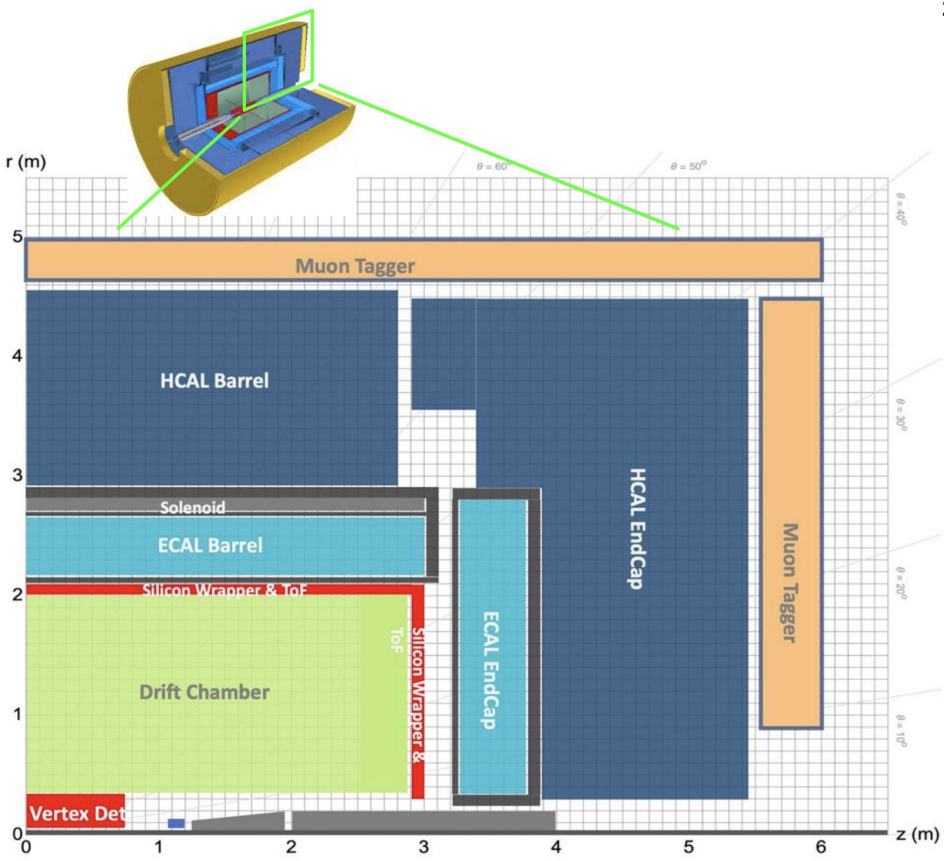
FCC TileCal

A. Ruiz, A. Valero, A. Arranz, C. Fernández, D. Hernández, F. Carrió, I. Redondo, I. Burriel, J. Valls, L. Fiorini, X. Poveda

FCC open day, 16 April 2026

ALLEGRO Detector Concept



A **L**epton-**L**epton collider **E**xperiment with **G**ranular **R**ead-**O**ut: https://allegro.web.cern.ch

General-purpose detector for FCC:

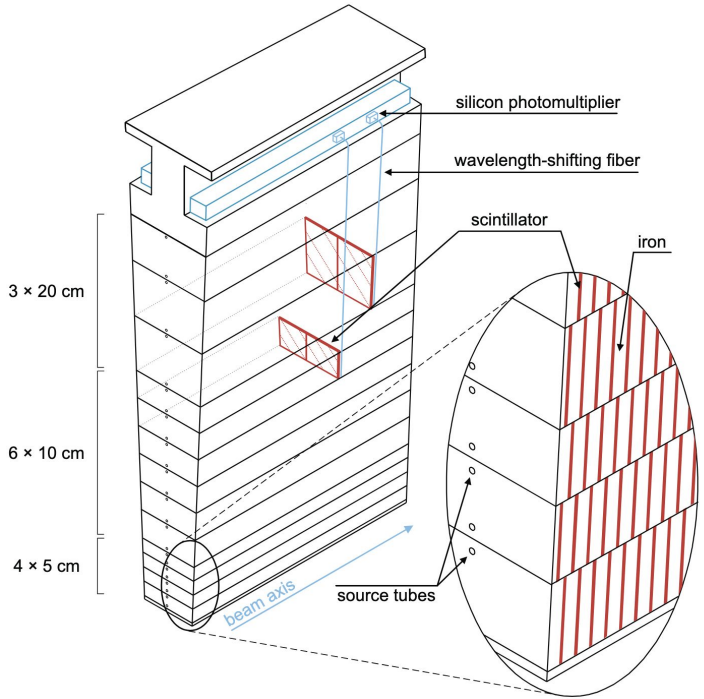
- Strong focus on jet reconstruction with highly segmented calorimeters
  - ECAL: noble liquid
  - HCAL: TileCal
  - Calorimeters similar to ATLAS (LAr + Tile) with enhanced segmentation
- Inner Vertex Detector
- Inner spectrometer: Drift Chamber + Si Wrapper
- PID tools: ToF with Si Wrapper, Muon Tagger

Next steps:

- R&D on subdetectors
- TDR expected in the coming 10 years

TileCal-like calorimeter for ALLEGRO

- Proposal to build a scintillator calorimeter with TileCal-like geometry for FCC:
  - Greater longitudinal and transverse segmentation → Improved spatial resolution
- Current TileCal-like design in simulation:
  - 5 mm steel absorber plates alternating with 3 mm scintillator plates
  - 128 modules in φ, 2 tile/module → Δφ = 0.025
  - 13 radial layers (4 x 5 cm, 6 x 10 cm, 3 x 20 cm)
- Scintillation light → WLS fibers → SiPM-based readout
  - 1 fiber/tile, 1 SiPM/fiber ⇒ O(1M) channels
- Contributing to the ALLEGRO HCAL activities

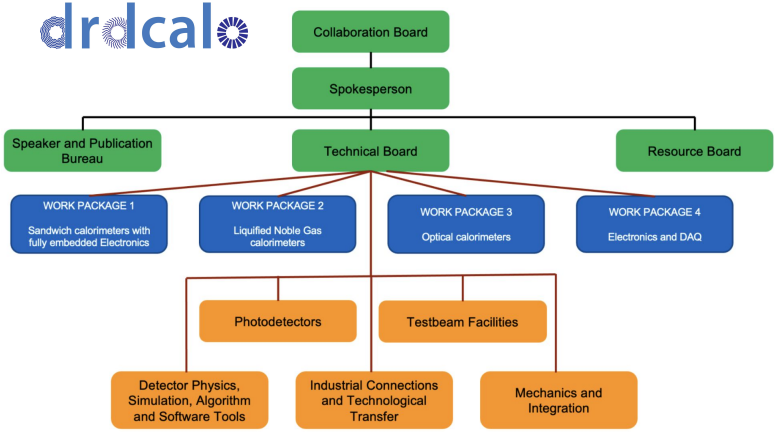


DRD Calo (DRD6) Collaboration - Organization

DRD Calo Collaboration: 134 institutes from 27 countries

Work Package 3 – Optical Calorimeters:

- Calorimeters based on scintillating materials and photodetectors for high-energy particle colliders
- Novel calorimeter designs taking advantage of the continuous technological progress from faster and more radiation-tolerant scintillators to compact and cheaper photodetectors such as SiPMs
- Explore, optimise and demonstrate prototypes with full shower-containment, new concepts of sampling and homogeneous calorimeters based on scintillating materials
- Improve the spatial granularity, the time and energy resolution and the radiation tolerance compared to state-of-the-art calorimeters
- Use of particle flow algorithms for event reconstruction
- 12 subtasks: **Work Package 3.3.2 - TILECAL**



(Sub)tasks	Calorimeter type	Focus
HGCCAL	Homogeneous and quasi-homogeneous EM calorimeters	Mostly e+e- colliders
MAXICC		
CRILIN		Mostly mu+mu- collider
OREO		Compact calorimeters with oriented crystals
GRAINITA	Sampling EM calorimeters	Fine sampling calorimeter for e+e- colliders
SPACAL		Timing transverse segmentation
RADICAL		Radiation tolerance (e.g. FCC-hh)
3DCaloNu		Neutrino physics
DRCAL	Sampling HAD calorimeters	Mostly e+e- colliders
TILECAL		
SCINTCAL	R&D on scintillators	
CRYODBD-CAL	Calorimeter at low	Neutrino physics: DBD

DRD Calo (DRD6) WP3 - Optical Calorimeters

2026 Milestones for WP3

M #	Subtask	Title
3.1.1	HGCCAL	New reconstruction software for the long-bar design and updated PFA
3.1.2	MAXICC	Joint testbeam of EM module prototype with dual-readout fibre calorimeter prototype (DRCAL)
3.1.3	CRILIN	Report on testbeam results
3.2.2	SPACAL	Specification of photon detector and improved simulation framework available
3.2.3	RADICAL	Paper on beam-test results for EM shower position, timing and energy
3.3.1	DRCAL	Testbeam campaign to assess module performance: result paper
3.3.1	DRCAL	Continue beam testing with alternative readout elx
3.3.2	TILECAL	Paper on beam test results
3.4.1	SCINTCAL	Dataset of scintillation and radiation hardness properties of various scintillation materials studied

2026 Deliverables for WP3

D #	Subtask	Title
3.1.1	HGCCAL	Large crystal module for hadronic performance, system integration studies and combined testbeam with HCAL
3.1.2	MAXICC	Full containment dual-readout crystal EM calorimeter prototype and testbeam characterisation
3.2.1	GRAINITA	Development of a GRAiNITA demonstrator as EM calorimeter prototype for e+e- collider (full shower containment)
3.2.2	SPACAL	Set of crystal samples, SPIDER ASIC prototype
3.2.2	SPACAL	Module-size prototypes (significantly larger than EM showers) built and validated in beam tests
3.2.3	RADICAL	3x3 array of RADiCAL modules built and tested
3.3.1	DRCAL	Construction of full-scale dual readout module with hadronic shower 2025 containment
3.3.2	TILECAL	Construction of up to 3 prototypes of a sampling tile calorimeter module with WLS fibres and SiPM readout (for beam tests after 2026)
3.3.2	TILECAL	Full hadron-shower containment prototype built and tested
3.4.1	SCINTCAL	Samples of a set of scintillators produced and characterised
3.4.1	SCINTCAL	Samples of most promising glasses produced and characterised
3.4.2	CRYODBDCAL	Scintillating polymer for 3D-printing, with optimal mechanical and light-production properties, produced and tested

DRD Calo (DRD6) WP3.3.2 - TILECAL

- Well established effort
- Regular participation in the **Work Package 3.3.2 - TILECAL**
- Work Package 3.3.2 agendas: https://indico.cern.ch/category/19081/ together with current (Henric Wilkens) and former (Oleg Solovyanov) ATLAS TileCal Project Leaders
- Current groups: CERN, FZU, ITIM Cluj-Napoca, IFIC Valencia, INFN Pisa, LIP, LPCA, TSU, Göttingen
- DRD Calo Work Package 3 kickoff meeting scheduled on May 19th

April 2026

29 Apr DRD Calo TileCal group meeting

17 Apr DRD Calo TileCal beamtest meeting

15 Apr DRD Calo TileCal group meeting

01 Apr DRD Calo TileCal beamtest meeting

March 2026

25 Mar DRD Calo TileCal group meeting

11 Mar DRD Calo TileCal group meeting

February 2026

25 Feb DRD Calo TileCal group meeting

January 2026

21 Jan DRD Calo TileCal group meeting

December 2025

17 Dec DRD Calo TileCal group meeting

November 2025

19 Nov DRD Calo TileCal group meeting

October 2025

22 Oct DRD Calo TileCal group meeting

Recent contributions for FCC and DRD Calo

FCC TileCal project at IFIC - group website: https://ateneagroup.ific.uv.es/ateneaweb/

- TileCal-IFIC Group: Readout electronics R&D for FCC, talk by Ximo Poveda
  Jornadas de la Red Española de Futuros Colisionadores, CIEMAT, Madrid, 23-24 September 2025
- MPPC Characterization for FCC Calorimetry, talk by Ana Arranz
  XVII CPAN DAYS, ADEIT, Valencia, 19-21 November 2025
- IFIC Tile CAL, talk by Arantxa Ruiz
  1st DRD Calo – Spain Meeting, IFIC, Valencia, 13 January 2026
- FCC Allegro/TileCal-like calorimeter, talk by Ana Arranz
  1st DRD Calo – Spain Meeting, IFIC, Valencia, 13 January 2026
- MPPC Characterization for FCC Calorimetry, poster by Ana Arranz
  9th FCC Physics Workshop, MPI of Physics, Munich, 26-30 January 2026

Recent FCC and DRD Calo workshops

9th FCC Physics Workshop, Munich, 26-30 Jan 2026

DRD Calo Collaboration Meeting at CERN, 7-10 Apr 2026

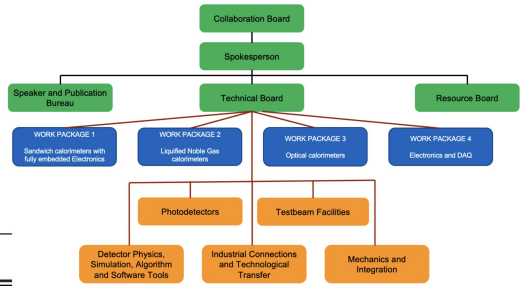
EoI for TileCal for ALLEGRO for FCC-ee

- Participated in the Expression of Interest for the ALLEGRO Full Detector Concept for FCC-ee and for its TileCal HCAL "A high granularity central hadronic calorimeter using scintillating tiles for the ALLEGRO detector concept", submitted in March 2025

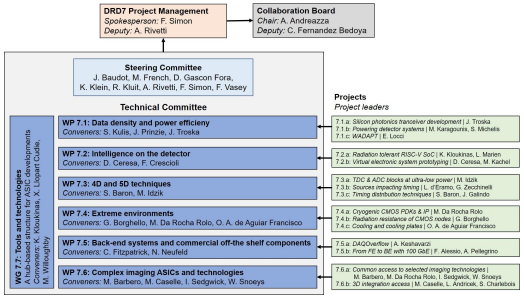
Sub-Detector	Institutes
Hadronic Calorimeter	ITIM Cluj Napoca (RO), LIP (PT), IFIC Valencia (ES), Bergen (NO), FZU (CZ), Charles Uni (CZ), Tbilisi (GE), CERN

- At that time, only planning to contribute to electronics also linked to our efforts to DRD7 (Electronics)
- Scope of our effort changed since September 2025 with a dedicated Prometeo project (CIPROM/2024/69)

drdcalo



DRD7 COLLABORATION



New FCC R&D calorimetry project ATENEA (IFIC-CIEMAT)

- **Advanced Data Processing Technologies for Exploring New Physics in Future Particle Colliders (ATENEA)**
  - Project funded with 600k € during 2025-2029 by Generalitat Valenciana under the Prometeo program for excellence research groups (**CIPROM/2024/69**)
- Researchers (physicist / engineer / full time in FCC):
  - **IFIC:** Arantxa Ruiz (PI), Ana Arranz, Iván Burriel, Fernando Carrió, David Hernández, Ximo Poveda, Alberto Valero, Juan Valls
  - **CIEMAT:** Cristina Fernández, Ignacio Redondo
- Context & Motivation:
  - Support **Future Circular Collider (FCC)** development.
  - Contribute to **ECFA Detector R&D Roadmap** in **DRD Calo** (Calorimetry) and **DRD7** (Electronics)
- **Main goals of the project:**

Physics case studies for FCC-ee & FCC-hh	**Develop advanced calorimeter components:** Multi-channel SiPMs / MPPCs, Radiation-hard readout/control electronics.	**Innovate DAQ systems** for massive data rates	**Real-time signal processing** with **NNs on FPGAs**	**Cross-disciplinary technology transfer** (electronics, computing, photodetectors)

New FCC R&D calorimetry project ATENEA (IFIC-CIEMAT)

Work plan organized in 6 WPs

Key activities / deliverables:

- Build test benches for SiPMs
- Design front-end & back-end electronics
- Implement high-speed optical links
- Develop FPGA-based AI algorithms
- Simulate detector performance & optimize designs
- Fabricate prototypes and validate in beam tests

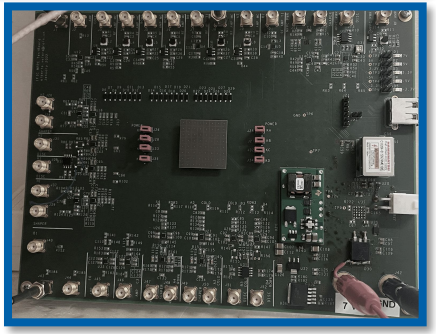
	2025		2026				2027				2028				2029		
Task	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3
Work Package 1 (WP1): Evaluation and Certification of Silicon Photomultipliers (SiPMs)																	
1. Identify commercially available and prototype SiPMs for evaluation.																	
2. Develop a PMT test bench for detailed performance analysis, including light yield, timing, and noise characteristics.																	
3. Test radiation tolerance and longevity under high-radiation environments.																	
4. Publish findings on SiPM performance for potential FCC applications.																	
Work Package 2 (WP2): Development of Readout and Control Electronics																	
1. Design front-end electronics for signal amplification, shaping and digitization.																	
2. Integrate control systems to manage device operation and calibration.																	
3. Prototype readout modules and validate their performance in a controlled laboratory environment.																	
4. Ensure compatibility with FCC detector system requirements.																	
Work Package 3 (WP3): Data Acquisition (DAQ) Systems Development																	
1. Design front-end DAQ components to digitize signals from SiPMs.																	
2. Develop high-speed optical links for data transfer.																	
3. Implement a modular back-end system for data processing and storage.																	
4. Test DAQ systems under simulated FCC data conditions.																	
Work Package 4 (WP4): Signal Processing and Reconstruction Algorithms																	
1. Develop neural network-based algorithms for real-time signal processing on FPGA platforms.																	
2. Optimize algorithms for noise filtering and particle flow reconstruction.																	
3. Benchmark the algorithm performance against traditional reconstruction methods.																	
4. Test and integrate algorithms with the DAQ system.																	
Work Package 5 (WP5): Feasibility Studies and Simulations																	
1. Develop simulation models for high-granularity calorimeter configurations in FCC-ee and FCC-hh environments.																	
2. Study energy resolution, efficiency, and particle flow reconstruction under different scenarios.																	
3. Analyze detector performance in terms of radiation hardness and long-term stability.																	
4. Provide optimization recommendations for detector designs based on simulation results.																	
Work Package 6 (WP6): Prototyping and Test Beam Campaigns																	
1. Fabricate 3,Äi5 prototype calorimeter modules based on DRD6 recommendations.																	
2. Integrate SiPMs, electronics, and DAQ systems into prototypes.																	
3. Conduct test beam campaigns at CERN SPS or similar facilities to validate performance.																	
4. Analyze results to refine detector design and implementation strategies.																	

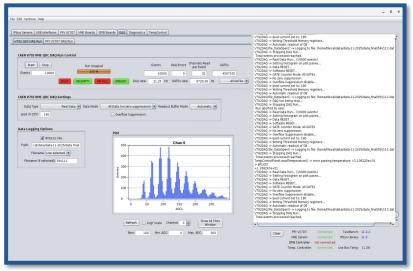
Responsibilities in the last 10 years (CIPROM/2024/69)

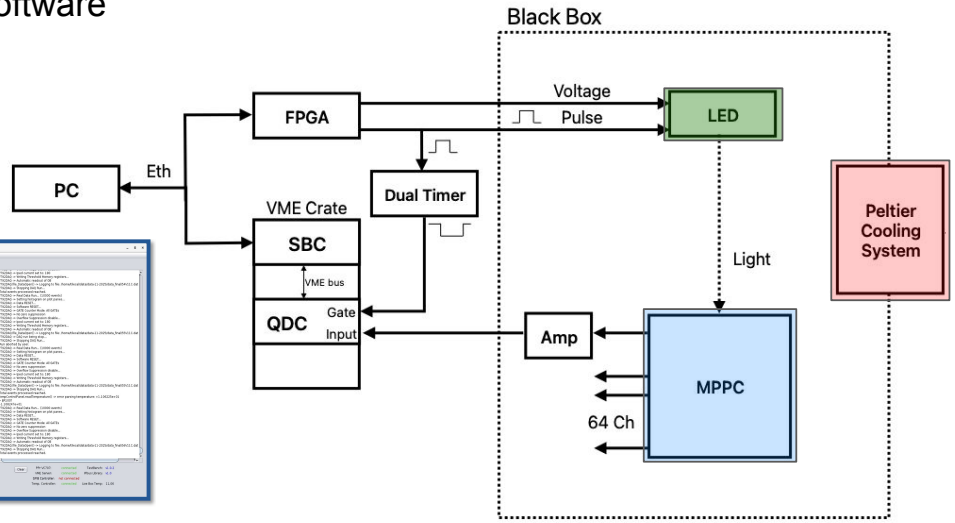
- A. Ruiz:
  - CERN Next Generation Trigger Project Task 2.7 leader, 2025-
  - LHC Higgs Working Group 4 (di-Higgs and multi-Higgs) Convener, 2024-
  - ATLAS Executive Board member, 2021-2022
  - ATLAS Trigger Coordinator, 2021-2022
  - ATLAS Deputy Trigger Coordinator, 2020-2021
  - ATLAS TDAQ Institute Representative, 2020-
  - ATLAS TDAQ Speakers Committee member, 2020-2021
  - ATLAS Trigger Menu and Signature Performance Coordinator, 2018-2019
  - ATLAS Trigger E/gamma Signature Coordinator, 2016-2017
- C. F. Bedoya:
  - CMS Link Person to the Funding Agency, 2025-
  - DRD7 (Detector R&D – Electronics) deputy IB chair, 2024-2026
  - Spanish DRD1 CNID convenor, 2024-2026
  - Editor of Frontiers in Detector Science and Technology, 2024-
  - Member of TWEPP Scientific Committee, 2023-
  - CMS L1 Trigger Resource Manager, 2021-
  - CMS Muon-DT Upgrade Coordinator, 2019-
  - CMS Muon-DT Project Manager, 2015-2019
  - Chair of the CMS DT Institutional Committee (DTIC), 2015-2018
  - CMS Drift Tubes Deputy Project Manager, 2012-2015
- J. Poveda:
  - ATLAS Publication Committee member, 2023-2025
  - ATLAS E/gamma Convener, 2020-2022
  - ATLAS Higgs Top Convener, 2018-2019
  - ATLAS Isolation and Fake Forum Convener, 2016-2017
- I. Redondo:
  - CMS L1 Trigger Upgrade Technical Coordinator, 2025-
  - Spanish delegate to the Advisory Committee of CERN Users (ACCU), 2022-
  - CMS Muon-DT Project Manager, 2019-2021
  - CMS Muon Technical Coordinator, 2018
  - CMS deputy Muon-DT Upgrade Manager, 2017
  - CMS LUMI POG Convenor, 2015
  - CMS Muon-DT Technical Coordinator, 2014-2018
- F. Carrió:
  - Special Issue Editor at the MDPI Electronics journal, 2024-
  - ATLAS Tile Calorimeter Phase-II Upgrade Deputy Project Leader, 2022-
  - ATLAS TileCal Electronics Upgrade Coordinator, 2019-
- A. Valero:
  - DRD6 (Detector R&D – Calorimetry) Speakers and Publications Bureau, 2024-
  - Speciality Chief Editor at Frontiers in Detector Science and Technology, 2023-
  - ATLAS TileCal Upgrade Deputy Project Leader, 2018-2019
  - ATLAS TileCal Upgrade Coordinator, 2016-2018

Setup at IFIC TileCal Lab

- **Black box** + Peltier for temperature control
- Multi-Pixel Photon Counter (MPPC) coupled to an interface board
- Light source: LED (470 nm wavelength)
- 32-channel QDC for signal read-out
- Modules for trigger and DAQ
- Custom DAQ software





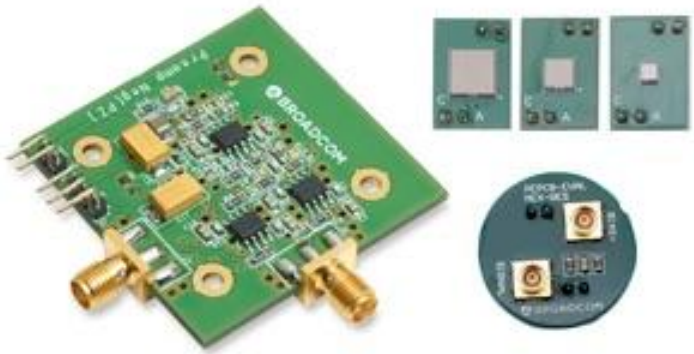


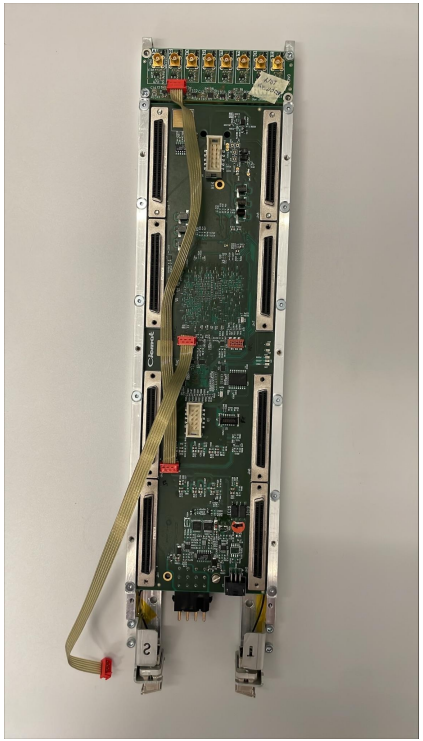
Setup at IFIC TileCal Lab

- Setup update replacing LED source with Laser Thorlabs NPL45C + Integrating sphere → Fully characterize several MPPC models
- Started some tests with radioactive sources
- Acquiring scintillator samples with high and rapid light response
- SiPMs (Broadcomm sensor 1x1, 3x3, 6x6 mm^2 and OnSemi)
- Evaluating the CIEMAT OBDT-theta board [Front. Detect. Sci. Technol. 3 (2025) 1517241] and a CAEN RADIOROC for the readout

Laser Thorlabs

Broadcomm sensors

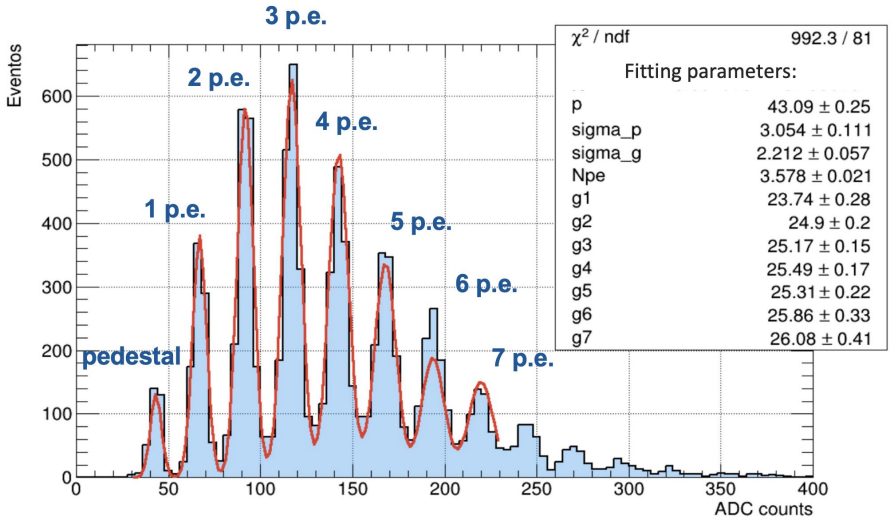


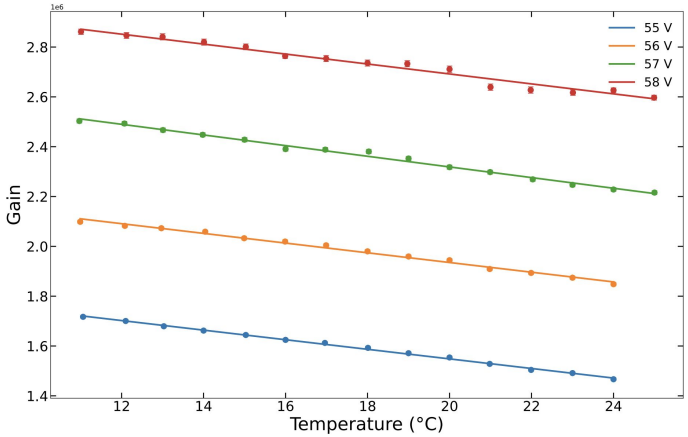


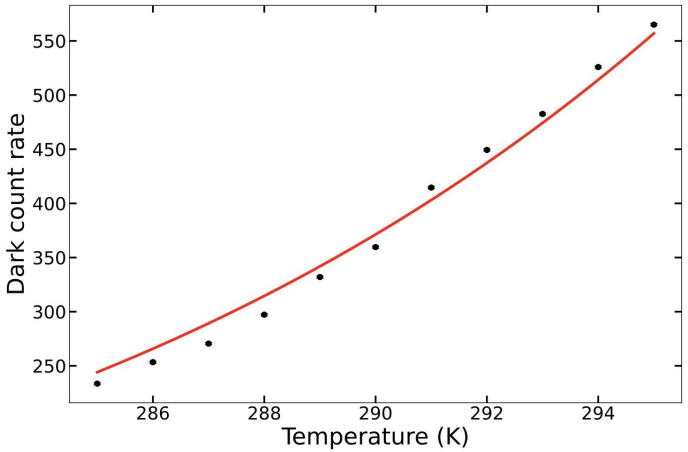
OBDT-theta

Characterization of MPPCs

- Discerning single photoelectrons → Pulse height spectra fitted to a **sum of Gaussians convoluted with Poissonians**
- **Mean gain versus temperature:** linear decrease and good agreement with Hamamatsu specifications
- Also measured **dark count rate** (pulses from thermally generated carriers in absence of photons)

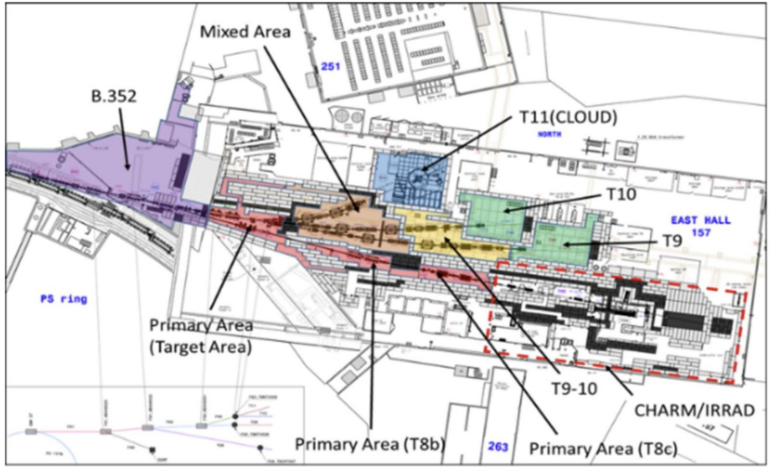


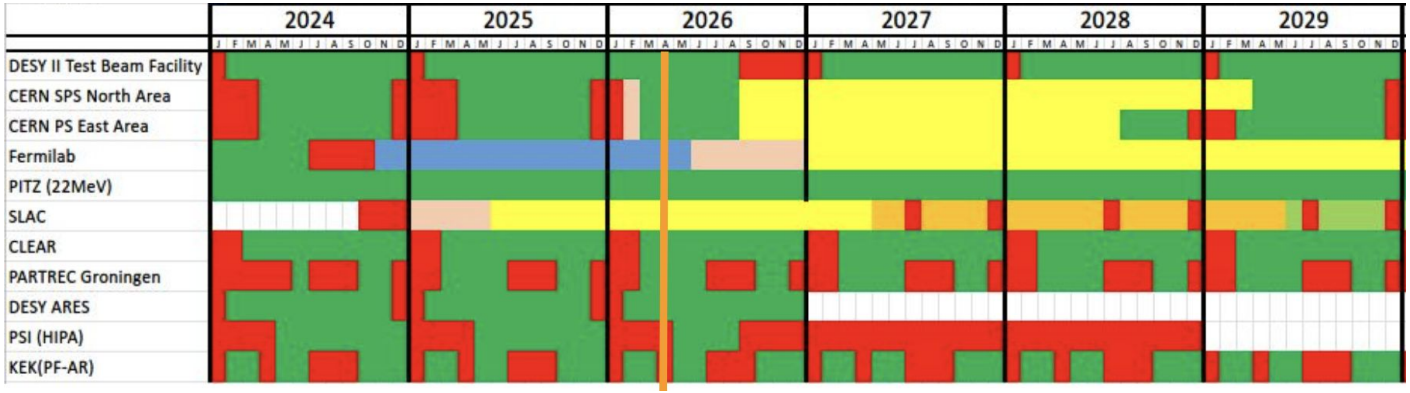




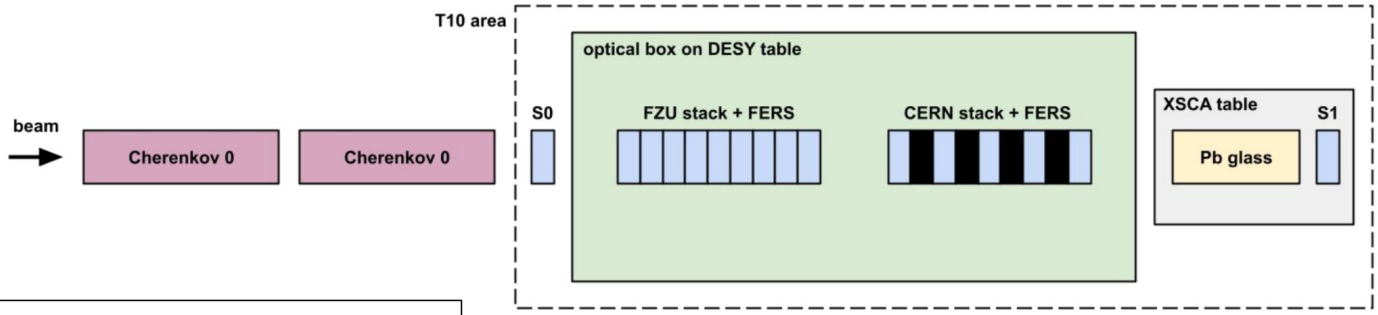
2026 ALLEGRO TileCal beam test

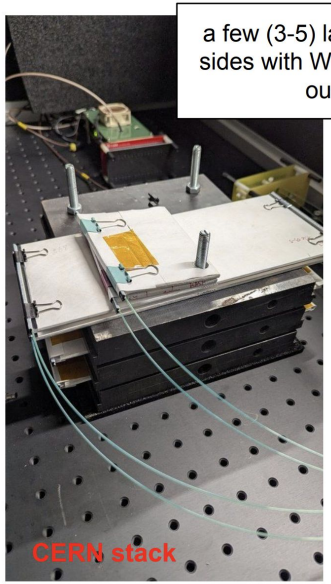
- Beam time allocated for 6-13 May 2026:
  Ana Arranz and Ivan Burriel participating from IFIC
- **Key step for construction of full scale prototypes (~2028)**
- East Hall T10 beam area, in building 157 (Meyrin site)
  - Beams from the PS: up to ~11.5 GeV
- PS and SPS in Long Shutdown soon → CERN will not be available for beam tests in the next 2-3 years
  - Alternatives: DESY, KEK, SLAC?



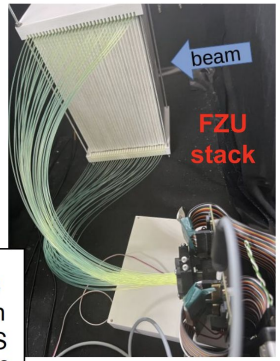


2026 ALLEGRO TileCal beam test setup





a few (3-5) layers of tiles read out by 1 or 2 sides with WLS fibres + steel plates ⇒ read out by individual SiPMs



stack of 32 tiles read out on both sides ⇒ 64 WLS fibres ⇒ on a 8*8 SiPM array

- Will test two different stacks of scintillating tiles (with and without steel plates)
  - Tiles coupled to WLS fibers and SiPMs
  - DAQ: commercial FERS boards and JANUS software by CAEN
- Beam test goals:
  - Test optical instrumentation (coupling tile - fiber - SiPM) and detector read-out
- **Results from the beam test will be published in a paper**

Conclusions

- The IFIC TileCal group is already part of the ALLEGRO community
- Also involved in DRD Calo (WP 3) and DRD7 (WP 7.5) collaborations
- Will have stronger contribution in coming years thanks to the ATENEA project (CIPROM/2024/69, Sep 2025 - Aug 2029) funded by Generalitat Valenciana in collaboration with CIEMAT
    - Develop new readout technologies for FCC, with the goal of building a calorimeter prototype
    - Personpower specifically devoted to FCC studies

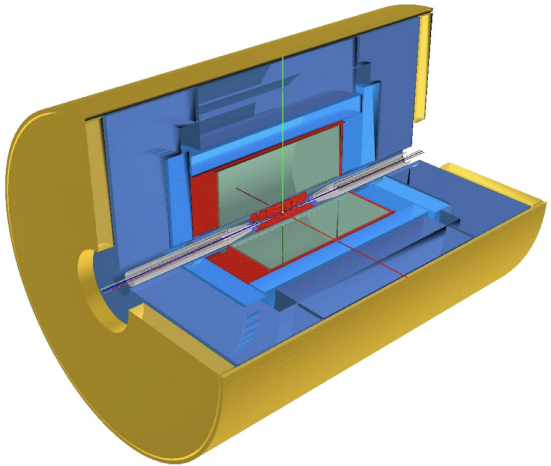
BACKUP

ALLEGRO detector concept

A Lepton-**L**epton collider **E**xperiment with **G**ranular **R**ead-**O**ut: https://allegro.web.cern.ch

General-purpose detector for FCC:

- **2015:** Noble-liquid EM calorimeter for future experiments, part of the FCC-hh reference detector
- **2019:** CDR and input for ESPPU2020
- **2021:** Focus shifted to FCC-ee: noble-liquid ECAL concept adapted to lepton collider experiment
- **2022:** Detector concept proposed based on noble-liquid ECAL, reasonable choices for other sub-detectors
- **2023:** More groups joined, detector name and logo chosen, website created
- **2025:** EoI for ESPPU2025



Next steps:

- R&D on subdetectors
- TDR expected in the coming 5 years

ALLEGRO

ATLAS TileCal geometry

- 64 modules in φ
- 11 radial rows of Tile
- 3 radial readout layers
  (3-6-2 in LB and 3-4-4 in EB)