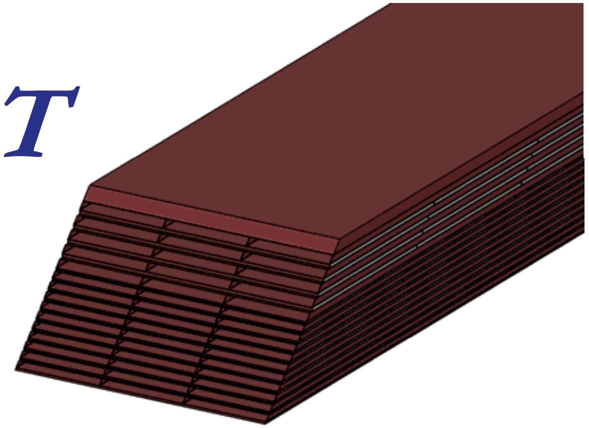
Mechanical R&D for Technological EUDET ECAL Prototype



Marc Anduze – CALICE Meeting – KOBE 10/05/07

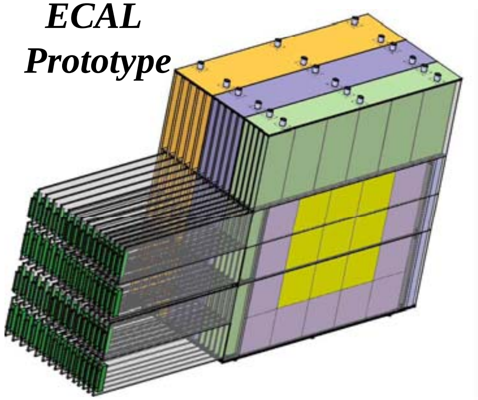
Why this prototype ?

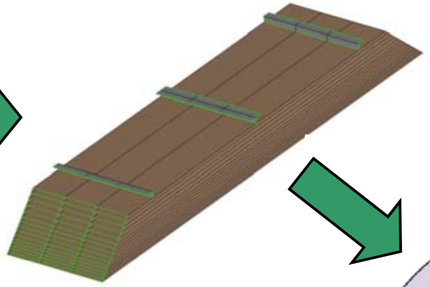
- Next step after the physics prototype and before the module 0
- To study “full scale” technological solutions which will be used for the final detector

(moulding process, thermal cooling, inlet/outlet, integration tools …)

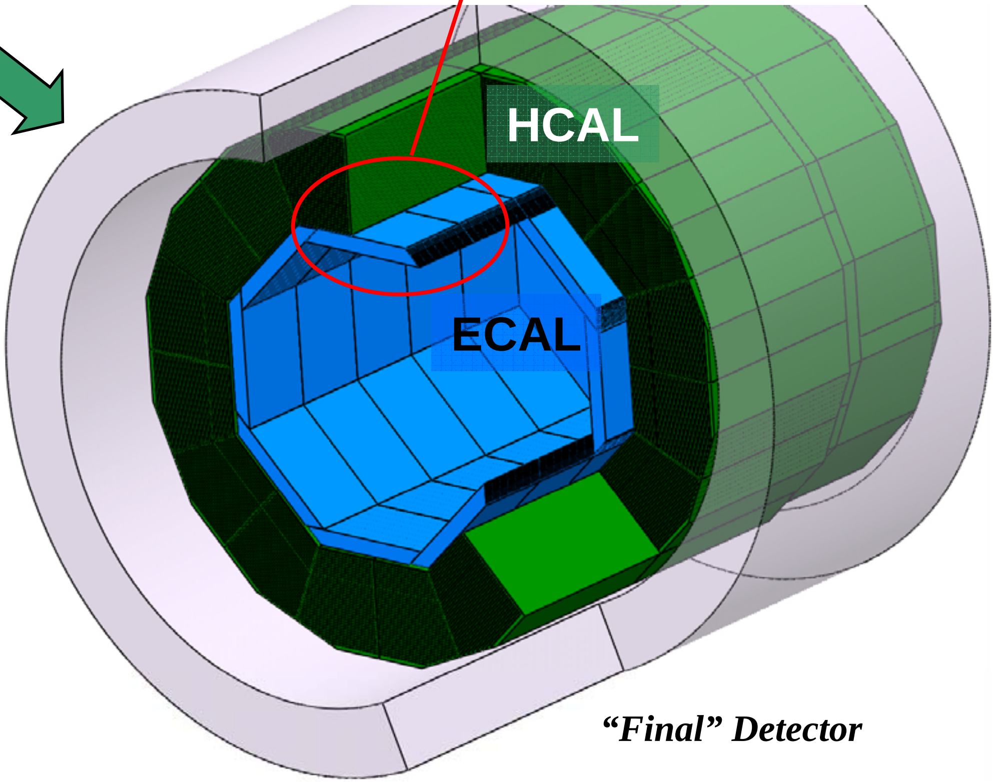
- To take account of the industrial point of view
- To estimate the cost of the future Si/W ECAL

ECAL Prototype

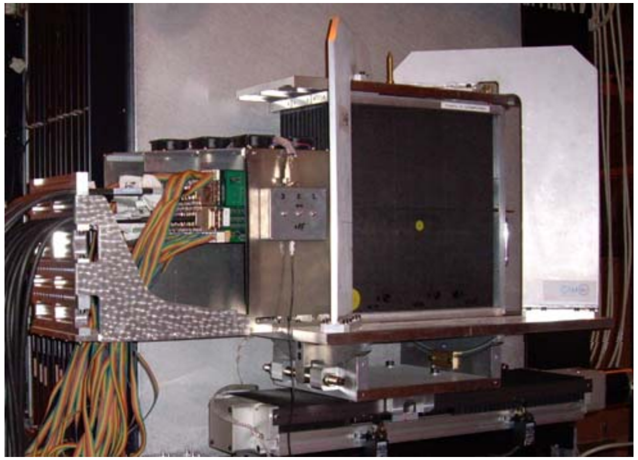




Tech. prototype



“Final” Detector

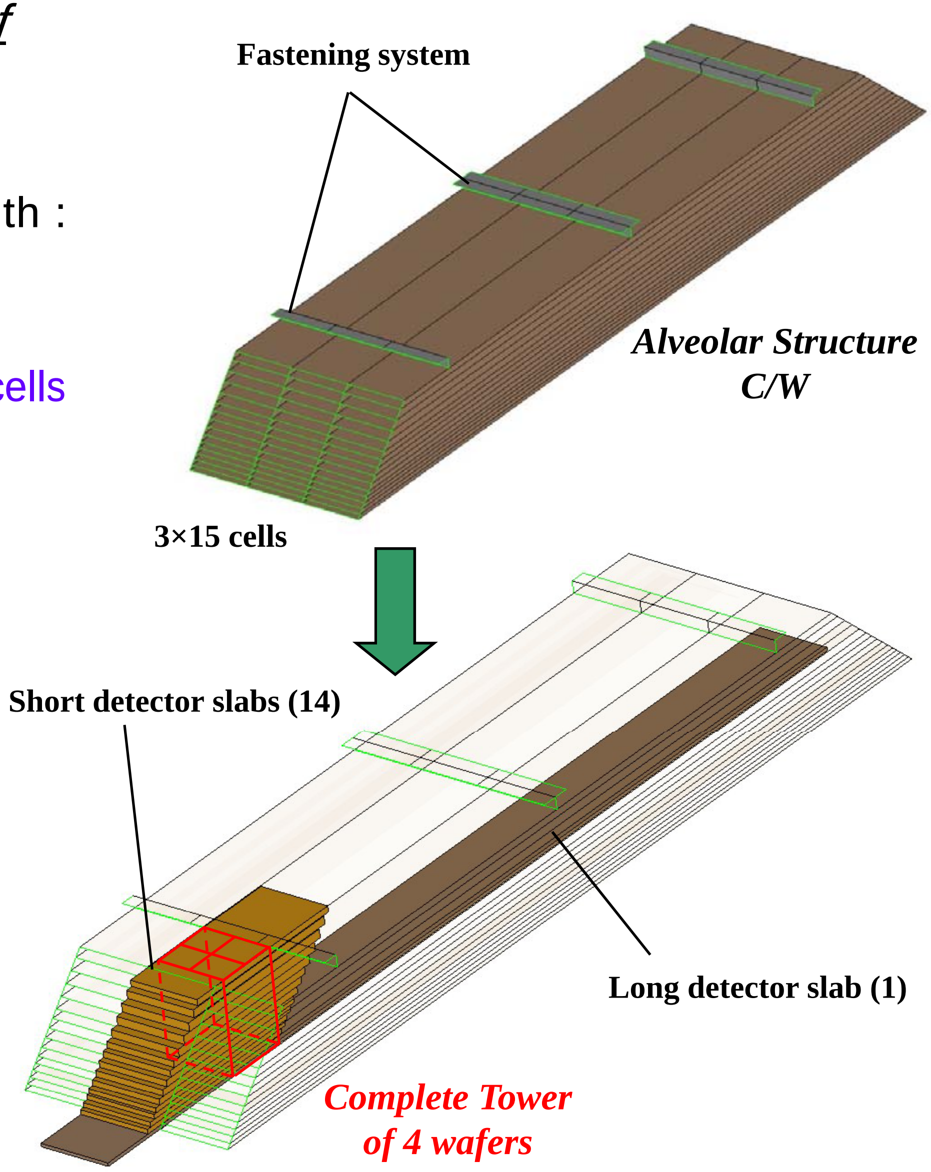


Global Presentation

Concept : to be the most representative of the final detector module :

- An alveolar composite/tungsten structure with :
  - same W sampling :
    20×2.1 mm and 9×4.2 mm thick
  - 3 columns of cells to have representative cells in the middle of the structure (with thin composite sheets)
    width : 124 mm ➡ **180 mm**
  - Identical global dimensions (1.5m long) and shape (trapezoidal)
  - fastening system ECAL/HCAL (include in the design of composite structure)

- 15 Detector slabs with FE chips integrated
  - 1 long and complete slab ? (L=1.3m)
  - 14 short slabs to obtain a complete tower of detection (typ. L=40 cm)
  - design of compact outlet (support system)

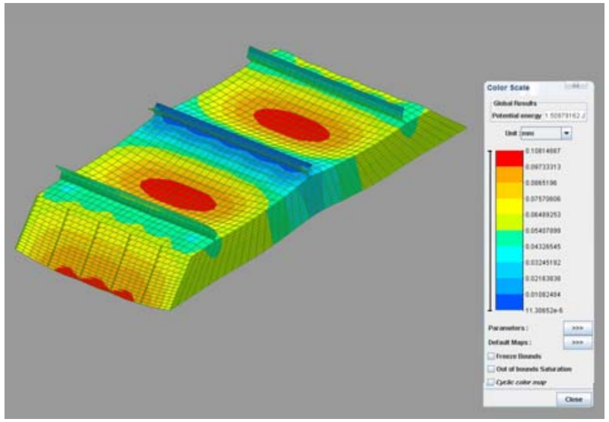


Design of the module…

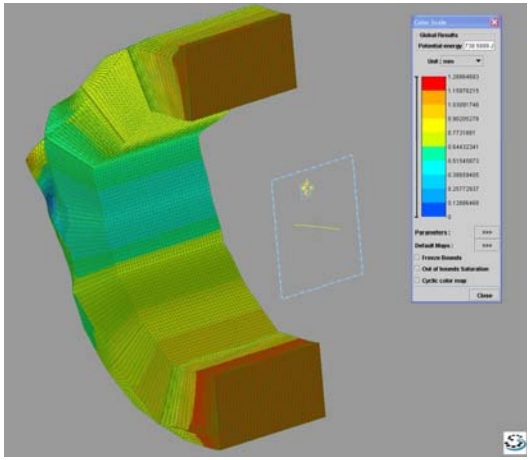
... based on mechanical simulations :

Linear Analysis of "full scale" ECAL and HCAL modules

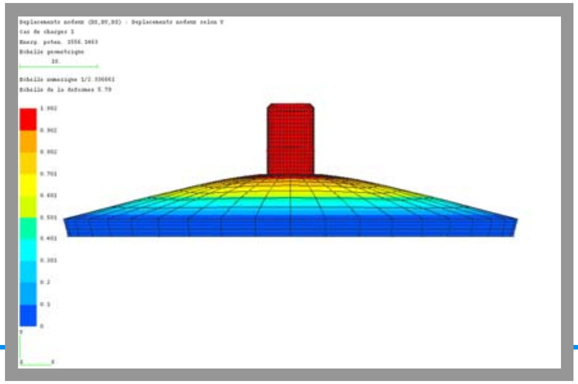
- Global simulations : global displacements and localization of high stress zone for different solutions (dimensions)
- Local simulations : more precise simulations and study of different local parameters to design correctly each part of this structure (thickness of main composite sheets, choice of fasteners : metal inserts, rails...)
- Check and validate simulation results by destructive tests for each issues



ECAL



HCAL



behaviour of an insert in composite with tensile loads

Design of the module …

… while taking account of Slab Thermal analysis

Thermal sources:

Pad size	Chan/ wafers	Ch/chip	Chip/wafer	Chip size mm²	Chan/barrel	Chan/ End-cap
5*5 mm ²	144	72	2	15x15	60.4 M	21.8 M

⇨ CALICE ECAL: ~ 82.2 M of channels

Assuming that the chip power is 25 µW/channel

total power to dissipate will be : 2055 W

⇨ external cooling OK for the “full scale ECAL”

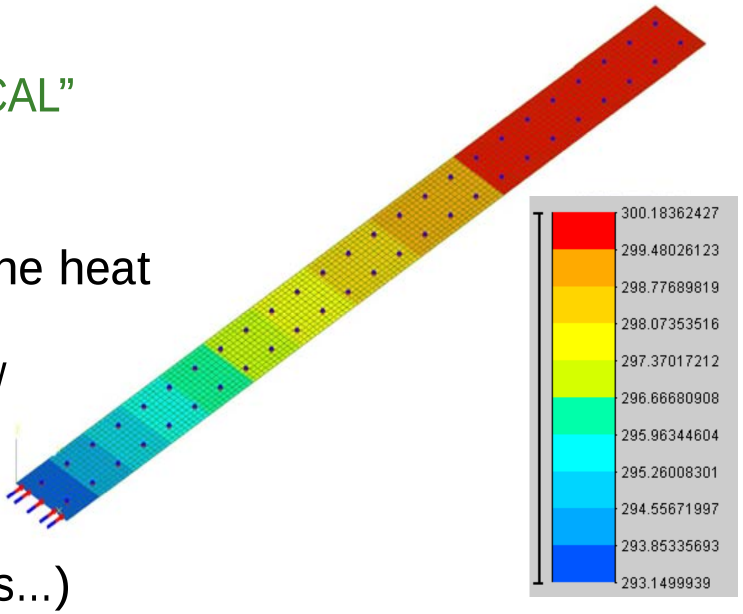
inside each slab :

necessity of cooling system but active or passive ?

Ex: Pessimist simulation of heat conduction just by the heat shield :

λ = 400 W/m/K (copper) ; $S = 124*0{,}4\ \mathrm{mm}^2$

$L = 1{,}55$ m ; $\Phi = 50*\ \Phi_{chip} = 0{,}18$ W

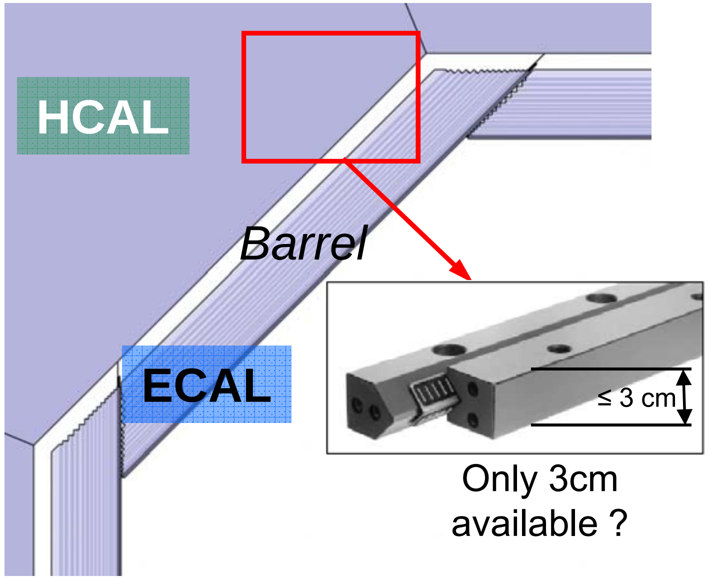


We can estimate the temperature difference along the slab layer around 7°C and without contribution of all material from slab (PCB, tungsten, carbon fibers…)

⇨ passive cooling OK :

Thermal conductors (heat shield) can be added in the slab to carry heat more efficiently along the slab direction.

Design of the module …

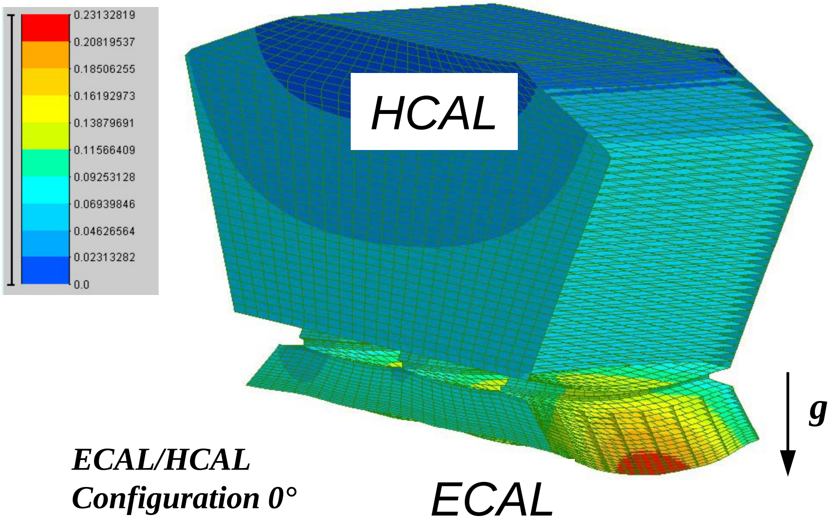


Only 3cm available ?

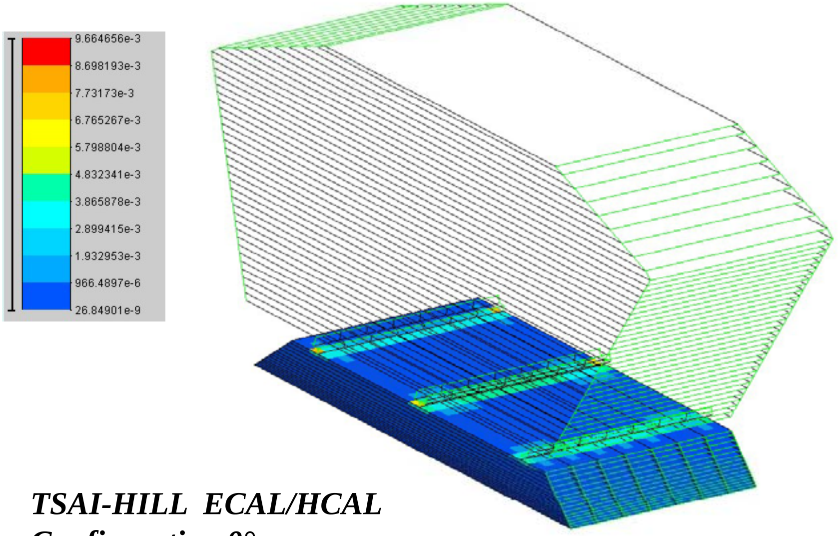
… including ECAL/HCAL interfaces (+ inlet/outlet) :

The fastening and connection system for the module has to be representative of the ECAL/HCAL interfaces.

- Choice of fasteners : rails directly glued on composite or metal inserts inside the structure ?
- Mechanical simulations of the ECAL/HCAL interface to take into account of its influence
- Design of connection system (power supply + cooling + outlets) : backend system ?



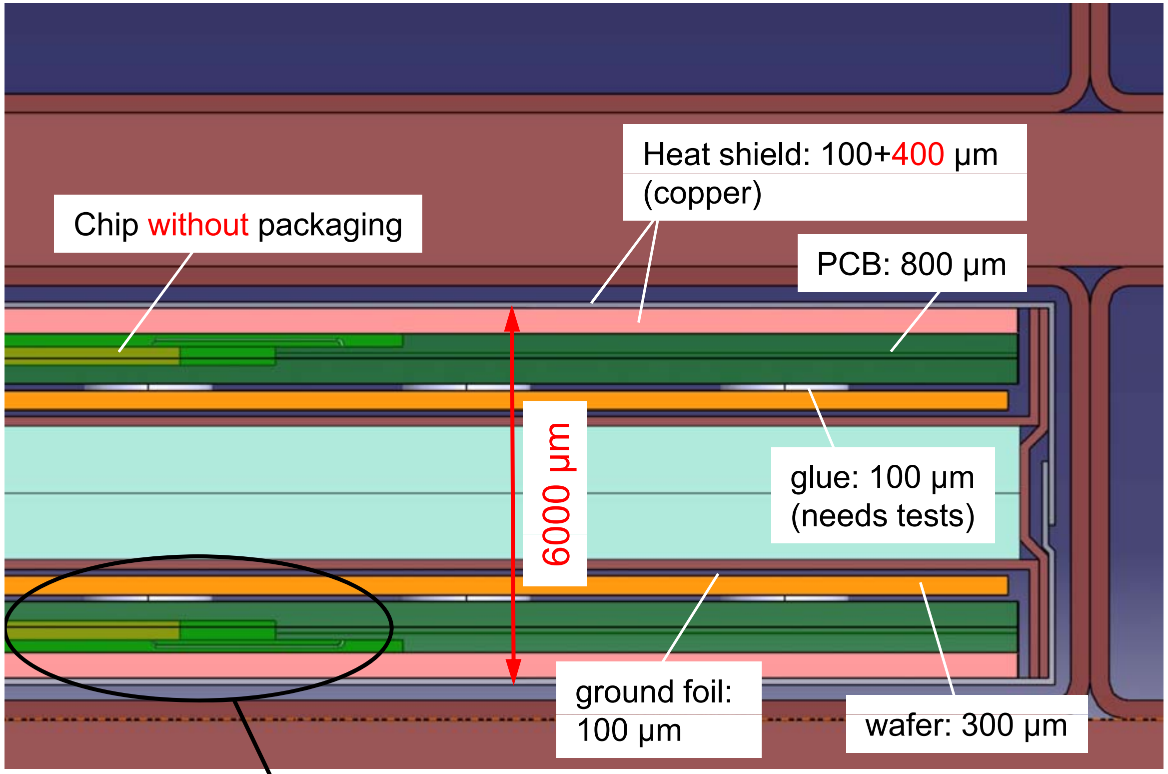
ECAL/HCAL Configuration 0°



TSAI-HILL ECAL/HCAL Configuration 0°

Design of the module…

… based on the definition of the detector slab :



Design EUDET Slab

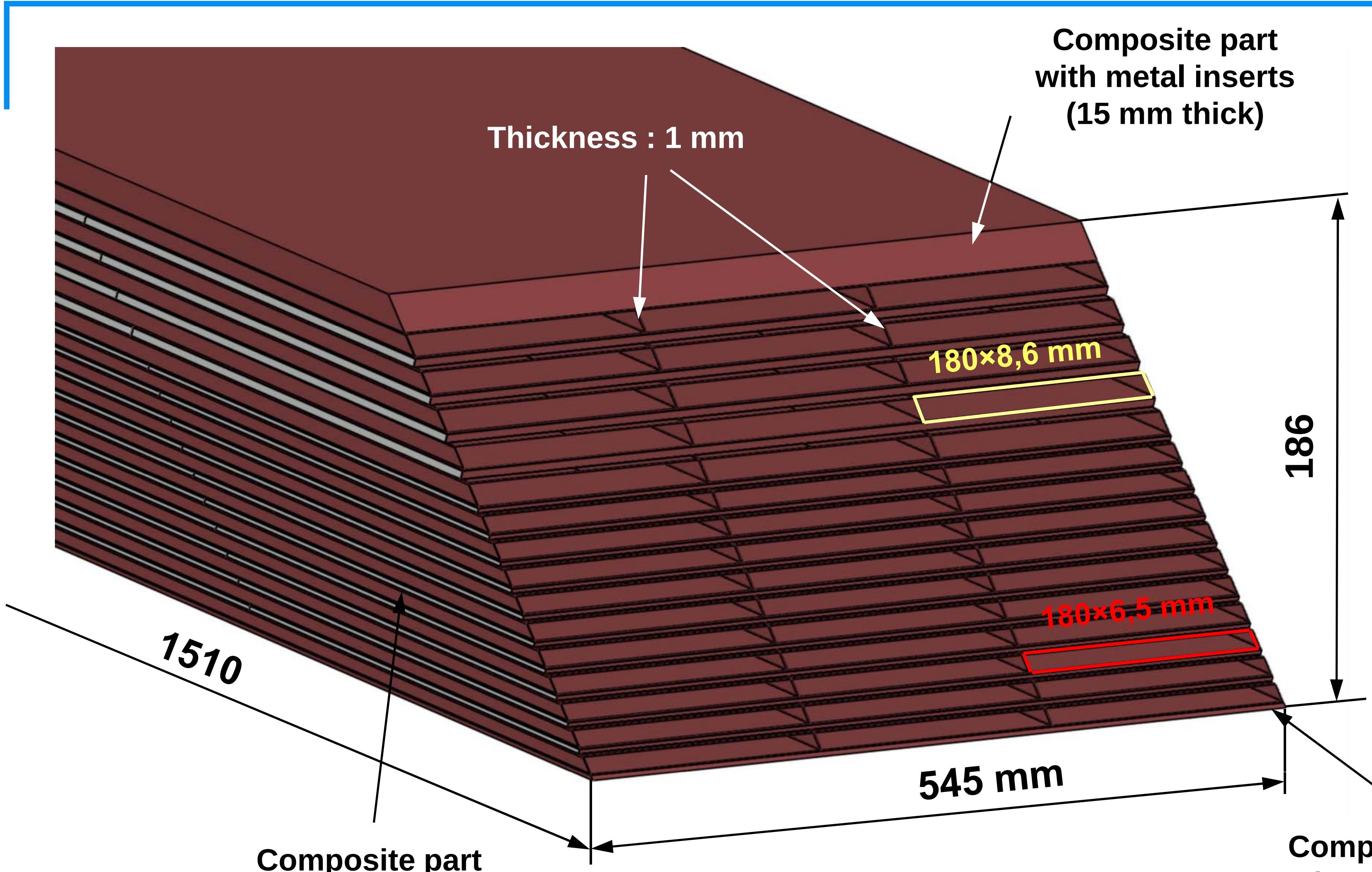
Chips and bonded wires
inside the PCB

The expected alveolar thickness
is 6.5 mm **if** :

- ⇨ Gaps (slab integration) : 500 µm - OK
- ⇨ Heat shield : 400 µm ?
  but real thermal dissipation ?
  (active cooling ?)
- ⇨ PCB : 800 µm
  but chips embedded in PCB ?
- ⇨ Thickness of glue : 100 µm ?
  study of the size of dots ?
- ⇨ Thickness of wafer : 300 µm ?
- ⇨ Ground or isolate foil : 100 µm ?
  AC vs DC ?
- ⇨ Thickness of W : 2100 µm - OK

Several technological issues
have to be studied and validated

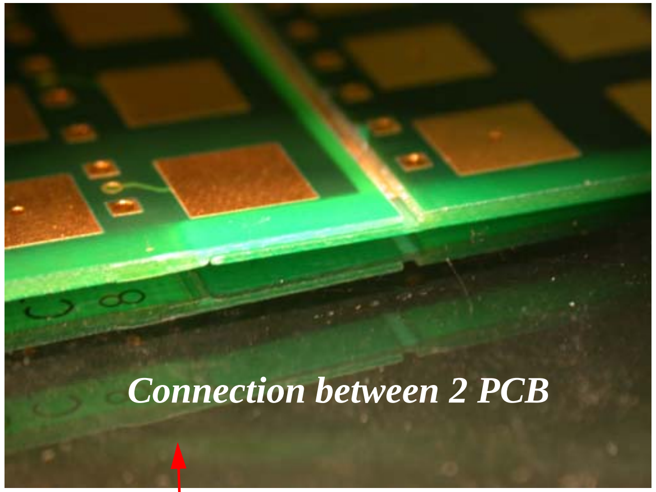
The Design of alveolar structure



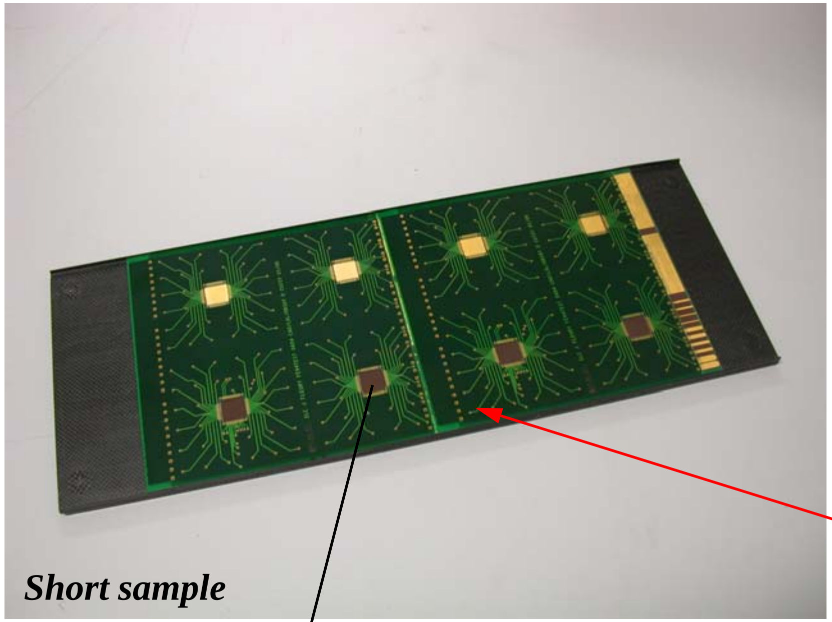
Weight ~ 650 Kg

Detector slab - principle

- Long slab is made by several short PCBs :
  - ❑ Design of one interconnection (glue ?)
  - ❑ Development easier : study, integration and tests of short PCB (with chips and wafers) before assembly
  - ❑ The length of each long slab will be obtained by the size of one “end PCB” (tools)

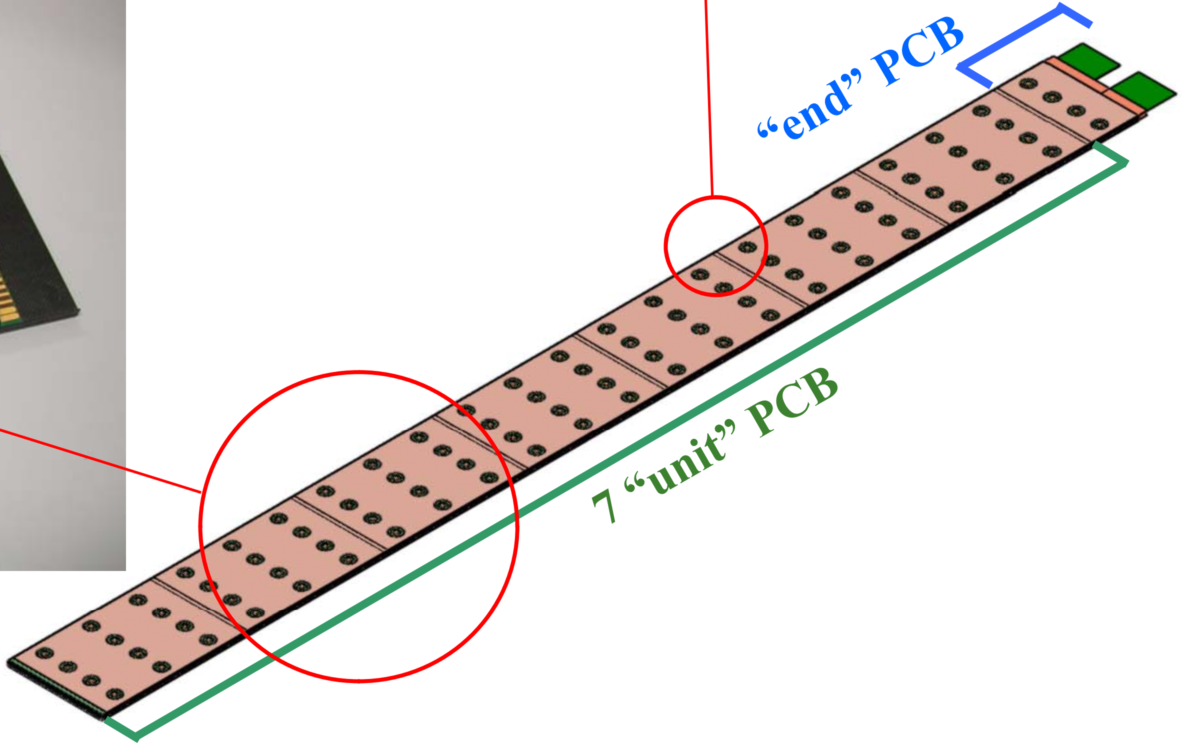


Connection between 2 PCB



Short sample

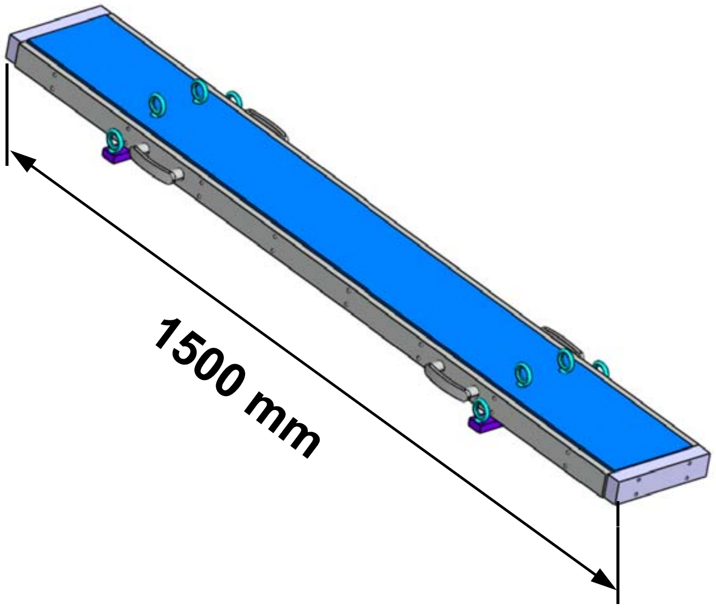
Chip « inside »

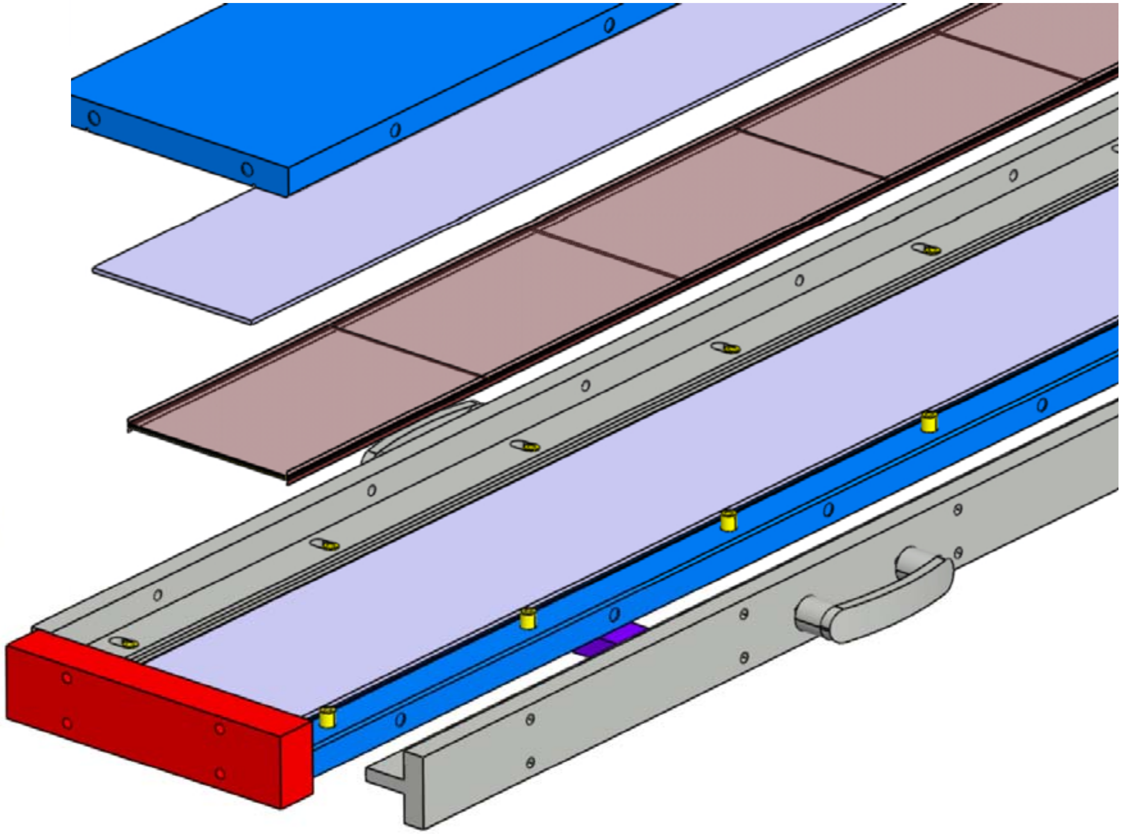


Composite H structure

Study and definition of the long mould :

- Same principle than the mould used to do H prototype structures
- One mould for long and short structures





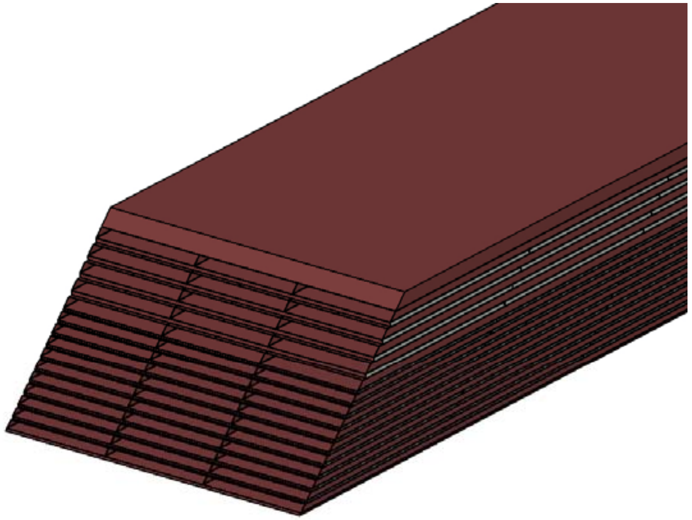
Composite Alveolar structure

Study of different principle (with industrial expertise):

- *Principle #1* : “one block” structure

  One curing step to obtain the final structure

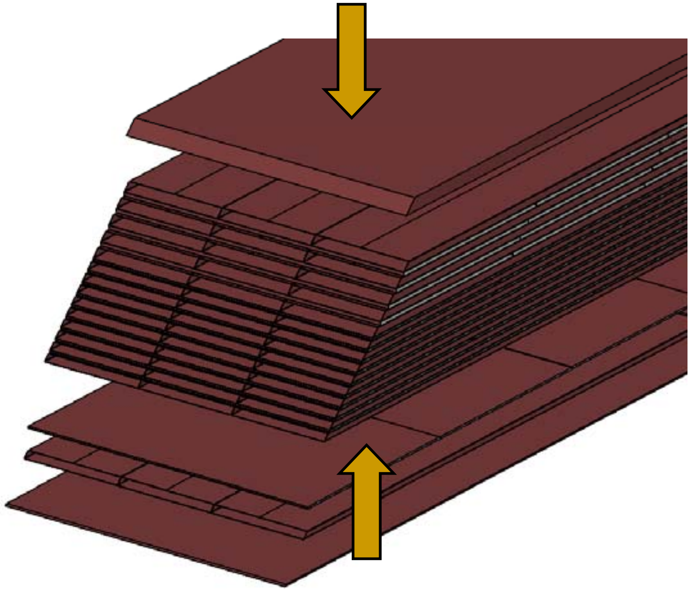
  - Final piece in one step
  - Better mechanical strength
  - Only one but more complex mould (45 cores)
  - Curing problems : thermal inertia, weigh of metal mould, control of curing parameters …
  - Important risks to fail the structure : what about W plates ?



- *Principle #2* : Assembled structure

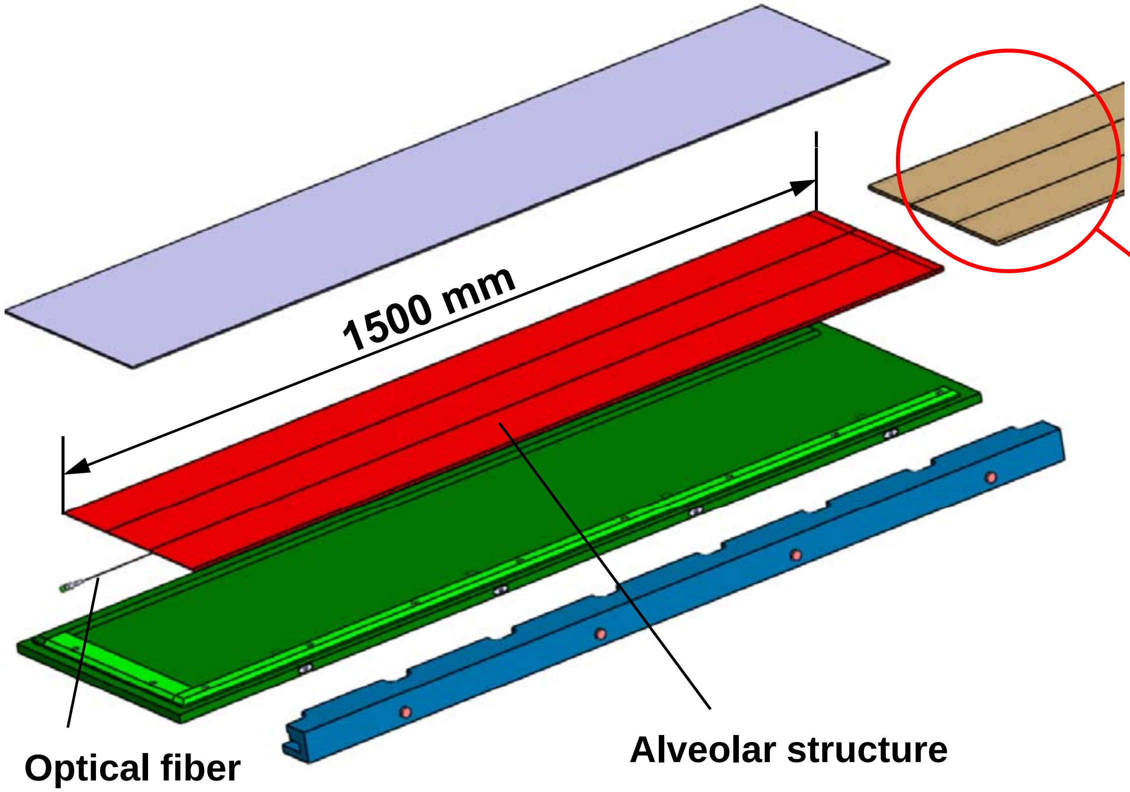
  Each alveolar layer are done independently, cut to the right length (with 45°) and assembled with W plates in a second curing step

  - Individual inspection and choice
  - Limit risks to lose W plates
  - Reduction of cost (simpler moulds)
  - 2 polymerization process : 2 moulds
  - Mechanical strength of “gluing” structures

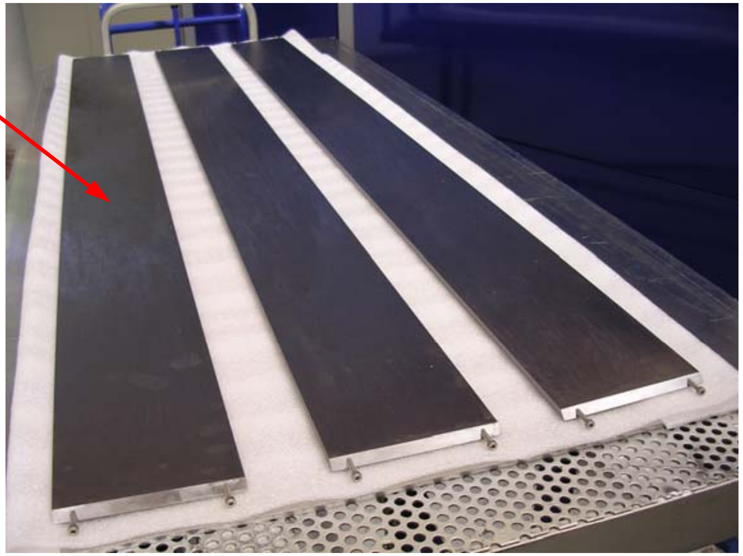


« Alveolar layer » mould

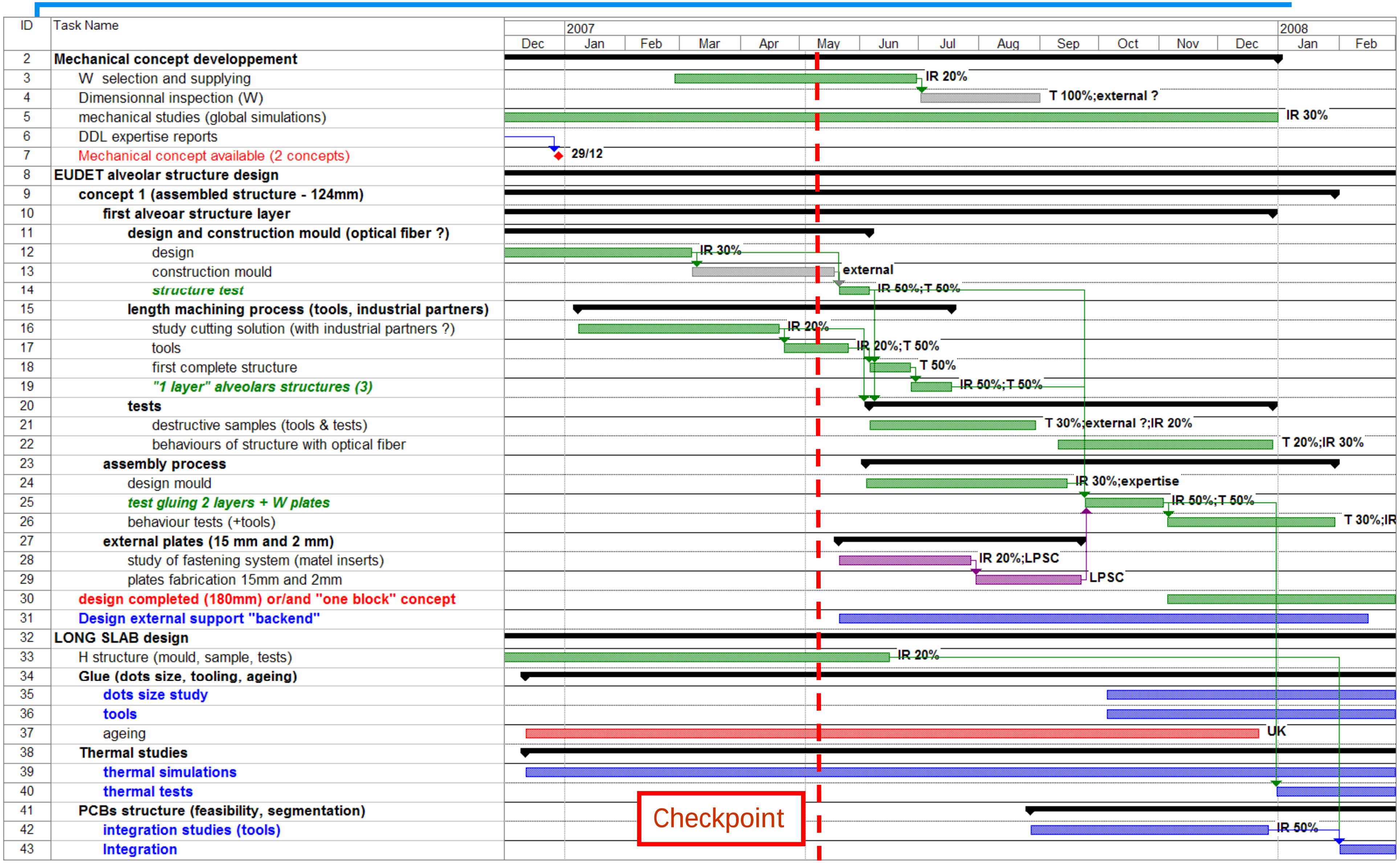
- <u>Study of one first mould based on principle#1 :</u>
  - Design of one mould for all alveolar layers
  - Possibility to integrate optical fiber with Bragg grating for Tests-Simulations Dialogue
  - The length of each layer will be obtained by machining one side (tools)
  - First samples will use to study mechanical behavior (destroy tests, dimensional inspections ...)



cores of the mould



Schedule 2007



ID	Task Name
2	**Mechanical concept developpement**
3	W selection and supplying
4	Dimensionnal inspection (W)
5	mechanical studies (global simulations)
6	DDL expertise reports
7	Mechanical concept available (2 concepts)
8	**EUDET alveolar structure design**
9	**concept 1 (assembled structure - 124mm)**
10	**first alveoar structure layer**
11	**design and construction mould (optical fiber ?)**
12	design
13	construction mould
14	***structure test***
15	**length machining process (tools, industrial partners)**
16	study cutting solution (with industrial partners ?)
17	tools
18	first complete structure
19	***"1 layer" alveolars structures (3)***
20	**tests**
21	destructive samples (tools & tests)
22	behaviours of structure with optical fiber
23	**assembly process**
24	design mould
25	***test gluing 2 layers + W plates***
26	behaviour tests (+tools)
27	**external plates (15 mm and 2 mm)**
28	study of fastening system (matel inserts)
29	plates fabrication 15mm and 2mm
30	**design completed (180mm) or/and "one block" concept**
31	**Design external support "backend"**
32	**LONG SLAB design**
33	H structure (mould, sample, tests)
34	**Glue (dots size, tooling, ageing)**
35	**dots size study**
36	**tools**
37	ageing
38	**Thermal studies**
39	**thermal simulations**
40	**thermal tests**
41	**PCBs structure (feasibility, segmentation)**
42	**integration studies (tools)**
43	**Integration**

🟩 **in charge by LLR**

🟦 **not taken !!!**