Shower shape analysis on the 2017 SiW-ECAL data

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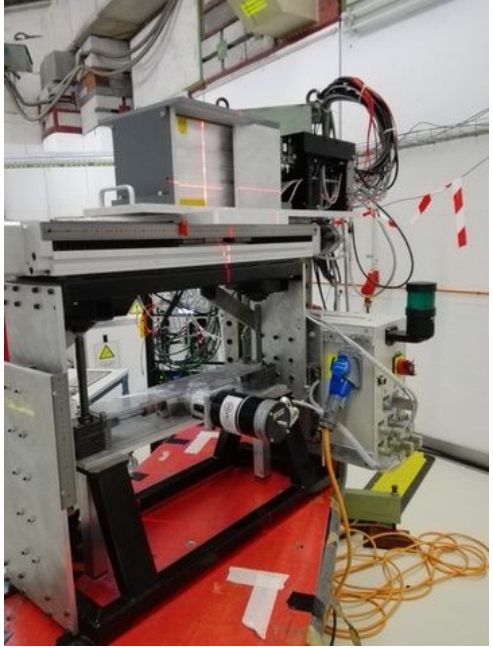
Outline

1. Data set from the SiW-ECAL 2017 Test Beam

2. Selection of events and cell hits for modelling electromagnetic showers

3. Shower modelling

Data used*



- Scans of various energies: 1, 2, 3, 4, 5, 5.8 GeV.

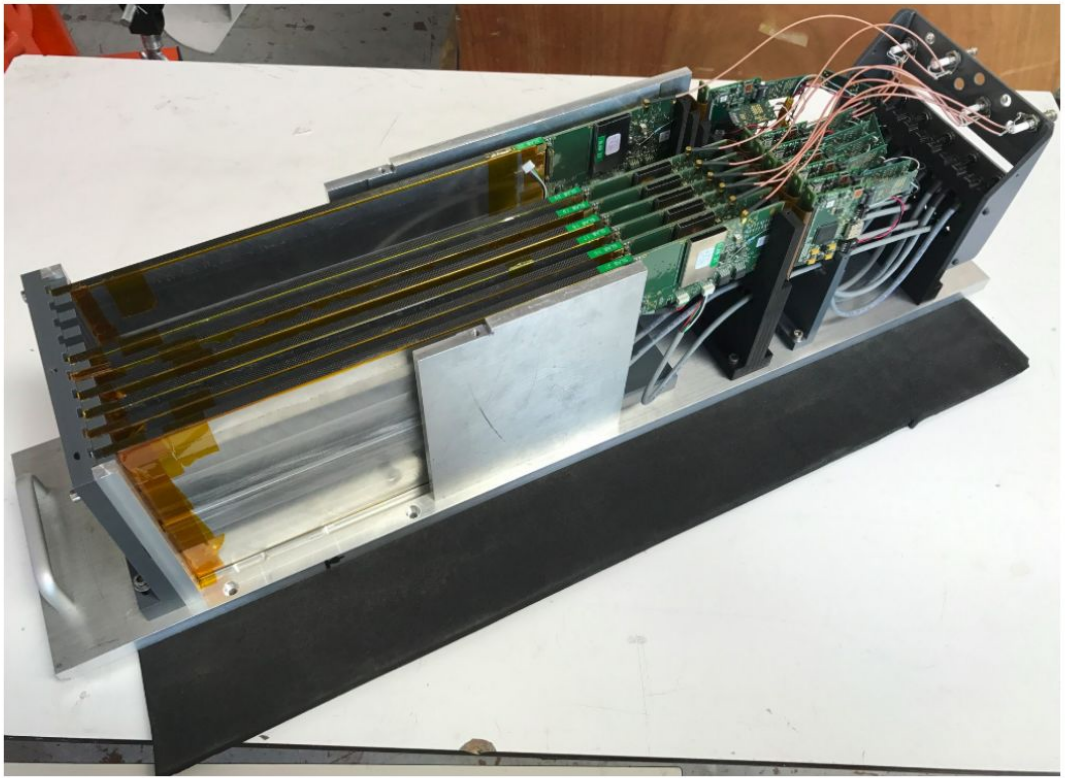
- Different W configurations with varying amounts of W in front of each slab:
  - W-configuration 1: 0.6, 1.2, 1.8, 2.4, 3.6, 4.8 and 6.6 X_0
  - W-configuration 2: 1.2, 1.8, 2.4, 3.6, 4.8, 6.6 and 8.4 X_0
  - W-configuration 3: 1.8, 2.4, 3.6, 4.8, 6.6, 8.4 and 10.2 X_0

- Energy calibrated to mips

→ **The goal is to use the data collected from positron beams to model EM shower profiles**

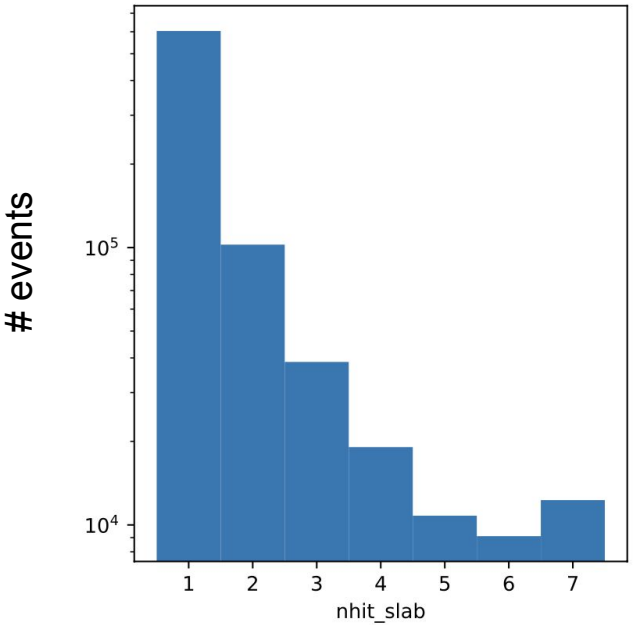
* Located in TB2017-06/DESY/ConvertedData/pass3/Tungsten/**conf{1,2,3}**/grid20/**{1, 2, 3, 4, 5, 5.8}**GeV_build.root

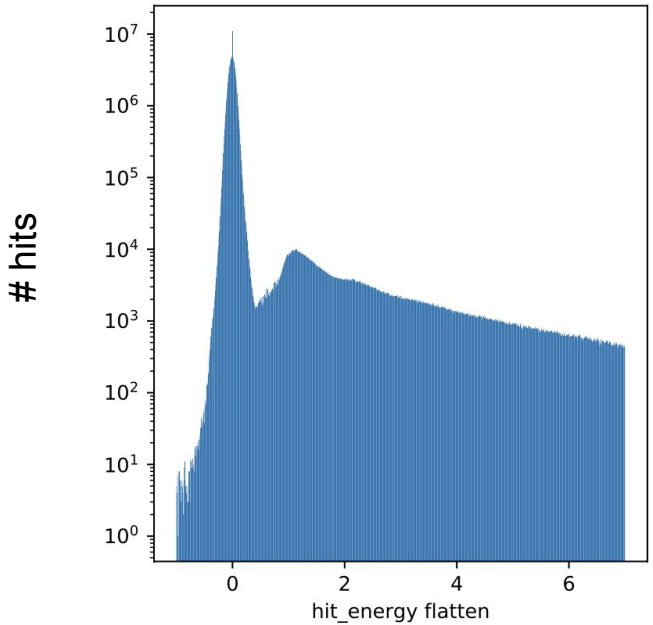
The prototype



Global selection of events

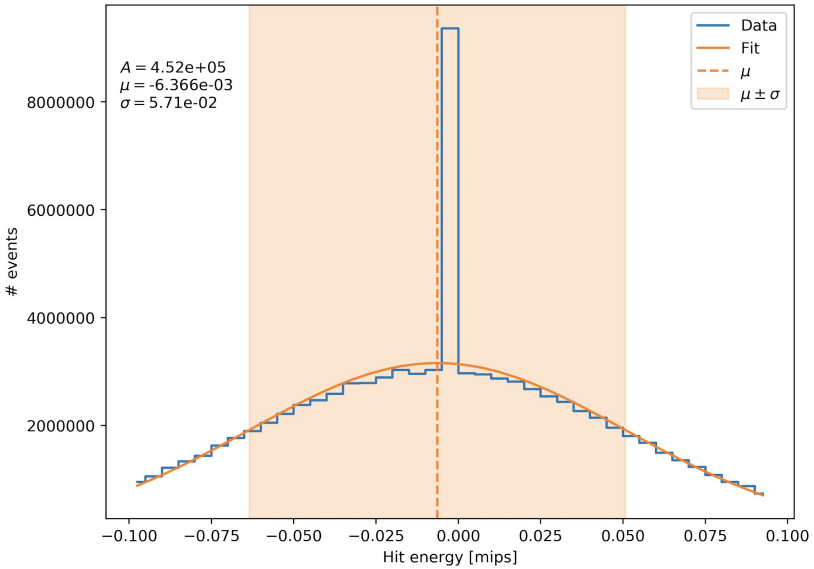
Use two criteria: 1. numbers of slabs hit by the shower and 2. Energy of hits in cells

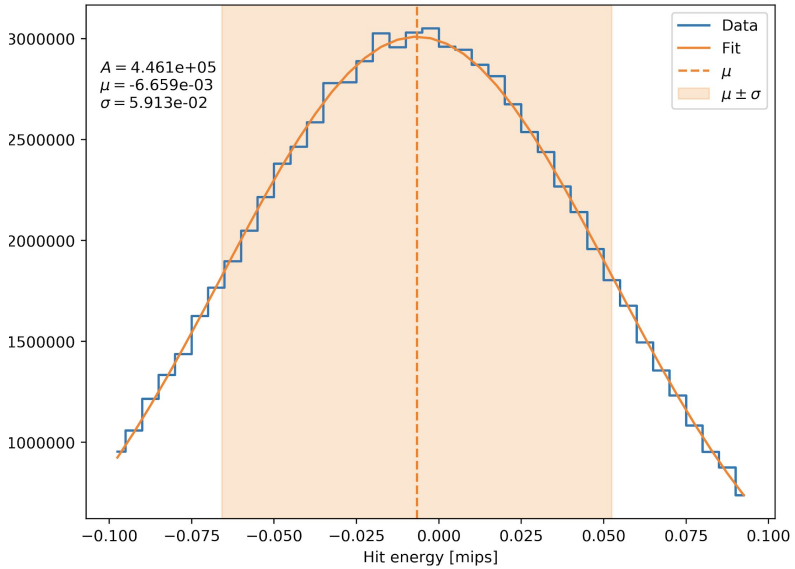




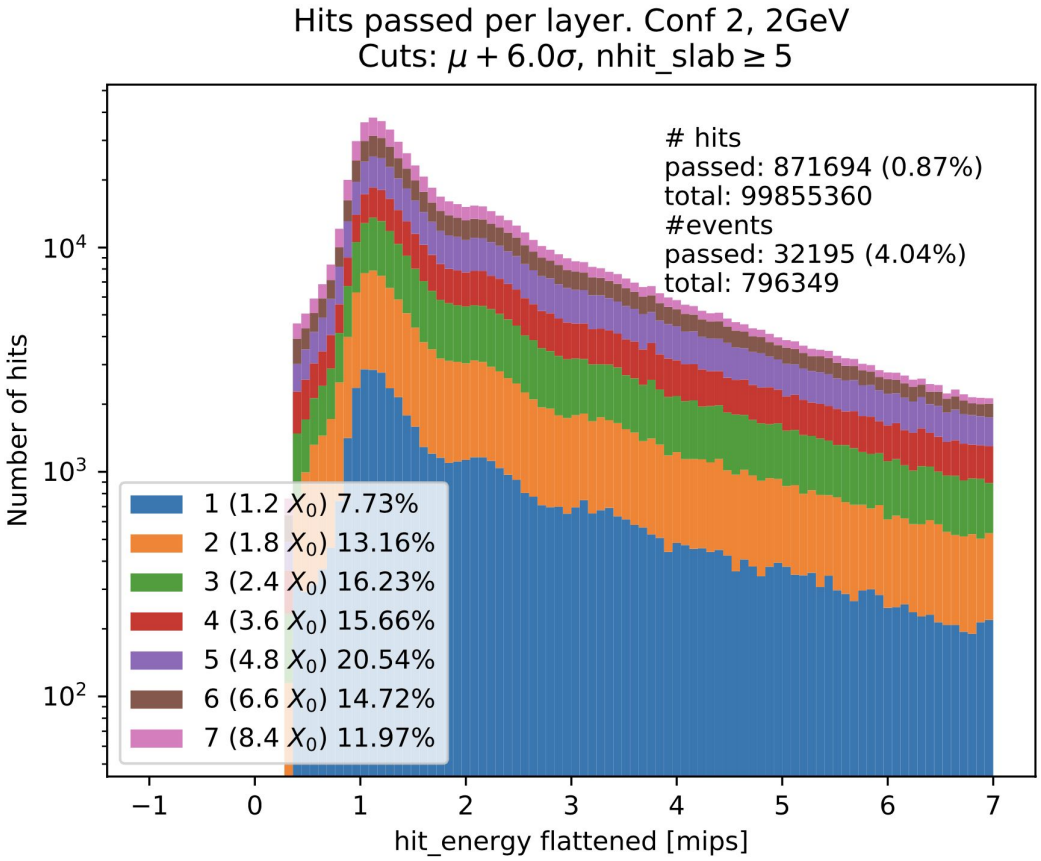
Pedestal gaussian fit

Energy pedestal of all hits in all showers (config. 2 @ 2 GeV) → a “spike” at 0 mips (removed)





After selection



Shower modelling

Shower model

Model the longitudinal and transversal energy profiles of showers

Transversal (per-layer) model

Double gaussian (6 parameters)
shared mean, no correlation (ρ1 = ρ2 = 0)
σ1 < σ2

$$A_1 \ \mathcal{N}(\boldsymbol{\mu}, \mathbb{1}\sigma_1) + A_2 \ \mathcal{N}(\boldsymbol{\mu}, \mathbb{1}\sigma_2)$$

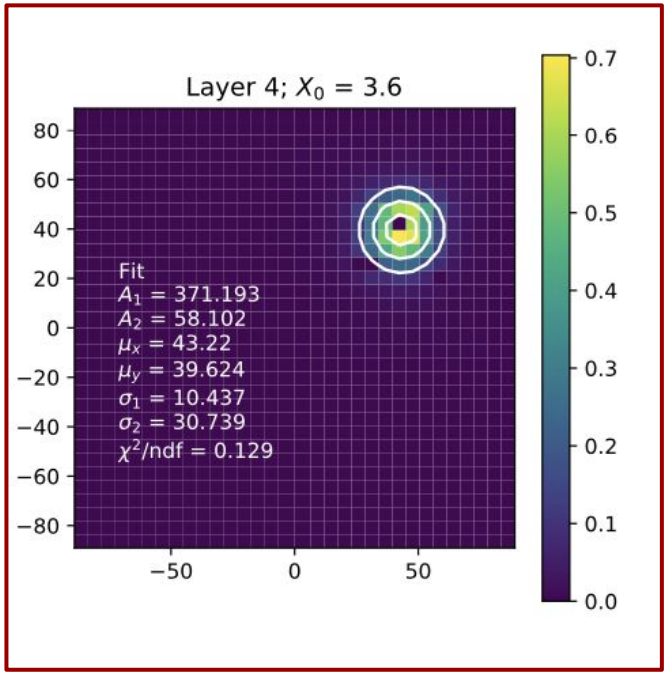
Longitudinal

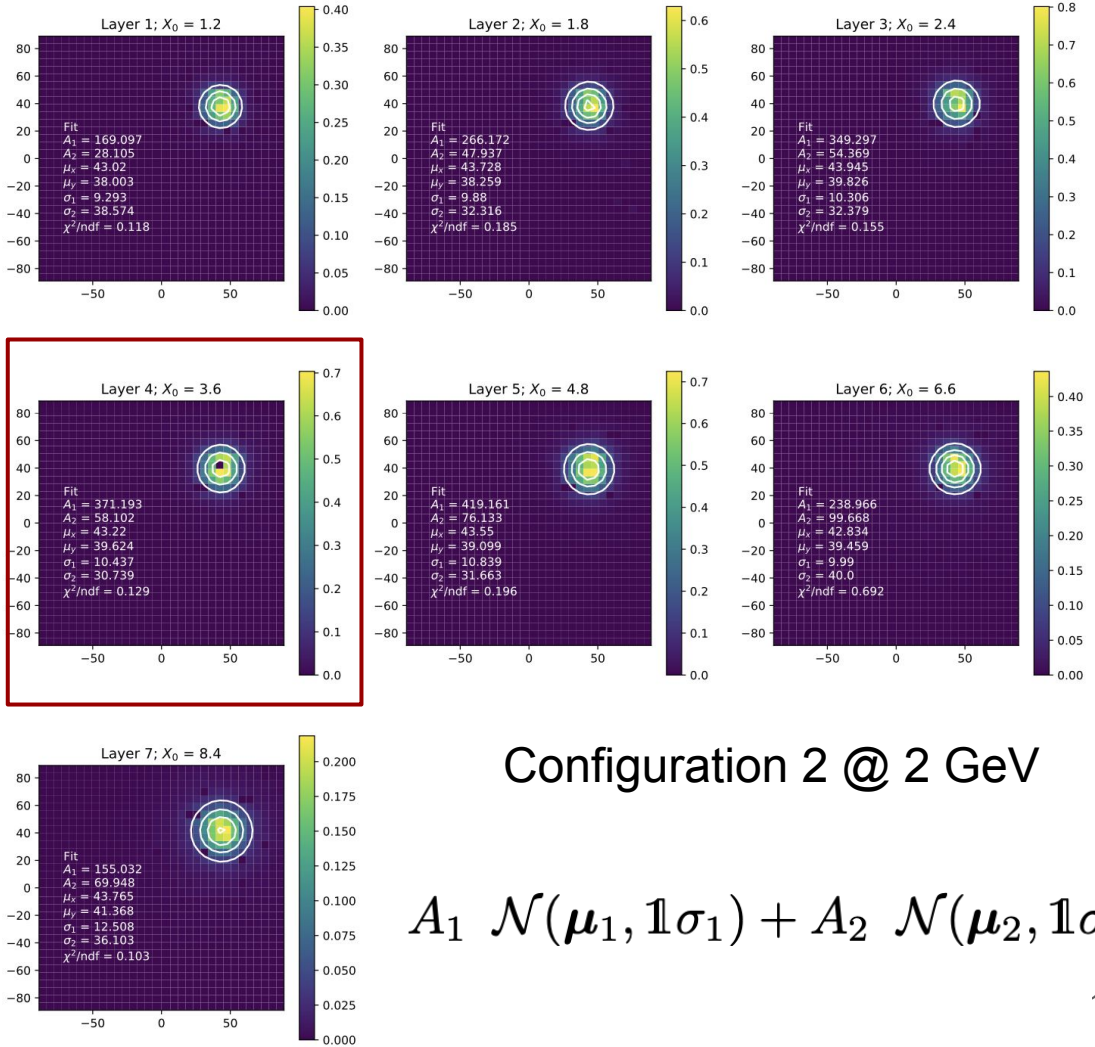
$$\frac{dE}{dt} = E_0\, b\, \frac{(bt)^{a-1} e^{-bt}}{\Gamma(a)}$$

- Fit the longitudinal and transversal parts separately
- Fit the longitudinal part using integral of double gaussian as prompt for E per layer

Transversal fits

Fit on each layer the double gaussian model

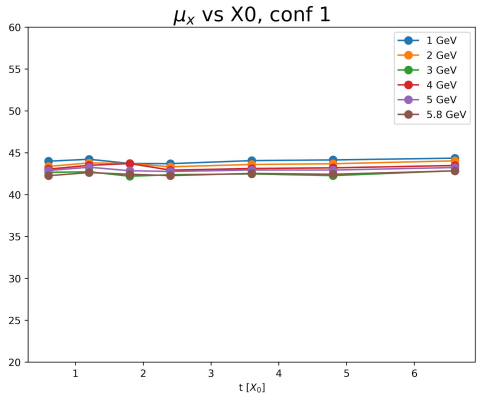


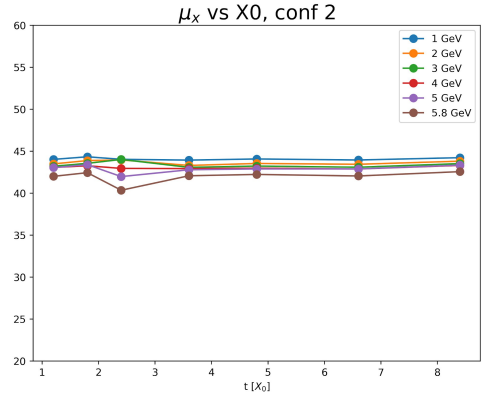


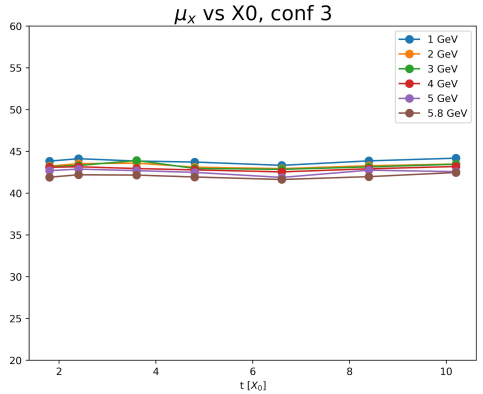
Configuration 2 @ 2 GeV

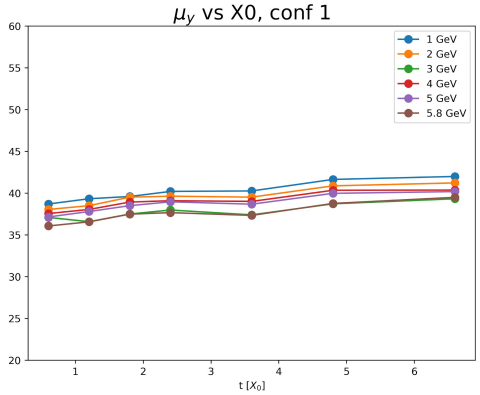
$$A_1 \ \mathcal{N}(\boldsymbol{\mu}_1, \mathbb{1}\sigma_1) + A_2 \ \mathcal{N}(\boldsymbol{\mu}_2, \mathbb{1}\sigma_2)$$

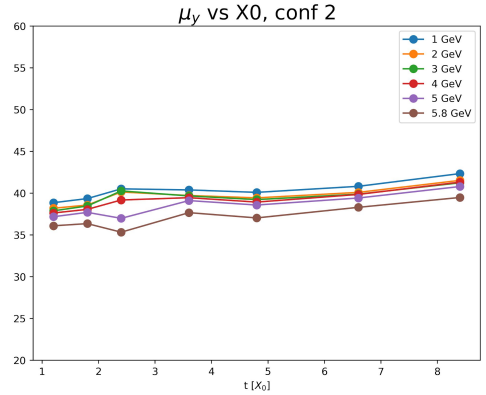
Evolution of mean x (top) and mean y (bottom)

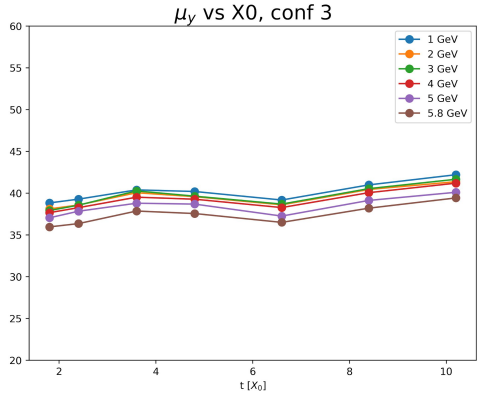






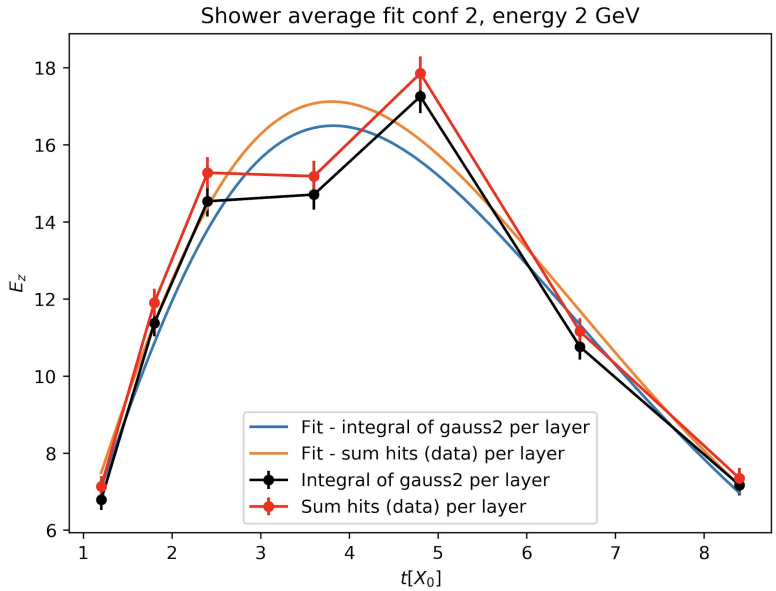






Longitudinal fits

$$\frac{dE}{dt} = E_0\, b\, \frac{(bt)^{a-1} e^{-bt}}{\Gamma(a)}$$



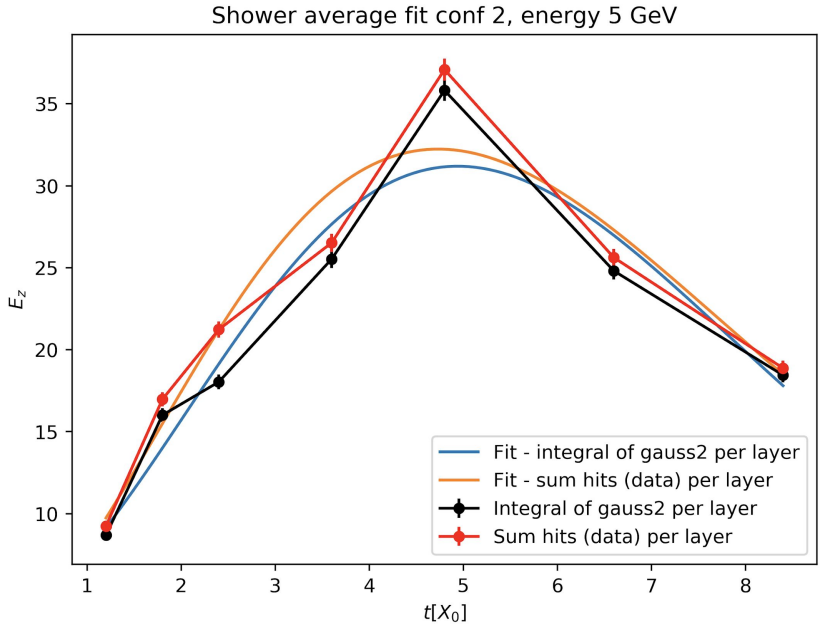
- Black dots come from integrating the model on each layer (prev. slide)
- Red dots are the sum of hit energies
- Solid lines are respective fits

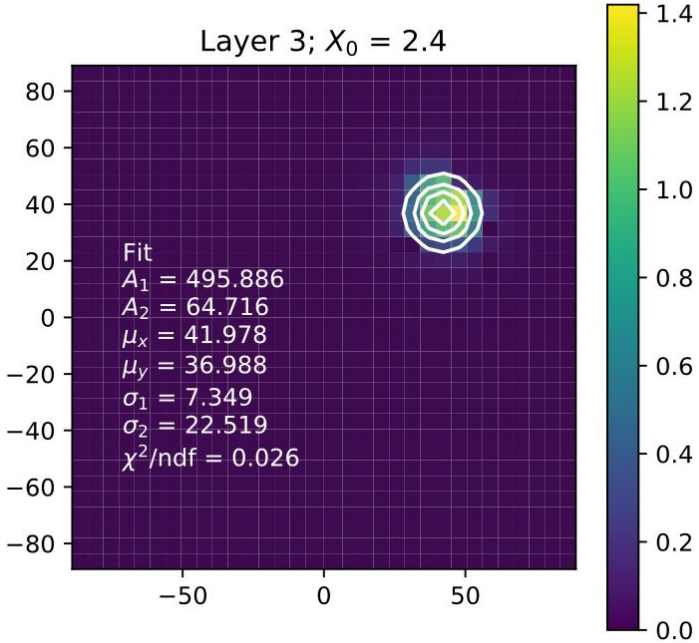
→ The integral of the model slightly underestimates the integral of hit energies

→ Function fit better than 4th layer deficit?

Two problematic layers/fits

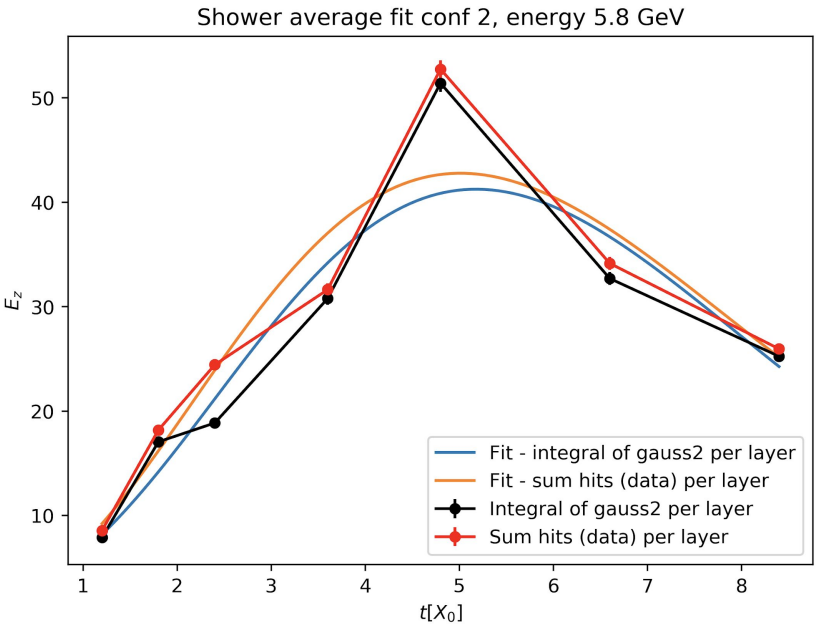
Conf 2, 5 GeV, third layer?

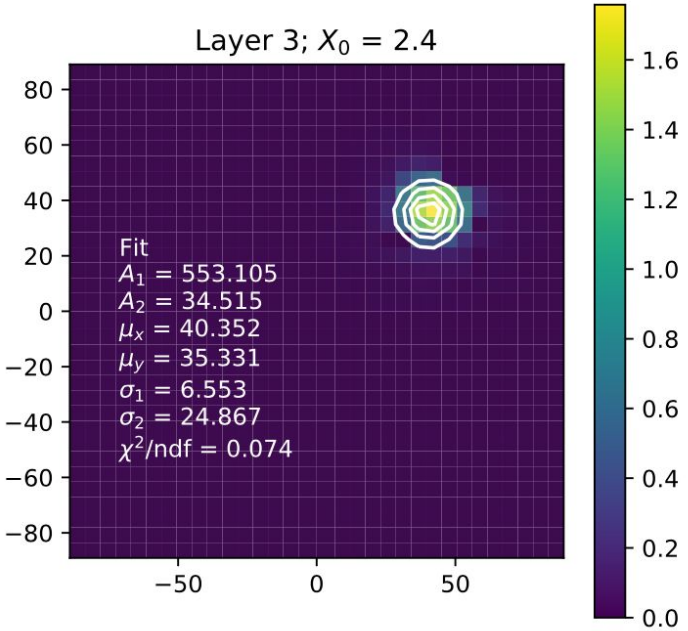




Two problematic layers/fits

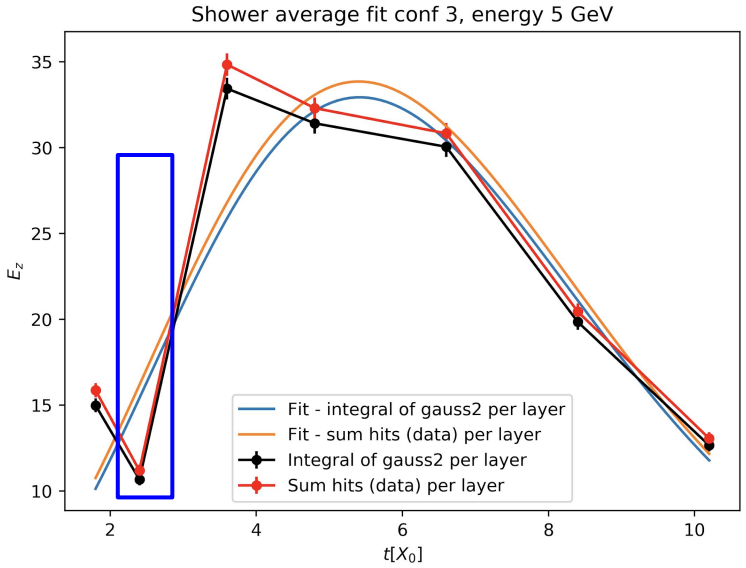
Conf 2, 5.8 GeV, third layer?

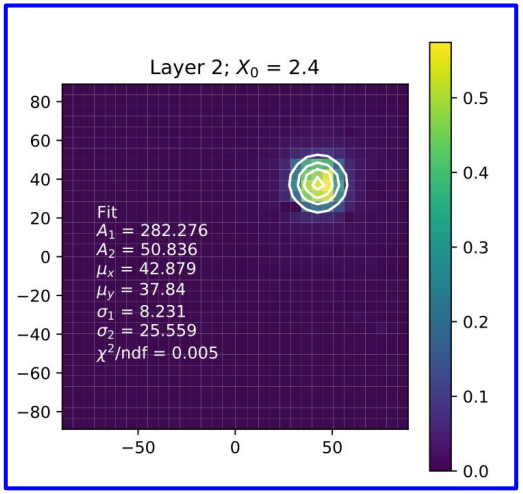


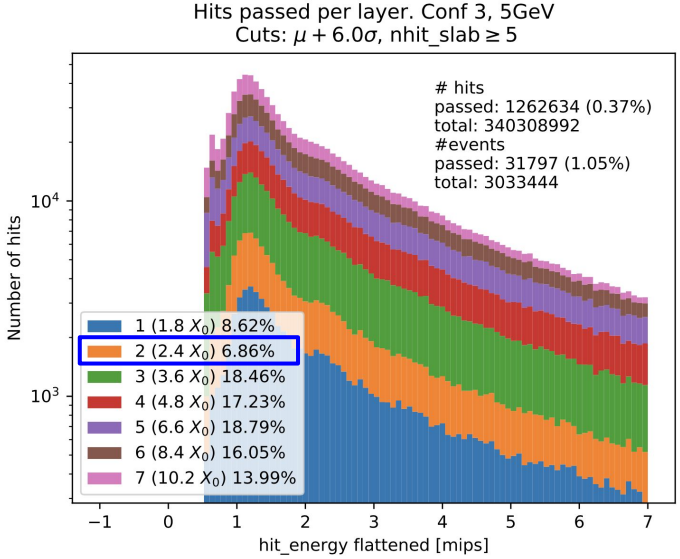


Problematic layer

Conf 3, 5 GeV, second layer?







Conclusion

- First attempt at fitting shower shapes on SiW-ECAL data (7 layers)
  - Might help handle masked cells
  - Still some issues with calibration mip→shower ?
    - To be x-checked
- To Do’s
  - Robustness against noise cuts
  - Robustness of method to be assessed on simulation data
  - Adapt to individual showers
    - Check beam profile
  - Use integrated (over cell surface) functions
    - Try various lateral shower profiles
  - Complete with full 3D profiles

Backup

Shower transversal model

- **Full single gaussian (6 param)**

$$A\ \mathcal{N}(\boldsymbol{\mu}, \boldsymbol{\Sigma})$$

- **Constrained single gaussian (4 param)**
  no corr. (ρ = 0), same cov. (σ = σx = σy)

$$A\ \mathcal{N}(\boldsymbol{\mu}, \mathbb{1}\sigma)$$

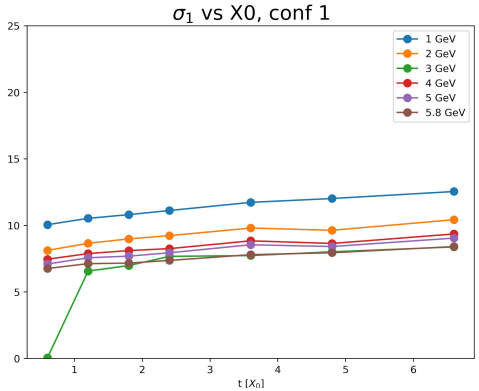
- **“Full” double gaussian (10 param)**
  shared mean, independent cov.

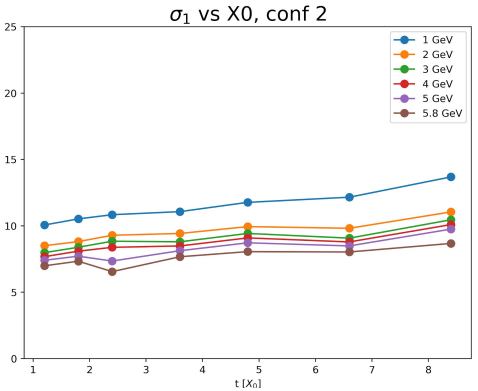
$$A_1\ \mathcal{N}(\boldsymbol{\mu}_1, \boldsymbol{\Sigma}_1) + A_2\ \mathcal{N}(\boldsymbol{\mu}_2, \boldsymbol{\Sigma}_2)$$

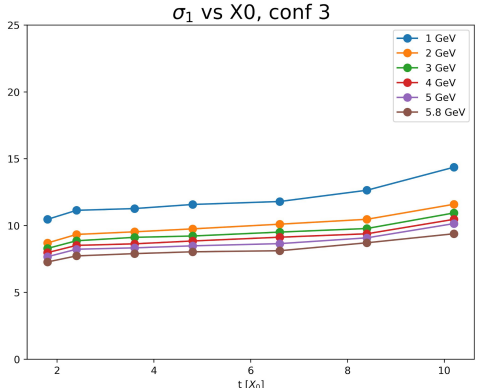
- **Constrained double gaussian (6 param)**
  shared mean, no corr. (ρ1 = ρ2 = 0)
  σ1 < σ2

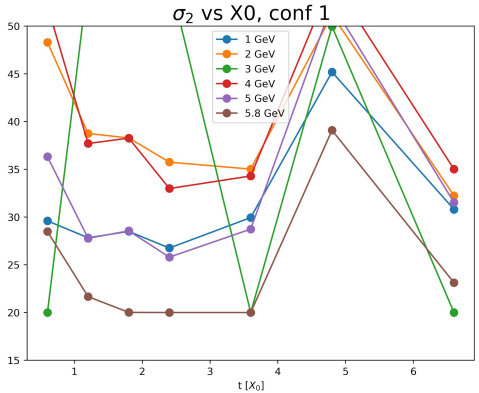
$$A_1\ \mathcal{N}(\boldsymbol{\mu}_1, \mathbb{1}\sigma_1) + A_2\ \mathcal{N}(\boldsymbol{\mu}_2, \mathbb{1}\sigma_2)$$

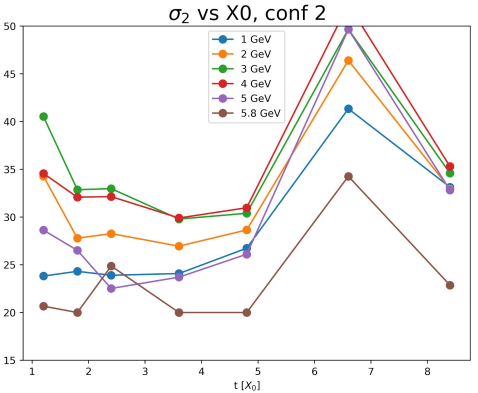
Evolution of sigma 1 (top) and sigma 2 (bottom)

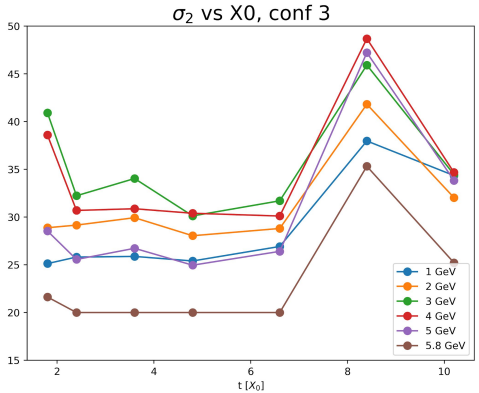




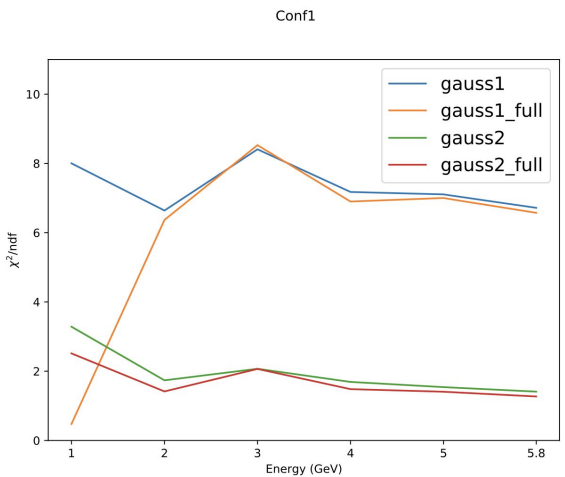


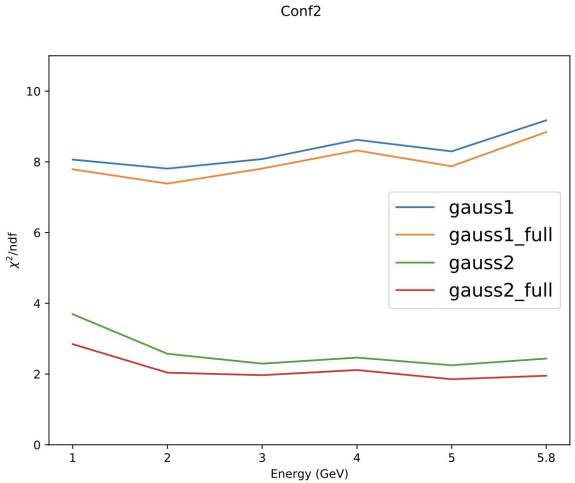


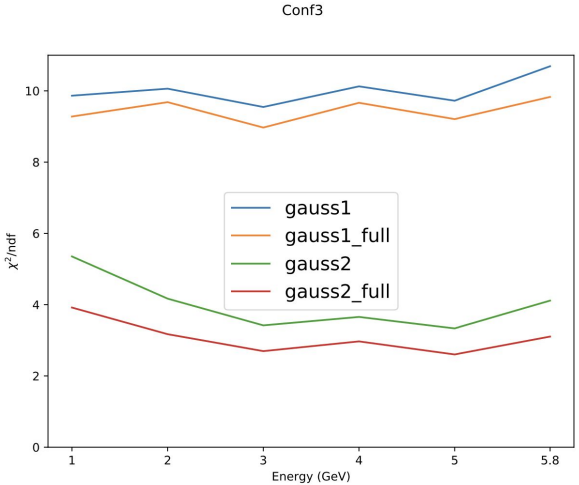




Fitting different models

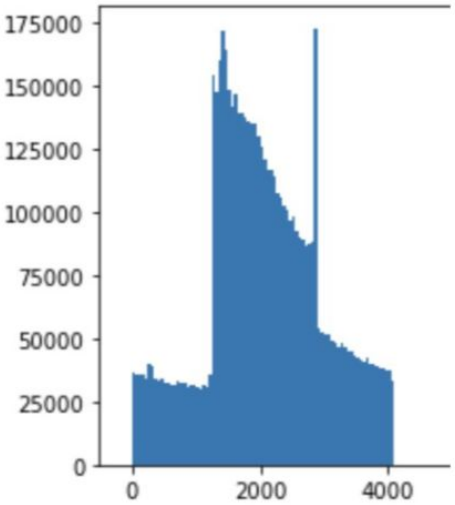




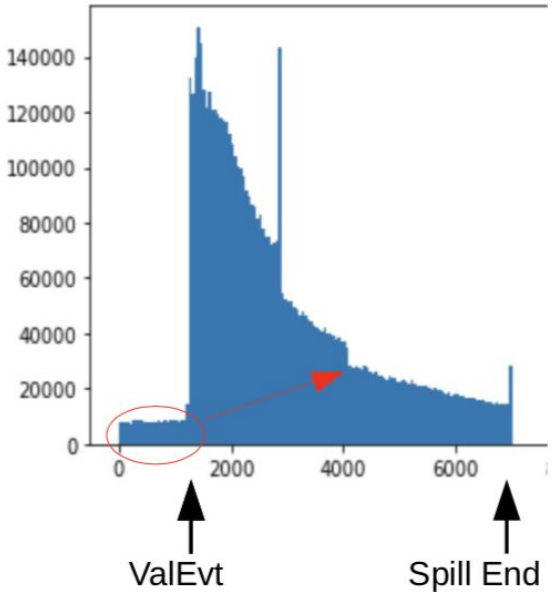


BCID*

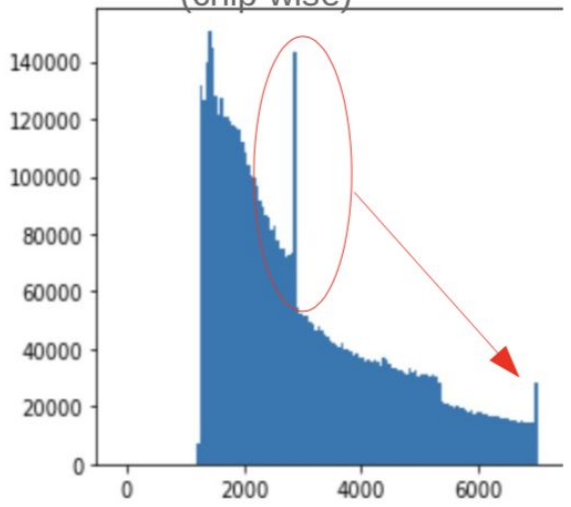
Looping BCID's at 4096



Corrected BCID
corr BCID = BCID +4096 if ≤ BCID in SCA-1
(chipwise)



Corrected BCID bis:
If BCID<(ValEvt) += 4096
(chip wise)



Example for conf2 @ 3 GeV

* Slide from Vincent

BCID Reconstruction*

- 1 event = BCID±1 (to account for over-the-clock-boundary events)
- What is the effect of bad reconstruction?
  - if corrected BCID wrong:
    - split events ⇒ worst case = Energy / 2 in 2 events (separated by 4096)
    - low tails in resolution or thrown-out events
  - if using uncorrected BCID (= true BCID%4096):
    - include ×2 the noise in the events → Small correction
- Ideally, either:
  - tag BCID crossing (force trigger @ BCID=4095?)
  - have spill length ≤ 4096×1/f ~ 0.8ms

* Slide from Vincent