Status of the GRPC Semi-Digital Hadronic Calorimeter

CIEMAT, Ghent, IPNL, LAL, LAPP, LLN, LLR, LPC, Protvino, Tsinghua, Tunis

Outline

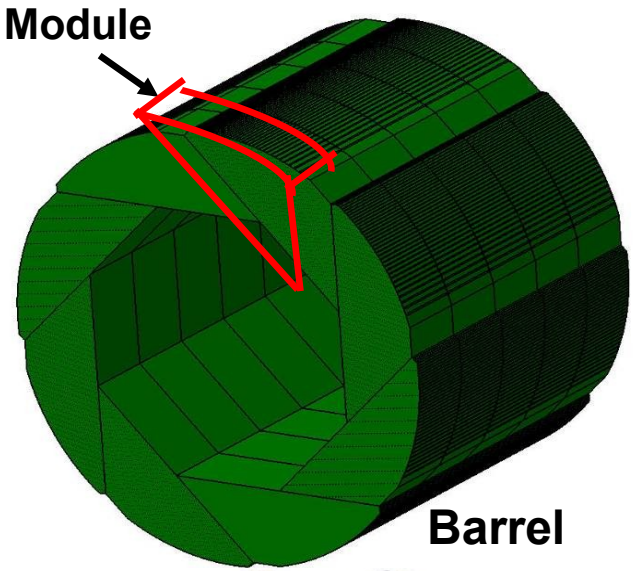
- Motivation
- Design and constraints
- Technical issues
- Prototype construction
- Test Beam and cosmics results
- Conclusion

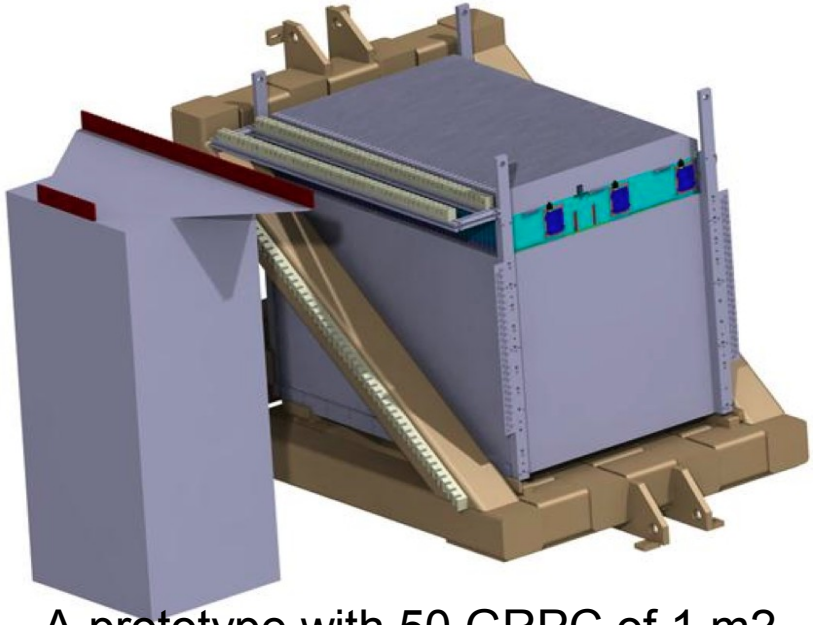
Motivation

-The Semi-Digital HCAL is one of two options proposed in the ILD LOI. It uses gaseous detectors as sensitive medium with embedded readout electronics providing 1cm2 lateral segmentation.
-A genuine mechanical structure is proposed for the SDHCAL.

GRPC was chosen as the baseline :
-Cost-effective
-High efficiency
-Adequate resolution

Challenges
-homogeneity for large surfaces
-Thickness of only few mms
-Services from one side
-Embedded electronics





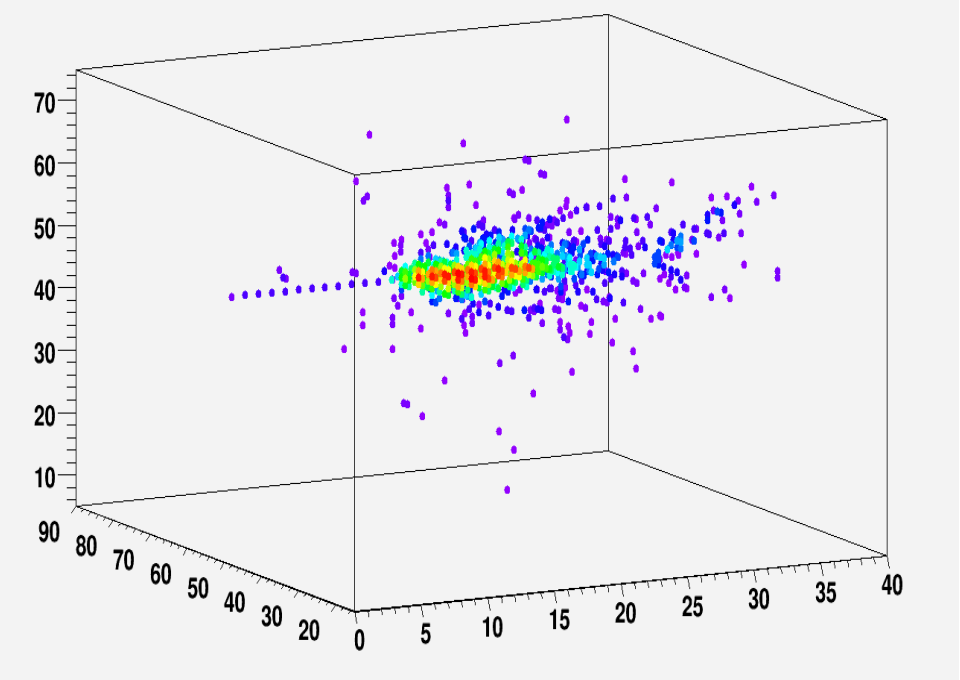
A prototype with 50 GRPC of 1 m2 was conceived as a demonstrator

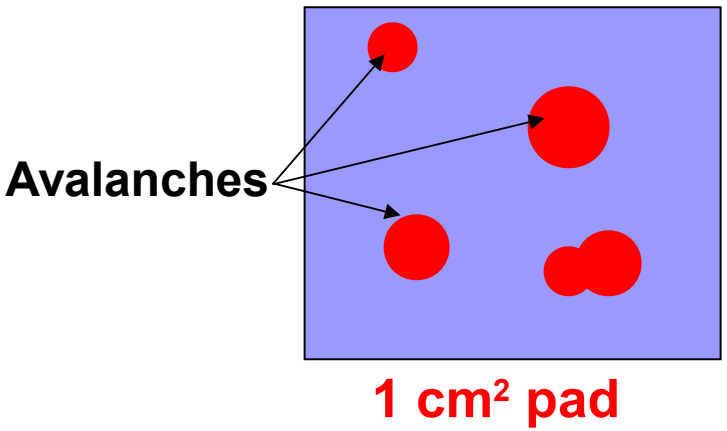
Motivation

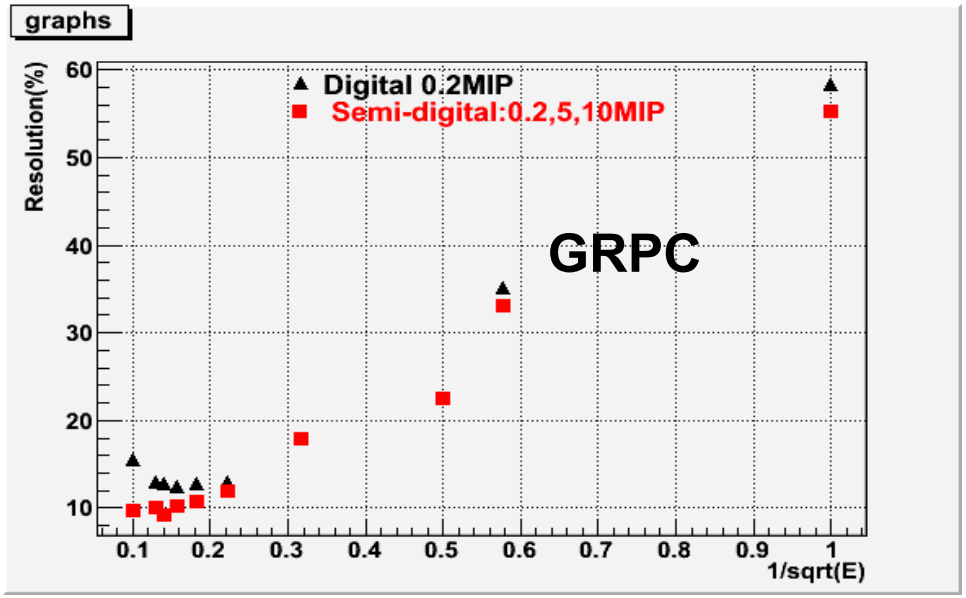
Electronics readout choice

At high energy the shower core is very dense→ simple binary readout will suffer saturation effect

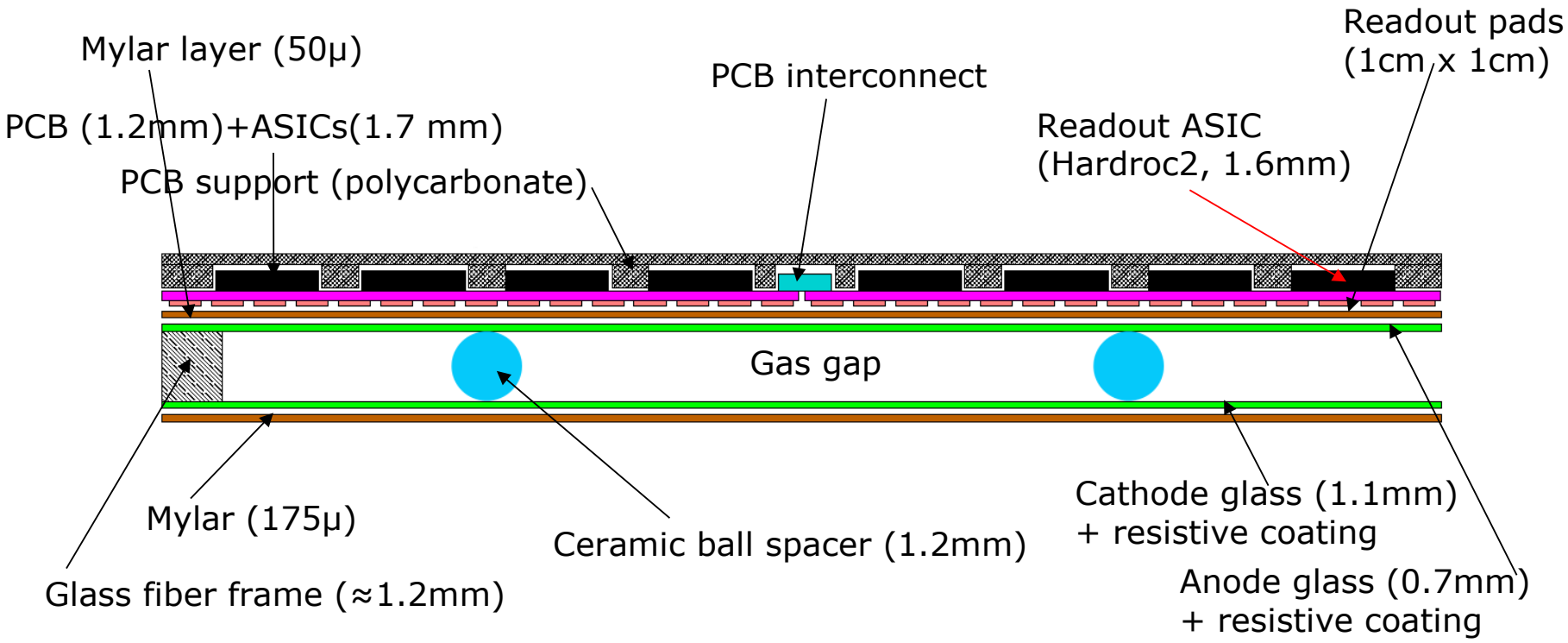
→ semi-digital readout (2-bit) can improve the energy resolution.







Cross-section of Lyon 1m² glass RPCs

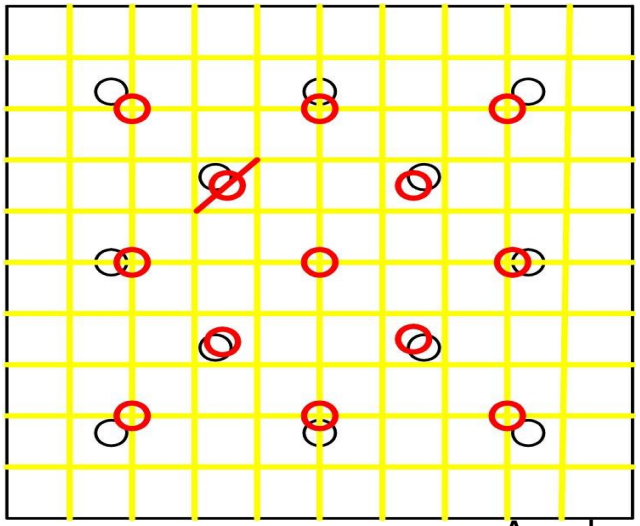


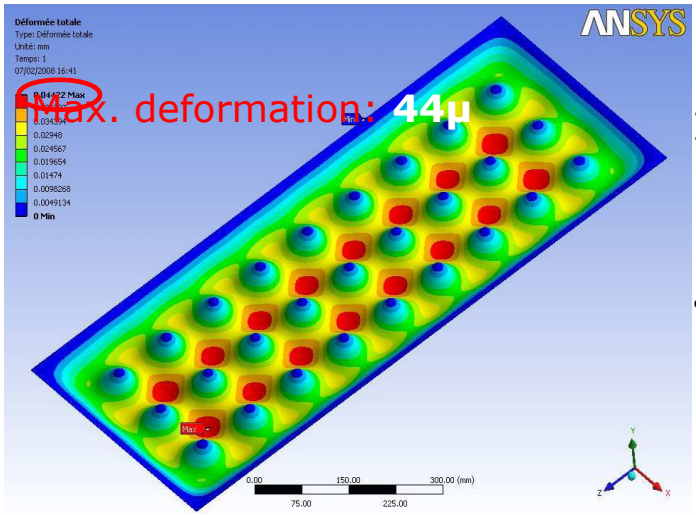
Total thickness: 6.0mm

The choice of ceramic balls rather than fishing lines aims at reducing both dead zones and noise.

Homogeneity study

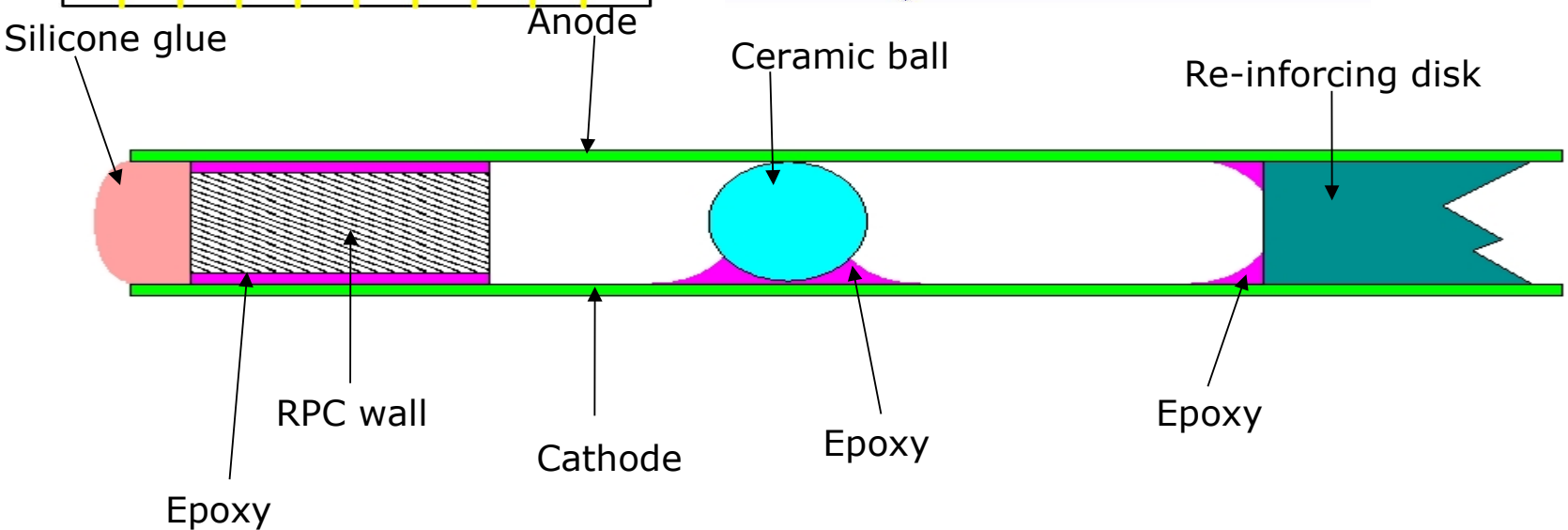
To maintain the same distance between the two glass plates, spacer are used every 10 cm : 68 ceramic balls+ 13 fiber glass disks.





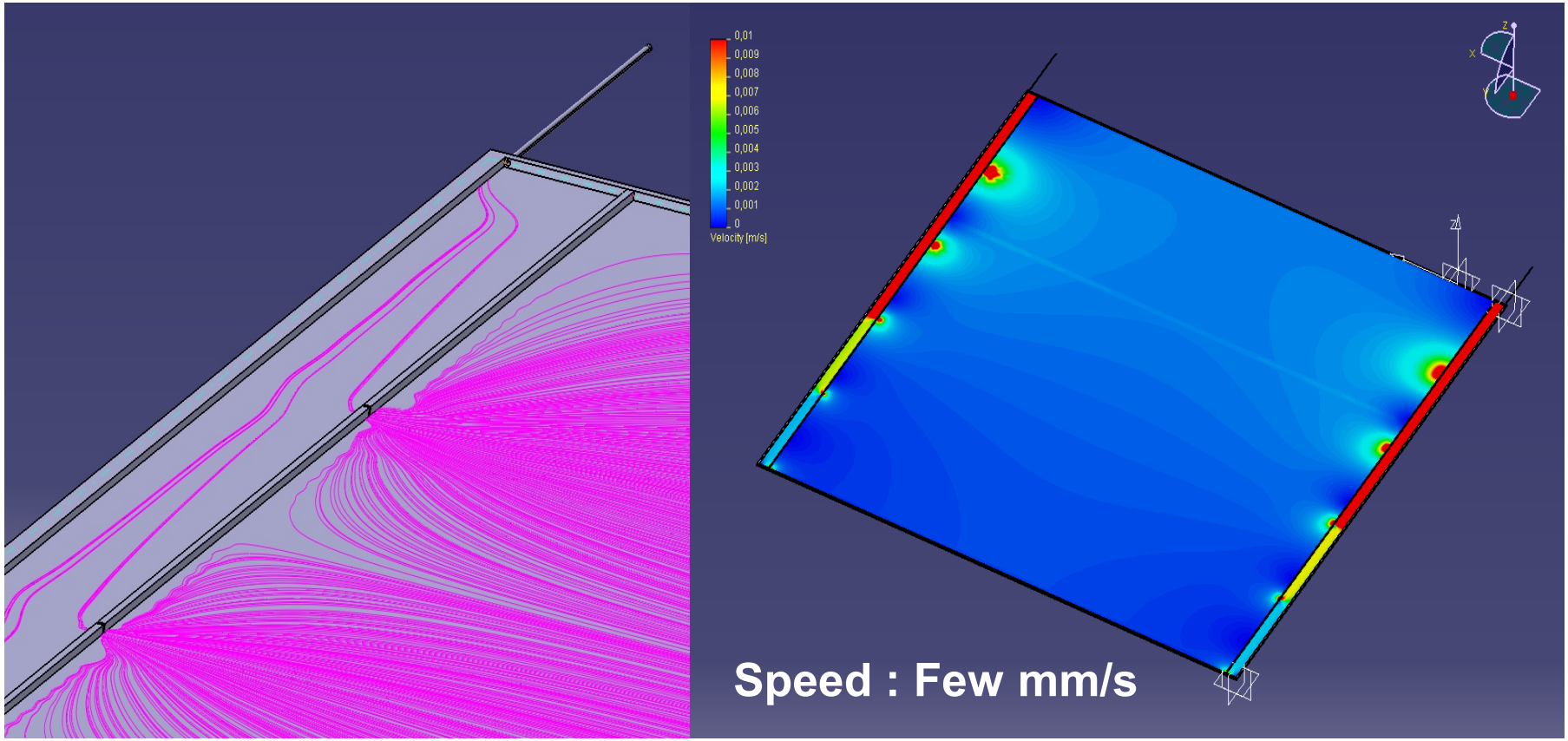
Included
- glass weigh
- electrostatic force

Not included
- Gas pressure



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.



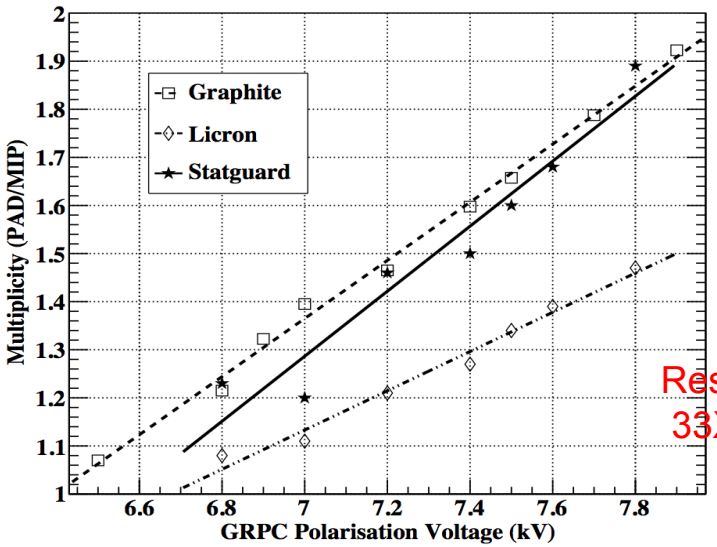
When diffusion is included→ Homogeneity is expected to be even better

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

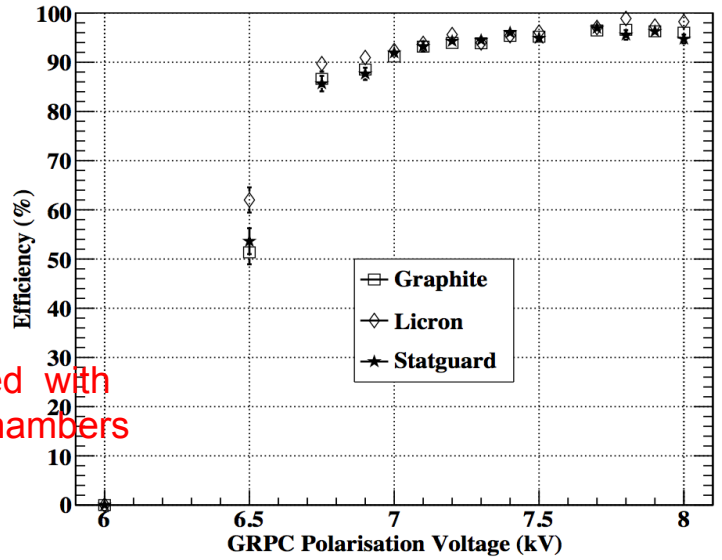
Resistive coating study

The resistive coating is needed to apply the HV on the two glass plates (electrodes). The resistivity value of this coating plays an important rôle of the pad multiplicity. The higher the resistivity the lower the multiplicity
Three kinds of coatings were tested :

	Licron	**Statguard**	**Colloidal Graphite type I**	**Colloidal Graphite type II**
Surface resistivity (MΩ/□)	~20	1-10	~0.5	Depends on mix ratio; choose ~0.7
Best application method	Spray	Brush	Silk screen printing	Silk screen printing



Results obtained with 33X8.3 cm2 chambers

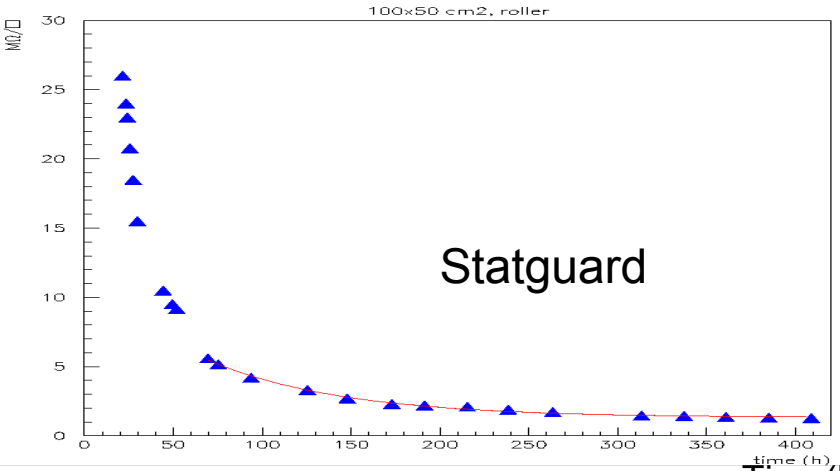


Resistive coating study

Licron and Statguard are more appropriate for low pad multiplicity. However :

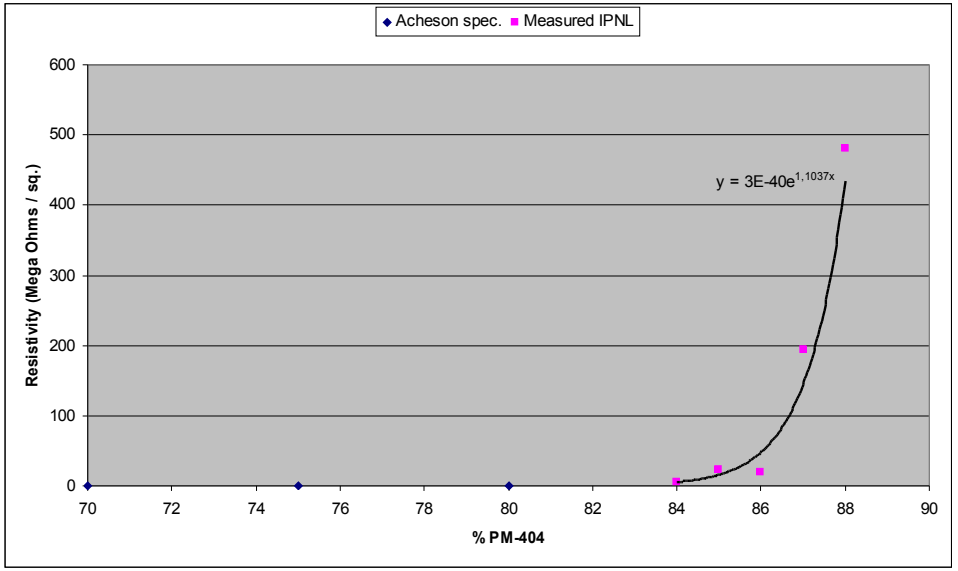
Licron : Loss of HV connection over time (1-2 months)

Statguard : long time constant for stable resistivity (2 weeks), poor homogeneity

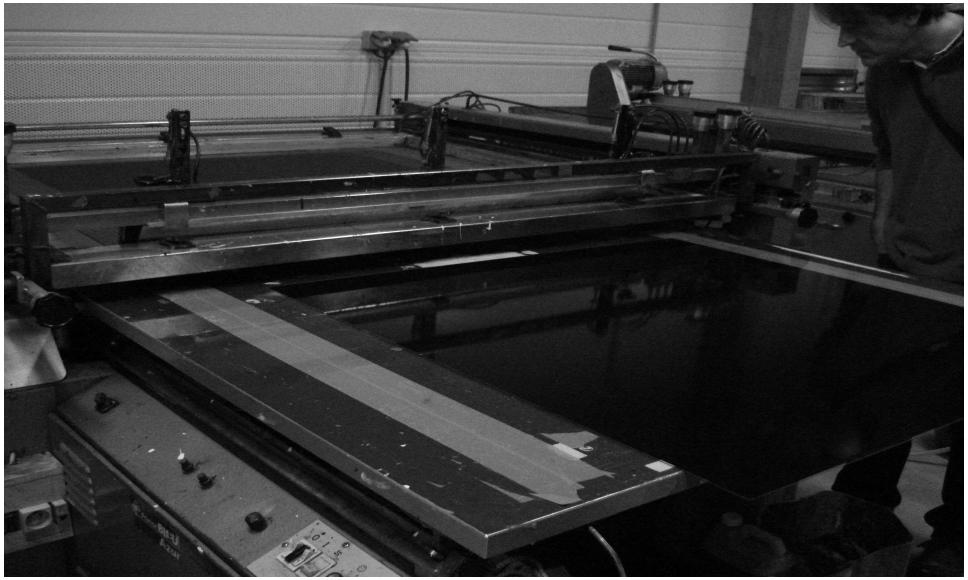


Time(h)

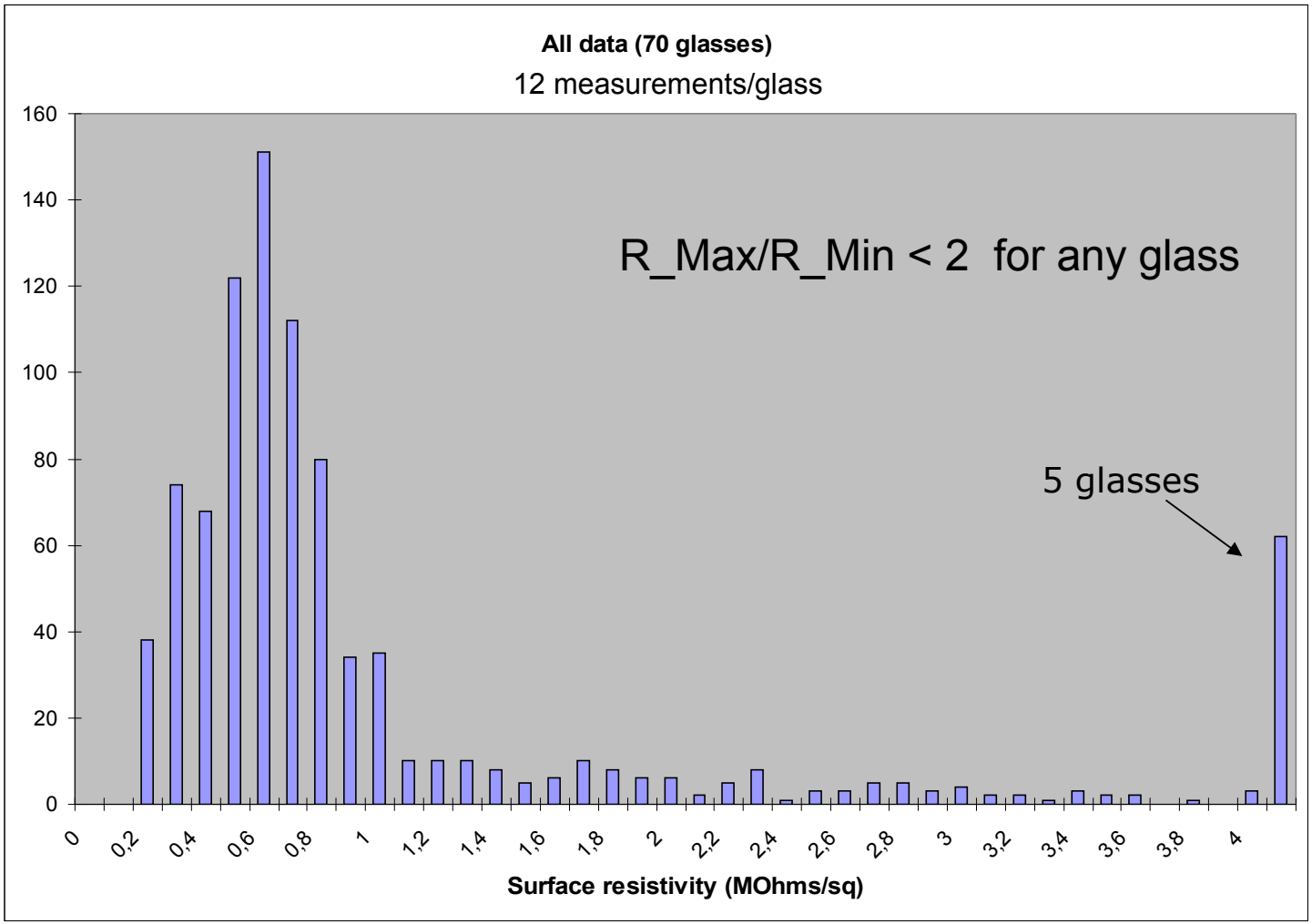
The colloidal graphite of type II is less expensive and allows to choose the needed resistivity even if this is a delicate operation



Measured resistivity as a function of the mix ratio

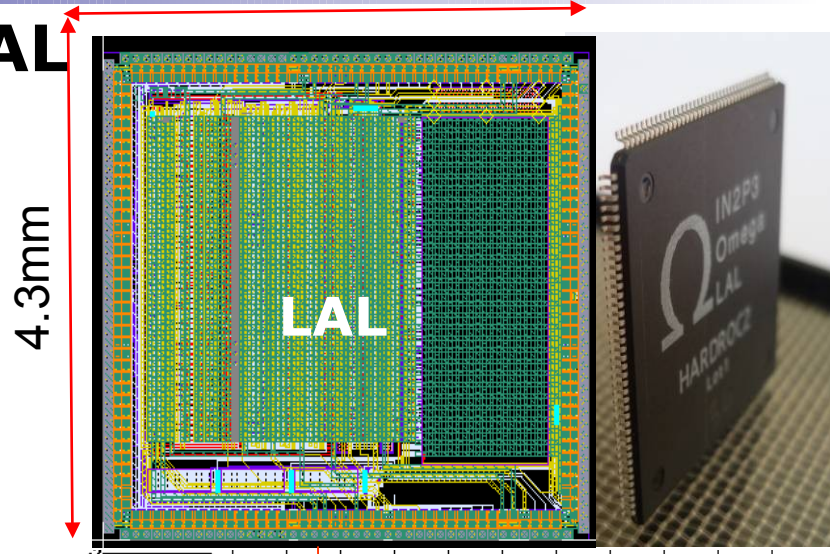


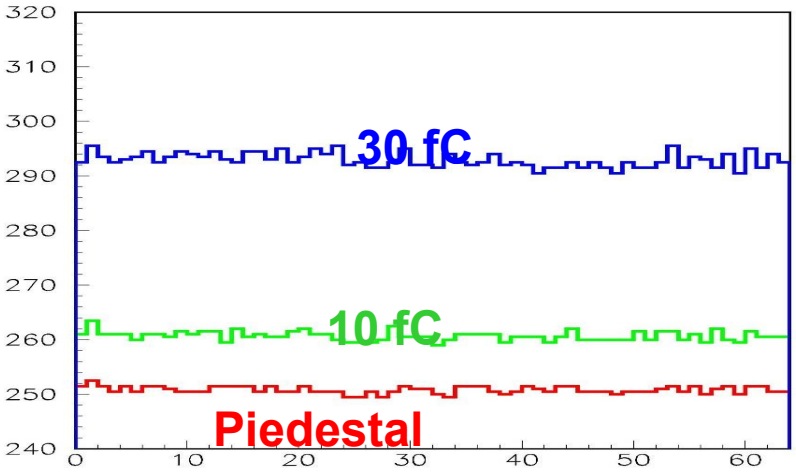
Silk-screen print method provides very good uniformity

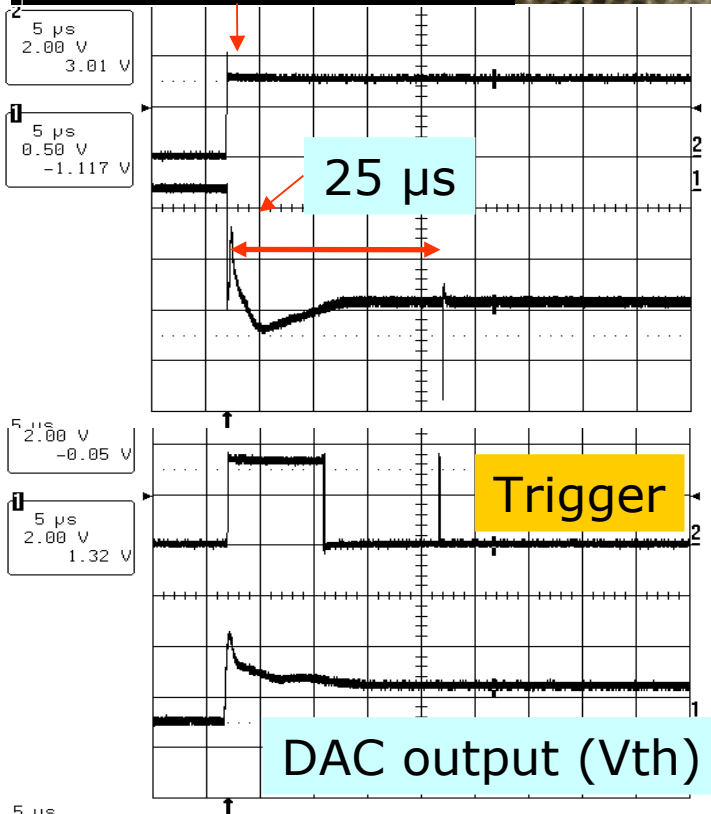

All data (70 glasses)
12 measurements/glass
R_Max/R_Min < 2 for any glass
5 glasses
160
140
120
100
80
60
40
20
0
0
0,2
0,4
0,6
0,8
1
1,2
1,4
1,6
1,8
2
2,2
2,4
2,6
2,8
3
3,2
3,4
3,6
3,8
4
Surface resistivity (MOhms/sq)

Electronics for GRPC-SDHCAL

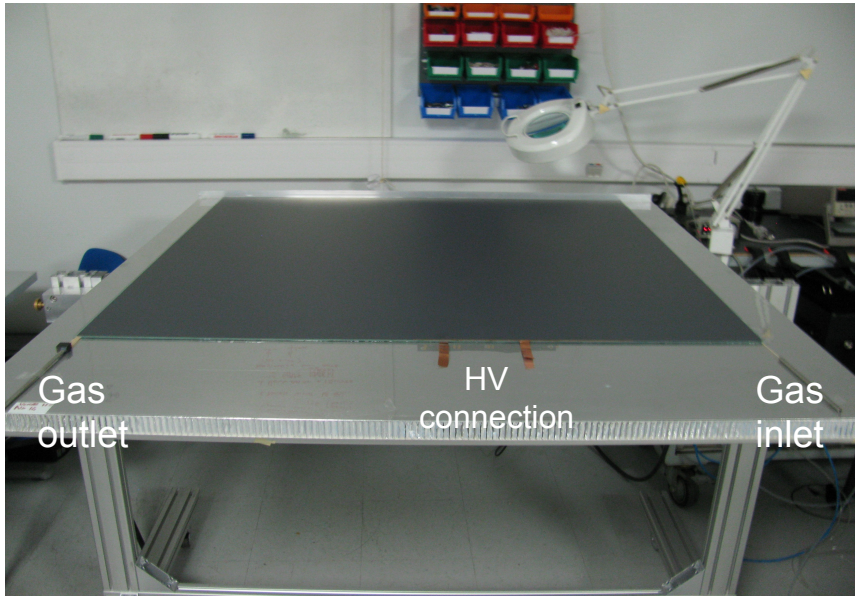
ASICs : HARDROC2
64 channels
Triggerless mode
Memory depth : 127 events
3 thresholds
Range: 10 fC-30pC
Gain correction → uniformity

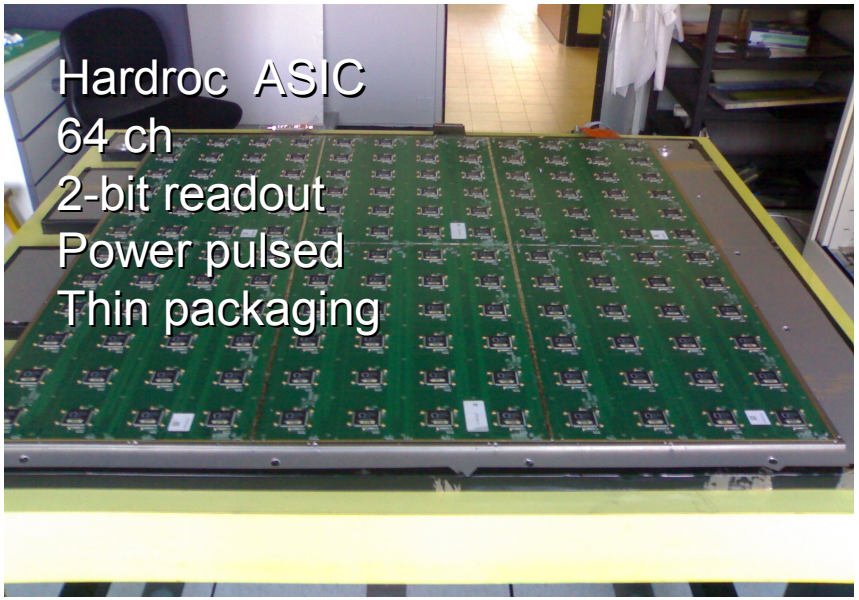




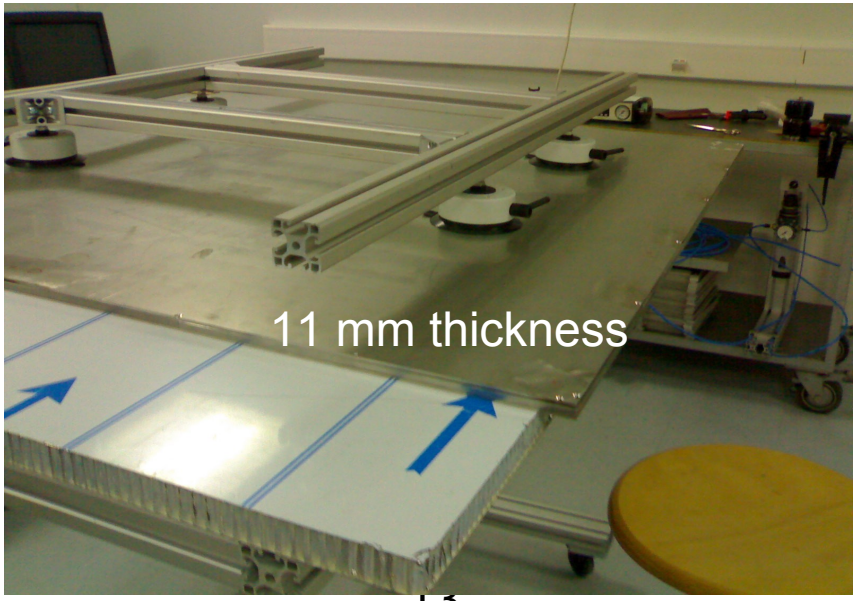


Power-pulsed→ consumption< 10µW/ch
(0.5% duty cycle), X-talk < 2%


Gas
outlet
HV
connection
Gas
inlet

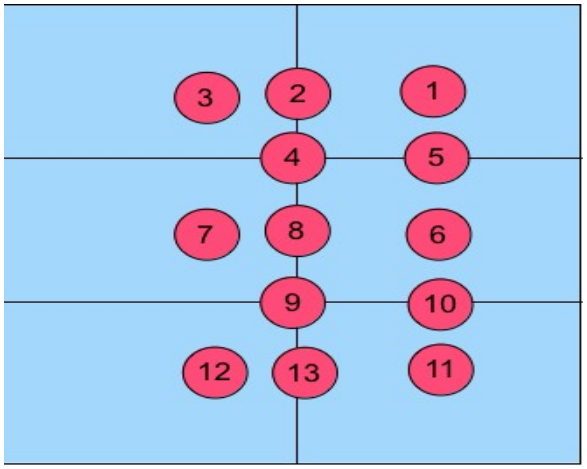

Hardroc ASIC
64 ch
2-bit readout
Power pulsed
Thin packaging

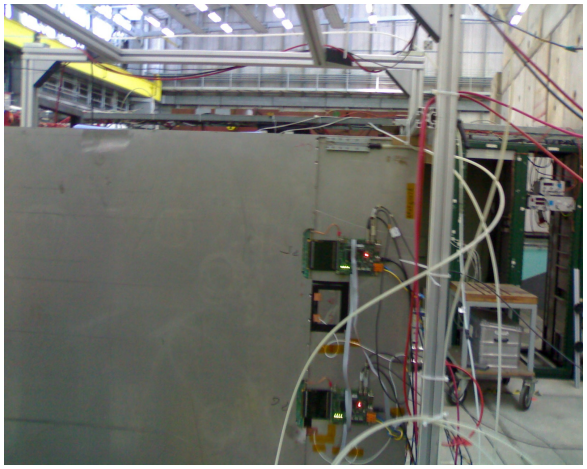

9216 ch/m2


11 mm thickness

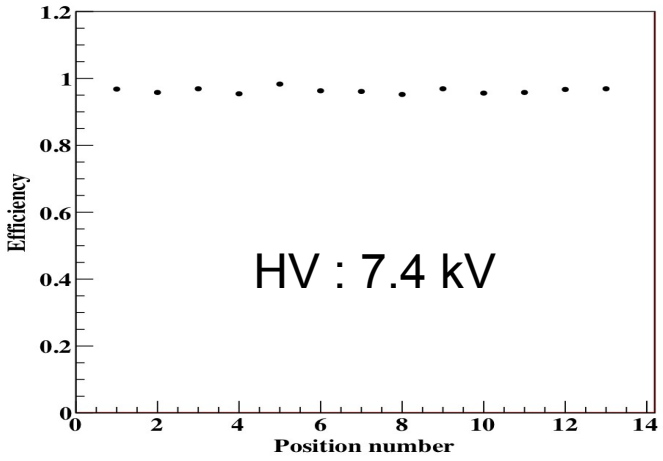
Validation

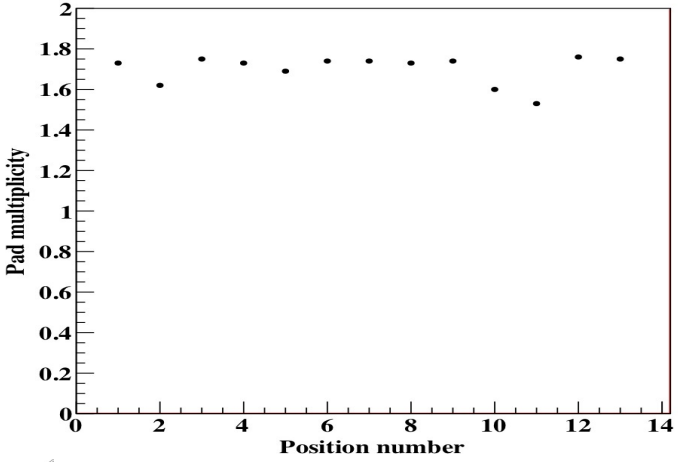
A full cassette was successfully tested at T9-PS May 2010
and H4-SPS in September 2010





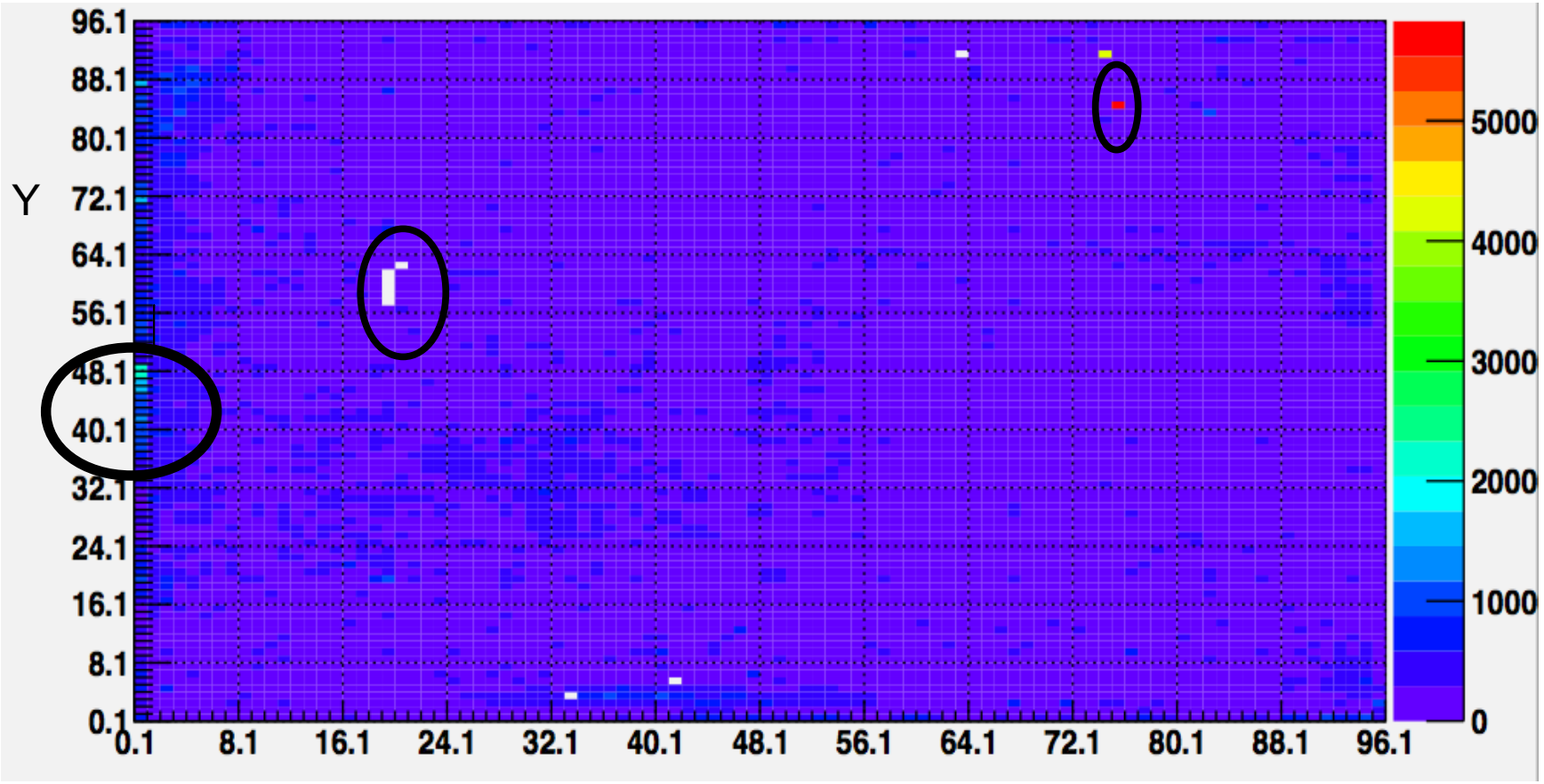
Gas mixture
TFE :94.5 %
CO2 : 5 %
SF6 : 0.5 %





Validation

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



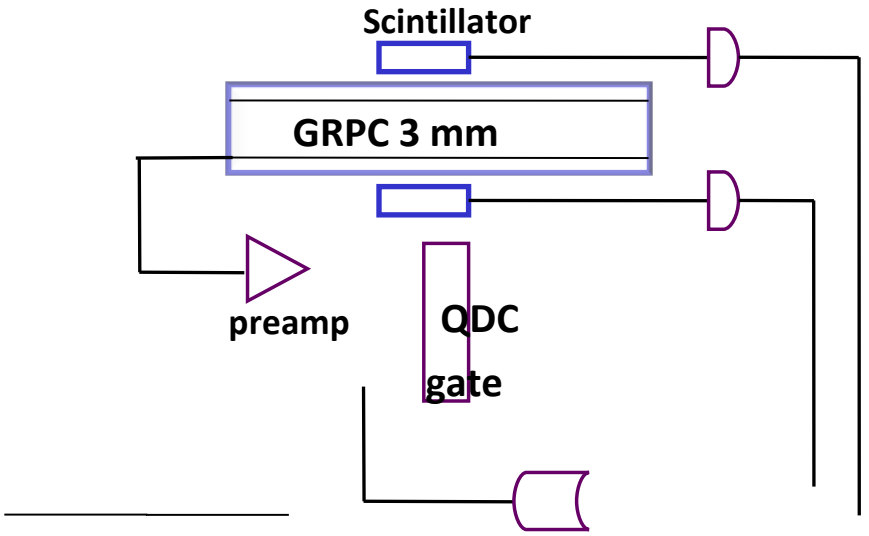
Noise Map

X

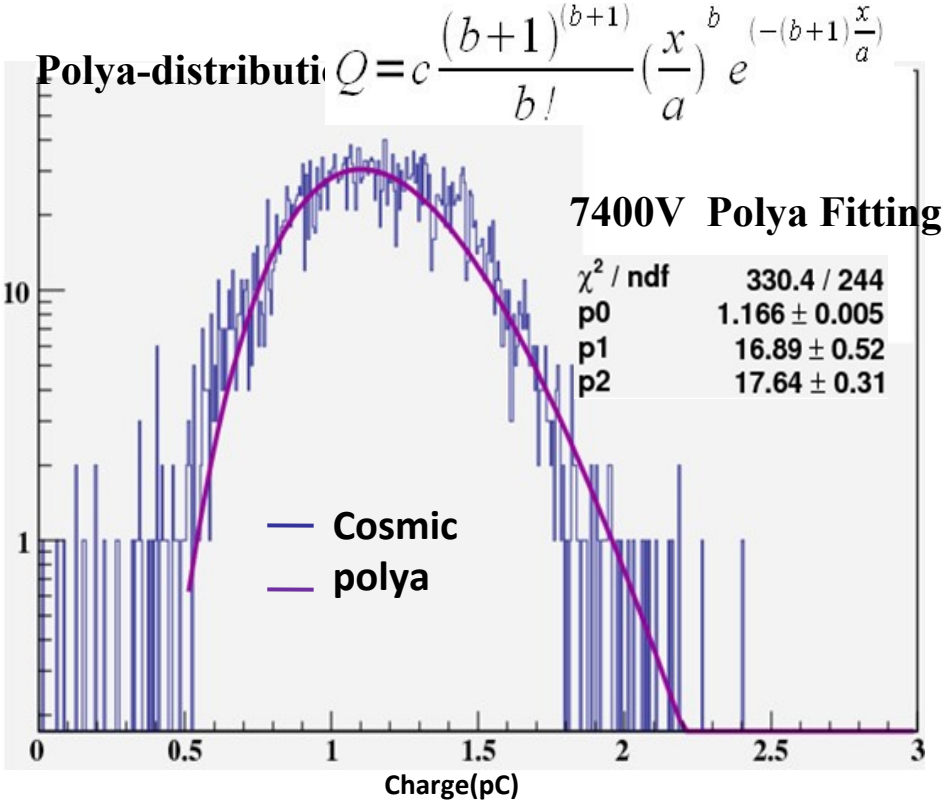
(after cooling)

Validation

Charge spectrum of our detector was carefully studied and understood. Polya distribution is successfully used to describe the data



Charge Spectrum Cosmic Test Set Up (analog readout)

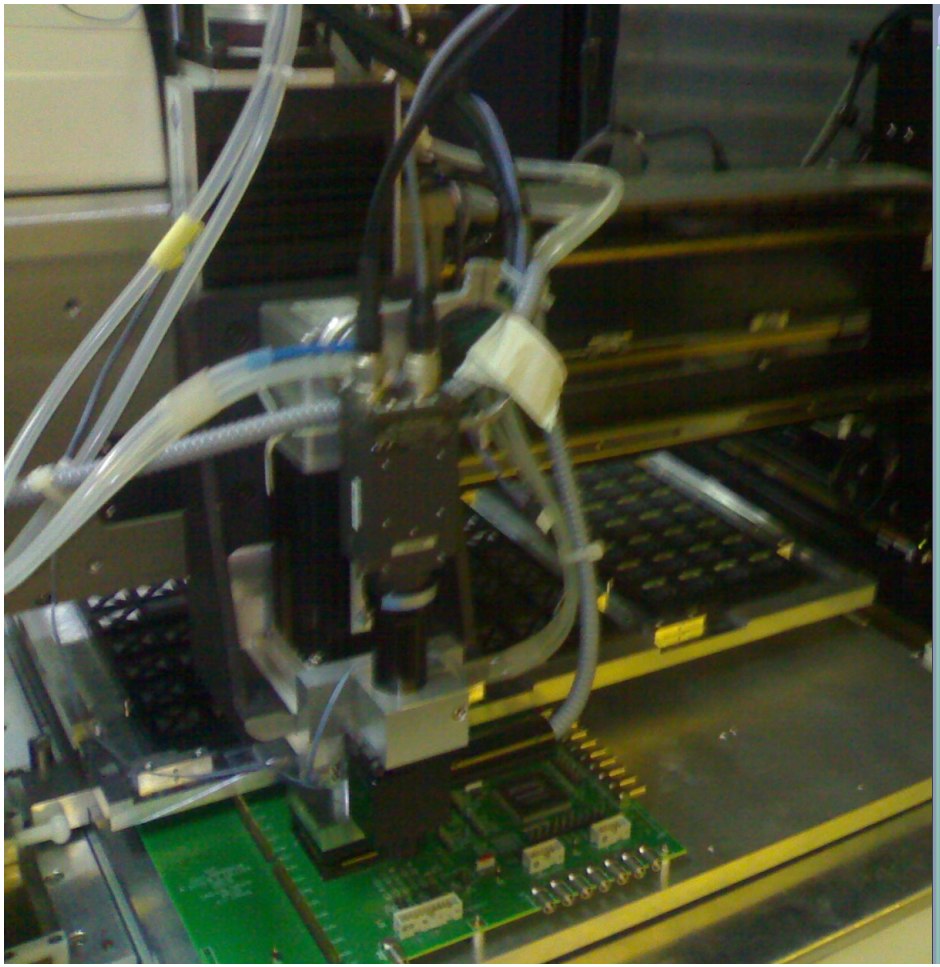


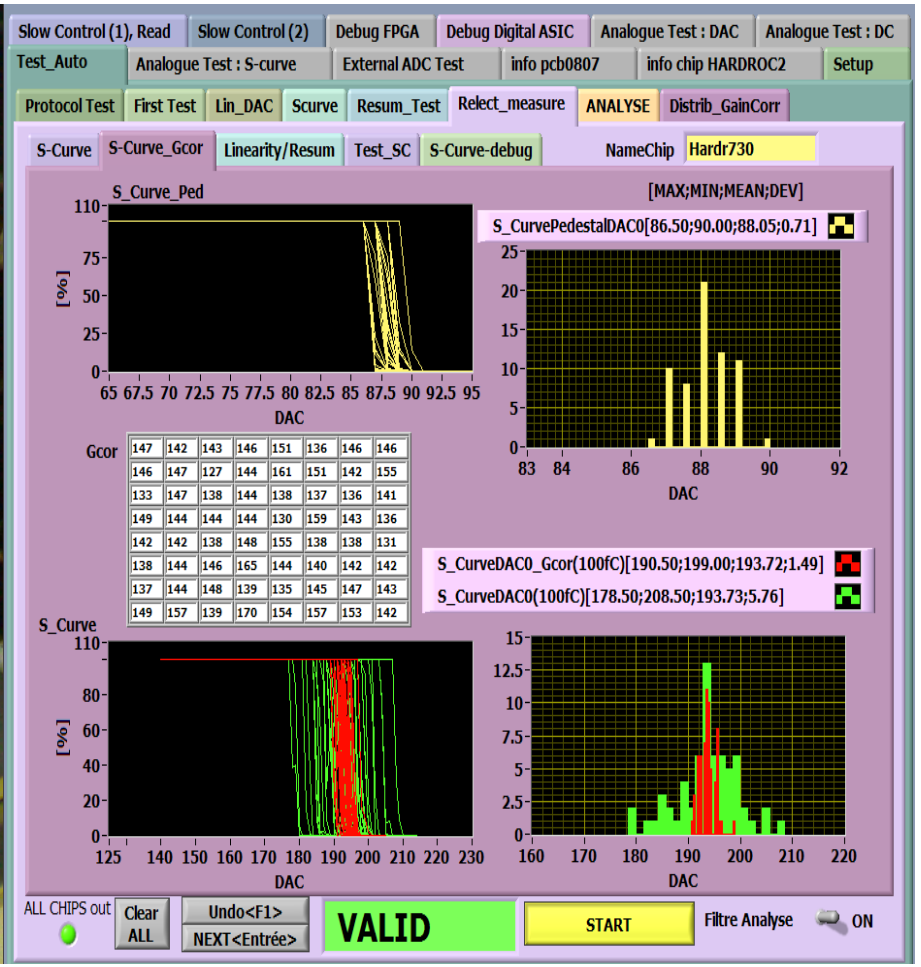
Electronics: ASICs stand test

A robot was used to test the 10500 ASICs

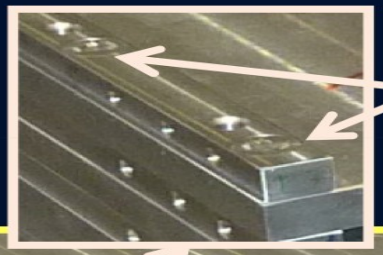
The procedure allows to select the good ASICs and calibrate them

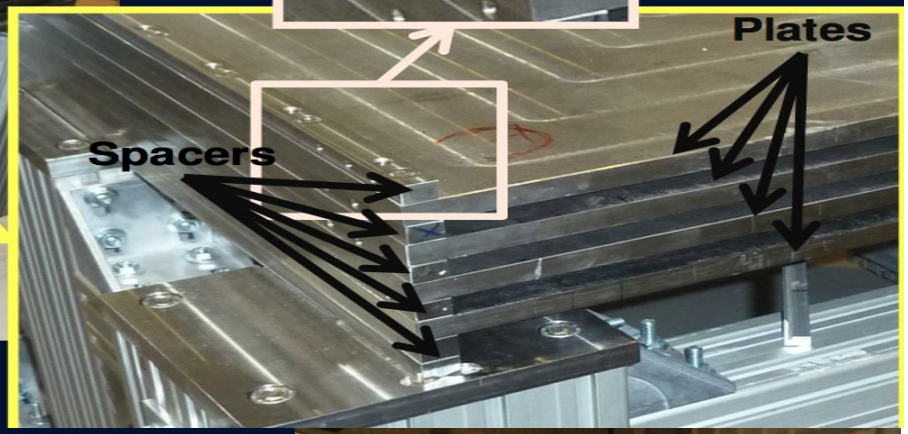
Yield 93%



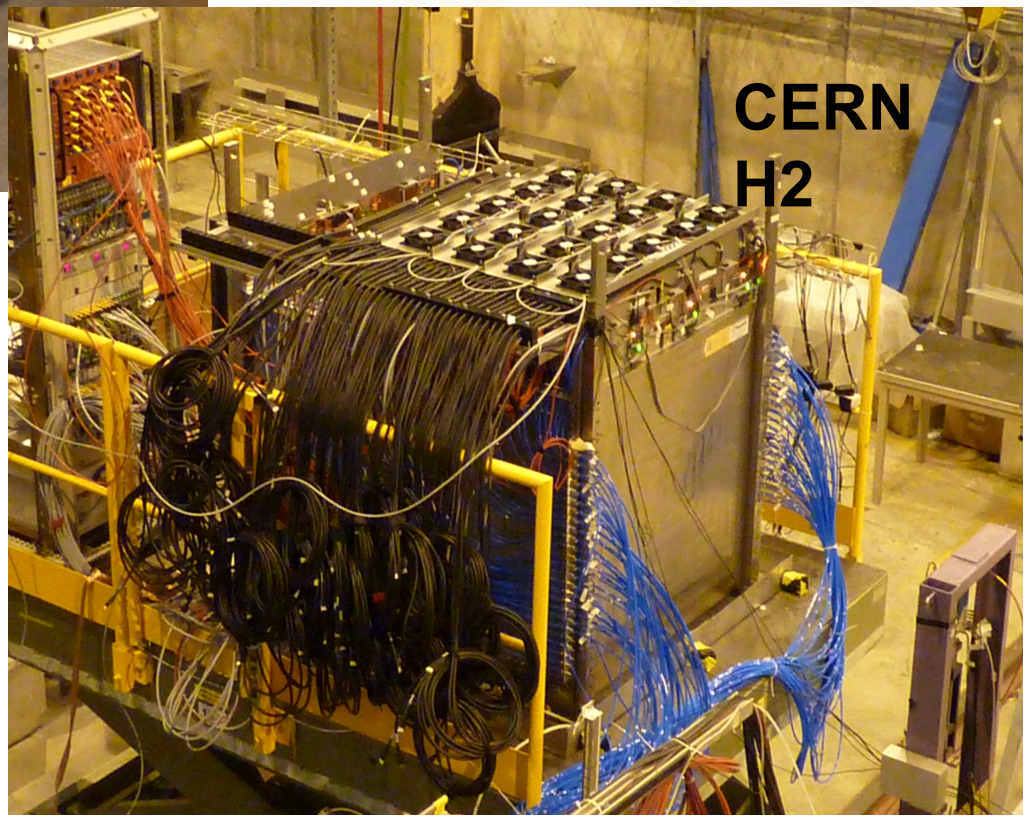


50 GRPC Chambers have been built
to be used in the SDHCAL prototype


Bolts

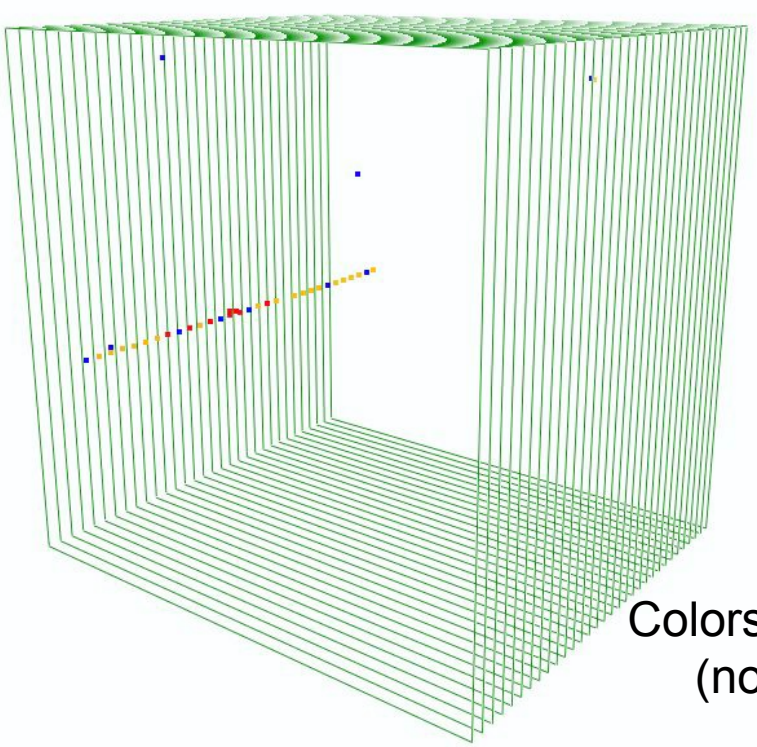

Plates
Spacers


Planarity Verification



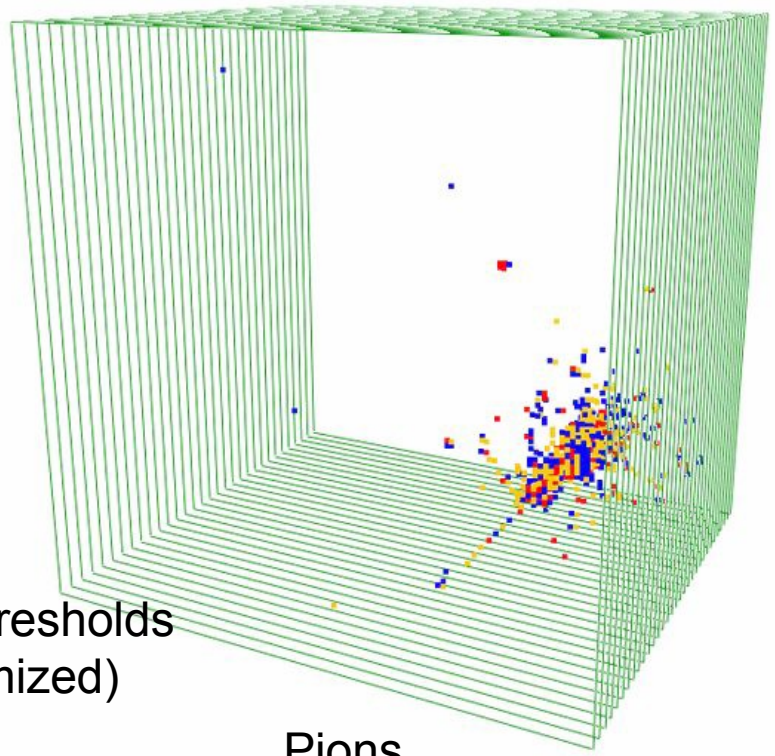
The SDHCAL prototype was assembled at CERN and then exposed to pion beam at H2-SPS in June 2011

First commissioning Test Beam at CERN in June 2011 SPS-H2 beam line
The CALICE-DAQ was not ready by that time, USB-based DAQ was used : very slow and problem with synchronization due to flat cables connecting 35X3 = 105 difs.



Muons (150 GeV)

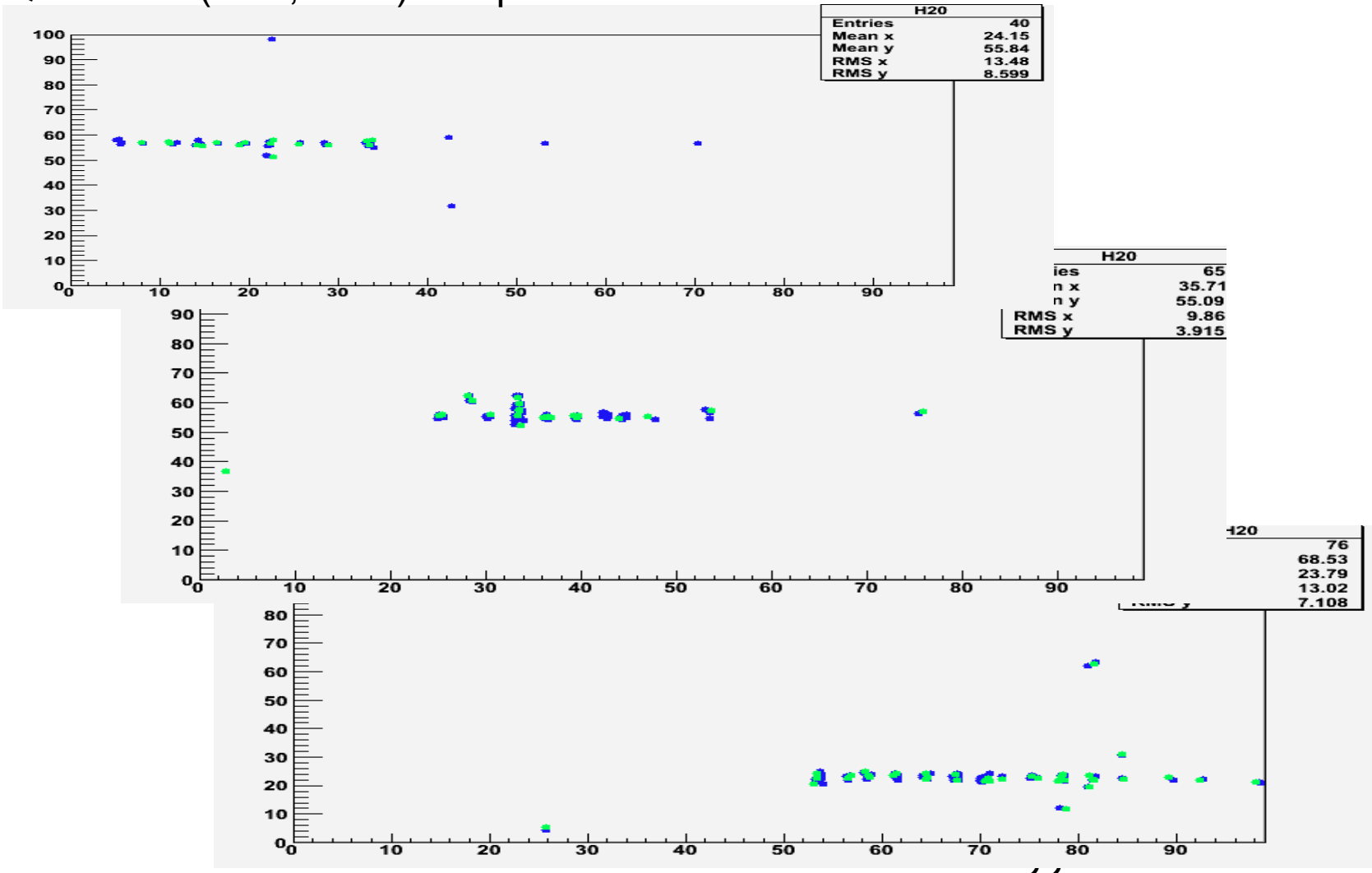
Colors : 3 thresholds
(not optimized)



Pions

Second Test Beam at CERN in October 2011 H8 beamline

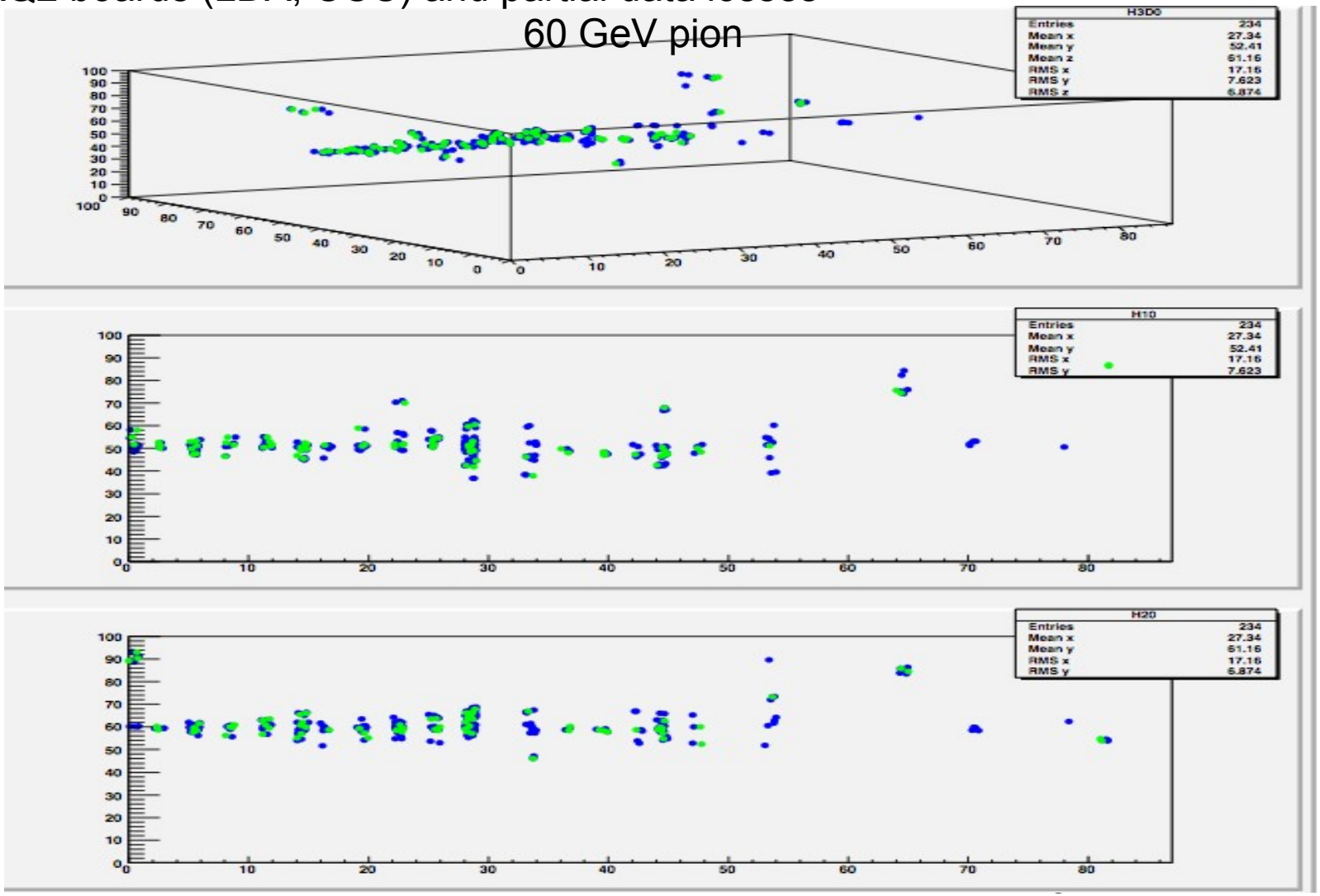
Using CALICE HDMI-based DAQ2: instabilities, mostly problems with the DAQ2 boards (LDA, CCC) and partial data losses



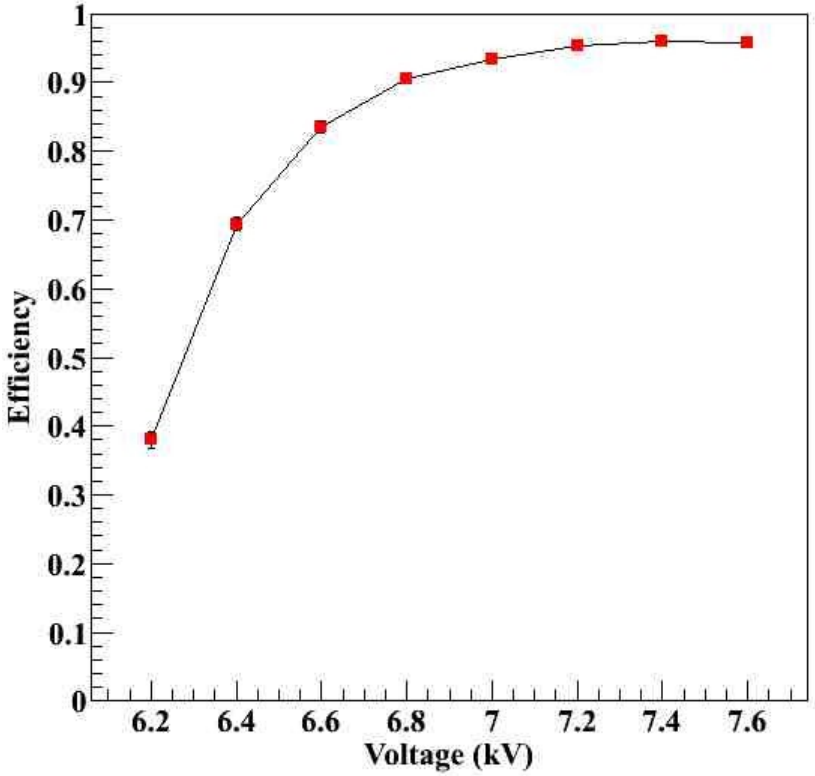
Second Test Beam at CERN in October 2011 H8 beamline

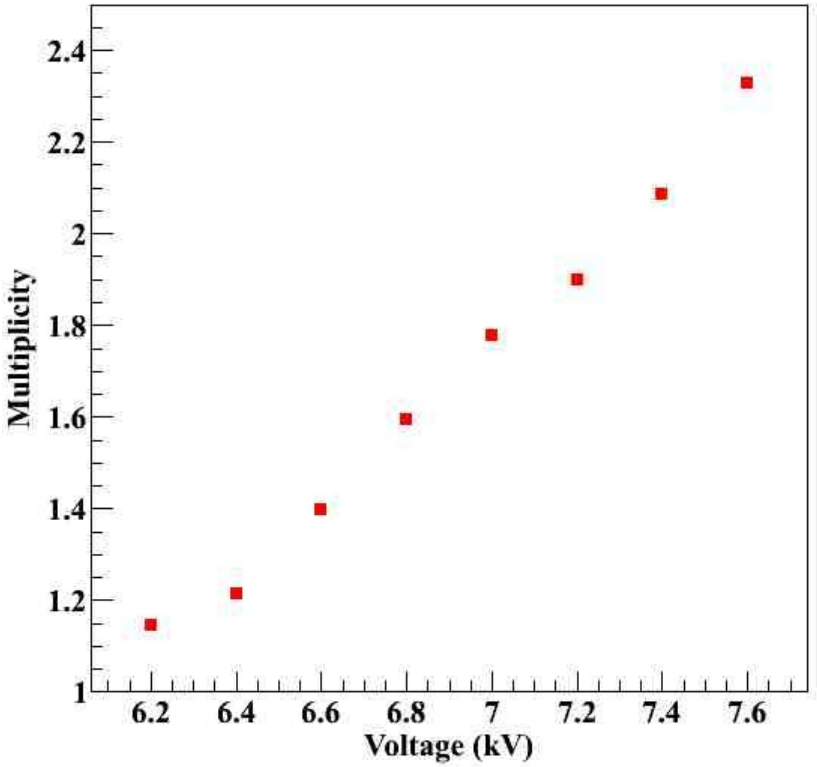
Using CALICE HDMI-based DAQ2: instabilities, mostly problems with the DAQ2 boards (LDA, CCC) and partial data losses

60 GeV pion



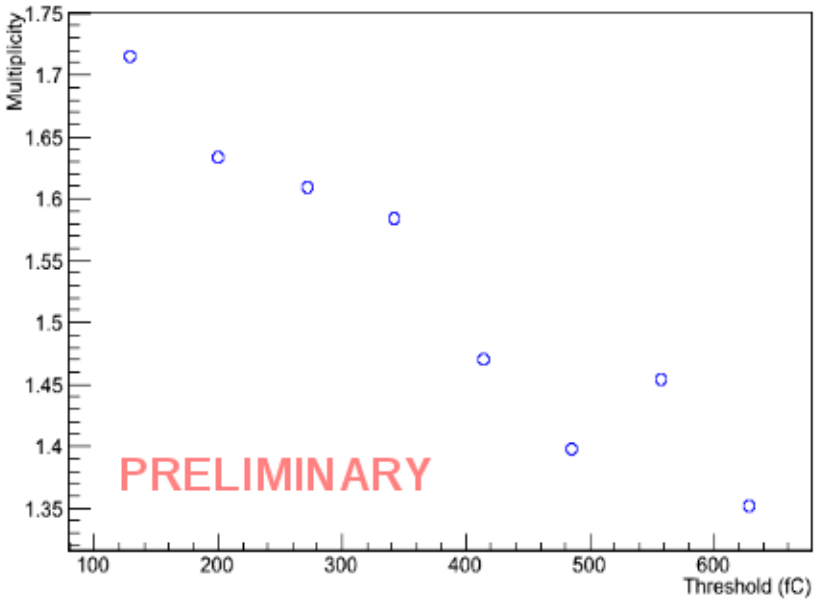
To check that the detectors and electronics are not at the origin of this...
A short beam test was organized at PS in November 2011 with 6 detectors taken from the prototype and using USB-DAQ system :

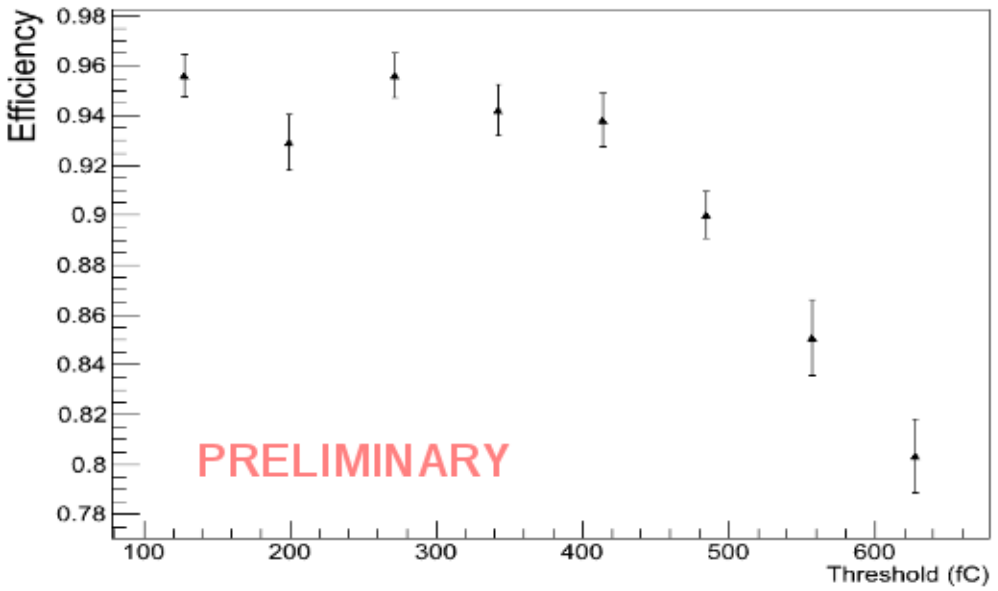




This shows that the problem was essentially the HDMI readout

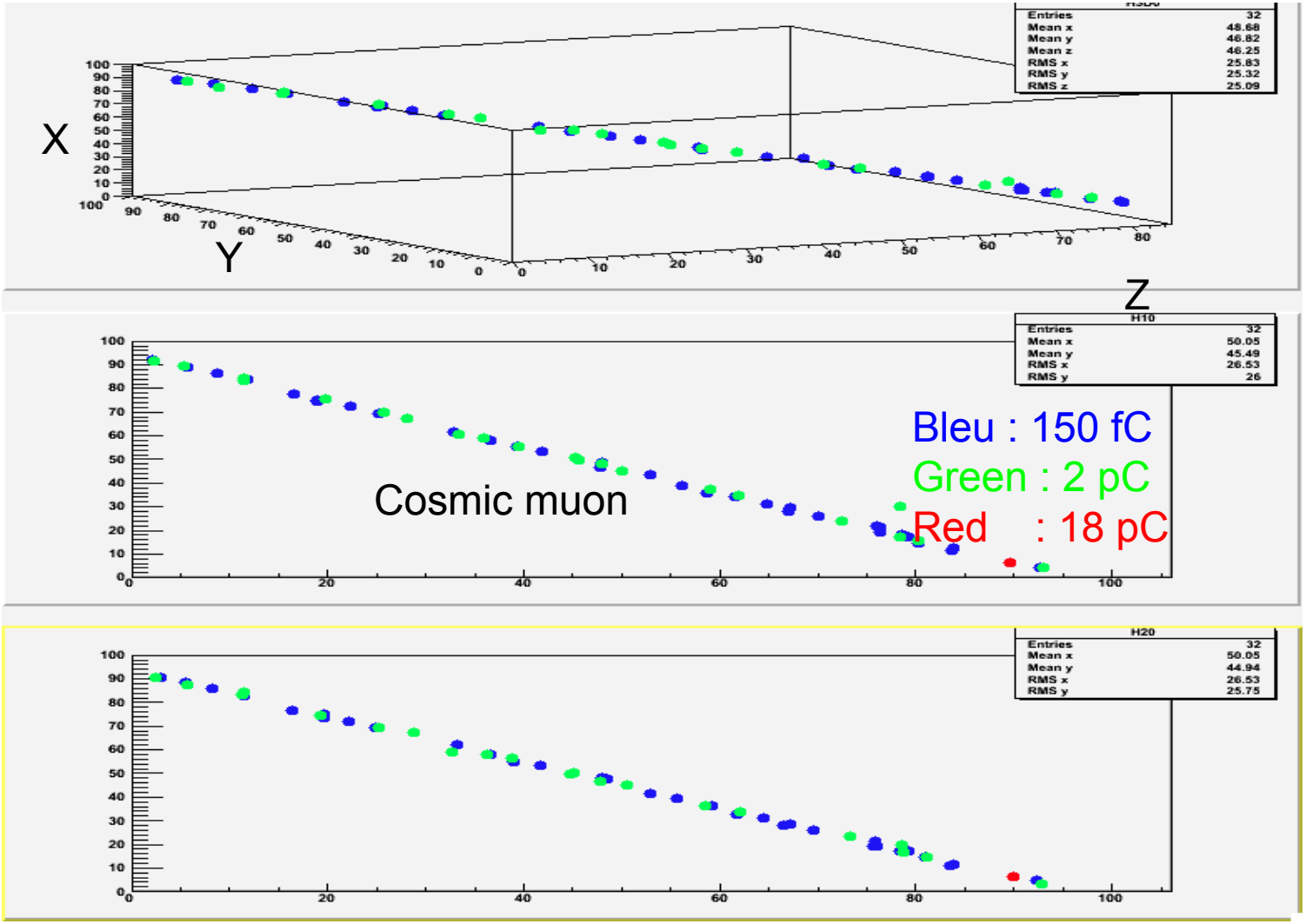
Threshold scan

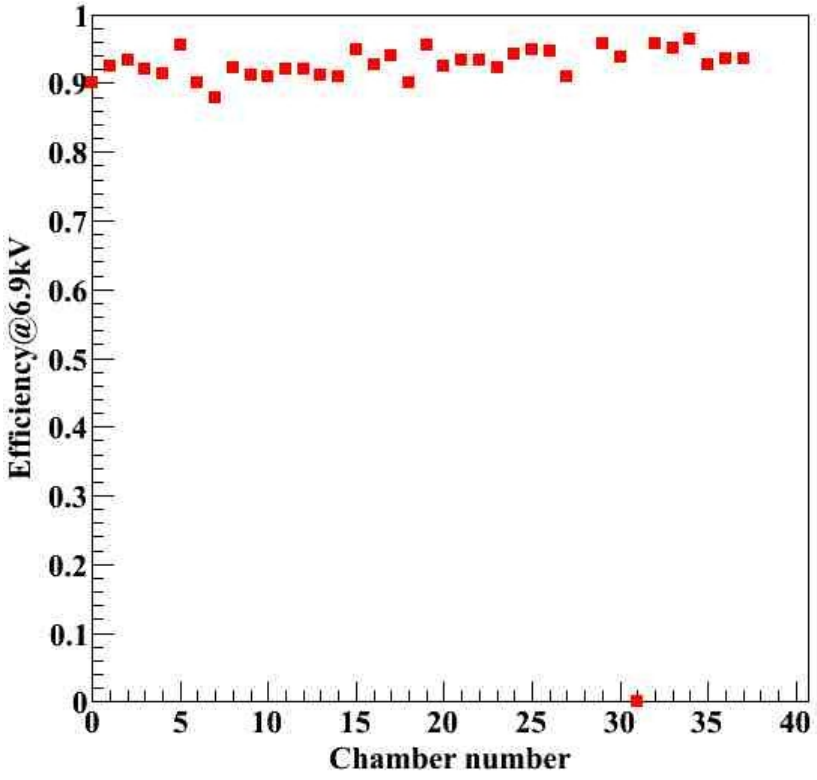


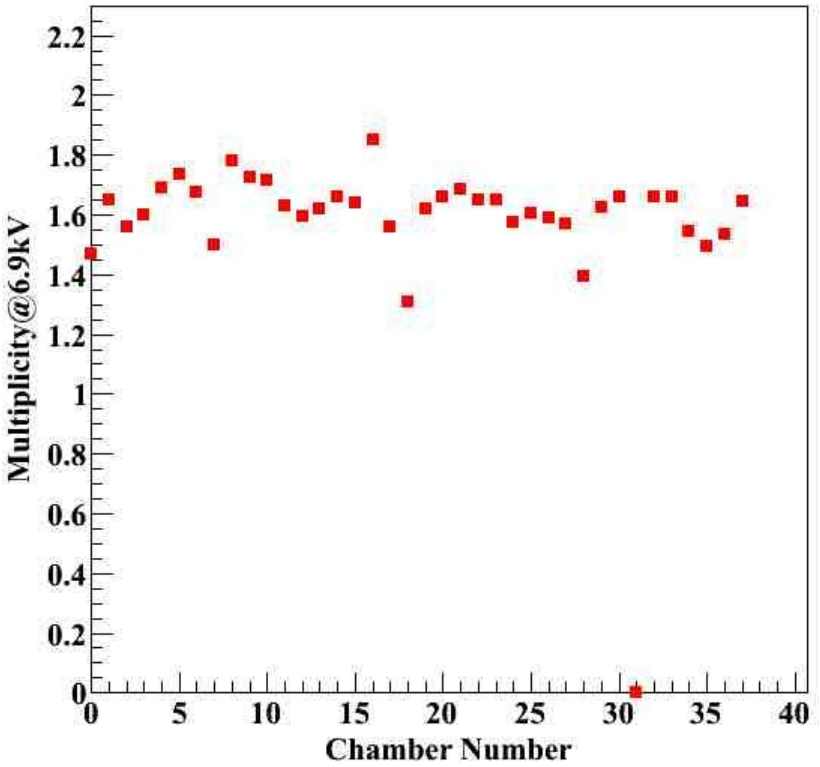


Despite the above mentioned problems, the stability of the electronics was remarkable (only 1/5400 died!)

An intermediate DAQ system has been developed for coming TB.
The DAQ2 HW (DCC) are used for the synchronization and the USB for the readout
It has been tested on 39 chambers and cosmics during the last month..

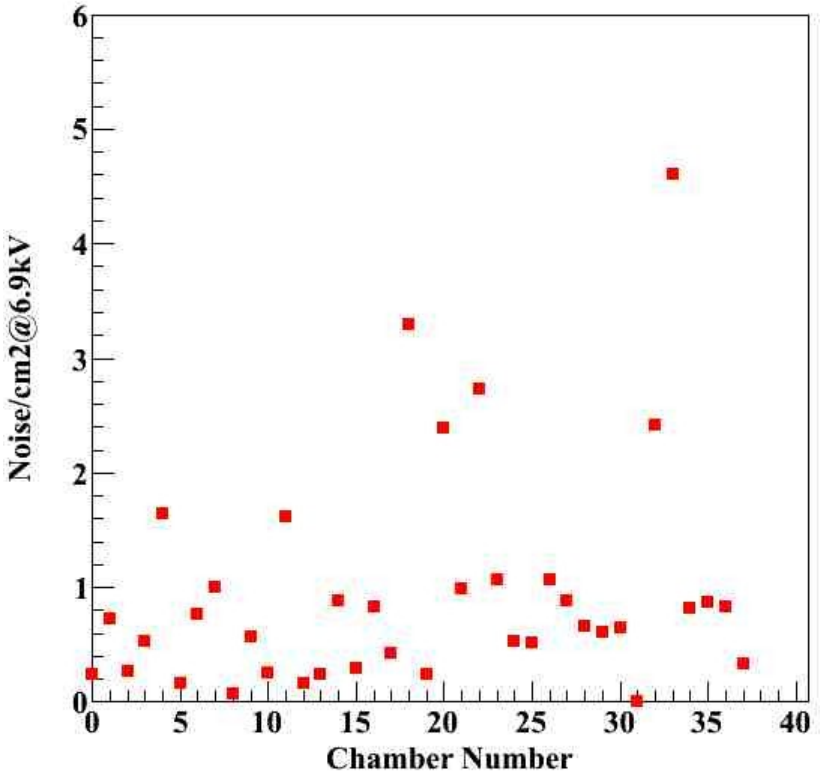




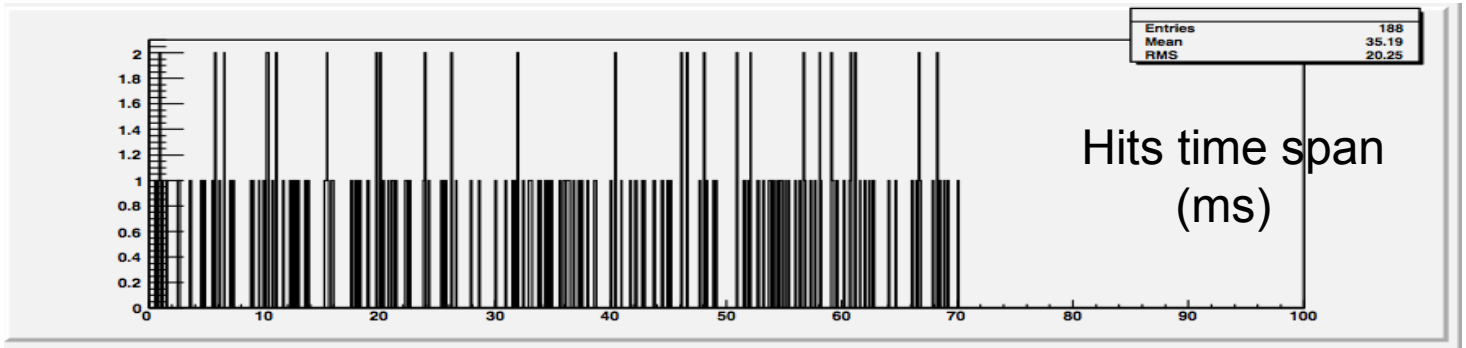


Efficiency and multiplicity@6.9kV

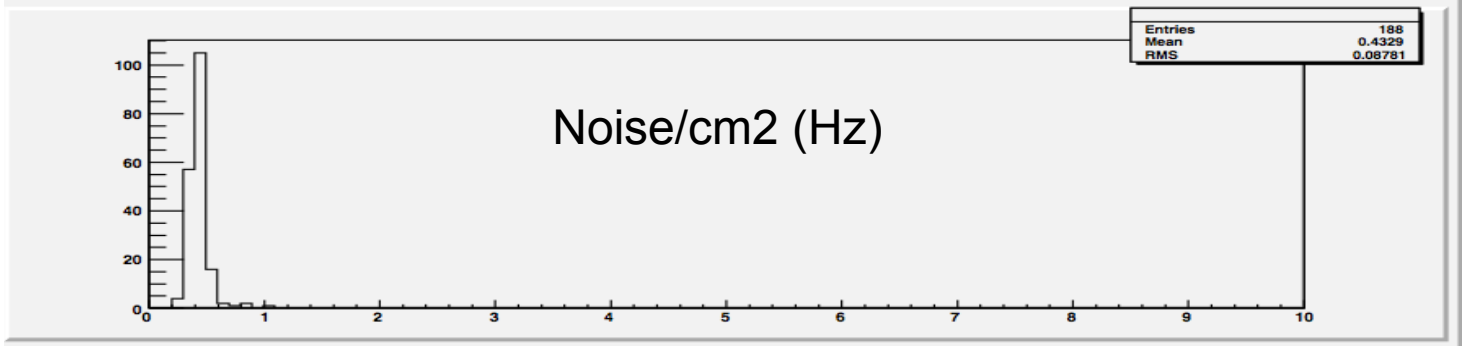
Noise in some chambers is essentially due to higher electric field
In the edges where the gas gap is less than the nominal one.
This could be corrected by reducing the electronics gain to compensate



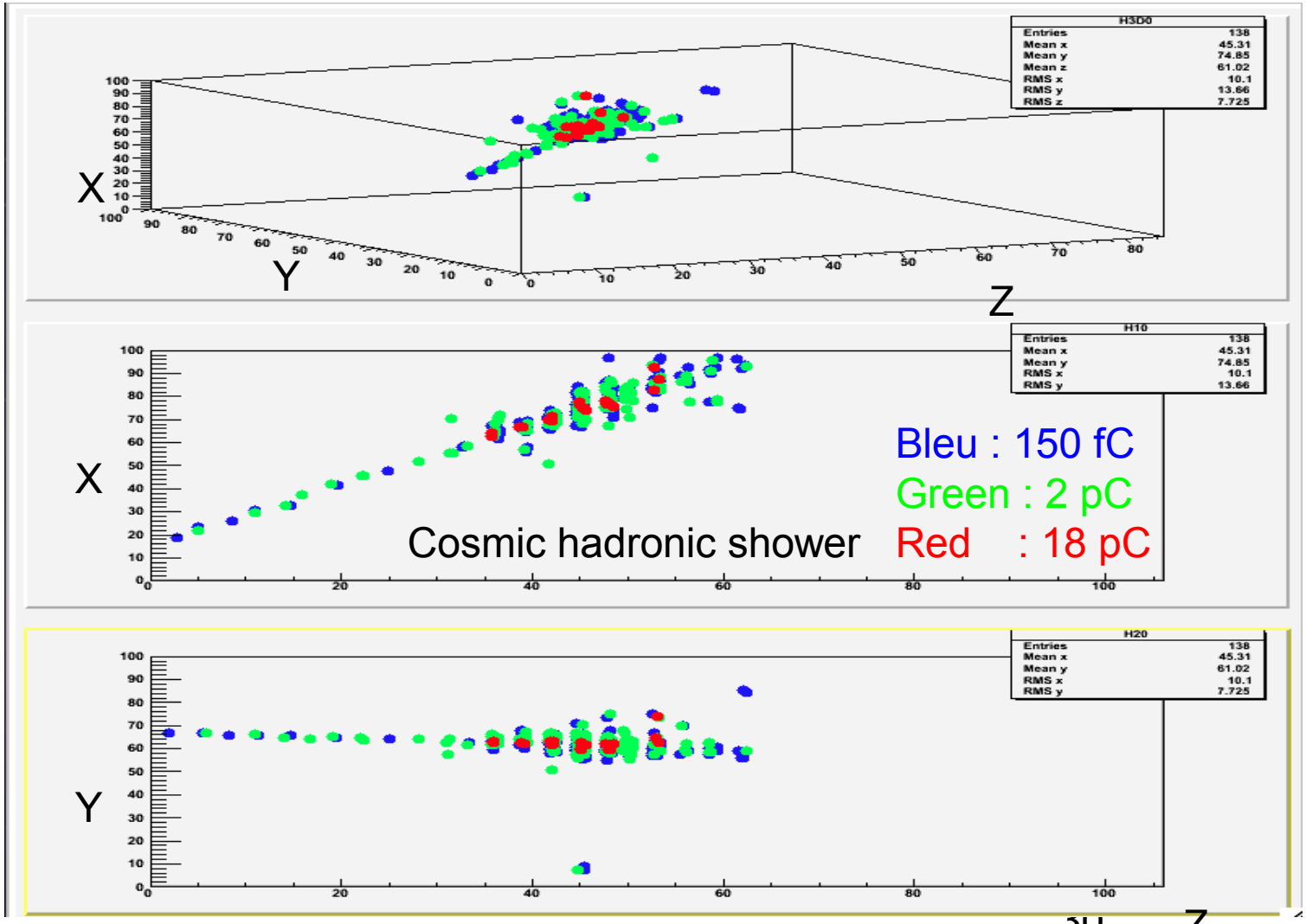
Noise@6.9kV


Entries 188
Mean 35.19
RMS 20.25
Hits time span (ms)


Entries 192
Mean 132.8
RMS 78.99
Hits/event


Entries 188
Mean 0.4329
RMS 0.08781
Noise/cm2 (Hz)

The interest of the the semi-digital readout electronics is not yet demonstrated in TB. However this can already be seen from hadronic showers of some cosmics



Conclusion&Perspectives

→ A prototype of the semi-digital HCAL using GRPC was built including most of the ILD technological requirements

→ 50 (+3) Large GRPCs equipped with embedded electronics have been built and tested

→ Commissioning of the prototype revealed some DAQ2 flaws for a large setups (such as the m³ SDHCAL)

→ An Intermediate solution using HDMI & DCC cards for synchronization and USB for config & readout was developed to cope with the emergency. It has proven stable; DAQ performance are being worked on to obtain high statistics.

→ Work is ongoing to include the Power Pulsing

→ We hope to provide you with nice physics results very soon