ECAL W/Si
End-Caps studies

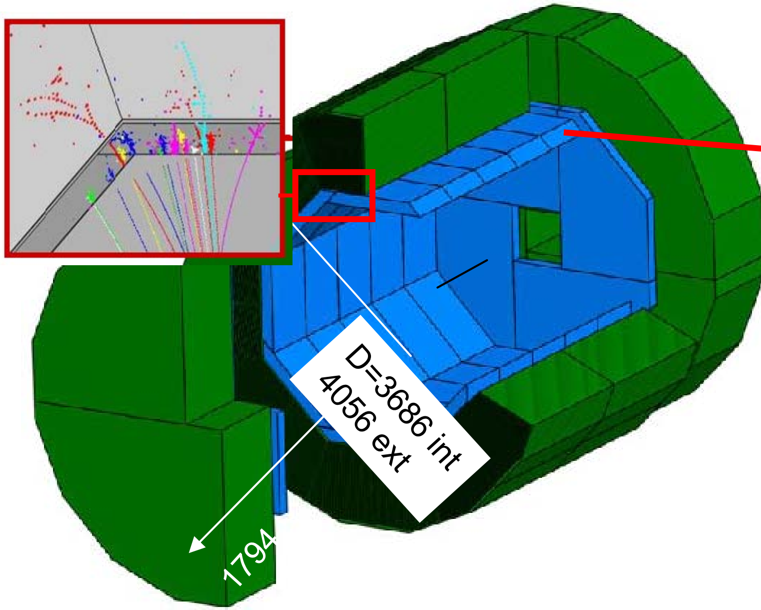
CALICE Meeting 2009 @ IPNL

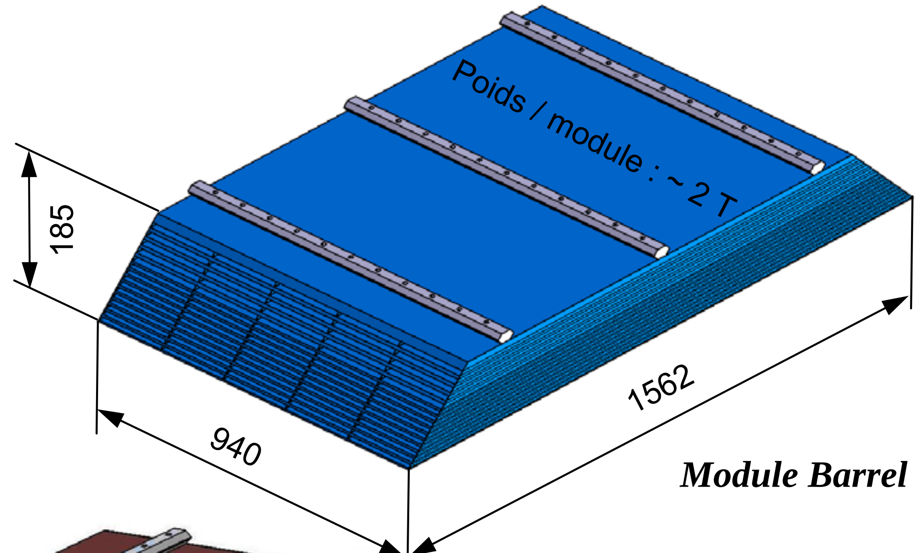
Denis Grondin – September 17th, 2009

Si-W ECAL – Current baseline

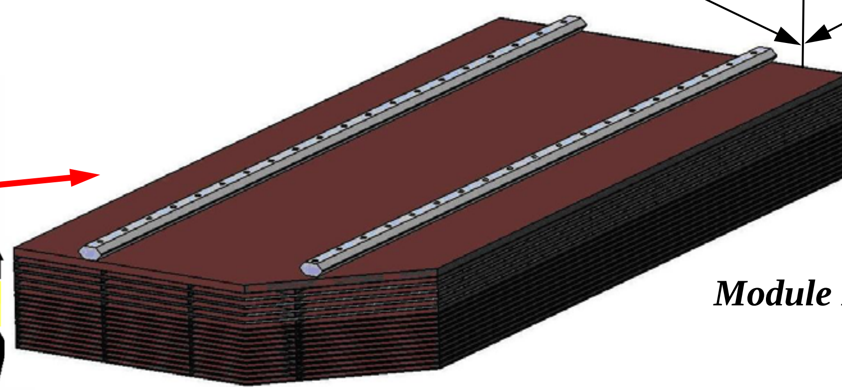
W/Si – ECAL weight:
~ 112 T (80 barrel+32 End-Cap)

- No dead zone, compactness
- 40 identical trapezoidal modules

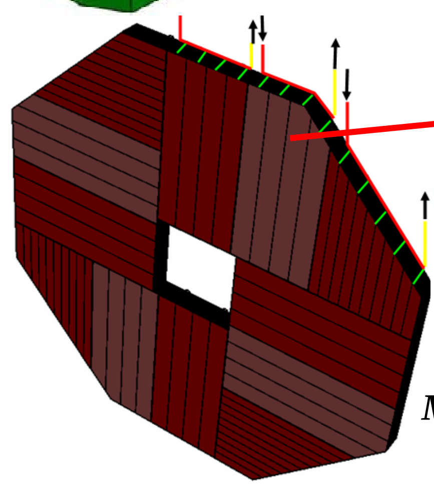




Module Barrel



Module End-Cap n°2



Multi-module End-Cap

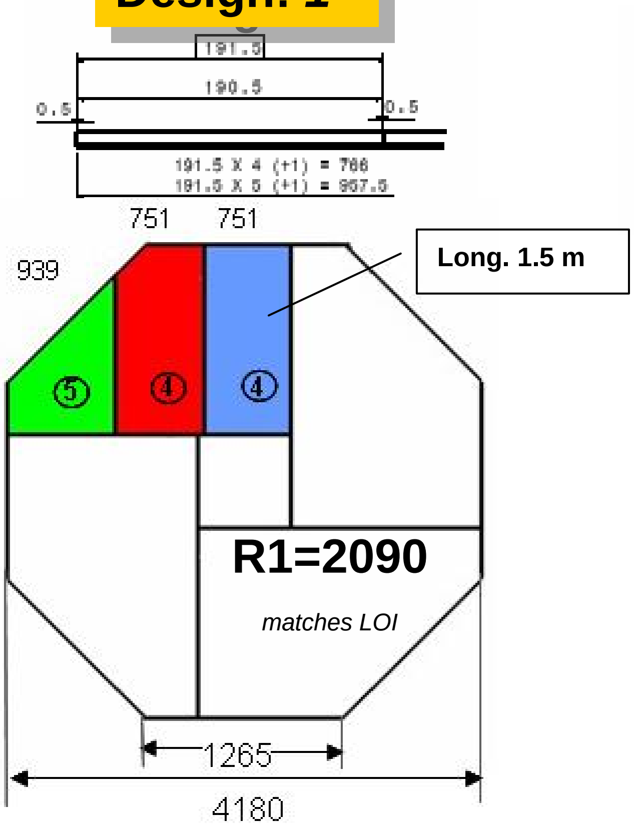
- 12 modules-3 distinct types
- Compactness, no dead zone if…

Si-W ECAL – End-Caps baseline *(1/4)*

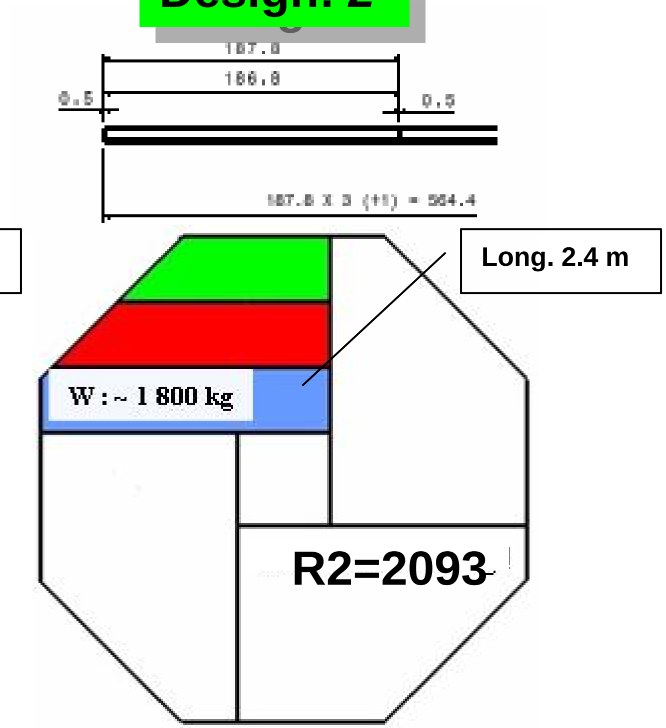
Due to the possible crack in the geometry of design 1 the same general shape could be saved with different size and position of modules, but…

- Thermal (2.50m instead of 1.50m for longest): T° dangerously rising in back-end of slabs
- Mechanical: >2.50m long thin alveoli maybe not feasible,
- Fastening system on HCAL /weight of module >3T ?
- Cost increasing: different shapes of long slabs.

Design: *1*

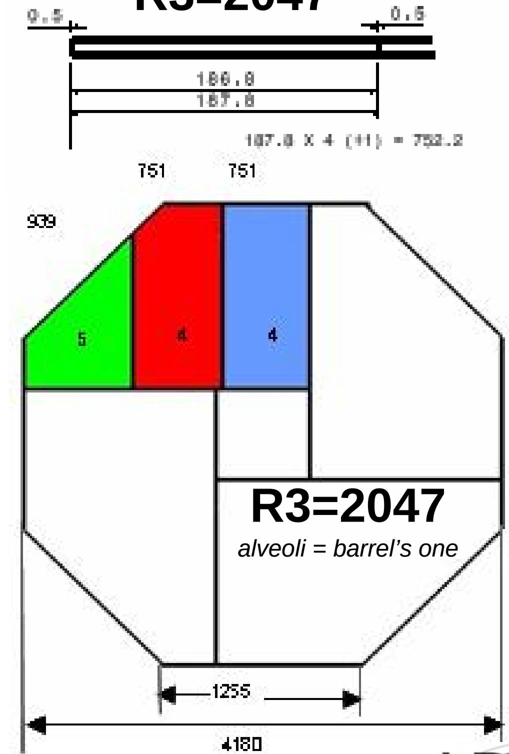


Design: *2*



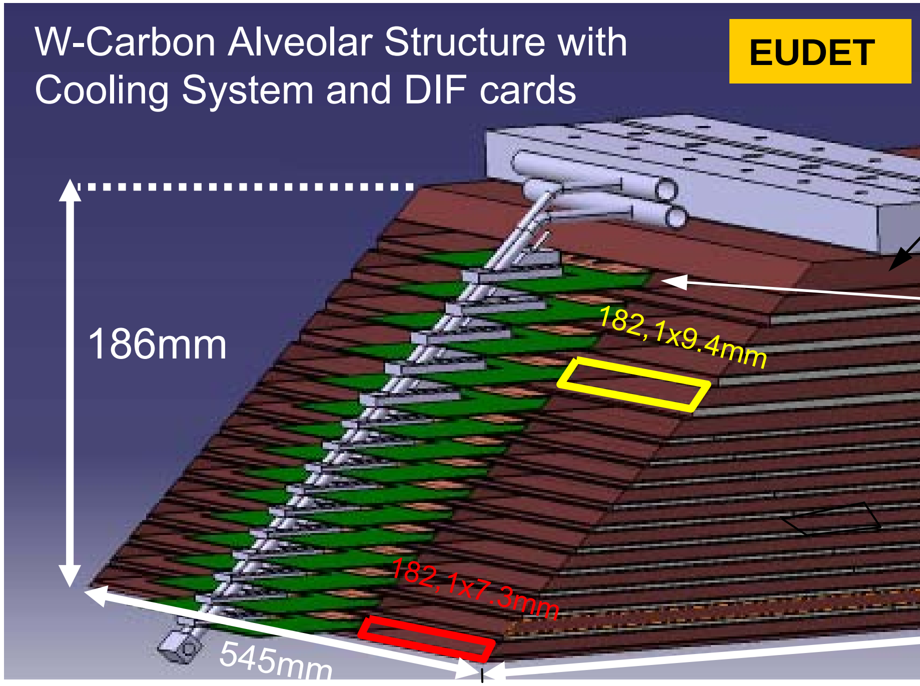
Design: *3*

R3=2047



End-Cap structure: long alveoli (2/4)

- Today, with the demonstrator and EUDET, the process for composite structure has been validated, with a built layer module width based on 182.1 mm for EUDET, and 1,50 m long.

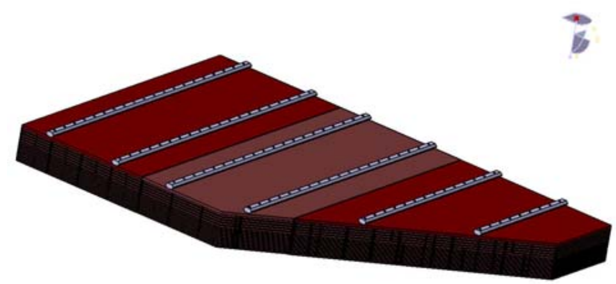


Composite Part with metallic inserts (15 mm thick)

Thickness : 1 mm inter alveolar sheet

¼ end-cap

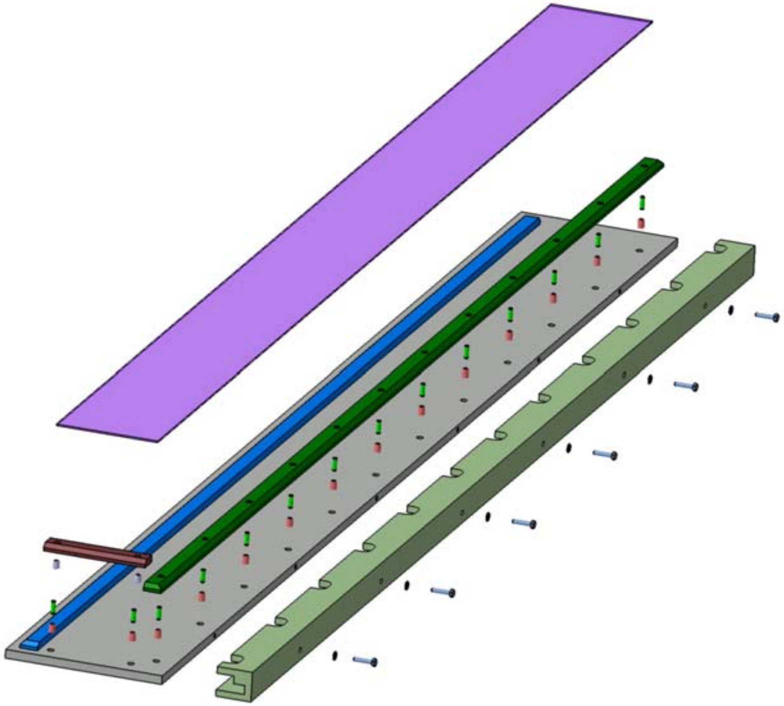
- ~same with & thickness of alveoli
- 1 m longer !
- Different shape



- End-cap structure : study and validation of most of technological solutions which could be used for the final detector (moulding process, cooling system, sizes of structures,...)
- Taking into account industrialization aspect of process
- Finest cost estimation of one module

End-cap – First alveolus & layer *(3/4)*

- For End-caps *(design 2)* the goal is now to build 2,50 m long alveoli, and to demonstrate whether or not the main process steps can be adapted.
- Several issues to be studied:
  - use of adjusted long metallic cores (monolithic or multi-parts)
  - After-curing step: demoulding



- **the end-cap layer consisted of**
- **1 long alveolar layer of 3 cells**
  (representative of the end-cap module n°2 layers)
- **Width of cells : 186.8 mm**
  (Design2-to fit LOI parameters (R~2090))
- **Thickness cells : 6.5 mm**
- **Length : 2.492 m**

⇨ Design & Technical drawing : ***OK***

⇨ Core : ***OK***

⇨ Machining: ***Oct 2009***

⇨ "Long Alveolus" mould reception : ***Nov 09***

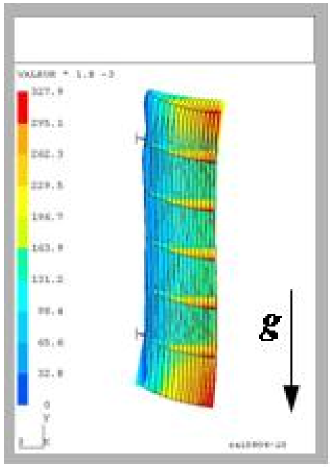
⇨ Long alveolus: ***Dec 2009***

Design of End-cap modules (4/4)

... based on mechanical simulations :

<u>*Linear Analysis of "full scale" ECAL modules (End-caps)*</u>

- Global simulations : global displacements and localization of high stress zone for different solutions (dimensions)
- Local simulations : more precise simulations and study of different local parameters to design correctly each part of this structure (thickness of main composite sheets, fastener's behaviour...)
- Check and validate simulation results by destructive tests for each issues



End-Cap module
Configuration 90°

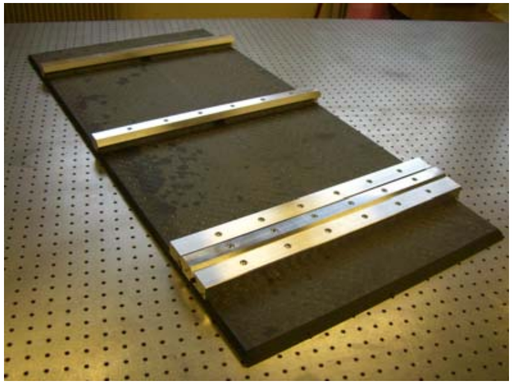
⇨ Global EC design updated : ***End 09***

⇨ Local simulation (flexion): ***Spring 10***

Fastening ECAL/HCAL (1/2)

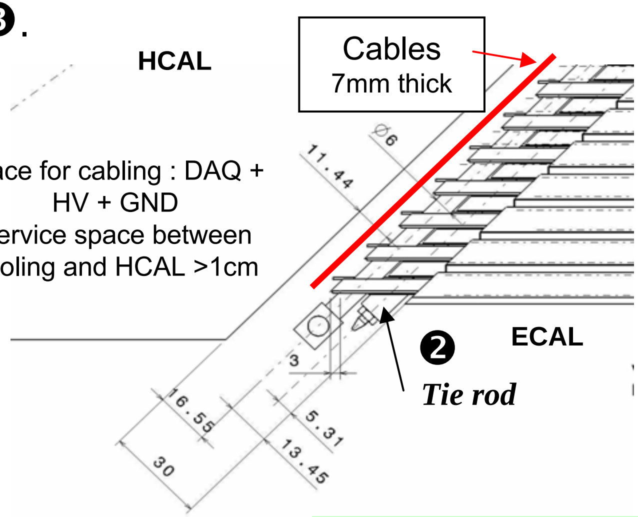
Constraints

- Fastening in a structure “wheel”: bending constraints
- Carbon structure (thick plates and support...)
- Electronics: place for cabling : DAQ + HV + GND
- Cooling pipes integration



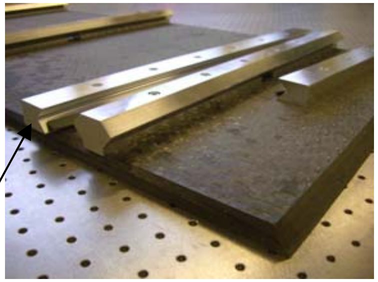
15mm thick plate with it’s rails; ready to be assembled with alveoli layers

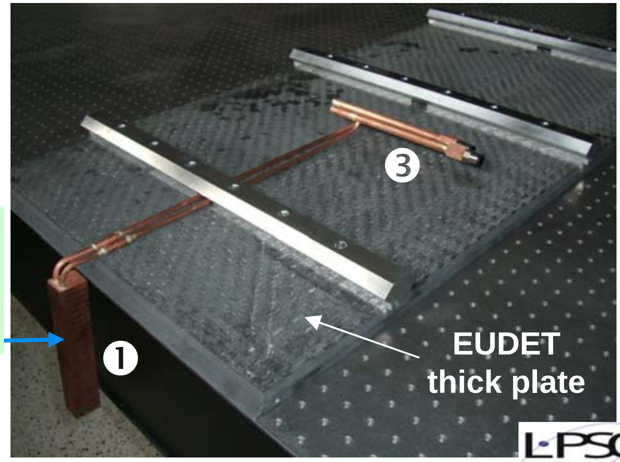
Design of connection system : each cooling system ❶ is inserted and screwed to each column of slab with a thread rod and spacers (❷) and connected to the cooling network in a second step ❸.



•Choice of fasteners : aluminum rails screwed through the medium of inserts. Non magnetic (B=4T !). Alternative: composite.

Rails to fix on HCAL





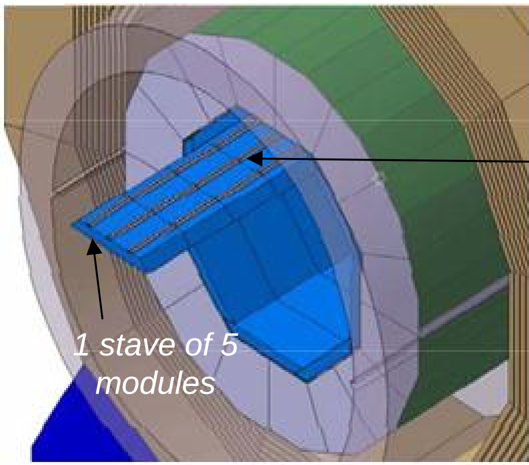
A column (cooling pipe), (25 mm wide minimum) to ensure quick thermal system’s connection

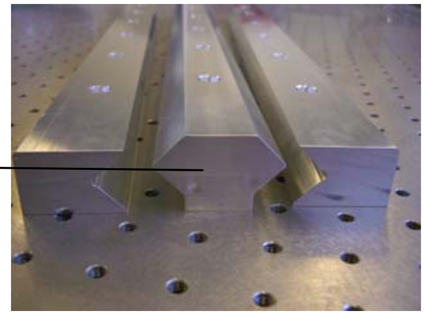
•Available space HCAL/ECAL

- **•Barrel: 3cm**
- **•End-Caps: 1,5 cm: Insufficient / cooling fastening**

Fastening ECAL/HCAL (2/2)

From metallic rails… to… composite structural system…

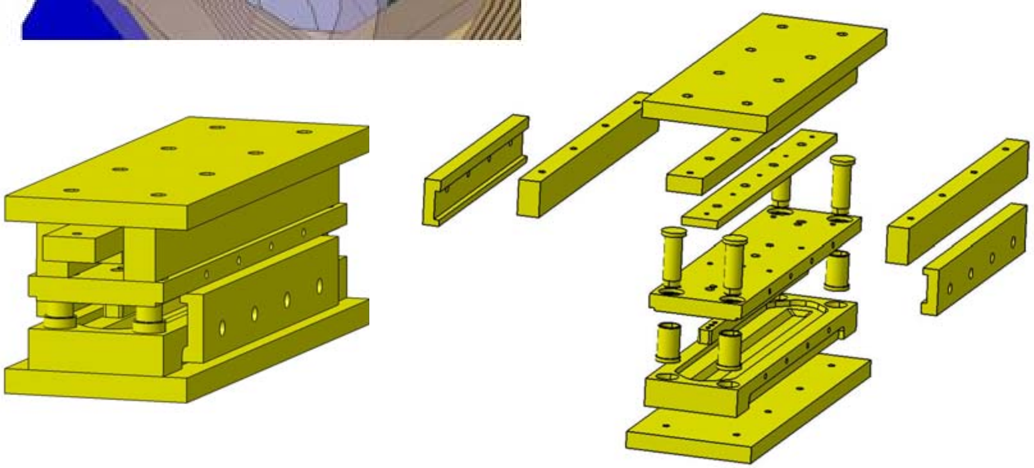




composite structural system

- validation of technological solution
- industrialization aspect of process

Mould delivered, ready to mould HexMC & SMC Carbon rails on a 80T heating press



<u>Solutions to investigate :</u>

- Alternative for fastening and positioning system: isostatic system
- Coupling of modules.
- Handling and positioning tools for modules

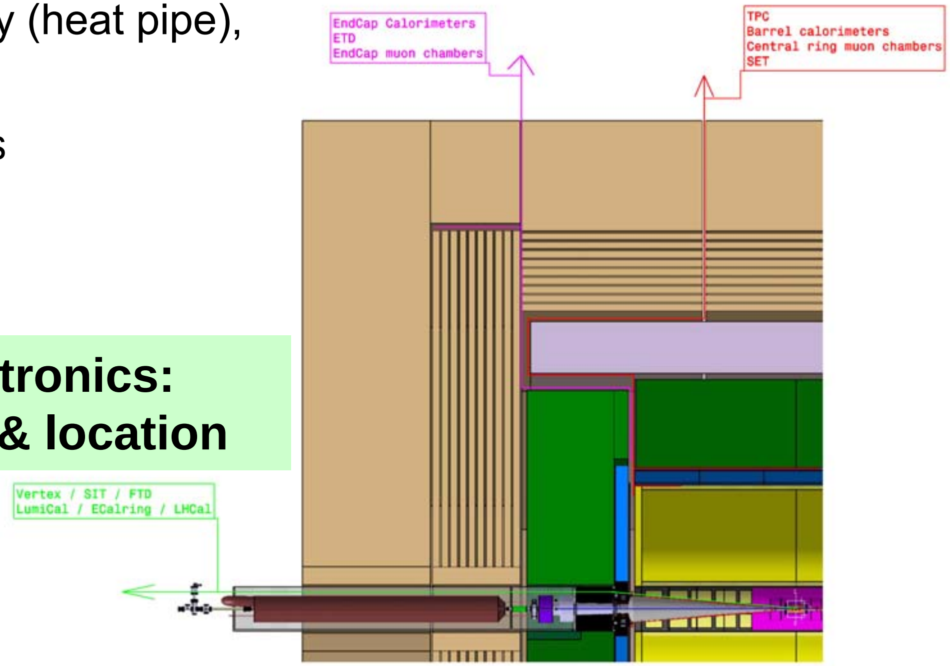
ECAL Cooling

Main Design Constraints for the cooling system:

- Cooling temperature maintained at ~ 20°C on the connexion SLAB / Cooler,
- Reduced volume,
- Quick & easy connection, according mounting procedure for modules,
- Service: fluid circulation &/or anti-gravity (heat pipe),
- Security & maintenance free.

- Barrel : 40 identical trapezoidal modules
- End-Cap : 12 modules (3 types)

  → ~ 4600 cells to join



Mechanical constraints on ECAL electronics:
Available space, heat sources power & location

Cooling Technology:

- Convective exchange with ambient as the cold source : not efficient
- Convective exchange with cold air : not enough space and pb / air pipe insulation
- Water cooling: satisfying due to T° control request – cost (full circuit or with heat pipes)
- Cooling system with gas cycling (Freon...) or with CO^2: extra cost, pressure... on study
- µ fluid-circulation on slab themselves: on study 2010

ECAL: Global COOLING

Cost / risk for global thermalization : per column

Power results :

2 FPGA per SLAB, power: 3 W each, then : 3 x 2 = 6 W
SKIROC : 0.54 W / slab → 0.3 W soit : 2 x 0.3 = **0.6 W**

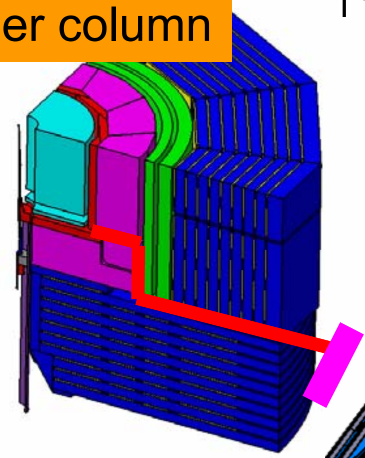
Barrel :

Global Power : 19484 W → 3029 W
Power per module : 487 W → 75.7 W
Power per column : 97.4 W → 15.1 W

End Cap :

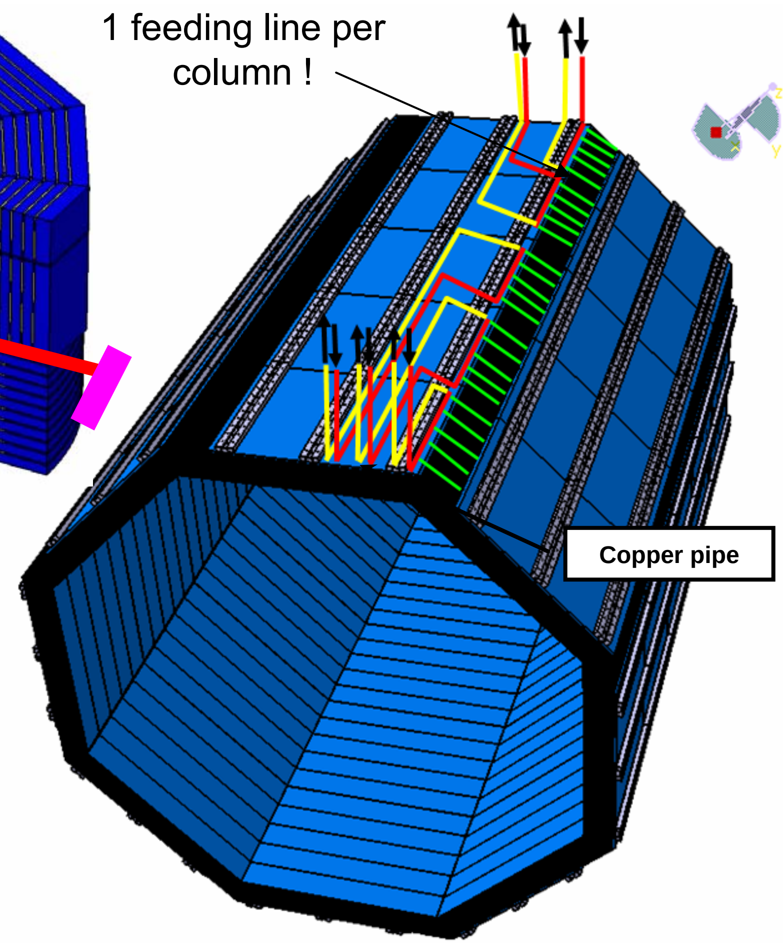
Power per End Cap : 5060 W → 768 W
Average power per module : 420 W → 64 W
Average power moyenne per column : 97 W → 15 W

Global Power : 30 000 W → 4565 W !



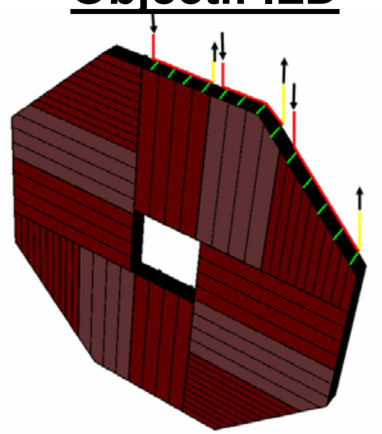
100 W/ colonne → **EUDET**

15 W/ colonne → **Objectif ILD**



Rough estimate on fluid circulation:

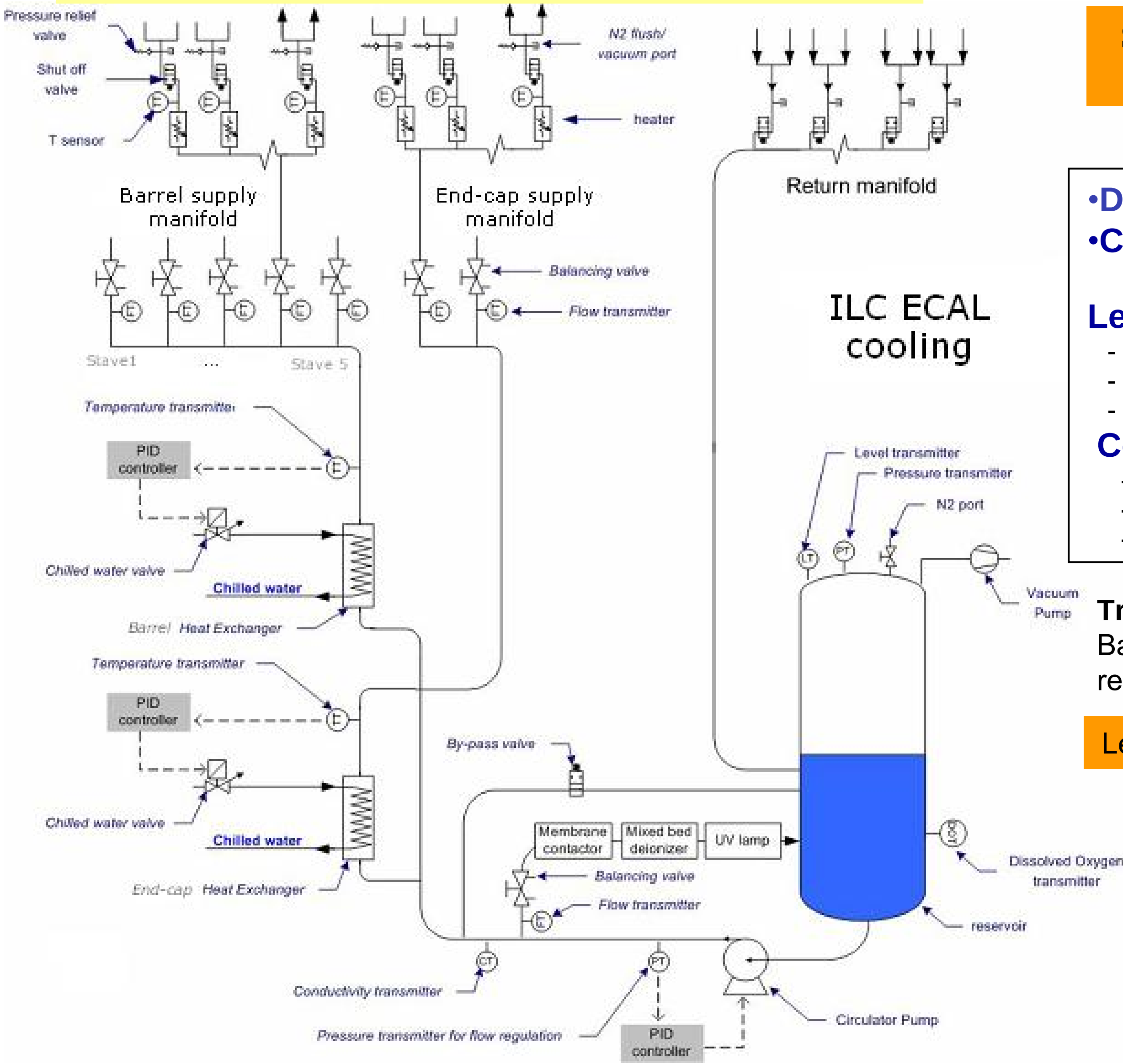
Global flow rate : 150 l/min
Variation of fluid temperature : in-out => 3°c
Fluid speed < 2 m/s
Maximal pressure drop : 1.2 bar



Depending on control…one per column, the cost of equipment near detector will be more complex and expensive… but more efficient

ECAL: Global COOLING

Simplified P&I diagram of cooling plant extrapolated from a CERN's Detector.



Study of the global cooling system for ECAL to continue:

- **Design including safety systems**
- **Cost estimation (several solutions)**

Leakless system :

- Low water speed
- Heat pipe termination
- Temperature and power range adapted

CO_2 system :

- *High pressure (30 bar)*
- Enable very low temperature
- Small pipes

True scale leakless cooling system test

Base line : leakless system with representative systems to control

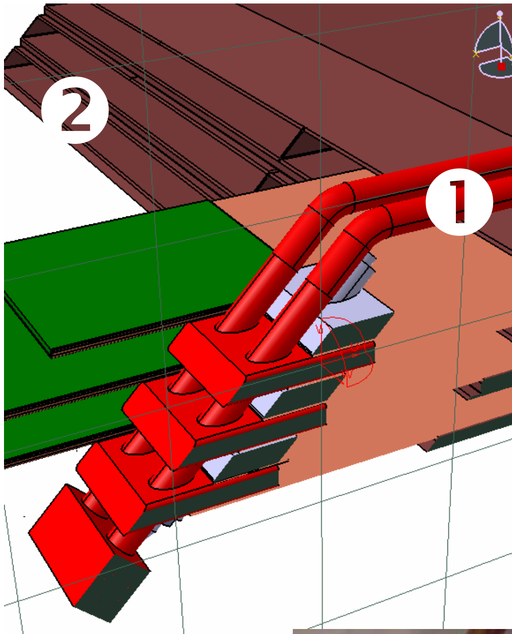
Leakless cooling system mock-up: **2010**

- the right components, sensors…
- process, regulation
- Interface and control

SLAB COOLING – tests on going

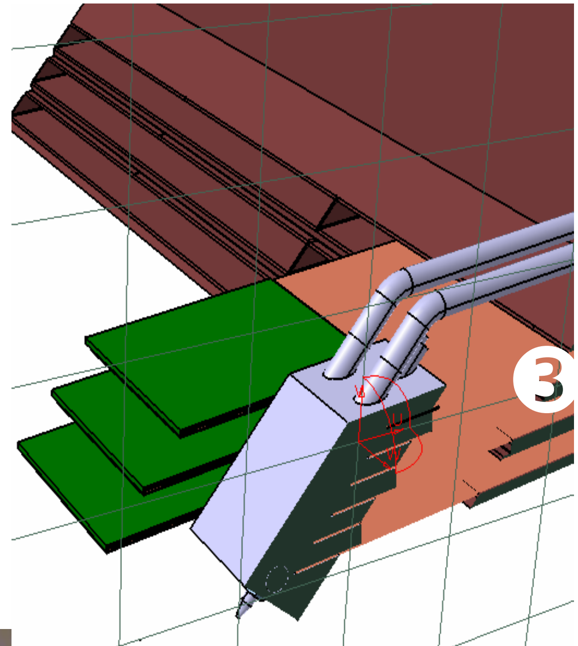
Cold plate : 3 Solutions

❶ Assembled solution



Water circulating into copper pipe (Internal diameter : 4 mm)

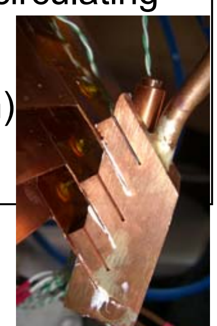
❷ Machining solution



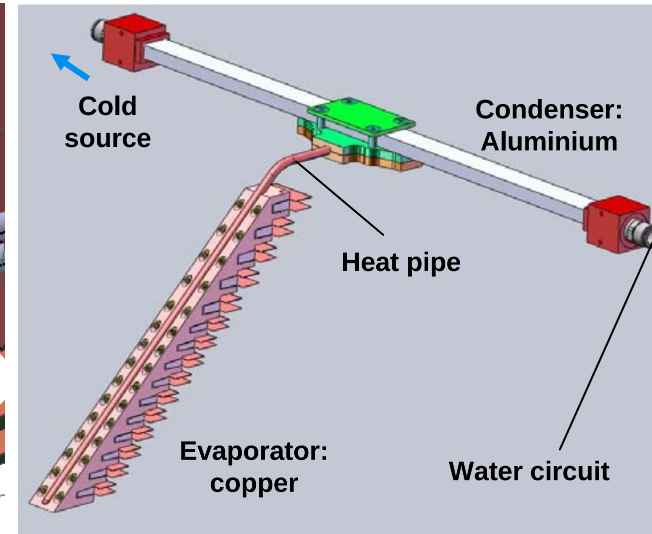
-1 block with water circulating into copper pipe

-(Internal dia.: 4 mm)

- Easier to build



❸ Heat pipe



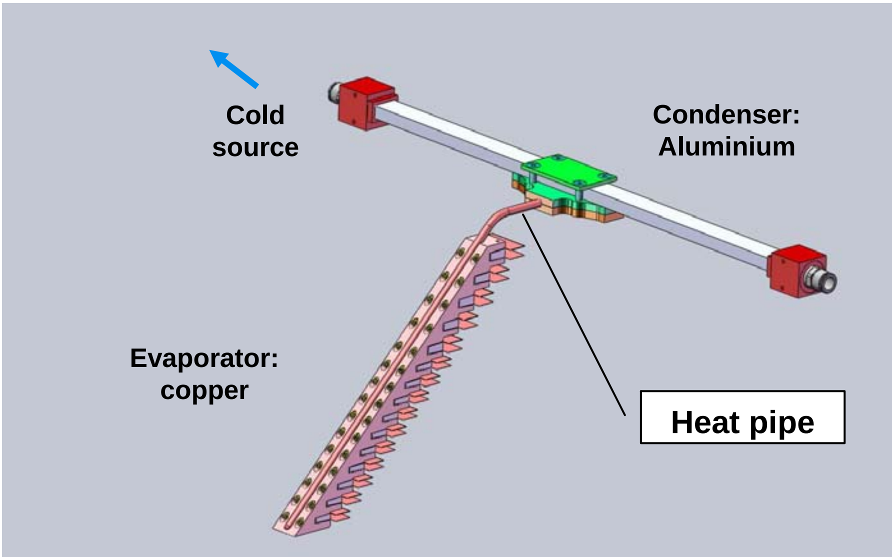
Main advantage :

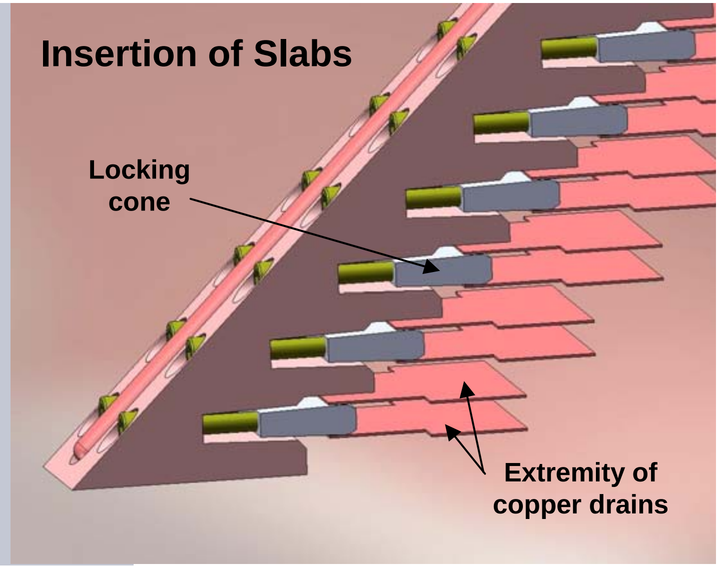
Connection between Heat pipe and water circuit => contact, far from front-end.

Easy to assemble and reduces leak risk

~ Same geometry

Heat pipe technology



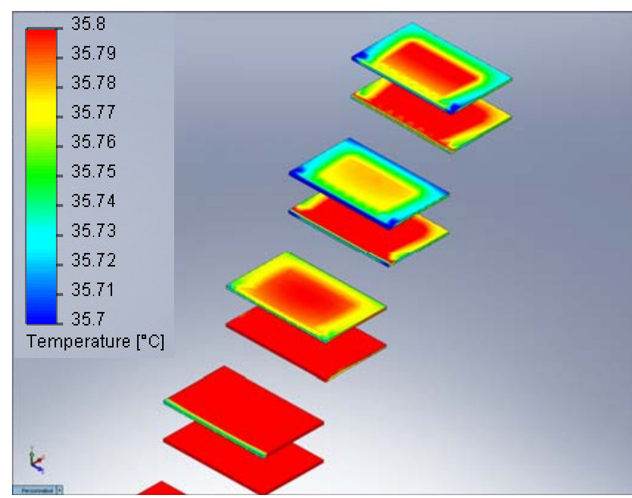


- ***Simulation vs. tests: contact resistances***

We have to know precisely the value of thermal contact resistances in opposition to heat transfer, in order to correlate simulations and the real system.

- In the simulation only the cold plate is used for cooling the system => no extra convection with the ambiant air or conduction with the support is taken into account.

Surface T° of copper drains



- **CONCLUSION (*today*)**

Cooling solution with little dimensions
A serial feeding network (connection easier to cooling circuit)

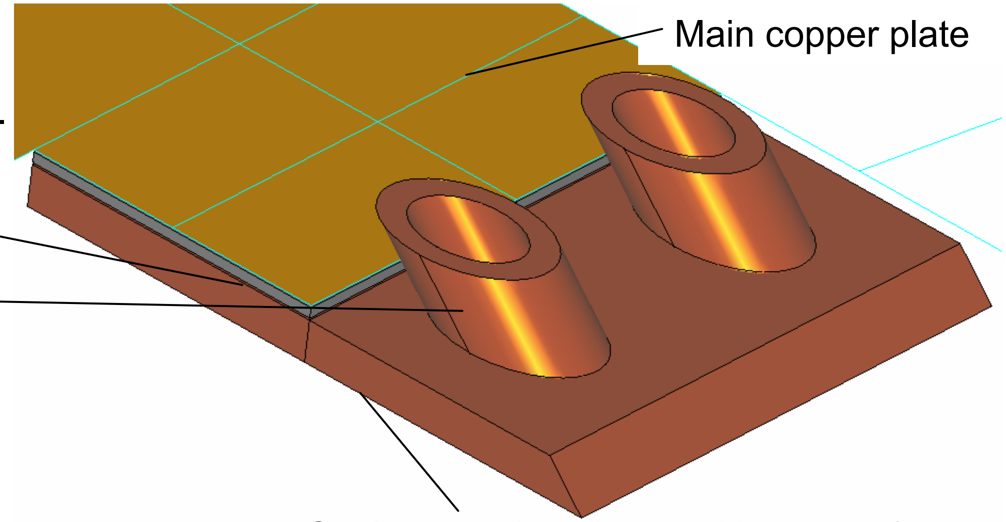
Slabs' cooling @ ± 1,1°C with ΔT = 10,7°C slabs' surface and cooling fluid

Heat pipe prototype : reception and tests: Sept 2009

EUDET: SLAB COOLING

Boundary condition:

4560 detectors «SLAB detectors» to thermalize.



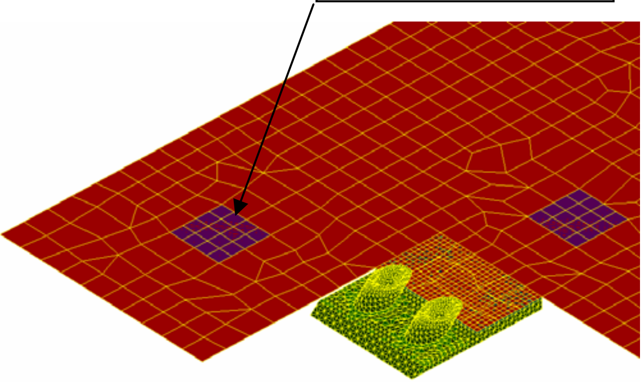
Main copper plate

Thermal foam : λ = 3 w/mK

Convective flux into pipe with fluid at 20°c (h = 3445 W/m².K)

Cold copper bloc inserted between 2 copper plate of 1 slab

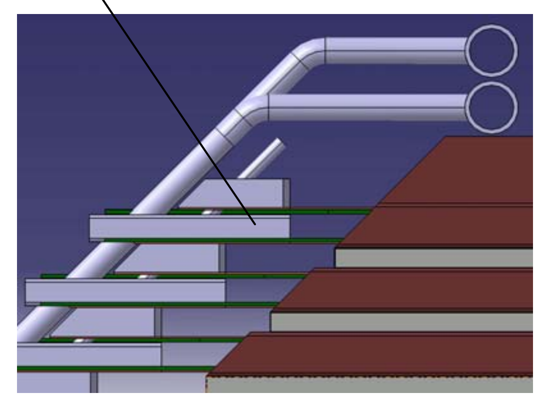
Heat surface and temperature point (FPGA location) 0.2 to 2W…



Φ= 0,27 W/layer
(25 μW per channel)

important implication upon cooling dimensions !

Ø pipe important / system for P<1 atm.

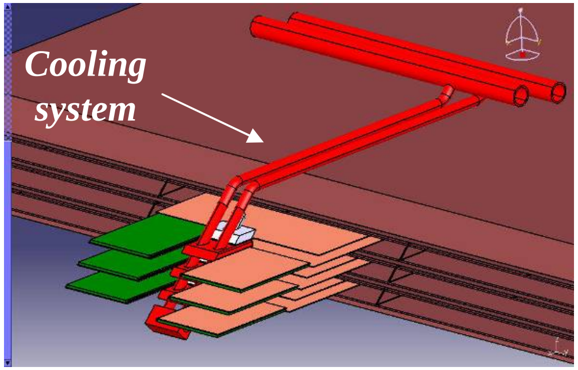


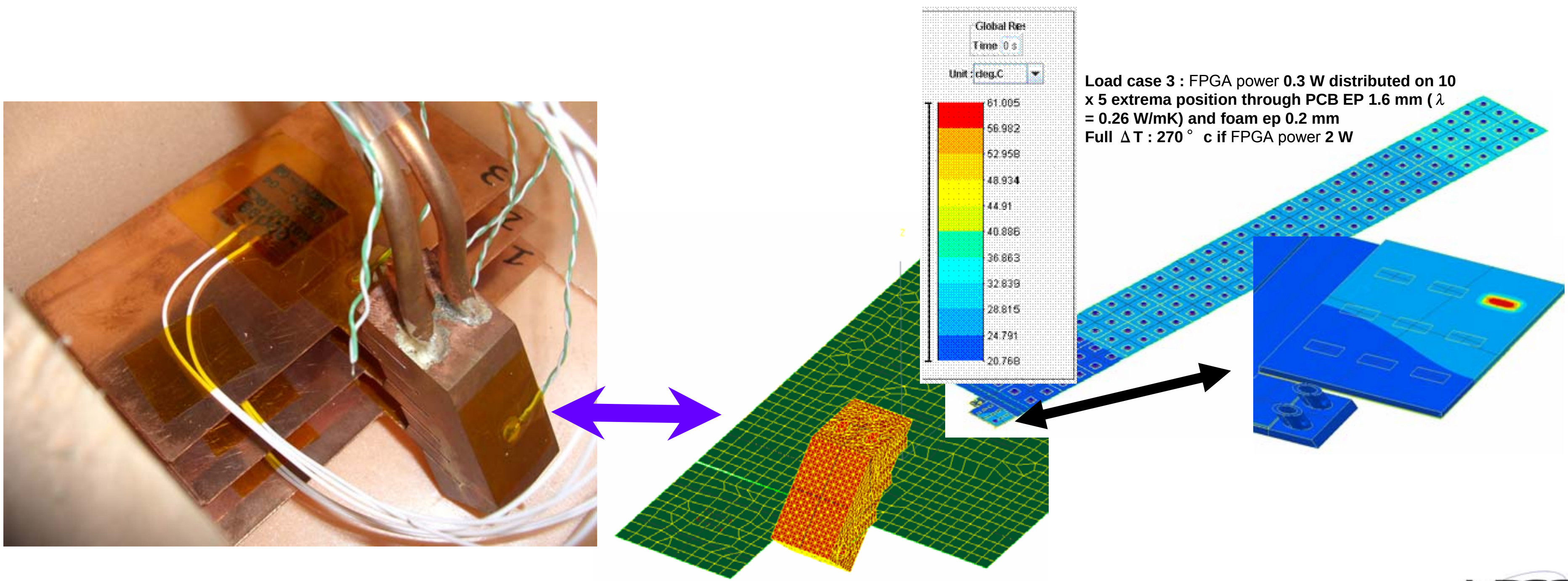
Simulation of heat conduction just by the heat copper shield : Influence of FPGA dissipation (DIF) on current design of cooling system -Limit Condition of 20°C, 500 μm Cu. Copper drain adapted / DIF card to be in contact with FPGA on DIF.

Cooling: Thermal Tests (1/2)

Goal of experimental tests: (1 Hot ASU + 8 thermal ASU):

- A real thermal test to be compared to numerical simulation
- Simplification of slab's numerical model
- To determine more precisely the transfer coefficients
- Validation of the cooling system (400 µm copper plate + pipes)
- To verify the thermal dissipation behaviour (EUDET design)





LPSC Summer Thermal Tests (2/2)

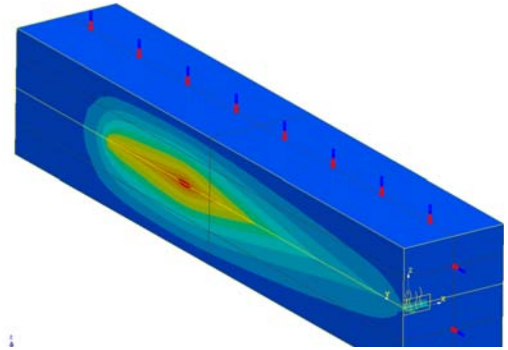
See Julien's talk today « Studies with demonstrator in 2009 »

•Thermal comportement along the slab:

Conclusion:

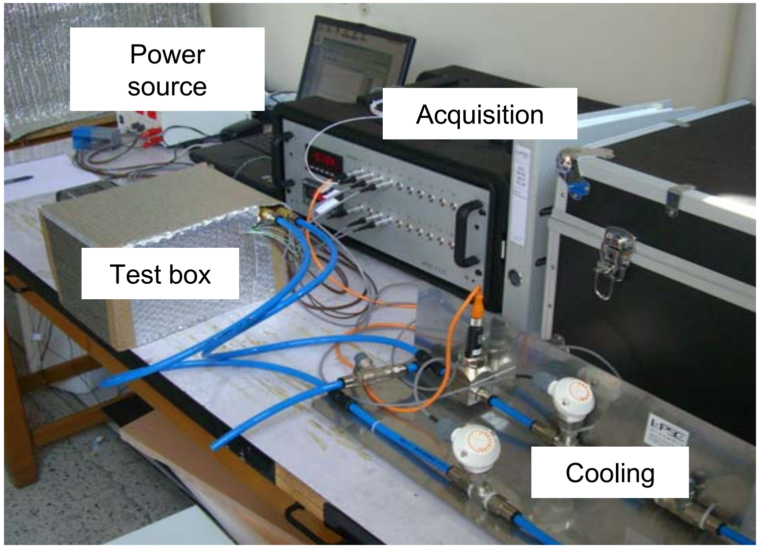
The thermal slab comportment can't be based to the comportment of the copper plate with conduction only.

⇒We need to take into account the whole structure (W, composite material…)



•Thermal contact resistance characterization:

→ Conductivity values with/without thermal paste



On going : global simulation on slab section…

Conclusion :

Cooling

- Slab cooling_tests in alveolar structure, heat pipe system (EUDET config.) **Oct 09**
- Cooling system for EUDET (water circulation with better thermal contact) **Fall 09**
- First Design for the whole detector cooling system **Spring 10**
- Correlation (thermal tests) with simulations (transfer coefficients, contacts...) **End 09**
- Alternative cooling system: CO², µ-circulation fluid, carbon pipes; MCP... **2010**
- First Design: hydraulic safety, hardened components, cooling supervision... **Sum 10**
- Design & build a "true scale test loop" : cooling system « Leakless » (<1atm) **2010**

Fabrication – tests - characterization

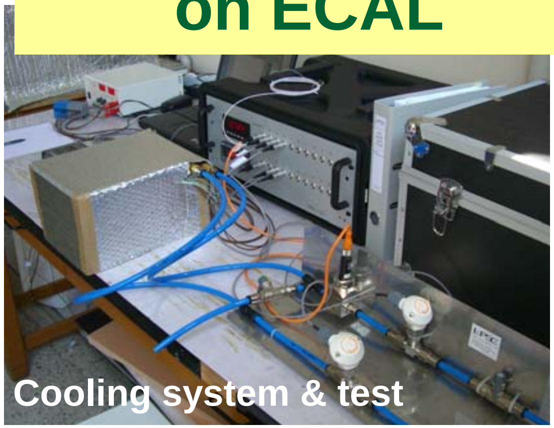
- First End-Cap alveolar cell and layer: mould reception **Nov 09**
- Cooling system: copper with better thermal contact for EUDET (45°) **Dec 09**
- Characterisation, tests & optimisation: composite elements and rails **Sum 10**

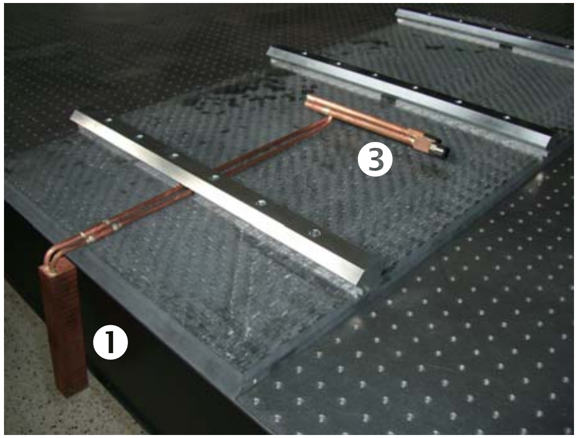
Conception - Simulation

- End-cap **design** & mechanical simulations **End 09**
- Moulds for a specific **End-cap** module's **cell & layer** (2,50m !) **Dec 09**
- **Fastening system** ECAL/HCAL: alternatives; modules' coupling. **Spring 10**
- Handling and positioning tools for modules **Spring 10**
- Collaboration to extend with Moroccan RUPHE (Univ.HassanII-Casablanca) **2010**

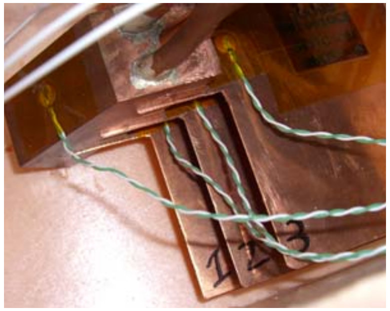
Thank you for your attention

Mechanical R&D on ECAL

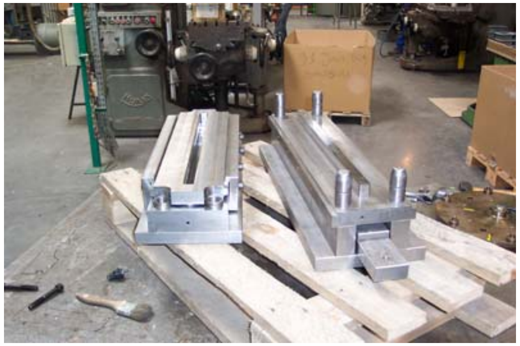

Cooling system & test


15mm thick plate with it's rails; ready to be assembled with EUDET's layers

THERMAL tests

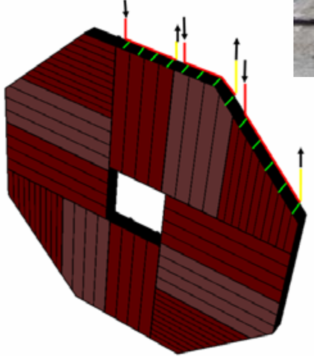


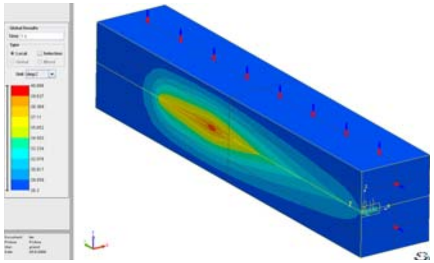

Destructive tests

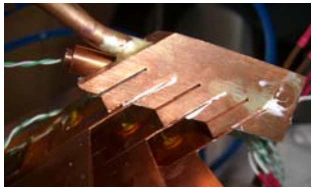



Water cooling block

End-cap design








Fastening system