Electromagnetic calorimeter using LAr technology for FCC-hh

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Outline

Calorimeter system in FCC-hh

- Requirements
- Technologies under consideration

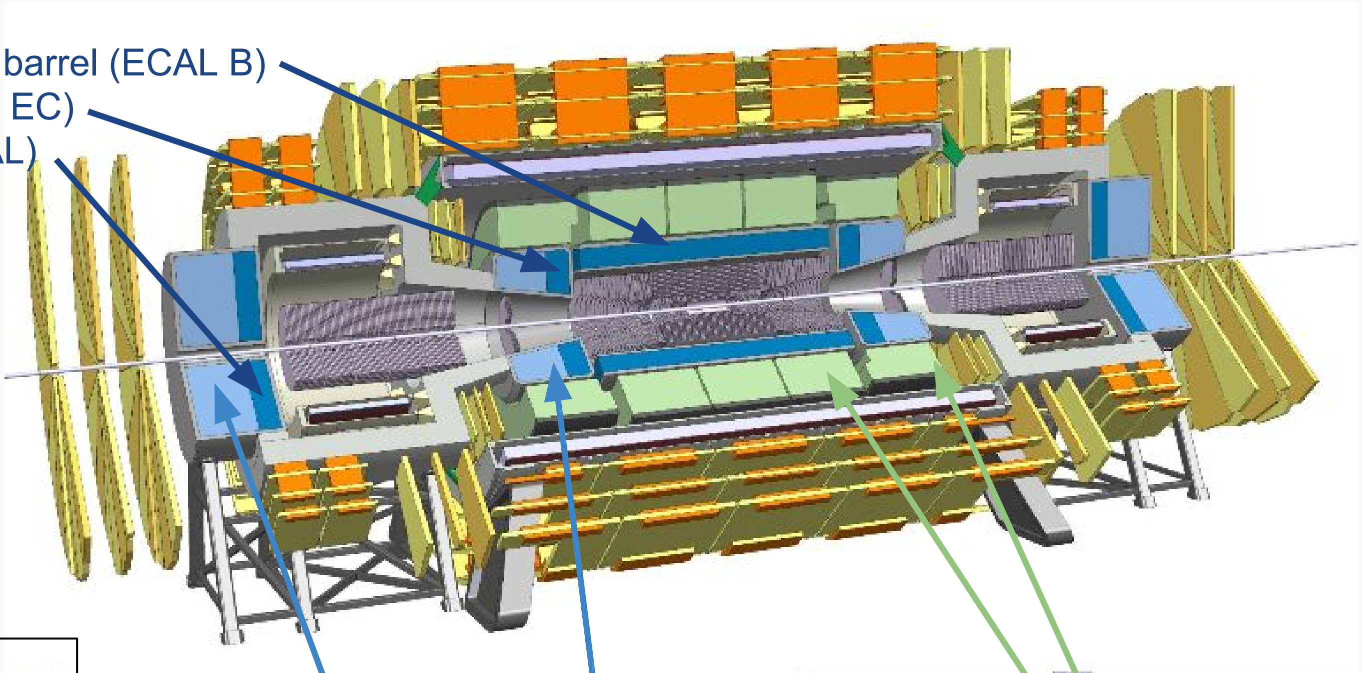
Electromagnetic calorimeter proposal

- Geometry
- Performance of single electrons

Calorimetry in FCC software

Conclusions

Calorimeters in FCC-hh detector



Coverage of the calorimeter system up to $|\eta| = 6.0$

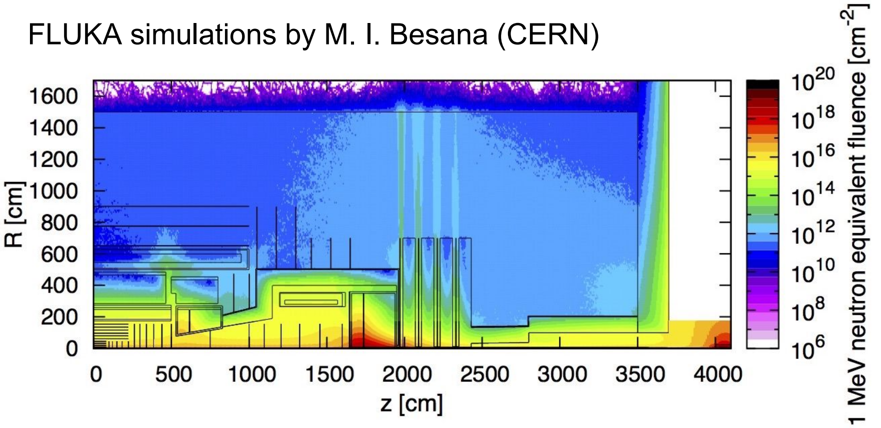
Requirements for calorimeters at FCC-hh

Electrons / photons, jets, taus, E_T^{miss} measurements

Requirements

- Good energy and angular resolutions
- Pile-up rejection
  (<μ> up to ~ 1000)
- Radiation hardness
  (5×10^{18} n_{eq}/cm^2,
  dose up to 5 GGy
  for 30 ab^{-1} in forward cal.)

Strong requirements on radiation hardness



Use of Particle Flow techniques → fine granularity

Timing detectors, radiation hard materials

Benchmark channels (ECAL)

Precision Standard Model measurements

Beyond Standard Model

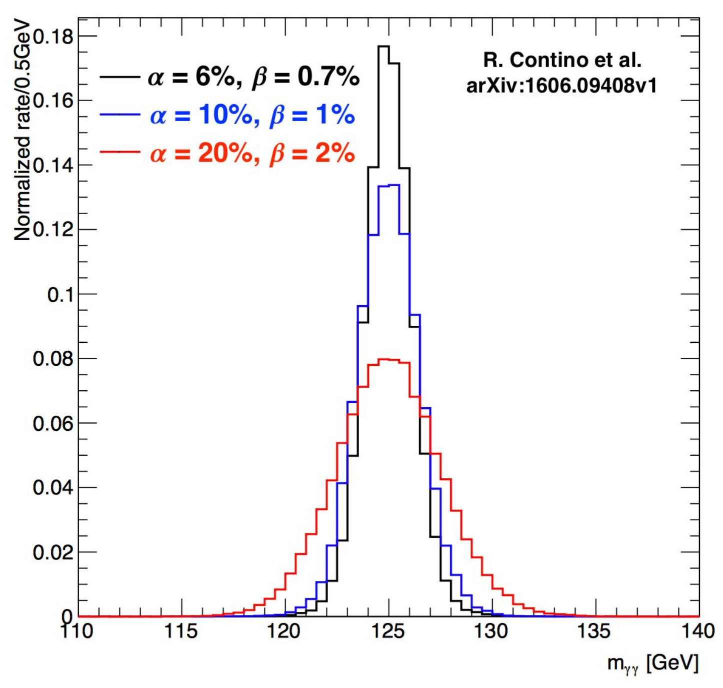
- Heavy resonances ($Z' \rightarrow ee$, $W' \rightarrow e\nu$, $X \rightarrow \gamma\gamma$, $X \rightarrow jj$)

Requirements

- High energy resolution
- High angular resolution for p_T measurements
- Good linearity of calorimeter response

Calibration & stability is crucial in such harsh environment

$$\frac{\sigma_E}{E} = \frac{\alpha}{\sqrt{E}} \oplus \beta$$



Technologies under consideration

Baseline geometry
(inspired by ATLAS calorimetry with excellent conventional calorimetry and in addition high granularity to optimise for Particle Flow techniques)

- LAr / Pb (Cu) (this talk)
  - ECAL + hadronic endcap / forward
- Scintillating tiles / Fe with SiPM (C. Neubüser)
  - HCAL barrel + extended barrel

Other options considered for ECAL

- Digital Si / W (T. Price)
- Analog Si / W (not yet studied)

HCAL granularity studies (S. Chekanov)

Strong requirements on radiation hardness

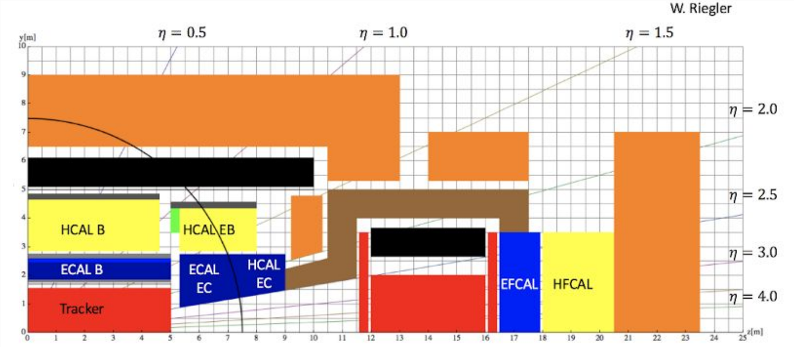
	Max. eq. fluence [n/cm^2]	**Max. dose [MGy]**
ECAL B	4×10^{15}	~0.1
ECAL EC	3×10^{16}	~1
HCAL EC	2×10^{16}	~1
FCAL	5×10^{18}	5×10^{3}
HCAL B	4×10^{14}	6×10^{-3}
HCAL EB	4×10^{14}	6×10^{-3}
1st layer IB	6×10^{17}	4×10^{2}

Baseline option for calorimeters

High-granularity calorimeter using LAr / Pb (Cu) + scintillators / Steel technologies

2-4 x better granularity than ATLAS calorimeters

- Granularity to be optimized based on further studies (e.g. pile-up rejection)



NAME	Technology	η coverage	# long.layers	$\Delta\eta \times \Delta\varphi$	# channels ($\times 10^6$)
ECAL B	LAr / Pb	< 1.7	8	0.01 x 0.012	1.3
ECAL EB	LAr / Pb	1.5 – 2.5	6	0.01 x 0.012	0.6
HEC	LAr / Cu	1.7 – 2.5	6	0.025 x 0.025	0.1
EFCal	LAr / Pb	2.3 – 6.0	6	0.025 x 0.025	0.5
HFCal	LAr / Cu	2.3 – 6.0	6	0.05 x 0.05	0.1
HCAL B	Scint. Tiles / Stain. Steel	< 1.3	10	0.025 x 0.025	0.2
HCAL EB	Scint. Tiles / Stain. Steel	1.0 – 1.8	8	0.025 x 0.025	0.07
Total	LAr / Pb				**2.3**
	LAr / Cu				**0.2**
	Scint. Tiles / Stain. Steel				**0.3**

ECAL barrel geometry

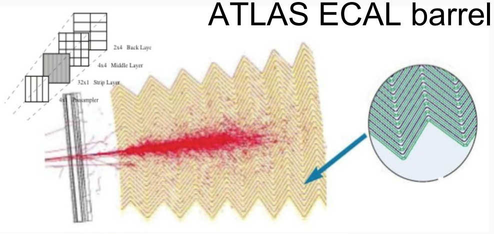
Detector with larger longitudinal and transversal granularity compared to ATLAS

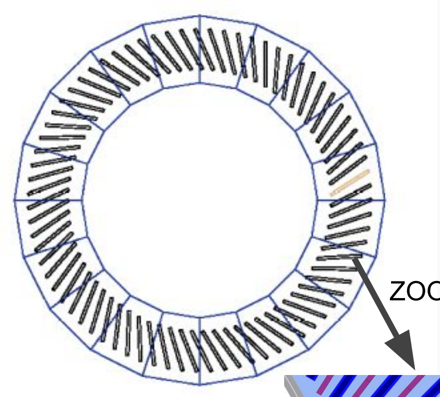
- Possible only with straight multilayer electrodes

Proposal: Inclined plates of absorber (Pb) + active material (LAr) + multilayer readout (PCB)

- Pros: Easy construction
- Cons: Sampling fraction changes with radius
    - Goal energy resolution of 10% / sqrt(E) ⊕ 1%

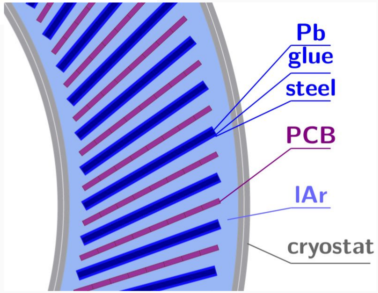
ATLAS ECAL barrel



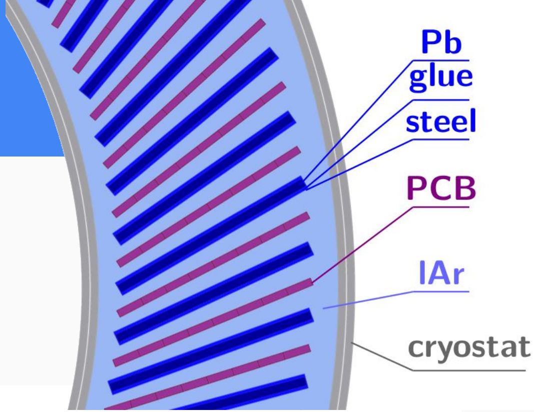


FCC ECAL barrel

ZOOM



ECAL barrel + endcap



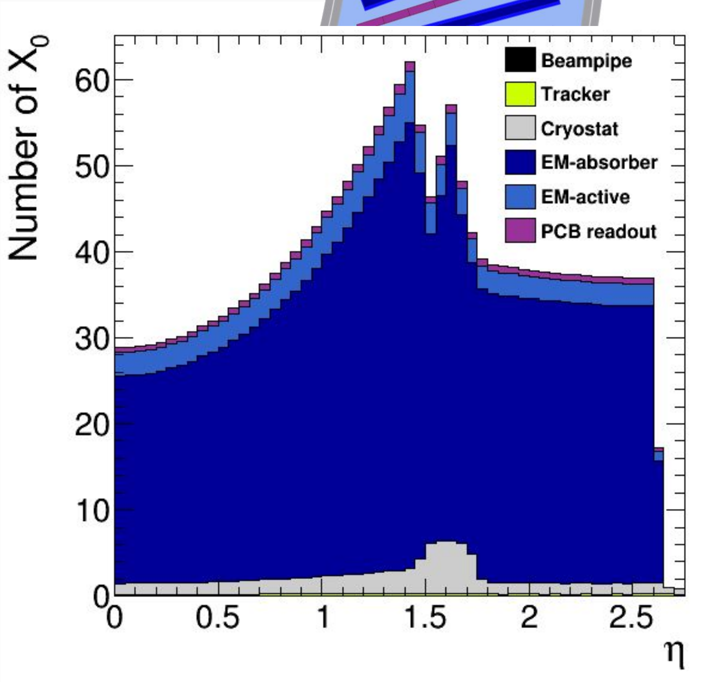
Barrel

- Absorber plates (2mm) inclined by angle of 30^0
- LAr thickness increasing with radius
  3 - 5.4 mm (LAr / Pb ratio: 1.5 - 2.7)
- 29 X_0 at $\eta = 0$ (1.5 X_0 in front of the active detector)

Endcaps

- Parallel discs of absorber

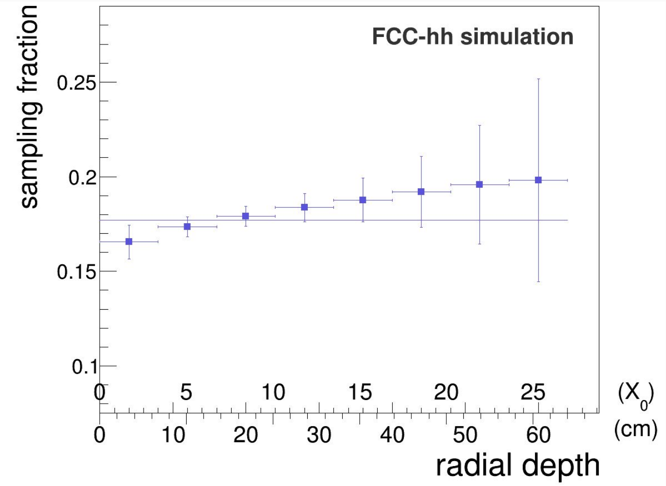
Cryostat material has to be optimized ($\eta > 1$)



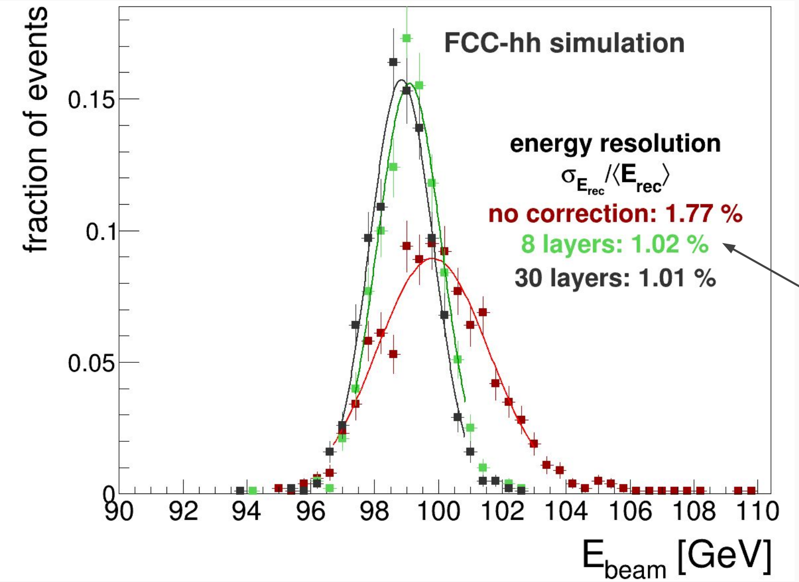
EM scale calibration

Sampling fraction changes with radius

- EM scale calibration done per layer



100 GeV electrons, η = 0, 1.5 X_0



Good energy resolution with 8 longitudinal layers

Performance of single electrons

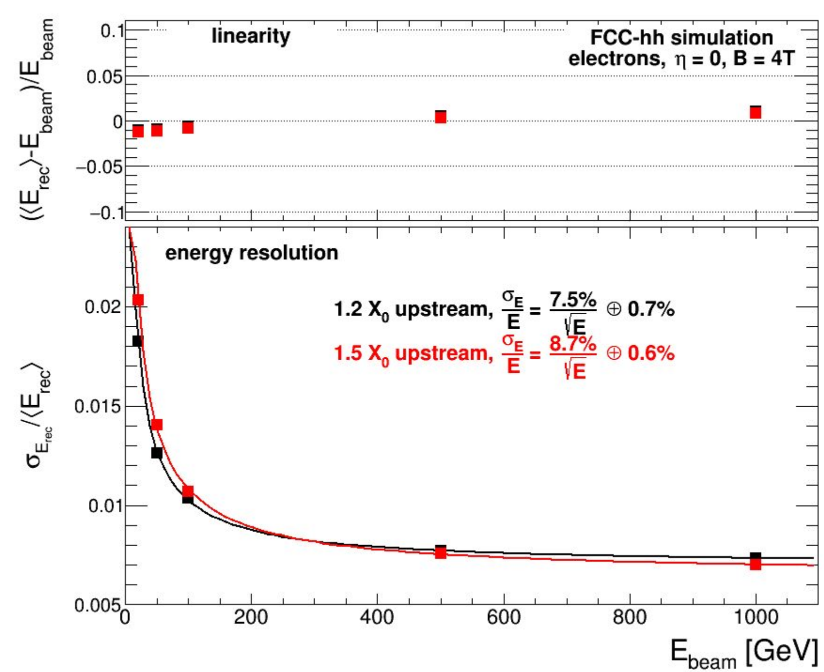
Simulations of single electrons

- Without pile-up and electronic noise

Correction for energy loss in cryostat calculated from the energy deposit in the 1st longitudinal layer

Goal energy resolution achieved

Good linearity



Pile-up

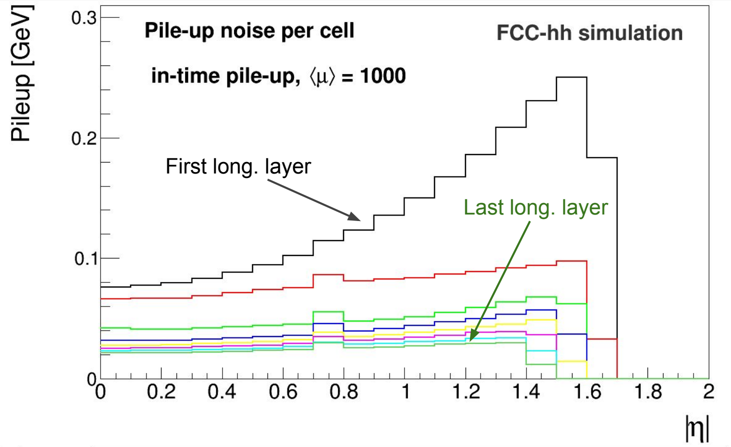
High pile-up (<μ> = 1000) at FCC-hh

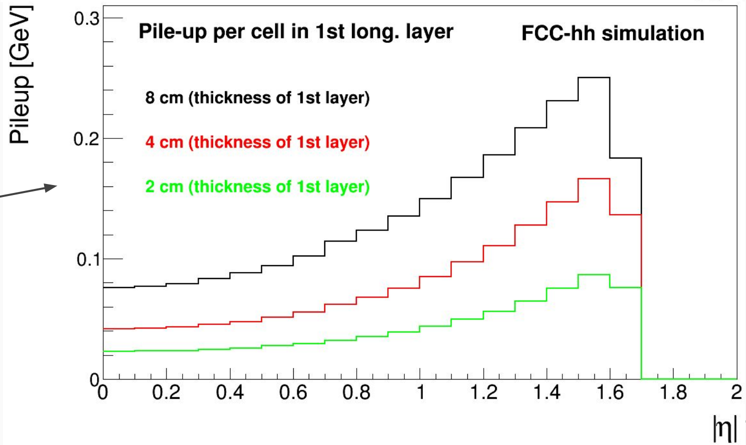
- Important to study the reconstruction under these conditions

Total noise: electronics ⊕ pile-up

Estimate of pile-up noise in calorimeter

- Longitudinal layers of the same size (~8 cm)
- Very high pile-up contribution in the 1st layer
  - Thinner layer is less sensitive to pile-up
- Geometry optimization needed





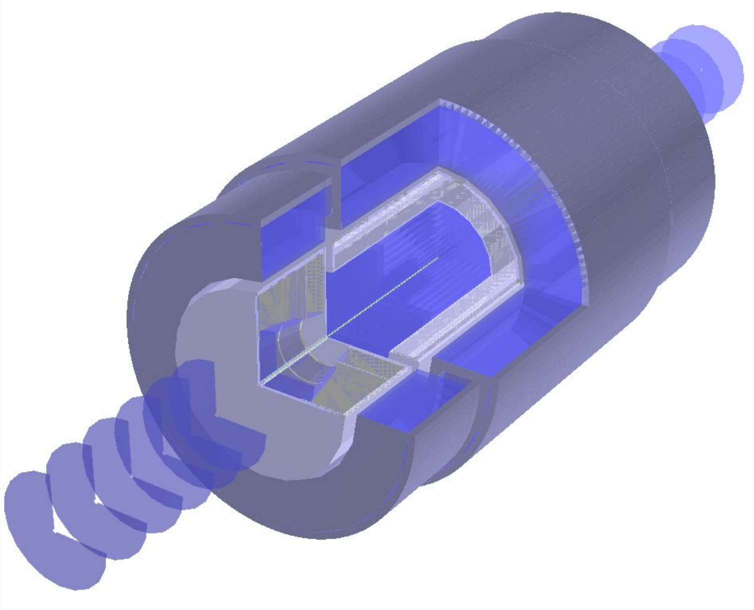
Calorimeters in FCC software

Baseline geometry

- ECAL barrel (done)
- Hadronic barrel + extended barrel (done)
- ECAL + hadronic endcaps (done)
- ECAL + hadronic forward (to be done)

Reconstruction

- Electron reconstruction with clustering algorithm (done)
- Topological clusters (work in progress)
- Particle flow (to be done)



Conclusions

All tools in place for a detailed design optimization studies up to $|\eta| = 6$

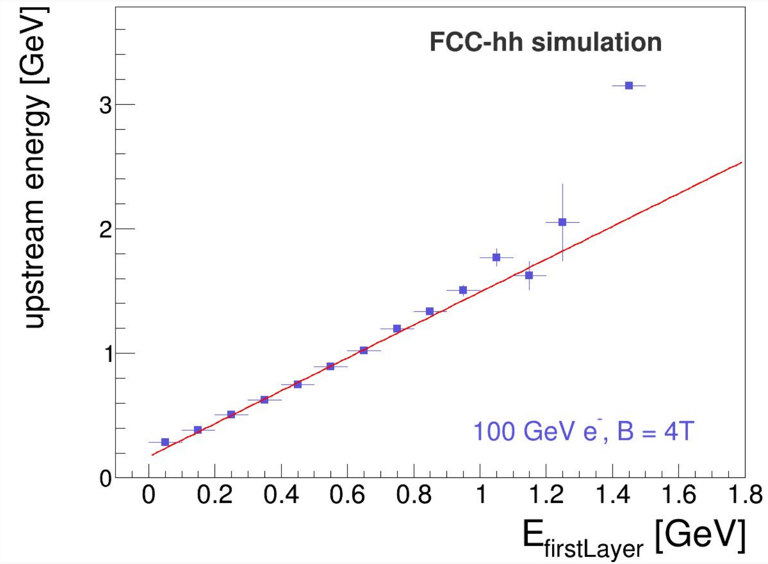
Goal energy resolution achieved in ideal conditions

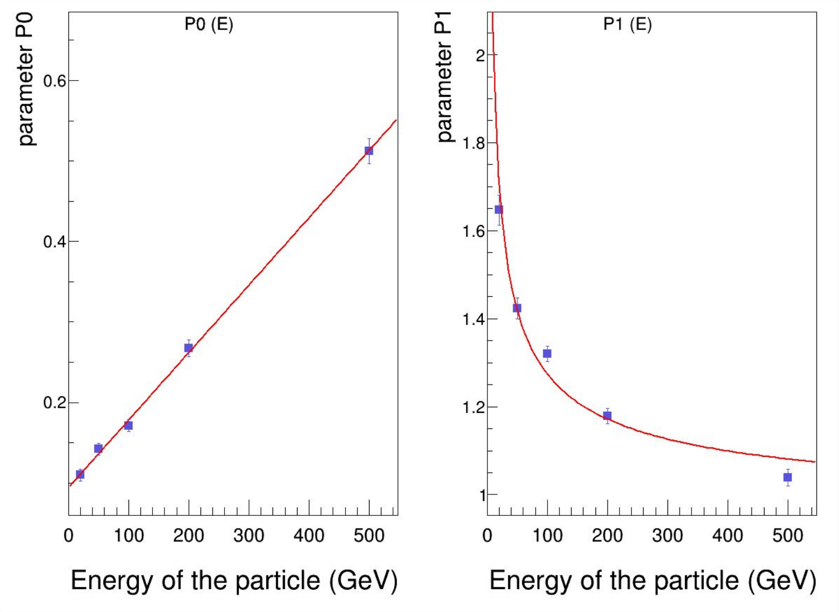
- To be studied in different η-regions
- To be optimized for high pile-up

Si/W option for ECAL to be studied

BACKUP

Upstream energy correction





Geometry optimization studies

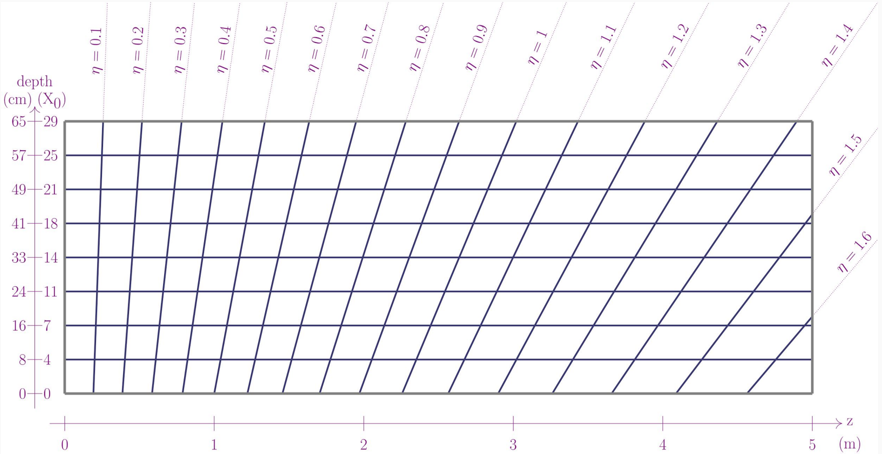
Pointing geometry

Upstream energy correction

Pile-up noise reduction

Neutral pions identification

Current geometry



Proposal for optimisation