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 Irles (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

HCAL 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 — **ScintGlassHCAL: 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: Resistivie 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))
MPGD-HCAL-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...

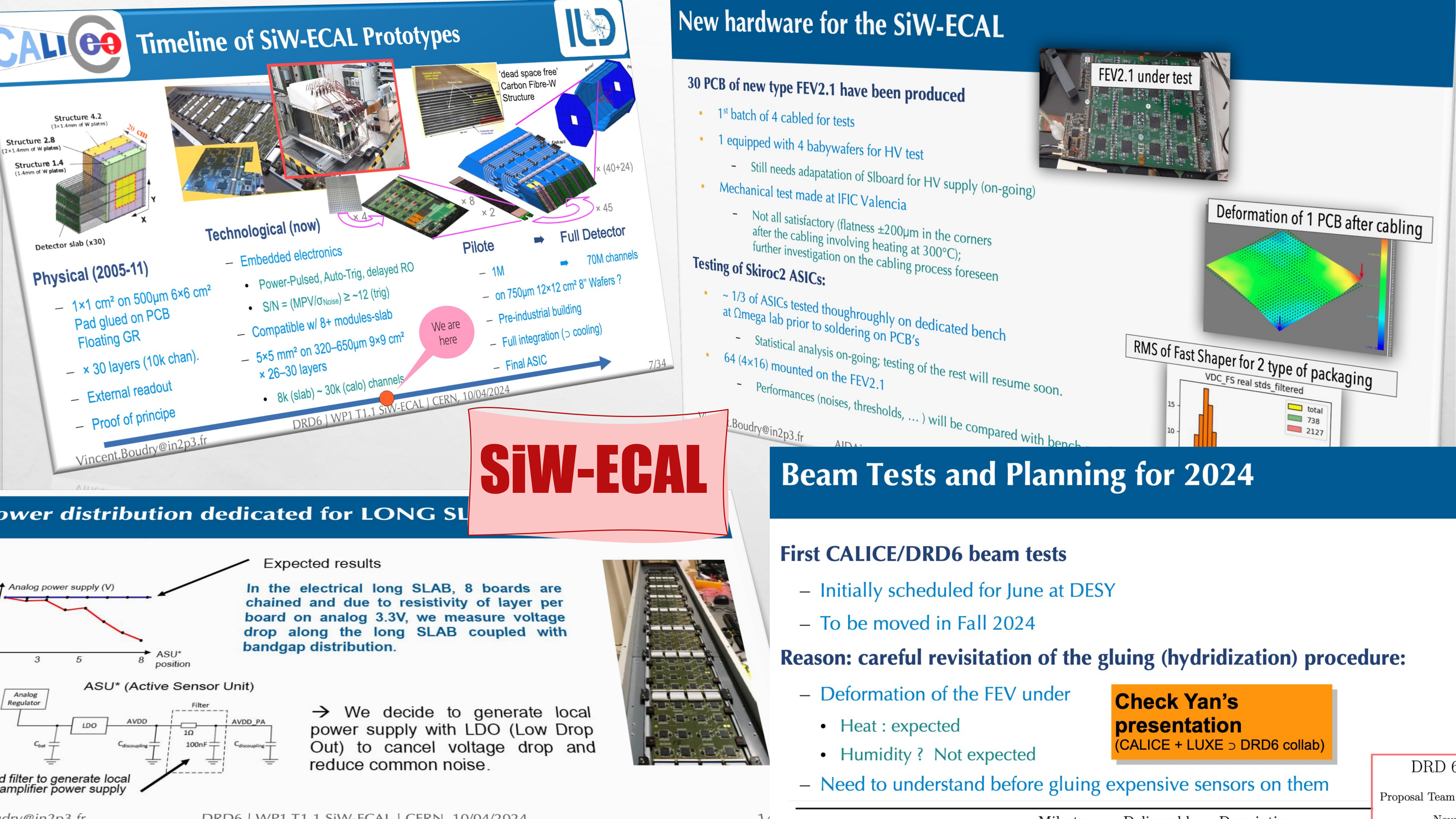
Tungsten absorber + some detector

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

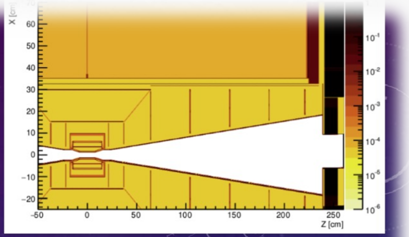

Timeline of SiW-ECAL Prototypes
Structure 4.2
Structure 2.8
Structure 1.4
Detector slab (x30)
'dead space free' Carbon Fibre-W Structure
Physical (2005-11)
– 1×1 cm² on 500μm 6×6 cm² Pad glued on PCB Floating GR
– × 30 layers (10k chan).
– External readout
– Proof of principle
Technological (now)
– Embedded electronics
• Power-Pulsed, Auto-Trig, delayed RO
• S/N = (MPV/σNoise) ≥ ~12 (trig)
– Compatible w/ 8+ modules-slab
– 5×5 mm² on 320–650μm 9×9 cm² × 26–30 layers
• 8k (slab) ~ 30k (calo) channels
We are here
Pilote
– 1M
– on 750μm 12×12 cm² 8" Wafers ?
– Pre-industrial building
– Full integration (⊃ cooling)
– Final ASIC
Full Detector
70M channels
Vincent.Boudry@in2p3.fr
DRD6 | WP1 T1.1 SiW-ECAL | CERN, 10/04/2024
7/34
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 adapatation 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 thoughroughly on dedicated bench at Ωmega lab prior to soldering on PCB's
– Statistical analysis on-going; testing of the rest will resume soon.
• 64 (4×16) mounted on the FEV2.1
– Performances (noises, thresholds, …) will be compared with bench
FEV2.1 under test
Deformation of 1 PCB after cabling
RMS of Fast Shaper for 2 type of packaging
SiW-ECAL
Power distribution dedicated for LONG SL
Expected results
Analog power supply (V)
ASU* position
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.
ASU* (Active Sensor Unit)
Analog Regulator
LDO
AVDD
Filter
AVDD_PA
→ We decide to generate local power supply with LDO (Low Drop Out) to cancel voltage drop and reduce common noise.
DRD6 | WP1 T1.1 SiW-ECAL | CERN, 10/04/2024
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 (hydridization) 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)

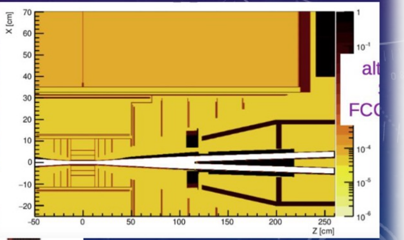
HIGHLY COMPACT CALORIMETER

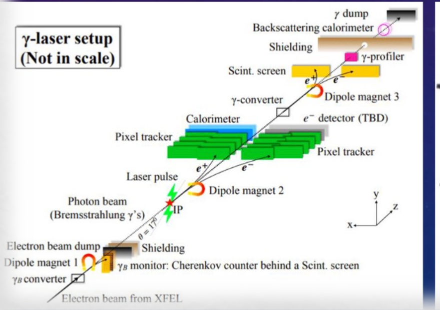
NEED FOR COMPACT CALORIMETER

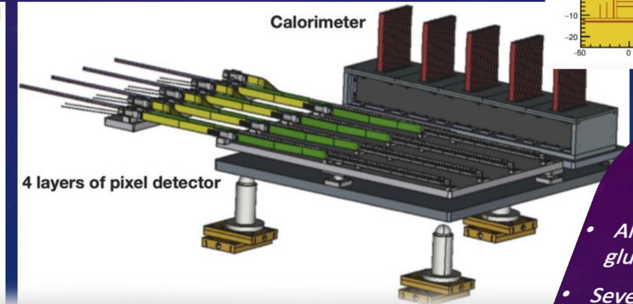
1 mm between W layers

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







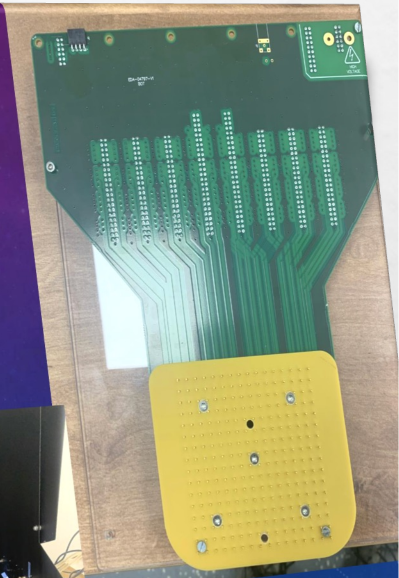


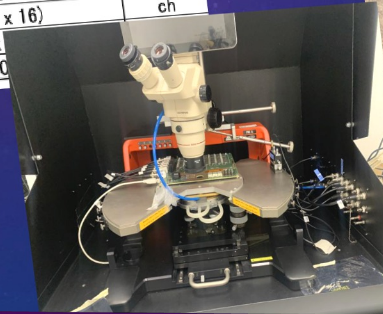
Common challenges with SiW-ECAL

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	μm
Active area	88480 x 88480	μm
Chip thickness	320±15	μm
Number of PIXELs	256(16 x 16)	ch
PIXEL pitch	5530 x	
PIXEL GAP	10	

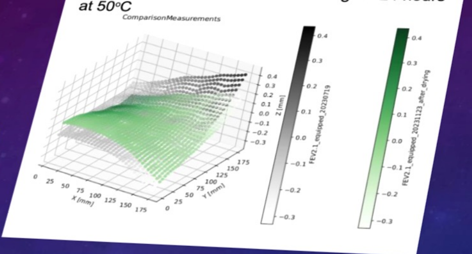




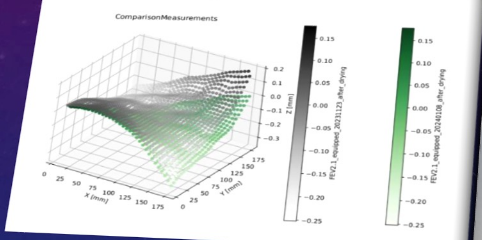
IFIC

- 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

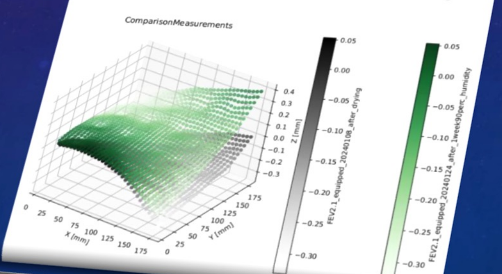
Deformation upon reception and after drying for 10 days in dry cabinet and heating for 24 hours at 50°C



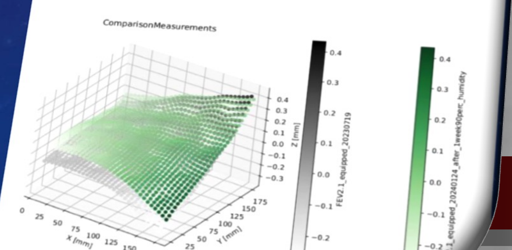
Immediately after drying and after drying + 1day



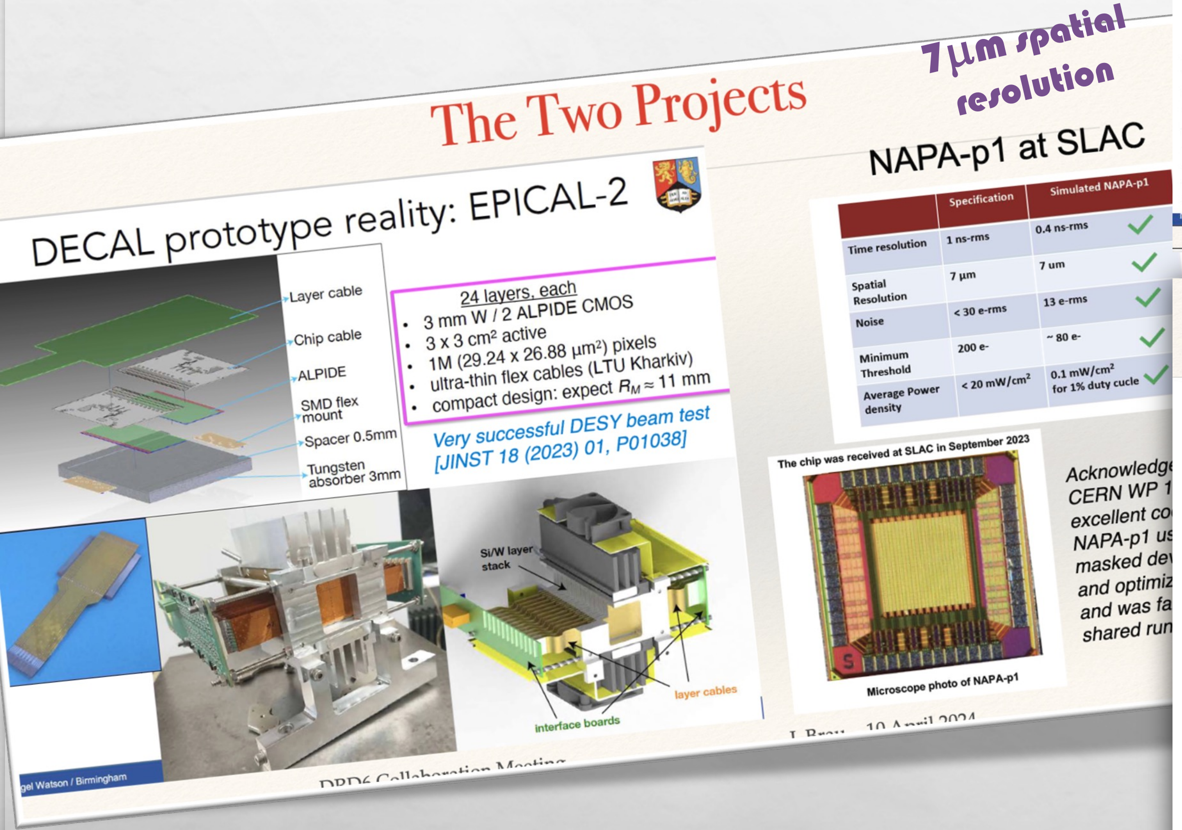
Additional drying and humidity cycles 3x72 cycles during nine days at 90% and 30°C



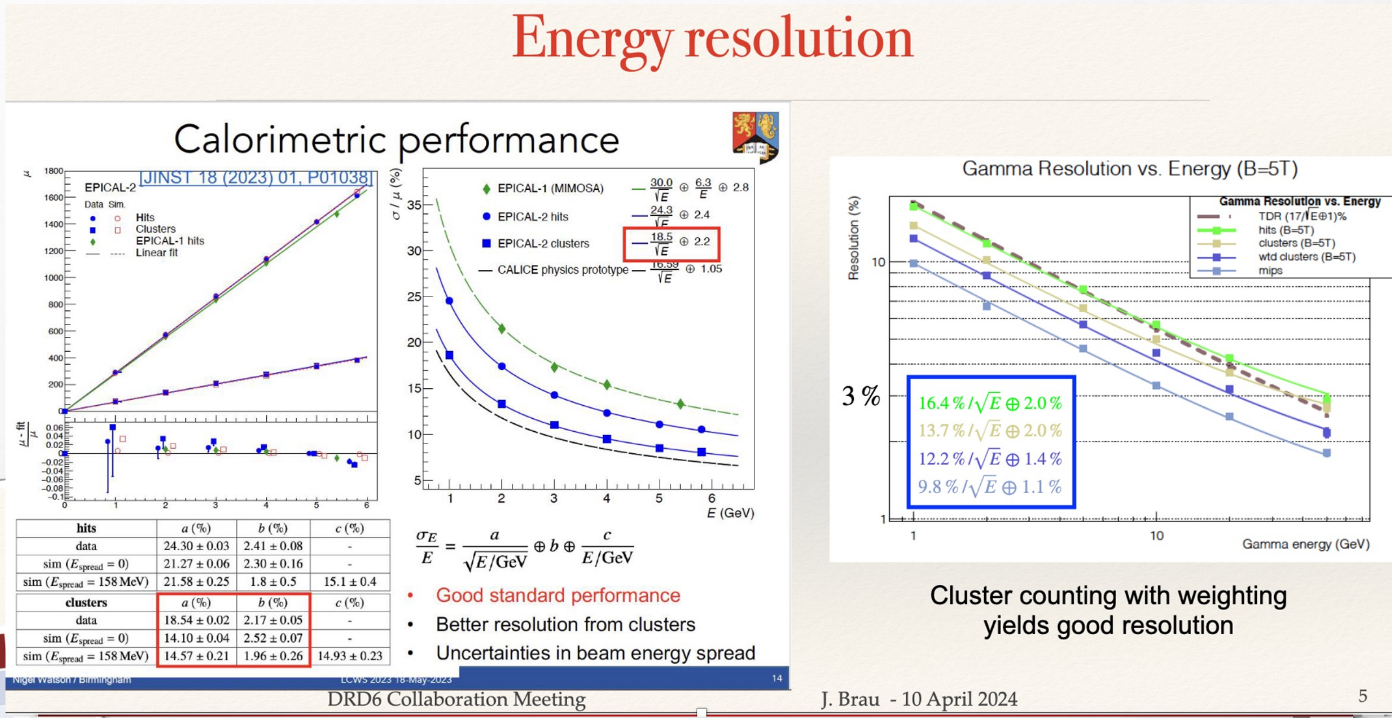
Humidity cycles and PCB upon reception



DECAL:
CMOS/MAPS TUNGSTEN ELECTROMAGNETIC SECTION

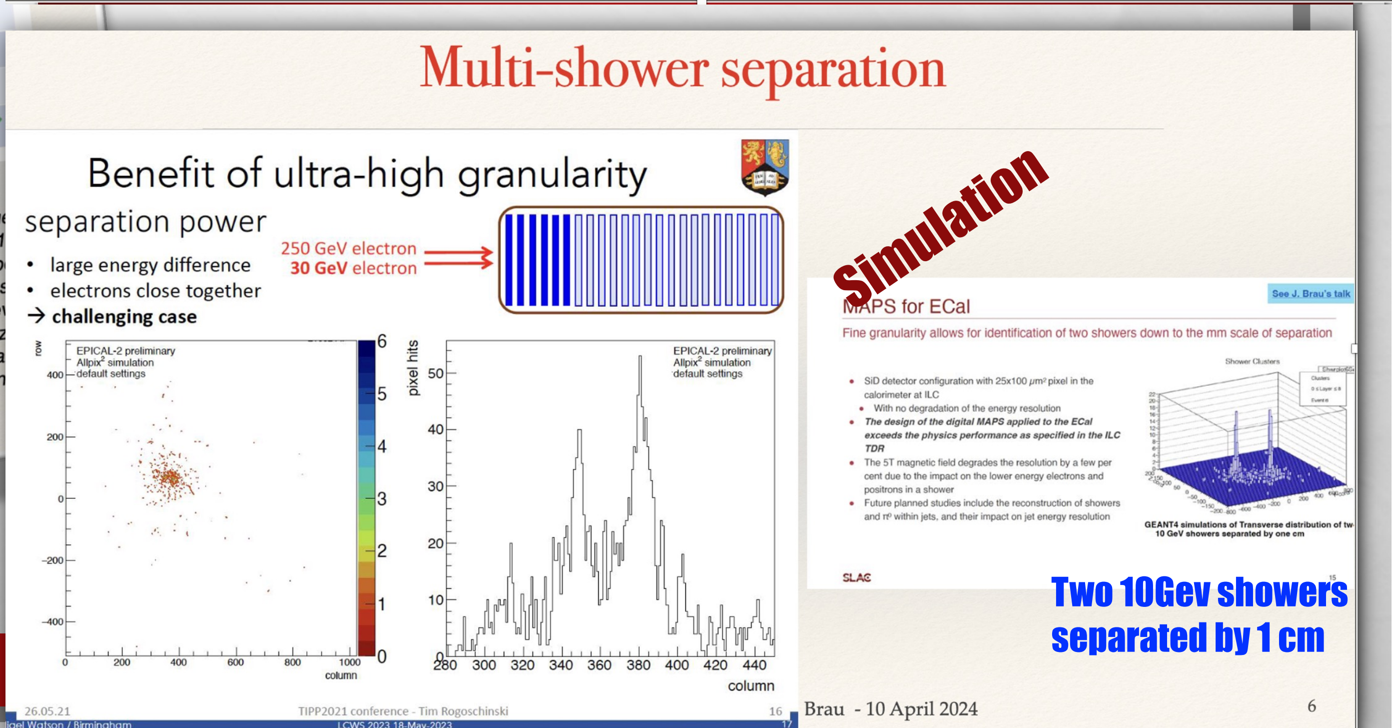


	Specification	Simulated NAPA-p1
Time resolution	1 ns-rms	0.4 ns-rms
Spatial Resolution	7 µm	7 um
Noise	< 30 e-rms	13 e-rms
Minimum Threshold	200 e-	~ 80 e-
Average Power density	< 20 mW/cm²	0.1 mW/cm² for 1% duty cucle

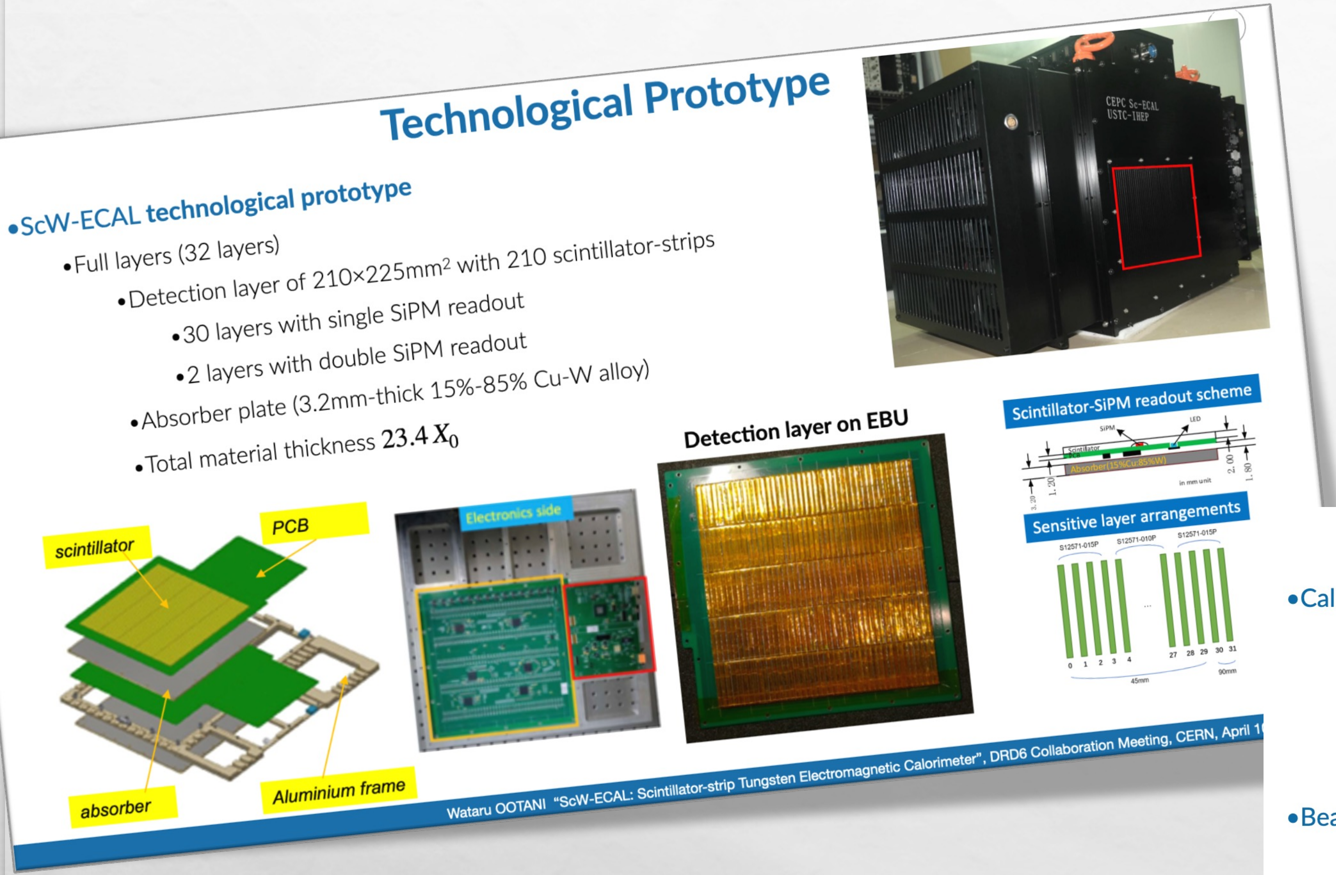


$$\frac{\sigma_E}{E} = \frac{a}{\sqrt{E/\text{GeV}}} \oplus b \oplus \frac{c}{E/\text{GeV}}$$

hits	a (%)	b (%)	c (%)
data	24.30 ± 0.03	2.41 ± 0.08	-
sim (E_{spread} = 0)	21.27 ± 0.06	2.30 ± 0.16	-
sim (E_{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_{spread} = 0)	14.10 ± 0.04	2.52 ± 0.07	-
sim (E_{spread} = 158 MeV)	14.57 ± 0.21	1.96 ± 0.26	14.93 ± 0.23



ScW-ECAL: SCINTILLATING PLASTIC STRIPS

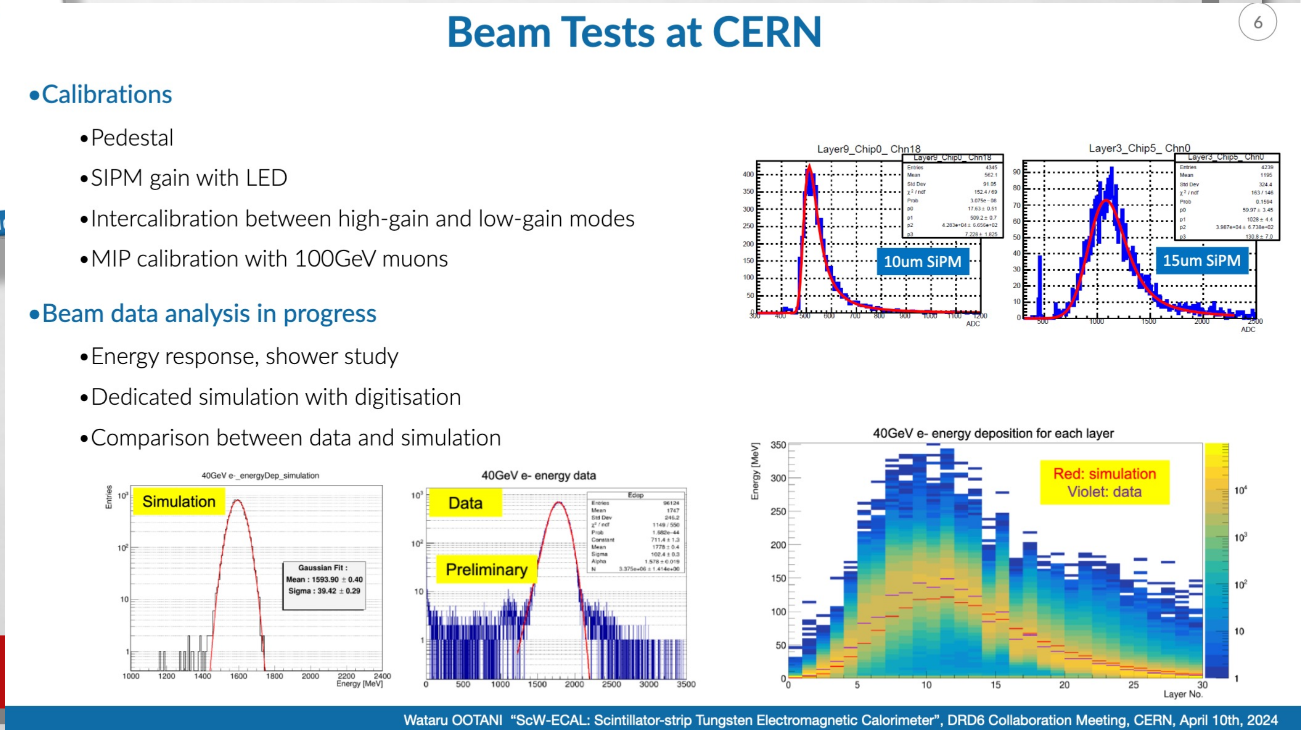


Combined beam tests with CEPC AHCAL

SPS October 16 – Mov 2 2022

SPS April 26-10 May 2023

PS May 2023



AHCAL: SCINTILLATION PLASTIC TILES AND STEEL HADRONIC SECTION

AHCAL in DRD6

Overall Context

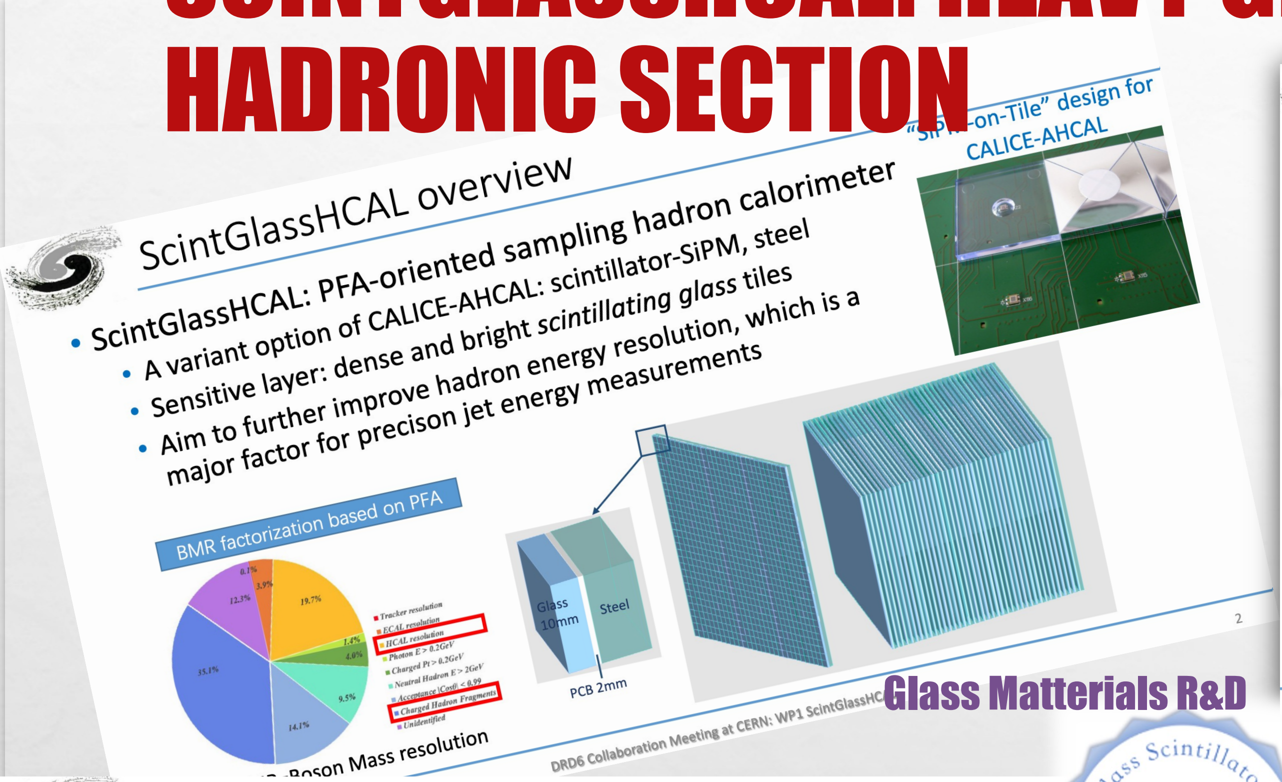
Karlsruhe Institute of Technology

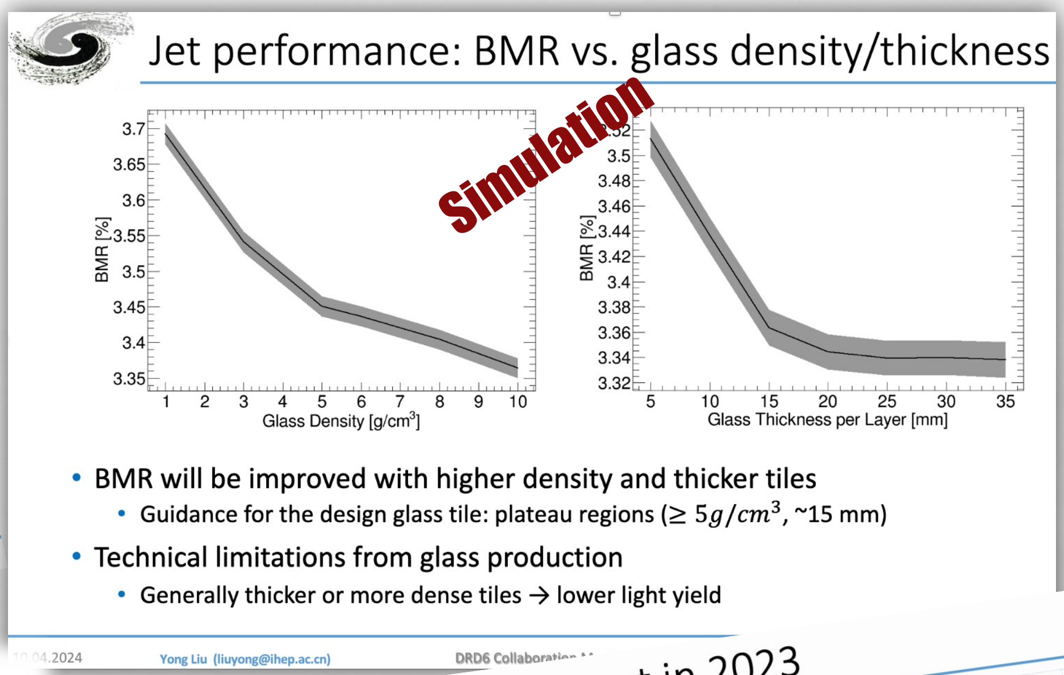
- Building on a mature technology:
  - SiPM-on-tile AHCAL prototype with 22k channels, 0.5 m^3 and 38 layers constructed 2017/18, operated in several beam tests
  - SiPM-on-tile section of CMS HGCAL using this technology - significant synergies, profit from prototyping and construction experience.

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

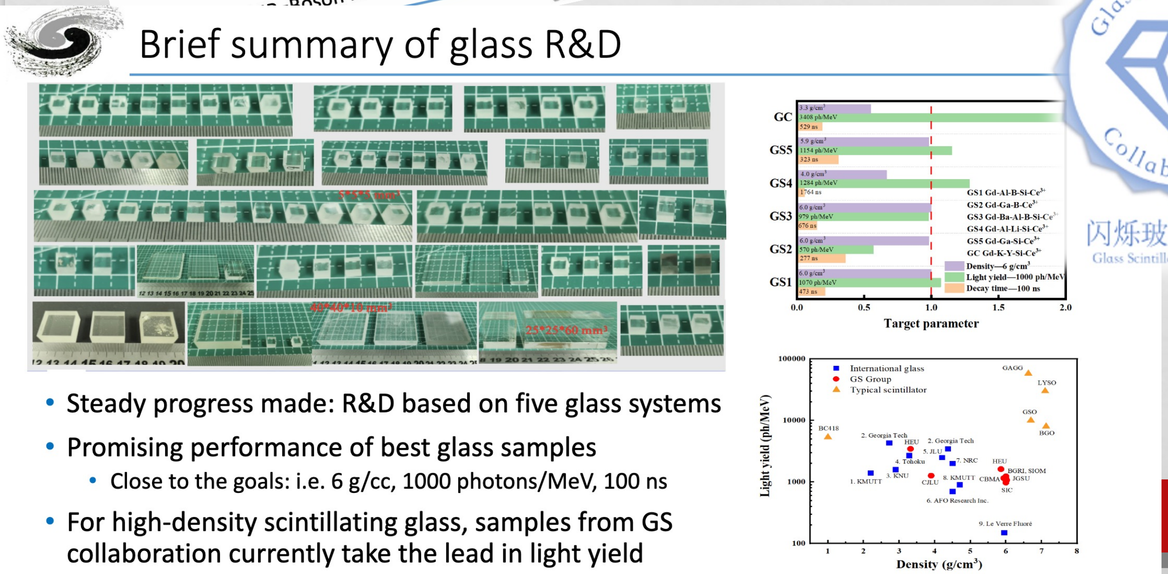


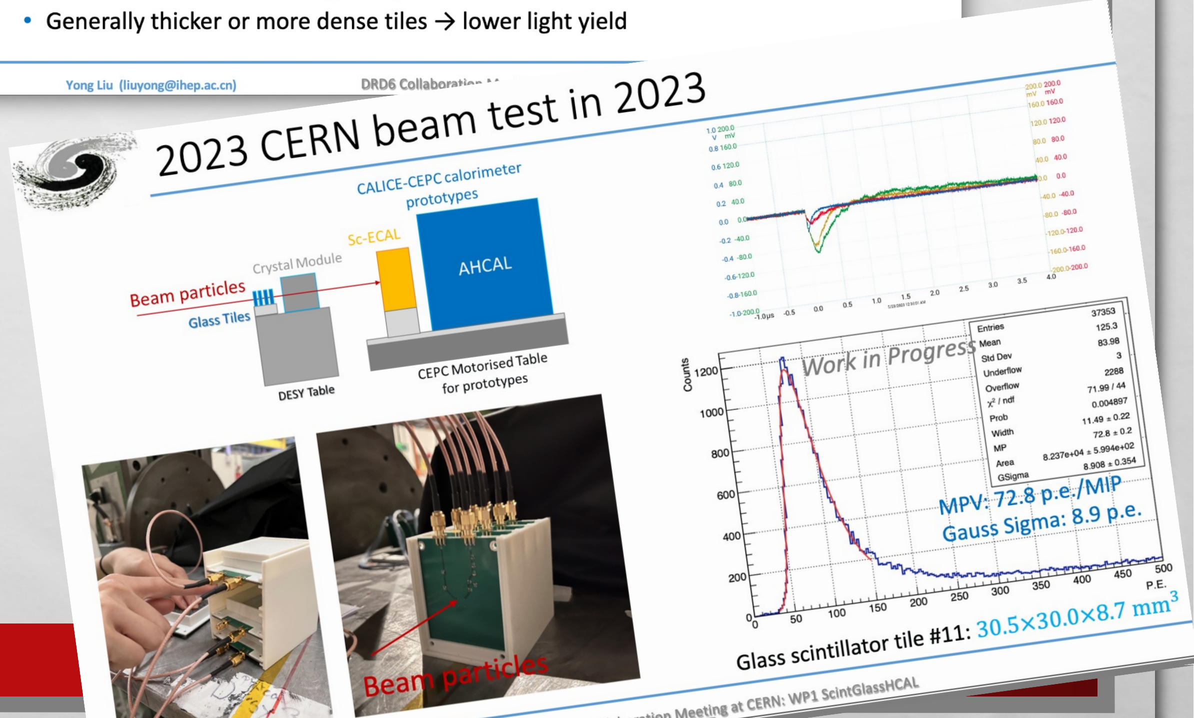


Glass Matterials R&D

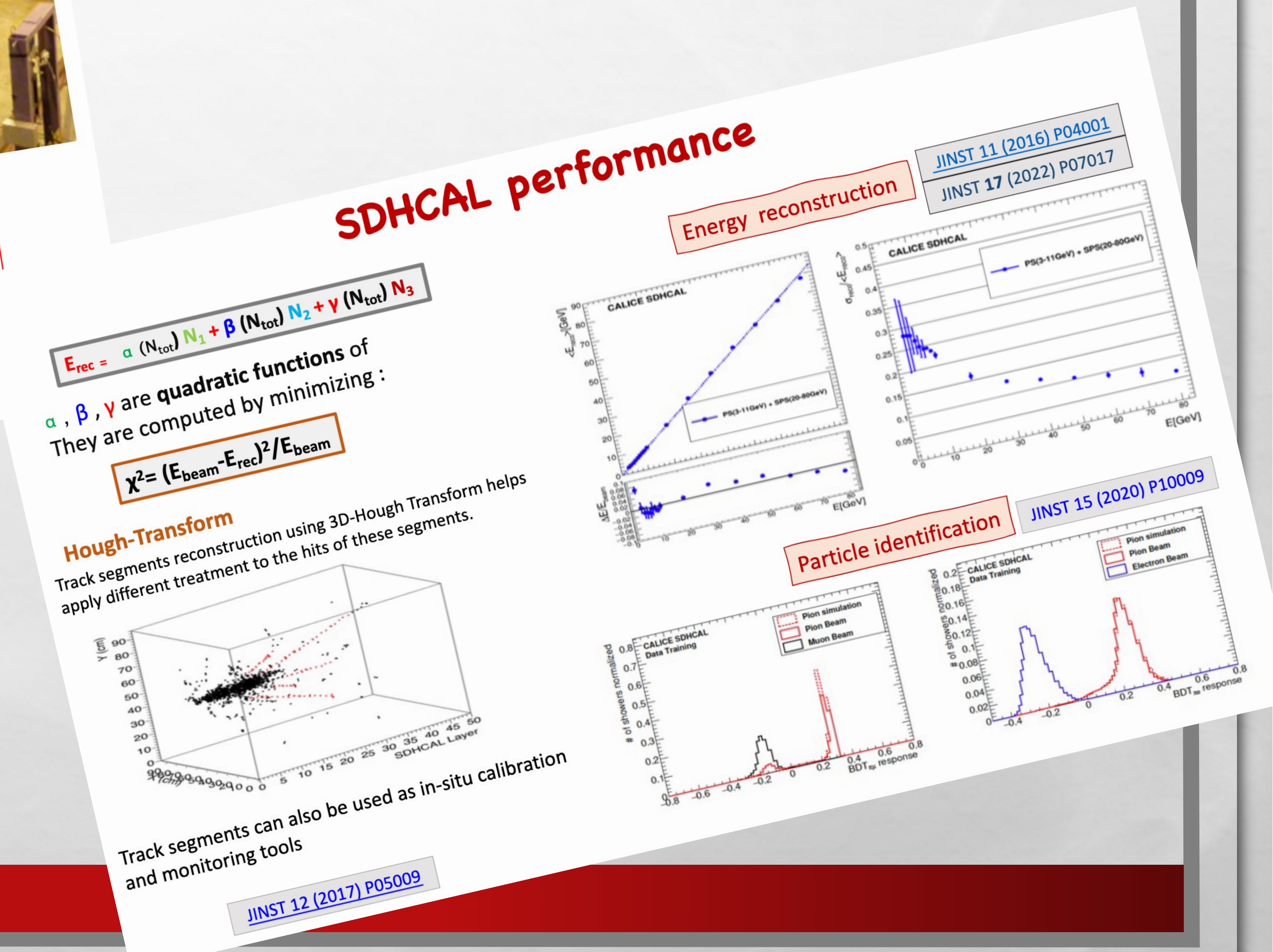
闪烁玻璃合作组

Glass Scintillator Collaboration

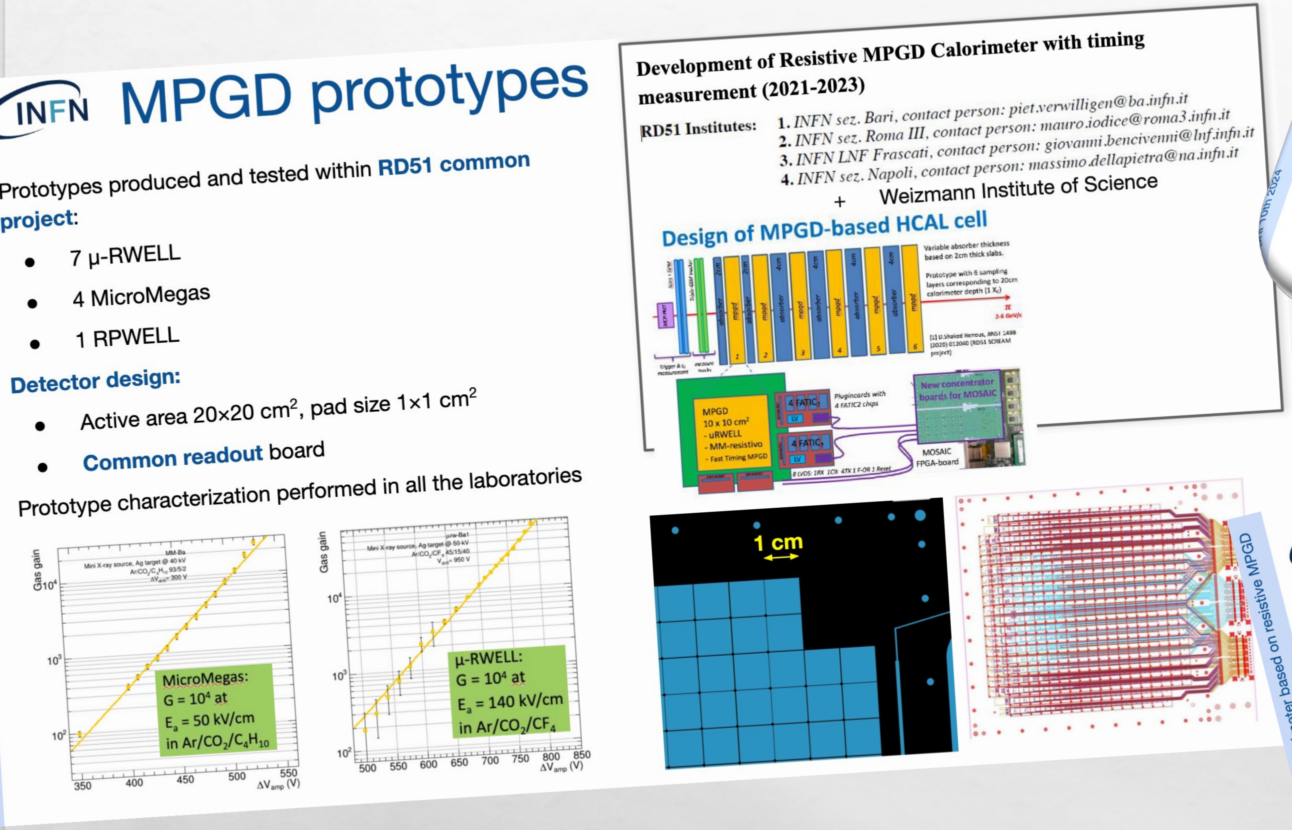


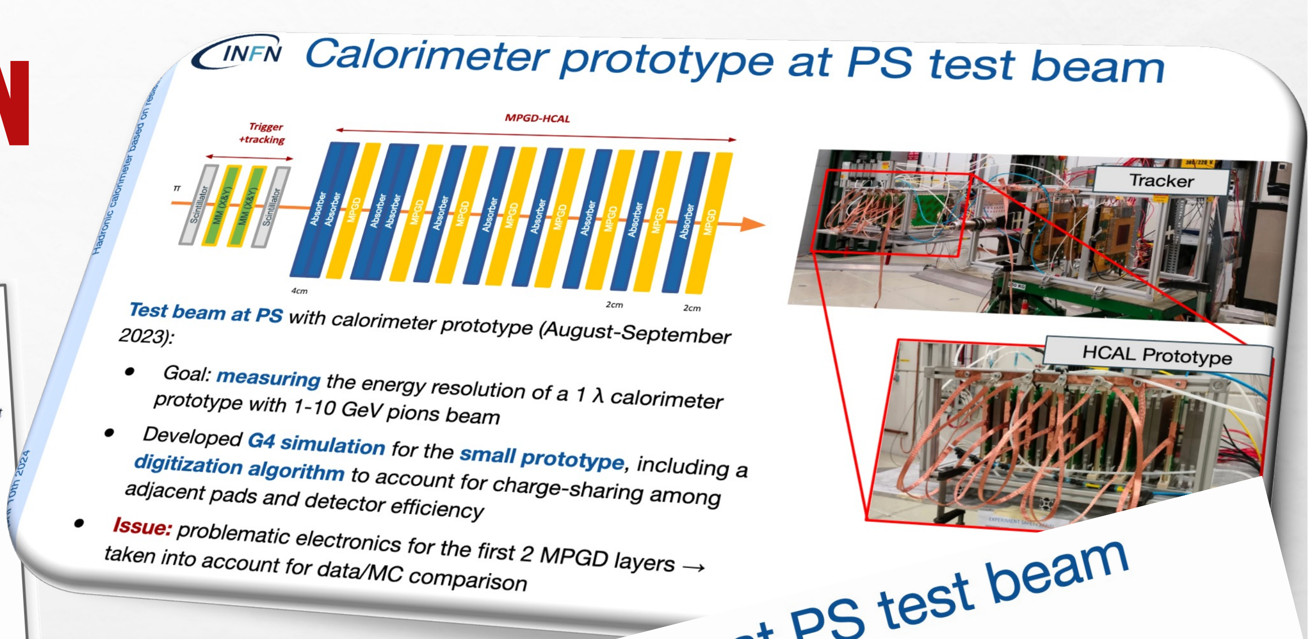


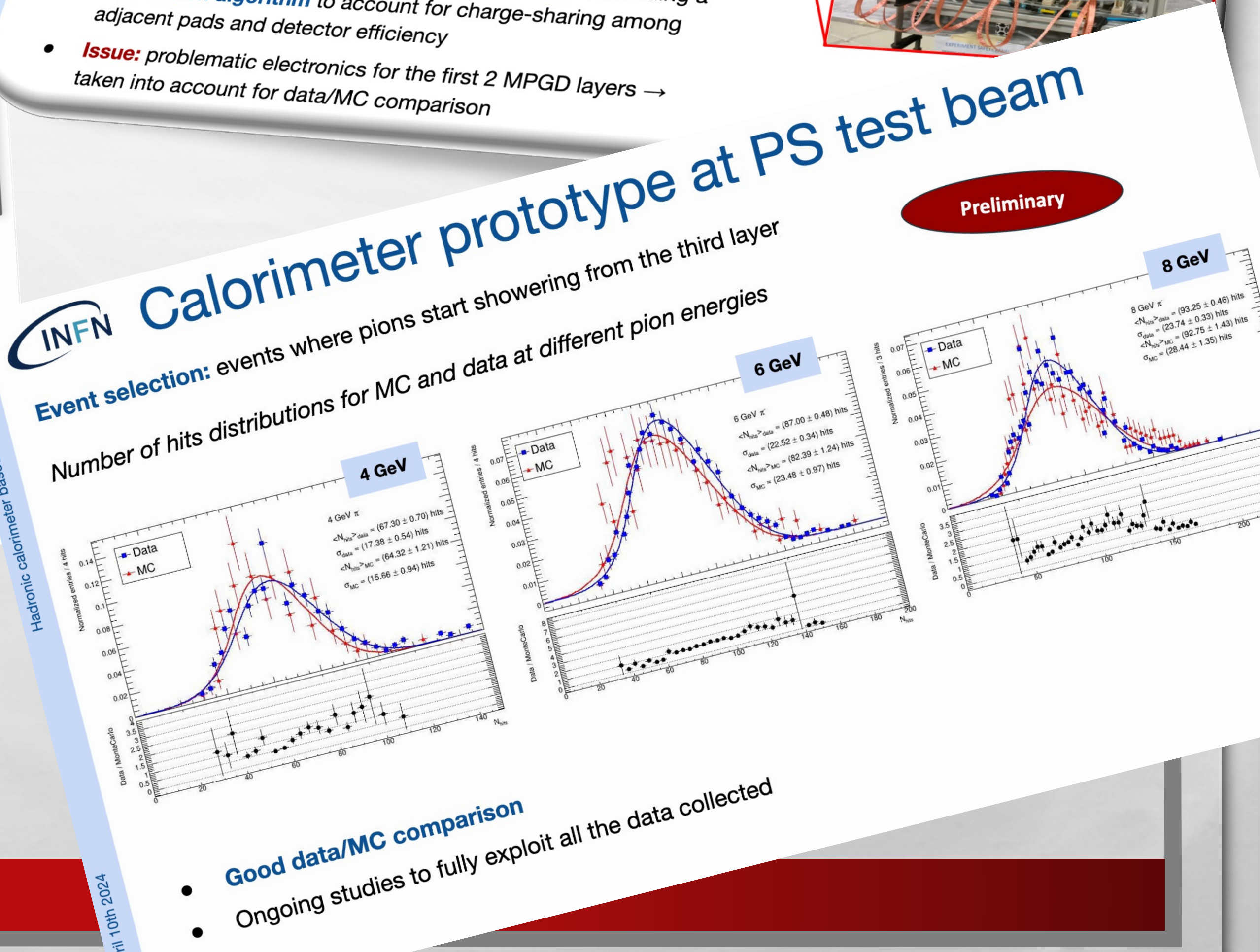
SEMIDIGITAL HCAL



MPGD-HGCAL: MULTIPATTERN GAS DETECTOR







ADRIANO3

ADRIANO3 Active Components

ABSORBER

- Cerenkov radiator: 3x3x2 cm^3 lead-glass tiles (typical size)
- Scintillator component: 3x3x 0.5 cm^3 scintillating tiles (typical size)

Mostly sensitive to EM component

Sensitive to charged component & neutrons thanks to high H2 content

- Neutron component: 10x10x1 cm^3 doped RPC
- Tiles readout: on-tile sipm
- RPC readout: pads

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.

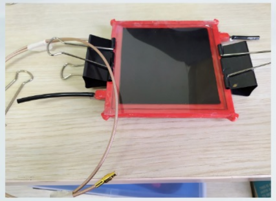
➔ RPCs with functional anodes

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

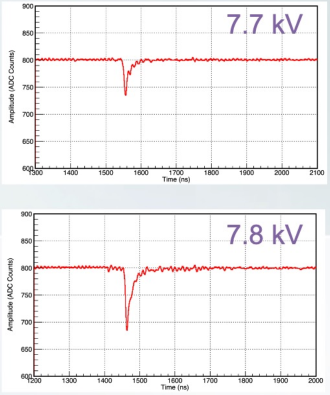
Coating of Al_2O_3 made with magnetron sputtering.

Coating of TiO_2 made with airbrushing after dissolving TiO_2 in ethanol.

RPCs obtain high efficiency at considerably lower high voltage settings.



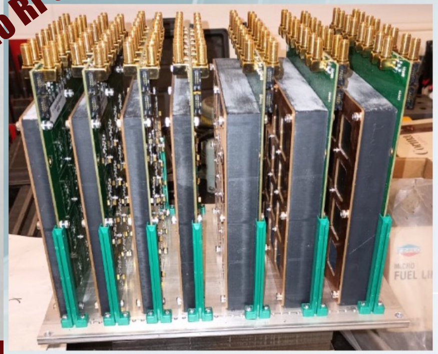
Cosmic muon response

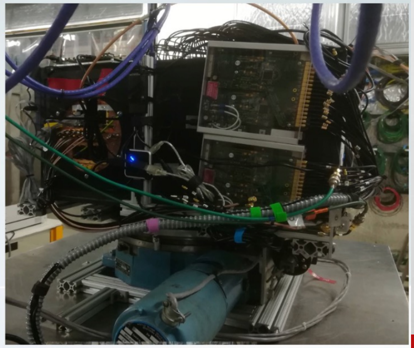


ADRIANO2 R&D in T1604 Collaboration

ADRIANO2 – Only tyles, no RPC

Currently in the beam at Fermilab: 7 layer, ~5X_0, 64 cells prototype, with Sampic & petiroc readout (CAEN DT5550W)



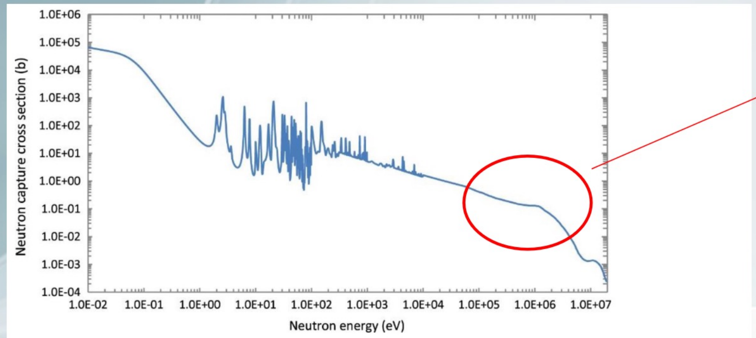


xG. Blazey, A. Dychkant, M. Figora, T. Fletcher, C. Gatto, K. Francis, A. Liu, S. Los, M. Murray, E. Ramberg, C. Royon, M. Syphers, R. Young, V. Zutshi, C. Le Mahieu, J. Marquez, A. Mane, J. Elam, Z. Sheemanto

Next Steps for ADRIANO3

➔ RPCs with functional cathodes

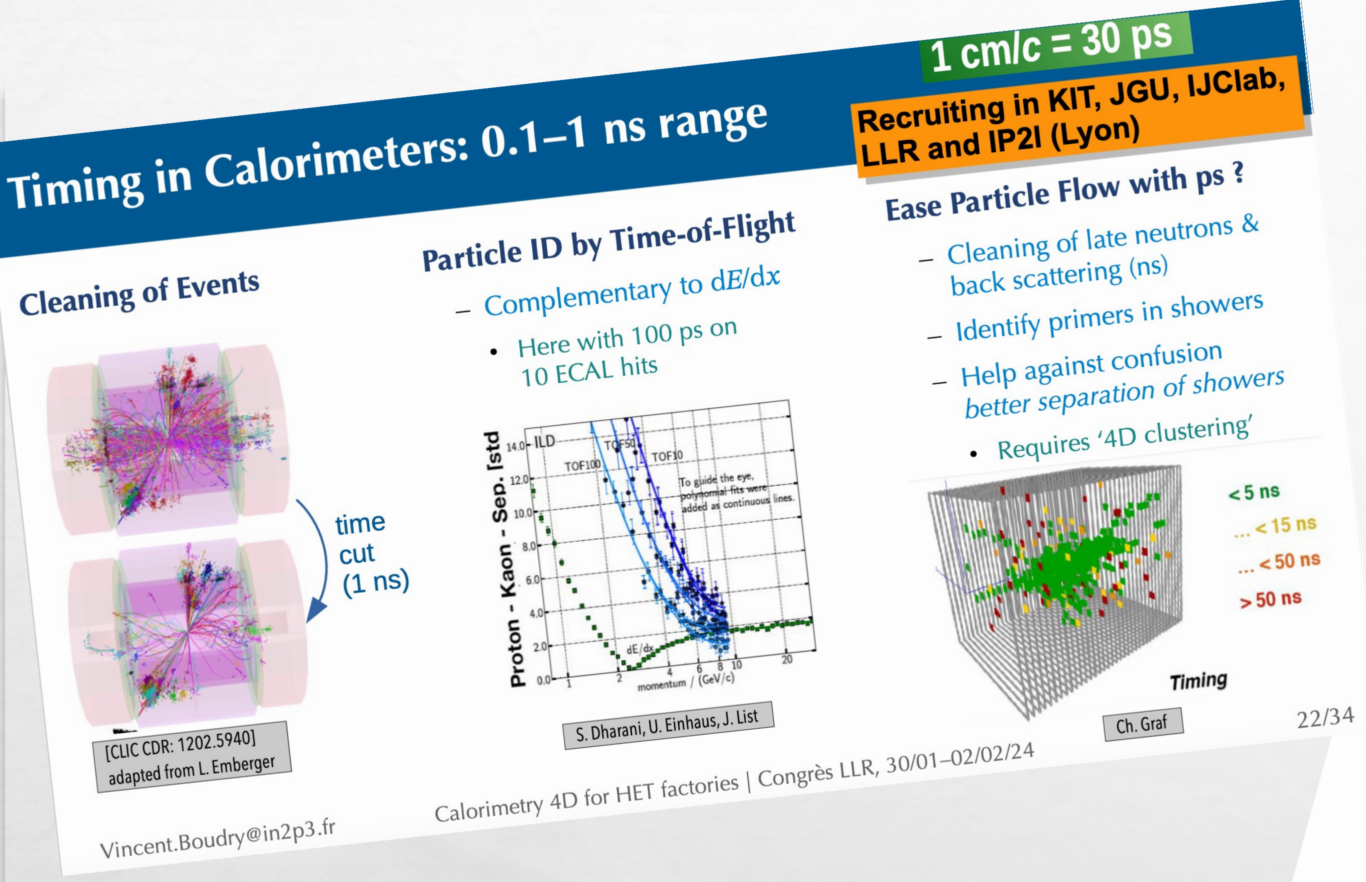
Dope the cathode glass of one-glass RPCs with Gd to introduce the neutron capture functionality.



Region of interest for hadron calorimetry

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

TIMING IS "COOL"



Simulation SDHCAL

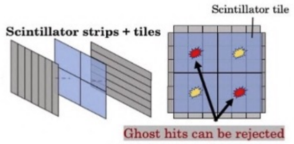
AND EVERYBODY WANTS TO BE COOL

DRD6 AHCAL Work Plan

Activities & Task Sharing

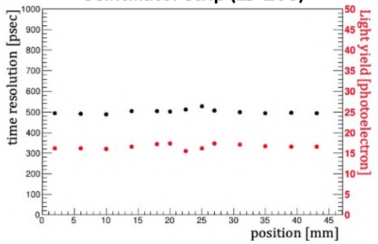
- Build a small AHCAL prototype ("EM stack") with continuous readout and with hit timing capability - starting with small reconfigurable prototype in first 3-year period.

- **Timing performance:** target timing resolution $\mathcal{O}(10\,\mathrm{ps})$
  - Timing resolution of the current scintillator strip ~500ps with 15p.e.
  - Dedicated timing layer
    - Scintillator tile ($15\times15\times3\mathrm{mm}^3$): <50ps 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

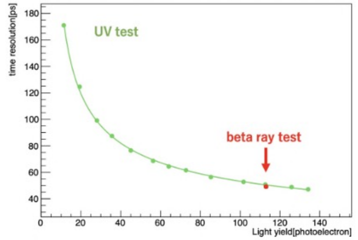


ScW-ECAL

Scintillator strip (EJ-200)



Scintillator tile (EJ-232)



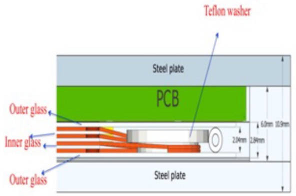
From SDHCAL to T-SDHCAL

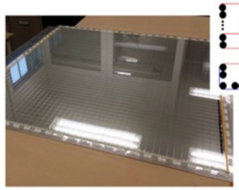
The Detector

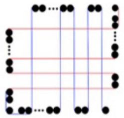
MultiGAP Glass RPC is an excellent candidate.

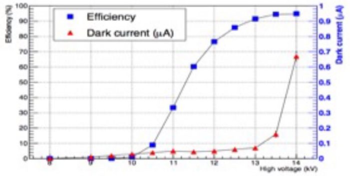
5-gap of 200 µm each separating glass plates of 250 µm thick can provide a time resolution of around 100 ps

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



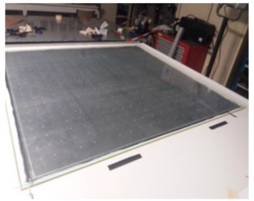






Threshold sets at 114 fC

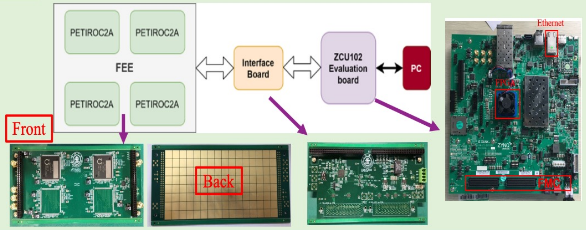
New and easy way of construction MRPC. Preliminary results show an efficiency > 93% with 5 gaps



Electronics Readout

Small ASU

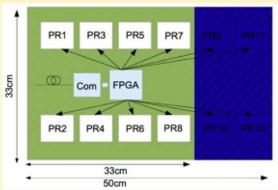
A board with 4 petiroc, 128 pads as well as the whole DAQ system was developed and being tested

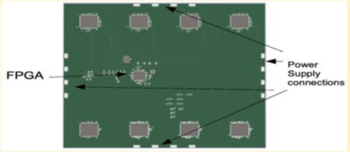


- Front-End Electronics for MRPC readout with high timing resolution
- The system includes a front-end board (FEB), a detector interface card (DIF) and a data acquisition system(DAQ) based on ZCU102.

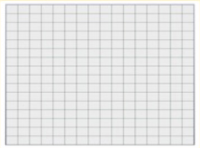
Large ASU

- 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





Top view



Bttom view

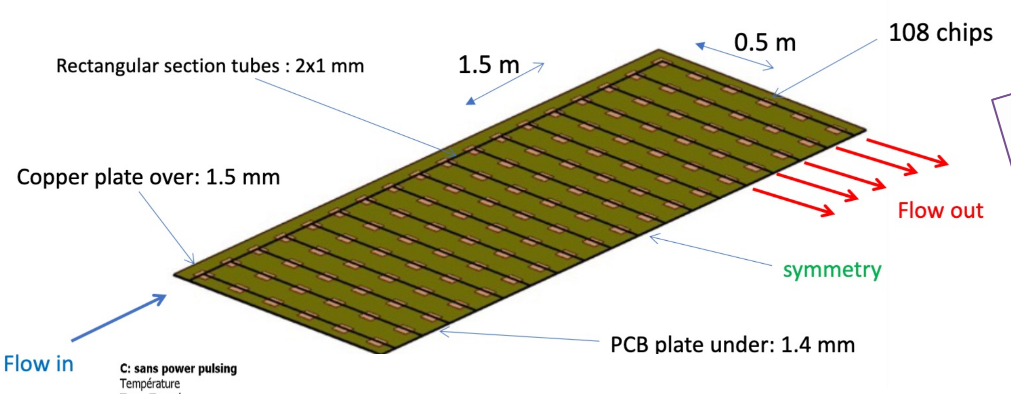
AND THE COOLING IS ALSO IMPORTANT FOR CIRCULAR e+e- COLLIDERS

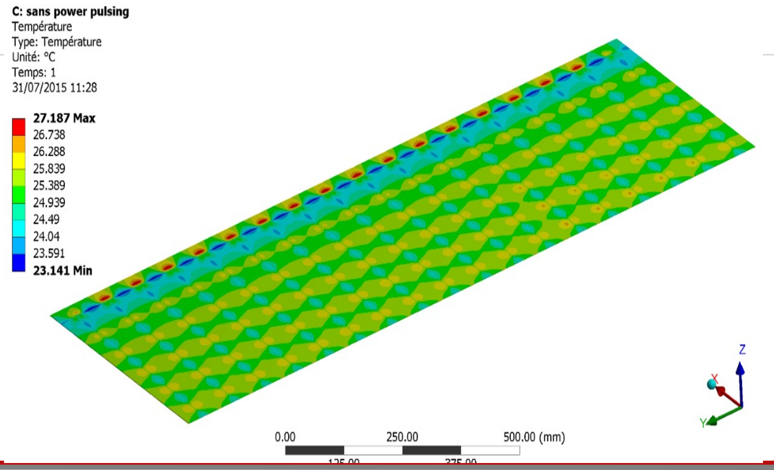
Large SDHCAL module

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





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], $\mathcal{L}$ ~ cst.
- Power pulsing : 5 [10–15]Hz × 1 [2] ms   Power ~ $\mathcal{L}$.

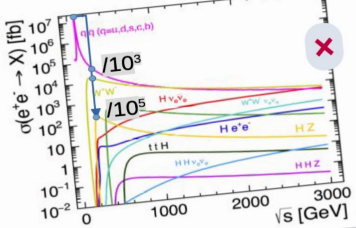
More diverse et stringent conditions:

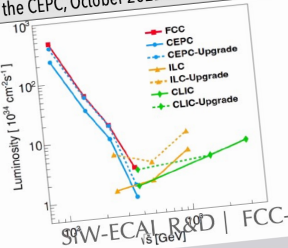
- 90GeV × 10^7 fb × $5 \cdot 10^{36}$ cm^{-2} s^{-1} (qq × 20,000 ILC @ 250)
- 150 GeV (WW) + 250 GeV (ZH)+ 365 GeV (tt) ~10^4 fb × $5 \cdot 10^{35}$ cm^{-2} s^{-1} (qq × 5–10 ILC @ 250)

From Pulsed to Continuous operation

- Power = cst + convertion+RO × local rates (P_{Conv}+P_{RO} ~ 40% P_{ACQ})
- ASIC, Power/Cooling, DAQ, *Granularity, Precisions (E, t), New ideas…*

Status of the CEPC, October 2022 J. Guimarães da Costa





HL-ILC:
- $\mathcal{L}$ × 4 (6)
- $N_{bunches}$ × 2 : τ_{Train} : 1 → 2 ms
- f_{rep} ×2 (3): 5 → 15 Hz

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

HL-CLIC:
- $\mathcal{L}$ × 2
- $N_{bunches}$ → : τ_{Train} : 176 ns
- f_{rep} ×2 : 50 → 100 Hz

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

FCC-ee parameters		Z	W⁺W⁻	ZH	ttbar
√s	GeV	91.2	160	240	350-365
Luminosity / IP	10^{34} cm^{-2} s^{-1}	230	28	8.5	1.7
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 x 10^{-3} at Z pole

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

SiW-ECAL R&D | FCC-France, Strasb… 4

DRD6 AHCAL R&D Questions

Towards Circular Colliders, Scalability & Mass Production

Karlsruhe Institute

- 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)   IPE Institute for Data Processing and Electronics

High-Rate capability

T-SDHCAL

(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.

Dopped glass (by Tsinghua group) could be a solution

PVdF and PEEK are very stable and chemically inert thermoplastic

-New kind of PVdF developed with the help of PolyOne company, doped with CNT → bulk resistivity of $10^{11\text{-}12}$ Ω.cm

-New charged PEEK developed with the help of Krefine company. doped with Black Carbon→ bulk resistivity of $10^{8\text{-}9}$ Ω.cm was achieved.

WP1 (AND DRD6) HAS A NICE ROAD IN FRONT

LET´S ENJOY