SDHCAL Status
Present & Future

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On behalf the SDHCAL groups of
CALICE

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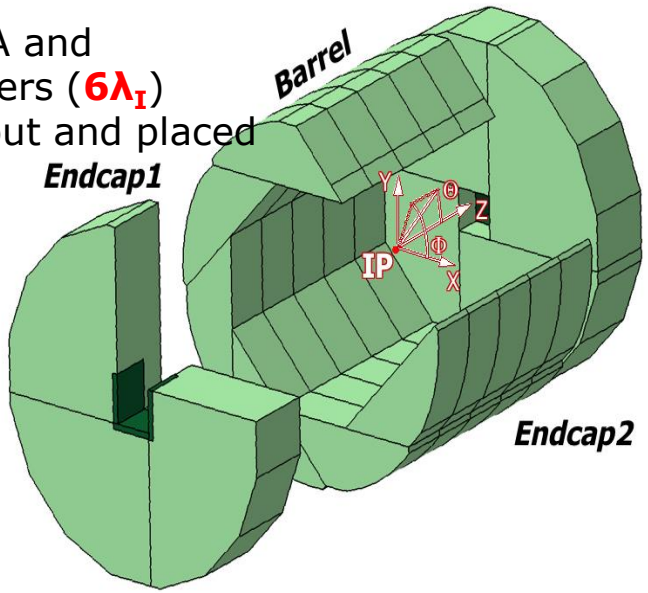
SDHCAL Status
Present & Future

- ✓ Construction of the technological prototype SDHCAL
- ✓ Beam tests results with the the SDHCAL
- ✓ R&D activities for the next generation of SDHCAL

SDHCAL-ILD

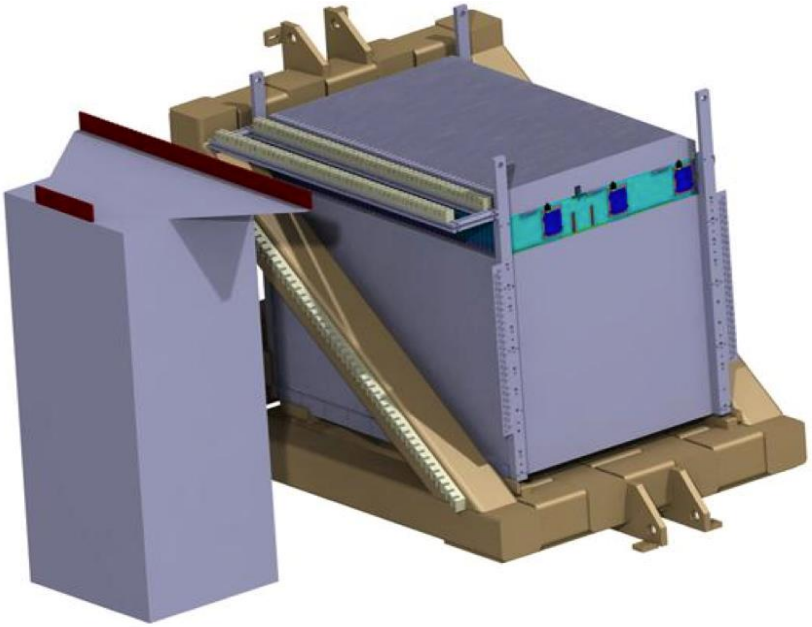
The SDHCAL-GRPC is one of the two HCAL options based on PFA and Proposed for **ILD of ILC**. Modules are made of 48 RPC chambers (**$6\lambda_I$**) equipped with **semi-digital, power-pulsed electronics** readout and placed in **self-supporting mechanical** structure to serve as absorber as well.



The structure proposed for the SDHCAL-ILD :

- very **compact** with negligible dead zones
- Eliminates projective cracks
- Minimizes barrel / endcap separation (services leaving from the outer radius)

SDHCAL Technological Prototype should be as much as possible similar to the ILD module and able to study **hadronic showers**



Challenges

-Homogeneity for large surfaces
-Thickness of only few mms
-Lateral segmentation of 1 cm X 1 cm
-Services from one side
-Embedded power-cycled electronics
-Self-supporting mechanical structure

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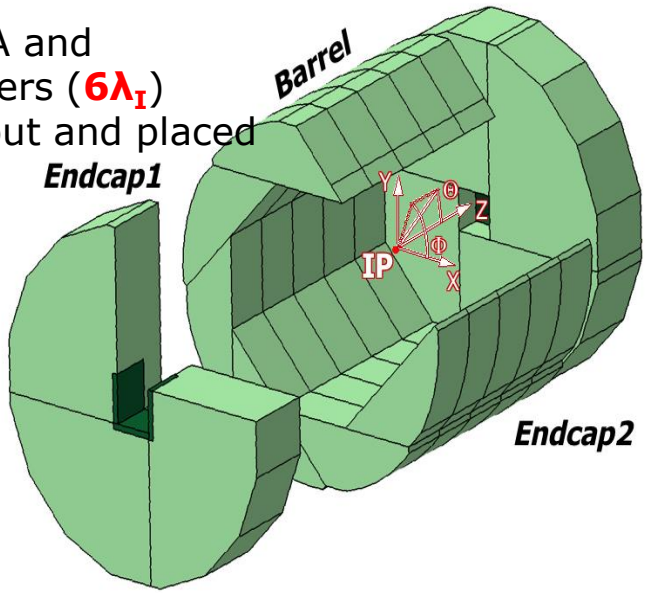

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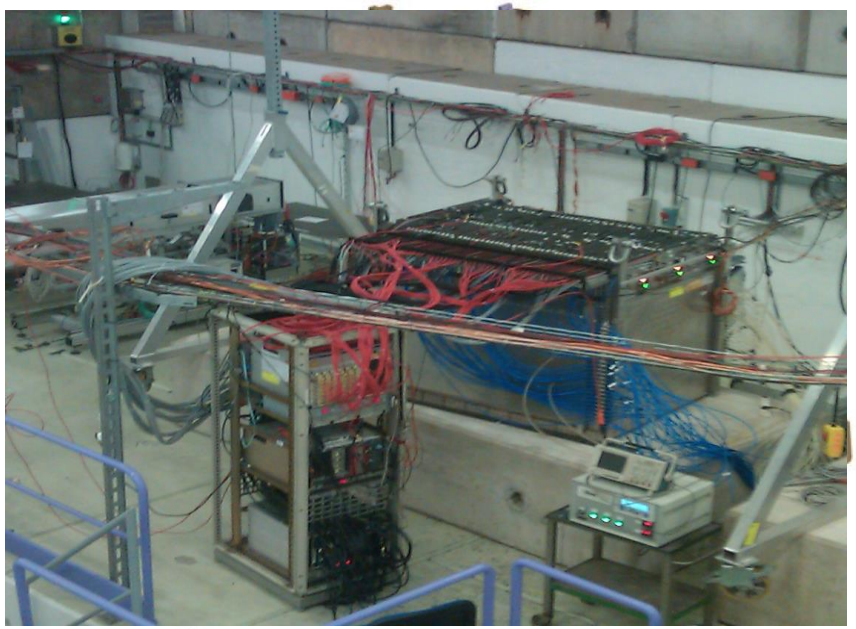

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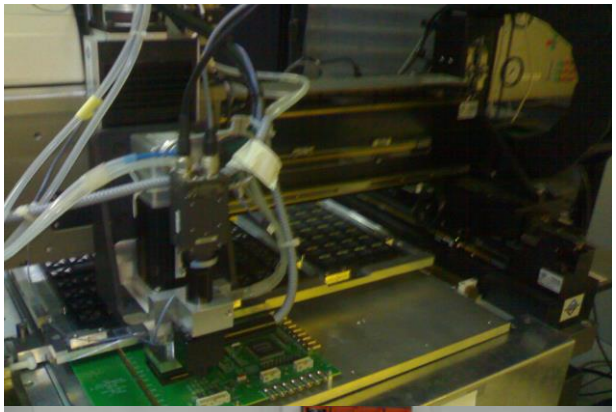
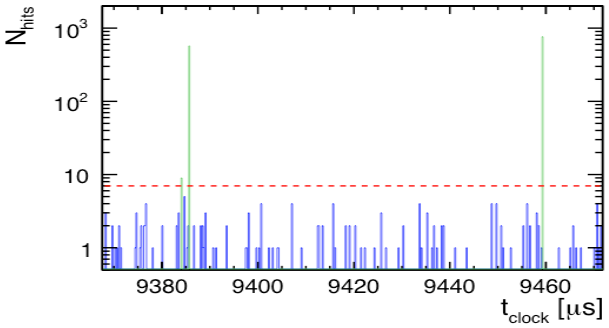
SDHCAL prototype construction

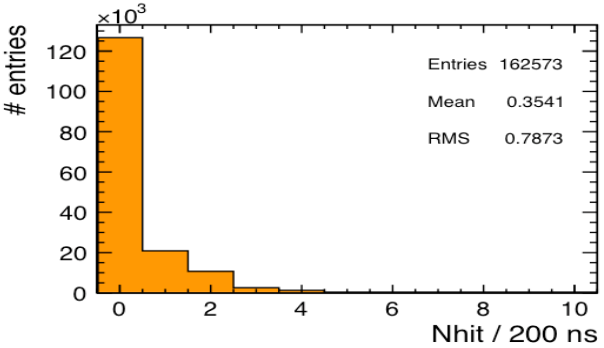
- ✓ 10500 64-ch ASIC were tested and calibrated using a dedicated (ASICs layout : 93%).
- ✓ 310 PCBs were produced, cabled and tested. They were assembled by sets of six to make 1m^2 ASUs
- ✓ 170 DIF, 20 DCC were built and tested.
- ✓ 50 detectors were built and assembled with their electronics into cassettes.
- ✓ Self-supporting mechanical structure.
- ✓DAQ system using both USB and HTML protocol was developed and used.
- ✓ Full assembly took place at CERN.

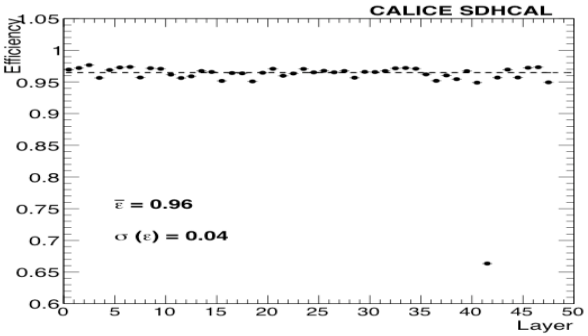


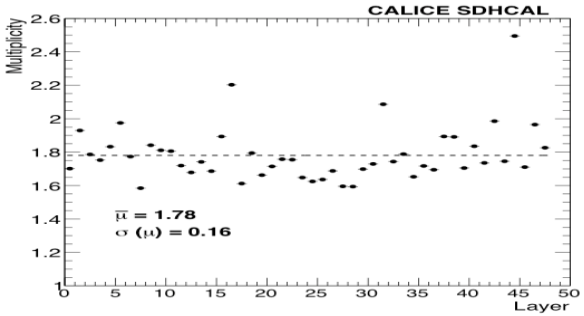
SDHCAL performance

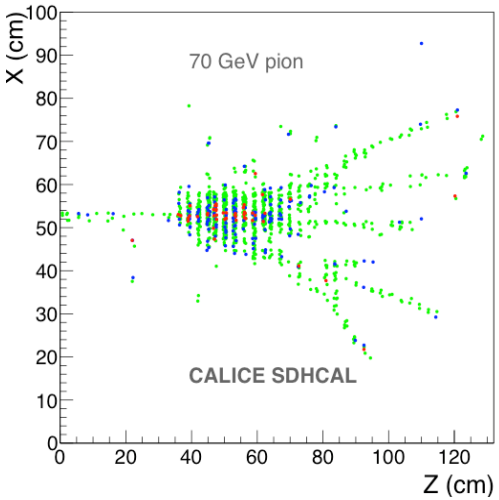
- The SDHCAL prototype was exposed to hadron, muon and electron beams in 2012 on both H6 and H6-SPS lines.
- **Power-pulsing** using the SPS spill structure was used to reduce the power consumption.
- **Self-triggering** mode is used but external trigger mode is possible
- The threshold information helps to improve on the energy rec. by better accounting for the number of tracks crossing one pad
- New data were taken in 2015 with an improved DAQ system

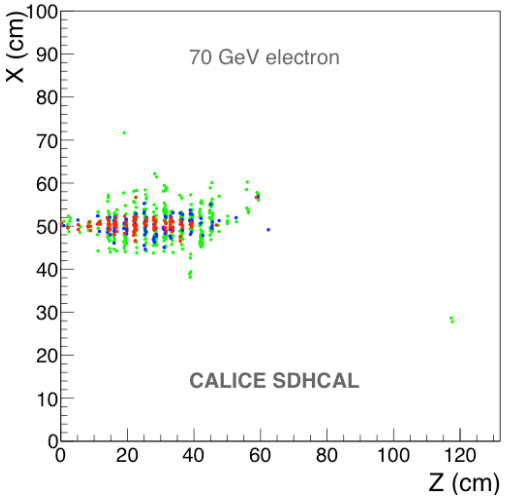








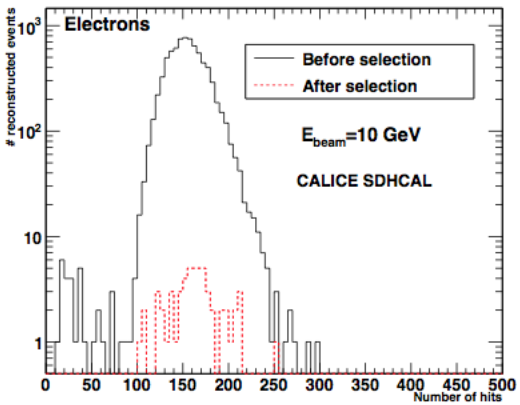


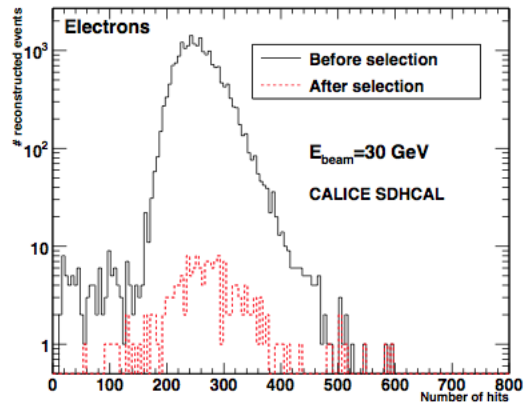


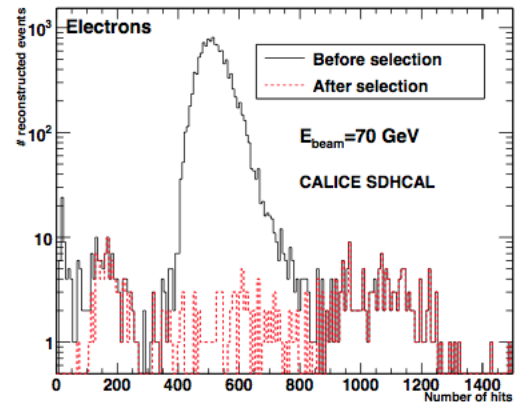
Event selection

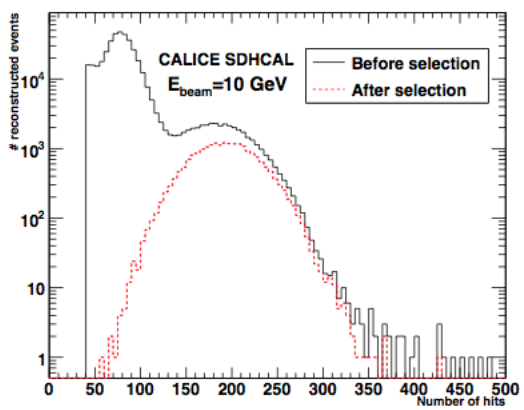
Electron rejection	Shower start ≥ 5 or $N_{layer} \geq 30$
Muon rejection	$\frac{N_{hit}}{N_{layer}} > 2.2$
Radiative muon rejection	$\frac{N_{layer} \backslash RMS > 5cm}{N_{layer}} > 20\%$
Neutral rejection	$N_{hit \in First\ 5\ layers} \geq 4$

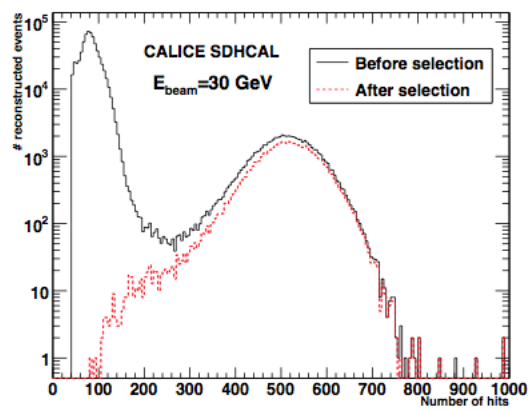
- No containment selection.
- No Cerenkov detector

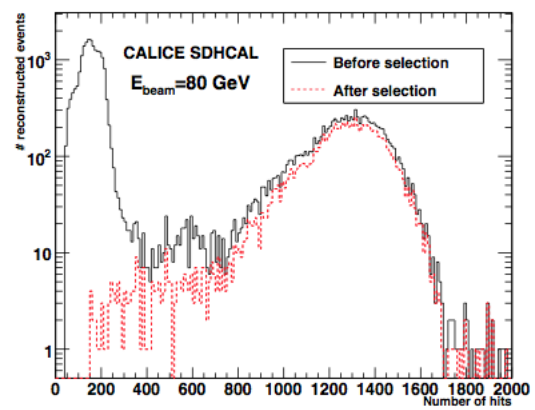












Energy estimation

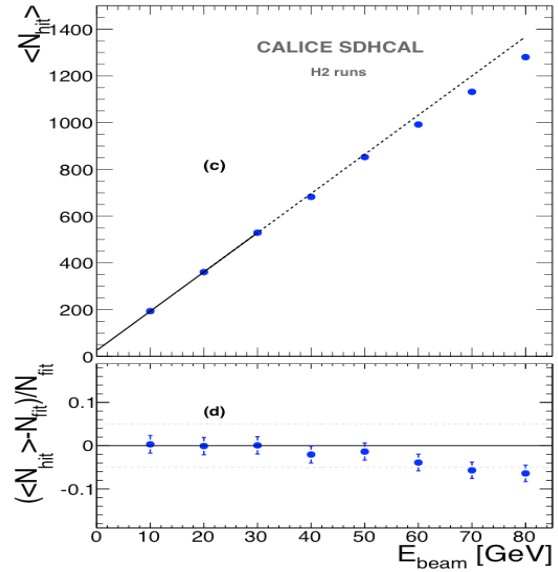
The thresholds weight evolution with the total number of hits obtained by minimizing a χ^2

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

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

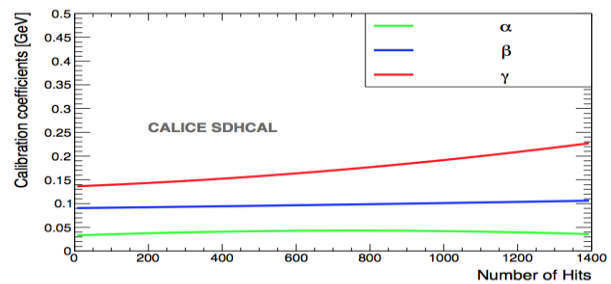
N_1,N_2 and N_3 : exclusive number of hits associated to first, second and third threshold.

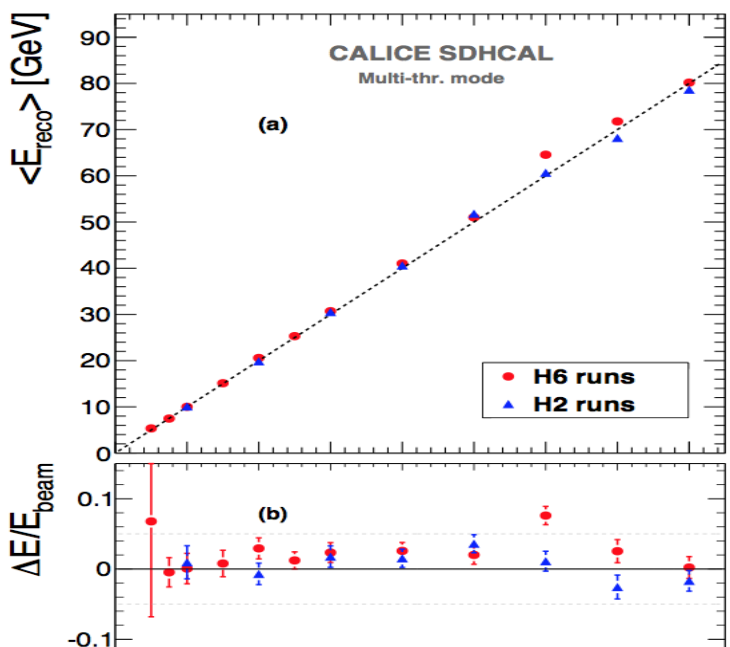
α, β, γ are quadratic functions of the total number of hits (N_{tot})

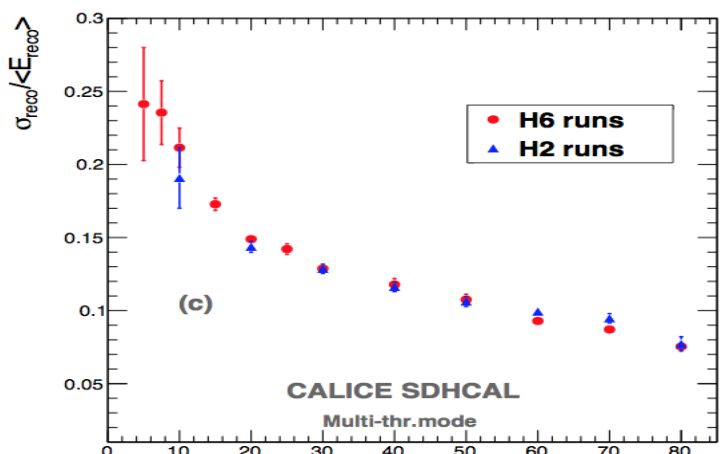


Events of H2 runs corresponding to energies : **5, 10, 30 , 60** and **80** GeV were used to fit the 9 parameters.

Then the energy of hadronic events in both H2(only pions) and H6 (presence of protons)





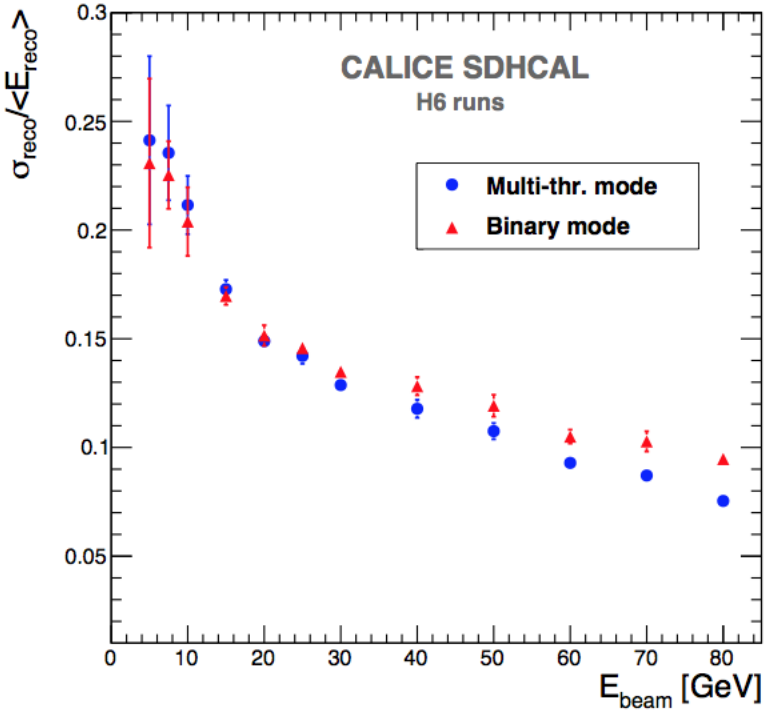


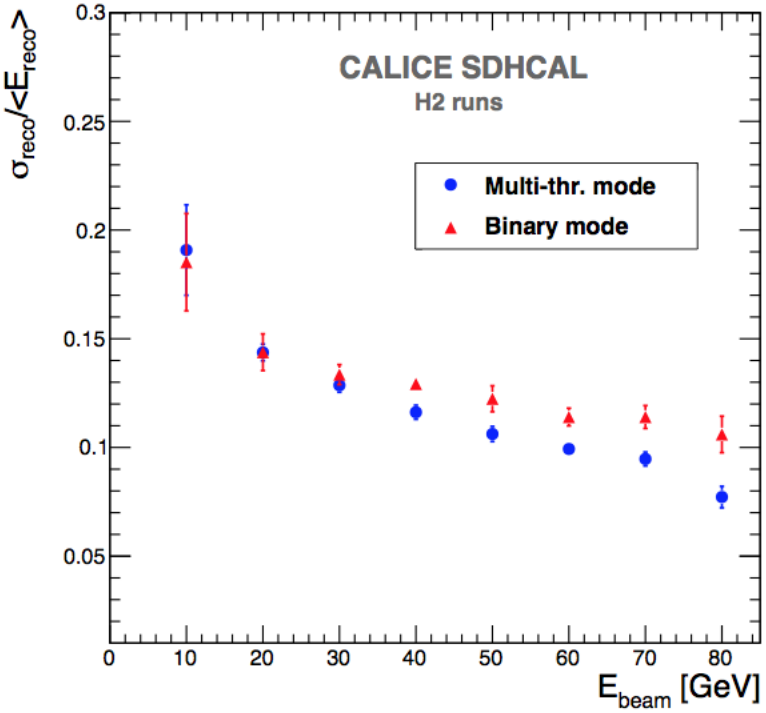
Energy estimation

Comparison semi-digital versus binary readout

E_{rec} (binary) = $C\, N_{tot} + D\, N^2_{tot} + F\, N^3_{tot}$

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

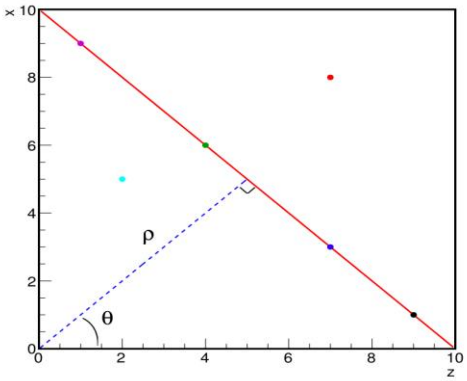


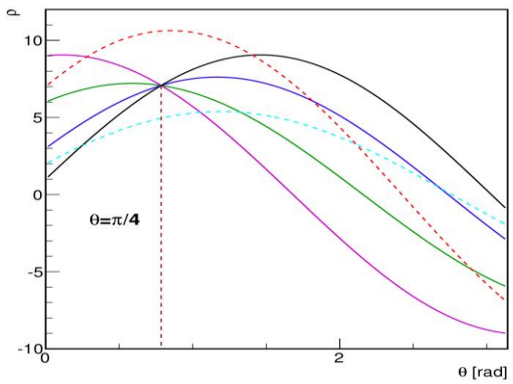


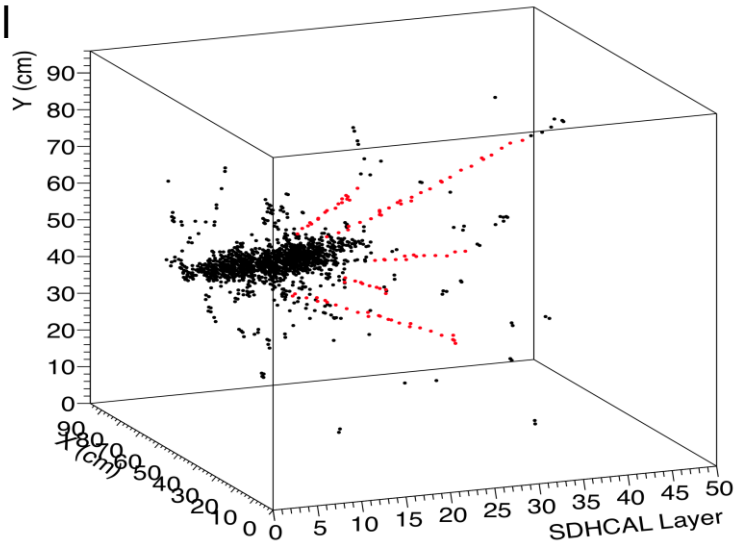
Substantial improvement a energy > 30 GeV

SDHCAL High-granularity impact

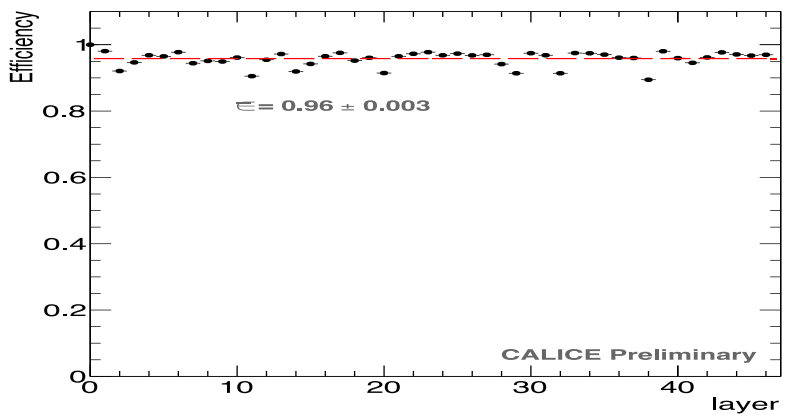
Hough Transform is an example to extract tracks within hadronic showers and to use them to control the calorimeter in situ

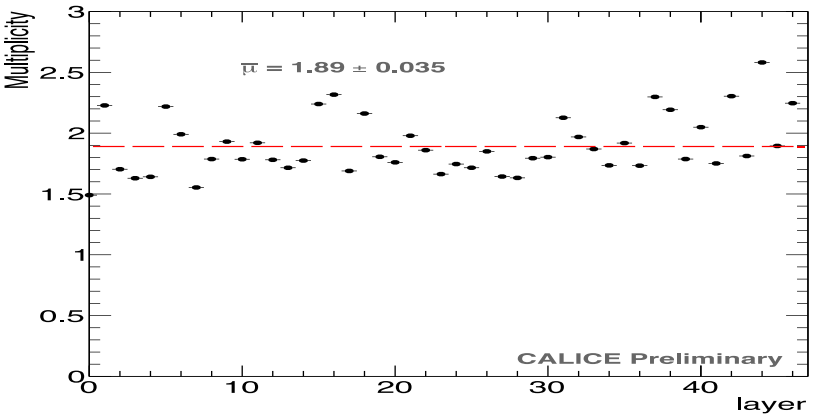






$$\rho_{xz} = z \sin(\theta) + x \cos(\theta)$$





Excellent agreement with results obtained with cosmic and beam-muons.

Good tool to discriminate electron/hadron

The technique is successfully extended to hadronic showers in presence of magnetic field.

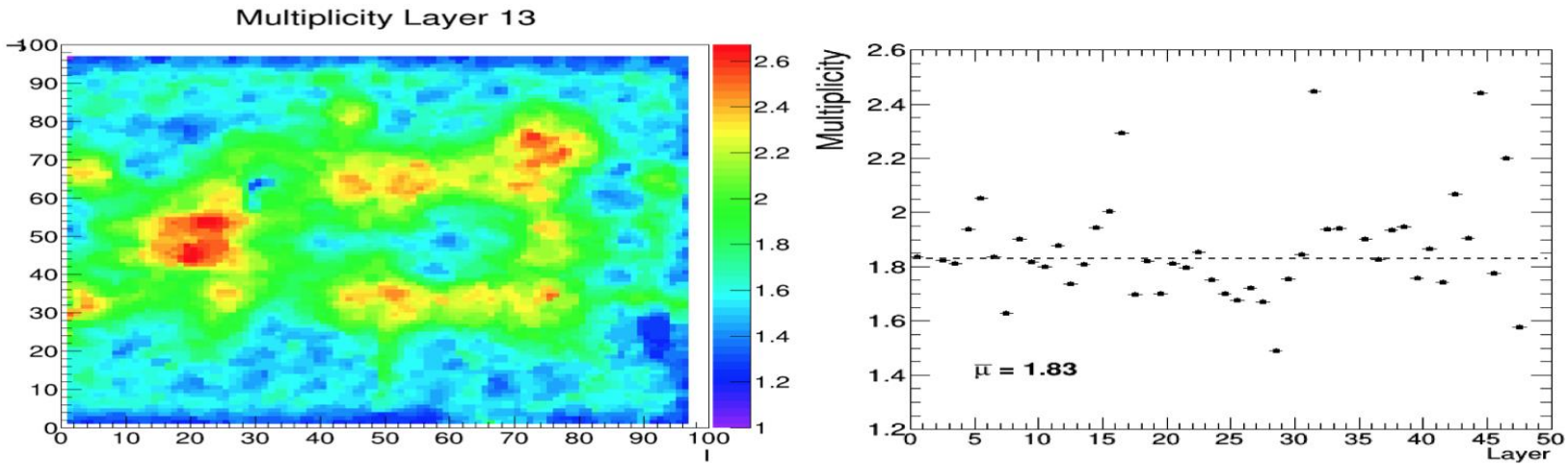
Ongoing activities

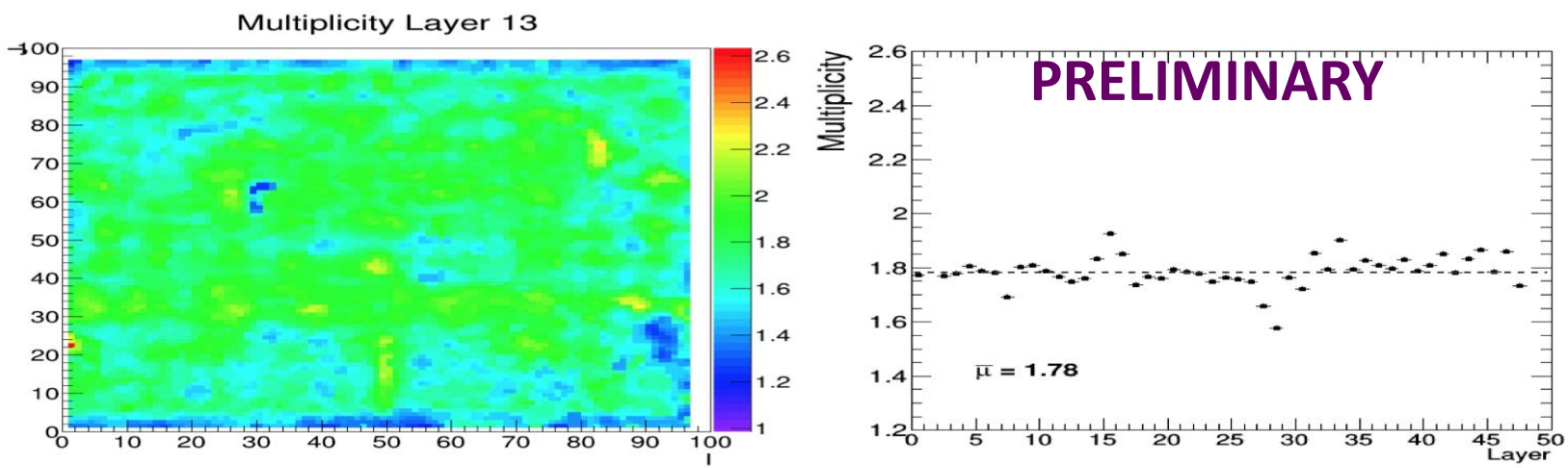
The results obtained with the 2012 were without any correction. Several methods are used to render the detectors response homogenous:

→ Gain correction based on noise level, on efficiency and multiplicity

→ Correction based on changing the threshold for each ASIC

We think this will improve on energy resolution by reducing the response dispersion





Ongoing activities

→ Response of the prototype to low energy

→ Response to hadrons with different inclination angles

→ Optimization of the threshold values

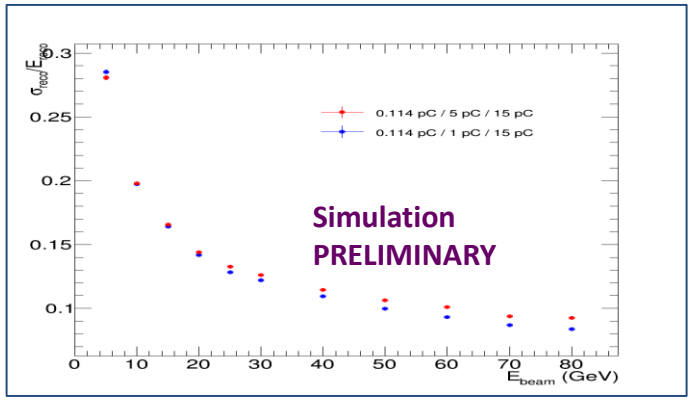
→ Using Cerenkov detector for particle identification

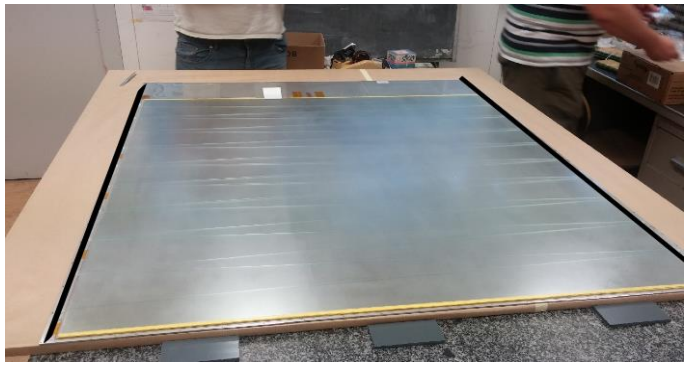
→ Realistic simulation of the SDHCAL

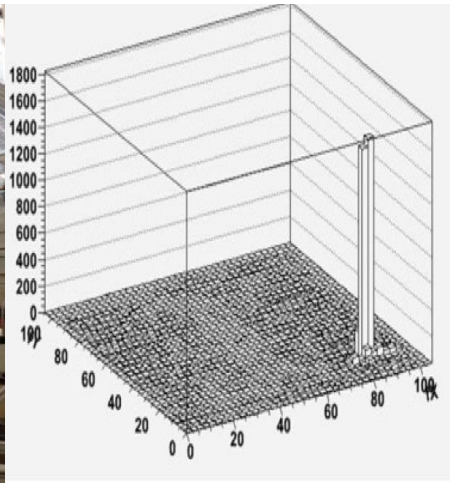
→ Optimize the hadronic shower separation in the SDHCAL

→ Studying the **MRPC** (**looking to exploit the hadronic shower timing structure**)

→ Preparation of common TB with the technological SiW prototype in front of SDHCAL in order to study realistically the performance of both.

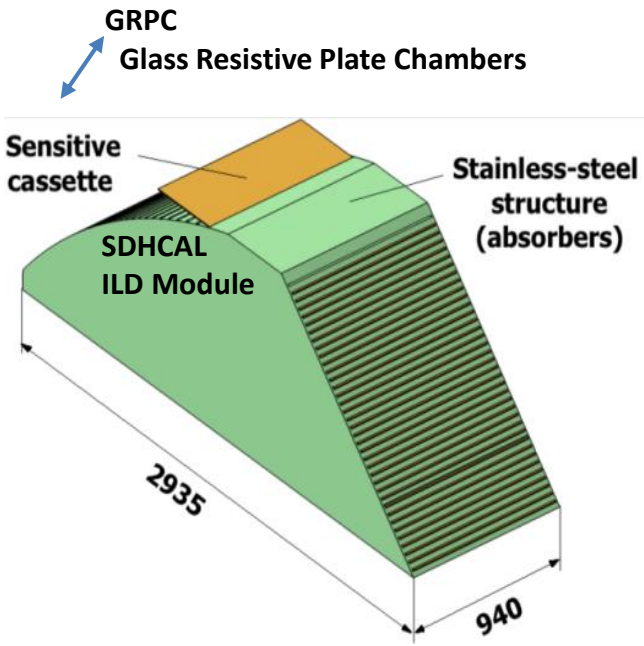






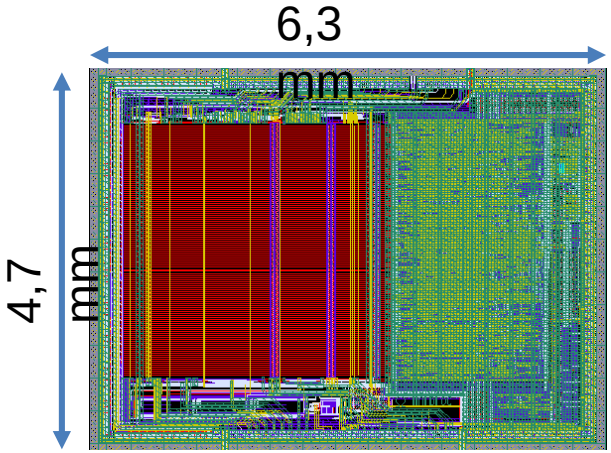
Validation of SDHCAL for future experiments

- ❑ Detectors as large as 3m X 1m need to be built
- ❑ Electronic readout should be the most robust with minimal intervention during operation.
- ❑ DAQ system should be robust and efficient
- ❑ Mechanical structure to be similar to the final one
- ❑ Envisage new features such timing, etc..



Goal: to build new prototype with few but large GRPC with the new components

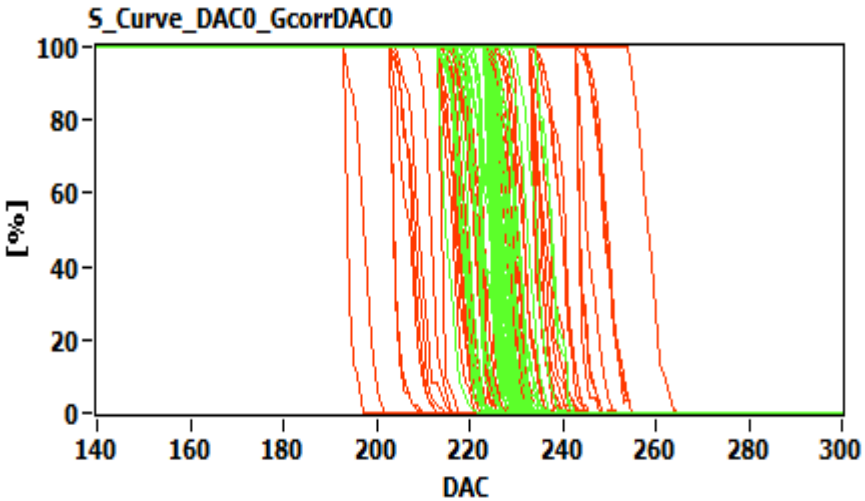
ASIC: HARDROC3

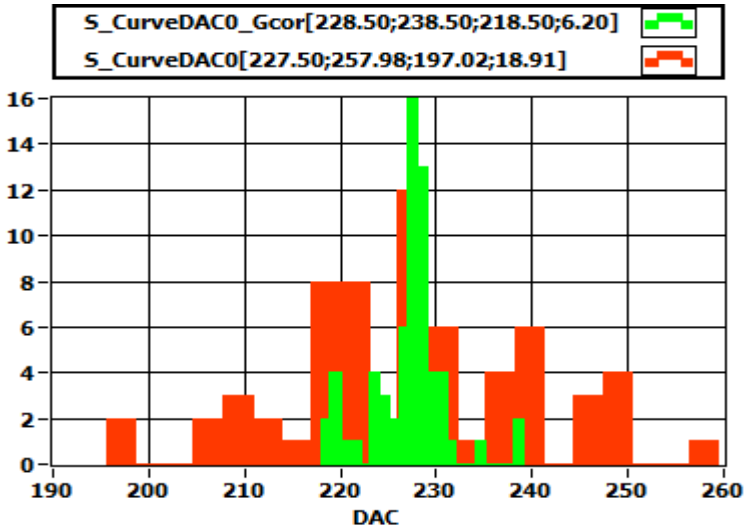


HR3 main features:

- 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)

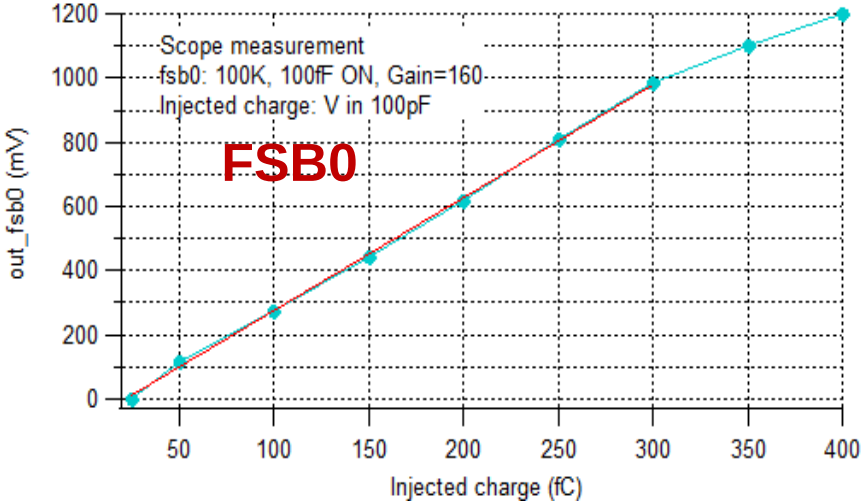
H3B TESTED : 786, Yield : 83.3 %

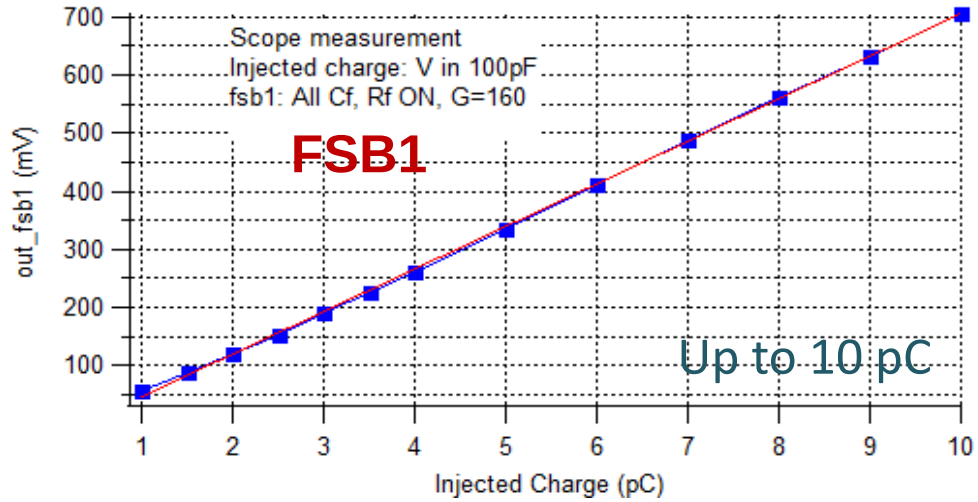


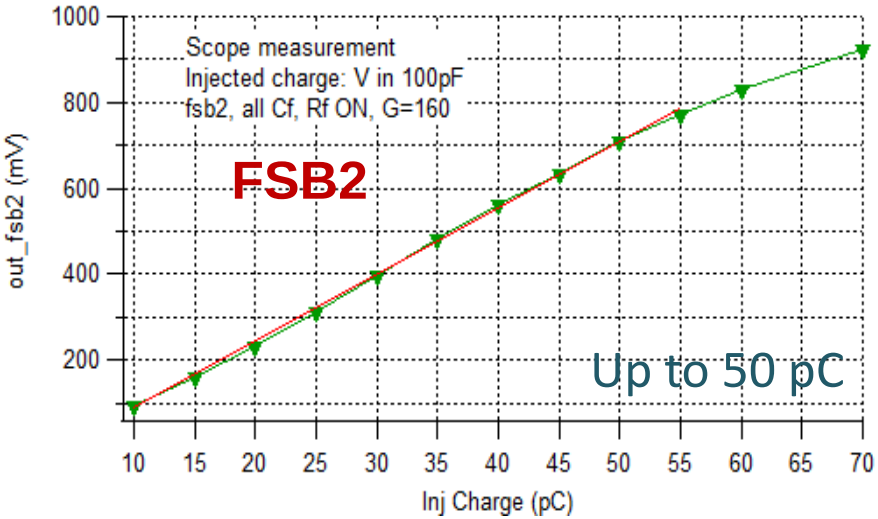


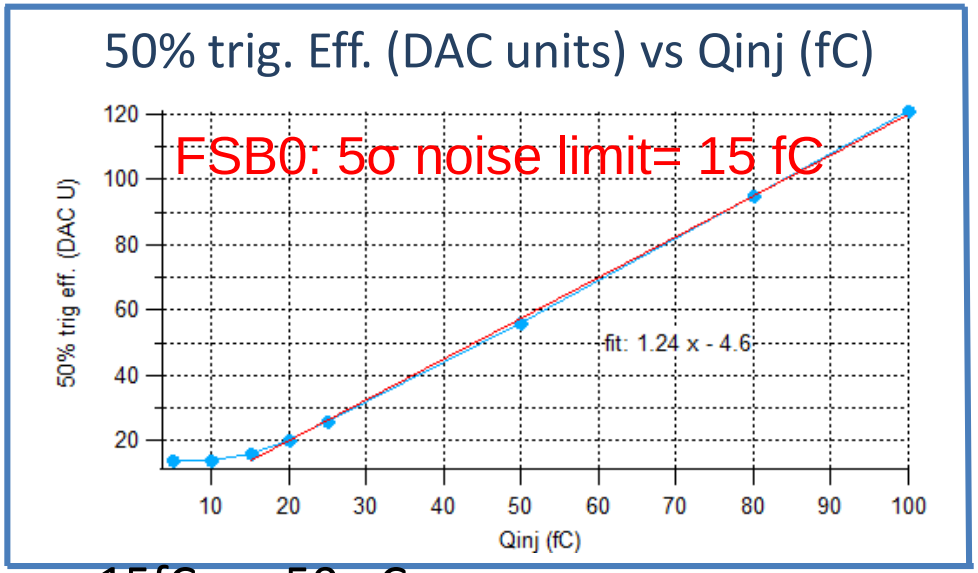
HR3: Analog linearity

Fast shaper outputs (mV) vs Qinj (fC)





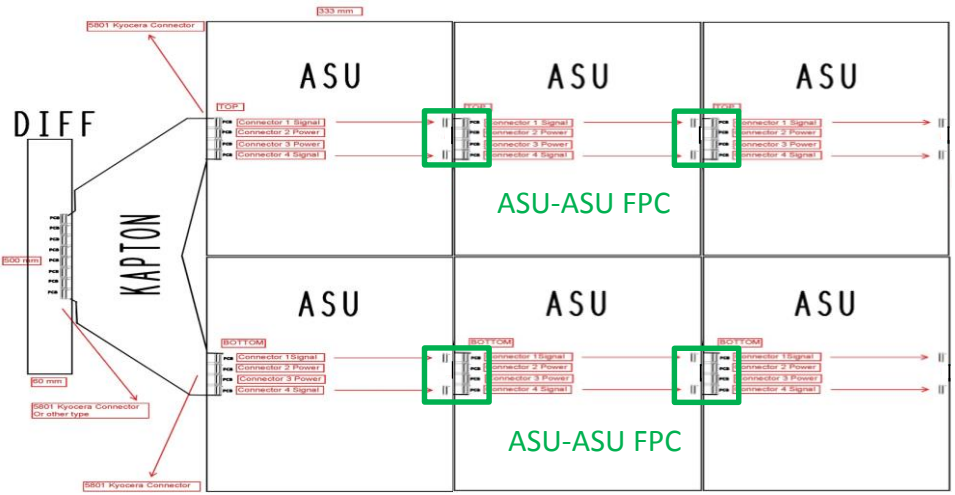


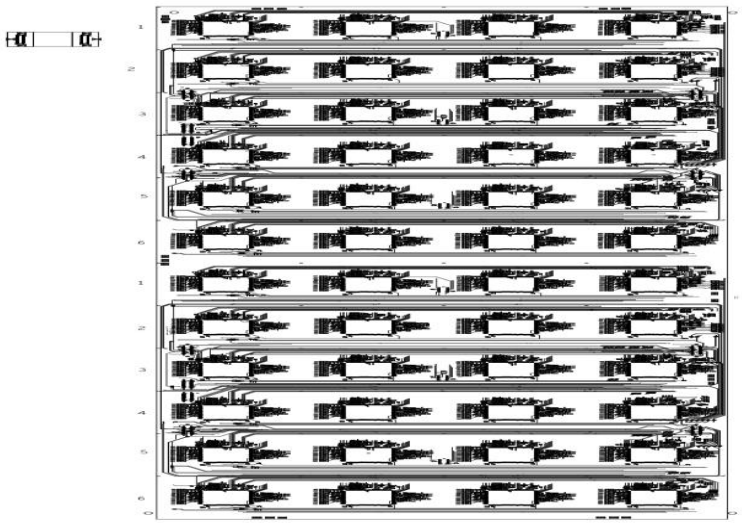


Dynamic range: 15fC - 50 pC

Electronic board

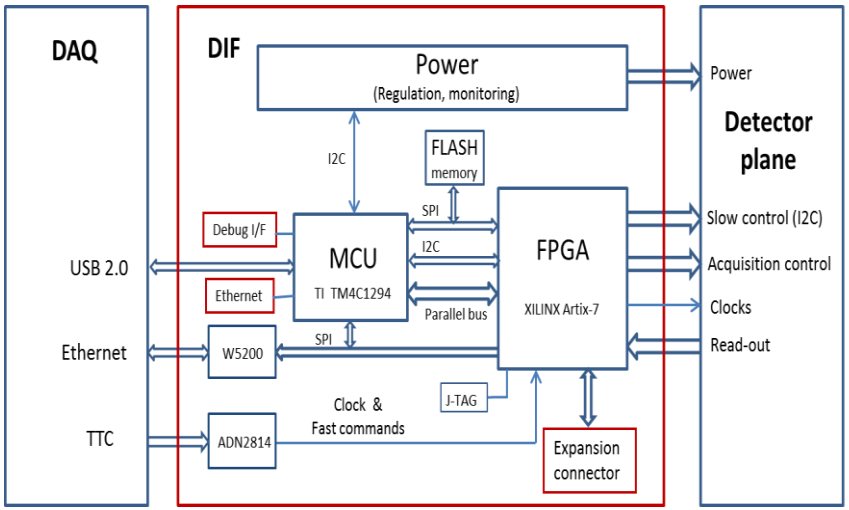
1m X 0.33 m, 12 layers ASU with new rooting design was conceived and will be produced soon





DAQ board

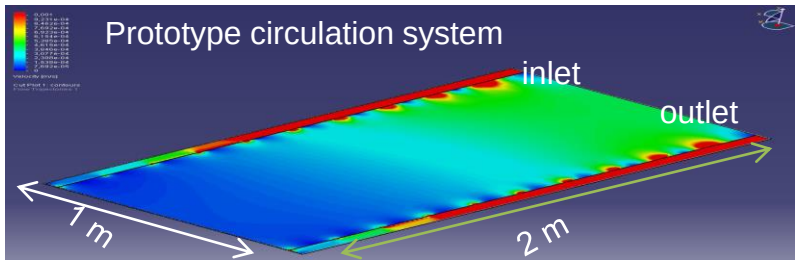
New Detector InterFace board was conceived and will be produced soon

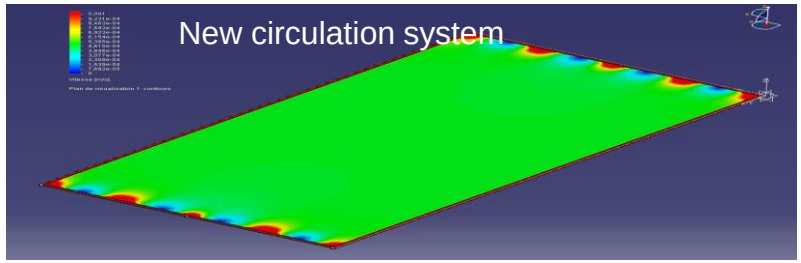


- Only one DIF per plane (instead of three)
- For the longest plane (1x3m) the DIF will handle 432 HR3 chips (vs 48 HR2 in previous DIF)
- HR3 slow control through I2C bus (12 IC2 buses). Keeps also two of the old slow control buses as backup & redundancy.
- Data transmission to/from DAQ by Ethernet
- 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

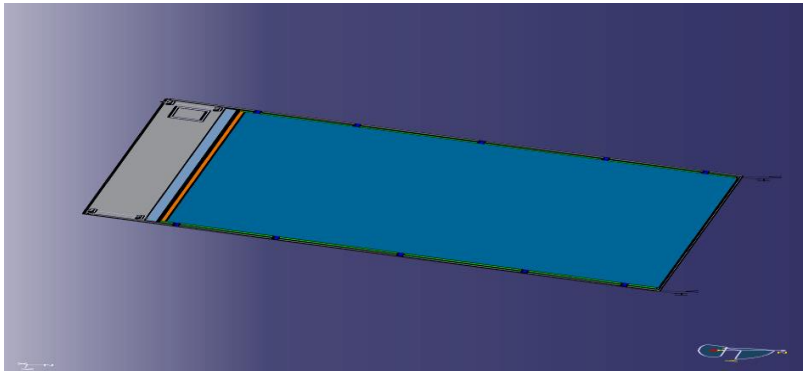
Detector conception

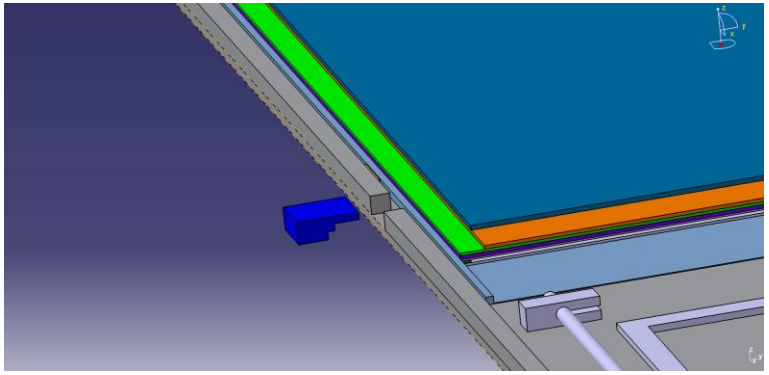
Construction and operation of large GRPC necessitate some improvement on the present scenario.
Gas distribution : new scheme is proposed



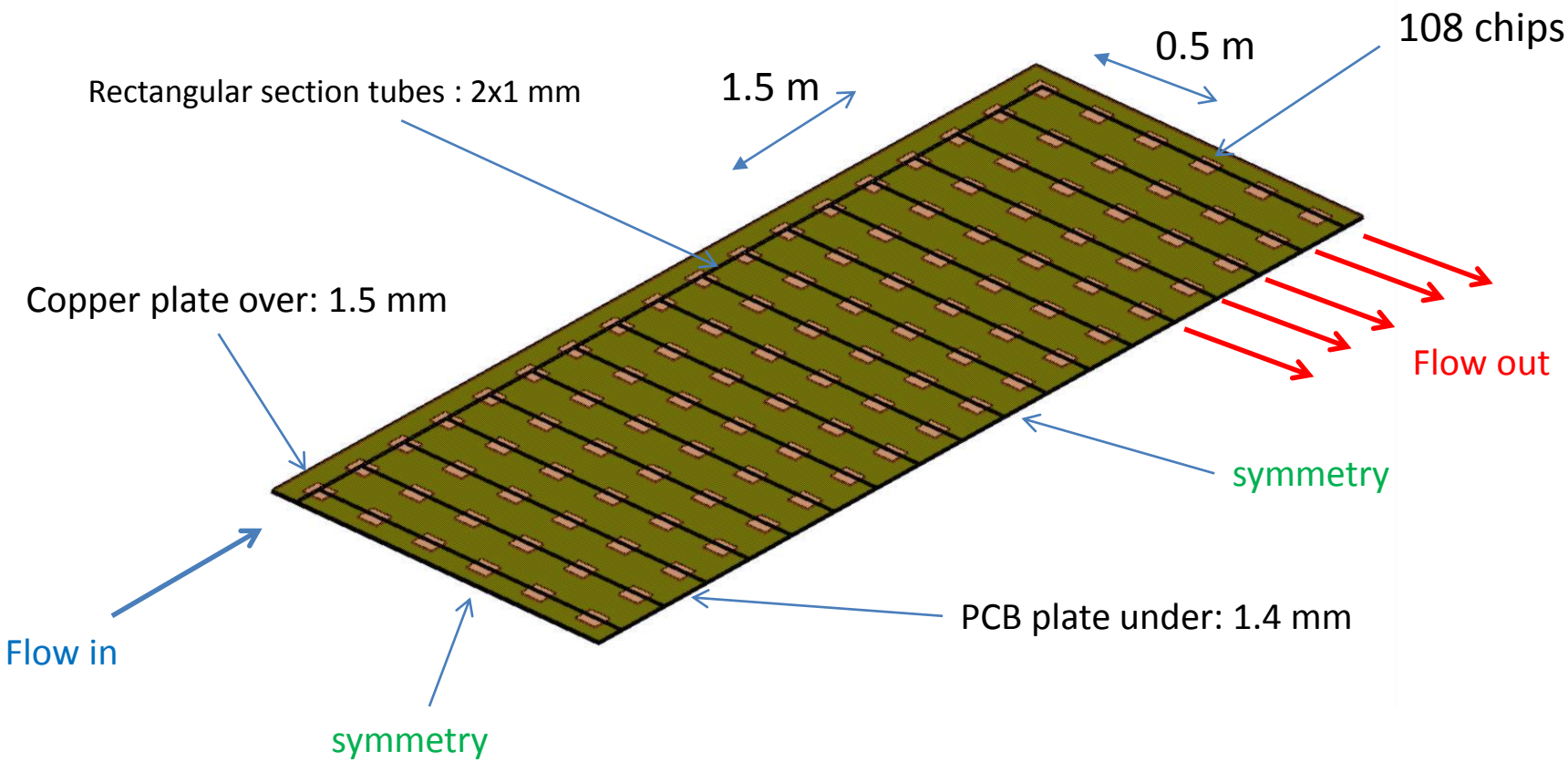


Cassette conception to ensure good contact between the detector and electronics is to be improved





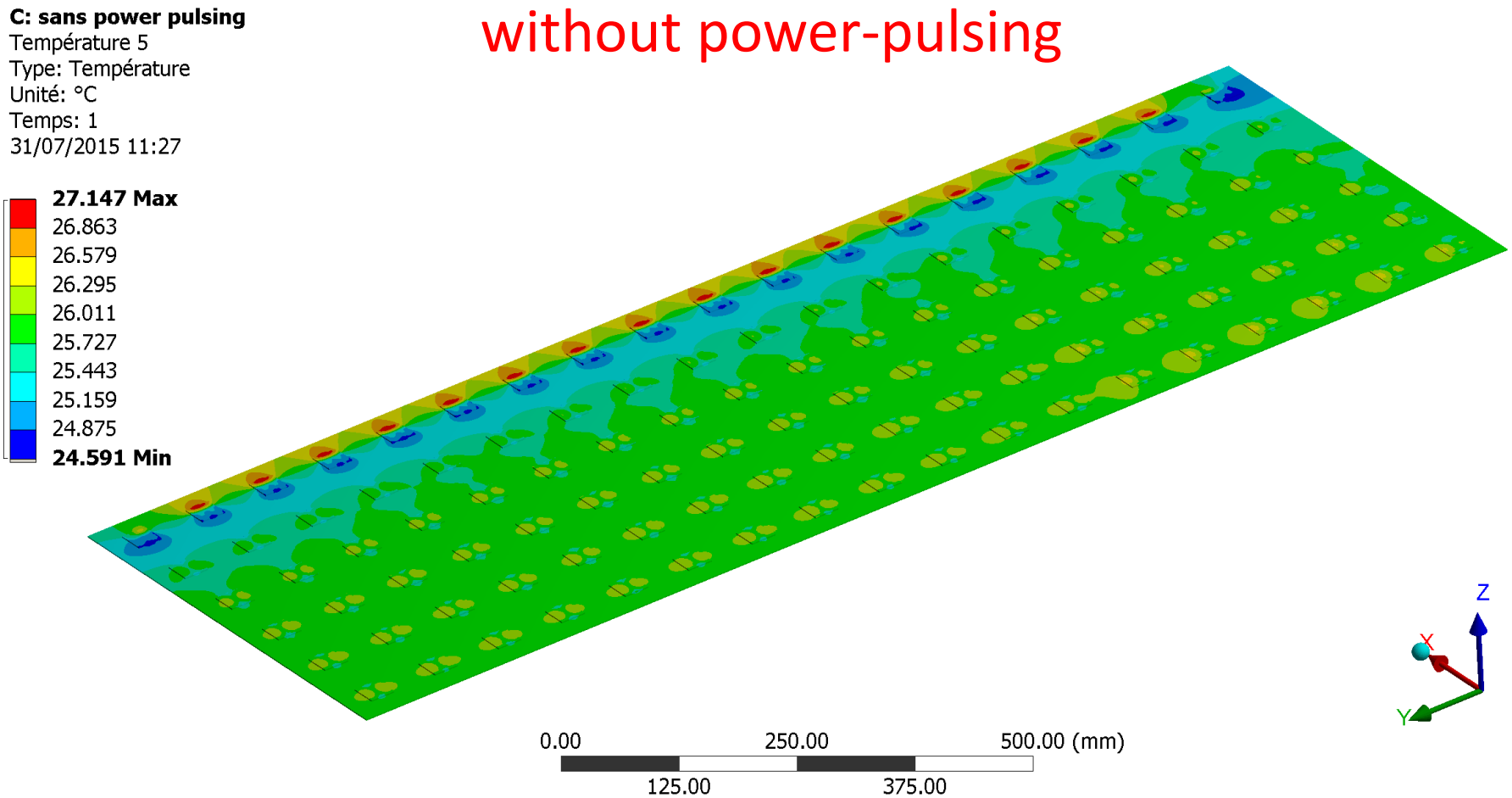
Cooling scheme



Water cooling : h = 10000 W/m²/k
thermical load : 80 mW/chips without power pulsing

Simulation ¼ structure pcb + chips

Cooling scheme

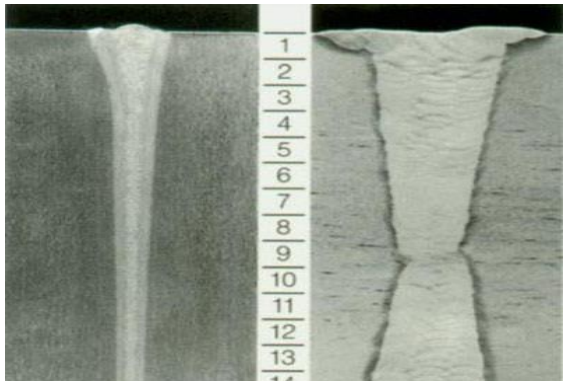


Simulation ¼ structure pcb + chips

Mechanical Structure

Improvement on the present system is being made by using Electron Beam Welding rather than bolts to reduce the deformation and the spacers thickness.

Industrial production of large absorber plates (3 m X 1 m) by roller leveling process with very good flatness (< 1mm)



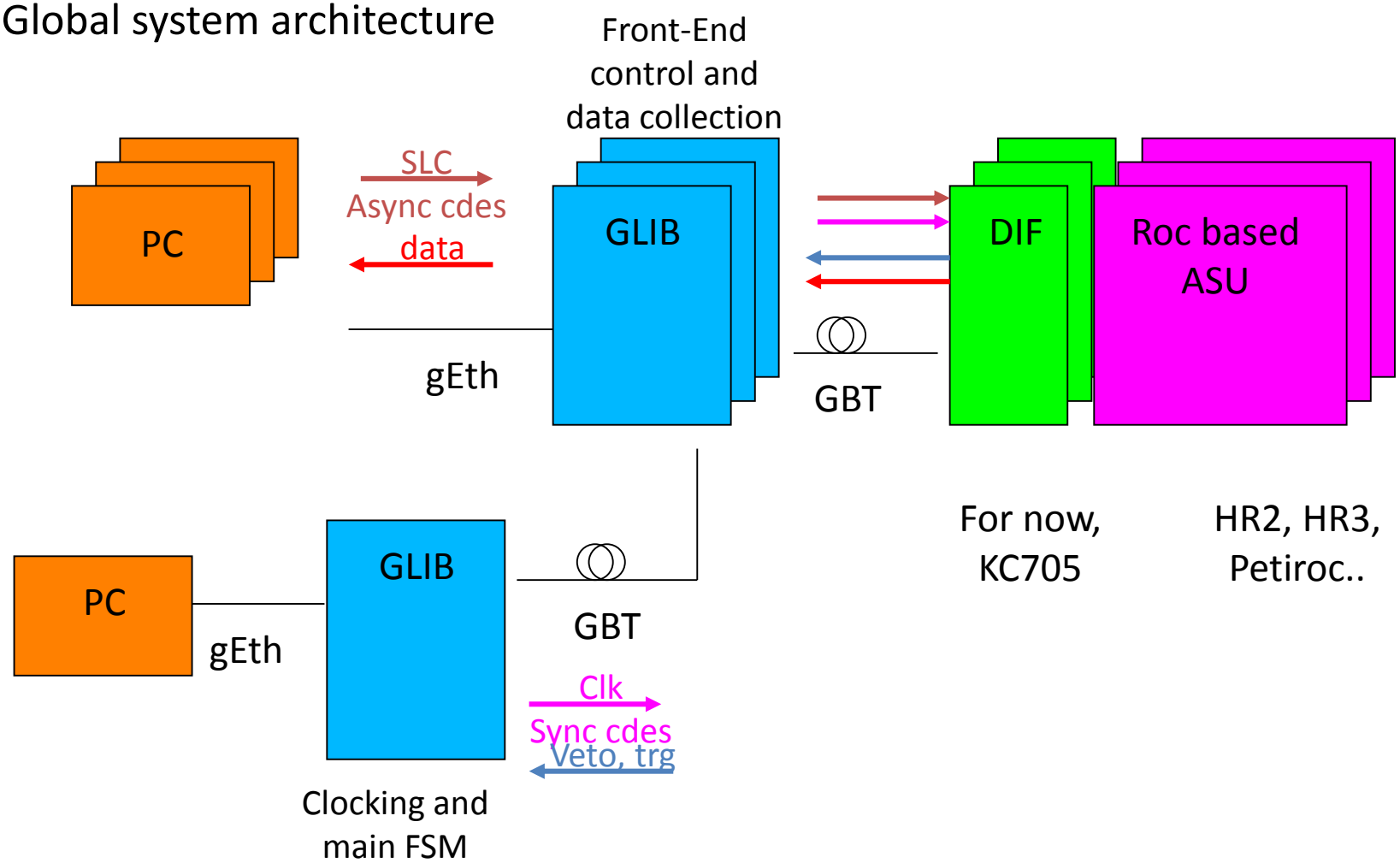
Promising results but better performance could be achieved by proceeding in a symmetrical way

1 mm flatness is obtained on 3m X 1 m, 1.5 cm thick stainless steel plate

DAQ

Implementation of a GBT-based communication system for ROC chips. This aims to reach higher performance using robust and well maintained system in the future

Global system architecture



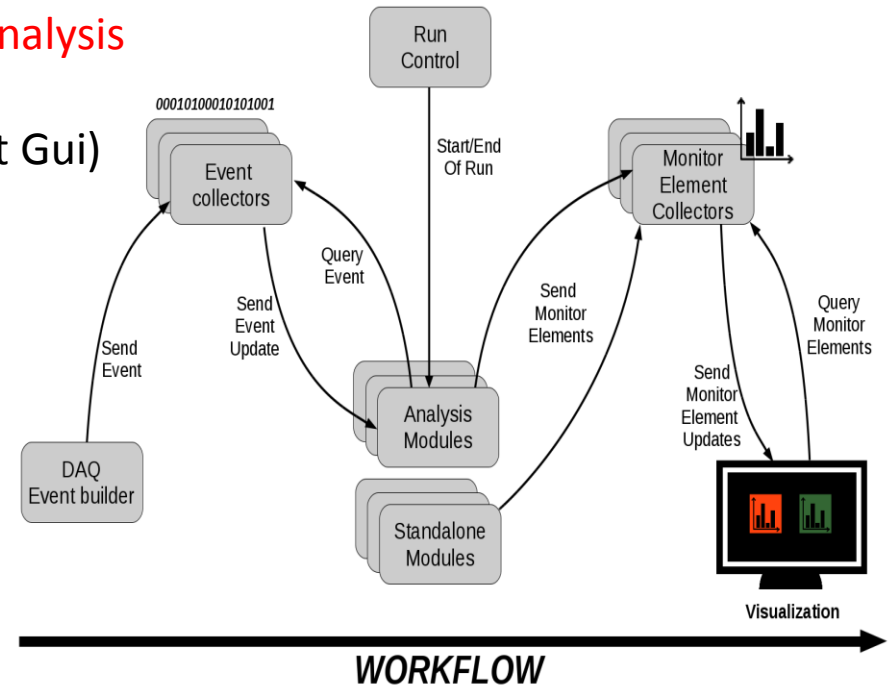
Online monitoring

DQM4HEP: Data Quality Monitoring for High Energy Physics

This is a generic C++ framework to perform online data analysis and data quality report. It deals with online application workflow, inter-process communication and memory management.

Main features :

-Event distributed system (client / server architecture)
-Set of user interfaces designed for data quality analysis
-Monitor element distributed system
-Graphical user interface for data visualisation (Qt Gui)
-Large scale remote process management
-Generic IO support for different experiments
-Designed for simple prototype monitoring up to complex systems like ILD or LHC detectors
-Logbook interface (ELog)

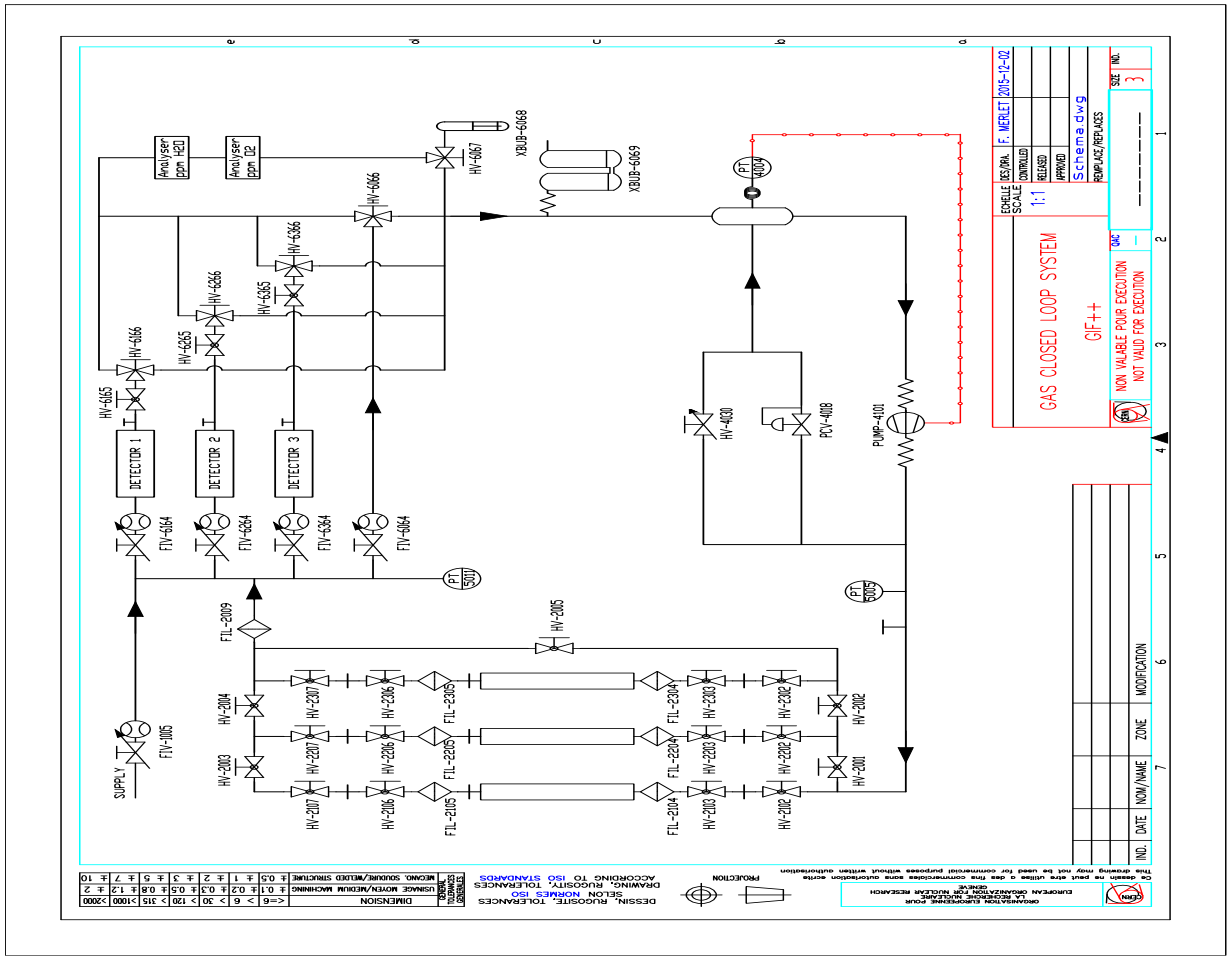


Gas purifier

-Goal: reduce the gas consumption to reduce the cost.

-Gas renewal of 5-10% rather than 100%

-Conceived by the CERN gas group



Conclusions and perspectives

→SDHCAL is the first technological prototype to be conceived and built for future ILC experiments.

→Results of beam tests validate the concept

→ Combined tests with ECAL should confirm the SDHCAL performance in a realistic scenario

→Comparing hadronic showers using the high granularity of SDHCAL is ongoing

→ New prototype is on the rails and in principle could be achieved before the end of 2017.