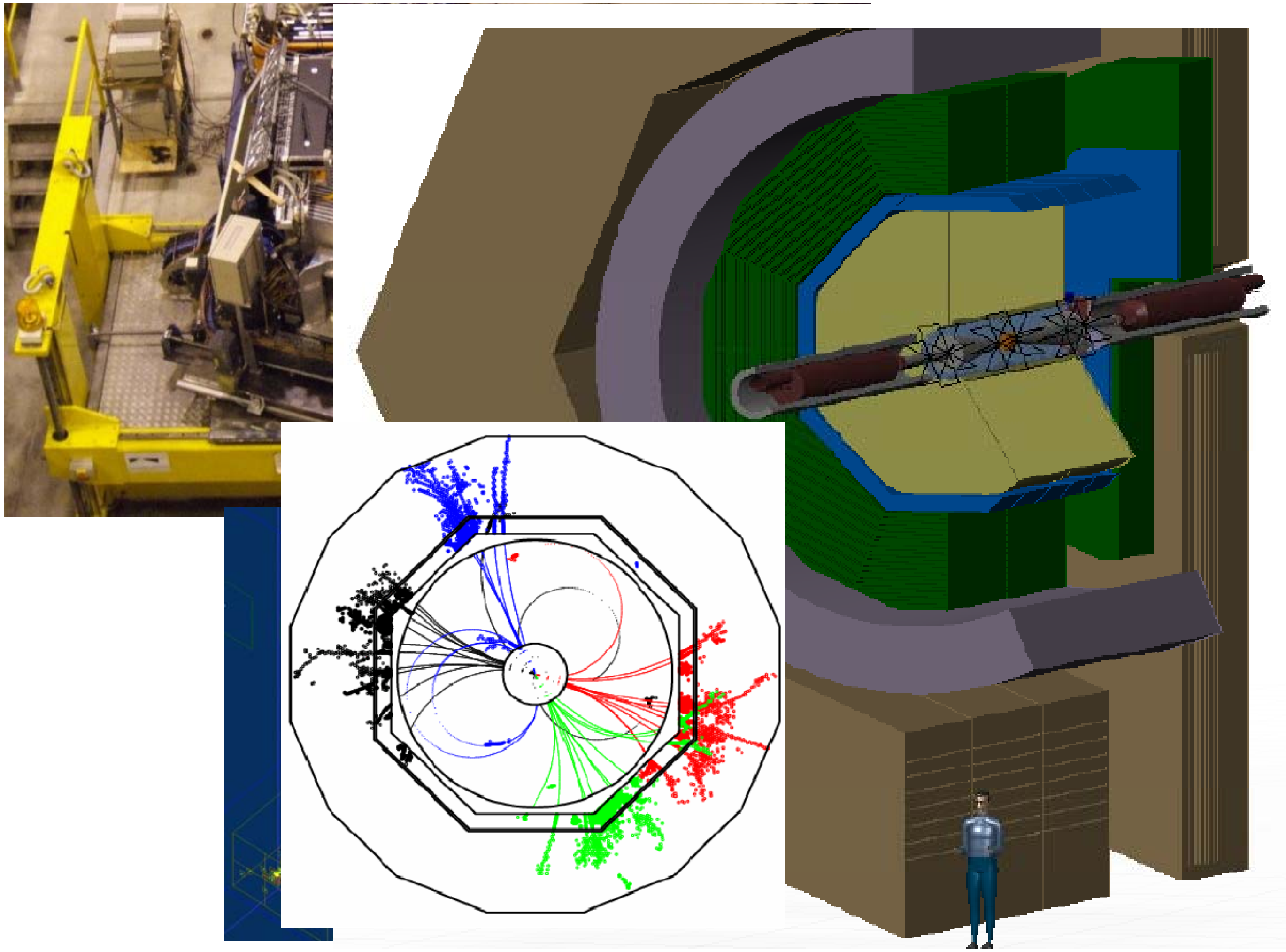
The ILD HCAL - towards a LoI

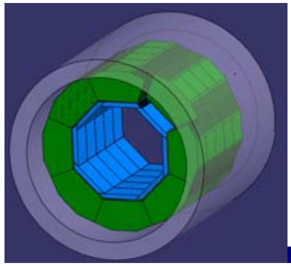
Felix Sefkow

Imad Laktineh

ECFA2008, Warsaw
June 11, 2008

From proof-of principle to reality





Options and collaboration

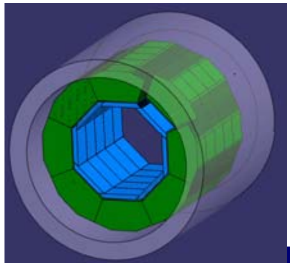
- Scintillator HCAL - analogue
  - Prague, DESY, Hamburg, Heidelberg, MPI Munich, Wuppertal, Moscow (ITEP, JINR, LPI. MEPHI), Kobe, Shinshu, N.Illinois

or semi-digital

- Gaseous HCAL – digital
  - RPC, GEM, Micromegas
    - Annecy, Lyon, LLR Palaiseau, IHEP Protvino, CIEMAT Argonne, Boston, FNAL, Iowa, UTA

Here: European / ILD part of the effort

- Electronics and DAQ: common design for ECAL, scintillator and gaseous HCAL
  - LAL; Cambridge, Manchester, Imperial, UCL, RAL



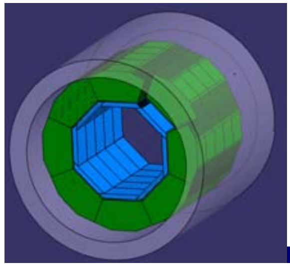
Towards the LoI

- Optimize geometry
- Validate particle flow performance
- Develop calibration scheme
- Demonstrate compact technology
- Study detector integration

Calorimeter for ILC

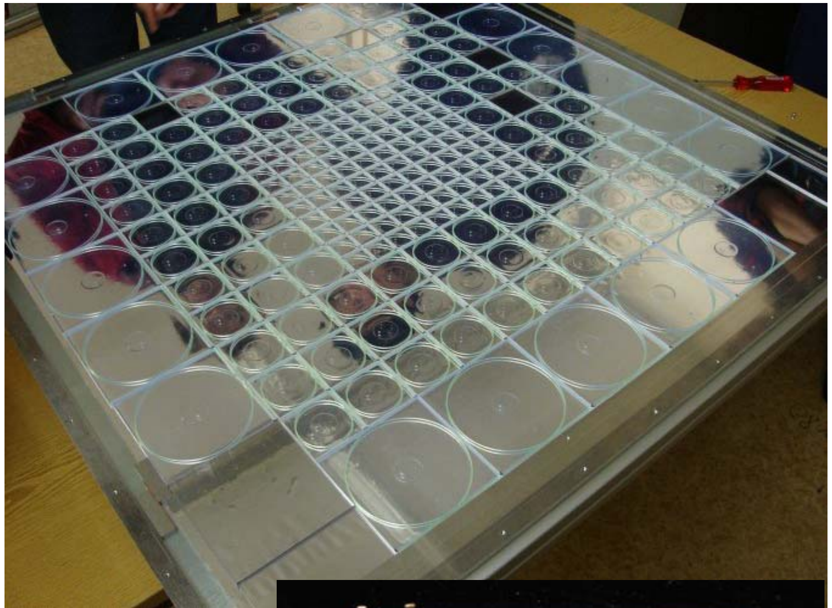
Test beam

Here could be your ILD logo!

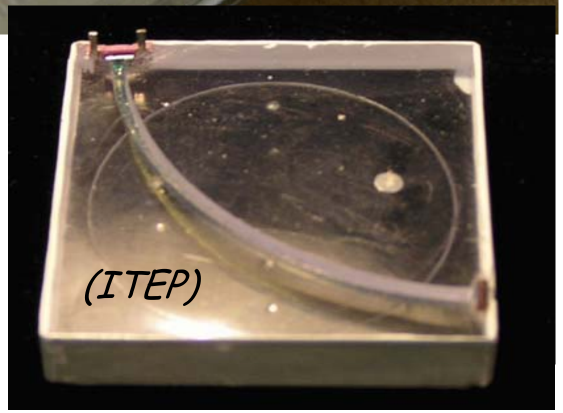


Scintillator HCAL

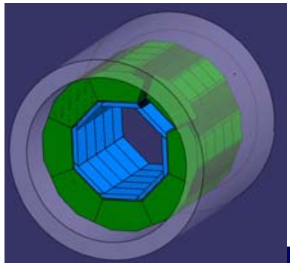
- Novel multi-pixel Geiger mode photo-diodes (SiPMs)
  - B-field proof, small, affordable
- High granularity with scintillator at reasonable cost
  - photo-sensors integrated
- Opens revolutionary design options:
  - embedded electronics and calibration system for minimal dead zones
  - thin readout gap
- Granular, compact, hermetic



(DESY)

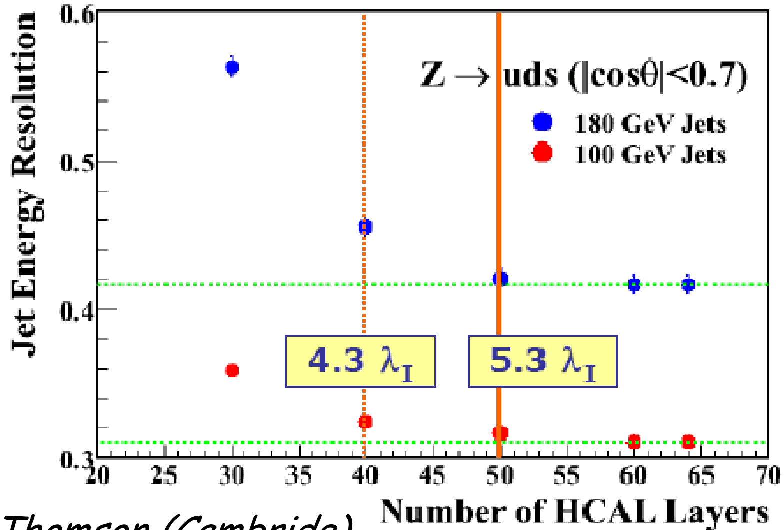


(ITEP)



Geometry optimization

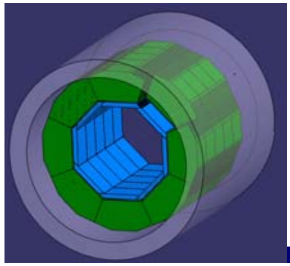
- Presently starting new round of detector optimization, using PANDORA and a new, much more detailed MOKKA simulation
- Baseline: stainless steel, square tiles
  - Also considered: brass or lead
  - Scintillator striplets



M. Thomson (Cambride)

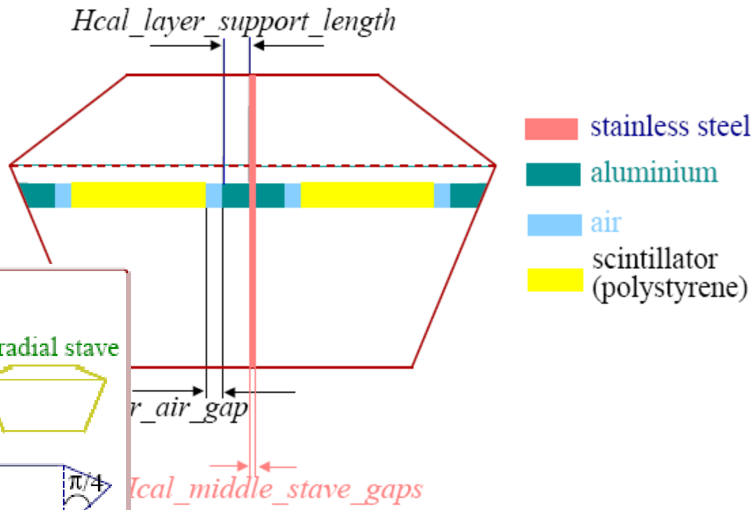
•Depth

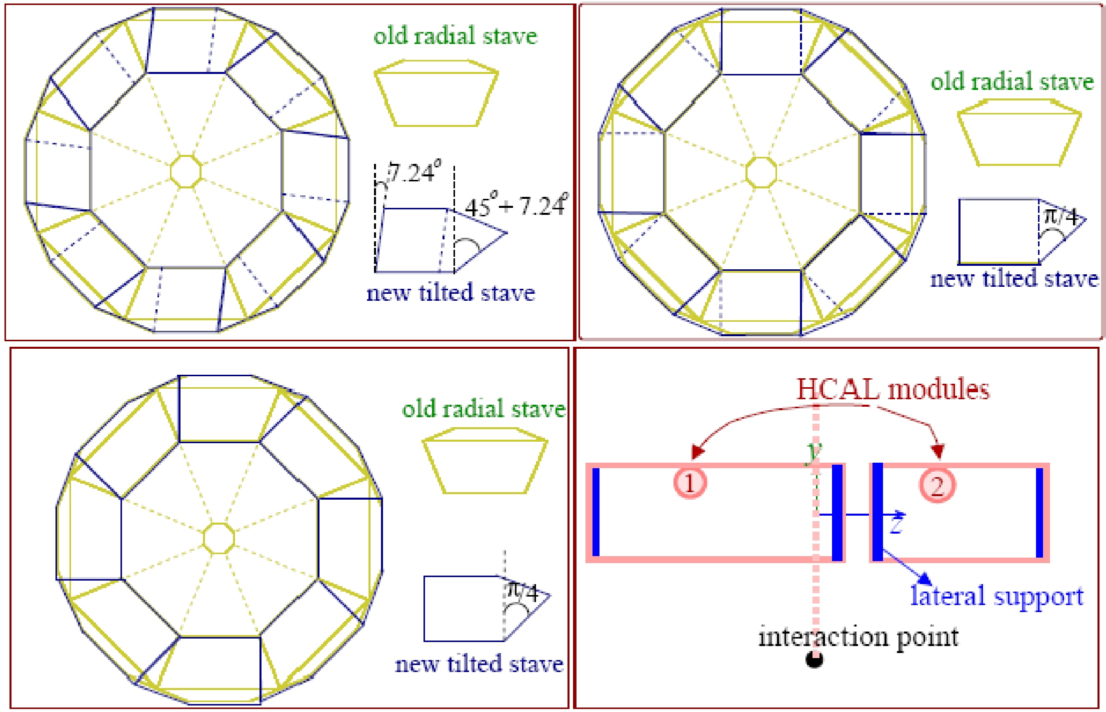
- Sampling structure: thicknesses of absorber and scintillator
- Cracks: number, width, position in z, orientation in rφ
- Radial variation of transverse segmentation; strips vs tiles
- ECAL HCAL transition
- Timing for PFLOW



New Mokka model

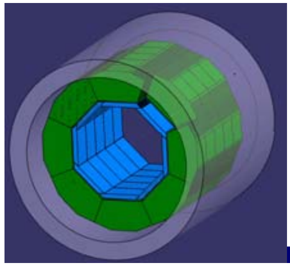
- Revised, refined, realistic parameterization
- New degrees of freedom





- Detailed modelling of layer edges
- Non-pointing cracks in rφ and z possible
- End caps

A. Lucaci, R. Diener (DESY)



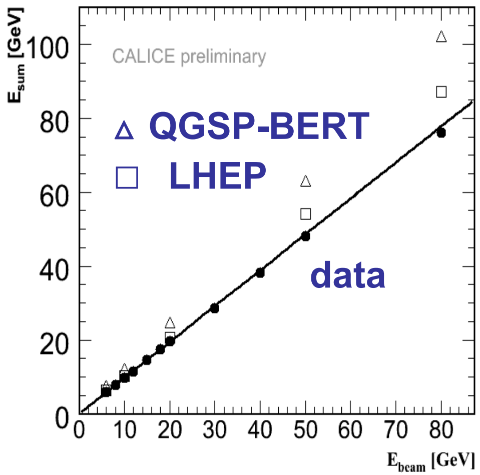
Validate shower models

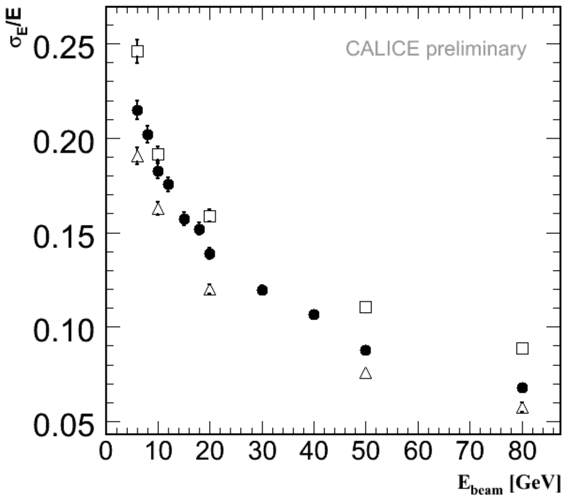
M. Thomson (Cambride)

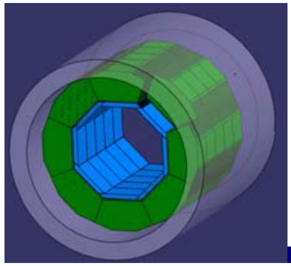
1. Model uncertainties on PFLOW performance

(PandoraPFAv02 +trackCheater)		E_{JET}	$\sigma_E/E = \alpha/\sqrt{E_{jj}}$ $\lvert\cos\theta\rvert<0.7$
LDC00Sc	QGSP_BERT	45 GeV	22.6 %
LDC00Sc	LHEP	45 GeV	23.2 %
LDC00Sc	QGSP_BERT	100 GeV	29.3 %
LDC00Sc	LHEP	100 GeV	30.2 %

2. Confront shower models with test beam data
   - First results on global properties
   - Next: fully exploit granularity for fine structure

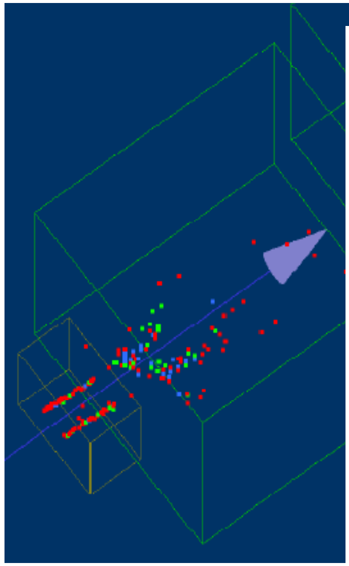


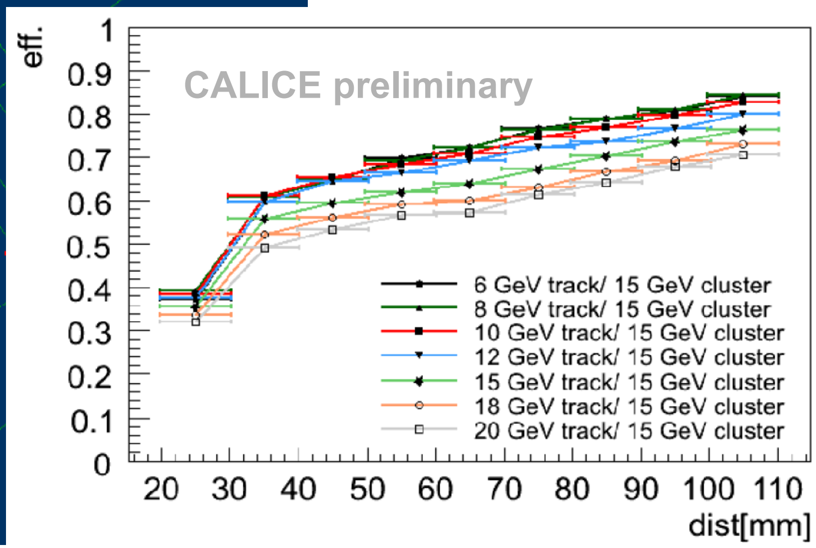


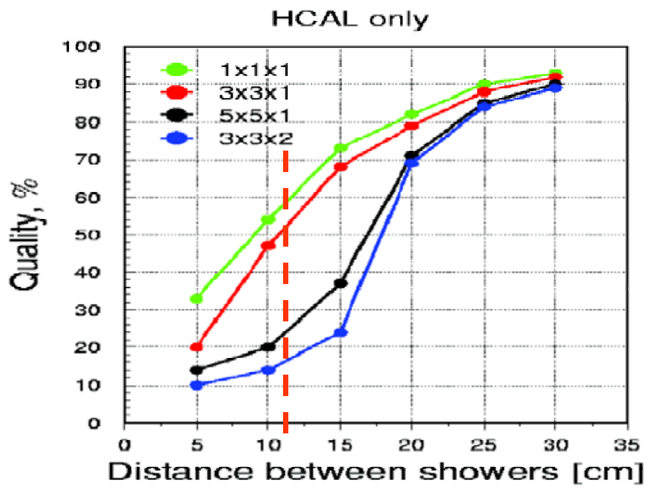


Validate PFLOW performance

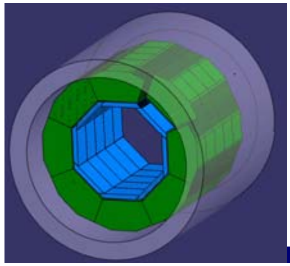
- Test beam 'jets' would require magnet and tracker (future)
- Jet energy resolution depends on hadronic energy resolution and confusion
- High granularity, low occupancy: use event overlay techniques
- Two particle separation in test beam data and Monte Carlo:





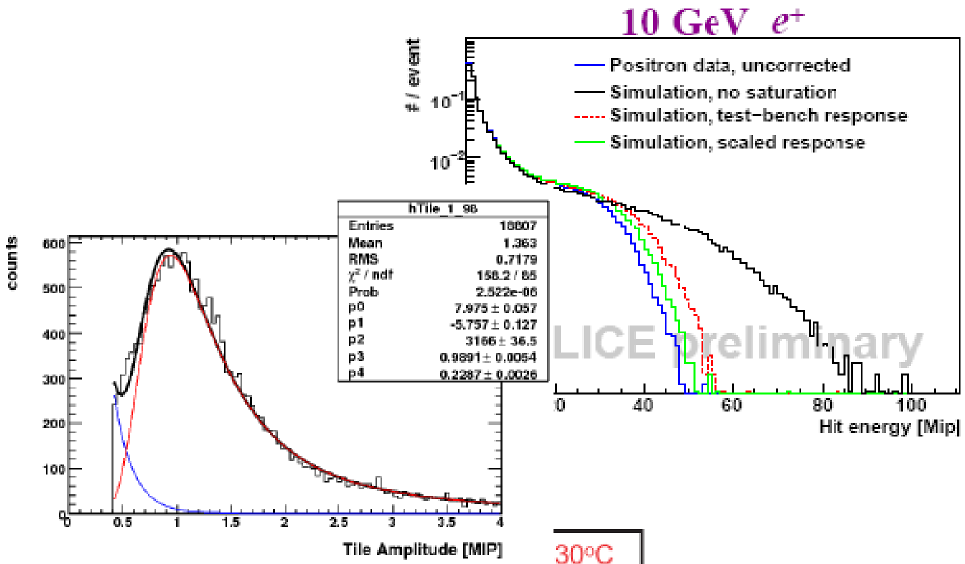


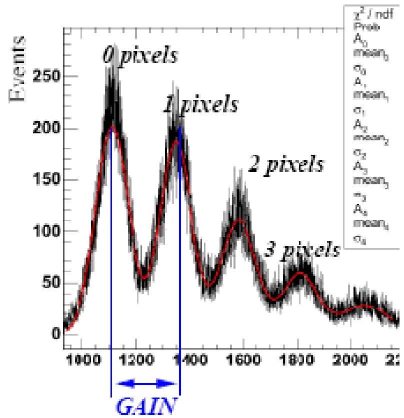
A. Raspereza

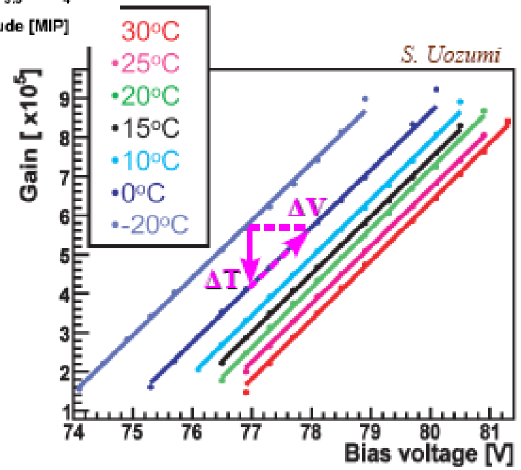


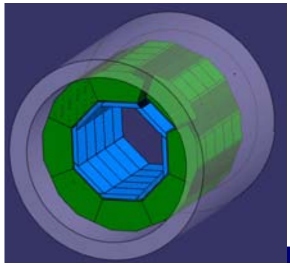
Calibration procedures

- Non-linearity correction: test with electron data
- MIP calibration: in test beam data, explore use of MIP segments in hadron showers
- Correct for temperature-induced variations
  - Use T-sensors and measured T dependences
- Use gain monitoring, adjust voltage



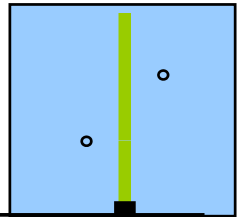


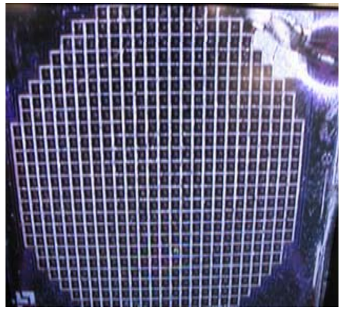




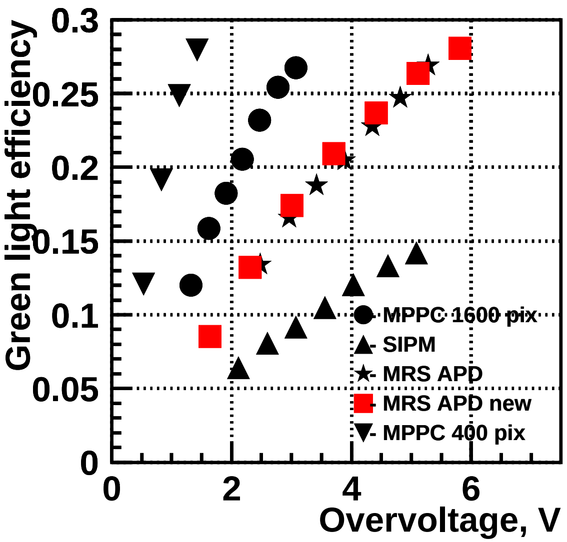
Tile sensor systems with WLS fibre

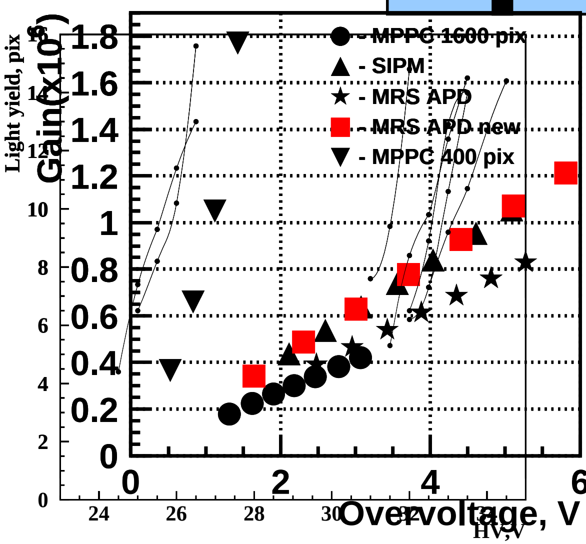
- Present test beam system
  - 5mm thick tile with fibre, MEPHI/ PULSAR SiPM, 15 pixels/MIP
- Several new options: reduce to 3 mm thick tiles
  - Hamamatsu MPPC-1600
  - MRS APDs (CPTA)

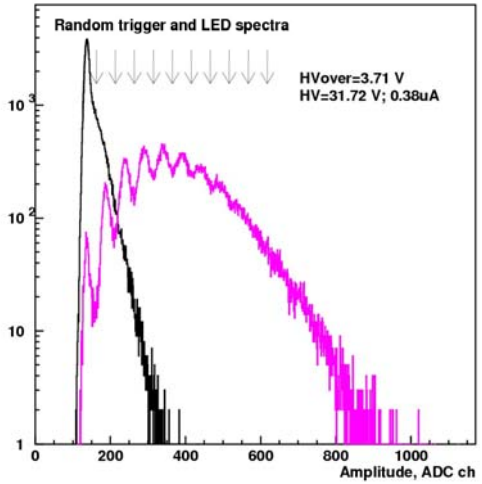


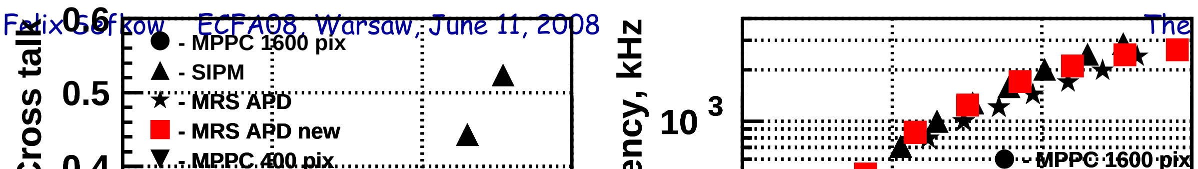


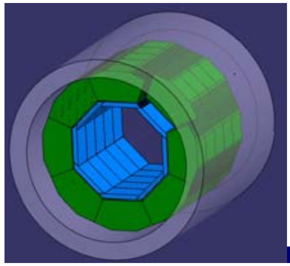
M.Danilov (ITEP)



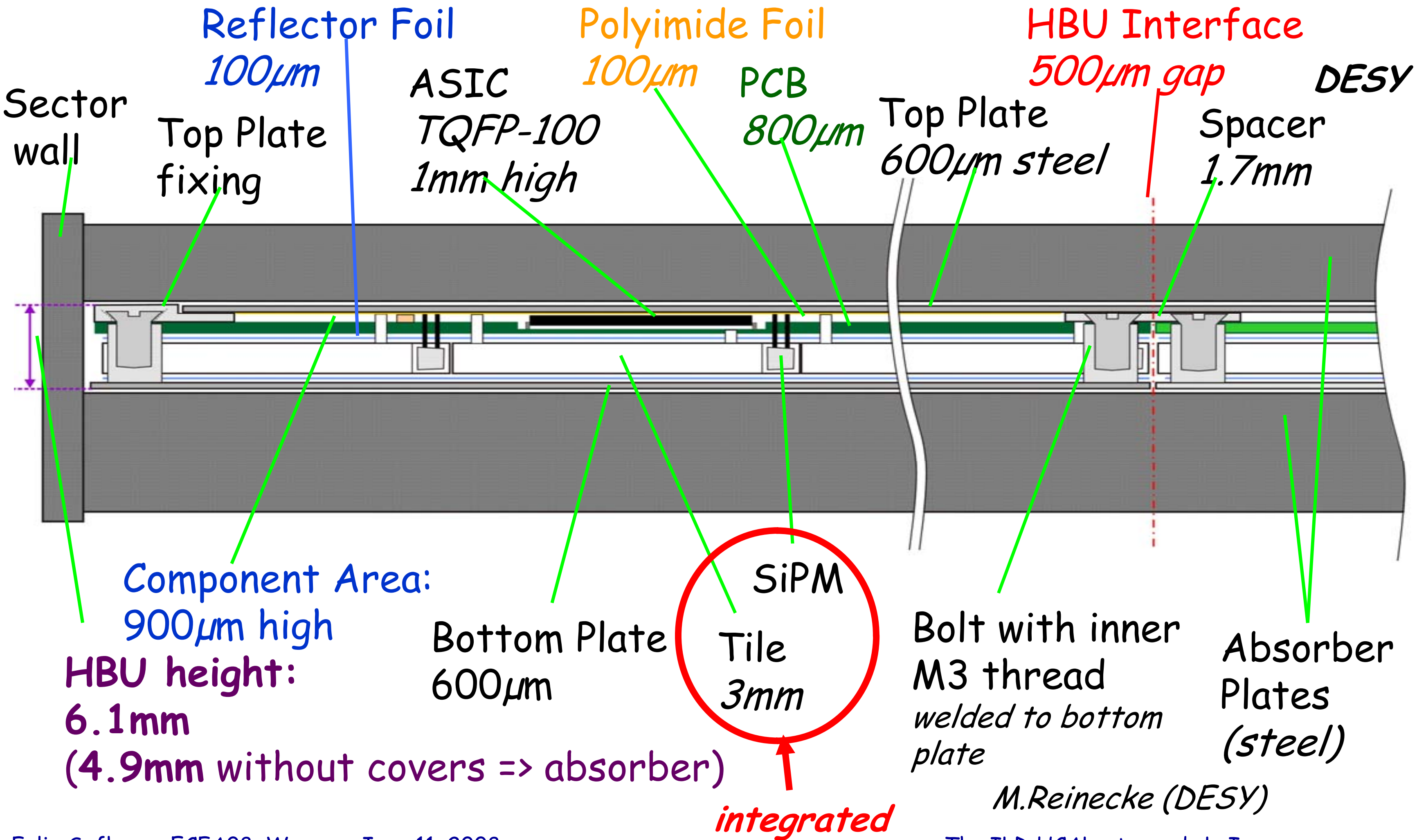


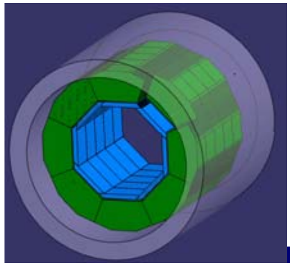






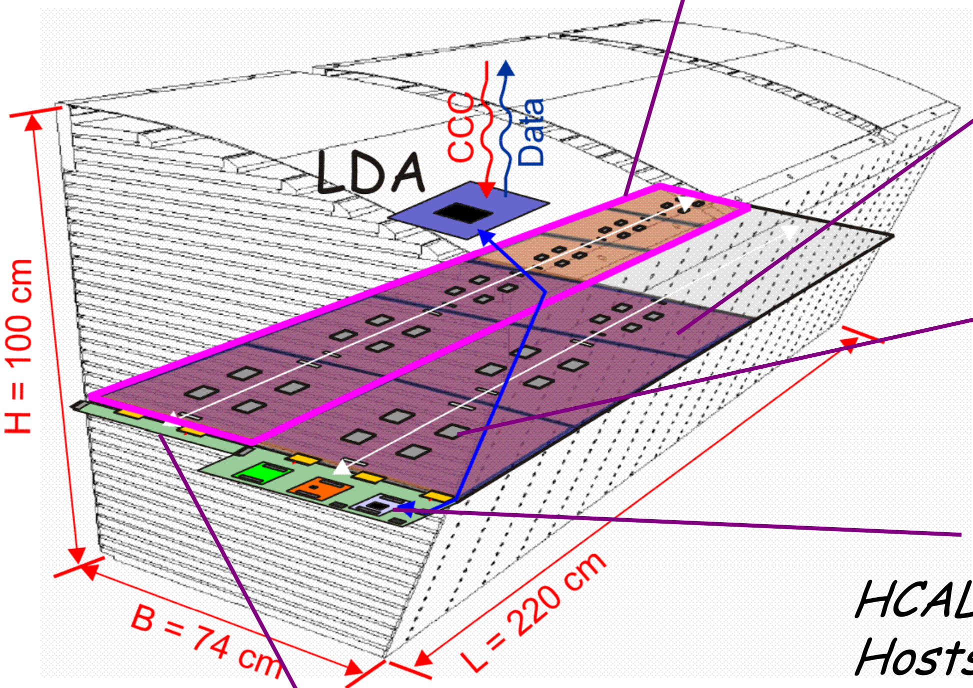
Compact layer design





Integrated electronics

1/16 of barrel half



AHCAL Slab

6 HBUs in a row

Front end ASICs embedded
Interfaces accessible

HBU

HCAL Base Unit

12 x 12 tiles

SPIROC

4 on a HBU

Power:

40 μW / channel

Heat:

T grad. 0.3K/2m

Time constant: 6 d

HEB

HCAL Endcap Board

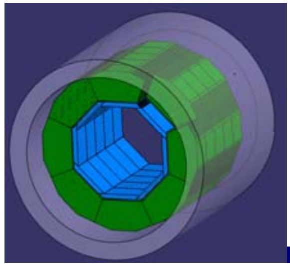
Hosts mezzanine modules:

DIF, **CALIB** and **POWER**

P.Goettlicher (DESY)

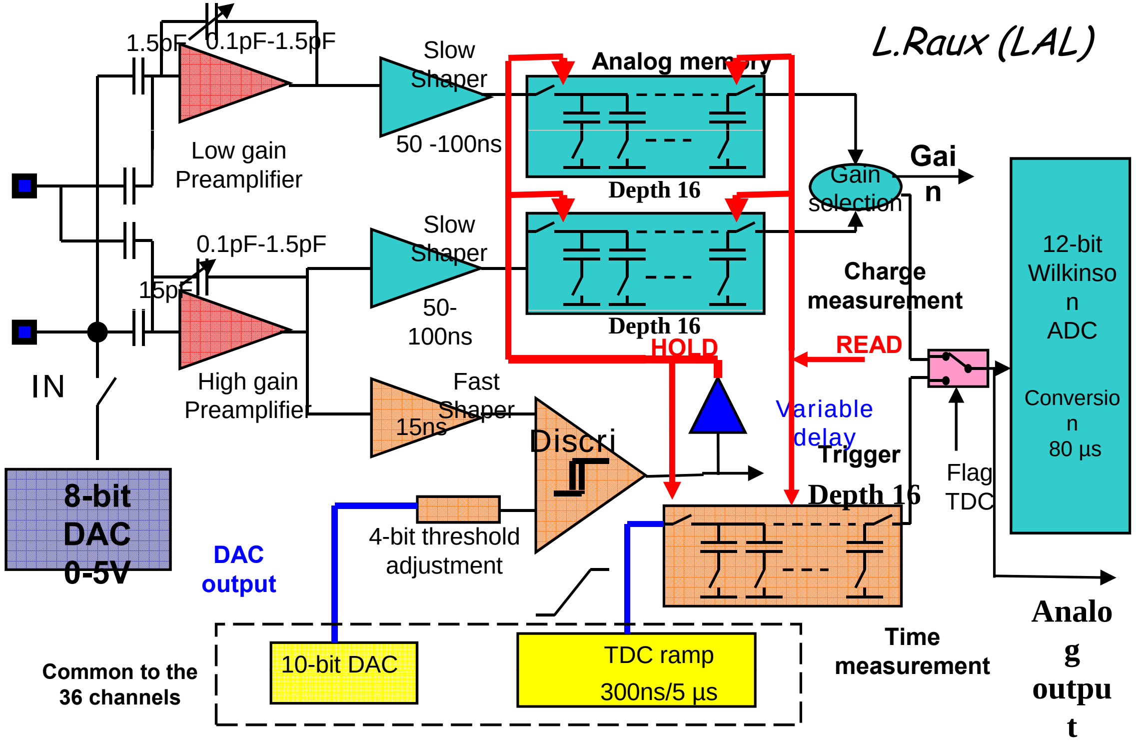
HLD

HCAL Layer Distributor

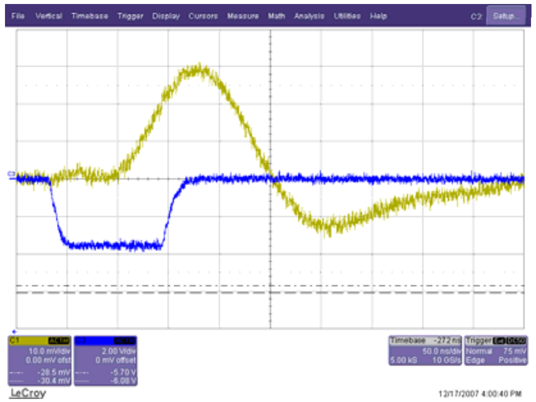


New ASIC on the test benches

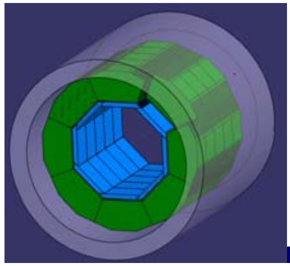
- Auto-triggering and time measurements
- ADC and TDC integrated
- Power pulsing, low (continuous) power DAC



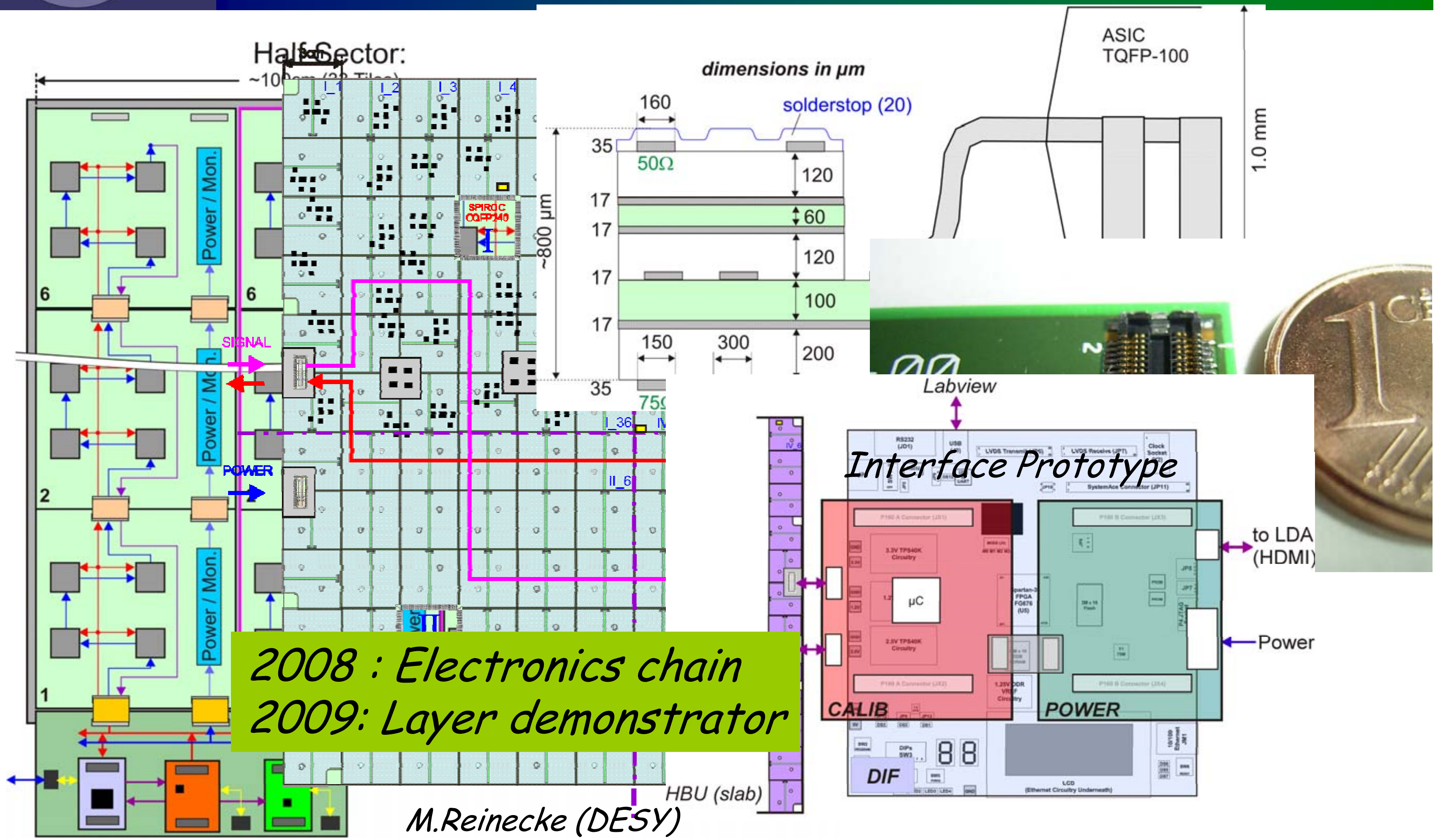
L.Raux (LAL)



R.Fabbri (DESY)



EUDET prototypes



2008 : Electronics chain
2009: Layer demonstrator

Digital HAdronic CALorimeter for ILC

Two efforts are followed in parallel to have high- granularity compact DHCAL:

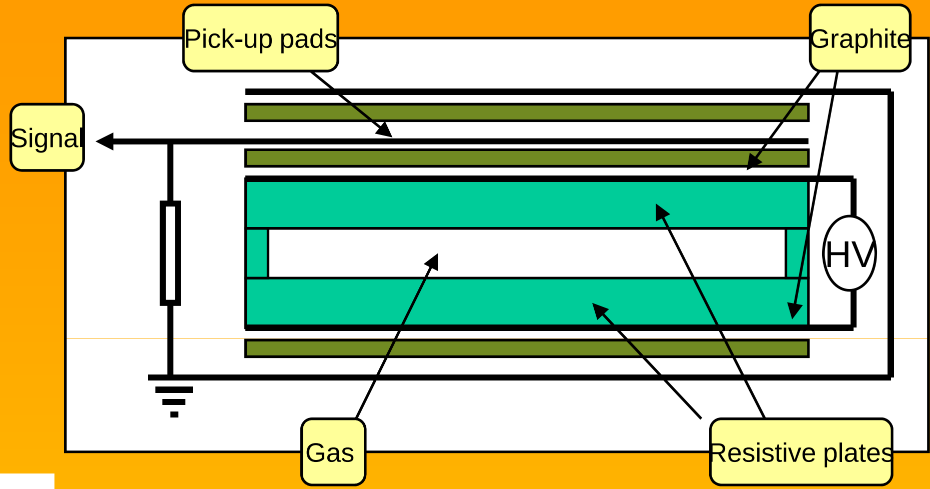
USA: using GRPC/GEM with binary readout (1 bit) → Physics Prototype

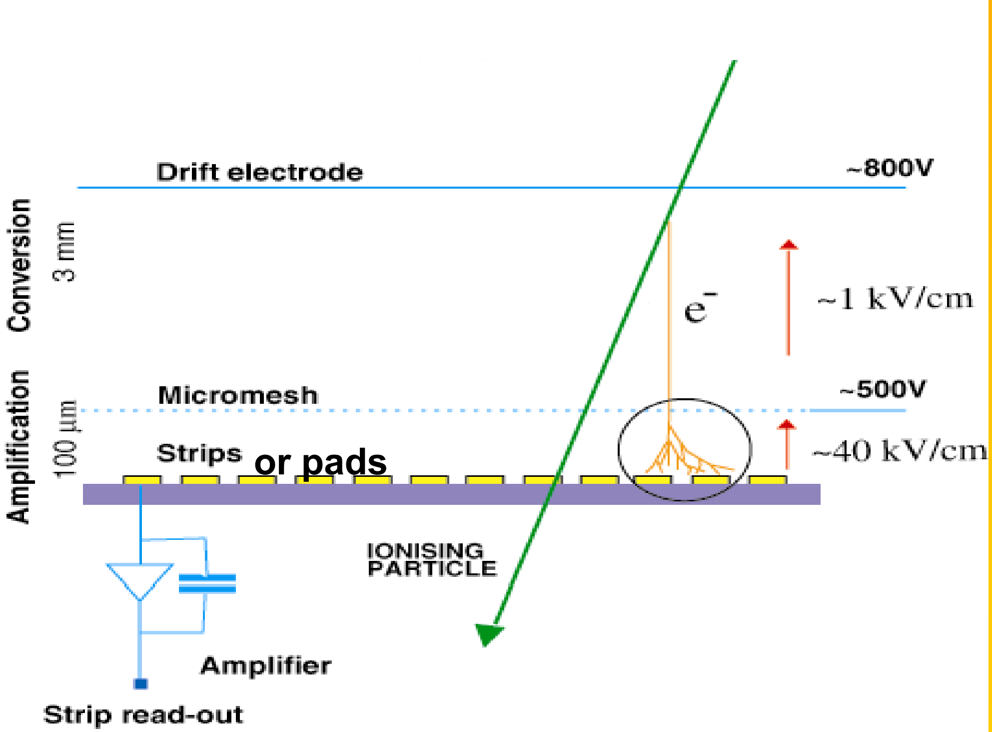
Europe: using GRPC/MICROMEGAS
with semi-digital readout and ILC-like features → Technological Prototype with the following guideline:

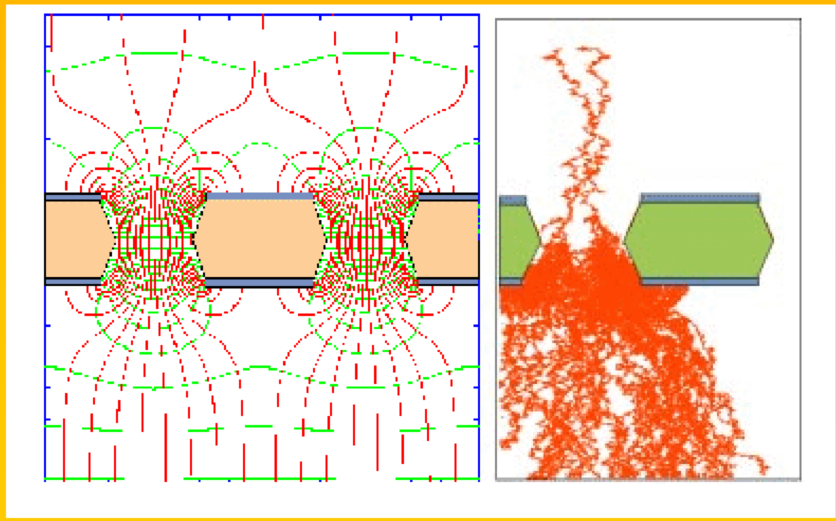
- DHCAL as compact and as hermetic as possible

Detectors for the DHCAL

Gas detectors:
Thickness of few millimeters
GRPC :
Robust but limited detection rate
µMEGAS,GEM :
delicate but high rate

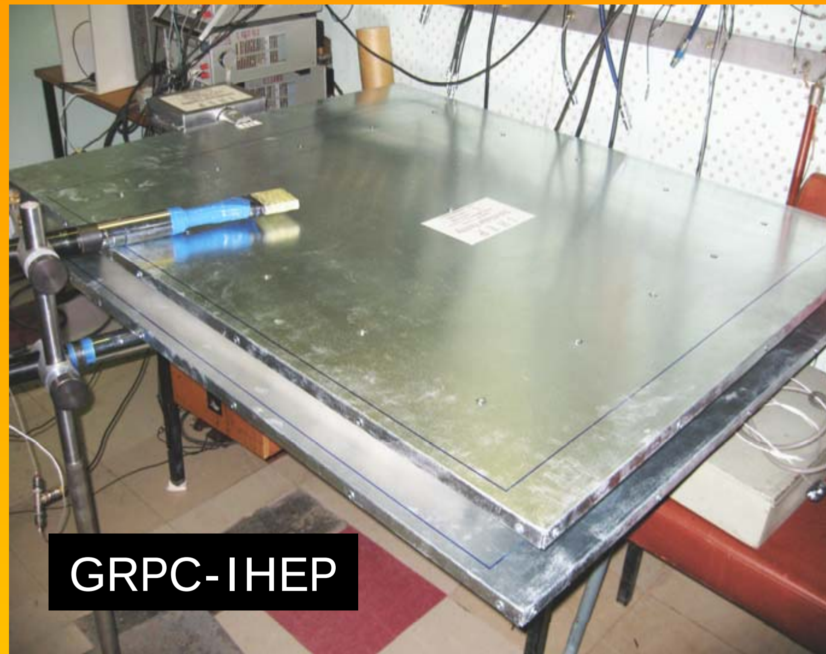




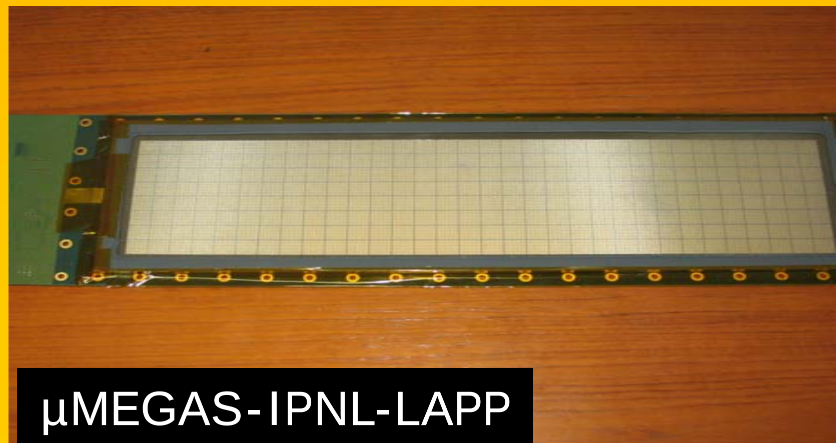


Detector dimensions :

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



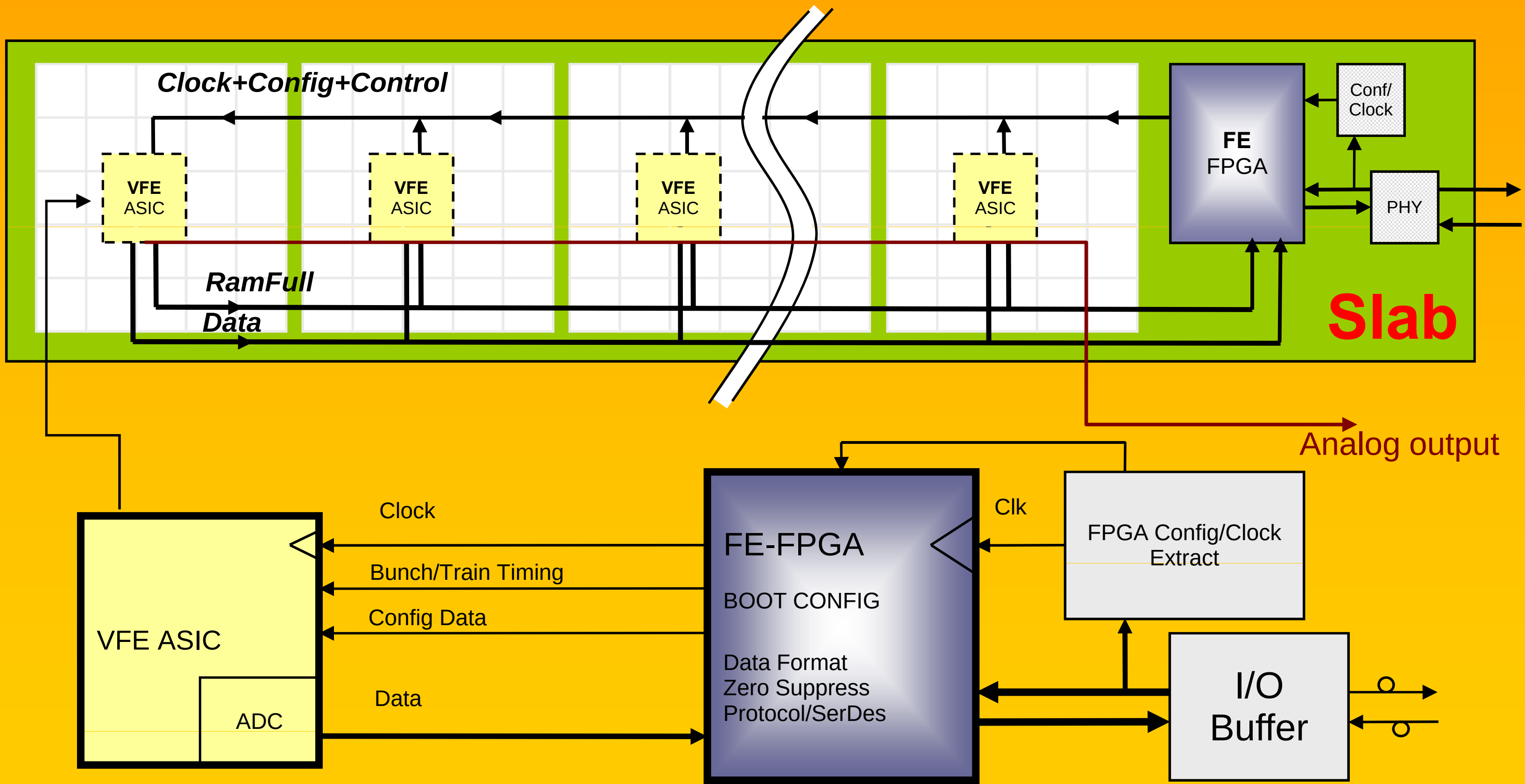
μMEGAS: 16×6, 32×8,32×12 1cm² produced and tested. Larger size detectors are under development



The challenge:

How to have a detector of few thousands m²
fully equipped with low consumption semi-digital readout
and still very compact !!!!?

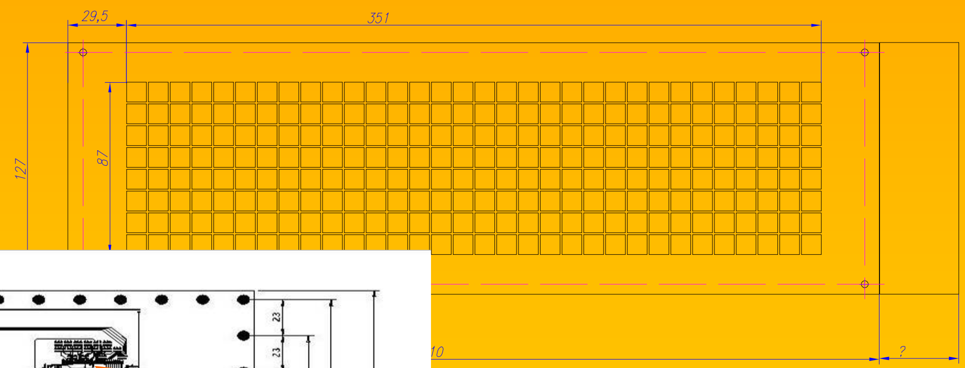
Embedded Daisy-chained electronics is the solution

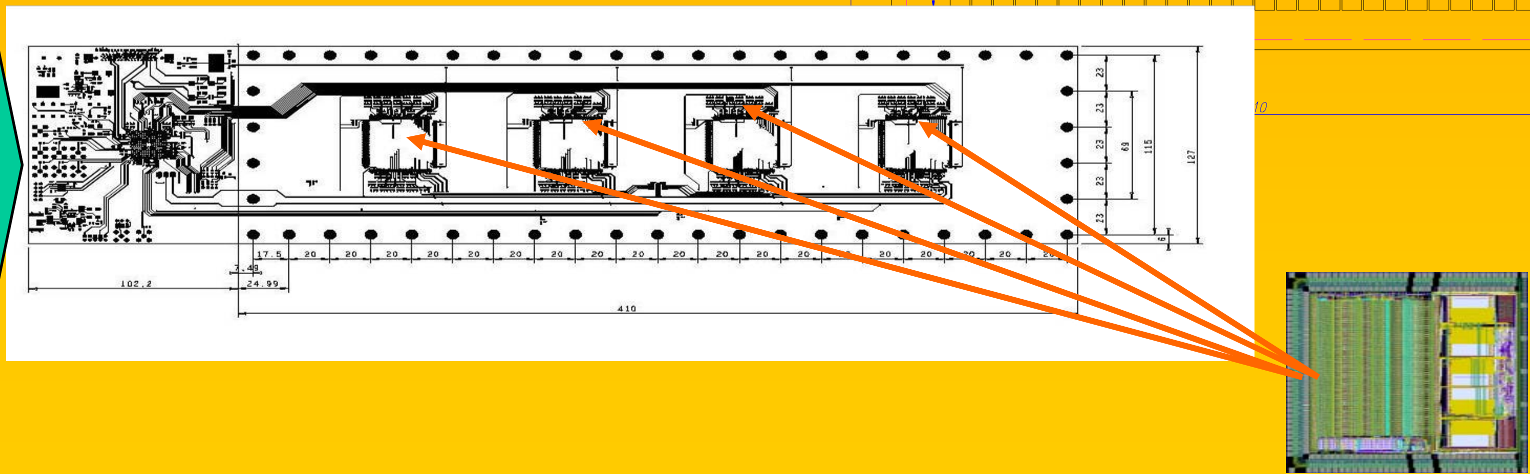


4-Chip project

Aim: Validate the new electronics/acquisition scheme for DHCAL

- 8×32 pads detector (GRPC and µMEGAS)
- 8-layer PCB
- 4 chips (64 ch)
- Readout USB + FPGA

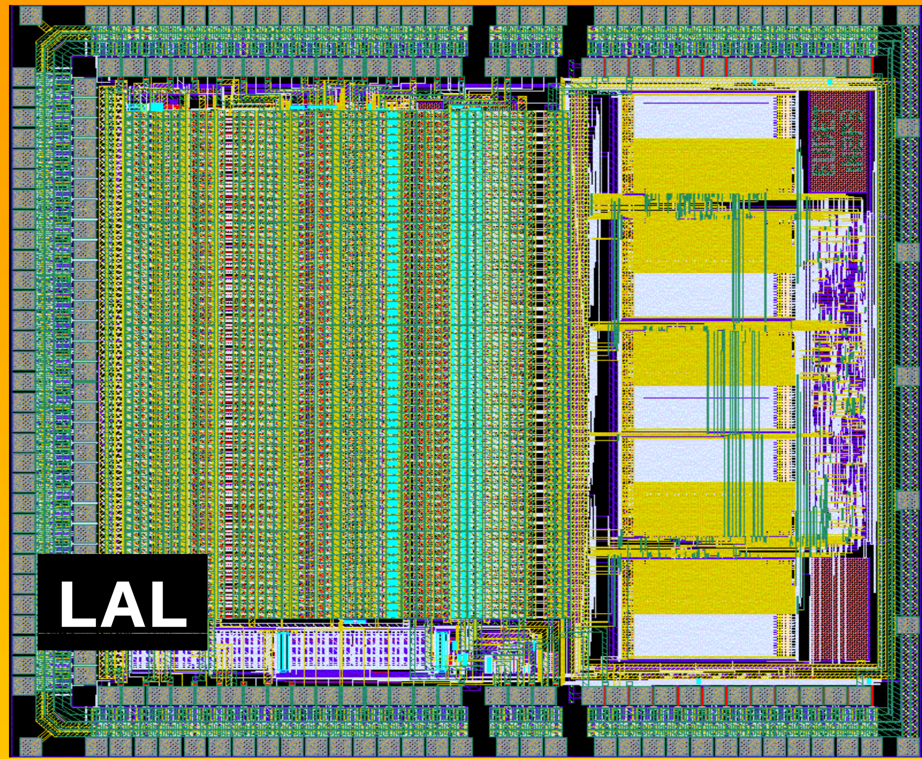




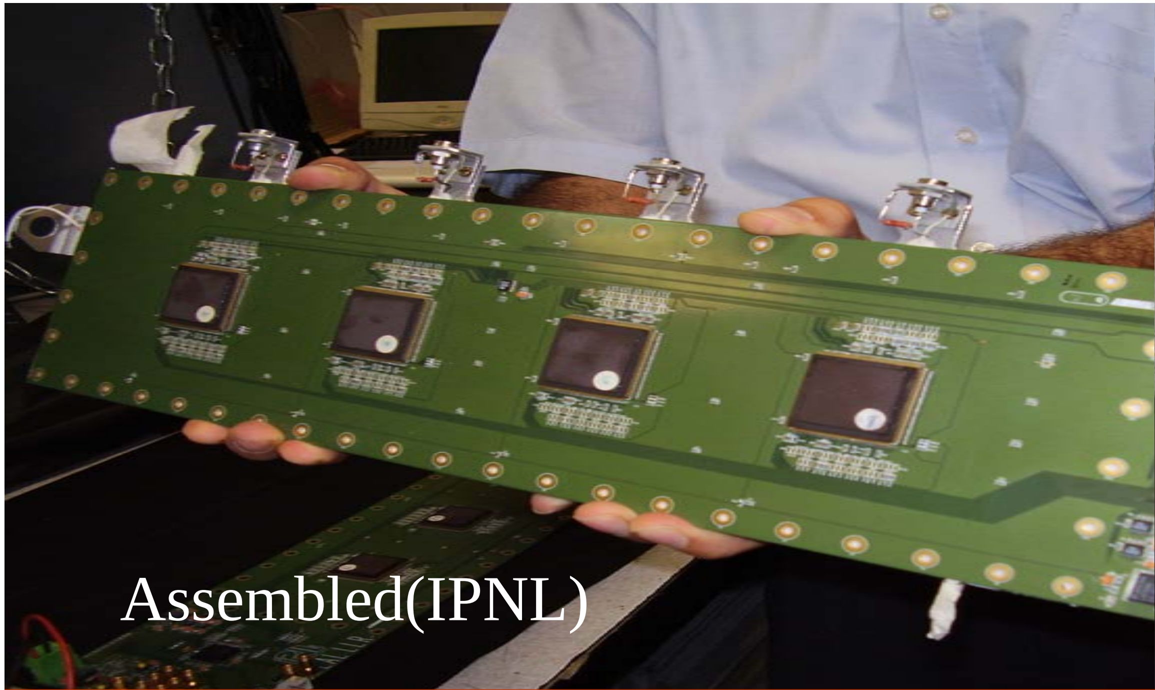
Electronics

HARDROC

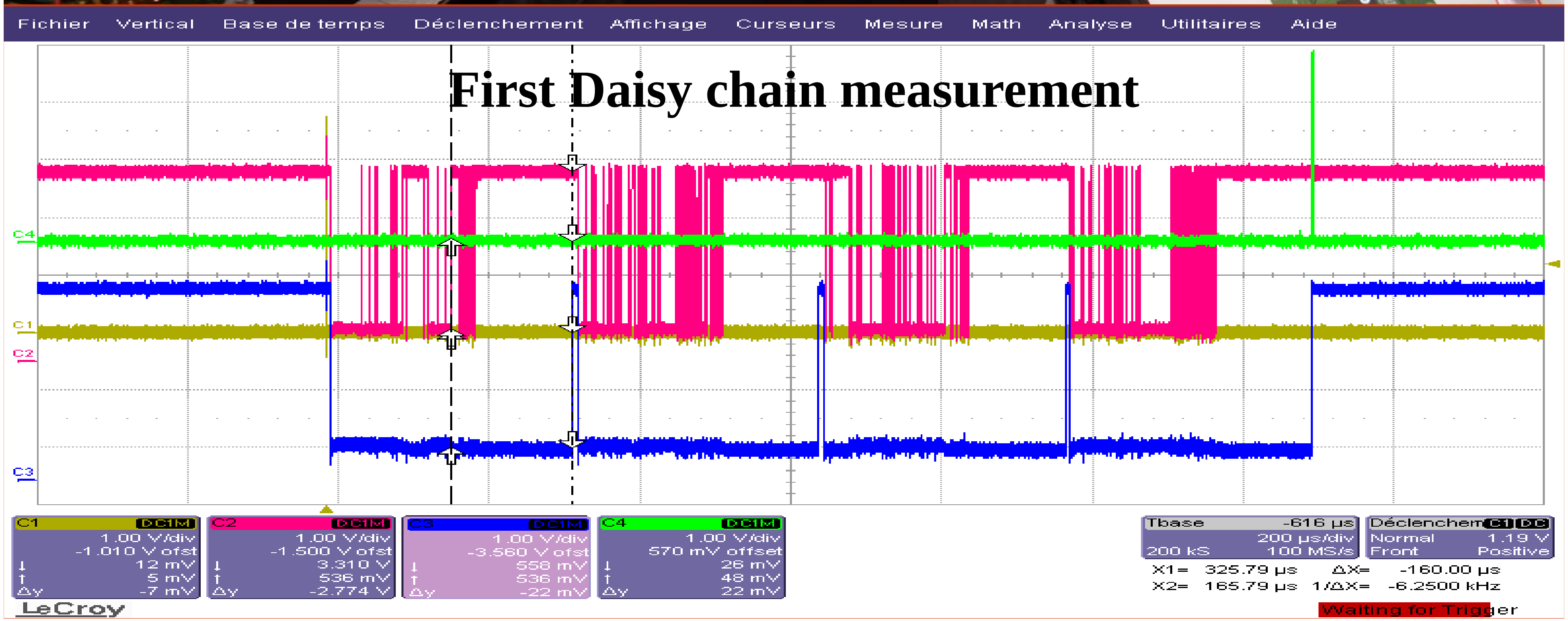
- 64 channels, 16mm²
- Digital/analog output.
- 2 thresholds(3 very soon)
- low consumption, power pulsing (< 10 µW/ch)
- Digital memory able to store up to 128 evts.
- Large gain range
- Xtalk <2%
- Adequate for GRPC* (threshold > 10 fc)



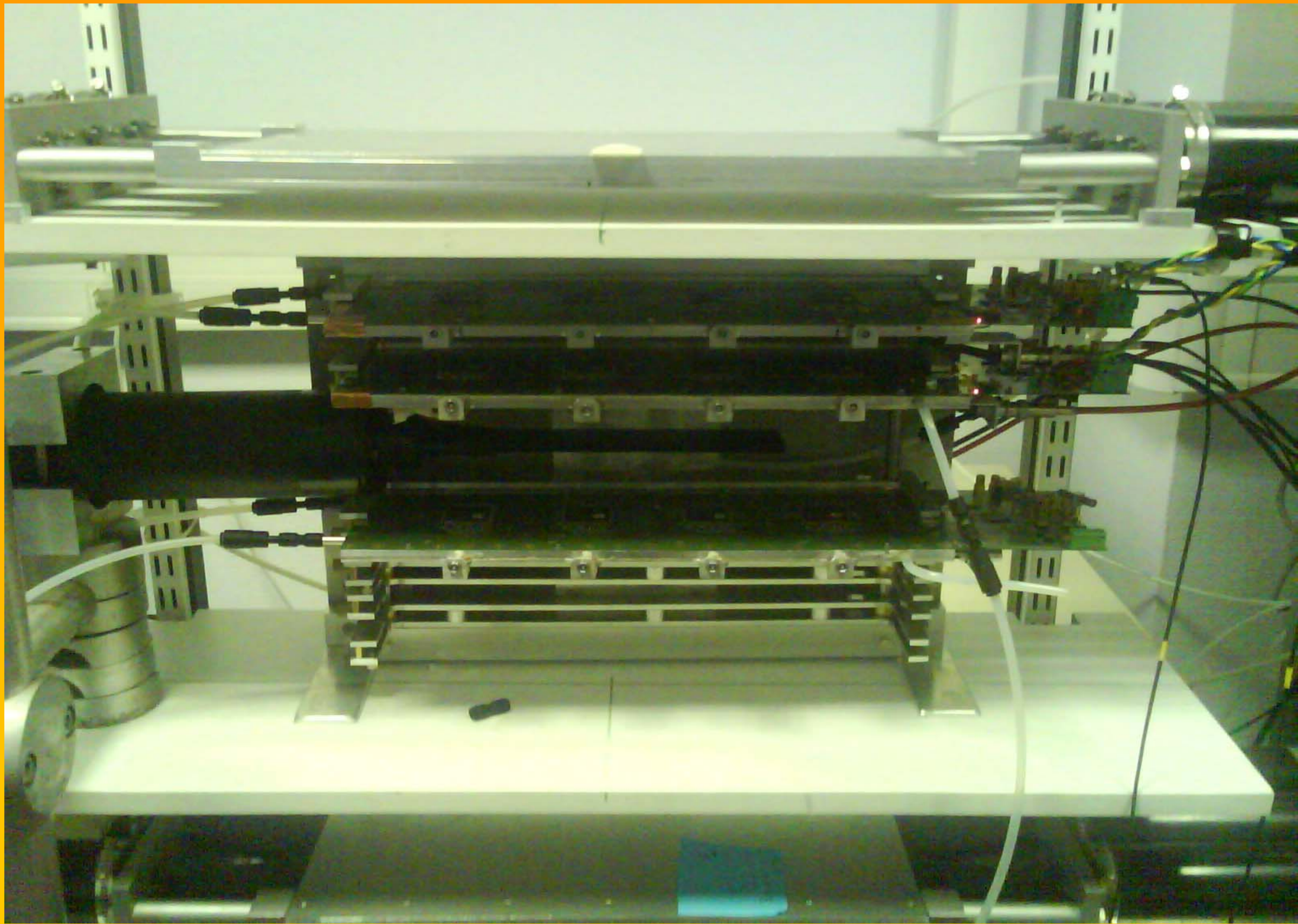
***For µMEGAS another ASIC is developed in Lyon with a threshold as low as 3 fc**


Assembled(IPNL)


Readout software (LLR)


First Daisy chain measurement
Fichier Vertical Base de temps Déclenchement Affichage Curseurs Mesure Math Analyse Utilitaires Aide
C4
C1
C2
C3
LeCroy
X1= 325.79 µs ΔX= -160.00 µs
X2= 165.79 µs 1/ΔX= -6.2500 kHz
Waiting for Trigger

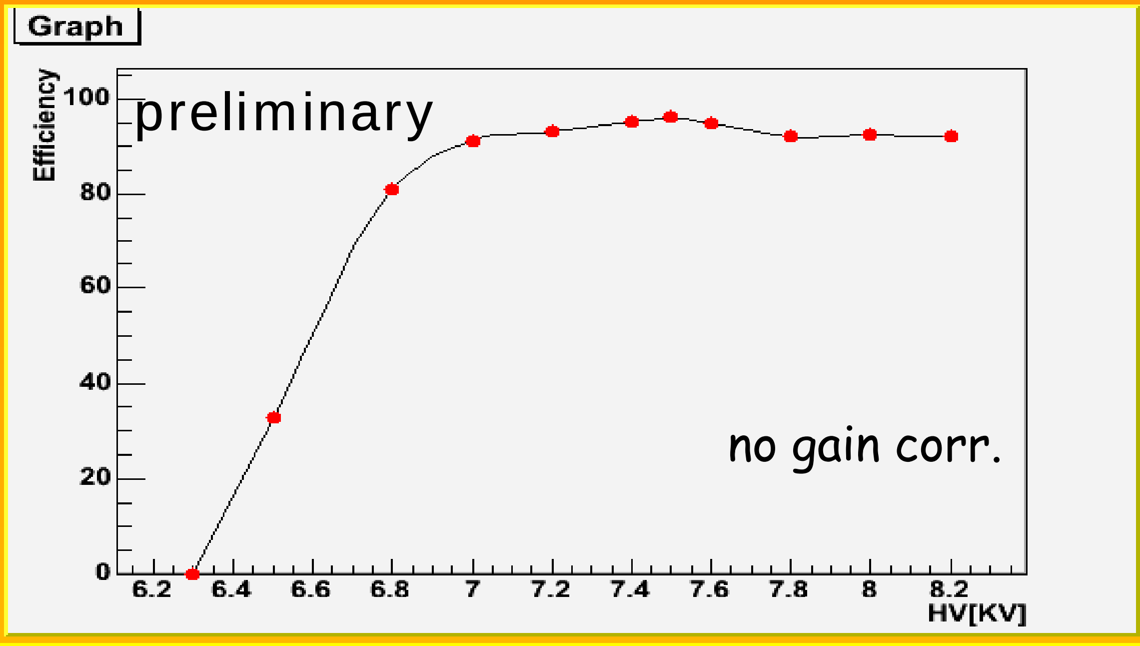
Slice test



On the test bench with GRPC

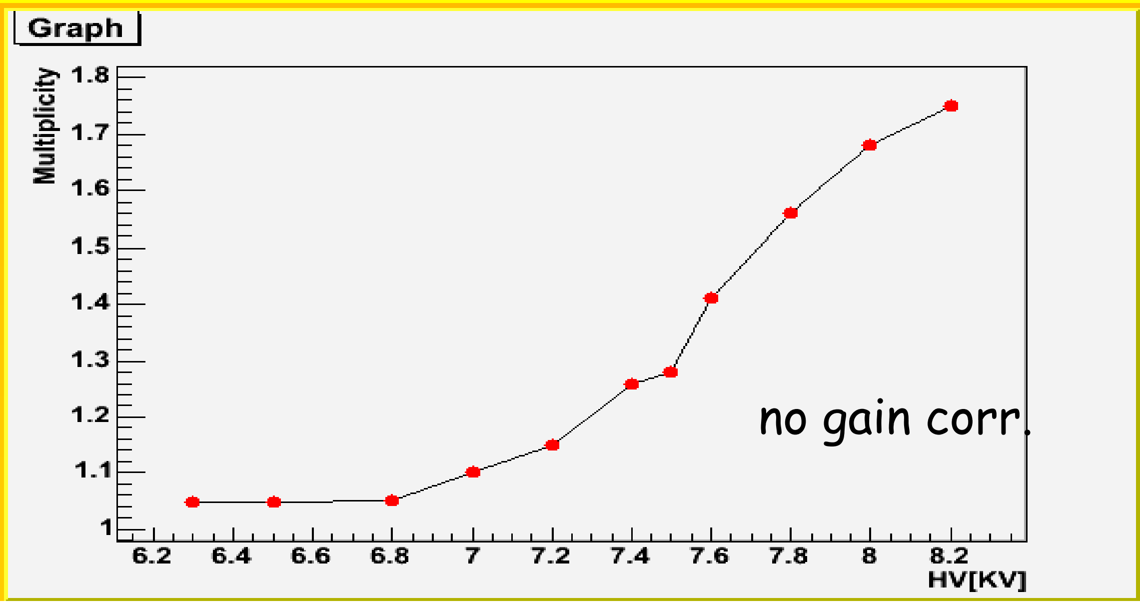
First results

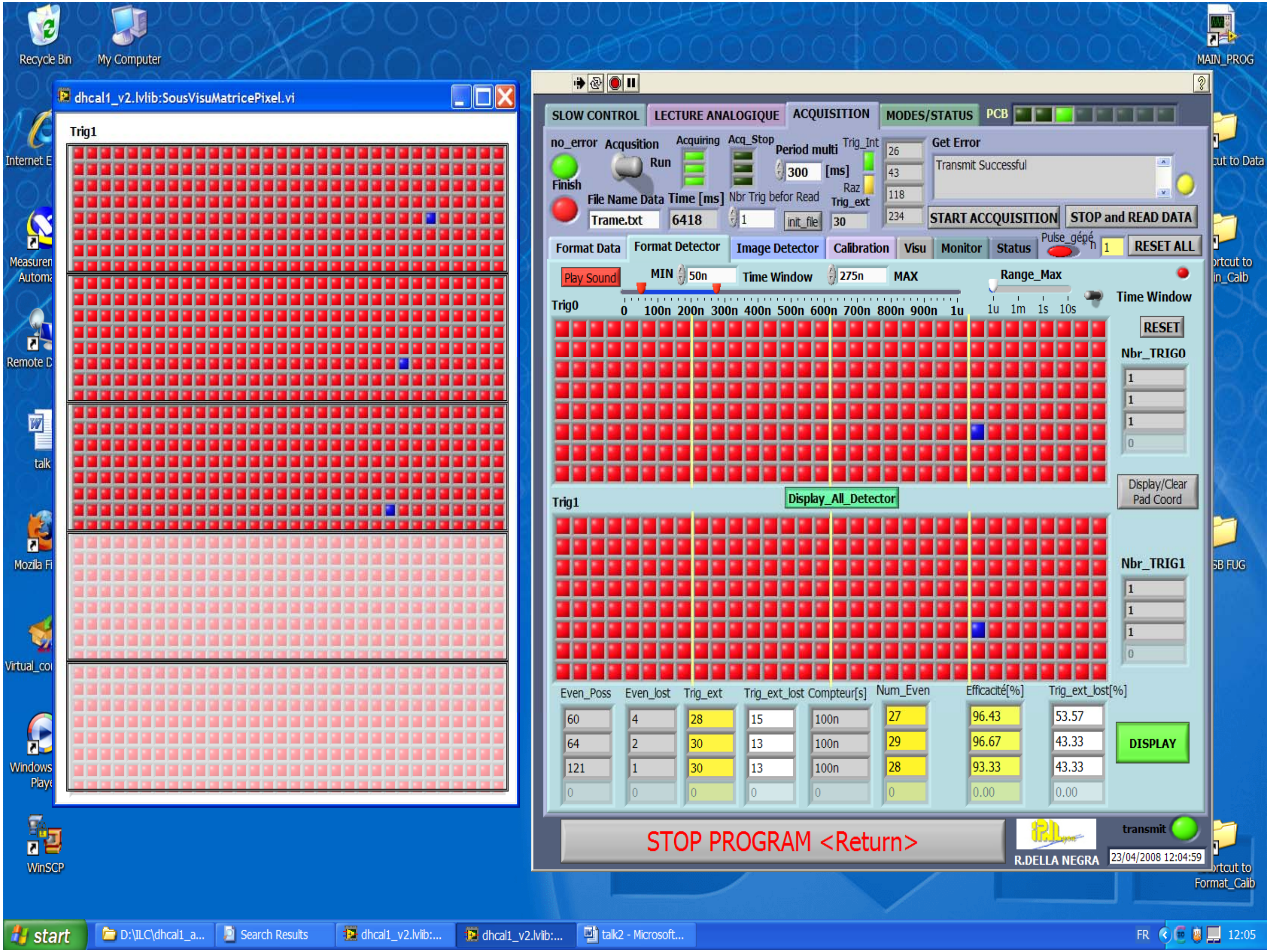
GRPC
32×8 pads
RP:licron



TFE 93%
Isobutene 5%
SF6 2%

Threshold ≈ 100 fc




dhcal1_v2.lvlib:SousVisuMatricePixel.vi
Trig1
SLOW CONTROL
LECTURE ANALOGIQUE
ACQUISITION
MODES/STATUS
PCB
no_error
Acqusition
Acquiring
Acq_Stop
Period multi
Trig_Int
Get Error
Run
300
[ms]
Transmit Successful
Finish
File Name Data
Time [ms]
Nbr Trig befor Read
Raz
Trig_ext
Trame.txt
6418
init_file
START ACCQUISITION
STOP and READ DATA
Format Data
Format Detector
Image Detector
Calibration
Visu
Monitor
Status
RESET ALL
Play Sound
MIN
50n
Time Window
275n
MAX
Range_Max
Trig0
Time Window
RESET
Nbr_TRIG0
Display/Clear Pad Coord
Trig1
Display_All_Detector
Nbr_TRIG1
Even_Poss
Even_lost
Trig_ext
Trig_ext_lost
Compteur[s]
Num_Even
Efficacité[%]
Trig_ext_lost[%]
DISPLAY
STOP PROGRAM <Return>
R.DELLA NEGRA
transmit
23/04/2008 12:04:59
start
12:05

Beam test

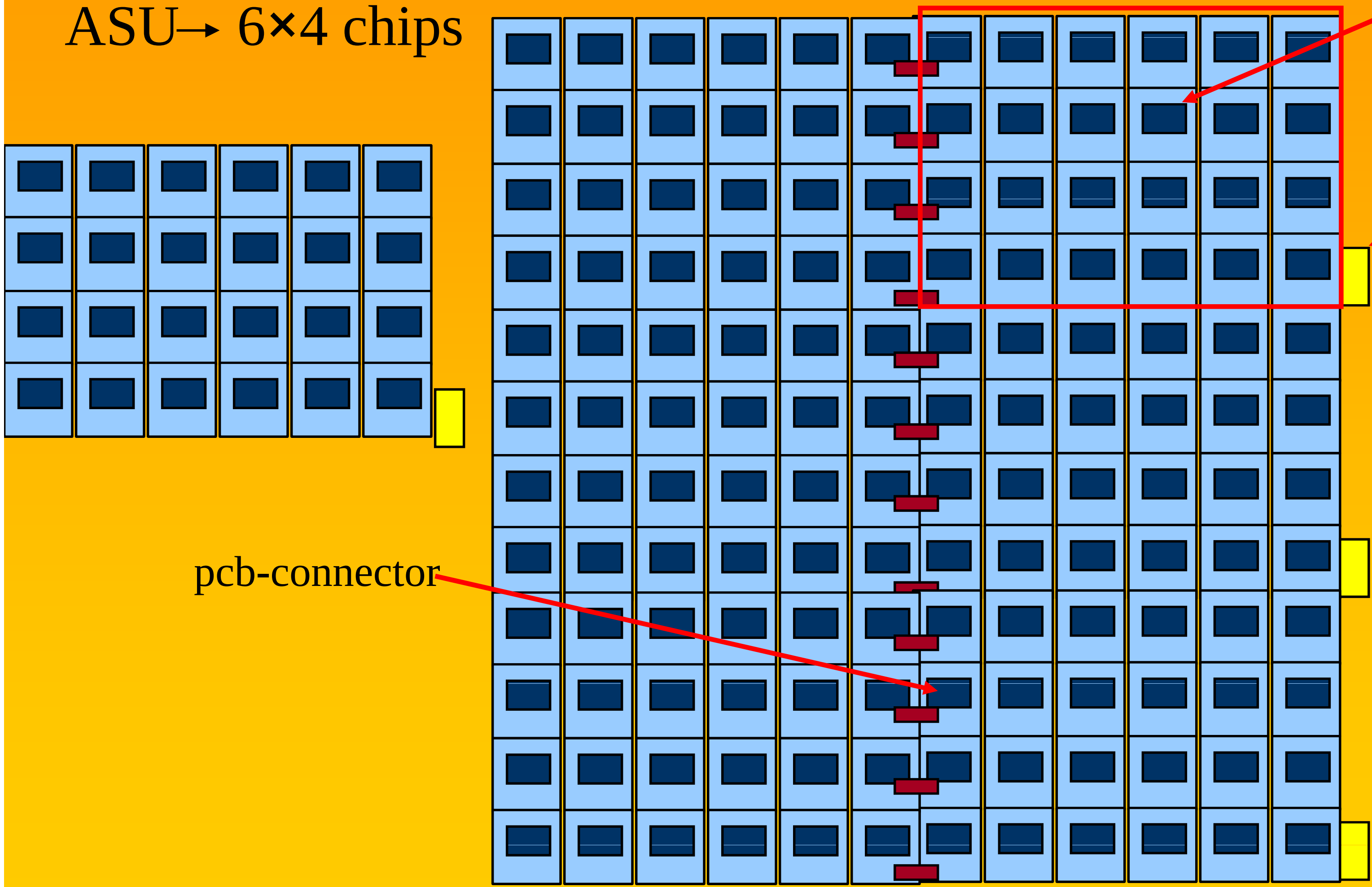
Final confirmation of the success of our electronic readout system will be coming soon with the beam tests with 5 fully equipped detectors (32×8 pads each):

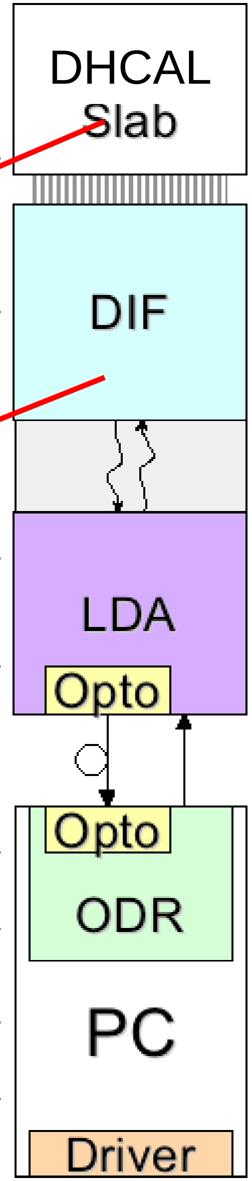
10-17 July :
beam test@ps-cern
3-11 August :
beam test@sps-cern

To study:
* Efficiency and multiplicity
  vs:angle, position, particle multiplicity
* but also the first phase of the Hadronic shower

$1m^2$ project

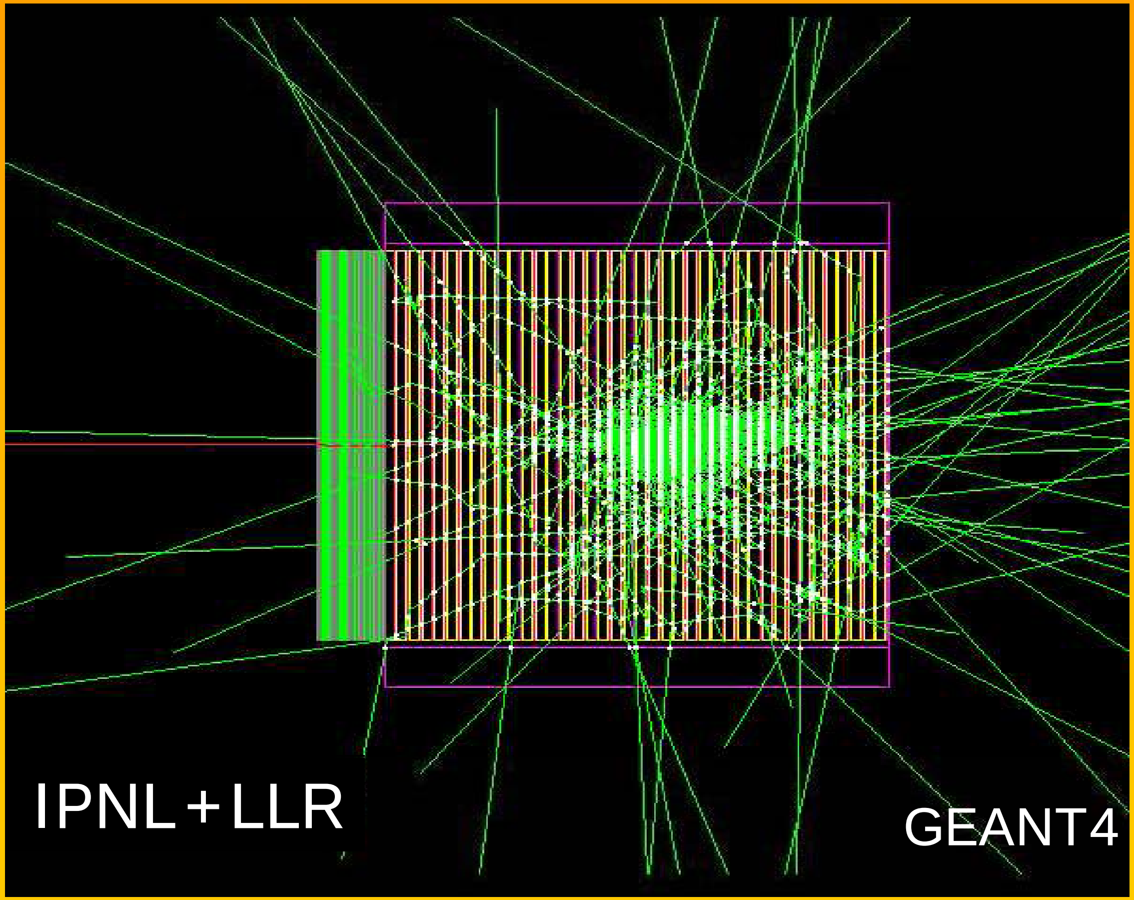
ASU→ 6×4 chips





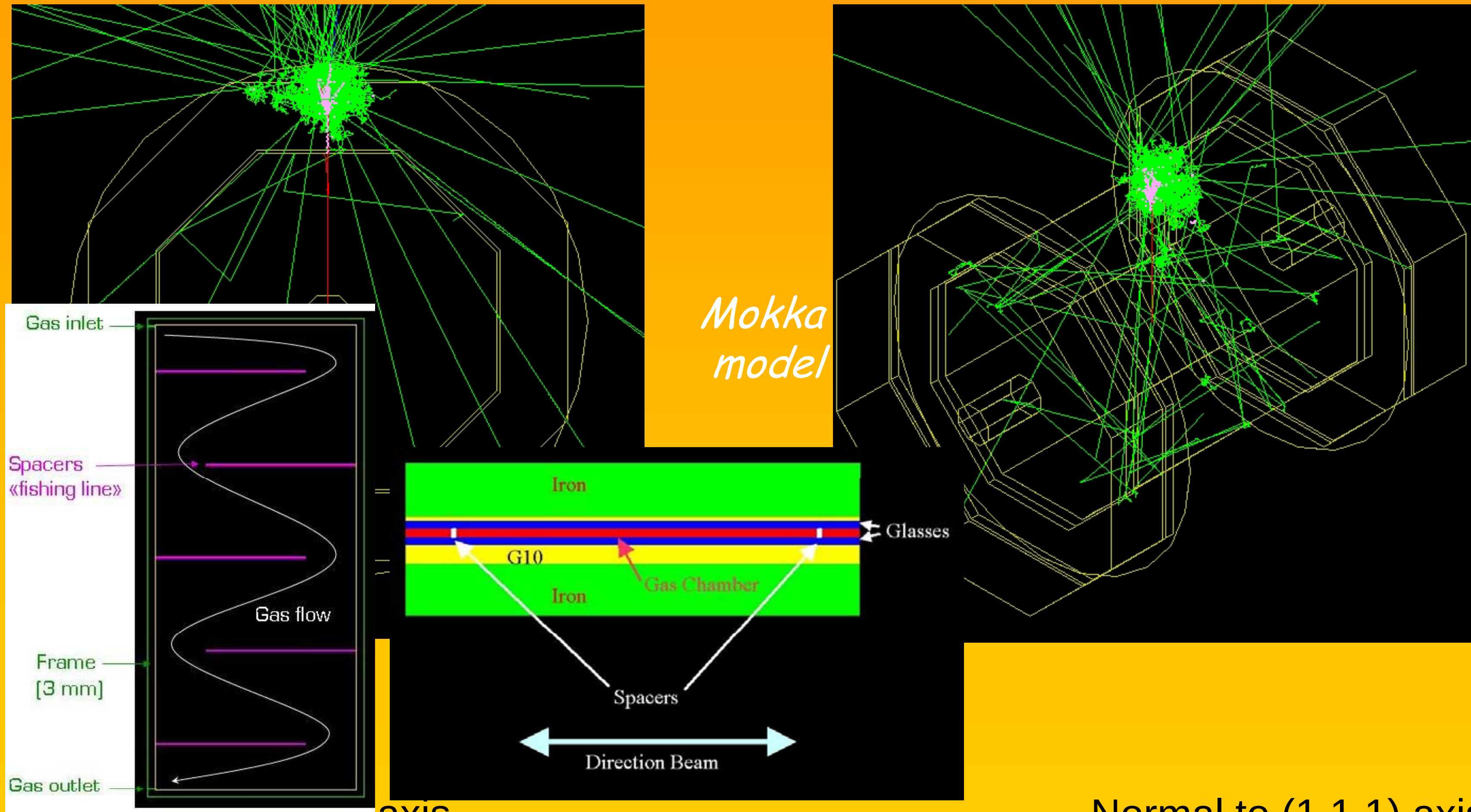
Perspectives

A technological prototype ILC-module0 to be built before 2010



The technological prototype optimization is going on to optimize the design

Event with a 20 GeV π

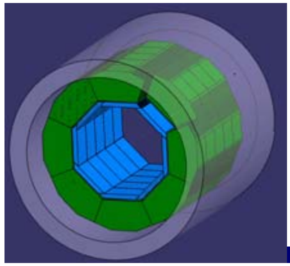


Normal to z-axis

Normal to (1,1,1) axis

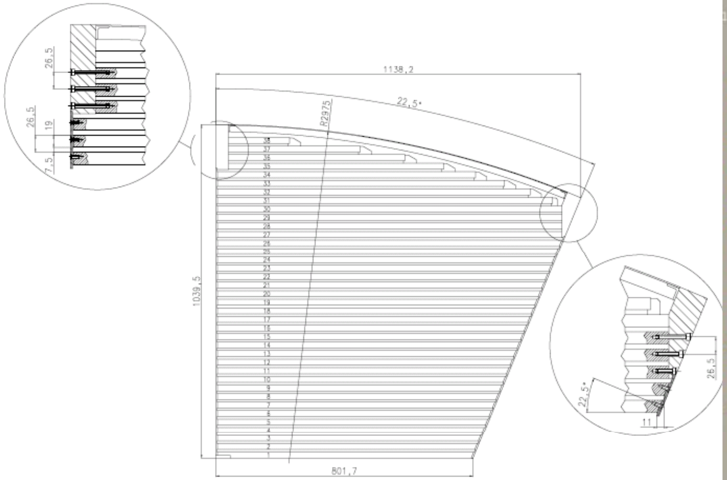
DHCAL Summary

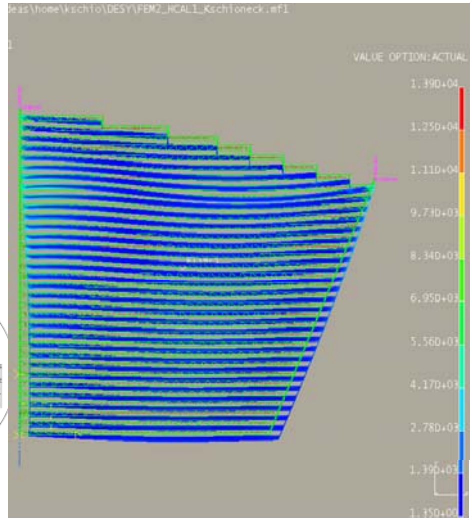
- A slice test with thin GRPC fully equipped with a new generation electronics was tested successfully
- Beam tests at CERN scheduled in July, August
- A 1 M2 detector is expected for October.
- A prototype is funded and to be built before 2010
- ILD Simulation and optimization tools in preparation

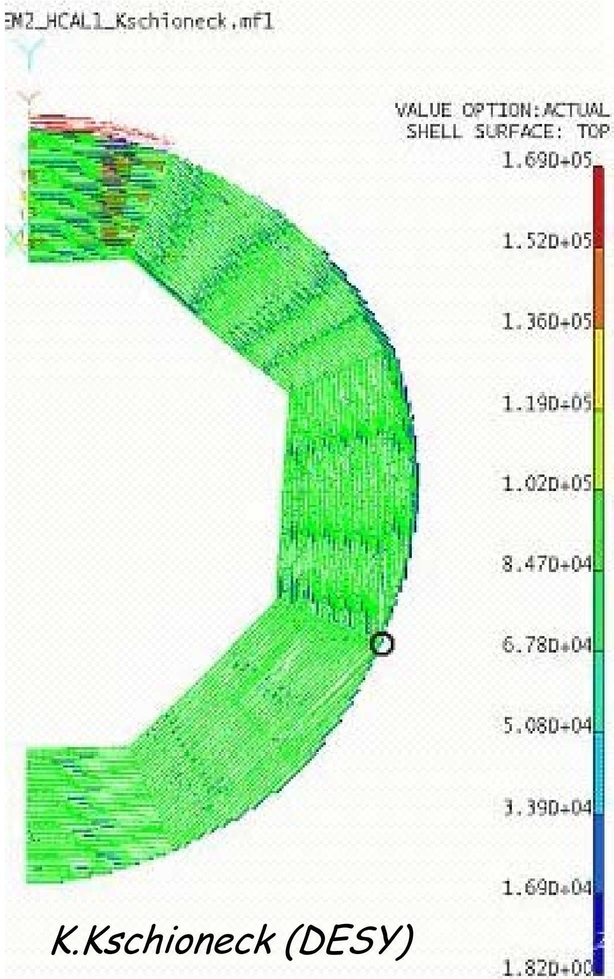


Mechanical structure, integration

- Aggressive design: 3mm walls
- No additional spacers
- FEM calculation with sector details for full barrel
  - Max displacement 2mm, stress ✓
  - Integration with cryostat and ECAL

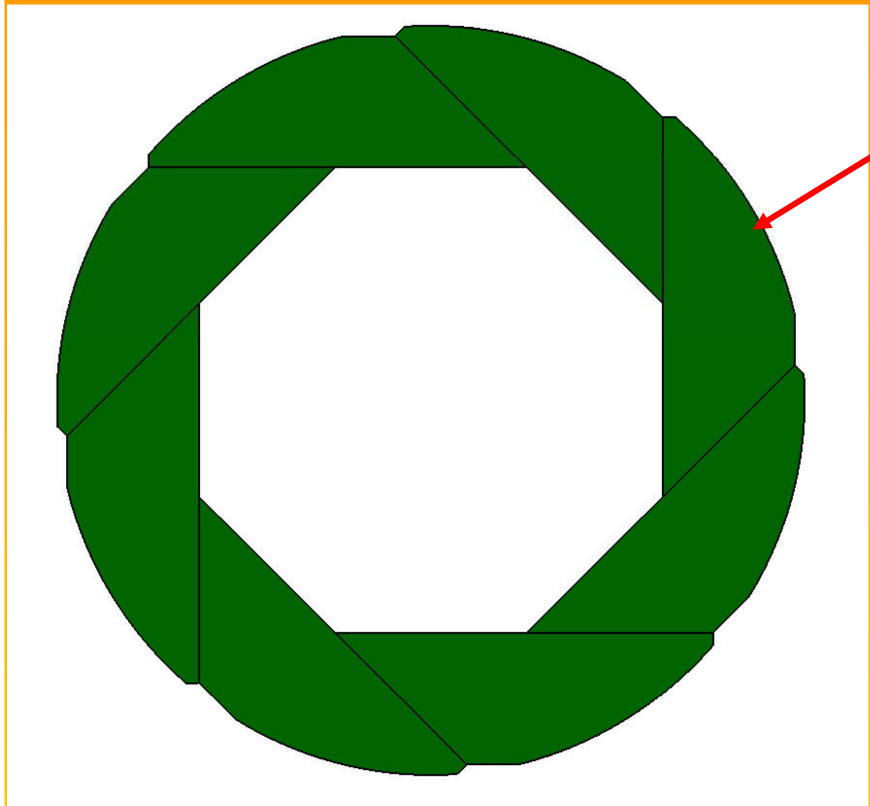


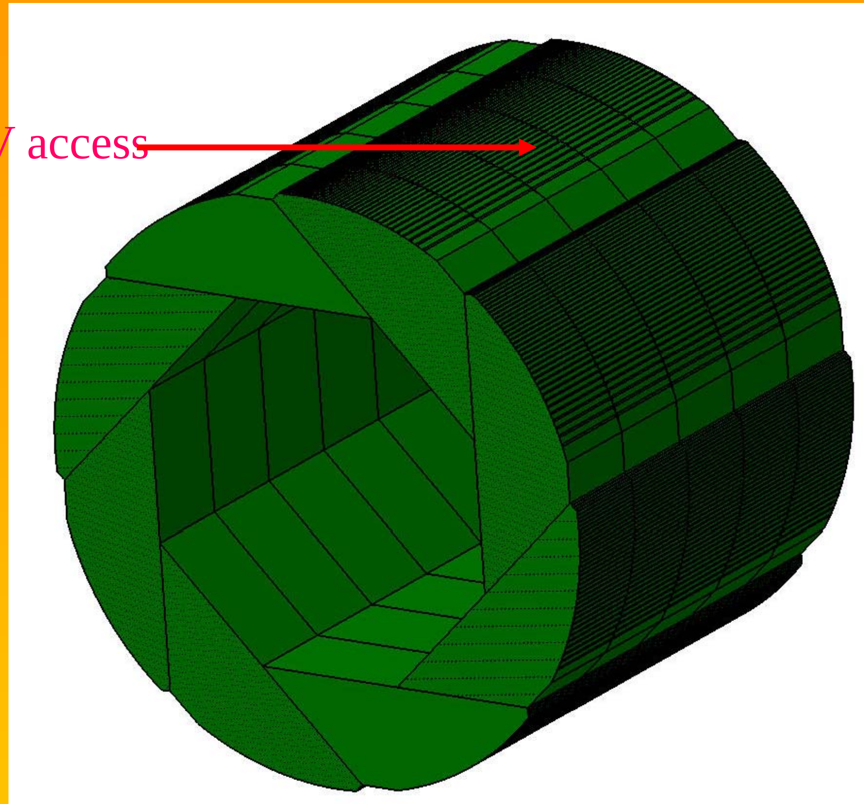




K.Kschioneck (DESY)

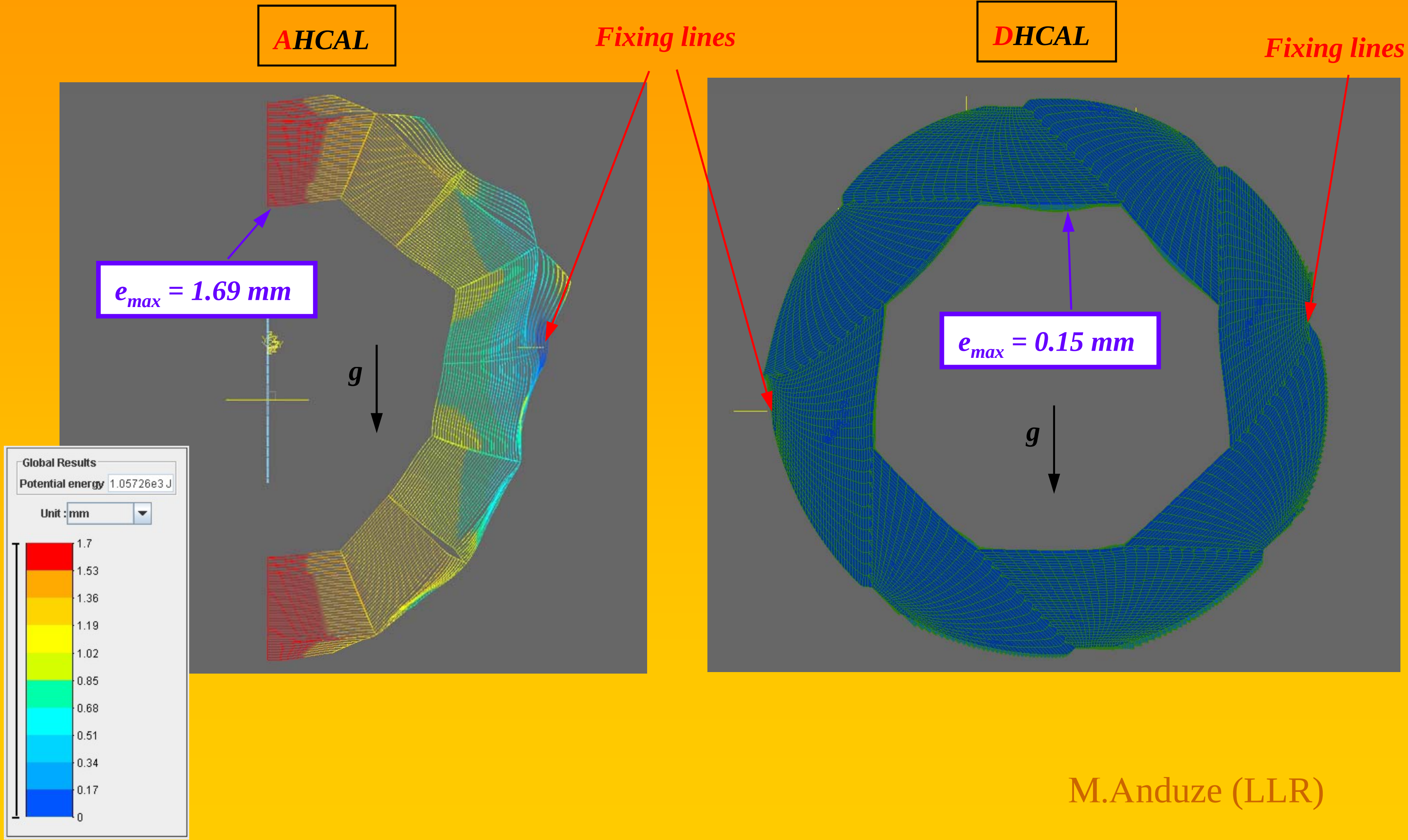
"DHCAL" Mechanical Structure



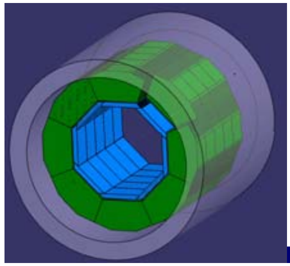


- No cracks: Each particle crossing the same number of detectors
- no problem concerning particles produced with the $\theta = \pi/2$
- HV cables,gas tubes, electronics board (DIF).. Cast between the DHCAL outerside and the coil

« AHCAL » vs « DHCAL » structures

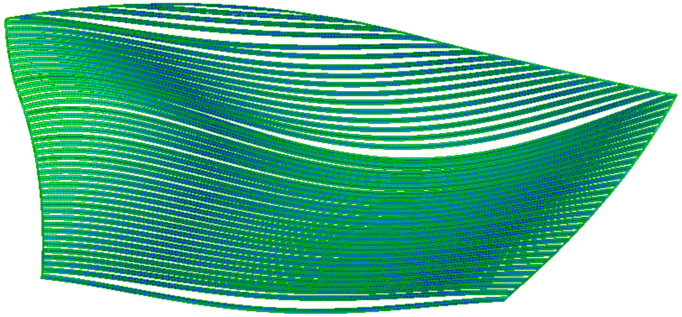


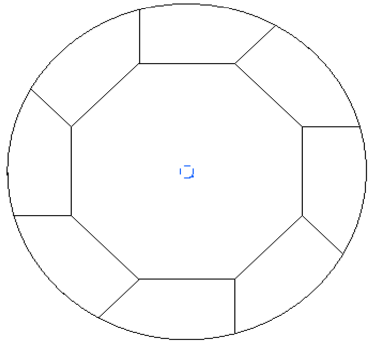
M.Anduze (LLR)

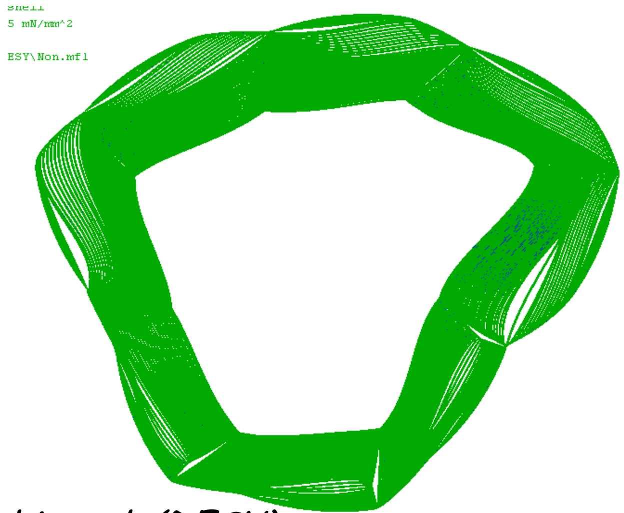


Non-pointing option

- Also possible with 2 rings and electronics at barrel end face

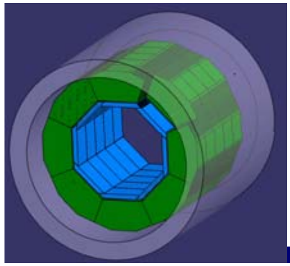






K.Kschioneck (DESY)

- Somewhat more complicated and less stable, but OK
- Do we need it?
  - No air gaps
  - almost complete filling
- Simulations will tell



Towards the LoI

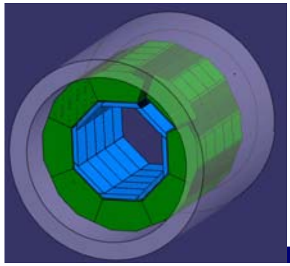
- Optimize geometry
- Validate particle flow performance
- Develop calibration scheme
- Demonstrate compact technology
- Mechanical structure & detector integration

Test beam

Here could be your ILD logo!

Will come along for both options
DHCAL emphasis presently on test beam preparation and technology

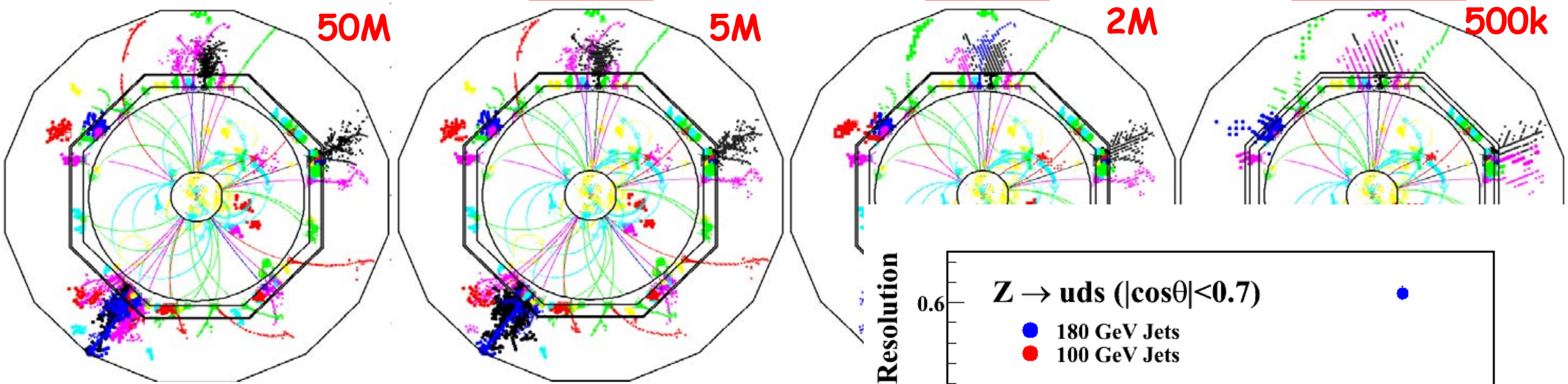
Backup slides

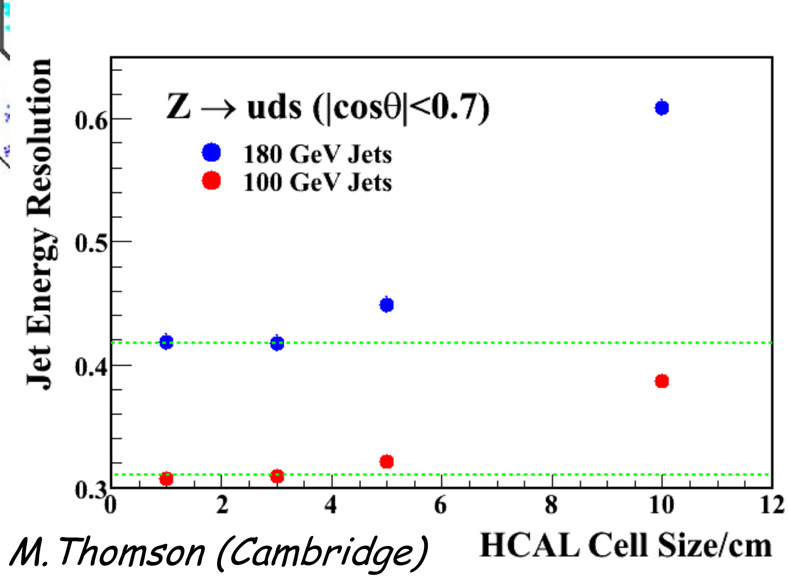


Tile granularity

- Studies with PANDORA algorithm, full simulation and reco.

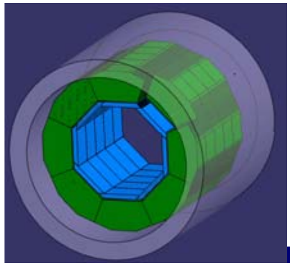
1x1 50M | 3x3 5M | 5x5 2M | 10x10 500k





M. Thomson (Cambridge)

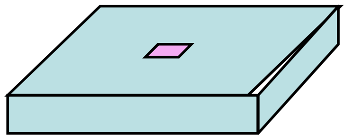
- Confirms earlier studies for test beam prototype
- 3x3 cm^2 nearly optimal

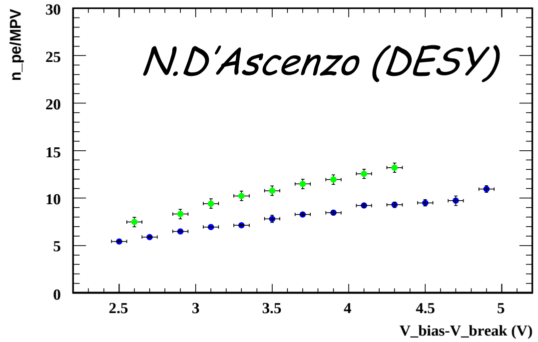


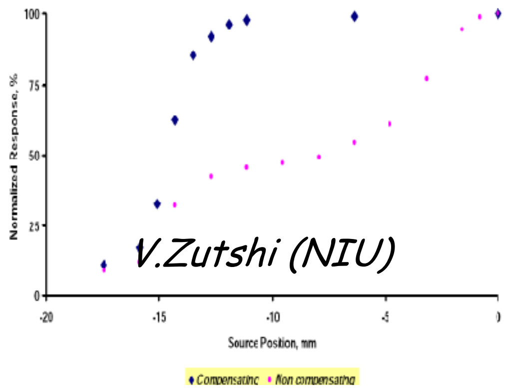
Tile sensor direct coupling

- Possible with blue-sensitive sensors
  - Hamamatsu MPPC 1600 (400)
- Obtain about 7 (11) px/MIP from 5 mm tiles; low noise
  - ➔ increase area
- Need to restore uniformity
  - Some add[al] light cost
- Other proven option: strips
  - CALICE SciW ECAL

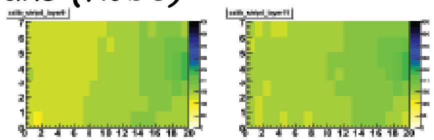
Tile 30x30x5 mm3

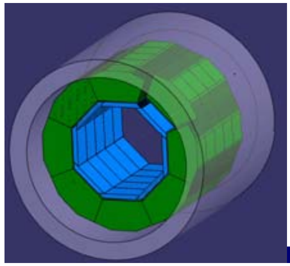






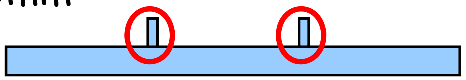
D.Jeans (Kobe)



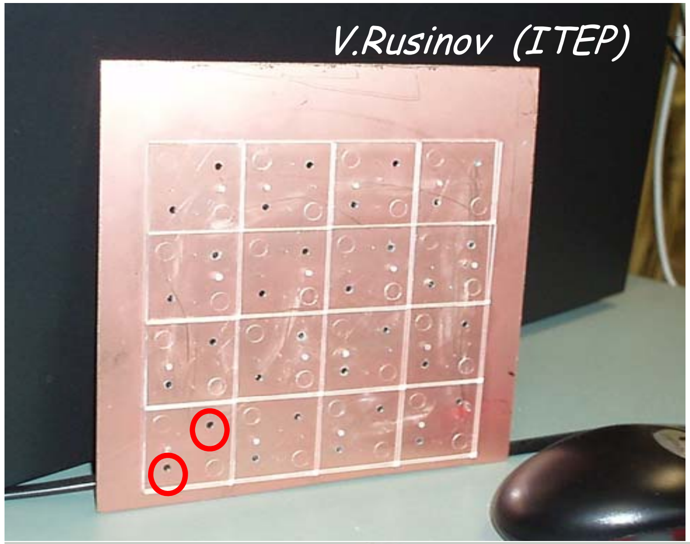


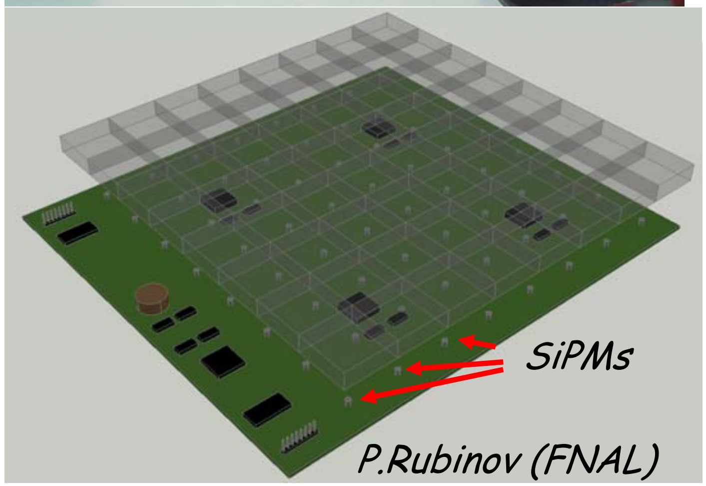
Tile PCB coupling

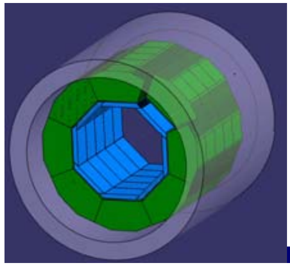
- Scintillator photo-sensor system has to match electronics PCB tolerances
- Several options
  - Mega-tiles (easier assembly, but some optical cross-talk
  - New: idea “lego” tiles with alignment pins
    - 30x30x3mm^3



- Other option: surface-mounted sensors on PCB
  - Different integration chain

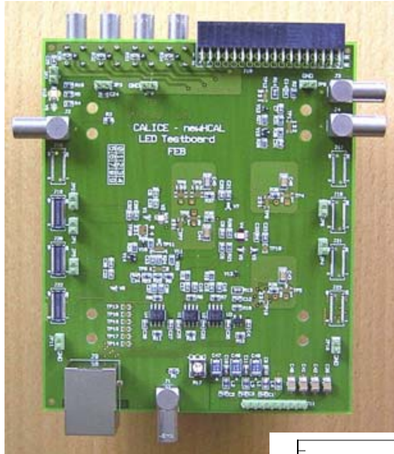




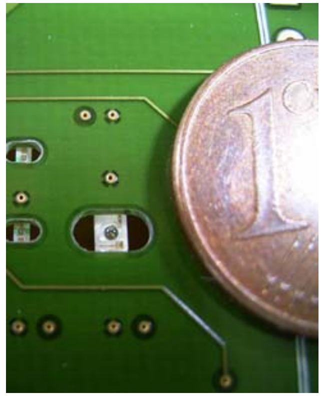


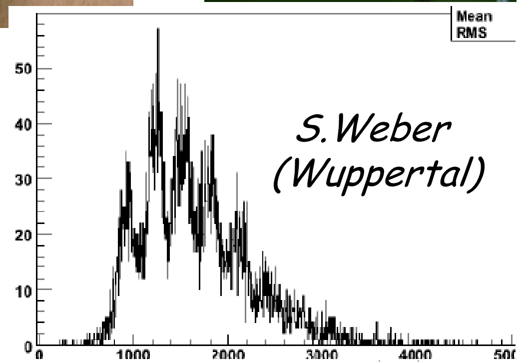
Optical calibration system

- SiPMs, MPPCs are self-calibrating
  - Ph.e. peak distance ~ gain
- Embedded LEDs
  - electronic signal distribution
  - tested, no cross-talk to sensors seen
  - To be optimized: dynamic range, LED uniformity
- Alternative: central driver and optical signal distribution

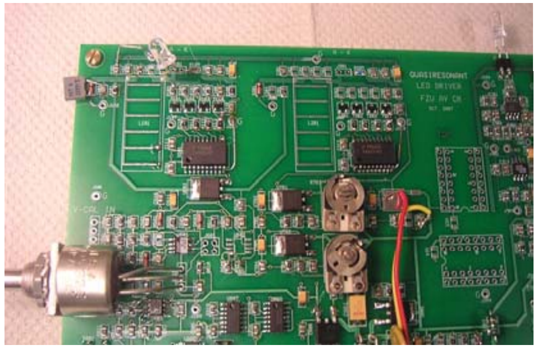


M.Reinecke (DESY)





S.Weber (Wuppertal)



I.Polak (Prague)