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Silicon tungsten ultraganular electromagnetic calorimeter

Jean-Claude Brient
Laboratoire Leprince-Ringuet
CNRS- IP Paris

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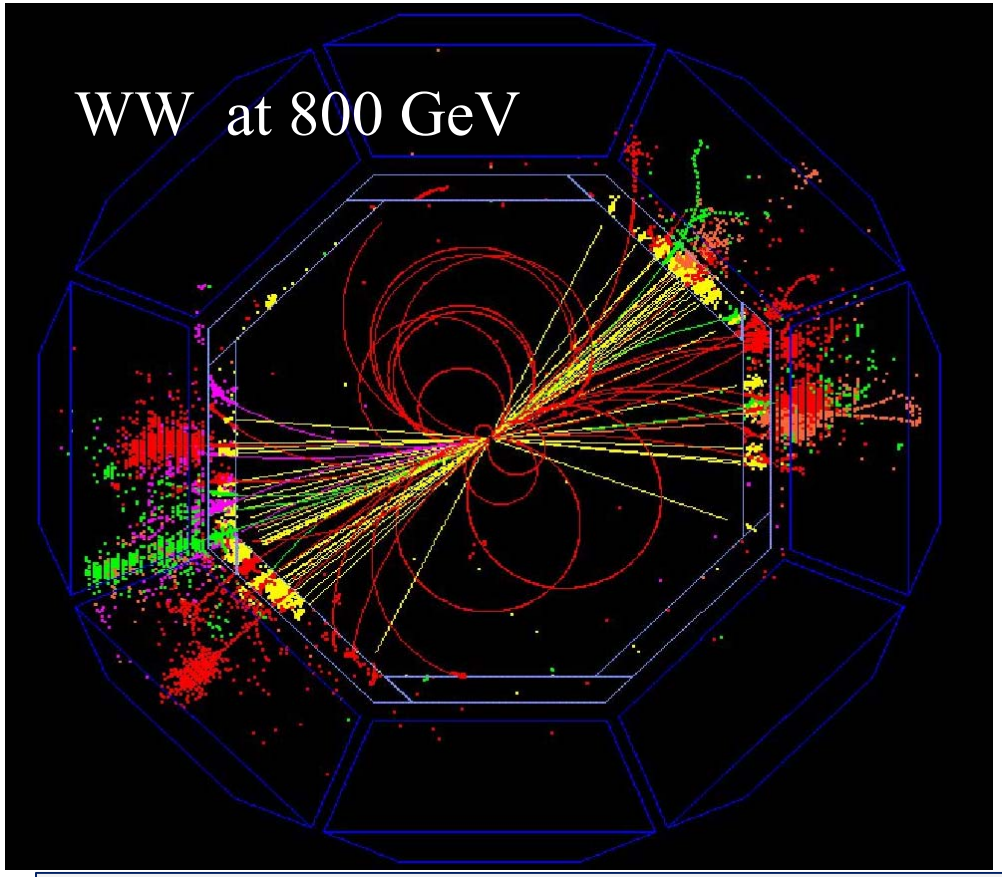
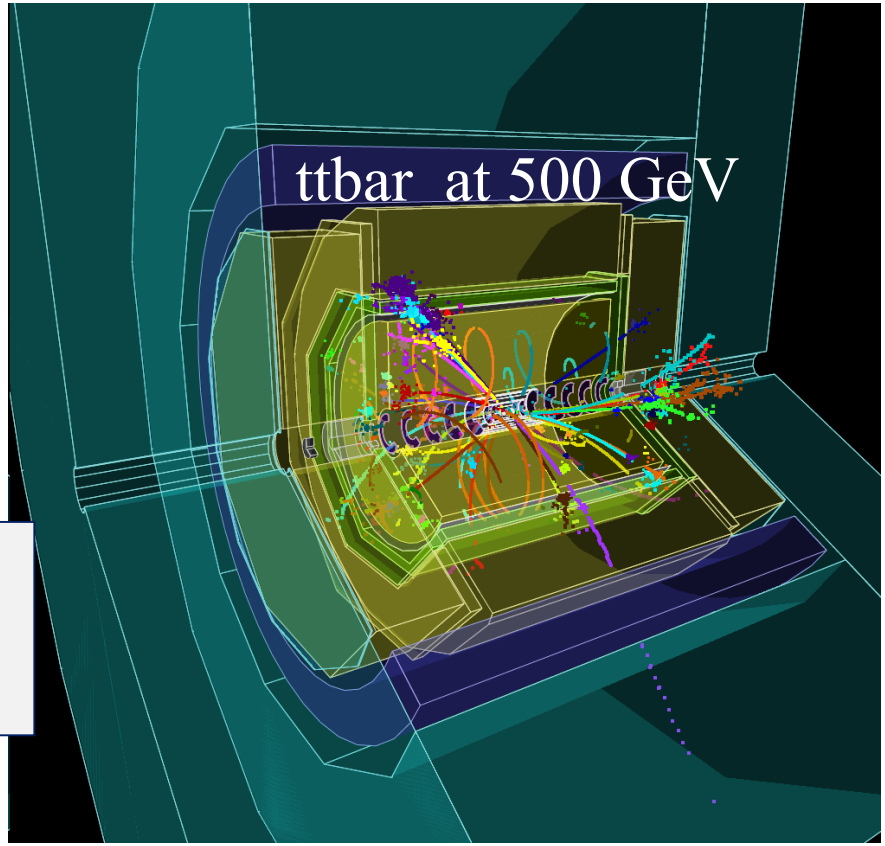
We are talking of Imaging calorimetry





From G4 simulation,
the expected performances are a convolution
of the detector design and recons. software !!!

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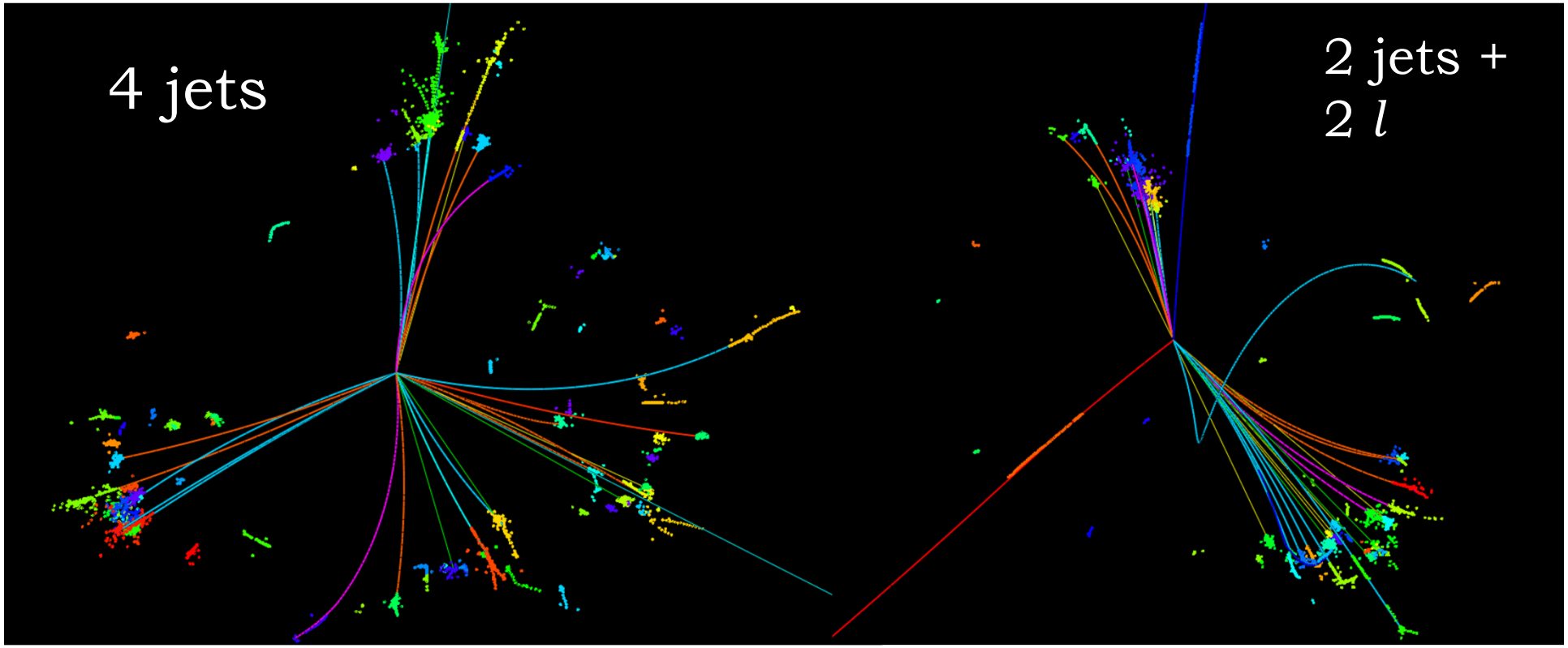
ZH final state at 250 GeV centre of mass energy



Thanks to Manqi Ruan , using ARBOR for CEPC

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Silicon tungsten ECAL

PRO

Why tungsten

- Smaller Moliere radius
- Very good ratio thickness/radiation length

Why Silicon

- Response uniform
- Stable , no aging
- S/N at the mip larger than 12
- All in industry
- Performances
- Possible time measrt for individual particle

Why carbon fiber

- No dead zone
- Auto hanging system
- overall ECAL thickness for 24X0

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CONS

Cost higher by about 15 to 20%

Tracker people interference on silicon

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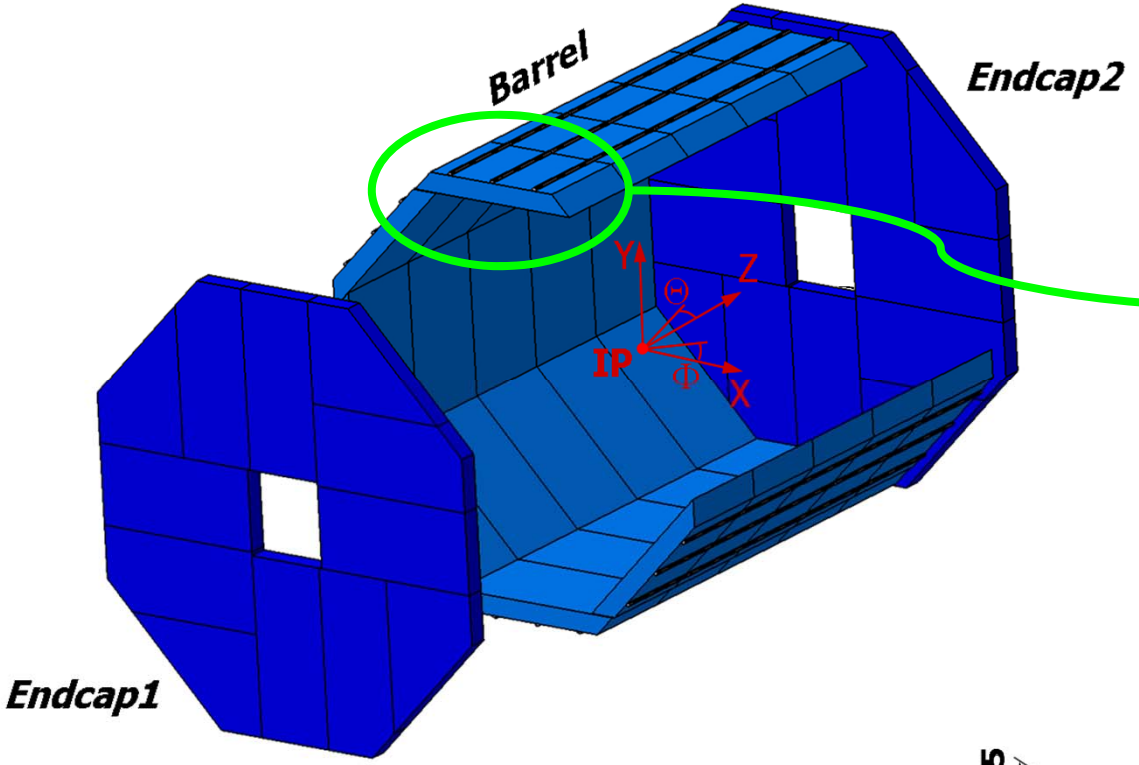
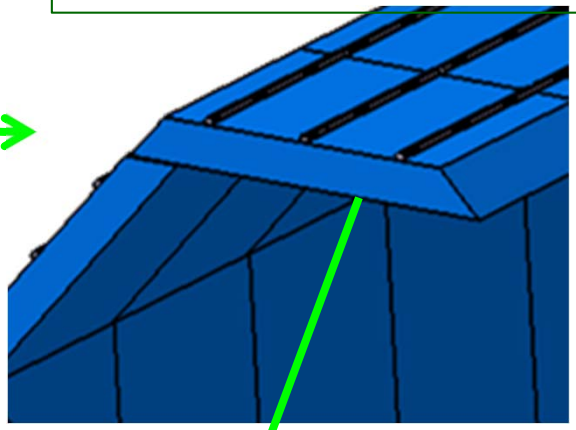
The gain in thickness for silicon Partially compensate the difference of cost on the rest of the detector

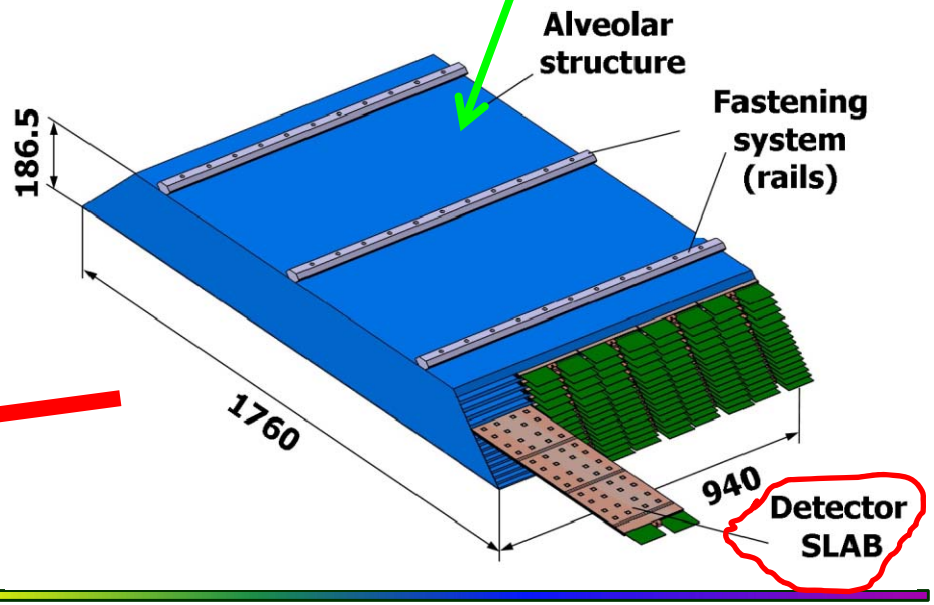
30 x (0.3 – 0.075) = 6.7 cm

Carbon fiber structure

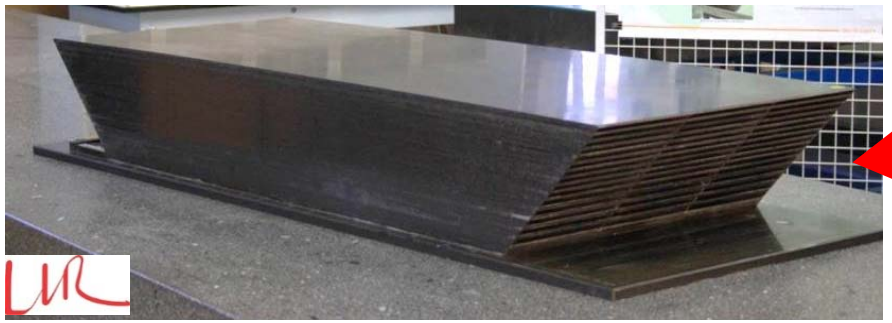


No DEAD ZONE !!!

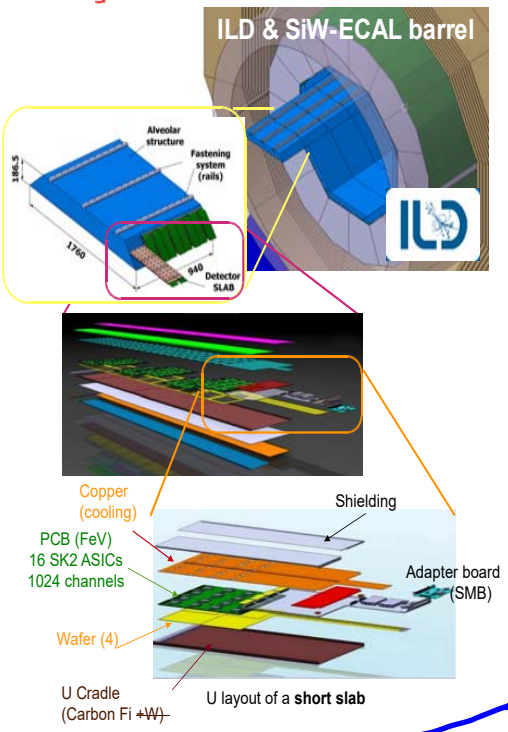




Carbon fiber –Tungsten structure with Alveola to slide in the active layers.

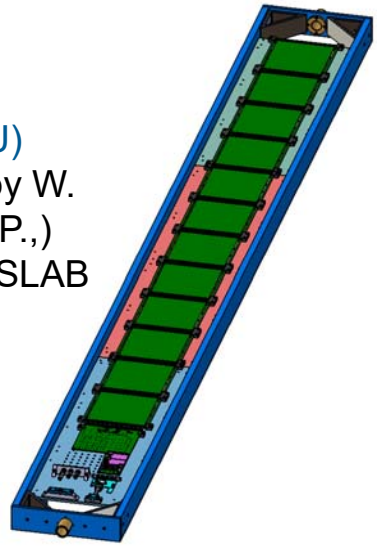


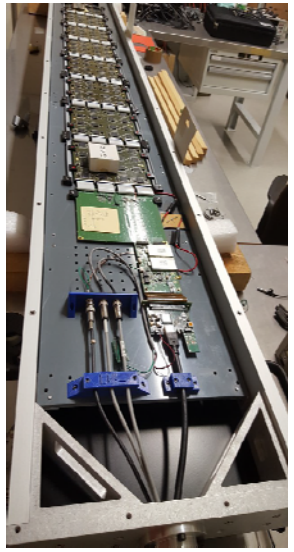
Silicon on PCB



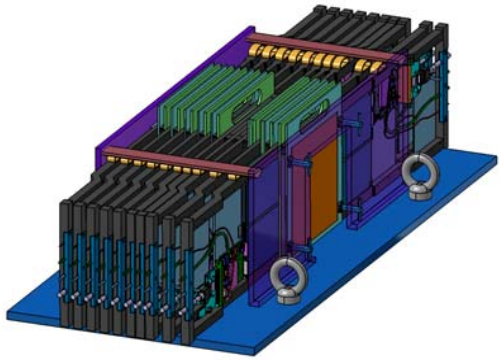
Long Slab (≤12 ASU)

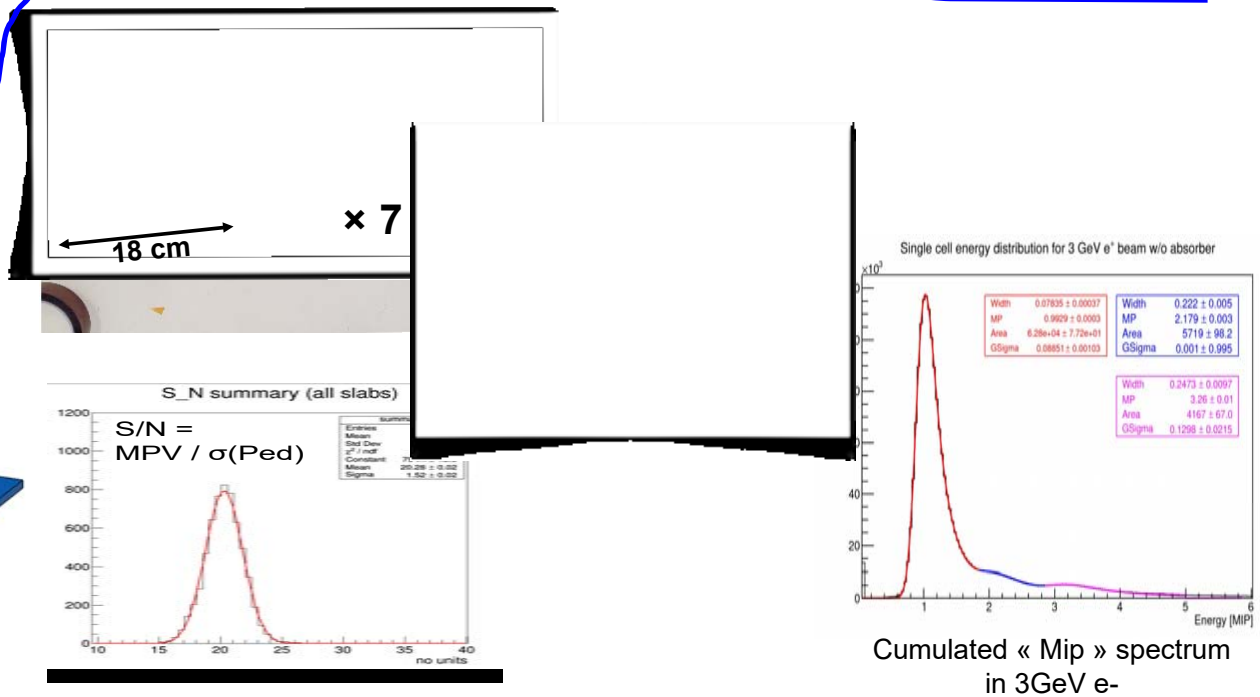
- électronics + Baby W. (Signals, Power P.,)
- Design Realistic SLAB





Prototype technologique





Cumulated « Mip » spectrum in 3GeV e-

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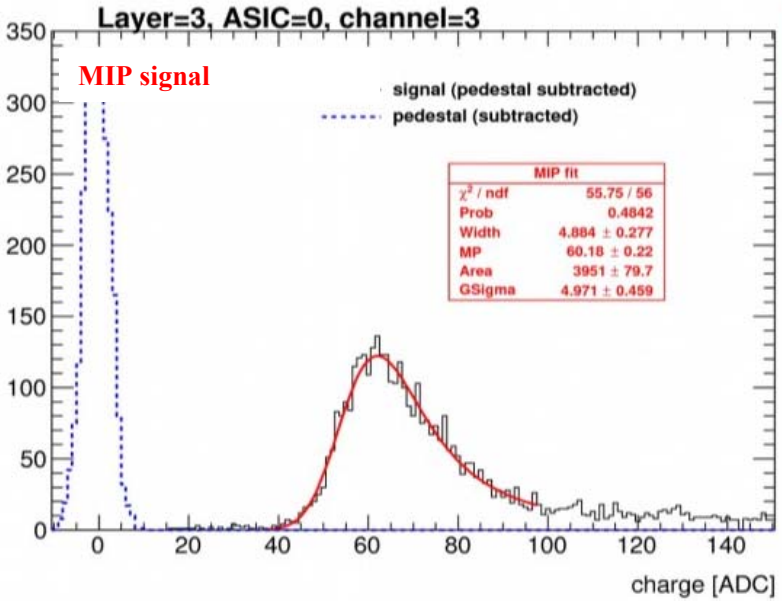
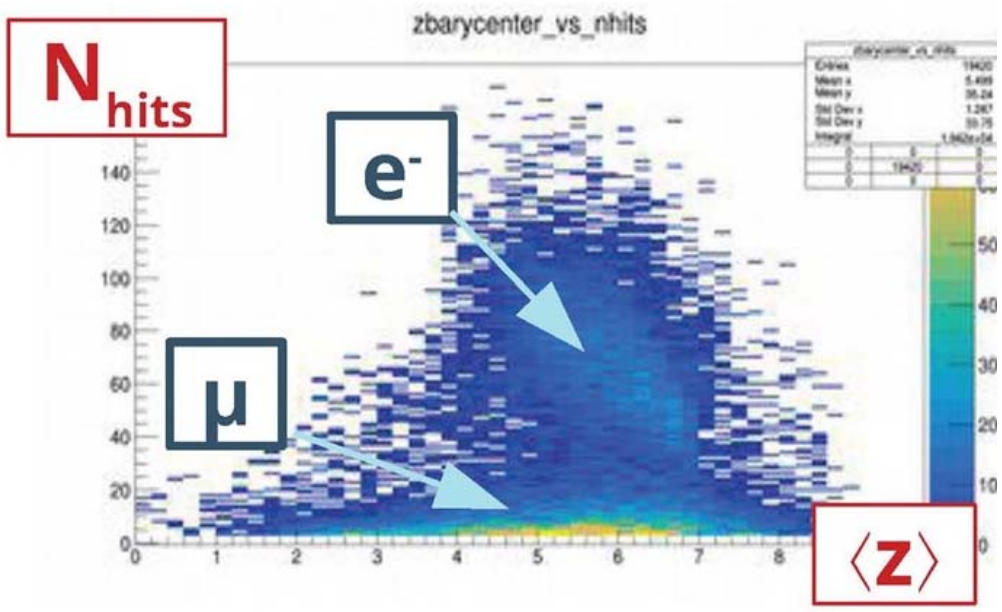
Beam test 2017-2018

Silicon diode
5x5 mm²
7 layers





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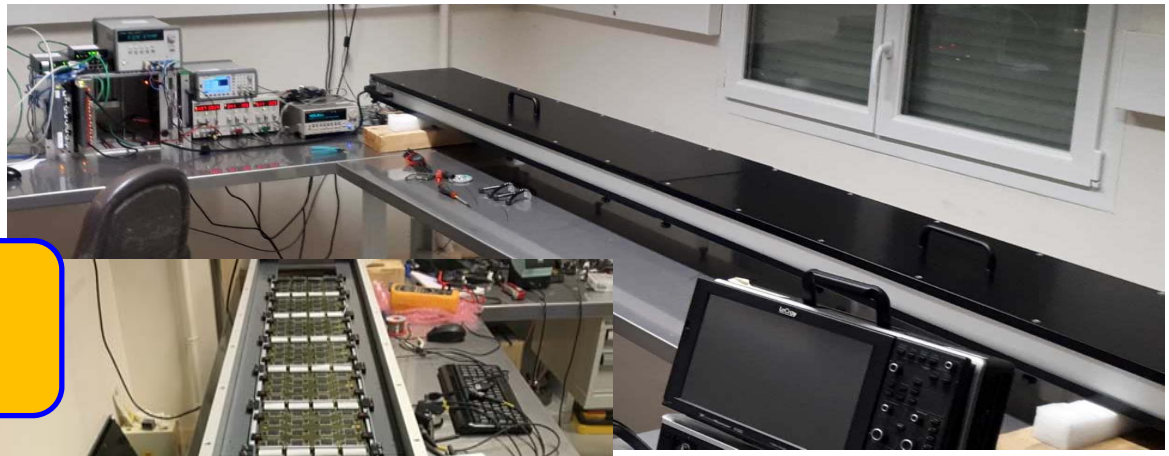
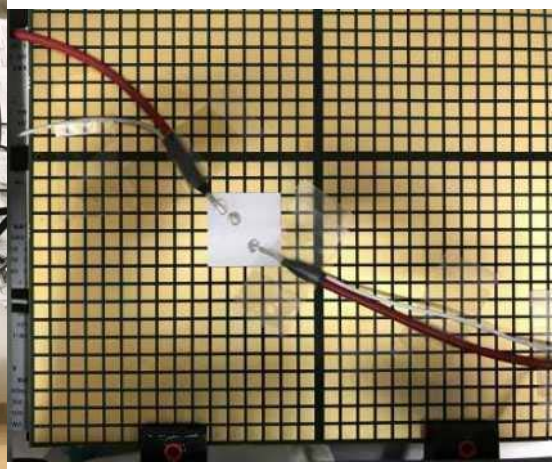
Long slab lab test





Scale to support electronics

- Support of interface boards + 12 ASUs (DBD)
- 2+6+4 ASUs = ~3.2 m Max length for Endcaps
- Total access to upper and lower parts
  - 320µm Baby wafers (20×20 mm², 4×4 pixels)

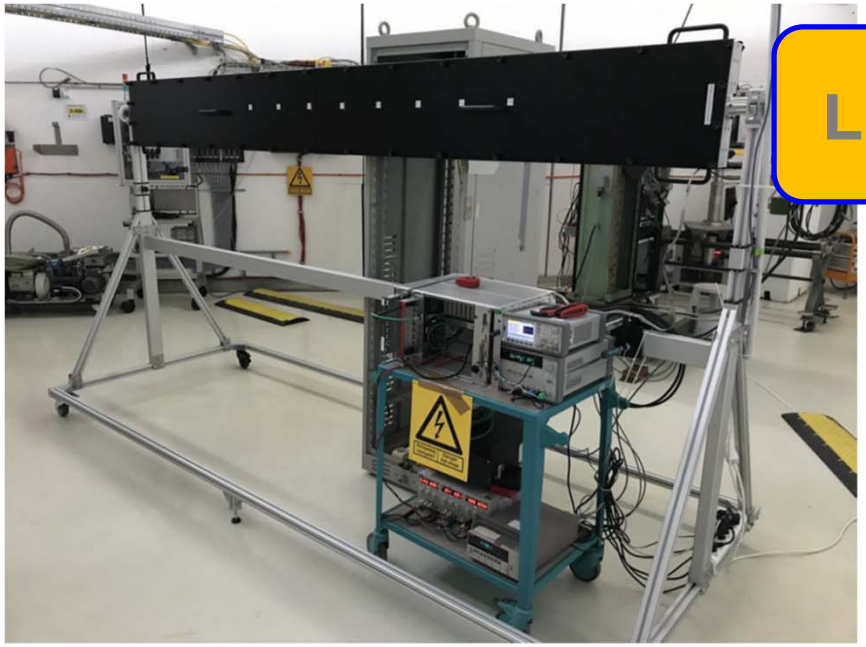
Mechanical characteristics

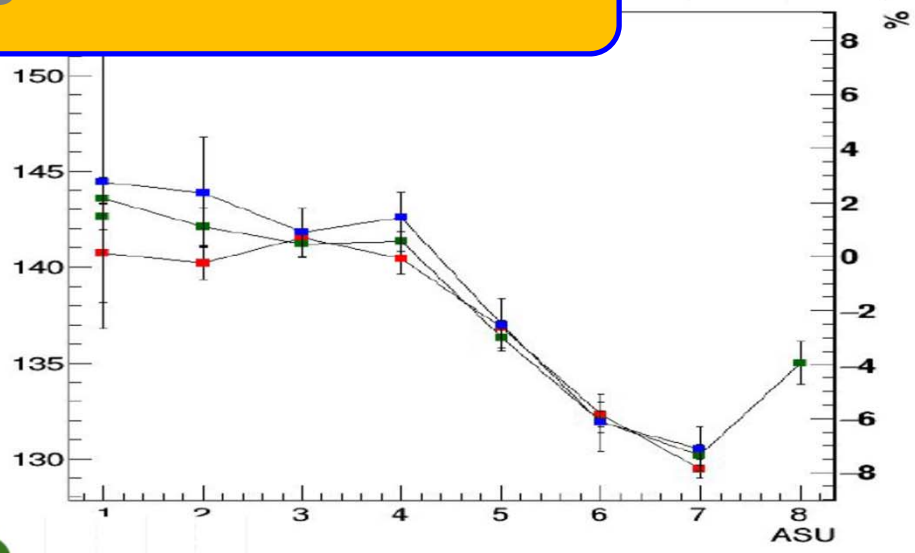
- Movable: table and to beam test
- Rotatably along long axis (for beam test)

  Rigidity : ≤ ~1 mm for 3m
- No electrical contacts scale / cards

Shielding vs Light and CEM

Long slab beam test



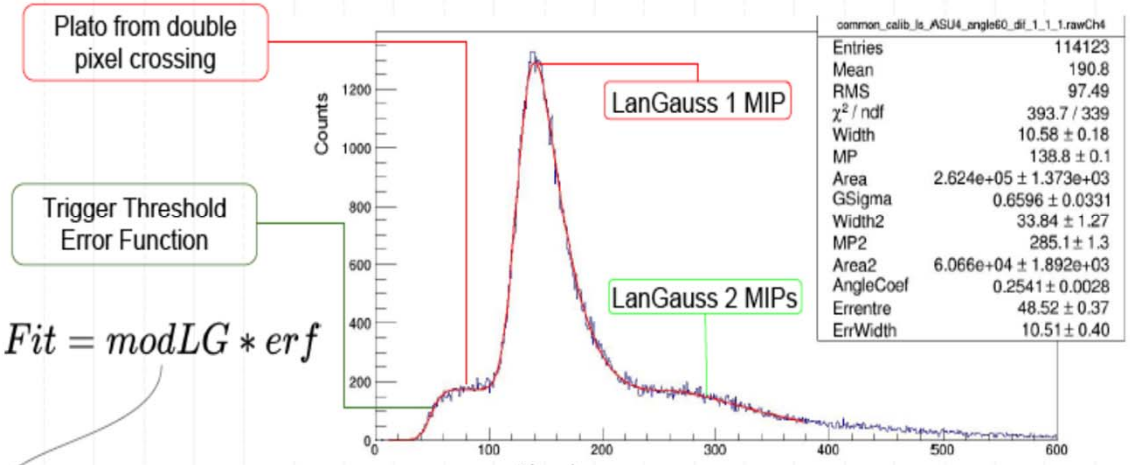


Fit with Mod LanGau function

Plato from double pixel crossing

Trigger Threshold Error Function

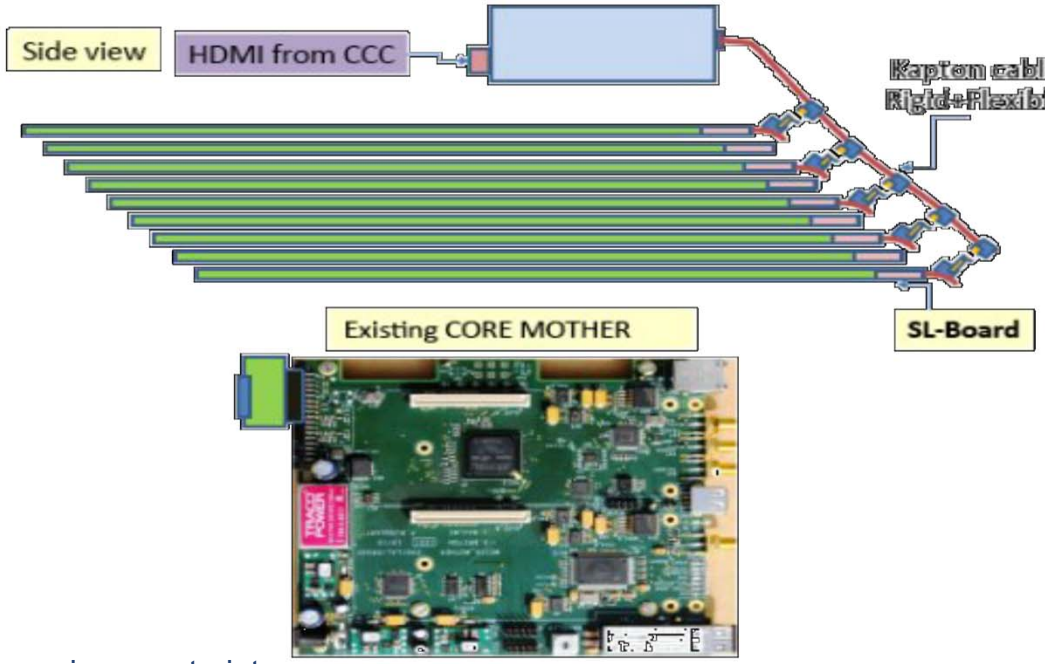
$$Fit = modLG * erf$$

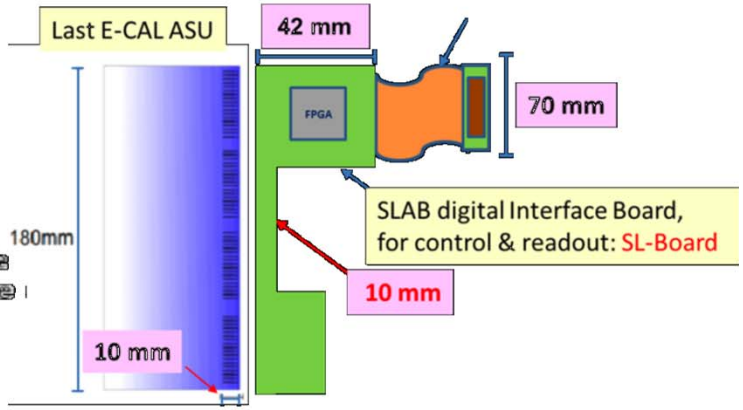


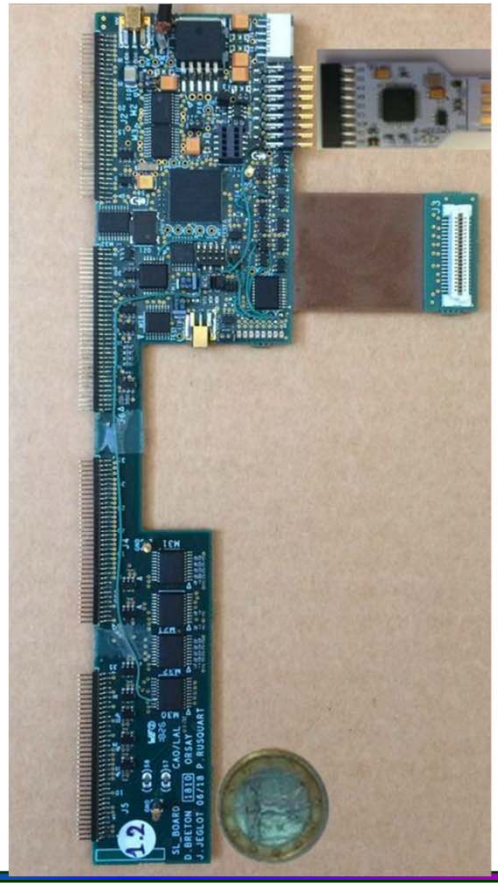
$$modL(x,\mu,\sigma) = (1-c) * L(x,\mu,\sigma) + c * \int_x^{+\infty} \frac{L(t,\mu,\sigma)}{t} dt$$

$$modLG = \int_{-\infty}^{+\infty} modL(t,\mu.\sigma) * G(x-t,\mu_G,\sigma_G) dt$$

DAQ system in reduced space







ILD spacing constraints:

• between ECAL and HCAL: 67 mm

Height ≤ 6 to 12 mm depending on the location

• L-shape because of the cooling system

• Control & Readout electronics at the extremity of the Slab

• Signal Integrity over a Slab: up to 8–12 interconnected ASUs (200 ASICs, ~10,000 ch)

• Very low Power consumption(~ 150 mA/ Slab) : needs to run in power pulsing mode

New HW: **SL-Board**

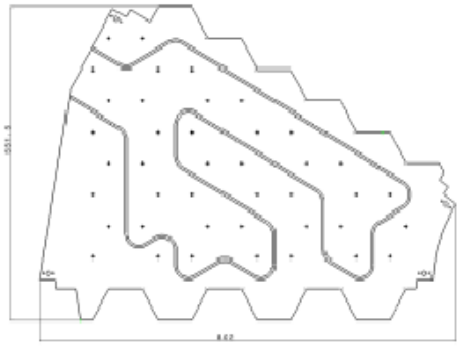
– Regulated PS: HV and LV + monitoring (ADC)

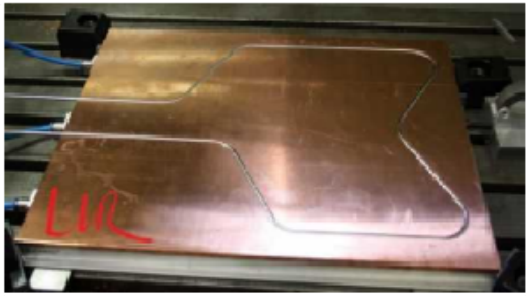
– Controls ASICs & perform RO: ALTERA MAX10 (CPLD+FPGA)

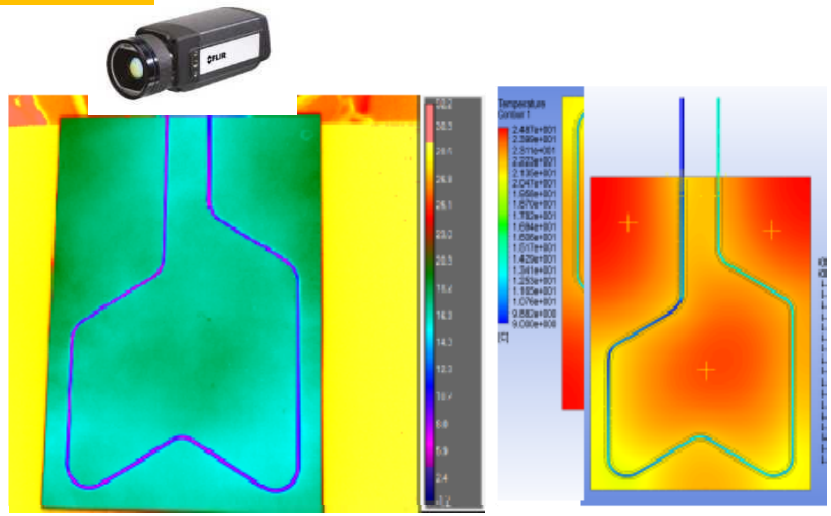
– Connection to CoreModule by single Kapton 40-pin cable

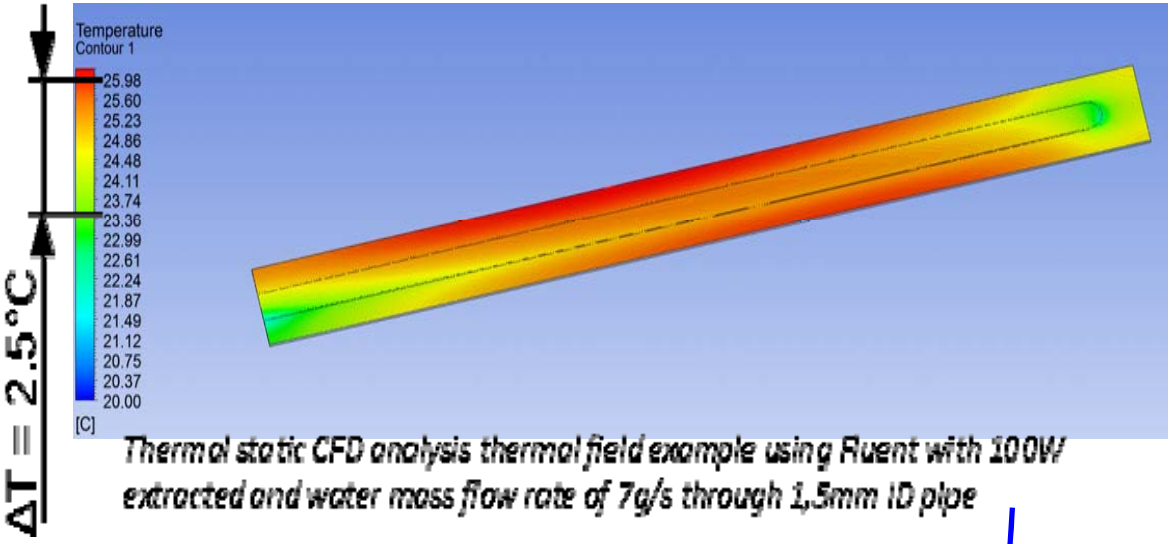
– Low power (<1W)

COOLING for continuous readout







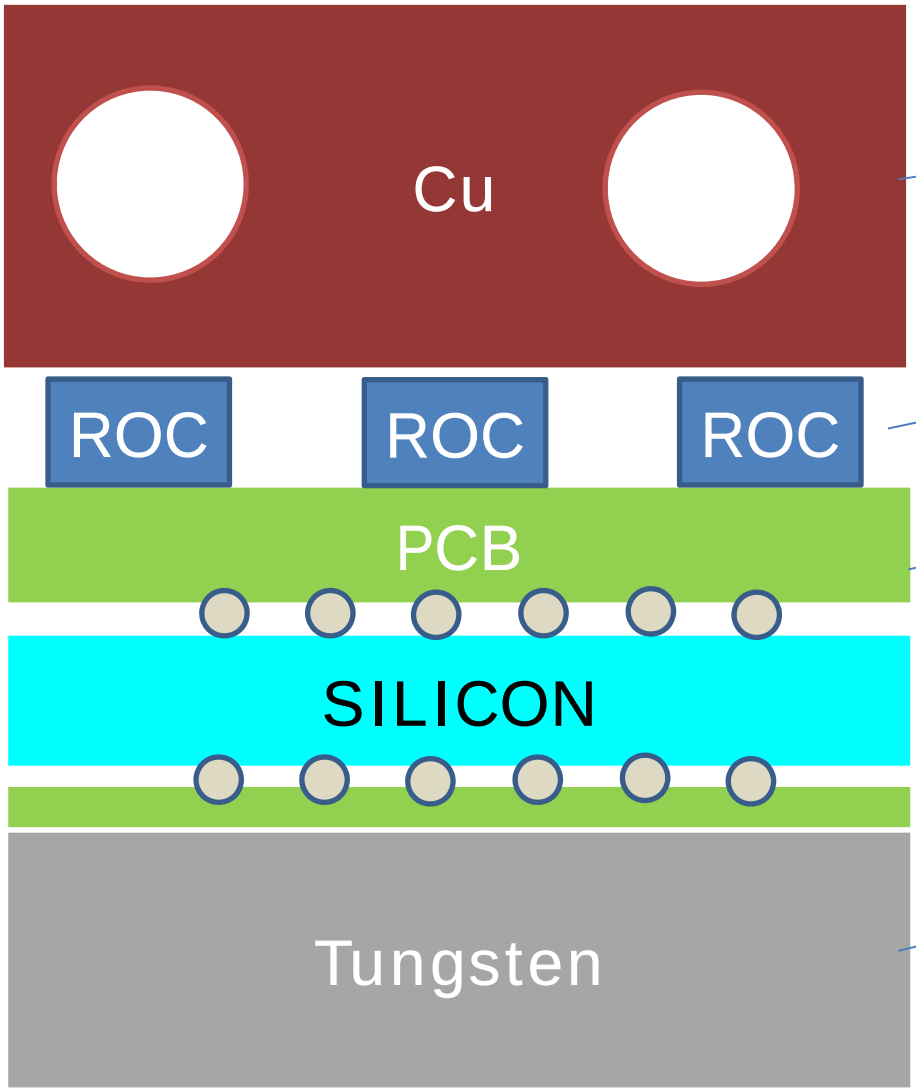


Thermal static CFD analysis thermal field example using Fluent with 100W extracted and water mass flow rate of 7g/s through 1.5mm ID pipe

= 2× cont. operation of a SLAB

COOLING for continuous readout

TOTAL is 1.2 cm/Layer



Cooper cooling 6 mm

ASIC BGA 0.8 mm

PCB 1.2 mm

Silicon 0.75 + 0.05 mm

Kapton 0.1 mm

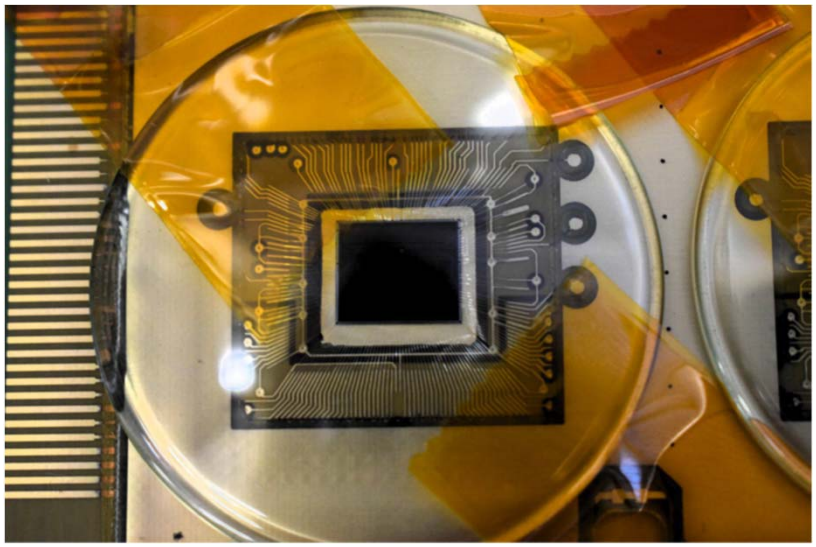
Tungsten 3 mm

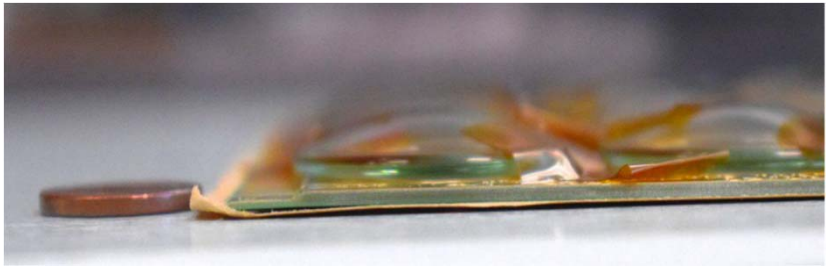
+ 0.1 mm for glue (2 points)

Korean industry and labs in France

SUNG KYUN KWAN UNIVERSITY(SKKU)

EOS EOS CORPORATION





FEV-COB (Chip-On-Board)

– 2 FEV12-COB, SK2a with one 6" wafer × 500µm
- long standing work from **LAL+Omega** +
- 1.2mm, 9 layer PCB
- Good planarity (metrology made in LAL)
- No extra components on board
- 4 boards wirebonded at CERN

– 2 FEV12-BGA, SK2a with one 6" wafer × 500µm

– Gluing @ LPNHE with 100% controlled Wafers pro & post-gluing

Connections to SL-Board made by GradConn connectors

A gain in thickness ….
mitigate the effect of 4-6 mm of cooper for active cooling

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NEXT

- Goes from 6 to 8” wafers and from 500 to 750µm thickness
- Use the rectangle of the edge of the wafer and estimate the effect
- 20 layers ECAL prototype in Test beam
- Take decision on COB or BGA
- Continue the collaboration with industry

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What to do to go for such a detector

Design (G4 and **Reconstruction**)

→ PANDORA ARBOR

Prototypes , tests beam , G4 based design

We are here

- **Industrial design**
- **Costing**
- **Engineering**
- **Organization at the stage of pre-construction**

Color code
Well advanced
In progress
Not really started

CONSTRUCTION

Organisation, resp. sharing,
Risks mitigation, industrial constraints,
Final design, etc…

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Summary

- Silicon tungsten ECAL is making a lot of progress toward a scalable version
- Performances on s/n in test beam is perfect, as expected
- Active cooling for CEPC … CMS-HGCAL as prototype
- No show-stopper , even the cost
- Going from labs to real detector will needs a lot of effort and people …. Open to collaboration

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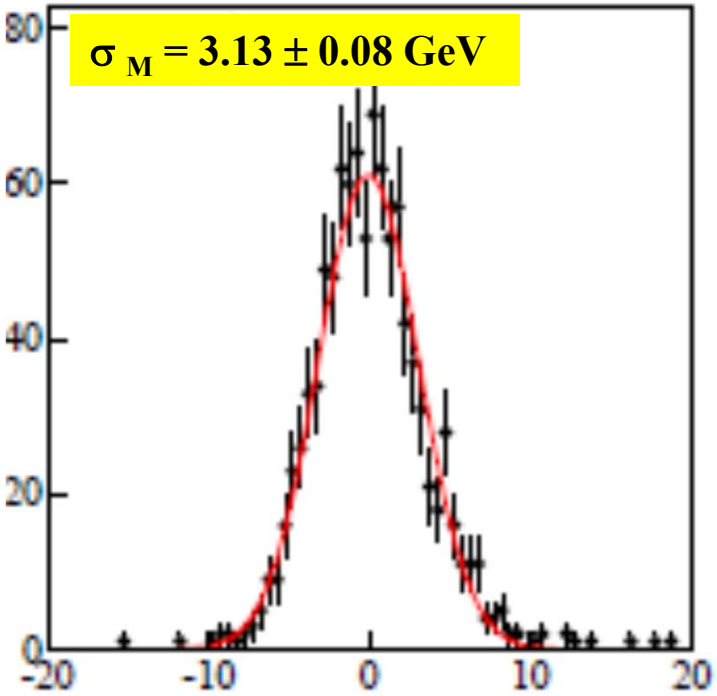
BACKUP

First study on PFA

Visible energy resolution with PFA
TESLA Report - 2001



The resolution is about 3.1 GeV !!

A factor 2 better than LHC experiments

J-C Brient , D.Orlando
TESLA Report

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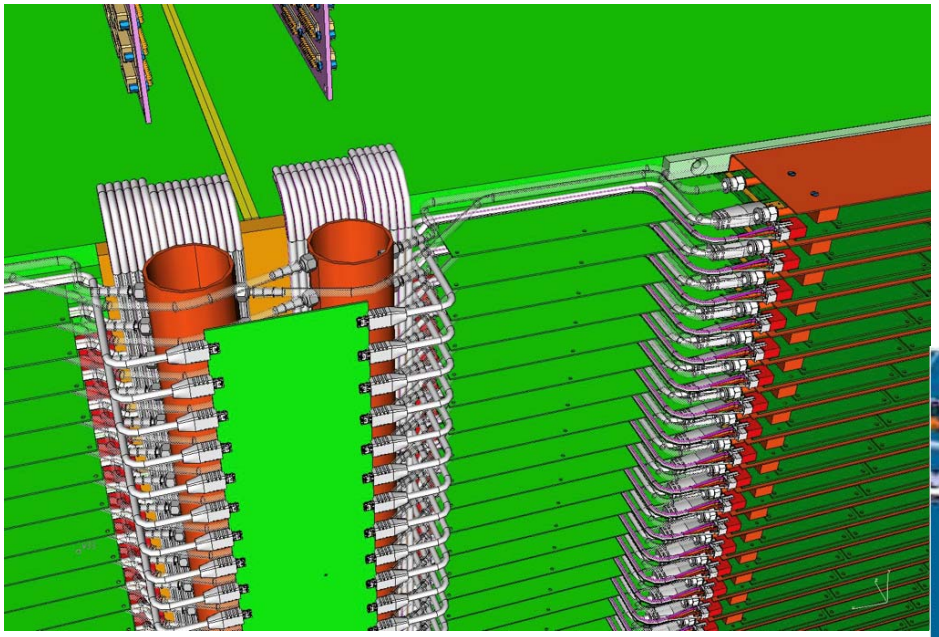
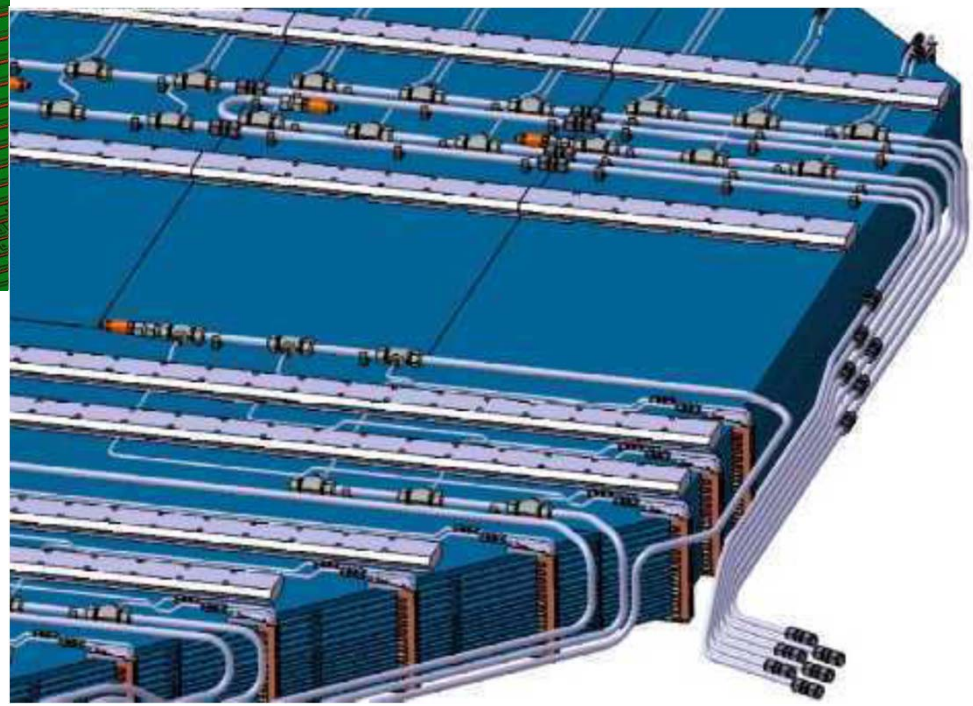
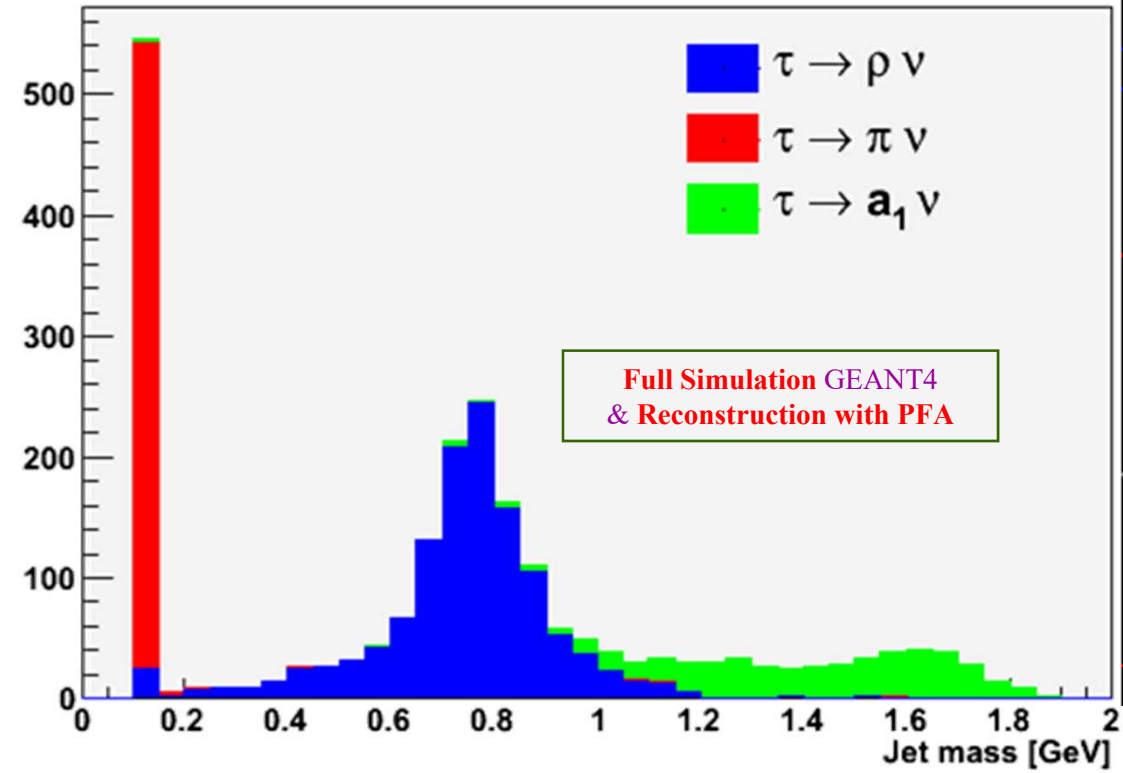
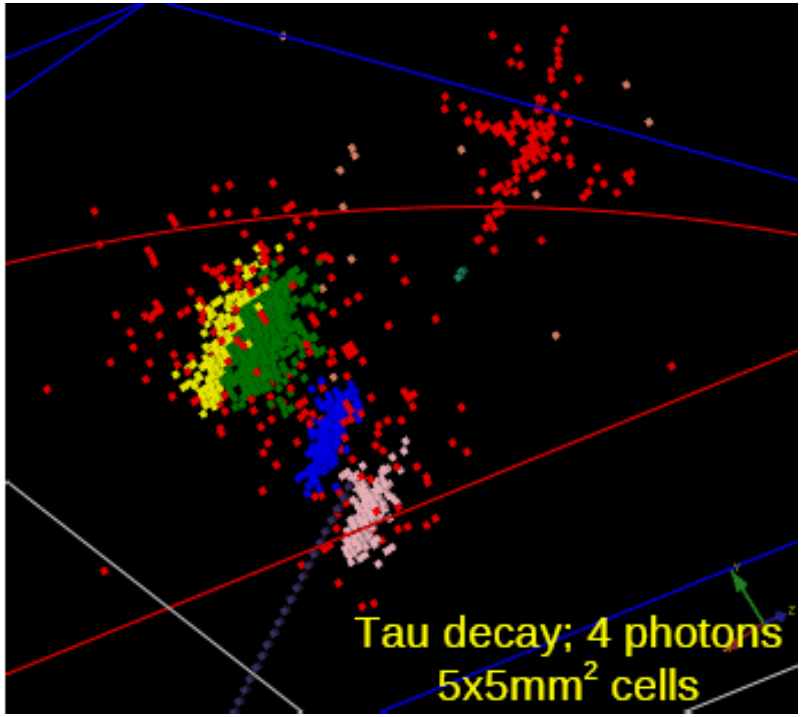
Enginering design of the cooling





Thanks you to granularity and segmentation !!



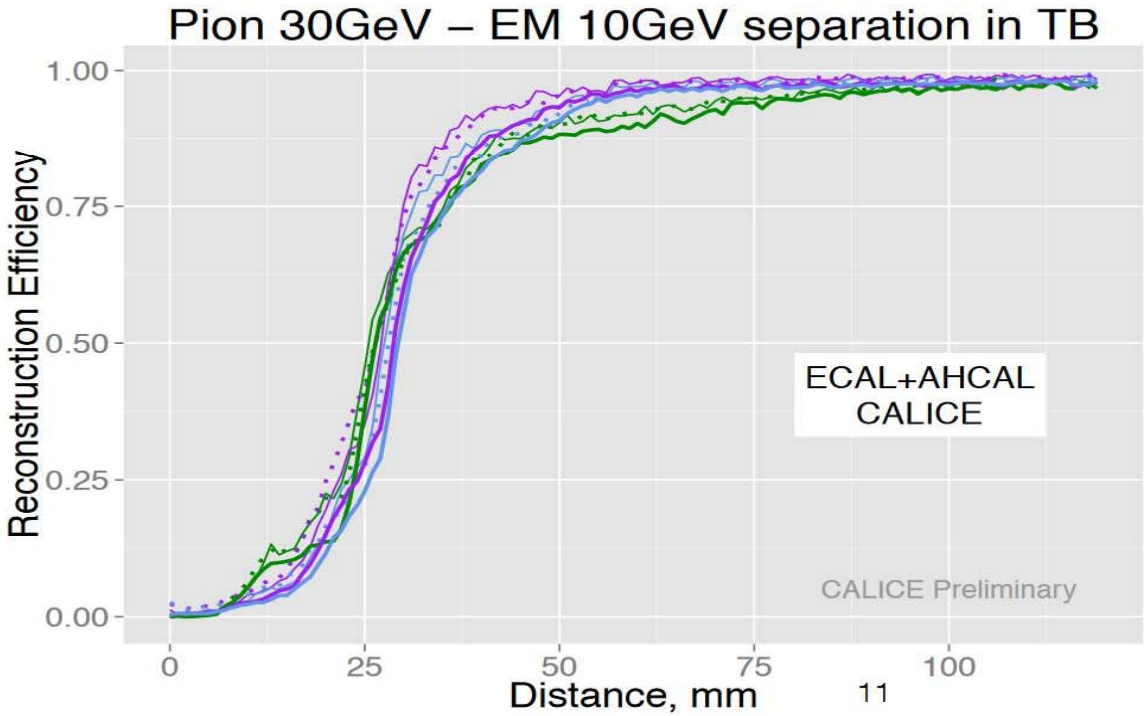


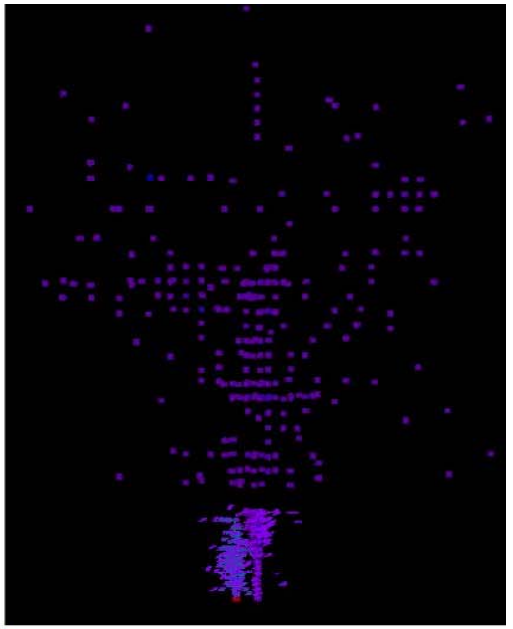
	Jet mass < 0.2	Jet mass in 0.2-1.1	Jet mass >1.1
$\tau \rightarrow \pi\nu$	90.2 %	1.7 %	8.1 %
$\tau \rightarrow \rho\nu$	1.7 %	87.3 %	7.4%
$\tau \rightarrow a_1\nu$	0.6 %	7.4 %	92.0 %

Hadron-EM separation: 30+10 GeV π^+–e^+ (TB+MC), π^+–γ (MC)

Probability to reconstruct exactly one γ & one π^+ for Pandora or one γ for Garlic (which does not reconstruct hadrons), Arbor not used for AHCAL.

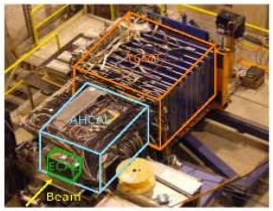
Good agreement between TB and MC.





Algorithm
- Garlic
- Pandora
- PandoraOLD

MCTBparticle
- MC:pi+e+
- MC:pi+phot
- TB:pi+e+



Data: π^+, e^+ CERN'07, ECAL+AHCAL
MC: π^+, e^+, γ TBCERN0807_p0709

PFA: Pandora (v00-14 & v02-04)
Garlic (v2.11), only ECAL

CALICE Calorimeter for ILC

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“LARGE” versus “SMALL”