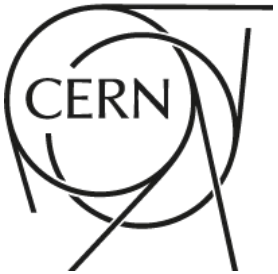
WG 3.1 Noble Liquid Calorimetry

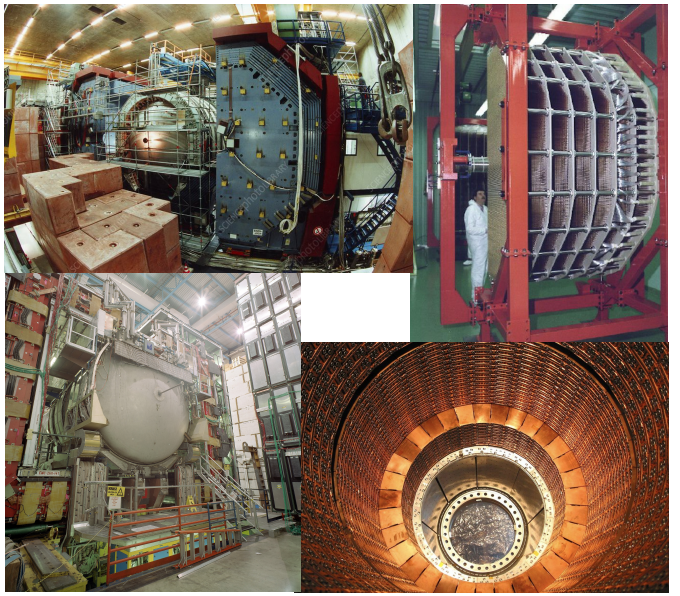
Brieuc François (CERN) on behalf of the
Noble Liquid Calorimetry group

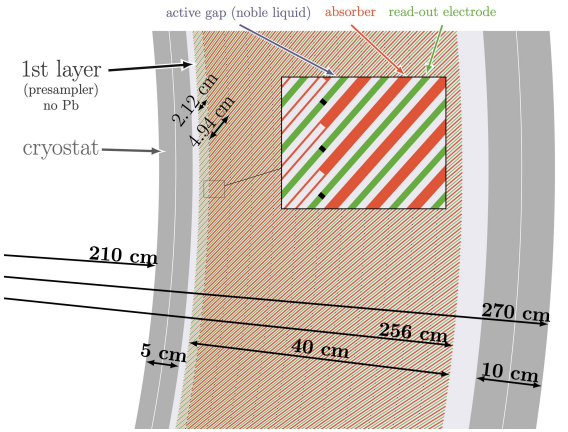
EP R&D Day 2023-1
Feb. 20th, 2023

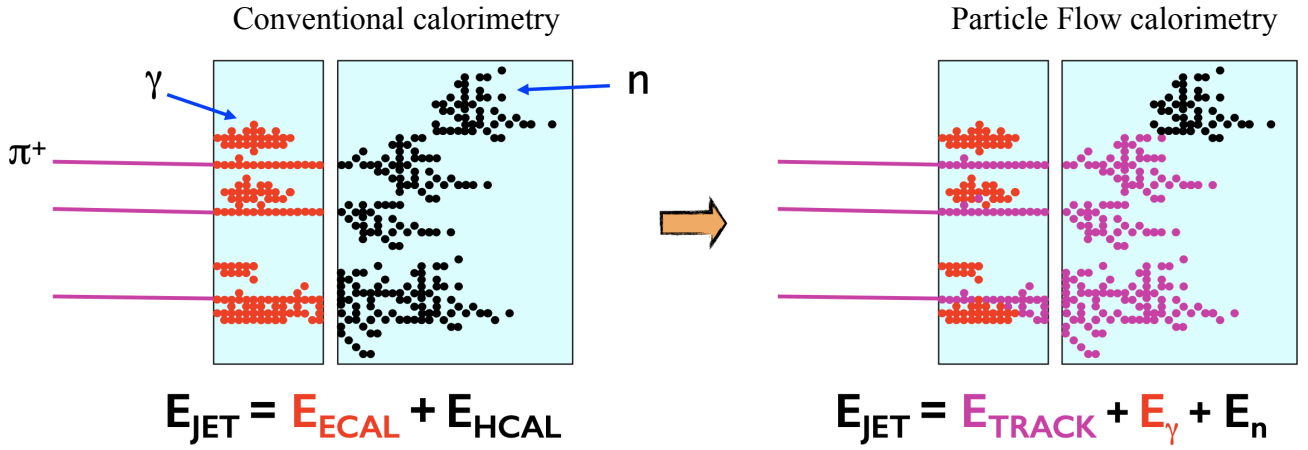


Introduction

- Noble Liquid calorimeters have been used in many HEP experiments and are proposed for several future facilities
  - FCC-hh, FCC-ee, LHeC, …
- Goal of WG 3.1: design and prototype the next generation for this technology
  - Further squeeze its **performance**
  - Complement its very good conventional calorimetry properties with **imaging capabilities** (Particle Flow calorimeter)
    - **Increase** by a factor 10-15 the **granularity** w.r.t. the state of the art ATALS implementation



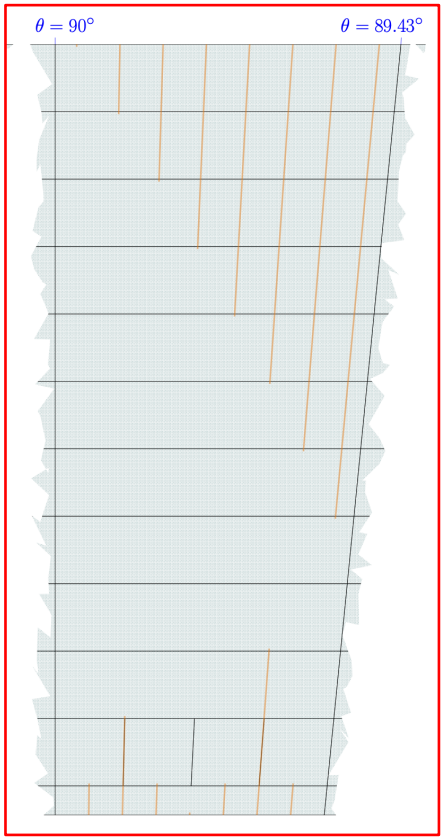




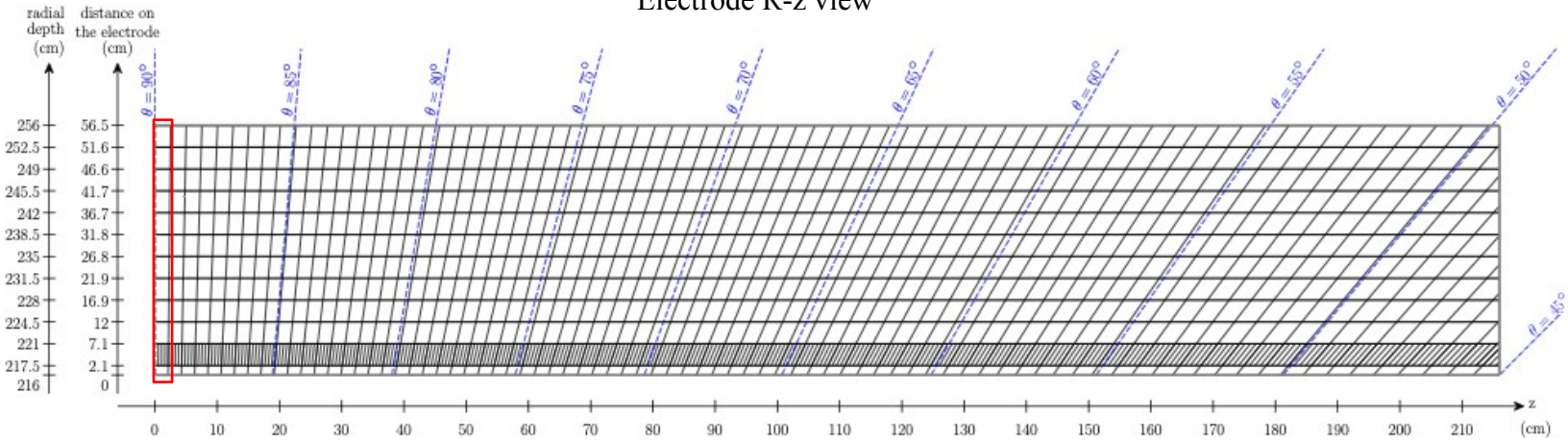
High Granularity Readout Electrodes

- High granularity readout electrode design
  - Challenge: analog signal extraction with high S/N and low x-talk
  - 7-layer PCB with signal extraction on a different layer as the signal pick-up pads + ground shields to mitigate x-talk

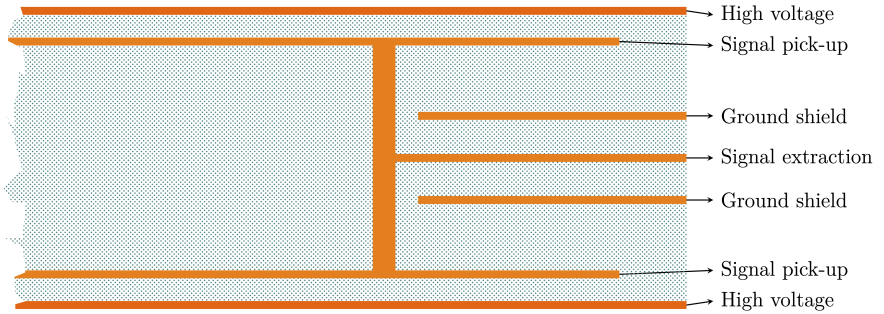
One 'theta' tower



Electrode R-z view

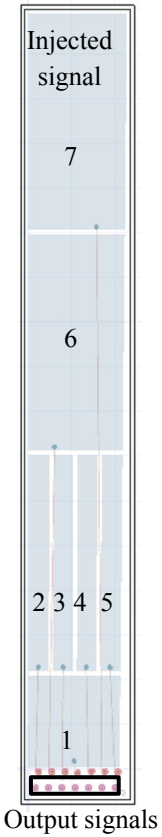


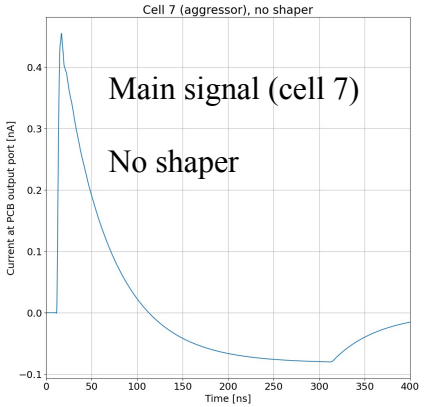
Electrode PCB transverse view

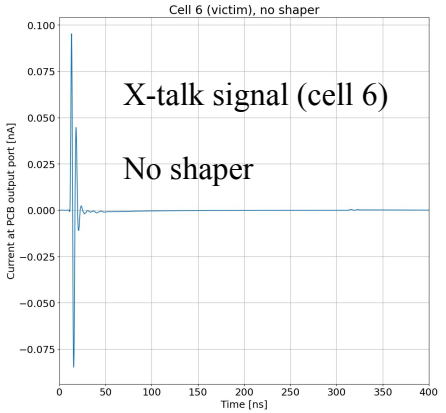


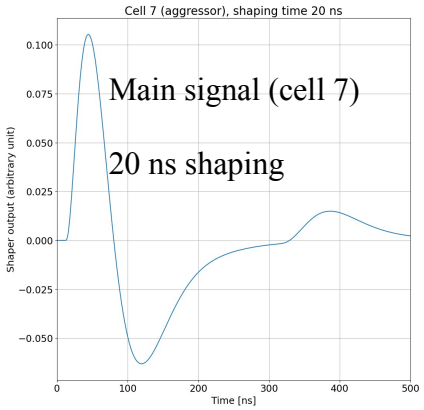
Noise and X-talk

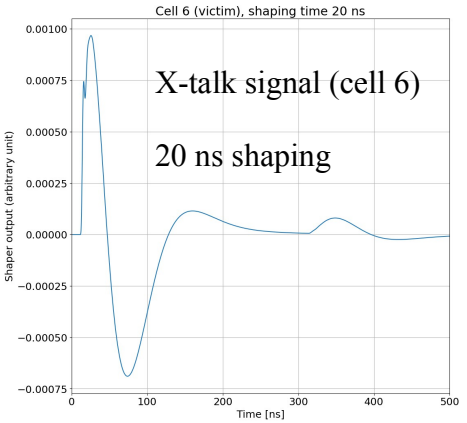
- X-talk studied with FEM tools
  - Simulation show that one can easily **reach sub-percent** peak-to-peak **x-talk** values with ground shields and signal shaping



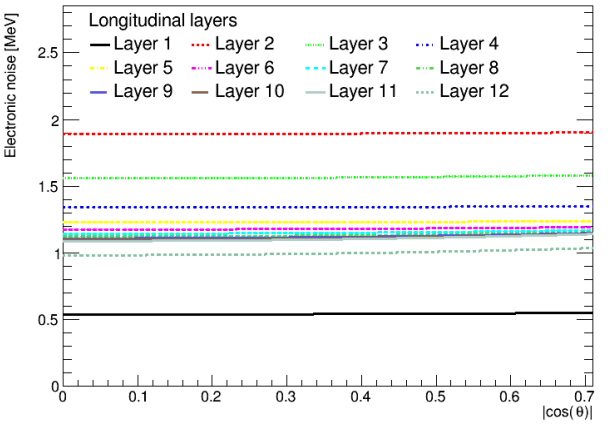




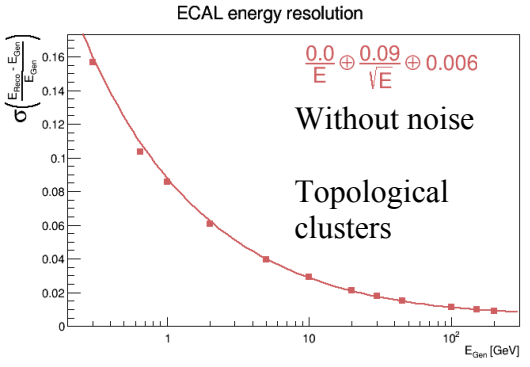


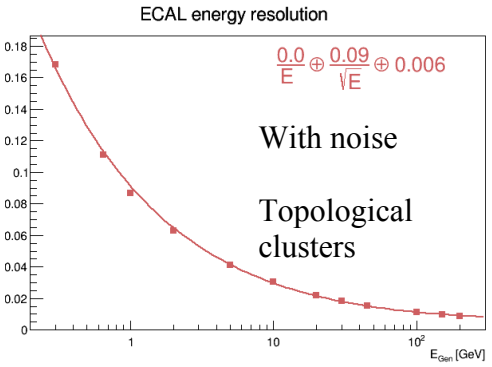


- Noise estimated from analytical description of readout chain + detector capacitance from FEM
  - Implemented in full-sim
  - Negligible impact on energy resolution > 1 GeV
  - **MIP S/N > 5** achievable



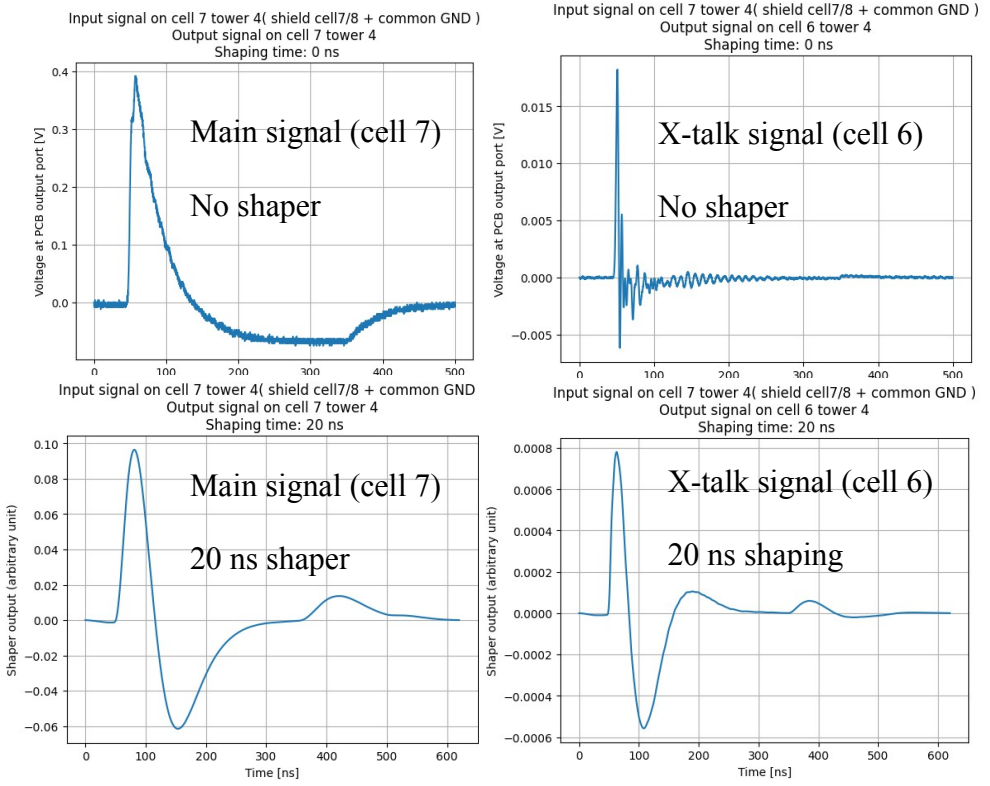
2 ground shields, 1 readout cell = 2 physical cells, 5 m 100 Ω coax, Charge preamp, e_n = 0.5 nV/√Hz, i_n = 1 pA/√Hz, shaping time = 200 ns

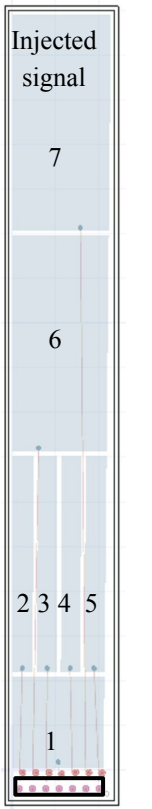


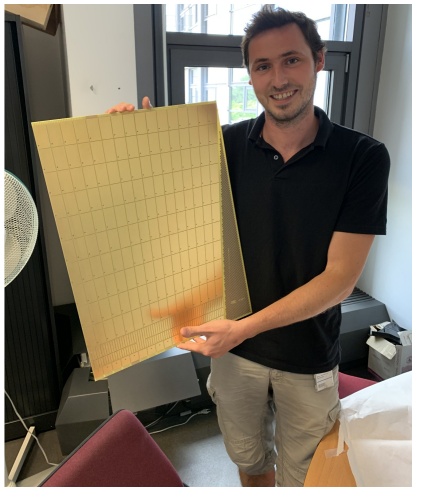


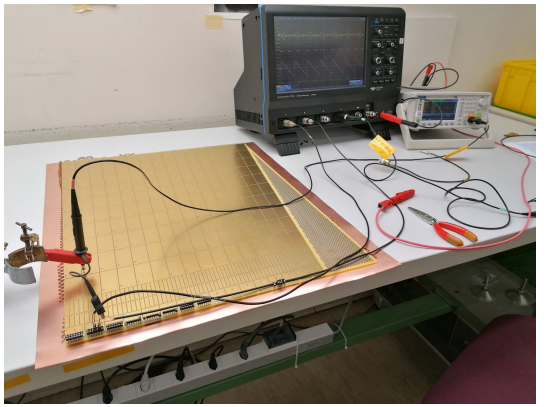
Readout Electrode Prototype

- Readout electrode prototype produced with the CERN PCB Design Office
  - X-talk measured with simple electrical tests
  - Confirmed that sub-percent x-talk is easy to reach
  - Good measurement/simulation qualitative agreement
    - Working on improving quantitative agreement



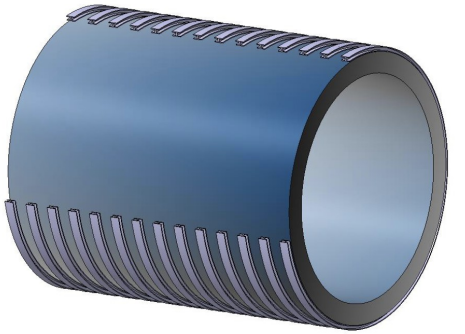


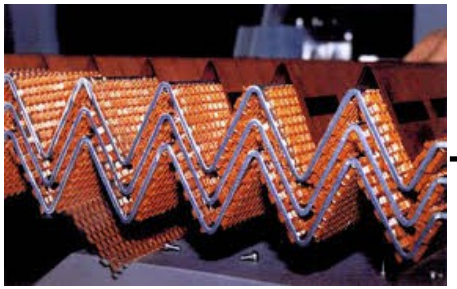


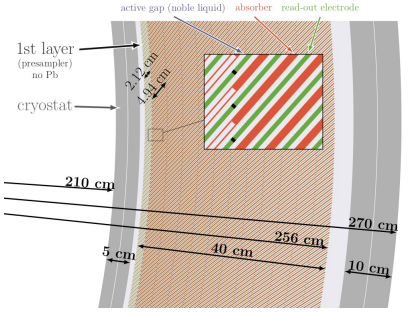


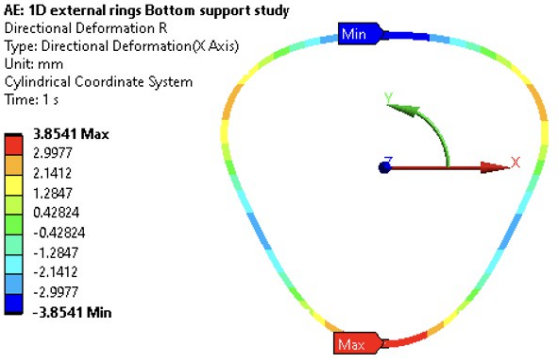
Mechanical Studies

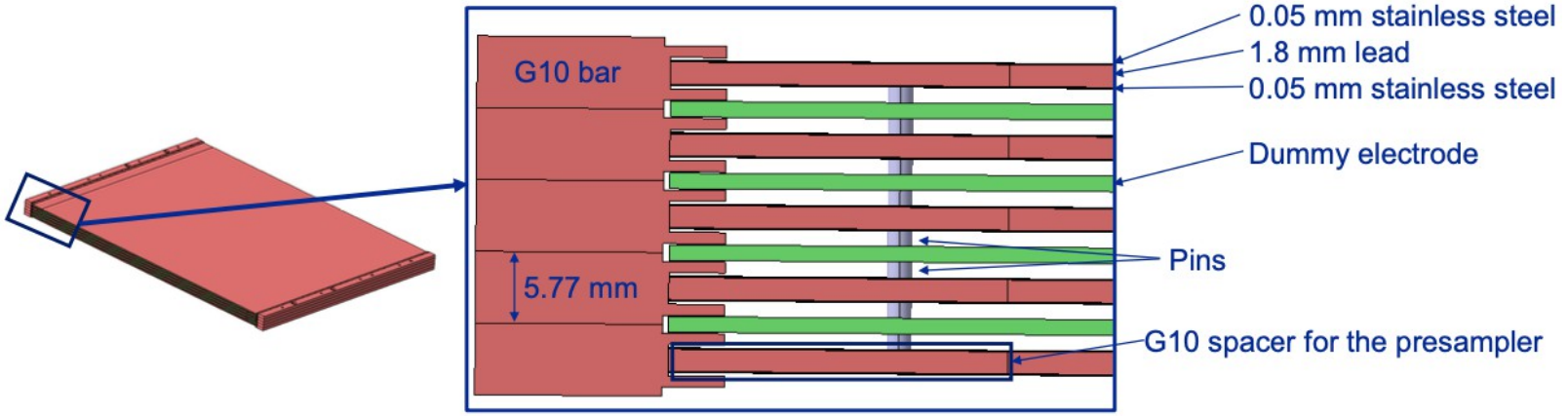
- Mechanical engineering campaign started
  - Future calorimeter is bigger → analysis of the external rings support
  - Design a solution for module assembly
    - Mechanical stability of straight absorbers (instead of accordion as in ATLAS)
    - G10 pre-sampler, spacers, …









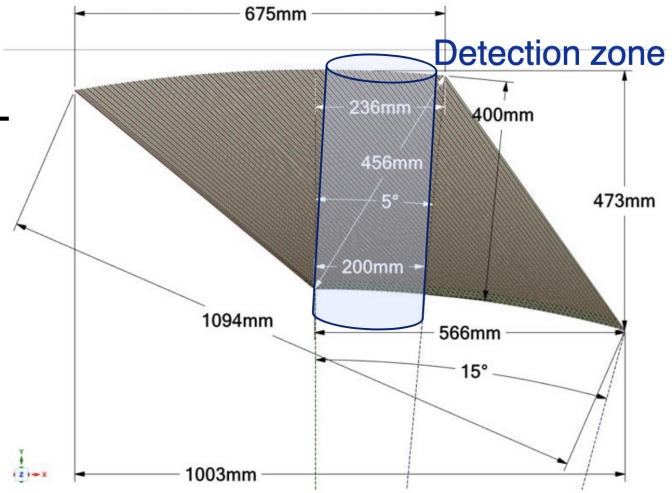


WG 3.1 Extension

Upcoming activities

- Further study **granularity needs** for e+e- experiments: π^0/γ identification, axion search, particle flow
  - **Gentner PhD student** that has started in Dec. 2022
- Re-optimize readout electrodes (noise/x-talk) for the defined granularity
  - Prepare for 'mass' production in view of a test beam module
- Together with external collaborators (IJCLab, BNL) **define** best-suited **front-end electronics** based on existing developments (HGCROC, DUNE)
- Mechanical design and production of a full depth (22 X_0: 1m x 0.5m x 0.5m) **module for test beam**
- Adaptation of existing **cryostat** being studied but **not covered** by this **extension** → use carbon fibre prototype from WP4.1b or external fundings

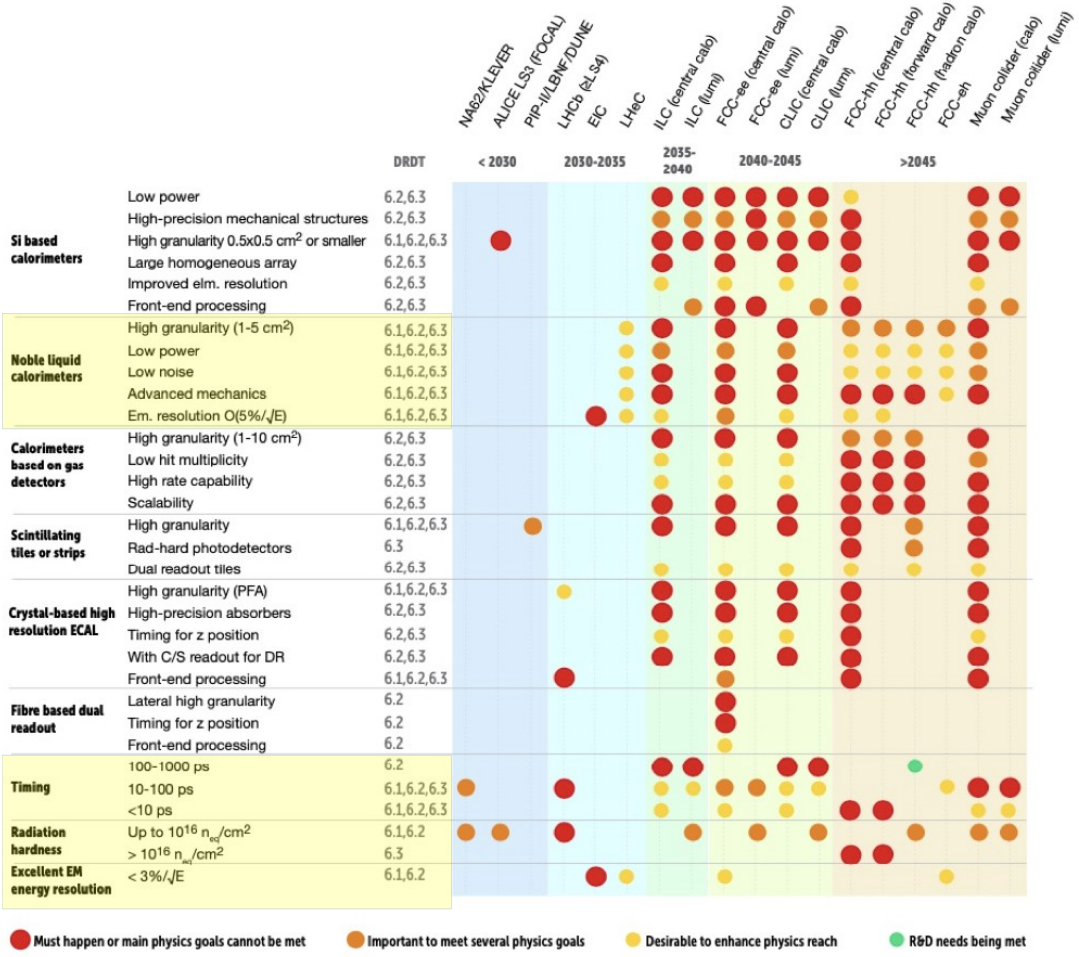
Prototype dimensions



Q4 2024	Q4 2025	Q2 2026	Q2 2027	Q4 2027
Prototype absorbers and electrodes	Design drawings of test module → review	Ready for production of test module	Test module assembled, test cryostat prepared	Warm tests finished, ready for testbeam

WG 3.1 Extension – ECFA Roadmap

- WG 3.1 fully in-line with ECFA Detector R&D (DRD) Roadmap on
  - Noble liquid calorimeters
  - Radiation hardness
  - Timing (10 – 100 ps)
  - Low noise
  - EM resolution optimization
- ECFA DRD on Calorimetry (TF6)
  - Divided into 3 (4) tracks
  - **Track 2: "Liquified Noble Gas Calorimeter"**
- International collaboration
  - CERN (CH), IJCLab (FR), BNL (US), Charles Univ. Prague (CZ), Copenhagen (DK) + potential new comers



Thank you!