Optimizing the design for a Noble-Liquid-based calorimeter for FCC-ee

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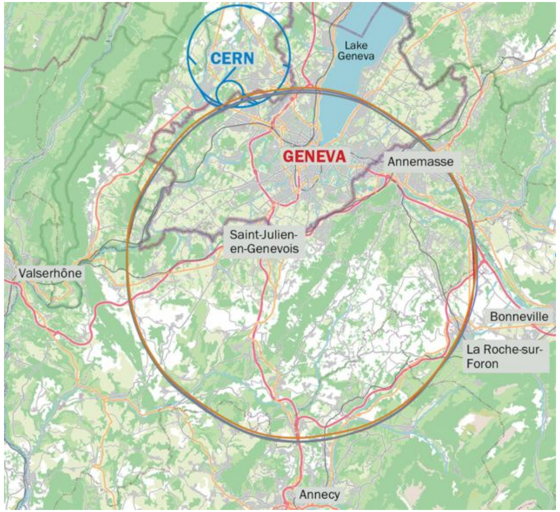
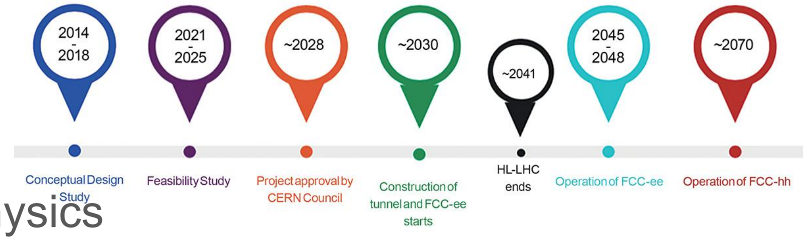
Future Circular Collider - Overview

- 90.7 km circumference, up to 4 interaction points possible
- Stage 1: FCC-ee (up to 356 GeV) as Higgs factory, electroweak & top factory at highest luminosities
- Stage 2: FCC-hh (~100 TeV) as natural continuation at energy frontier



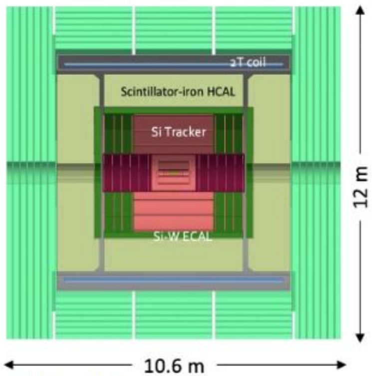
Midterm review very positive, no show-stoppers identified so far



R&D ongoing to optimize detectors for ambitious physics programme (particle flow ⟶ high granularity)

Detector Concepts

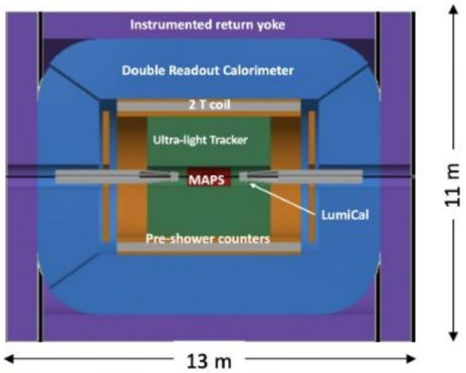
CLD



- Well established design
  - ILC -> CLIC detector -> CLD
- Full Si vtx + tracker
- CALICE-like calorimetry;
- Large coil, muon system
- Engineering still needed for operation with continuous beam (no power pulsing)
  - Cooling of Si-sensors & calorimeters
- Possible detector optimizations
  - σ_p/p, σ_E/E
  - PID ($\mathcal{O}$(10 ps) timing and/or RICH)?

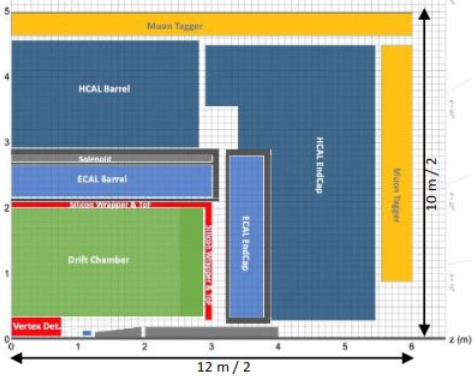
CDR

IDEA



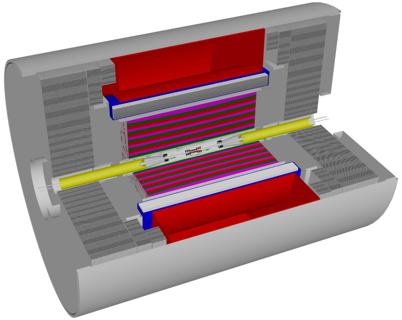
- A bit less established design
  - But still ~15y history
- Si vtx detector; ultra light drift chamber with powerful PID; compact, light coil;
- Monolithic dual readout calorimeter;
  - Possibly augmented by crystal ECAL
- Muon system
- Very active community
  - Prototype designs, test beam campaigns, …

ALLEGRO



- The "new kid on the block"
- Si vtx det., ultra light drift chamber (or Si)
- High granularity Noble Liquid ECAL as core
  - Pb/W+LAr (or denser W+LKr)
- CALICE-like or TileCal-like HCAL;
- Coil inside same cryostat as LAr, outside ECAL
- Muon system.
- Very active Noble Liquid R&D team
  - Readout electrodes, feed-throughs, electronics, light cryostat, …
  - Software & performance studies

ALLEGRO

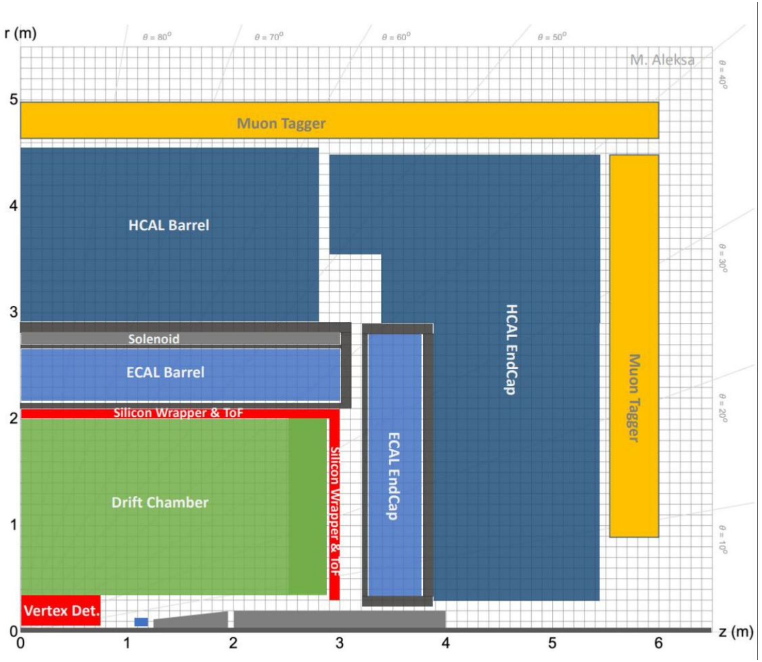


A **L**epton **L**epton collider **E**xperiment with **G**ranular **R**ead-**O**ut

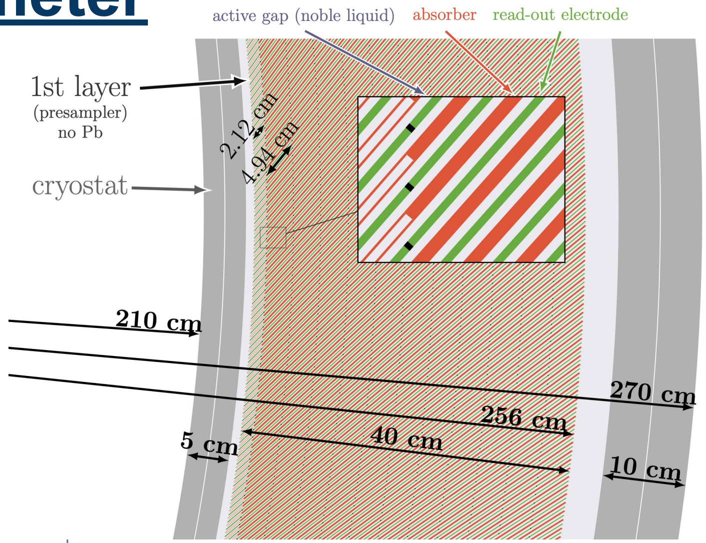
- Noble liquid based calorimetry successful in several high energy physics experiments

- 2 T solenoid between electromagnetic and hadronic calorimeter

- Interesting for lepton collider experiments due to uniformity, linearity, stability



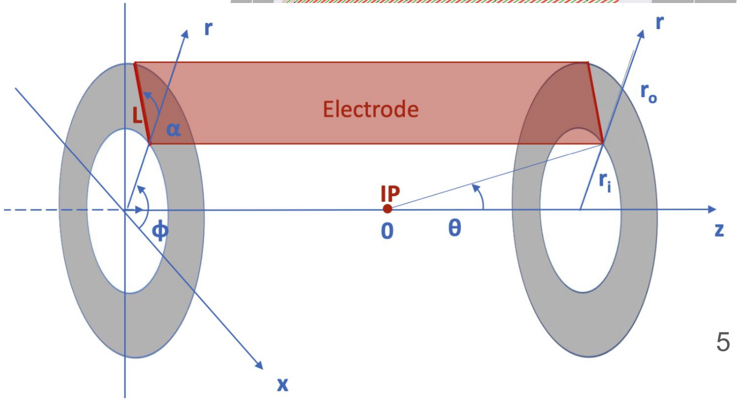
Noble Liquid Electromagnetic Calorimeter



Baseline geometry:

- Liquid argon as active material, lead absorbers
- 1536 plates inclined by 50° (phi uniformity)
- $22X_0$ (40cm), 12 longitudinal layers
- Lightweight carbon fibre cryostat
- Granularity: $\theta \times \phi \times r \sim 2 \times 1.8 \times 3\ cm^3$

Multilayer printed circuit boards (PCB) for readout



Prototypes

Absorbers

1.8 mm lead + 50µm steel

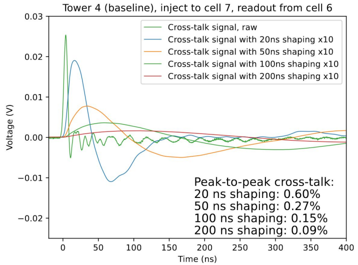
Strength tests

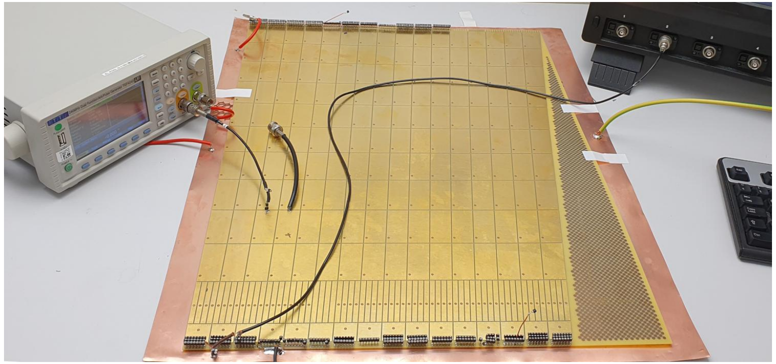
Thermo-mechanic studies

PCB

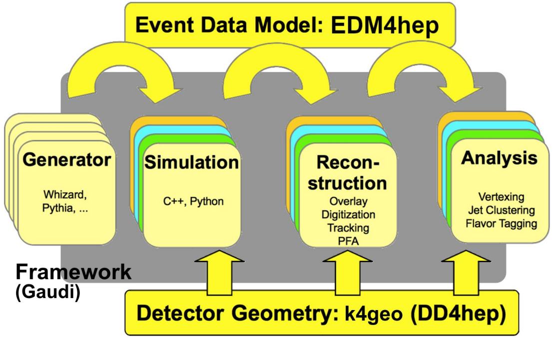
Strips in front layer with 4x finer segmentation for π^0

Cross-talk <1%, with long shaping time even 0.1%





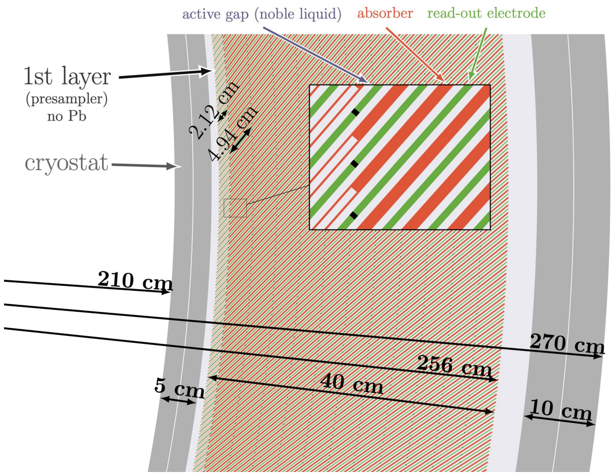
Performance Studies



Simulations of ECAL barrel using FCCSW: software for future collider studies based on Key4Hep software framework

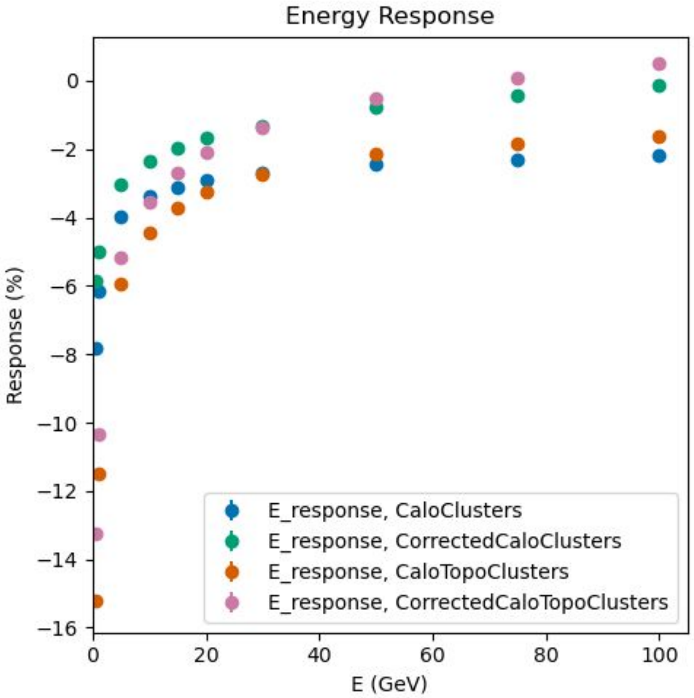
How to optimize detector parameters to reach best performance?

Accounting for increasing sampling fraction and energy loss in cryostat



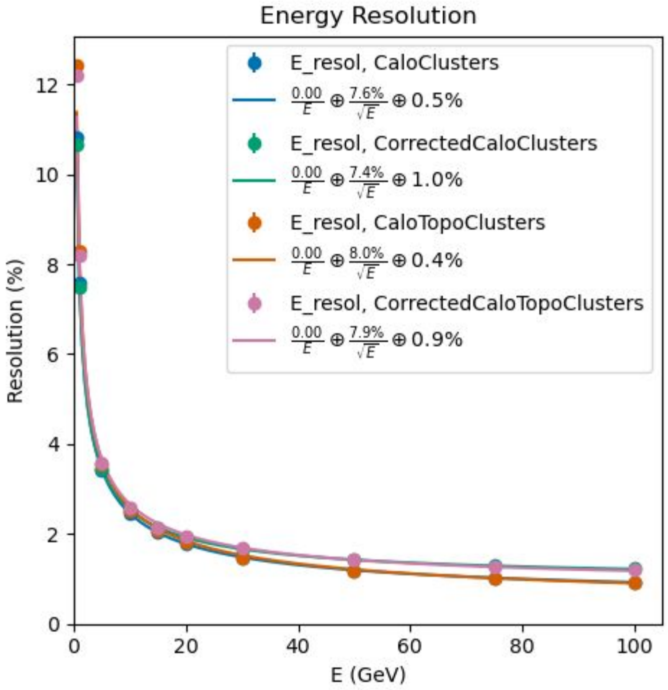
- Energy response:

$$\frac{E_{rec} - E_{truth}}{E_{truth}}$$



- Energy resolution:

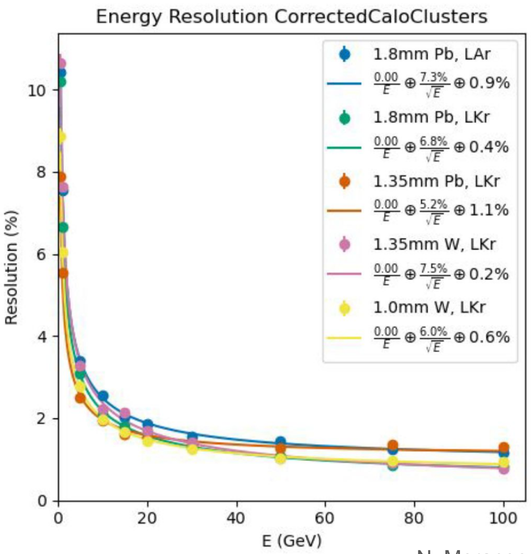
$$\frac{\sigma}{E} = Noise\ term \oplus stochastic\ term \oplus constant\ term$$



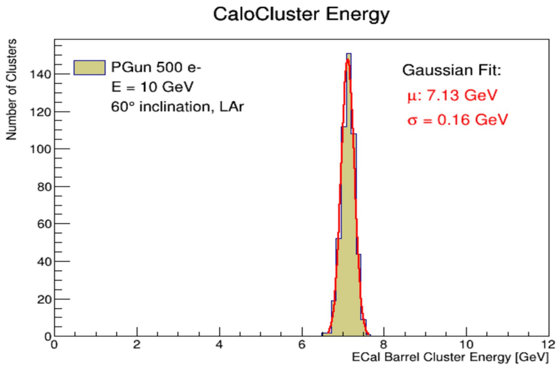
Performance Studies

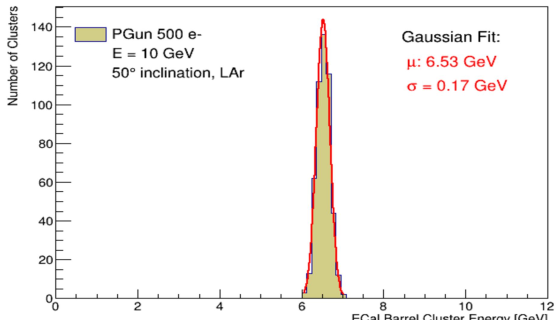
Study impact of geometry modifications of ECAL barrel:

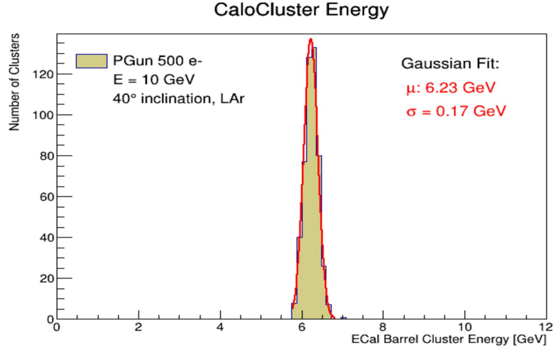
- Inclination of plates
- Choice of material
- Segmentation



N. Morange





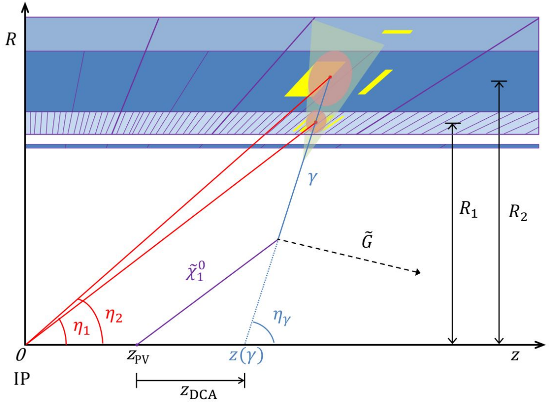


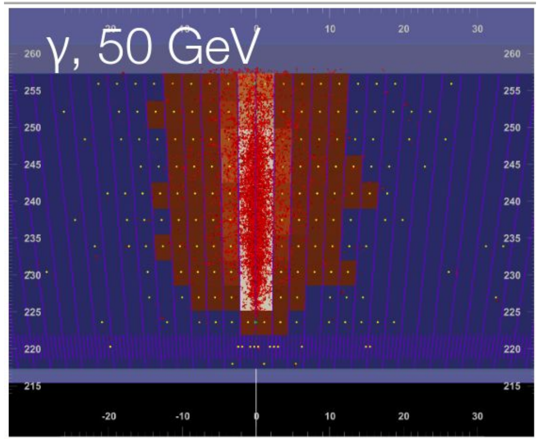
π^0/γ identification

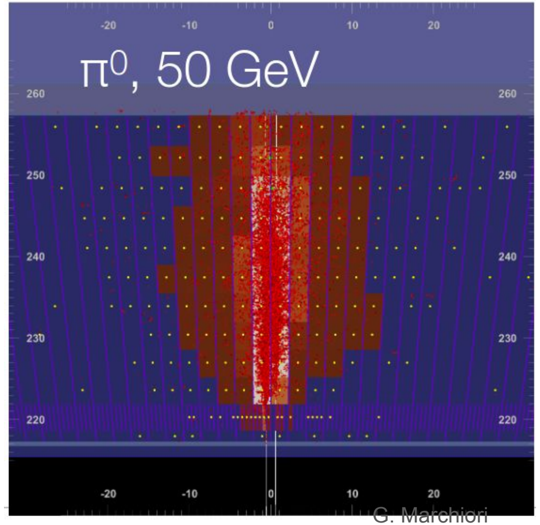
- $\pi^0 \rightarrow \gamma\gamma$, little angular separation towards high energies:

$$\theta = 2arc\tan\left(\frac{mc^2}{2E}\right)$$

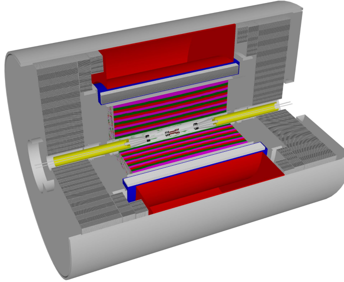
- Which granularity for optimal π^0 rejection?
- Study shower shape variables
- Enabling searches for long lived particles







G. Marchiori



Summary

ALLEGRO - General purpose detector for FCC-ee with ECAL based on Noble Liquid Technology

High granularity, optimized for e+e- collider programme (Particle Flow)

Particle identification properties under study, focus in particular on π^0/γ rejection

First prototypes (readout PCBs & absorbers) are being tested

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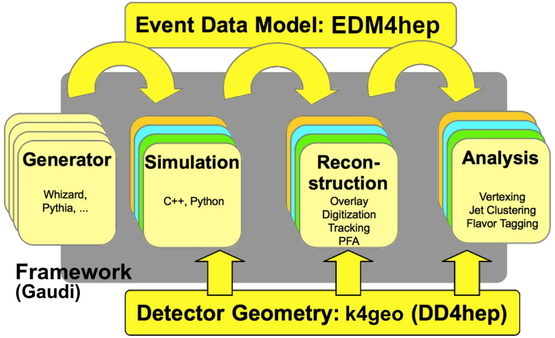
Backup

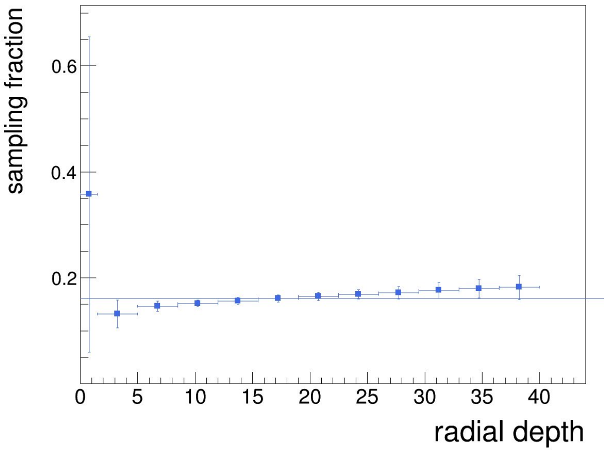
Optimization Studies

- Common software for future collider studies based on Key4Hep software framework

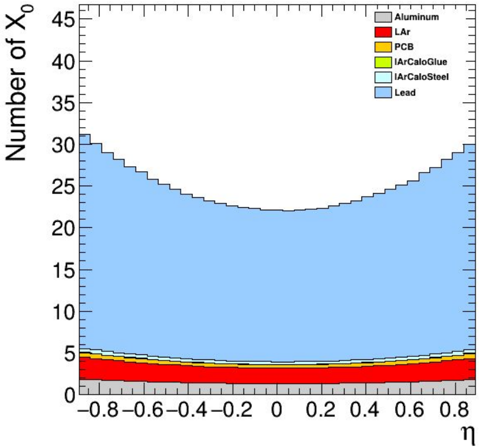


- Sampling fraction: $f = \dfrac{E_{active}}{E_{active} + E_{absorber}}$

Sampling fractions in layers



Material depth



Correcting for energy lost in cryostat