Studies of the P/T detector response

“A benchmark for the tests underground.”

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CYGNO Experiment

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Topics:

- A quick revision of the literature
- Experiment setup
- Data selection & analysis
- Charge and EL response to P/T
- Conclusions & possible improvements

Introduction

A (quick) revision of the literature

The charge gain of a detector, G, is related to the first Townsend coefficient, *G=exp(αx)*, which depends inversely on the electron's mean free path, λ, during the avalanche process.

$$\lambda = \frac{1}{N\sigma}$$

N → molecular density of the gas,
σ →molecular cross-section for the avalanche process

The molecular density of the gas depends on P and T:

$$N = \frac{N_A \times P}{R \times T}$$

N_A → Avogadro's number,
R →ideal gas constant

This results in:

$$\lambda = \frac{R \times T}{N_A \times P \times \sigma} \Longleftrightarrow G \propto \exp(P/T)$$

Reference: J.E. Bateman (1998), "Gain Stabilisation in Proportional Counters."

Fitting the detector gain to equation

$$G = A\exp(b \cdot P/T)$$

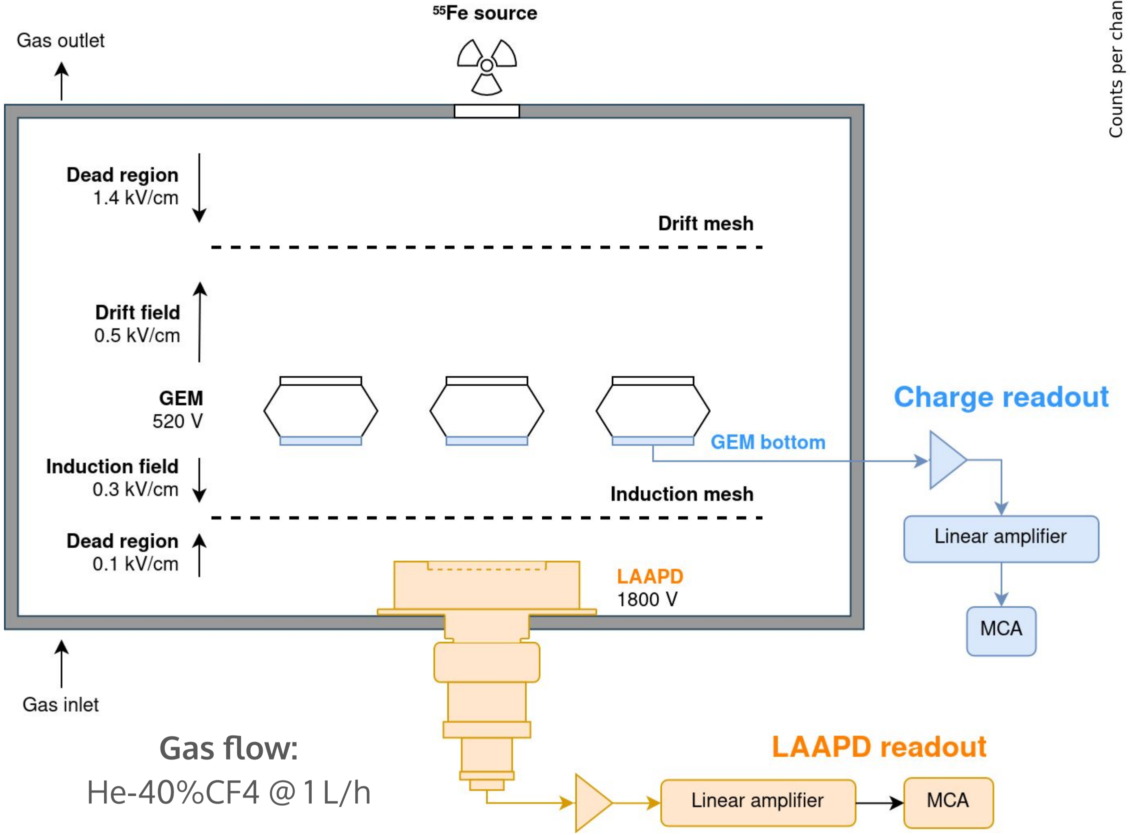
The **gain sensitivity** is given by b [K/mB], which allows the comparison between different detectors:

Increasing fluctuations

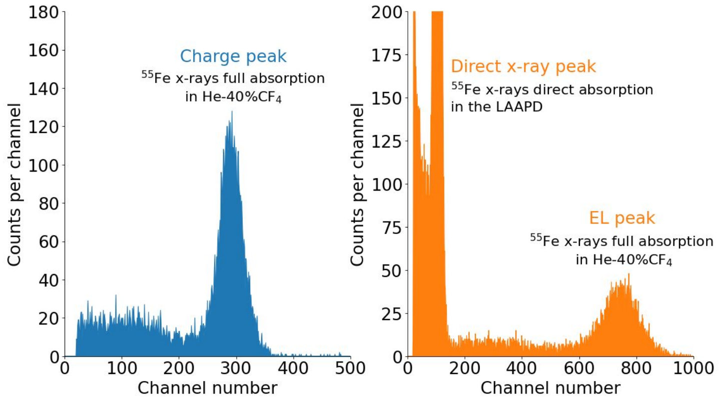
Detector	Duration	b [K/mB]
Parallel plate proportional counter	Several weeks	-8.4
Pin detector	Several weeks	-4.6
GEM-100	2 weeks	-4.0
GEM	1 month	-1.55
Wire counter	Several weeks	-1.4
GEM-MIGAS	Several weeks	-1.37(2)
MSGC	Several weeks	-1.1
MSGC	1 week	-0.28

We found no EL sensitivity studies to P/T in the literature.

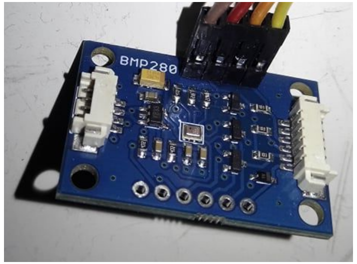
Experiment Setup



Gas flow:
He-40%CF4 @ 1 L/h



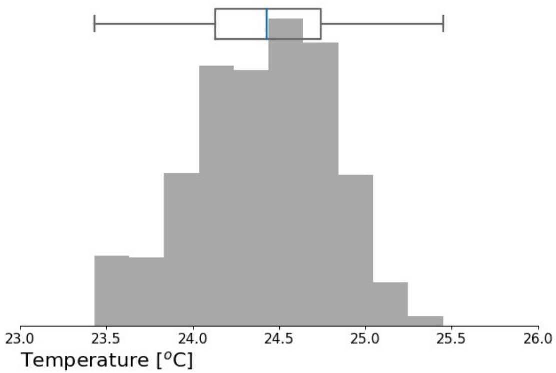
Spectra of **1 min** were acquired **every 5 min** at the charge and EL readout **over a week**.

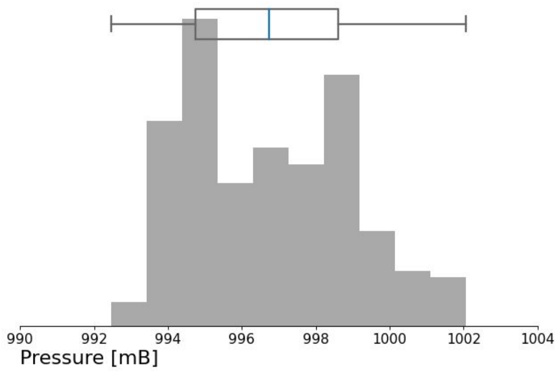


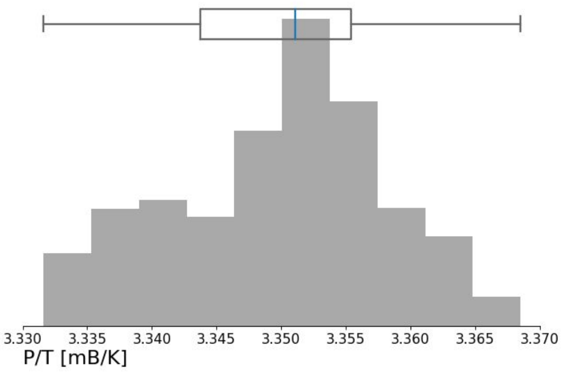
Temperature and pressure were recorded **close to the detector** with a BMP 280 sensor coupled to an Arduino.

The spectra and P/T variables were linked through their timestamps.

Ambient Variable Range







Temperature

- Max: 25.45°C
- Min: 23.43°C
- Mean: 24.4(4)°C
- Range: 2.02°C

Pressure

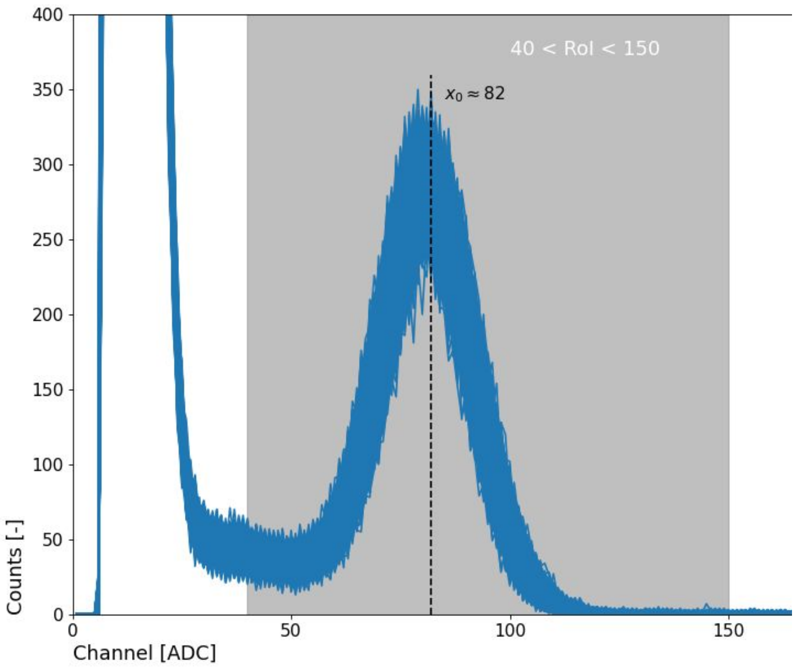
- Max: 1002.0584 mB
- Min: 992.4672 mB
- Mean: 996.8(22) mB
- Range: 9.5912 mB

P/T

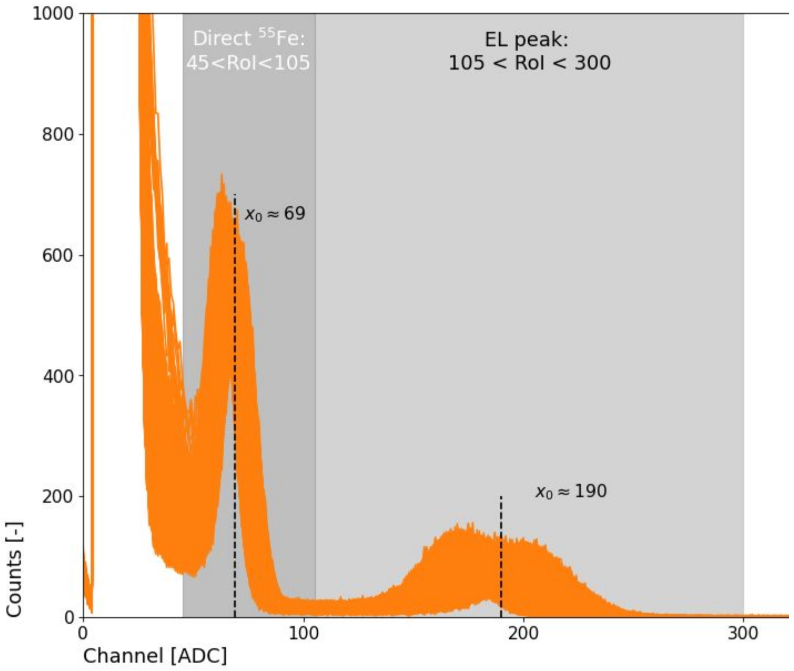
- Max: 3.3685 mB/K
- Min: 3.3316 mB/K
- Mean: 3.350(8) mB/K
- Range: 0.0369 mB/K

Charge Gain and EL yield determination

We selected a Region of Interest (RoI) to fit the charge peak, direct x-ray peak and EL peak.



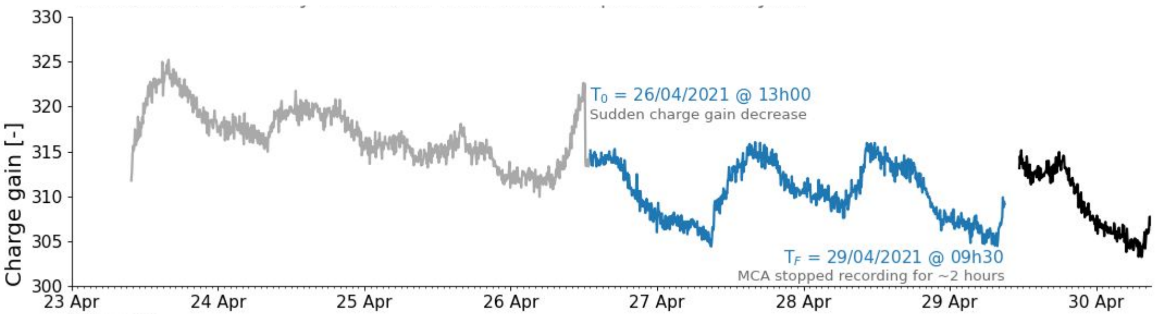
Charge spectra

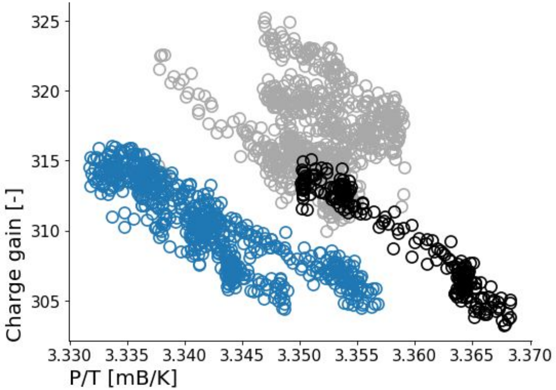


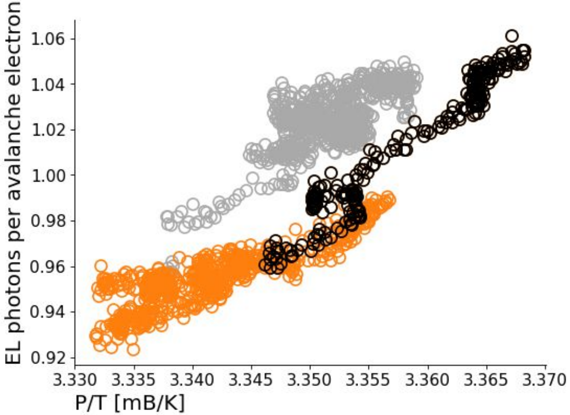
EL spectra

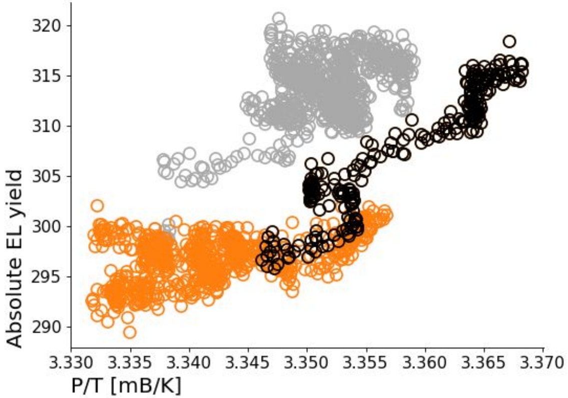
Preliminary analysis

The charge gain response of the detector was not stable over the entire acquisition. There were two events that influenced the general behaviour of the detector.





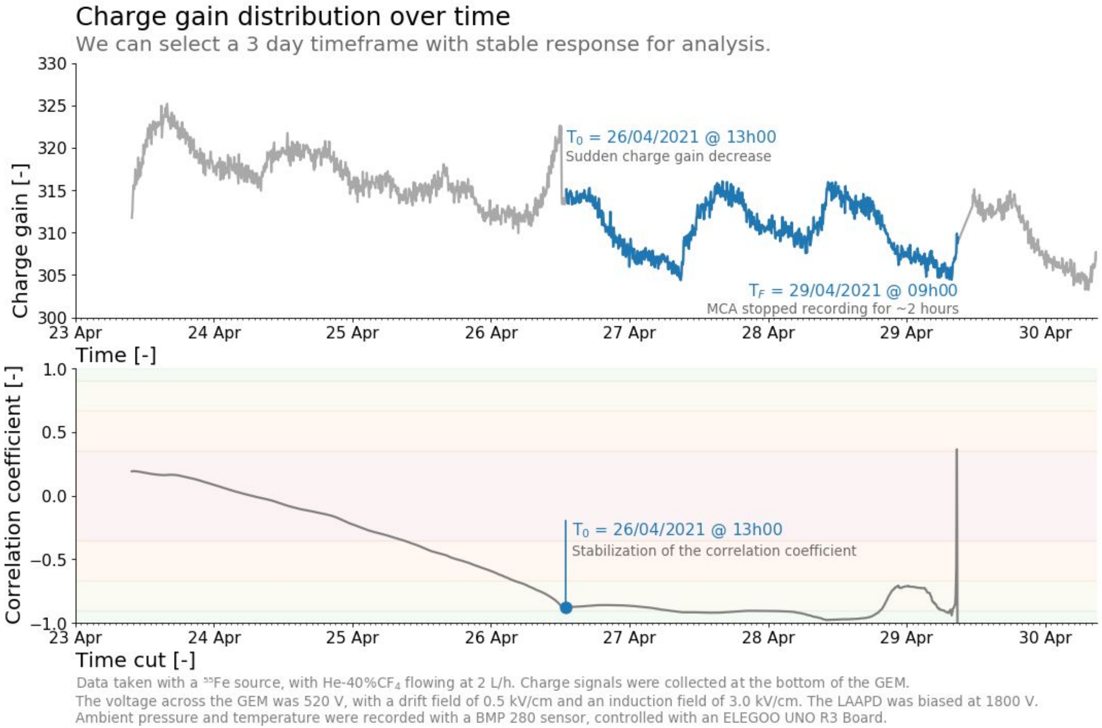




We needed to **select the data** for further analysis.

Data selection

We decided to perform the data selection based on the correlation coefficient between the charge gain and P/T.



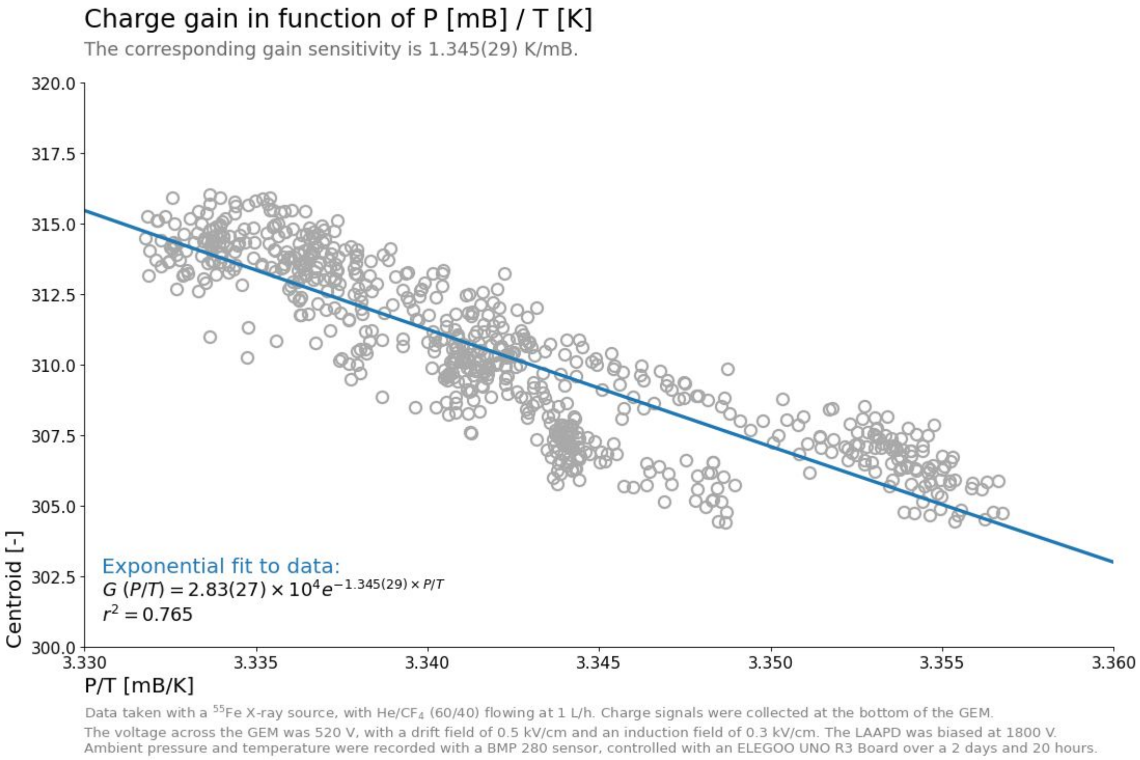
Data Selection:

T_0 →The correlation coefficient stabilized after the sudden decrease of the charge gain.

T_F →We did not consider data points taken after the MCA stopped working (could be a power shortage that also would affect the detector bias).

Because the EL yield depends on the amount of electrons produced in the GEM holes, **we performed the same data selection for the EL data as for the charge data.**

Charge gain as a function of P/T



Charge gain

- **Sensitivity of -1.345(29) K/mB**

  Agrees with what was obtained for a standard GEM : -1.55 K/mB

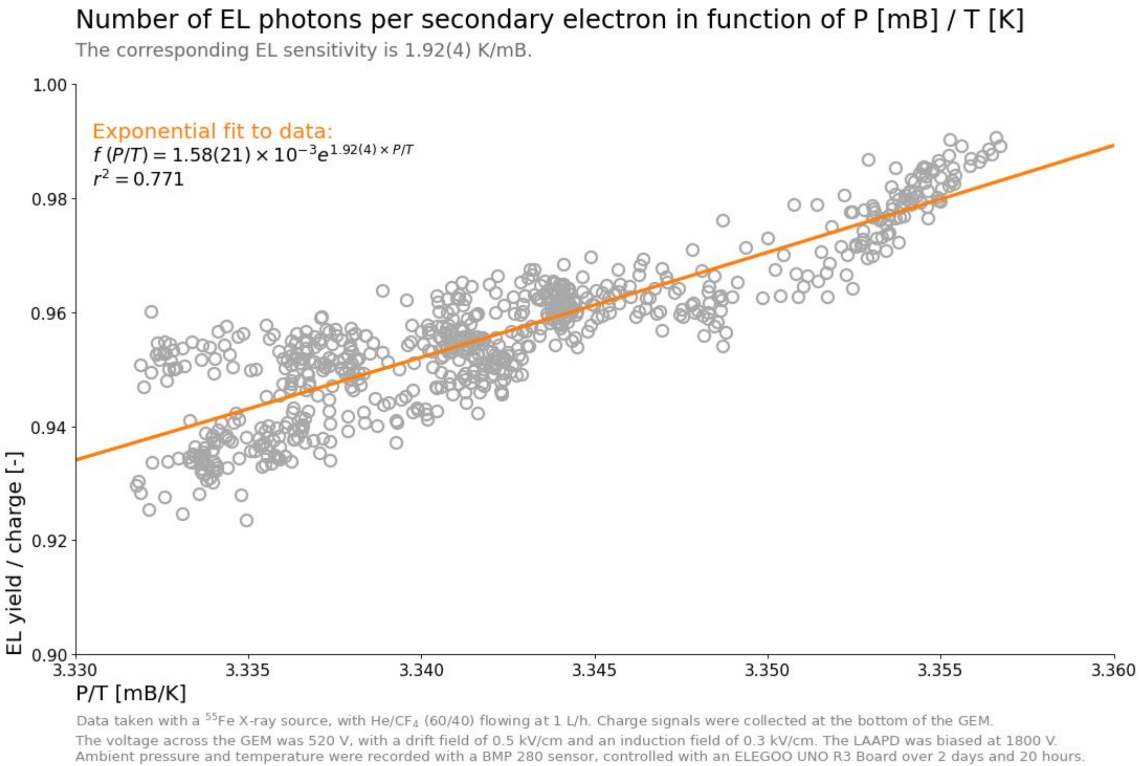
- **Increases with increasing T**

  A variation of +7.40(15)% is expected for P = 1 bar and T = 20°C → 25°C.

- **Decreases with increasing P**

  A variation of -9.61(21)% is expected for T=20°C and P=1000 mB→1020mB

EL yield per avalanche electron as a function of P/T



EL yield per avalanche electron

- **Sensitivity of 1.92(4) K/mB**

  more sensitive to P/T variations than the charge gain.

- **Decreases with increasing T**

  A variation of -11.58(26)% is expected for P = 1 bar and T = 20°C → 25°C.

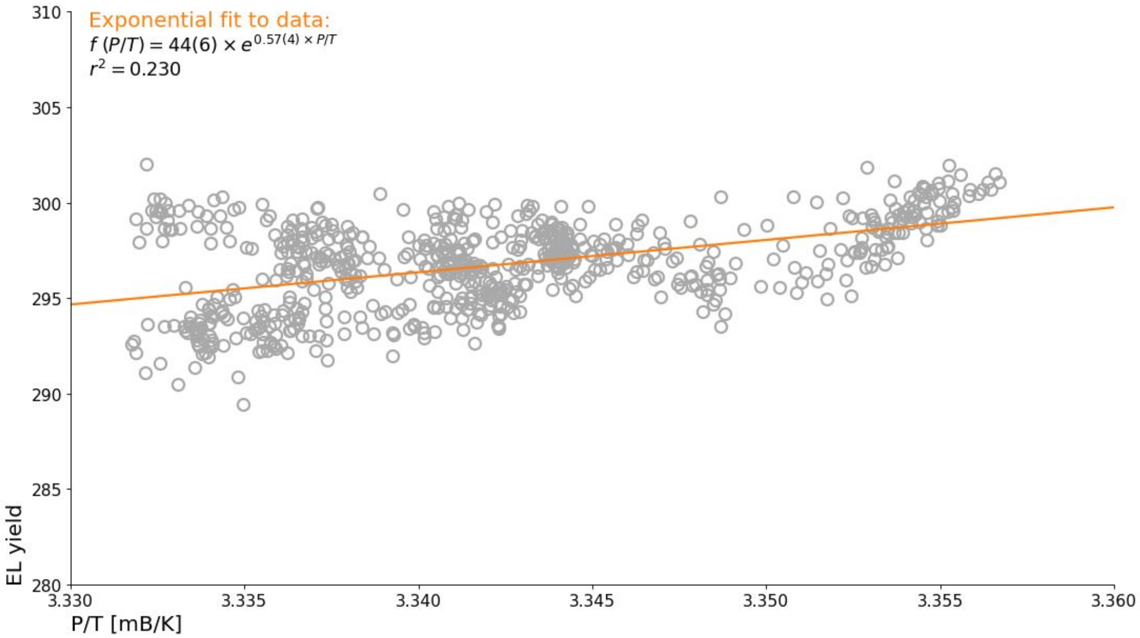
- **Increases with increasing P**

  A variation of 12.25(24)% is expected for T=20°C and P=1000 mB→1020mB

Absolute EL yield as a function of P/T

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

The corresponding EL sensitivity is 0.57(4) 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 1800 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.

Absolute EL yield

- **Sensitivity of 0.57(4) K/mB**

  less sensitive to P/T variations than the charge gain.

- **Decreases with increasing T**

  A variation of -3.32(24)% is expected for P = 1 bar and T = 20°C → 25°C.

- **Increases with increasing P**

  A variation of 3.82(26)% is expected for T=20°C and P=1000 mB→1020mB

Conclusions

Gain sensitivities to P/T showed that:

- The EL yield/charge has the largest number of fluctuations, with 1.92(4) K/mB.
- The charge gain has fluctuations compatible with the results found in the literature, with 1.345(29) K/mB.
- The absolute EL yield has a small number of fluctuations, with 0.57(4) K/mB.

What can be improved

- Longer acquisition times
- Longer P/T range
- Addition of a sparking monitor

Increasing fluctuations

Detector	Duration	b [K/mB]
Parallel plate proportional counter	Several weeks	-8.4
Pin detector	Several weeks	-4.6
GEM-100	2 weeks	-4.0
GEM	1 month	-1.55
Wire counter	Several weeks	-1.4
GEM-MIGAS	Several weeks	-1.37(2)
GEM in He-40%CF_4 (Gain)	**3 days**	**-1.345(29)**
MSGC	Several weeks	-1.1
MSGC	1 week	-0.28

Grazie per l'attenzione
Any questions or suggestions?

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