EL yield and charge gain in He/CF_4/isobutane mixtures

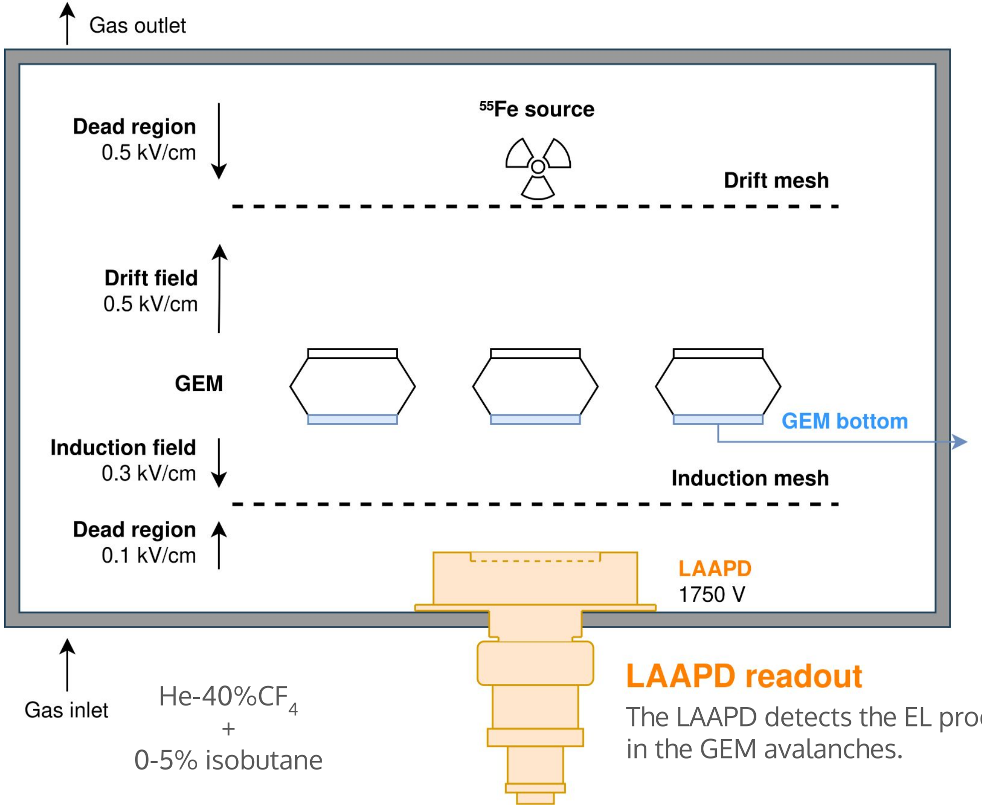
Rita Roque, Daniel Mano, Fernando Amaro, Cristina Monteiro, Joaquim Santos

Topics:

- Charge Gain
- EL yield
- Energy resolution

Experimental Setup

Detector Layout



Charge readout

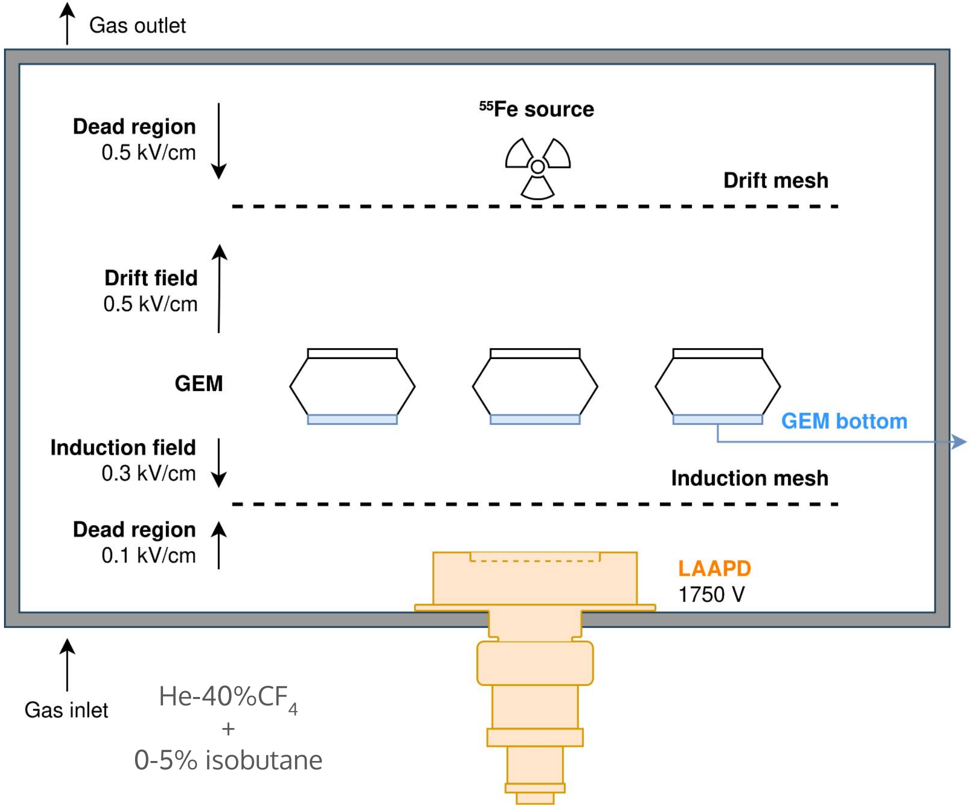
Secondary electrons are collected at the bottom of the GEM.

LAAPD readout

The LAAPD detects the EL produced in the GEM avalanches.

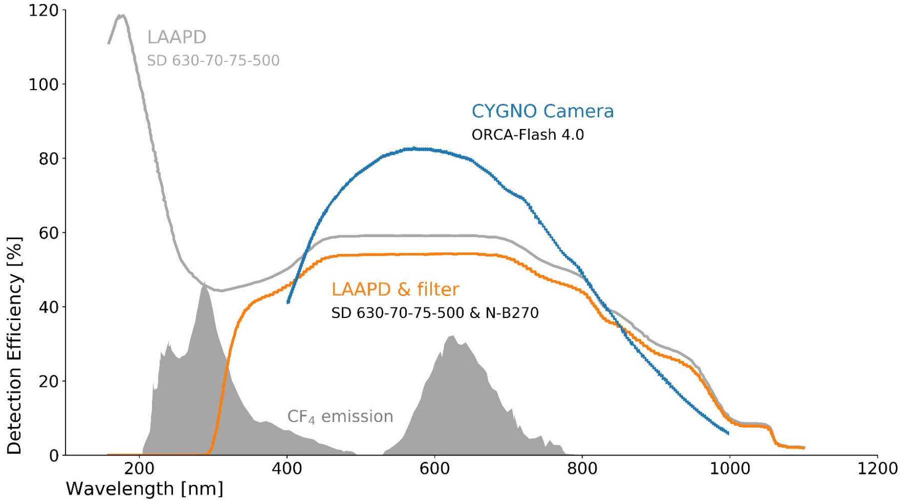
Experimental Setup

Detector Layout



Detector Components:

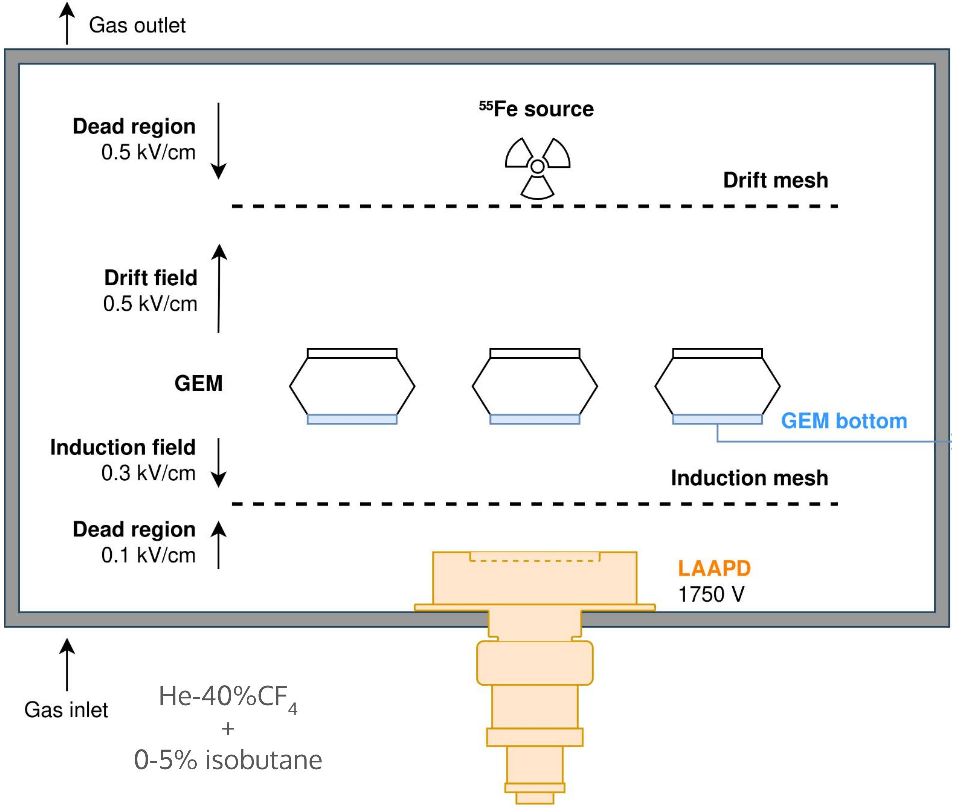
- **Meshes** with ~84% optical transparency;
- **Standard GEM** with 3 x 3 cm² area;
- **LAAPD:**
    - Active diameter: 16 cm;
    - Range: 150 - 1000 nm.



We will use a N-B270 glass window to filter out the UV component of the CF_4 EL.

Experimental Setup

Detector Layout



He-40%CF_4
+
0-5% isobutane

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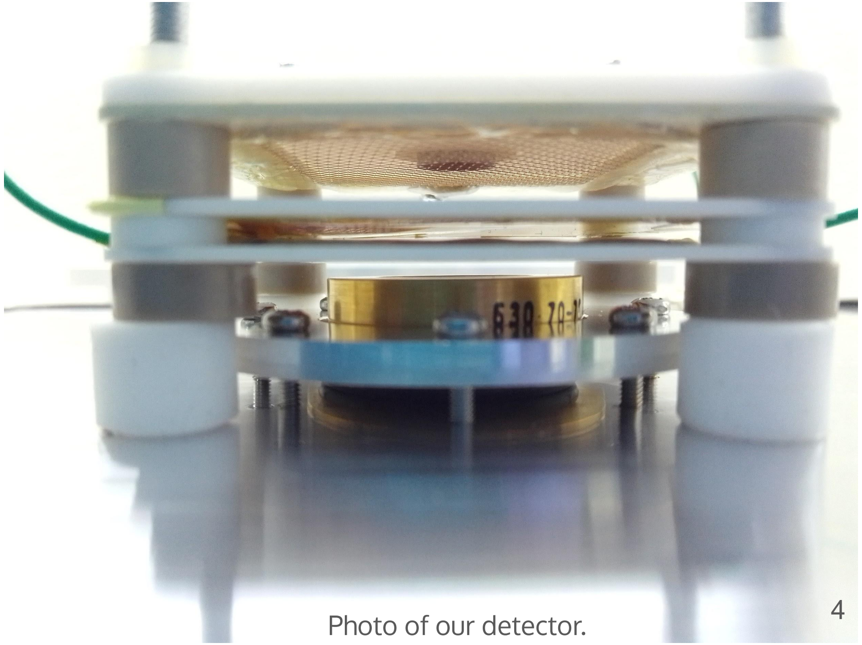
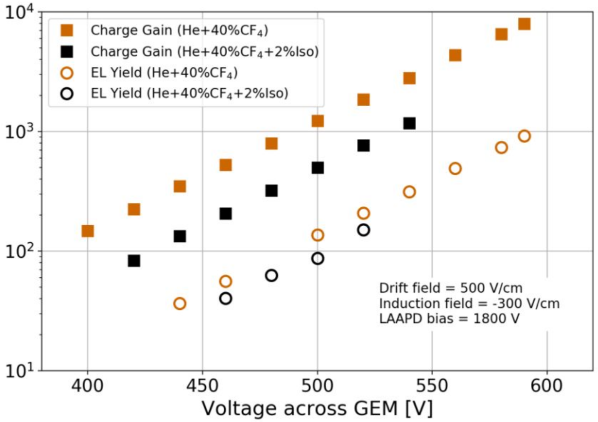


Photo of our detector.

Experimental Setup

Improvements in the gas flow

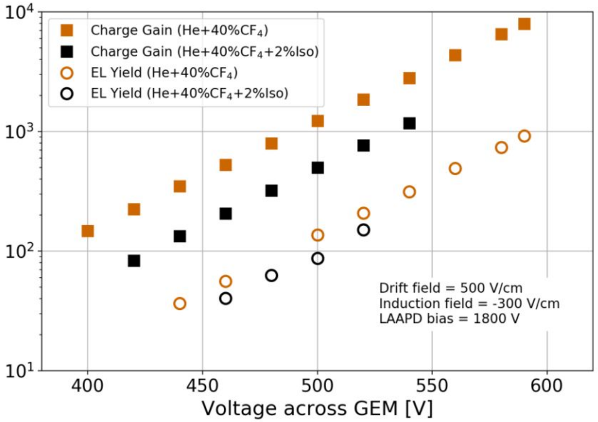


Results presented in 14/01/2021.

Experimental Setup

Improvements in the gas flow

- **Reduced errors in the gas percentages** by going from 1 L/h to 4 L/h.



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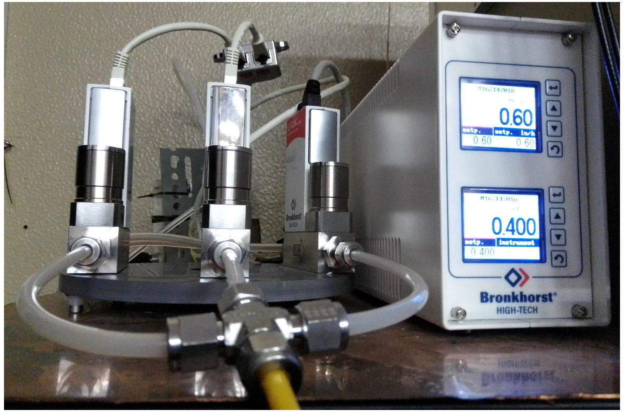


Gas flow controllers.

Experimental Setup

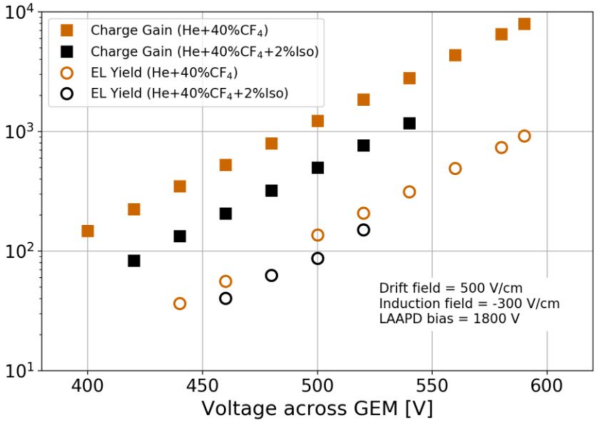
Improvements in the gas flow

- **Reduced errors in the gas percentages**
  by going from 1 L/h to 4 L/h.

- **Maintained He/CF_4 ratio in all measurements**
  by keeping He/CF_4 flowing at 60/40 and then adding the required % of isobutane (1% - 5%).

Before, the He/CF_4 ratio was not constant:

	0% isobutane	2% isobutane	5% isobutane
He/CF_4/isobutane	60/40	58/40/2	58/37/5
He/CF_4 ratio	1.5	1.45	~1.57



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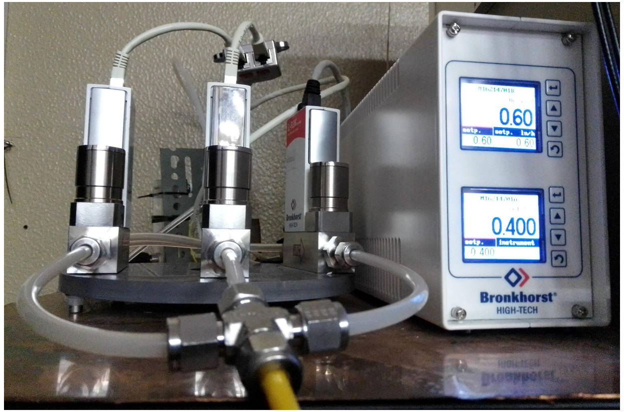
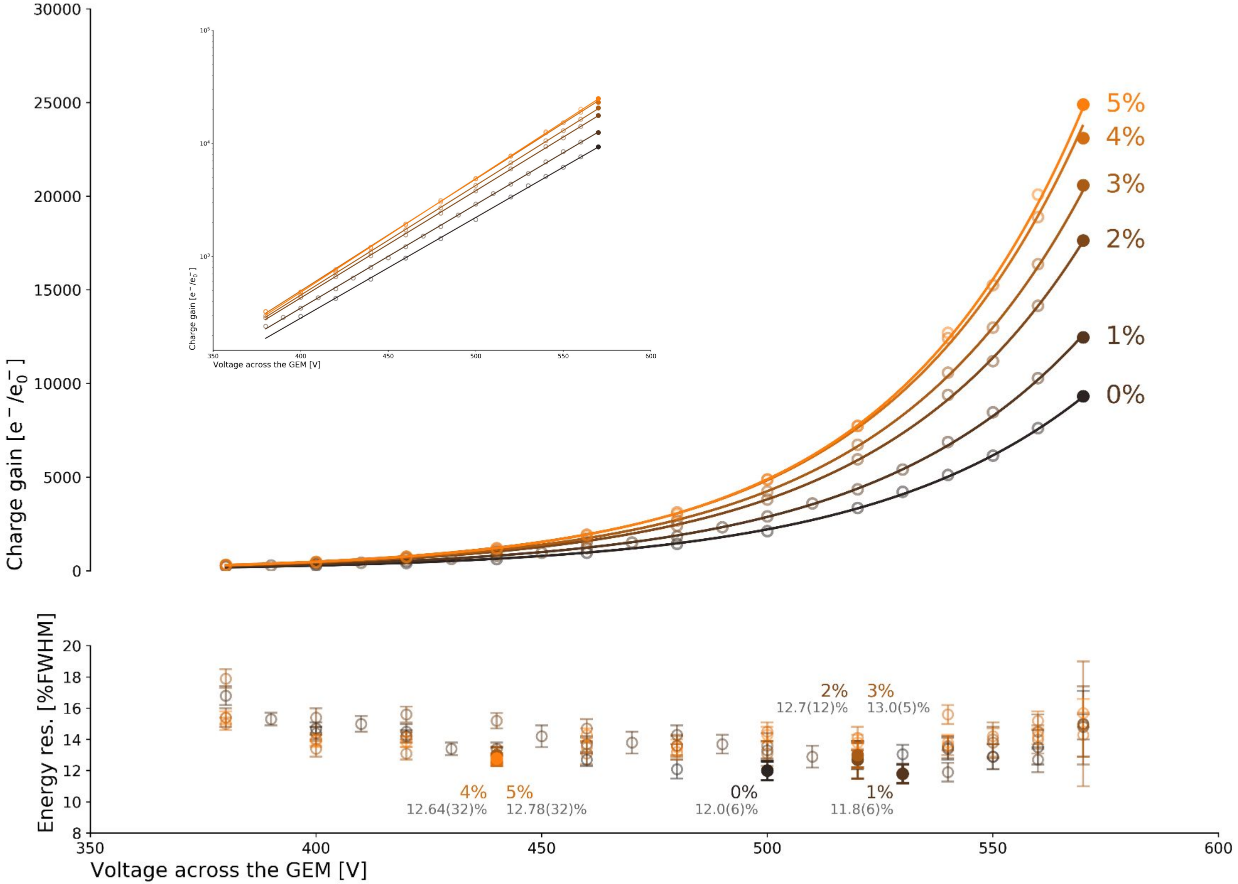


Gas flow controllers.

Results He/CF_4 (60/40) + isobutane



Charge Signals

Charge gain increases with isobutane content

We attribute this behavior to *Penning Transfers:* the energy stored in He metastable states (19.8 eV and 20.6 eV) ionizes isobutane molecules (10.67 eV), thus creating more electron-ion pairs.

For more information:

- "Penning Transfers", by O. Sahin (2008)
- I Korolov et al 2020 J. Phys. D: Appl. Phys. 53 185201

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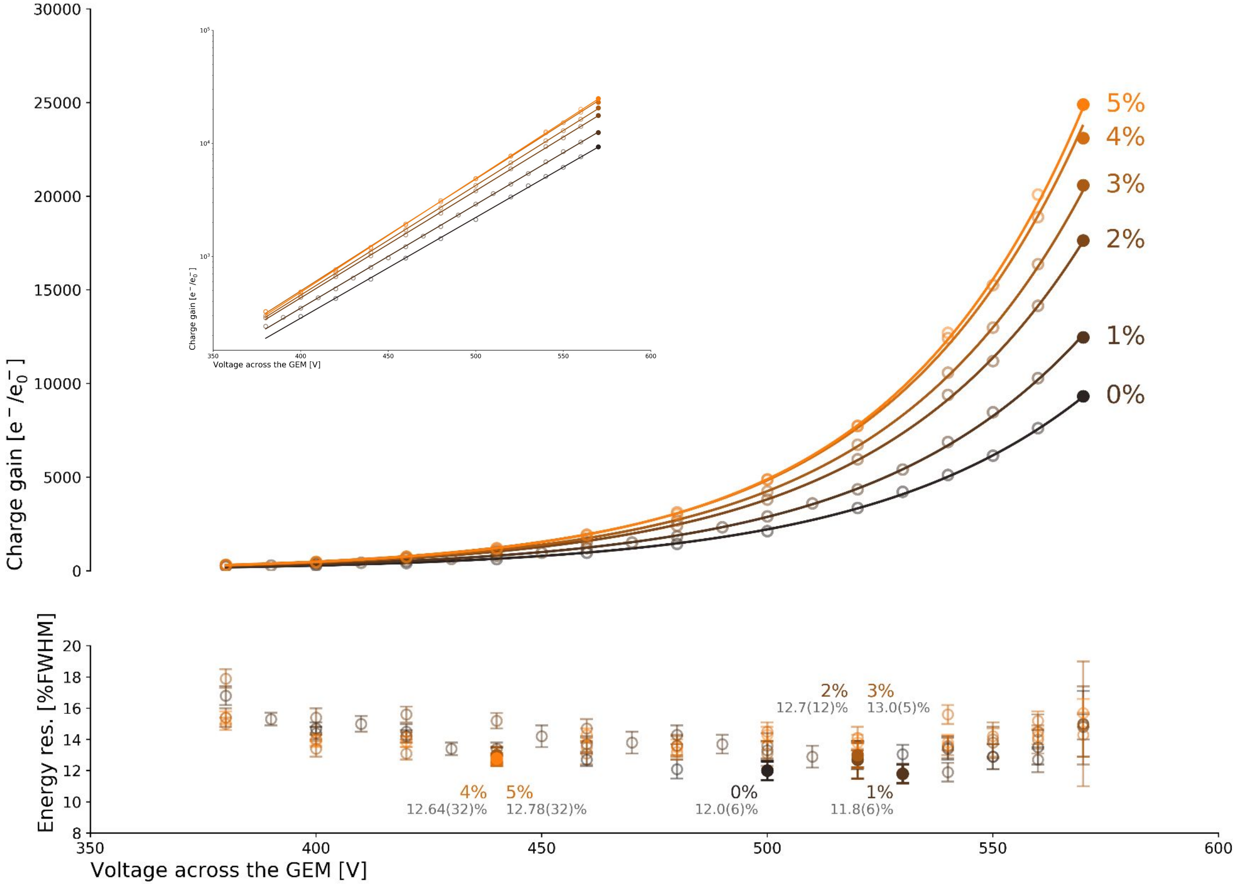

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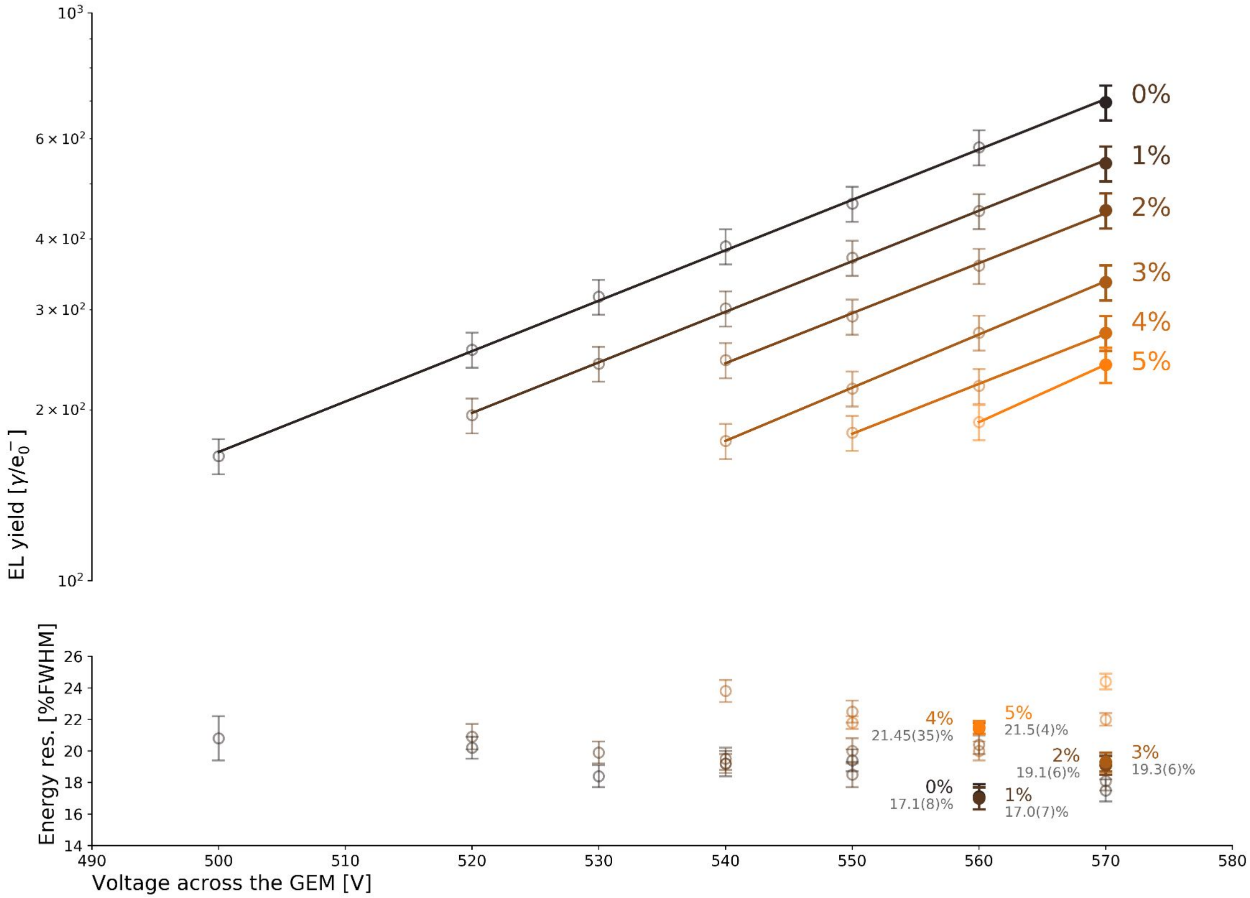
Energy resolution does not depend on the isobutane content

All studied mixtures had an energy resolution (FWHM) around 12%.

Results He/CF_4 (60/40) + isobutane

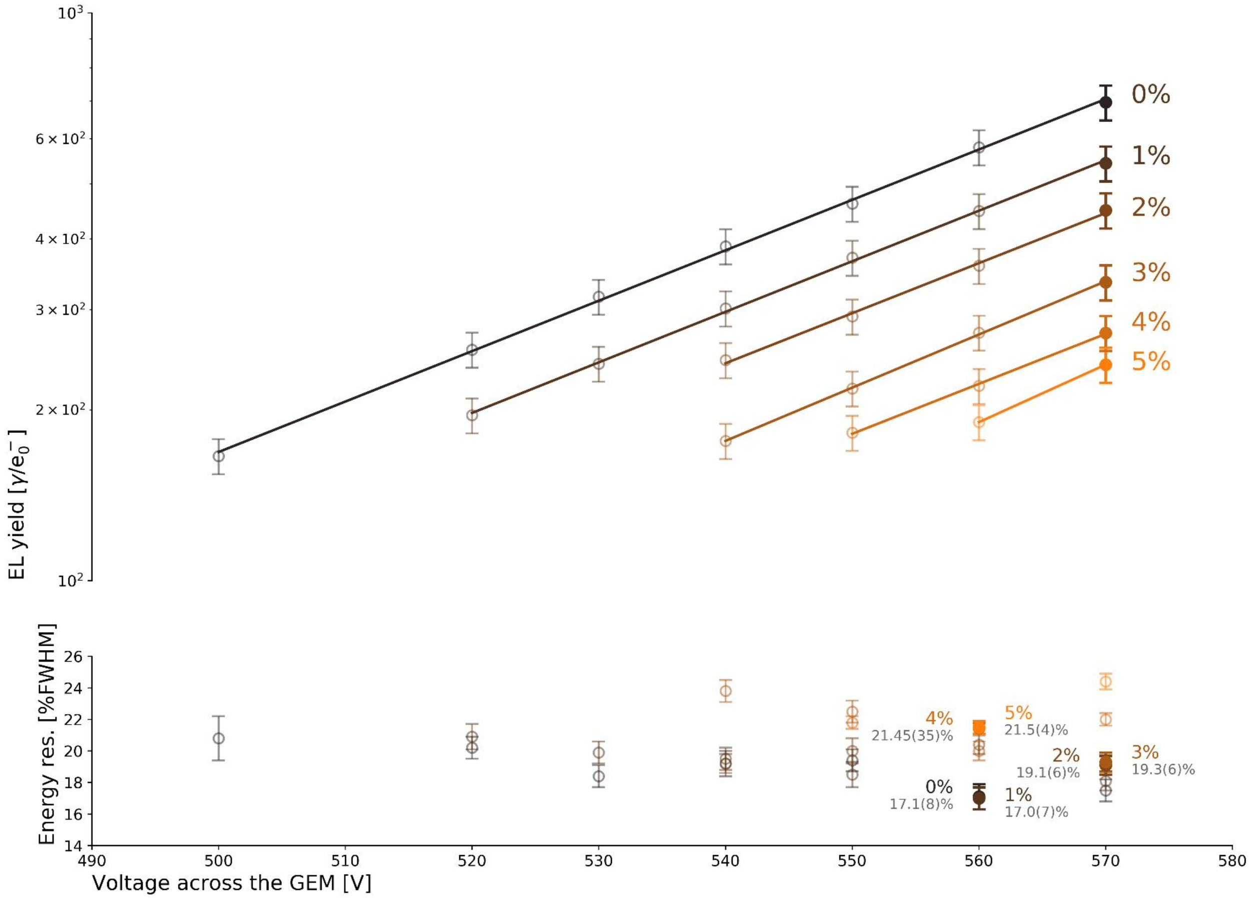


Absolute EL yield

Absolute EL yield decreases with isobutane content

The number of EL photons emitted per primary electron decreases with the concentration of isobutane: isobutane converts EL photons into vibrational and rotational states.

Results He/CF_4 (60/40) + isobutane



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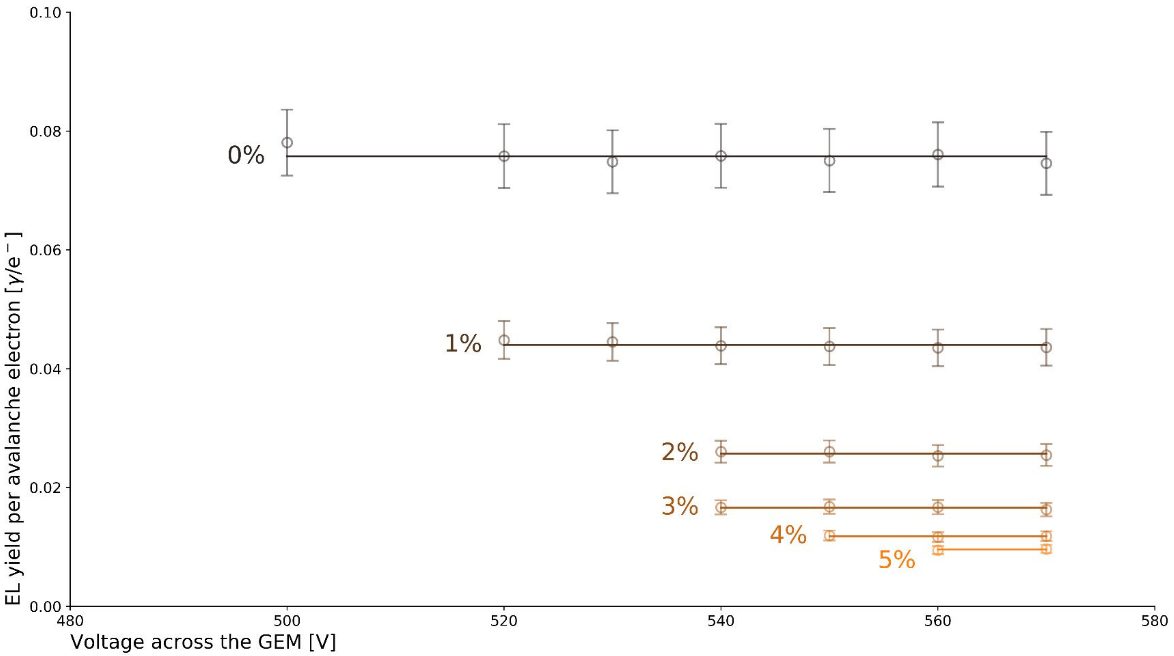
Energy resolution does not depend on the isobutane content

The gradual degradation in energy resolution is attributed to low statistics and not to decreased detector performance.

Results He/CF_4 (60/40) + isobutane



EL yield per avalanche electron

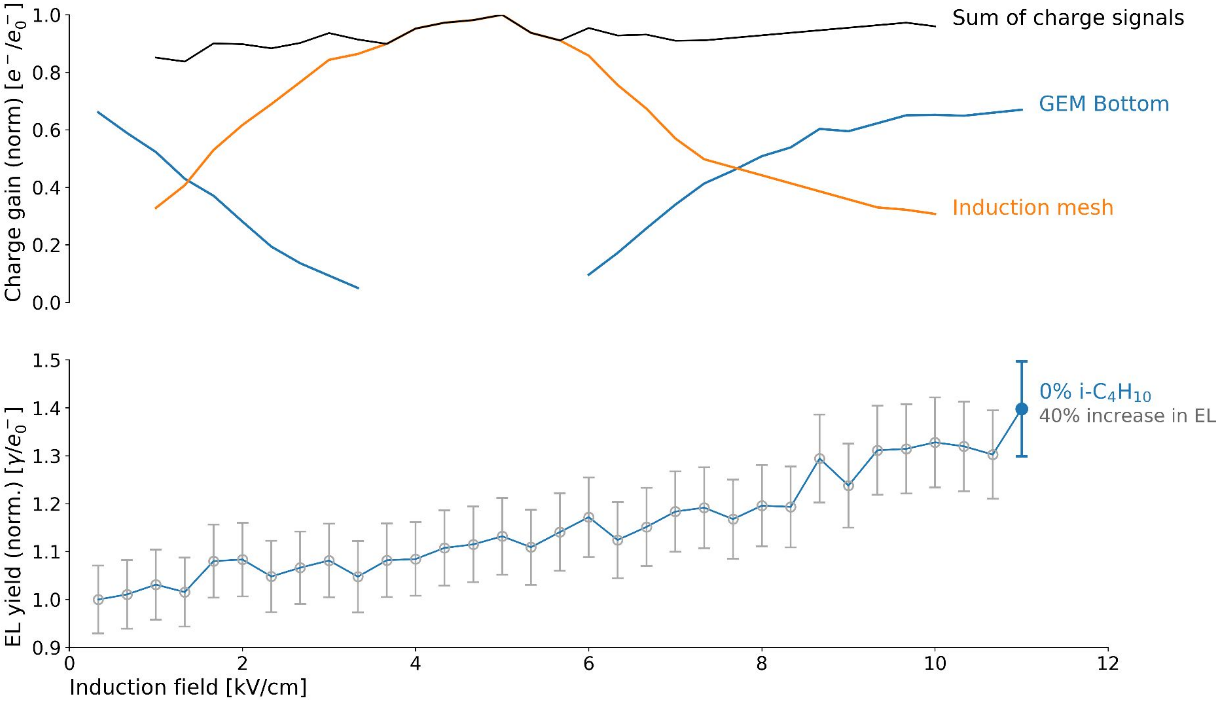
EL yield per avalanche electron decreases with isobutane content

The number of EL photons emitted per avalanche electron decreases with the concentration of isobutane: this is a combination of the *Penning effect* (increased charge gain) and EL decrease (quenching).

% Isobutane	0%	1%	2%	3%	4%	5%
Average EL photons per avalanche electron	0.0757(12)	0.0440(5)	0.0257(4)	0.01661(21)	0.01181(14)	0.00956(14)

Results He/CF_4 (60/40)

Conditions: The voltage across the GEM was kept at 540 V and the induction field was reversed to collect the electrons in the induction mesh.

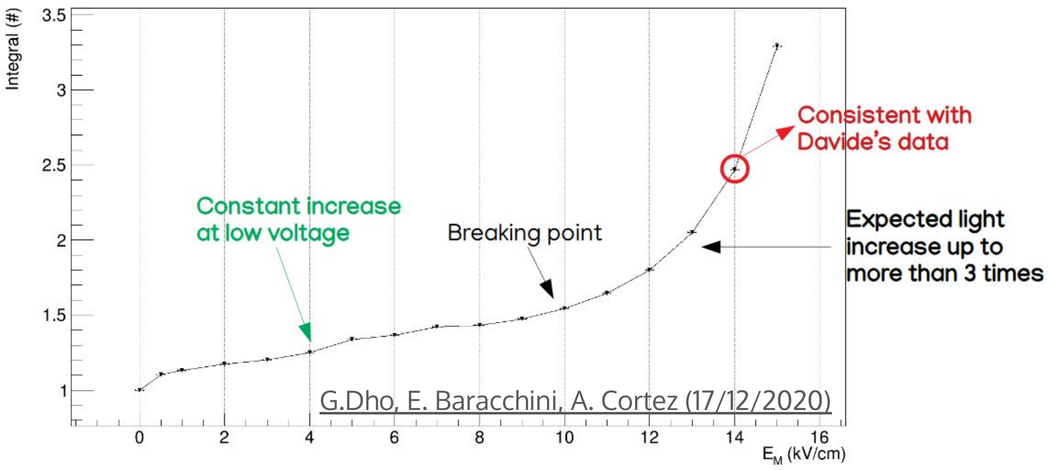


Producing additional EL in the induction region

Irregularities in the charge collection process

For fields above 5 kV/cm, the electrons are not fully collected at the anode: we attribute this effect to the characteristic properties of CF_4 in terms of electron attachment, diffusion and drift velocity (under study).

Results He/CF_4 (60/40)



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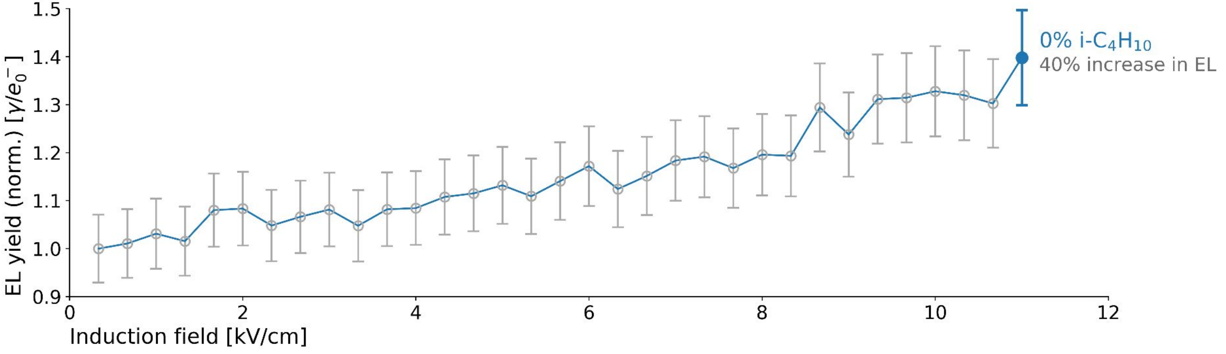

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We see a 40% increase in absolute EL for 11 kV/cm

We saw a gradual increase in absolute EL, which is consistent with the results reported in the presentation G.Dho, E. Baracchini, A. Cortez (17/12/2020)

Conclusions

With increasing isobutane content:

- **Charge gain increases** due to *Penning Transfers*.
- **EL yield decreases** due to photon quenching.
- **Energy resolution stays unaffected:** ~12% for charge signals and ~20% for EL signals (FWHM @ 5.9 keV).

Conclusions

With increasing isobutane content:

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- **EL yield decreases** due to photon quenching.
- **Energy resolution stays unaffected:** ~12% for charge signals and ~20% for EL signals (FWHM @ 5.9 keV).

Future Work

- **Matching the CYGNO's camera spectral sensitivity** — Install the optical glass window to remove the VUV component;
- **Increase the EL yield** — Explore other MPGDs with additional amplification regions (MHSP/Cobra_125);

  Return to sealed mode operation (using *getters*).

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CYGNO

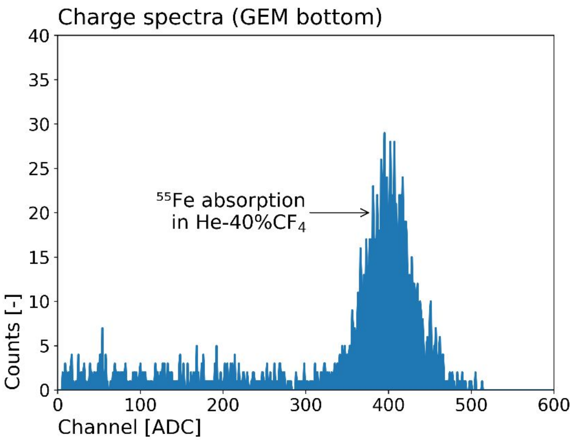
1290 UNIVERSIDADE D COIMBRA

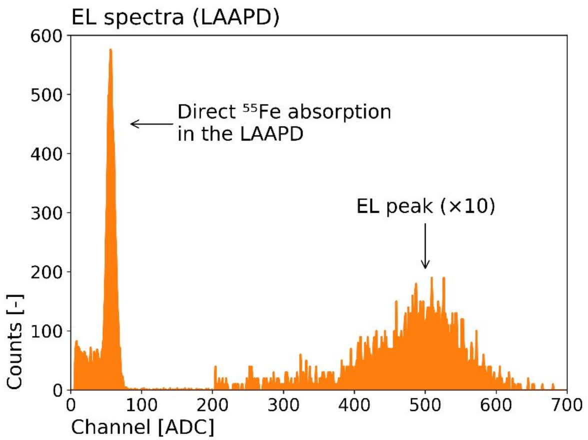
LIBPhys-UC

Grazie per l'attenzione

Any questions?

Backup





EL and ^{55}Fe X-rays peak ratio

$$Y_{\mathrm{EL}} = \frac{\eta_\gamma}{\eta_{e_0^-}} = \frac{w(\mathrm{gas})}{w(Si)} \times \frac{A_{EL}}{A_X} \times \frac{1}{QE \times \Omega \times T}$$

w-value (silicon and gas)

quantum efficiency, solid angle, mesh transparency

Absolute EL yield

Definition: number of secondary scintillation photons produced in the electron avalanches per primary electron created in the drift region.

The LAAPD detects the direct ^{55}Fe X-rays and the EL photons

The EL peak depends on the EL yield, LAAPD biasing and temperature.

The direct X-ray peak depends only on the LAAPD biasing and temperature.

The direct X-ray peak enables in-spectra calibration and the determination of the absolute EL yield.

For more information:

- M. Moszyński et al 2002 Nucl. Instr. and Meth. A. 485 504-521
- C.M.B. Monteiro, PhD Diss. 2011.