SiW ECAL

Mechanics/cooling

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ECAL / End caps structures and cooling studies

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)

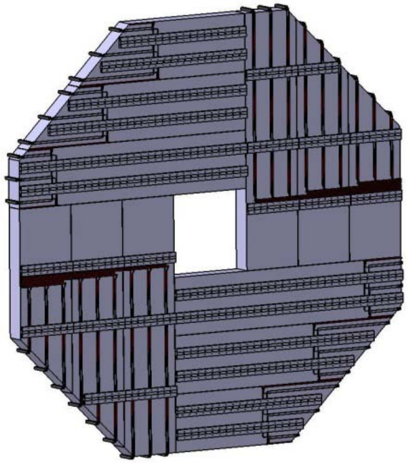
- 3D design & tests of fastening system => 30 mm thick & double row sized rails

2013... Tests & *optimization* / simulation of best *localisation* on modules

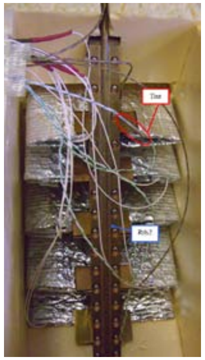
Validation of technological solutions (bending of modules)

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

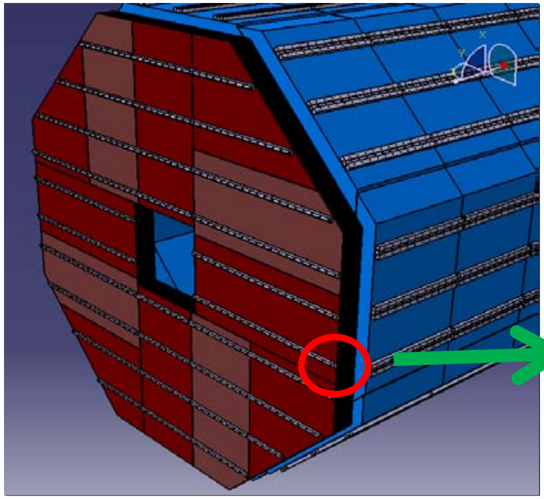


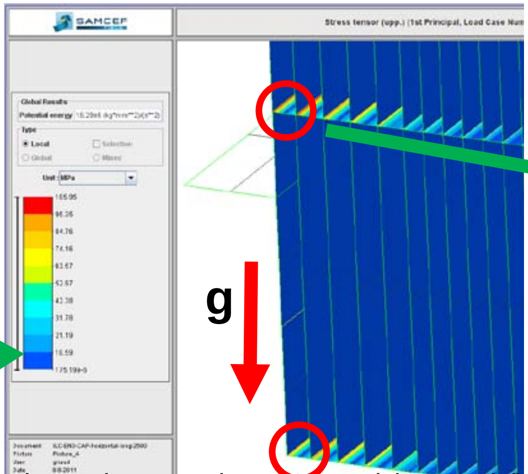
Front End
Water cooling block

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

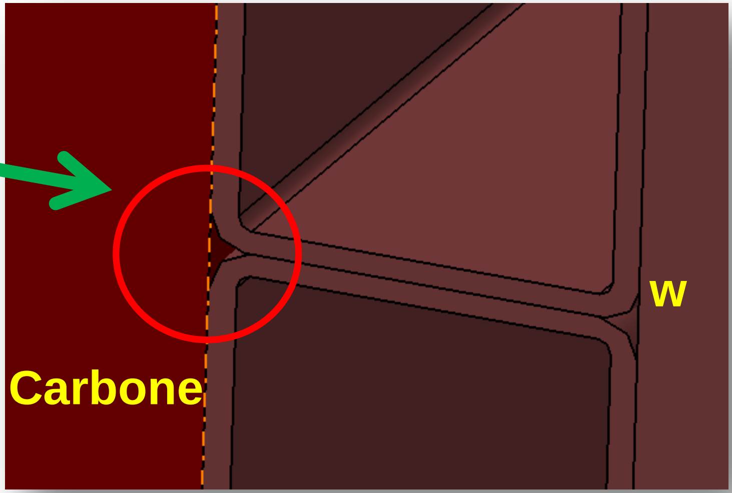
ECAL End caps: evolution of skin thickness

Problem of bending stress of alveoli skins

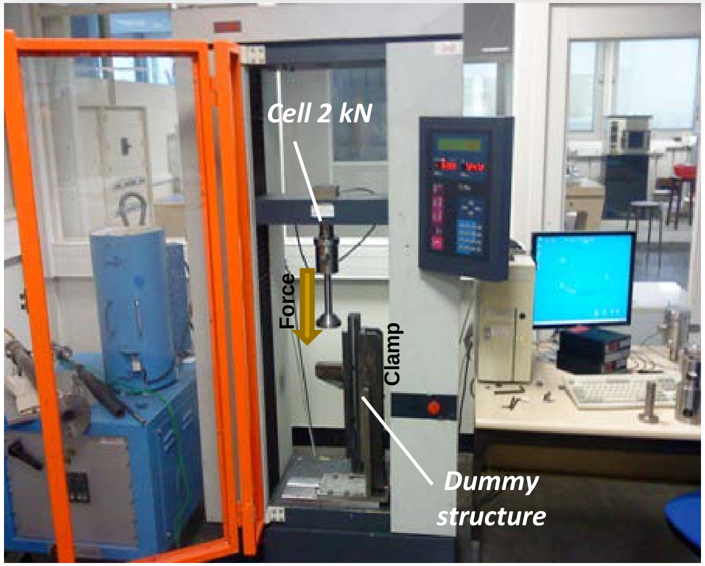




First main constraint: 106 Mpa (plate model)

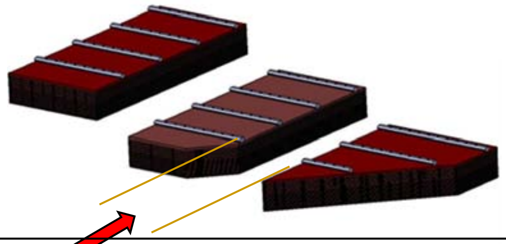


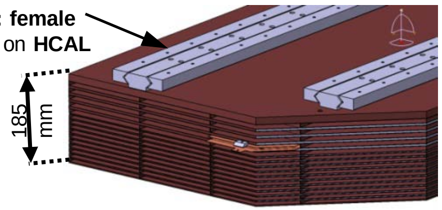
Influence of modification of external ply thickness on the first main constraint of external and internal walls



Optimization of deflection values

With a magnitude of maximal deflection of 1 mm, the maximal stress has a value greater than 13 Mpa (eligible tensile criteria)





1 of the 3 « standard » modules of each quarter

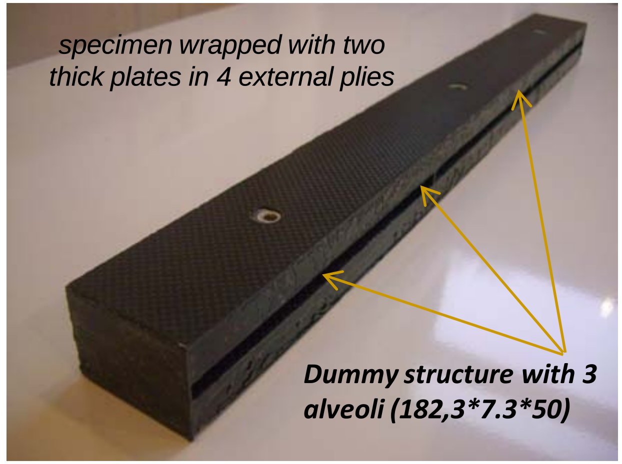
Impact on dead zone if external plies thickness increases (up to 5 mm in order to have a 10 MPa constraint)

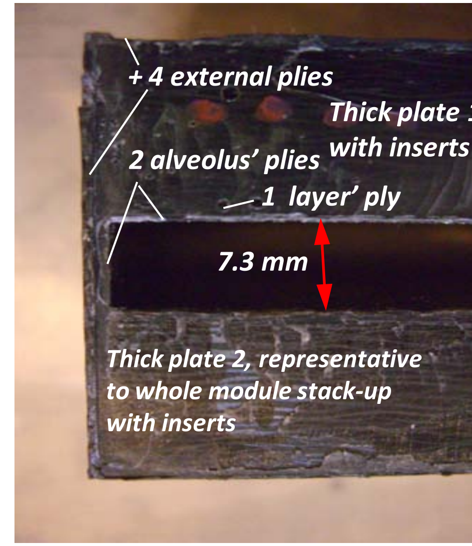
Tests: acceptable maximal stress (+safety factor) → destructive tests

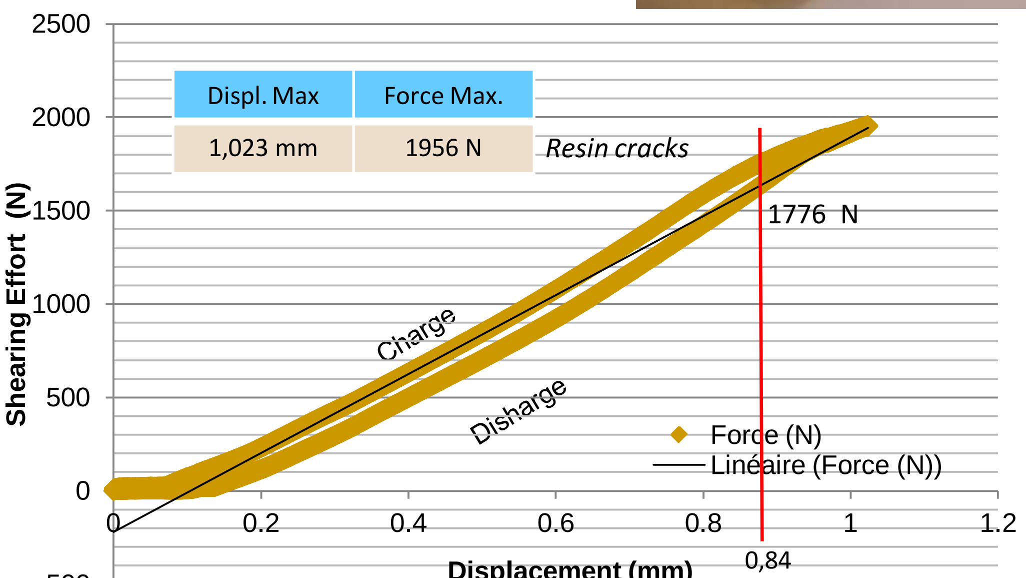
ECAL End-Caps: shearing tests

Dummy structure and tests: *nov. 2012*

From the structure of a real module (barrel or End-cap) Thick plate / alveoli / tungsten...







- Each tensile specimen: same polymerization cycle of resin / process used for the real structure
- 2 tests performed on dummy structures (up to cell's limit) with no rupture ! F Max~ 1800N Displacement ~0.85 mm
- The shearing allowable stress obtained with these tests: **6,6 MPa** before the first decline in the curve

- The calculated stress is relatively low compared to the allowable stress that can withstand the test specimen (before the first cracks, the composite structure, bears apparently perfectly shear stresses) - safety factor: 2,9 to 3.7 (correct for normal operating conditions) with respect to the stress induced by the weight of the largest module (2,5 m – 25,5 kN)

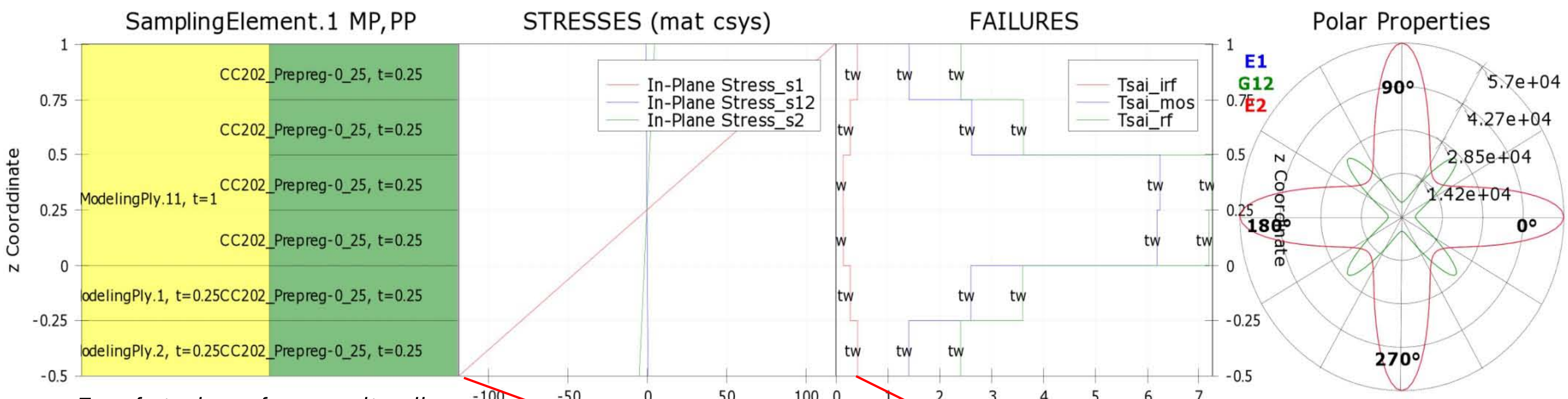
- The charge & discharge cycle thus shows an hysteresis in specimens' behaviour which certainly evolve towards a progressive decrease in the force / displacement with the gradual breakdown of the resin before destruction of the composite.

FEA simulations / test of the structure

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

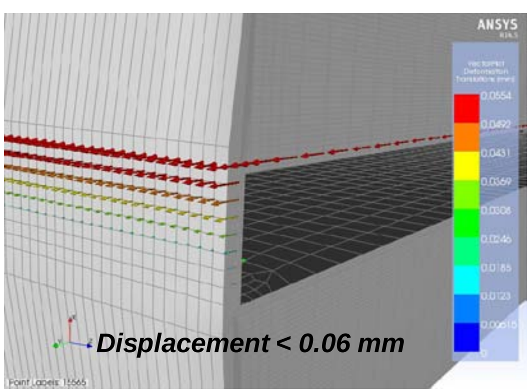
illustration and evaluation of the laminate properties of the lateral stackup

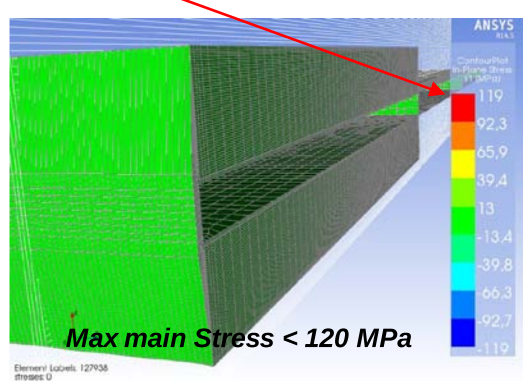
Assumptions of the Classical Laminate Theory

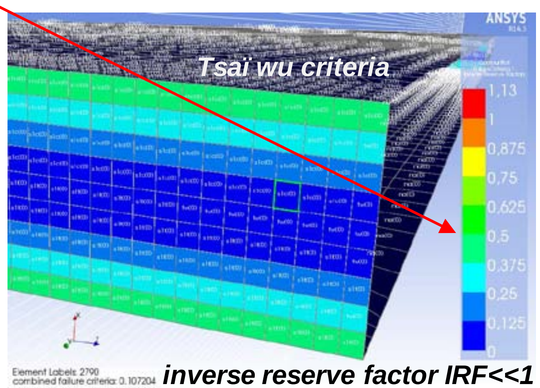


Ex. of stackup of composite plies on external wall (1,5mm thick)

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



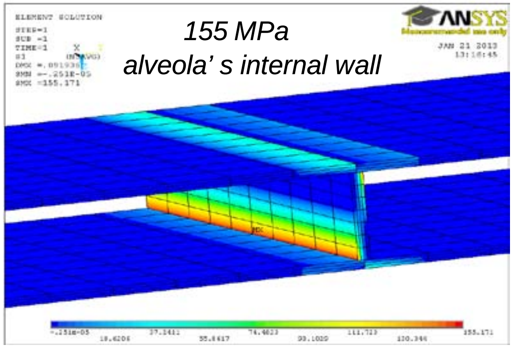




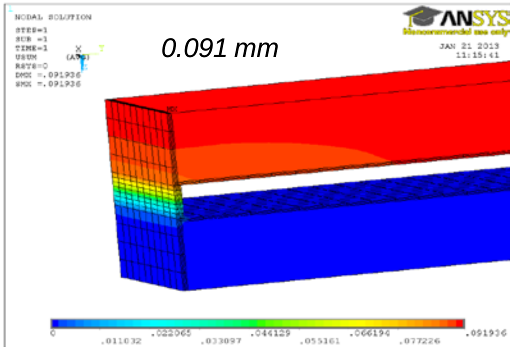
FEA simulations / test of the structure

Correlation of *FEA simulations / tests*

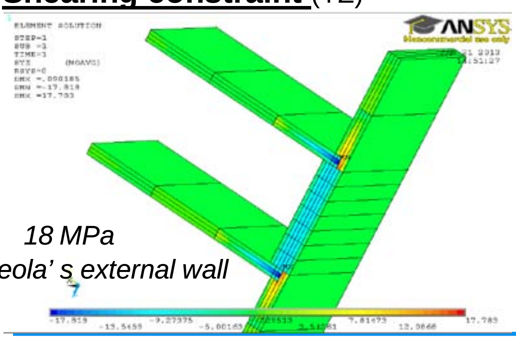
Main Constraints (S1)



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...

- **Destructive tests with charge & discharge cycles** (localized and progressive failure of the resin up to rupture) weakening of the structures during repeated or dynamic 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 & fastening

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**

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

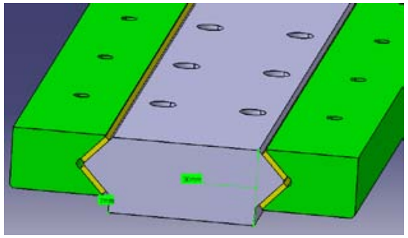
Easy manual extraction

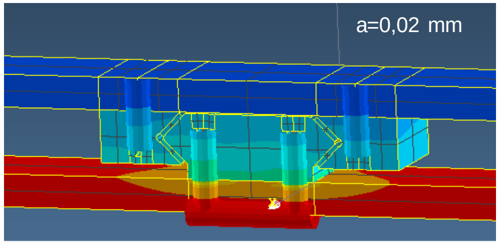
Next test: **Long End-Cap alveolar layer (April 2013)**
with new system woven-resin

- Design of specific tools for long draping
- Optimisation of rails positioning

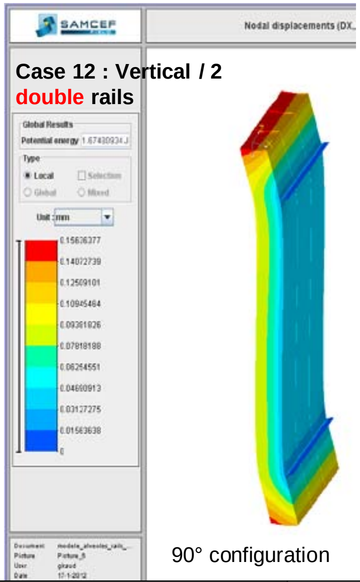
3D design of different fastening system

⇒ Thickness 30 mm & double row sized





Finite element calculation to determine the stiffness of the rails



90° configuration

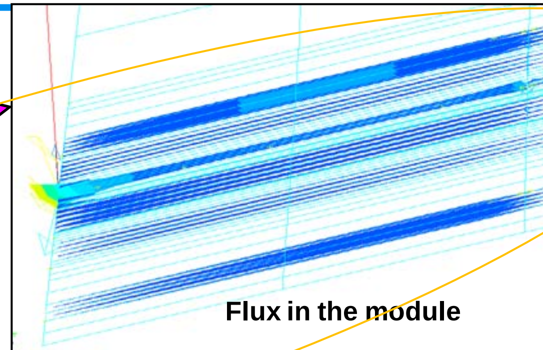
Type d'accrochage (vertical, horizontal)	Vertical
Nombre de rails	2
Type de rail (simple, bouble)	Double
Première contrainte principale (11411) (MPa)	8
Critères de TSAI Hill Version 1 (7621)	9.90E-03
Déplacement (mm)	0.16

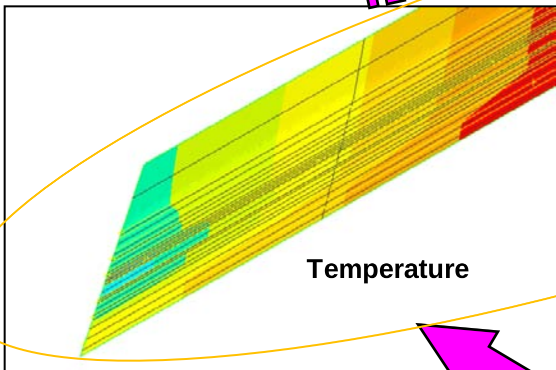
Opening in rails for cooling and services on each column (EUDET)

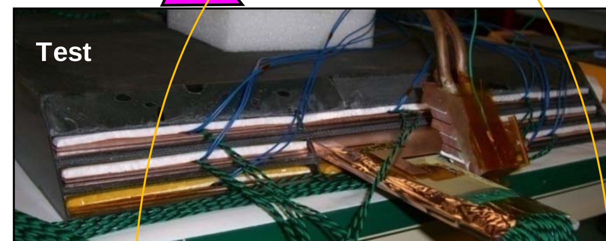
Finite element End Cap simulation : MODULE N°1
2.5 m long / 3 columns / position 0° and 90° / M = 2550 Kg
⇒ Goal of simulations: Influence of **position / nbr** of fastening systems on the mechanical behaviour (displacement / stress) …
⇒ Even if module is fastened with 2 double rails instead of 3 simple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

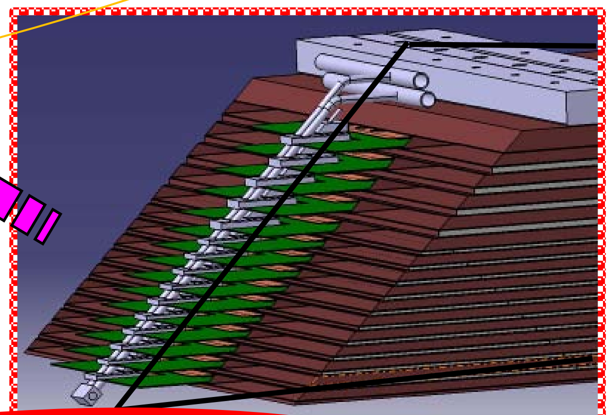
Work performed in cooling during 2012 and before

2 : Connection module / cooling

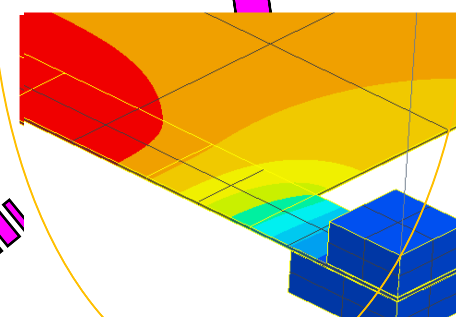




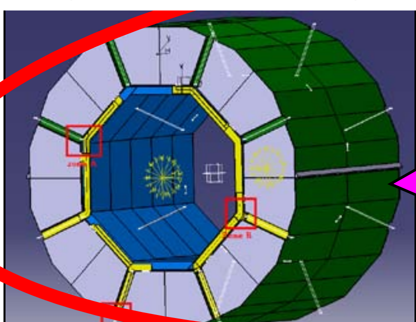


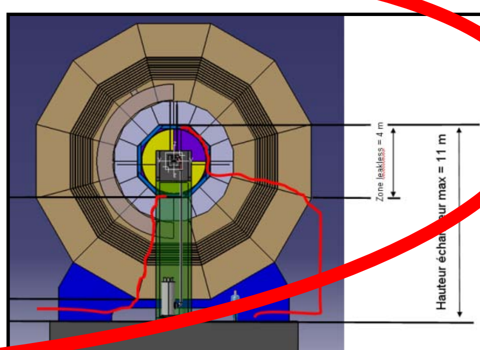


1 : Thermal transfert inside the module



Cooling distribution (see integration talk tomorrow)



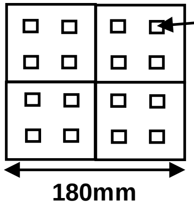


3 : Cooling global / Pipe integration

ECAL / Thermal flux inside modules

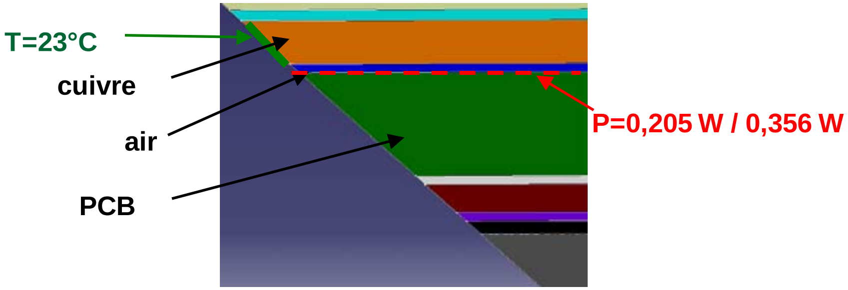
Inlet

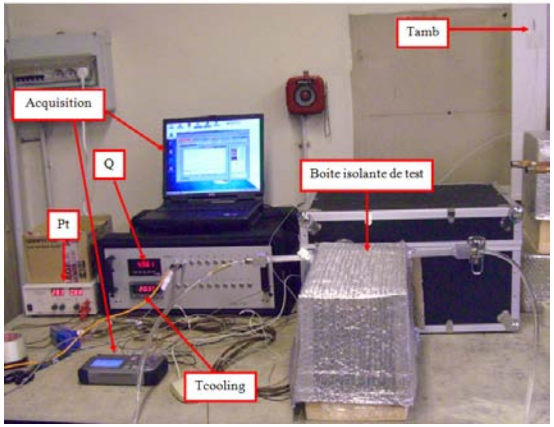
Power on PCB = 0,205 W / 0,356 W

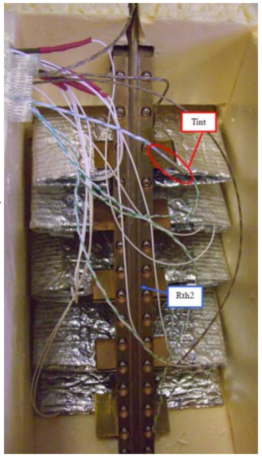


Barrel : (1,6.10-3*16)/180*1445=0,205 W
EndCap : (1,6.10-3*16)/180*2500=0,356W

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





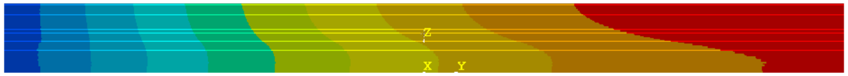


Results

Barrel : (1.5m)

ΔT = 2,2°C

End Cap : (2.5m)

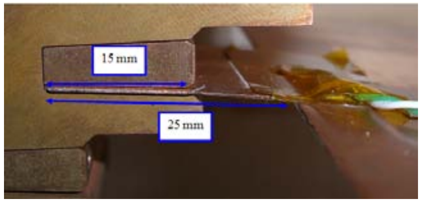


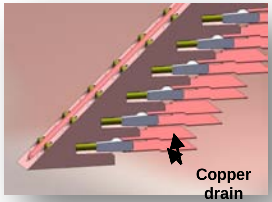
ΔT = 6°C

Conclusion

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

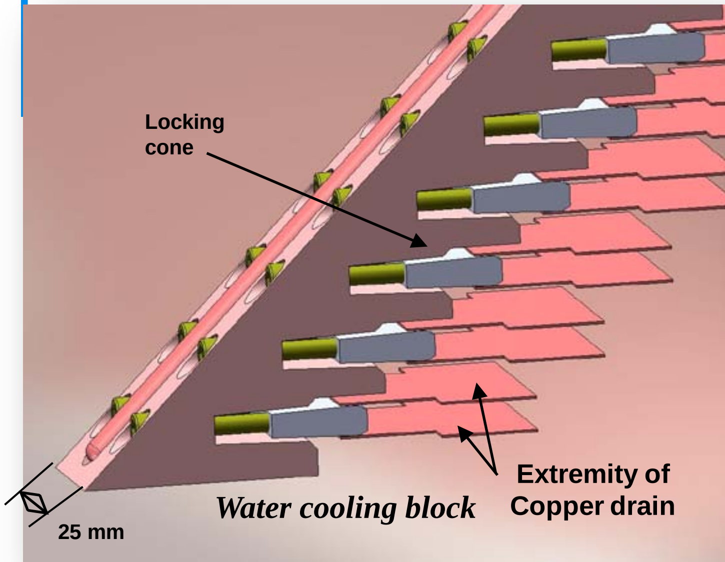
Confirmation: **25 mm** free opening in DIF for extraction of cooling system

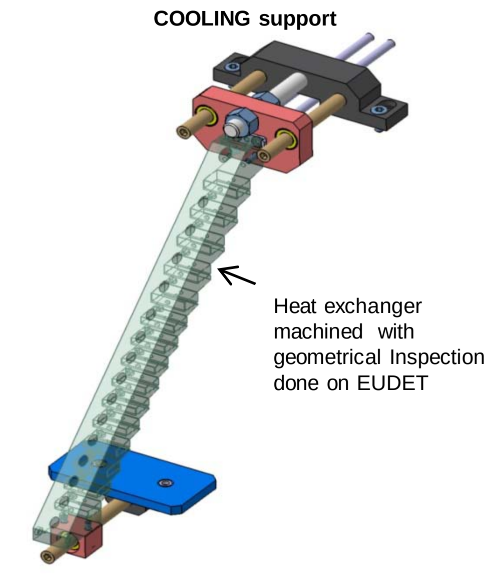


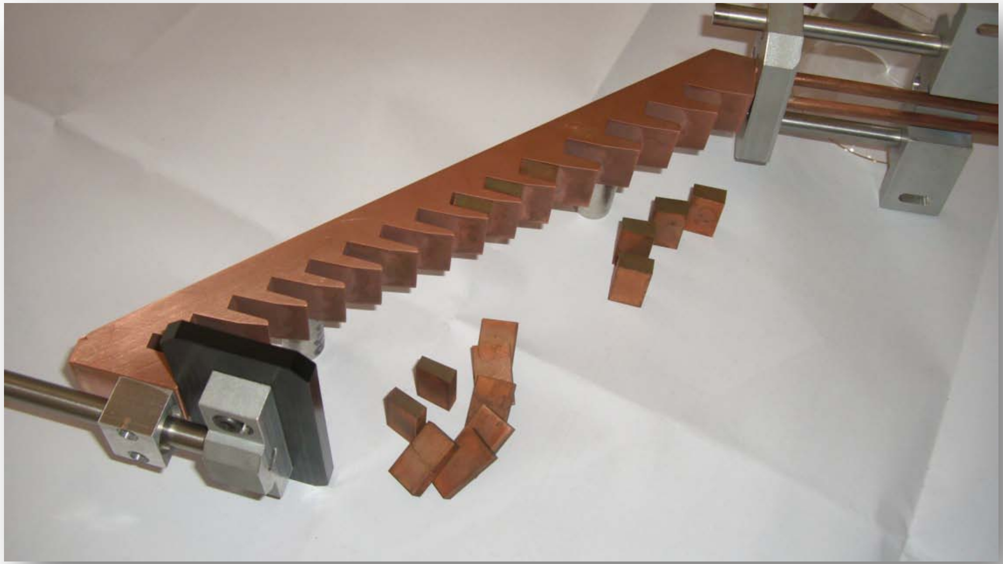


Copper plate / heat exchanger link

ECAL / Cooling / EUDET prototype



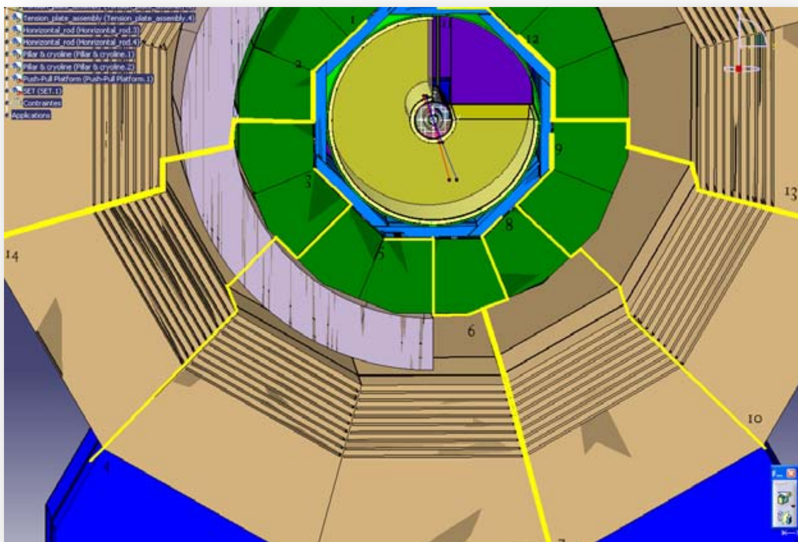




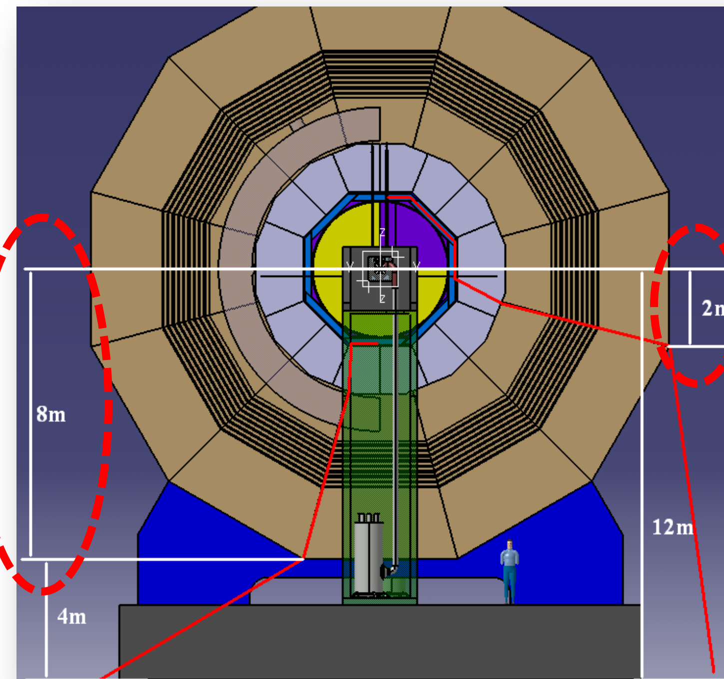
To be tested: Heat exchanger of EUDET
Test of the full heating column (15 layers)
Delivery: **November 2012**

ECAL / Cooling general setup

Fluid : Water
System : Leak less through all ILD
Power to be removed : 3 Kw to 30 Kw (5°c fluid temperature variation)
Electronic temperature will be maintained between 20° and 40°
Pipe inner diameter : 12 to 14 mm



Pipe path



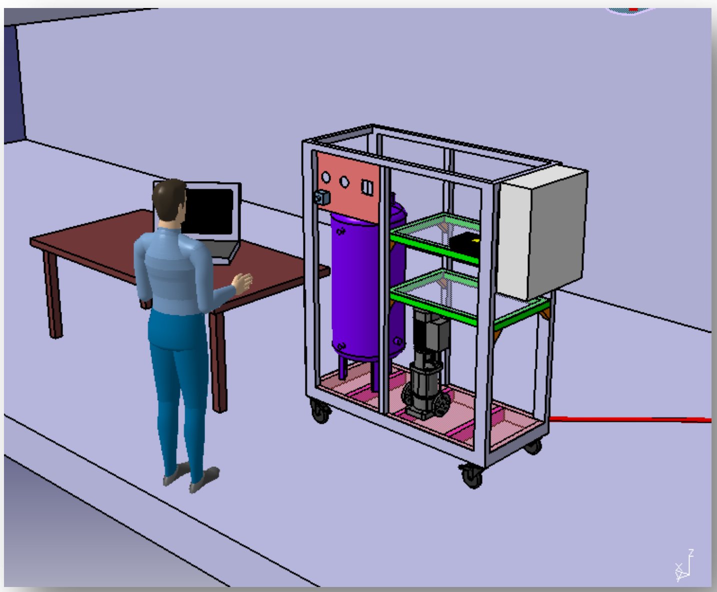
Leak less zone

Leak less test loop is important to validate the 8 m leak less zone

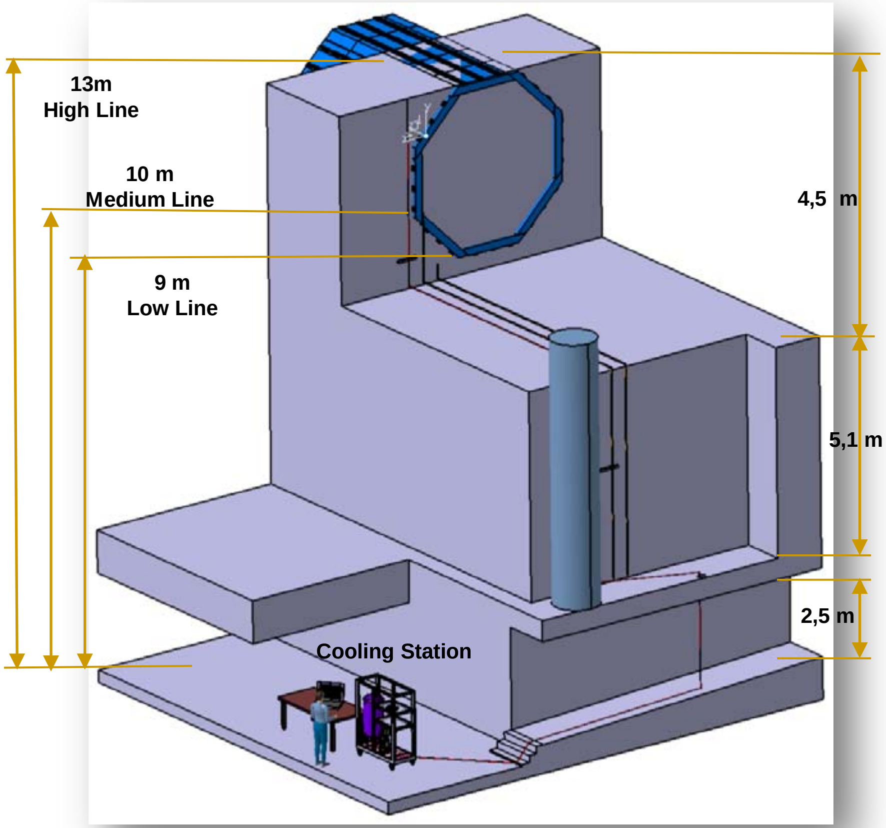
ECAL / Leak less test loop

Test loop goal :
- Validate the theory of the whole leak less system.
- Find maximum leak less zone versus pipe diameter.
- Minimum equipment needed for control (pressure transmitter, fluid flow transmitter…)
- Test heat exchanger / pipe connection

2013 :
- Skid assembling and testing
- First test with 3 loops => fall 2013



Cooling skid



LPSC test loop