Status of ECAL Mechanical and thermal R&D in Grenoble

FJPPL'08

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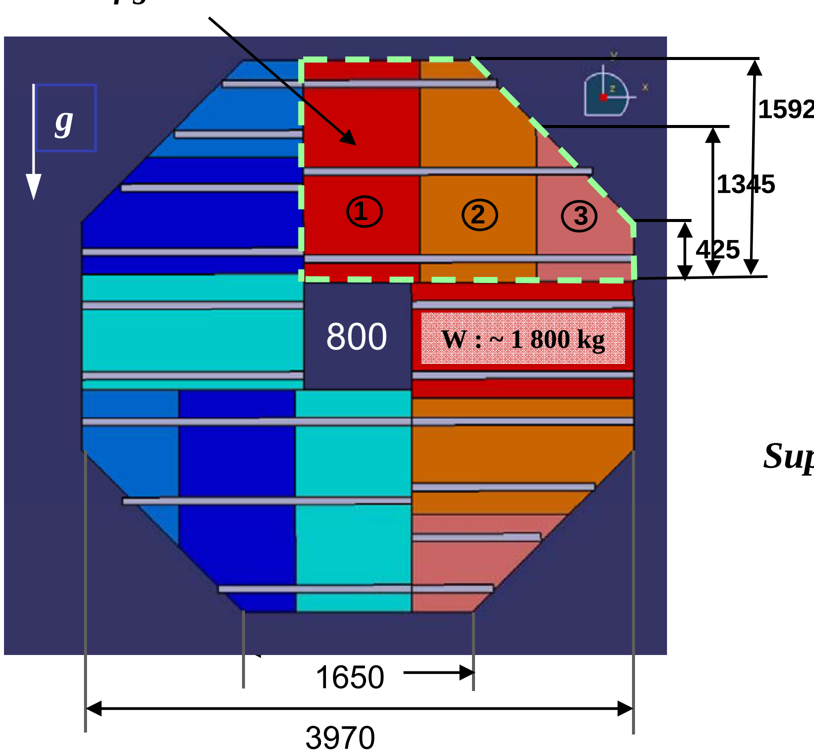
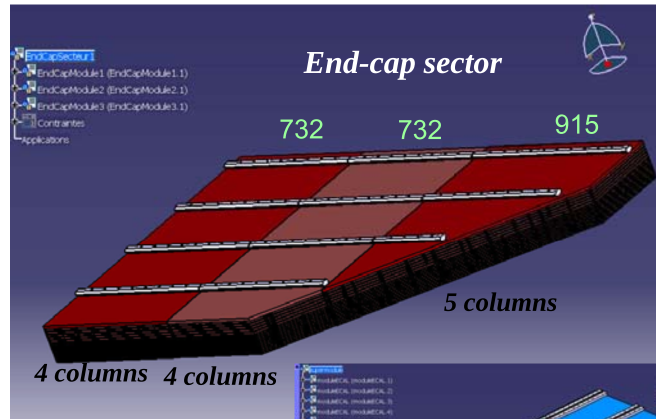
ECAL - End-Caps design (1)

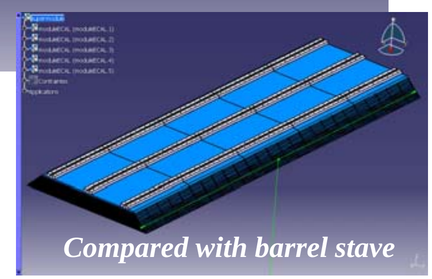
Design: *1*

- 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)

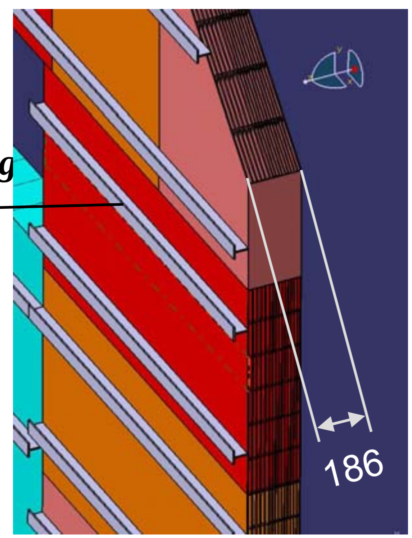
Configuration 0°







Supporting rails



Weight of each End-Cap : ~ 16 T

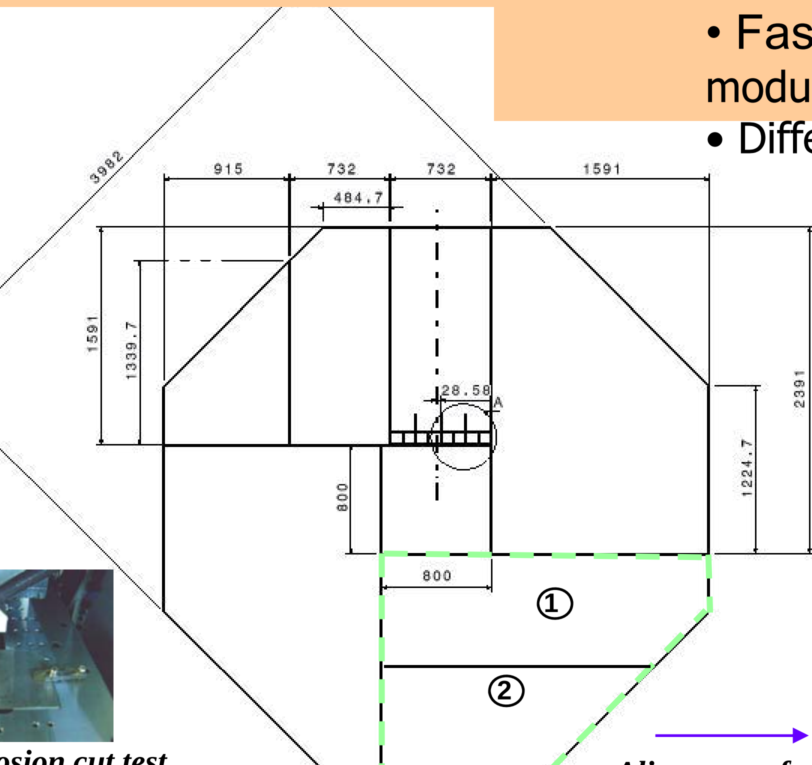
ECAL - End-Caps design (2)

Design: *2*

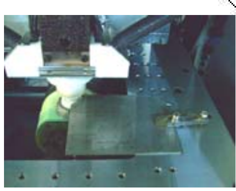
- Due to the possible crack in the geometry of design 1 *(H.Videau-LLR)* the same general shape could be saved with different size and position of modules
- Instead of 12 modules from 3 distinct types: 8 super-modules from 2 distinct types

Difficulties:

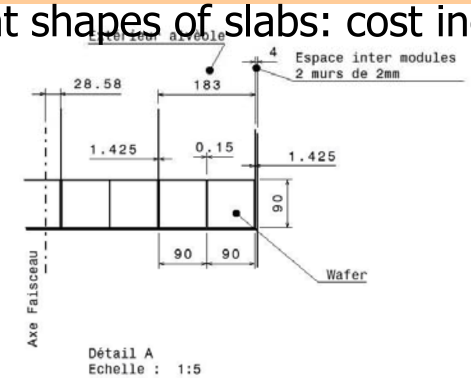
- Thermal (2.40m instead of 1.50m for longuest): T° dangerously rising in back-end of slabs
- Mechanical: >2.40m long thin alveoli maybe not feasible,
- Fastening system on HCAL /weight of module >3T ?
- Different shapes of slabs: cost increasing

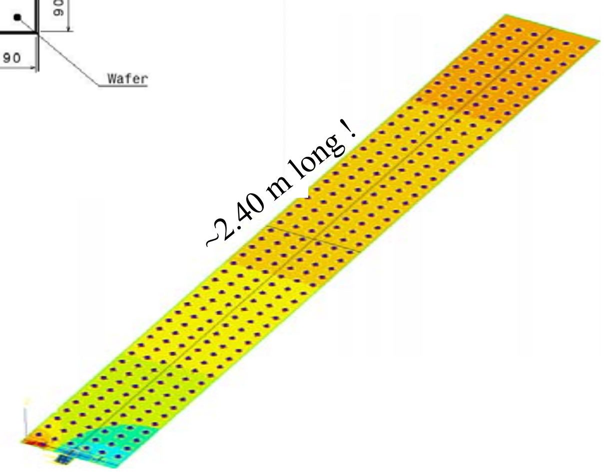


Alignment of slabs



W wire erosion cut test

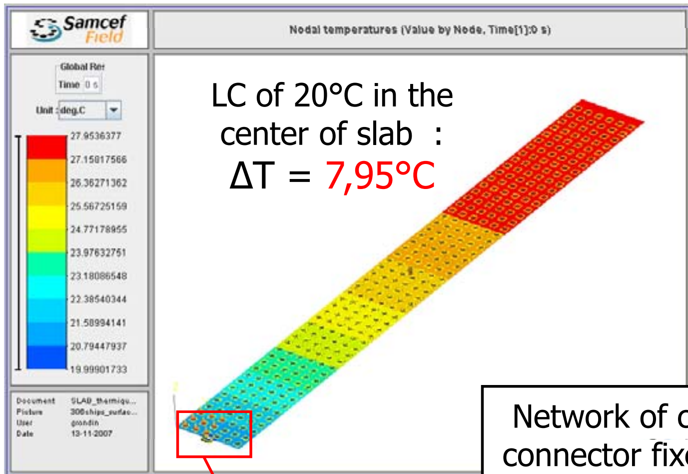




Thermal analysis of slab

Simulation of heat conduction just by the heat copper shield :

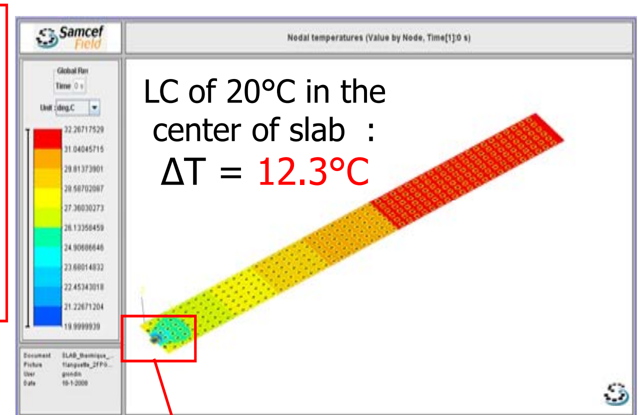
Influence of the FPGA dissipation (DIF) on current design of cooling system (Limit Condition of 20°C) :



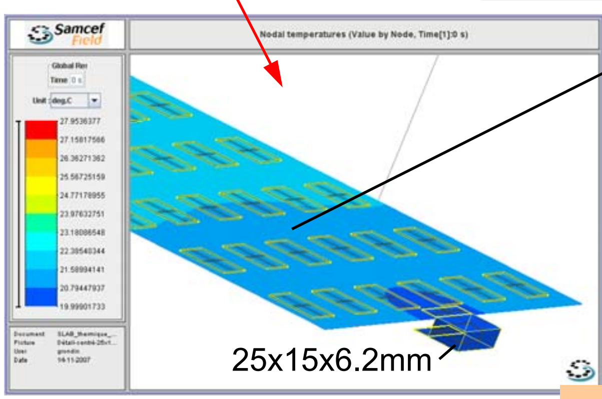
← Φ= 0,27 W/layer (25 µW per channel)

Φ_{FPGA} = 3 W/layer →

Copper layer : λ = 400 W/m/K
S = 180*0,4 mm2 ; L = 1,55 m

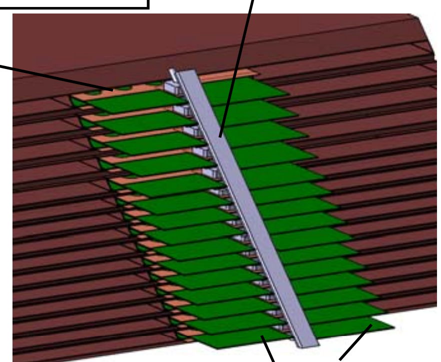


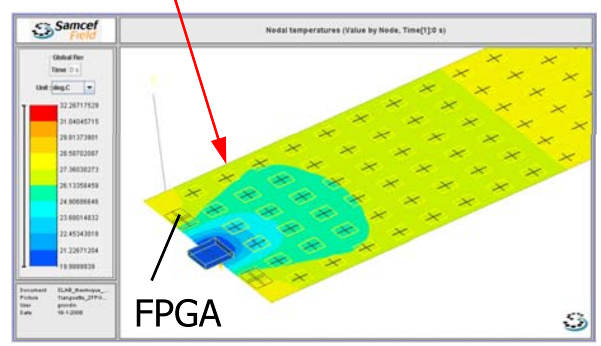
Network of contact areas / connector fixed on the 2 layers



1 copper layer

Cooling Pipe



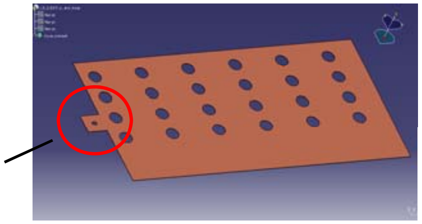


ΔT and size of cooling pipe increase (**ΦT= 8.1 W to 98.1 W**)

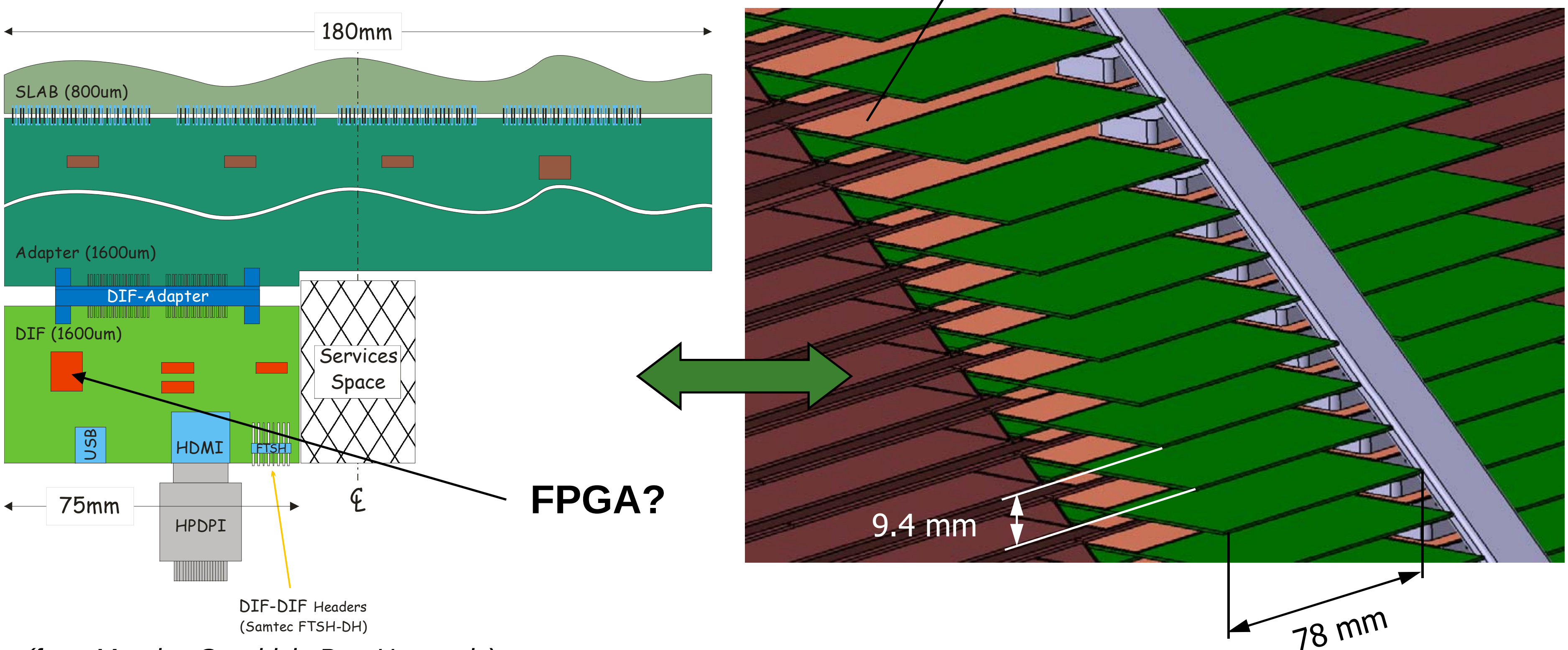
Design of interface slab/DIF

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



(from Maurice Goodrick, Bart Hommels)

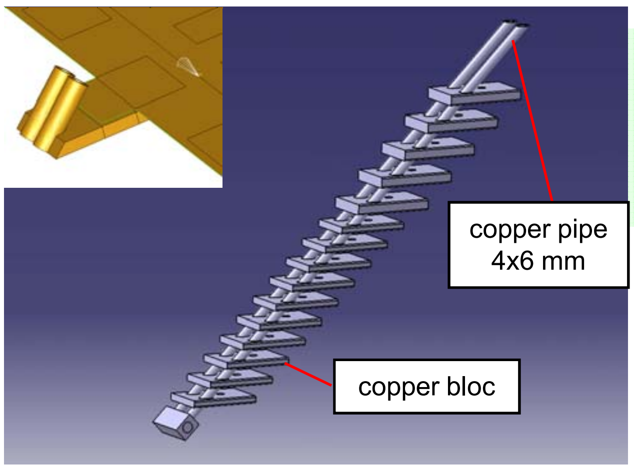
External cooling system

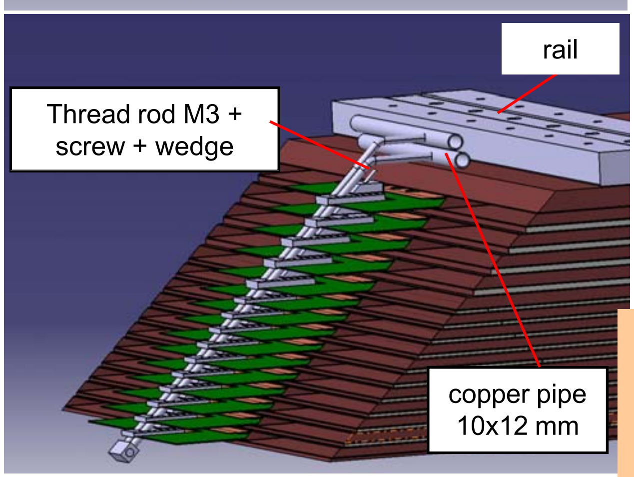
… taking into account thermal analysis of slab

2 types of cooling systems to test:

❶ Copper pipes brazed

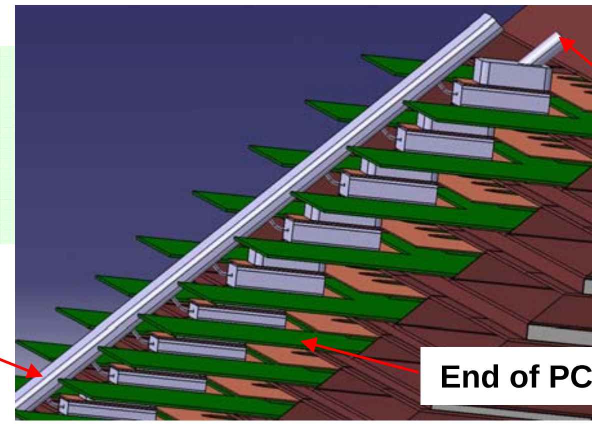
❷ Heat pipes

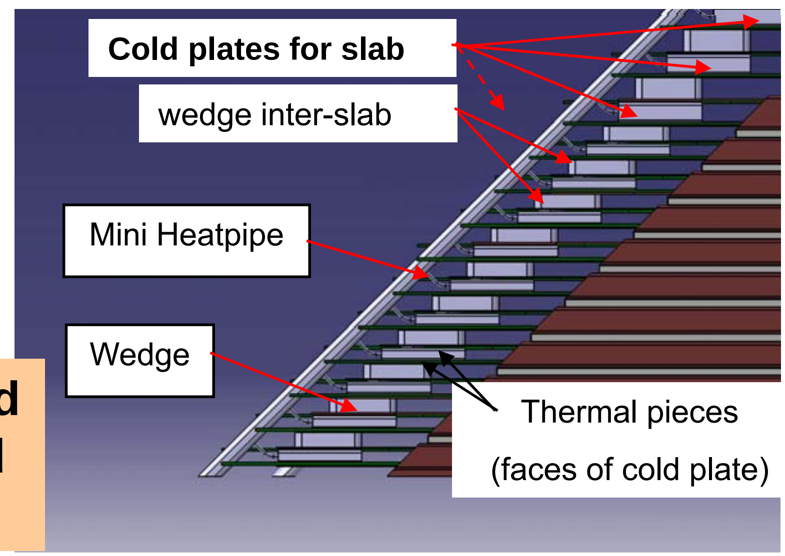




**A column,
(25 mm wide minimum)
to ensure quick thermal system's connection**

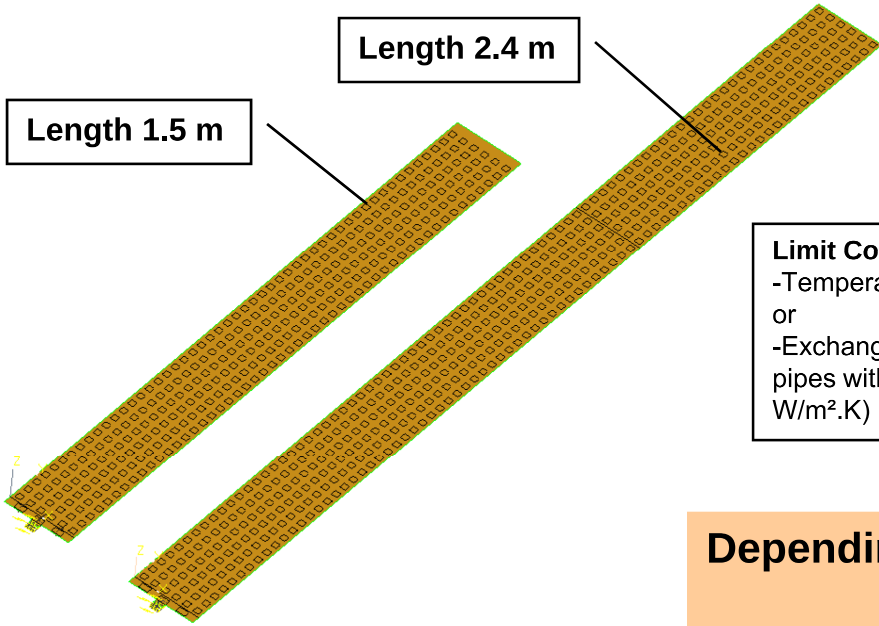
Cold plate for column



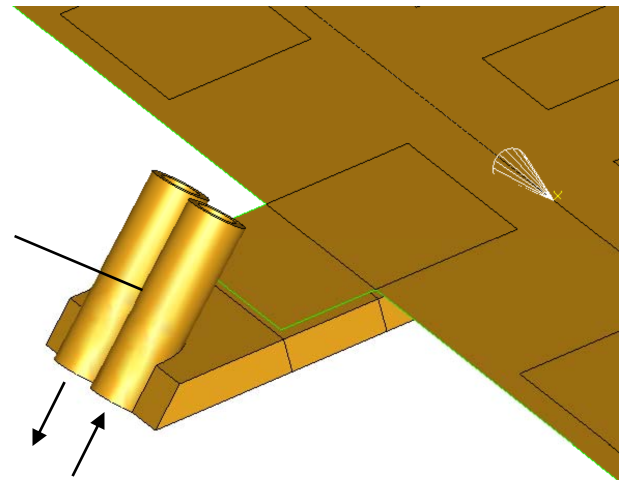


Both to be tested on : EUDET and demonstrator

Performance/cooling system



Limit Conditions:
-Temperature imposed of 20°c
or
-Exchange coefficient in the pipes with fluid at 20°c (h = 3445 W/m².K)



Depending on:

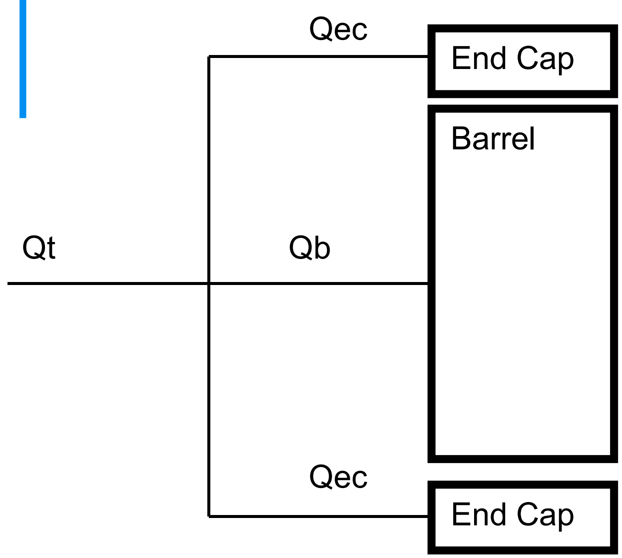
- length of slab

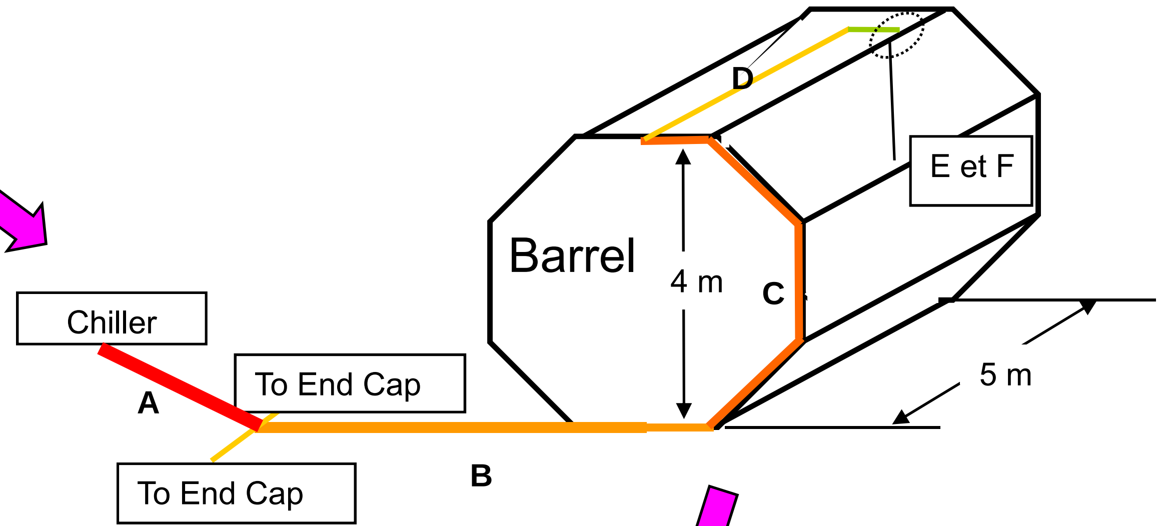
- type of cooling system

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

	SLAB : 1,5 m						**SLAB : 2,4 m**						
FPGA	with			without			with			without			
Temperature (°c)	Tmin	Tmax	Difference	Tmin	Tmax	Difference	Tmin	Tmax	Difference	Tmin	Tmax	Difference	Comments
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
Exhange 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
Exhange 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
Exhange 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

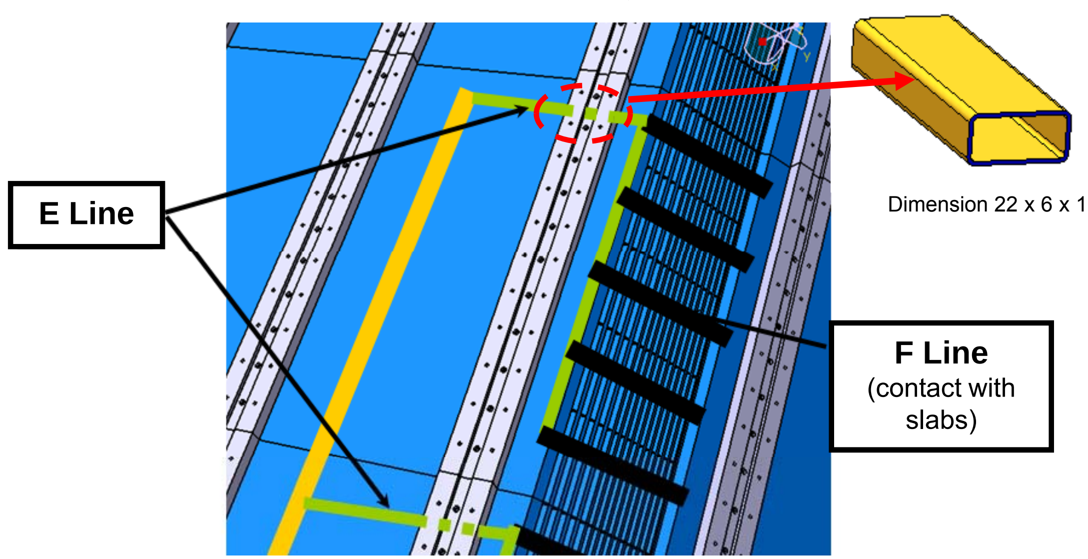
Cooling: global circulation (1)





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



Only feeding circuit represented

Cooling: global circulation (2)

Power results :

2 FPGA per SLAB, power: 3 W each, then : 3 x 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

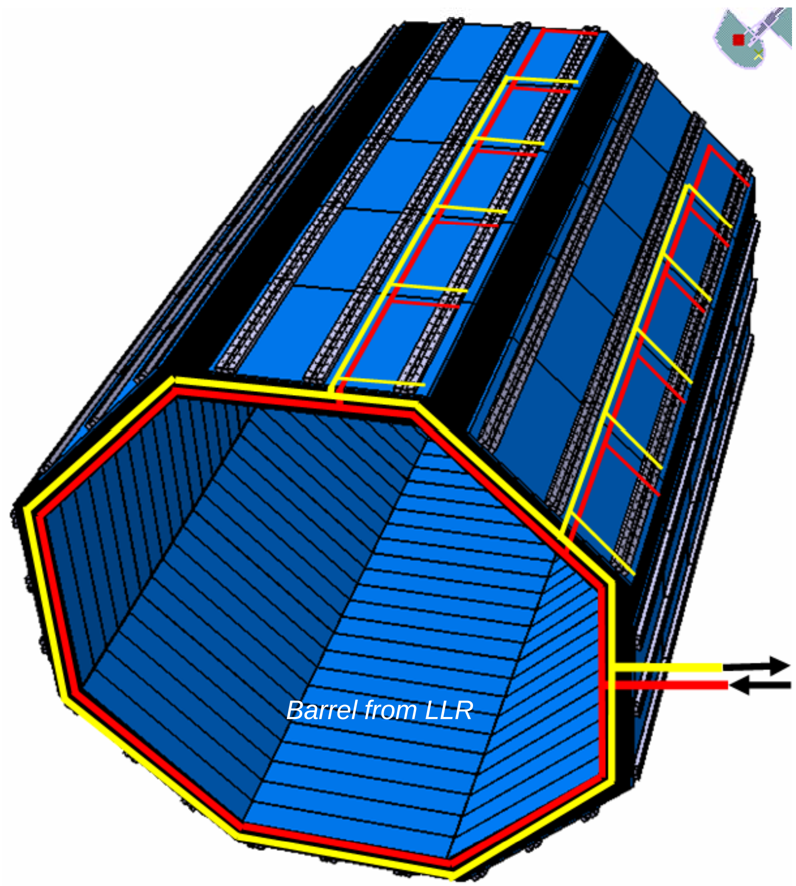
Rough estimate on fluid circulation:

Global flow rate : 150 l/min

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

Fluid speed < 2 m/s

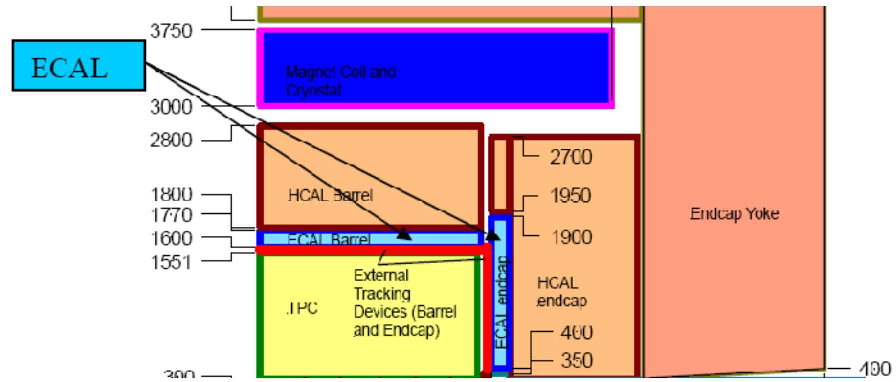
Maximal pressure drop : 1.2 bar

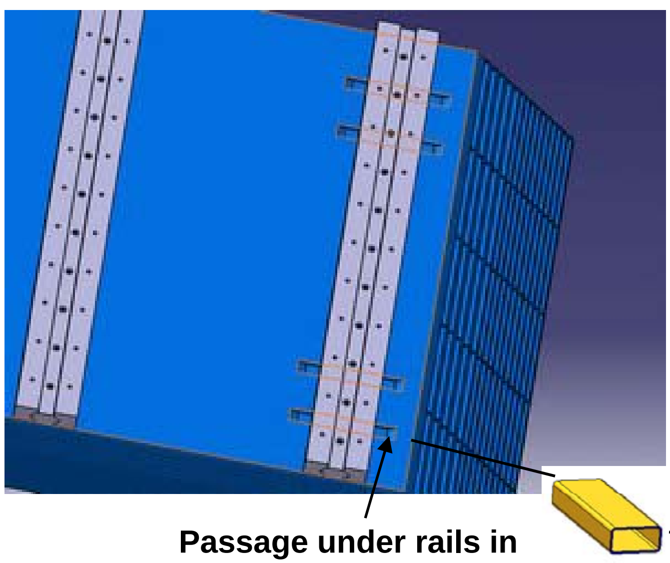


Fluid circulation /mounting

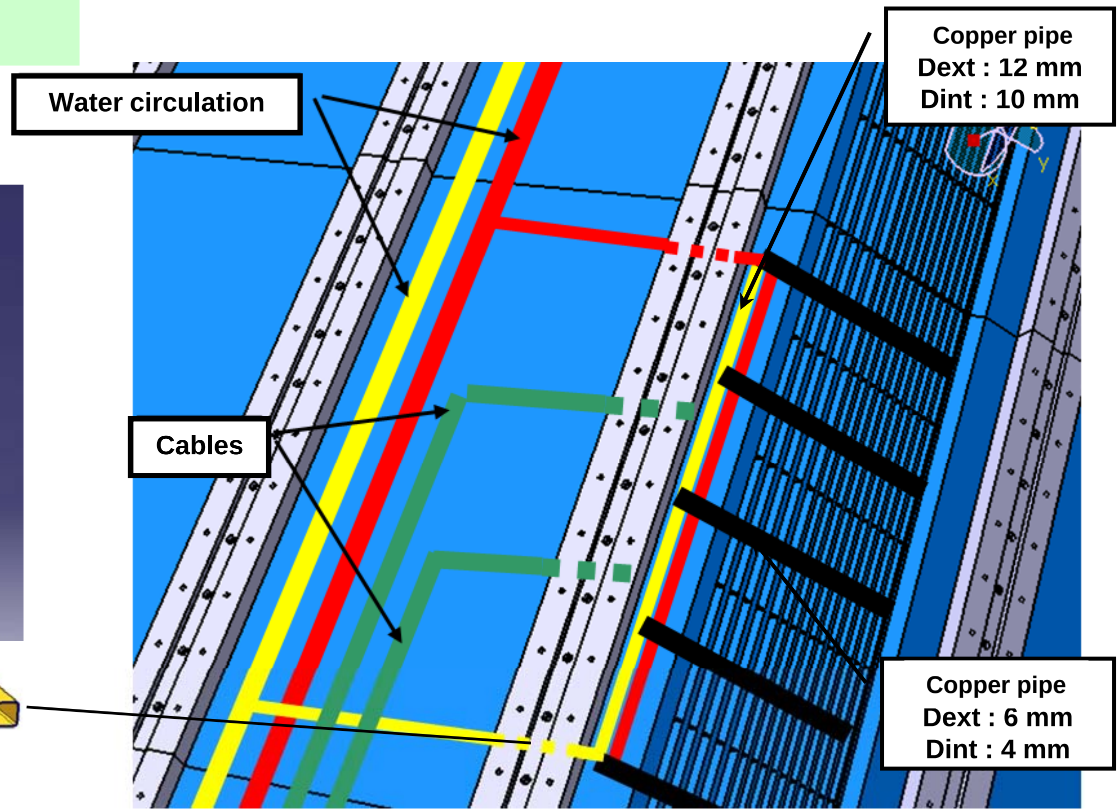
Fluid circulation => passages for pipes toward exterior of detector => free space to find and to adapt:

- **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



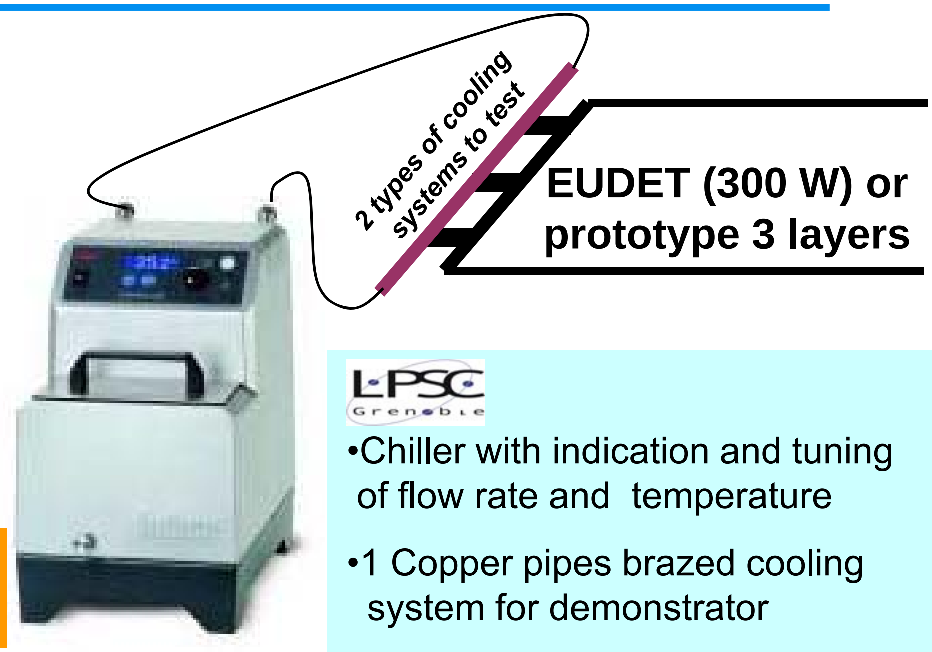
Means for cooling tests

Use : EUDET and demonstrator

Mounting characteristics :

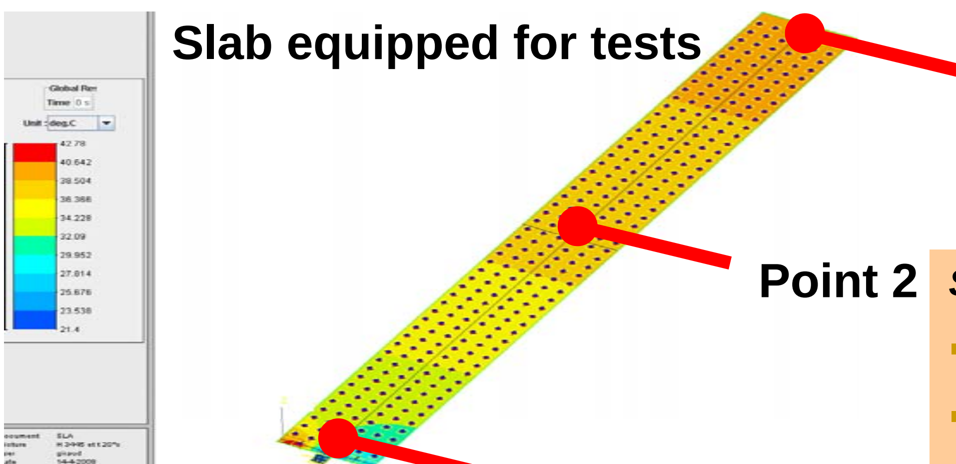
- Flow rate : 0.5 l/min to 1 l/min
- Power to drain off : 100 W (3 layers) to 300 W
- Temperature of fluid control at 20°C

ajustable parameters : temperature & flow rate



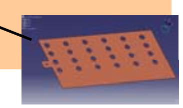
- Chiller with indication and tuning of flow rate and temperature
- 1 Copper pipes brazed cooling system for demonstrator
- 1 Copper pipes brazed + 1 heat pipe cooling system for EUDET module
- Test procedures and recalculating

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



SLAB prototype to equip with: ?

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



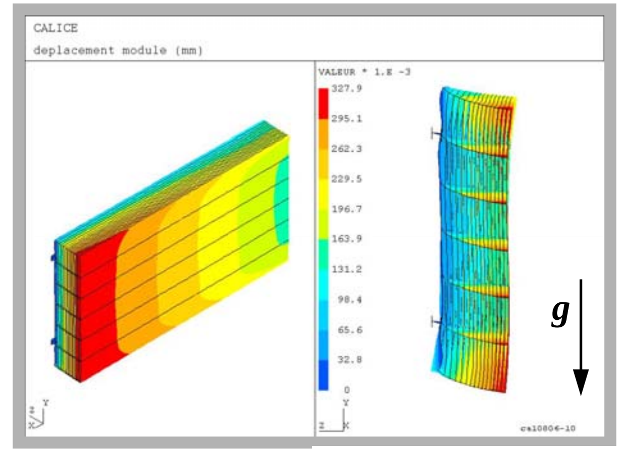
Design of module …

… based on mechanical simulations :

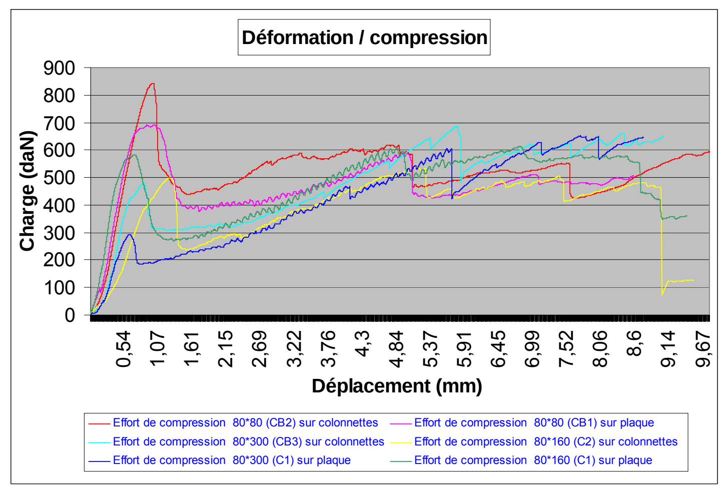
Linear Analysis of "full scale" ECAL modules (barrel and End-caps)

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

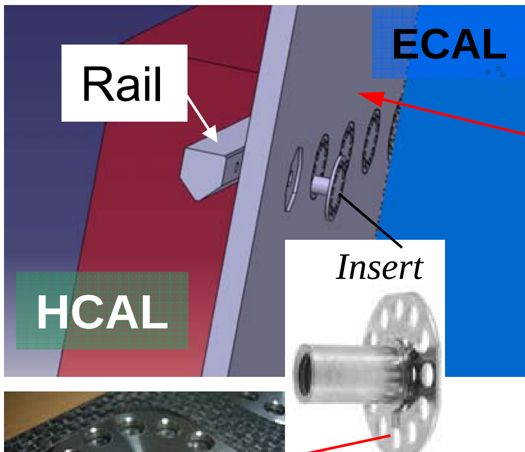


End-Cap module
Configuration 90°

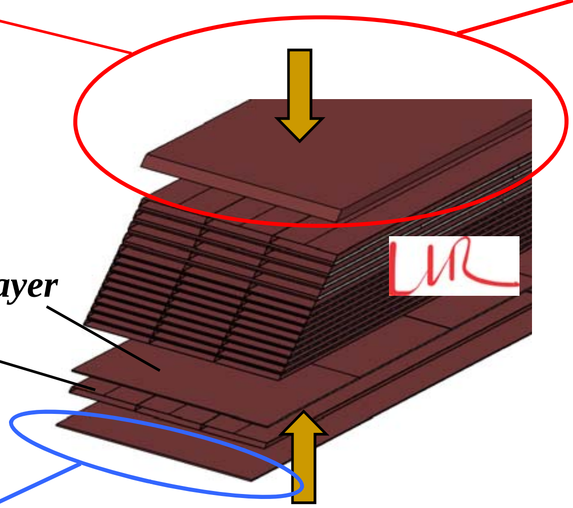


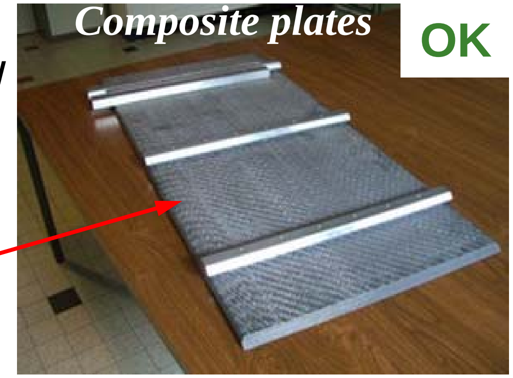
Fastening system ECAL/HCAL

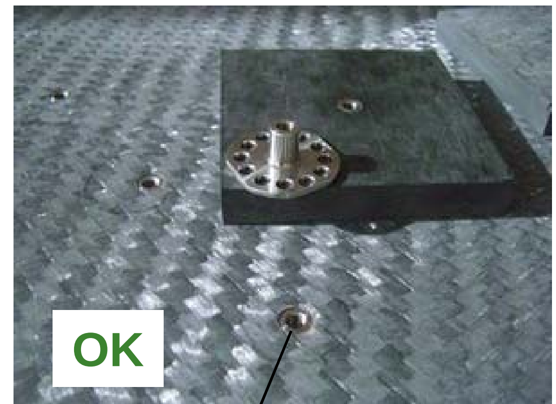
Assembled structure : Each alveolar layer are done independently, cut to the right length (with 45°) and assembled alternatively with W plates in a second curing step.



Uniform dispatch of 18 inserts on the 15mm thick plate







Fastening system (inserts)

***Composite plates** 2mm&15 mm*

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)

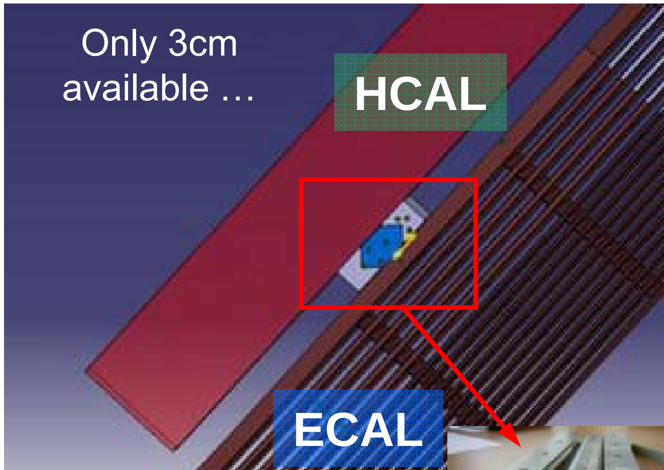
⇨ Ready : 4 composite plates (15mm and 2 mm)

Fastening system ECAL/HCAL

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

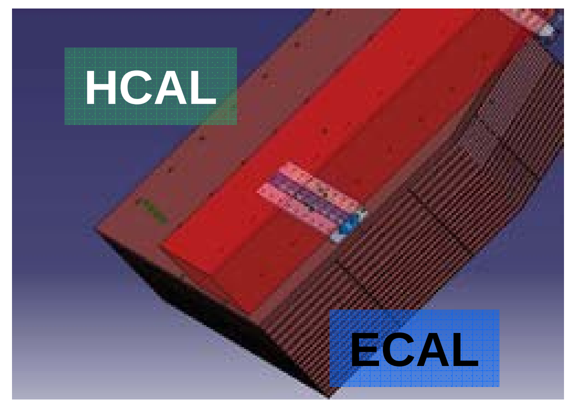
- Choice of fasteners : rails screwed through the medium of inserts. Non magnetic (B=4T !)
- Mechanical simulations of the ECAL/HCAL interface to take into account of its influence
- Design of connection system (power supply + cooling + outlets) and of DIF cards support

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



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

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



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

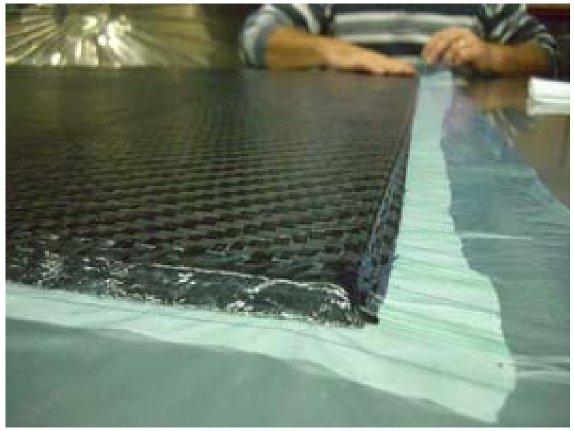
Machine for destructive tests

tools for tensile and compression tests

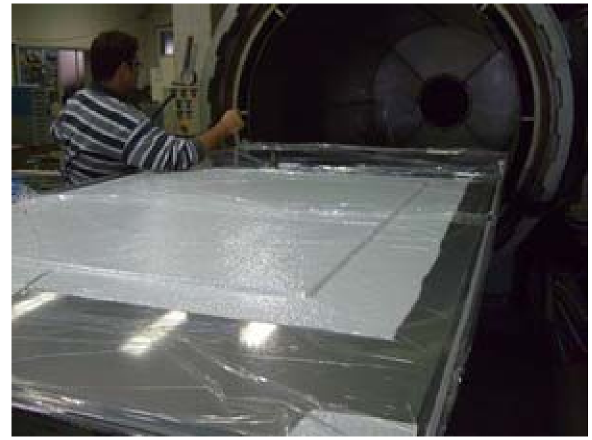
- Check and validate simulation results by destructive tests for each issues : OK
- Similar type of tests to be performed for:
  - characterization and calculation of LLR inter-alveoli thin sheets of composite (soon)
  - Checking of full equiped demonstrator fastening system (soon)

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

Schedule

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 15mmm & 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: 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)**