R&D on Noble Liquid Calorimetry for FCC-ee

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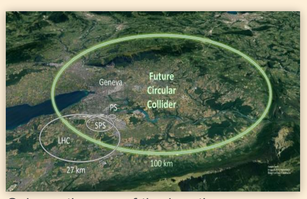
Motivation

Future Circular Collider (FCC)



Schematic map of the location

Candidate for CERN's next flagship accelerator

First stage: **Lepton collider** facility up to 356 GeV

- 91 km circumference
- up to 4 experiments

Ambitious and diverse physics programme:
Higgs, electroweak and top factory at highest luminosities

Detector Requirements:

- High jet energy resolution (4% at 50 GeV)
- High granularity
- Particle ID capabilities
- Small systematics

Challenges for calorimetry

Noble Liquid Calorimetry

Well-proven, successful technology:

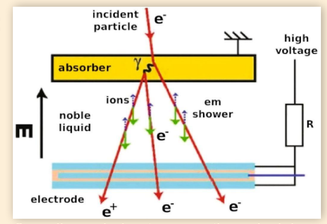
Good energy resolution ✓
Linearity ✓
Stability ✓
Uniformity of response ✓
Easy to calibrate ✓

Absorber/passive material:

- shower initiation
- energy loss

Active material:
Incoming particles produce signal by ionization

Readout:
Ions drift towards electrode and induce signal



Sampling calorimeter operation principle

ALLEGRO

Detector Concept

ALLEGRO (**A** **L**epton **L**epton Collider **E**xperiment with **G**ranular **R**ead-**O**ut)

NEW

General-purpose detector concept featuring **high granular noble liquid sampling electromagnetic calorimeter (ECal):**

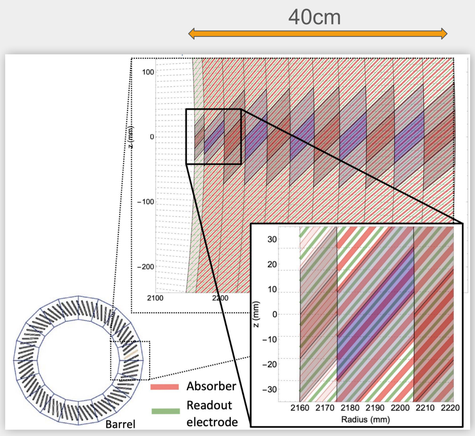
1536 straight inclined (50°) absorber plates

Baseline design: liquid argon as **active material** and **lead absorbers**

11 longitudinal layers, 22 X_0

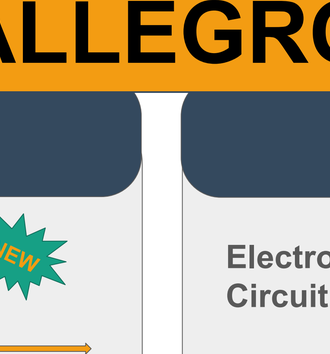
Lightweight carbon fibre cryostat

Granularity: $\theta \times \phi \times r \sim 2 \times 1.8 \times 3\,cm^3$



Cross-section of the ECal barrel layout

High granularity reached by **segmentation of readout electrode** → Crucial for advanced reconstruction methods like **particle flow**!



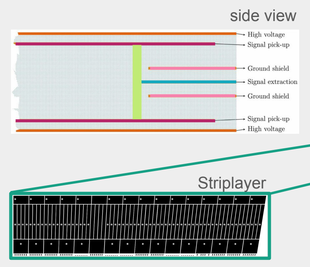
Readout

Electrodes for readout realized on Printed Circuit Boards (PCB)

NEW

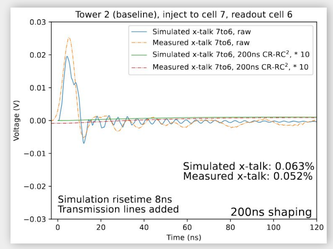
Multilayer:

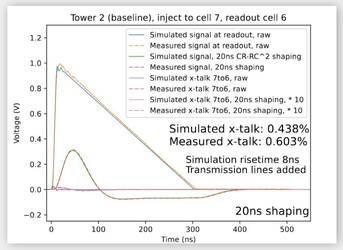
- High voltage layers
- Pads collect ionization signal
- Shields to minimize cross-talk




First prototype tested in the lab

Studies show that **cross-talk** signal **below 1%** easily achievable, down to **0.1%** feasible with **long shaping time**





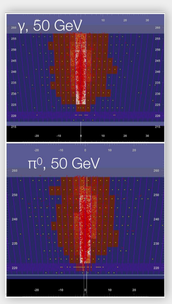
Ansys simulations show good agreement with lab measurement

Many **new ideas** for the **next prototype**!

Performance

Full simulation integrated within FCC software & key4hep, geometry based on DD4hep & Geant4

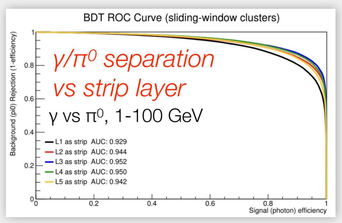
π^0 rejection capability



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

How can we **separate** them?

→ "**Striplayer**" with **4x higher** granularity

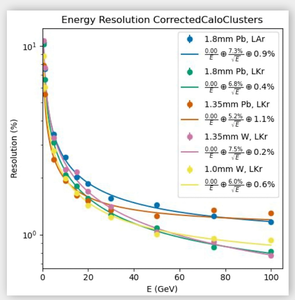


Analysis of showers indicates that **placement in 3rd** or even **4th layer** should be considered

Energy resolution

Noise term ⊕ stochastic term ⊕ constant term

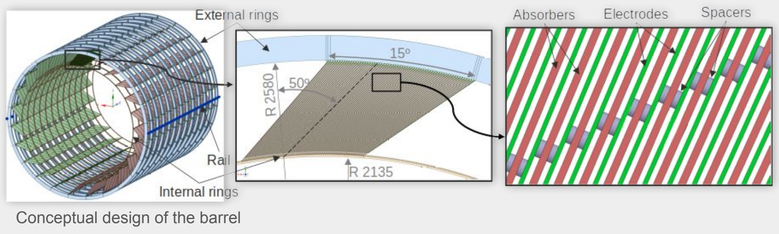
Study how potential **material choices** impact resolution power → minimization of stochastic term!
Krypton and **tungsten** improve resolution in comparison to **argon** and **lead**



Mechanics

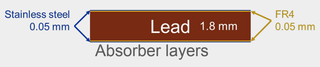
Support structures design and thermo-mechanical studies

Overall structure is given by **support rings**



Conceptual design of the barrel

Absorbers:



Absorber layers

Lead, clad with steel

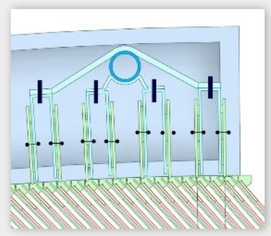
First thermal studies showed that **0.1 mm** steel is **better suited** to prevent deformations


Cold test with absorber prototype

Electrodes:

Placed between absorbers using **spacers, ensuring the liquid argon gap** remains **constant**

Cooling via conduction using aluminium plates linking front end boards to liquid nitrogen pipes



Outlook

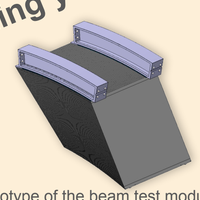
New PCB prototypes featuring different segmentation setups, signal tracing and shielding configurations **arriving in 2/2025!**

Simulation studies ongoing to evaluate various material choices as well as optimizing granularity for γ/π^0

Particle Flow studies starting to further study **granularity** requirements

First tests on implementation and cooling of **electronics** about to start this year

Testbeam prototype of full module in the **upcoming years**


Prototype of the beam test module

The future is exciting, come and join us!

Scan to learn more about the
FCC: FCC Software:

Vienna Conference on Instrumentation 2025
17-21 February

Contact: martina.koppitz@cern.ch

R&D on Noble Liquid Calorimetry is part of the "**D**etector **R**esearch and **D**evelopment Collaboration for Calorimeters" (DRD6), forming work package 2 (WP2)