

# *Status of ECAL*

## *Mechanical and thermal*

### *R&D in Grenoble*



**SiW Ecal Meeting 03.06.08**

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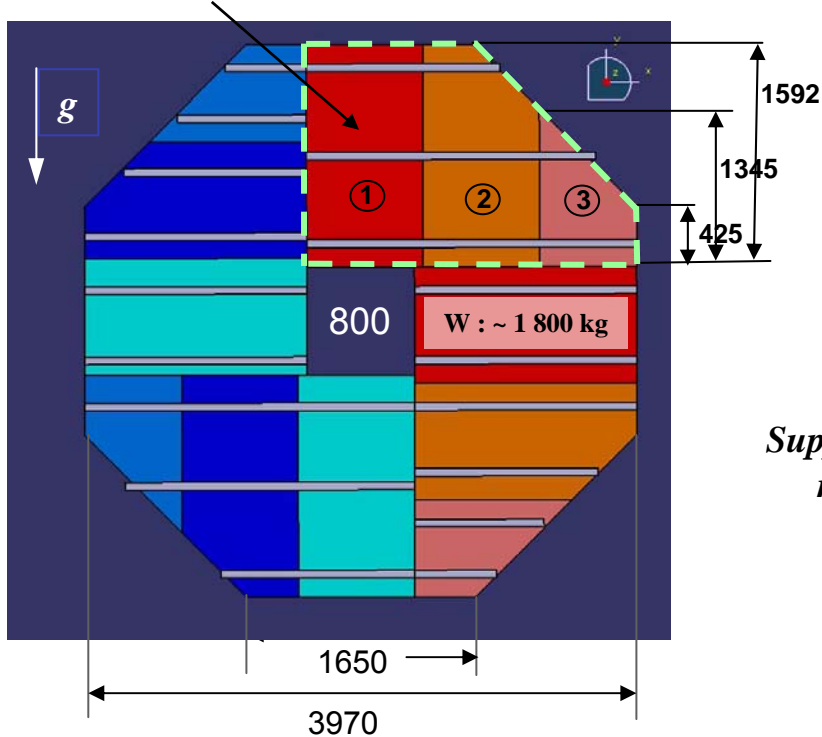


# ECAL - End-Caps design (1)

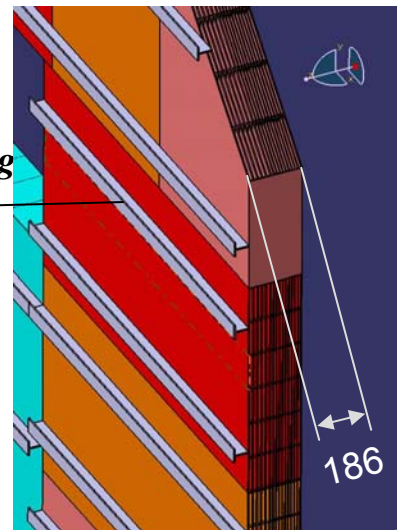
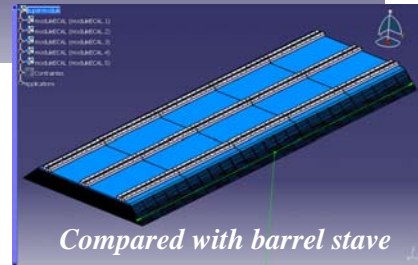
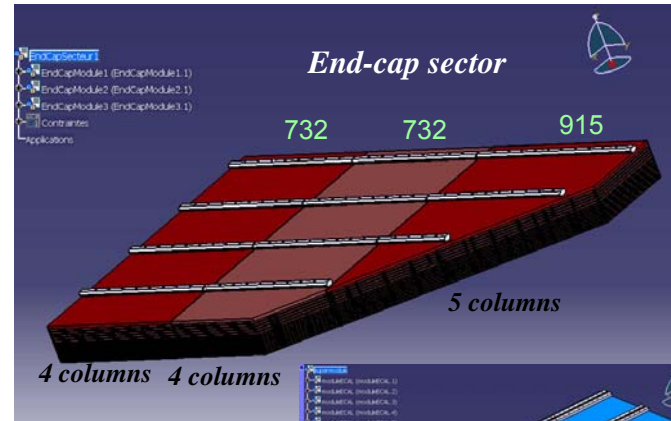
## Design: 1

- The same principle than barrel with an alveolar composite/tungsten structure, with **different shapes** and **different sizes (end of slabs)**
- **Difficulty:** getting shape for W plates
- **12 modules-3 distinct types** (780 cells & detectors slab)

Configuration 0°



Weight of each End-Cap : ~ 16 T



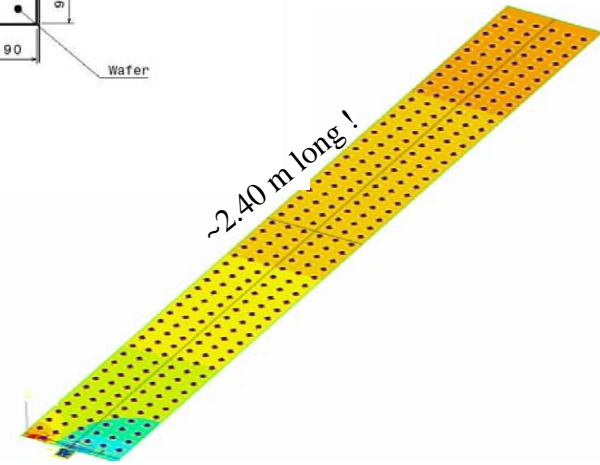
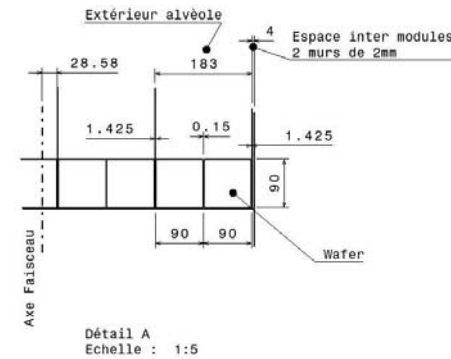
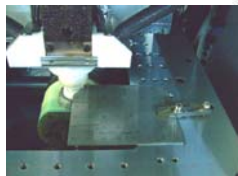
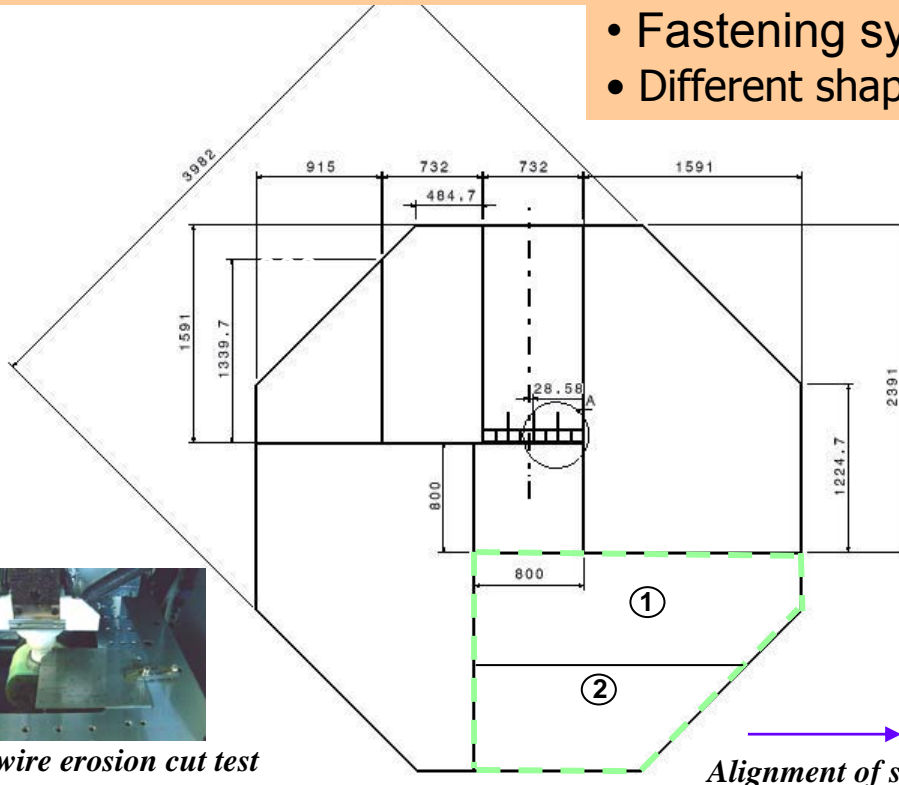
# ECAL - End-Caps design (2)

## Design: 2

- Due to the possible crack in the geometry of design 1 (*H.Videau-LLR*) the same general shape could be saved with **different size and position of modules**
- Instead of 12 modules from 3 distinct types: **8 super-modules from 2 distinct types**

### Difficulties:

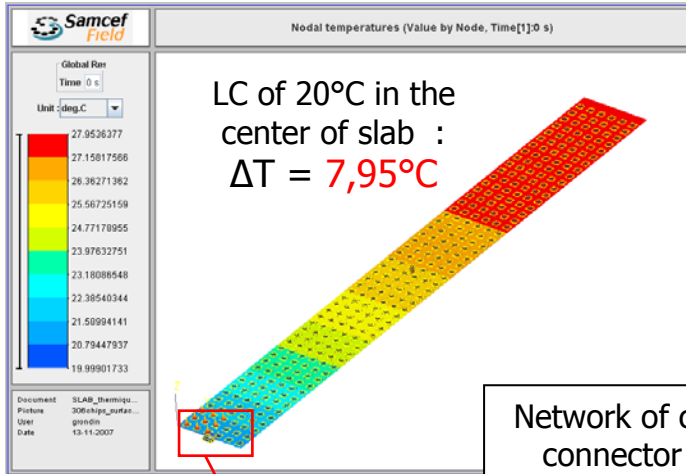
- Thermal (2.40m instead of 1.50m for longest): T° dangerously rising in back-end of slabs
  - Mechanical: >2.40m long thin alveoli maybe not feasible,
  - Fastening system on HCAL /weight of module >3T ?
  - Different shapes of long slabs: cost increasing



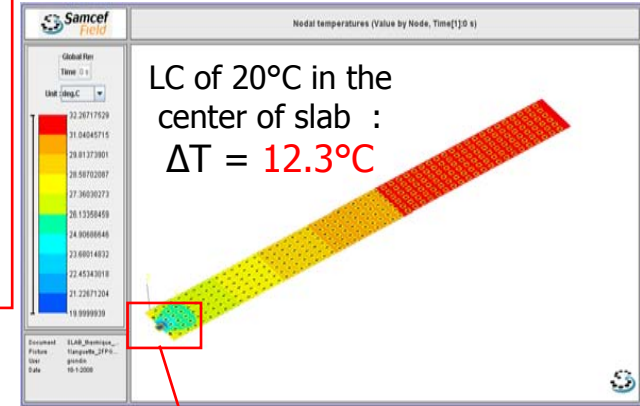
# Thermal analysis of slab

**Simulation** of heat conduction just by the heat copper shield :

Influence of the **FPGA dissipation** (DIF) on current design of cooling system  
(Limit Condition of 20°C) :

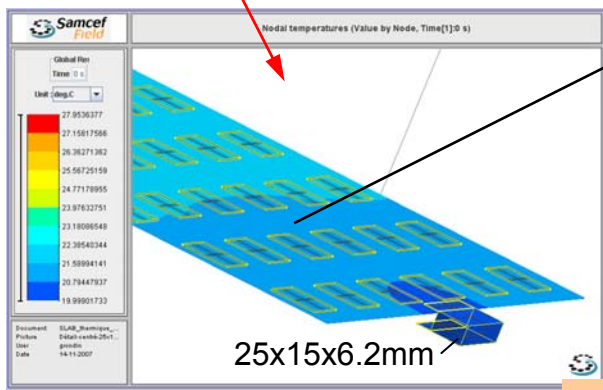


←  $\Phi = 0,27 \text{ W/layer}$   
(25  $\mu\text{W}$  per channel)  
 $\Phi_{\text{FPGA}} = 3 \text{ W/layer}$  →  
**Copper layer** :  $\lambda = 400 \text{ W/m/K}$   
 $S = 180 \times 0,4 \text{ mm}^2$  ;  $L = 1,55 \text{ m}$

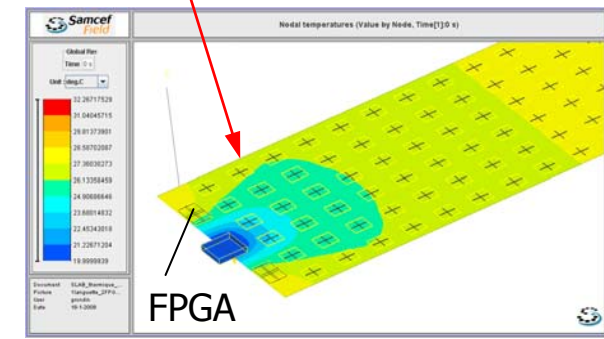
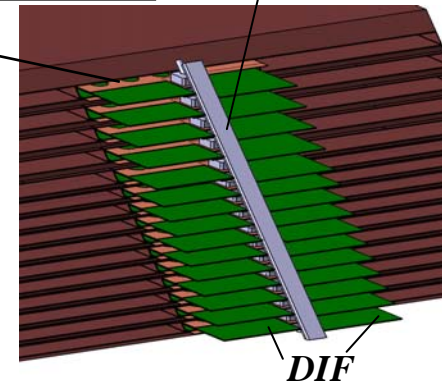


Network of contact areas / connector fixed on the 2 layers

Cooling Pipe



1 copper layer

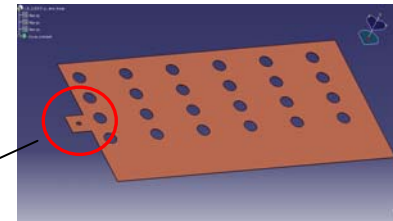


$\Delta T$  and size of cooling pipe increase ( $\Phi T = 8.1 \text{ W}$  to  $98.1 \text{ W}$ )

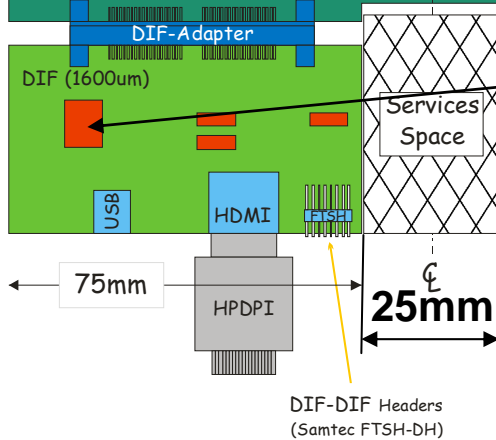
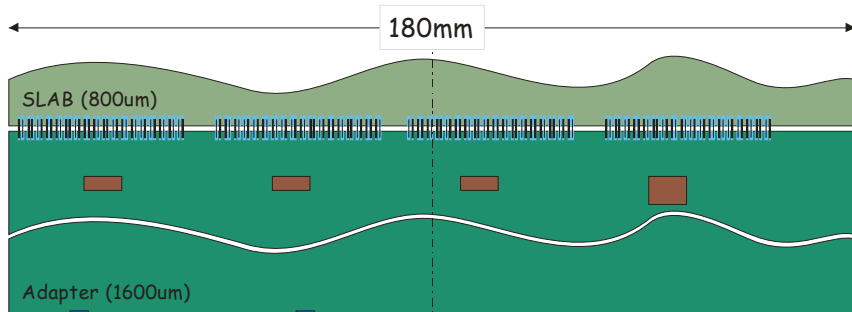
# Design of interface slab/DIF

Current Module design **compatible** with proposal from Cambridge

- Adapter board (size, thickness ...)
- Components size
- Connectors size
- Fastening devices / back-end system

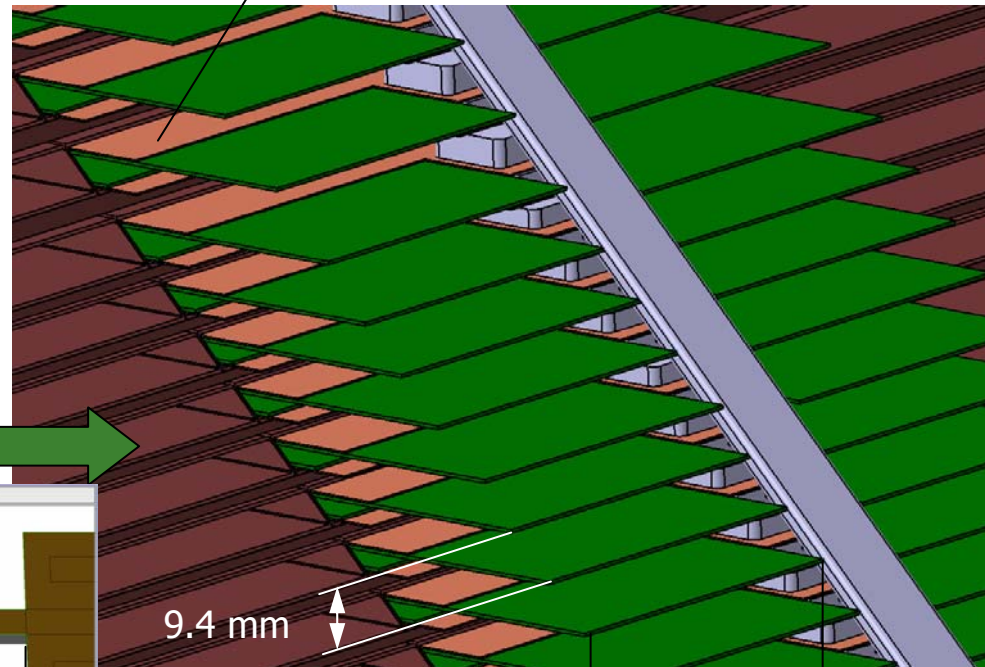
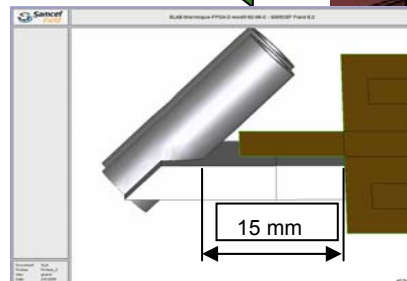


Copper plate on the PCB



DIF-DIF Headers (Samtec FTSH-DH)

FPGA?



9.4 mm

78 mm

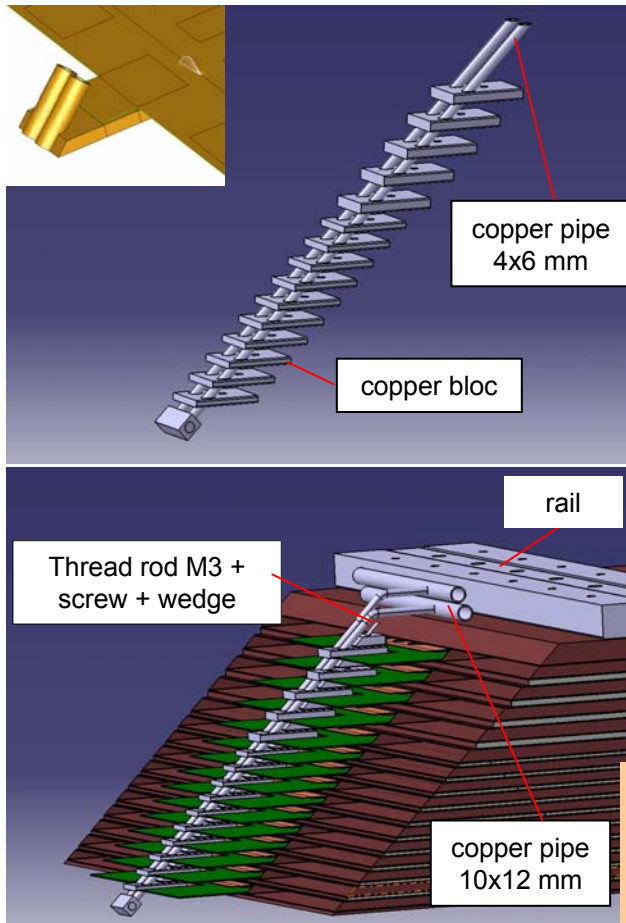
(from Maurice Goodrick, Bart Hommels)

# External cooling system

... taking into account thermal analysis of slab

**2 types of cooling systems to test:**

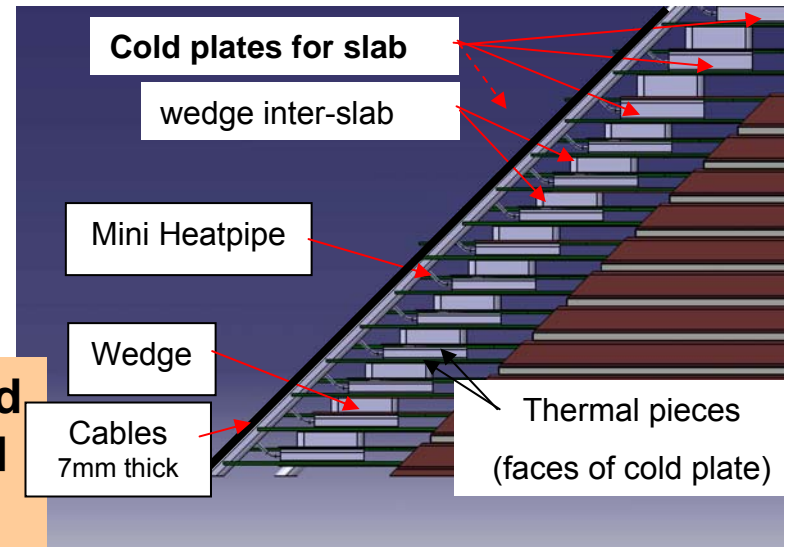
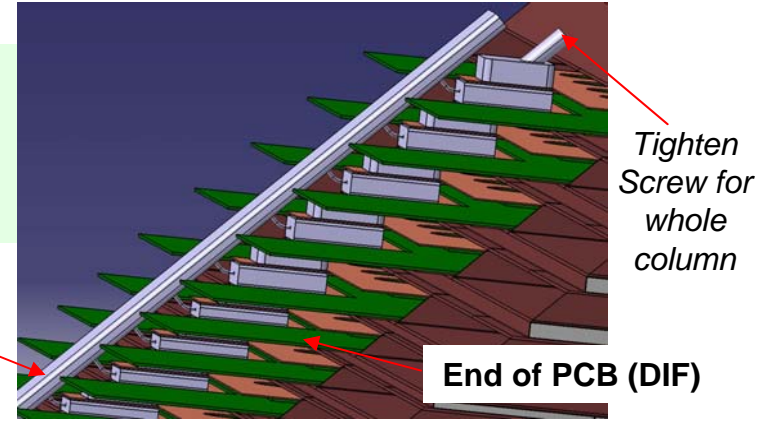
## ① Copper pipes brazed



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

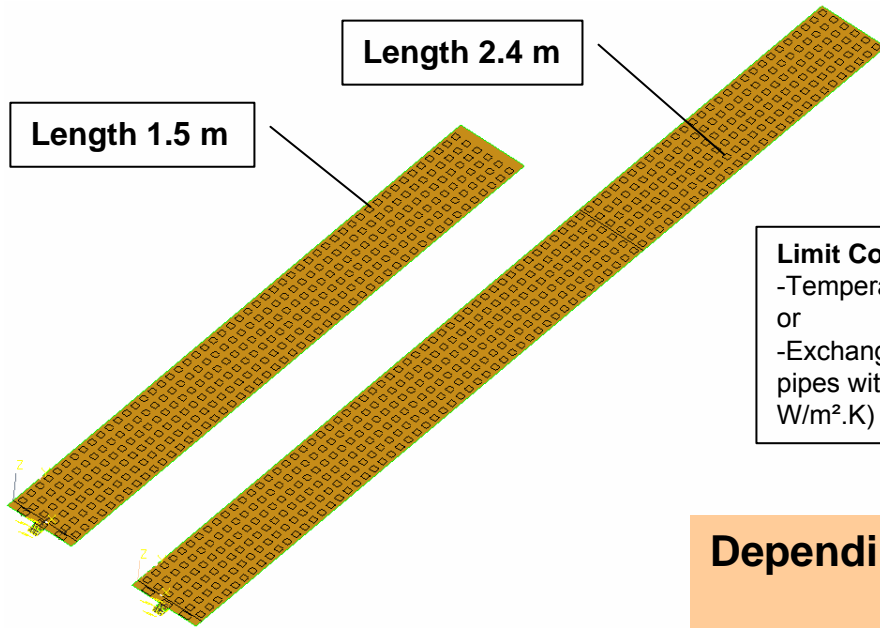
Cold plate for column

## ② Heat pipes

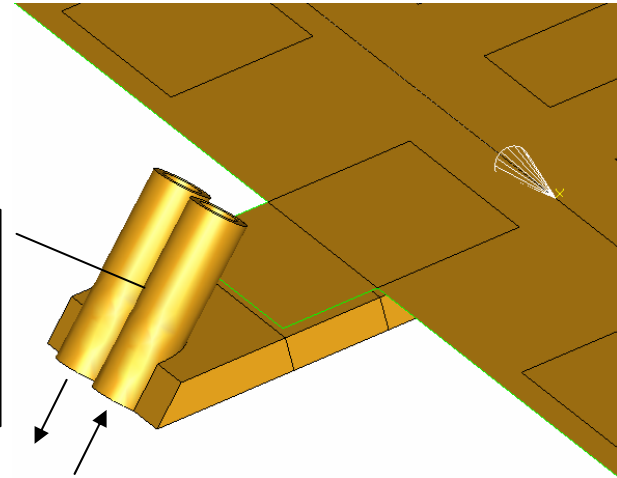


**Both to be tested on : EUDET and demonstrator**

# Performance/cooling system



**Limit Conditions:**  
 -Temperature imposed of 20°C  
 or  
 -Exchange coefficient in the pipes with fluid at 20°C ( $h = 3445 \text{ W/m}^2\cdot\text{K}$ )



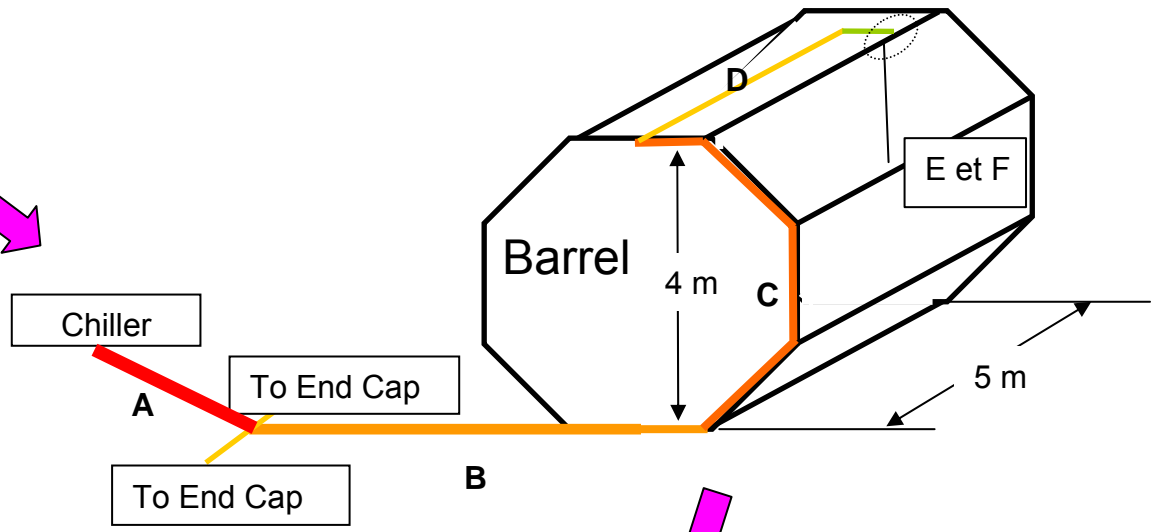
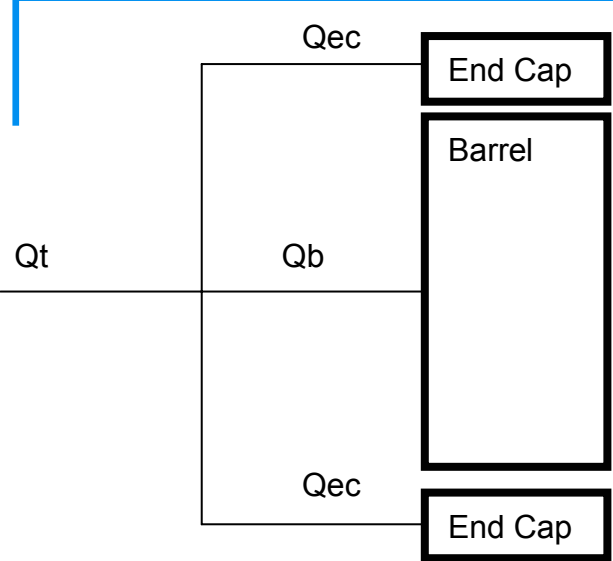
**Depending on:**

- length of slab
- *type of cooling system*

load : 1/2 SLAB	
FPGA power (one side of the SLAB)	3 W
SKIROC SLAB 1,5 m	0,27 W
SKIROC SLAB 2,4 m	0,42 W

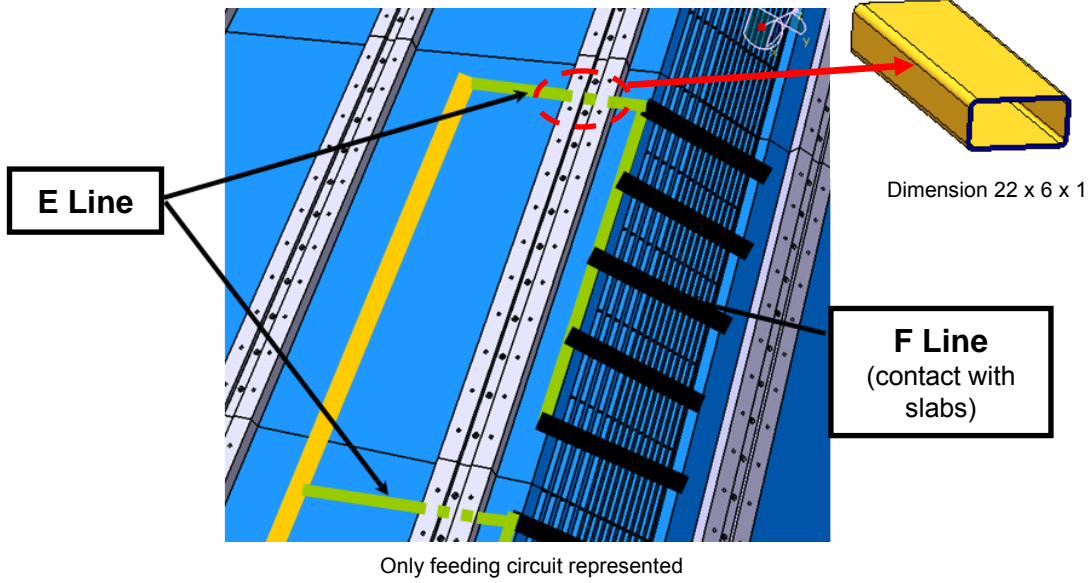
FPGA	SLAB : 1,5 m						SLAB : 2,4 m						Comments
	with			without			with			without			
Temperature (°C)	Tmin	Tmax	Difference	Tmin	Tmax	Difference	Tmin	Tmax	Difference	Tmin	Tmax	Difference	
20°C imposed at one SLAB extremity	20	37,79	17,8	20,0	27,7	7,7	20,0	44,3	24,3	20,0	38,0	18,0	Uniform copper thickness : 0,4 mm
Exchange coefficient inside pipe and fluid temperature of 20°C	21,4	42,78	21,4	20,1	28,1	7,9	21,5	50,2	28,7	20,2	38,8	18,6	Uniform copper thickness : 0,4 mm
Exchange coefficient inside pipe and fluid temperature of 20°C and copper thickness different near FPGA	21,4	38,8	17,4	20,1	27,9	7,8							Copper thickness : 0,4 mm except near FPGA : 0,6 mm
Exchange coefficient inside pipe and fluid temperature of 20°C and copper thickness uniform							21,5	41,9	20,4	20,2	32,7	12,5	Uniform copper thickness : 0,6 mm

# Cooling: global circulation (1)



Taking into account length and diameter for study

Zone	Longueur (m)	Diamètre intérieur (mm)
A	50	45
B	15	35
C	7	25
D	5	15
E	1,5	10
F	0,3	4





# Cooling: global circulation (2)

## Power results :

2 FPGA per SLAB, power: 3 W each, then :  $3 \times 2 = 6$  W

SKIROC : 0.54 W / slab

### Barrel :

Global Power : 19484 W

Power per module : 487 W

Power per column : 97.4 W

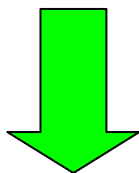
### End Cap :

Power per End Cap : 5060 W

Average power per module : 420 W  $(390+390+480)/3$

Average power moyenne per column : 97 W

Global Power : 30 000 W



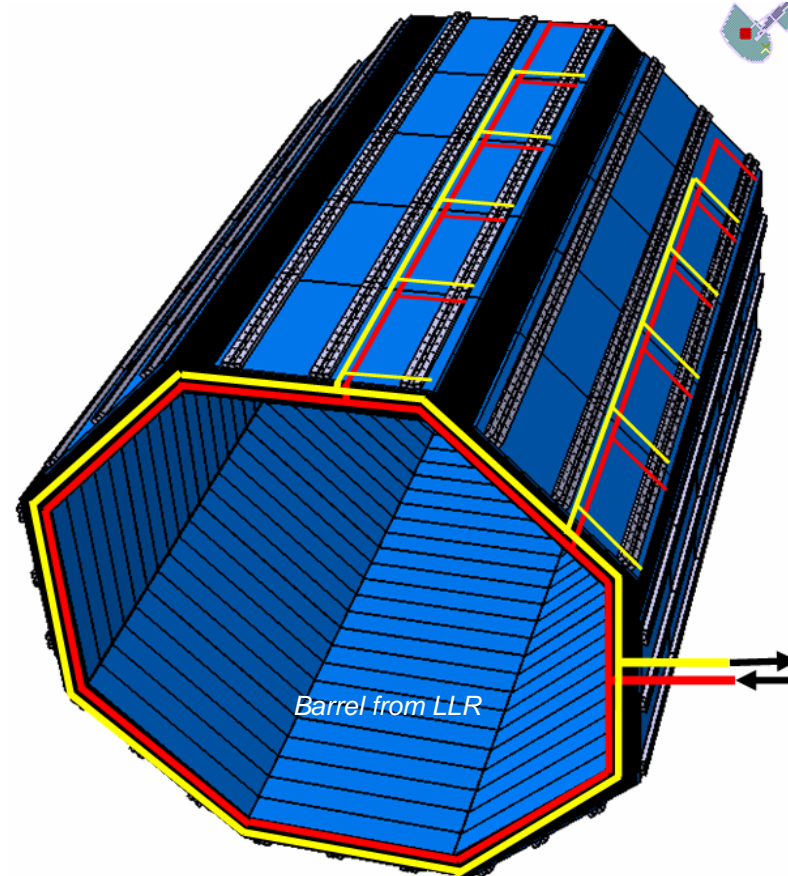
## Rough estimate on fluid circulation:

Global flow rate : 150 l/min

Variation of fluid temperature : in-out => 3°C

Fluid speed < 2 m/s

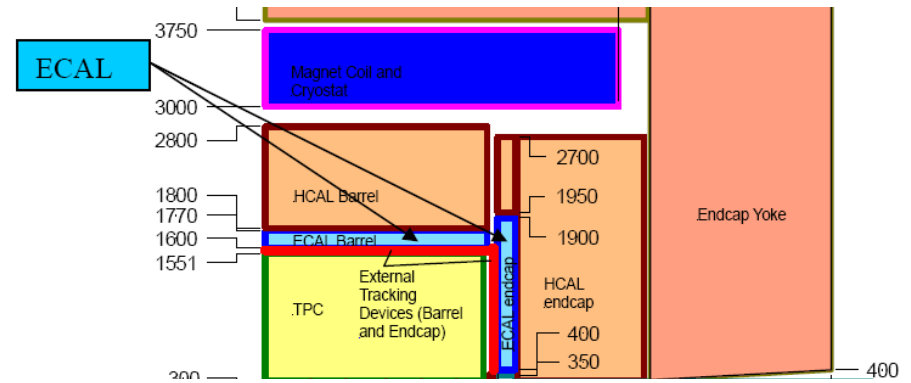
Maximal pressure drop : 1.2 bar



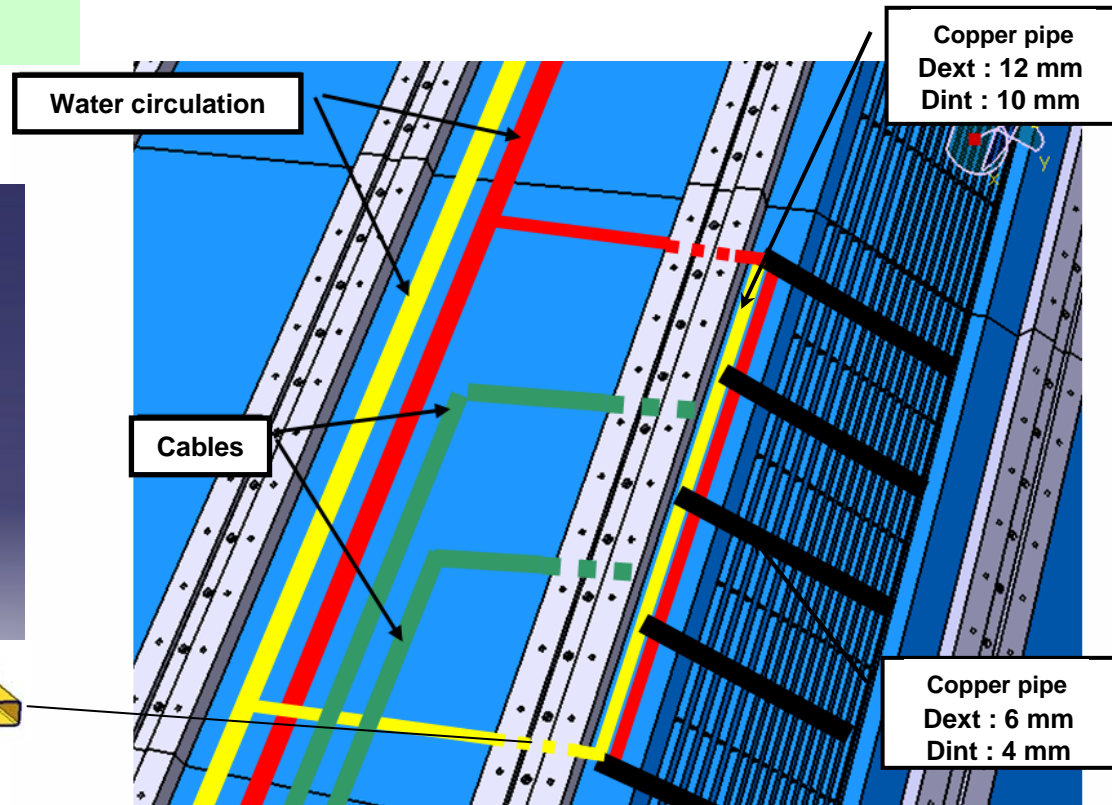
# Fluid circulation / mounting

Fluid circulation => passages for pipes toward exterior of detector => free space to find and to adapt:

- Passage for pipes and cables under rails (machining on composite surface)
- Connection of pipes according mounting procedure for modules (per 5 / 3 and 2 / 1 after each)



Passage under rails in 15mm thick plate for both pipes and cables



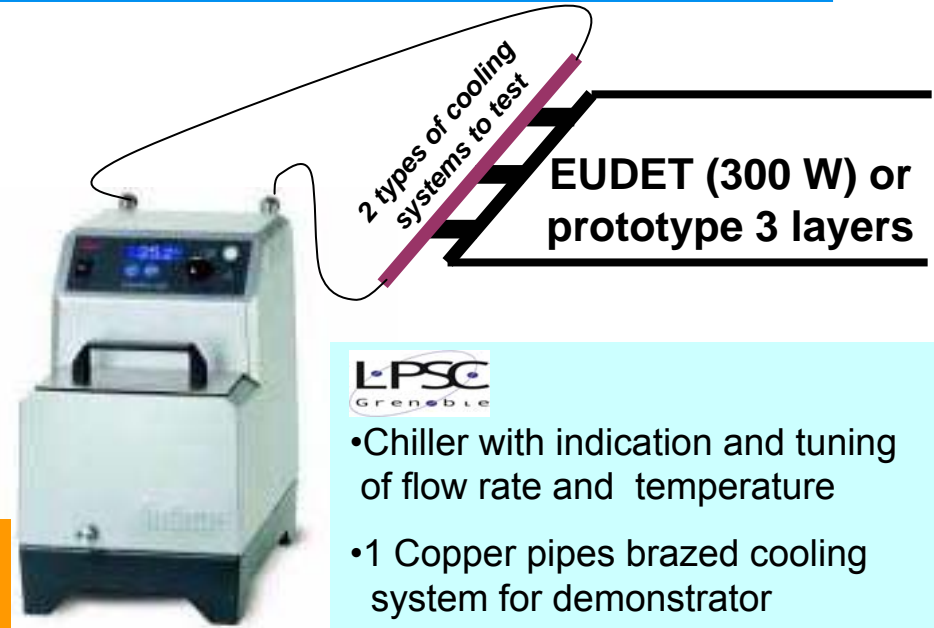
# Means for cooling tests

**Use : EUDET and demonstrator**

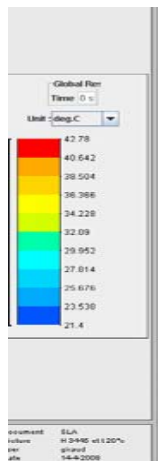
**Mounting characteristics :**

- Flow rate : 0.5 l/min to 1 l/min
- Power to drain off : 100 W (3 layers) to 300 W
- Temperature of fluid control at 20°C
- ajustable parameters : temperature & flow rate

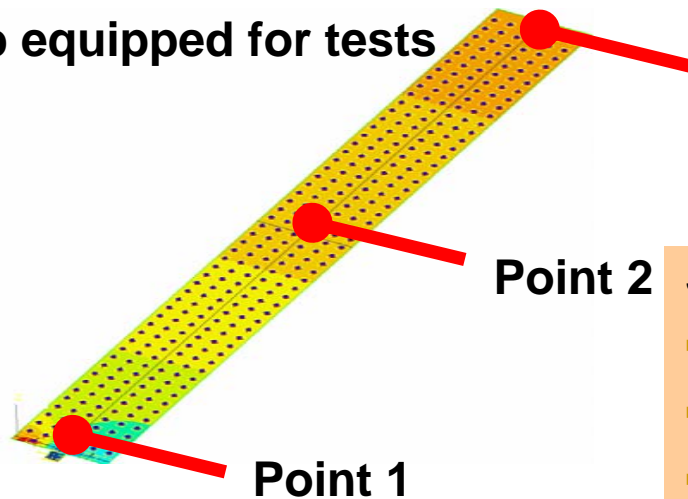
**Localization of measurement points for temperature survey (PT100 probe):**



- Chiller with indication and tuning of flow rate and temperature
- 1 Copper pipes brazed cooling system for demonstrator
- 1 Copper pipes brazed + 1 heat pipe cooling system for EUDET module
- Test procedures and recalculating



**Slab equipped for tests**



**Point 3**

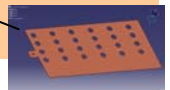
**Point 2**

**Point 1**

**SLAB prototype to equip with:**



- Remote power to simulate a real detector
- Copper shielding (drains) with specific geometry
- 3 measuring points inside



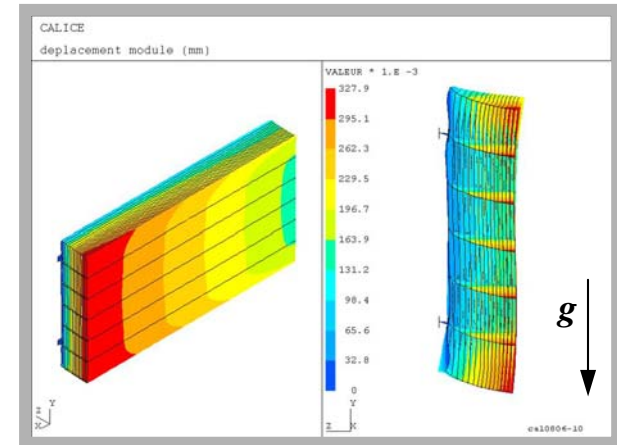
# Design of module ...

... based on mechanical simulations :

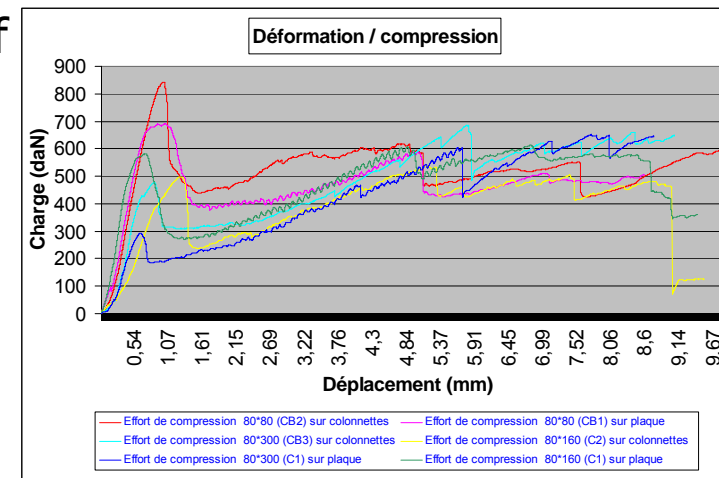
Linear Analysis of "full scale" ECAL modules (barrel and End-caps)

OK

- **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

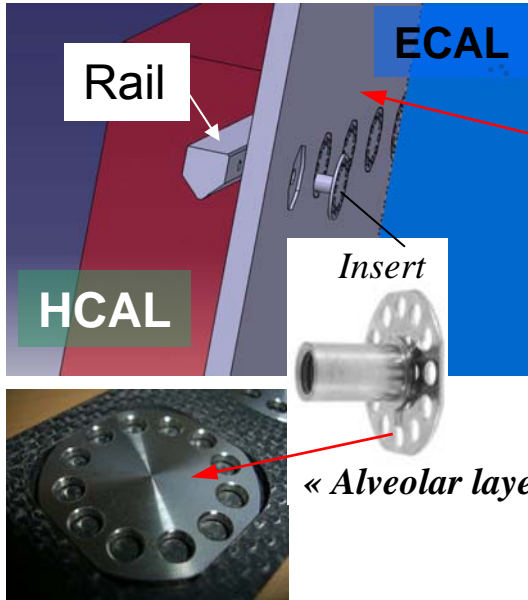


End-Cap module  
Configuration 90°

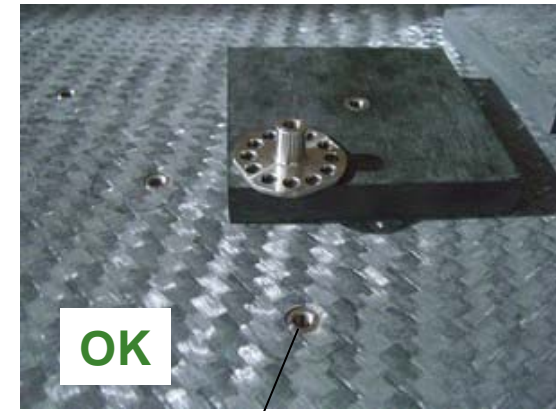
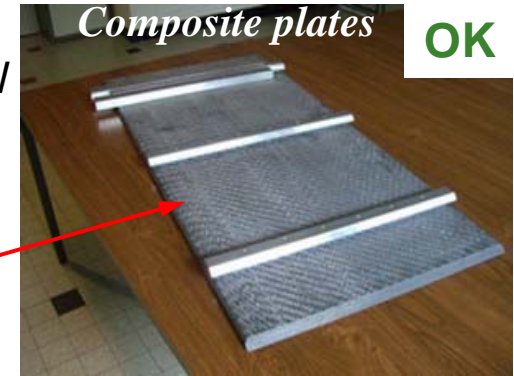
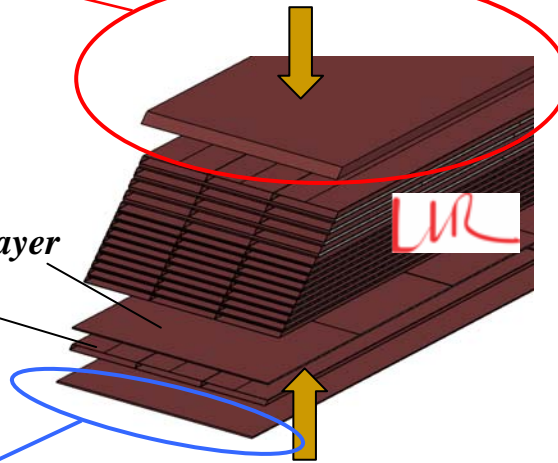


# Fastening system ECAL/HCAL

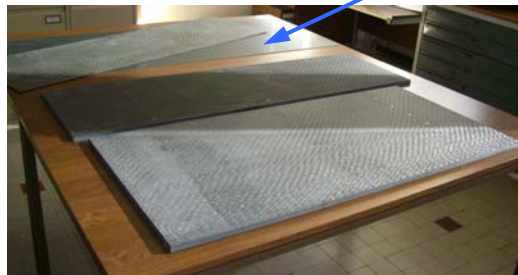
**Assembled structure** : Each alveolar layer are done **independently**, **cut** to the right length (with 45°) and **assembled** alternatively with W plates in a second curing step.



Uniform dispatch of 18 inserts  
on the 15mm thick plate

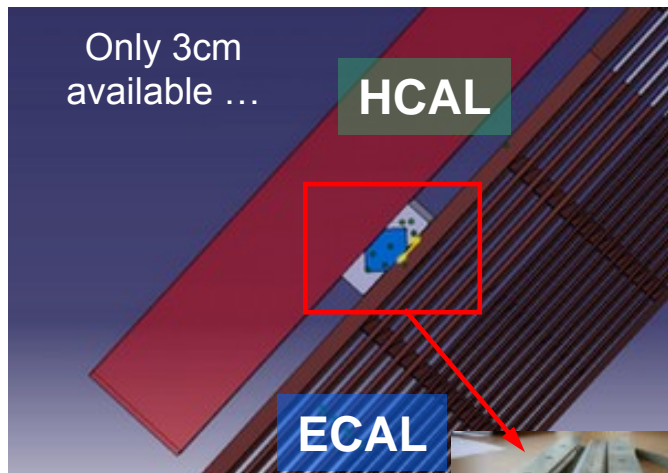


Composite plates 2mm & 15 mm



Fastening system (inserts)

**principle #2** : assembled structure :  
This principle allows to **introduce** metallic inserts before assembling in 15 mm thick composite plate. Inserts are **glued** into the plate (epoxy resin)  
⇒ **Ready** : 4 composite plates (15mm and 2 mm)



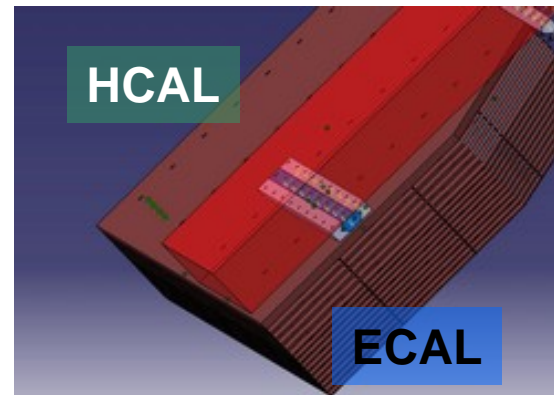
*EUDET 15mm thick plate with it's rails;  
ready to be assembled with alveoli layers*

Rails fixed by the way of inserts **directly** on ECAL modules.

... including ECAL/HCAL interfaces (+ inlet/outlet) :

- Choice of **fasteners** : rails screwed through the medium of inserts. Non magnetic ( $B=4T$  !)
- Mechanical simulations of the ECAL/HCAL interface to take into account of its **influence**
- Design of **connection system** (power supply + cooling + outlets) and of DIF cards support

Choices will have to comply with specificities of barrel and End-caps (size, wires, cooling ...)

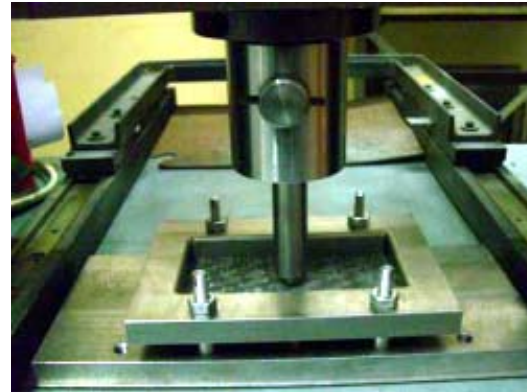


*ECAL/HCAL – End-Cap  
Configuration 0° - central module*

# Interface ECAL/HCAL (1)

## Mechanical tests of interface (feb 2008):

- **Destructive tests** of fastening elements: until breaking of interface in order to evaluate **constraints** and **elongations** under different loading cases:
  - Tensile / Compression
  - Cutting / Bending



*tools for tensile tests*

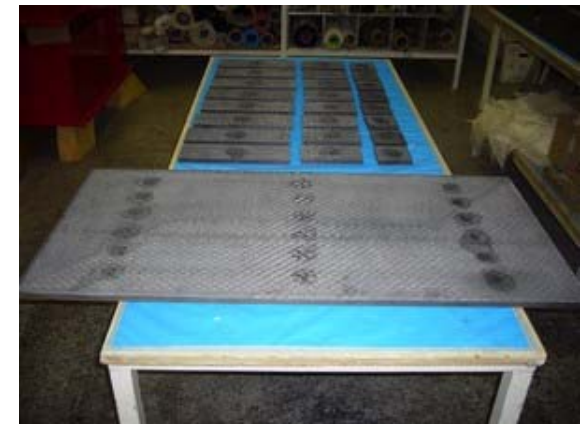


*Machine for destructive tests*



*tools for tensile and compression tests*

- Check and validate simulation results by **destructive tests** for each issues : **OK**
- Similar type of tests to be performed for:
  - **characterization and calculation** of LLR inter-alveoli thin sheets of composite (**soon**)
  - Checking of full equipped demonstrator **fastening system** (**soon**)

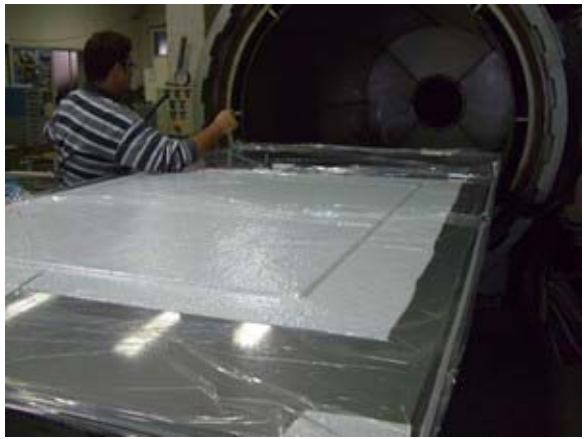
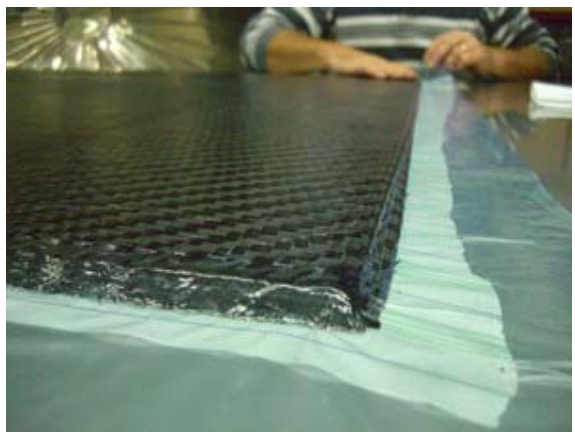
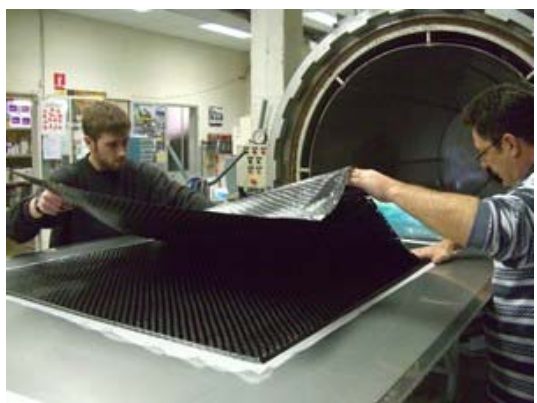


*Test pieces (interface)*

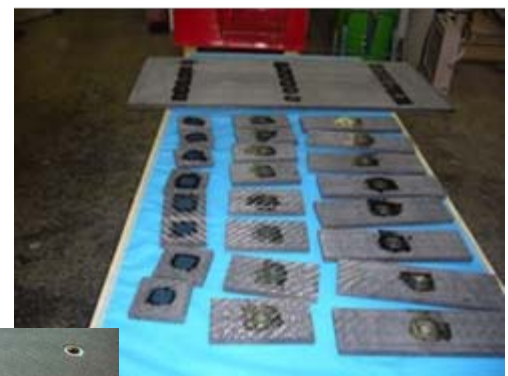
# Interface ECAL/HCAL (2)



**Winter 2007-08**



**Fabrication and destructive tests of 15mm thick composite samples with inserts ( For Eudet & demonstrator)**



**ILC - ECAL  
Mechanical R&D**

**1 for loading test with rails - 1 for mechanical tests with inserts  
Next one in february 2008 for Eudet**





## Modules: studies

- *Finite Element Model of end-cap modules to estimate the overall deflection, with new cells 180x8.6. Geometry confirmation on End-cap (max.length of slabs). Thermal simulations.*
- *Optimization of composite sheets : studies of best parameters for thick plates*
- *Fastening system design (rails, facilitated insertion of modules) and inserts drawings : OK*
- *Cooling system and technology: Thermal study - design of copper pipes & heat pipes*

## Modules: Tests

- *Metrology & Machining tests of tungsten plates: OK Cutting tests on demonstrator: Oct.08*
- *Moulding of the composite parts 15mm & 2mm thick with metal inserts: OK*
- *Destructive tests on composite samples with inserts: OK. On LLR « I » thin walls: june 08*
- *Prototype of cooling system: 1st of 2 solutions of connection kit for slabs: summer 2008...*
- *Fastening system ECAL/HCAL: destructive tests on the demonstrator: summer 2008*

## Collaboration: needs



Backend system (DIF support): **Confirmation of FPGA consumption and position...**



Composite **Structures** : **demonstrator** (3 layers – 126mm) and **EUDET module structures** to be assembled and tested with fastening and cooling system.



Detector slabs **integration for thermal tests** with tuned power, copper shields with specific geometry and 3 temperature probes.

Other studies & tests on going on Composite Structures & Services for **CALICE (End-Caps)**