Summary of latest acivities on reconstruction and analysis

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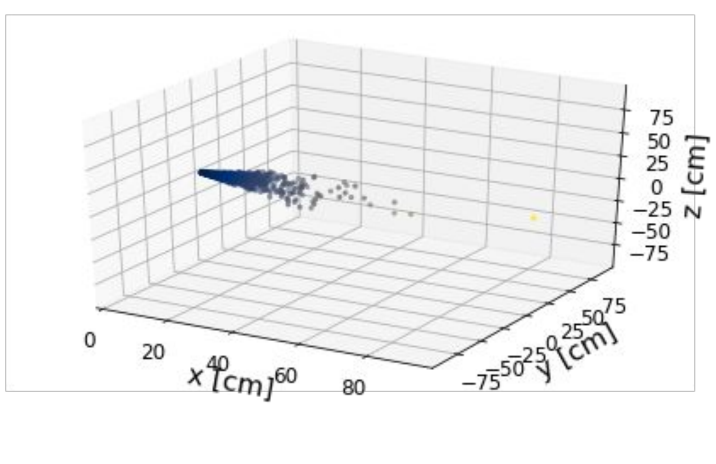
General meeting, 13 October 2022

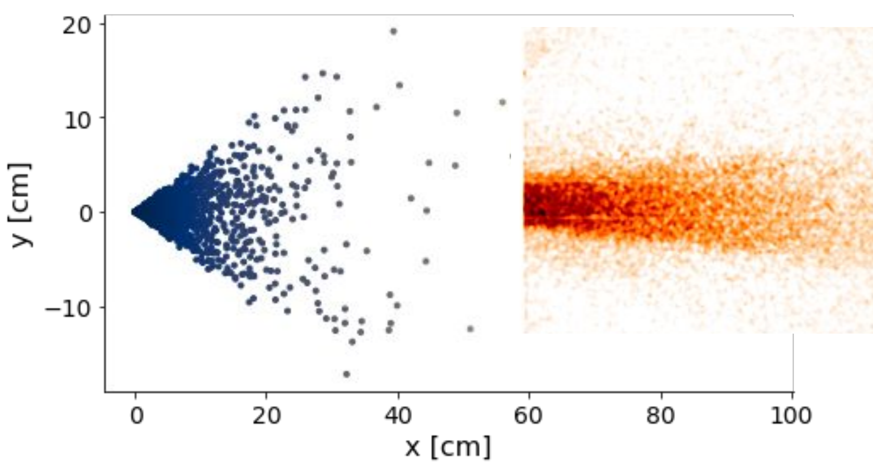
Absorption length study

- Lime data with ^{55}Fe used to measure the gas absorption length (λ)
  - projecting the flux in 2D decreases the “apparent” assorption length (λ_{eff})
  - the bias in the estimate depends on the opening angle of the beam (α)

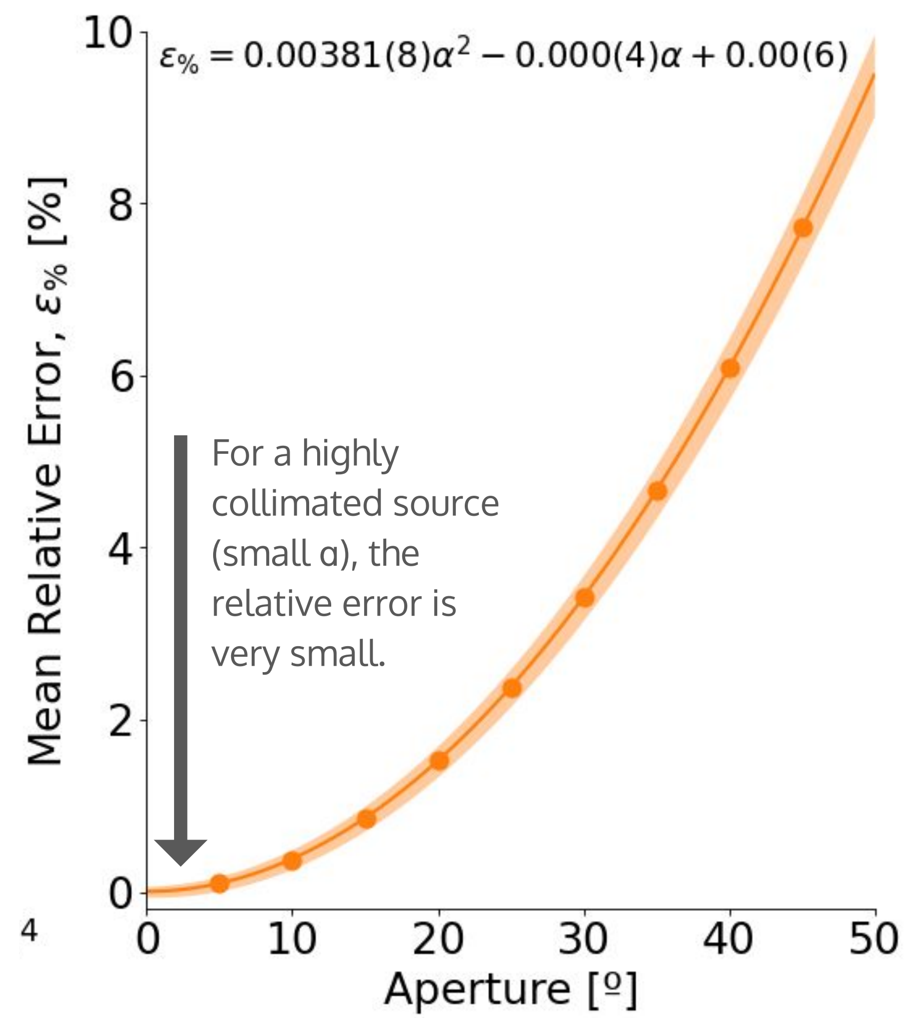
3D Real Case



2D Projection (what we are doing)



Rita Roque



- Toy MC to compute the bias vs α: can be used to correct the bias knowing α
- It could be applied to the λ measurements done with different sources (measurements at E< 6 keV to be checked also for the high bkg contribution)

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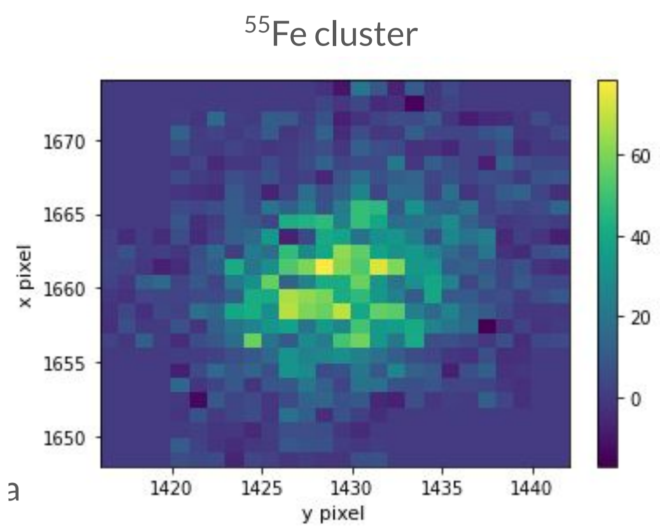
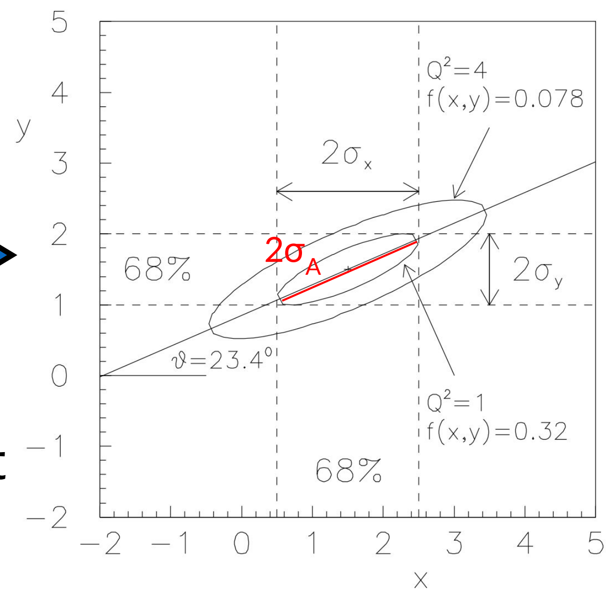
Optical effects: analysis

- Use the ^{55}Fe clusters cluster shapes (resolution vs x and y σ_x and σ_y) to check possible optical distortions of the image

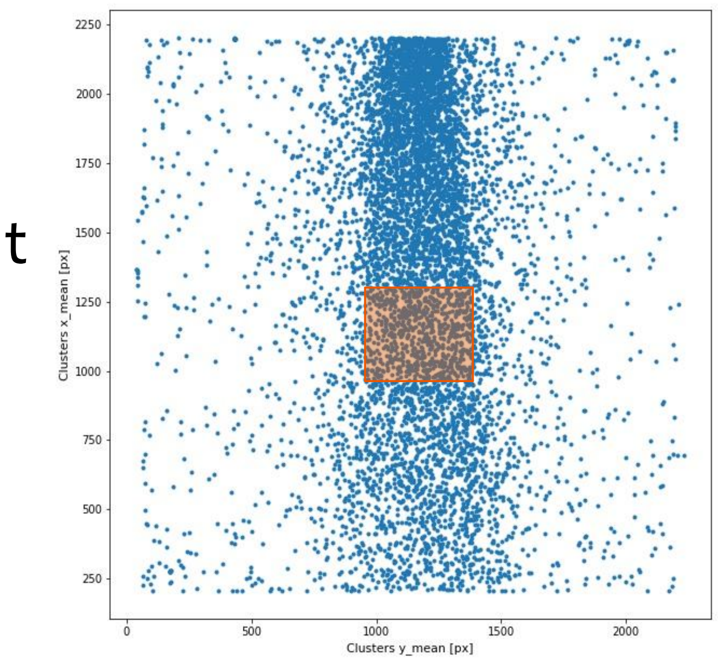
Francesco Borra

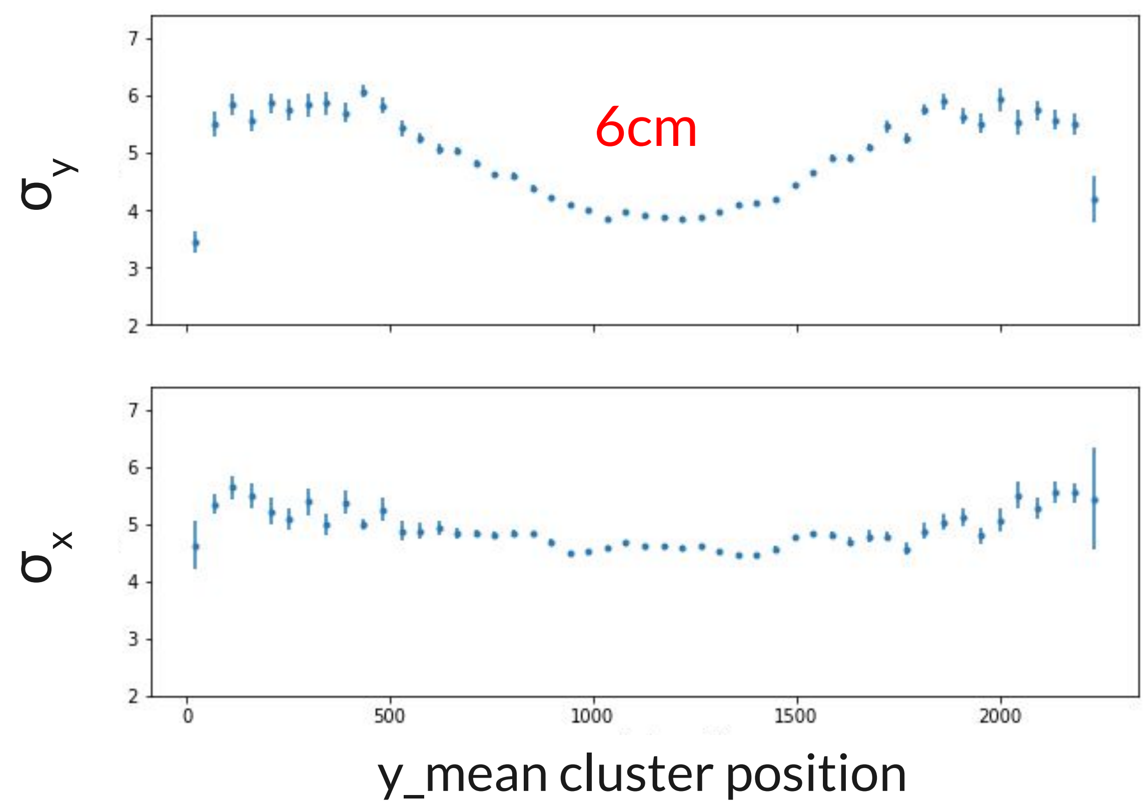


principal component analysis



in different zones: vs X, vs Y





It seems that σ_y (and also σ_x for a smaller extent) depends on the position of the cluster

Possible cause: optical distortion of the image.

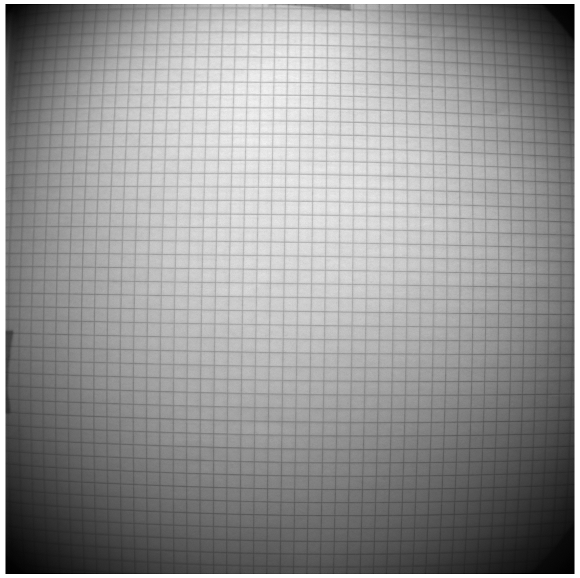
Can we cure it? ==> see next slide

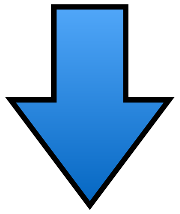
Optical distortions: corrections

- This known effect can be cured with standard image correction packages.
  - eg OpenCV python library
- It needs a calibration image using a grid of straight lines
- Tested with MANGO camera setup

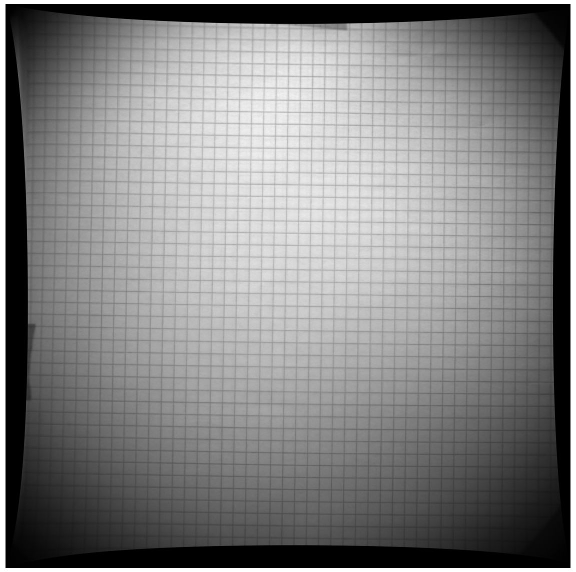
- Open points: the correction depends on the inclination of the camera wrt the GEM plane:
- it would need a "calibration" image in-situ.
  - we use the vertical lines of the GEM modules, but they are in one direction only
  - need to be well illuminated

Original





Corrected

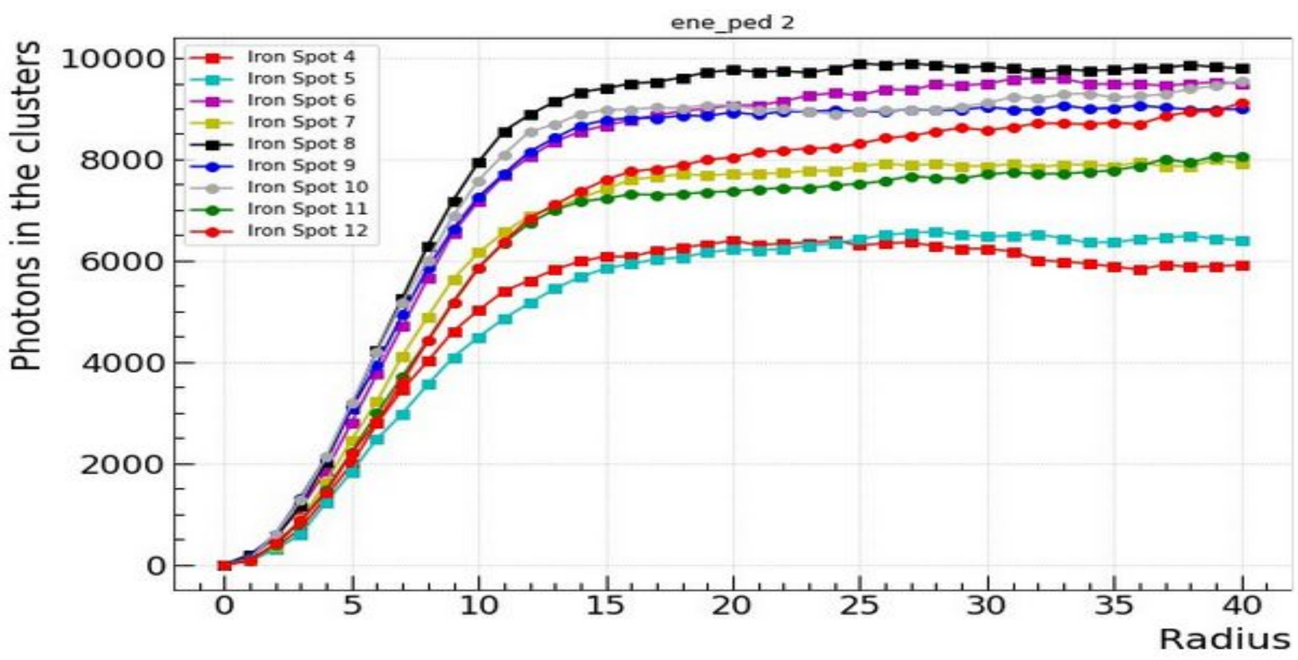


Stefano Piacentini

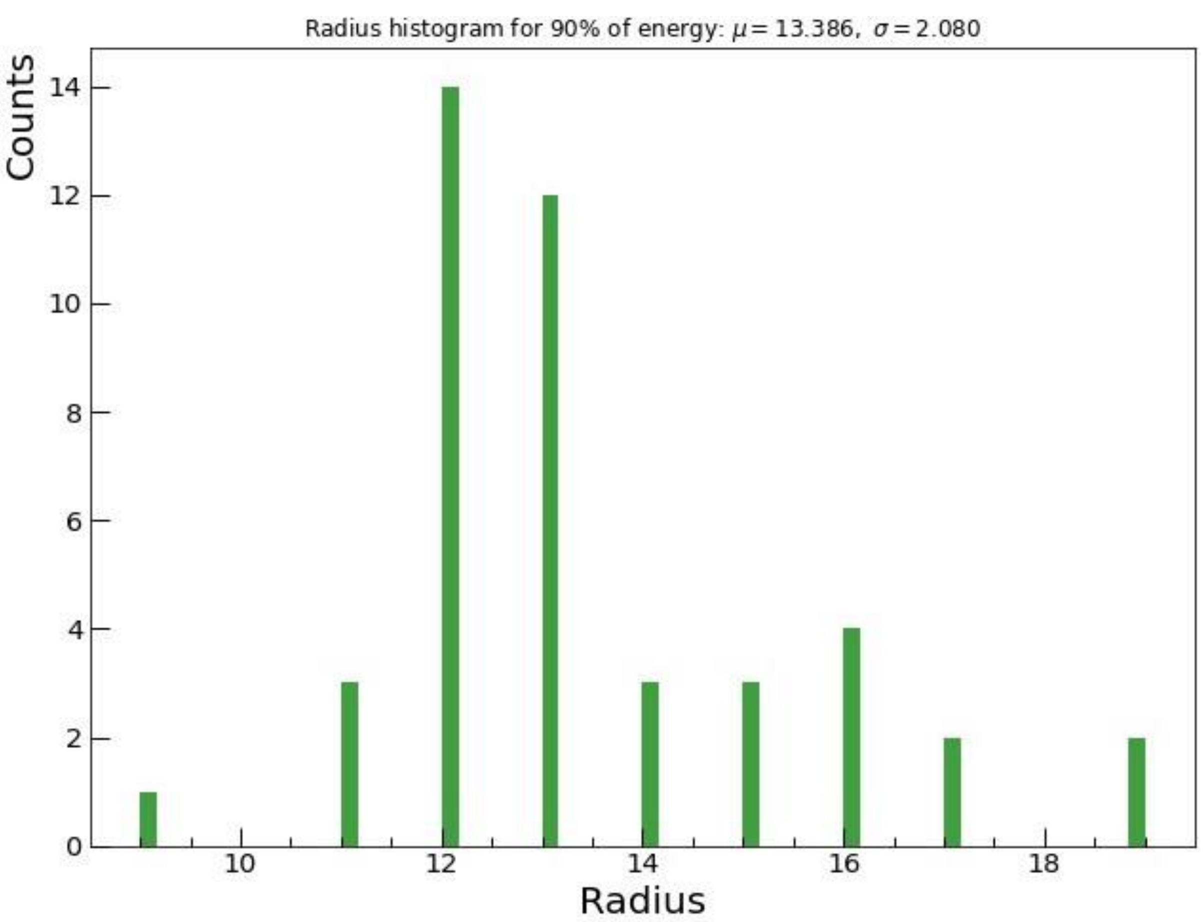
Clustering efficiency vs xy position

- ^{55}Fe clusters used also to study efficiency of reconstructing a cluster and efficiency of gathering all the illuminated pixels in a cluster
  - optimize the seed cluster (DBSCAN) radius

Lucas Coelho



Radius for 90% of the iron spot energy.

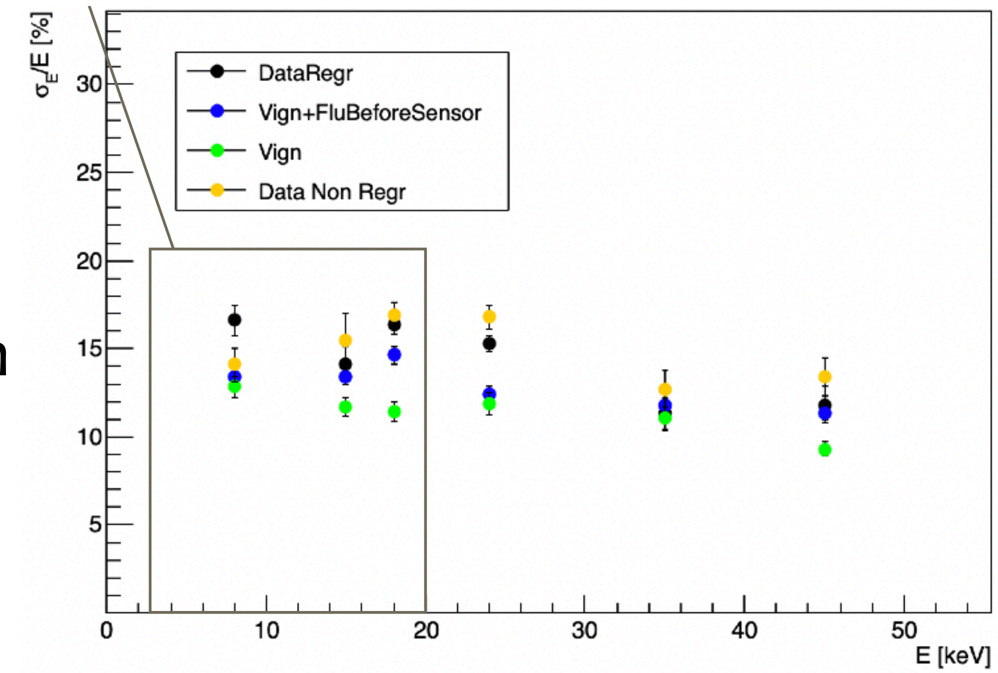


- The collected light depends on the position in x,y, as expected, but the efficiency plateau is reached for the same radiuus (~12 pixels)
  - => common cluster seed parameters for every position in x-y can be used

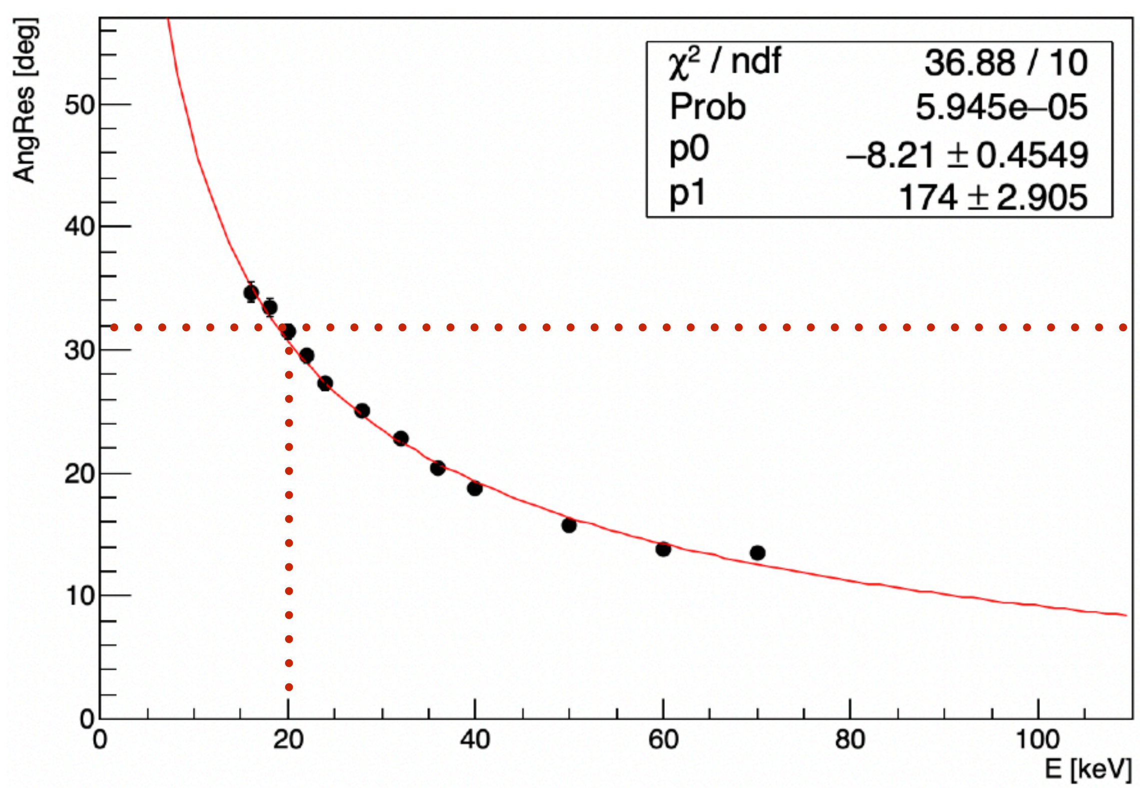
Update on directionality

- Study of the angular resolution of the colliding particle in simulation with improved:
  - algorithm parameters (optimized)
  - newest cluster reconstruction code (current LIME one)
  - newest saturation, diffusion, gain fluctuations in the SIM

Samuele Torelli



- Sanity check that the these changes improve the Data/Sim agreement for energy response and resolution



$\approx 32^{\circ}$ for E~20 keV improved wrt last study

Also Impact Point resolution improved:
~1 mm for E=20 keV

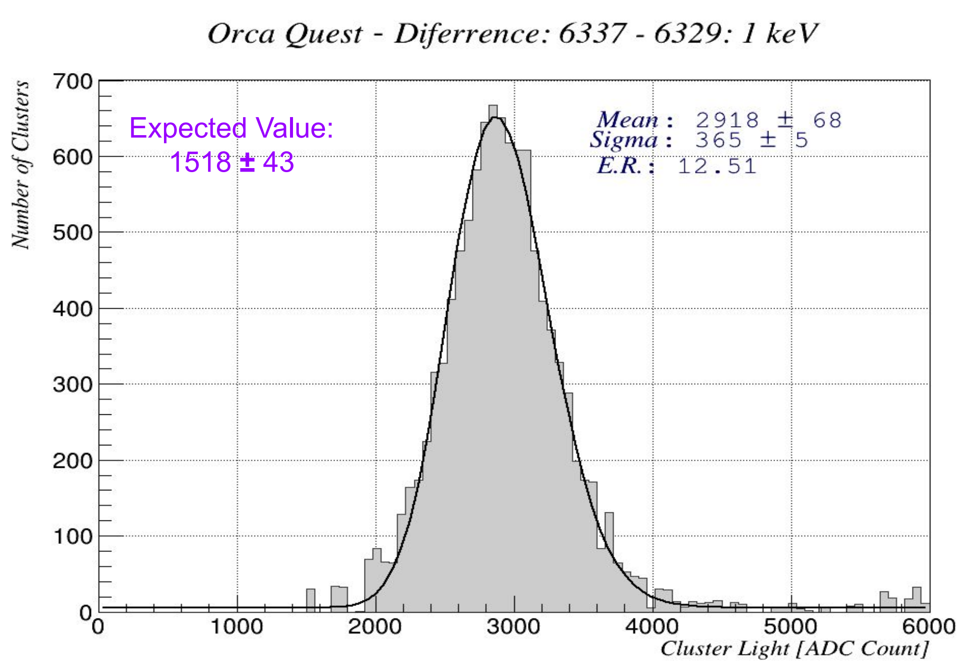
Starting to apply this for the Solar neutrinos case

Sensor noise and effect on energy

- Measured the noise for different sensors
  - Orca Fusion BT, Orca Quest, Thorit

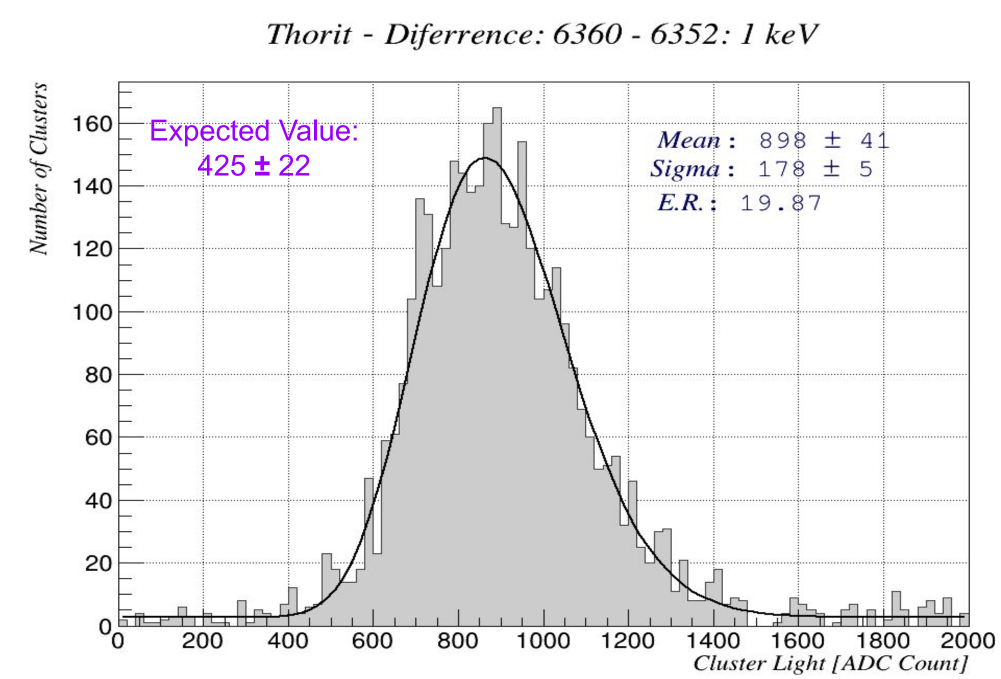
Bernardo Deps

- Evaluate sensitivity (ADC count per keV) and energy resolution of each sensor
- Evaluate detection performance with 5.9 keV ^{55}Fe for different V_{GEM} values (to mimic lower energies: E = [6, 5, 2, 1, 0.5, 0.3] keV



Eg. Quest, E~1 keV

$\sigma_E/E \approx 11\,\%$



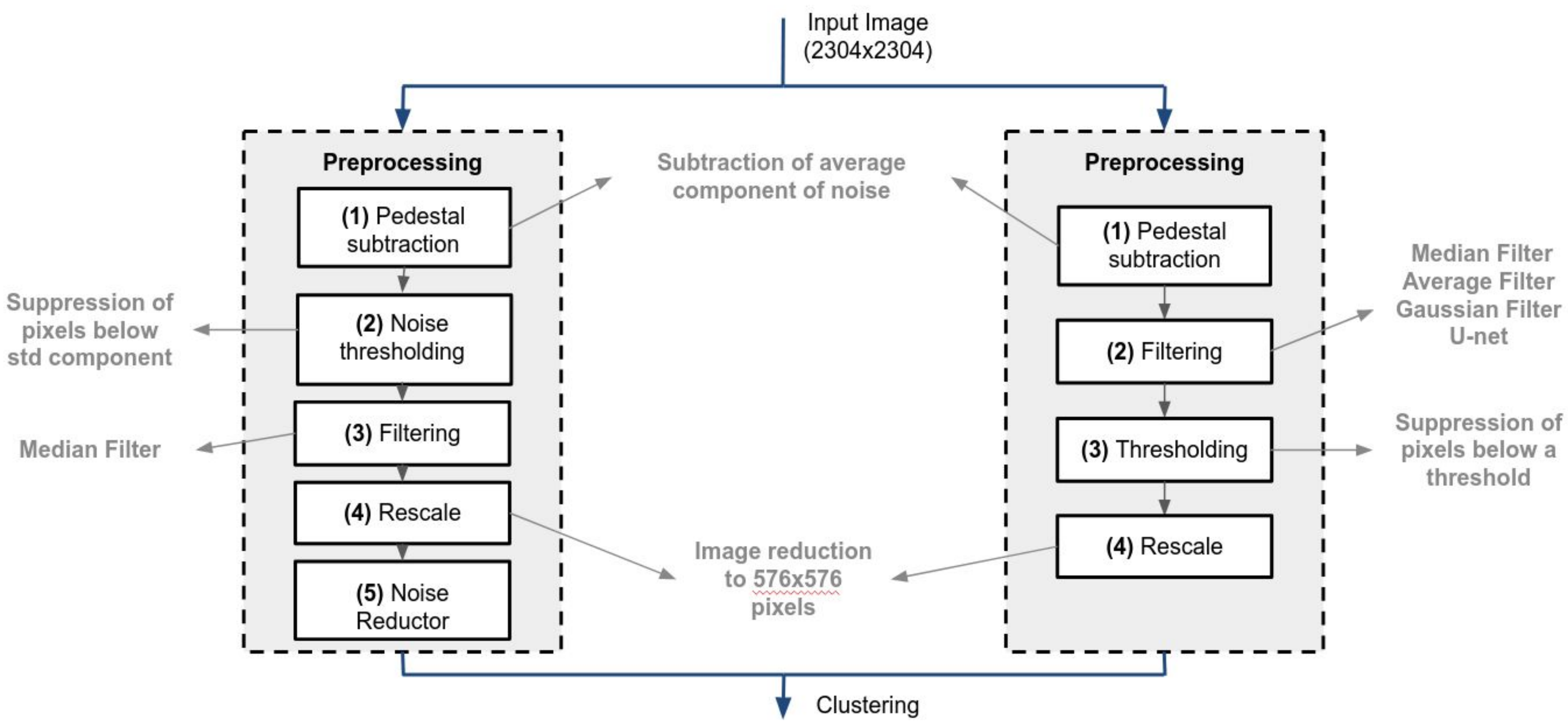
Eg. Thorit, E~1 keV

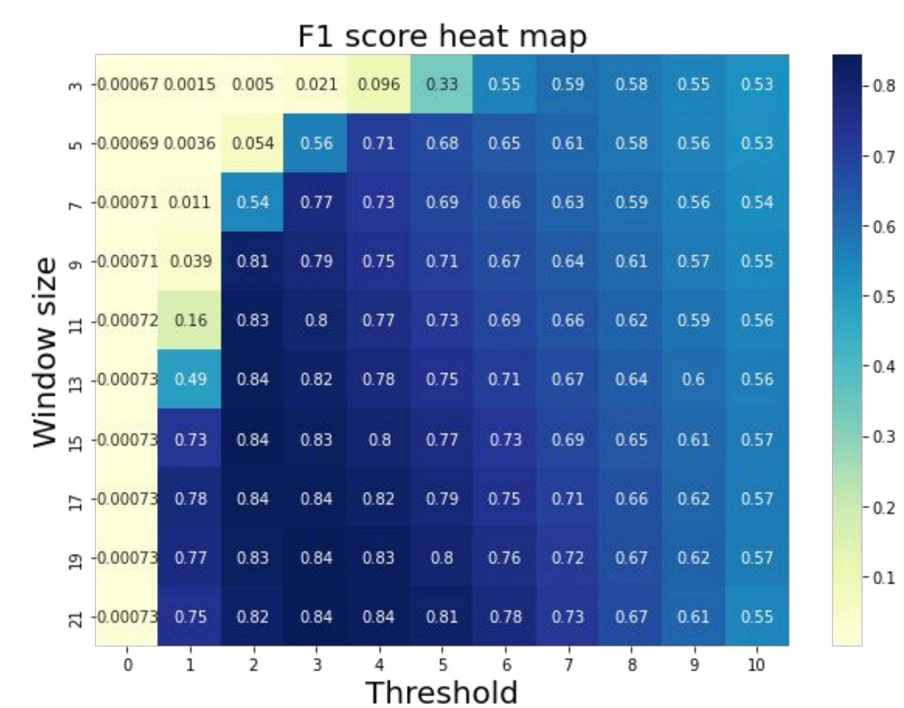
$\sigma_E/E \approx 20\,\%$

Noise filtering

- We currently use a simple zero-suppression based on measured pixel noise, then a median filter
- studies to improve with alternative algorithms: Gaussian filter, average filter, NN…

Igor Pains





optimization of filter parameters (eg average filter)

- each filter has been systematically been optimized.
- after optimization not huge differences, but it seems that the current one is best for efficiency, others improve the fake rejection

Usage of AI here and there

- Neural networks studies in different steps:
  - Trigger (CNN)
  - Noise filtering (U-net structure)

Guilherme Lopes

Test of noise filtering with U-Net

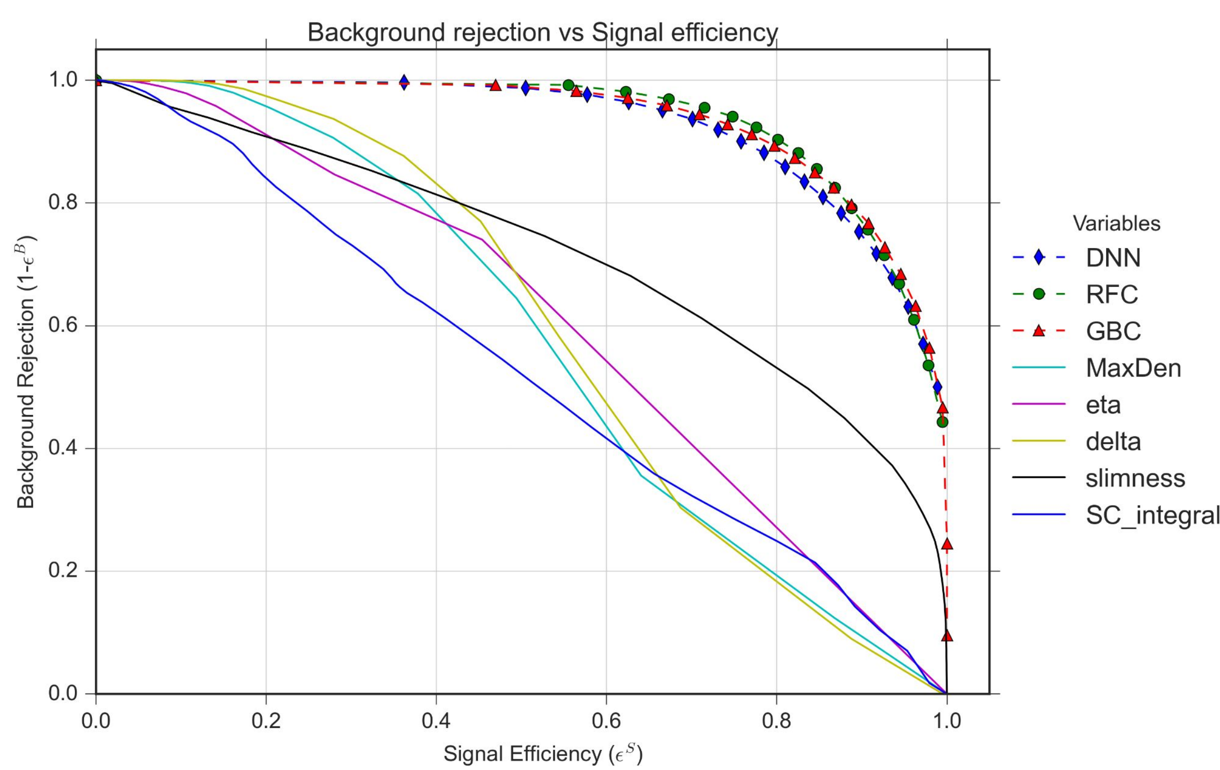
Algorithm	Total time (869)(1 core)
cygno	55h 30m
median	**12h 04m**
U-Net (1x GPU P4 16 Gb)	**5h 32m**

~ 4.5x faster
using median

~ 10.0x faster
using U-Net(gpu)

- Cluster discrimination
  - tested DNN, vs Random Forest, Gradient Boost Classifier
  - from simulation overperforming single input variable discrimination

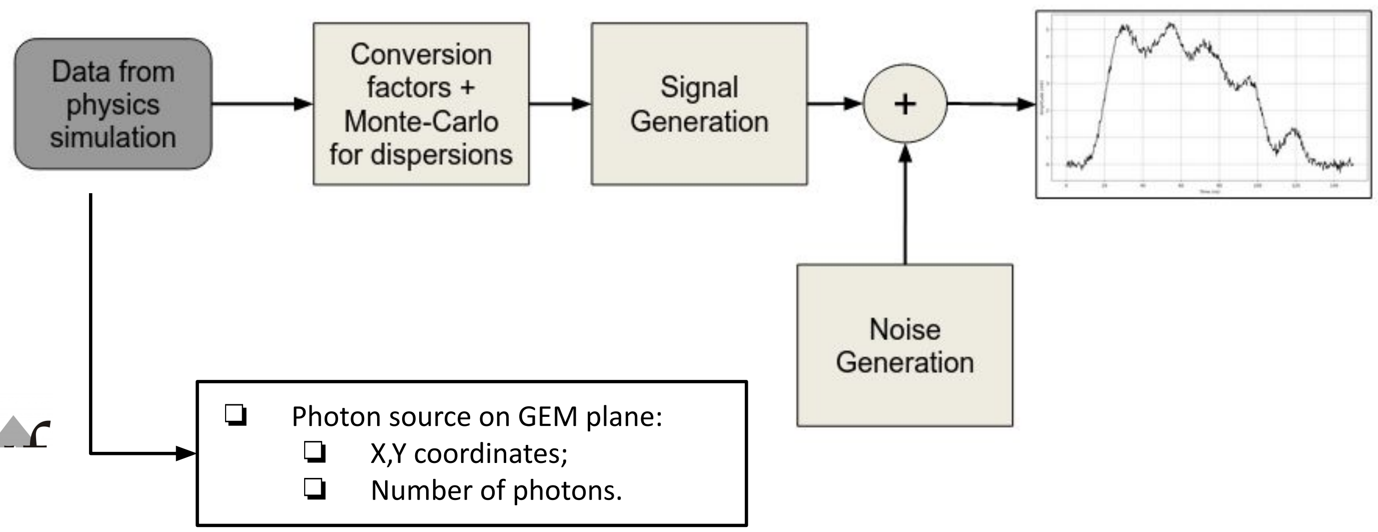
Atul Prajapati

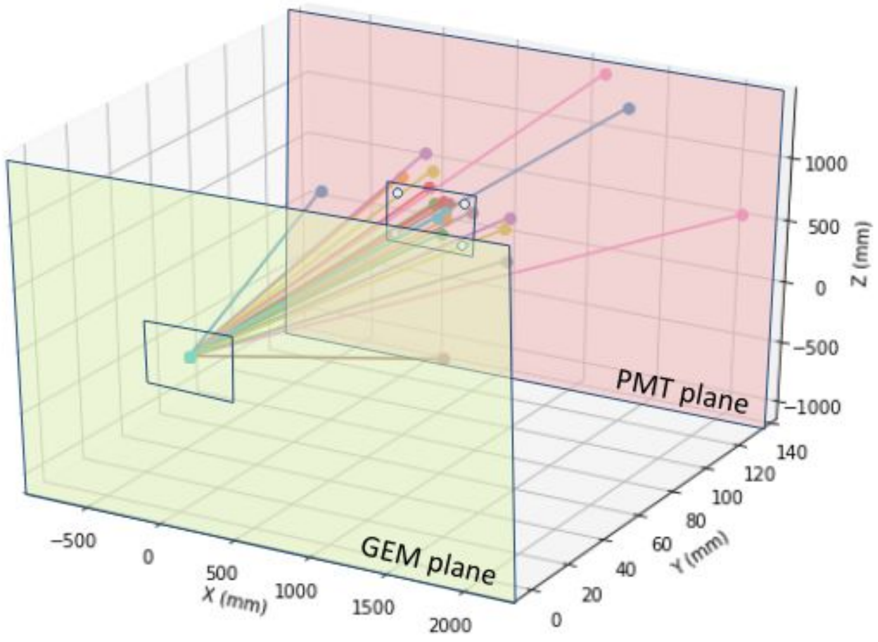


PMT simulation

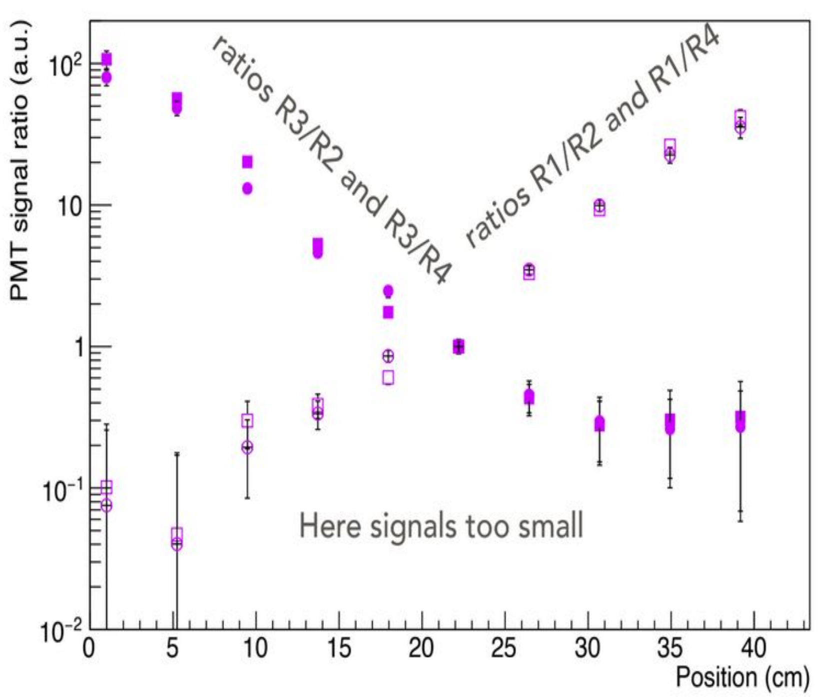
- Objectives

- Simulate photons propagation GEM → PMTs
- Simulate PMT signals

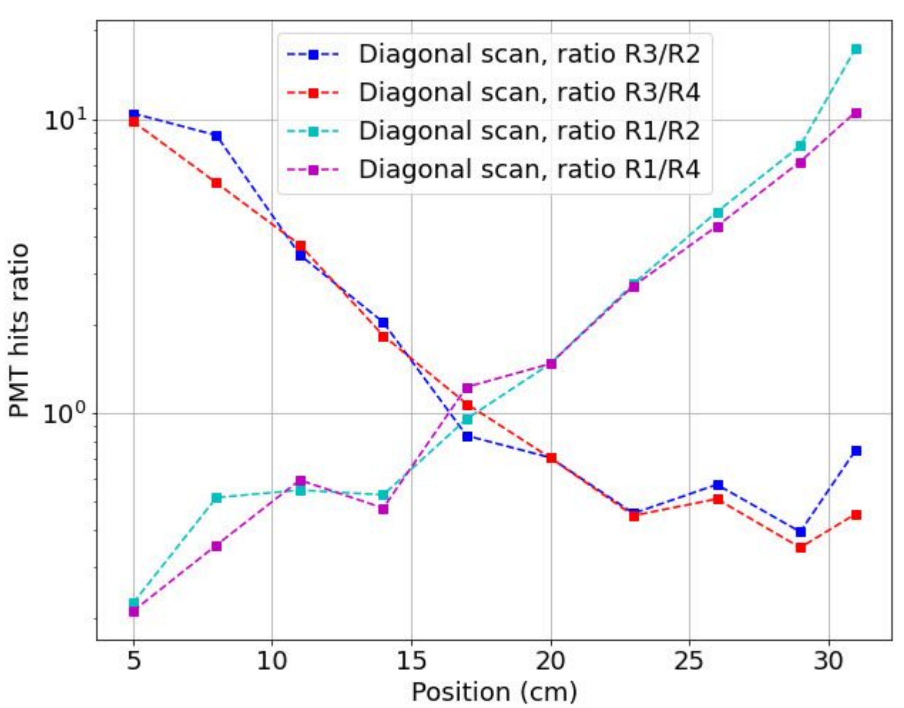




Real data



Simulation data (using N=100k photons)



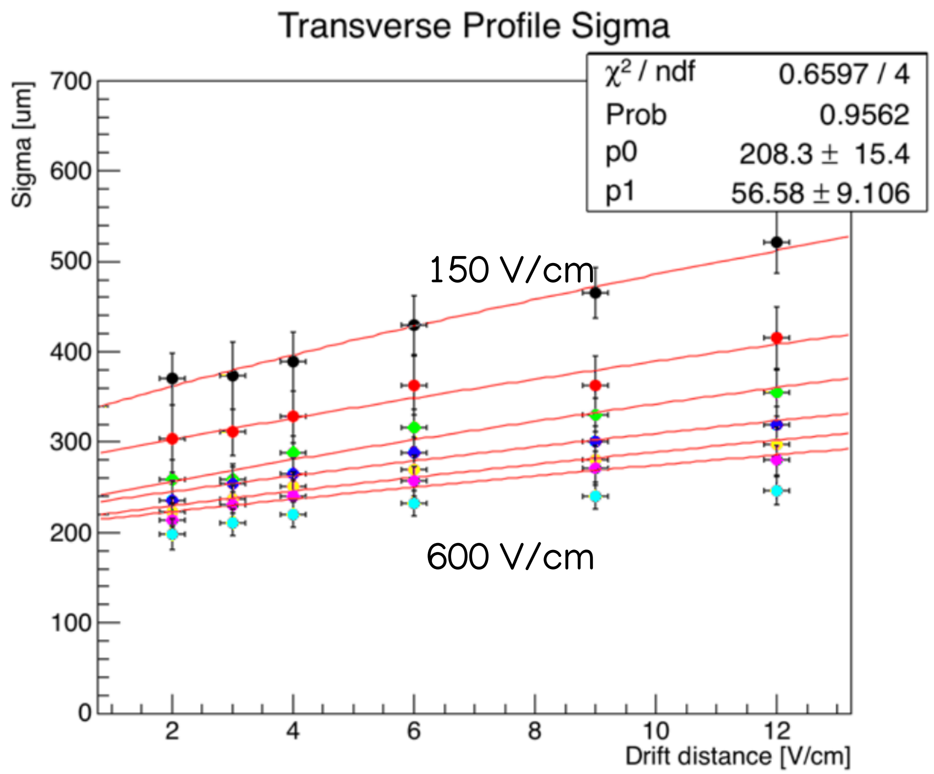
compared with data using scans in x, y and diagonal

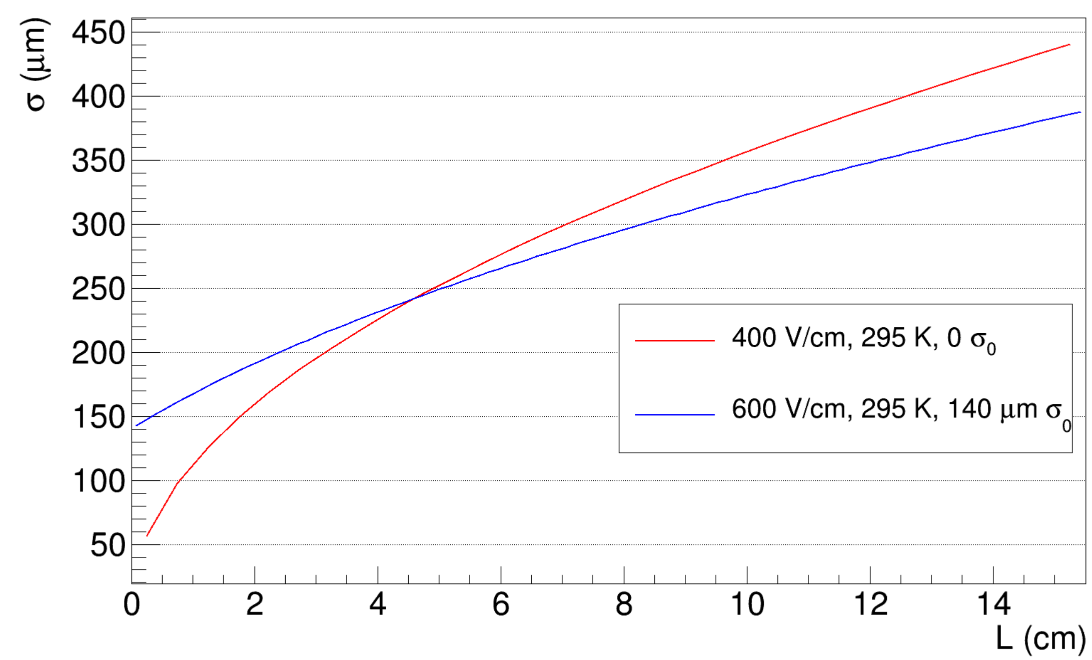
Mariana Migliorini

Update on negative ions

- Studies continuing with MANGO showing that the diffusion on NI is below what initially expected by the thermal limit: $\sigma^2 = \dfrac{2k_B TL}{eE}$

Giorgio Dho





Contribution on diffusion by GEM is null in theoretical calculation

- explained using Rolandi-Blum extension of the simple formula considering the scattering on the lighter component of the gas (He fraction in the mixture)

$$\sigma^2_{diff} = \frac{6k_B T}{e} \cdot \frac{F(y)}{\left(1+\frac{1}{y}\right)} \frac{1}{E}$$

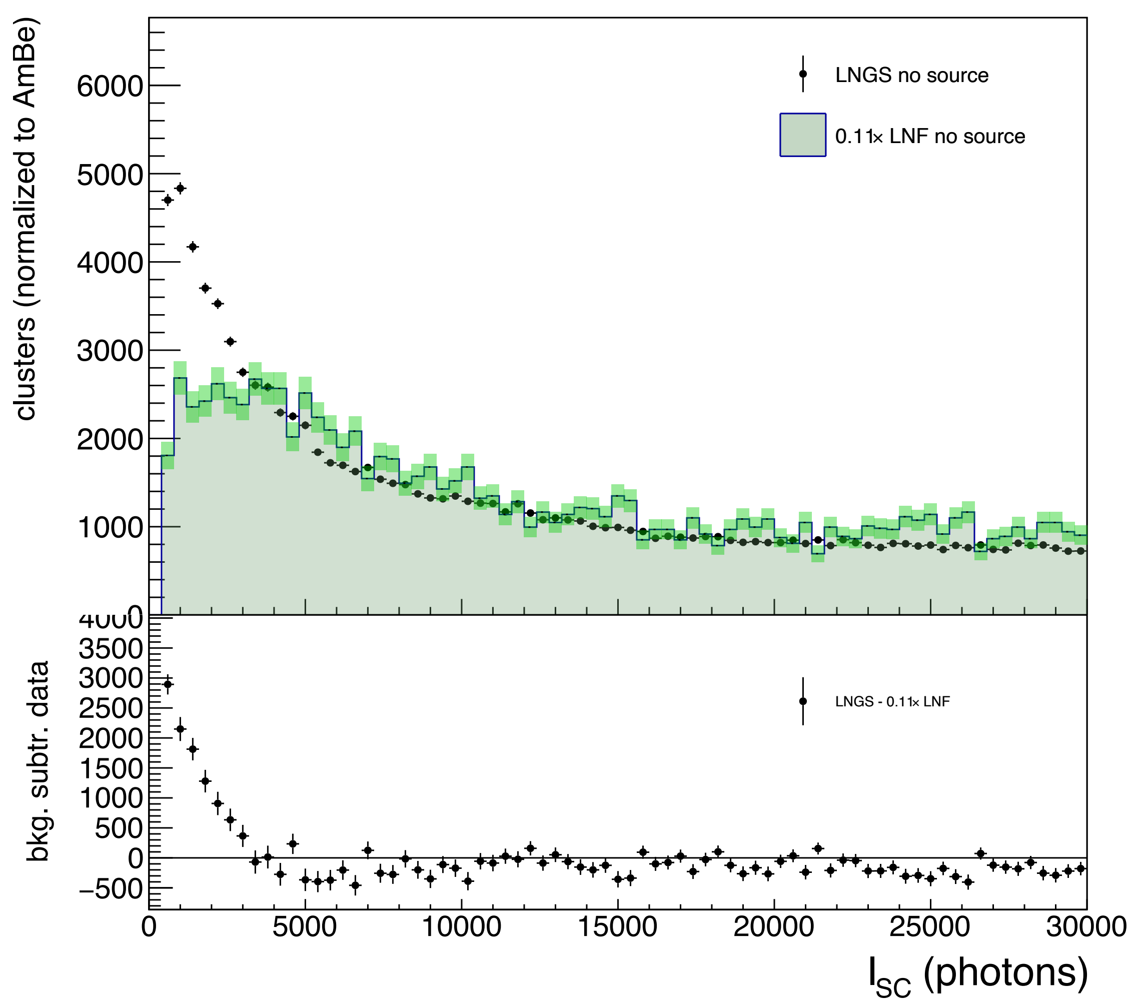
$92 \frac{\mu m}{\sqrt{cm}}$	$65 \frac{\mu m}{\sqrt{cm}}$	$47 \frac{\mu m}{\sqrt{cm}}$
Thermal limit	Calculated value	Measured value

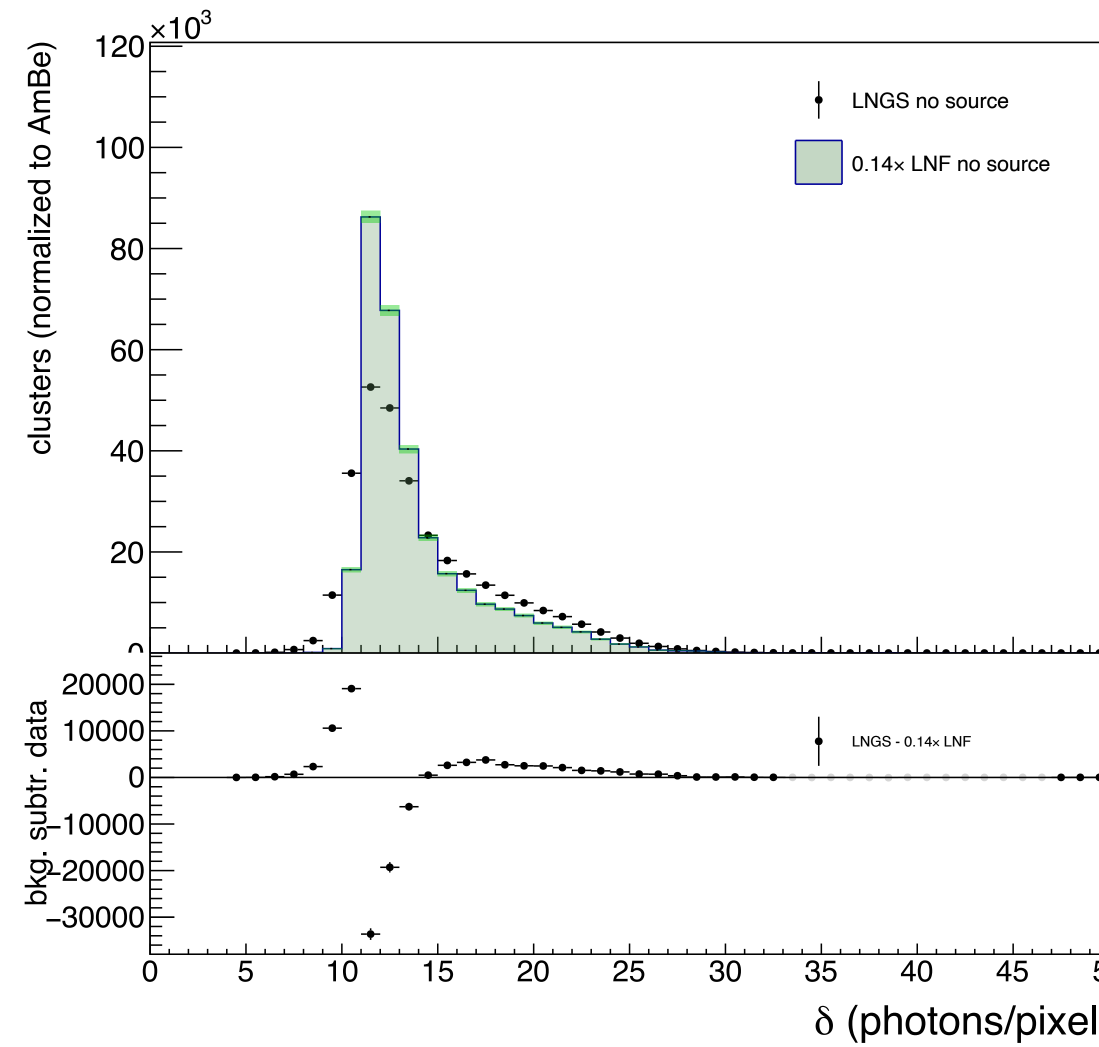
Using F(y)=2/3

First look at LNGS data

- Data taken with LIME before summer analyzed, OK at a first look
- They are uncalibrated: no data with radioactive source taken, => energy scale is unknown
  - $\delta = N_{\gamma}/N_{\rm pix} \approx 11$ => the scale is roughly unchanged wrt LNF

Emanuele Di Marco





- Need to understand the extra background at lower energies in LNGS data.
  - Most probaly are fake clusters reconstructed with lower thresholds, to be confirmed

Summary

- Developments on reconstruction code:
  - there is a stable version for LNGS that can be used as benchmark for developments
  - e.g. sensor noise filtering, application for the trigger etc
- Analysis on the LNGS data:
  - clusters analysis => check the contribution of the fake clusters (D. Marin), then compare quantitatively LNF and LNGS
- PMT studies:
  - simulation studies advanced. Need to boost analysis of the current data taken with LIME (need some effort to unpack the new data format from MIDAS DAQ)
- Performance studies ongoing:
  - on MANGO: negative ions incouraging results on small diffusion being scrutinized
  - on LIME simulation: angular resolution for directionality improved with the new simulation
  - on LIME data: need calibration data (^{55}Fe and other sources) for the energy studies
    - possibly AmBe data for neutrons would be nice to be repeated with the lower LNGS bkgs
    - effort ongoing to wangle radioactive sources compliant with the maximum allowed rate at LNGS (G. Cavoto)