Further studies on He-CF_4-isobutane mixtures for the CYGNO TPC and studies of the P/T detector response

Rita C. Roque, R. Daniel P. Mano, Joaquim M.F. dos Santos, Cristina M.B. Monteiro and Fernando D. Amaro
LIBPhys, Department of Physics, University of Coimbra, 3004-516 Coimbra, Portugal

CYGNO Experiment

1 2 9 0 UNIVERSIDADE D COIMBRA

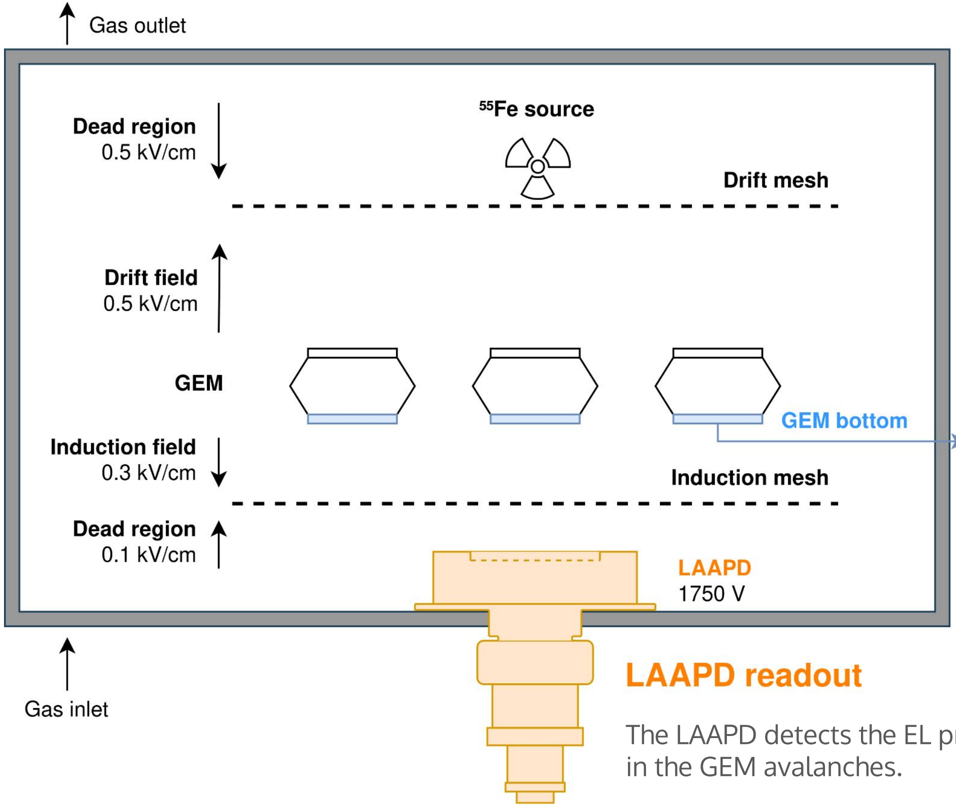
LIBPhys-UC

Topics:

- Influence of isobutane on the EL yield
- Additional EL yield in the induction gap
- Measurements of the visible EL
- Detector stability test

CYGNO International Collaboration Meeting 2021
Gran Sasso Science Institute, L'Aquila, Italy, 20 - 21 December 2021

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.

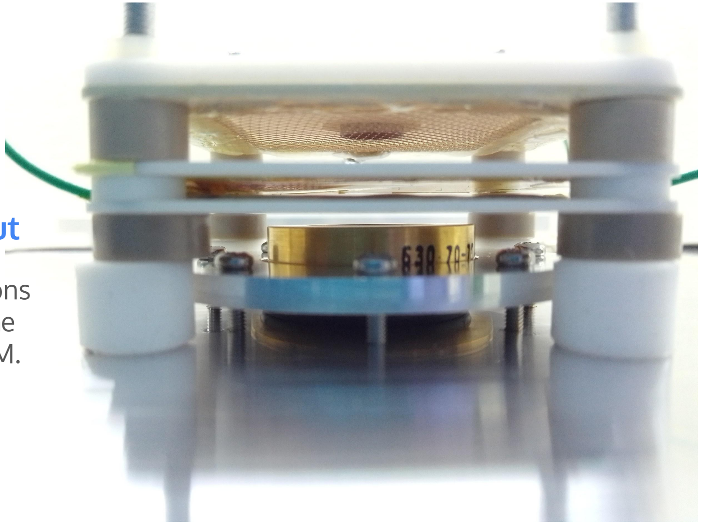
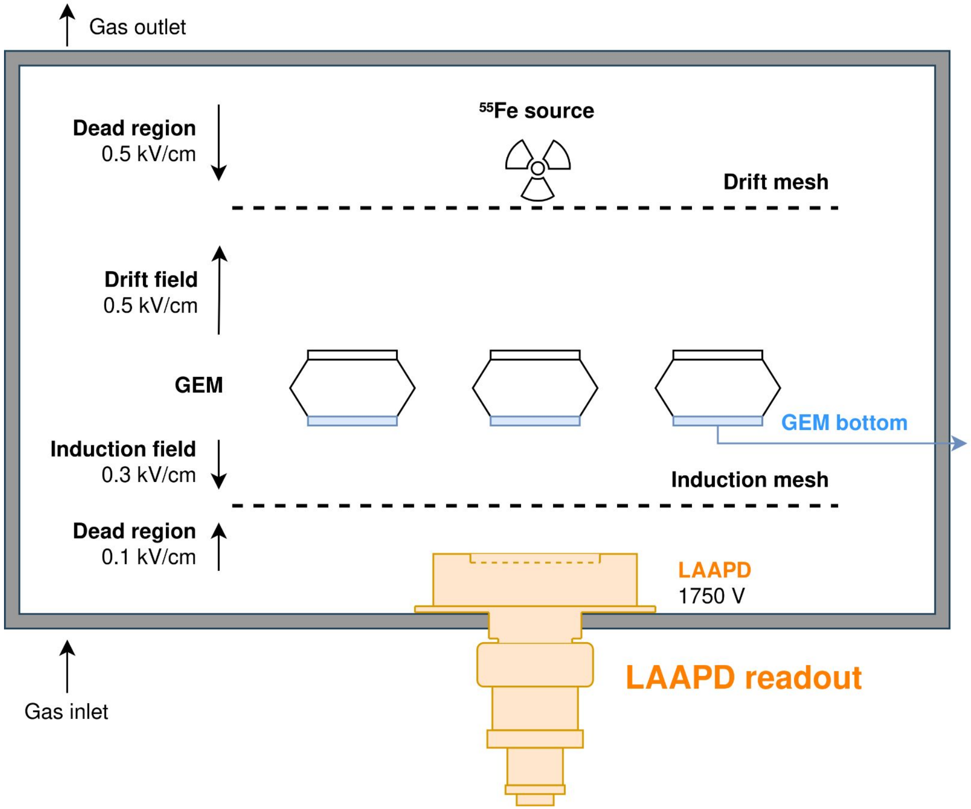
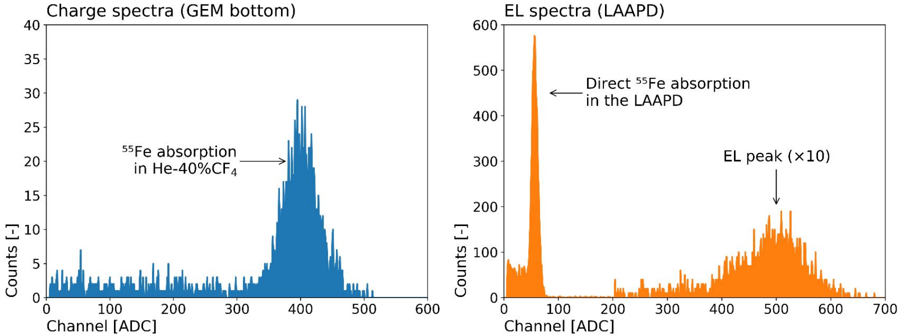


Photo of our detector.

Full spectra
(150 nm - 1000 nm)

Experimental Setup





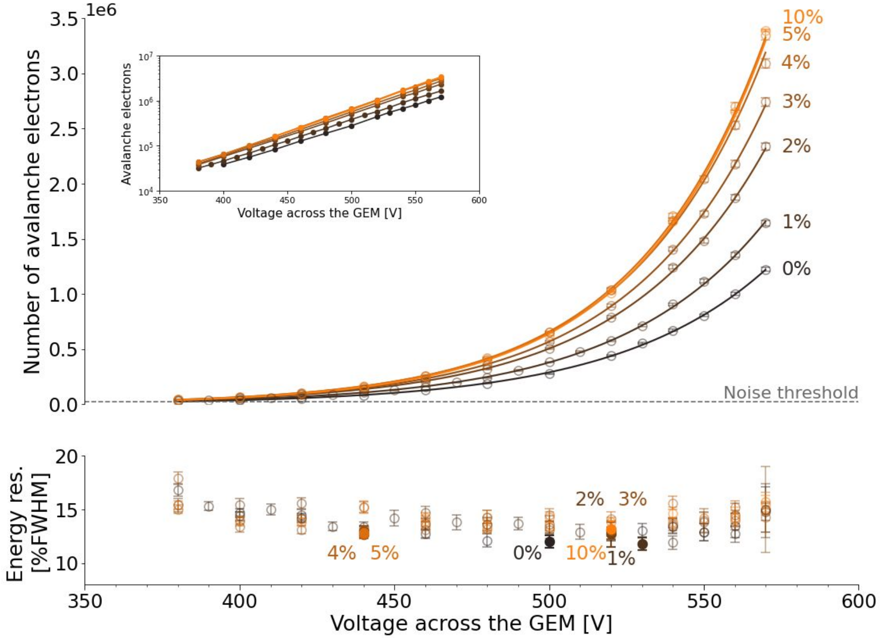
EL and ^{55}Fe x-rays peak ratio

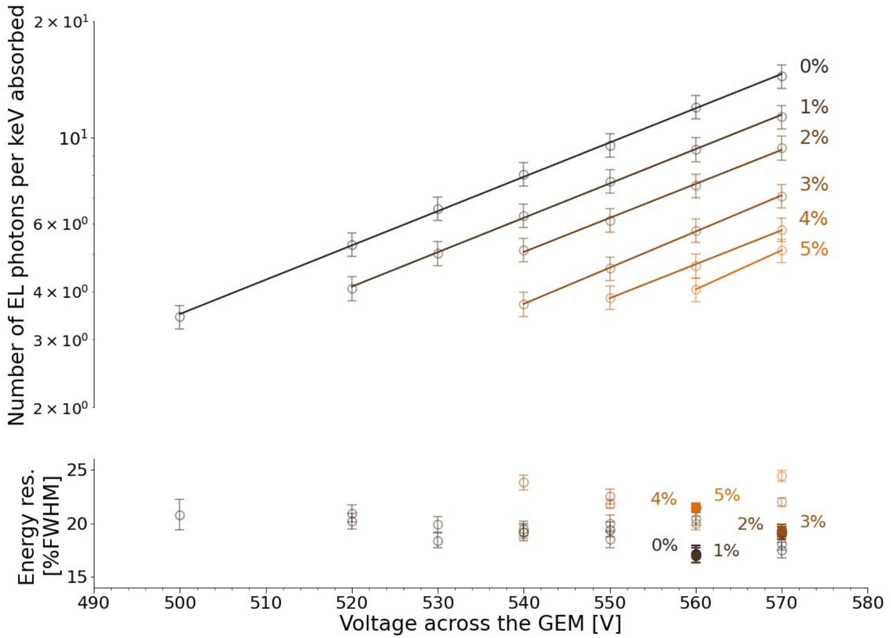
$$\frac{\eta_\gamma}{\mathrm{keV}} = \frac{A_{EL}}{A_X} \times \frac{1}{w(Si) \times QE \times \Omega \times T}$$

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

Full spectra
(150 nm - 1000 nm)

Former results (a reminder)

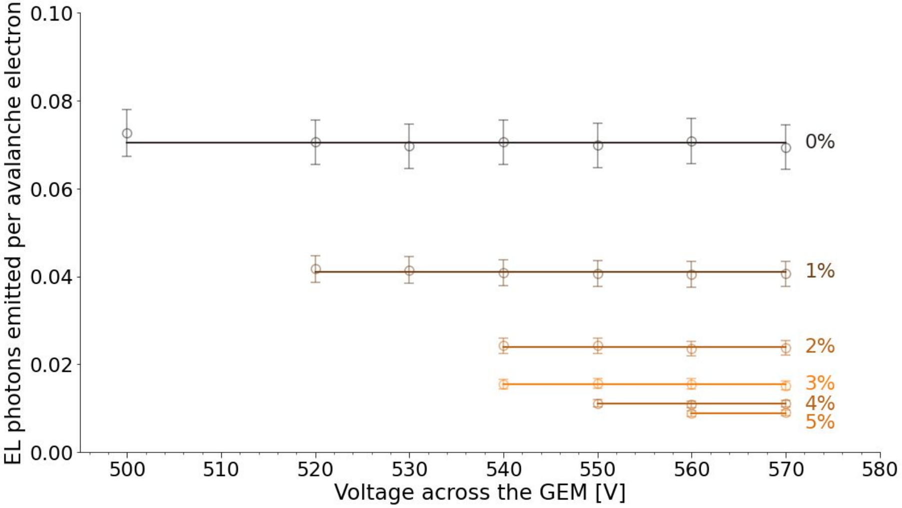


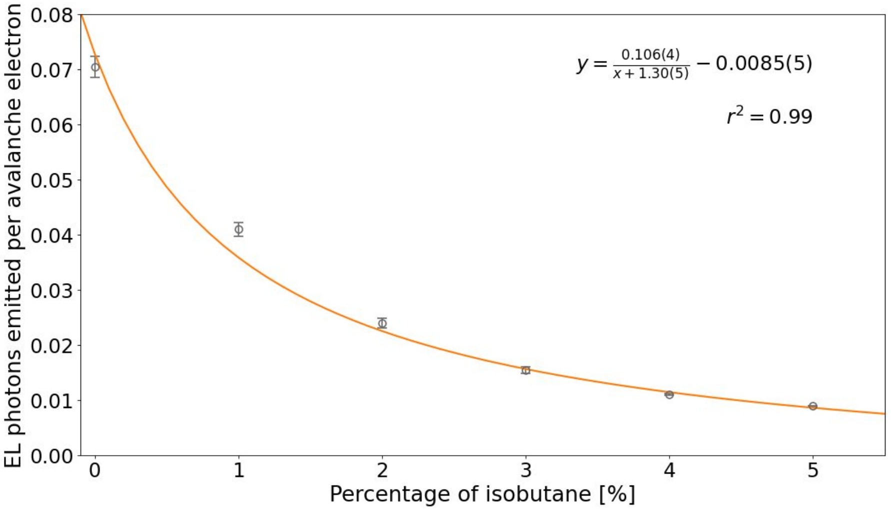


- The number of avalanche electrons increases with increasing content of isobutane.
- Energy resolution unaffected (charge signals).

- EL yield decreases with increasing content of isobutane.
- Energy resolution degradation (EL signals).

EL photons emitted per avalanche electron



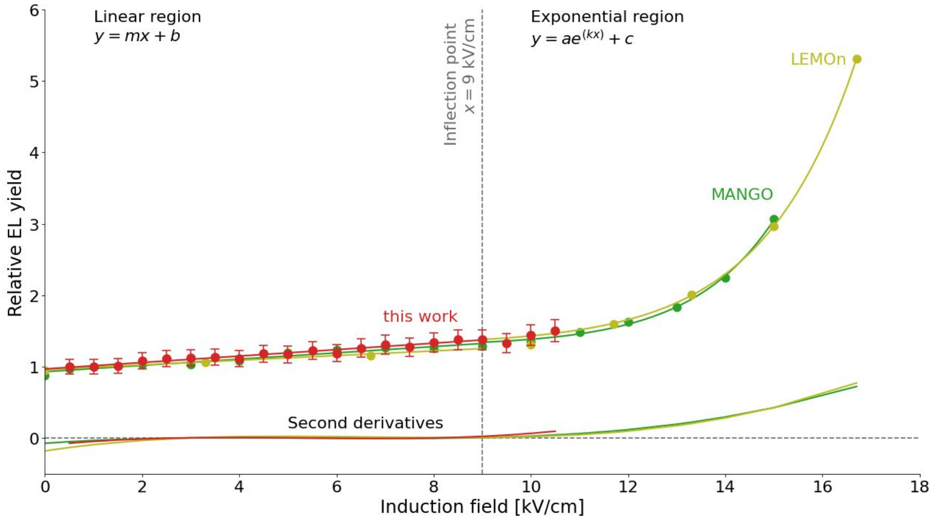


The number of EL photons emitted per avalanche electron is approximately **inversely proportional** to the percentage of isobutane present in the mixture.

Full spectra
(150 nm - 1000 nm)

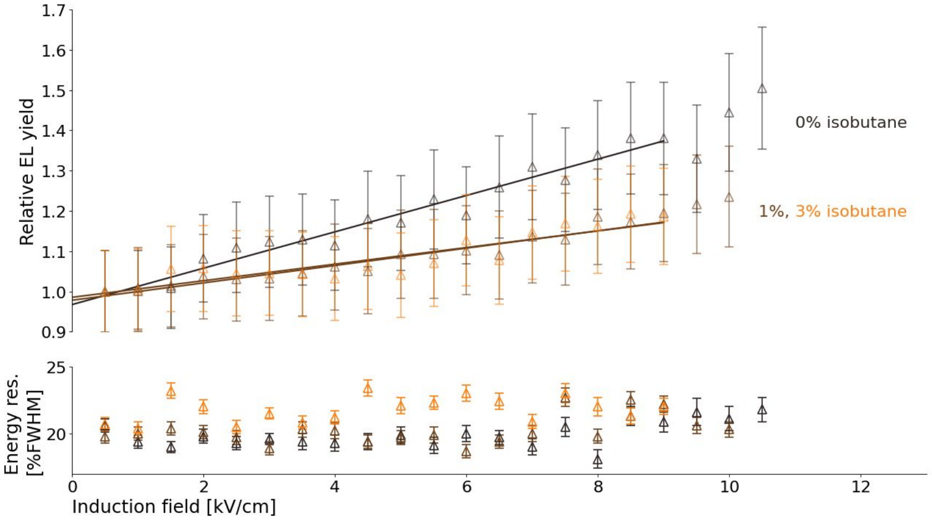
Producing additional EL photons in the induction gap

He-40%CF_4



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

He-40%CF_4 + isobutane



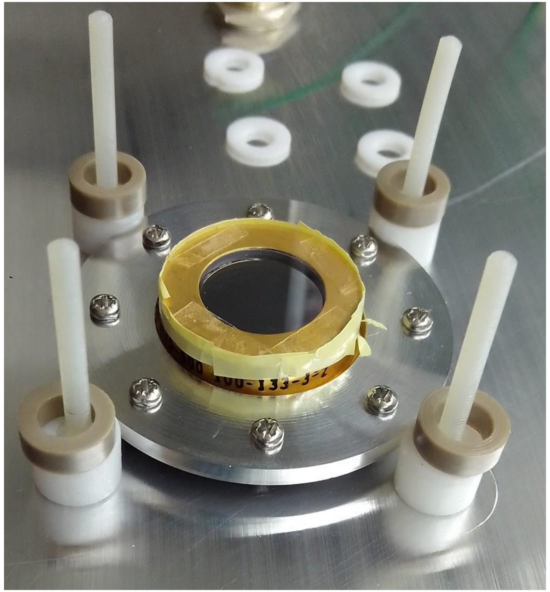
- 40% decrease in EL due to the addition of isobutane.
- Similar results for 1% and 3% isobutane content.

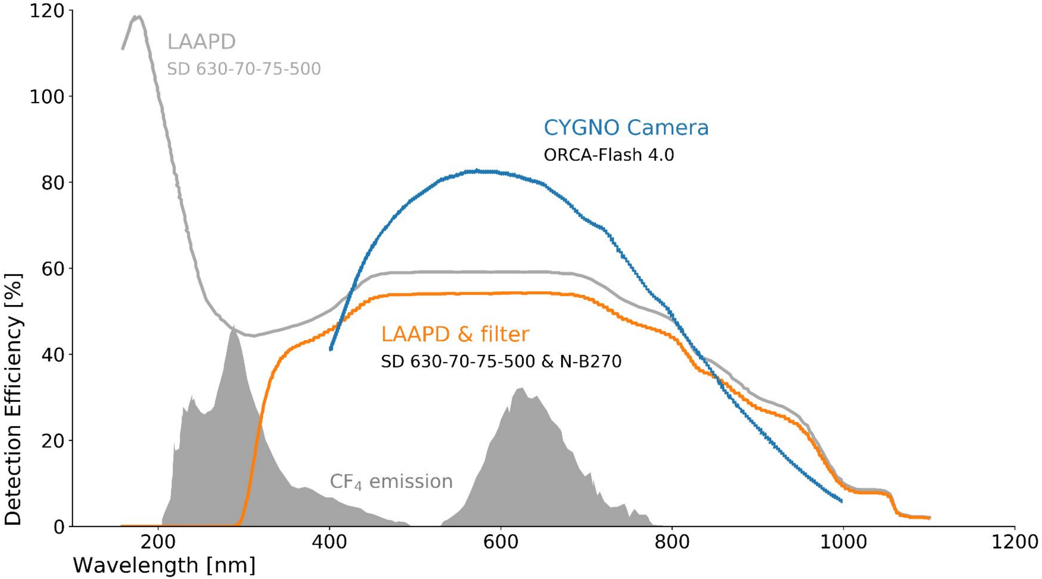
Visible EL
300 nm - 1000 nm

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**.





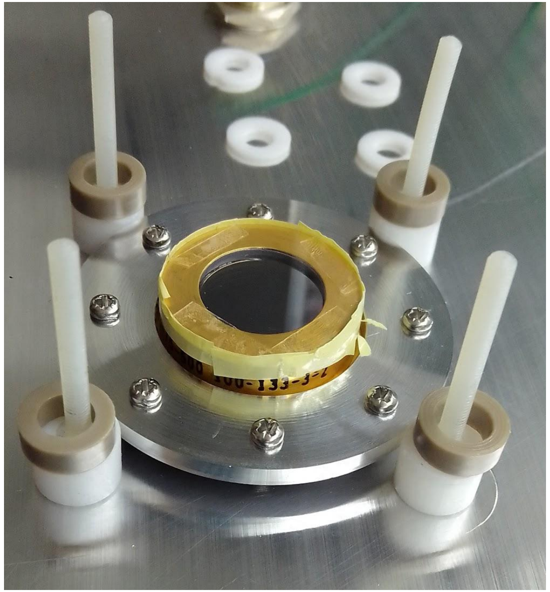
Visible EL
300 nm - 1000 nm

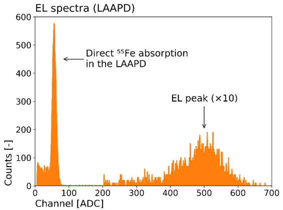
New measurements

Preliminary results.
Not calibrated.

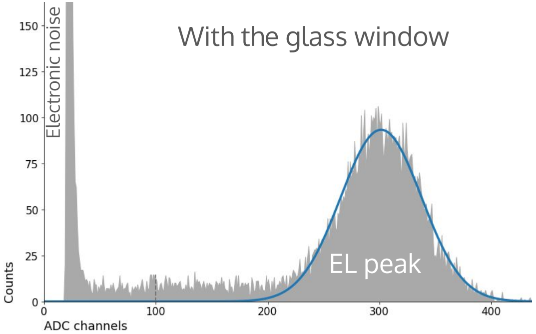
We have placed a **borosilicate glass** window (filter) to **cut off the VUV-UV photons** and, this way, match the CYGNO's camera spectral sensitivity range.

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





Without the glass window



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

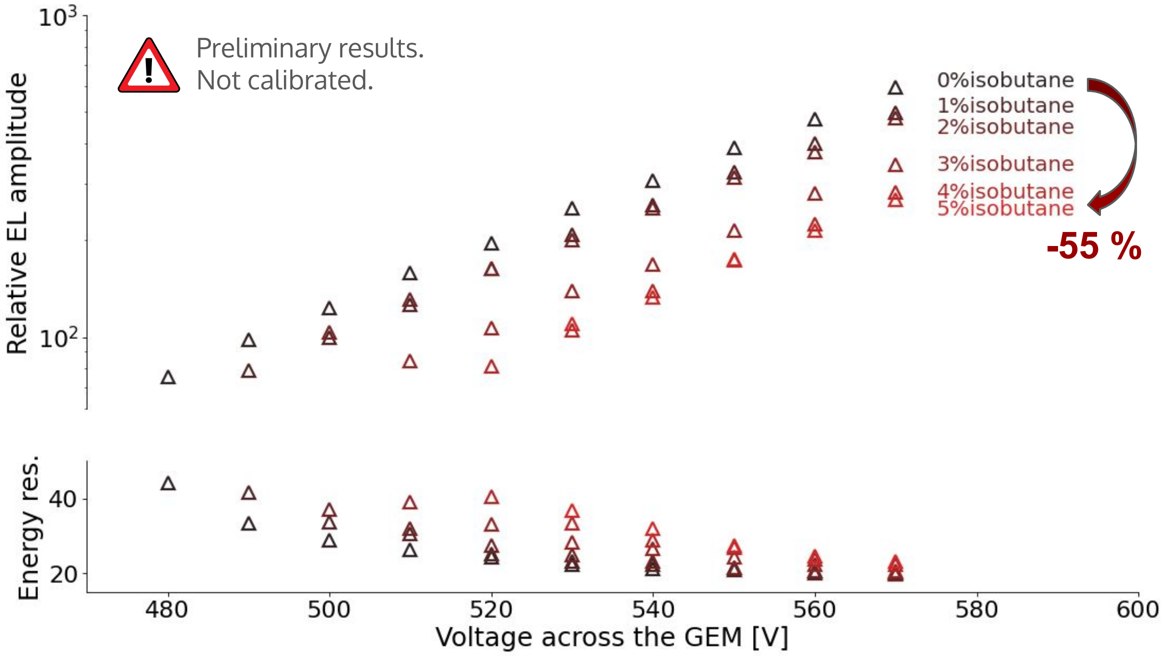
The EL spectra do not have the direct ^{55}Fe absorption peak for calibration
=> calibration ***à posteriori***.

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

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

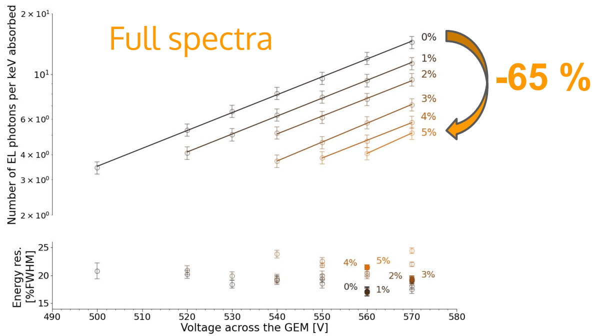
Visible EL
300 nm - 1000 nm

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.

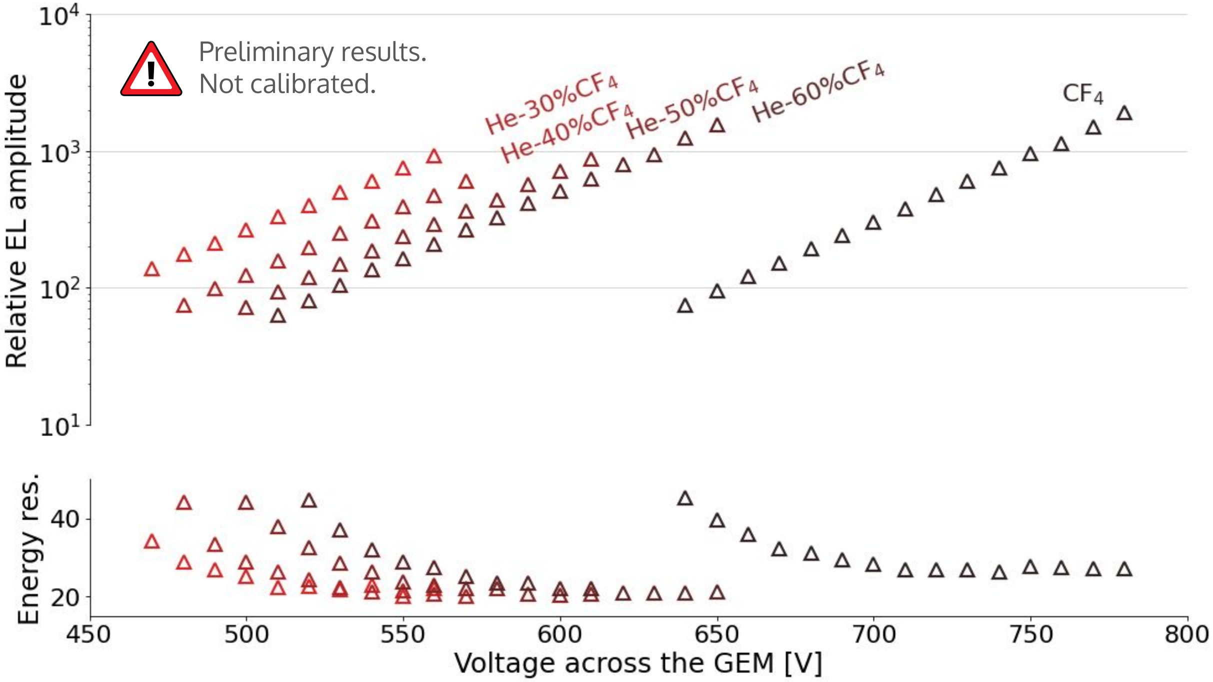
Isobutane slightly degrades the energy resolution: this is probably due to low statistics and not to decreased detector performance.



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

He-CF_4 mixtures

Visible EL
300 nm - 1000 nm

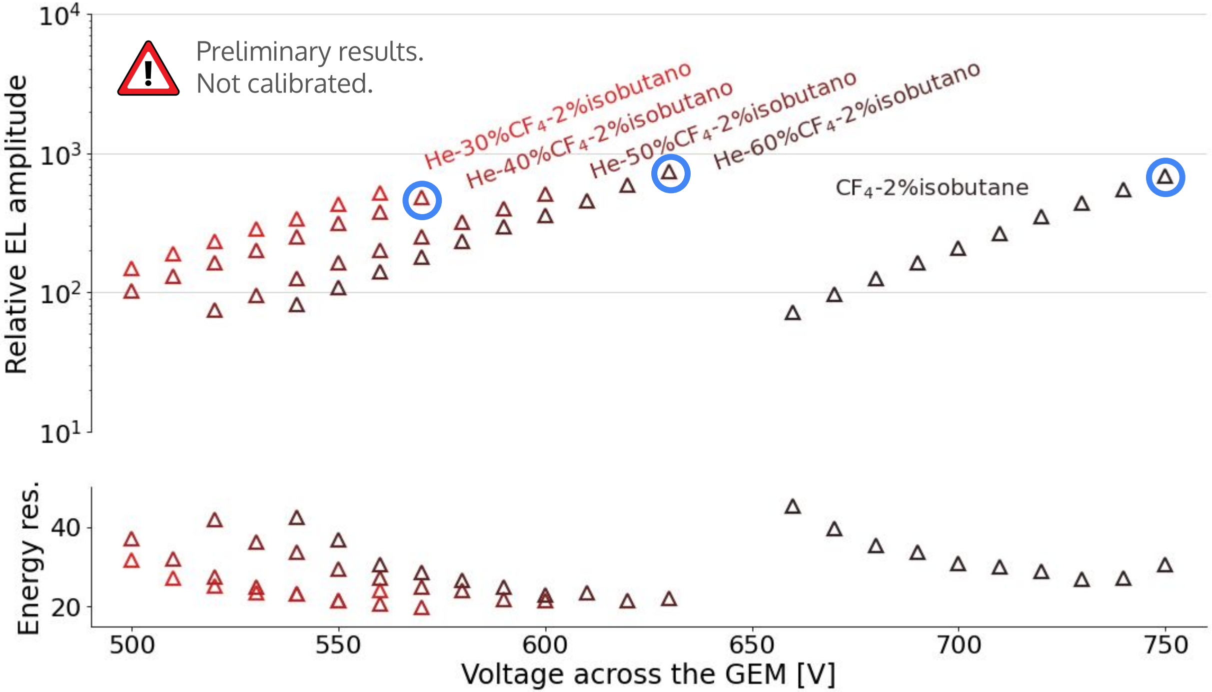


Increasing the amount of CF_4 increases the EL(max) peak amplitude, because the GEM sustains higher voltages before the onset of micro-discharges.

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



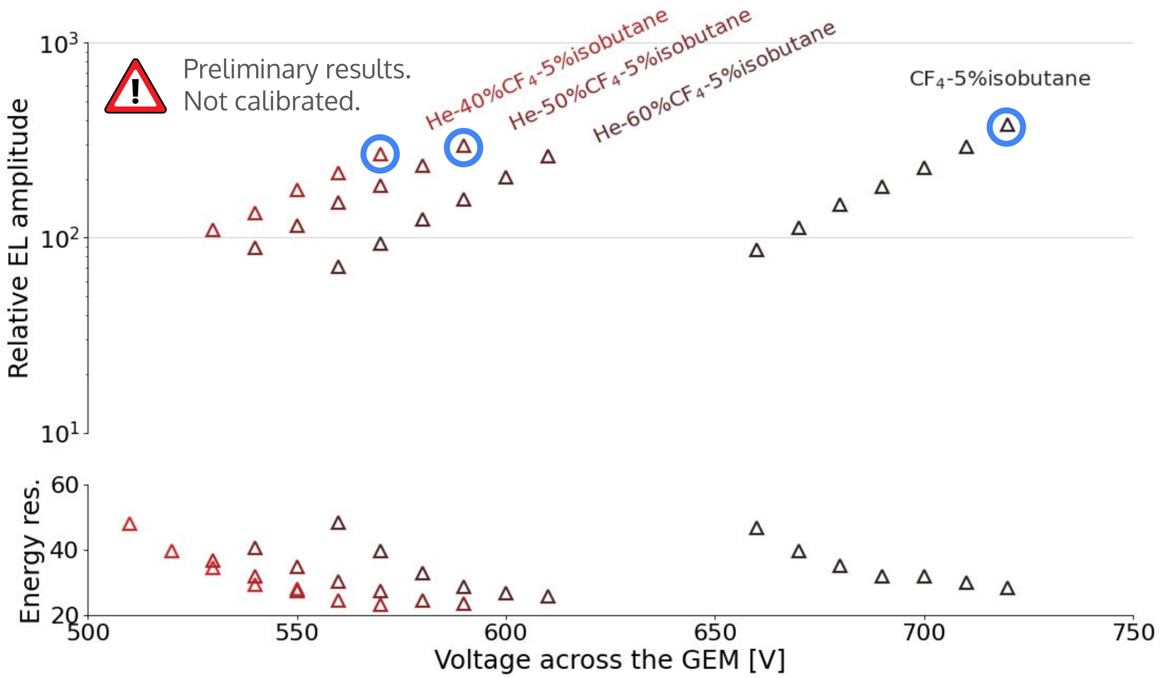
Increasing the amount of **CF_4** in the mixture may **compensate** for the EL **quenching** due to the addition of **2% isobutane**.

	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 %

Visible EL
300 nm - 1000 nm

He-CF_4 mixtures + 5% isobutane

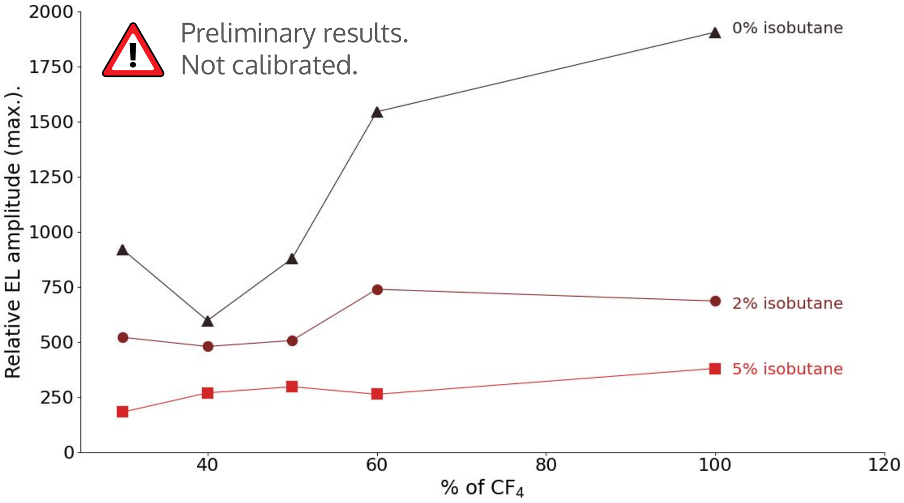


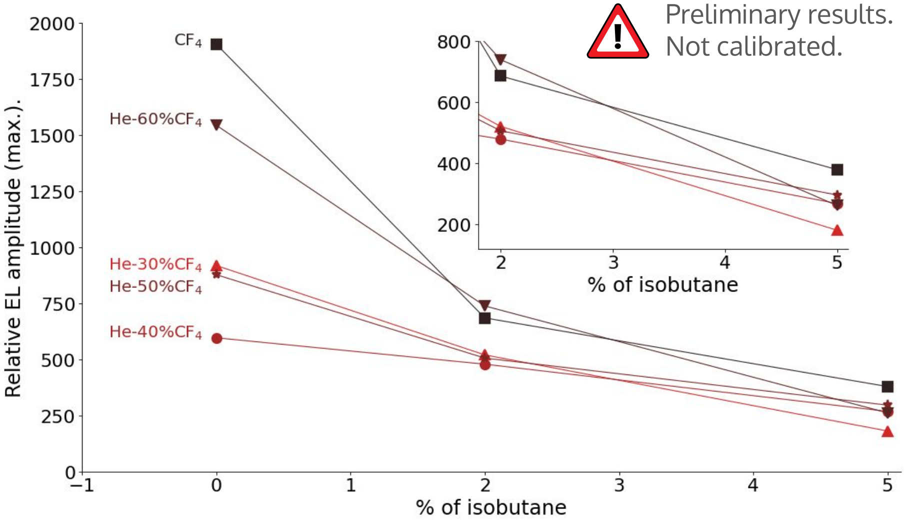
For **5% isobutane**, **EL(max) is similar** for **all %CF_4** in the He-CF_4 mixtures.

	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



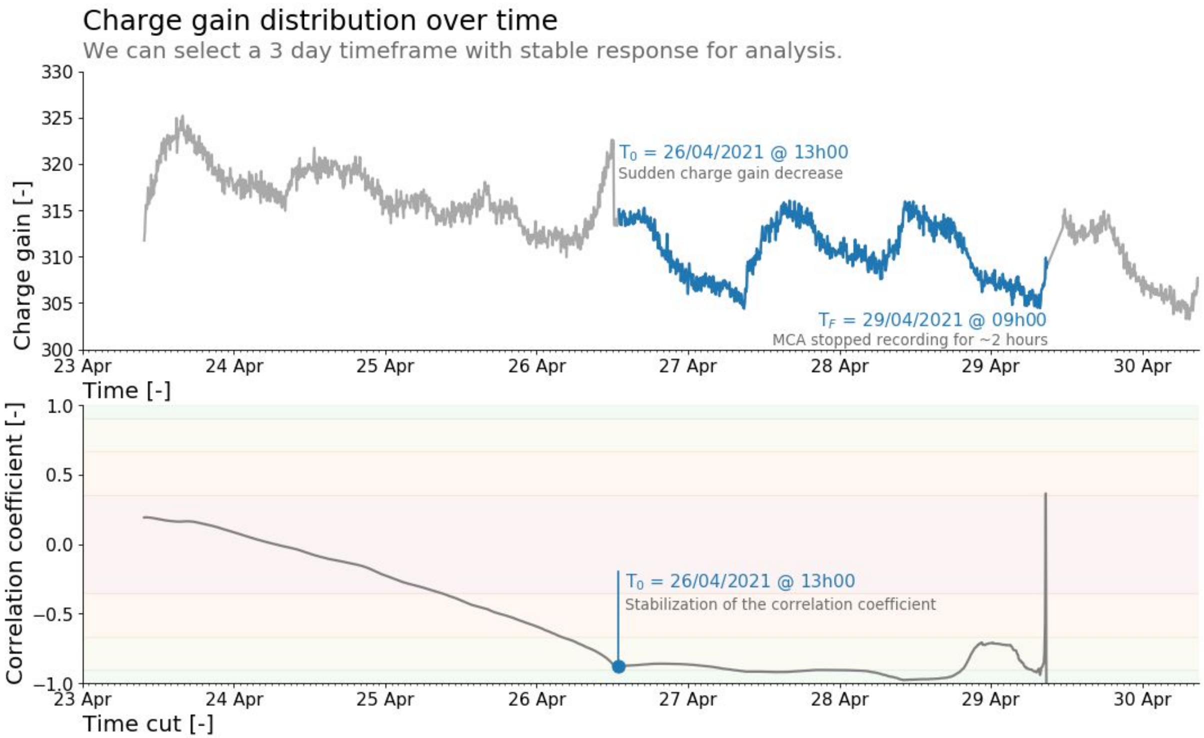


- With 2% isobutane there is 50% more EL(max) for 60%CF_4 than for 40%CF_4 (which has been used so far).
- With 5% isobutane the amount of EL(max) is similar for 60%CF_4 and 40%CF_4 and 50-67% lower than with 2% isobutane.
- With 5% isobutane EL(max) is always lower independently of %CF_4

- 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.

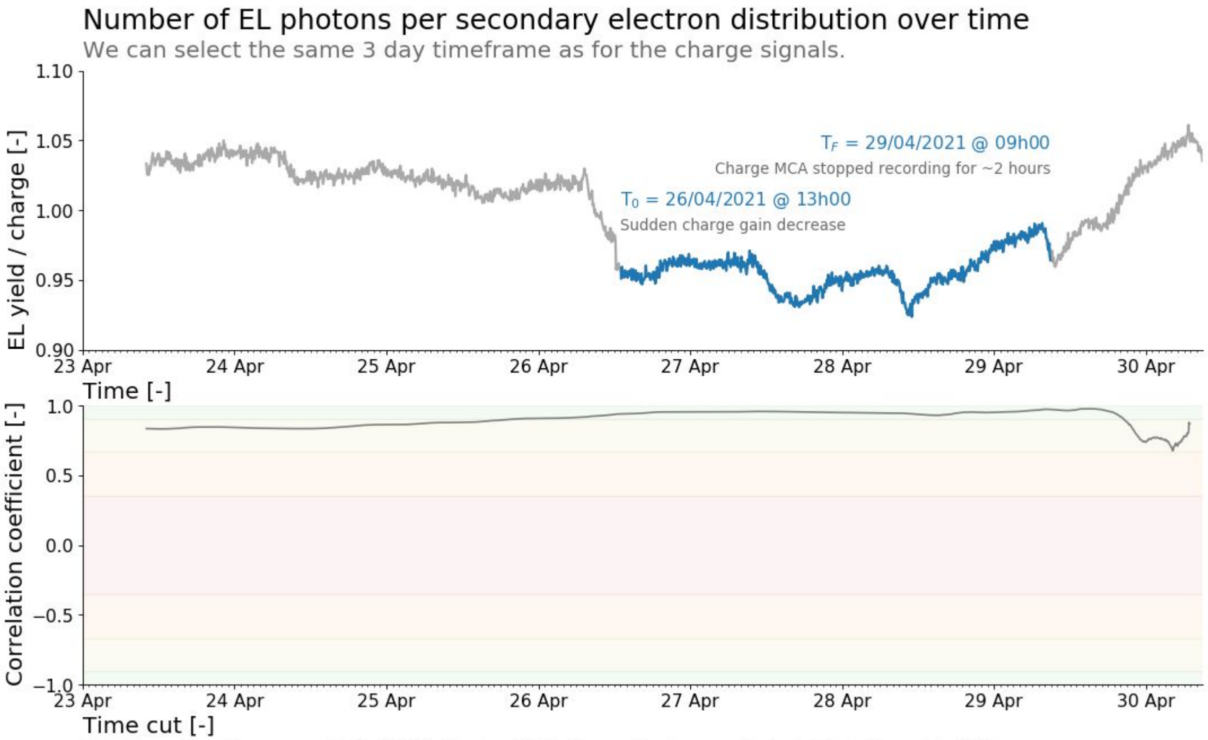
Full spectra
(150 nm - 1000 nm)

Detector stability test to ambient variables (P/T)



Data taken with a ^{55}Fe source, with He-40%CF_4 flowing at 2 L/h. Charge signals were collected at the bottom of the GEM.
The voltage across the GEM was 520 V, with a drift field of 0.5 kV/cm and an induction field of 3.0 kV/cm. The LAAPD was biased at 1800 V.
Ambient pressure and temperature were recorded with a BMP 280 sensor, controlled with an ELEGOO UNO R3 Board.

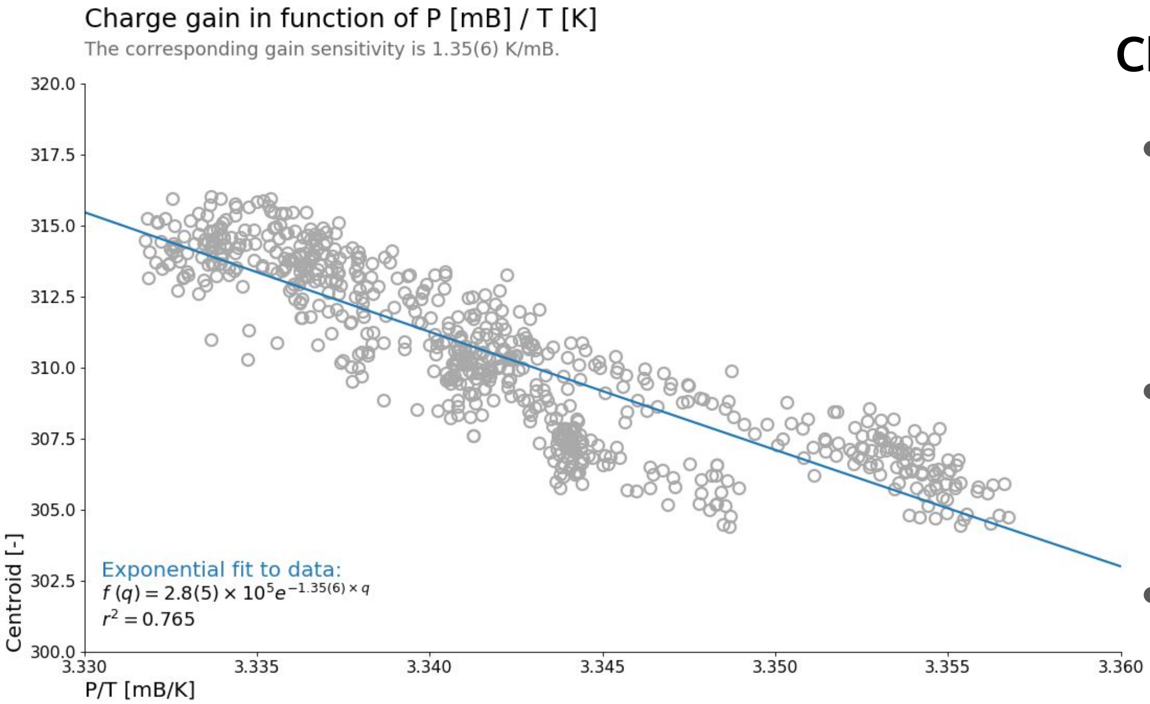
Detector stability test to ambient variables (P/T)



Data taken with a ^{55}Fe source, with He-40%CF_4 flowing at 2 L/h. Charge signals were collected at the bottom of the GEM.
The voltage across the GEM was 520 V, with a drift field of 0.5 kV/cm and an induction field of 3.0 kV/cm. The LAAPD was biased at 1800 V.
Ambient pressure and temperature were recorded with a BMP 280 sensor, controlled with an ELEGOO UNO R3 Board.

Full spectra
(150 nm - 1000 nm)

P/T detector response - charge gain



Data taken with a ^{55}Fe X-ray source, with He/CF_4 (60/40) flowing at 1 L/h. Charge signals were collected at the bottom of the GEM. The voltage across the GEM was 520 V, with a drift field of 0.5 kV/cm and an induction field of 0.3 kV/cm. The LAAPD was biased at 1750 V. Ambient pressure and temperature were recorded with a BMP 280 sensor, controlled with an ELEGOO UNO R3 Board over 2 days and 20 hours.

Charge gain

- **Sensitivity of 1.35(6) K/mB**

  in agreement to what is obtained in a standard GEM : 1.55 K/mB, J.A. Mir et al (2007).

- **Increases with increasing T**

  for P=1 bar and a rise in T = 20°C → 25°C, the gain variation is +7.4%.

- **Decreases with increasing P**

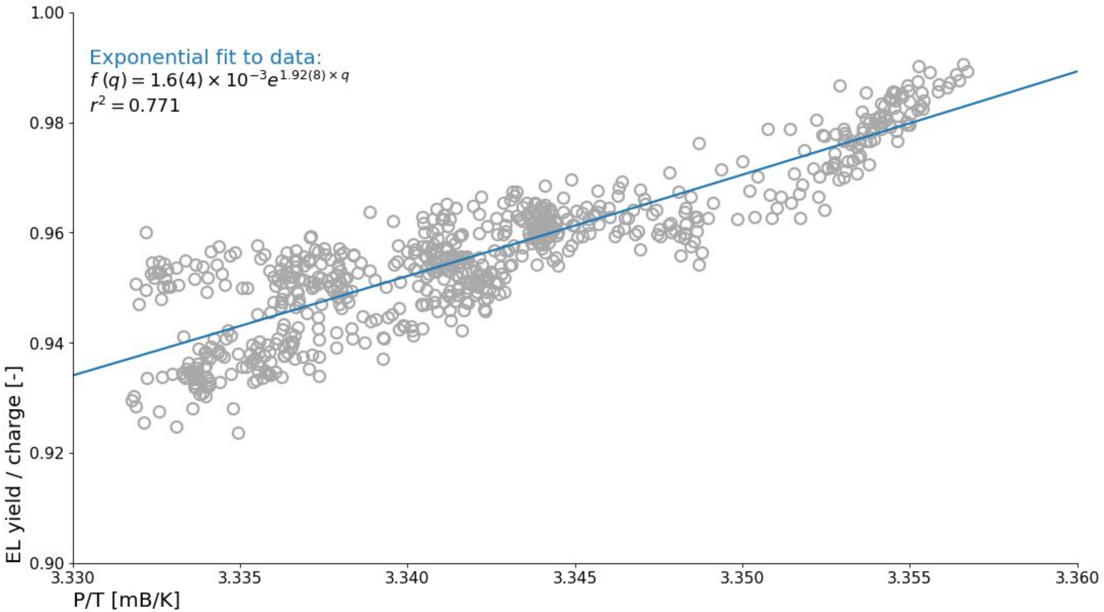
  for T=20°C and a rise in P=1000 mB → 1020 mB, the gain variation is -9.6%.

Full spectra
(150 nm - 1000 nm)

P/T detector response - EL yield

Number of EL photons per secondary photon in function of P [mB] / T [K]

The corresponding EL sensitivity is 1.92(8) K/mB.



Data taken with a ^{55}Fe X-ray source, with He/CF_4 (60/40) flowing at 1 L/h. Charge signals were collected at the bottom of the GEM. The voltage across the GEM was 520 V, with a drift field of 0.5 kV/cm and an induction field of 0.3 kV/cm. The LAAPD was biased at 1750 V. Ambient pressure and temperature were recorded with a BMP 280 sensor, controlled with an ELEGOO UNO R3 Board over 2 days and 20 hours.

EL photons per secondary e$^-$

- **Sensitivity of 1.92(8) K/mB**

  42% more sensitive to temperature and pressure variations than the charge gain.

- **Decreases with increasing T**

  for P=1 bar and a rise of T = 20°C → 25°C, the gain variation is -11.6%;;

- **Increases with increasing P**

  for T=20°C and a rise of P=1000 mB → 1020 mB, the gain variation is +12.3%;

Conclusions

- 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.
- The number of EL photons per avalanche electrons increases with P/T with a sensitivity of 1.92(8) K/mB (full spectra);

What we will do next:

- **Calibrate the visible EL results** for calculating **absolute EL yield** values;
- **Install the WLS in the detector** to **convert the UV** EL i**nto the visible range** and, in this way, collect all the produced EL but within the ORCA spectral sensitivity range.

★ **Studies of EL yield : COBRA_125 vs GEM**

Grazie per l'attenzione
Any questions?

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.

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.