SDHCAL status

I.Laktineh

For the SDHCAL groups

Outline

SDHCAL technological prototype
- ✓ Ongoing work

R&D for large SDHCAL modules
- ✓ Detectors
- ✓ Electronics
- ✓ DAQ

Conclusion

On going work

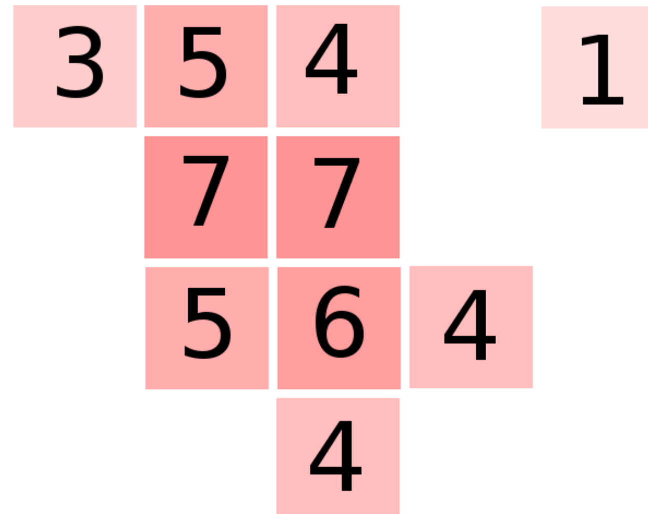
SDHCAL energy reconstruction

→ Using MVT methods (Bing's talk on Friday). A note is being (re)written.

→ Improve on standard energy construction(Guillaume's work)

→ Finalize the paper on nearby hadron separation using an adapted version of Arbor algorithm (Rémi's work).

Energy reconstruction



- Linear (currently used in ILD reconstruction)

$$E_{lin}=\sum_i \alpha_i N_i \qquad i\in\{1,2,3\}$$

- Quadratic :

$$E_{quad}=\sum_i \alpha_i N_t \quad i\in\{1,2,3\}$$

$$\alpha_i=\alpha_{i0}+\alpha_{i1}N_T+\alpha_{i2}N_T^2$$

- Linear formula using density :

$$E_{dens}=\sum_i \sum_d \alpha_{id} N_{id}$$

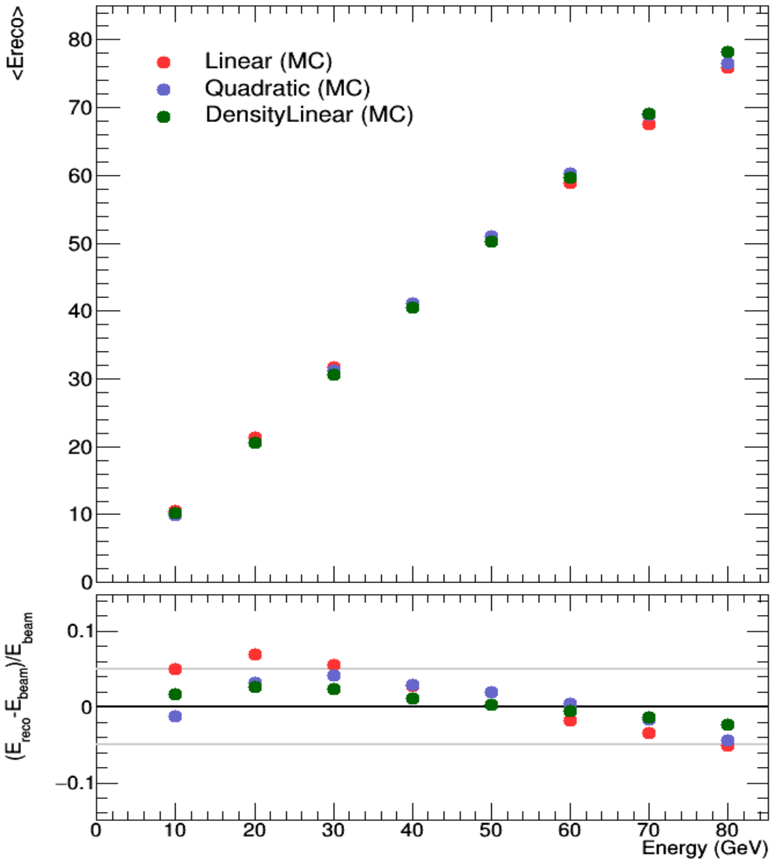
$$i\in\{1,2,3\} \quad d\in\{1\ldots9\}$$

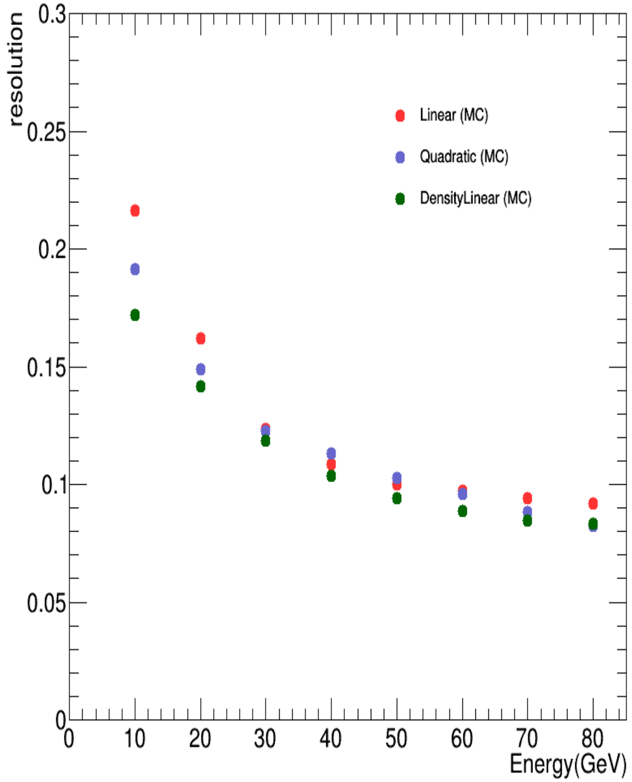
- The density of each hit is the number of hits in the surrounding 3x3 cells (including itself)
- It can vary from 1 (lone hit) to 9 (completely surrounded)

- For these 3 formulas, the α parameters are found using a chi2 minimisation :

$$X^2=\sum_i \frac{(E^i_{beam}-E^i_{reco})^2}{E^i_{beam}}$$

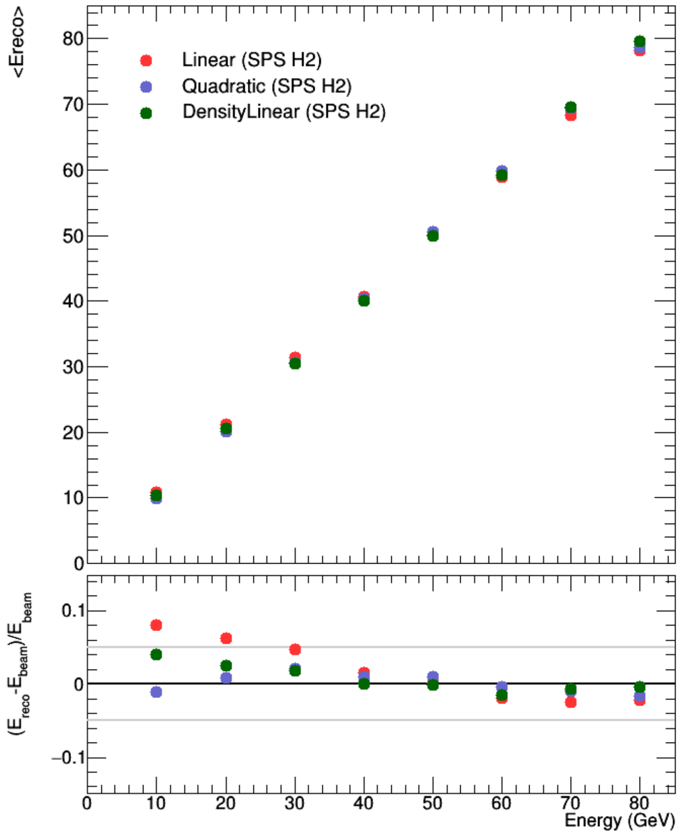
SDHCAL Simulation

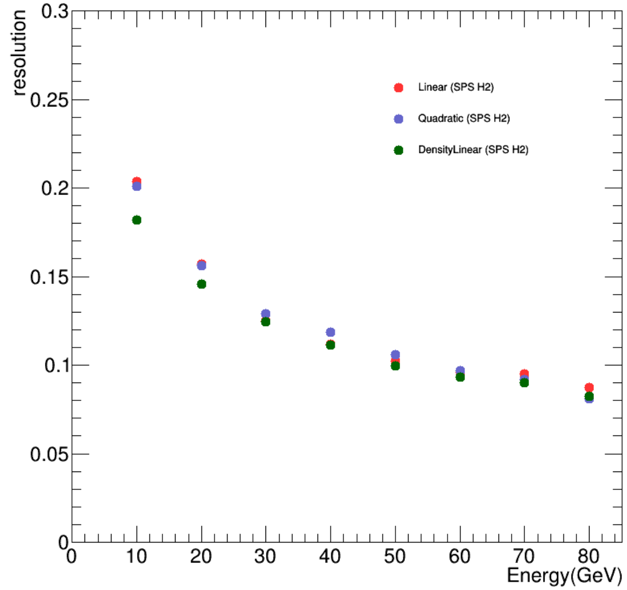




- Linear formula shows bad linearity at low energy
- The Density formula seems to improve linearity and resolution compared to Linear/Quadratic formulas

SDHCAL DATA (SPS H2 2015 beam test)





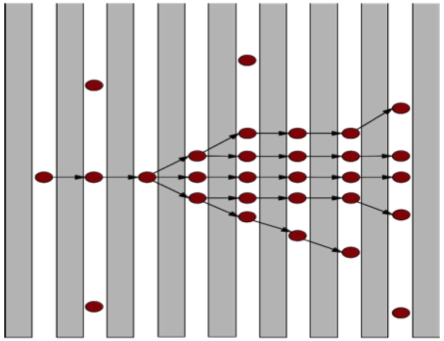
- The Linear and Quadratic formulas have comparable resolutions, but the Linear formula has much worse linearity
- As in the simulation, the Density formula improves the resolution (best improvement for low energy)
- This first simple try of taking into account the density of the hits shows that there is some room to improve the energy estimation in the SDHCAL

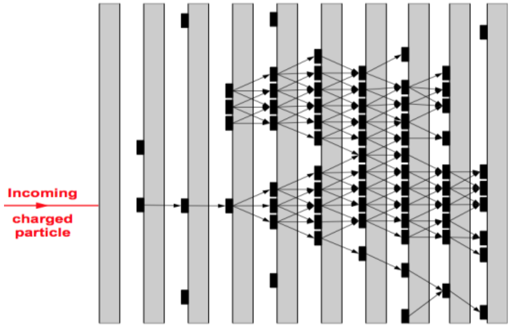
Arbor@SDHCAL

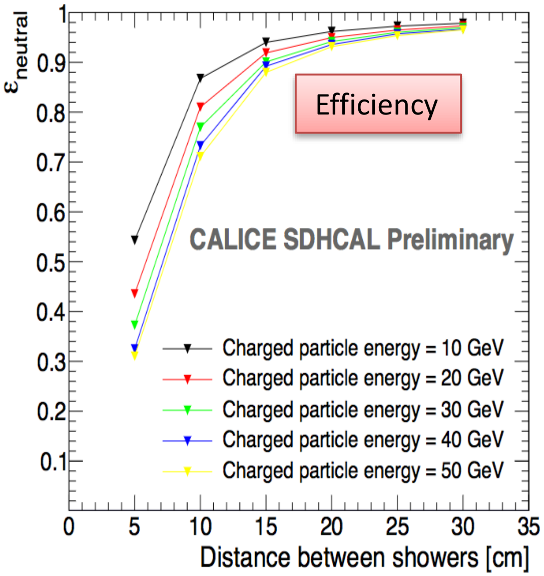
Granularity helps to optimize the connection of hits belonging to the same shower by using first the topology and then the energy information

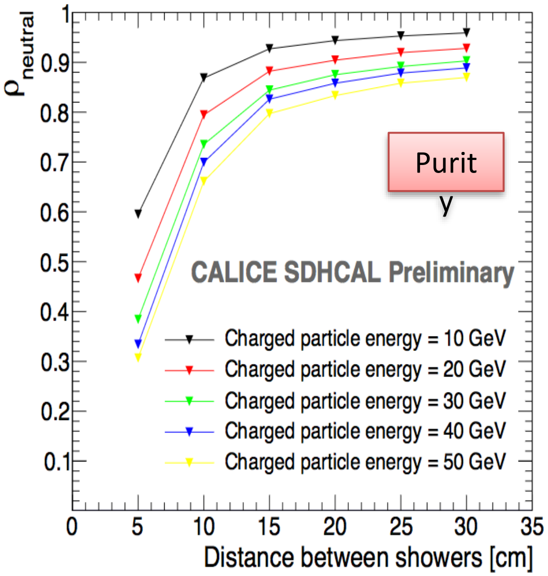
ArborPFA algorithm*:

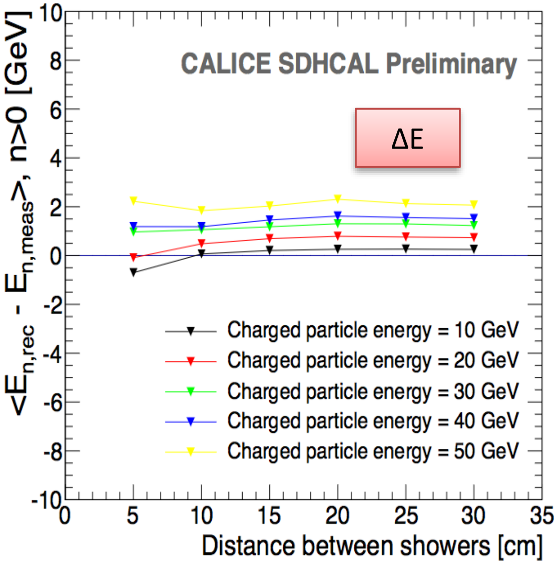
It connect first hits and then their clusters using distance and orientation information then correct using tracker information (momentum)







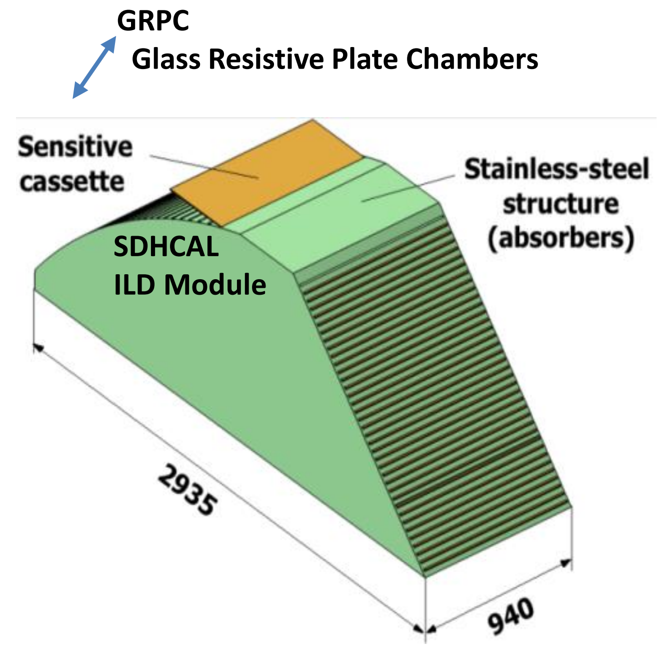




CALICE note CAN054→Paper

SDHCAL R&D

- ❑ 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..

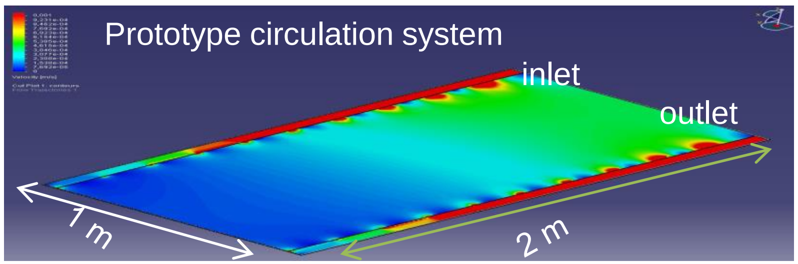


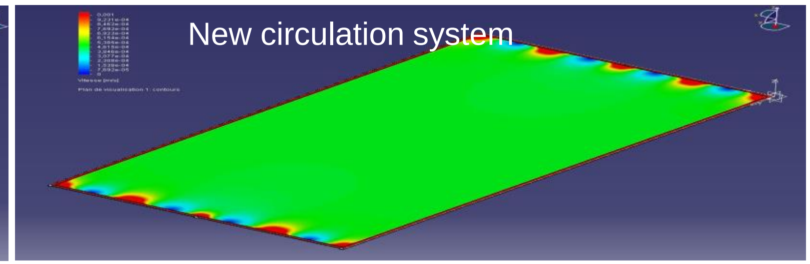
Goal: to build new prototype with few but large GRPC with the new components
→ **ILD Module0**

Detector conception

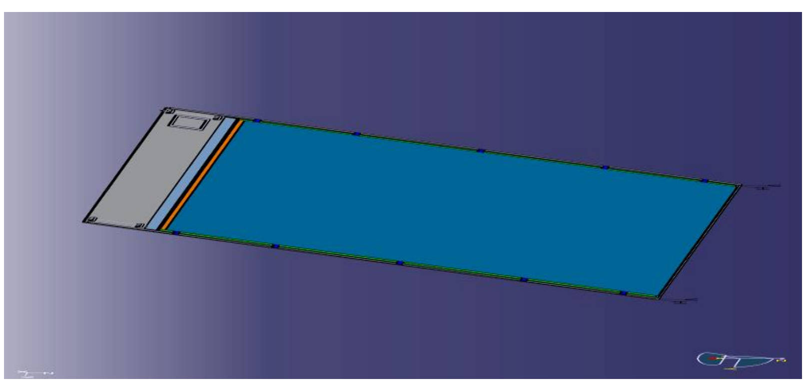
Construction and operation of large GRPC necessitate some improvements with respect to the present scenario.

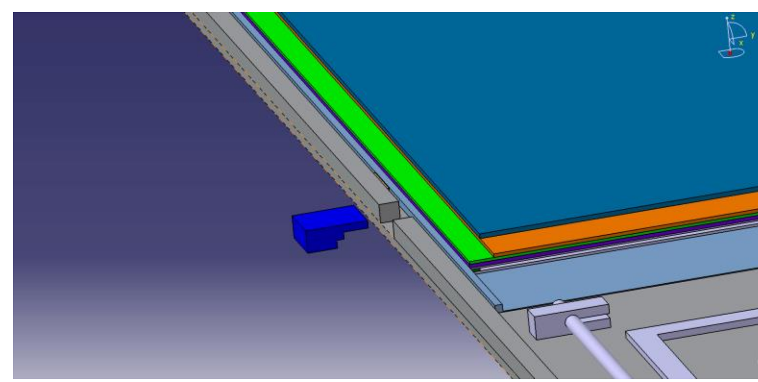
Gas distribution : new scheme is proposed





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





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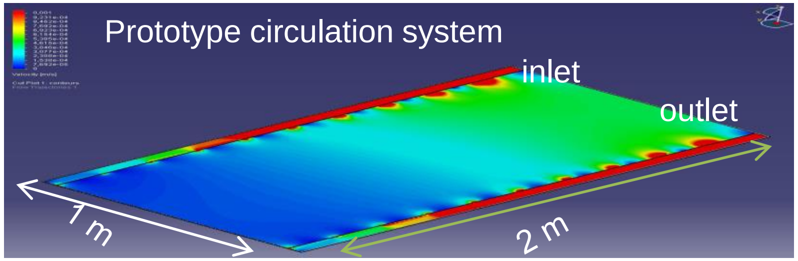

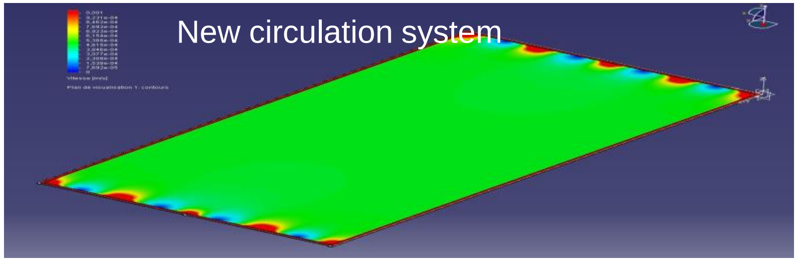

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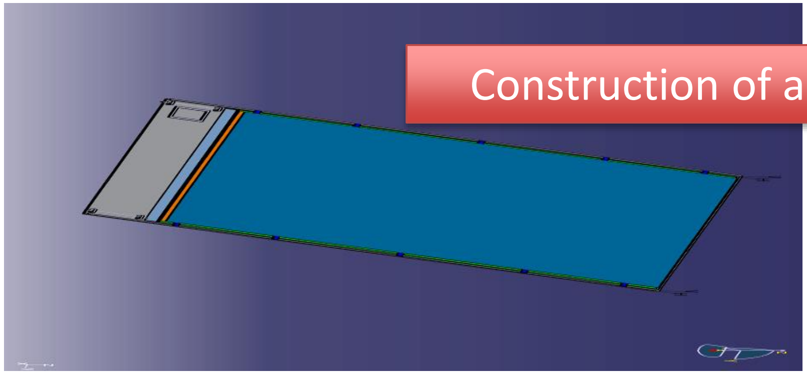
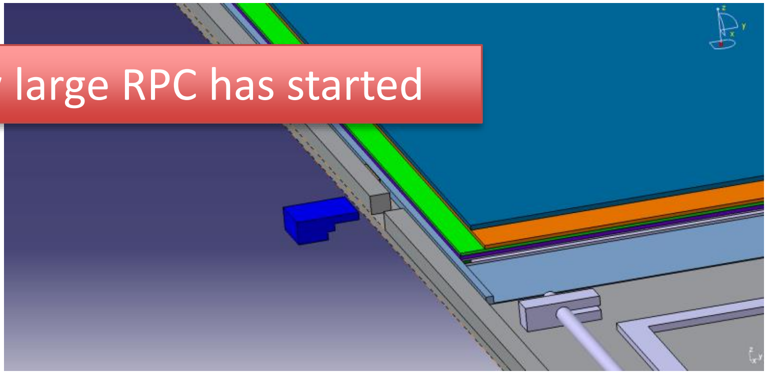


Construction of a few large RPC has started




Construction of a few large RPC has started

New electronics

Electronics readout for the 1m^3 prototipo

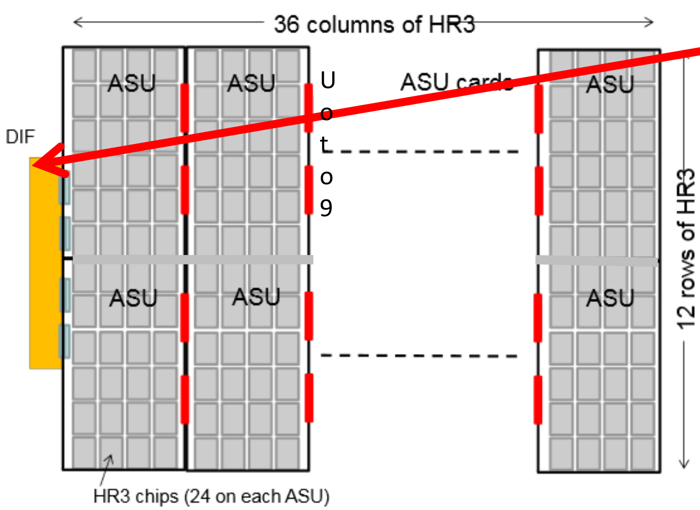
HADROC chip (ASIC)

1m^2 board ➔ 6 ASUs hosting 24 ASICs

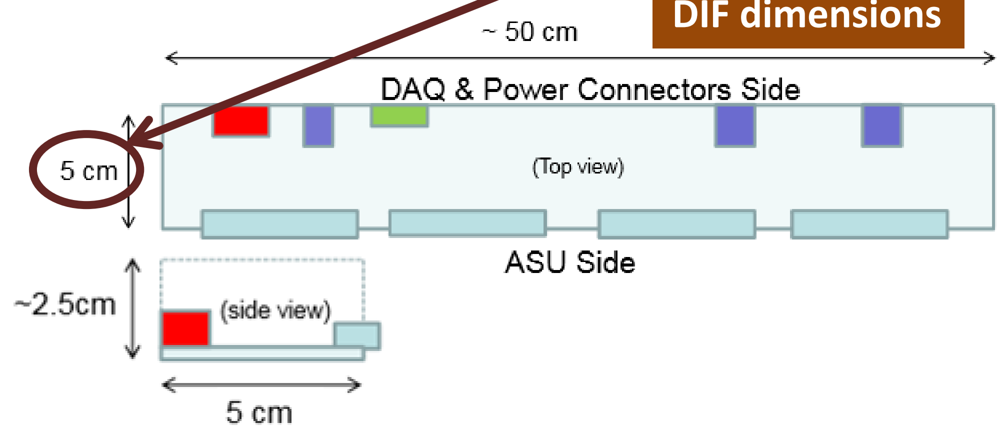
1 DIF (detector InterFace) for 2 ASU (Active Sensor Unit.- PCB+ASICs) ➔ **3 DIFs for ONE 1m2 GRPC detector**

Electronics readout for the final detector

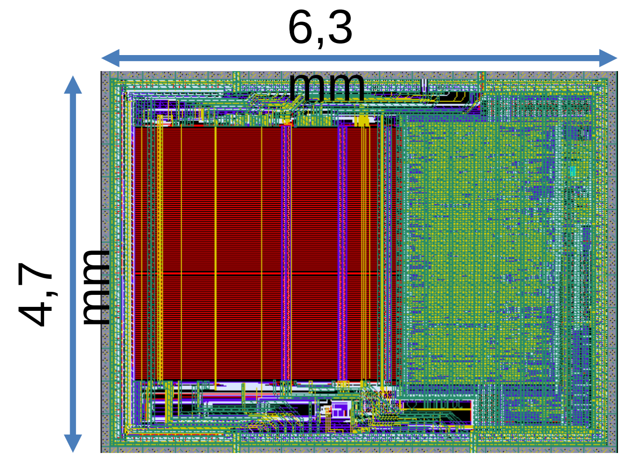
Only **1 DIF per GRPC (any size)** with small dimensions to fit in the **small** space available at the **ILD detector**



DIF dimensions



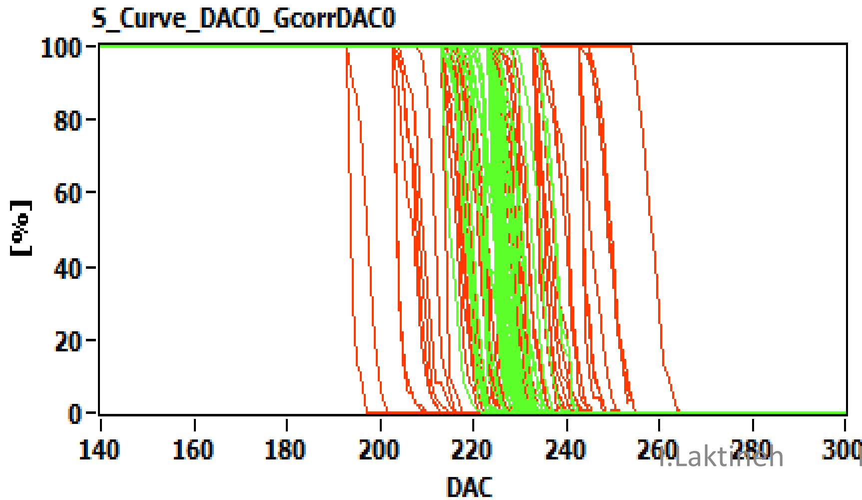
New electronics: ASIC

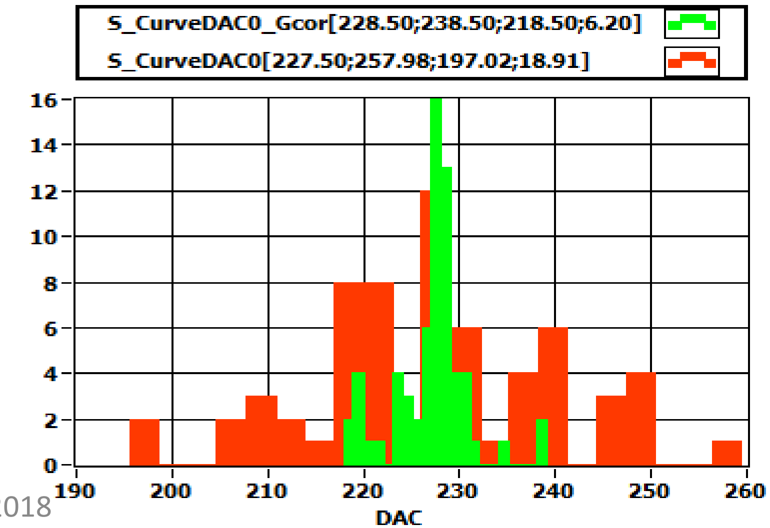


HARDROCR3 main features:

- **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)

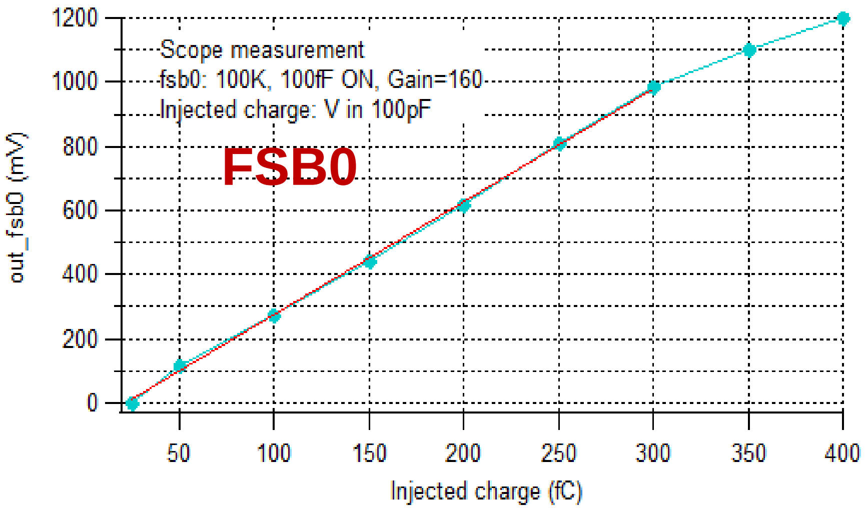
H3B TESTED : 786,   Yield : 83.3 %

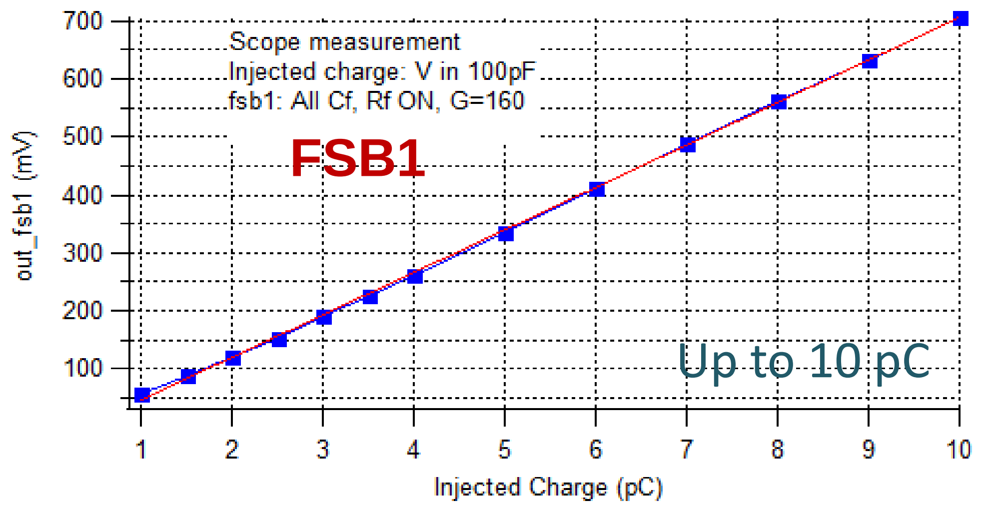


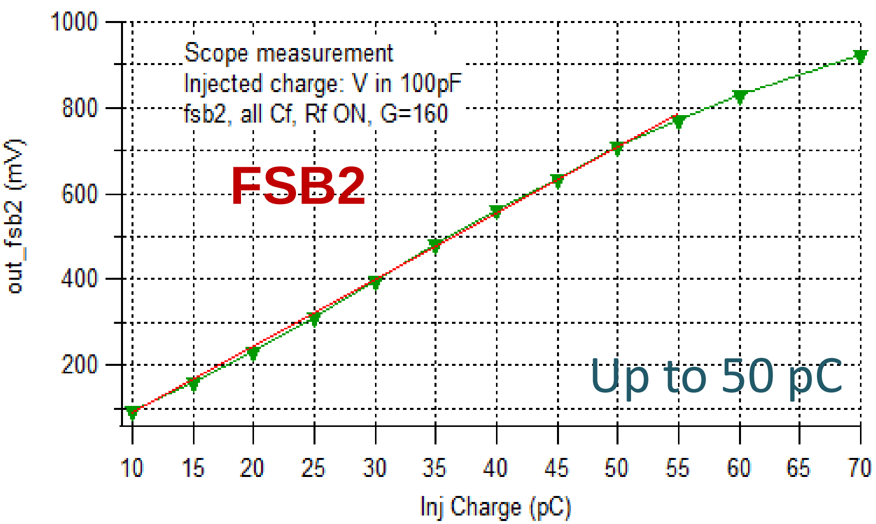


HARDROC3: Analog linearity

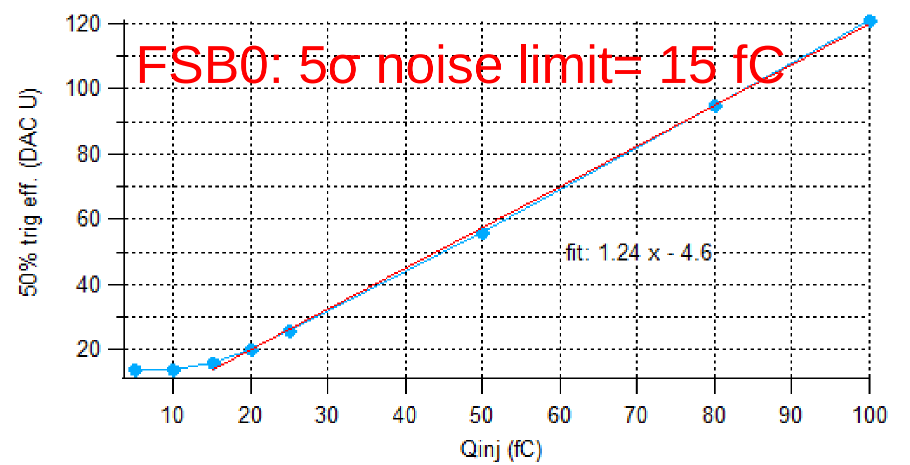
Fast shaper outputs (mV) vs Qinj (fC)







50% trig. Eff. (DAC units) vs Qinj (fC)



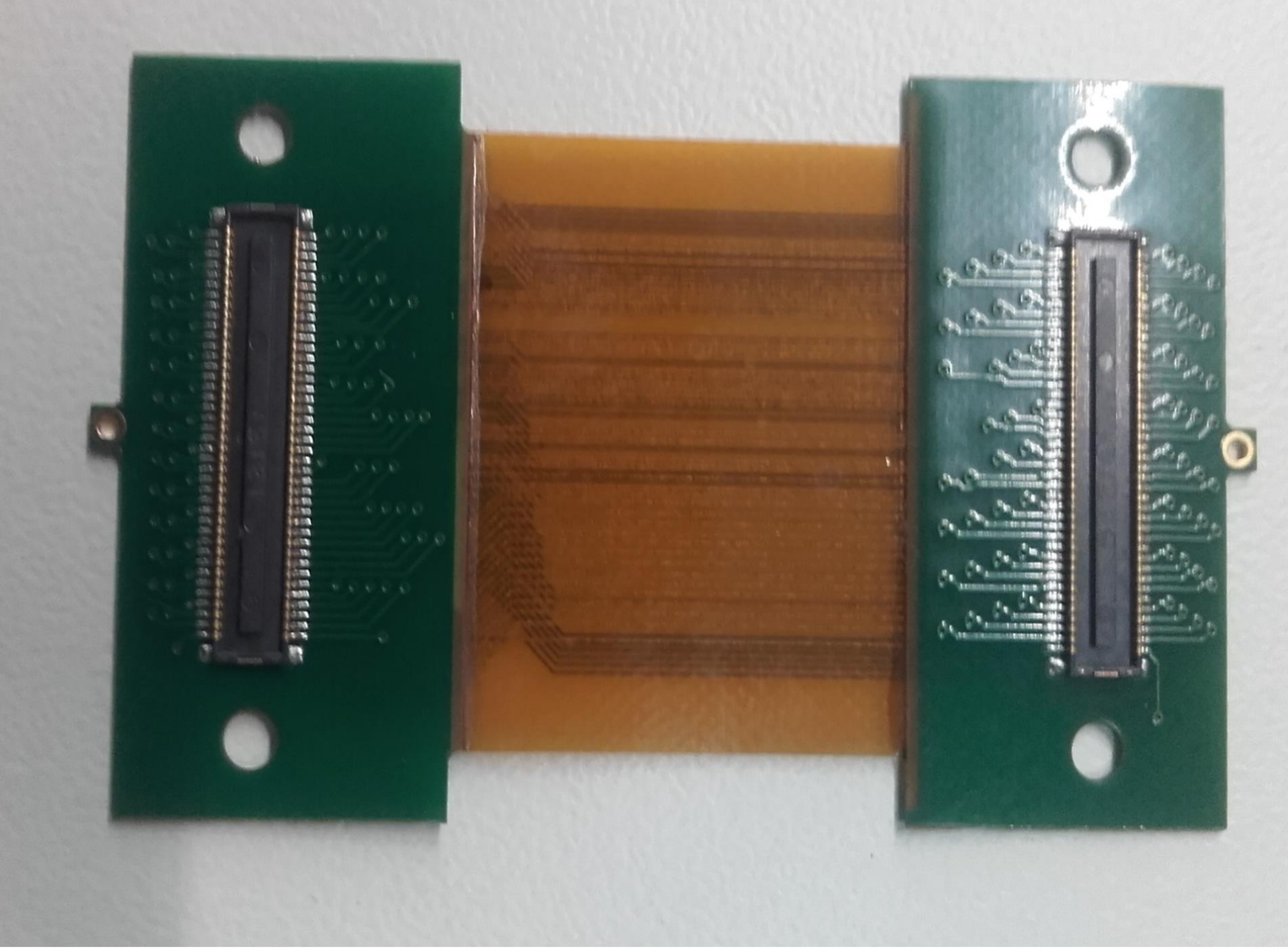
Dynamic range: 15fC - 50 pC

ASU (Active Sensor Unit)

An important challenge is to build a PCB up to 1m length with good planarity to have a homogeneous contact of pads with RPCs in order to guarantee an uniform response along all the detector.

A company was found and ***1x0.33 m2 with 13 layer ASUs*** have been built.

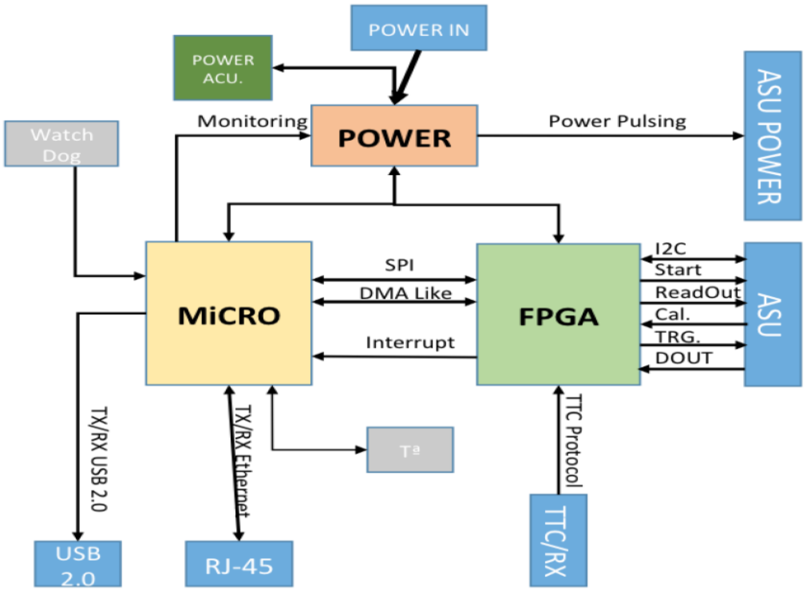
The ASU-ASU (= ASU-DIF) connections also produced



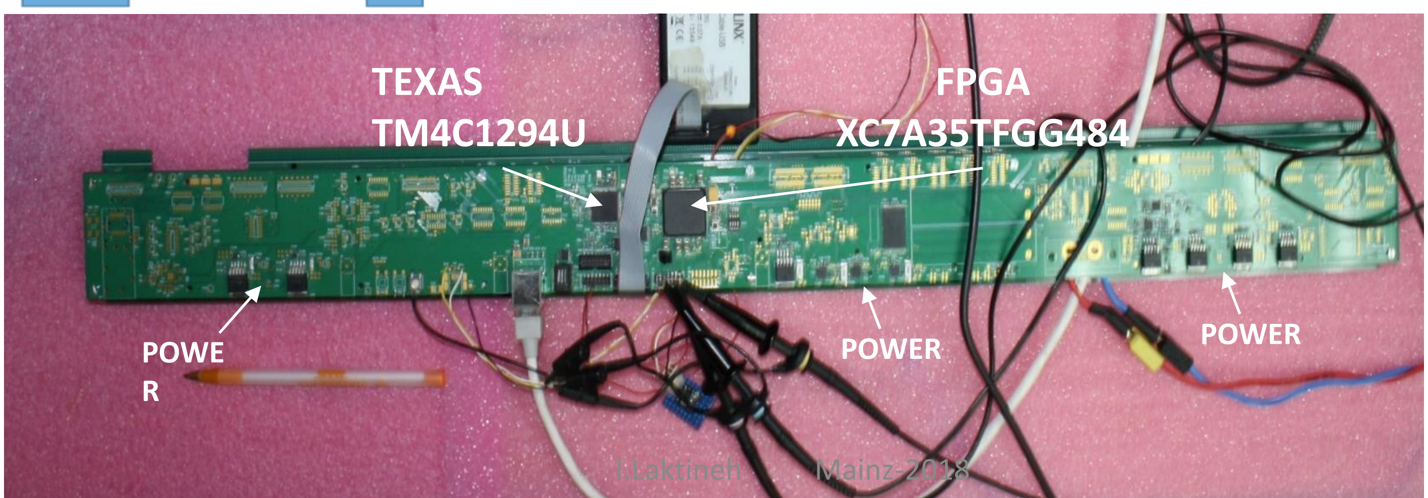

HR40
PAD
Lock
PAD
Lock

New electronics : DIF

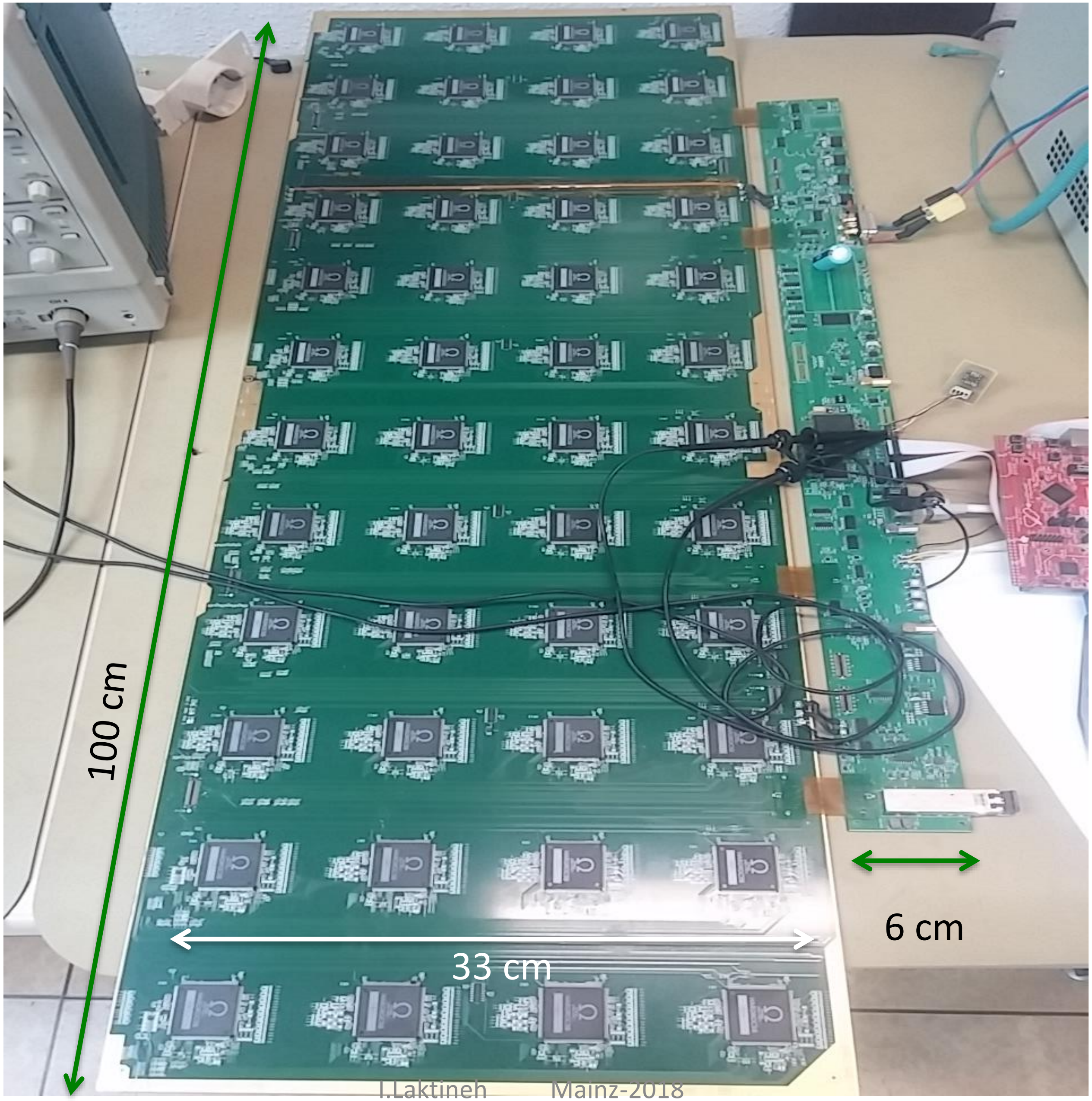
DIF sends DAQ commands (config, clock, trigger) to front-end and transfer their signal data to DAQ. It controls also the ASIC power pulsing



- Only **one DIF per plane** (instead of **three**)
- DIF handle up to **432 HR3 chips** (vs **48 HR2** in previous DIF)
- HR3 **slow control** through **I2C bus (12 IC2 buses).** Keeps also **2 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**

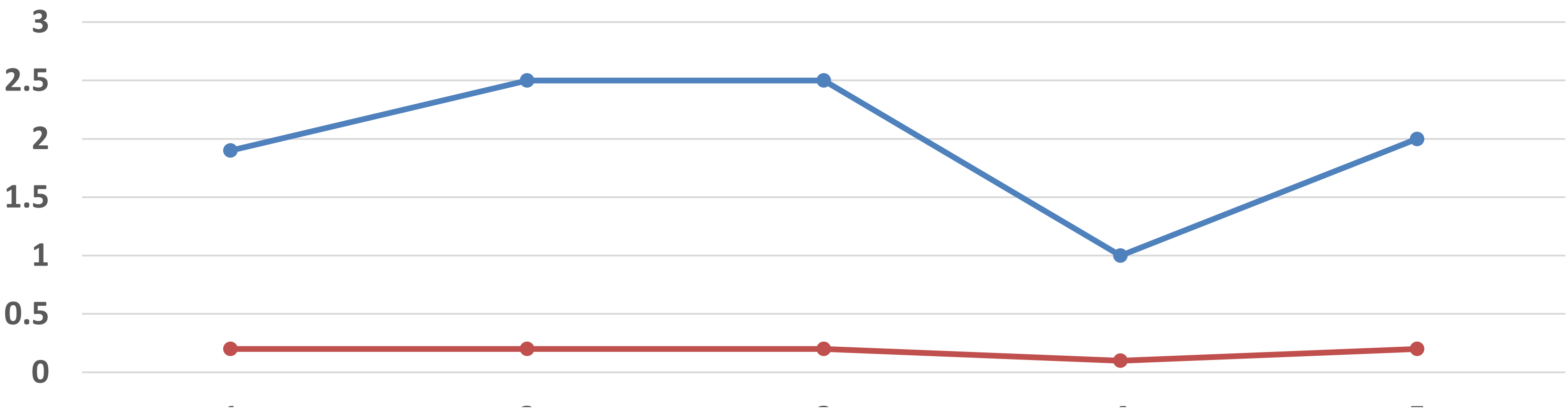


New readout electronics is being tested



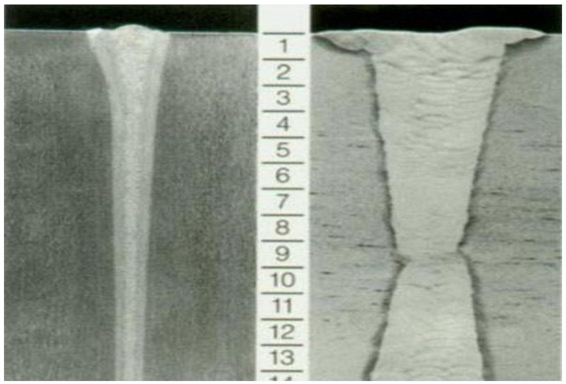
Mechanical Structure

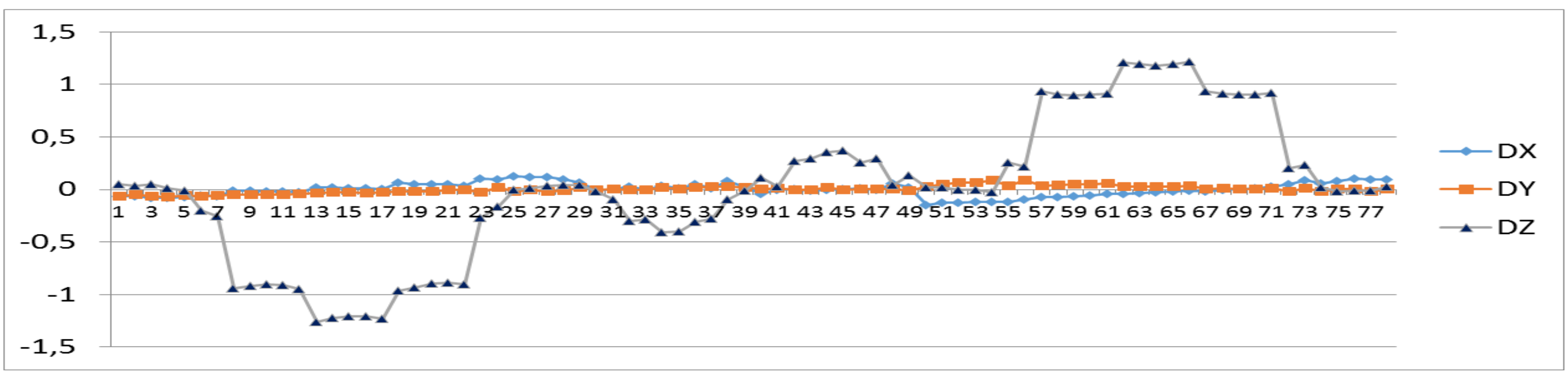
Industrial production of **flat** large absorber plates (3 m X 1 m) by **roller leveling** process



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.





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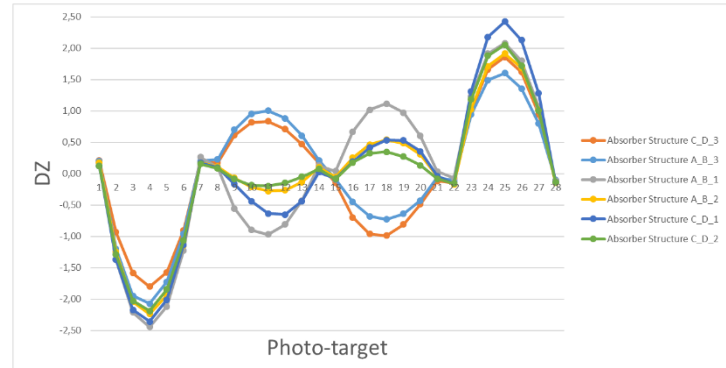
New Tests

Welded pieces for the *“qualitatively”* smaller tests: **Several ways tested.**

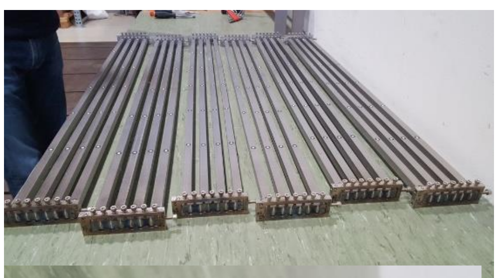
Penetration ~10 mm

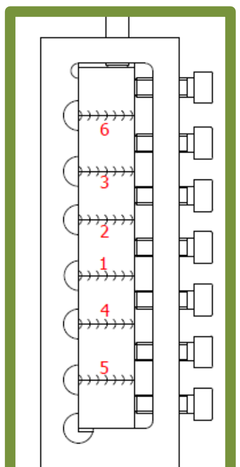
Welding Secuence (Secuencia de Soldadura)						
Step (Paso)	test A-B_1	test A-B_2	test A-B_3	test C-D_1	test C-D_2	test C-D_3
1er. (2 mm depth)	1, 2 (side A)	1, 2 (side A)	5, 6 (side A)	1, 2 (side C)	1, 2 (side C)	5, 6 (side C)
2nd. (2 mm depth)	1, 2 (side B)	1, 2 (B)	5, 6 (B)	1, 2 (D)	1, 2 (D)	5, 6 (D)
3rd. (2 mm depth)	3, 4 (side B)	6, 5 (B)	3, 4 (B)	3, 4 (D)	6, 5 (D)	3, 4 (D)
4th. (2 mm depth)	3, 4 (A)	6, 5 (A)	3, 4 (A)	3, 4 (C)	6, 5 (C)	3, 4 (C)
5th. (2 mm depth)	5, 6 (A)	4, 3 (A)	1, 2 (A)	5, 6 (C)	4, 3 (C)	1, 2 (C)
6th. (2 mm depth)	5, 6 (B)	4, 3 (B)	1, 2 (B)	5, 6 (D)	4, 3 (D)	1, 2 (D)
7th. (10 mm depth)	1, 2 (B)	1, 2 (B)	5, 6 (B)	1, 2 (D)	1, 2 (D)	5, 6 (D)
8th. (10 mm depth)	1, 2 (A)	1, 2 (A)	5, 6 (A)	1, 2 (C)	1, 2 (C)	5, 6 (C)
9th. (10 mm depth)	3, 4 (A)	6, 5 (A)	3, 4 (A)	3, 4 (C)	6, 5 (C)	3, 4 (C)
10th. (10 mm depth)	3, 4 (B)	6, 5 (B)	3, 4 (B)	3, 4 (D)	6, 5 (D)	3, 4 (D)
11th. (10 mm depth)	5, 6 (B)	4, 3 (B)	1, 2 (B)	5, 6 (D)	4, 3 (D)	1, 2 (D)
12th. (10 mm depth)	5, 6 (A)	4, 3 (A)	1, 2 (A)	5, 6 (C)	4, 3 (C)	1, 2 (C)



Option 2 have been chosen

Z-axis deformations close to 2 mm





Insertion test of the cassette: One cassette was tested on the previous welding test pieces produced.

Two identically prototypes (plates ~0.4x1 m^2) will be welded with those parameter to validate the procedure (PT4).

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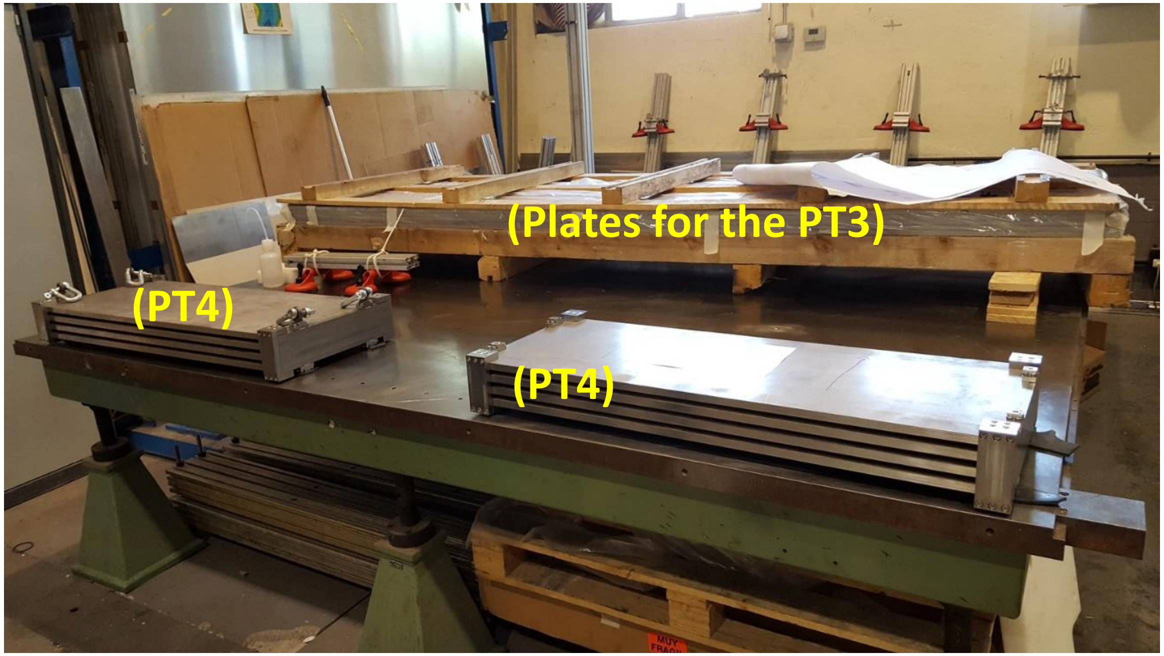
Next Welding tests

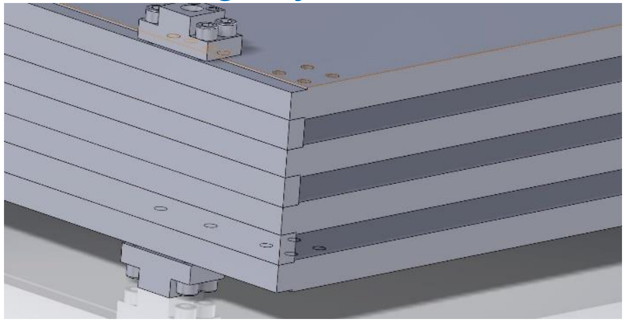
Two identical small prototypes (PT4): 2x (4 plates 0.4x1 m^2)

Welding will be performed **following the results of the previous welding tests**:



Complete Penetration ~10 mm

Greater strength of the structure.



Pieces produced at CIEMAT (and ARKU) and waiting at CERN for the EBW. *To be done during February-March 2018).*

Once validated the procedure, will be welded the Final Prototype (plates ~3mx1m)

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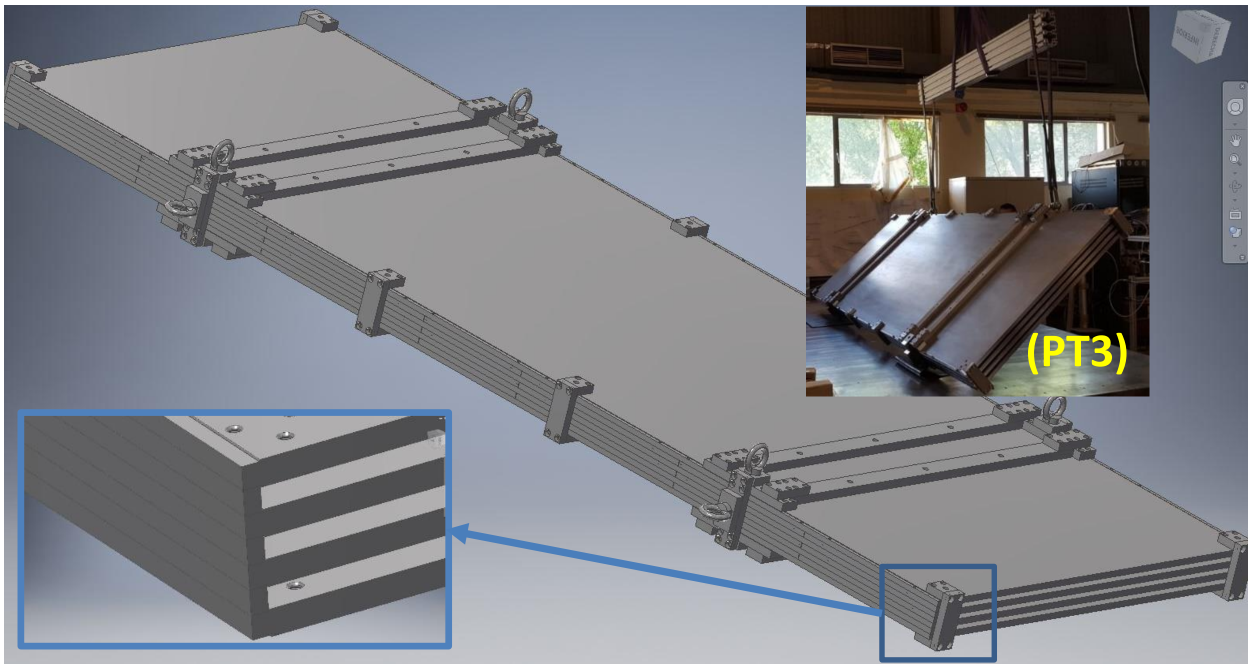
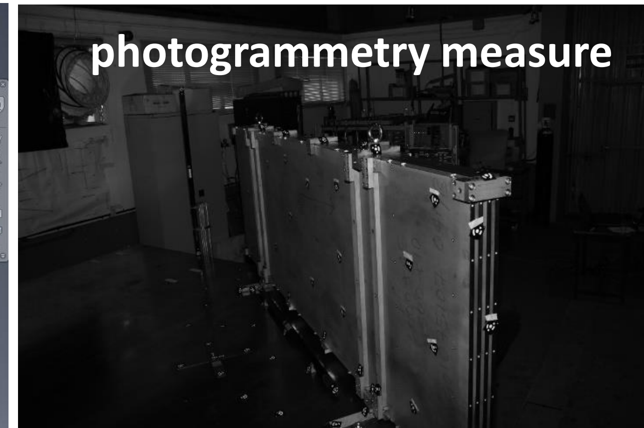
Next Welding tests

‘Final’ calorimeter prototype : 4 plates 3x1 m²

Complete Penetration ~10 mm
Greater strength of the structure.





Pieces for this prototype produced and the preliminary assembly test & measures are done at CIEMAT.
The EBW will follow after optimizing the procedure on medium

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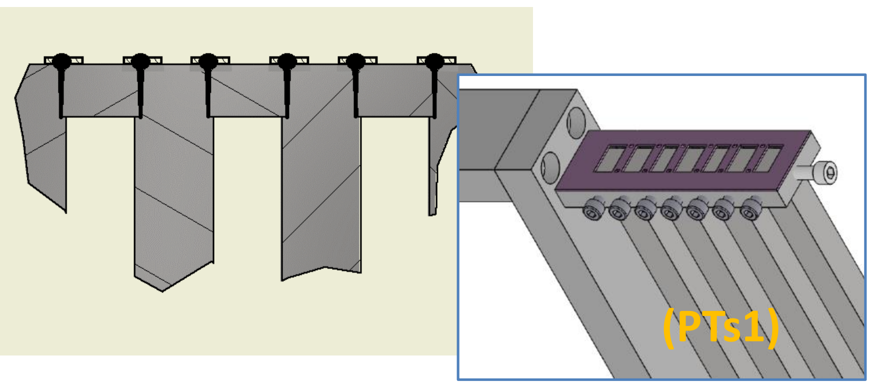
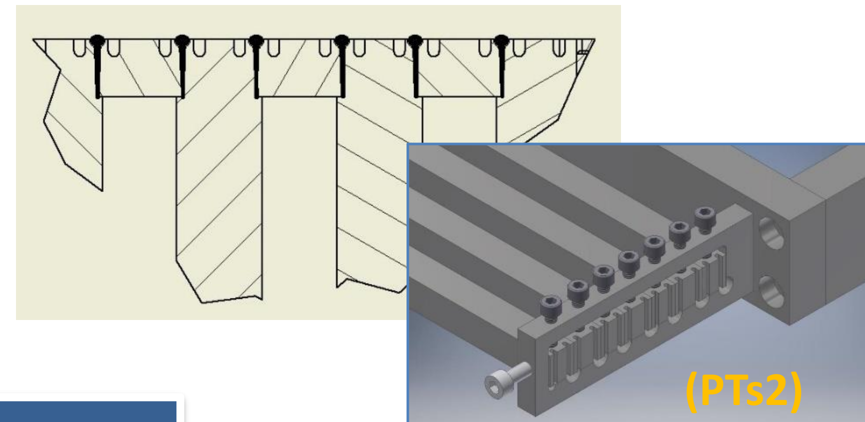
Additional tests to minimize the welding deformation

Contact people for EBW at CERN, Manuel Redondas & Thierry Tardy, propose two method to reduce the distortion produced by EBW:

→ Placing a 1-2 mm sheet on the welding zone and welding through it. And to remove the first 1 or 2 mm which contain the beginning of the welding cone, maintaining only the narrowest and parallel welding zone, avoiding local stress.

→Producing slots, parallel to the weld, that absorb the stress that is produced by the beginning of the welding cone.





Small test prototype: 2 x PTs1 & 2x PTs2

Complete Penetration ~10 mm

Some tests using **smaller pieces** are foreseen to evaluate "qualitatively" those two options **(PTs1 &PTs2)**.

Pieces were produced at Ciemat. Delivered to CERN and assembled during December 2017.

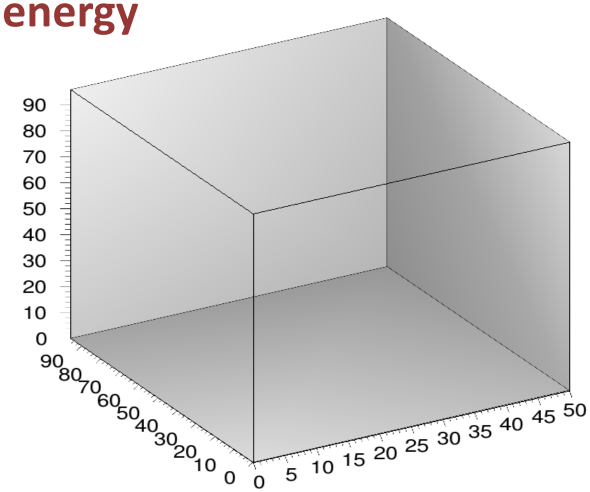
To be welded at CERN during February-March 2018.

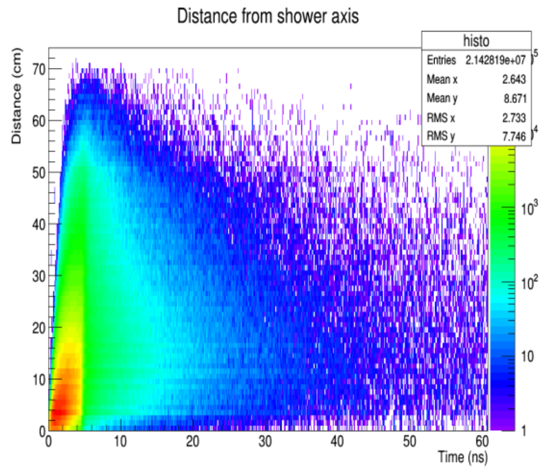
If this method works, it could be implemented on the previous prototypes, to validate it.

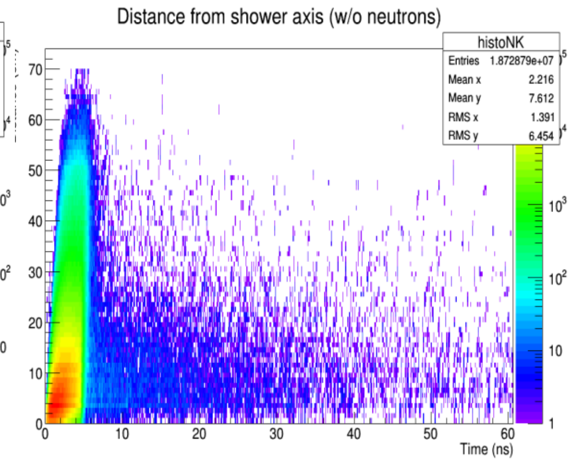
A new challenge

Timing

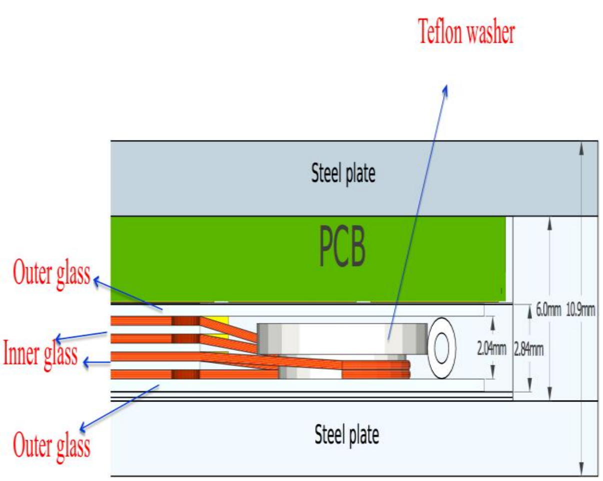
Timing could be an important factor to identify delayed neutrons and **better reconstruct their energy**

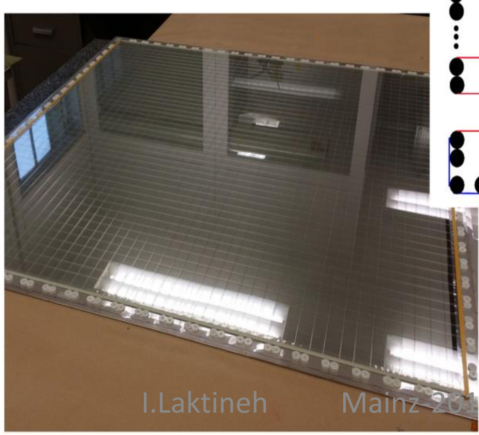


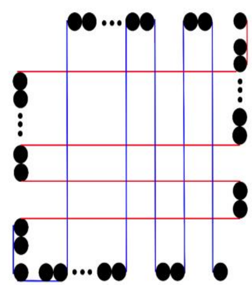




Multi-gap RPC are excellent fast timing detectors
Several were designed and built . Excellent efficiency when tested with HARDROC ASICs. **Next step use PETIROC (< 20 ps time jitters)** to single out neutron contributions.







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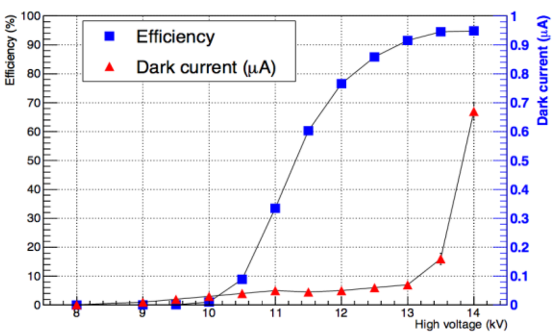
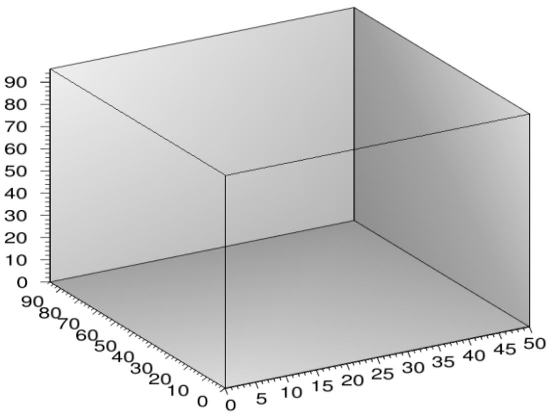
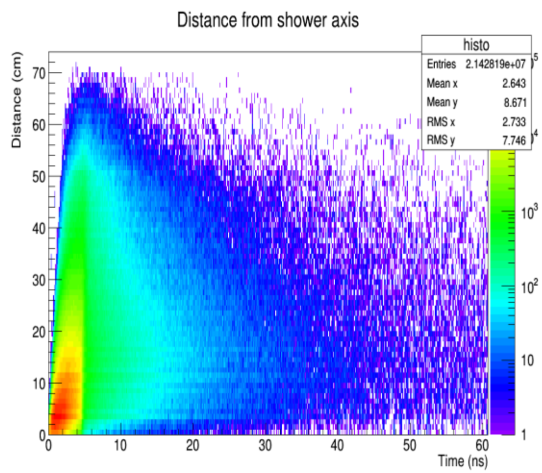


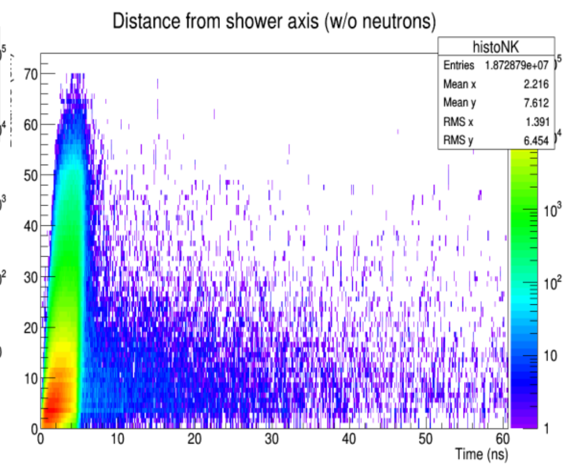
Threshold sets at 114 fC

Timing

Timing also could be an important factor to **separate showers** and reduce confusion

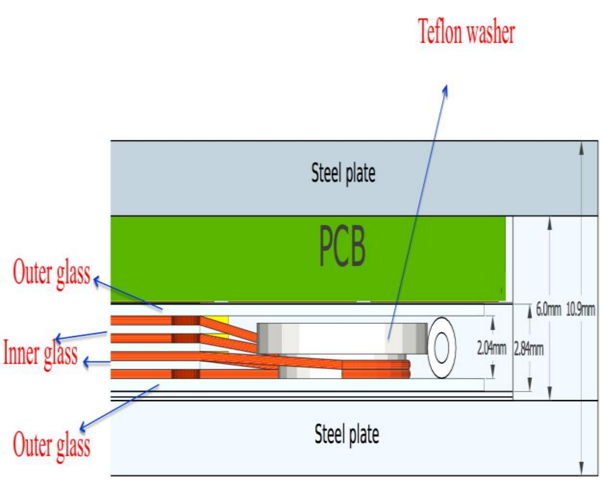


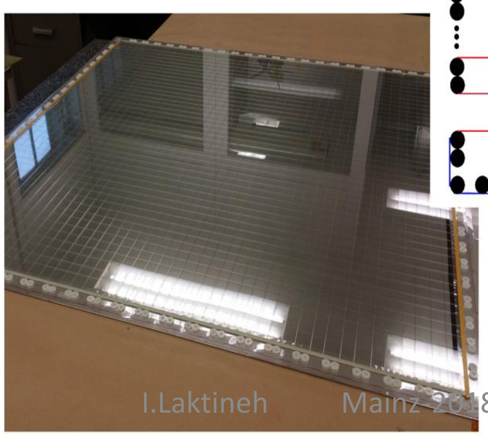


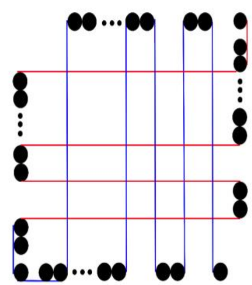


Multi-gap RPC are excellent fast timing detect

Several were designed and built . Excellent efficiency when tested with HARDROC ASICs. **Next step use PETIROC (< 20 ps time jitters)** to single out neutron contributions.







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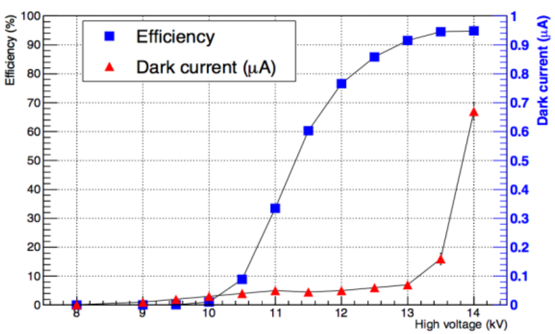

Threshold sets at 114 fC

Conclusions and perspectives

→Several SDHCAL analyses are ongoing. New ones to start soon

→ New (module0) prototype is on the rails and in principle could be achieved in 2018.

→ New features such as timing will play important role in future R&D for future colliders. SDHCAL with its (M)RPC is an excellent tool to achieve that.

Gas system

Gas recycling is necessary to reduce cost :

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

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

-Conceived by the CERN gas group