

REPORT FROM WP1 PARALLEL SESSION

M.C FOUZ

DRD6 COLLABORATION MEETING AT CERN

11 APRIL 2024

CAVEAT






Many interesting things and very difficult to summarize every thing in less than 20 minutes

This talk represents "my view" and "my interpretations"






Sorry to the speakers for the bias and any possible error/misinterpretation

Thanks to all the WP1 speakers for the very nice presentations

ECAL TALKS

09:00 → 10:30	WP1 - Parallel session 1
09:00	SiW-ECAL: Silicon Tungsten electromagnetic section Speaker: Vincent Boudry (LLR, CNRS, École polytechnique, Institut Polytechnique de Paris)  2024-04-10@DRD6_...
09:20	Highly compact calorimeter, electromagnetic forward section Speakers: Adrian Irlas (IFIC CSIC/UV), Yan Benhammou (Tel Aviv University (IL))  april24pptx.pdf  april24pptx.pptx
09:40	DECAL: CMOS/MAPS tungsten electromagnetic section Speaker: Jim Brau (University of Oregon (US))  DRD6-DECAL-brau.p...
10:00	ScECAL: Scintillating plastic strips Tungsten, electromagnetic section Speaker: Wataru Ootani (ICEPP, University of Tokyo)  DRD_ScECAL.pdf

HICAL TALKS

11:00 → 12:30	WP1: Parallel Session 2	503/1-001 - Council
11:00	AHCAL: Scintillation plastic tiles and steel hadronic section Speaker: Frank Simon (KIT - Karlsruhe Institute of Technology (DE))  DRD6_WP1_AHCAL....	
11:18	ScintGlassHICAL: Heavy glass tiles and steel hadronic section Speaker: Yong Liu (Institute of High Energy Physics, Chinese Academy of Sciences)  2024_0410_DRD6_...	
11:36	T-SDHCAL: Resistive plate chambers and steel hadronic section Speaker: Mary-Cruz Fouz Iglesias (CIEMAT - Centro de Investigaciones Energéticas Medioambientales y Tec. (ES))  TSDHCAL_April202...	
11:54	MPGD-HGCAL: Multipattern gas detector and steel hadronic section Speaker: Luigi Longo (Universita e INFN, Bari (IT))  MPPG-HICAL-DRD6....	
12:12	ADRIANO3: Resistive Plate Chambers + Scintillator Plastic Tiles/Heavy Gralls hadronic section Speaker: Burak Bilki (Beykent University (TR), The University of Iowa (US))  DRD6-CERN202404...	

Tungsten absorber + some detector

Silicon detectors or Scintillators

Steel absorber + some detector

Except ADRIANO3

Gaseous detectors or Scintillators

R&Ds at different stages. From first designs towards very advanced prototypes
Some commonalities and possible synergies between different tasks



Physical (2005-11)

- 1x1 cm² on 500μm 6x6 cm² Pad glued on PCB Floating GR
- x 30 layers (10k chan).
- External readout
- Proof of principe

Technological (now)

- Embedded electronics
 - Power-Pulsed, Auto-Trig, delayed RO
 - S/N = (MPV/σ_{Noise}) ≥ ~12 (trig)
- Compatible w/ 8+ modules-slab
- 5x5 mm² on 320-650μm 9x9 cm² x 26-30 layers
 - 8k (slab) ~ 30k (calo) channels

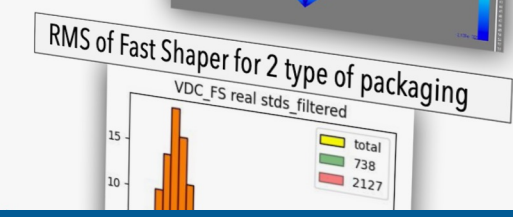
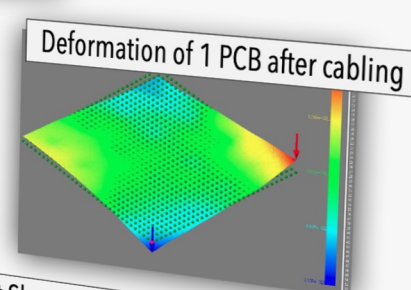
Pilote → **Full Detector**

- 1M → 70M channels
- on 750μm 12x12 cm² 8" Wafers?
- Pre-industrial building
- Full integration (> cooling)
- Final ASIC

DRD6 | WP1 T1.1 SiW-ECAL | CERN, 10/04/2024

New hardware for the SiW-ECAL

- 30 PCB of new type FEV2.1 have been produced
- 1st batch of 4 cabled for tests
 - 1 equipped with 4 babywafers for HV test
 - Still needs adaptation of SIboard for HV supply (on-going)
 - Mechanical test made at IFIC Valencia
 - Not all satisfactory (flatness ±200μm in the corners after the cabling involving heating at 300°C); further investigation on the cabling process foreseen
- Testing of Skiroc2 ASICs:**
- ~ 1/3 of ASICs tested thoroughly on dedicated bench at Omega lab prior to soldering on PCB's
 - Statistical analysis on-going; testing of the rest will resume soon.
 - 64 (4x16) mounted on the FEV2.1
 - Performances (noises, thresholds, ...) will be compared with bench



SiW-ECAL

Power distribution dedicated for LONG SLAB

Expected results

In the electrical long SLAB, 8 boards are chained and due to resistivity of layer per board on analog 3.3V, we measure voltage drop along the long SLAB coupled with bandgap distribution.

→ We decide to generate local power supply with LDO (Low Drop Out) to cancel voltage drop and reduce common noise.

ASU* (Active Sensor Unit)

Filter to generate local amplifier power supply



Beam Tests and Planning for 2024

First CALICE/DRD6 beam tests

- Initially scheduled for June at DESY
- To be moved in Fall 2024

Reason: careful revisitation of the gluing (hybridization) procedure:

- Deformation of the FEV under
 - Heat : expected
 - Humidity ? Not expected
- Need to understand before gluing expensive sensors on them

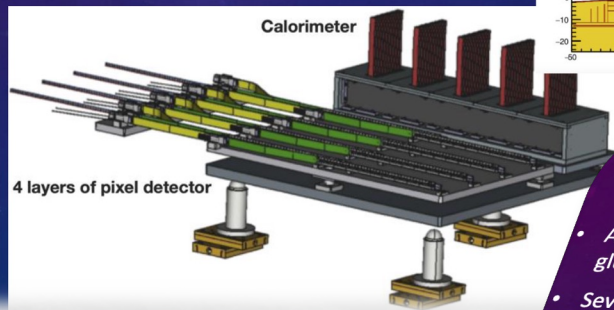
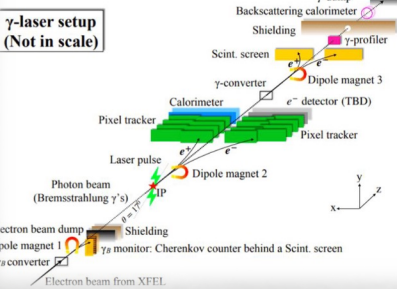
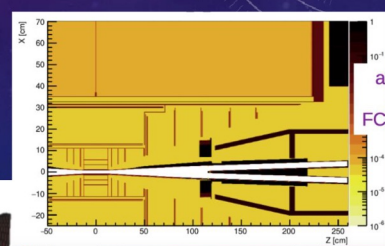
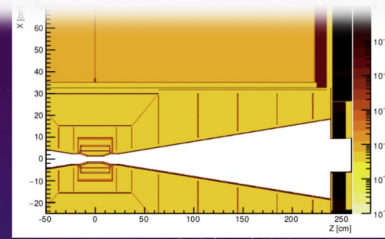
Check Yan's presentation
(CALICE + LUXE > DRD6 collab)

HIGHLY COMPACT CALORIMETER

NEED FOR COMPACT CALORIMETER

1 mm between W layers

- Compact calorimeter is interesting in :
 - Linear/circular/asymmetric collider to measure the luminosity
 - In LUXE, to measure the number of positrons and their energy spectrum in the e- laser interaction

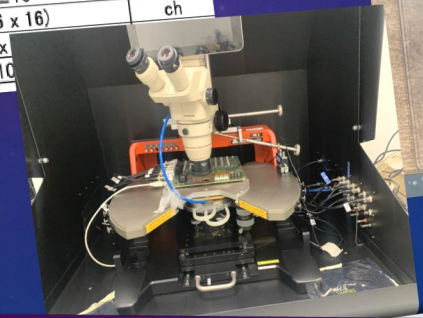
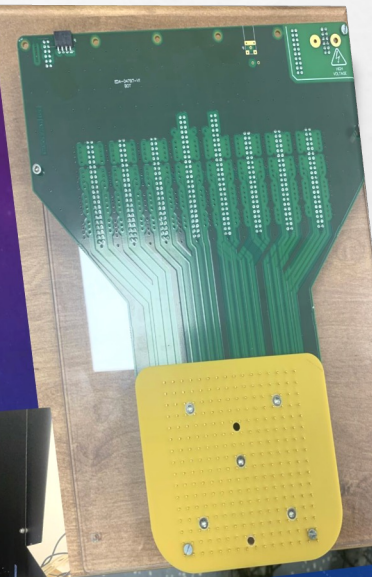


Common challenges with SiW-ECAL

SENSORS AND PROBE STATION

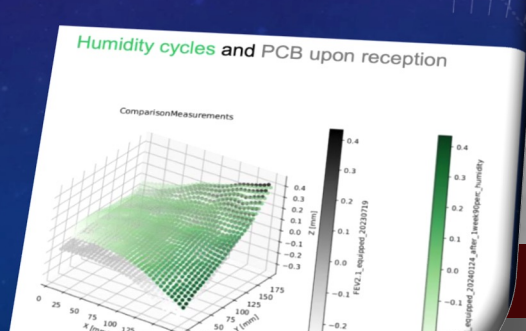
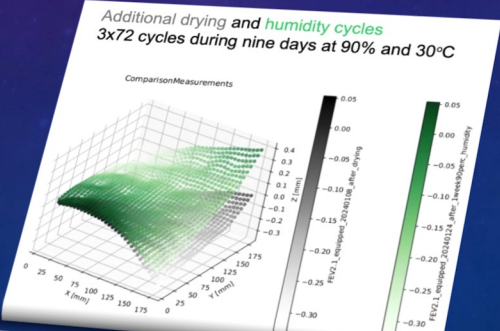
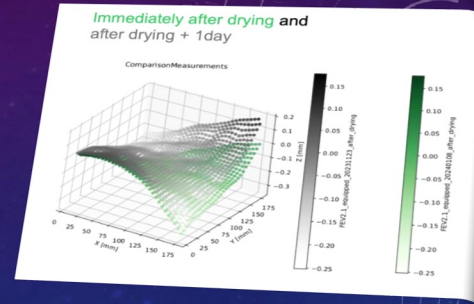
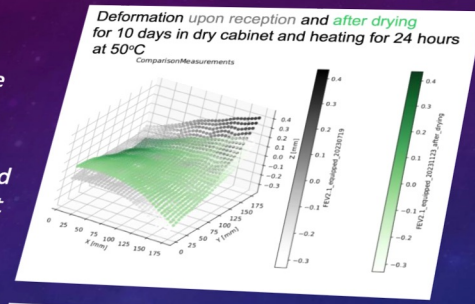
- 90 CALICE sensors received from Hamamatsu. 320 um thickness, 16x16 pads (5.5x5.5 mm²)
- Labeled and stored in dry cabinet with membrane boxes

Parameter	Rating	Unit
Device type	P+ PIXEL on N substrate	
Chip size	89700 ± 40 x 89700 ± 40	μ m
Active area	88480 x 88480	μ m
Chip thickness	320 ± 15	μ m
Number of PIXELs	256(16 x 16)	ch
PIXEL pitch	5530 x	
PIXEL GAP	10	



IFIC

- All the sensors will be sent to IFIC to be glued to a flexible PCB
- Several challenges in conductive gluing/hybridization procedure are shared between SiWECAL and the highly compact calo
- IFIC is leading the R&D studies on gluing/hybridization
- R&D on rigid PCB hybridization in collaboration with IJCLab



DECAL: CMOS/MAPS TUNGSTEN ELECTROMAGNETIC SECTION

The Two Projects

7 μm spatial resolution

NAPA-p1 at SLAC

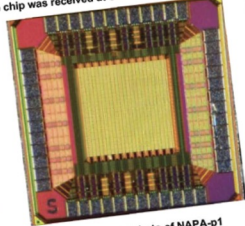
DECAL prototype reality: EPICAL-2

- 24 layers, each
- 3 mm W / 2 ALPIDE CMOS
- 3 x 3 cm² active
- 1M (29.24 x 26.88 μm²) pixels
- ultra-thin flex cables (LTU Kharkiv)
- compact design: expect $R_M \approx 11$ mm

Very successful DESY beam test
[JINST 18 (2023) 01, P01038]

Specification	Simulated NAPA-p1
Time resolution	0.4 ns-rms ✓
Spatial Resolution	7 μm ✓
Noise	< 30 e-rms ✓
Minimum Threshold	200 e- ✓
Average Power density	< 20 mW/cm ² for 1% duty cycle ✓

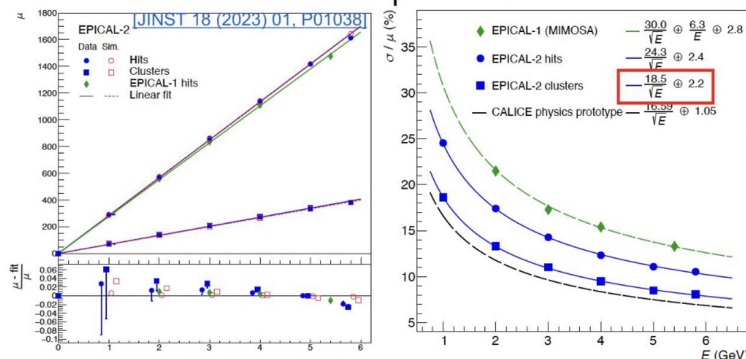
The chip was received at SLAC in September 2023



Acknowledged CERN WP 1 excellent collaboration NAPA-p1 used masked development and optimization and was fast shared run

Energy resolution

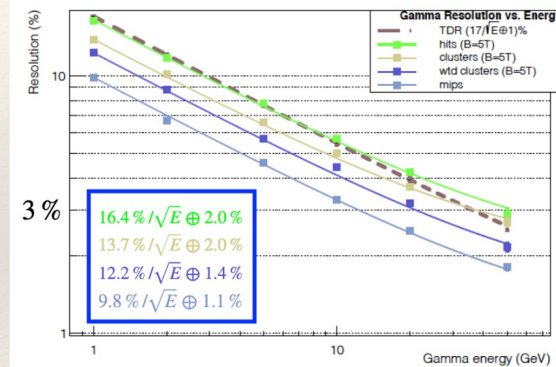
Calorimetric performance



hits	a (%)	b (%)	c (%)
data	24.30 ± 0.03	2.41 ± 0.08	-
sim ($E_{\text{spread}} = 0$)	21.27 ± 0.06	2.30 ± 0.16	-
sim ($E_{\text{spread}} = 158$ MeV)	21.58 ± 0.25	1.8 ± 0.5	15.1 ± 0.4
clusters	a (%)	b (%)	c (%)
data	18.54 ± 0.02	2.17 ± 0.05	-
sim ($E_{\text{spread}} = 0$)	14.10 ± 0.04	2.52 ± 0.07	-
sim ($E_{\text{spread}} = 158$ MeV)	14.57 ± 0.21	1.96 ± 0.26	14.93 ± 0.23

- Good standard performance
- Better resolution from clusters
- Uncertainties in beam energy spread

Gamma Resolution vs. Energy (B=5T)



Cluster counting with weighting yields good resolution

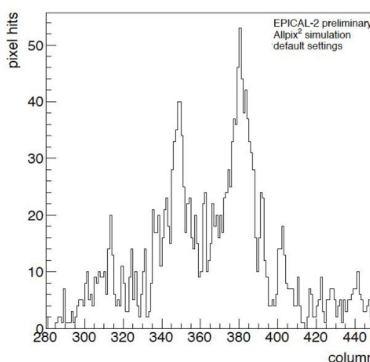
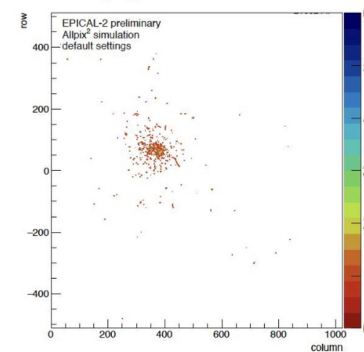
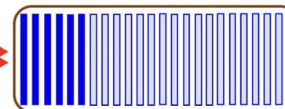
Multi-shower separation

Benefit of ultra-high granularity

separation power

- large energy difference
 - electrons close together
- challenging case

250 GeV electron
30 GeV electron

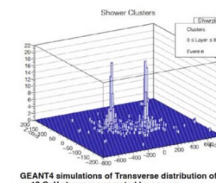


Simulation

MAPS for ECal

Fine granularity allows for identification of two showers down to the mm scale of separation

- SiD detector configuration with 25x100 μm² pixel in the calorimeter at ILC
- With no degradation of the energy resolution
- The design of the digital MAPS applied to the ECal exceeds the physics performance as specified in the ILC TDR
- The 5T magnetic field degrades the resolution by a few per cent due to the impact on the lower energy electrons and positrons in a shower
- Future planned studies include the reconstruction of showers and τ within jets, and their impact on jet energy resolution



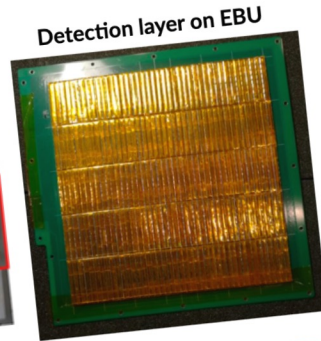
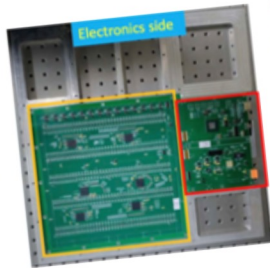
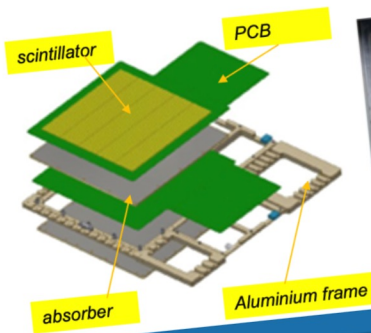
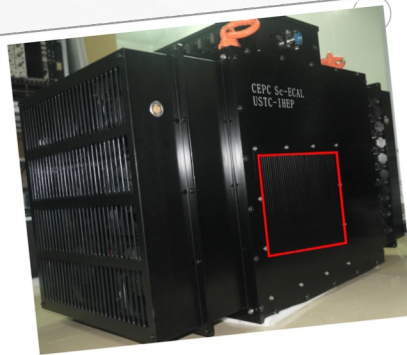
Two 10GeV showers separated by 1 cm

ScW-ECAL: SCINTILLATING PLASTIC STRIPS

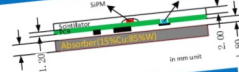
Technological Prototype

ScW-ECAL technological prototype

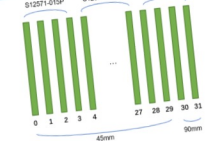
- Full layers (32 layers)
- Detection layer of 210x225mm² with 210 scintillator-strips
 - 30 layers with single SiPM readout
 - 2 layers with double SiPM readout
- Absorber plate (3.2mm-thick 15%-85% Cu-W alloy)
- Total material thickness 23.4 X₀



Scintillator-SiPM readout scheme



Sensitive layer arrangements



Wataru OOTANI "ScW-ECAL: Scintillator-strip Tungsten Electromagnetic Calorimeter", DRD6 Collaboration Meeting, CERN, April 1

Combined beam tests with CEPC AHCAL
SPS October 16 – Nov 2 2022
SPS April 26-10 May 2023
PS May 2023

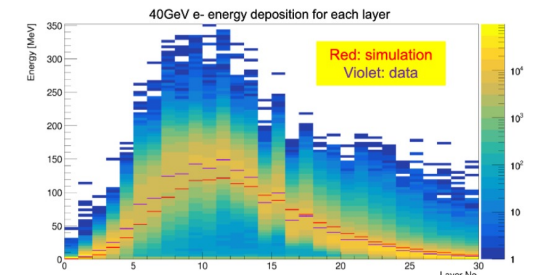
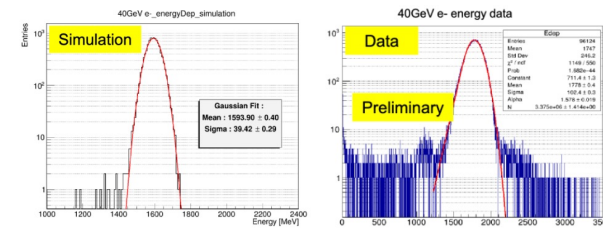
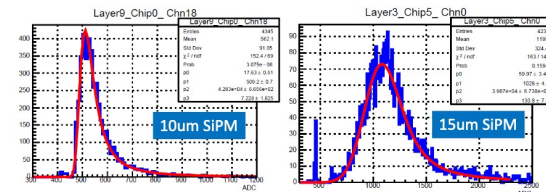
Beam Tests at CERN

• Calibrations

- Pedestal
- SiPM gain with LED
- Intercalibration between high-gain and low-gain modes
- MIP calibration with 100GeV muons

• Beam data analysis in progress

- Energy response, shower study
- Dedicated simulation with digitisation
- Comparison between data and simulation



AHCAL: SCINTILLATION PLASTIC TILES AND STEEL HADRONIC SECTION

AHCAL in DRD6

Overall Context



- Building on a mature technology:
 - SiPM-on-tile AHCAL prototype with 22k channels, 0.5 m³ and 38 layers constructed 2017/18, operated in several beam tests
 - SiPM-on-tile section of CMS HGCal using this technology - significant synergies, profit from prototyping and construction experience.

Hope to connect to AHCAL studies of CALICE and CMS HGCal partners in the US

- Plans for DRD6: Further develop the technology in the Higgs Factory context.
Main focus: system aspects.
 - Address specifics of circular colliders - current prototype uses linear collider readout scheme
 - Develop alternative scintillator integration concepts and materials: Mass production, cost reduction

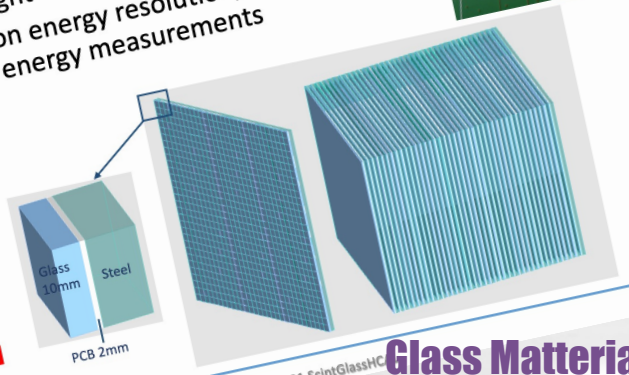
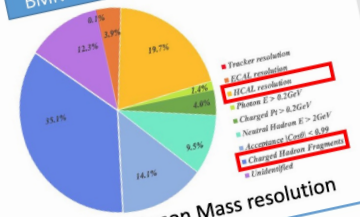
SCINTGLASSHCAL: HEAVY GLASS TILES AND STEEL HADRONIC SECTION

ScintGlassHCAL overview

- ScintGlassHCAL: PFA-oriented sampling hadron calorimeter
- A variant option of CALICE-AHCAL: scintillator-SiPM, steel
- Sensitive layer: dense and bright scintillating glass tiles
- Aim to further improve hadron energy measurements
- Major factor for precision jet energy measurements

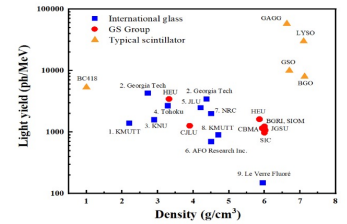
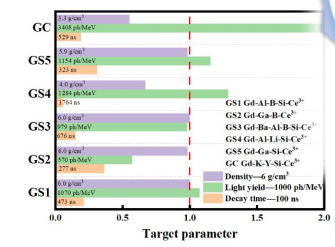
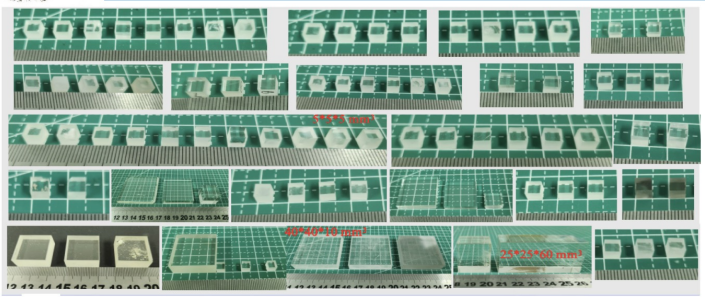
"Stitch-on-Tile" design for CALICE-AHCAL

BMR factorization based on PFA



DRD6 Collaboration Meeting at CERN: WP1 ScintGlassHCAL Glass Materials R&D

Brief summary of glass R&D

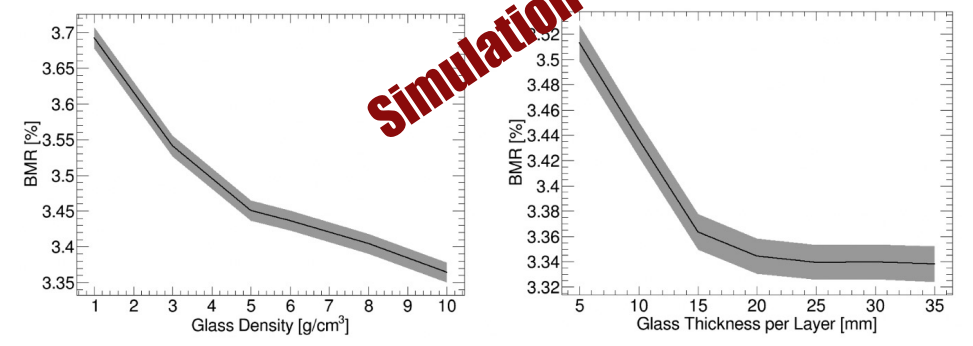


- Steady progress made: R&D based on five glass systems
- Promising performance of best glass samples
 - Close to the goals: i.e. 6 g/cc, 1000 photons/MeV, 100 ns
- For high-density scintillating glass, samples from GS collaboration currently take the lead in light yield



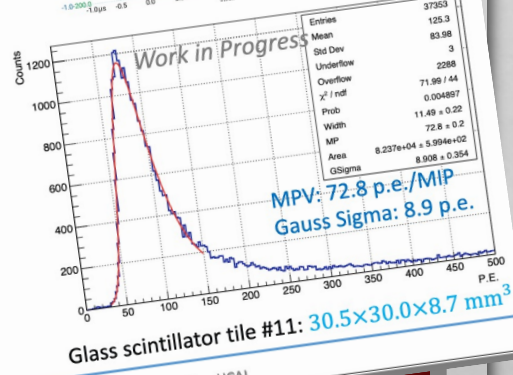
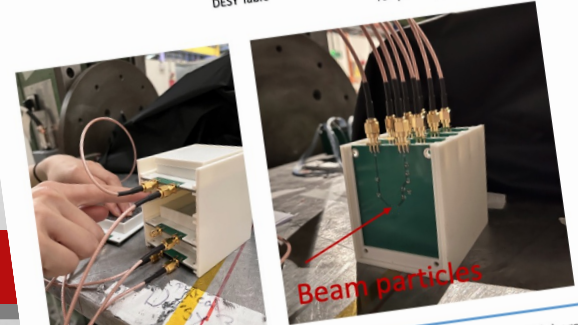
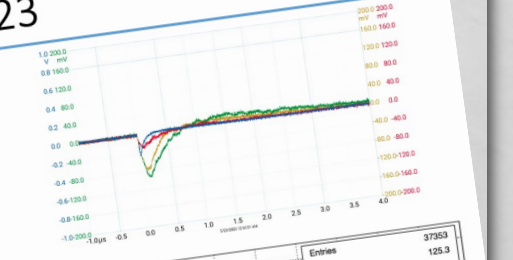
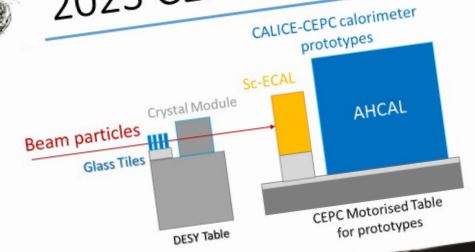
闪烁玻璃合作组
Glass Scintillator Collaboration

Jet performance: BMR vs. glass density/thickness



- BMR will be improved with higher density and thicker tiles
 - Guidance for the design glass tile: plateau regions ($\geq 5 \text{ g/cm}^3$, $\sim 15 \text{ mm}$)
- Technical limitations from glass production
 - Generally thicker or more dense tiles \rightarrow lower light yield

2023 CERN beam test in 2023



DRD6 Collaboration Meeting at CERN: WP1 ScintGlassHCAL

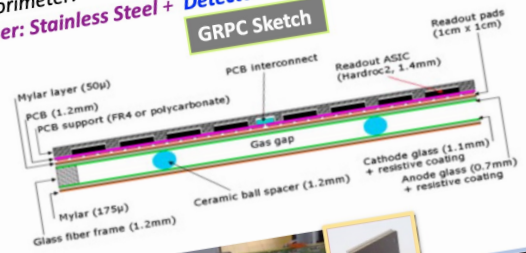
SEMIDIGITAL HCAL

CALICE SDHCAL Since 2012



SDHCAL - Semi-Digital Hadronic CALorimeter

Sampling calorimeter:
Absorber: **Stainless Steel** + Detector: **Glass Resistive plate Chambers**



- 48 layers ($\sim 6\lambda_1$)
- 1 cm x 1 cm granularity
- 3-threshold, 500000 channels
- Power-Pulsed
- Triggerless DAQ system
- Self-supporting mechanical structure

Published: [JINST 10 \(2015\) P10039](#)



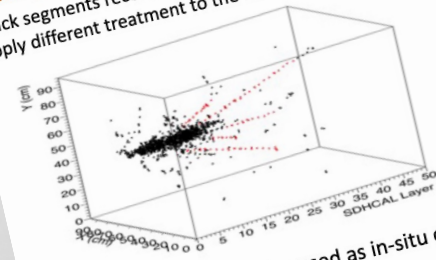
SDHCAL performance

$$E_{rec} = \alpha (N_{tot}) N_1 + \beta (N_{tot}) N_2 + \gamma (N_{tot}) N_3$$

α, β, γ are quadratic functions of N_{tot} . They are computed by minimizing:

$$\chi^2 = (E_{beam} - E_{rec})^2 / E_{beam}$$

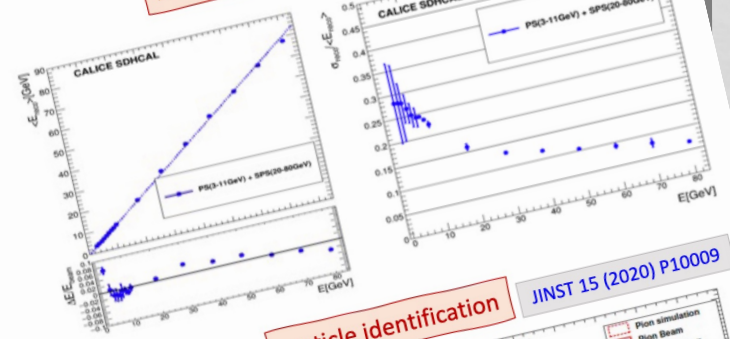
Hough-Transform
Track segments reconstruction using 3D-Hough Transform helps apply different treatment to the hits of these segments.



Track segments can also be used as in-situ calibration and monitoring tools

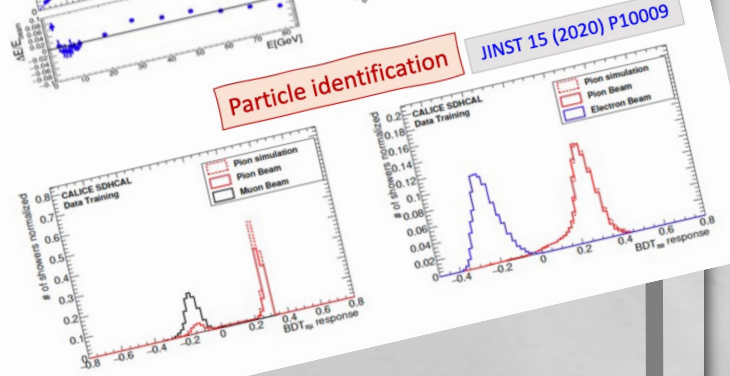
[JINST 12 \(2017\) P05009](#)

Energy reconstruction



[JINST 11 \(2016\) P04001](#)
[JINST 17 \(2022\) P07017](#)

Particle identification



[JINST 15 \(2020\) P10009](#)

MPGD-HGCAL: MULTIPATTERN GAS DETECTOR

INFN MPGD prototypes

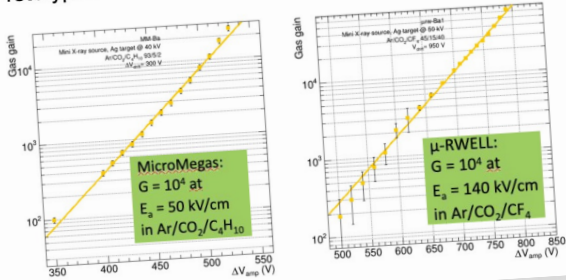
Prototypes produced and tested within **RD51 common project**:

- 7 μ -RWELL
- 4 MicroMegas
- 1 RPWELL

Detector design:

- Active area 20x20 cm², pad size 1x1 cm²
- **Common readout board**

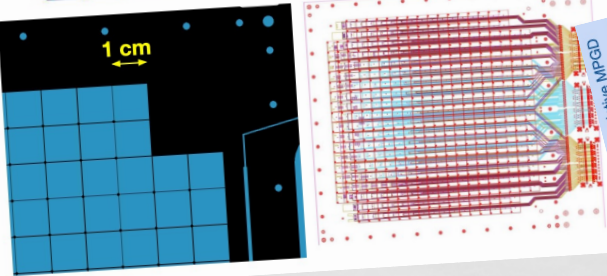
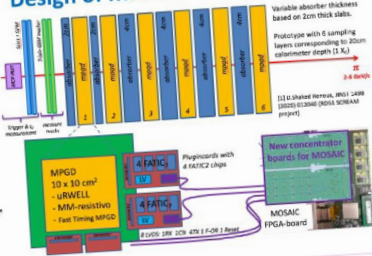
Prototype characterization performed in all the laboratories



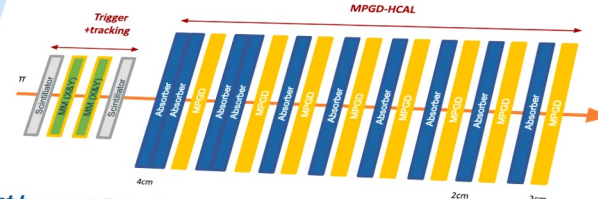
Development of Resistive MPGD Calorimeter with timing measurement (2021-2023)

- RD51 Institutes:
1. INFN sez. Bari, contact person: piet.verwilligen@ba.infn.it
 2. INFN sez. Roma III, contact person: mauro.iodice@roma3.infn.it
 3. INFN LNF Frascati, contact person: giovanni.bencivemi@lnf.infn.it
 4. INFN sez. Napoli, contact person: massimo.dellapetra@na.infn.it
- + Weizmann Institute of Science

Design of MPGD-based HCAL cell

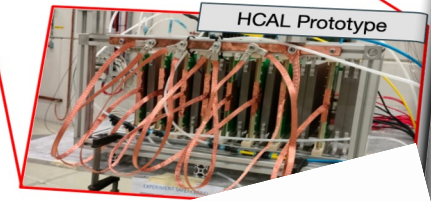
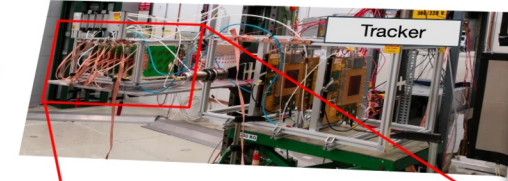


INFN Calorimeter prototype at PS test beam



Test beam at PS with calorimeter prototype (August-September 2023):

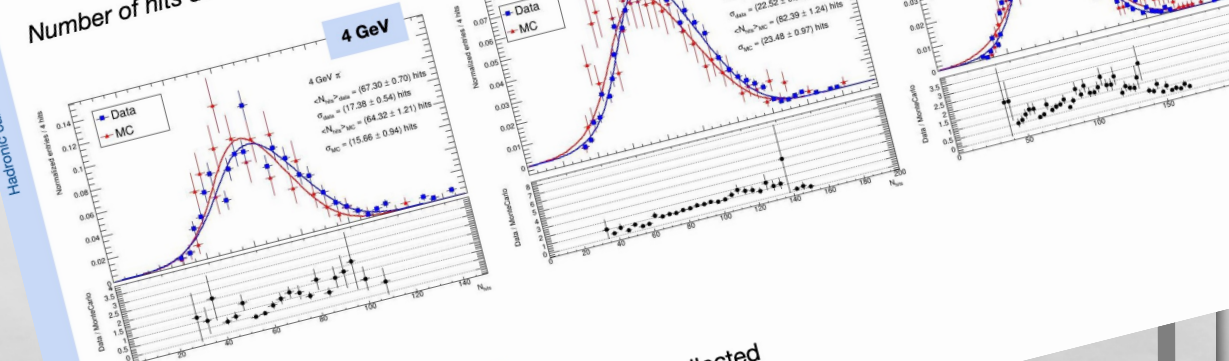
- Goal: **measuring** the energy resolution of a 1 λ calorimeter prototype with 1-10 GeV pions beam
- Developed **G4 simulation** for the **small prototype**, including a **digitization algorithm** to account for charge-sharing among adjacent pads and detector efficiency
- **Issue**: problematic electronics for the first 2 MPGD layers \rightarrow taken into account for data/MC comparison



INFN Calorimeter prototype at PS test beam

Event selection: events where pions start showering from the third layer

Number of hits distributions for MC and data at different pion energies



- **Good data/MC comparison**
- Ongoing studies to fully exploit all the data collected

ADRIANO3

ADRIANO3 Active Components

ABSORBER

- }

 - Cerenkov radiator: 3x3x2 cm³ lead-glass tiles (typical size)
 - Scintillator component: 3x3x 0.5 cm³ scintillating tiles (typical size)
 - Neutron component: 10x10x1 cm³ doped RPC
 - Tiles readout: on-tile sipm
 - RPC readout: pads

Mostly sensitive to EM component

Sensitive to charged component & neutrons thanks to high H2 content

ADRIANO2 - Only tiles, no RPC

ADRIANO2 R&D in T1604 Collaboration

Currently in the beam at Fermilab: 7 layer, ~5X0, 64 cells prototype, with Sampilc & petiroc readout (CAEN DT5550W)



xG. Blazey, A. Dychkant, M. Figora, T. Fletcher, C. Gatto, K. Francis, A. Liu, S. Los, M. Murray, E. Ramberg, C. Royon, M. Syphers, R. Young, V. Zutshi, C. Le Mahieu, J. Marquez, A. Mane, J. Elam, Z. Sheemanto

Development of Hybrid RPCs

Probing a hybrid readout where part of the electron multiplication is transferred to a thin film of high secondary emission yield material coated on the readout pad with the purpose of reducing/removing gas flow and enabling the utilization of alternative gases.

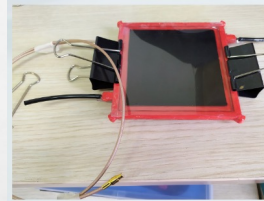
→ RPCs with functional anodes

Built several 10 cm x 10 cm chambers with single pad readout.

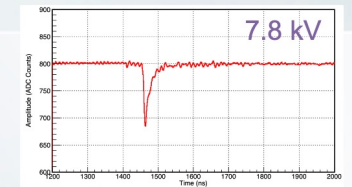
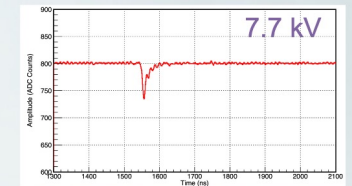
Coating of Al₂O₃ made with magnetron sputtering.

Coating of TiO₂ made with airbrushing after dissolving TiO₂ in ethanol.

RPCs obtain high efficiency at considerably lower high voltage settings.



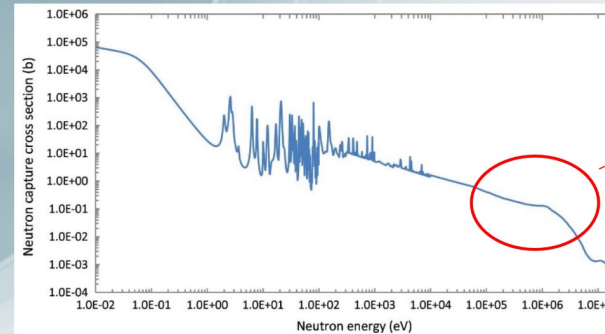
Cosmic muon response



Next Steps for ADRIANO3

→ RPCs with functional cathodes

Dope the cathode glass of one-glass RPCs with Gd to introduce the neutron capture functionality.



Region of interest for hadron calorimetry

Fig. 2. Capture cross section as a function of neutron energy for natural Gd (IRDF-1.0).

Timing in Calorimeters: 0.1–1 ns range

1 cm/c = 30 ps

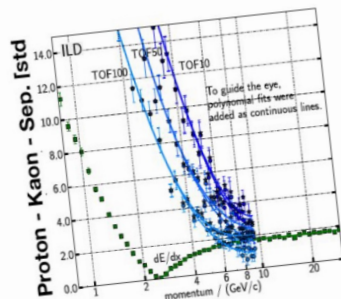
Recruiting in KIT, JGU, IJCLab, LLR and IP2I (Lyon)

Ease Particle Flow with ps ?

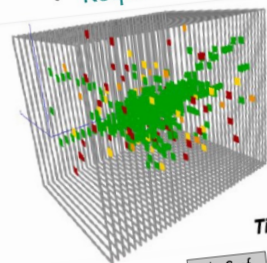
- Cleaning of late neutrons & back scattering (ns)
- Identify primers in showers
- Help against confusion better separation of showers
- Requires '4D clustering'

Particle ID by Time-of-Flight

- Complementary to dE/dx
- Here with 100 ps on 10 ECAL hits



S. Dharani, U. Einhaus, J. List



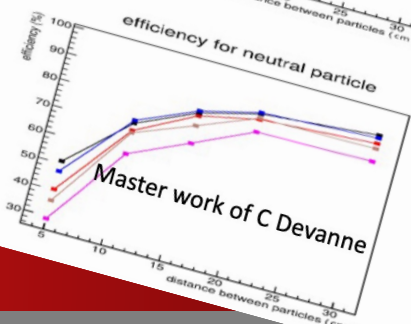
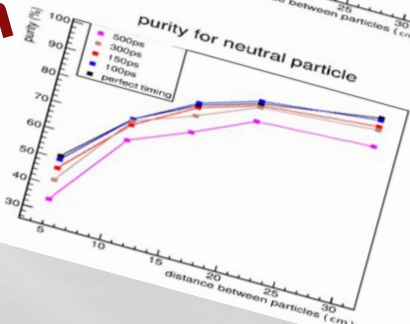
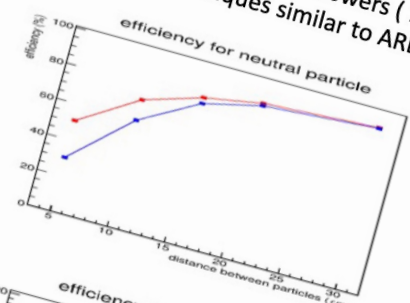
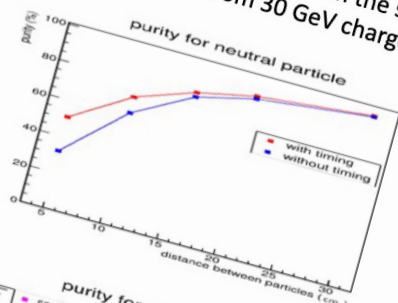
Ch. Graf

22/34

TIMING IS "COOL"

Improvements on shower separation when including timing

Including time information in the simulation to separate hadronic showers (10 GeV neutral particle from 30 GeV charged particle) using techniques similar to ARBOR's ones.



Simulation SDHCAL

Master work of C Devanne

[CLIC CDR: 1202.5940] adapted from L. Emberger

Vincent.Boudry@in2p3.fr

Calorimetry 4D for HET factories | Congrès LLR, 30/01–02/02/24

AND EVERYBODY WANTS TO BE COOL

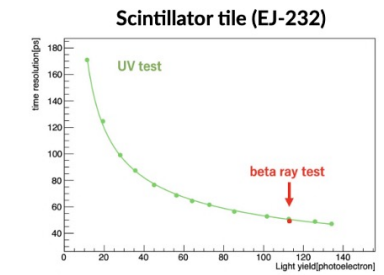
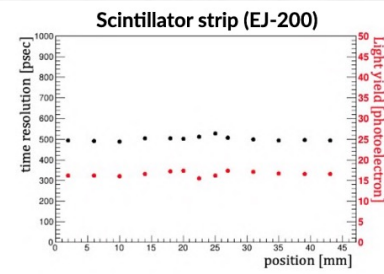
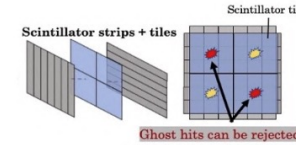
DRD6 AHCAL Work Plan

Activities & Task Sharing

- Build a small AHCAL prototype ("EM stack") with continuous readout and with hit timing capability - starting with small reconfigurable prototype in first 3-year period.

Timing performance: target timing resolution $\mathcal{O}(10\text{ ps})$

- Timing resolution of the current scintillator strip $\sim 500\text{ps}$ with 15p.e.
- Dedicated timing layer
 - Scintillator tile ($15 \times 15 \times 3\text{mm}^3$): $< 50\text{ps}$ with 100p.e.
 - mitigate ghost hit problem as a bonus
 - Cherenkov detector?
- Improved scintillator materials
 - Light yield, time constant, quantum dot technology
 - Even longer time constant to mitigate SiPM saturation?
 - in collaboration with WP3, DRD4, DRD5



SCW-ECAL

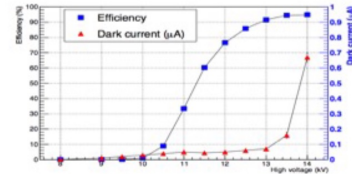
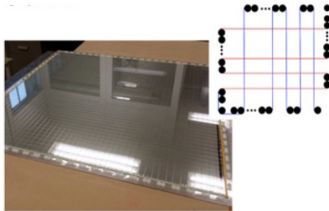
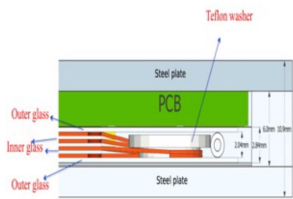
From SDHCAL to T-SDHCAL

The Detector

MultiGAP Glass RPC is an excellent candidate.

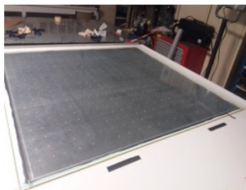
5-gap of 200 μm each separating glass plates of 250 μm thick can provide a time resolution of around 100 ps

The standard method to build MRPC is based on using fishing line



Threshold sets at 114 fC

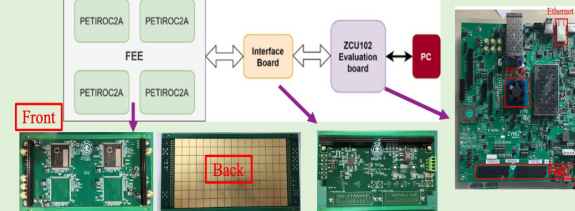
New and easy way of construction MRPC. Preliminary results show an efficiency $> 93\%$ with 5 gaps



Electronics Readout

Small ASU

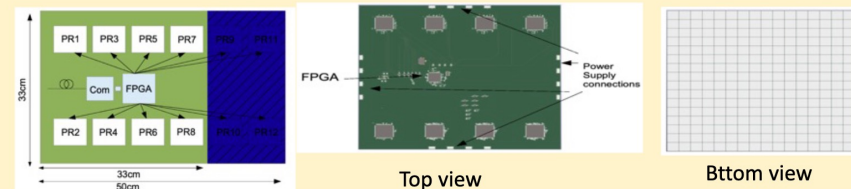
A board with 4 petiroc, 128 pads as well as the whole DAQ system was developed and being tested



- Front-End Electronics for MRPC readout with high timing resolution
- The system includes a front-end board (FEB), a detector interface card (DIF) and a data acquisition system (DAQ) based on ZCU102.

Large ASU

- Board with 8 (could be extended to 12) Petircoc2B ASICs
- Pads 2cm x 2cm, 256 channels
- Local FPGA (Xilinx Spartan-6 TQFP) embedded on board



AND THE COOLING IS ALSO IMPORTANT FOR CIRCULAR e+e- COLLIDERS

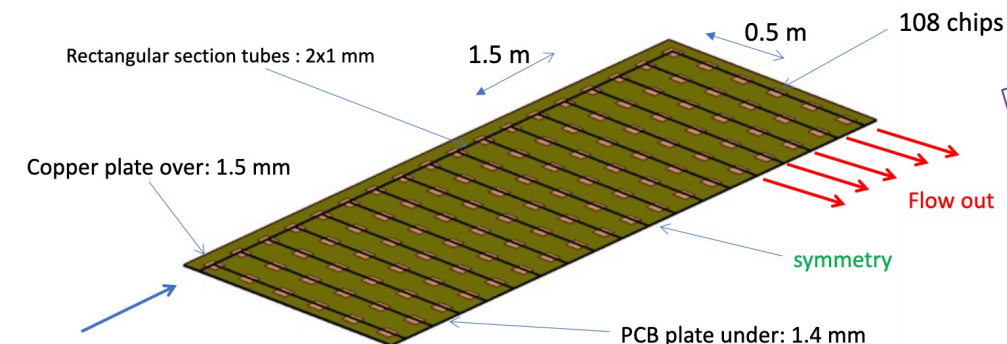
Large SDHCAL module

SDHCAL power consumption and cooling

The duty cycles of CEPC/FCCee are different from that of ILC and no power pulsing is possible. The power consumption is therefore increased by a factor of 100-200 with respect to ILC and active cooling is needed.

Lyon and Shanghai groups worked on a simple cooling system for SDHCAL based on using water circulating into copper pipes

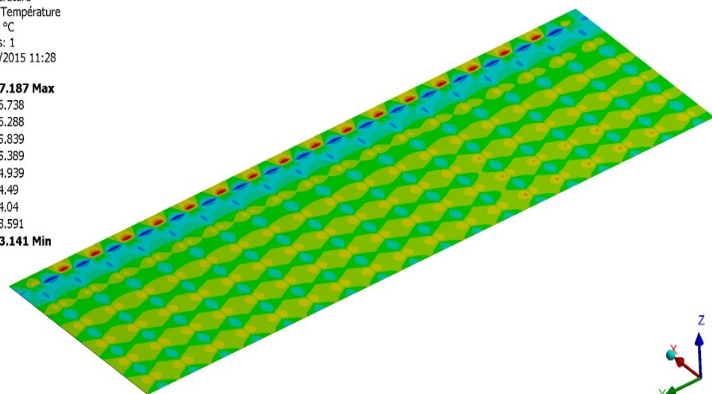
0.8 mW/chips with power pulsing → 80 mW/chips without power pulsing



Flow in

C: sans power pulsing
 Température
 Type: Température
 Unité: °C
 Temps: 1
 31/07/2015 11:28

27.187 Max
 26.738
 26.288
 25.839
 25.389
 24.939
 24.49
 24.04
 23.591
 23.141 Min



AHCAL

- Main items to study:
 - ⇒ Re-evaluate need for active cooling:
 - What would be the effect on energy resolution, PFA reconstruction, missing energy, tau ID, ...?
 - Can we avoid it by changing granularity, readout ASICs with lower power consumption?

SCW-ECAL

• Active cooling system

- Even with the advantage of the strip configuration for the power consumption, it would still be an issue for the continuous operation in circular colliders
- Active cooling system with minimal influence on the detector performance will be developed

FROM LINEAR TO CIRCULAR e+e- COLLIDERS IMPORTANT FOR CALICE DETECTORS

Linear → Circular Collider's Conditions

Linear (ILC, HL-ILC...)

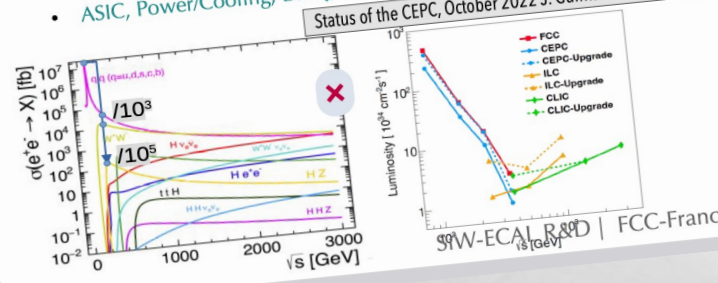
- 250 GeV (ZH), 365 GeV (tt), 500 GeV (ZHH) + [1000 GeV], $\mathcal{L} \sim \text{cst.}$
- Power pulsing : 5 [10–15]Hz × 1 [2] ms Power $\sim \mathcal{L}$.

More diverse et stringent conditions:

- 90GeV × 10⁷ fb × 5 · 10³⁶ cm² s⁻¹ (qq × 20,000 ILC @ 250)
- 150 GeV (WW) + 250 GeV (ZH) + 365 GeV (tt)
~10⁴ fb × 5 · 10³⁵ cm² s⁻¹ (qq × 5–10 ILC @ 250)

From Pulsed to Continuous operation

- Power = cst + conversion+RO × local rates ($P_{\text{conv}}+P_{\text{RO}} \sim 40\% P_{\text{ACQ}}$)
- ASIC, Power/Cooling, DAQ, Granularity, Precisions (E, t), New ideas...



HL-ILC:

- $\mathcal{L} \times 4 (6)$
- $N_{\text{bunches}} \times 2 : T_{\text{Train}} : 1 \rightarrow 2 \text{ ms}$
- $f_{\text{rep}} \times 2 (3) : 5 \rightarrow 15 \text{ Hz}$

Dominated by ACQ time:
P (~25μW/ch) × 6

HL-CLIC:

- $\mathcal{L} \times 2$
- $N_{\text{bunches}} \rightarrow : T_{\text{Train}} : 176 \text{ ns}$
- $f_{\text{rep}} \times 2 : 50 \rightarrow 100 \text{ Hz}$

Dominated by Set-up &
Conversion time: P (~82μW/ch) × 2

FCC-ee parameters	GeV	Z	WW	ZH	ttbar
\sqrt{s}		91.2	160	240	350-365
Luminosity / IP	10 ³⁴ cm ⁻² s ⁻¹	230	28	8.5	3000
Bunch spacing	ns	19.6	163	994	3000
"Physics" cross section	pb	35,000	10	0.2	0.5
Total cross section (Z)	pb	40,000	30	10	8
Event rate	Hz	92,000	8.4	1	0.1
"Pile up" parameter [μ]	10 ⁻⁶	1,800	1	1	1

Experimentally, Z pole most challenging

- Extremely large statistics
- Physics event rates up to 100 kHz
- Bunch spacing at 20 ns
 - "Continuous" beams, no bunch trains, no power pulsing
- No pileup, no underlying event ...
 - ...well, pileup of 2 × 10³ at Z pole

<https://indico.cern.ch/event/1064327/contributions/4893208/>
Mogens Dam @ FCC Week, 10/06/2022

DRD6 AHCAL R&D Questions

Towards Circular Colliders, Scalability & Mass Production

- The key next step for the AHCAL: Establish capability for running at circular collider (=FCC-ee) conditions on the system level.
- The main aspect: Continuous readout, no power pulsing.
- Main items to study:
 - ⇒ Re-evaluate need for active cooling:
 - What would be the effect on energy resolution, PFA reconstruction, missing energy, tau ID, ...?
 - Can we avoid it by changing granularity, readout ASICs with lower power consumption?
 - ⇒ Evaluate consequences of higher data rates:
 - Do we need changes to data concentration strategy (trigger needed?)
 - Possible impact on powering, cooling, services, overall detector integration
 - ⇒ Evaluate / re-optimize detector geometry (sampling structure, granularity), also in view of overall detector layout (maximum expected particle energy, magnetic field, tracker radius)
 - ⇒ Consolidate and possibly improve cell-by-cell time resolution.
 - ⇒ Scintillator materials, geometry, photon sensors.

AHCAL in DRD6 - DRD6 Collaboration Meeting, April 2024

Frank Simon (frank.simon@kit.edu)



High-Rate capability

(M)RPC are low-rate capability detectors due to the resistive nature of the electrodes. The capability could be significantly increased by developing low resistivity materials.

Doped glass (by Tsinghua group) could be a solution
PEEK and PEEK are very stable and chemically inert thermoplastic

T-SDHCAL

- New kind of PVdF developed with the help of PolyOne company, doped with CNT → bulk resistivity of 10¹¹⁻¹² Ω.cm
- New charged PEEK developed with the help of Krefine company. doped with Black Carbon → bulk resistivity of 10⁸⁻⁹ Ω.cm was achieved.

WP1 (AND DRD6) HAS A NICE ROAD IN FRONT

LET'S ENJOY

