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

First studies of the anode deck structure

(Thermal and mechanical simulations)

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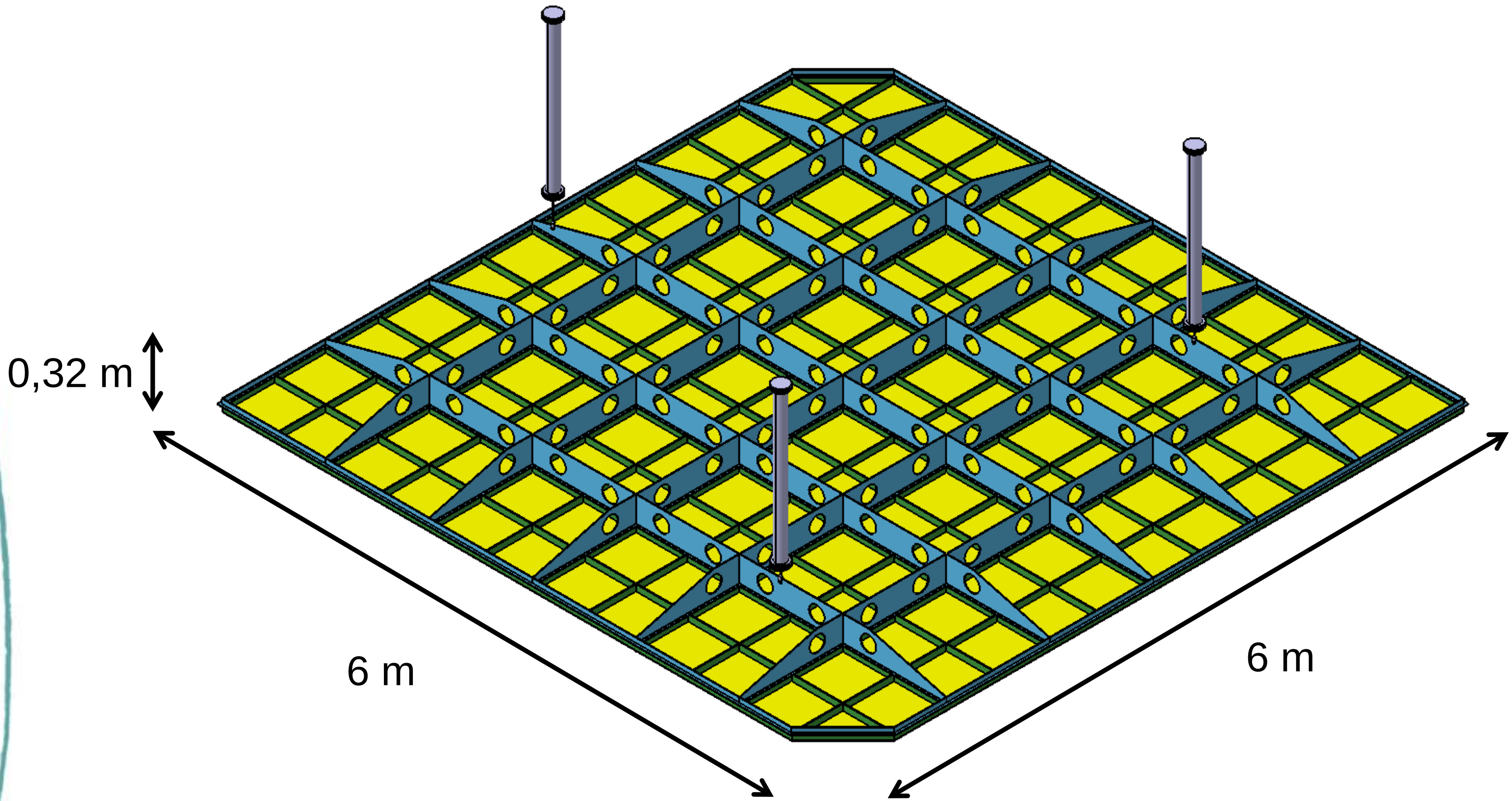
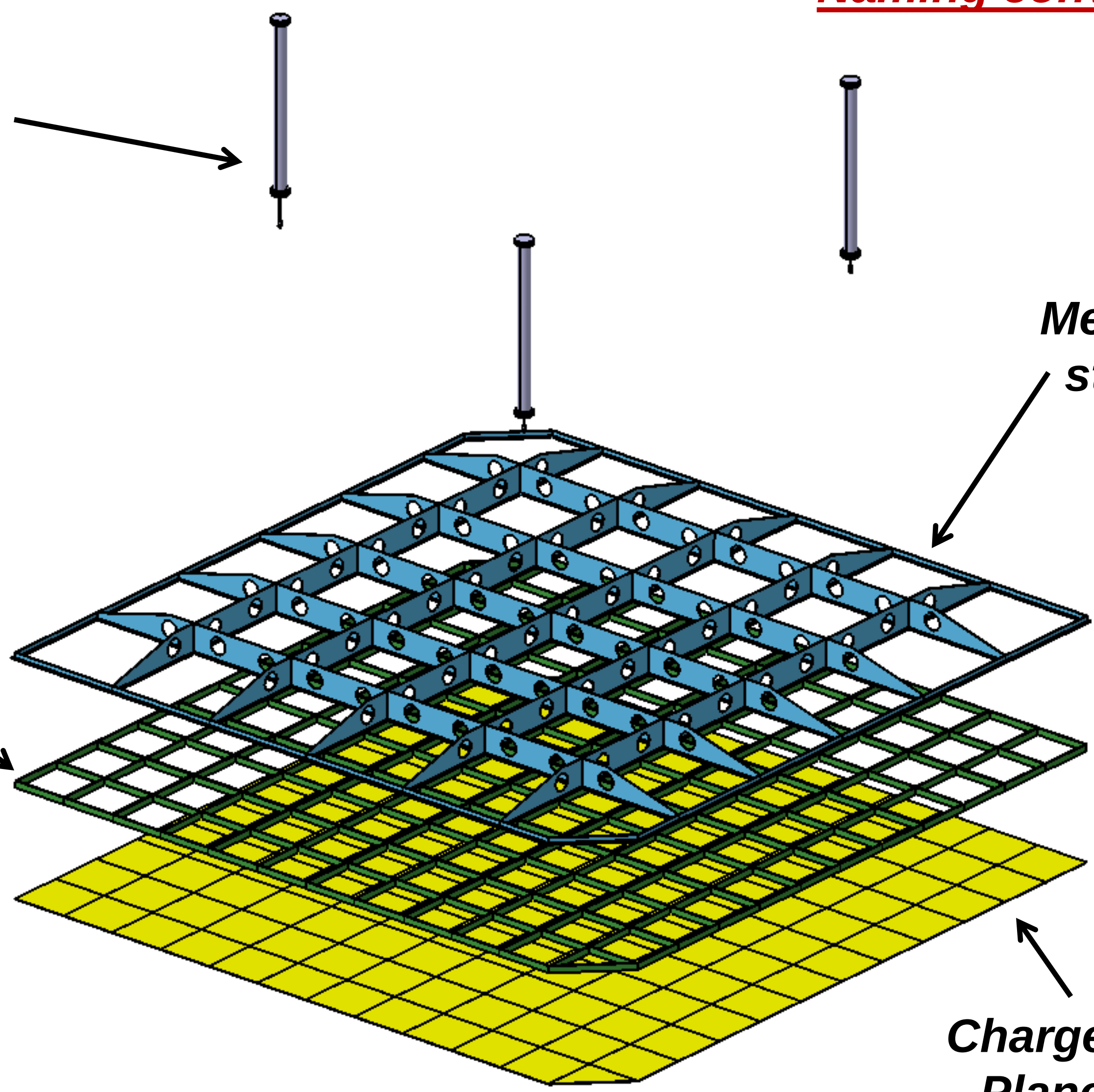
Baseline design

CAD model from Adamo Gendotti



Baseline design

Naming conventions



FEA assumptions 1/2

➢ ***G10 properties :***

- E = 24.000 MPa
- ν = 0,3
- $\rho = 1850\ kg/m^3$
- $\alpha = 1{,}5.10^{-5}\ K^{-1}$

NB:

- **E** : Elastic Modulus
- **ν** : Poisson coefficient
- **ρ** : Density
- **α** : Thermal expansion coefficient

➢ ***Stainless steel properties :***

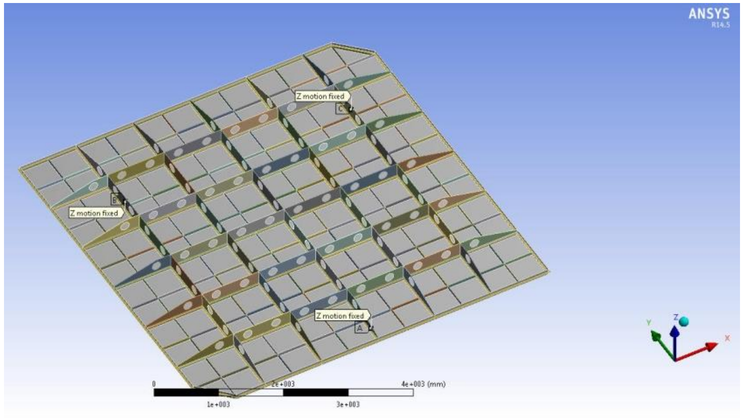
- E = 210.000 MPa
- ν = 0,3
- $\rho = 7850\ kg/m^3$
- $\alpha_{304L} = 1{,}7.10^{-5}\ K^{-1}$
- $\alpha_{316L} = 1{,}6.10^{-5}\ K^{-1}$

➢ ***Added mass :***

- $10\ kg/m^2$ over $36\ m^2$ for electronics, mesh and tensioning system
- Distributed on CRP

FEA assumptions 2/2

- ***Boundary conditions:***
  - Z motion fixed for cables anchoring locations
  - X and Y motions free for all the structure



- ***Static loading:***
  - Gravity acting along –Z direction

- ***Thermal loading:***
  - Thermalization of the structure (same temperature on all nodes)
  - From 22°C to -186° C, imposed on the whole model

Comments on assumptions

- ***G10 properties :***
  - E = 24.000 MPa
  - v = 0,3
  - ρ = 1850 kg/m^3
  - $\alpha = 1{,}5.10^{-5}\ K^{-1}$
- ***Stainless steel properties :***
  - E = 210.000 MPa
  - v = 0,3
  - ρ = 7850 kg/m^3
  - $\alpha_{304L} = 1{,}7.10^{-5}\ K^{-1}$
  - $\alpha_{316L} = 1{,}6.10^{-5}\ K^{-1}$
- ***Added mass :***
  - 10 kg/m² over 36 m² for electronics, mesh and tensioning system
  - Distributed on CRP

- G10 considered *isotropic*
- All values (E, v, α) *at 22°C*
- *Large range of α values* for stainless steel
- Added mass *roughly estimated* *(as suggested)*
- *Mesh tensioning system* has no influence on the structure

Goal to reach

The objective is to find a structure whose deformations, occurring during data taking phases, respect the criterion:

"The CRP displacements of any node cannot exceed *+/- 0,5 mm along the vertical direction*"

(ie perpendicularly to the LAr free surface)

Which is similar to:

The peak to peak value **llDzll** of the CRP displacements must fulfil :

llDzll < 1mm

Simulation 1

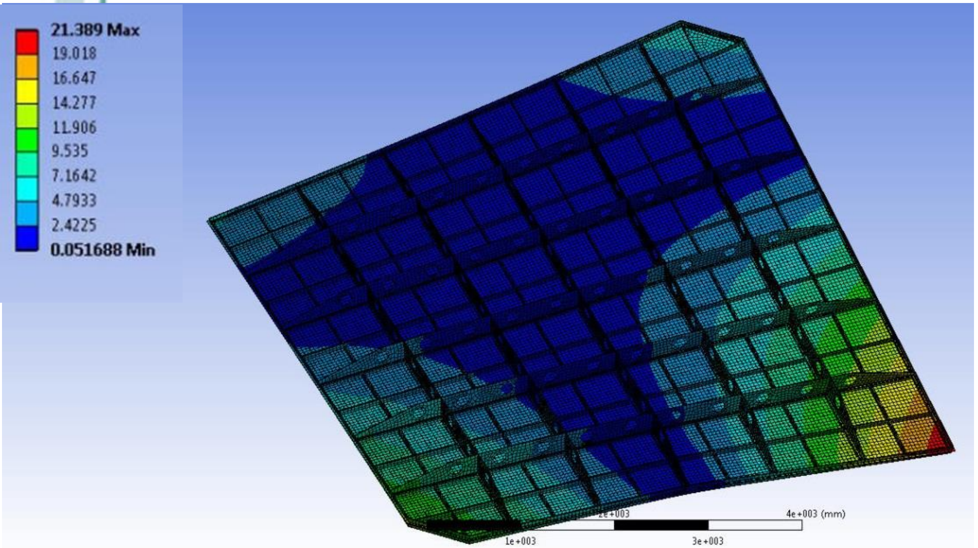
Short description:

- Baseline design
- CRP and Connection structure made of G10
- Mechanical structure made of 316L stainless steel
  (closest thermal expansion coefficient wrt G10 one)
- Hanging system = 3 cables

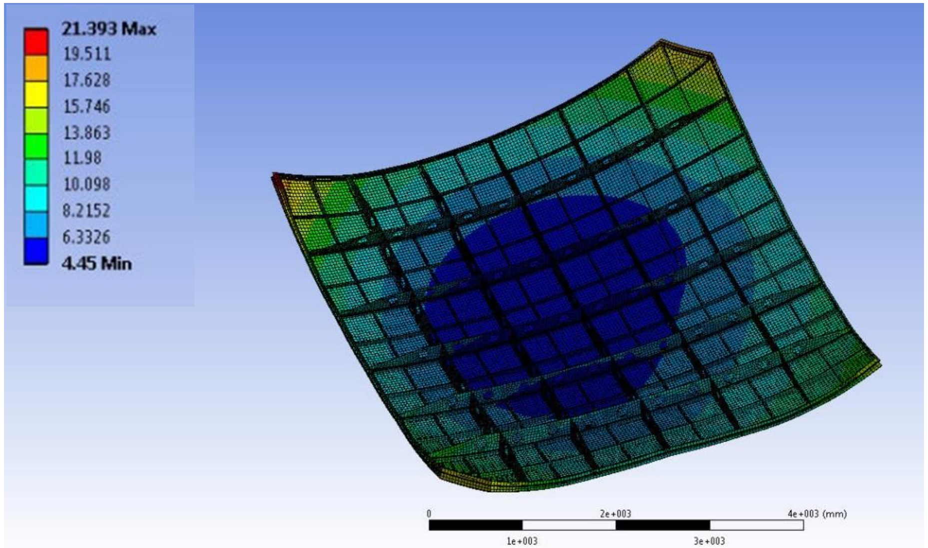
Simulation 1

Amplitude of 3 displacements (dX, dY, dZ)

Step 1: gravity ONLY



Step 2: gravity + ΔT (+22° to -186°C)



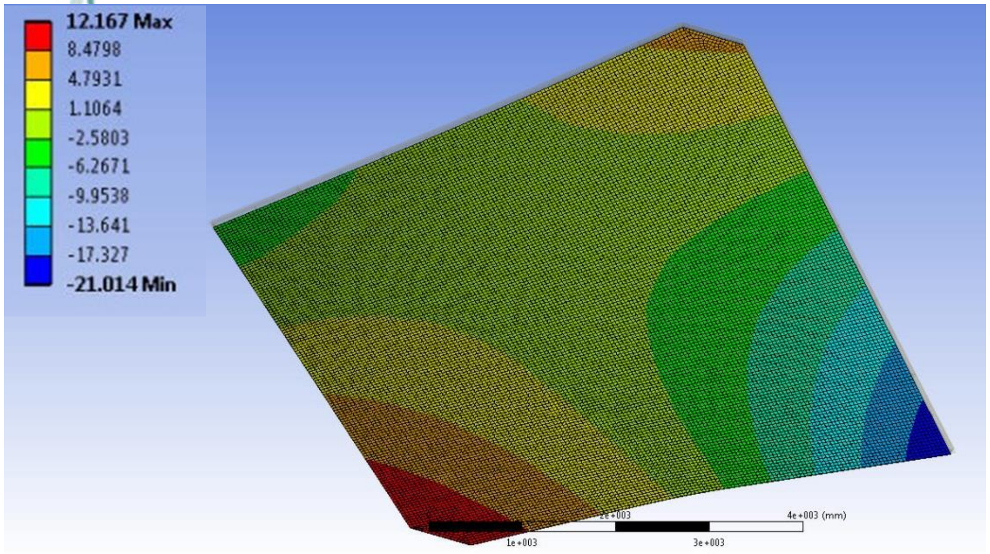
Huge change of shape !

Non negligible influence of ***thermal bi-material effect***

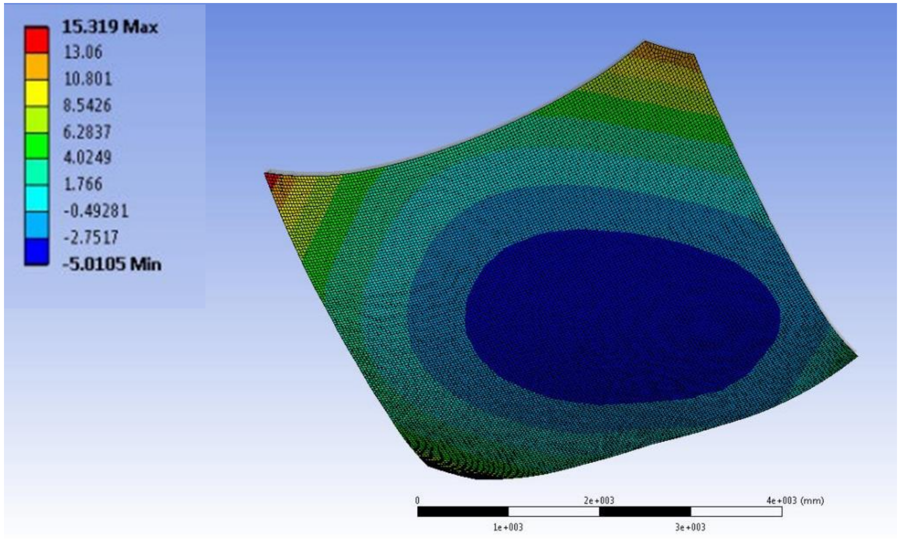
Simulation 1

Displacements of CRP along Z direction

Step 1: gravity ONLY



Step 2: gravity + ΔT (+22° to -186°C)



	Step 1		Step 2		
	$[Dz_{min} ; Dz_{max}]$	**‖Dz‖**	$[Dz_{min} ; Dz_{max}]$	**‖Dz‖**	Model mass
Simulation 1 G10 + SSteel / 3 cables	[-21 ; 12,2]	**33,2 mm**	[-5 ; 15,3]	**20,3 mm** (>1mm)	1868 kg

Simulation 2

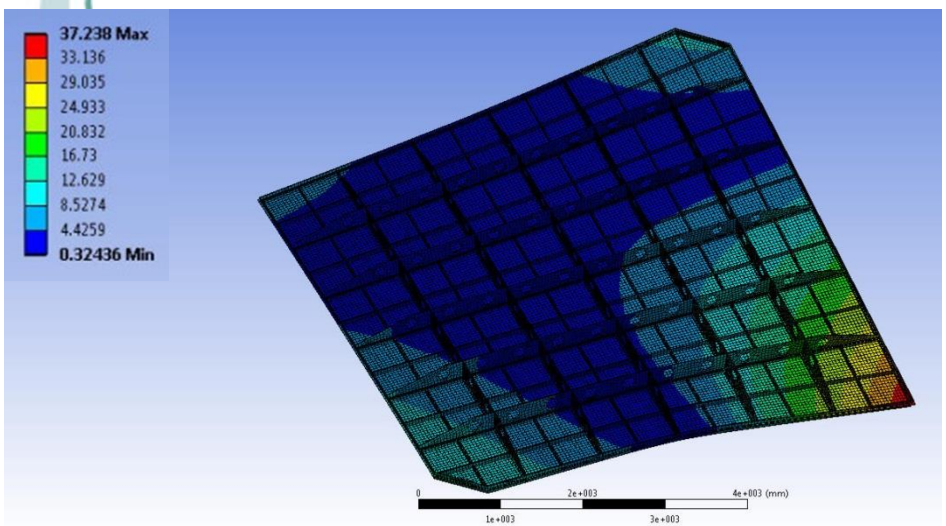
Short description:

- Baseline design
- All the structure made of G10
- Hanging system = 3 cables

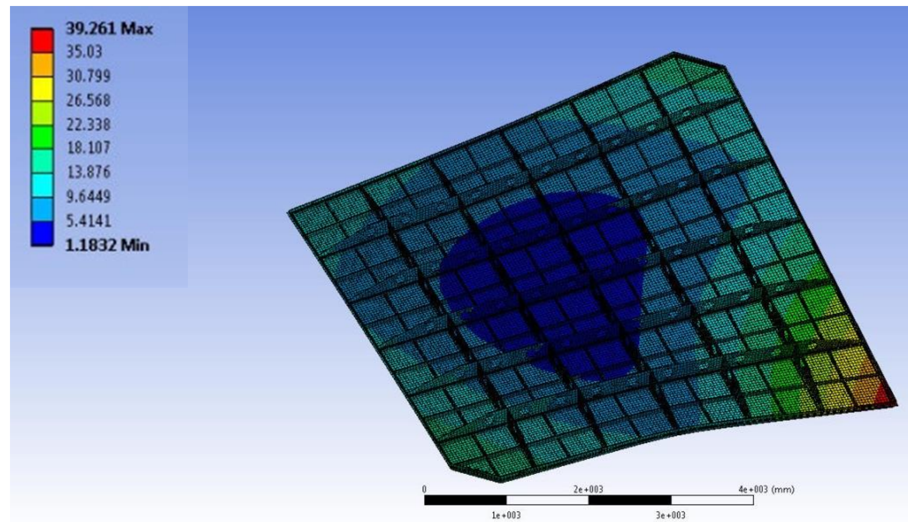
Simulation 2

Amplitude of 3 displacements (dX, dY, dZ)

Step 1: gravity ONLY



Step 2: gravity + ΔT (+22° to -186°C)



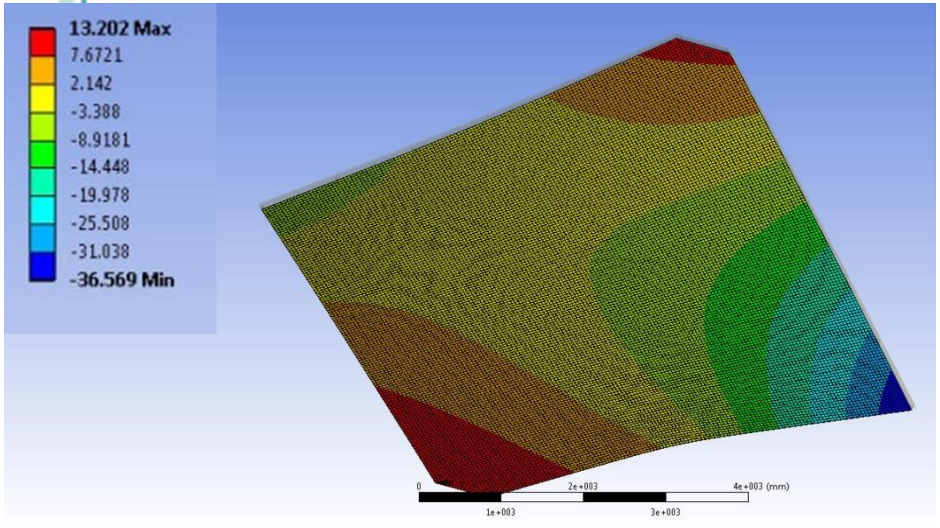
No change of shape

Thermal effect negligible on this full G10 structure

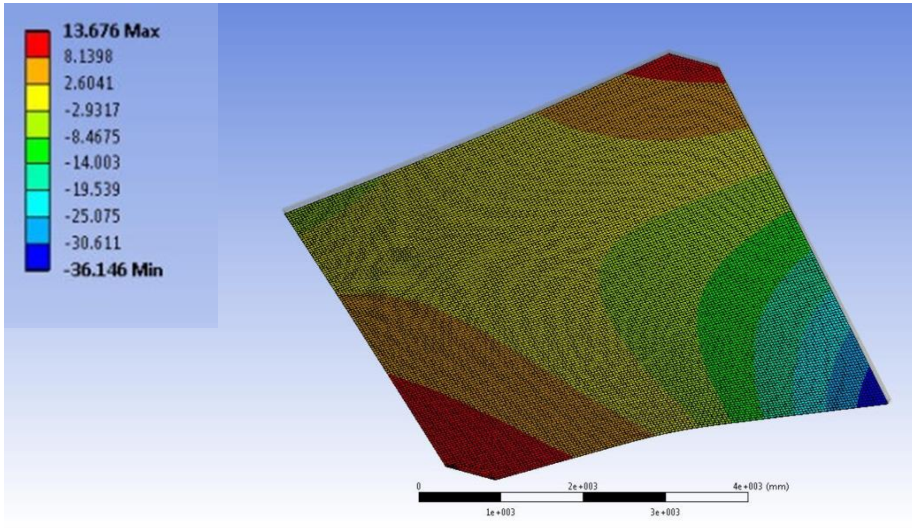
Simulation 2

Displacements of CRP along Z direction

Step 1: gravity ONLY



Step 2: gravity + ΔT (+22° to -186°C)



	Step 1		Step 2		
	$[Dz_{min} ; Dz_{max}]$	**‖Dz‖**	$[Dz_{min} ; Dz_{max}]$	**‖Dz‖**	Model mass
Simulation 2 G10 / 3 cables	[-36,6 ; 13,2]	**49,8 mm**	[-36,2 ; 13,7]	**49,9 mm** (> 1 mm)	1167 kg

First comparison

Step 1:
gravity ONLY

Step 2:
gravity + ΔT (+22° to -186°C)

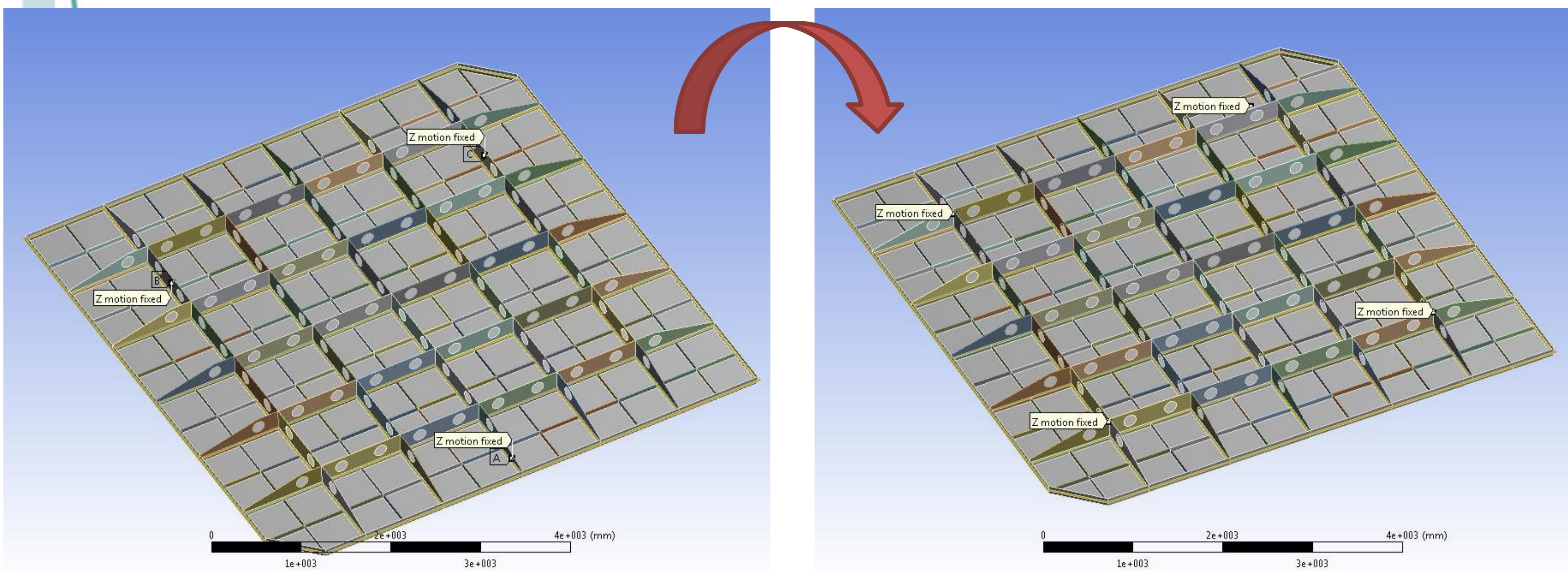
	Step 1		Step 2		
	[Dz_{min} ; Dz_{max}]	**‖Dz‖**	[Dz_{min} ; Dz_{max}]	**‖Dz‖**	Model mass
Simulation 1 G10 + SSteel / 3 cables	[-21 ; 12,2]	**33,2 mm**	[-5 ; 15,3]	**20,3 mm** (> 1mm)	1868 kg
Simulation 2 G10 / 3 cables	[-36,6 ; 13,2]	**49,8 mm**	[-36,2 ; 13,7]	**49,9 mm** (> 1 mm)	1167 kg

- Full G10 structure is obviously less stiff than G10 + Stainless steel
- Full G10 structure has a “neutral” behavior on thermal loading
  (CRP deformations = in plane deformations !)

Change of boundary conditions

Let’s change the boundary conditions:

- by using *4 cables instead of 3*
- by fixing these cables *at the tips of a square*



Simulation 3

Short description:

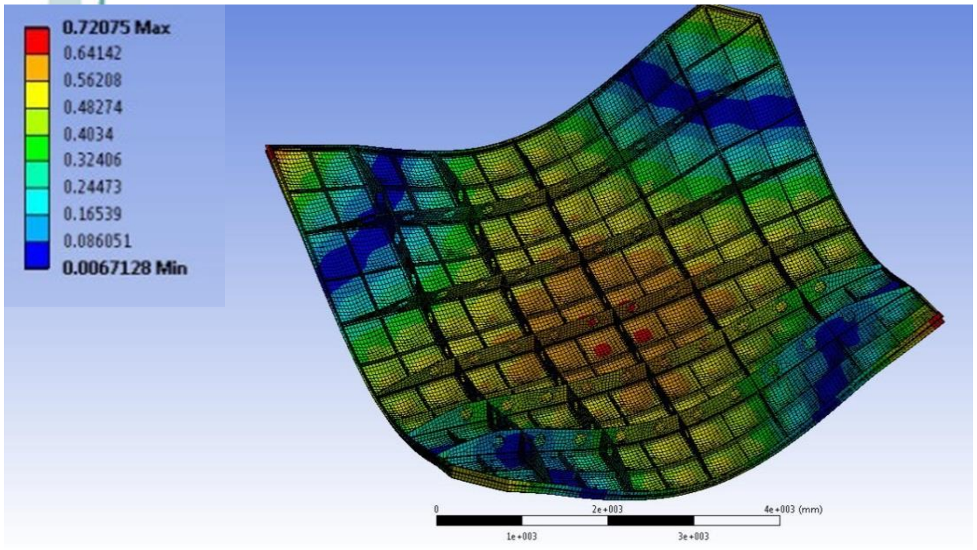
- Baseline design
- CRP and Connection structure made of G10
- Mechanical structure made of 316L stainless steel
  (closest thermal expansion coefficient wrt G10 one)
- Hanging system = 4 cables

NB : same than simulation 1 with 1 more cable !

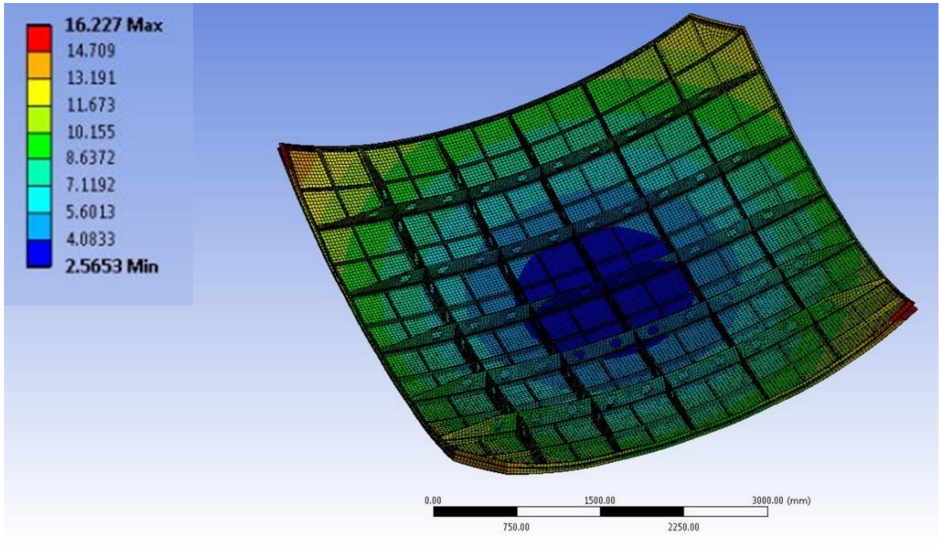
Simulation 3

Amplitude of 3 displacements (dX, dY, dZ)

Step 1: gravity ONLY



Step 2: gravity + ΔT (+22° to -186°C)



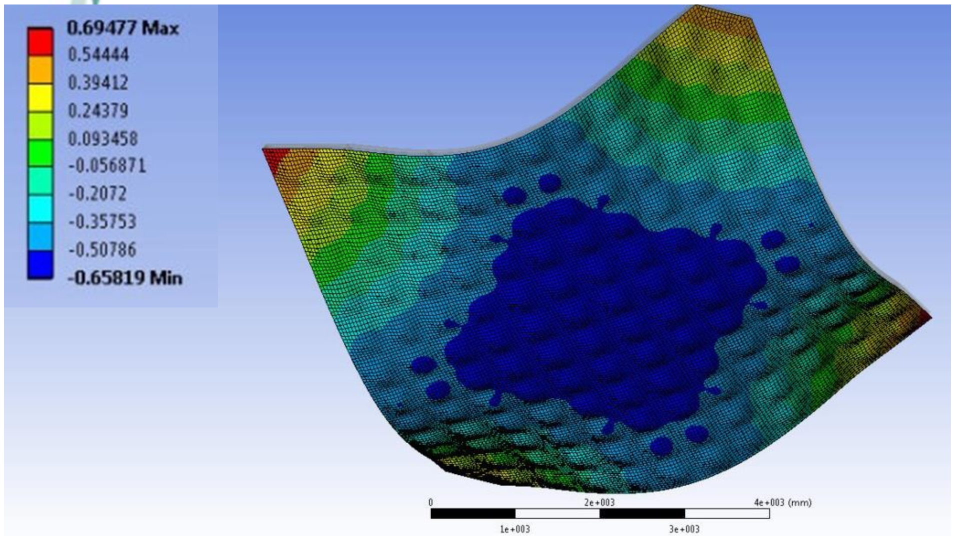
Big reduction of displacements

(compared to the same solution with 3 cables)

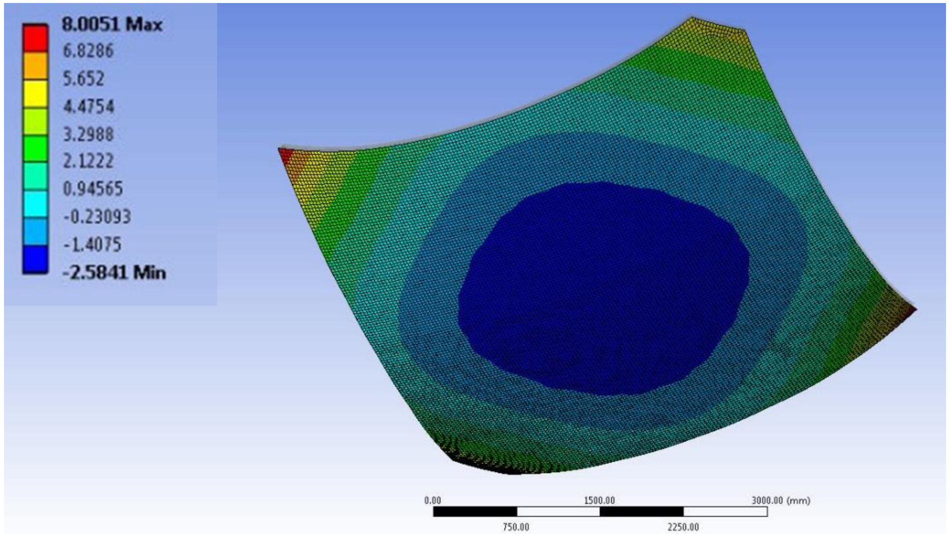
Simulation 3

Displacements of CRP along Z direction

Step 1: gravity ONLY



Step 2: gravity + ΔT (+22° to -186°C)



	Step 1		Step 2		
	[Dz_{min} ; Dz_{max}]	**‖Dz‖**	[Dz_{min} ; Dz_{max}]	**‖Dz‖**	Model mass
Simulation 3 G10 + SSteel / 4 cables	[-0,7 ; 0,7]	**1,4mm**	[-2,6 ; 8]	**10,6** (> 1 mm)	1868 kg

Still thermal bi-material effect non negligible

Simulation 4

Short description:

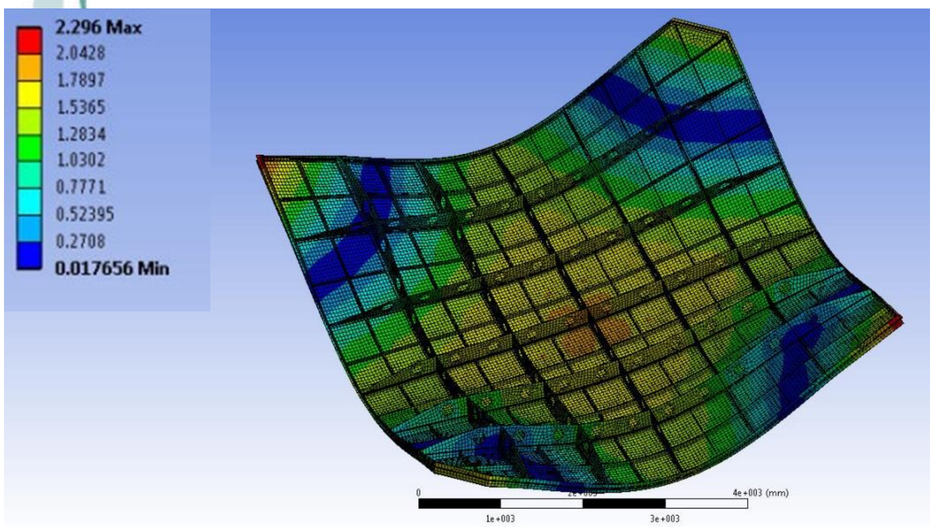
- Baseline design
- All the structure made of G10
- Hanging system = 4 cables

NB : same than simulation 2 with 1 more cable !

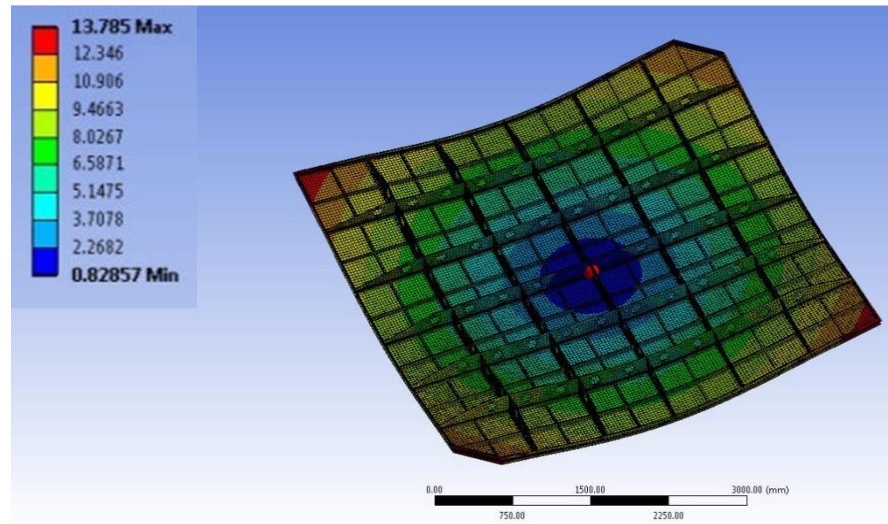
Simulation 4

Amplitude of 3 displacements (dX, dY, dZ)

Step 1: gravity ONLY



Step 2: gravity + ΔT (+22° to -186°C)



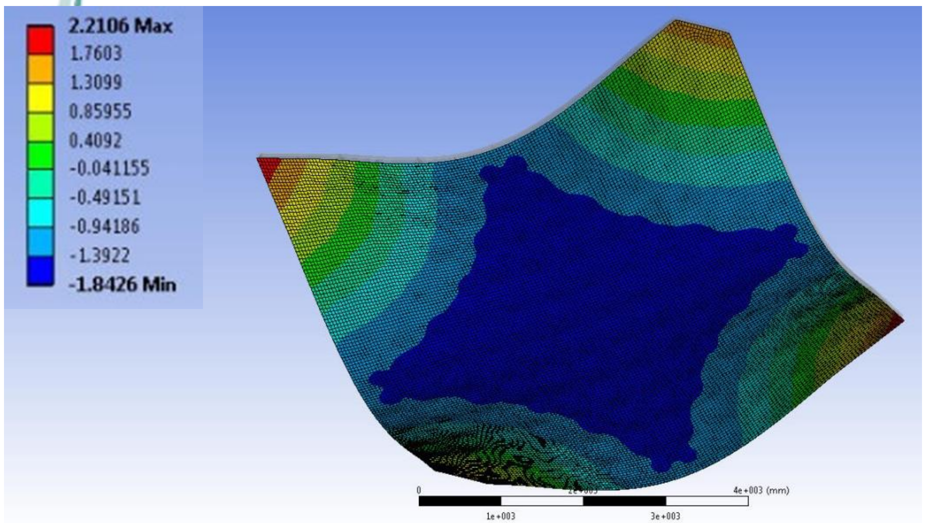
Big reduction of displacements
(compared to the same solution with 3 cables)

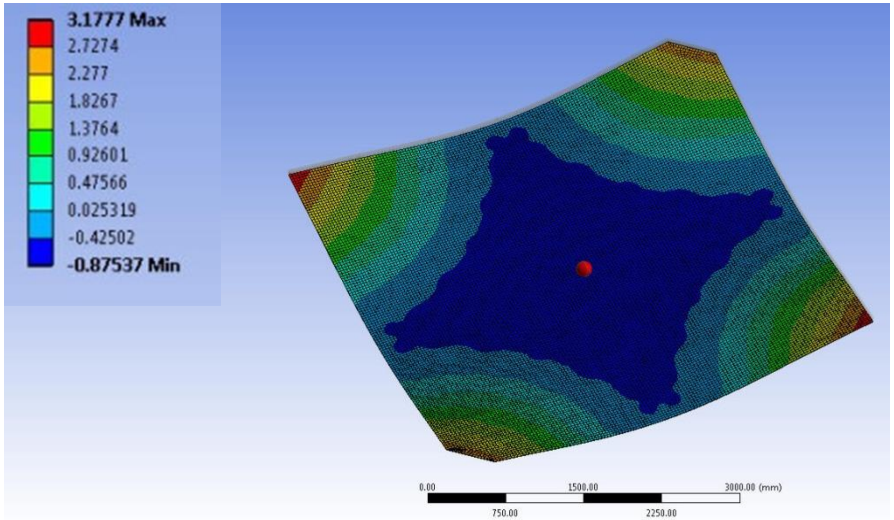
Simulation 4

Displacements of CRP along Z direction

Step 1: gravity ONLY

Step 2: gravity + ΔT (+22° to -186°C)





	Step 1		Step 2		
	[Dz_{min} ; Dz_{max}]	**‖Dz‖**	[Dz_{min} ; Dz_{max}]	**‖Dz‖**	Model mass
Simulation 4 G10 / 4 cables	[-1,8 ; 2,2]	**4mm**	[-0,9 ; 3,2]	**4,1** (> 1 mm)	1167 kg

→ “neutral” behavior on thermal loading

Second comparison

Step 1:
gravity ONLY

Step 2:
gravity + ΔT (+22° to -186°C)

	Step 1		Step 2		
	[Dz_{min} ; Dz_{max}]	**||Dz||**	[Dz_{min} ; Dz_{max}]	**||Dz||**	Model mass
Simulation 1 G10 + SSteel / 3 cables	[-21 ; 12,2]	**33,2mm**	[-5 ; 15,3]	**20,3**	1868 kg
Simulation 2 G10 / 3 cables	[-36,6 ; 13,2]	**49,8mm**	[-36,2 ; 13,7]	**49,9 mm**	1167 kg
Simulation 3 G10 + SSteel / 4 cables	[-0,7 ; 0,7]	**1,4mm**	[-2,6 ; 8]	**10,6**	1868 kg
Simulation 4 G10 / 4 cables	[-1,8 ; 2,2]	**4mm**	[-0,9 ; 3,2]	**4,1**	1167 kg

- *4 cables help a lot* to drastically decrease the CRP displacements
- Full G10 structure seems to be a *promising option*

Comments

- Full G10 structure has a very interesting thermal behavior
- It is nevertheless less stiff than associated with stainless steel

Why not keep the *full G10 option*

&

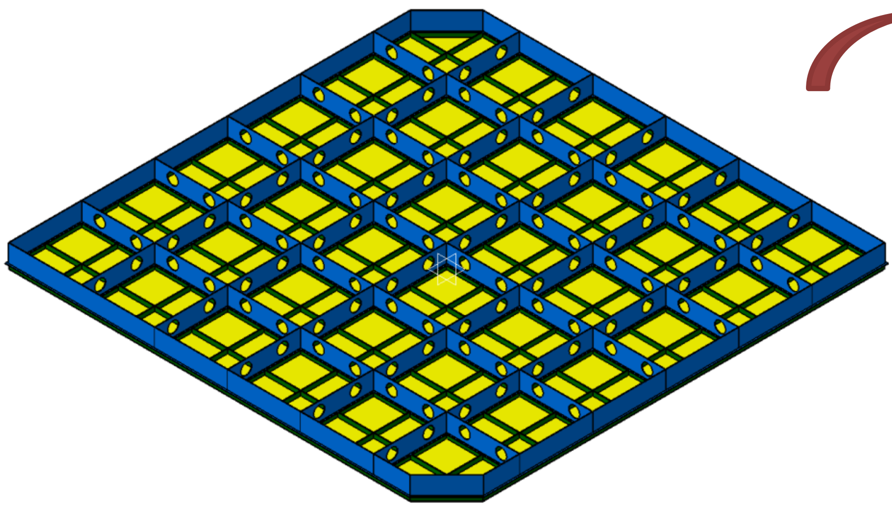
try to find a stiffer design (for static loading) ?

New design proposal

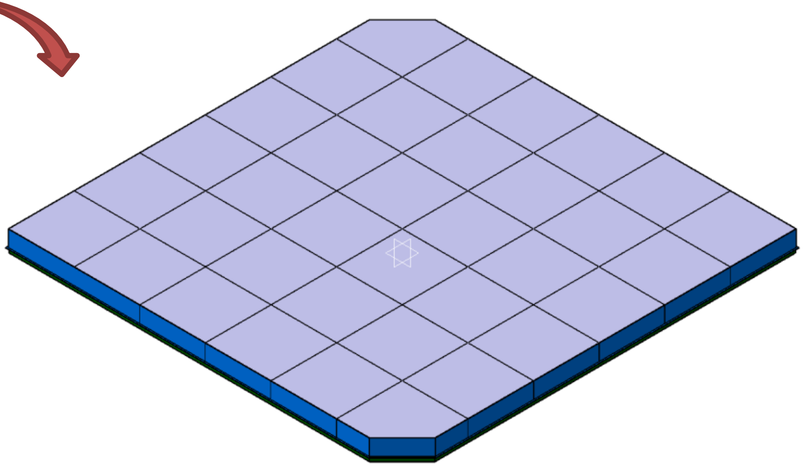
Based on "*Adamo design*" (same structure thickness), the use of a "closing plate" could improve the static behavior of the structure

Slight modifications

(Belt surrounding the structure)



Closing plate added



Simulation 5

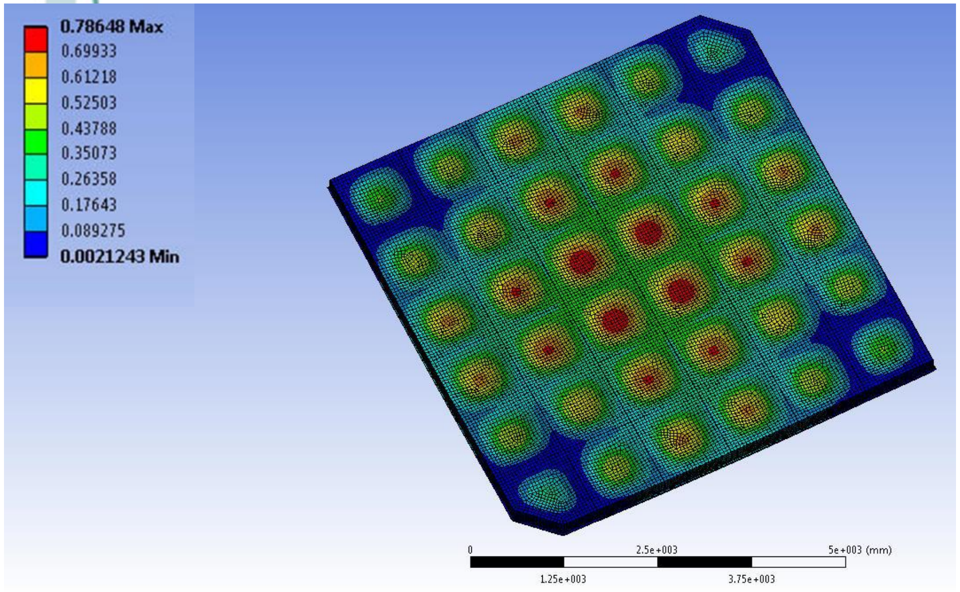
Short description:

- Baseline design + belt + closing plate
- All the structure made of G10
- Hanging system = 4 cables

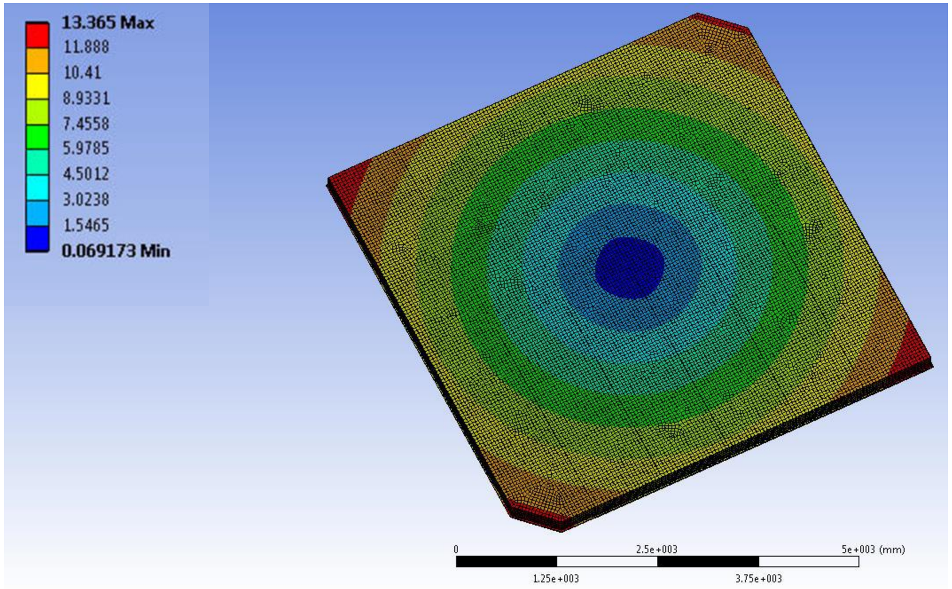
Simulation 5

Amplitude of 3 displacements (dX, dY, dZ)

Step 1: gravity ONLY



Step 2: gravity + ΔT (+22° to -186°C)

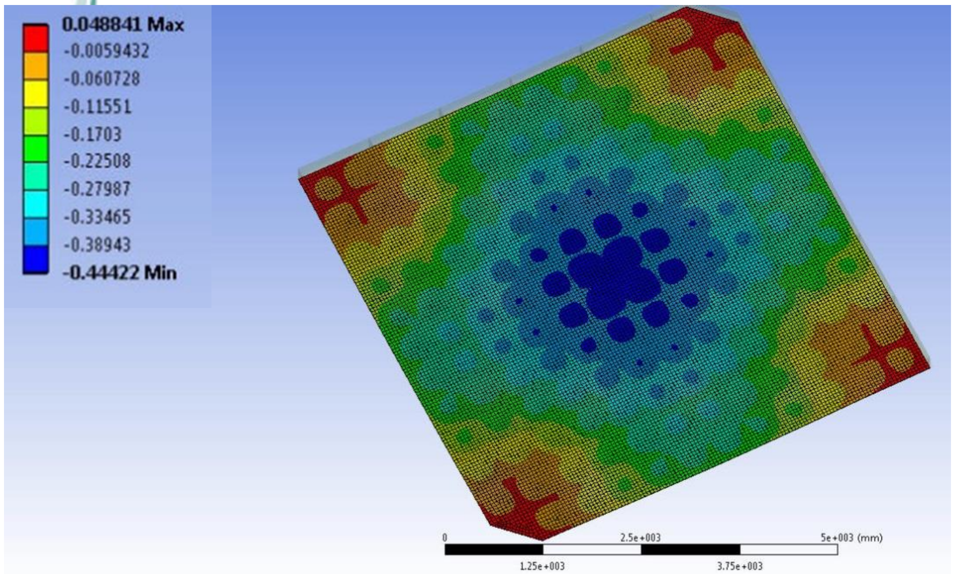


Small static displacements and homogeneous structure expansion

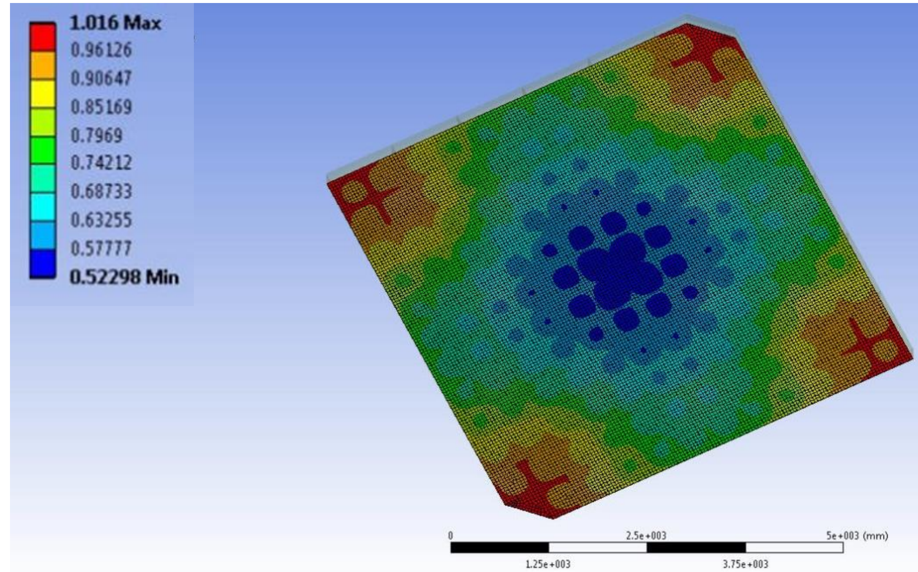
Simulation 5

Displacements of CRP along Z direction

Step 1: gravity ONLY



Step 2: gravity + ΔT (+22° to -186°C)



	Step 1		Step 2		
	$[Dz_{min} ; Dz_{max}]$	**‖Dz‖**	$[Dz_{min} ; Dz_{max}]$	**‖Dz‖**	Model mass
Simulation 5 G10 / 4 cables / closing plate	[-0,44 ; 0,05]	**0,5mm**	[0,5 ; 1]	0,5	1600 kg

This model fulfills the "1mm max" requirement !

Advanced thermal simulations

In the previous simulations, the thermal loading is extremely simple:
+22°C to -186 °C is applied to all the structure.

In reality, a thermal gradient can happen due to:

- Temperature variation as a function of altitude / LAr free surface: $\Delta T = f(z)$?
- Thermal flux (heat source) coming from electronics & power/data cables ?
- Thermal flux (heat source) coming from chimneys / supporting cables ?
- Thermal radiation from insulating walls ?

A more realistic simulation would take into account these loadings

Advanced thermal simulations

As a result a thermal gradient would appear in the structure

In order to illustrate the behavior of the structure, a temperature gradient has been applied *thanks to a surface flux*.

This thermal loading is *arbitrary*.
It will nevertheless help us to understand how behaves the anode deck structure.

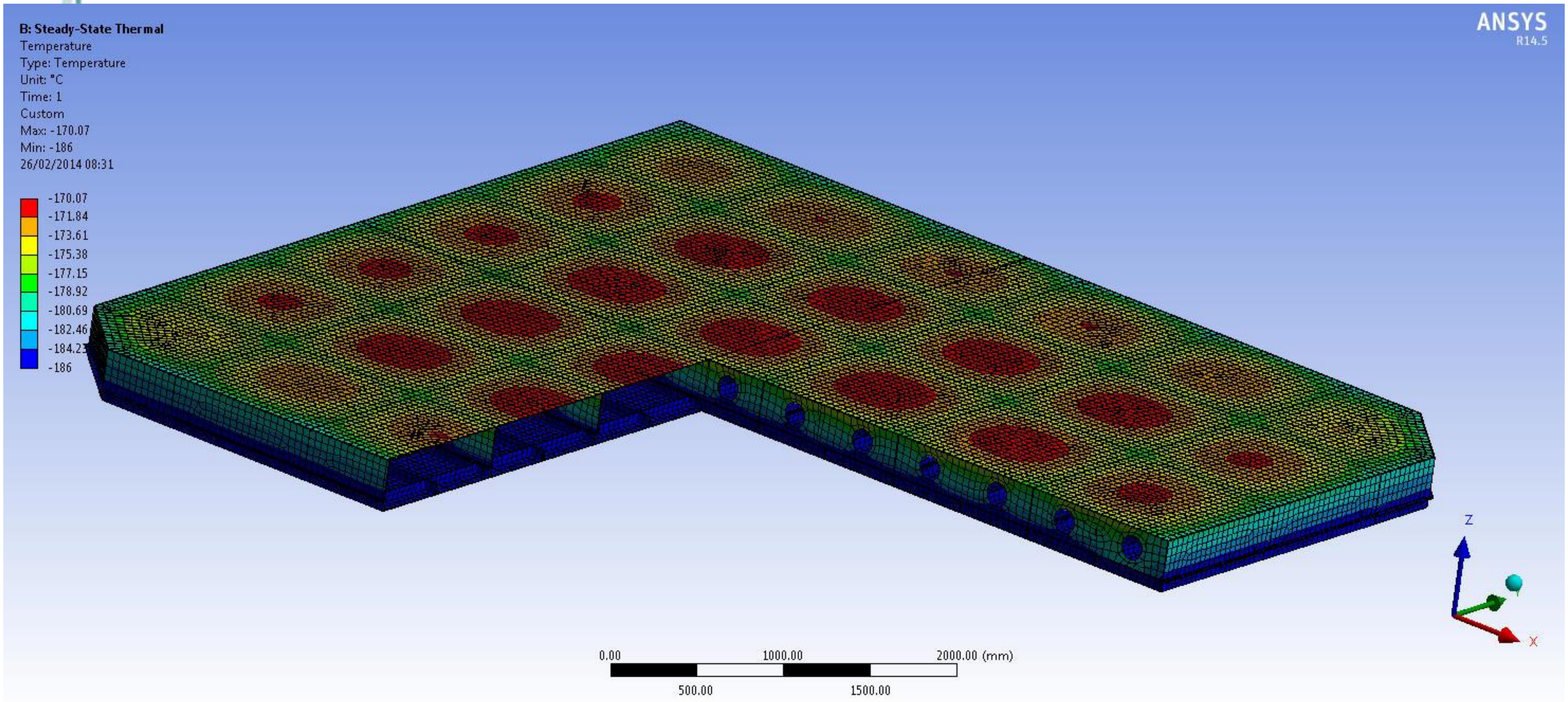
Note that:

- The arbitrary surface flux is applied to the closing plane (to simplify).
- The flux is a parameter which varies between [0 ; 1.10^{-7} W/mm²]
- For zero flux, the results are the same than for simulation #5.

Advanced thermal simulations

For the max. heat flux, we observe a 16°C gradient

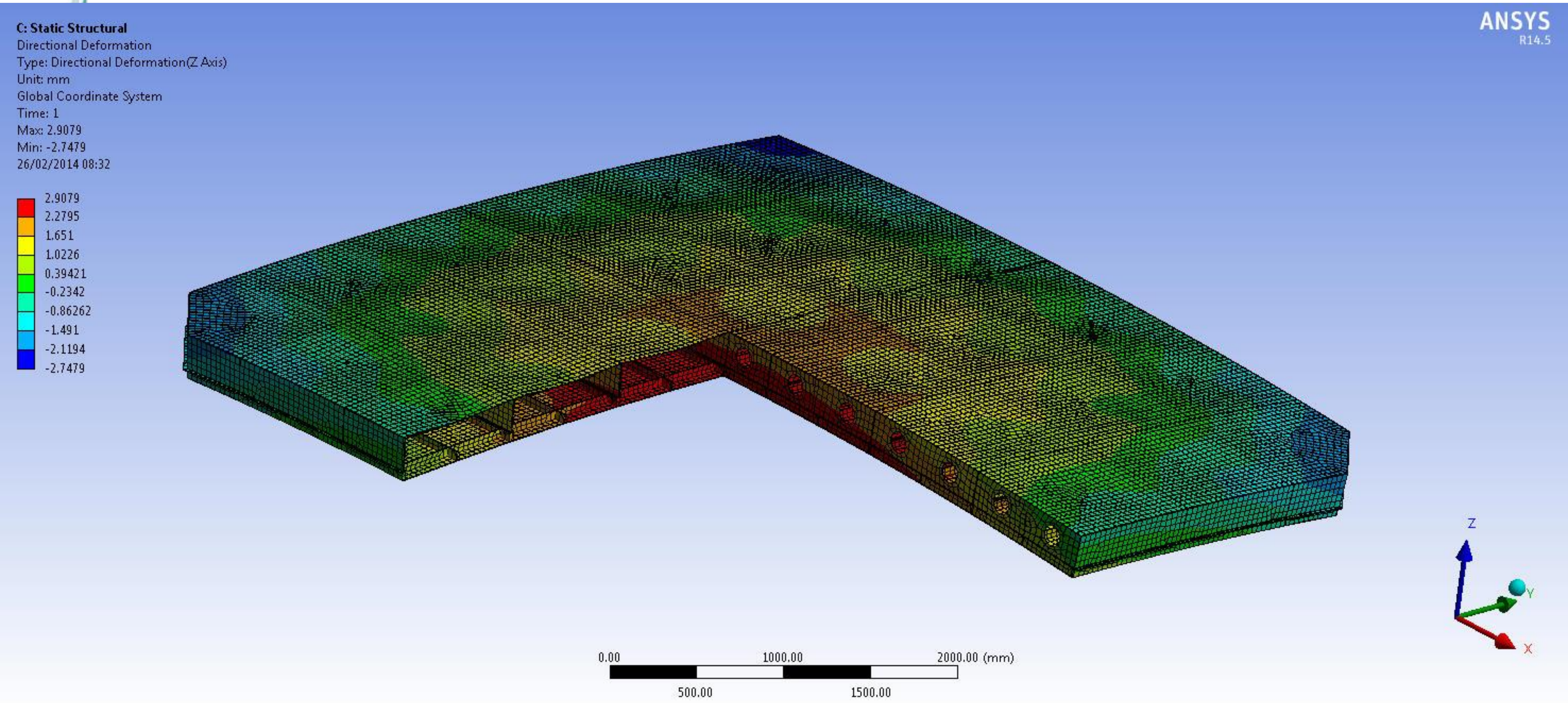
It is maybe overestimated but it is useful to understand this parametric study



NB: Cutting planes are used to illustrate the temperature gradient.

Advanced thermal simulations

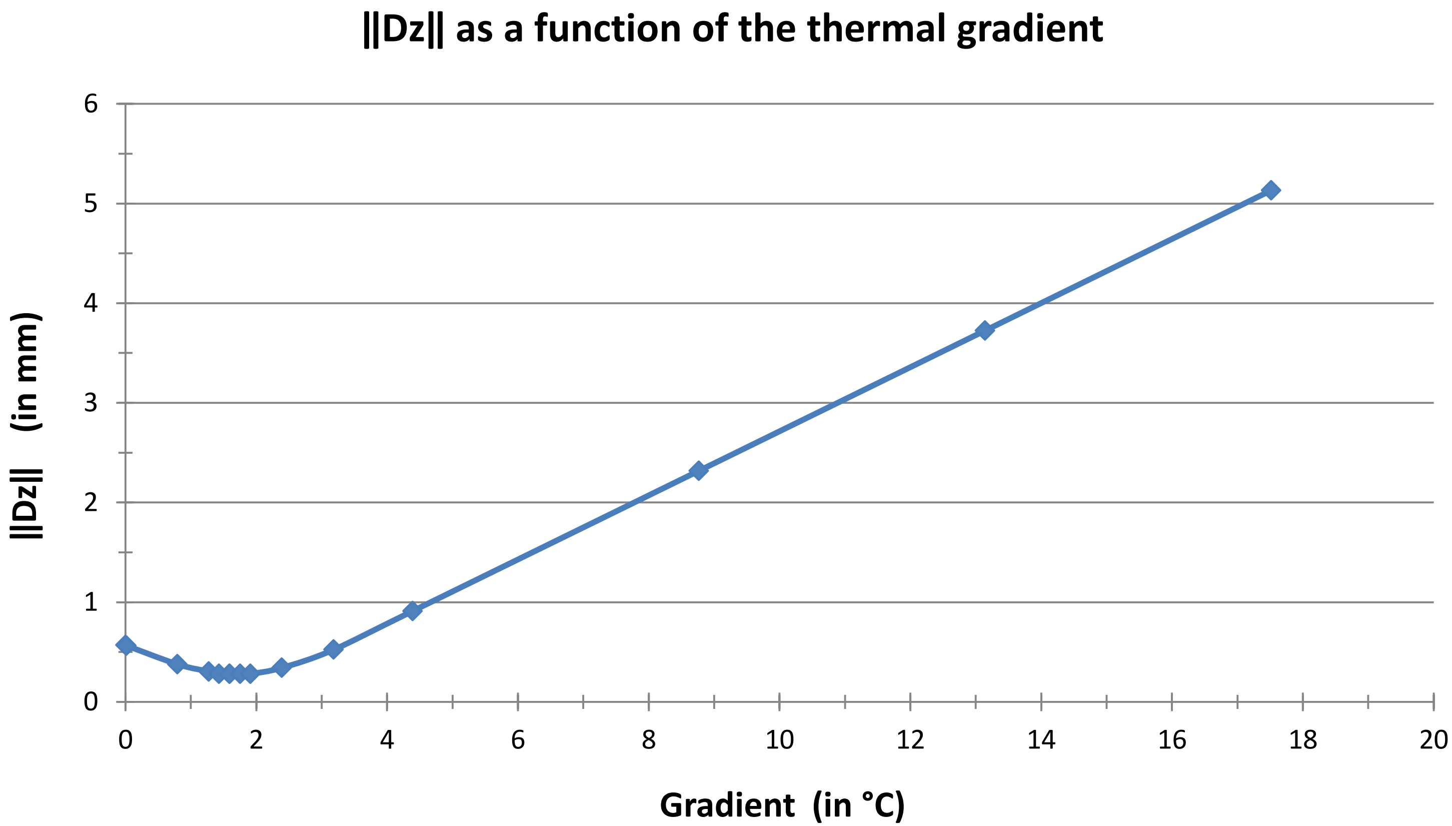
Structure displacements resulting from the 16°C gradient



5mm peak to peak displacement for the CRP

Advanced thermal simulations

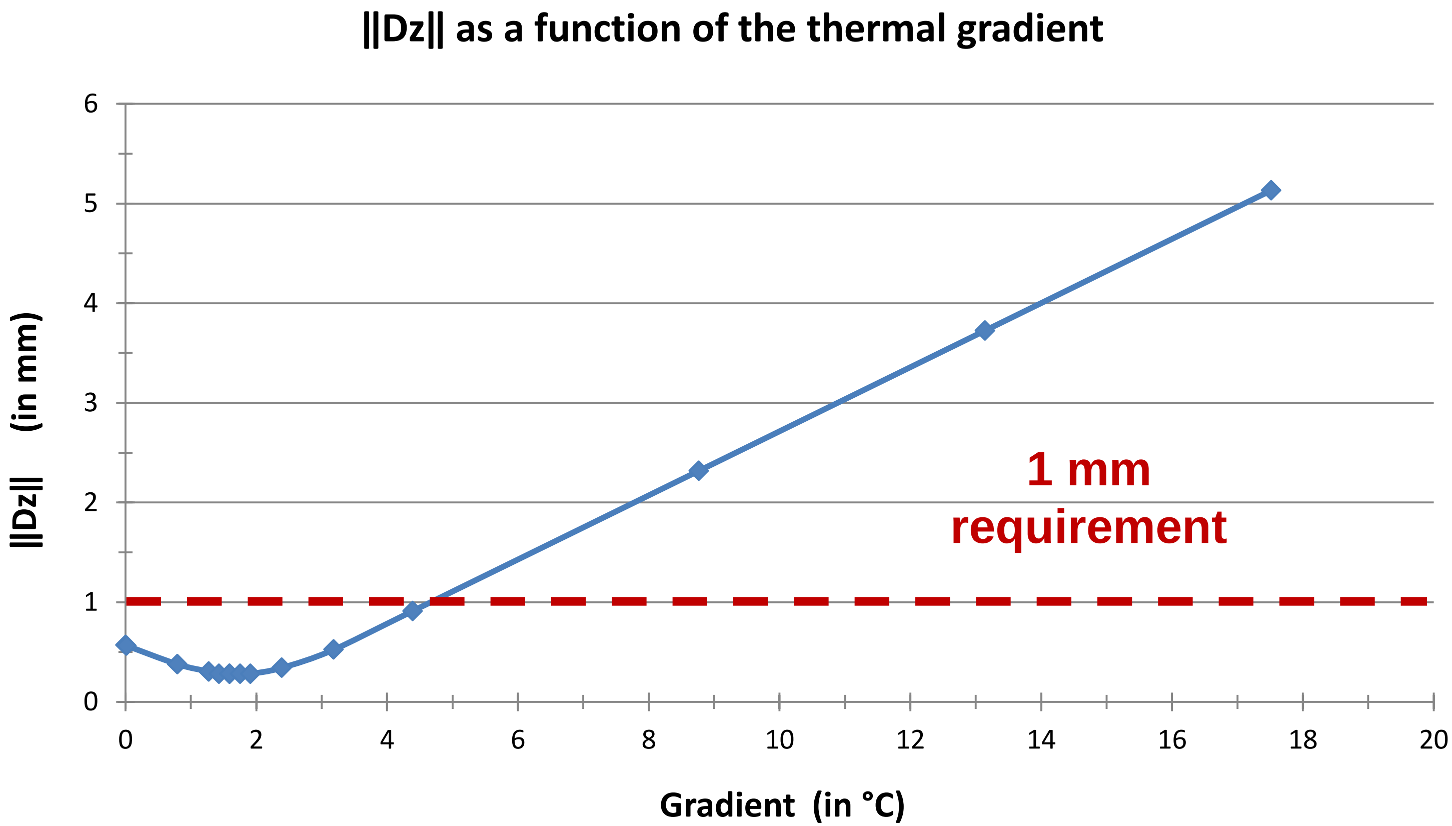
By varying the heat flux ([0 ; 1.10^{-7} W/mm²]) to get a given gradient,
we calculate the peak to peak displacements of CRP



NB: the max heat flux (1.10^{-7} W/mm²) leads to ***3,6 W***

Advanced thermal simulations

By varying the heat flux ([0 ; 1.10^{-7} W/mm²]) to get a given gradient, we calculate the peak to peak displacements of CRP



4,5°C gradient would lead to the max allowable value of 1 mm !

Conclusions 1 /2

For the TDR:

We would like to detail the model
corresponding to *simulation #5 which fulfils the 1mm requirement*

provided that all the structure is thermalized to the same temperature !

Simulation #5 :

- Baseline design + belt + closing plate
- All the structure made of G10
- Hanging system = 4 cables

Conclusions 2 /2

Structure is sensitive to thermal gradient

↓

For the next studies:

We have to discuss about *thermal inputs*

- to go further into details
- to implement realistic loadings.