SFGD Box

Update

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SUMMARY

SUMMARY OF THE FEA

Model Simplification

- All the materials properties are tuned according to the INR tests and includes holes
- Carbon Fiber is modeled as a stackup of 8 Layers according to CompositeDesign prototipe (2,3mm thickness of 8 Layers at different angles)
- Bolts conections between Panels-Panels and Bracket-Panels are not implemented (Bonded contact is used)
- Pads for the PCBs simplified by taking the thinner thickness of the Panel (coservative)
- Weight of the cubes is simulated as a Force in order to be conservative.
- For the Vibration Study attempt to caracterize the cubes

FEA Studies

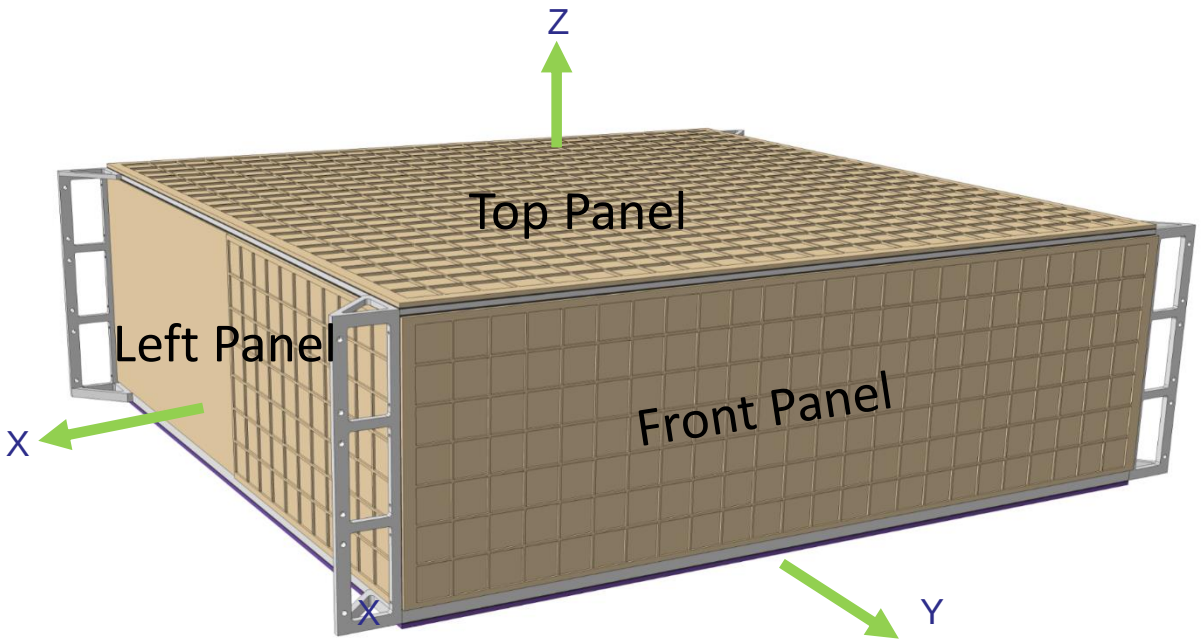
- First Static study is considered as the normal operation load: Earth Gravity at the Box and Cube weight.
- Second Static Study is cosidering Earth Gravity and 0.65g aceleration at each direction. This in order to spot critical «situation» at the level of stresses and deformations
- Third dinamic study is considering the PSD spectrum provided by KEK and simulate the PSD response at each direction. In this study the cubes have to be implemented. Since is very difficult to caracterize the Cubes behaviour, a simpification was needed. Anyway the study, to my point of you, can give a good idea of the situation. In PSD study all connection are bonded (linear)

SUMMARY OF THE FEA

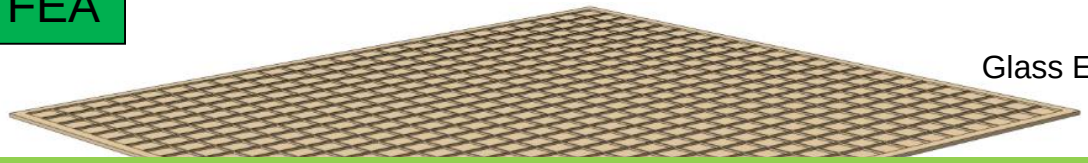
Sandwich Materials and Thickness

- Accroding to the design at the current status the Material used for the Box are below listed:

• Bottom Panel	→ Carbon Fiber – Acrylic – Carbon Fiber	Thickness 33.6 mm
• Top Panel:	→ Carbon Fiber – Acrylic – Carbon Fiber	Thickness 16.6mm
• Front and Back Panels:	→ Carbon Fiber – Divinycel H250 – Carbon Fiber	Thickness 19.6mm
• Left and Righ Panels:	→ Carbon Fiber – Divinycell H250 – Carbon Fiber	Thickness 24.6mm



SUMMARY OF THE FEA



Glass Epoxy Readout Panel

- Readout panels and hard panels for Cubes Installation (blue) are G10 (glass epoxy)
- Soft Foam Panels (yellow) consists in Polipropilene Foam (used only when cubes are implemented)
- Brackets material is Aluminum

Soft Foam

Glass Epoxy for Cube Installation

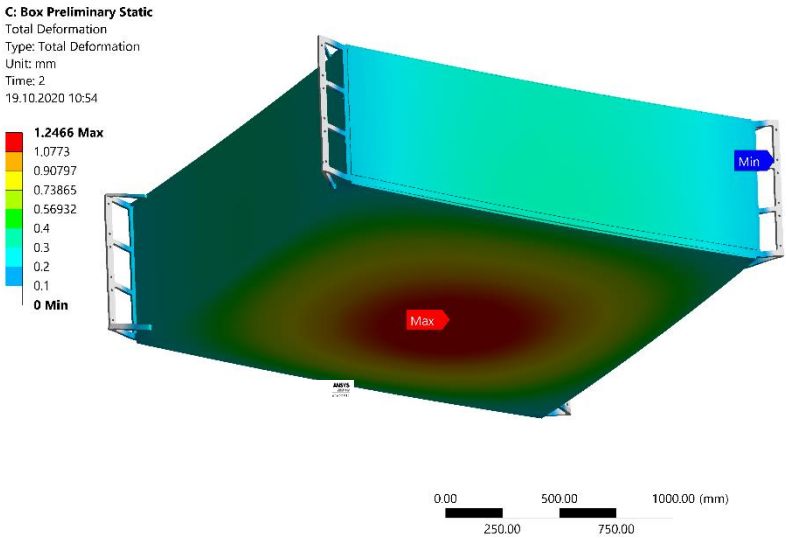
Glass Epoxy Readout Panel

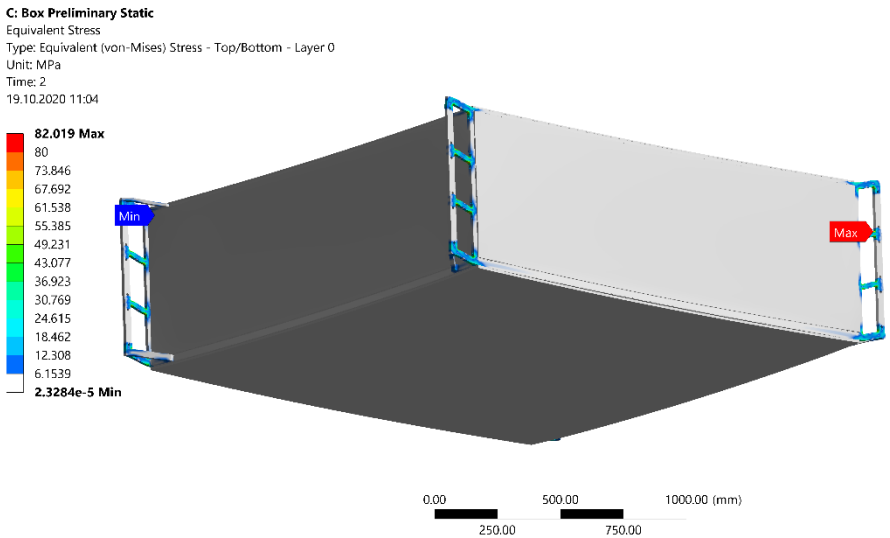
FIRST STATIC STUDY

Gravity on z axis (Weight of the cubes with force 2.22 Tons)

Z- direction:

Maximum deformation at the Bottom Panel:	1.5 mm
Maximum deformation at the Top Panel:	0.85 mm
Max Stress at the Brackets:	82 Mpa
Max Stress at Alu Frames (Bracket connect.):	35.5 Mpa
Max Stress at Acrylic Bottom panel	~1.26 Mpa
Failure Safety Factor at Carbon Fiber	SF: 4



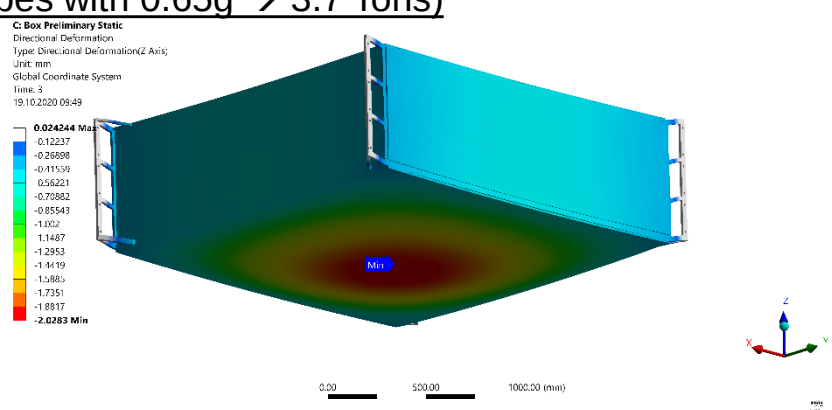


SECOND STATIC STUDY

Gravity on z axis + 0.65g in every direction (Weight of the cubes with 0.65g → 3.7 Tons)

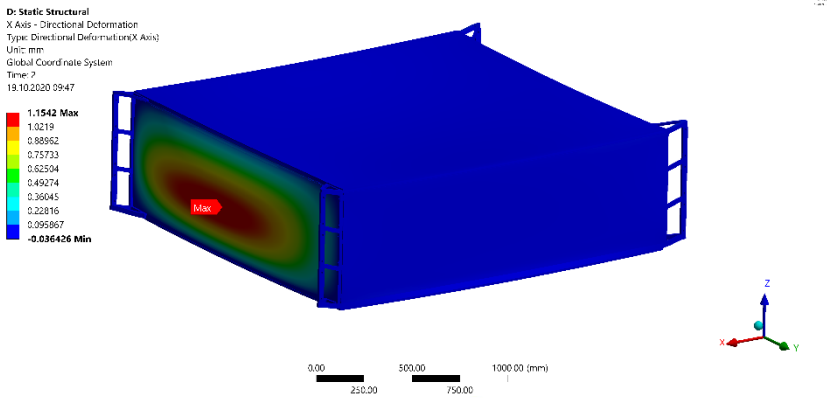
Z- direction:

Maximum deformation at the Bottom Panel:	2.03 mm
Maximum deformation at the Top Panel:	~1.4 mm
Max Stress at the Brackets:	135.11 Mpa
Max Stress at Alu Frames (Bracket connect.):	~50Mpa
Max Stress at Acrylic Bottom panel	~2Mpa
Failure Safety Factor at Carbon Fiber	SF: 3.8



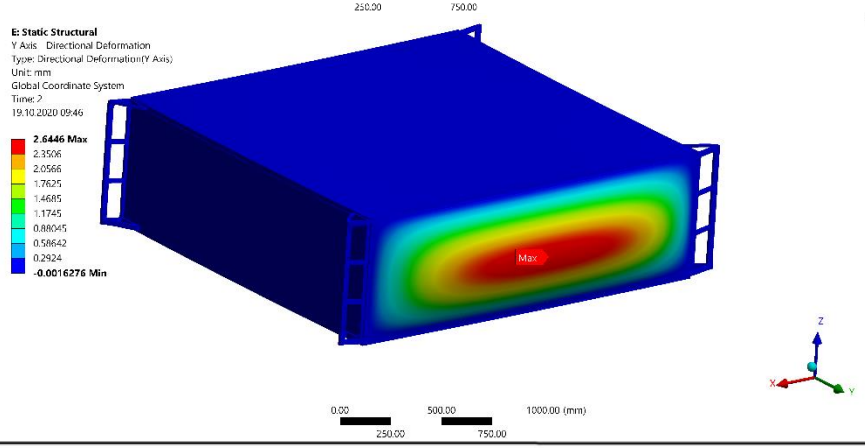
X- direction:

Maximum deformation at the Left/Right Panel:	1.16 mm
Max Stress at the Brackets:	86.26 Mpa
Max Stress at Alu Frame	<10Mpa
Max Stress at Foam core	<10Mpa



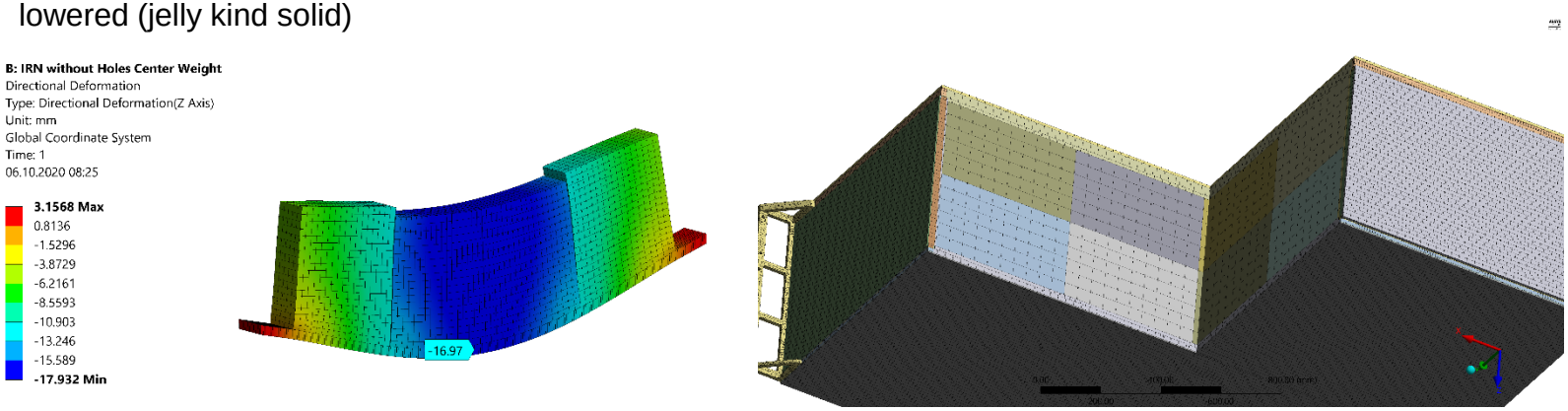
Y- direction:

Maximum deformation at the Front/Back Panel:	2.65 mm
Max Stress at the Brackets:	85.8 Mpa
Max Stress at Alu Frame	46 Mpa
Max Stress at Foam core	10Mpa
Failure Safety Factor at Carbon Fiber	SF: 4

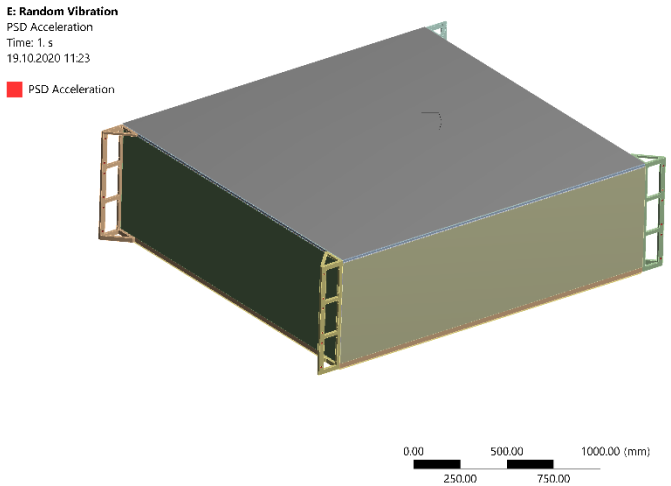


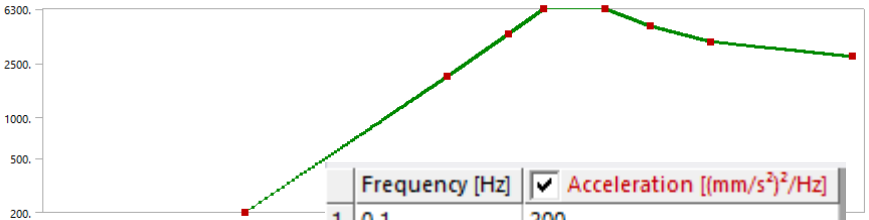
THIRD DINAMIC STUDY – PSD Response

- Cubes caracterized as a solid (best approximation up to now). Cubes Envelope divided in 32 Solid and Young's modulus lowered (jelly kind solid)



- Static calculation (non linear to verify if results are close to the first study)
- Modal Analysis → automatically considered as linear (all the contacts are bonded)
- PSD response from acceleration spectrum given by KEK
  → Random Vibration applied at the Bracket fixed supports and calculated at all 3 directions with preload from static





	Frequency [Hz]	Acceleration [(mm/s²)²/Hz]
1	0.1	200.
2	1.	2000.
3	2.	4100.
4	3.	6300.
5	6.	6300.
6	10.	4700.
7	20.	3600.
8	100.	2800.
*		

THIRD STUDY – PSD Response

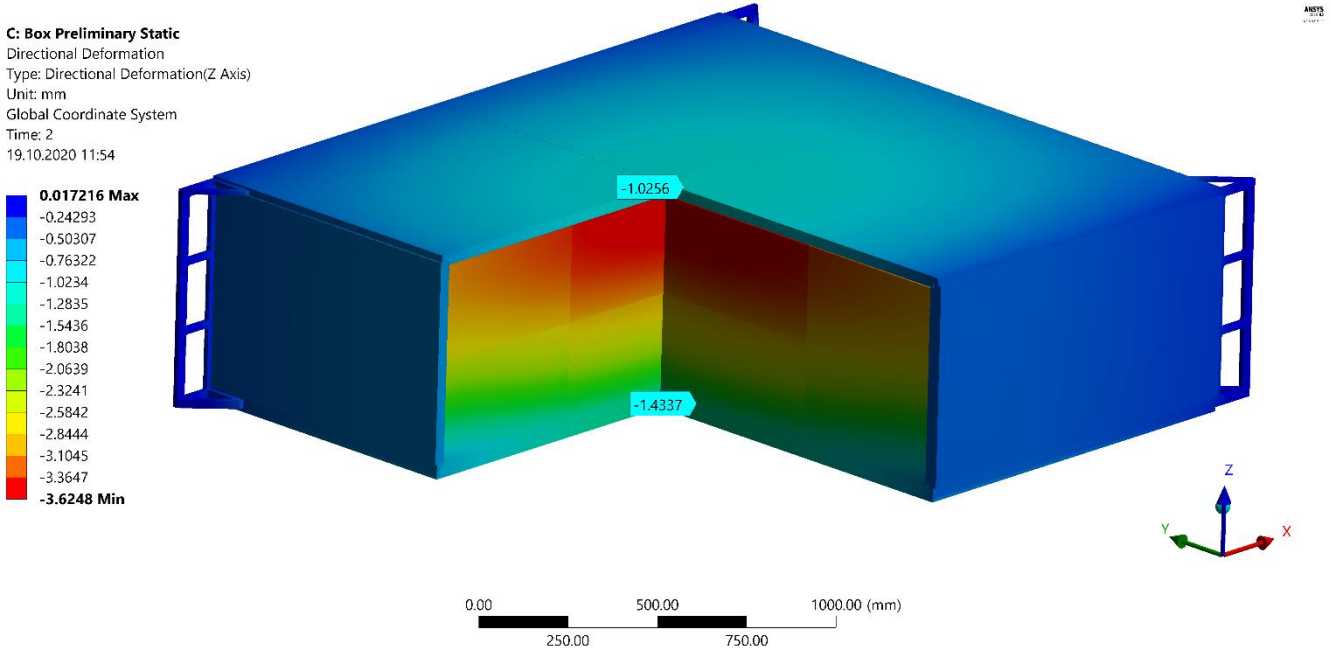
Static Calculation verification

Maximum deformation at the Bottom Panel:	1.44 mm
Maximum deformation at the Top Panel:	1 mm
Max Stress at the Brackets:	82 Mpa
Max Stress at Alu Frames (Bracket connect.):	27 Mpa
Max Stress at Acrylic Bottom panel	~1.26 Mpa
Failure Safety Factor at Carbon Fiber	SF: ~3.8

Very similar to the first static Study

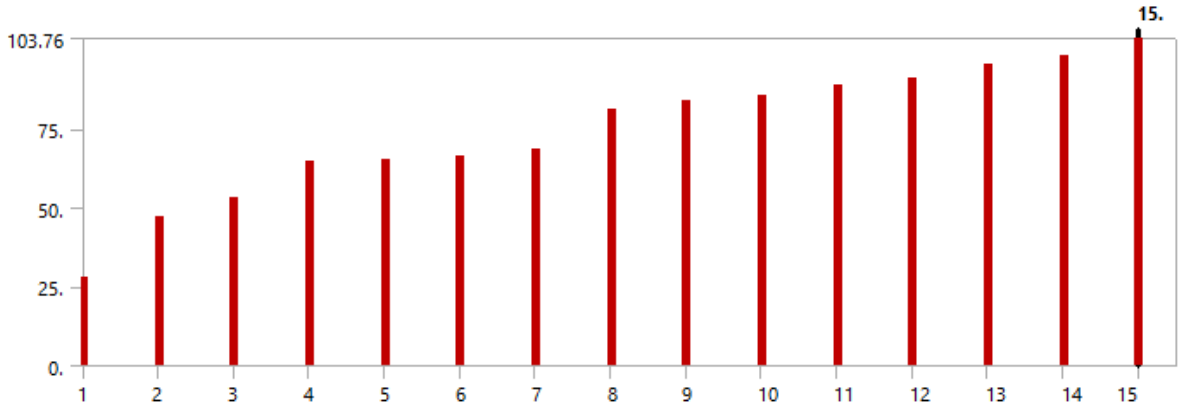
Maximum deformation at the Bottom Panel:	1.5 mm
Maximum deformation at the Top Panel:	0.85 mm
Max Stress at the Brackets:	82 Mpa
Max Stress at Alu Frames (Bracket connect.):	35.5 Mpa
Max Stress at Acrylic Bottom panel	~1.26 Mpa
Failure Safety Factor at Carbon Fiber	SF 4

Cubes behave almost as pressure due to low Young's module



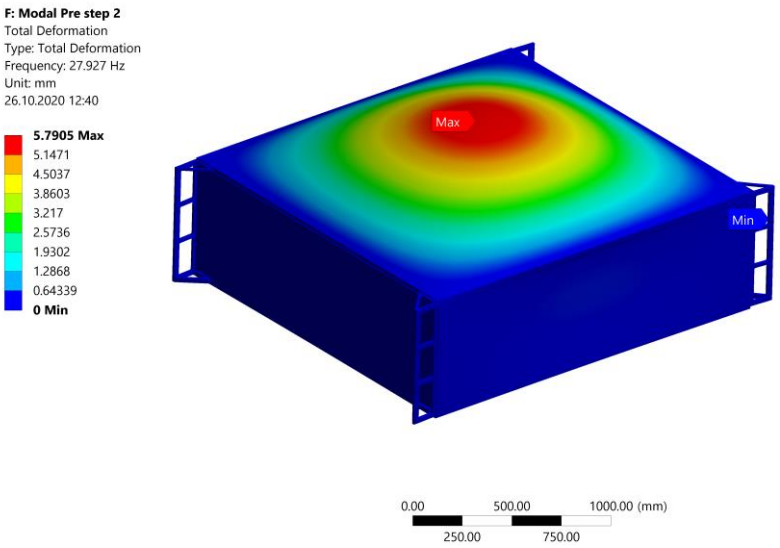
THIRD STUDY – PSD Response

Modal without cubes implemented

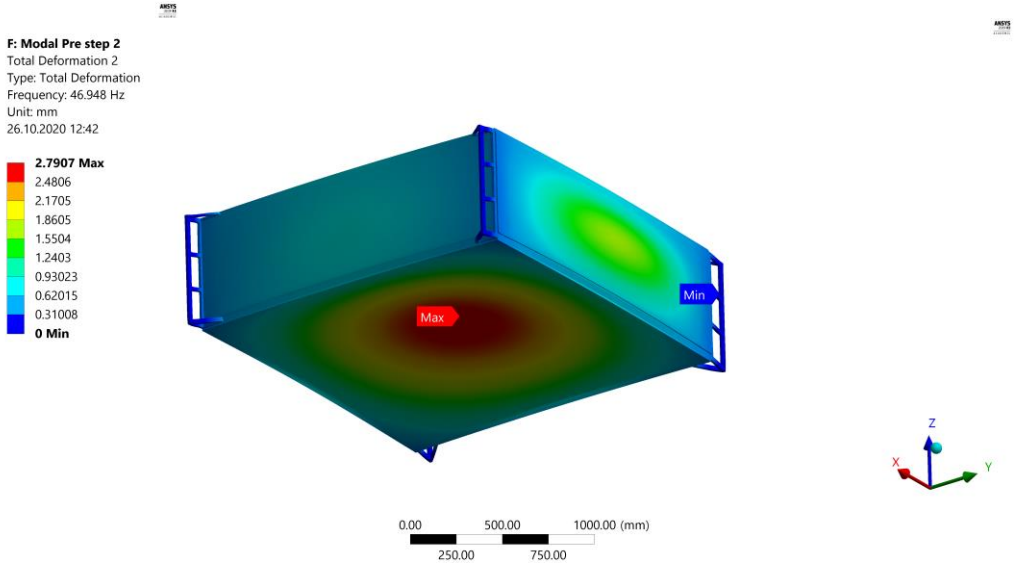


	Mode	Frequency [Hz]
1	1.	27.927
2	2.	46.948
3	3.	53.353
4	4.	64.682
5	5.	65.171
6	6.	66.616
7	7.	68.485
8	8.	81.17
9	9.	83.826
10	10.	85.41
11	11.	89.126
12	12.	91.311
13	13.	95.384
14	14.	98.156
15	15.	103.76

First mode at ~28 Hz (Top Panel)

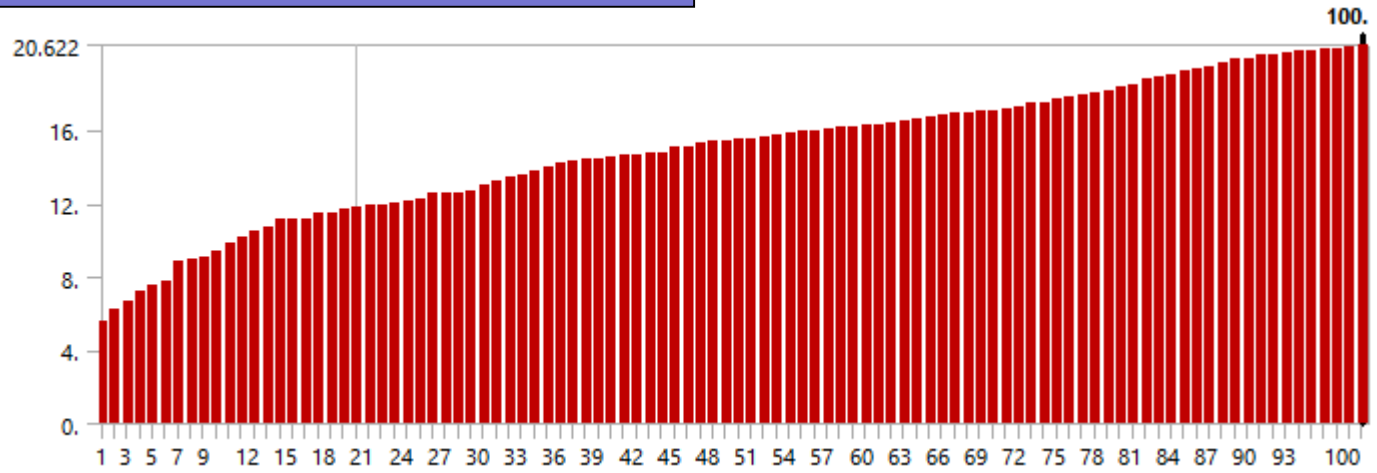


Second mode at ~47 Hz (Bottom Panel)

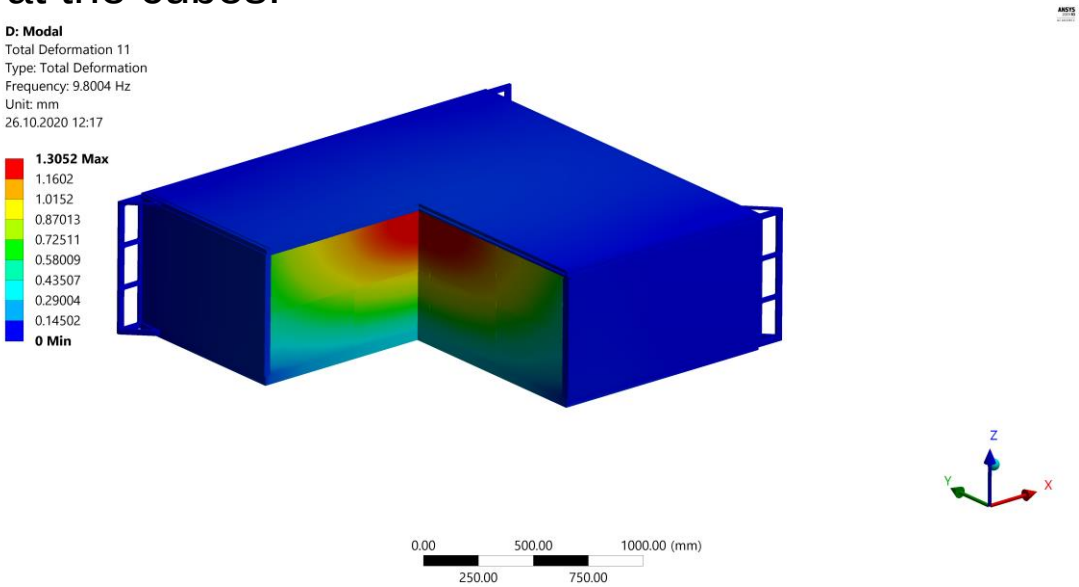


THIRD STUDY – PSD Response

Modal with cubes implemented

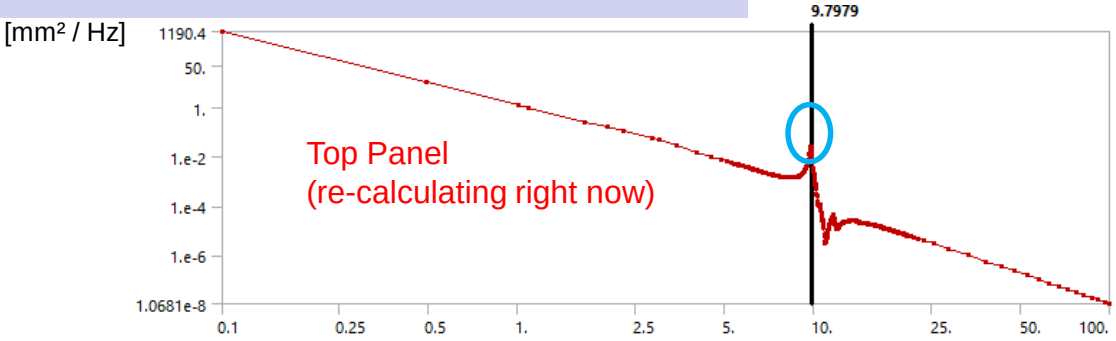


Modal Analysis at preloaded static model with cubes implemented: first 100 modes are at the cubes.

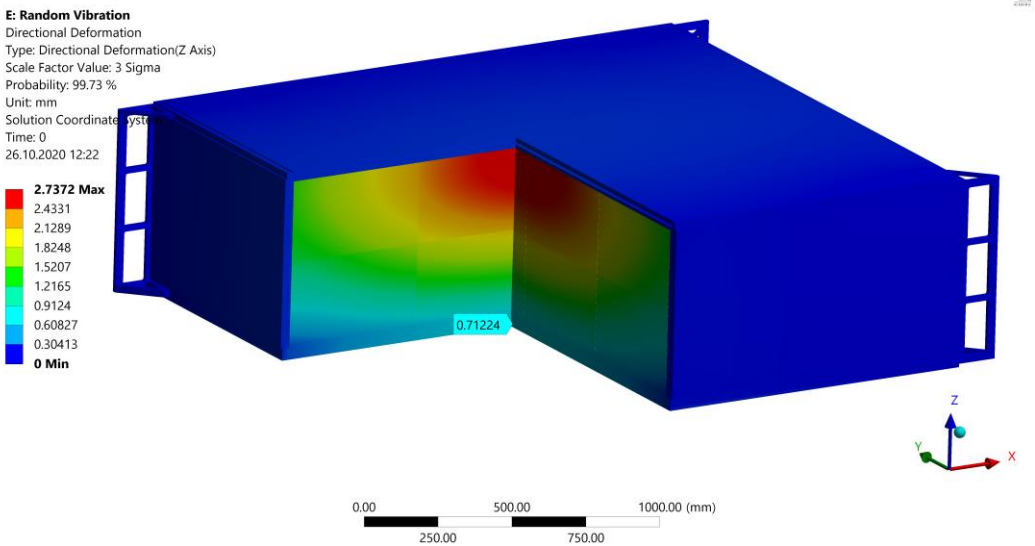


THIRD STUDY – PSD Response

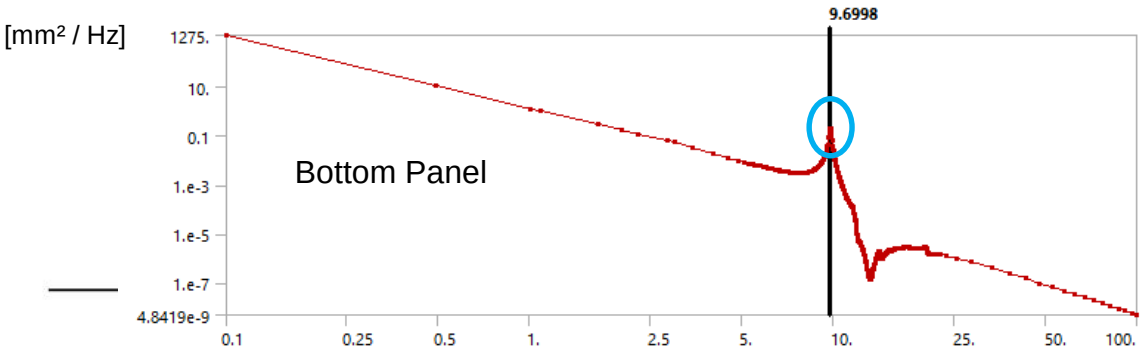
Random Vibration in Vertical Direction



!Checked all the responses in all directions and the critical case is in the vertical direction at the Top Panel!



Scale Factor	3 sigma
Probability:	99,73 %
Max Def Top Panel	0.25mm
Max Def. Bottom	0.72mm
Max Strees:	11Mpa (@Bracket)



THIRD STUDY – PSD Response

Conclusion

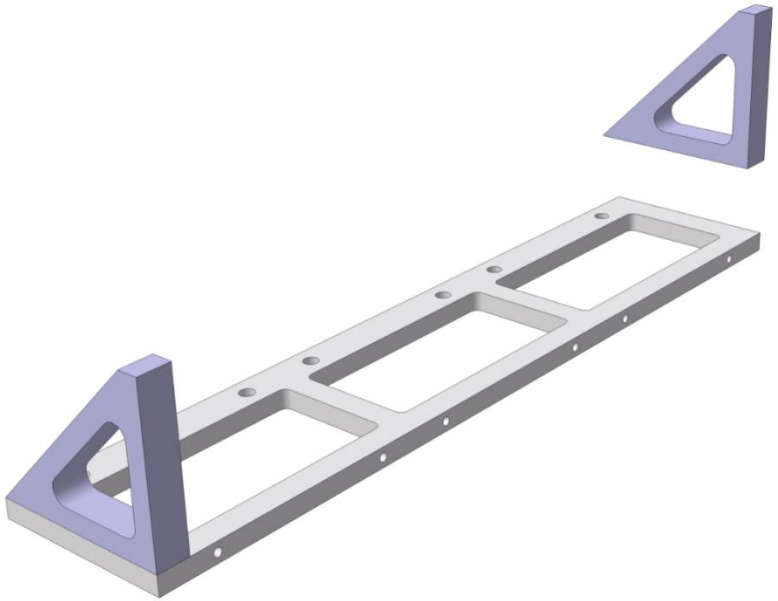
- Good caracterization of the Cubes behaviour is almost impossible.
- Deformations and stresses are considered mostly in order to get an idea of the Box behaviour under Random vibrations.
- Stresses and Deformations at the panels are always very low.
- Considering the real case of having all the cubes with frictional contact (to eachother and to the Panels) it would reduce significantly the deformation at the panels due to vibrations The single cubes would damp a lot the vibrations. → !!My Opinion!!
- Top Panel would be actually not connected to the Cubes and free to vibrate. Increasing the thickness of the Top panel would anyway increase the first mode vibration and reduce the deformation.

CONCLUSION

Modification at the Box

- **Increase** top Panel thickness same as the Bottom Panel and use Divinycell H250 as a core instead of Acrylic.
  →This would give less deformation in case of an Earthquake and would slighlty increase the Resonance frequency.
  → Reduce the possibility to hit the cubes in case of shaking

- Use 316L (non magnetic stainless steel) for the Bracket → Giving an extra safety. In case of using Aluminum, it would be necessary to use special/reinforced alloy.



Divide the Bracket in parts bolted or welded togheter.
The shape could be lasered (company I'm in contact can laser up to 30mm Stainless Steel)

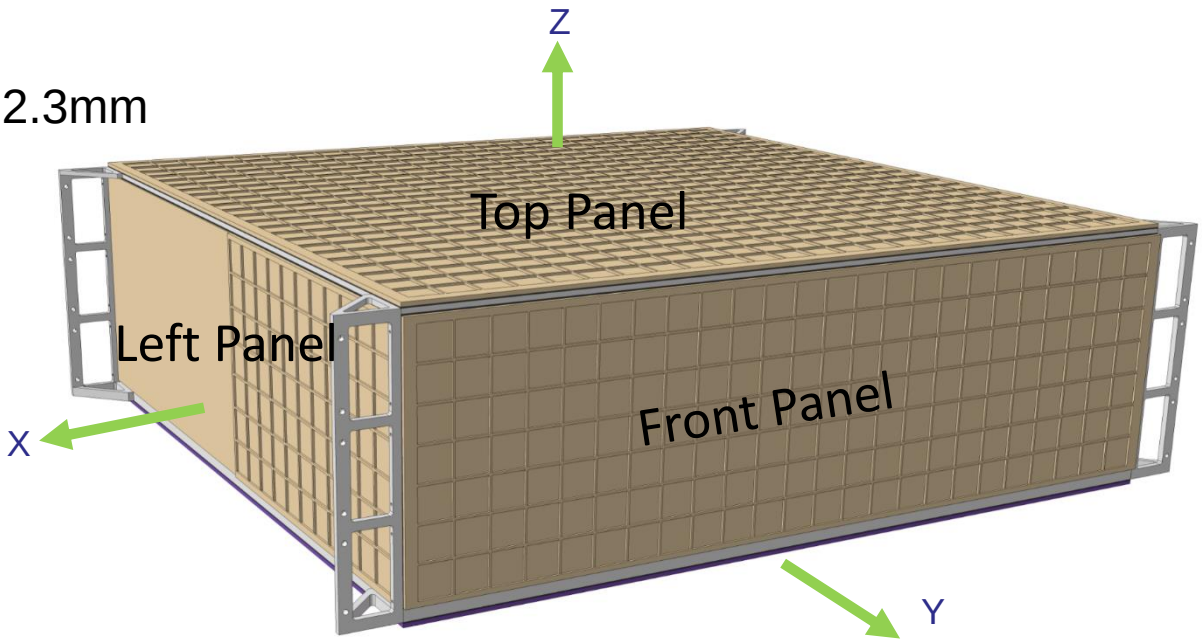
EMDE Laser Company

Carbon steel	Stahl bis 25mm
Stainless steel	Edelstahl bis 30 mm
Alu	Aluminium bis 25 mm
Copper	Kupfer bis 10 mm
Brass	Messing bis 10 mm

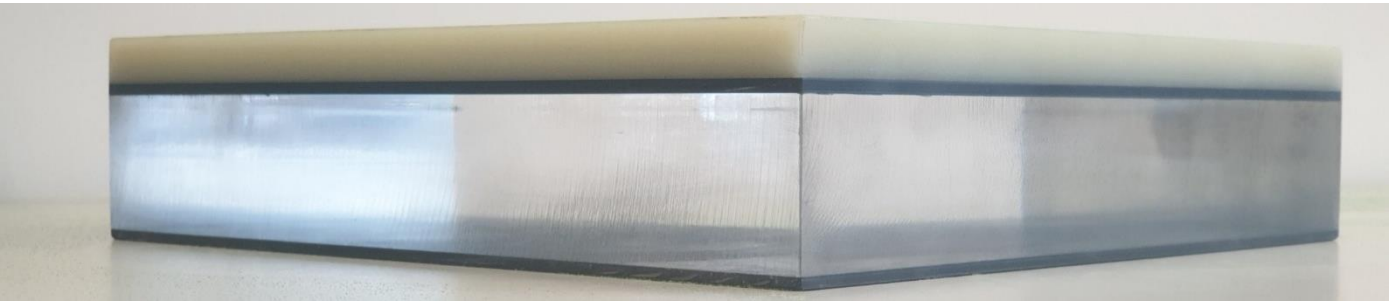
Final Sandwich thickness Materials

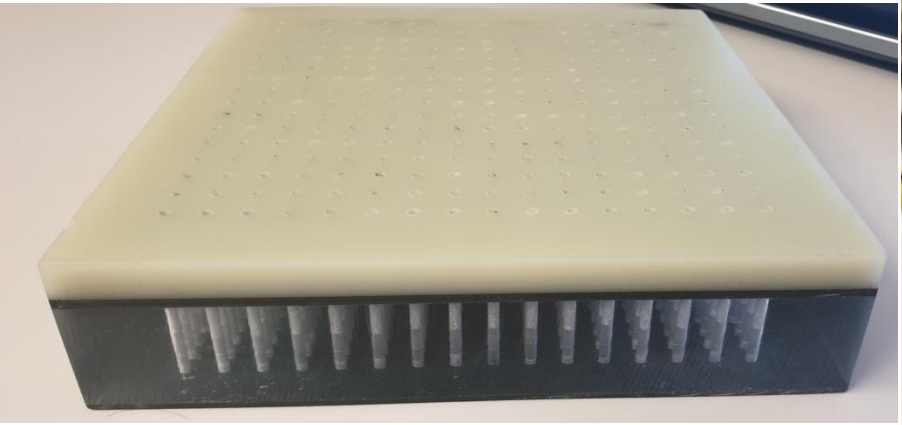
- Accroding to the design at the current status the Material used for the Box are below listed:
  - Bottom Panel → Carbon Fiber – Acrylic – Carbon Fiber Thickness 33.6 mm→ waiting
    - Waiting for composite design to know the exact core dimension between 29mm and 30mm
  - Top Panel: → Carbon Fiber – Acrylic – Carbon Fiber Thickness 16.6mm →Change
    - Increase the thickness at 33.6mm (check with Franck if there is enough clearance) and Divinycell Core
  - Front and Back Panels: → Carbon Fiber – Divinycel H250 – Carbon Fiber Thickness 19.6mm
  - Left and Righ Panels: → Carbon Fiber – Divinycell H250 – Carbon Fiber Thickness 24.6mm

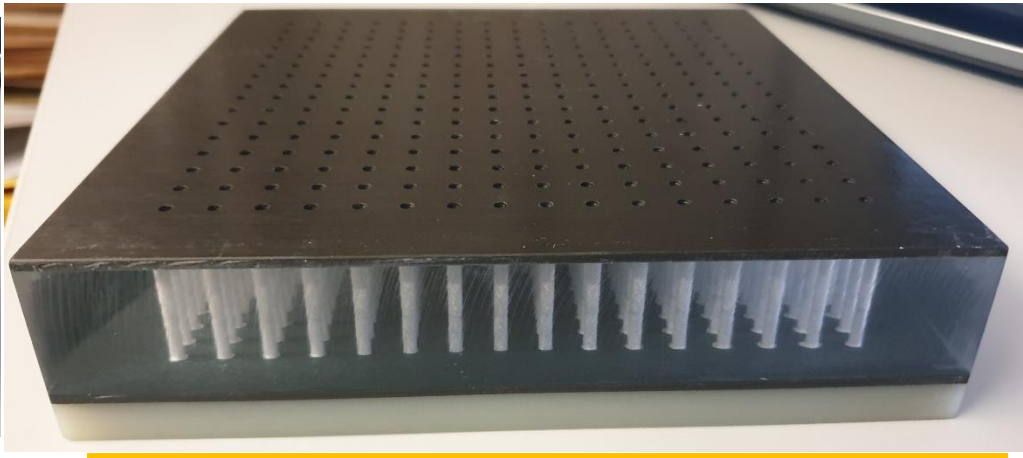
Carbon Fiber Layer is always 2.3mm
Glue is 0.1mm

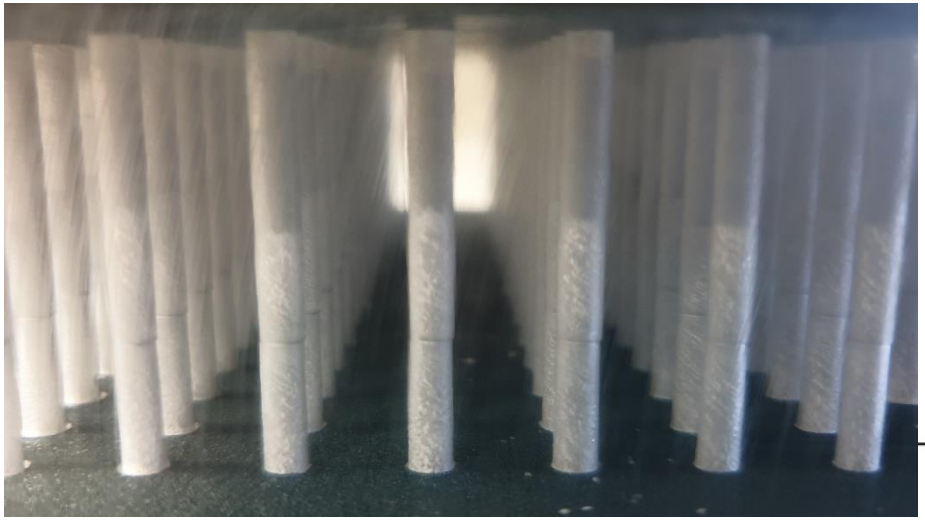


ACRYLIC PROTOTYPE









- 200x200mm prototype received from CompositeDesign
- 3mm Holes drilled through by CIMFORM company
- Visual Check doens't show any crack in the acrylic and glued parts looks good.
- Contacted CERN to perform stress test to verify bending etc..

- Purchasing New Prototype for INR:
  - Black G10
  - Black Acrylic
  - Size of 2000mmx150mm