Construction and Status of a Semi-Digital Hadronic Calorimeter

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On behalf of the **CALICE** SDHCAL-GRPC groups

CIEMAT, Ghent University, IPNL,LAL,LAPP, LLR, Tsinghua University, Tunis, UCL

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outline

- The SDHCAL concept
- Technological prototype construction
- Test Beam
- Perspectives and Conclusion

Semi-Digital HCAL Concept

Ultra-granular HCAL can provide a powerful tool for the **PFA** leading to an excellent Jet energy resolution.

It is based on two points:

1- Gaseous Detector

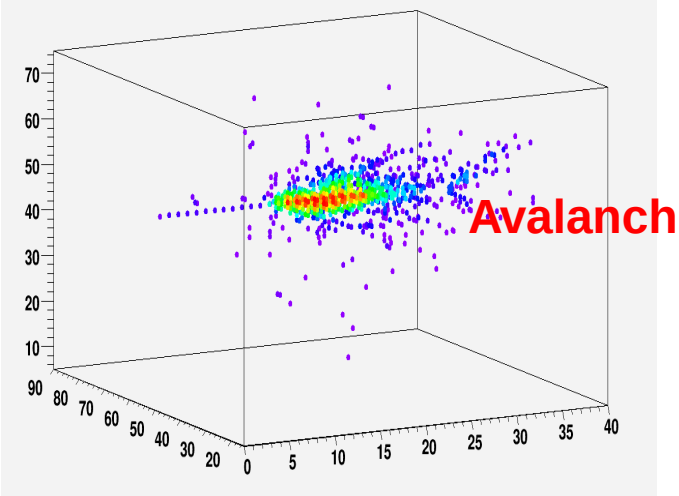
Gaseous detectors like **GRPC** are homogenous, cost-effective, and allow high longitudinal and transverse segmentation.

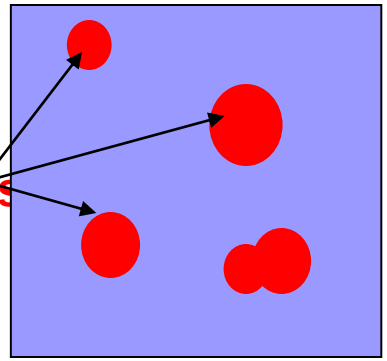
2- Embedded electronics Readout

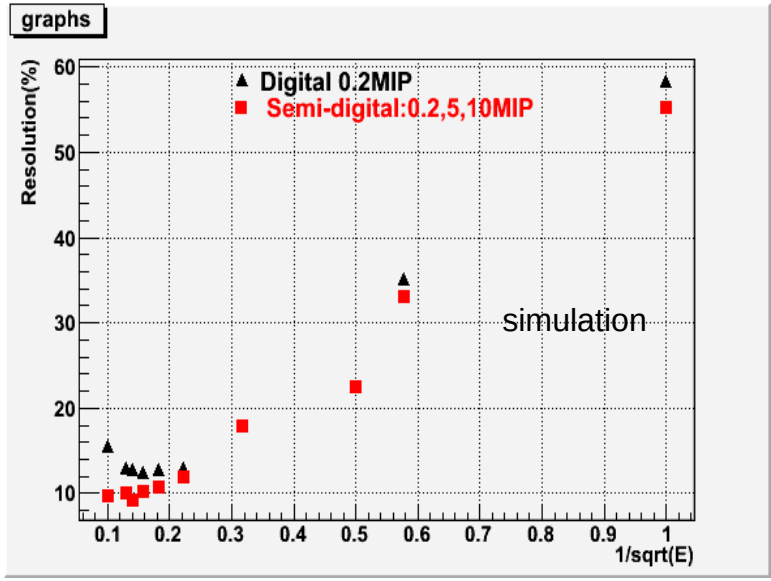
A simple binary readout leads to a very good energy resolution

However, at high energy the shower core is very dense and saturation shows up

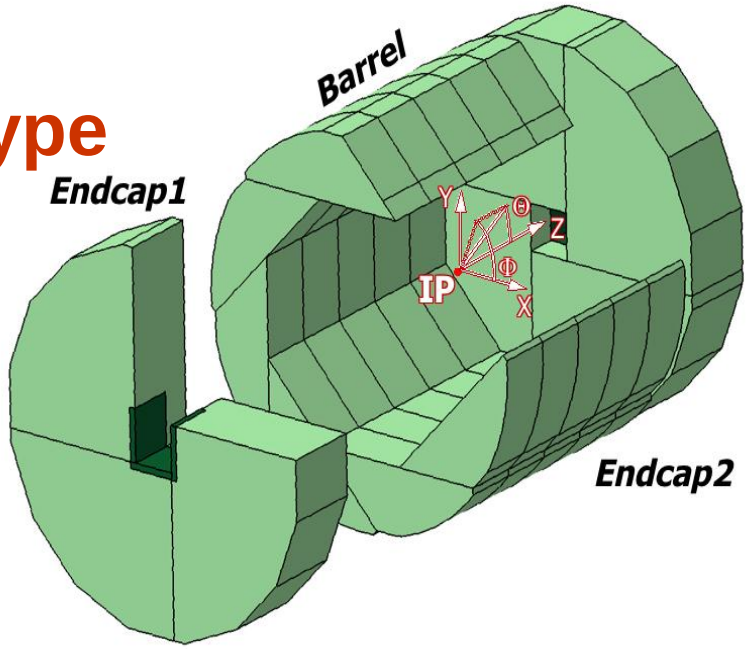
→ 2-bit readout improves on energy resolution at energies> 30 GeV







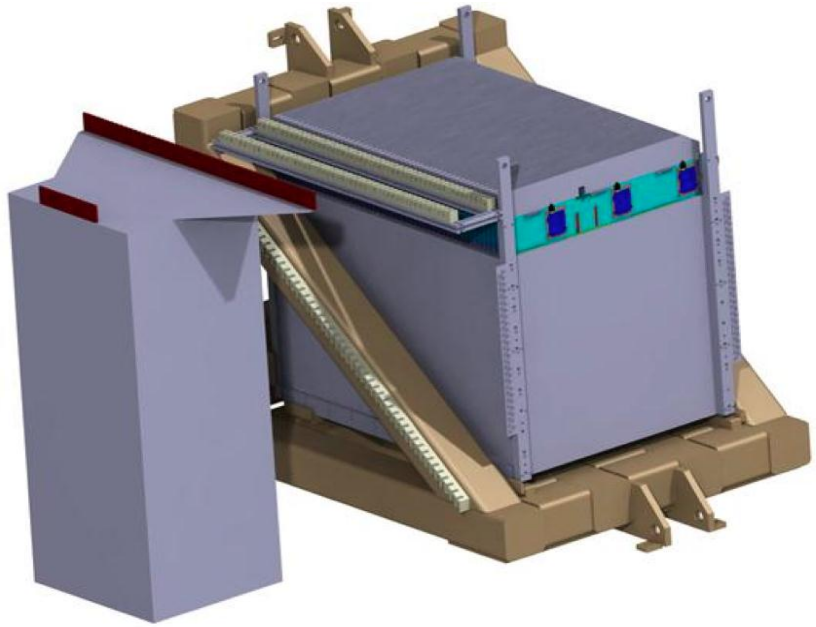
SDHCAL technological prototype



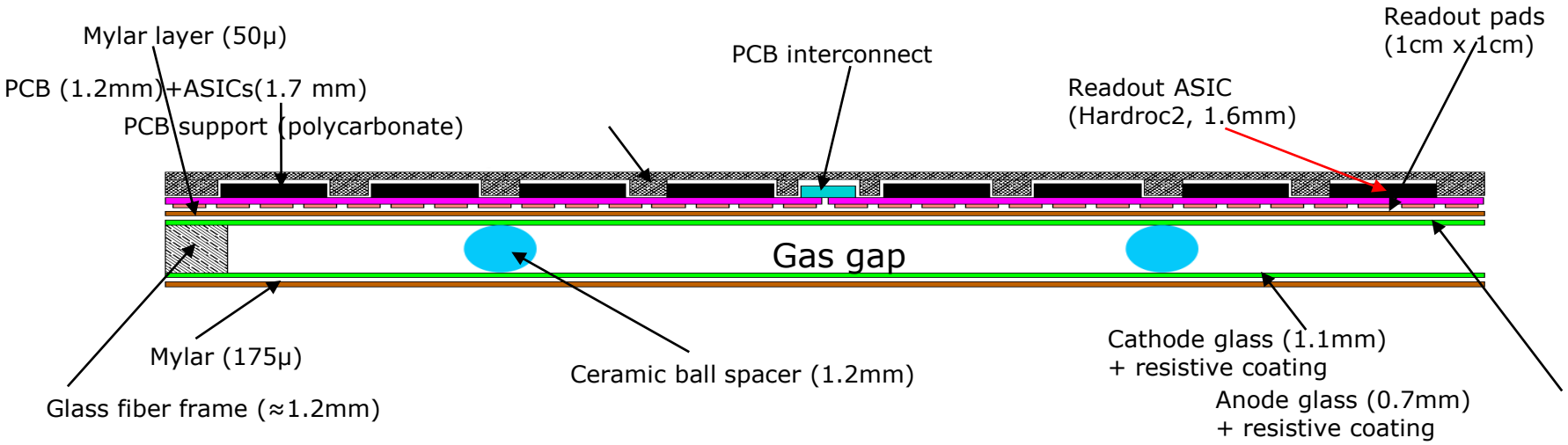
SDHCAL is one of the two HCAL options of the ILD project.
It was proposed with a genuine mechanical structure with no projective cracks and no dead zone between the Barrel and the Endcaps since services are on the periphery

Challenges
-homogeneity for large surfaces
-Thickness of only few mms
-Services from one side
-Embedded power-cycled electronics
-Self-supporting mechanical structure

Technological prototype
A prototype with 48 GRPC of 1m2 and stainless steel absorber corresponding to 6 λ_I was conceived as a demonstrator

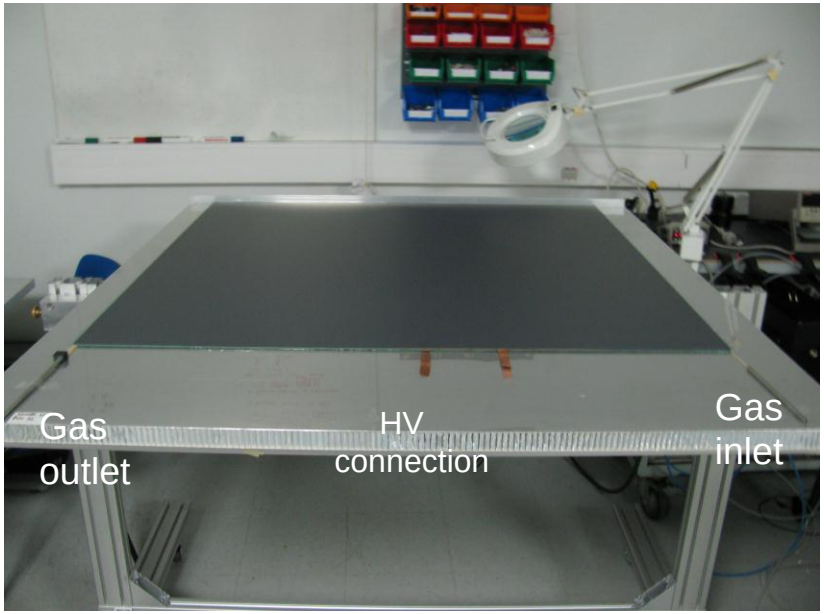


Structure of an active layer of the SDHCAL

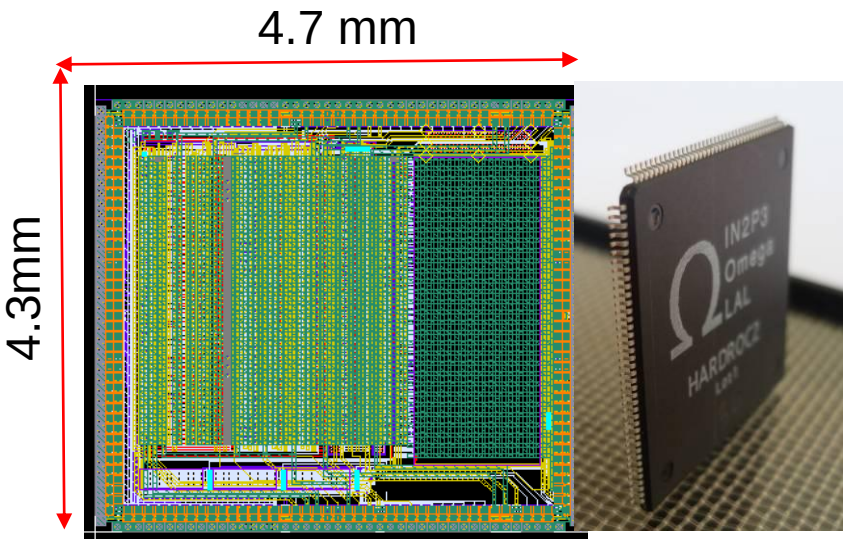


Large GRPC R&D

- ✓ Negligible dead zone (tiny ceramic spacers)
- ✓ Efficient gas distribution system (channeling gas inlet and outlet)
- ✓ Homogenous resistive coating (special paint mixture, silk screen print)



Electronics readout system R&D

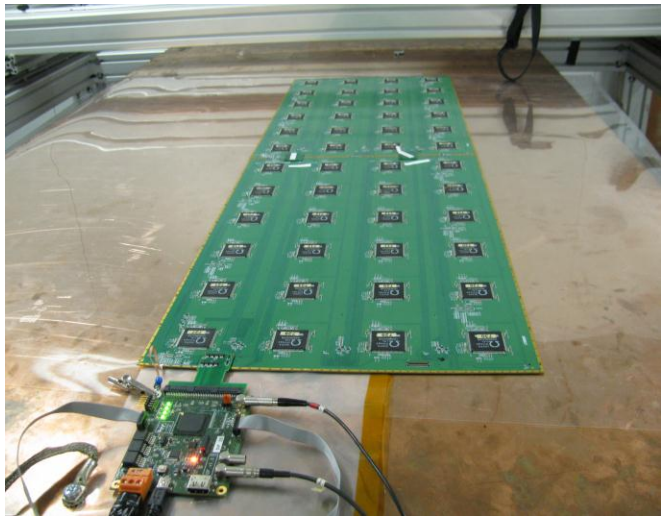


ASICs : HARDROC2
64 channels
Trigger less mode
Memory depth : 127 events
3 thresholds
Range: 10 fC-15 pC
Gain correction → uniformity
Power-Pulsed (7.5 μW in case of ILC duty cycle)

Printed Circuit Boards (PCB) were designed to reduce the x-talk with 8-layer structure and buried vias.

Tiny connectors were used to connect the PCB two by two so the 24X2 ASIC are daisy-chained.

DAQ board (DIF) was developed to transmit fast commands and data to/from ASICs.



Cassette R&D

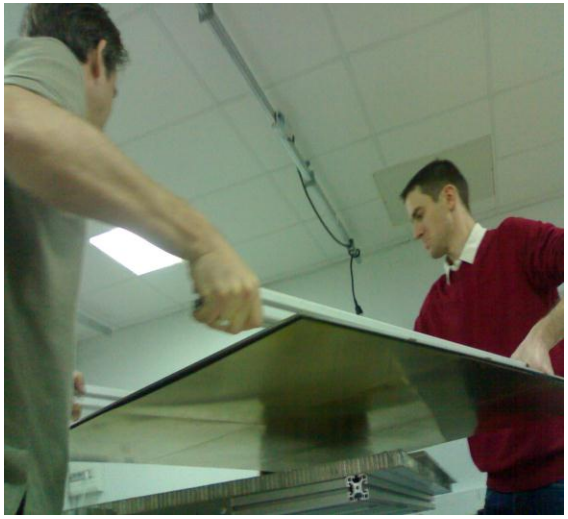
Cassettes were conceived

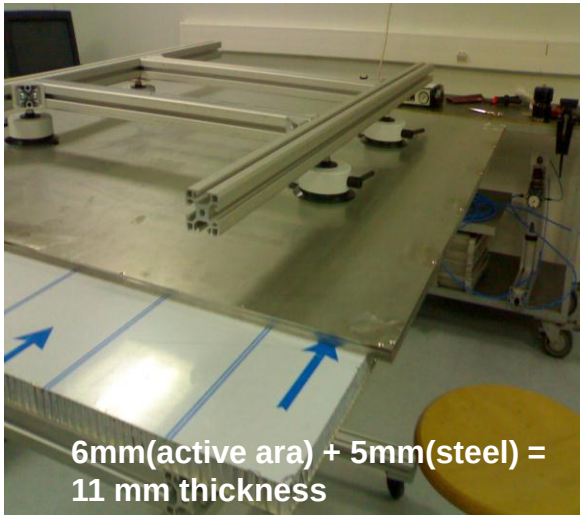
✓ To provide a robust structure.

✓ To maintain good contact between the readout electronics and the GRPC.

✓ To be part of the absorber.

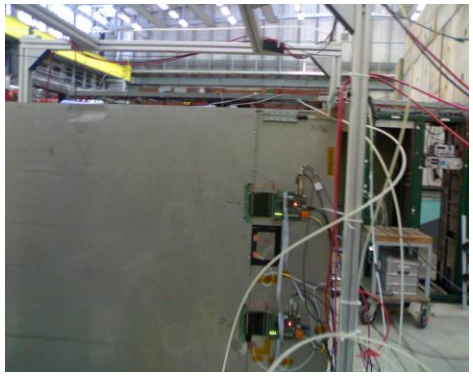
✓It allows to replace detectors and electronics boards easily.

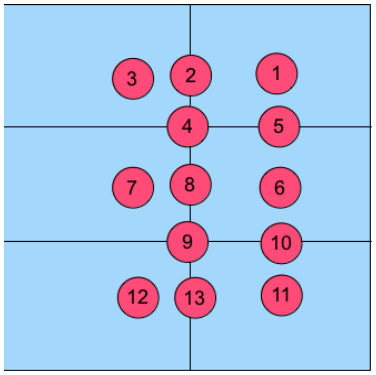




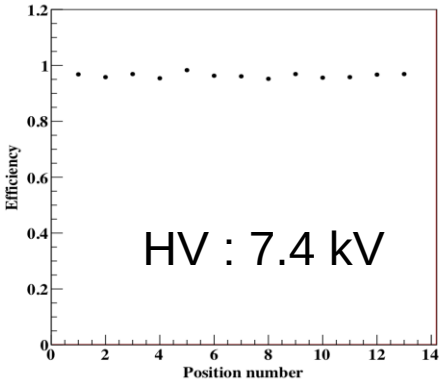
The cassettes are built of no-magnetic stainless steel walls 2.5 mm thick each
→ Total cassette thickness = 6mm (active layer)+5 mm (steel) = 11 mm

The homogeneity of the detector and its readout electronics were studied

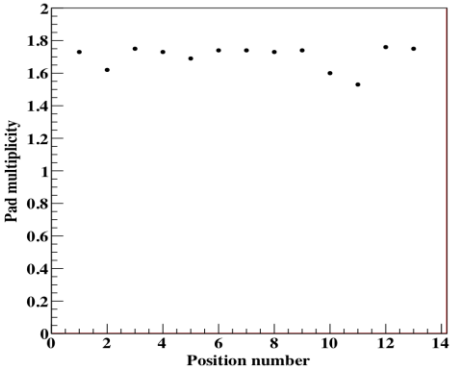




Beam spot position



Efficiency

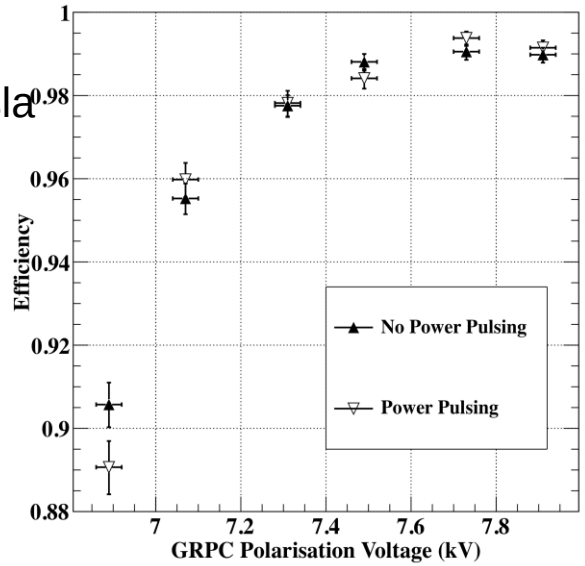


Multiplicity

Power-Pulsing mode was tested in a magnetic field of 3 Tesla

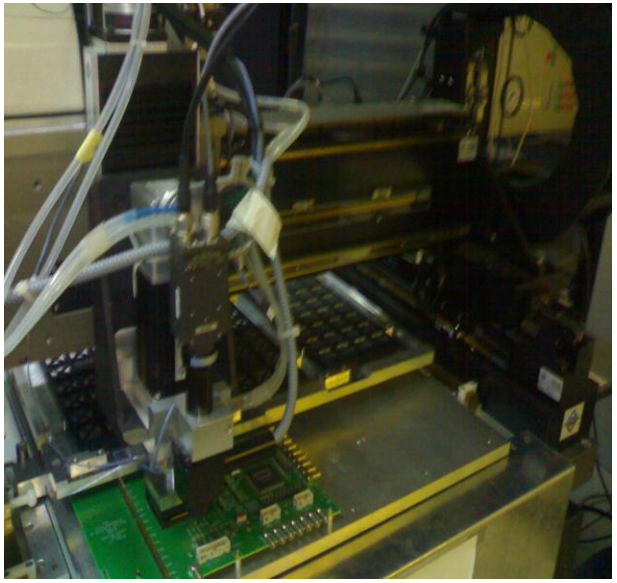
The Power-Pulsing mode was applied on a GRPC in a 3 Tesla field at H2-CERN
(2ms every 10 ms)
No effect on the detector performance

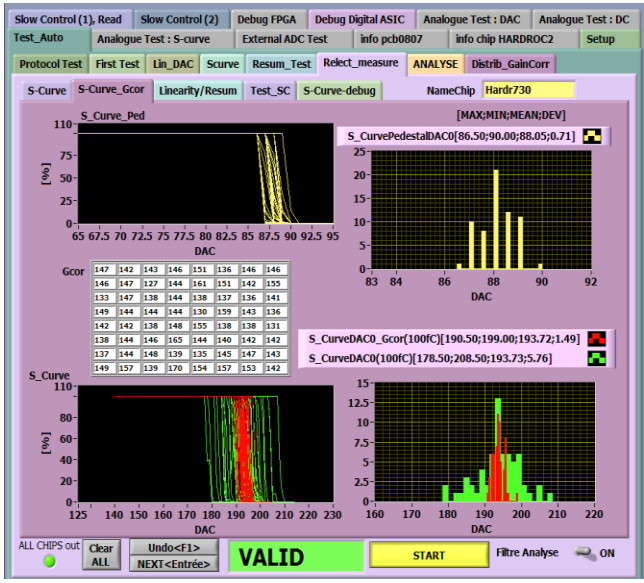
ILC duty cycle :
1ms (BC) every 200 ms



SDHCAL prototype construction

✓ 10500 ASIC were tested and calibrated using a dedicated robot(93% layout)
✓ 310 PCBs were produced, cabled and tested according to strict quality control rules

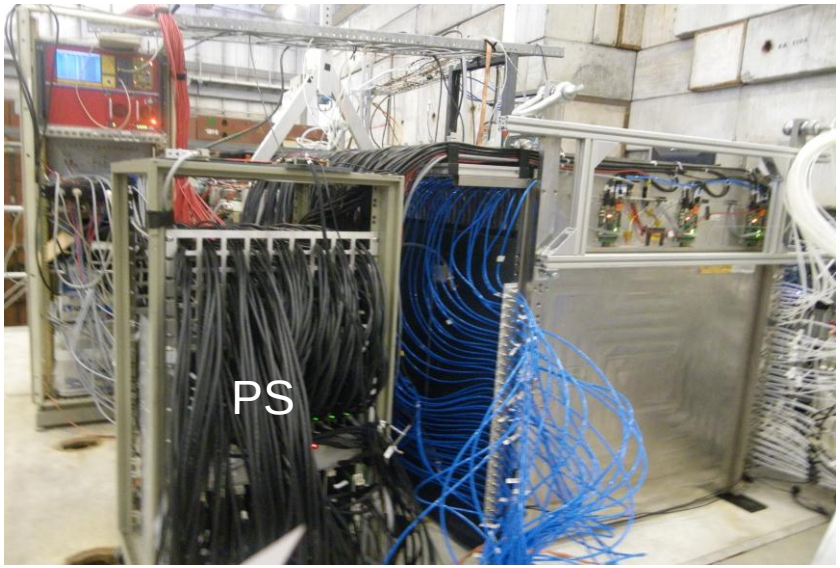


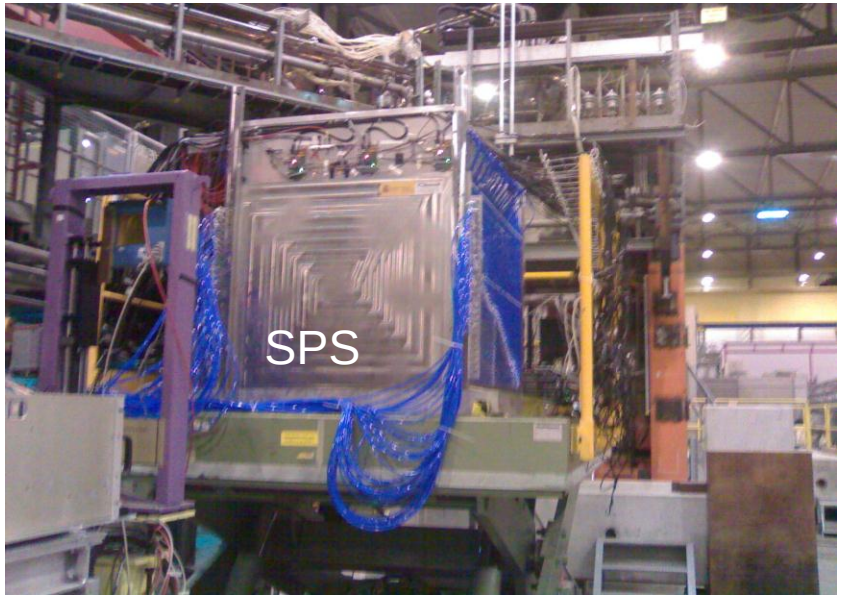


✓ self-supporting mechanical structure was conceived and built.

✓ 51 stainless steel 15mm thick plates with planarity <250 μm were machined and tested

Prototype integration

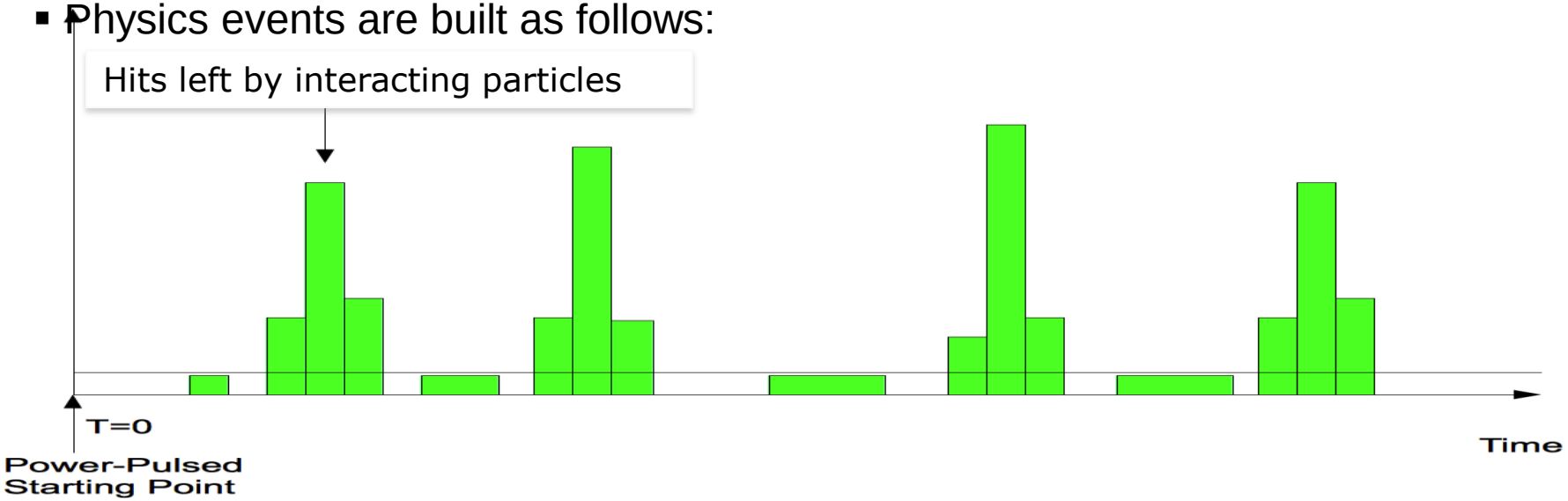




Prototype data acquisition

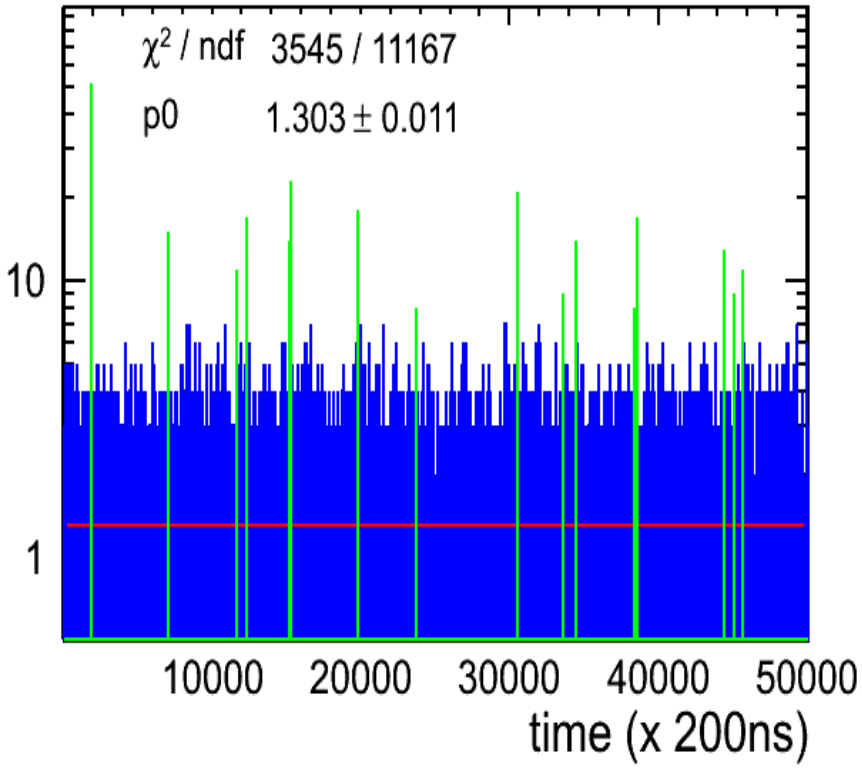
- Trigger less mode : Recording events until memory is full, then data transfer and restart.
- Power-Pulsed mode : ASIC is idle between two spills. According to the time spill structure (NX400 ms (PS)*, 10 s(SPS) every 45 s)

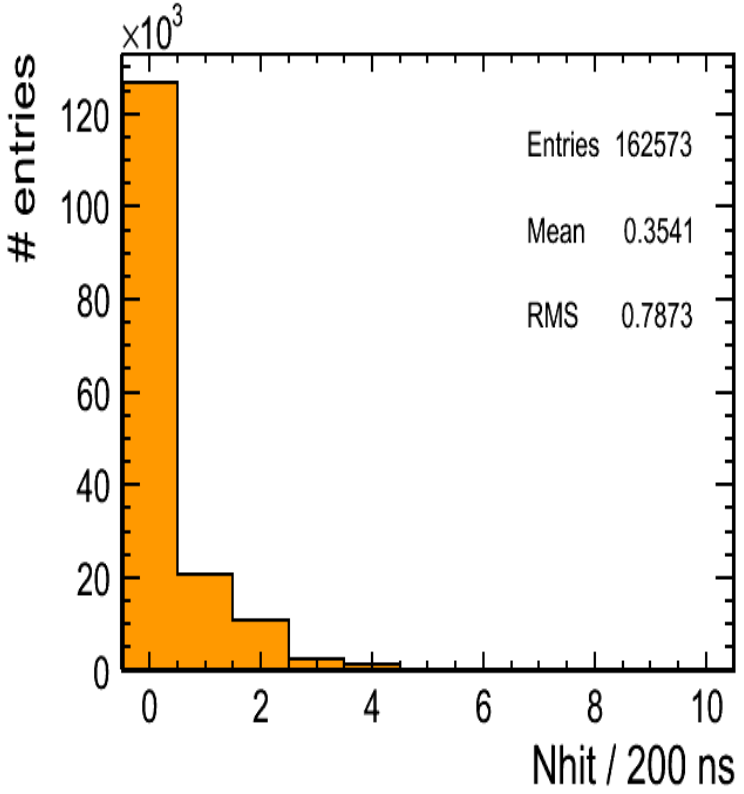
- No gain correction applied for this TB.
- Physics events are built as follows:



* N is often 1 and sometimes 2-3 spills/cycle

Prototype data acquisition





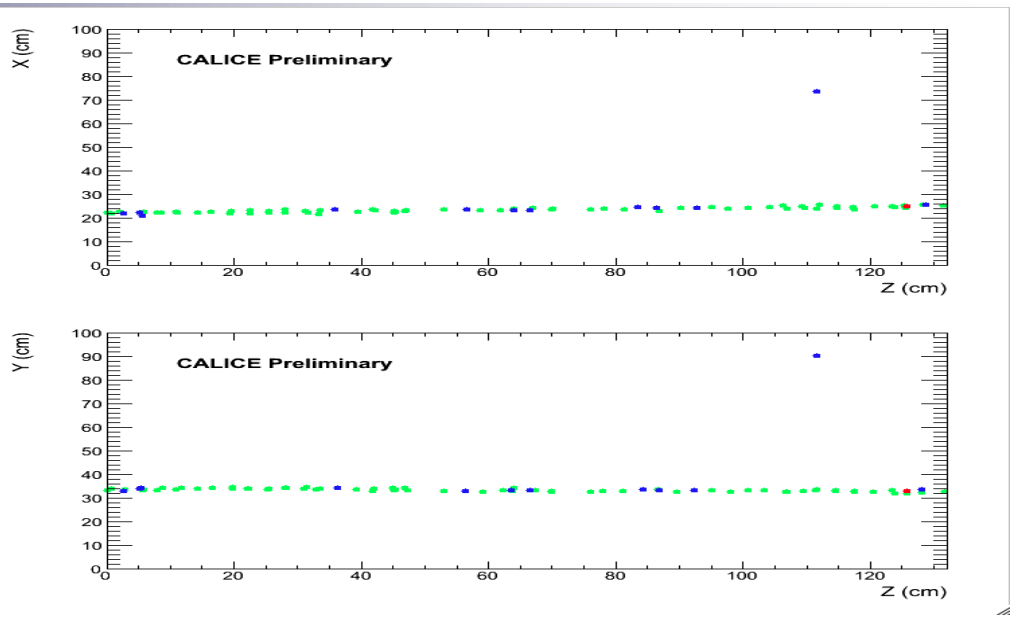
An event is made by the addition of hits belonging to the three time slots of 200 each built around the one having more than 7 hits (green ones in the figure)

→ Number of noise hits/event is about 1 hit

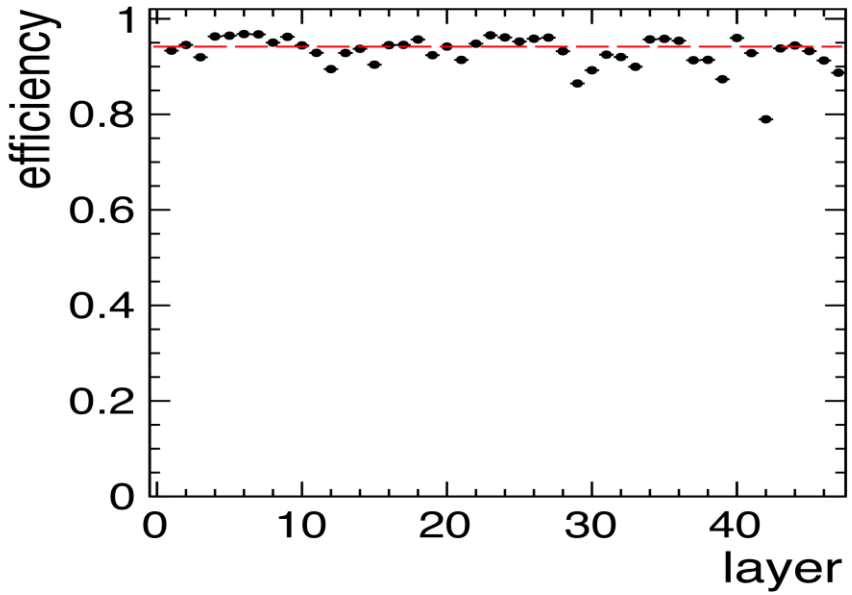
Prototype data acquisition

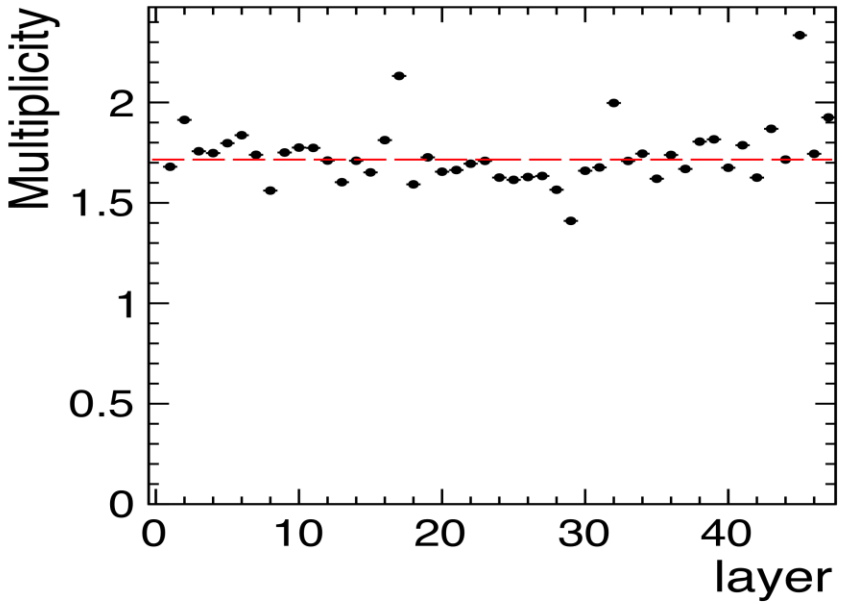
Muons are used to study the GRPCs behaviour during the TB

HV : 6.9 kV
Gas flow : 2 l/h
Gas mixture:
93% R134A, 5% CO_2, 2% SF_6



Colours correspond to the three thresholds: Green (100 fC), Blue (5 pC), Red (15 pC)

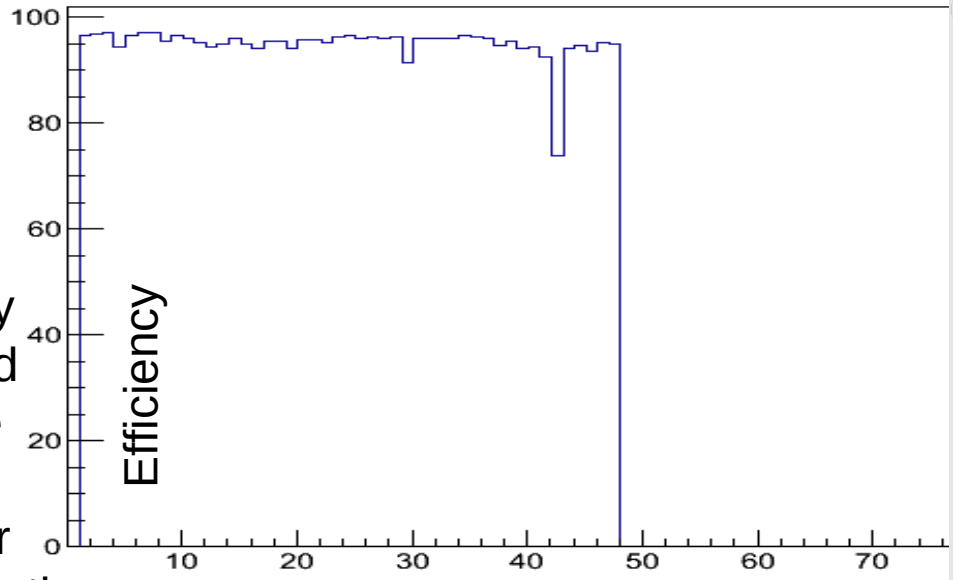




Prototype data acquisition

Online control

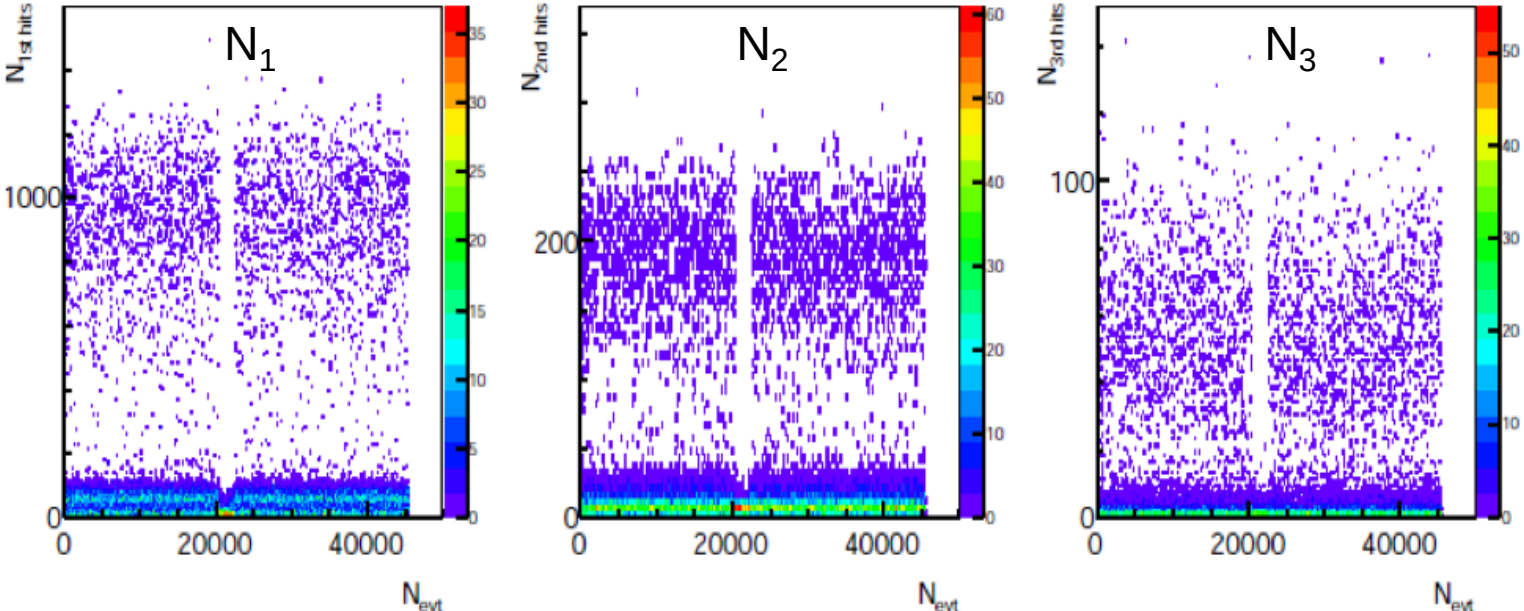
During data taking, efficiency and multiplicity are estimated ever now and then using the muon beam, cosmics. This allows to control the detector quality and its stability during the run.

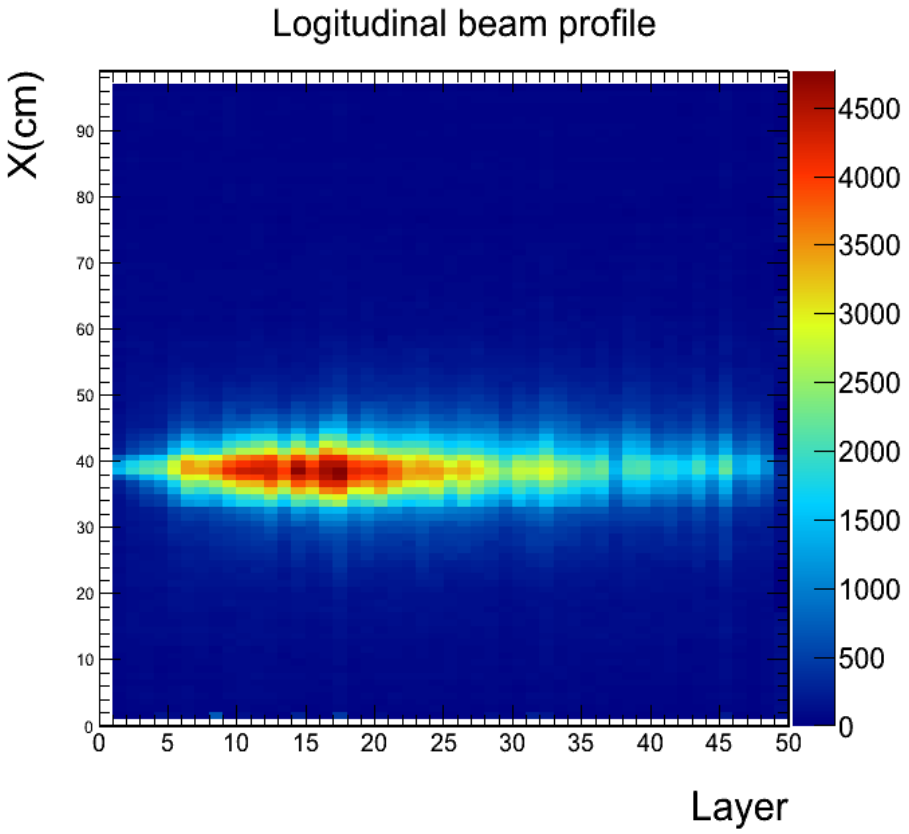


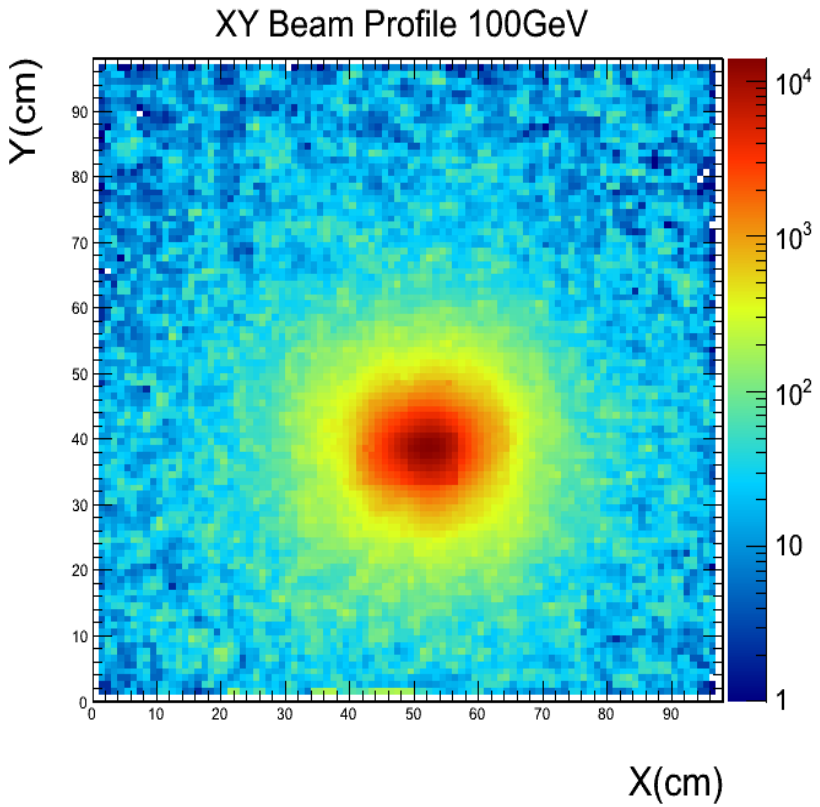
Efficiencies for 43138

|1|298770|288178|96
|2|299923|289999|96
|3|300587|291836|97
|4|302290|285384|94
|5|303182|292831|96
|6|304359|295212|96
|7|303836|295208|97
|8|303234|289097|95
|9|301413|290684|96
|10|299341|287161|9
|11|296713|282710|9
|12|295025|278118|94
|13|292102|277133|94
|14|289232|277629|9
|15|287725|273191|94
|16|285409|268881|94
|17|283921|271082|9
|18|281189|268578|9
|19|279243|262735|94
|20|276900|265080|9
|21|274932|263257|9
|22|273358|260185|9
|23|271427|261003|9
|24|269284|260190|9
|25|267388|256939|96
|26|265796|255818|96
|27|264488|253723|9
|28|262853|253066|96
|29|260714|238445|9
|30|258935|248365|95
|31|257347|247229|96
|32|256354|246290|96
|33|255078|244701|9
|34|253576|244776|96
|35|252403|243090|96
|36|251564|241647|96
|37|250462|237246|94
|38|249468|237927|9
|39|248213|233770|94
|40|252447|238044|94
|41|251368|232604|9
|42|249871|184524|7
|43|247550|232840|94
|44|245550|232342|94
|45|243090|227223|9
|46|240189|228552|9
|47|237527|225465|94

Stability of the three thresholds is also controlled by the hits distribution hadronic showers

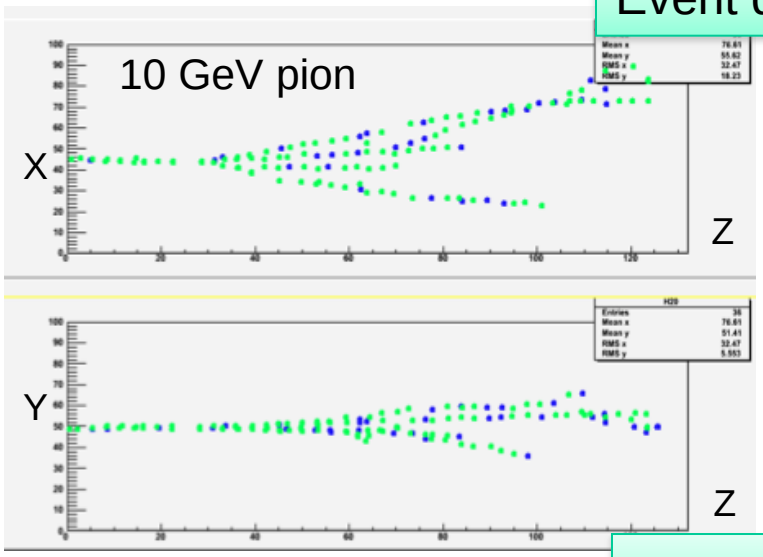


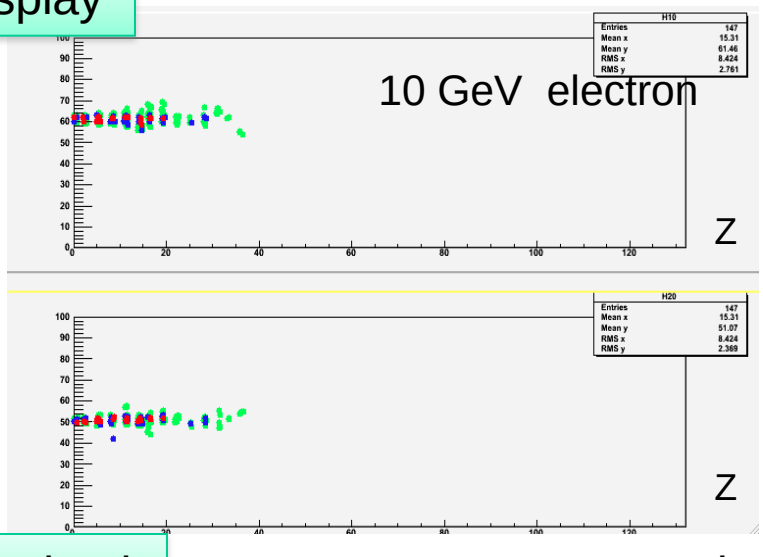




100 GeV pions

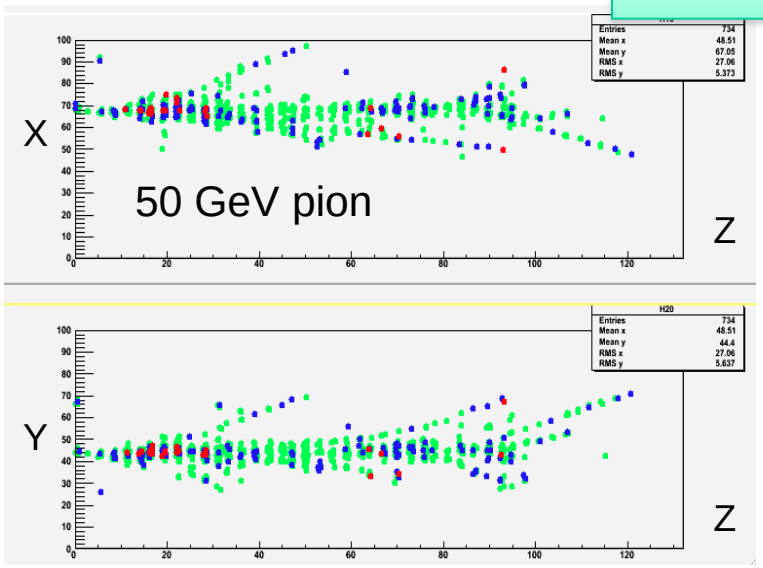
Event display

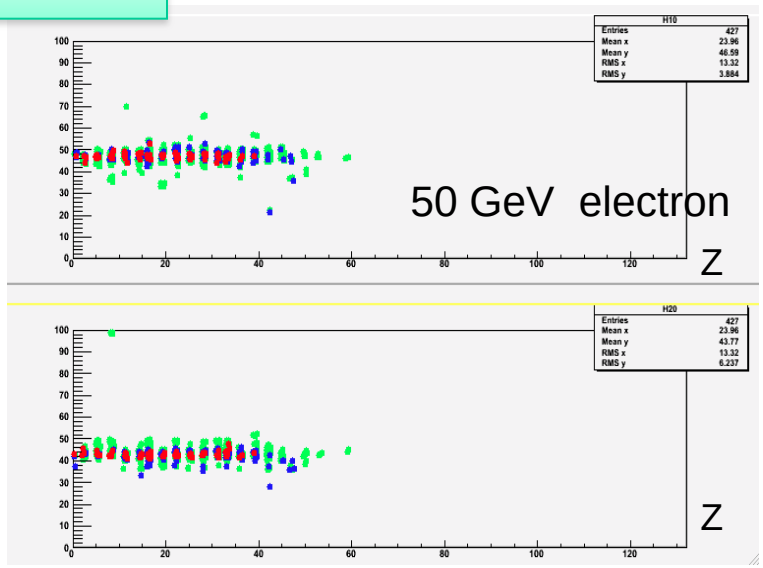




Power-Pulsed

units in cm





Colours correspond to the three thresholds: Green (100 fC), Blue (5 pC), Red (15 pC)

Raw data, no treatment except time hit clustering

Perspectives and Conclusion

✓ 50 GRPC will used for the November TB at CERN. Gain correction will be applied. A tail catcher using 4 chambers of MicroMegas will be used

✓ Work on very large GRPC 2-3 m^2 have started and will be completed next year. This includes new ASIC generation (HR3), new PCB and an improved DAQ system.

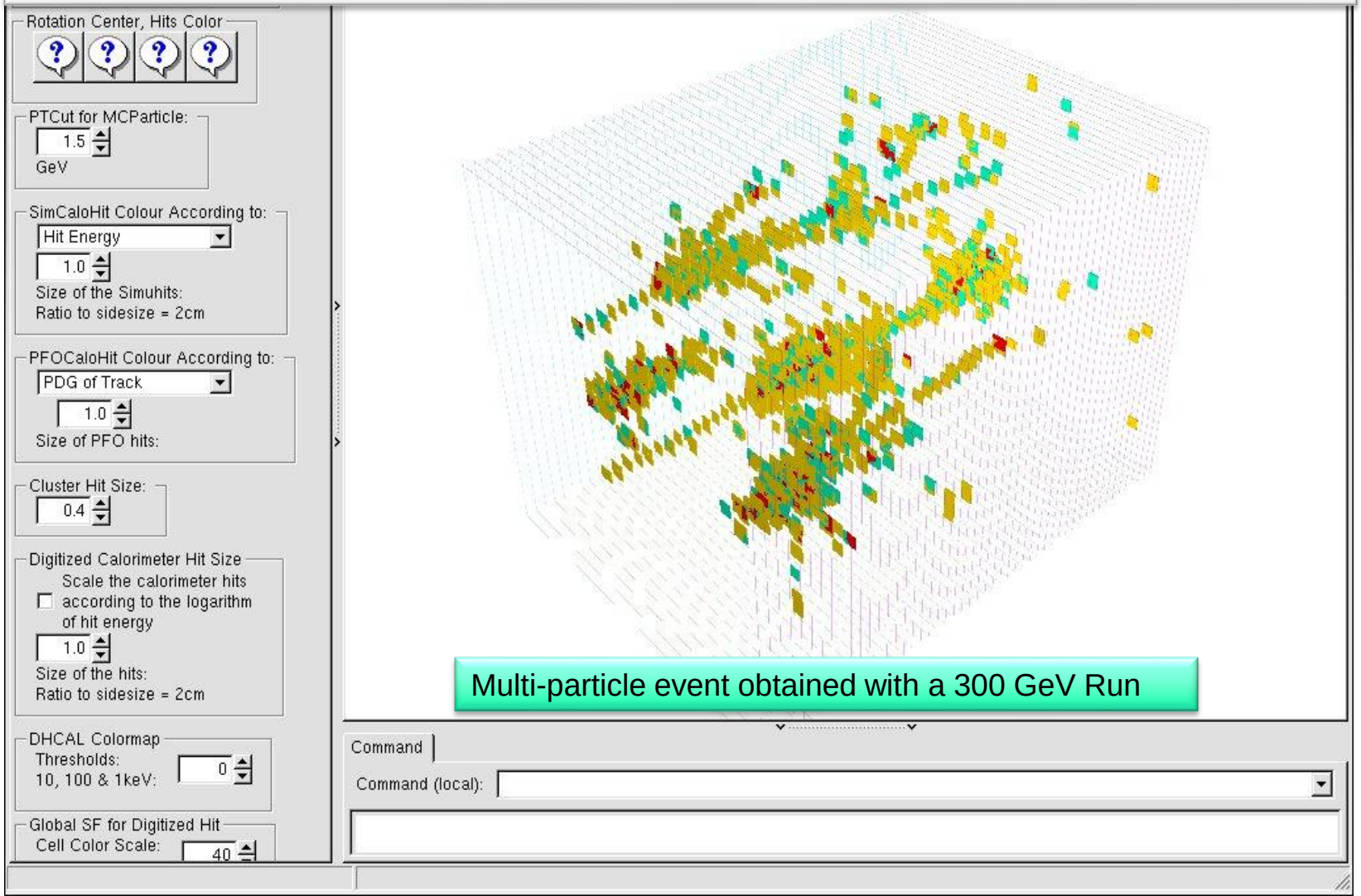
✓ A semi-digital , high granular hadronic calorimeter seems an excellent tool to achieve PFA in the future linear collider. experiments.

✓ A prototype of 6 λ_I was build using GRPC as active layers.

✓The quality of the collected data with almost no treatment is very satisfactory.

✓First results will be shown in next talk by v.Boudry

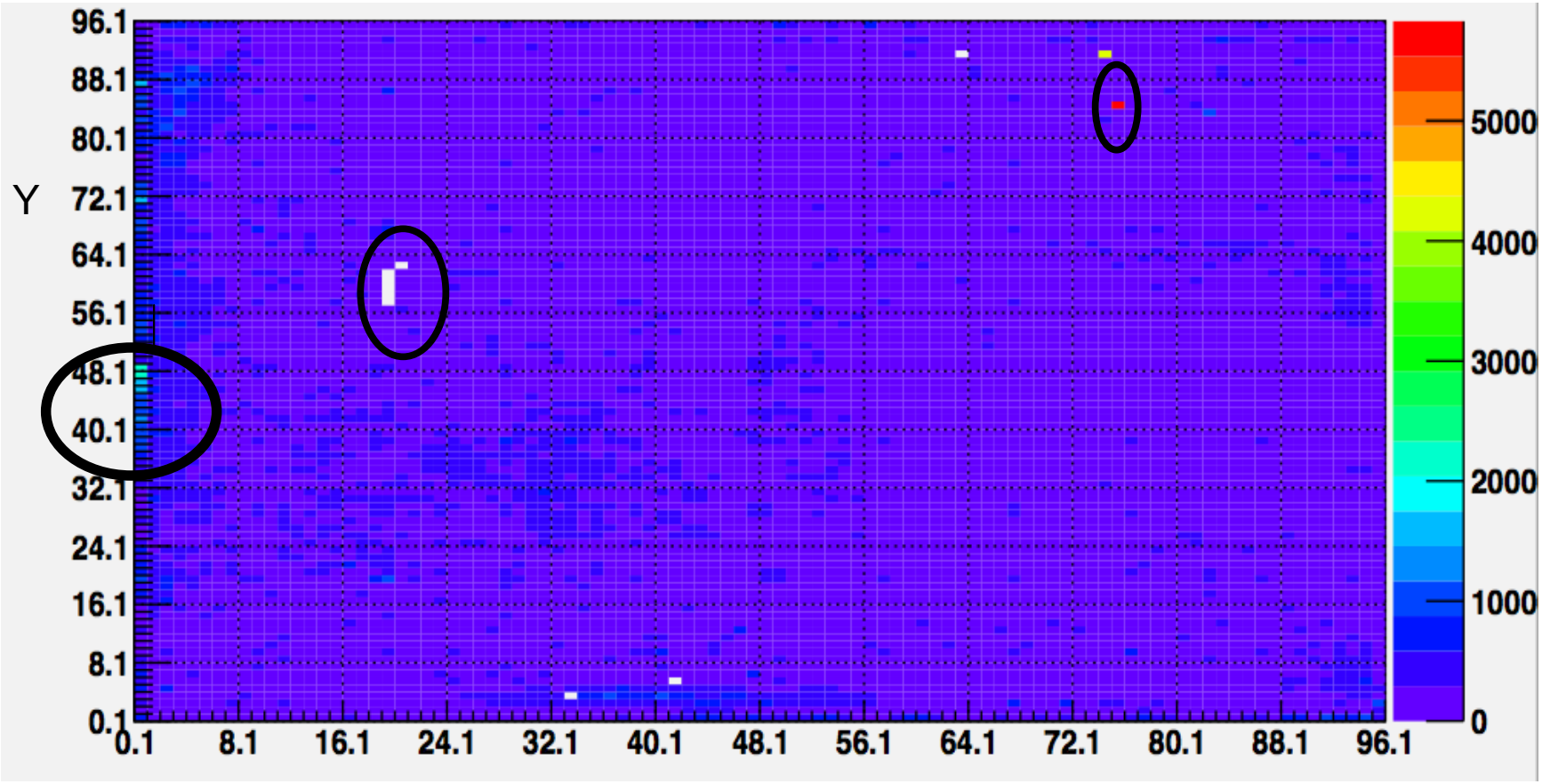
✓The SDHCAL granularity will allow to separate easily close-by hadronic showers.
✓Hough Transform and Minimum Spanning Tree algorithms are being adapted to be used in this Tracker-calorimeter



Backup Slides

Validation

Noise was measured and found to be < 1 Hz/cm2 outside the channeling tubes and HV connection zones



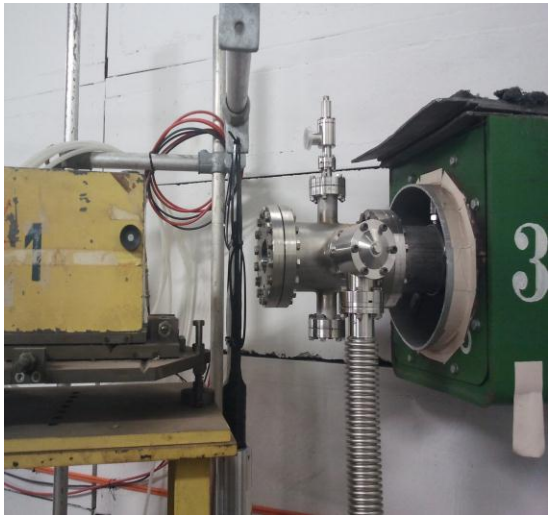
Noise Map

X

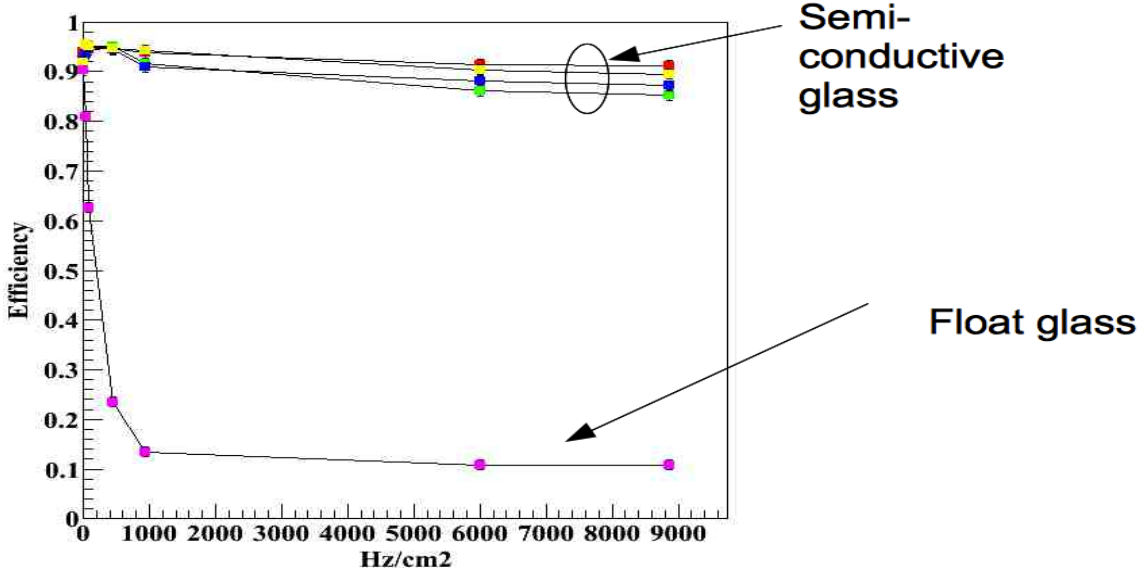
High-Rate GRPC

High-Rate GRPC may be needed in the very forward region

✓Semi-conductive glass (10^{10} Ω.cm) produced by our collaborators from Tsinghua University was used to build few chambers.
✓4 chambers were tested at DESY as well as standard GRPC (float glass)

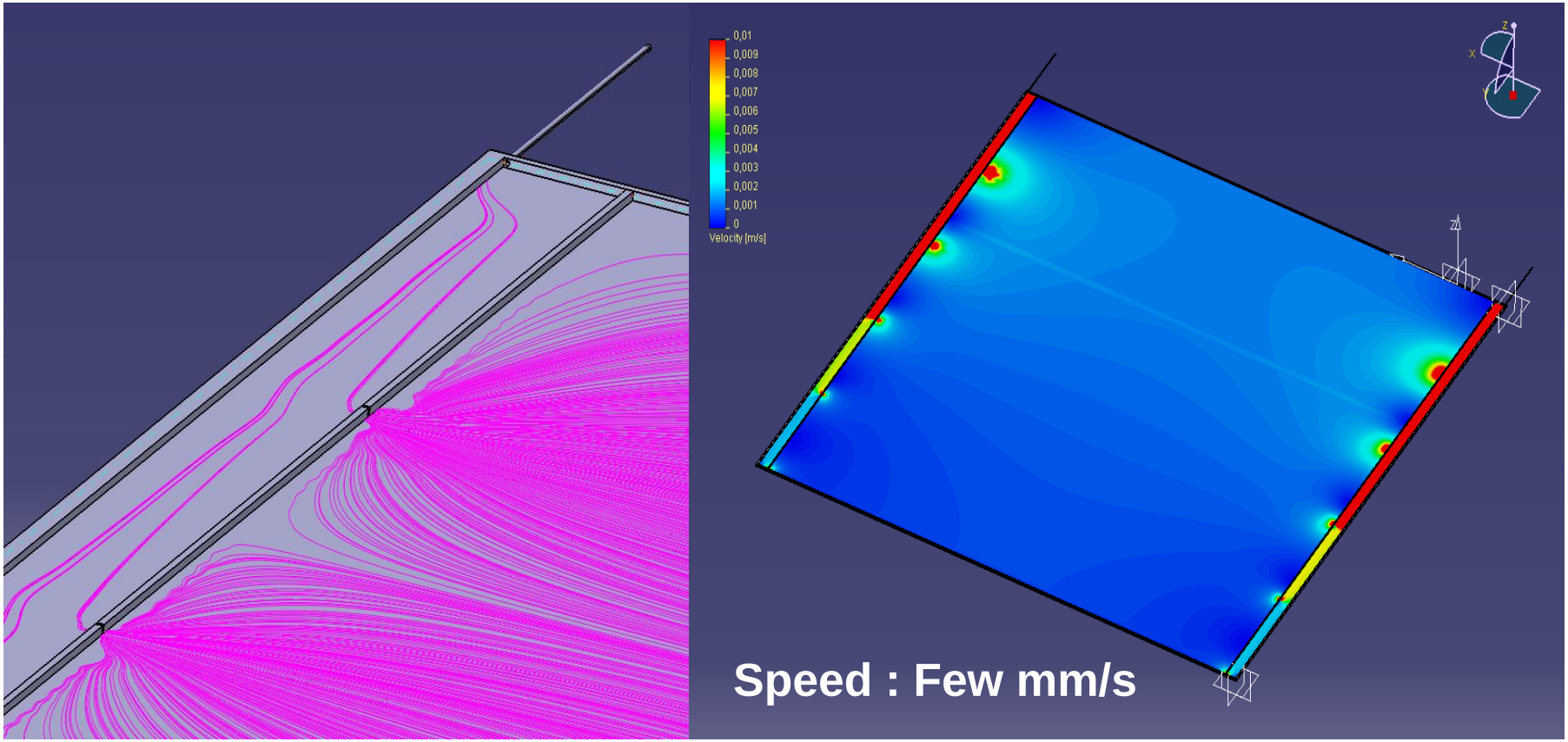


Performance is found to be excellent at high rate for GRPCs with the semi-conductive glass and can be used in the very forward region if the rate > 100 Hz/cm^2



Gas distribution system

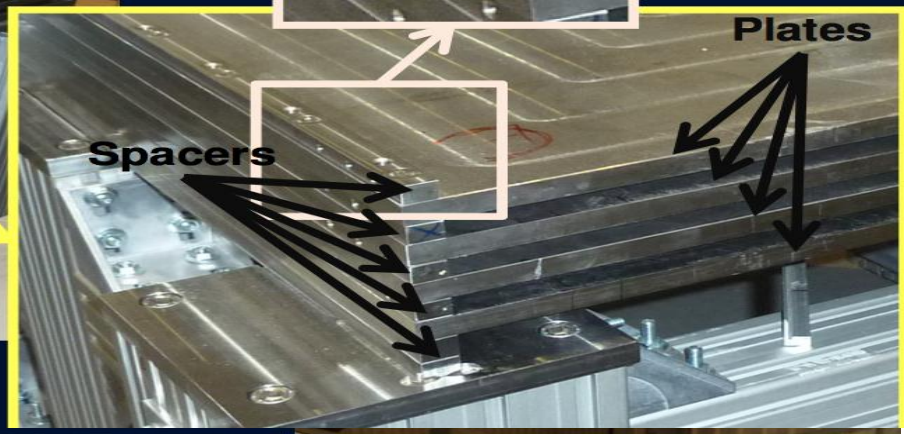
The services being on one side of the detector, a new gas distribution design is used. It allows to distribute the gas uniformly in the large chamber.



When diffusion is included→ Homogeneity is expected to be even better

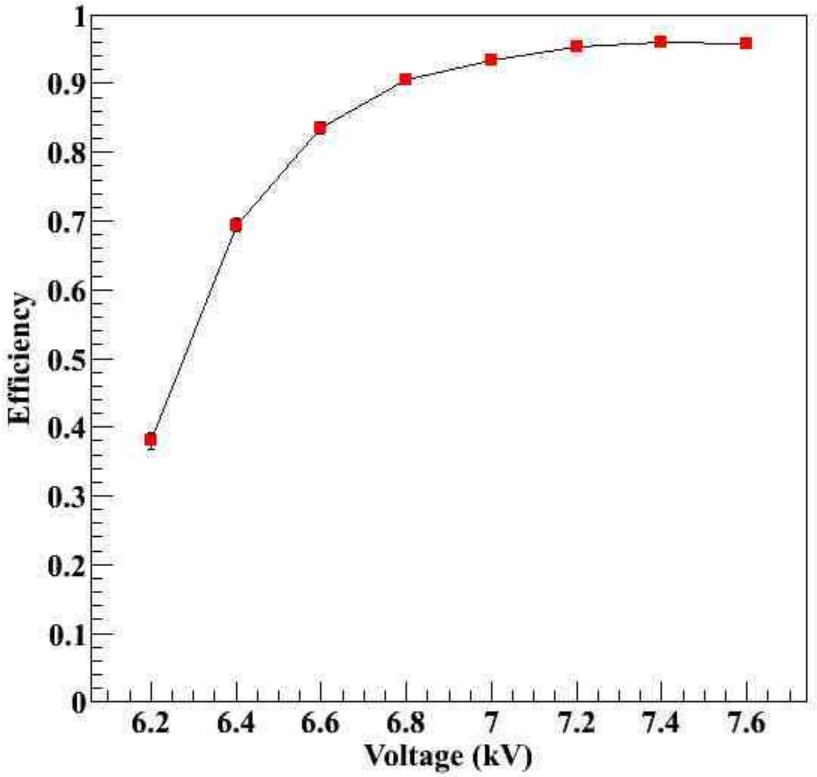
A test using Kr83m radioactive gas is scheduled to monitor online the gas distribution

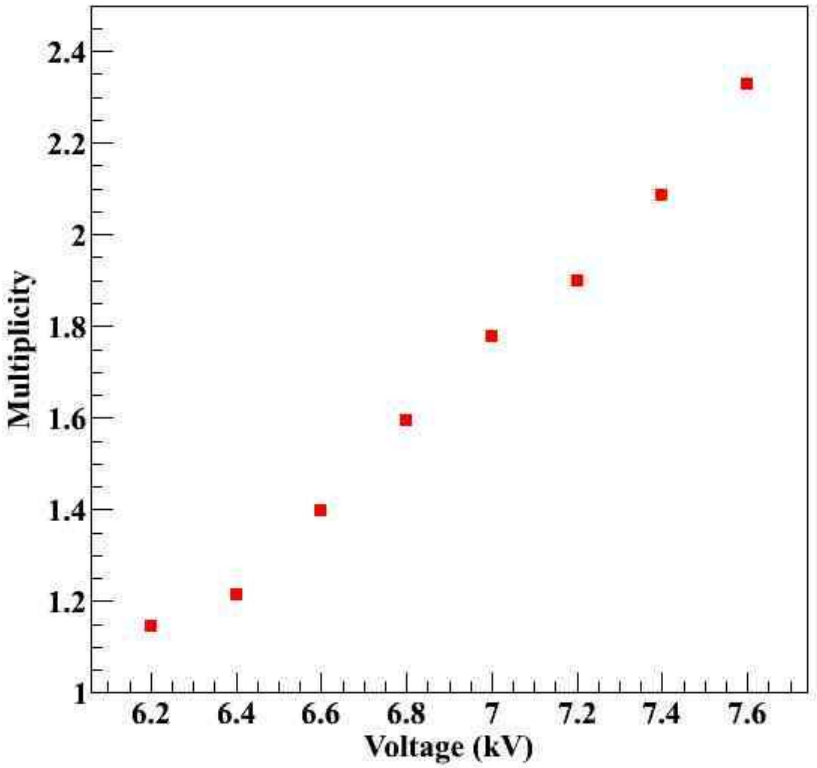

Bolts


Plates
Spacers


Planarity Verification

To check that the detectors and electronics are not at the origin o
A short beam test was organized at PS in November 2011 with 6
taken from the prototype





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