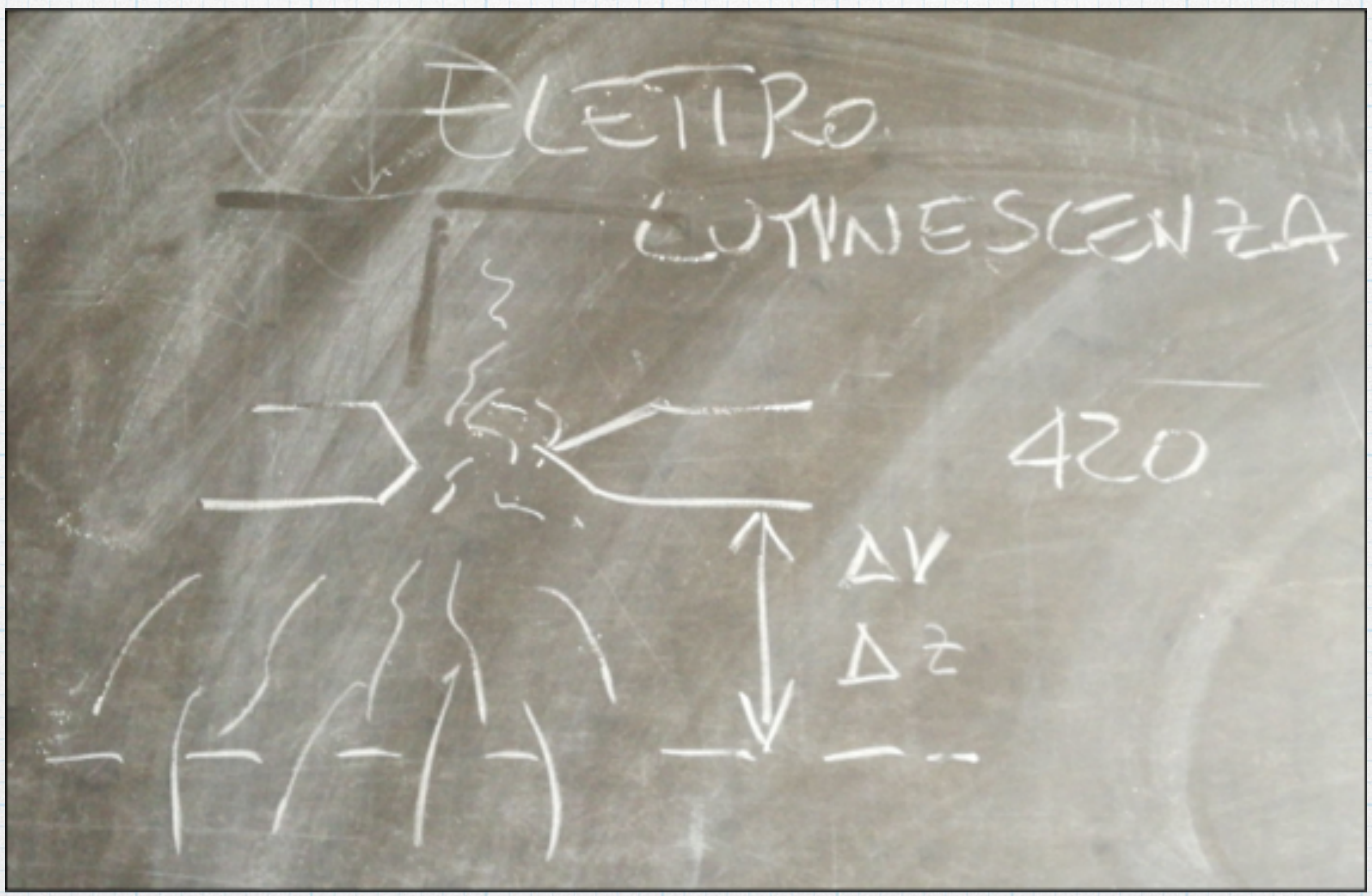
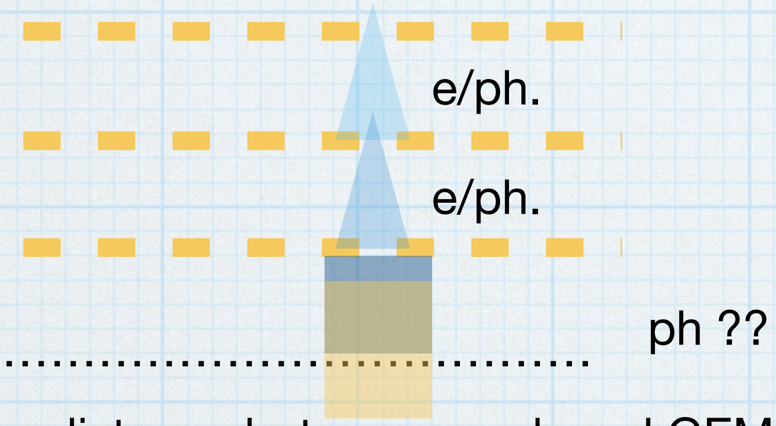
Electroluminescence



Principle of operation

We can add a grid below the Triple GEM structure:



Δz=distance between mash and GEM

ΔV= tension between mash and GEM

We can decrease the gain of GEMs so that e.g. for 1 electron reaching the GEM 10^5 electron are produced in third GEM (more than half of the will be captured by the GEM electrode, let's say 2/3).

In the very high fields inside the GEM we get 8 x 10^3 photons;
In the low electric field below the GEM we'll have 3 x 10^4 electrons.
If we manage to make each electron creating a 2 or 3 photons we can have the same amount of light.

To have an idea about the number of photons we can produce, we started from a phenomenological formula (valid for Xe)

[Development and Characterization of a Multi-APD Xenon Electroluminescence TPC]

$$\eta = 140\left(\frac{\Delta V}{p\Delta z} - 0.83\right)p\Delta z$$

p= gas pressure

Δz=distance mesh - GEM3

ΔV= tension mesh - GEM3

The Bible we started in 2015

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The GEM scintillation in He–CF_4, Ar–CF_4, Ar–TEA and Xe–TEA mixtures

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Beaune 2002

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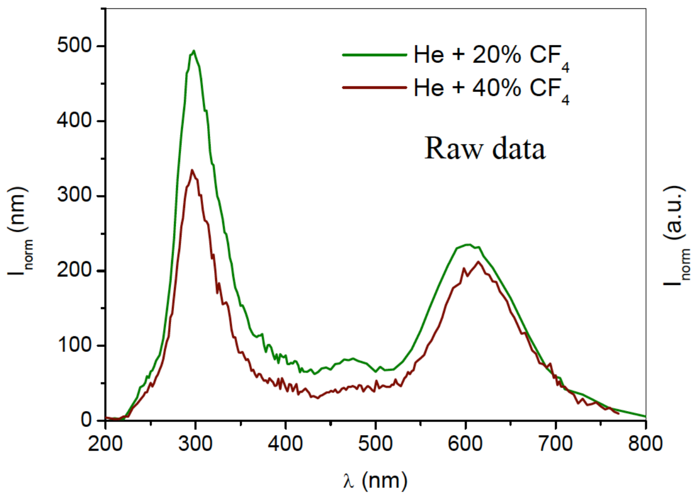
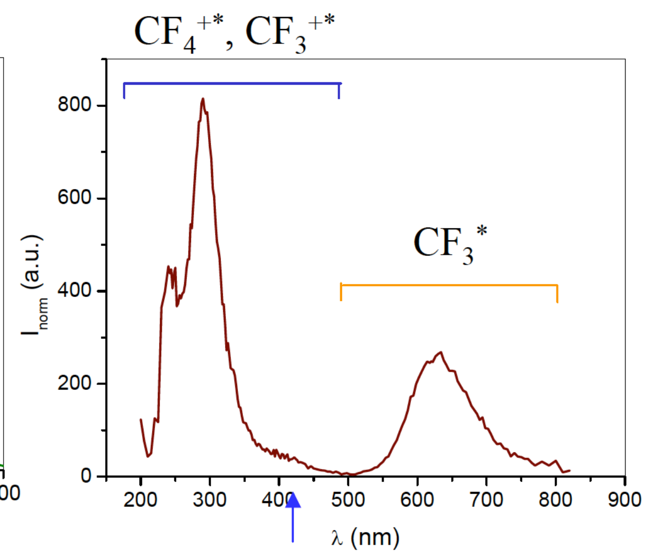
Experimental setup

Emission spectra of He-CF_4 mixtures



He+20% CF_4 : G = 335
He+40% CF_4: G = 175
$\Delta\lambda$ = 4 nm



Emission spectrum of He+40%CF_4 , corrected for 2nd order diffraction effects and the quantum efficiency of the detection system.

Dissociation into neutral fragments in CF_4

$$e^- + CF_4 \rightarrow CF_3 + F + e^-$$

Energy threshold: 10 - 12.5 eV (?)

Dissociation energy: D(CF_3 — F) = 5.25 eV

Observed electronic transitions:

CF_3^* ($1E', 2A_2'' \rightarrow 1A_1'$(*repulsive state*)) visible ~ 620 nm

dissociate or predissociate with high probability. The broad band in the visible region results from the excitation of a Rydberg state of the CF_4 molecule that dissociates into an emitting CF_3 fragment [8,11]. The energy threshold for this emission, CF_3^* ($1E', 2A_2'' \rightarrow 1A_1'$), is set to 12.0 eV.

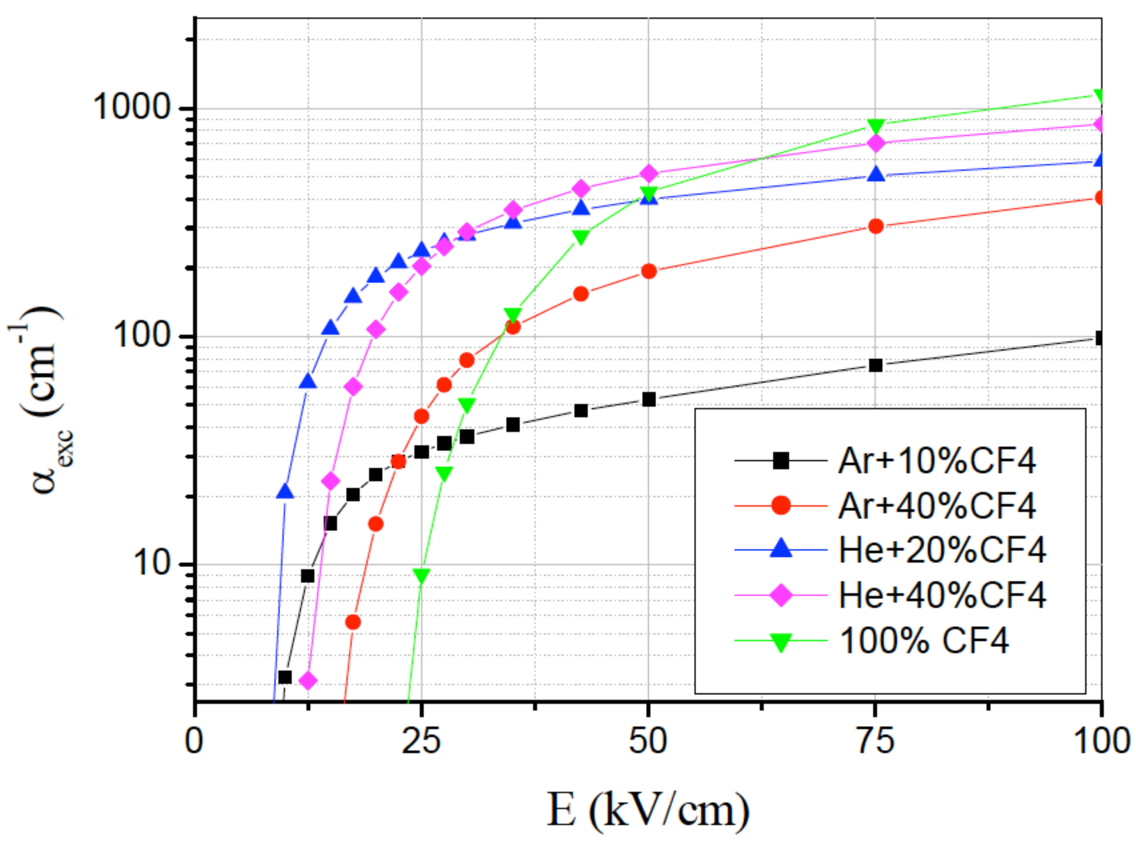
Light around 620 nm is produced in CF_4 dissociation processes

Very high energy threshold;
Close to ionization threshold;

CF_4

Process		Threshold (eV)
Direct vibrational excitation	ν_4 ν_3	0.078 0.159
Indirect vibrational excitation		4.0
Electron attachment		4.3
Electronic excitation (dissociation into neutral fragments)†		12.5 (10)
Dissociative ionization†		15.9

Experimental setup

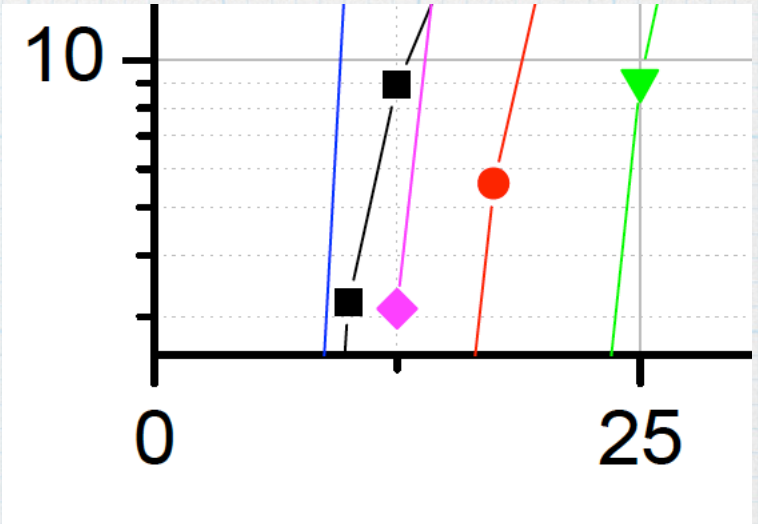


Number of collisions per cm leading to dissociation of CF_4 into neutral fragments, as a function of the electric field.

Very high threshold translate in very high electric field to start the process

Something between 10 and 12 kV/cm

At 12 kV/cm mean free path of 3.3 mm



Experimental setup

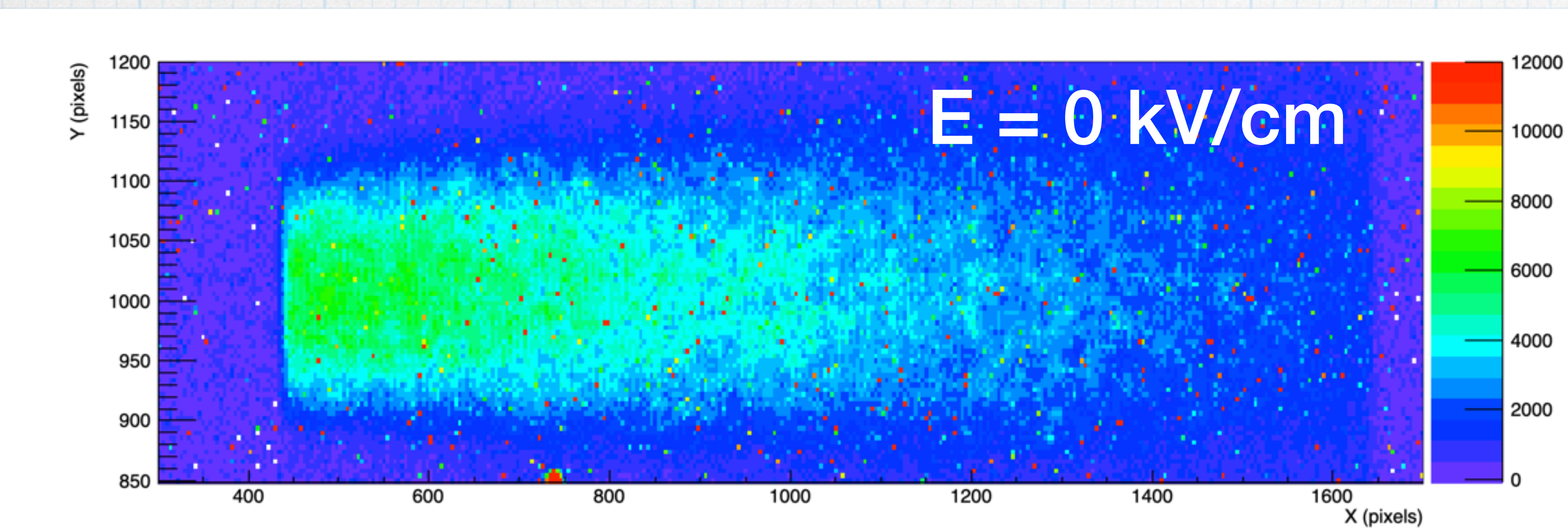
Since it was found that CF_4 electroluminescence has a very high energy threshold, we decided to modified MANGO adding a **grid** with **Δz=3 mm** and **ΔV up to 4 kV** in order to have electric fields up to 10/12 kV/cm

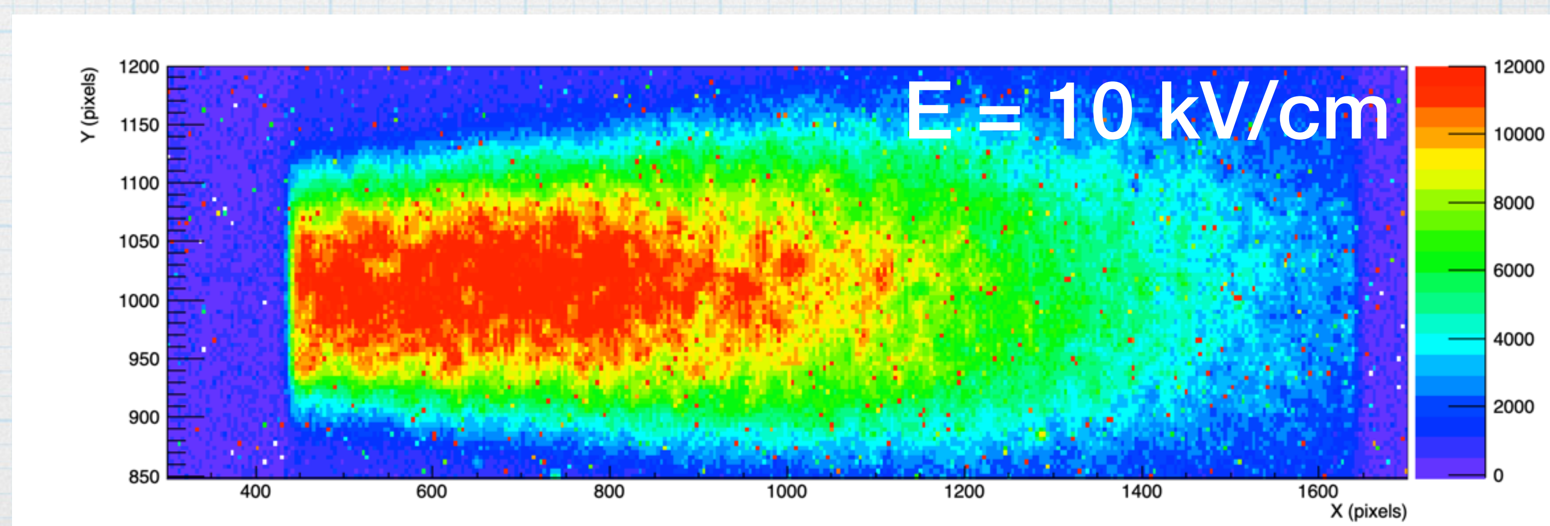
Unfortunately there were discharges at 3.5 kV and we stopped there (i.e. 10 kV/cm)

Then, we tested everything with ^{55}Fe X rays.

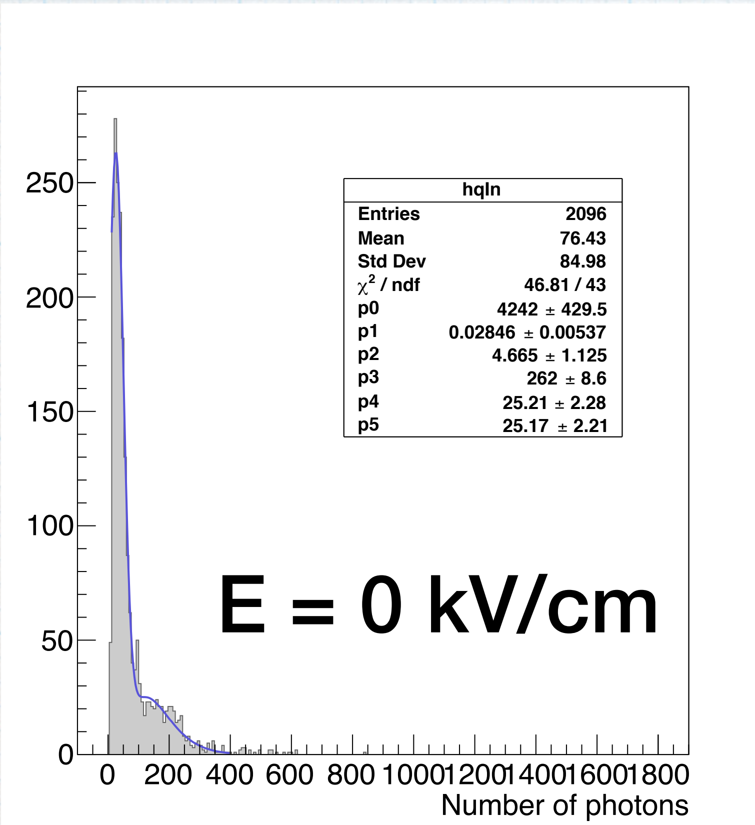
While keeping GEM at 400 V and scanning in **ΔV** we took two kinds of data:

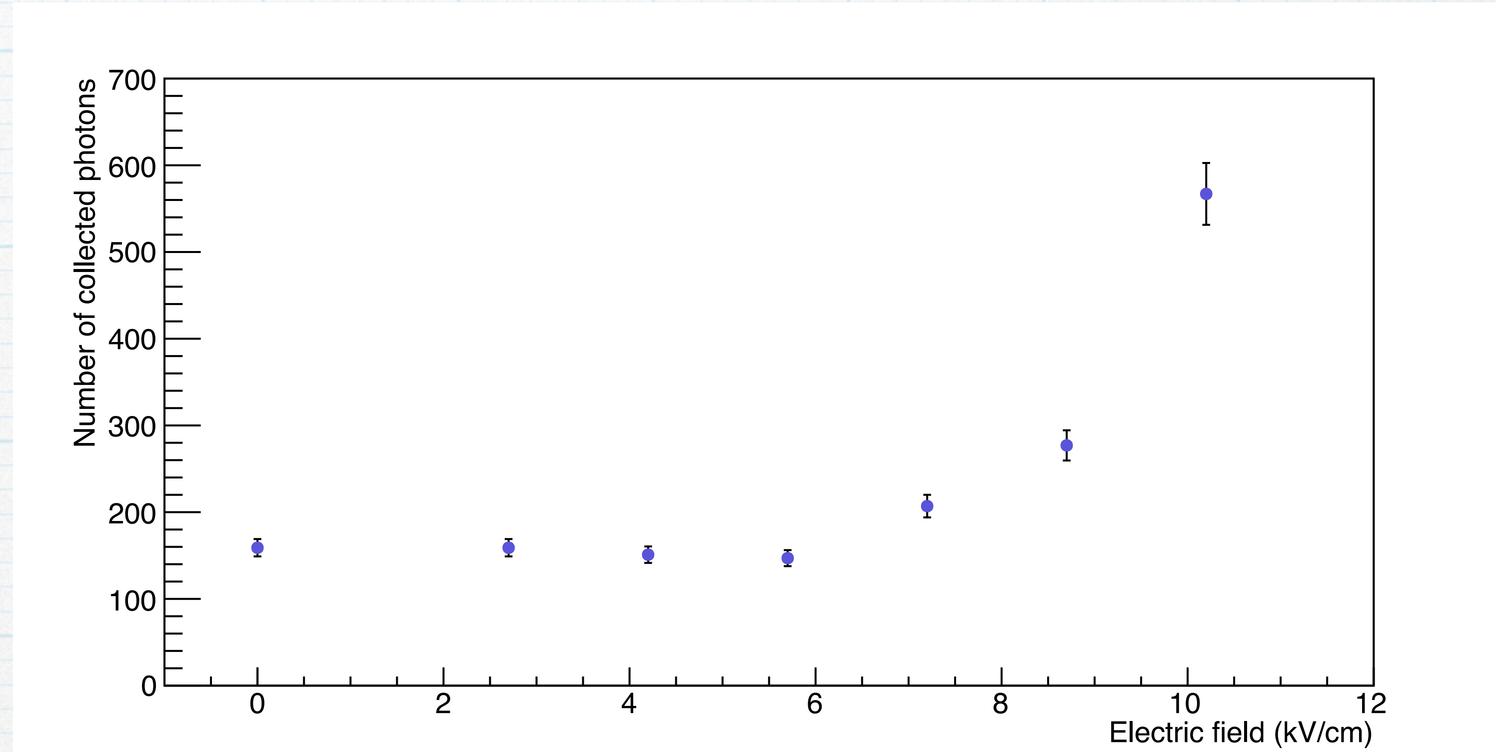
1) Long exposure images (30x10sec) to quickly measure the total amount of light produced;

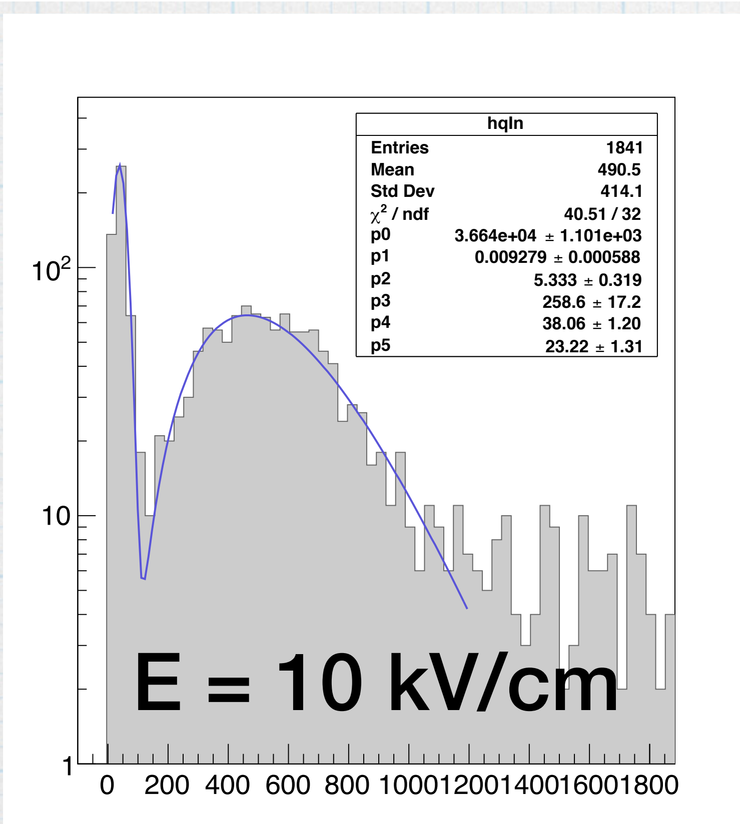


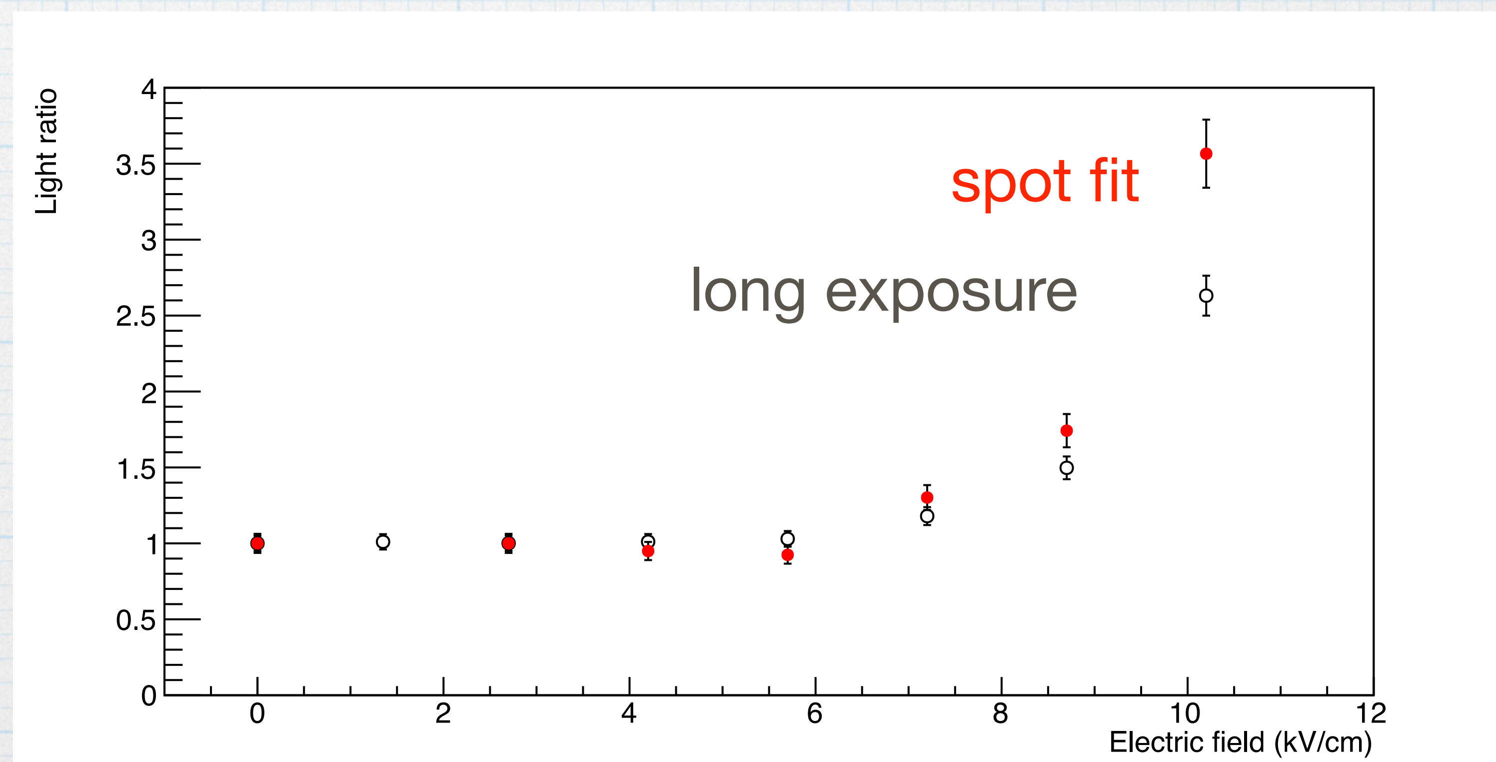


Short exposure data (100 x 0.5 sec) to study in detail the ^{55}Fe peak position;

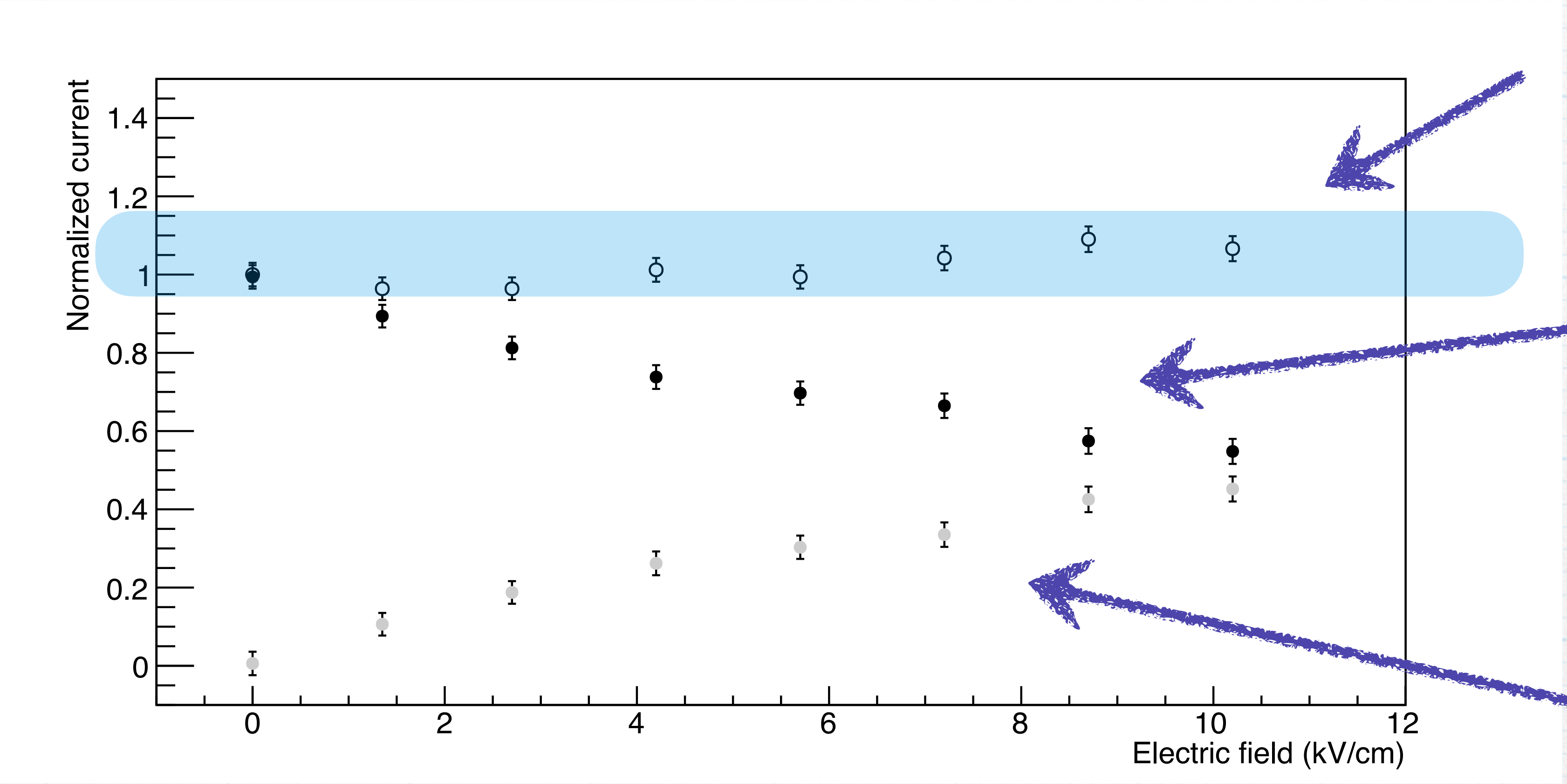








The currents drawn by the bottom electrode of last GEM and by the mesh were monitored, to check possible increase in total charge, indicating a multiplication process

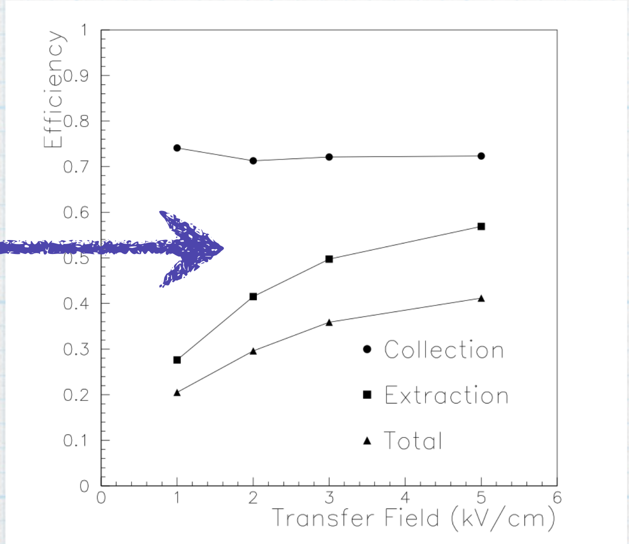


Sum of currents

Fraction of current on $G3_{down}$

Fraction of current on Mesh

Garfield simu



Sum is constant and sharing changes

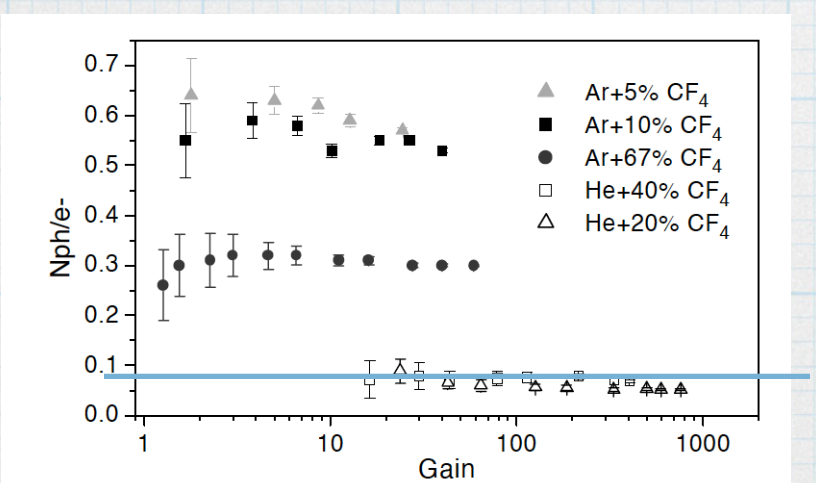
We can now evaluate the “photon production efficiency” (α_{Mesh})

$$N_{GEM} = n_{el} \times \alpha_{GEM} \times \Omega \times T_{mesh}$$

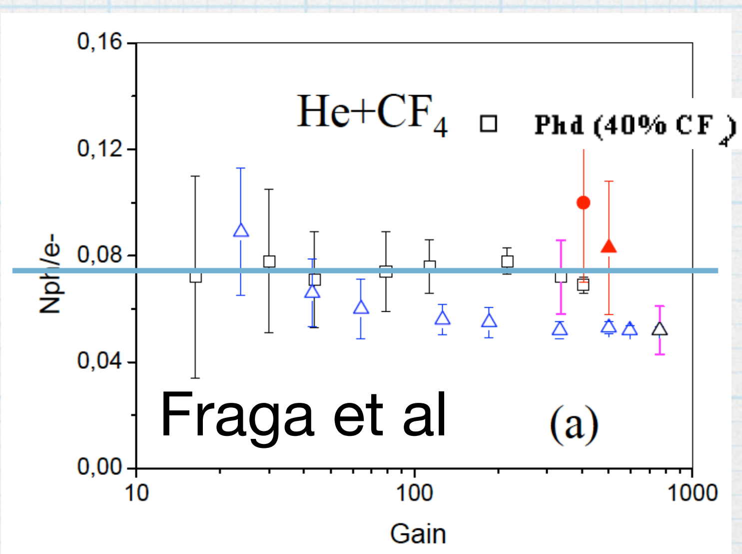
- N_{GEM}: Number of photons produced by the GEM structures
- n_{el}: Number of electrons produced by the GEM structures
- α_{GEM}: GEM structure photon production efficiency (photon/electron)
- Ω: Solid angle covered by camera
- T_{mesh}: Optical transparency of the Mesh

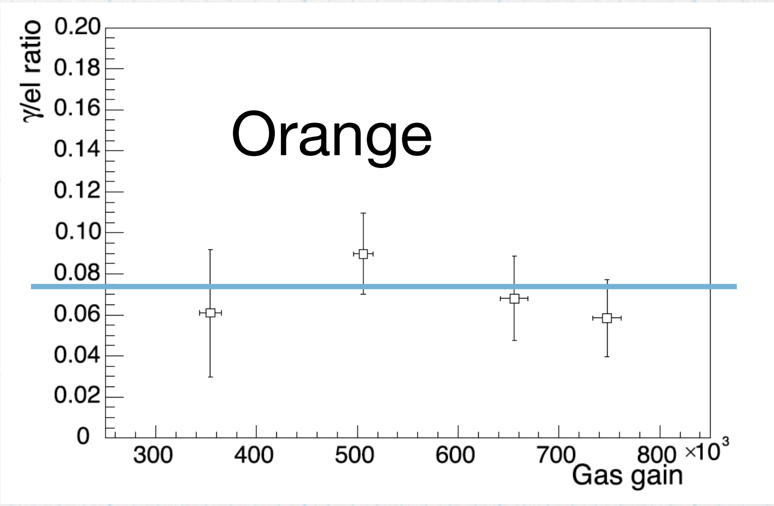
N_{GEM} is measured with 0 kV/cm = 160 photons

α_{GEM} is found in literature



Fraga et al





α_{GEM} = 0.08

We can now evaluate the "photon production efficiency"

$$N_{Mesh} = n_{el} \times \epsilon_{extr} \times \alpha_{Mesh} \times \Omega \times T_{mesh}$$

Number of photons produced by the Mesh

Number of electrons produced by the GEM structures

Fraction of electron extracted from the GEM and accelerated

Mesh structure photon production efficiency (photon/electron)

Solid angle covered by camera

Optical transparency of the Mesh

N_{Mesh} is the difference of total number of photons collected and number with 0 kV/cm = 400 photons

ϵ_{extr} was evaluated to be 0.5 at 10 kV/cm

We can now evaluate the "photon production efficiency"

$$\alpha_{Mesh} = \alpha_{GEM} \times \frac{1}{\epsilon_{extr}} \times \frac{N_{Mesh}}{N_{GEM}} = 0.08 \times \frac{1}{0.5} \times \frac{400}{160} = 0.4$$

0.4 ph/electron in 3 mm gaps, means a mean free path of about 1 cm

Reasonable agreement