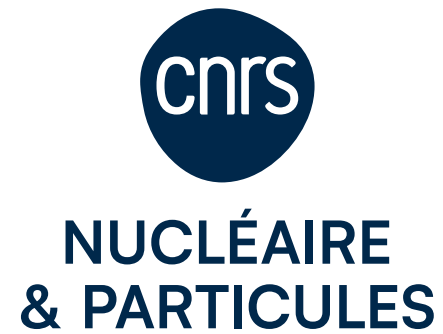


DRD Calo

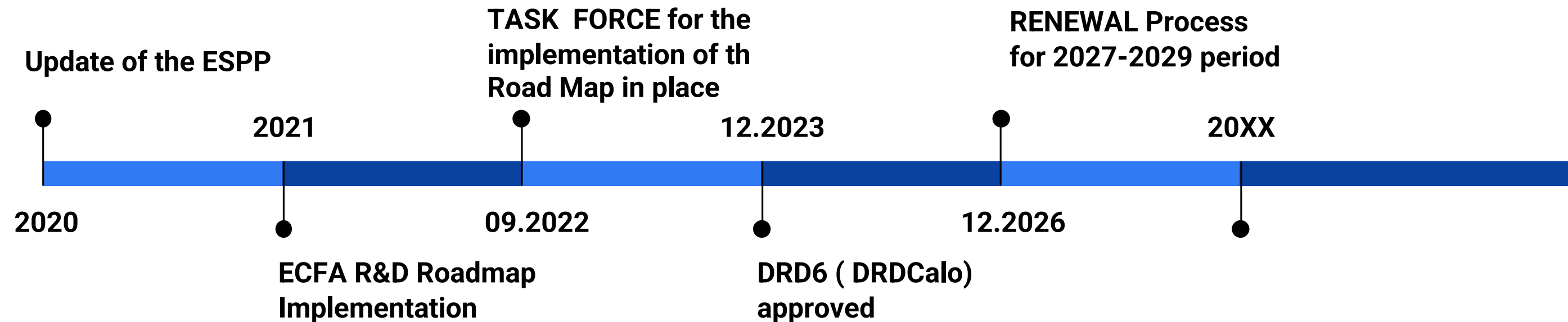
Status and Plans

Roman Pöschl
On behalf of the DRD Calo Collaboration



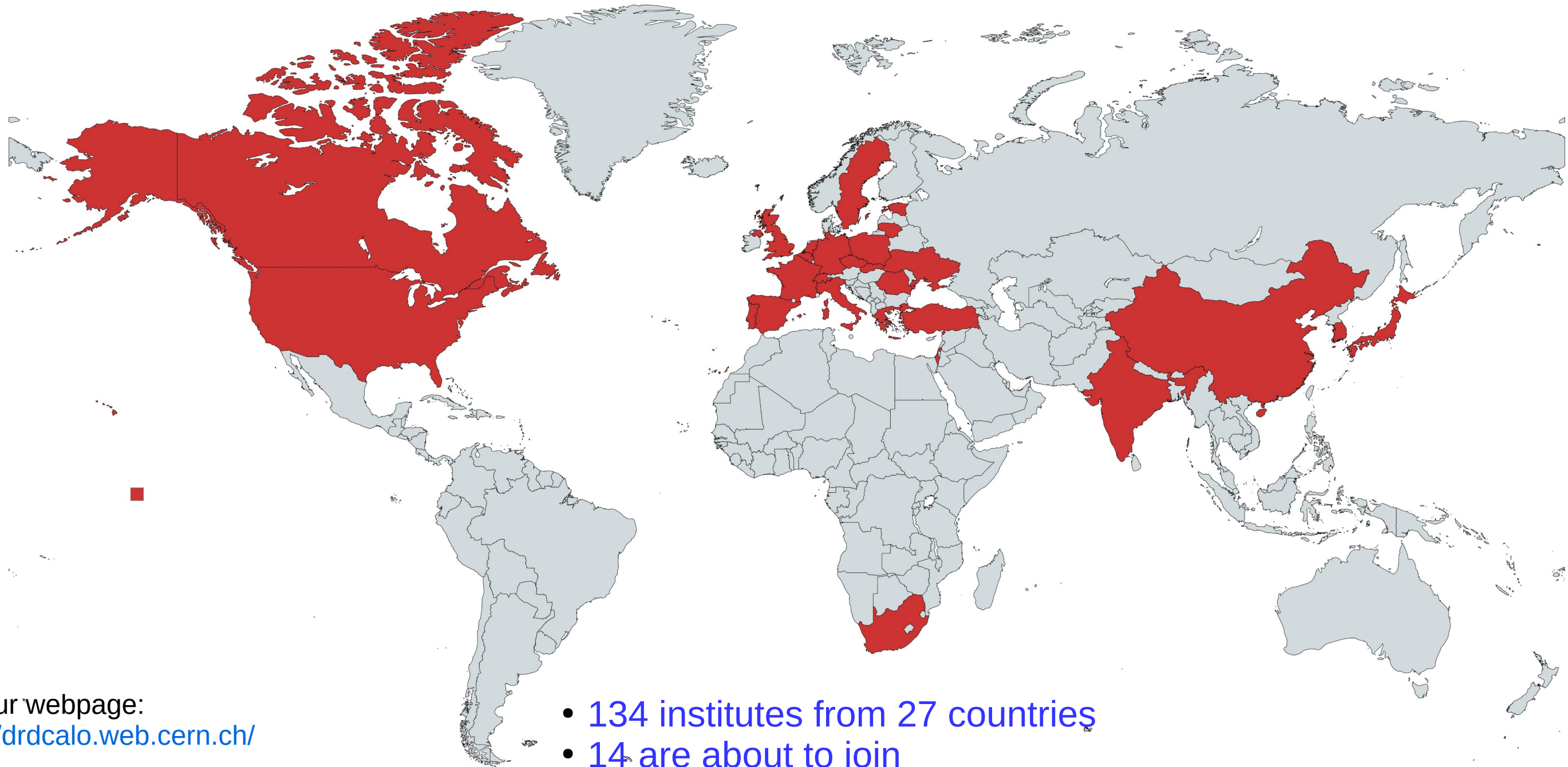
CPAD Meeting – October 2026 Seattle/WA US

R&D collaboration hosted by CERN as implementation of the ECFA R&D roadmap [1], following the 2020 Update of the European Strategy for Particle Physics



- Overview on DRDs by Thomas Bergauer on Wednesday

[1]CERN-ESU-017 <https://cds.cern.ch/record/2784893>



Visit our webpage:
<https://drdcalo.web.cern.ch/>

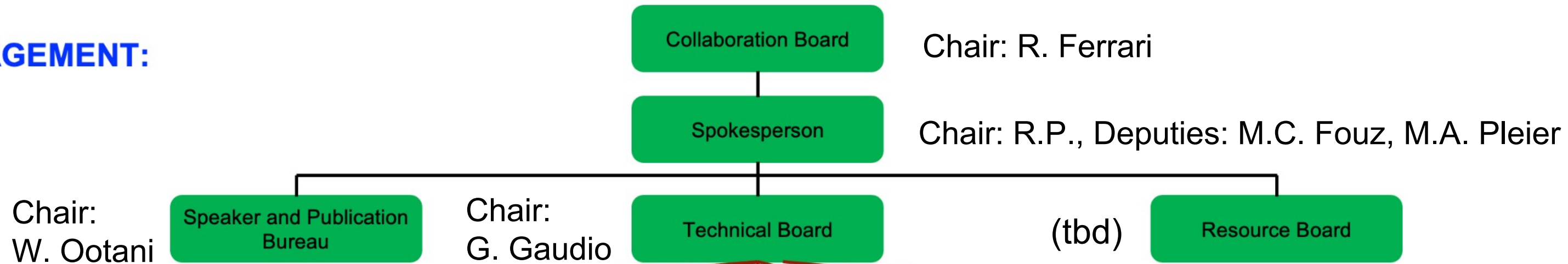
- 134 institutes from 27 countries
- 14 are about to join

Created with mapchart.net



- 28 US institutes currently member
 - 5 further will join soon
 - US is largest single country in DRD Calo
- **Marc-Andre Pleier (BNL)**
 - Deputy Spokesperson
- **Carlos Eugenio Perez Lara (Hofstra)**
 - Work Package Co-Coordinator
- **Grace Cummings (FNAL)**
 - Contact for FNAL and SLAC Testbeams
- **US DRD Calo Meeting during CALOR26**
 - To be repeated !?

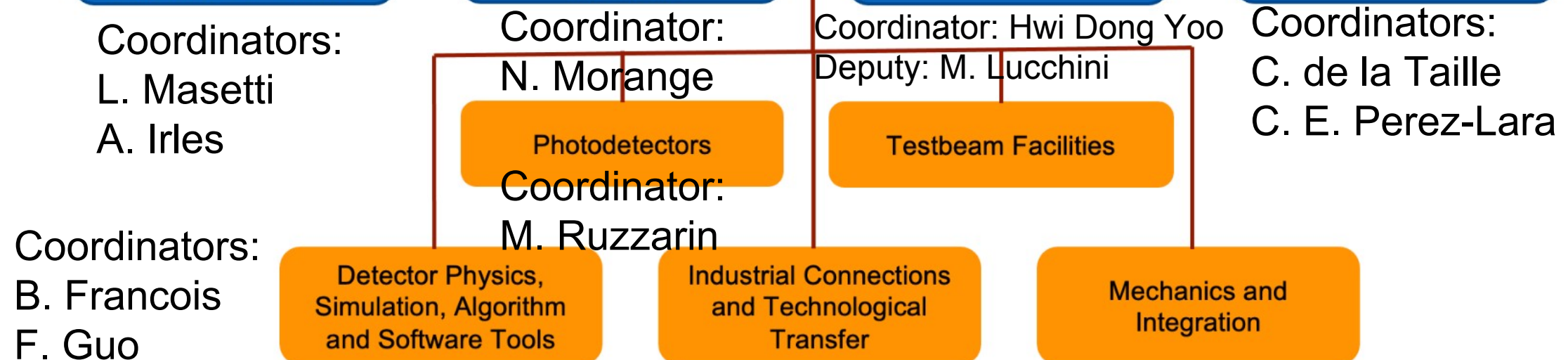
MANAGEMENT:



WORK PACKAGES:



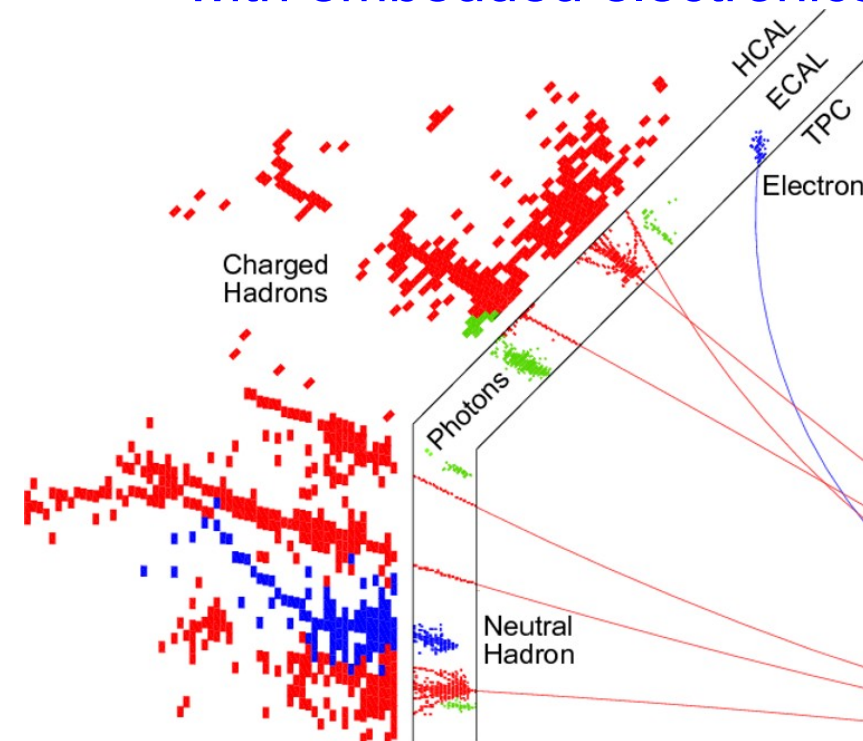
WORKING GROUPS:



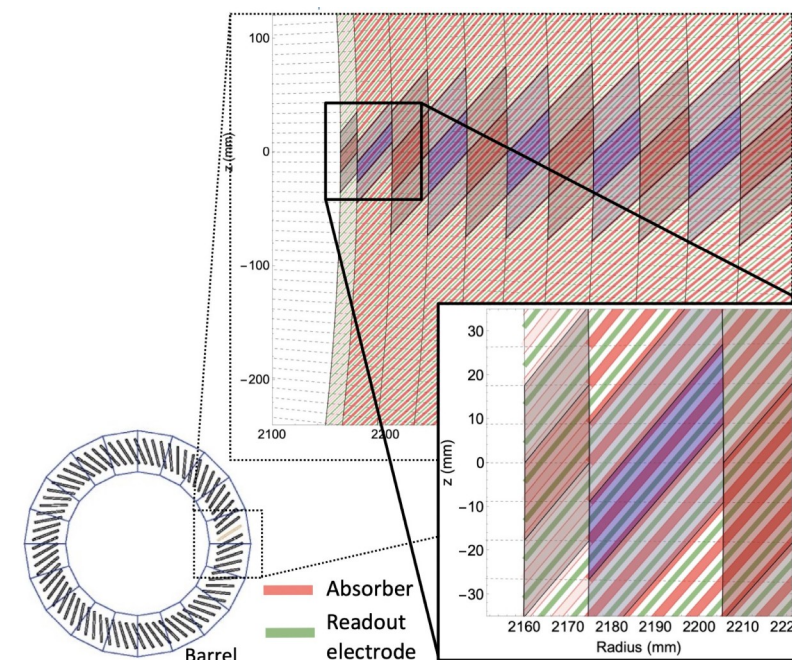
- Subject to change -> See later

- Scientific programme organised around four Work Packages
 - Subdivided in tasks and subtasks
 - Subtasks loaded with milestones and deliverables

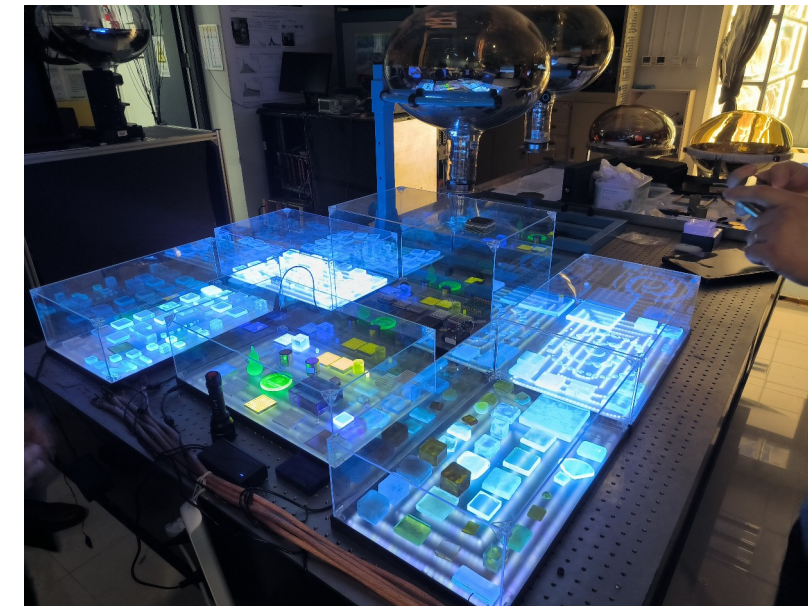
Sandwich calorimeters with embedded electronics



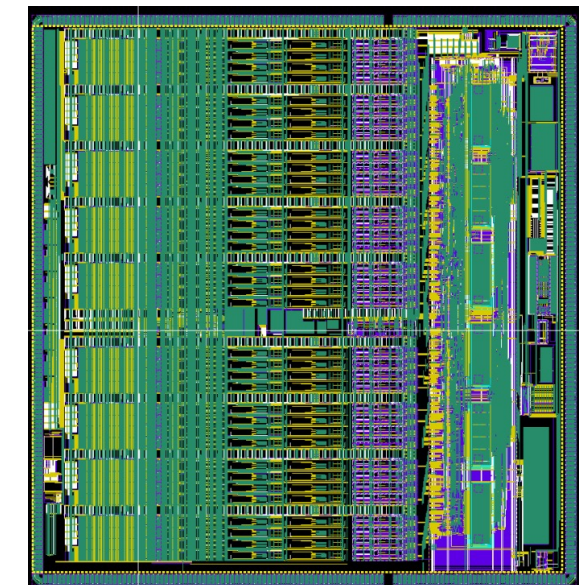
Liquid Noble Gas Calorimeters



Optical Calorimeters

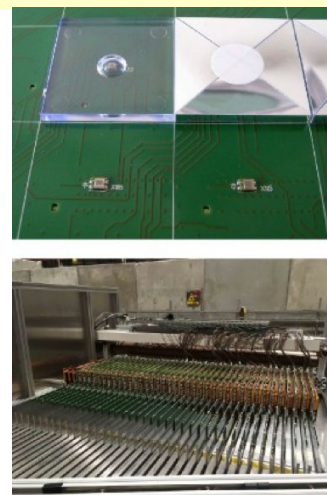


Electronics and DAQ

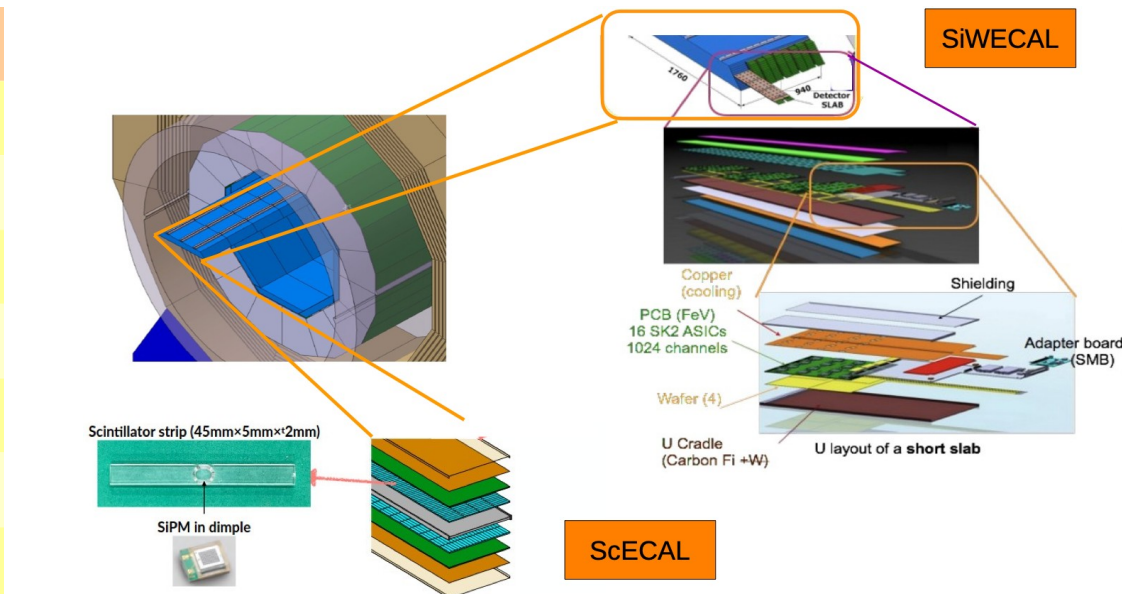
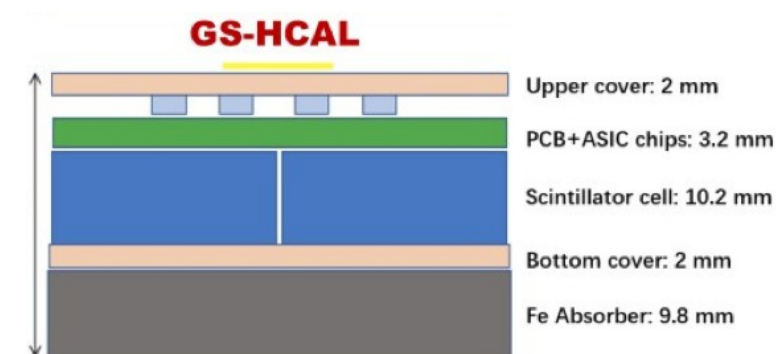


- Coherence ensured by five Working Groups
- Overview on achievements in 2024-2026 backup
- A few highlights with focus on US activities in the following

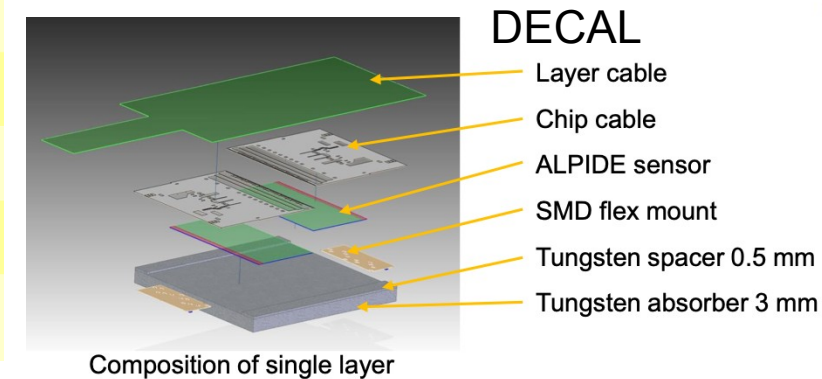
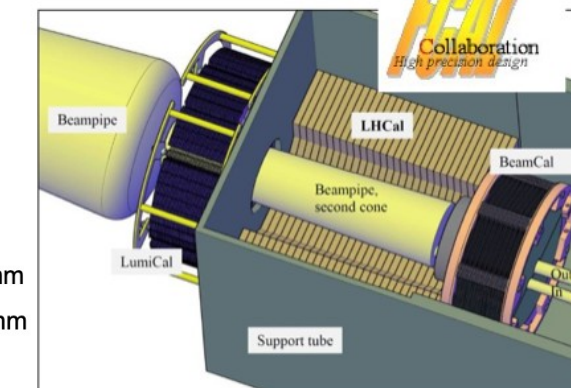
Task/Subtask	Sensitive Material/ Absorber
Task 1.1: Highly pixelised electromagnetic section	
Subtask 1.1.1: SiW-ECAL	Silicon/ Tungsten
Subtask 1.1.2: Highly compact calo	Solid state (Si or GaAs)/Tungsten
Subtask 1.1.3: DECAL	CMOS MAPS/Tungsten
Subtask 1.1.4: Sc-Ecal	Scintillating plastic strips/Tungsten
Task 1.2: Hadronic section with optical tiles	
Subtask 1.2.1: AHCAL	Scintillating plastic tiles/Steel
Subtask 1.2.2: ScintGlassHCAL	Heavy glass tiles/Steel
Task 1.3: Hadronic section with gaseous readout	
Subtask 1.3.1: T-SDHCAL	Resistive Plate Chambers/Steel
Subtask 1.3.2: MPGD-HCAL	Multipattern Gas Detectors/Steel
Subtask 1.3.3: ADRIANO3	Resistive Plate Chambers+Scintillating plastic tiles/ Heavy Glass



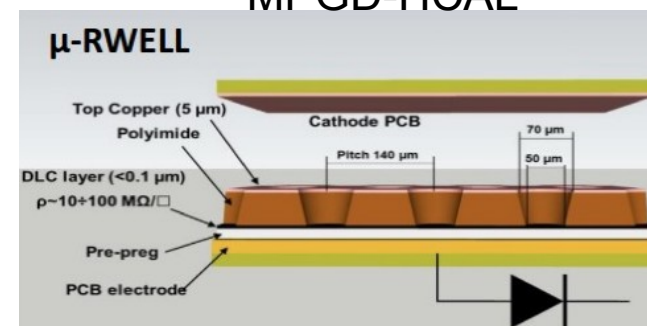
AHCAL



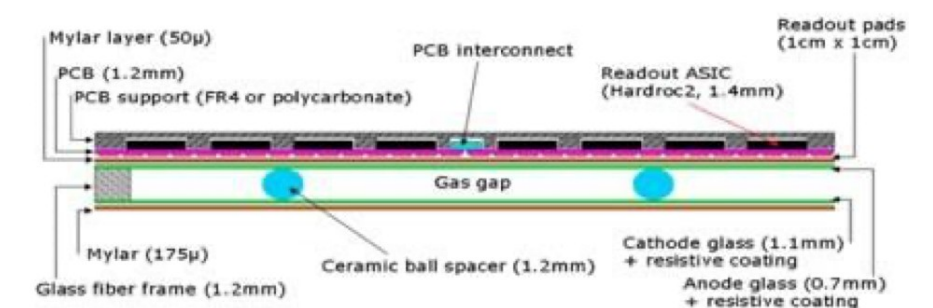
Highly
Compact
Calo



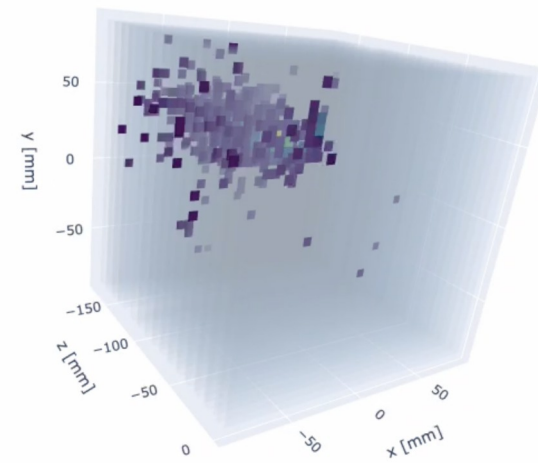
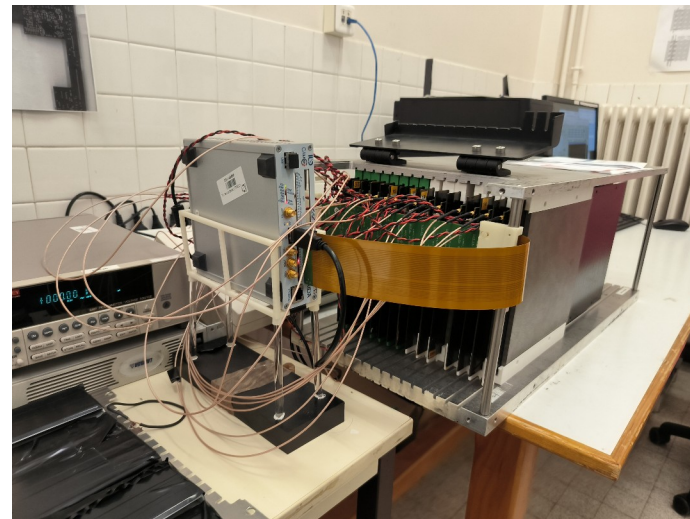
MPGD-HCAL



SDHCAL



SiW ECAL



- 15 layers, 21 X_0 , 15360 cells
- Seamless operation over one week

Compact Calo



250 M

events, about 1 kHz

1–5.6 GeV

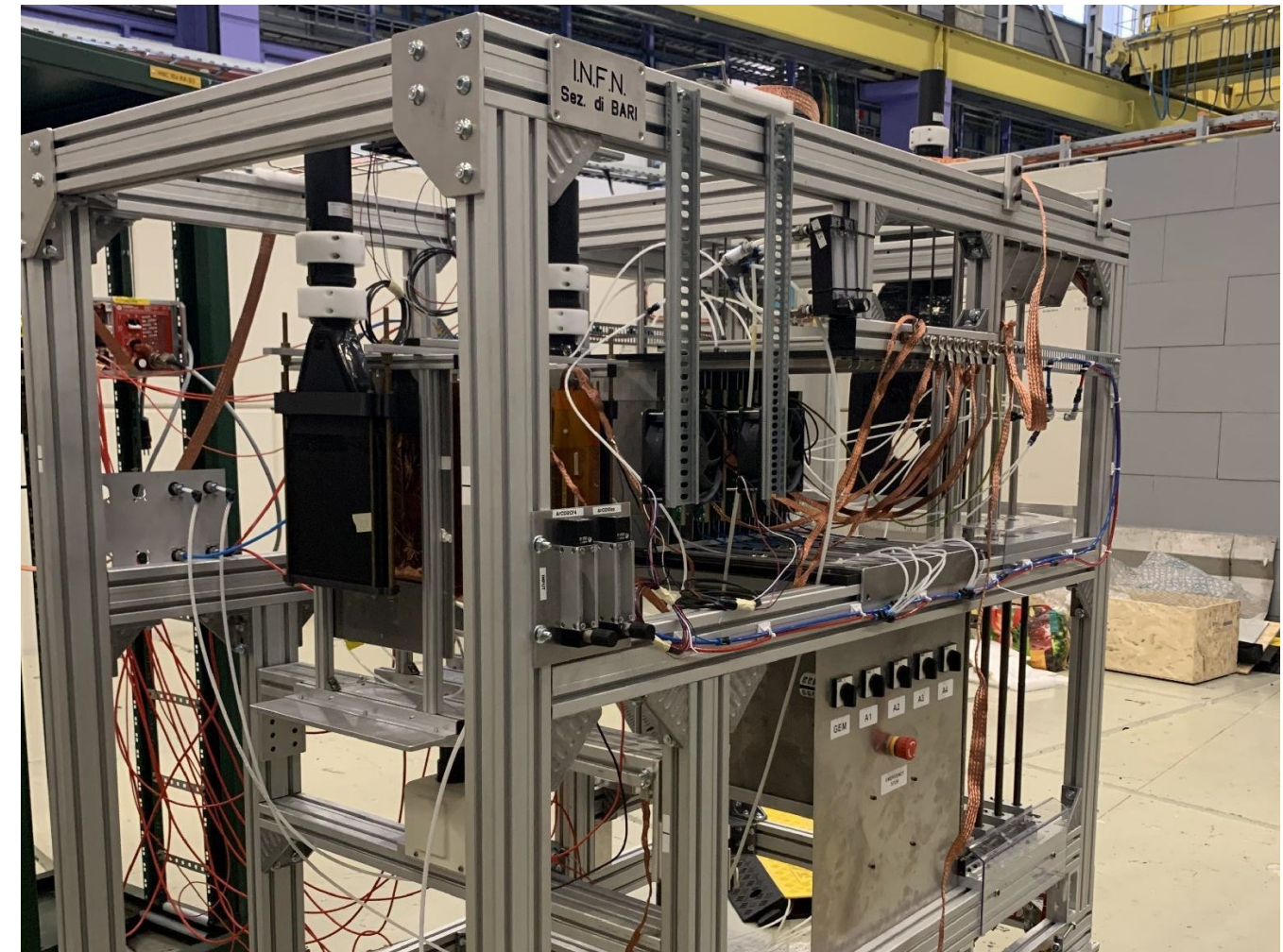
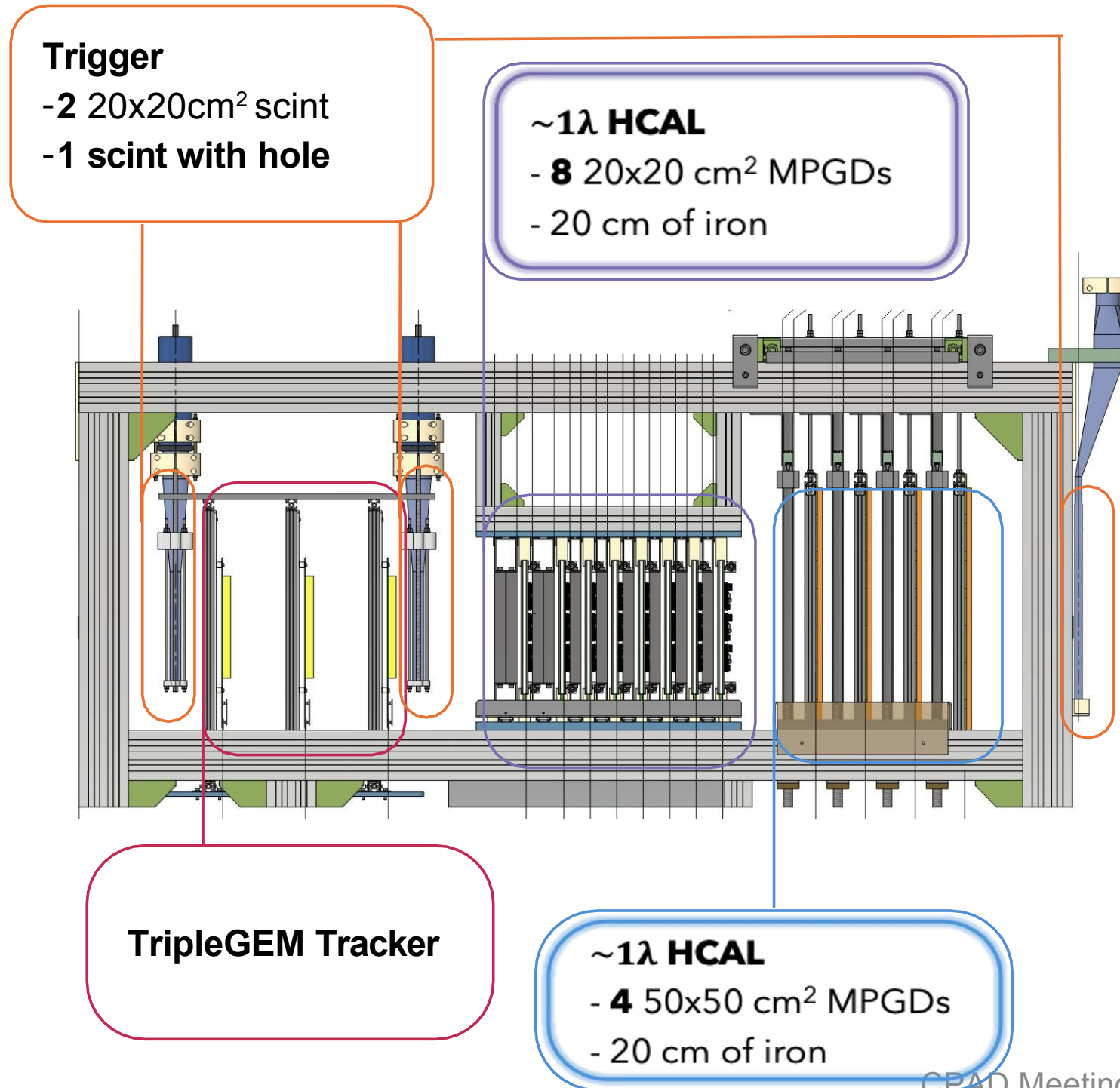
electron beam at DESY

11 layers

Si-W, extra W in front, 6
ALPIDE telescope planes

1.2 Gbps

after FPGA data reduction at 1
kHz; stable to 2 kHz



- **Active layers** made of **Micromegas** or **μRWell**
- **Pad size** of ~ **1x1cm²** → **~11300 channels**
- **Electronics:**
 - **APVs-based** for the **first tests** → used for the small prototype with 8 20x20 cm² active layers
 - Slowly **moving** to **VMM3a electronics**

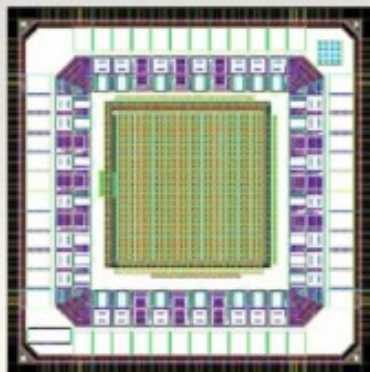


MAPS offer excellent performance for future collider tracking and calorimetry



Tracking sets the primary requirements for MAPS in future colliders:

- **7 μm resolution, $< \text{ns}$ timing, 1/4 mip threshold;**
- **Power consumption** ($< 10 \text{ mW/cm}^2$) compatible with large area and low material;
- **Fault-tolerant circuit strategies for wafer-scale MAPS;**
- **Stitching** for $\sim 75 \text{ m}^2$ tracking system.



NAPA-p1
 & now NAPA-p2
 demonstrating
 performance.
 talk by Jim today

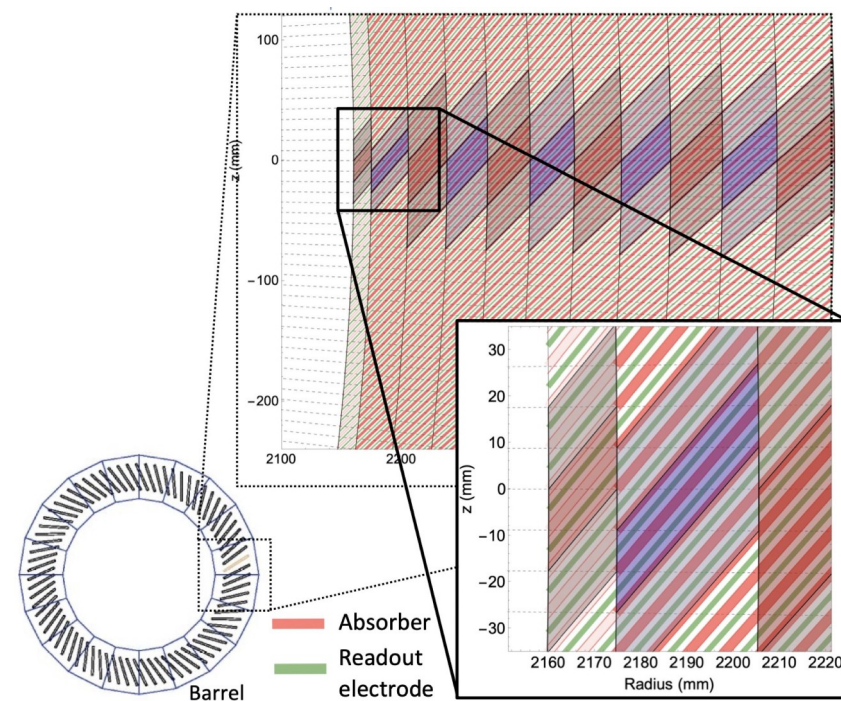
Calorimetry benefits from achieving these tracking motivated detector development goals:

- **Stitching** for $\sim 1200 \text{ m}^2$ calorimeter system;
- **mm scale separation** of shower constituents;
- **Detailed jet reconstruction**, aiding and improving particle flow reconstruction;
- **Energy resolution** performance exceeding energy resolution requirement for electroweak and Higgs physics.

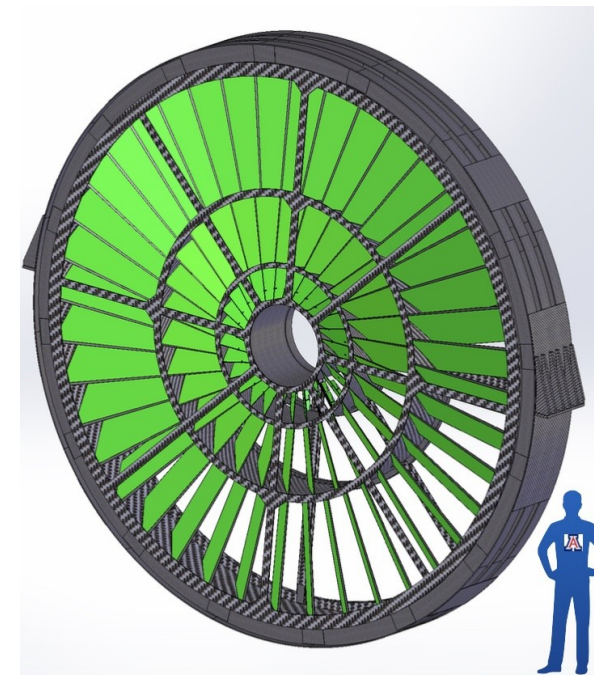
Particle flow calorimetry builds on
high precision tracking
 with **high granularity calorimetry**
 to distinguish the source of energy depositions.

- **DRDCalo WP1 technologies mostly being adapted for FCC-ee**
 - Calorimeters optimised for particle flow reconstruction originally developed in other context
 - Adapting demonstrated concepts to the FCC-ee environment
- **Examples of common tasks:**
 - Addition of active cooling
 - Readout to cope with continuous data taking
 - Addition of timing capabilities for better particle separation
 - Layout optimisation within specific detector concept

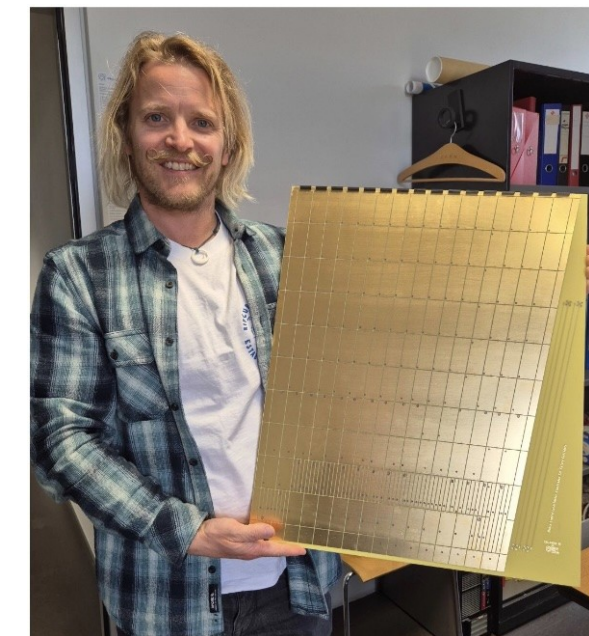
- Focused on R&D on noble-liquid calorimetry
- Main target on foreseeable future: sampling EM calorimeter for e+e- factories - one of key features of “ALLEGRO” detector concept for FCC-ee (<https://allegro.web.cern.ch/>)
 - highly granular calorimeter with absorber planes inclined in r-phi (barrel) / arranged in turbine-like structure (endcap)
 - Read out by segmented PCB planes alternated with Pb (or W) absorbers, gaps in-between filled with LAr (or LKr)



barrel

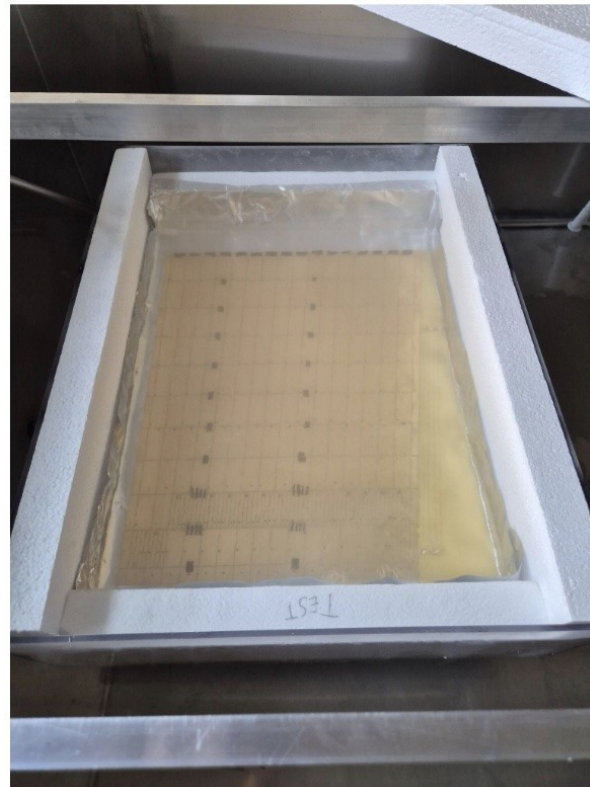


endcap

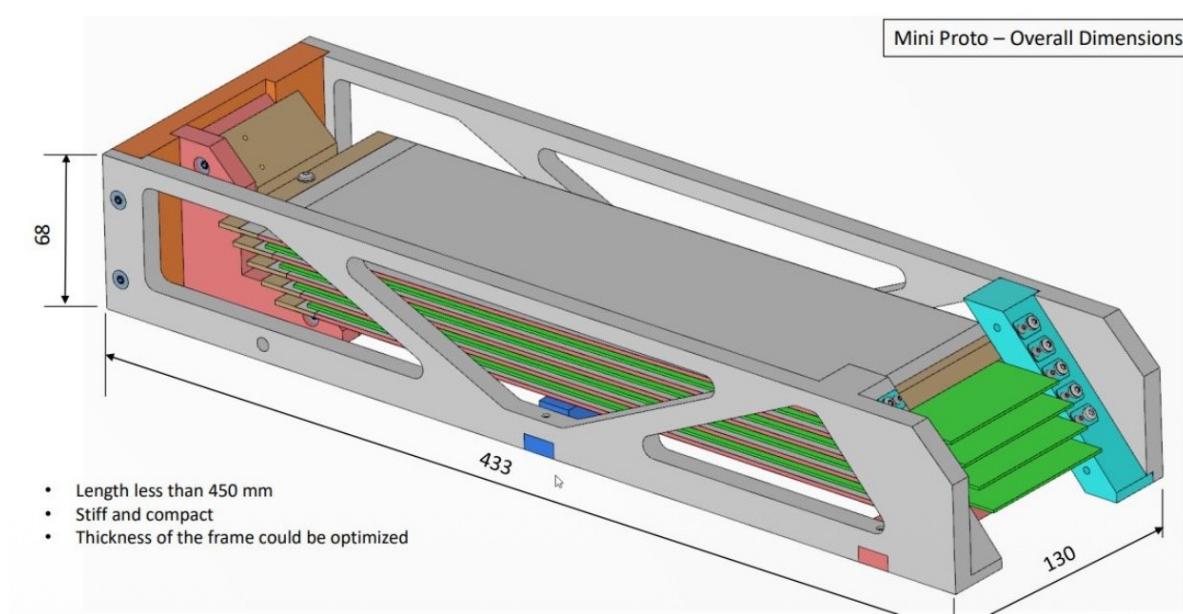


PCB (readout)
Current main focus of
hardware development

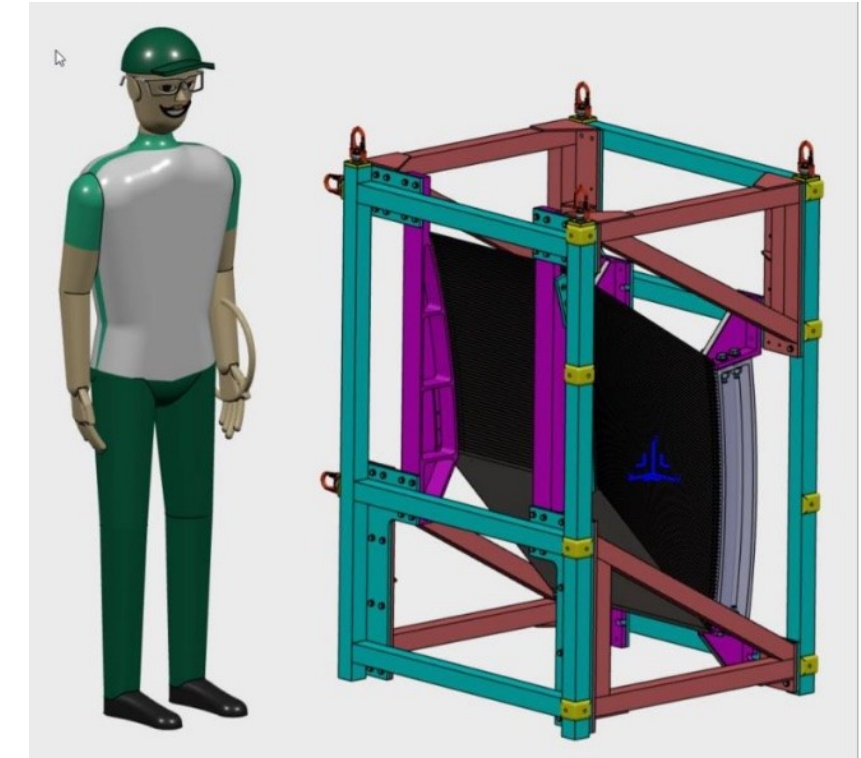
Main challenge – Cold electronics



Next step – Mini prototype



R&D Goal – Prototype module

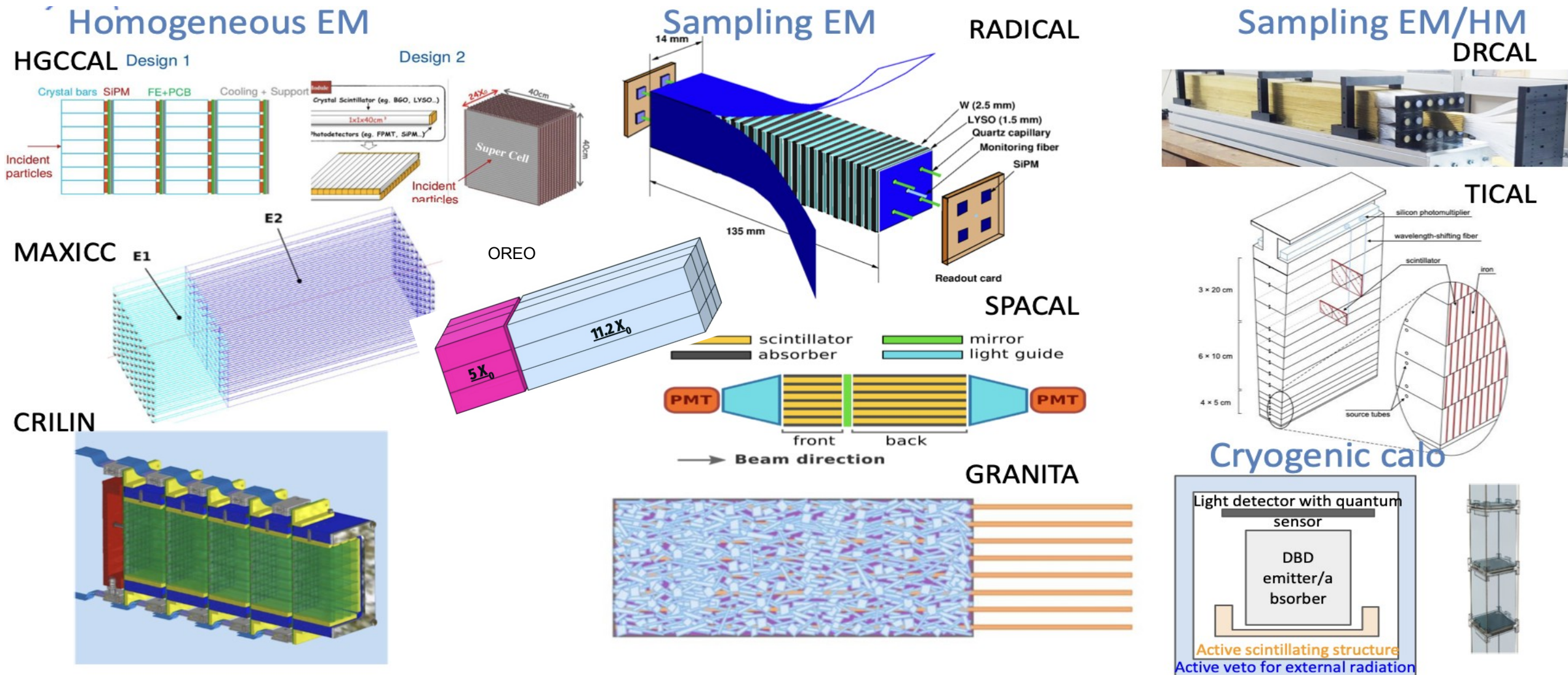


- Would reduce dramatically impact of capacitive noise
- Would facilitate detector design
 - e.g. less feedthroughs
 - No complex active cooling system
- ... but requires very low power electronics
 - ... to prevent liquid noble gas from boiling

- 2027 - 2028
- 4-5 layers
- Study of detector integration
- First testbeam experience with new electrodes (e.g. DESY)

- For reopening of CERN testbeams
- 65 layers (5000 cells)
- -> full elm. shower containment
- Realistic mechanical structures

- Involvement of **~70 institutes** working on **12 different projects**
- **The goal:** explore, optimise and demonstrate with full shower-containment prototypes, new concepts of **sampling and homogeneous calorimeters** based on **scintillating materials**
- Various target projects (FCC-ee, CEPC, Muon Collider and Neutrino experiments [Long Baseline, low energy])



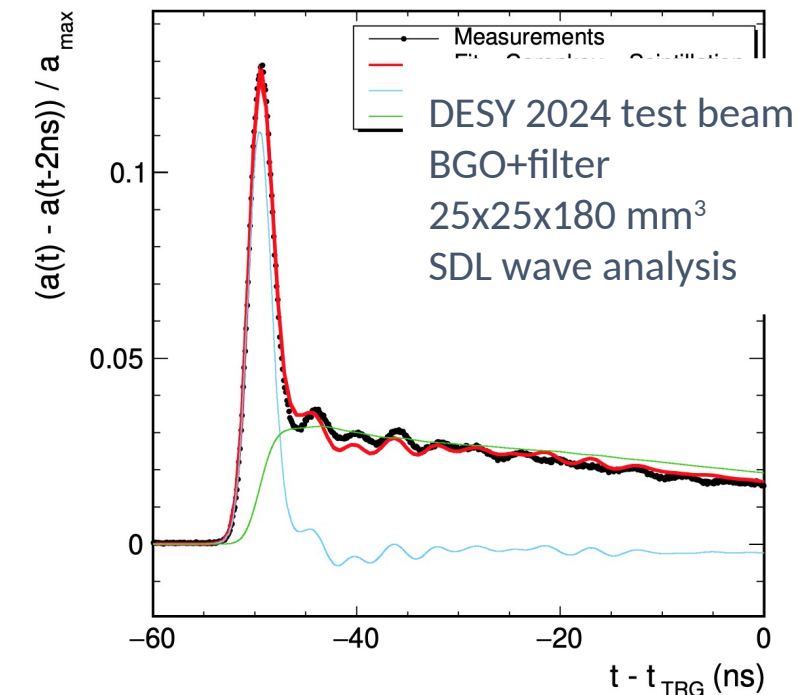


in MAXICC Subtask

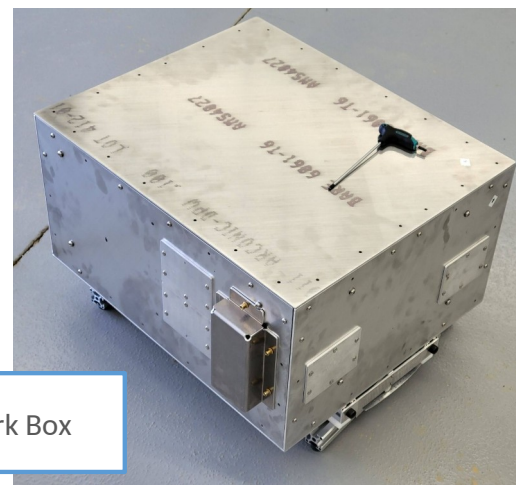
Further details in talk by Bob

Complementary tests of homogeneous segmented crystal calorimeter for [ID](#)
[EA detector concept](#) for FCCee:

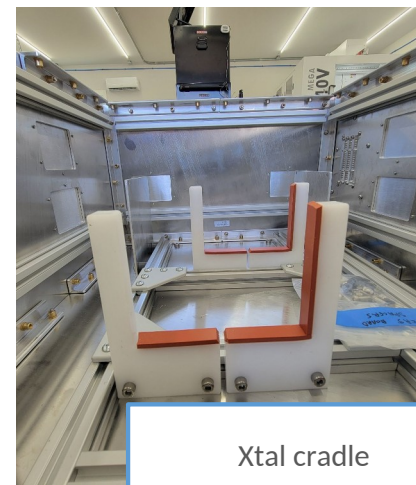
- **REAR Matrix:** BGO Crystal ($22 \times 22 \times 160 \text{ mm}^3$) with U330 notch filter to enhance S/C separation in waveform analysis. Four $6 \times 6 \text{ mm}^2$ Broadcom SiPMs (40 μm) + readout with CAEN DRS
- **Front Matrix:** options modified due to export delays affecting BGO sources (adjusting short term plans)
 - + implement a PWO front matrix ($10 \times 10 \times 50 \text{ mm}^3$ shipping now)
 - + alternate front matrix using larger granularity salvaged BGO
 - + $3 \times 3 \text{ mm}^2$ (10 μm) Hamamatsu SiPMs, FERS R.O.
 - + full, higher granularity BGO matrix in ~2027



S/C signal decomposition in BGO for 2 GeV e^- . Observed $N_{\check{C}} \sim 160$ PE/GeV w/ 4 SiPM R.O.



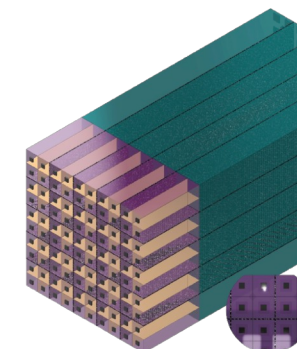
Dark Box



Xtal cradle

CERN/DESY Test beams in Aug/Sept

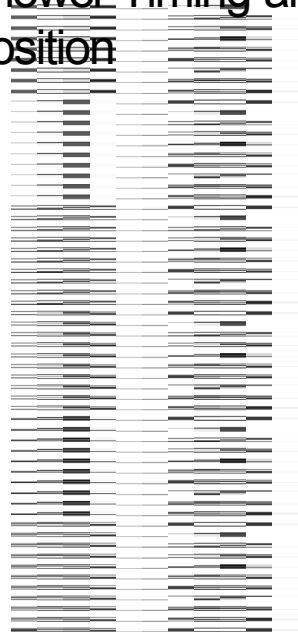
- + Enhance studies of C/S measurement (e/hadrons)
- + Energy resolution w/ EM shower containment



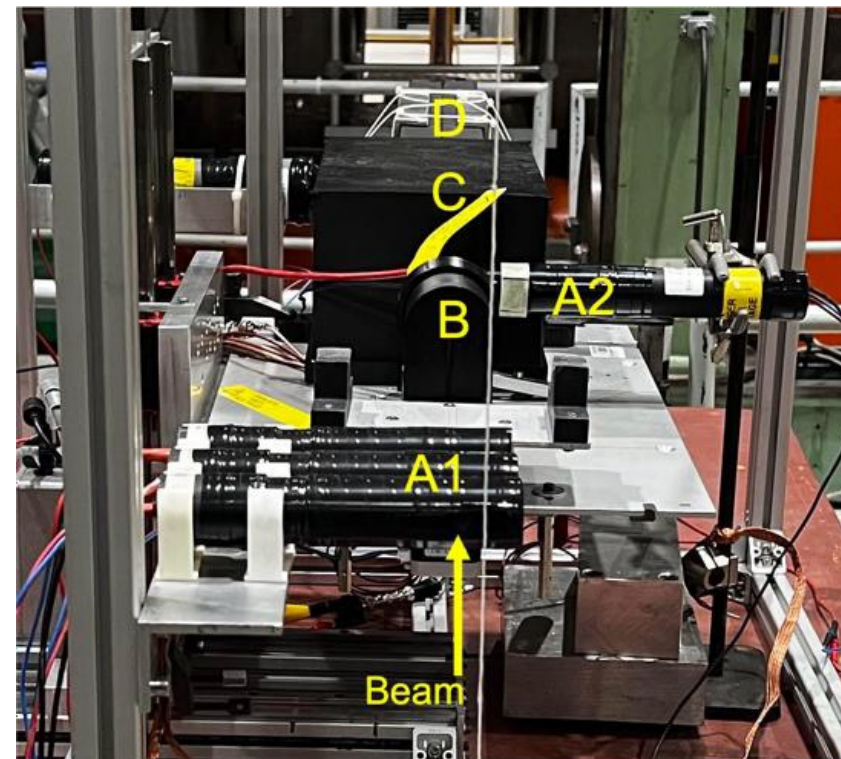
Rear BGO crystals, matrix configuration, new optimized electronics

RADICAL Principle

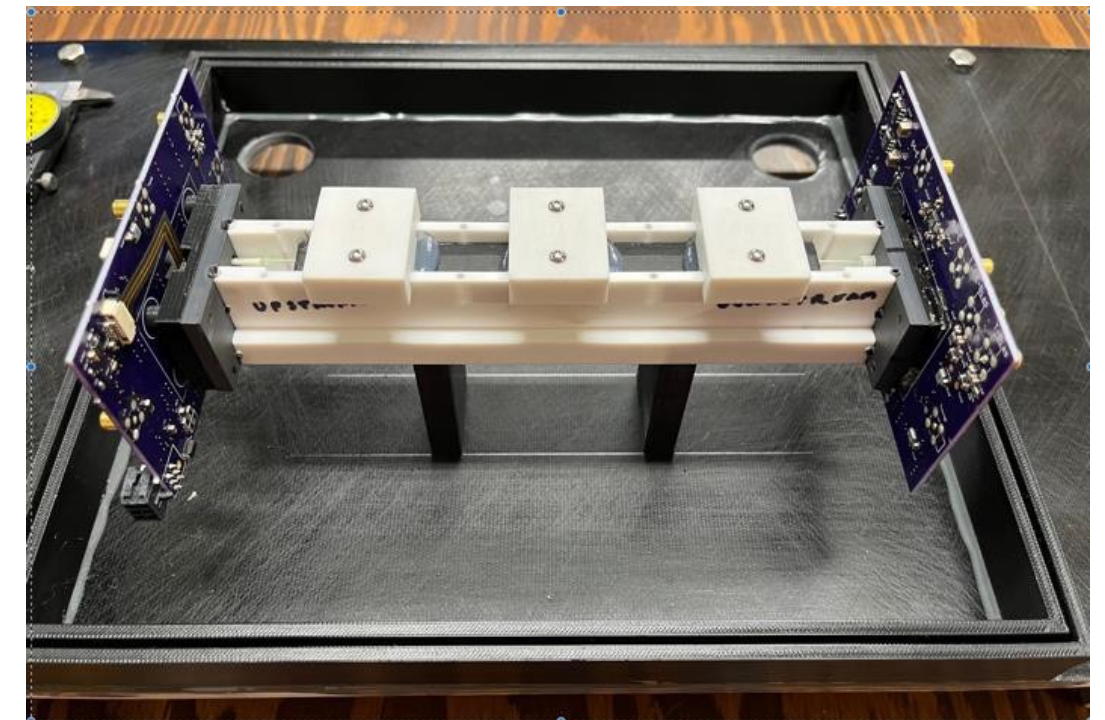
WLS positioned for EM Shower Timing and Position



CERN H2 test beam.
 Arrangement of instrumentation.
 Beam incident from below. A1/2-Trigger,
 B-MCP, **C-RADiCAL**, D-Pb glass array

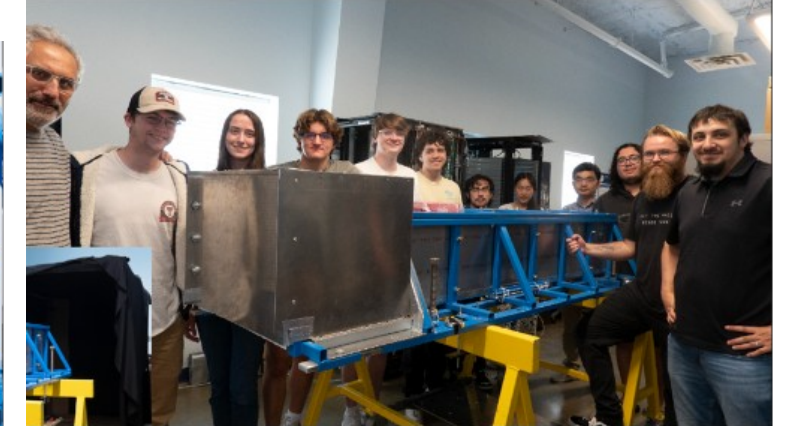
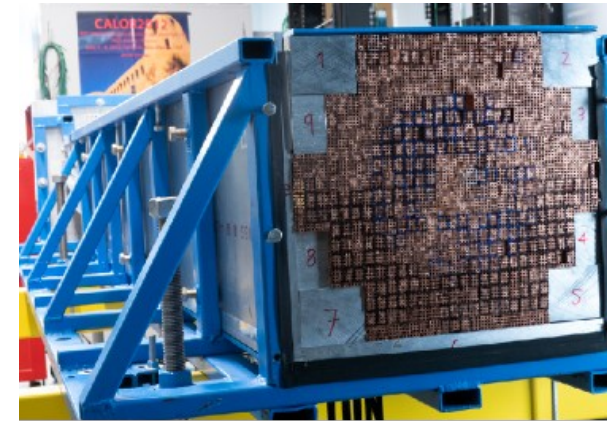


RADiCAL Module with
 SiPM front end readout cards.
 Beam incident from left.

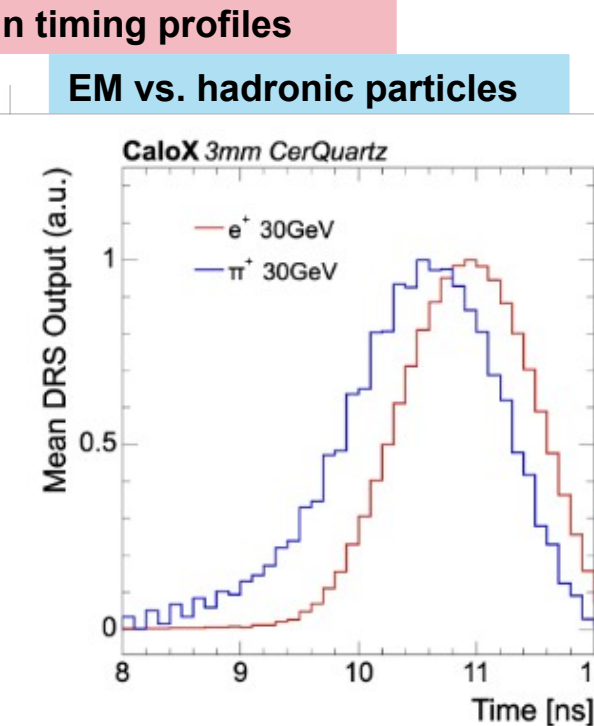
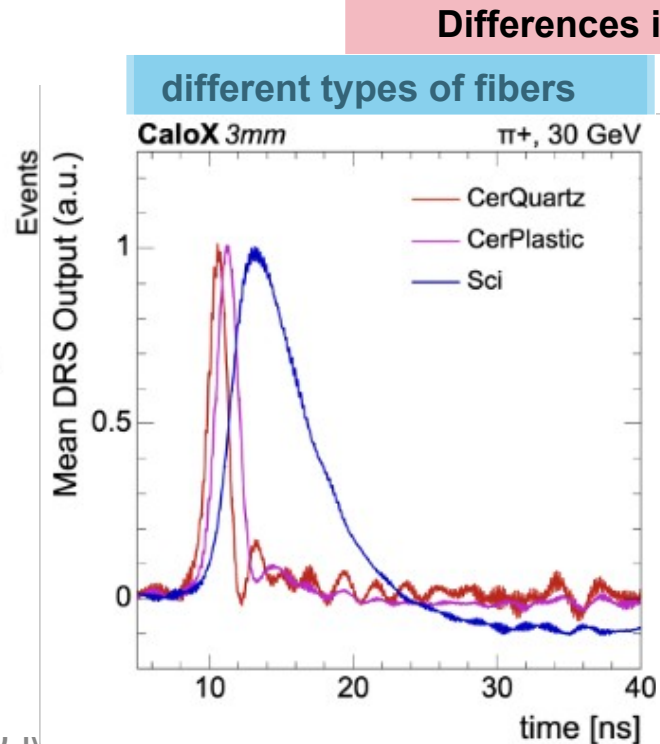
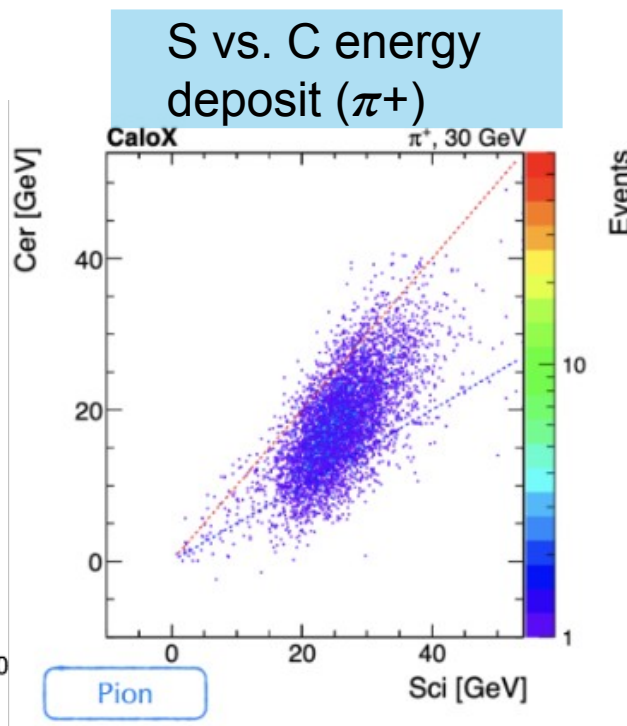
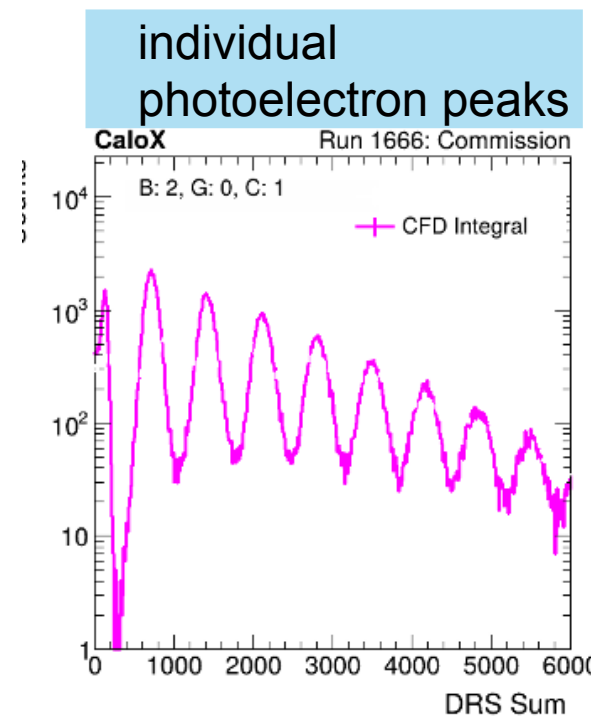


Dual Readout Calorimeter – US Contributions

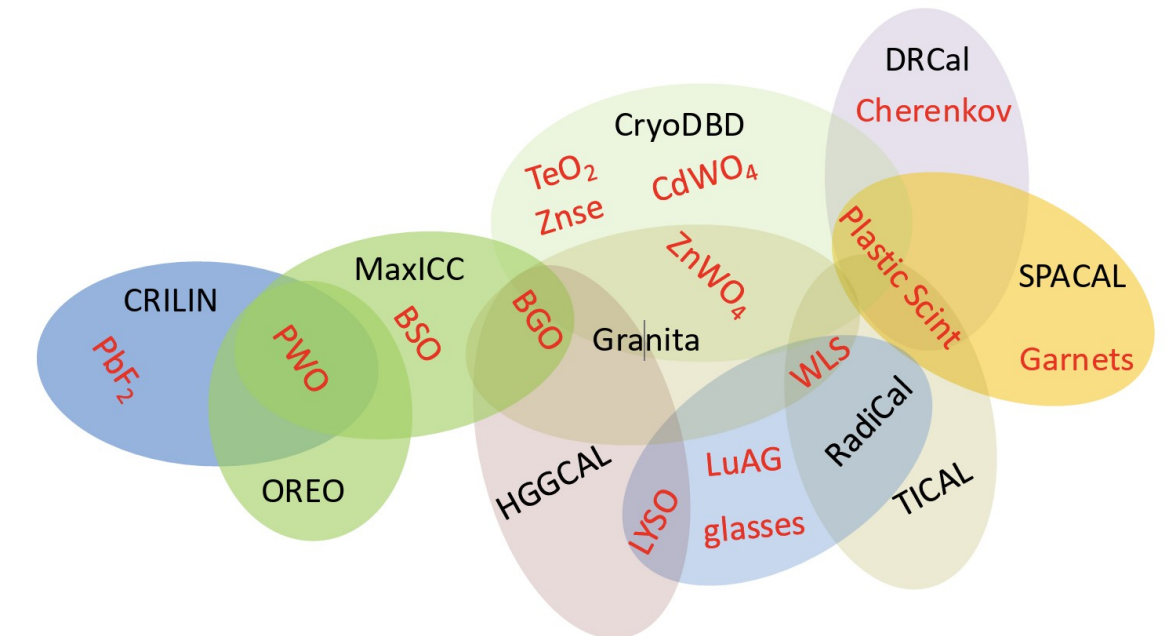
- **TB2026 setup**
 - Higher granularity: PMTs -> SiPMs, improved readout electronics
 - Fast response for better timing capability, together with much higher granularity, to capture fine shower structures
- **Data analysis is ongoing in various aspects**
 - Energy measurements, timing profiles etc.



Further details in talk by Yongbin



- **Broad Portfolio:** 12 active subtasks in WP3 driving the future of optical calorimetry
- **Excellent Performances:** Demonstrating high precision in energy resolution, PID, and picosecond-level timing across multiple detector concepts
- **Cutting-Edge Innovations:** Successful validation of novel materials, manufacturing techniques, and software integration
- **Solid Path to 2027 - 2029:** Transitioning from component-level R&D to system-wide scalable prototypes and joint beam-test campaigns
- **Stay tuned for more exciting progress in the future**
- **New subtask OL3D (opaque liquid scintillator) under discussion, awaiting approval by CB**
 - Proposed by BNL and University of Alabama, see also talk by Guang

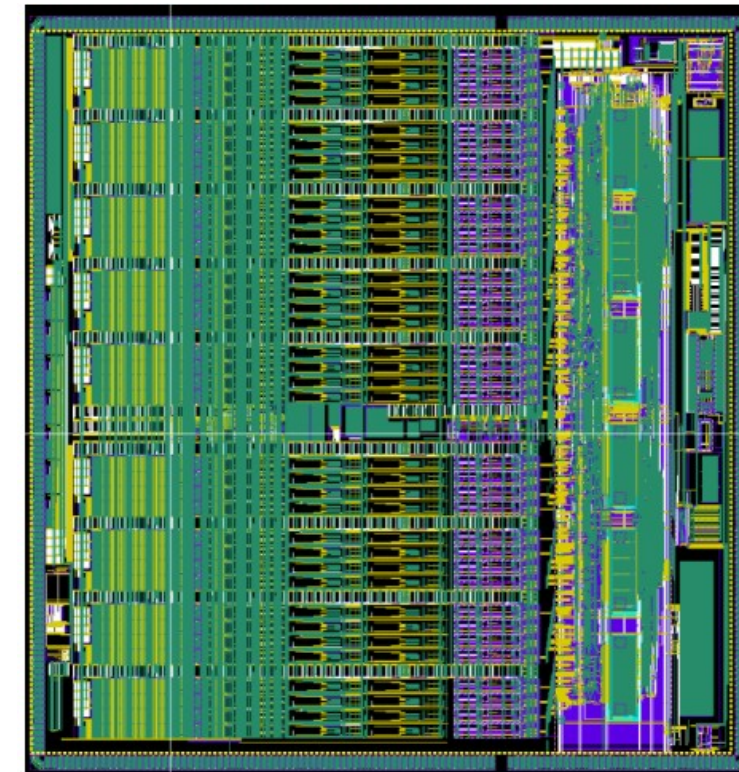


- Common development of front-end electronics for calorimetry
 - ASIC development
 - Coordination of engineering run(s)
- Organisation of DAQ in DRDCALO coming up
 - Aim to share HW/FW/SW + experience as much as possible
 - Allow common testbeam and maximise commonalities
- Electronics and DAQ is obviously a transversal activity
 - -> Will be transformed (back) from WP to WG

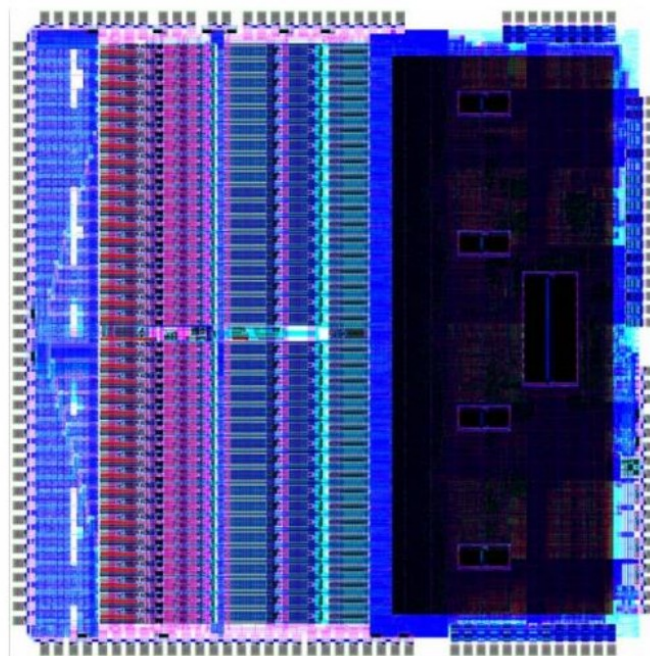
Example CALOROC ASIC

36 channels 15 mW/ch.

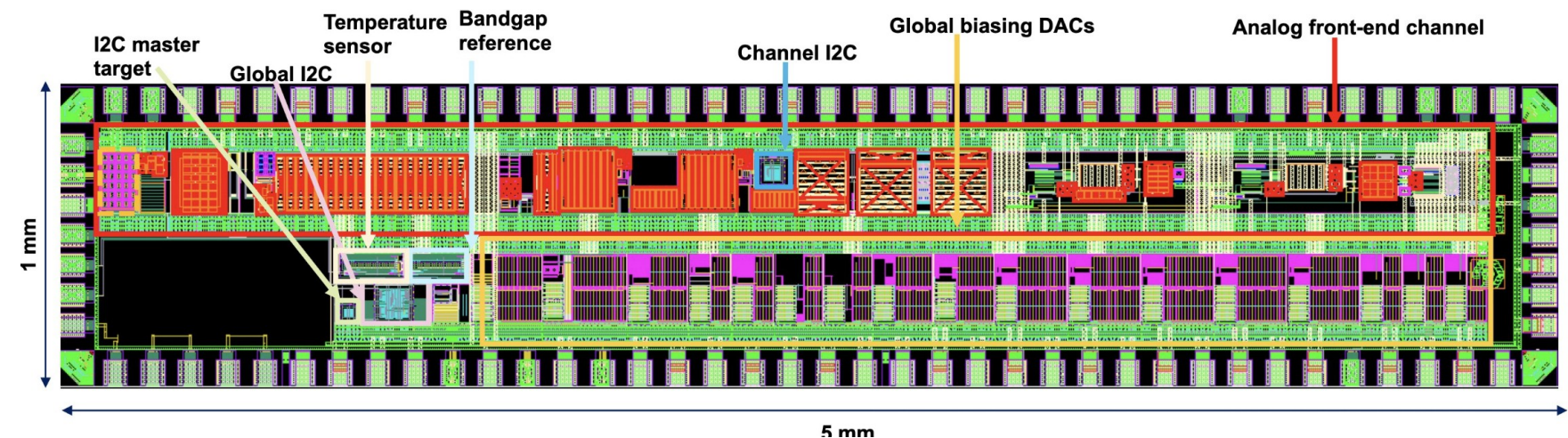
130 nm TSMC



- Arrived last may and now under test
- CALOROC 1A,B for SiPM
- CALOROC 1C for Liquid Noble and semiconductor based detectors



36-channel KLauS6 (2021 until now)



SiPM readout ASIC developed for CALICE AHCAL & ScECAL

- Target on low gain SiPMs (10/25 μm pixel, 1x1/3x3 mm^2 area, charge range 15 fC – 150 pC)
- Process : UMC 180 nm mixed-mode 1.8 V/3.3 V CMOS technology
- Power consumption : ~3 mW/channel (~26 μW @ 0.5% duty cycle)
- Current version KLauS6 with 36 channels (-> future KLauS7)
- Analog front-end + ADC + TDC + Digital interfaces (I2C, SPI, LVDS)

CHARMS250 ASIC being developed at BNL

(adaptation of Dune LArASIC => Electronics at Cryogenic Temperatures)

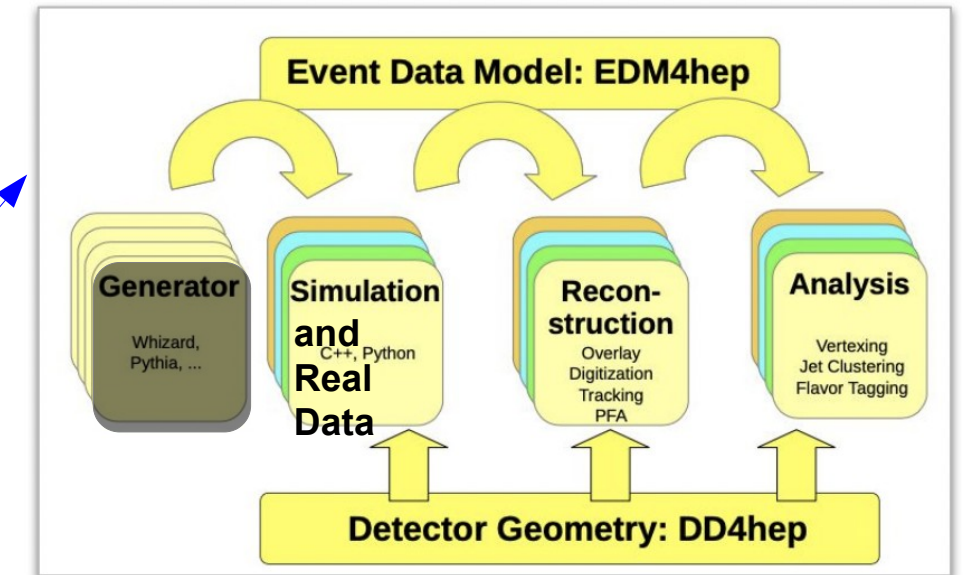
- 6-11 mW/channel
- Simulation well advanced, noise well below MIPs
- Single-channel prototype submitted for fabrication
- R&D ongoing to extend the full-scale input charge range to 10 pC (12-bit dynamic range)

Data Acquisition and Monitoring



Your favorite
Calo Prototype(s)

Data/Event Processing (Key4hep)



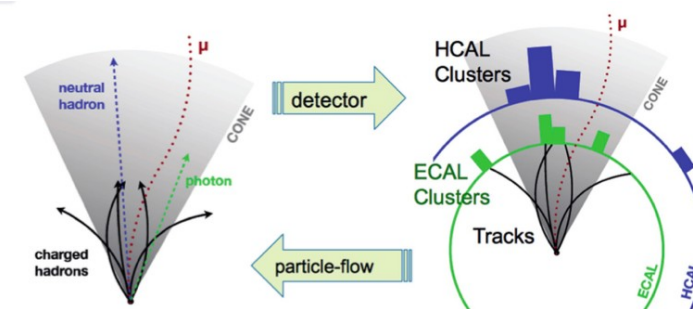
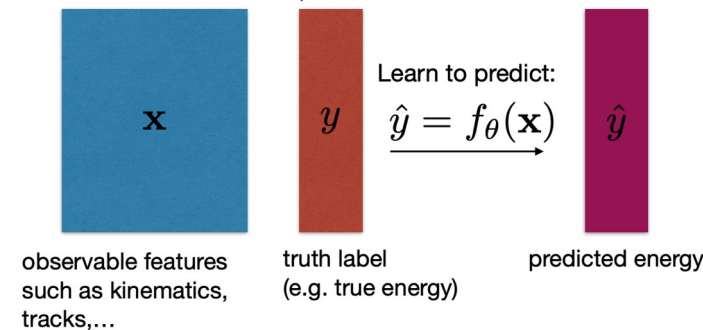
... and data management

Physics output

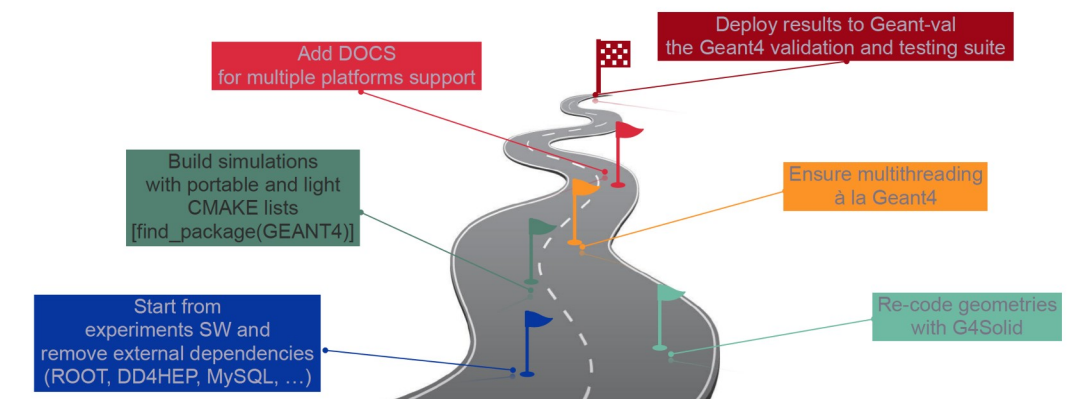
Exploitation:

Pattern recognition, s/w compensation

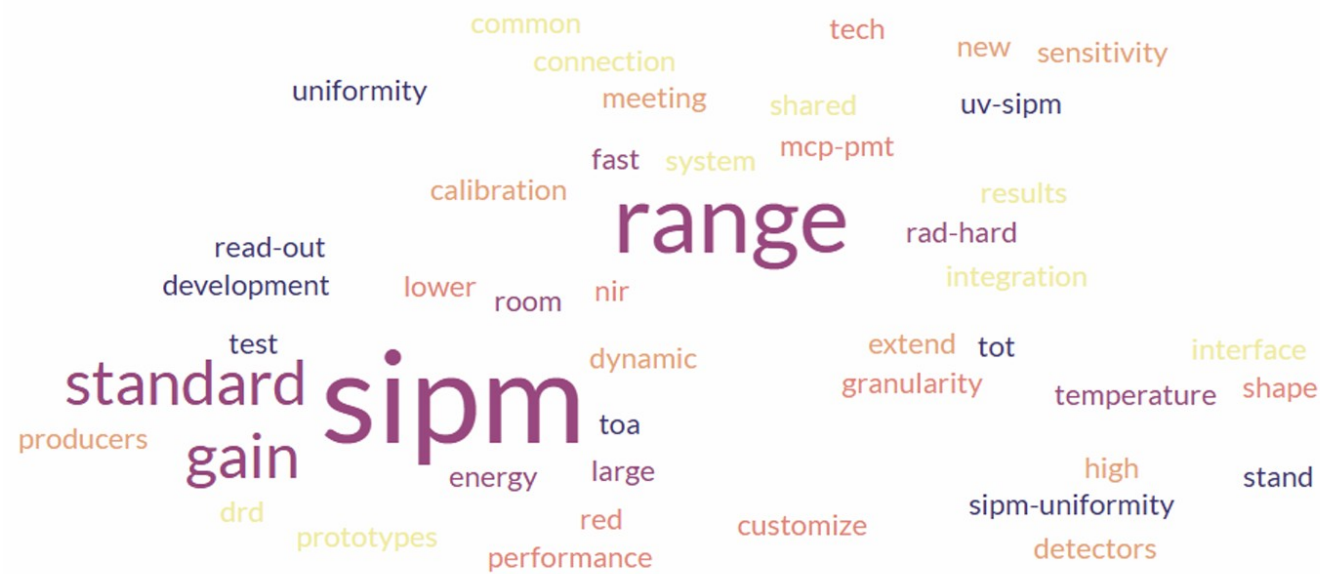
Use training data with known labels
(often from Monte Carlo simulation)



From experiments to geant-val, a winding road 



Survey on preferred photodetectors in DRD Calo subtasks



SiPM is the “working horse”

- **Short term plans**
 - Strengthen communication channels and newsletter updates
 - Collect detector needs across WPs and consolidate requirements
 - Increase interaction with DRD4 and other WGs
 - Organise interaction with vendors and manufacturers
- **Long term plans**
 - Annual vendor meetings (FBK, Hamamatsu, NDL and others)
 - Align sensor developments with detector R&D priorities
 - Foster synergies between photodetector R&D and front-end electronics developments
 - Support prototype production and qualification programmes
 - Build a common technology roadmap for future calorimeter projects

Generic Equipment and Tools



Beam Line Infrastructure



Your favorite
Calo Prototype(s)

- Many items are common to all projects
- Common coordination will streamline beam test programme

CPAD Meeting – October 2026

Overall Planning



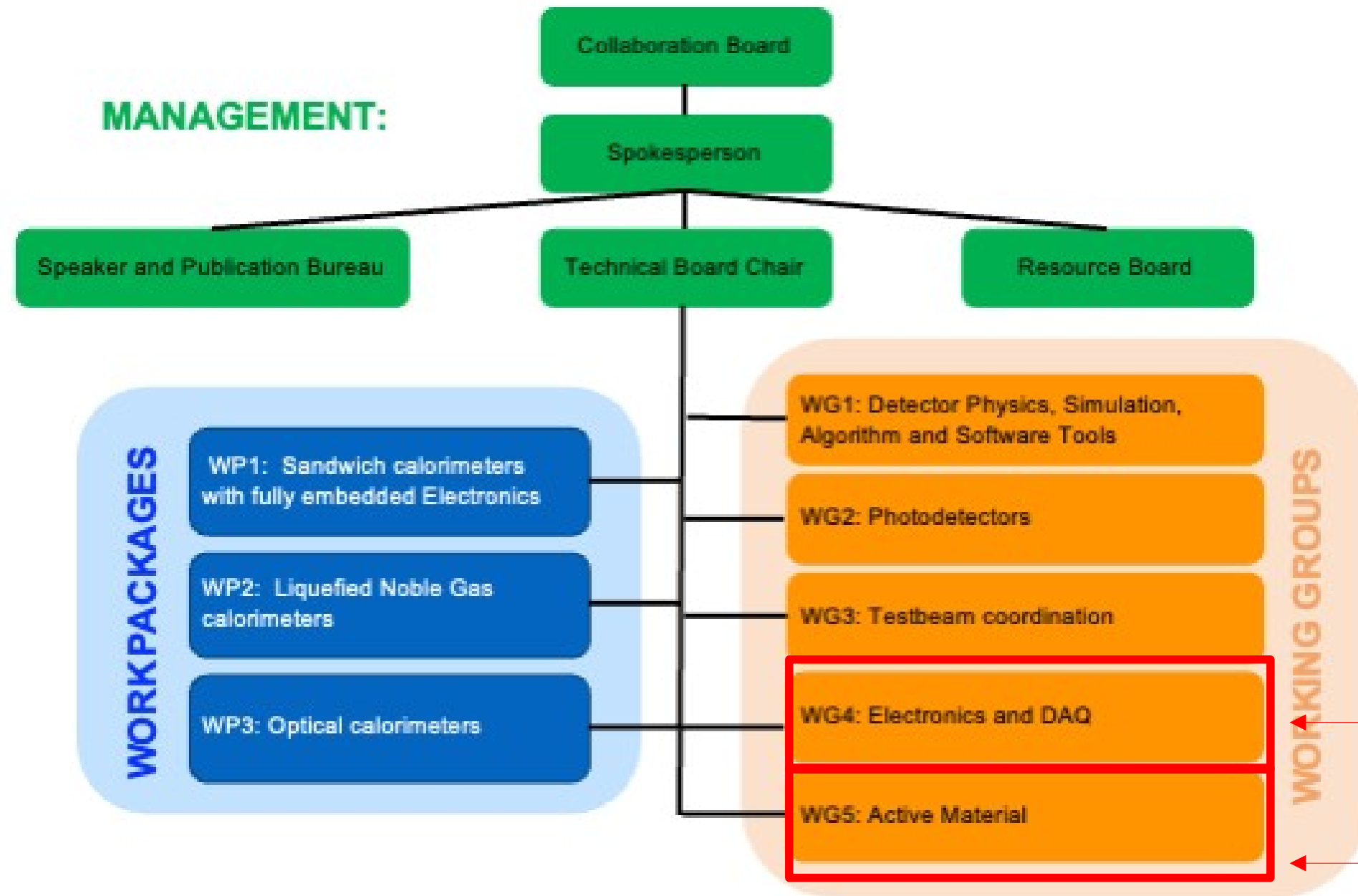
Communication with Operators

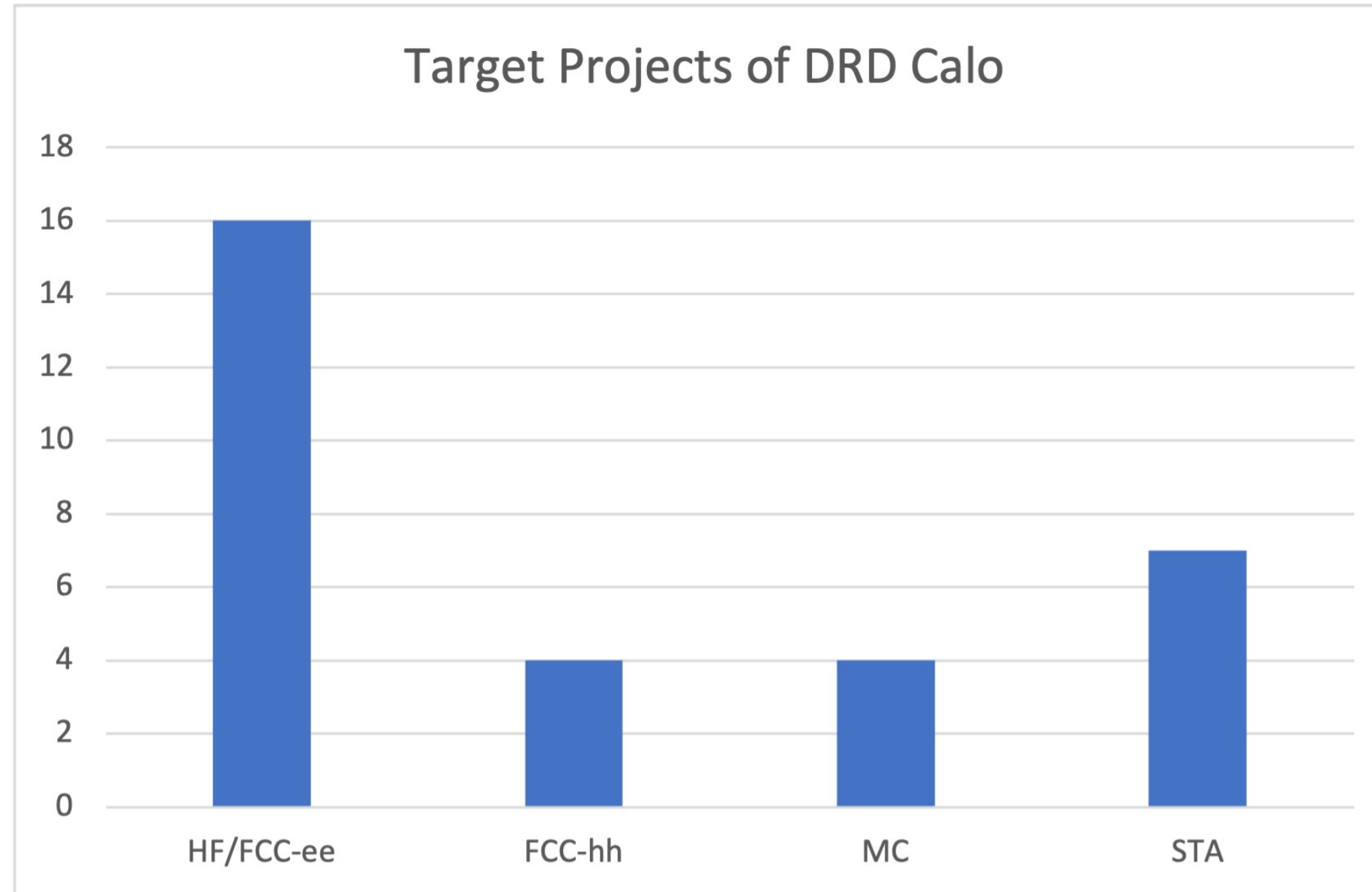




- CERN Council Session has adopted ESG recommendations during Special Session in May 2026 in Budapest
 - -> FCC-ee highest priority for CERN
 - Preparing for decision on go, no-go of FCC-ee in 2028
 - Some member states have required to present options as part of their decision making process

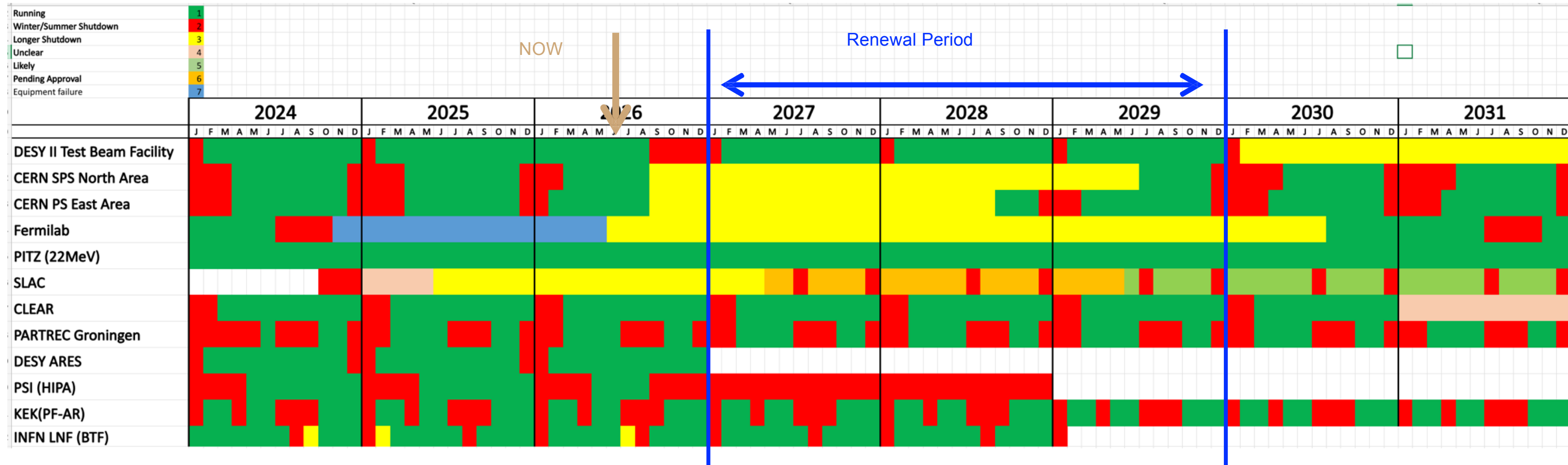
- We used the summer to collect information about future plans
 - Collection has been followed up in Technical Board
- June 30th and July 7th "Open TB Meetings", i.e. WP Coordinators did present plans but everyone was invited
- Since Middle of July: Working on draft of summary 2024-2026 and proposal document for 2027-2029
 - Submission of first version to DRDC on Sept. 22nd
 - Update on October 16th
 - Pre-meeting with DRDC on October
- We are in transit from the collection phase to the consolidation phase in terms of renewal plans
 - Recent collaboration meeting helped a great deal on this
 - V3 for ~November 6th
- November 12th and 13th DRDC Meeting at CERN
- Approval for next three years by CERN Research Board in December 2026





- **DRD Calo is heading toward the end of a successful first three-year cycle**
 - Good organisation and efficient use of available funding
 - US groups play an important role in scientific programme (partially driving activities)
 - See examples in this talk
 - Regular participation to collaboration meetings (online **and in-person!**)
 - Personal Opinion: Strong US involvement requires further consolidation
 - Interaction with CPAD?
- **Scientific harvest is starting**
 - Coordination by Speakers Bureau
 - 59 Conference talks and seminars, 10 conference proceedings and 10 papers referring to DRD Calo
 - Complete list is [here](#)
- **Renewal process in full swing**
 - Kick-off at Collaboration Meeting in April, two Open Technical Board Meetings in June/July
 - Report(s) submitted to DRDC
 - Consolidation phase ongoing
- **DRD Plans well in phase with ESG recommendations**
 - Visible support for and involvement in FCC-ee activities
 - DRD Calo has and will maintain a broad portfolio of activities
 - ... to cover e.g. short term applications that start taking data around or before 2030

Backup



Electron beam (> GeV):

- KEK up to 5 GeV
- DESY up to 6 GeV
- SLAC up to 8 GeV
- FNAL up to 32 GeV

Hadron beam (> GeV):

- CERN PS up to 15 GeV
- CERN SPS up to 450 GeV
- FNAL up to 120 GeV

- Our mandate is to care that ANY possible future facility program will not be delayed due to detector developments being not ready (or not on schedule)
- We are well prepared to respond to the Strategy Update
 - Many projects target future Higgs factories, new electronics allow for continuous r/o, cooling studies started
 - Overall plans, see slides above
 - WP1-3 leads are also calorimetry conveners in FCC-PED
- It is however also important that we keep a broad portfolio of activities
- Future flagship projects are still ~20 years ahead of us
 - May have an interest to understand where developed technologies can be used (and therefore scrutinised) before. Examples are:
 - Spacal in LS4
 - DUNE ND
 - Fixed target experiments that will come online in the early 2030s (maybe even earlier)

Scintillator based sampling calorimeters (EM/HAD)

Dual Readout Fiber Calorimeter
for Higgs Factories

R&D on Spaghetti (EM) Calorimeter
technologies for LHCb Upgrade II, Higgs
factories, FCC-hh

Fast-timing, ultracompact, radiation
hard, EM calorimetry (*RADICAL*)
for FCC-hh

High sampling fraction EM calorimeter
with crystal grains (*GRAiNITA*) for FCC-ee

Scintillating Tile HCAL
for FCC-hh, FCC-ee

Homogeneous EM crystal calorimeters

Maximum Information Crystal
Calorimeter for Higgs Factories
(MAXICC)

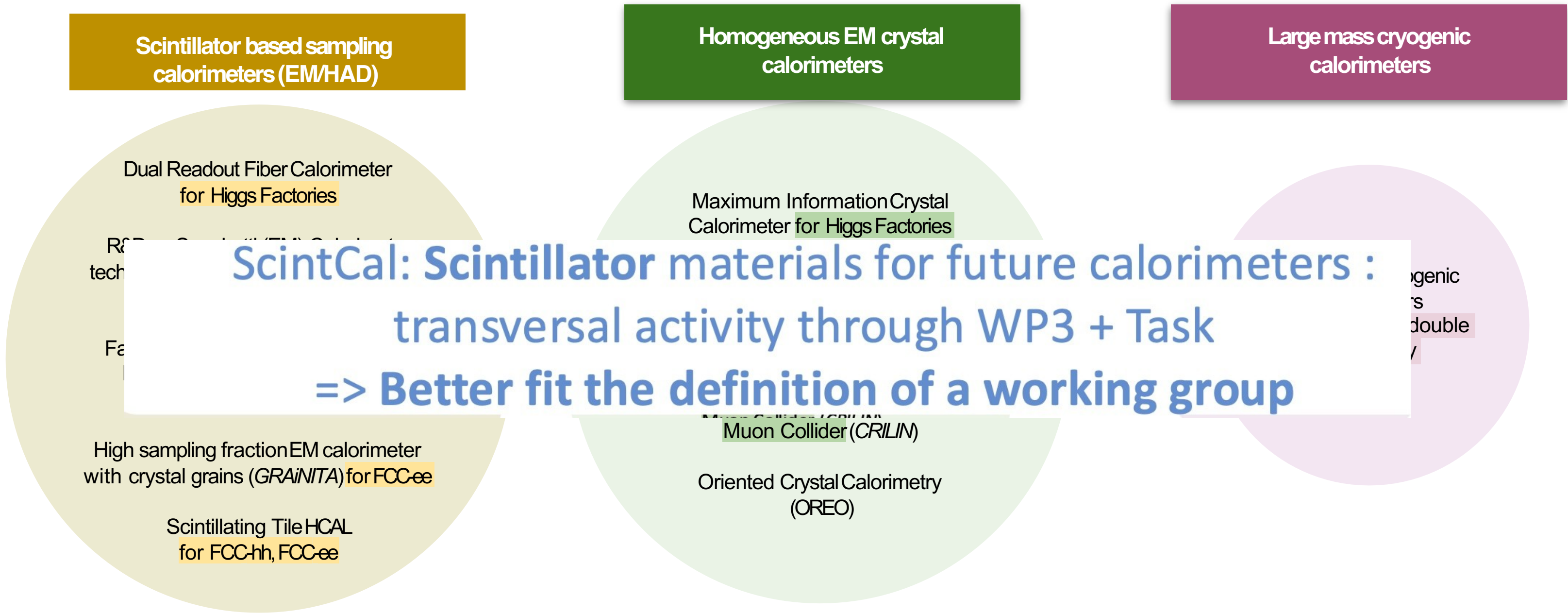
High Granularity Crystal Calorimeter for
Higgs Factories
(HGCCAL)

Fast, segmented Crystal calorimeter for
Muon Collider (*CRILIN*)

Oriented Crystal Calorimetry
(OREO)

Large mass cryogenic calorimeters

Large mass cryogenic
calorimeters
for neutrinoless double
beta decay



WP1

	Deliverable	Description	Date Achieved
Task 1.1: Highly pixelised electromagnetic section			
Subtask 1.1.1: SiW ECAL	D1.1	Revised 15 layer stack	2026
Subtask 1.1.2: High compact calo	D1.17	Partially instrumented HighCompact Calo	2025
Task 1.3: Hadronic section with gaseous readout			
Subtask 1.3.2: MPGD-HCAL	D1.13	Completion of 6-layer prototype $20 \times 20 \text{ cm}^2$	2024
	D1.14	10-layers prototype (6L: $20 \times 20 \text{ cm}^2$ +4L: $50 \times 50 \text{ cm}^2$)	2025

WP4

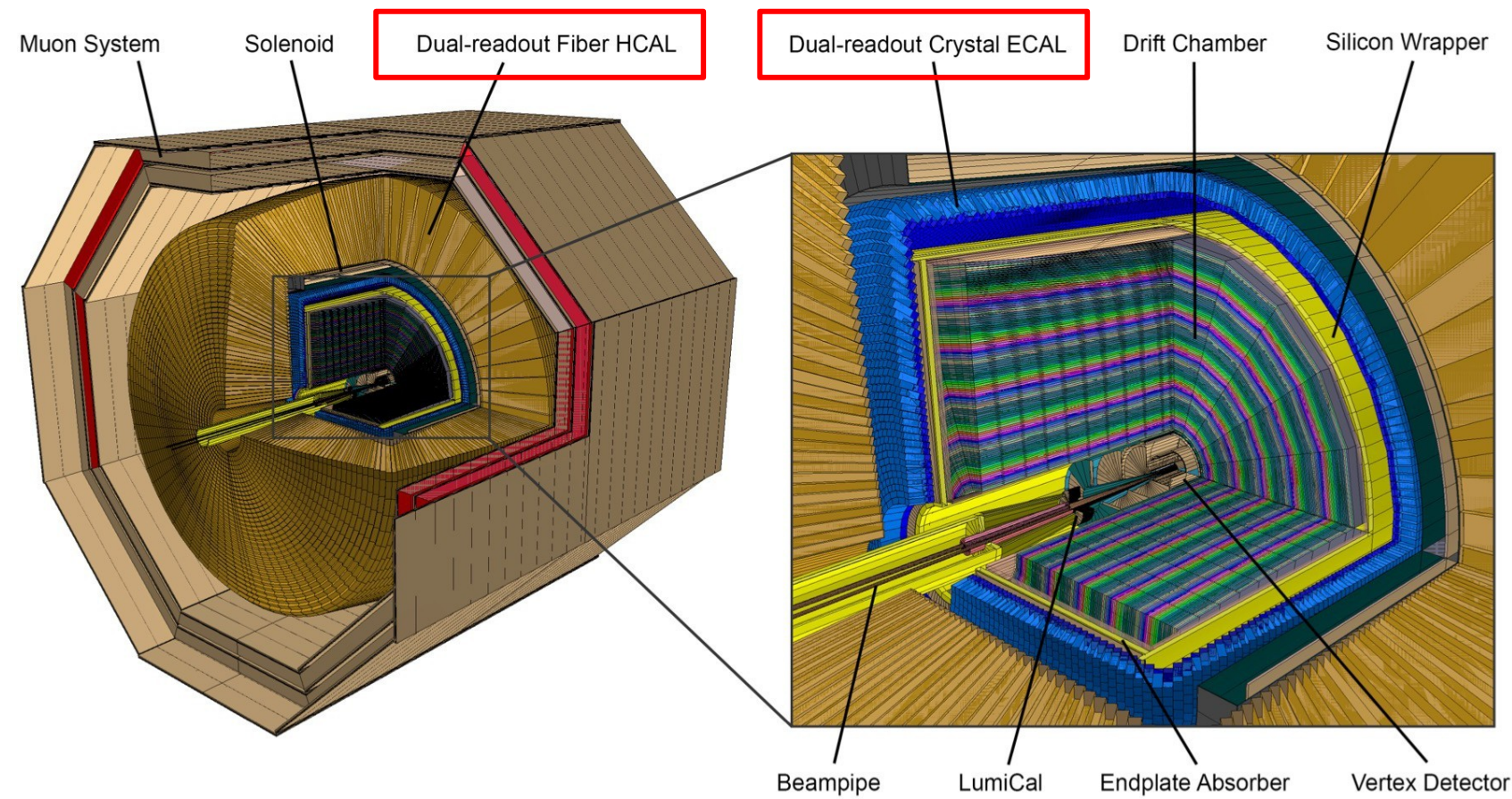
Deliverable	Description	Date Achieved	Document
D4.1	Common ASIC production	2026	Document

- 19/26 deliverables reached compared with proposal from 2023 (plus partial revision during 2024)

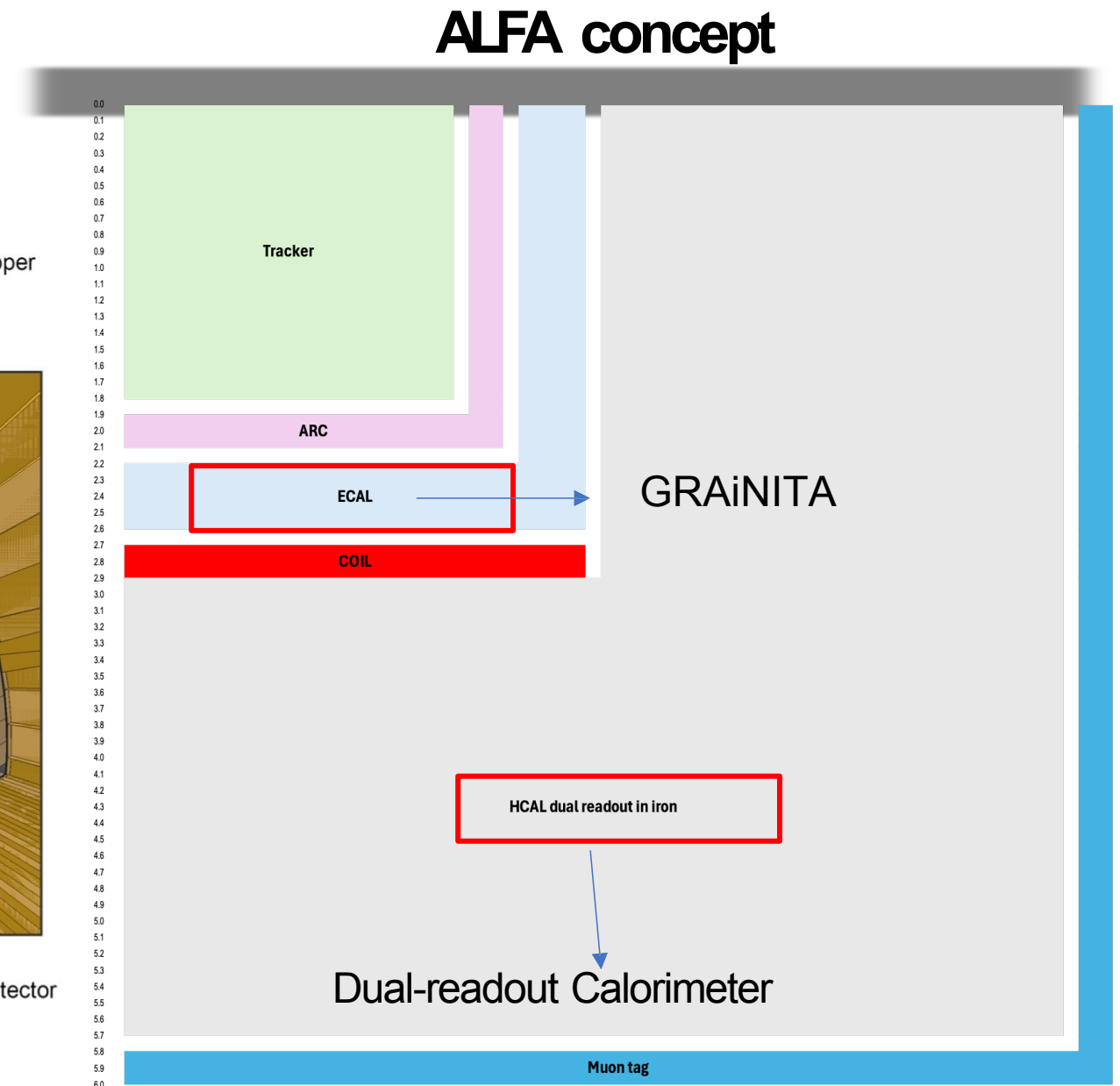
WP3

	Deliverable	Description	Date Achieved	Document
Task 3.1 : Homogeneous and quasi-homogeneous EM calorimeters				
Subtask 3.1.1 HGCCAL	D3.1	Development of 1-2 crystal EM modules to be exposed to beam tests	2025	Document
Subtask 3.1.2 MAXICC	D3.3	Full containment dual-readout crystal EM calorimeter prototype and testbeam characterisation	2026	TB in 2026
Subtask 3.1.3 Crilin	D3.4	Acquisition and tests of crystals and SiPMs; design and production of electronics boards; design and production of the mechanical components	2025	Document
		Calorimeter fully assembled	2025	Document
Subtask 3.1.4 OREO	D3.18	Two layer PWO-UF prototype fully assembled	2025	Document
	D3.19	Final MC package in Geant4	2026	
Task 3.2: Innovative Sampling EM calorimeters				
Subtask 3.2.1 Grainita	D3.20	Characterisation of the small size prototype with muons	2024	Document
Subtask 3.2.2 SpaCal	D3.7	Tungsten and lead absorbers for module-size prototypes	2024	Document
	D3.8	Set of crystal samples, SPIDER ASIC prototype	2026	Crystal samples: CERN-EP-RDET-2025-004, CERN-EP-RDET-2026-001; SPIDER prototype: Document
Subtask 3.2.3 RADiCAL	D3.10	Single module with prototype scintillating crystals, SiPMs and front-end electronics cards built and tested	2024	Document
Task 3.3: (EM+)Hadronic sampling calorimeters				
Subtask 3.3.1 DRCAL	D3.12	Construction of different options of dual-readout prototypes with hadronic shower containment	2026	Document
Task 3.4: Materials				
Subtask 3.4.1 ScintCal	D3.15	Samples of a set of scintillators produced and characterised	2026	Document
Subtask 3.4.2 CryoDBDCal	D3.17	Scintillating polymer for 3D-printing, with optimal mechanical and light-production properties, produced and tested	2026	Document
	D3.24	Cryogenic outer veto prototype (BGO)	2026	Document

- Participate in IDEA and ALFA detector concepts

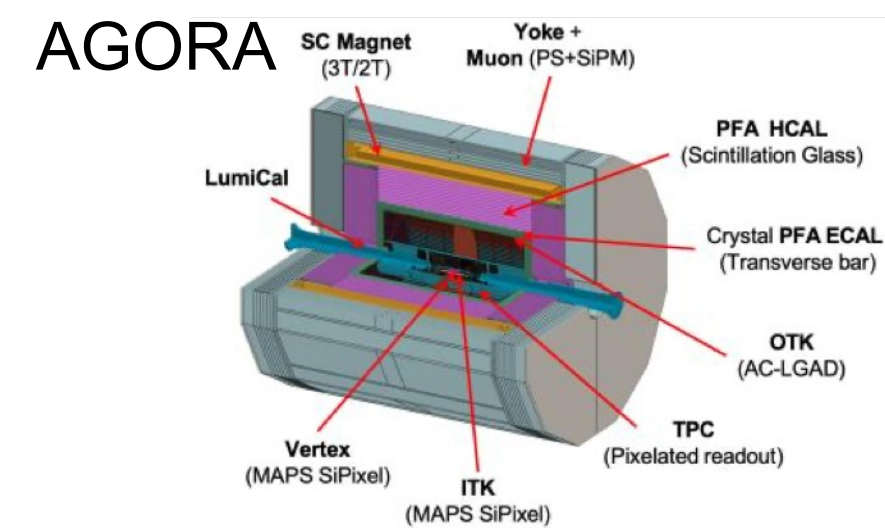
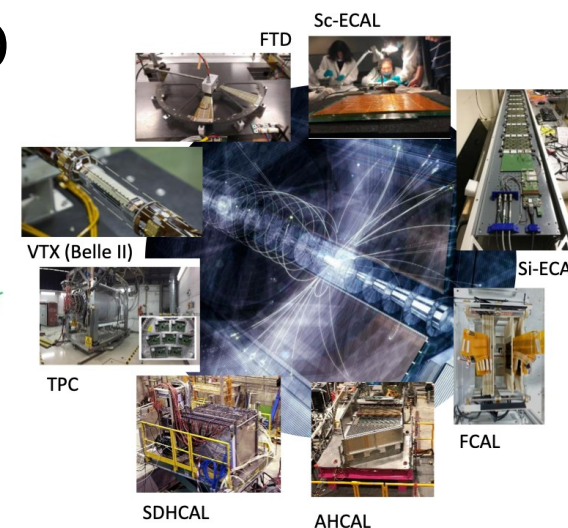
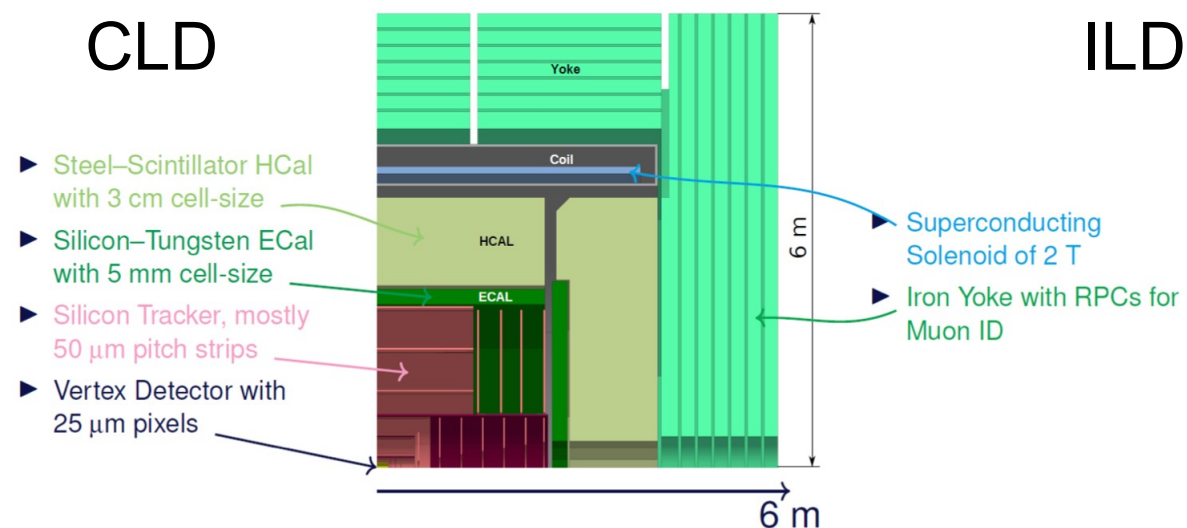


IDEA concept

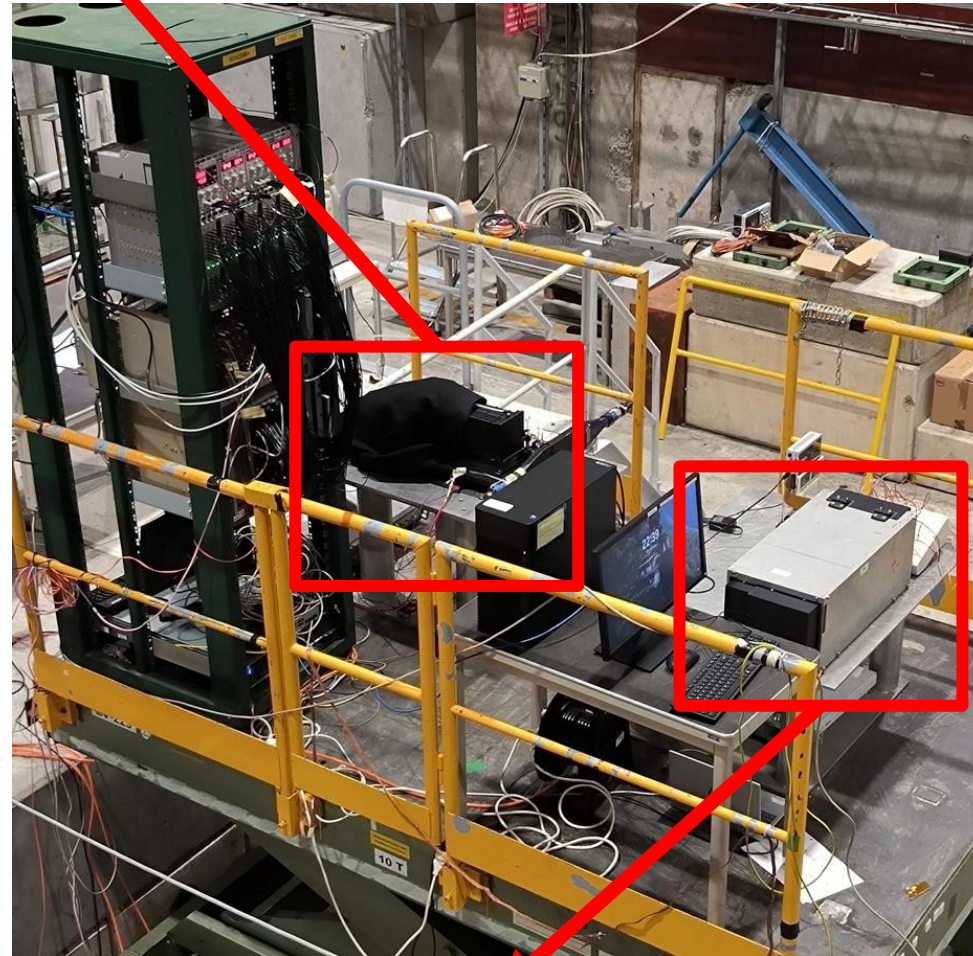


ALFA concept

- **Some technologies already adopted for HL-LHC upgrades**
 - CMS HGCal with silicon pads and scintillator tiles
 - ALICE FoCal with MAPS
- **Detector concepts for FCC-ee**
 - CLD and ILD designed around the particle flow reconstruction principle
 - To be adapted from linear collider concepts to cope with continuous readout
 - AGORA: adaption from CEPC reference detector



Crilin



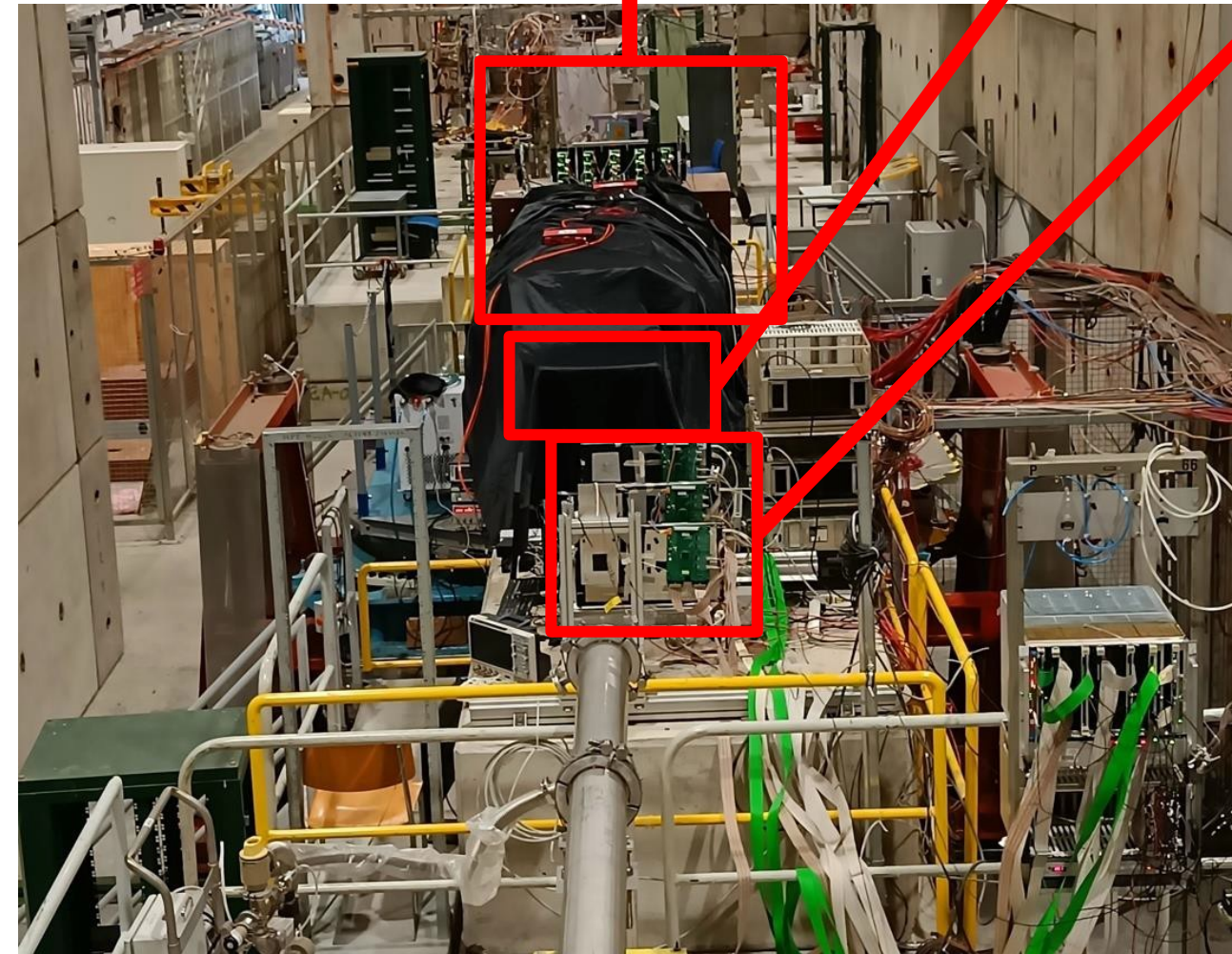
SiW ECAL

6

DRCalo

MAXICC

Si tracker
Insubria (OREO)



- Groups shared allocated beam time
- and/or organised combined ECal/HCal testbeams

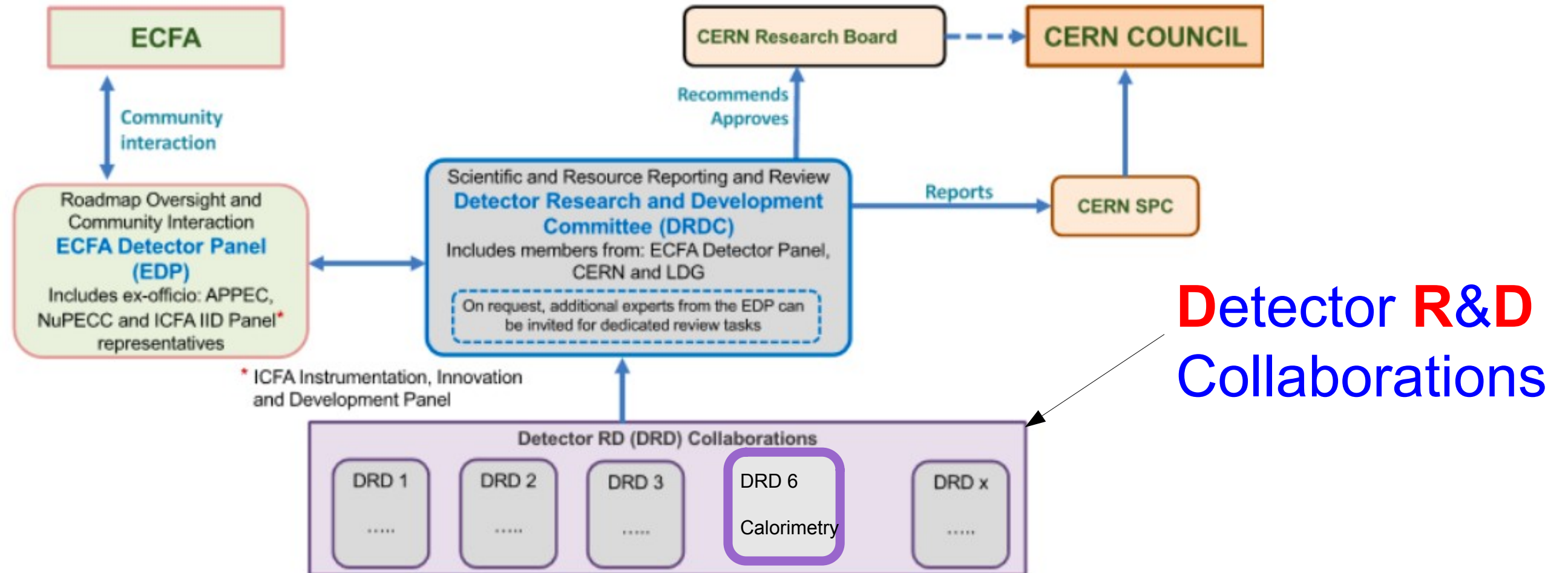
- Coordinating the testbeam requests at different facilities
 - CERN (TB Chair - ad interim)
 - DESY K. Kruger
 - US (Fermilab, SLAC): G. Cummings
 - KEK: W. Otani

- Next years will be crucial
 - Still pending request for dedicated area at CERN SPS => take advantage of the shutdown period to set it up until the beam will restart in 2029
 - DESY and the other beam facilities will be overcrowded => coordinating requests

- Update of European Strategy will give guidance for the renewal process. That's good!
- Non-availability of major sites with hadrons and high energy electron testbeams
 - CERN SPS (at least) three years
 - Future of FTBF at FNAL?
- Test beams have to be carried out at DESY, KEK and SLAC (?)
 - => Projects may have to demonstrate how to profit from these facilities
 - Projects that require high energy beams have to get prepared for the reopening of CERN
- High priority of HL-LHC may limit margins for detector R&D for another few years
- Funding in general scarce and some particularly bad news during last winter
 - How to maintain R&D projects that will suffer from various funding crises
 - Hopefully OTELLO will be approved upon 2nd attempt
- Research goals may have to be adapted to the boundary conditions
- Important to emphasise that analysis of data is ongoing and that in the next phase we can expect numerous publications
 - Use the structures and tools that have been put in place!
 - Important aspect that (in principle) deserves dedicated funding

- ECR Forum
 - DRD Calo should become a home and a career trampolin
 - Essential mission of collaboration to promote young scientists
 - A dedicated ECR Forum may become regular event at collaboration meeting
- Diversity, equity and inclusion
 - DRD Calo may want to adopt a DEI Policy
 - Guidelines and implementation
- Still high on agenda but lot of time was again eaten by MOU business

- AIDAinnova ended on September 30th 2025
- New project OTELLO
 - Submitted September 18th
 - HORIZON-INFRA-2025-01-TECH-02 call, around 45 MEUR in total, 10-15 MEUR for OTELLO
- Research proposal largely picked from DRD research programme
 - Calorimetry is one of the Work Packages
 - Katja member of Proposal Team
 - Supported by facilitators (Gabri, Michaela, Lucia, Philipp, Nicolas, Imad, Christophe (electronics) and Mary Cruz)
- OTELLO rejected by EU in February 2026
- New submission in June 2026
 - Project revision is ongoing
 - More news in Gabri's talk



- **DRD is hosted by CERN and therefore legal CERN collaborations**
 - Significant participations by non-European groups is explicitly welcome and needed => World wide collaborations!
- **The progress and the R&D is overseen by a DRDC that is assisted by ECFA**
 - Thomas Bergauer of ÖAW/Austria appointed as DRDC-Chair
- **The funding will come from national resources (plus eventually supranational projects)**

- Key technologies and requirements are identified in ECFA Roadmap

- Si based Calorimeters
- Noble Liquid Calorimeters
- Calorimeters based on gas detectors
- Scintillating tiles and strips
- Crystal based high-resolution Ecals
- Fibre based dual readout

- R&D should in particular enable

- Precision timing
- Radiation hardness

- R&D Tasks are grouped into

- Must happen
- Important
- Desirable
- Already met

