Saturation Improvements with ELY

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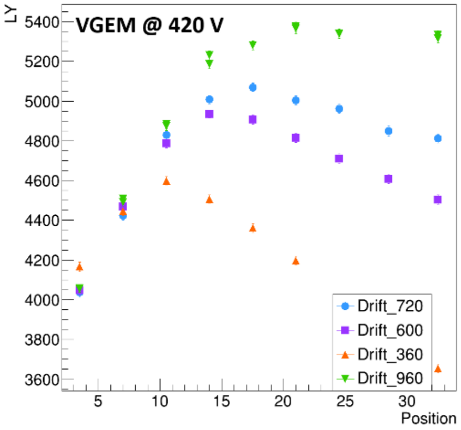
Saturation

- We know we saturate with regular LIME operation of GEMs
- Best solution up to now: lower the GEM voltage and drift field
  - → Increased diffusion -> loss of tracking capability
  - → Light yield decrease-> 60% less (factor 2.5 less)

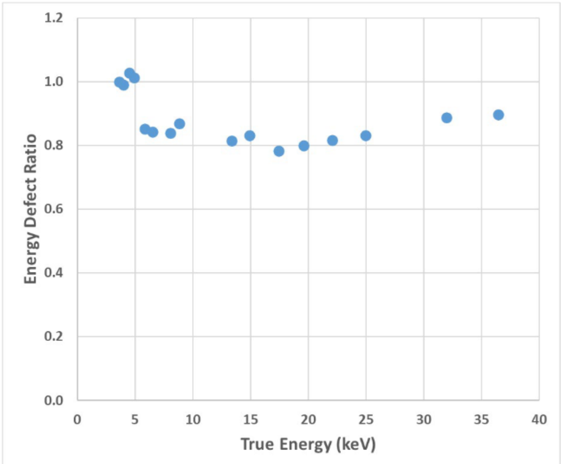
- How to know we have saturation?

Look at the light vs distance from the GEM of a fixed energy source



Easiest to notice saturation,
Closely related to the phenomenon of charge density
harder to measure it

Check with different sources until when your response is linear



Requires at least 3 radioactive sources,
Measures saturation

Scan in VGEM1

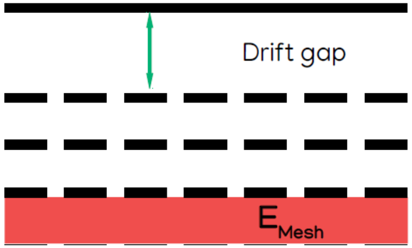
?

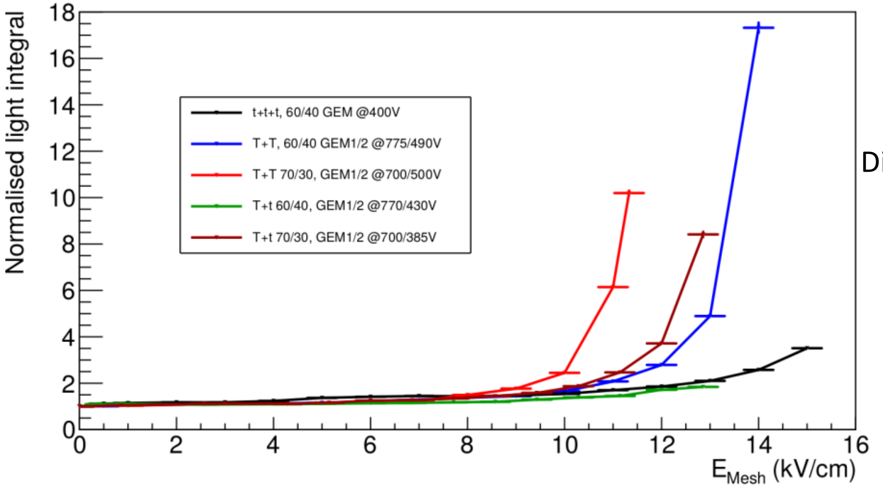
VGEM1 scan simulates larger energy deposits

Measures saturation relative to a fixed configuration

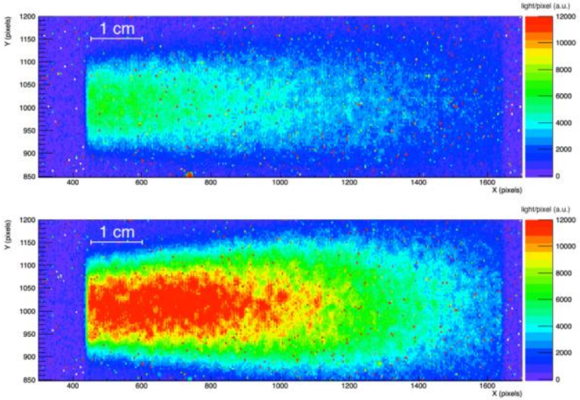
Studies with EL

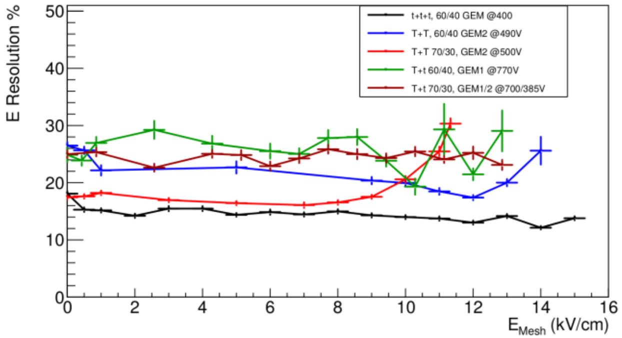
- From ELY studies we know we can enhance the light yield with a strong electric field below GEM3, without degrading energy resolution and diffusion

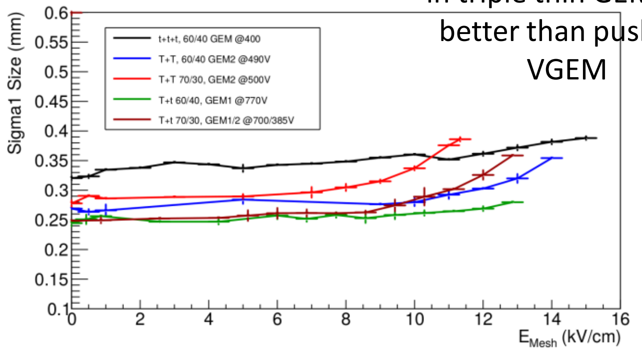




Different GEM stacks were used







Diffusion worsens but in triple thin GEM it is better than pushing VGEM

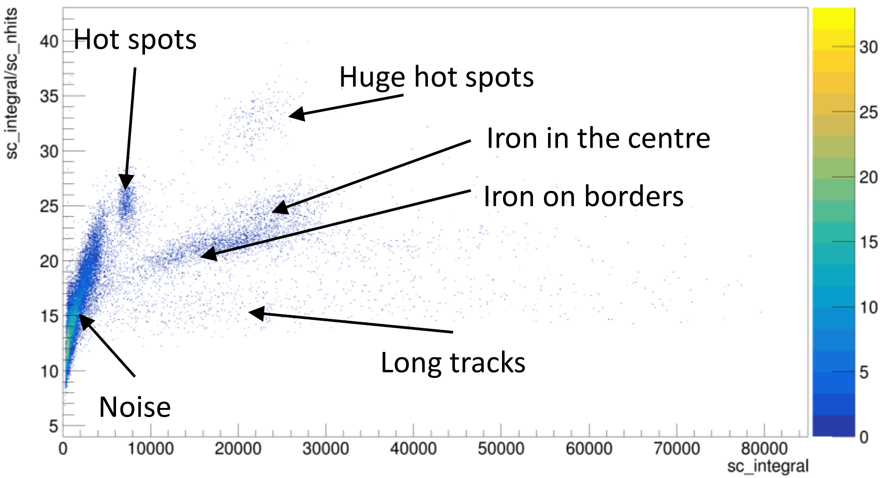
Scan VGEM1

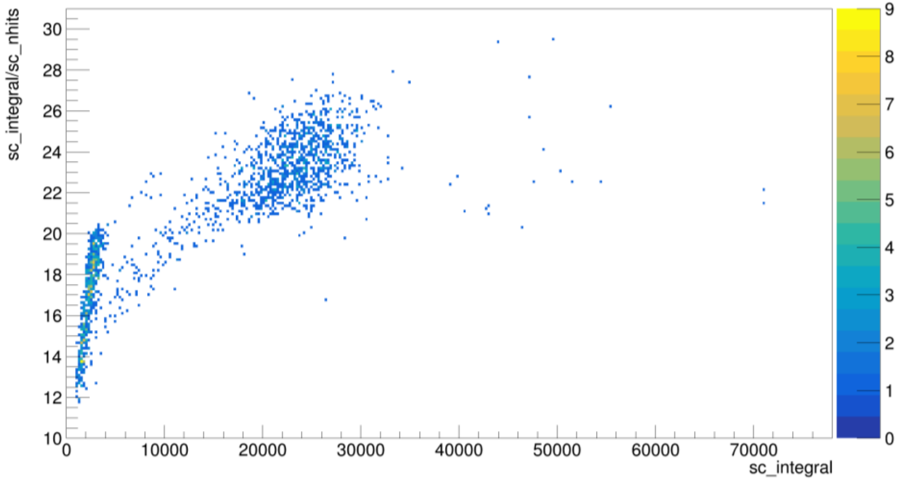
- The idea is to scan VGEM1 in different GEM and E_{ind} conditions and look at the total light yield and its relative increase (E_{drift} fixed at 1 kV/cm)
  - With GEM2 and GEM3 very high and no E_{ind}, we know we have saturation
  - With GEM2 and GEM3 very low and no E_{ind}, we do not expect to be saturated
  - A certain increase in light output due to more charge produced in GEM1 fakes a larger energy released in the gas (only for what concerns total light, not energy resolution)
  - The configuration with larger relative increase is the least saturated (hopefully non saturated)
  - The relative difference in light increase is an estimation of the saturation (if one believes that the standard configuration is not saturated)
  - Data taken with MANGO with <1cm drift (least diffusion in the gas possible)
  - LNGS overground pressure of about 900 mbar (LIME ~910 mbar, LNF ~990 mbar) (from MANGO to LNF ~ 20 V per thin GEM to have similar gain)

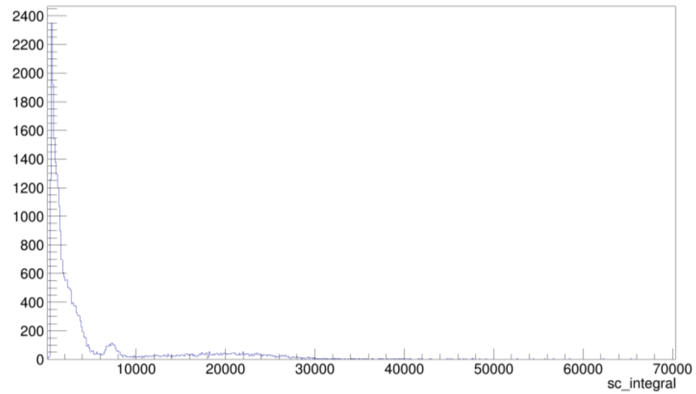
Data cuts

- GEMs had a lot of hot spots so cuts were needed.
- Cuts optimized looking at debug images

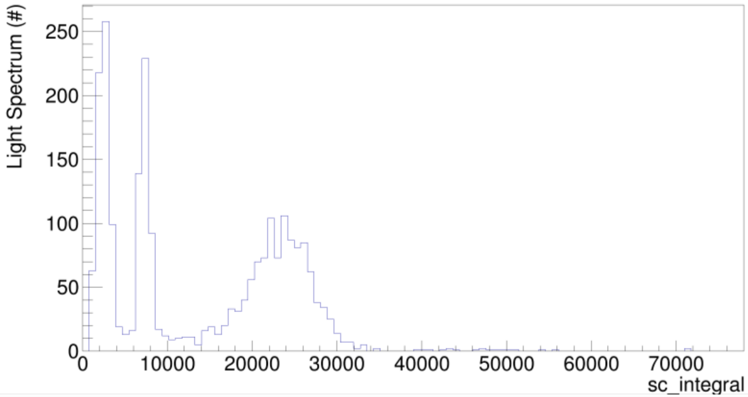
sc_integral<80000 && sc_integral/sc_nhits<40 && sc_width/sc_length>0.65 && sc_width>20 && sc_ymean>800 && sc_ymean<1600 && sc_xmean>800 && sc_xmean<1600 && sc_integral/sc_nhits<(22+0.00045*sc_integral)





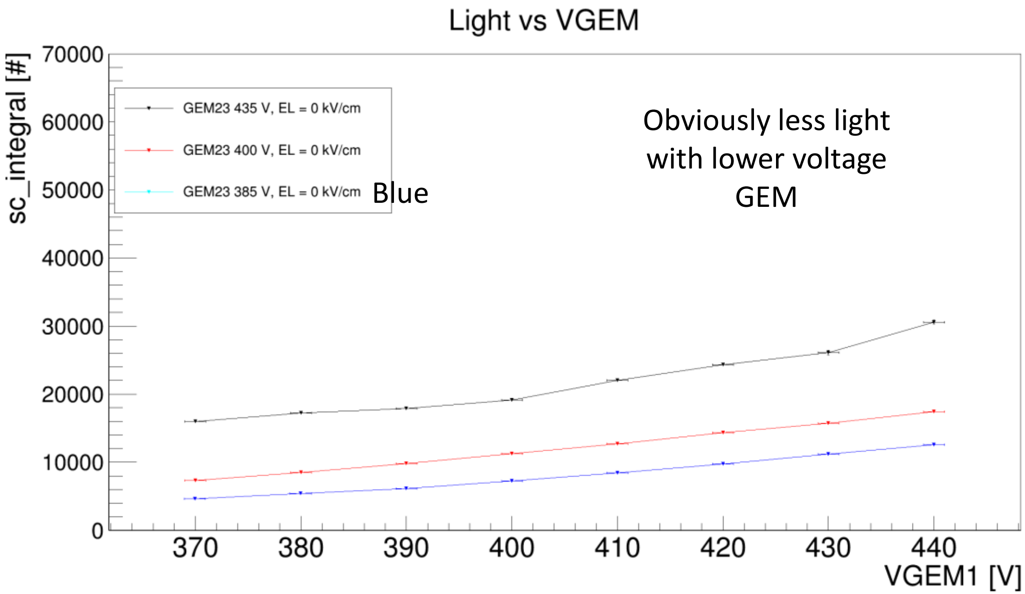


Cuts on slimness, density vs sc_integral, position

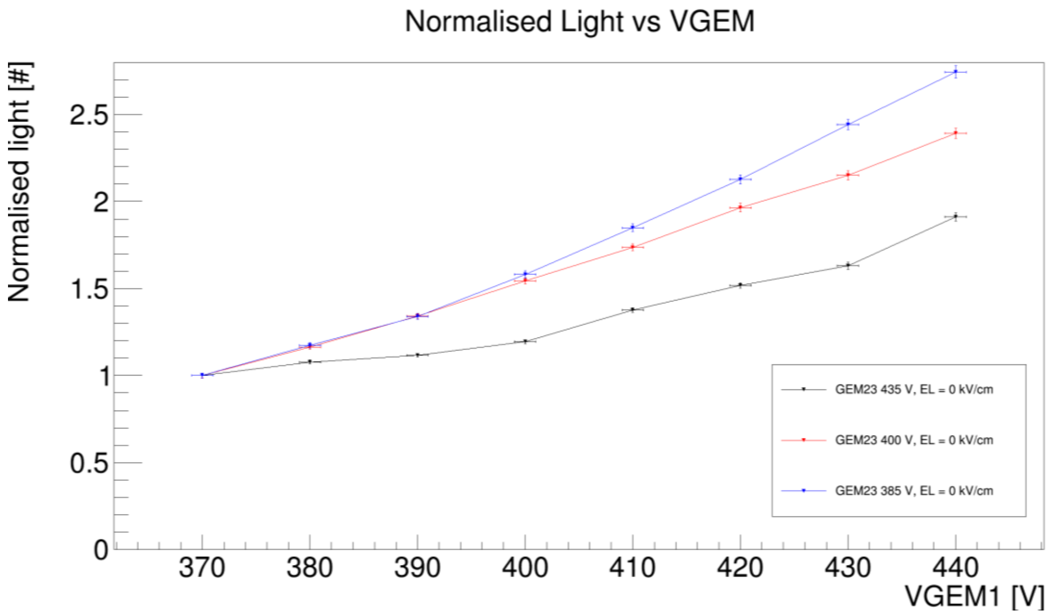


No EL_{ind} configurations

- When E_{ind} is not used, 3 VGEM configurations were tested



Obviously less light with lower voltage GEM

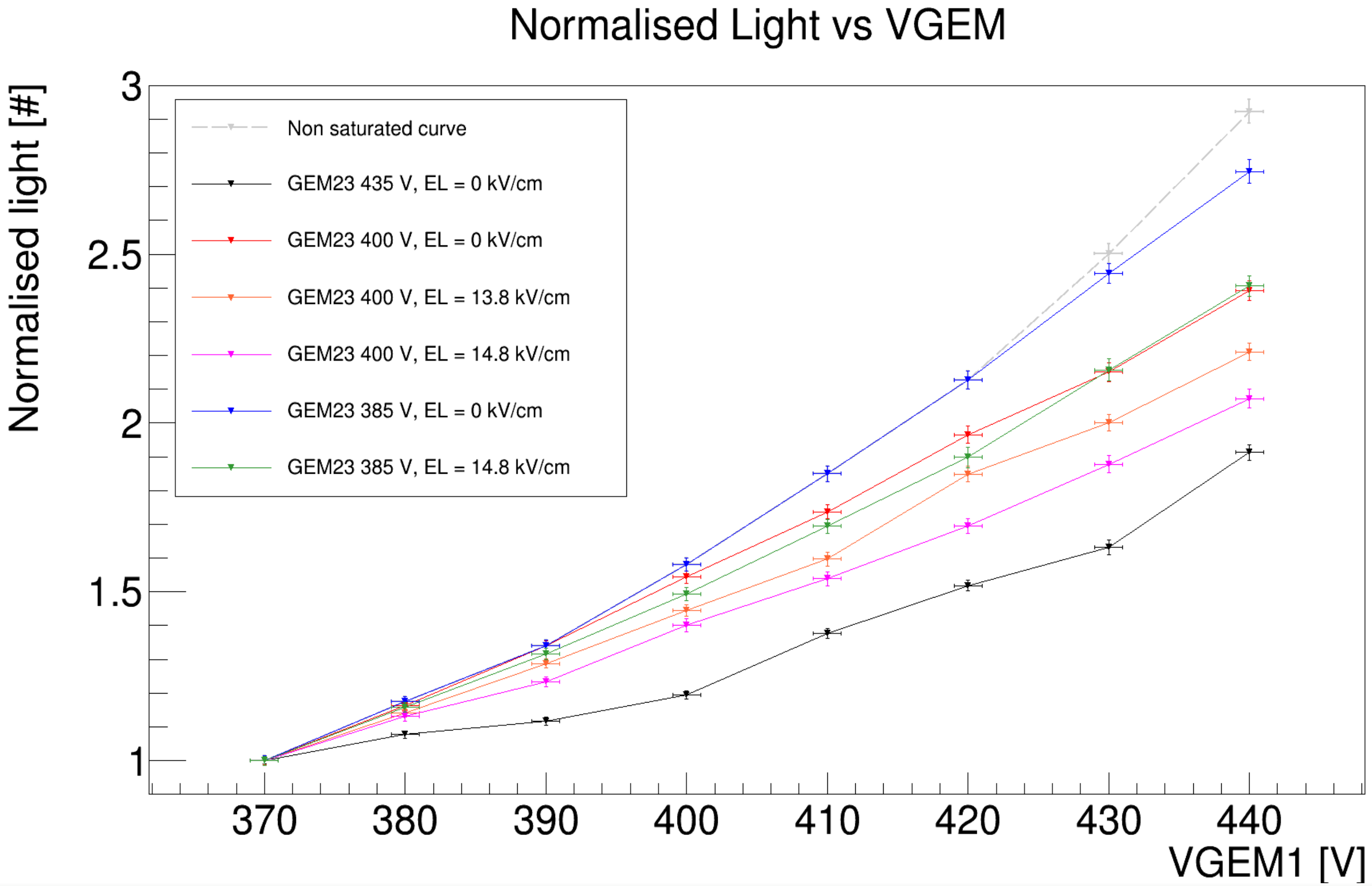


400-400-400 already saturated

430-435-435 very much saturated

EL_{ind} configurations

- When EL_{ind} is used, other 4 configurations were tested



EL_{ind} configurations

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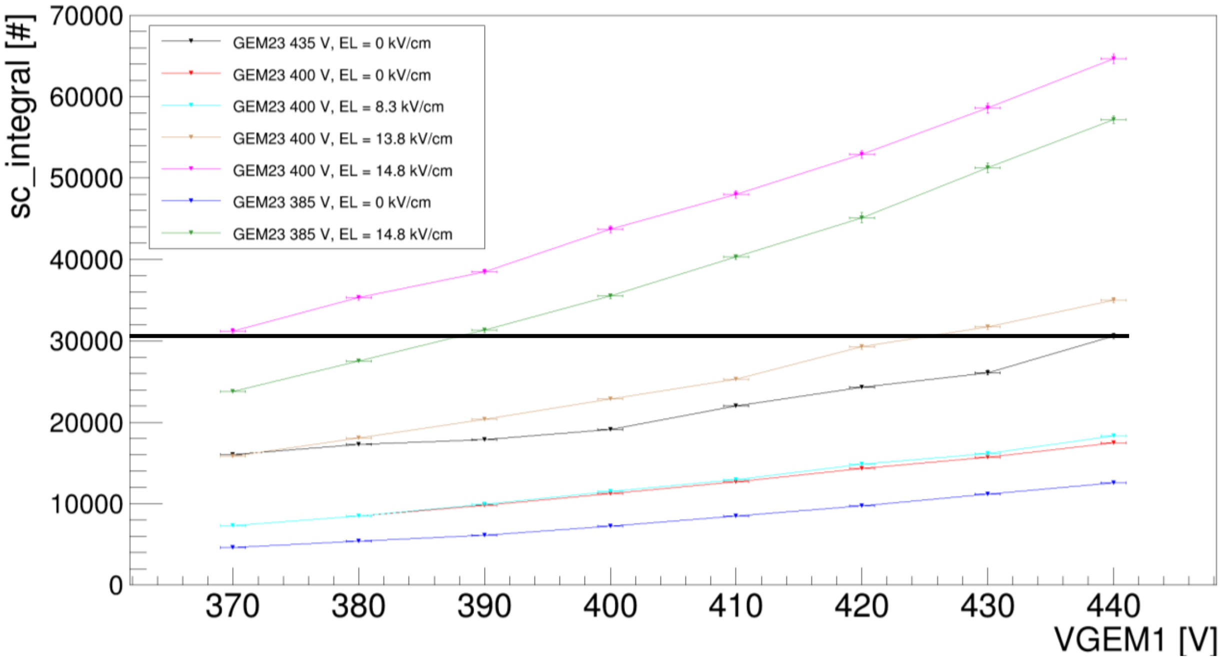
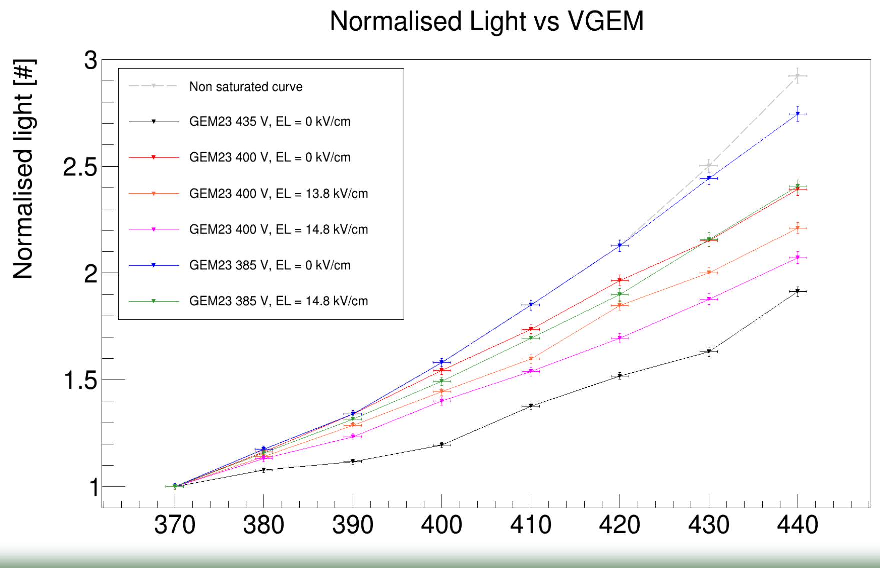
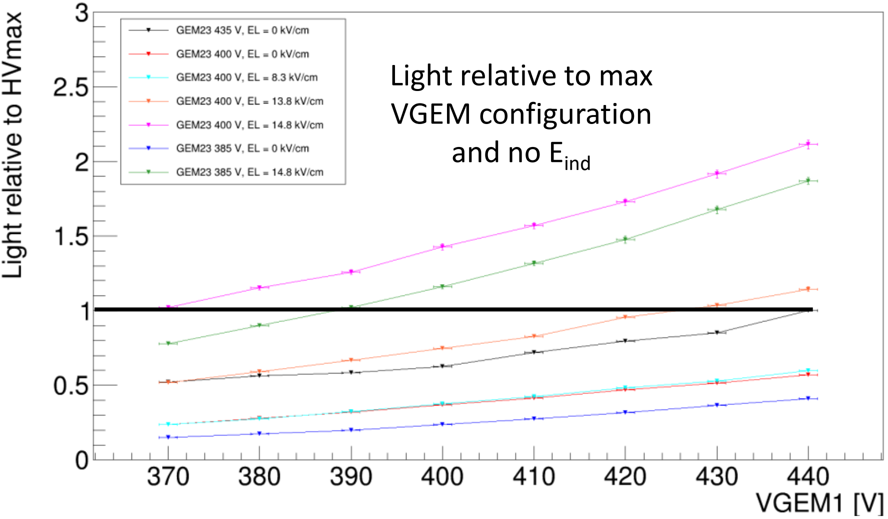
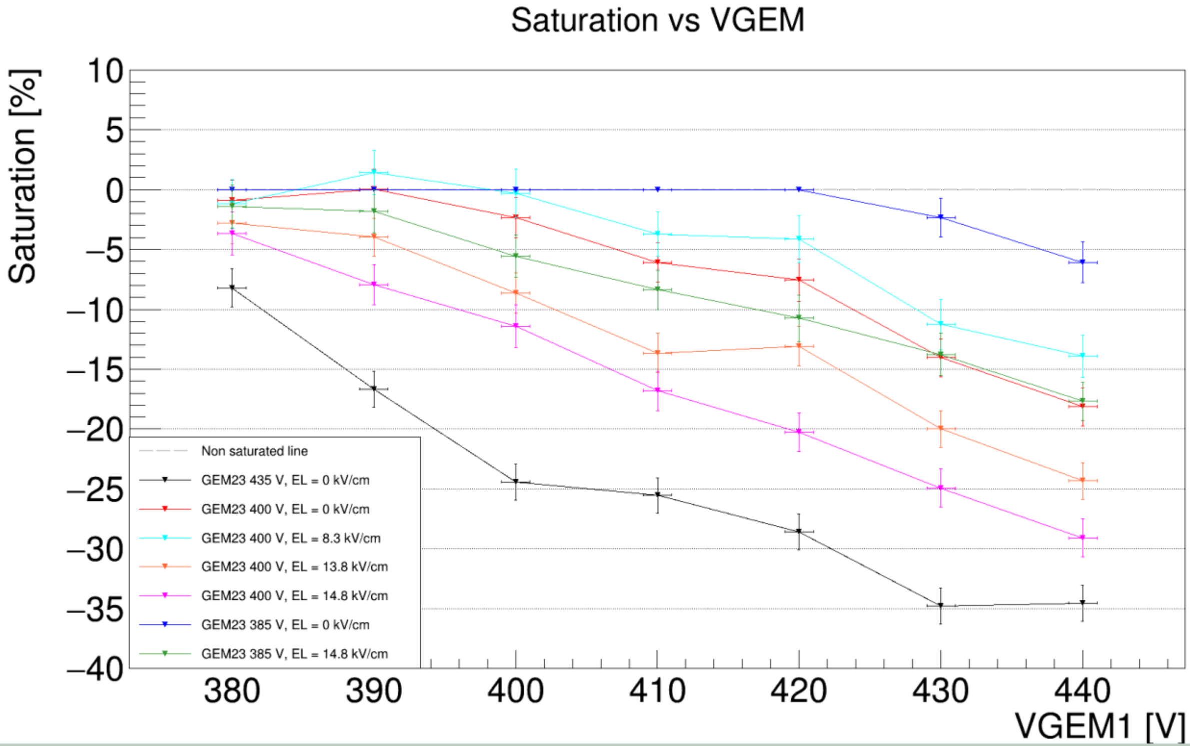




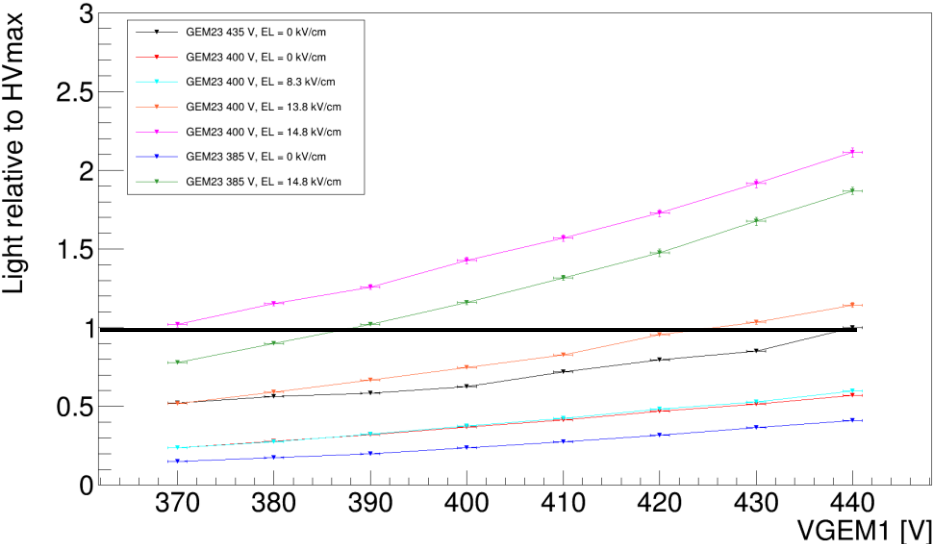
Saturation levels



Saturation estimated point by point as relative difference of the normalised increase in light with respect to the gray curve



Saturation levels

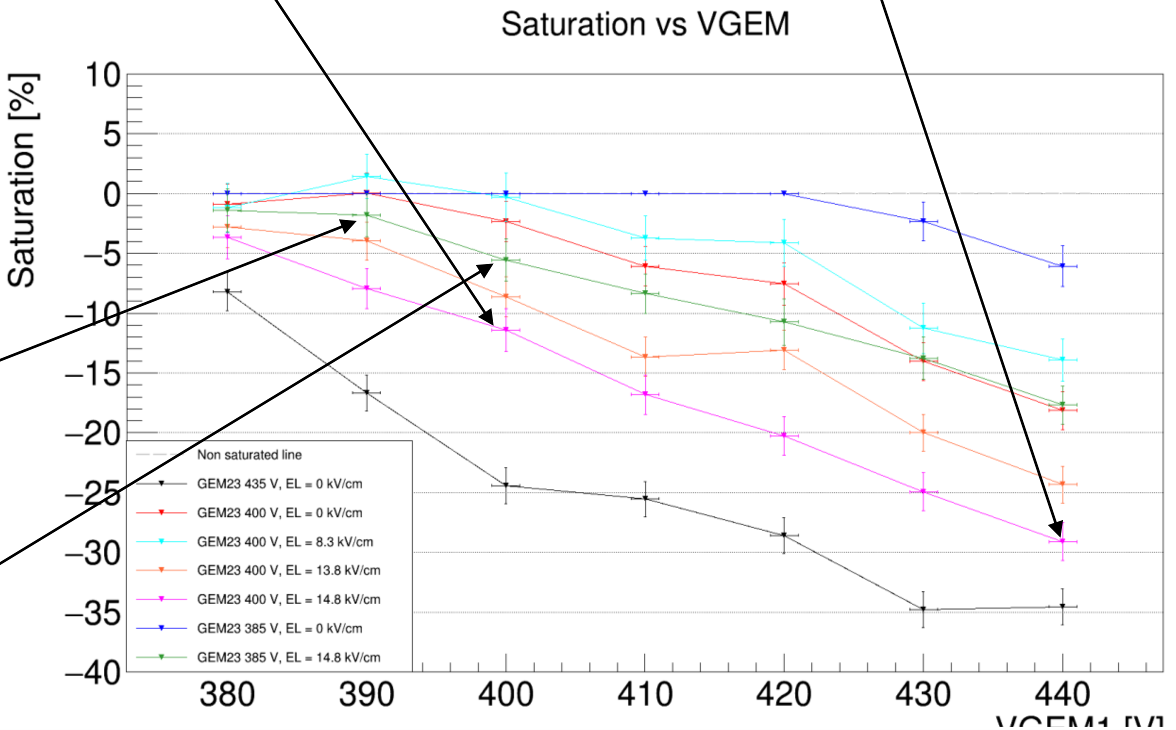


SetPoint1:

LY	1.43
Tgauss	1.06
Eres	14%
Satu	11%

SetPoint2:

LY	2.11
Tgauss	1.17
Eres	16%
Satu	29%



SetPoint3:

LY	1.03
Tgauss	0.98
Eres	16%
Satu	2%
Non sat at	5.1 keV

SetPoint4:

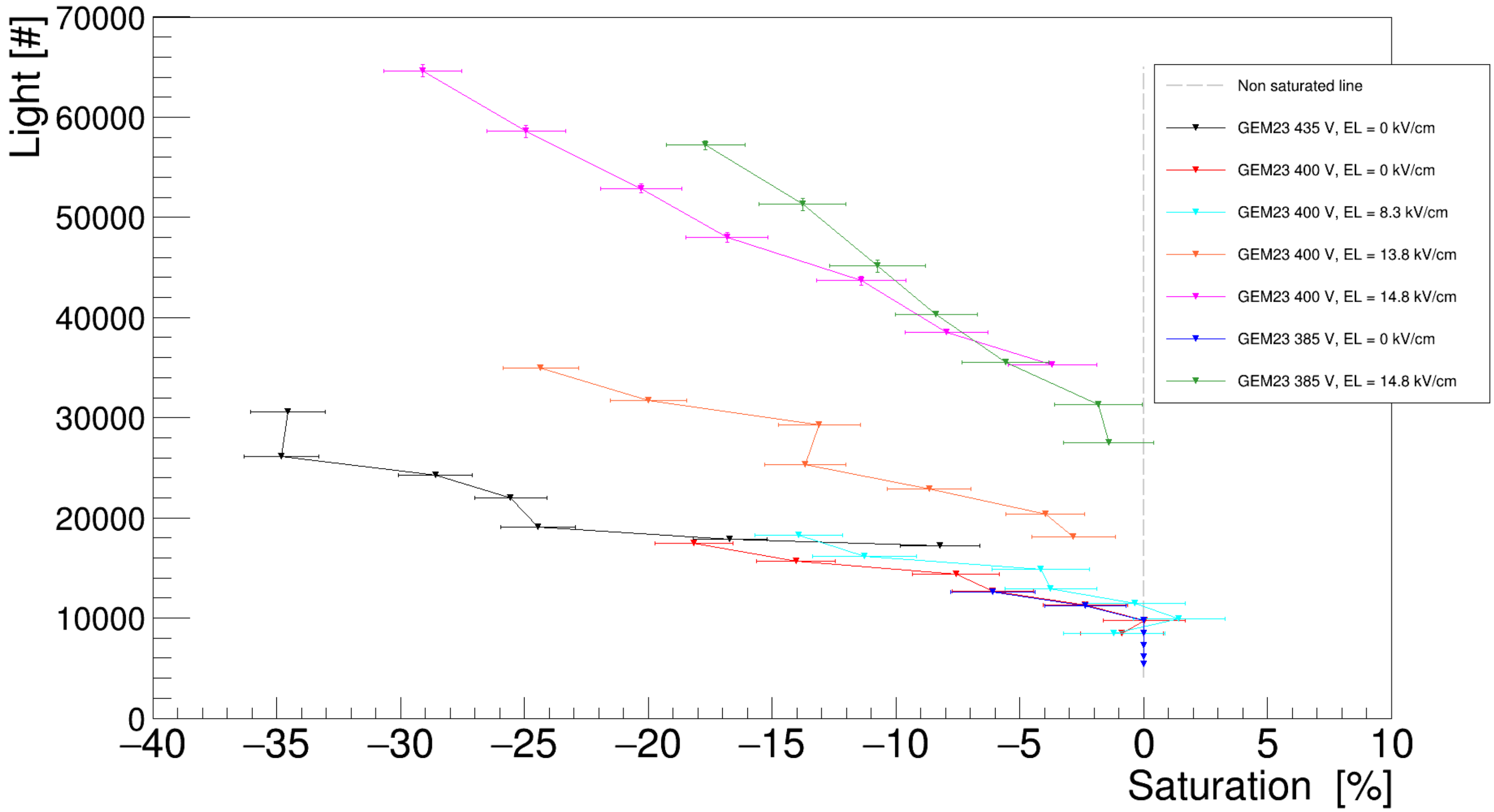
LY	1.16
Tgauss	1.01
Eres	15%
Satu	5.5%
Non sat at	4.6 keV

LY and Tgauss values estimated with respect to max VGEM point:

440-435-435-EL0:

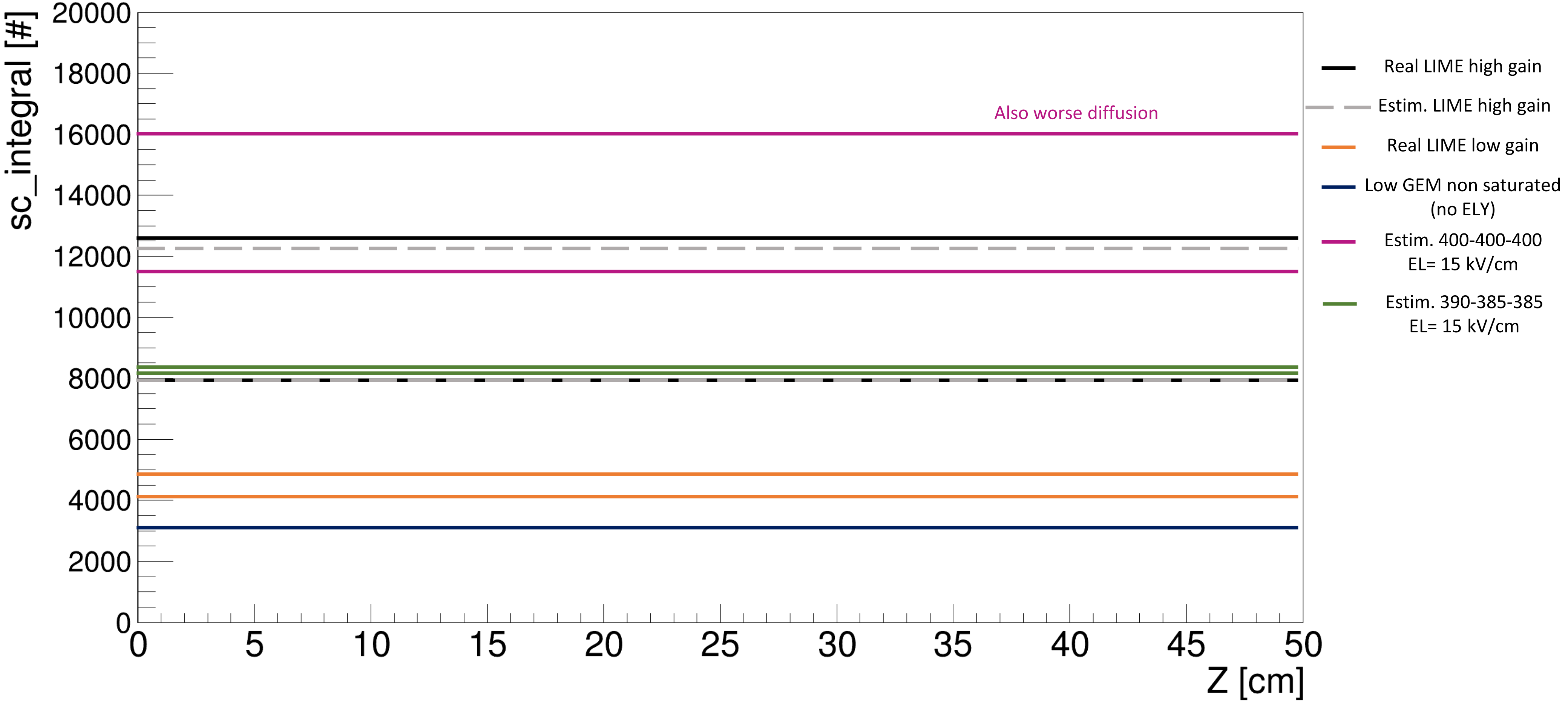
LY	30600
Tgauss	7.92
Eres	20%
Satu	34%
Non sat at	1.9 keV

Saturation vs light



Estimation of expected light yield vs Z

- Estimated (2 to 5% uncertainty) or real ranges of light yield expected in LIME with different configurations for ^{55}Fe



Caveat

- The saturation estimation is believable until we know the blue curve is not saturating.
  - Since the red and blue curve superimpose at low VGEM1, we can consider those points non saturated
  - The light yield at 390-400-400 (last point non saturated of red curve) is equivalent to the LY at 420-385-385.
  - The blue curve can be considered non saturated ntil 420 V of VGEM1
  - The gray curve can be estimated as the non-saturated starting from the blue and the red in the region where blue is not saturated and red is
- The LY ratios are referred to the 1 cm drift gap.
  - When the source is positioned farther away, LY is recovered (the more it was saturated the more it is recovered)
  - So the LY ratio are not meant as absolute value for all distances
  - It could be possible to estimate the ratio of LY of the different configurations at infinite distance
  - Unfortunately we cannot really model the dependence of saturation as a function of distance so this estimation would be a bit useless

Conclusions

- The amount of saturation can be studied with a scan in VGEM1
- Estimation made at the minimum distance from the GEM and at LNGS overground pressure
- Already 400 V on each GEM shows signs of saturation
- Using very low VGEM and E_{ind} it is possible to recover the light output of a 440 V for each VGEM, with extremely limited (if none saturation)
- This could be very useful for CYGNO-04 or CYGNO-30 and HypeX, but a better way to glue the ITO glass is required to grant long-term stability

    - I would like to present the ELY paper content with this additional info to MPGD 2024