

Si-ECAL Granular & Compact Calorimetry for FCC



Adrián Irles on behalf the AITANA Detector R&D team
IFIC, CSIC-UV



VNIVERSITAT
DE VALÈNCIA

IFIC INSTITUT DE
FÍSICA
CORPUSCULAR

**EXCELENCIA
SEVERO
OCHOA**



 **Financiado por
la Unión Europea**
NextGenerationEU

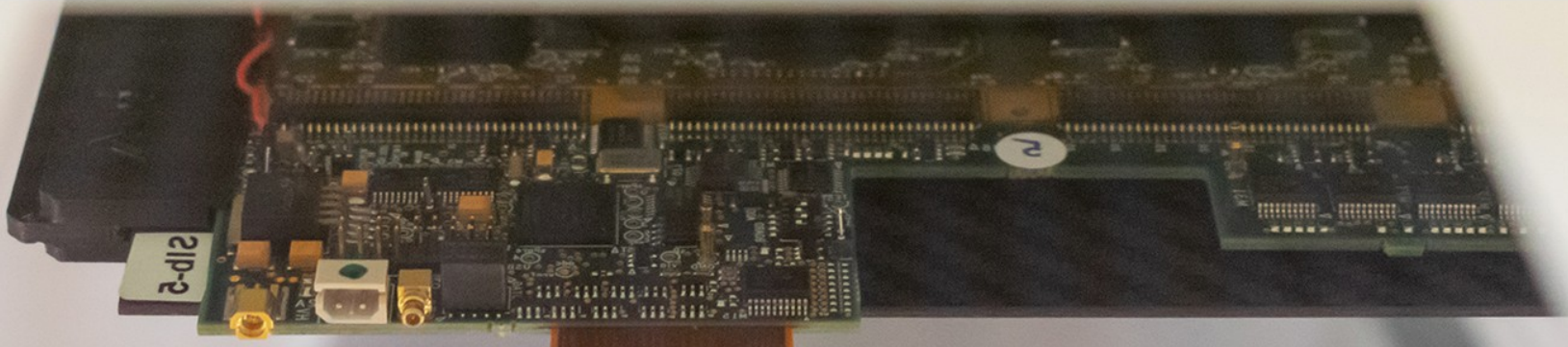

Plan de Recuperación,
Transformación y Resiliencia

 **GENERALITAT
VALENCIANA**

GVANEXT
Fondos Next Generation
en la Comunitat Valenciana

Gen=T

AITANA



GROUP MEMBERS

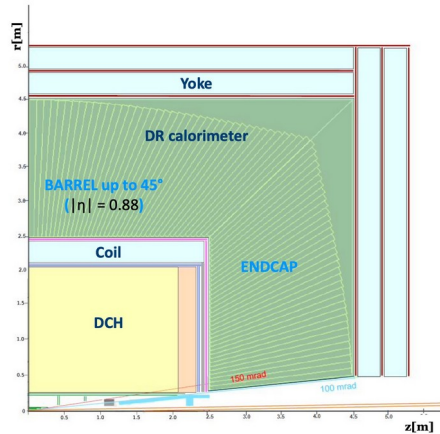
Technology: Detector R&D

- Juan Fuster Verdú
- Daniel Esperante Pereira
- Marcel Vos
- Adrián Irlés Quiles
- César Blanch Gutiérrez
- Shan Huang
- Carlos Orero Canet
- Melissa Almanza Soto

Calos: “drivers” of new detector designs for Higgs Factories (few examples)

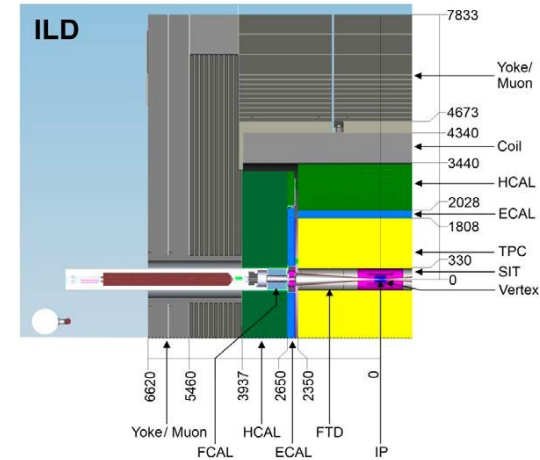


ALLEGRO:
A Lepton Lepton collider
Experiment with Granular
Read-Out
(built “around” a **LAr calo**)



IDEA:
Innovative Detector for E+e-
Accelerator
(built “around” a **Dual
Readout** calorimeter)

ILD:
International Large
Detector (a **Particle Flow
Calorimetry** detector)

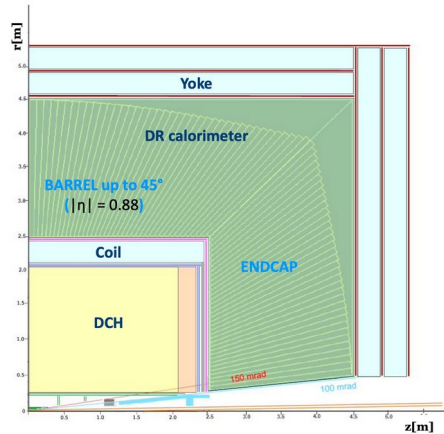


*CLD, SiD, ClicD, CEPC
Baseline, etc were born all as
modifications/evolutions of
ILD

Calos: “drivers” of new detector designs for Higgs Factories (few examples)

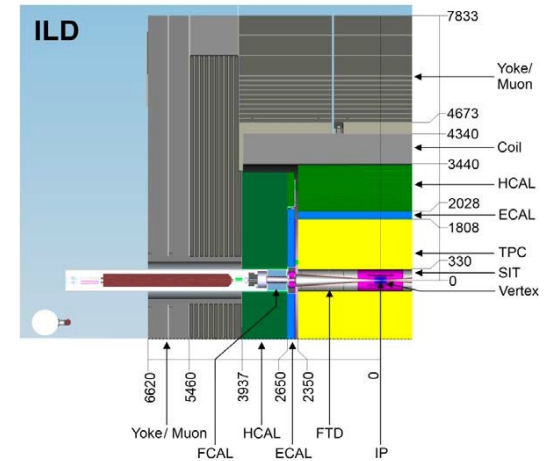


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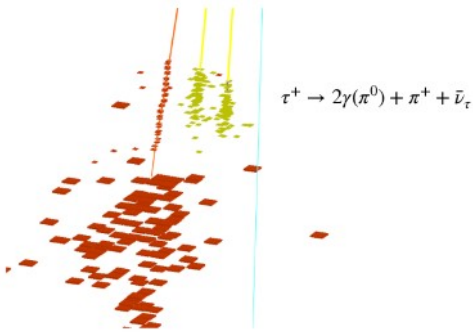


all embracing the
high granular calorimetry
Concept at different levels...

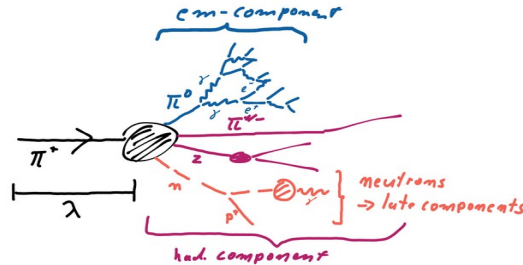
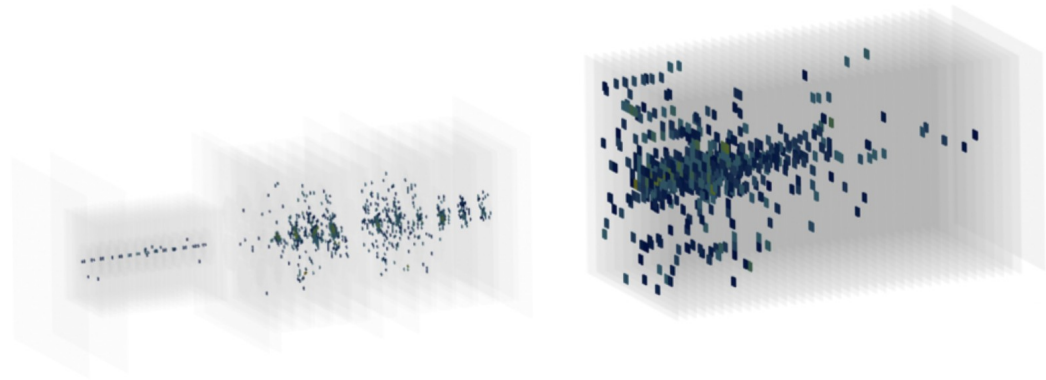


High Granularity Calorimetry concept

aka sandwich calorimetry
aka Imaging Calorimetry
aka 5D calorimetry
aka Particle Flow Calorimetry

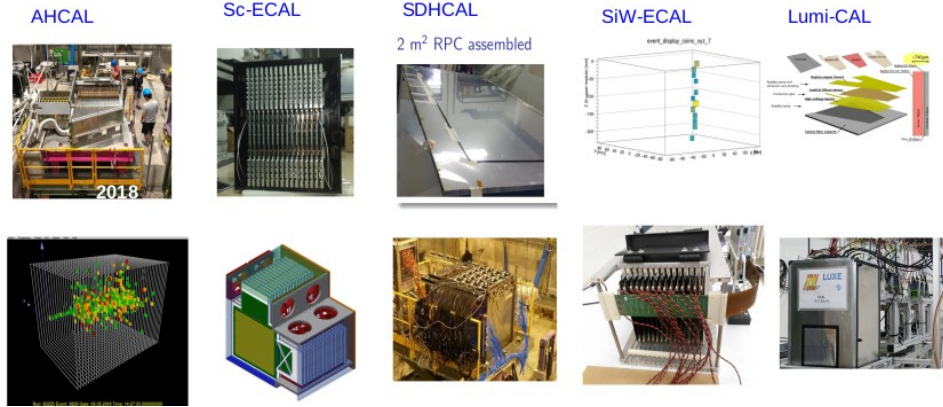


- Results in close-by / overlapping electromagnetic and hadronic showers



High Granularity Calorimetry concept

▷ R&D and proof of concept initiated by the **CALICE** and **FCAL** collaborations, now a larger community within **DRD6**

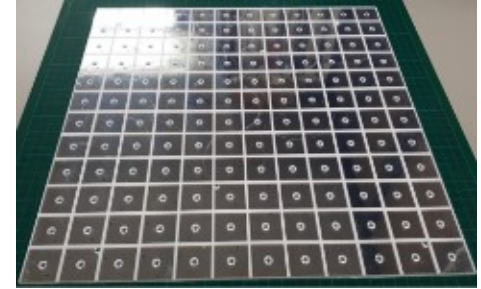


▷ **Exported to HL-LHC** Upgrade of existing detectors (ALICE FoCAL pixel calorimeter, HGCAL with high granular Si and SC calorimeter systems)

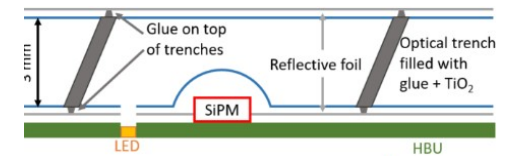
▷ **Adapted to lower energy** experiments

- Strong-Field QED experiments (LUXE)
- Dark Photon, ALPs Experiments (LUXE-NPOD, EBES -KEK, Lohengrin - Bonn,...)

High Granular detectors Sc Tiles



Highly integrated (very) front end Electronics and RO

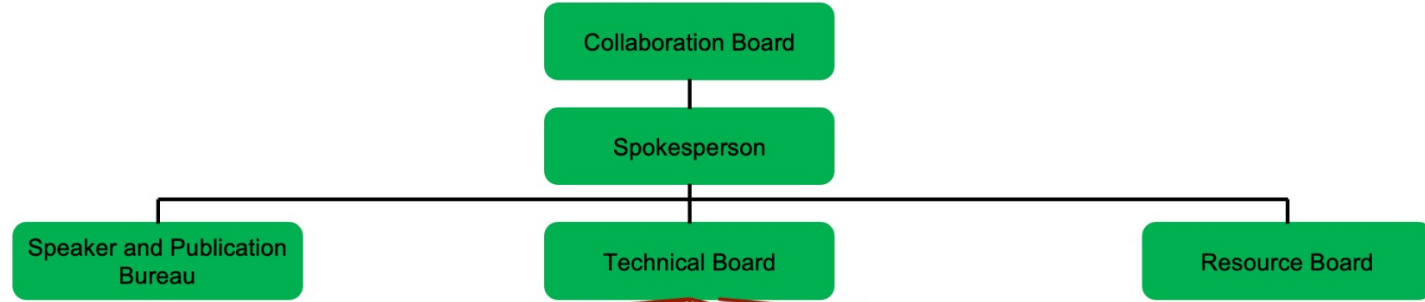


Achieved milestones in the past: FCAL, CALICE (and CALICE+CMS) beam tests campaign of large size prototypes

DRD Calo

▷ As of September 2025, the DRD Calo consists of 134 institutes from 27 countries.

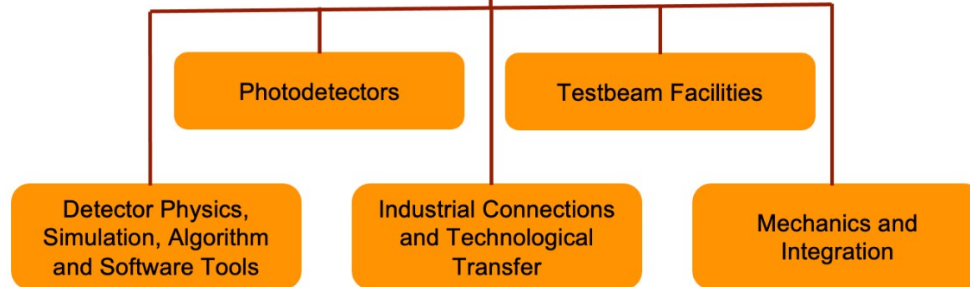
MANAGEMENT:



WORK PACKAGES:



WORKING GROUPS:

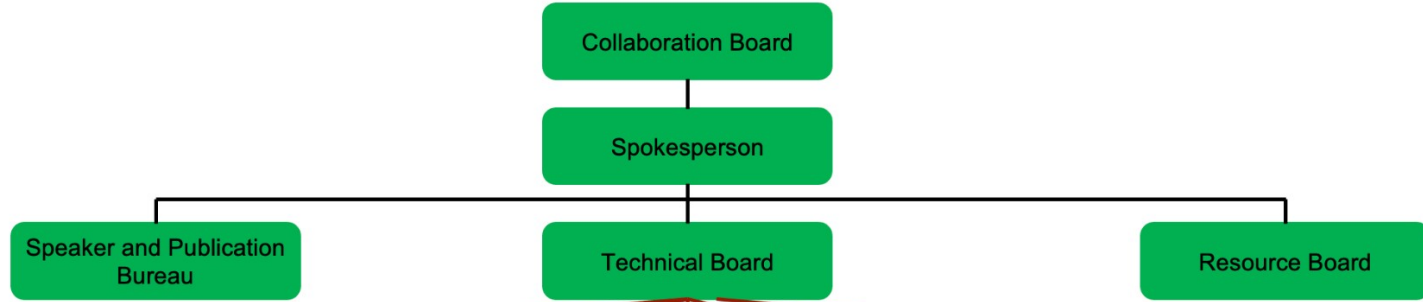


<https://drdcalo.web.cern.ch/>

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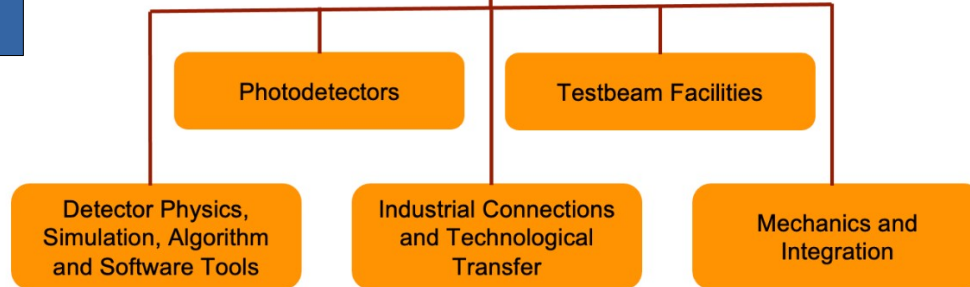


WORK PACKAGES:



A. Irlés co-ordinator of WP1

WORKING GROUPS:



<https://drdcalo.web.cern.ch/>



AITANA contributions in R&D



Controlled access clean Room with HEPA filters.

Qualified as **ISO7**.

Compatible with **ISO5** with in-situ measurements of particles below 1um

The **TARDIS-Lab** is a new installation at IFIC devoted to **characterization** and **hybridization** of **silicon sensors** for **high granularity calorimetry**.

It is a **unique facility** in Europe, key in the R&D programs of the **DRD-Calo** and **FCAL collaborations**.

- ✓ Key installation for DRD Calo WP1
- ✓ Prototypes for ECAL barrel and Luminometers in construction at IFIC
- ✓ Stepping stone before any Higgs Factories: LUXE/ShiP/...

<https://agenda.linearcollider.org/event/10594/contributions/57544/>



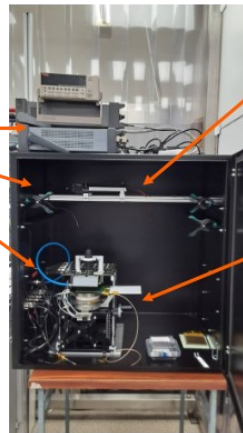
Programmable 3D robot (PDS-400-3) for positioning and control of volumetric deposition (PeciFluid). Planetary Mixer and degassing PMIX100

Usual epoxy-silver glues: epotek H20E, MGChem 9410



Work area and control PC: probe-station; PDS-400-3, readout modules for sensor commissioning.

Slow control monitoring (humidity, temperature)

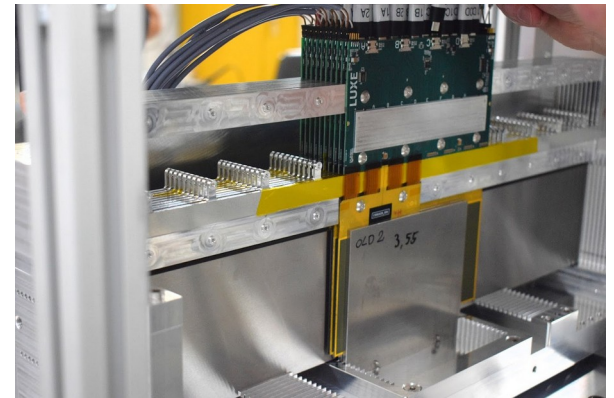


Single module set-up with radioactive sources (Sr90 8kBq) and cosmic rays

Probe-station with dedicated electronics to characterize **CALICE-Hamamatsu sensors with IV/CV**

- ARRAY HGC Sensor - Switching matrix
- CALICE 6-inc Probe Card
- Keithley 6487
- Keysight E4980A/AL
- Keithley 2470

Nozzles for N₂ injection. WIP: temperature control



Testbeam campaigns: 2025 DESY
2026 CERN

Its external dimensions are: **3,0 x 2,5 x 2,7m³**

Its internal dimensions are unknown but it was established that *it is bigger in the inside.*



Eol: A Silicon-Tungsten ECAL for the FCC Detectors

A Silicon-Tungsten ECAL for the FCC Detectors

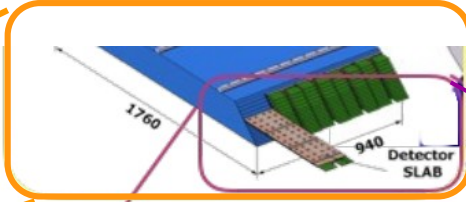
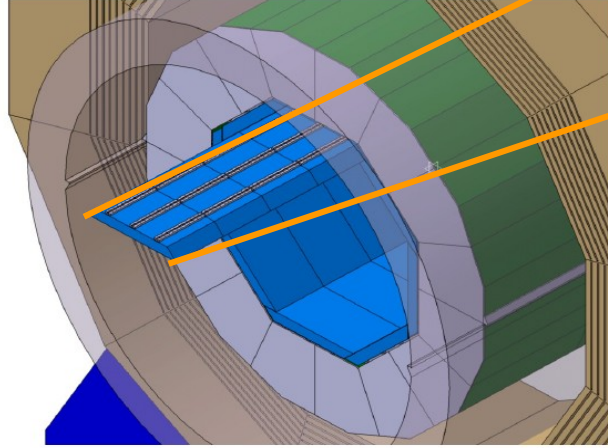
V. Boudry* (LLR), J.C. Brient (LLR), L. Diehl (CERN), A. Irles (IFIC - CSIC/UV),
D. Lacour (LPNHE), R. Poeschl* (IJClab), E. Sicking (CERN), T. Suehara (U. Tokyo),
Ch. de la Taille (Omega), H. Videau (LLR), D. Zerwas (DMLab),
P. Dauncey (Imperial College London), A.-M. Magnan (Imperial College London),
J. Zhang (Argonne), A. Paramonov (Argonne), J. Brau (U. Oregon), C. Vernieri (SLAC)

* Contact persons: Vincent.Boudry@llr.in2p3.fr, Roman.Poeschl@ijclab.in2p3.fr

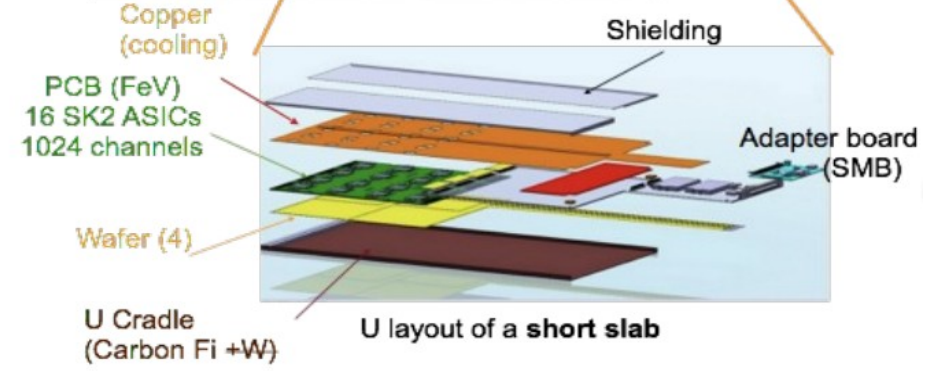
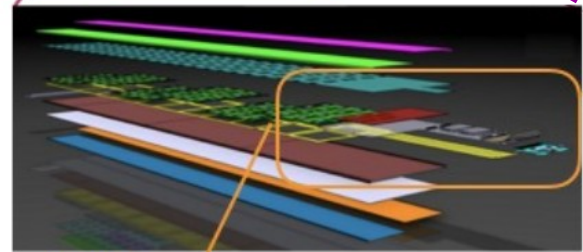
https://indico.cern.ch/event/1529896/contributions/6436820/attachments/3036750/5363080/2025%E2%88%9201_FCC_Eol_det_SiW_ECAL_v4-040225.pdf

- ▷ Baseline ECAL for: ILD-ILC, ILD-FCC, SiD, CLD
- ▷ R&D developed within CALICE (until 2024) and DRDCalo (since 2024) – Task 1.1.1
 - Strong collaboration with FCAL (and FCAL-LUXE) Collaboration

Barrel SiW-ECAL



SiWECAL



Irène Joliot-Curie Laboratoire de Physique des 2 infinis
 L.M.
 L-PSC Grenoble
 LPNHE PARIS
 OMEGA Microelectronics
 CNRS
 IN2P3 Les Deux Alpes

東京大学

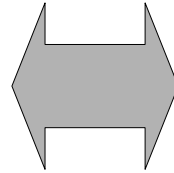
iThemba LABS

Ciemat Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas
 IFIC

SiW-ECAL for FCC and DRD Calo

▷ Goals stated in FCC – EoI (up to ~2028)

- Uniform prototype – 20-24X0
- Assessment (hardware and simulation studies) of 5D calorimetry capabilities (timing!)
- Continuous Mode operation (assess of cooling requirements, impact of such in physics)
- MAPS – feasibility of MAPs in the barrel Si-ECAL



▷ Milestones and deliverables of the Task 1.1.1 in DRD Calo (up to 2027)

<https://cds.cern.ch/record/2886494>

- D: Revised 15 layer stack + Novel hybridization techniques (by **IFIC**)
 - D: Engineering module for Higgs Factory
 - M: Specification for timing & cooling
- ▷ Very positive DRDC and Technical Board evaluation of the task
- ▷ Beyond 2027
- Proposal in progress. Aligned with FCC EoI

The Si-ECAL proposal for FCCee has:

- and R&D program embedded in the **DRD Calo** → and supported by years of development in **CALICE**
- strong synergies with detector concepts (**ILD** and **CLD**) and simulation studies.
- support from **Europe** (France/Germany/Spain/UK), **Asia** (Japan) and **USA**

EoI: Development of a Compact SiW Luminosity Calorimeter for FCC-ee Detectors

Expression of Interest: Development of a Compact SiW Luminosity Calorimeter for FCC-ee Detectors

Jørgen B. Hansen¹, Veta Ghenescu², Marek Idzik³, Adrian Irlles⁴, Patrick Janot⁵, Ulrik I. Uggerhøj⁶,
Contact persons: Yan Benhammou⁷, and Mogens Dam¹

¹Niels Bohr Institute, Copenhagen University, Copenhagen, Denmark

²Institute of Space Science, Bucharest, Romania

³Faculty of Physics and Applied Computer Science, AGH University of Krakow, Krakow, Poland

⁴IFIC, CSIC and Universitat de València, Paterna, Spain

⁵CERN, EP department, Geneva, Switzerland

⁶Aarhus University, Aarhus, Denmark

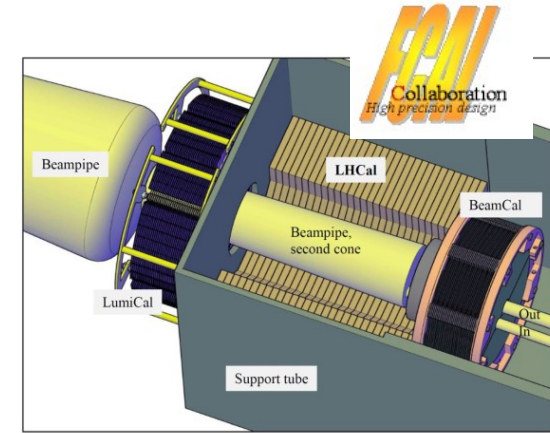
⁷School of Physics and Astronomy, Tel Aviv University, Tel Aviv, Israel

https://indico.cern.ch/event/1529896/contributions/6436849/attachments/3036727/5363056/FCC_LumiCal_EoI.pdf

- ▷ Concept created for ILD (ILC and FCC), now under study for all detector concepts
- ▷ R&D developed within FCAL (until 2022) and DRDCalo (since 2024) – Task 1.1.3
 - Strong collaboration with SiW-ECAL and LUXE experiment

Forward Calorimetry (extreme compactness)

- ▷ LumiCal for precise luminosity measurement (Counting Bhabhas)
- ▷ BeamCal for fast luminosity measurement (using beamstrahlung)
- ▷ Technology choice: Si or GaAs/W sandwich calorimeters
- ▷ 1 X0 absorber thickness per layer, 20 (30) layers in optimized for linear colliders
 - Optimal geometries for FCC being studied



- ▷ Recent progress:
 - investigation of new GaAs sensors with integrated signal routing → similar signal size to silicon sensor (Eur.Phys.J.C 85 (2025) 6, 684)
 - **FLAME and FLAXE ASICS** development and production (ongoing)

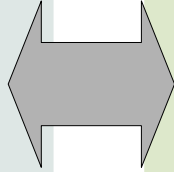
**Production of a large scale prototype
(adapted to LUXE)**



ForwardCalo for FCC and DRD Calo

▷ Goals stated in FCC – EoI (up to ~2028)

- Engineering studies – mechanical precision of 1µm
- Detailed engineering layout (compactness, minimal services, including services)
- Detailed simulation studies (including radiation dosage, occupancy...) → Sensor optimization.
- Design and test of compact electronics and test in beam test (full scale prototype)



▷ Milestones and deliverables of the Task 1.1.2 in DRD Calo (up to 2027) <https://cds.cern.ch/record/2886494>

- M: Test of FLAXE (LUXE) and FLAME (Higgs Factories) electronics with beam and real sensors.
 - D: Partially Instrumented Stack tested in + Novel hybridization techniques (by **IFIC**)
 - M: Prototype of new sensors (si or GaAs) with strip readout.
 - D: Full Prototype tested in beam → and adapted to be operated in LUXE.
- ▷ Very positive DRDC and Technical Board evaluation of the task
- ▷ Beyond 2027
- Proposal in progress. Aligned with FCC EoI

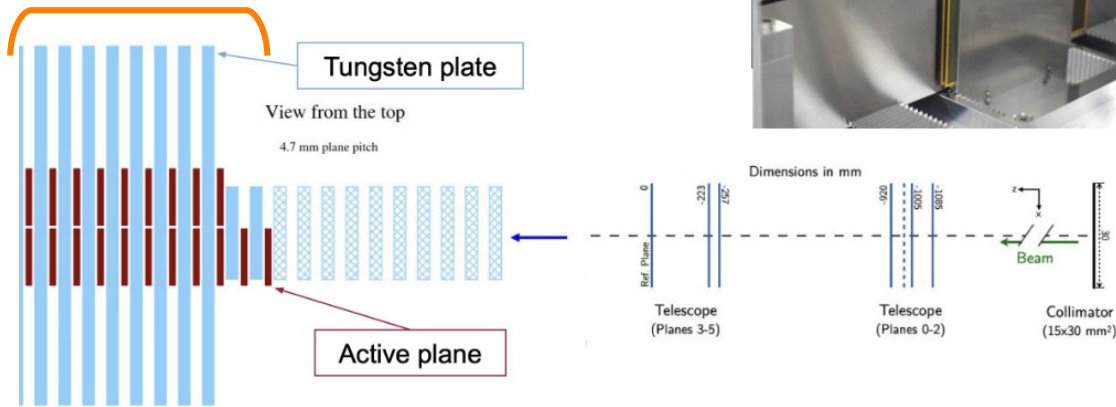
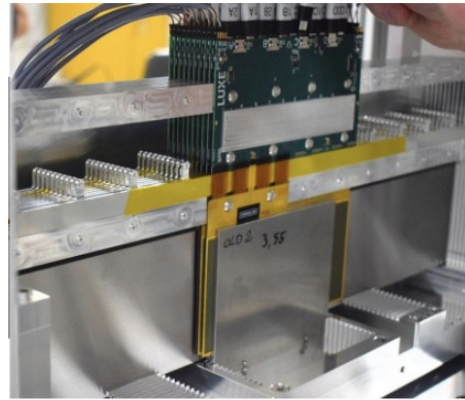
The Luminometer proposal for FCCee has:

- and R&D program embedded in the **DRD Calo** and **FCAL**
- strong synergies with detector concepts (**ILD** and **CLD**) and performance studies.
- very strong european leadership (Israel/Poland/CERN/Denmark//**Spain**)

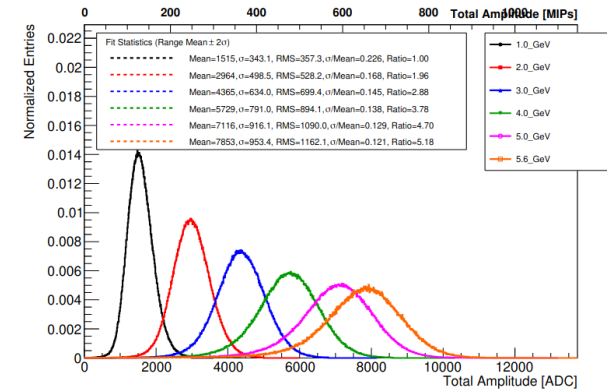
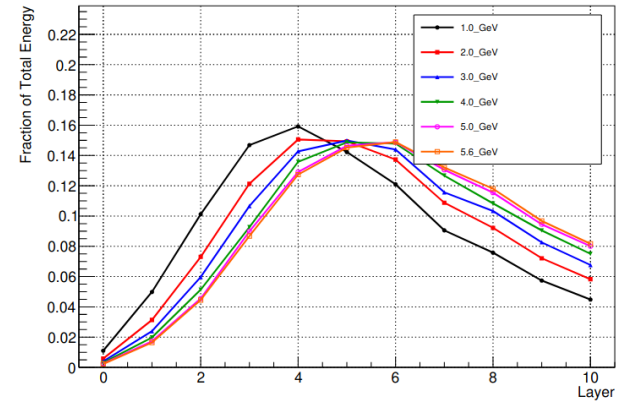
ForwardCalo for FCC and DRD Calo

1 to 5.6 GeV electron beam
 Telescope: 6 planes with Alpid sensor
 ECALp: 11 Si-W layers (additional W in front)
 and 11 FEBs in compact mechanical frame

10X0 & 5120cells
 4.6x18x9cm³ thick detector



Deposited Energy vs Layer



Testbeam at DESY in 2025
 20 9x9cm² PiN diode sensor (Hamamtsu)
 10 layers of x2 individual sensors
All sensors characterized at IFIC and all modules assembled at IFIC

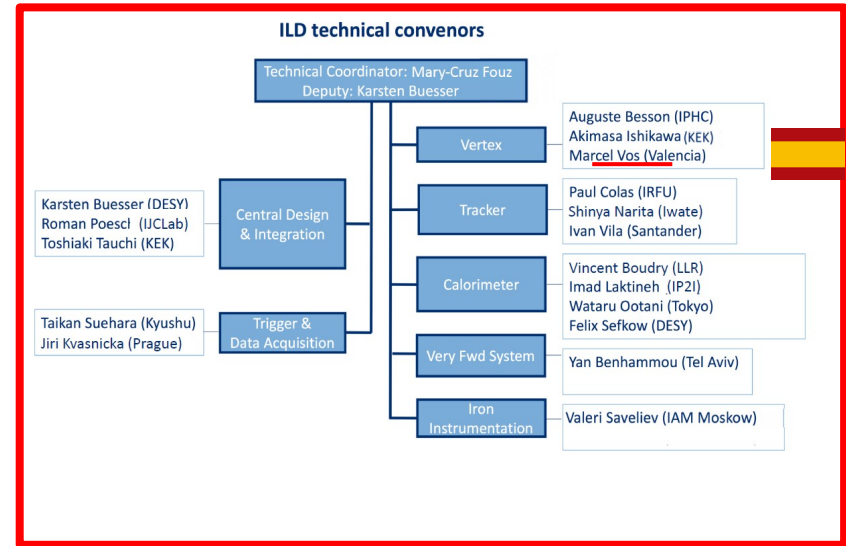
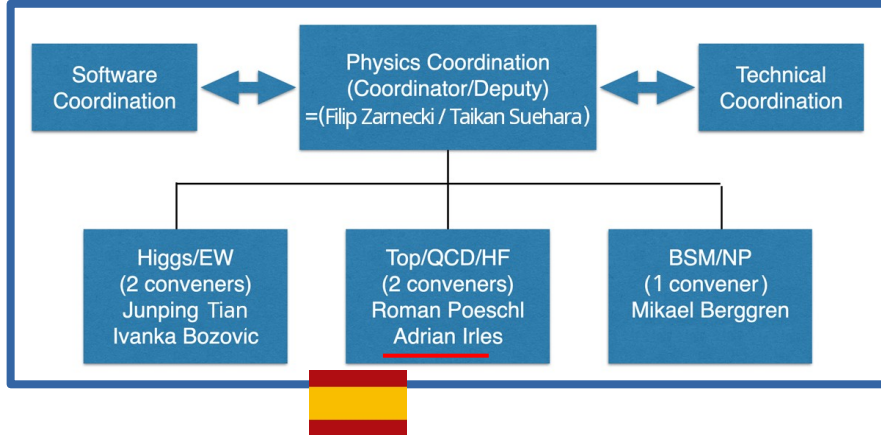
AITANA contributions in detector concepts and performance studies

Strong positioning in the **ILD detector concept**:

Institute Assembly Chair by A. Irlles

Coordination roles for physics/technical positions

Contributions to physics and detector optimization studies.



ECFA Higgs, electroweak, and top Factory Study

The ILD Detector: A Versatile Detector for an Electron-Positron Collider at Energies up to 1 TeV

EoI by the ILD concept group for an experiment at FCC-ee

etc

International Forums (some recent highlights)

- ▷ 9th FCC week- Munich – Talk on behalf DRD Calorimetry “Sandwich highly granular calorimeters with fully embedded electronics”
- ▷ LCWS---2025: International Workshop on Future Linear Colliders 20-24 Octubre 2025 - Conference chairs by several contributions form AITANA
- ▷ 13th Beam Telescopes and TestBeams Workshop 19-23 May 2025 -> Talk on Behalf the DRD-Calo collaboration Testbeams for DRD6 on calorimetry
- ▷ VCI2025 - The 17th Vienna Conference on Instrumentation: 17-21 February M.Almanza-Soto, poster awarded with "Young Scientist Award"
- ▷ US-FCC meeting 2025 – Invited talk on Physics Performance with qqbar signatures.
- ▷ eeFACT 2025 - 70th ICFA Advanced Beam Dynamics Workshop o High Luminosity Circular e+e- Colliders 3-7 March 2025 → Invited talk
- ▷ 2023 International Workshop on the CepC – talk on behalf DRD Calo
- ▷ 2022-2023 ECFA Higgs Factory Workshops (session convenerships) + several contributions in detector&physics sessions
- ▷ 57th Rencontres de Moriond - EW+U 2023 18-25 March - Young Scientifics Forum talk: Detector Challenges of the strong-field QED experiment LUXE at the European XFEL
- ▷ 2023 International Workshop on the CepC – talk on SiWECAL (on behalf CALICE)
- ▷ CALICE2022 organized in Valencia

Funding

▷ Ongoing:

- Plan GenT Doctor de Excelencia CIDEAGENT/2020/021 (01/01/2021-31/12/2026)
- PID2024

▷ Recent:

- Ayudas para Incentivar la Consolidacion Investigadora CNS2022-135420 (Agencia Estatal de Investigacion) (01/09/2023-01/09/2025)
- Si4HiggsFactories ASFAE/2022/015 (01/09/2022-31/12/2025)
- Plan GenT Doctor con Experiencia Internacional CDEAGENT 2019/003 (01/07/2020-31/12/2020)
- CIPROM2021, PID2021

Summary

- ▷ Two EoI FCC sub-detector based on silicon-calorimetry
 - Common R&D in sensor hybridization.
- ▷ Both are supported by years of R&D in FCAL, CALICE and now DRD Calo
 - Projects are under continuous scientific scrutiny and evaluation
- ▷ Both are producing full scale imaging calorimeters.
- ▷ The technology R&D and physics performance of compact/granular calorimeter opens many doors.
- ▷ Several **synergies**/collaborations of detector **R&D collaborations and experiments lepton colliders**
 - Strong field QED experiments LUXE
 - Dark matter searches with fixed target experiments (LUXE-NPOD, Lohengrin, EBBES)
- ▷ Several **synergies**/collaborations of detector **R&D collaborations and experiments hadron colliders too**
 - Potential contributions to SHiP

Thanks for your attention

	Milestone	Deliverable	Description	Due date
Task 1.1: Highly pixelised electromagnetic section				
Subtask 1.1.1: SiW ECAL	M1.1	D1.1	Revised 15 layer stack	2024
			Specifications for timing and cooling	2025
		D1.2	Engineering module for Higgs factory	>2026
Subtask 1.1.2: High compact calo	M1.2	D1.3	Updated set of compact detection layers	2024
			Prototype for GaAs sensors with strip readout	2026
		D1.4	Set of validated GaAs sensors	>2026
Subtask 1.1.3: DECAL	M1.3		Requirements for DECAL-specific sensor design established	2024
	M1.4		Full evaluation of (ALPIDE-based) EPICAL-2 performance	2025
	M1.5		Design for next-generation sensor with DECAL-specific optimisation (with machine-specific options)	2026
		D1.5	New sensors produced and evaluated in EPICAL-3 prototype	>2026
Subtask 1.1.4: Sc-ECAL	M1.6		Improved components (engineering for production, timing, active cooling, etc.)	2024
		D1.6	40-layer prototype and testbeam	2025



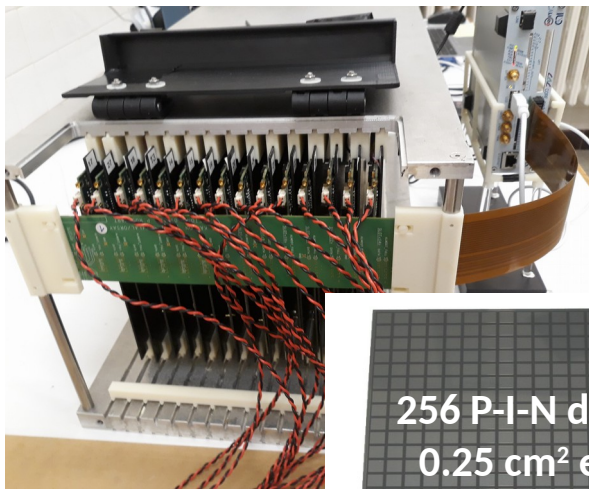
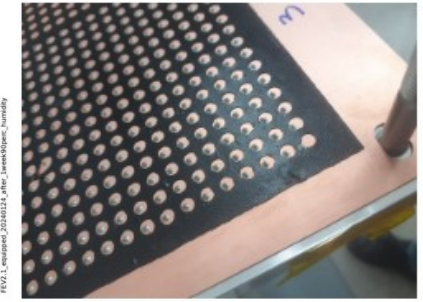
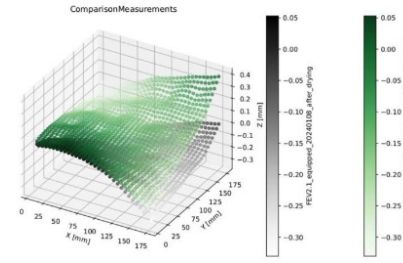
SiW-ECAL

SiW-ECAL (<2020)

- 15 layers 18×18 cm²
- 0.5×0.5 cm² Si cells
- 2.8+5.6 mm W (21 X₀)
- 100 kg, 0.4×0.4×80 cm³
- 15k channels
- Sensor delamination issues



Additional drying and humidity cycles
3x72 cycles during nine days at 90% and 30°C



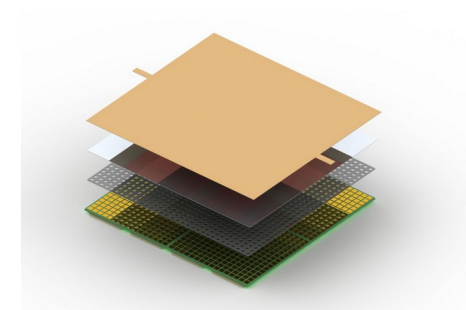
256 P-I-N diodes
0.25 cm² each
9 x 9 cm² total area

EUDET layout

Prototype from Hamamatsu

SiW-ECAL (ongoing)

- Goal 15 layers 18×18 cm²
- New PCB generation & ASICs
- R&D on optimized hybridization
- Ongoing studies on requirements for Circular Colliders:
 - - high fluxes
 - - cooling
- 5d calorimetry



SiW-ECAL beam test at DESY&CERN (2025/26)

▷ **3 layers** (1-chip on board, 2 **new FEV2.1 boards** optimized for power-pulsing)

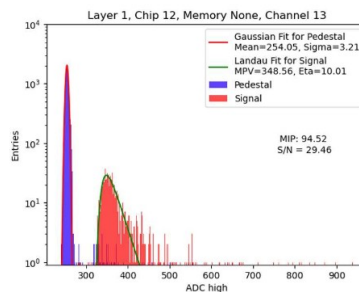
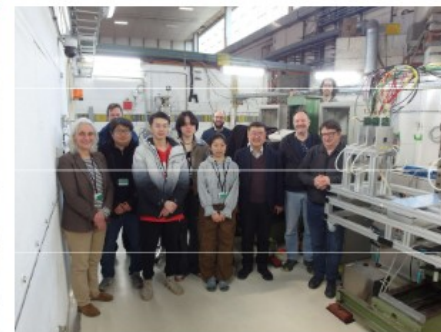
- **New hybridization** techniques → developed at IFIC
- 32x32 cells of 5.5 x 5.5mm²

▷ Two weeks of data taking

- **ECAL** standalone MIP calibration (and TDC calibration)
- **ECAL+HCAL** → common data taking using AIDA TLU + EUDAQ

June 2026 – TB with 15 Layers
Up to 20-24X₀

During 2026
First integrations with CALOROC
(see C. De La Taille talk)



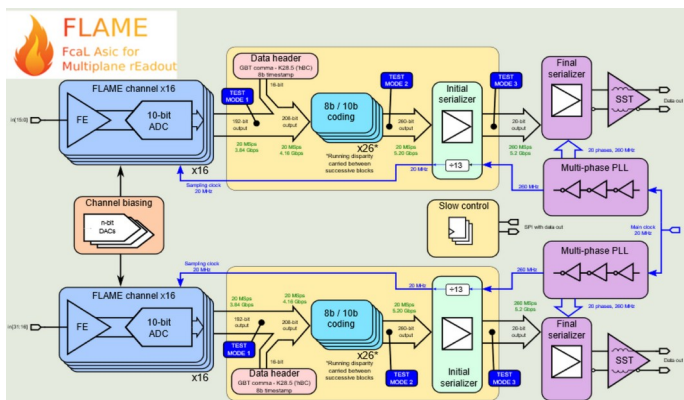
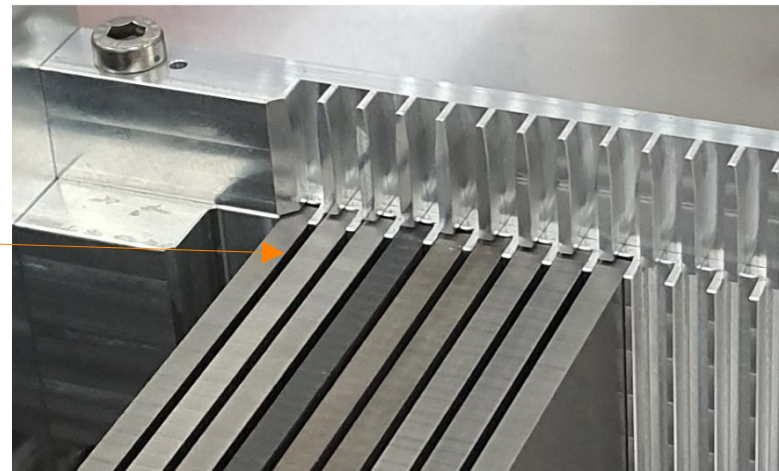
ECAL+AHCAL ← Beam

Towards a full 20X0 prototype

▷ Large sensors (9x9cm²) and **flexible PCBs (compact calo)**

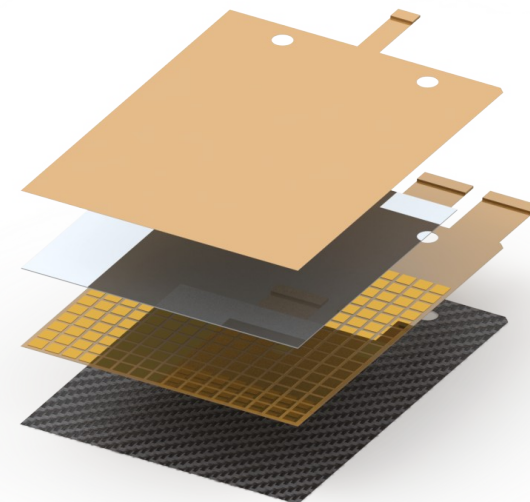
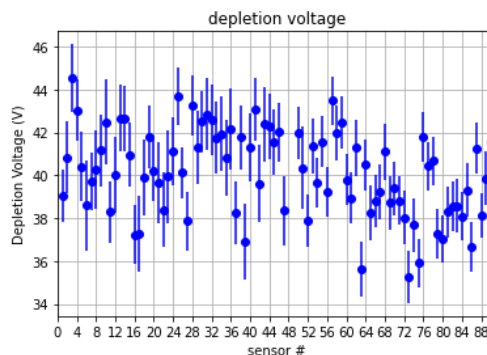
▷ **Material budget, thickness:**

- **Total bellow 1mm**
- 200um CF + 320um sensor
- ~500um for fanout + HV kapton + 3 layers of glue/Adhesive



▷ Same Si sensors as SiWECAL

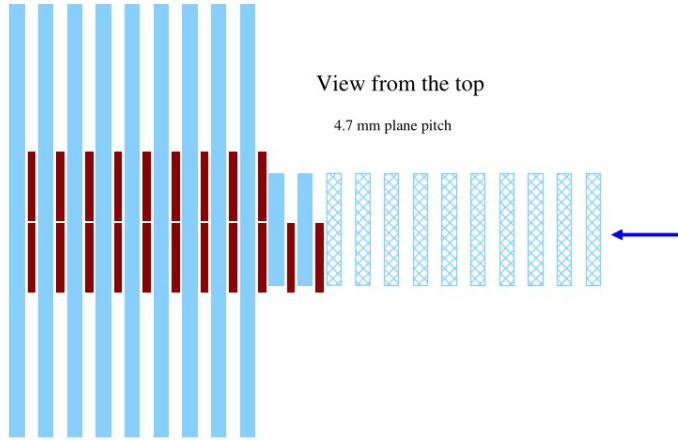
- 9x9cm², 256 pads



New readout with FLAXE for LUXE (based on FLAME)

Towards a full 20X0 prototype

$$10X_0 = 4.5\text{cm}$$



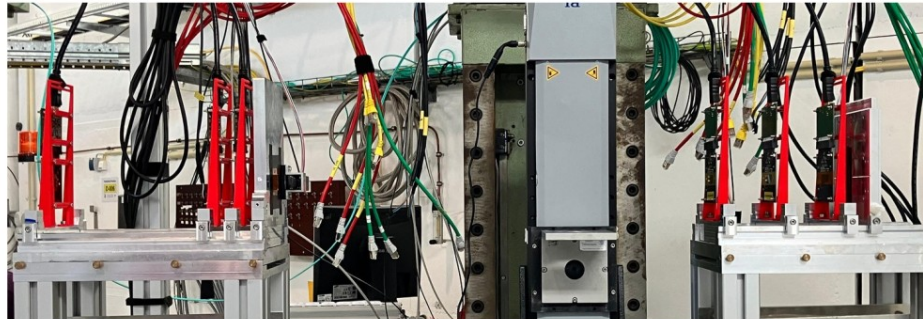
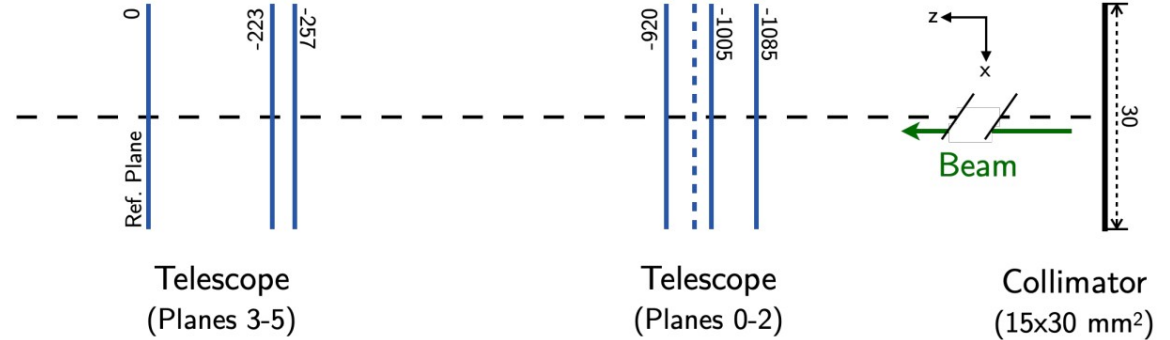
20 sensors in 11 planes

Two running configurations:

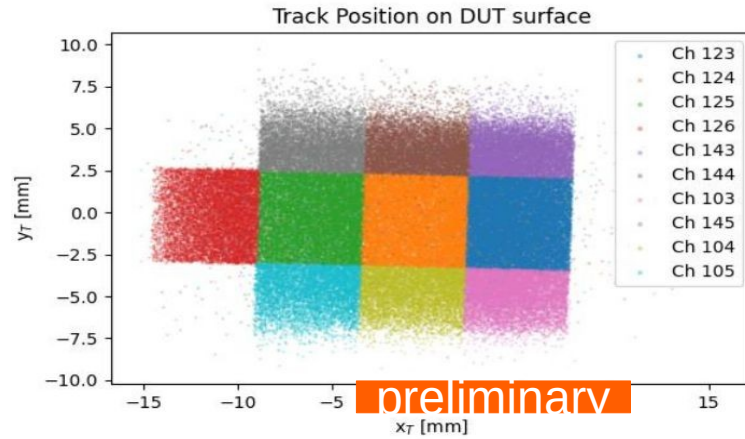
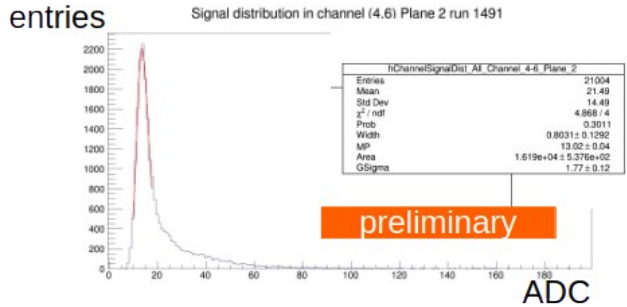
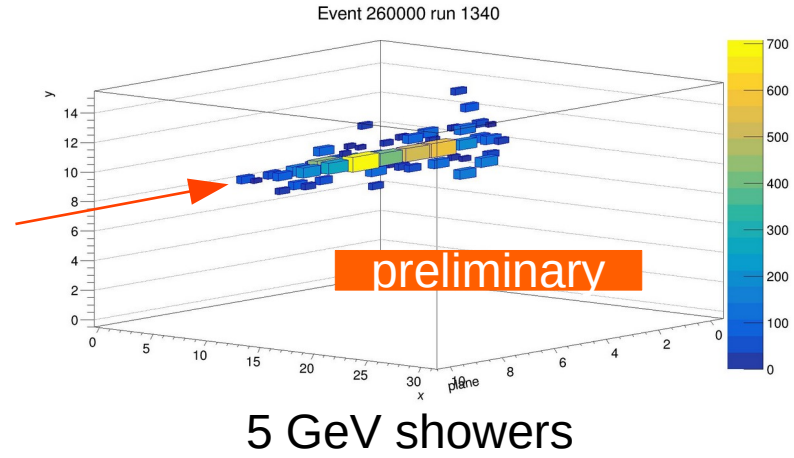
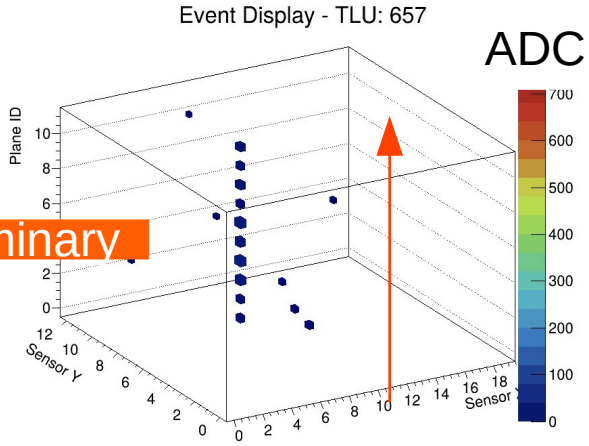
- without absorber (tracker mode)
- with 11 to 21 tungsten plates (calorimeter mode)

LUXE ECAL

Dimensions in mm



Analysing the data – starting effort

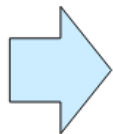


Hough Transform

Very Rich Physics Programme → Challenging Detectors

Higgs Factory Programme

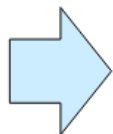
- At $\sqrt{s}=240$ and $\sqrt{s}=365$ GeV collect 2.6M HZ and 150k WW → H events
- Higgs couplings to fermions and bosons
- Higgs self-coupling ($\sim 4 \sigma$) via loop diagrams
- Unique possibility: s-channel $e^+e^- \rightarrow H$ at 125 GeV



- **Momentum resolution** $\sigma(p_T)/p_T \approx 10^{-3}$ @ $p_T \sim 50$ GeV
 - $\sigma(p)/p$ limited by multiple scattering → minimise material
- **Jet** $\sigma(E)/E \approx 3-4\%$ in multijet events for Z/W/H separation
- **Superior impact parameter resolution for b, c tagging**
- **Hadron PID for s tagging**

Precision EW and QCD Programme

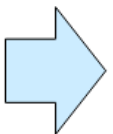
- 6×10^{12} Z and 2×10^8 WW events
- $\times 500$ improvement of statistical precision on EWPO:
 $m_Z, \Gamma_Z, \Gamma_{inv}, \sin^2\theta_W, R_b, m_W, \Gamma_W, \dots$
- 2×10^8 tt events: $m_{top}, \Gamma_{top},$ EW couplings
- Indirect sensitivity to new physics up to tens of TeV



- **Absolute normalisation of luminosity to 10^{-4}**
- **Relative normalisation to $\lesssim 10^{-5}$** (e.g. Γ_{had}/Γ_ℓ)
 - Acceptance definition to $\mathcal{O}(10 \mu\text{m})$
- **Track angular resolution < 0.1 mrad**
- **Stability of B field to 10^{-6}**

Heavy Flavour Programme

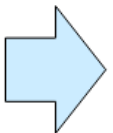
- 10^{12} bb, cc, 2×10^{12} $\tau\tau$ (clean and boosted): $10 \times$ Belle II
- CKM matrix, CP measurements
- rare decays, CLFV searches, lepton universality



- **Superior impact parameter resolution**
- **Precise identification and measurement of secondary vertices**
- **ECAL resolution at few %/√E**
- **Excellent π^0/γ separation for τ decay-mode identification**
- **PID: K/ π separation over wide p range → dN/dx, RICH, timing**

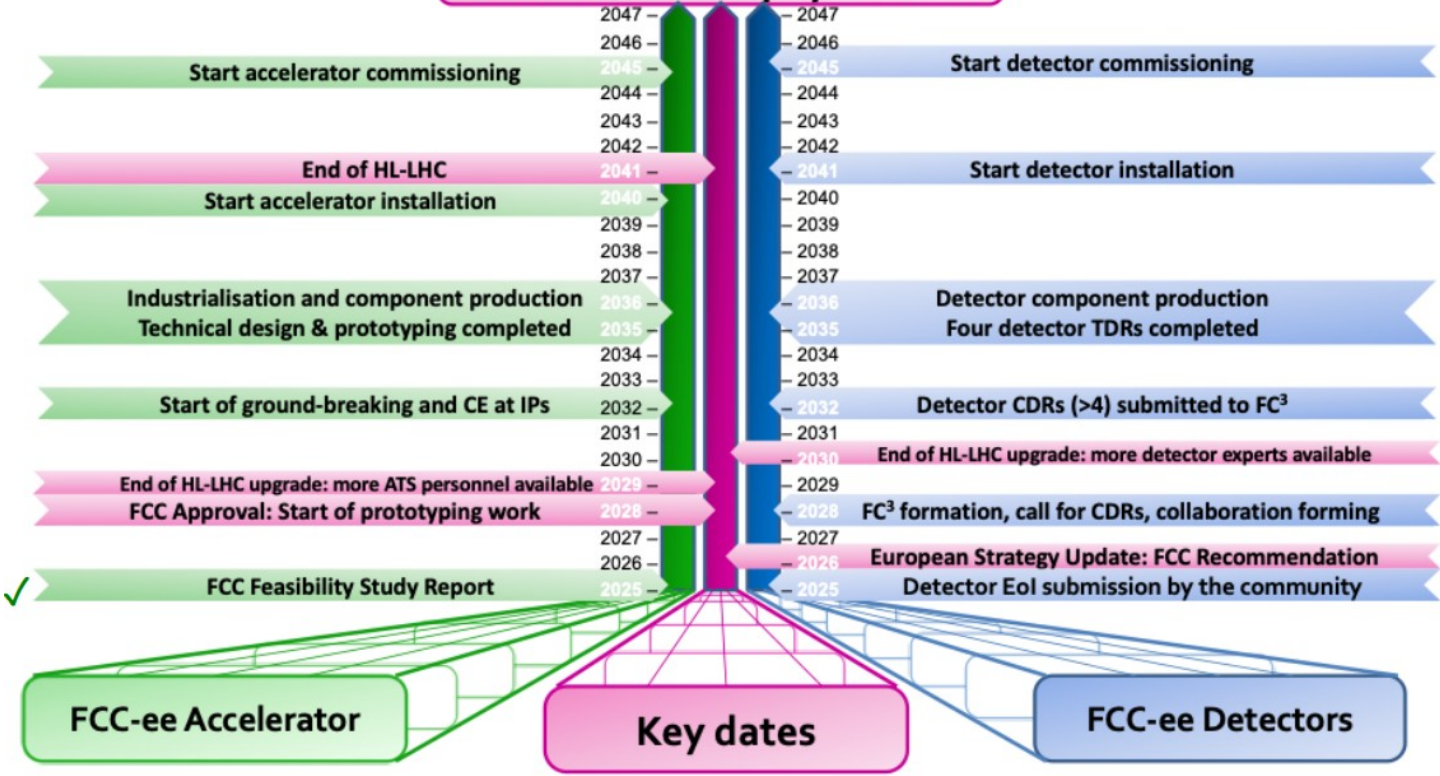
Feebly coupled particles Beyond SM

- Opportunity to directly observe new feebly interacting particles with masses below m_Z
- Axion-like particles, dark photons, Heavy Neutral Leptons
- Long-lifetime LLPs



- **Sensitivity to (significantly) detached vertices (mm → m)**
 - tracking: more layers, "continuous" tracking
 - calorimetry: granularity, tracking capabilities
- **Precise timing**
- **Hermeticity**

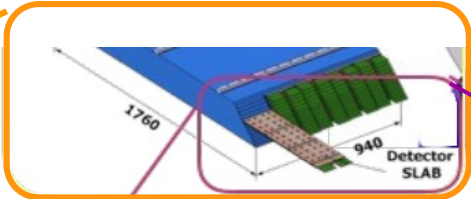
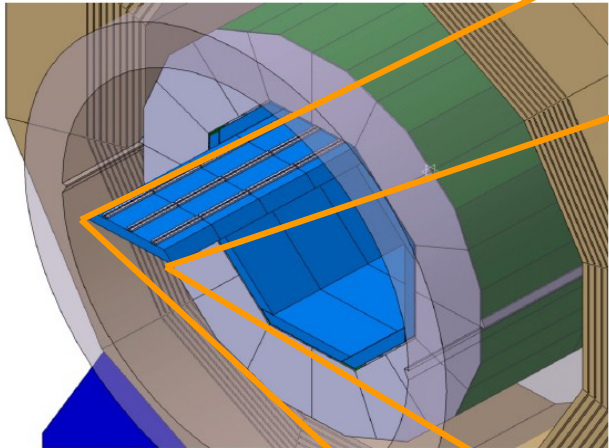
Start of FCC-ee physics run



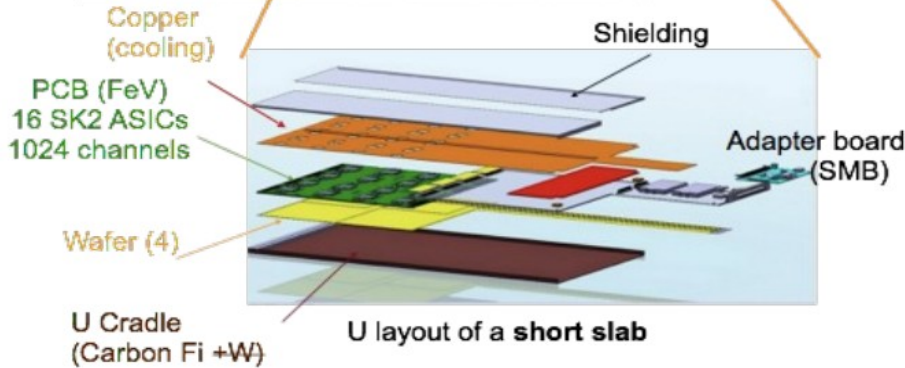
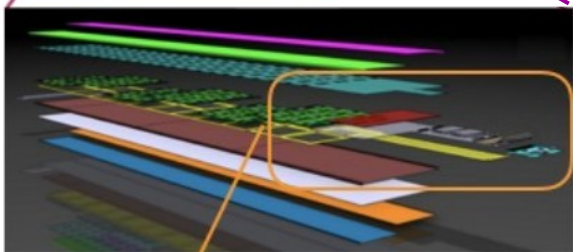
- 2030-33
 - Scalable prototypes
- 2027-30
 - System demonstrators
- 2024-27
 - Optimisation
 - Component R&D



Barrel ECALs



SiWECAL



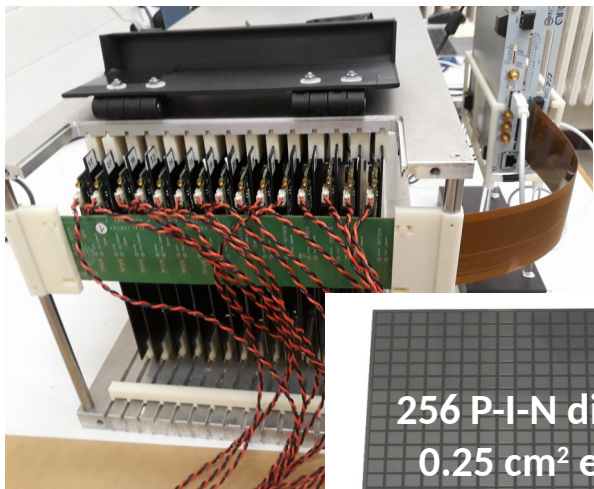
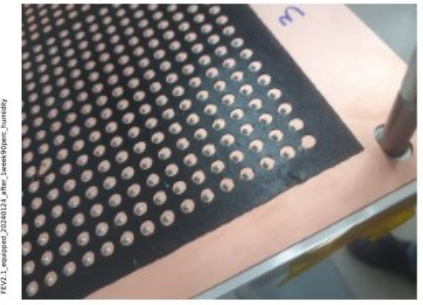
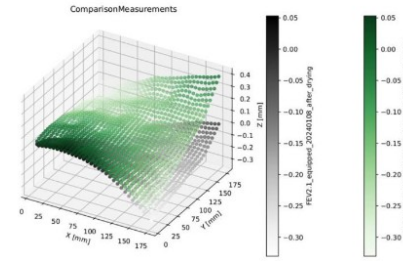
SiW-ECAL

SiW-ECAL (<2020)

- 15 layers 18×18 cm²
- 0.5×0.5 cm² Si cells
- 2.8+5.6 mm W (21 X₀)
- 100 kg, 0.4×0.4×80 cm³
- 15k channels
- Sensor delamination issues



Additional drying and humidity cycles
3x72 cycles during nine days at 90% and 30°C



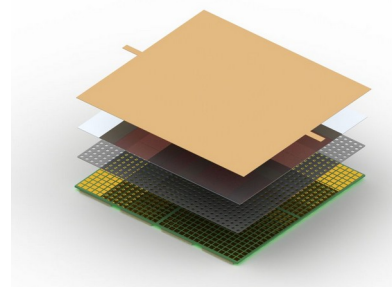
256 P-I-N diodes
0.25 cm² each
9 x 9 cm² total area

EUDET layout

Prototype from Hamamatsu

SiW-ECAL (ongoing)

- Goal 15 layers 18×18 cm²
- New PCB generation & ASICs
- R&D on optimized hybridization
- Ongoing studies on requirements for Circular Colliders:
 - - high fluxes
 - - cooling
- 5d calorimetry



SiW-ECAL beam test at DESY (2025)

▷ **3 layers** (1-chip on board, 2 **new FEV2.1 boards** optimized for power-pulsing)

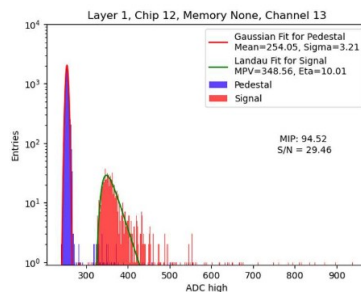
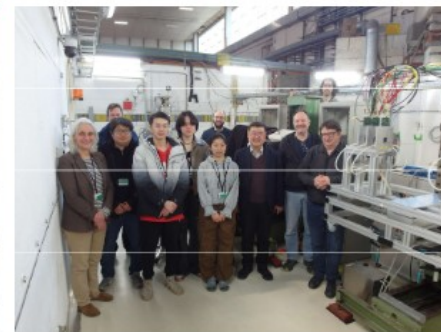
- **New hybridization** techniques → developed by CNRS/IFIC
- 32x32 cells of 5.5 x 5.5mm²

▷ Two weeks of data taking

- **ECAL** standalone MIP calibration (and TDC calibration)
- **ECAL+HCAL** → common data taking using AIDA TLU + EUDAQ

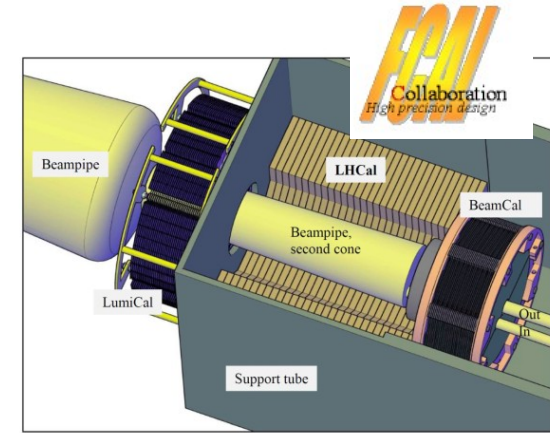
June 2026 – TB with 15 Layers
Up to 20-24X₀

During 2026
First integrations with CALOROC
(see C. De La Taille talk)



Forward Calorimetry (extreme compactness)

- ▷ LumiCal for precise luminosity measurement (Counting Bhabhas)
- ▷ BeamCal for fast luminosity measurement (using beamstrahlung)
- ▷ Technology choice: Si or GaAs/W sandwich calorimeters
- ▷ 1 X0 absorber thickness per layer, 20 (30) layers in ILC (CLIC)
 - Optimal geometries for FCC being studied
- ▷ Recent progress:
 - investigation of new GaAs sensors with integrated signal routing → similar signal size to silicon sensor (Eur.Phys.J.C 85 (2025) 6, 684)
 - **FLAME and FLAXE ASICs** development and production (ongoing)



**Production of a large scale prototype
(adapted to LUXE)**

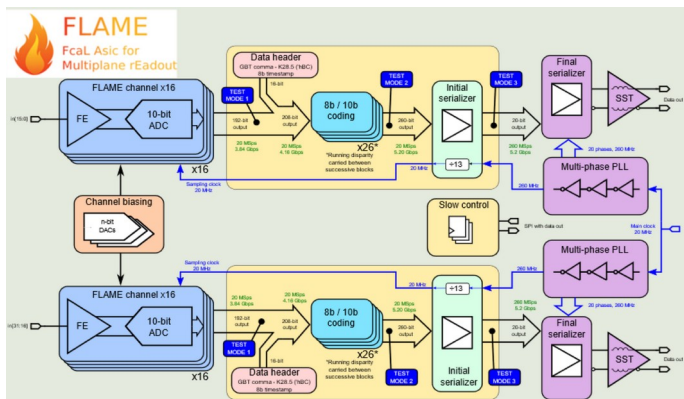
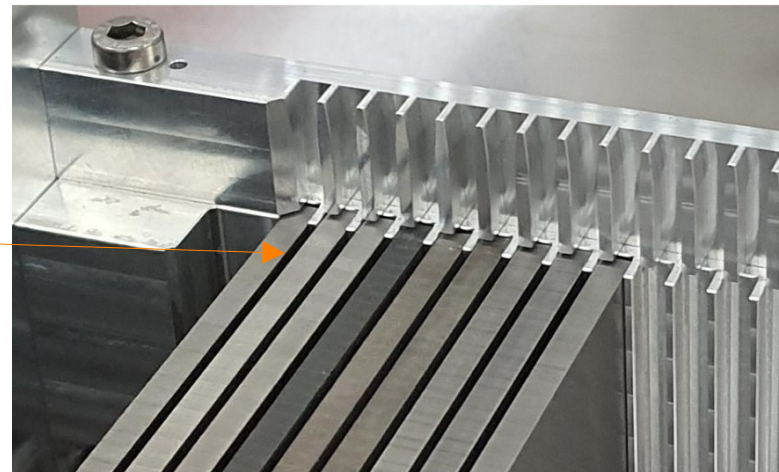


Towards a full 20X0 prototype

▷ Large sensors (9x9cm²) and **flexible PCBs (compact calo)**

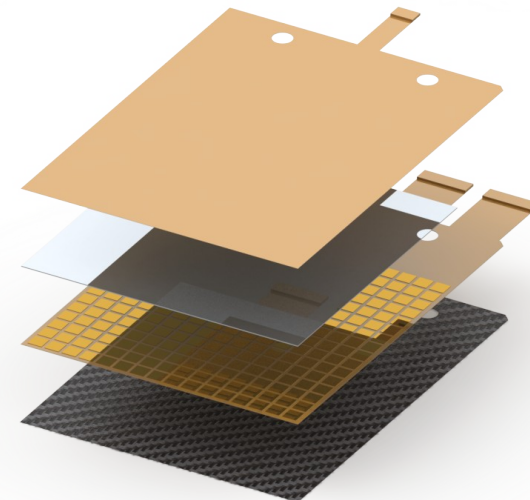
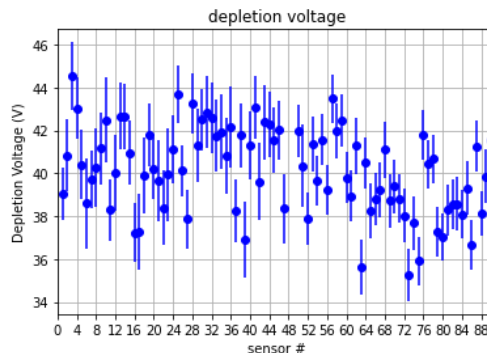
▷ **Material budget, thickness:**

- **Total bellow 1mm**
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- ~500um for fanout + HV kapton + 3 layers of glue/Adhesive



▷ Same Si sensors as SiWECAL

- 9x9cm², 256 pads

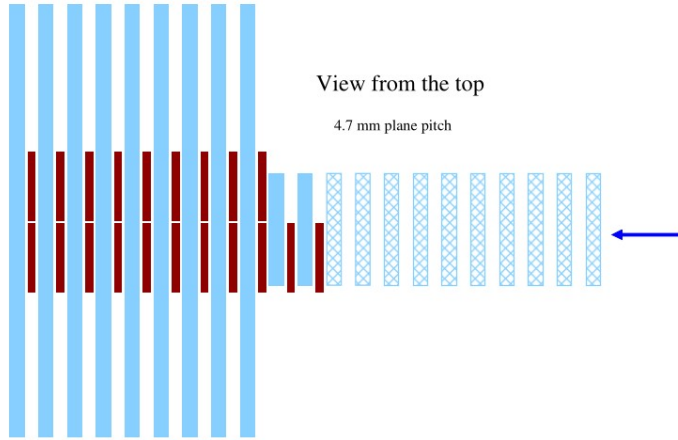


New readout with FLAXE for LUXE (based on FLAME)



Towards a full 20X0 prototype

$$10X_0 = 4.5\text{cm}$$



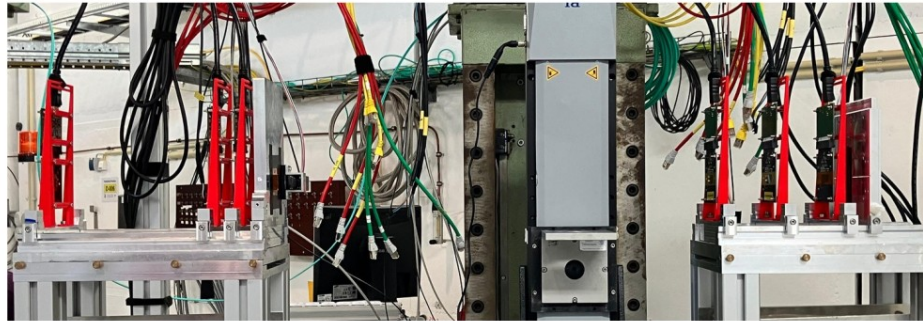
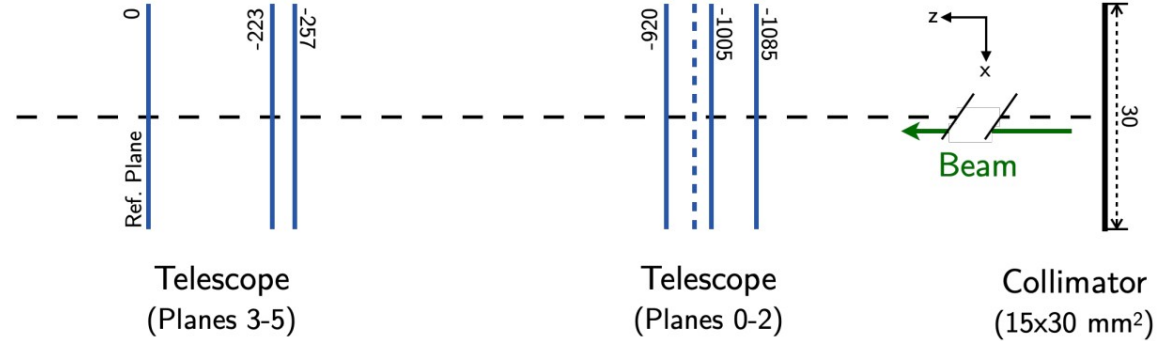
20 sensors in 11 planes

Two running configurations:

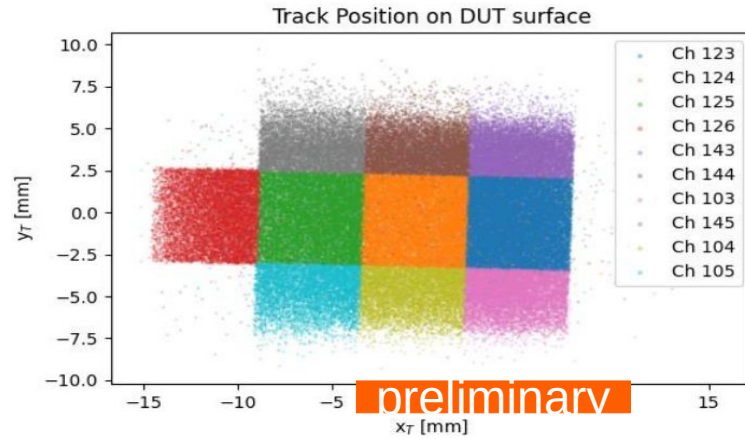
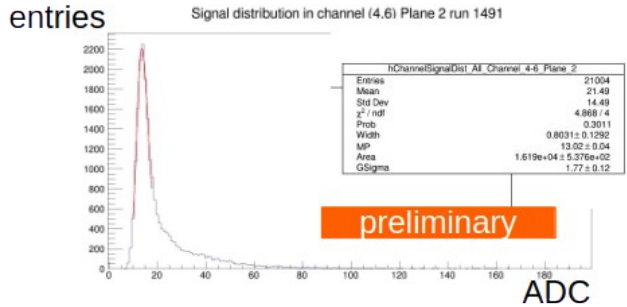
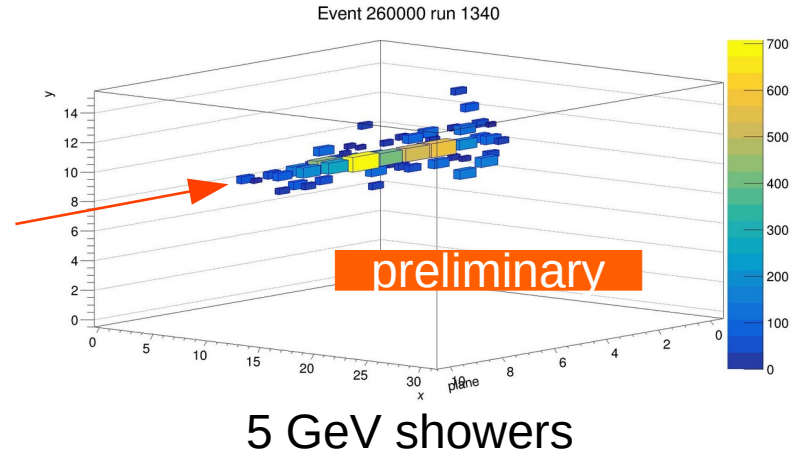
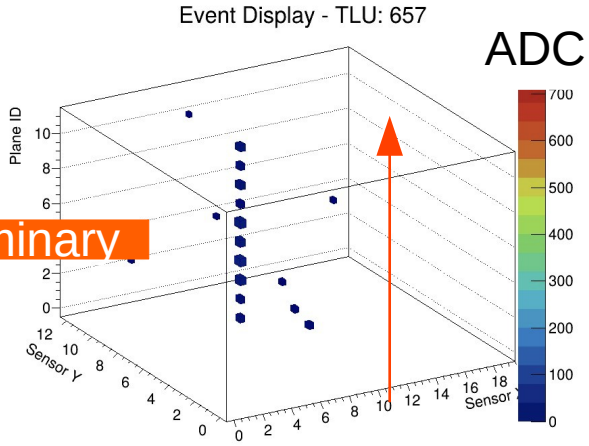
- without absorber (tracker mode)
- with 11 to 21 tungsten plates (calorimeter mode)

LUXE ECAL

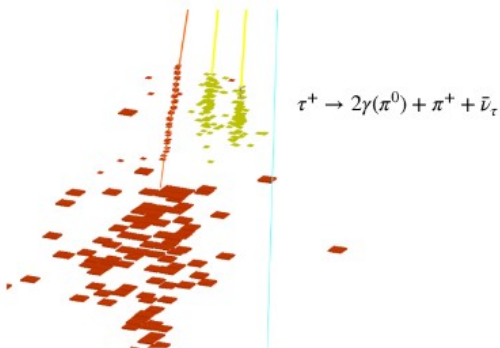
Dimensions in mm



Analysing the data – starting effort



Hough Transform



- Results in close-by / overlapping electromagnetic and hadronic showers

▷ **Silicon Electromagnetic Calorimeters** is one of the **most** robust and **advanced** concepts, optimal for Flavour physics, Higgs/EW physics, QED (**luminosity**)

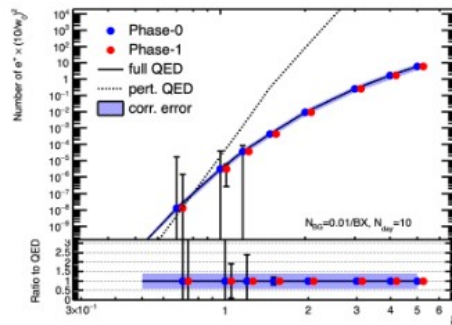
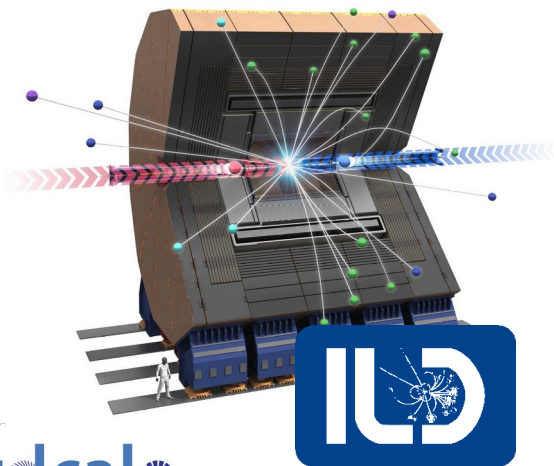
▷ **ECAL** barrel proposals

- *Optimal for Particle Flow Higgs Physics and High Precision Flavor Physics*
- refs *ILD for ILC* *ILD for FCC and LC* *SiW-ECAL for FCCee (Higgs)*

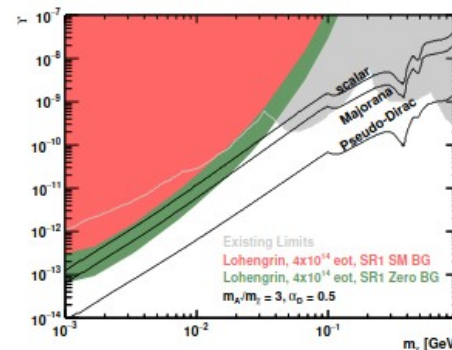
▷ **Si-ECAL for Luminometers**

- *Crucial for all physics program – speciall the EW physics program of FCC*
- *Si-ECAL for FCCee (lumi)*

▷ Prototypes are **also adapted for Strong-Field QED** and direct **Dark Matter** experiments (LUXE, LUXE-NPOD, Lohengrin, ShiP, EBBES)

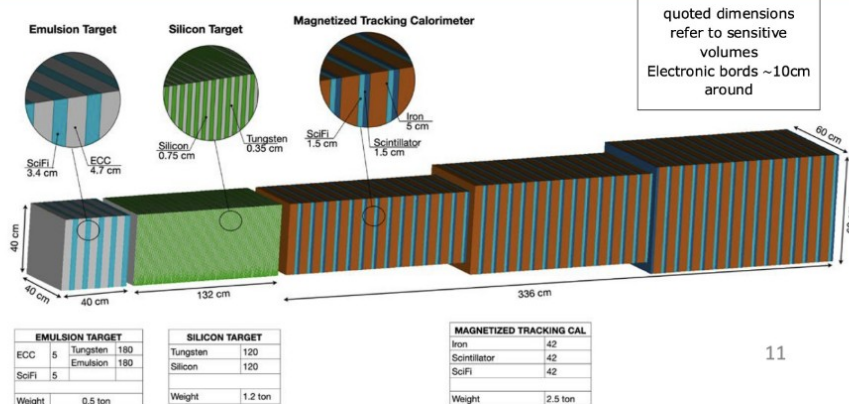


LUXE and LUXE-NPOD
<https://arxiv.org/pdf/2308.00515>



Lohengrin <https://arxiv.org/pdf/2410.10956>

A SiW Ecal for SND?



11

• Questions

- How many SiW Ecal layers and where?
- Rear part of target or MTC or both

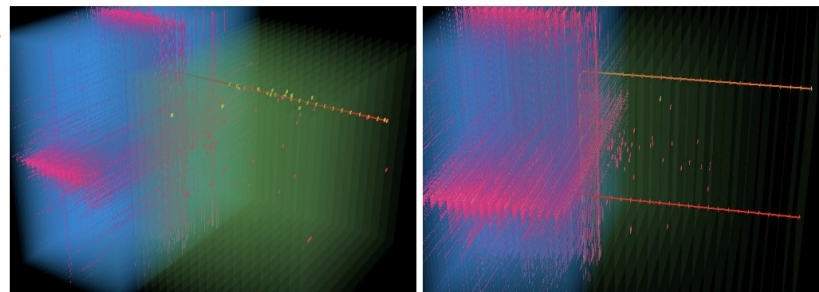
• Where would it fit?

- MTC – Up to 3cm!
 - Comfortable
 - Could increase number of sensitive layers and/or render MTC more compact
 - I hope that we won't need cooling (-> power cycling of FEE)
- Si target – 7mm between W layers (see Christian' talk)
 - Possible

SHIP Collaboration Meeting – June 2025

Event display (hits & ACTS tracks)

- Simulations with 50 GeV PG, 20 layers of each detector
- My Hough seeding can discard showers and retain the muon tracks!



1 $\mu^- 1 e^-$

2 $\mu^- 1 e^-$

17

J. P. Márquez | DRDCalo 2026

drdcalo

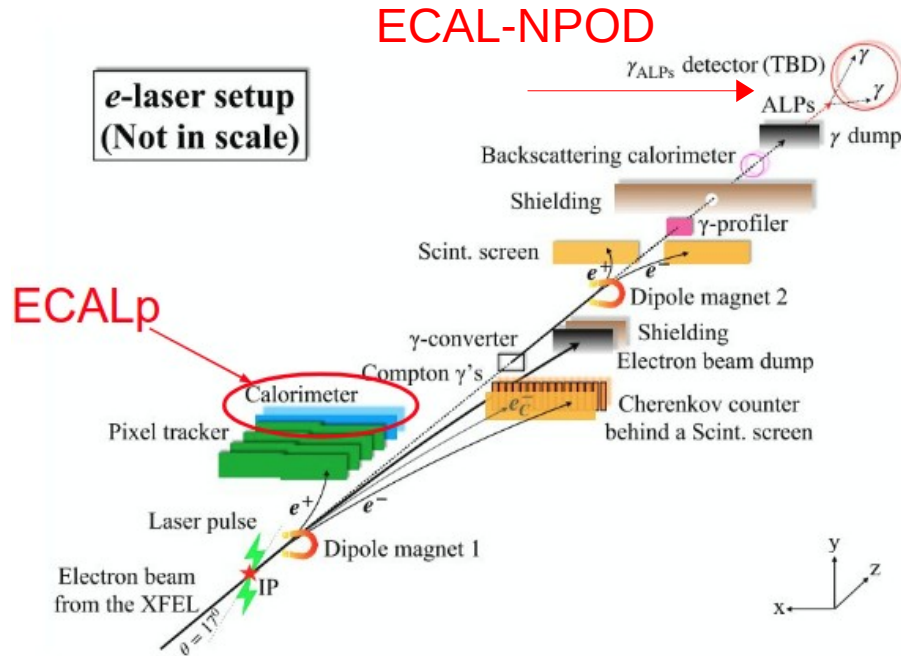
11

<https://indico.cern.ch/event/1618975/contributions/7004462/>

The LUXE ECAL systems

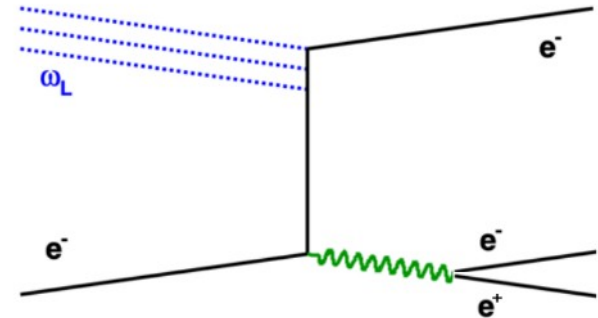
▷ LXUE Dedicated to Strong Fields Quantum Electrodynamic studies

- Makes use of 17.5 GeV Eu.XFEL electron beam colliding with intense optical laser pulses
- Dedicated searches of BSM profiting from intense gamma beam (non-linear compton)



ECAL-NPOD

$$e^- + n\omega_L \rightarrow e^- + e^- + e^+$$



Positron-electron pair production not accessible in “standard” QED...
 ⇒ “smoking gun” for non-linear processes...

Layout optimization for the LUXE-NPOD experiment
 (Quispe, Trevisani et al) <https://arxiv.org/abs/2507.17716>

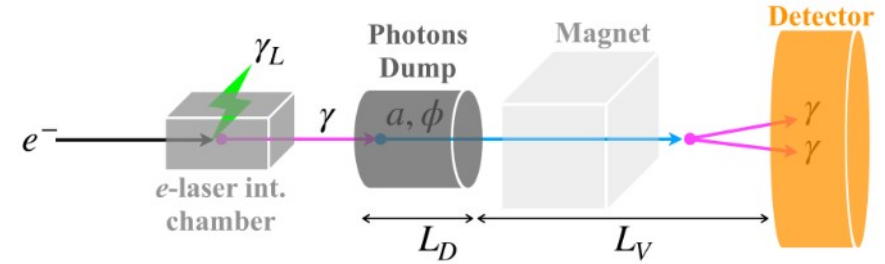
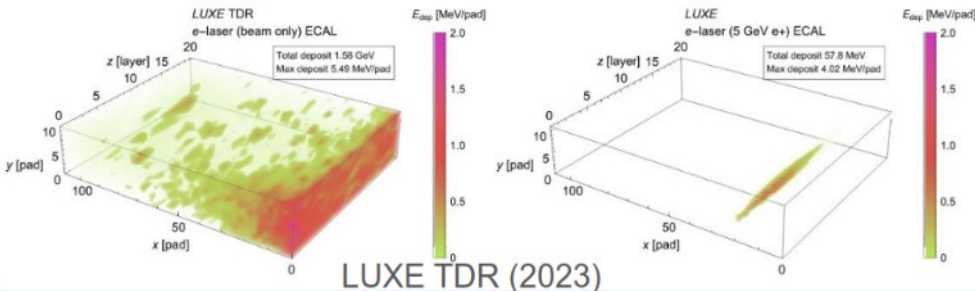
Challenges – proposed solutions

▷ (main) Challenges SF-QED

- Two modes with expected number of positrons varying from 10^{-4} to 10^7
- EM shower overlap at high multiplicity
- Low multiplicity showers immersed in low energy widely spread background

▷ (main) Challenges BSM searches

- Very low multiplicity of events,
- Low mass ALPs decaying into two photons ($E \sim 1-3\text{ GeV}$)
- Background rejection capabilities



▷ Similar solutions for both

- Compact sampling calorimeter
- Small Molière radius
- High granularity

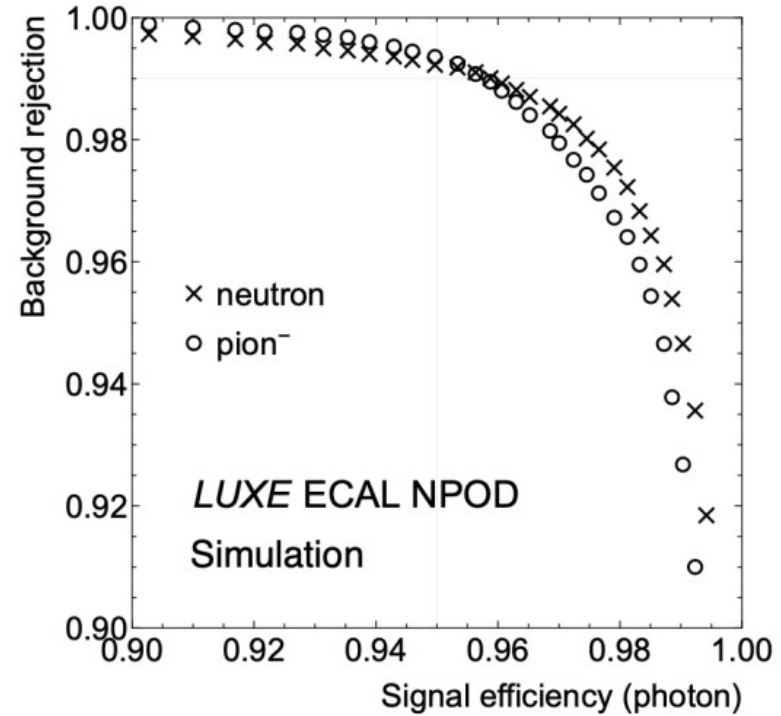
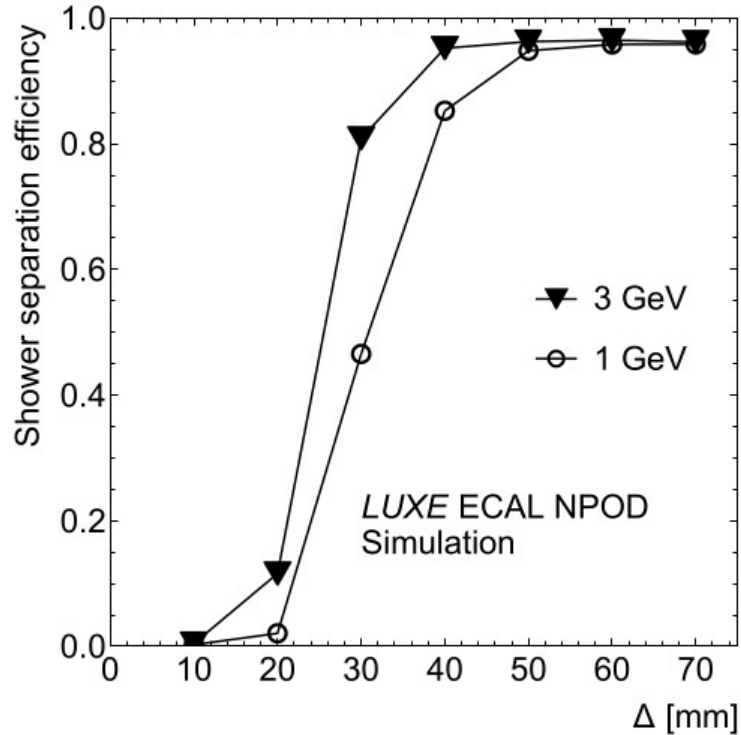


ECALe = proposed by FCAL group
 ECAL-NPOD = proposed by SiWECAL group



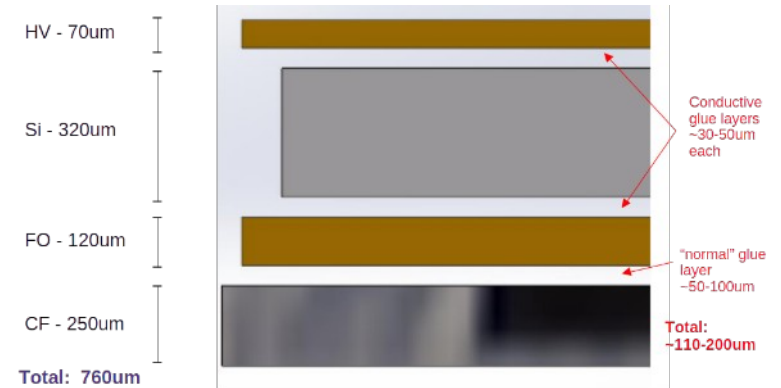
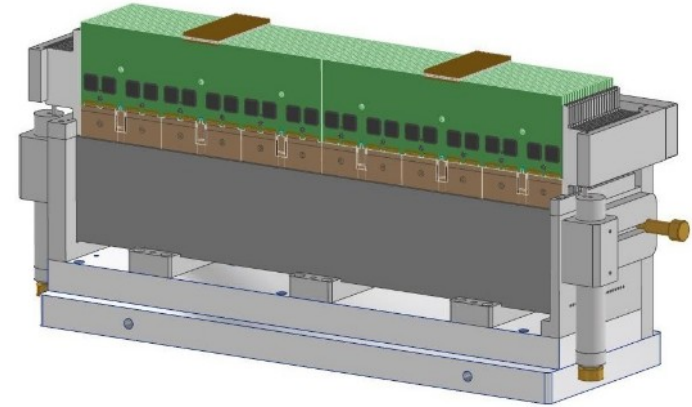
ECAL-NPOD (aka SiWECAL)

Layout optimization for the LUXE-NPOD experiment <https://arxiv.org/abs/2507.17716v1>



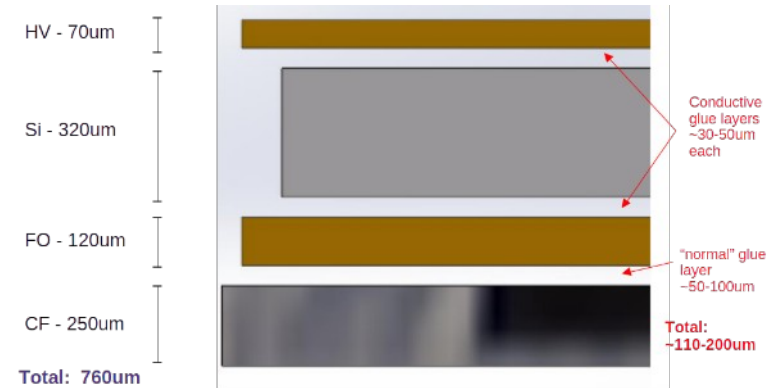
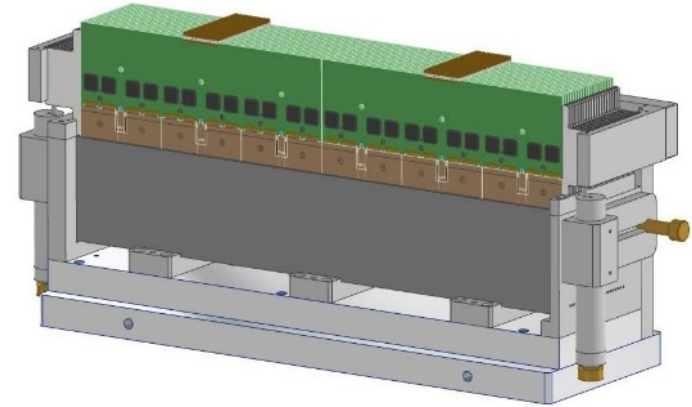
ECALp (aka. HighCompactCalo - FCAL)

- ▷ Positron calorimeter
- ▷ Highly compact and modular calorimeter to minimize the Molière radius.
- ▷ Design based on the concept considered by the FCAL collaboration for compact calorimeters
 - 21 tungsten plates of 1 X0
 - 1 mm sensor gaps between
 - 20 active planes with 6 sensors per plane
 - Front-End-Boards (FEB) above the sensors
 - Requires dedicated sensor sandwich design (designed and produced at IFIC)
 - dedicated FEB, readout scheme and mechanics.
- ▷ Realistic design presented in LUXE TDR.
- ▷ Tests of the first prototype took place in June 2025.

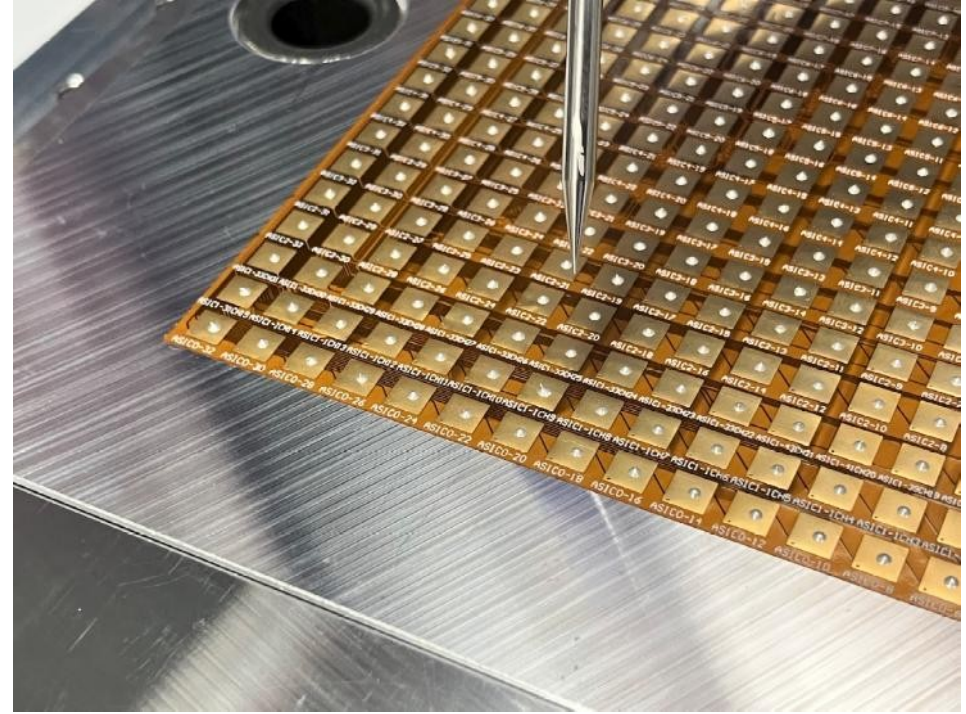
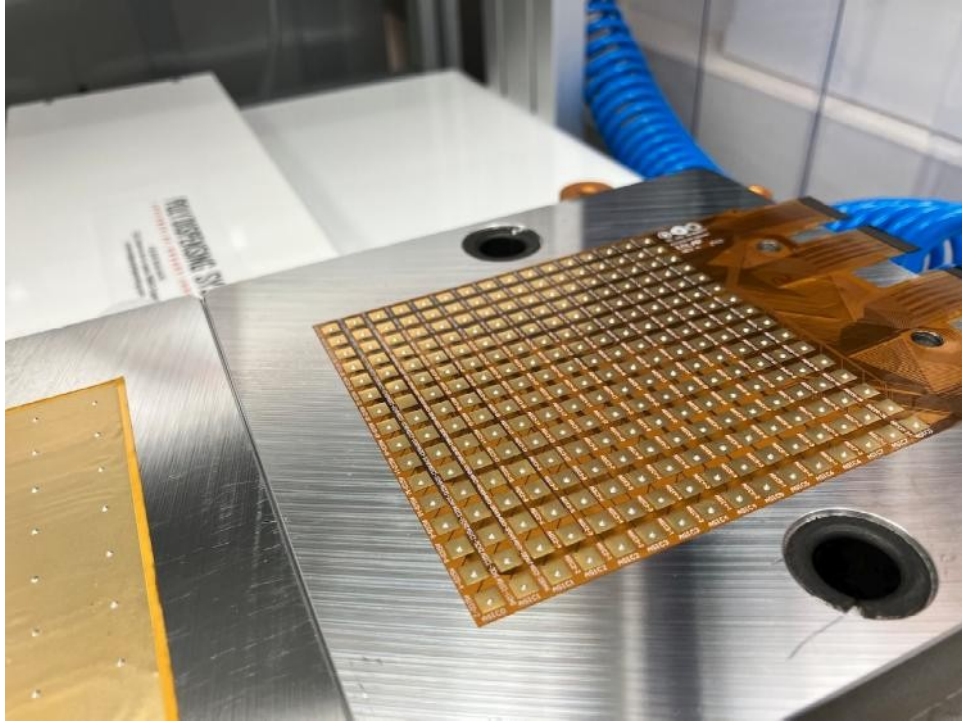


ECALp (aka. HighCompactCalo - FCAL)

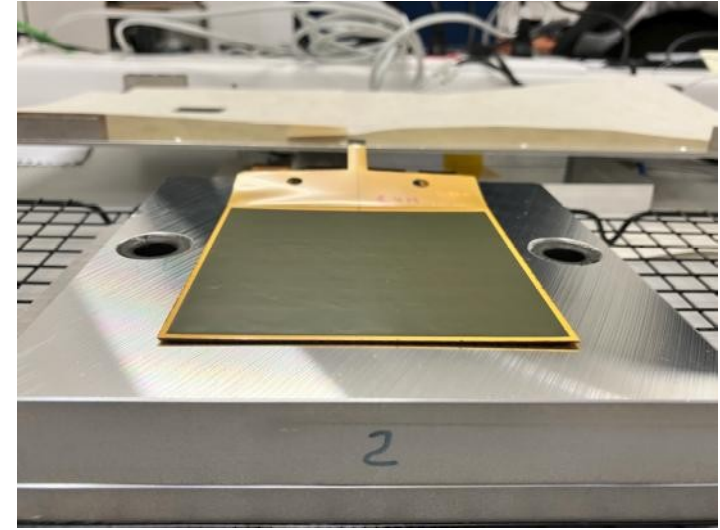
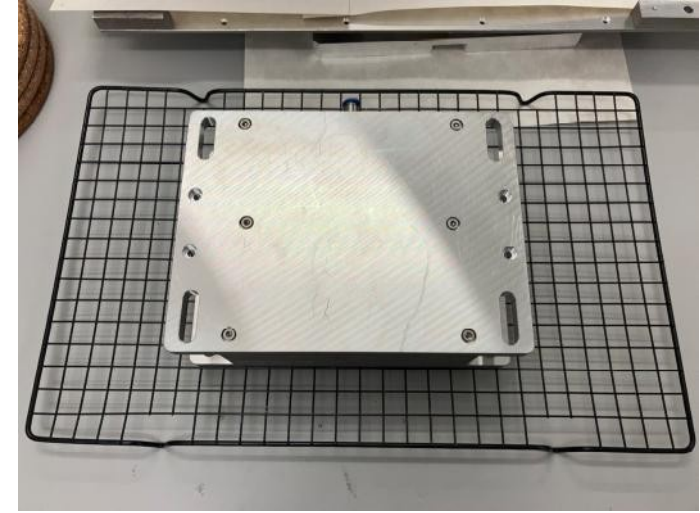
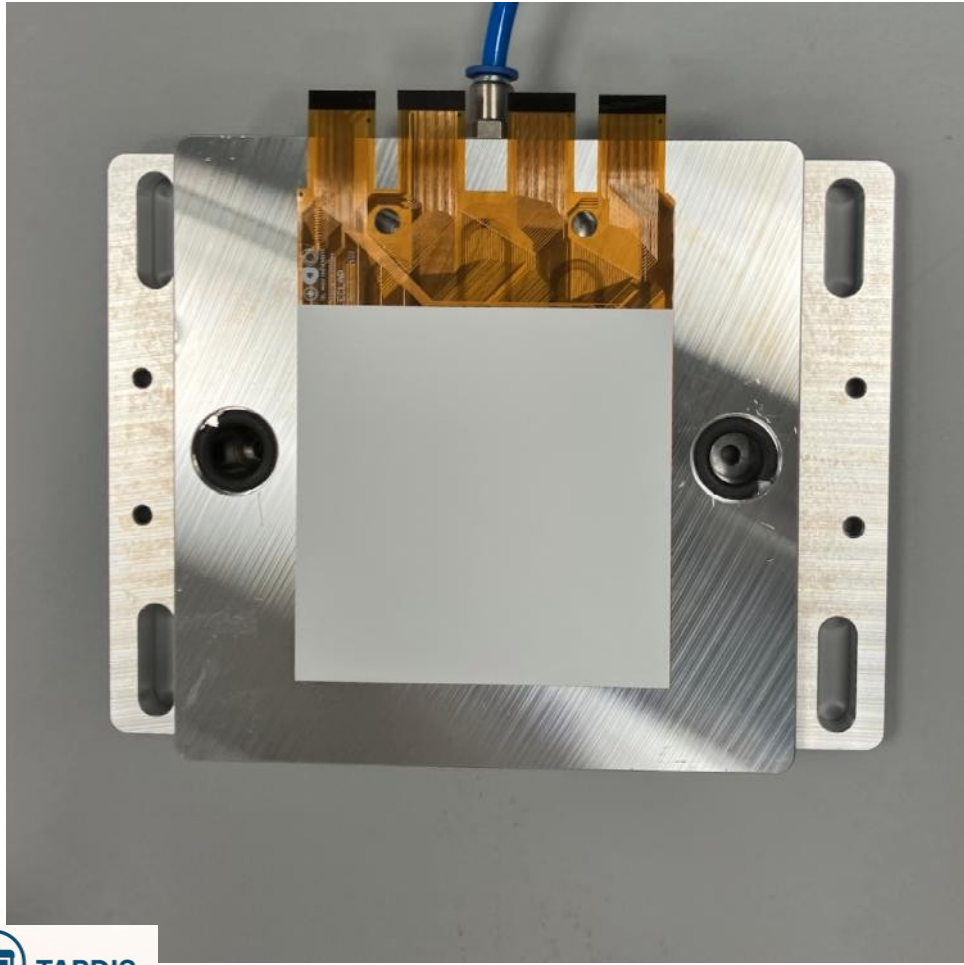
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- ▷ Realistic design presented in LUXE TDR.
- ▷ Tests of the first prototype took place in June 2025.



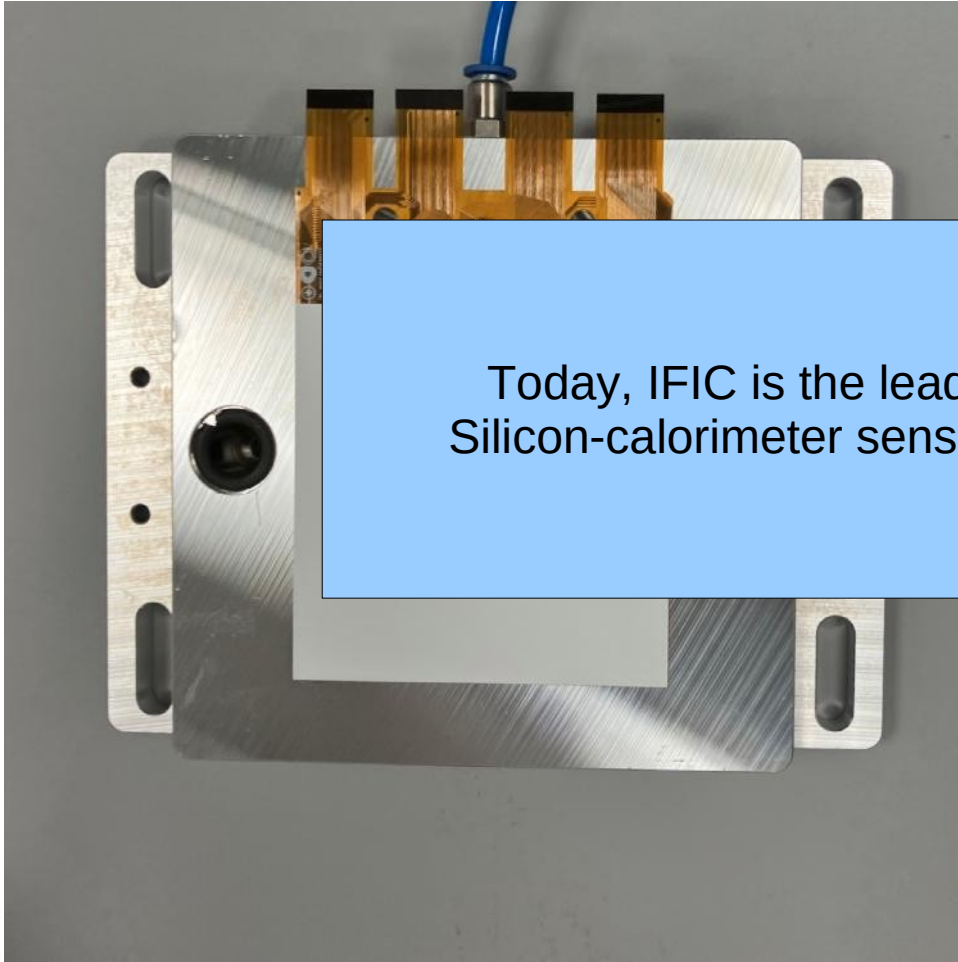
TARDIS-Lab for ECAL hybridization



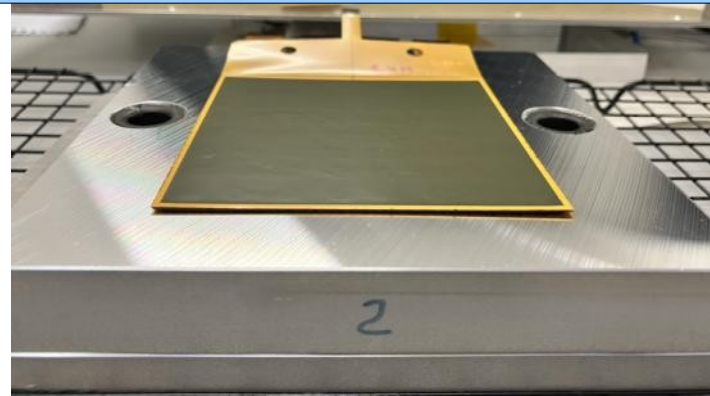
TARDIS-Lab for ECAL hybridization



TARDIS-Lab for ECAL hybridization



Today, IFIC is the leading center in the DRD-Calo on Silicon-calorimeter sensor assembly and characterization



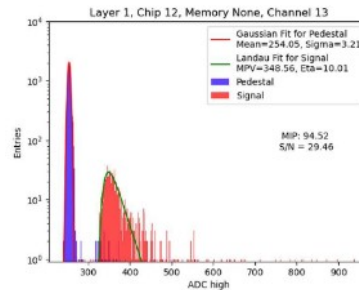
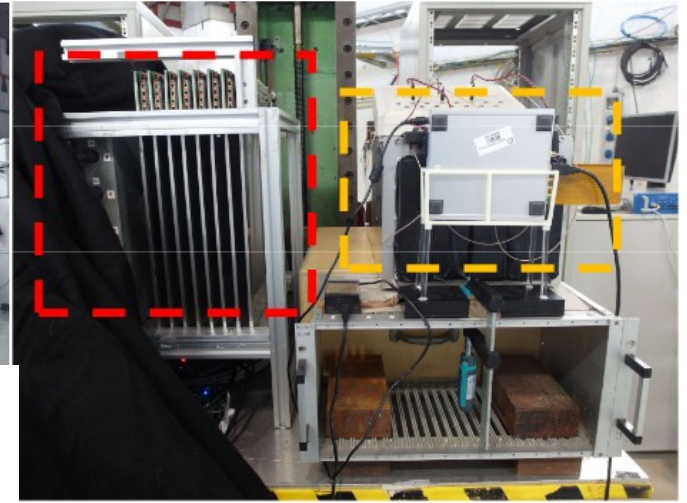
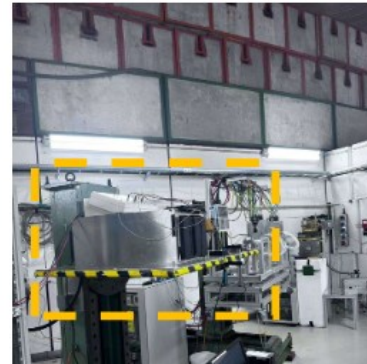
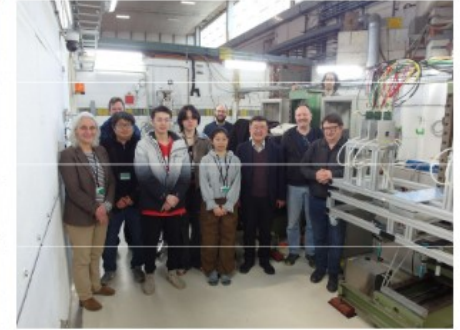
SiW-ECAL beam test at DESY

▷ 3 layers (1-chip on board, 2 new FEV2.1 boards optimized for power-pulsing)

- New hybridization techniques → developed by CNRS/IFIC
- 32x32 cells of 5.5 x 5.5mm²

▷ Two weeks of data taking

- ECAL standalone MIP calibration (and TDC calibration)
- ECAL+HCAL → common data taking using AIDA TLU + EUDAQ



ECAL+AHCAL ← Beam



Context: comparing FCC-ee vs HL-LHC

Compare triggered **HL-LHC** (ATLAS/CMS) vs **FCC-ee** T/DAQ variants

- Assume a single **HL-LHC** event is 4 MB, and a single **FCC-ee** event is 0.2 MB
- Assume the full FCC-ee physics rate at the Z pole is 200 kHz

	Raw input	Trigger	Filter input	Filter	Storage input
HL-LHC	40 MHz 160 TB/s	→	1 MHz 4 TB/s	→	10 kHz 40 GB/s
<hr/>					
FCC-ee	50 MHz 10 TB/s		0.5 MHz 0.1 TB/s		200 kHz 40 GB/s
	Streaming, with filter		50 MHz 10 TB/s		500 kHz 100 GB/s
			Streaming, no filter		50 MHz 10 TB/s

DAQ is capable of FCC-ee streaming readout: compatible with triggered HL-LHC

- However, streaming no-filter readout straight to disk may take too much space

The precision demands of the FCC-ee

FCC-ee physics case demands exquisite precision of the trigger system, if used

- Trigger efficiency uncertainty must be negligible compared to luminosity
- Any trigger bias between event types must be controlled to 1 part in 10^6
- These constraints motivate a streaming readout

M. Dam

HL-LHC DAQ hardware is perfectly capable of FCC-ee streaming readout

- However, this comes with a lot of associated material and power
- DAQ hardware for streaming readout may therefore degrade physics potential

Very preliminary assumptions on data size
Occupancy levels
(specially in the inner and forward tracking systems)