CYGNO

Digitization: Gain Fluctuations

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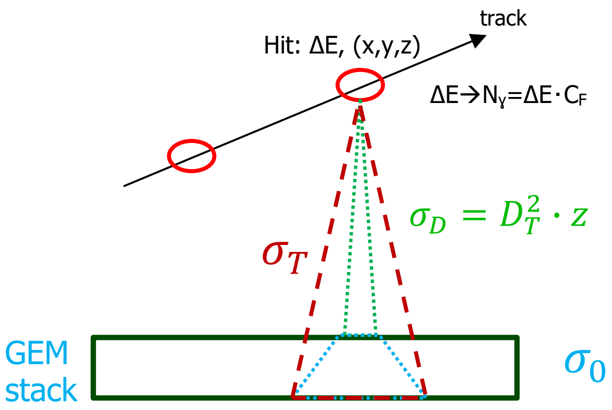
Diffusion and image creation from simulation

"old" implementation



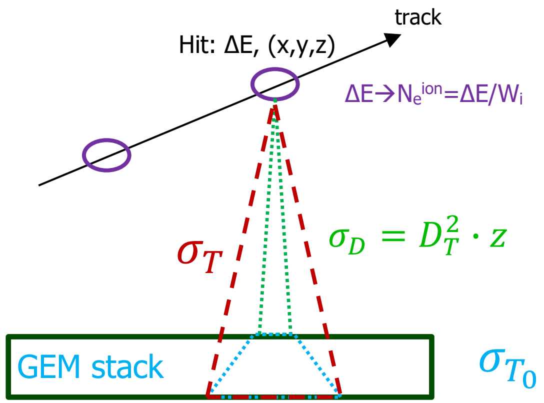
ɣ's positions to generate the image: random extractions of N_γ positions from a gaussian with $\sigma=\sigma_T$

- N_γ=ΔE·C_F C_F ~ 500 ɣ/keV (for LEMON)
- So far, a constant value of σ_T=500 μm was used

  $\sigma_T=\sqrt{\sigma_0 + B^2 \cdot z}$ where:
  - $\sigma_0 \sim 300\mu m$
  - D_T = 130 μm/√cm
- it's like if we were looking at events at a distance z~9 cm from the GEMs.
- The dependence on z has been introduced and tested by Atul

inserting gain fluctuations

1. For each hit, a mean of $Nmean_e^{ion}$ ionization electrons are produced:
   $Nmean_e^{ion}=\Delta E/W_i$ (W_i=46.2 eV/pair in He/CF_4 60/40)
2. The actual number N_e^{ion} of ionization electrons is obtained from a Poisson distribution with a mean of $Nmean_e^{ion}$
3. Ionization electrons diffuse in the drift region: $\sigma_D = D_T^2 \cdot z$
   (diffusion is considered only at the end…)
4. Ionization electrons arrive at the GEM stack;
   - gain fluctuations of the first foil only are relevant:
   - For each ionization electron → $N_e^{G1,k}$ multiplication electrons in the first GEM (k=1, N_e^{ion}) extracted using an **exponential distribution with mean=G_{GEM}**
   (G_{GEM} is the gain of a single GEM foil, see next)
   - Total number of multiplication electron for the first foil: $N_e^{G1} = \sum N_e^{G1,k}$
5. The total number of multiplication electrons is computed considering the gain in the other two foils: $N_e^{tot} = N_e^{G1} \cdot (G_{GEM})^2$
6. Electrons diffuse in the GEM stack: σ_{T_0}



inserting gain fluctuations (II)

7. The mean total number of photons is obtained using 0.07 ɣ/e:

   $$N_\gamma^{mean,tot} = N_e^{tot} \cdot 0.07\ {}^{\gamma}/_{e}$$

8. The actual number of total photons N_γ^{tot} is obtained from a Poisson distribution with mean value $N_\gamma^{mean,tot}$

9. The number of photons hitting the sensor depends on the solid angle ratio Ω:

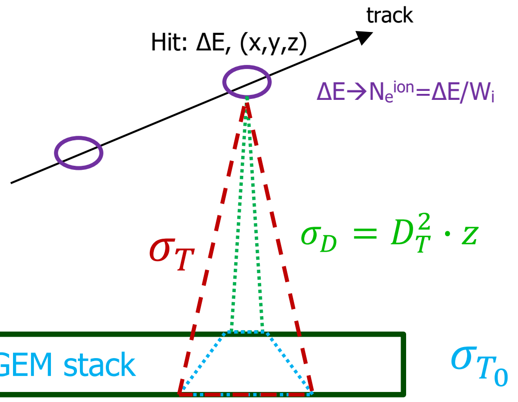
   $$N_\gamma = N_\gamma^{tot} \cdot \Omega$$

   $$where: \ \Omega = \frac{1}{(4(\delta+1)a)^2};$$

   $$\delta = \left(\frac{object\ dimension}{image\ dimension}\right) = \frac{25cm}{1.33\ cm}\left(for\ LEMON, \frac{35}{1.33} for\ LIME\right);$$

   $$a = 0.95\ aperture$$

10. ɣ's positions are obtained with random extractions of N_γ positions from a gaussian around the initial hit position, with $\sigma_T = \sqrt{\sigma_{T_0} + \sigma_D}$



inserting gain fluctuations (III)

CYGNO

- the GEM gain **G** varies according to operating conditions and detector configuration
  → we fix it to obtain the correct light yield;
- we can fix it to obtain (on average) the same number of photons as in the "old" version of the digitization:

$N_\gamma = \Delta E \cdot C_F$ (in the "old" digitization)

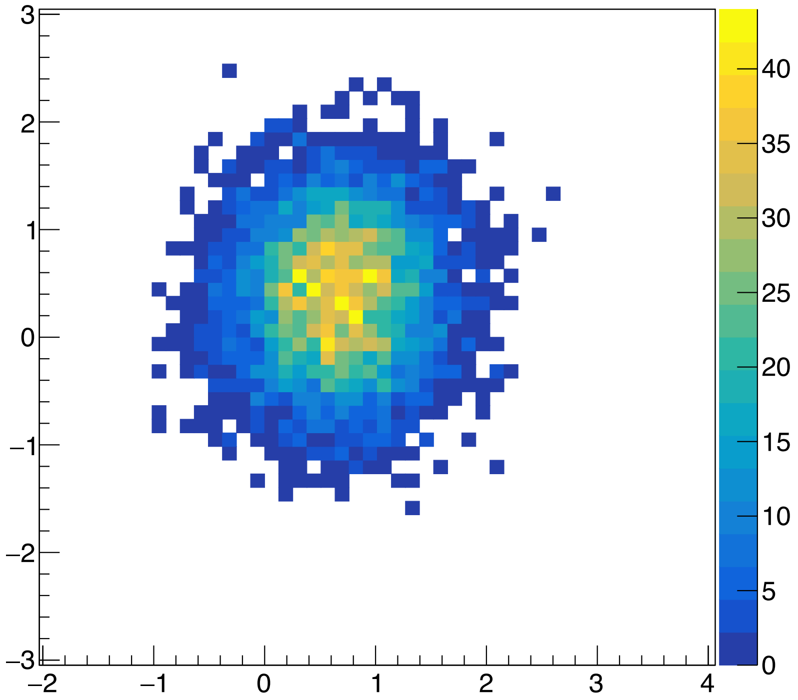
$\bar{N}_\gamma = {}^{\Delta E}/_{W_i} \cdot G \cdot 0.07 \cdot \Omega$ (in the new approach)

$G = \frac{C_F \cdot W_i}{0.07 \cdot \Omega} = 1.8 \cdot 10^6$ (for LEMON where $C_F = 500$ γ/keV)

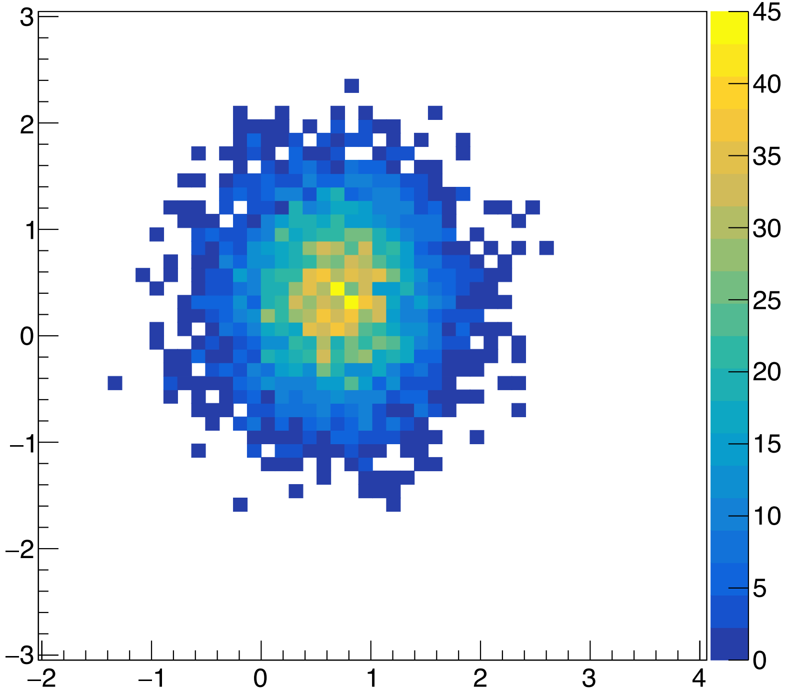
$G = (G_{GEM})^3 \rightarrow G_{GEM} = 123$ single GEM gain (to be used in the exponential extraction)

NO background,
same 10 keV ER simulated event

"old" digitization



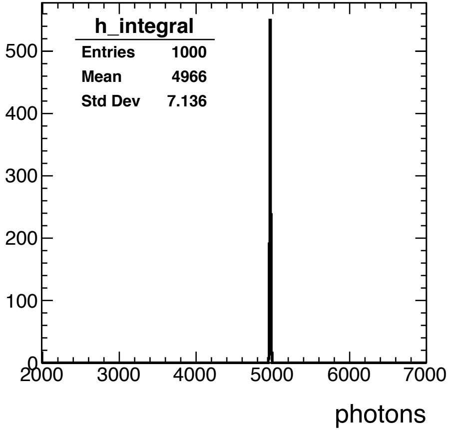
"new" digitization

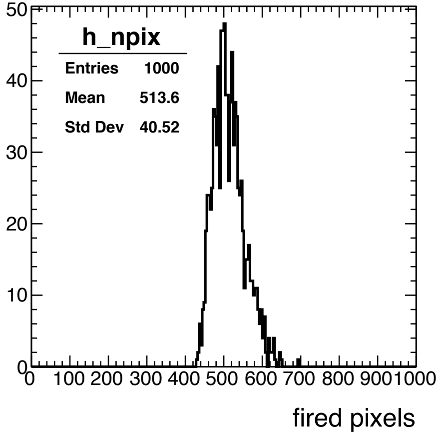


At a first glance, images looks very similar...

ER 10 keV example

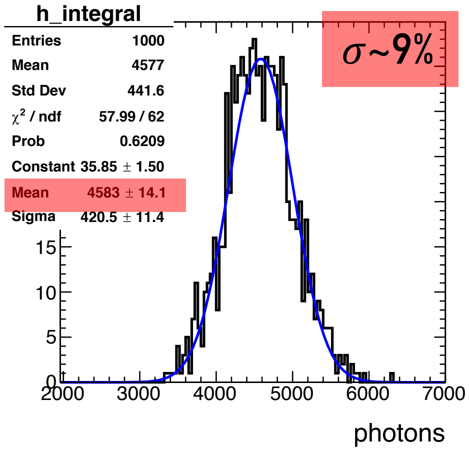
"old" digitization

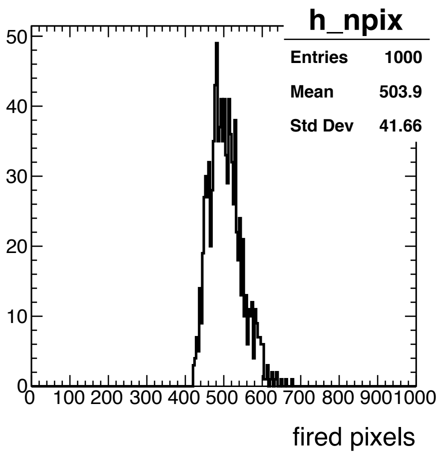




"new" digitization

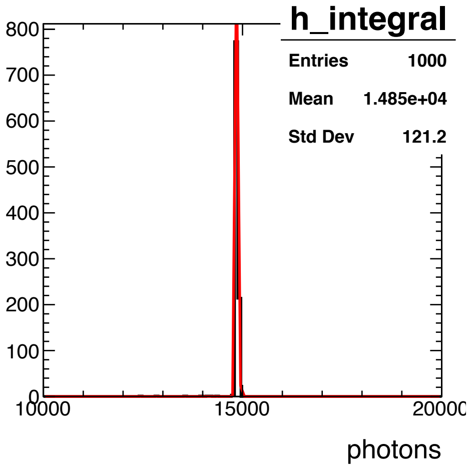
adjust the gain to properly match the light yield

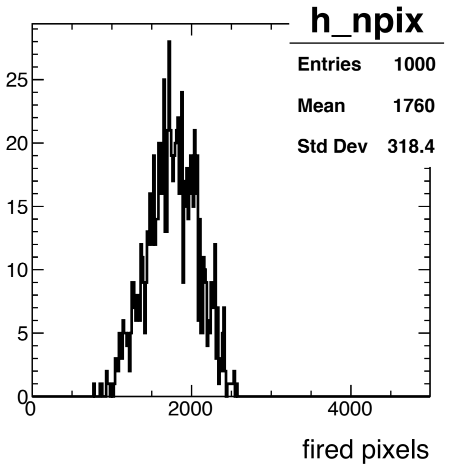




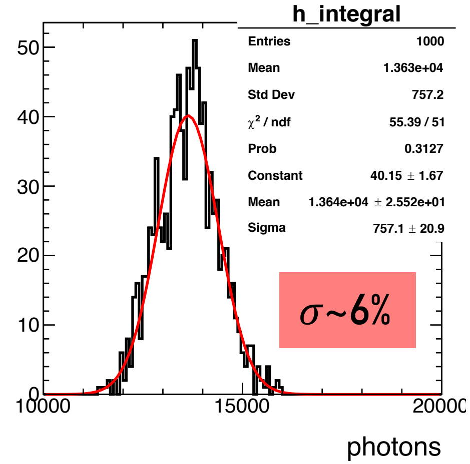
ER 30 keV example

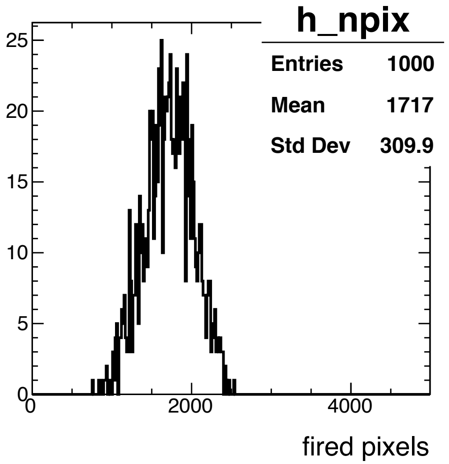
“old” digitization





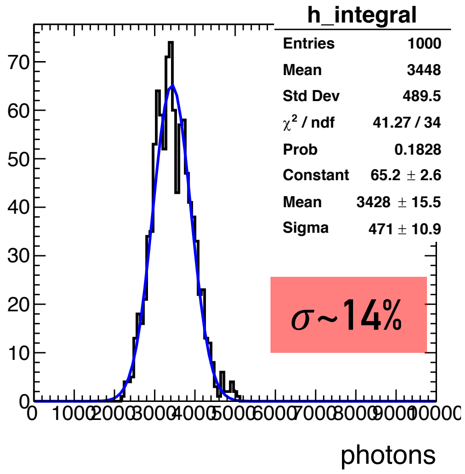
“new” digitization

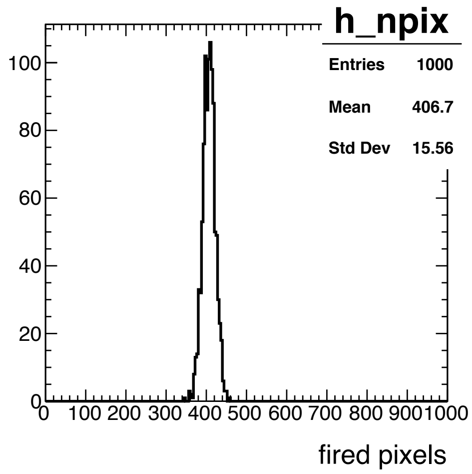




NR examples

- NR 10 keV





- NR 100 keV