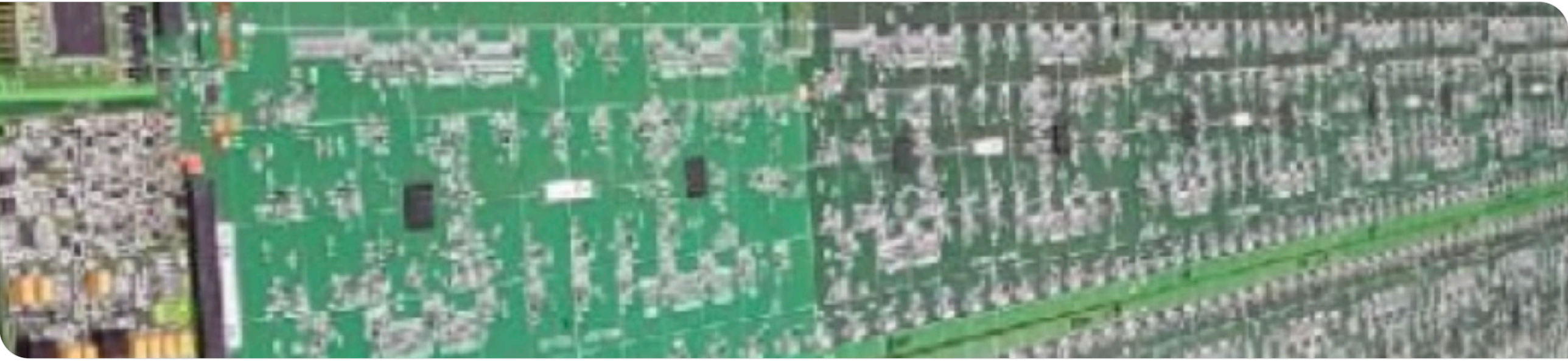
Karlsruher Institut für Technologie

Institute for Data Processing and Electronics

WP1
Brief Introduction

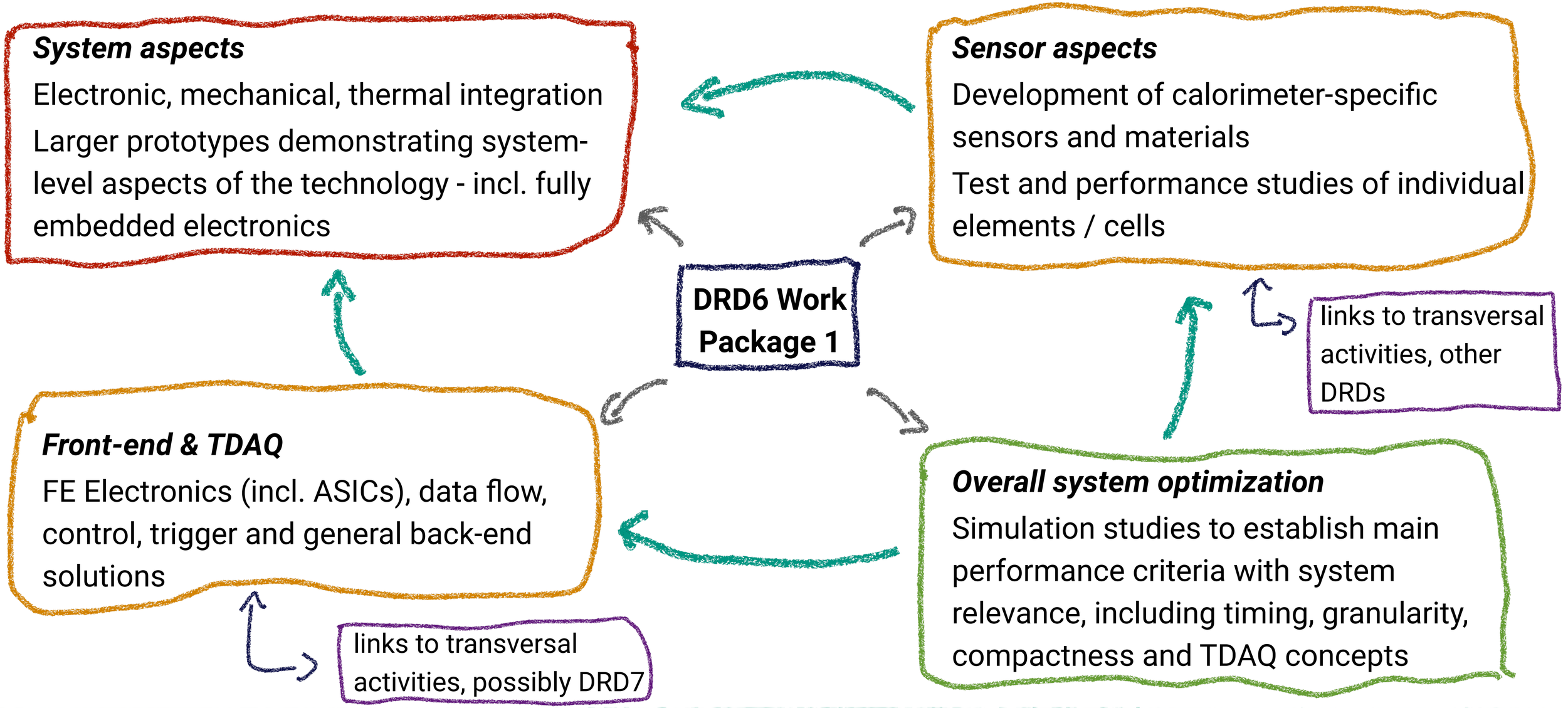
Frank Simon

DRD6 Collaboration Meeting, April 2024



WP1

High-level Summary



WP1 Technology Areas

The Menu Overview

- ***General approach***: Highly granular calorimeters as integrated systems - but often still with separate requirements and correspondingly separate technological solutions for electromagnetic and hadronic sections.
- ***Overarching goals***: Establish (where not existing already) large-scale prototypes that allow to demonstrate the technologies, both stand-alone and in combined tests of different electromagnetic and hadronic sections.

- High-level structure: Tasks covering technology areas
  - Task 1.1: Highly pixelised electromagnetic section
  - Task 1.2: Hadronic section with optical tiles
  - Task 1.3: Hadronic section with gaseous readout

Frank Simon (frank.simon@kit.edu)

WP1 Technologies

Highly pixelised electromagnetic section

Task/Subtask	Sensitive Material/ Absorber	DRDTs	Target Application	Current Status
Task 1.1: Highly pixelised electromagnetic section				
Subtask 1.1.1: SiW-ECAL	Silicon/ Tungsten	6.2	e^+e^- collider central detector	Prototype for finalising R&D for LC, Specification for CC and of timing for PFA needed
Subtask 1.1.2: Highly compact calo	Solid state (Si or GaAs)/ Tungsten	6.2	e^+e^- collider forward part	Prototypes with non-optimised sensors, Sensor optimisation and data transfer studies ongoing
Subtask 1.1.3: DECAL	CMOS MAPS/ Tungsten	6.2, 6.3	e^+e^- collider central detector. Future hadron collider	Prototypes with non-optimised sensors, Sensor optimisation ongoing
Subtask 1.1.4: Sc-Ecal	Scintillating plastic strips/ Tungsten	6.2	e^+e^- collider central detector	Prototype for finalising R&D for LC, Specification for CC and of timing for PFA needed

WP1 Technologies

Hadronic section with optical tiles

Task/Subtask	Sensitive Material/ Absorber	DRDTs	Target Application	Current Status
Task 1.2: Hadronic section with optical tiles				
Subtask 1.2.1: AHCAL	Scintillating plastic tiles/ Steel	6.2	e^+e^- collider central detector	Prototype for finalising R&D for LC, Specification for CC and of timing for PFA needed
Subtask 1.2.2: ScintGlassHCAL	Heavy glass tiles/ Steel	6.2	e^+e^- collider central detector	Material studies and specifications for prototypes

Frank Simon (frank.simon@kit.edu)

WP1 Technologies

Hadronic section with gaseous readout

Task/Subtask	Sensitive Material/ Absorber	DRDTs	Target Application	Current Status
Task 1.3: Hadronic section with gaseous readout				
Subtask 1.3.1: T-SDHCAL	Resistive Plate Chambers/ Steel	6.2	e^+e^- collider central detector	Prototype for finalising R&D for LC, Specification for CC and of timing for PFA needed
Subtask 1.3.2: MPGD-HCAL	Multipattern Gas Detectors/ Steel	6.2, 6.3	$\mu^+\mu^-$ collider central detector	Small prototype for proof-of-principle, Lateral and longitudinal extension envisaged
Subtask 1.3.3: ADRIANO3	Resistive Plate Chambers +Scintillating plastic tiles/ Heavy Glass	6.1, 6.2, 6.3	e^+e^- collider central detector BSM searches in MeV-GeV range	RPC, Scintillating Tiles advanced status, R&D on heavy glass needed

Frank Simon (frank.simon@kit.edu)

WP1 Milestones

Highly pixelised electromagnetic section

	Milestone	Deliverable	Description	Due date
Task 1.1: Highly pixelised electromagnetic section				
Subtask 1.1.1: SiW ECAL		D1.1	Revised 15 layer stack	2024
	M1.1		Specifications for timing and cooling	2025
		D1.2	Engineering module for Higgs factory	>2026
Subtask 1.1.2: High compact calo		D1.3	Updated set of compact detection layers	2024
	M1.2		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 producted 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

WP1 Milestones

Hadronic section with optical tiles

	Milestone	Deliverable	Description	Due date
Task 1.2: Hadronic section with optical tiles				
Subtask 1.2.1: AHCAL	M1.7		Concept for continuous readout	2024
	M1.8		First layer with continuous readout	2025
		D1.7	EM prototype demonstrating system aspects	2026
		D1.8	Full-size layer and multi-layer demonstrator	>2026
		D1.9	Engineering prototype	>2026
Subtask 1.2.2: ScintGlassHCAL	M1.9		cm-scale tiles	2024
		D1.10	15-layer EM module	2025
		D1.11	40-layer prototype	>2026

WP1 Milestones

Hadronic section with gaseous readout

	Milestone	Deliverable	Description	Due date
Task 1.3: Hadronic section with gaseous readout				
Subtask 1.3.1: T-SDHCAL	M1.10		Study of the impact of timing on PFA performance	2024
	M1.11		Specifications for first layers	2025
	M1.12		First T-SDHCAL layers	2026
		D1.12	40-layer prototype	>2026
Subtask 1.3.2: MPGD-HCAL		D1.13	Completion of 6-layer 20×20 cm^2 prototype	2024
	M1.13		Specifications for 50×50 cm^2 prototype	2025
	M1.14		Design of 50×100 cm^2 layers	2026
		D1.14	10-layers prototype (6L: 20×20 cm^2 +4L: 50×50 cm^2)	2026
		D1.15	3 100×100 cm^2 layers	>2026
Subtask 1.3.3: ADRIANO3	M1.15		Small-scale test layers	2024
	M1.16		Small-scale prototype	2025
		D1.16	Large-scale prototype & testbeam	2026

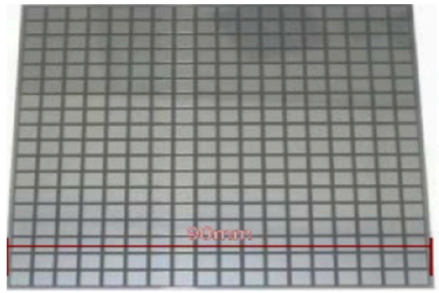
Extras

Project Information from Input Proposals

SiW ECAL

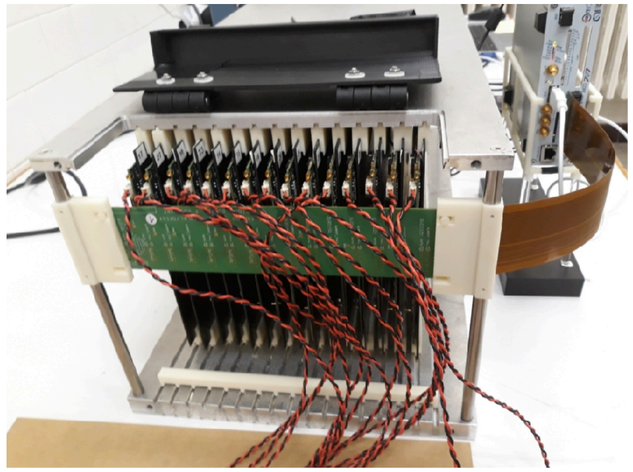
LLR, IJCLab, LPNHE, OMEGA, IFIC, Kyushu U, KEK, CERN

- Primary experimental context: Higgs Factories, possible near-term applications in LUXE and others
- A SiW-ECAL using silicon pad sensors with analog readout
  Builds on CALICE SiW ECAL technological prototype



- Main R&D topics
  - Extension of current prototype based on power pulsing
    to continuous operations: reduction of power consumption,
    of cooling
  - Study of the addition of timing, either dedicated layers or volume timing

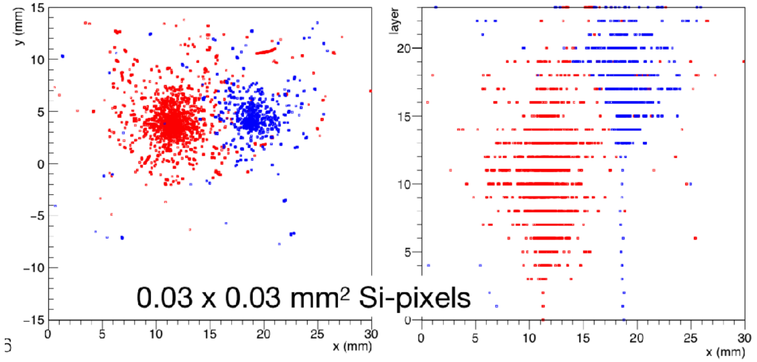
- 15 single-ASU prototype in beam in 2024
  current technology)
- Design for HF pilot module in 2025



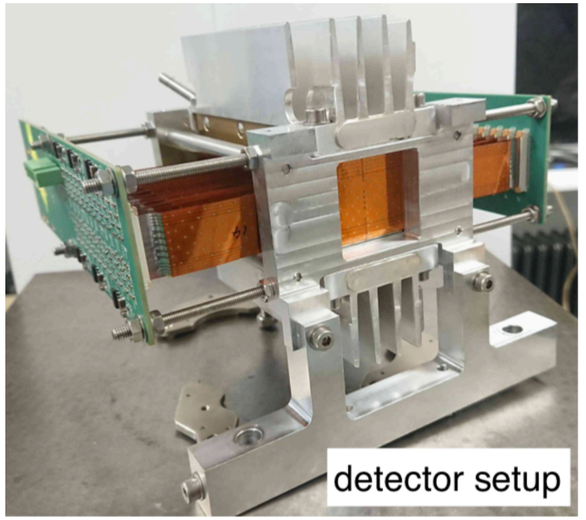
DECAL - Digital ECAL based on MAPS

HU Berlin, U B'ham, DESY-Z, HEPHY & NTU Athens, IC, Frankfurt, Rutherford, Sussex, Utrecht

- Primary experimental context: ALICE FOCAL, Higgs Factories
- A MAPS-based digital Silicon-Tungsten ECAL,
  building on current DECAL and EPICAL projects, partially integrated in CALICE



- Main R&D topics:
  - Full exploitation of existing EPICAL-2 prototype to evaluate performance
  - Establish requirements of a sensor dedicated for digital calorimetry
  - Design of next-generation sensor with calorimeter-specific optimisation (overlaps with DRDs 3, 7), and evaluation of sensor design
- Small-scale digital ECAL prototype in 2026, sensor submission early 2025

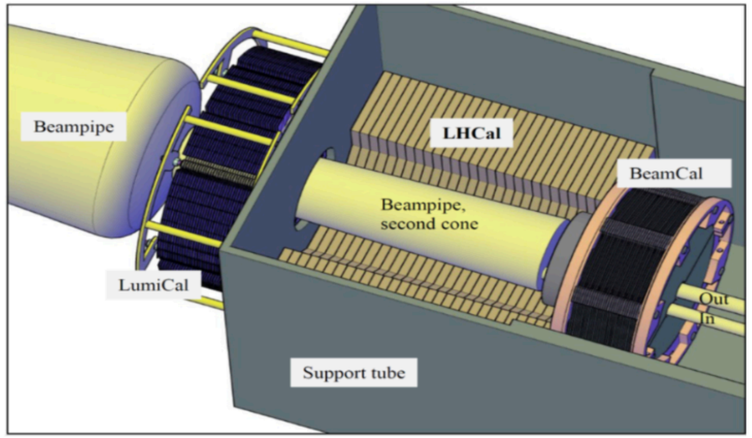


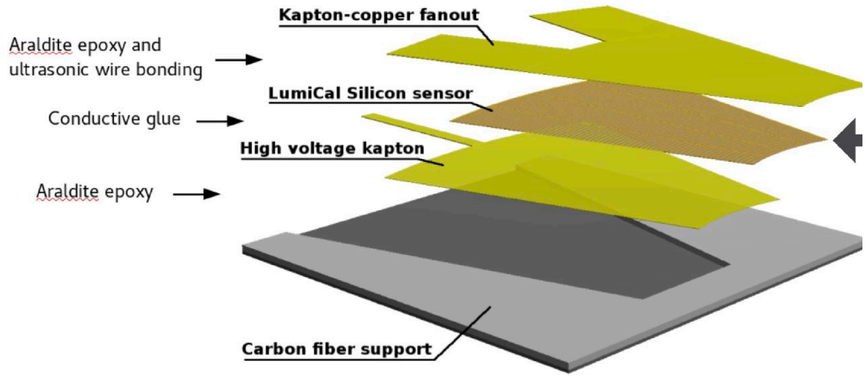
Note: Also relevant activities (and interest) at SLAC, U Oregon -
with connections to CERN

Highly Compact ECAL

TAU, AGH Cracow, U Warsaw, IFIC, ISS Romania

- Primary experimental context: Higgs Factories, possible near-term applications in LUXE
- Highly compact electromagnetic calorimeter with semiconductor sensors
  Builds on developments in FCAL
- Main R&D topics:
  - R&D on Si and GaAs sensors, including optimisation of readout integration
  - Development of thin conductive gluing
  - Development of readout electronics:
    - Readout of FLAME ASICs; development of FLAXE variant for LUXE
    - Wireless data transmission, joining WASAPT program
  - Mechanics with minimal tolerances
  - Simulation studies



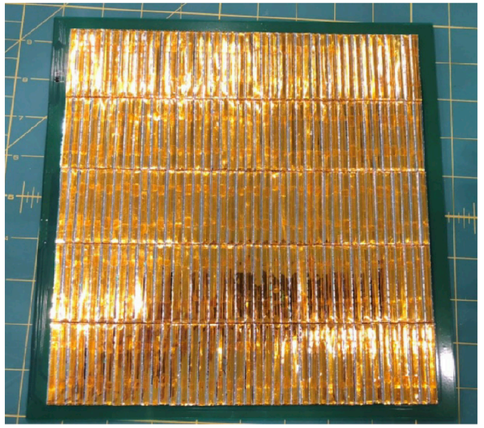


- Design of prototype in 2024, construction & performance studies in 2026
- Design for HF calorimeter in 2026

Highly Granular Scintillator-strip Calorimeter

U Tokyo, USTC, IHEP, Shinshu U, SJTU

- Primary experimental context: Higgs Factories
- A tungsten-scintillator-strip (with SiPM readout) calorimeter
  Building on CALICE technological prototype
- Main R&D goals for next period:
  - Engineering study for large-scale production
  - Timing performance - possibly by introducing dedicated timing layer(s)
  - Scintillator material - also extending to new ideas such as quantum dot material
  - Scintillator strip design
  - Active cooling system
  - Mechanical structure and services
  - Electronics - including low-power readout ASIC
  - Trigger-DAQ system - studied for Circular Colliders
- Construction of a new prototype as main deliverable



MPGD-based Hadronic Calorimeter

INFN & U Bari, Weizman Inst.

- Primary experimental context: Muon Collider
- Inspired by CALICE DHCAL & SDHCAL
- Using MPGDs (examples uRWELL, resistive Micromegas) for higher-rate environments
- Already ongoing activities: testing of detectors, test of a small calorimeter prototype with up to 6 GeV pions in 2023
- Main R&D topics
  - Simulation for HCAL design definition
  - Construction of a prototype with 50 x 50 cm^2 active layers, further extensions
  - Test beam campaigns

- NB: At the moment prototypes do not have integrated electronics: R/O at detector edges

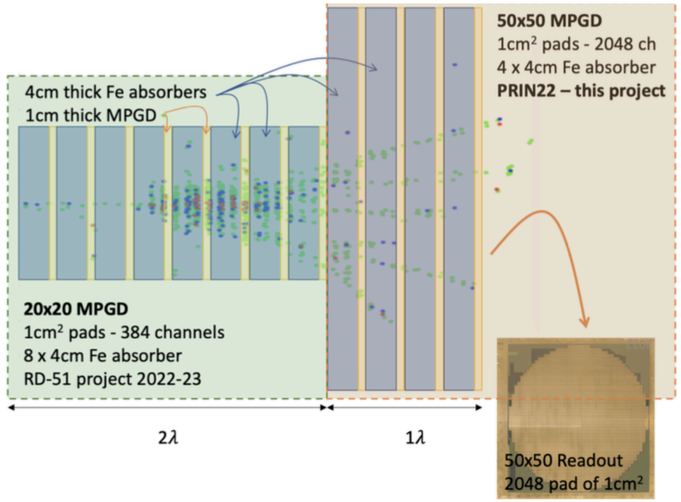
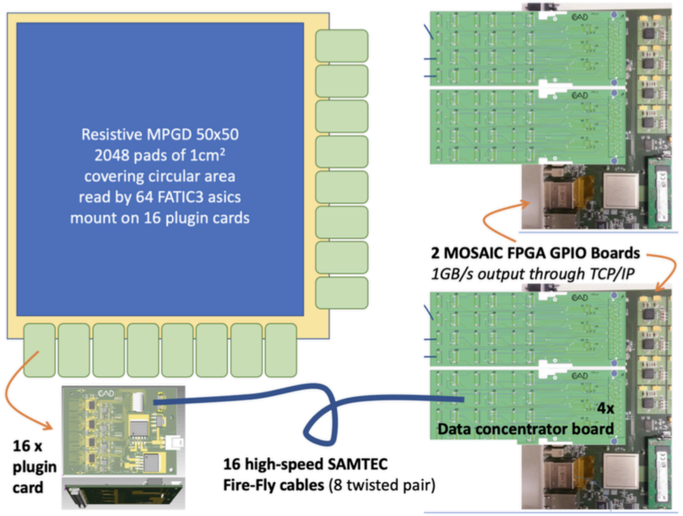


Fig. 2.4: Layout of the HCAL prototype with 3λ depth. The first 2λ is made of the 20x20cm² prototype developed in the RD-51 project in 2022, while the last λ necessary to contain longitudinally (95%) protons and pions of 1-6 GeV is made of 50x50cm² detectors developed in this project.



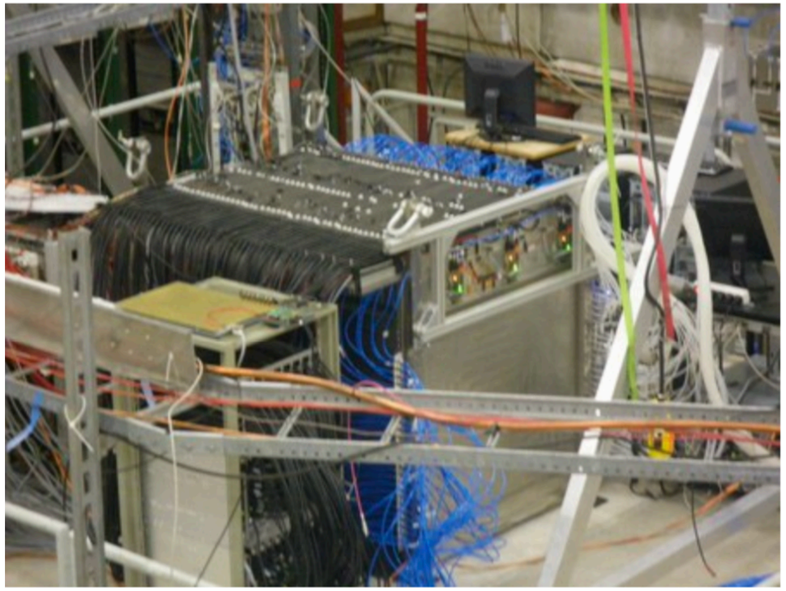
Frank Simon (frank.simon@kit.edu)

T-SDHCAL

IP2I Lyon, CIEMAT; VUB, OMEGA, U Cordoba, Yonsei Cancer Center, GWNU, SJTU, U Tunis El Manar

- Primary experimental context: Higgs Factories
- A RPC-based semi-digital HCAL with timing capability
  Builds on CALICE SDHCAL technological prototype
- Main R&D directions
  - Simulation studies extending to time information
  - Study and development of cooling and cassette concepts
  - Fast timing electronics
  - Development of DAQ system
  - Construction of detector units, validation in beam tests

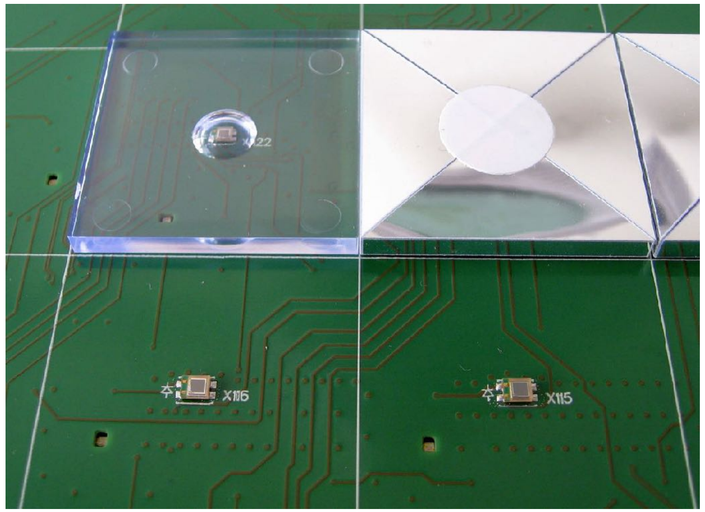
- Until 2026: Complete initial R&D steps to propose T-SDHCAL concept for circular HF



SiPM-on-Tile AHCAL

DESY, U Göttingen, U Hamburg, U Heidelberg, KIT, U Mainz, FZU Prague, OMEGA

- Main experimental context: Higgs Factories
- SiPM-on-tile / steel HCAL
  Builds on CALICE AHCAL Technological Prototype



- Main R&D topics:
  - Extension of current detector concept to circular colliders with continuous readout
    - evaluate consequences of higher data rate
    - re-evaluate need for cooling
    - re-optimisation of detector to ensure optimal performance while respecting new constraints
- Corresponding hardware development: ASICs (KLAuS, OMEGA), HBU and interfaces, mechanical and thermal design; scintillator geometry

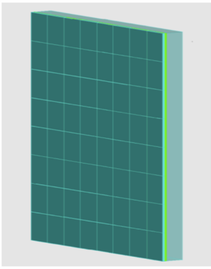
- First layers for new system design in 2026, EM stack with ~15 layers ~ 2029

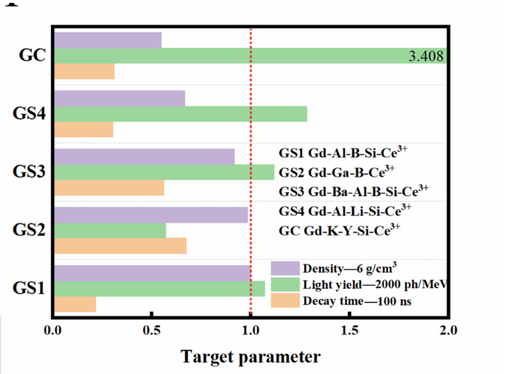
Highly Granular HCAL with Glass Scintillator Tiles

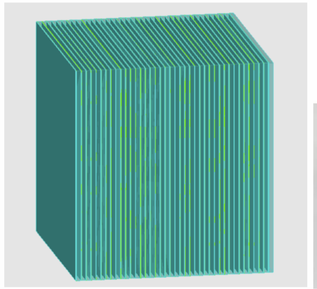
IHEP

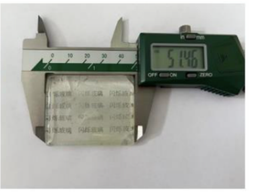
- Primary experimental context: Higgs Factories
- A variation of the CALICE AHCAL concept: Using glass scintillator tiles instead of plastic
  - Increased sampling fraction - with the potential for improved energy resolution

- Main R&D directions:
  - R&D of scintillator material - main targets: high density, high light yield, low cost
  - Simulation studies of hadronic performance: single particles, jets
  - Development of modules:
    - setup for characterization,
    - EM prototype ~2025
    - HCAL prototype ~ 2027







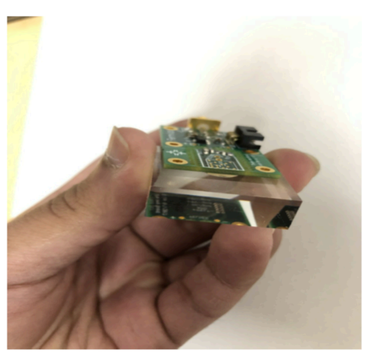


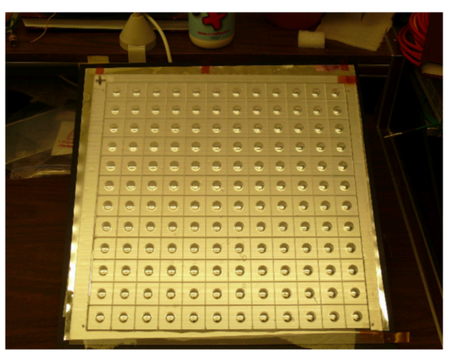
ADRIANO3 - Triple Readout Calorimeter

Beykent, U Iowa, NIU, INFN; ANL, Fairfield U, U Tokyo, Fermilab, Shinshu U, U Kansas

- Primary experimental context: REDTOP
- Extension of ADRIANO2 (fully active granular dual readout calorimeter) to three readout modes to achieve 5D shower measurement, disentangling the neutron component of the shower. Technologies:
  - High-density glass as Cherenkov Medium (and absorber)
  - Plastic scintillator tiles
  - RPCs with cm^2 pad readout
- Key R&D goals
  - optimization of the construction technique in terms of:
  - light yield, RPC efficiency, timing resolution, and cost
  - Test layers in 2024, small-scale prototype 2025
  - Larger-scale prototype 2026-2027
- Plans to use ultrafast ASICs for RPC readout Source (DRD7) may need discussion

Initial focus on optical materials and RPCs:
Track 3 as home?

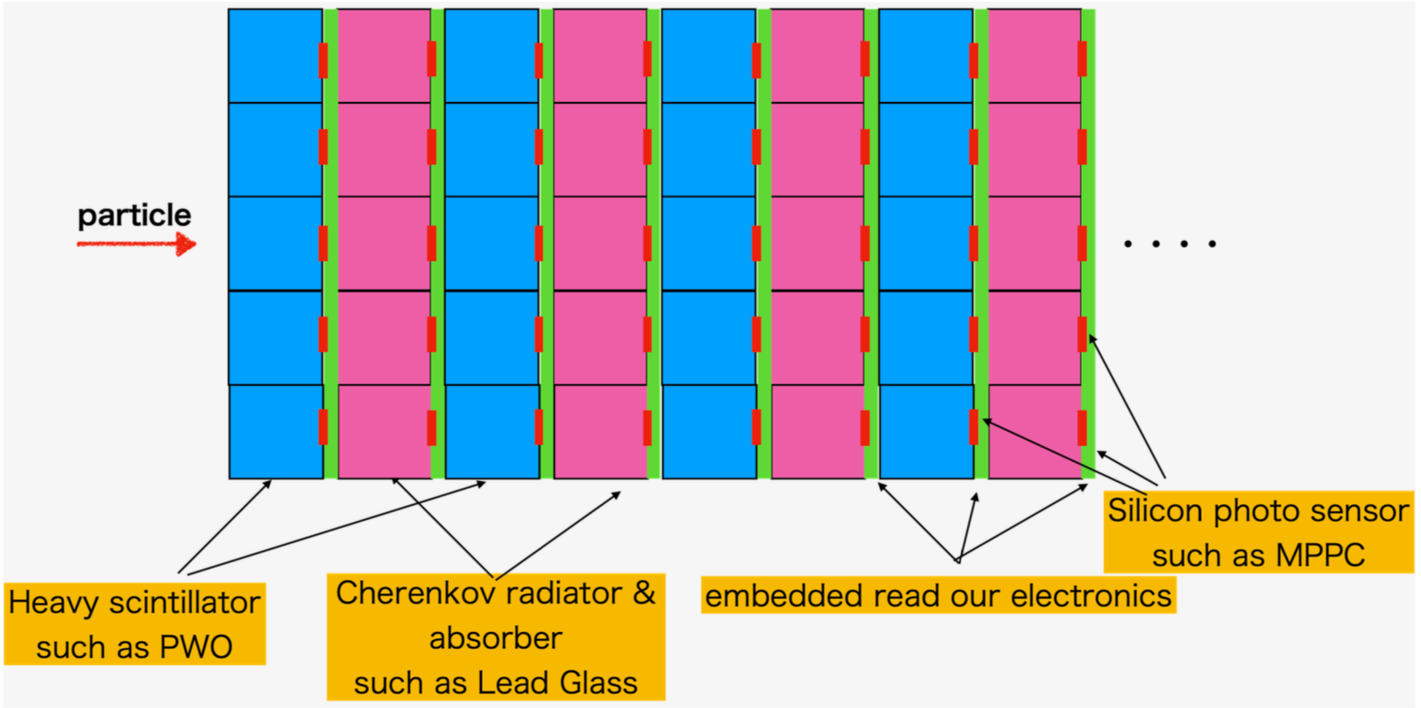




Double Readout Sandwich Calorimeter

Shinshu U

- Primary experimental context: Higgs Factories
- A concept for an (almost) fully active hadron calorimeter
  - Alternating layers of heavy scintillator (PWO) and Cherenkov medium (lead glass)
    Each read out by embedded SiPMs
- Currently studied in simulations only on the system level, studies of individual prototype cells in progress
- Goal: construction of up to 5 layers in 2024, a 20 layer prototype in 2026



Initial focus on optical materials and RPCs:
Track 3 as home?

Calorimeter ASICs

OMEGA, AGH Krakow, CEA IRFU

- An overarching proposal for the further development of the ASIC family currently in use in highly granular calorimeters. Not just Track 1, but clearly highly relevant here.
  - Builds on the experience in CALICE

- The goal is to develop ASICs than can serve most different input elements in use in DRD6:
  Silicon, gas detectors, scintillators (crystals, tiles, fibers -> SiPM readout), liquid Argon
  - A central goal: reduction of power consumption by ~ 1 order of magnitude compared to HGCROC as current state-of-the-art

NB: Proponents (and project-specific developments) in part also included in other input proposals.

Not in Track 1, but as a transversal activity!

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