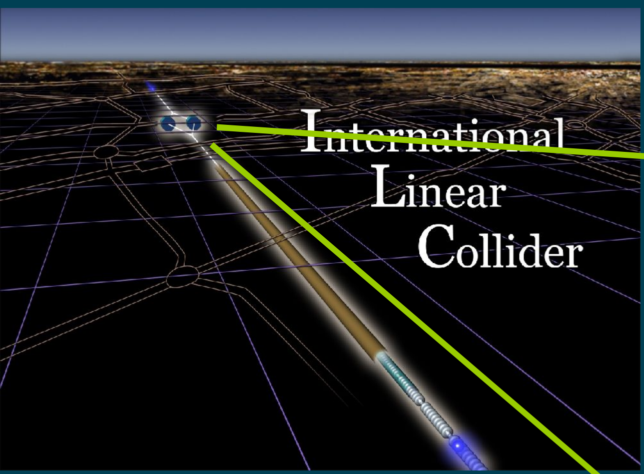
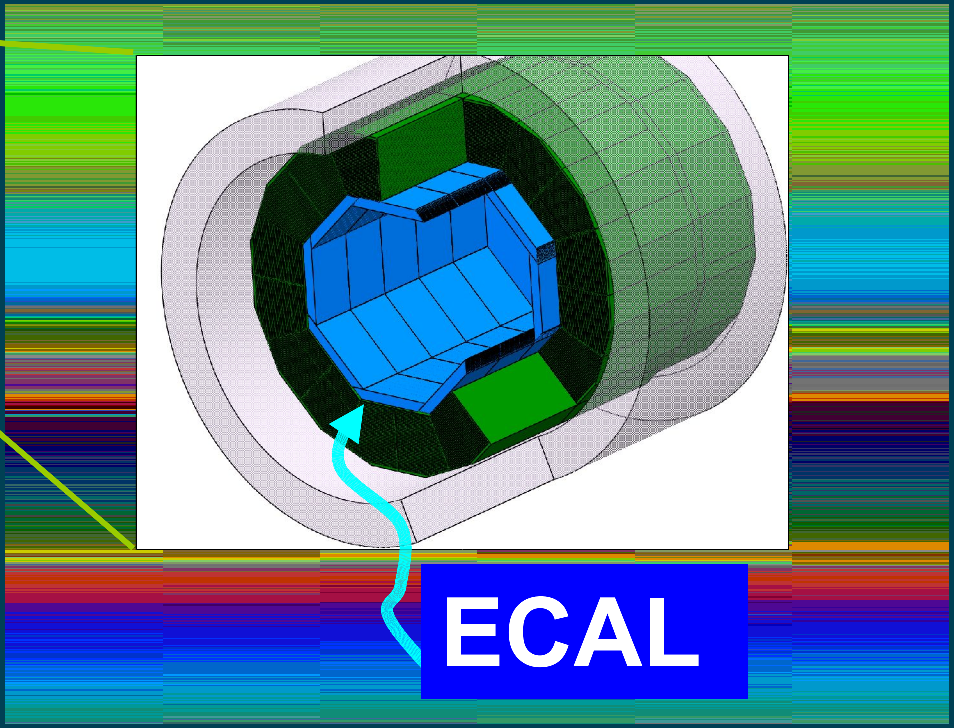
R & D on silicon tungsten ECAL

CALICE ECAL Groups

presented by Henri Videau

LLR





Just trying to tell you that we hope we know what we are trying to do

A development of ECAL technology by stages

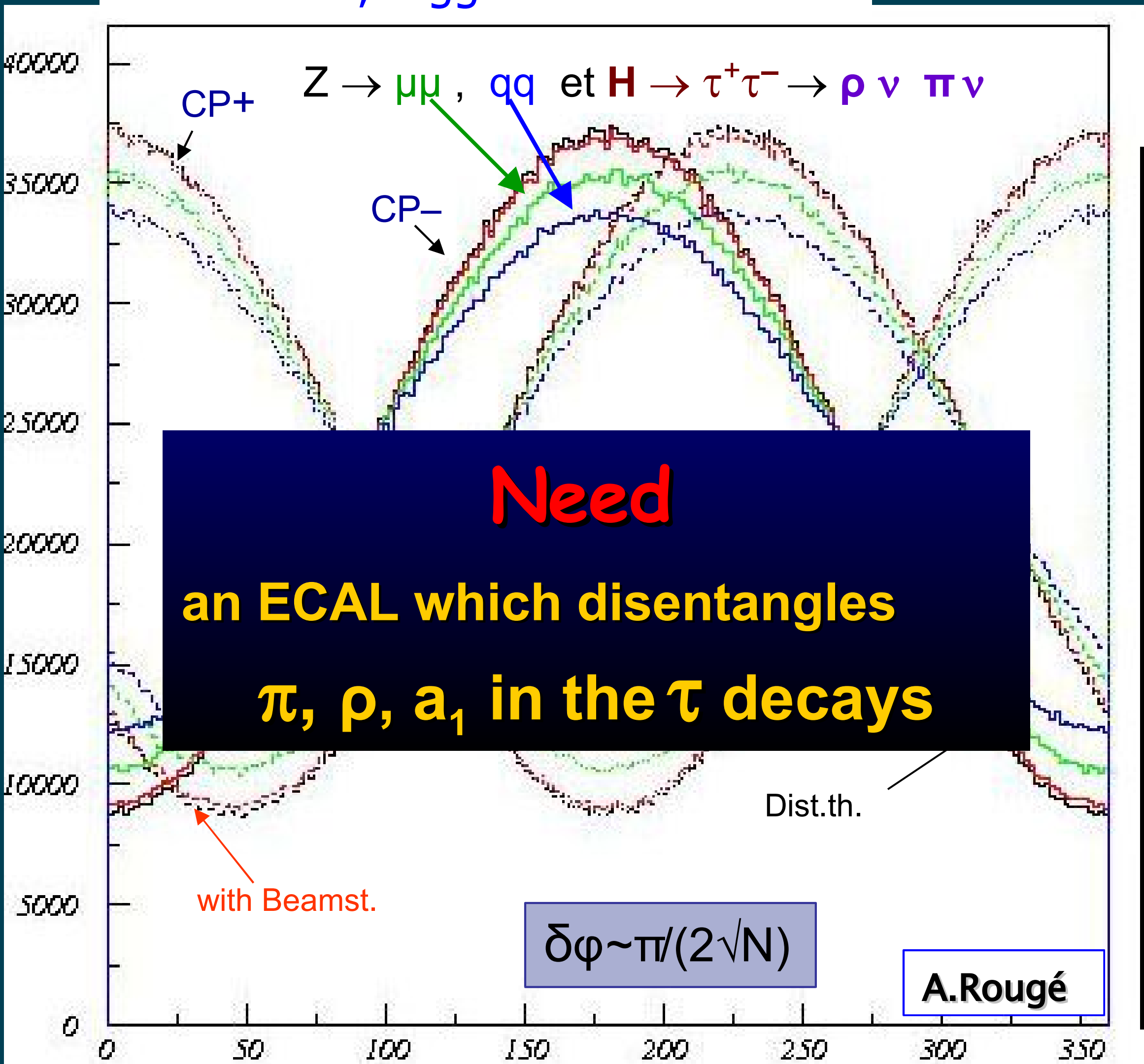
- Understanding the physics and the simulation and approach the technologies to identify possible show stoppers. Physics prototype

- Then develop the different technologies, including software adequate for ILC detectors Technological prototypes

We do not do R&D merely for fun along flowing years but try to address in a coherent and rigorous mind what we think are the ILC calorimetry challenges.

In addition to PFA for jets → Direct impact on ECAL

CP violation, Higgs sector



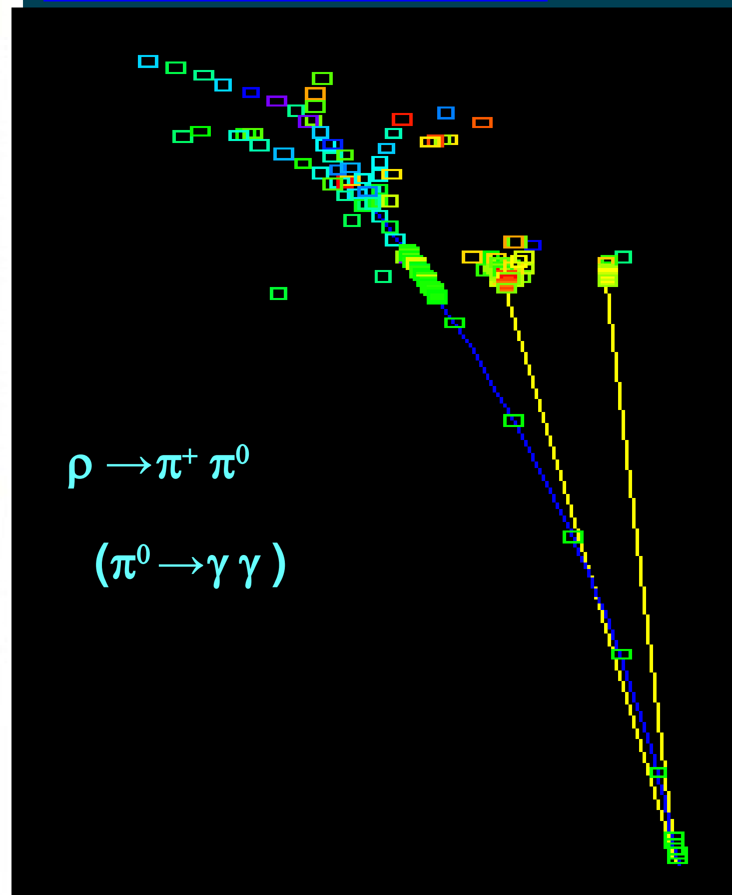
Need

an ECAL which disentangles

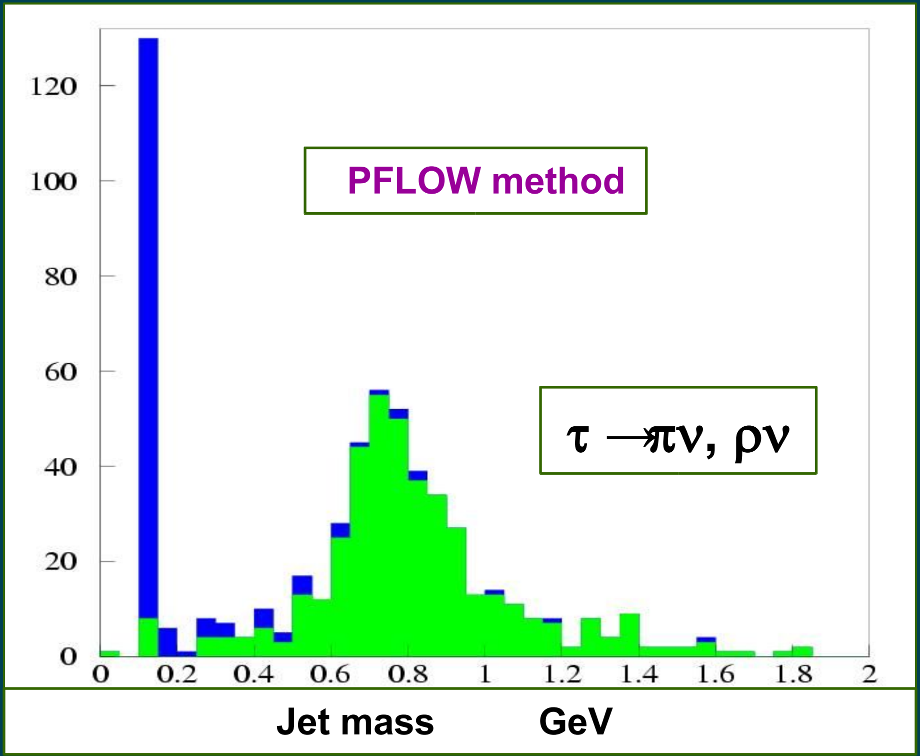
π, ρ, a_1 in the τ decays

CP angle analyser

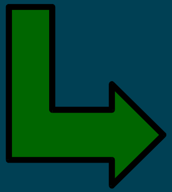
$e^+ e^- \rightarrow ZH$



This PFLOW method allows to analyse the Taus decays
Which are an excellent polarization analyzer



Doing Higgs physics with taus.



	Jet mass < 0.2	Jet mass in 0.2-2
$\tau \rightarrow \pi\nu$	82%	17%
$\tau \rightarrow \rho\nu$	2%	90%

We want a calorimeter with

- A good separation between close showers — PFLOW
- A QUASI Perfect efficiency to find photons in jet — PFLOW
- A QUASI Perfect efficiency to find neutral hadrons in jet — PFLOW
- A good separability e/π
- A good reconstruction of photon direction (GMSB, long life particle), — ECAL requir.
- An ECAL which allows analysing the tau decays

Together with a detector

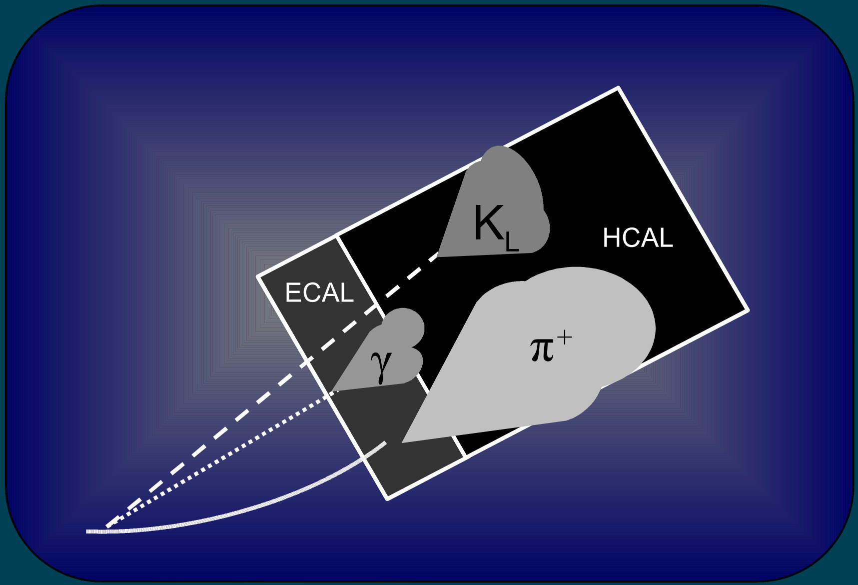
- as compact as possible (cost and feasibility of the magnet)
- Running in a B-field from 3 to 5 T (imposed by background)
- A running stable with time, temperature, noise from machine,…

Separation and reconstruction are more important than the energy resolution itself

To summarize

Optimising the performances on the « particle flow »

Granularity and resolution on direction/energy of the jets



Resolution on the jets δE_{jet}	**2-3** better than LHC
Granularity/segmentation of the calorimeter	**>10**$^{2\text{-}3}$ x LHC

Specific R&D mandatory

The proposed solutions

ECAL : Sampling calorimeter

Solution 1 :

tungsten (density) – silicon (pixel size ≪ Molière radius)

Pixels size $<1 cm^2$ and about 20–30 readout layers
(15 to 250 Millions channels)

or silicon (pixel size ~ Mip density in showers)

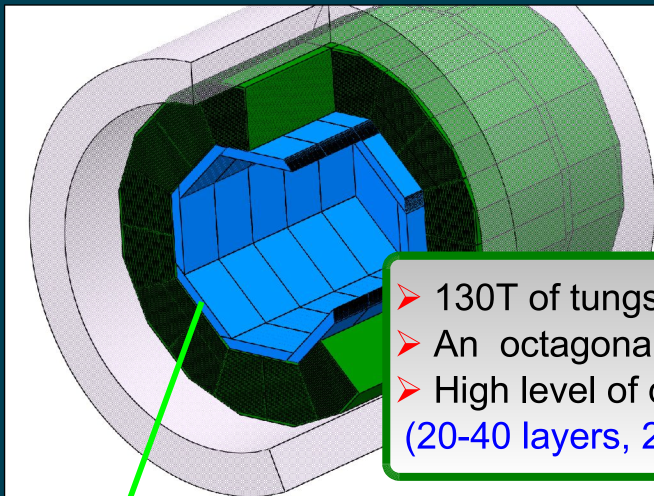
Pixels size ~ $50x50\ \mu m^2$
(Tera Pixel Calorimeter)

Solution 2 :

tungsten – MPPC and scintillator strip

Scint. Strip 1x4–5 cm X, Y and about 30 readout layers
(about 10 Millions channels)

The Silicon Tungsten electromagnetic calorimeter

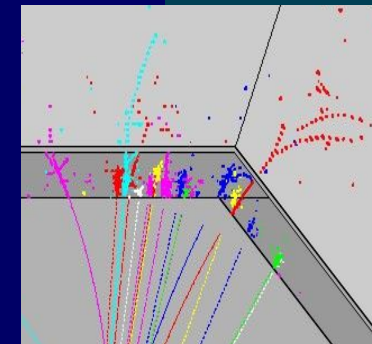


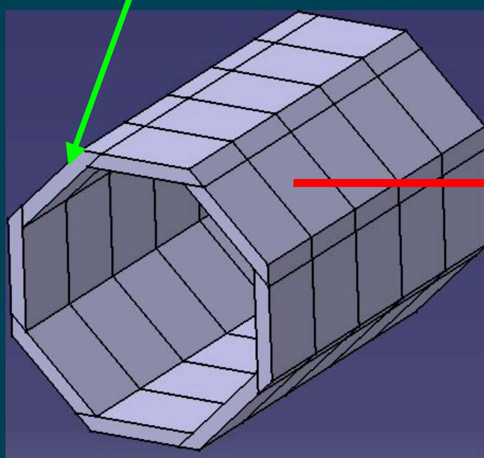
- 130T of tungsten
- An octagonal geometry
- High level of density

(20-40 layers, 24X0 in ~170mm)

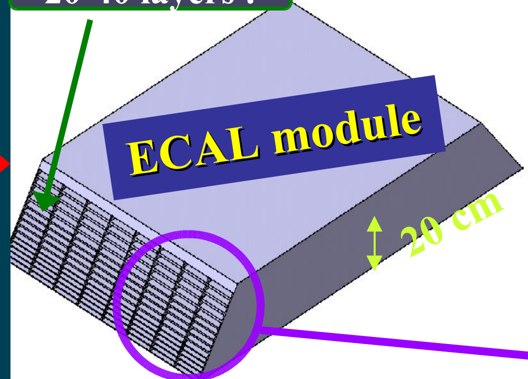
CALICE – W-Si ECAL

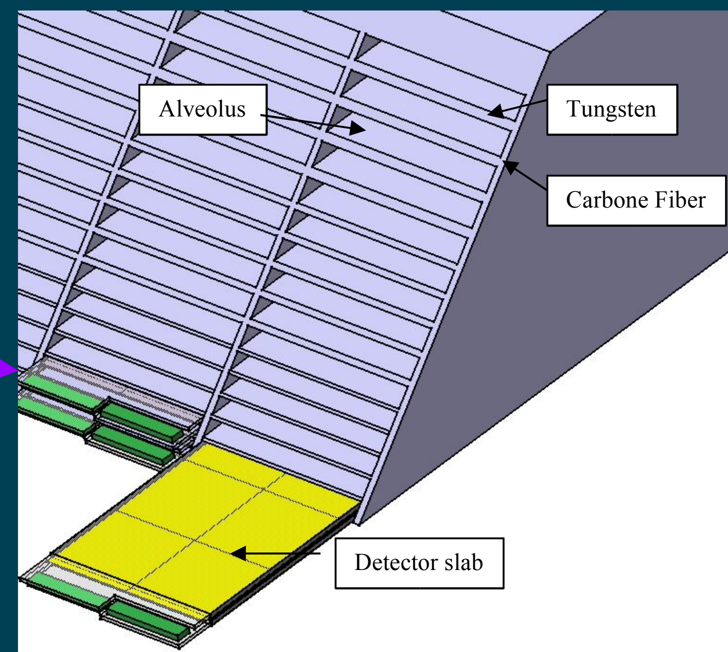
- Ewha Univ., Sungyunkwan Univ., Kangnung NU , Yonsei Univ.
- LAL,LLR,LPC-Ct, LPSC, PICM
- BARC-Mumbai
- ITEP,IHEP, MSU
- Prague (IOP-ASCR)
- Imp. Coll, UCL, Cambridge, Birmingham, Manchester, ,RAL, RHUL





20-40 layers !





- No large area of dead zone
- All modules are identical (Tungsten wrapped by Cfi)
- The detector slabs would be tested before assembling

Constraint on the ECAL calorimeter

- Small Molière radius ⇒ small thickness for non-W material (15mm)
- Threshold <mip ⇒ large mip signal ⇒ wafer not too thin (300µm)
- S/N at mip > 10 ⇒ small noise
- Weak coherent noise ⇒ pick-up, ground, power supply etc…
- Large dynamic (16bits) ⇒ multi preamp ?? , shaper multigains
- Weak power dissipation (electronics) ⇒ power cycling
- Behaviour of the VFE chip when 500-600 GeV em shower goes through
- For WSi Keep under control the silicon cost ⇒ labos in contact with privates companies

DETECTOR MATRICES

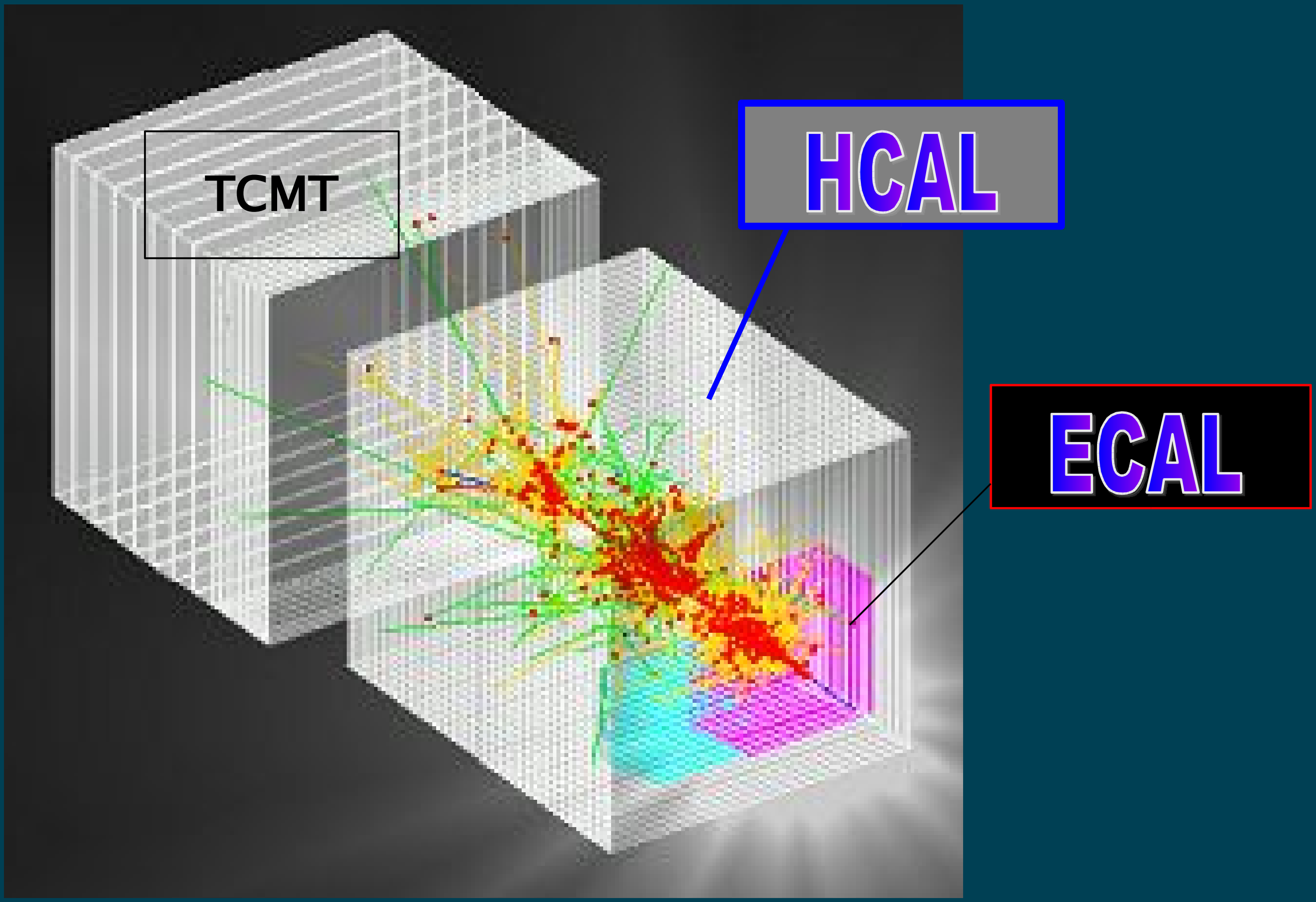
Relatively crude object when compared to a microstrip of pixels VDET

Number of mask	~ 4-5
Industrial yield	~ 80%
Use of large wafers	6 or 8" ?

The goal is
< 2 $/cm²

For the 2006 RDR cost estimation of the detector, 3$ have been used

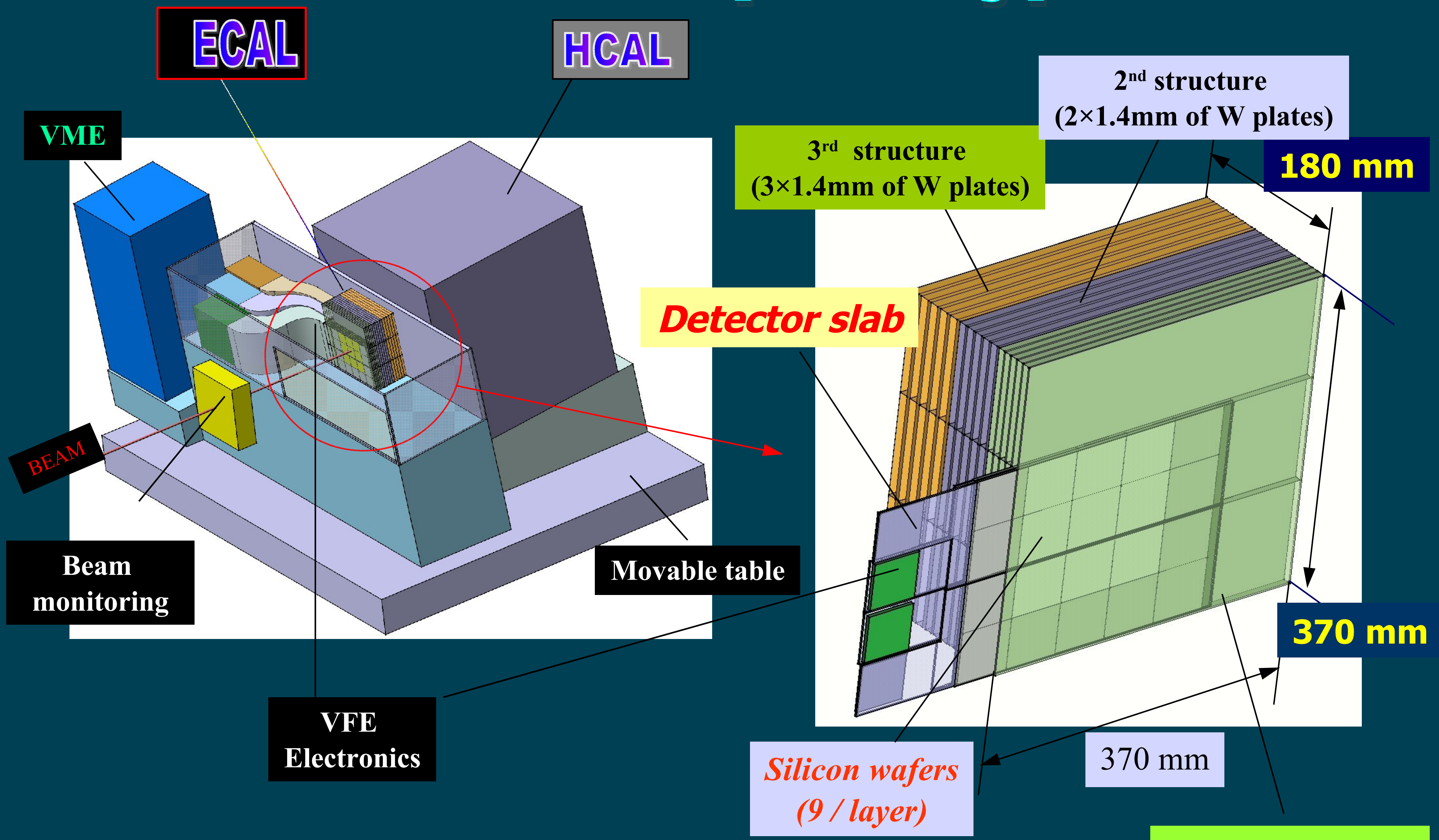
Going to test beam



The physics prototyping. Simulation compared to reality.

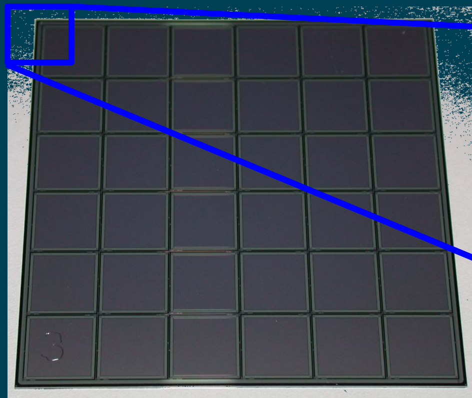
A first approach to technology.

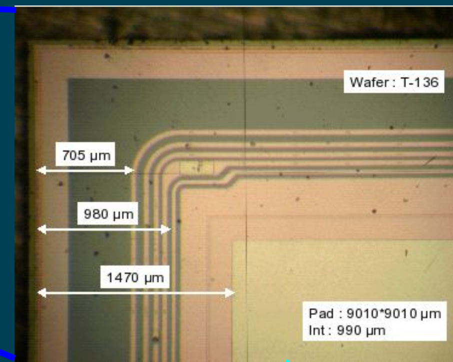
TEST BEAM prototype

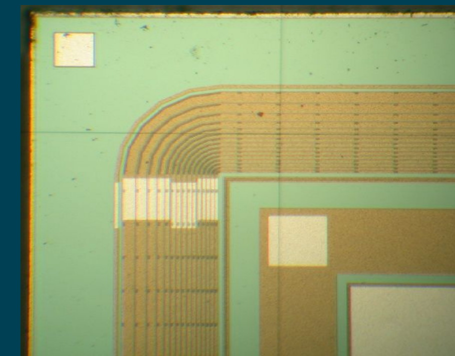


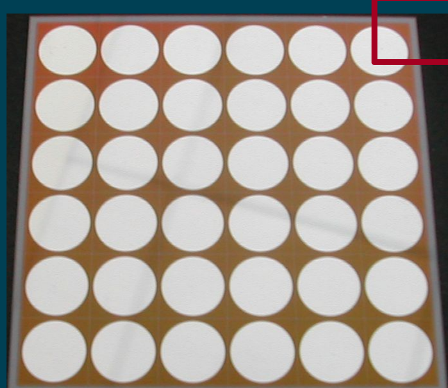
NB : more channels in $(18cm)^3$ than for LHCb calorimeter
(or if you prefer CMS, it is 1/8 of the full ECAL)

DETECTOR MATRICES







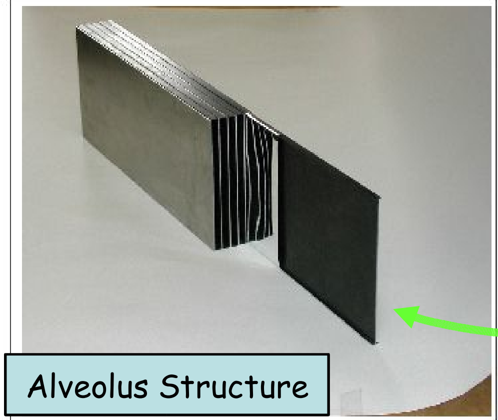


Works with producers and labs in

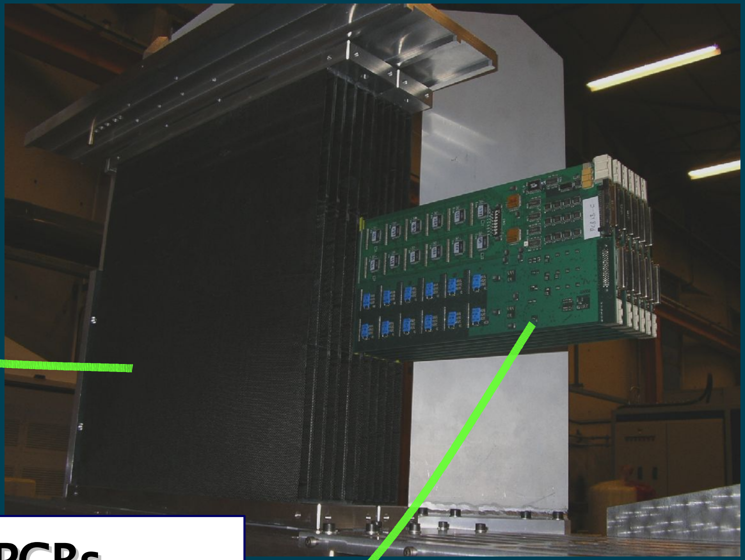
- Brazil
- Czech republic
- India
- Japan
- Korea
- Russia

The diode matrices are the driving cost.

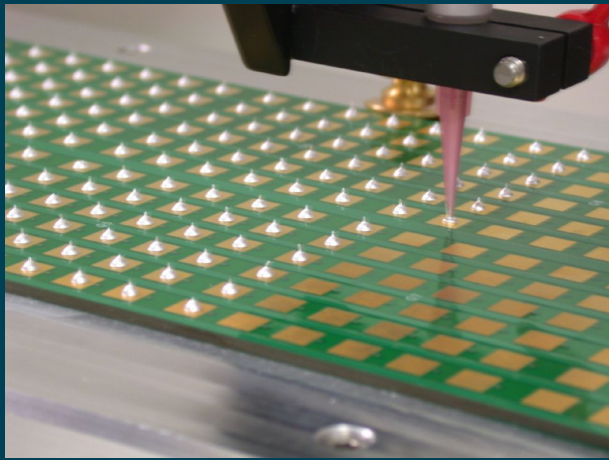
The prototype



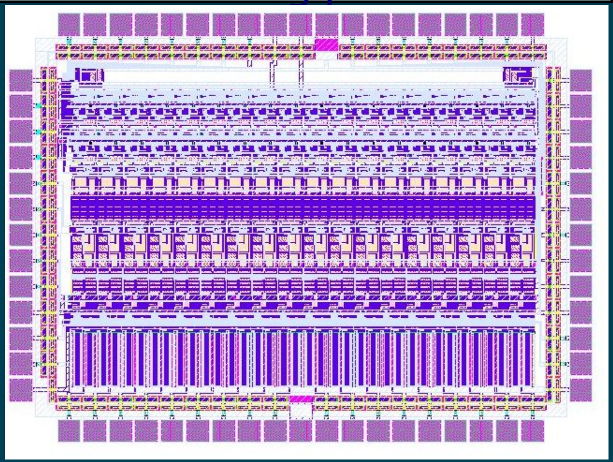
Alveolus Structure

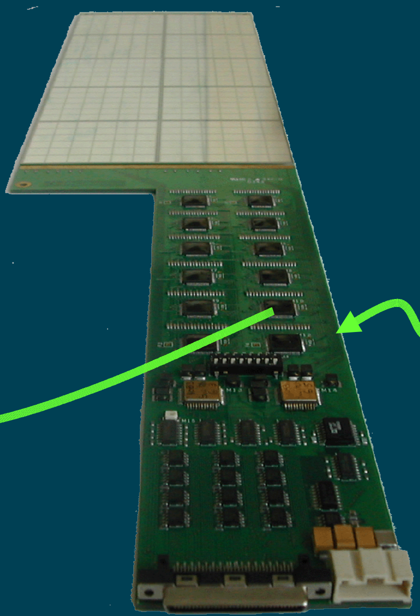


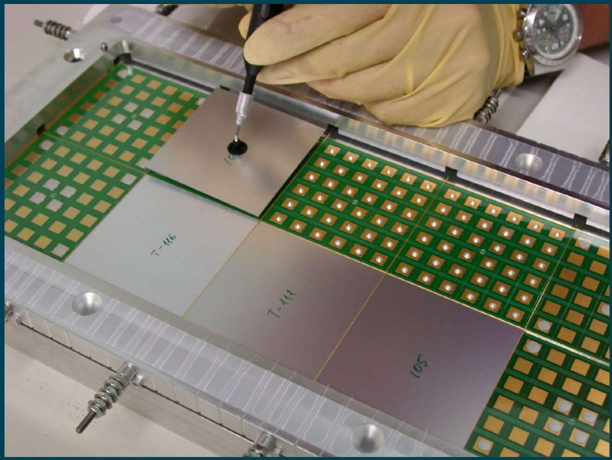
PCBs



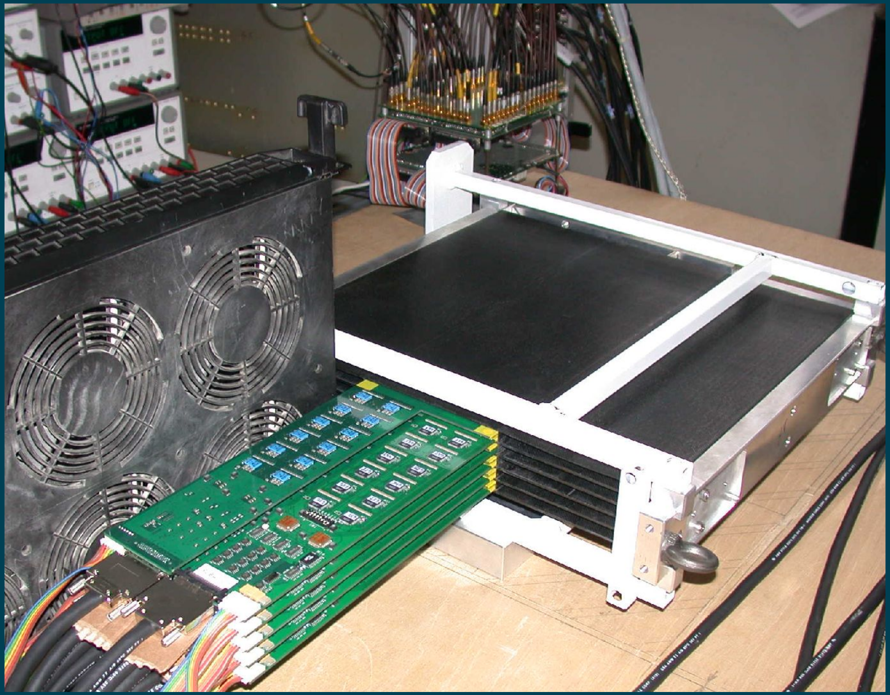
Front-end electronic
analog part



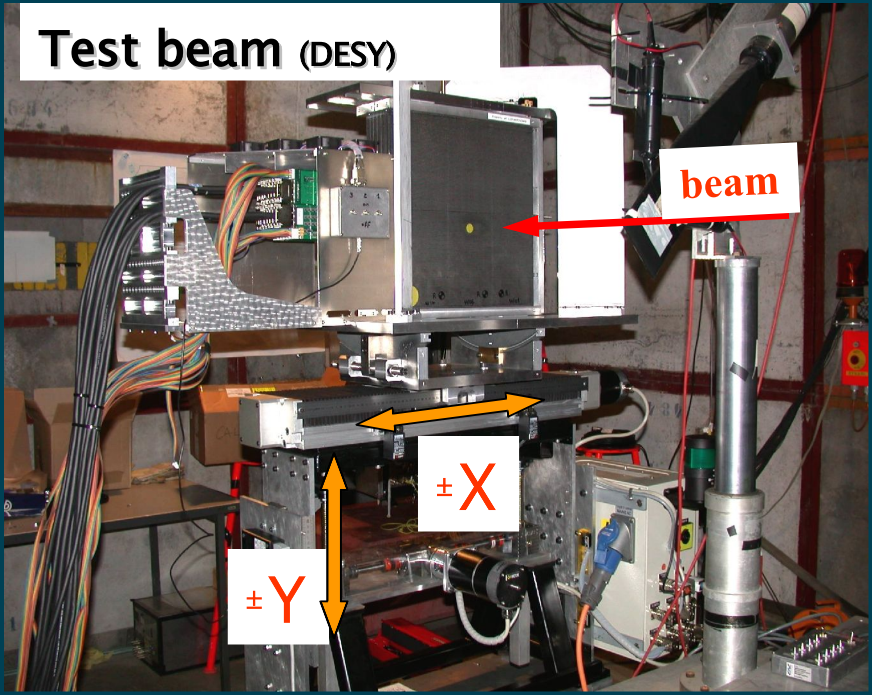




Cosmic test bench (LLR)

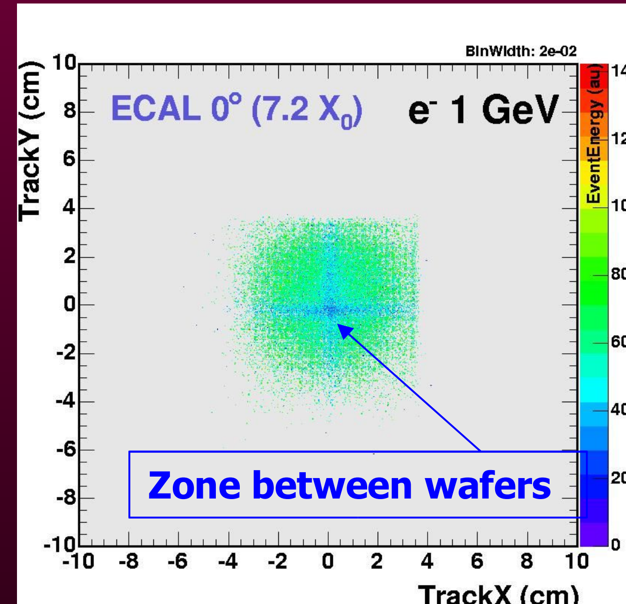


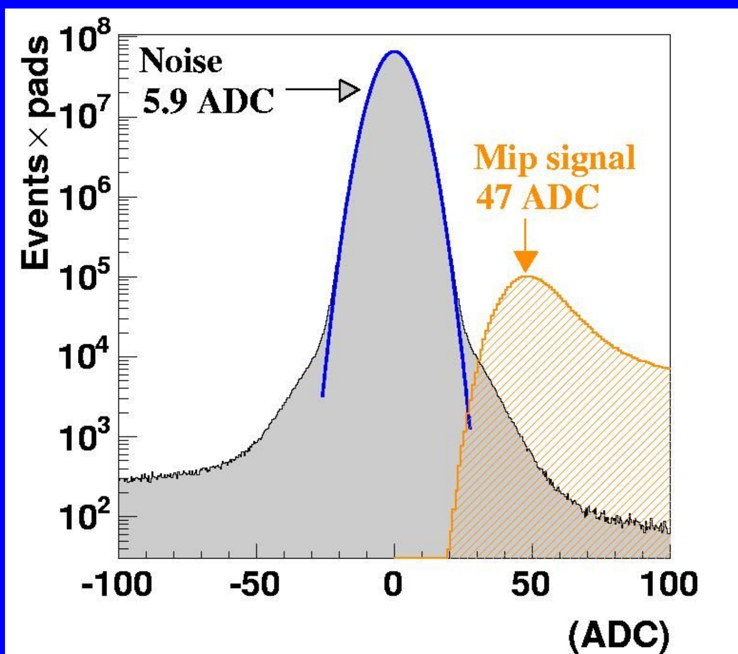
Test beam (DESY)



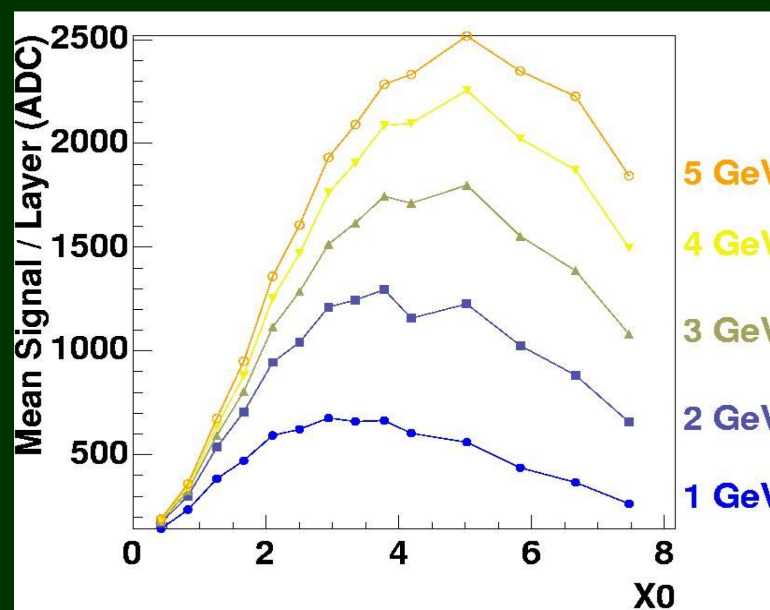
First results of the DESY beam test with ECAL prototype

Recent data still to be analysed

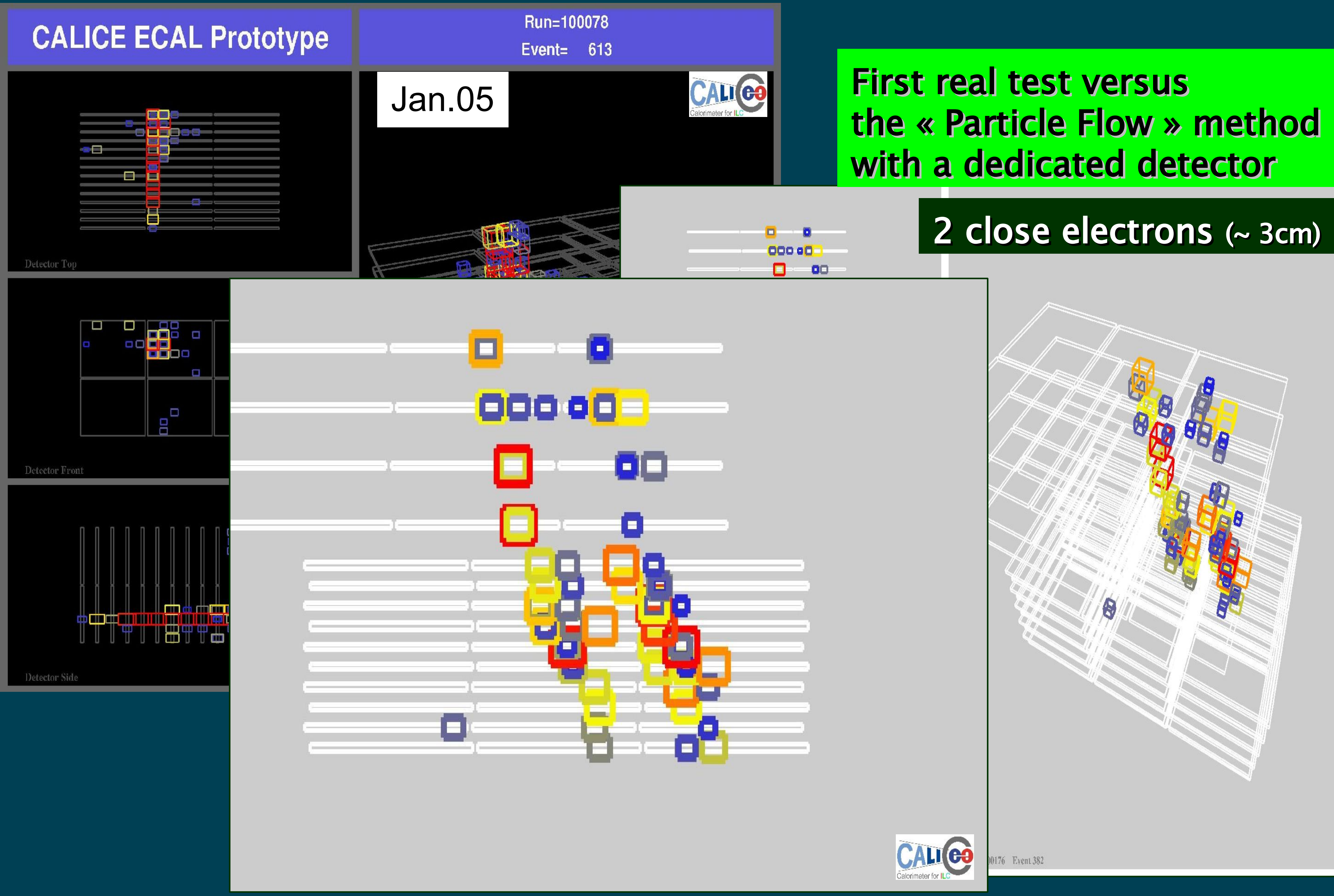




S/N ~ 8 !!

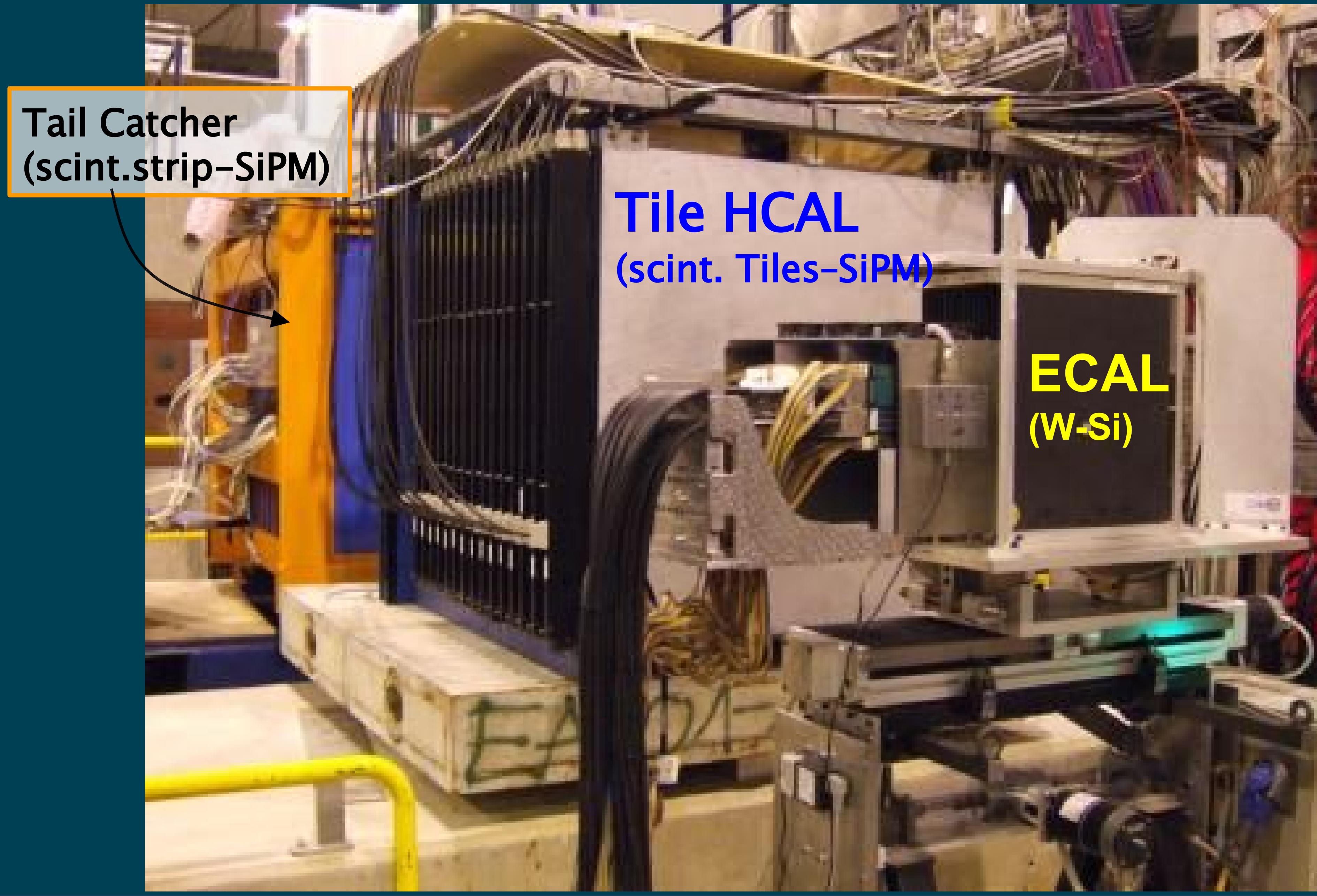


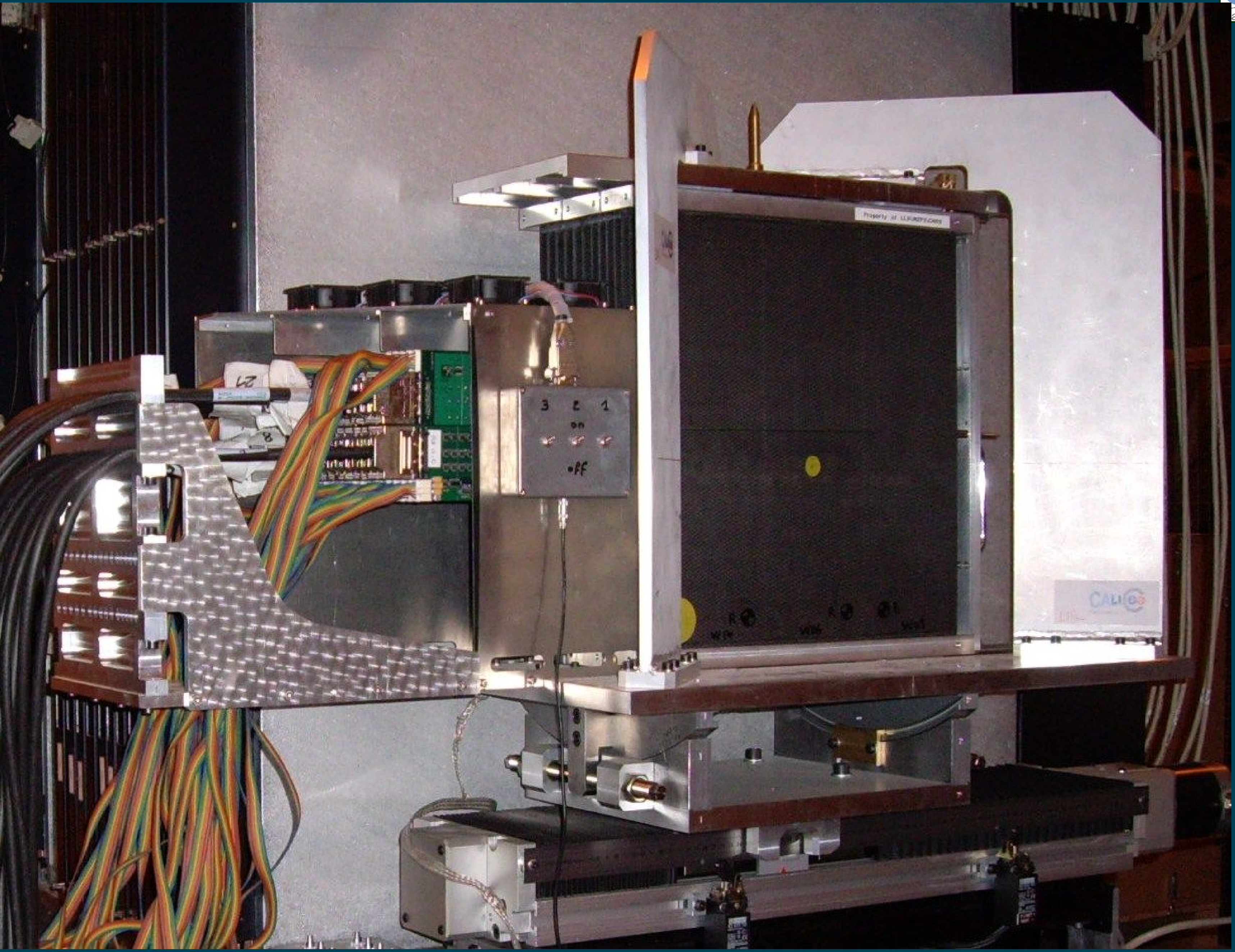
ECAL prototype – first test at DESY (FNAL/CERN 2006…)



First real test versus the « Particle Flow » method with a dedicated detector

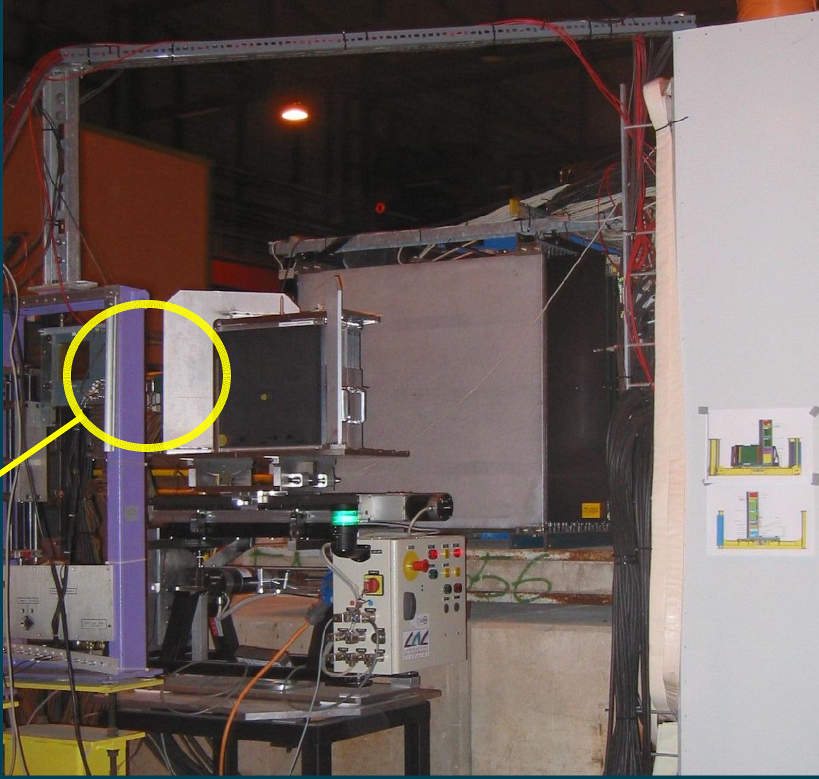
2 close electrons (~ 3cm)

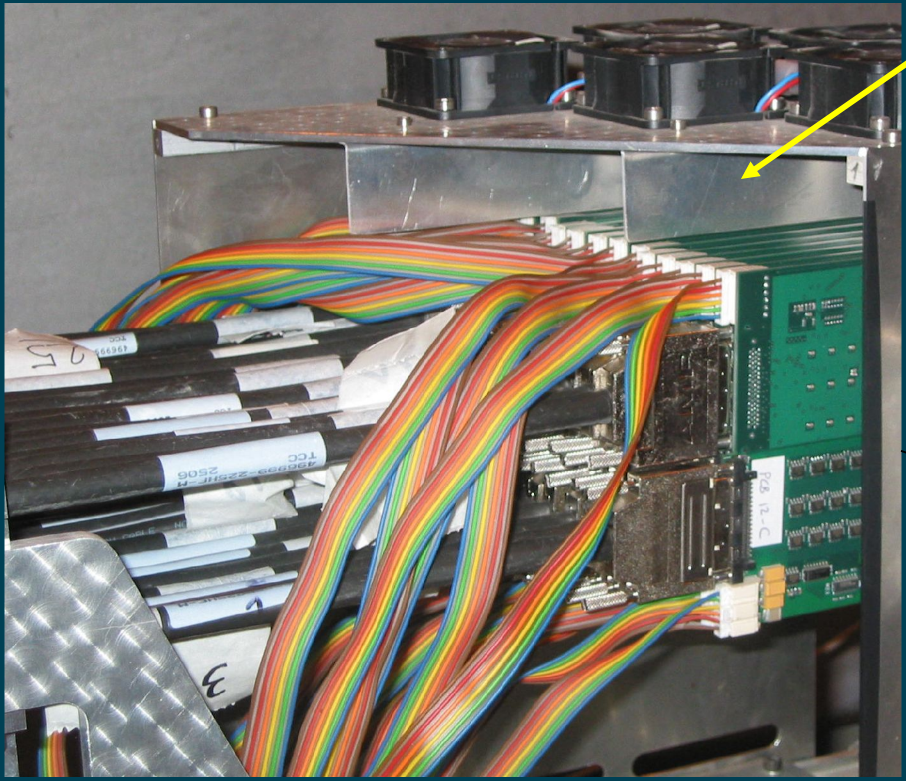

Tail Catcher
(scint.strip-SiPM)
Tile HCAL
(scint. Tiles-SiPM)
ECAL
(W-Si)


3 2 1
on
off

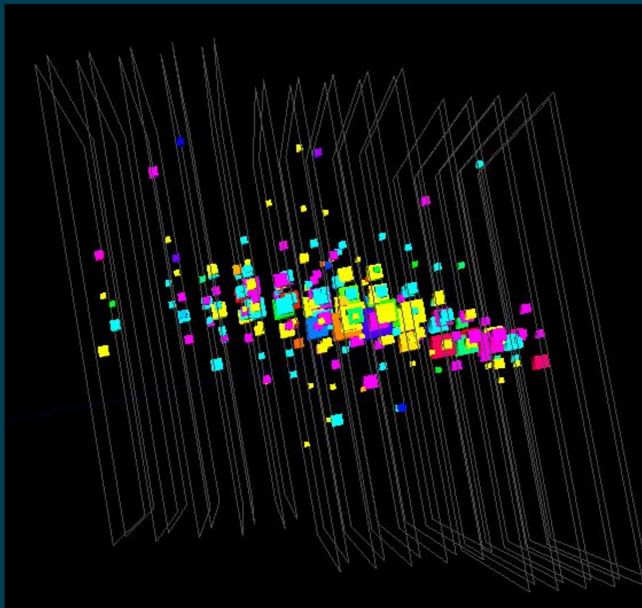
Test at CERN Summer/fall 2006

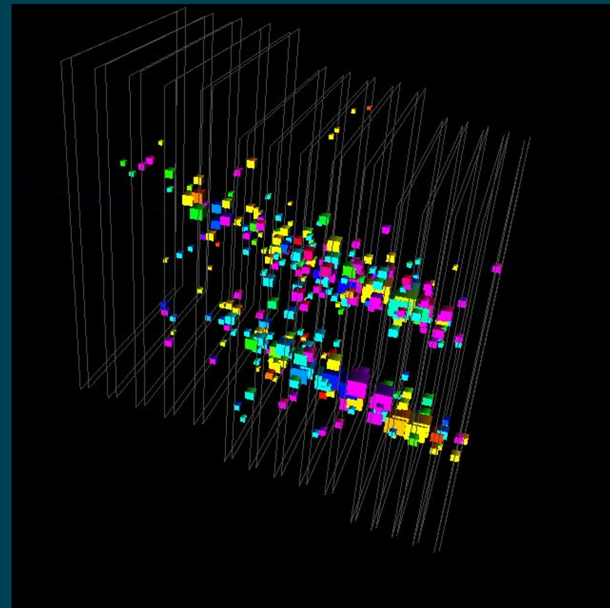
Test at CERN Summer 2007





For the full scale detector it is mandatory to change the design of the device



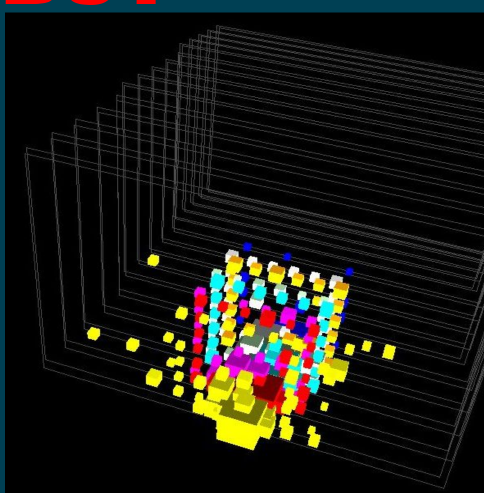


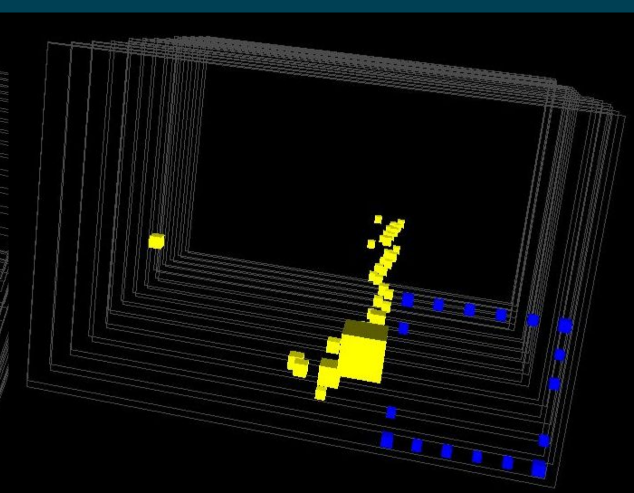
GLOBALY, nice performance (see D.Ward)

Tests at CERN

Effect of dead zones between wafers

BUT

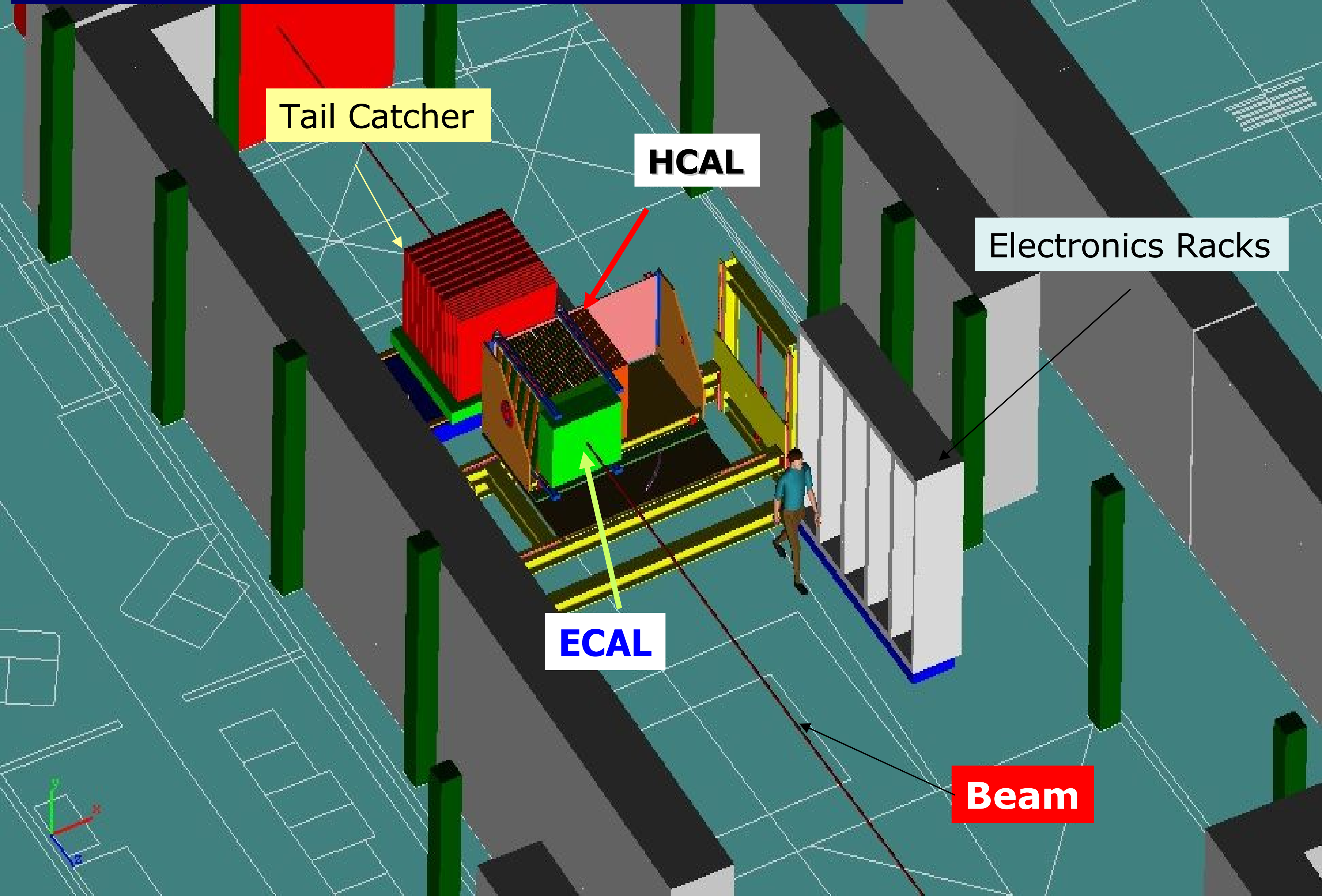




cross talk effect through the wafers guard rings

new designs of guard rings under development.

Possible setup at FNAL MTBF



Next steps

- Test with electrons (may be low energy hadrons)
  - test of running with the VFE chip INSIDE the detector
  - Test beam with AHCAL+ECAL for debugging

  and … single layer test (new design) …

  CERN 2007 for the W-Si and AHCAL

- Test with hadrons

  CERN Summer 2007
  MTBF From fall 2007

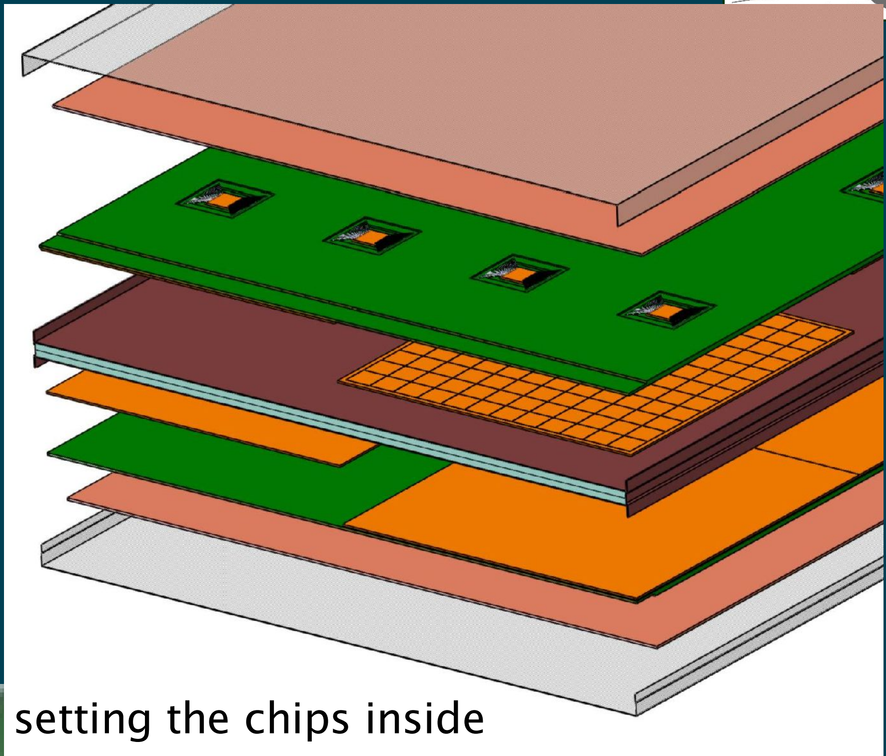
- Toward a second generation of prototypes: Technological models including ½ ECAL final module with all news developments + Digital HCAL module + AHCAL + ECAL strip + …

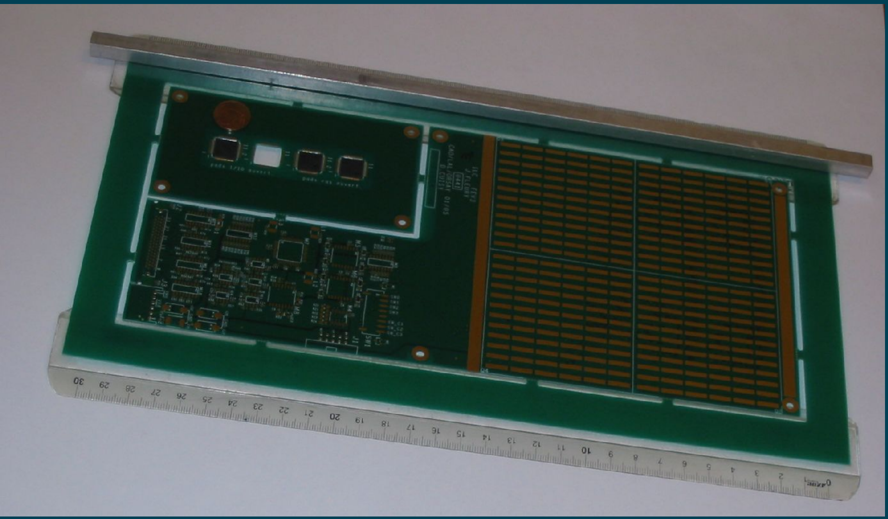
2008 – 2010 Second generation prototypes in test beam FNAL

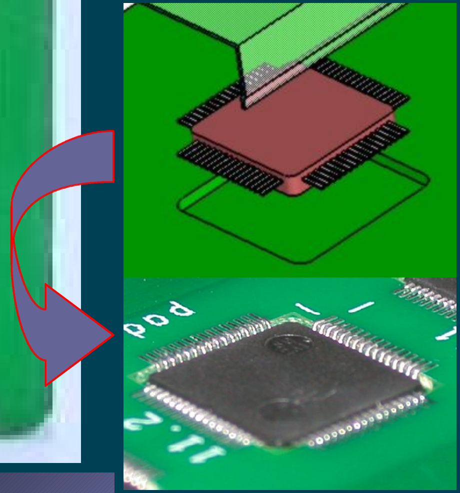
NEW DESIGN

for the
ECAL Detector Slab

- Better for mechanical behaviour
- Better Molière radius, thinner
- Better for indust. assembling
- DAQ based on FPGA
- better for VFE
- etc…





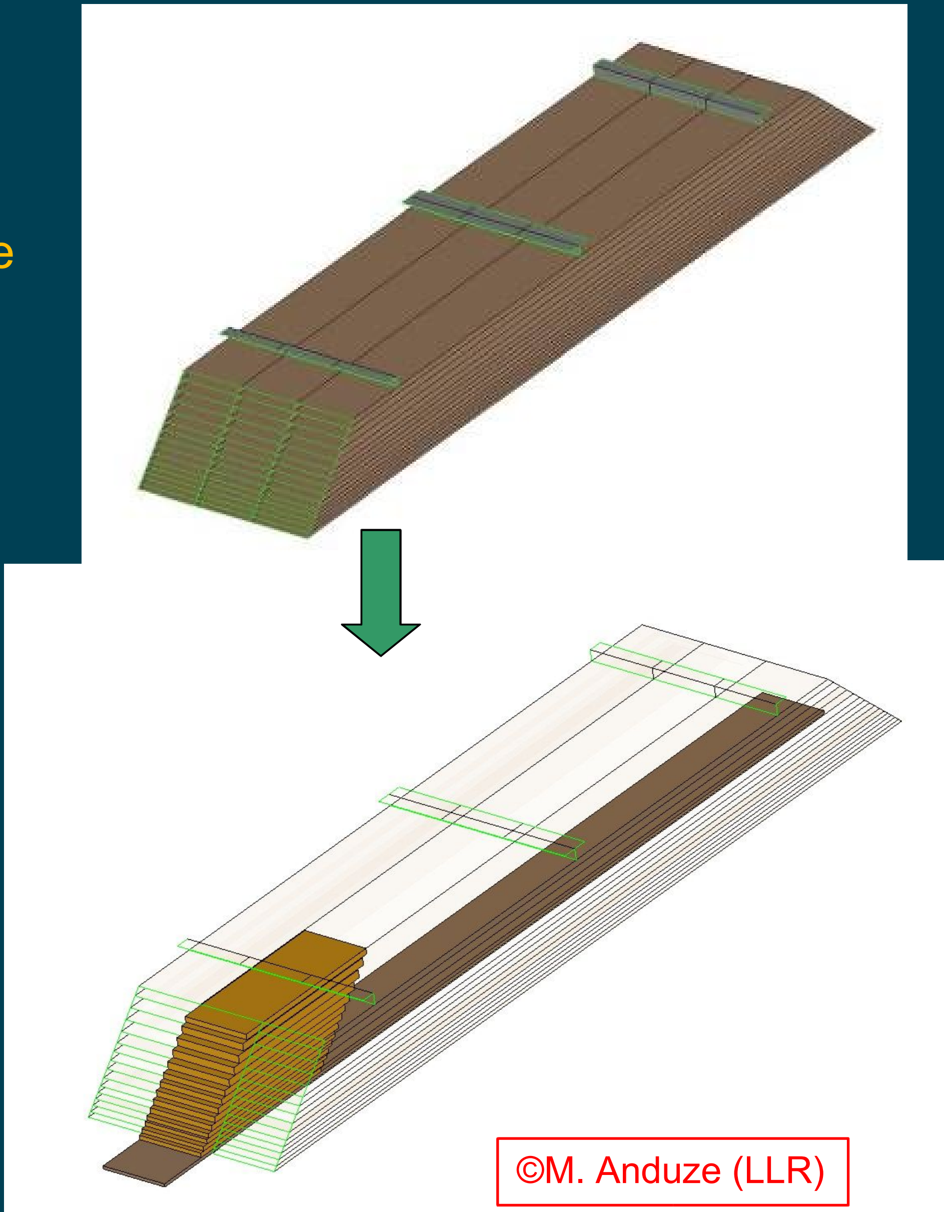


Tested at industrial level

Technological prototype

- Mechanical prototype of a (~ 1/2) module

  150 cm long, 3x18 cm wide, 30 layers
  - partially equipped with detector: **one line & one column, 5x5 mm^2 cells**
  - 1800 + 10800 channels
  - Test full scale mechanics + PCB
  - Can go in test beam
  - Test full integration + edge connections
- Similar in channel # to physics prototype



Using the same structure

The Si diodes can be replaced by MAPS.

A Tera Pixel Calorimeter

The physics is the same, the mechanics as well;

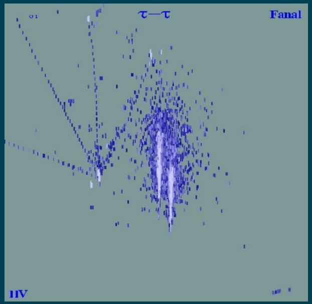
The 5x5 mm^2 cells read analogically are replaced by 50x50 μ^2 read digitally.

Do we need to improve on the cell size?

Digital counting improves clearly resolution at low E killing Landau tails.

A way to go digital which may provide a lot of freedom

and could end up being cheaper.

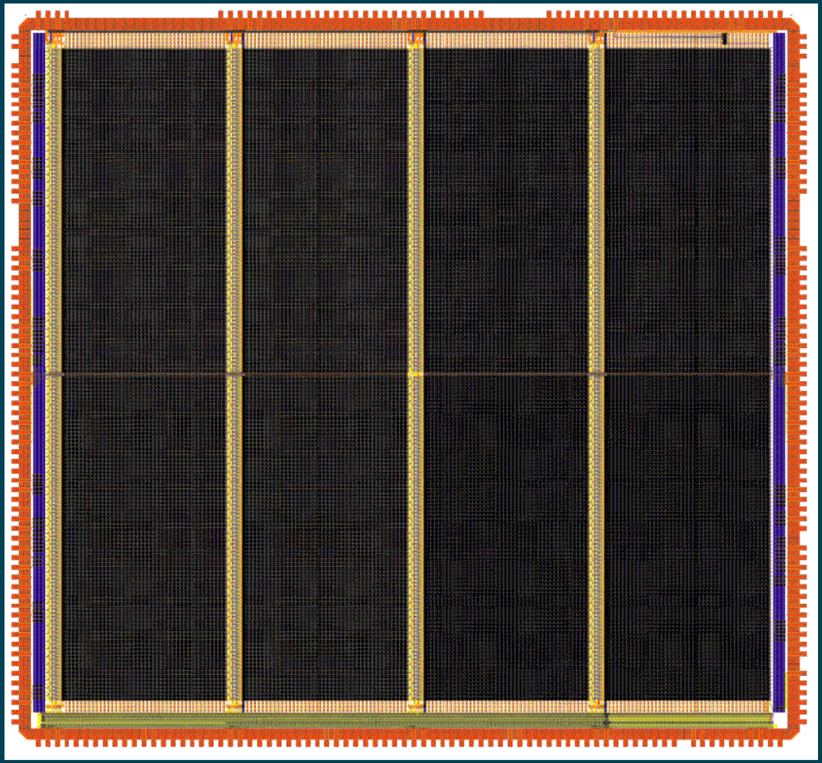


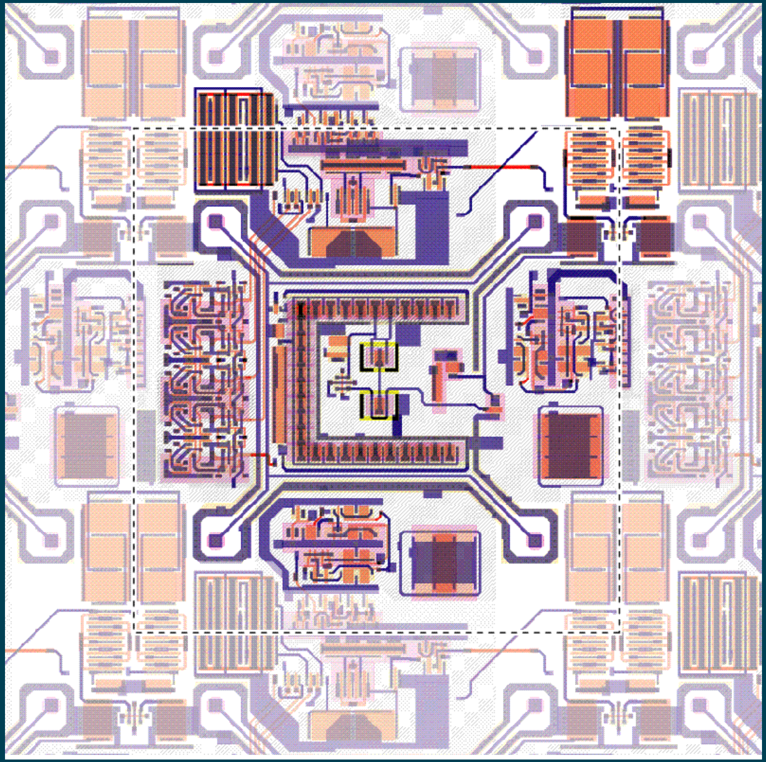
What we need is to know if that works!

Power?

Quick Reminder on MAPS

- Monolithic Active Pixel Sensor : based on CMOS technology, in-pixel comparator and logic.
- Really small for an ECAL, large for a standard MAPS : 50*50 μm^2 pixels.
- 10^{12} pixels = digital readout.
- Noise objective : probability of 10^{-6} hits above threshold = DAQ has to handle ~10^6 hits per event! Output will be a simple list of geometrical indices of hits above threshold.
- First design of sensors submitted !! Will be back in July.





Left: Schematic of complete MAPS sensor submitted for fabrication.

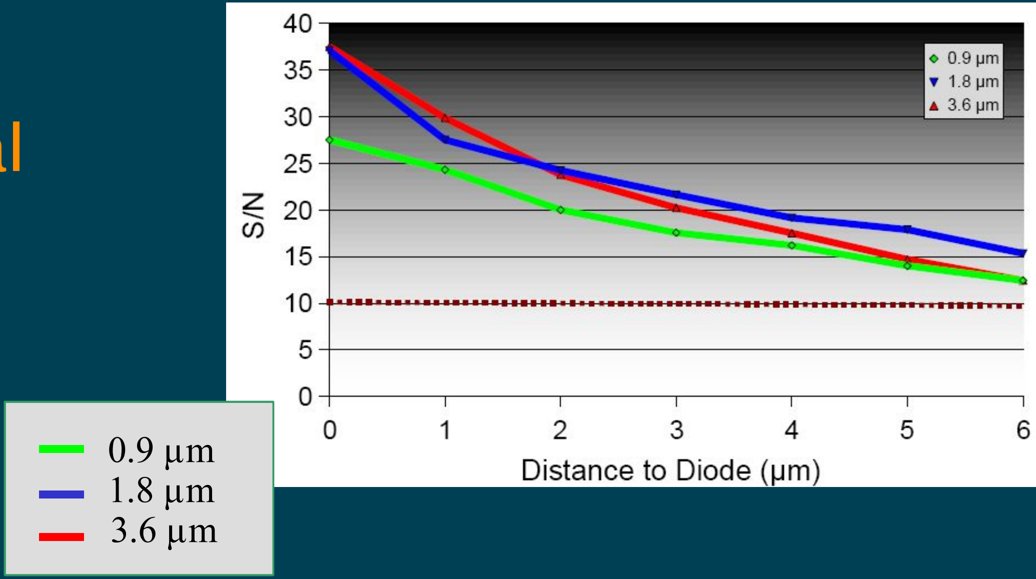
The logic and memory storage areas are clearly visible as the four vertical stripes

Right: Schematic of a pixel layout. The electronics associated with a single pixel is highlighted in colour.
The pixel boundary is shown by the dashed line.

Optimisation of some parameters

Signal over noise

- Diode size has been optimised in term of signal over noise ratio, charge collected in the cell in the worst scenario (hit at the corner).
- Diodes place is restricted by the pixels designs, e.g. to minimise capacitance effects



A study has been done on the impact of the threshold applied

still preliminary

When the threshold is set to ½ mip

and a reasonable clustering done on the pixels

the resolution achieved is the same as with large diodes,

the effect of dead zones seems marginal.

Conclusion

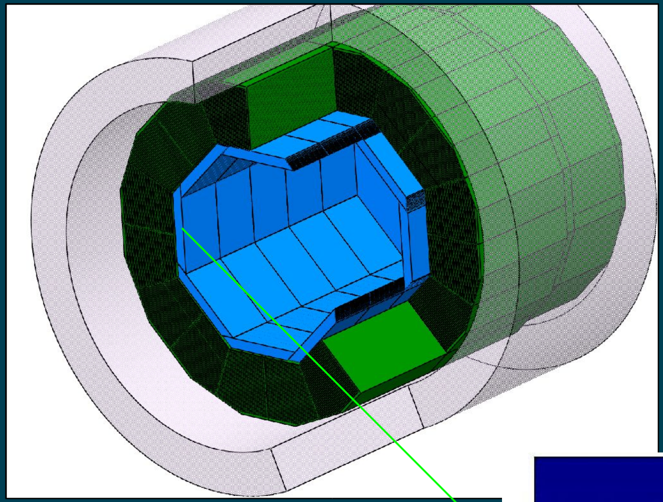
- The W-Si ECAL is one of the options of the CALICE collaboration

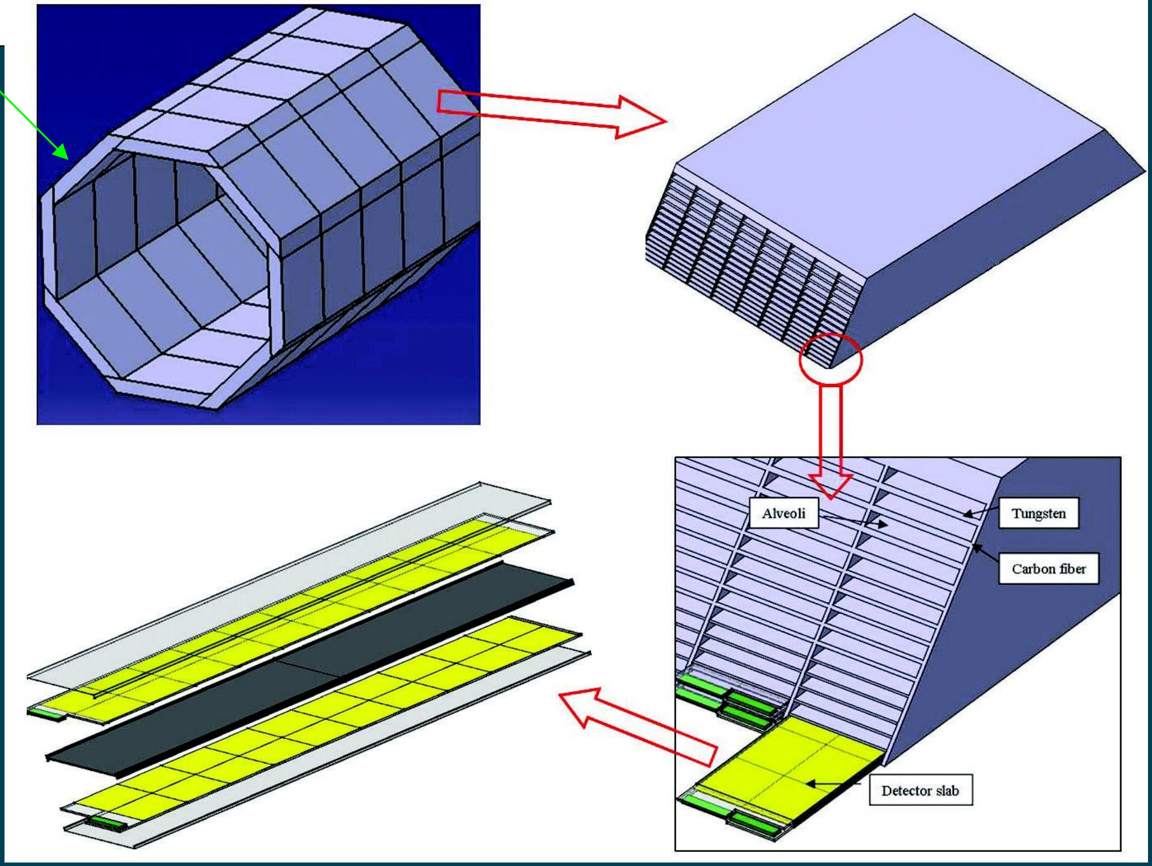
- The first prototype, physics, is in test beam and begins to produce interesting results, recycled in technological developments

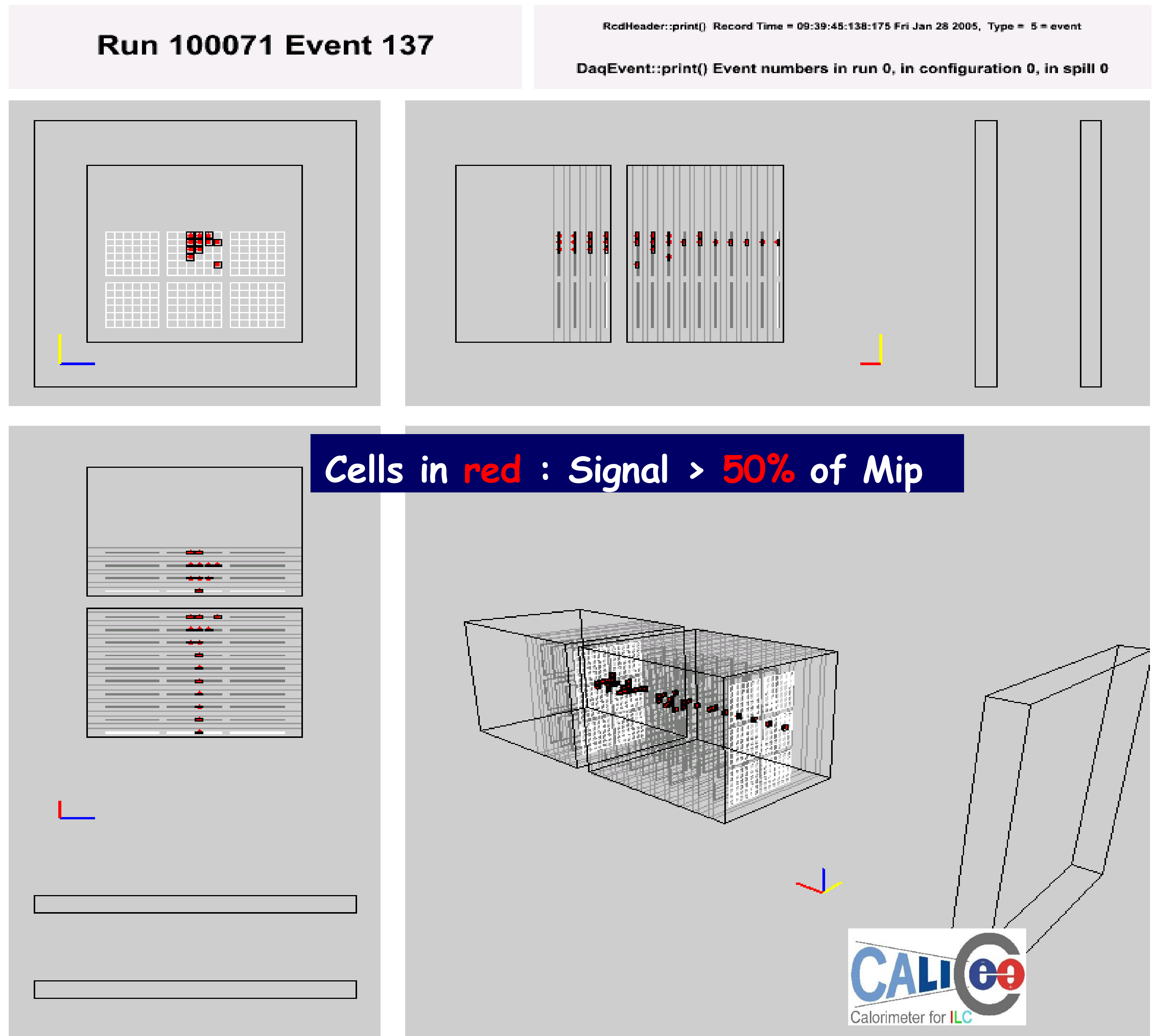
The second generation, a technological prototype now, is being designed, construction begins soon

- If all goes well the MAPS will be tested at that stage.

We do not do R&D for fun along flowing years
but try to address in a coherent and rigorous mind
what we think are the ILC calorimetry challenges
in the timetable of the accelerator.




Alveoli
Tungsten
Carbon fiber
Detector slab


Run 100071 Event 137
RcdHeader::print() Record Time = 09:39:45:138:175 Fri Jan 28 2005, Type = 5 = event
DaqEvent::print() Event numbers in run 0, in configuration 0, in spill 0
Cells in red : Signal > 50% of Mip

Results on the energy resolution vs threshold after each step

VERY PRELIMINARY