# Electroluminescence and gas studies with MANGO

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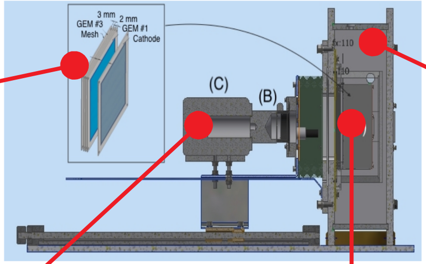
# SETUP

GEMs:




Plastic gas-tight box

sCMOS Camera
Orca fusion C14440

2304x2304 pixels

noise <1 ph/pixel

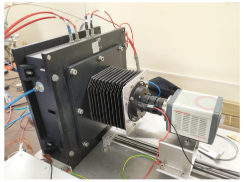
www.hamamatsu.com.

TPC volume:

Max volume 500 $cm^3$
(10x10 $cm^2$) area

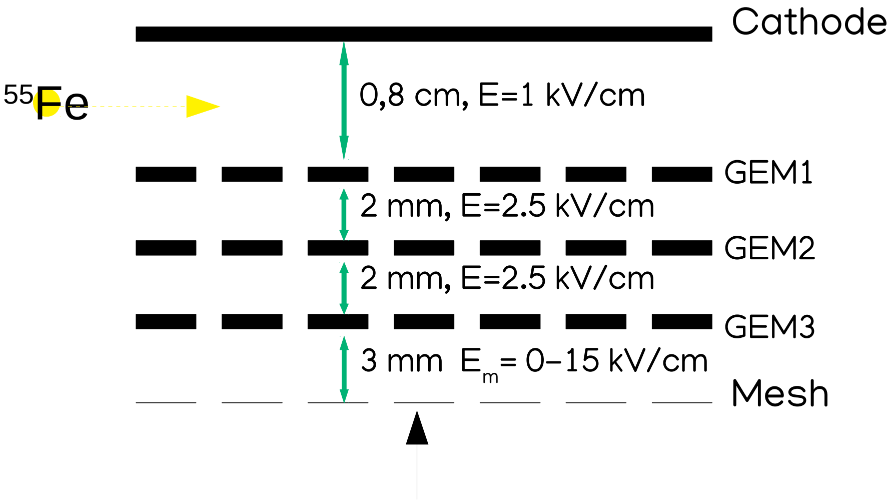
$He:CF_4$ mixture 60/40

Atmosferic pressure



- Typical setup used in the past with DAQ system to acquire waveforms together with picture

50um GEM , 70um holes 140um pitch



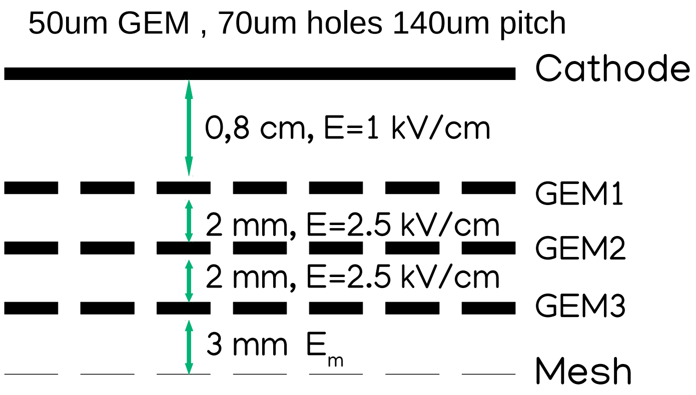

Transparency ~50/60 %

Later replaced by ITO (~90% transparency)

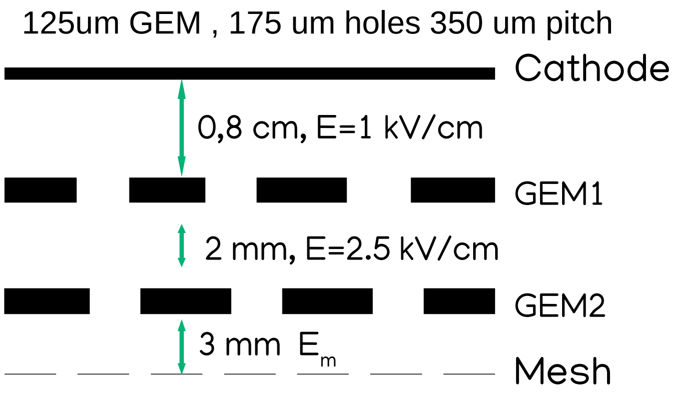
# SETUP

- Since March we started changing the GEM stack configurations

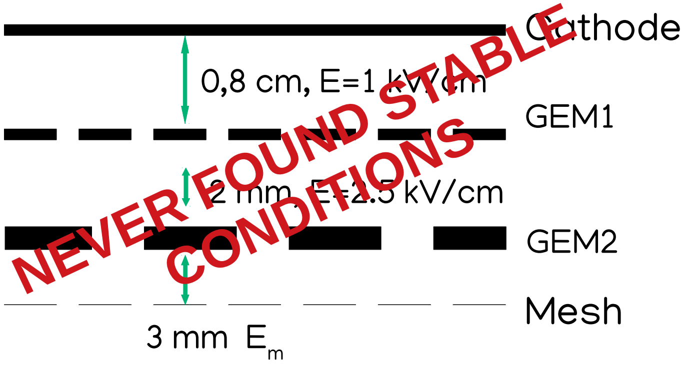
1.




2.




3.

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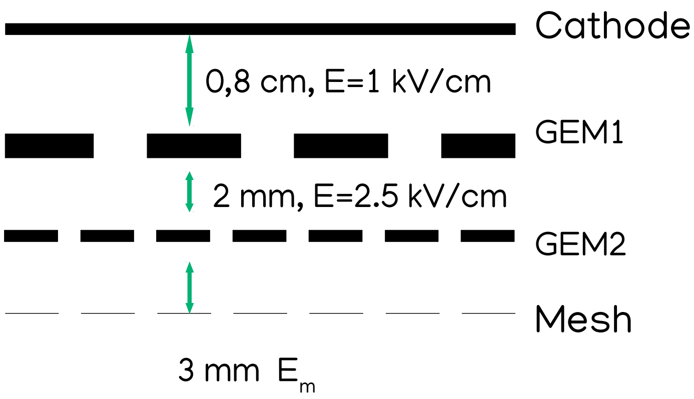
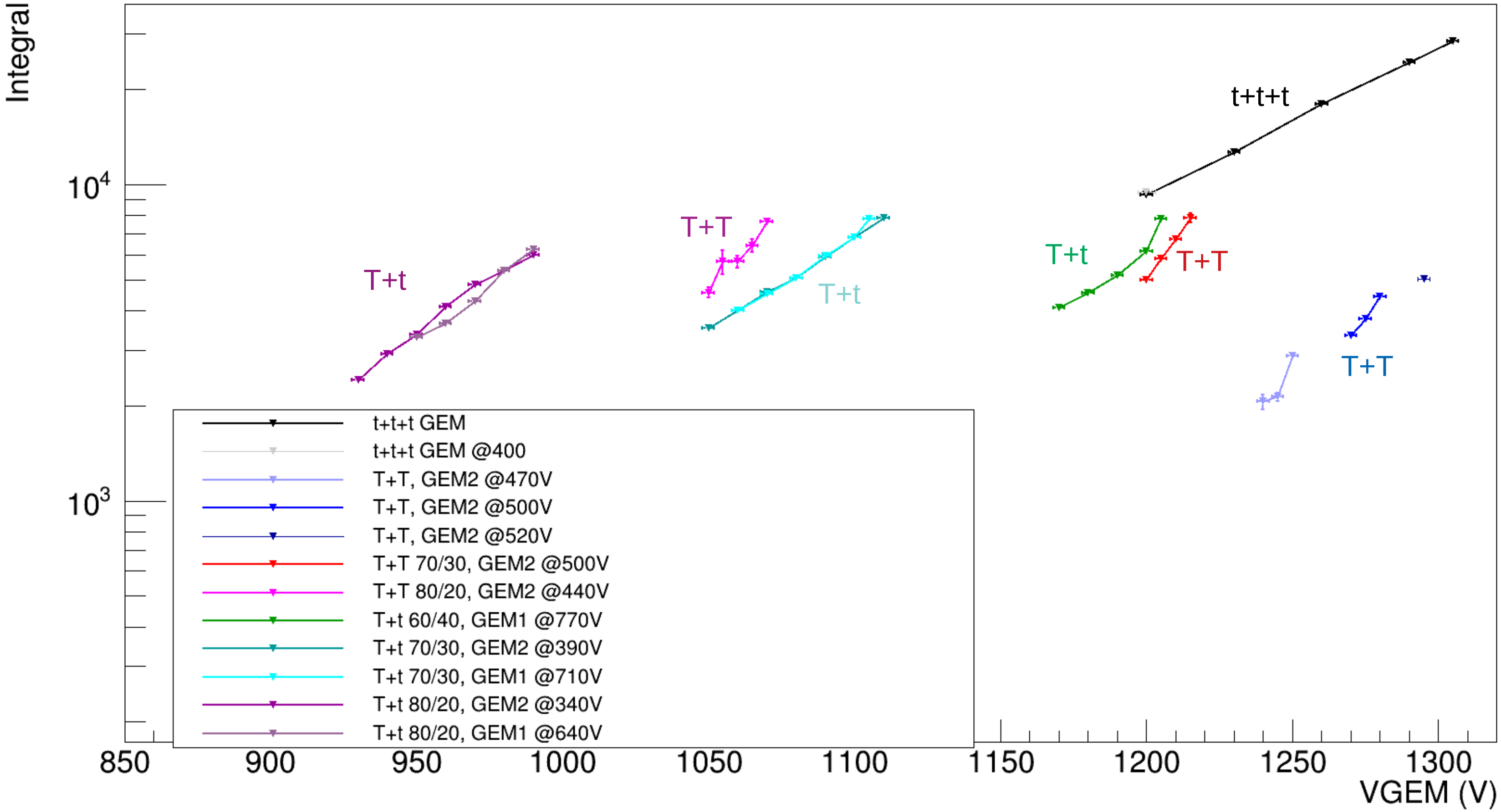


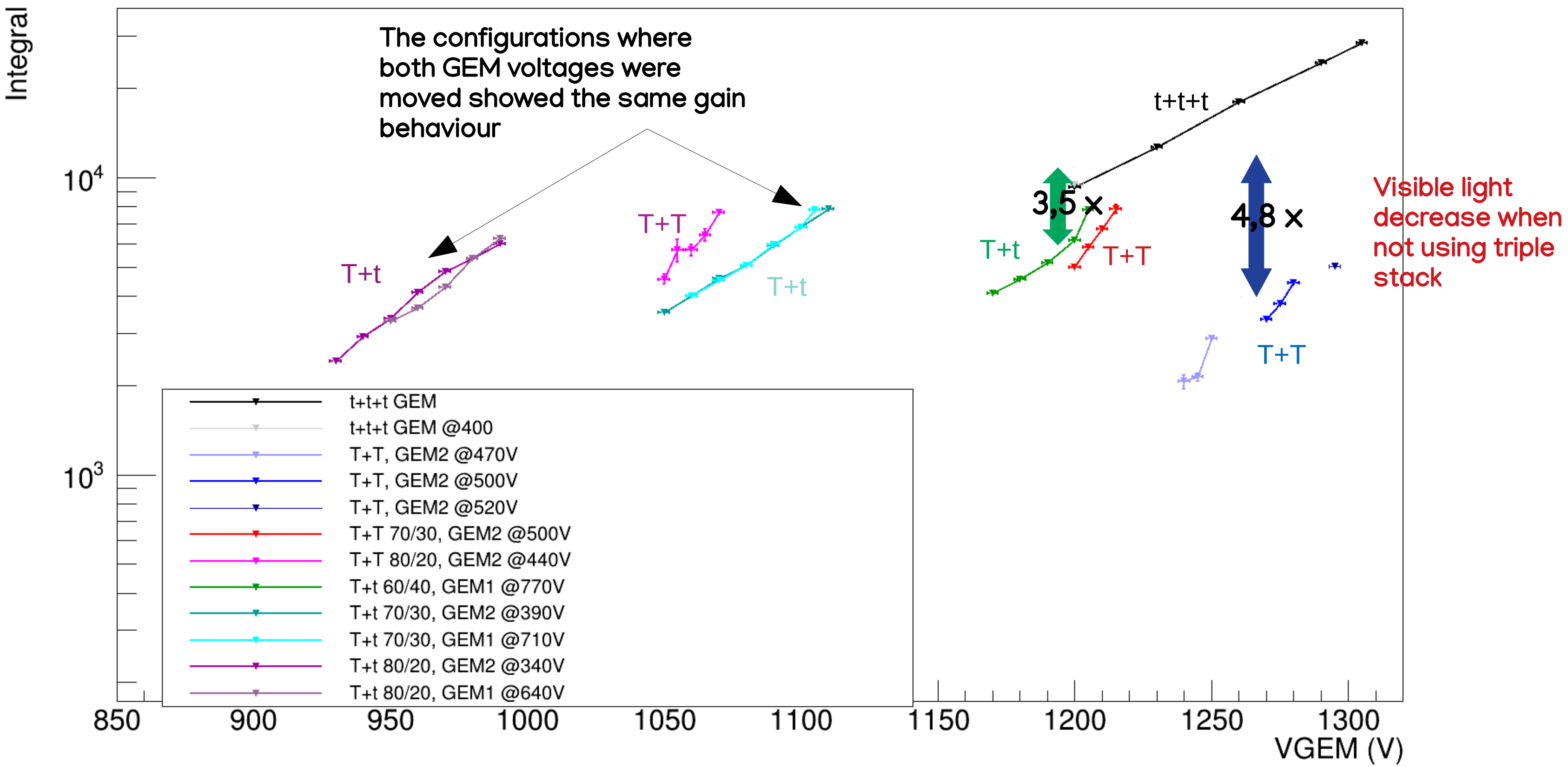
# GAIN SCAN

# Gain Scan

- Looking at the light collected with the camera



# Gain Scan



Integral
$10^4$
$10^3$
The configurations where both GEM voltages were moved showed the same gain behaviour
T+t
T+T
T+t
t+t+t
3,5 ×
4,8 ×
T+t
T+T
T+T
Visible light decrease when not using triple stack
t+t+t GEM
t+t+t GEM @400
T+T, GEM2 @470V
T+T, GEM2 @500V
T+T, GEM2 @520V
T+T 70/30, GEM2 @500V
T+T 80/20, GEM2 @440V
T+t 60/40, GEM1 @770V
T+t 70/30, GEM2 @390V
T+t 70/30, GEM1 @710V
T+t 80/20, GEM2 @340V
T+t 80/20, GEM1 @640V
850
900
950
1000
1050
1100
1150
1200
1250
1300
VGEM (V)

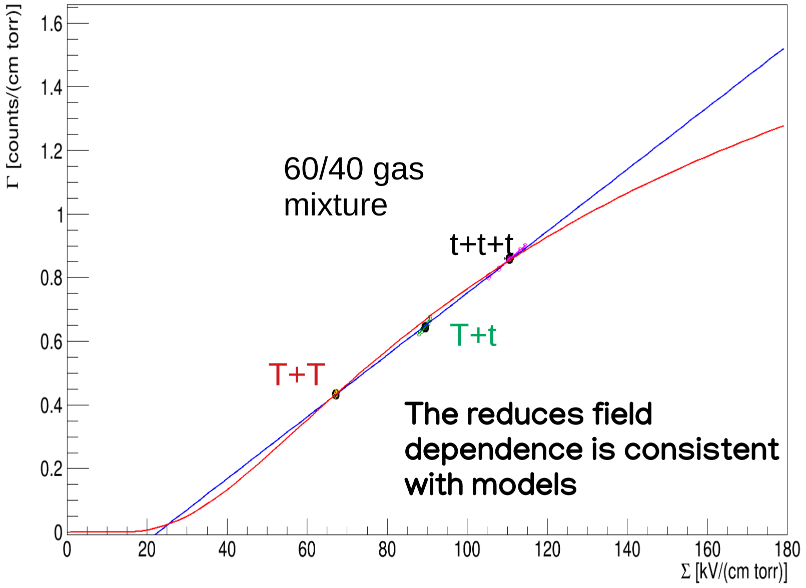
# Energy Resolution

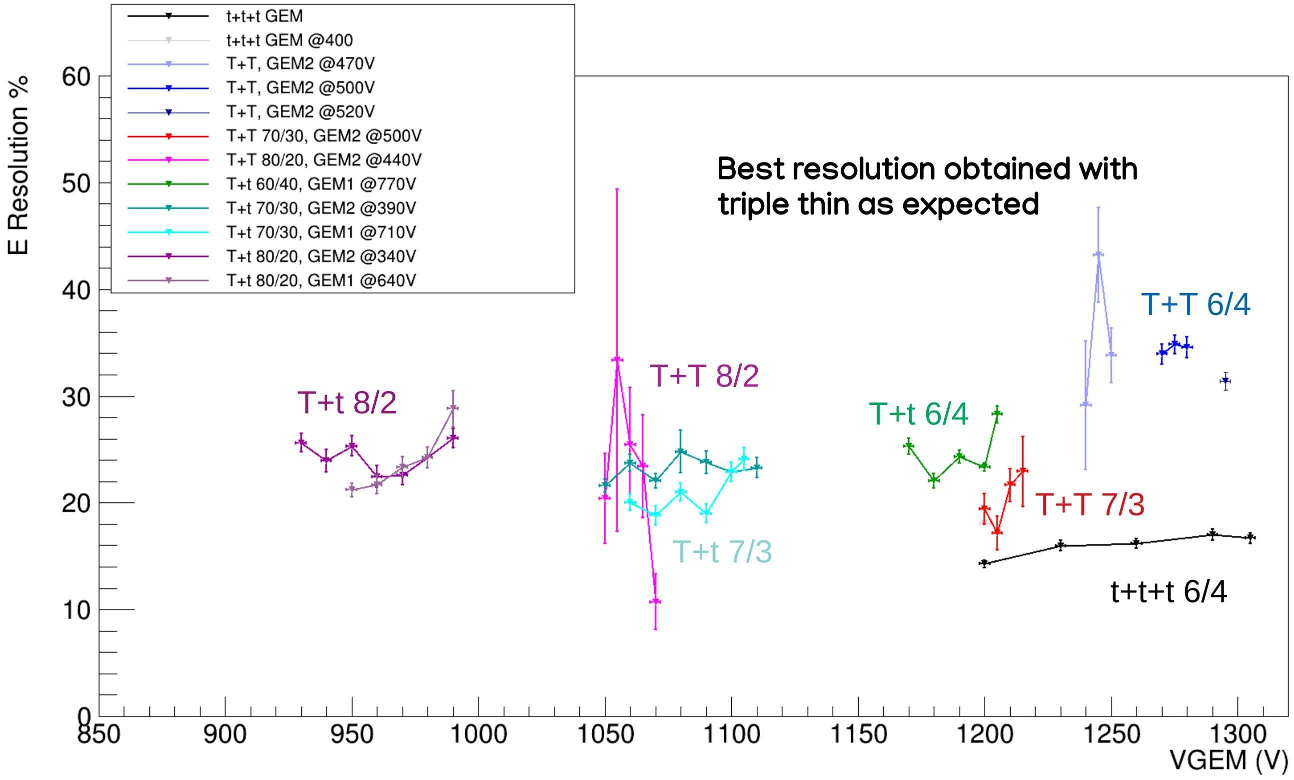
- It can be shown that the resolution is best when the field in the GEM holes is maximum

$$\Gamma = A\Sigma^{m} e^{-B\Sigma^{m-1}}$$ $0<m<1$

$$\Gamma = a_1 \Sigma + a_2$$ m=1 and voltage offset

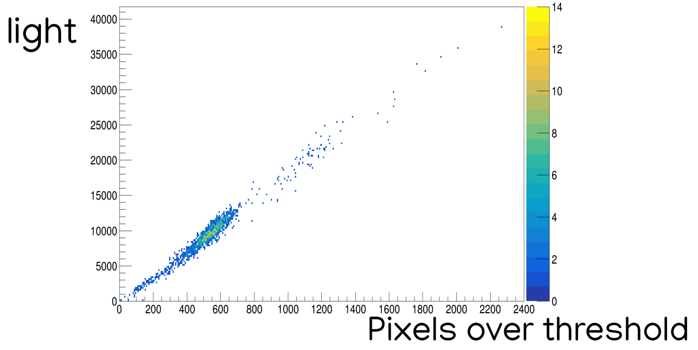
$$\Gamma = A' e^{\frac{-B}{\Sigma}}$$ m=0



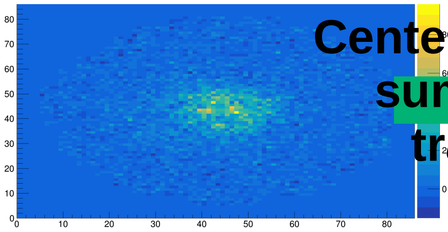



# Spot Size

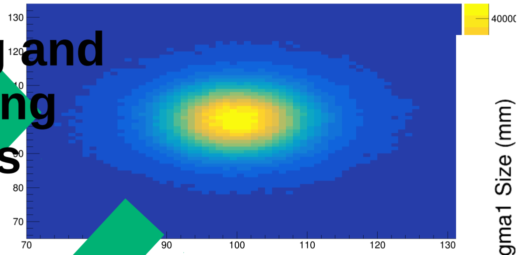
- We want to quantify the dimension of the spots independently of light output



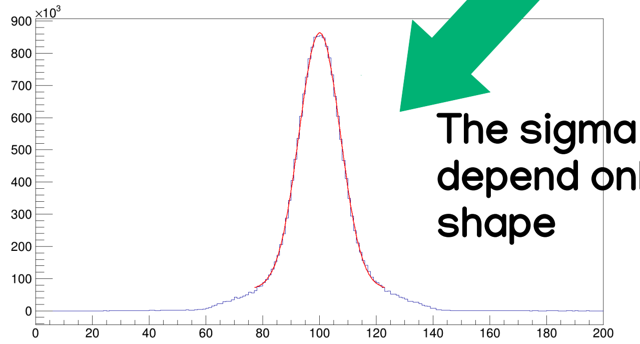

- All spots are centred and summed and then fitted



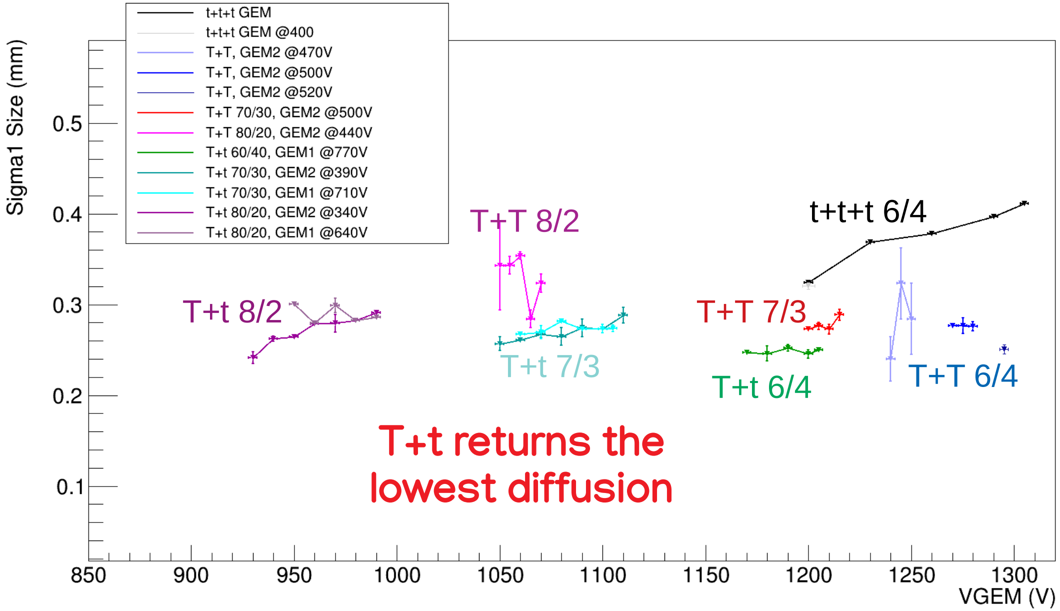
Centering and summing tracks



Projections



The sigma should depend only the shape



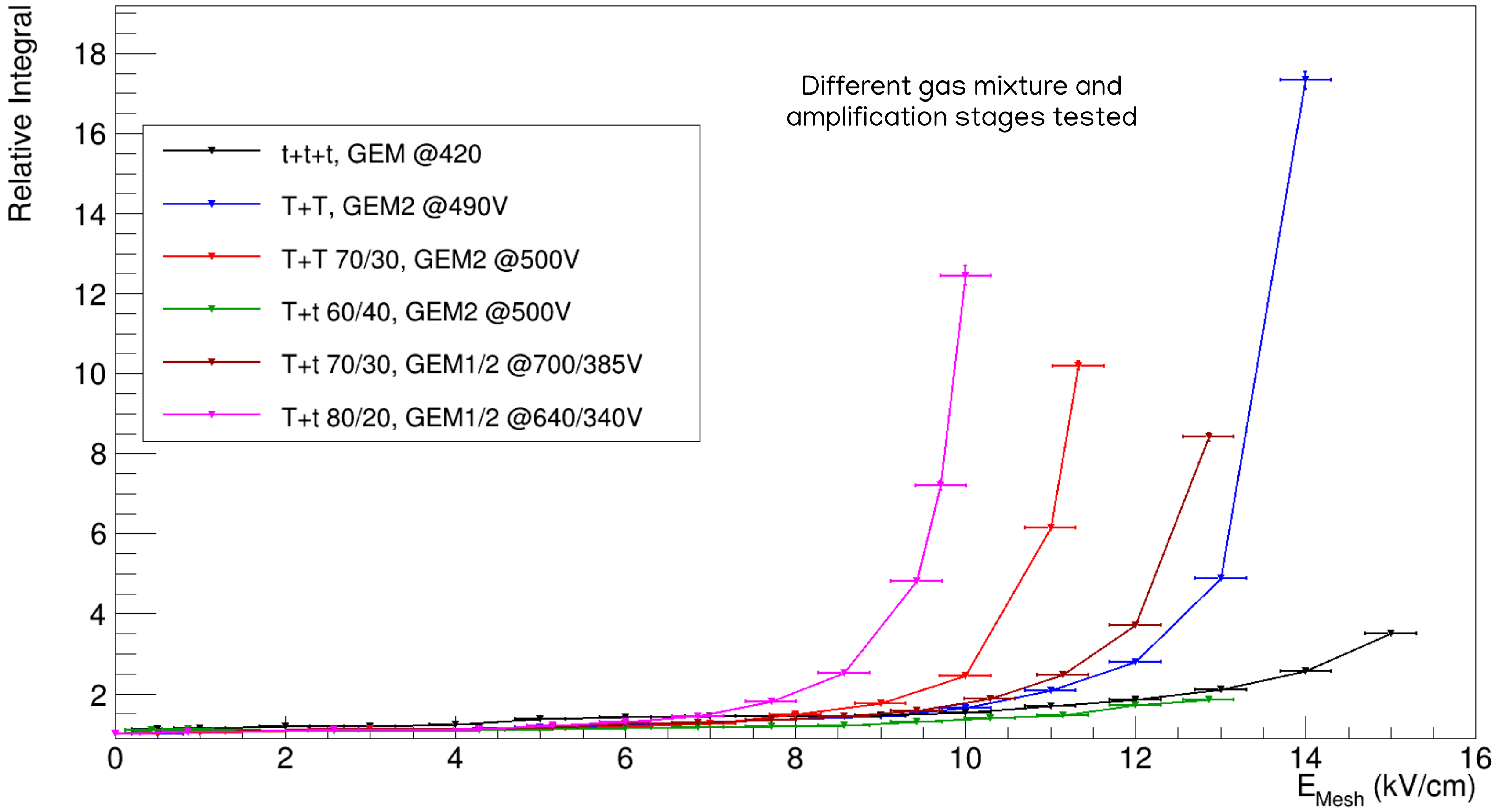

T+t returns the lowest diffusion

# Next

- The configuration of thick–thin is optimal for minimal diffusion
- The configuration of 3 thin is optimal for light output
- Need to find the best optimization also considering saturation and electroluminescence
- $^{55}Fe$ simulations with saturation on MANGO is under study not only to consistently check the simulation with data, but also to have some information on the shape of the iron spots

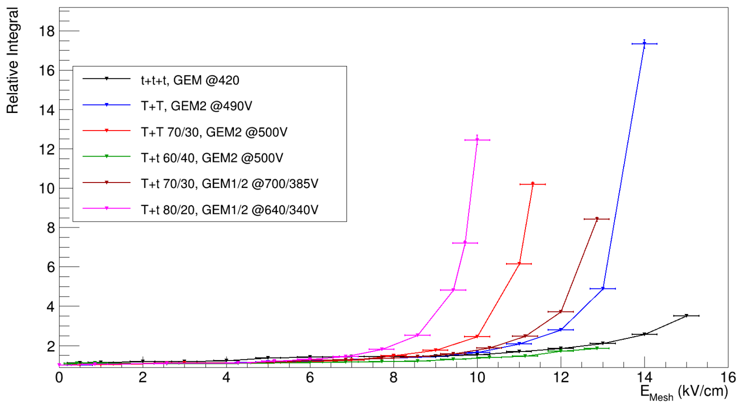
EL

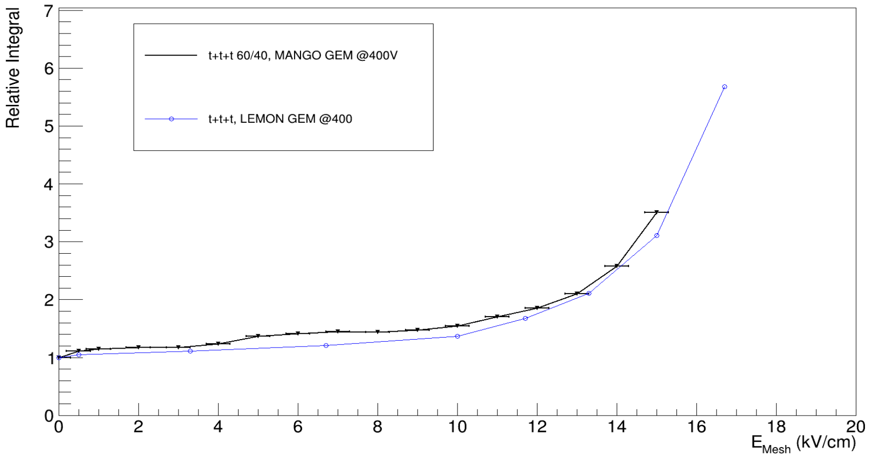
# Light From The Camera

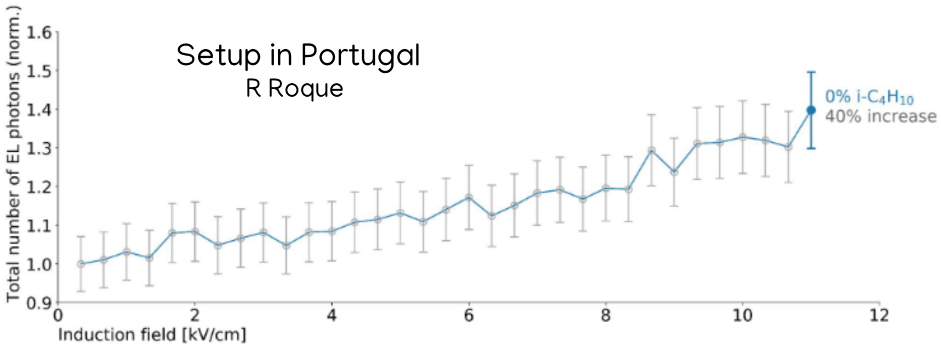


# Light From The Camera

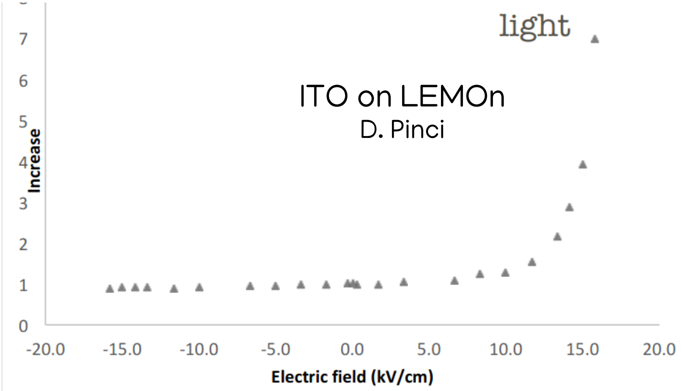
- Consistent behaviour of light yield also with different detectors (MANGO and LEMOn), different electrodes (metallic mesh and ITO)



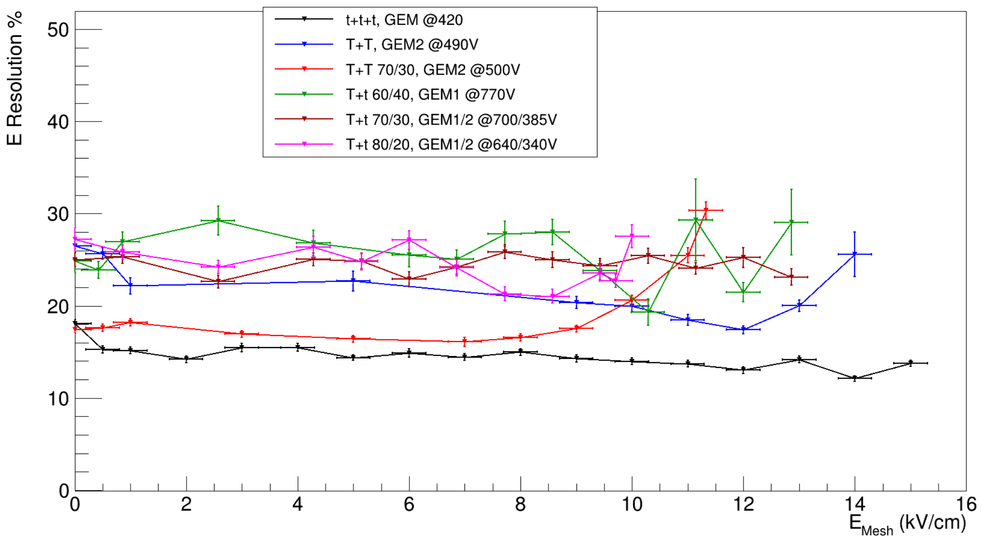




Setup in Portugal
R Roque




ITO on LEMOn
D. Pinci

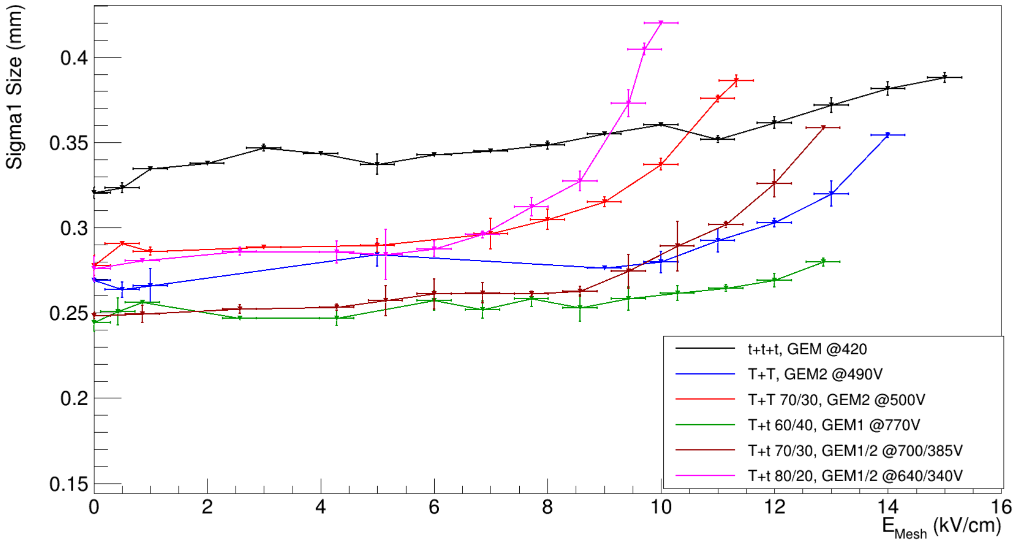
# Spot Size and Energy Resolution




Energy resolutions stays **pretty stable throughout** all the scan except for the T T configurations which diverges towards the end

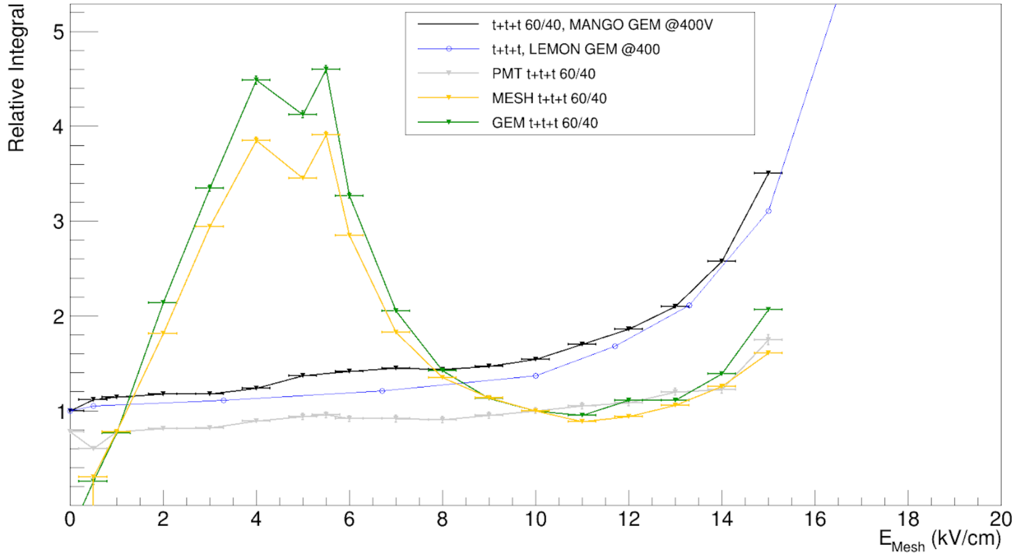
The spot dimensions seem to move along with the phenomenon.

The increase differs in each case, although never very dramatic

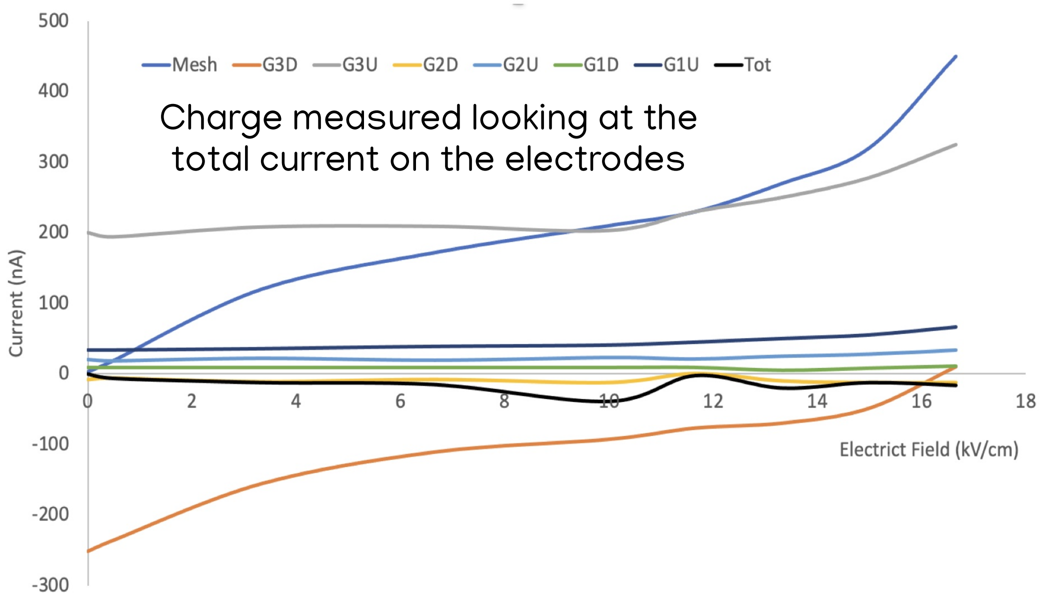


# Charge From The Camera

- This is an example of the typical behaviour of the charge and the light. There is an increase at higher intense electric fields, but lower than the light increase




Charge measured integrating the waveform of the signals



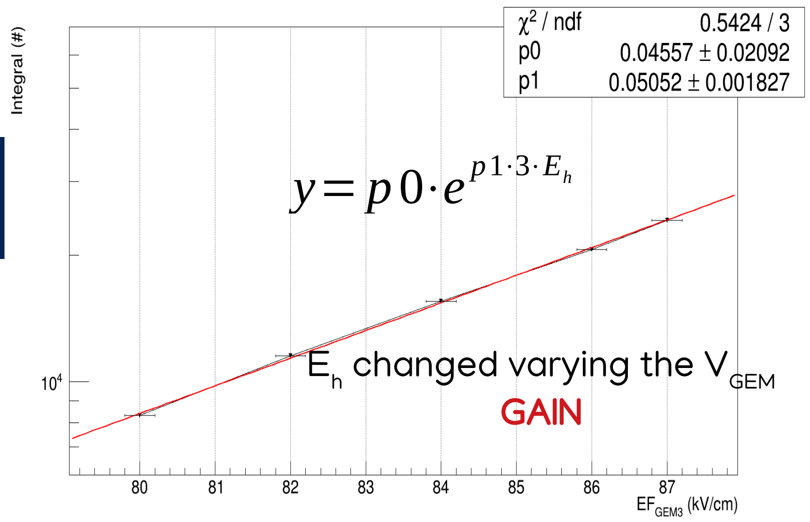

Charge measured looking at the total current on the electrodes

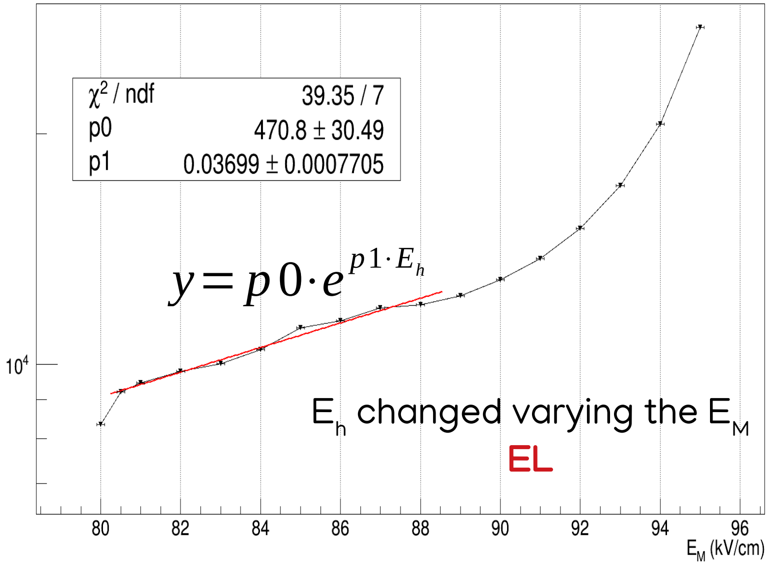
# EL Camera Light Threshold

- Are we increasing the EF in the hole by adding a field between GEM and Mesh?

Assuming

$$E_h = \frac{V_{GEM}}{50\mu m} + E_M$$



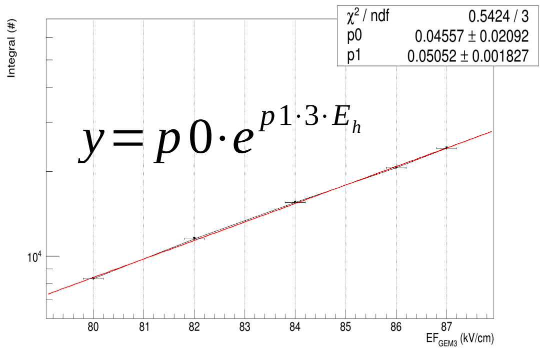



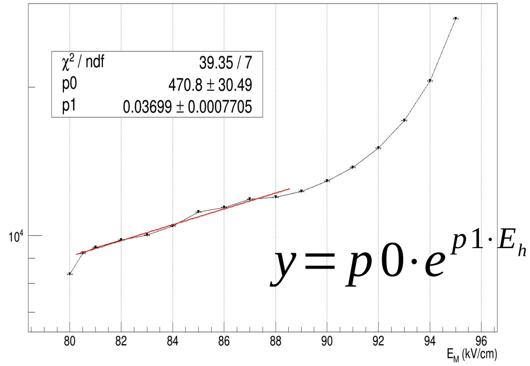
# EL CAMERA LIGHT THRESHOLD

- Are we increasing the EF in the hole by adding a field between GEM and Mesh?

Assuming

$$E_h = \frac{V_{GEM}}{50\mu m} + E_M$$

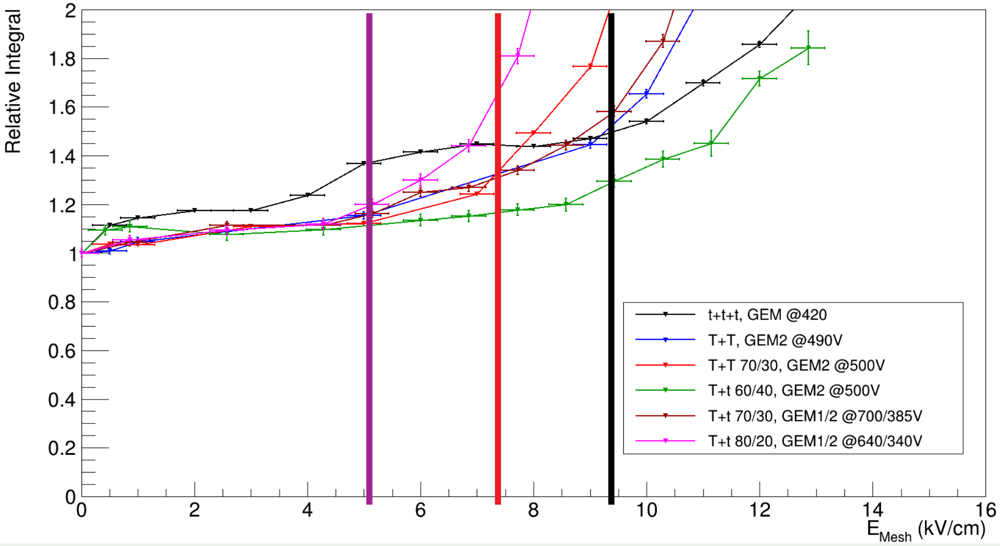



Similar behavior for all the setups and gas mixture

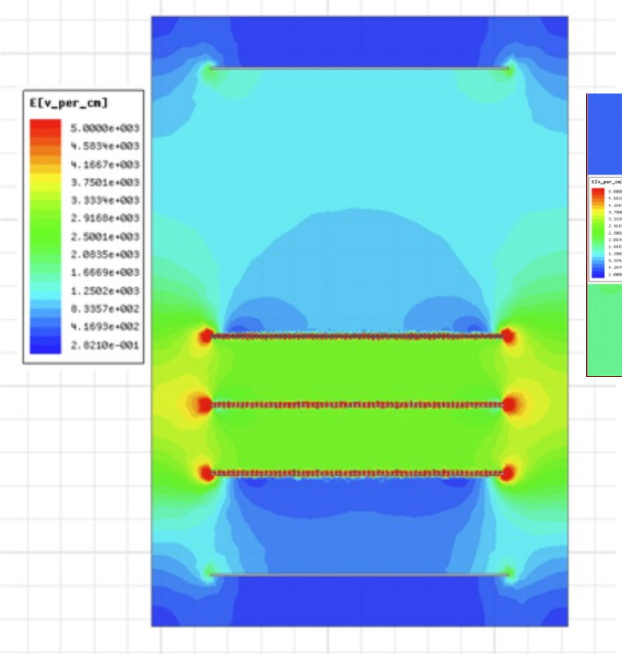
**Threshold** for the process:
Influenced by the the **gas mixture**

**Intensity of the increase:**
It seems it could depend a bit on the amplification stage, namely the last GEM used

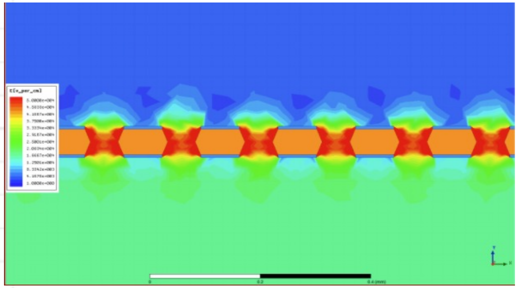


# Maxwell Simulation

- To better understand the phenomenon, David started a Maxwell simulation of the electric fields in MANGO focusing on the last GEM to the induction field



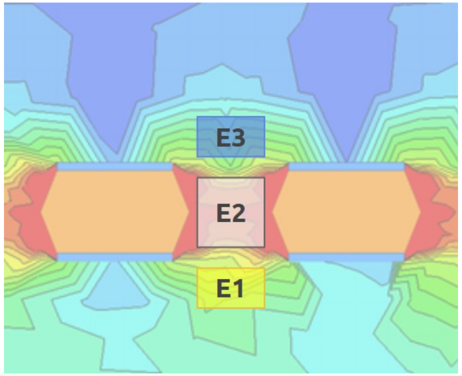

EF in the induction gap very constant when on (here it is off)



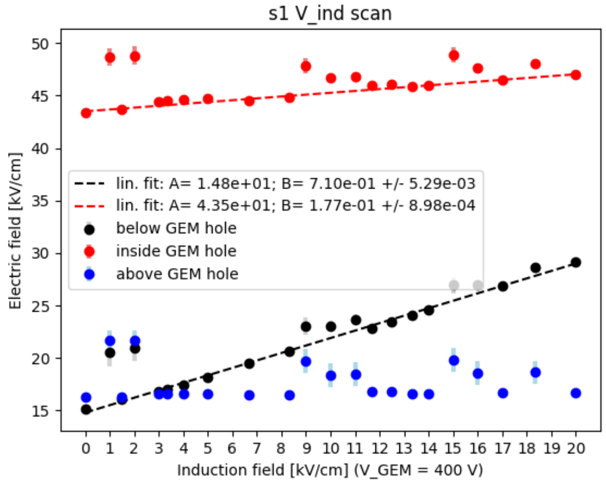
To perform a quantitative study 3 regions were defined:

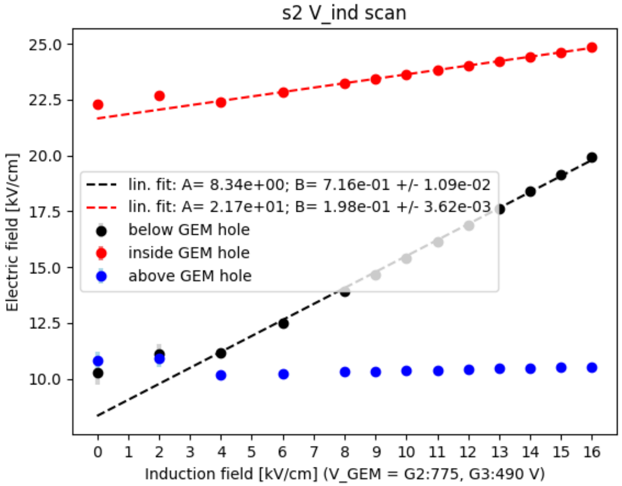
- E1: just below the GEM hole
- E2: inside the GEM hole
- E3: just above the GEM hole

In the region the field is averaged and then the mean value of 10 different holes is taken

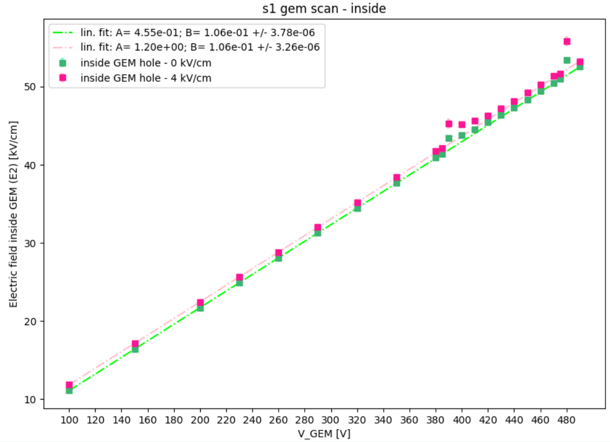


# Induction and Gem volt Scan

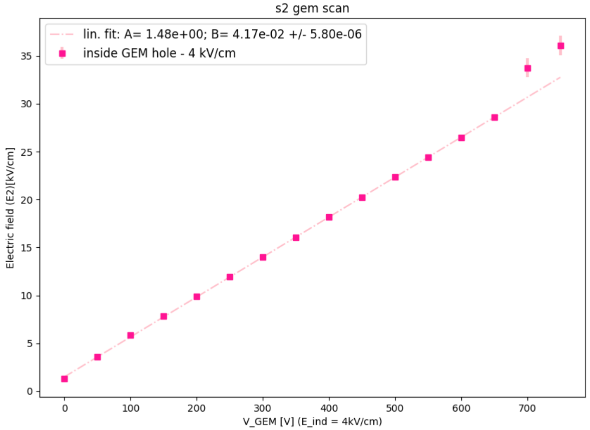



ttt



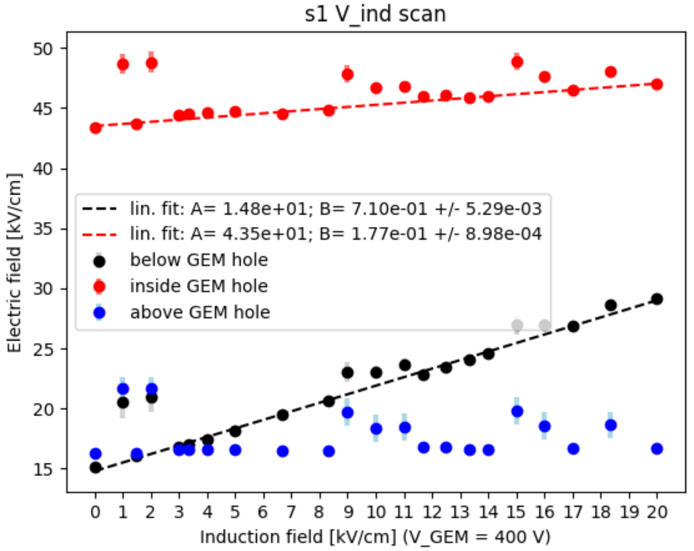

TT



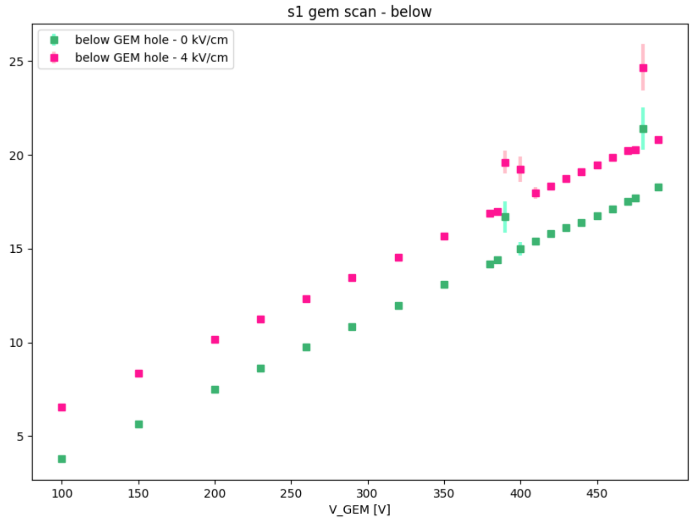

- In both configurations the electric field **above** the GEM seems unefected → **no transparency effect to enhnace the light output**
- The field **inside** the GEM is indeed increased linearly with the induction field. The intensity is comparable a variation of less than 10 Volts on the GEM → **too low to explain such an increase in light output**
- The filed **below** the GEM **increases** linearly as one could expect
- **The values reached by the field below the GEM become quite high up to raise the suspicion of a possible amplification**

# Electric Field Below the GEM

- Could this field below the GEM explain the light production?




ttt

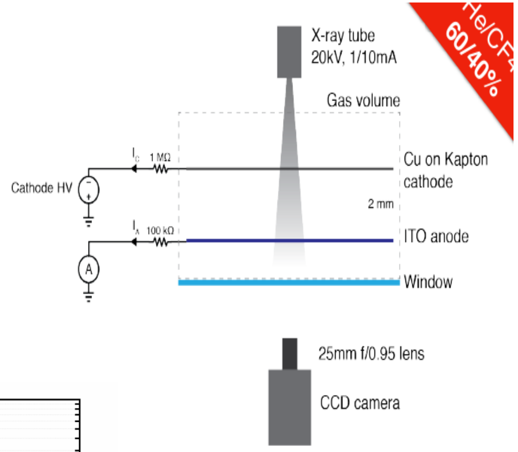


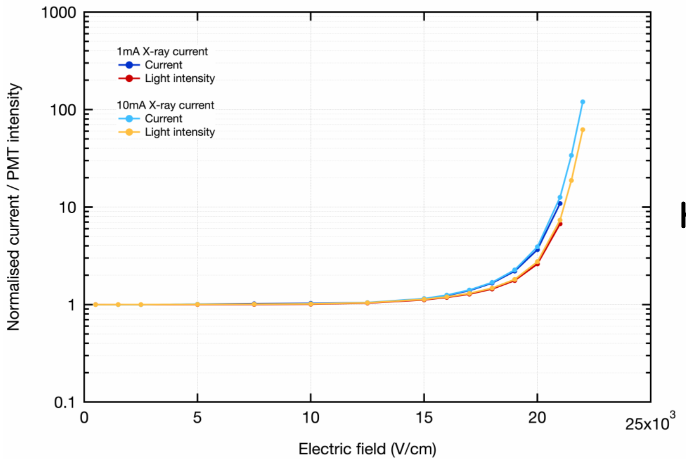

The field grows when increasing the voltage across the GEM, but less than with the induction field

**Garfield++ simulation could give insights on the the relevance of this field**

# Comparing with Florian

- Florian BrunBauer at CERN is also trying to replicate the effect with a different setup
  - No GEM used just parallel plate
  - X-ray tube used for the signal generation
  - CCD used as optical sensor

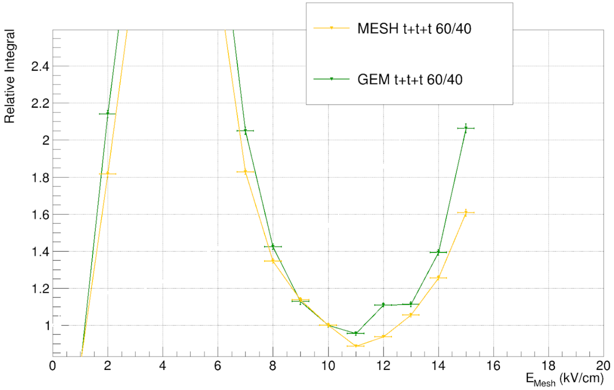


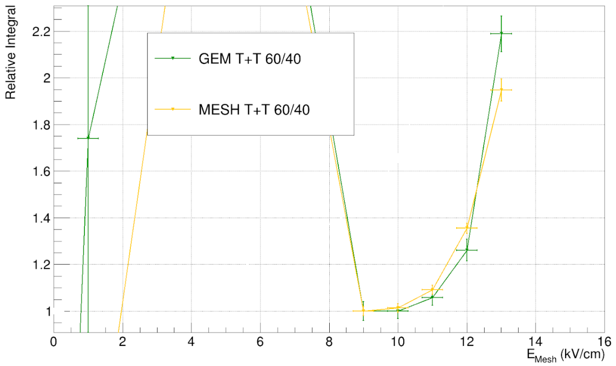



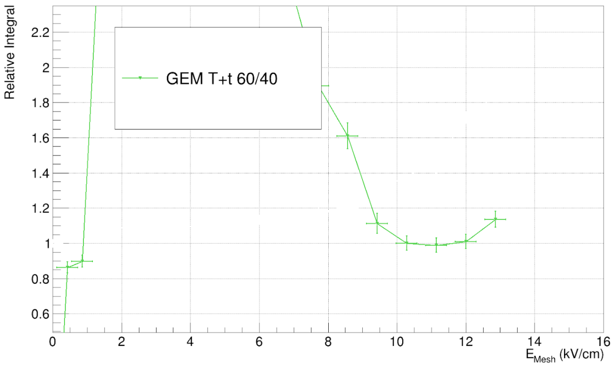

He does not see any light excess

# Charge Measurements

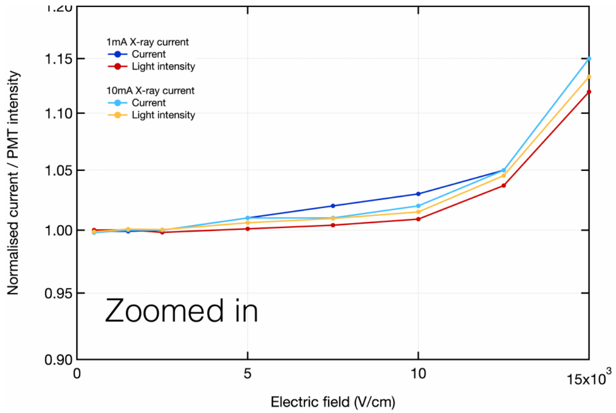
- Our most critical measurements are the charge ones  (we do not use preamplifiers, very noisy waveforms and after an RC filter), but they seem to match theirs



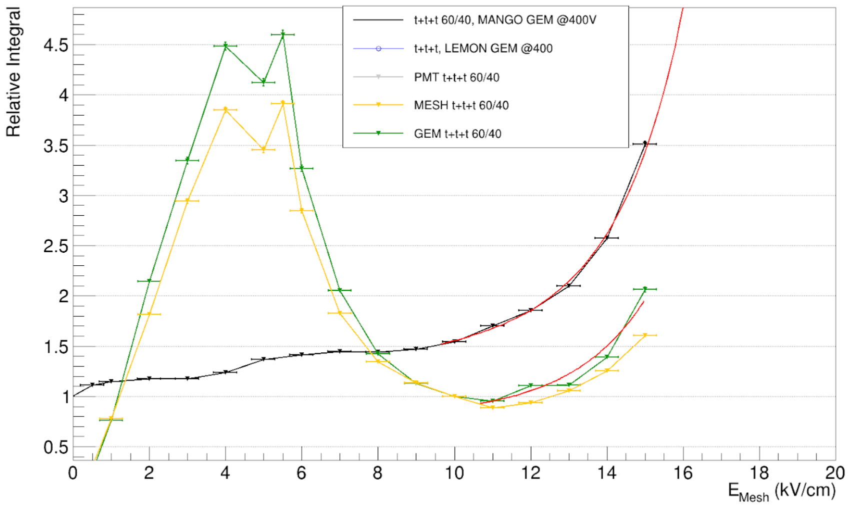

He says they overestimate the field of ~20% so 15–> 12/13 kV/cm

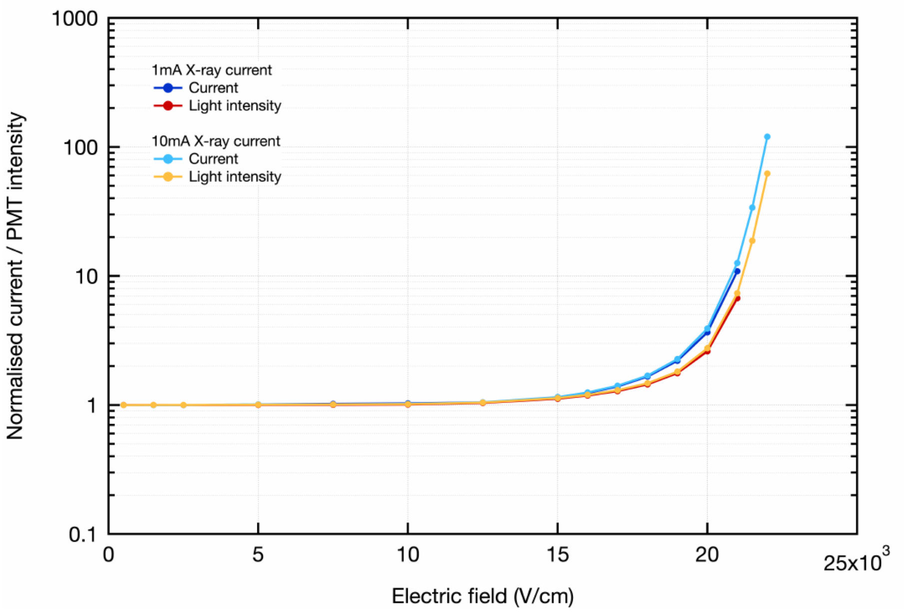



**At those fields we both see around 15/20% more charge**

# Light Measurements

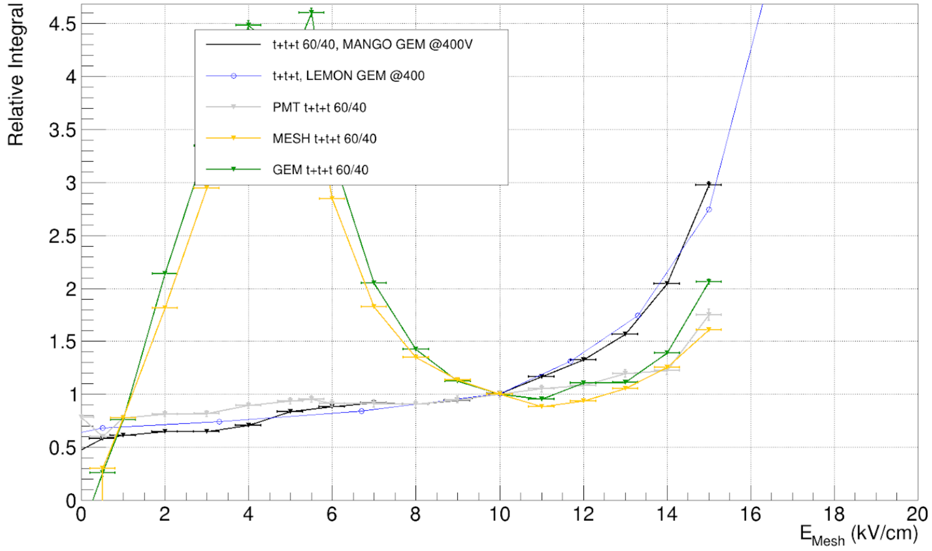
- Differently though we consistently see more light than him

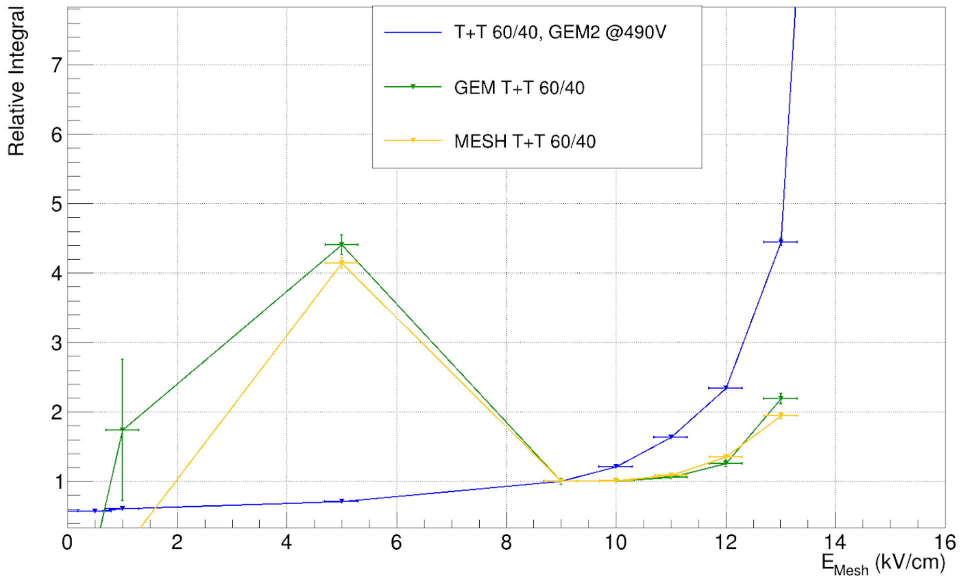


# Light Measurements Renormalized

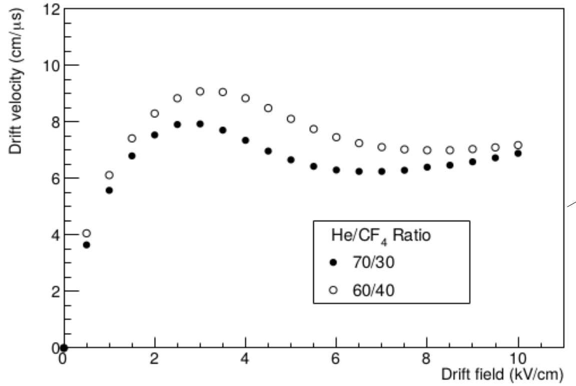
- Normalizing the light output to 10 kV/cm and eliminating the light output raise supposely given by the GEM, the light still is more than the charge



# PMT Measurement

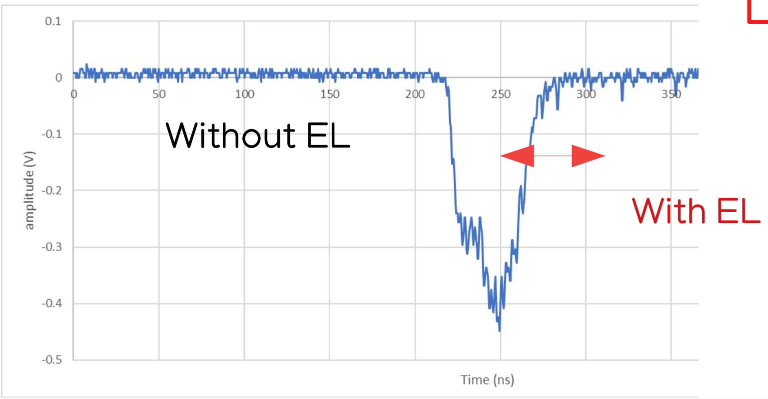
- Could the PMT solve any doubt?




To cross the induction gap of 3 mm, the electrons should take around 30–40 ns

With the EL that we suppose, the emission of photons should take place through all the gap

The PMT signal should convolve with a continuos emission along 40 ns



# Conclusion

- Different configurations of GEM stacks were characterized in order to optimize GEM induced diffusion and light output
- Data to evaluate the effectiveness of the saturation correction were taken and to be analysed
- The electroluminescence phenomenon is still under study with data always suggesting an increase of the light yield
- Maxwell studies deepened our knowledge and suggested us where to look
- Garfield simulation data could help to finally put aside any doubt

# Backup

# Voltages Used

- We looked for the working point of this configuration moving GEM voltages until we could see signal on the camera with a certain stability (based on the number of sparks)

| Config | GEM1 (V) | GEM2 (V) | GEM3 (V) |
|---|---|---|---|
| t+t+t 60/40 | 420 | 420 | 420 |
| T+T 60/40 | 775 | 500 | / |
| T+T 70/30 | 705 | 500 | / |
| T+T 80/20 | 620 | 440 | / |
| T+t 60/40 | 770 | 430 | / |
| T+t 70/30 | 700 | 385 | / |
| T+t 80/20 | 640 | 340 | / |

# Gain Scan

- On (14/07/21) Tom Thorpe presented at the gas meetings https://arxiv.org/abs/2106.15568

and showed that the gain process can be be written as afunction of these variables

Average reduced field

$$\Sigma = \frac{V_G}{n_g\,pt}$$

Reduced Townsend coefficient

$$\Gamma = \frac{\ln(G)}{n_g\,pt}$$

Number of GEMs

Pressure

Thickness of GEM

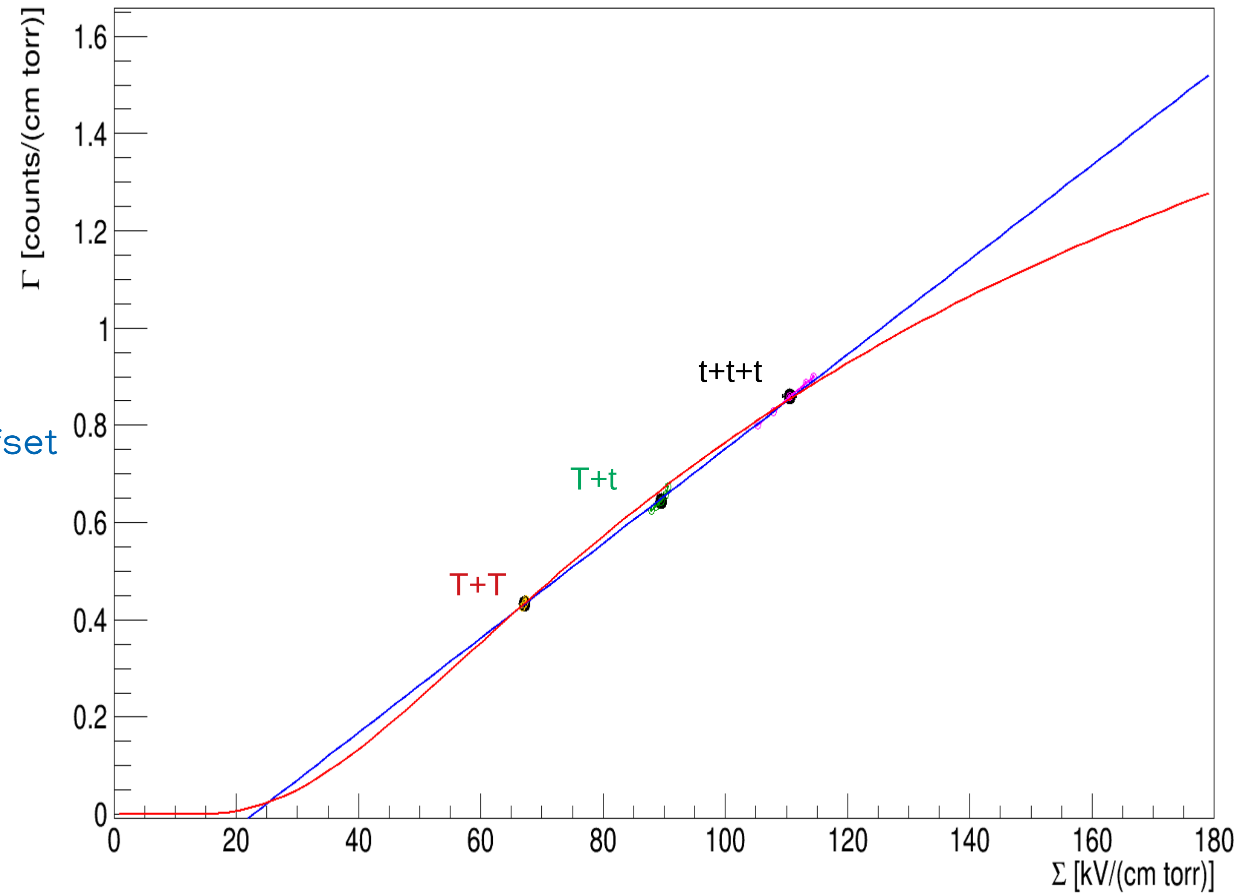
# Gain Scan

- The results on our data for 60/40 (not using yet the actual gain but soon I will correct it)

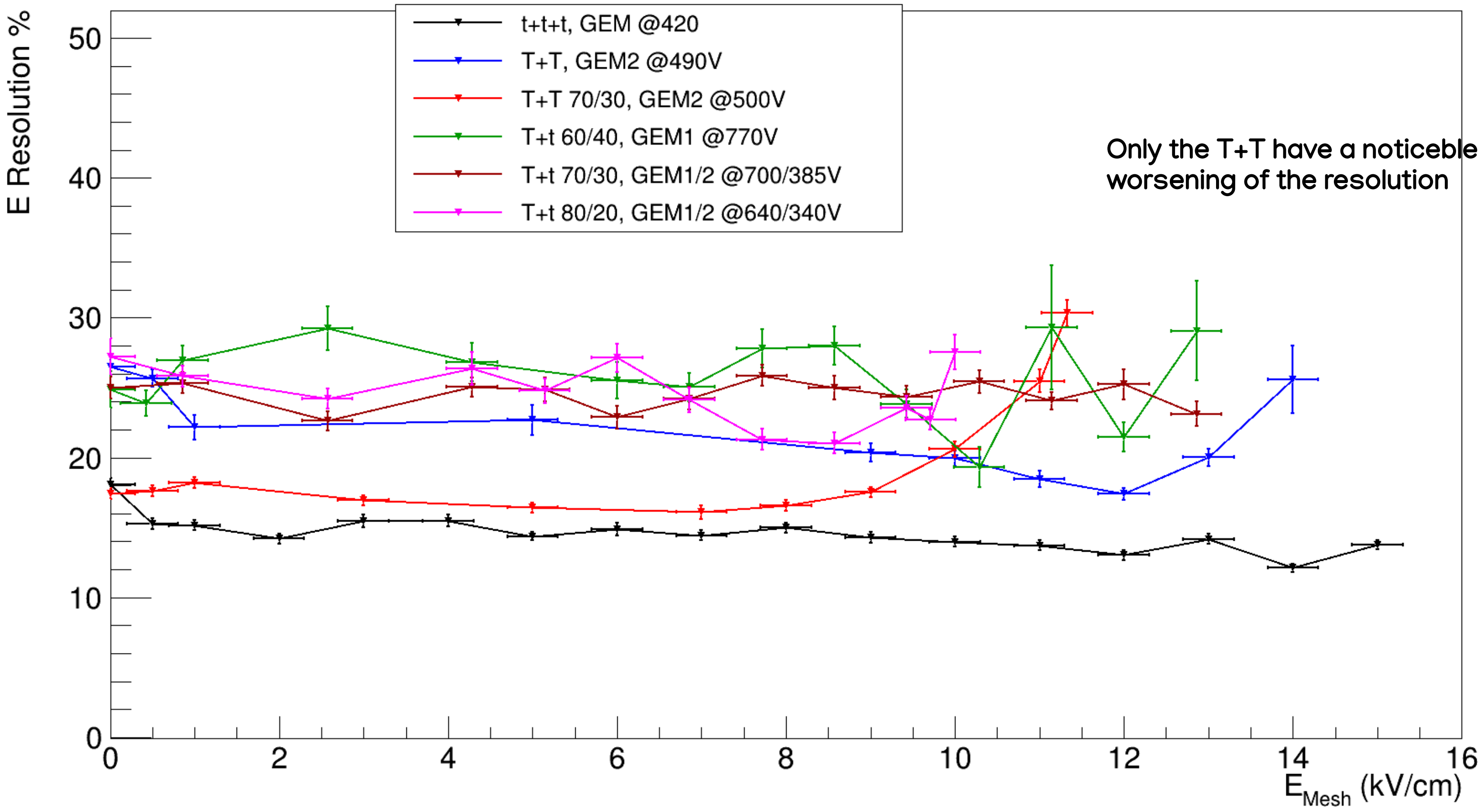
$$\Gamma = A\Sigma^m e^{-B\Sigma^{m-1}}$$ 0<m<1

$$\Gamma = a_1\Sigma + a_2$$ m=1 and voltage offset

$$\Gamma = A' e^{\frac{-B}{\Sigma}}$$ m=0

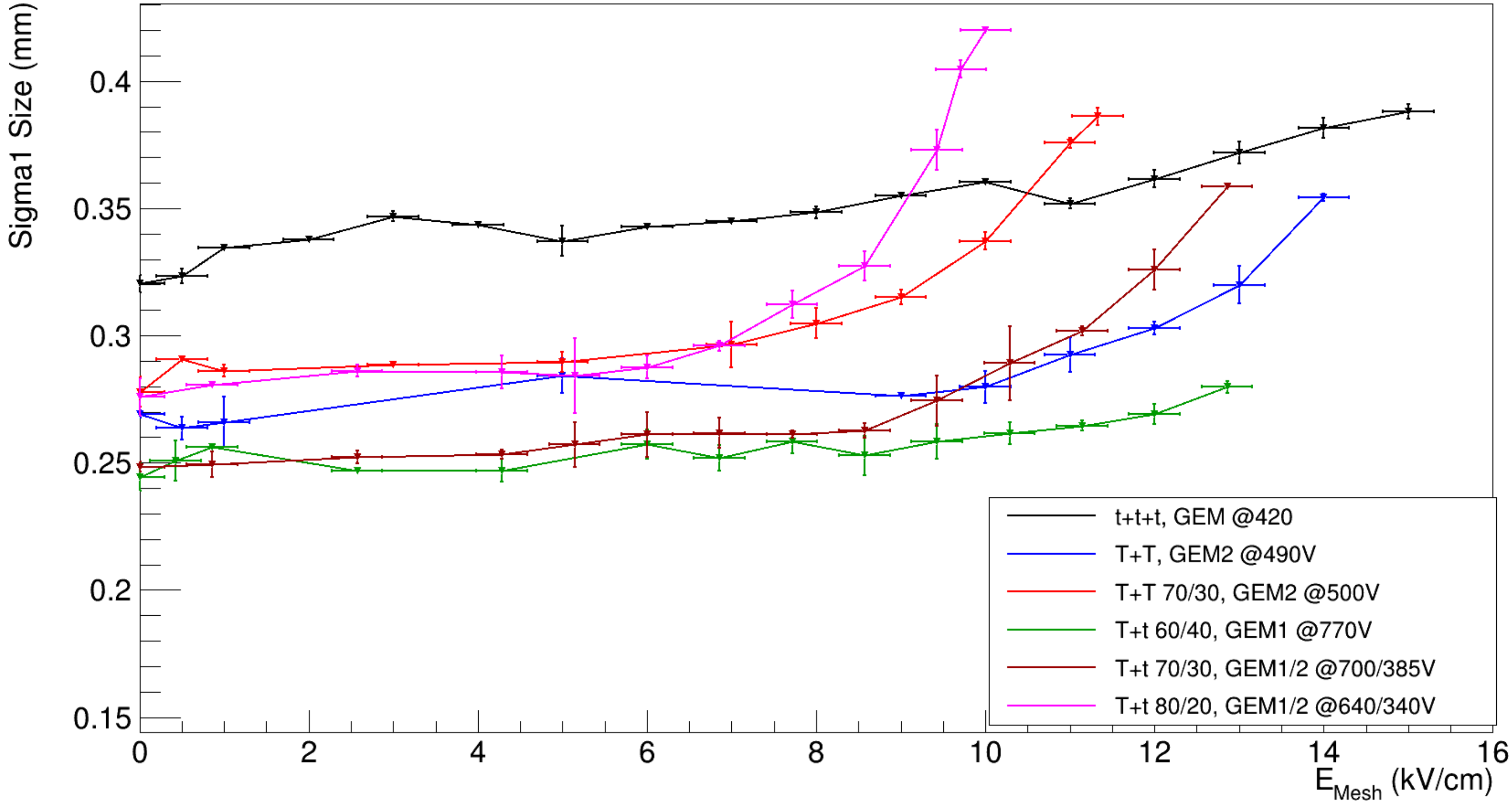


# EL Energy Resolution




Only the T+T have a noticeble worsening of the resolution

# EL Size



Sigma1 Size (mm)
0.4
0.35
0.3
0.25
0.2
0.15
0
2
4
6
8
10
12
14
16
$E_{Mesh}$ (kV/cm)
t+t+t, GEM @420
T+T, GEM2 @490V
T+T 70/30, GEM2 @500V
T+t 60/40, GEM1 @770V
T+t 70/30, GEM1/2 @700/385V
T+t 80/20, GEM1/2 @640/340V

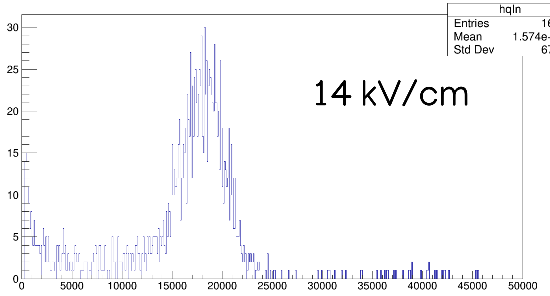
# Light from the camera

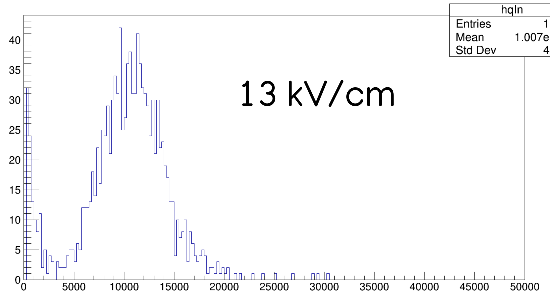
- Looking at the signal distribution at the highest electric fields the thick ones seem to behave differently

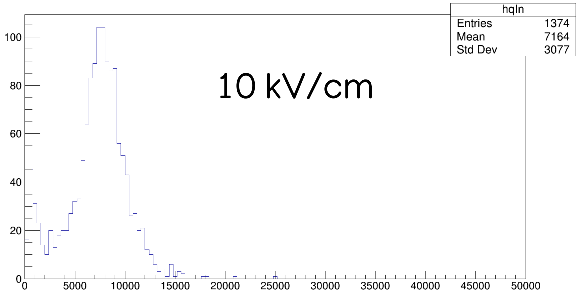
t + t + t (60/40)

T + T (60/40)

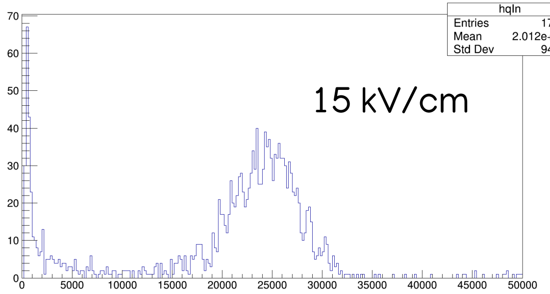
T + T (70/30)

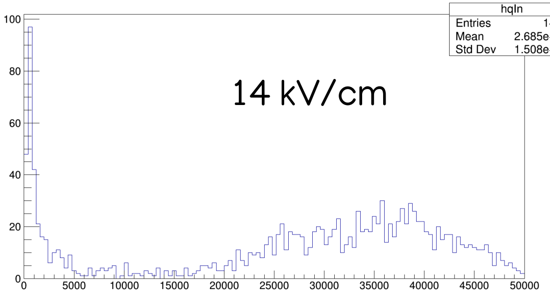


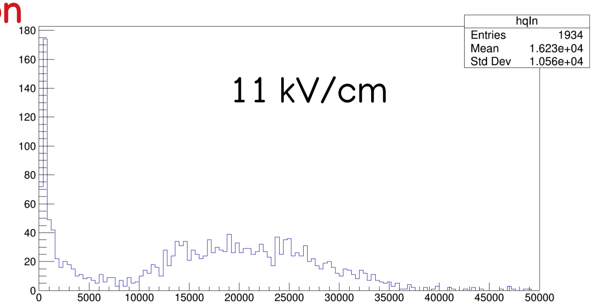




Strong degradation of resolution



# Light from the camera

- Looking at the signal distribution at the highest electric fields the thick ones seem to behave differently