Recent development of Semi-Digital HCAL using GRPC

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Overview

The Semi-Digital HCAL concept

Detector and readout development

- Small GRPC & Readout
- Current R&D for 1m^2 GRPC

Test Beam Results with small GRPCs

- Detector performances
- Hadronic showers

Current development

- 1m^2 detector fully equipped
- 1m^3 project

Simulation and Integration activities

- Hadronic showers containment
- First resolution studies with PFA

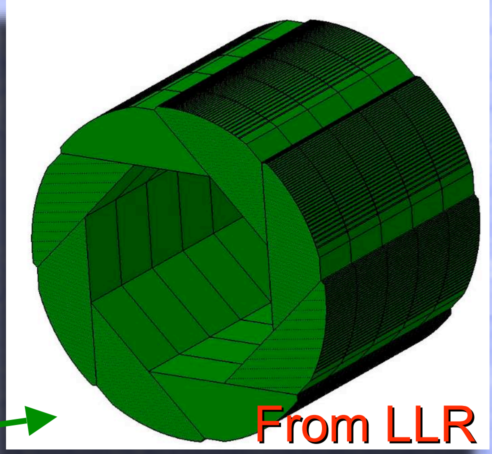
Conclusion & outlook

The Semi-Digital HCAL concept

A digital HCAL with a very high granularity (1cm² cells), is one of the two options proposed for ILD.

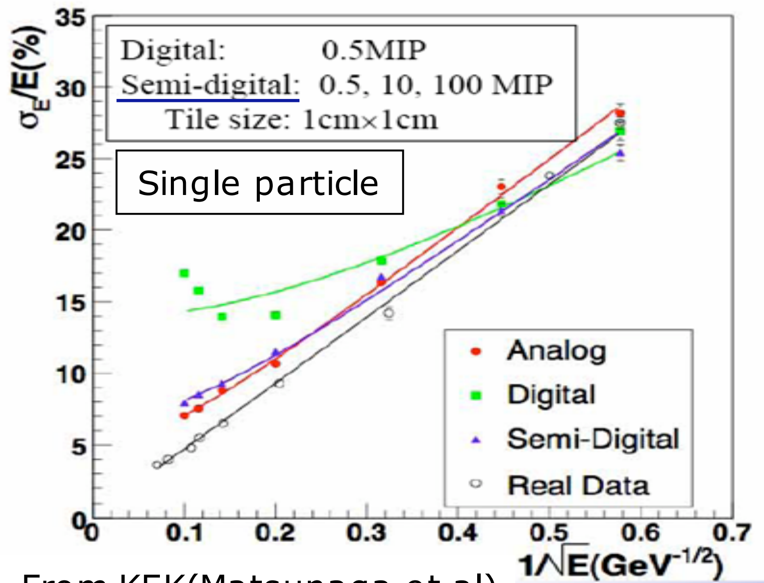
Choice of Glass Resistive Plate Chamber (GRPC):

- Efficient, homogeneous, low cost.
- The detector plans are being developed with embedded readout.



To **avoid projective cracks**, a new mechanical design is under study.

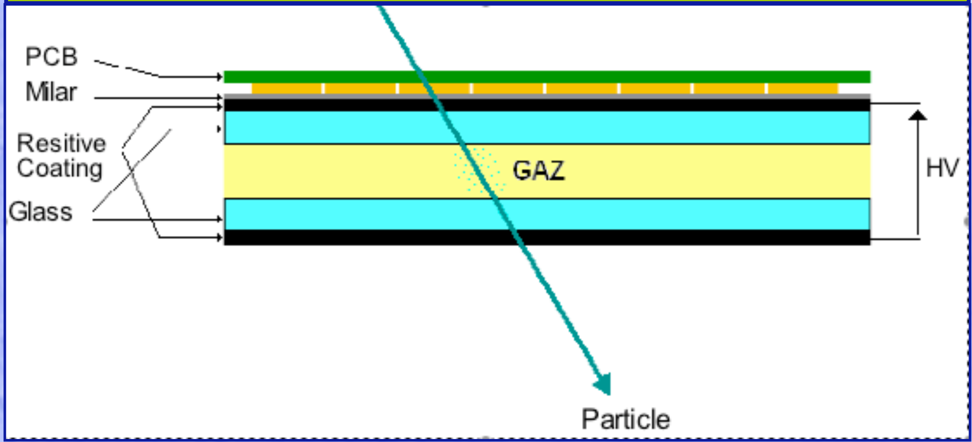
This detector concept associated to Particle Flow Algorithms, would achieve a very good jet energy resolution.



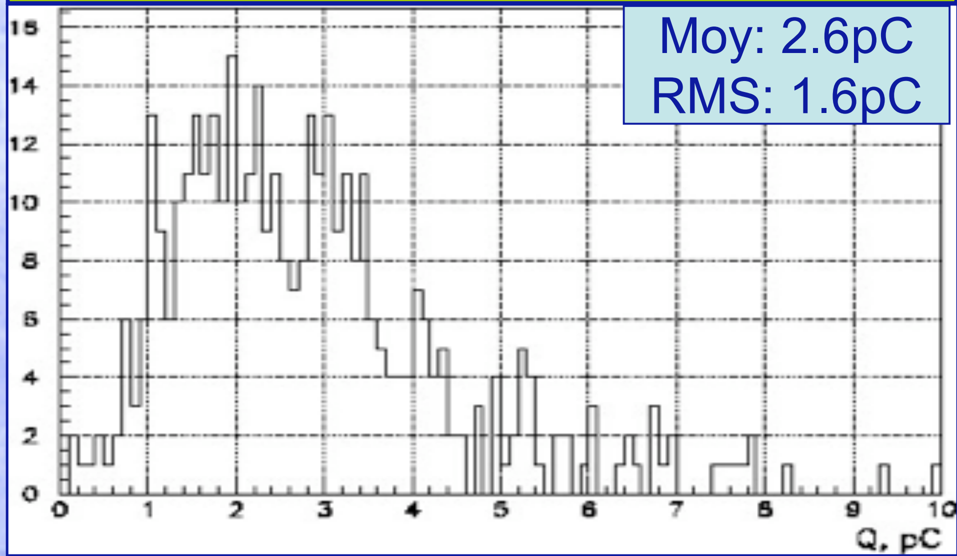
From KEK(Matsunaga et al)

GlassRPCs spec.

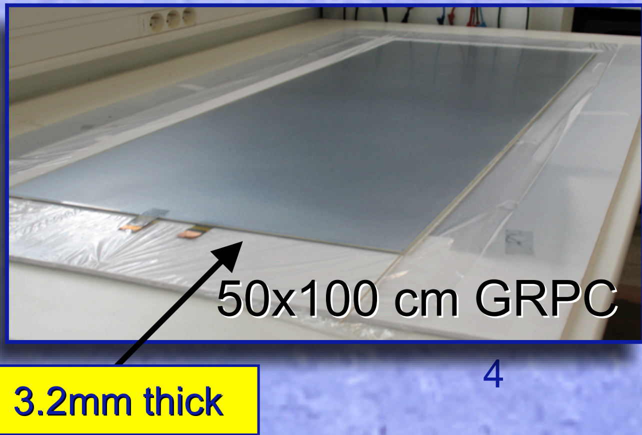
Schematical view of the GRPC



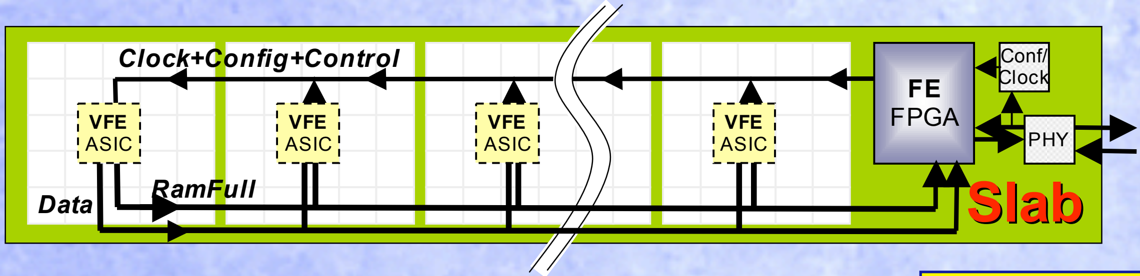
GRPC mip spectra (From Protvino lab)

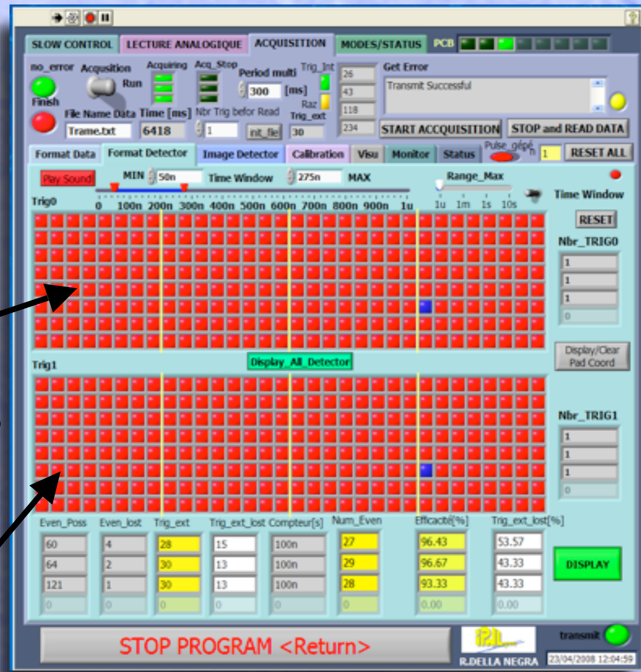


- Polarisation: 6.5 kV to 8 kV (avalanche mode)
- GRPC thickness: 3.2 mm (1.2 mm gas gap + 1.2 & 0.7 mm glass plates + mylar foil)
- Gas mix: 93% TFE, 5% Isobutane, 2% SF_6
- Inductive readout (Noise rate 1 Hz/cm²)
- Easy/low-cost to build, robust, good efficiency !



First Semi Digital Readout





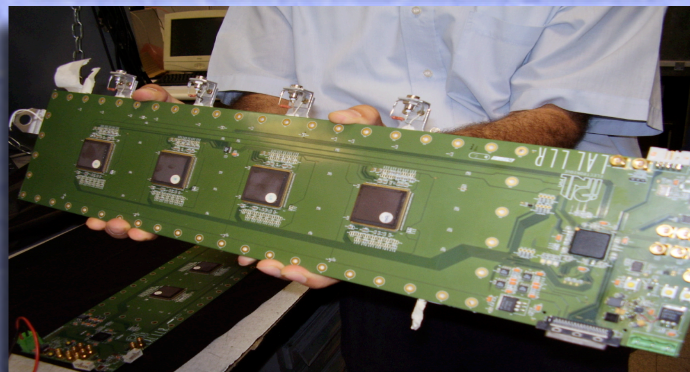
Threshold 2

Threshold 1

- 8 layers PCB (800 µm thick)
- Readout chip: 4x daisy chained HADROCs

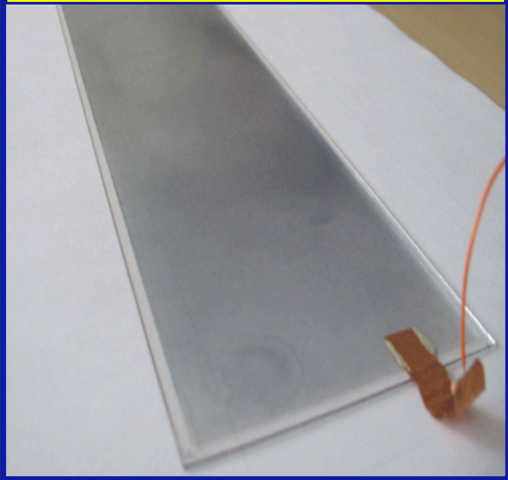
(64 semi digital channels each)

- 256 sensitive pads (1x1 cm^2)
- Acquisition:
  - -> FPGA +USB
  - -> Graphical interface: Labview
- Slow control parameters:
  - -> Gain of each channel (from calibration)
  - -> 2 Thresholds levels
- Signal format: Timing Flag (BCID)+ Threshold(s) reached



Current GRPC R&D

HV Connexion (tests)

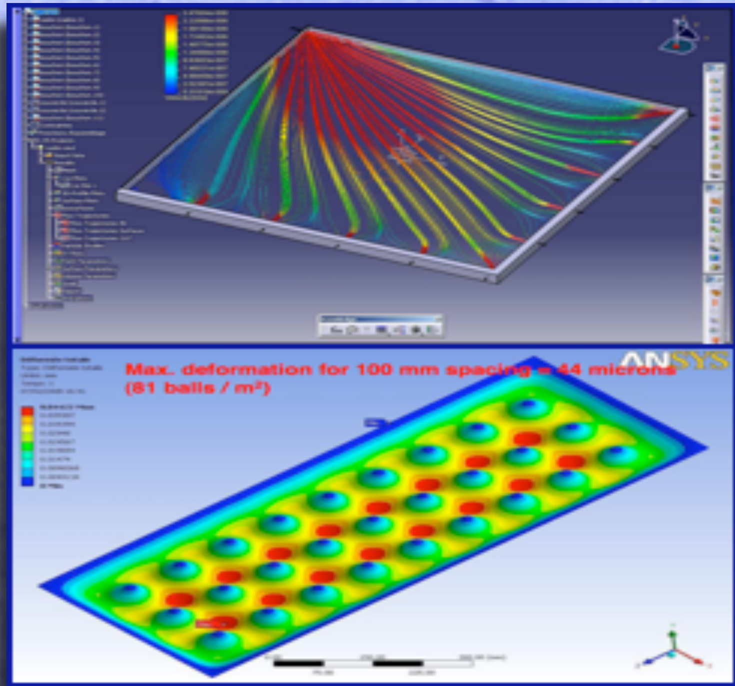


Electrodes optimisation:

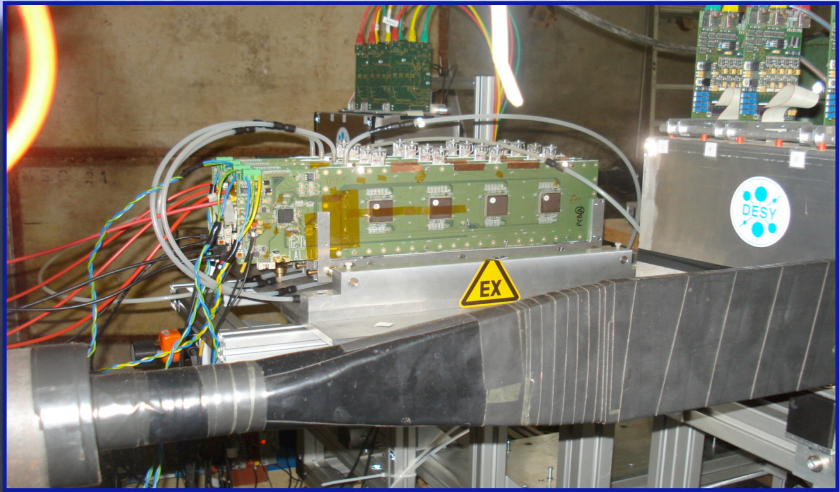
- Test of different resistive coating materials: Licron, Statguard, Graphite (see test beam results)
  -> Impact on detector hit multiplicity , and suitable rate.
- Optimisation of resistive coating connexion to supply
  -> Improve the GRPC lifetime (critical point on GRPC)
  -> Minimise noise generated by the interface copper/coating
- Build electrodes with semi conductive glass (10^{10} Ω.cm)
  ->Improve detection rate up to 28 kHz/cm^2

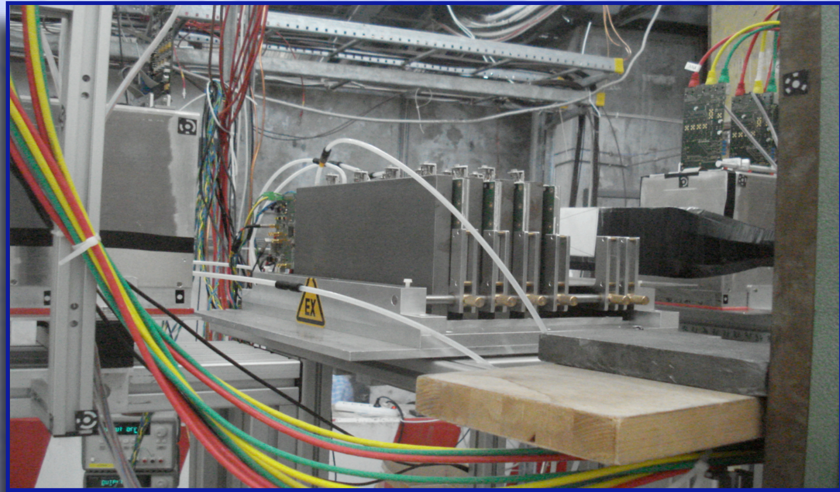
Gas flux optimisation:

- Gas flux simulation
  -> Improve gas renewal for an homogeneous efficiency
- Minimise chamber's dead zones:
  -> Use of ceramic ball as ponctual spacers
  -> Chamber's frame used as gas distributor



Test Beam @ CERN

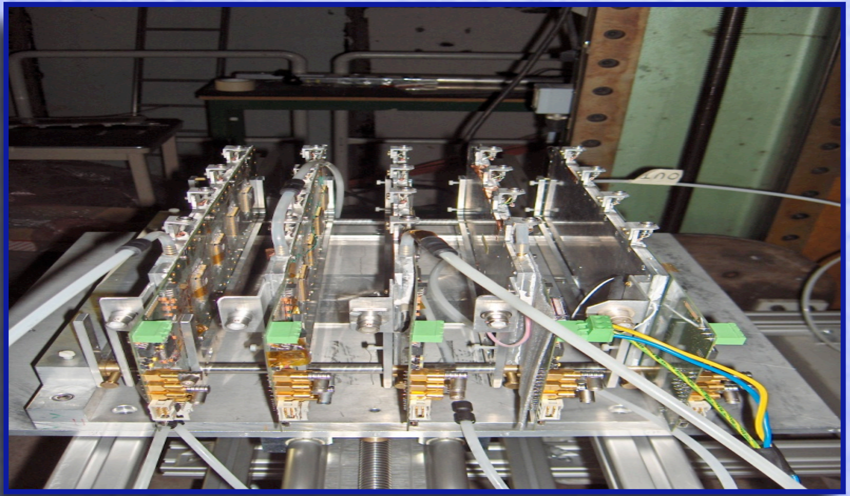


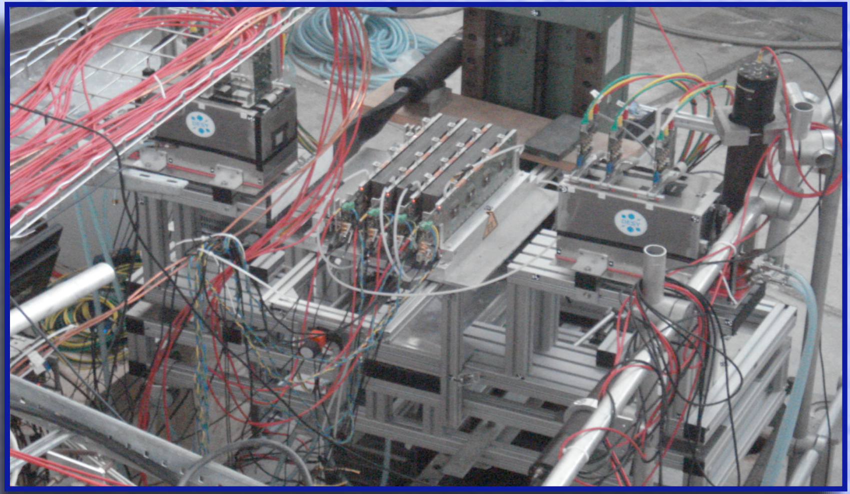


Main goals:

- Test small GRPC performances (32x8 PADs):
  - Different energies (1-12 GeV).
  - Different beam rates (20-6000 triggers/spill).
  - Scan of impact angles.
  - Use of EUDET pixel telescope (Track reconstruction).
- Test of the electronic readout:
  - Under realistic flux conditions (about 100Hz).
  - Evaluation of detector's response according to the DAC's threshold level.
- First record of hadronic shower with mini DHCAL (iron slab between detectors).

Test Beam @ CERN

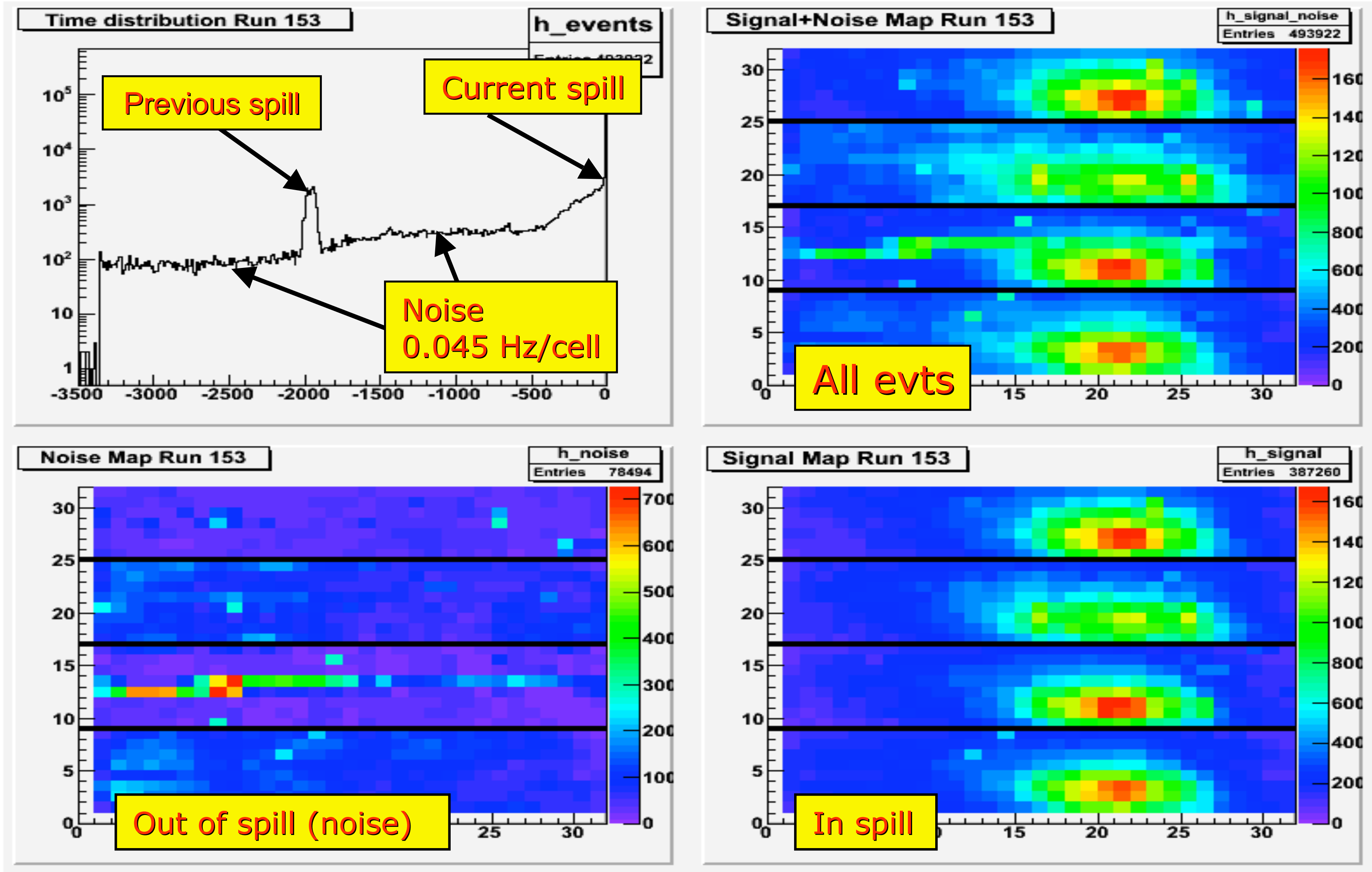




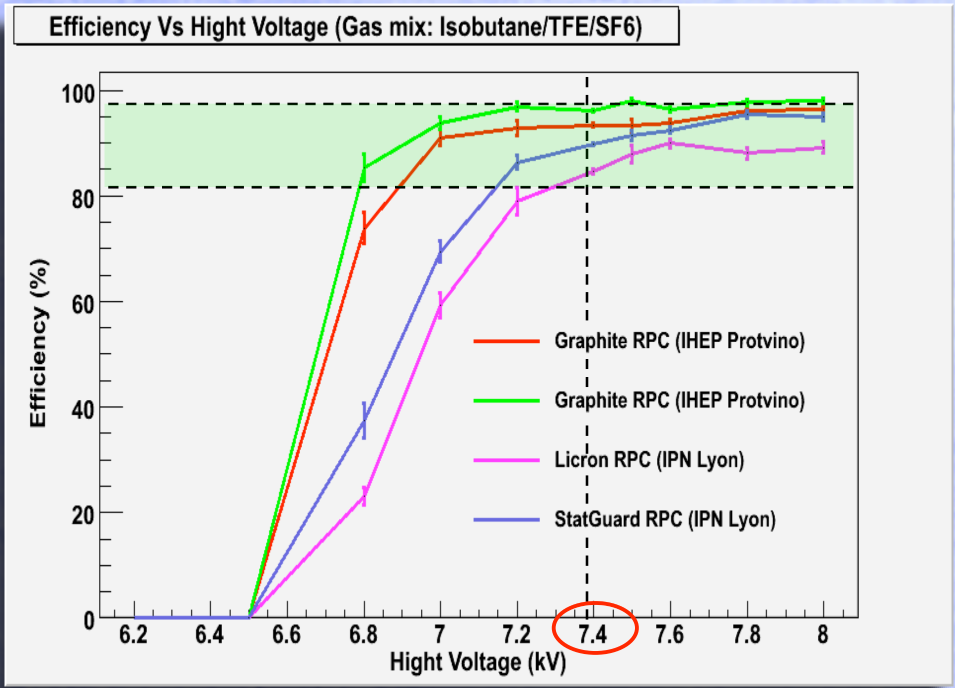
Beam test periods:

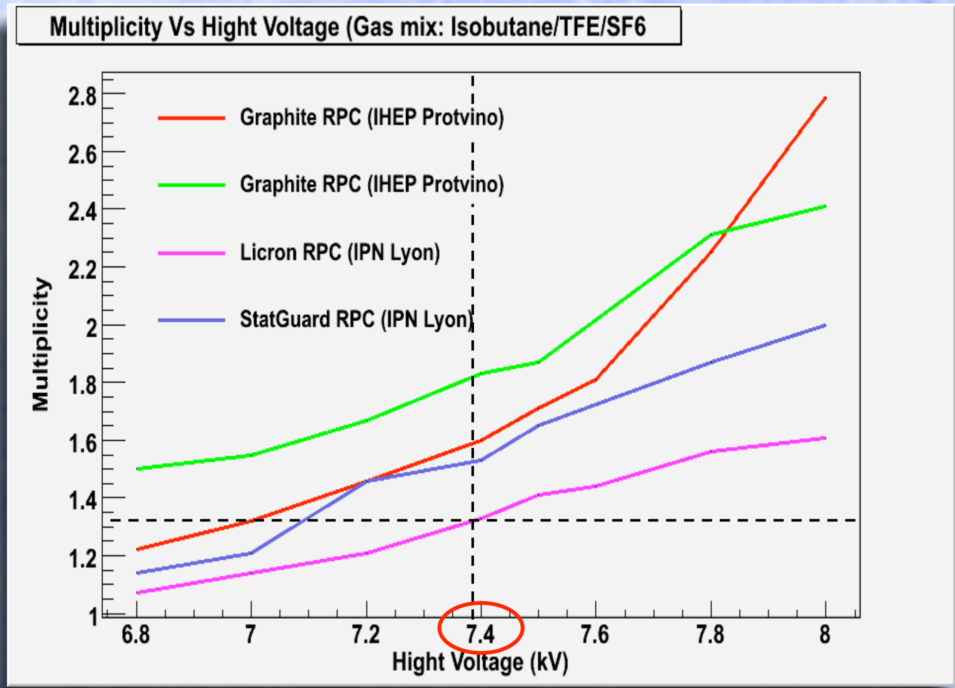
PS T10	17-24 July	260 kEvents
PS T9	28 July - 4 August	80 kEvents
PS T9	7-12 November	65 kEvents

Selecting events



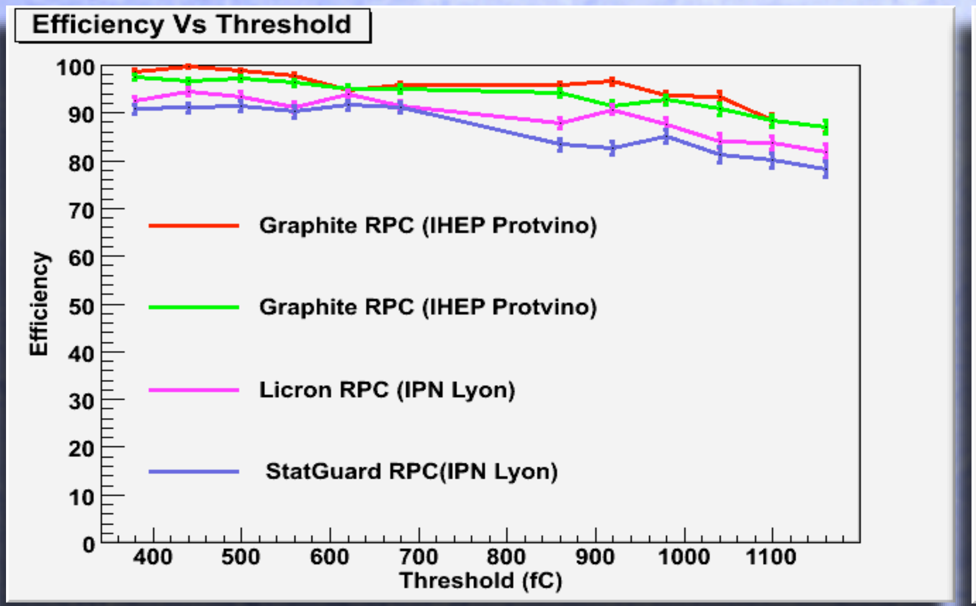
High Voltage scan

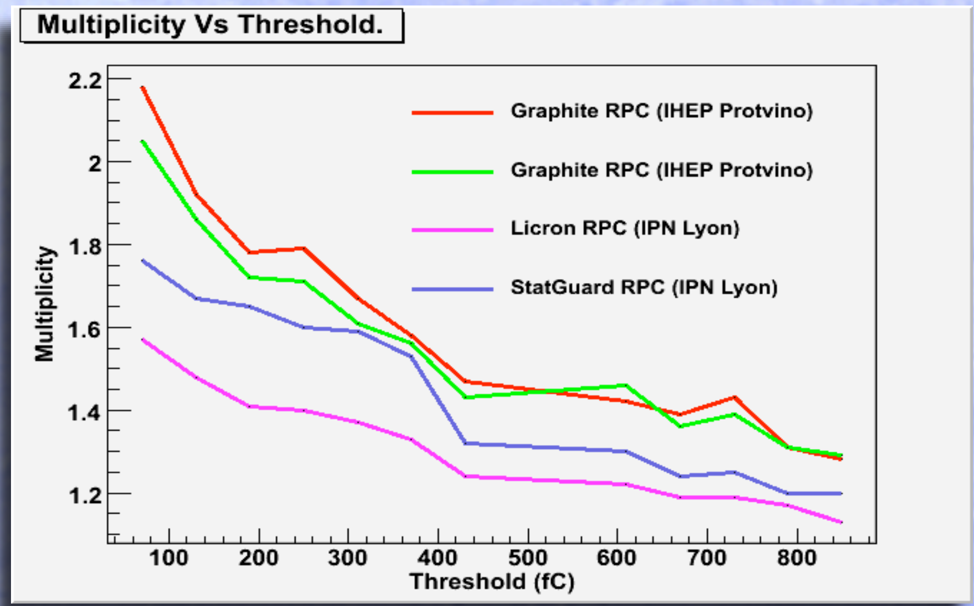




- DAC's **Thresholds**: lower 120 fC / higher 450fC
- **Plateau:** 7.2 to 8 kV
  - -> Efficiency between 80 and 98%
- Lower multiplicity is preferred.
  - -> Best ratio multiplicity/efficiency: around 7.4 kV
- Until now the licron coated detector seems to be **the best candidate**:
  - -> it has the **lowest multiplicity** and shows **very good efficiency** performance.

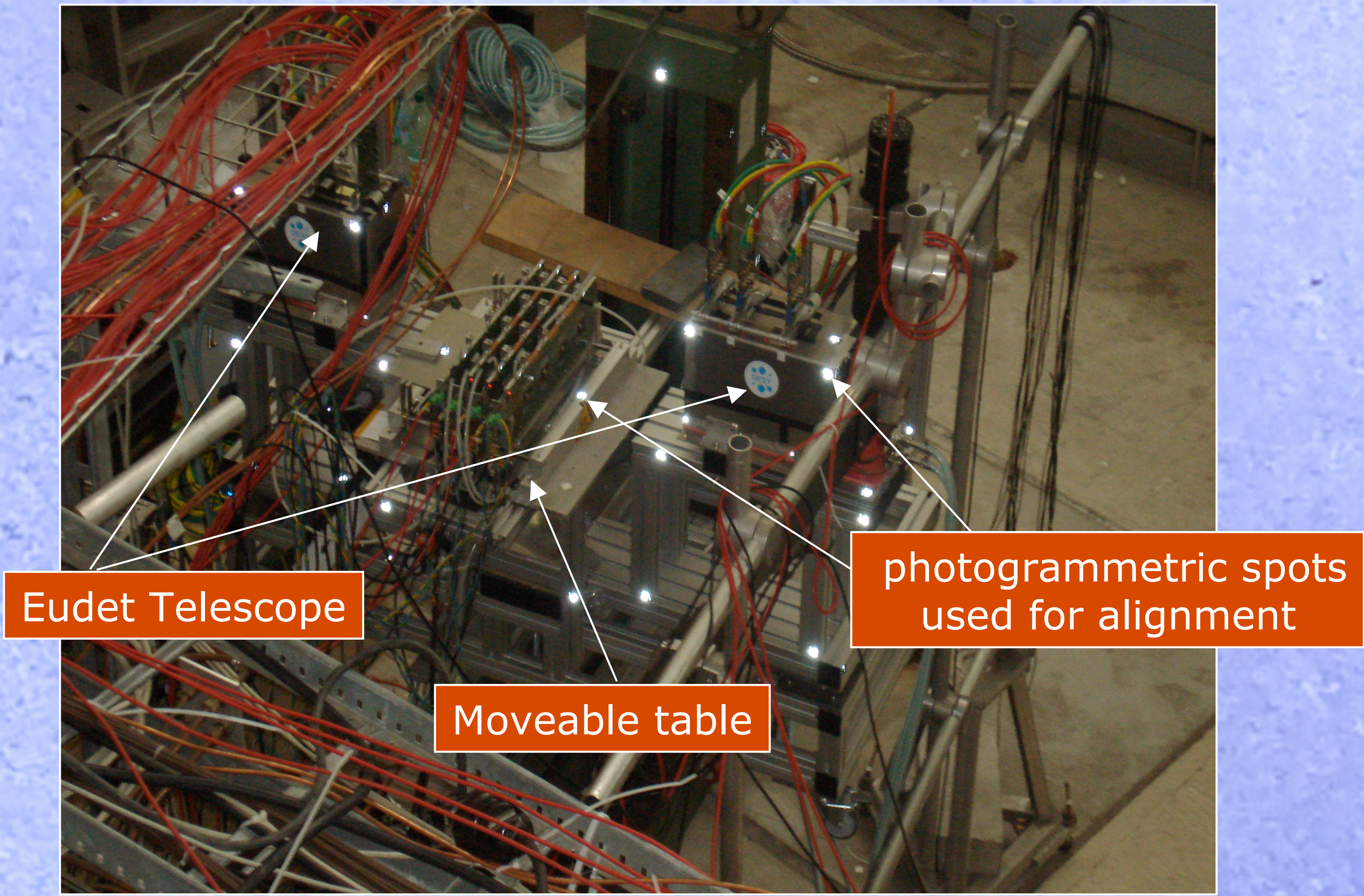
Threshold scan



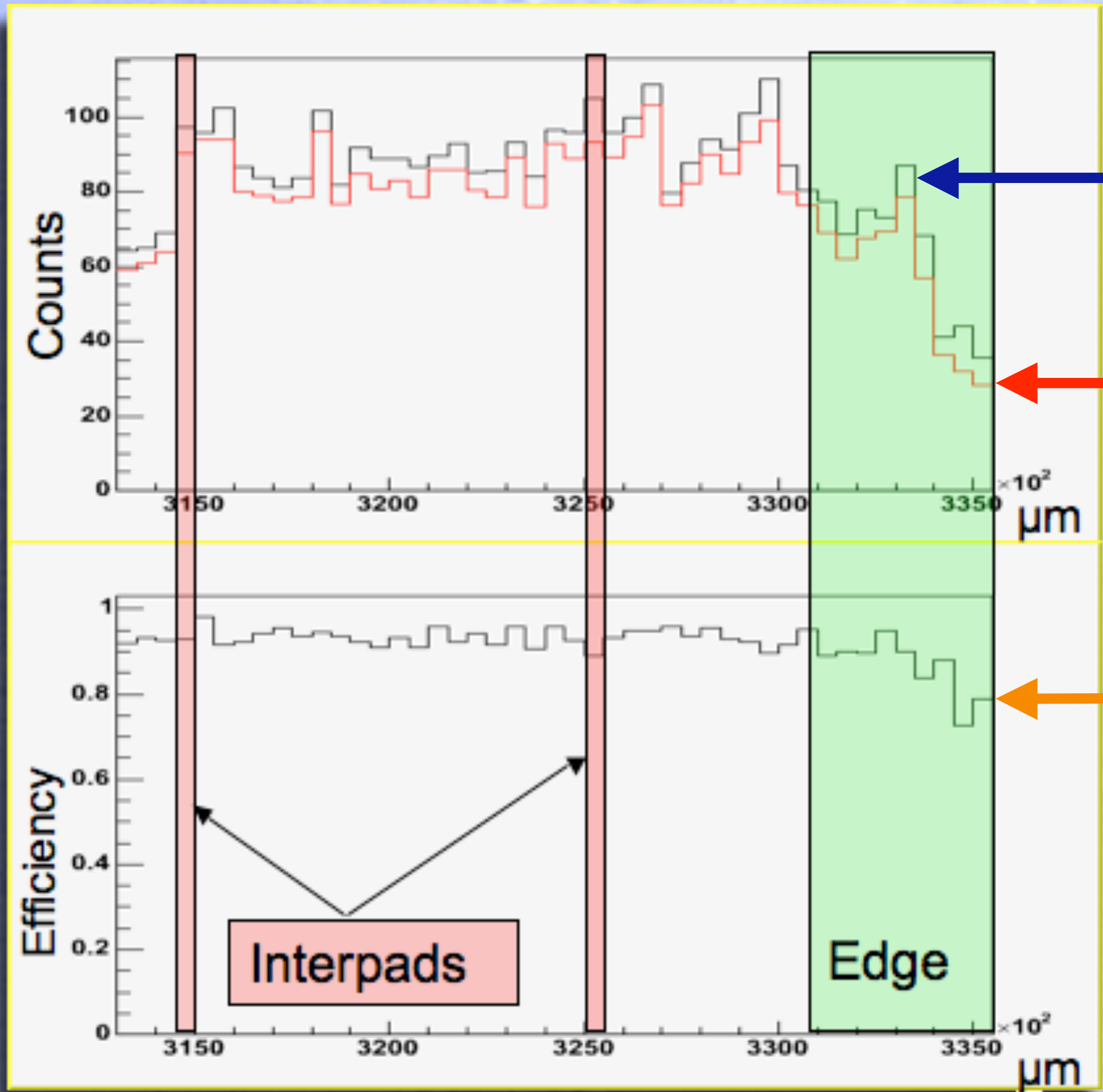


- Multiplicity moving as expected => **lowering as threshold increases.**
- Efficiency **decreasing** down to 80% at 1.1 pC threshold.

Use of EUDET Pixel Telescope



Use of EUDET Pixel Telescope



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

Red : matched digital hits (EuTel + GRPC)

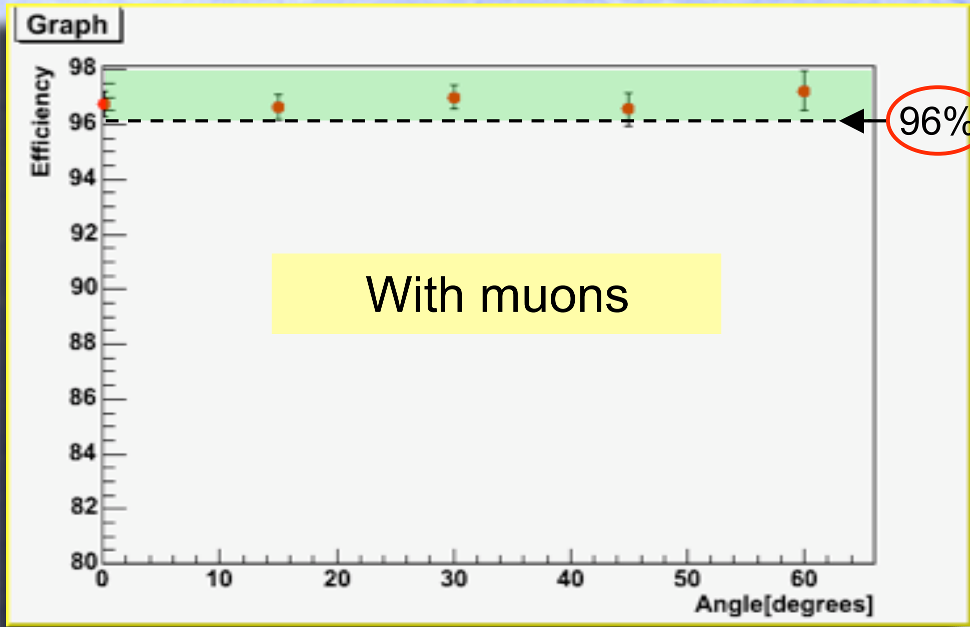
Efficiency: Red/Black

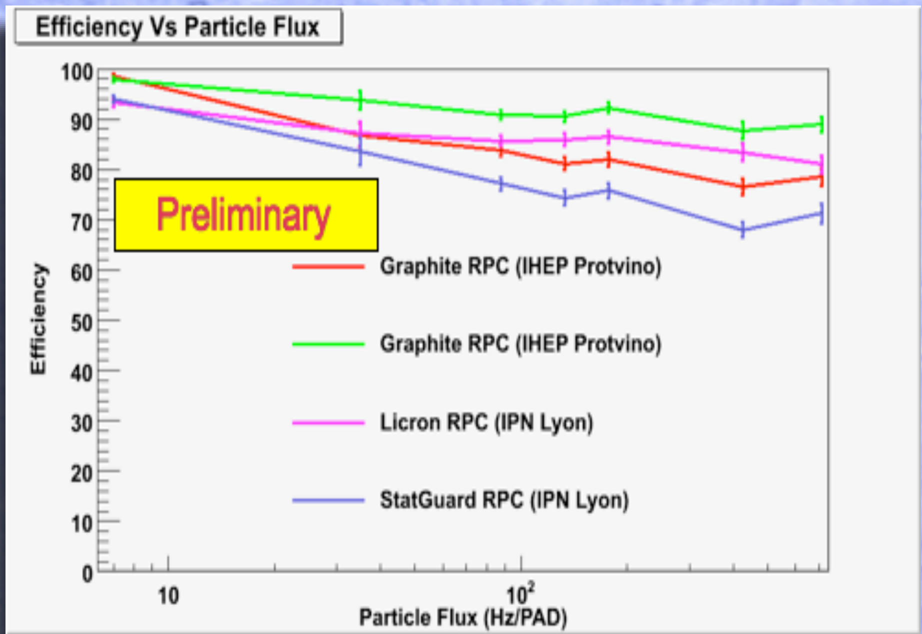
Using EuTel, we can evaluate efficiency on the detector edges, and between two pads.

Other studies

Angle scan:

- Efficiency quite constant, even for large angles.
- It allows good reconstruction in detector's end-caps.

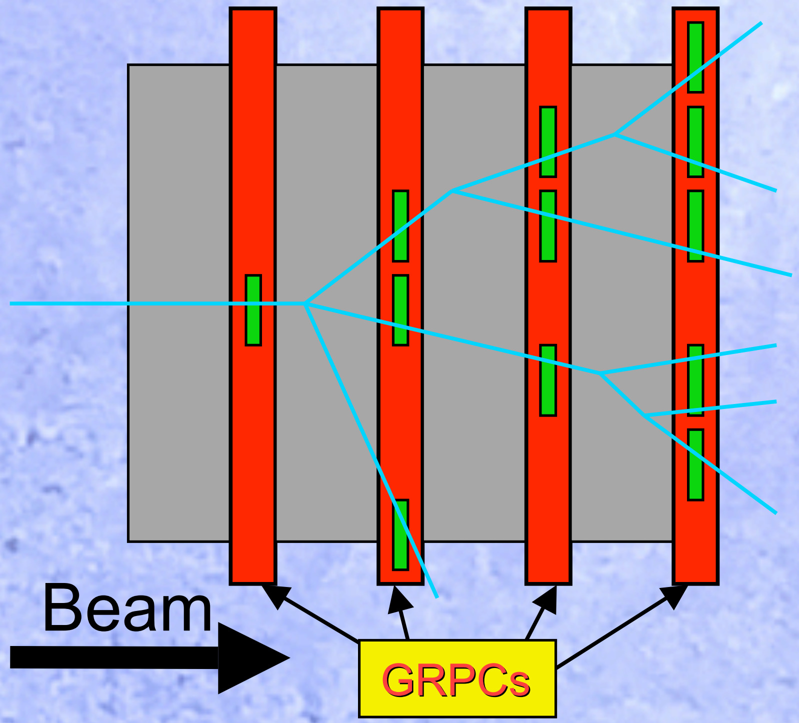


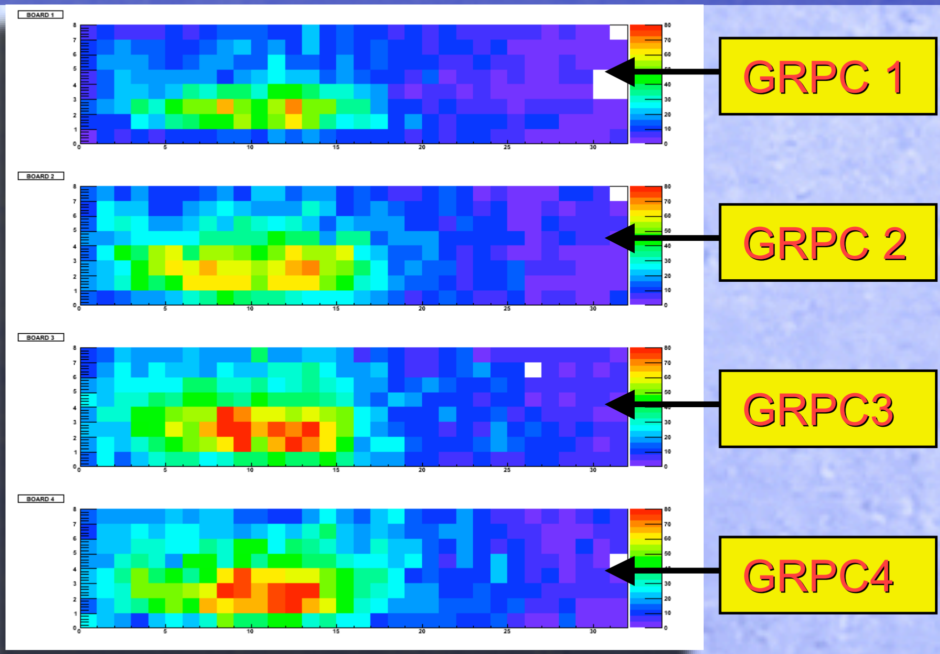


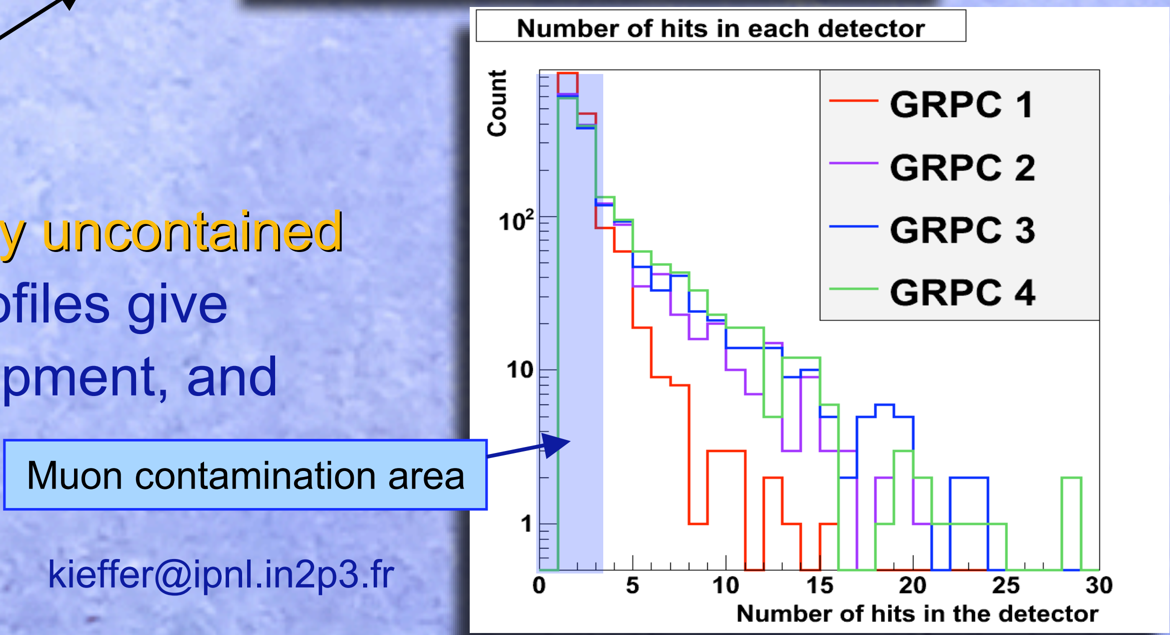
Evolution of performances with particle flux :

- Me made some correlation with particle flux (obtained with scintillators), and chamber's efficiency.
- It gives us some preliminary results about GRPC running in ILC beam conditions.

Hadronic showers

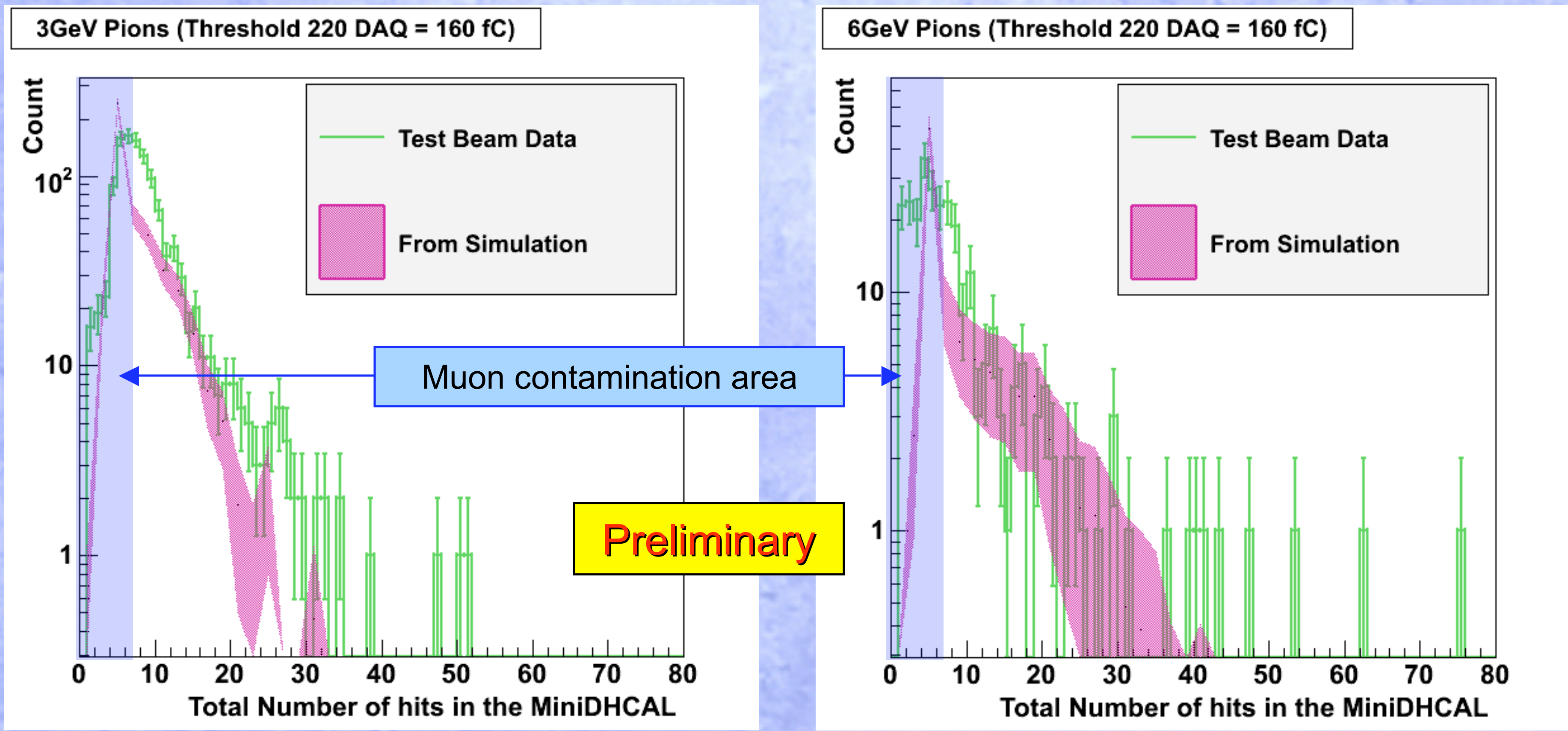






Hadronic showers are mostly uncontained in Mini DHCAL but these profiles give a first idea of shower development, and energy deposition.

Hadronic showers Vs Simulation



Here are the distribution of **hit's total number** in mini DHCAL for test beam data and simulated data.

Test beam summary

Total data: 325 kEvent (First DAQ's rate 20Hz)

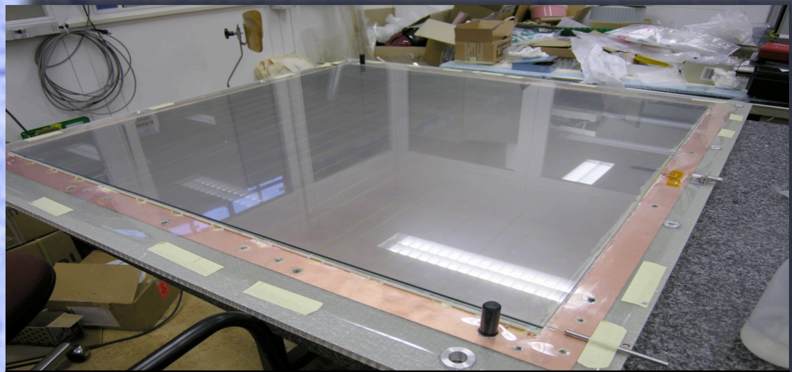
- Most part of the data analyzed.
- **Best understanding of our detector**, leading to realistic 1m2 detector development.
- We learn a lot about DAQ in beam conditions.
- That was the first record of hadronic showers in a $1cm^2$ **Mini DHCAL**

Current development: 1m^2 GRPCs

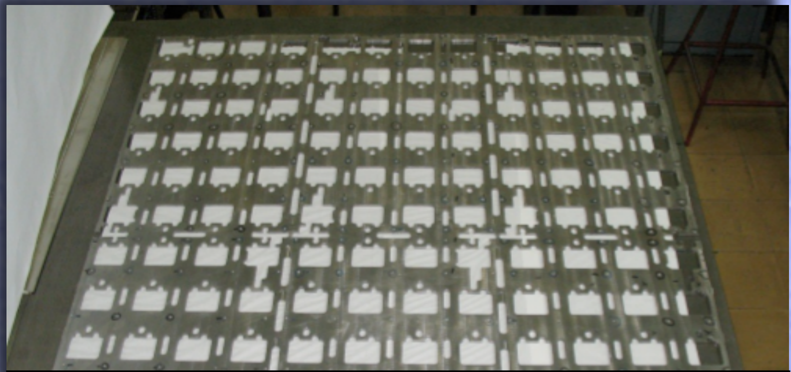
Lyon GRPC (licron coating)

Lyon GRPC (statguard coating)

1m2 GRPCs were built with **different options,** and a mechanical structure as been done by CIEMAT to **support electronics**.

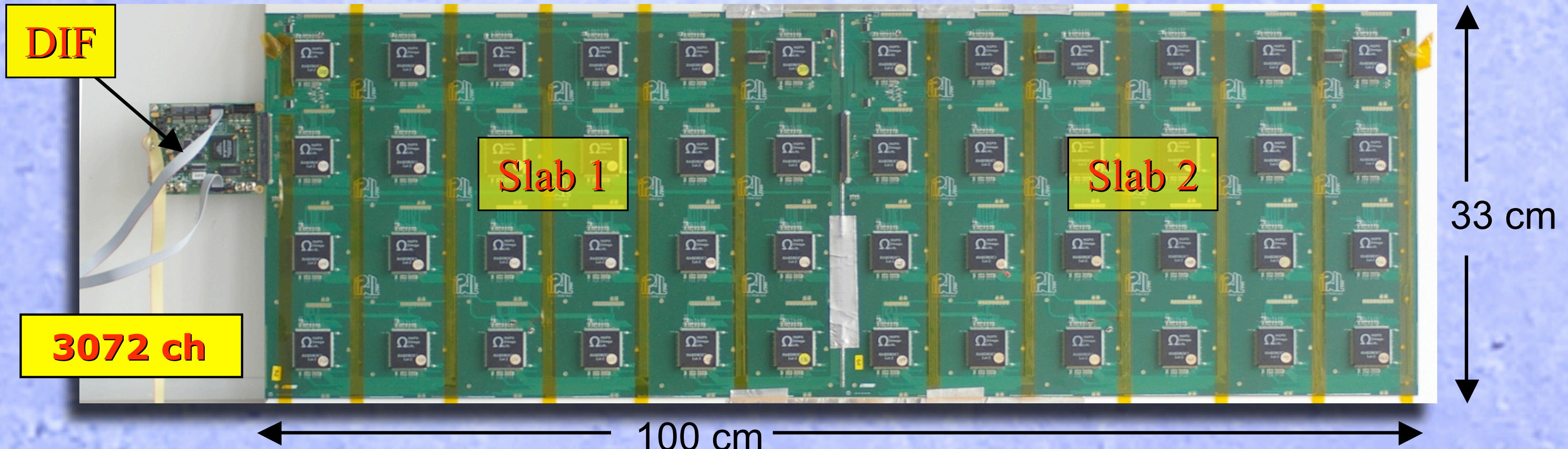


Multigap GRPC (INFN bologne)



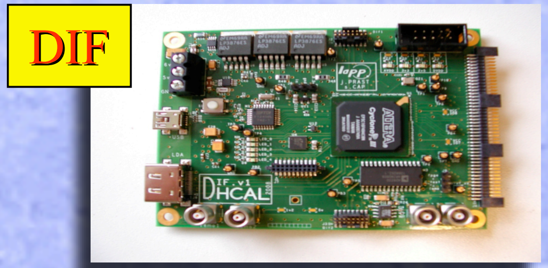
Mechanical support (CIEMAT)

Current development: 1m² DAQ



DIFF+ASU:

- 6 slabs of 24 asic each, were produced and equiped whith **HARDROC1**.
- Slabs connected 2 by 2 using "zero" resistors.
- Software using Xdaq/USB was developed (as debug mode).
- **Slow control & data acquisition** were successfully tested ! (in cosmic mode).
- More info on DAQ see C.Combaret's talk.



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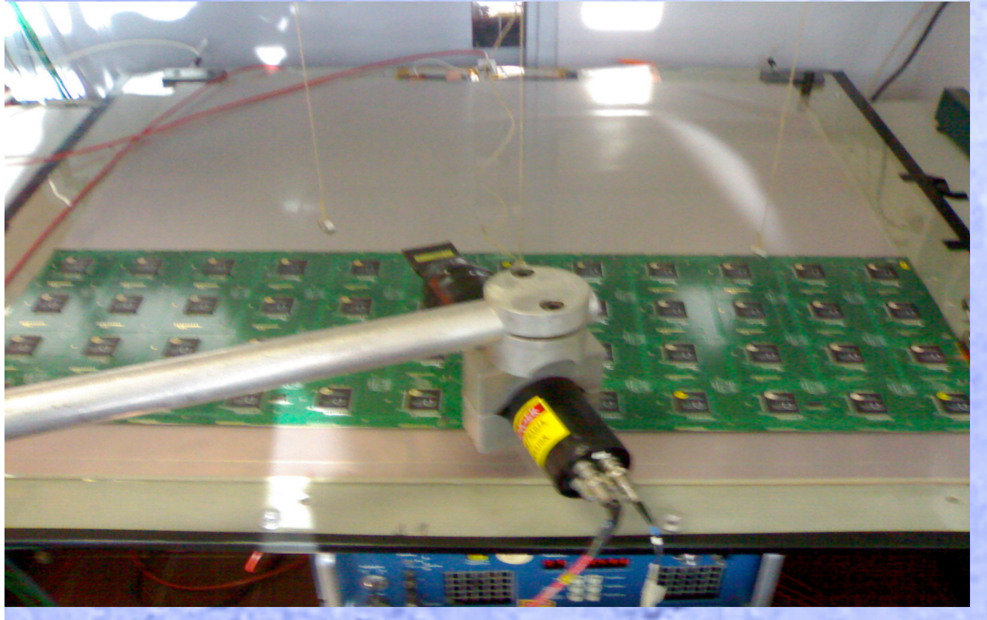
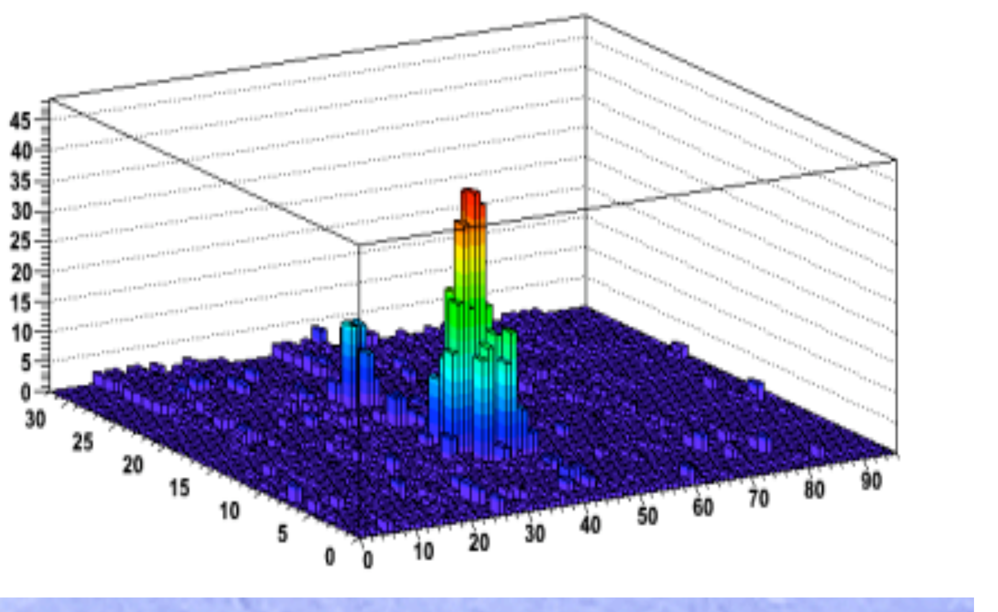
$1m^2$ Cosmic tests

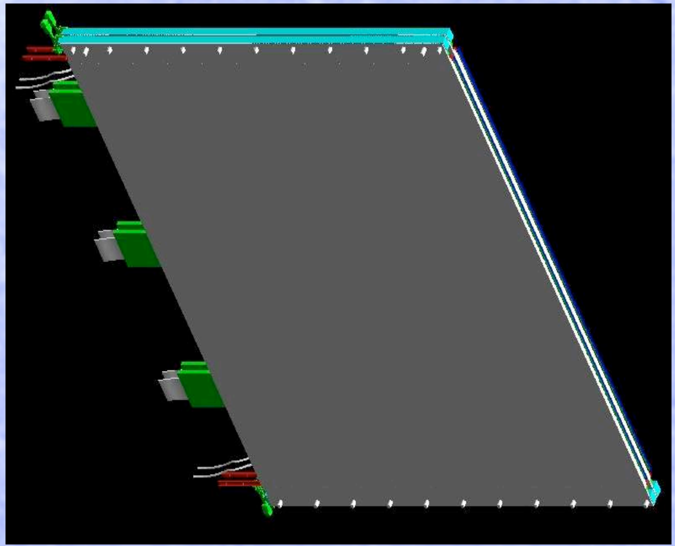




First data taking on a large detector, using cosmic bench (scintillator trigger)

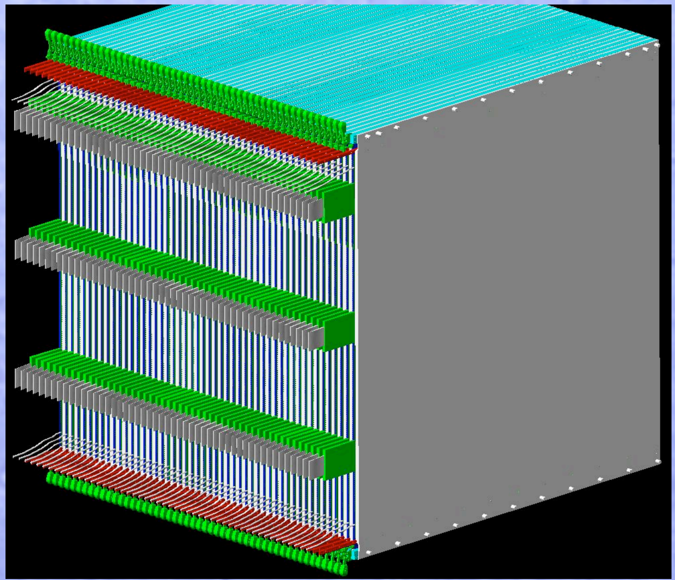
Next step: 1m^3 Project

The aim is to build a realistic prototype, validating the technological solution we propose for the ILD concept.



Technological prototype is made with:

- 40 planes of 1m^2
- One plane composed by:
  20 mm s.steel absorber + 6 mm GRPC/PCB
- A mechanical structure supporting the planes.
- A parallel gas distribution system.

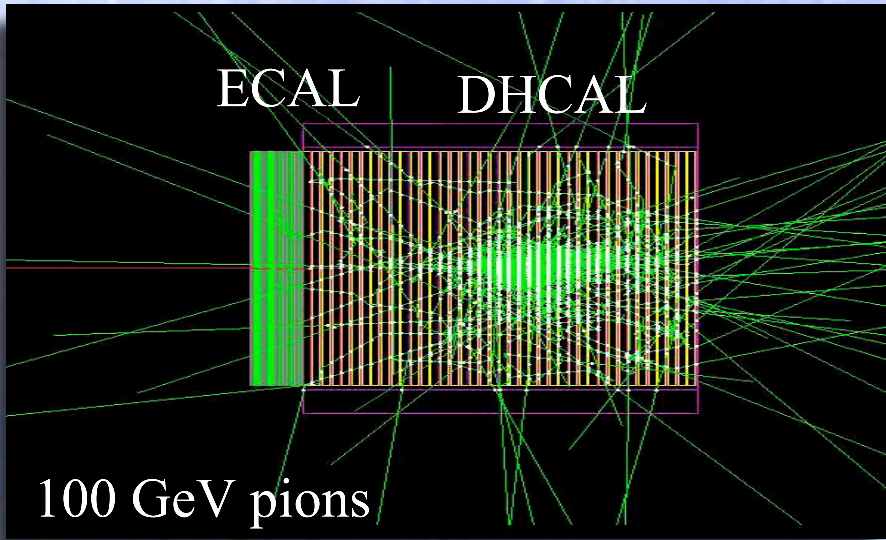


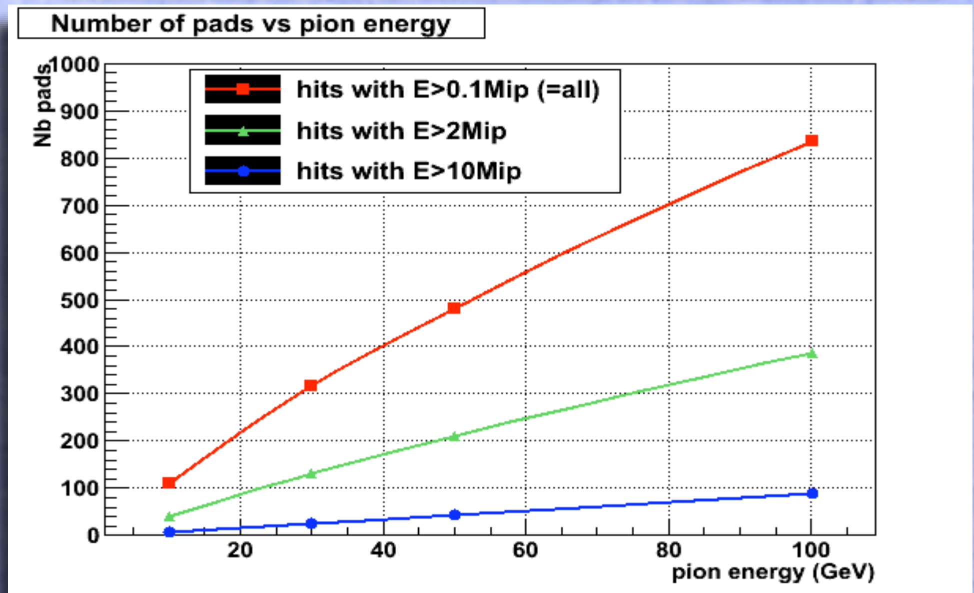
Important points:

- Mechanical structure development:
  1m^3 of (Absorber+GRPC) is about **6 ton** weight.
- Use of gas system with re-cycling option.
- Semi Digital readout of 368.640 channels **:**
  DAQ, event buiding, & data storage.

$1m^3$ containment simulations

- With a **$1m^3$ DHCAL**, hadronic shower could be mainly contained, even for high energy pions (about 100 GeV).
- We already try to evaluate the **energy deposition** to help the $1m^3$ design.
- The 40 planes of 9216 channels each, will permit us to have the complete profile of the showers, with a very high granularity.
- As the **HARDROC2** will have 3 thresholds, we try to evaluate the number of fired pads for different thresholds values, to better reconstruct the energy.



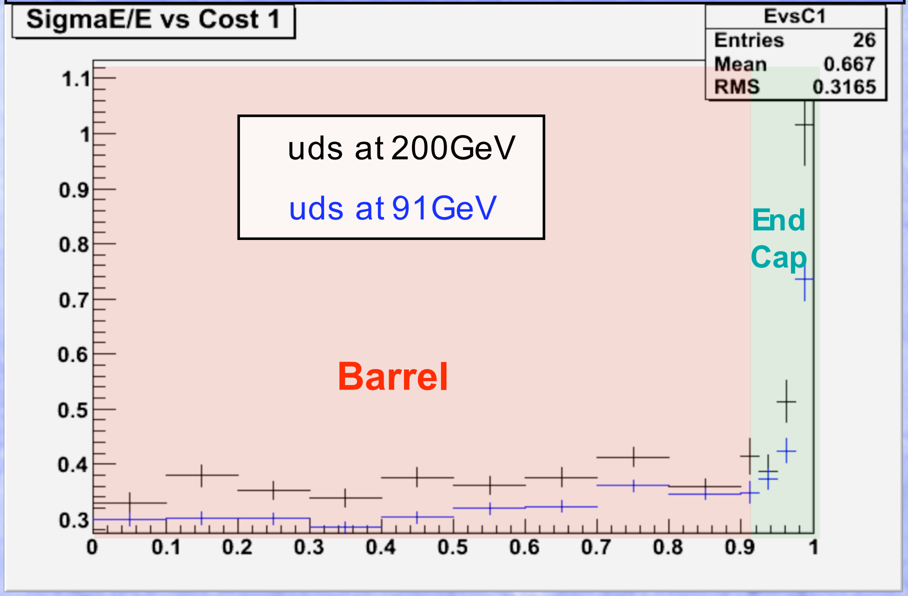


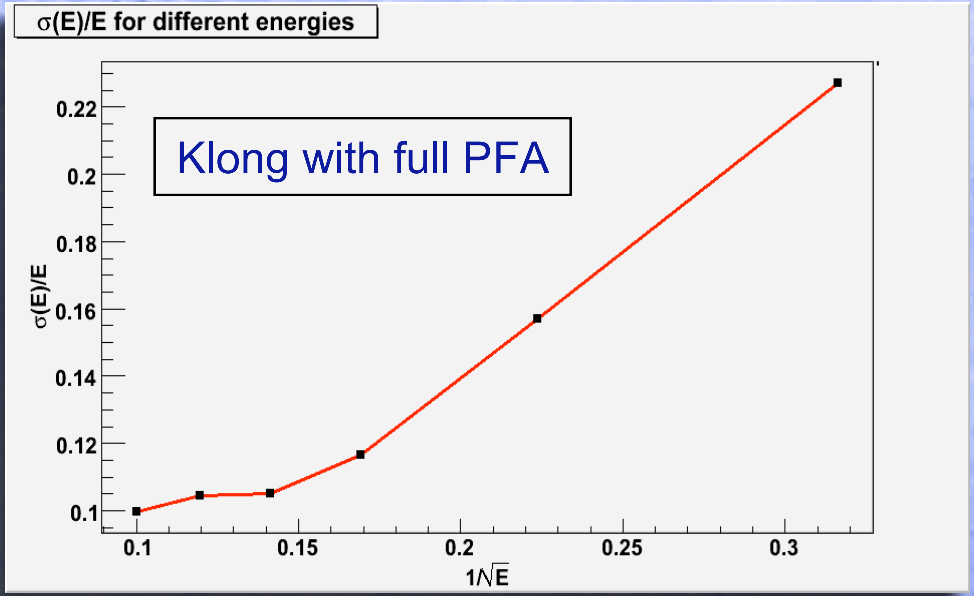
Simulations for an ILD integration

- Simulations were done with Mokka software integrating DHCAL geometry. **Event produced:** single klong & uds.

- First analysis was done using Marlin with single threshold at 0.1 MIP in Mark Thomson's PFAnalysis module.

Detector's resolution through polar angle





SemiDigitalHCAL with PFA:

- **P**article **F**low **A**lgorithm need to be optimized to use the **full potential** of a multi threshold DHCAL.

- More work has to be done for it.

Conclusion & Outlook

An hadronic calorimeter with semi-digital readout is a very promising candidate for future linear colliders experiments !

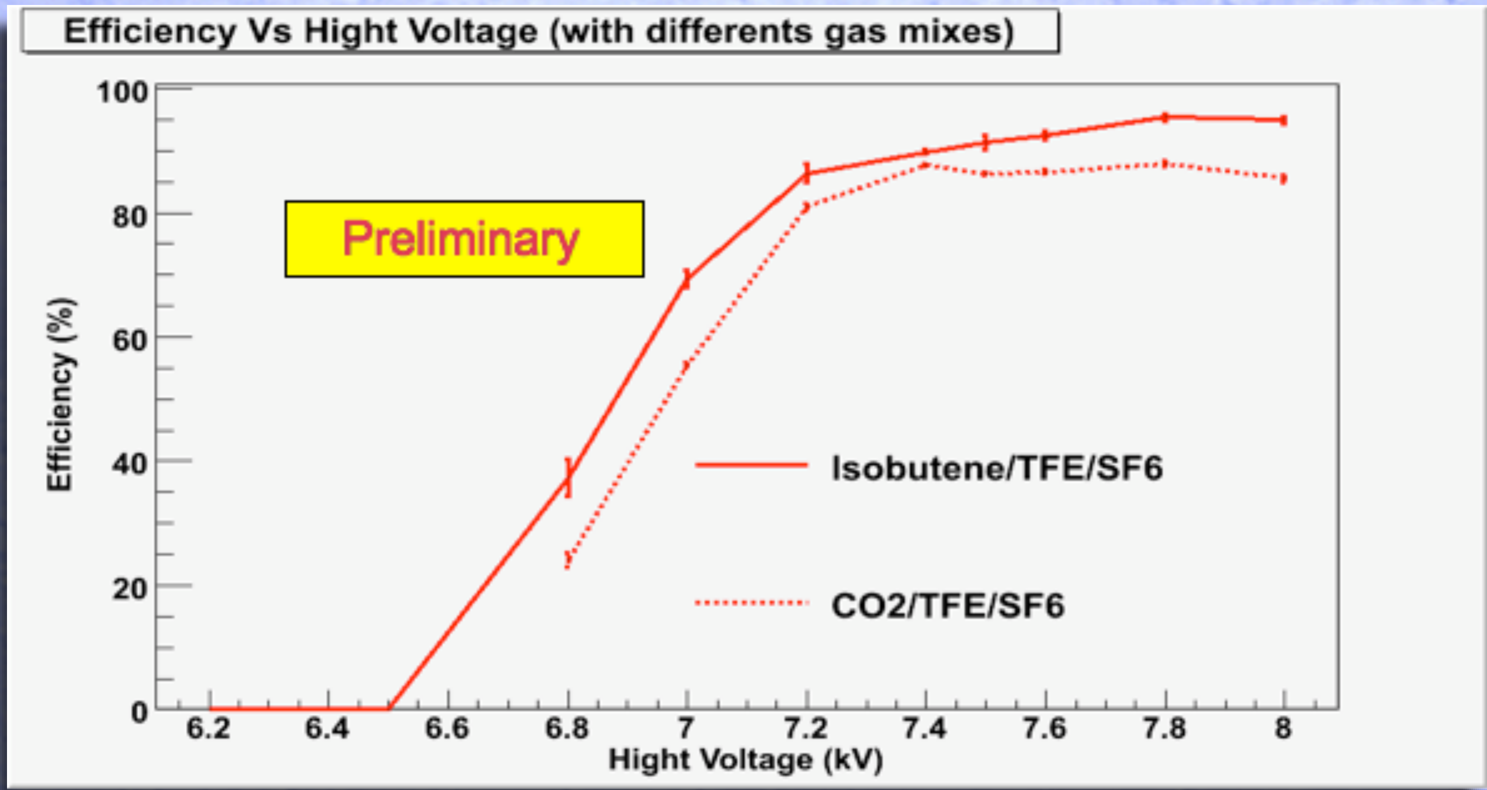
- We **learn a lot with** test beams.
- $1m^2$ chambers have been produced **minimizing dead zones**.
- Electronic was tested for both **small chamber** (test beam), and **$1m^2$** ones (cosmic).

Outlook & plans:

- Bring $1m^2$ chambers fully equipped on test beam at CERN (End of June)
- Use CERN's Gamma Irradiating Facility to learn about **detector's lifetime**.
- Start $1m^2$ **chambers production** for the $1m^3$ prototype (40 to be done)
- Built $1m^3$ mechanical structure
- Have a **test beam with $1m^3$ in second half of 2010**
- Improve PFA algorithms to optimize reconstruction.

Thanks for your attention.

Other studies

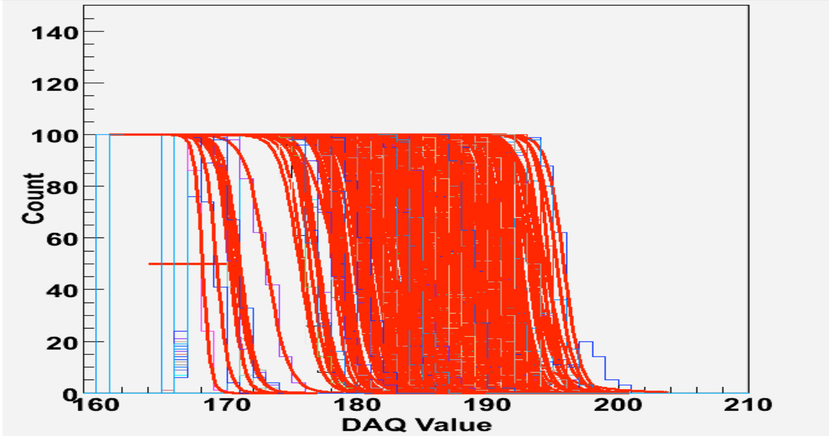


The **first tests** using CO_2 to **replace isobutane** are quite promising.

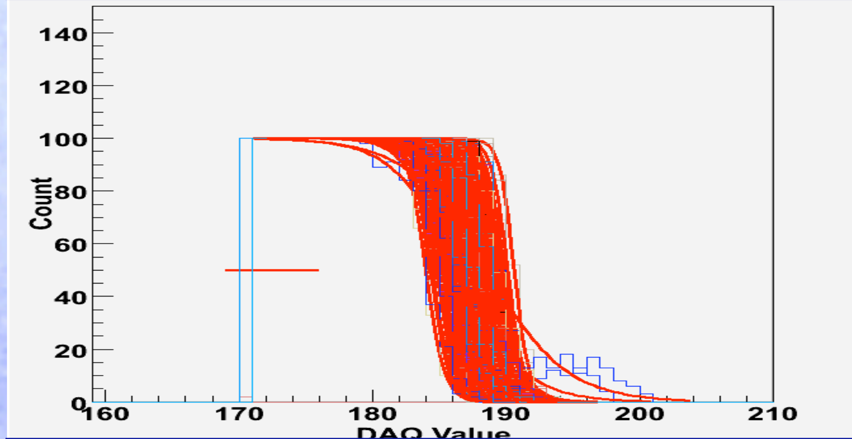
(Gas mix with $C0_2$ will be intensively tested next test beam)

Readout Calibration

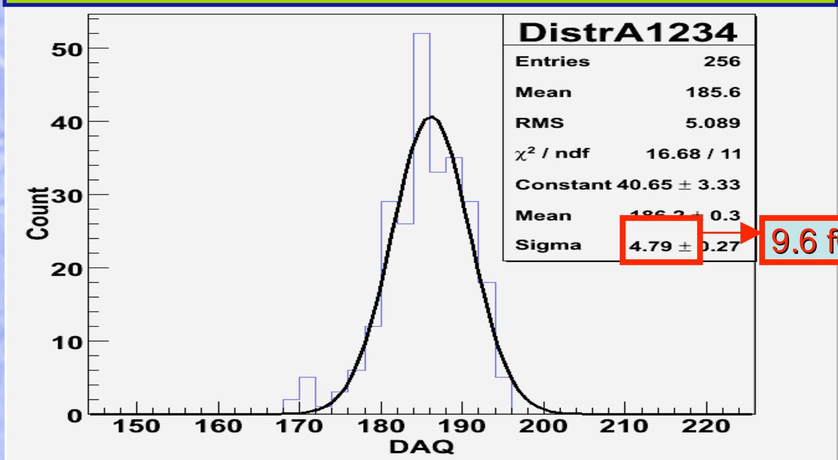
256 channel's SCurves (before correction)



256 channel's SCurves (after correction)

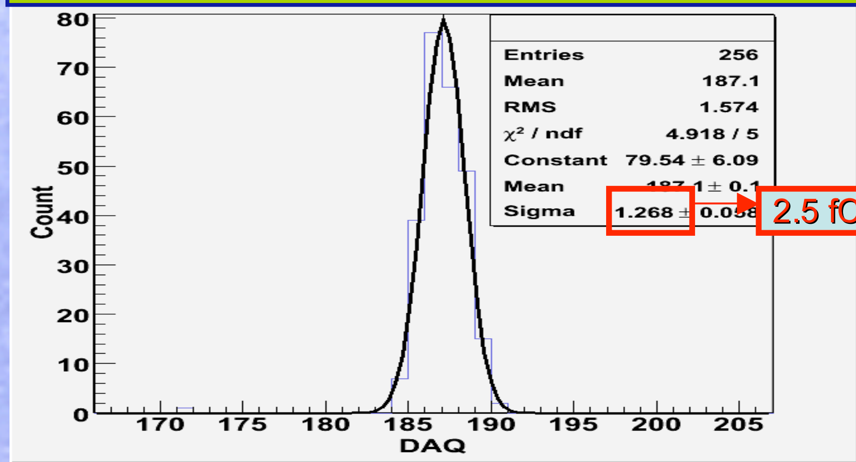


Threshold distribution (before correction)



9.6 fC

Threshold distribution (after correction)



2.5 fC

1DAQ = 2±1 fC (Injected charge: 100 fC)

Reduction of channel dispertion by a factor 3