Laboratoire d'Annecy-le-Vieux de Physique des Particules

Alpine Pixel detector

Thermal & static

FEA results

IVW - Pixel meeting - 29th of April, 2013

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Outline

- Thermal studies:
    - Poco
    - TPG
    - Mountain
- Static study : design improvement
- Masses consideration
- Pixel design
- Conclusions
- Prospects

Thermal study – Poco 1/3

Status:

The baseline is a stave made of ***K9-foam*** (both for barrel and mountains)

Possible improvement:

Use of ***Poco-foam*** for mountains only, to enhance the sensor cooling.
(thanks to a higher thermal Conductivity values)

Study objectives:

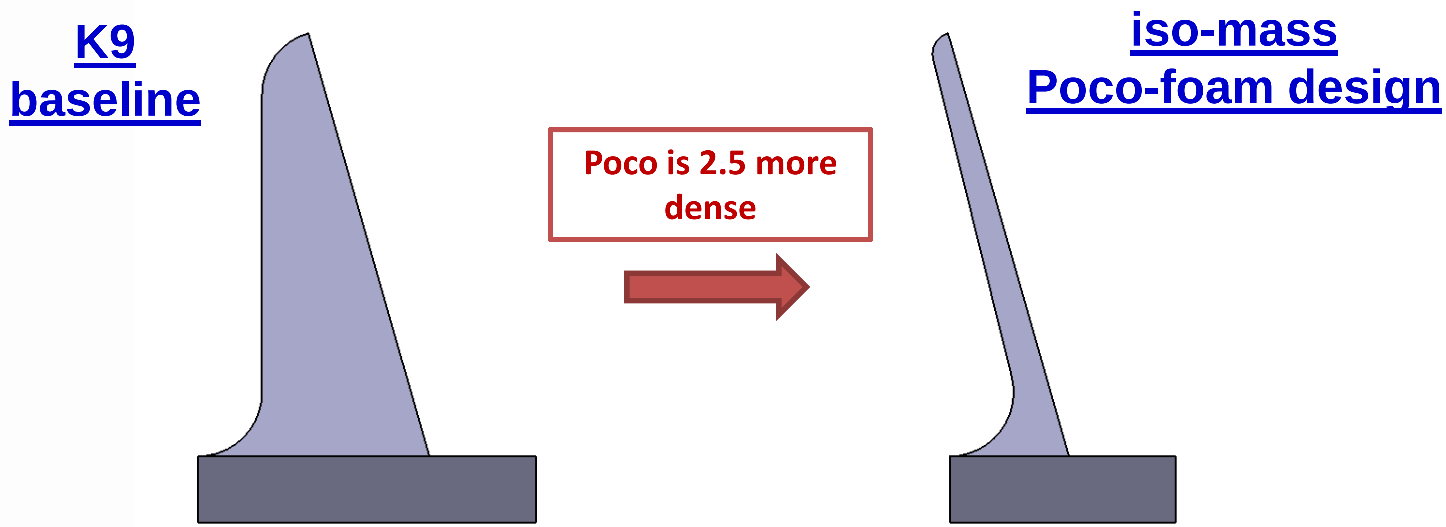
- Comparison of cooling for K9 and Poco-foam

K9-foam :	C = 40 W/mK	(isotropic)	d = 0.22 g/cc
Poco-foam :	C = 135 or 45 W/mK	(orthotropic)	d = 0.55 g/cc
~~***Poco-HTC :***~~	~~C = 245 or 70 W/mK~~	~~(orthotropic)~~	~~d = 0.9 g/cc~~

Comparison for same mass of mountain !

Thermal study – Poco 2/3

Comparison for same mass of mountain
leads to a modification of mountain design

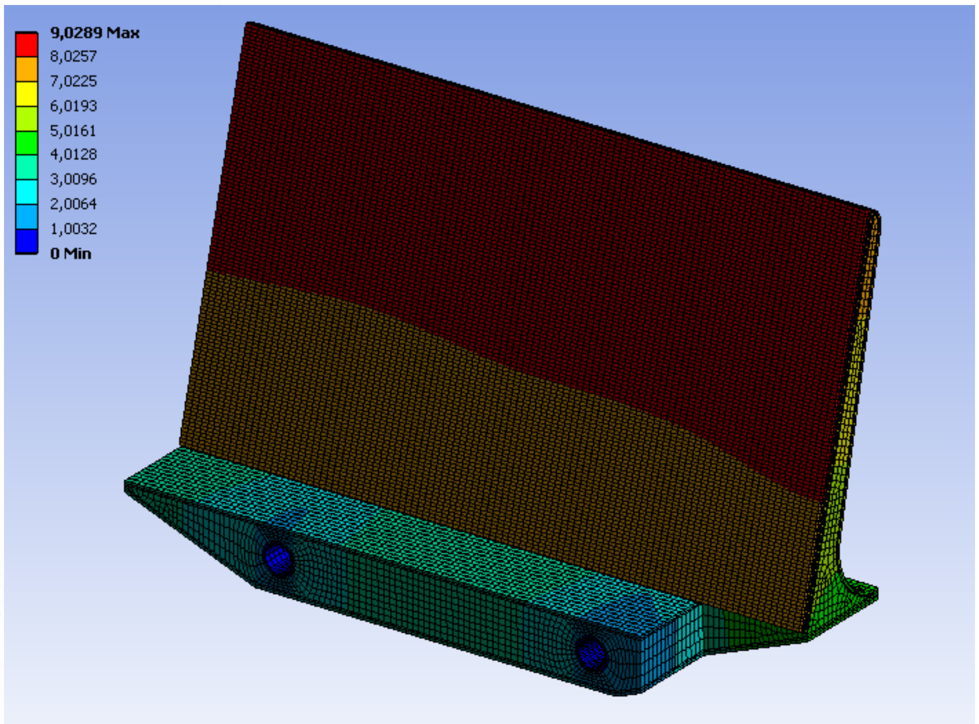


NB : Please note that the *mountain angle is not changed*, *neither nor the face area dedicated to the module*.

Thermal study – Poco 3/3

Poco foam being an orthotropic material
a parametric study has been carried out tofind
the best 1st orientation of material

(1st orientation has higher thermal conductivity value)



T_{max} = ***9°C***
for Poco-foam

instead of

T_{max} = ***7.5°C***
for K9

We choose not to replace K9 by Poco !

NB : *Best angle is 100°*
(106° being the sensor orientation with respect to the longitudinal face-plate)

Thermal study – TPG 1/2

Status:

An independent CF laminate is glued on the face of the mountain (between foam and sensor).

Indeed it is laminate is not continuous between mountain backside and barrel region.

Possible improvement:

Use of another material to enhance the sensor cooling. (ie. with better thermal Conductivity values)

Study objectives:

- Evaluate the sensor cooling with TPG instead of CF laminate (K13C-RS3)

CF laminate:	96	0.5	0.5	W/m/K
TPG :	1500	1500	10	W/m/K

Thermal study – TPG 2/2

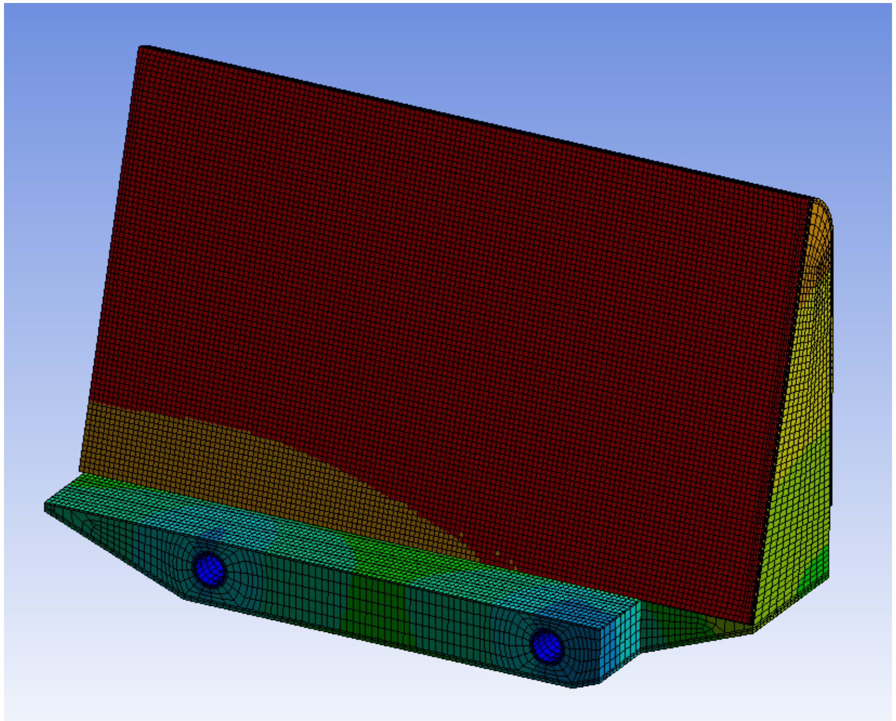
Assumption:

TPG and CF laminate have the same thickness (0.145mm)

With *CF* :
T_{max} = 7.3°C

Change of material

With *TPG* :
T_{max} = 5.7°C



- d_{CF} = 1.7 g/cm^3
- d_{TPG} = 2.2 g/cm^3

NB: Mass increase due to TPG: Δm = +0.05g

Thermal study – Mountain 1/6

Status:

Cooling is better if we use TPG instead of CF laminate (between foam and sensor).

Possible improvement:

Decrease the amount of K9 foam: optimization of mountains design

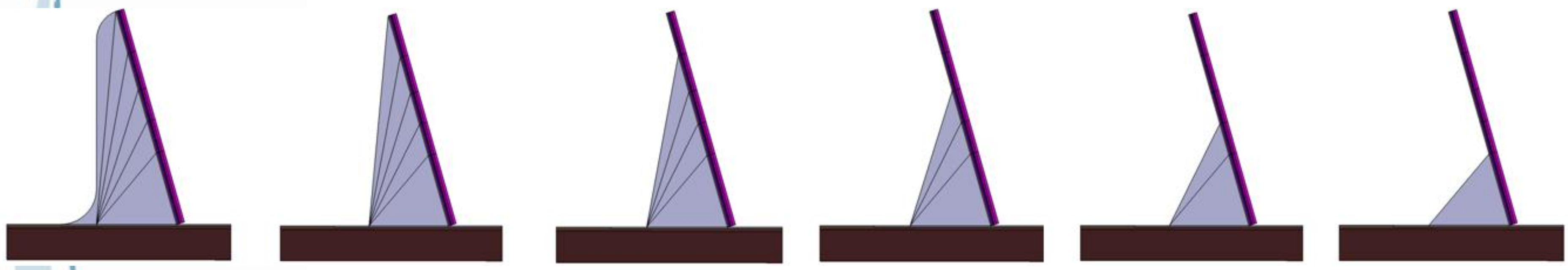
Study objectives:

- Evaluate the sensor cooling with different shapes of mountain (2 parameters)

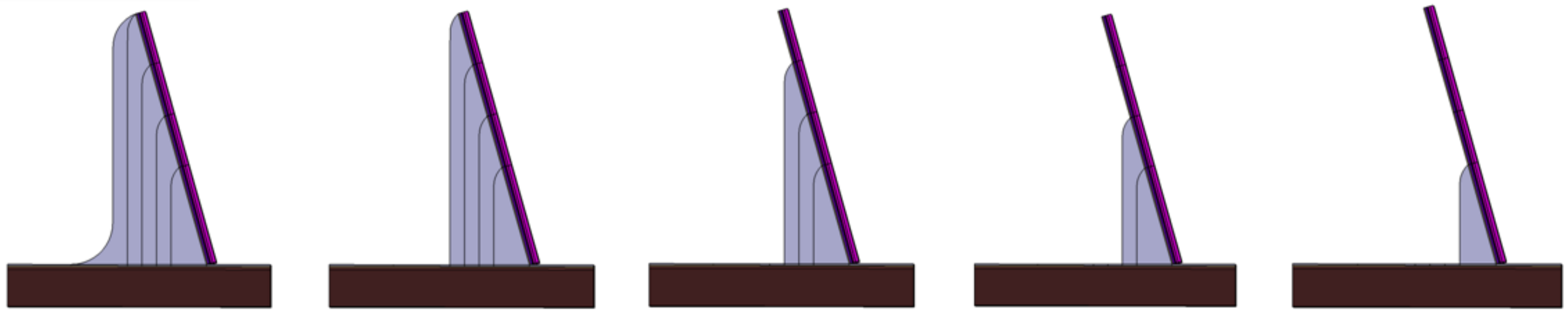
1. ***Backside angle (Same base)***
2. ***Smaller homothetic design (smaller base)***

Thermal study – Mountain 2/6

1. ***Backside angle (Same base)***

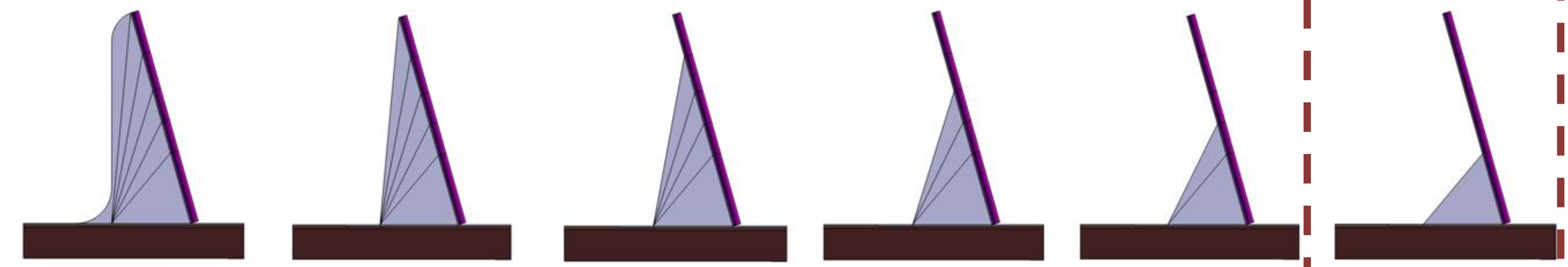


2. ***Smaller homothetic design (smaller base)***



Thermal study – Mountain 3/6

1. ***Backside angle (Same base):*** 6 computations

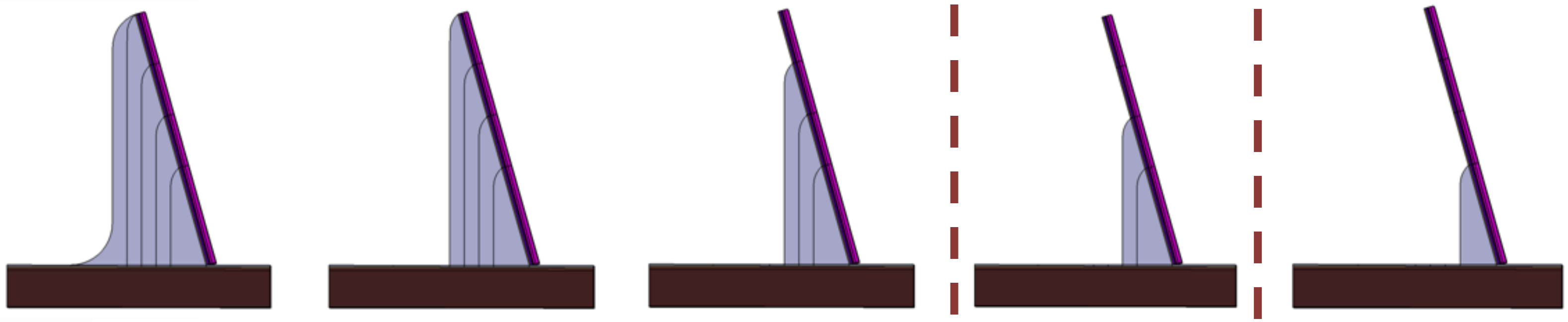


Comp.	#1	#2	#3	#4	#5	#6
T_{max}	**5.7°C**	**5.9°C**	**6.1°C**	**6.3°C**	**6.7°C**	**7.3°C**
Foam mass (in the model)	1g	0.9g	0.8g	0.7g	0.6g	0.5g

NB: Mass increase due to TPG: $\Delta m = +0.05g$

Thermal study – Mountain 4/6

2. Smaller homothetic design (smaller base): 5 computations

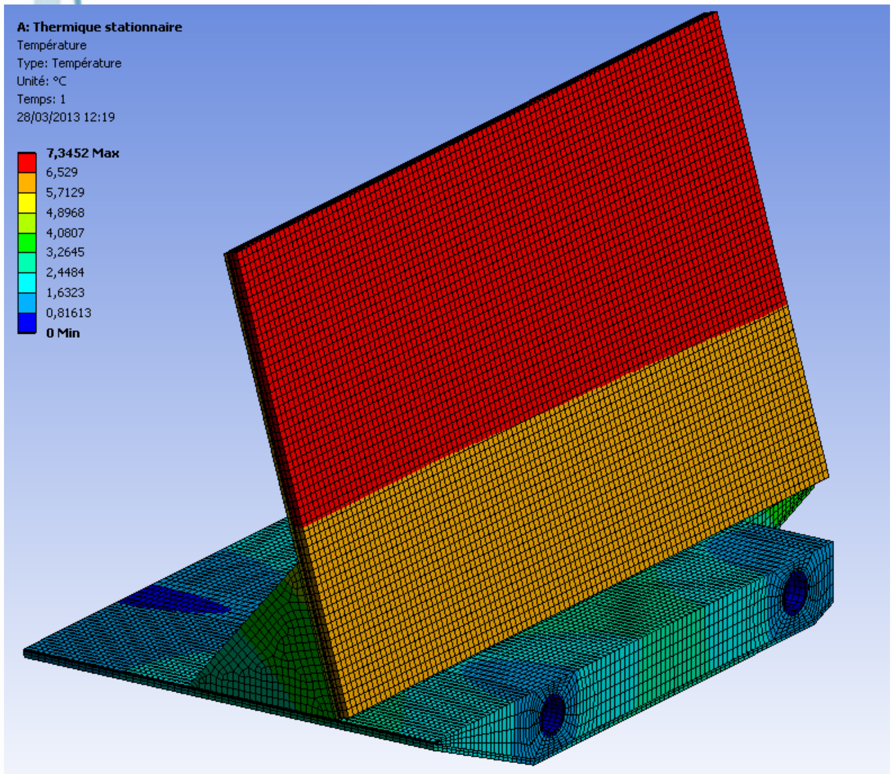


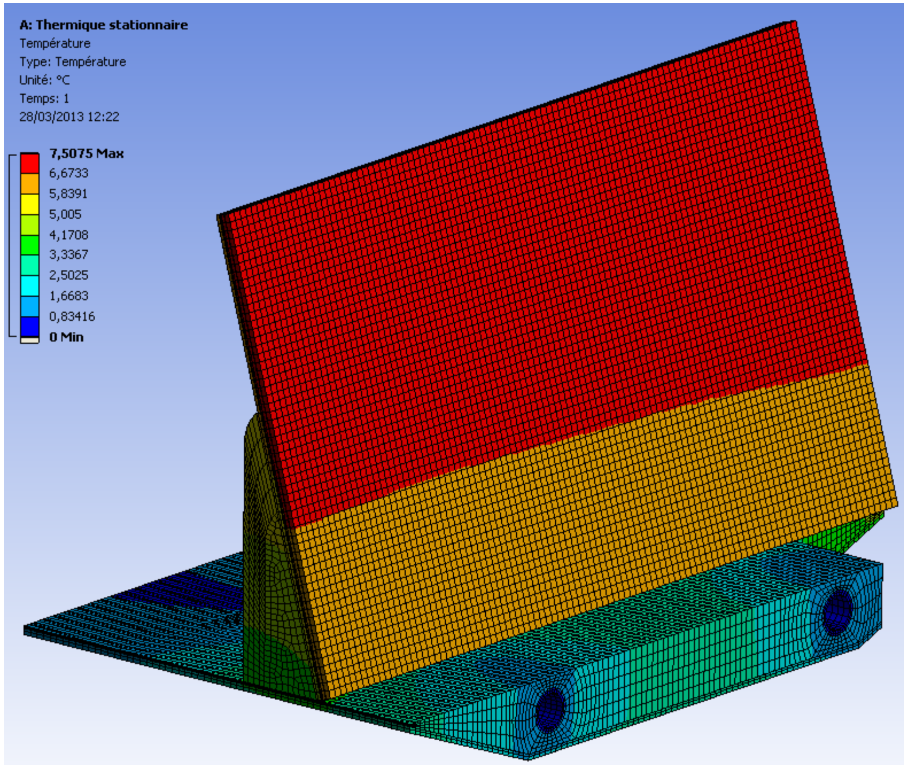
Comp.	#1	#2	#3	#4	#5
T_{max}	5.7°C	6.2°C	6.8°C	7.5°C	8.5°C
Foam mass (in the model)	1g	0.8g	0.7g	0.55g	0.4g

NB: Mass increase due to TPG: $\Delta m = +0.05g$

Thermal study – Mountain 5/6

1. ***Backside angle (Same base)***
2. ***Smaller homothetic design (smaller base)***





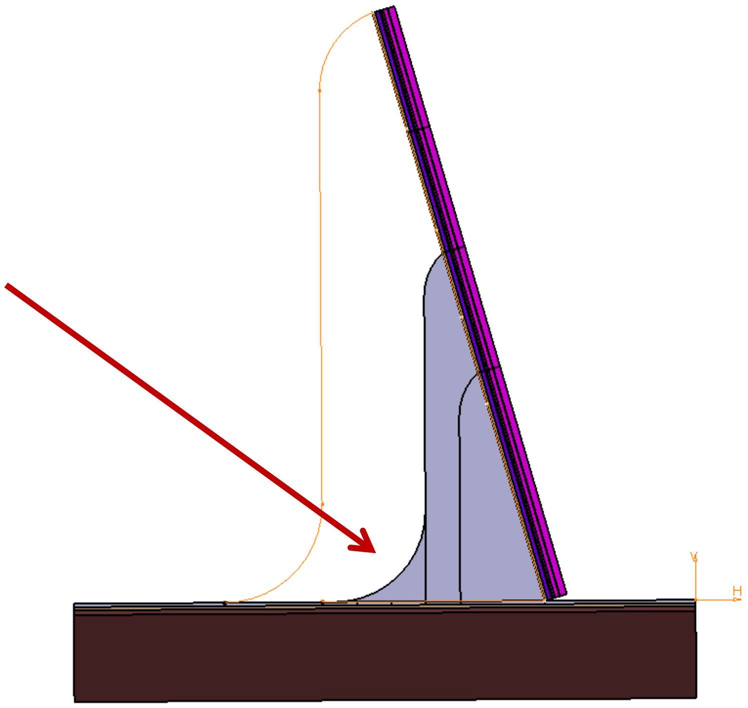
Thermal study – Mountain 6/6

1. ***Backside angle (Same base)***
2. ***Smaller homothetic design (smaller base)***

Combination of both parameters :

homothetic design with increased base

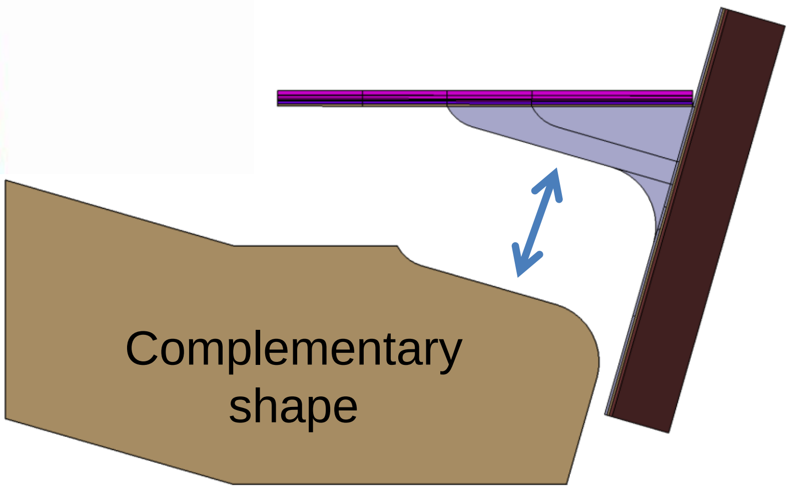
(Radius of curvature for CF-laminate gluing)

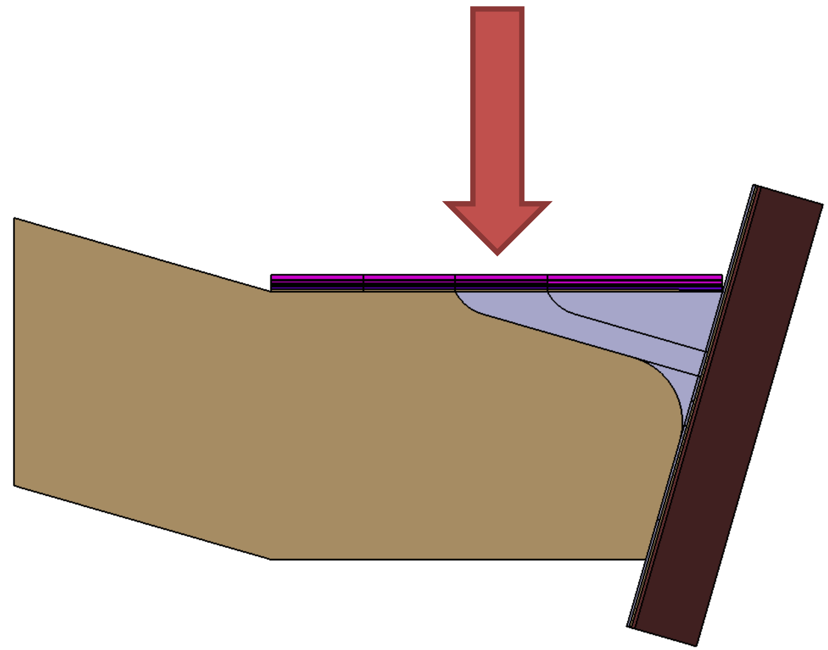


Process of TPG / sensor gluing

Assembly option

Pressure for gluing



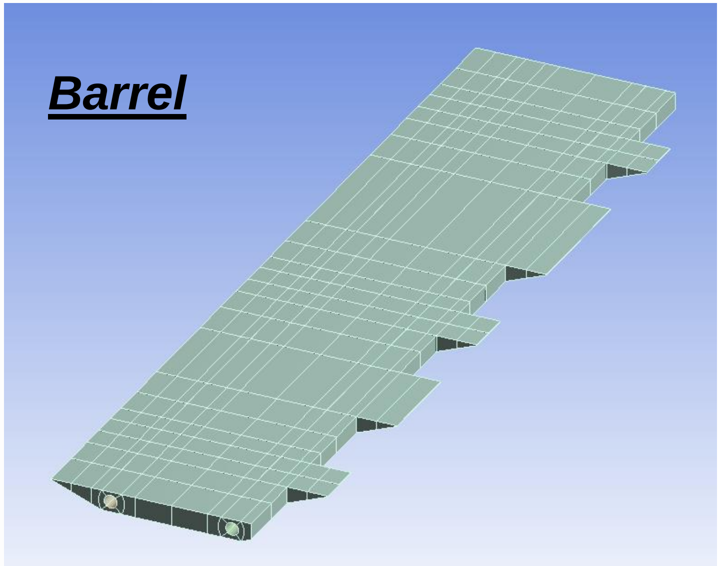


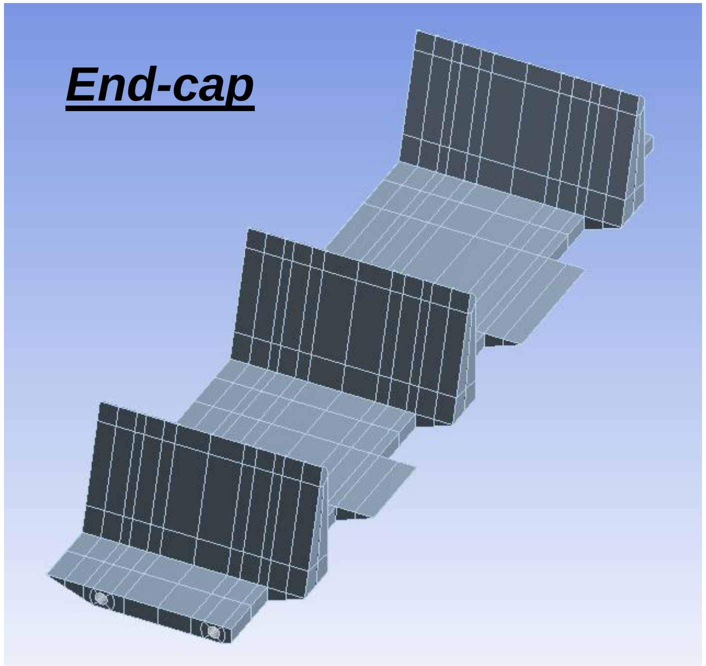
Use of a complementary part not to break the module !

Static study 1/9

What is the effect of mountains on static behavior (loose of stiffness ?)

Mountains 5,6 & 7 of stave layer 2
(134mm roughly)





Evaluation of relative stiffness between barrel and end-cap

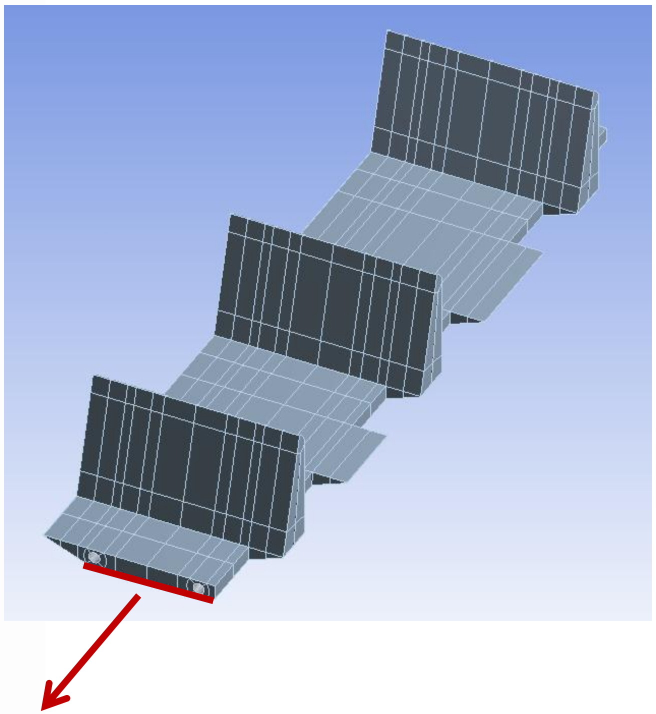
For more facility: *barrel is the same than end-cap without mountains*

Note : obviously a continuous omega like for the barrel (no cuts for tiling assembly) would improve the static behavior…

Static study 2/9

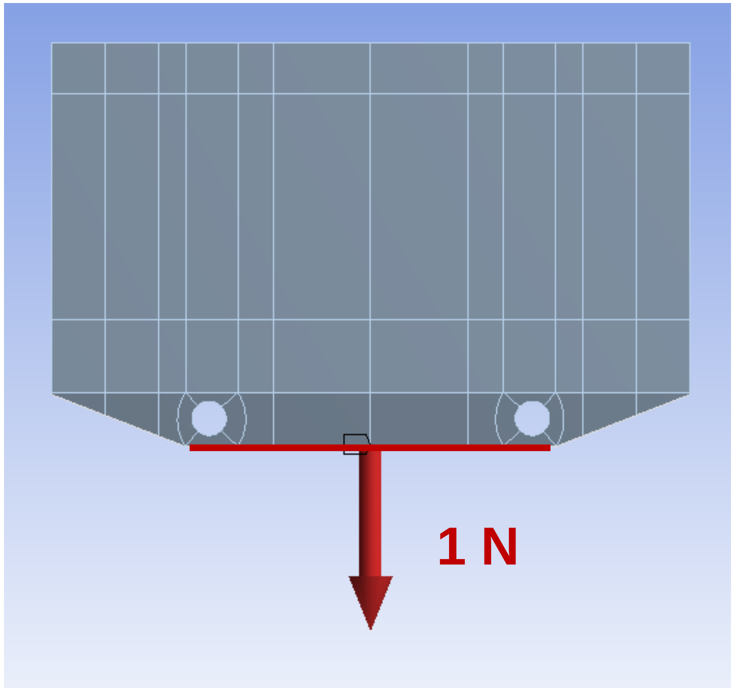
Details of boundary conditions & loading

Stave fixed at both extremities
(2 edges of omega)



$U_x = U_y = U_z = 0$

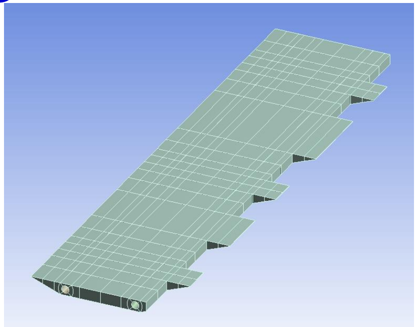
1N distributed on the flex location
(common faces to all models leading to the same loading !)



NB : 1N is an arbitrary loading

Static study 3/9

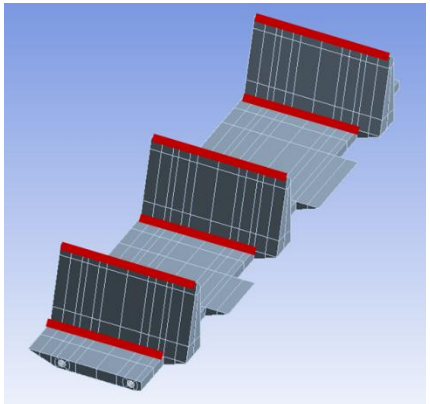
Model 1 :
- No mountain
- Classical omega *(cuts on 1 side)*
- Continuous face plate



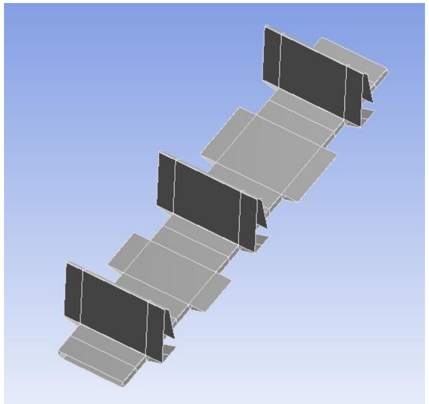
Laminate discontinuities in red

Model 2 :
- 3 mountains
- Classical omega *(cuts on 1 side)*
- Discontinuous face plate

(independent laminate for the mountain face)

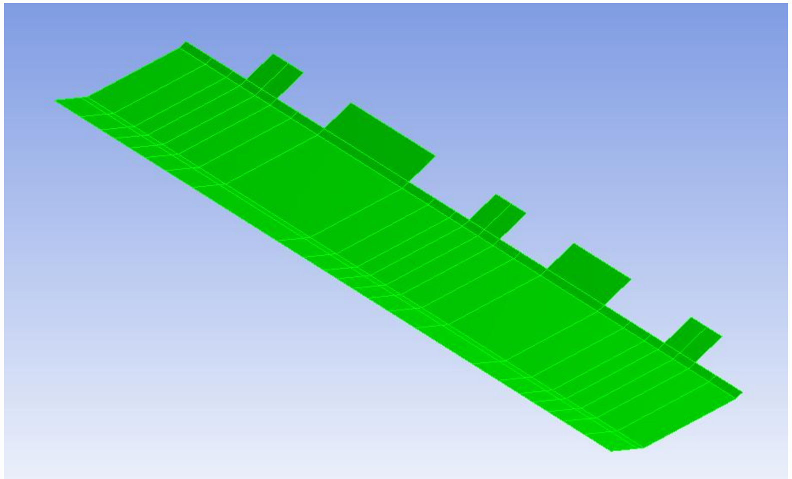


Model 3 :
- 3 mountains
- Symmetric omega *(cuts on both sides)*
- Discontinuous face plate

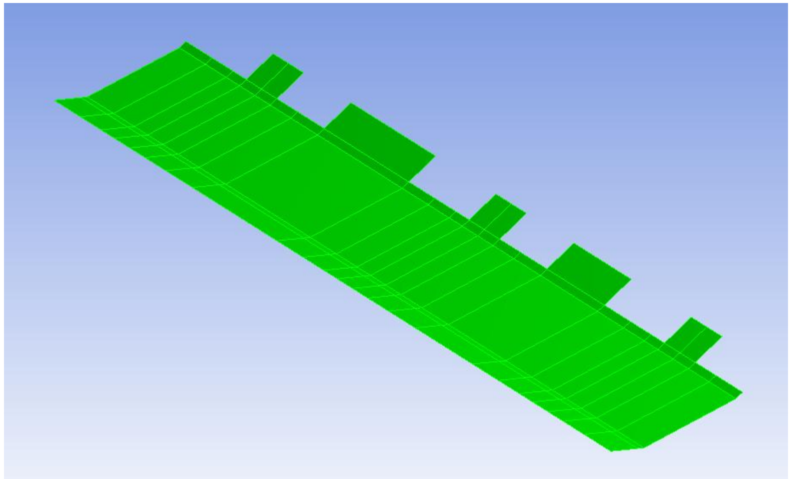


Static study 4/9

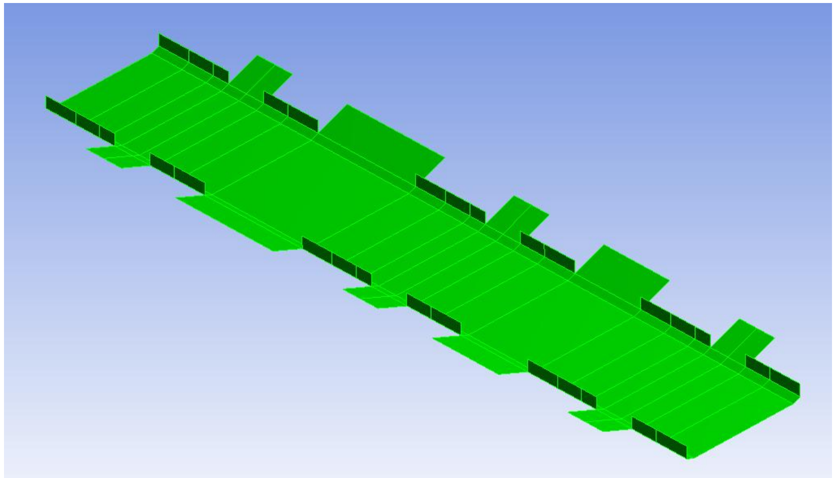
Model 1



Model 2

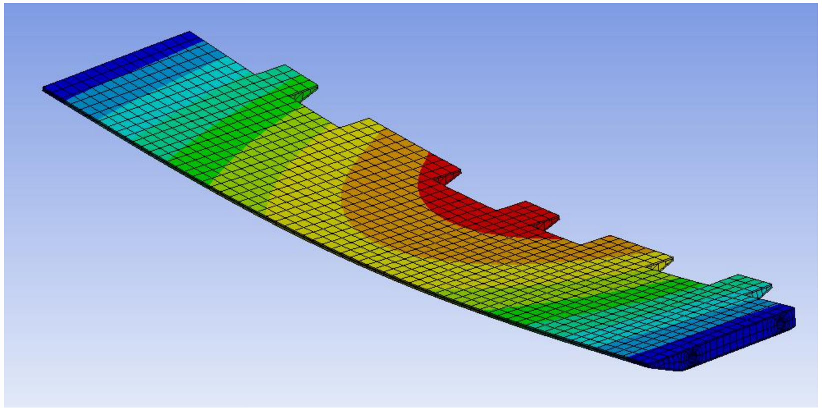


Model 3



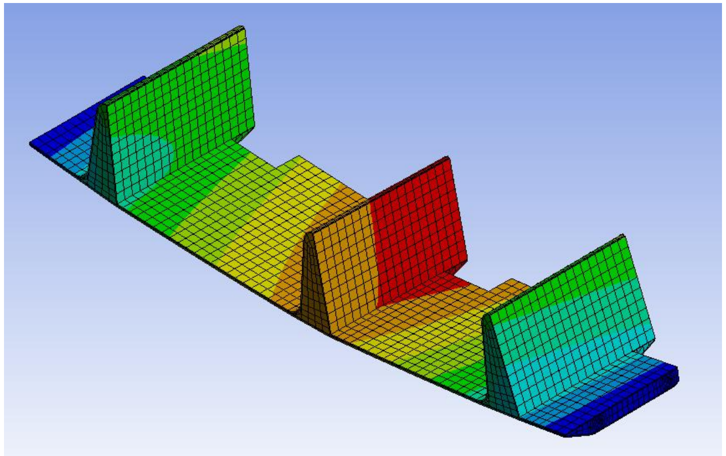
Static study 5/9

Model 1



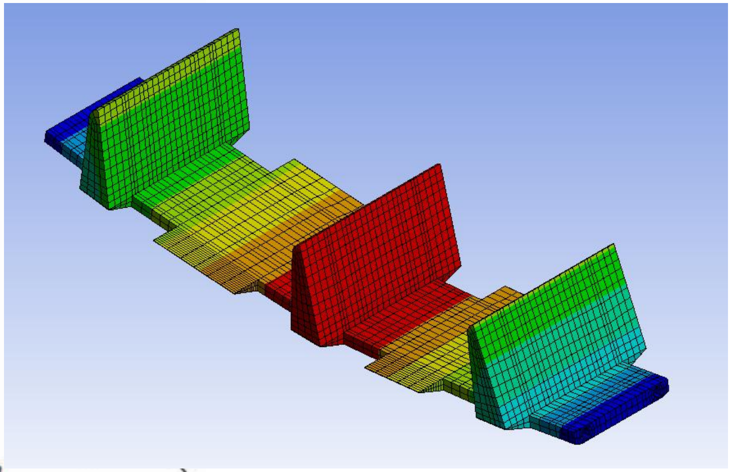
- U_{max} = 6 µm
- Obviously the best (continuous FP)

Model 2



- U_{max} = 20 µm
- Influence of mountains not negligible

Model 3

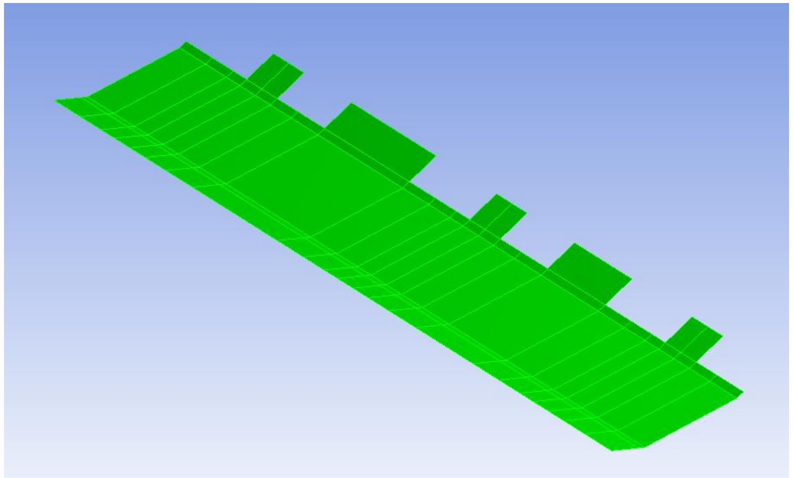


- U_{max} = 23 µm
- Influence of both:
  - discontinous back-plate
  - U-like profile has lower inertia

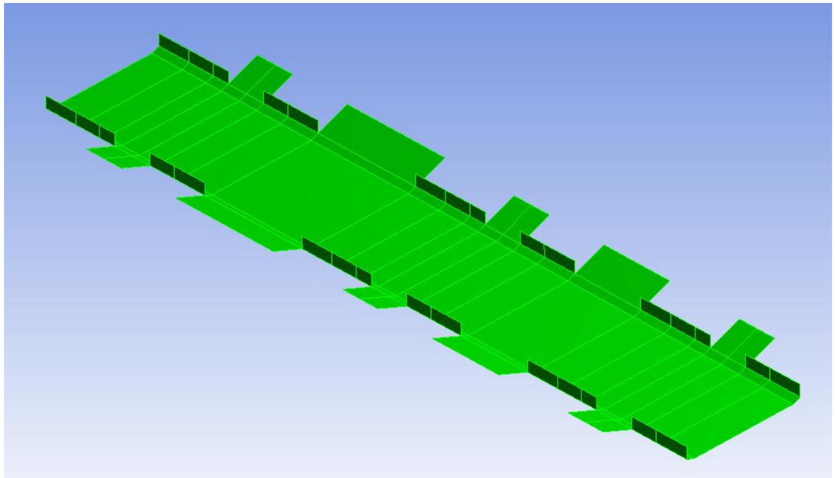
NB : the loading does NOT dependent on the mass !

Static study 6/9

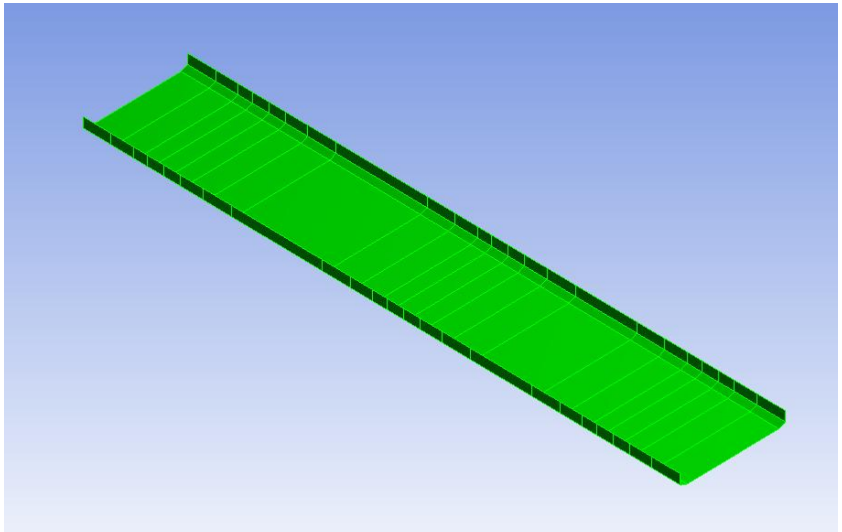
Model 1 & 2



Model 3



Model 4

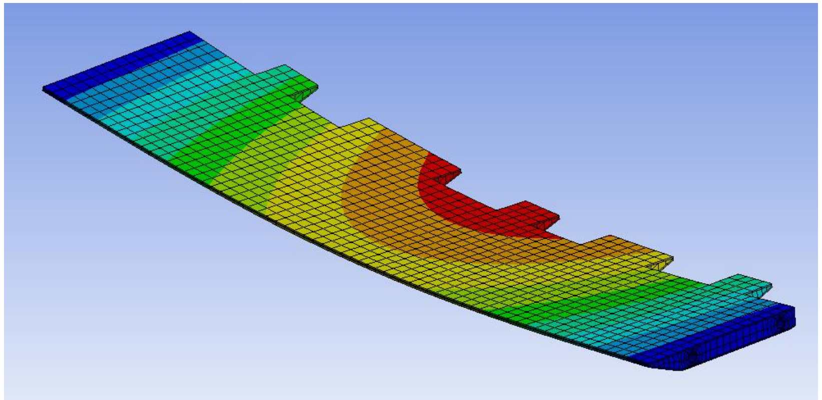


- Cutting both sides of stave leads to a decrease of material.
- Even with a lower inertia the U-backplate is maybe interesting.

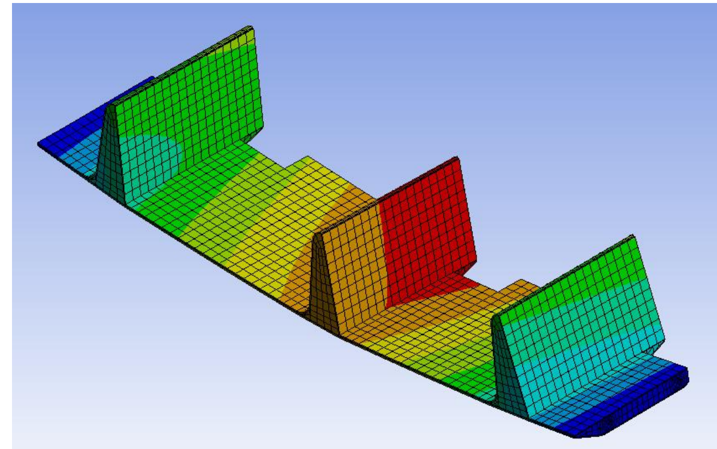
Model 4 :
continuous U-backplate

Static study 7/9

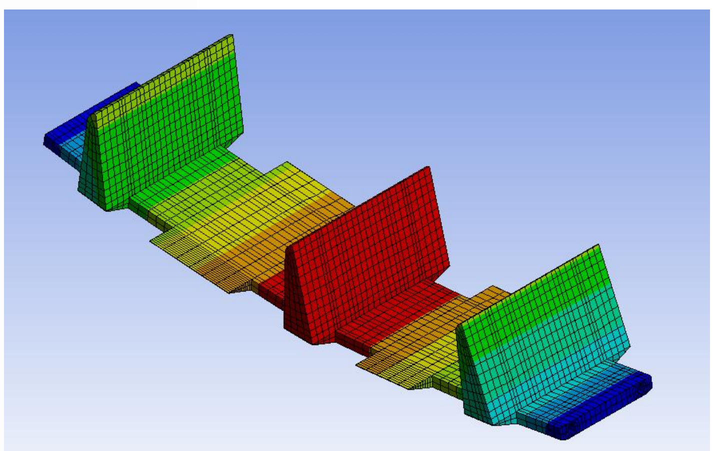
Model 1: U_{max} = 6 µm



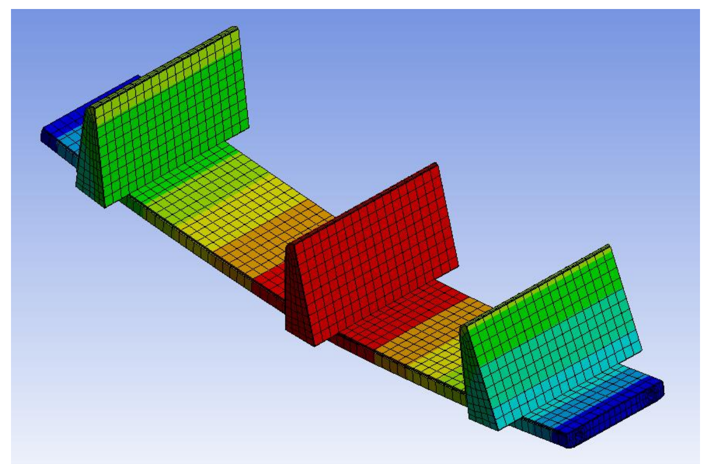
Model 2: U_{max} = 20 µm



Model 3: U_{max} = 23 µm



Model 4: U_{max} = 17 µm



NB : the loading does NOT dependent on the mass !

Static study 8/9

2 types of cross-sections

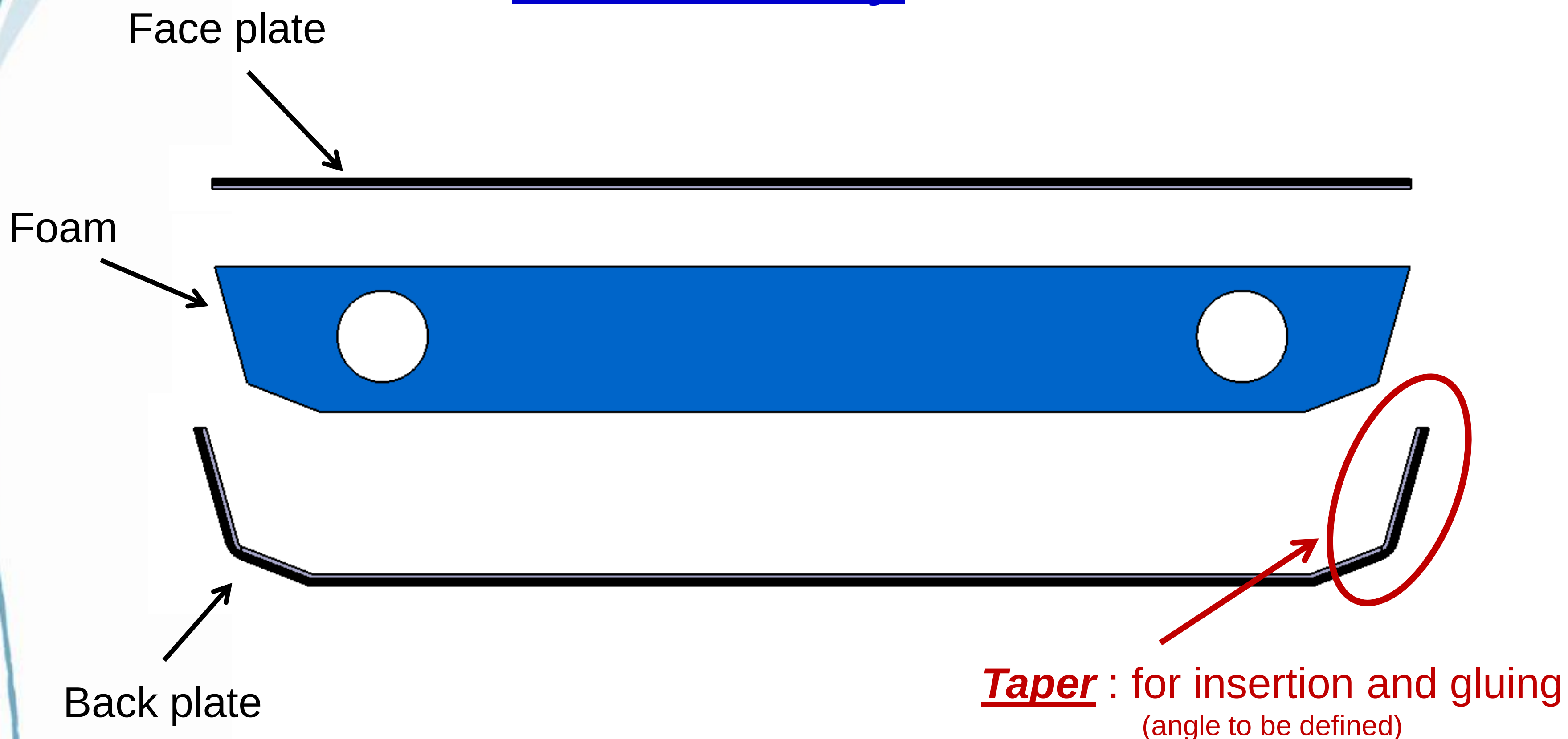
NB : discontinuities on 1 side for tiling assembly

Model 2:

Model 4:

NB : vertical laminates on both sides more convenient for calculation

Static study 9/9



Realistic Assembly :

Masses considerations 1/4

Linear Mass = $(14 + 3)_{foam} + (13 + 7)_{stycast} + (12 + 6)_{CF}$ = **56 g/m**

Linear Mass = $(14)_{foam} + (13 + 1)_{stycast} + (12 + 1)_{CF}$ = **41 g/m**

Mass reduction = 27 %

Linear Mass = $(5)_{foam} + (5 + 1)_{stycast} + (12 + 1)_{CF}$ = **24 g/m**

Mass reduction = 57 %

Mountains not taken into account

Masses considerations 2/4

Details on module's components

Module Components	Thickness (mm)	Density (kg/m3)	Mass (g)
Parylen	0.05	1420	0.05
Grease	0.07	3000	0.15
FEI4-chip	0.15	2320	0.25
Bump bonding	0.02	1420	0.02
Sensor	0.23	2320	0.38

Total mass = 0.85g

- Chip and sensor assumed to be made of silicon
- *Mass of IBL planar module: **m = 1.03g*** (before assembly, ie. no grease neither nor parylen)

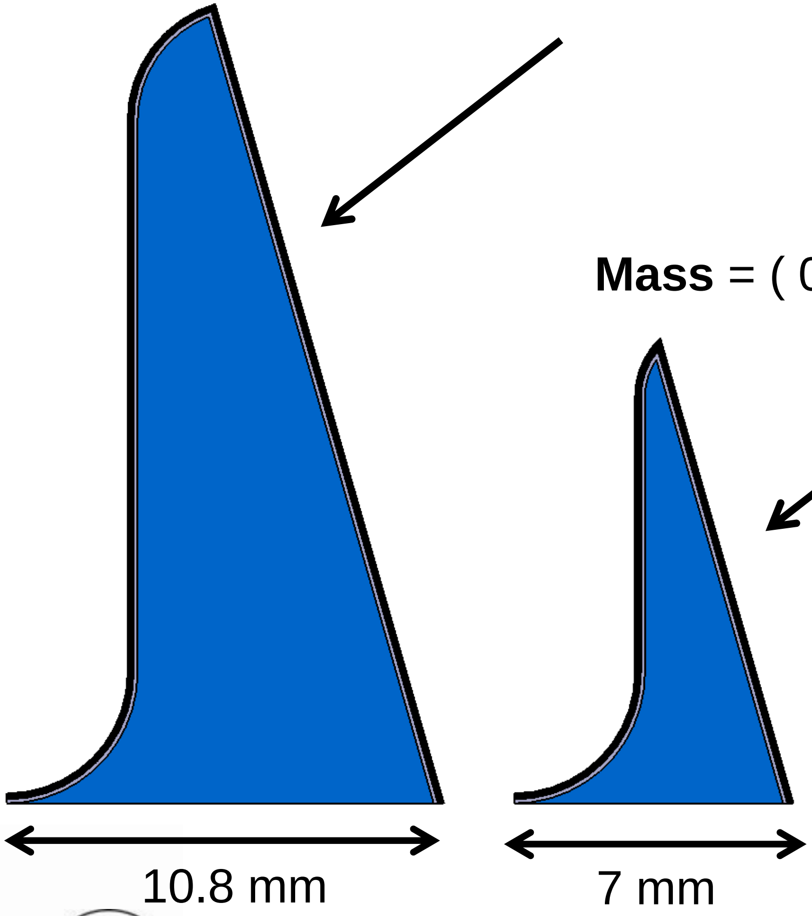
*Let's assume **1.2g** for the whole module in this study*

Masses considerations 3/4

Smaller mountain in case of TPG :

Mass = $(0.7)_{foam} + (0.4)_{stycast} + (0.4)_{CF}$ = **1.5 g**

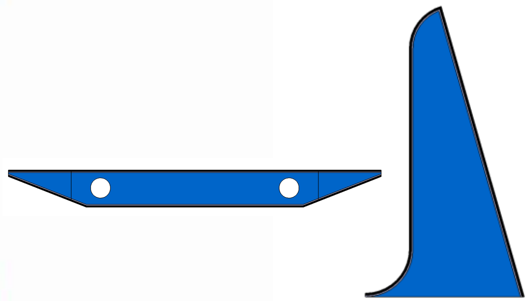
Mass = $(0.2)_{foam} + (0.2)_{stycast} + (0.2)_{CF}$ = **0.6 g**



Mass reduction = 60 %

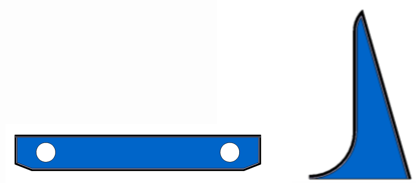
Masses considerations 4/4

Stave – layer #2:
end-cap length = 835mm for 13 modules



Mass = $(56 \times 0.835)_{base} + (13 \times 1.5)_{mount.} + (13 \times 1.2)_{module}$ = **81.9 g**

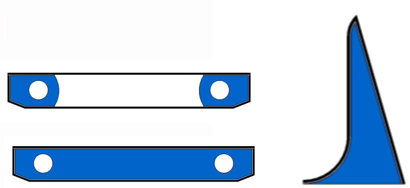
M_{base}= 46.8g M_{mount}= 19.5g M_{module}= 15.6g



Mass = $(41 \times 0.835)_{base} + (13 \times 0.6)_{mount.} + (13 \times 1.2)_{module}$ = **57.6** g

M_{base}= 34.2g M_{mount}= 7.8g M_{module}= 15.6g

Mass reduction = 30 %



M_{base} = (24 x 0.744 + 41 x 0.091) = 21.6 g

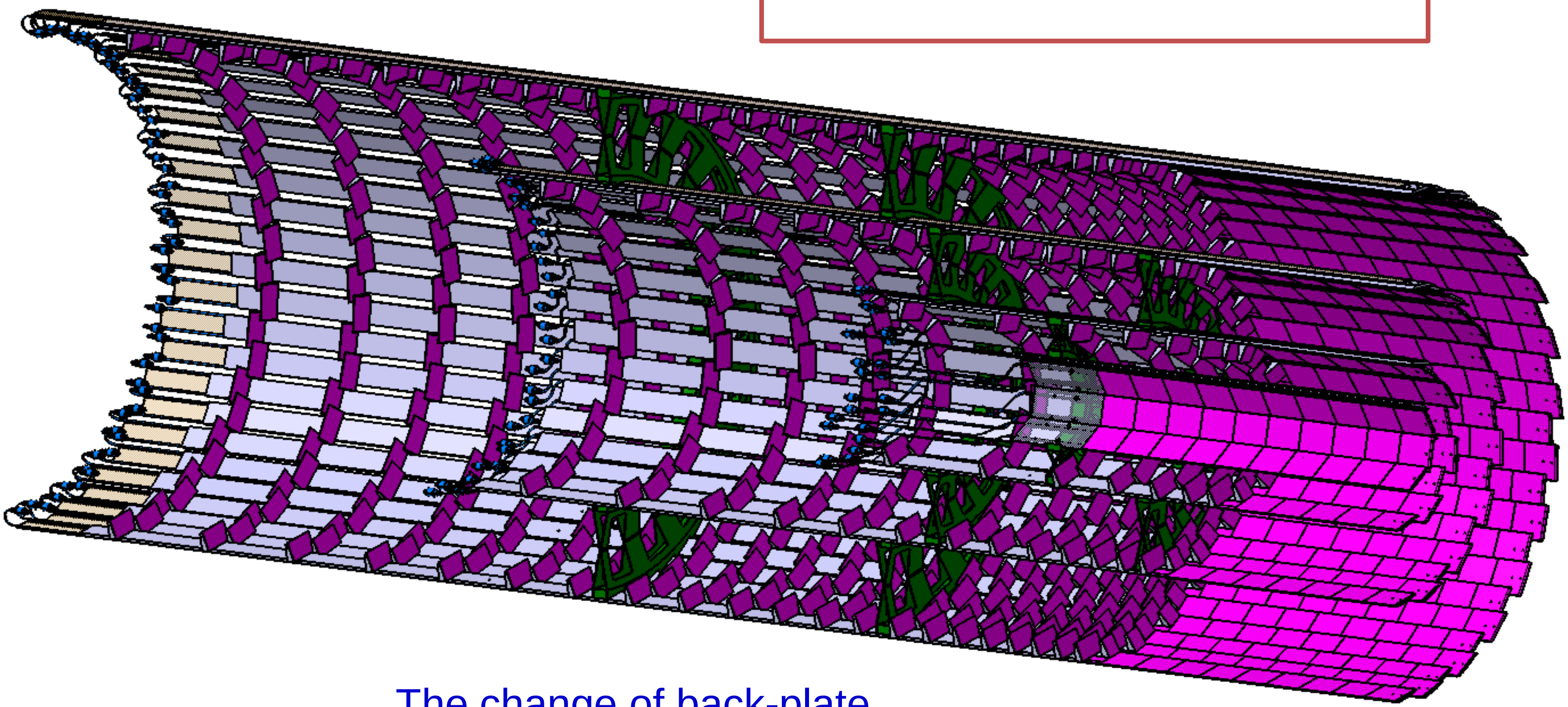
Mass = $(21.6)_{base} + (13 \times 0.6)_{mount.} + (13 \times 1.2)_{module}$ = **45 g**

M_{mount}= 7.8g M_{module}= 15.6g

Mass reduction = 45 %

Pixel design 1/3

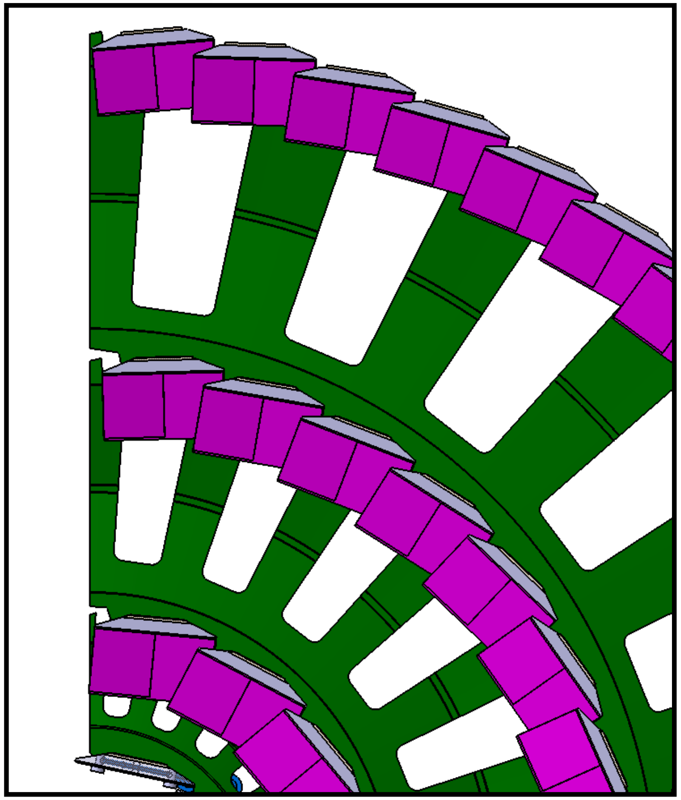
Consequences on PIXEL design



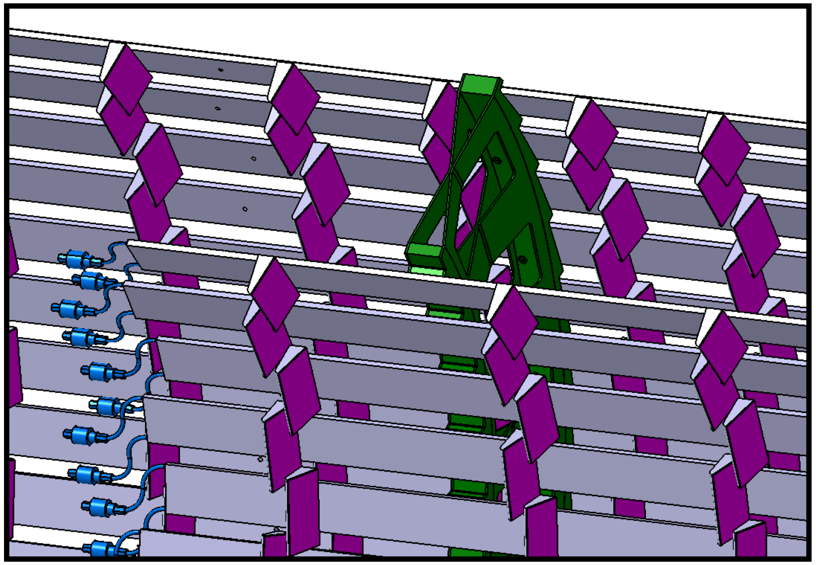
The change of back-plate
(U profile instead of Omega)
leads to ***spaces between staves***

Pixel design 2/3

The change of back-plate is only for the end-cap region



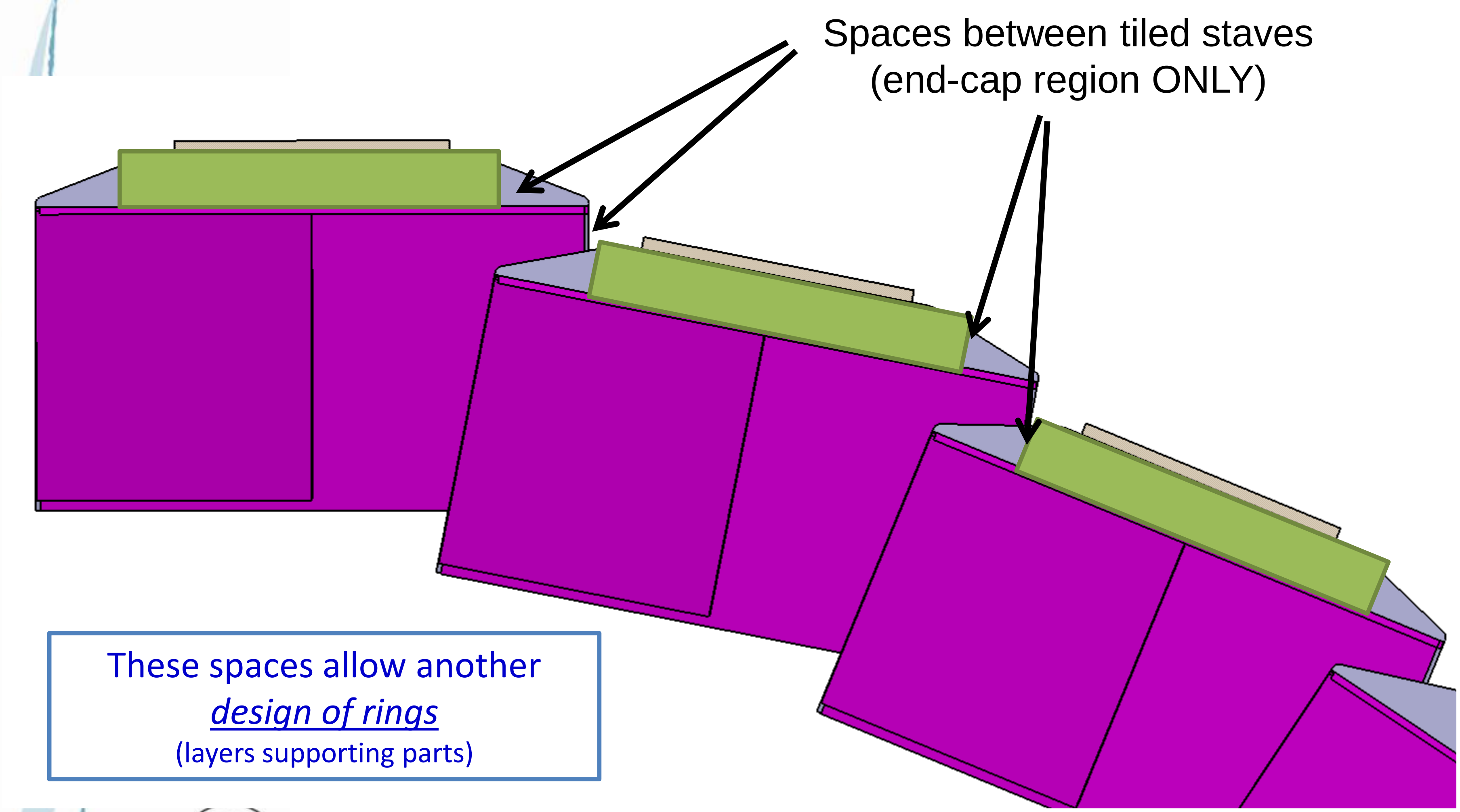
View from Z_0 plane :
no change for the barrel



3D view of the end-cap
(layers 2 & 3)
spaces between staves

Pixel design 3/3

View from Z_0 plane



These spaces allow another
design of rings
(layers supporting parts)

Conclusions

$$\omega = \sqrt{\frac{K}{M}}$$

*Criterion based on the eigen-frequency of the **structure***

As high as possible / bigger than 50Hz ?

Thanks to a continuous U - back plate :
- the stiffness K increases (a little bit)
- the mass M decreases.

➡ **It goes in the desired direction**

Evaluate the global behavior (K and M):

not of a single stave BUT of global layer taking into account rings

(at Z_0, at the end of stave and intermediate supports)

Prospects

Work on the support system in a global approach (one layer to begin) to identify if we need:

- to redesign the stave,
- to make an effort on rings design, number and locations
- redesign both : supports and stave

→ ***Modelling of a layer***