Studies on He-CF_4-isobutane mixtures for the CYGNO TPC

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(on behalf of the CYGNO collaboration)

CYGNO Experiment

LIBPhys-UC

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UNIVERSIDADE D COIMBRA

CYGNUS 2022 Online Meeting, 10 - 11 January 2022

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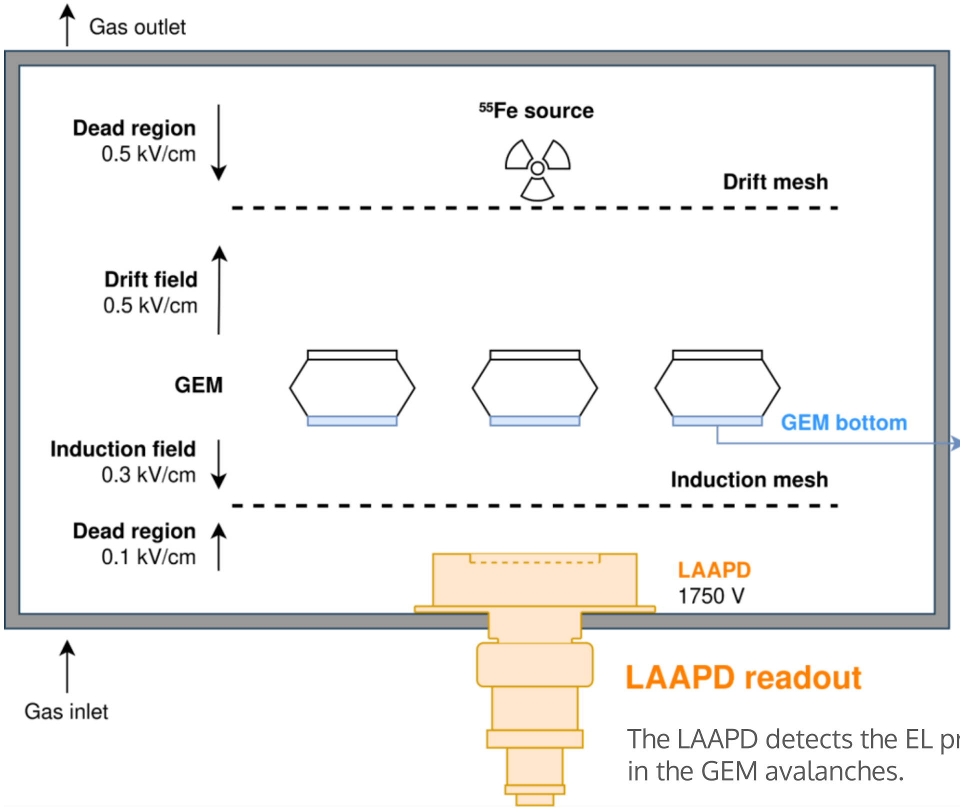
Experimental Setup



Charge readout

Secondary electrons are collected at the bottom of the GEM.

LAAPD readout

The LAAPD detects the EL produced in the GEM avalanches.

Detector Components:

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

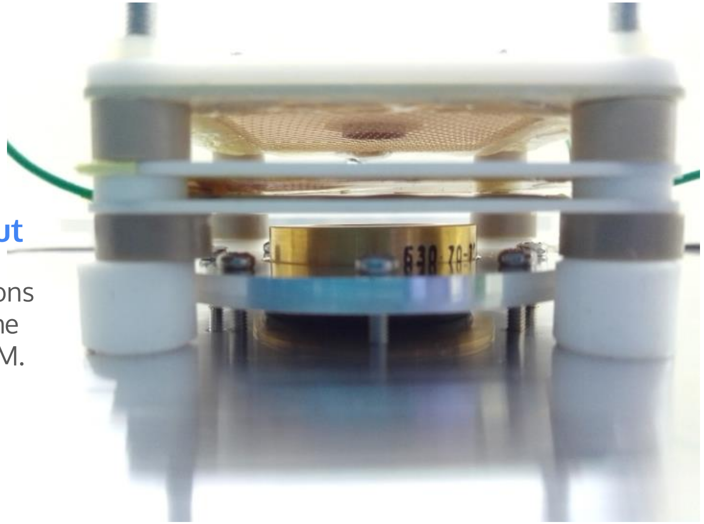
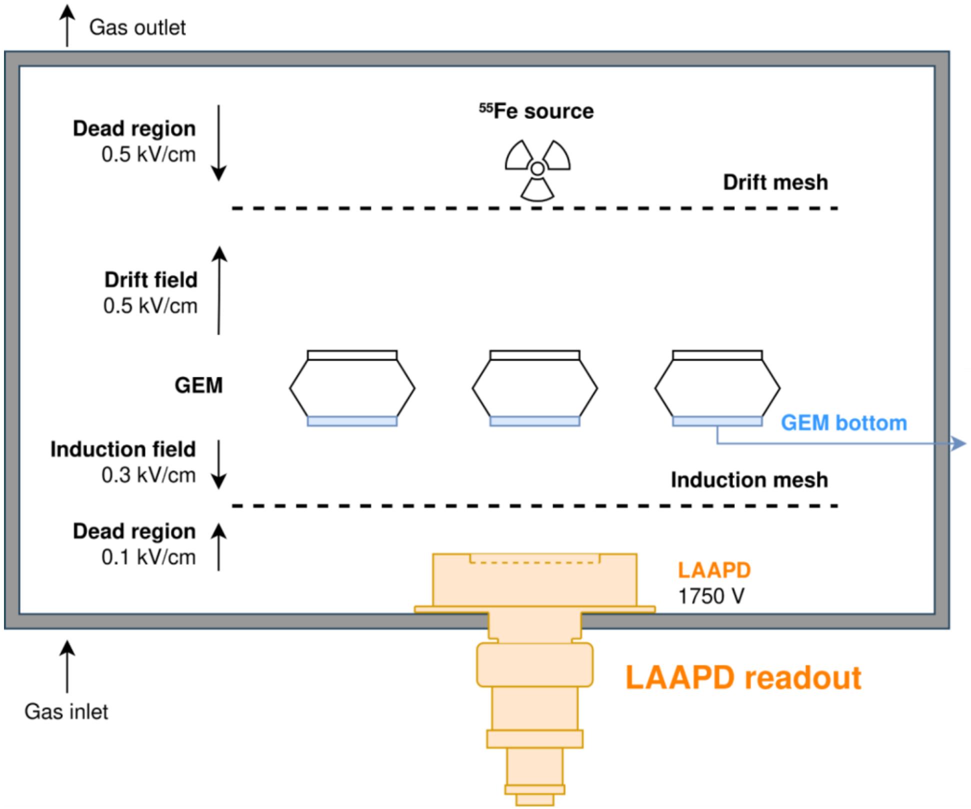
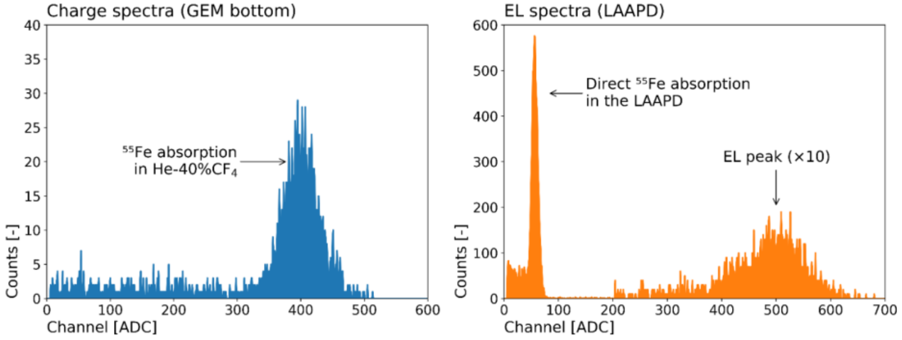


Photo of our detector.

Experimental Setup





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

$$\frac{\eta_\gamma}{\mathrm{keV}} = \frac{A_{EL}}{A_X} \times \frac{1}{w(Si) \times QE \times \Omega \times T}$$

w-value (silicon), quantum efficiency, solid angle, mesh transparency

EL: former studies

Studies of electroluminescence yield (number of photons / primary electron/unit path length)

In different electric field geometries:

- **uniform electric field**: parallel grids;
- **non-uniform electric field:** avalanche-generated EL in very high fields inside the holes of GEM, THGEM, MHSP, MicroMegas;

In pure nobel gases and their mixtures:

- Ar, Xe, Kr, Xe-He, Ne-Xe, Ar-Xe

In mixtures with molecular gases :

- CF4;
- Xe-CF4, Xe-CH4, Xe-CO2, P10

@C.M.B. Monteiro et al., *Secondary scintillation yield in* ***pure xenon***, 2007 JINST 2 P05001

@C.M.B. Monteiro et al., *Secondary scintillation yield in* ***pure argon***, Phys. Lett. B 668 (2008) 167-170

@A.F.M. Fernandes et al. *Low-diffusion* ***Xe-He*** *gas mixtures for rare-event detection: Electroluminescence Yield*, JHEP 04 (2020), 034;

@A. S. Conceição et al., ***GEM*** *scintillation readout with avalanche photodiodes*, 2007 JINST 2 P09010

@C. M. B. Monteiro et al., *Secondary scintillation yield from gaseous* ***micropattern electron multipliers*** *in direct Dark Matter detection*, Phys. Lett. B 677 (2009) 133-138

@C.M.B. Monteiro et al., *Secondary scintillation yield from* ***GEM*** *and* ***THGEM*** *gaseous electron multipliers for direct dark matter search,* Phys. Lett. B 714 (2012) 18-23

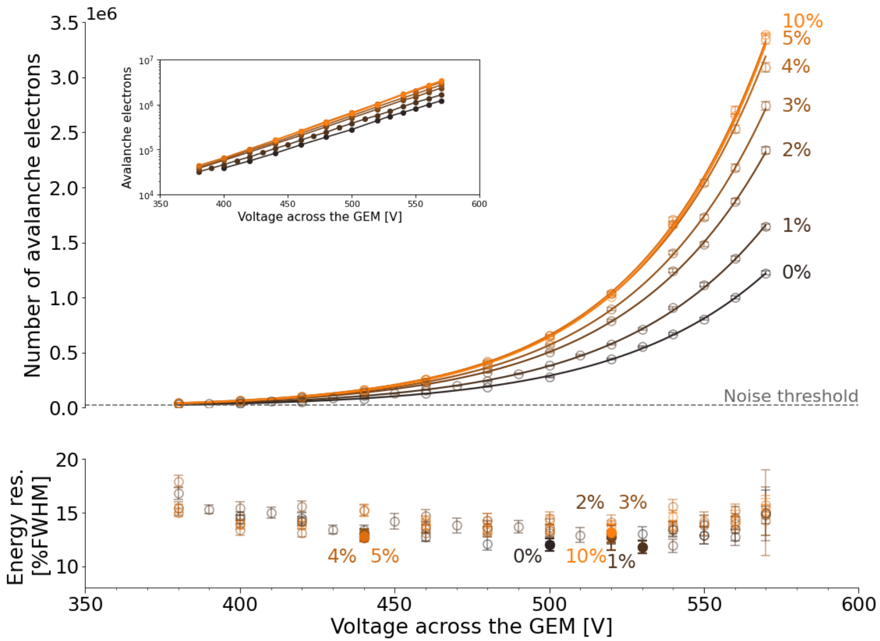
@H. N. da Luz et al., ***GEM*** *Operation in High-Pressure* CF_4*: Studies of Charge and Scintillation Properties*, IEEE TNS 56 (2009) 1564 - 1567

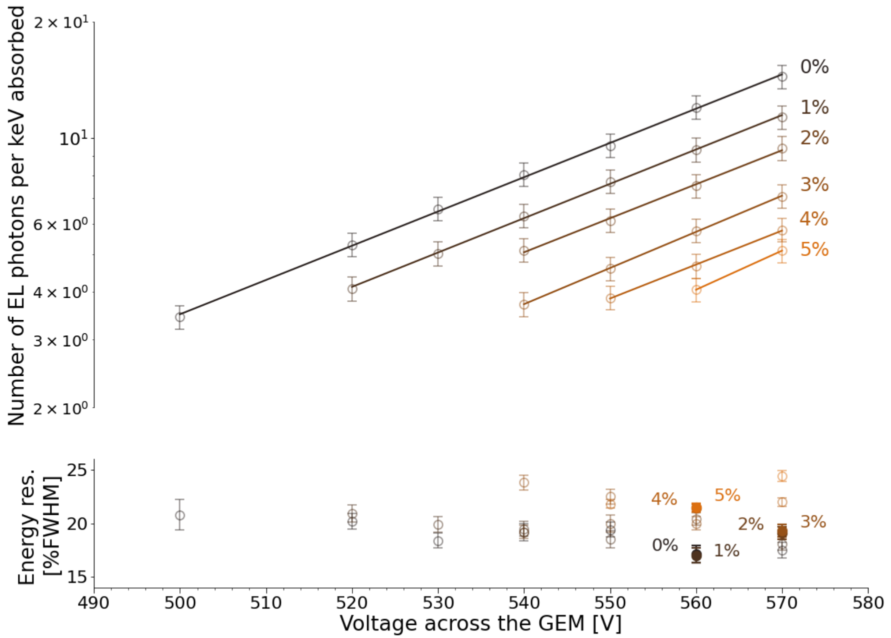
@C.A.O. Henriques, et al., *Electroluminescence* ***TPC****s at the thermal diffusion limit,* JHEP 01 (2019) 027. (**xenon** with **CO2**, **CH4** and **CF4**)

@C.A.O. Henriques et al., *Secondary scintillation yield of Xenon with sub-percent levels of* ***CO2 additive*** *for rare event detection,* Phys. Lett. B 773 (2017) 663-671

Experimental results for He-CF4 (60/40)+isobutane

Full spectra
(150 nm - 1000 nm)

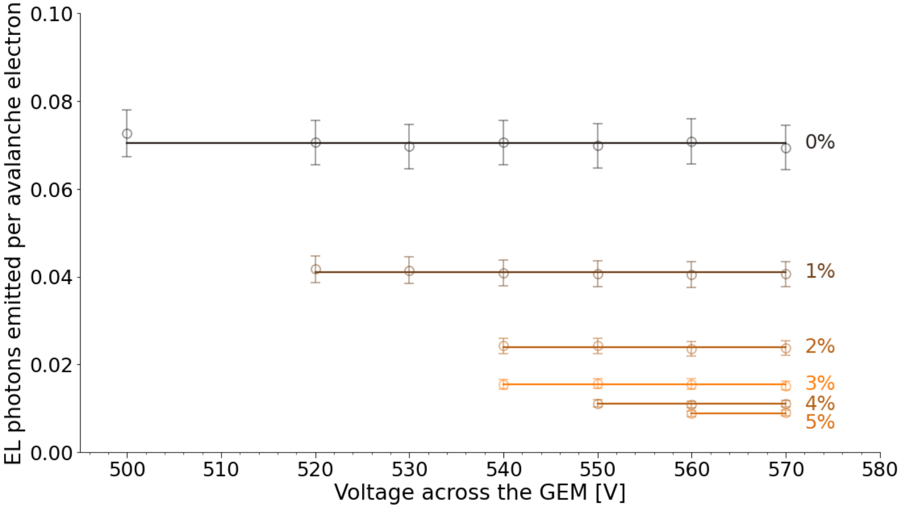


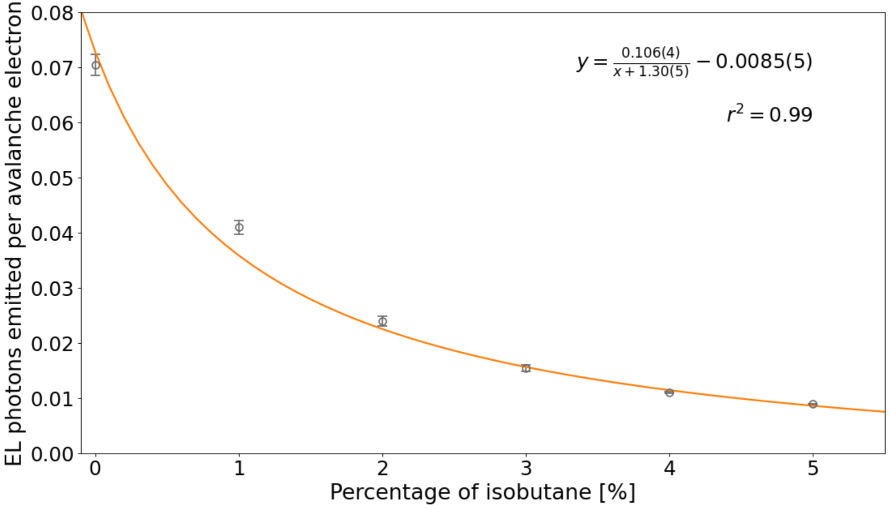


- The number of avalanche electrons increases with increasing content of isobutane.
- Energy resolution unaffected (charge signals).
- EL yield decreases with increasing content of isobutane.
- Energy resolution degradation (EL signals).

EL photons emitted per avalanche electron He-CF4 (60/40)+isobutane

Full spectra
(150 nm - 1000 nm)



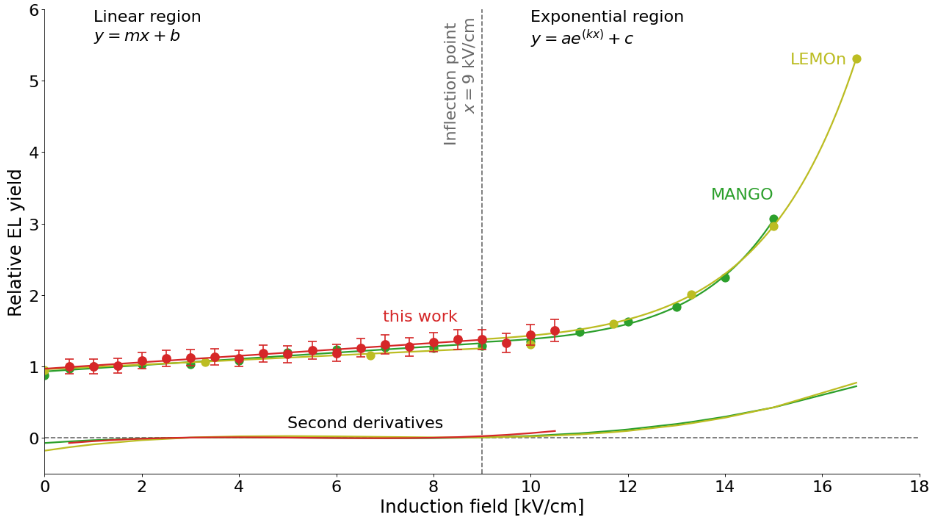


The number of EL photons emitted per avalanche electron is approximately **inversely proportional** to the percentage of isobutane present in the mixture.

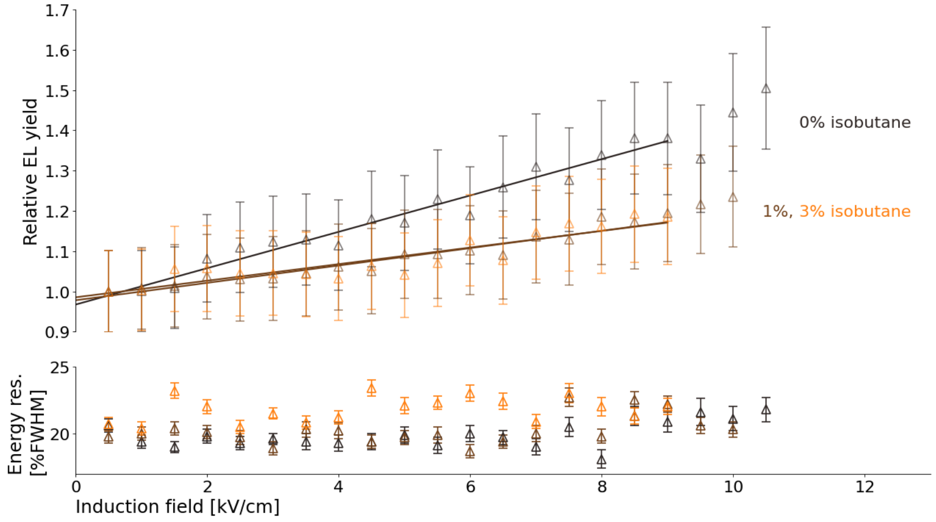
Producing additional EL photons in the induction gap He-CF4 (60/40)+isobutane

Full spectra
(150 nm - 1000 nm)

He-40%CF_4



He-40%CF_4 + isobutane



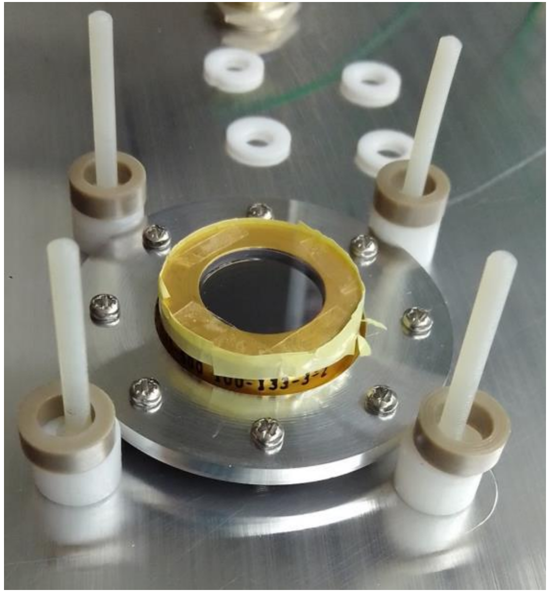
- EL yield increases with increasing Induction field.
- Maximum values limited by detector discharges.

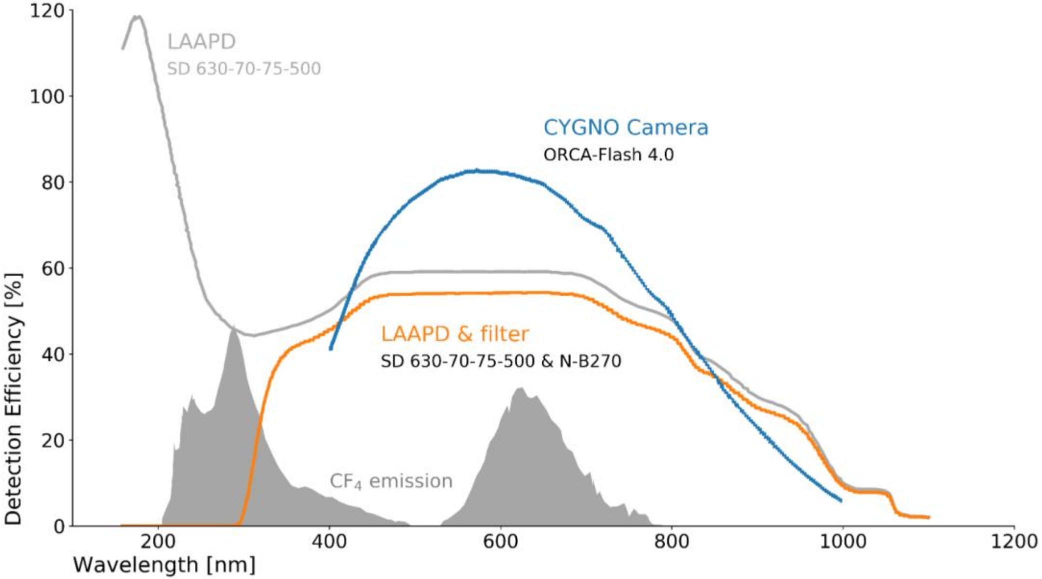
- 40% decrease in EL due to the addition of isobutane.
- Similar results for 1% and 3% isobutane content.

New measurements

We have placed a **borosilicate glass** window (filter) to **cut off the VUV-UV photons** and, this way, match the CYGNO's camera spectral sensitivity range.

With this setup, we can evaluate the EL emission in the spectral range from **300 - 1000 nm**.





Visible EL
300 nm - 1000 nm

Preliminary results. Not calibrated.

New measurements

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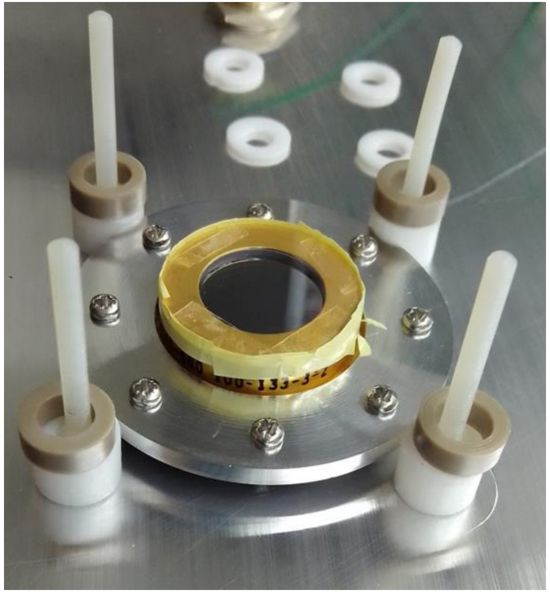
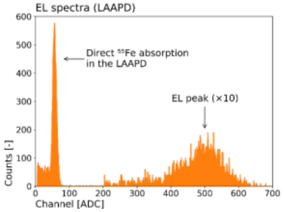
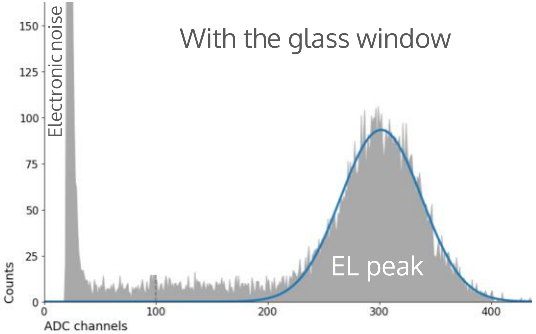




Without the glass window



With the glass window

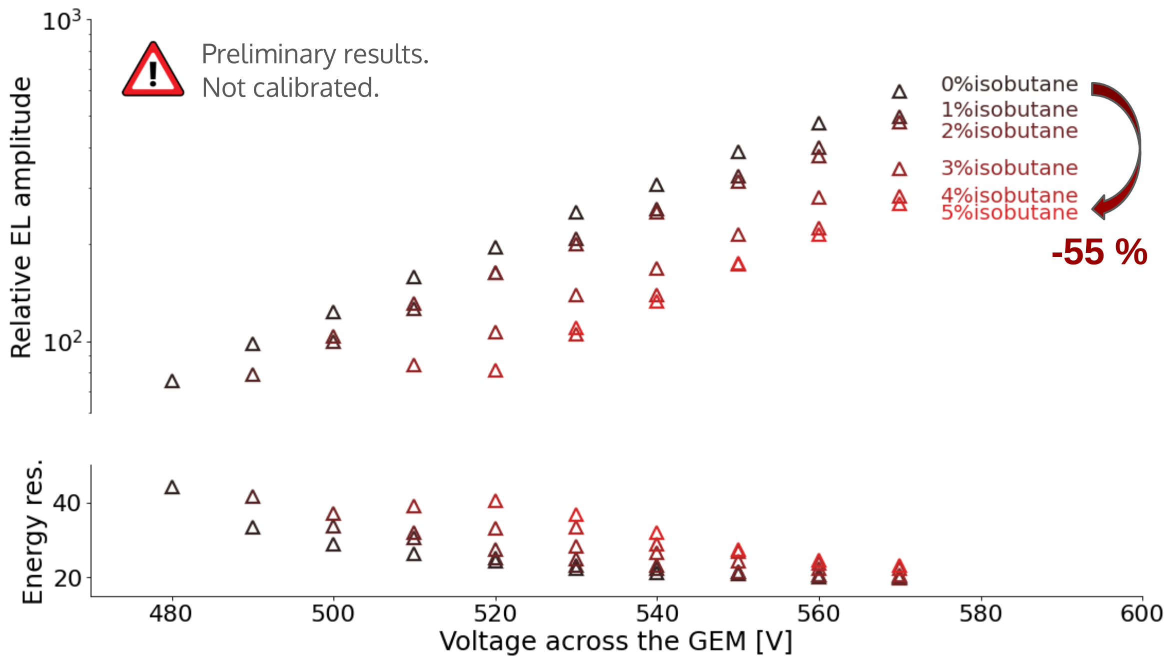
The glass absorbs the 5.9 keV => no direct x-rays in the LAAPD.

The EL spectra do not have the direct ^{55}Fe absorption peak for calibration => calibration ***à posteriori***.

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

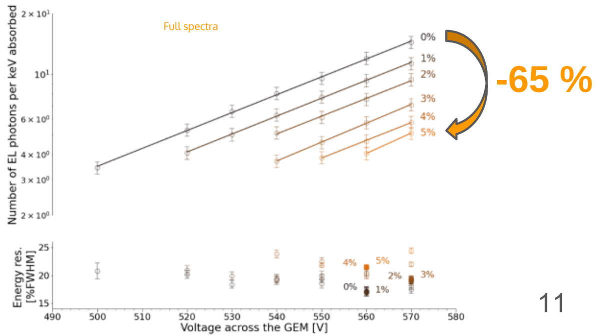
$$\frac{\eta_\gamma}{\text{keV}} = \frac{A_{EL}}{A_X} \times \frac{1}{w(Si) \times QE \times \Omega \times T}$$

He-40%CF_4 + isobutane mixtures



Isobutane seems to quench visible EL photons emitted by He-40%CF_4: the EL peak amplitude decreases with increasing isobutane content.

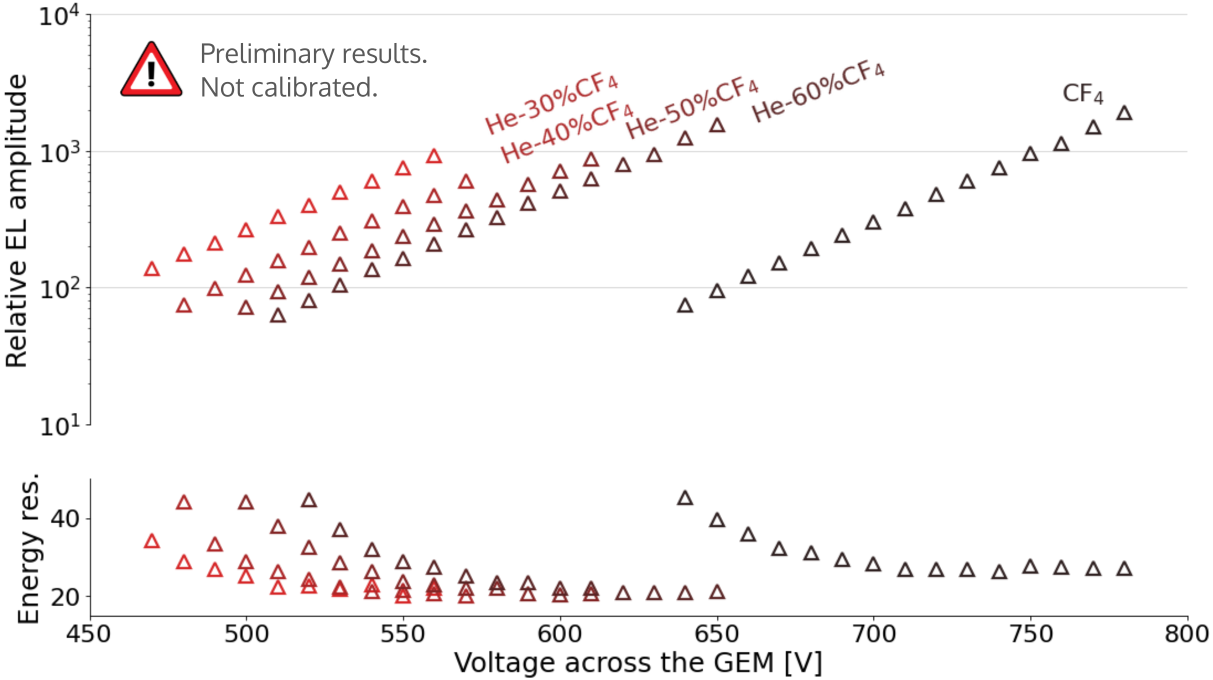
Isobutane slightly degrades the energy resolution: this is probably due to low statistics and not to decreased detector performance.



Good validation:
charge measurements are within 10% of those obtained without the glass window.

Visible EL
300 nm - 1000 nm

He-CF_4 mixtures



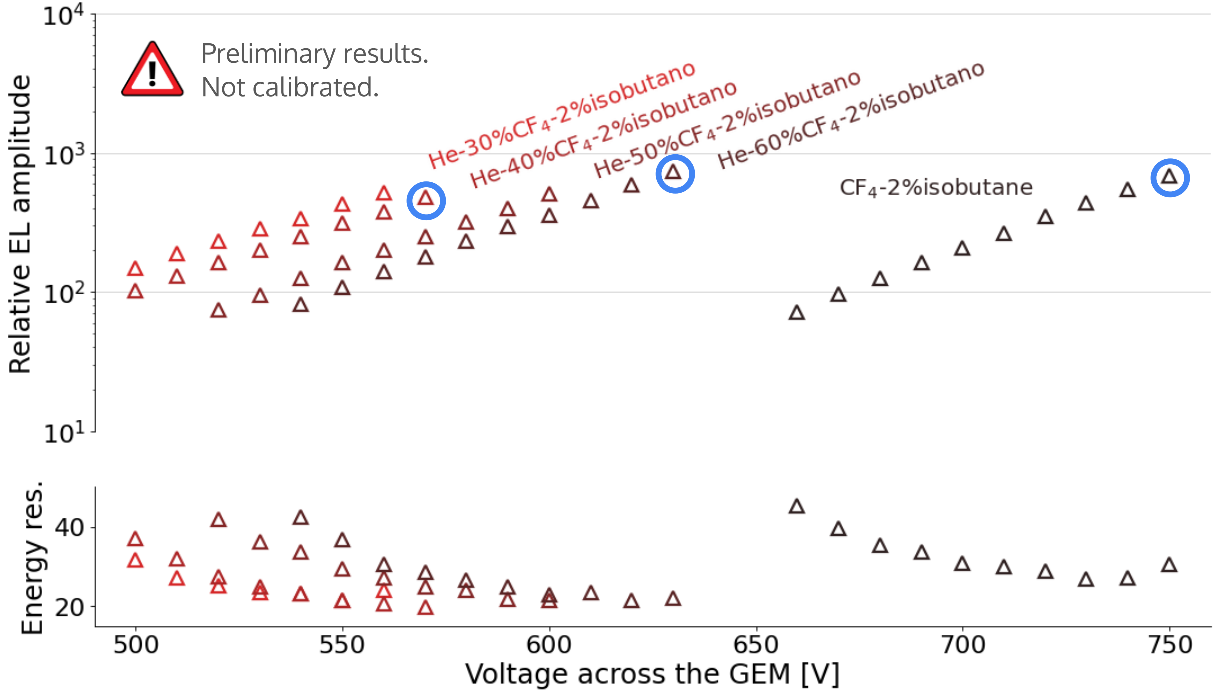
Increasing the amount of CF_4 increases the EL(max) peak amplitude, because the GEM sustains higher voltages before the onset of micro-discharges.

Helium improves the energy resolution of the EL signals:

The minimum energy resolution obtained was around **20%**.

He-CF_4 mixtures + 2% isobutane

Visible EL
300 nm - 1000 nm

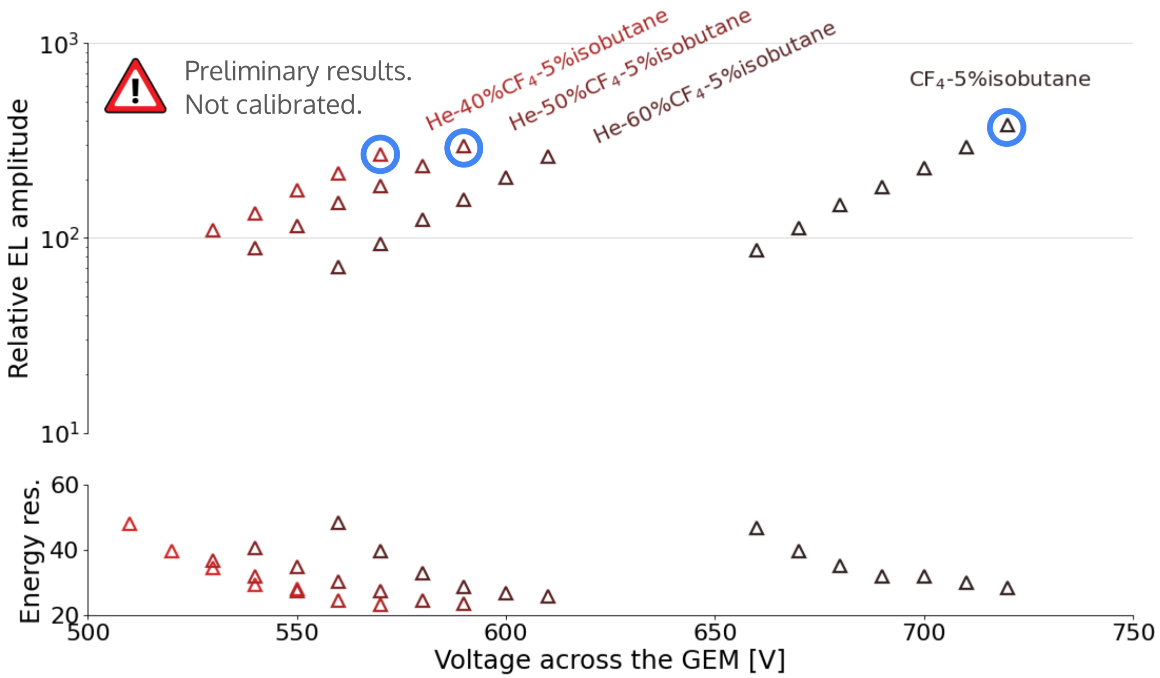


Increasing the amount of **CF_4** in the mixture may **compensate** for the EL **quenching** due to the addition of **2% isobutane**.

	EL(max) centroid
He-40%CF_4	596.3
He-40%CF_4 + 2% isobutane	478.7 ▼ 20%
He-60%CF_4 + 2% isobutane	738.4 ↑ 24%

+54 %

He-CF_4 mixtures + 5% isobutane

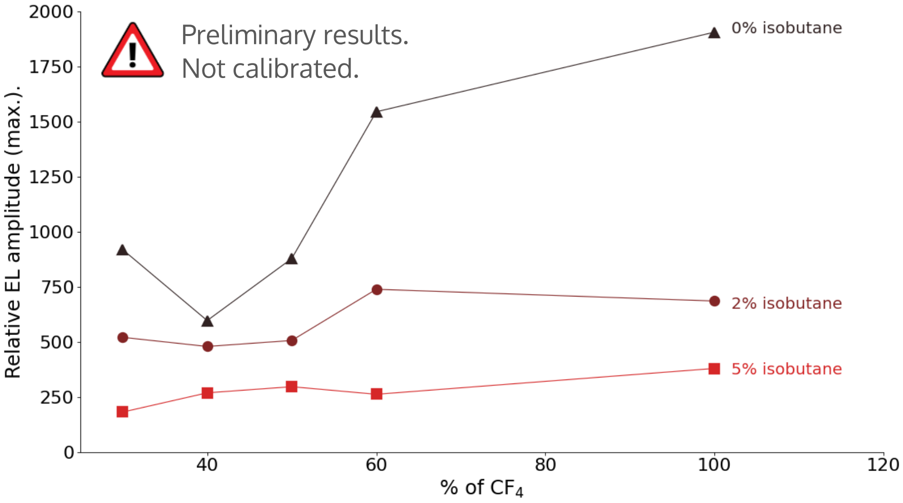


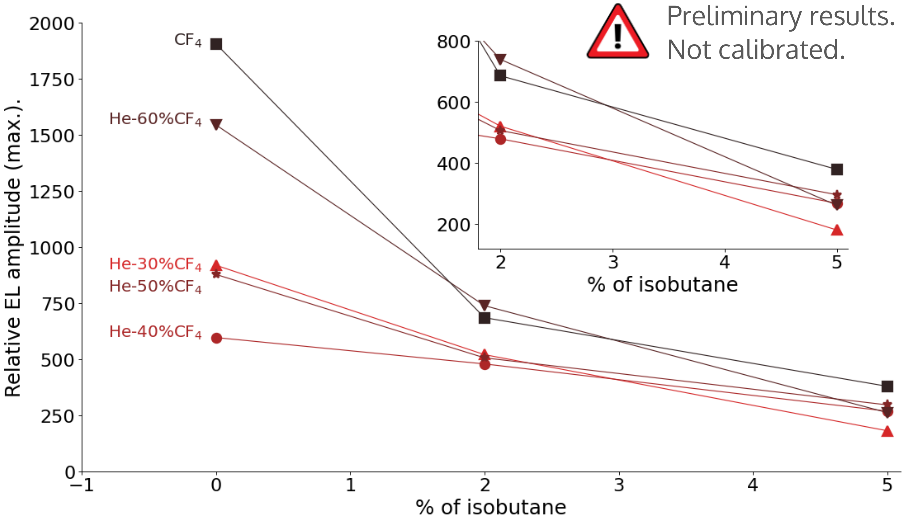
For **5% isobutane**, **EL(max) is similar** for **all %CF_4** in the He-CF_4 mixtures.

	EL(max) centroid
He-40%CF_4	596.3
He-40%CF_4 + 5% isobutane	268.09 ▼ **55%**
He-50%CF_4 + 5% isobutane	295.99 ▼ **50%**
CF_4 + 5%isobutane	378.91 ▼ **36%**

Maximum EL amplitudes (EL(max)) of He-CF_4-isobutane

Visible EL
300 nm - 1000 nm





- With 2% isobutane there is 50% more EL(max) for 60%CF_4 than for 40%CF_4 (which has been used so far).
- With 5% isobutane the amount of EL(max) is similar for 60%CF_4 and 40%CF_4 and 50-67% lower than with 2% isobutane.
- With 5% isobutane EL(max) is always lower independently of %CF_4

- 60%CF_4 and 2% isobutane shows the highest EL(max).
- Above 60%CF_4 EL(max) will not improve, it is already roughly as high as for 100%CF_4.
- For 5% isobutane EL(max) is similar for contents above 30%CF_4.

In summary

- The number of EL photons emitted per avalanche photon is **inversely proportional** to the percentage of isobutane present in the mixture (full spectra);
- Additional EL yield can be produced in the induction gap with isobutane admixtures, although with less efficiency than for He-40%CF_4 (full spectra);
- Isobutane seems to quench visible EL photons emitted by He-40%CF_4. Increasing the amount of CF_4 in the mixture may compensate the light quenching of 2% isobutane.

Thank you

CYGNO Experiment

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Acknowledgement is due to the FCT PhD studentship (ref. SFRH/BD/143355/2019).
This work is supported by CERN/FIS-INS/0026/2019 and UID/FIS/04559/2020 (LIBPhys), funded by national funds through FCT/MCTES and co-financed by the European Regional Development Fund (ERDF) through the Portuguese Operational Program for Competitiveness and Internationalization, COMPETE 2020.

FCT Fundação para a Ciência e a Tecnologia · COMPETE 2020 · PORTUGAL 2020 · UNIÃO EUROPEIA Fundo Europeu de Desenvolvimento Regional

INITIUM Project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 programme (grant agreement No 818744). CYGNO Project is funded by INFN.

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