CYGNO simulation of GEM saturation

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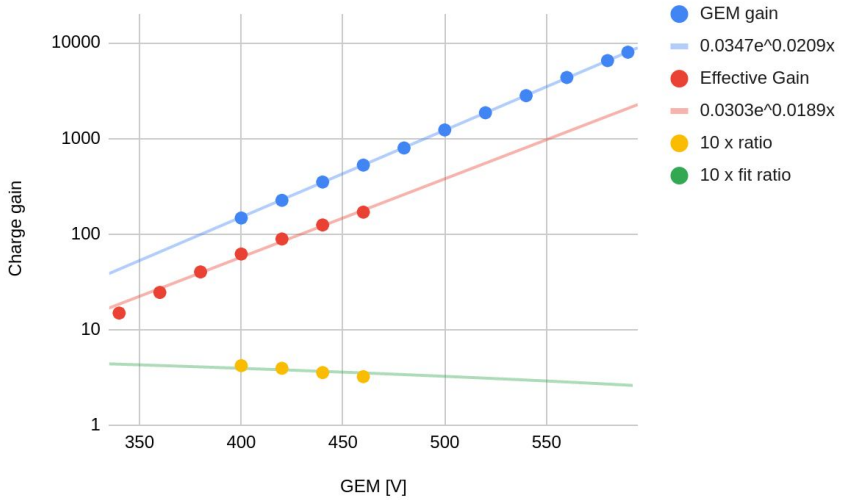
CYGNO simulation meeting

GEM measurements summary

- Functional dependence of the GEM gain vs HV
  `gain = 0.0347 exp(0.0209 * HV)`
- Functional dependence of the GEM efficiency vs HV
  `efficiency = effective/tot gain = 0.873 exp(-0.002 * HV)`

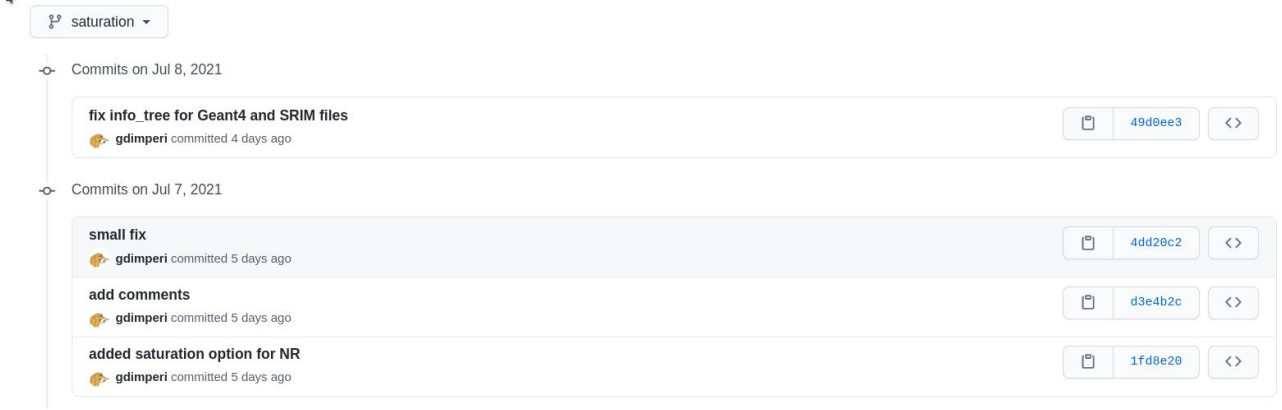


- GEM gain from Fernando's measurements
- Effective gain from Francesco&Karolina's measurements

Digitization code recent updates

Updates in the “saturation” branch of the git repo:
https://github.com/CYGNUS-RD/digitization/tree/saturation

- Added absorption length for electron in gas
- Added parameterization of GEM gain vs HV
- Added parameterization of GEM efficiency vs HV
- Added saturation implementation also for ER and NR (GEant4 and SRIM data format)



Simulation of GEM gain + light production

- Single GEM gain for HV @450V from portugues group measurement
- Extraction x Collection efficiency of electrons in GEM1 and GEM2 from F&K measurements
- 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)

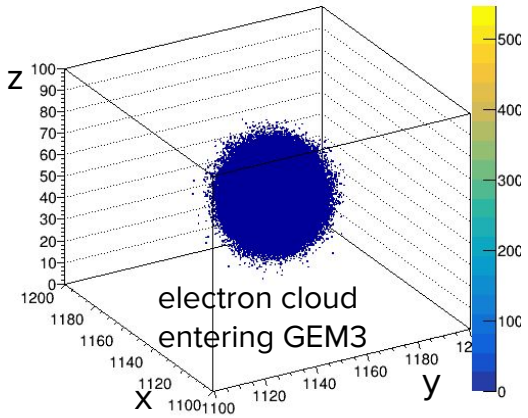
Saturation simulation

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

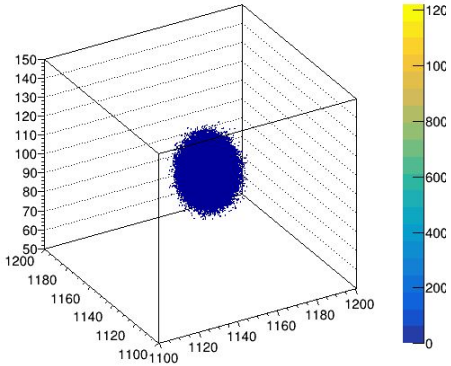
Example event: 6 keV ER

Results with parameters tuned “manually”:

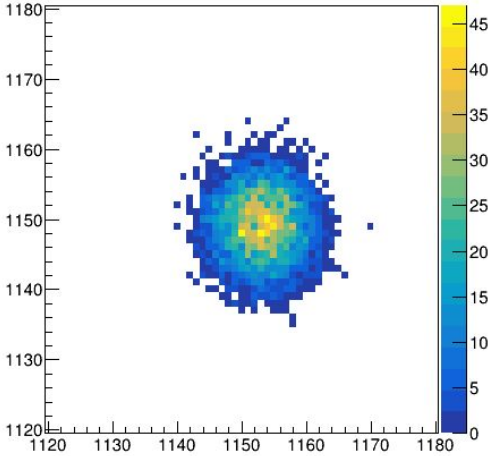
- A = 1.
- $1/n_h = \beta = 0.5e\text{-}5$
- $\lambda = 100$ cm
- z = 20 cm

```
tot num of sensor counts after GEM3 including saturation: 4932
tot num of sensor counts after GEM3 without saturation: 7935
Gain GEM3 = 342.059401   Gain GEM3 saturated = 212.606568
```

Electron cloud entering GEM3



Final image on the sensor 6 keV ER



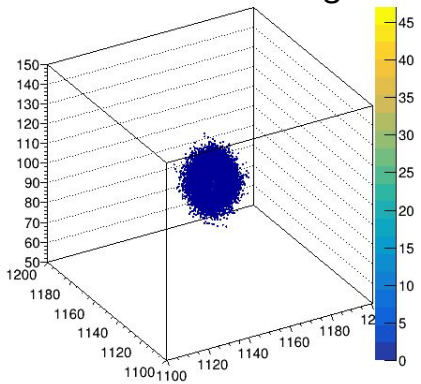
Example event: 6 keV NR

Results with parameters tuned “manually”:

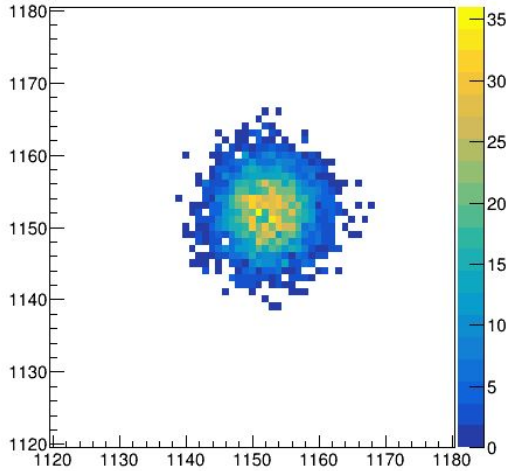
- A = 1.
- $1/n_h = \beta = 0.5e\text{-}5$
- $\lambda = 100$ cm
- z = 20 cm

```
tot num of sensor counts after GEM3 including saturation: 3472
tot num of sensor counts after GEM3 without saturation: 4744
Gain GEM3 = 342.059401   Gain GEM3 saturated = 250.293355
```

Electron cloud entering GEM3



Final image on the sensor 6 keV NR



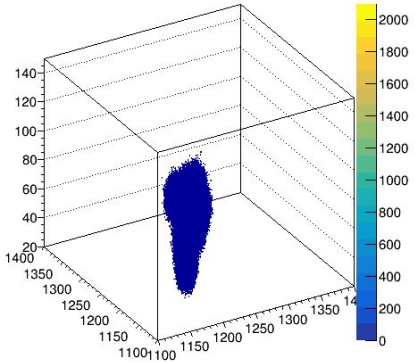
Example event: 30 keV ER

Results with parameters tuned “manually”:

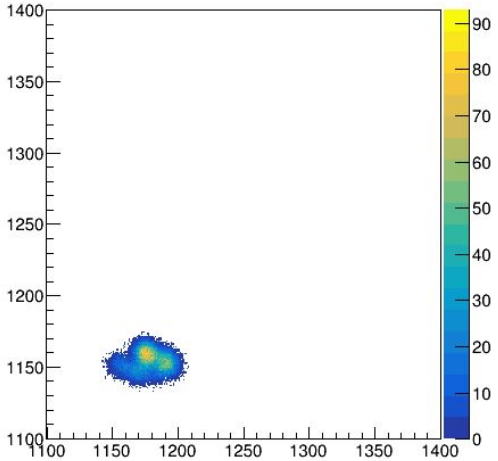
- A = 1.
- $1/n_h = \beta = 0.5e\text{-}5$
- $\lambda = 100$ cm
- z = 20 cm

```
tot num of sensor counts after GEM3 including saturation: 29385
tot num of sensor counts after GEM3 without saturation: 47384
Gain GEM3 = 342.059401   Gain GEM3 saturated = 212.126131
```

Electron cloud entering GEM3



Final image on the sensor 30 keV ER



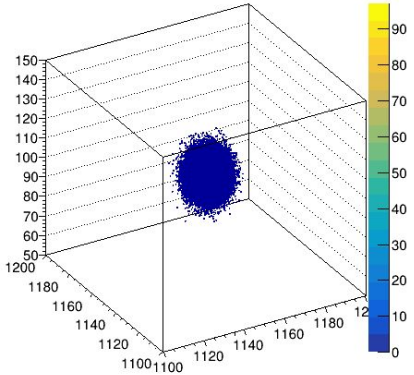
Example event: 30 keV NR

Results with parameters tuned “manually”:

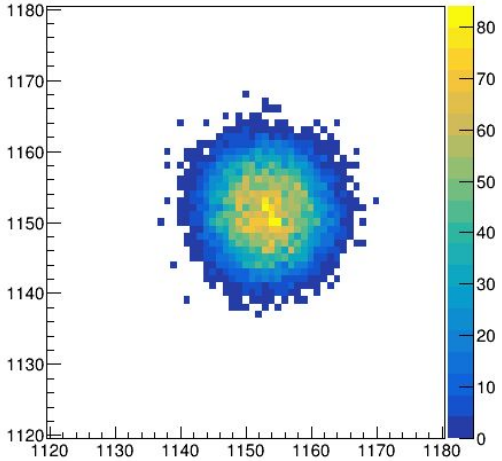
- A = 1.
- $1/n_h = \beta = 0.5e\text{-}5$
- $\lambda = 100$ cm
- z = 20 cm

```
tot num of sensor counts after GEM3 including saturation: 12964
tot num of sensor counts after GEM3 without saturation: 41579
Gain GEM3 = 342.059401   Gain GEM3 saturated = 106.649307
```

Electron cloud entering GEM3



Final image on the sensor 30 keV NR

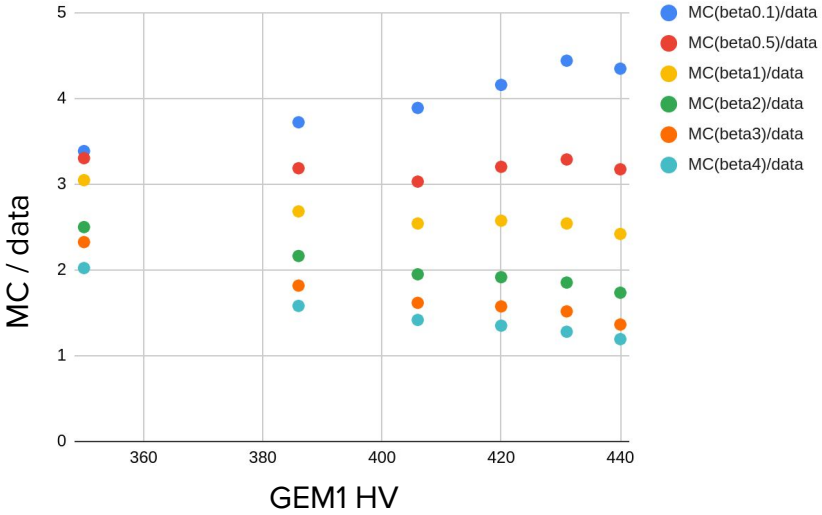


Comparison with ^{55}Fe data with GEM1 HV scan

- 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
  - 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

Comparison with ^{55}Fe data (MC no background)

- Distance from the GEM is 20 cm
- MC without background
- Donatella & Davide analysis

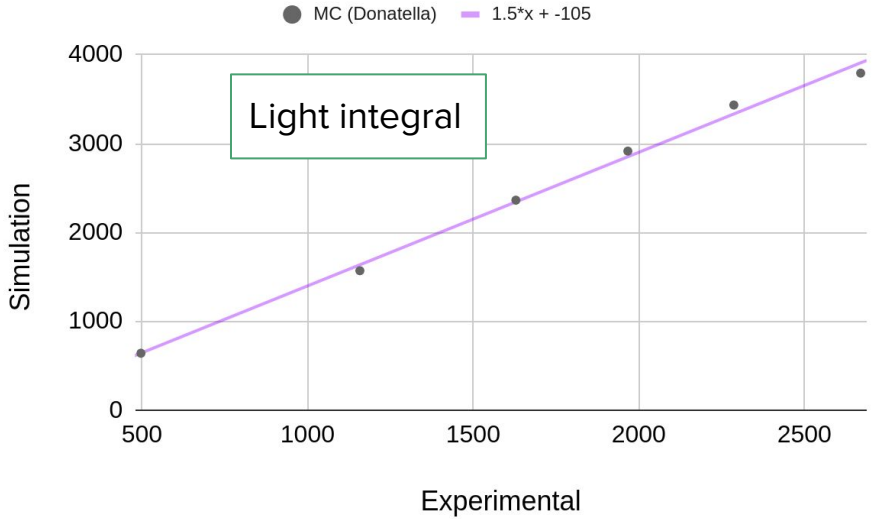


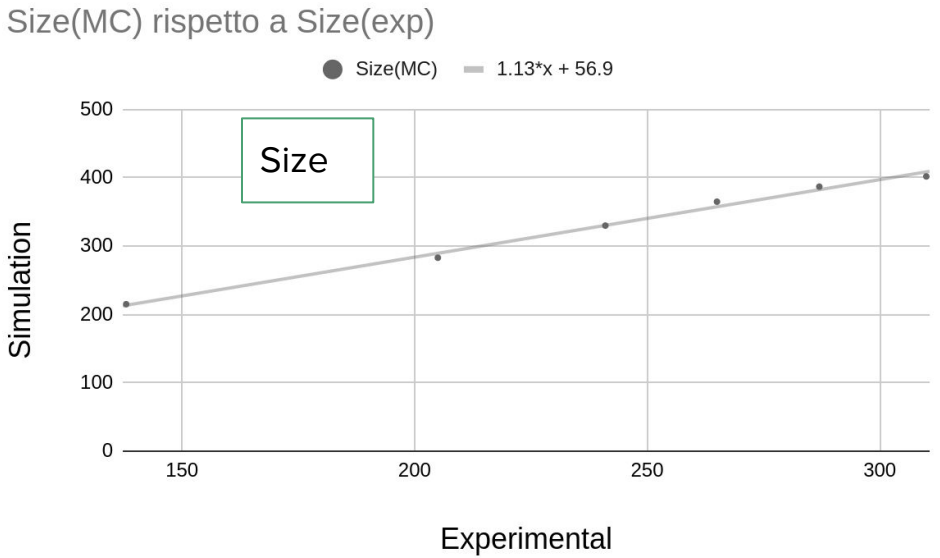
HV GEM1	beta=0.5e-5	data (Don_corr)	MC(beta0.5)/data
350	1326.16	578	3.305207612
386	2477.38	1159	3.18797239
406	3496.73	1624	3.032038177
420	4231.39	1960	3.204408163
431	4860.13	2280	3.290197368
440	5517.5	2661	3.175700864

- 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

Comparison with ^{55}Fe data (MC bkg from run 3944)

Donatella & Davide analysis

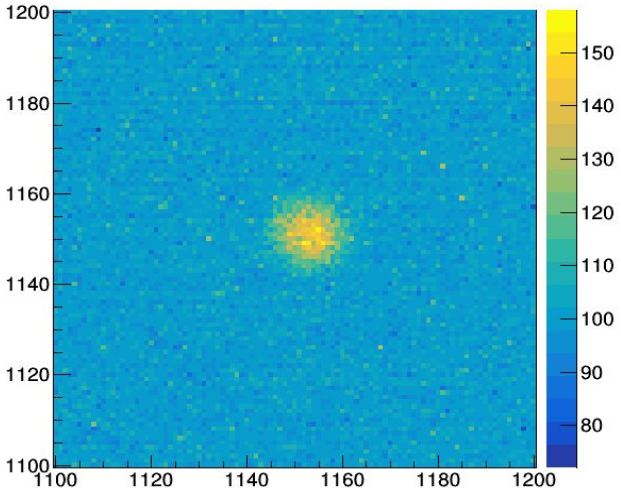


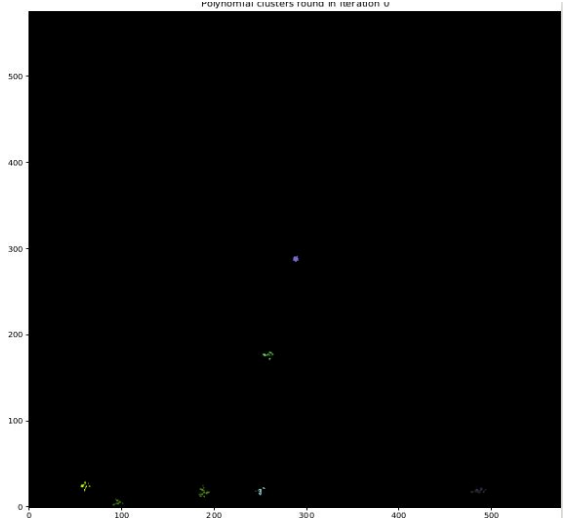


- Linear behaviour as expected
- Linear coefficient not exactly 1 and intercept not 0 ➜ to be understood

Signal + background simulation

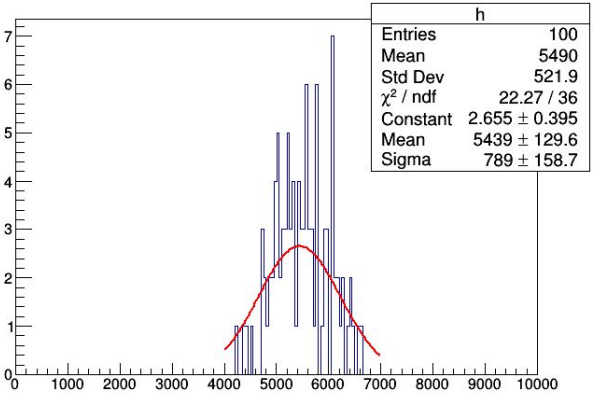
- Use pedestal run taken before the HV scan (4159)
- Use official reconstruction code (by Emanuele)
- (Simple) selection:
  - round spots: sc_lgaussmean/sc_lgaussmean < 1.5
  - MC density cut : sc_integral/sc_nhits > 13 (to avoid fake clusters)

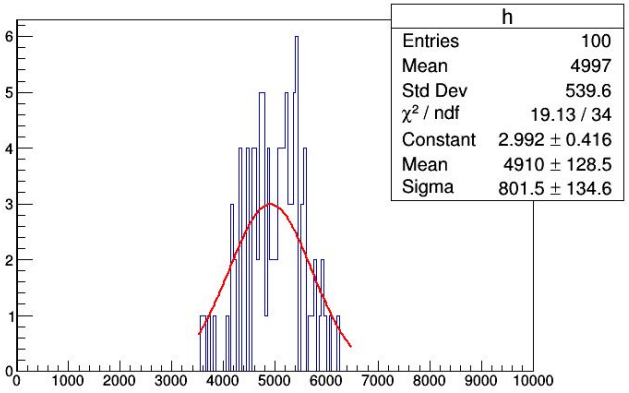


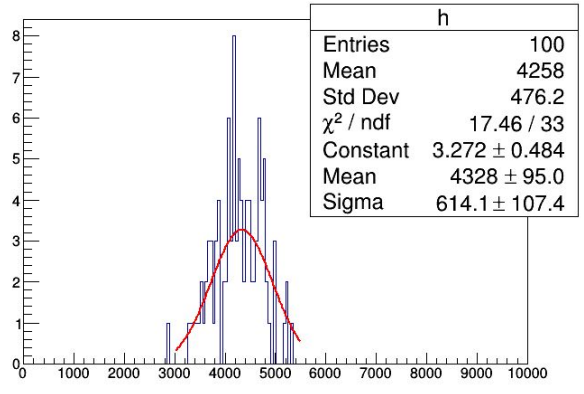


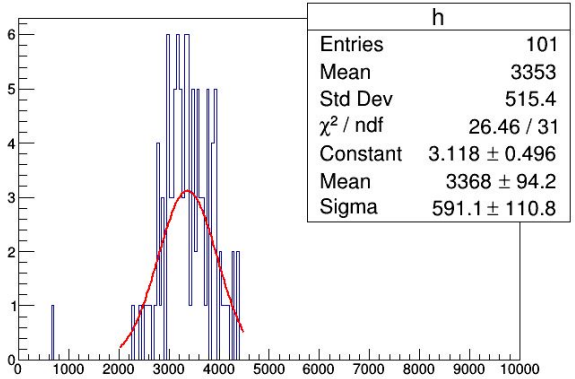
some small “fake” superclusters in the lower part of the image

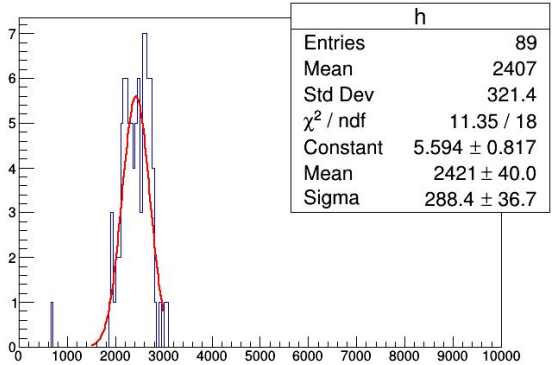
Reconstructed MC: light integral

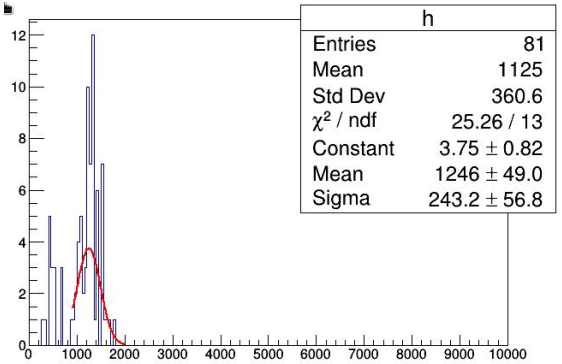






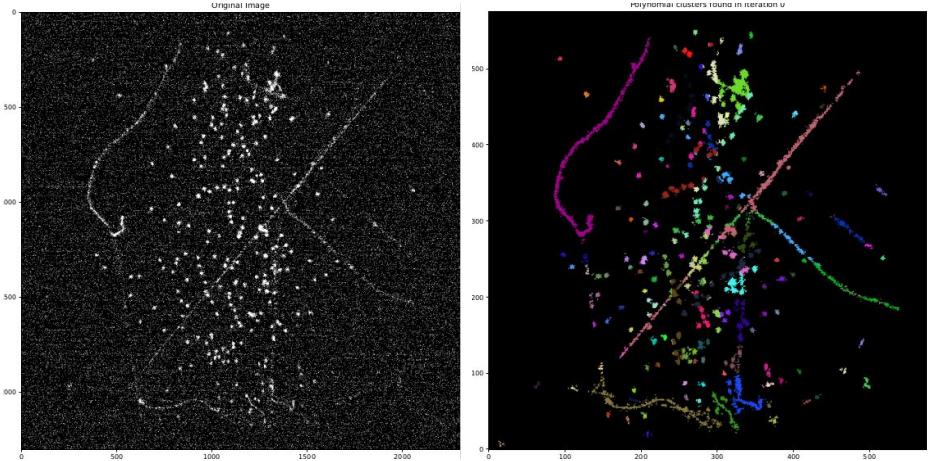




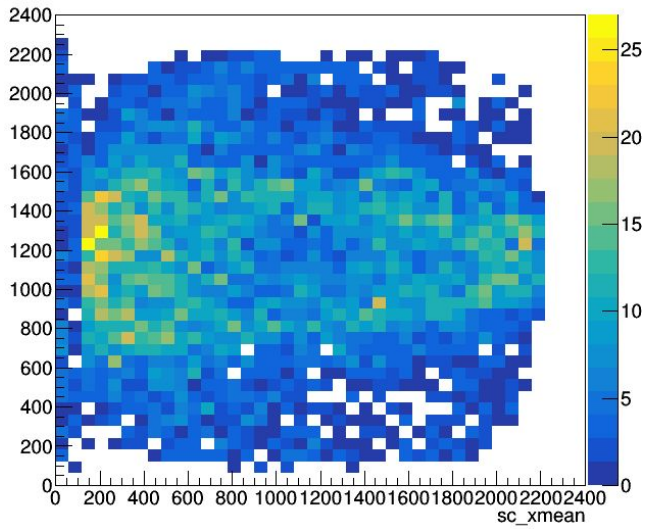


Data reconstruction example

- Use pedestal run taken before the HV scan (4159)
- Use official reconstruction code (by Emanuele)
- (Simple) selection:
  - round spots: sc_lgaussmean/sc_lgaussmean < 1.5
  - data density cut : 8 < sc_integral/sc_nhits < 18



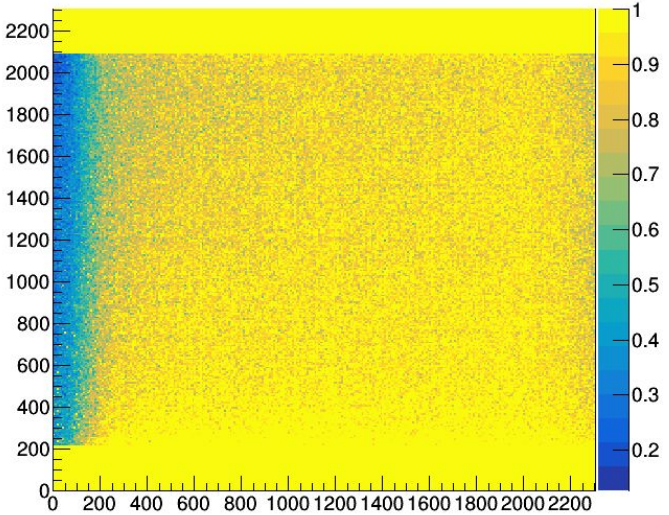
Map of reconstructed superclusters in run 4160

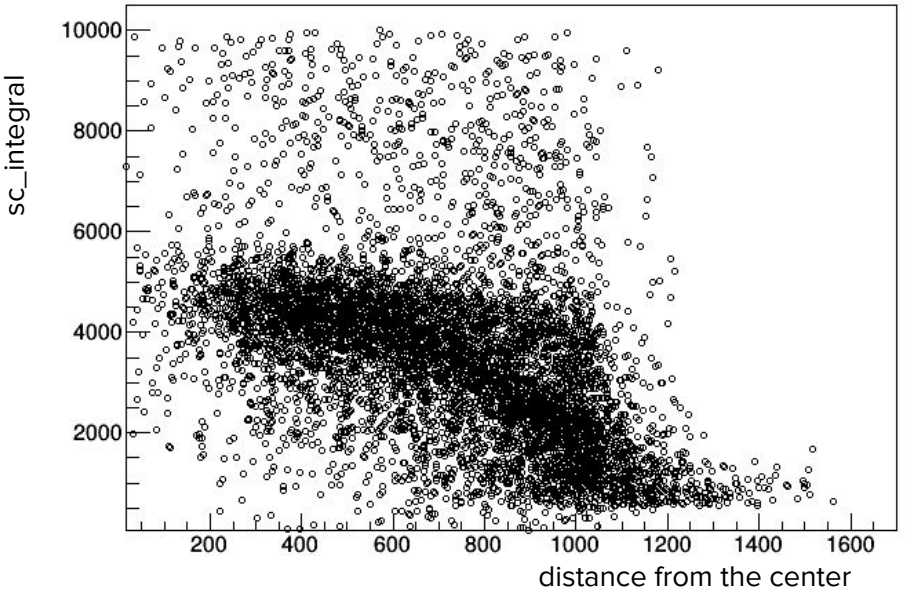


Vignetting correction

Vignetting correction is not working properly, need to fix and/or restrict the analysis to the center of the active area

Vignetting map calculated from run 4159





Vignetting correction

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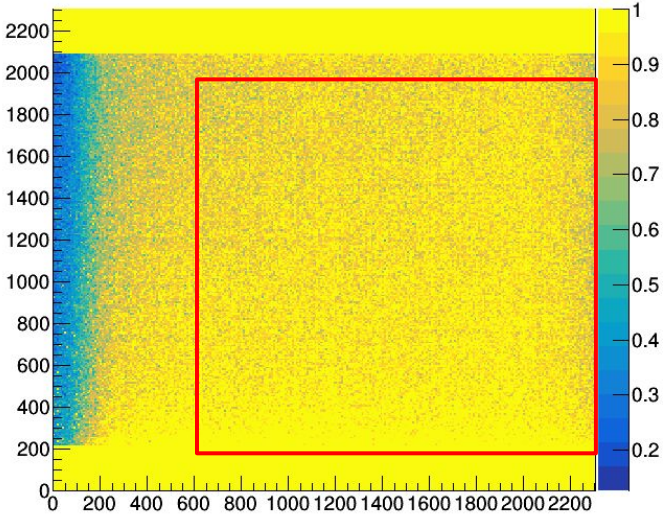
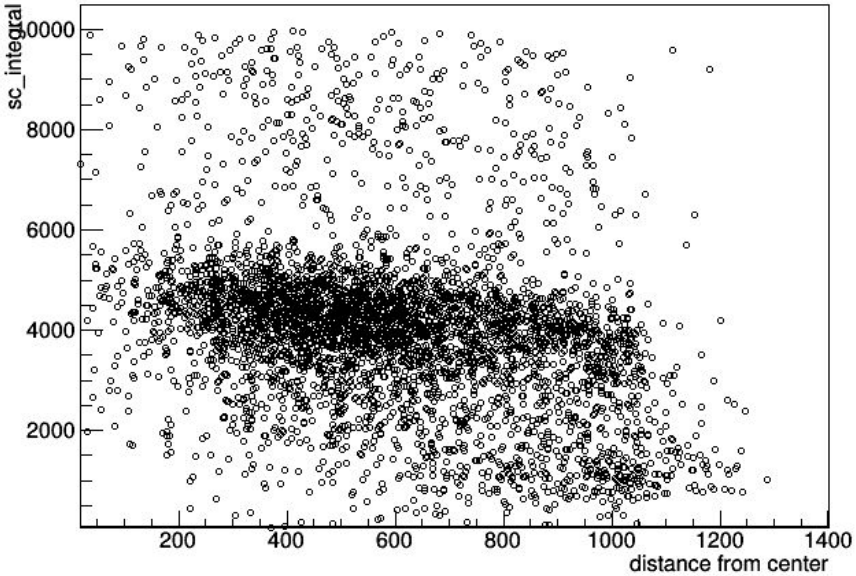
Vignetting map calculated from run 4159

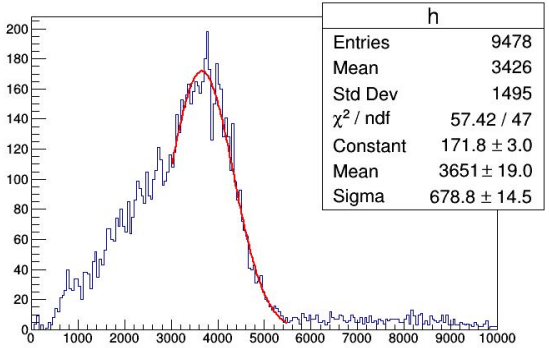


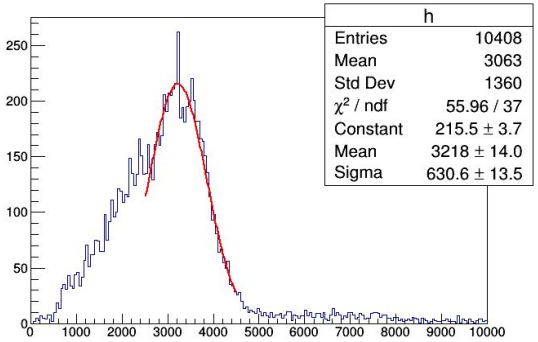
Restricting to red area: x>500, y<2000

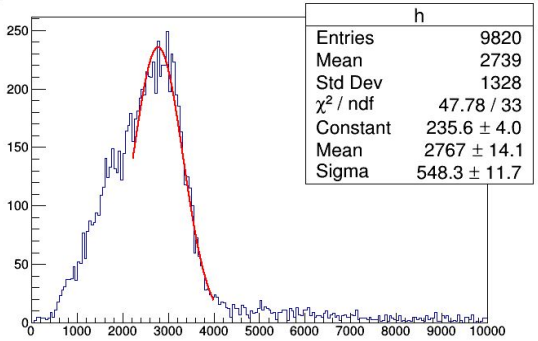


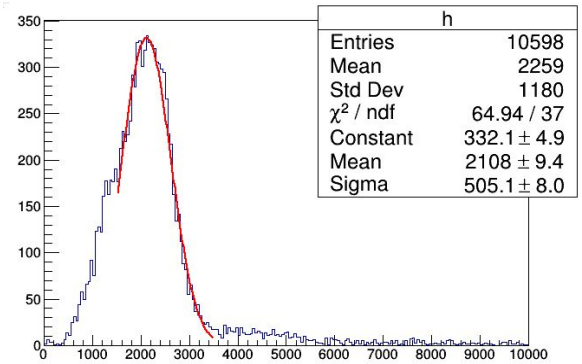
Data: light integral

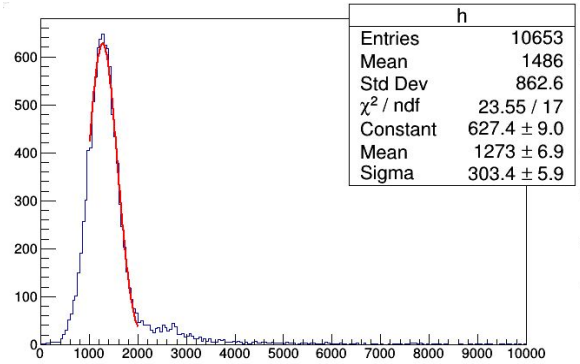
No selection in supercluster position ➜ affected by vignetting problem

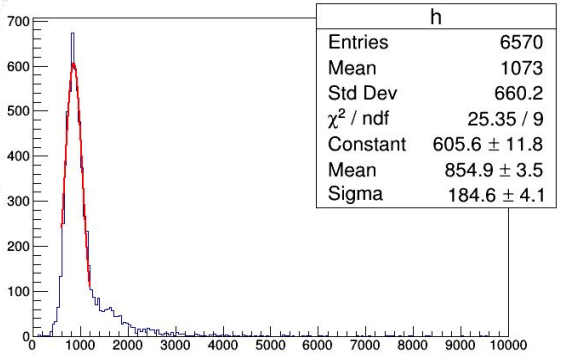






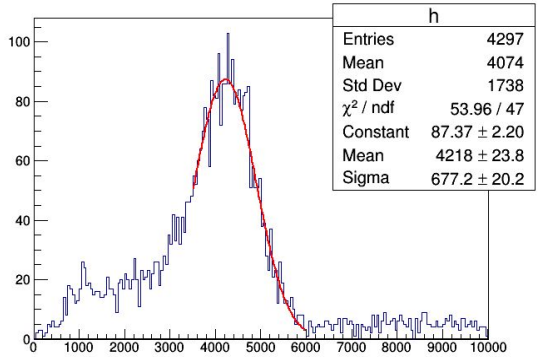


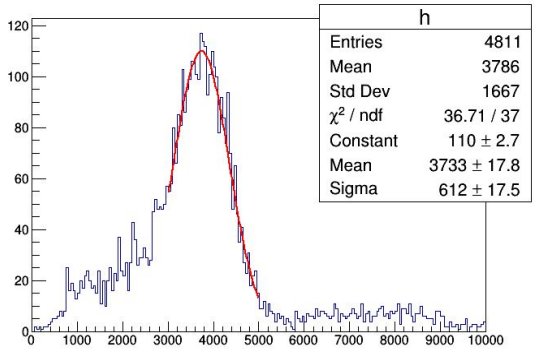


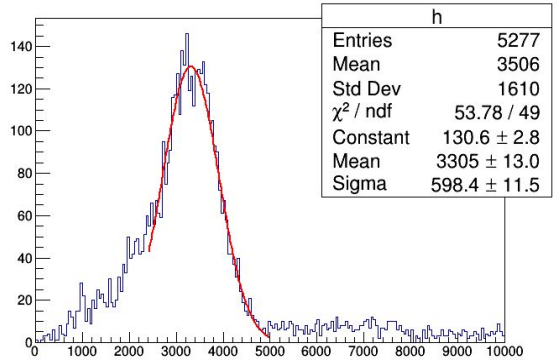


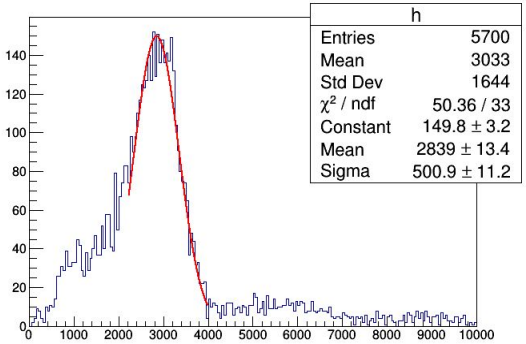
Data: light integral

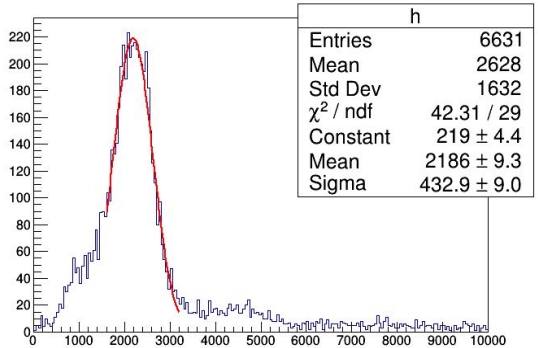
Add selection in supercluster position: sc_xmean>600 && sc_ymean<2000

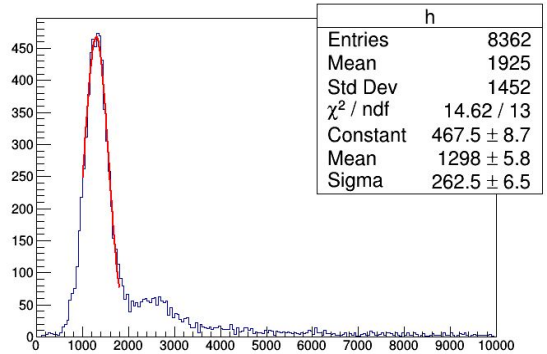




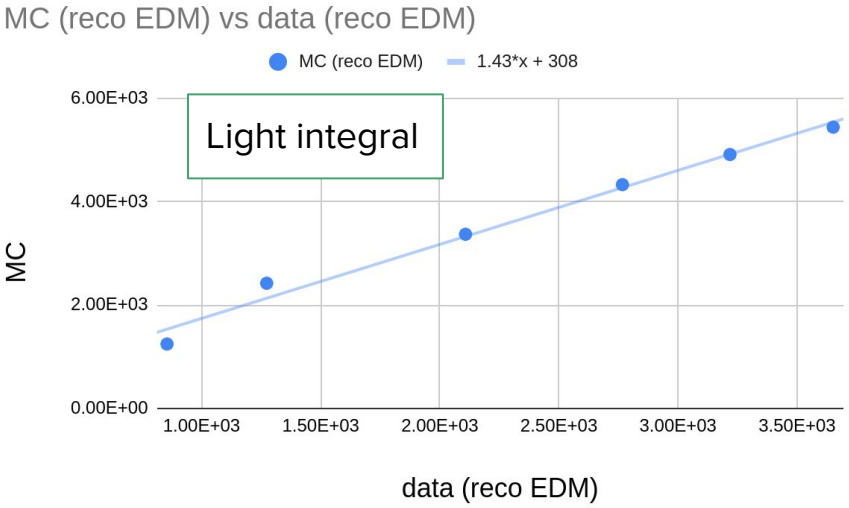




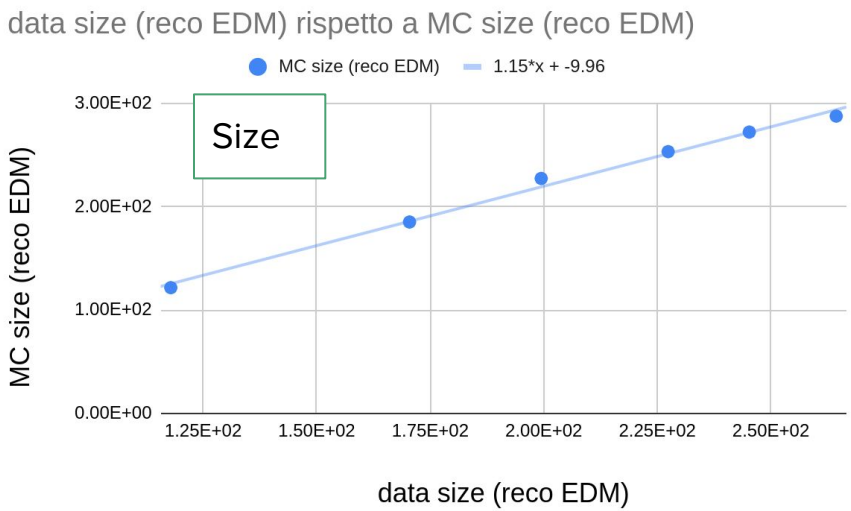




Comparison data vs MC



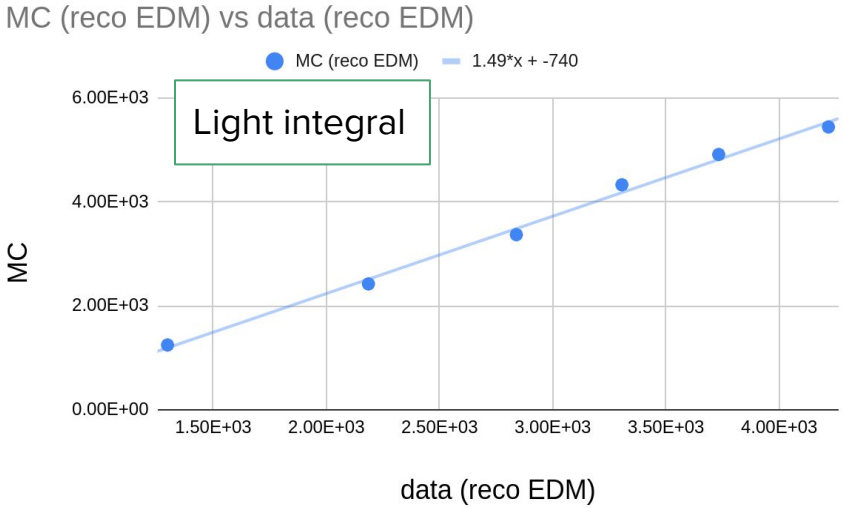
variable name in ntuple: sc_nhits

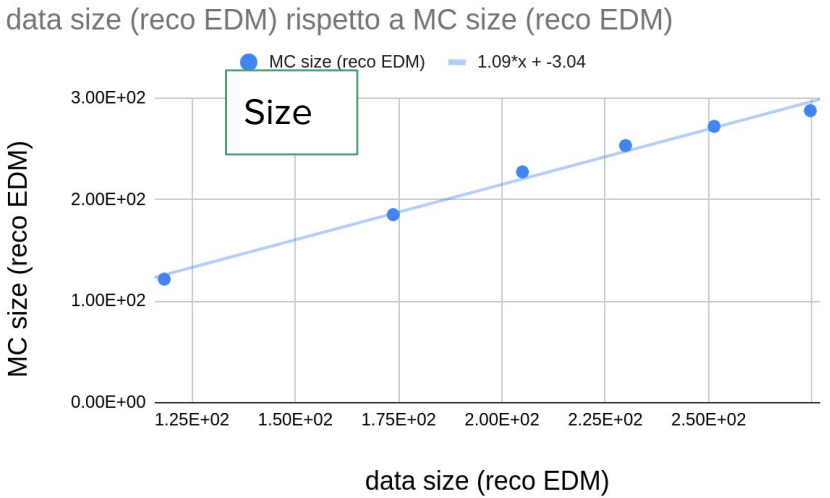


- Linear behaviour as expected
- Linear coefficient not exactly 1 and intercept not 0
- result similar to what obtained with the independent analysis by Donatella, but absolute values of light and size

Comparison data vs MC

Add selection in supercluster position: sc_xmean>600 && sc_ymean<2000





- Linear behaviour as expected
- Linear coefficient not exactly 1 and intercept not 0
- result similar to what obtained with the independent analysis by Donatella, but absolute values of light and size

Conclusions & next steps

- Saturation simulation is able to the non-linear behaviour of the saturated gain vs GEM HV
- Some parameters of the simulation still to be tuned
  - coefficient of linear behaviour not1, intercept not 0
- Need to check also analysis parameters
  - vignetting
  - pedestal subtraction
  - selection
  - other differences between analysis code versions