Test beam studies for a Highly Granular GRPC Semi-Digital HCAL

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(on behalf of the CALICE collaboration)

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Motivation

Highly Granular GRPC Semi-Digital HCAL

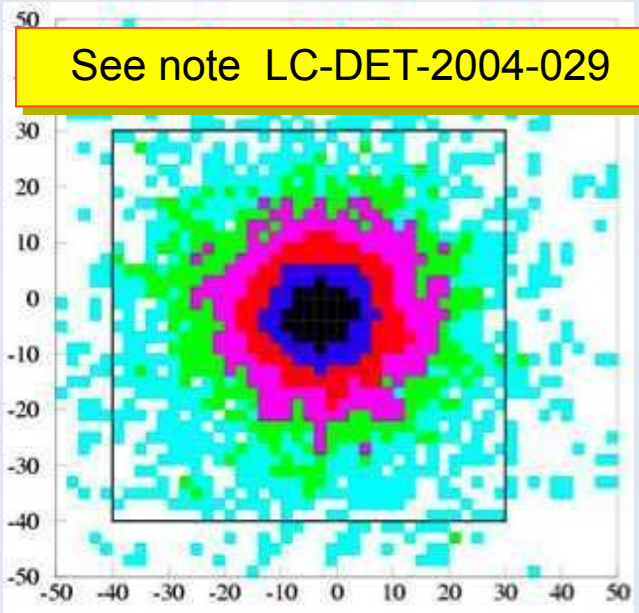
Particle Flow Based
- 1×1 cm² × 48 layers
- Imaging calorimety
  - Tracking in calorimeter
  - Energy loss recovery (see Henri's talk)

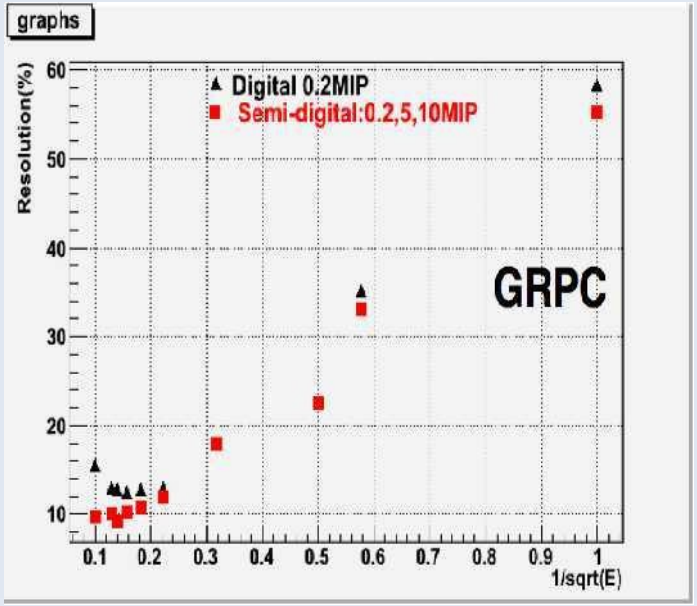
Gaseous calorimetry
- Lower sensitivity to *n*
  - Narrow showers (99% of 100 GeV π in 70×70cm²)
  - Less fluctuations (wrt H containing con

GRPC's
- Cheap
- Simple
- Reliable
- Large uniform surface (calibration of 70M ch.)

2 bits per cell
- Simplified electronics
  - reduced cost
  - less heat
- Improvement of energy rec. at High E.

See note LC-DET-2004-029



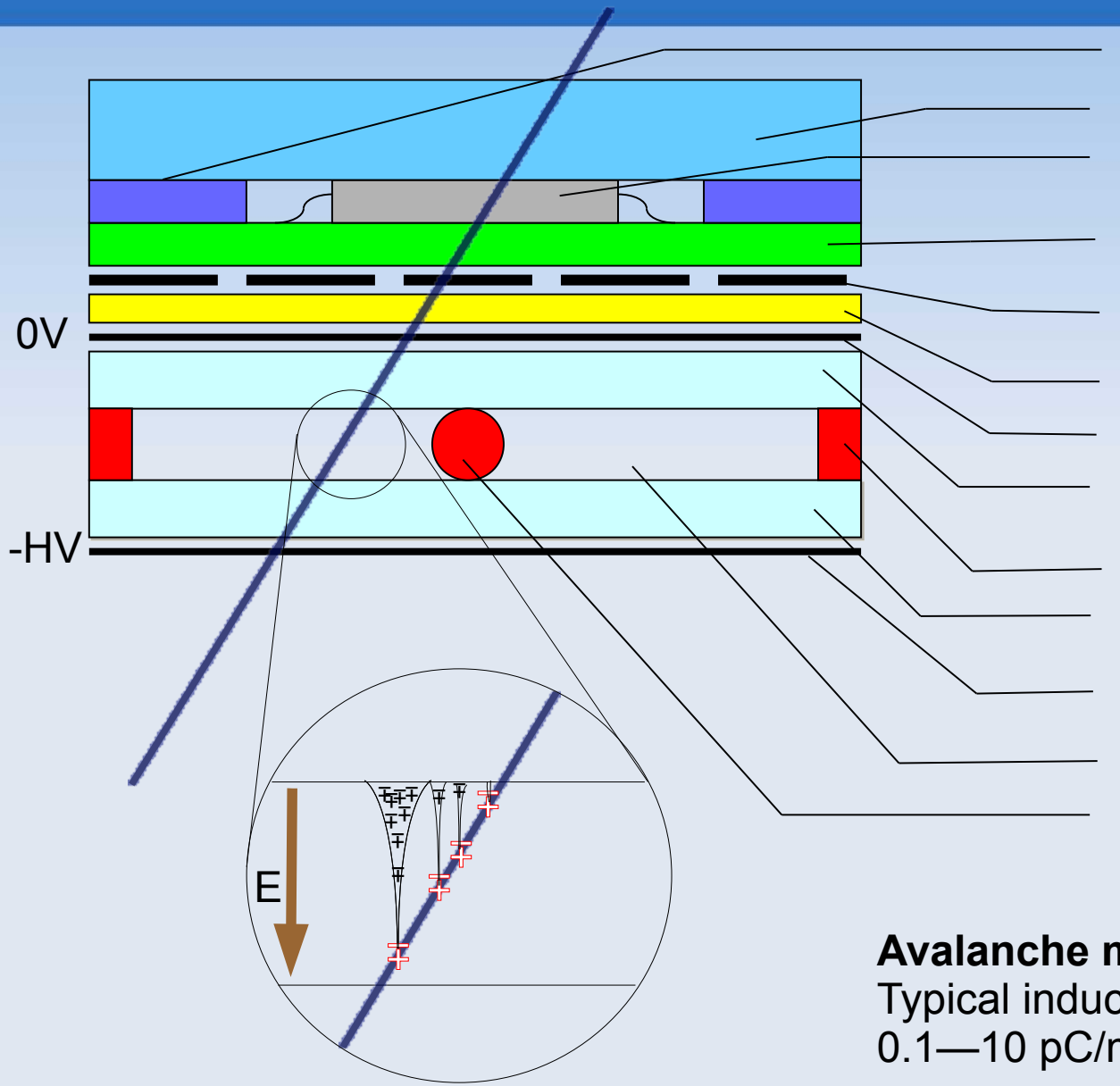


Motivation

- Check the elements for a Cubic meter project (I. Laktineh's talk)
  - 40 layers of 1×1m²
- Check critical elements for the ILD detector
  - Semi-Digital Energy reconstruction
    - counting → ε and multiplicity per track
    - 70 MCh → uniformity of detector
  - ILC mode (bunch train @ 5 Hz) → auto-trigger + local storage
    - Noise should be controlled
    - Rates

IPNL (France): M. Bedjidian, C. Combaret, G. Grenier, N. Lumb, I. Laktineh, R. Kieffer, M. Vander Dockt
LLR (France): K. Belkadhi, V. Boudry, D. Decotigny, M. Ruan
CIEMAT (Spain): M-C. Fouz, J. Puerta Pelayo
CP3 (Belgium): E. Cortina, S. Manai
FST (Tunisia): K. Manai
LAL-Omega (France): F. Dulucq, N. Seguin-Moreau, G. Martin-Chassard, Ch. de la Taille
TSINGHUA (China): Y. Wang, W. Ding

Glass Resistive Plate Chamber



Grid (Steel)

(Absorber (2 cm))

ASIC (HARDROC1)

PCB

Pads (copper, 1 cm2)

Insulation (Mylar)

Anode coating(~1 MΩ/□)

Glass plate (0.7mm)

Chamber wall (1.2mm)

Glass plate (1.1mm)

Cathode coating(~1 MΩ/□)

Gas

Spacer

Avalanche mode:
Typical induced charge of
0.1—10 pC/mip with rising time ~10 ns

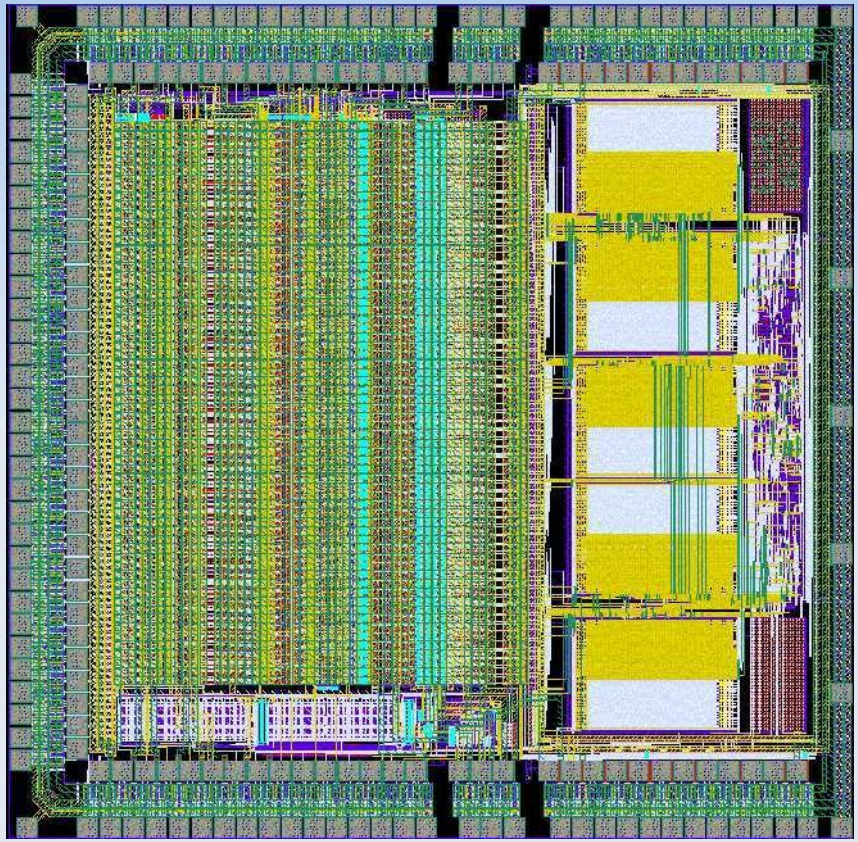
Prototypes

- Chambers
  - Gas:
    - 93% TFE → 8 ionisation/mm
    - 5% IsoButane (γ quencher)
    - 2% SF6 (e quencher)
  - Chambers:
    - 33.55×8.35 cm²
      - Float glass
        - Graphite, Licron, Statguard
      - Semi-conductive glass (Tsinghua U.)
        - Licron, Statguard
    - 1×1m²
      - Float glass
      - Colloidal Graphite coated (1-2 MΩ/□)

Coating	Resistivity [MΩ/□]
Graphite	0.4
Statguard	2
Licron	20

Electronics: HarDROC v1
(Hadronic Rpc Detector Read Out Chip)

- AMS SiGe 0.35µm, 16 mm²
- 64 channels
- Digital/analogue output
- 2 independent thresholds
- low consumption
  - ~7 µW/ch with 0.5% Duty Cycle
  - Power pulsing
- Digital memory
  - 128 events
  - ASIC ID (8b), BC ID (24b), hits
- Large gain range (6bits)
  - Channel wise
- X-talks < 2%
- Threshold ≥ 10 fC

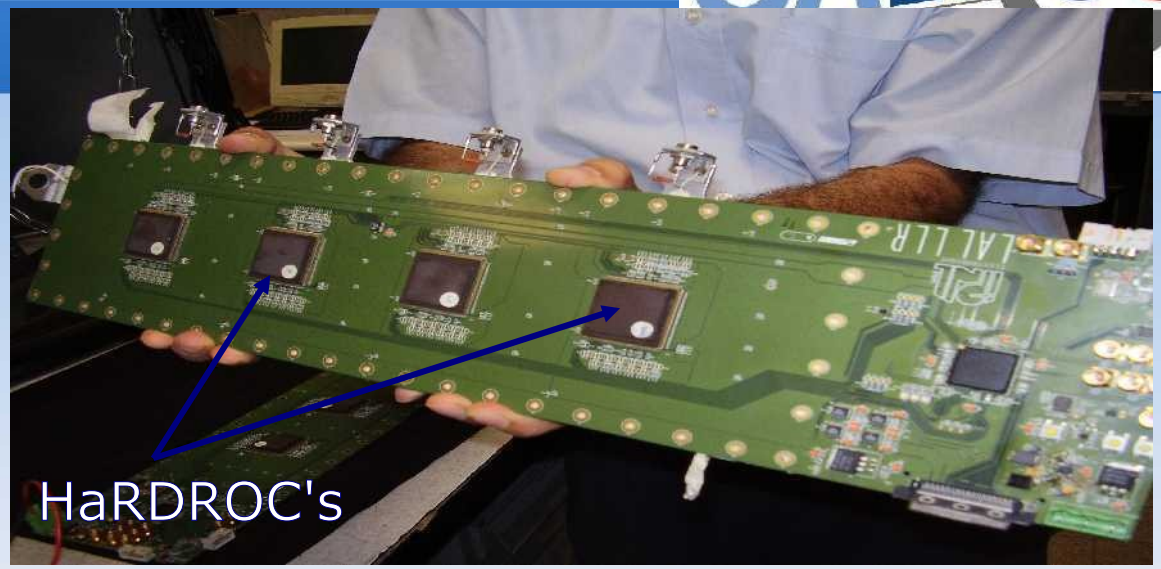


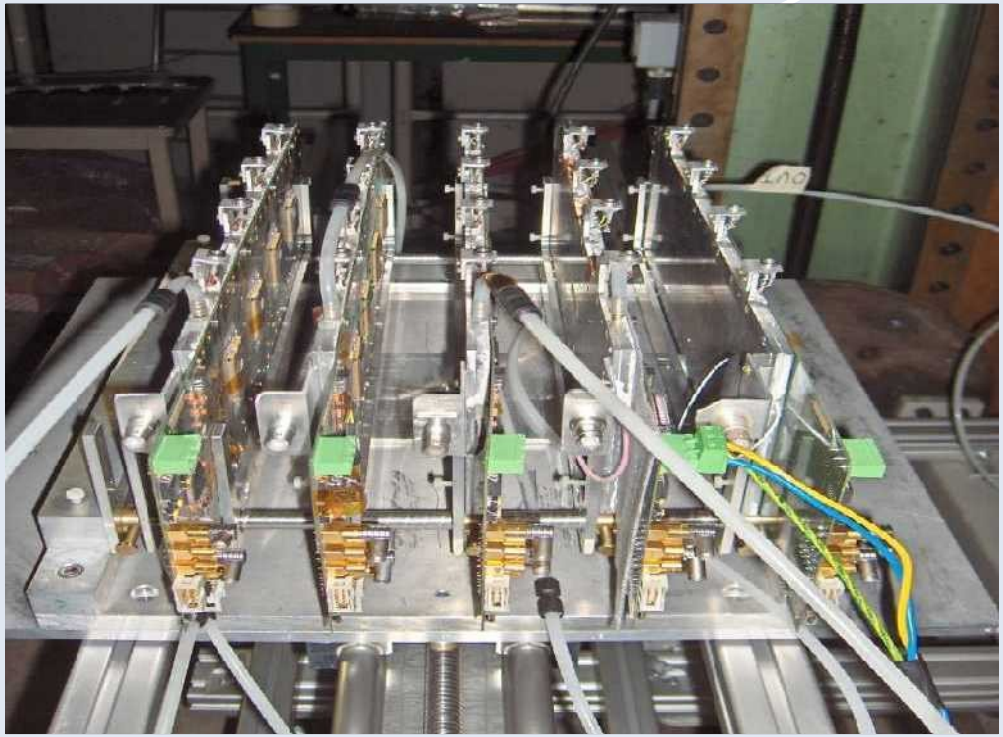
OMEGA-LAL

Check Ch. de la Taille presentation for a global view

Mini DHCAL

- **8-layer**, **800 µ** thick PCB
  buried and blind vias
  x-talk <0.3 %
- 4 hardroc chips
- Readout **FPGA** → USB
- **8×32** pads detector





Acquisition modes :
With auto-triggering
a) Train (ILC mode)
(sync @ start)

b) External trigger :
cosmic rays & test beam
(sync @ stop)

Data output:
digital and analogue

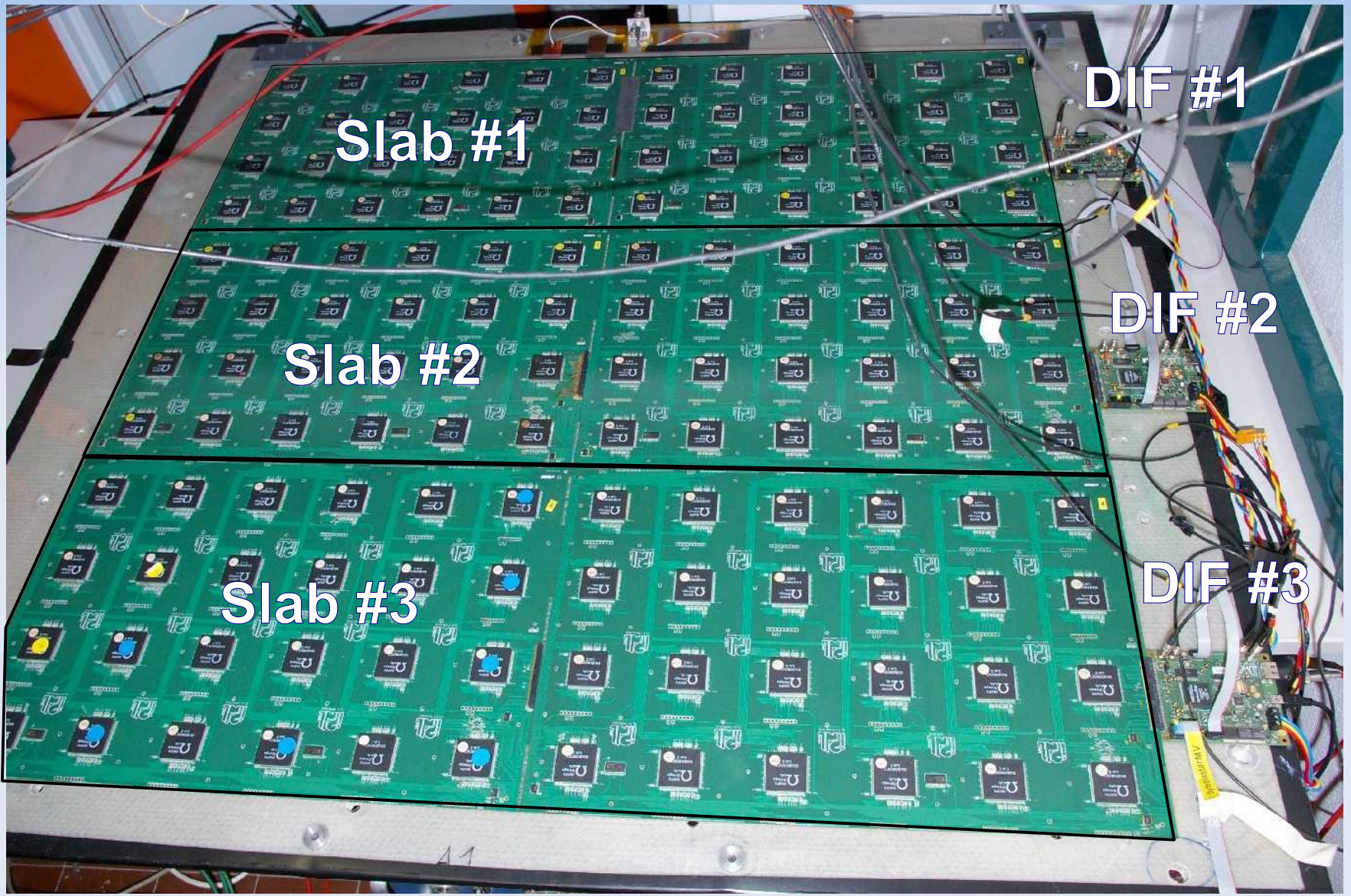
The 1 m² electronics

DIF (Detector InterFace)
- 10-layer board (6 for signals)
- Designed for the future DAQ of the CALICE collaboration

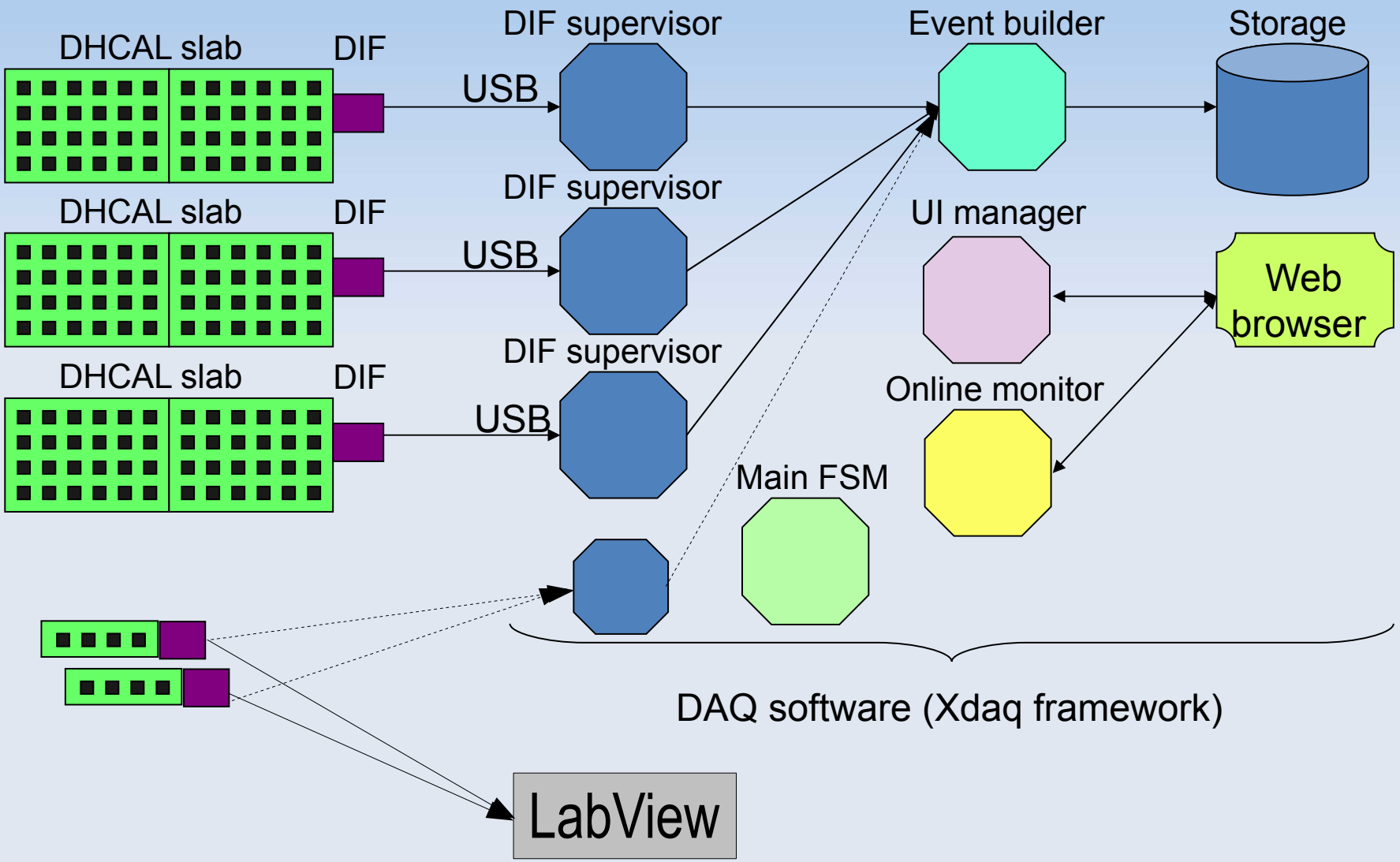
ASU (Assembly Single Unit)
- 8-layer board
- 500×33.3×1.2 mm³
- Connections between adjacent PCB

Acquisition Software
based on Labview & XDAQ
USB readout

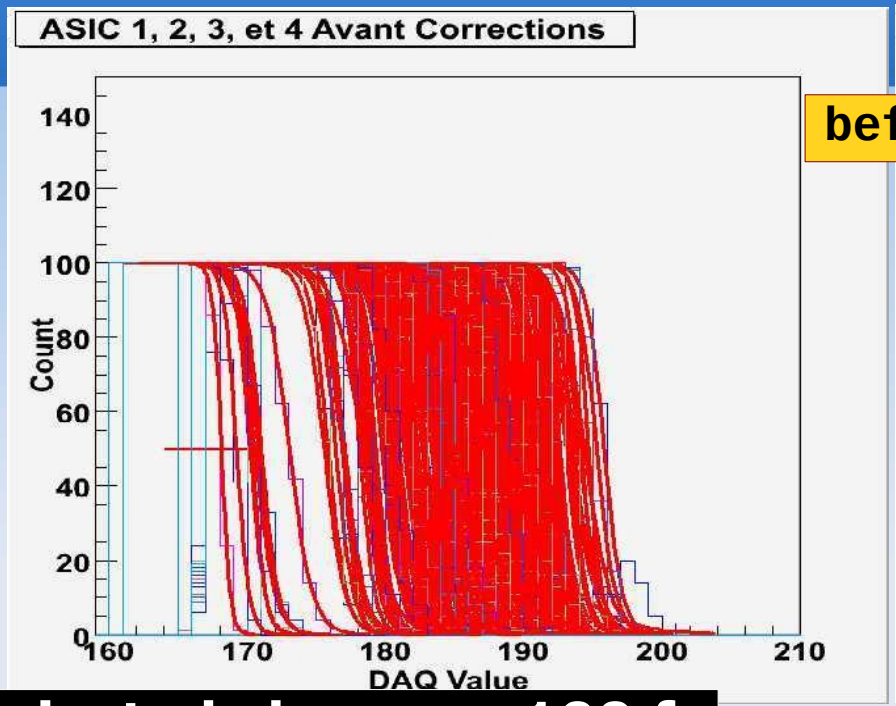
1 m² of equipped detecto



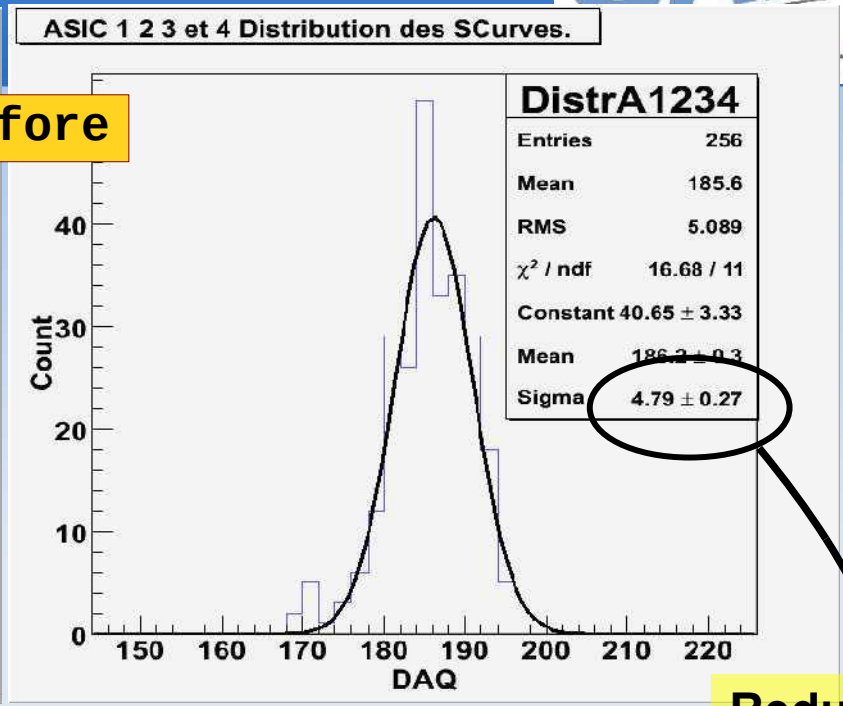
DAQ Schematic view



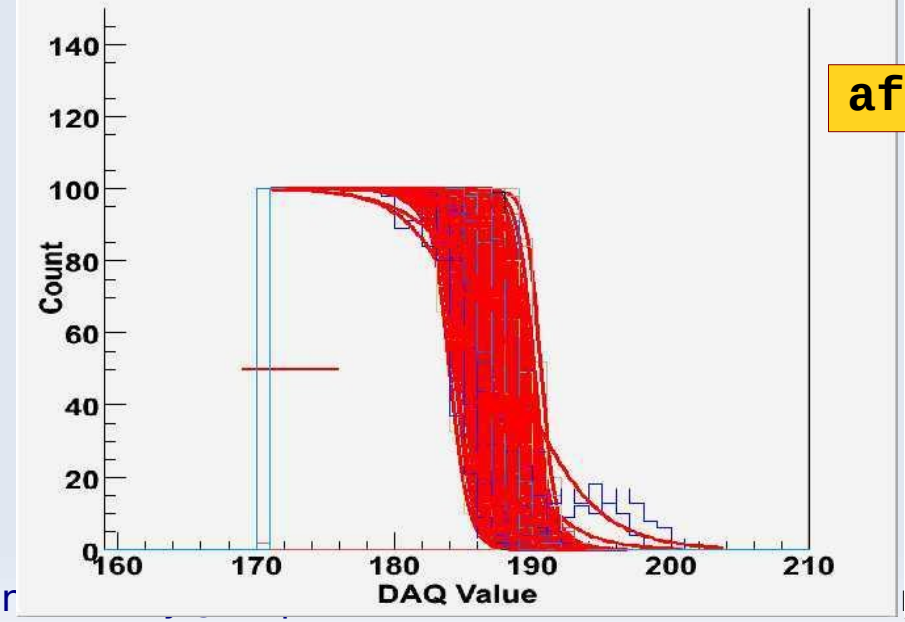
Gain correction



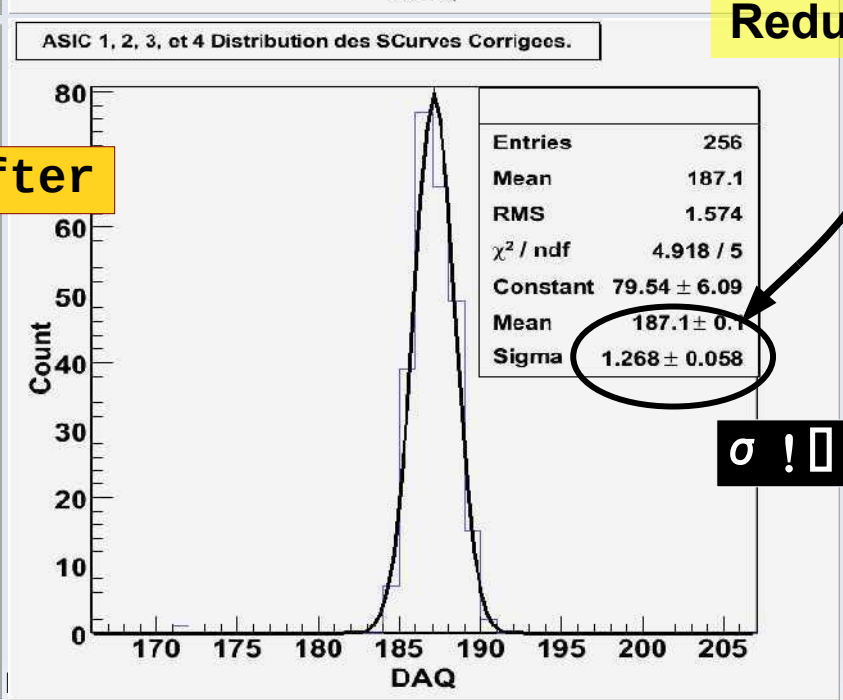
before



Injected charge = 100 fc



after

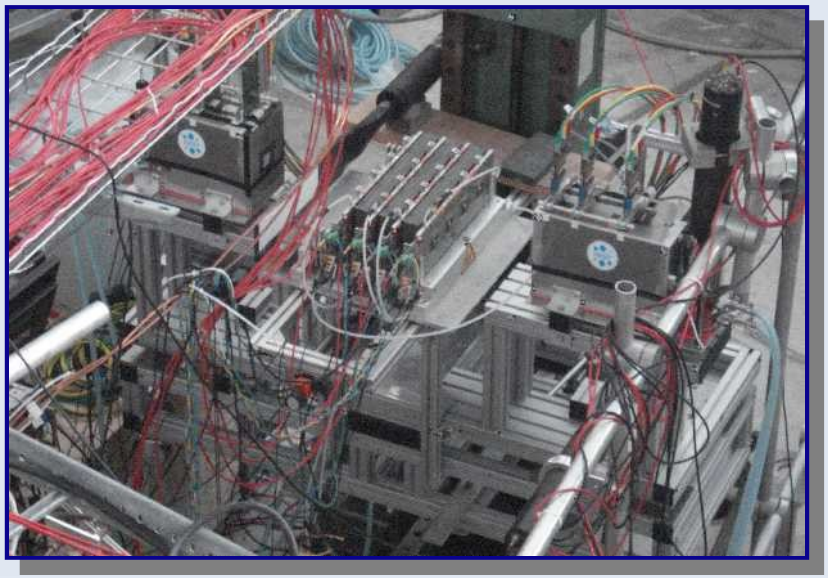


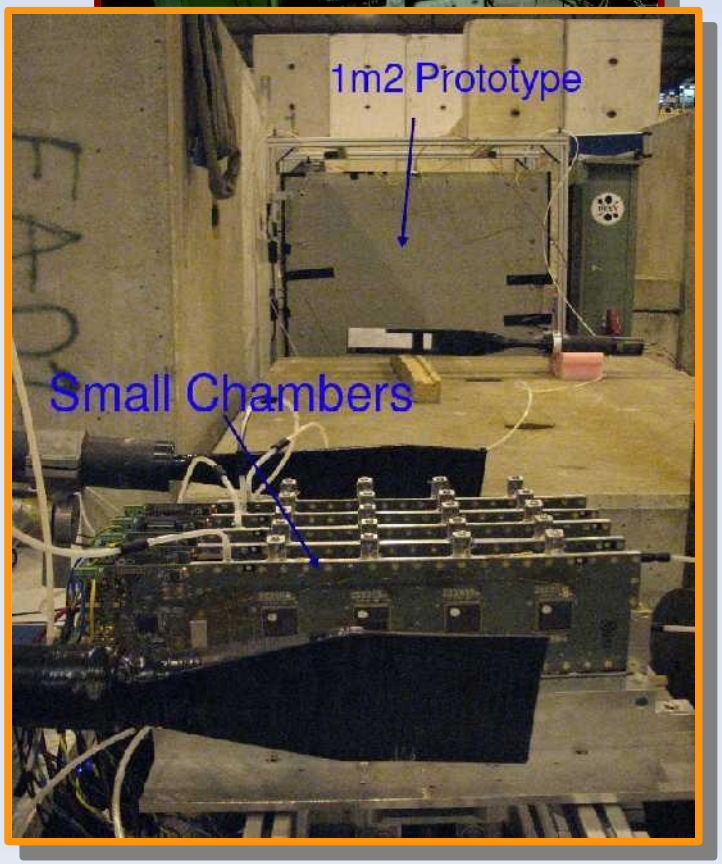
Reduction:4

σ ! 2.5 fc

Beam tests

2008	July/August **Mini sDHCAL** *340k triggers* 3-12 GeV Pions PS@CERN	November **Mini sDHCAL** *65k triggers* 6 GeV Pions PS@CERN
2009	June July **Mini sDHCAL + 1 M²** *361k trigger* 3-12 GeV Pions PS@CERN	August **Mini sDHCAL + 1 M² with Absorber** *364k triggers* 10-150 GeV Pions&Muons SPS@CERN

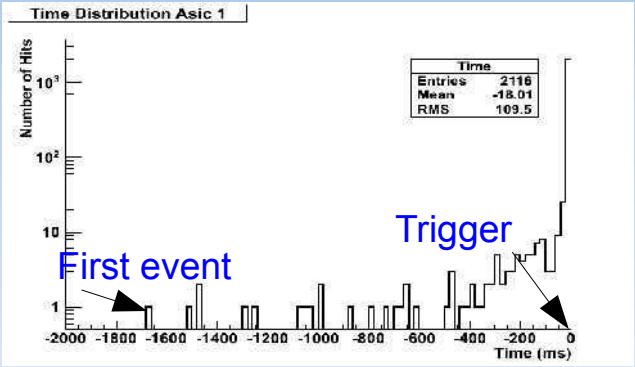


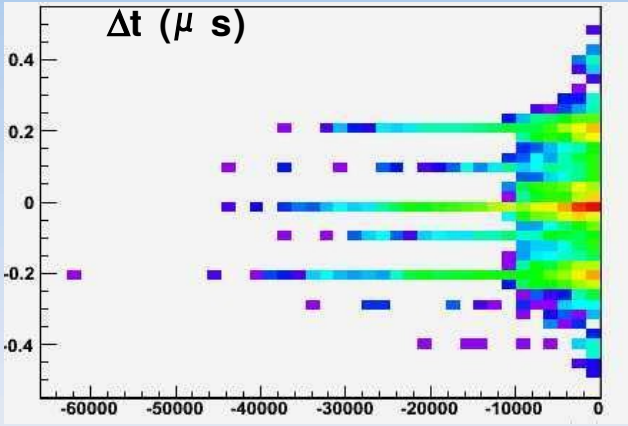


Time reconstruction

Acquisition

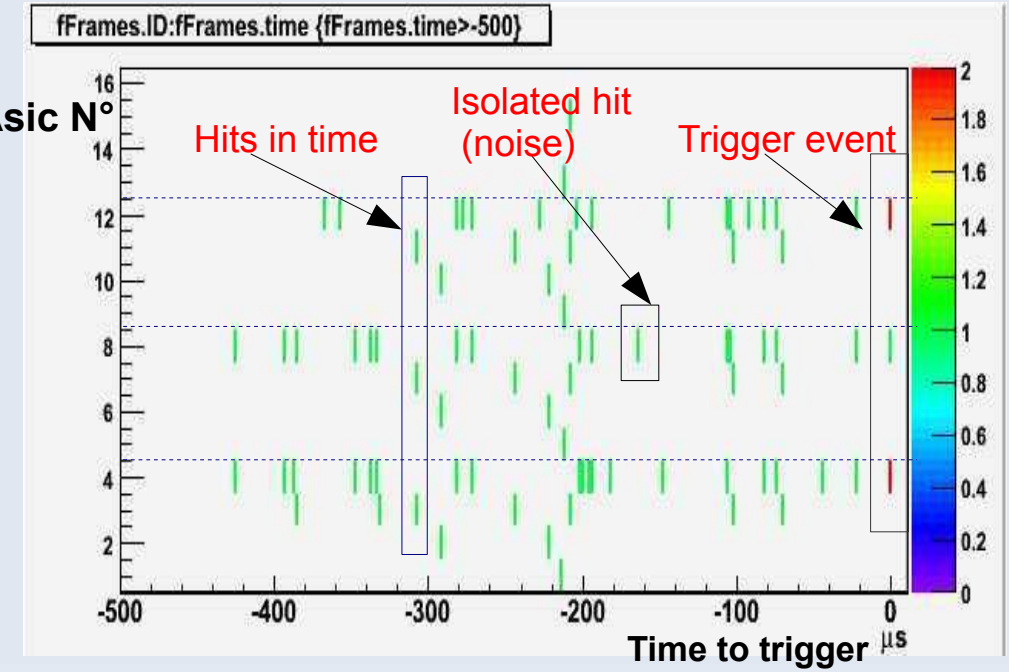
1) Events are recorded in ASICs with corresponding time, channel ID & thresholds (auto-trigger)
2) Memory full → Reset of Board
3) Ext. Trigger from scintillators: → stop all boards & R/O





Time structure:

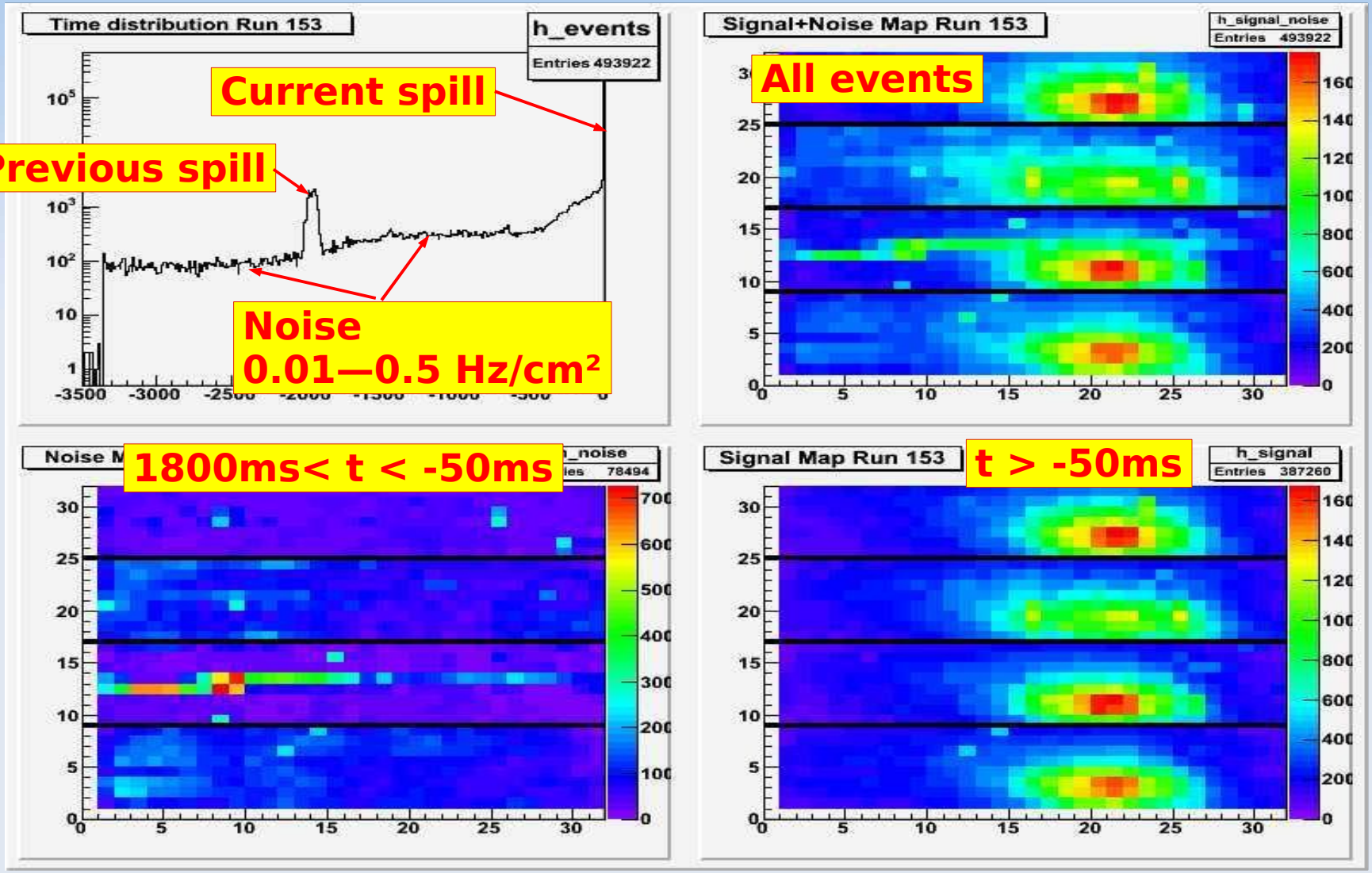
unfolded from Ext. Trigger time backward



Time reconstruction

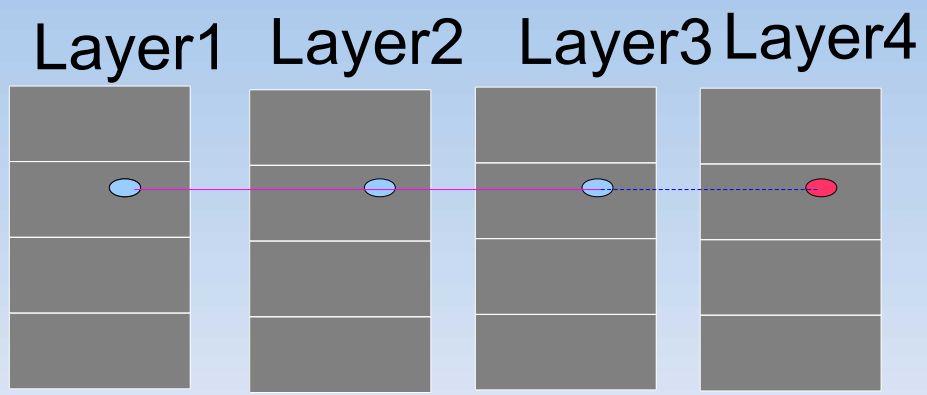
- Hits belonging to the same event have $|\Delta t| < 200$ ns: selection criteria for tracks reconstruction
- Identical to ILC mode (trains of ~3000 BC with $\Delta t \sim 400$ ns)

Noise & signal

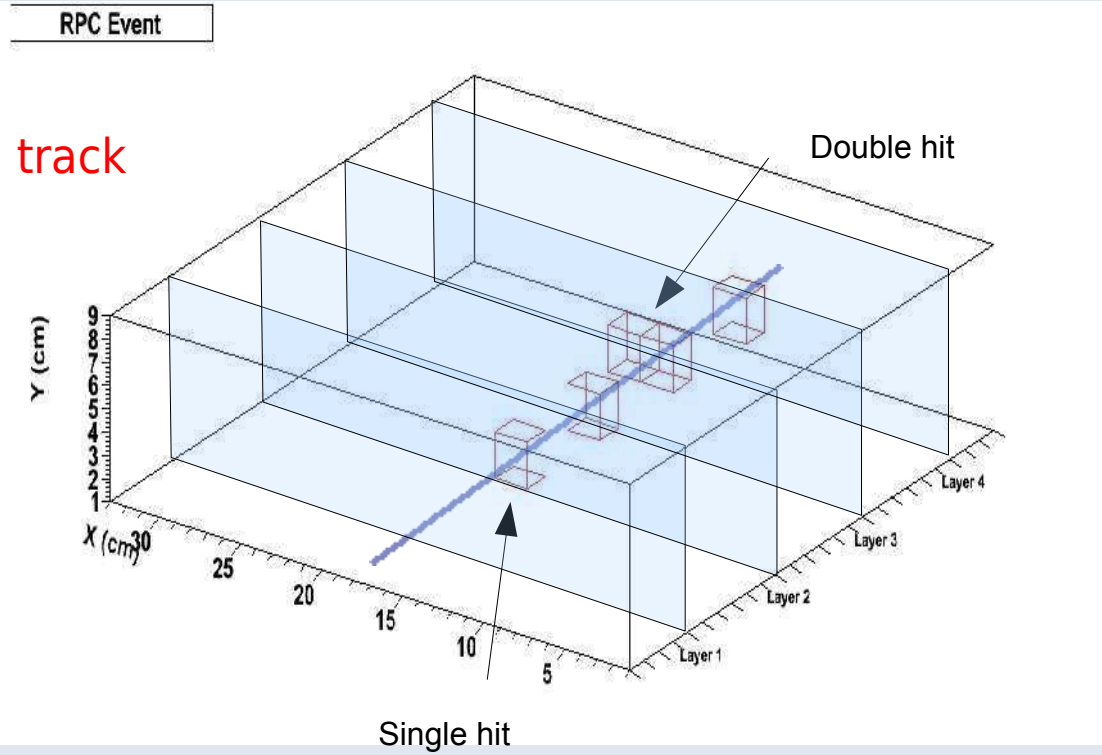


Tracks Reconstruction

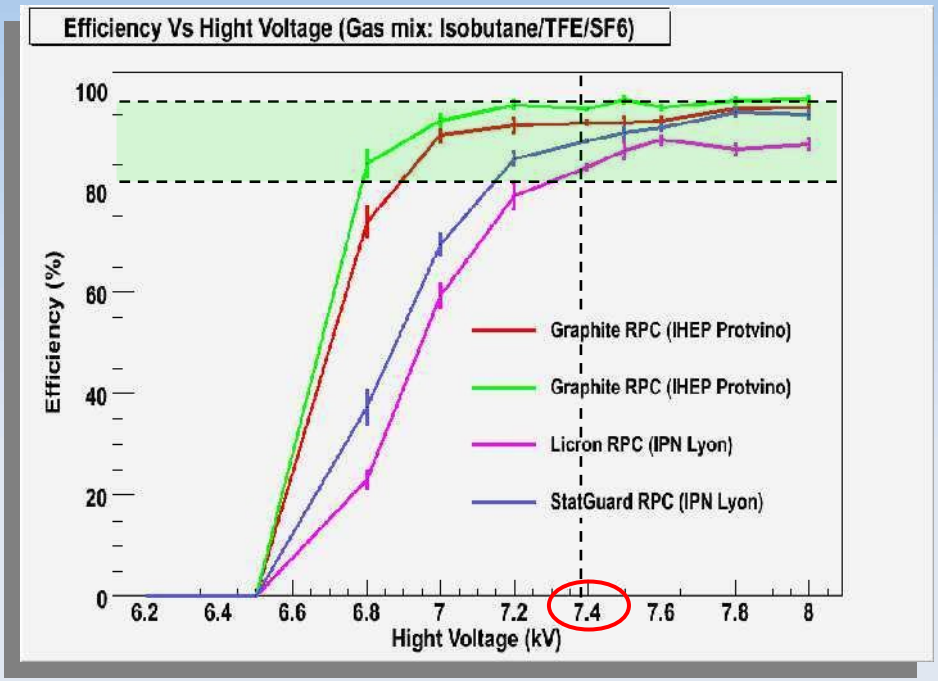
- Efficiency/Multiplicity determination:
  - **Tracking method:**
    - 3 RPC used as trackers
    - Average position used to build a track
    - Search hits in the studied layer around the expected impact
  - Multiplicity ≡ Number of cells around track when the chamber responded (≥1)

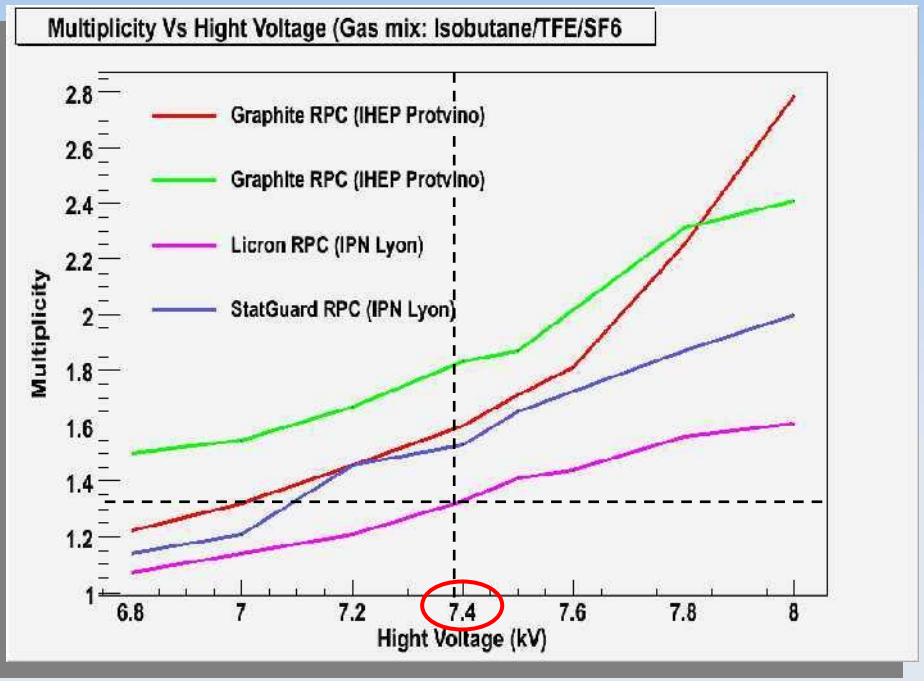


Event Selection:
- **Last Event**
- or **Train**
  - |Δt|<200
  - t>First Event in every chamber
- ≥1 hit per selection layer
- ΔX & ΔY = ± 1 cm on all layers



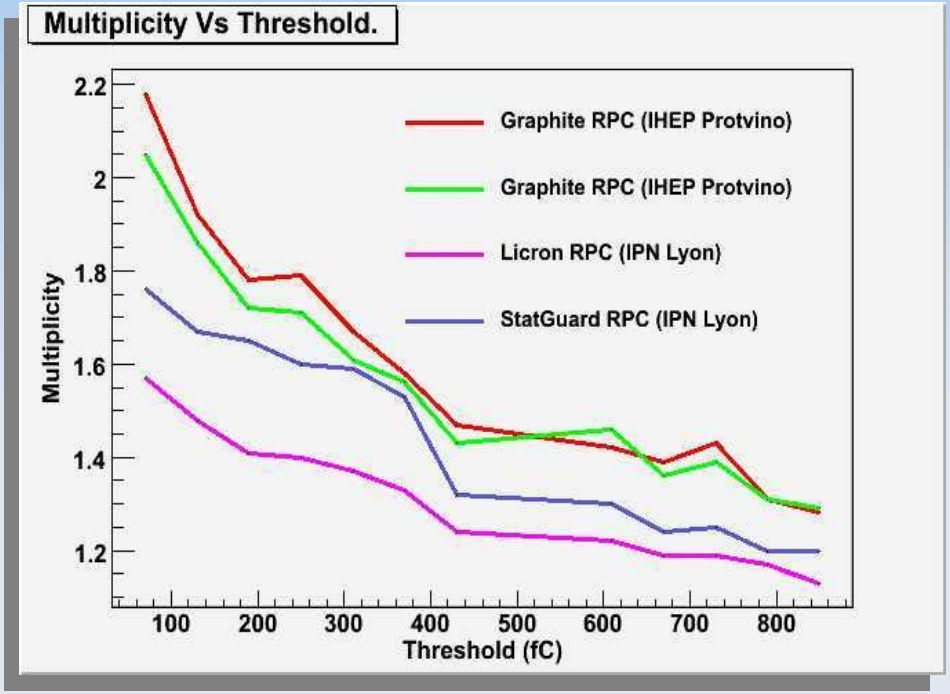
Mini DHCAL: HV Scan

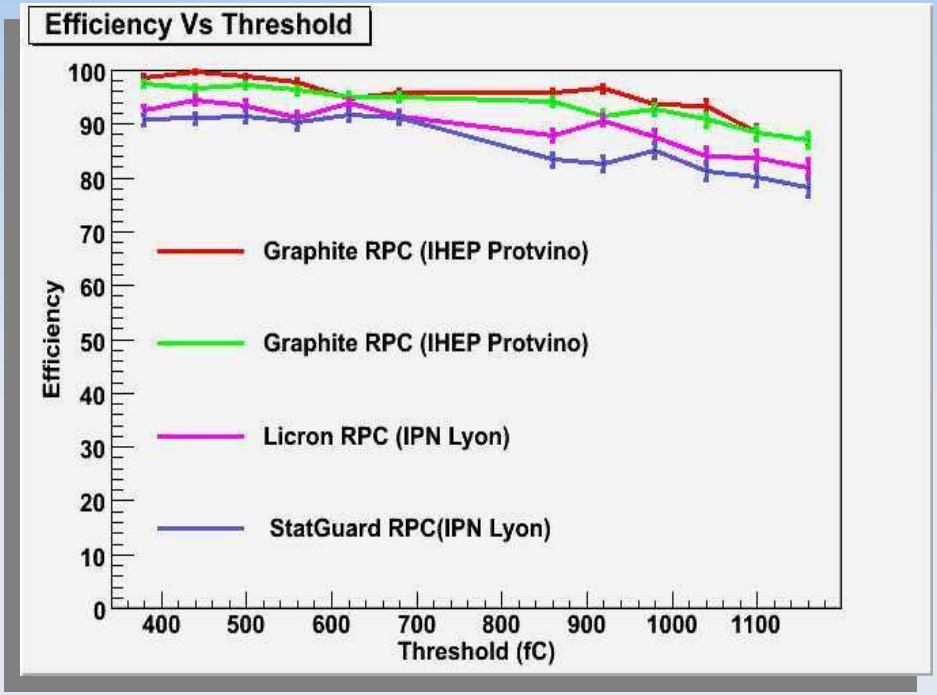




- DAC's **Thresholds**: lower 165 fC / higher 450fC
- **Plateau:** 7.2 — 8 kV → Efficiency between 80 and 98%
- Lower multiplicity is preferred.
  → Best ratio multiplicity/efficiency: around 7.4 kV
- The LICRON coated detector shows best performances:
  → **lowest multiplicity** and **very good efficiency**

Mini DHCAL: Threshold Scan

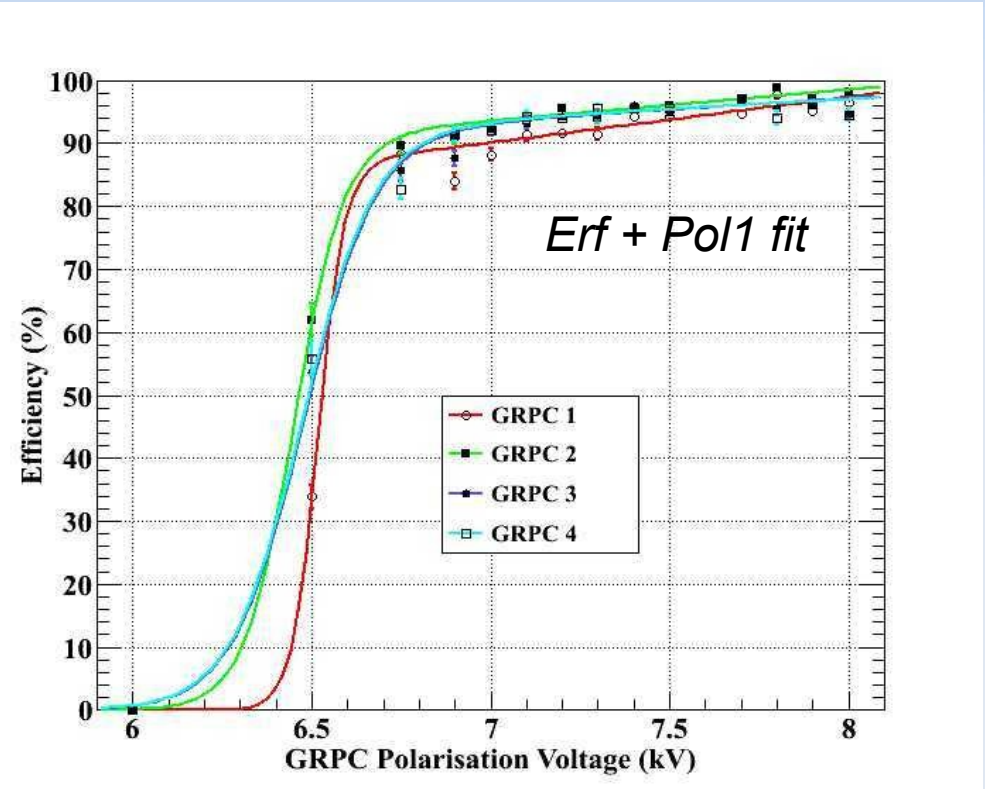


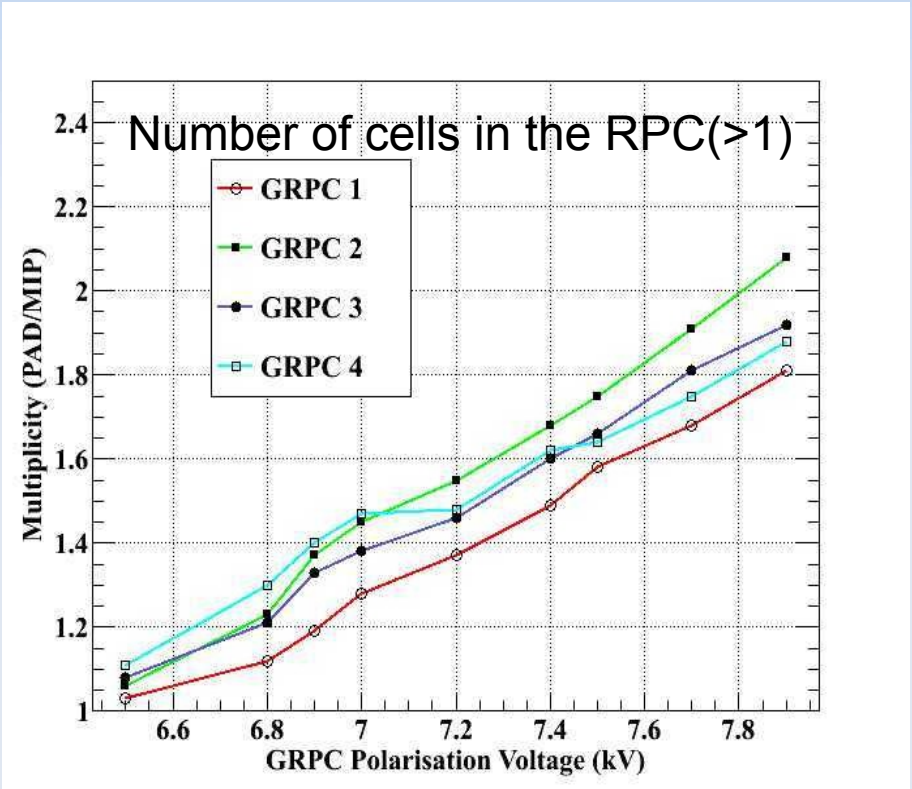


- Multiplicity moving as expected => **lowering as threshold increases**.
- Efficiency **decreasing** down to 80% at 1.1 pC threshold.
- Will be used to model the response

Uniformity between chambers

Reference setup: 4 Graphite RPCs (IHEP protvino)
Triggered event data sample



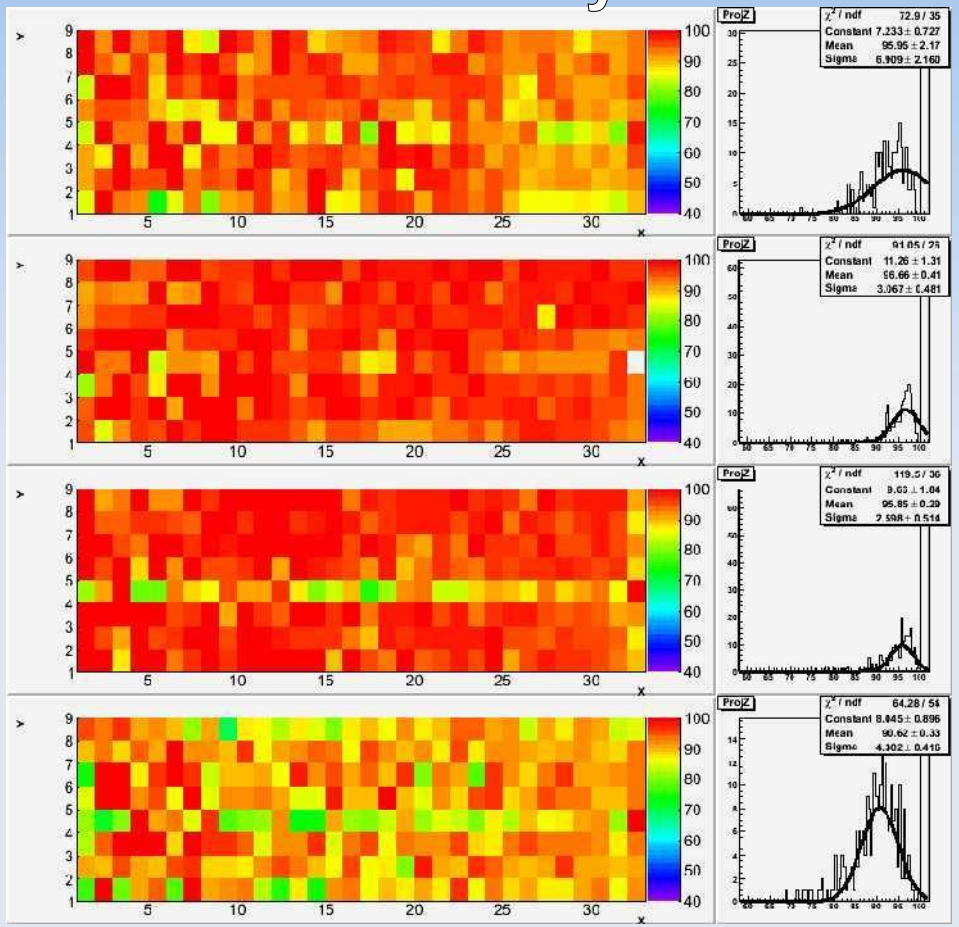


- HV scan
- Threshold 220 DAQ value (165 fC)
- 6 GeV pions beam

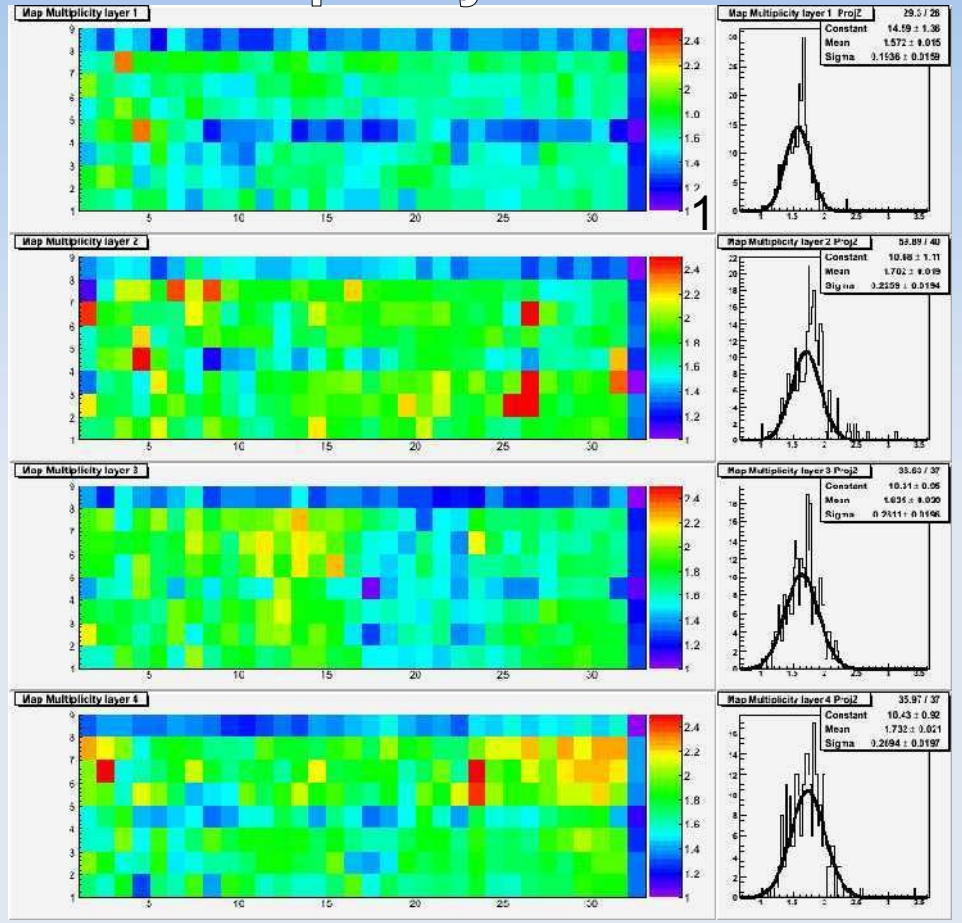
- Uniform behaviour for the 4 RPCs
- 95% of efficiency reached at 7.4 kV
- Multiplicity of ~ 1.6 ±0.4 at 7.4 kV

Uniformity of response

Efficiency



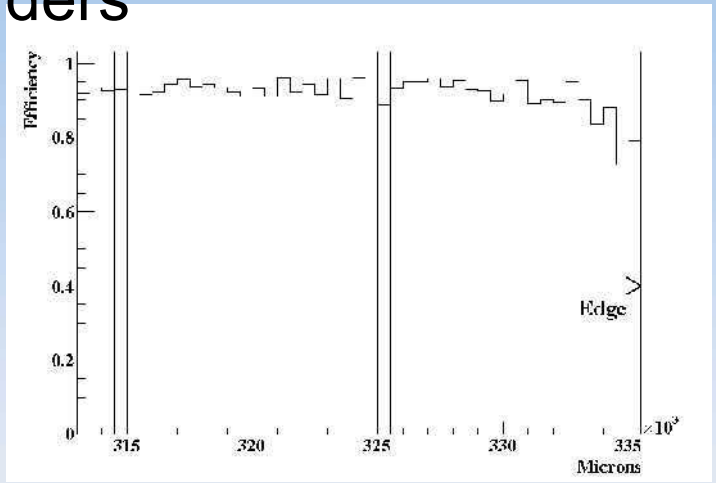
Multiplicity



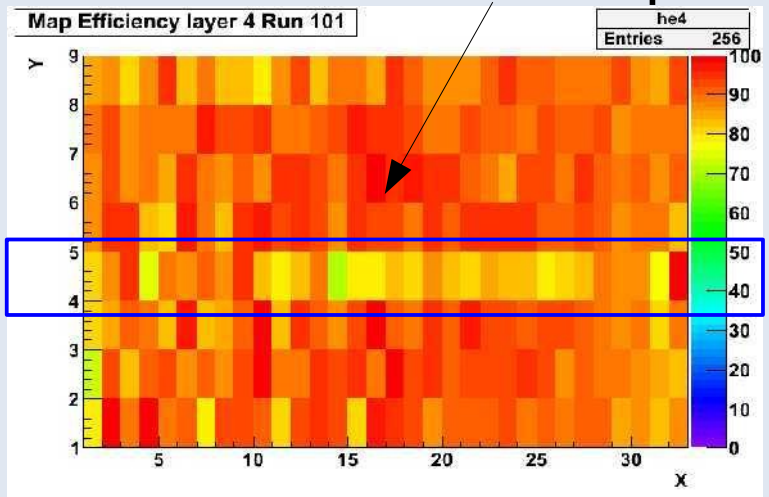
- Full train reconstruction (→ ×10 in statistics)
- Global *efficiency* spread (⊃ statistics [25k evts] & defaults) ~ **3%**
- Multiplicity spread in a chamber ~0.2 (⊃ borders & fish line)
  - ≤3% between chambers

Systematic Effects

Borders



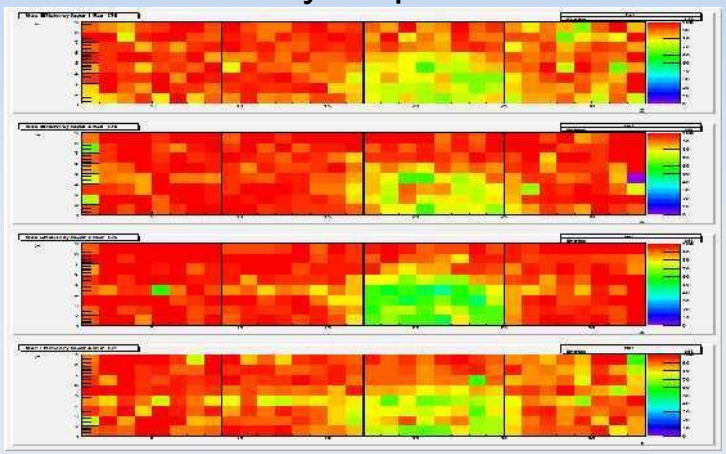
Fish line between the two plates



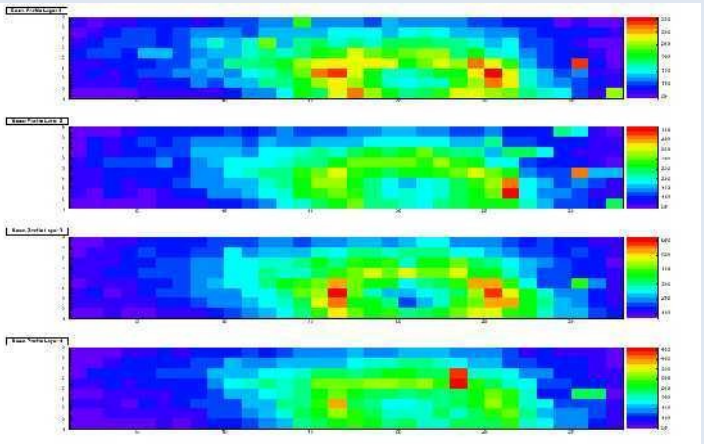
Fish line replaced by ceramic balls
to reduce contact surface for 1m²

High rate areas (19 kHz/cm²)

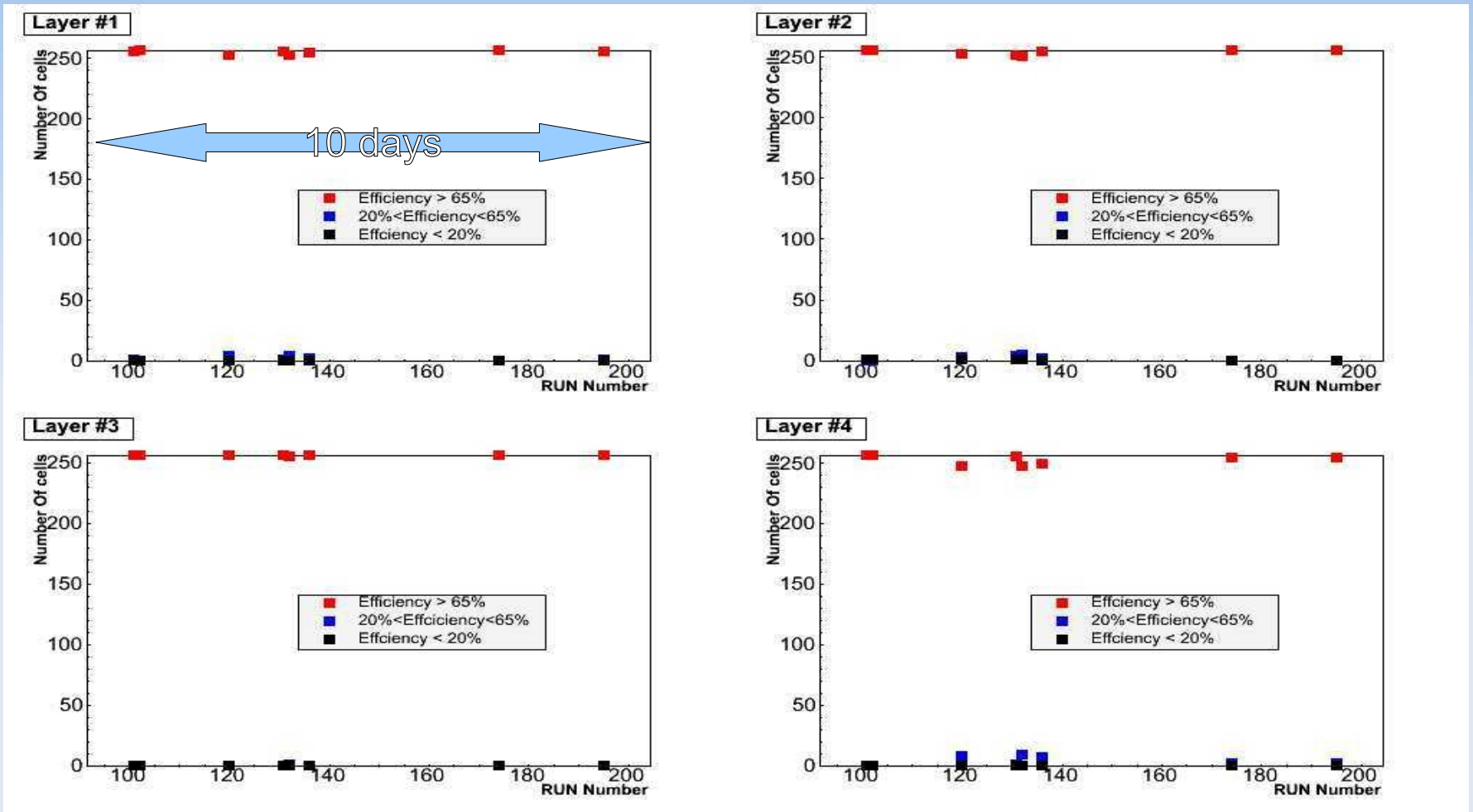
Efficiency map RUN 179



Beam profile

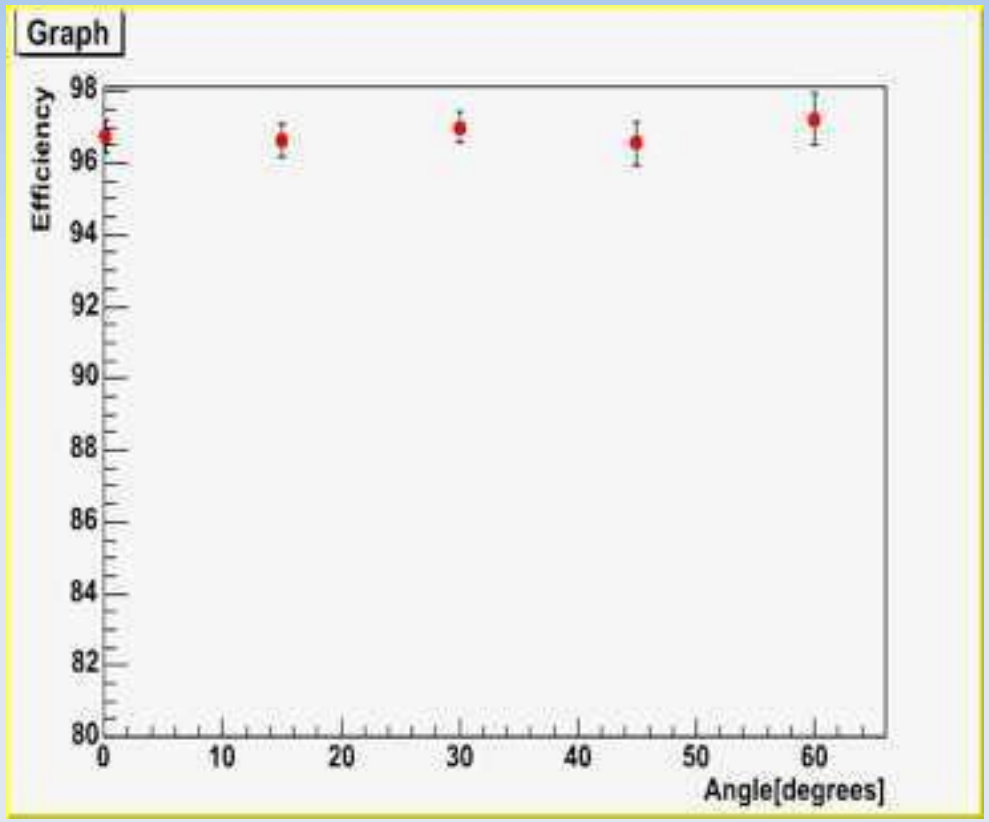


Efficicency Stability



- Low number of inefficient cells
- Constant over time.

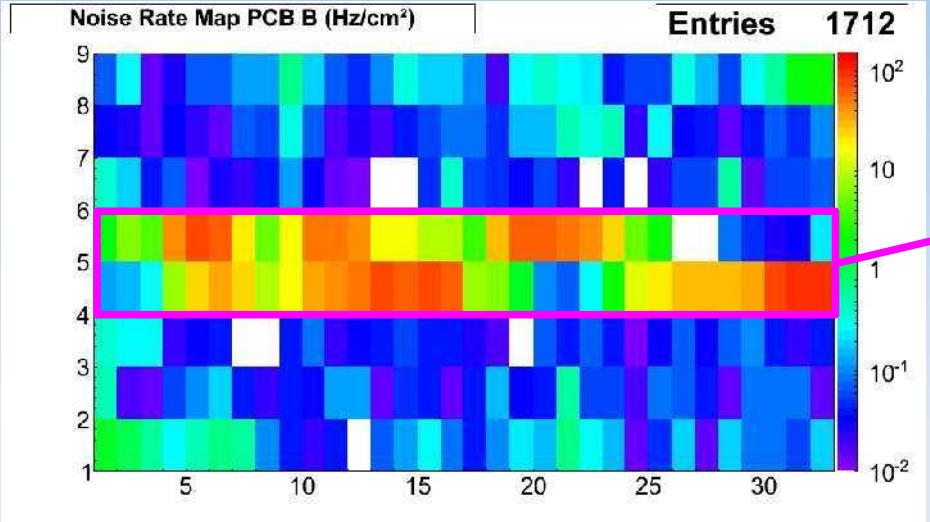
Angle dependance

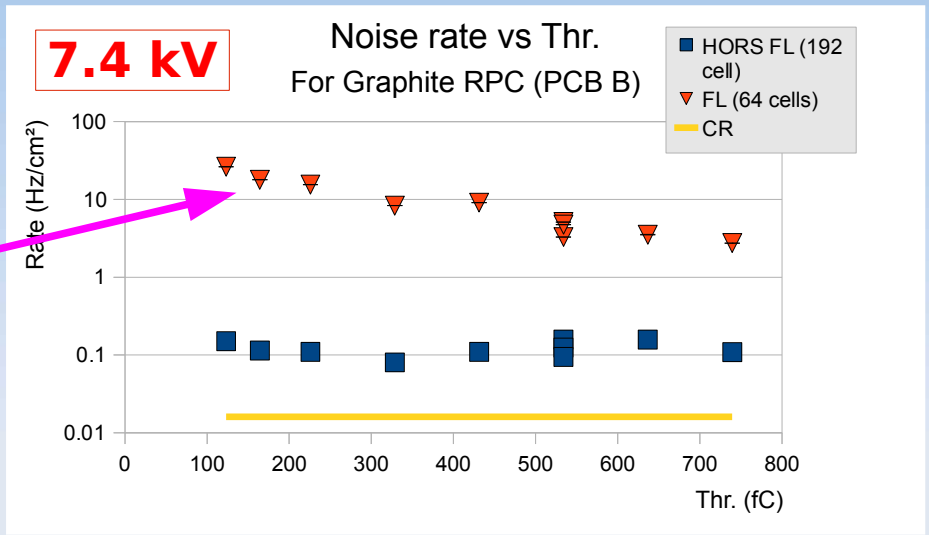


HV = 7.4 kV
Thr = 165 fC
Graphite chambers

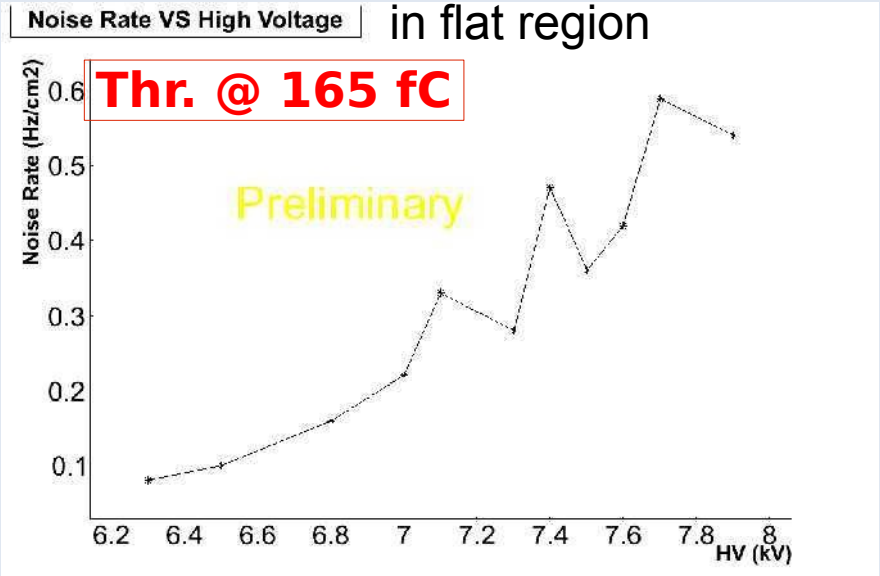
- No effect seen from angle
  - Ease reconstruction of tracks in calorimeter
    - in showers, barrel and endcap
- Multiplicity to be checked

Noise evolution



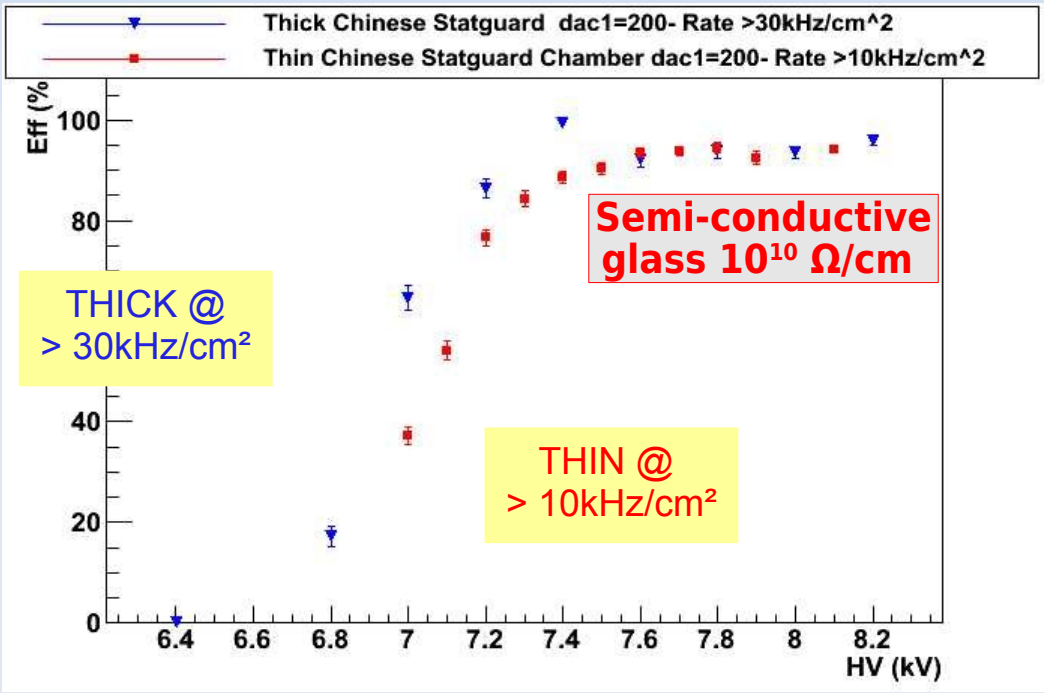


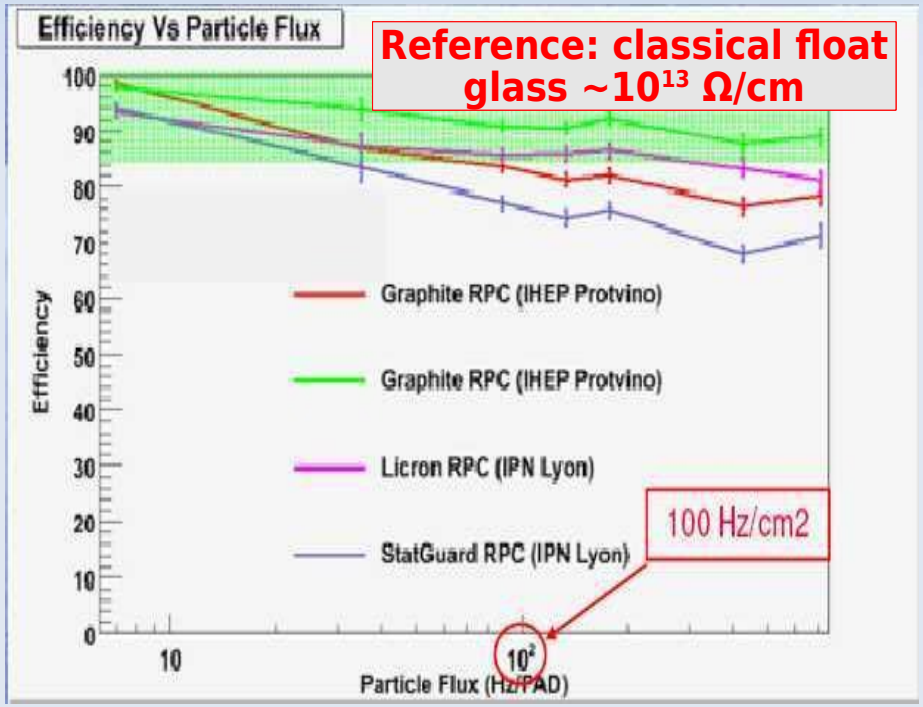
- Noise mainly near Fish line (& borders)
  - Should improve largely with large chamber equipped with balls (~1/100 cm²)
  - Stability with time under studies



Semi conductive GRPC

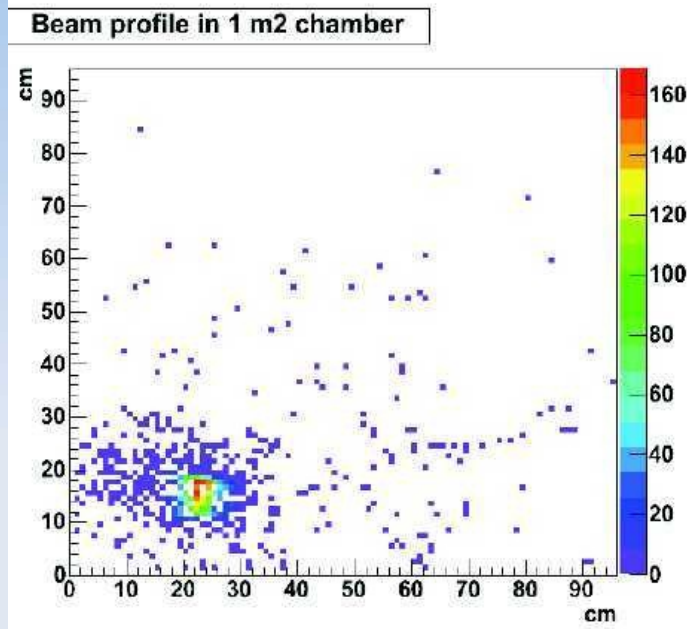
- Semi-conductivite glass [10^{10} Ω/cm] provided by Tsinghua University:
- 2 chambers with 32×8 pads:
  - **thin:** 1.1 mm at both side + Licron coating
  - **thick**: 1.1mm on cathode + 0.83 mm at readout + Statguard coating

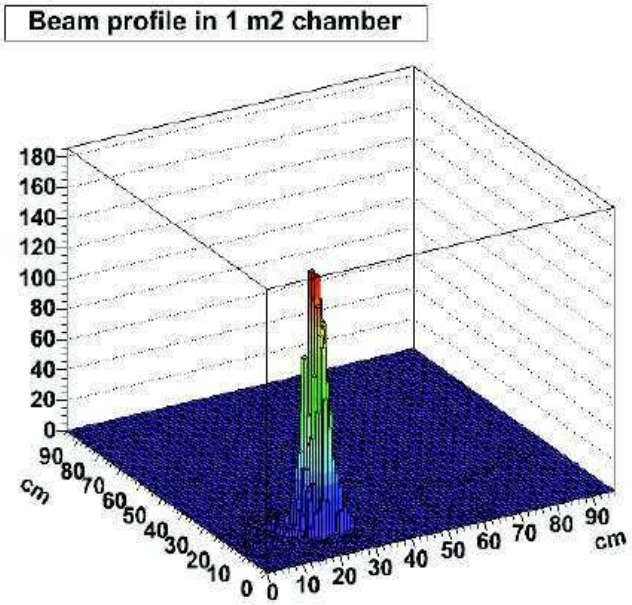




- Good efficiency at high event rate (>10kHz/cm²),
  Classical glass has significant efficiency drop @ rate > 0.1—1kHz/cm²

1 m² : beam profile





Pads over (low) threshold

DAQ successful in testbeam mode
With 3 DIFs synchronised
Up to 93% efficiency

HV connection

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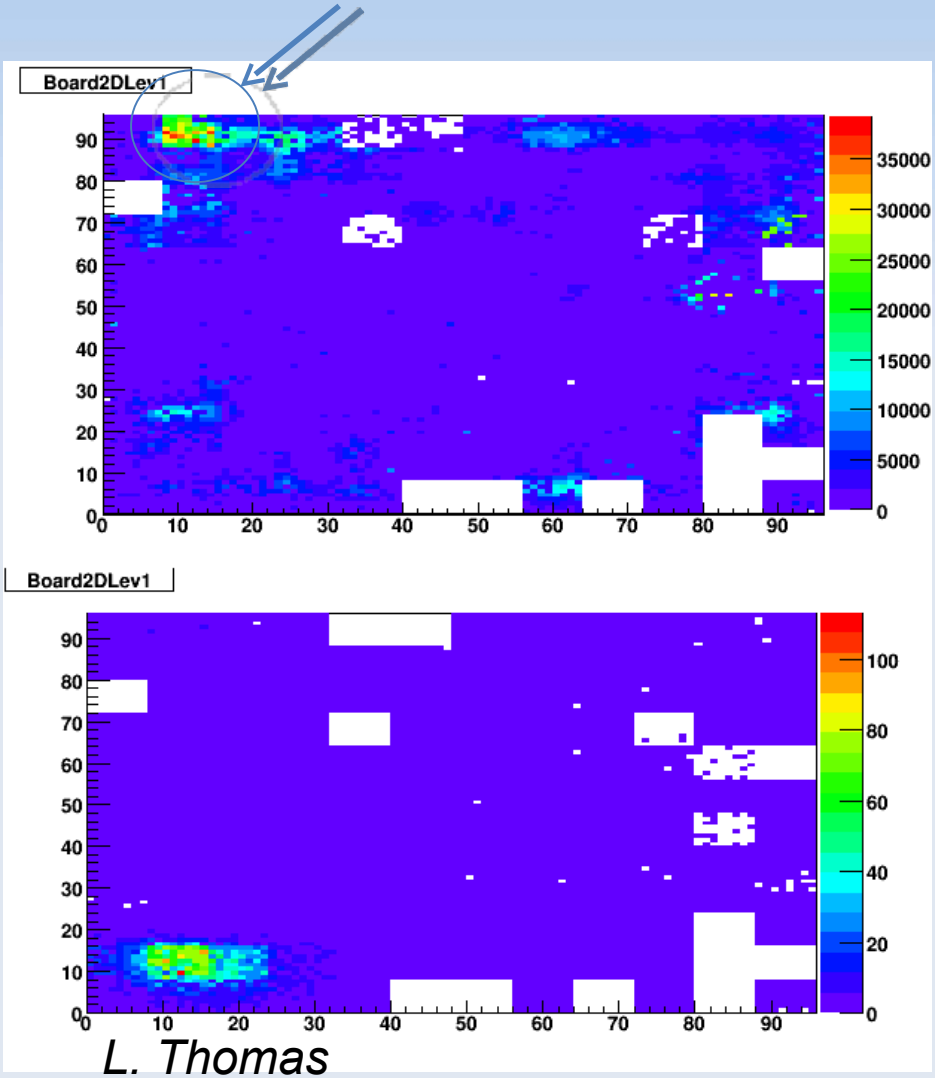
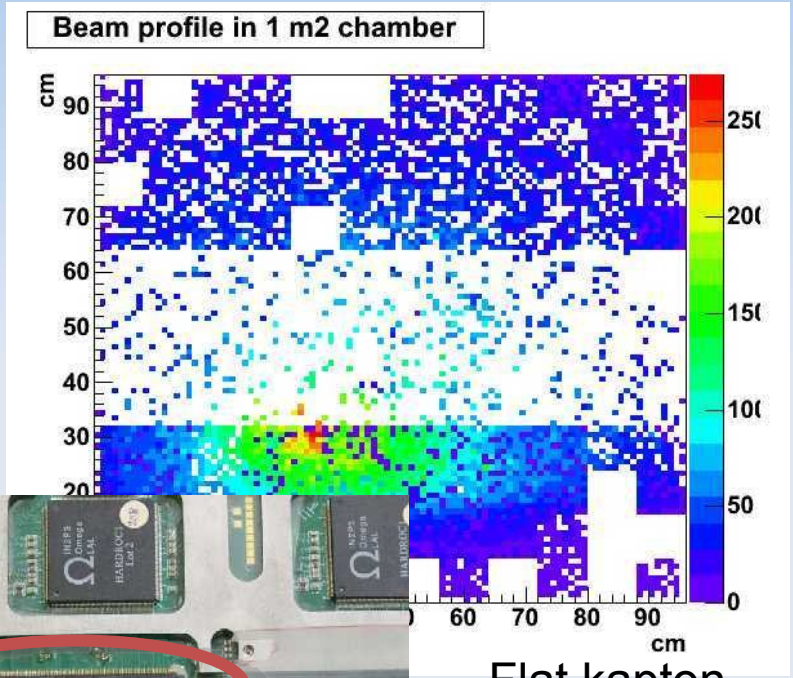
Some issues (solved)

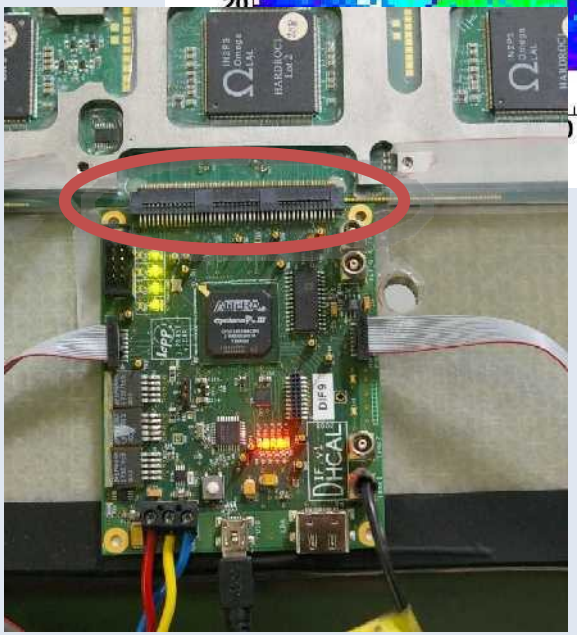
Some noise in the HV connector region



L. Thomas

Electric connections

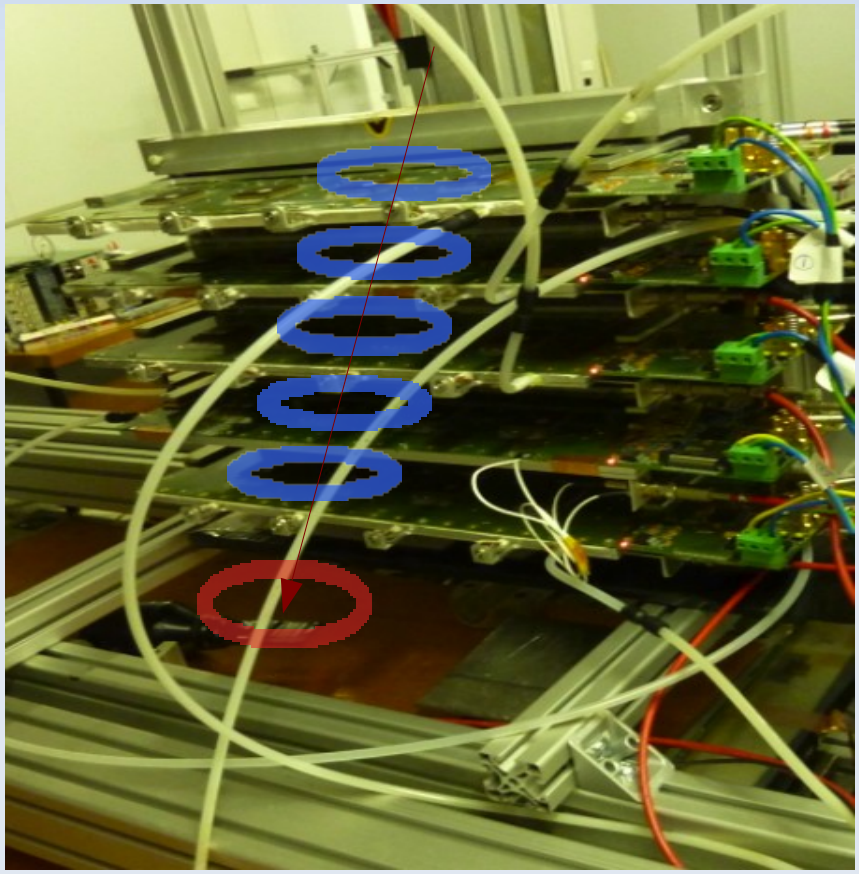




Flat kapton cable under development for next prototype

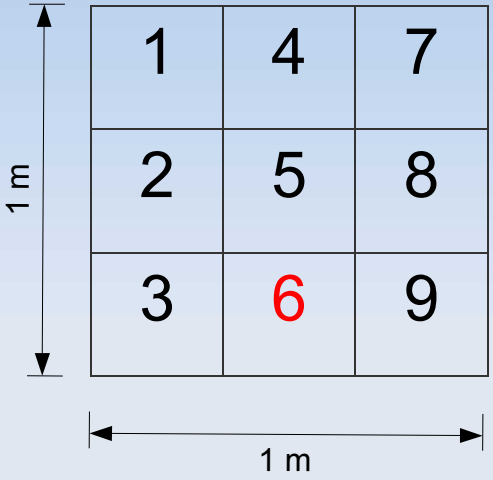
M²: cosmic test bench

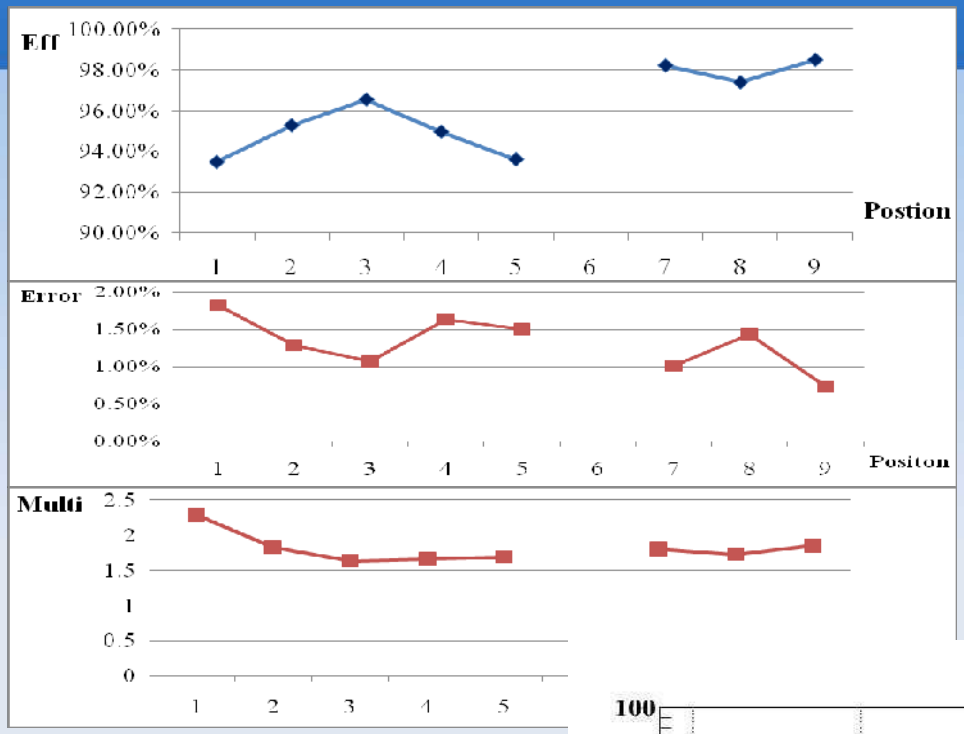
Small set-up (mini-DHCAL) used as tracking device for the large chamber



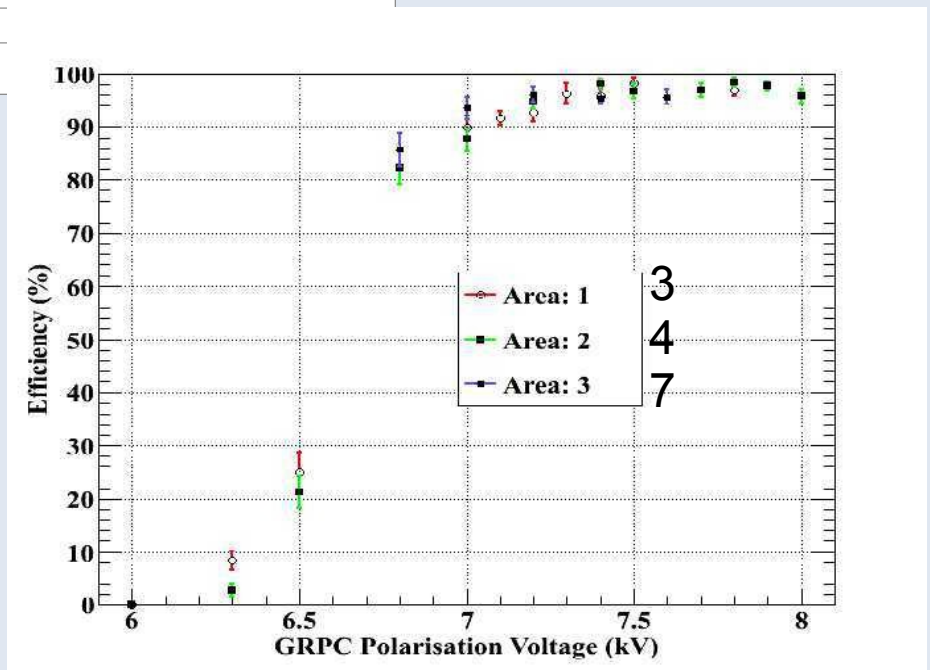
M²: Efficiency and Multiplicity (cosmics)

Position scan





Results without gain correction
and at different T,P,H
(to be controlled in next beam tests)

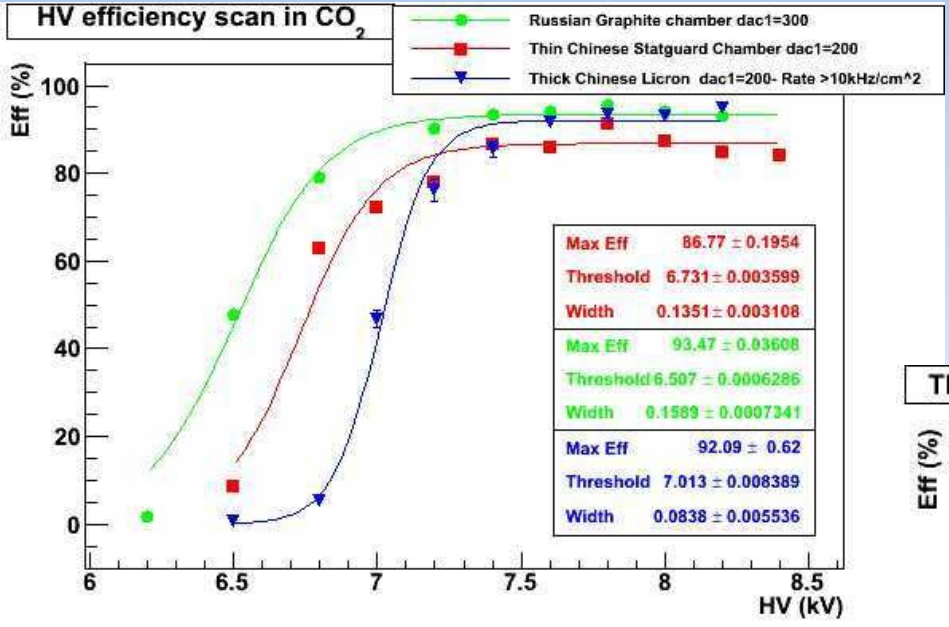


- Raw performances identical to small chambers

Conclusions & perspectives

- A Semi-Digital GRPC Hadronic Calorimeter with embedded readout is a very promising candidate for future linear colliders experiments
- Main critical components checked on small chambers
  - a High efficiency (95%) and low multiplicity (1.6)
  - angular response,
  - Uniformity of efficiency & multiplicity,
  - Noise
- Semi-conductive glass RPC show promising performances
- Next:
  - Two additional large RPCs being assembled
  - Two scheduled beam tests:
    - May'10: 2 weeks PS beam
    - Sept'10: 11 days SPS beam

Test with CO_2 gas



- Isobutane
  - inflammable
  - Might be banned for large Detector

- Shallower raise as with Isobutane
- wrt to standard GRPC wider distribution from the thick semiconductive glass