SuperB ECAL MECHANICAL DESIGN

Status report on Structural Design

M.Lebeau, EVO 2010 12 15

Structural analysis

Next step (coming soon) of the structural design is **Finite Element Analysis**

The ECAL support structure is a **complex object** for which a specific analysis method has to be developed

Goals of the analysis

- **Dimensioning**
  - Confirm or modify geometry
  - Crystal dimensions
  - Impact on detector integration
- **Stress and strain levels**
  - Compliance with safety and engineering codes
  - Validation of clearances and tolerances

A specific analysis method

- Inspired from personal experience with CMS ECAL barrel
- Reduce model complexity
- Use of experimental data
- For this we need
  - a second prototype module
  - a small test bench
  - an updated CAD model of the crystal array

A model for the module*

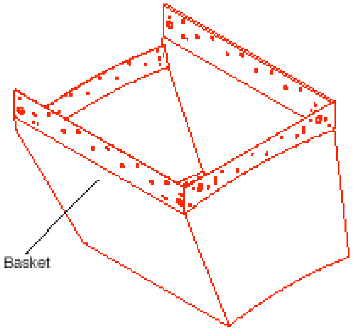
Super-elements were successfully used for the structural analysis of the 36 CMS barrel ECAL super-modules, each of them of mass 2500kg and containing 170 alveolar modules (treated as super-elements) of 2 x 5 cells in 17 different types connected to a complex shell structure (Super Basket), itself subdivided into *unit cells* [1],[2]

[1] H.Rezvani, Doctoral thesis, Technical University of Vienna, Aug. 2001

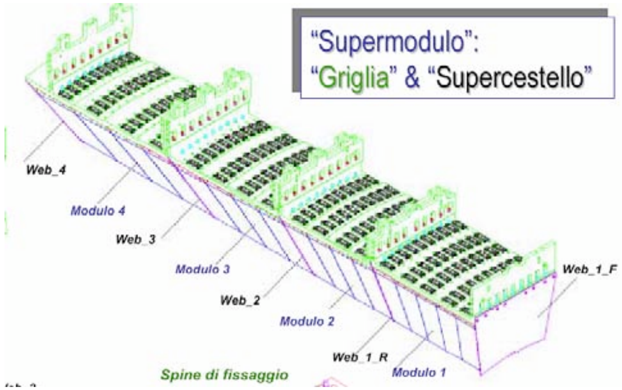
[2] M.Lebeau, F.Mossière, H.Rezvani, WCCM Vienna, July 2002

* Excerpts from a presentation prepared for a meeting to come in Perugia

CMS ECAL tests and FEA *

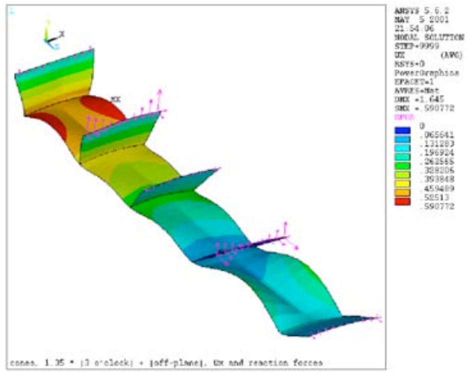


Modular structure for tests



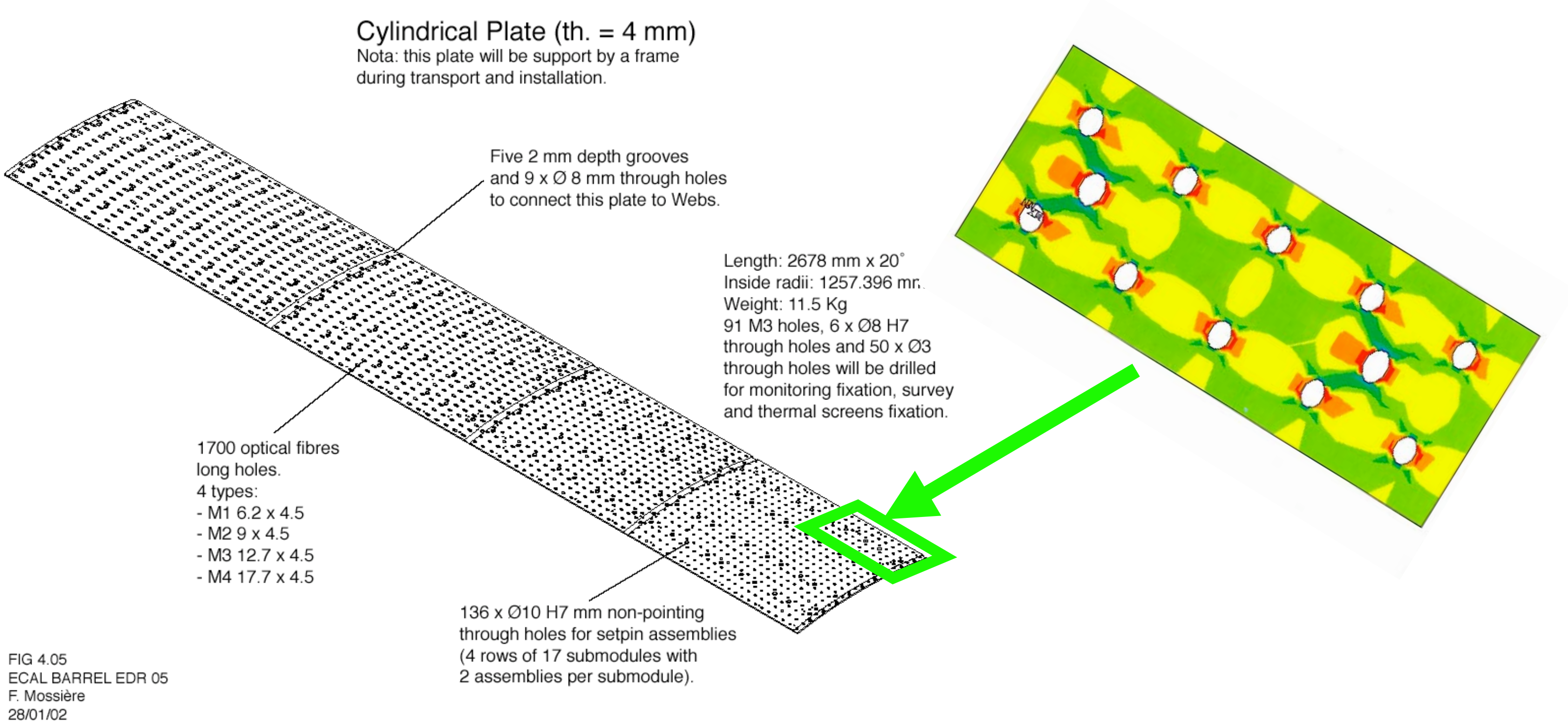
Supermodule of 4 modules

Loading test of module



FEA of Supermodule with input of module test data

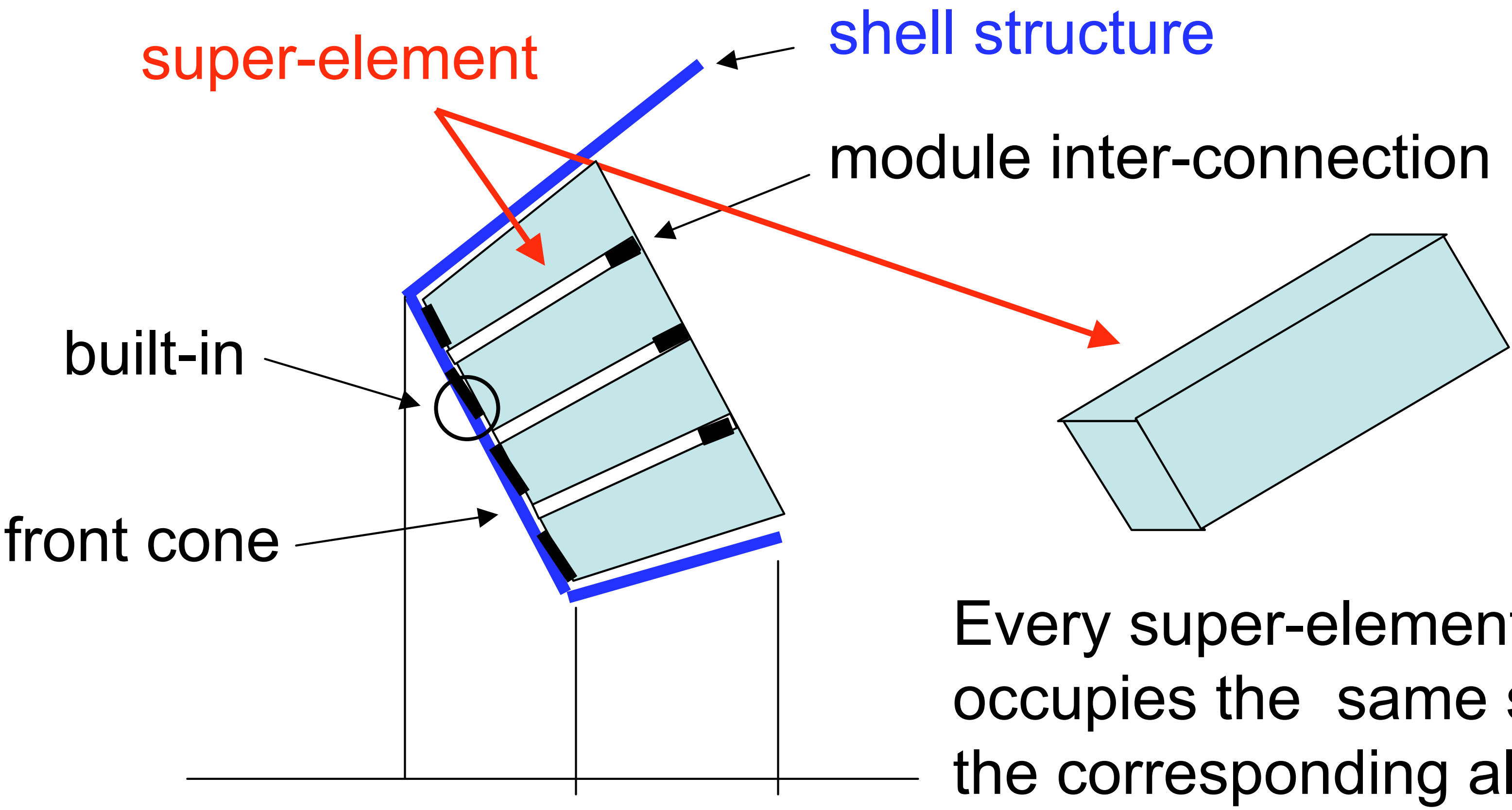
CMS ECAL SuperBasket * sub-division in *unit cells*



The complex shell of a SuperBasket (>2000 holes) is reduced to 170 *unit cells* (or super elements)

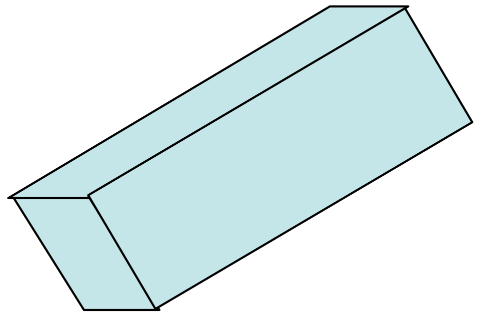
SuperB ECAL case

Alveolar modules are reduced to "super-elements"



Every super-element occupies the same space as the corresponding alveolar module, i.e. there should be 4 types of super-elements

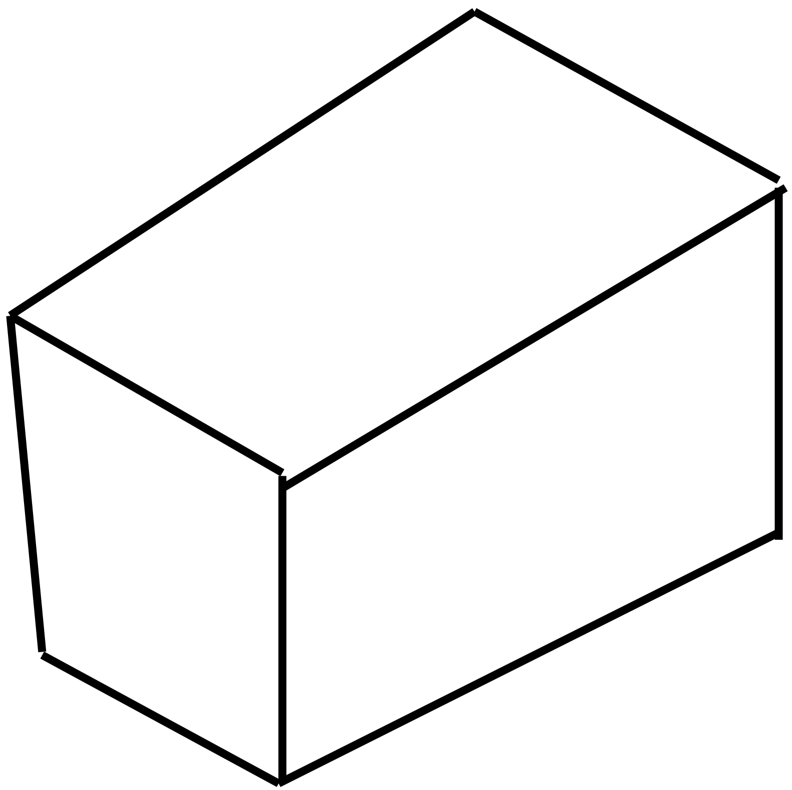
The super-element*



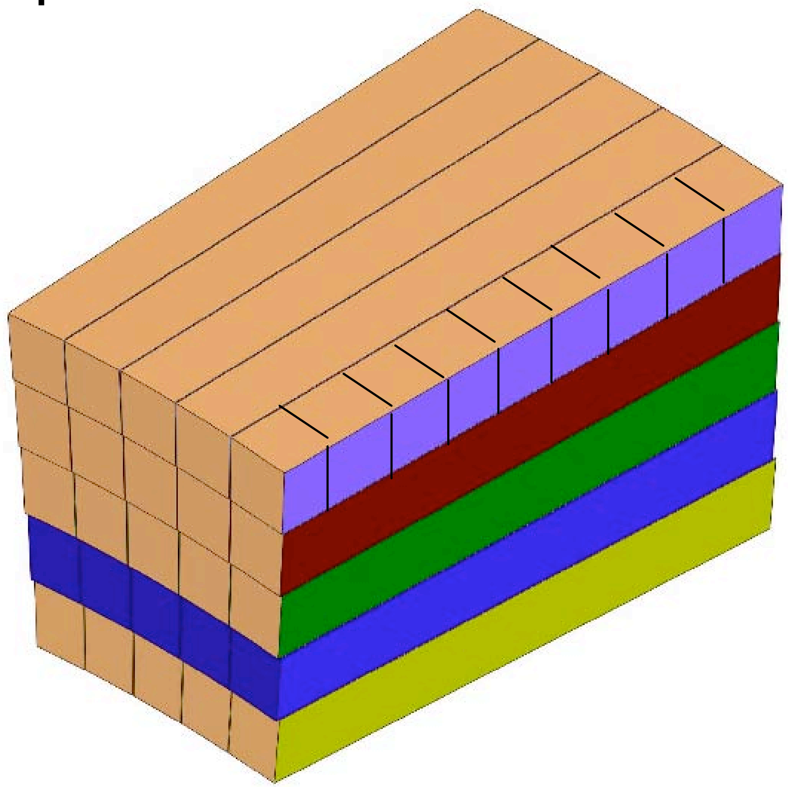
The super-element (or its sub-division) is characterised by the module overall shape and by the **virtual Young's modulus** obtained first by a **computed estimate**, second by the load / deformation ratio from **test results**

Super-element elaboration*

single solid Finite Element



division following the prismatic shape of the 25 cells

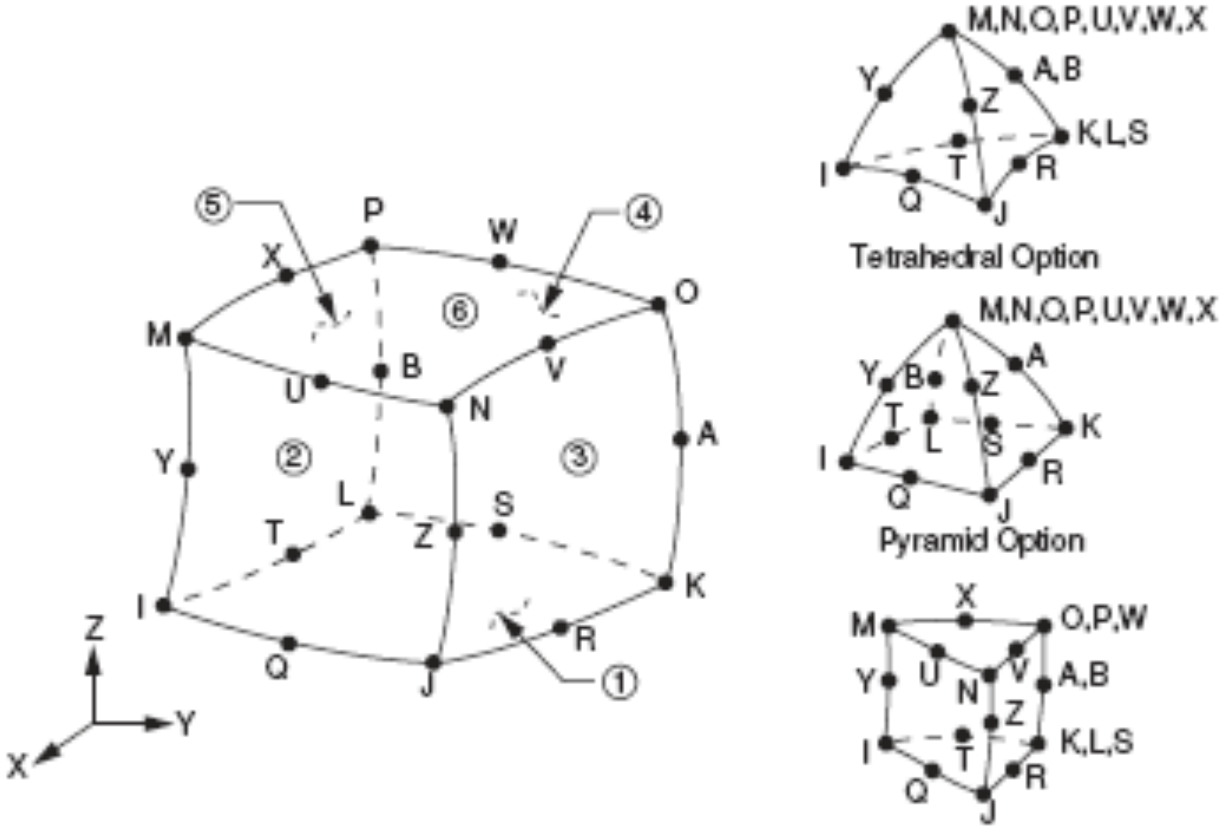


cell volume sub-divided into several solid elements

Solid Element 186*

as an example

Figure 1: SOLID186 Homogenous Structural Solid Geometry



Computed virtual E *

The computed (first step of the analysis) super element is based on the equivalent rigidity of the alveolar and that of a solid body
The alveolar and the solid body have identical deformation under identical load and boundary conditions

- alveolar rigidity = solid equivalent rigidity

$$E_c I_c = E_f I_f$$

with **E** the Young's modulus (isotropic medium)
I the cross section inertia

- we obtain a virtual Young’s modulus (isotropic)

$$E_f = E_c I_c / I_f$$

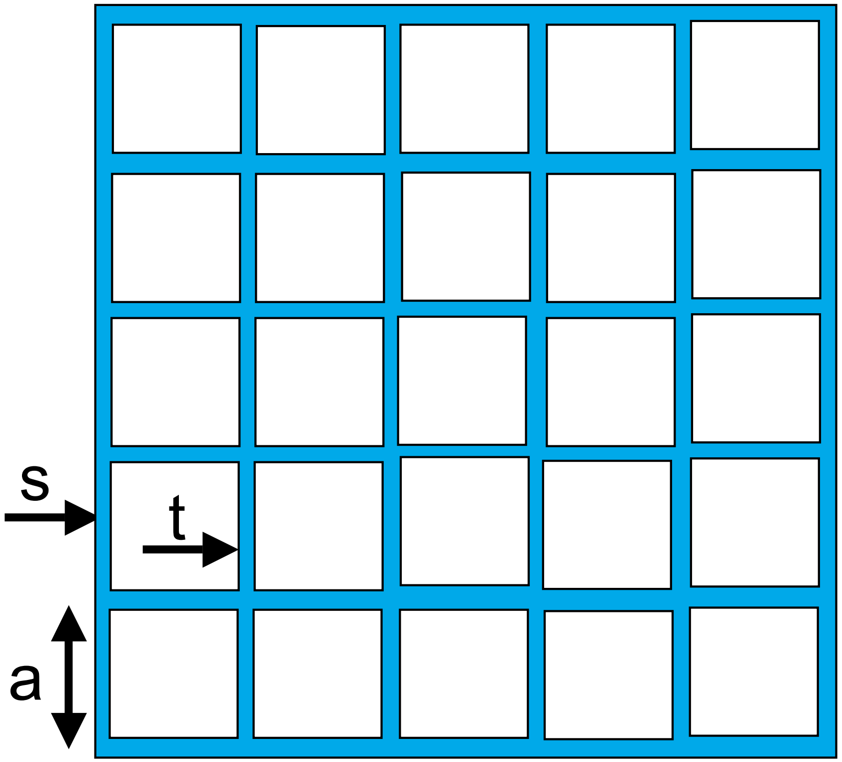
Alveolar cross section inertia*

- Crystal average size 22 x 24 x 200 mm^3

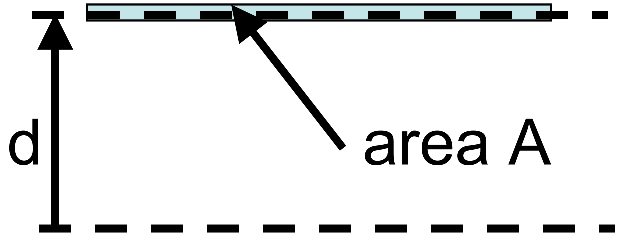
  a = 23

  s = 0,3

  t = 0,2



$I_v = bh^3/12$



$I_h = Ad^2$

$$I_c = \Sigma I_v + \Sigma I_h$$

$$I_c = (100/3)\, a^3\, (t + 2s)$$

Computed virtual E_f *

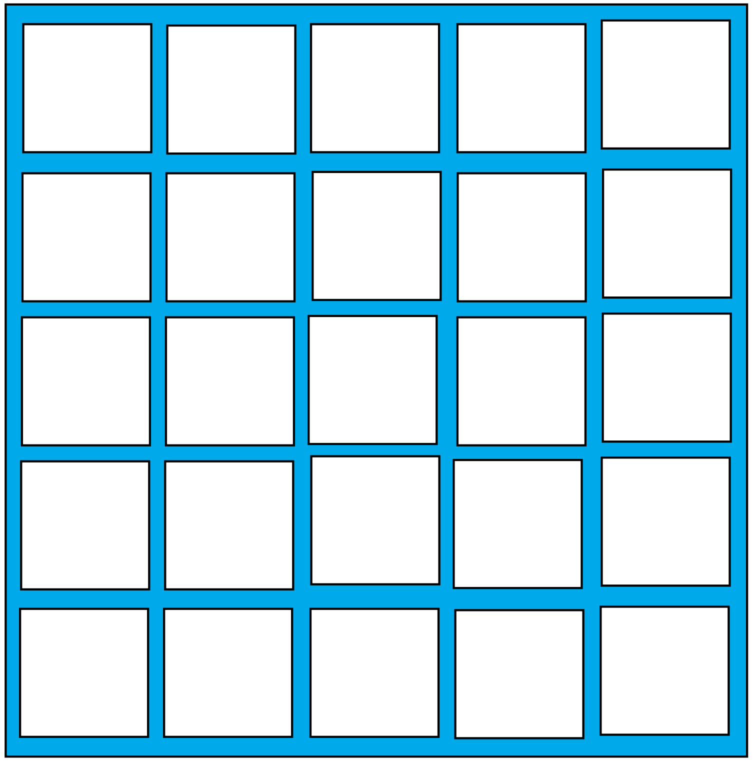
$E_f = E_c I_c / I_f$

$E_f = E_c \times 16 (2s+t) / 25 a$

Numerical application

($a = 23$ $s = 0{,}3$ $t = 0{,}2$ $E = 60$GPa : Al cells)

$E_f = 1{,}34$ GPa



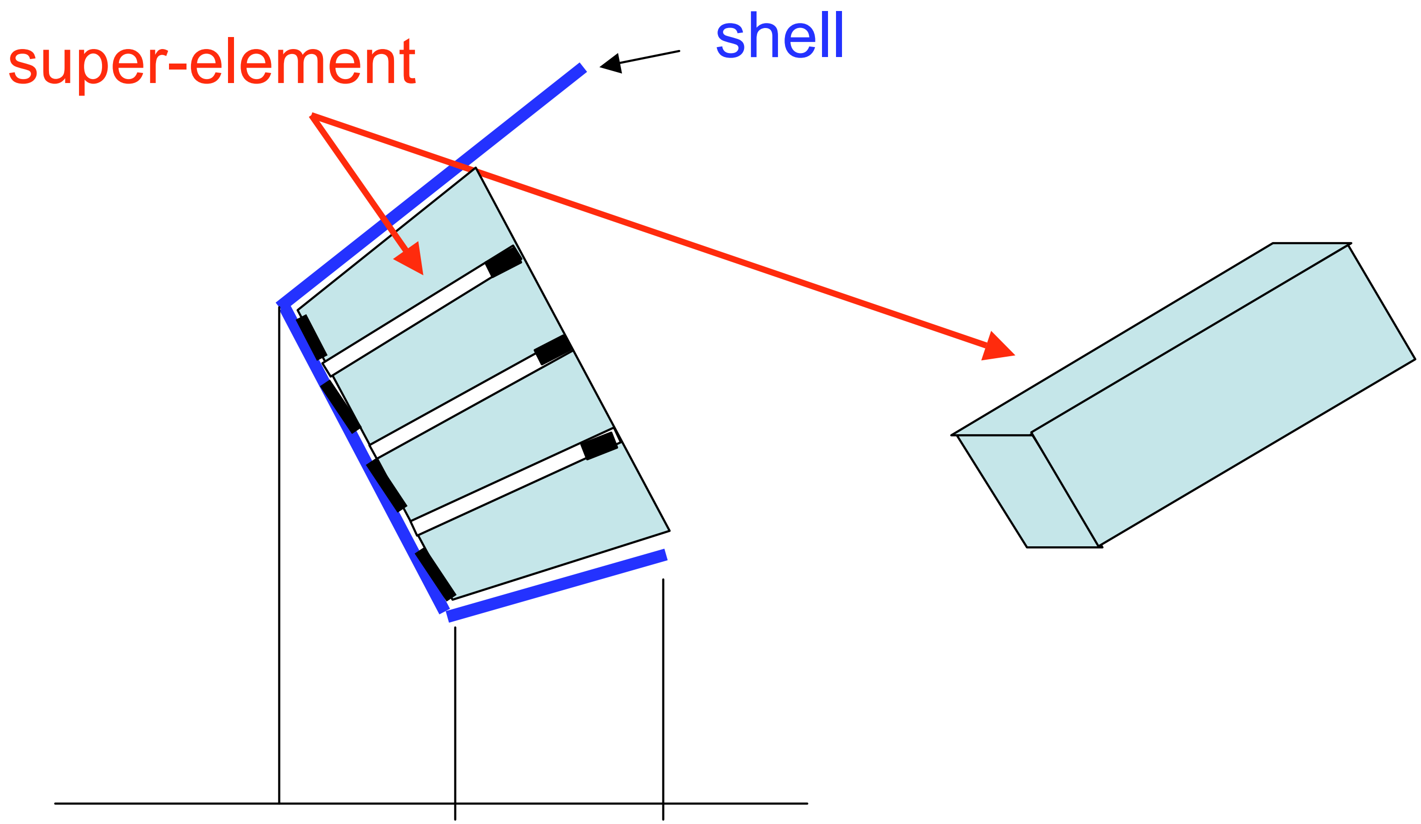
$I_c = (100/3)\, a^3 (t + 2s)$

$I = bh^3/12$

$I_f = 625\, a^4/12$

SuperB ECAL case

The module properties, first as **computed** above, then as **measured**, are introduced in the FEA model



Test module geometry *

- The alveolar module that shall be used for the proposed tests is identical to that used for the physics beam test of October 2010
- It corresponds to the **initial geometry** proposed for the calorimeter (in ring 2 of 41 modules)

Final geometry *

- The geometry envisaged for the final design, has crystal sizes only slightly reduced, cell wall thickness unchanged, 5x5 division kept for the modules, and the overall shell envelope in its present limits
- For these reasons **the proposed analysis**, based on tests with a module of the initial geometry, is considered **applicable to the new geometry**
- Whatever the possible evolution in symmetries and dimensions, the FEA model shall not be altered, and the tests shall not be repeated for new input
- Should it be necessary, the analysis results would be **cautiously extrapolated**

Shell stress and strain *

- The proposed analysis purpose is the best possible knowledge of the state of **stress and strain of the shell**
- The **elastic properties of the super element** (first deduced from **computation**, then obtained by the proposed **load tests**) are used as input data for the most realistic loading case of the shell in the FEA
- **Global deformations of the alveolar array** are significant, and essential for checking the absence of interference with the shell inside (inner and outer cone) and the absence of crystal stressing (cell bending < play) in a first approximation

Alveolar stress and strain *

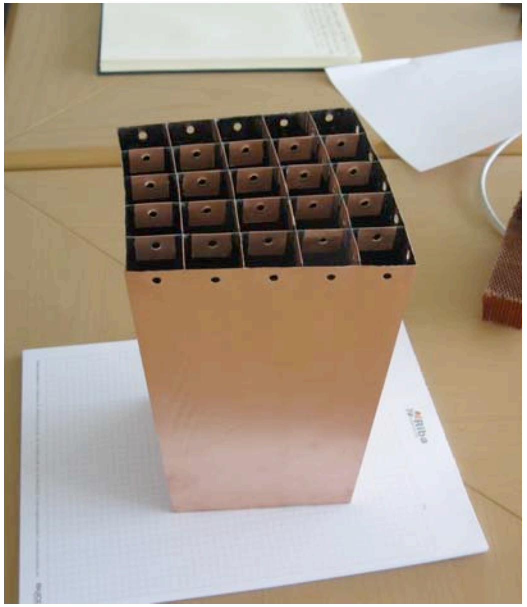
- For a detailed knowledge of the alveolar state of stress and strain, one suggests a FEA on a **model of a single alveolar module** of 5x5 cells, the most deformed one as primarily indicated by the super element array of the initial model. The condition (cell bending < crystal play) can thus be verified with a better accuracy.
- This latter analysis is **not included in the proposed program.**

The test piece: Success of Prototype Module 1

- Realistic
  - We found a competent specialised company
- Economy
  - A full detector is affordable this way
- Material selection compatible with physics and technology
- Accuracy matching design demands

Test pieces: a 2nd module

- Offer of prototype module 2
  - Identical to Module 1 (same spec)
  - discussed in June
  - New offer being prepared
  - Perugia's budget and follow-up



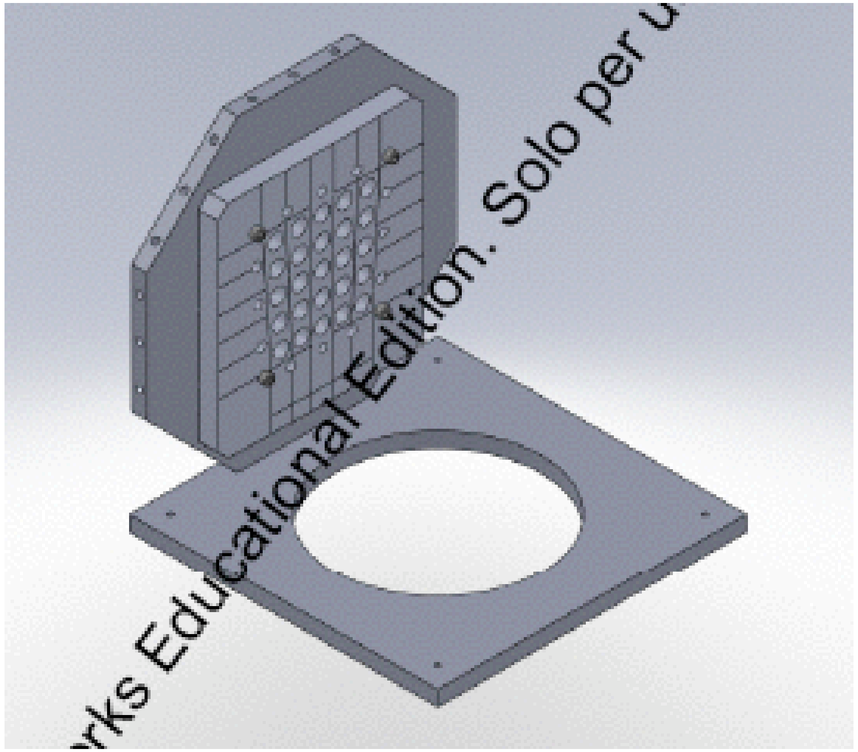
Test pieces: a test bench

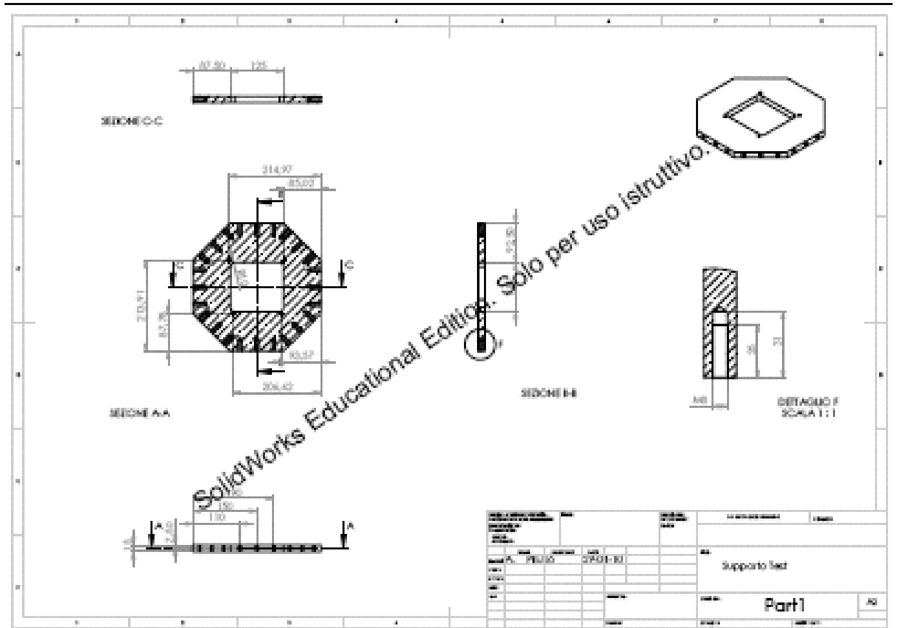
Test bench designed by Perugia

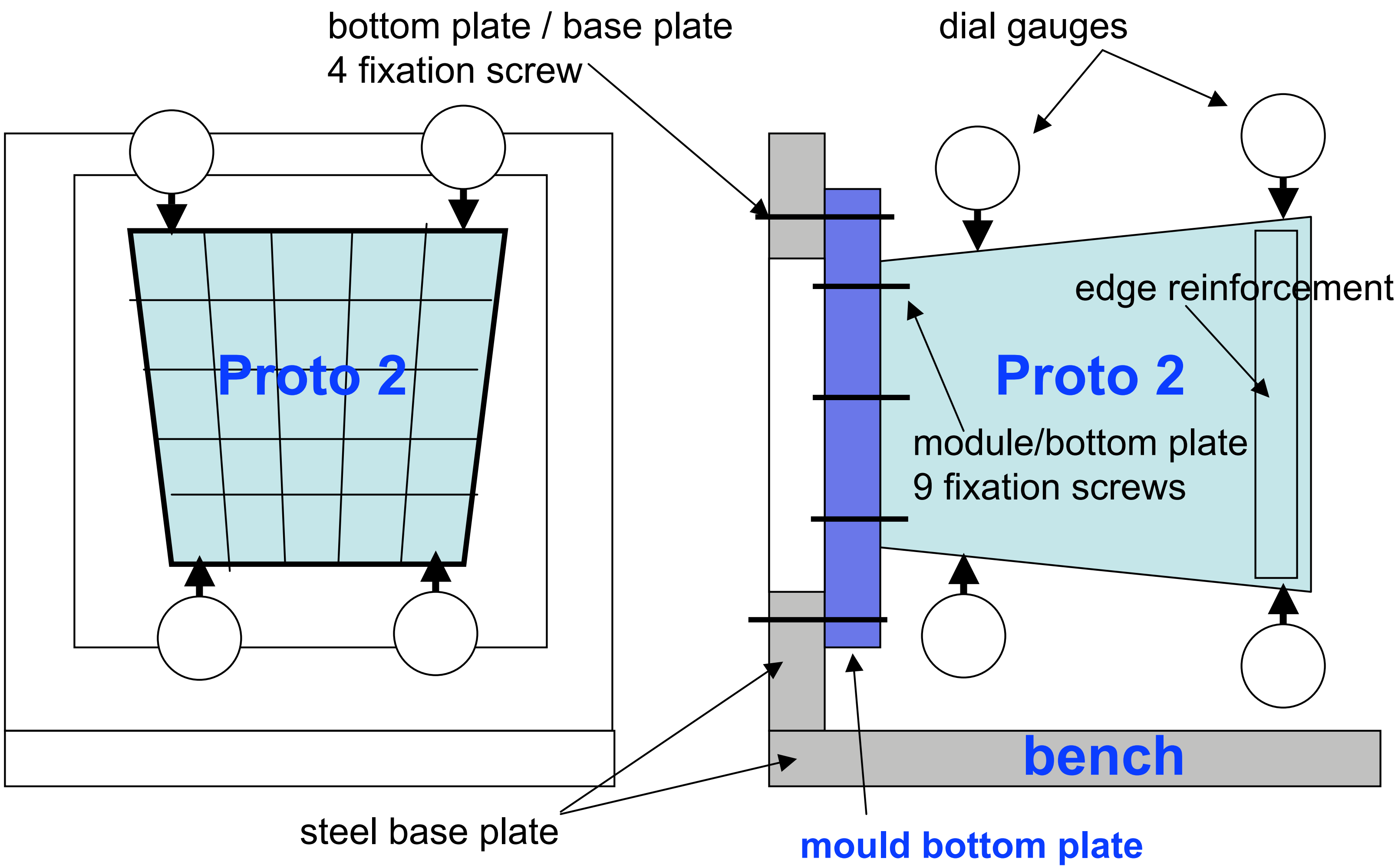
- Tentative offer (price estimate) was ca. € 500 including material, machining and surface protection
– Perugia's budget
– Delivery time should match prototype delivery

The prototype module mould bottom plate is used as fixation plate on the bench

Test bench prod. dwgs

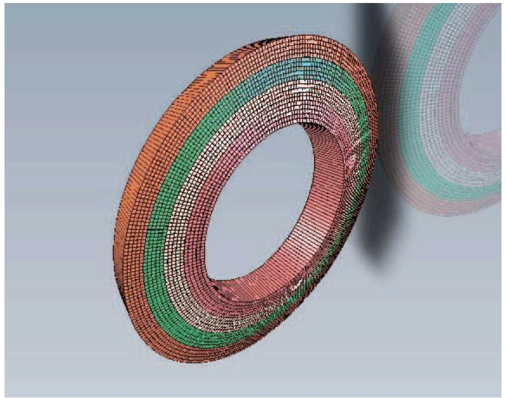






The test setup

The CAD model



- a 3-D model generated by CAD exists
- a new model has to be produced according to
  - agreed symmetries
  - ECAL barrel boundaries
  - preliminary assumptions about dimensions

  (first FEA run)
- the complete specification for the CAD model exists (detailed document by ML)
- CAD 3-D model production is Perugia technical staff's responsibility

Organisation of the analysis

- A team has to be formed to ensure the **continuity** of the task
- Advanced plans for integrating a new partner:
- Polytechnic University of **Ancona** (Italy)
  - Dept. of Material Sciences
  - Dept. of Mechanics
- Institute in close collaboration with ML since 12 years, and well connected with Perugia
- Agreement to have the core of the analysis treated as a **Diploma work** (Tesi)
- Concrete participation of graduating students framed with their teachers

Specialised meeting

- Ground breaking meeting:
  - early in January
  - in Perugia
  - Professors from mentioned Depts
  - Student(s)
  - Perugia's Physics and Technical staff
- Detailed presentation of the **problem** and of the **method** by ML
  - complete documentation exists

Agenda of meeting

- Presentation of SuperB
  - The experiment
  - The ECAL and its constraints
- Presentation of the analysis method
- Limits of the analysis task
  - Time and human resources
  - Technical resources (computers and codes)
- Communication
- Decision making
- Project milestones
- Reports to (and responsibility vs.) SuperB

Steps of the analysis (1/3) *

1. **Empty shell**
   - Crystal load uniformly distributed on front cone
   - Average bending moment of crystals uniformly distributed on front cone
   - First check of shell thickness 10mm and change if needed
2. **Shell and computed super-elements**
   - Super-element properties from **alveolar module calculated** average inertia, Young's modulus and mass
   - Inter-module boundary conditions introduced
   - Check of shell thickness

Steps of the analysis (2/3) *

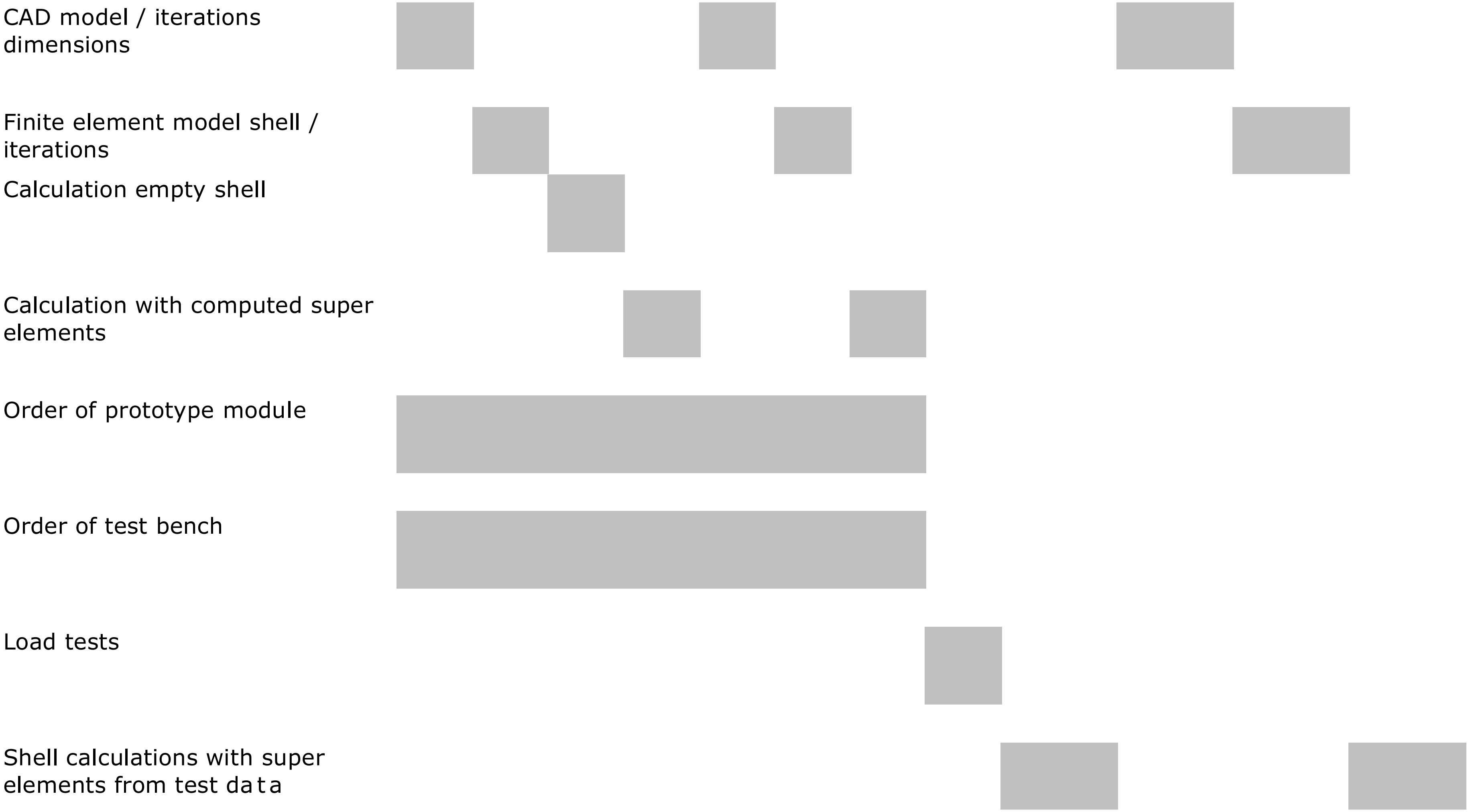
3. Shell and **experimental** super-elements

- Super-element properties from **tested alveolar module prototype**, using
  - average inertia of a solid body
  - Young's modulus
  - Calculated mass
- Inter-module boundary conditions introduced
  - runs with radial, tangential and both connections

4. Analysis

- Deformations
  - interpretation of super-element deformation to check absence of stressed contact between cell wall and crystal : 0,1mm play remains > 0 (to be developed)
  - Verification of absence of interference between alveolar and shell (1mm play remains > 0)
- Stress (on shell only)

Steps of the analysis (3/3) *



Next to come

Report from the meeting in Perugia submitted to SuperB ECAL community in due time

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