RPC based Semi-Digital HCAL
with an embedded readout

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LCWS'08
U. Of Illinois at Chicago
15—20 nov. 2008

ÉCOLE POLYTECHNIQUE

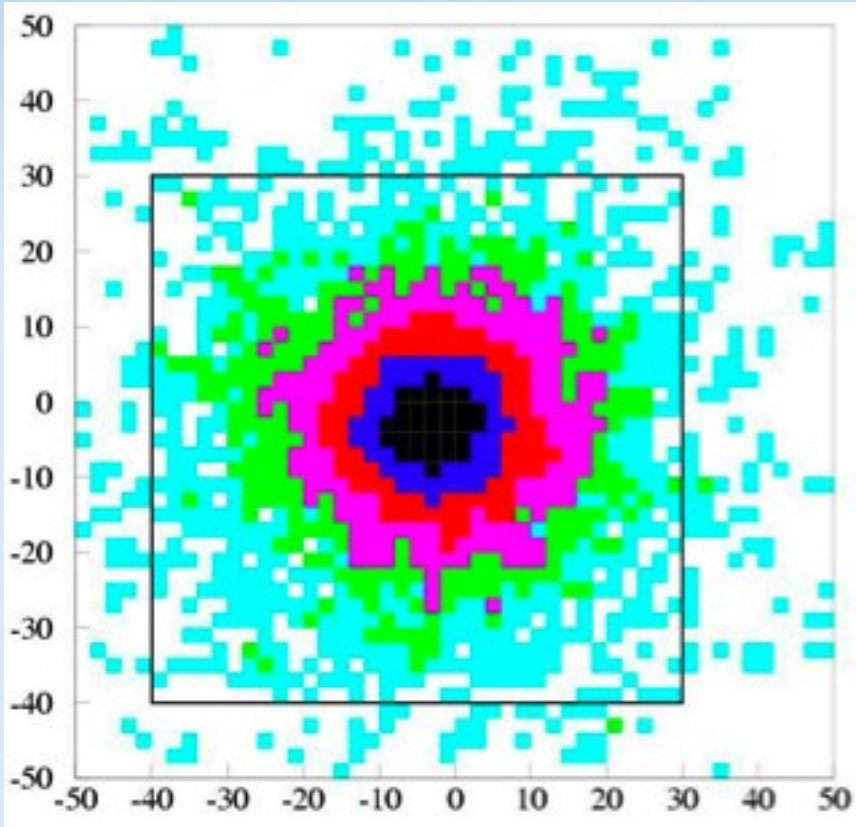
Overview

- Case for a digital calorimeter
- Detectors :
  - RPC, MGRPC
  - µMEGAS, GEMs
- Digital Readout by embedded ASICs
  - HARDROC
  - *DIRAC*
- Integration & Debug Card: DHCAL1 & readout
- Cosmic tests
- Beam tests

- 1 m^2 prototype
  - Validation of large surface detector & readout
- 1 m^3 prototype
  - First use of 2^{nd} gen DAQ
    - see V. Bartsch talk
- *Efforts of integration in ILD & SiD*
  - *Mechanical & simulation*

Case for a Digital HAdronic CALorimeter

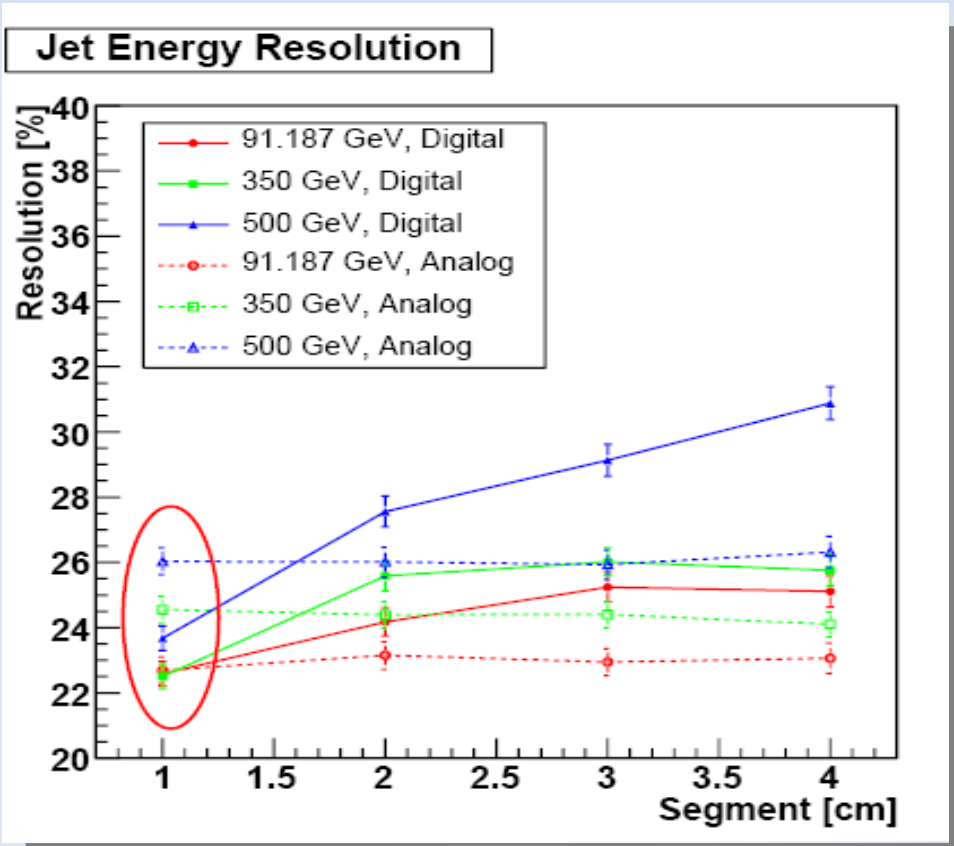
- 1 or 2 bits of information per cell
  - Finer granularity → 1×1 cm² × 48 planes
    - Ideal for a **PFA** approach
  - Cheaper, simpler, more robust detectors
    - GRPC, MGRPC, µMEGAS, GEM's
- Gaseous detectors
  - insensitivity to neutrons
    - narrower showers (99% of hits in 70×70 cm² for 100 GeV π)
    - suppression of big fluctuations
- Recovery of information
  - counting
    - improvement: 3 thresholds
  - topology
    - clustering

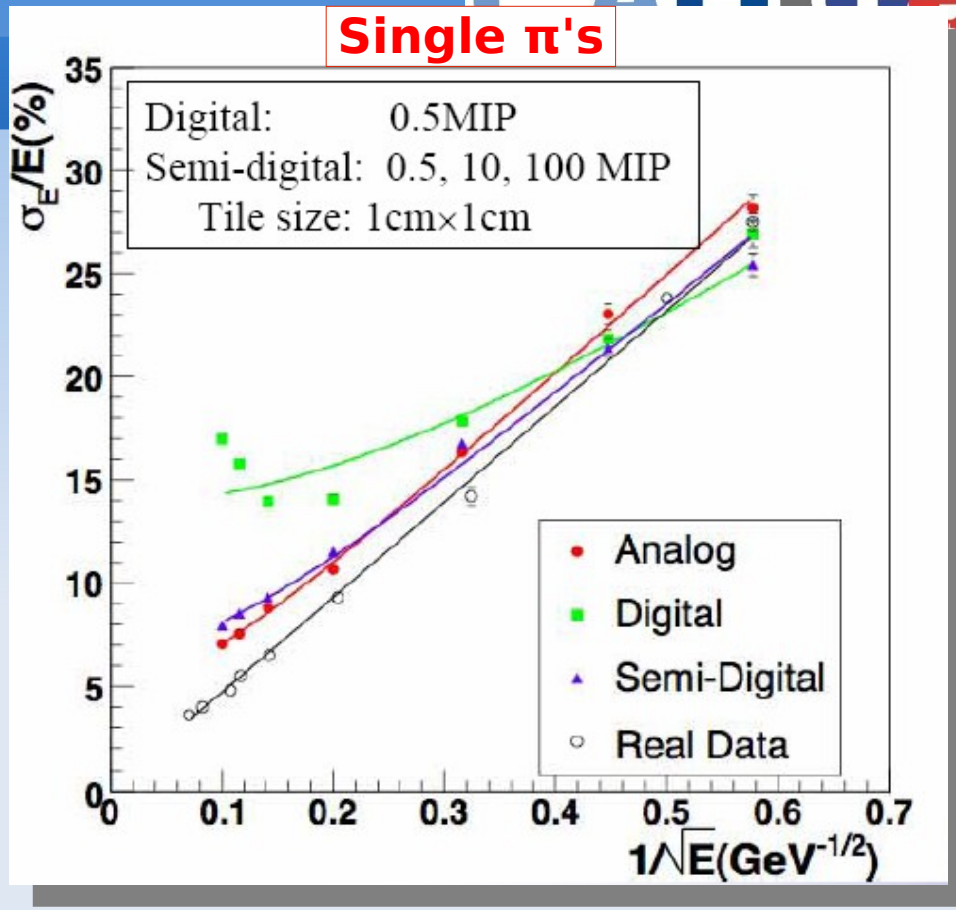


See note LC-DET-2004-029

Resolution studies

- GLD HCAL study by KEK Group
  - 3 thresholds (0.5, 10, 100 MIP's)
  - 1×1 cm² **scintillator tiles**
- 1 bit better @ low E





- $e^+e^- \rightarrow qq$ (uds)
  - $\sqrt{s}$ = 91, 350, 500 GeV
- Assuming Perfect PFA
  - Improved jet resolution

H MATSUNAGA
Pramana J. Phys., Vol. 69, No. 6, December 2007

DHCAL: Gaseous Detectors

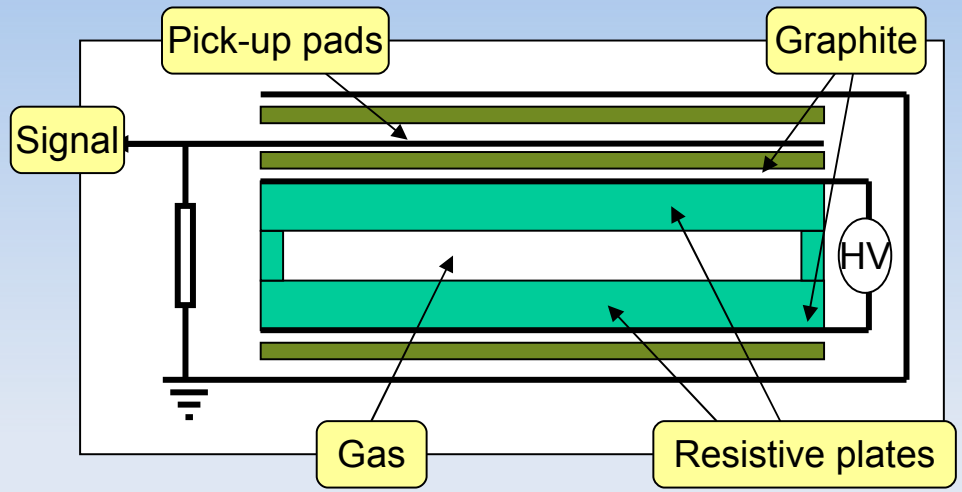
- Performance studies
  - MIP efficiency
  - Hit multiplicity

  ⇒ Uniformity / detector / cell
  - Ease of calibration (30 M cells ⇒ 30 M elect. channels)
  - Recovery time (RPC)
  - Discharge rate (GEM, µMegas)
  - Behaviour in hadronic shower (detector & electronics)
  - Operation in high magnetic field
- Technological challenges
  - Large surfaces
  - Thickness
  - Low cost and industrial process
  - Aging: no performances degradation

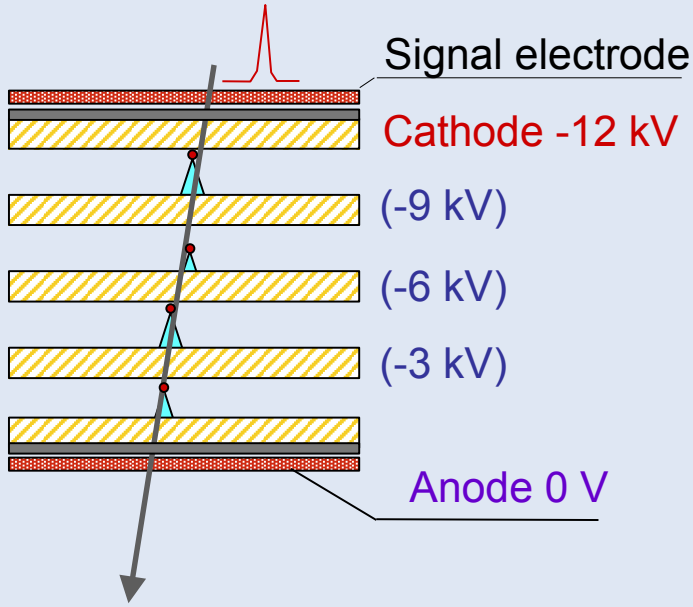
RPC Gaseous detector prototypes

TFE	93%
Isobutene	5%
SF6	2%

- GRPC *(IHEP+IPNL)*
  - simple, robust, rate ≤ 100 Hz/cm²
    - 1.2 mm gaz gap
    - 400 µm glass plate
    - Graphite/Licron/Statguard resistive cover
    - ~ 7.4 kV

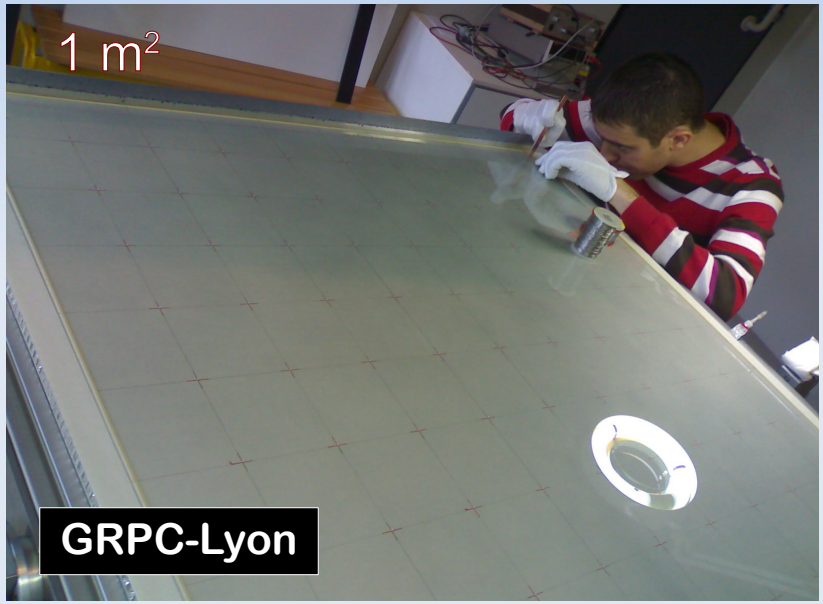


- Multi-gap RPC *(INFN Bologna-CERN)*
  - Higher rates & efficiency
  - Idem Alice ToF system
    - 4 x 250µm gaz gaps
    - 400 µm inner glass plates
    - 550 µm ext. glass plates
    - ~ 10—12 kV

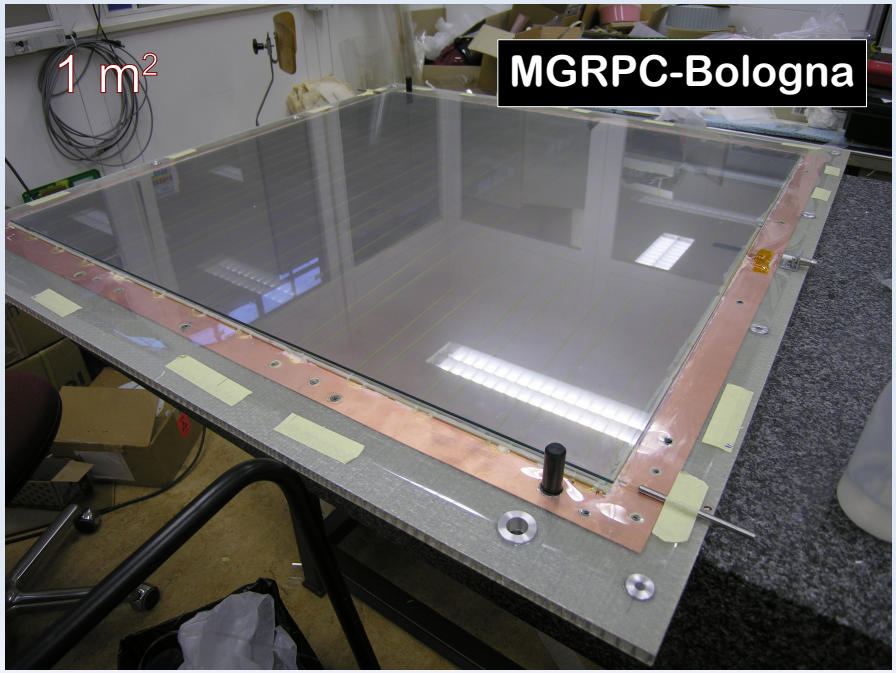


Small & large prototypes

- GRPC:
  - 8×8, 32×8, 50×32, 100×32, 100×100
    1 cm²-pad : already produced and tested.



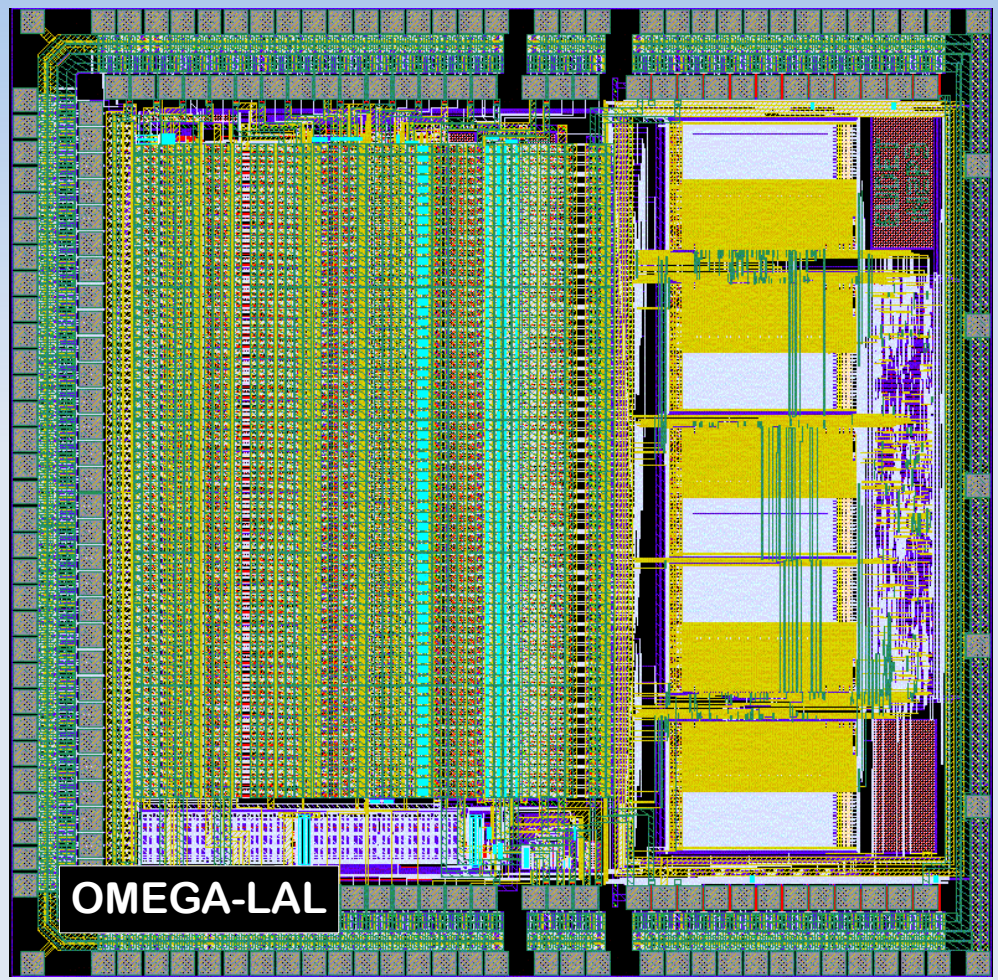
- MGRPC
  - 32×8, produced & tested
  - 100x100 under development



improve on gas distribution system, spacers and resistive painting, dead zones

HarDROC (Hadronic Rpc Detector Read Out Chip)

- AMS SiGe 0.35µm, 16 mm^2
- 64 channels
- Digital/analogue output
- 2 independant thresholds
- low consumption
  - < 10 µW/ch
  - 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



*** DIRAC: Another ASIC developed in IPNL/LAPP aims at a threshold of 3 fC**

HArDROC2

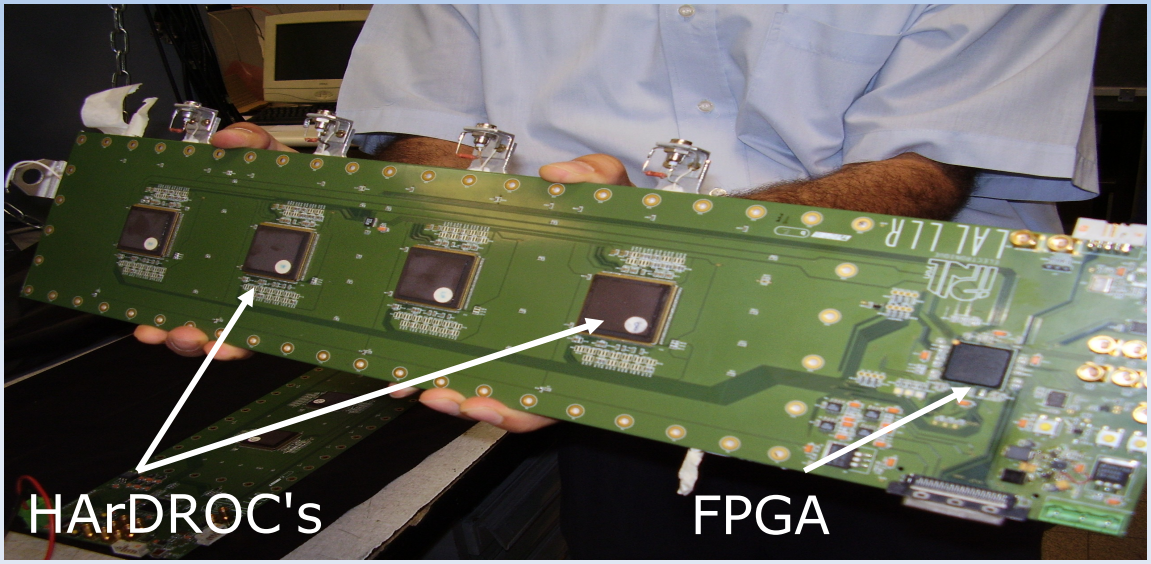
2nd gen in electronic tests

- First batch (460 chips) produced and being tested
  - Will be used for the m^2
- Correction of the minor bugs of HR1
  - Mask, memory pointer (dummy frame)
  - Shift registers improvment (configuration loading)
  - Bypass on critical signals
- Improvement on Power Pulsing
  - Now also digital part ⇒ comsumption ≤10µW/chan
- Dynamic range extension
  - Gain correction: 8 bits instead of 6
- 3 shapers and 3 threshold (3 indept DAC) coded on 2 bits
  - 10 fC, 100fC, 1pC (for µMEGAS)
  - 100 fC, 1pC, 10pC (for GRPCs)

Mini DHCAL project

Aim: Validate the new electronics/acquisition scheme for the DHCAL (GRPC/ μMEGAS)

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

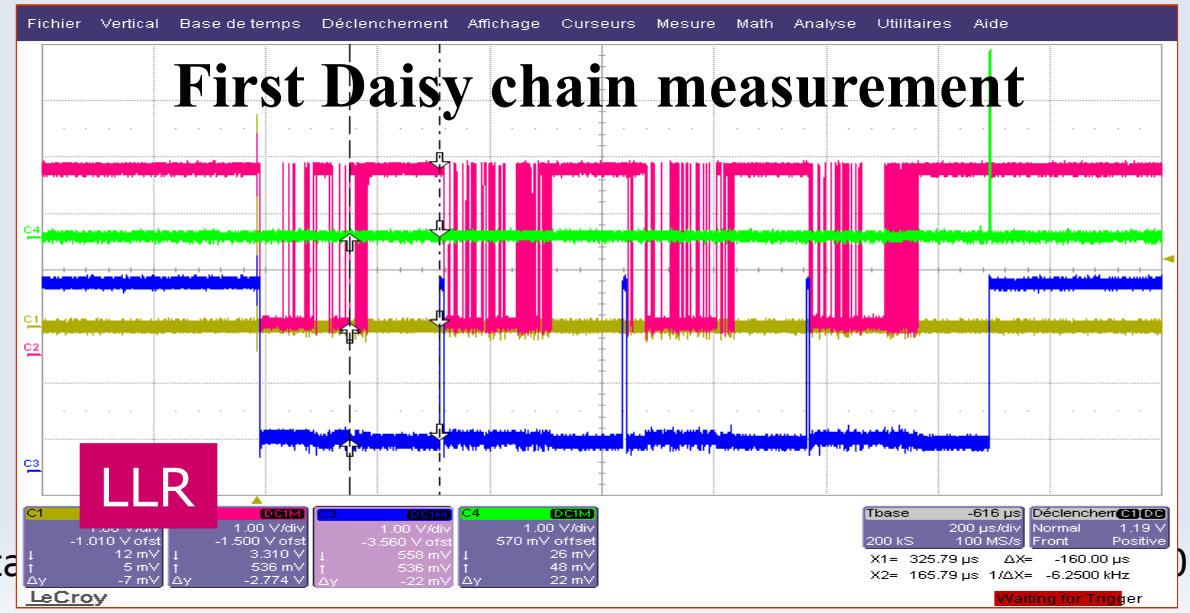


Acquisition modes : different modes are allowed:

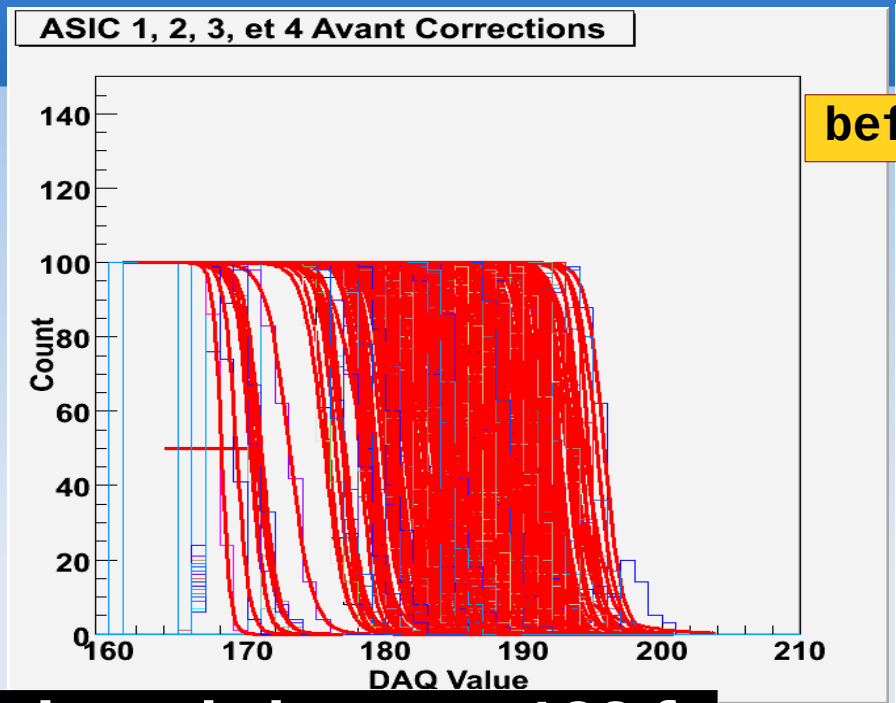
a) Train (ILC mode)

b) External trigger :
cosmic rays & test beam

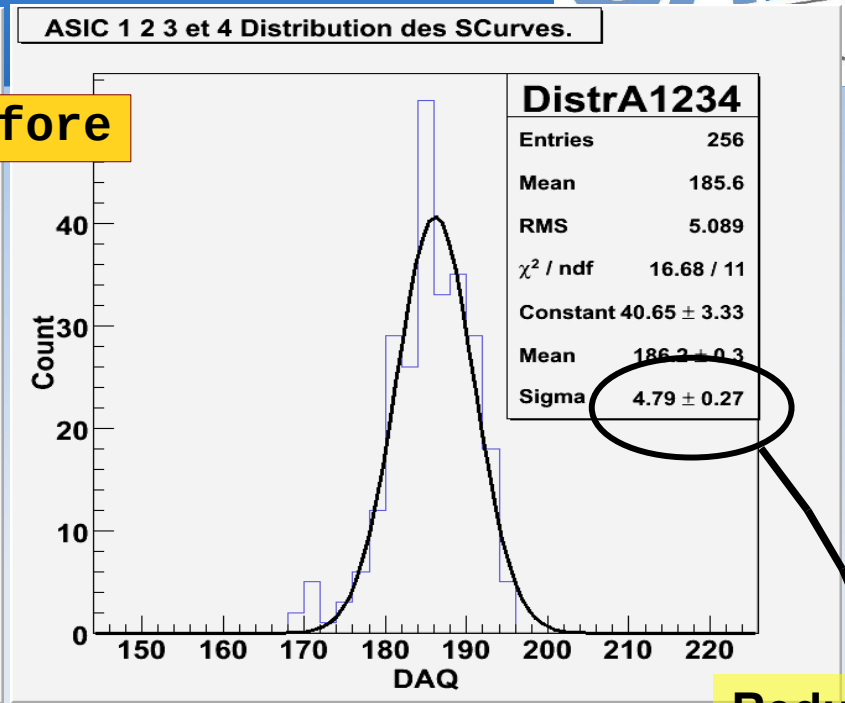
Data output:
digital and analogue



Gain correction

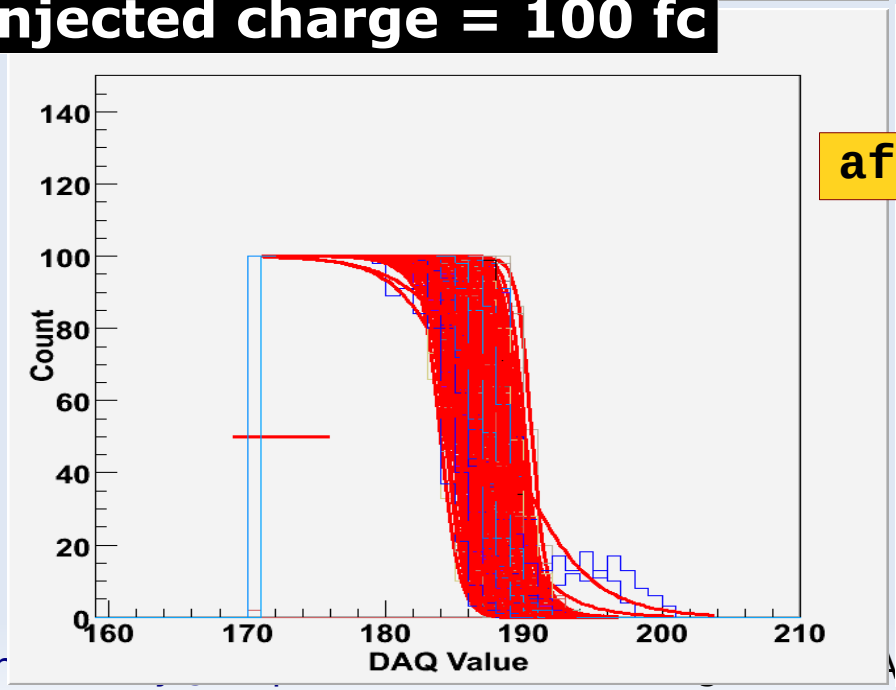


before

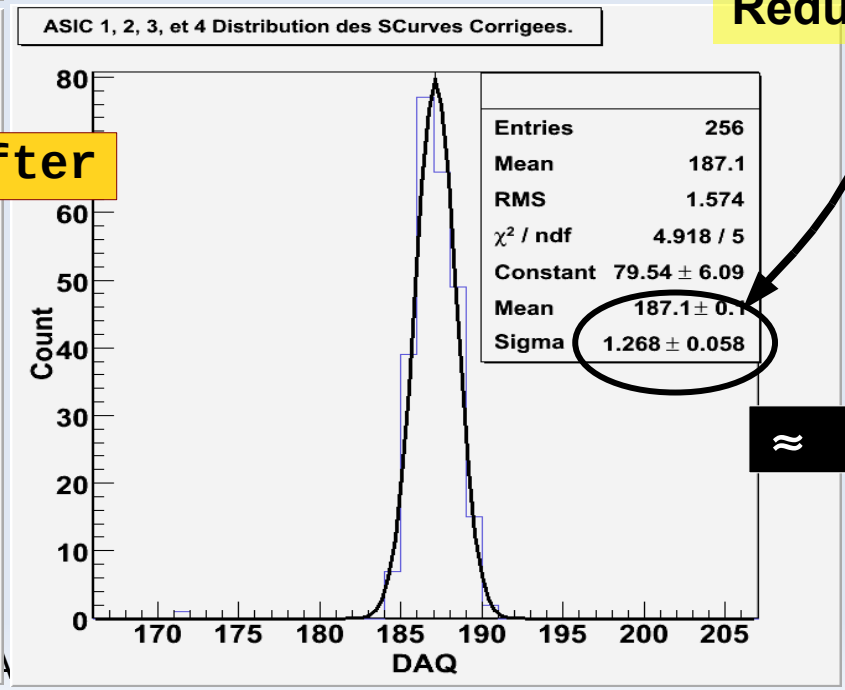


Injected charge = 100 fc

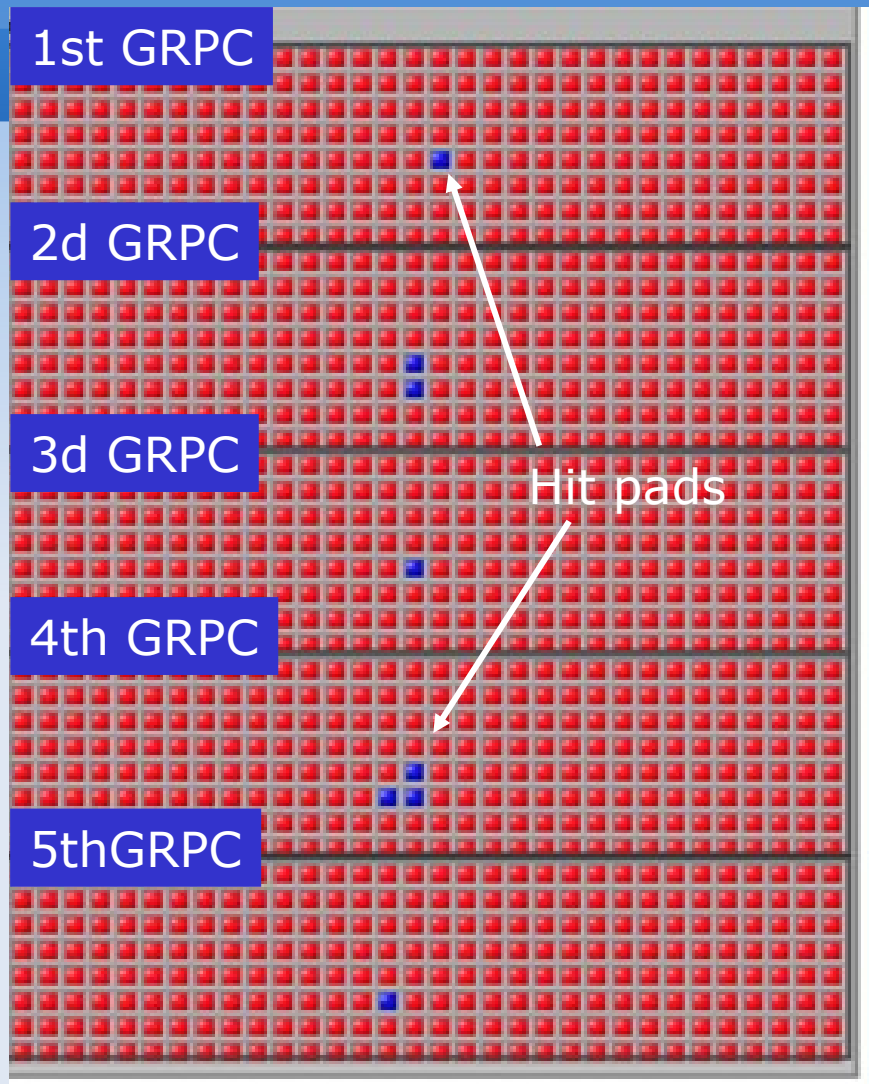
Reduction:4

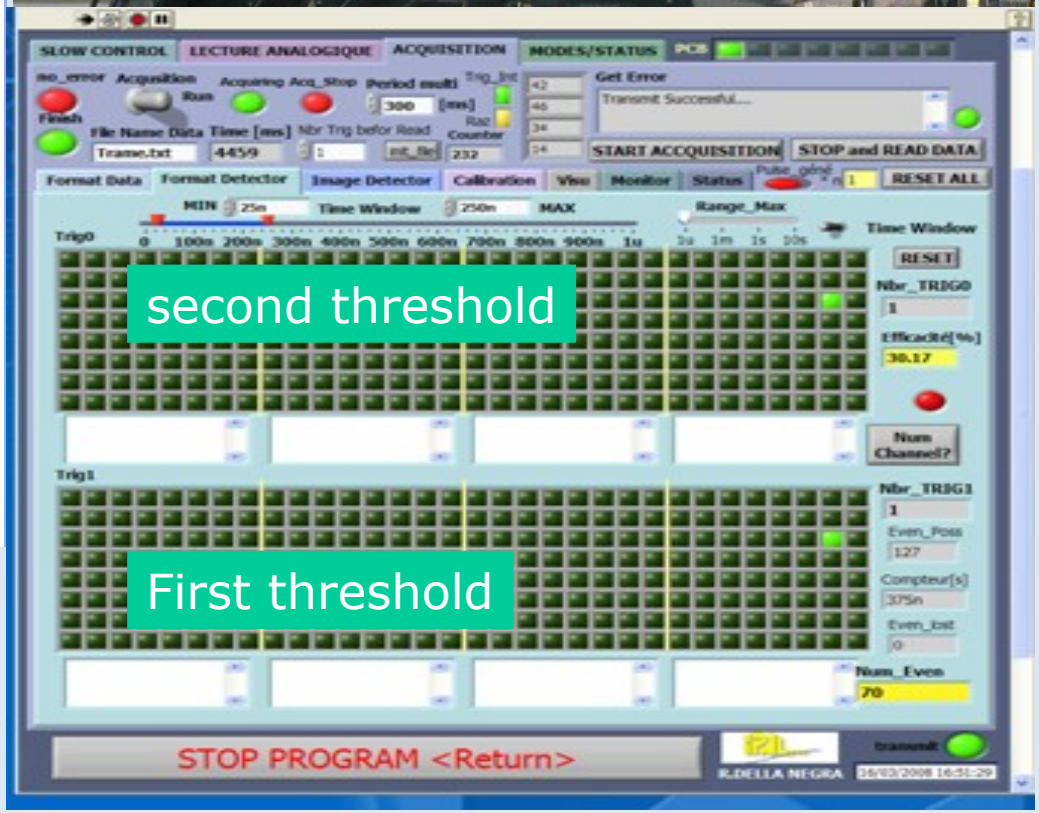


after



≈ 2.5 fc



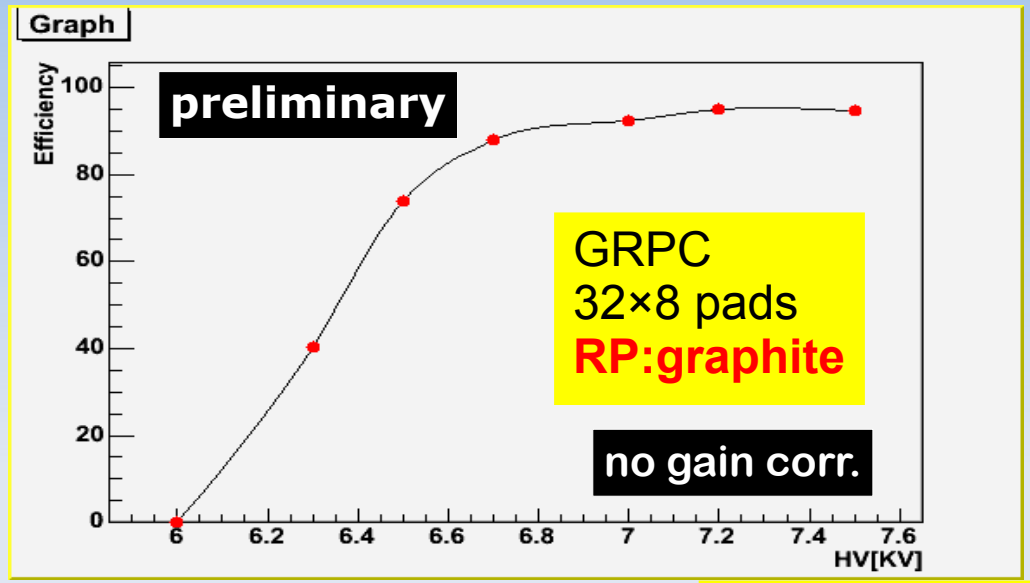


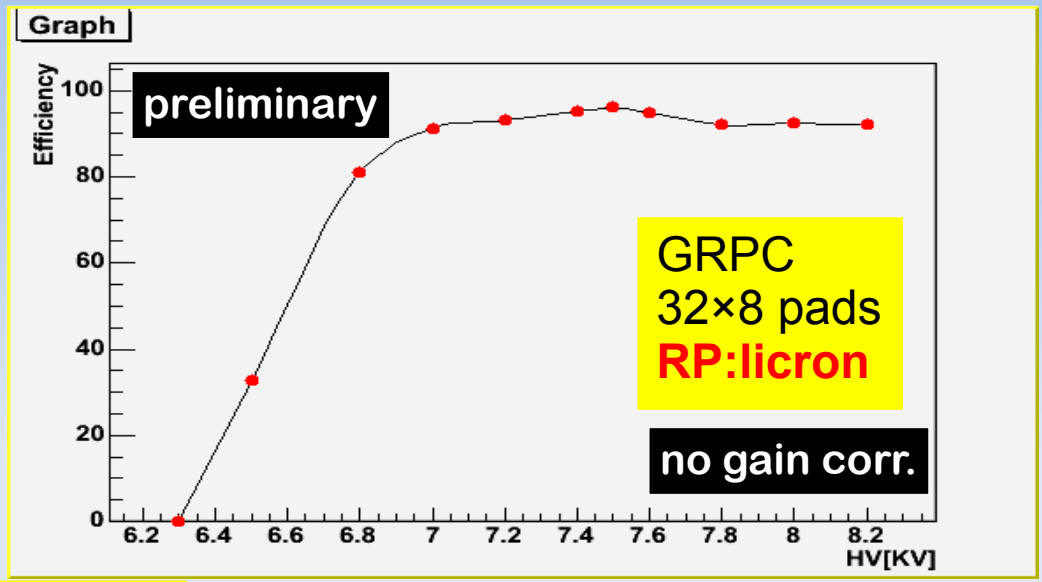
Example of a recorded mip
5-GRPC cosmic rays test bench
Thr. ~ 100fC

GRPC Efficiency & Multiplicity

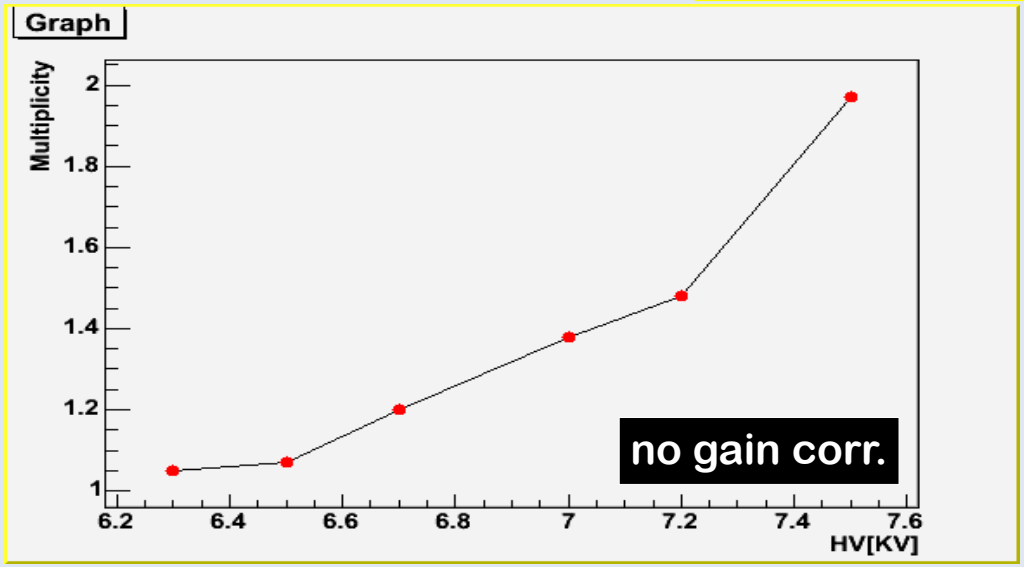
TFE	93%
Isobutene	5%
SF6	2%

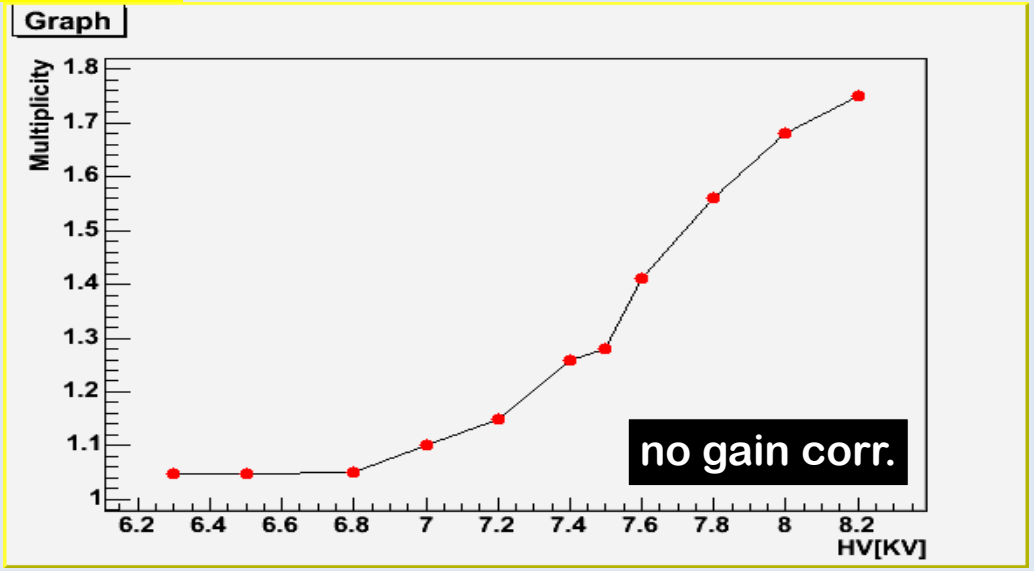
Calorimeter for ILC





Threshold ≈ 100 fc

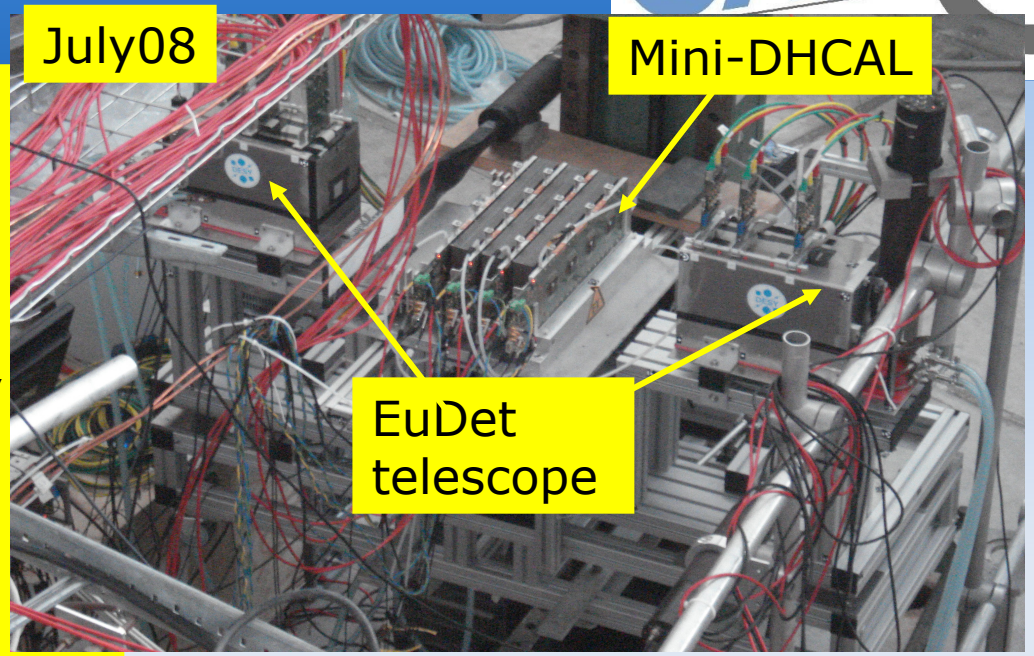




GRPC Mini-DHCAL test at CERN

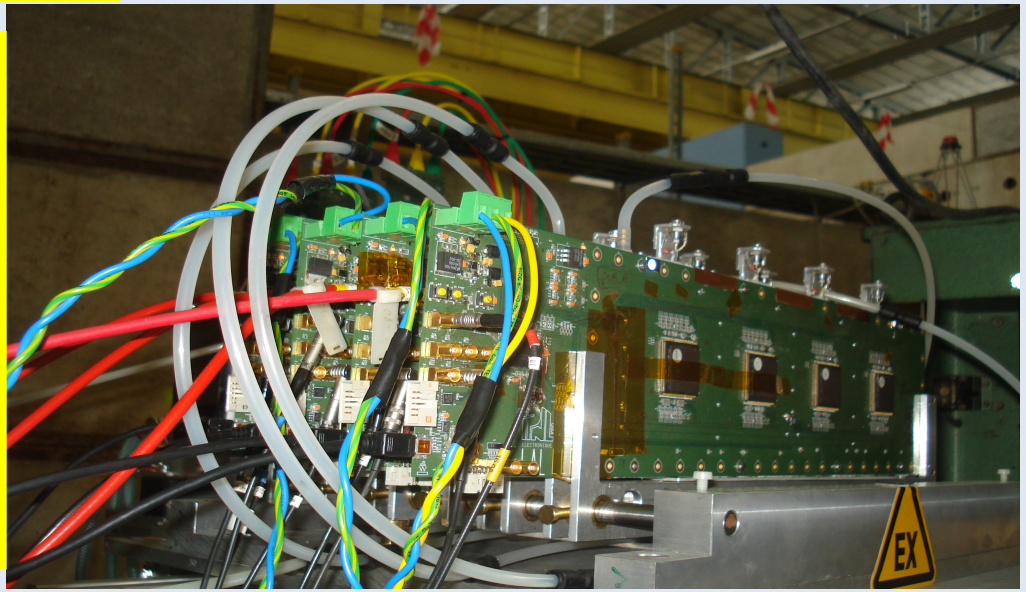
Aim:

- Validate the whole electronics readout system in beam conditions
- Study the GRPC behavior vs (HV, thresholds, angle, position, rate)
- Study the first phase of the hadronic shower (pion energy 1-12 GeV)



- About 400 k evts were collected (DAQ rate : 20 Hz) and being analyzed

- The readout system as the GRPCs performed very well: stability and efficiency



Beam test periods

PS: Mostly π (3-12 GeV) + few μ, very few e-

PS T10 17—24 july with the EUDET telescope: ~260k trig evts

- With EUDET Pixel Telescope: 7×7 mm² active sensors
- **Angle & position** scans
- Other data: trigger large scintillators (10×40 cm²)

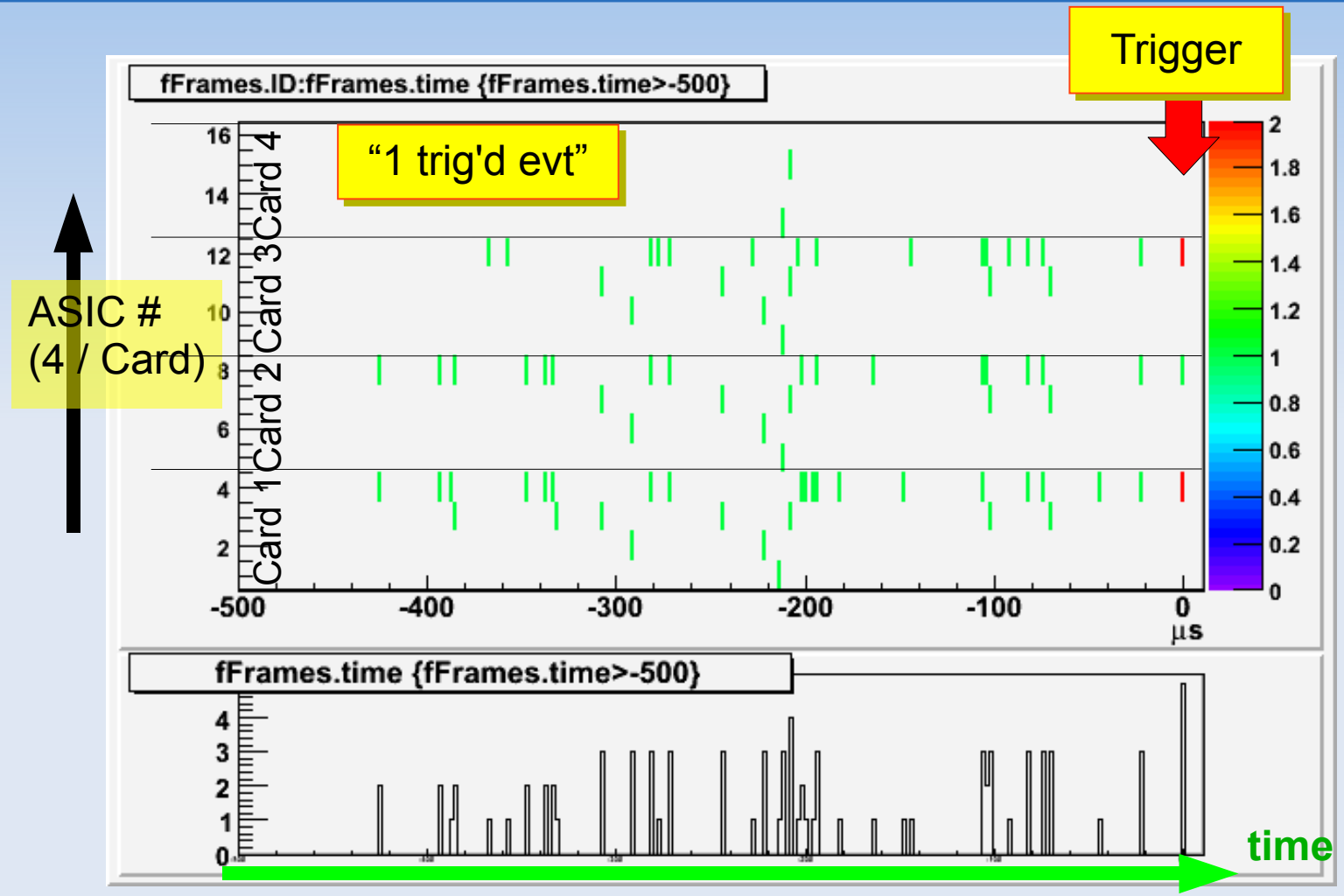
PS T9: 28/07 — 04/08 ~80k trig evts

- Complement Pion data with 2 λ of W, **angular** scan
- Analogue readout of 1 chamber
- Test of a wide RPC: 100×35cm² (readout with 4 PCB ⇒ ~32×32cm²)

PS T9: 07/11 — 12/08 ~65k trig evts

- Shared test with μMegas (≠set-up)
- Complement test: **HV** scan, **thr.** Scan, **CO2** (as repl. of Isobutane), **Beam intensity** scan
- ***Tentative***: m² + 24 HR1 PCB + new DAQ elec & soft (DIF)

Timing: single event + auto-trig

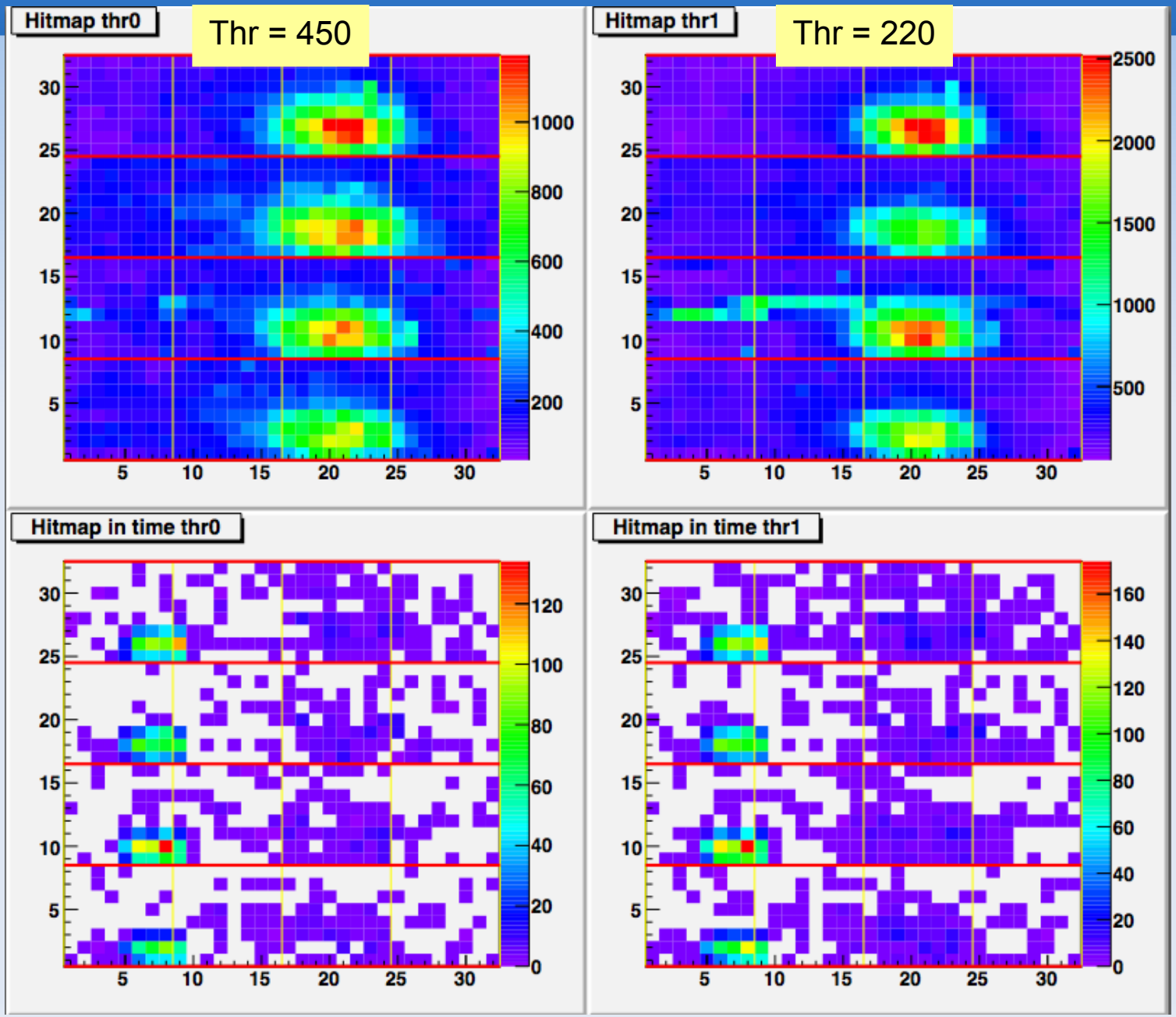


Many More stat Available with proper time reconstruction

Expt'd: 830

- CERN PS: **400 ms** spills every 48 or 33s (day/night cycles).
- Running mode: **single event with auto trig**
  + BUSY logic & automatic RAMFULL recovery (⊃ BUSY signal)

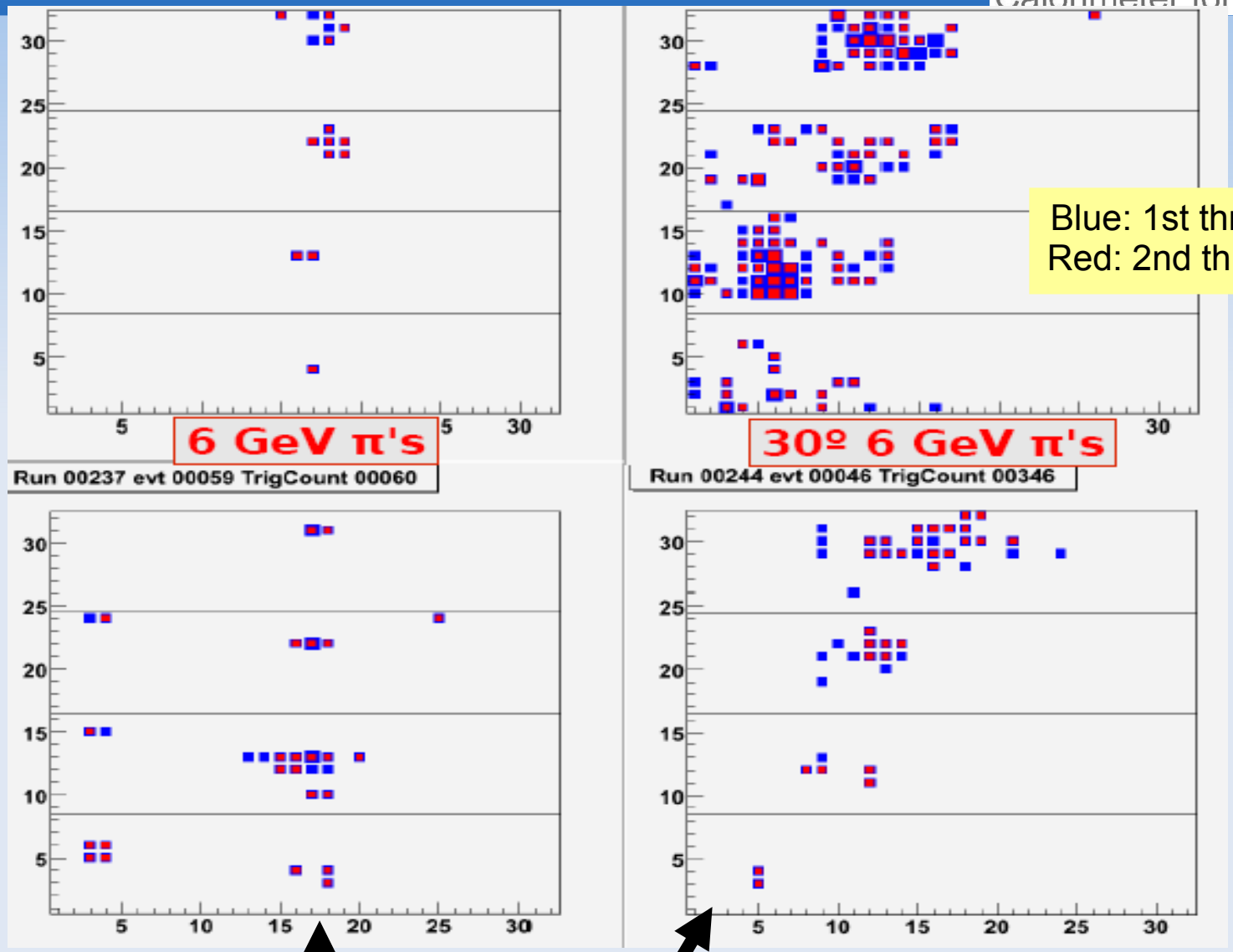
First displays



All Events

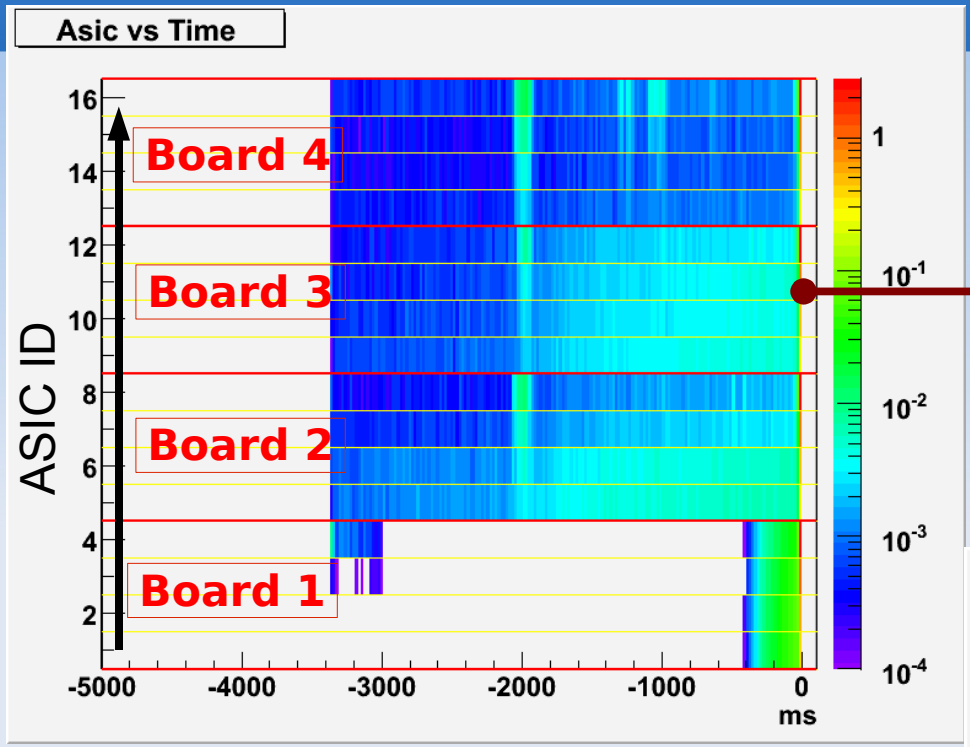
in time
With ext.
trigger

GRPC Mini-DHCAL test at CERN

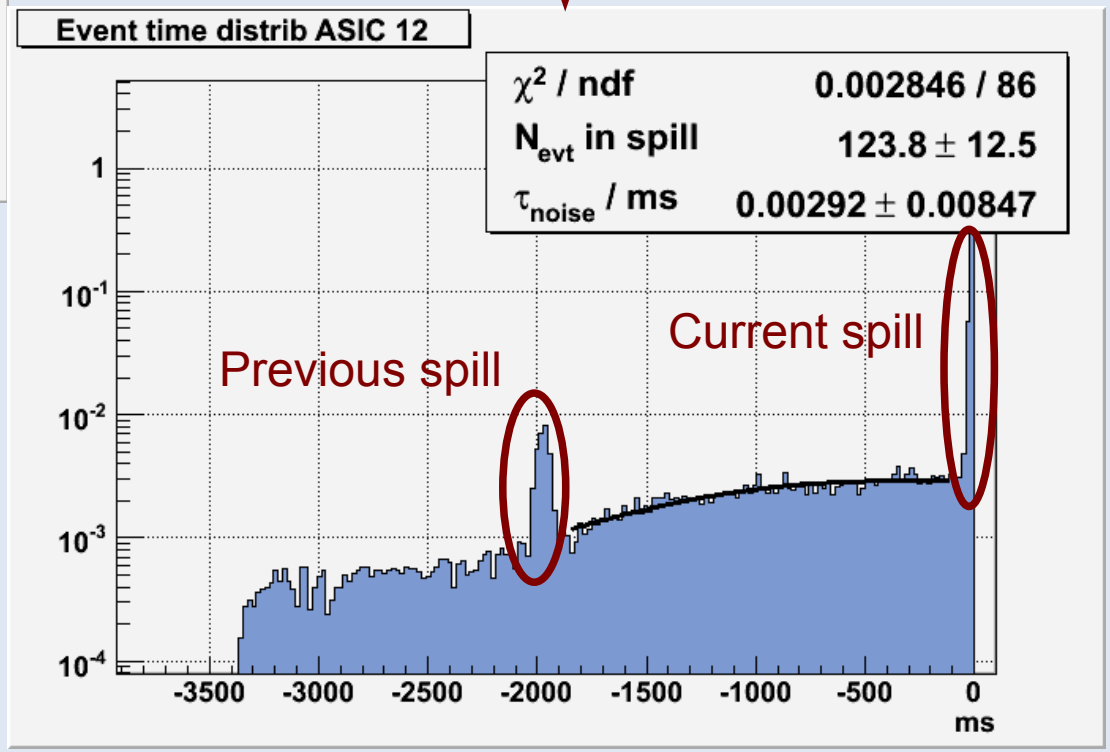


With 2 cm Stainless-Steel absorbers

Noise & ROC study



Run00101
Hit rates for each triggered event

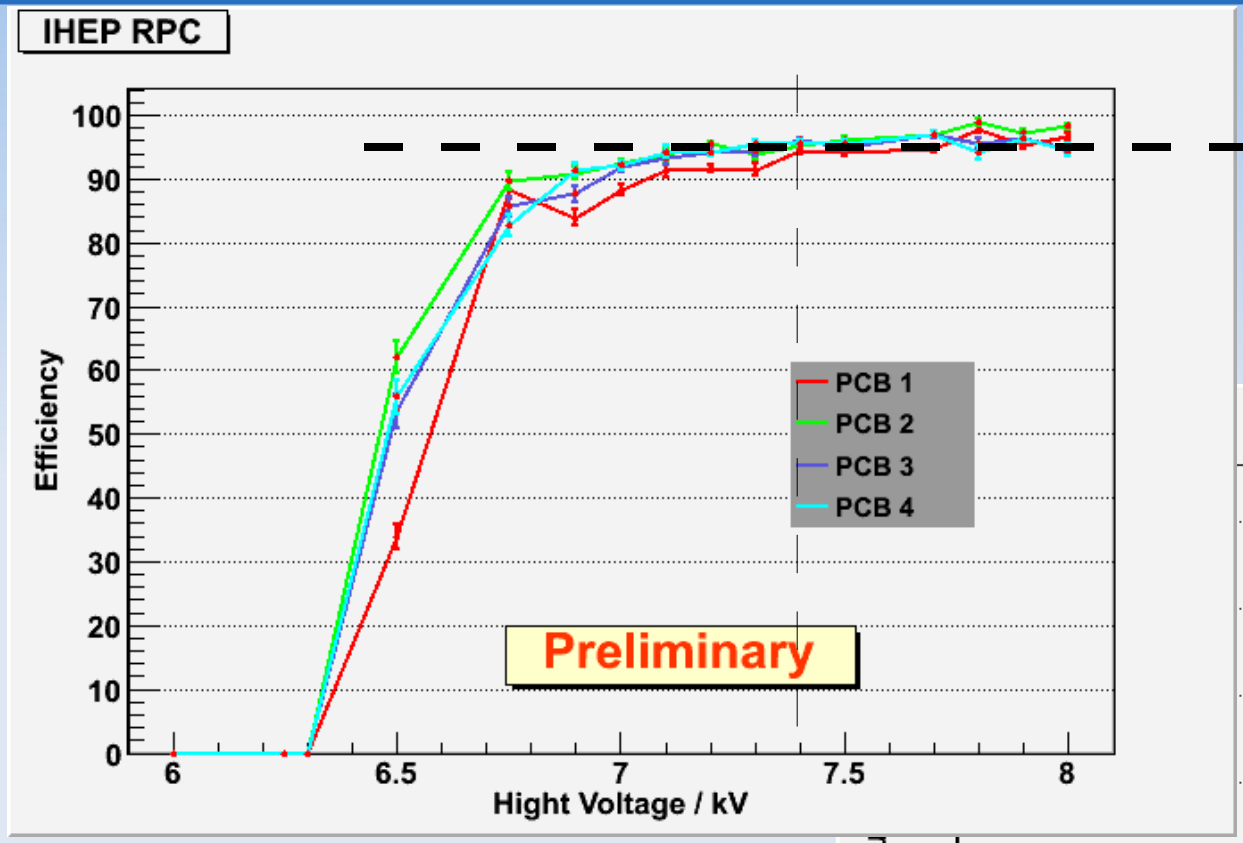


Shape:

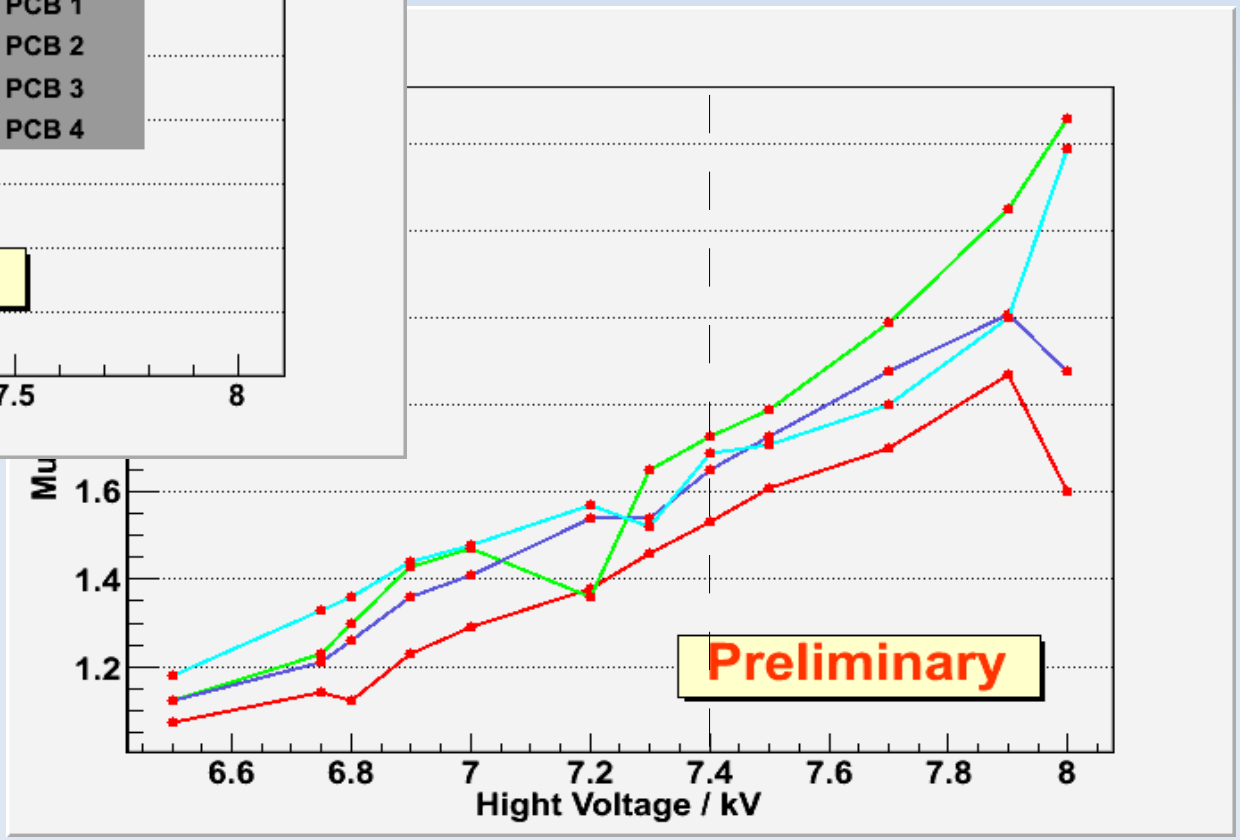
- flat noise+event rate τ
- modified by RAMFull (Loss of memory)
- probability at **-t =**
  - (1- P(avail. mem, t × τ))
  - avail. mem = 128 evts – **N_{evt} in spill**

$$P(a, x) = \frac{1}{\Gamma(a)} \int_0^x t^{a-1} e^{-t}\, dt$$

IHEP GRPC: Efficiency & multiplicity

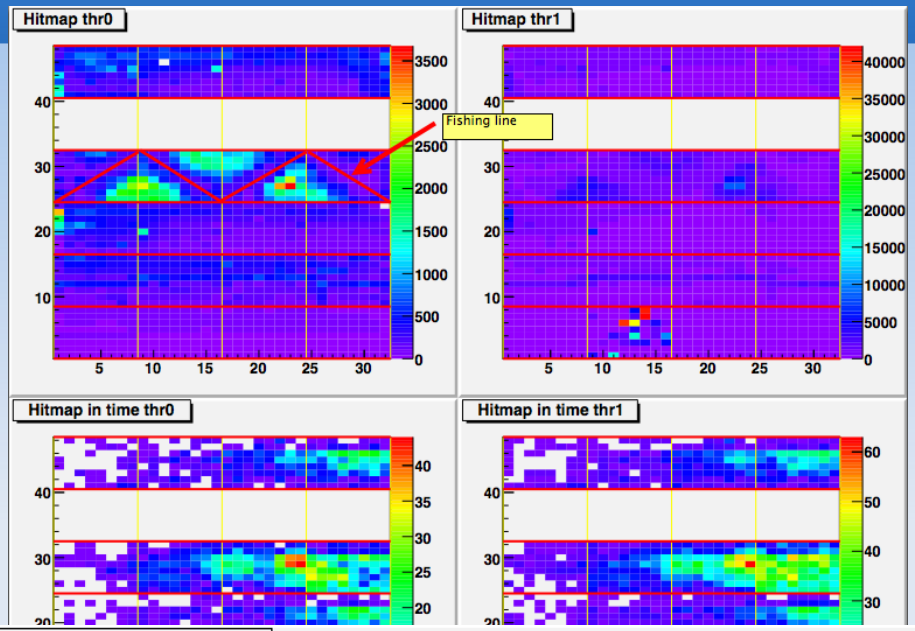


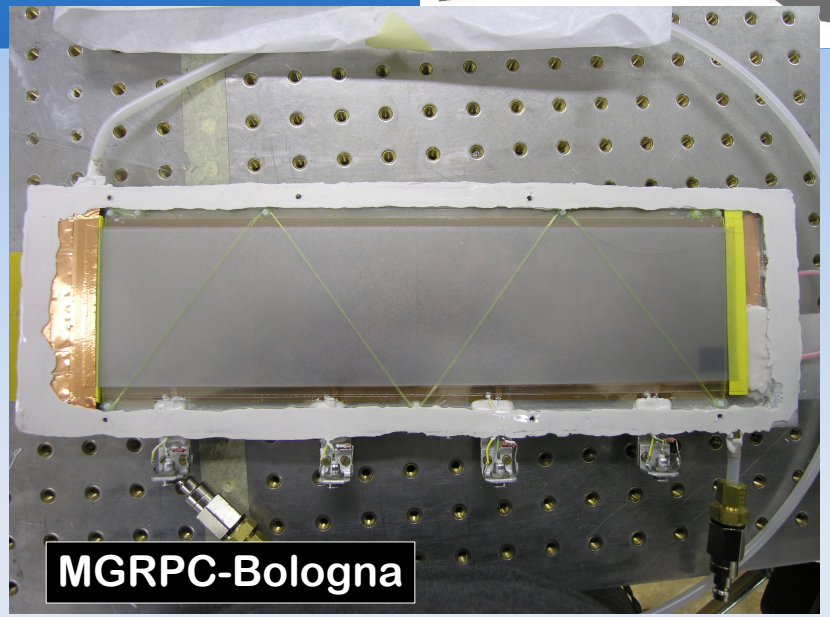
Working point: 7.4 kV
95% efficiency
1.6 pad/track

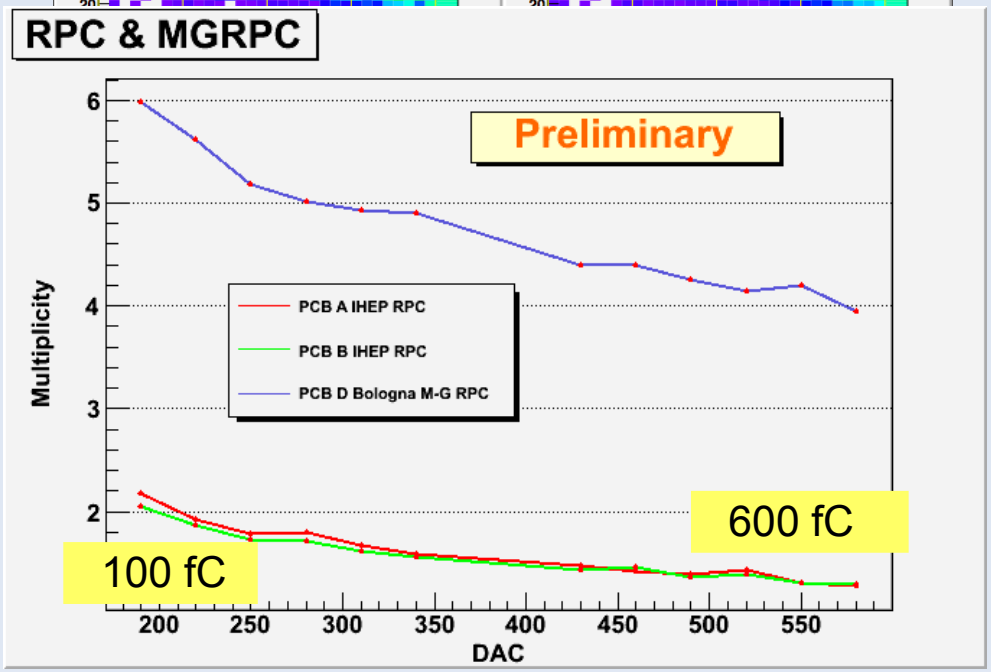


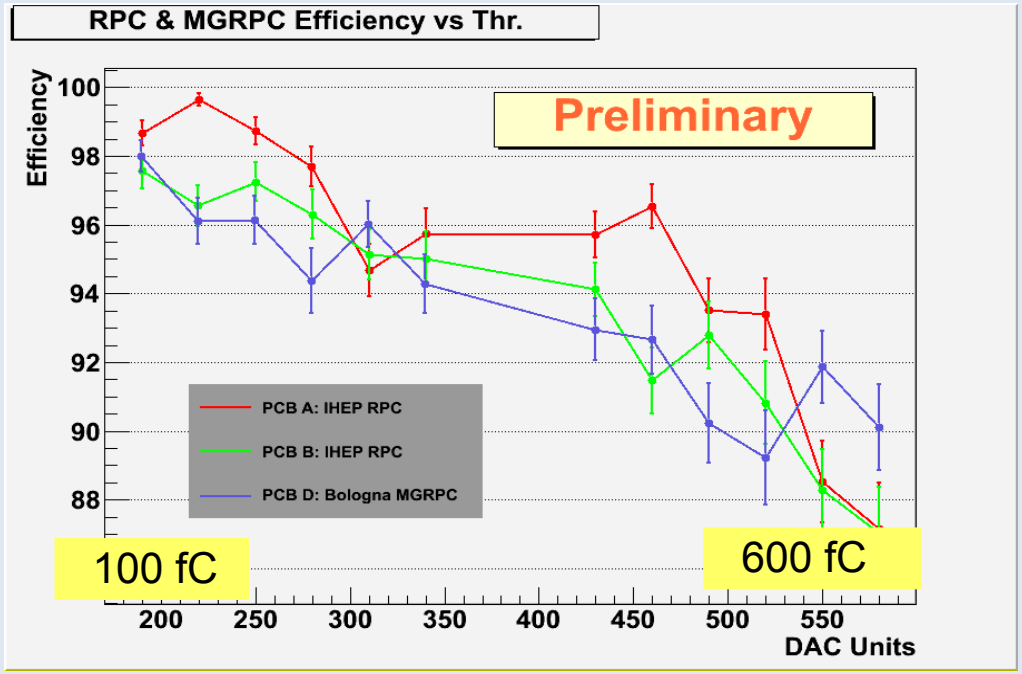
- Track reconstruction
- Threshold @100fC

RPC vs. Multi-Gap RPCs



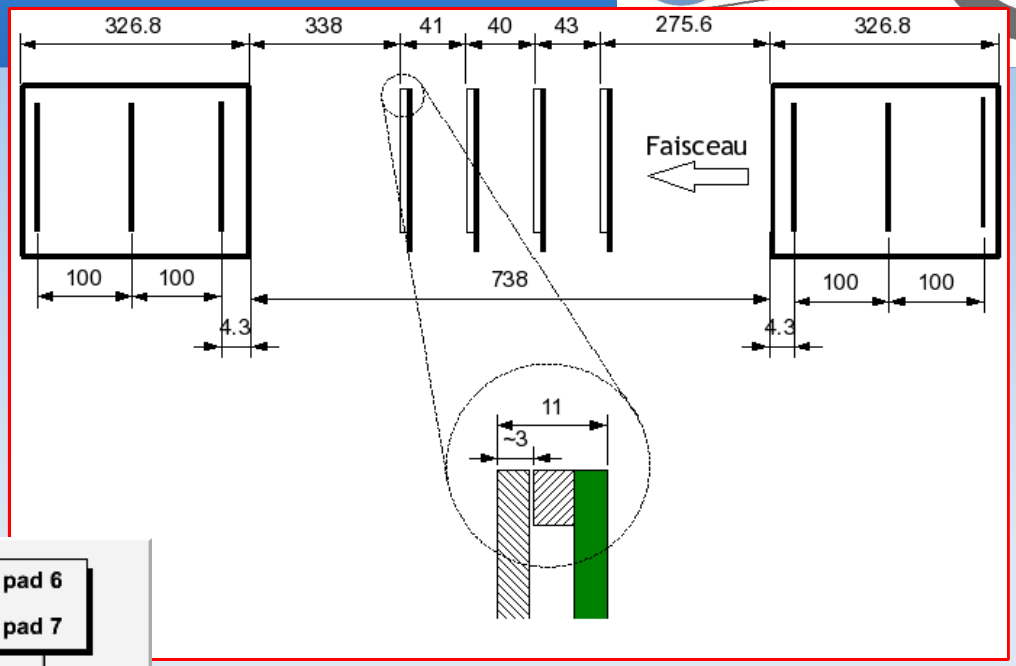


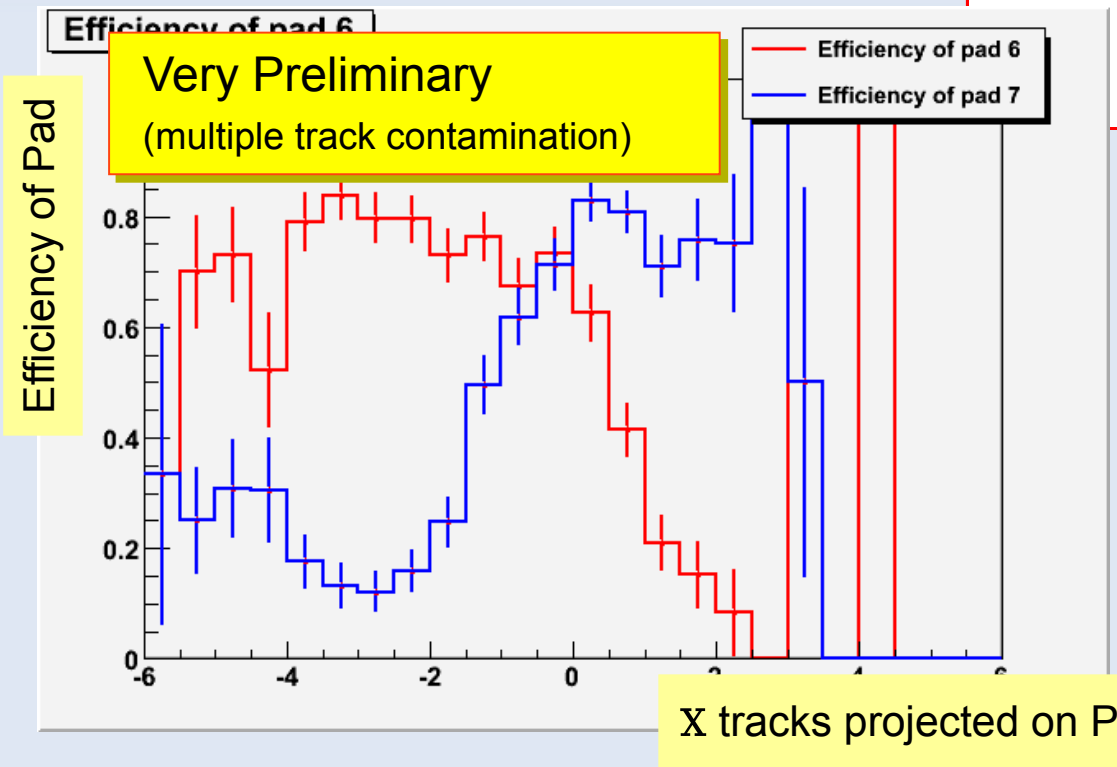




Data with EUDET pixel telescope

- 2 independent DAQ's
  - → Shift of 1 evt
- small surface: 7×7mm²
- Track precision: ≤5 µm



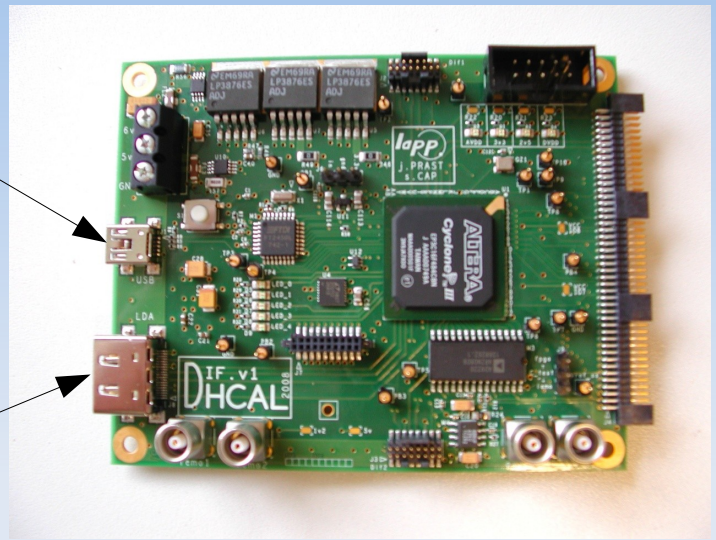


Clean-up (multiple tracks, multiple hits) and multiple runs analysis on going....

The 1 m² project

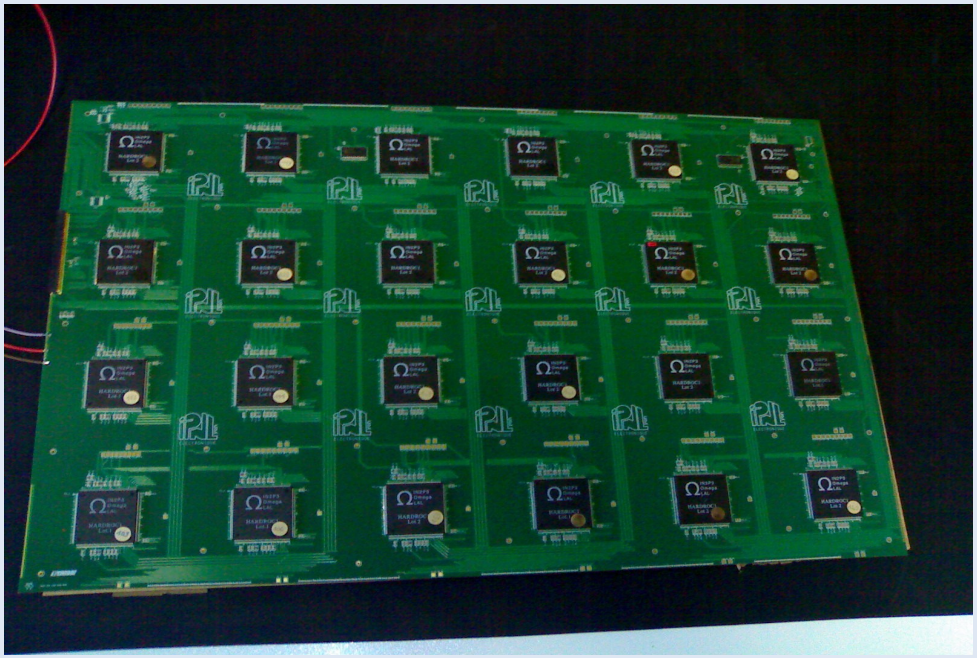
DIF

- 10-layer board (6 for signals) designed and prototype produced
- FirmWare & SoftWare operationnal and tested in beam (with 4 HR μMegas card)



ASU

- 8-layer board designed and produced
- 500×33.3×1.2 mm³
- Connections between adjacent PCB foreseen
- ASICs were tested and plugged

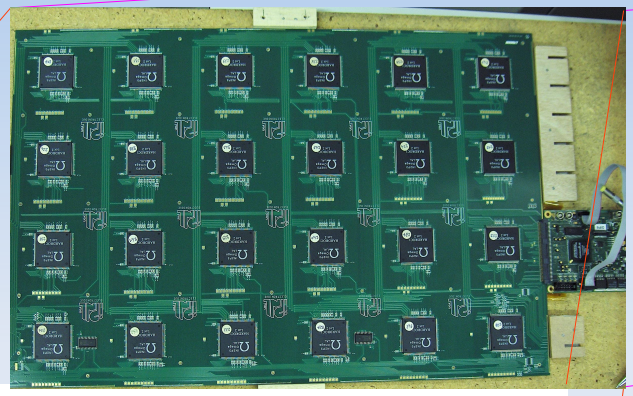


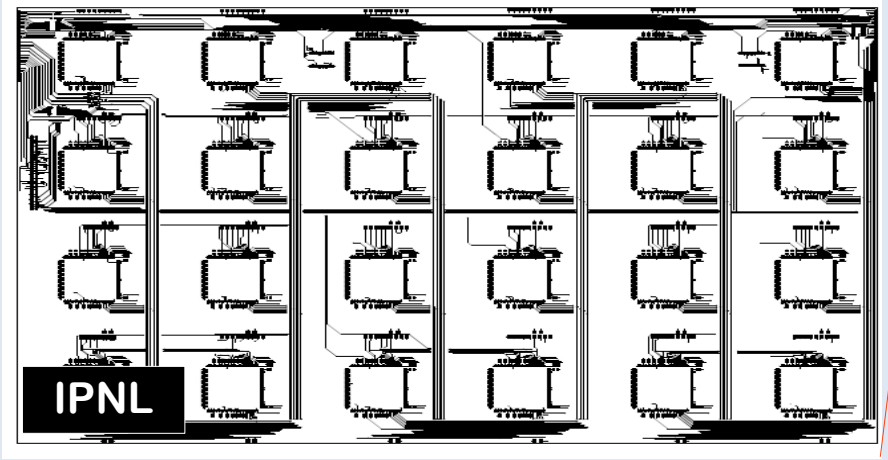
Software

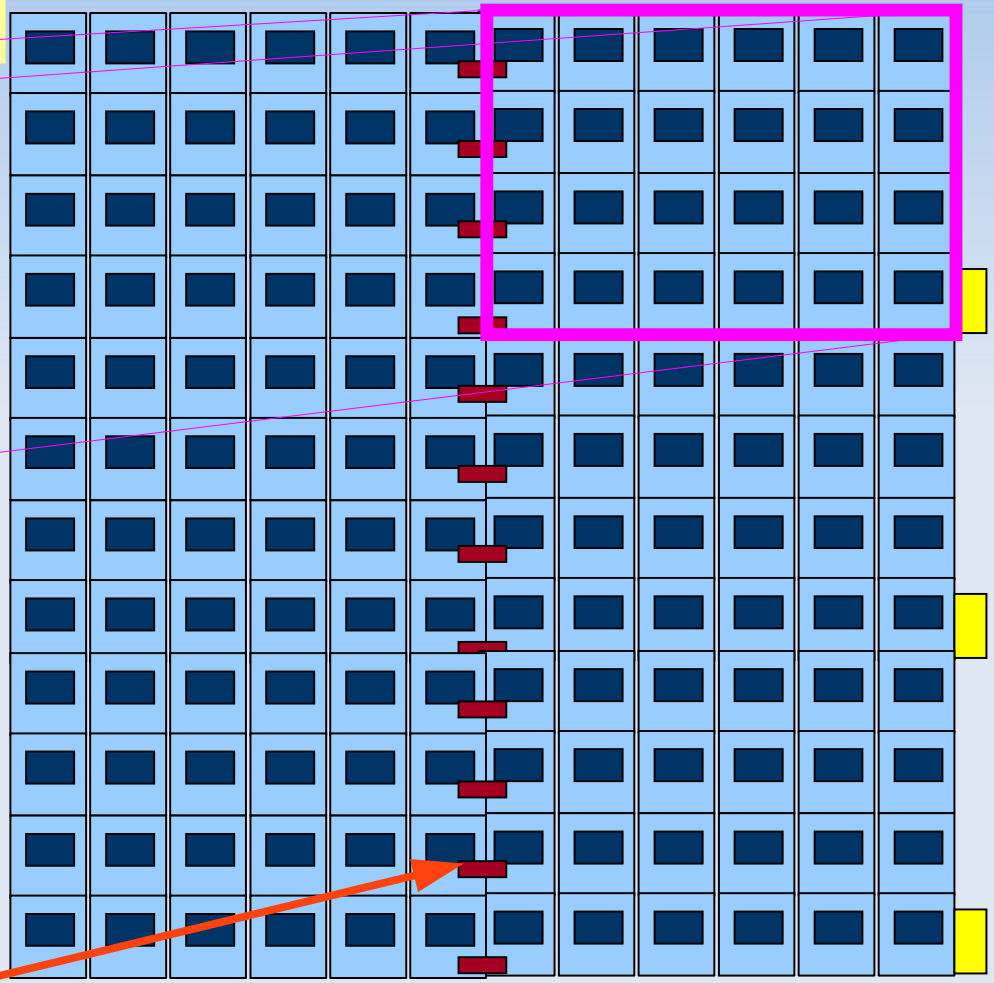
Acquisition software based on US/XDAQ developed

Next steps: m² ASIC support Units

1 ASU → 6×4 chips



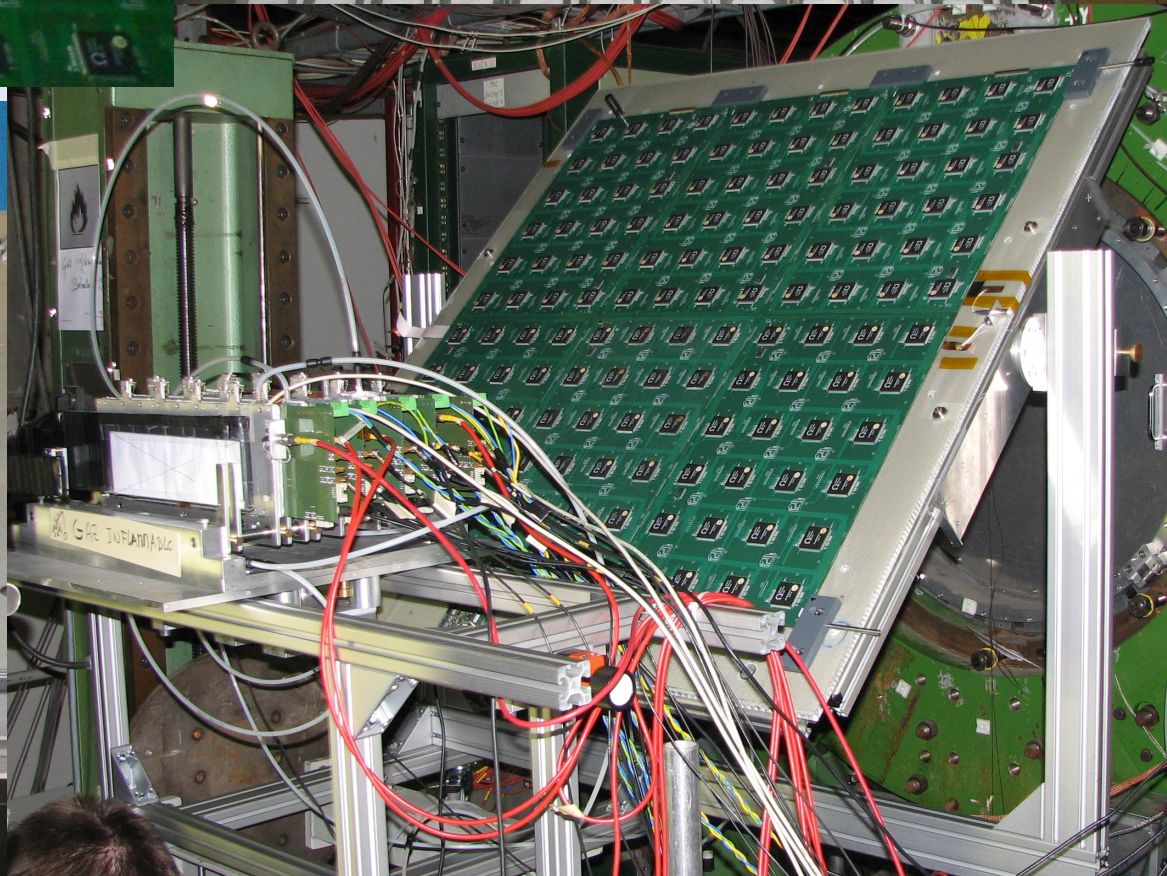




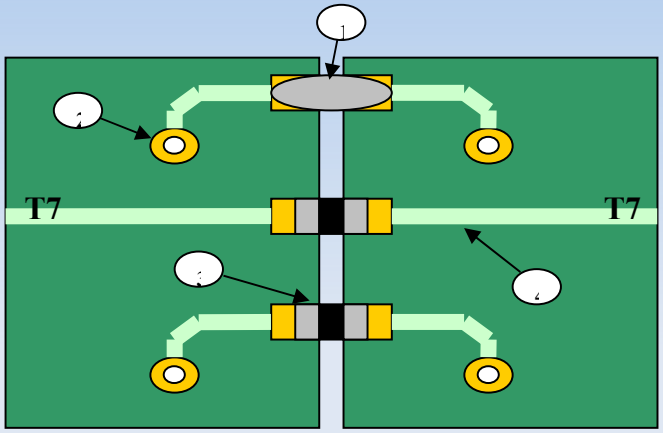
pcb-connector

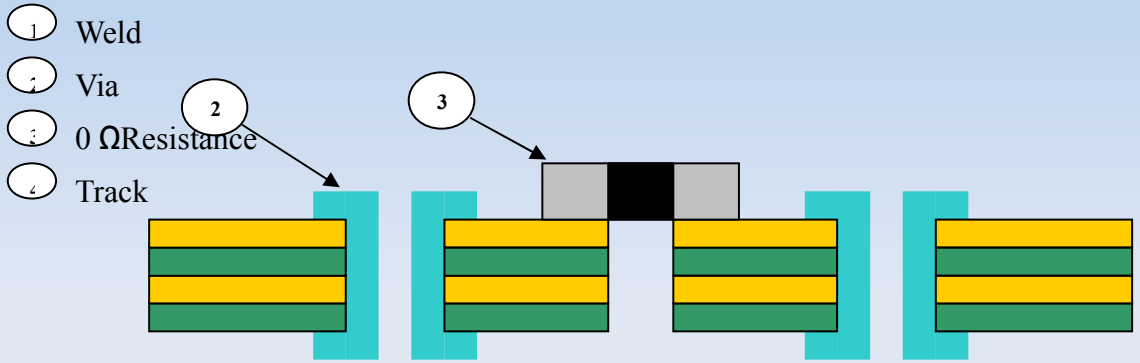
ASU hosting 24 HARDROC chips produced and being tested

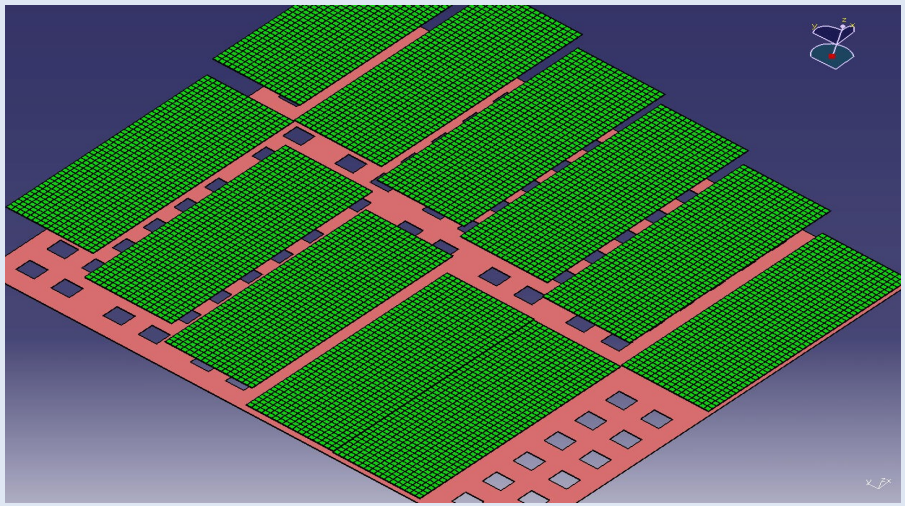
Support is being realized
CIEMAT

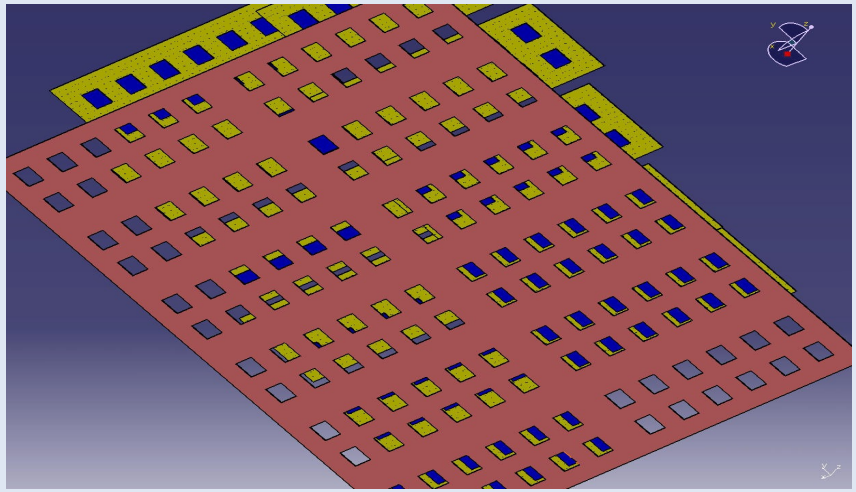


Connection between the different ASU is under study: signal transmission+ mechanics (IPNL+CIEMAT)

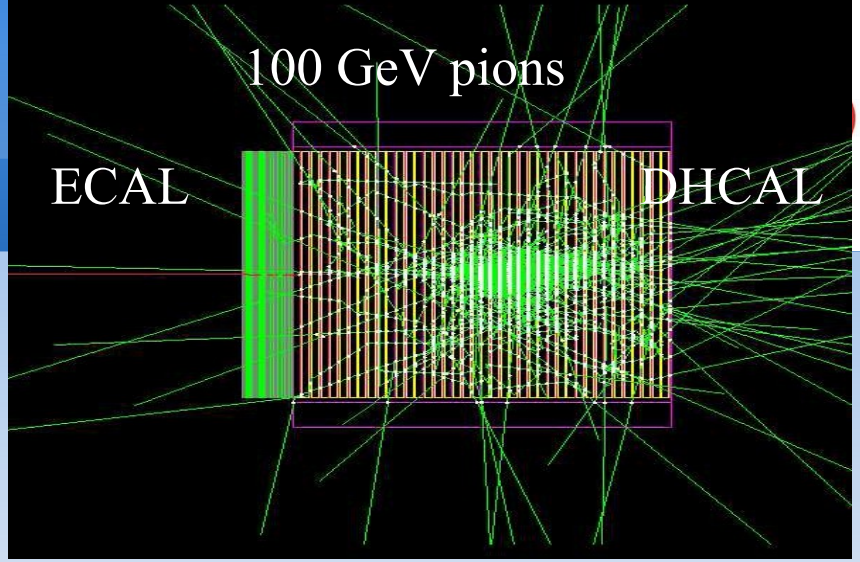






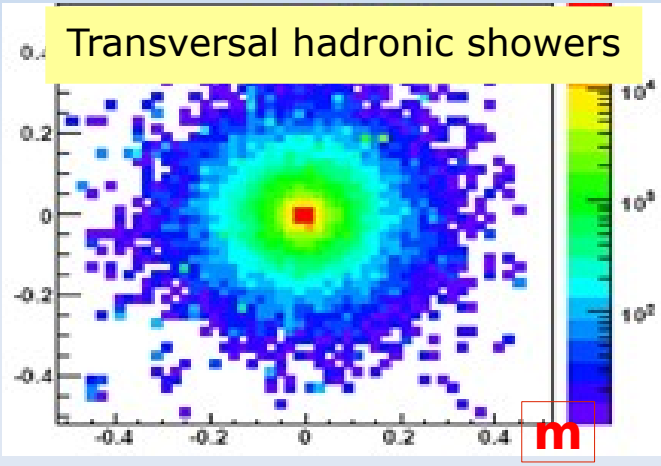


The 1 m³ project



Aims:

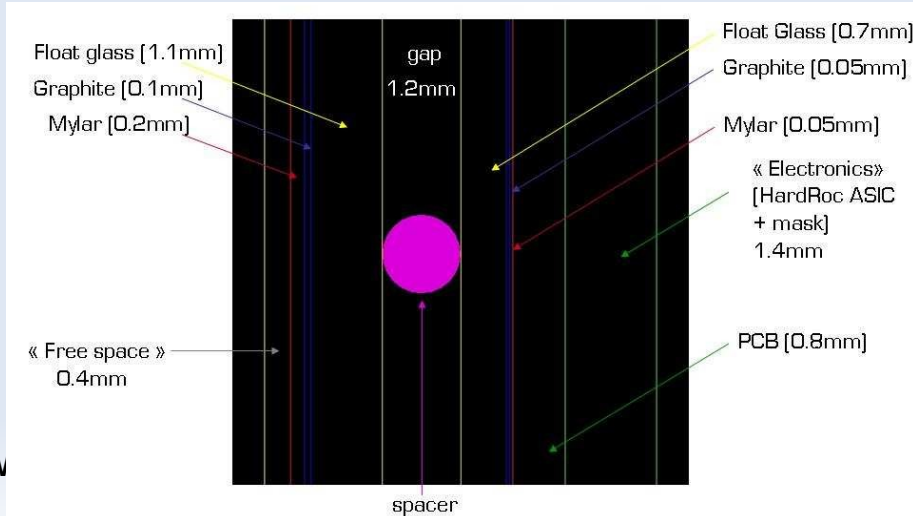
- Demonstrate the Digital SDGHCal concept
- Learn as much as possible how to build a DHCAL for ILC (technological prototype)
- Study hadronic showers extensively



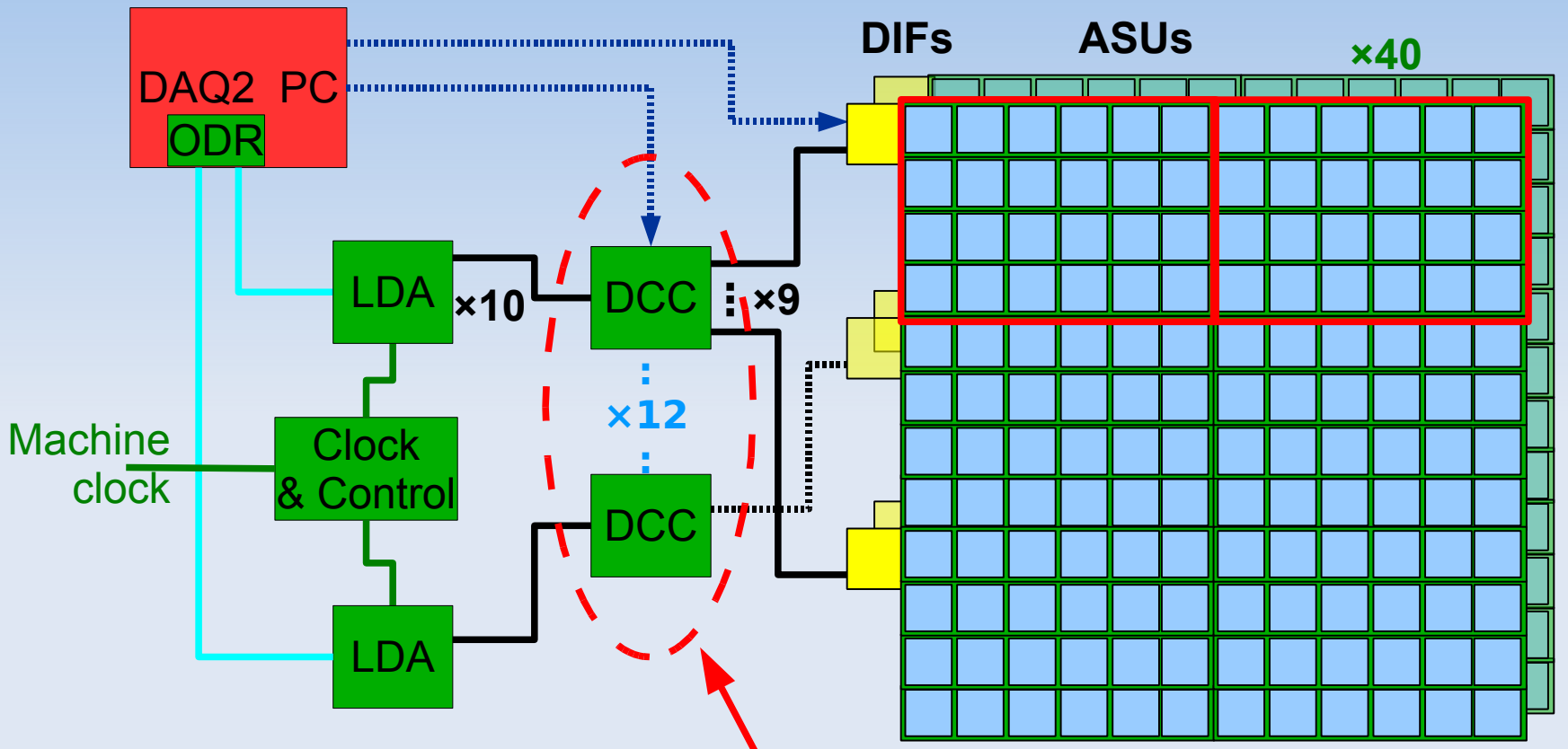
Implementation:

- 40 GRPC/µMegas interleaved with
- 40 stainless steel absorbers (2cm thick)
  ⇒ 4.5 $\lambda_{had.}$

- Design optimization is on going using
- GEANT4 with **full cell details**



M³: First use of EUDET DAQ2



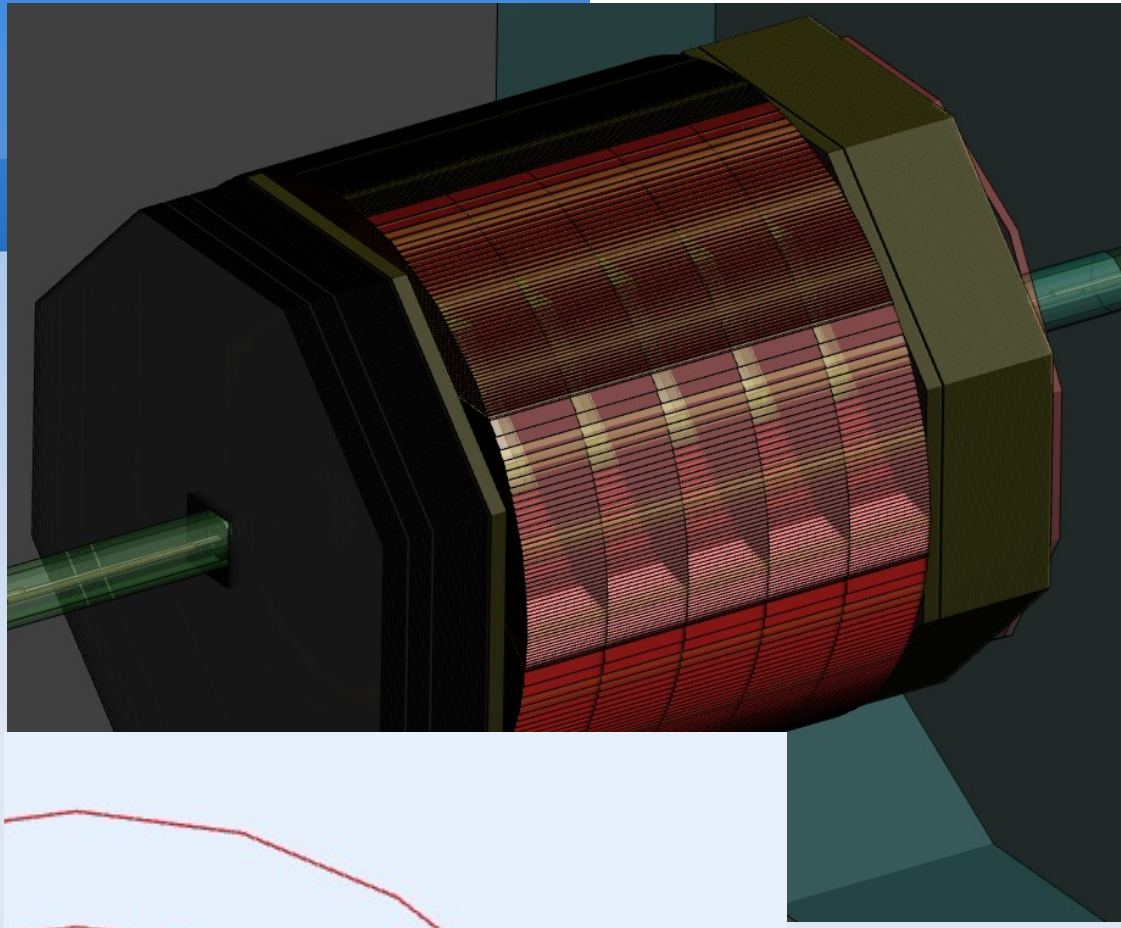
Additionnal concentrator card
Being developped

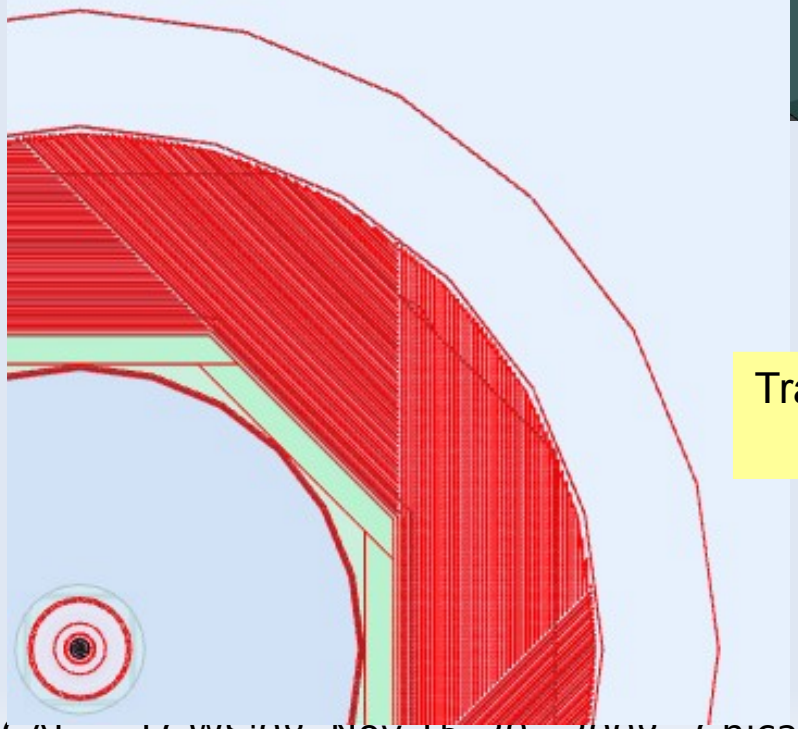
See V. Bartsch talk on EUDET DAQ

Reminder: 40×100×100 cells = 400k channels!!!

ILD integration

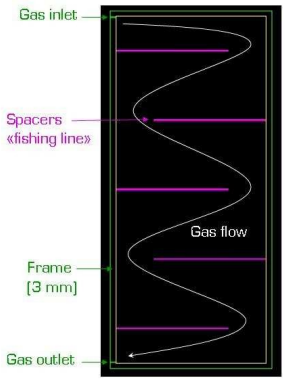
- Geometry in ILD simulation
  - 5 wheels + endcaps
  - 8 Modules/wheel
  - 48 layers/module
- Electronics, gaz and cooling on the periphery
  - Jointive barrel & endcaps
- Rigid mechanical structure





Tranverse cut

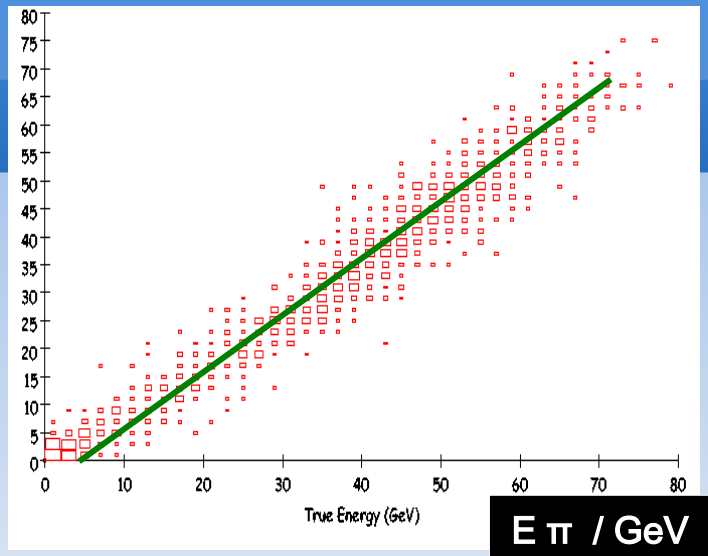
Gaz flow study



Conclusions & perspectives

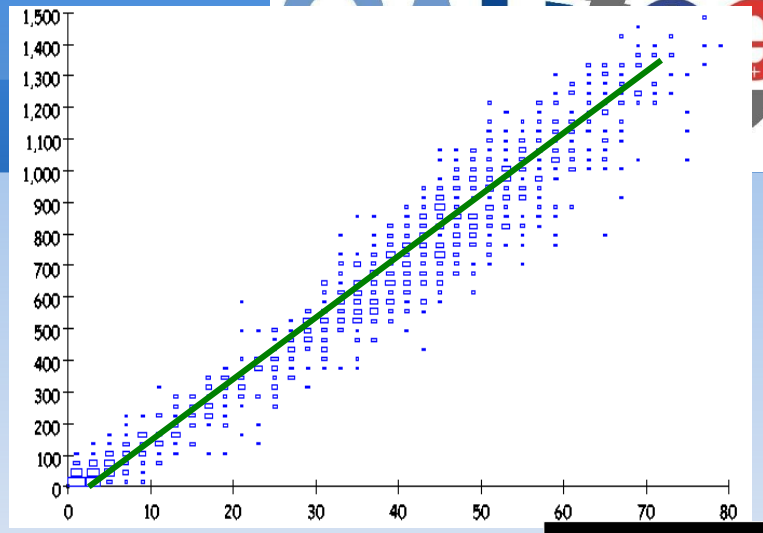
- A Semi-Digital Gaz Hadronic Calorimeter with embedded readout is a very promising candidate for future linear colliders experiments
- A mini SDGHCal based on first generation readout with GRPC was successfully tested in laboratory and in test beam at CERN
  - the first results are arriving
- Active development on RPC's and MGRPC
- 1 m^2 project is ongoing
  - first equipped 1m^2 GRPC plan is expected before the end of 2008.
- A technological prototype “1 m^3” is funded and expected in 2009-2010

Edep



E π / GeV

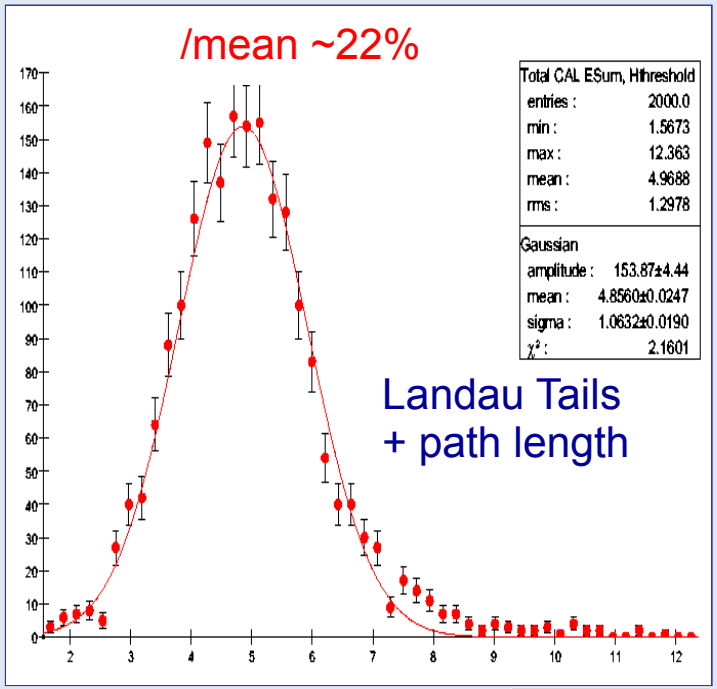
N hits



E π / GeV

Simulation
Calice

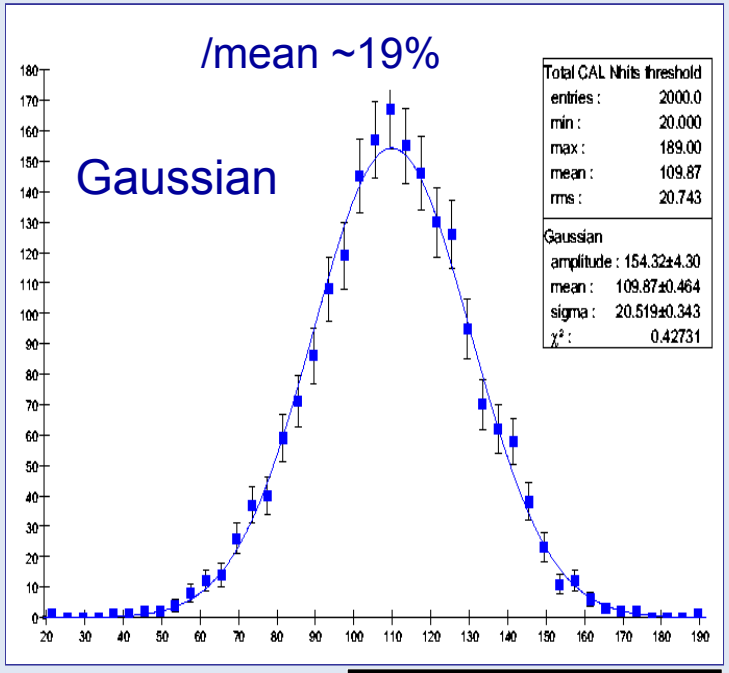
Analog



E / GeV

0^+ 5 GeV

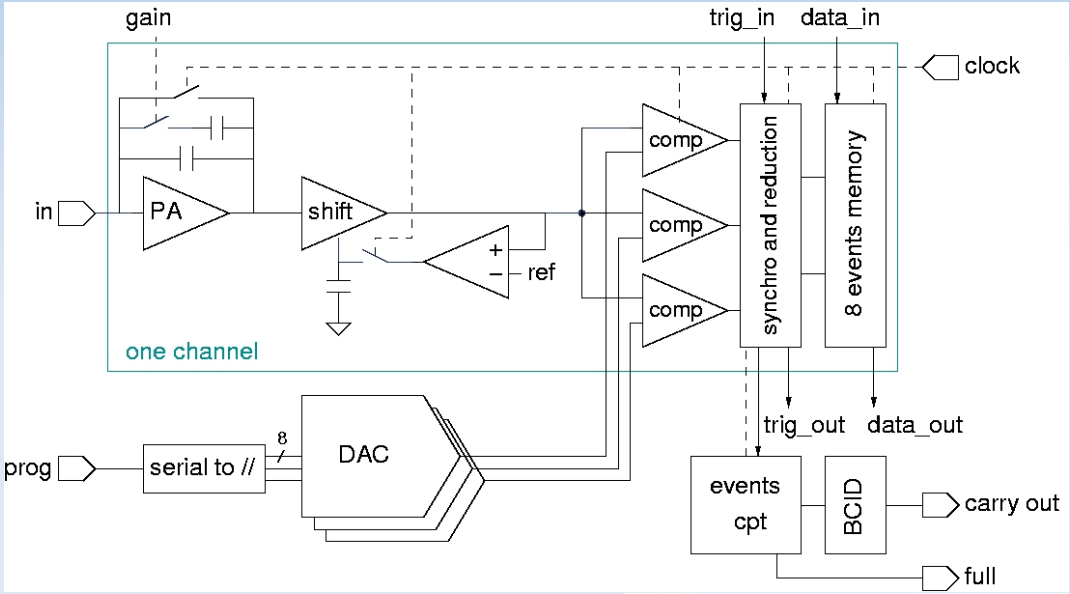
Digital-1bit



Number of hits

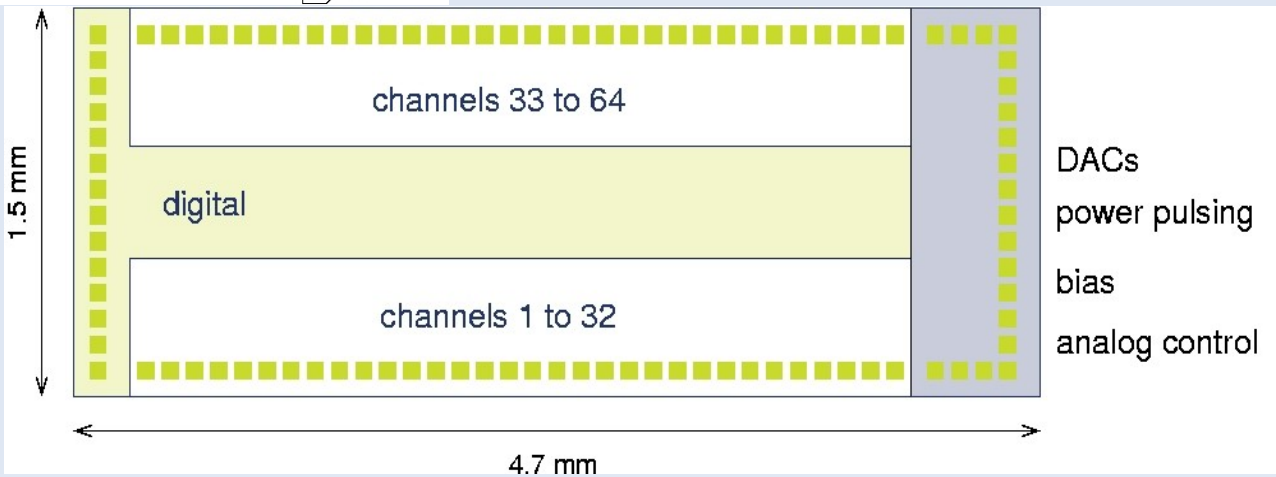
DIRAC ASIC

A new chip with a low threshold for µMEGAS
is under development @IPNL

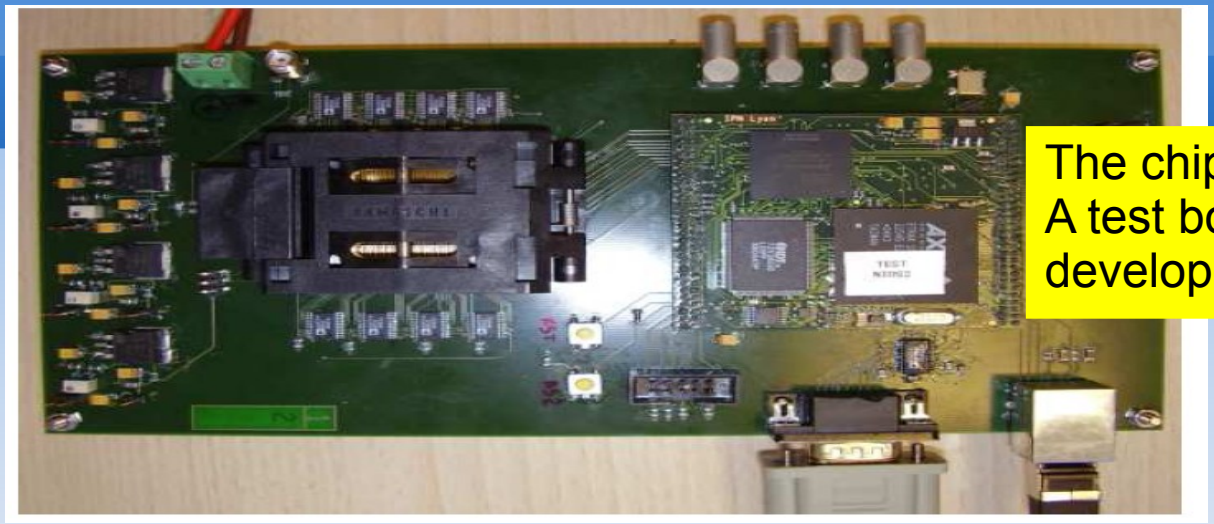


3 DACs (8 bits each)
BCID = 12 bits
memory depth= 8 evts

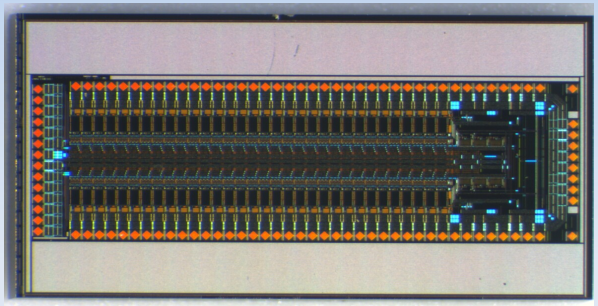
64-ch chip
CMOS tech
power pulsed

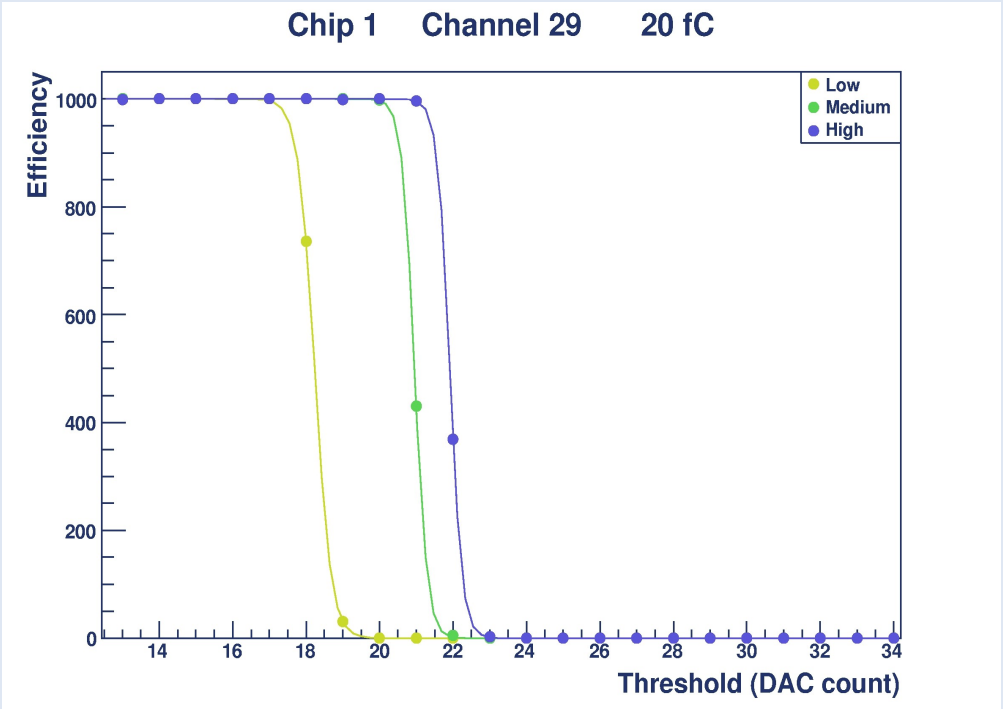


Simple geometry



The chip was designed and produced.
A test board using OPERA DAQ developed @IPNL was used.





First results:
Mode µMEGAS
0.8 fc/DAQ
Resolution < 2.5 fc

Tests and improvement are going on

HARDROC: Power pulsing