Scintillation light readout of Micromegas detector

F.J. Iguaz

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Glass Micromegas

Energy resolution:

- **13.5% FWHM** at 5.9 keV.
- 15% FWHM (bulk).
- 11% FWHM (microbulk).

Optically readout detector:

- Scintillation light.
- Light yield & spectrum.
- X-ray radiography.

- Interest for bulk technology.
- Other developments:
  - Thin-mesh, β-mesh
  - Ceramic readout.

- GEMs used since: Fraga et al. *NIMA* **471** (2001) 125-130.
- First time with Micromegas?
- Potential better energy & spatial resolution.

Optically readout detector

ADVANTAGES:

- Intuitive pixelated readout with **megapixel imaging sensors**.
- High **spatial resolution**.
- **Integrated** imaging approach.
- **Lenses and mirrors** to enable adjustable magnification and camera location.

DISADVANTAGES:

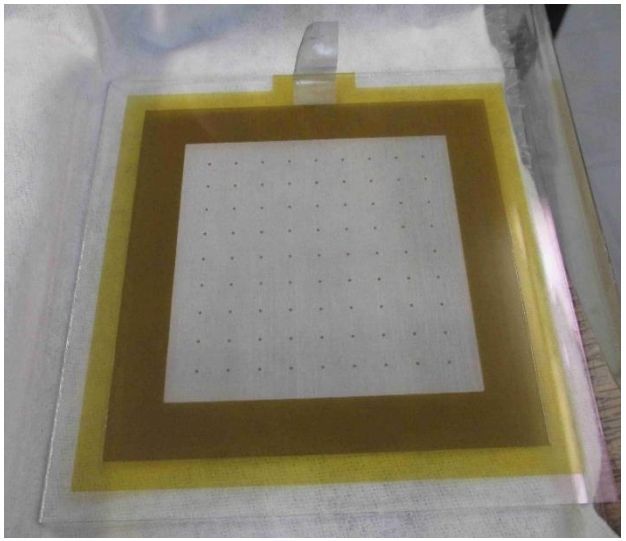
- Limited **frame rate**.
- **Radiation hardness** of imaging sensors.
- Need of **CF4**-based gas mixtures or **wavelength shifters**.

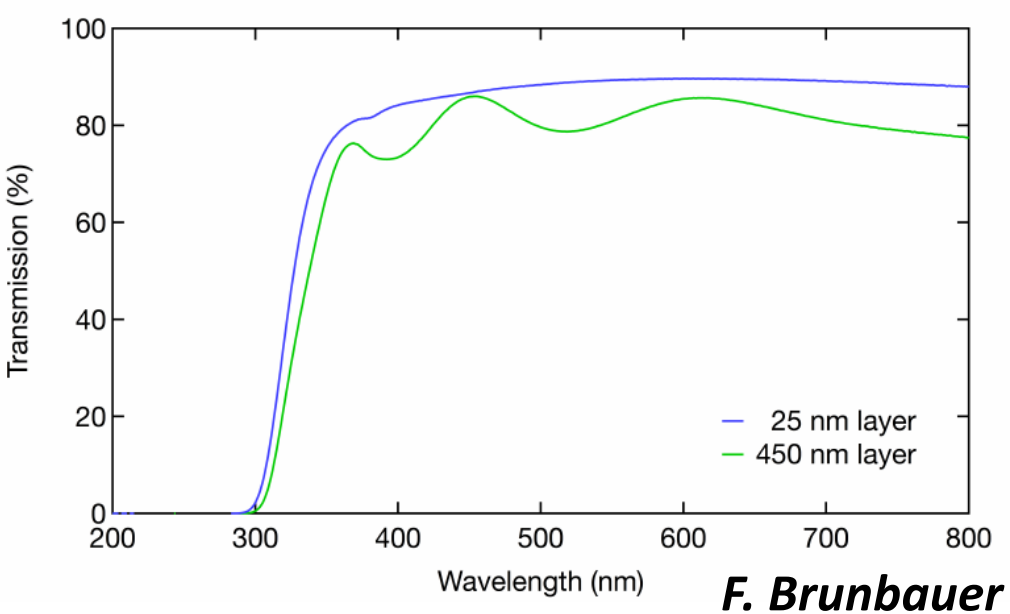
Recording scintillation light with imaging sensors

More info tomorrow at 10h at F.M. Brunbauer's presentation.

Glass Micromegas readout

Glass surface (1.1 mm) +
Indium Tin Oxide (ITO) layer.





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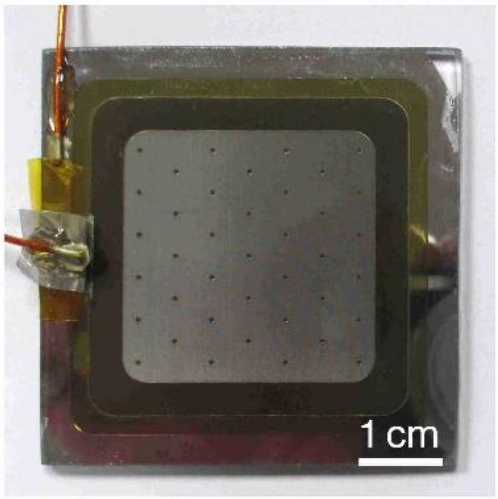
Anode resistivity depends on the layer thickness:

- 25 nm -> 100 Ω/□
- 450 nm -> 4 Ω/□

Glass Micromegas detectors

1



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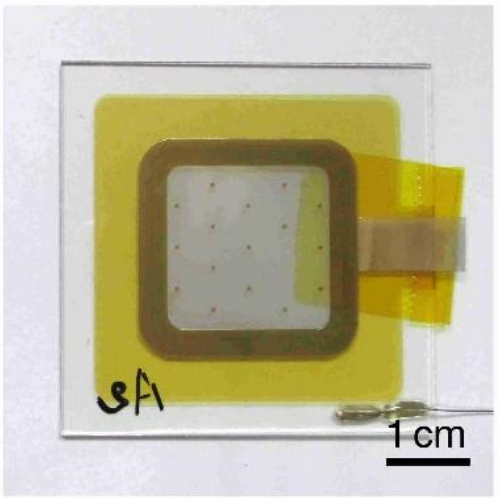

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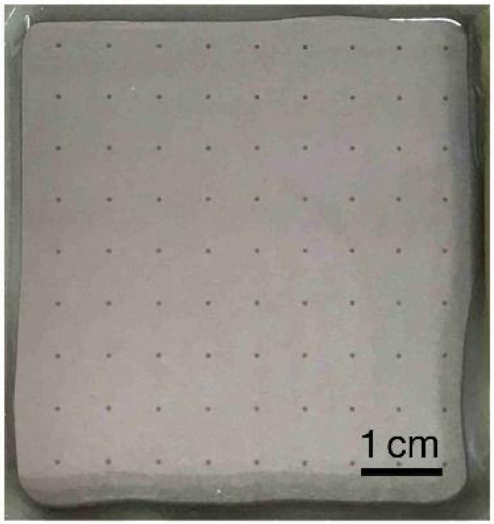
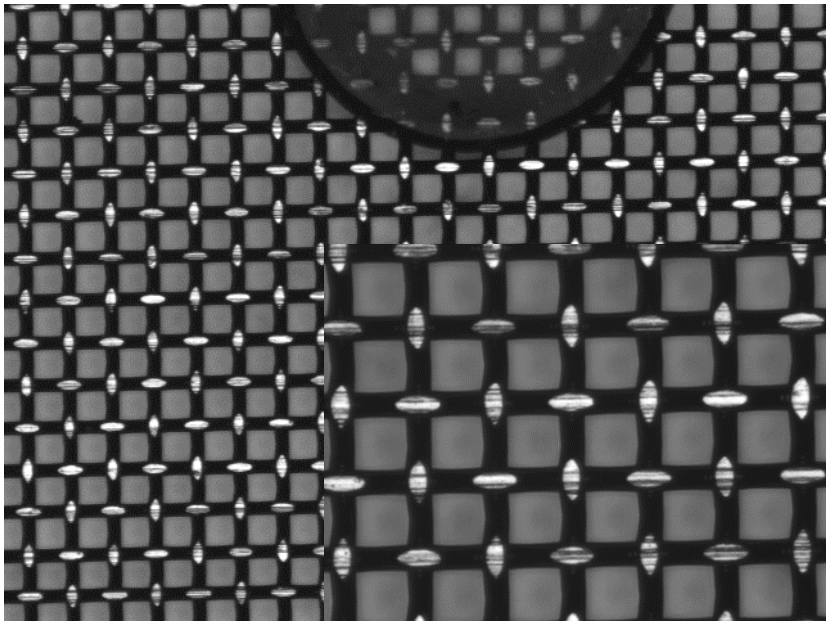
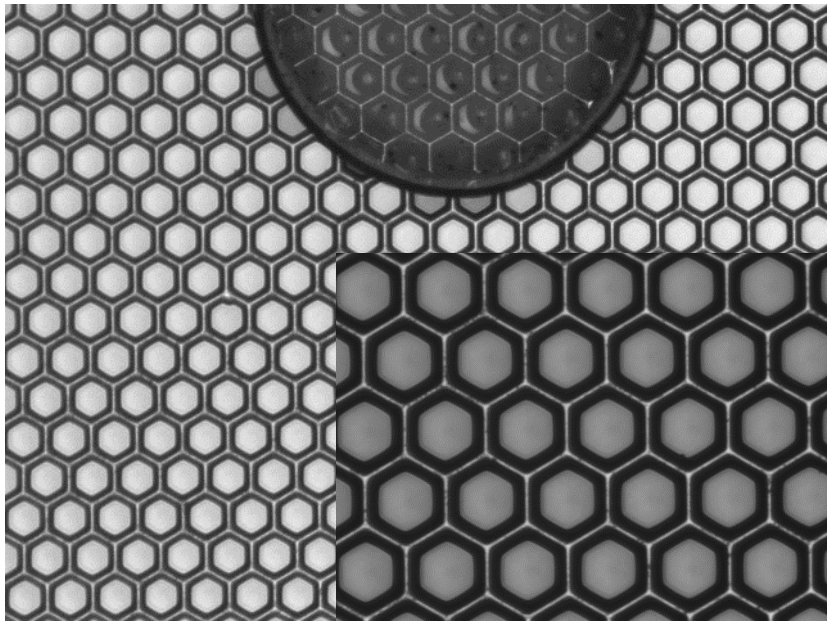


#	Samples	Area (cm^2)	Base	Thick	Mesh type
1	2	3 x 3	Glass+Cr	3 mm	Woven-1 & β-mesh
2	4	2.5 x 2.5	ITO	1.1 mm	β-mesh
3	2	6 x 6	ITO	1.1 mm	Woven-2

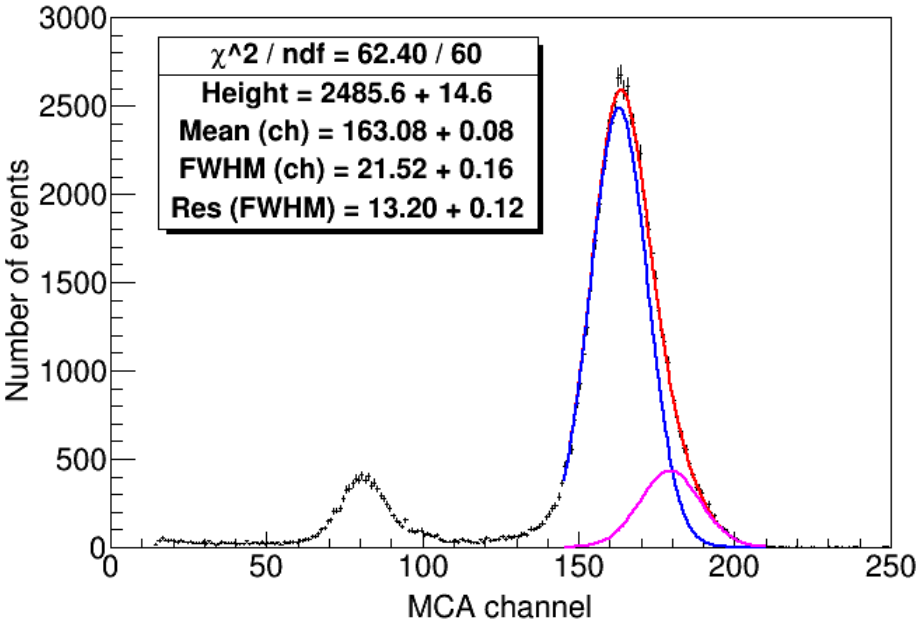
Woven mesh vs β-mesh



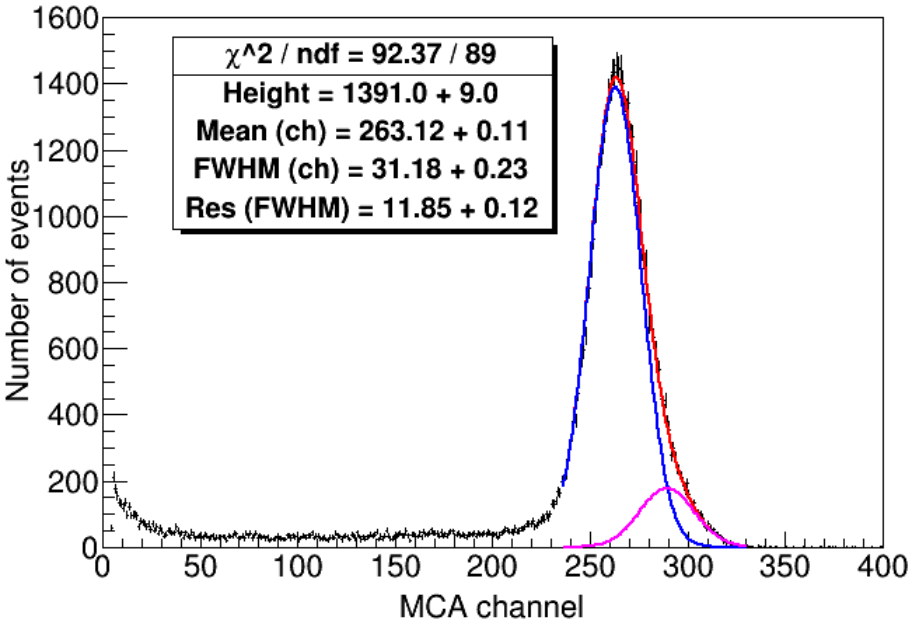


Type	Pattern	Gap	Wire thick	Pitch	Hole pitch
Woven-1	Squared	128 µm	21 µm	65 µm	42 µm
β-mesh	Hexagonal	128 µm	23 µm	69 µm	46 µm
Woven-2	Squared	128 µm	18.5 µm	62.5 µm	44 µm

Characterization in Ar/Ne-iso



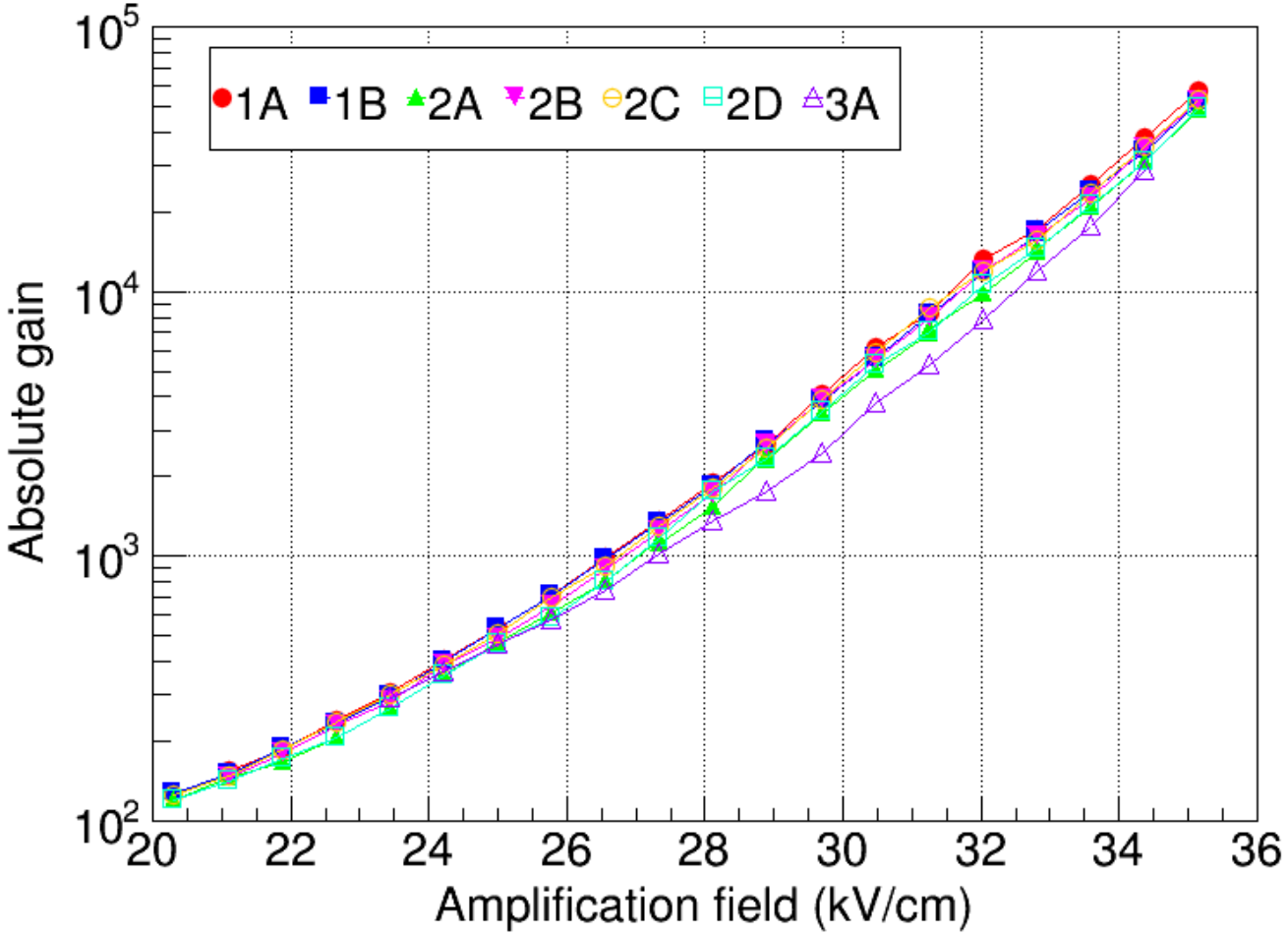
Ar+5%iso, A = 380 V



Ne+10%iso, A = 500 V

- Gases: Ar+5%iso & Ne+10%iso at 1 bar, 5 l/h flow.
- Energy spectra fitted to two gaussians: 5.9 & 6.4 keV x-rays.
- Energy resolution of the 5.9 keV line expressed in % FWHM.

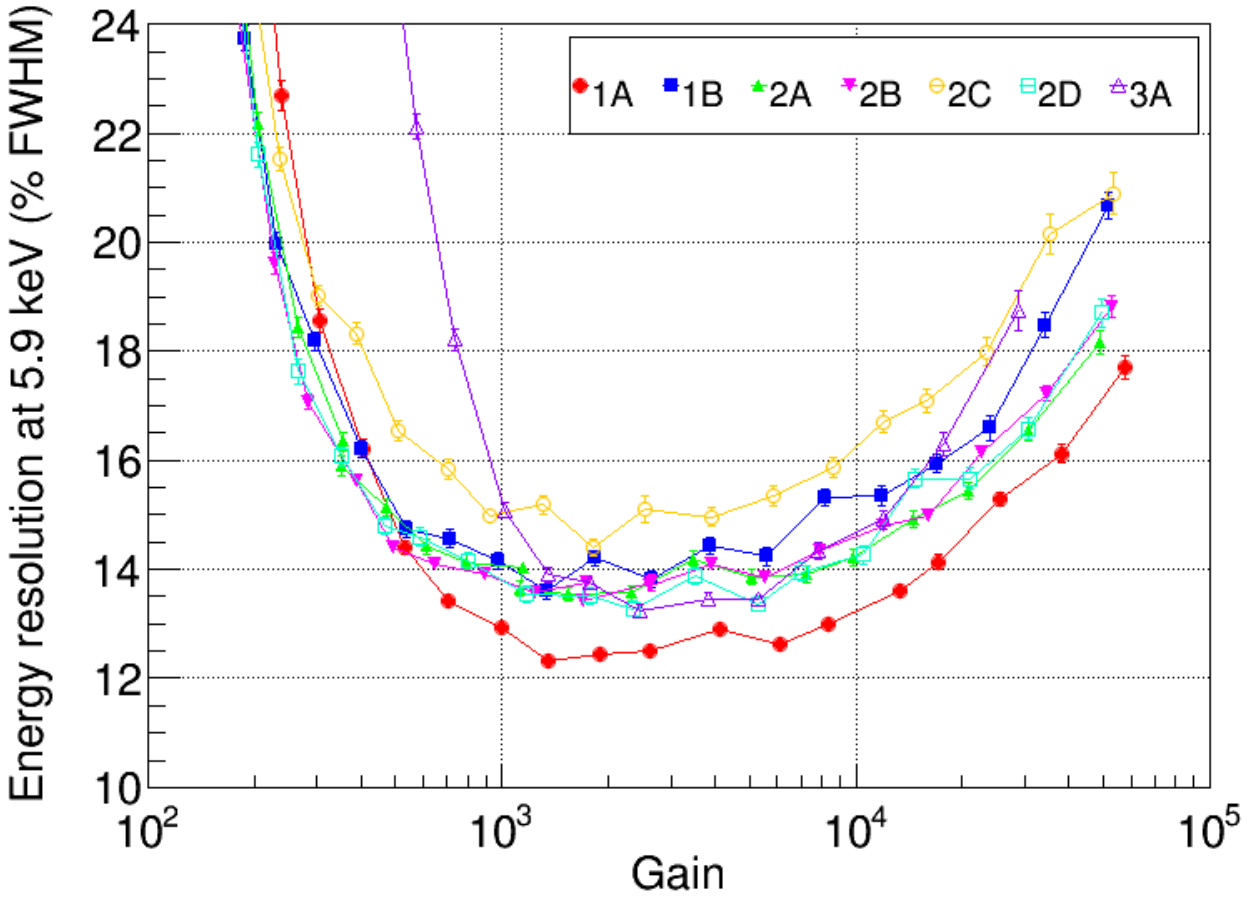
Gain curves in Ar+5%iso



Maximum gain:

- 1-2: **5 x 10^4**.
- 3: **3 x 10^4**.

Energy resolution in Ar+5%iso



Sample	Best value
1, A	12.3 ± 0.1
1, B	13.4 ± 0.1
2, A	13.5 ± 0.1
2, B	13.4 ± 0.1
2, C	14.4 ± 0.1
2, D	13.3 ± 0.1
3, A	13.2 ± 0.1

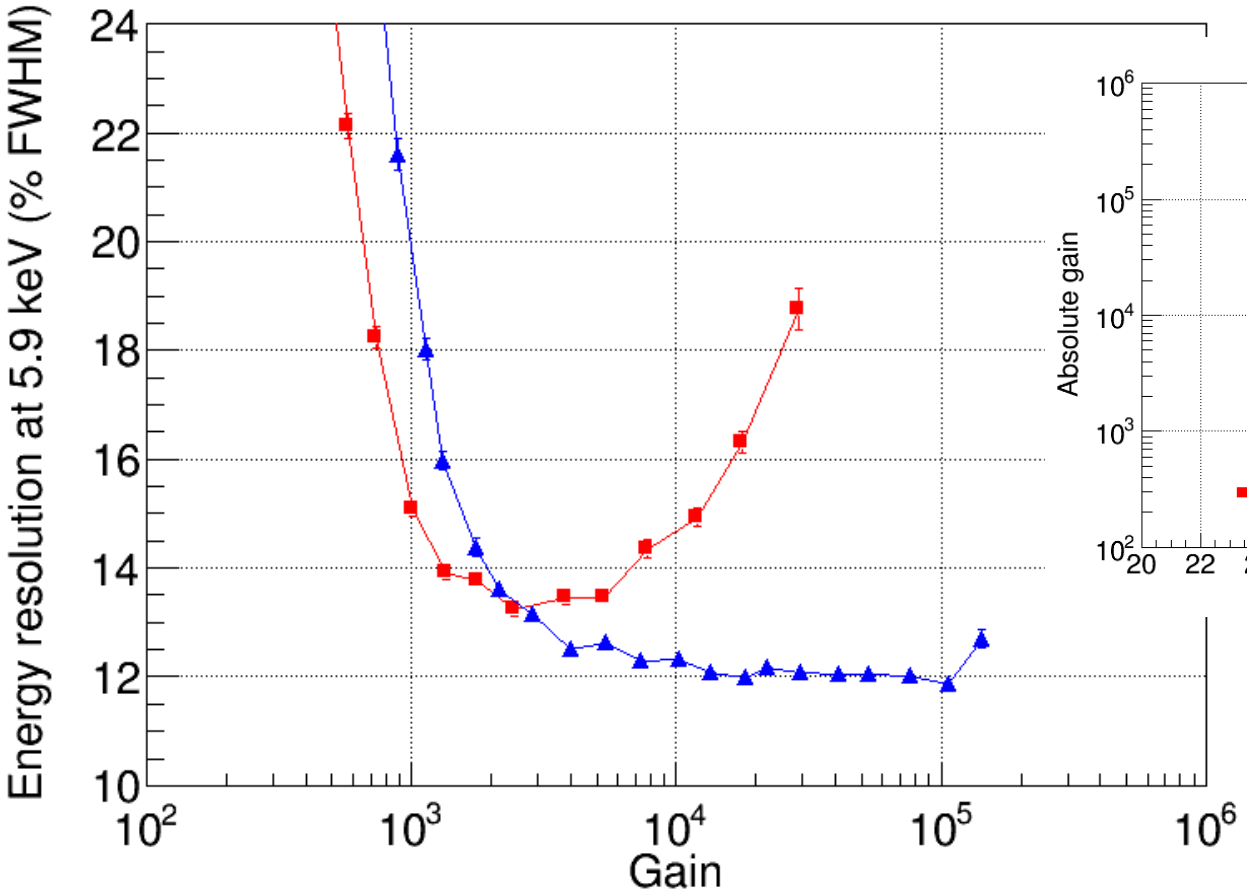
Energy resolution:

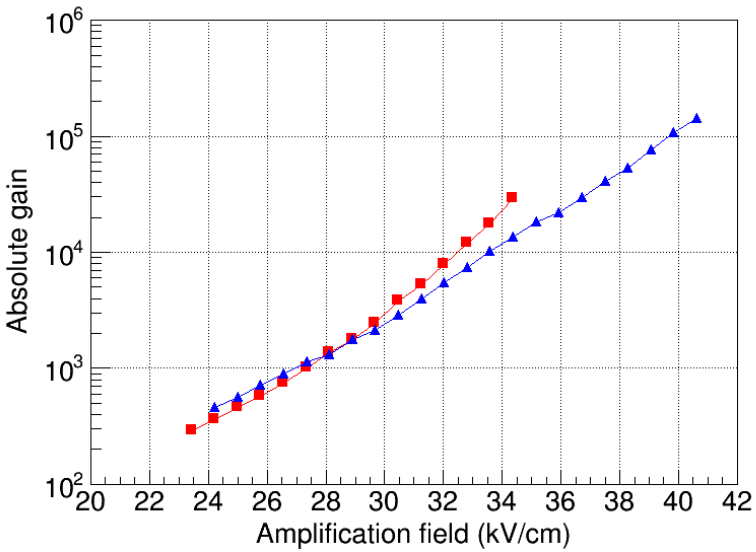
- Ar: **13.4% FWHM.**
- No effect of mesh.

Results in Ne+10%iso

Red: Ar+5%iso

Blue: Ne+10%iso

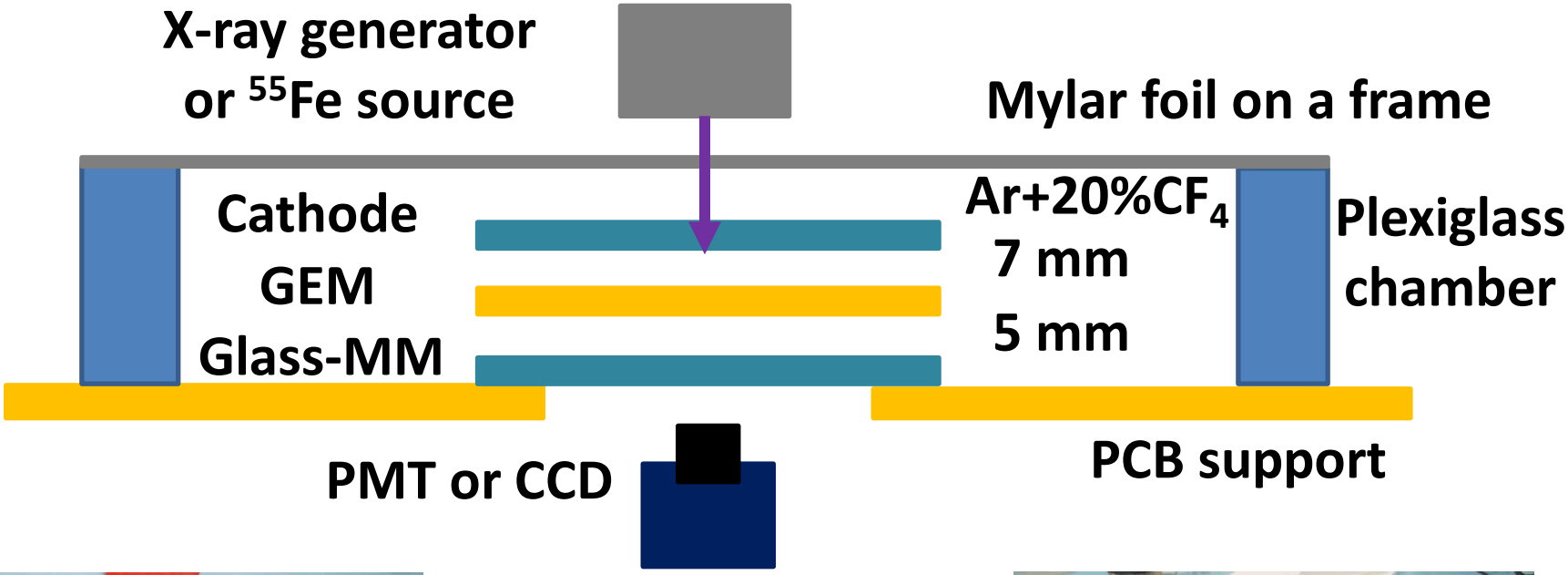


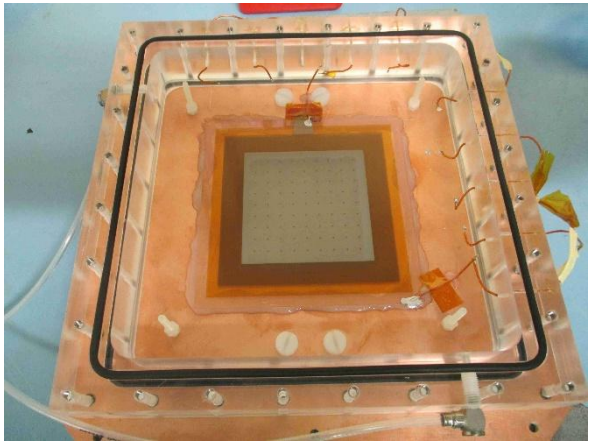


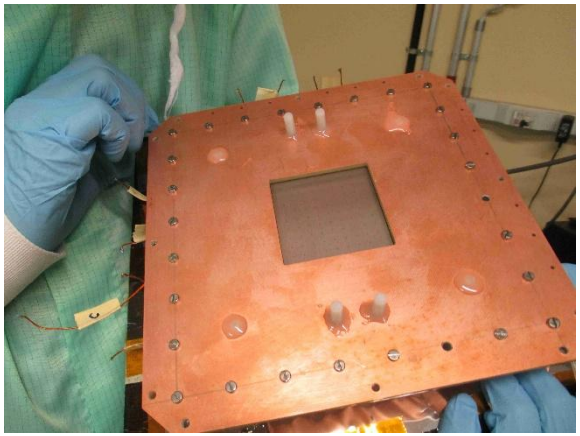
Energy resolution:

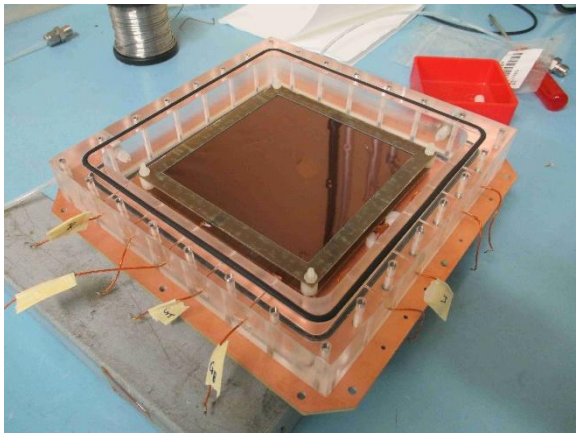
- Ar: **13.4% FWHM.**
- Ne: **12.0% FWHM**

Optical read out MM-based detector

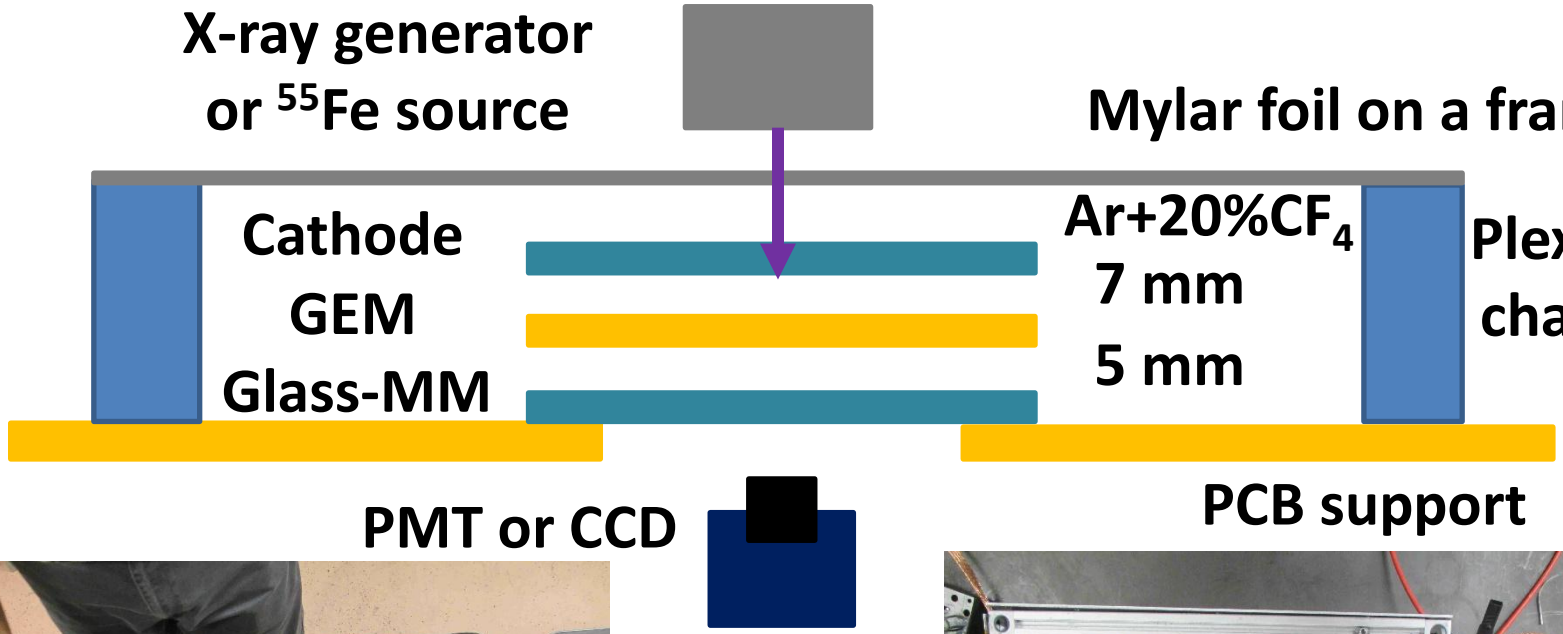


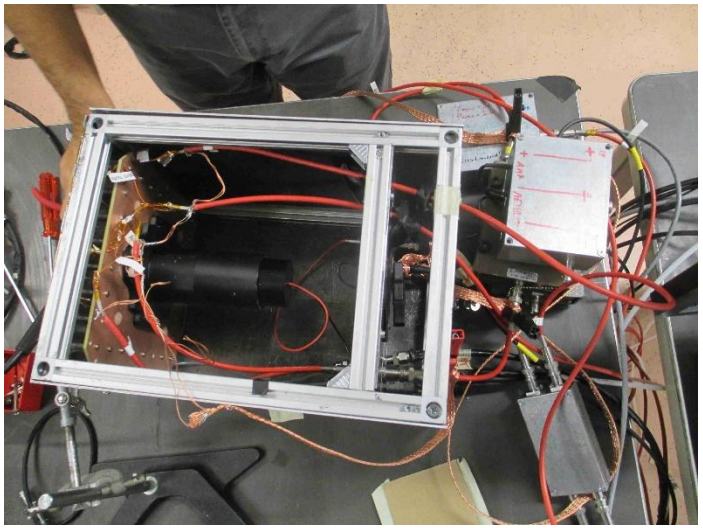


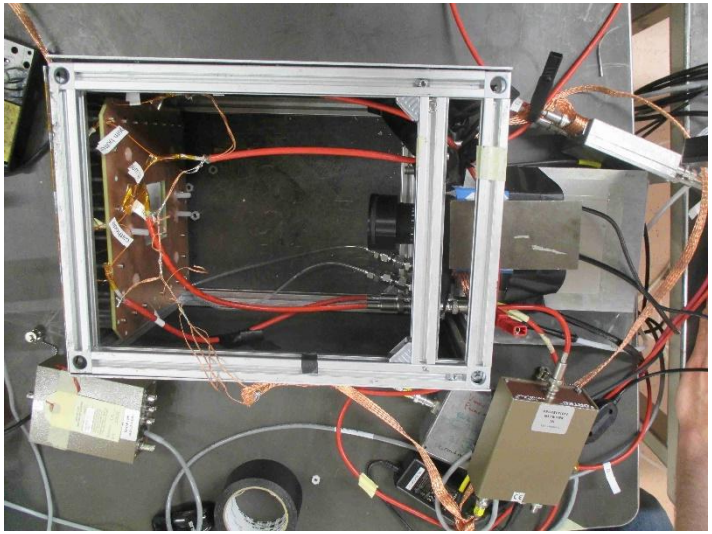




Optical read out MM-based detector







Optical read out MM-based detector

Setup:

- Micromegas (500-600 V)
- Micromegas (530-580 V) + 1 GEM (@400, G = 100)

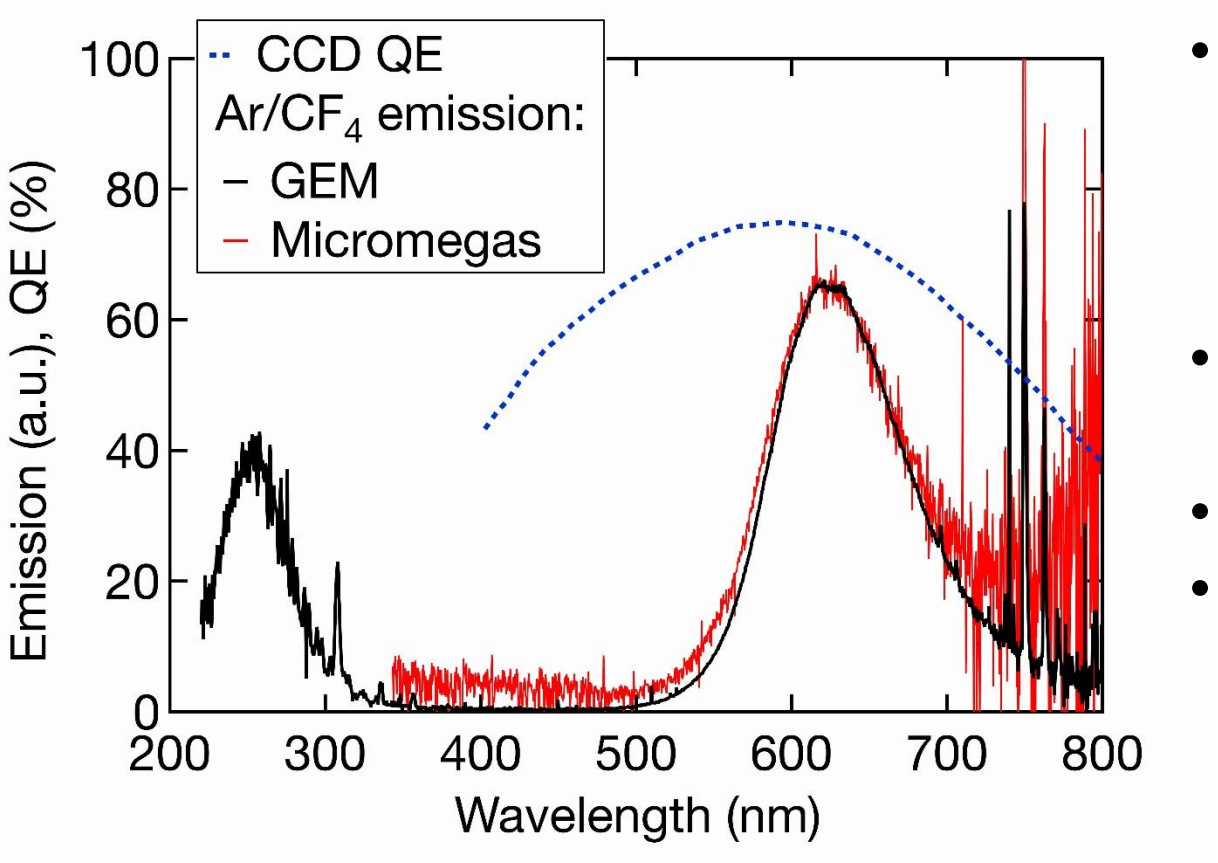
Preliminary results:

- Scintillation light spectrum compatible with GEM one.
- High resolution images with x-ray radiography.
- Single x-ray photon events observed.
- Energy resolution: **20-25% FWHM** at 5.9 keV.

Under investigation:

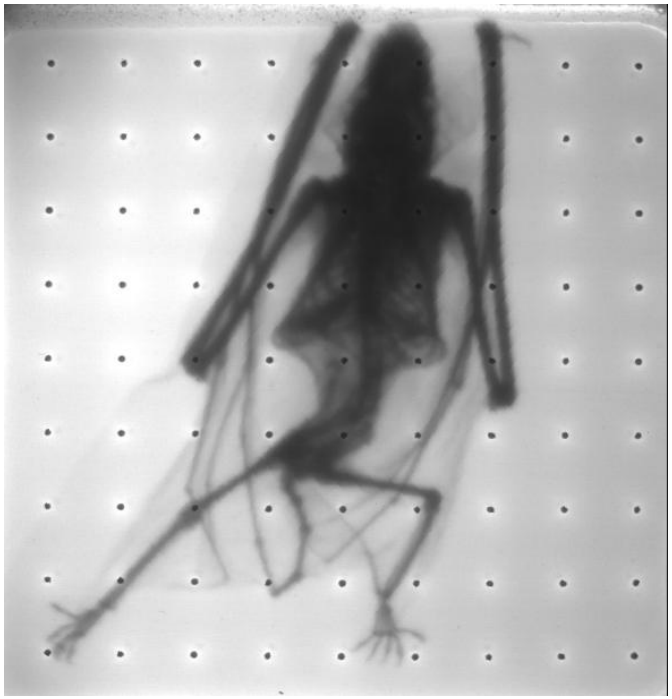
- Iron spectrum only observed if source was collimated.
- Better energy resolution when GEM was on!

Scintillation light spectrum

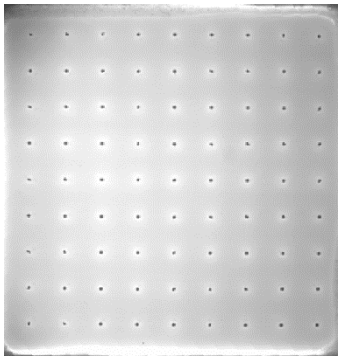


- Recorded by a UV-VIS spectrometer coupled to a collimating lens.
- MM at 560 V (2 µA) in x-ray generator.
- Similar to GEM.
- No UV emission band due to glass or ITO absorption.

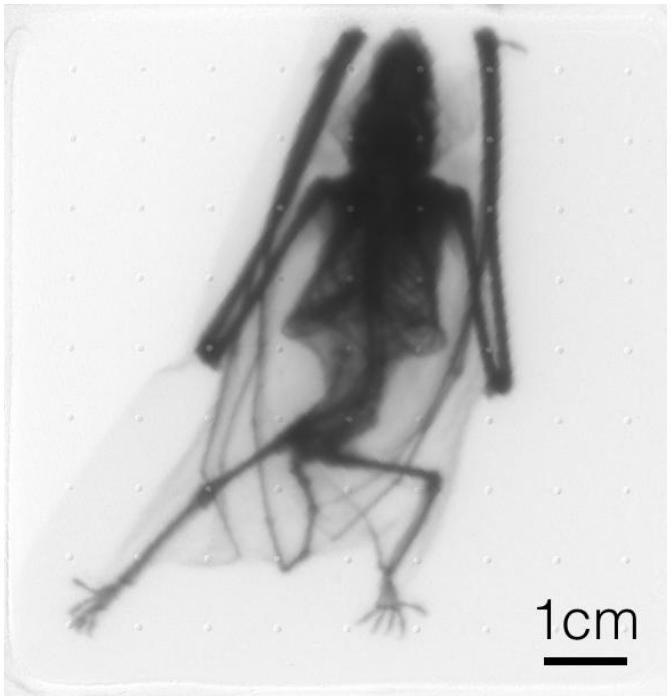
X-ray radiography



Background substracted



“White” image

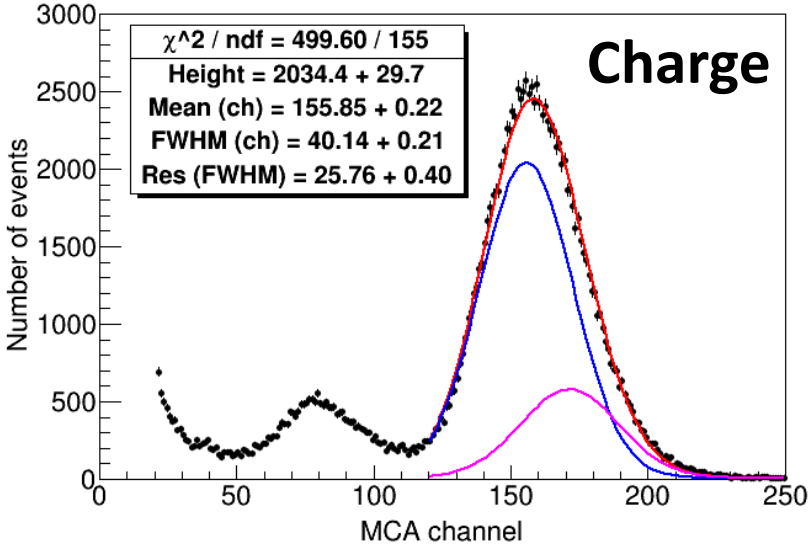


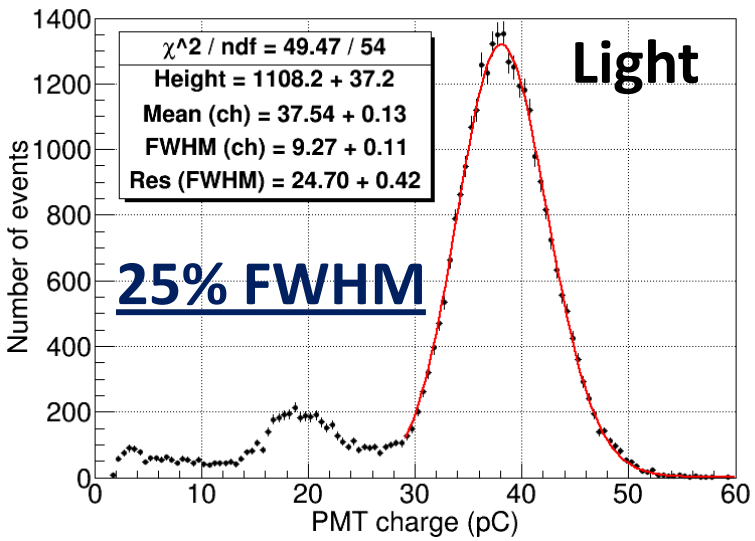
Flat-field corrected

- Images acquired by averaging several 10s exposure times.
- Beam profile shape removed by dividing by “white” image.
- High resolution images are obtained.

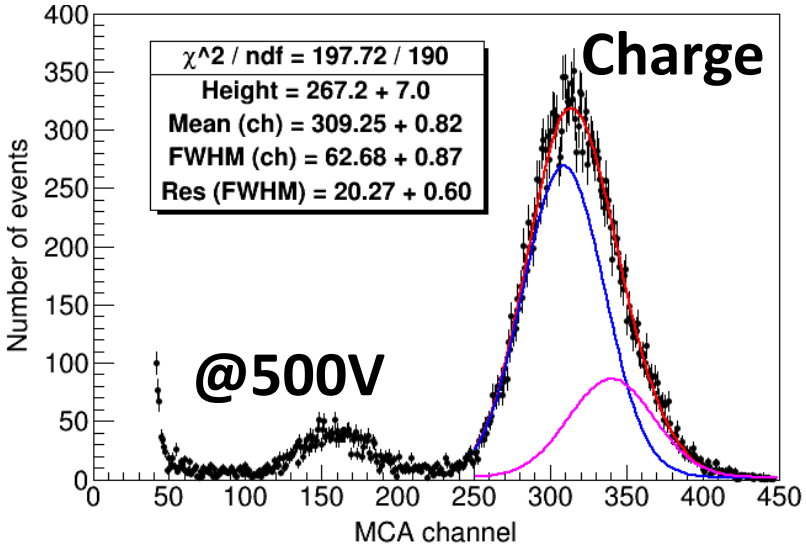
Energy resolution in Ar+20%CF_4

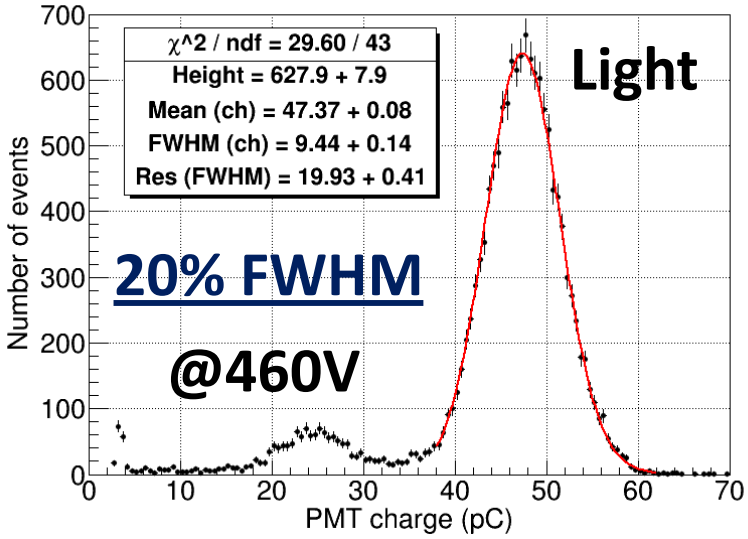
MM @570V





MM + GEM



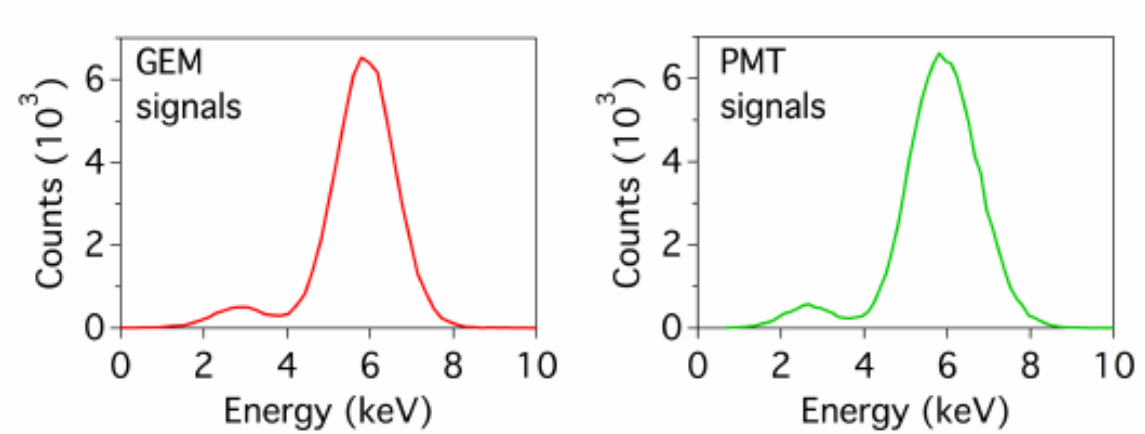


Energy resolution in Ar+20%CF_4

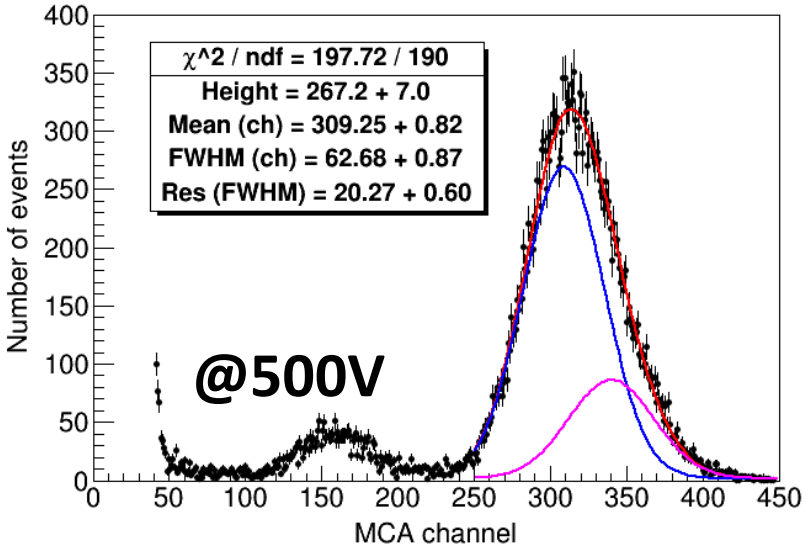
Triple-GEM

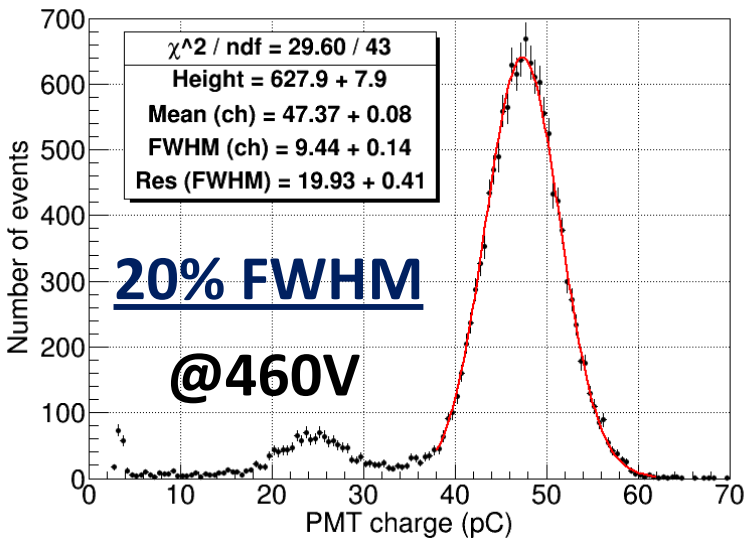
32% FWHM

F.M. Brunbauer *et al.*, *JINST* **13** (2018) T02006



MM + GEM





Summary

Energy resolution:

- Glass (bulk) MM show better performance than standard bulk:
  - Maximum gain: **3-5 x 10^4** (Argon), **10^5** (Neon).
  - Energy resolution: **13.4% FWM** (Argon), **12.0% FWM** (Neon).
- No clear difference between woven-meshes or β-mesh.

Optical TPC:

- Scintillation light spectrum compatible with GEM one.
- High resolution images with x-ray radiography.
- Single x-ray photon events observed.
- Energy resolution: **20-25% FWHM** at 5.9 keV.

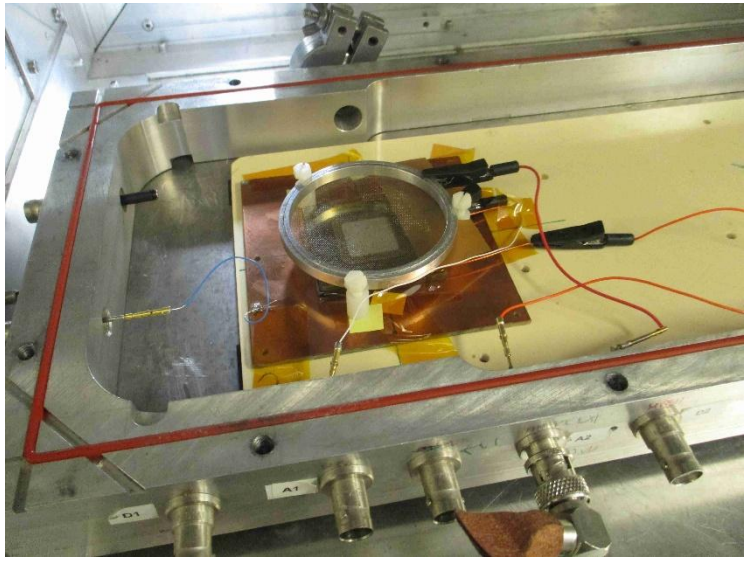
Summary

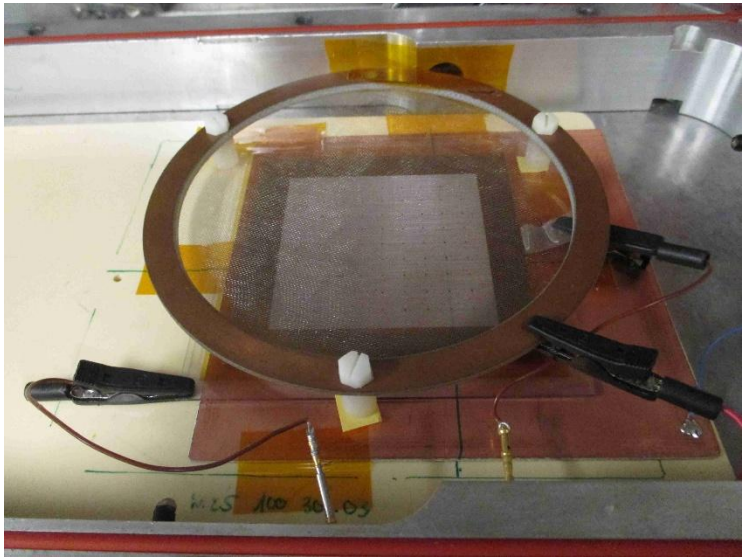
Next steps:

- Spatial resolution with a linear pair pattern & a MTF pattern.
- Remeasurement of light yield.
- Iron spectrum with short exposure images.
- Radon track images.
- Other possible improvements: thinner drift gap, helium gas.

Back-up slides

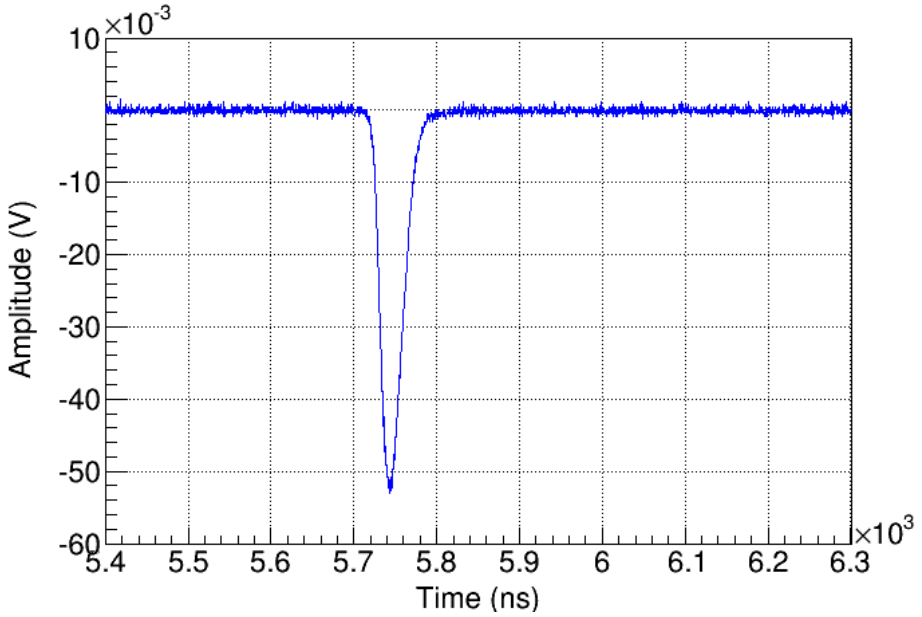
Detector characterization

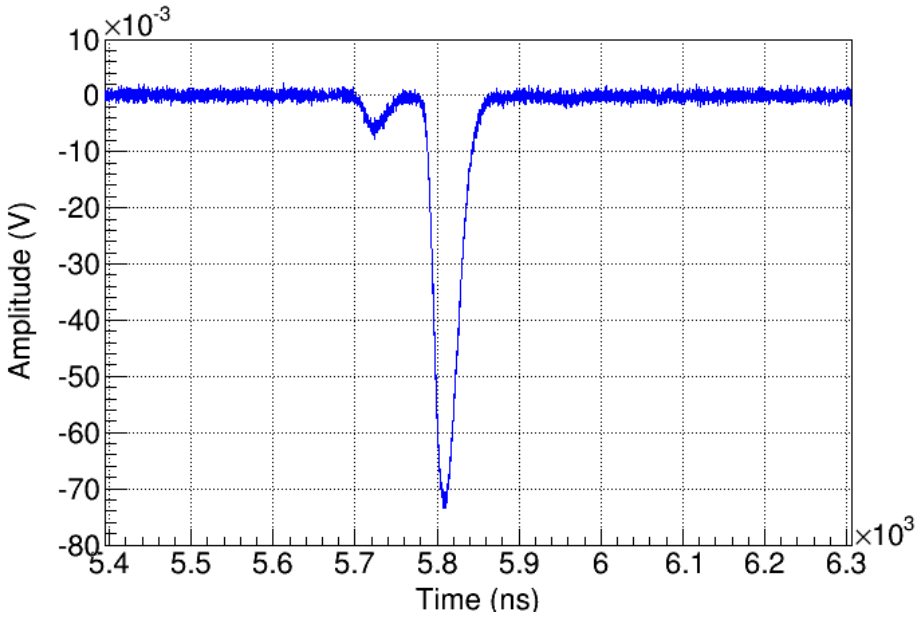




- Gases: Ar+5%iso & Ne+10%iso at 1 bar, 5 l/h flow.
- Arnaud's test chamber, ^{55}Fe source situated outside.
- Drift gap: ~10 mm.
- Large range of anode & drift scanned voltages.

PMT pulses in Ar+20%CF_4





Only Micromegas

Cathode = 150 V

Anode = 570 V

MM + GEM

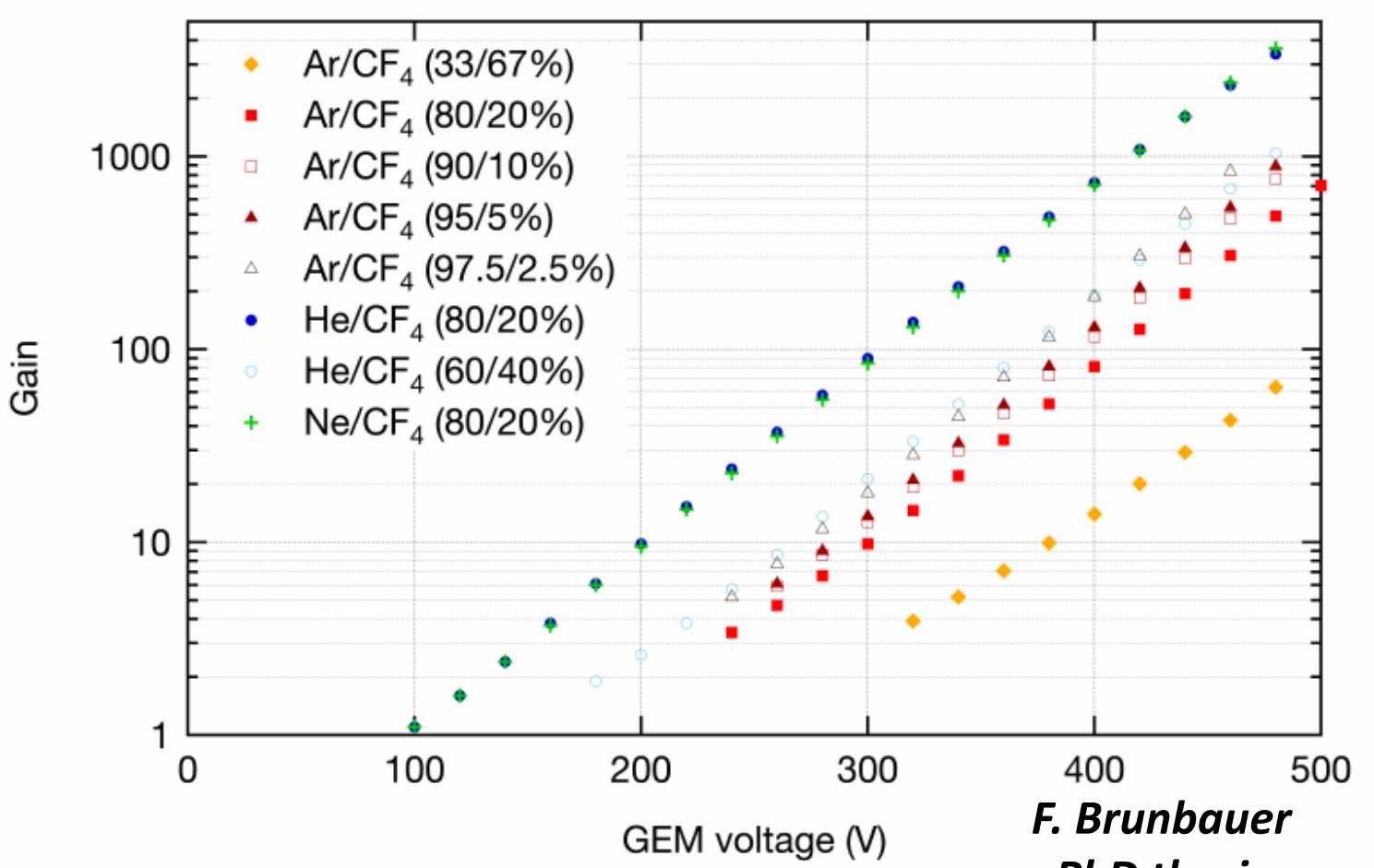
Cathode = 150 V

GEM = 400 V

Anode = 460 V

We resolve the light produce in each amplification stage.

Gain in single-GEM



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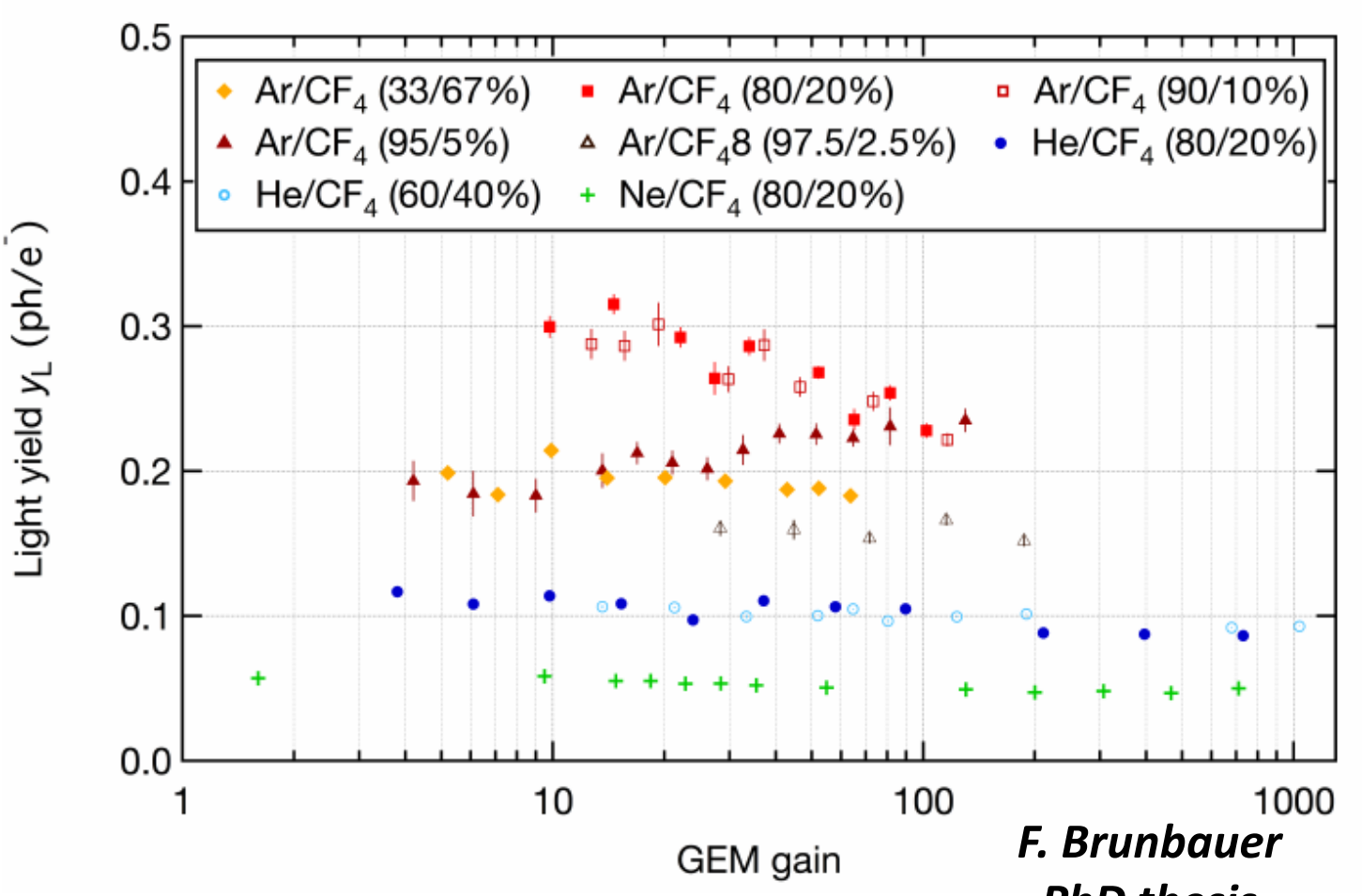
Light yield in single-GEM



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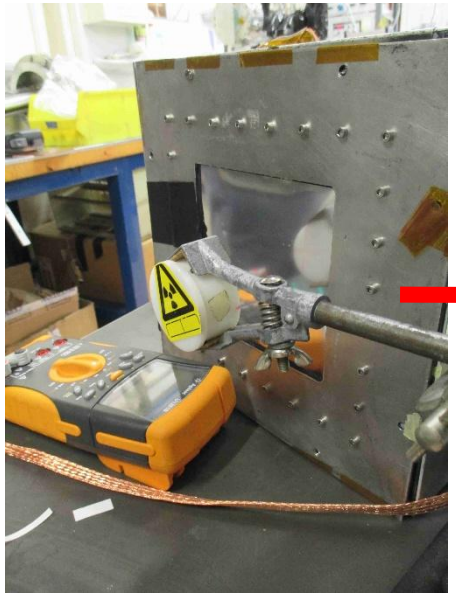
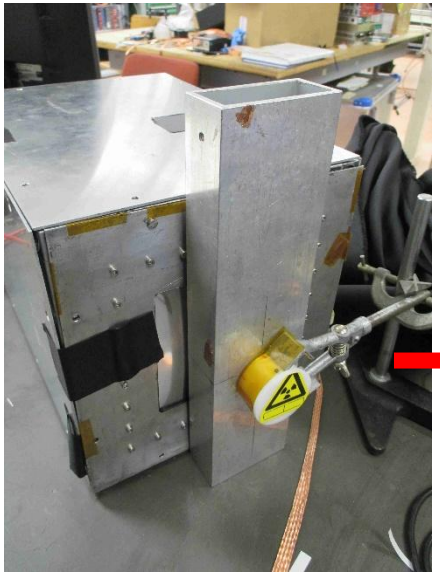
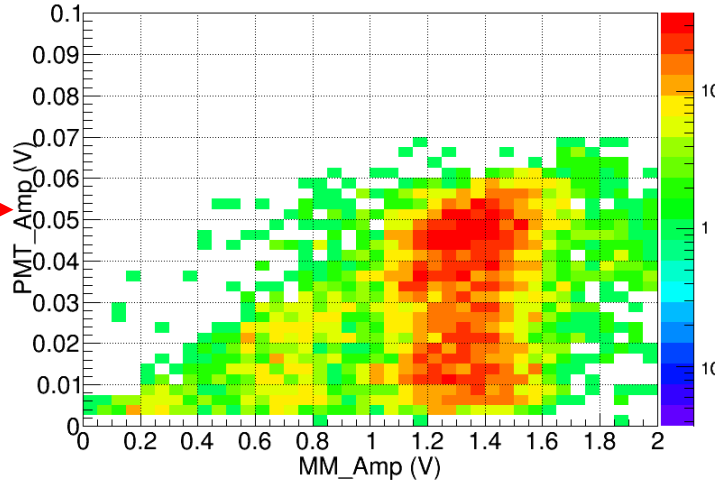
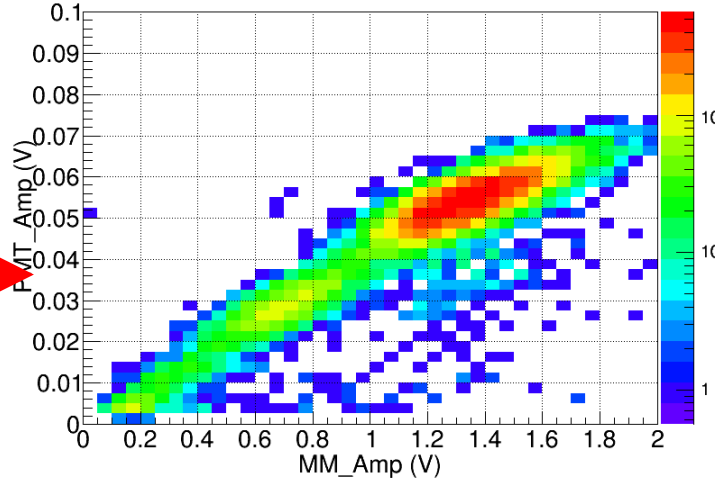
Light spectrum



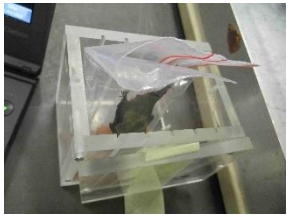




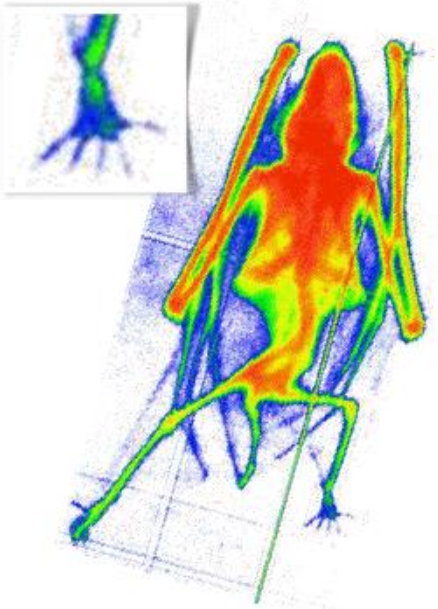


^{55}Fe spectrum only observed if source was collimated

X-ray radiography

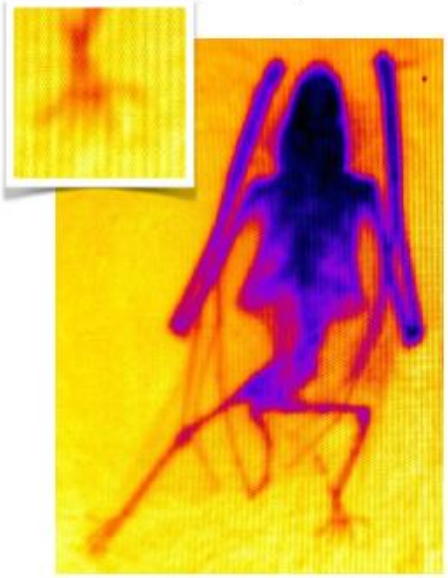


Charge readout
(1998)



https://gdd.web.cern.ch/GDD/gemreadout.htm

Optically read out GEMs
(2016)



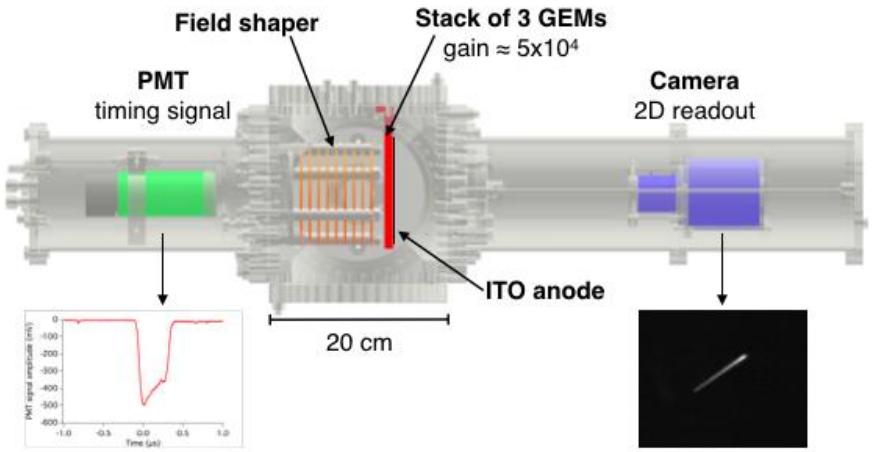
Optically read out MMs
(2018)

F. Brunbauer (CERN)

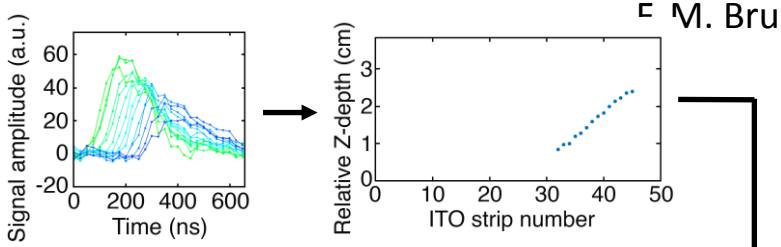
Combined Optical and Electronic Readout for Event Reconstruction in a GEM-based TPC

Authors: F. M. Brunbauer, F. García, M. Lupberger, E. Oliveri, D. Pfeiffer, L. Ropelewski, P. Thuiner, and M. van Stenis[1]

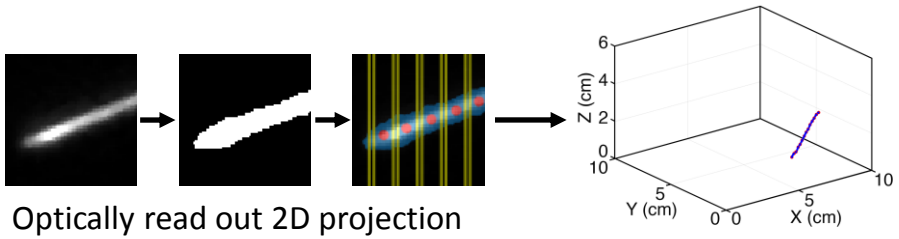
Presented by F. M. Brunbauer



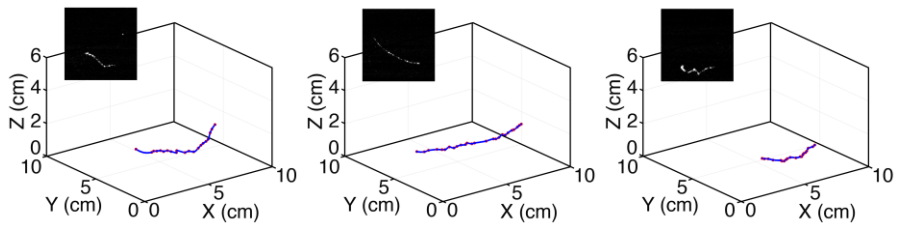
Optically transparent **ITO strip anode** permits simultaneous readout of electronic signals and secondary scintillation light.
ITO can be structured with photolithography and etching in HCl.



Depth information from electron arrival times



Optically read out 2D projection



Combined optical and electronic readout extends 3D reconstruction capabilities to complex track geometries.