Impact of a strong electric field below the GEM on light yield and saturation in a He:CF_4 based Time Projection Chamber

Giorgio Dho on behalf of CYGNO coll.

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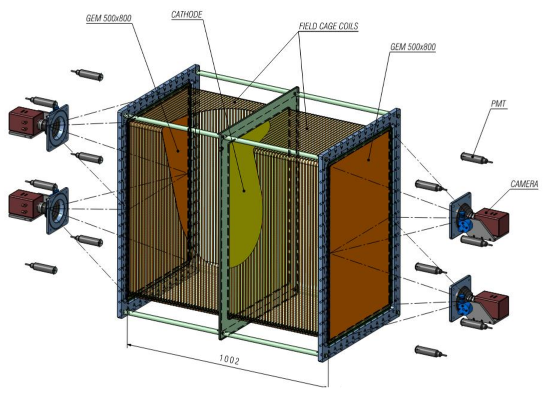
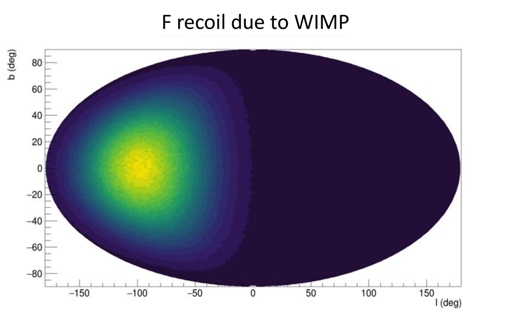
The Experiments

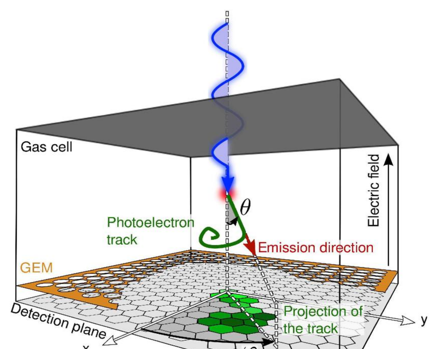


CYGNO experiment

Directional detector for rare event low energy searches, such as dark matter or Solar neutrinos

See D. Fiorina's presentation:" The CYGNO experiment, a Gaseous TPC for directional Dark Matter searches"



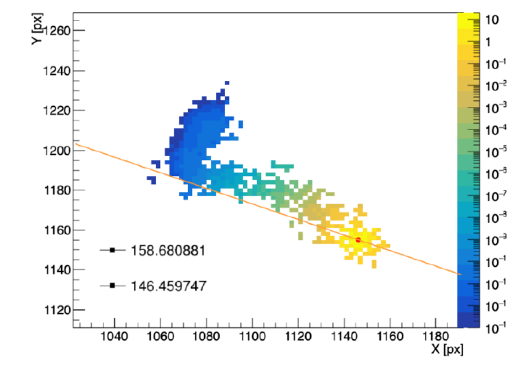


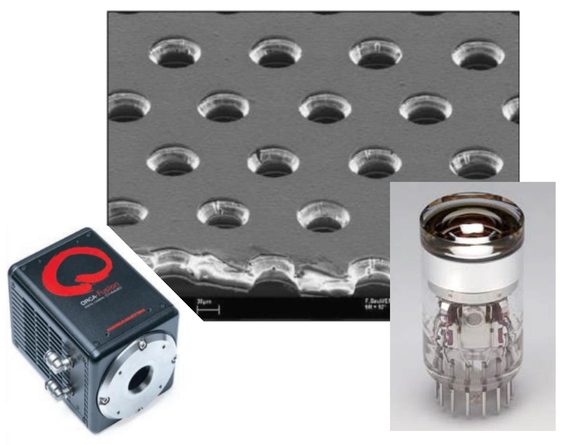
Muleri, Astrophysical Journal, 782 1(2014)

HypeX

Directional detector space measurements of X-ray polarization

See D. Fiorina's presentation:" Development and Preliminary Results of a Large-Volume Time Projection Chamber for X-ray Polarimetry"





Concept

Gaseous TPC with triple 50 μm-thick GEM amplification stage

He:CF_4 (60:40) mixture with scintillating properties

Optical readout made of PMTs and sCMOS camera for 3D reconstruction

Searching for nuclear and electron recoil (NR and ER) of >0.5 keV

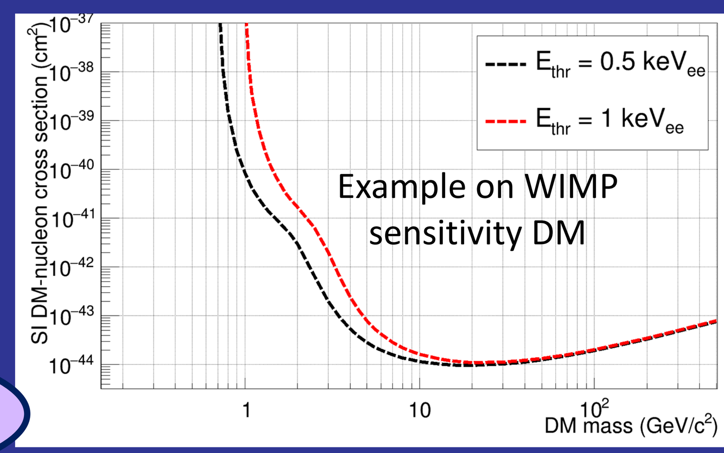
Why, What and How

WHY:

Low energy deposits
- ER track beginning
  - NR of few keV

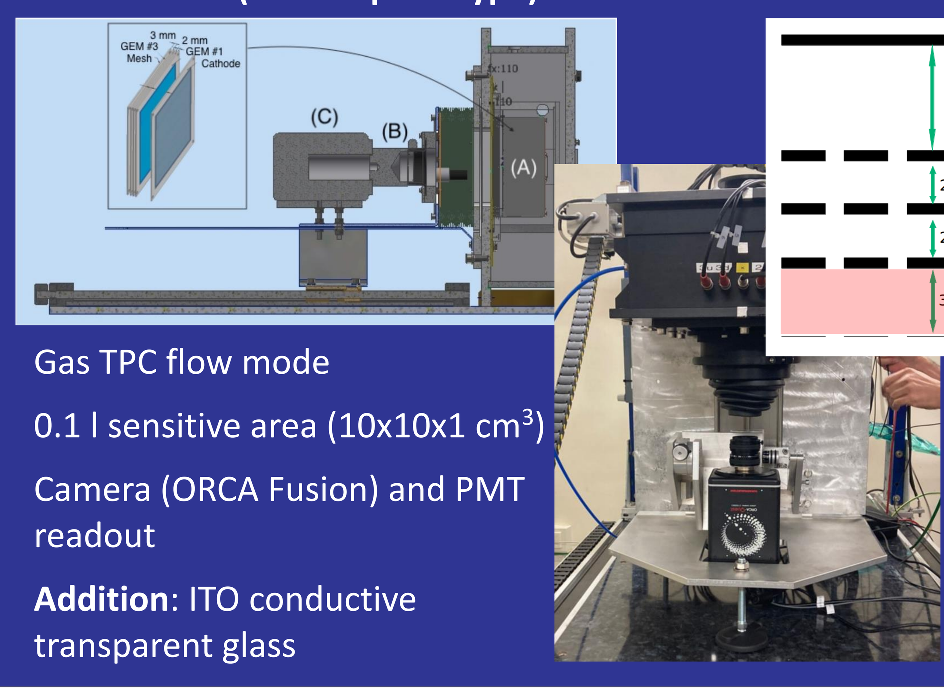
Optical readout:
The larger the area imaged the lower the acceptance (10^{-4} to image 35x35 cm^2)

→ Need of Large gain $O(10^6)$



WHAT: Optimisation of amplification stages required

MANGO (CYGNO prototype)

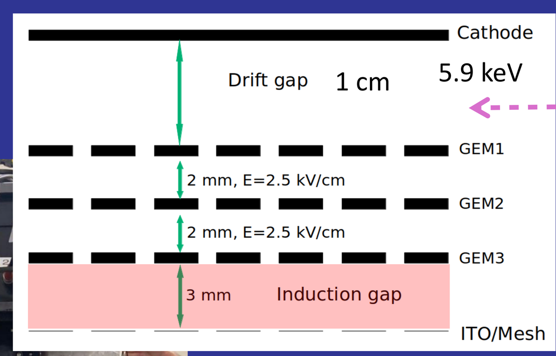


Gas TPC flow mode

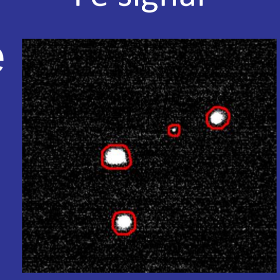
0.1 l sensitive area (10x10x1 cm^3)

Camera (ORCA Fusion) and PMT readout

Addition: ITO conductive transparent glass



^{55}Fe signal



HOW:

Introduce a strong electric field (>10 kV/cm) in the induction region to enhance the amplification and production of light

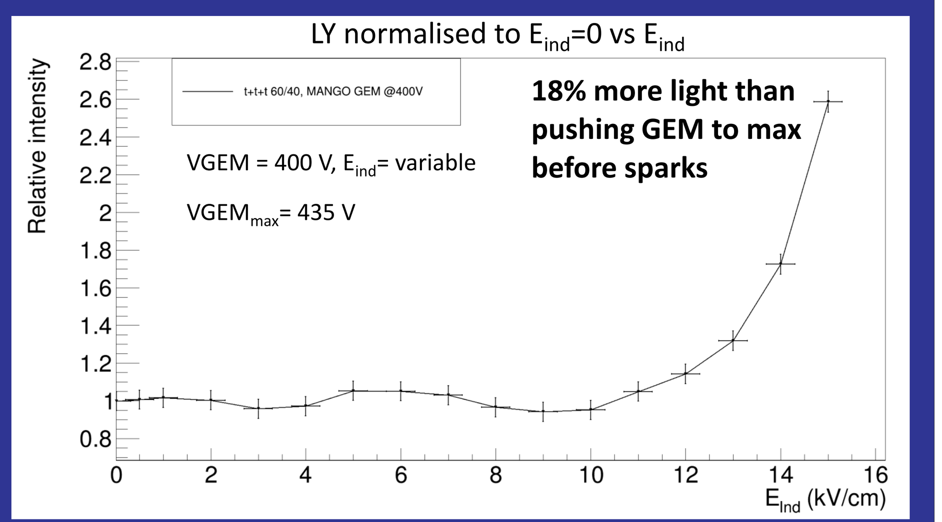
Effect of the induction field

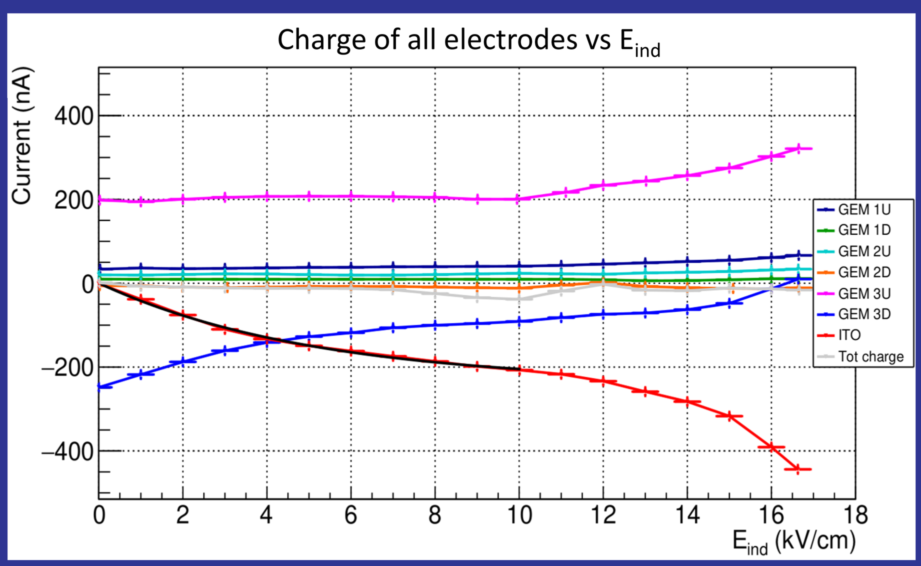
Amaro et al., https://arxiv.org/abs/2406.05713 (accepted and reviewed by EPJ C)

Light yield (LY) obtained by analysing the ^{55}Fe spots intensity in the images

Light yield increases exponentially with threshold around 9.5 kV/cm of induction field

Maximum light yield surpasses the one achieved with only GEMs





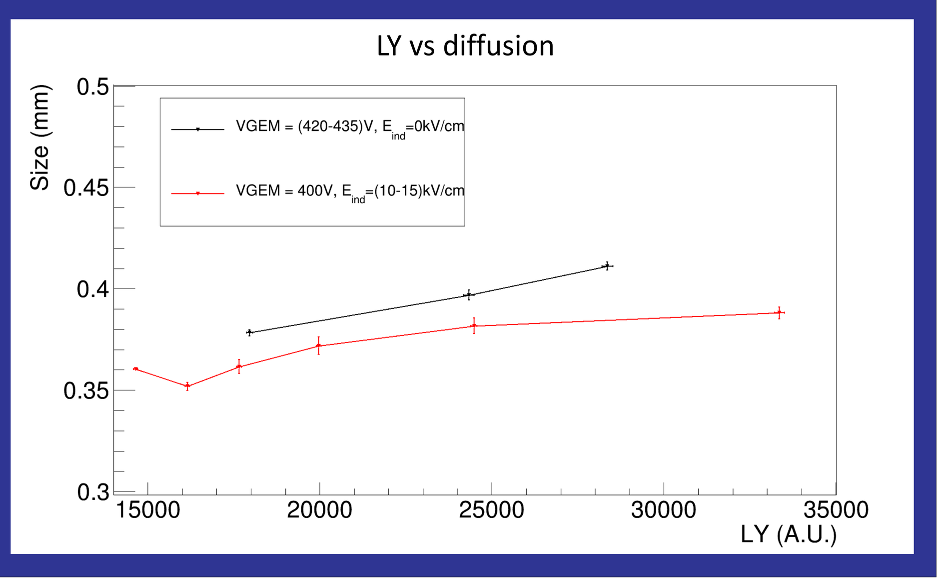
Current from all electrodes collected (using very intense source)

Clear behaviour break after 10 kV/cm

Not only light but also charge is produced

The dimension of the ^{55}Fe spots used to estimate the intrinsic diffusion of the amplification stage (very small drift region)

Break above threshold but keeps below regular GEM usage

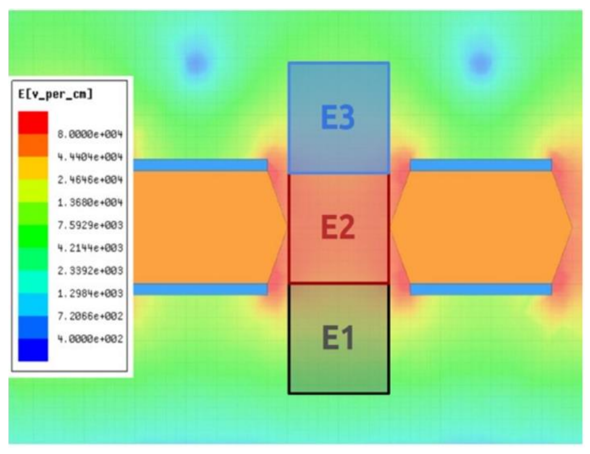


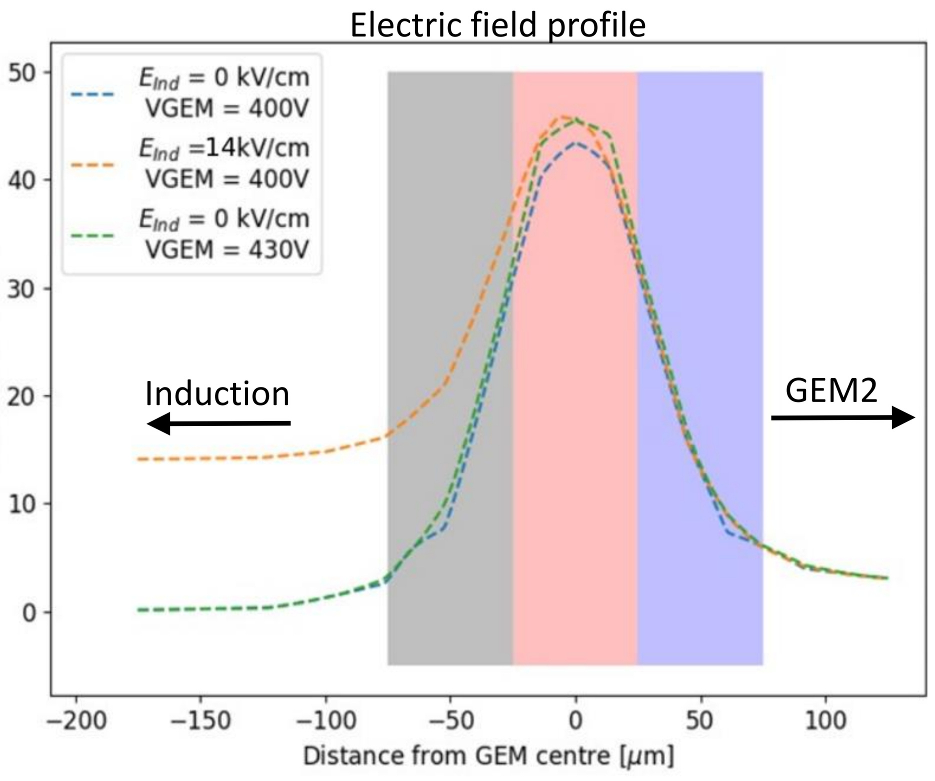
Electric field simulation

Electric field simulation with Ansys software

Field distortion in a region of about 50-100 μm away from GEM holes

Simulation performed varying:
- the voltage across the GEMs
- induction field



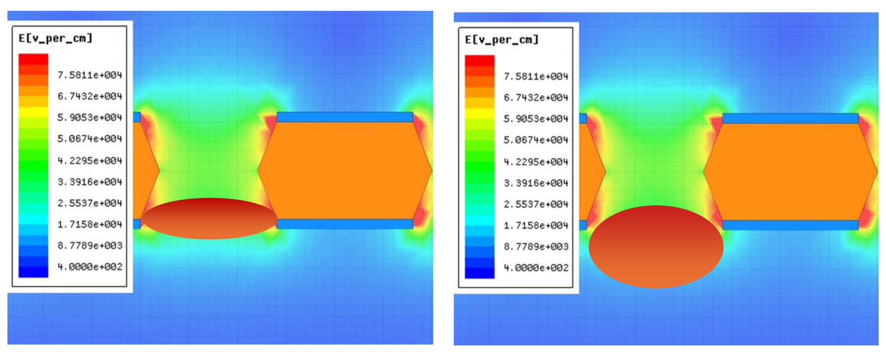


Scanning VGEM → Symmetrical modification of the electric field profile

Scanning E_{ind} → Large deformation of the field towards the induction and inside the GEM hole

The induction field increases the region where the electric field is strong enough to generate charge and light

Amplification region enhanced with more space and slightly lower field



Saturation measurement

Achieving large gain is not all. We need the response to be **linear**

VGEM1 scan

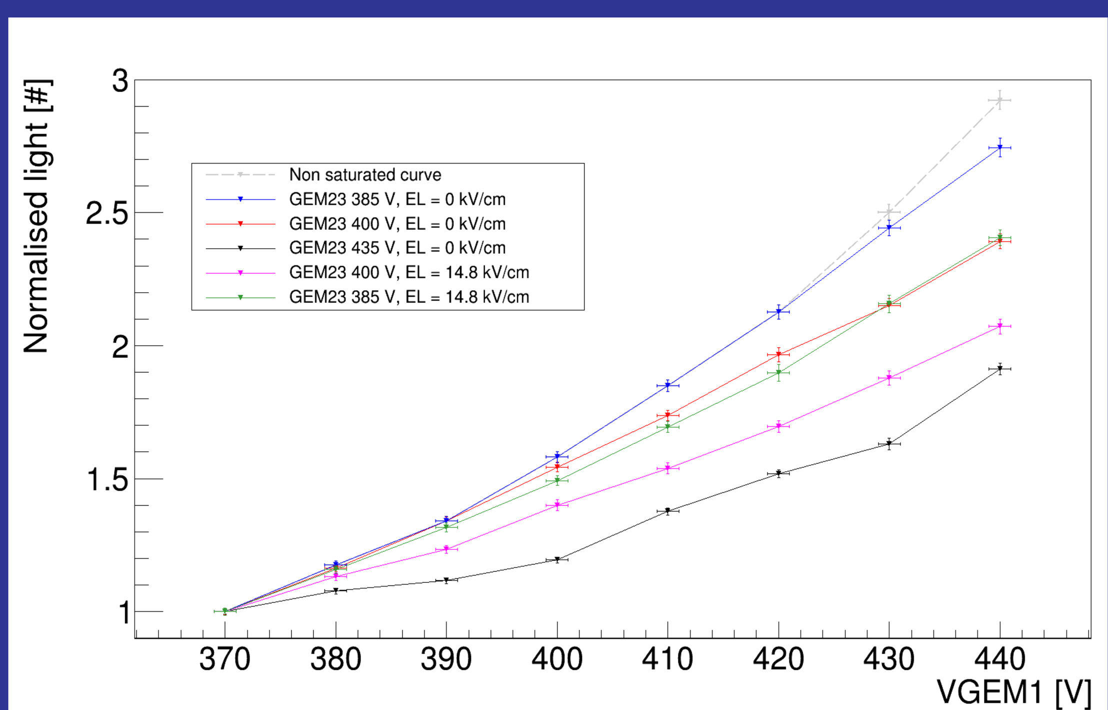
GEM1 voltage is scanned from 370 to 440 V

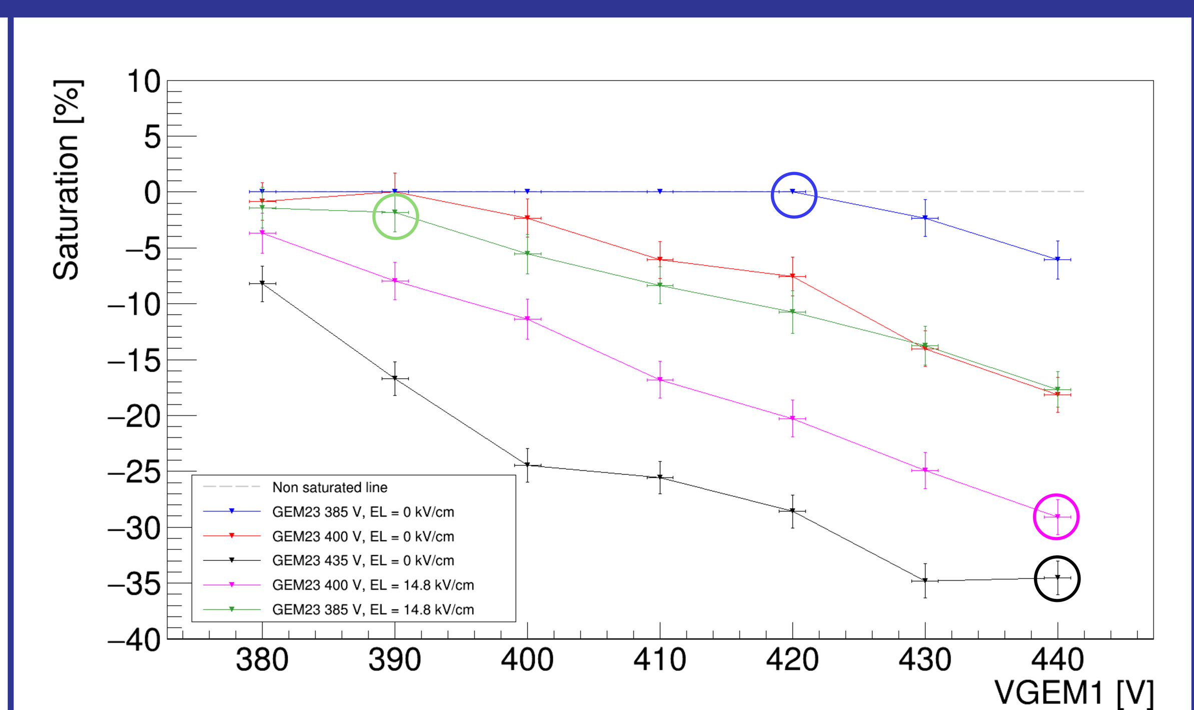
GEM2/3 and induction field are kept constant in different configurations

Light normalised to the VGEM1=370V of each configuration

Low GEM voltage configurations allow to find the non-saturated curve

Large GEM gains lead to space-charge effect: **Saturation**





Saturation

Low VGEM no E_{ind}:	
LY	9800 ± 150
Sat	0%
High VGEM no E_{ind}:	
LY	30700 ± 200
Sat	(34.5 ± 1.6)%
Low VGEM high E_{ind}:	
LY	31300 ± 200
Sat	(1.7 ± 1.5)%
Med VGEM high E_{ind}:	
LY	64700 ± 400
Sat	(29.1 ± 1.5)%

From the gray curve, the saturation level is estimated for the different configurations

Strong induction field allows to enhance the light yield suppressing the space-charge effect

Conclusion

- Optimisation of amplification structures in gas detectors to maximise light output while keeping linearity is crucial for future experiments
- Large increment in gain of the amplification were found up to factor 2 with respect to regular GEM use
- The wider region of amplification allows to significantly reduce the saturation of the GEM gain

Next

- Repeat the measurement at larger distances to evaluate the saturation conditions as a function of distance
- Start working on tests of large area ITO and possibly use segmented ones with readout
- Try other noble gases, like Ar (more suited for polarimetry)