CYGNO simulation plans

Giulia D'Imperio

19/09/22
CYGNO simulation meeting

Simulation progress of last months

- LIME background simulations
  - finalized shielding design for LIME underground
  - completed background simulations (energy spectrum, no hits information)
  - finalized plans for LIME measurements and MC validation
- CYGNO background simulations and ER simulations
  - full simulation for CYGNO 1m3, background for CYGNO_04 estimated from scaling
- NR simulations
  - completed framework ready using SRIM
  - improved QF simulation
- Digitization
  - introduced saturation
  - done many data/MC comparison and found the best set of parameters to reproduce data
  - improved/optimized the code

Plans & to do

- LIME background simulations
  - to be validated with LIME data underground
  - full simulation of tracks (including hits info in the output file + digitization)
- CYGNO background simulations and ER simulations
  - to do full background simulation using latest design
- NR simulations
  - produce high statistic samples to study CYGNO performance
- Digitization
  - produce high statistic samples to study CYGNO performance
- PMT simulations
  - finalize PMT simulations and integrate in digitization code

Simulation workflow

1. Interactions of ER/NR in the gas ➜ tracks (x,y,z,dE)

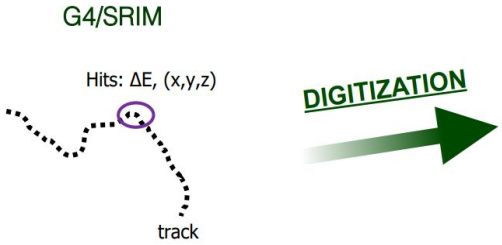
Geant4 (ER) / SRIM (NR)

2. Calculate electron diffusion in CYGNO gas

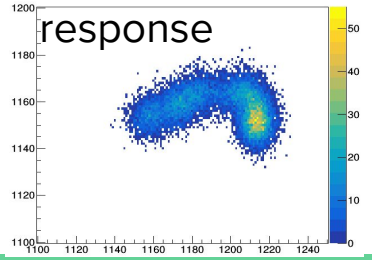
Garfield

3. Simulation of primary electrons + transport to the GEMS
4. Simulation of GEM multiplication with saturation effect
5. Simulation of light production
6. Simulation of the camera (geometry, sensor, noise)

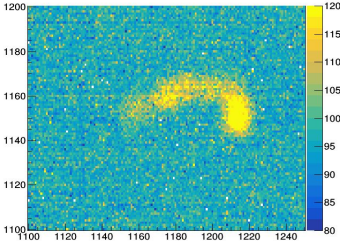
digitization code



Detector response

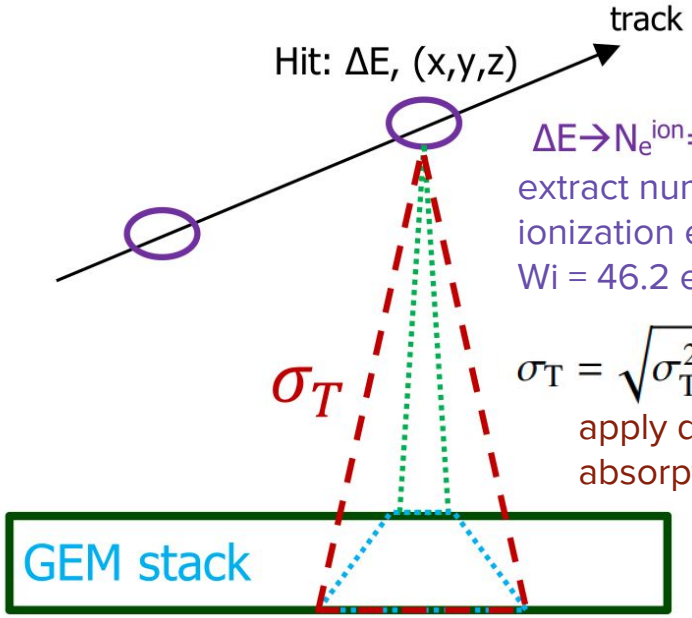


Detector response + noise



Simulation of primary electrons

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

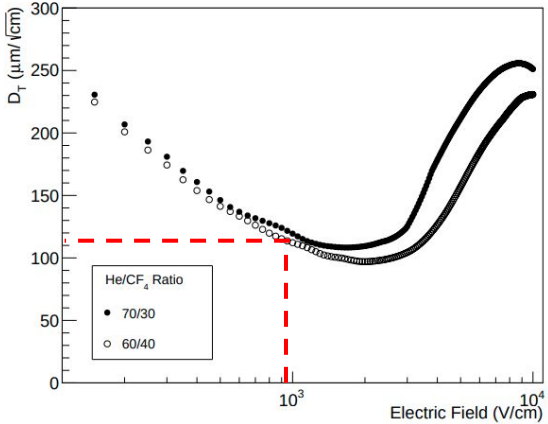
Wi = 46.2 eV

σ_T

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

apply diffusion

absorption length = 1.4 m



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

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

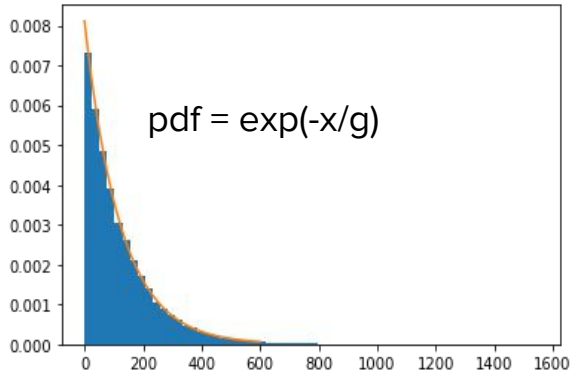
For 930V/cm drift field

Simulate electron multiplication & light production in GEM stack

F. Petrucci

GEM gain simulation

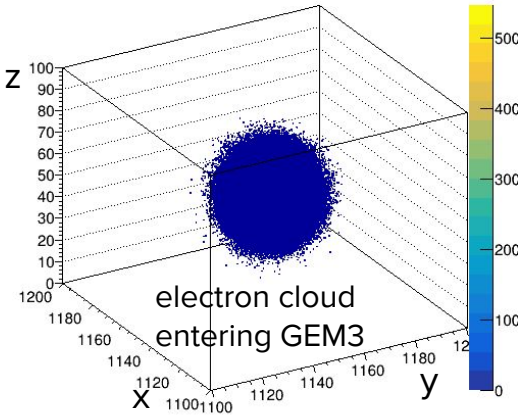
- Single GEM gain parameterized as a function of HV (portugues group measurement)
- Extraction x Collection efficiency of electrons in GEM1 and GEM2: 0.33
- Gain fluctuations:
  - Gain of 1st GEM (G1) is extracted from an exponential distributions and multiplied by $\varepsilon_{extr} \times \varepsilon_{coll}$
  - G2 from parameterization vs HV
  - G3 add saturation effect



Saturation simulation (only GEM3)

- 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
  - apply formula of saturated gain in each voxel

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

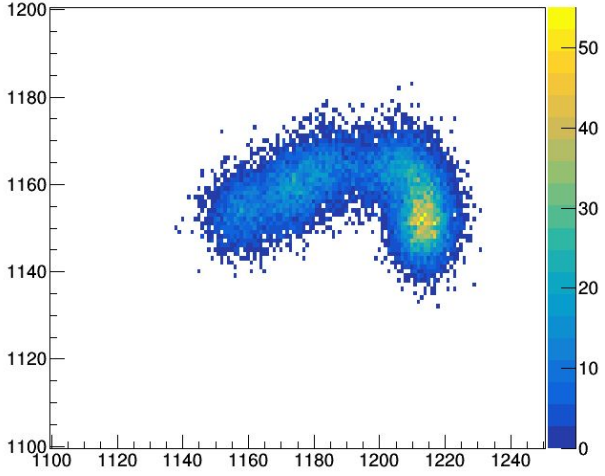


Parameters of saturations tued with comparison with ^{55}Fe data:

- A = 1.47 (free parameter of the model)
- beta 1e-5

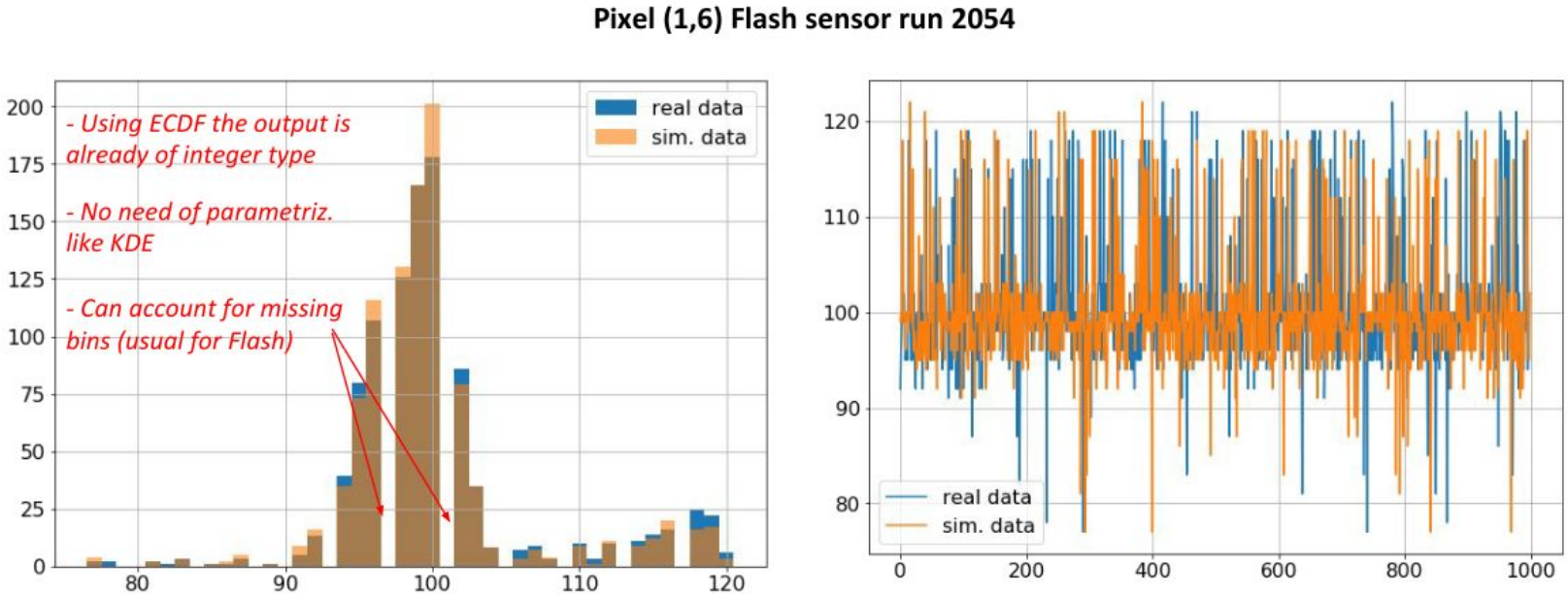
Simulation of light production

- ORCA Fusion:
  - 2304 x 2304 pixels
  - Camera aperture 0.95
  - Sensor size 14.976 mm
  - Sensor calibration ➜ 1 photon = 2 sensor counts
- Active area: 34.6 cm x 34.6 cm (for LIME)
- Diffusion parameters from https://arxiv.org/pdf/2007.00608.pdf
  - sigmaT0 : 350 um, sigmaT : 0.11 mm/sqrt(cm)
  - sigmaL0 : 260 um, sigmaL : 0.099 mm/sqrt(cm)
- Geometry factor of light collection: $\Omega=1/(4(d+1)*a)^2$
  - d = ratio between image size (346 mm) and sensor size (14.976 mm)
  - a = camera aperture (0.95)

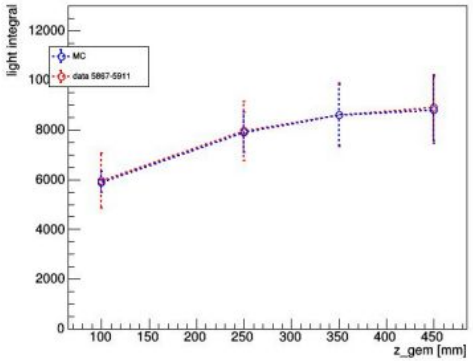


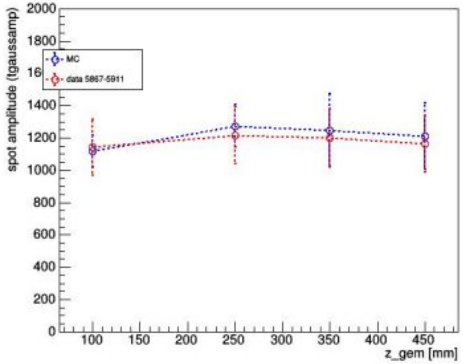
Simulation of camera noise

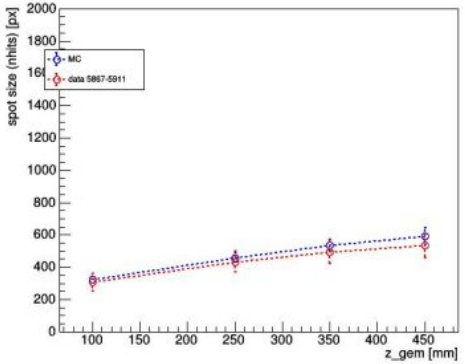
Simulation using ECDF

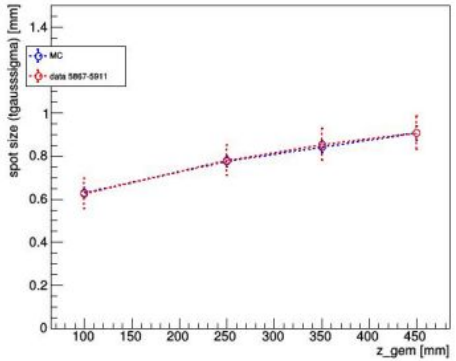


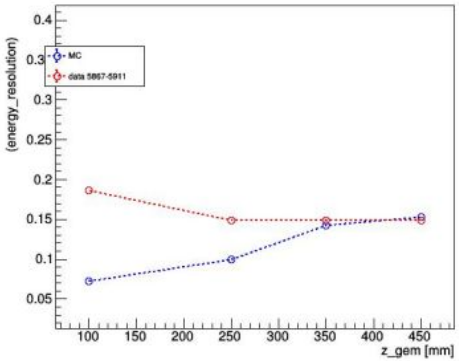
Comparison with ^{55}Fe data z scan







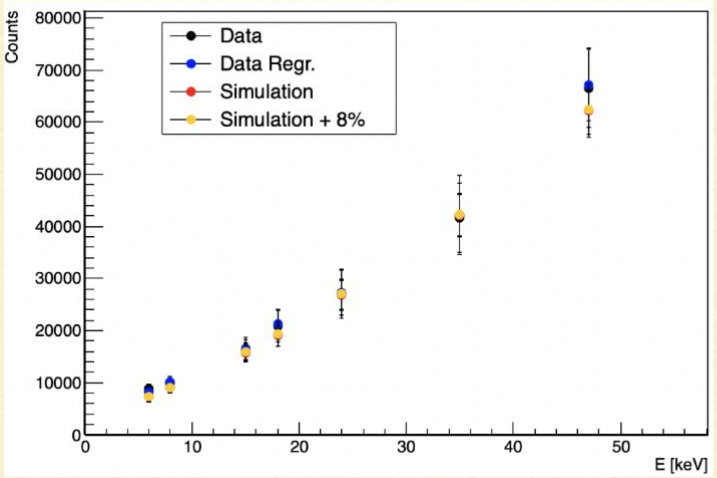


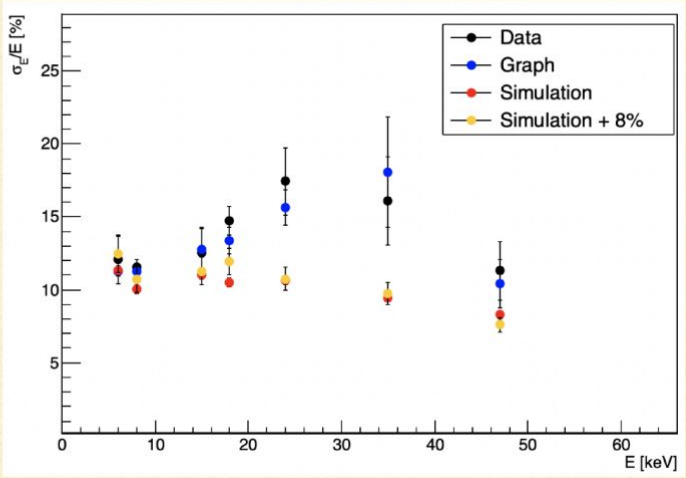


Best digitization parameters
(z_rand=0 mm)

Comparison vs data xray sources

- Data < 300 px
- Regressed data < 300 px
- Simulation with fluctuation before sensor + vignetting < 300 px
- Simulation with fluctuation before sensor + vignetting + 8% gaussian fluctuation on electron exiting from GEM 3 (overall fluctuation to take into account variation on GEM 2 and GEM 3)





Who does what?

- LIME background simulations
  - to be validated with LIME data underground
  - full simulation of tracks (including hits info in the output file + digitization)

  Flaminia, Giulia + ?
- CYGNO background simulations and ER simulations
  - to do full background simulation using latest design

  Giulia + ?
- NR simulations
  - produce high statistic samples to study CYGNO performance

  Flaminia + ?
- Digitization
  - produce high statistic samples to study CYGNO performance

  Samuele + ?
- PMT simulations
  - finalize PMT simulations and integrate in digitization code

  Mariana, Rafael + ?

INFN Cloud

- We should move simulation workflow to INFN cloud
  ➜ in principle easier to upgrade resources (cpu, storage)
- Geant4 simulation tested on cloud and working
- Condor queues tested and working
- Digitization not yet tested but in principle possible
- Reconstruction tested...?

The best is to do all the steps (simulation+analysis) on the cloud