New MPGD-based structures for electroluminescence TPCs

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IGFAE
Instituto Galego de Física de Altas Enerxías

next

supported by '*new scintillating gases and structures for next-generation scintillation-based gaseous detectors*'
(RD51 common project)

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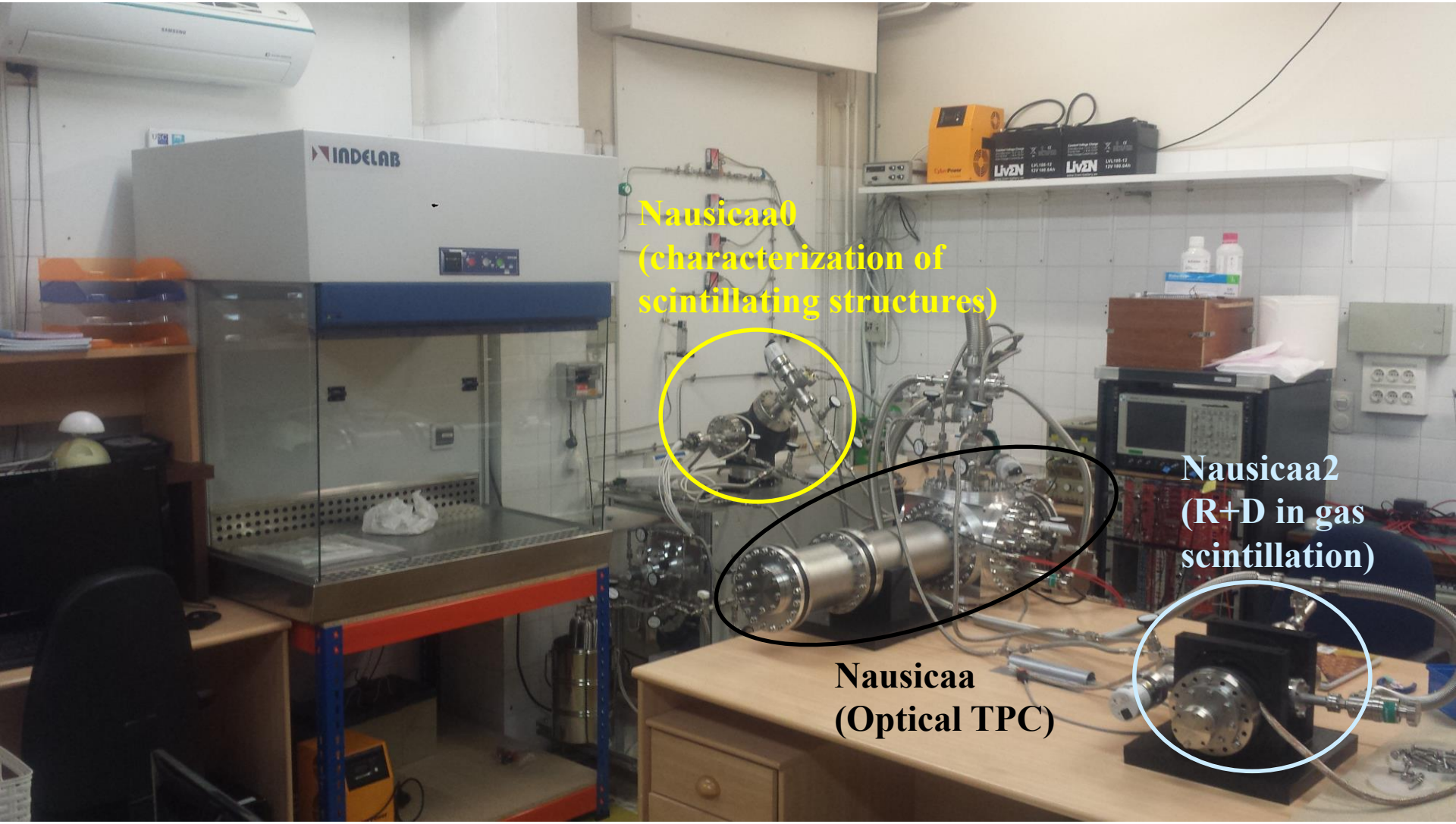
circa March 2017

now

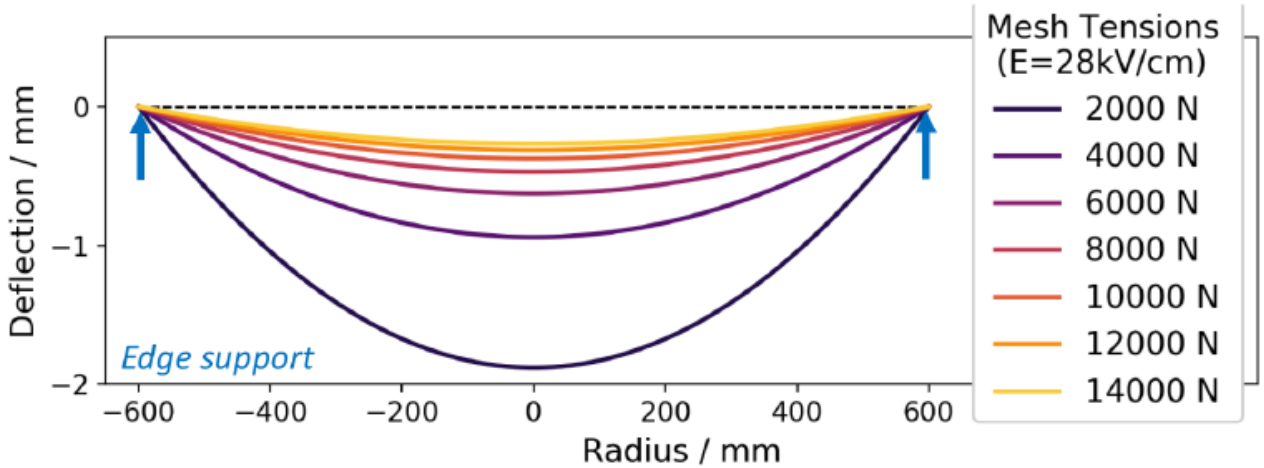

INDELAB
Nausicaa0
(characterization of
scintillating structures)
Nausicaa2
(R+D in gas
scintillation)
Nausicaa
(Optical TPC)

development of very thick acrylic (PMMA) GEMs

(idea 1: look for an alternative to the use of meshes to produce scintillation on large areas

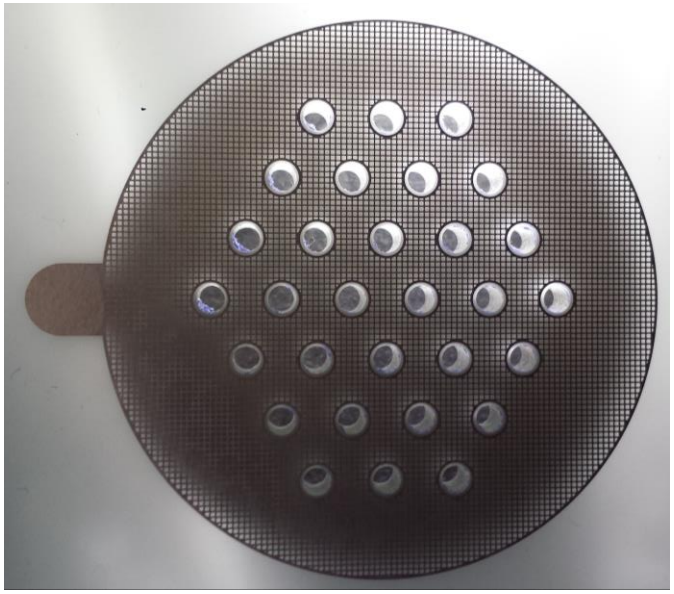
idea 2: there are no specialized structures for scintillation… plenty of room for new developments and ideas)

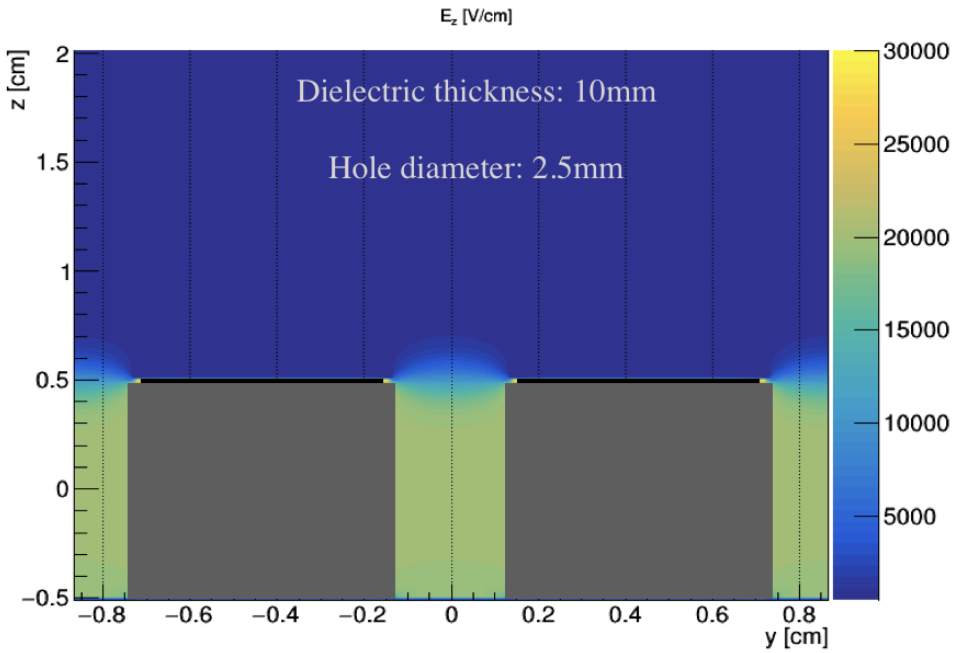
the sagging problem with conventional meshes



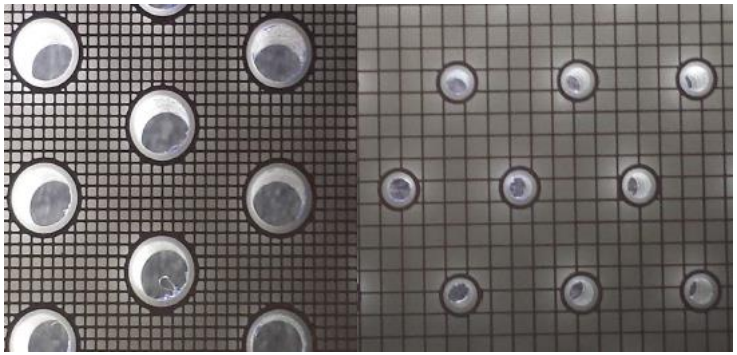
FAT-GEM: **F**ield **A**ssisted **T**ransparent **G**as **E**lectroluminescence **M**ultiplier

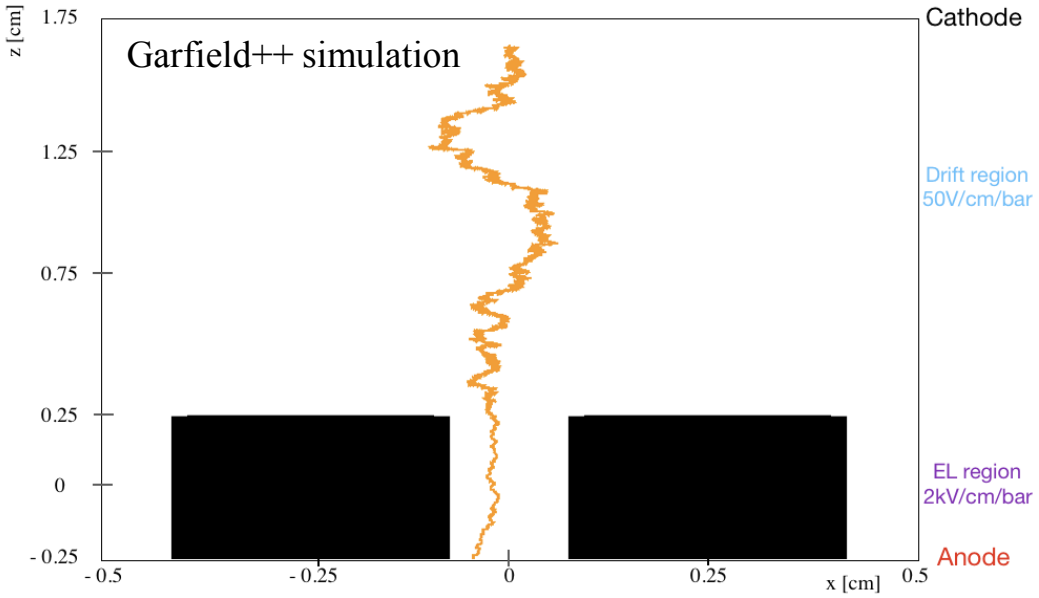
a 'super-thick' (5mm) acrylic GEM with semitransparent electrodes





several geometries procured at the RD51 workshop





PROs ☺

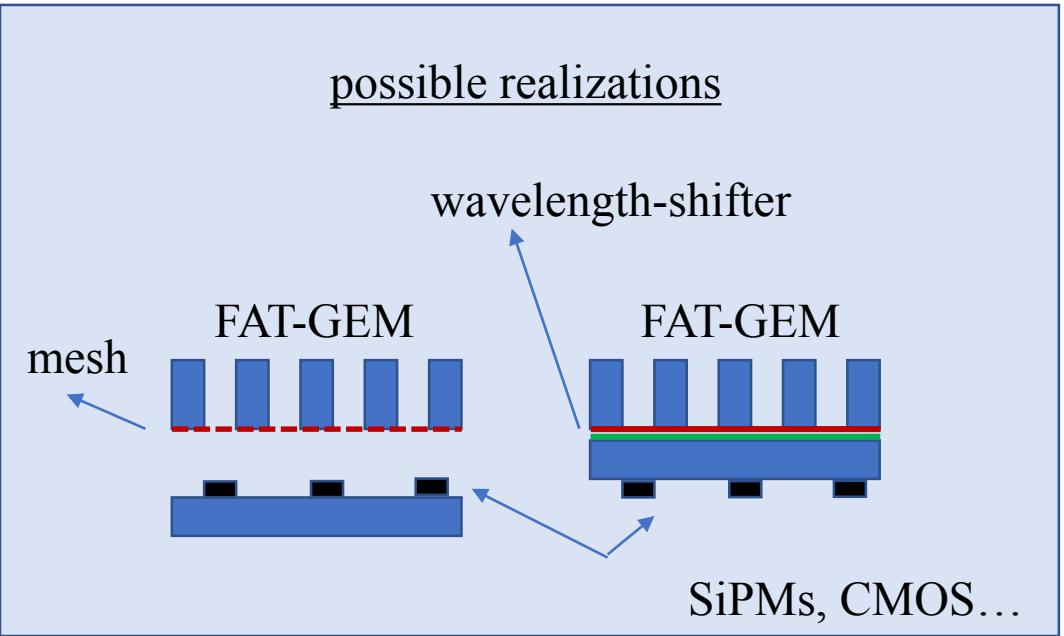
- Radiopure.
- Very robust.
- Large feature sizes (visible to the naked eye!).
- Semi-transparent.
- Customizable (e.g., through resistive or wavelength-shifting coatings).
- Energy resolution is Fano-limited (in principle).
- No ion backflow.
- Allows operation in pure noble gases, with S/N of several 100's at least.
- Compatible with small addition of impurities for TPC parameter-tuning.

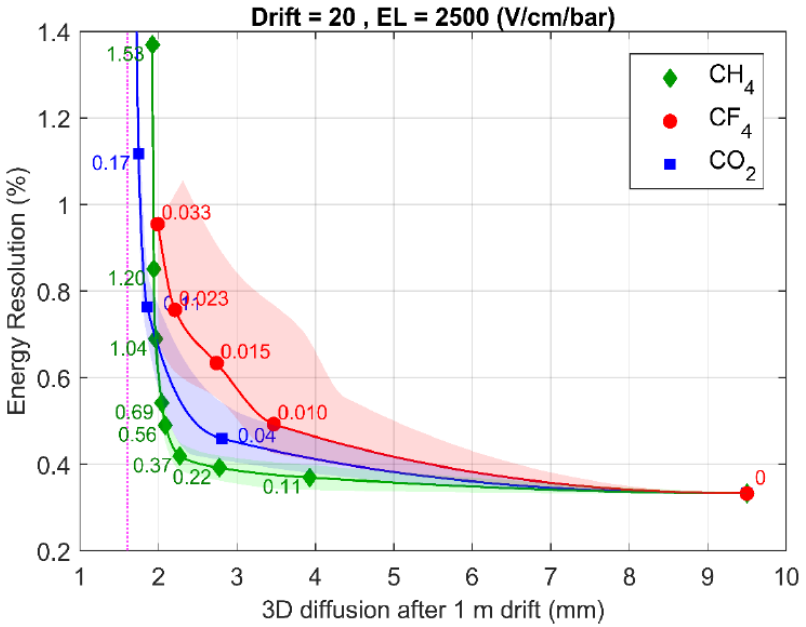
UNKNOWN 😐

- Tolerance to sparks?
- Maximum HV? -> Surface discharges?
- Charging-up?
- Will the outgassing of acrylic quench electroluminescence?
- Light collection?
- Charge losses to walls?

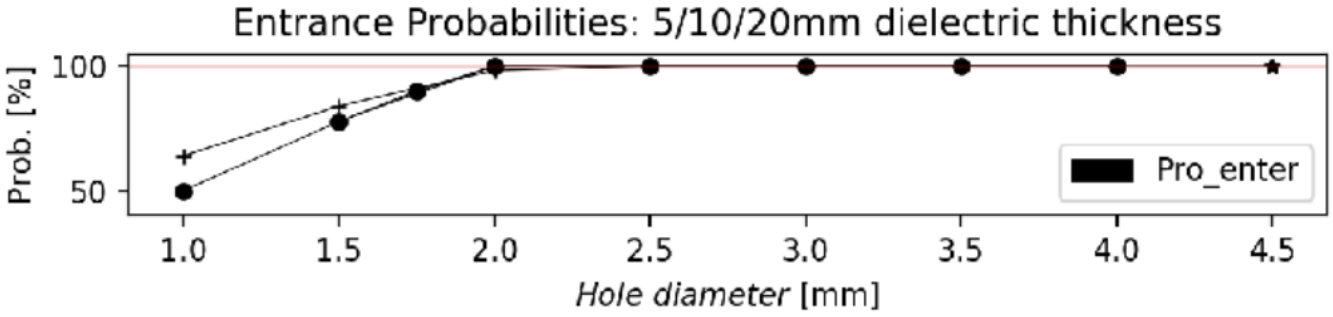
CONs ☹

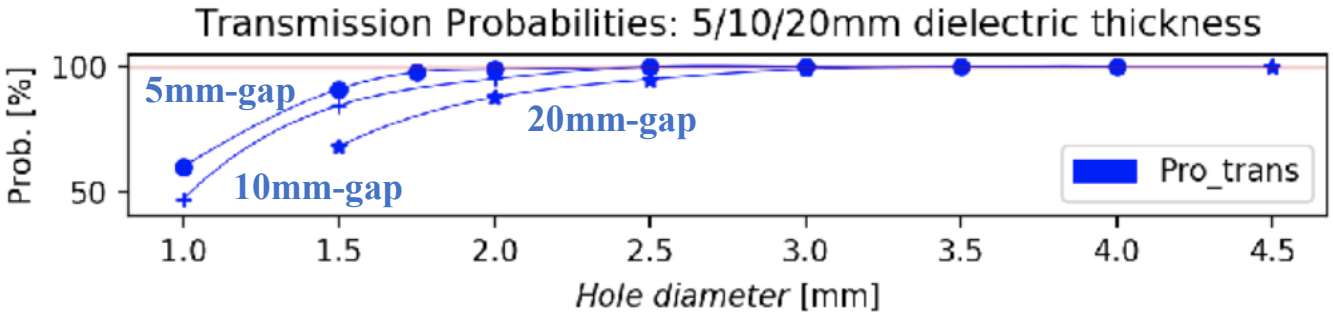
- Space *discretization* limited to few mm (space resolution can be much better).



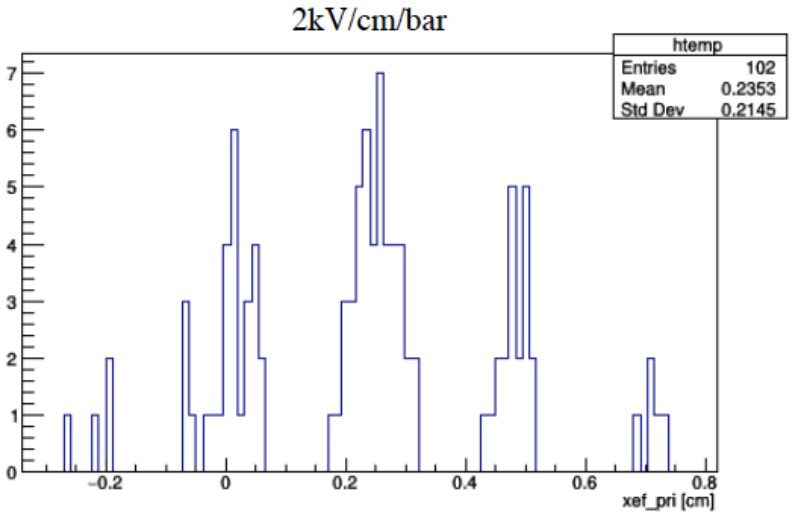


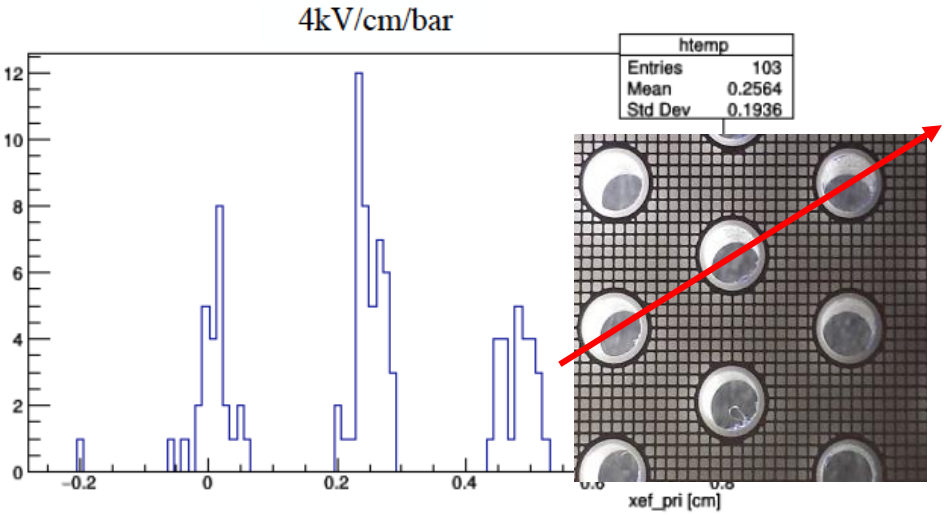
simulation results





E_d = 50 V/cm/bar
E_{EL}= 2 kV/cm/bar
Xenon, P=10bar

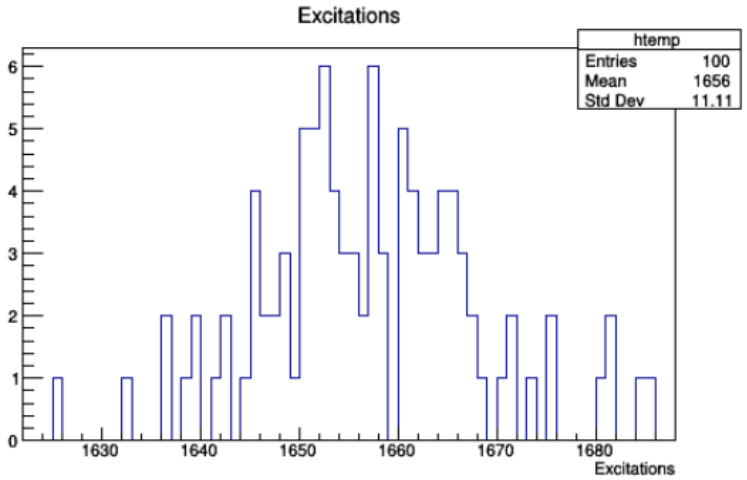




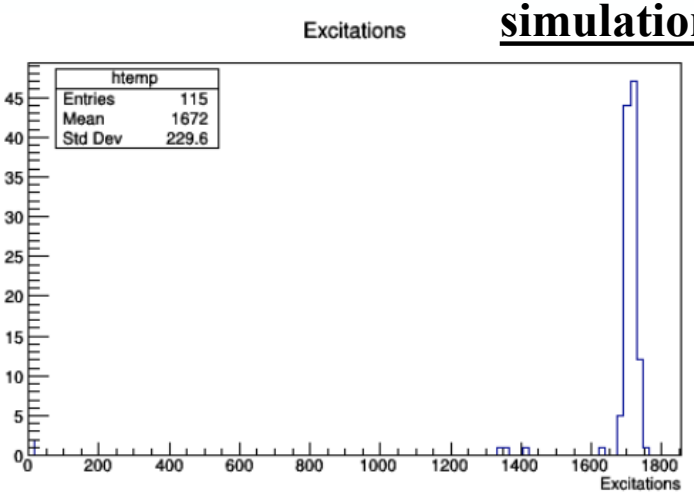
distance along hole-GEM plane

field focusing plays a role in both entrance and transmission through FAT-GEM channels

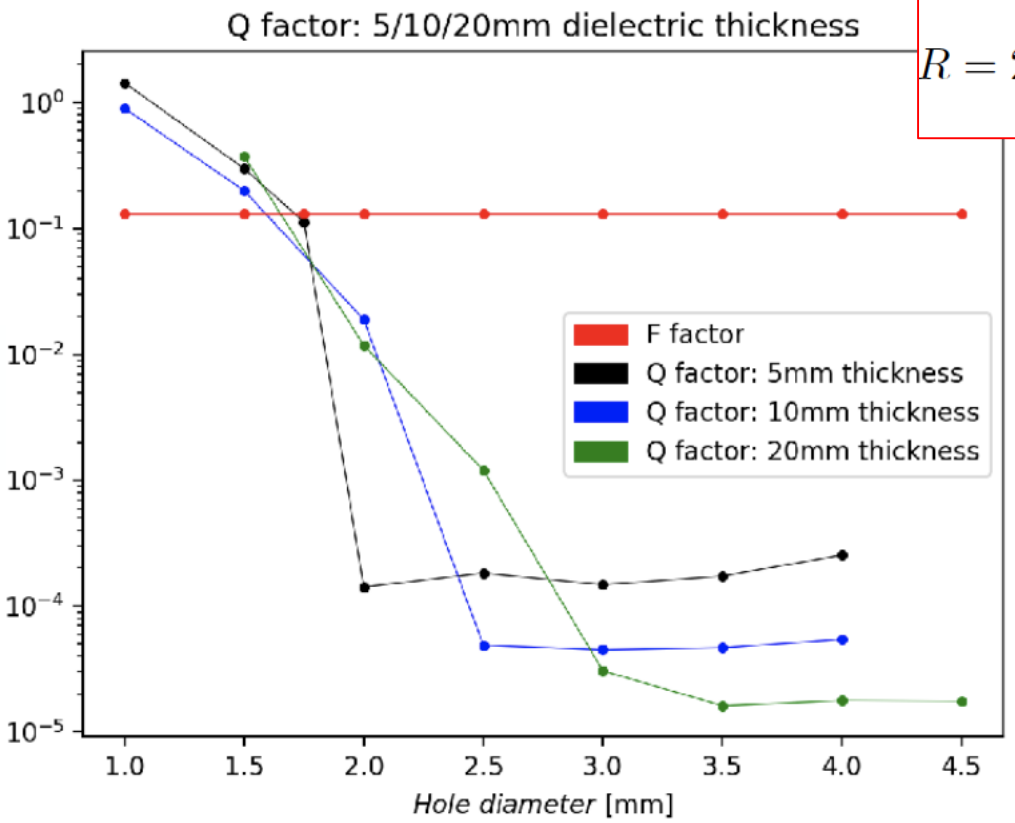
simulation results



Hole diameter: 3mm

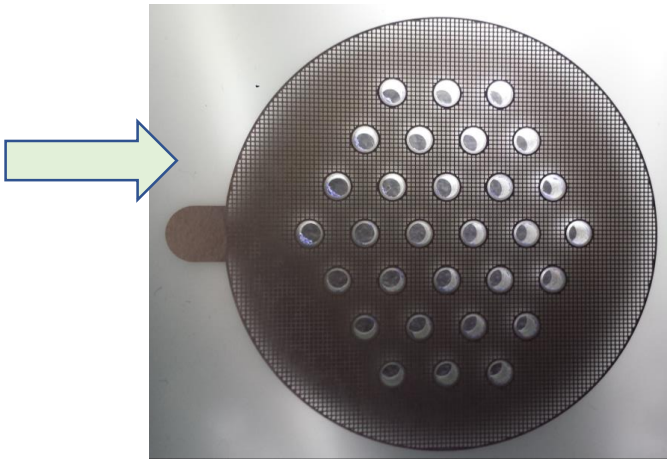


Hole diameter: 2mm



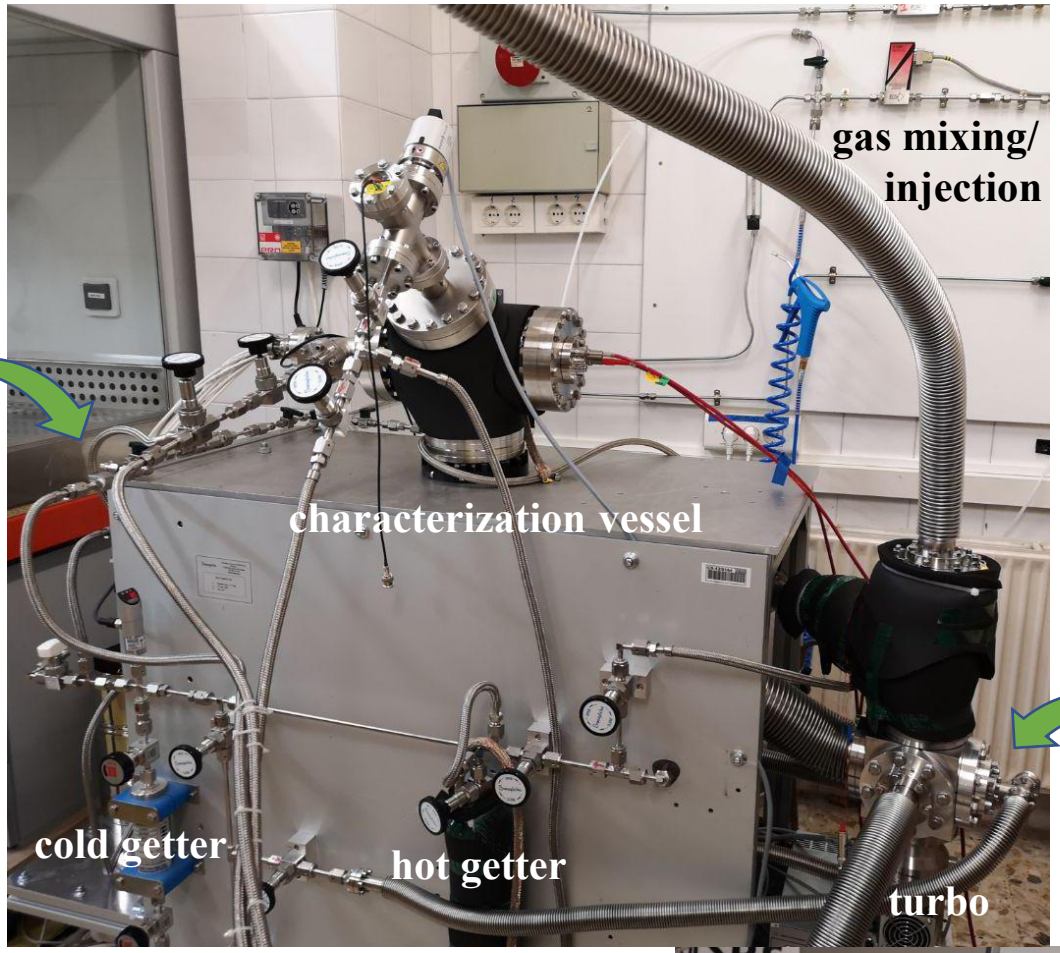
$$R = 2.355\sqrt{\frac{F}{N_e} + \frac{Q}{N_e} + \frac{1}{N_{pe}}\left(1 + \frac{\sigma_G^2}{G^2}\right)}$$

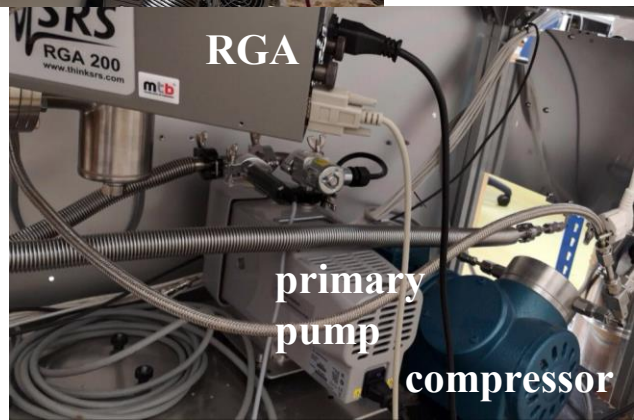
$$Q = (\sigma_{el}/N_{el})^2$$



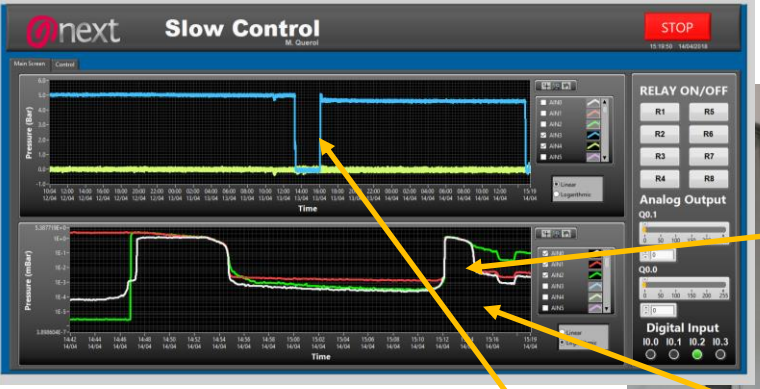
2mm hole, ~5mm thick, 5mm pitch

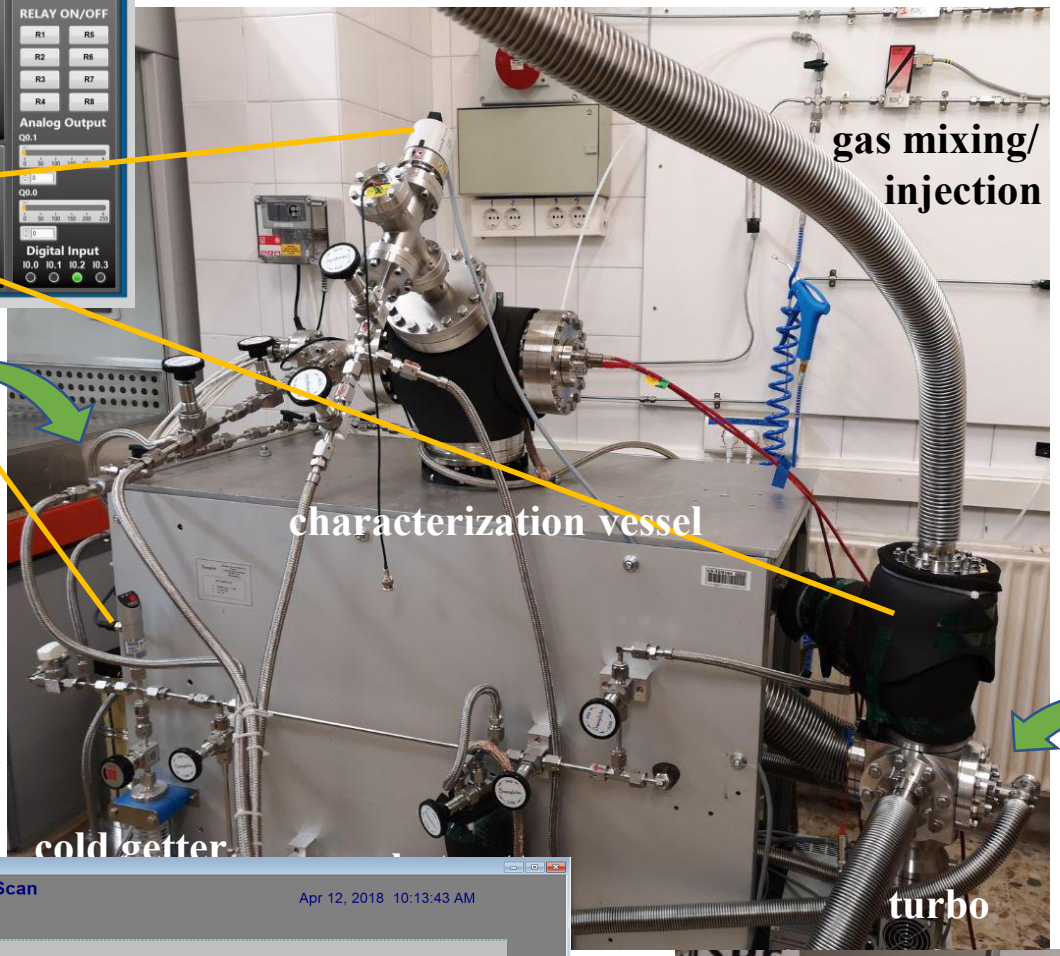
experimental setup

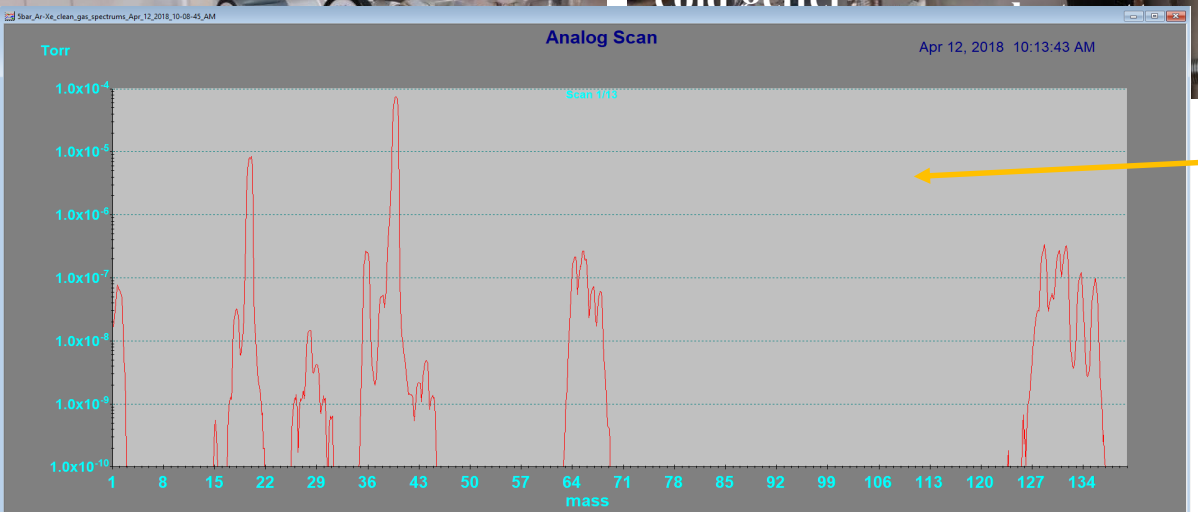


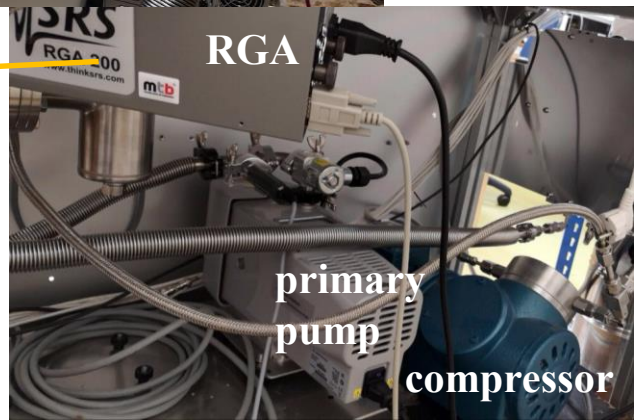


experimental setup





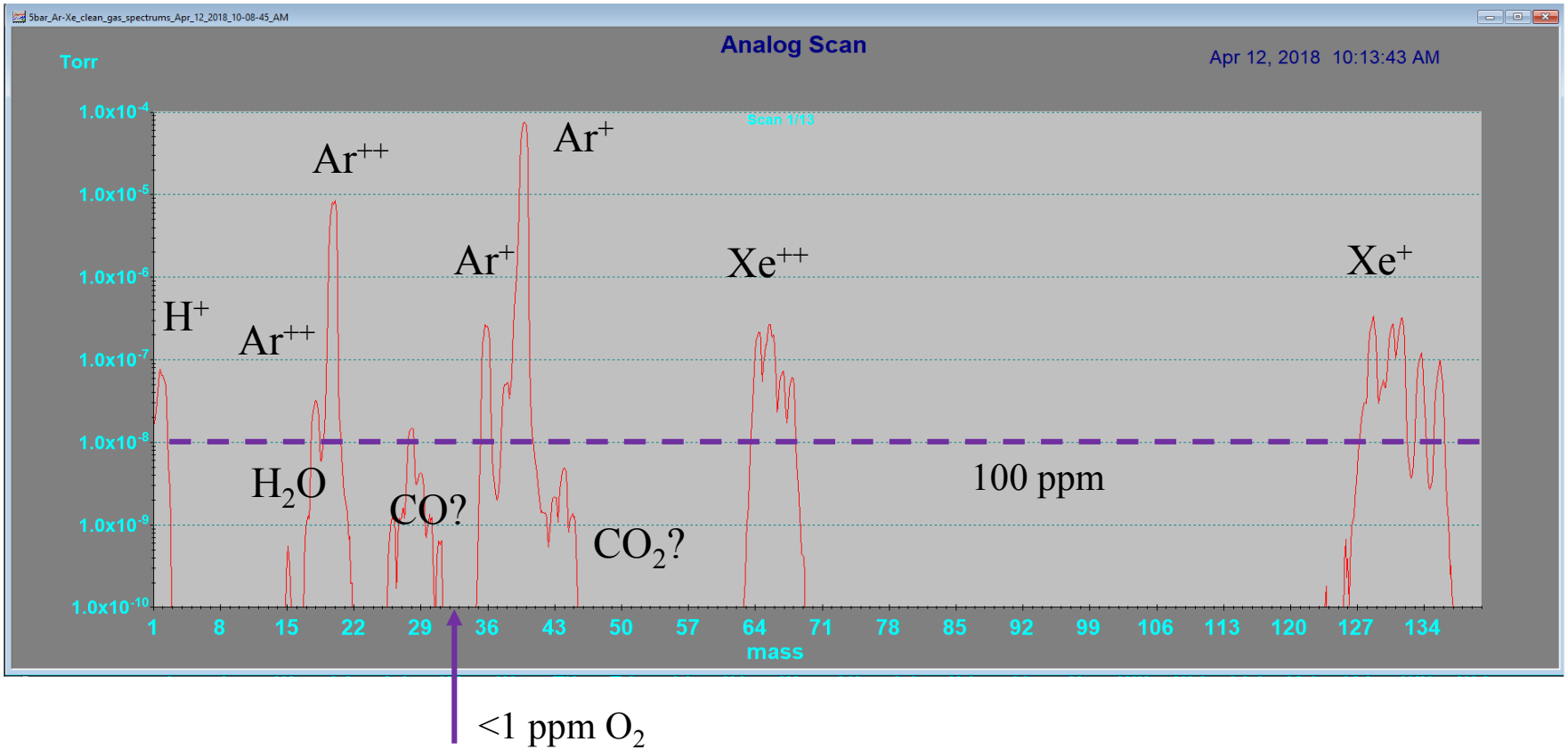




general performance of gas system

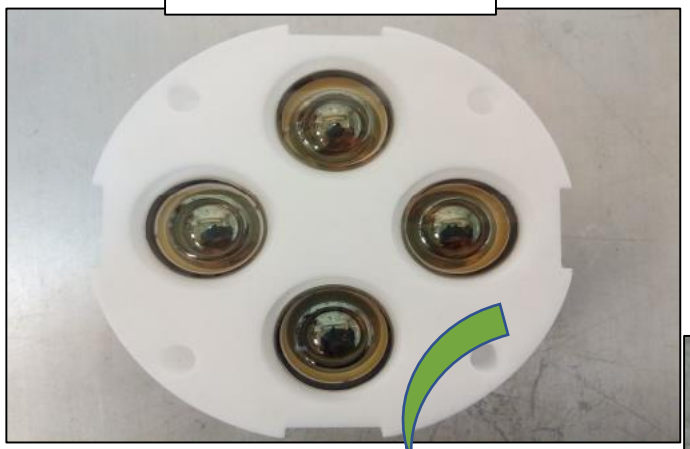
1. Commissioned in the range 0-10 bar, with gas quality down to less than 1ppm of O_2.
2. Leak tested with He. P=2-3 10^{-8} mbar in vacuum region. Leak rate generally below 10^{-4} mbar l/s.

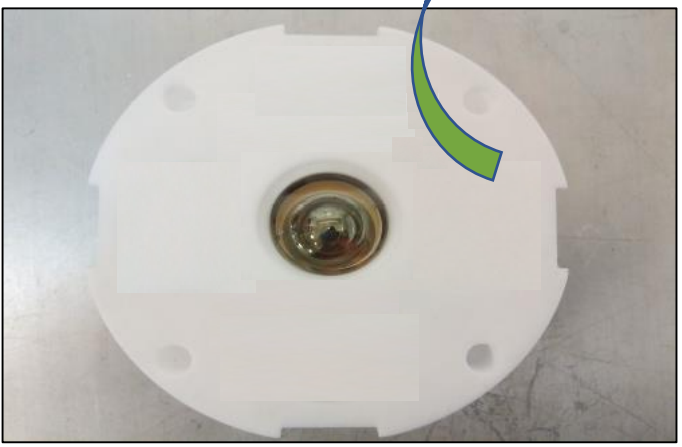
test setup at 5 bar Ar/Xe (97/3) measured through leak in valve:

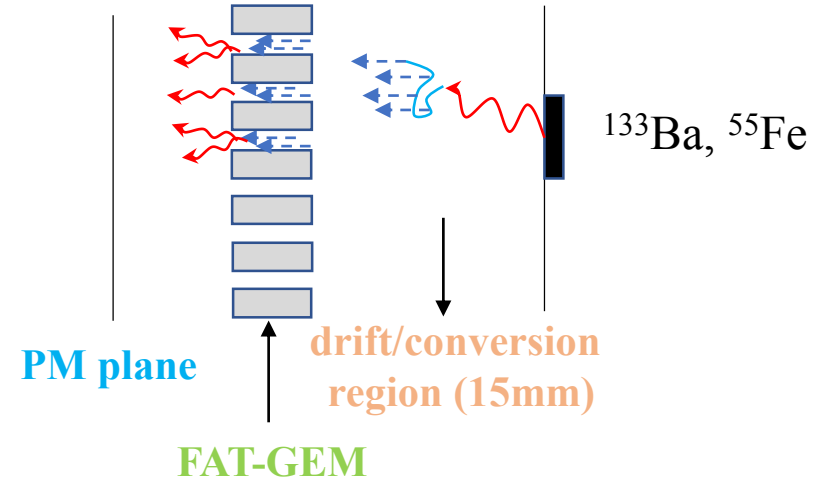


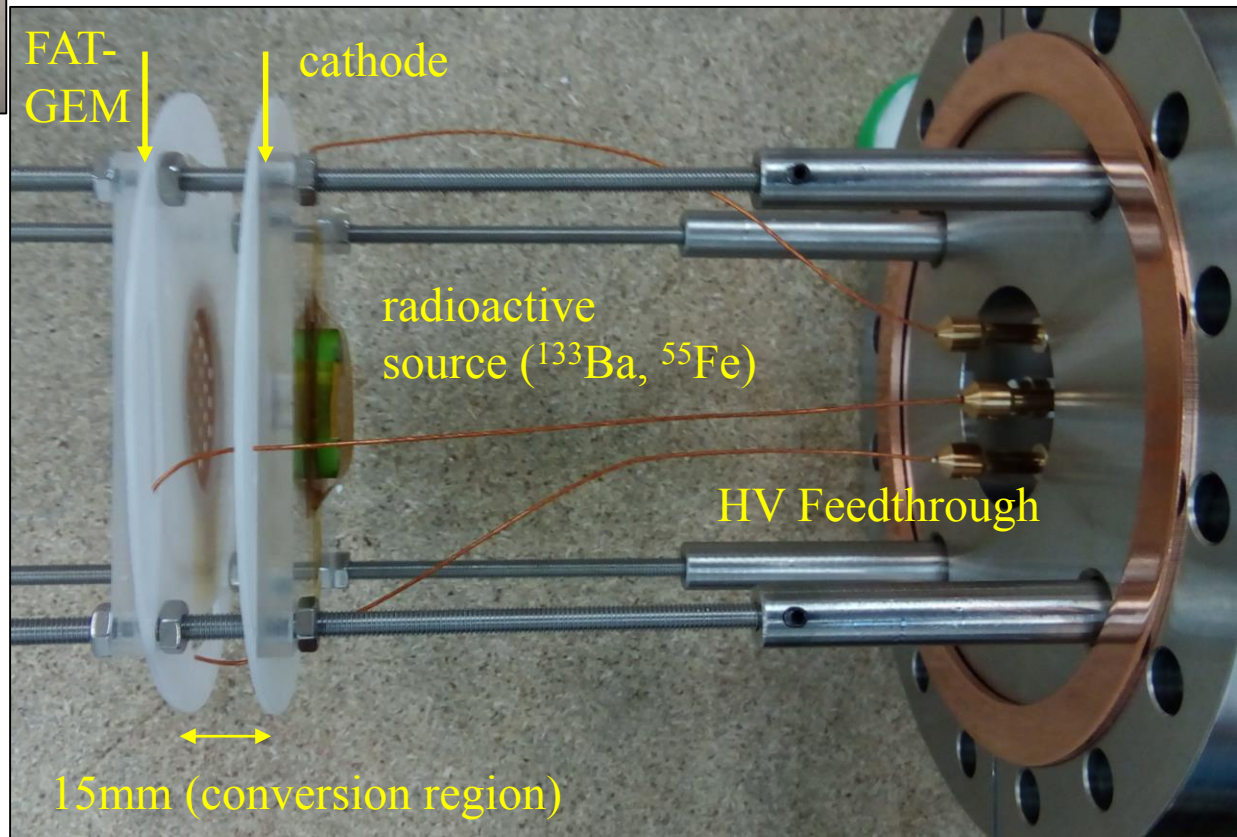
characterization setup

PM assemblies



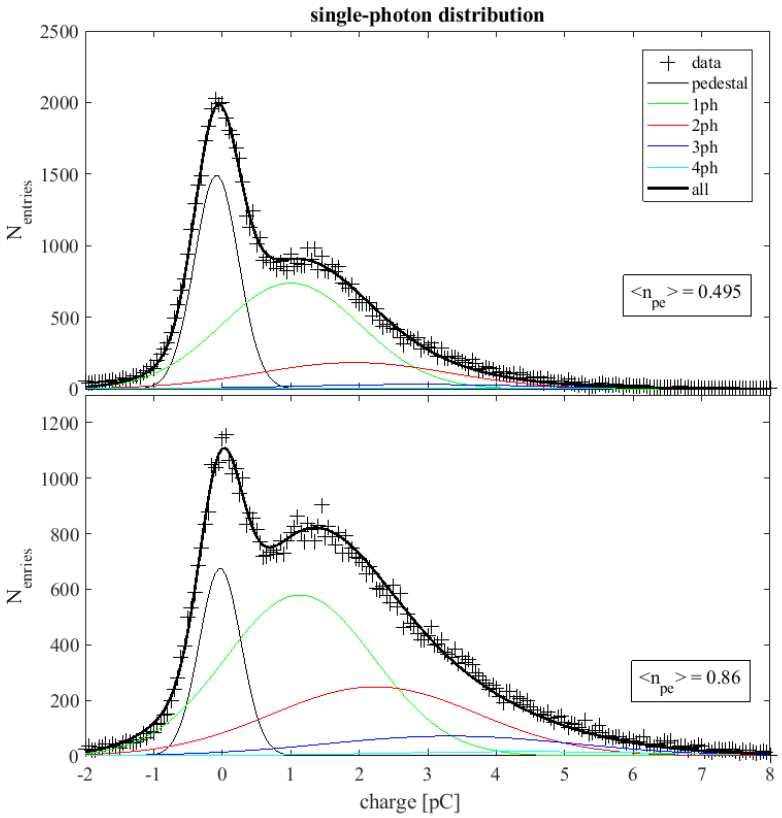






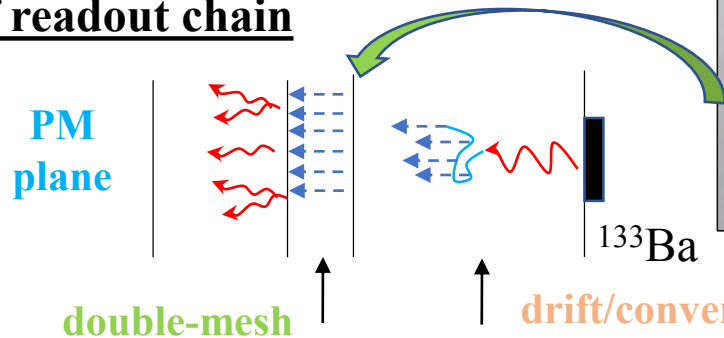
calibration of readout chain

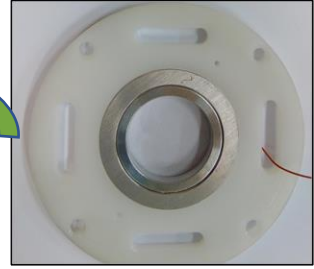
single-photon calibration with LED

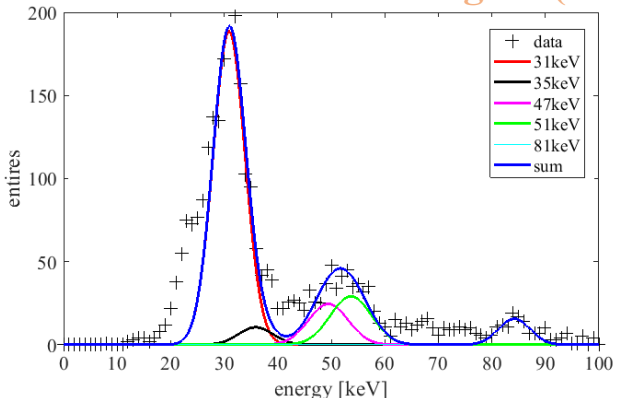


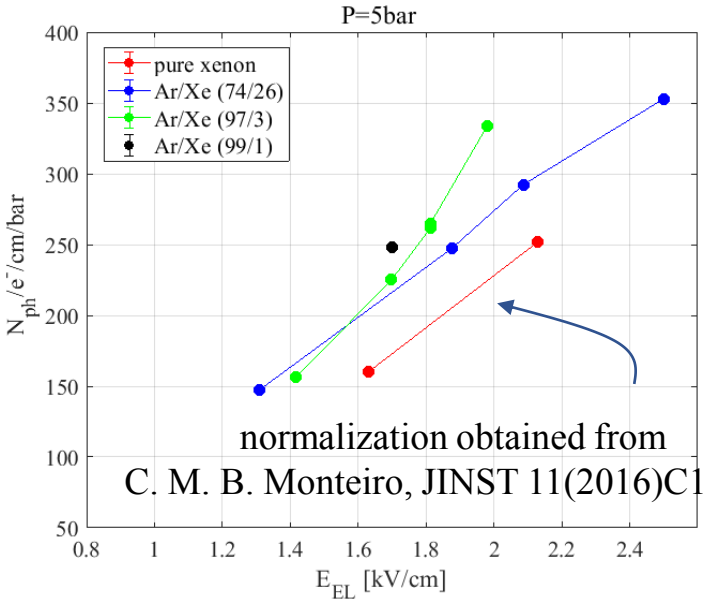
1ph/1pC (20% estimated uncertainty)

high purity gas!!





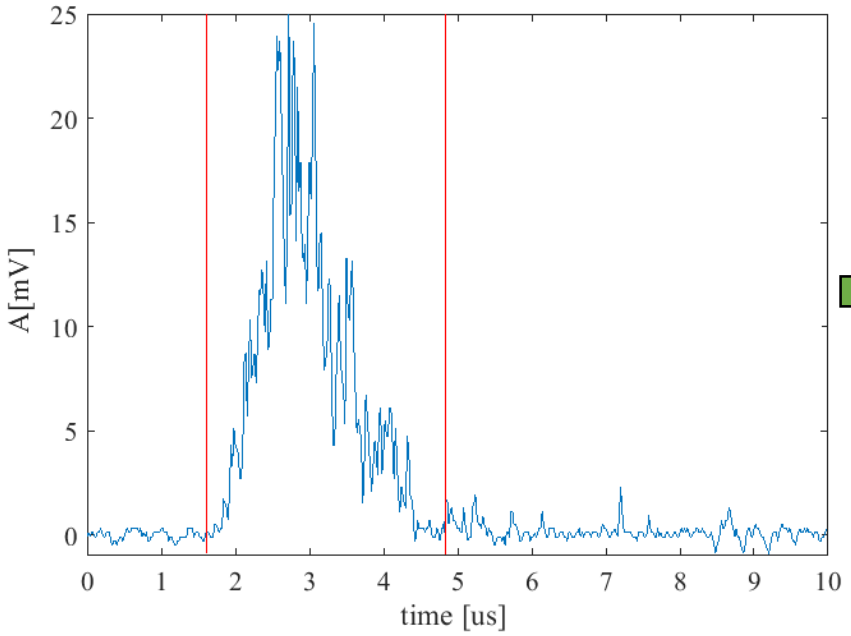




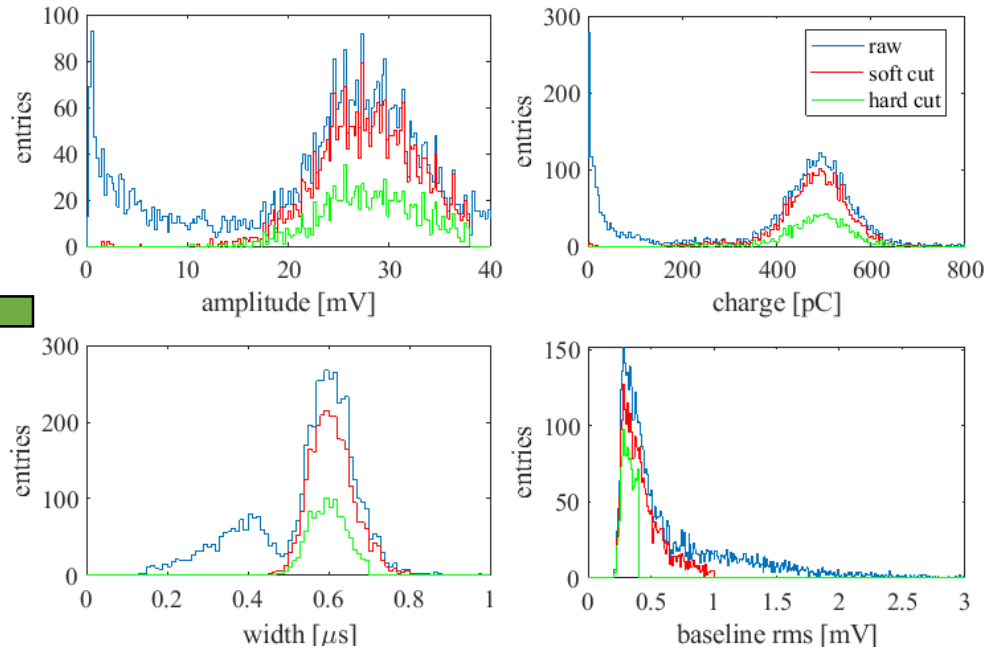
normalization obtained from
C. M. B. Monteiro, JINST 11(2016)C12079

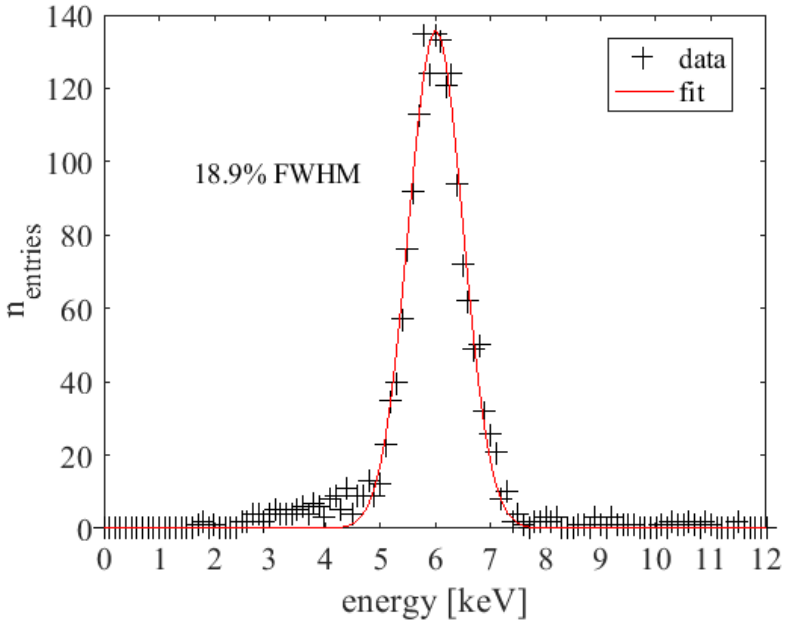
pulse shape-analysis

recorded pulse

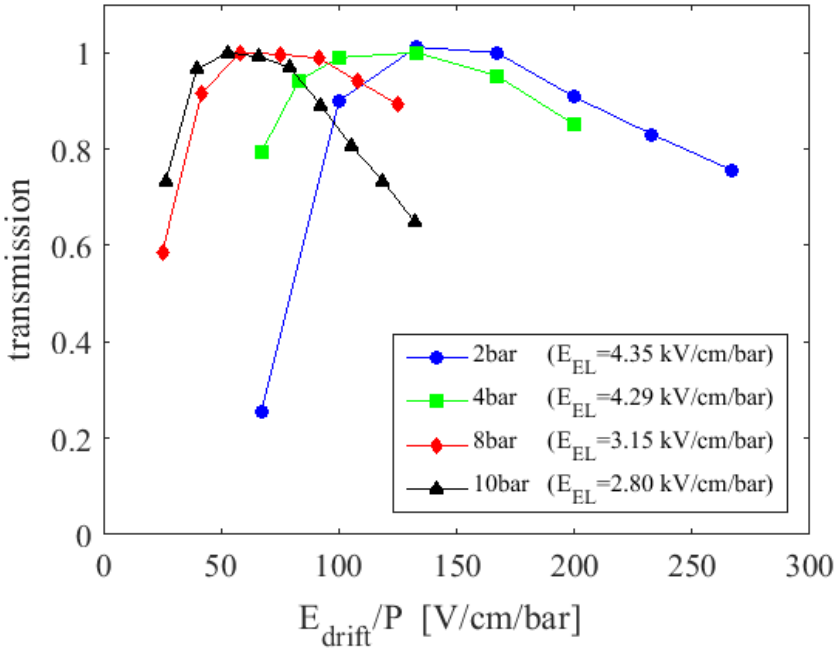


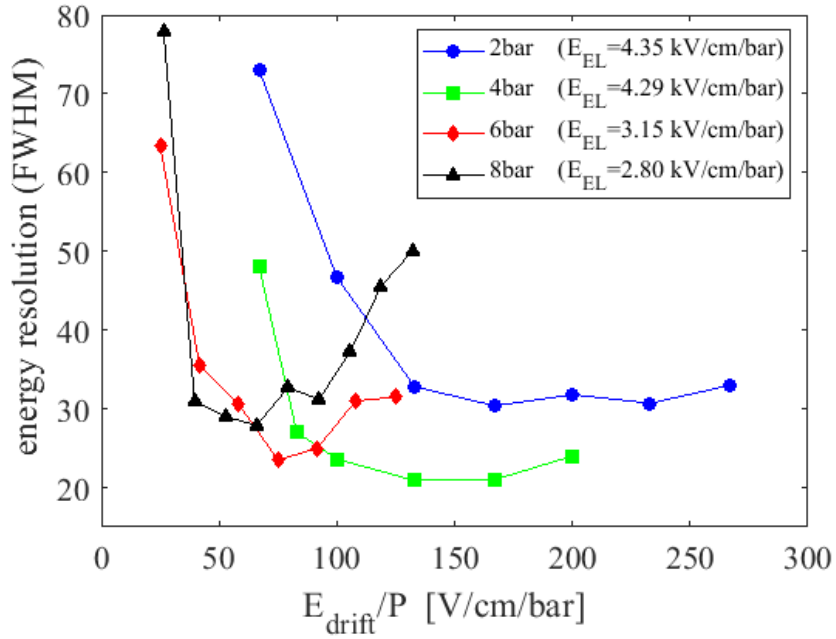
event selection



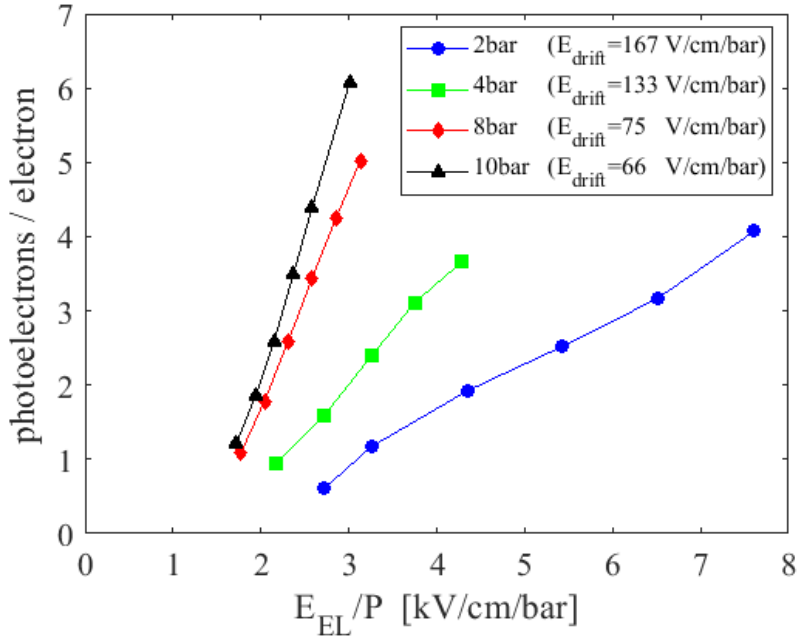


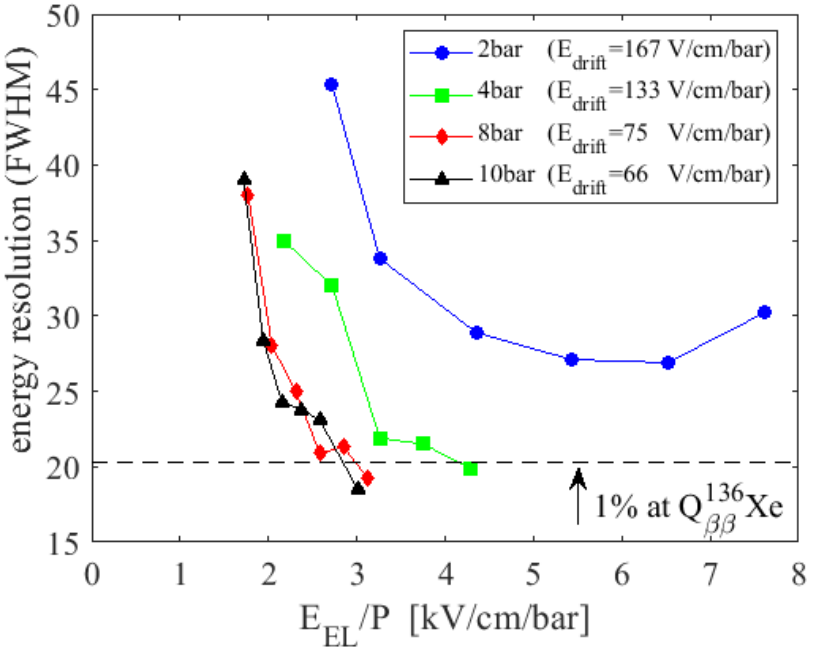
drift field scan



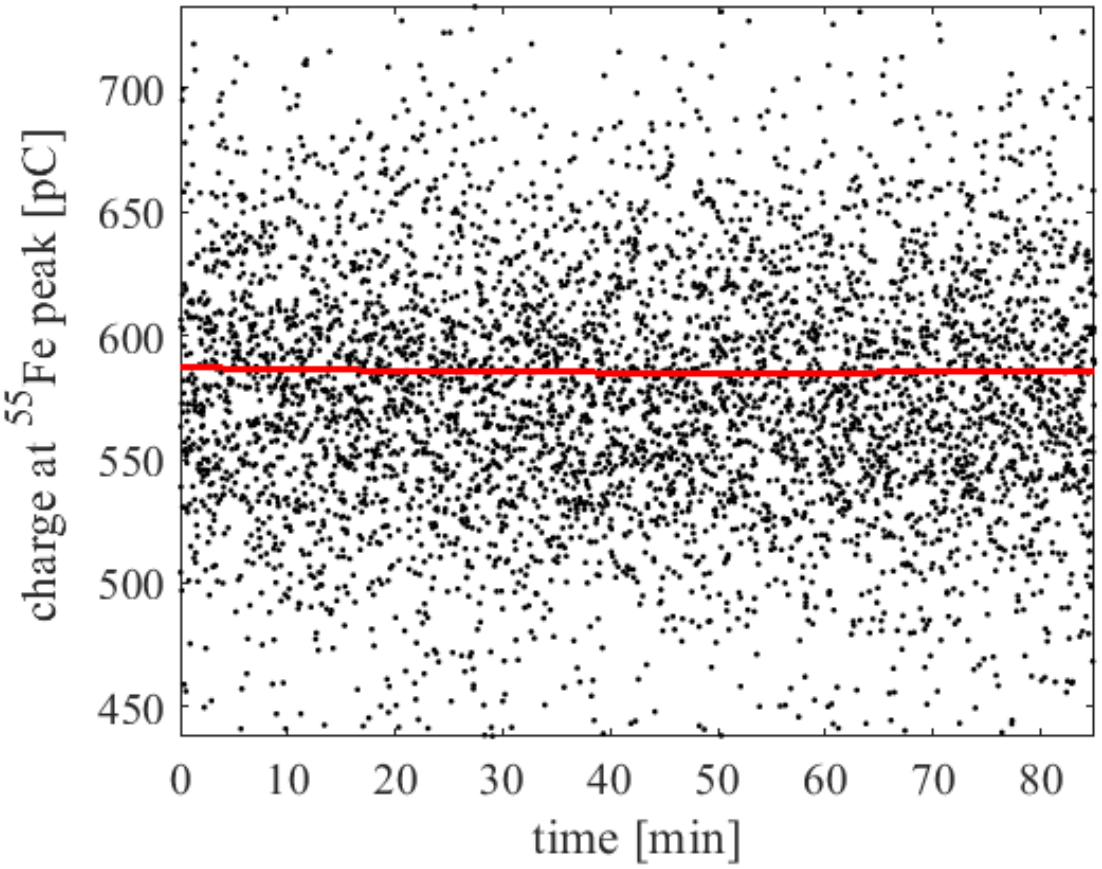


EL field scan



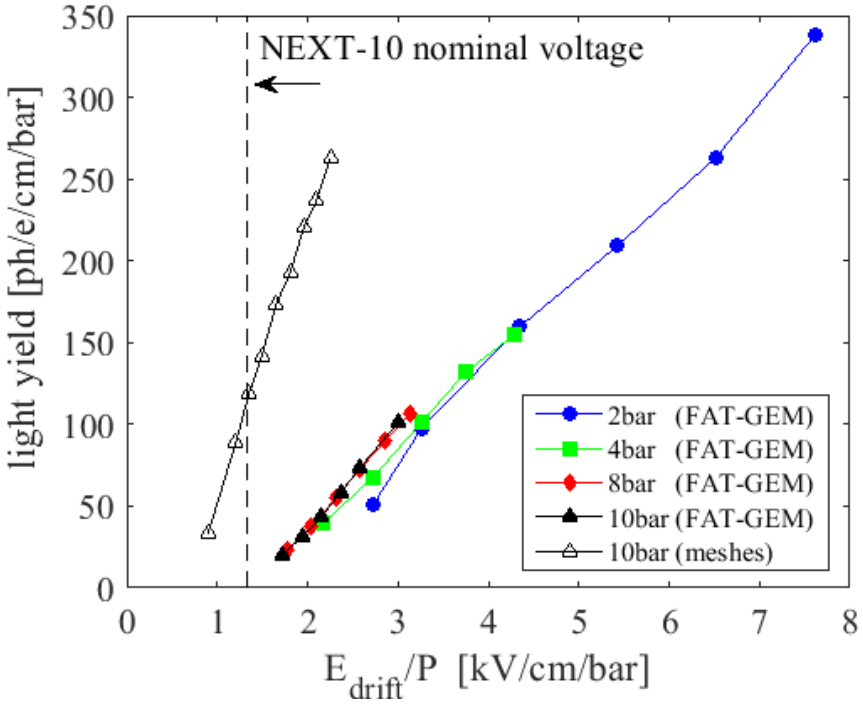


no charging-up!

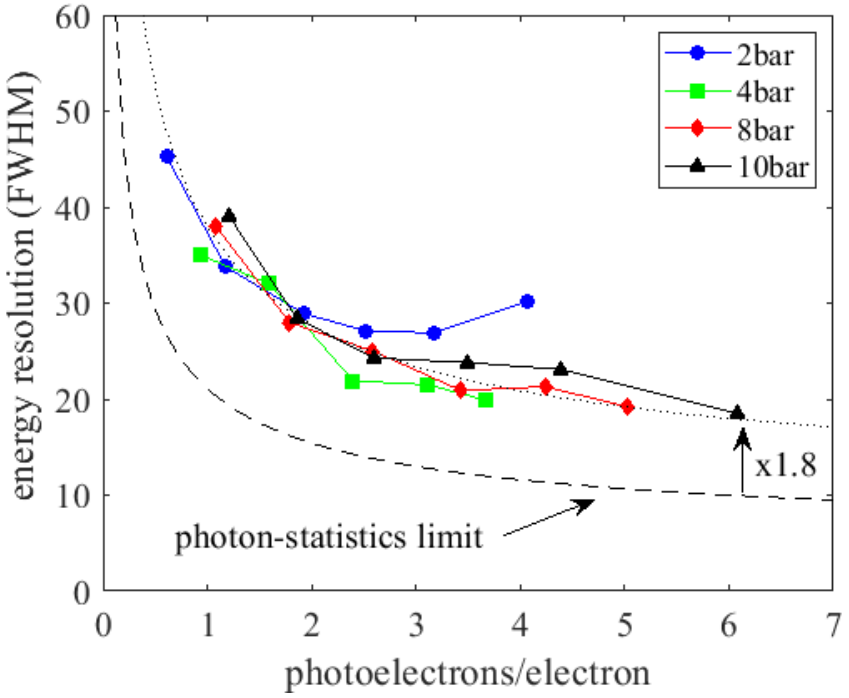


scaling behaviour

light yield per bar after solid angle correction



energy resolution vs number of photoelectrons



$$R = 2.355\sqrt{\frac{F}{N_e} + \frac{Q}{N_e} + \frac{1}{N_{pe}}\left(1 + \frac{\sigma_G^2}{G^2}\right)}$$

comparison with other results obtained in high pressure xenon

gas	structure	1/√E-extrapolated resolution	@$Q_{\beta\beta}$(^{136}Xe)	P[bar]	gain	field
Xe-TMA	Microbulk micromegas	9.6%(22.1keV)	0.90%	10	400e/e	11kV/cm/bar
Xe	Teflon-GEM (ELCC)	7.3%(28.8keV)	0.80%	4	~600ph/e	2.7kV/cm/bar
Xe	acrylic-GEM (FAT-GEM)	18.9%(5.9keV)	0.93%	10	500ph/e	3kV/cm/bar

conclusions

- A new type of electroluminescence-based structure has been introduced.
- The structure stands operation at 10bar of Xenon, with an optical gain of around 500, and an energy resolution of 18.9%FWHM at 5.9keV.
- The HV applied (15kV) is presently limited by the setup, not by the structure, corresponding to an EL field above 3kV/cm/bar.
- When operated close to the breakdown voltage at P=2-4bar, the induced sparks did not cause any damage.
- These results extrapolate to an energy resolution of 0.9%FWHM at the energy of the $Q_{\beta\beta}$ in ^{136}Xe.

outlook and next steps

- Understand the present energy resolution and bring it closer to the Fano factor. A systematic campaign targeting different geometries will follow.
- Increase the light output by means of TPB coating.
- Tests with optical TPC and 15cm diameter tile. Currently ongoing!.