SiW ECAL

Cooling & Endcap structures

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Julien GIRAUD - giraud@lpsc.in2p3.fr +33(0)4.76.28.41.13
Denis GRONDIN - grondin@lpsc.in2p3.fr +33(0)4.76.28.41.56

ECAL / End caps structures and cooling studies

CALICE Calorimeter for ILC

1. Design of the EM end-caps (alveolar structure)

- 2 End-Caps: modular structure of 2x12 modules - composite structure molding

2013… *Evolution of skin thickness* (optimization of deflection values)
Industrialization aspect of process / long modules (~ 540 cells up to 2,50m)
Study of molds and parts for long module development

2. Cooling system (end-caps + barrel)

- Leakless system
- Global Cooling / pipe Integration - design of cooling station + network
- Water heat exchanger design near detector

2013... Work on real scale *leakless loop* including *tests* on a real drop of 13m (<1atm)
Representative process to control/ electronic / sensors
First Design: hydraulic safety, hardened components, *cooling supervision*

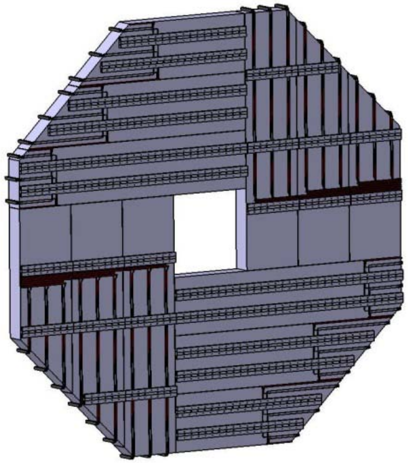
3. Assembly of the EM calorimeter (rails, guiding system ; ends-caps + barrel)

- 3D design & tests of fastening system => 30 mm thick & double row sized rails

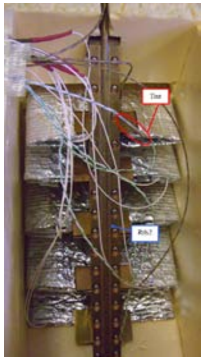
2013... Tests & *optimization* / simulation of best *localisation* on modules
Validation of technological solutions (bending of modules)

4. Contribution to prototypes (demonstrator, EUDET module, AIDA, etc.)

- Thick composite plates with inserts and rails for Demonstrator & EUDET
- Heat exchanger of EUDET – Characterization of water cooling & heat pipe systems
- *Shearing tests to determine stress in the alveolar wall in a case of loading at 90°*
- *Improve the simulation about the global mechanical behavior of End-caps*
- *Conception of* transport and handling tools for integration…



1 ECAL End-Cap ~25,5 T
Intrados with cooling lines

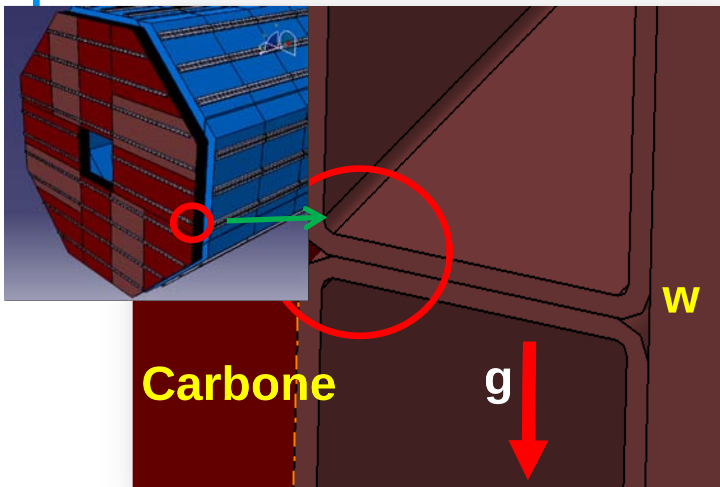


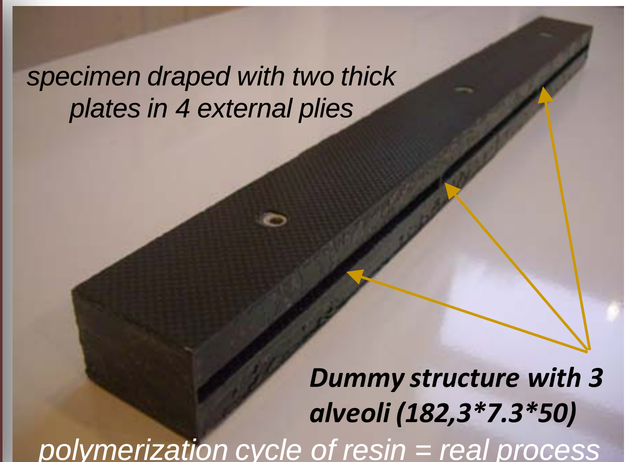
Front End
Water cooling block

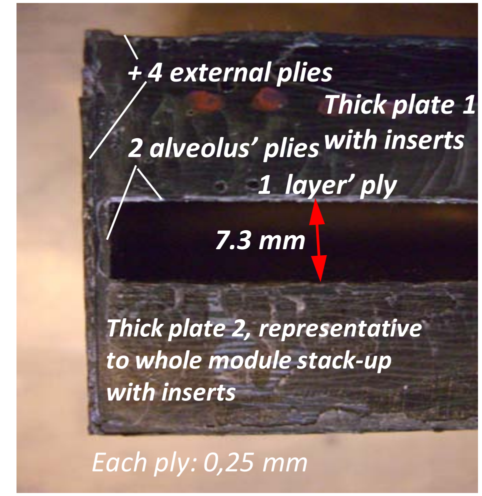
The 1st long layer of 3 alveoli demolded (186,8 x 6,5 mm x 2,5m – 0,5 mm thick)

ECAL End-Caps: shearing tests

Problem of bending stress of alveoli skins / evolution of external plies

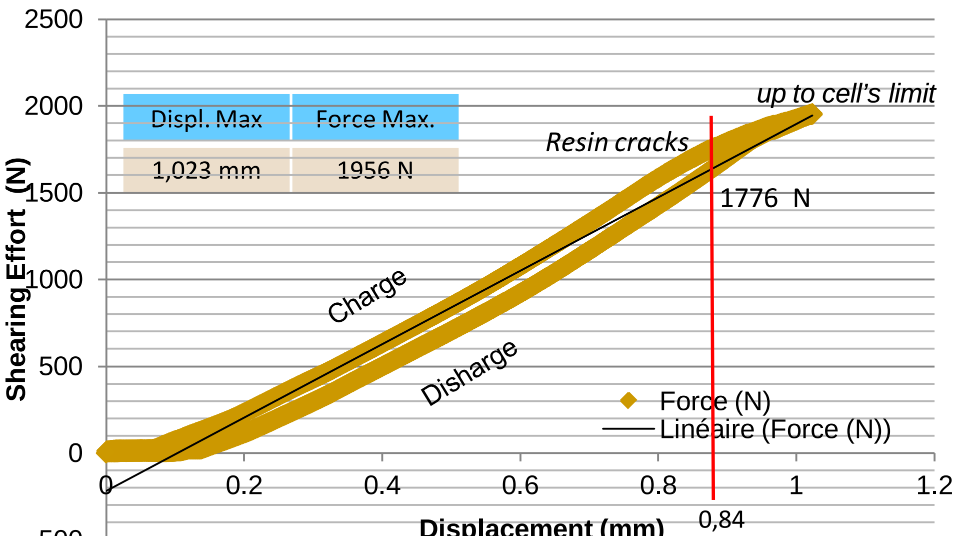






Influence of modification of external ply thickness on the first main constraint of external and internal walls

If external plies thickness increases **=> Impact on ECAL dead zone => Optimization of deflection values**



- 2 tests performed on dummy structures with no rupture !
- The charge & discharge cycle thus shows an hysteresis in specimens' behaviour which certainly evolves towards a progressive decrease in the force / displacement with the gradual breakdown of the resin before destruction of the composite.
- Shearing allowable stress / tests: **6,6 MPa** before first crack
- safety factor: 2,9 to 3.7 (correct for normal operating conditions) with respect to the stress induced / largest module (2,5m–25,5 kN)

Ongoing developments 2013-2014

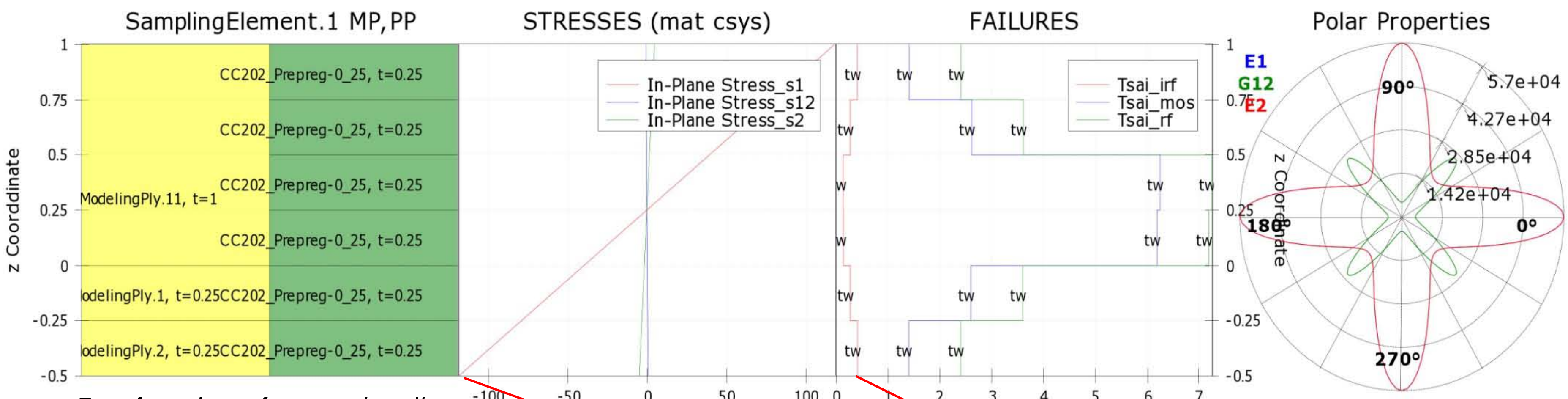
-2 dummy structures moulding / shearing tests / **strain**
-Destructive tests (up to 1st resin cracks) / **verification**
-FE simulations / (0°- 90°) load cases & correlation /tests
-**Draping** optimization

FEA simulations / test of the structure

Goal: ***adapt FEA parameters to simulate the whole structure / shearing results***

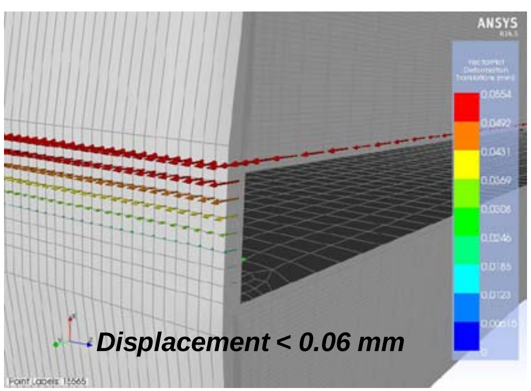
illustration and evaluation of the laminate properties of the lateral stackup

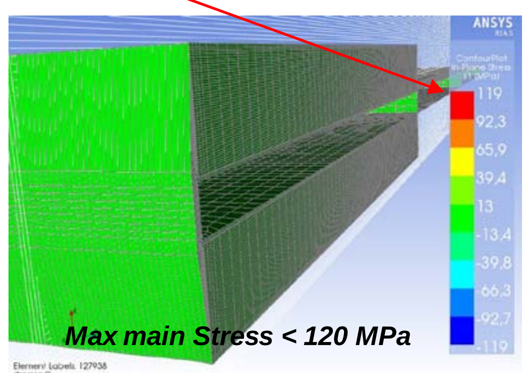
Assumptions of the Classical Laminate Theory

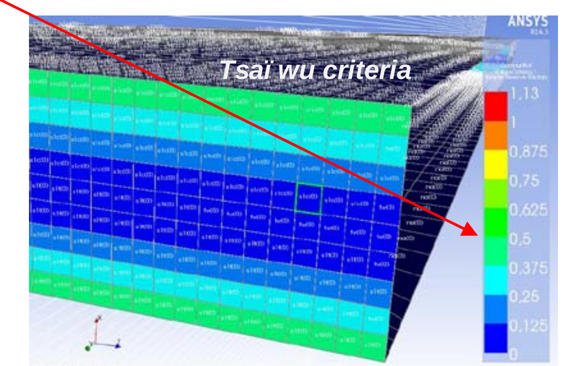


Ex. of stackup of composite plies on external wall (1,5mm thick)

In-plane laminate engineering constants (E1, E2, G12) orthotropy of the laminate (woven)





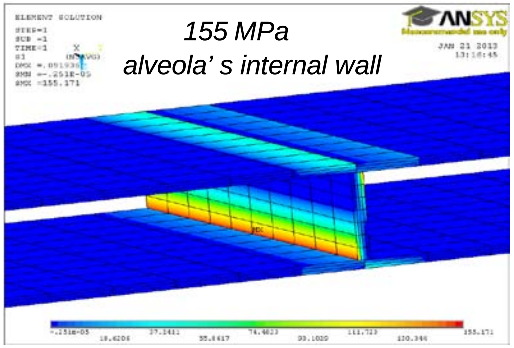


inverse reserve factor IRF<<1

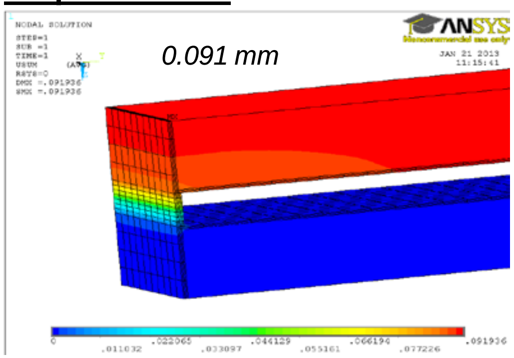
FEA simulations / test of the structure

Correlation of *FEA simulations / tests*

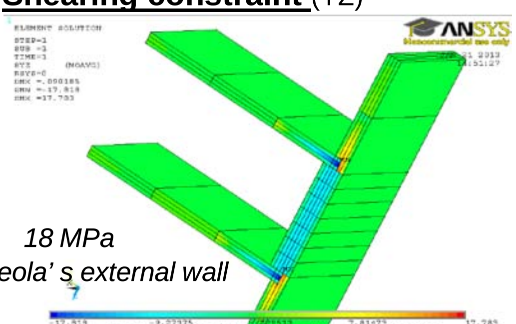
Main Constraints (S1)



Displacements



Shearing constraint (YZ)



Comparison of several simulations vs tests

Mise en Donnée / Résultats	ANSYS APDL	SAMCEF	ANSYS ACP	Shearing test
Cells' geometry	183.5x7.3x50 mm (thick plate 16 mm)			
Layup	4 (6) x 0.25 mm ext. (left & right) 4 x 0.25 mm inter alveolus 3 x 0.25 mm up & down			
Bondary conditions	Locking Ux,Uy et Uz on1 face Effort 1776 N on upper face			
Displacements	0.091 mm	0.1 mm	0.06 mm	0.84 mm
Main contraints	155 MPa	159 MPa	119 MPa	/
Shearing constraint	18 MPa	11.5 MPa	1.81 MPa	6 (1,8/wall) MPa
Tsai-Wu criteria	0.3	0.23	< 0.5	/

These initial results seem to validate the theoretical model of bonded structures even if models or not yet optimized (composite parameters, flexion inclusion…)
Greater displacements are possible on real structure (tests) but after 1st cracks simulated

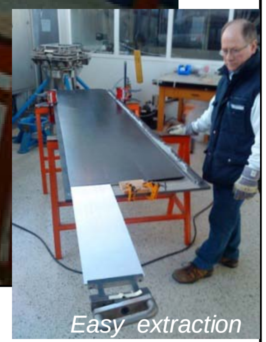
Tests & simulations to be performed: 2013-14

- **Destructive tests with charge & discharge cycles**
(progressive failure of the resin up to rupture) weakening of the structures during repeated stresses)
- **Process: increase intercoat adhesion with structural adhesive film**
- **Process: obtaining reliable thicknesses of walls** (specific long moulds, tooling development)
- **Reliability tests: good & uniform impregnation of parts, good compacting**
- **Destructive test on a real structure** (demonstrator ?)
- **Resistance to earthquake**
- **"Mass" production conception** *(ply book enhancement, tooling, process)*

Long alveoli moulding

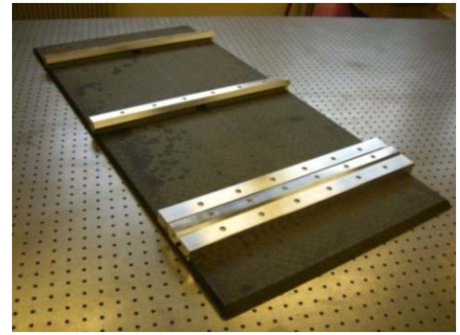
Calorimeter for ILC

2.5 m alveoli layer molding



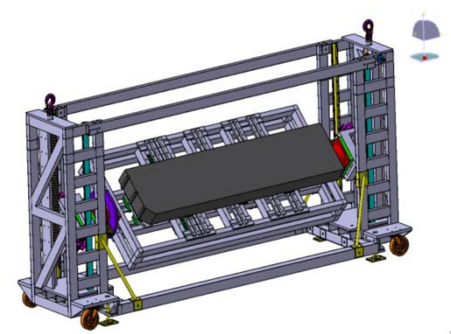
- **The end-cap layer test consisted of**
- **3 long alveoli** (representative of end-cap module longest layers)
- **Width of cell : 182,3 mm** like barrel's one (for electronic uniformity) ➡ Design don't fit LOI parameters (R~2062 / 2090 of LOI)
- **Thickness of cells : 7.3 mm - wall: 0.5 mm**
- **Length : 2.490 m**

Thick plates / fastening



Carbon HR plate 13 mm thick metallic inserts single & double row (*LPSC plate for loading tests / module EC n°2*

Design of handling tool for # modules



Ongoing developments

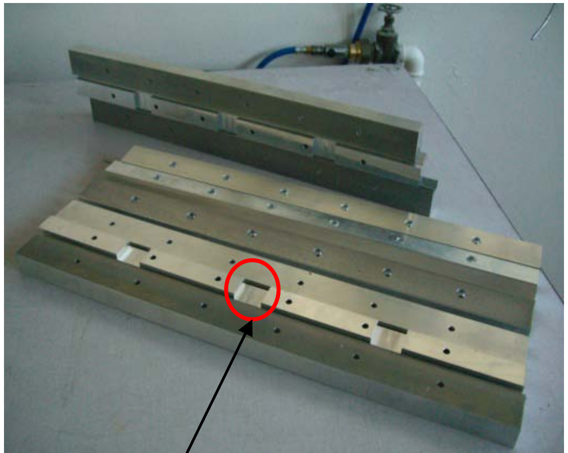
2013-2014

- Long End-Cap alveolar **layer (26/09/13)** with new system woven-resin (C202+ET445)
- Design of specific tools for long draping
- **Validation of technological solutions (plates distortion / double row rails)**
- **Industrialisation study of process / long alveoli layers**
- **Continuing the mounting of the handling tool of modules & design /quarters End-Cap**
- **Thick composite plate for double rails**

Fastening and guiding

Guiding/fastening system of modules

Stiffness of the supporting structure & Transparency / φ

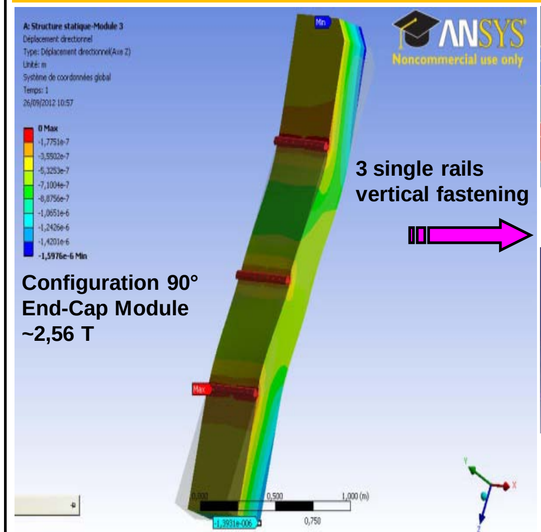


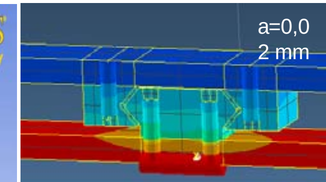
Opening in rails for cooling pipes and services on each column (EUDET)
Ongoing development on sliding interface

Carbon HR Rails

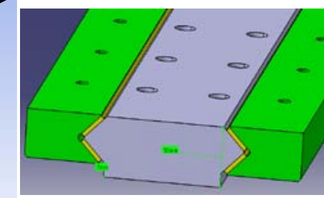
3D design of different fastening system

⇒ Thickness 30 mm & double row sized





F.E.simulation to define the stiffness of the rails



Design of double rails
Development of new rails

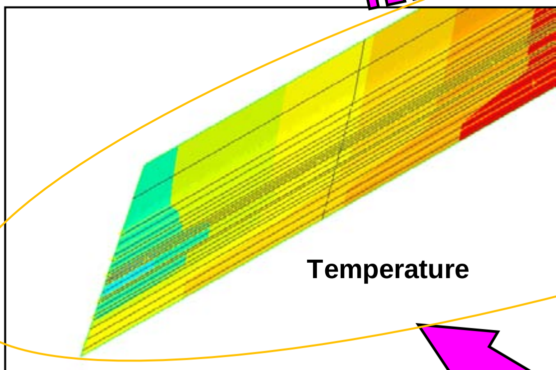
Finite element End Cap simulation : MODULE N°1
2.5 m long / 3 columns / position 0° and 90° / M = 2550 Kg
⇒ Goal of simulations: Influence of **position / nbr** of fastening systems on the mechanical behaviour (displacement / stress) …
⇒ Even if module is fastened with 2 double rails instead of 3 simple rails, deflections are less important.

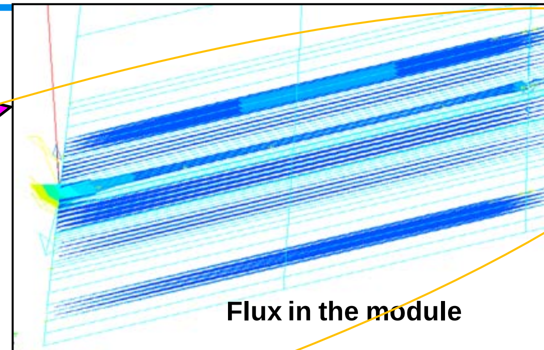
Ongoing developments

2013-2014

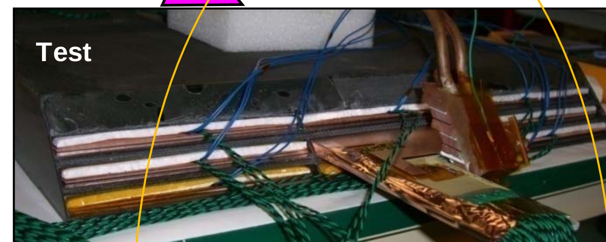
- **Validation of technological solutions (sliding interface/ double row rails)**
- **Industrialisation study of process**
- **Coupling of modules, pipes & services installation**
- **Characterization, tests & optimization: low section rails** (thickness)
  positioning on module

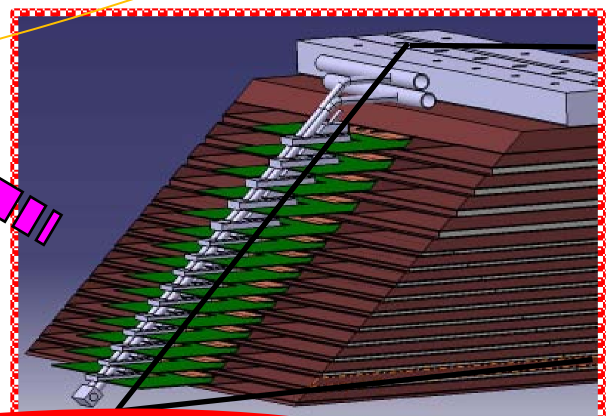
Work performed in cooling during 2012 and before



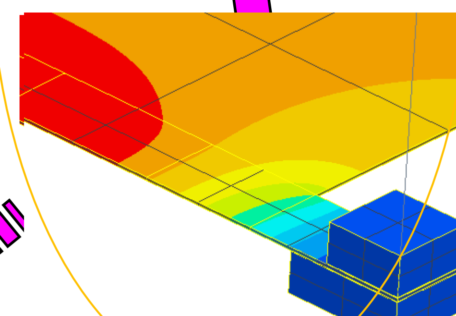


2 : Connection module / cooling

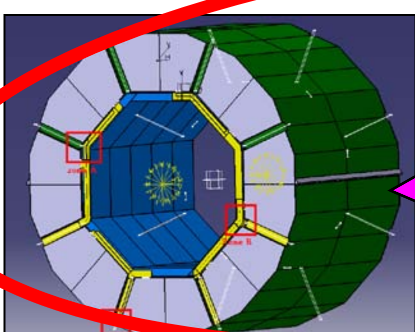


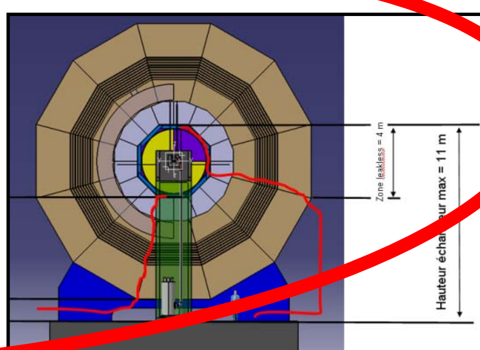


1 : Thermal transfert inside the module



Cooling distribution

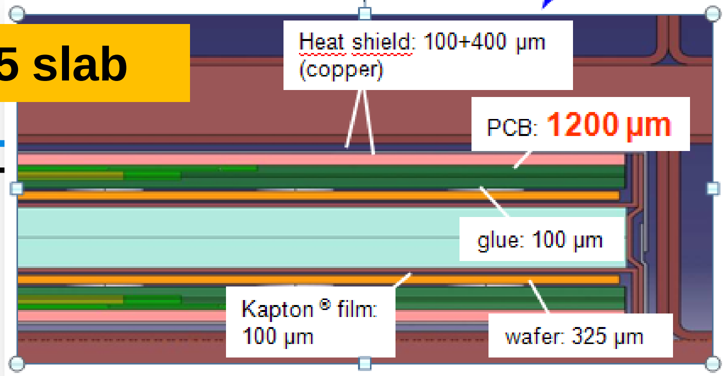




3 : Cooling global / Pipe integration

ECAL / Thermal flux inside modules

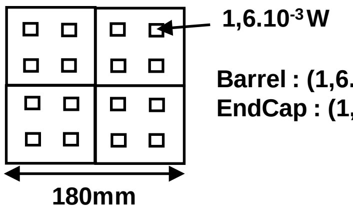
15 slab



TEST and simulation on old design

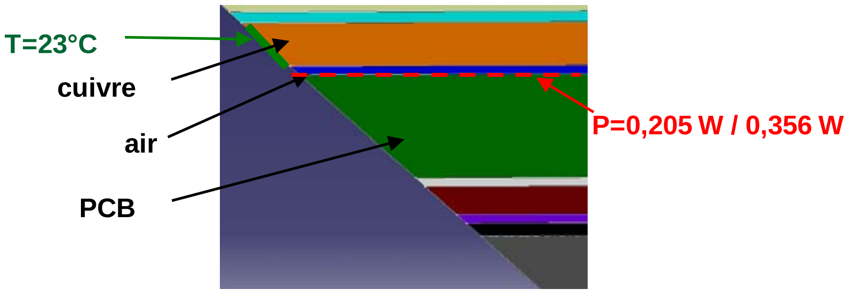
Inlet

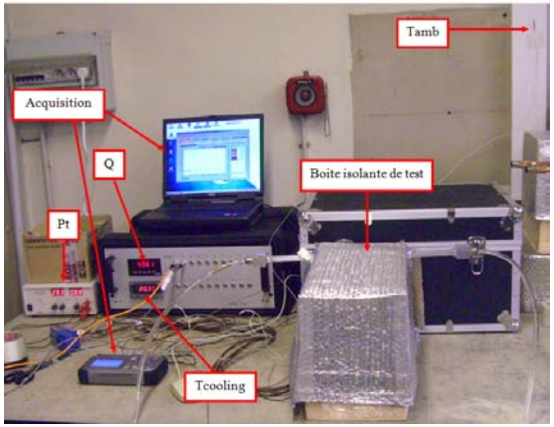
Power on PCB = 0,205 W / 0,356 W

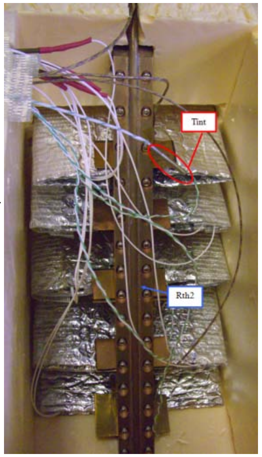


Barrel : (1,6.10-3*16)/180*1445=0,205 W
EndCap : (1,6.10-3*16)/180*2500=0,356W

Boundary condition T = 23 °C beginning of the copper plate
Air between copper plate and pcb is in the model

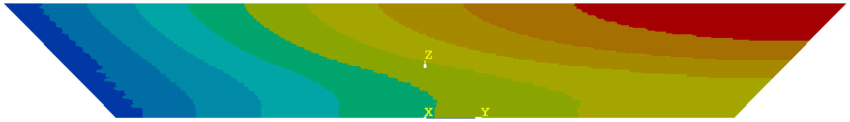






Results

Barrel : (1.5m)



ΔT = 2,2°C

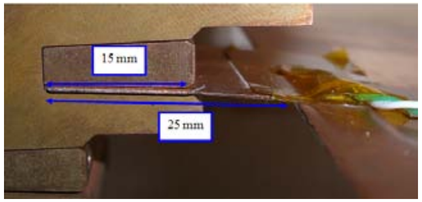
End Cap : (2.5m)

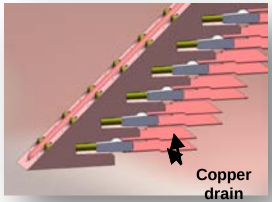
ΔT = 6°C

Conclusion

Low T° gradient -> cooling system suitable
Cooling front –end (front of slab sufficient)

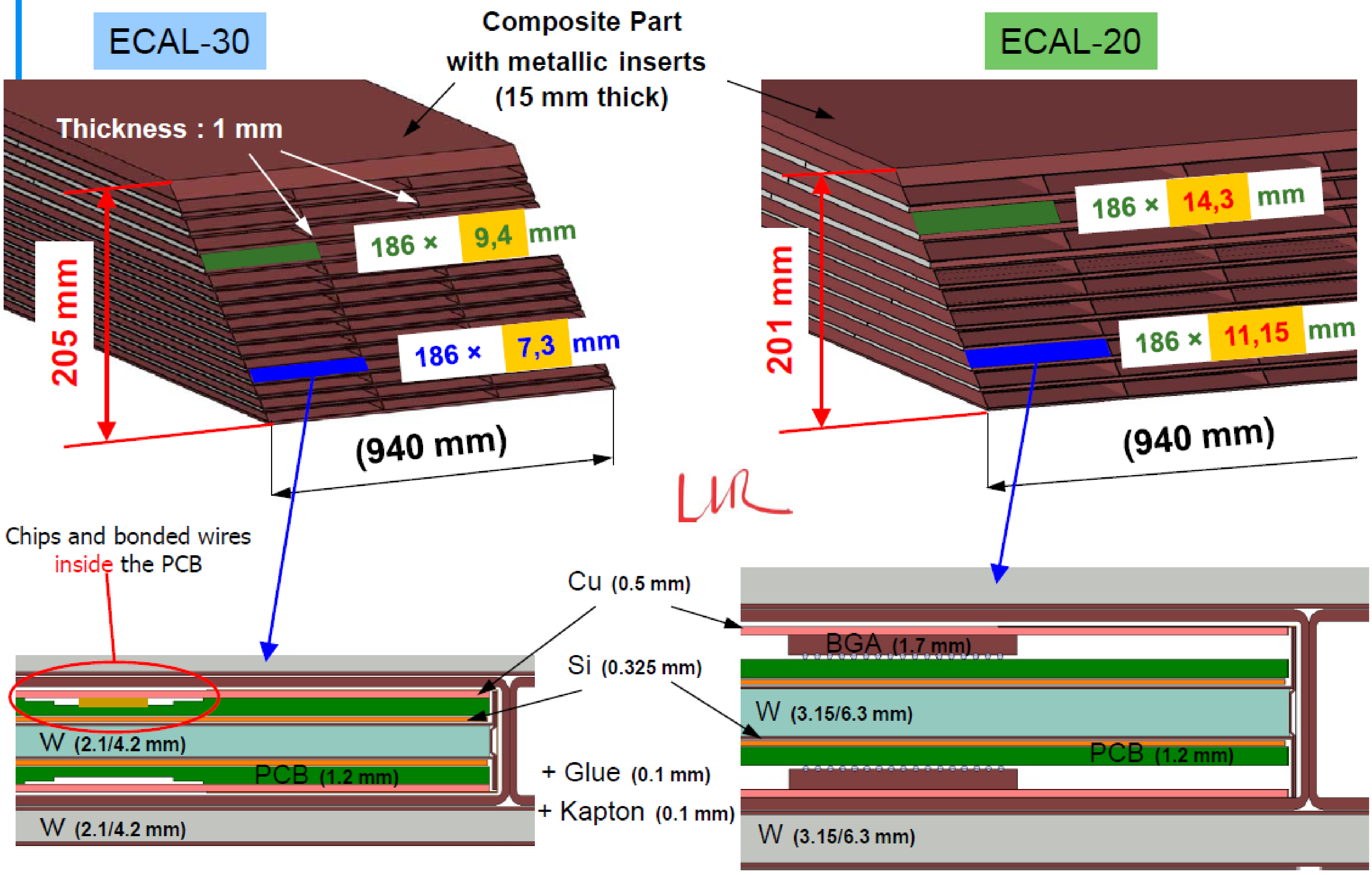
Confirmation: **25 mm** free opening in DIF for extraction of cooling system





Copper plate / heat exchanger link

ECAL Barrel : 30 layers vs 20 layers

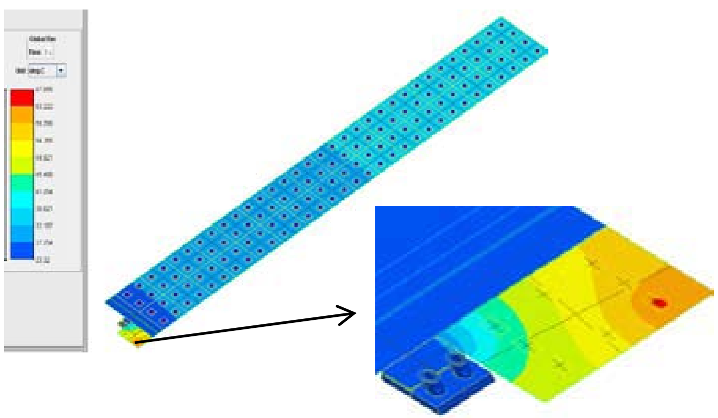


ECAL / Thermal study

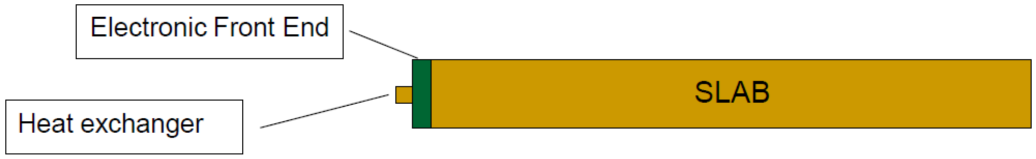
Update needed in thermal study:

- Number of SLAB.
- SLAB constitution (material distribution).
- Power variation.
- Power location (Front end or SLAB).

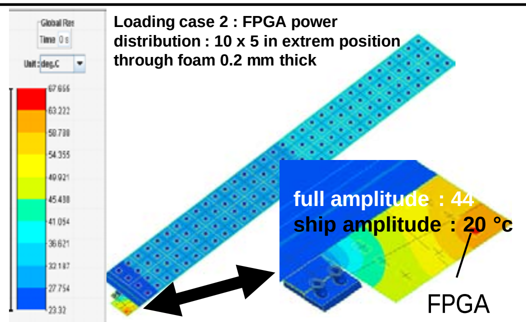
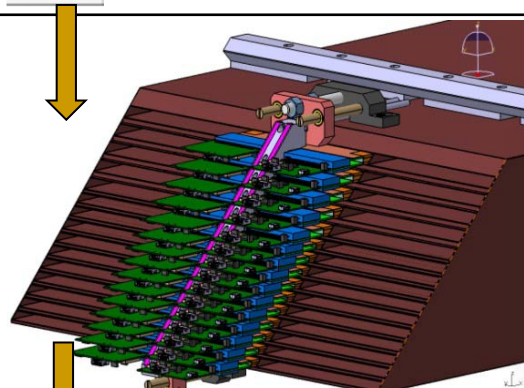
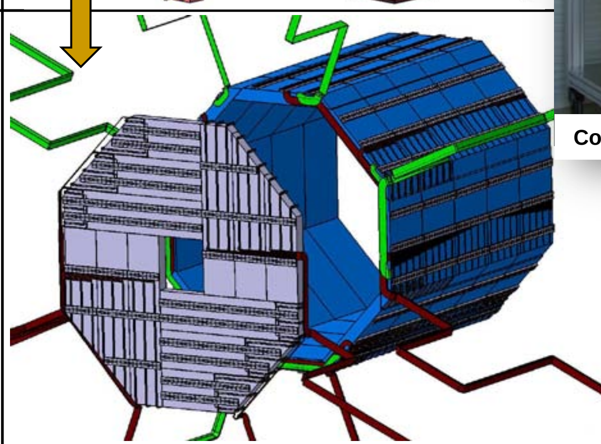
From 4,5 kW to…?

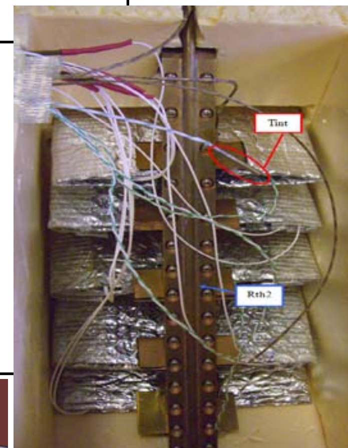


		1/2 SLAB						
/ Electronic consumption		Front electronic (W)	Wafer (W)	Total ECAL (W)	Temparature variation near the exchanger (°c) (Thermal contact resistance)	Temperature variation along the SLAB (°c)	Température at the end of the SLAB (°c) (water temp : 18°c)	Remark
Configuration 1	ECAL Goal	0.3	0.205	4500	0.5	2.2	20.7	Passive cooling : OK
Configuration 2	Front elec x 10	3	0.205	30 000	3.2	2.2	23.4	Front SLAB electronic close to the heat exchanger => low impact of the SLAB temperature
Configuration 3	Wafer x 10	3	2.05	45 000	5.1	24	47.1	Passive cooling may work
Configuration 4	Wafer x 100	3	20.5	205 000	24	250	292	Passive cooling will not work !! We need to work on active cooling in the SLAB

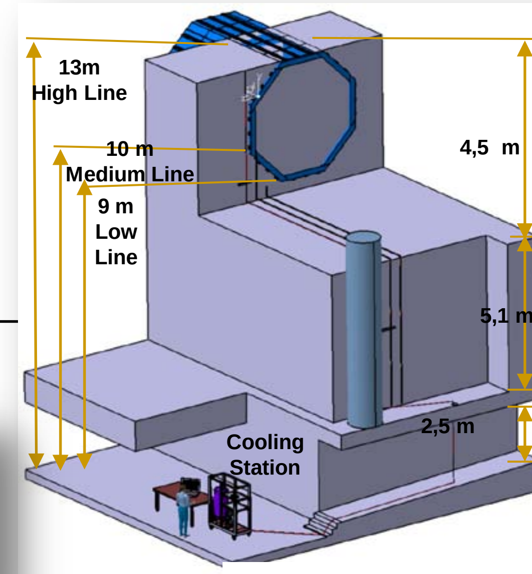


ECAL / Thermal study

	Simulations & tests	2013 - 2014
1/ Thermal transfert **Slab**		
2/ Connexion **Thermal Exchanger**		
3 : Global Cooling **Leakless loop**		



Cooling station in progress



Leak less loop

2013-2014

- Continuing the mounting of true scale test loop – leakless cooling
- Update of thermal prototype of exchanger
- Thermal tests / simulations power variations (limits / pulsing)