CYGNO simulations update

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18/09/23
CYGNO simulation meeting

Open developments

- Improve data/MC agreement of LIME background spectra
  - LIME underground run 1 (no shield), run 2 (4 cm Cu), run 3 (10 cm Cu)
- Simulation of X-Y non-uniformities in images (“vignetting effect”)
- Improve data/MC agreement of source data (energy resolution)
  - data from 55Fe, multi x-ray source, AmBe
- Simulation of sensor readout
  - incomplete tracks
- PMT simulations
- CYGNO-04 background

Datasets useful for data/MC comparisons

Milestone by the end of 2023: MC validation with data/MC comparisons

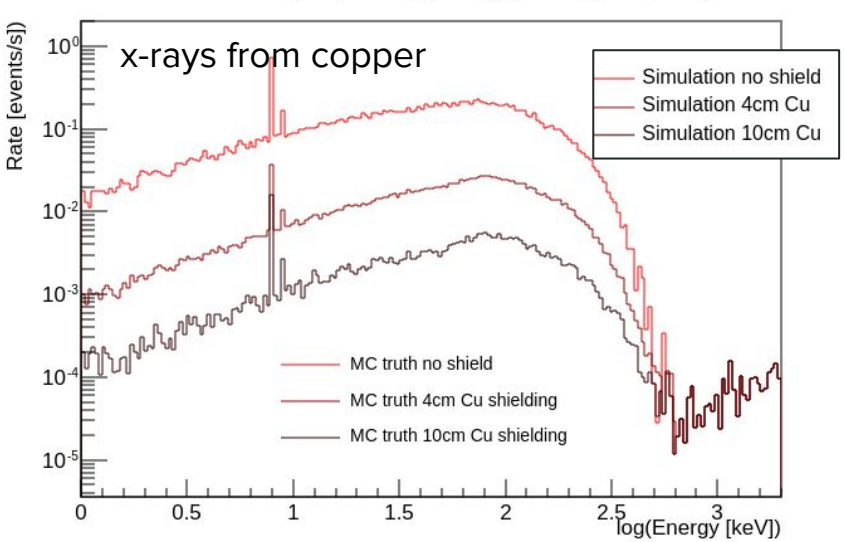
- LIME source data:
  - 55-Fe scan vs z and HV (LNF, underground LNGS)
  - X-ray multi-source scan vs z (LNF)
  - Am-Be (LNF, underground LNGS)

- LIME background data
  - Run 1 ➜ no shield
  - Run 2 ➜ 4 cm copper shield
  - Run 3 ➜ 10 cm copper shield

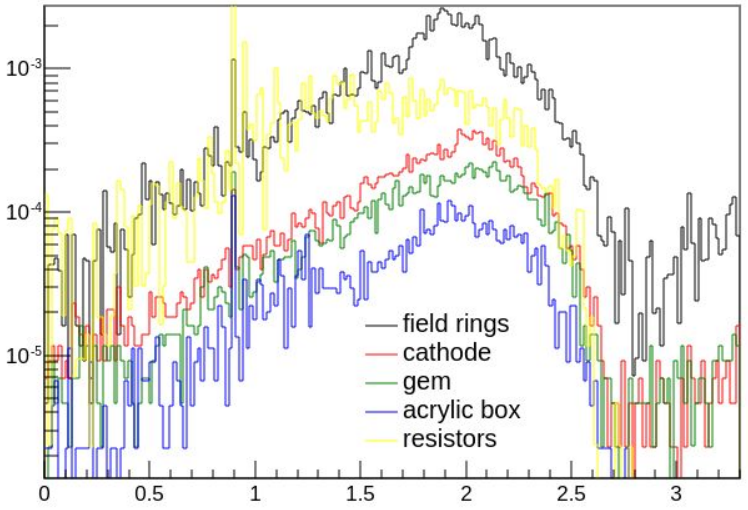
Simulations of LIME underground

- Monte Carlo truth ➜ energy spectrum from Geant4 simulation
- Copper x-rays ~8 keV (setup parts activated by external gammas)

External + Internal backgrounds



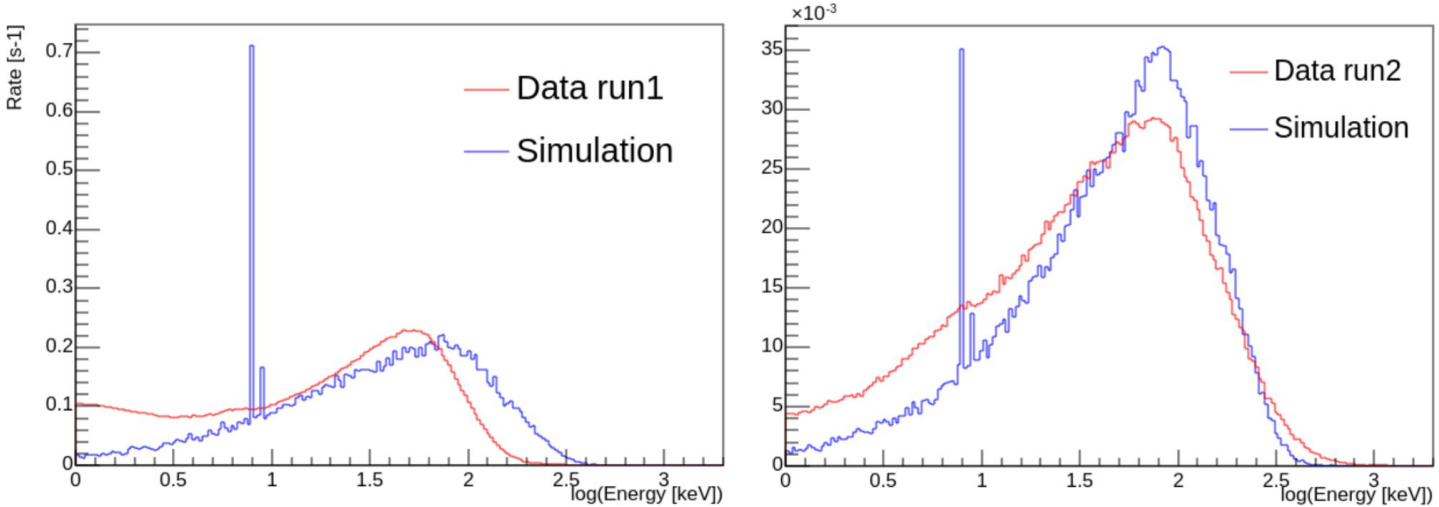
Internal backgrounds only



Note the log scale ➜ x=0 corresponds to 1 keV energy

Data/MC comparison of LIME underground

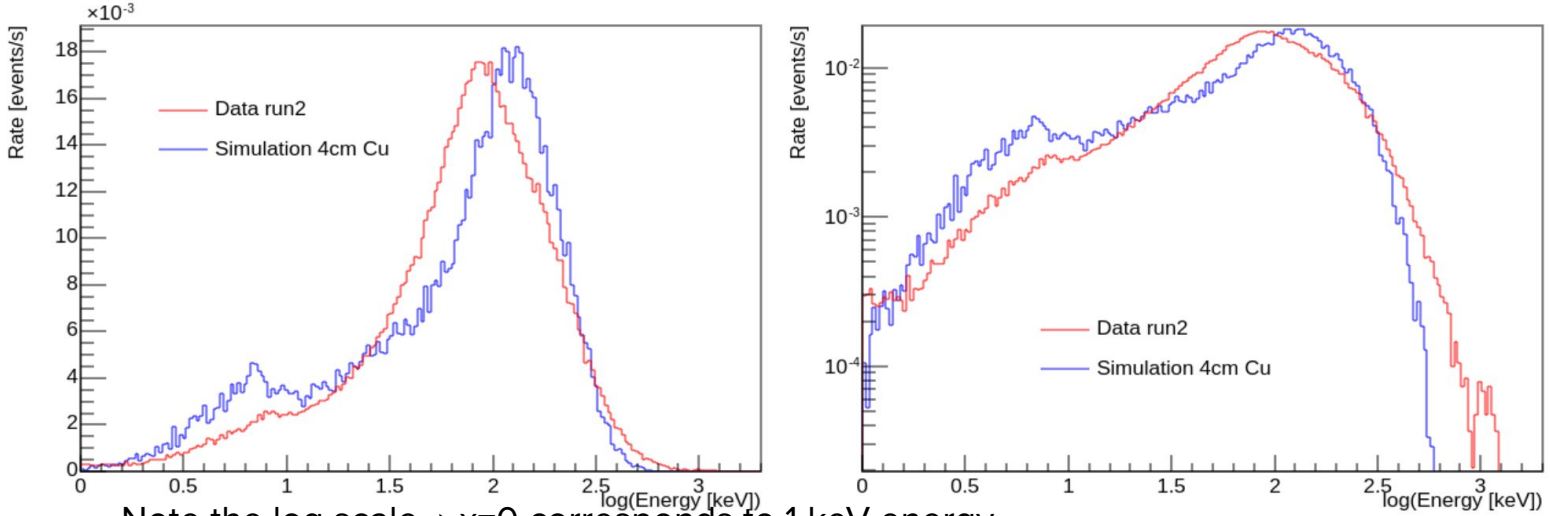
- Monte Carlo truth (energy spectrum from Geant4 simulation)
  ➜ detector effects (resolution, etc) NOT included
- Data from LIME underground runs



Note the log scale ➜ x=0 corresponds to 1 keV energy

Data/MC comparison of LIME underground

- Full Monte Carlo: Geant4 + digitization + reconstruction
  ➜ takes into account efficiencies, energy resolution and linearity
- Data from LIME underground runs



Note the log scale ➜ x=0 corresponds to 1 keV energy

Summary LIME background MC

- Spectrum shape is qualitatively in agreement between data and MC
- Low energy calibration ok, high energy calibration some disagreement

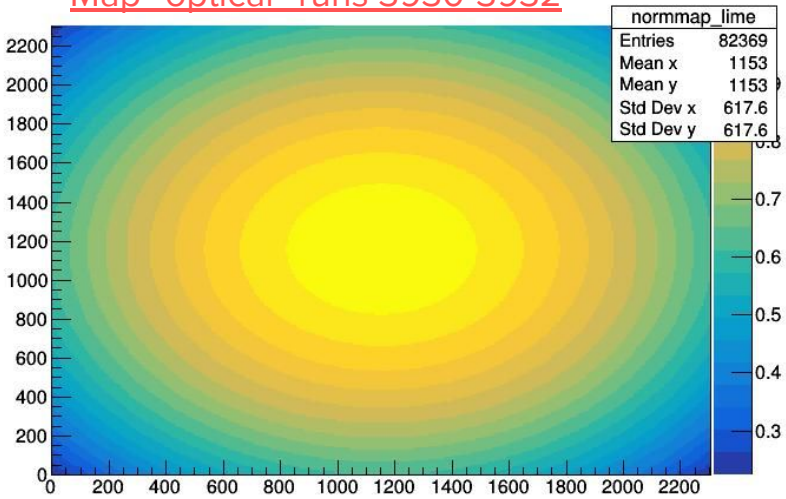
Caveats in previous plots:

- Sensitive region in simulations 32 x 32 cm^2 vs GEM area 34 x 34 (?) cm^2
- Cut in MC energy < 500 keV for digitization
- Sensor readout time effect not included
- Vignetting effect: only optical correction applied in reconstruction

X-Y non-uniformity

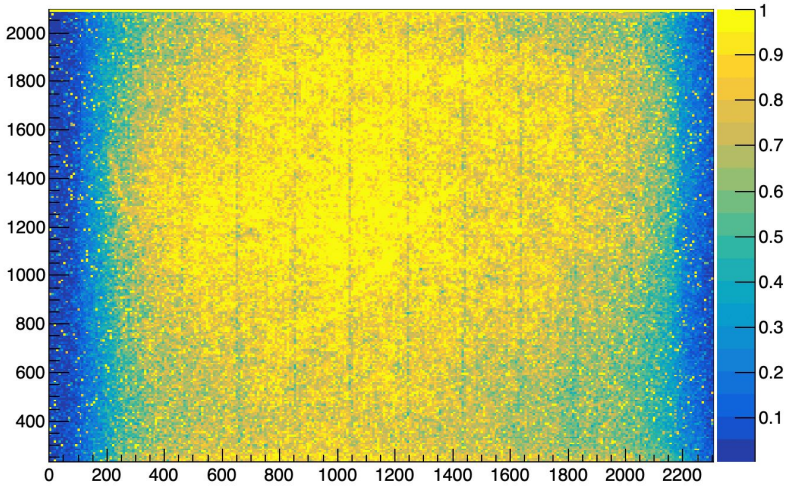
- Optical vignetting form the lens
- Other non-uniformities (field, GEM, gas, ...)

Map “optical” runs 3930-3932



- Obtained from pictures to white wall
- Includes only optical vignette from the lens

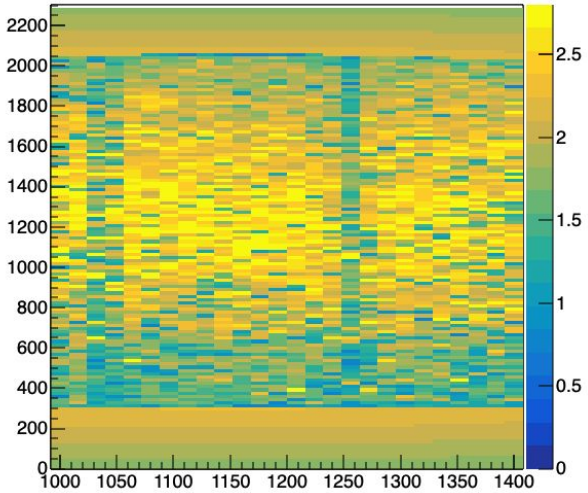
Map “cosmics” run 4117



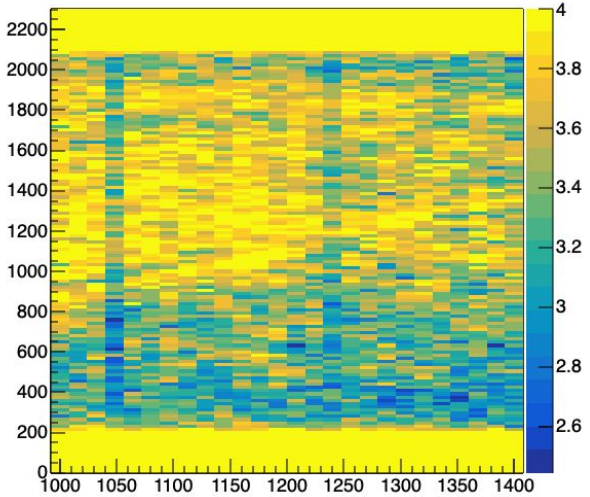
- Obtained from long exposure to cosmics @LNF
- Includes **all** non-uniformities

Regression correction vs X-Y non-uniformity

- Optical vignetting correction applied in the data reconstruction
- Regression should correct residual non-uniformities of the response (X-Y but also Z), trained in the center of the sensor with 55-Fe data
- Effect of regression+vignetting in the center of the sensor similar to “cosmics” map



Ratio Energy regression/raw



Cosmics map run 4117

Proposed test

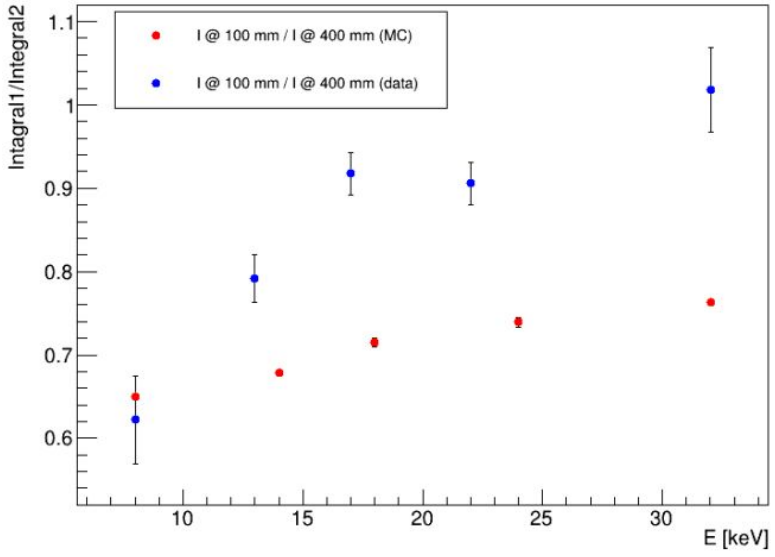
- Include xy non-uniformities with “cosmics” map in MC
- Reconstruct both data and MC of 55-Fe using cosmics map correction
- Reconstruct both data and MC of 55-Fe using optical map correction
- Compare energy resolution (no regression) data/MC in the two cases
- Check center of the sensor vs border of the sensor

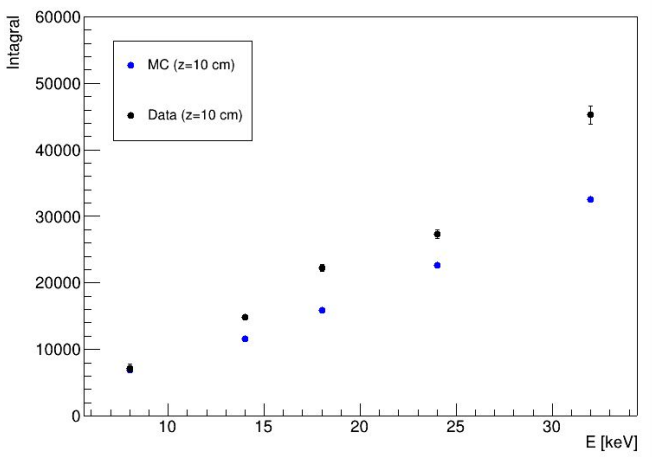
If energy resolution is better with
cosmics map correction

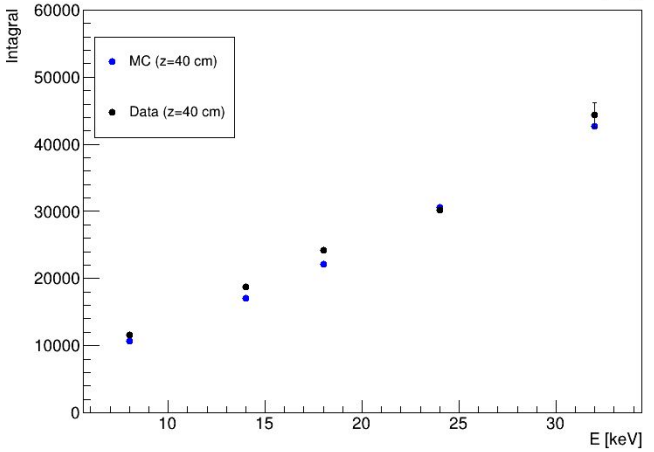
- Re-train regression after the cosmics map correction
  - now regression should correct only for z non-uniformities
- Apply regression to both data and MC reconstruction
- Compare data/MC with and w/o regression (after re-training)

Saturation effect vs track energy

- Data from x-rays multi source z scan (run 4470-4489)
- Saturation effect in MC seems not well modeled for energy > 10 keV and small z







Proposed test

- Check data/MC agreement at different z
  - other z scans?
  - can we select on z on LIME bckg data?

- Check data/MC agreement vs x-y selection
  - center of the sensor vs border of the sensor
  - both source and background data

➜ this should help to understand if we are treating vignetting correctly

- Plot Energy true vs Energy digi
  - both source and background data

➜ how digi(+saturation) shifts energy

Sensor exposure effect

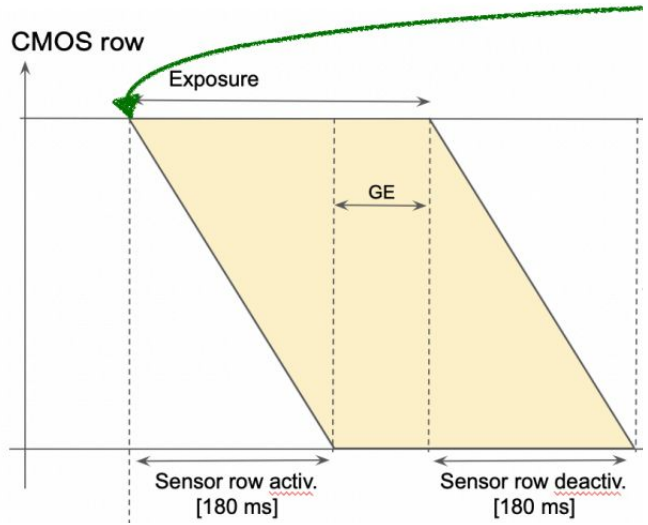
1. Simulate x between 0 and 480

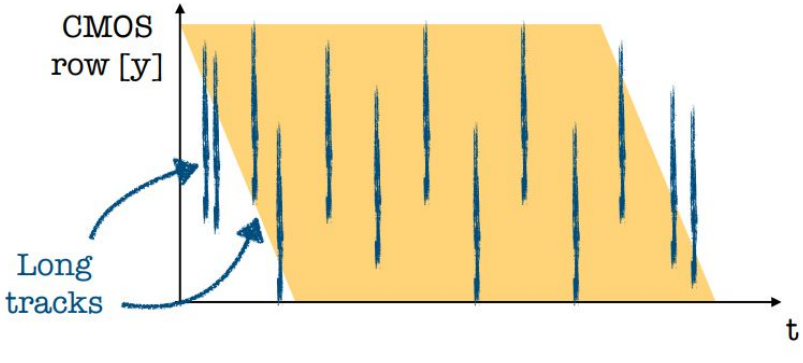
2. If x < 180 ➜ cut track below line x * 2304/180

3. If 180 < x < 300 ➜ save all track

4. If x > 300 ➜ cut track above line (x-300) * 2304/180

This was recently included by Flaminia, not yet merged in github master. See Flaminia's slides.





Optimize file format

Present file format produced by digitization is not optimized:

- images containing the sum of signal + noise
  ➜ noise from pedestal runs (limited number of images repeated many times)
  ➜ no flexibility if exposure time changes
  ➜ no access to signal only

Proposed format:

- signal only image ➜ full track
- additional step before reco to simulate the sensor readout time and add pedestal

Tasks & people

- Improve data/MC agreement of LIME background spectra — **Flaminia**
  - LIME underground run 1 (no shield), run 2 (4 cm Cu), run 3 (10 cm Cu)
- Simulation of X-Y non-uniformities in images (“vignetting effect”) — **Samuele**
- Improve data/MC agreement of source data (energy resolution) — **Samuele + Pietro**
  - data from 55Fe, multi x-ray source, AmBe
- Simulation of sensor readout — **Flaminia + ?**
  - incomplete tracks
- PMT simulations — **Pietro + Stefano**
- CYGNO-04 background — **Giulia + ?**
- Optimize file format — **?**