Summer student program 2025

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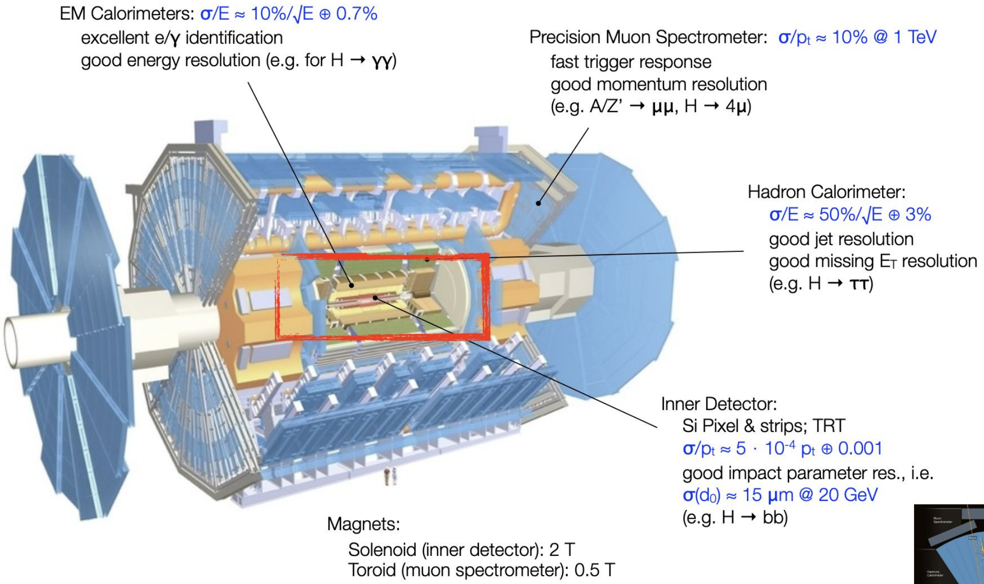
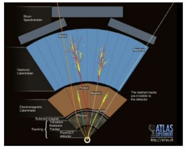
Context of project: *Run 3 Forward Electron Energy Calibration in ATLAS*

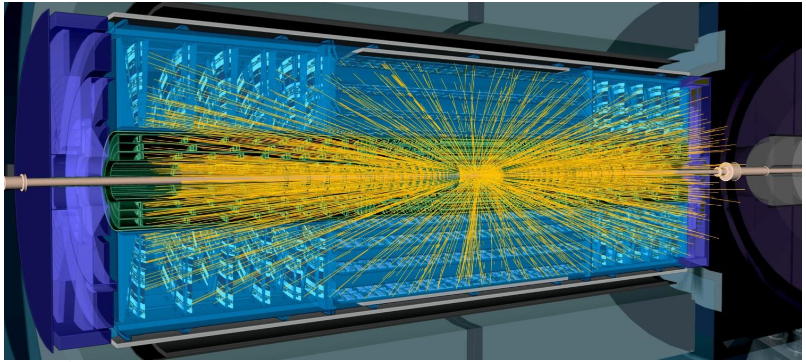
Dedicated study of pileup noise in the forward calorimeter in ATLAS, corresponding to electron with eta>2.47 and reconstructed in the forward part of the calorimeter. **The goal is to estimate and better understand the pileup noise in the simulation.**

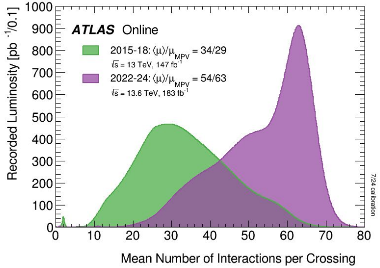
ATLAS





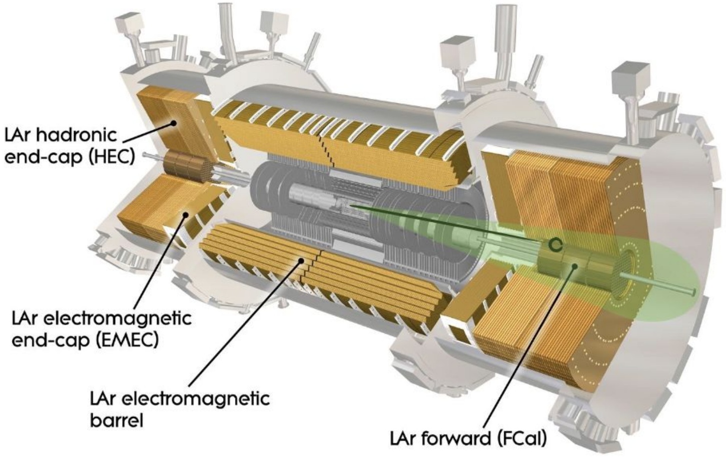
Pile-UP

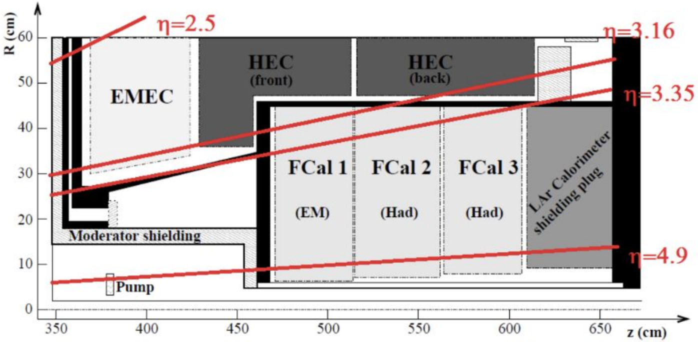


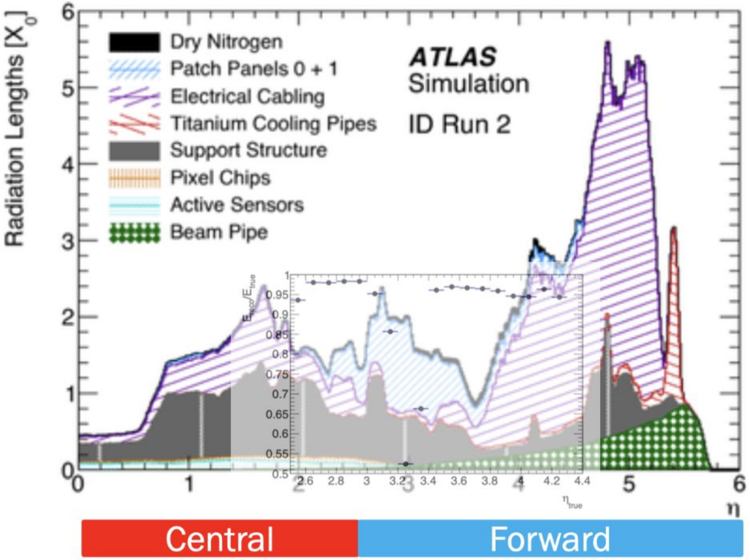


Forward (fwd) electron: cluster only outside tracing acceptance $|\eta| > 2.5$

Project





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Eta bins = {2.5, 2.6, 2.7, 2.8, 2.9, 3.00, 3.10, 3.16, 3.35, 3.6 ,4.0, 4.3, 4.6, 4.9} ;
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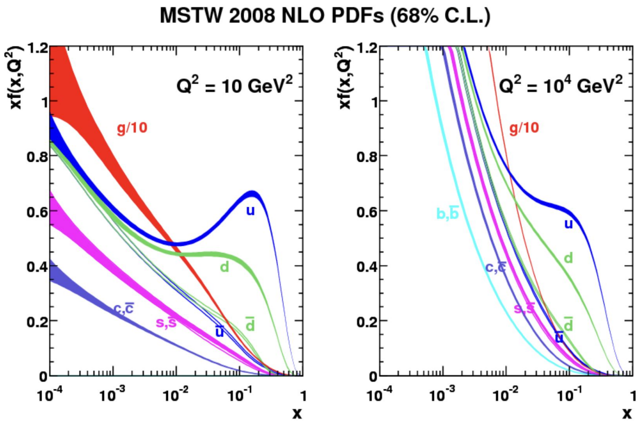
Physics of forward electron

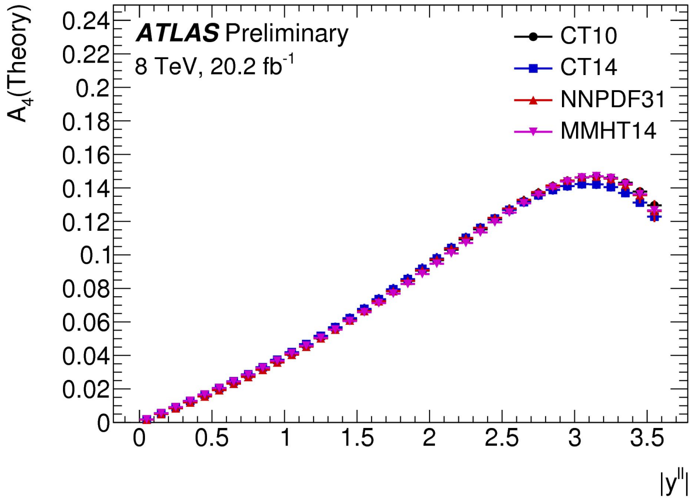
- **Proton Parton Distribution Function** with high and low Bjorken x values (TBC as Ludovica mentioned during lunch yesterday)



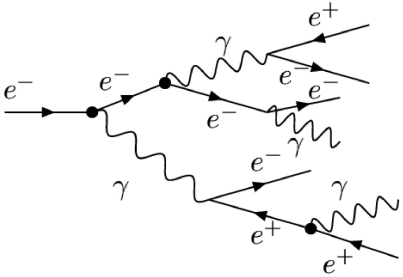
$$\sigma(s) = \sum_{a,b} \int dx_a\, dx_b\, f_a^A(x_a)\, f_b^B(x_b)\, \hat{\sigma}_{ab}(\hat{s})$$

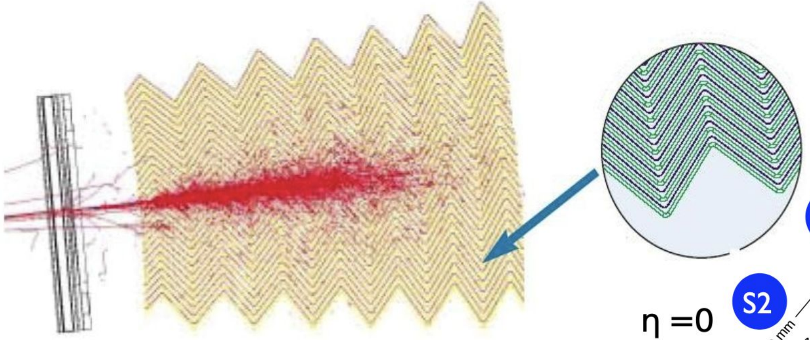
- **Measurement of EW mixing angle sinθw**, with the Z→e(central)e(forward)

ATLAS-CONF-2018-037

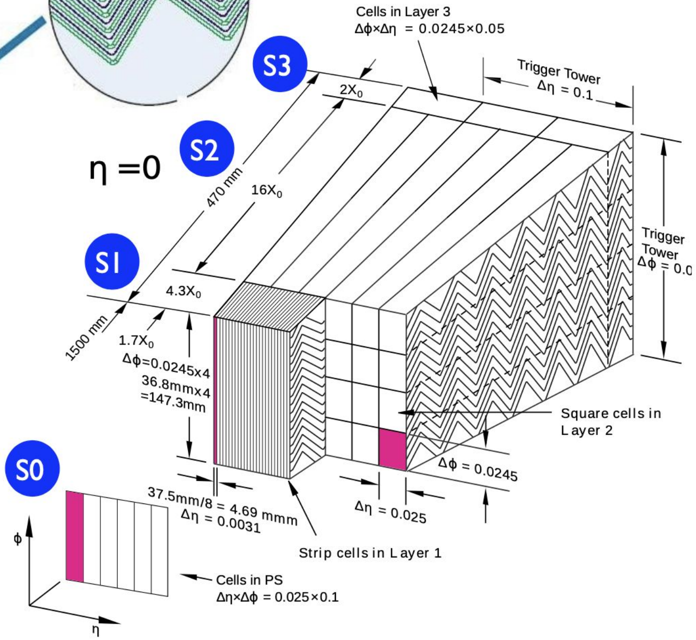


Cluster reconstruction





sampling calorimeter
Pb-LAr



10 % 250 MeV 0.7%

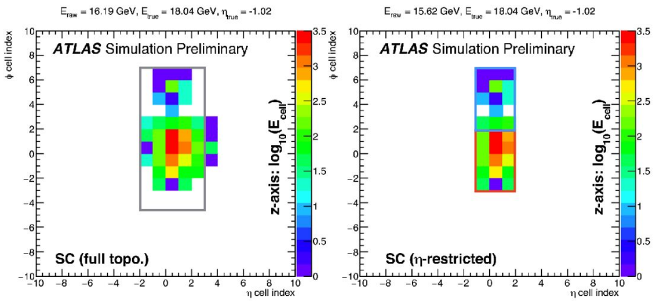
$$\frac{\sigma_E}{E} = \frac{a}{\sqrt{E}} \oplus \frac{b}{E} \oplus c$$

- S0 (Presampler) Energy loss correction
- S1 (Strips) γ/π^0 separation 4.3 X_0
- S2 (Middle) Main energy deposit 16 X_0
- S3 (Back) High energy showers 2 X_0

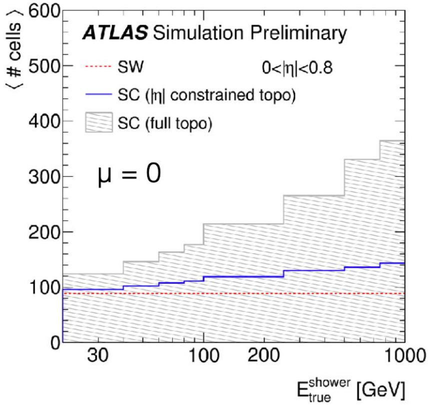
Cluster reconstruction

In the central case …

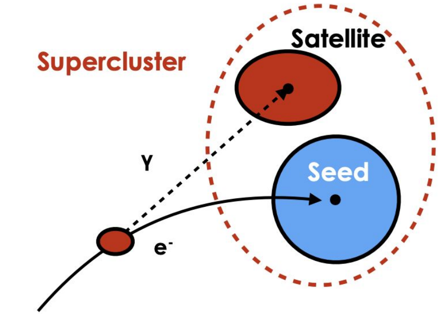
To guarantee a linear lateral response (eg. lateral leakage (the fraction of true shower energy not contained in a cluster) roughly constant with increasing energy) *restrict η width to 3 (5) cells in barrel (end-cap) → also limit growth in the number of cells vs E (and pileup-robustness).*

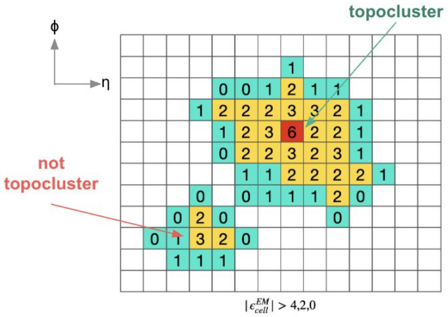


Bremsstrahlung recovery by capturing the energy of the satellite cluster (φ direction)

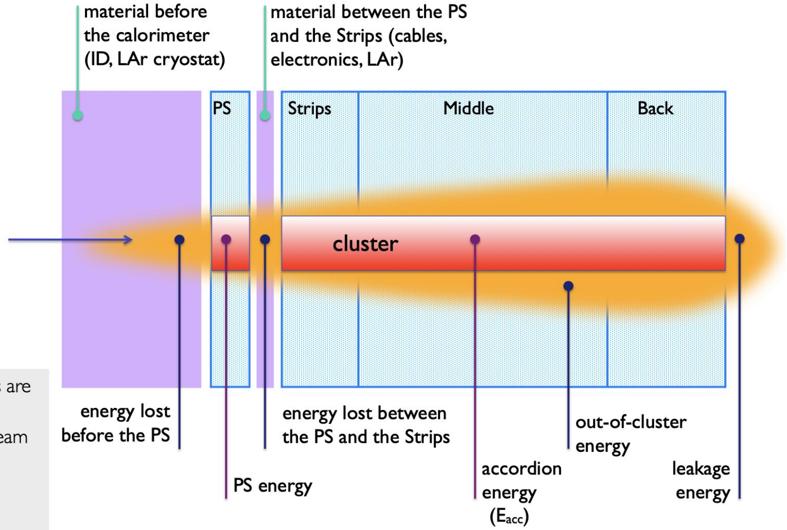


To select the cells of a supercluster: only use cells from the EM calorimeter (+ presampler and E4 scintillator in the crack)





How energy is reconstructed



Reconstructed e/γ clusters are calibrated to correct for:

- energy lost in the upstream material
- energy deposited in the neighbours eta/phi cells
- energy lost beyond the LAr calorimeter

$$\frac{E_{reco}}{E_{true}}$$

Energy resolution = Spread between the True energy and the reconstructed energy

Relative energy resolution

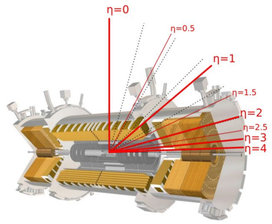
- The relative energy resolution for electrons and photons is given by:

$$\frac{\sigma_E}{E} = \frac{a}{\sqrt{E}} \oplus \frac{b}{E} \oplus c$$

10% (a), 250 MeV (b), 0.7% (c)

sampling term, noise term, constant term

- $a \rightarrow$ due to the stochastic behaviour of shower evolution
- $b \rightarrow$ due to electronic and pile-up noise
- $c \rightarrow$ due to non-uniformities in the detector, radiation damage etc.



- The terms *a*, *b*, *c* depend on pseudorapidity η due to the amount of material encountered by the particle

$$\eta \equiv -\ln\left[\tan\left(\frac{\theta}{2}\right)\right]$$

https://www.desy.de/~schleper/lehre/Det_Dat/SS_2018/06_lecture_calorimetry_EM.pdf

Energy resolution

Energy resolution = Spread between the True energy and the reconstructed energy

Relative resolution

$$\sigma^2 = \frac{1}{E}A^2 + \frac{1}{E^2}B^2 + C^2$$

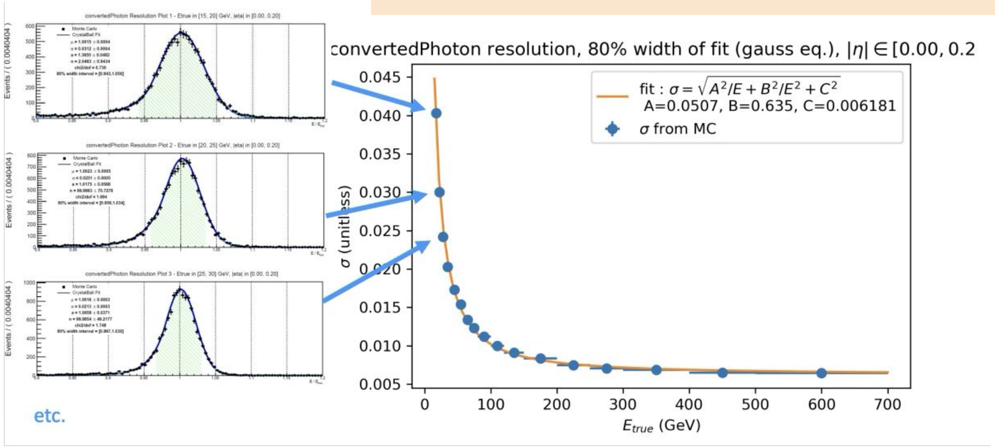
resolution

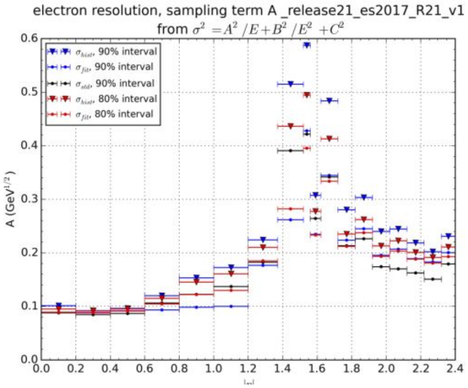
sampling term

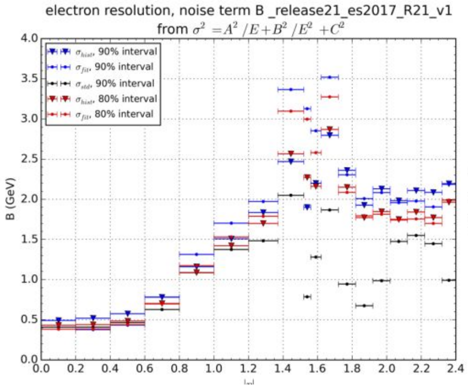
noise term

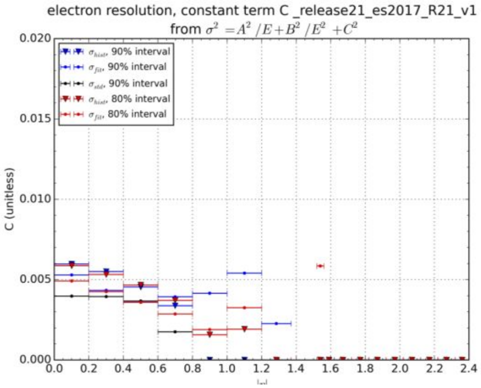
constant term

$$b = \sigma_{pileup} \oplus \sigma_{electronic}$$





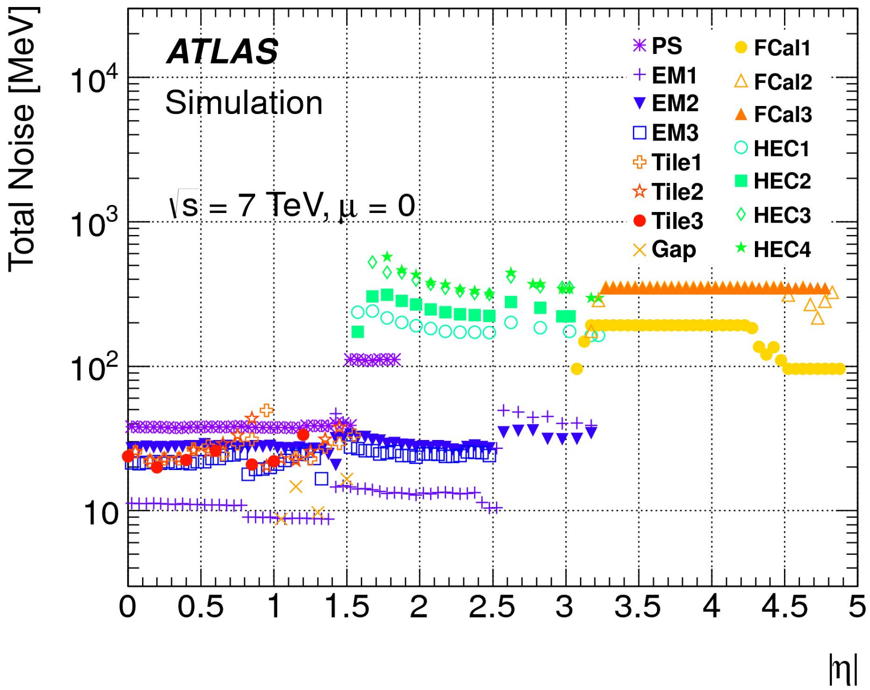


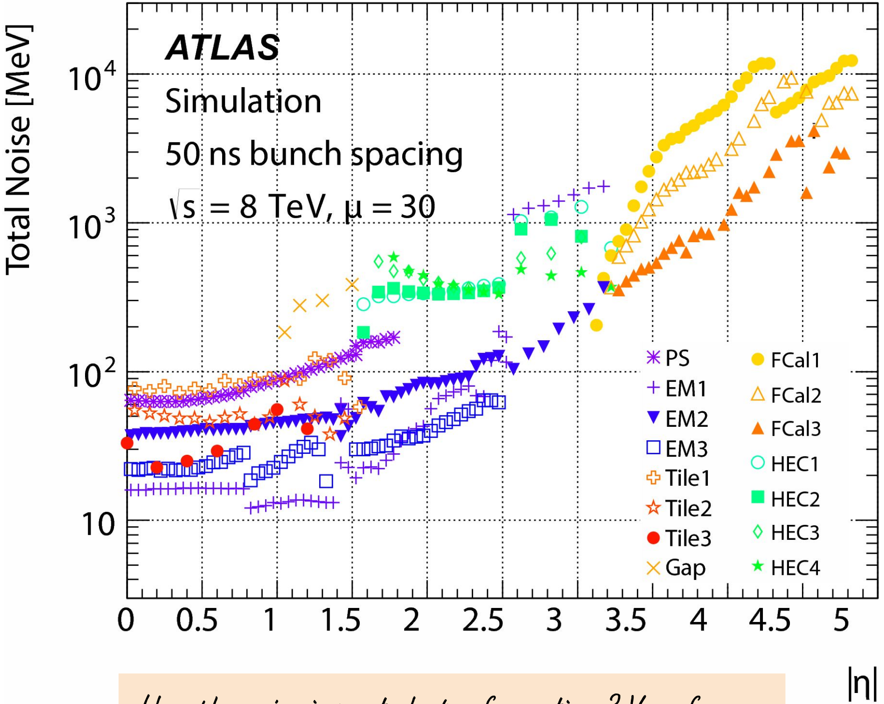


https://indico.cern.ch/event/780184/contributions/3252257/attachments/1770615/2877462/2018-12-13_eGamma_calibration_photonResolution_.pdf

https://cds.cern.ch/record/2651890/files/ATL-COM-PHYS-2018-1720.pdf

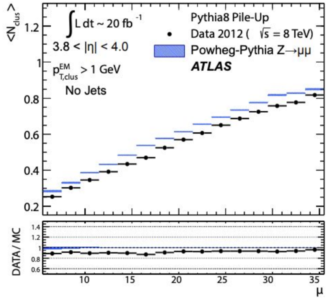
How the pileup noise affects energy resolution ?





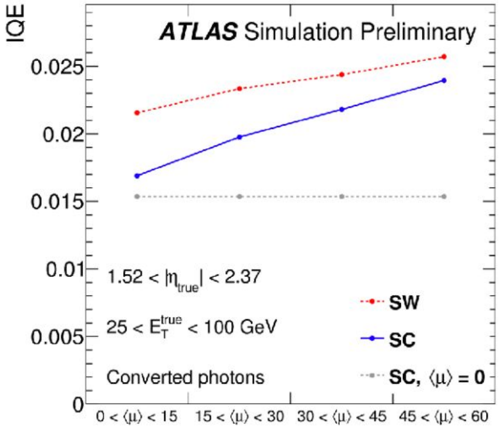
How the noise impact cluster formation ? Very fancy display of this here

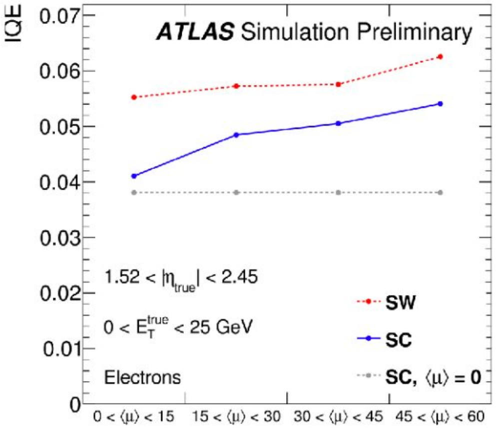
How the pileup noise affects energy resolution ?

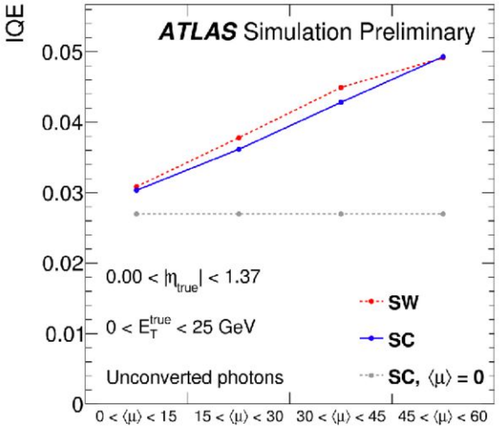


(f)

- ***Indications that super-clusters could bring increased robustness with pileup***
  - Very important to have noise thresholds already tuned for individual topo-clusters [topo-cluster noise threshold tuned for $\langle \mu \rangle$ ~ 40]
- Interquartile efficiencies (IQE) show little sensitivity to pileup by construction
  - With increasing <μ>, the performance of both clustering algorithms degrades due to clusters containing more noise on average, in addition to the true shower energy.







How the pileup noise affects energy resolution ?

- *Indications that super-clusters could bring increased robustness with pileup*
  - Very important to have noise thresholds already tuned for individual topo-clusters [topo-cluster noise threshold tuned for $\langle\mu\rangle \sim 40$]
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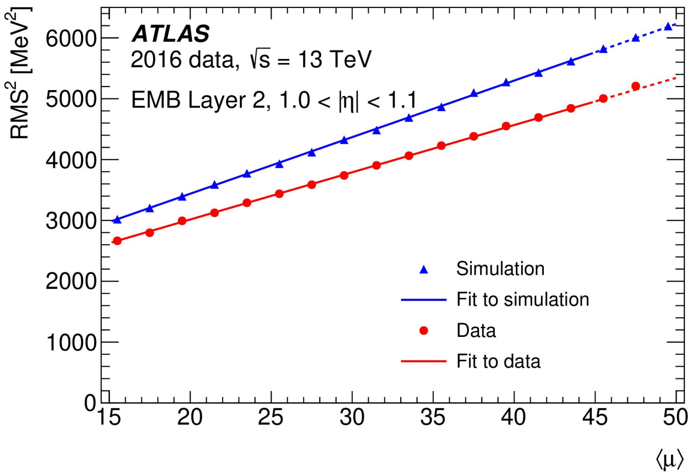

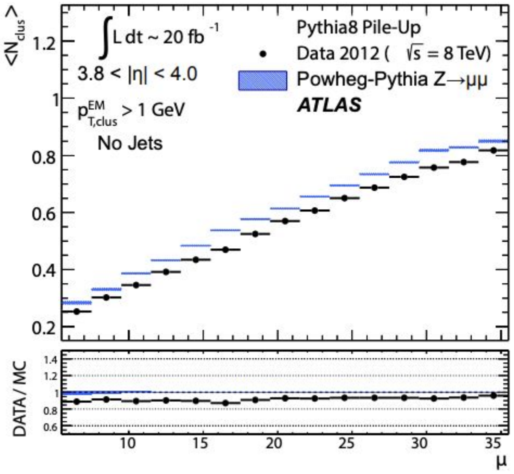

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Large noise was simulated than real data

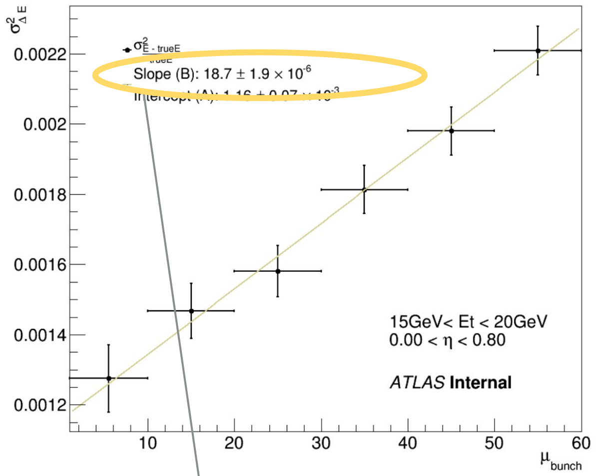
How to quantify Pileup noise

Previous CC studies here

Pileup noise receives contribution from bunch crossing number (μ)-dependent part and constant part:

$$\frac{\sigma_{pileup}}{E_t}(\eta) = \beta(\eta)\sqrt{\mu} \oplus \alpha$$

with $\beta(\eta)$ = pileup noise per $\sqrt{\mu}$ in E_t, expected to depend weakly on η and E_t for superclusters.



$$\left(\frac{\sigma_E}{E}(\mu)\right)^2 = \frac{\beta^2\mu}{E_t^2} + Constants$$

Backup

Calorimeter