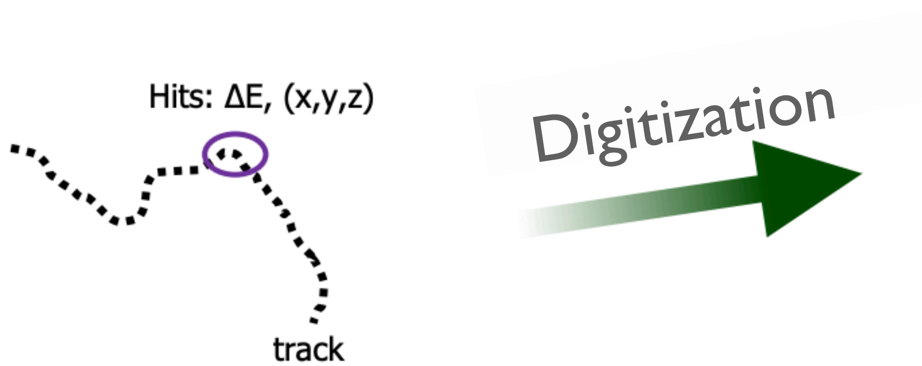
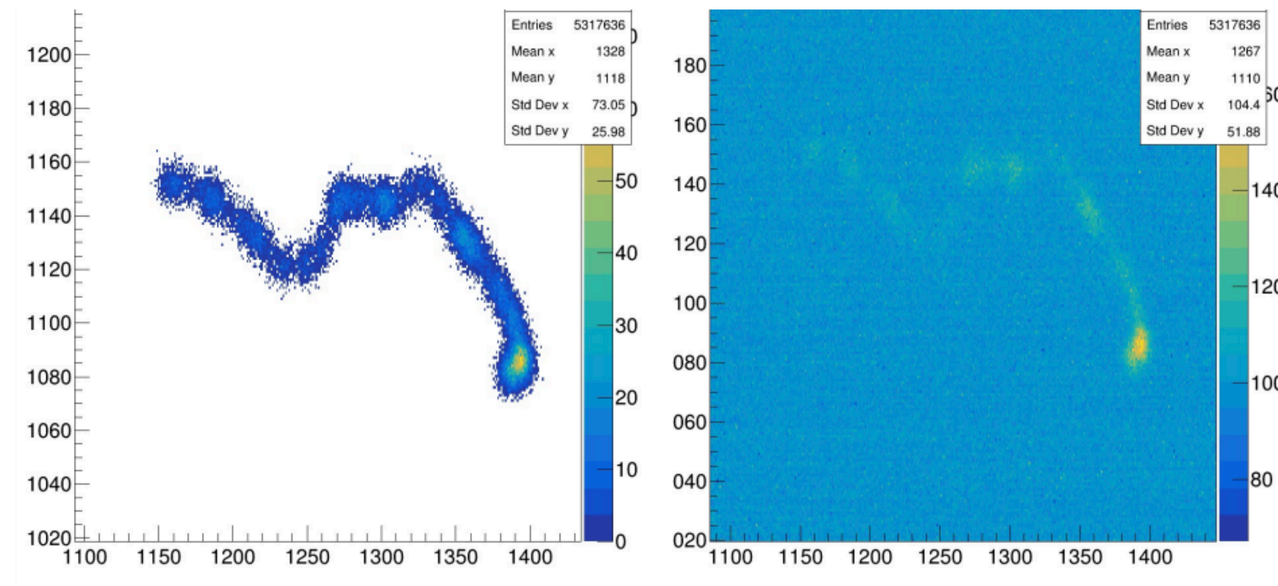
Recap on Simulation flow and Data-MC comparison

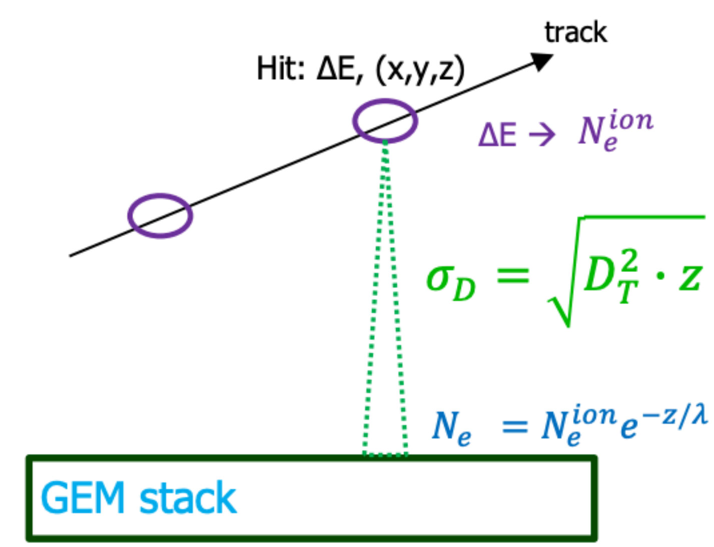
Digitizzation flow

From a GEANT4 track → To a sCMOS-like image



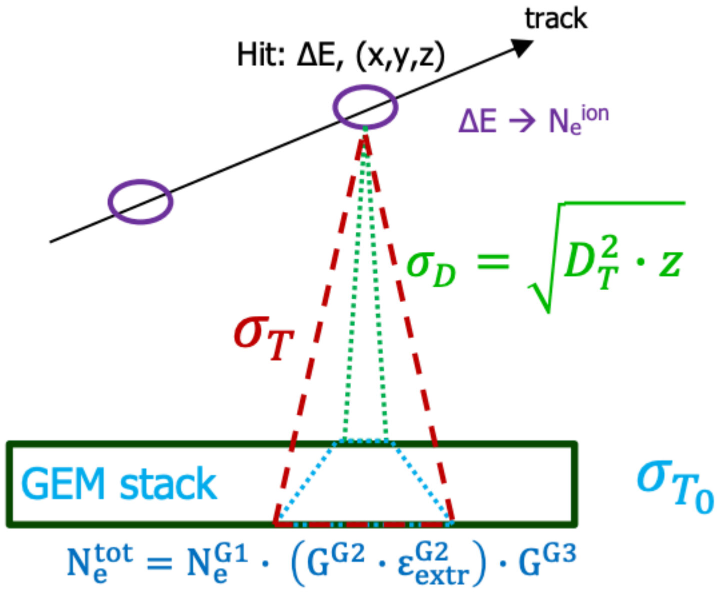


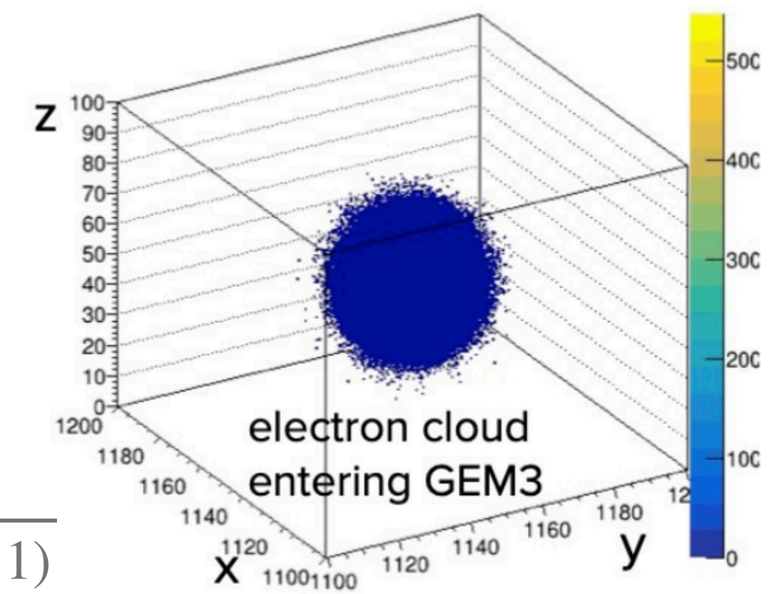
- For each hit of the track:
  - A mean number of ionization electrons are produced: $\bar{N}_e^{ion} = \Delta E / W$ (W =46.2 eV/pair in He/CF4 60/40)
  - The actual number N_e^{ion} of ionization electrons is obtained from a Poisson distribution with mean = $\bar{N}_e^{ion}$
  - Ionization electrons are partially absorbed in the gas: $N_e = N_e^{ion} e^{-\frac{z}{\lambda}}$ where z is the distance from the GEM stack



Digitizzation flow

- GEM gain fluctuation and diffusion
  - Gain fluctuations in 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}) are extracted using an exponential distribution with mean = G^{G1} (G^{G1} is the gain of the first GEM foil)
  - Total number of multiplication electron for the first foil:
    $N_e^{G1} = \sum_k N_e^{G1,k} \cdot \epsilon_{extr}^{G1}$ (ϵ_{extr}^{G1} : extraction efficiency for the first GEM)
  - The total number of multiplication electrons computed considering the gain of other GEM foils and the extraction efficiency of the second foil:
    $N_e^{tot} = N_e^{G1} \cdot (G^{G2} \cdot \epsilon_{extr}^{G2})$





- Saturation:
  - Electrons from G1/2 diffused in 3D voxels: $\sigma_T = \sqrt{\sigma_{T_0}^2 + \sigma_{D,T}^2}$ $\sigma_L = \sqrt{\sigma_{L_0}^2 + \sigma_{D,L}^2}$
  - The number n of electrons in each voxel is multiplied by a gain $G^3 = A\dfrac{g}{1 + \frac{n}{n_h}(g-1)}$

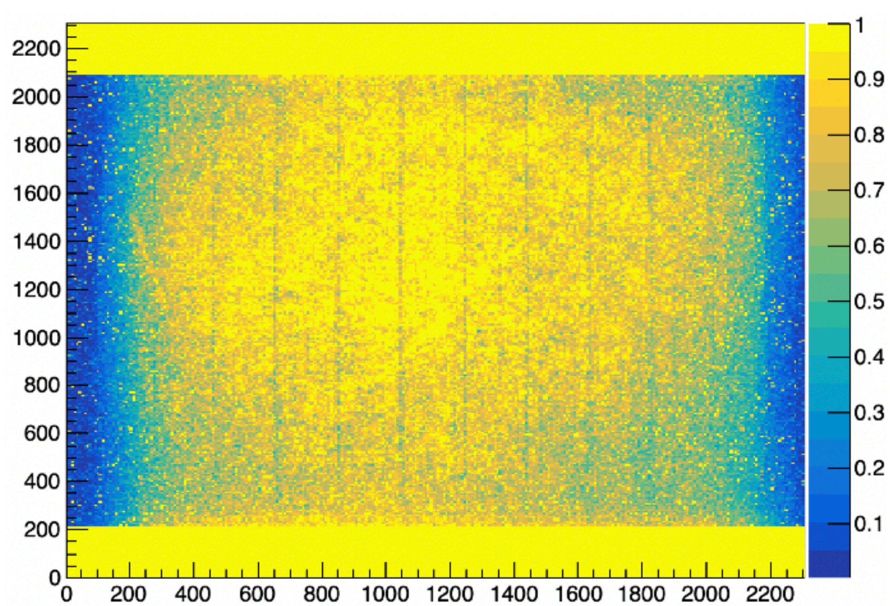
    (where g is the non-saturated gain and A is an overall free parameter)
  - Finally the total number of electron is the sum of the electrons in all the voxels along the drift direction

Digitizzation flow

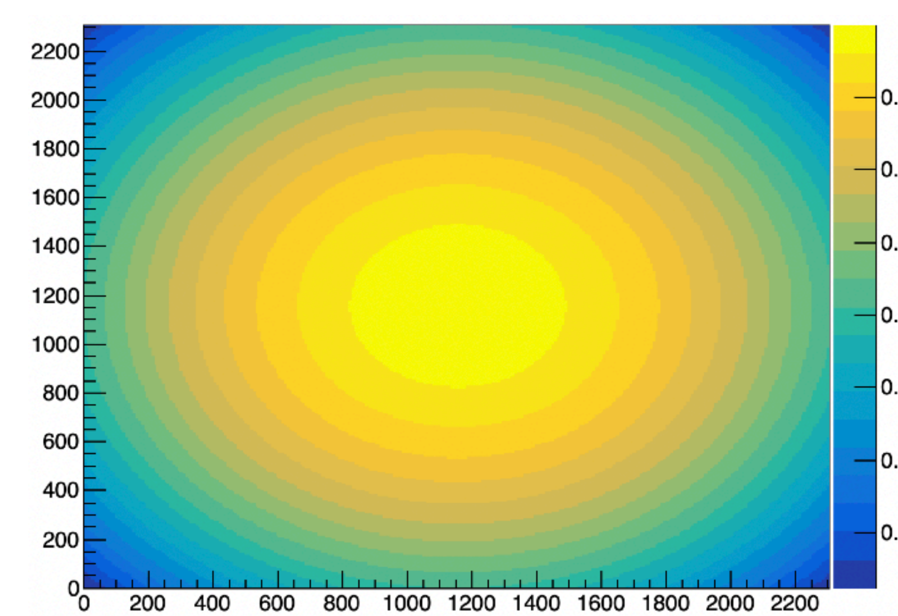
- Photon collection:
  - The mean total number of photons per pixel is obtained using 0.07 γ/e : $\bar{N}_\gamma^{tot} = N_e^{tot} \cdot 0.07\ \gamma/e$
  - The number of total photons N_γ^{tot} extracted from a Poissonian distribution with mean value $\bar{N}_\gamma^{tot}$
  - The number of photons hitting the sensor depends on the solid angle ratio $N_\gamma = N_\gamma^{tot} \cdot \Omega$ where $\Omega = \dfrac{1}{(4 \cdot (\delta + 1)a)}$; where $\delta = \dfrac{image\ size}{sensor\ size}$ and a=0.95 aperture
  - 2D histogram filled with the numbers of photons reaching given pixel

- Vignetting effect:
  - Each pixel of the track is multiplied by the value of the vignetting map (<1)

Map Applied : GEM + Lens effect



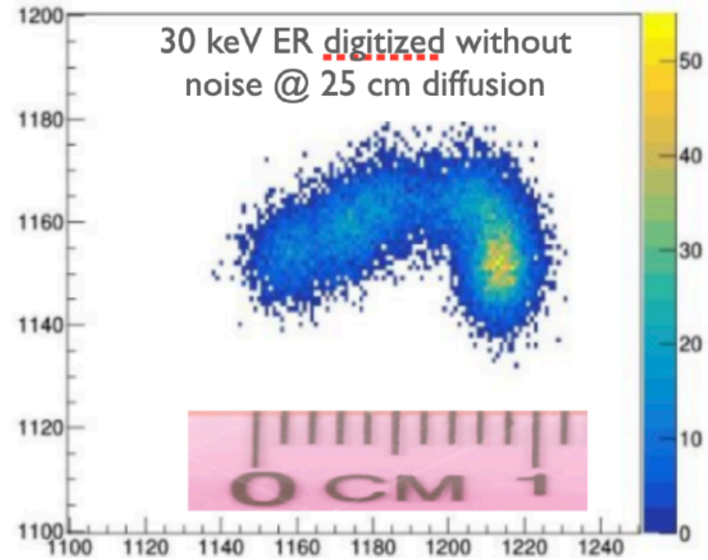
Map 4 Correction (in reco) : Lens effect

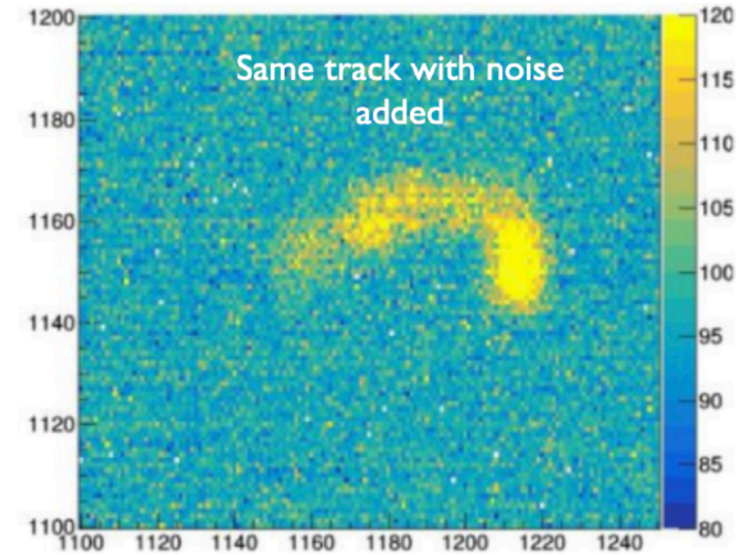


Consistent? Yes, in data, we have the GEM + lens effect, but we correct only for lens

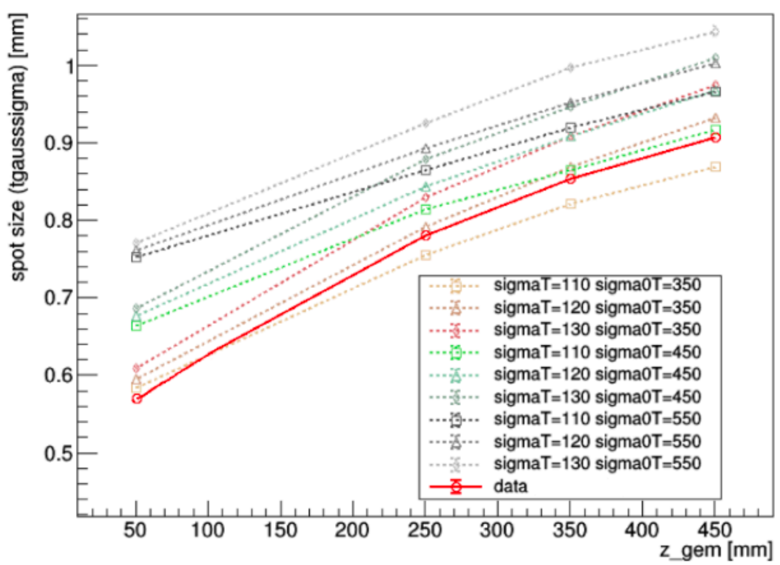
Digitizzation flow

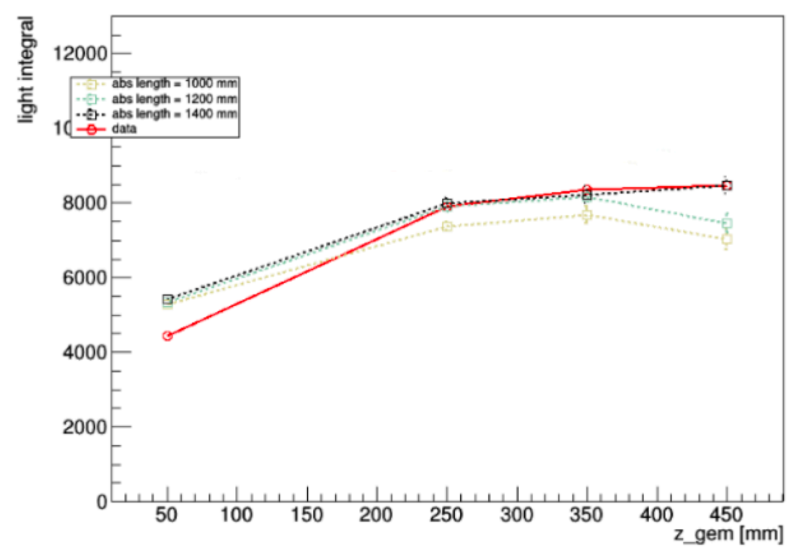
- Pedestal addition:
  - The tracks produced are then superimposed to real sCMOS pedestal to obtain the picture

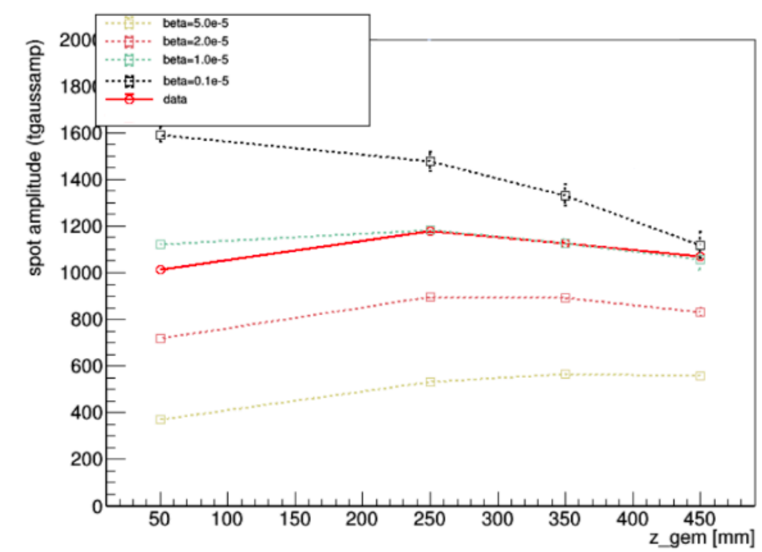




- Extensive campaign on parameter to find and agreement between data and MC (from Pietro)







- W-value from PDG

https://pdg.lbl.gov/2019/reviews/rpp2019-rev-particle-detectors-accel.pdf

- Gain par from measurements

https://arxiv.org/pdf/2007.00608.pdf

- Extraction efficiency from measurement

https://cds.cern.ch/record/2313231/files/CERN-THESIS-2018-027.pdf

- Lambda par from pure optimization around a value

https://arxiv.org/abs/2007.00608

- Diffusion par from Garfield + optimizes

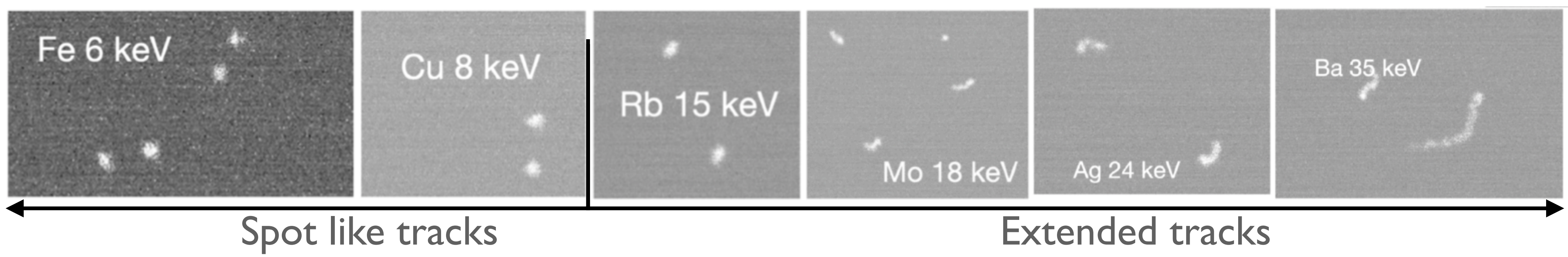
https://arxiv.org/pdf/2007.00608.pdf

- Saturation par from optimization

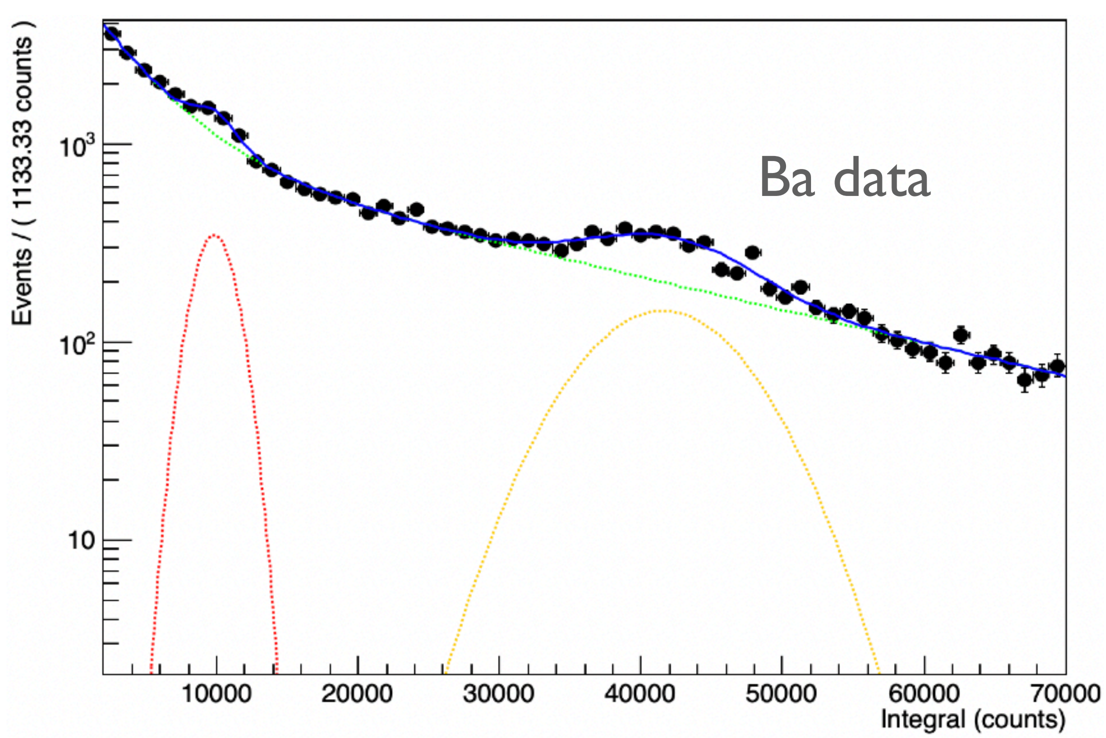
- Voxel size from pixels size

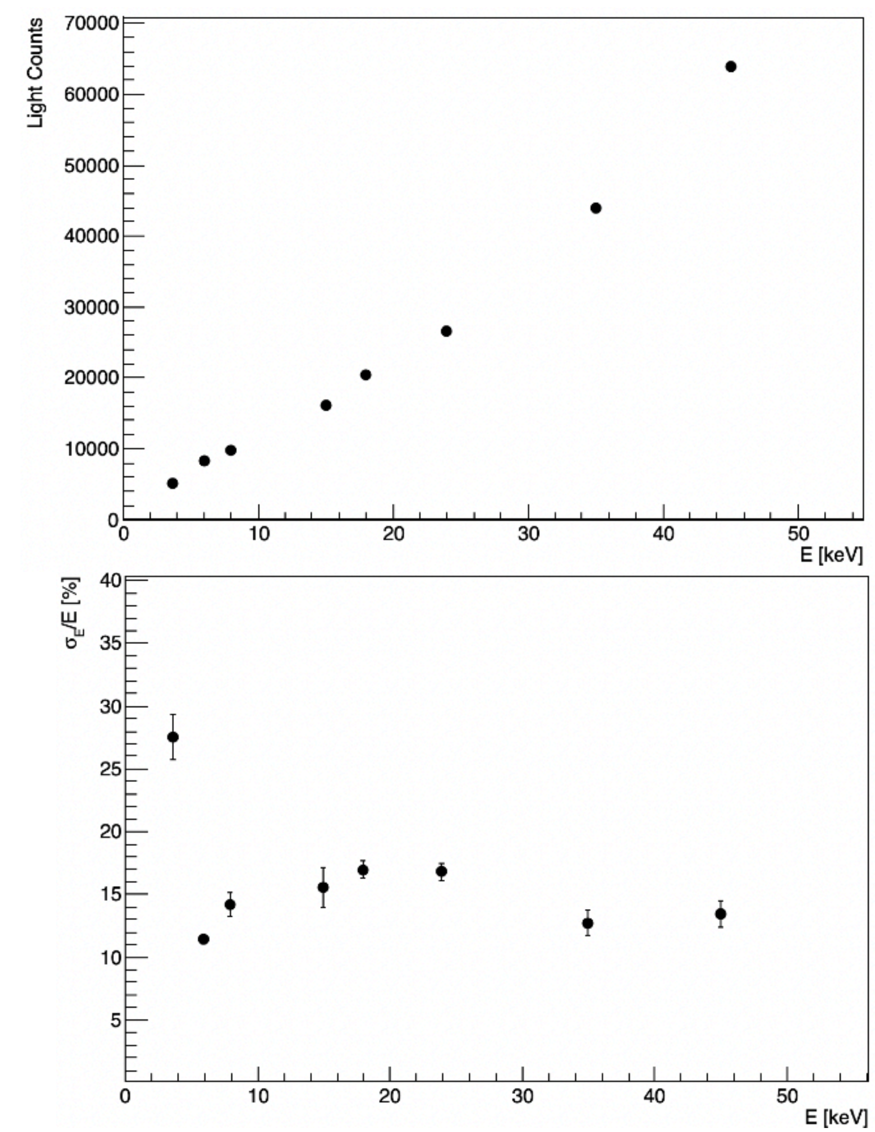
Energy response and resolution on data

- Study of linearity and energy resolution performed overground with low energy electron recoils from X-Rays



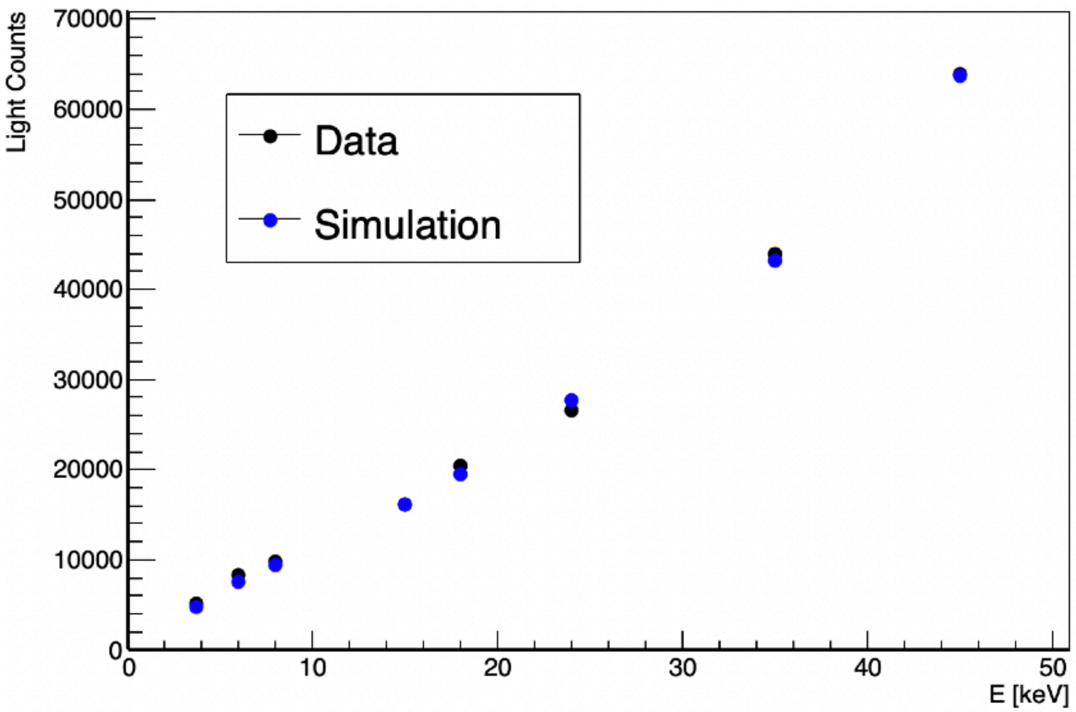
- Fit with 2 exponential + gaussians

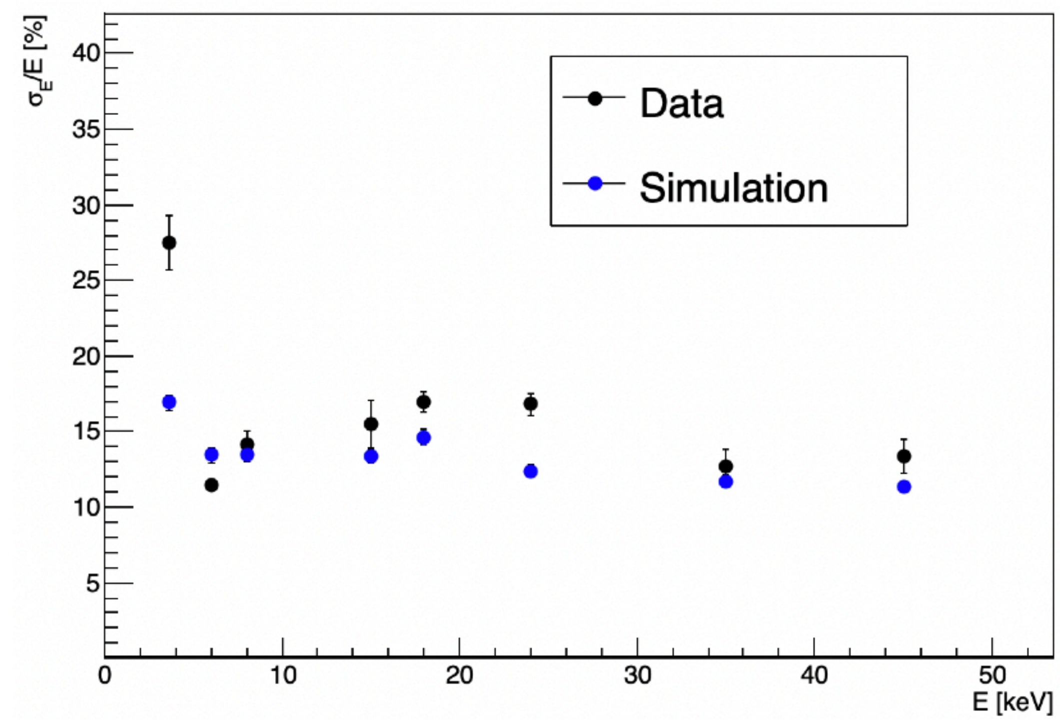




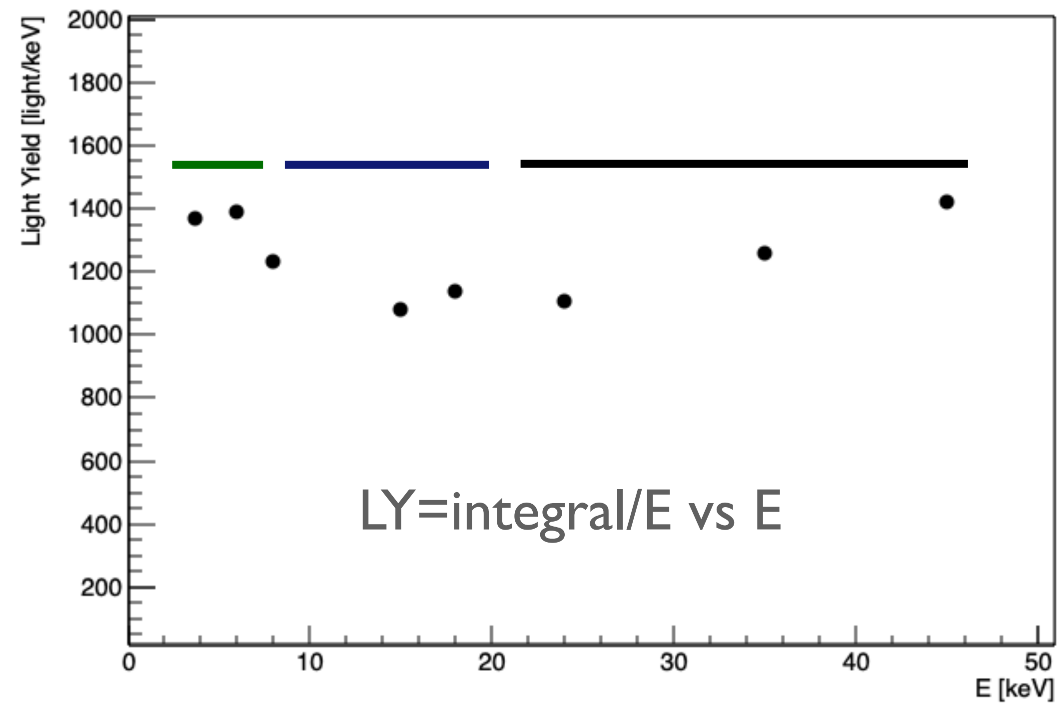
- No difference observed or worsening by reconstructing data with the GEM+Lens correction
- No significant difference in energy resolution and linearity fitting with separately the kalpha and kbeta shell

Data-MC comparison



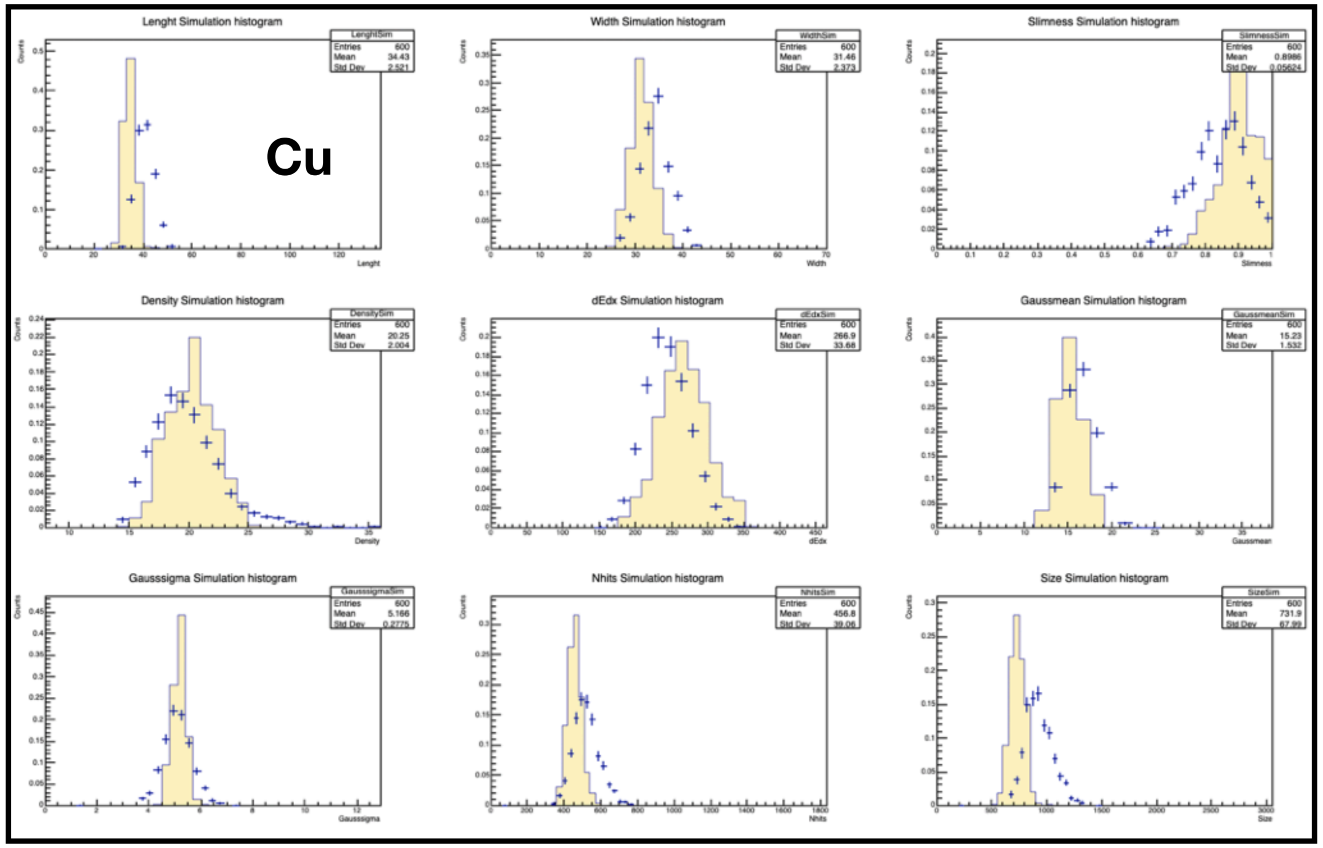


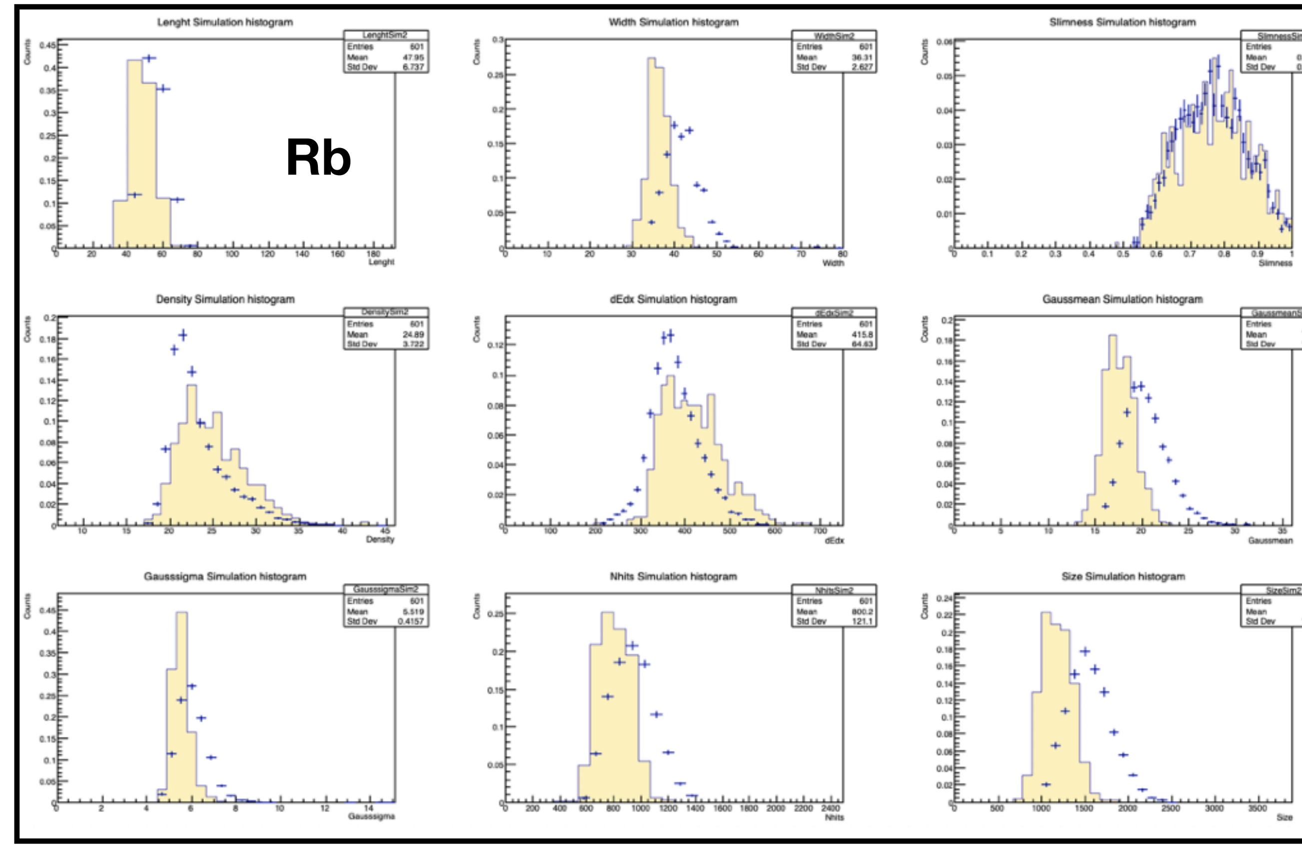
- Track as a spot with few light (small or no saturation)
- Track as a spot with increasing in light →saturation→LY decrease (negligible tail)
- Track starts to have a consistent non saturated tail, dominating the light→saturation less effective on total light→LY decrease

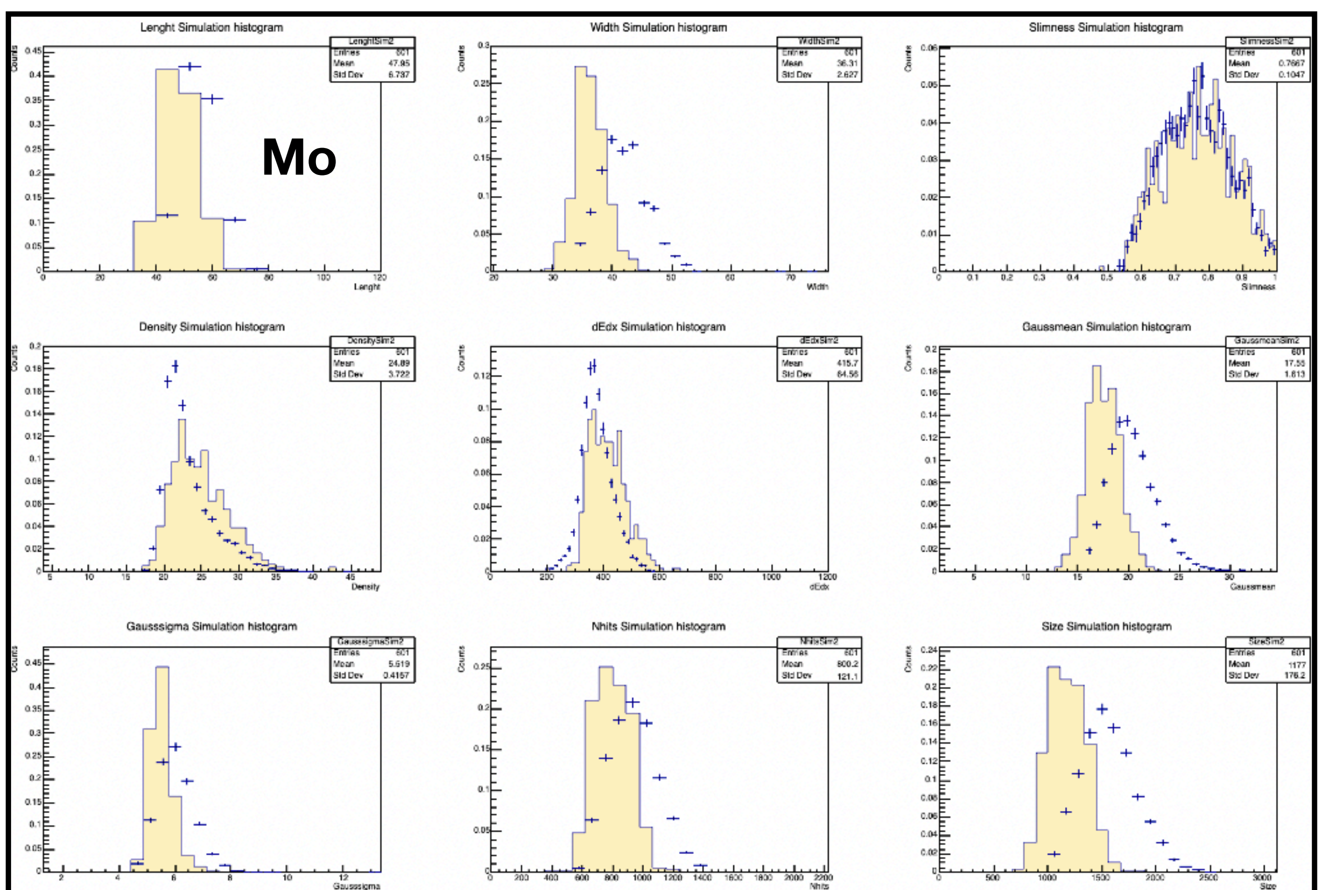


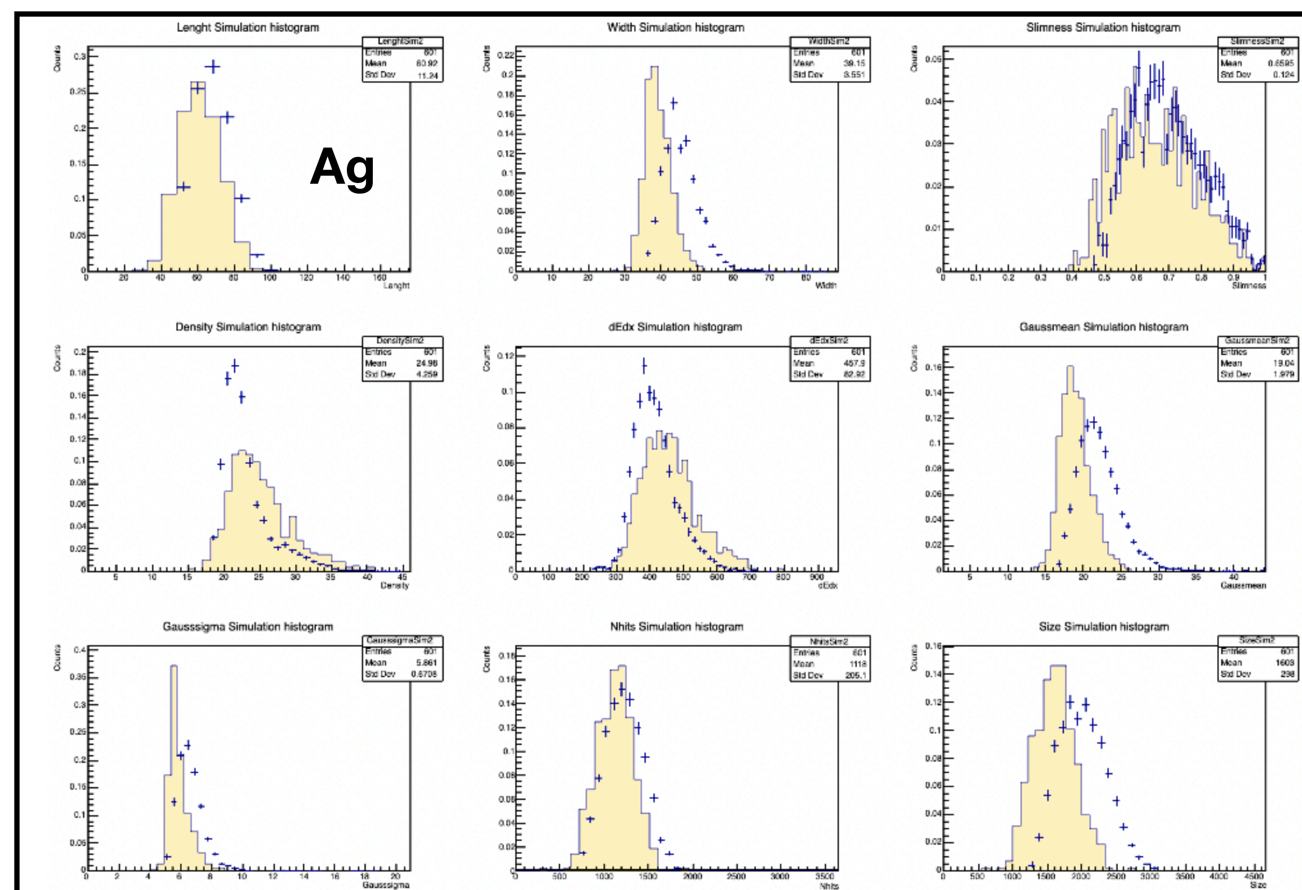
Track shape variables comparison

Simulation Data



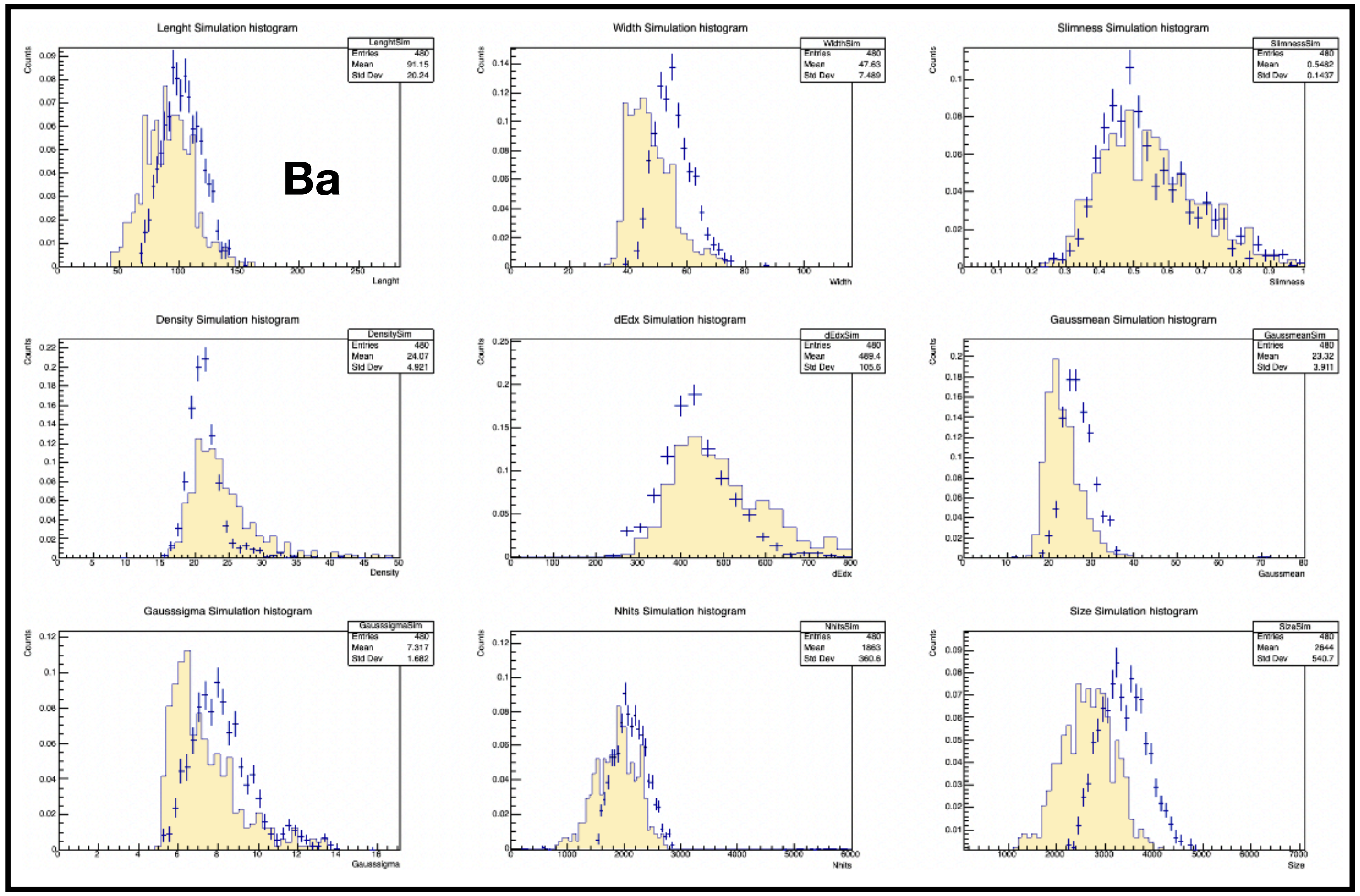


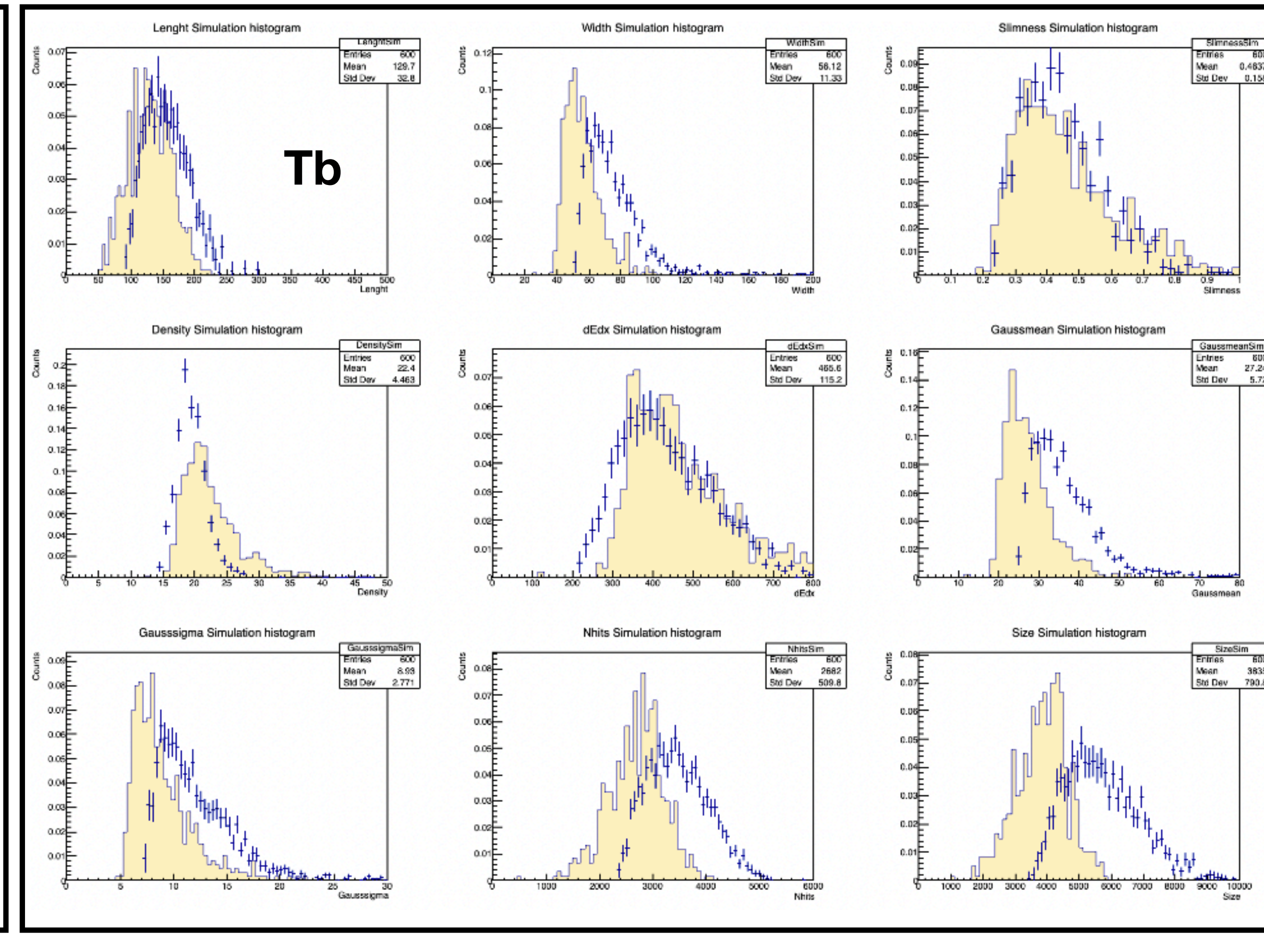




Track shape variables comparison

Simulation   Data



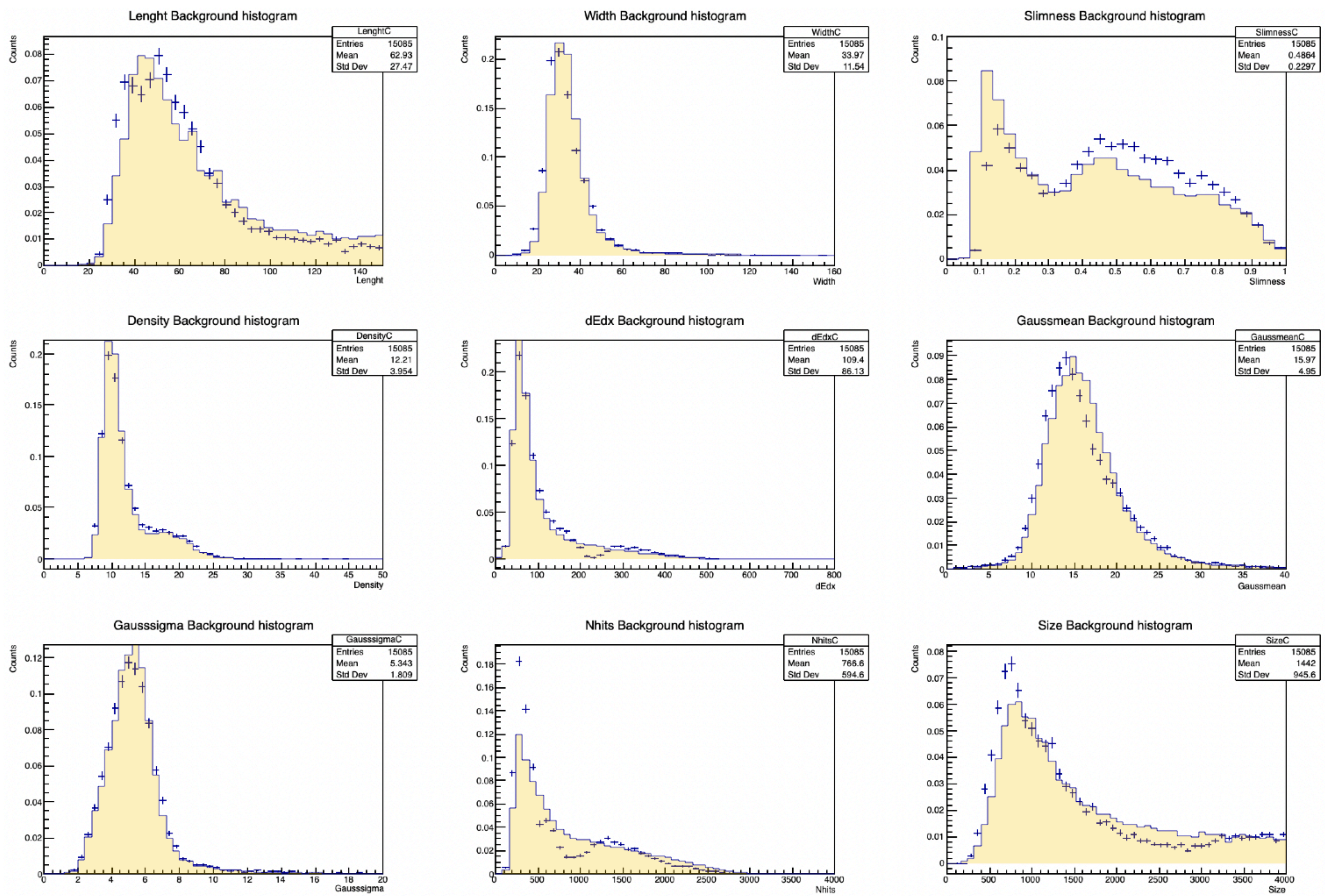


- Nice agreement in the distributions, some fine tuning of the parameters needed

Bkg crosscheck

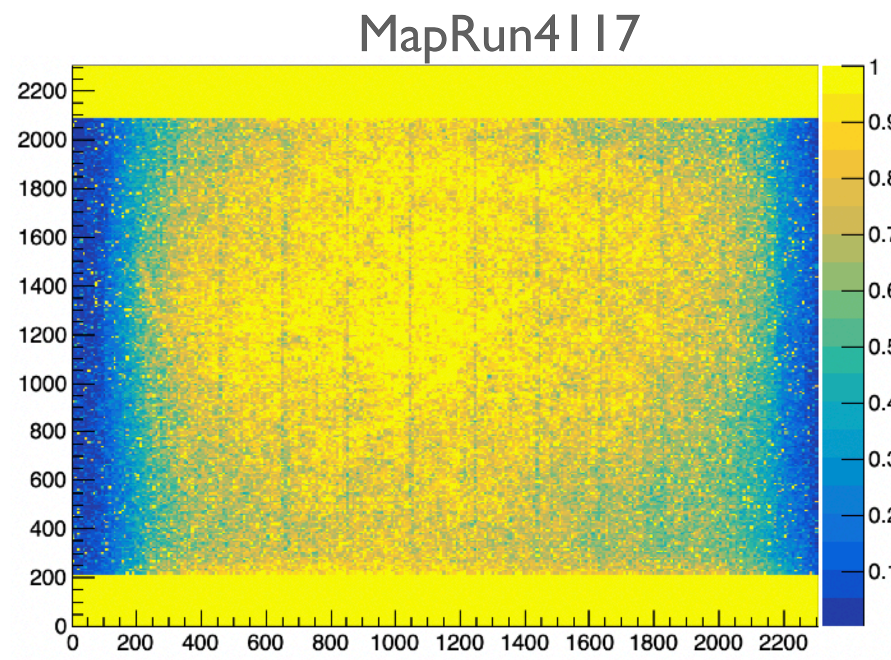
- As a crosscheck the pure bkg distribution have been compared with no source run

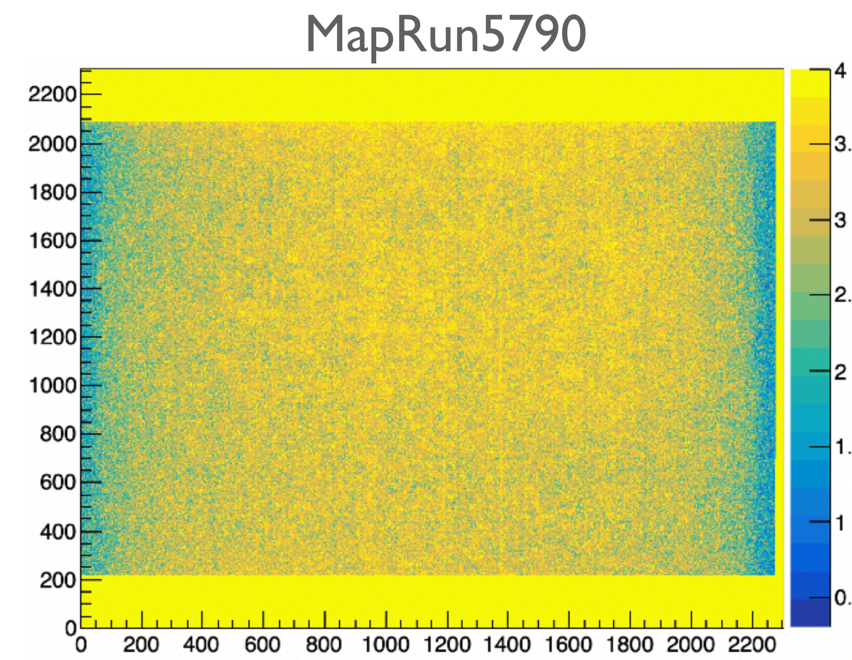
Cosmic run   Pure bkg extracted distrib.



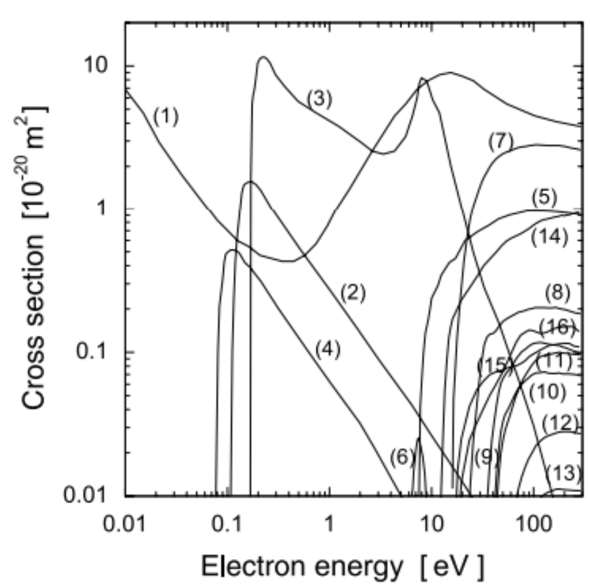
Open questions (also for the paper)

- Would it be better to use the map from run 5791-5800? Taken just before the X-Ray
- Track shape variables could change
- We could test it





- Any reference from $\lambda_{absorption}$?



Attachment cross section is (6)

Should be negligible at our e energy ~0.1eV

From $\sigma_T^2 = \frac{2k_BT}{eE}$

https://www.researchgate.net/publication/230902873_Monte_Carlo_studies_of_electron_transport_in_crossed_electric_and_magnetic_fields_in_CF4

See also : https://arxiv.org/pdf/2007.00608.pdf

$$\lambda_{att} = \frac{1}{\sigma_{att}\rho_{mol}}$$

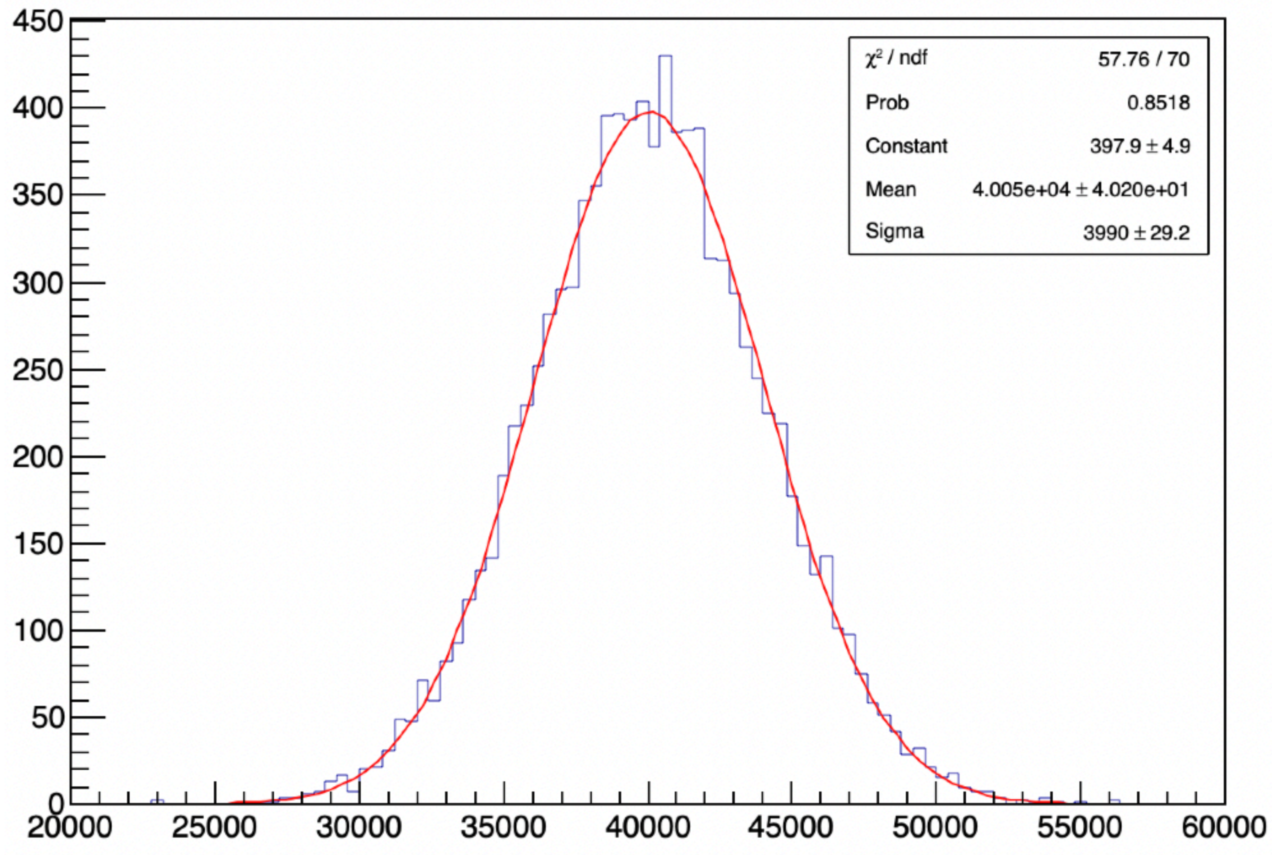
$\rho_{mol} \sim 2.5 \cdot 10^{19} cm^{-3}$ $\sigma_{att} = 10^{-19} @ 5eV$

- Does the energy resolution explanation convince you?

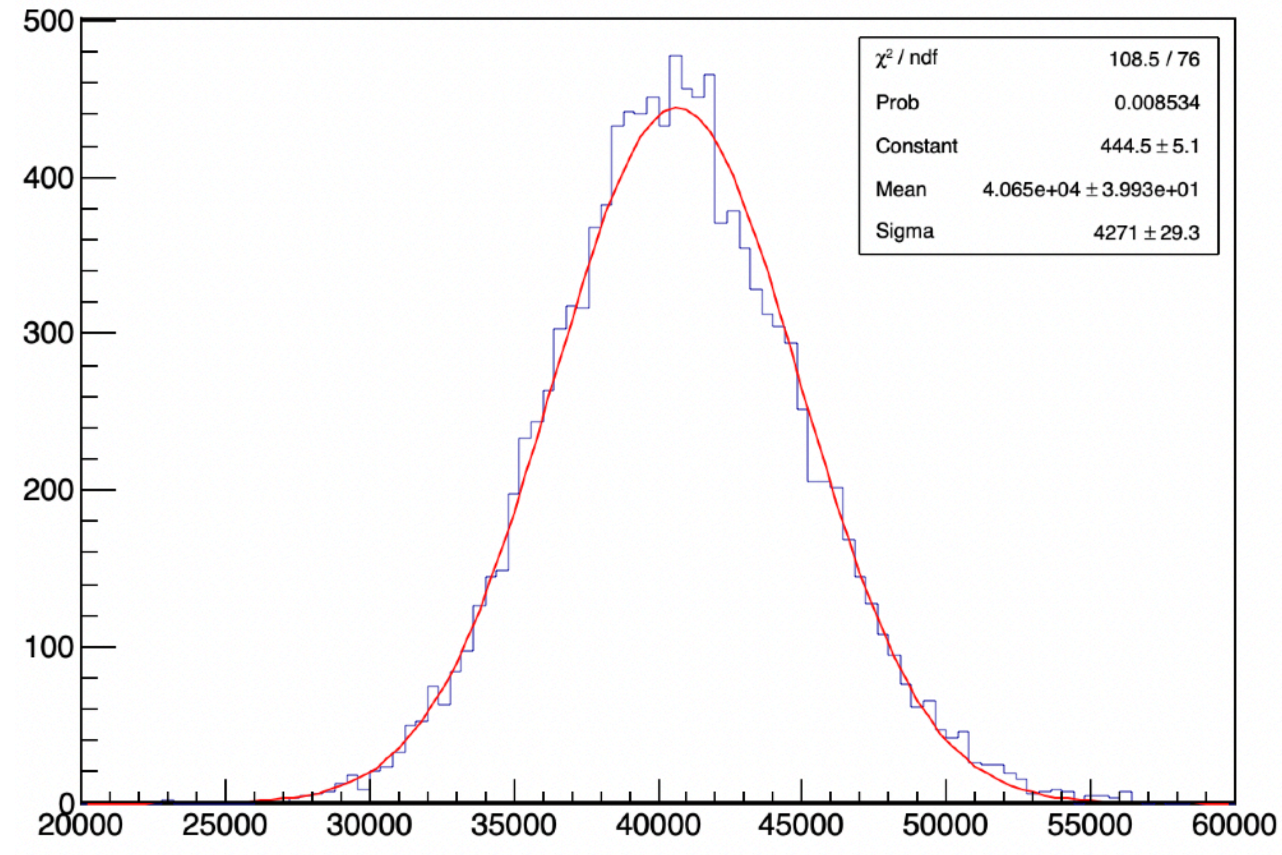
Backup slides

Only 1 gaussian?

Only kalpha



kalpha+kbeta



Difference of 0.5% in energy resolution not even appreciable in data

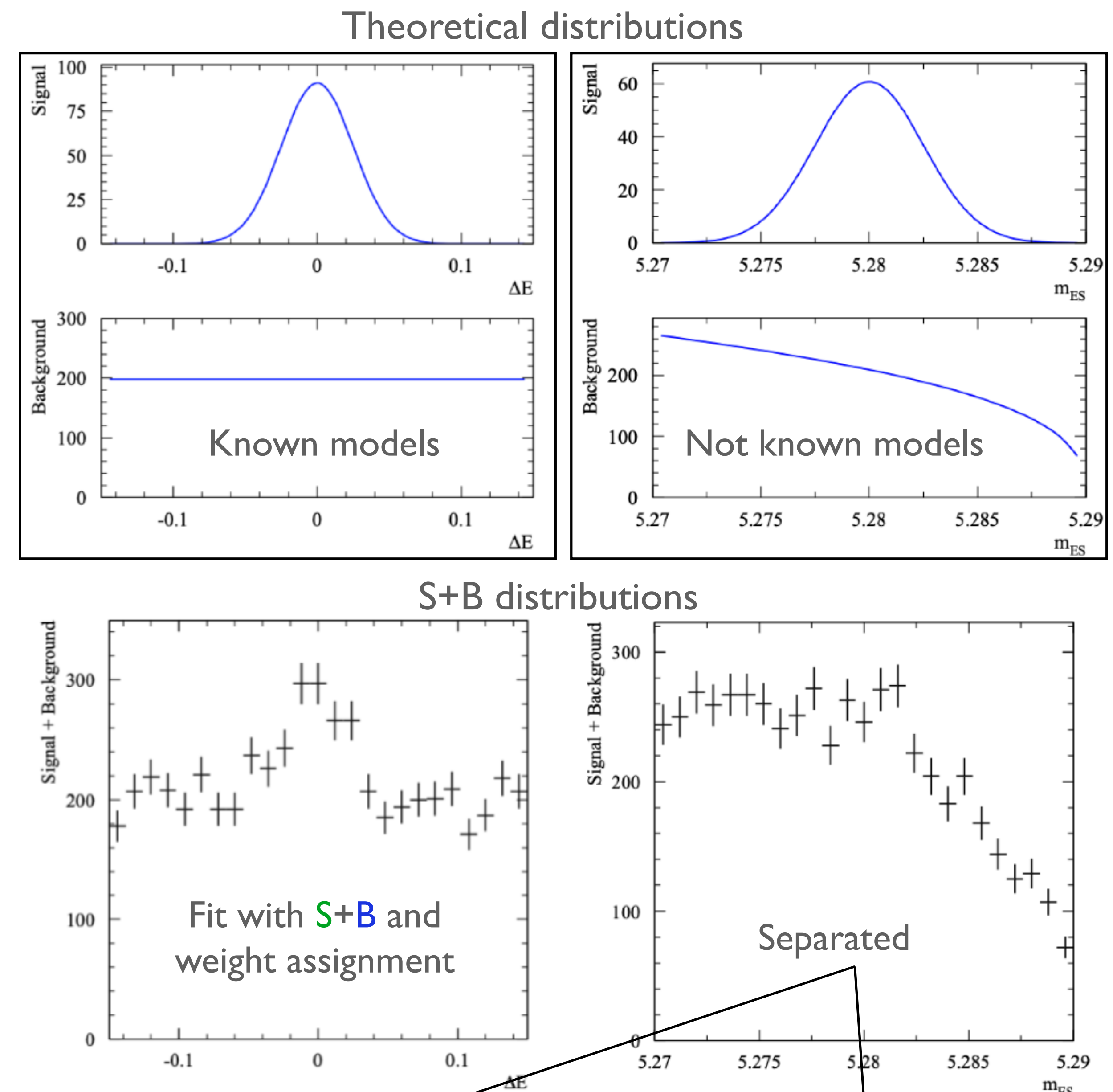
sPlots: a statistical tool to unfold data distributions

- Dataset containing two variables (consisting of signal S and background B)

- By fitting one distribution (with S + B model)

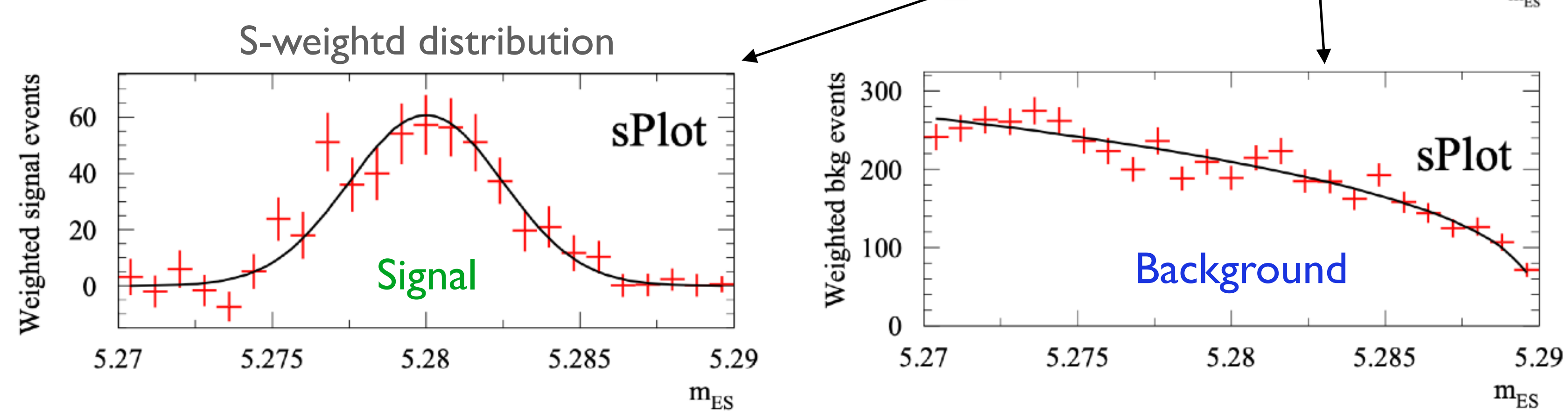
  ↓

  S weight and B weight assigned to each event proportional to probability of being S and B



- The pure S and pure B distribution can be unfolded by weighting each event by the weight of being S and B

- Since the weight can be positive or negative plotting the pure signal distribution the negative weight cancels the background part



Nucl.Instrum.Meth.A 555 (2005), 356-369