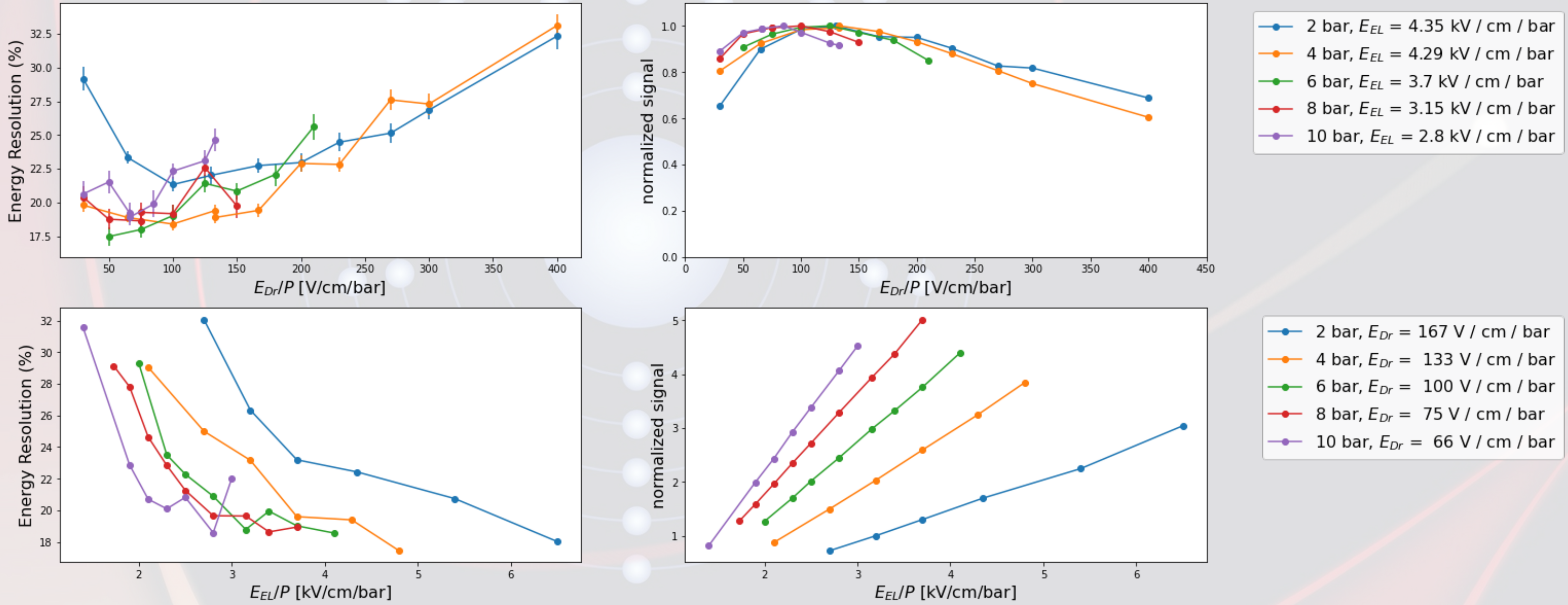
Experimental campaign

- Data taken with 2, 4, 6, 8 and 10 bar of Xenon, 5.9 keV Fe source

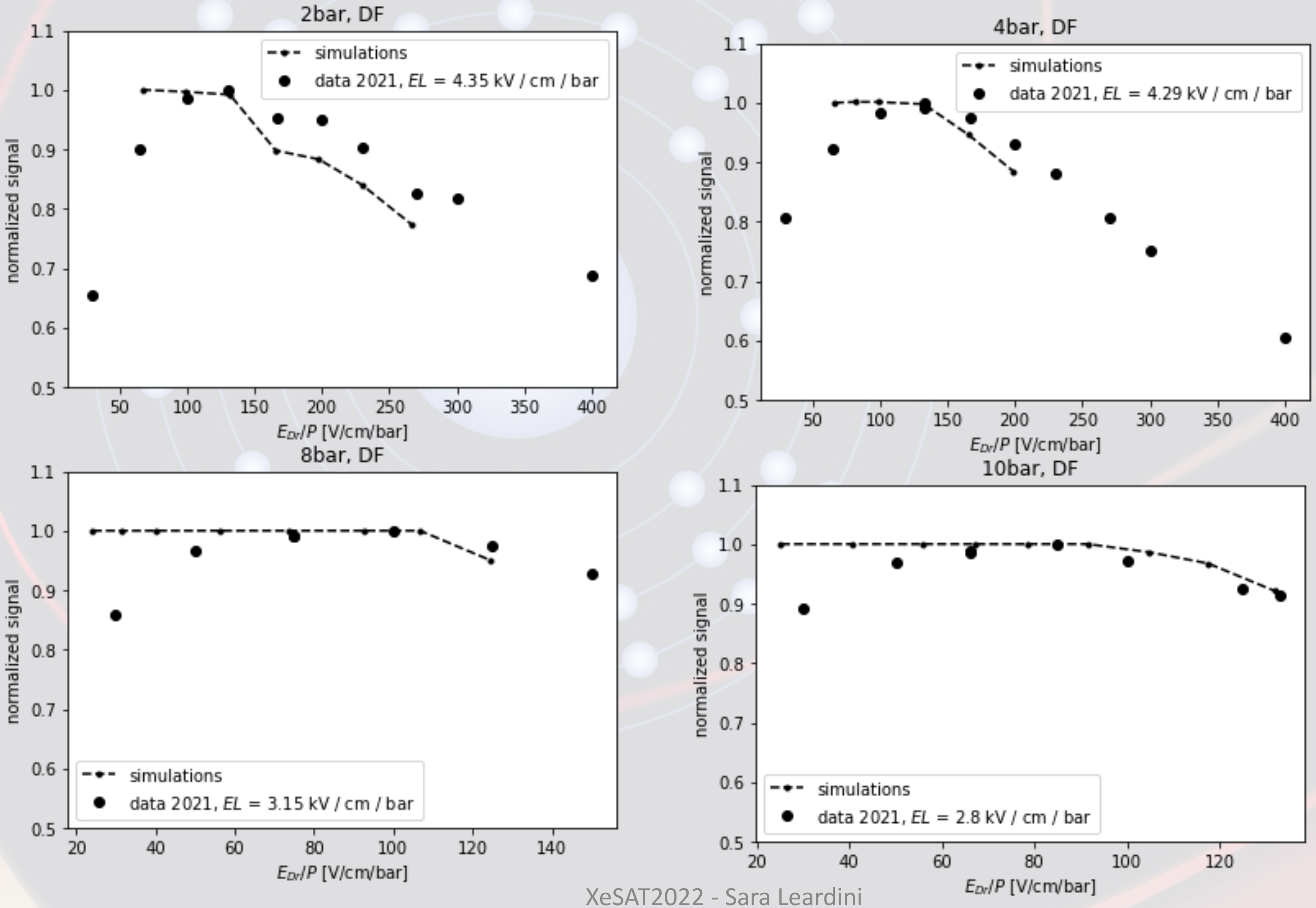
- Structures studied:
  - 2 mm hole, 5 mm pitch
  - 3 mm hole, 5 mm pitch
  - 4 mm hole, 6 mm pitch

- Procedure:
  - scan of drift field with a fixed electroluminescence field (E_{EL})
  - find the optimal drift field (E_{Dr})
  - scan of E_{EL}

2 mm hole structure

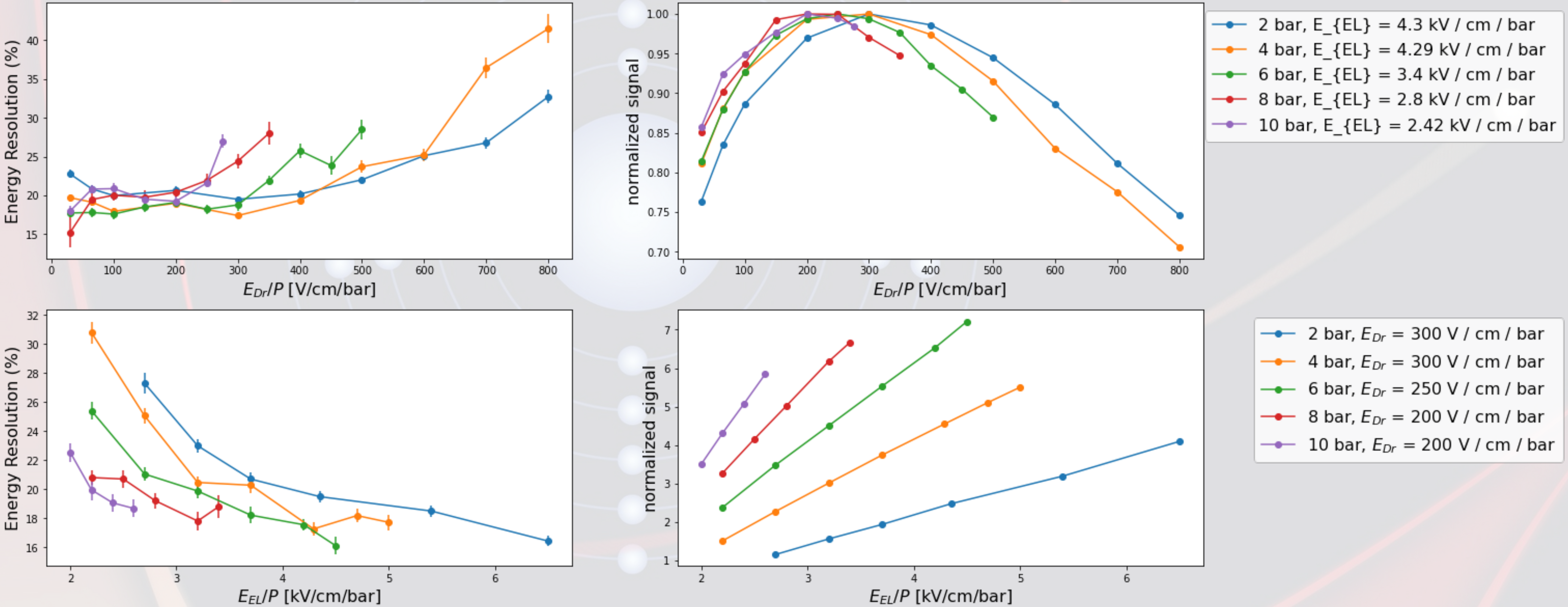


Comparison with simulations – 2 mm hole

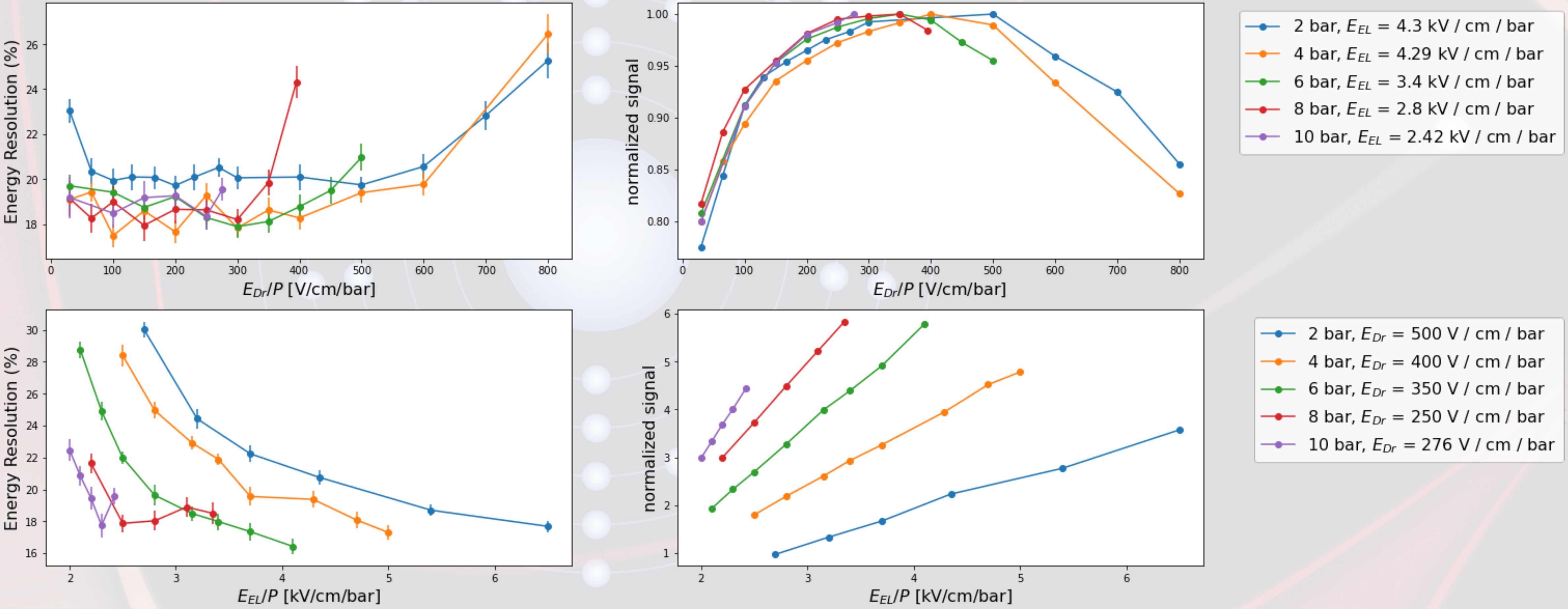


PRELIMINARY

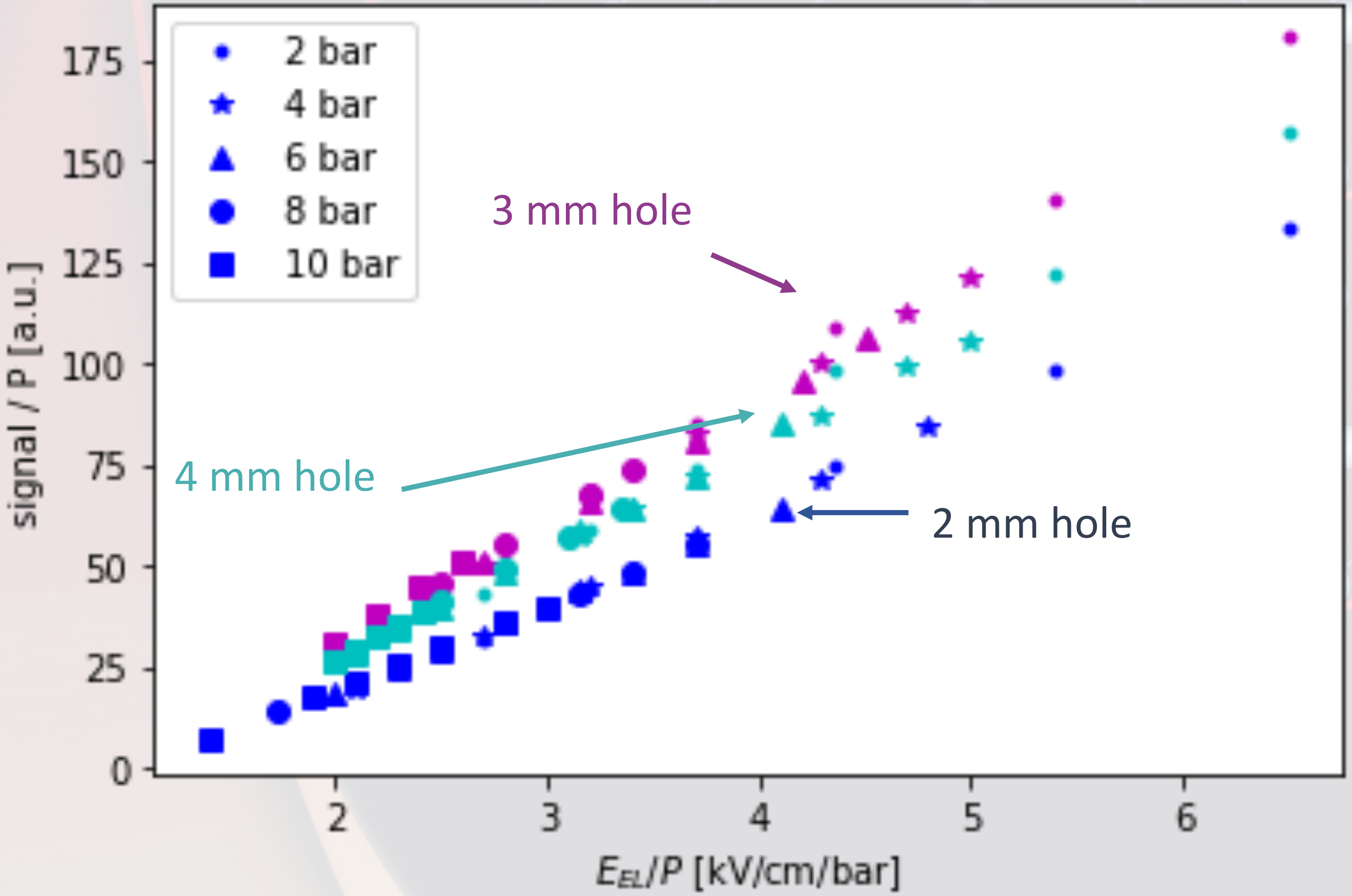
3 mm hole structure

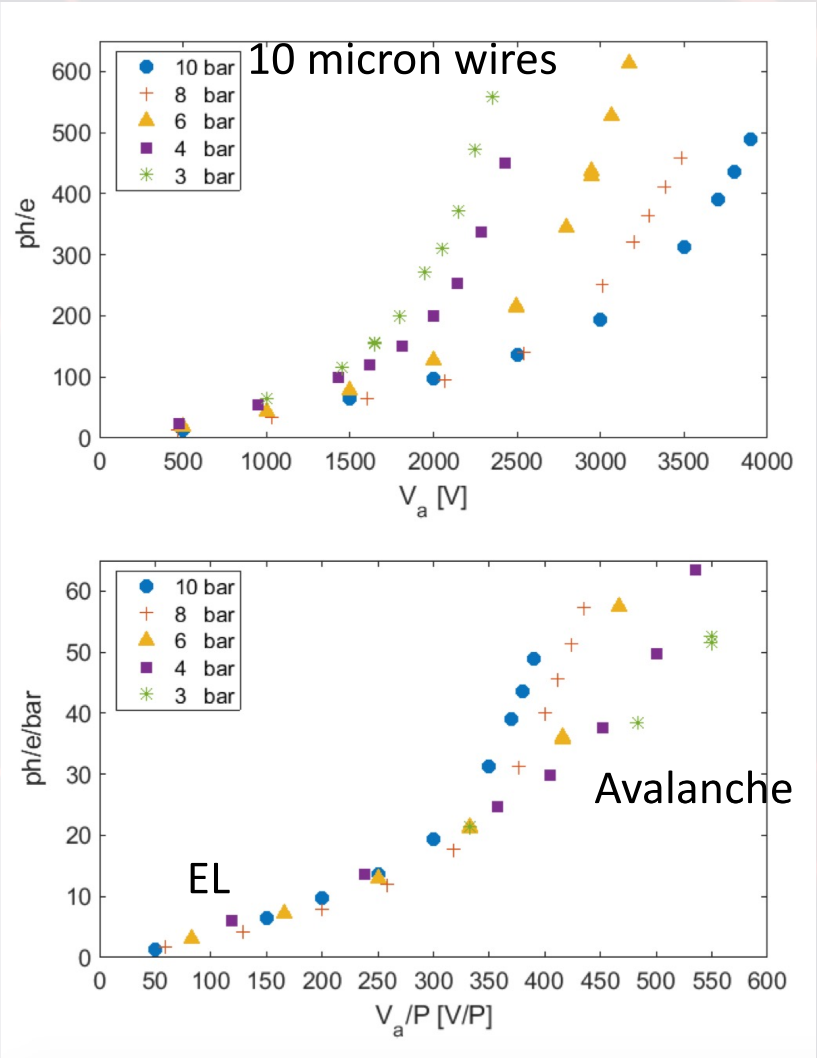


4 mm hole structure



Yields comparison between the 3 structures at different pressures





Leardini et al., Eur. Phys. J. C (2022) **82**: 425

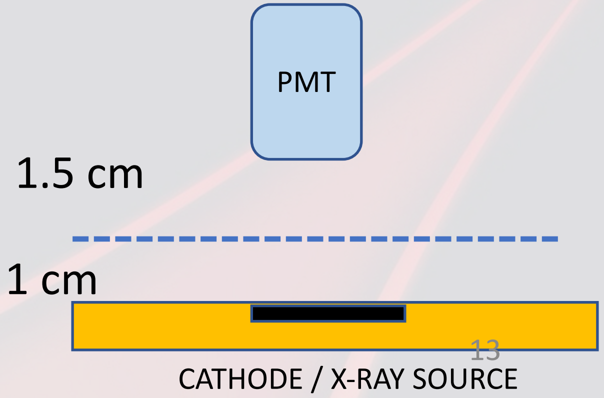
Further studies

- Changed other variables:

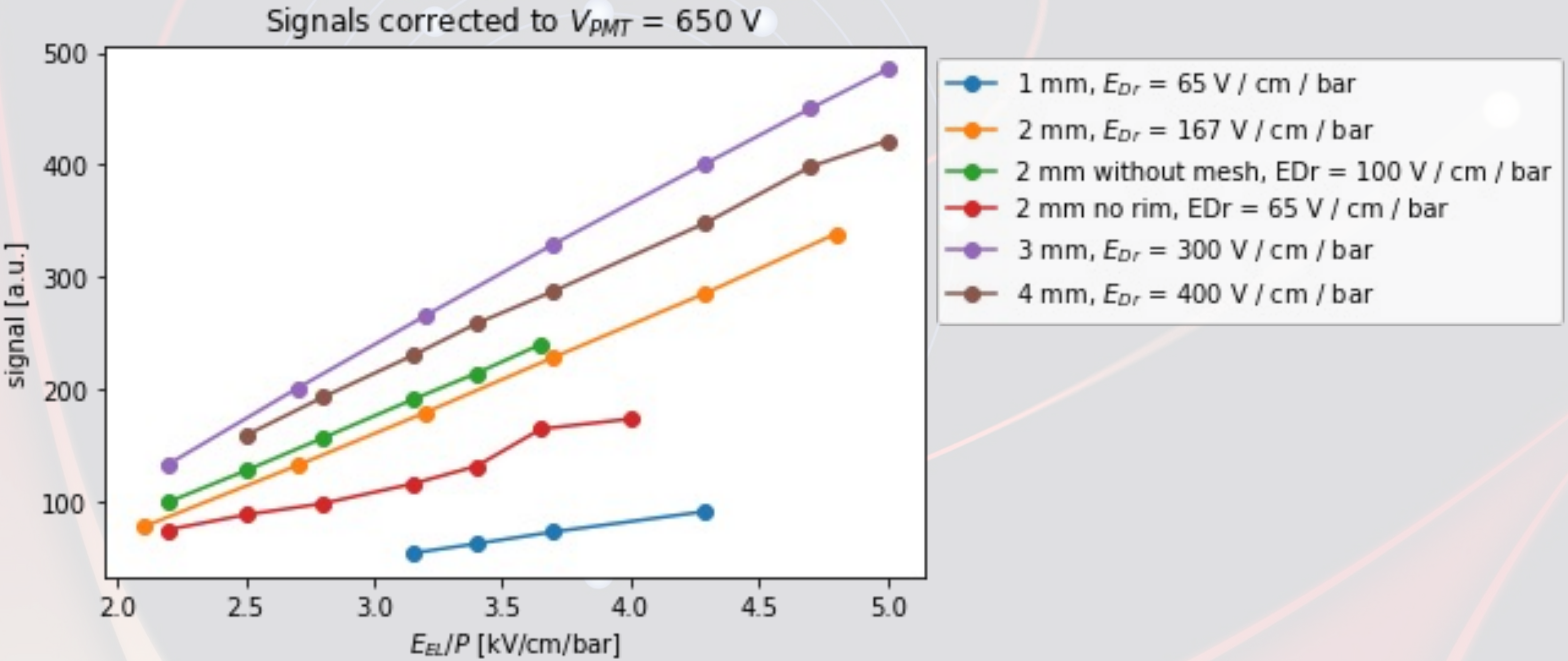
- Removed anode mesh (2 mm holes)
- Structure with no rim (2 mm holes)
- Structure with 1 mm holes

} @ 4 bar

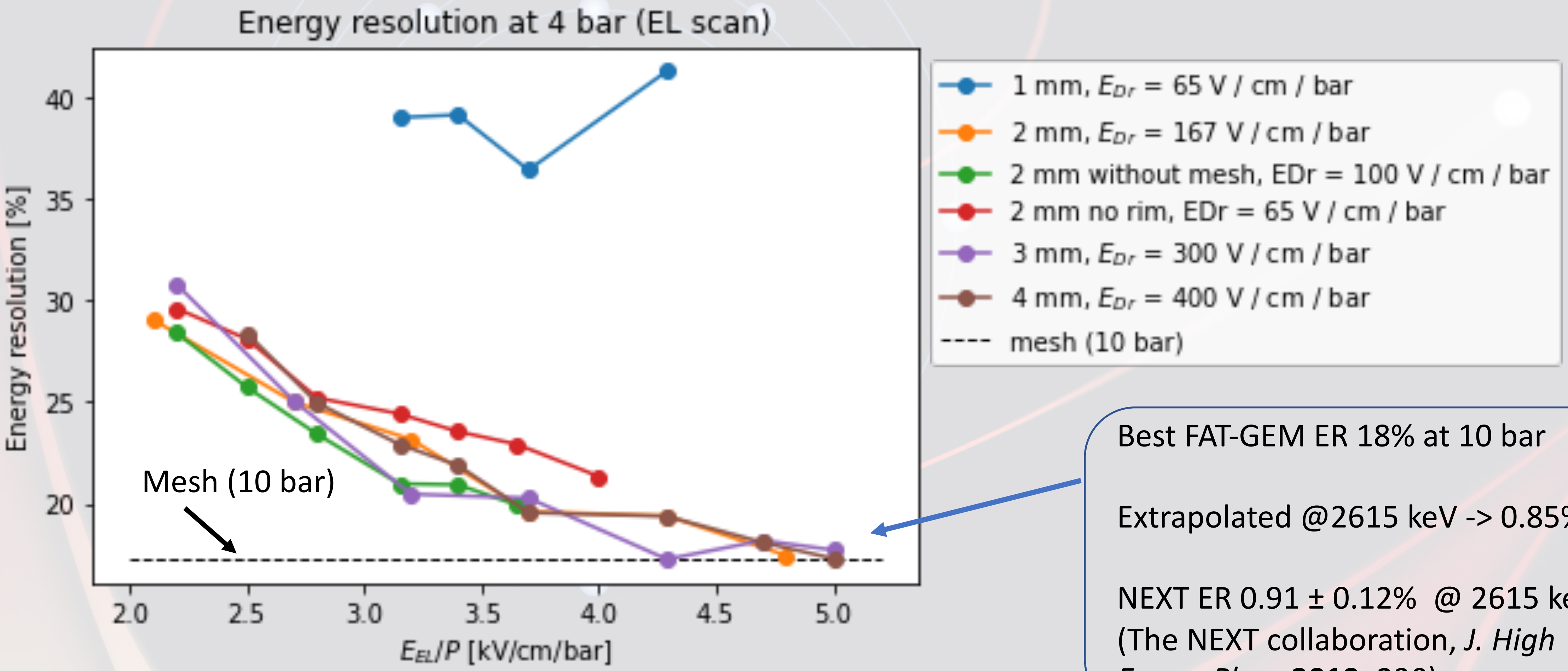
- Comparison with mesh performance (10 bar)



EL yields – all structures



EL energy resolution – all structures



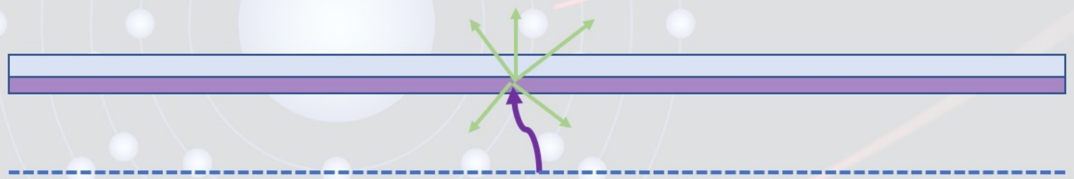
Best FAT-GEM ER 18% at 10 bar

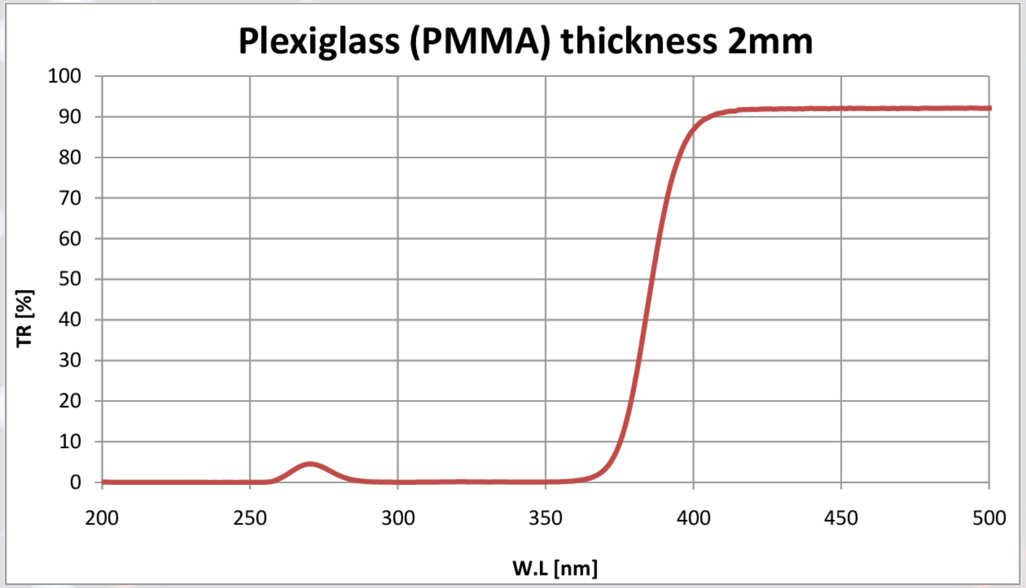
Extrapolated @2615 keV -> 0.85%

NEXT ER 0.91 ± 0.12% @ 2615 keV
(The NEXT collaboration, *J. High Energ. Phys.* **2019,** 230)

VUV transparent FAT-GEMs

- PMMA itself not transparent to VUV
- For Argon PMMA + TPB used for wavelength shifting after mesh -> isotropic emission -> 50% loss at the TPB plane and 50% loss at the production point





Joram, 2009, PH-EP-Tech-Note-2009-003

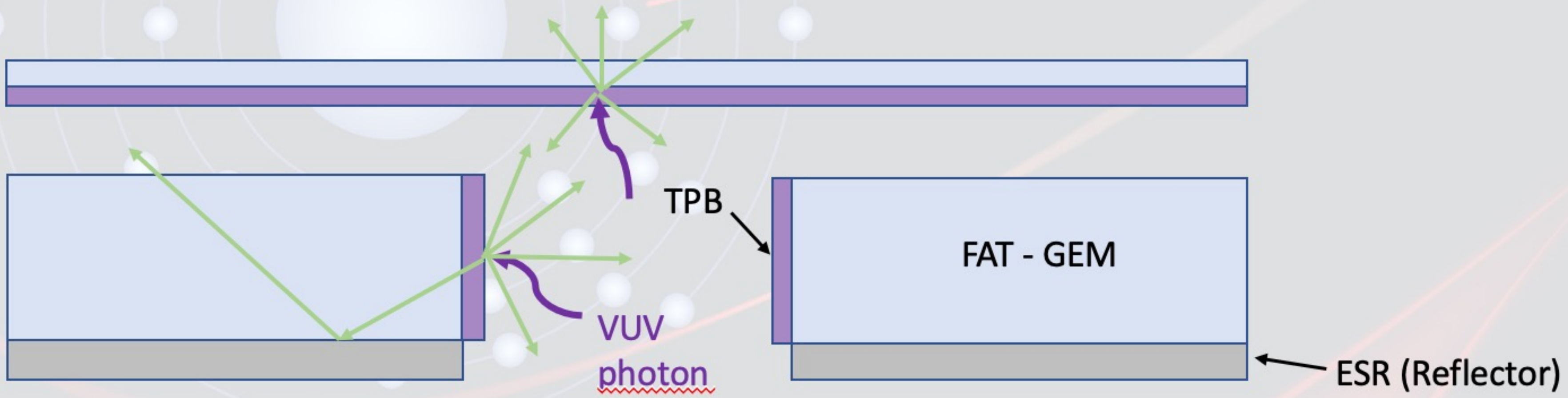
Coating FAT-GEM holes with TPB -> light collection x1.8 with respect to mesh configuration

VUV transparent FAT-GEMs- 2

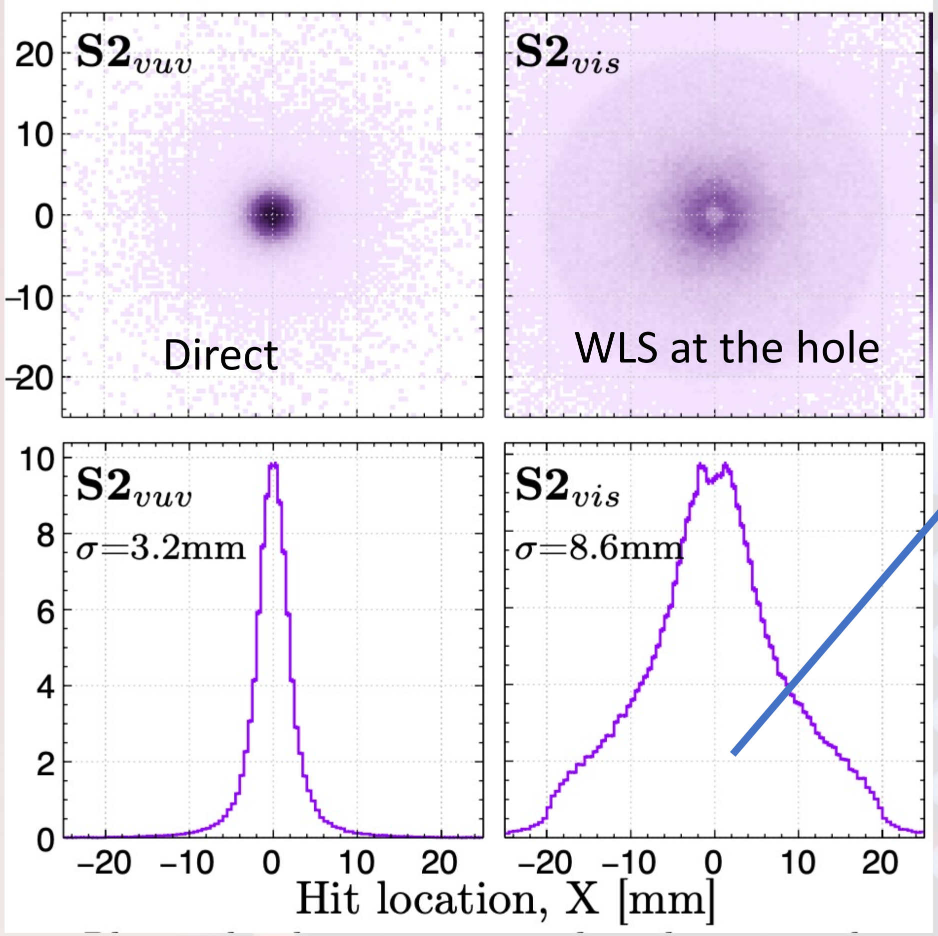
- Possible to add a reflector layer -> improves light collection x2.9 with respect to mesh configuration (according to Geant4 simulations)

Nphe_FATGEM = Nph(VUV) * WLSE * QE + Nph(VIS) *QE

Nphe_mesh = Nph(VUV) * WLSE * QE

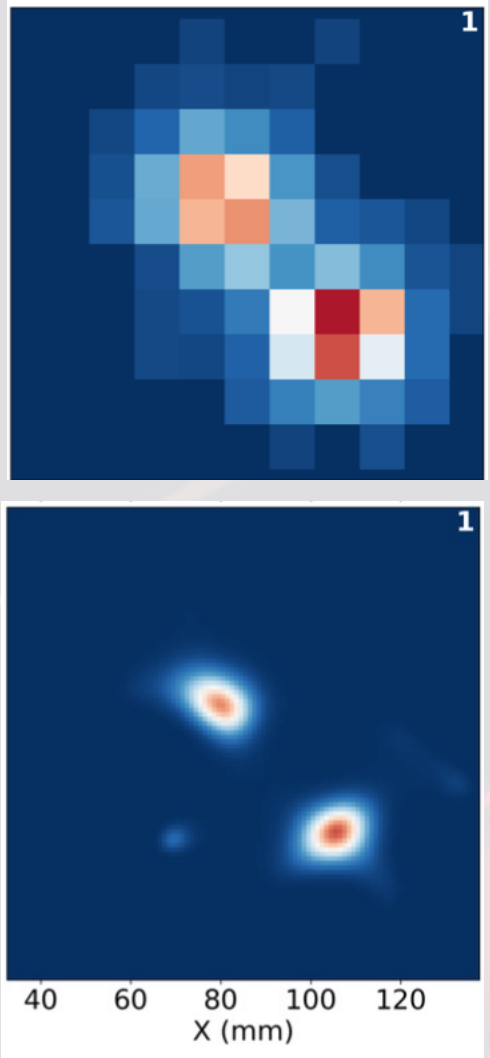


PSF Geant4 simulations



Kuzniak et al., The European Physical Journal C volume 81, Article number: 609 (2021)

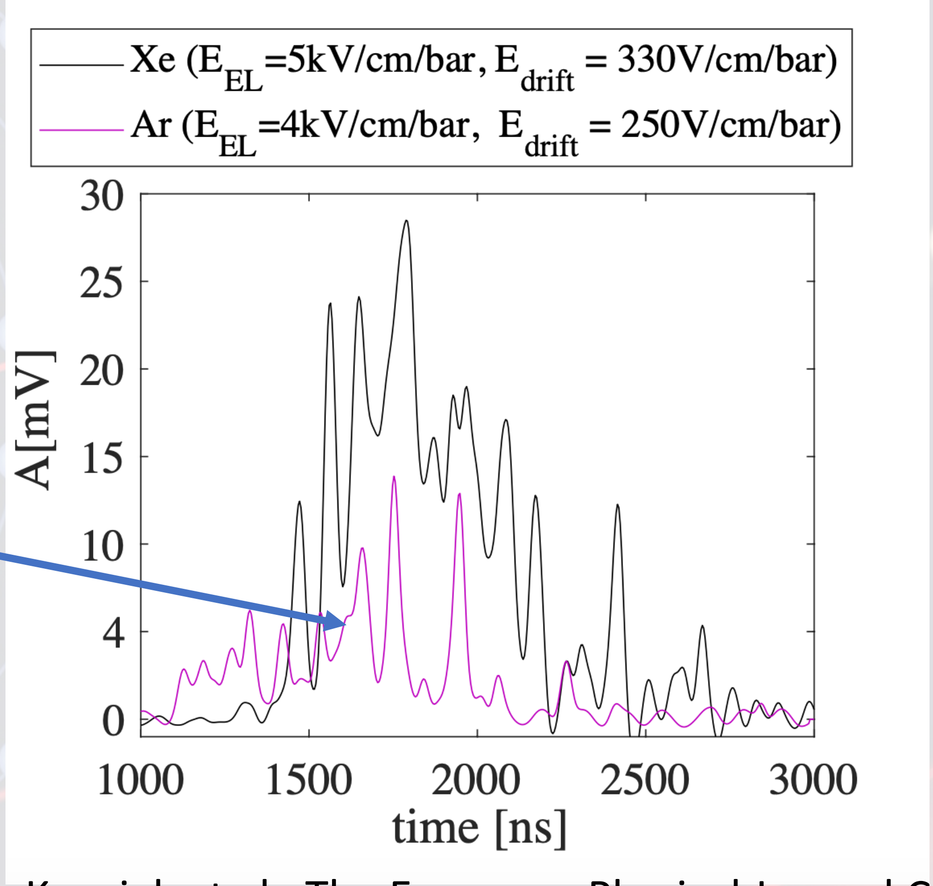
PSF of order 10 mm-σ can be deconvoluted



(A. Simón *et al* 2022 *JINST* **17** C01014)

VUV transparent FAT-GEMs – first light

Observed S2 waveform in Argon – PMT not sensitive to 128 nm!
-> hints of WLS



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- New structures with TPB inside the holes and reflectors currently under test

Conclusions and outlook

- FATGEMs are promising radiopure and scalable structures for secondary scintillation – based detectors
- Testing different structures, we were able to reach (and slightly exceed) the energy resolution scale of the NEXT experiment
- The structures characterized so far do not make use of the transparency of the bulk material. Recent success at evaporating the TPB inside the holes at AstroCeNT. Stay tuned!

Thanks for your attention!