Recent developments of the SDHCAL prototype

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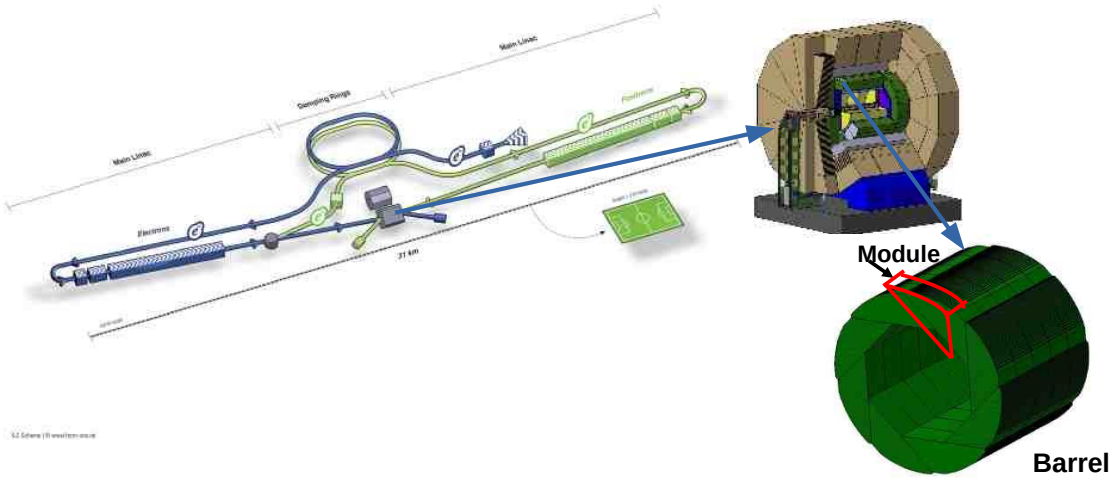
on behalf of SDHCAL collaboration
PANIC 2021

IP2I/IN2P3/CNRS/Université Lyon 1

September 8^{th} 2021

SDHCAL

- The Semi-Digital Hadronic CALorimeter
- One of two options proposed for ILD.

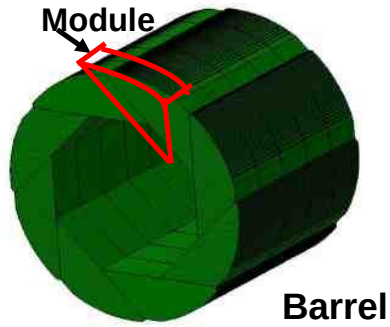


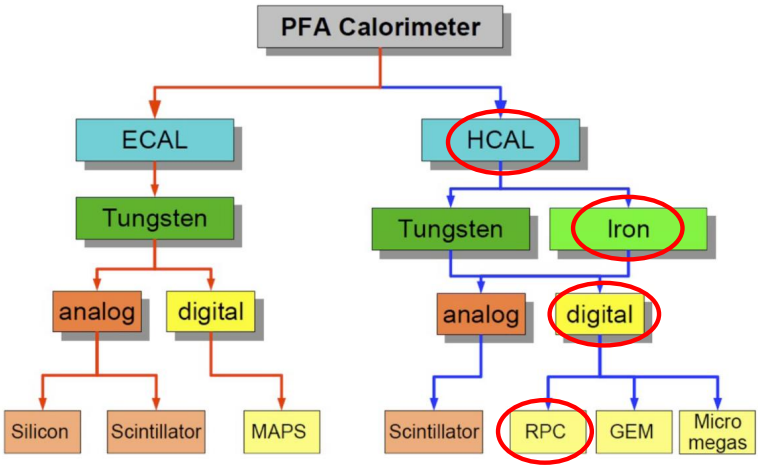
SDHCAL collaboration within CALICE collaboration

France	IP2I, LPC, OMEGA
Spain	CIEMAT
Belgium	Ghent University
China	SJTU
Korea	GWNU

The Semi-Digital HCAL in brief

- Sampling calorimeter.
- Glass-RPC detectors as sensitive medium with embedded readout electronics providing 1cm^2 lateral segmentation.
- Design for Particle Flow Analysis (PFA).
- An ingenious mechanical structure.
- Member of the CALICE technology family.



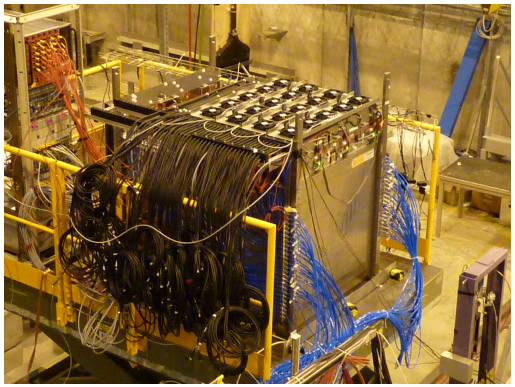


Challenges

- Homogeneity for large surface.
- Active detector thickness of only few mm.
- Services from one side.
- Embedded electronics.
- Low power consumption.

The SDHCAL prototype

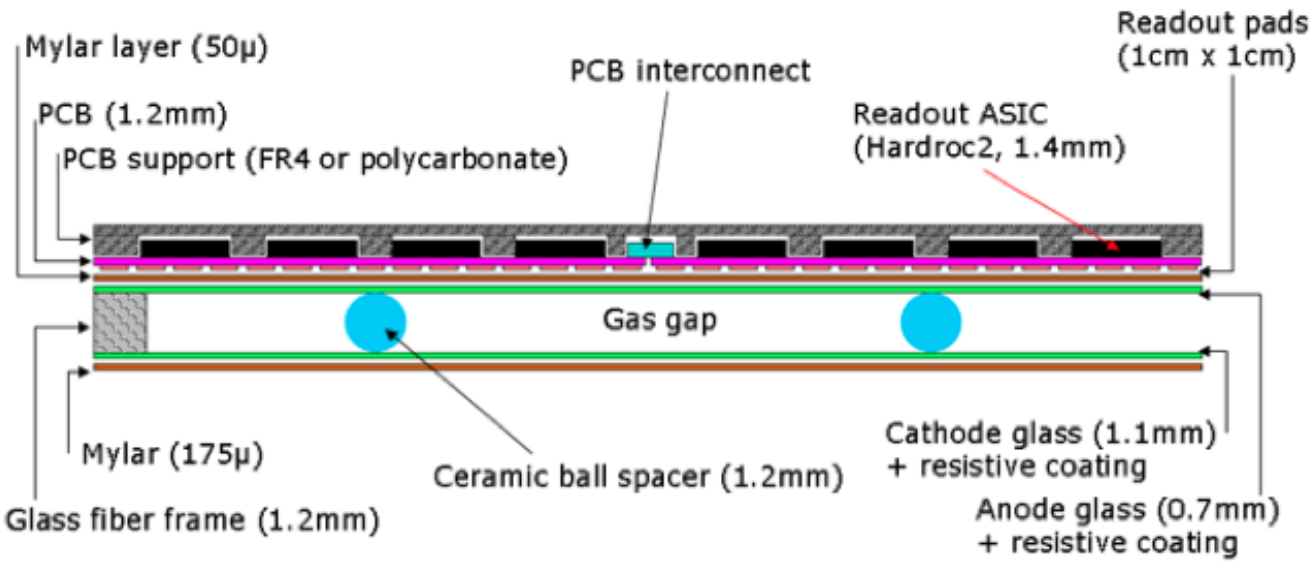
A technological prototype with up to 50 GRPCs of 1 m^2 conceived as a demonstrator.



- Self-supporting stainless-steel structure.
- Up to 50 slots to insert GRPC cassette.
- Cassette = GRPC+embedded electronics+ steel cover (11 mm thick).
- 1 m^2 GRPC read by 1 cm^2 readout pads.
- $96 \times 96 \times 50$ channels for the full Prototype = 460800 channels.
- Less than 1‰ dead channels.
- All services on one side.

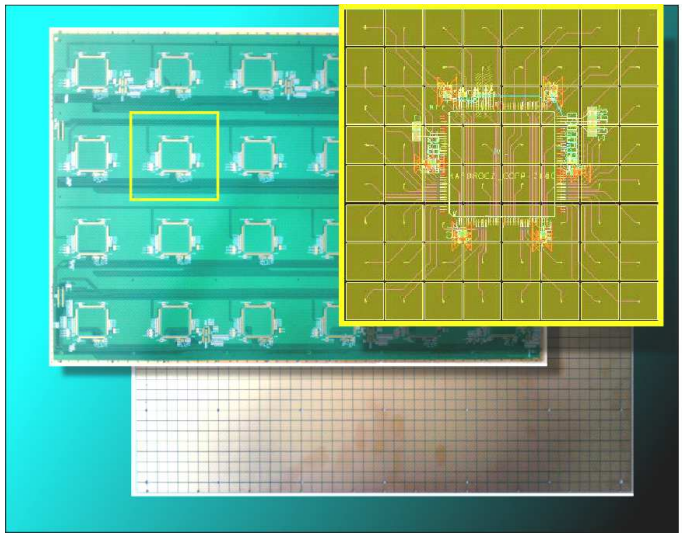
Chamber cross-section view

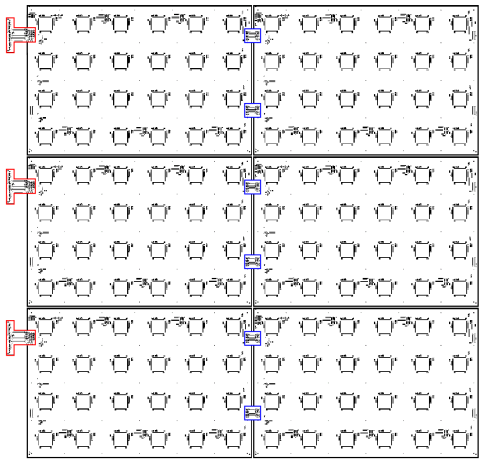
- 1 m^2 GRPC.
- Saturated avalanche mode : spatial charge distribution on glass anode $\sim$ 1 mm^2.
- Read by 1 cm^2 copper pads : max particle density in shower $\sim 100/cm^2$: 3 readout thresholds.
- Embedded readout electronics.



Total thickness: 6.0 mm.

Readout electronics



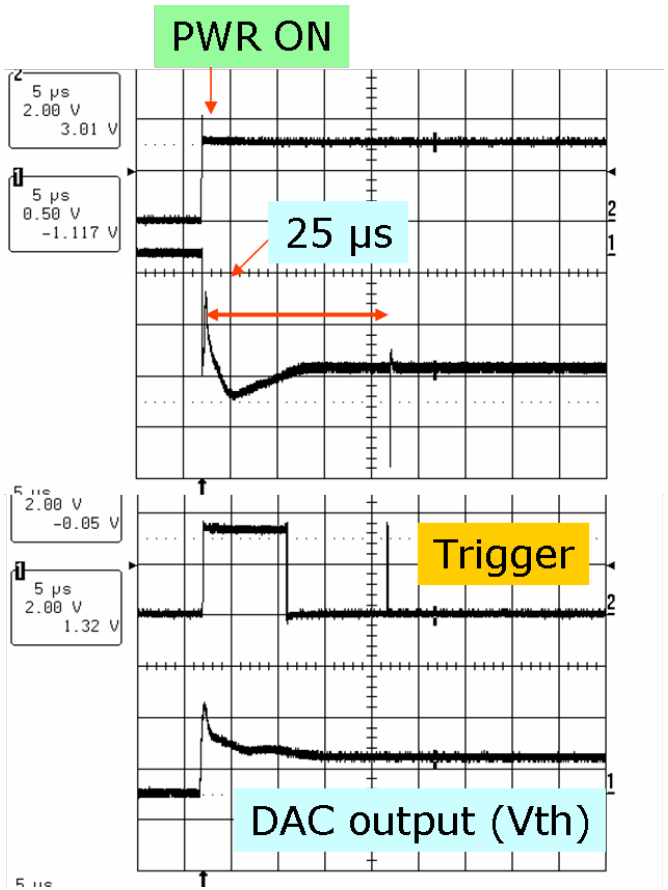


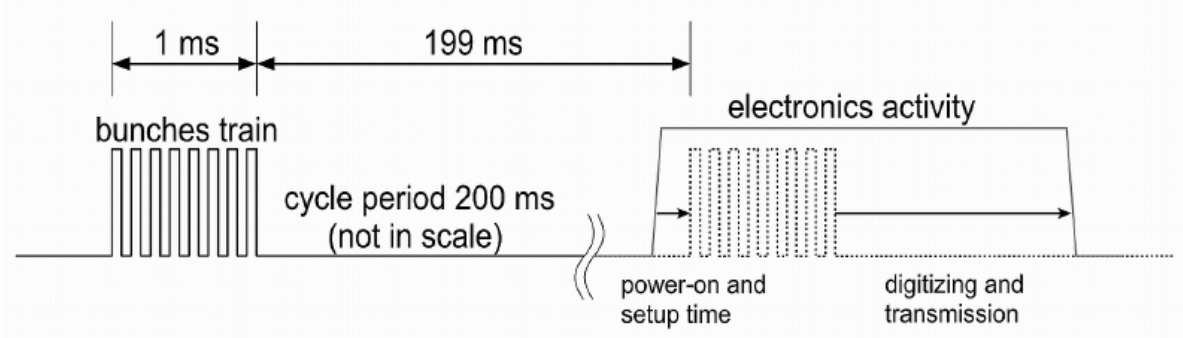
ASICs=HARDROC2

- Each ASIC reads 64 copper pads,
- Amplification, shaping, 3-level discriminator (dynamic range 10 fC to 30 pC), triggerless : store up to 127 first threshold crossing (pad ID and time (200 ns clock))
- Daisy-chained (data readout, configuration)
- Semi-digital readout (2-bit, 3 thresholds).

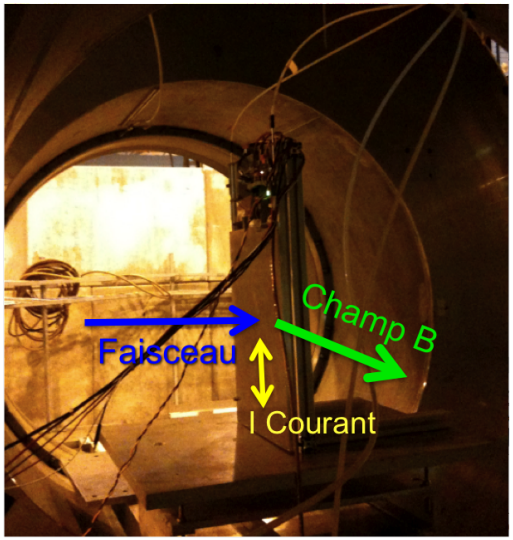
3 DIF (Detector InterFace boards) to read 1 m^2.

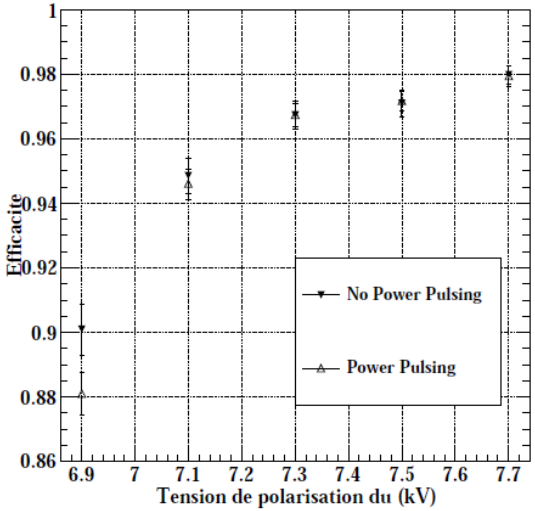
SDHCAL power pulsing





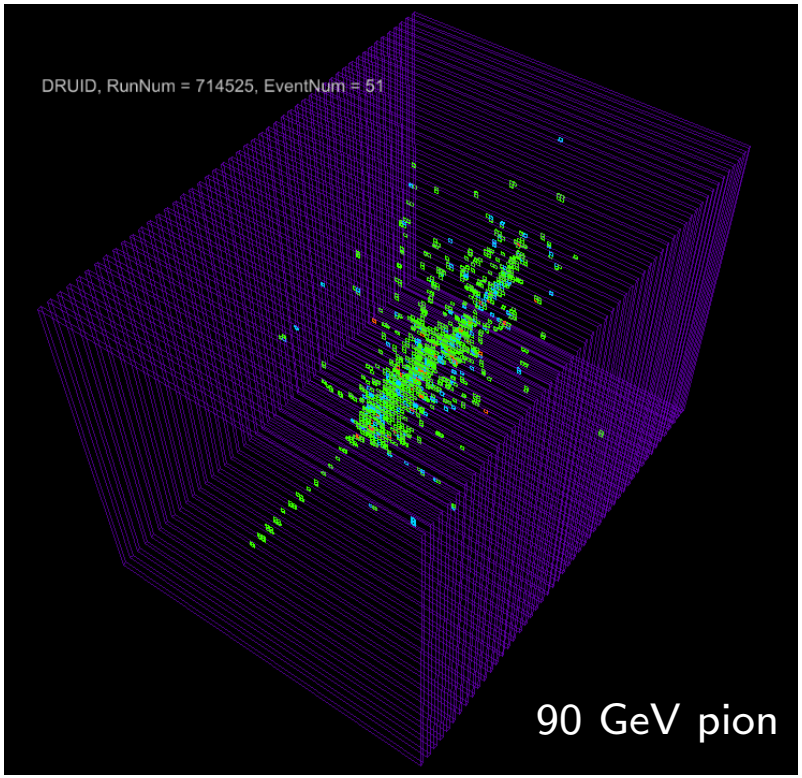
Tests in 3T magnetic field

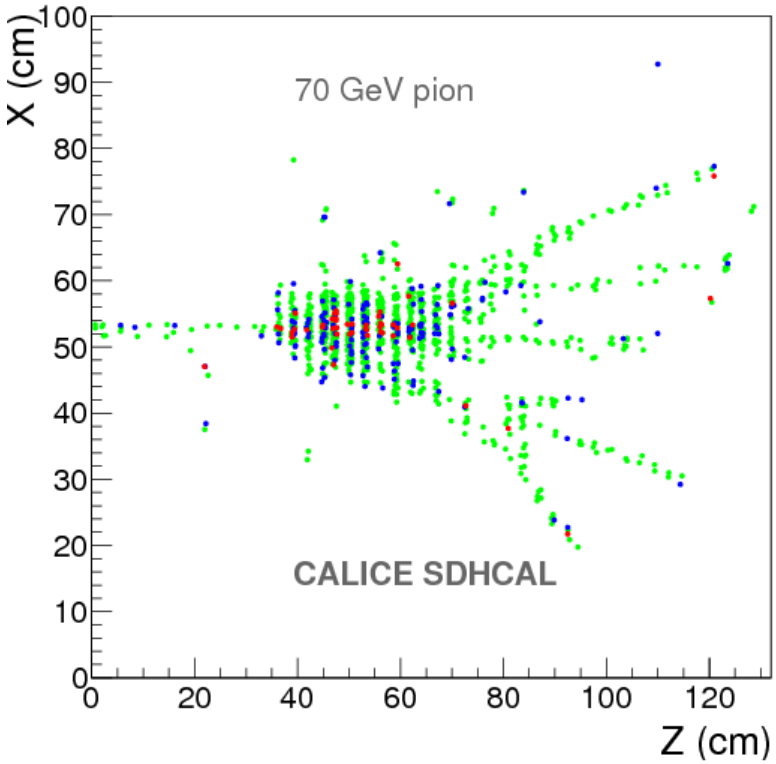




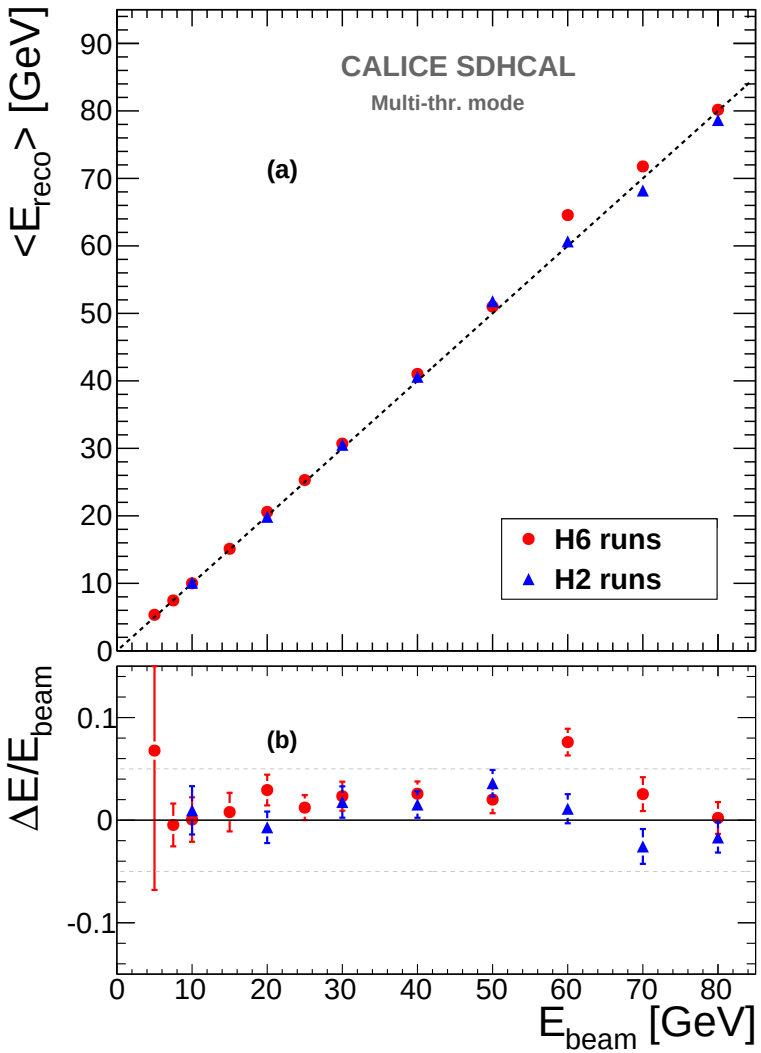
Event displays

Events recorded at beam tests

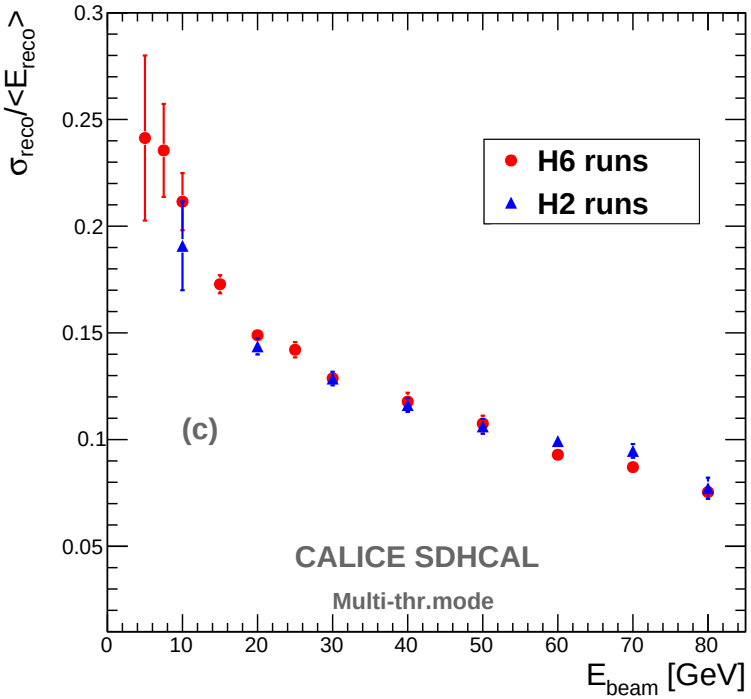




Energy reconstruction



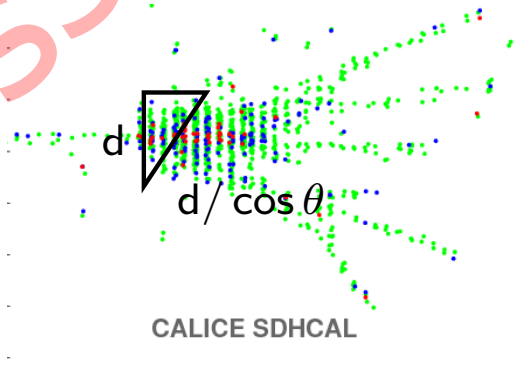
- $E_{reco} = \alpha N_1 + \beta N_2 + \gamma N_3$
- α, β, γ, quadratic functions of $N_{tot} = N_1 + N_2 + N_3$
- N_i Number of hits with i the highest crossed threshold.



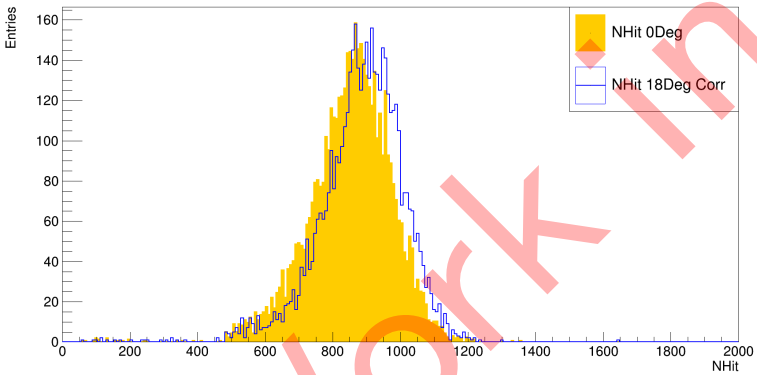
CERN SPS H2 and H6 beam line

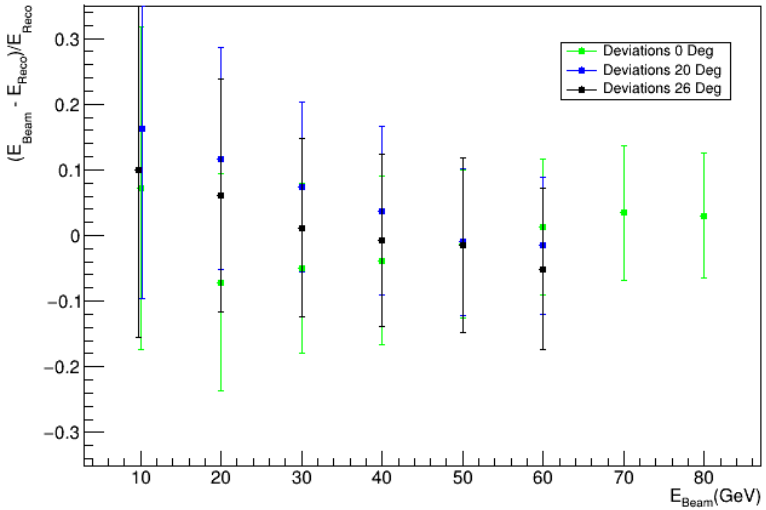
Incidence angle effect

- Rotation of the prototype in front of a beam.
- Geometrical effect
  Number of hits in hadronic shower varies as $1/\cos(\theta)$,
  θ=incidence angle.

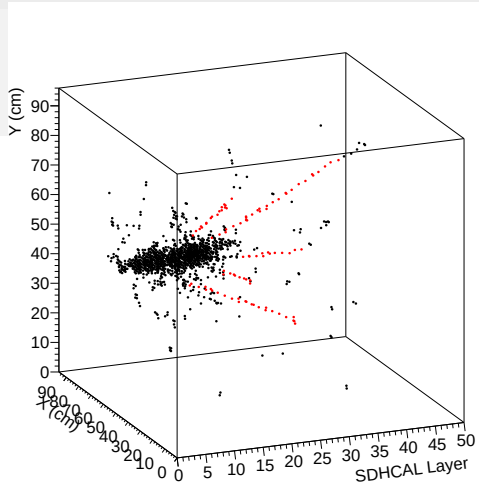


Correcting N_1, N_2, N_3 with $\cos(\theta)$ factor recovers energy reconstruction.

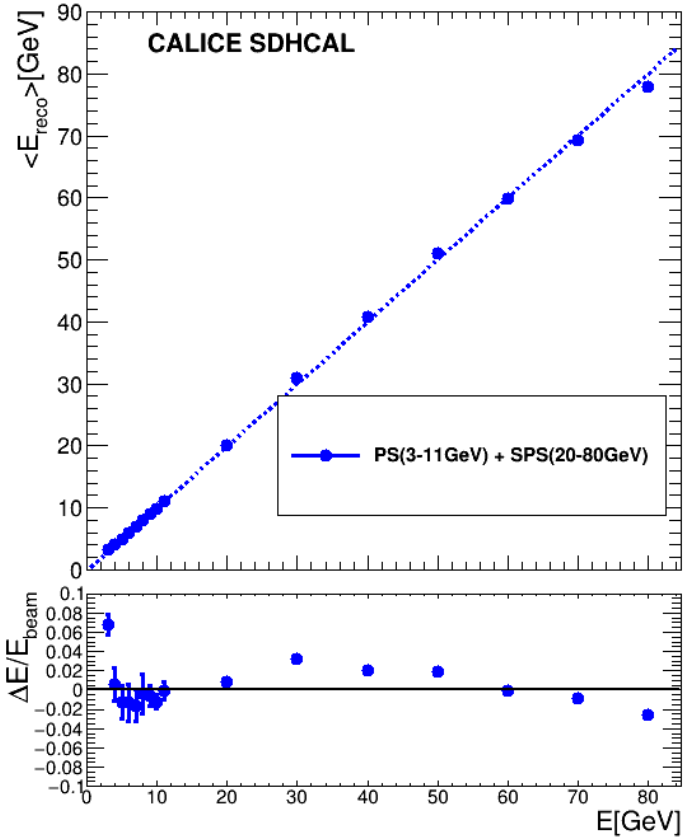




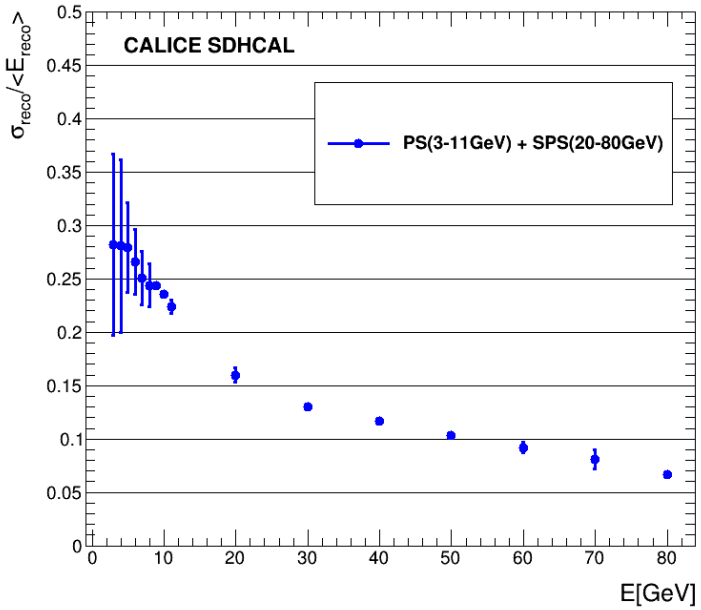
Low energy reconstruction



Combining advance reconstruction techniques (tracking with Hough transform) and use of TMVA's BDT allows to select pion with high purity even at low energy.

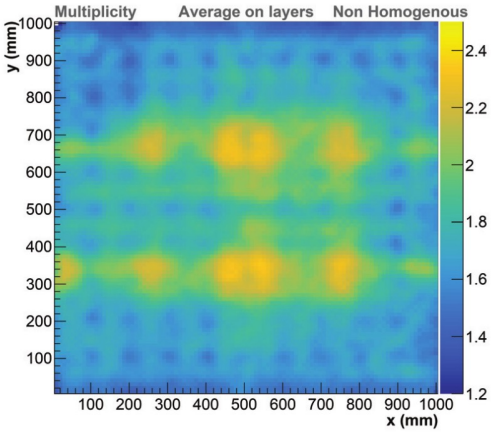


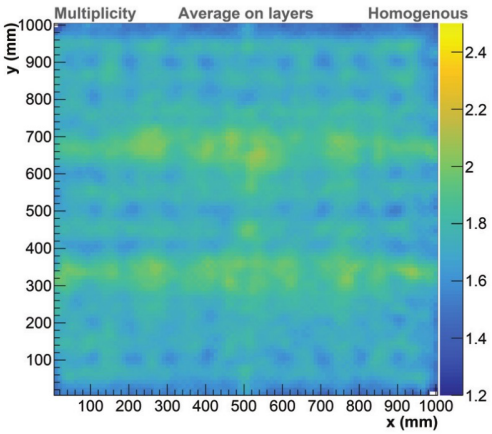
80 GeV pion simulation

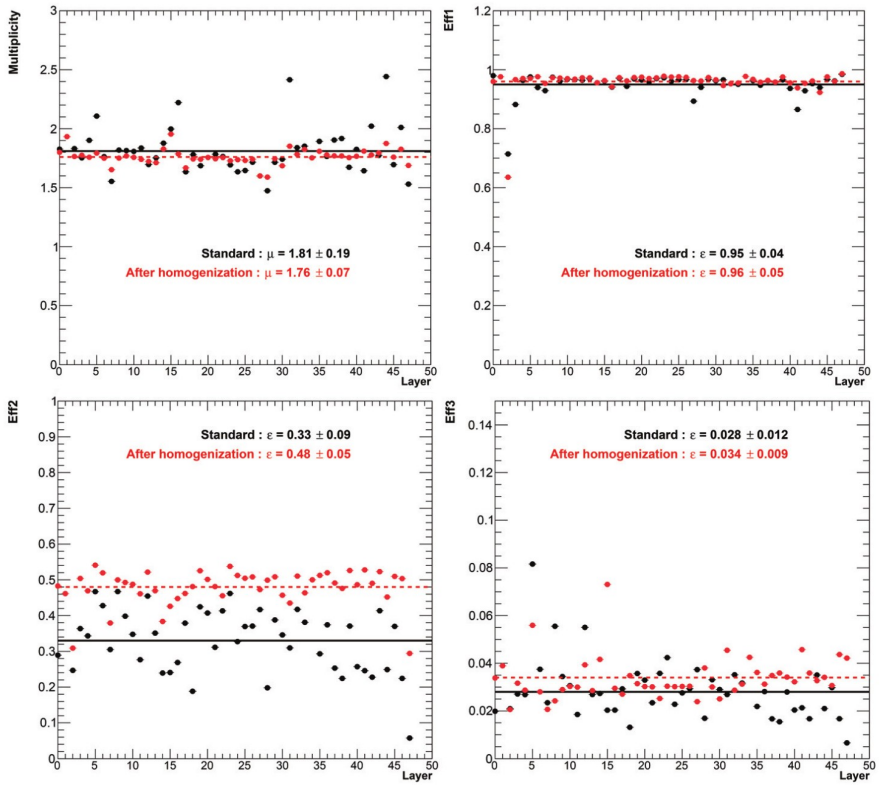


GRPC uniformity

- Efficiency and multiplicity vary. Can be measured per layer, per ASIC, per pad, depending on statistics.
- SDHCAL : Equalize response by adjusting ASIC thresholds or gains.

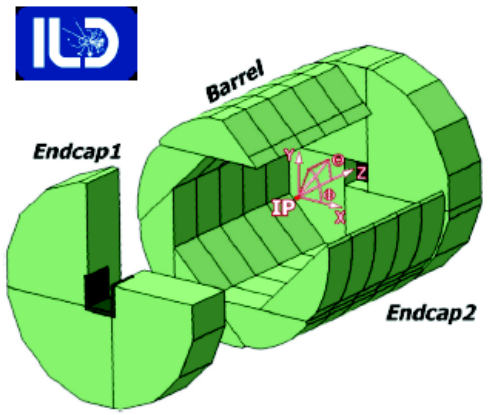


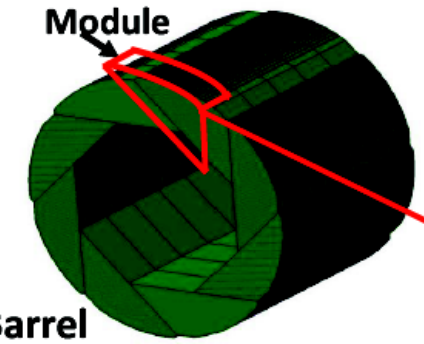


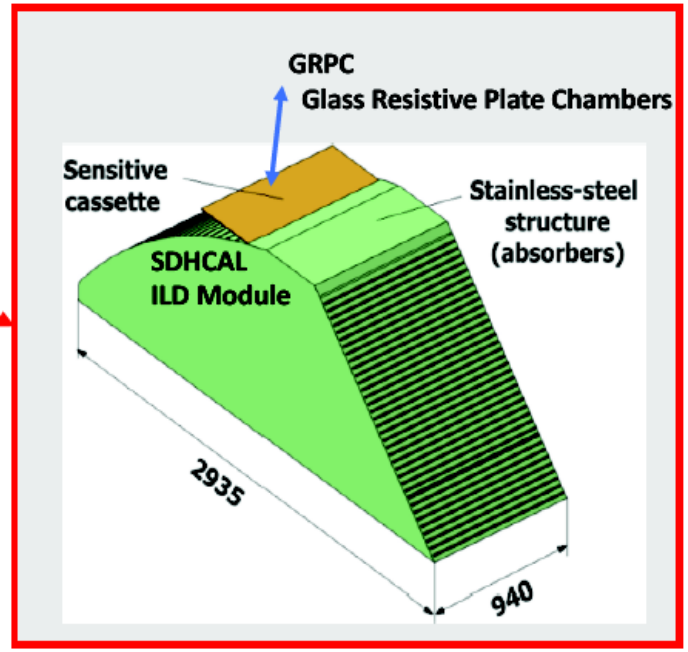


Impact on pion shower reconstruction under study.

SDHCAL developments for ILD







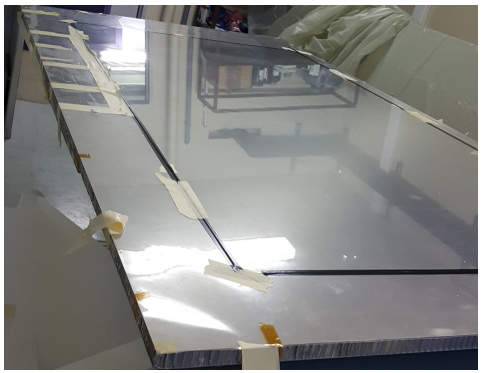
Prototype has 1 m^2 GRPC.
ILD needs up to 3 m^2 GRPC.

- Mechanical structure to be similar to the final one
- Electronic readout should be the most robust with minimal intervention during operation.
- DAQ system should be robust and efficient
- Envisage new features such timing, etc..

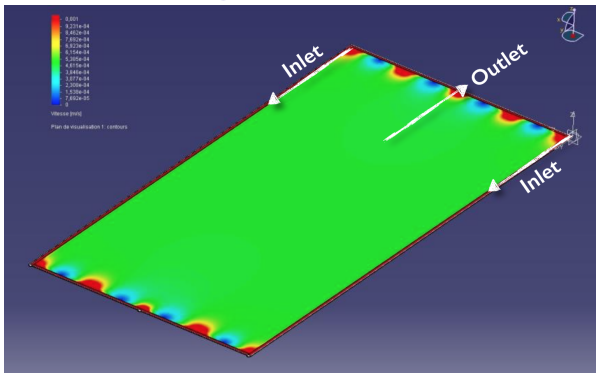
Build new prototype with few but large GRPC with the new components.

Larger GRPC

2 m^2 RPC assembled



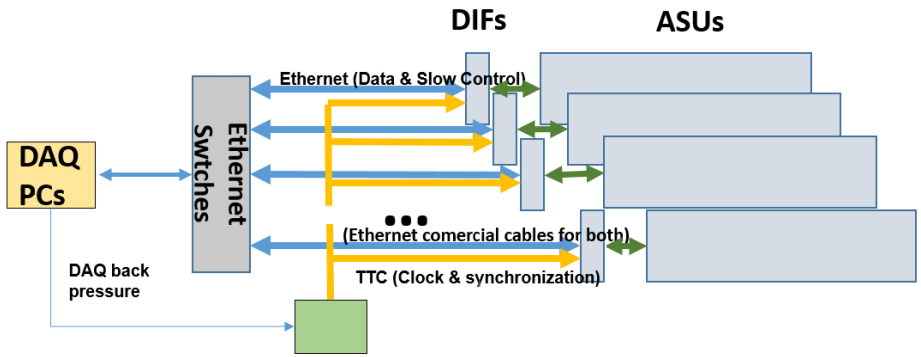
Scalable gas distribution

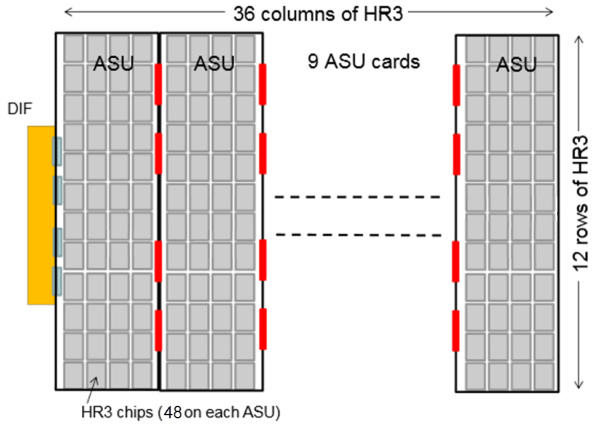


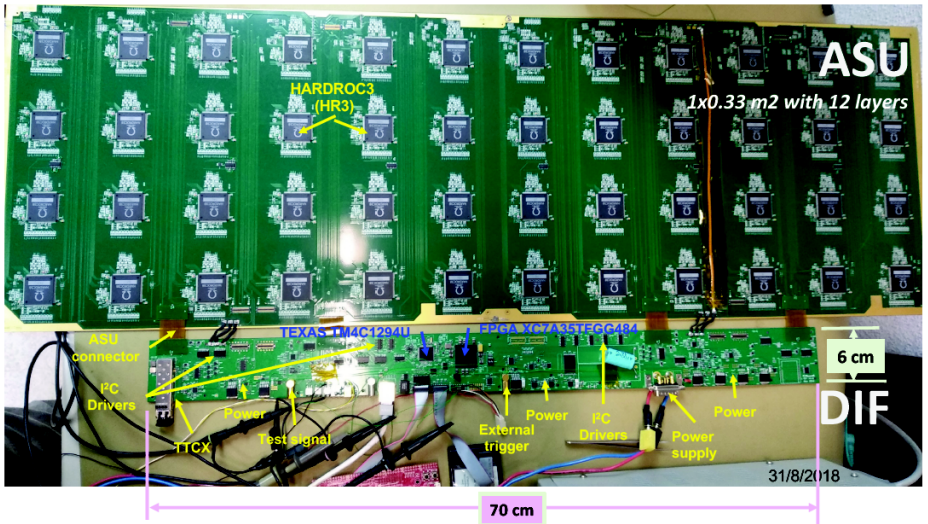
Mechanical structure

Industrial production of flat large absorber plates (3 m X 1 m) by roller leveling process + Electron Beam Welding $\Longrightarrow$ aplanarity less than 1mm.

New electronics



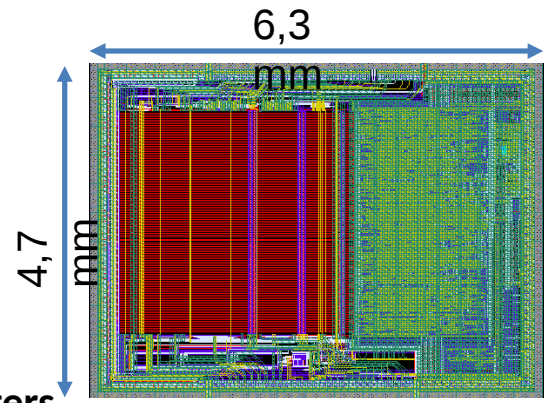




- 1 DIF can handle up to 432 HARDROC3.
- Front end PC on the DIF.
- DIF-ASIC communication through I^2C links.

New electronics

New electronics: ASIC



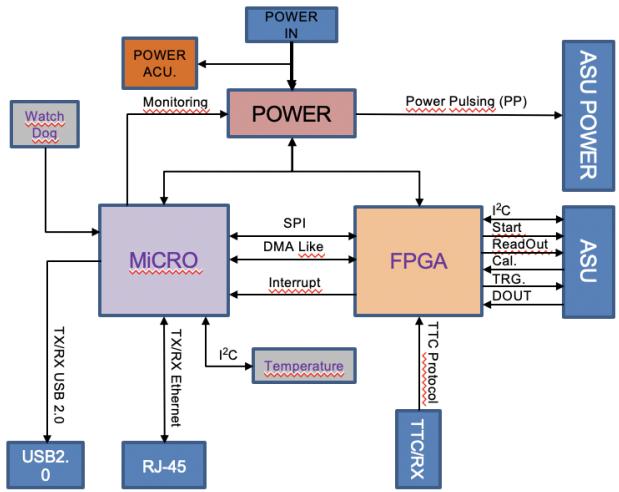
HARDROCR3 main features:

- **Independent channels**
- **Zero suppress**
- Extended dynamic range (**up to 50 pC**)
- **I2C link with triple voting for slow control parameters**
- packaging in QFP208, die size ~30 mm^2
- Consumption increase (internal PLL, I2C)

HR3 dynamic range 15 fC to 50 pC

DIF architecture

- Only **one DIF per plane** (instead of **three**)
- DIF handle up to **432 HR3 chips** (vs **48 HR2** in previous DIF)
- **Clock and synchronization** by **TTC** (already used in LHC)
- **93W Peak power supply** with super-capacitors (vs **8.6 W** in previous DIF)
- Spare I/O connectors to the FPGA (i.e. for GBT links)
- Upgrade **USB 1.1** to **USB 2.0**

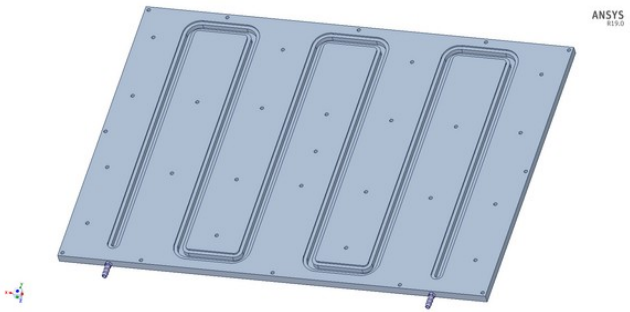


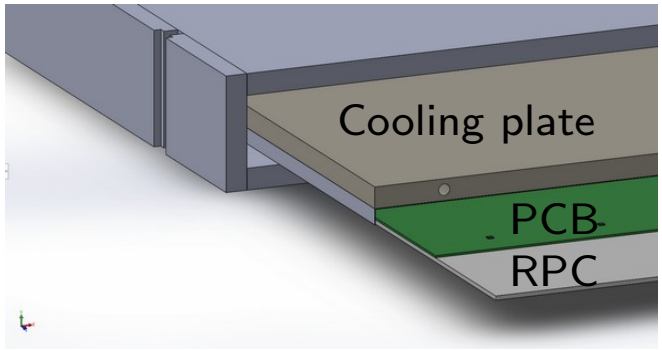
Active cooling

For circular collider (CEPC), continuous running, active cooling necessary.

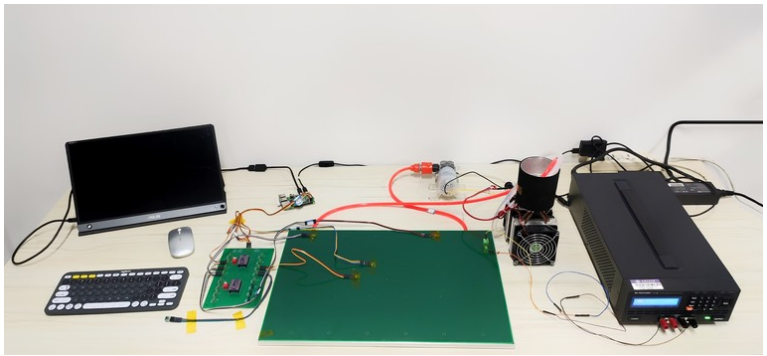
Cooling plates

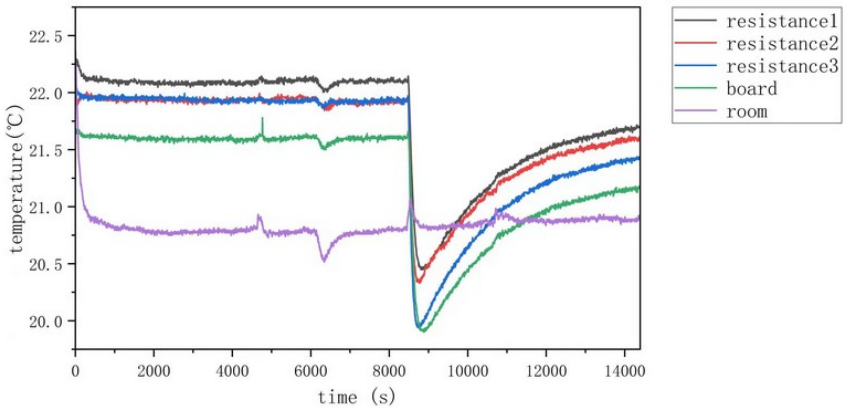
water pipes imbedded in metal plates. Cooling ability $\sim$ kW/m^2.





measurement with resistance to simulate ASIC heat.





Time measurement

precise timing in HCAL

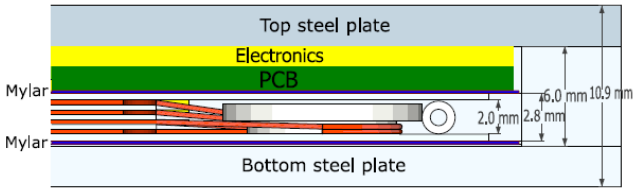
- Clean delayed neutron signal.
- Help separate close by showers.

New electronic

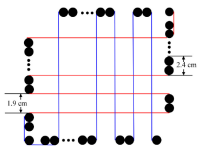
PETIROC ASIC

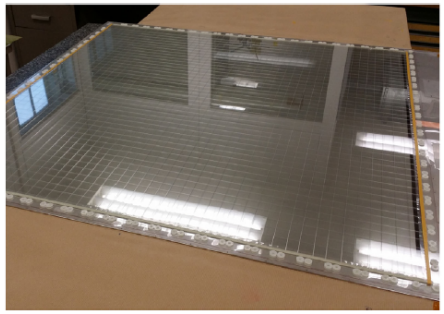
- 32-channels, < 3 mW/ch,
- high bandwidth preamp (GBWP$>$ 10 GHz),
- dual time and charge measurement (Q$>$50 fC) jitter $<$ 20 ps rms at Q$>$0.3 pC

Multigap GRPC

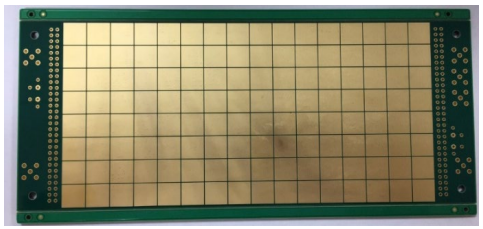


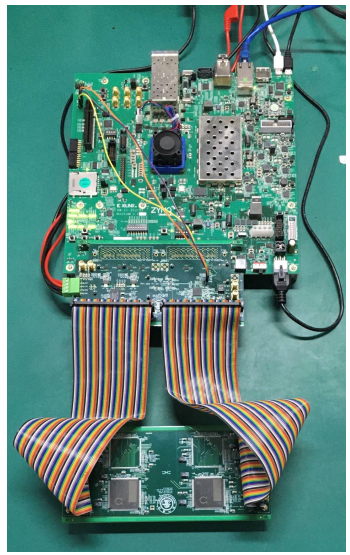
Efficiency = 94%





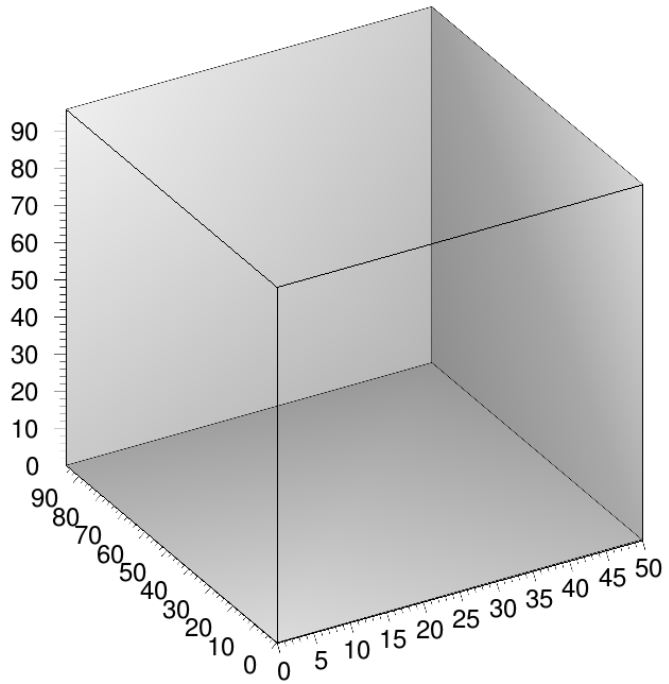
New ASU, DIF designed



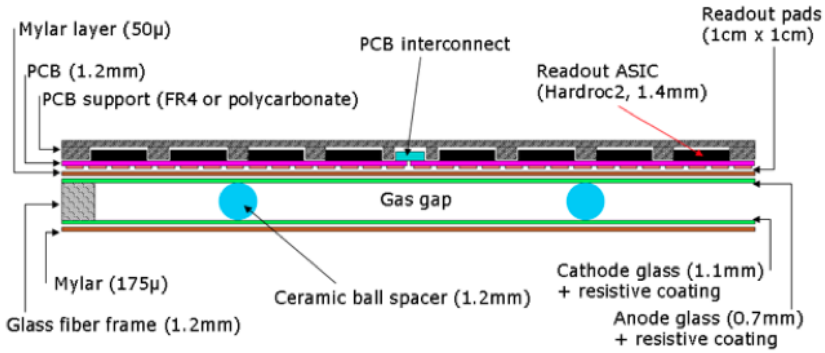


Concluding remarks

- The SDHCAL technological prototype is a high granularity sampling hadronic calorimeter designed for PFA studies.
- Good energy resolution has been achieved and can be improved using various techniques (uniformisation, use tracks in calorimeter, angular corrections, MVA techniques, ...)
- R&D continues on
  - Design of a length-scalable active unit. Expecting to test in beam next year.
  - Design active cooling for circular collider.
  - Add timing with resolution below 100 ps for 4D (almost 5D) calorimetry.



Backup


Mylar layer (50µ)
PCB (1.2mm)
PCB support (FR4 or polycarbonate)
PCB interconnect
Readout pads
(1cm x 1cm)
Readout ASIC
(Hardroc2, 1.4mm)
Gas gap
Mylar (175µ)
Glass fiber frame (1.2mm)
Ceramic ball spacer (1.2mm)
Cathode glass (1.1mm)
+ resistive coating
Anode glass (0.7mm)
+ resistive coating


FlatMaster 120
AMADA