SiW ECAL

Mechanics/cooling

ILD meeting LPNHE 4th June 2013

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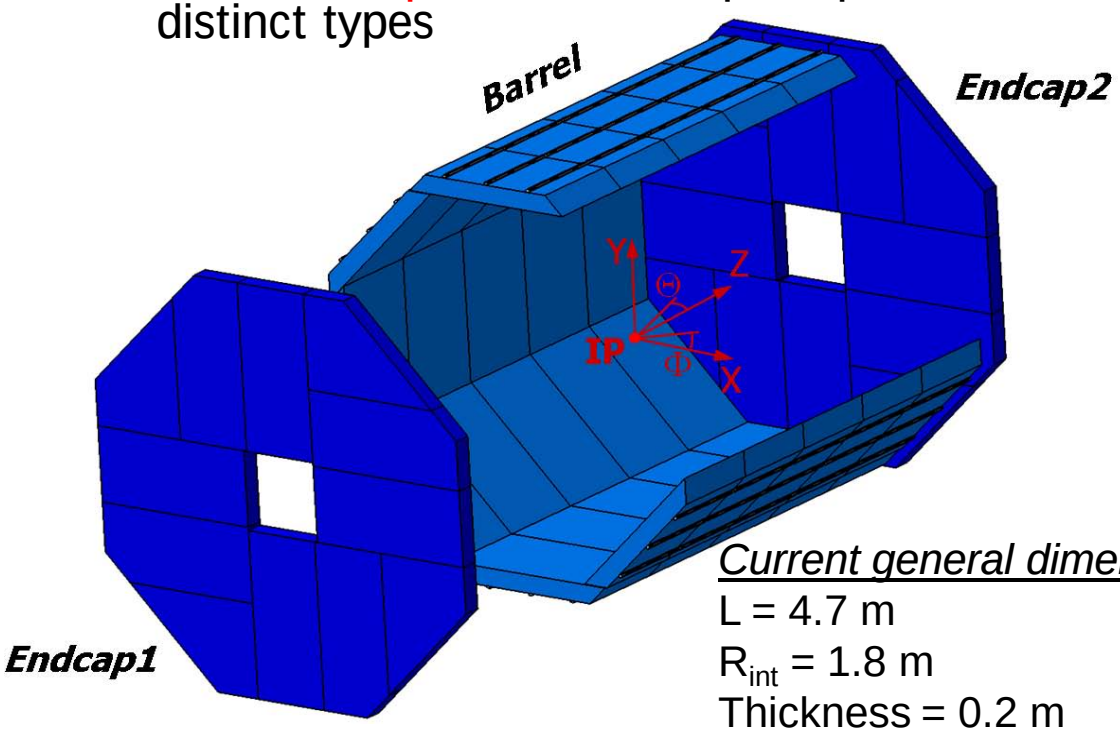
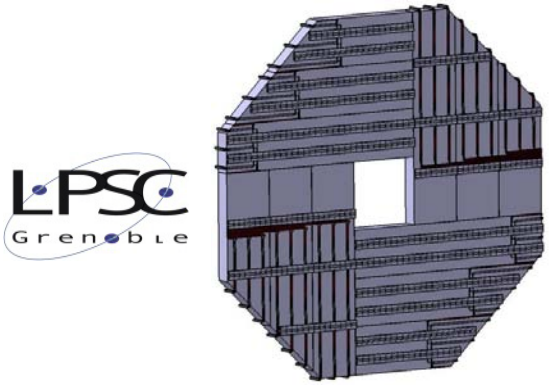
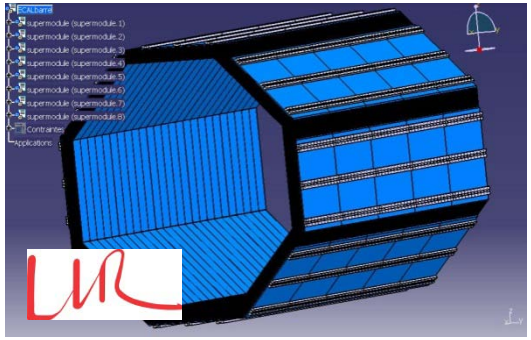
ILD - ECAL concept

- The calorimeter of ILD is divided in depth in an electromagnetic section (**ECAL**), and a hadronic section (**HCAL**). To follow the symmetry imposed by the beams and the coil, the electromagnetic calorimeter is divided into a cylindrical barrel and two end-caps.
- The ECAL barrel consists of 40 identical trapezoidal modules of tungsten absorber plates (~80 t) interleaved with layers of Silicon detectors with very fine segmentation of the readout (5x5 mm^2)
- ECAL endcaps : The same principle than barrel (~50 t) with 12 modules of 3 distinct types







Current general dimensions:

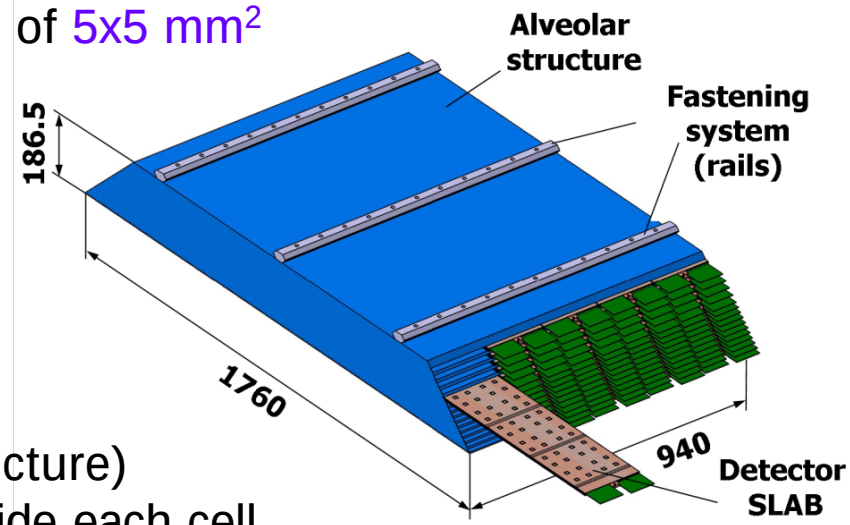
L = 4.7 m

R_{int} = 1.8 m

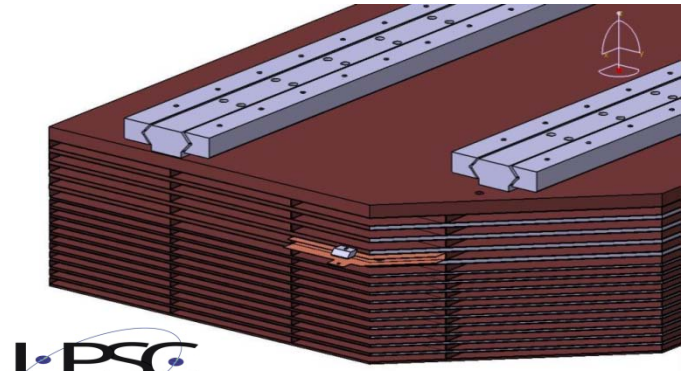
Thickness = 0.2 m

Main features of the ECAL

- Multilayer calorimeter Silicon/Tungsten as compact as possible (small Molière radius) with pixel of 5x5 mm^2
- Sampling of W in depth according to the need of energy resolution : ~23 X_0
- Half of the tungsten plates is incorporated into a self-supporting alveolar composite structure (carbon) to avoid machining step and reduce dead zone
- Half of W plates in supports (H-shaped structure) called detector slab, which are then slid inside each cell
- fastening system ECAL/HCAL is included in the design (rails)



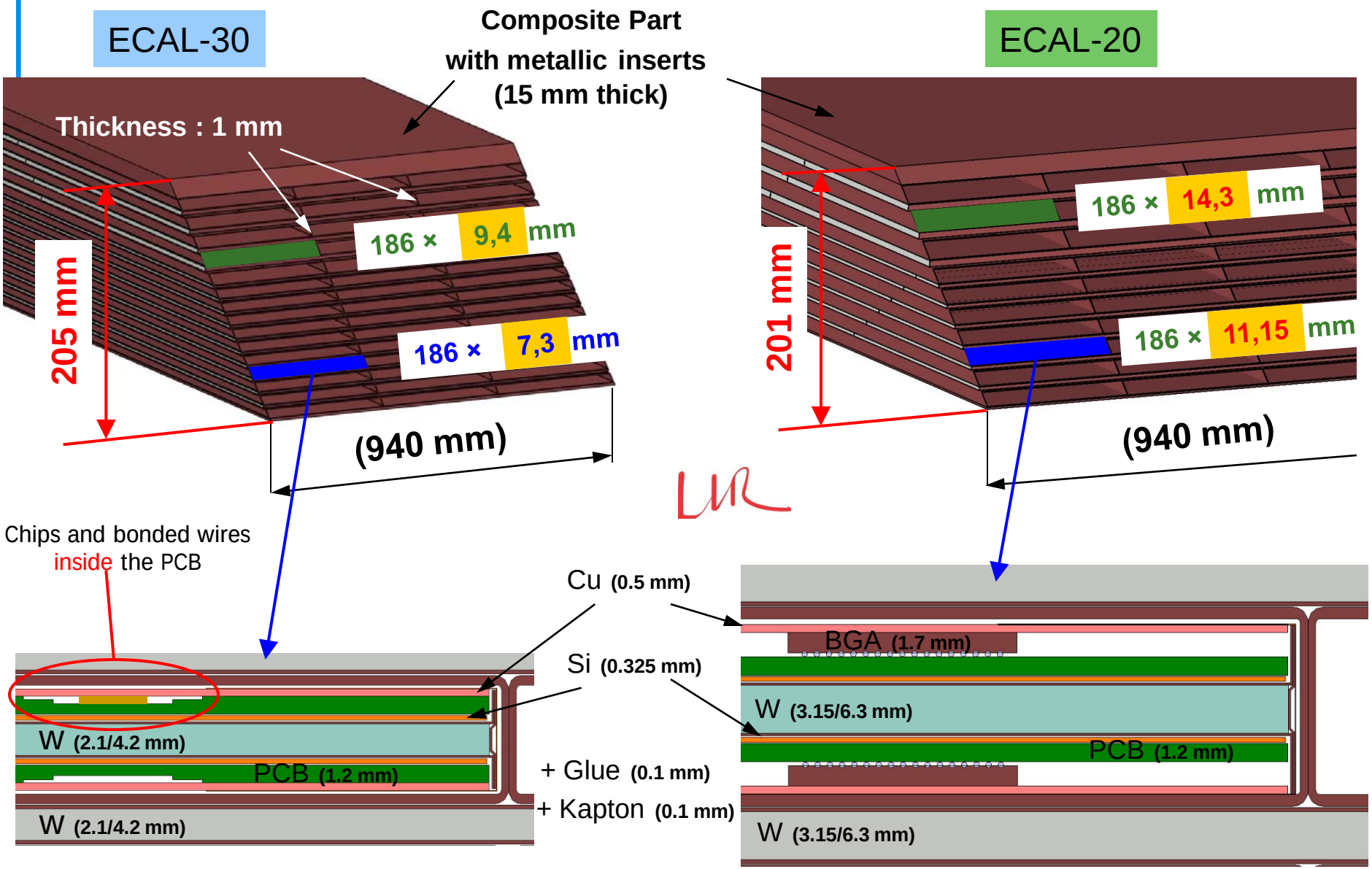
Alveolar Structure (Technological proto)



Endcap module design

1 of the 3 « standard » modules

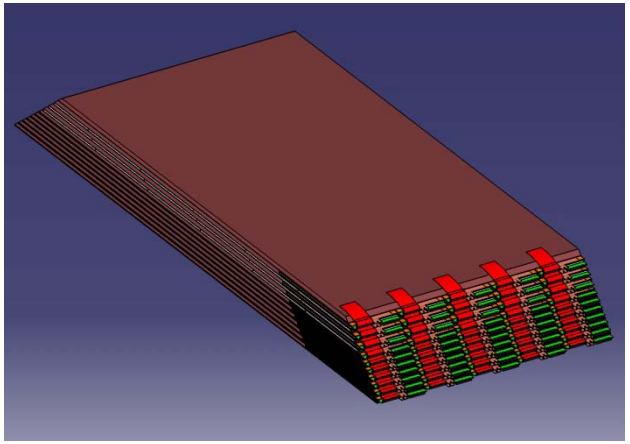
ECAL Barrel : 30 layers vs 20 layers

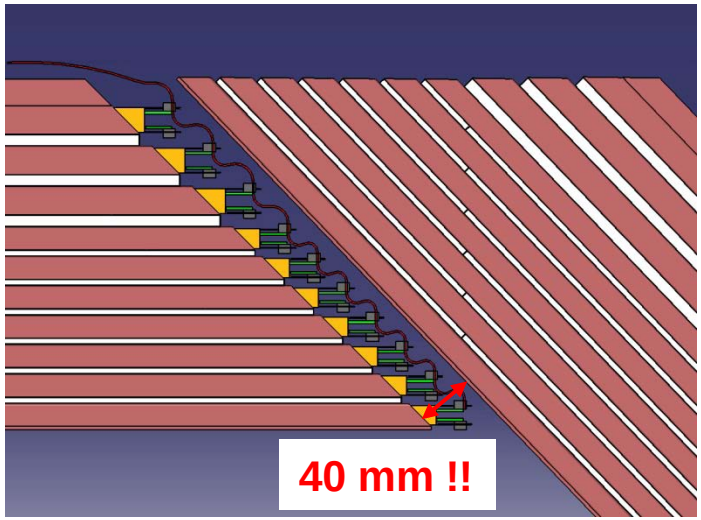


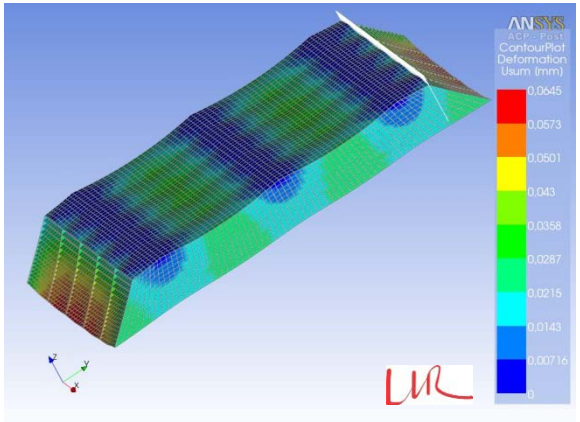
ILD Design : ECAL-20

- CAD model is completely parameterized for barrel: can be adapted according to results of physics simulations (nb of layers, dimensions ...)

Current design of the barrel module with a proposal of the interface using ribbons of cables







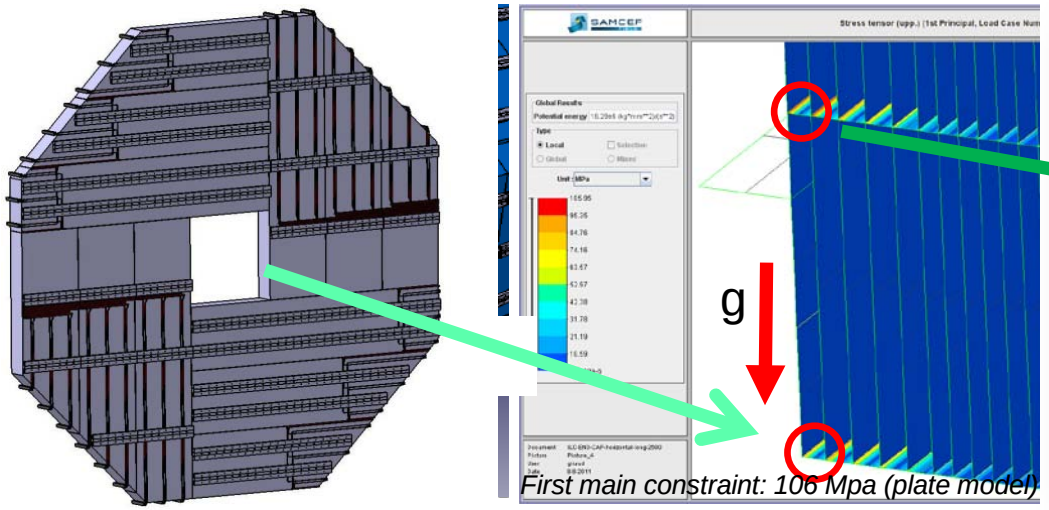
- Mechanical Simulations

- Need to perform mechanical simulations with ANSYS to check all loads cases (0°, 45° and 90°)

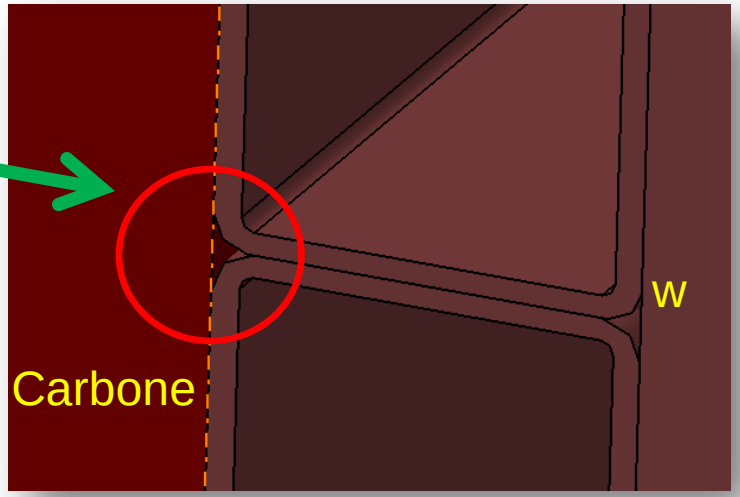
- Need to continue destructive tests on materials and prototypes (typ. the thermal proto instrumented with bragg grattings) to implement correctly simulations and define all the margins of security of the model.

ECAL: evolution of skin thickness

Problem of bending stress of alveoli skins



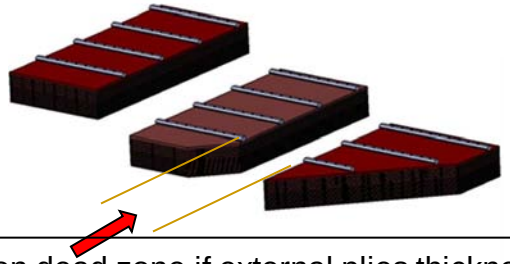
First main constraint: 106 Mpa (plate model)



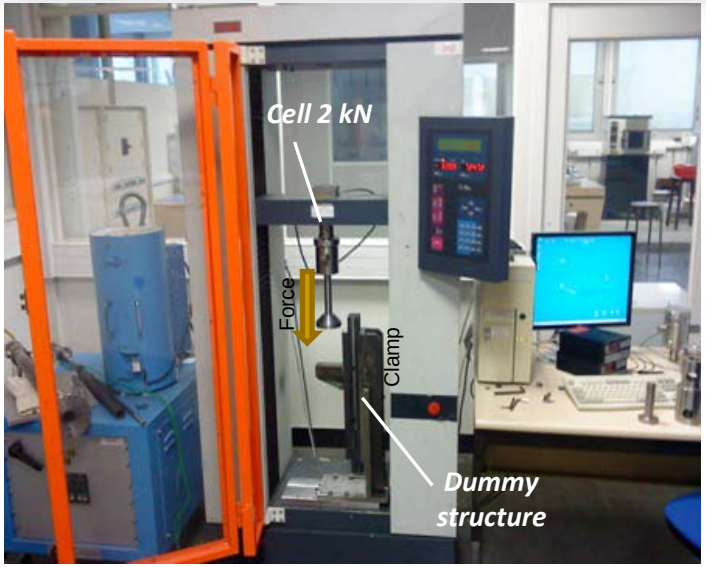
Influence of modification of external ply thickness on the first main constraint of external and internal walls

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) ⚠



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

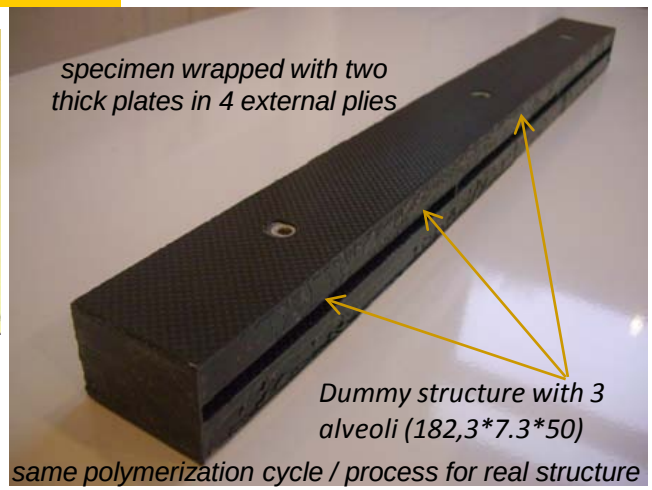


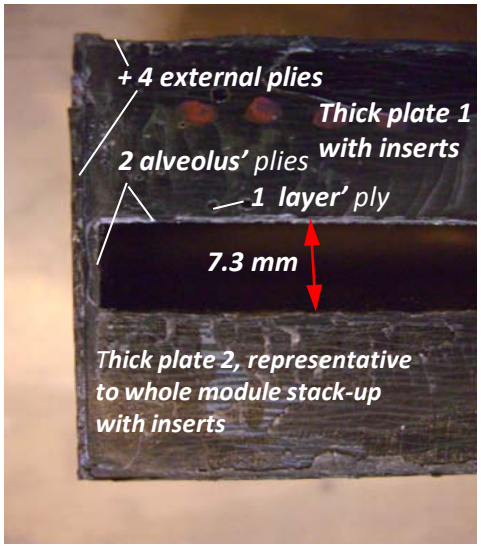
Tests: acceptable maximal stress (+safety factor) → destructive tests...

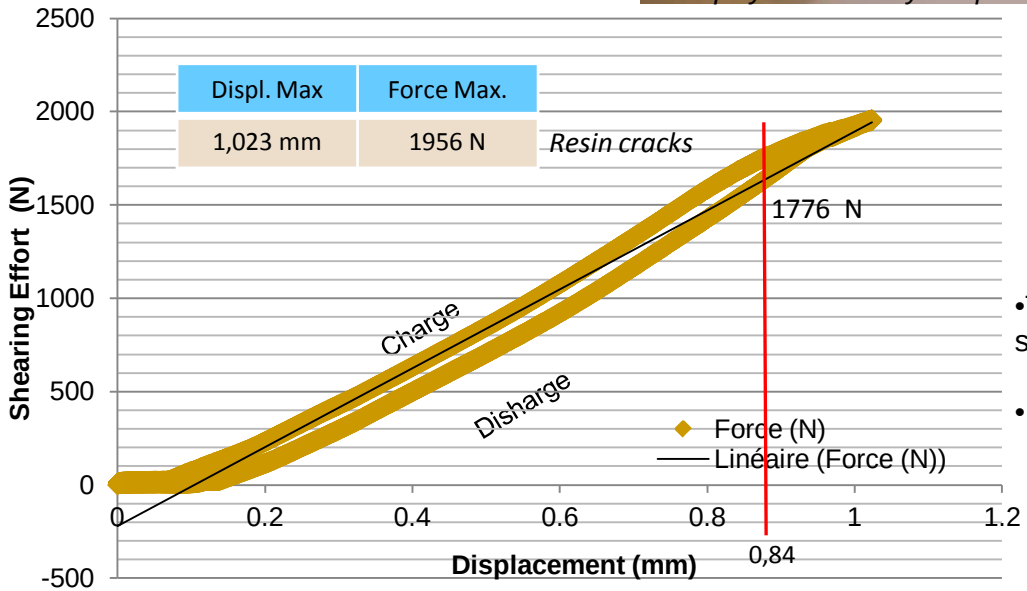
ECAL End-Caps: shearing tests

Dummy structure and tests

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







- 2 tests performed on dummy structures with no rupture !
- 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
- 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 evolves towards a progressive decrease in the force / displacement with the gradual breakdown of the resin before destruction of the composite… Tests to be continued.

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**

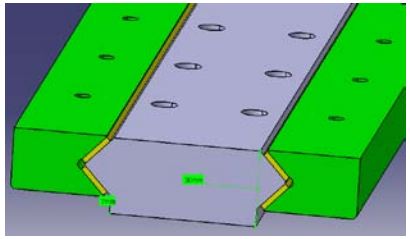
The 1st long layer of 3 alveoli demolded (186,8 x 6,5 mm x 2,5m – 0,5 mm thick)

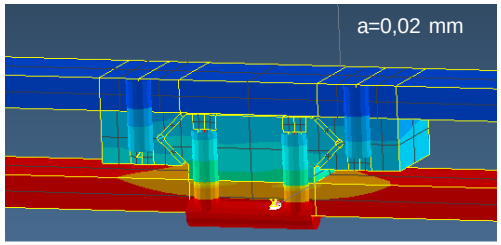
Easy manual extraction

Next test: Long End-Cap alveolar layer with new system woven-resin

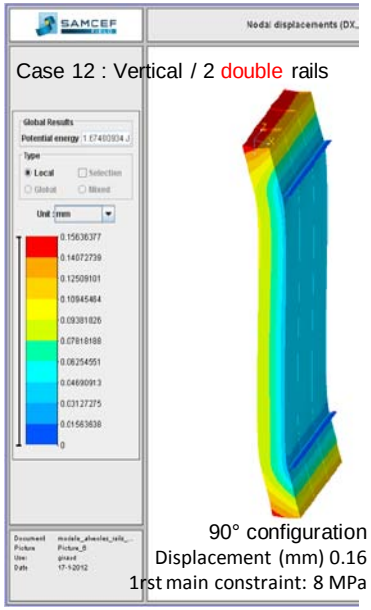
- Design of specific tools for long draping
- Optimisation of rails positioning

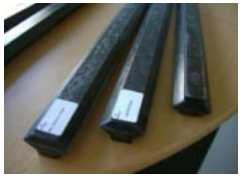
3D design of different fastening system ⇒ Thickness 30 mm & double row sized





Finite element calculation to determine the stiffness of the rails





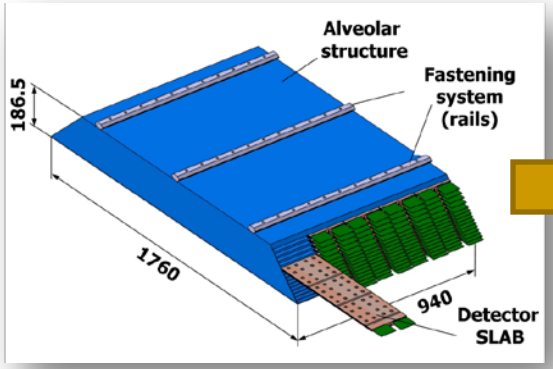
Design and prototypes of
- aluminium rails
- Carbone composite rails

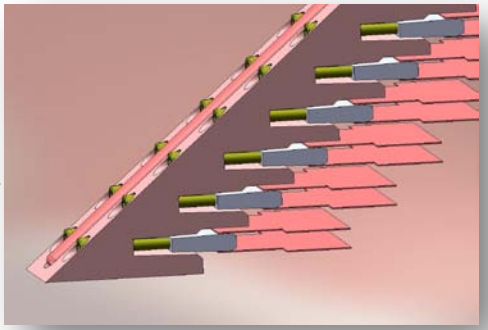
Finite element End Cap simulation : MODULE N°1
2.5 m long / 3 columns / position 0° and 90° / M = 2550 Kg

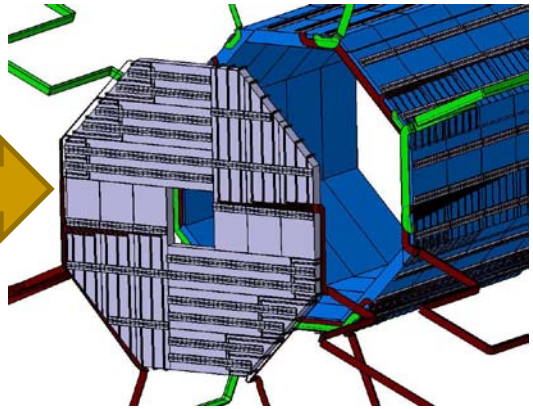
⇒ Goal of simulations: Influence of position / nbr of fastening systems on mechanical behaviour (displacement / stress) …
⇒ deflections less important with 2 double rails / 3 simple rails

Cooling: leakless water system

Study from the power source to the global cooling

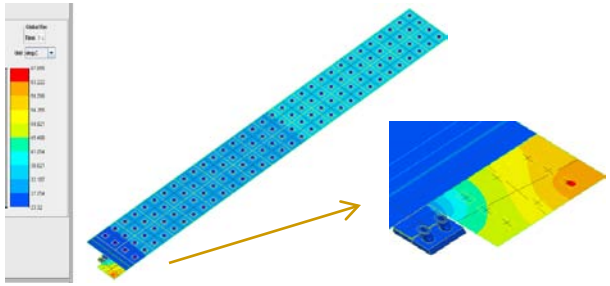






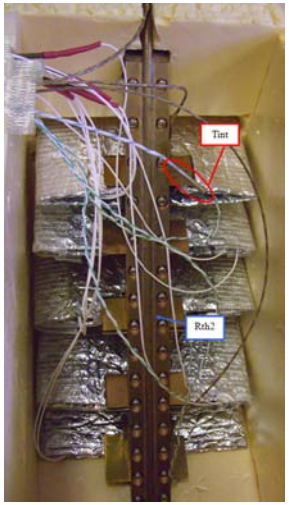
SLAB

Thermal simulation and test on Slab



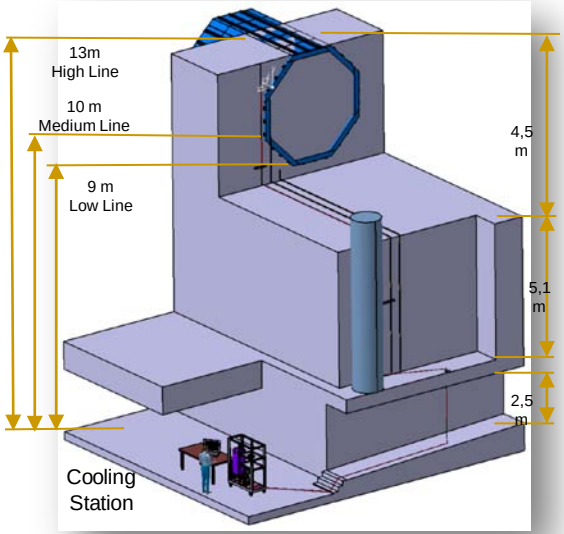
Heat exchanger

Simulation and test on different type of heat exchangers



Global cooling

True scale leak less loop

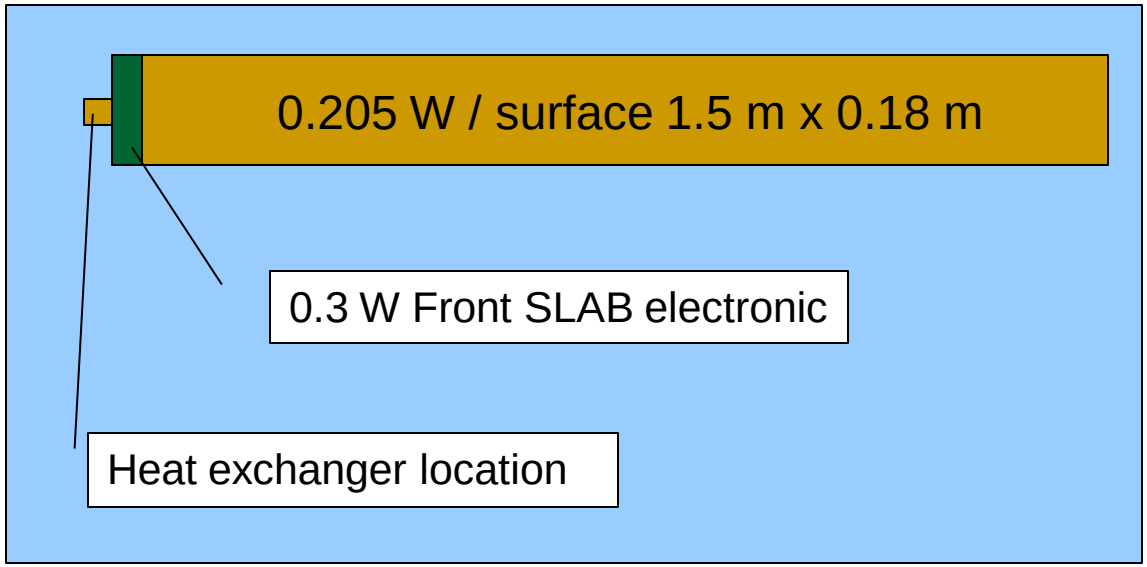


Cooling capability

Power dissipation : Final goal with power pulsing 1/100 s

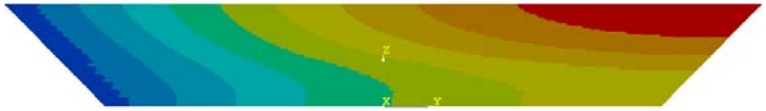
For ½ SLAB from barrel
Wafers consumption : 0.205 W
Front SLAB electronic : 0.3 W

Ecal detector : 4.5 Kw



Passive cooling : OK

Barrel : (1.5m)



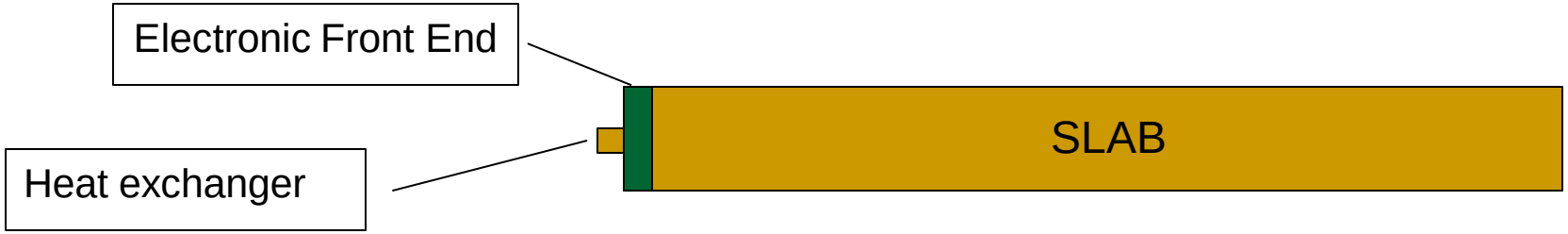
ΔT = 2,2°C

End Cap : (2.5m)

ΔT = 6°C

Cooling capabilities

/ Electronic consumption		1/2 SLAB						
		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



To do …

Composite / structure:

- Mechanical simulations with ANSYS to check all loads cases (0°, 45° and 90°)
- 2.5 m x 3 alveoli carbon End cap fabrication test
- Dummy structure shearing tests
- Destructive tests on materials and prototypes

(typ. the thermal proto instrumented with bragg grattings) to implement correctly simulations and define all the margins of security of the model

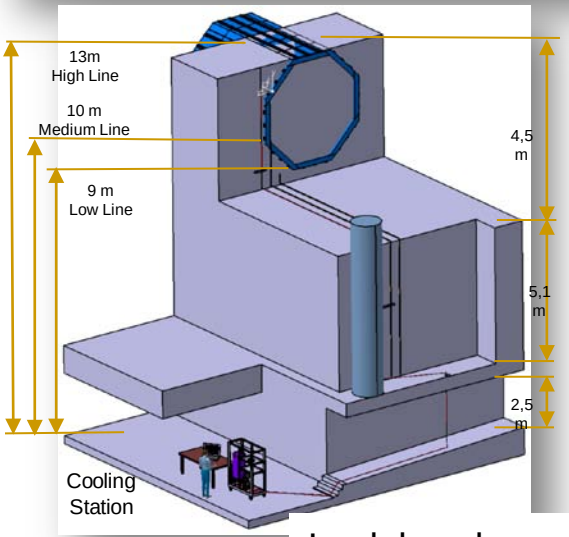
*Dummy structure with 3 alveoli (182,3*7.3*50)*

Cooling:

- True scale leak less loops
- Validation of heat exchanger on full column

EUDET Water heat exchanger

Cooling station



Leak less loops