CYGNO simulations update

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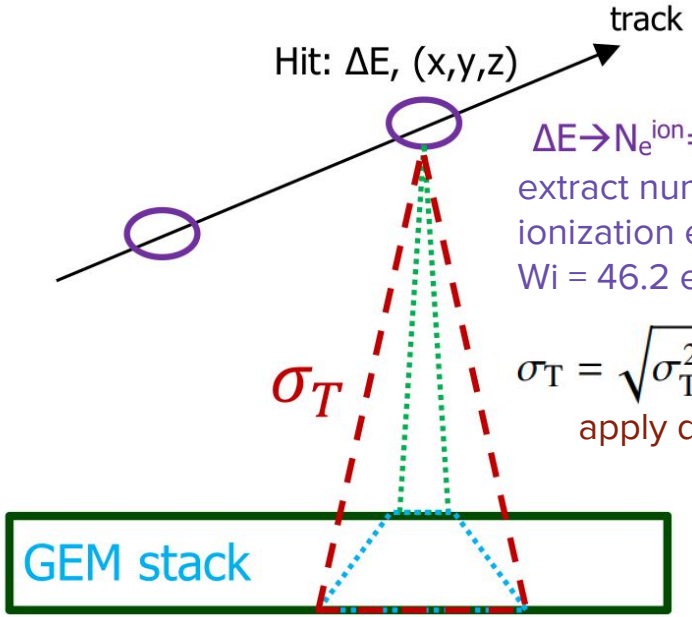
CYGNO simulation meeting

Simulation of images

Spatial distribution of energy depositions ΔE,(x,y,z) from MC truth GEANT4 (SRIM) for ER (NR)



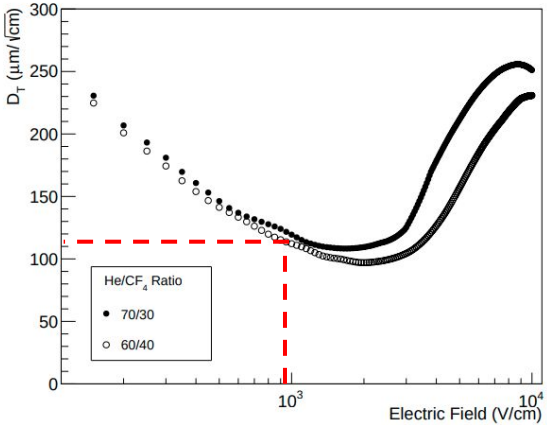
$\Delta E \rightarrow N_e^{ion} = \Delta E / W_i$

extract number of ionization electrons

Wi = 46.2 eV

$$\sigma_T = \sqrt{\sigma_{T0}^2 \oplus D_T^2 \cdot z}$$

apply diffusion



$$D_T^{60/40} = 115 \ \frac{\mu m}{\sqrt{cm}}$$

$$\sigma_{T0}^{60/40} = (280 \pm 60) \ \mu m$$

For 930V/cm drift field

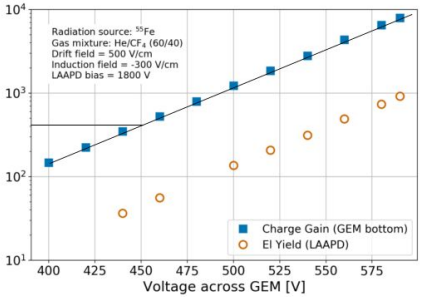
Simulate electron multiplication & light production in GEM stack

F. Petrucci

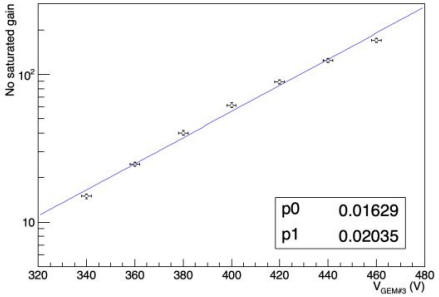
Simulation of GEM gain + light production

- Single GEM gain for HV @450V: 400 (portugues group measurement)
- Extraction x Collection efficiency of electrons in GEM1 and GEM2: 0.33

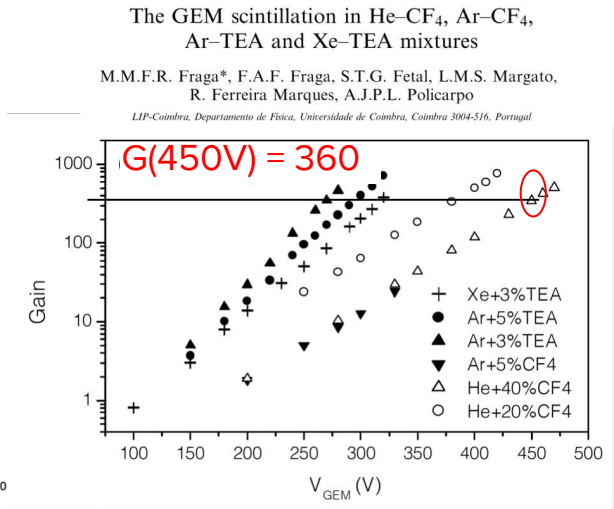
$$G(450V) = 400$$



Single GEM gain as measured by Fernando



Single GEM gain by Fraga et al.



Single GEM gain as measured by F&K

$$\frac{I_3}{I_2}(450V) = G(450V) \times \epsilon_{extr}^{GEM\#2} \times \epsilon_{coll}^{GEM\#3} = 132$$

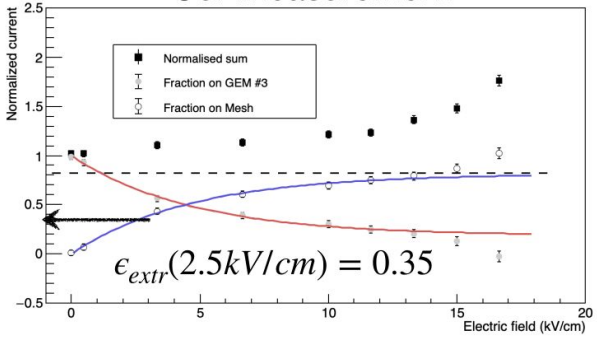
$$\epsilon_{extr}^{GEM\#2} \times \epsilon_{coll}^{GEM\#3} = 0.33$$

D. Pinci

Simulation of GEM gain + light production

- Single GEM gain for HV @450V: 400 (portugues group measurement)
- Extraction x Collection efficiency of electrons in GEM1 and GEM2: 0.33

Our measurement



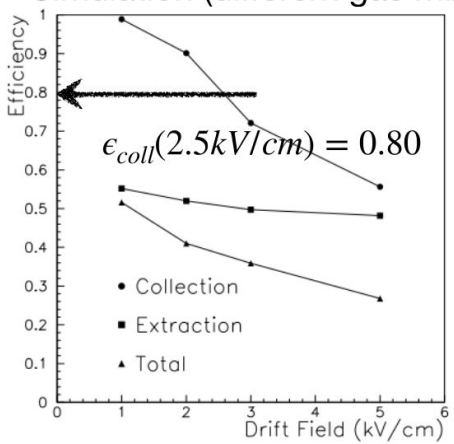
$\epsilon_{extr} \times \epsilon_{coll} = 0.33$ Reasonable

Therefore:

$G_1 = G_2 = 130$;

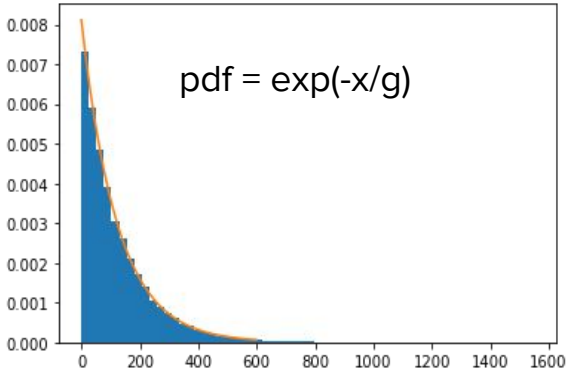
$G_3 = g = 400$;

Simulation (different gas mix)



Gain fluctuations

➜ Gain of 1st GEM (G1) is extracted from an exponential distributions and multiplied by $\varepsilon_{extr} \times \varepsilon_{coll}$



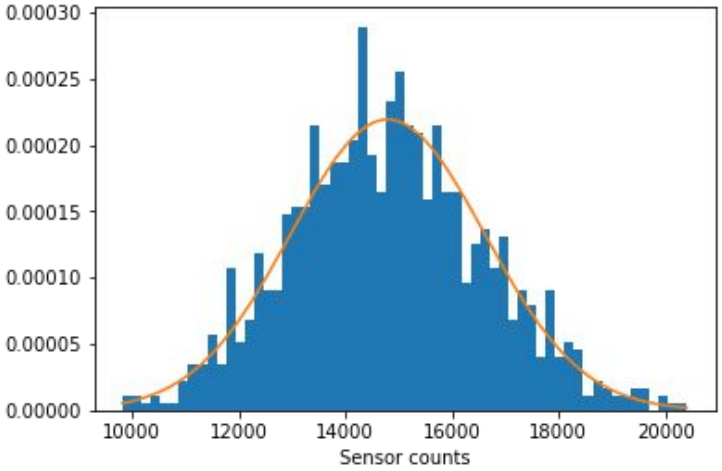
Simulation of GEM gain + light production

- Single GEM gain for HV @450V: 400 (portugues group measurement)
- Extraction x Collection efficiency of electrons in GEM1 and GEM2: 0.33
- Light yield: 0.07 photons/electrons
- ORCA Fusion:
  - 2304 x 2304 pixels (1 pixel 6.5 um x 6.5 um)
  - Camera aperture 0.95
  - Sensor size 14.976 mm
  - Sensor calibration ➔ 1 photon = 2 sensor counts
- Active area: 35 cm x 35 cm
- Distance from the GEM: 30 cm
- Geometry factor of light collection: $\Omega=1/(4(d+1)*a)^2$
  - d = ratio between image size (350 mm) and sensor size (14.976 mm)
  - a = camera aperture (0.95)

Light for ^{55}Fe spot

Prediction from toy MC

- GEM voltage: 450V



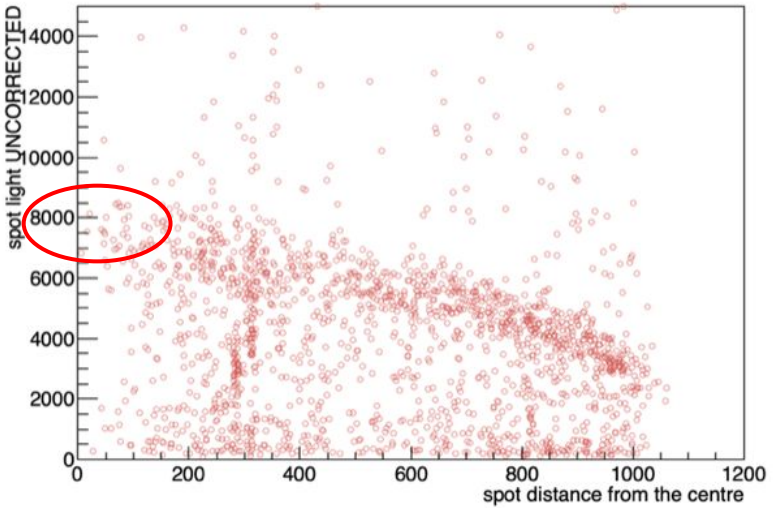
mean = 14783 counts

sigma = 1811

resolution = 0.122

Run 3645 in LIME: GEM @450V, z = 30 cm

- no vignetting correction
- no saturation correction
- select round spots



In the center (vignetting correction =1) ~8000 counts

➜ about **1.8 factor** less than MC

➜ from saturation simulations by Davide we expect **1.7**

Residual data-MC difference explained by saturation

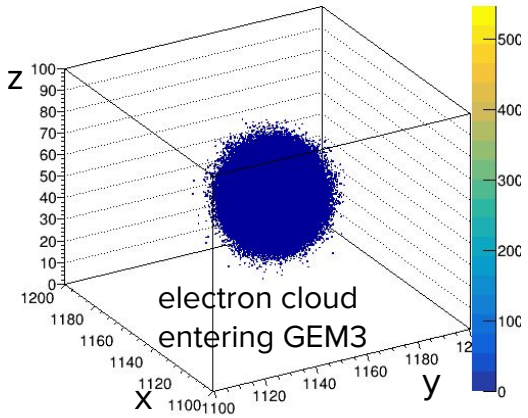
Saturation simulation

Presentation by Davide: https://cernbox.cern.ch/index.php/s/tJIyEZZPLdkSrH6/download
Jupyter notebook test: https://github.com/gdimperi/cygno-digi-test
New branch in digitization repository: https://github.com/CYGNUS-RD/digitization/tree/saturation

Method:

- Add absorption length parameter for e- in the gas λ: $n = n_0 \exp(-z/\lambda)$
- Only GEM3 saturated, G1 and G2 simulated as before
- Simulate the 3D cloud of electrons entering GEM3:
  - spatial smearing given by σ_{0T},σ_T and σ_{0L},σ_L and drift distance z
  - divide electron cloud in voxels 152(x) x 152(y) x 100(z) μm^3
  - x and y voxels correspond to pixels (to be changed)
  - apply formula of saturated gain in each voxel

$$G = A \frac{g}{1 + \frac{n}{n_h}(g-1)}$$



- Conversion to number of photons as before

Example event

Results with parameters tuned “manually” by Davide:

- A = 1./0.68
- $1/n_h = \beta = 2.5e\text{-}5$
- $\lambda = 100$ cm
- z = 30 cm

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tot num of sensor counts after GEM3 including saturation: 7193
tot num of sensor counts after GEM3 without saturation: 10687
Gain GEM3 = 400
Gain GEM3 saturated = 269
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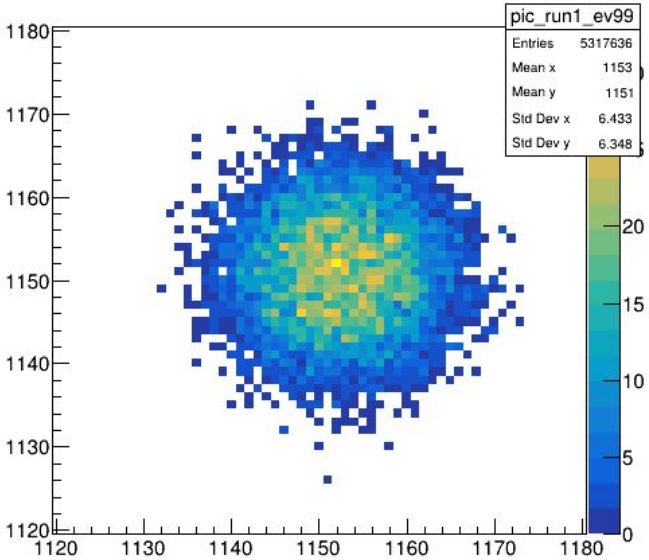
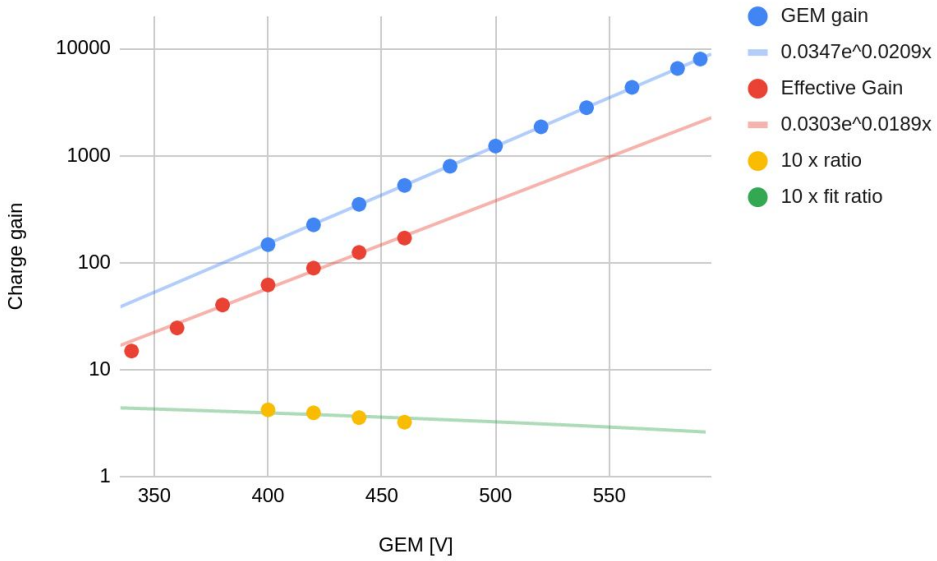
- Time of simulation increases significantly
  ➜ 15s/event for spots of 6 keV

Final image on the sensor 6 keV ER



Comparison with ^{55}Fe data and GEM1 HV scan

- Introduce functional dependence of the GEM gain from HV
  gain = 0.0347 exp(0.0209 * HV)



- GEM gain from Fernando's measurements
- Effective gain from Francesco&Karolina's measurements

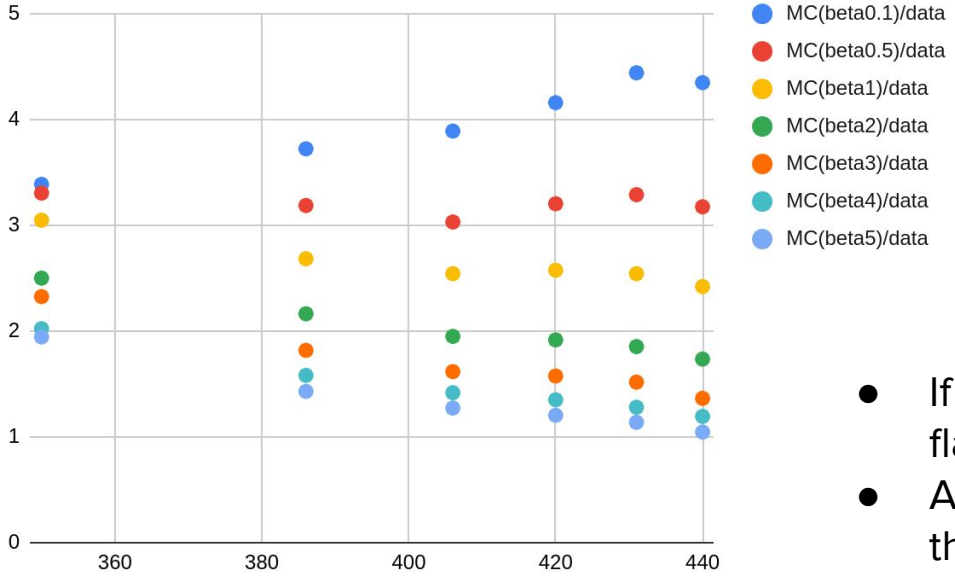
(see slide 3)

Comparison with ^{55}Fe data and GEM1 HV scan

- Introduce functional dependence of the GEM gain from HV
  gain = 0.0347 exp(0.0209 * HV)
- Config file parameters to reproduce data by Donatella&Davide
  - Distance from GEM = 20 cm
  - GEM1_HV ➔ scan: 350, 386, 406, 420, 431, 440 V
  - GEM2_HV = 440 V
  - GEM3_HV = 440 V
  - extraction_eff =0.37
  - A = 1.47 (free parameter of the model, to be fixed)
  - beta ➔ scan to find the best value for our model: 0.1e-5, 0.5e-5, 1e-5, 2e-5, 3e-5, 4e-5, 5e-5
  - absorption_l = 1 m
- No background

Comparison with ^{55}Fe data and GEM1 HV scan

Distance from the GEM is 20 cm



HV GEM1	counts MC beta=0.5e-5	counts data	MC(beta0.5)/ data
350	1910.41	578	3.305207612
386	3694.86	1159	3.18797239
406	4924.03	1624	3.032038177
420	6280.64	1960	3.204408163
431	7501.65	2280	3.290197368
440	8450.54	2661	3.175700864

- If the saturation model is correct we expect flat ratio between MC and data
- A is a free parameter, should be changed so that the ratio is 1
- The best value for beta seems beta = 0.5e-5

Summary and to do

- Model for GEM saturation developed by Davide has been integrated in the digitization code
  - not yet complete, and not clear how to implement in an efficient way for general tracks (not simple spots)
- Preliminary tests and data/MC comparison are encouraging
  - beta ~ 0.5e-5
- Add background, run reconstruction and repeat the data/MC comparison to be sure that the model still holds, and if the choice of parameters change
- Study the *spot size* variable;
- Study the *z* dependence;