Digital Hadronic CALorimete For ILC using GRPC

OUTLINE :

- Motivations
- GRPC development
- Electronics development
- Mini DHCAL
- 1m3 DHCAL project
- Collaboration IN2P3/Tsinghua

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IPN-Lyon

Motivations

Jet energy resolution is a key feature of the future Linear Colliders experiments

E_{jet} =	$E_{charged\ tracks}$ +	E_{γ} +	$E_{h}0$
fraction	65%	26%	9%

Charged tracks resolution	$\Delta p/p \sim$ few10^{-5}
Photon(s) energy resolution	$\Delta E/E \sim 12\%$
Neutral hadrons energy resolution	$\Delta E/E \sim 45\%$

$$\sigma^2 \text{ jet} = \sigma^2 \text{ ch.} + \sigma^2 \gamma + \sigma^2 h^0 + \sigma^2_{\text{confusion}}$$
$$= (0.15)^2 E_{Jet} + \sigma^2_{\text{confusion}}$$

PFA: *Particle Flow Algorithms* :

High granularity → Topological separation → Reduce confusion → Improve on jet energy resolution

Motivations

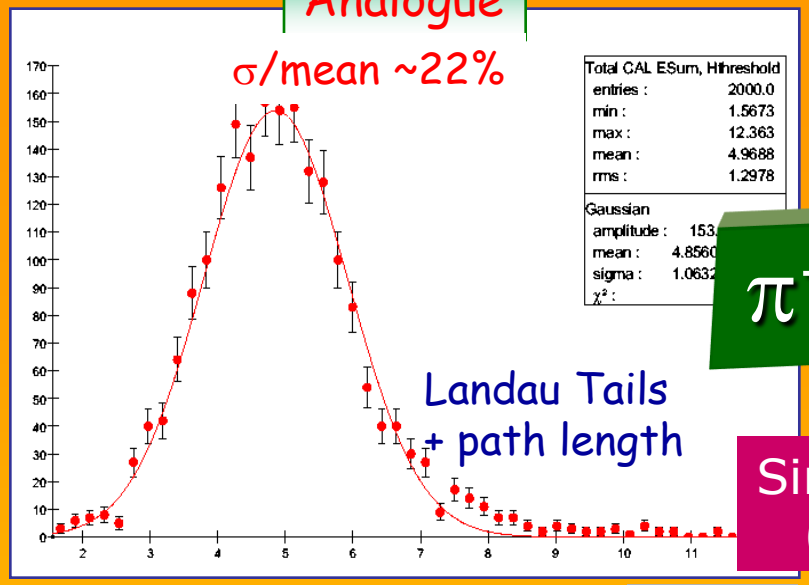
Why the digital solution?

Going from analogue readout to **1:2-bit** readout electronics:

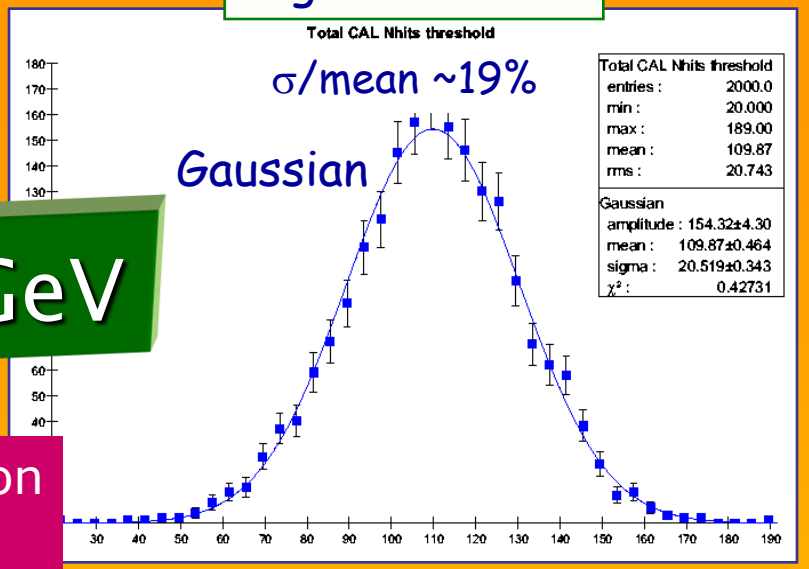
- One can increase detector **granularity** and hence **PFA** performance.
- **GRPC : Cheap**, **robust, homogenous** suitable for the digital version
- **Electronics** : **simple**

Does the digital option mean energy measurement degradation?

Analogue



Digital-1bit

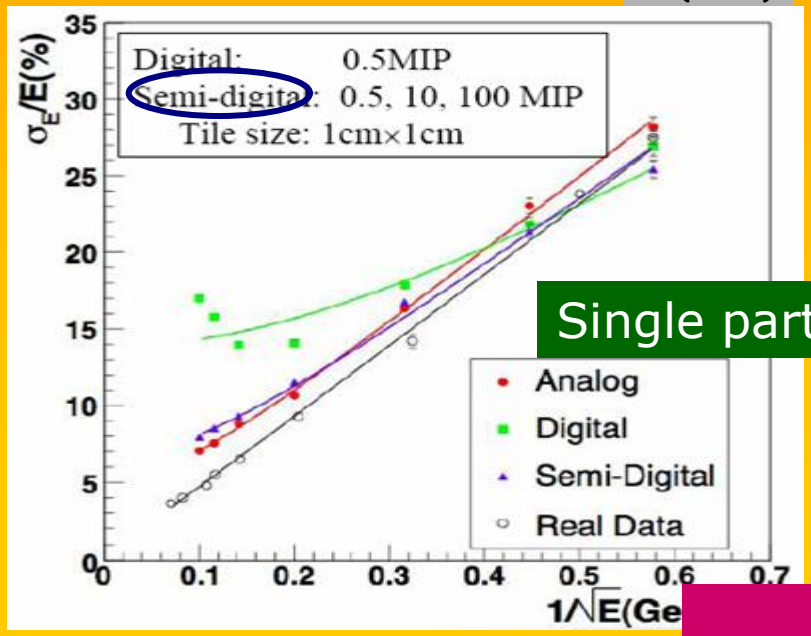


π^+ 5GeV

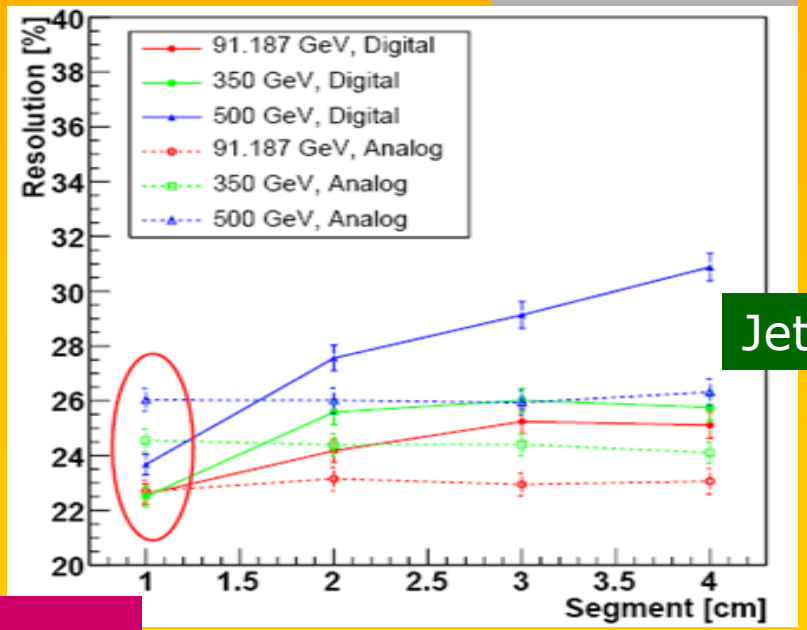
Simulation (calice)

E (GeV)

Number of hits



Single particle



Jet

KEK (Matsunaga et al)

Development of a Semi-DigitalHCAL using GRPC is one of the CALICE collaboration activities

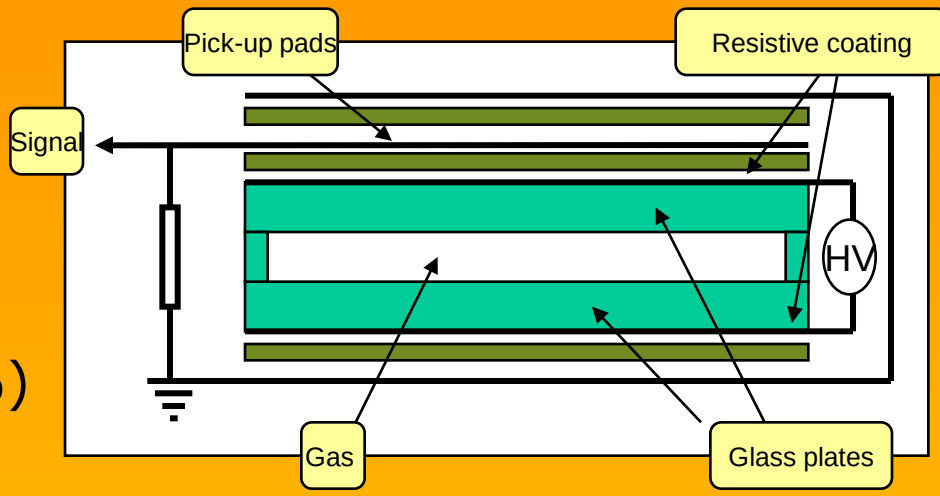
Belgium : Louvain-La-Neuve, Ghent
China : Tsinghua Uni.
France : IPNL, LAL, LAPP,LLR
Italy : Bologna INFN
Russia : IHEP
Spain : CIEMAT

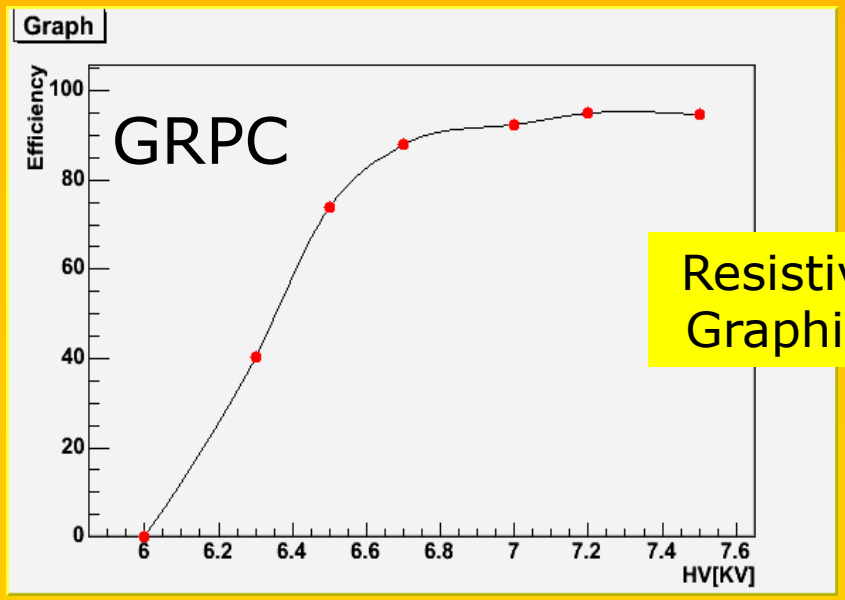
Glass Resistive Plate Chambers

Baseline GRPC:

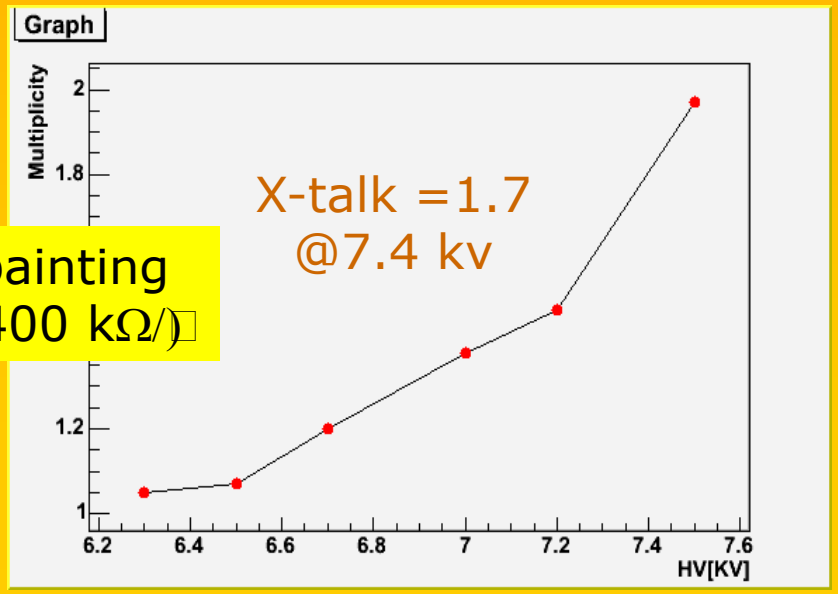
- Thickness of few millimeters (<3 mm)
- Avalanche mode :

-Gas mixture :
TFE(93%);Isobutane(5%),SF_6(2%)
-High Voltage: < 8 KV
Charge: 100c-10pc
→Efficiency: >90%, Multiplicity 1.4-2 pads/mip





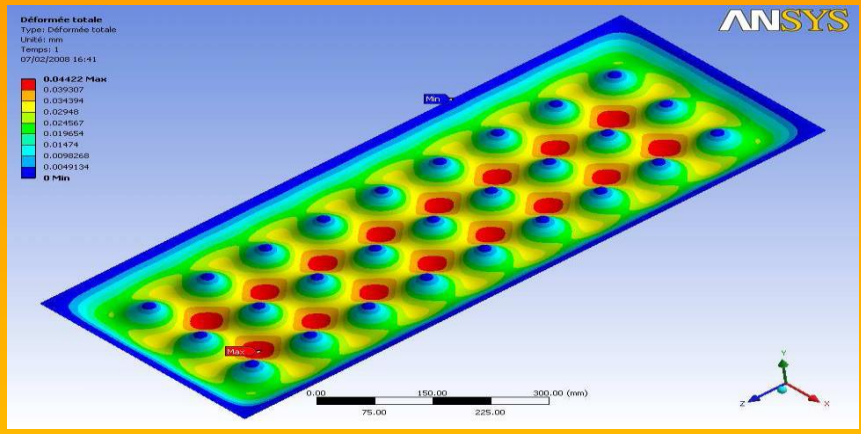
Resistive painting
Graphite(400 kΩ/□)



Glass Resistive Plate Chambers

Efficient PFA application implies hermitic HCAL.
HCAL should also be compact (cost, construction) with uniform sensitive media. This derives the R&D on GRPC

- Dead zones: spacers, frame :
  Tiny ceramics balls as spacers, hollow frame used for gas distribution to reduce dead zones
- Uniformity: resistive coating
  Using silk screen printing to guarantee a uniform coating on large surface
- Low multiplicity :
  Replacing graphite (few 10^5 Ω/▯) by other paintings like Licron , Statguard (few MΩ/▯) results in reduced multiplicity



GRPC: 3.2 mm thick
Ceramics ball spacers+Licron

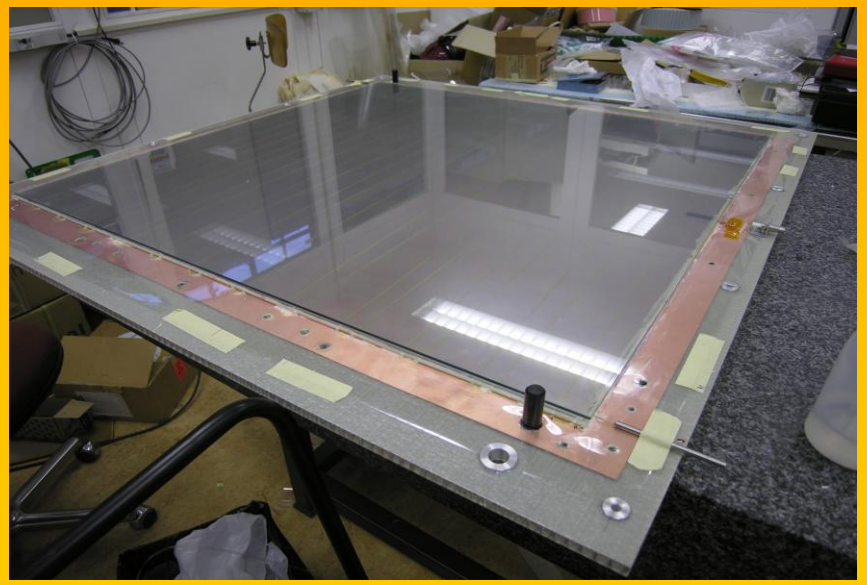
Glass Resistive Plate Chambers

- Long term stability:
  HV connection to the resistive coating using new fixation glues

- High rate detection:
  Using semi-conductive glass ~10^{10} Ω.cm leads to detection rate up to 28 KHz/cm^2

- Reduced mip charge spread:
  To use efficiently the semi-digital electronics readout with gas detector. Multi-gap GRPC provides less charge spread but higher multiplicity.

  Few 1m^2 GRPCs were built with different options

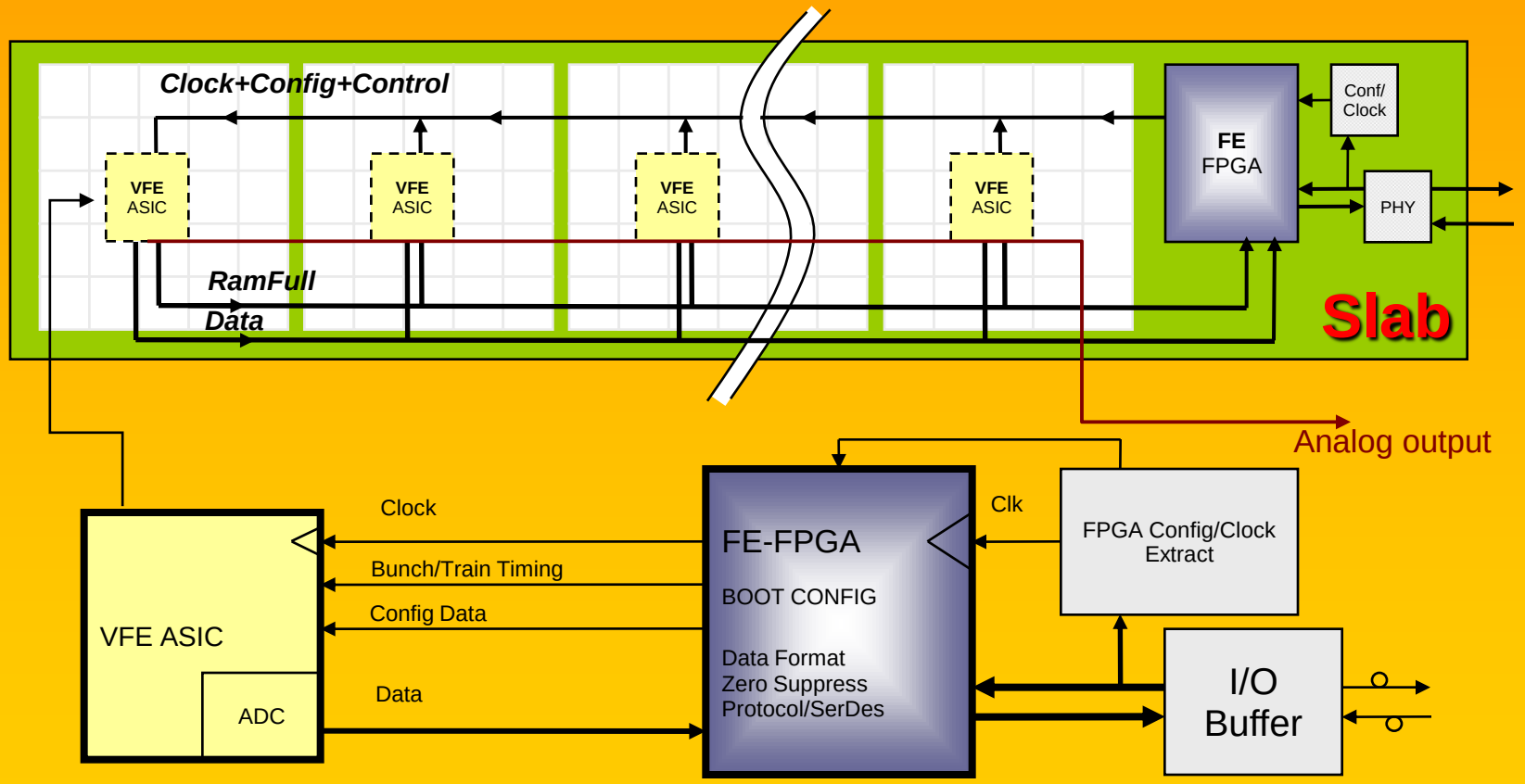


MGRPC: 4 gaps,total thickness 3.2 mm

Semi-digital electronics readout

Challenge: HCAL with few thousands m² fully equipped with low consumption semi-digital readout and still hermitic and compact

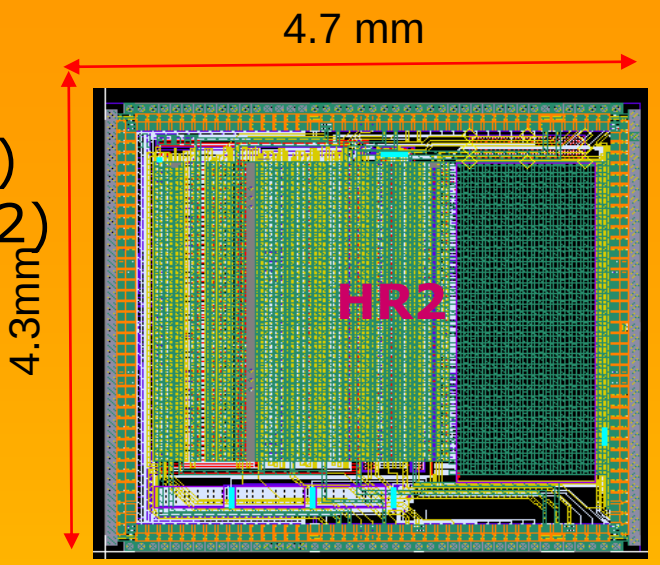
Embedded Daisy-chained electronics can be the solution



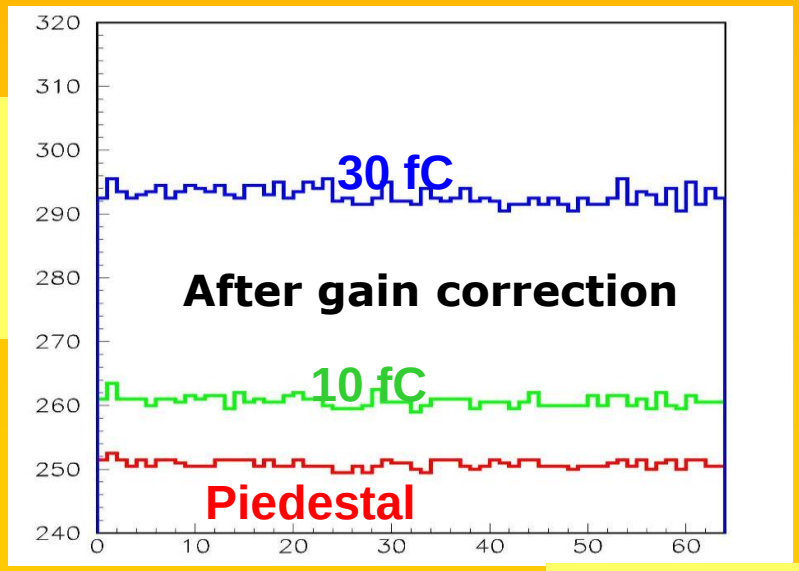
Semi-digital electronics readout

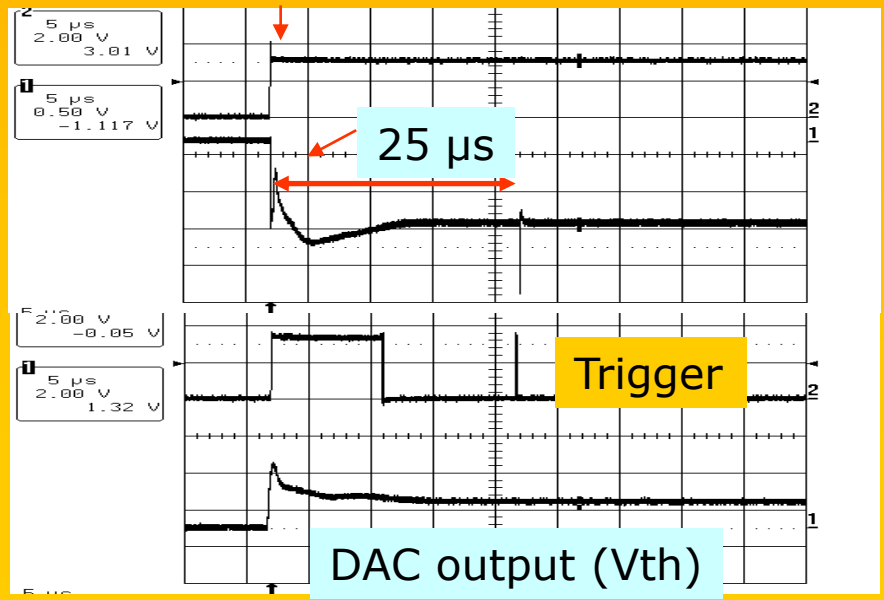
ASIC: Hardroc

- **64** channels, 16mm²
- 2bit: **2/3 thresholds** (HR1/HR2)
- Gain correction 6/8 bits(HR1/HR2)
- low consumption, power pulsing **(< 10 µW/ch**)
  ILC : 0.5% duty cycle
- Digital memory: **128 evts**.
- Xtalk **<2%**
- Adequate for GRPC: **threshold>10 fc**



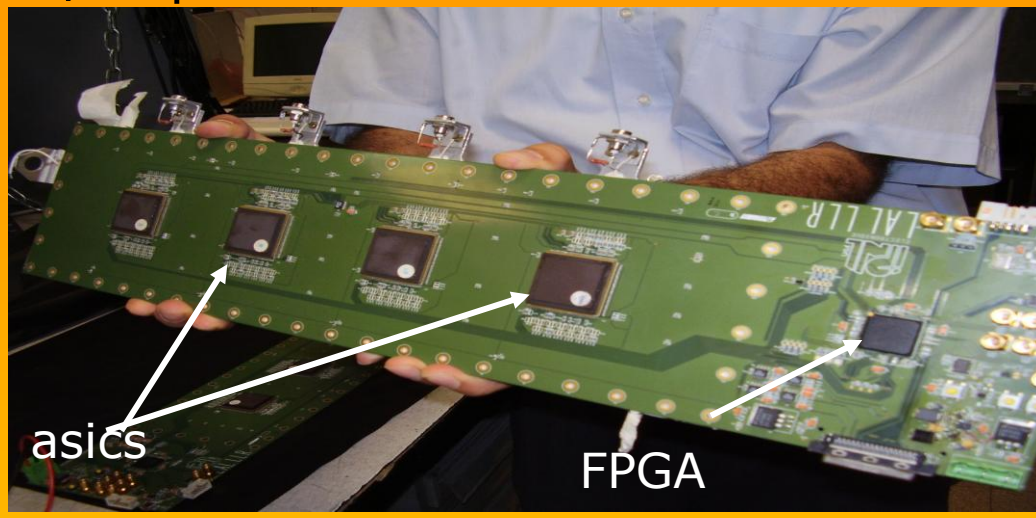
1.4 mm thick





Semi-digital electronics readout

Aim: Validate the new electronics/acquisition scheme for the DHCAL

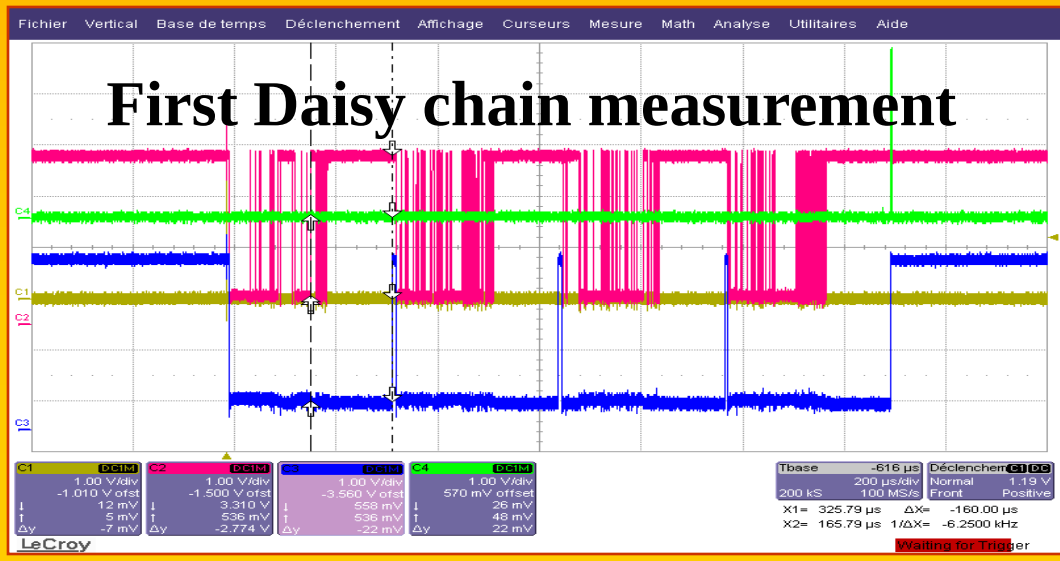


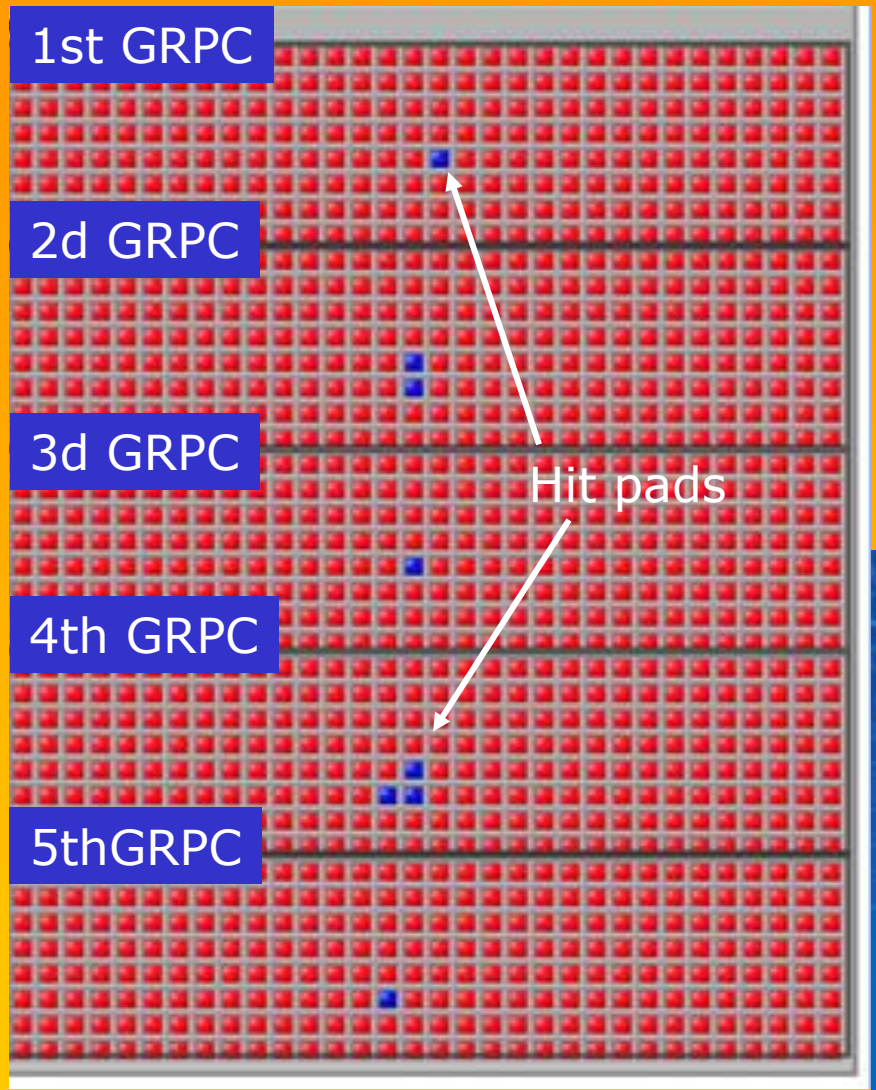
- **8-layer**, **800 µ** thick PCB
  buried and blind vias
  x-talk <0.3 %
- 4 hardroc1 chips
- Readout **FPGA** → USB
- **8×32** pads detector
  (1 cm^2 pads)

Acquisition modes :

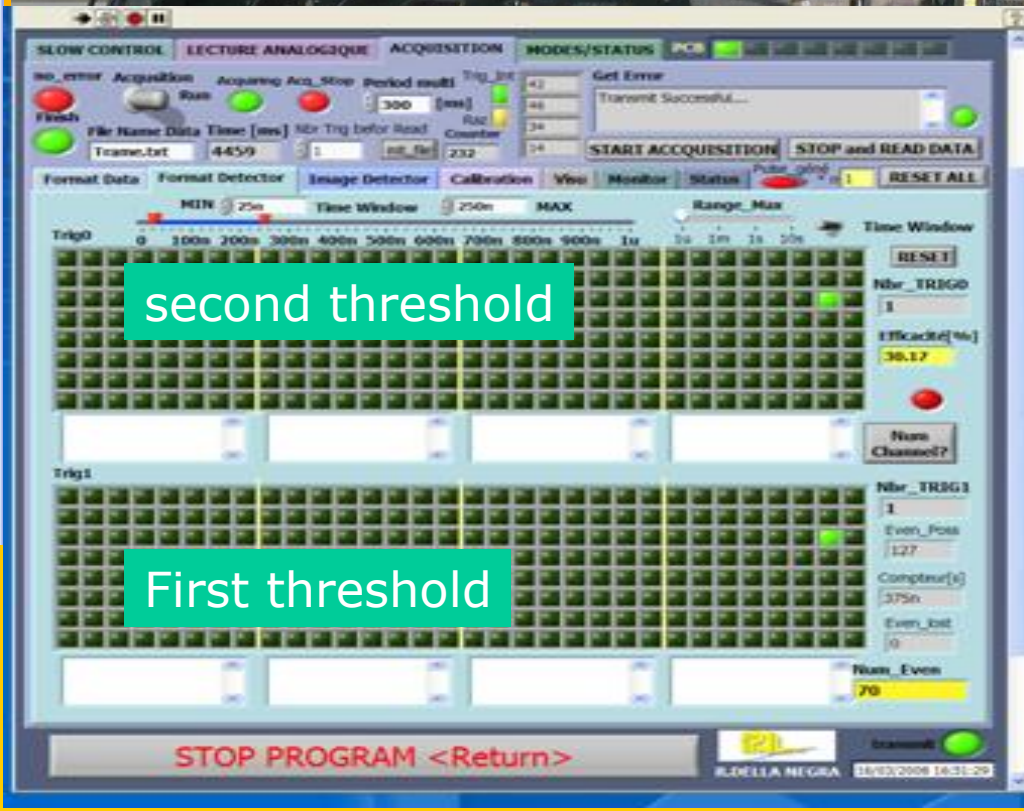
a) Triggerless (ILC mode)

b) External trigger :
cosmic rays & test beam





Example of a recorded mip in 5-GRPC cosmic rays test bench



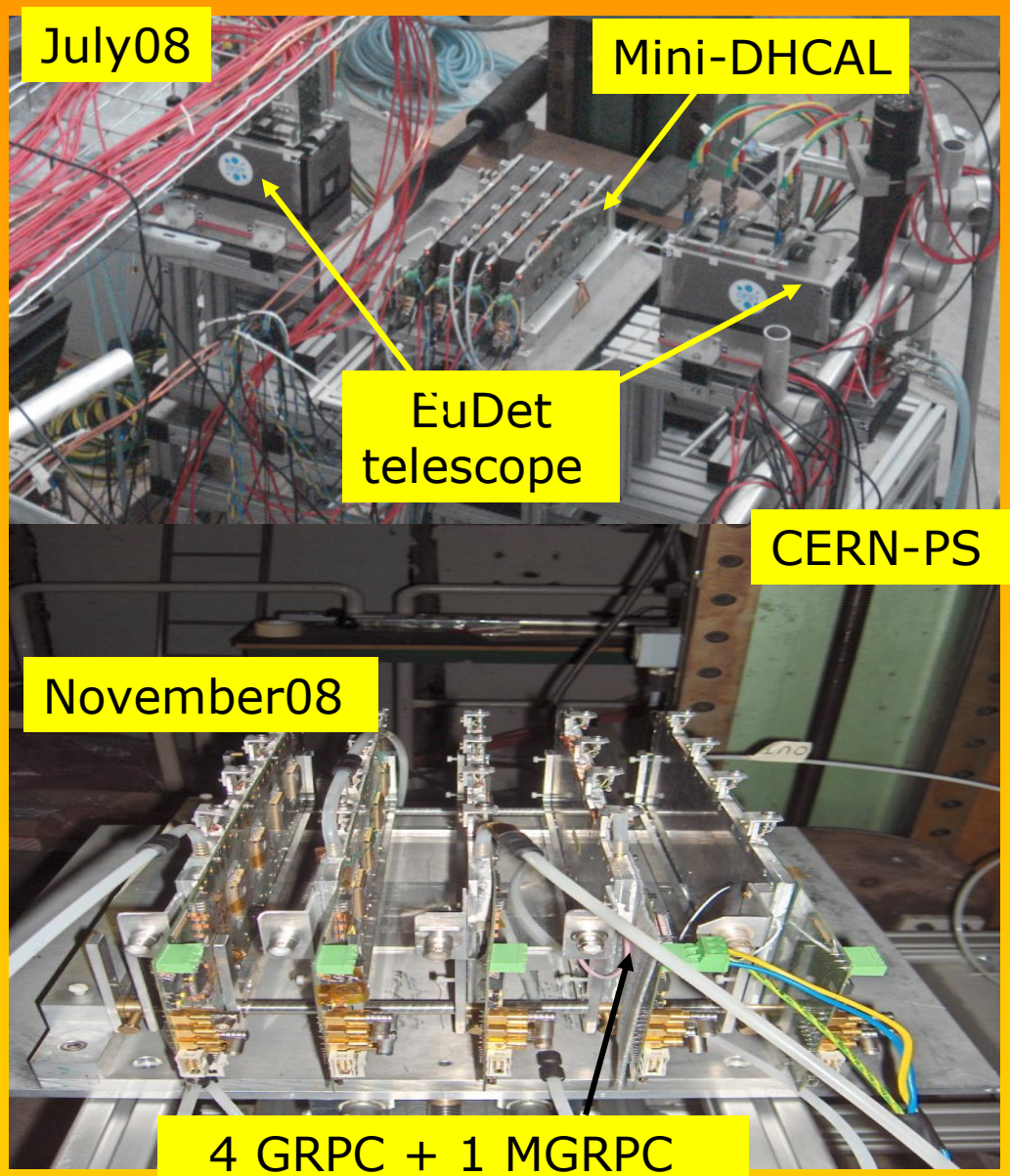
GRPC Mini-DHCAL test at CERN

Aims:

- Validate electronics readout system in beam conditions
- Study the GRPC behavior vs: HV, thresholds, angle, position and gas mixture (*see backup slides*)
- Noise, stability
- Study the first phase of the hadronic shower (pion energy 1-12 GeV)

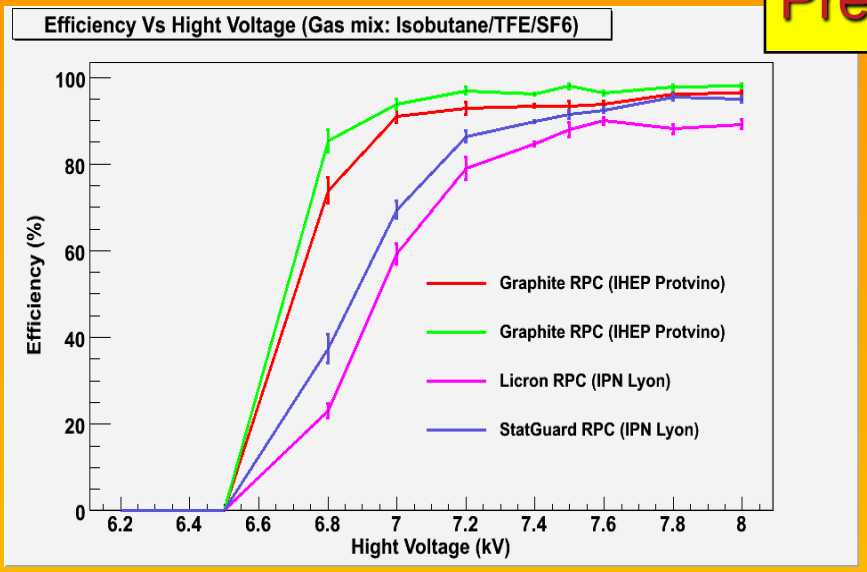
About 500 k evts collected with single trigger mode + busy logic+auto. Ramfull recovery

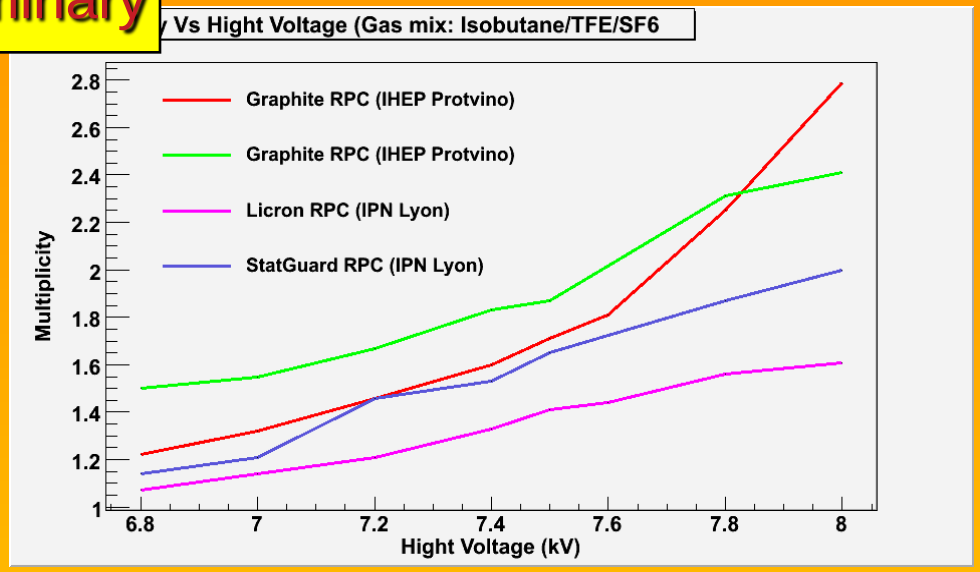
→ DAQ rate : 20 Hz

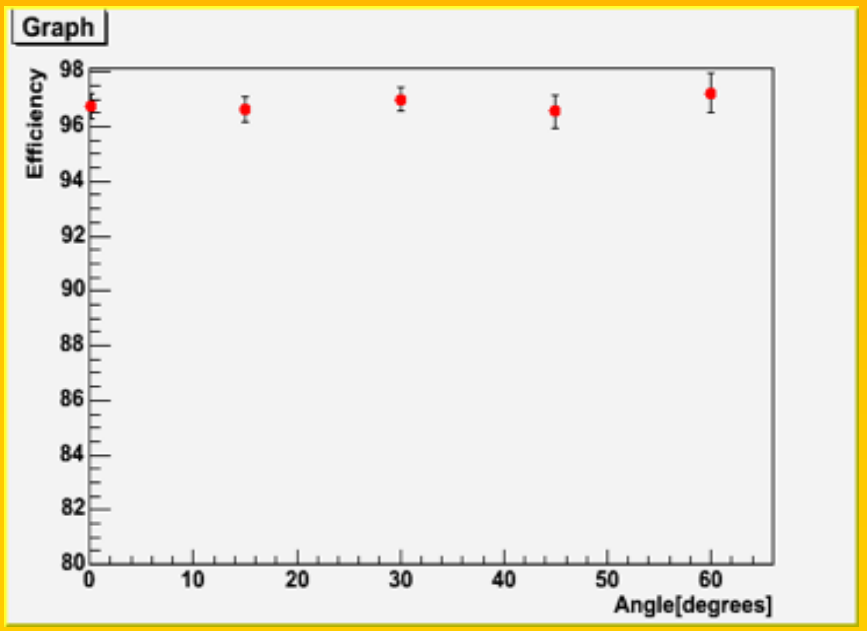


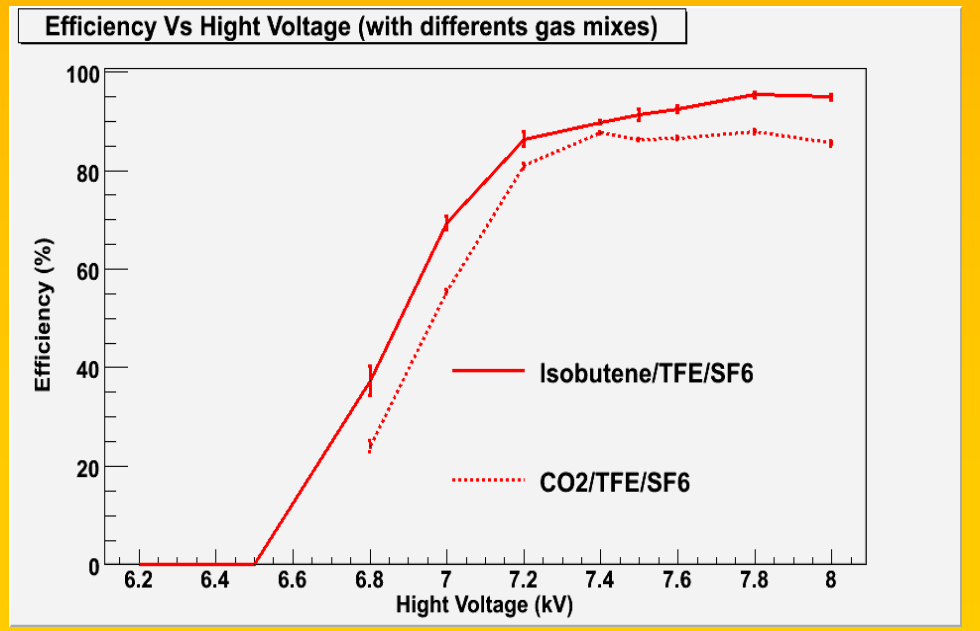
GRPC in TB

Preliminary



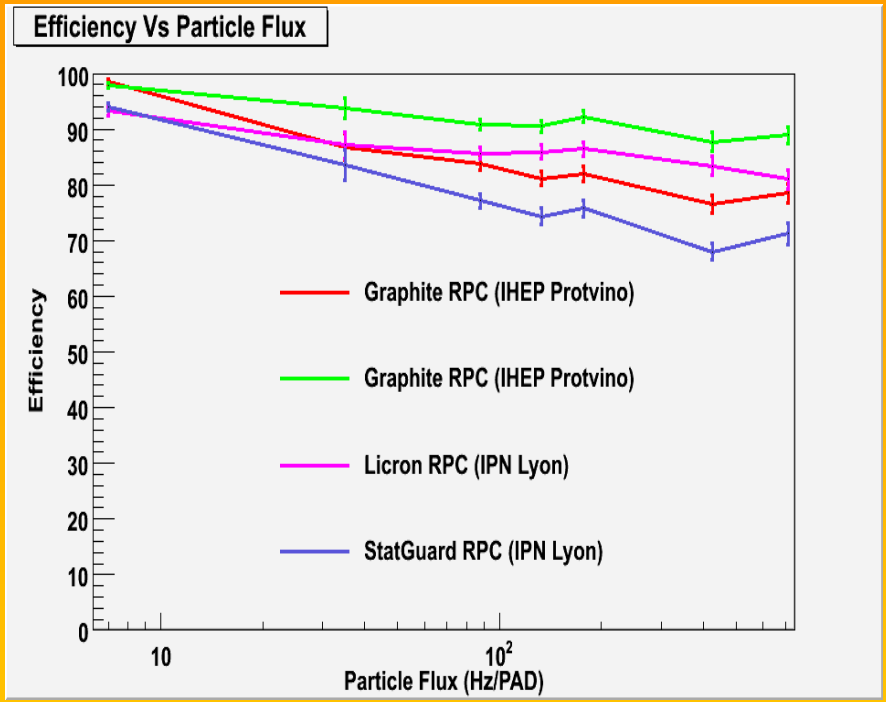


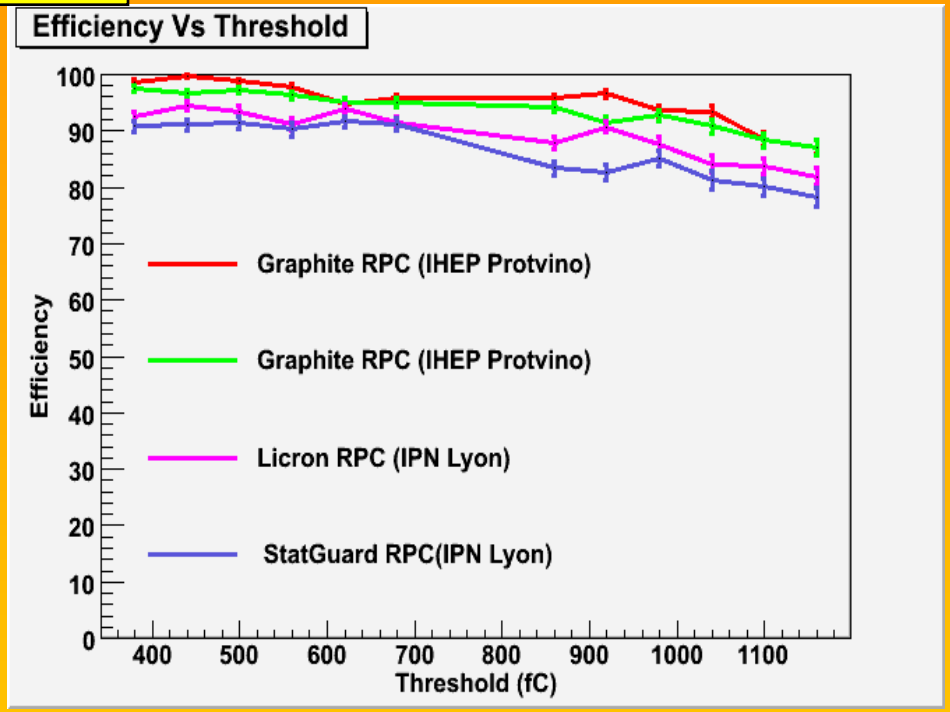




GRPC in TB

Preliminary

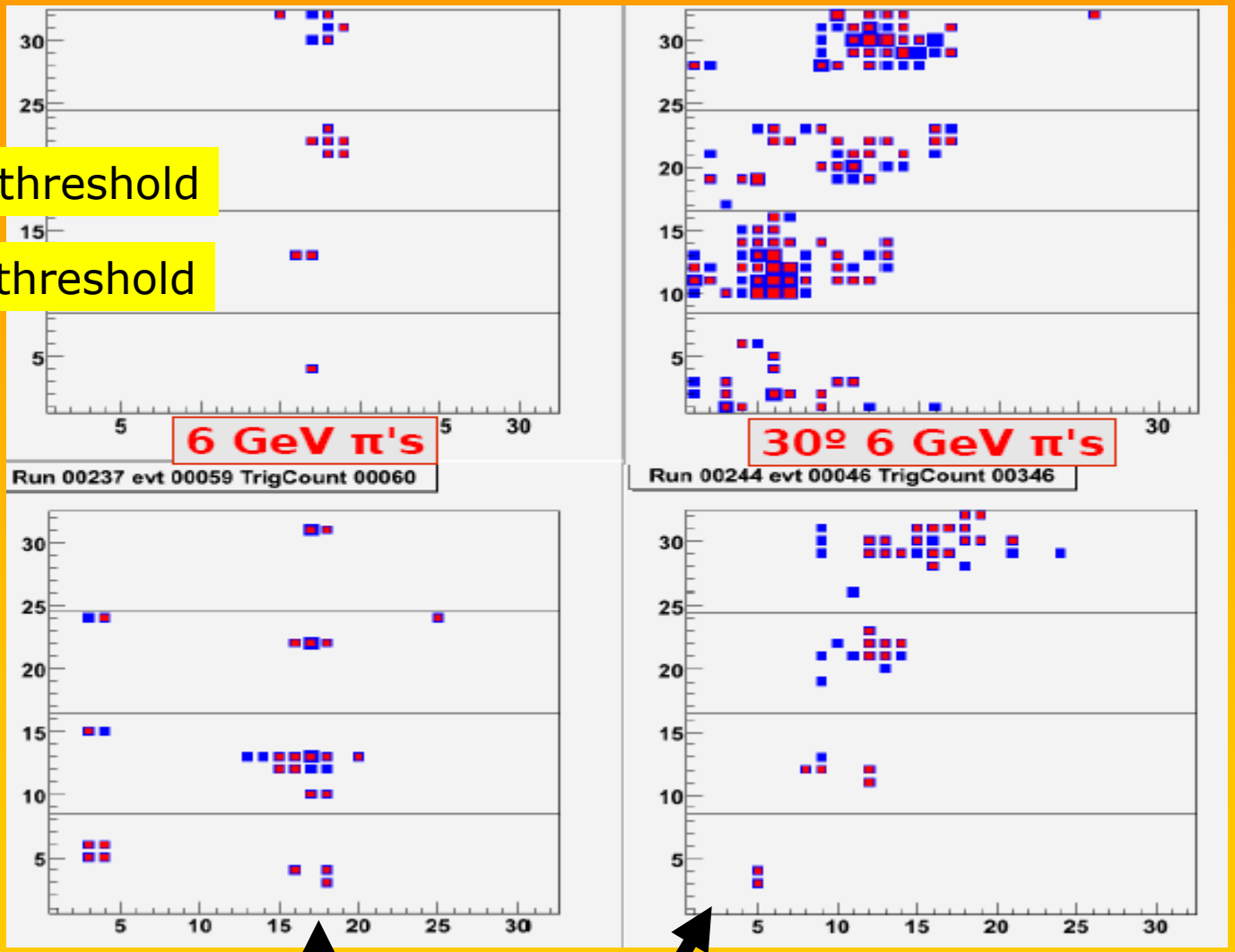




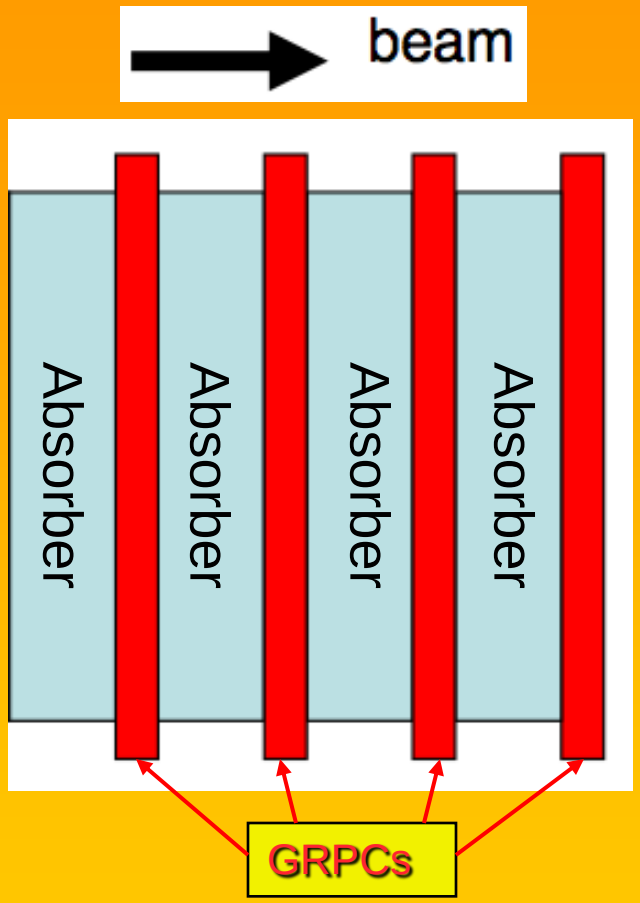
GRPC Mini-DHCAL test at CERN

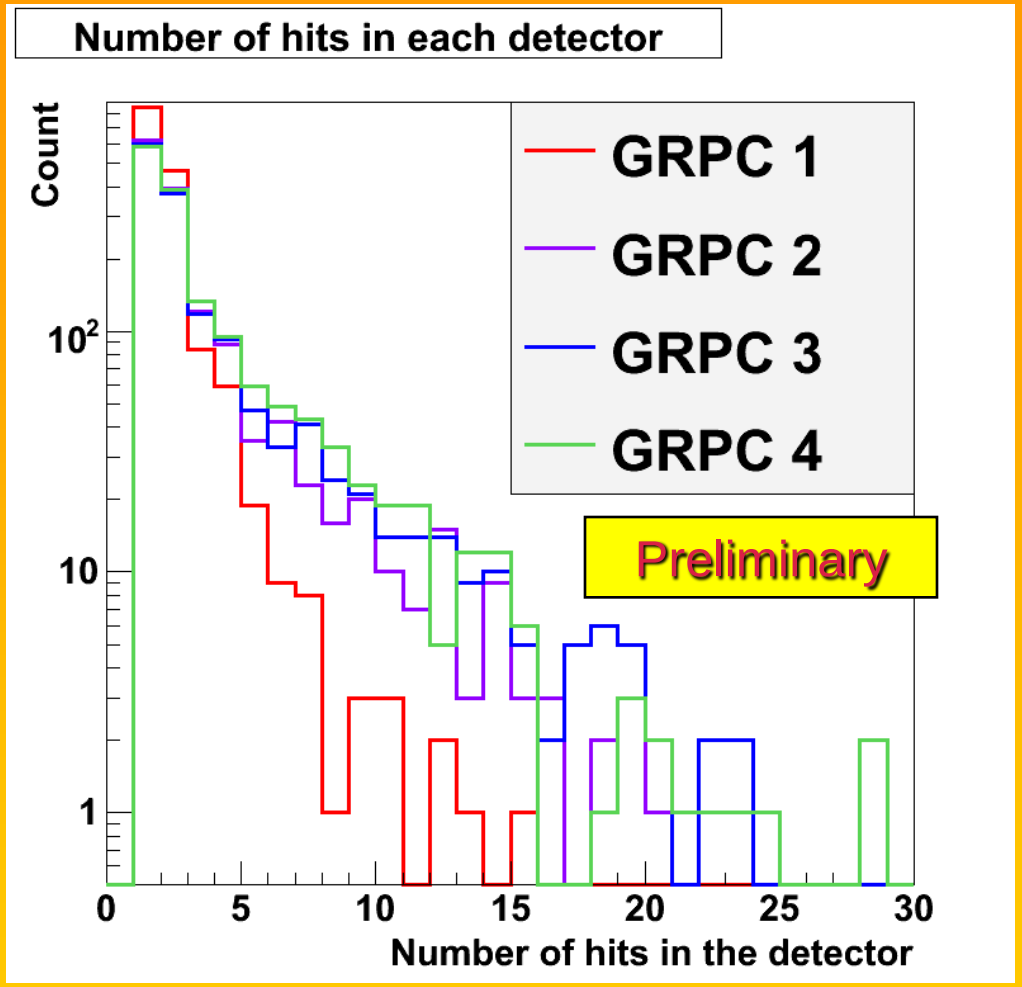
Blue: 1st threshold

Red: 2d threshold



Beam(pions)

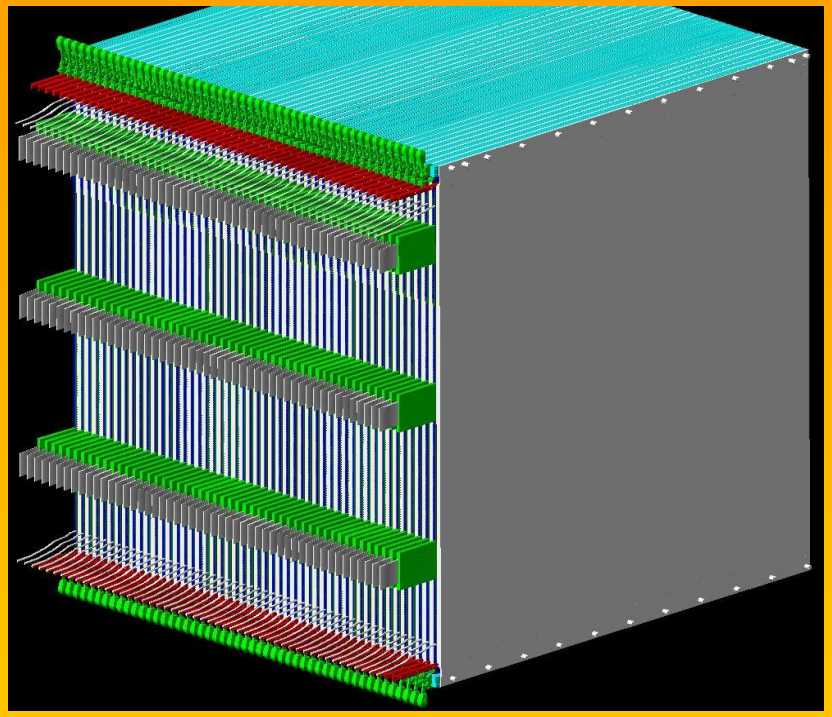




Hadronic showers are mostly not contained in MiniDHCAL but the profile gives an idea of shower devloppment to be compared soon with simulation

1m^3 technological prototype project

The aim is to come as close as possible to what we would like to have for ILC.



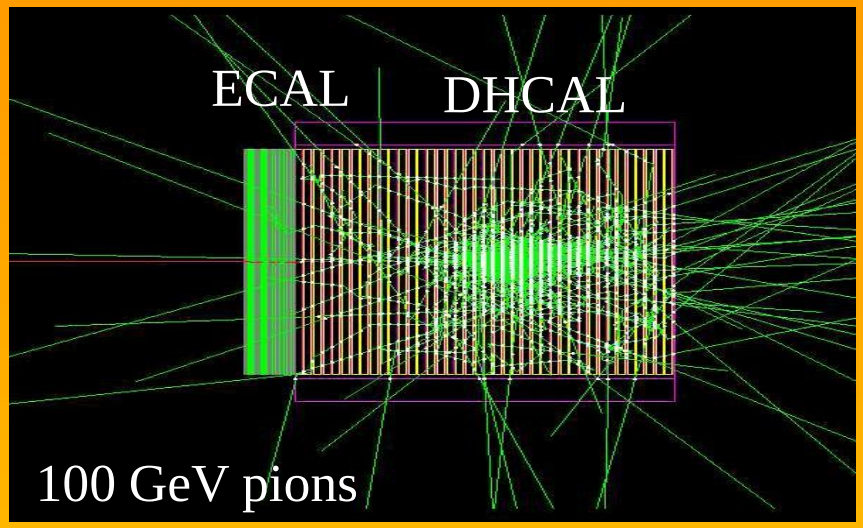
Technological prototype :
40 plans of 1m^2 :
16mm s.steel absorber
4mm s.steel support
6mm GRPC

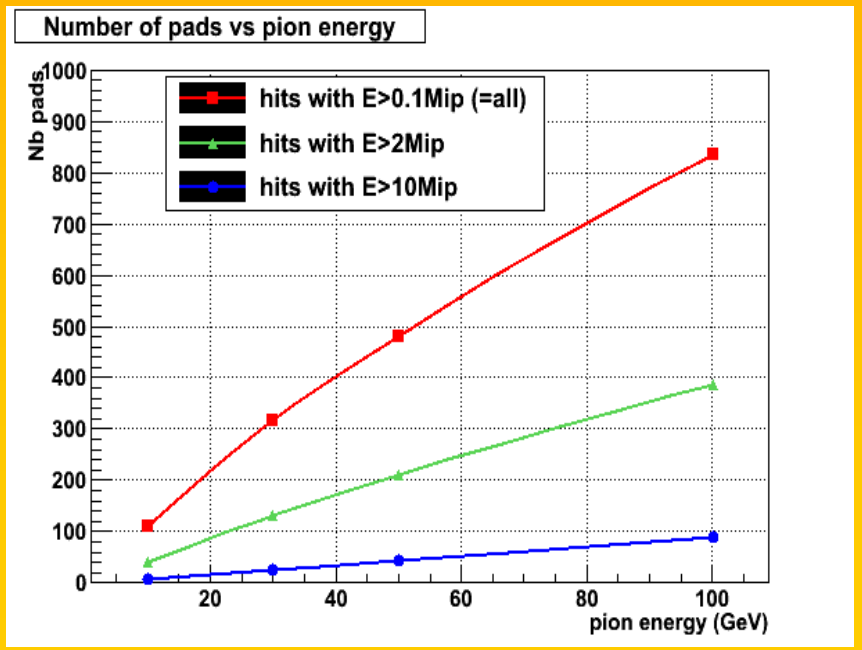
Important points:
Semi-digital readout, mechanical structure, gas system, DAQ, event building, data storage.

The project is essentially funded by French ANR-BLANC (2008-2010)

1m^3 technological prototype project

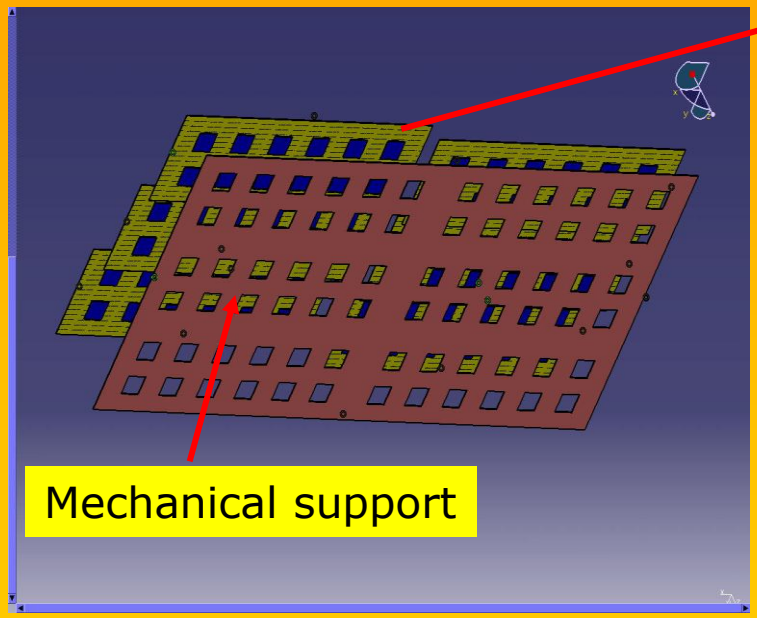
- Pions with different energies were simulated to better understand the containment
- Analyses to exploit the three thresholds have started for energy reconstruction
- Digitization is being worked out (conversion mip/charge)

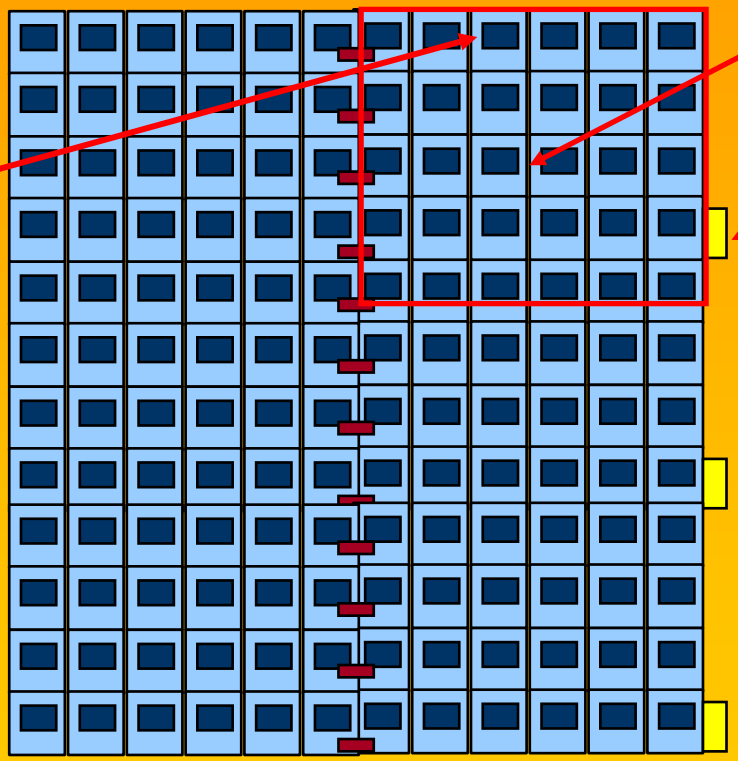


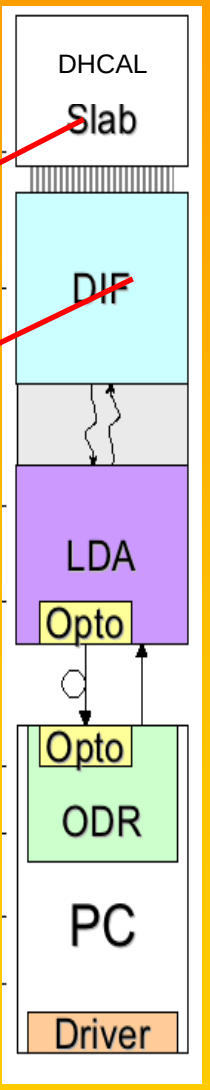


1m^3 technological prototype project

To build large detectors: Large electronics boards with the required quality are not currently available! so smaller boards need to be assembled







PCB dimensions and PCB connections were optimized

1m^3 technological prototype project

ASU

- 8-layer board designed and produced : 500X33.3X1.2 mm3
- Connections between adjacent PCB are foreseen
- Asics were tested and plugged

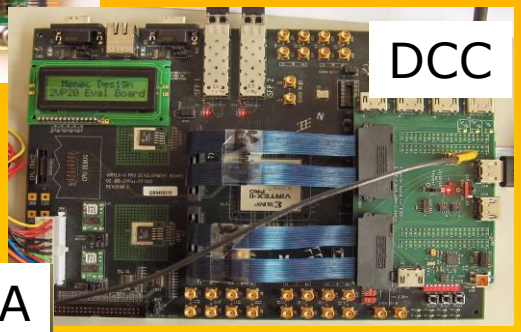
DIF

- 10-layer board (6 for signals)
- Firmware with the two acquisition modes was realized and debugged

DCC

Data concentrator card is being developed

1 DCC for 9 DIF



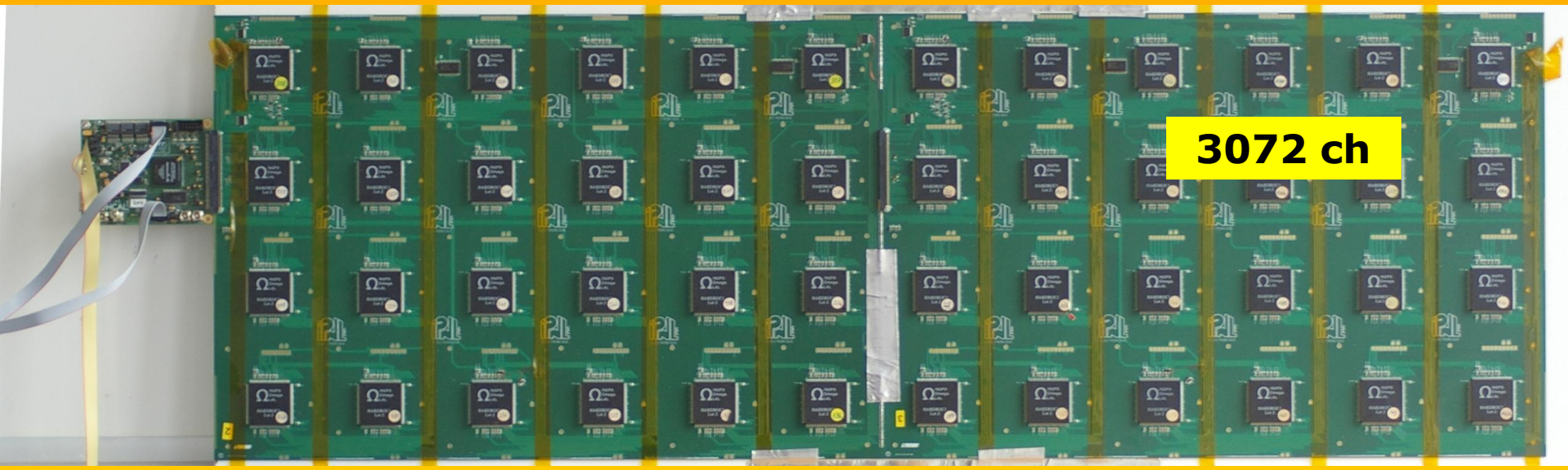
LDA+ODR

DAQ DAQ is being developed by U.K groups for the different kinds of calorimeters:EuDet

HW ok, FW+SW are ongoing

1m^3 technological prototype project

- 6 slabs of 24-asic each, were produced and equipped with HR1
- Slabs connected 2 by 2 using "zero" resistors
- DIF firmware was adapted to deal with large number of asics
- Software using Xdaq/USB was developed (as debug mode)
- Slow control and data acquisition were successfully tested



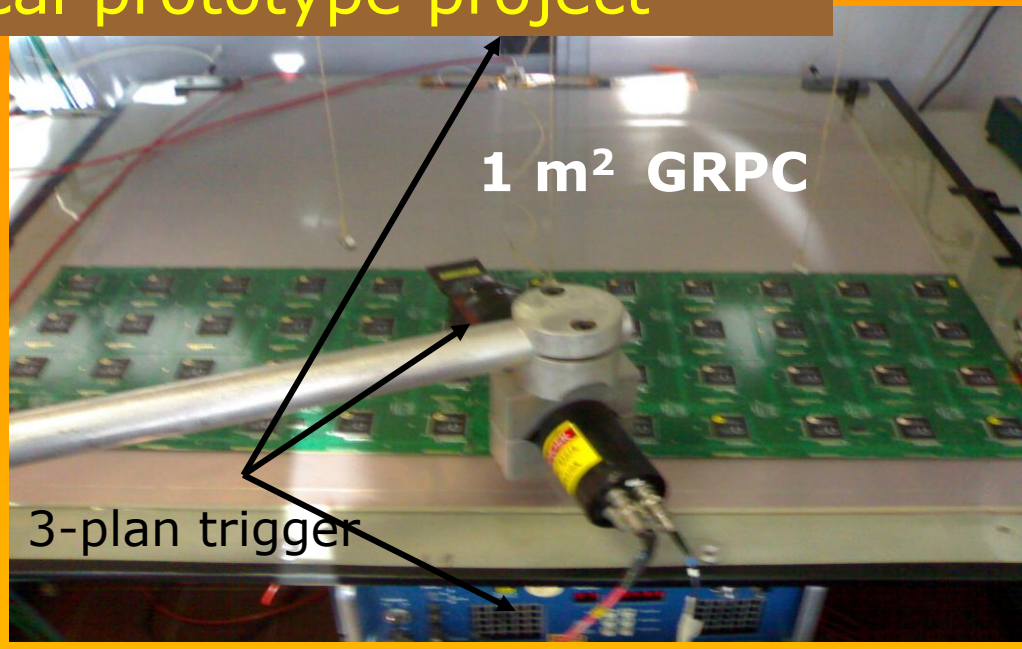
$1m^3$ technological prototype project

$1m^2$ GRPC chambers were tested with the small electronics board (4HR1)

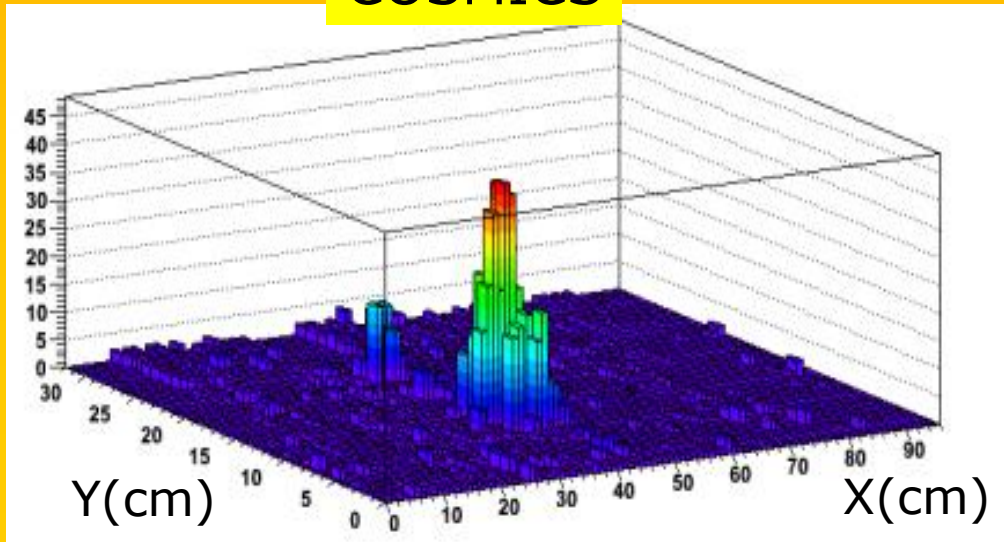
PCB-doublets (3072 ch each) are tested independently

PCB-doublet on $1m^2$ are being tested

Fully equipped large detector to be soon tested in cosmic rays bench and in test beam at cern in **June09**



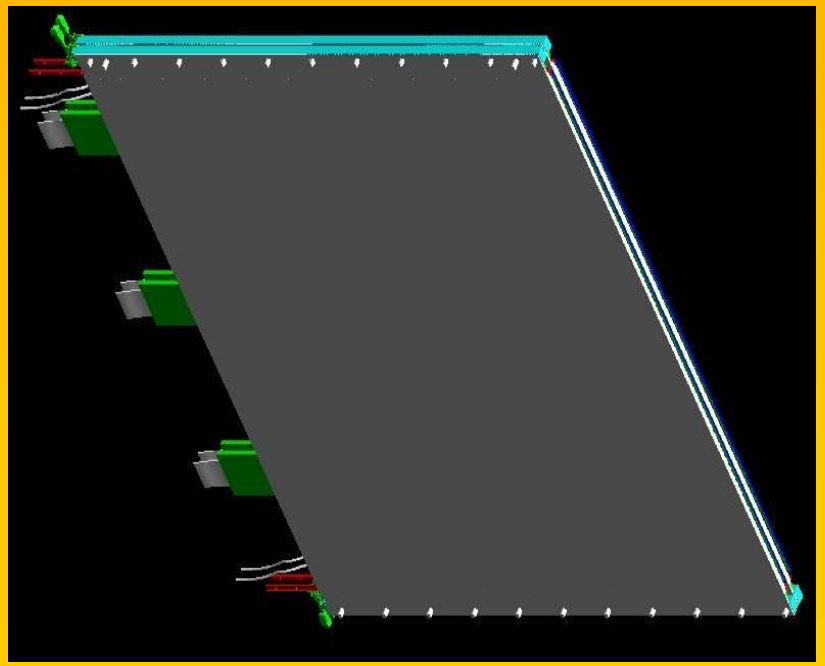
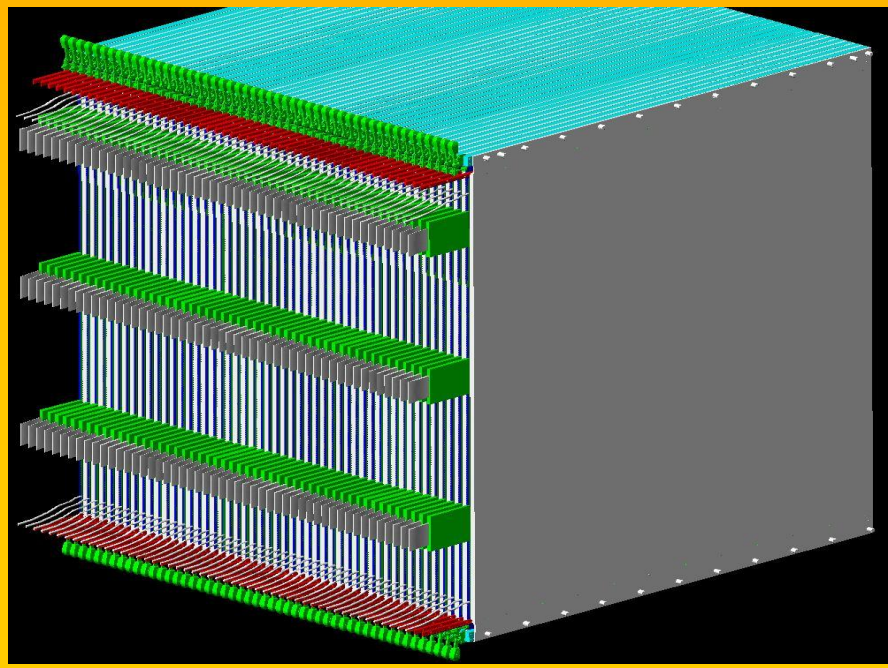
COSMICS



$1m^3$ technological prototype project



Ongoing.....

Collaboration

The aim of the collaboration between French groups (IPN and LAL) and Tsinghua group is to exchange expertise in

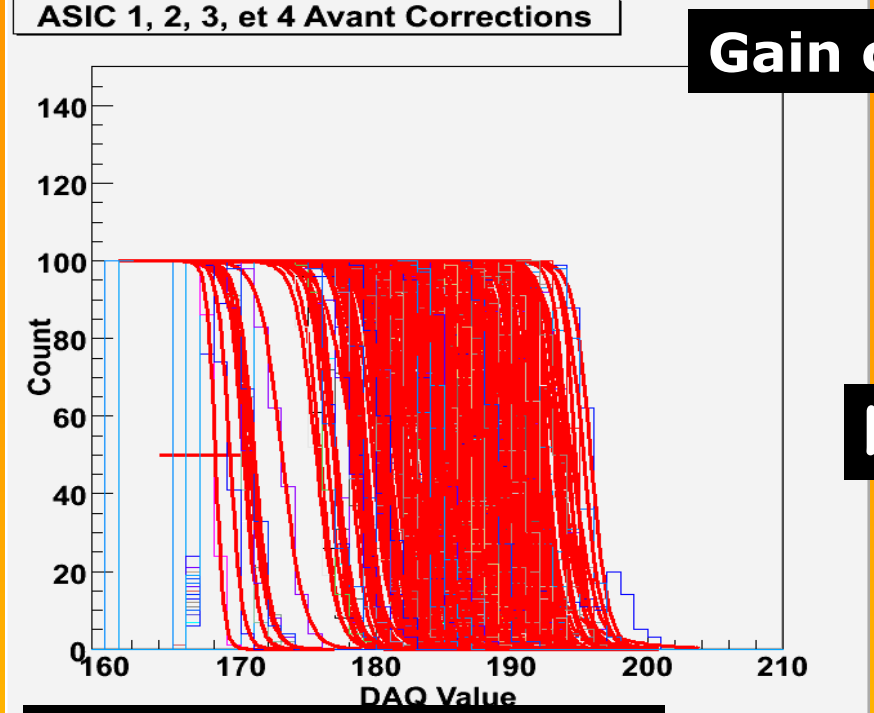
- Detectors : Simple, Multi-gap , semi-conductive GRPC
- Electronics : ASICs, PCB..

It intends also to harmonize R&D activities and share responsibilities in building the $1m^3$ prototype and analyzing the obtained results in TestBeams.

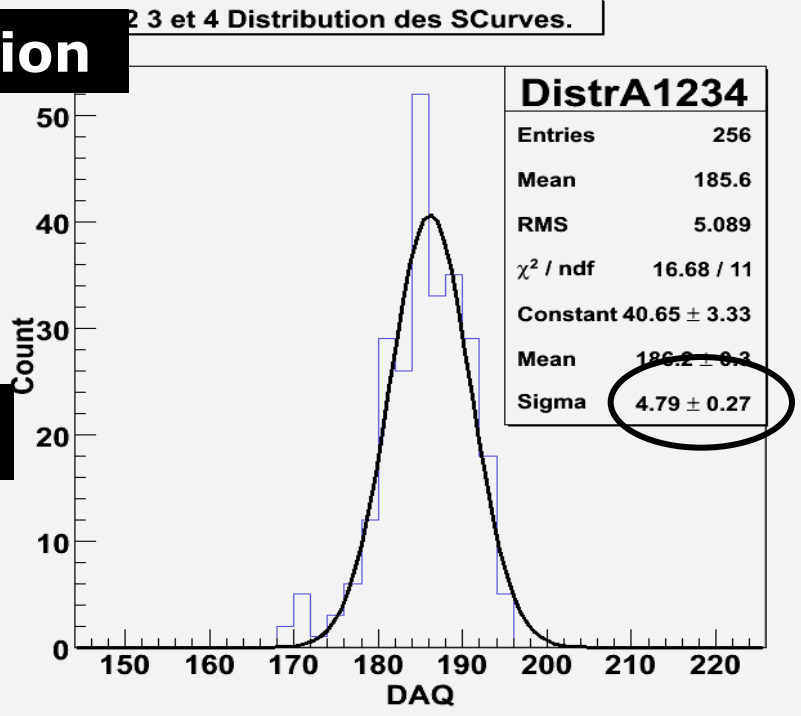
French groups : 2 physicists, 3 engineers, 1 PhD student
Chinese group : 3 physicists, 2 PhD students

We plan to use high rate GRPC detector in the June TB at CERN this year.

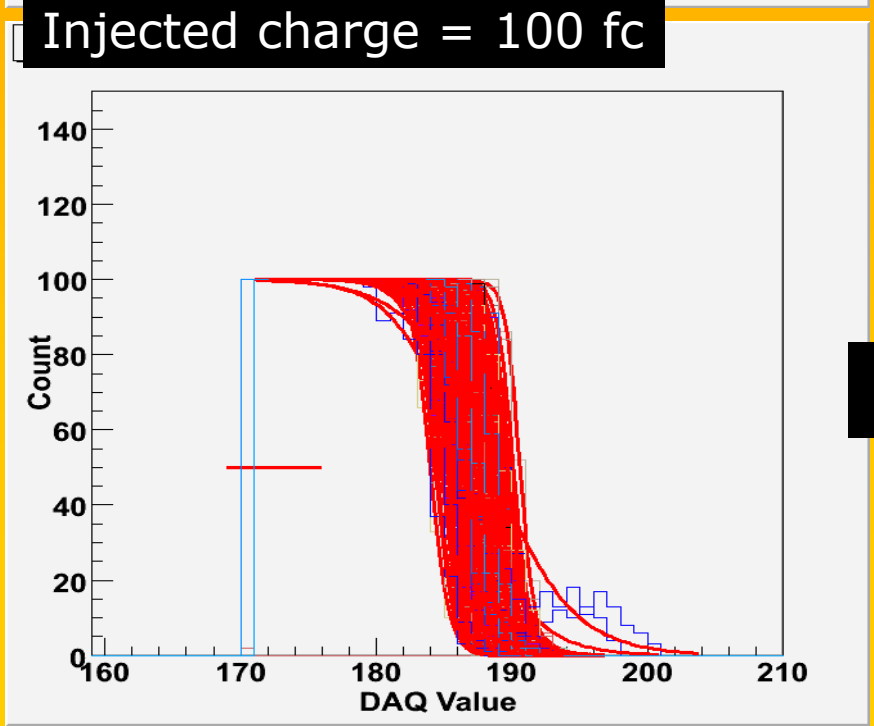
Gain correction



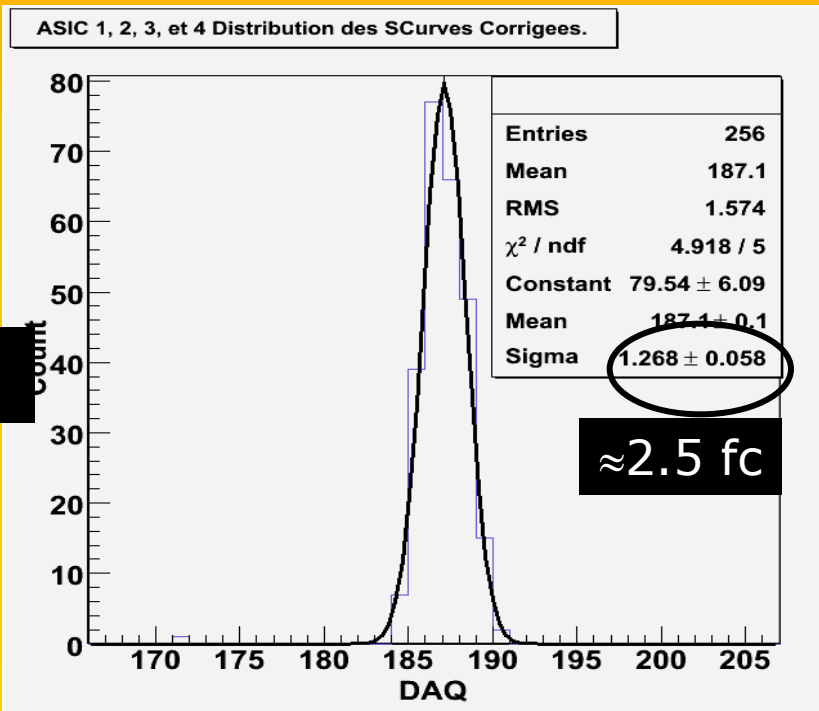
before



Injected charge = 100 fc

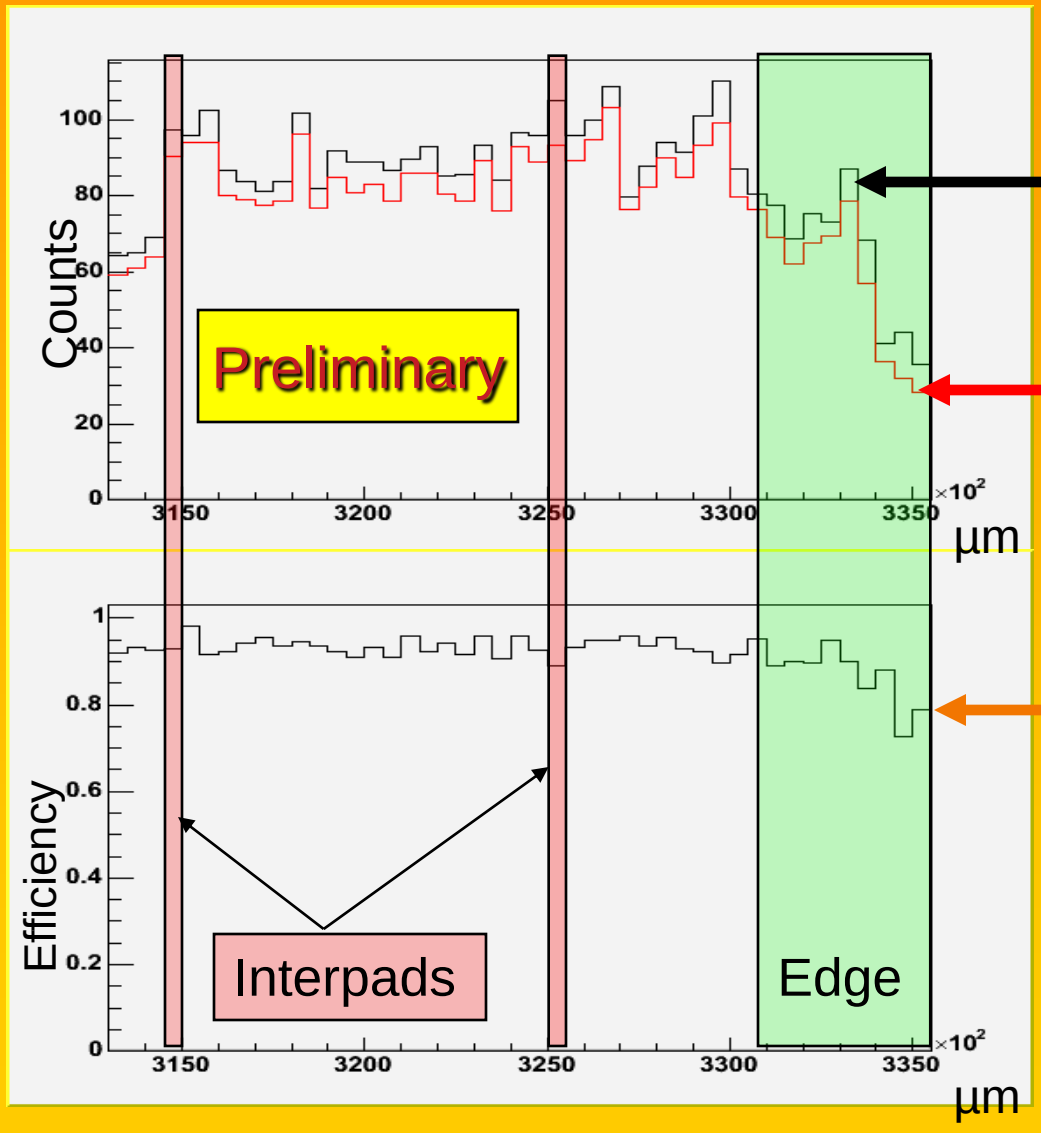


after



≈2.5 fc

GRPC in TB



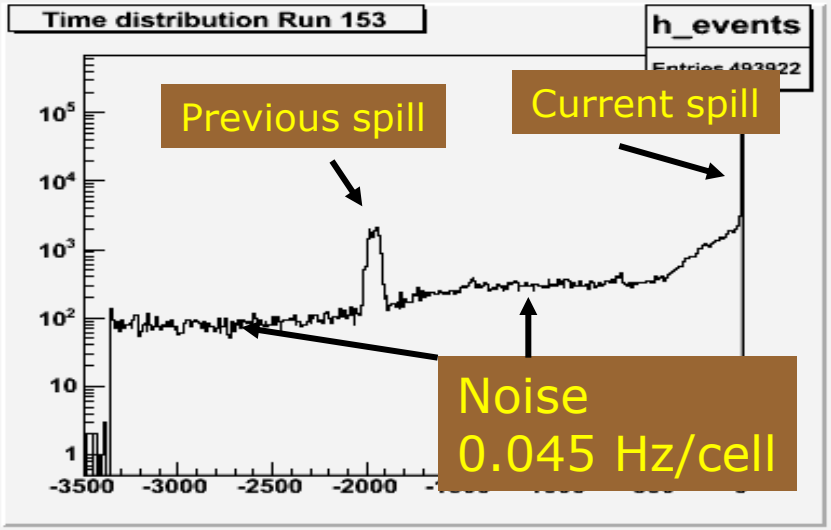
Black (Trigger): spatial prediction of hits in GRPC, from EuTel.

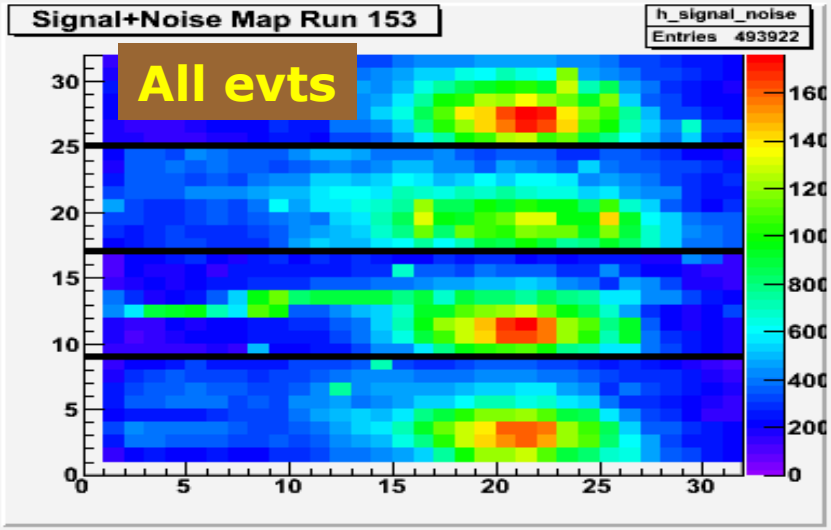
Red : matched digital hits (EuTel + GRPC)

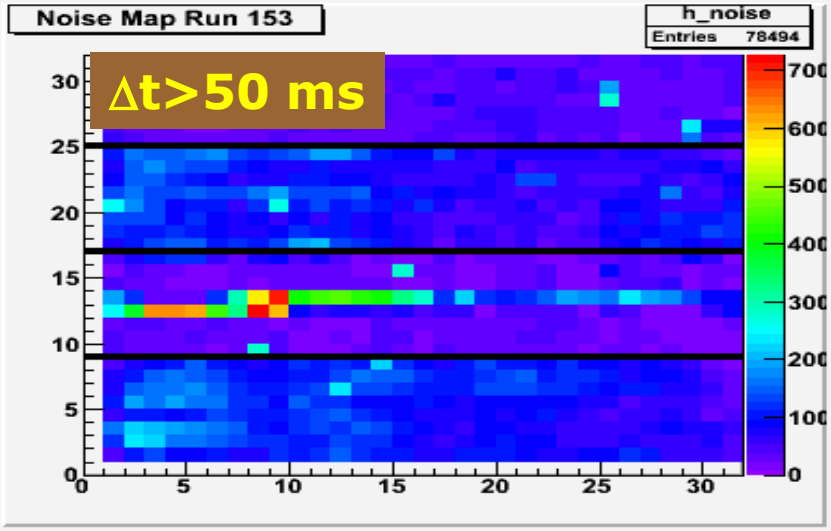
Efficiency: Red/Black

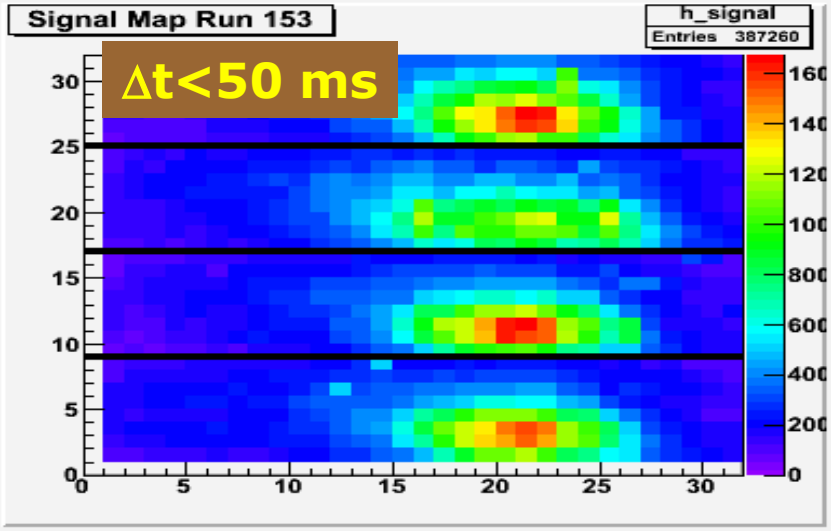
Using EuTel, we can evaluate efficency on the detector edges, and between two Pads.

GRPC Mini-DHCAL test at CERN









Beam structure : 400 ms spill every 48/33s (day/night)

Δt: evt. time difference with respect to the trigger.

1m^3 technological prototype project

Planning

- GRPCs construction is to start in the second half of 2009
- Mechanical structure for 1 m^3 was designed and construction will be achieved in second half of 2009
- ASICs and PCB production should start in July-September.
- GRPC+elctronics plan assembling in the first half of 2010
- Test Beam in second half of 2010