New thermal simulations in Valencia

PXD Meeting – 12th January

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In previous simulations…

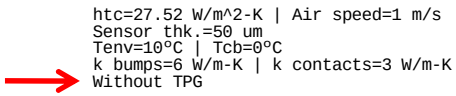
A generic ladder was implemented (see my talk in Barcelona for details)

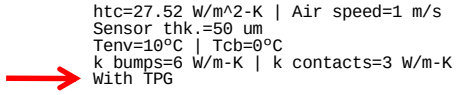
- CVD-Diamond finger conecting the ladder to the cooling block

Ladder length=65.5mm
Ladder width=15mm
Length DCD+DHP balcony=28mm
Width Switcher's balcony=2mm

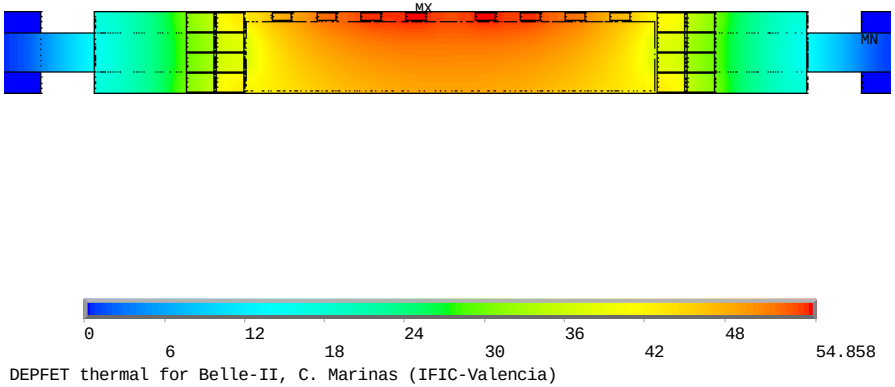
Sensor width=12.5mm
Sensor length=37.5mm

Diamond width=7mm
Diamond length=10mm
Diamond thickness=400µm

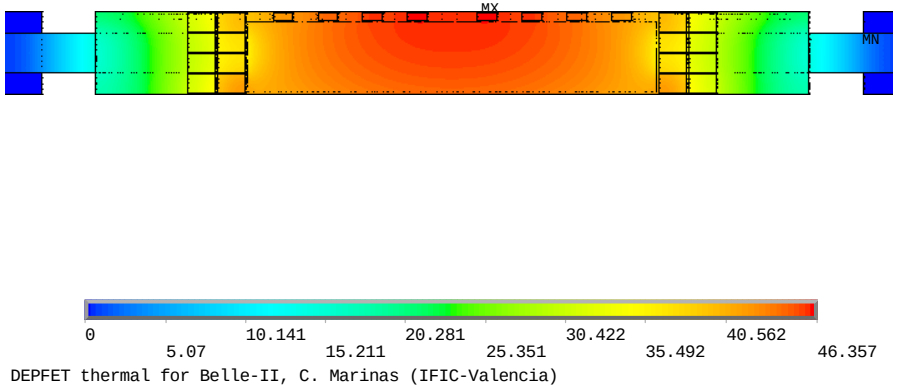




With TGP strip (1mm wide)



T_{max}=55ºC



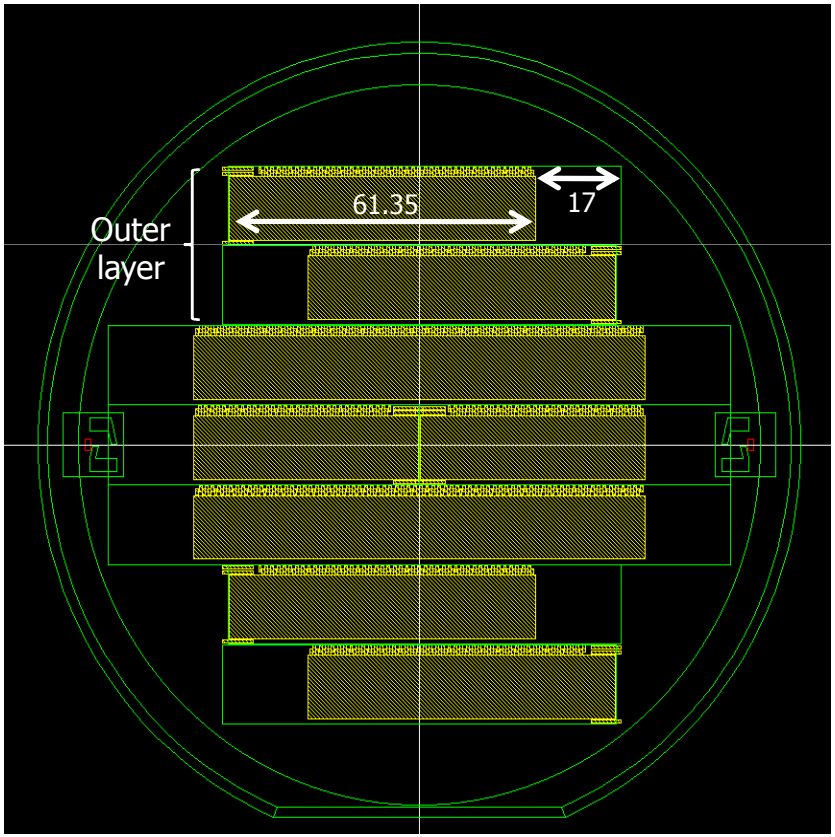
T_{max}=46ºC

The TPG strip underneath the SW's balcony was mandatory (~10ºC less)

Layout for the mechanical dummies (Laci's proposal)

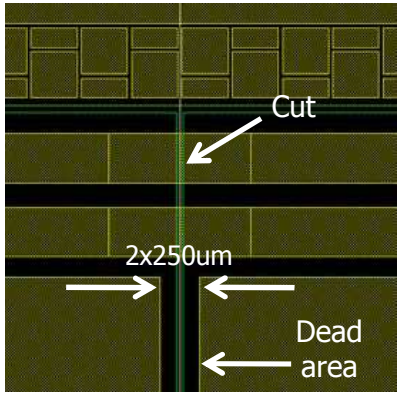
Ladder length=78.35mm
Ladder width=15mm
Length DCD+DHP balcony=17mm
Width Switcher's balcony=2mm

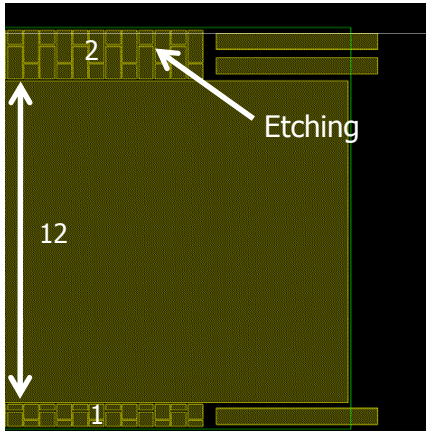
Sensor width=12mm
Sensor length=61.35mm



The geometry is now different

- New ladder dimensions
- Insensitive area to glue both halves
- Etching on balconies to reduce material



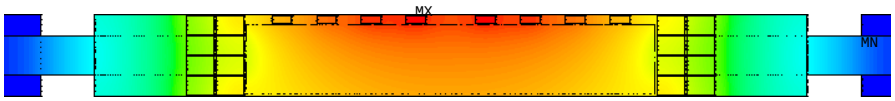


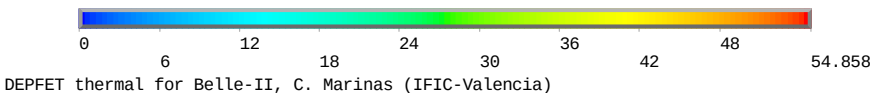
Outer layer implemented in ANSYS (no etching)

'Old' generic geometry

htc=27.52 W/m^2-K | Air speed=1 m/s
Sensor thk.=50 um
Tenv=10ºC | Tcb=0ºC
k bumps=6 W/m-K | k contacts=3 W/m-K
Without TPG

P_{sensor}=1W



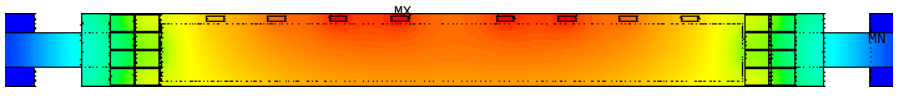


T_{max}=55ºC

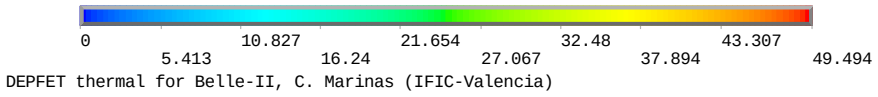
'New' outer layer geometry

htc=27.52 W/m^2-K | Air speed=1 m/s
Sensor thk.=50 um
Tenv=10ºC | Tcb=0ºC
k bumps=6 W/m-K | k contacts=3 W/m-K
Without TPG

P_{sensor}=1.57W to compensate the bigger area, and compare both results



$$\frac{\text{Power}_{\text{Old geometry}}}{\text{Power}_{\text{New geometry}}} = \frac{\text{Sensor Area}_{\text{Old geometry}}}{\text{Sensor Area}_{\text{New geometry}}}$$



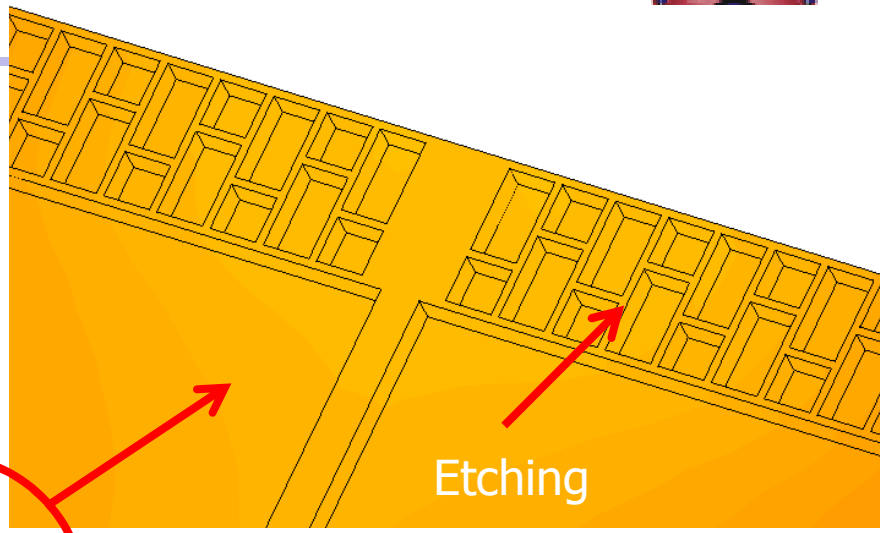
T_{max}=49.5ºC

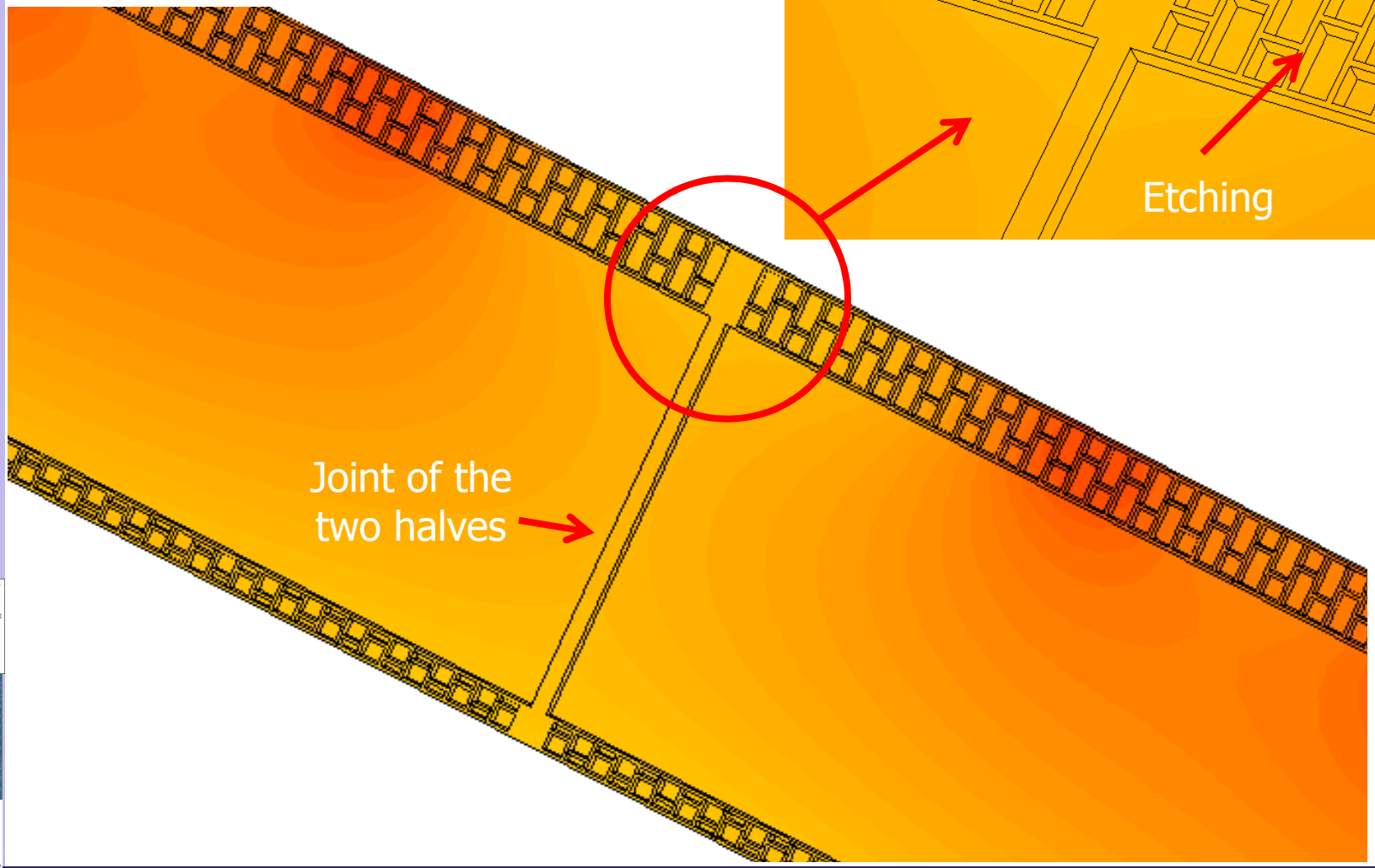
→ The new 'spacing' helps to cool down the detector

How many pixels do we have in the outer layer (power consumption)?

Frame perforation

Simplification: Rectangles instead of prisms





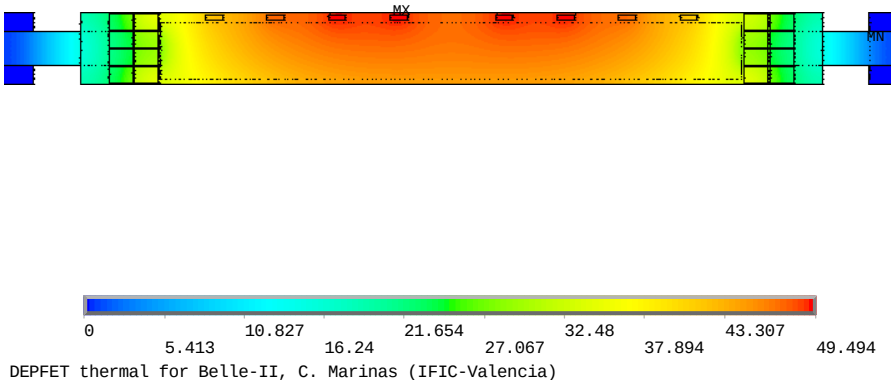
New geometry implemented in ANSYS (with etching)

➢ Will the etching modify the heat path?

'New' geometry (w/o etching)

htc=27.52 W/m^2-K | Air speed=1 m/s
Sensor thk.=50 um
Tenv=10ºC | Tcb=0ºC
k bumps=6 W/m-K | k contacts=3 W/m-K
Without TPG

P_{sensor}=1.57W

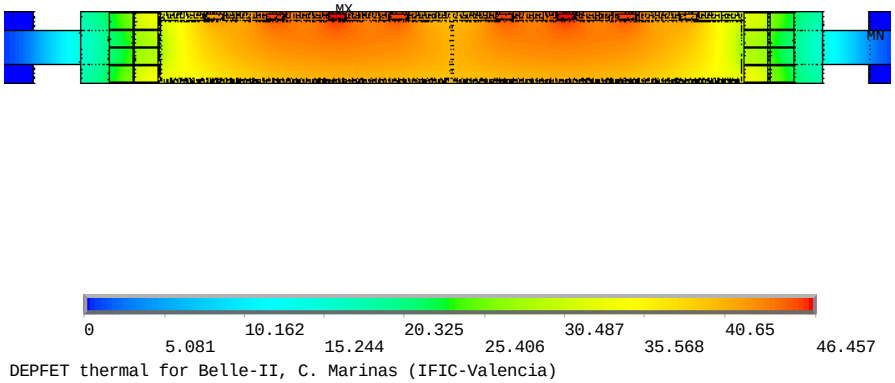


T_{max}=49.5ºC

'New' geometry (with etching)

htc=27.52 W/m^2-K | Air speed=1 m/s
Sensor thk.=50 um
Tenv=10ºC | Tcb=0ºC
k bumps=6 W/m-K | k contacts=3 W/m-K
Without TPG

P_{sensor}=1.57W



T_{max}=46.5ºC

→ The opened holes increase the heat exchange with the sorrounding air (convection)

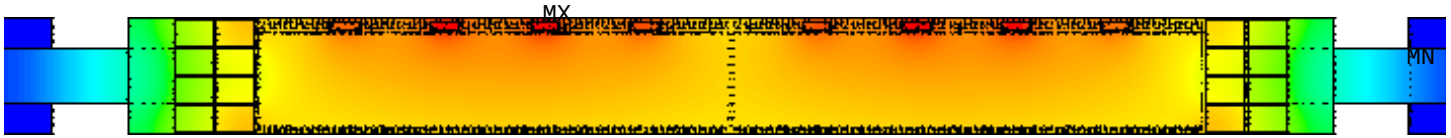
‘Relaxed’ environment constraints

Starting point…

T_{env}=10ºC
$T_{coolingblock}$=0ºC
Diamond width=7mm
Diamond length=10mm
NO TPG
P_{sensor}=1Watt

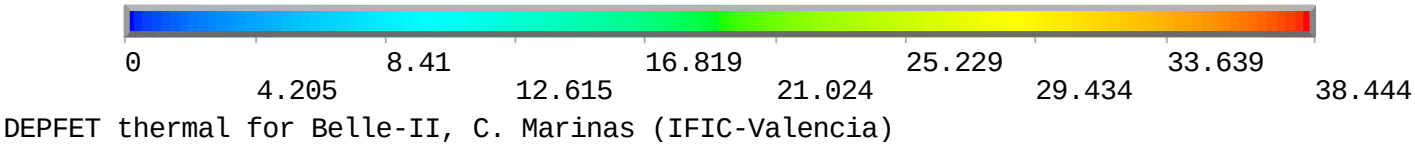
```
htc=27.52 W/m^2-K | Air speed=1 m/s
Sensor thk.=50 um
Tenv=10ºC | Tcb=0ºC
k bumps=6 W/m-K | k contacts=3 W/m-K
Without TPG
```

T_{max}=38.5ºC → Quite high…



In order to reduce the temperature, we can play with:

a. Diamond geometries
b. Environment conditions

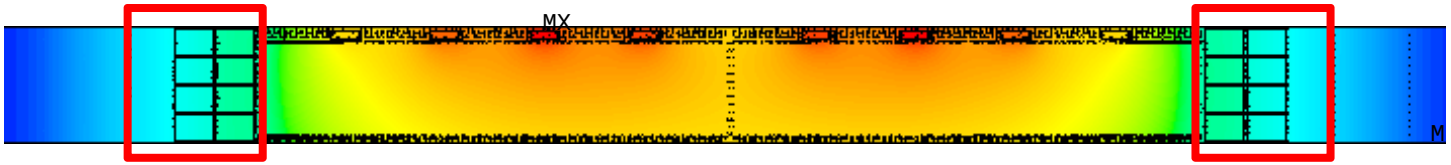


a. Diamond geometries (Wider)

T_{env}=10ºC
$T_{coolingblock}$=0ºC
→ Diamond width=15mm → Wider diamond
Diamond length=10mm
NO TPG
P_{sensor}=1Watt

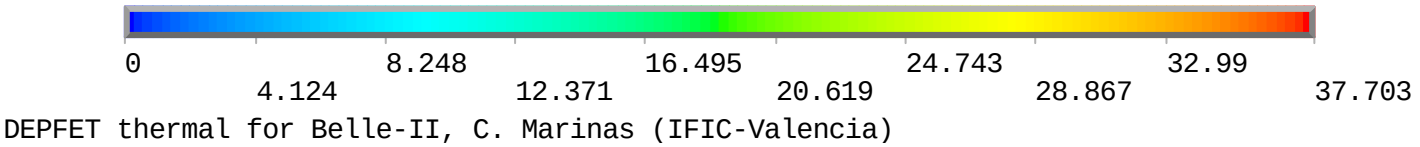
```
htc=27.52 W/m^2-K | Air speed=1 m/s
Sensor thk.=50 um
Tenv=10ºC | Tcb=0ºC
k bumps=6 W/m-K | k contacts=3 W/m-K
Without TPG
```

T_{max}=37.7ºC



$\Delta T = T_{W=15mm} - T_{W=7mm} \sim -10ºC$

- The temperature is dramatically decreased at both ends (~10ºC less)
- T_{max} is almost the same; the center is an issue for the air, as demonstrated



Diamond geometries (Wider+shorter)

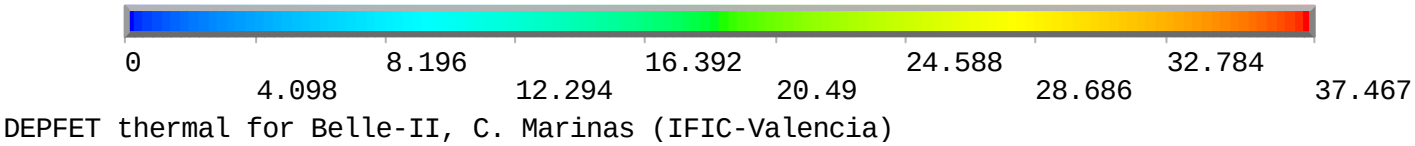
```
htc=27.52 W/m^2-K | Air speed=1 m/s
Sensor thk.=50 um
Tenv=10ºC | Tcb=0ºC
k bumps=6 W/m-K | k contacts=3 W/m-K
Without TPG
```

T_{env}=10ºC
$T_{coolingblock}$=0ºC
Diamond width=15mm
→ Diamond length=0mm
NO TPG
P_{sensor}=1Watt

T_{max}=37.5ºC

- The temperature is slightly lower
- T_{max} is almost the same

➢ No such a big improvement!



b. Environment conditions

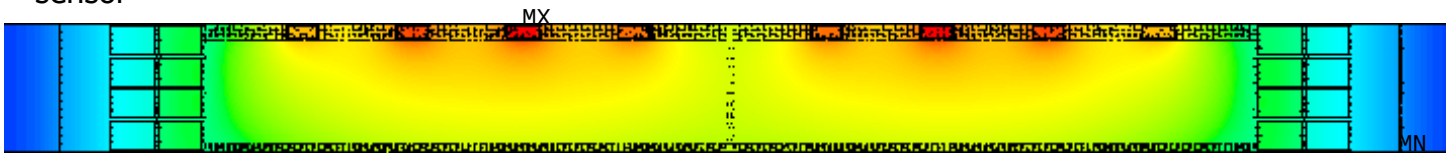
Proposal to build a common dry volume SVD+PXD

htc=27.52 W/m^2-K | Air speed=1 m/s
Sensor thk.=50 um
Tenv=-8ºC | Tcb=0ºC
k bumps=6 W/m-K | k contacts=3 W/m-K
Without TPG

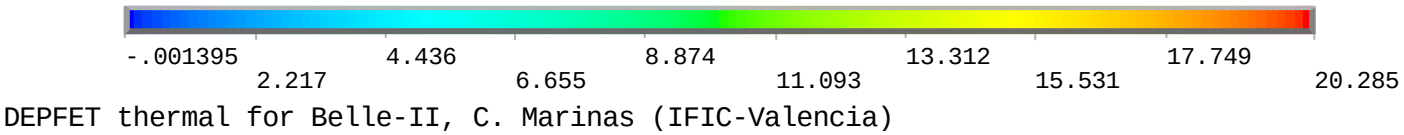
→ T_{env}=-8ºC
→ $T_{coolingblock}$=0ºC
Diamond width=15mm
Diamond length=0mm
NO TPG
P_{sensor}=1Watt

The tempereture decreased 17.5ºC playing with the environment

T_{max}=20ºC



With this option… the cooling problem is solved!
➢ Now we have an engeneering problem!



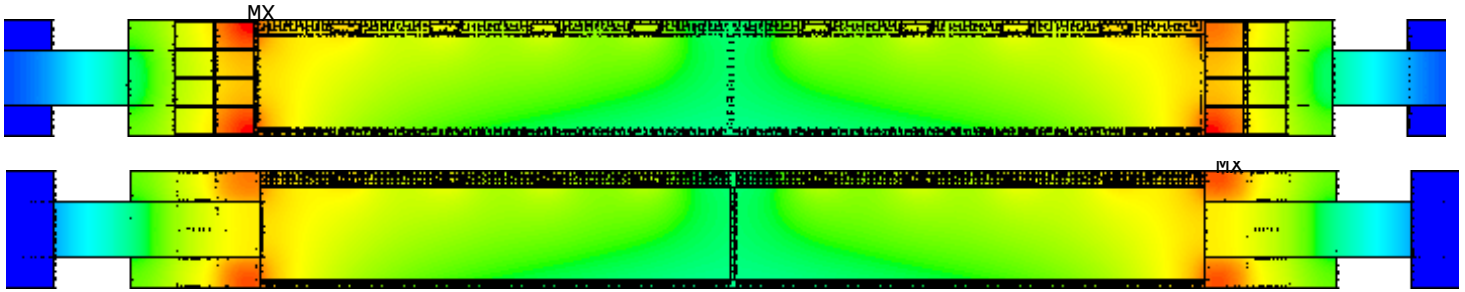
Environment conditions

T_{env}=-8ºC
$T_{coolingblock}$=0ºC
→ Diamond width=7mm
→ Diamond length=10mm
NO TPG
P_{sensor}=1Watt

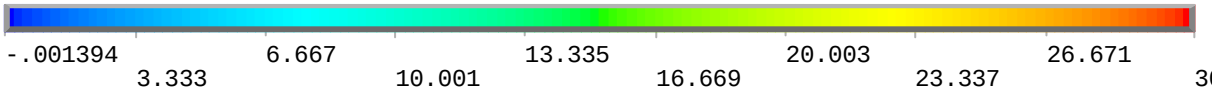
```
htc=27.52 W/m^2-K | Air speed=1 m/s
Sensor thk.=50 um
Tenv=-8ºC | Tcb=0ºC
k bumps=6 W/m-K | k contacts=3 W/m-K
Without TPG
```

→ Long and thin diamond

T_{max}=30.5ºC



With this 'hard' conditions… almost any solution cope with the temperature requirements (even thin and long diamond).



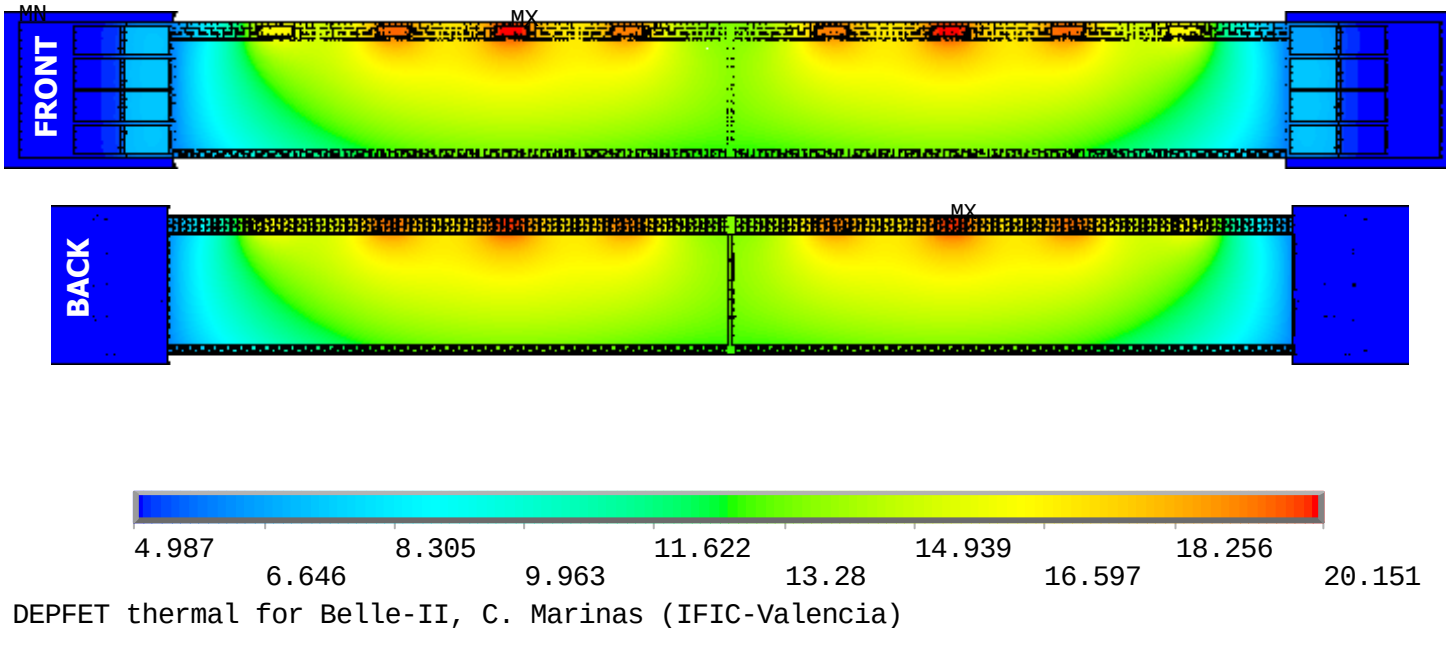
Direct contact ('Diamond-less' design)

Completely new cooling concept

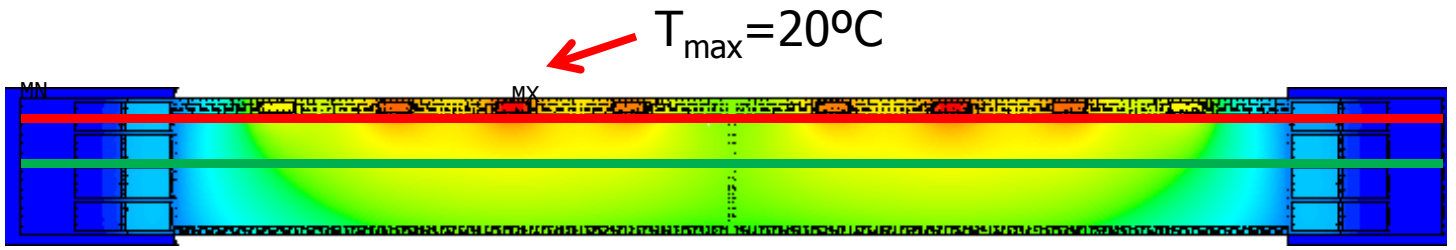
htc=27.52 W/m^2-K | Air speed=1 m/s
Sensor thk.=50 um
Tenv=-8ºC | Tcb=5ºC
k bumps=6 W/m-K | k contacts=3 W/m-K
Without TPG

T_{env}=-8ºC (Cold-dry volume)
$T_{coolingblock}$=5ºC (Water-alcohol cooling)
NO TPG
P_{sensor}=1Watt

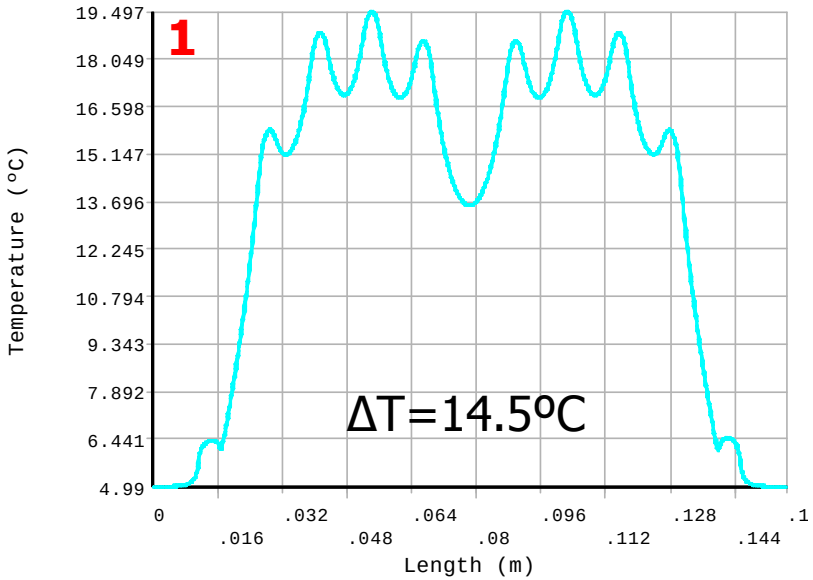
T_{max}=20ºC

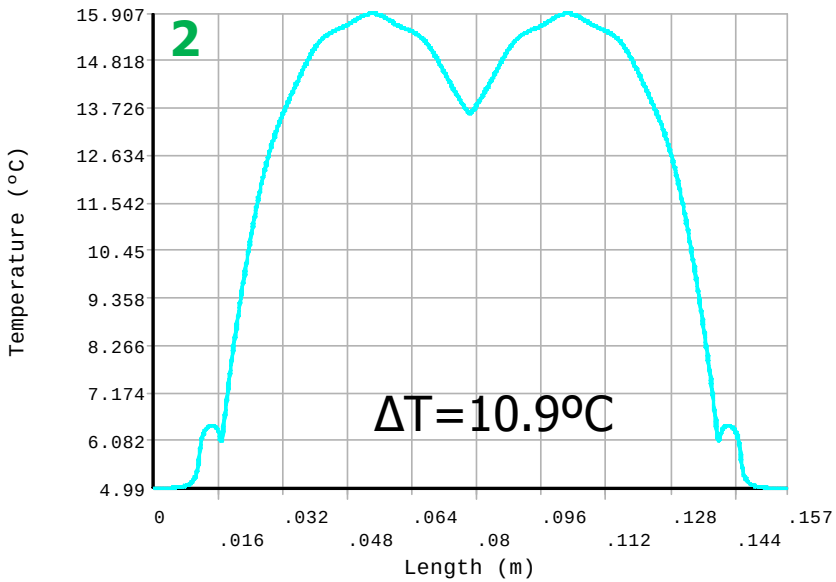


Paths ('Diamond-less' design)



htc=27.52 W/m^2-K | Air speed=1 m/s
Sensor thk.=50 um
Tenv=-8ºC | Tcb=5ºC
k bumps=6 W/m-K | k contacts=3 W/m-K
Without TPG





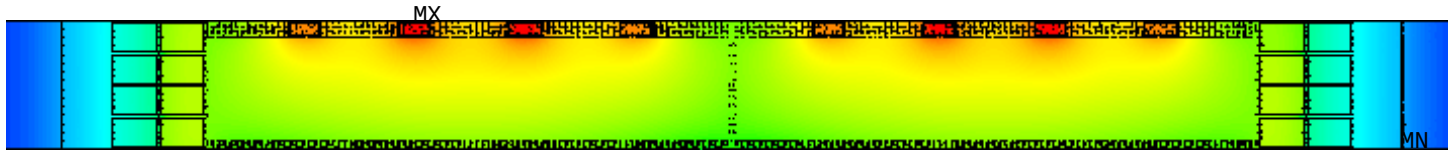
Temperature distribution all over the path points

Comparison of the two options (with/without CVD)

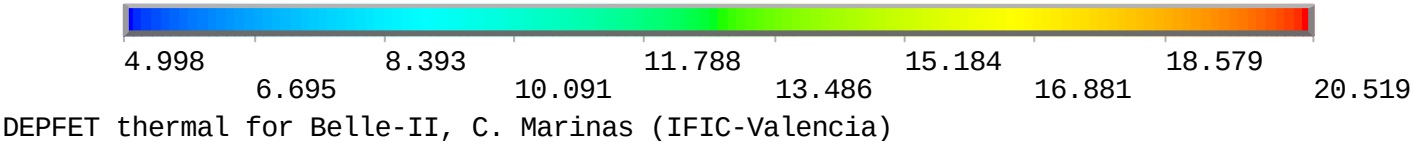
htc=27.52 W/m^2-K | Air speed=1 m/s
Sensor thk.=50 um
Tenv=-8ºC | Tcb=5ºC
k bumps=6 W/m-K | k contacts=3 W/m-K
Without TPG

T_{env}=-8ºC (Cold-dry volume)
$T_{coolingblock}$=5ºC (Water-alcohol cooling)
Diamond width=15mm
Diamond length=0mm
NO TPG

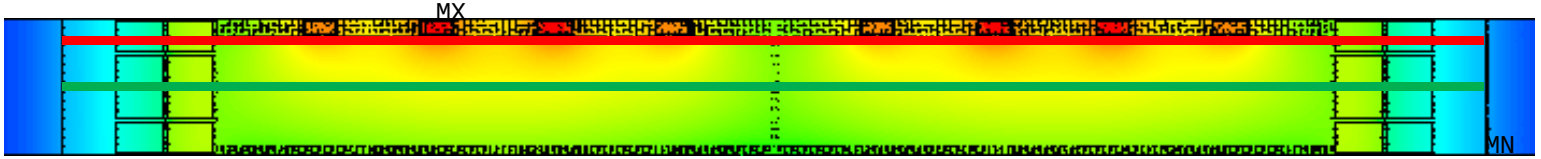
T_{max}=20.5ºC



- This solution (without TPG) works as well
- The temperature is even more homogeneously distributed all over the sensor… but the 'diamond-less' option is simpler!
- The advantage of this option is that we don't have to press the silicon but only the diamond.

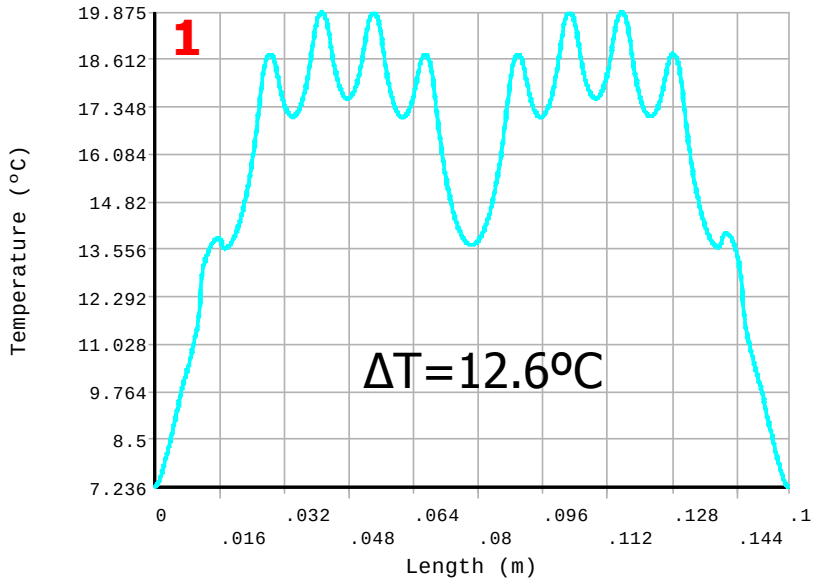


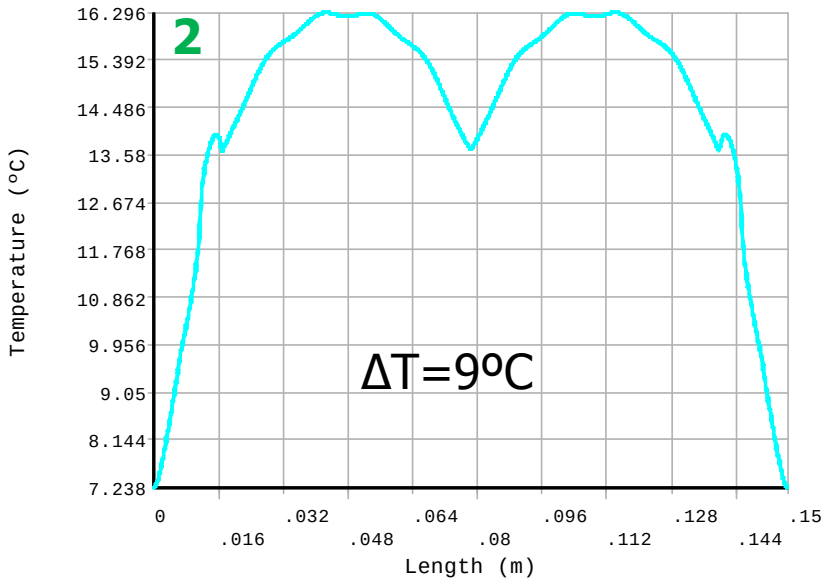
Comparison of the two options



htc=27.52 W/m^2-K | Air speed=1 m/s
Sensor thk.=50 um
Tenv=-8ºC | Tcb=5ºC
k bumps=6 W/m-K | k contacts=3 W/m-K
Without TPG

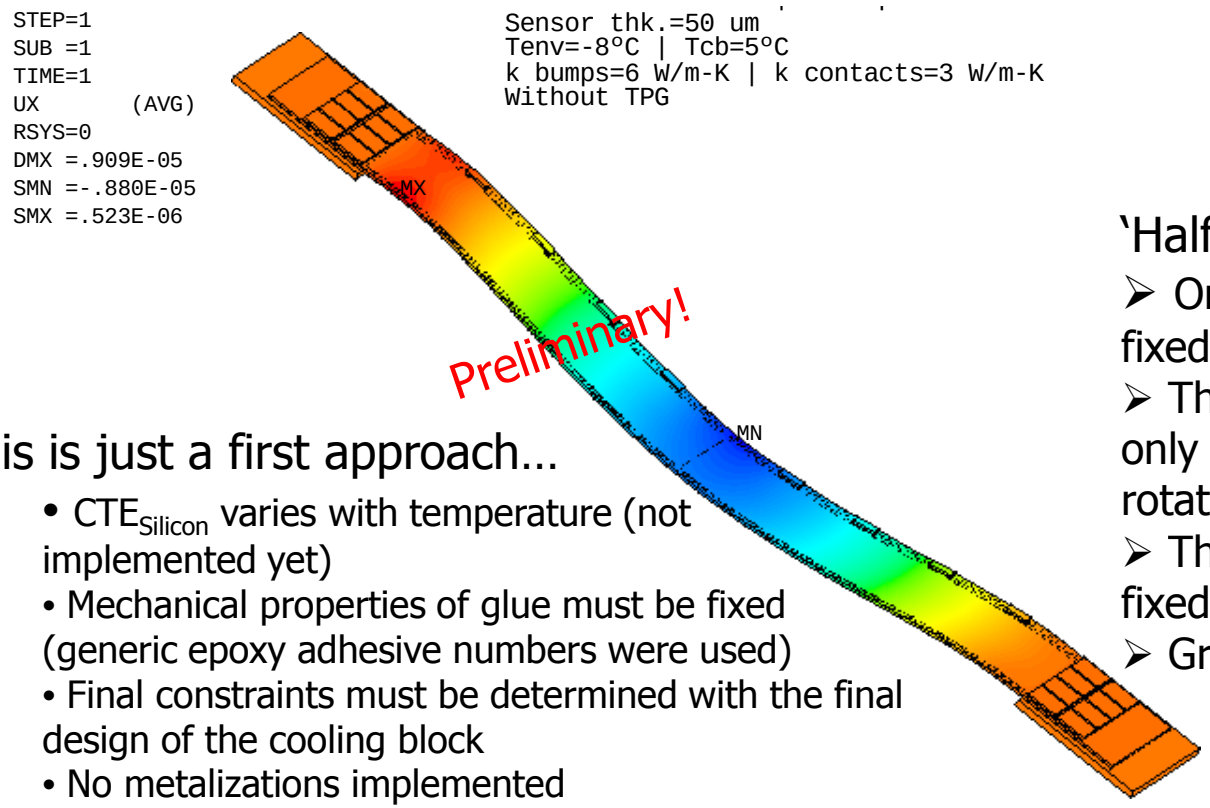
Similar behaviour in both options…





DEPFET thermal for Belle-II, C. Marinas (IFIC-Valencia)

Bowing due to self weight and temperature distribution

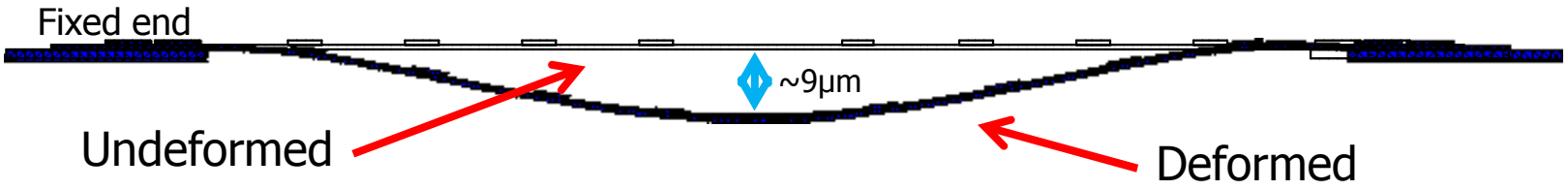


This is just a first approach…

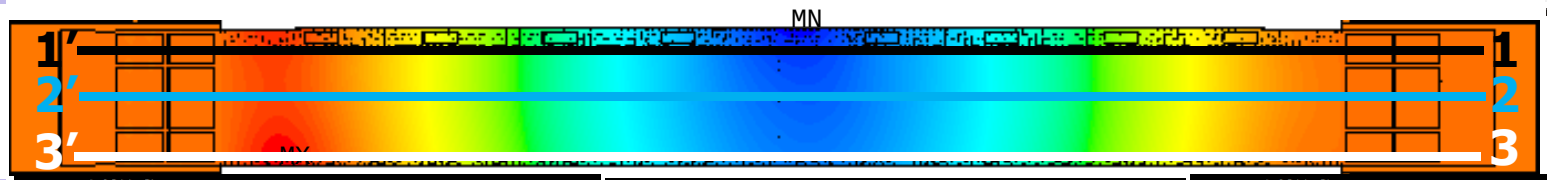
- $CTE_{Silicon}$ varies with temperature (not implemented yet)
- Mechanical properties of glue must be fixed (generic epoxy adhesive numbers were used)
- Final constraints must be determined with the final design of the cooling block
- No metalizations implemented

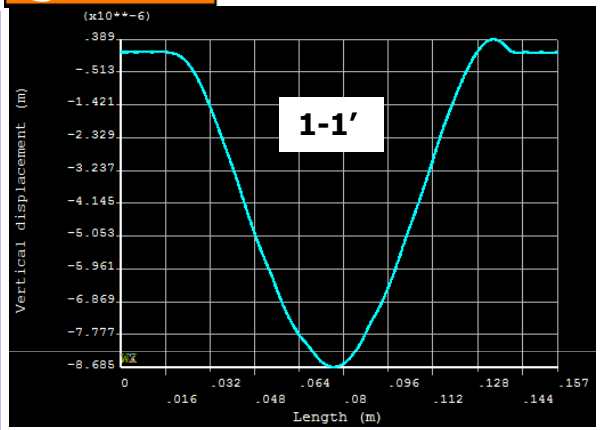
'Half free'

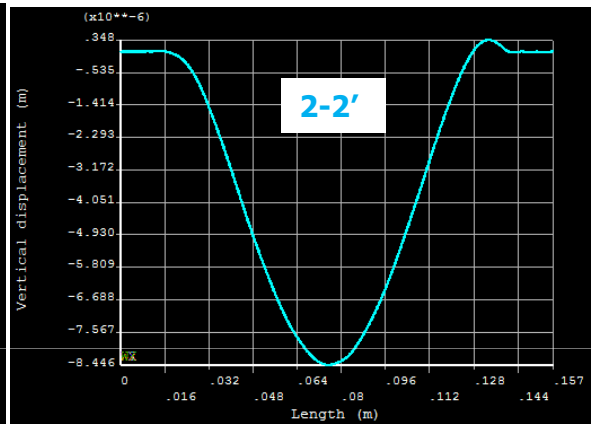
- One end is completely fixed
- The other one, can move only longitudinally (no rotations allowed)
- The cooling blocks are fixed
- Gravity+temperature

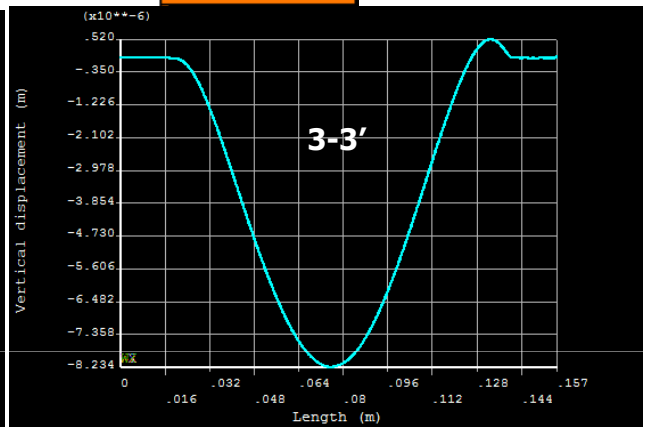


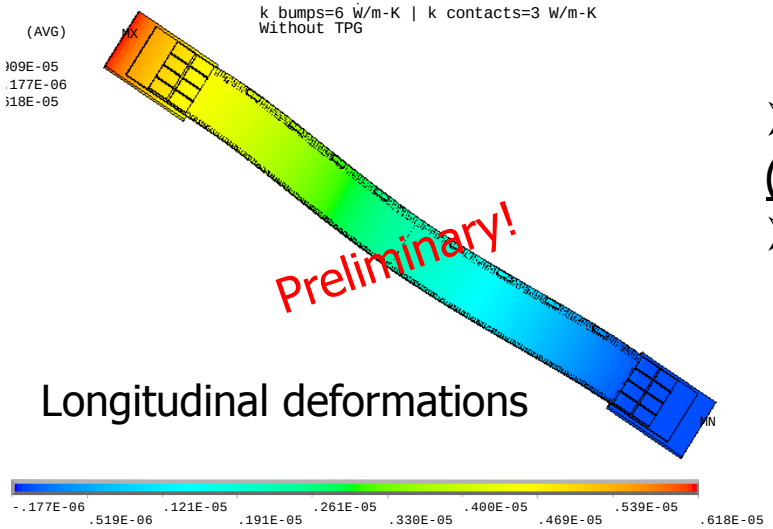
Bowing due to self weight and temperature distribution









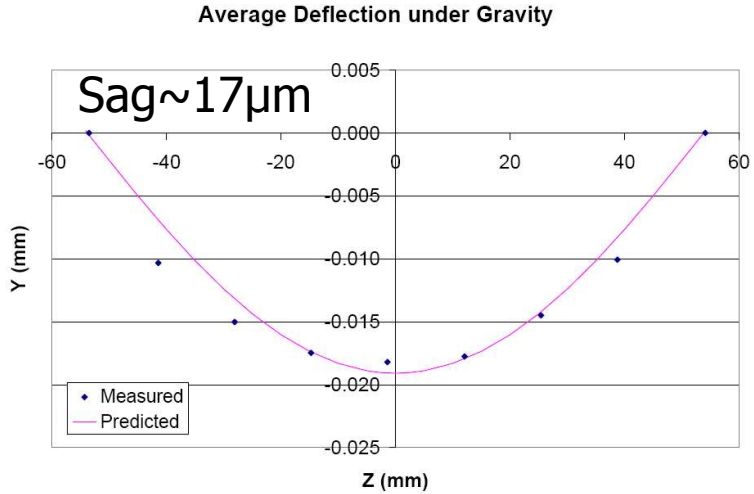


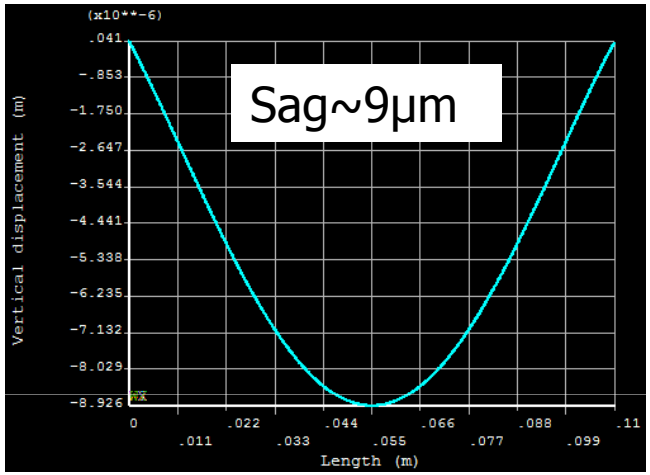
Longitudinal deformations

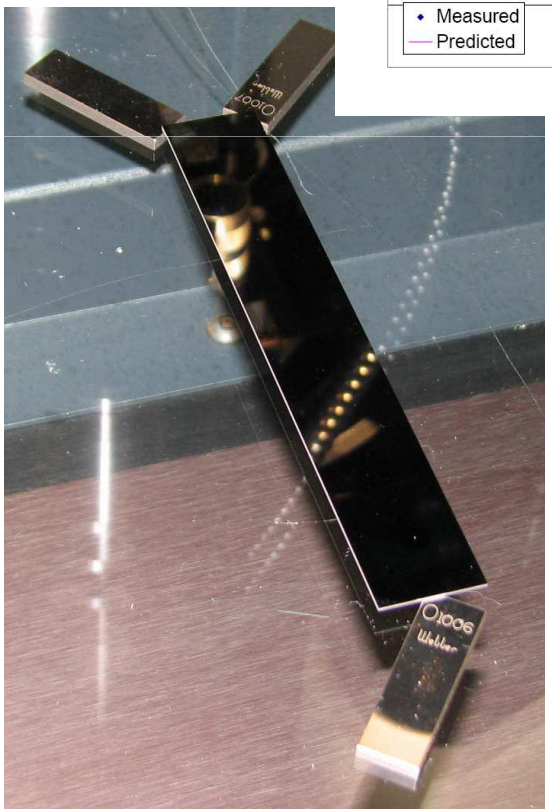
- Deformation in vertical direction ~9µm (~12µm if upside down)
- Deformation in longitudinal direction ~7µm

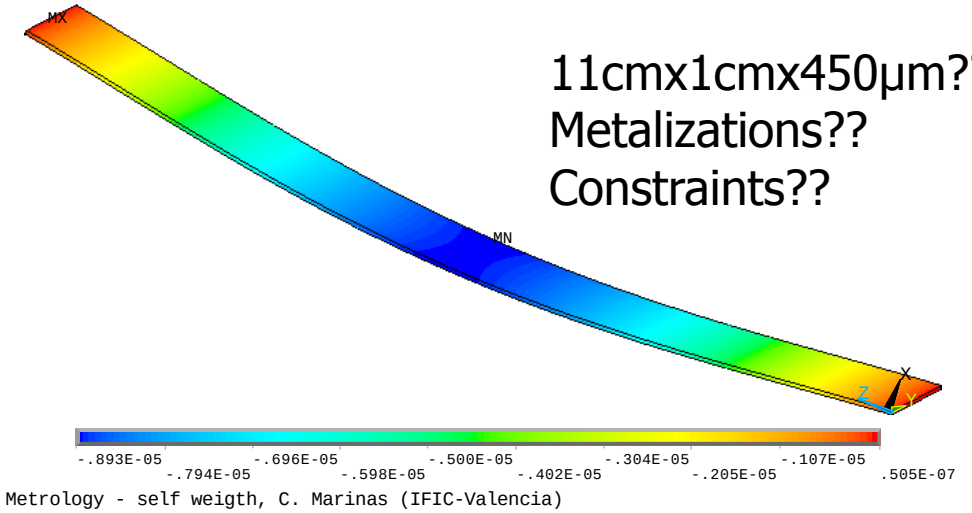
→ One end has to be free to move in the longitudinal direction!

Cross-check with measurements









11cmx1cmx450µm??
Metalizations??
Constraints??

Metrology - self weigth, C. Marinas (IFIC-Valencia)

Final remarks

• Results to be checked with Karlsruhe in a short time.

• All the machinery is ready to simulate the multiple environment conditions and geometries with and without diamond, and to produce the plots to be included in the TDR. Very short time needed for the 'plot' production.

Thank you very much!