DHCAL

- Introduction
- DHCAL in Europe
- Detectors activities
- Electronics activities
- Acquisition activities
- Beam tests
- Perspectives

I.Laktineh
IPN-Lyon

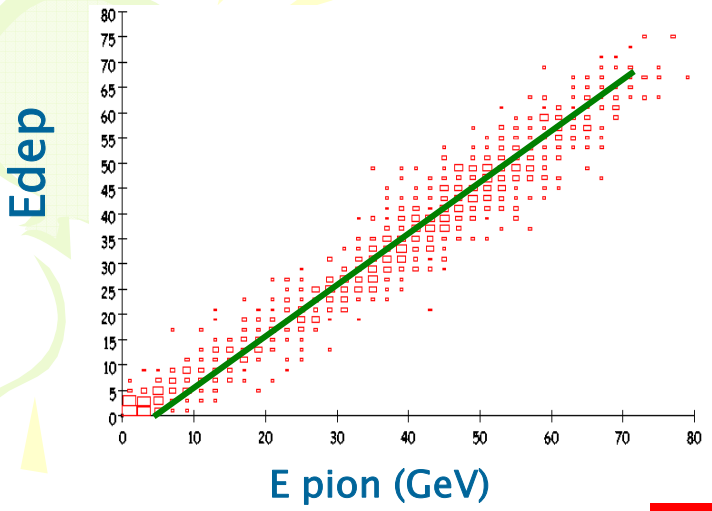
Introduction

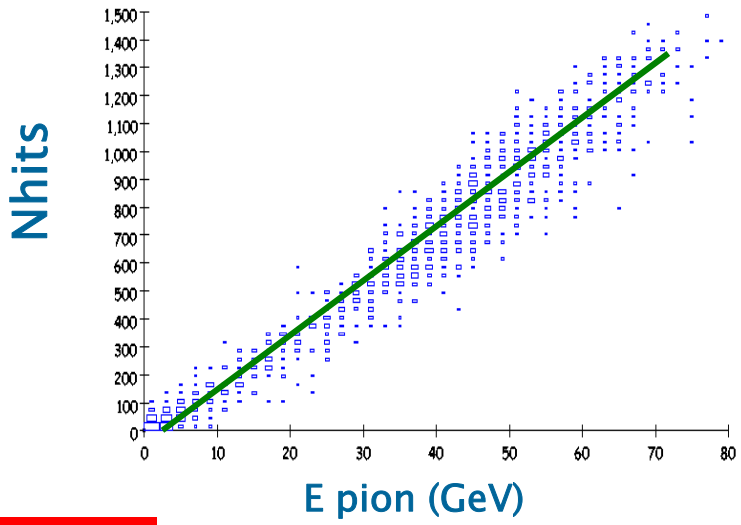
Why the digital solution?

Going from analog readout to 1:2-bit readout electronics:

- One can increase detector granularity and hence PFA performance while reducing cost.
- Cheap, robust detectors suitable for the digital version exist and are very attractive: GRPC, µMEGAS, GEM...

Does the digital option mean energy measurement degradation?



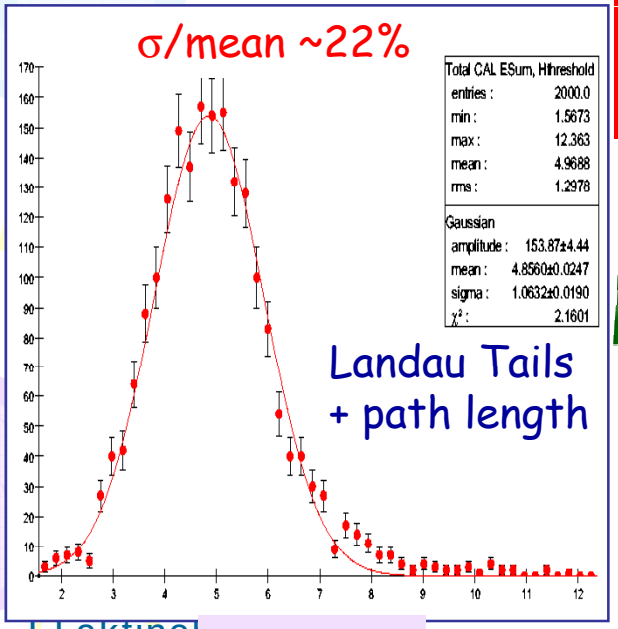


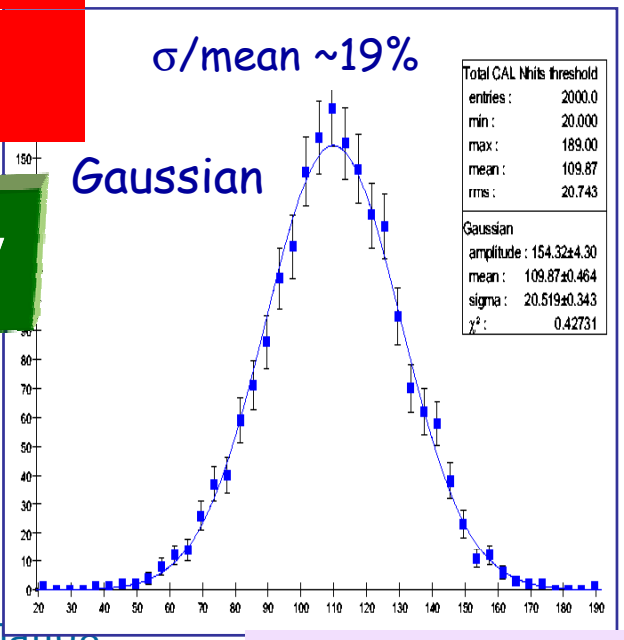
Analog

Digital-1bit

Simulation calice

π^+ 5GeV





- 1-bit digital solution is better at low energy
- Analog solution is favored at high energy due to high number of particles in the central region.

But what about the 2-bit readout solution?

The study of KEK group for the GLD HCAL using : 2-bit, 3 thresholds (.5, 10,100 MIPs) associated to 1X1 cm2 tile size shows :

- Similar energy resolution with respect to the analog readout version for single particle

Comparison of Energy Resolutions

$$\frac{\sigma}{E} = \sqrt{\frac{\sigma_{stochastic}^{2}}{E} + \sigma_{constant}^{2}}$$

- Analog : $\sigma_{sto} = 48.9 \pm 0.6$ %
  $\sigma_{con} = 5.0 \pm 0.2$%
- Digital : $\sigma_{sto} = 37.0 \pm 0.9$%
  $\sigma_{con} = 13.8 \pm 0.2$%
- Semi : $\sigma_{sto} = 45.1 \pm 0.6$%
  $\sigma_{con} = 6.8 \pm 0.1$%
- Real data (analog) :
  $\sigma_{sto} = 46.7 \pm 0.6$%
  $\sigma_{con} = 0.9 \pm 0.9$%

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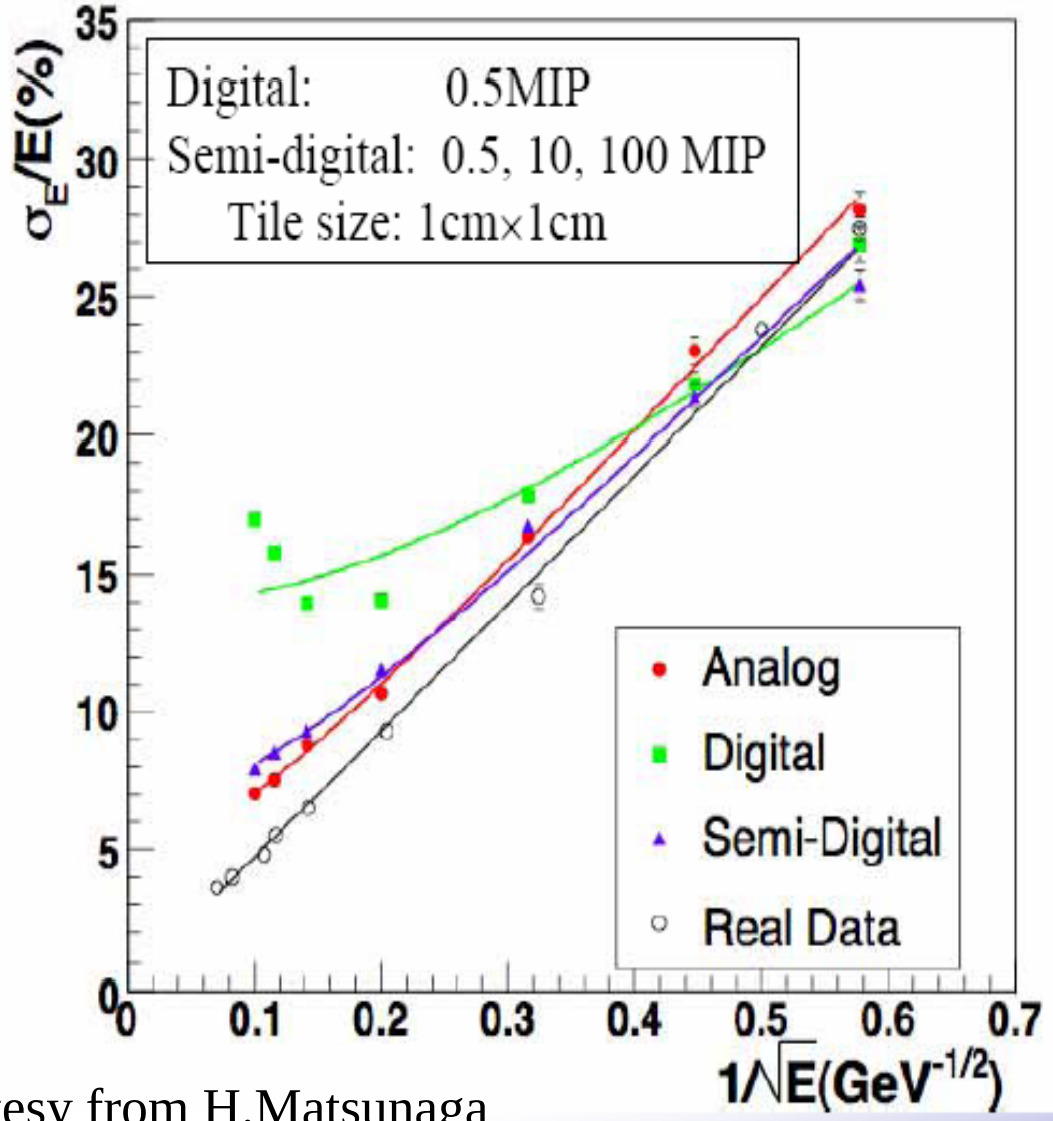


courtesy from H.Matsunaga

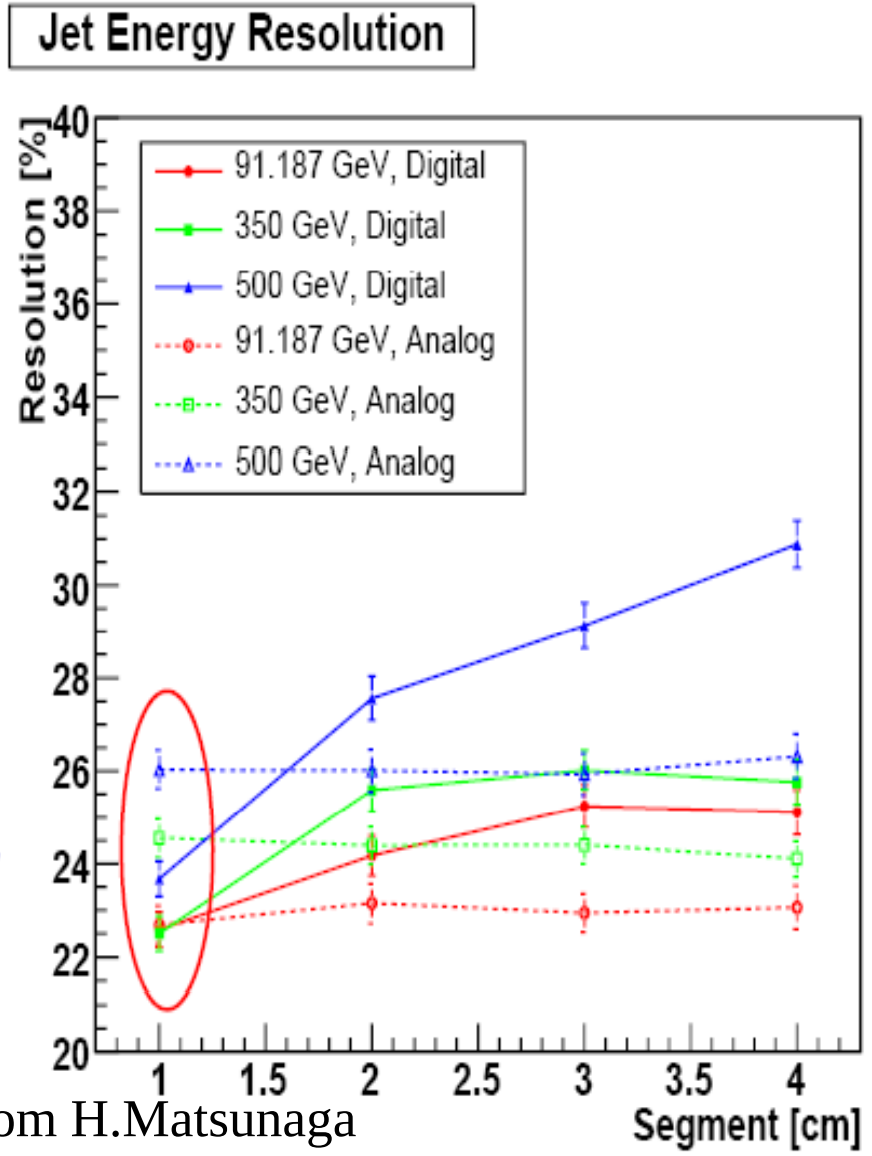
- 1-bit digital solution is better at low energy
- Analog solution is favored at high energy due to number of particles in the central region.

But what about the 2-bit readout solution?
The study of KEK group for the GLD HCAL using :
2-bit, 3 thresholds (.5, 10,100 MIPs) associated to 1X1 cm2
tile size shows :

- Equivalent energy resolution with respect to the analog readout version for single particle
- Better energy resolution for JETs

Jet Energy Resolution

- $e^+e^- \rightarrow qq$ (u/d/s)
  - $\sqrt{s} = 91, 350, 500$ GeV
- Energy measurement with (perfect) PFA
- In case of 1×1 cm^2 tile size, digital calorimeter achieved similar or slightly better jet energy resolution



courtesy from H.Matsunaga

DHCAL in Europe

part of

CALICE international collaboration

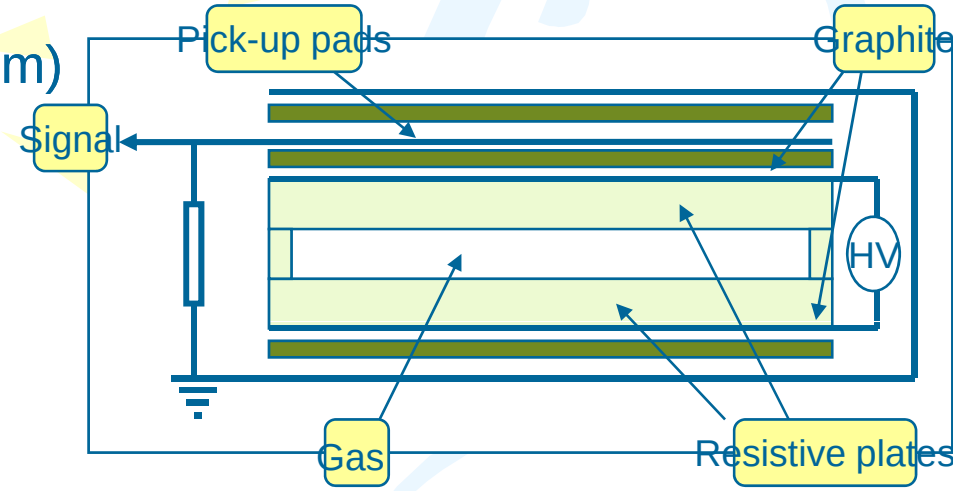
Groups : CIEMAT, IPNL, LAL, LAPP, LLR, IHEP, SACLAY

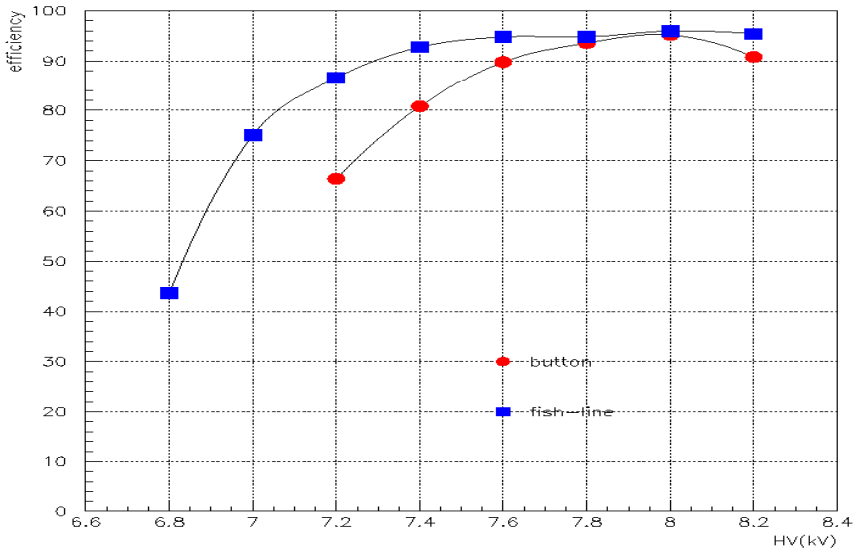
Detectors	:	IHEP,IPNL,LAPP,SACLAY
Electronics	:	IPNL,LAL
Acquisition	:	IPNL,LAL,LAPP,LLR
Mechanics	:	CIEMAT,IPNL,LAPP,LLR
Coordination	:	IPNL

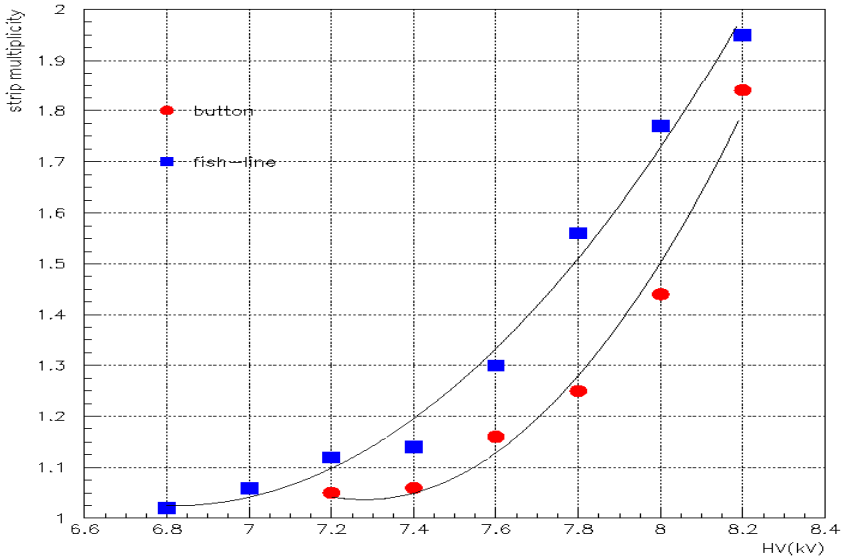
Detectors

GRPC :

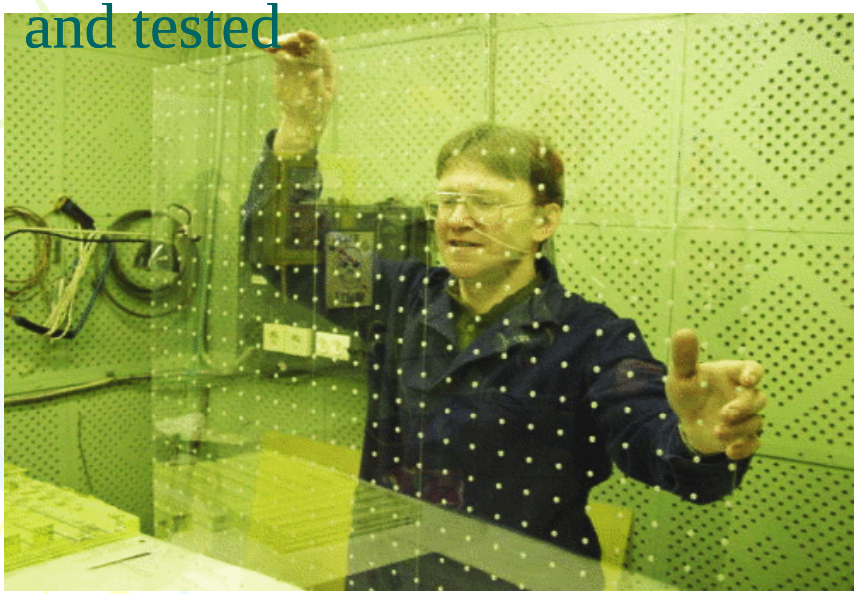
- Total thickness (including elect. <6 mm)
- Fine segmentation (1X1 cm2 pads)
- GRPC is robust detector
- Avalanche mode allows higher rate than the streamer one (50-100 Hz/cm2 vs 1-5 Hz/cm2)
- Charge: 0.1-10 pc
- Efficiency >90% for gas mixture (TFE-Isobutane-SF6:93-5-2)







Detector dimensions :
8X8, 8X32, 100X100 1cm2-pad, 3.2 mm thick: already produced and tested

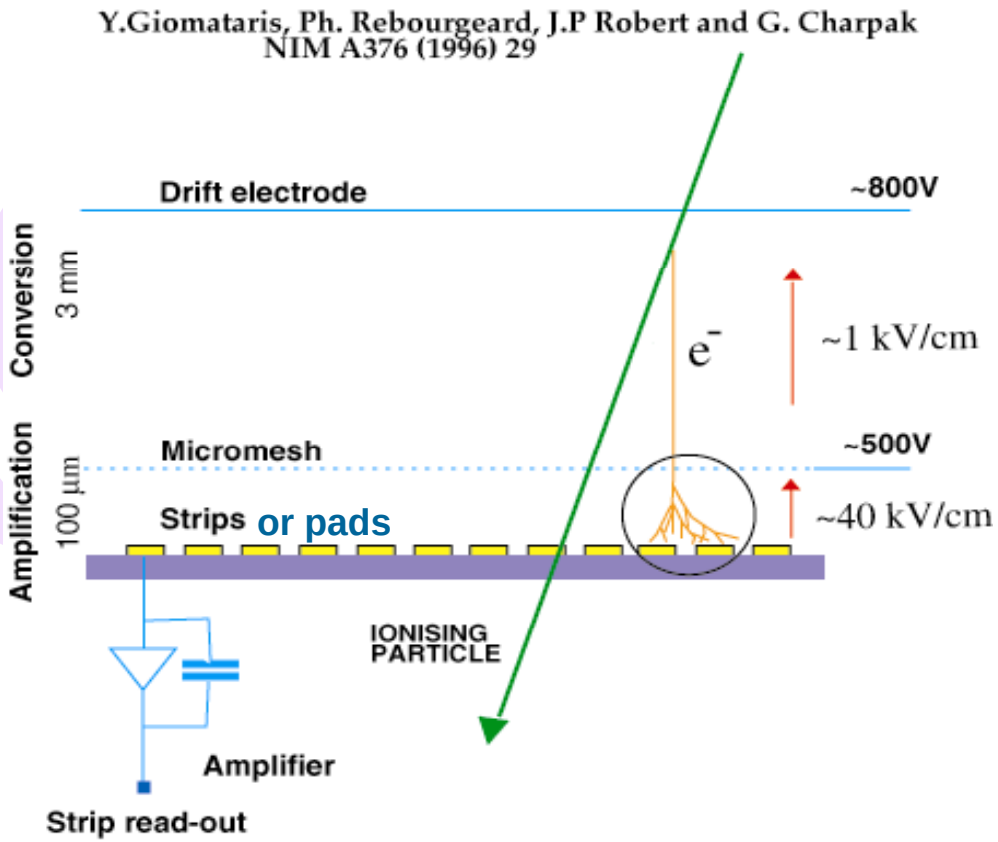


Still to be done :

- **Large size detectors up to 100X300 1cm2-pad :**
  Contribution from BELL colleagues is very welcome
- **New gas mixtures to be found**
  (Isobutane -> CO2, SF6->freonless)

Detectors

µMEGAS :



- **Fine segmentation**
- **High rate counting**
- **Total thickness < 6 mm**
- **Charge : few-500 fc**

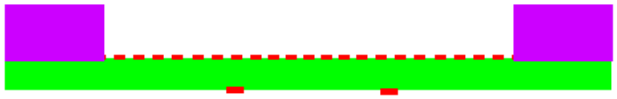
Detectors

- Standard mesh

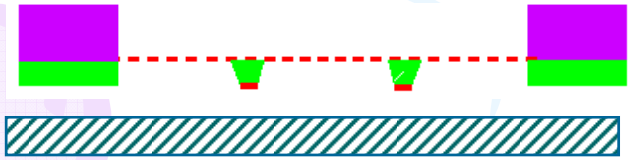
Raw Material

Image Transfer + Copper Etching

Frame Gluing

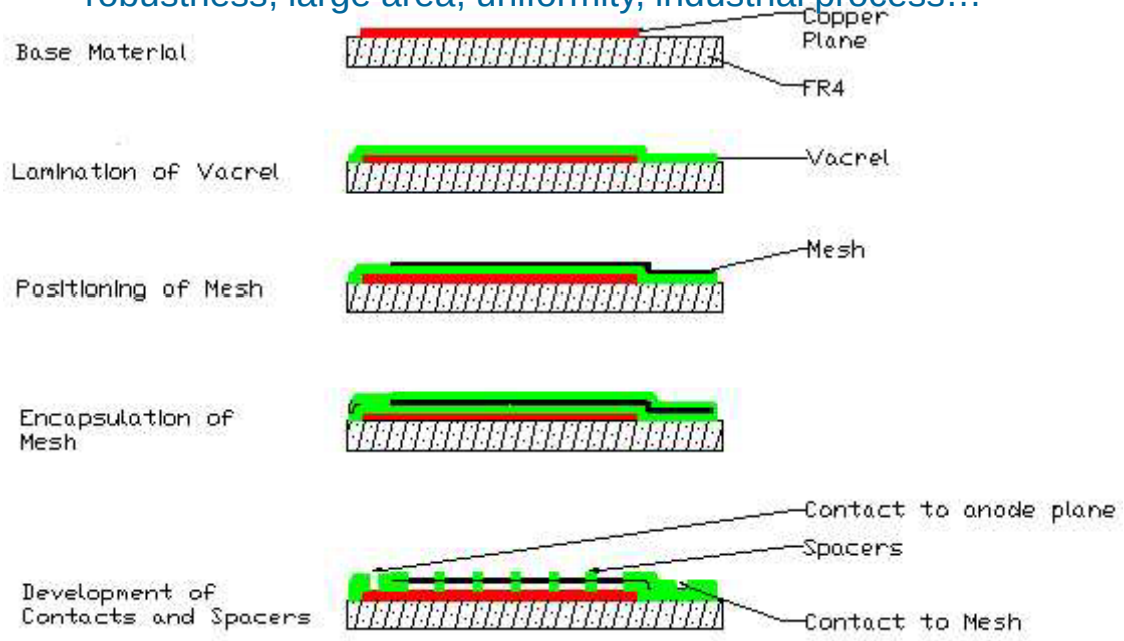


Polyimide Etching + Cleaning

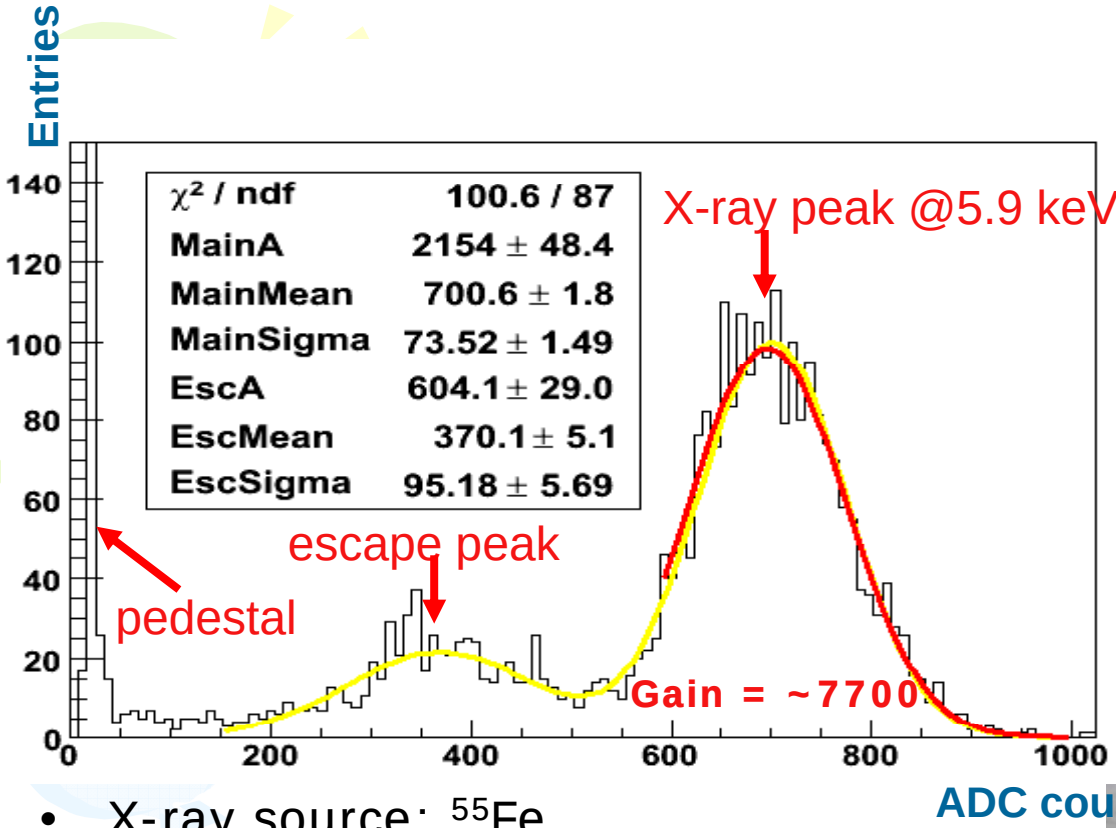


- Bulk

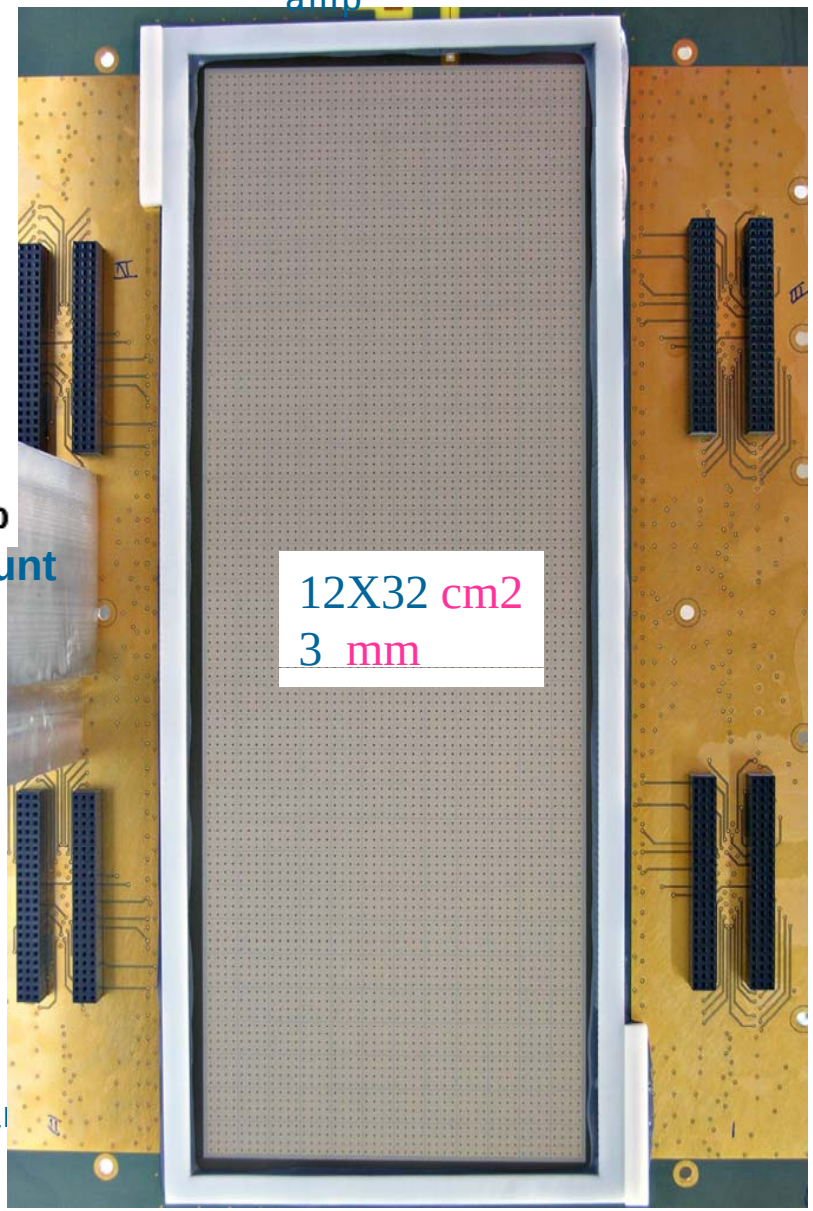
robustness, large area, uniformity, industrial process…



mesh+PCB interdependent



V_{mesh} = 420V
$V_{cathode}$ =470V
E_{drift} = 167V/cm
E_{amp} = 35KV/cm



- X-ray source: ^{55}Fe
- Trigger using the mesh (preamp+discri)

Still to be done :

- Efficiency, homogeneity;
- Gas mixture studies;
- Building large area detectors : CERN

Electronics

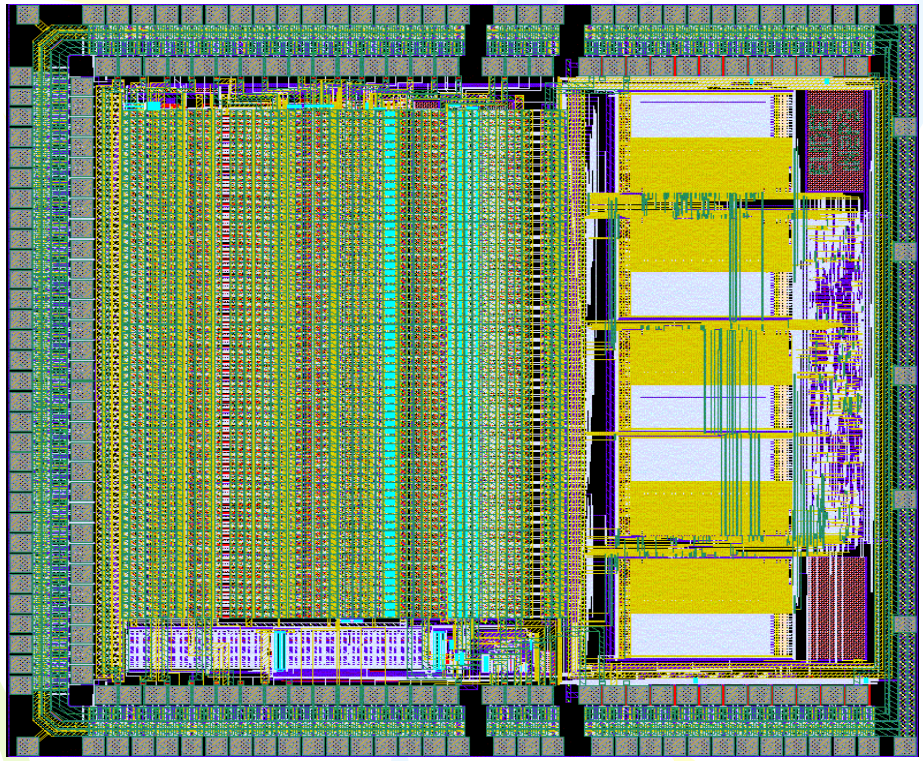
DHCAL for ILC will have >25 million channels.
So the electronics should be :

- Tiny, embedded electronics
- Low consumption (<10 μW/ch)
- Semi-digital (2-3 thresholds)
- Fast (< 100-200 ns)
- Capable to store the events during data train
- Low cost

Electronics

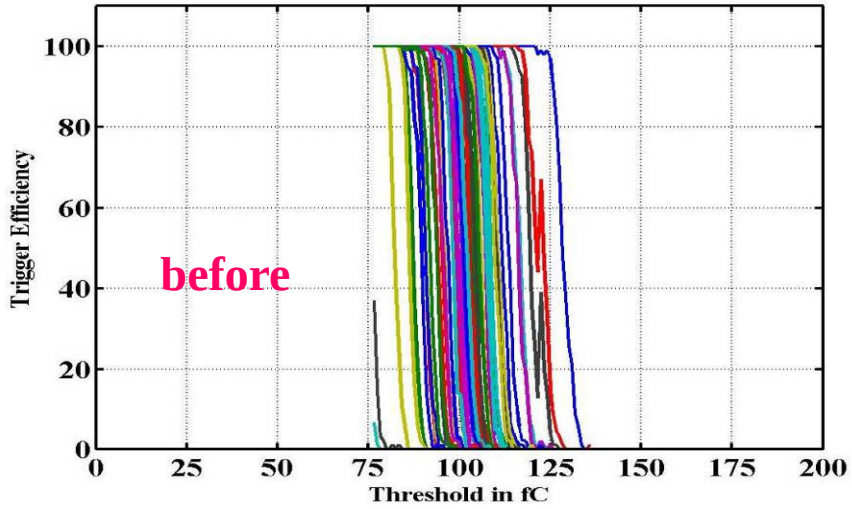
HARDROC

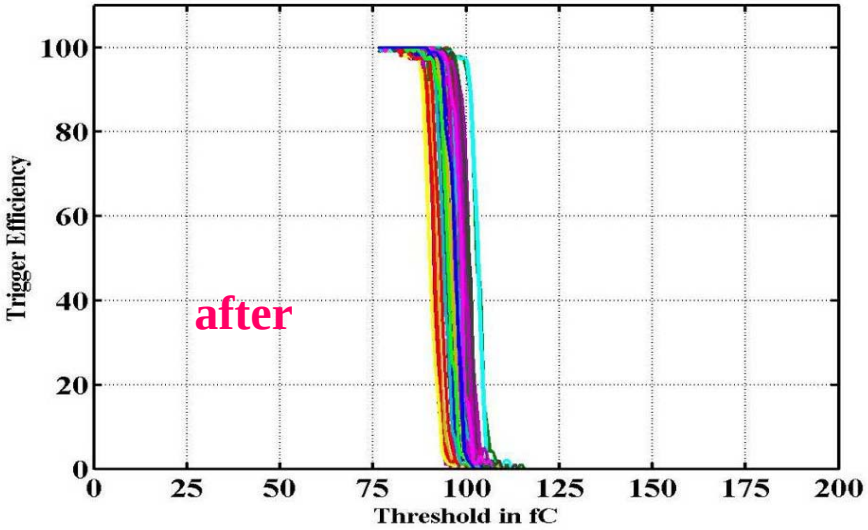
- 64 channels, 16mm²
- Digital/analog output.
- 2 thresholds
- low consumption, power pulsing (< 10 µW/ch)
- Digital memory able de store up to 128 evts.
- Large gain range
- Adequate for GRPC* (threshold > 10 pc)

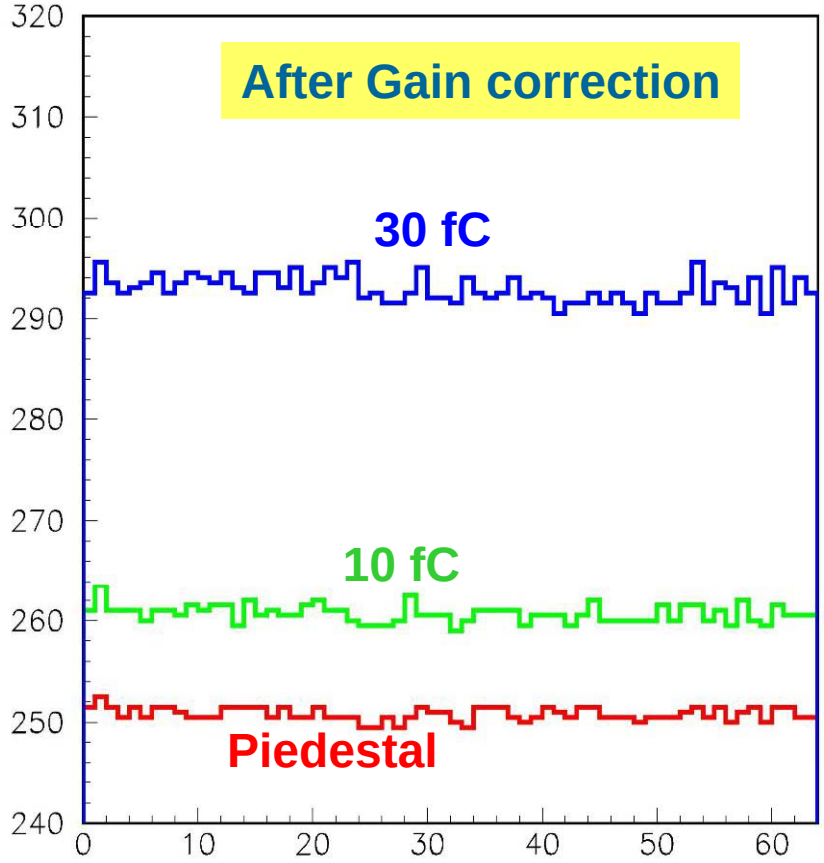


❖ *Another chip is currently under development to reduce the threshold down to 2 fc for µMEGAS*

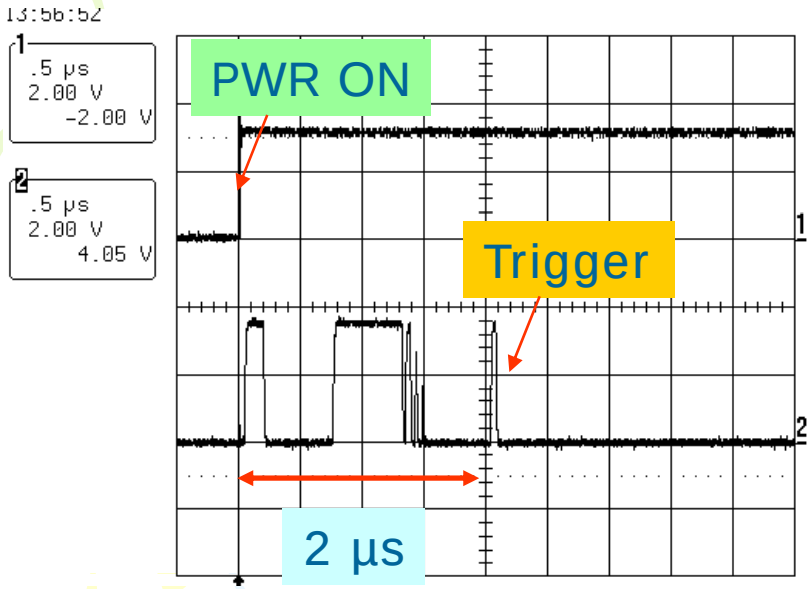
HARDROC: Scurves of 64 channels

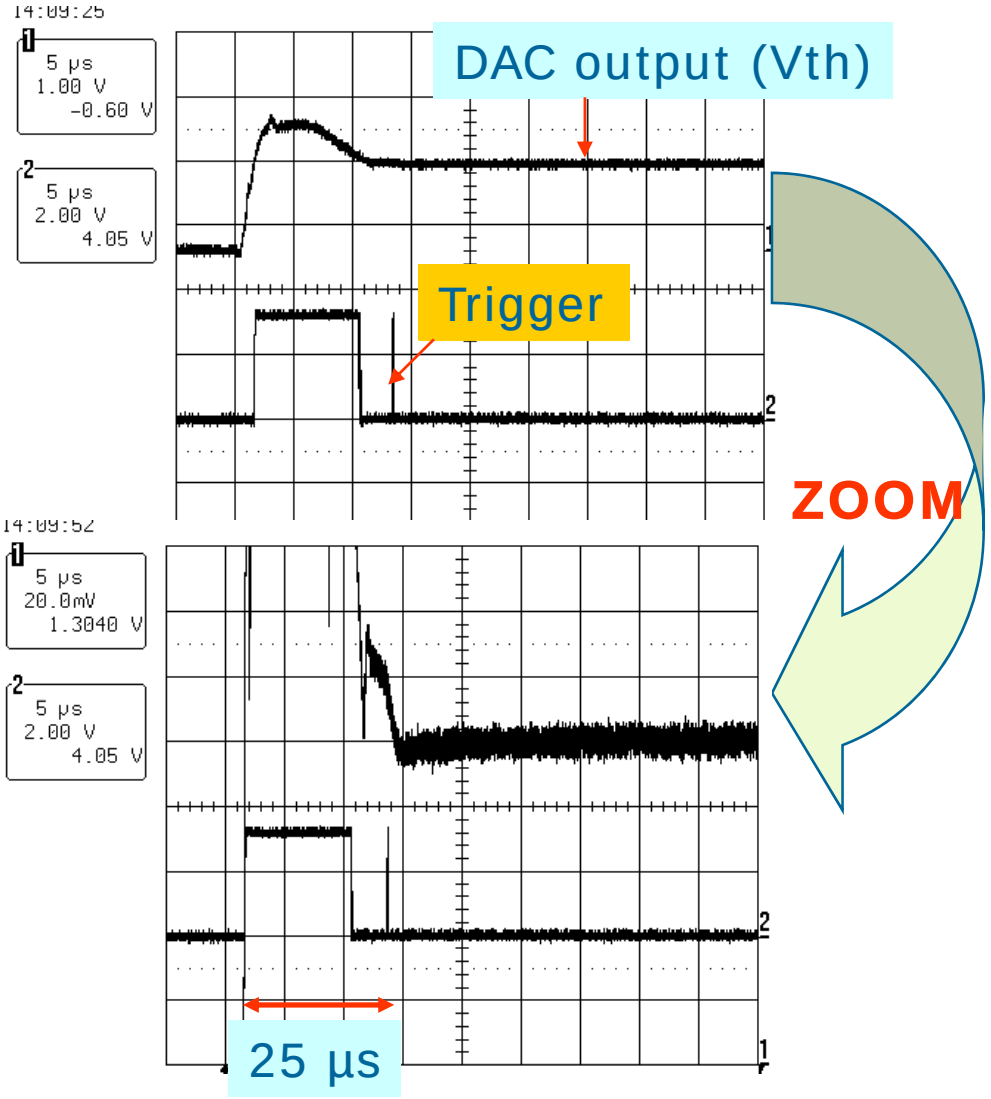






HARDROC Power pulsing

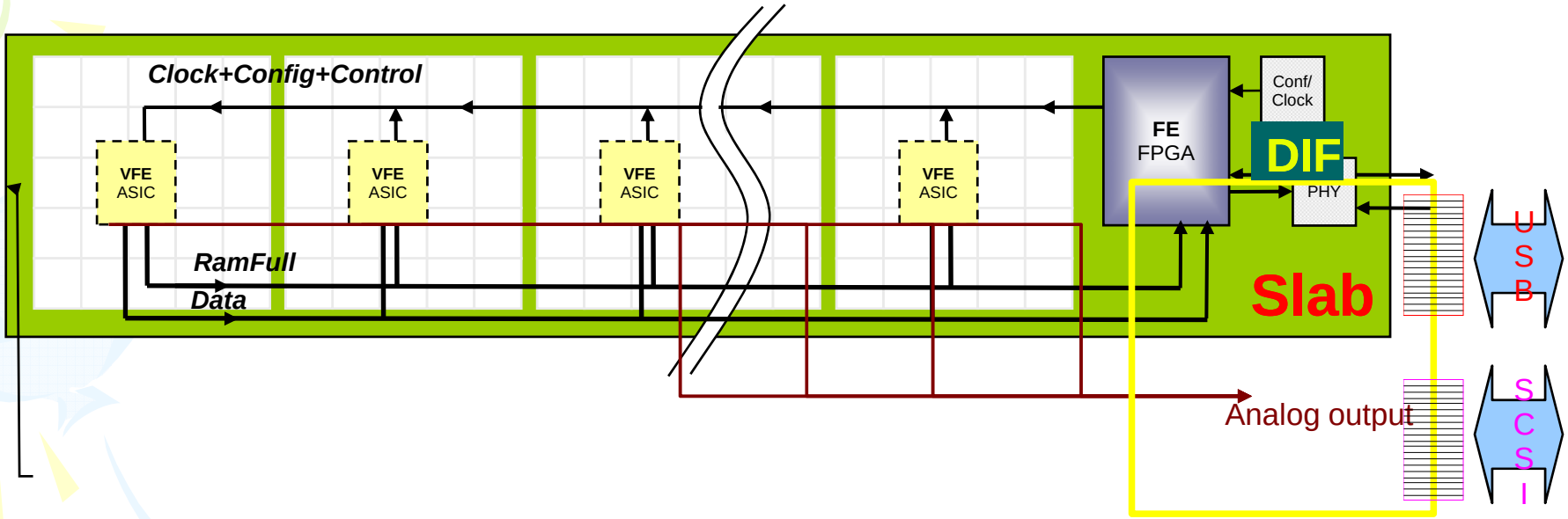


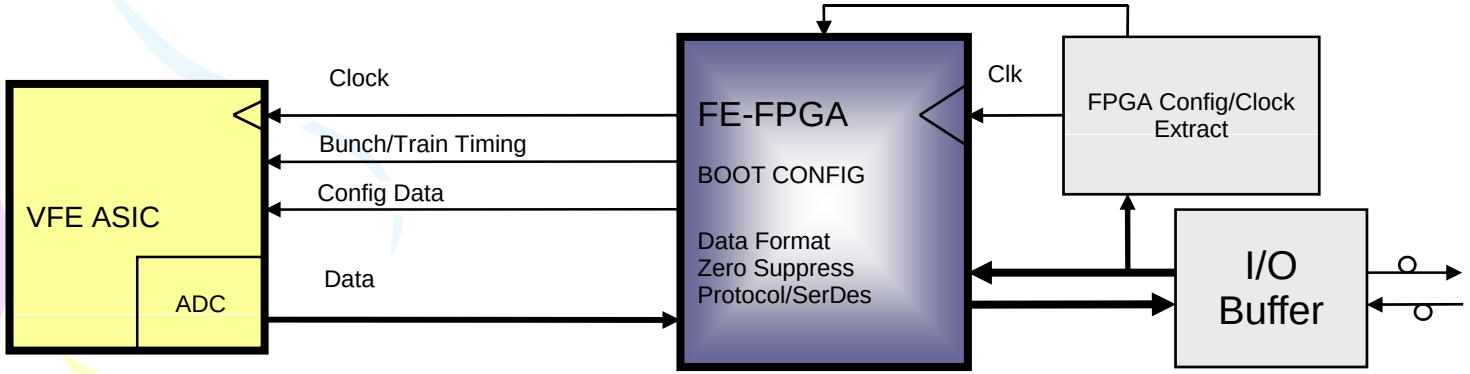


- PWR ON: ILC like (1ms,199ms)

Acquisition

ILC detectors should be as compact as possible with identical elements
This can be realized thanks to a daisy chain acquisition scheme



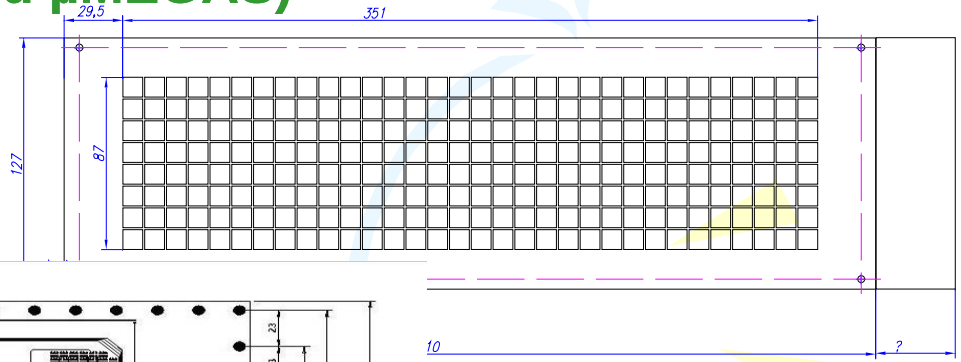


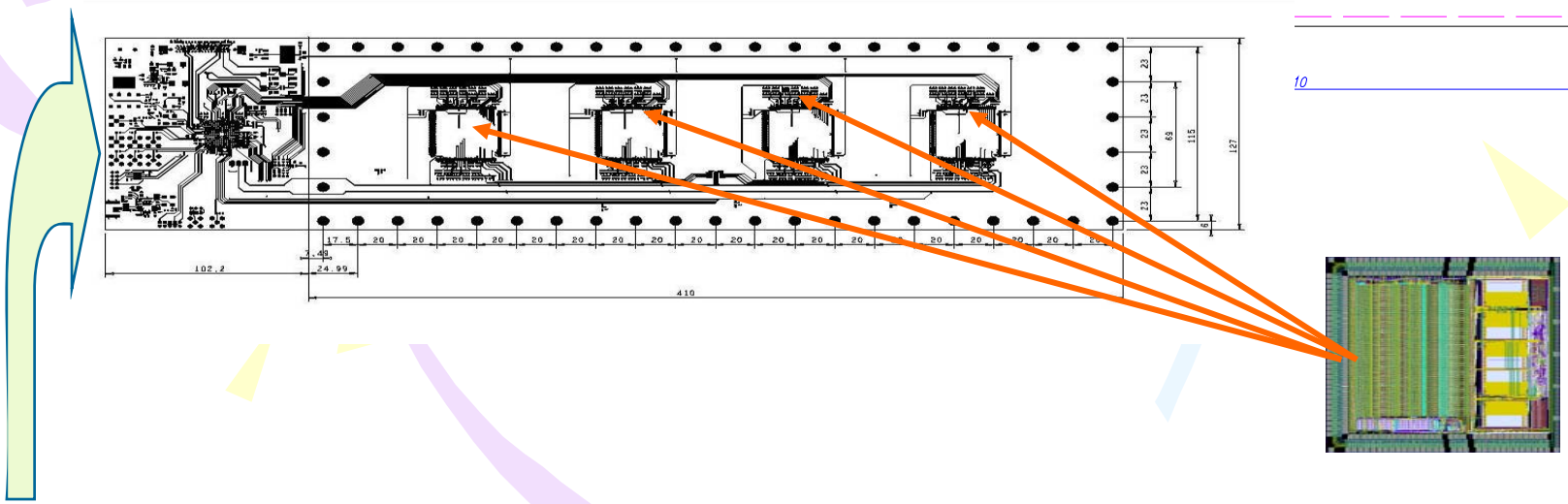
4-Chip board

Aims:

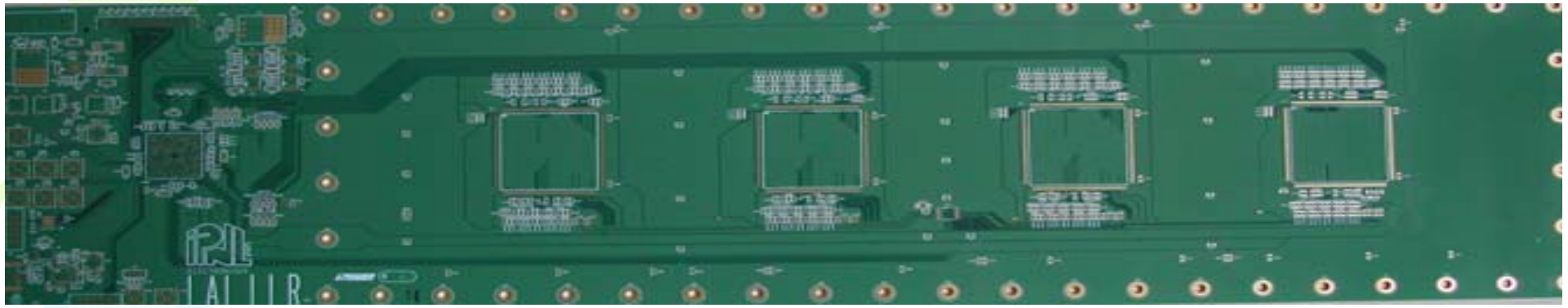
- **Validate the electronics/acquisition scheme for DHCAL**
- **Study the different detectors behavior with the same electronics.**

- **8X32 pads detector (GRPC and µMEGAS)**
- **8-layer PCB**
- **4 HARDROC**
- **Readout** USB + FPGA

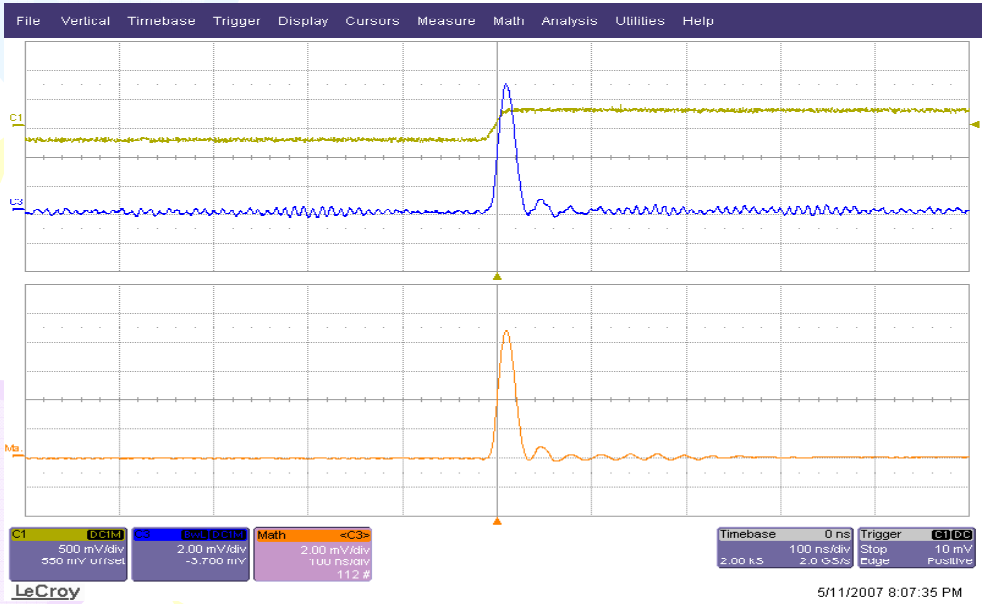


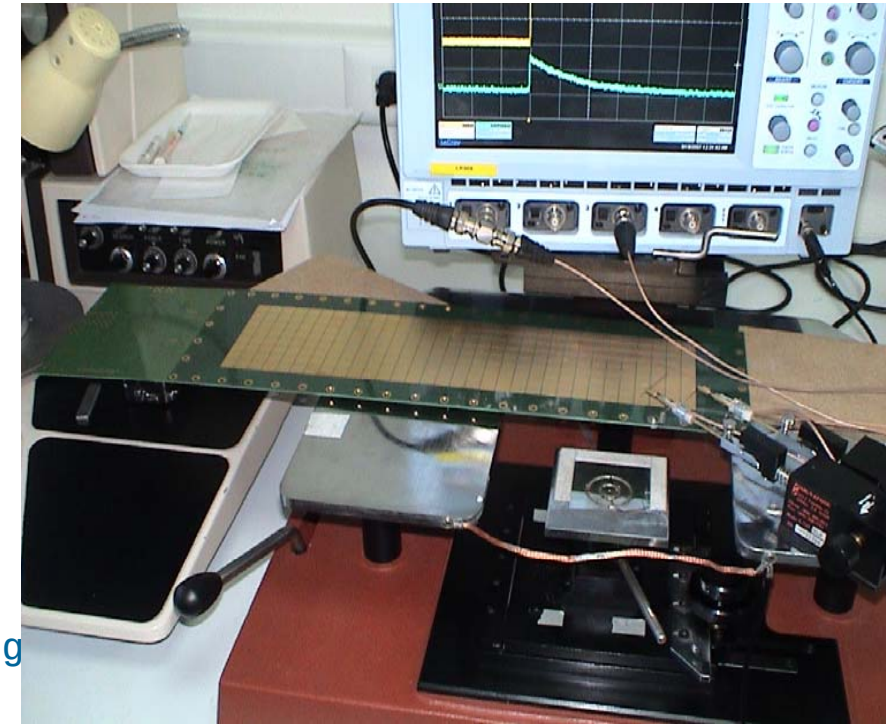


- 8-layer PCB , 800 µ thick (with buried vias)
- 8X32 pads of 1 cm2 and 500 µ separation



See Hervé talk

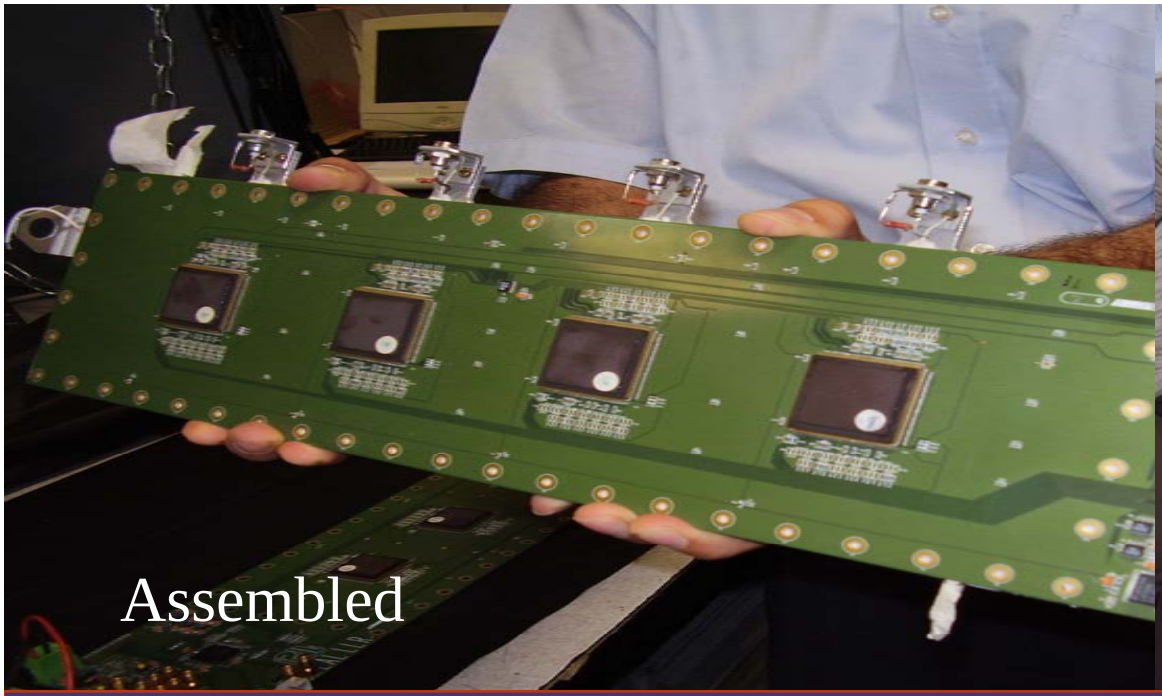




J.Laktineh

X-talk (<0.5 %)

First ILD meeting



Assembled

Readout software

Fichier Vertical Base de temps Déclenchement Affichage Curseurs Mesure Math Analyse Utilitaires Aide

First Daisy chain measurement

C4
C1
C2
C3

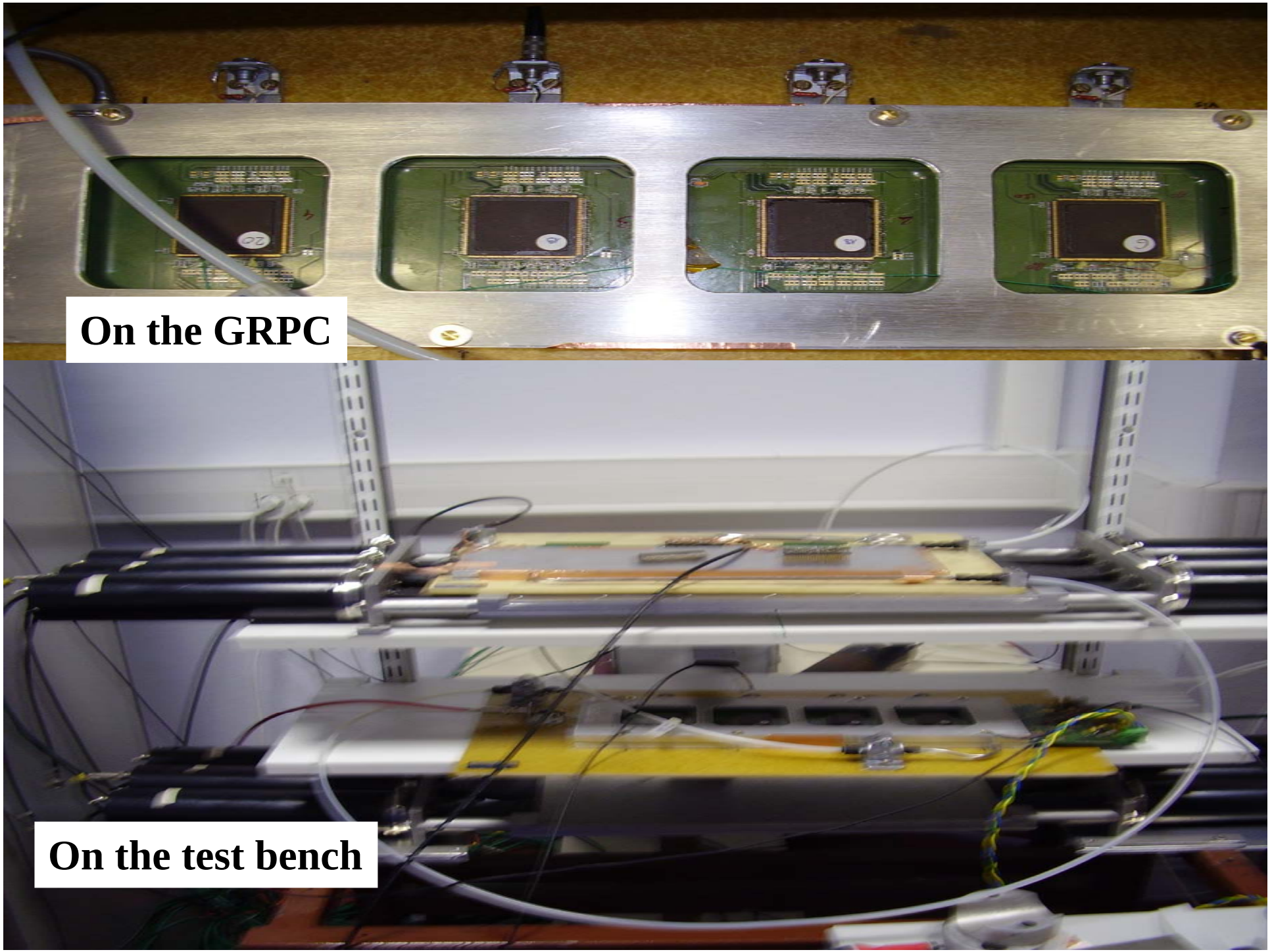
C1 DC1M	C2 DC1M	C3 DC1M	C4 DC1M
1.00 V/div	1.00 V/div	1.00 V/div	1.00 V/div
-1.010 V ofst	-1.500 V ofst	-3.560 V ofst	570 mV offset
↓ 12 mV	↓ 3.310 V	↓ 558 mV	↓ 26 mV
↑ 5 mV	↑ 536 mV	↑ 536 mV	↑ 48 mV
Δy -7 mV	Δy -2.774 V	Δy -22 mV	Δy 22 mV

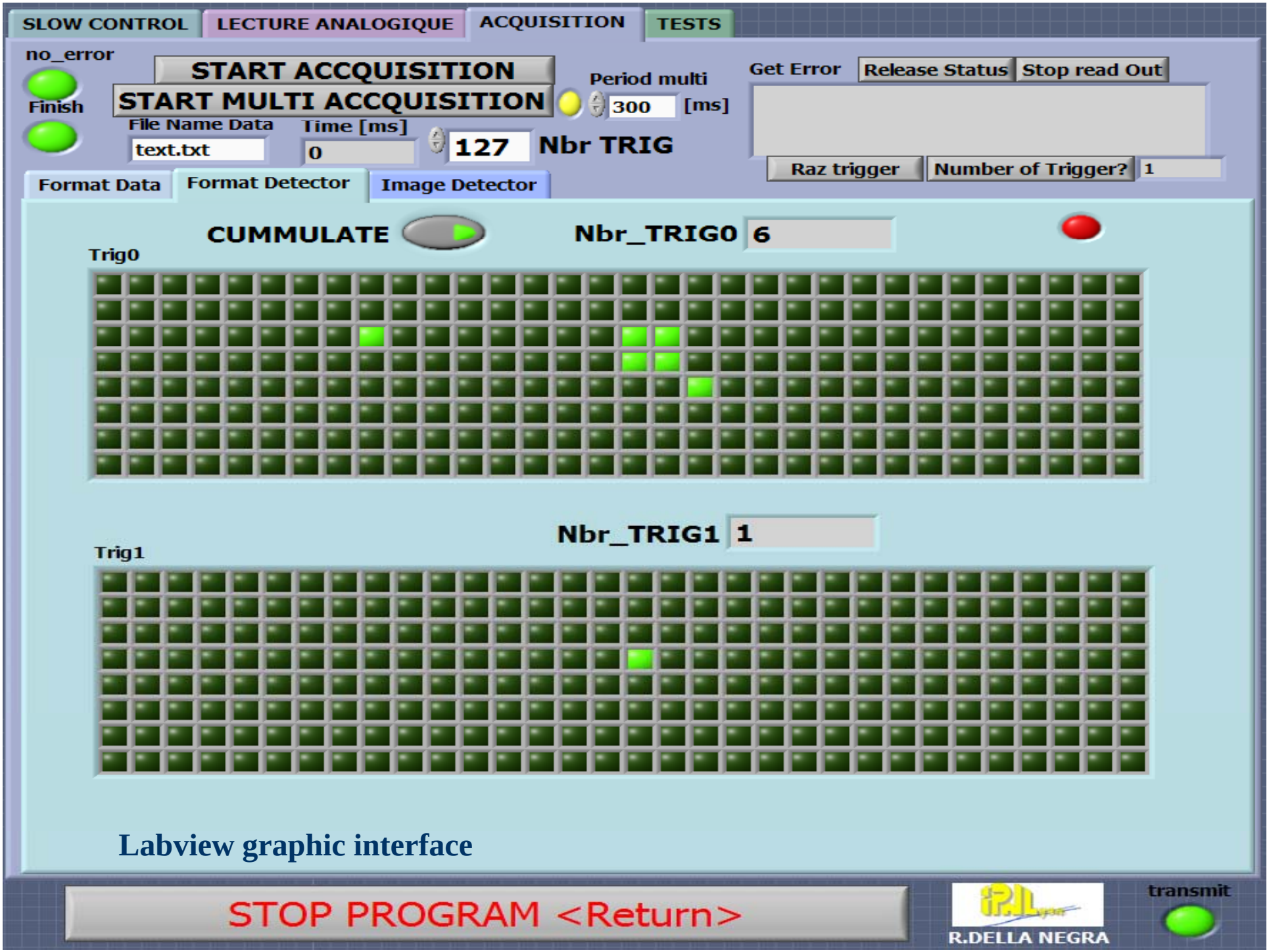
LeCroy

Tbase	-616 µs	Déclenchem C1 DC
200 kS	200 µs/div 100 MS/s	Normal 1.19 V Front Positive

X1= 325.79 µs ΔX= -160.00 µs
X2= 165.79 µs 1/ΔX= -6.2500 kHz

Waiting for Trigger

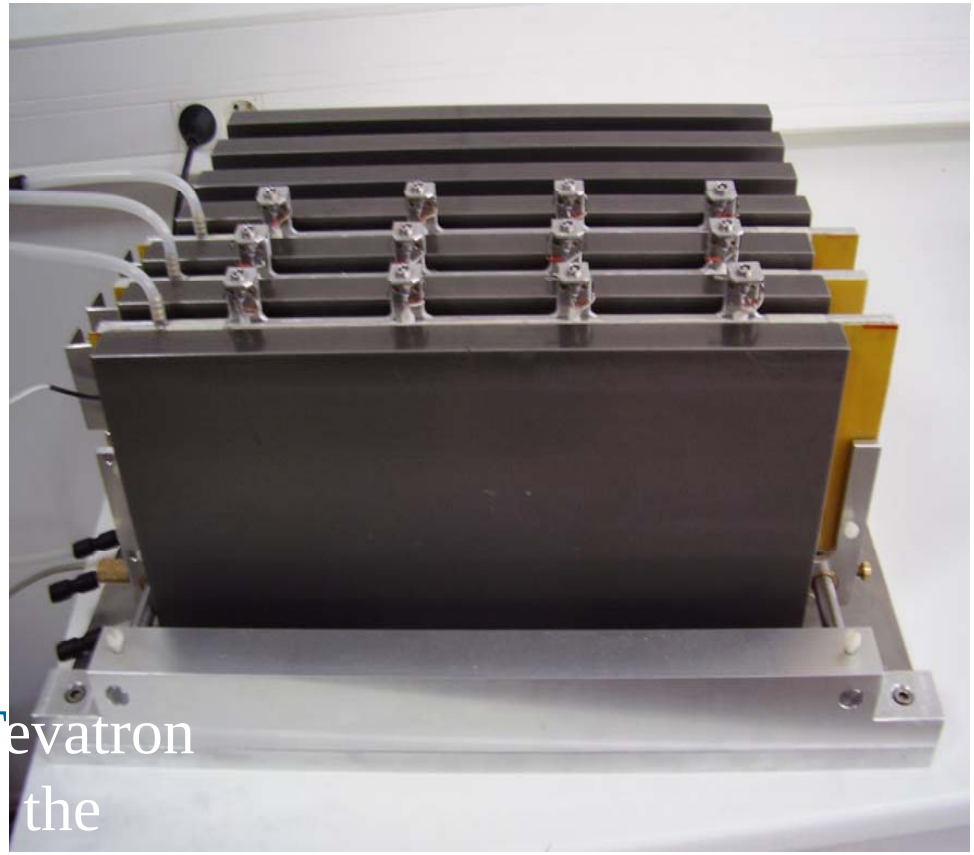

On the GRPC
On the test bench



Labview graphic interface

Beam tests

Almost completed:
A slice test setup
with 6 detectors fully equipped :
4 GRPC
2 µMEGAS/GEM
6 Stainless steel slabs
and with Multi-detector readout system



Exposure to PS/SPS at CERN or Tevatron in the first half of 2008 to validate the whole chain

Perspectives

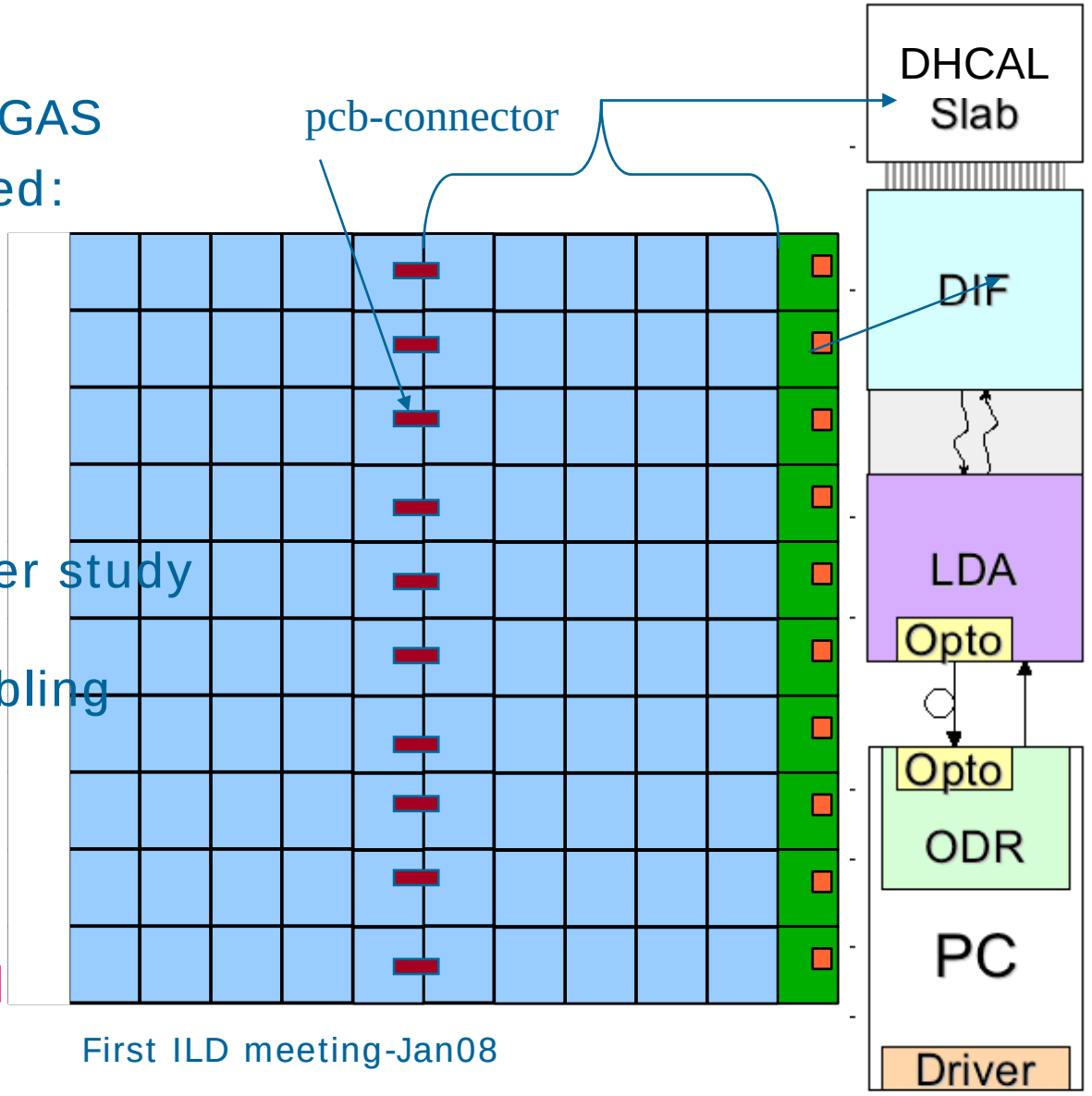
2008:

90X90 cm^2 GRPC/µMEGAS detectors fully equipped:

- Detectors:
  GRPC produced
  µMEGAS not yet
- chips: produced
- PCB : designed
- PCB-connectors under study
- DIF: under study
- PCB-detector assembling under study

1- To be completed by **September 2008**

2- Completely **funded**



Perspectives

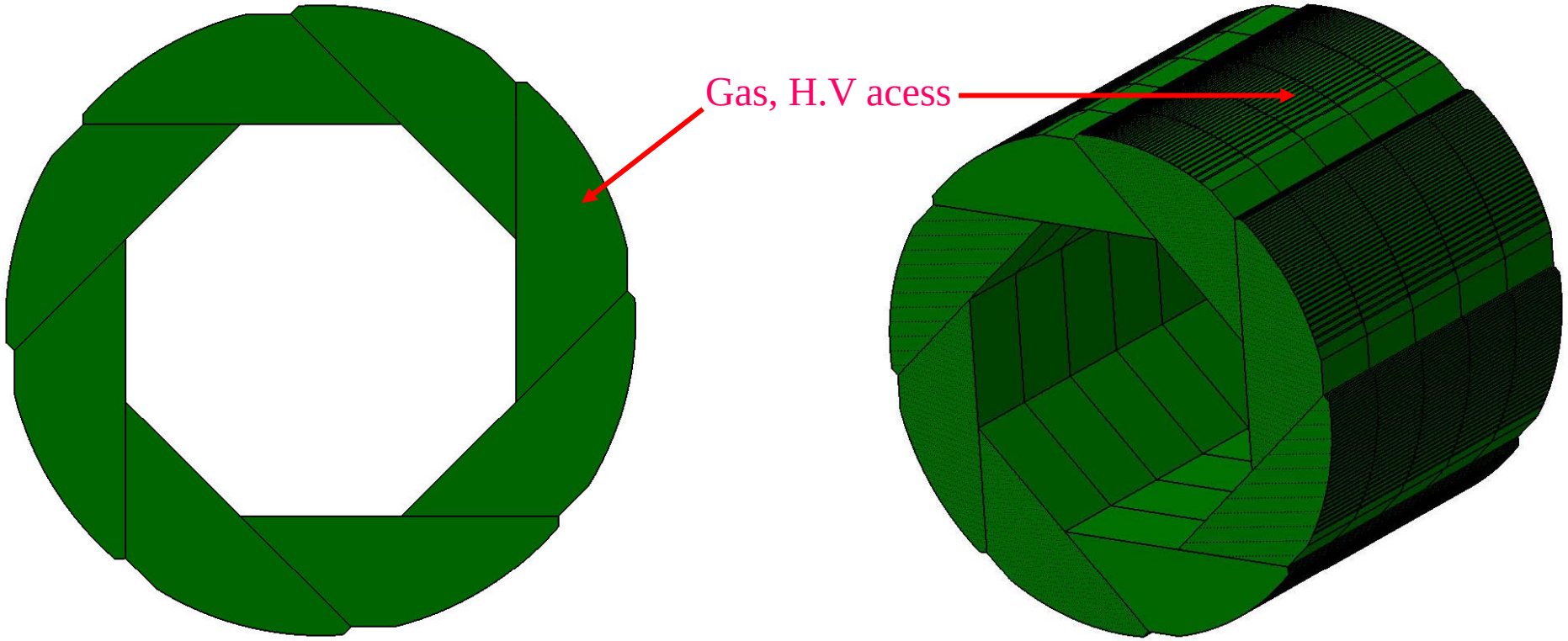
2009 :

Technological prototype = 40 detector+absorber planes with full electronics readout : 40X (6+20 mm)
Funded essentially by ANR-France (2008-2010)

In order to make this prototype as close as possible to the ILC module we need to determine :

- Detectors dimension
- Global mechanical structure

Taking into account the gaseous nature of our detectors, our favored DHCAL architecture is the one proposed by H.Videau:

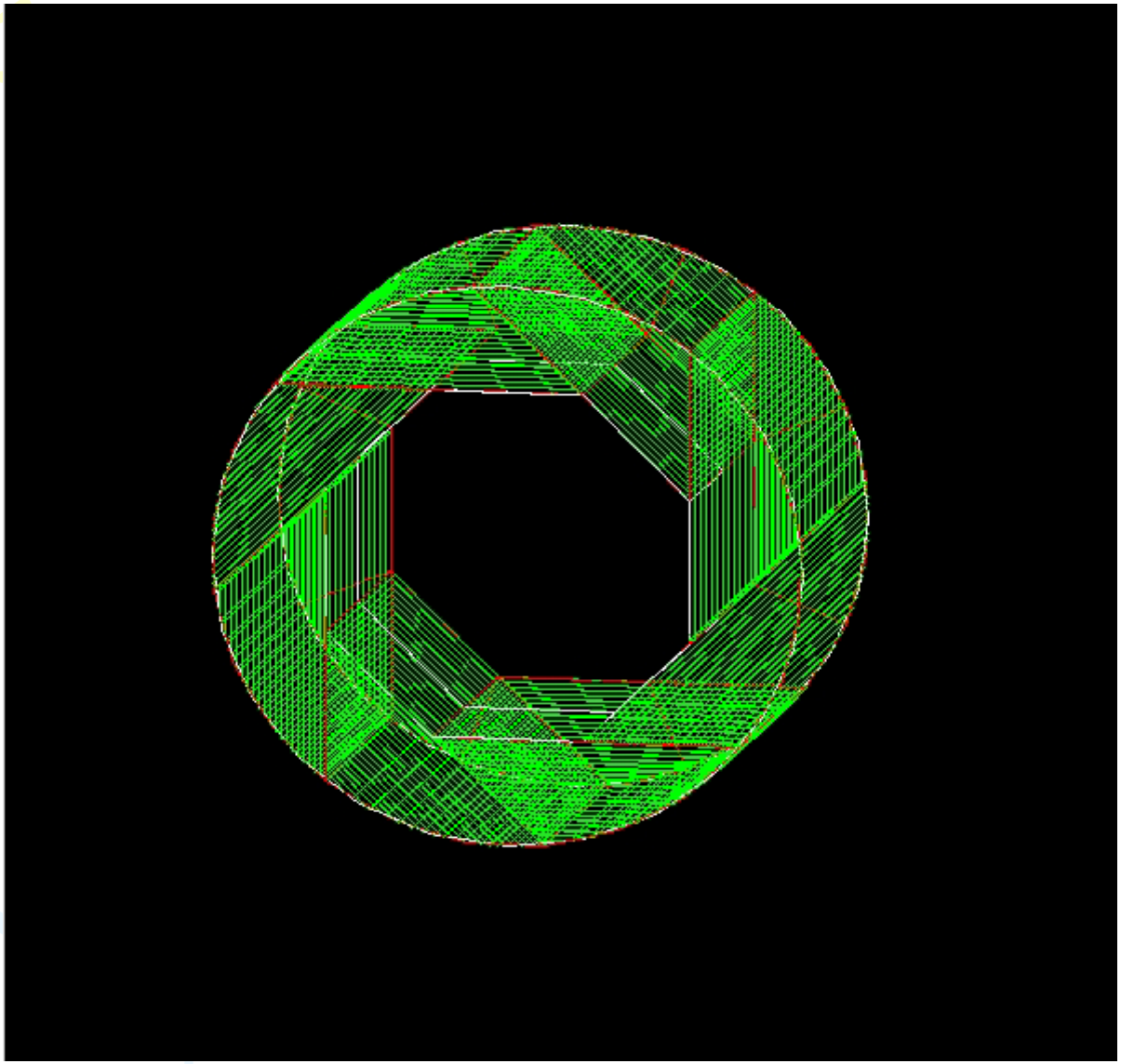


In addition :

- No cracks: Each particle crossing the same number of detectors
- no problem concerning particles produced with the $\theta = \pi/2$
- Easy access to each element of the DHCAL from the outside

Conclusion

- Hadronic calorimeter with gaseous detectors and semi-digital electronic readout seems to be robust, efficient and low-cost solution and can be a good choice for ILD.
- First results confirm the expectations
- Large prototype is expected in the near future and will enable a comparative study with the analog solution
- The HCAL structure proposed by H.Videau is an attractive one. It implies however larger size detectors but this is ongoing R&D. This structure with GRPC has been added to mokka recently. Optimization to select 8-fold or 12-fold should be done in the near future.

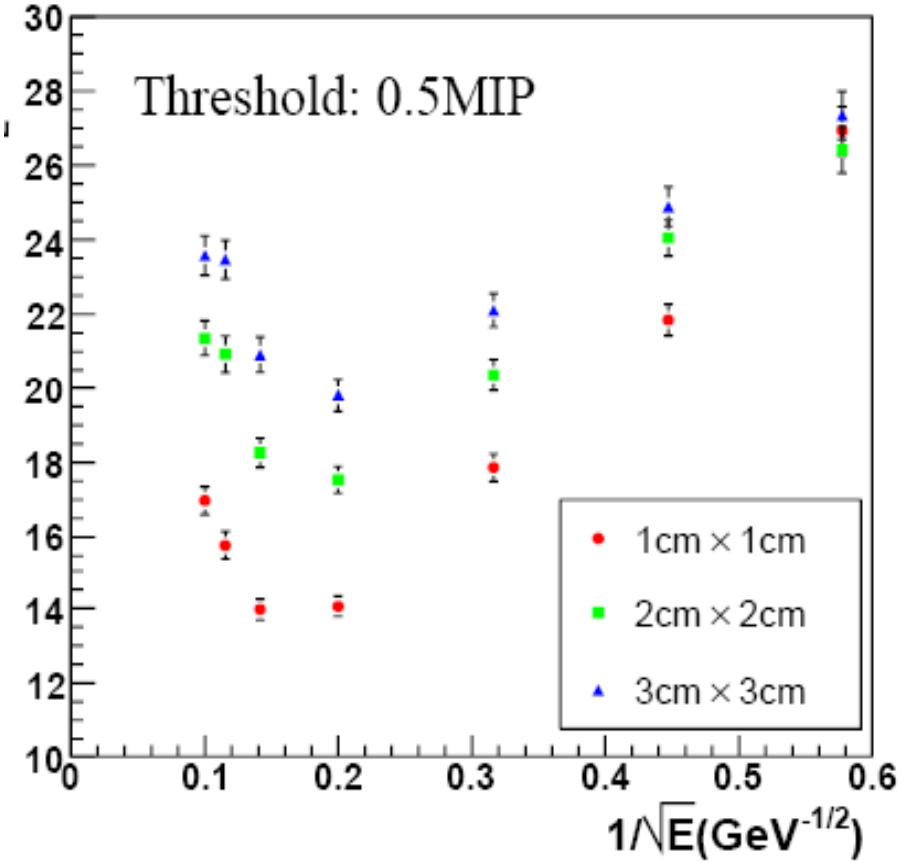


8-fold GRPC-DHCAL structure has been added to MOKKA

Backup

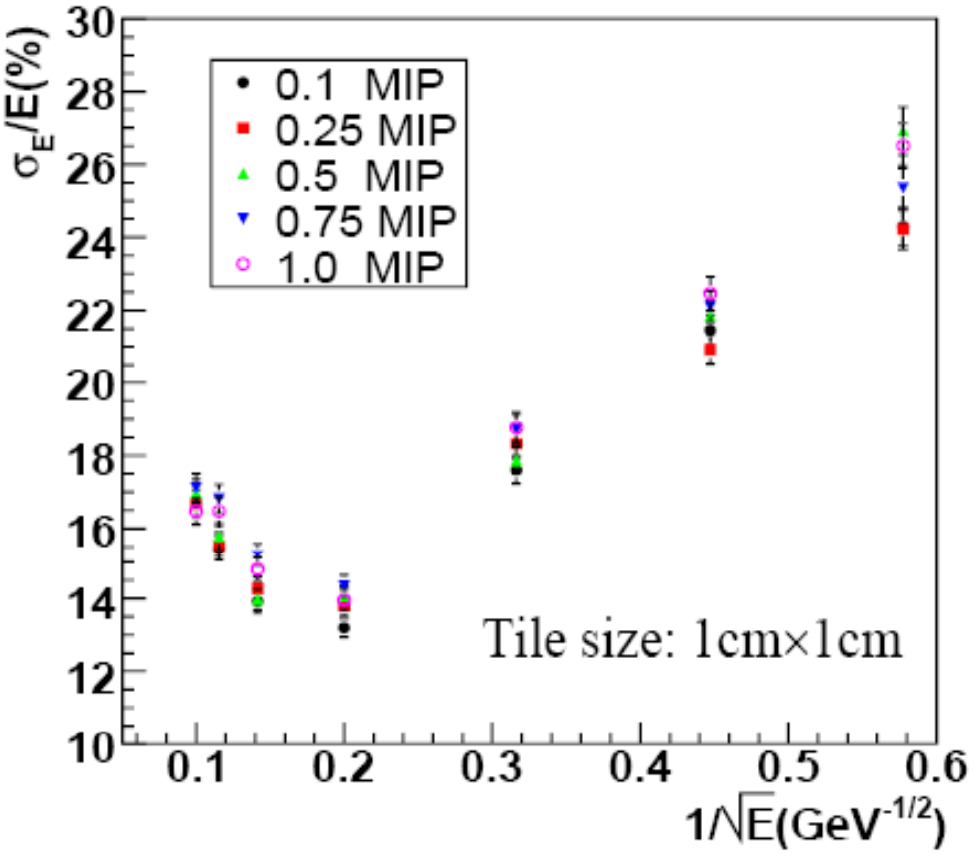
Energy Resolution

Segmentation dependence

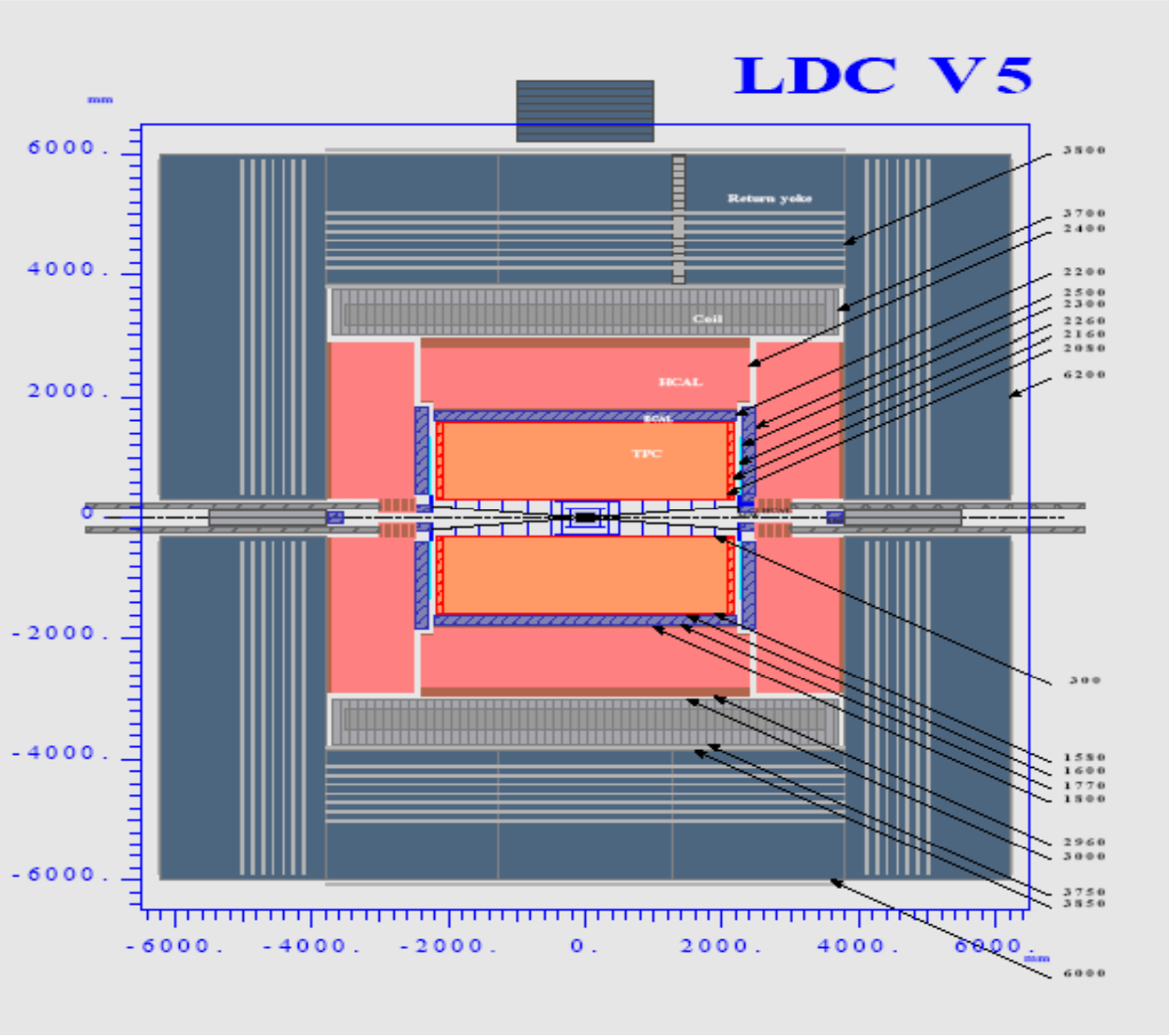


→ Smaller size is better in high energy region

Threshold dependence



→ No significant difference


LDC V5
mm
6000.
4000.
2000.
0
-2000.
-4000.
-6000.
-6000.
-4000.
-2000.
0.
2000.
4000.
6000.
mm
Return yoke
Coil
HCAL
ECAL
TPC
3800
3700
2400
2200
2500
2300
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2160
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6200
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1580
1600
1770
1800
2960
3000
3750
3850
6000

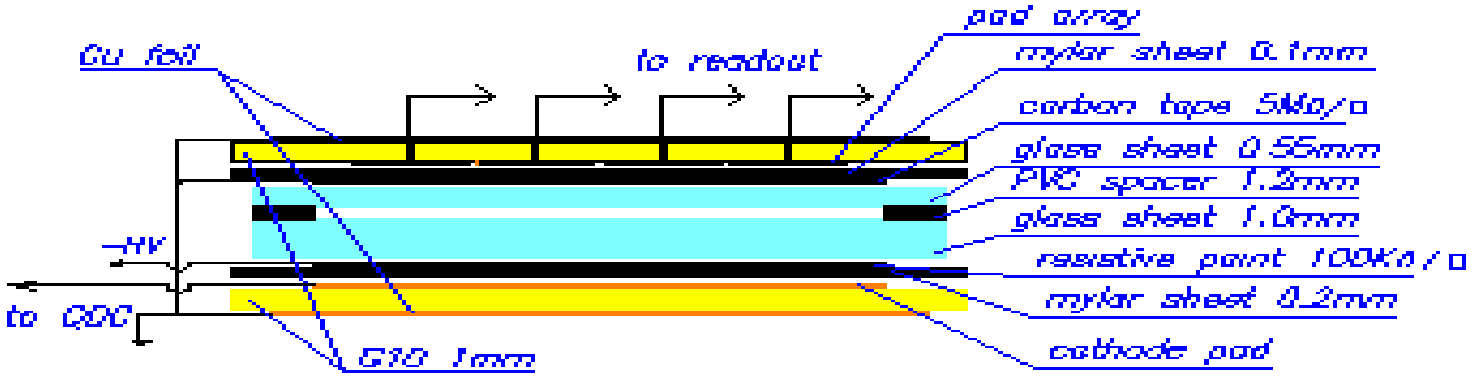

Fig.1a Standard glass RPC.

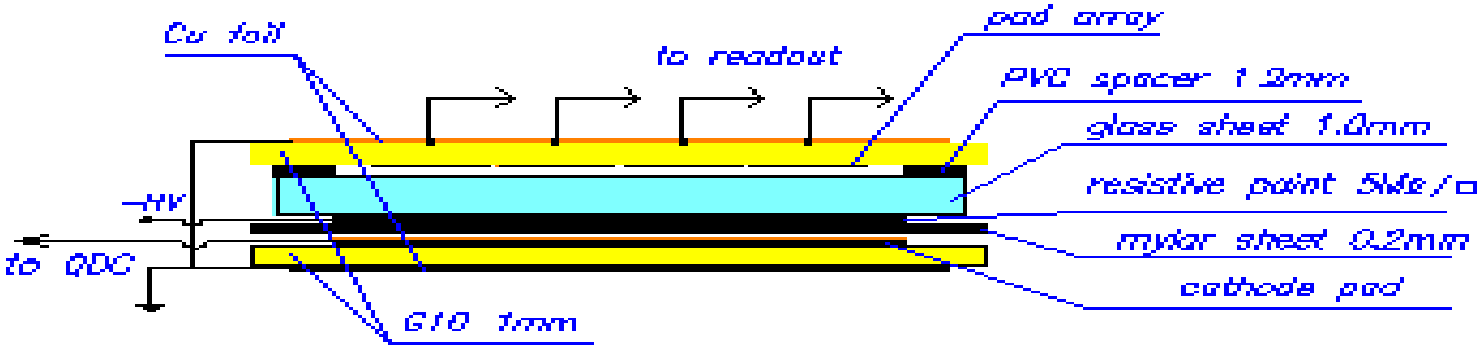

Fig.1b Combined RPC.