Update on calorimeter studies

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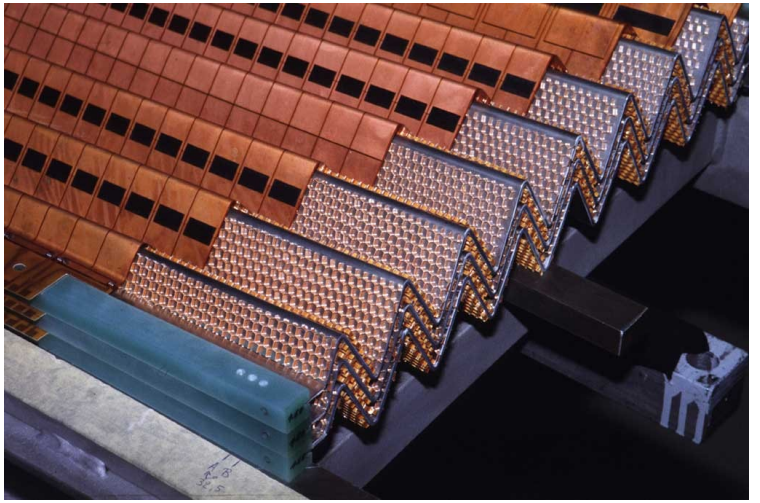
Outline

- **Calorimeter software**
- **Estimates of noise in ECAL**
  - Electronic & pile-up noise extrapolation from ATLAS

Calorimeter under FCC software

- **ECAL geometry description (Detector/DetFCChhECalSimple)**
  - Tube geometry with alternating layers of active (LAr) and passive (Pb) materials
  - Using $\eta - \Phi$ segmentation
  - Calorimeter cells defined by a layer in $R + \eta - \Phi$ segment
- **Calorimeter reconstruction software (Reconstruction/RecCalorimeter)**
  - **Cell energy reconstruction from Geant4 energy deposits**
    - Merge Geant4 energy deposits in cells
    - Calibrate Geant4 energy to EM scale
    - Add noise hits to cells (same noise for all cells at the moment)
  - **Next steps**
    - More complex noise description (read constants from root file)
    - Clustering algorithm

ECAL barrel in ATLAS



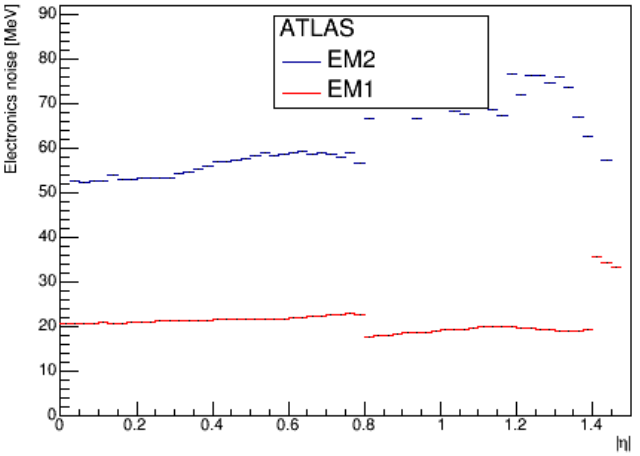
- **LAr/Lead sampling calorimeter**
  - Accordion shape
- **Segmentation in the barrel (|η|<1.35)**

	$\Delta\eta$	$\Delta\Phi$	ΔR at η=0
EM1	0.025/8	0.1	4.3 X_0
EM2	0.025	0.025	16 X_0
EM3	0.05	0.025	2 X_0

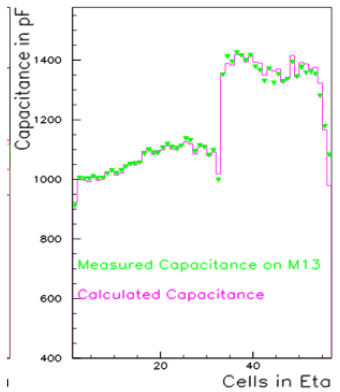
Middle layer

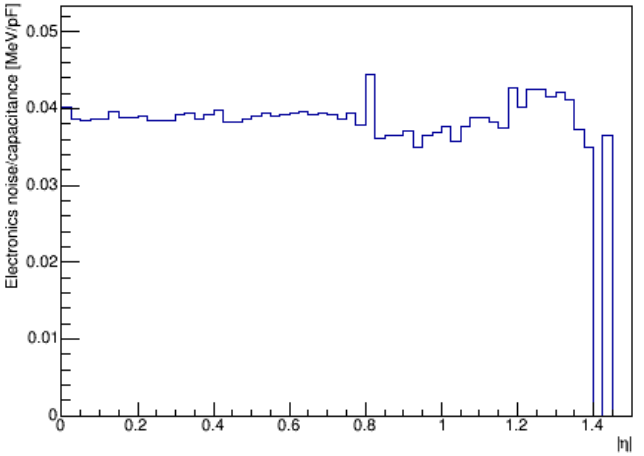
Electronics noise in ATLAS

- **Electronics noise per cell**
  - Depends on the readout electronics
  - Scales with detector capacitance (ATL-LARG-95-010)



- **Electronics noise vs capacitance in ATLAS middle layer**
  - Measurement of capacitances (LARG-PUB-2007-005)
  - Electronics noise/capacitance ~ constant



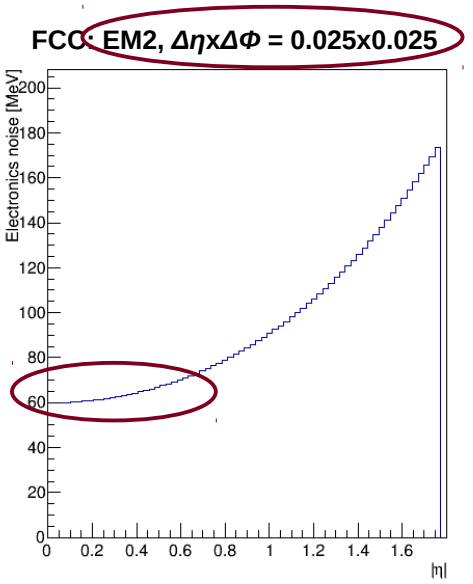


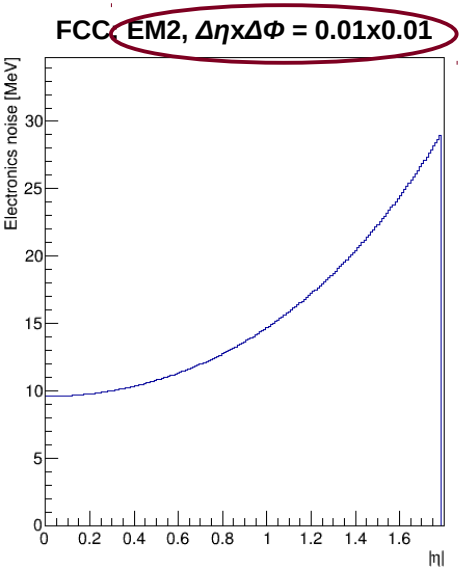
Electronics noise in FCC

- **Extrapolation of ATLAS noise to FCC**
  - Calculate capacitances of the ECAL cells
  - Multiply the capacitance with the noise/capacitance factor → electronics noise
- **Capacitance of a plane capacitor:** $C = \epsilon_0 \epsilon_r \frac{A}{d}$
  - Increases with the area of the capacitor *A*
  - Decreases with the distance between the plates *d*

  → **Same scaling for the electronics noise**
- **FCC ECAL noise per cell**
  - ATLAS-like middle layer thickness
  - LAr thickness 2*2 mm
  - Pb thickness 2 mm

Comparable to ATLAS





Pile-up contribution per cell

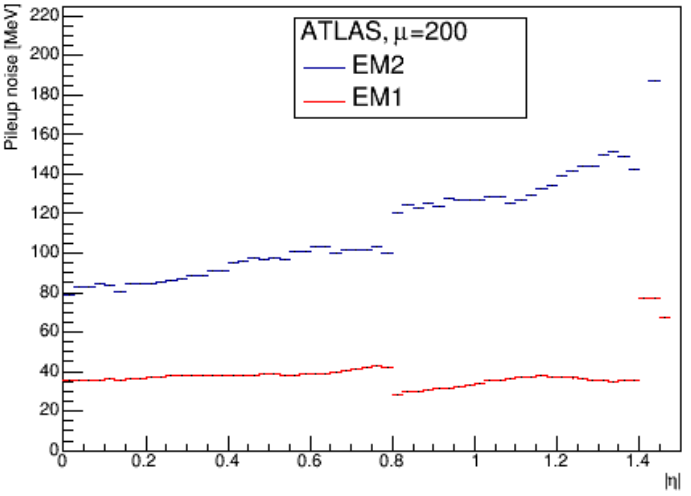
- **ATLAS Phase II upgrade simulations**
  - Average number of min. bias events = 200
- **Extrapolation to FCC**

$$\sigma_{pileup}^{FCC} = \frac{[\Delta\eta \times \Delta\phi]^{FCC}}{[\Delta\eta \times \Delta\phi]^{ATLAS}} * \sigma_{pileup}^{ATLAS} * \sqrt{\mu} * f\left(e_{100\,TeV}/e_{13\,TeV}, R, \eta\right)$$

Scales with sqrt of average number of minimum bias events

Extrapolation factor *f*: average energy densities of minimum bias events at 100 TeV and 13 TeV

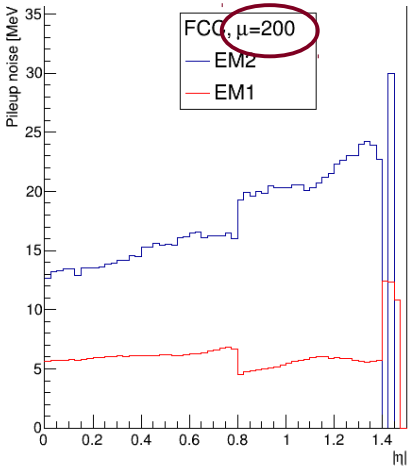
– To be derived from MC simulations

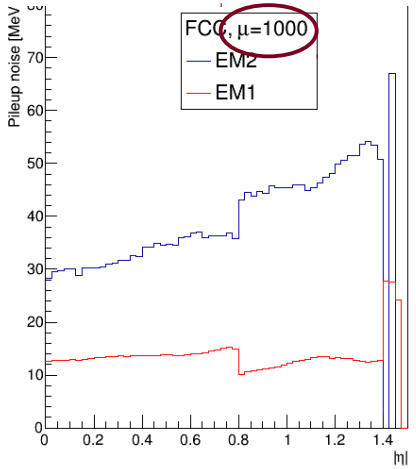


FCC pile-up estimation

Assuming *f* = 1

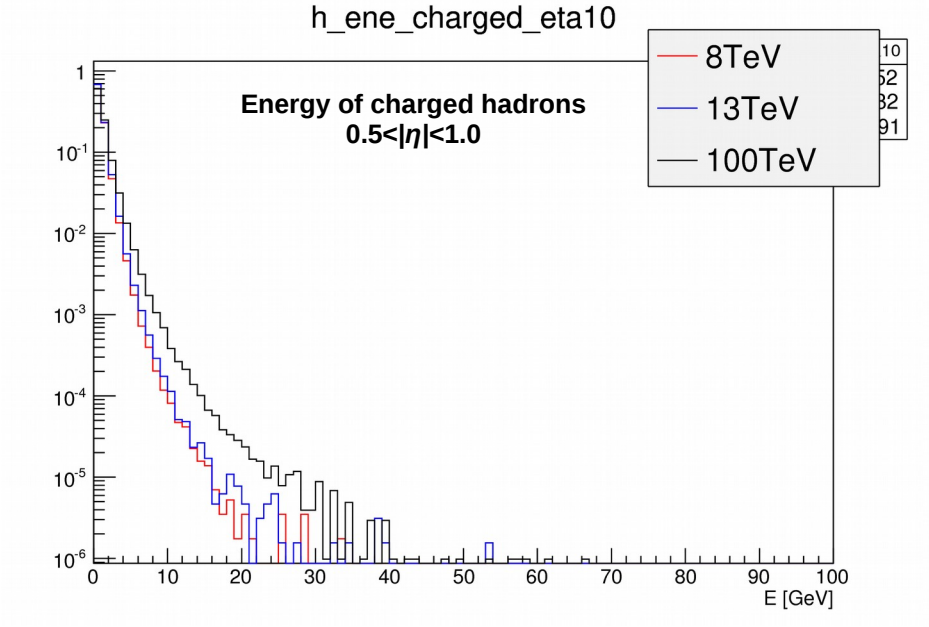
Cell size: $\Delta\eta$ x $\Delta\Phi$ = 0.01 x 0.01

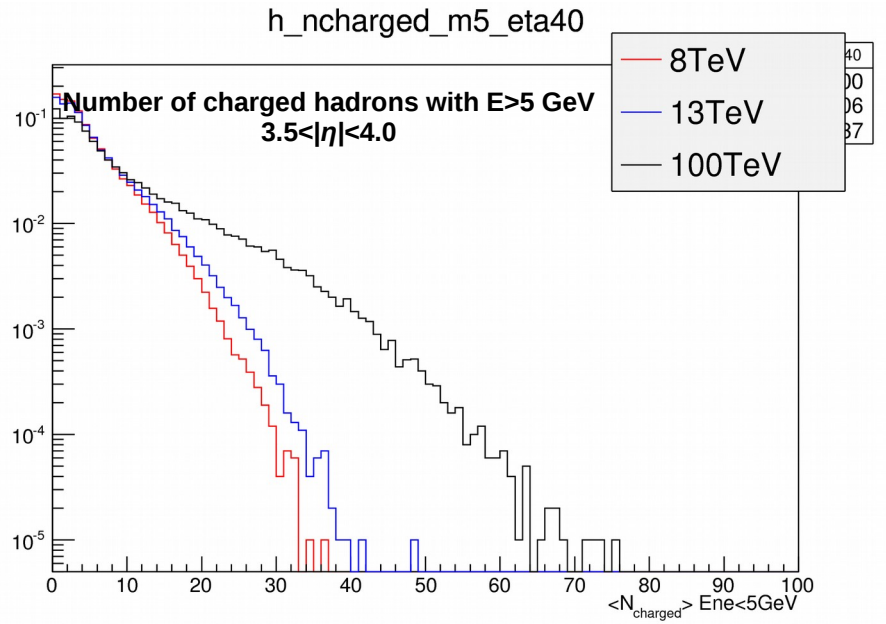




Minimum bias events simulations

- **Simulations at 8, 13 and 100 TeV center of mass energies**
  - Generated with Pythia8
  - 100 000 events at each energy

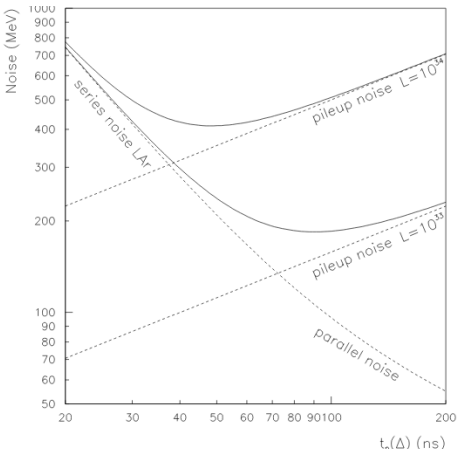




- **Higher energies and multiplicities at 100 TeV compared to 13/8 TeV**
  - To be evaluated and used as a correction factor for the FCC pile-up predictions

Noise optimization

- **Total noise in the calorimeter cells**
  - Sum of the electronics noise and pile-up in quadrature
  - Non-trivial cell-by-cell correlations
- **Electronics noise per cell**
  - Increases with the area of the capacitor
  - Increases with the cell size in *R*
  - Decreases with larger LAr gaps
    - Larger gaps: better energy resolution, larger X_0
- **Pile-up noise**
  - Increases with the area in $\Delta\eta$ x $\Delta\Phi$
  - Decreases with *R*
- **Integration time of the readout**
  - Smaller time → larger electronics noise, better for pile-up suppression
  - Optimization in ATLAS: 40 ns (ATL-LARG-95-010)



Conclusions

- **Work on the calorimeter reconstruction under FCC software ongoing**
- **Electronics & pile-up noise constants per cell**
  - Extrapolation from ATLAS
  - Need to be optimized for FCC
- **Next steps**
  - Implementation of a clustering algorithm (sliding window) in the FCC software
  - Redo electron cluster studies with the realistic noise distribution