WA105/ProtoDUNE-DP

Charge Readout Plane
Construction and Installation procedures

WA105 – protoDune-DP Technical Review – 24th of April 2017

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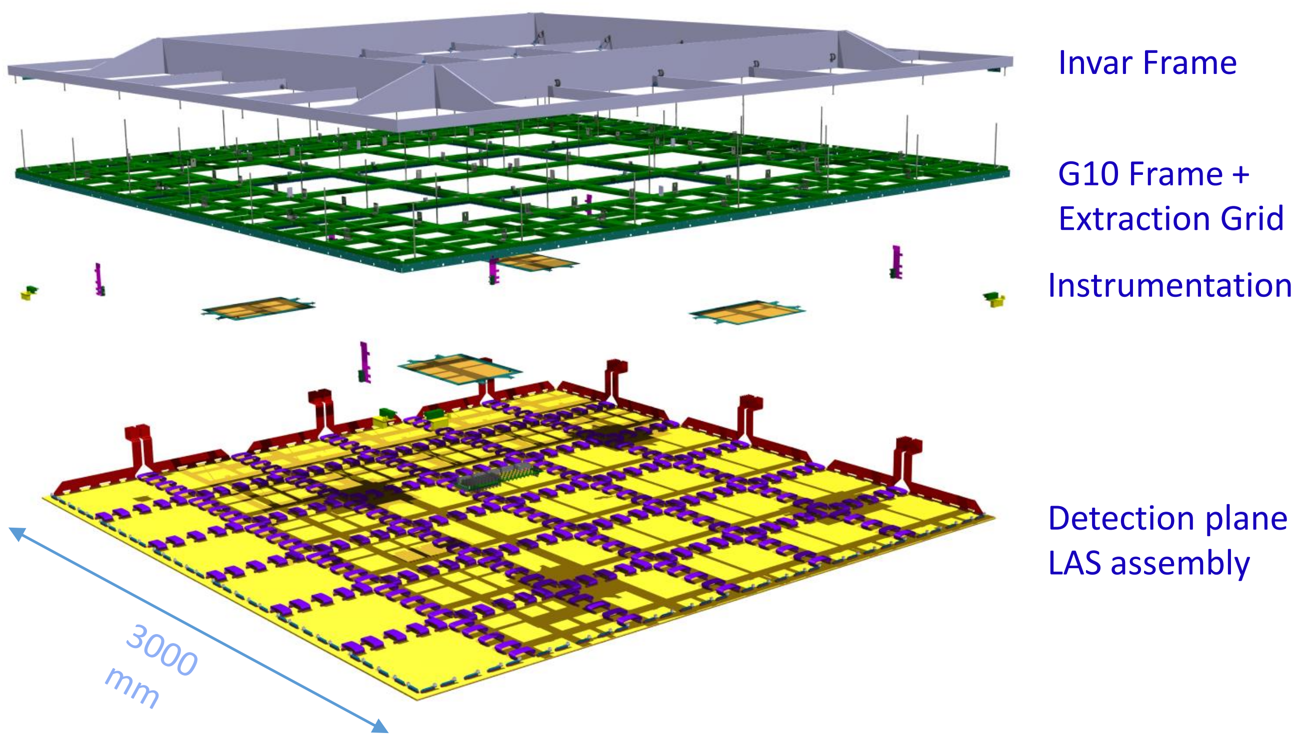
Outline

- Invar structure production
- CRP Assembly in Clean Room (CR185)
  - *Procedure*
  - *Grid production Tooling and QA*
  - *Invar structure*
- Suspension system and hanging procedure



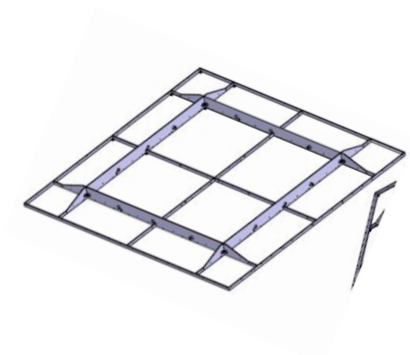
Invar Frame manufacturing

The following manufacturing process has been validated with the manufacturer (SDMS) :

Test model manufacturing

Process validation :

- Plates rectification
- Lazer cuting
- Assembly
- Welding
- Geometrical controls

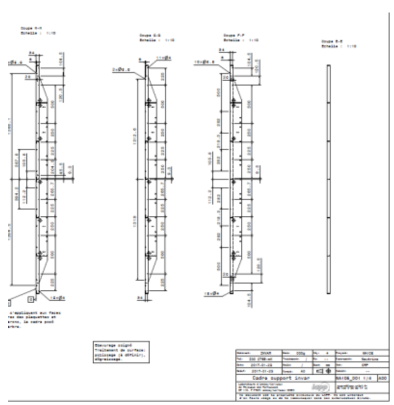


Module 1

Production :

If test model OK, re-used for first module production :

- Plates rectification
- Lazer cuting
- Assembly
- Welding
- Geometrical controls
- Washing
- Packing
- Shipping

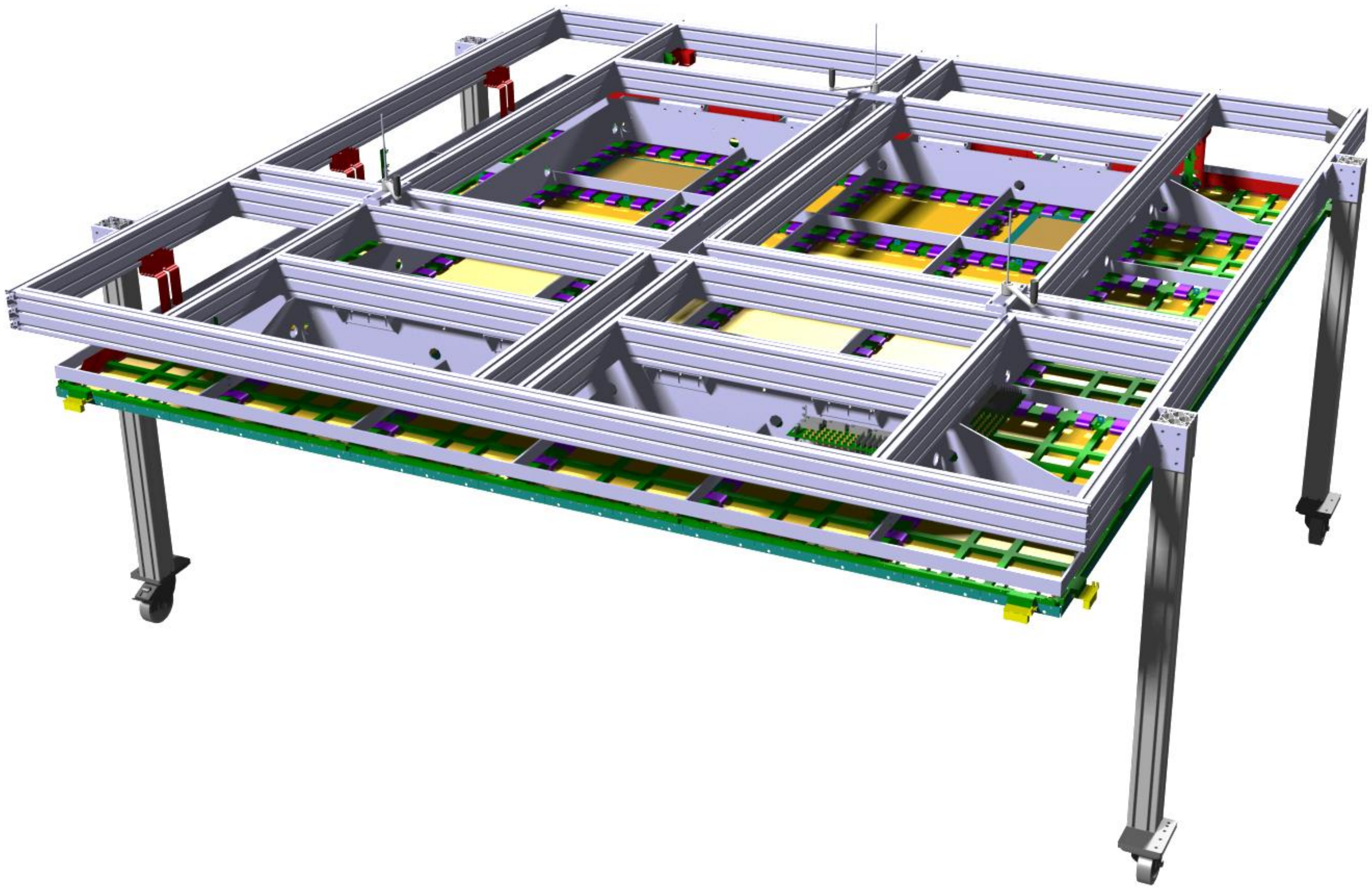


Modules 2, 3, 4

Production :

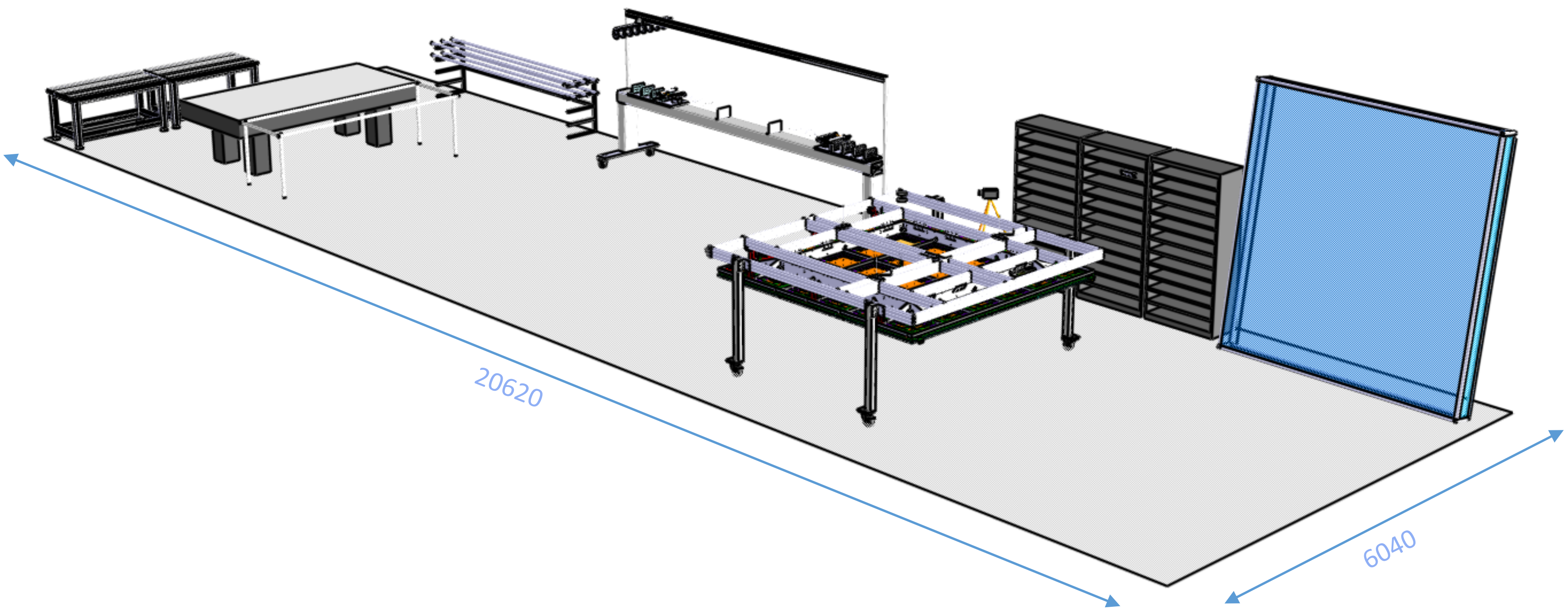
- Plates rectification
- Lazer cuting
- Assembly
- Welding
- Geometrical controls
- Washing
- Packing
- Shipping

CRP Assembly : Clean Room 185

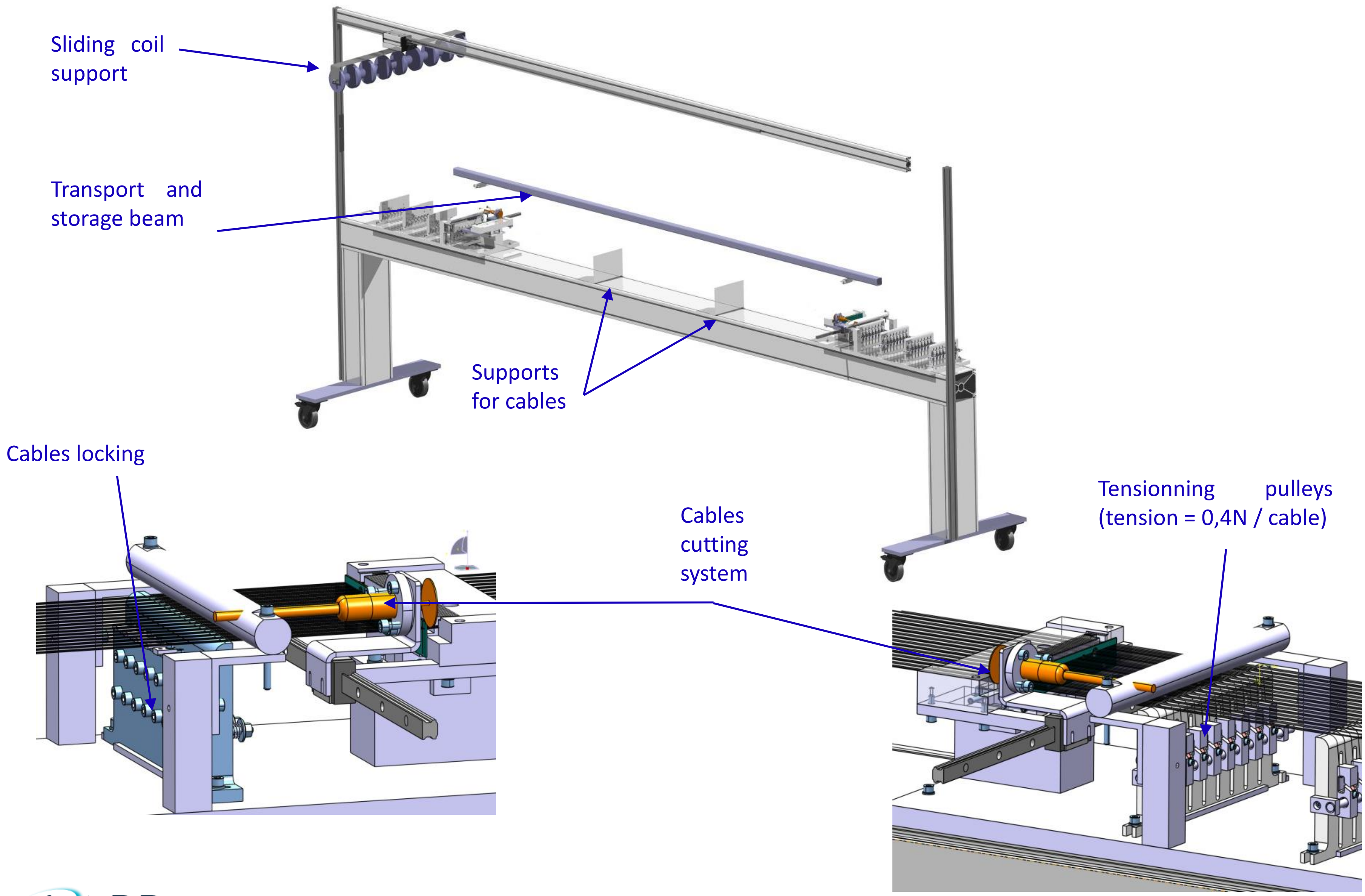


Assembly in Clean Room 185

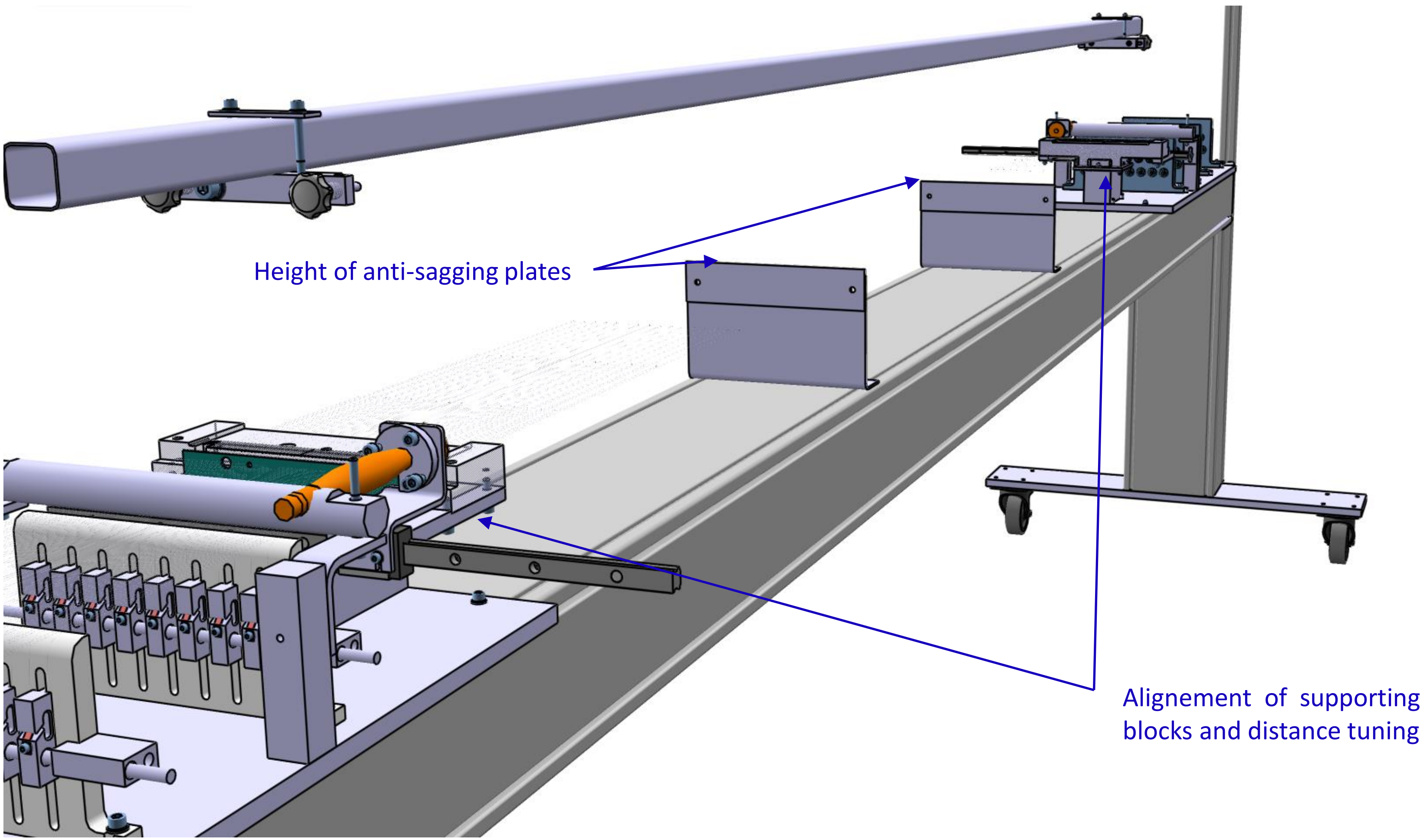
- See the animation of the assembly : https://youtu.be/jcnJjlU-Cyc



Tooling for Grid production



Tooling for Grid production – Metrology operations

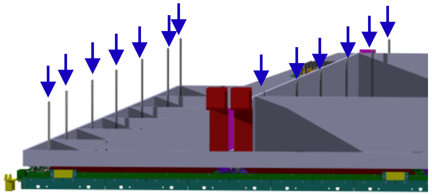


Each G10 frame is measured, then tooling dimension is adapted.

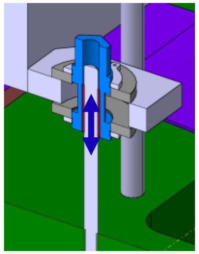
Planarity tuning – Grid tension

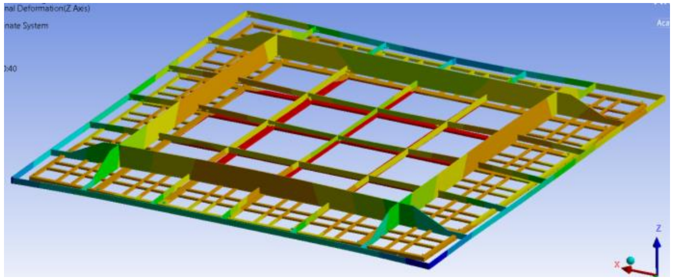
More details on planarity calculations are given in spare slides

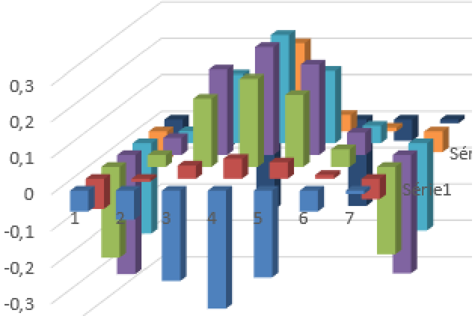
- Deformation of the whole module is simulated and optimised following real installation procedure
  - *Step 1 : Assembly*
  - *Step 2 : Planarity tuning*
  - *Step 3 : Severe cooling sequence*
  - *Step 4 : Operation*



- Initial grid tension is based on real tension measurement (prototype)
- Material properties are validated from manufacturer and tests
  - *Wires elasticity, G10 (Cryolab) and Invar (Aperam) thermal contraction…*
- Critical materials are already tested by prototypes

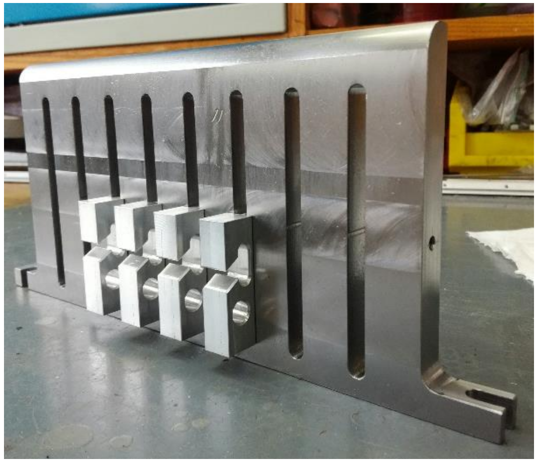




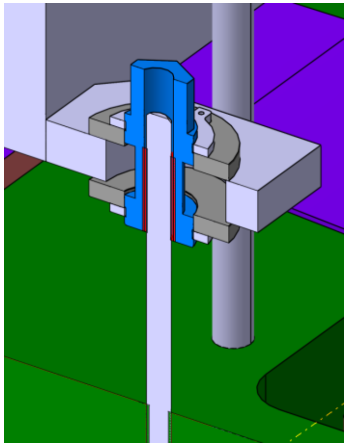


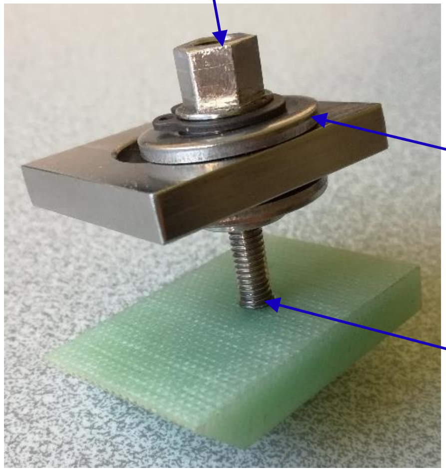
Final planarity defect calculation (mm)

Grid production : various tests and prototypes



Pulleys and pulleys support for production tooling – Initial tension measurement





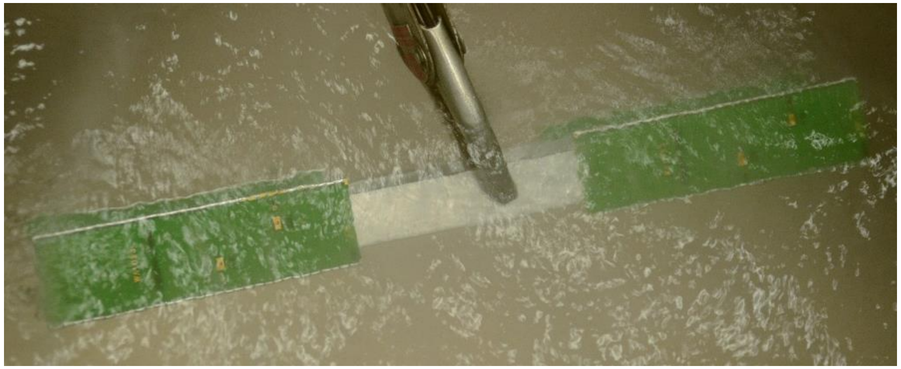
Thread braking

Sliding

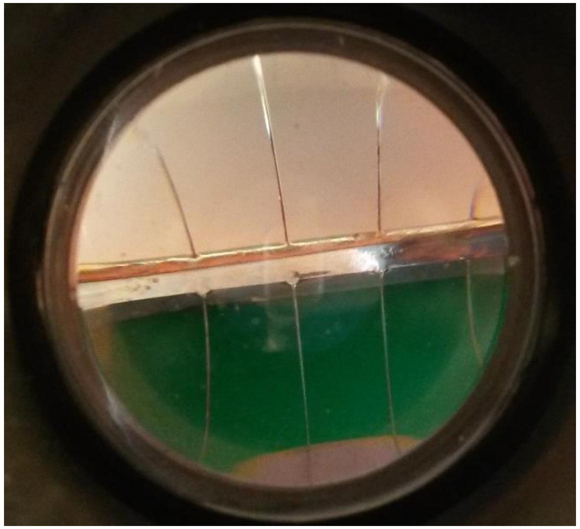
Glueing

Grid production : various tests and prototypes

Test of grid brazing



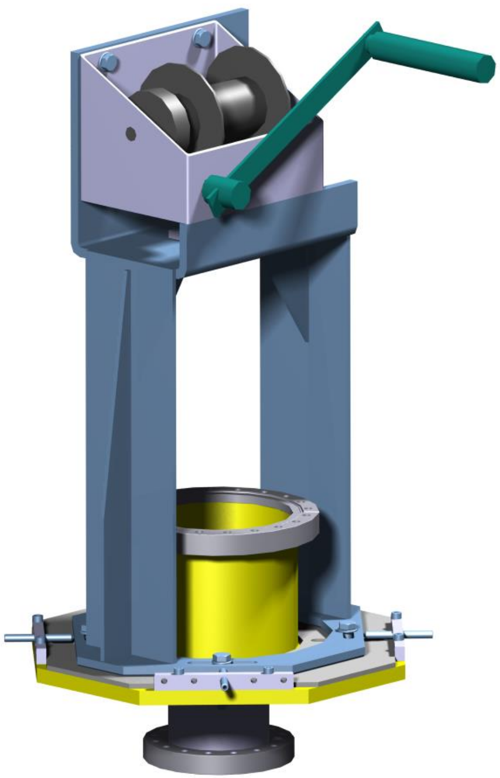
Grid prototype in liquid nitrogen, for cold test of the brazing



Test of grid brazing

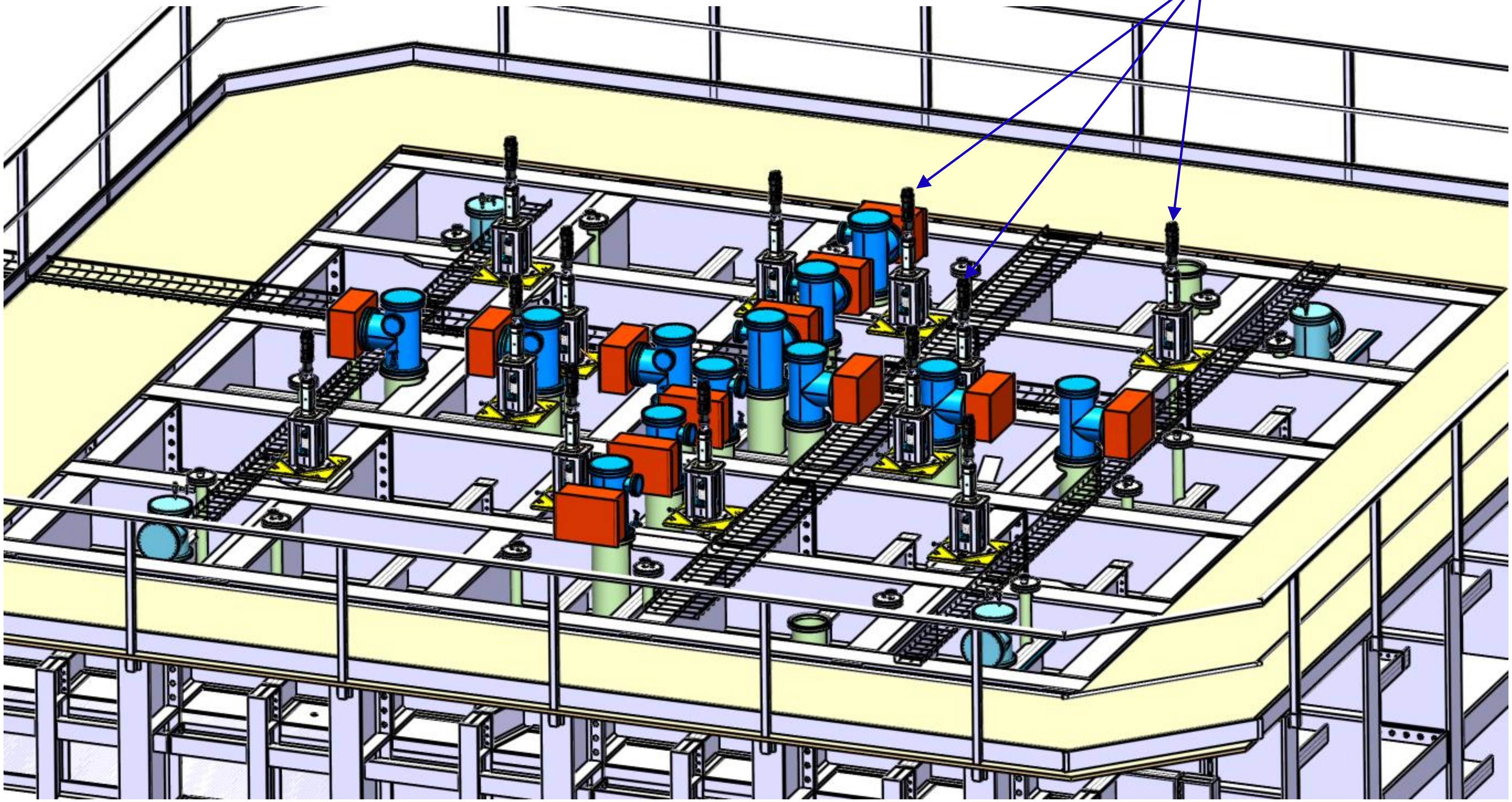
- Zero defect soldering process validated (use of phosphoric acid to improve brazing)
  - Tests with « low brazing skill » operators --> OK

Suspension Feedthrough



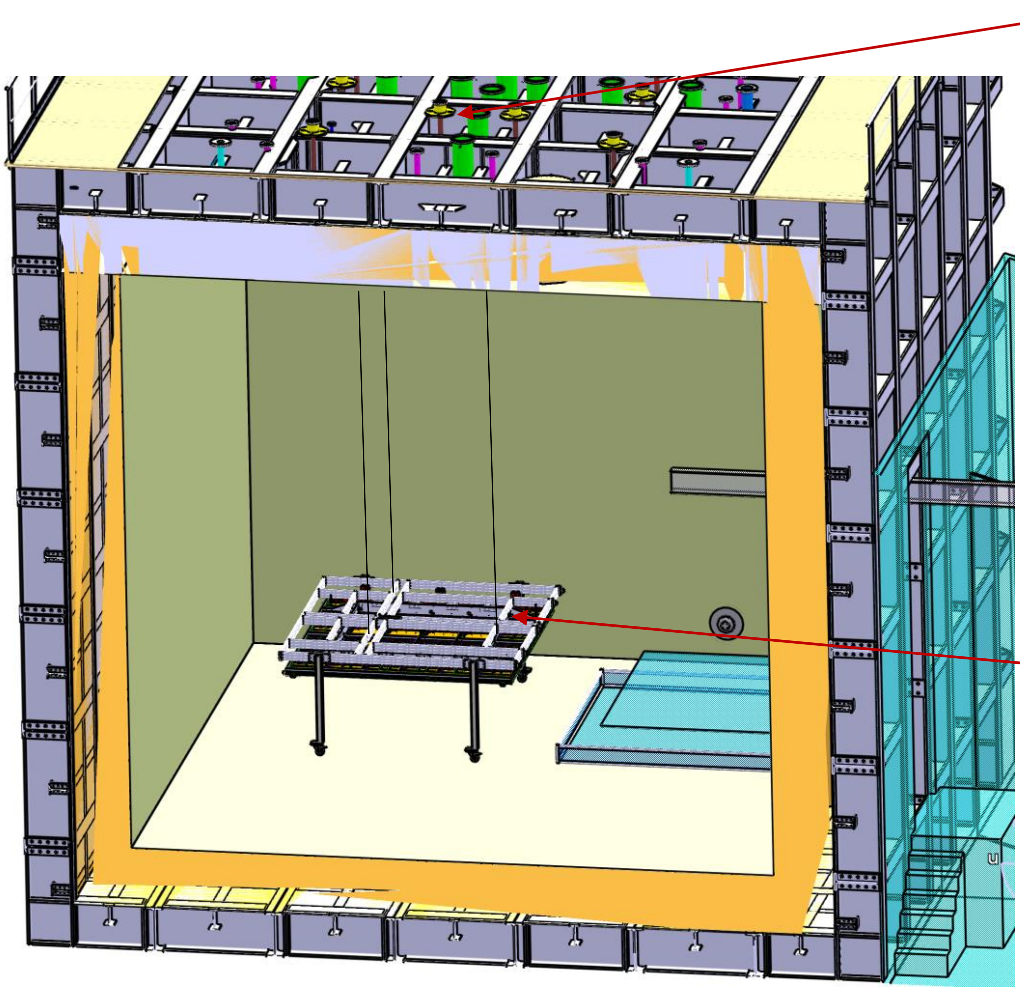
SPFTs on detector's roof

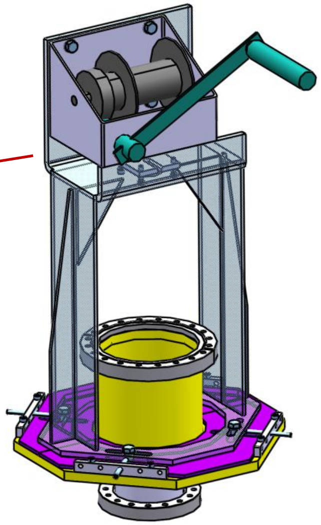
Suspension
Feedthrough
(SPFT)



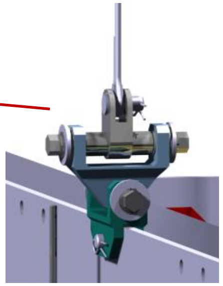
Cryostat insertion

The box is placed below its SPFT chimneys
The top and the bottom of the box are removed
Cables from the SPFT are connected to the module





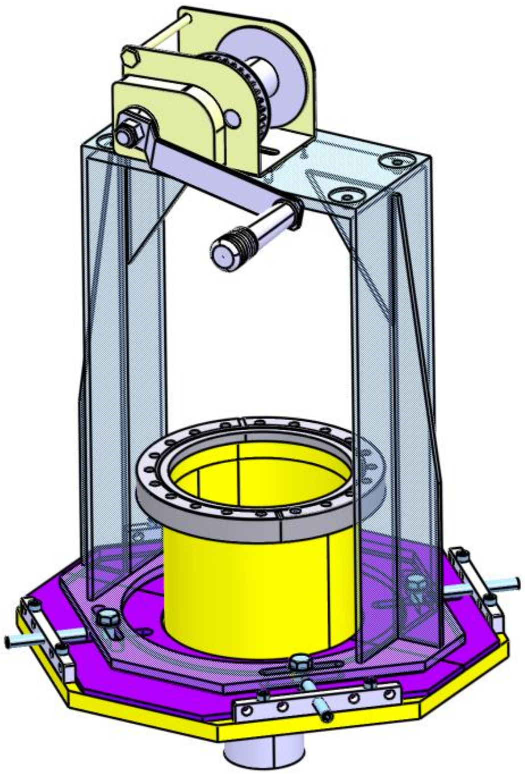
SPFTs are equiped with special winches at this time

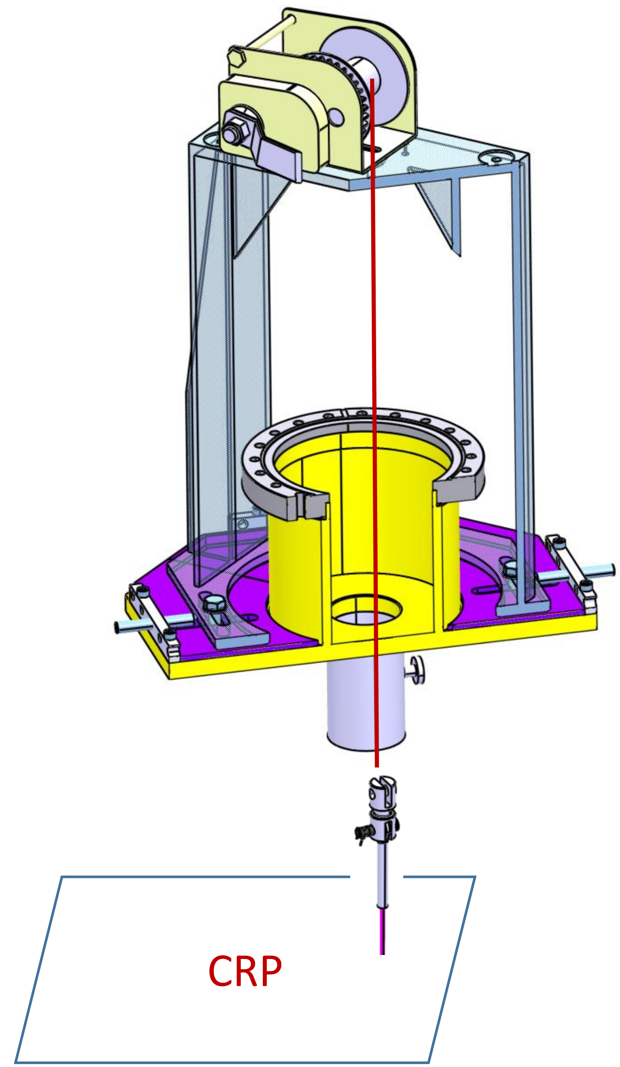


CRP suspension systems

Installation procedure on roof

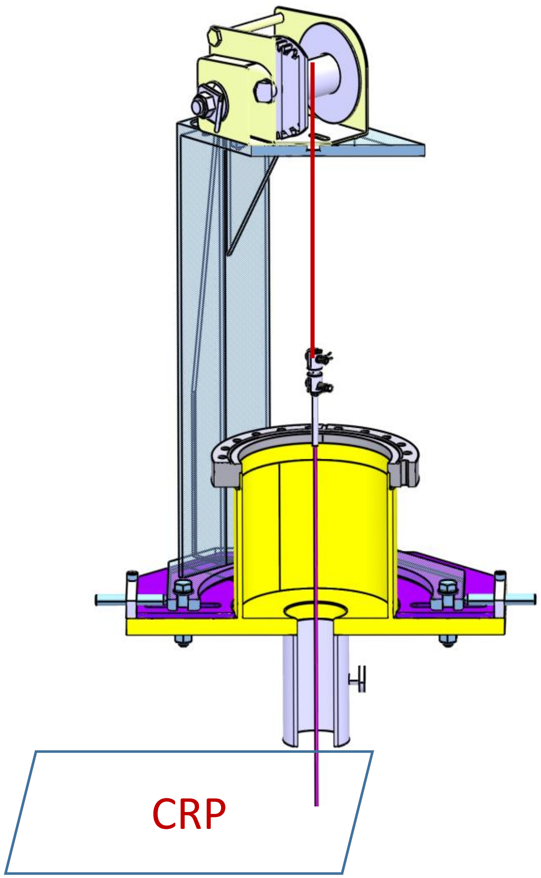
Cable from the winch is descended through the chimney to attach the CRP final cable :

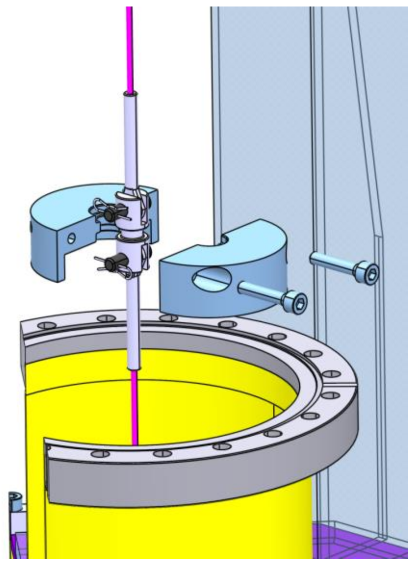


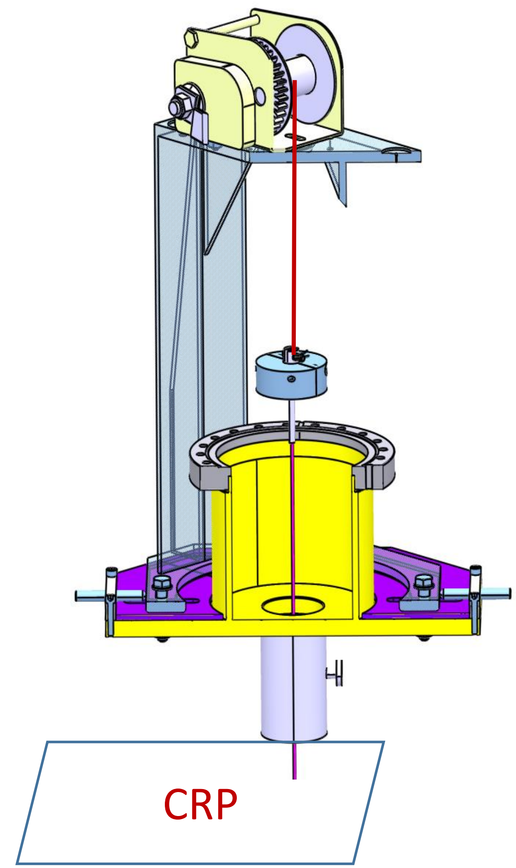


Installation procedure on roof

CRP is raised up with the winches, then the mechanical stop is assembled





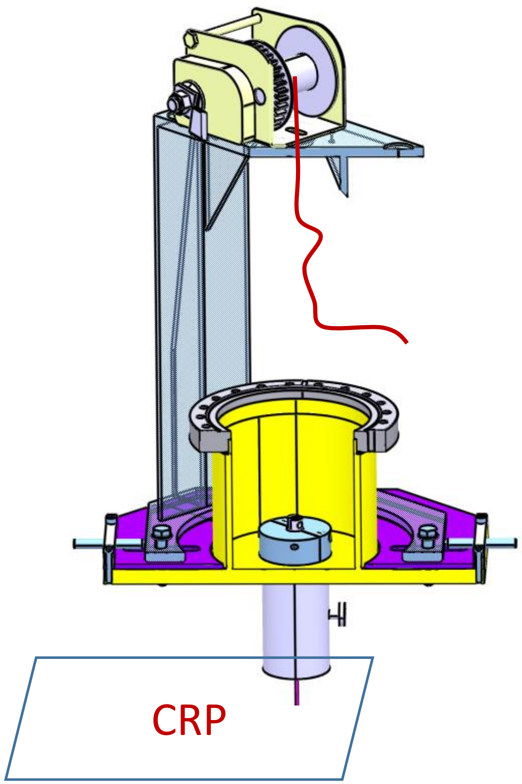


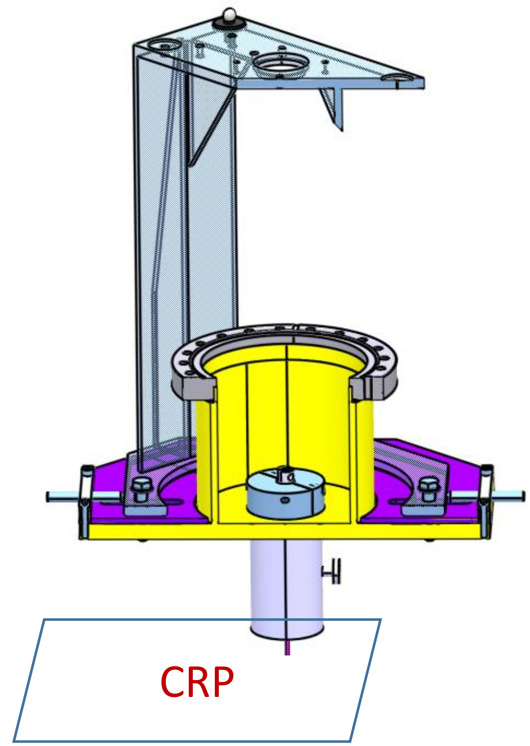
Installation procedure on roof

The CRP is laid down on the mechanical stop

The winch cable is disconnected

The winch is removed

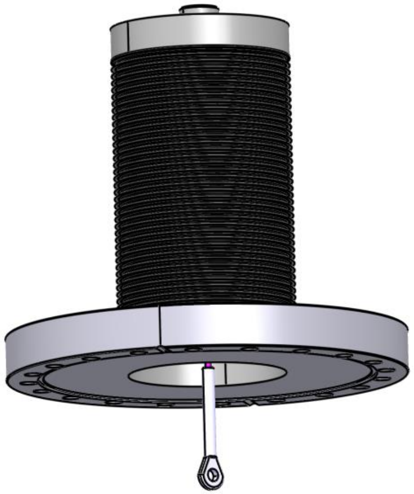


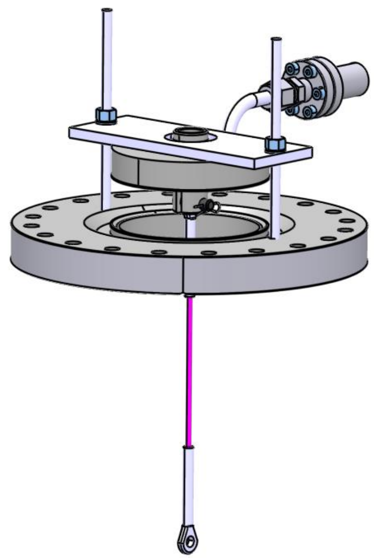


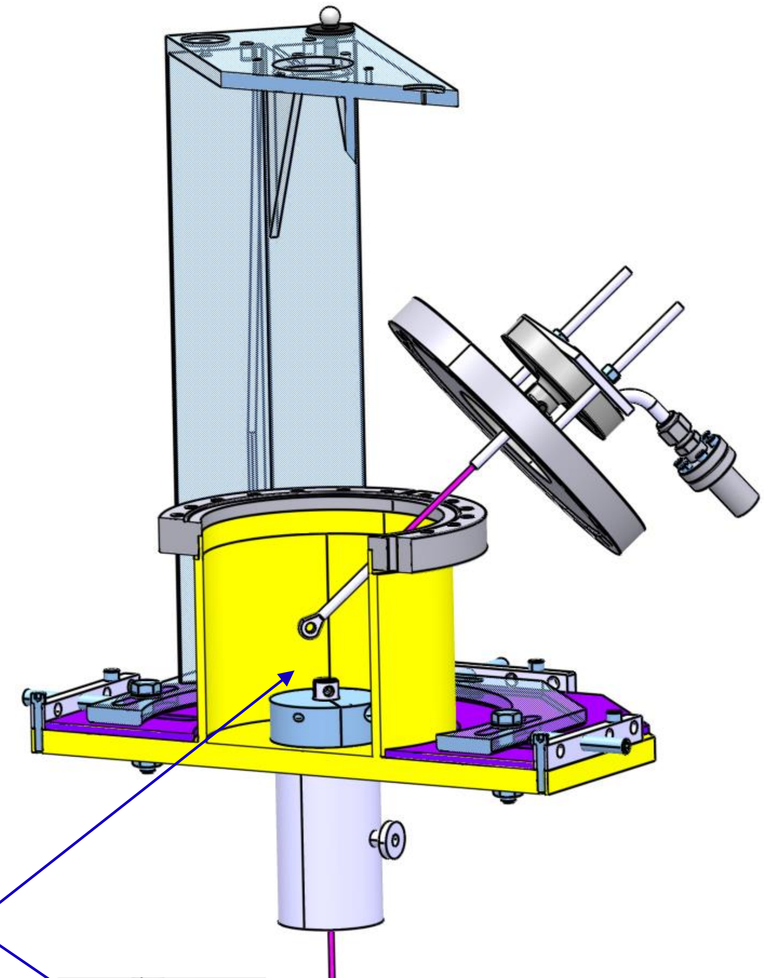
Installation procedure on roof

The bellow is compressed thanks to special tooling

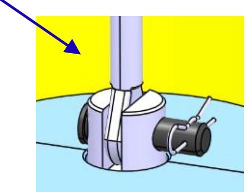
The cable from the bellow is connected with a pin







Connection with a pin

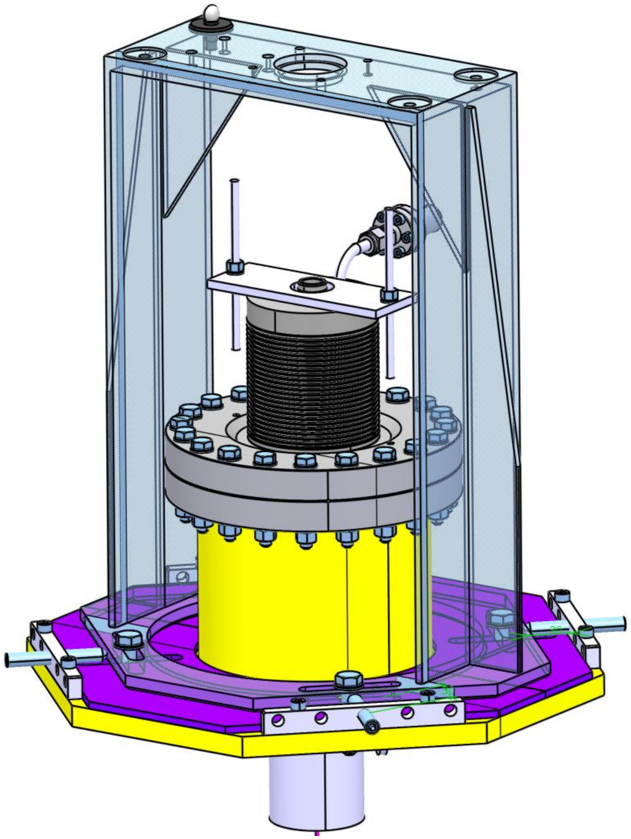


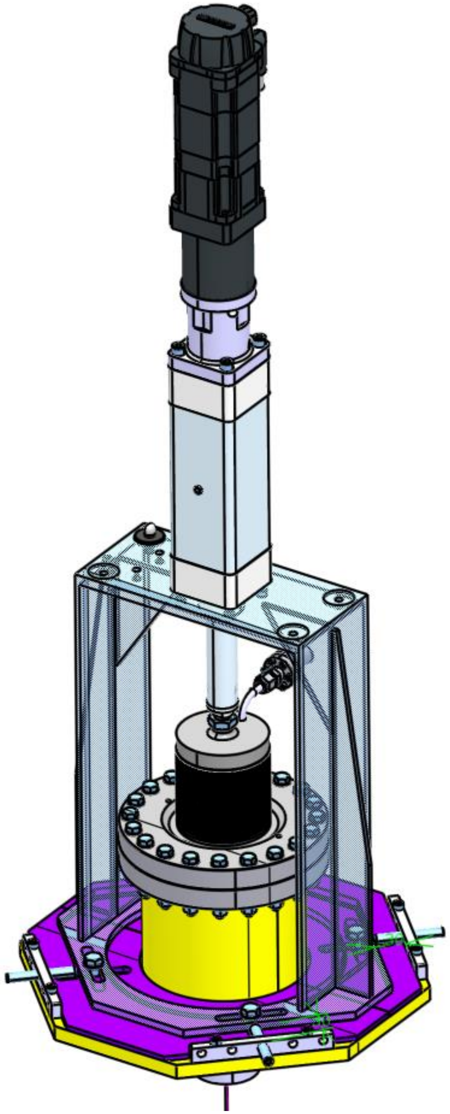
Installation procedure on roof

The compression tool is removed and the bellow fixed

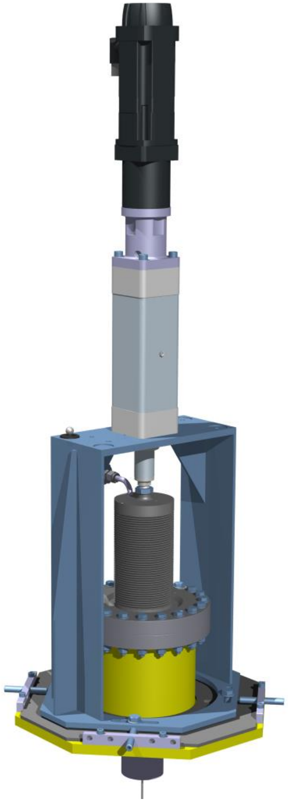
The motor is inserted and screwed from the top

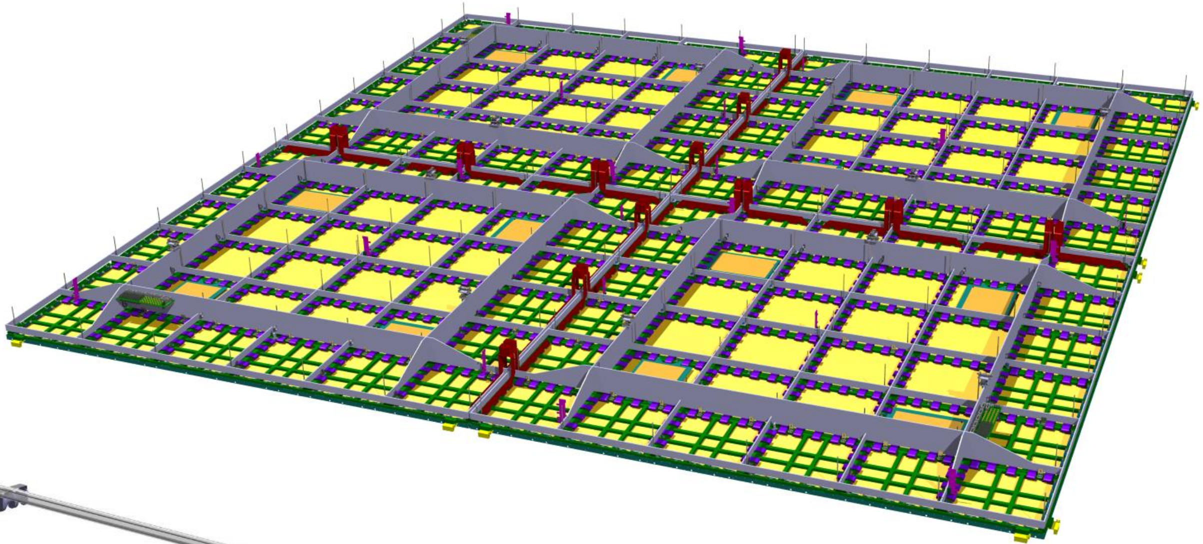
The assembly is complete and operationnal

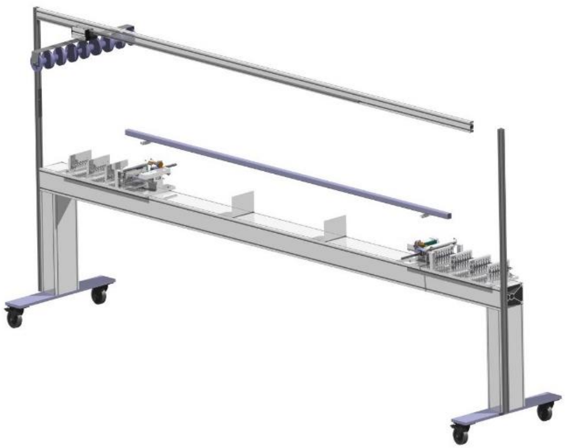




Thanks for your attention



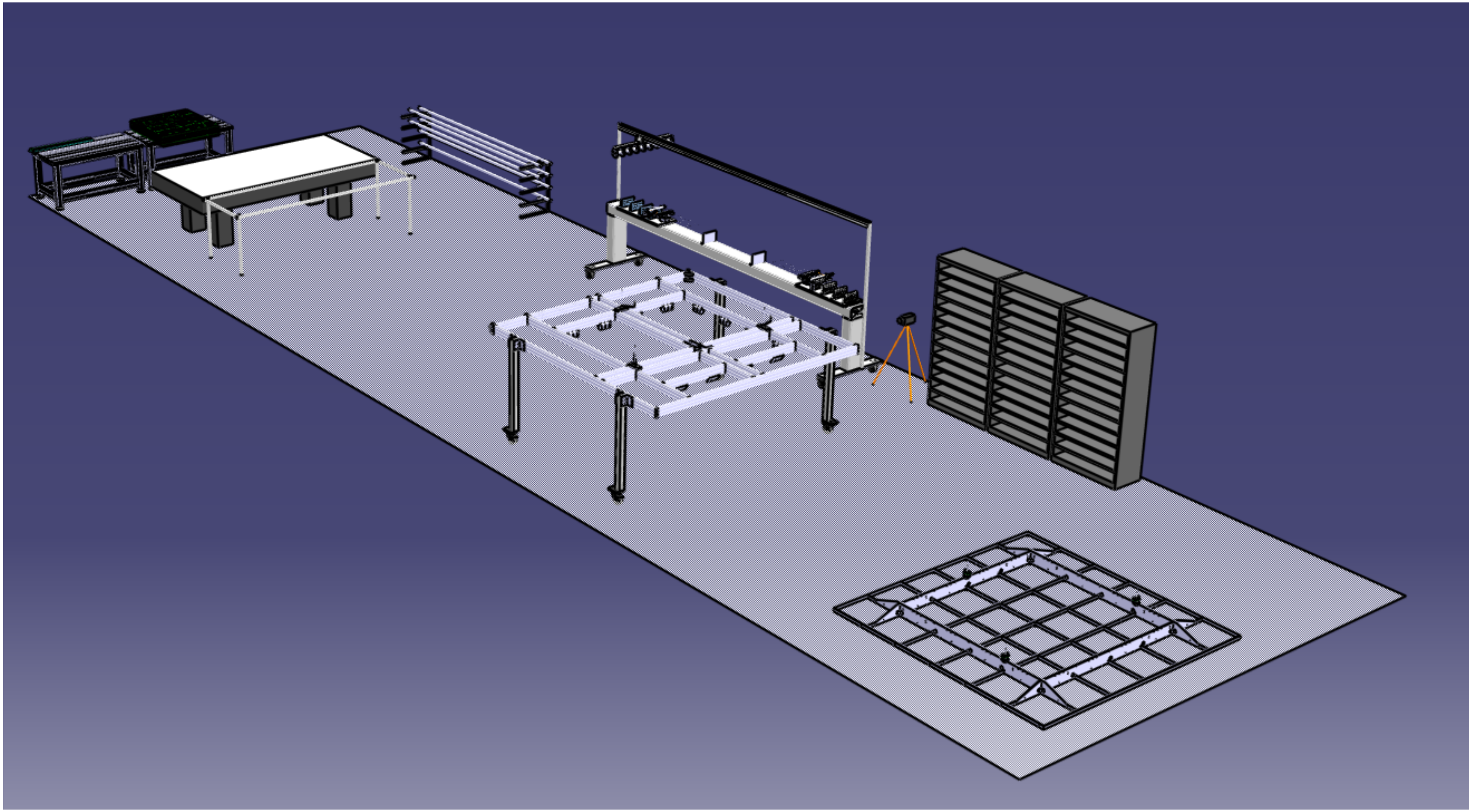




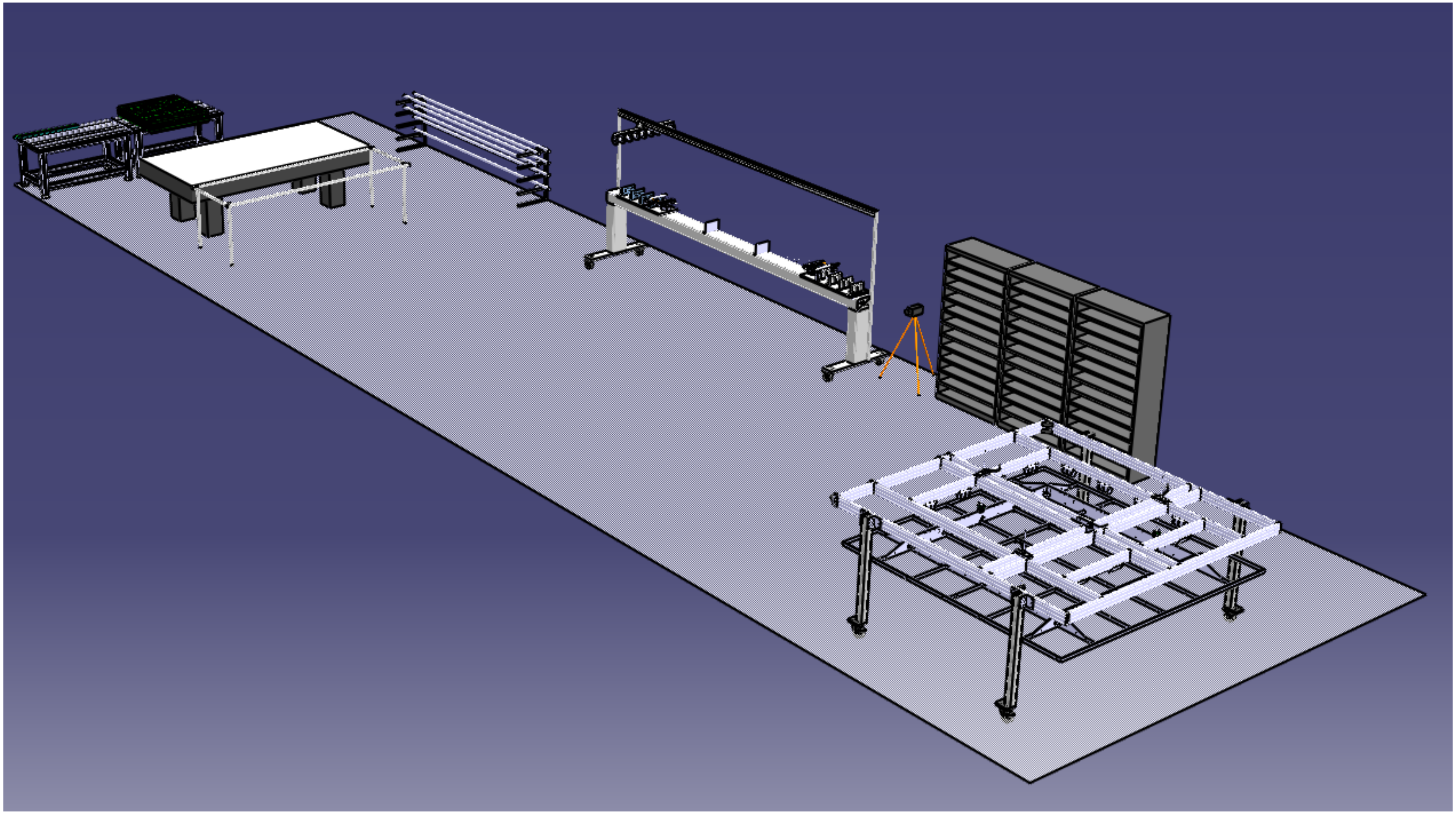
Spare slides

CR185 Installation

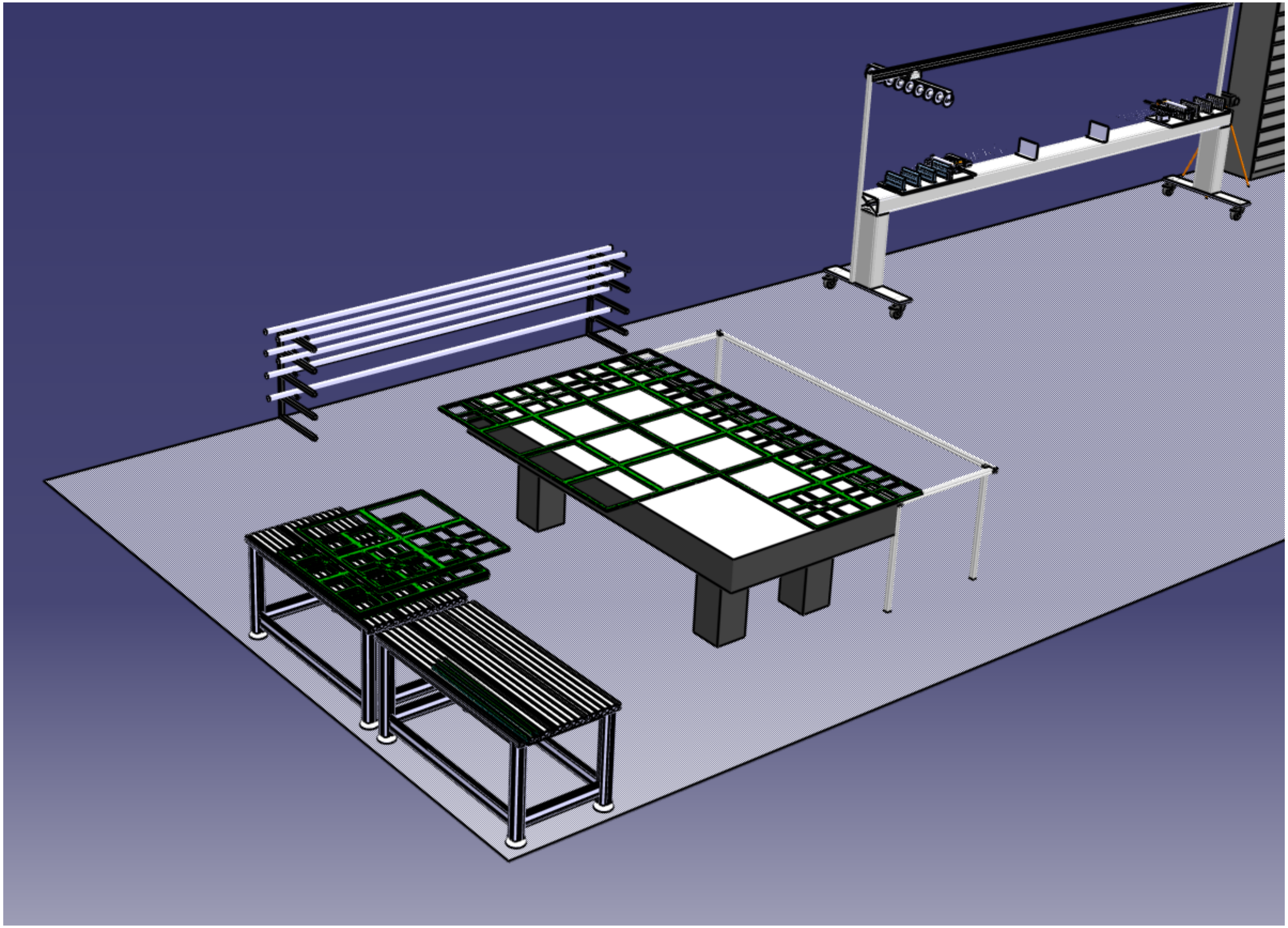
CRP Assembly



CRP Assembly



CRP Assembly



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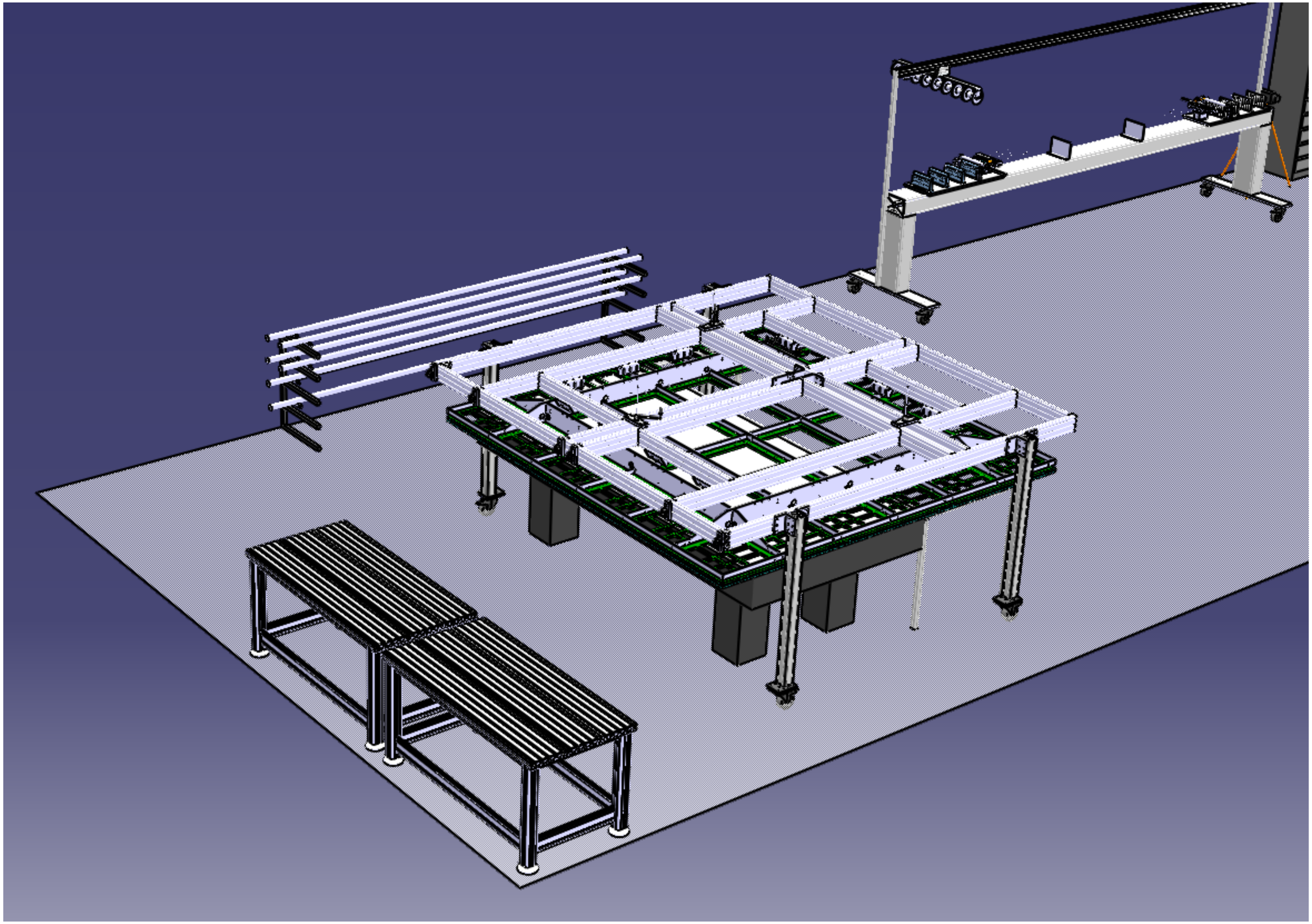

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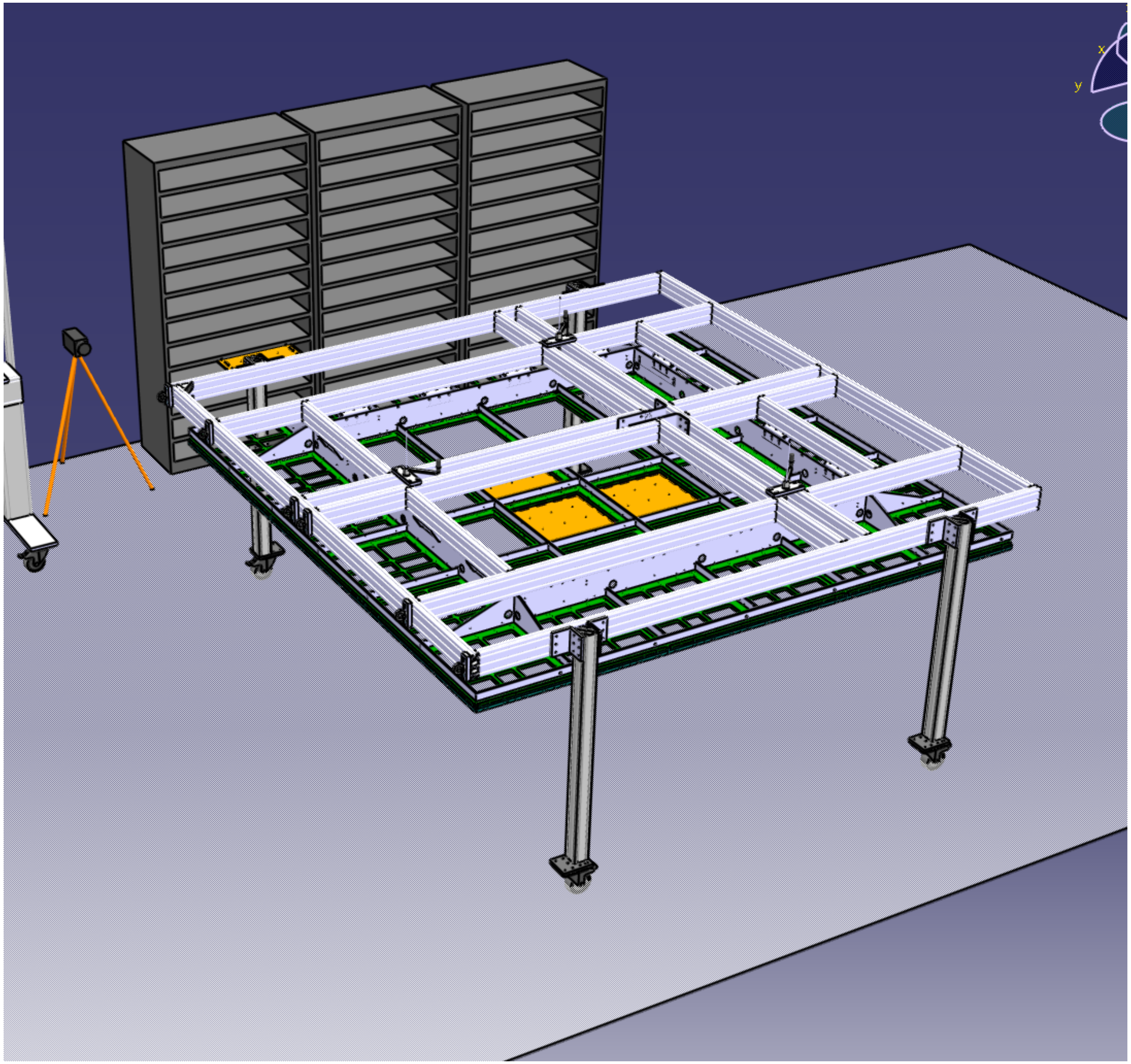

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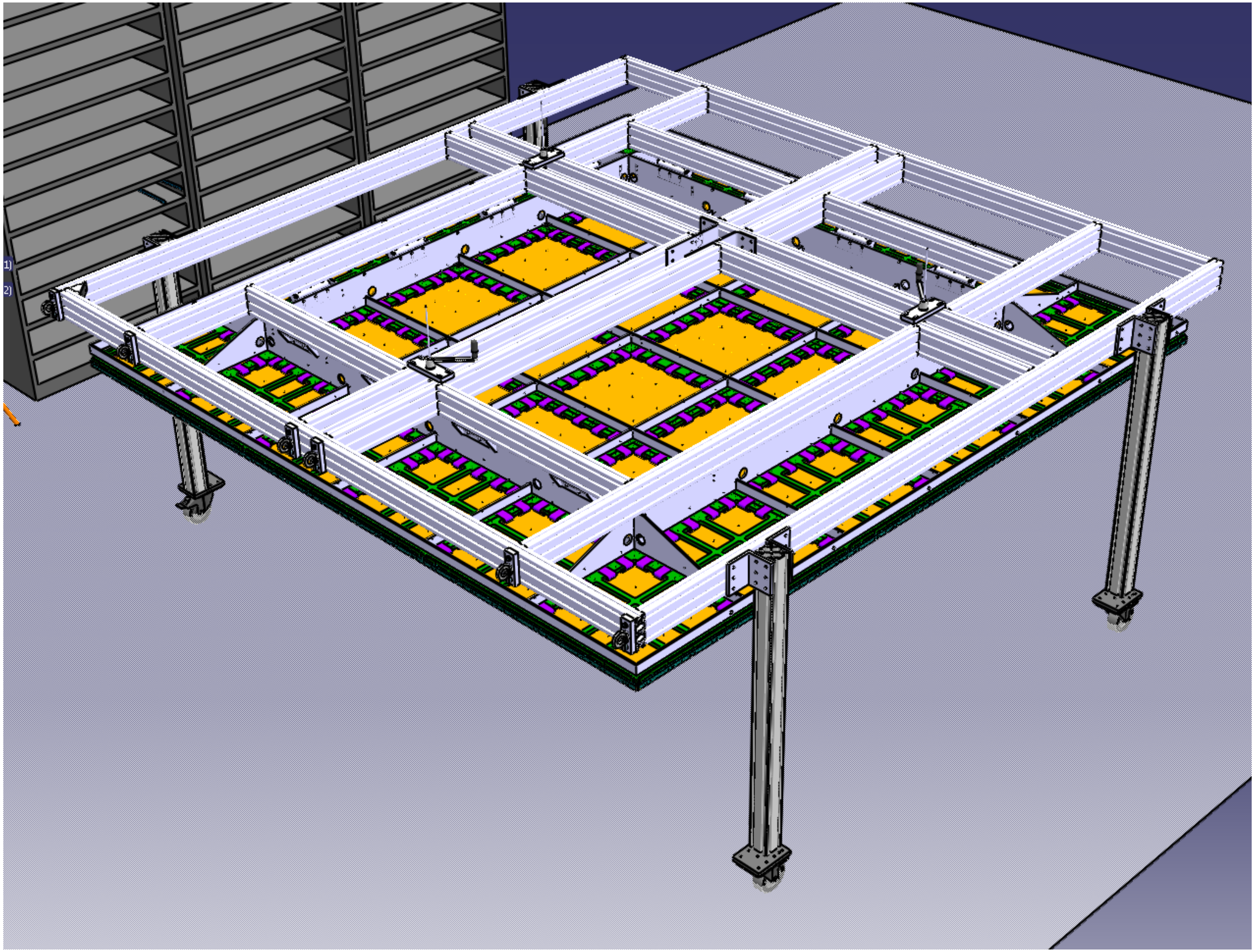

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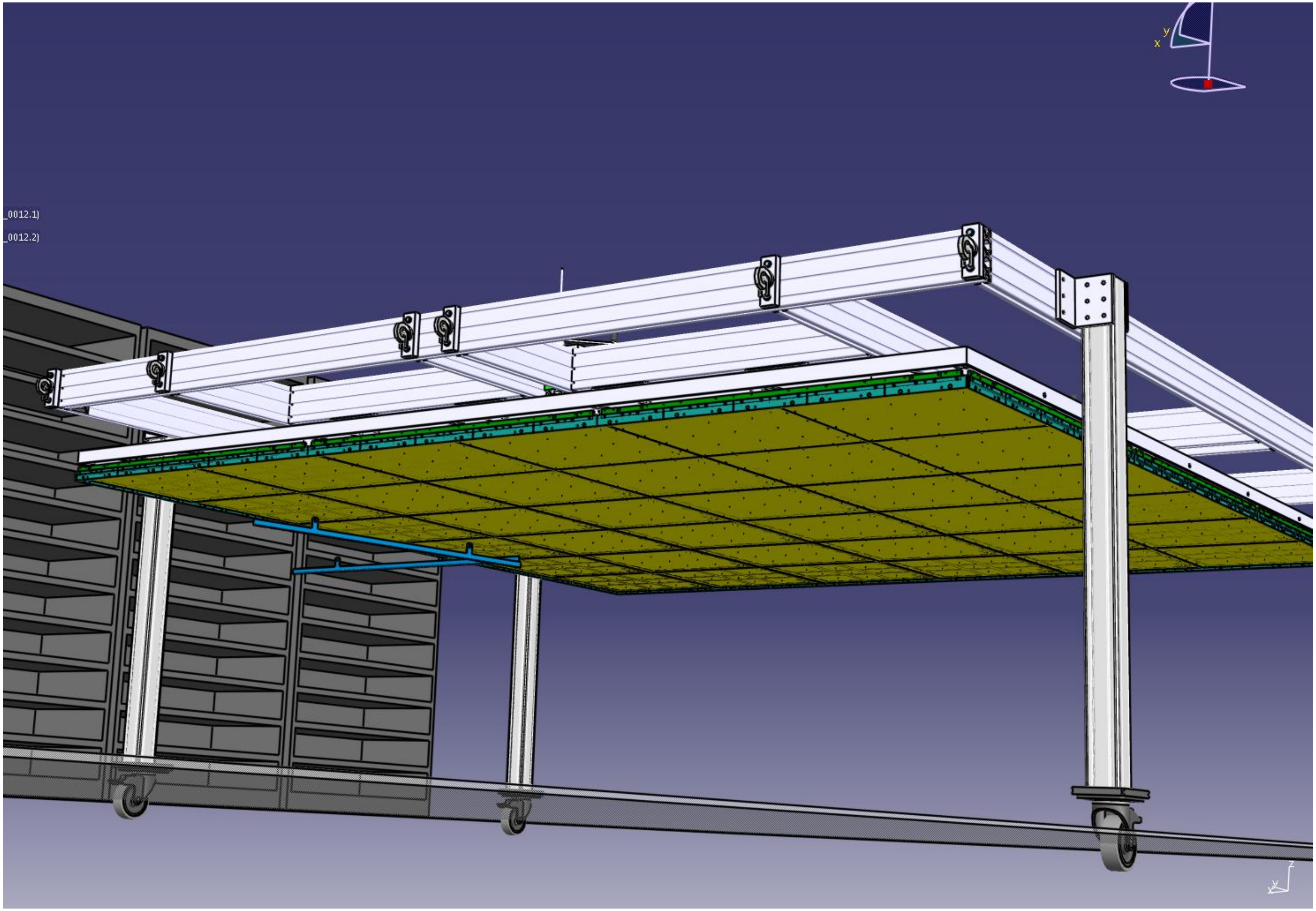

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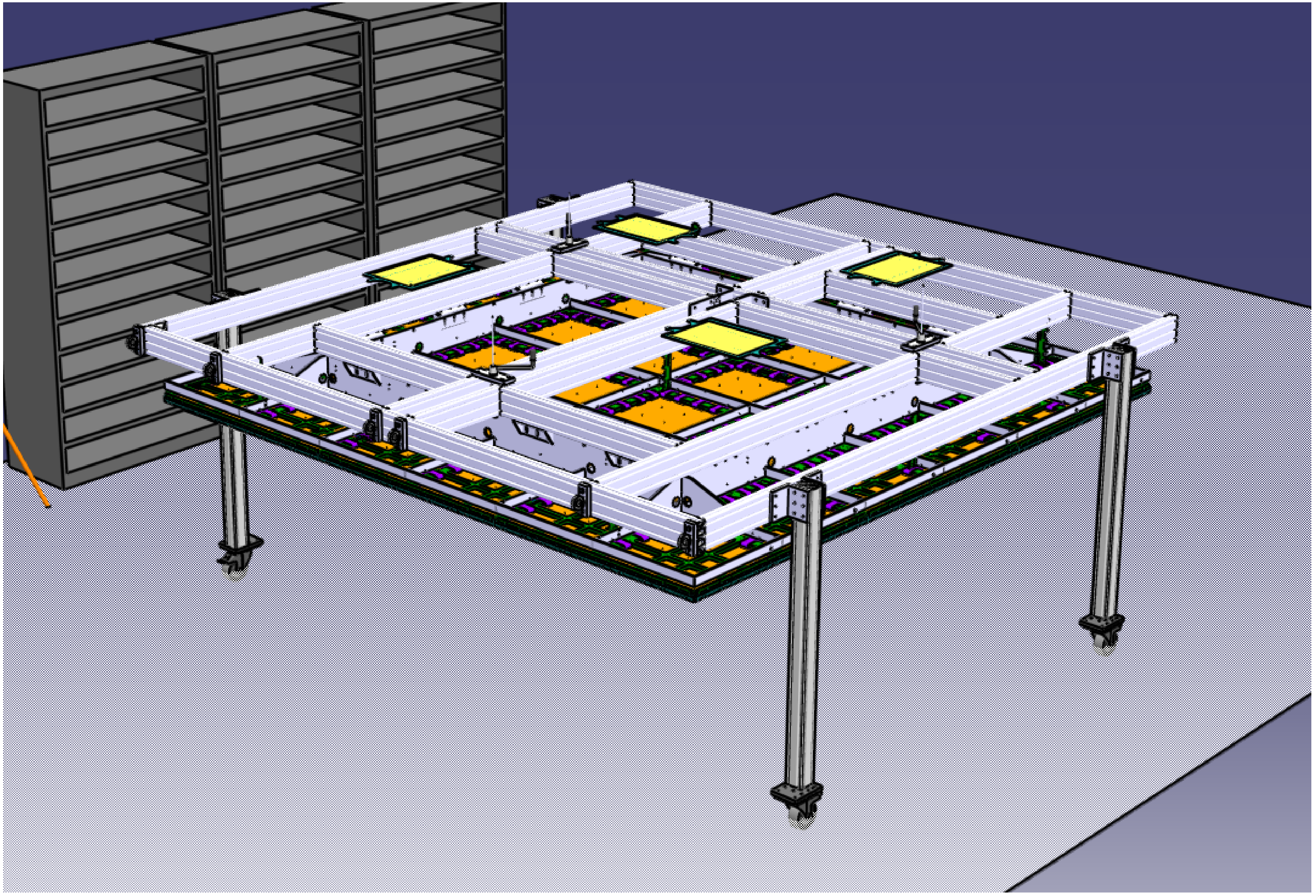
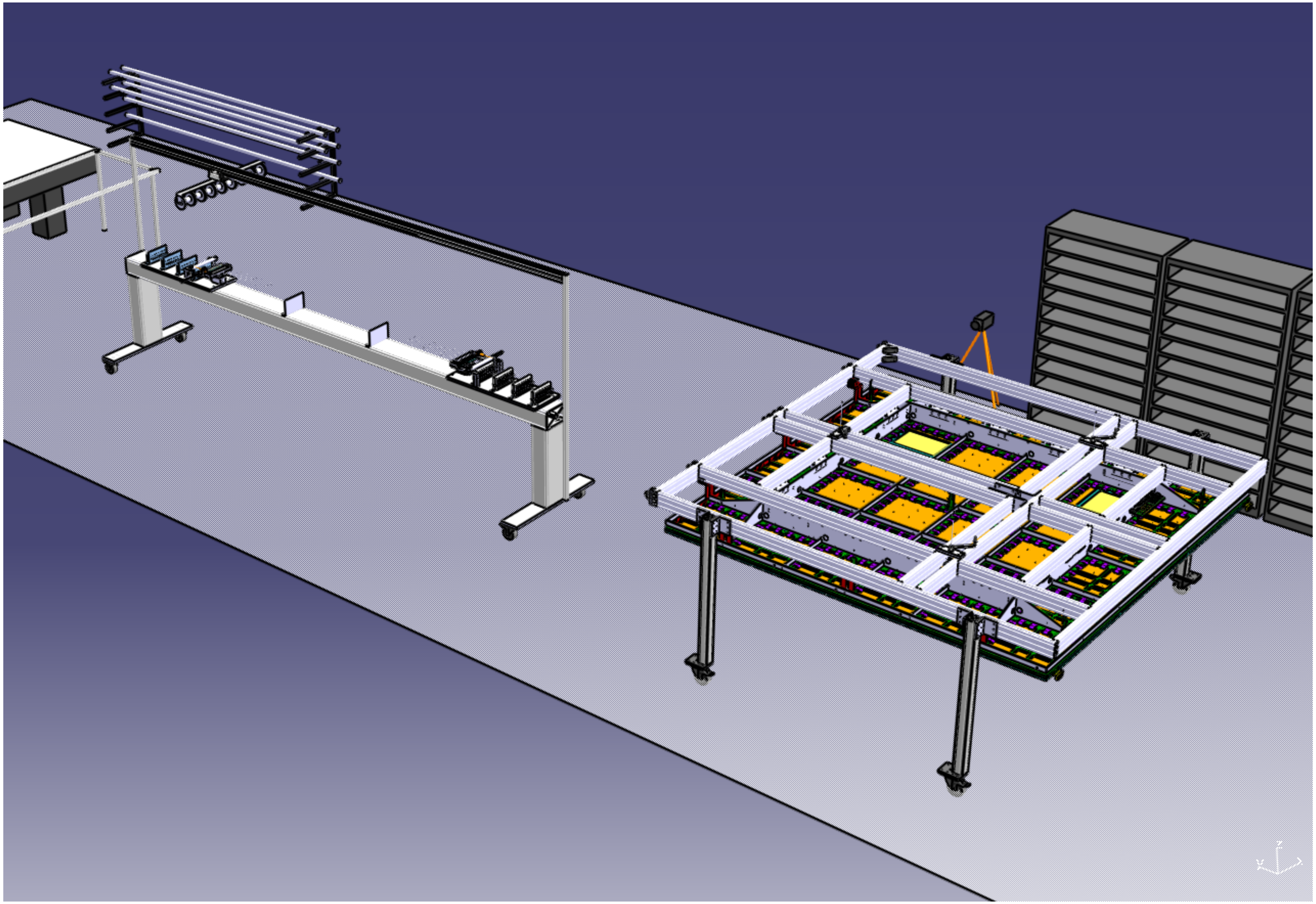
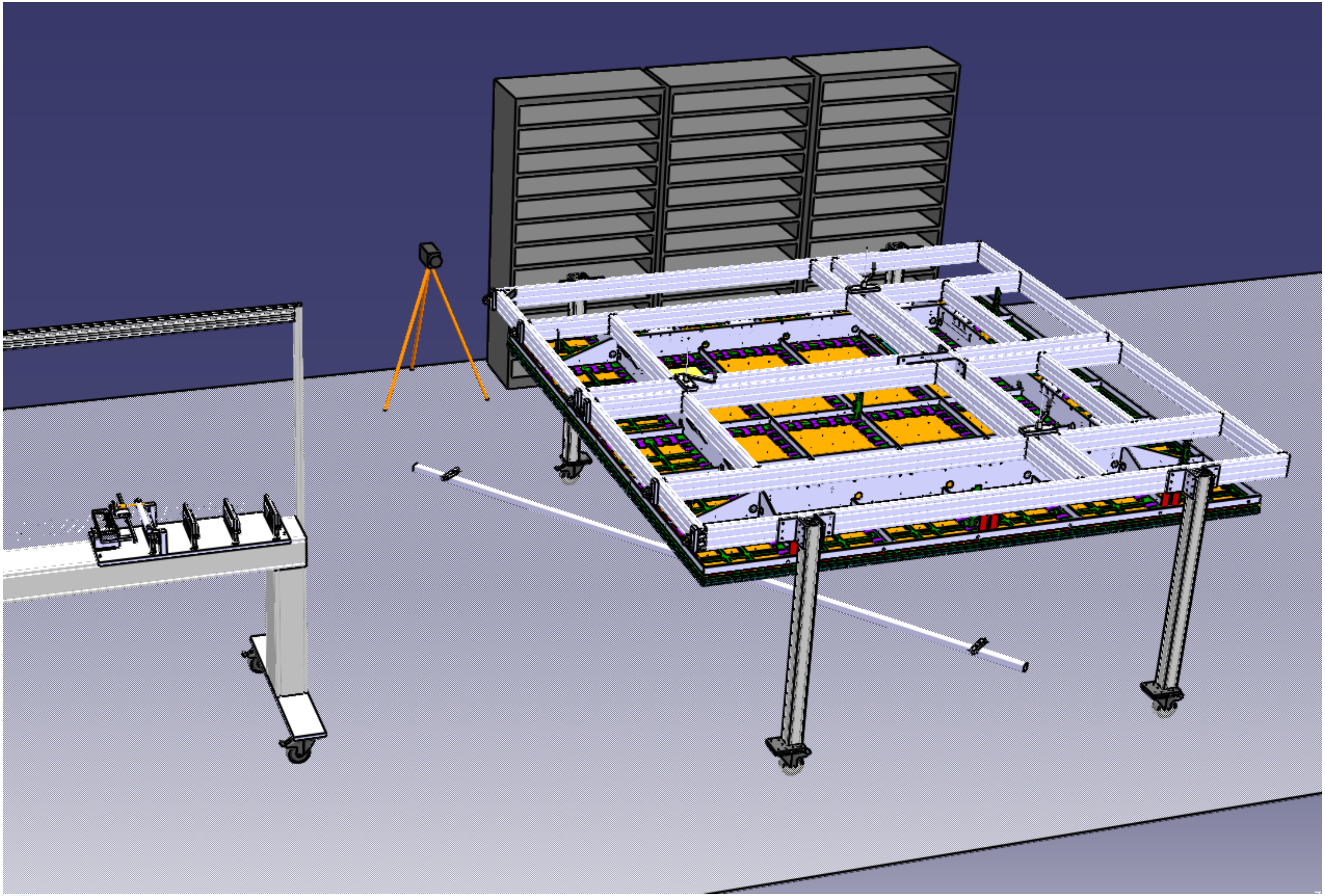


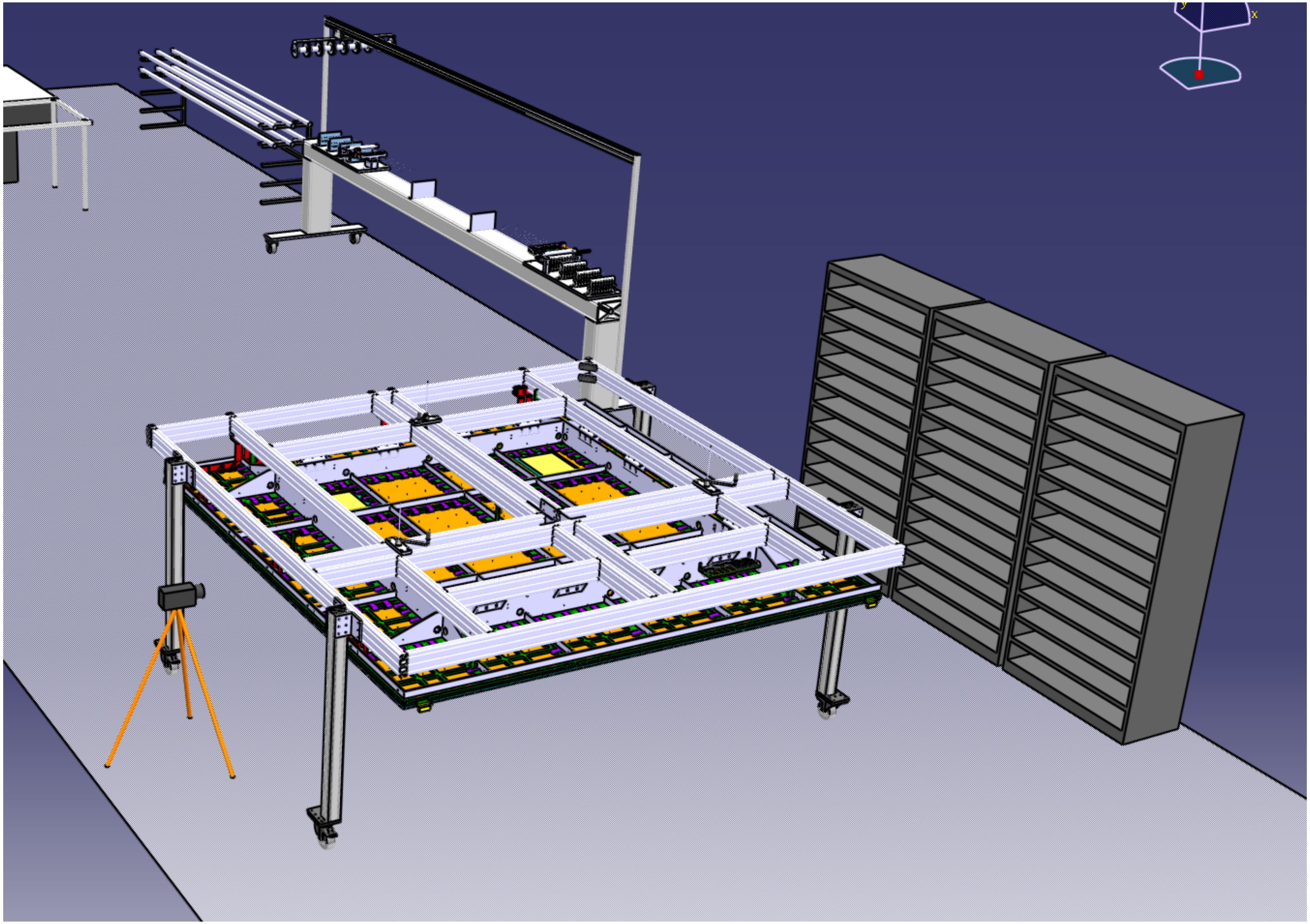
CRP Assembly



CRP Assembly



CRP Assembly



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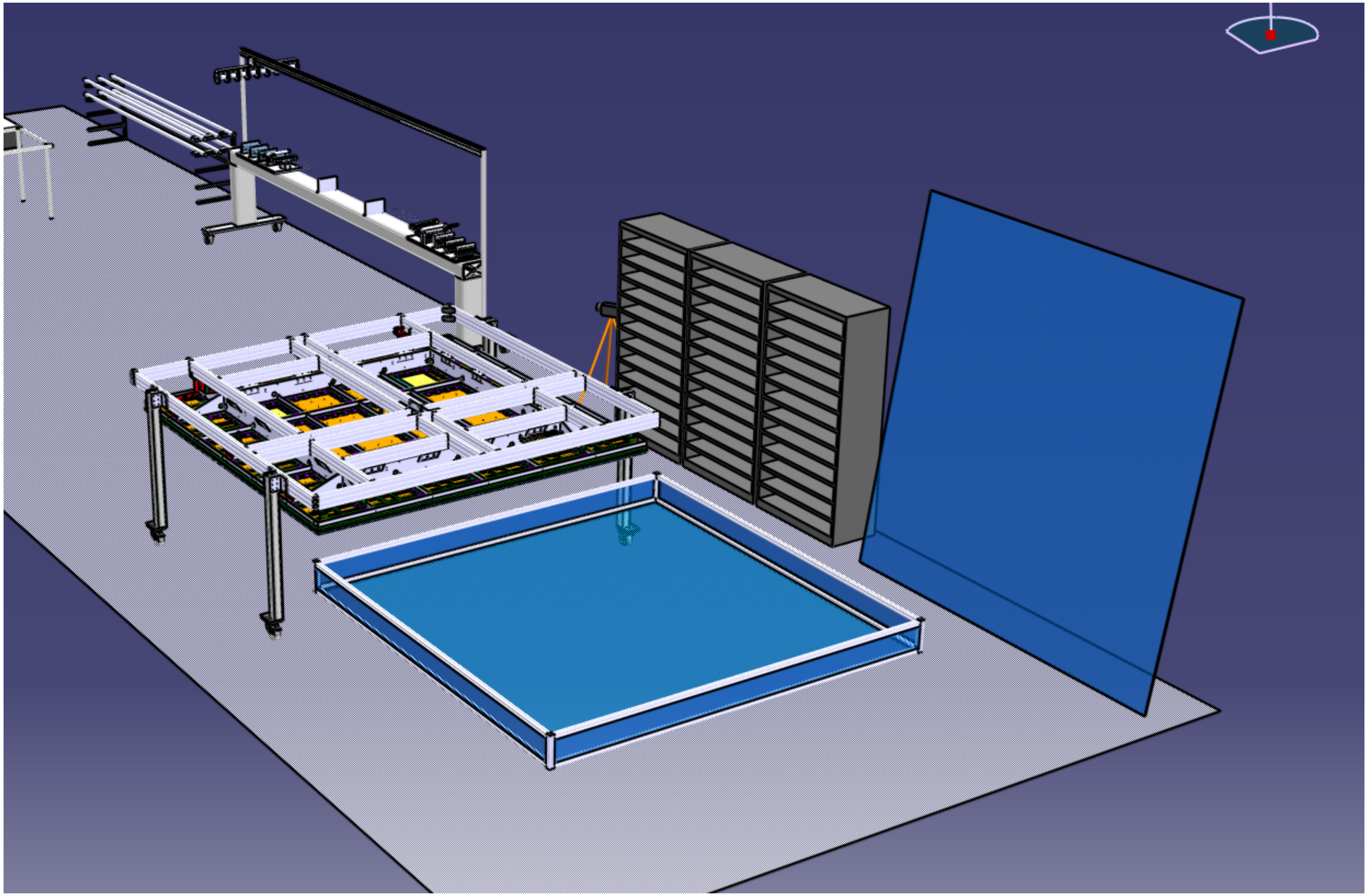
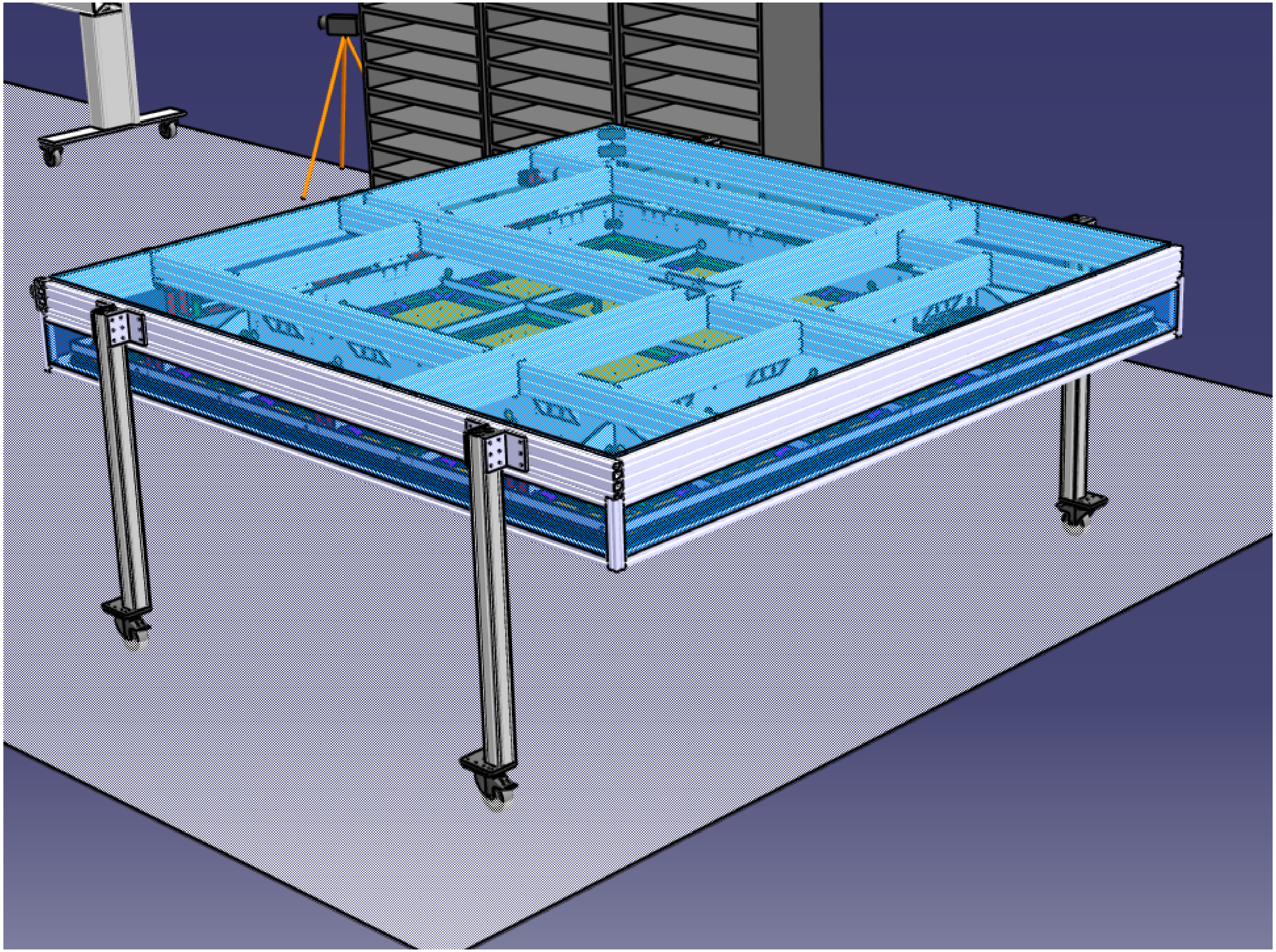
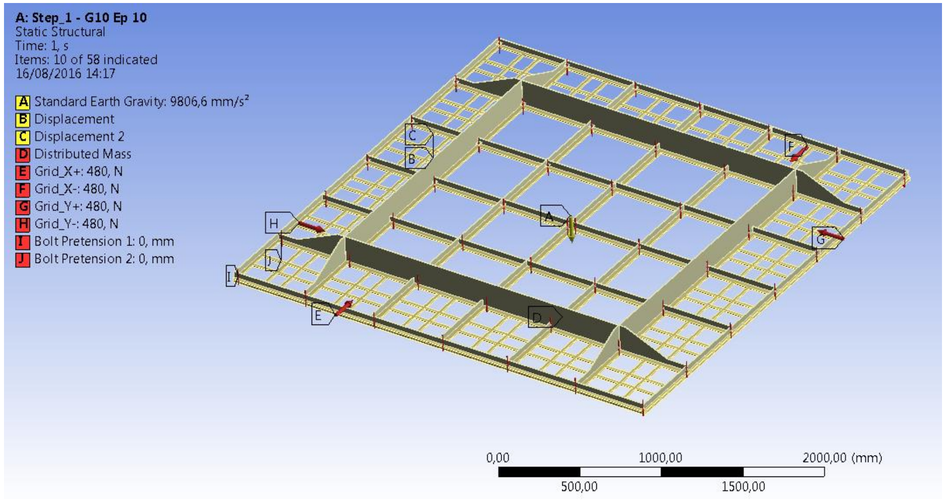


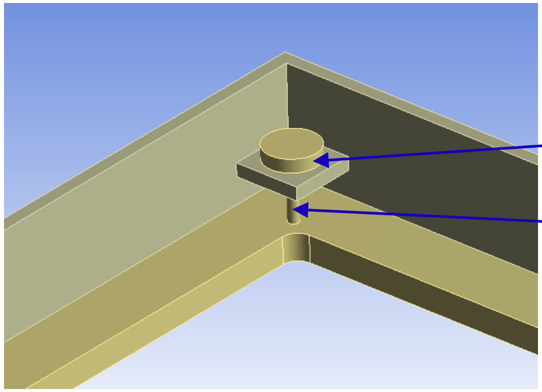
CRP Assembly



CRP Planarity and wires tension modeling

Initial geometry





Contact

Adjustable length for planarity tuning

Added Mass (for LEMs and electronic) : **150 kg**

INVAR Frame :

- ***H = 150 mm***
- ***h = 40 mm***
- ***Ep = 5 mm***
- ***Frame mass : 112,3 kg***

G10 Frame :

- ***Thickness = 15 mm***
- ***Frame mass : 67,7 kg***

Material properties

- ***Invar properties :***

  - E = 139.000 MPa minimum (around -150°C)
  - ν = 0,228
  - ρ = 8125 kg/m^3
  - α = 1,5.10^{-6} K^{-1} between 22°C and -186°C

- ***G10 properties :***

  - Isostatic
  - E = 24.000 MPa minimum (around -150°C)
  - ν = 0,11
  - ρ = 1850 kg/m^3
  - α = 8.10^{-6} K^{-1} between 22°C and -186°C

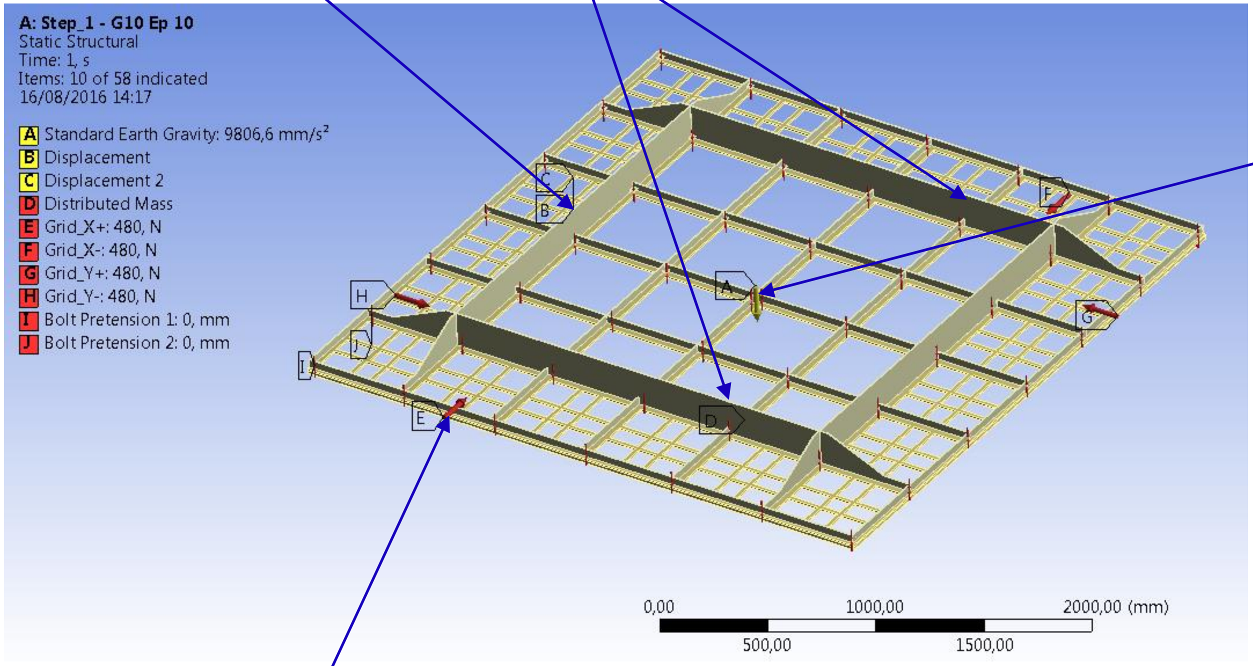
- ***Stainless Steel properties (Extraction grid) :***

  - E = 210.000 MPa minimum (around -150°C)
  - α = 1,36.10^{-5} K^{-1} between 22°C and -186°C
  - Cables diameter : 0,1mm
  - Cable stiffness : 0,5498 N/mm

Initial geometry

X, Y and Z locking

Z locking



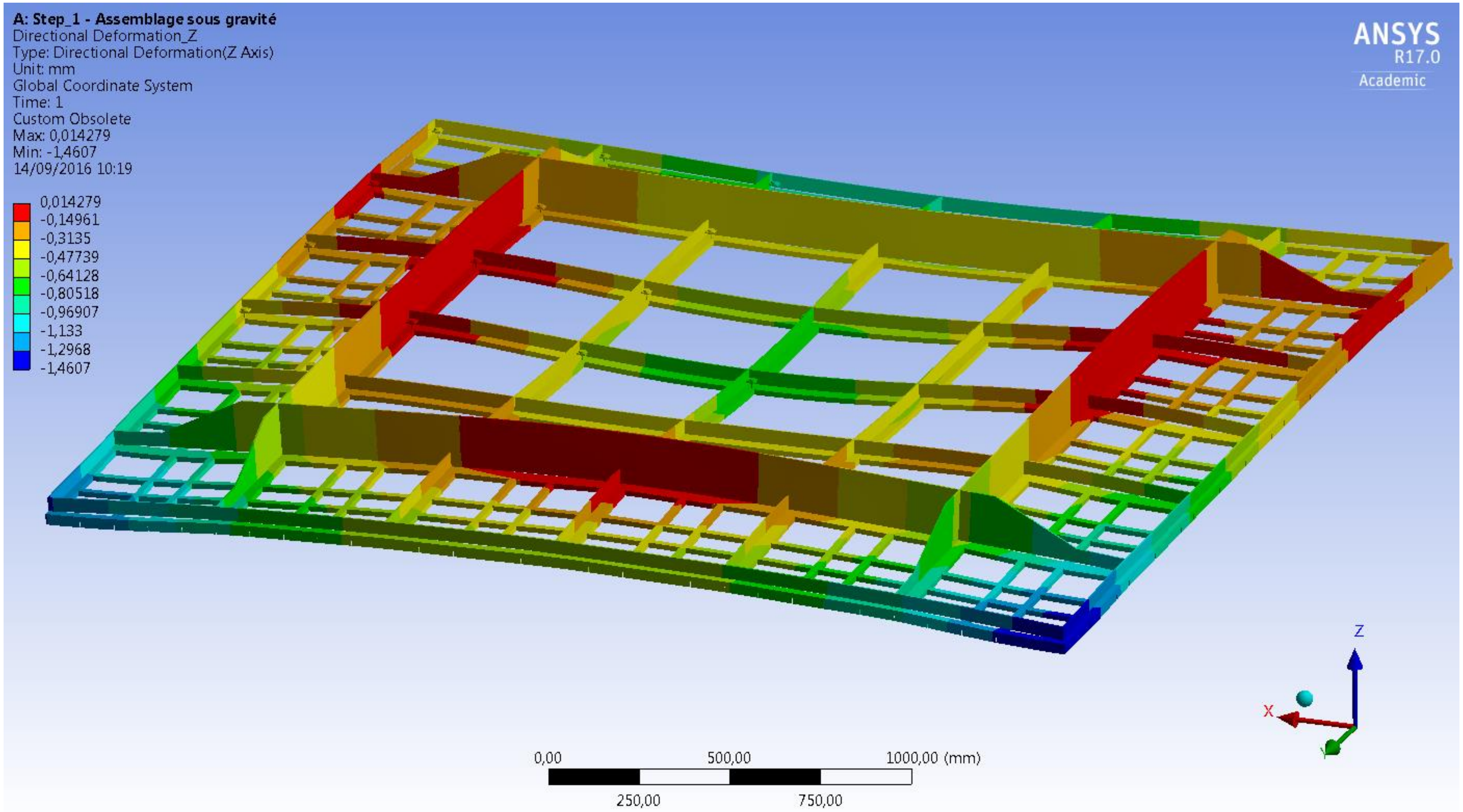
G10 and Invar locked on this point

All other links are only locking Z relative displacements

All link length can be adjusted for planarity tuning

Grid wires as springs (along each side of the module)

Step 1 : Module assembled, warm conditions, no tuning



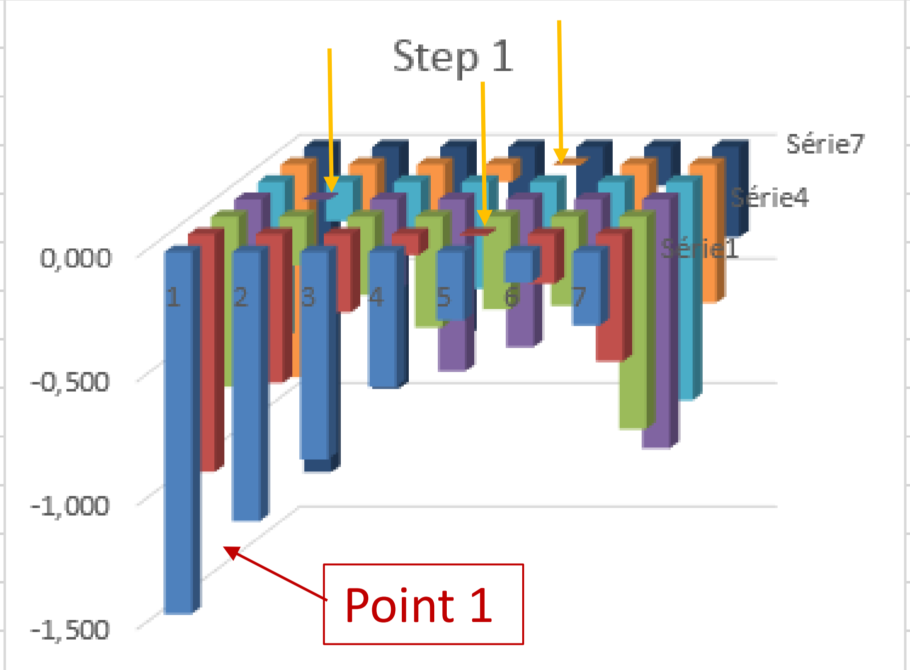
Loading case :

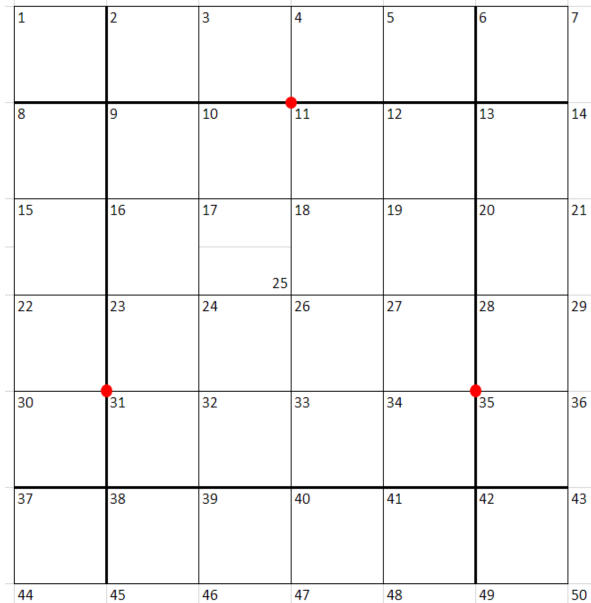
- Gravity
- No Grid tension : grid installed but not thermaly tightened

G10 Planarity results for step 1 – Tension init 1 mm

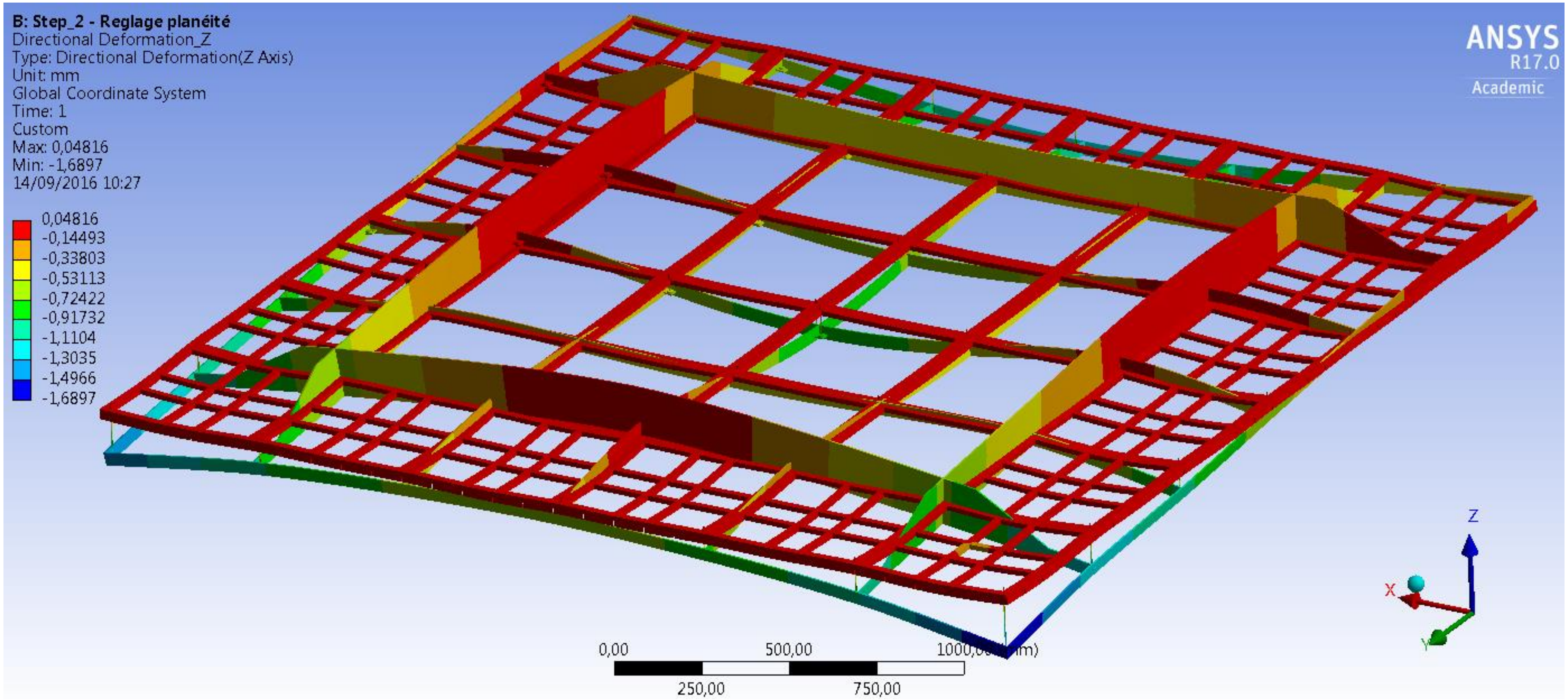
-1,460	-1,086	-0,837	-0,544	-0,276	-0,122	-0,297
-0,957	-0,598	-0,314	-0,083	-0,005	-0,198	-0,512
-0,685	-0,194	-0,315	-0,445	-0,372	-0,358	-0,855
-0,570	-0,002	-0,370	-0,693	-0,596	-0,433	-1,004
-0,635	-0,158	-0,291	-0,432	-0,372	-0,370	-0,880
-0,858	-0,524	-0,265	-0,070	-0,004	-0,221	-0,559
-1,312	-0,975	-0,764	-0,525	-0,273	-0,156	-0,365

Mini	-1,460
Maxi	-0,002
Delta	1,458





Step 2 : Module assembled, warm conditions, Planarity tuned



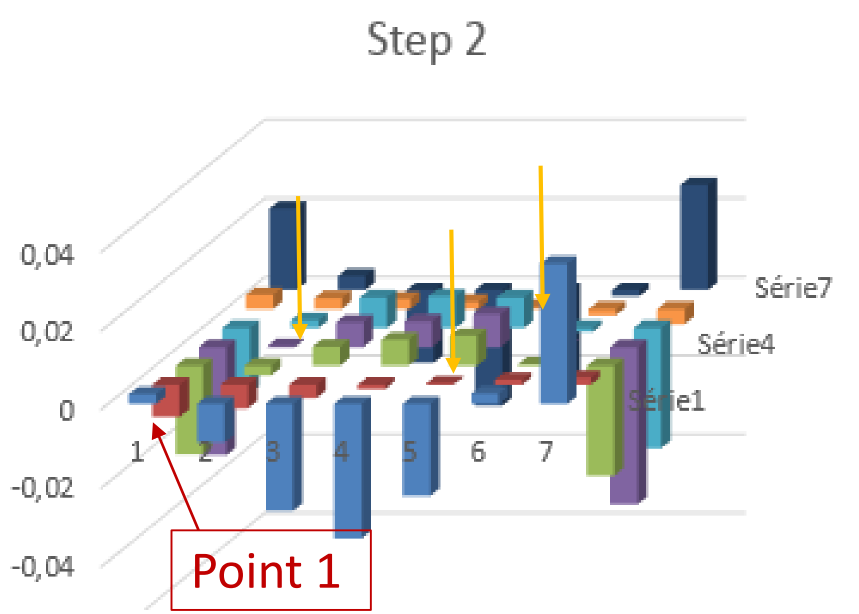
Loading case :

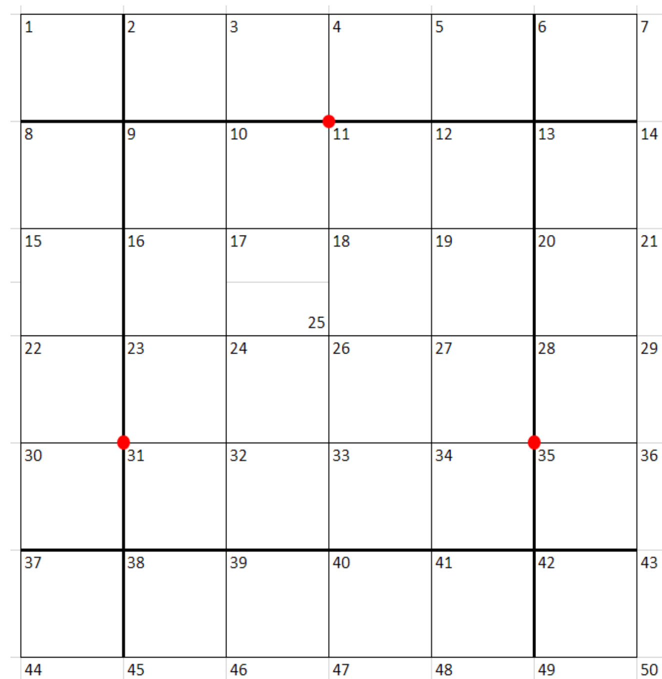
- Gravity
- No Grid tension : grid installed but not thermaly tightened
- Planarity tuning

G10 Planarity results for step 2 (2nd tuning iteration) – Tension init 1 mm

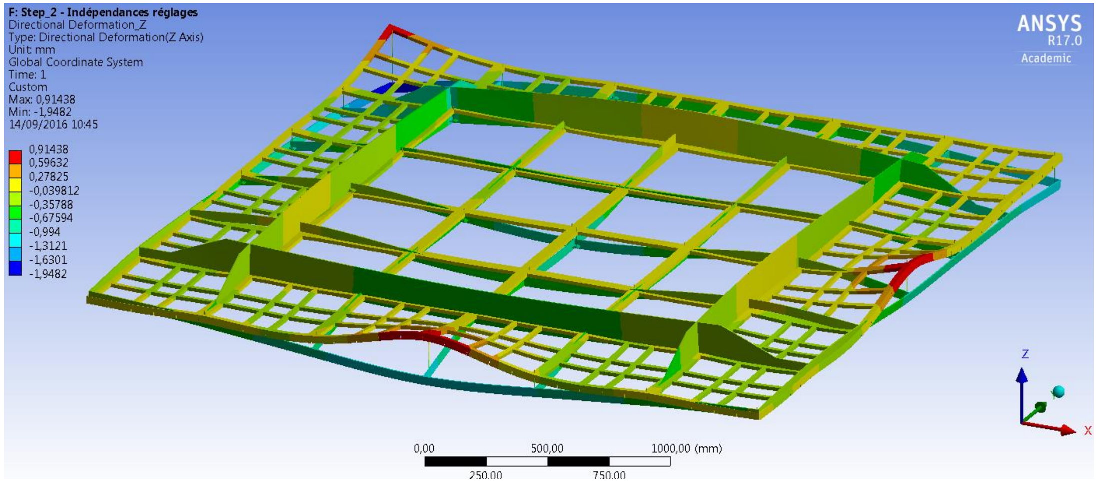
0,0025	-0,01	-0,027	-0,034	-0,023	0,0027	0,0357
-0,008	-0,006	-0,003	-0,001	0,0004	0,0013	0,0018
-0,022	-0,002	0,0049	0,0067	0,0076	0,0004	-0,028
-0,027	0,0003	0,0063	0,0065	0,0083	-3E-04	-0,04
-0,017	0,0019	0,0077	0,008	0,0077	-0,001	-0,031
0,0036	0,0028	0,0025	0,0018	0,0005	-0,002	-0,004
0,0207	0,0035	-0,018	-0,029	-0,023	-0,002	0,0267

Mini	**-0,040**
Maxi	**0,036**
Delta	**0,076**

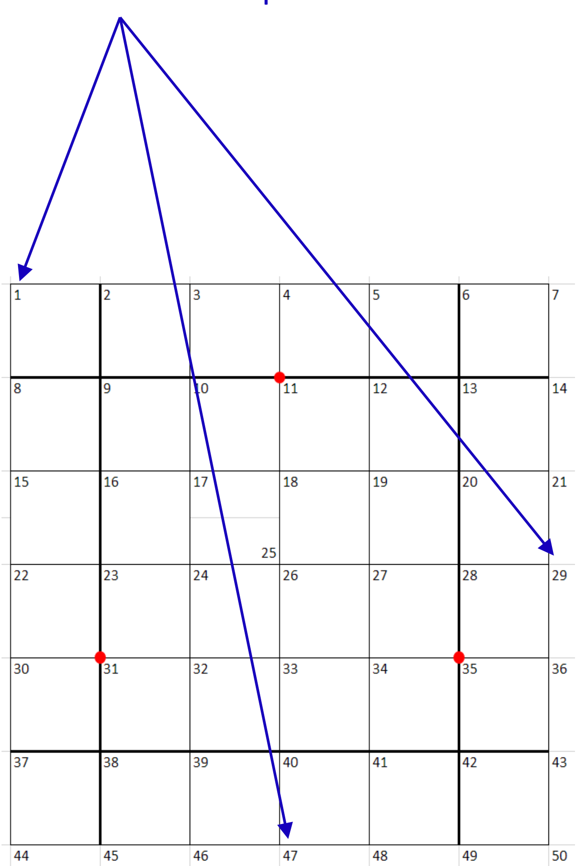




Planarity tuning independency



+1mm on those points



Loading case :

- Gravity
- No Grid tension : grid installed but not thermaly tightened
- Planarity tuning

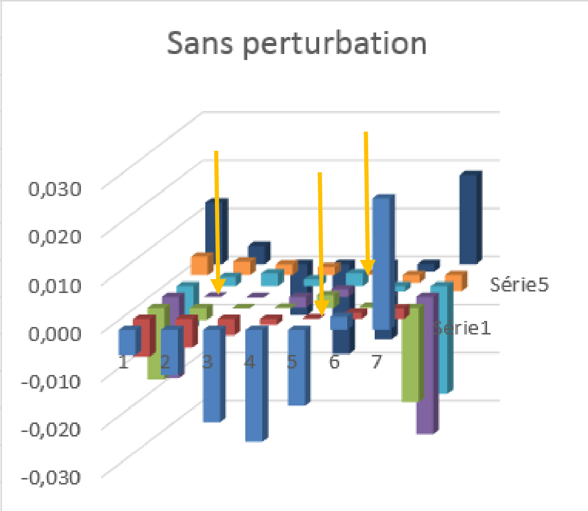
- +1mm perturbations on points 1 - 29 - 47

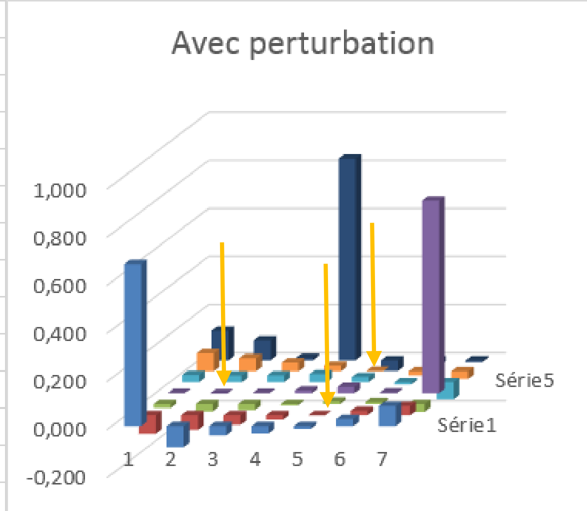
Planarity tuning independency

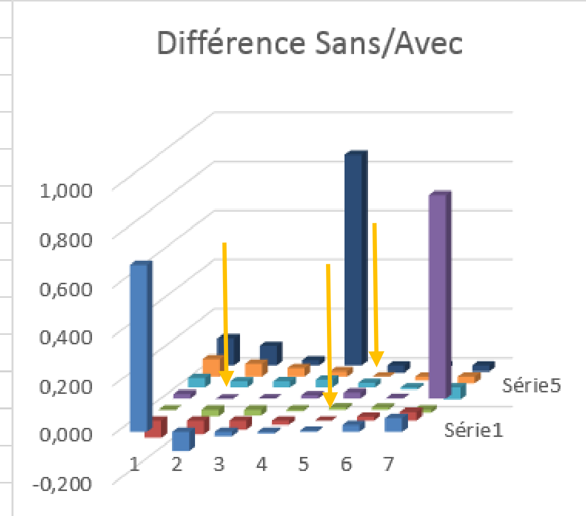
-0,005	-0,009	-0,019	-0,023	-0,016	0,003	0,027
-0,008	-0,006	-0,003	-0,001	0,000	0,001	0,002
-0,015	-0,003	0,000	0,000	0,003	0,000	-0,020
-0,017	0,000	0,000	-0,002	0,002	-0,001	-0,029
-0,009	0,002	0,003	0,001	0,003	-0,001	-0,022
0,004	0,003	0,002	0,002	0,000	-0,002	-0,003
0,013	0,004	-0,011	-0,019	-0,016	-0,002	0,019

0,674	-0,088	-0,038	-0,030	-0,011	0,029	0,083
-0,078	-0,061	-0,040	-0,018	0,000	0,018	0,038
-0,016	-0,030	-0,024	-0,006	0,011	0,008	-0,032
0,001	-0,001	0,001	0,011	0,026	0,003	0,801
0,030	0,028	0,028	0,034	0,022	-0,009	-0,071
0,075	0,054	0,036	0,023	0,001	-0,017	-0,032
0,123	0,083	0,011	0,839	-0,045	-0,021	-0,007

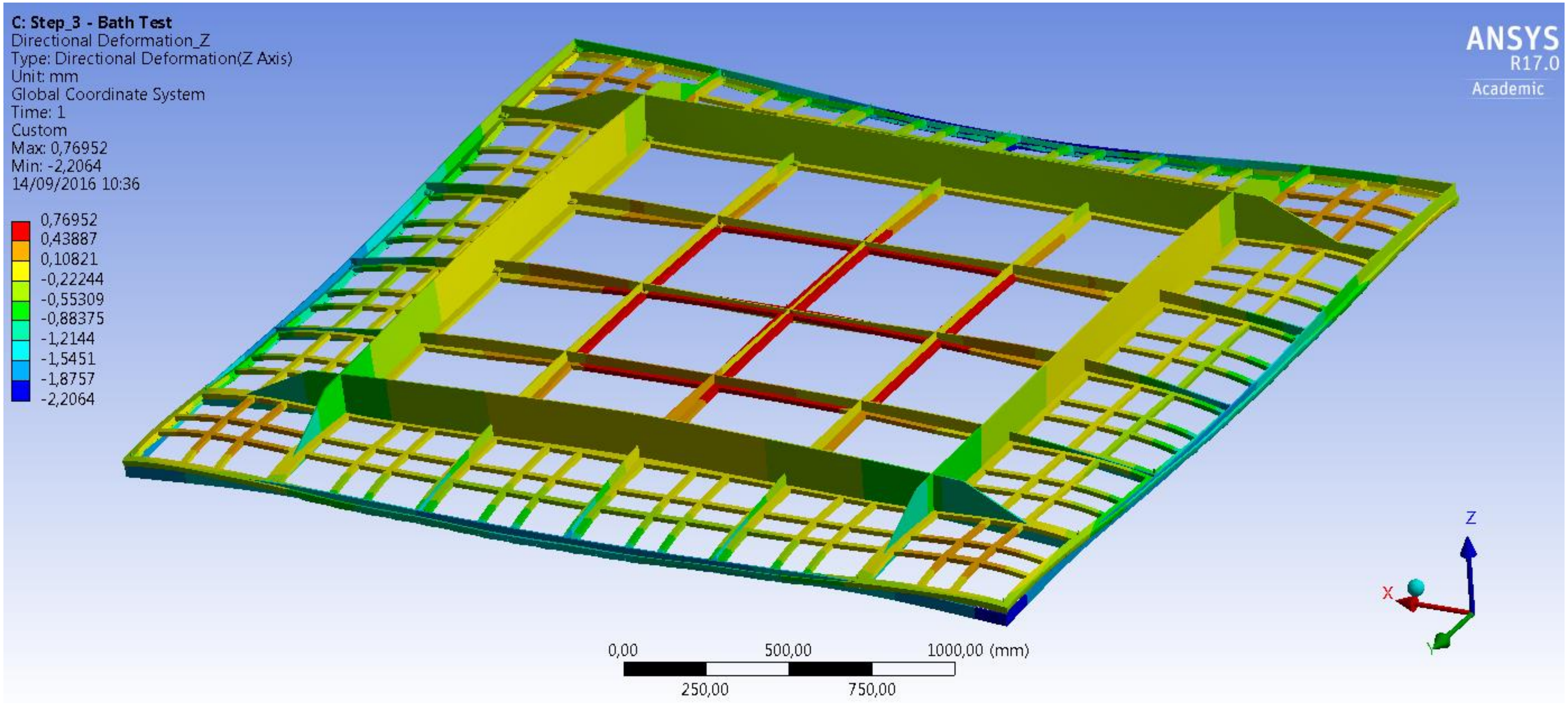
0,679	-0,078	-0,019	-0,007	0,005	0,027	0,056
-0,070	-0,055	-0,036	-0,017	-0,001	0,016	0,035
-0,001	-0,027	-0,024	-0,006	0,009	0,008	-0,013
0,018	-0,001	0,001	0,013	0,024	0,003	0,829
0,040	0,026	0,026	0,032	0,019	-0,008	-0,049
0,071	0,052	0,034	0,022	0,001	-0,016	-0,028
0,110	0,080	0,021	0,858	-0,029	-0,019	-0,026







Step 3 : Module assembled, warm conditions, maxi grid tension



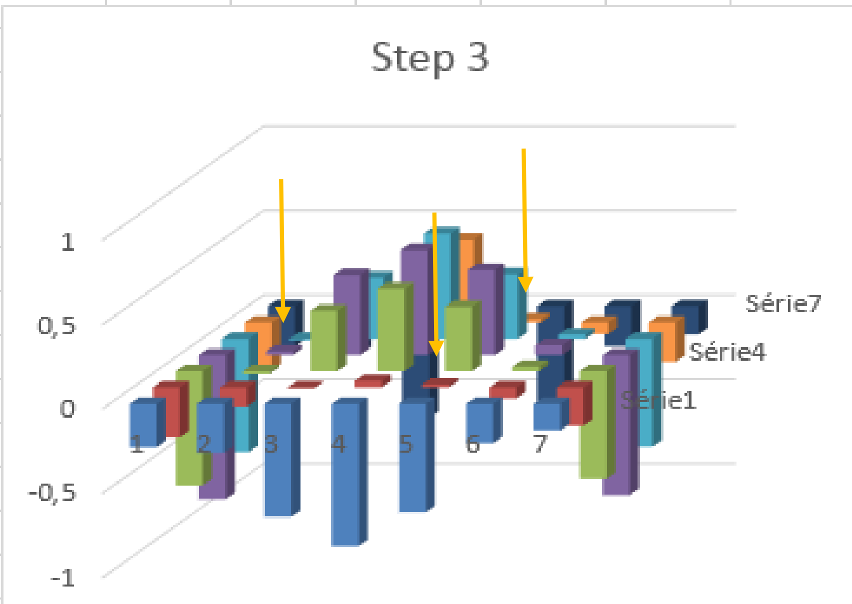
Loading case :

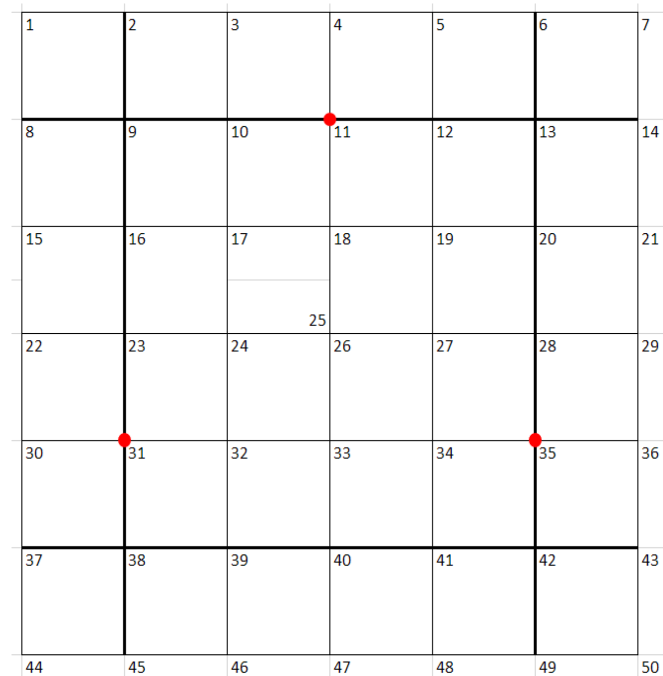
- Gravity
- Grid tension : -10,51mm (thermal contraction with alpha=1,7e-5) – tension measured ~ 5,3N/cable
- Planarity tuning from Step 2

G10 Planarity results for step 3 – Tension Init 1 mm

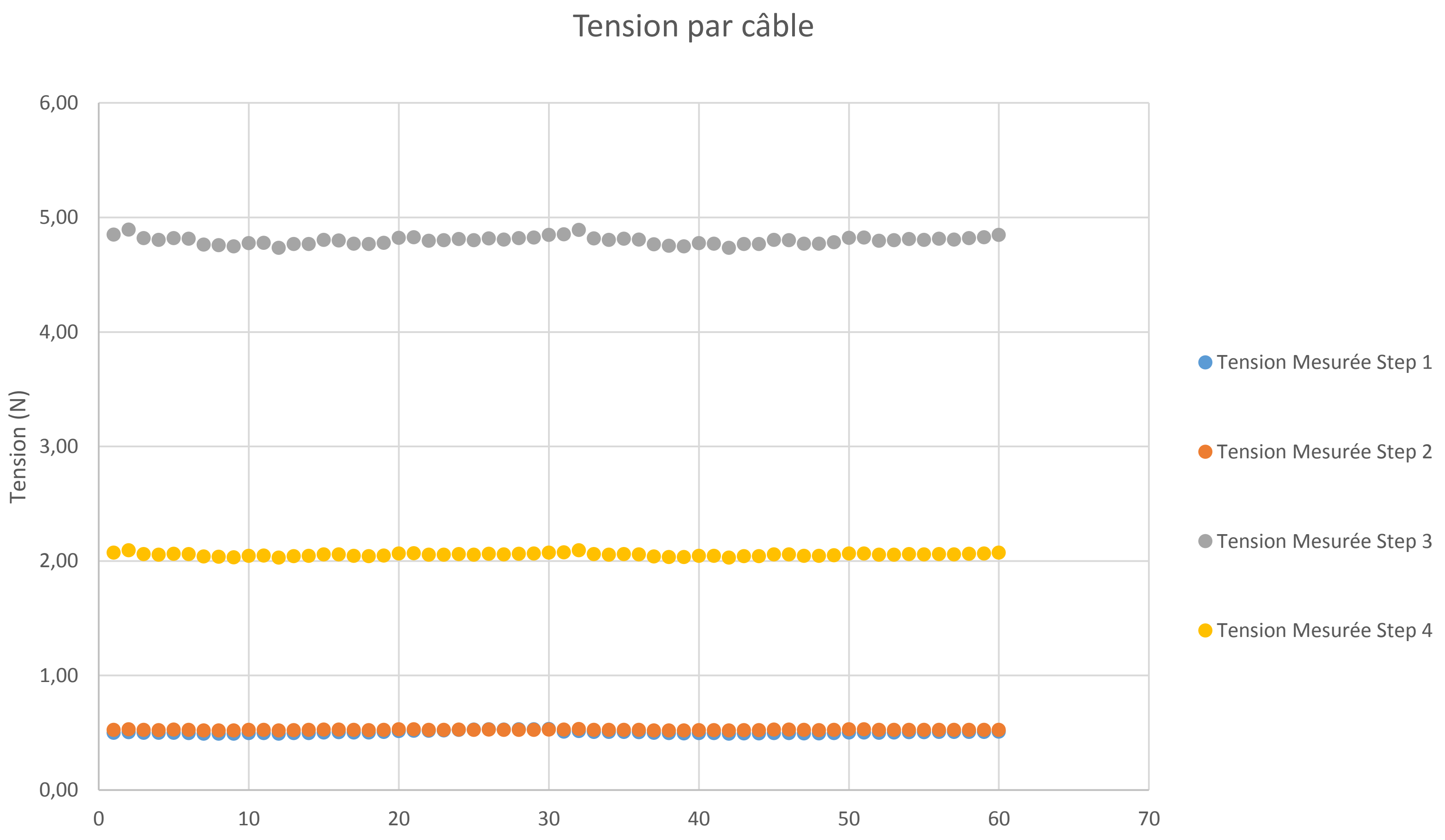
-0,257	-0,289	-0,67	-0,843	-0,642	-0,233	-0,157
-0,296	-0,113	-0,005	0,0411	0,0182	-0,064	-0,226
-0,677	-0,014	0,3588	0,49	0,3826	0,0273	-0,636
-0,855	0,0221	0,4745	0,622	0,5042	0,0599	-0,831
-0,671	-0,009	0,3619	0,6229	0,3828	0,0258	-0,641
-0,284	-0,103	0,0009	0,491	0,0183	-0,068	-0,233
-0,238	-0,276	-0,662	0,0435	-0,642	-0,238	-0,166

Mini	-0,855
Maxi	0,623
Delta	1,478



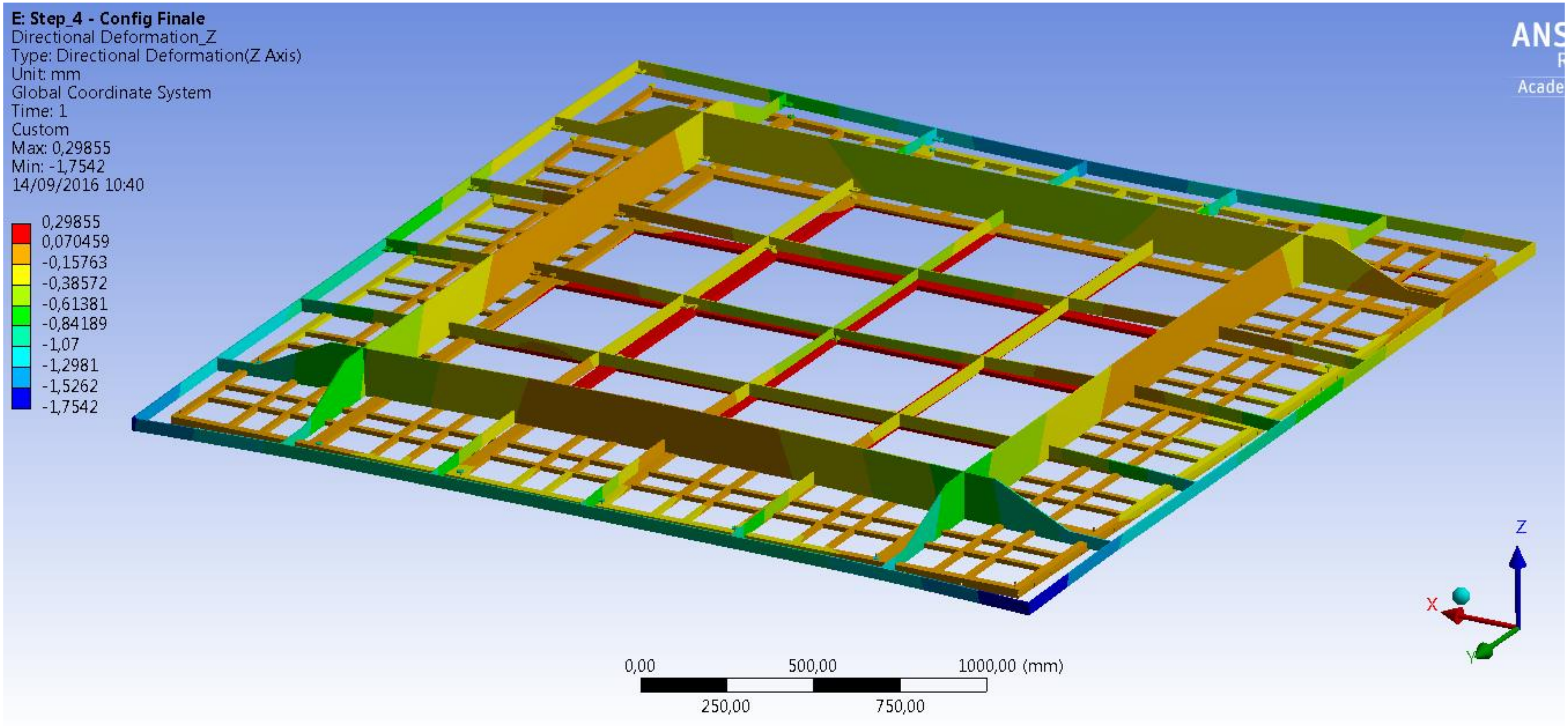


Tension in the extraction grid – Tension Init 1 mm



No de câble
Axe X : 1-30
Axe Y : 31 -60

Step 4 : Module assembled, Cold conditions, final grid tension



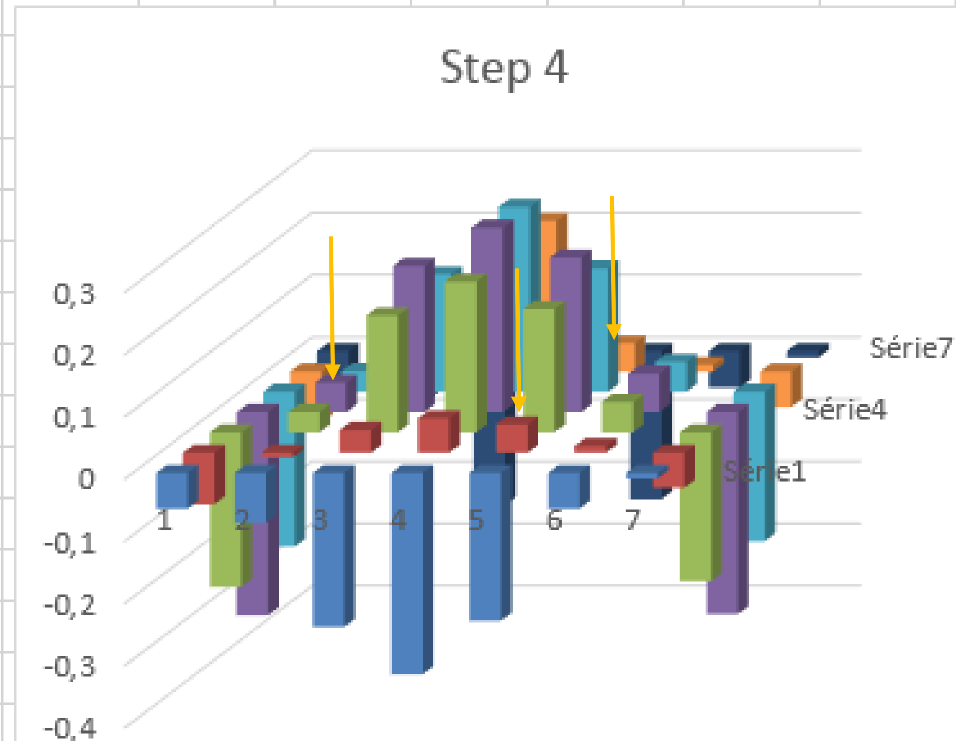
Loading case :

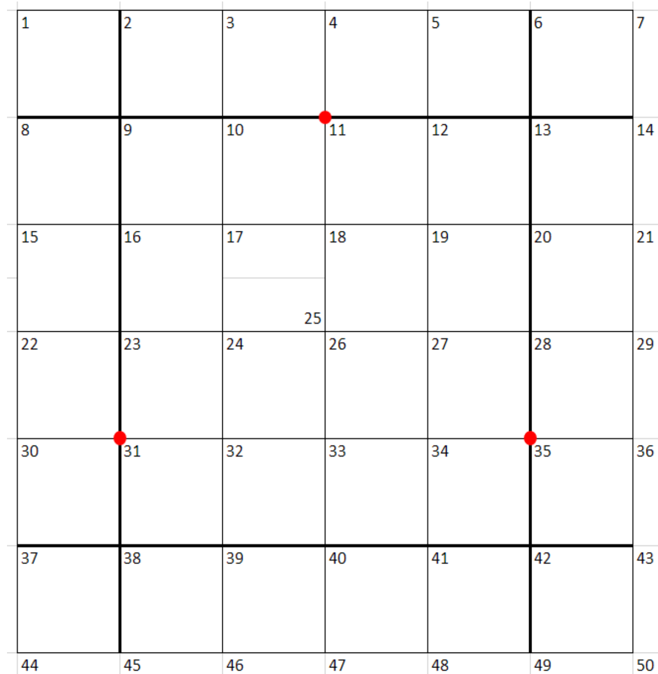
- Gravity
- Grid tension : -10,51mm (thermal contraction with alpha=1,7e-5) – final tension measured ~ 1,5 - 1,6 N/cable
- Planarity tuning from Step 2
- Temperature : -186°C

G10 Planarity results for step 4 – Tension Init 1 mm

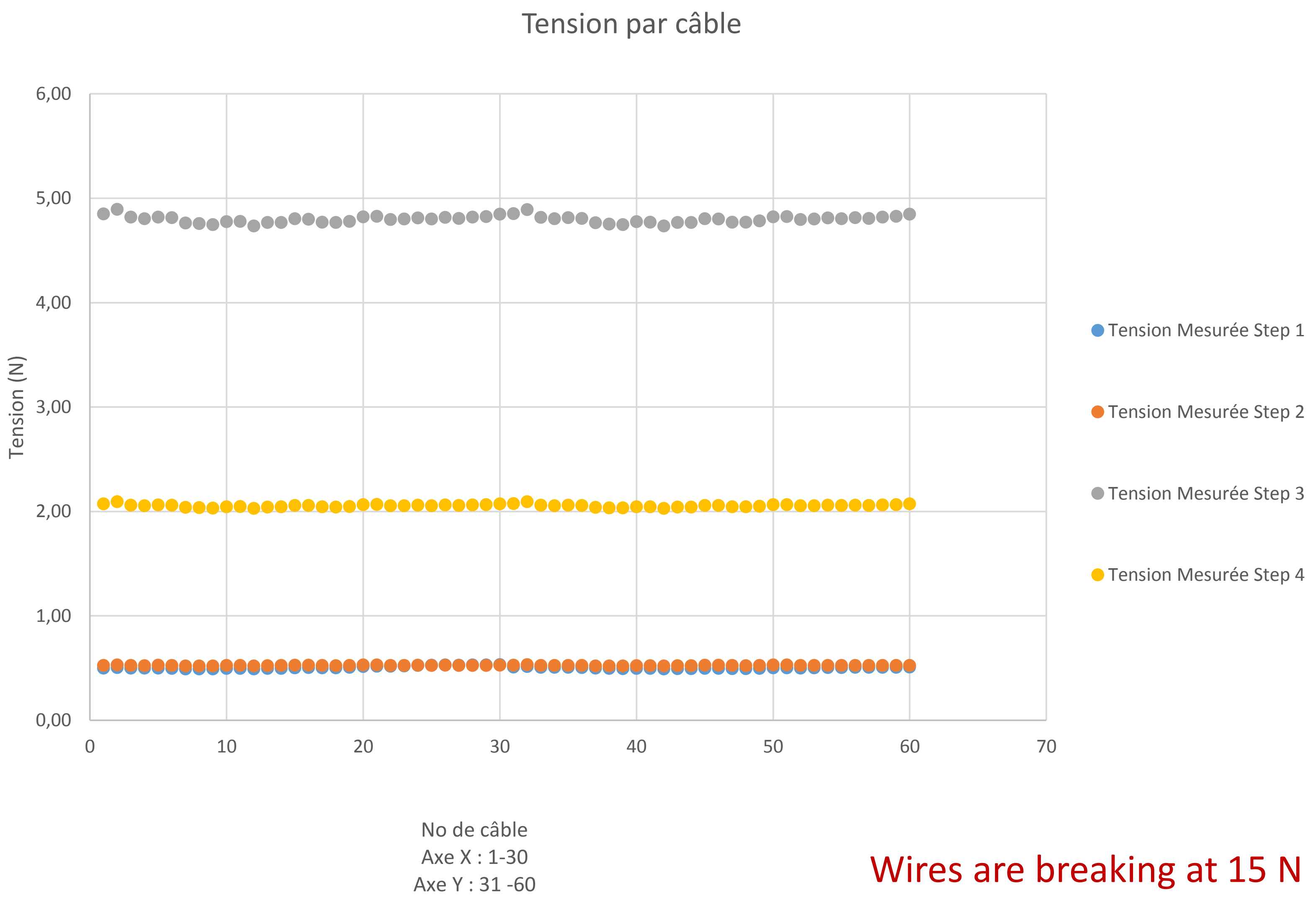
-0,058	-0,08	-0,248	-0,324	-0,238	-0,058	-0,009
-0,083	-0,008	0,0362	0,055	0,0453	0,0107	-0,056
-0,249	0,0326	0,1878	0,2422	0,1982	0,0486	-0,239
-0,327	0,047	0,2349	0,2965	0,2484	0,062	-0,325
-0,249	0,0333	0,1885	0,2969	0,1982	0,0483	-0,24
-0,082	-0,007	0,0366	0,242	0,0455	0,0103	-0,057
-0,056	-0,08	-0,248	0,0548	-0,238	-0,058	-0,01

Mini	**-0,327**
Maxi	**0,297**
Delta	**0,624**





Tension in the extraction grid for Step 3 & 4



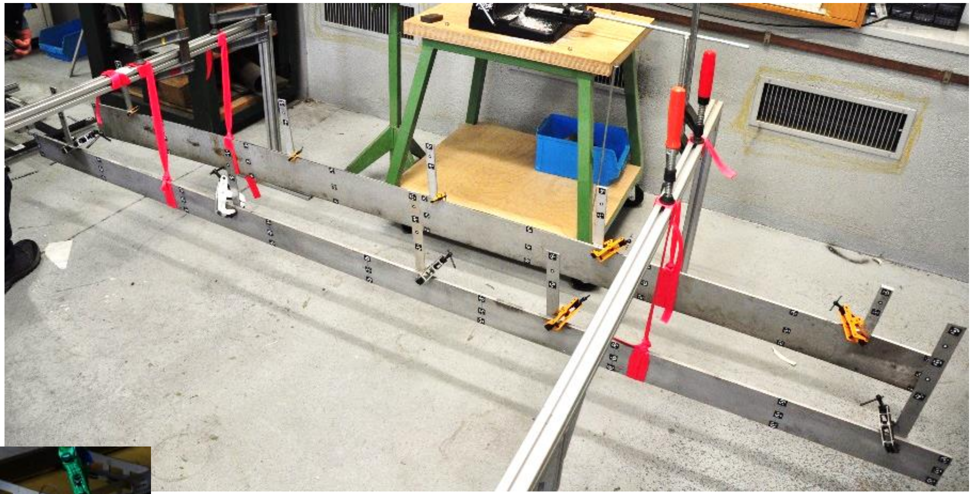
Wires are breaking at 15 N

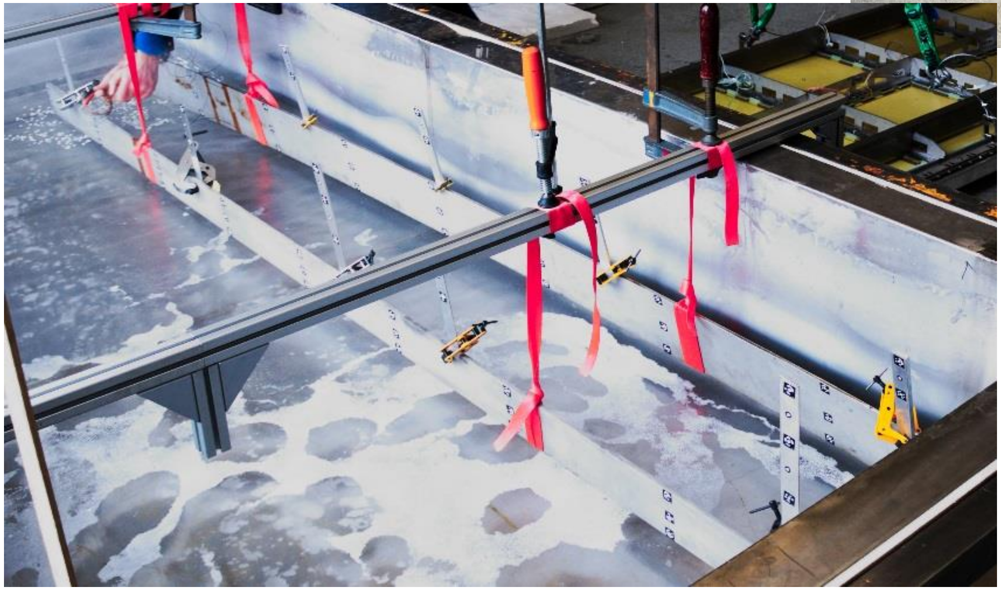
Why invar?

Thermal shrinkage *Real tests on Stainless Steel plates*

Stainless Steel plates above the 3x1 Argon bath

(Measurements by Dirk in photogrammetry)

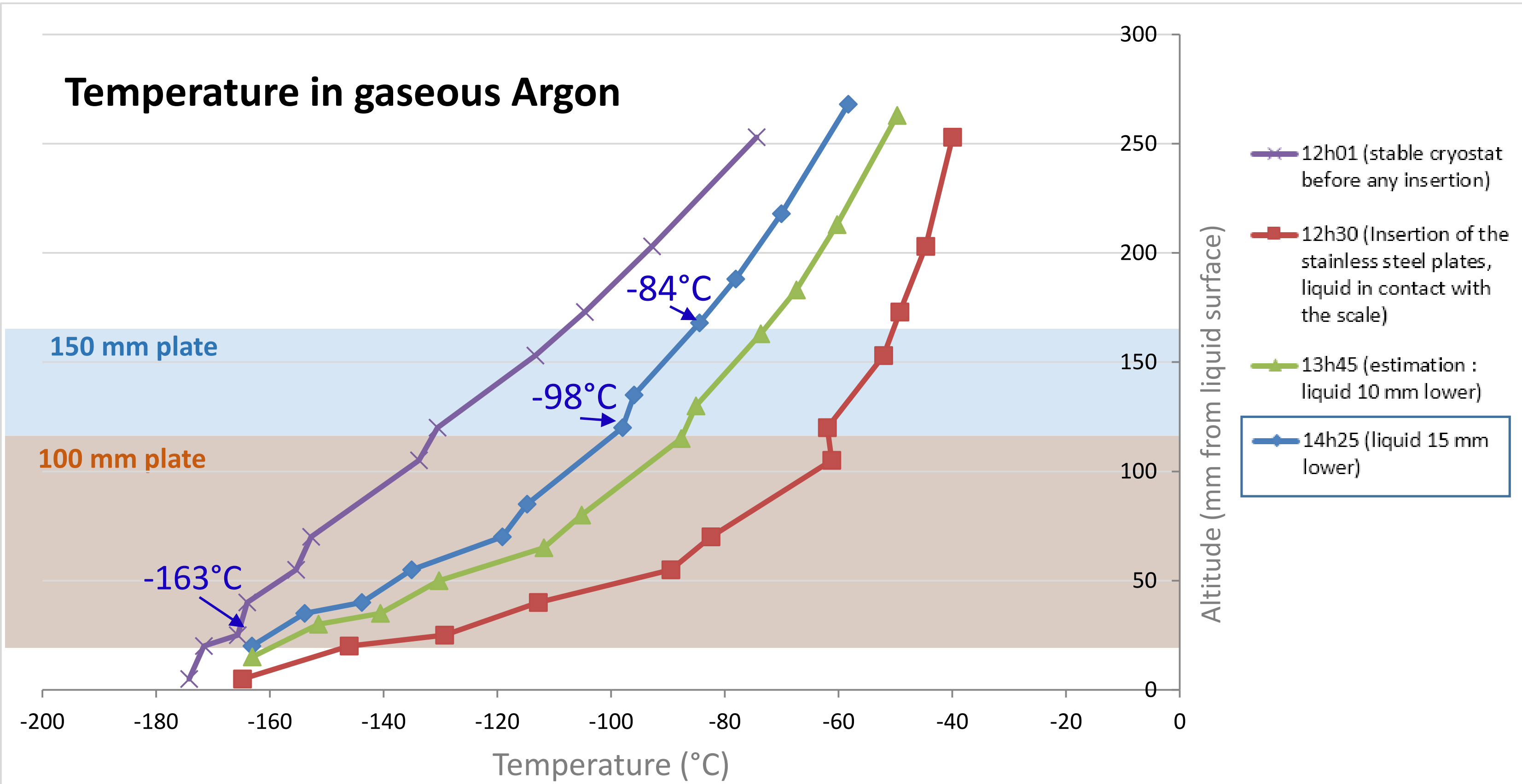




Thermal shrinkage *Temperatures in gaseous Argon*

Temperatures **in gaseous Argon** around the plates (@ 14h25) :

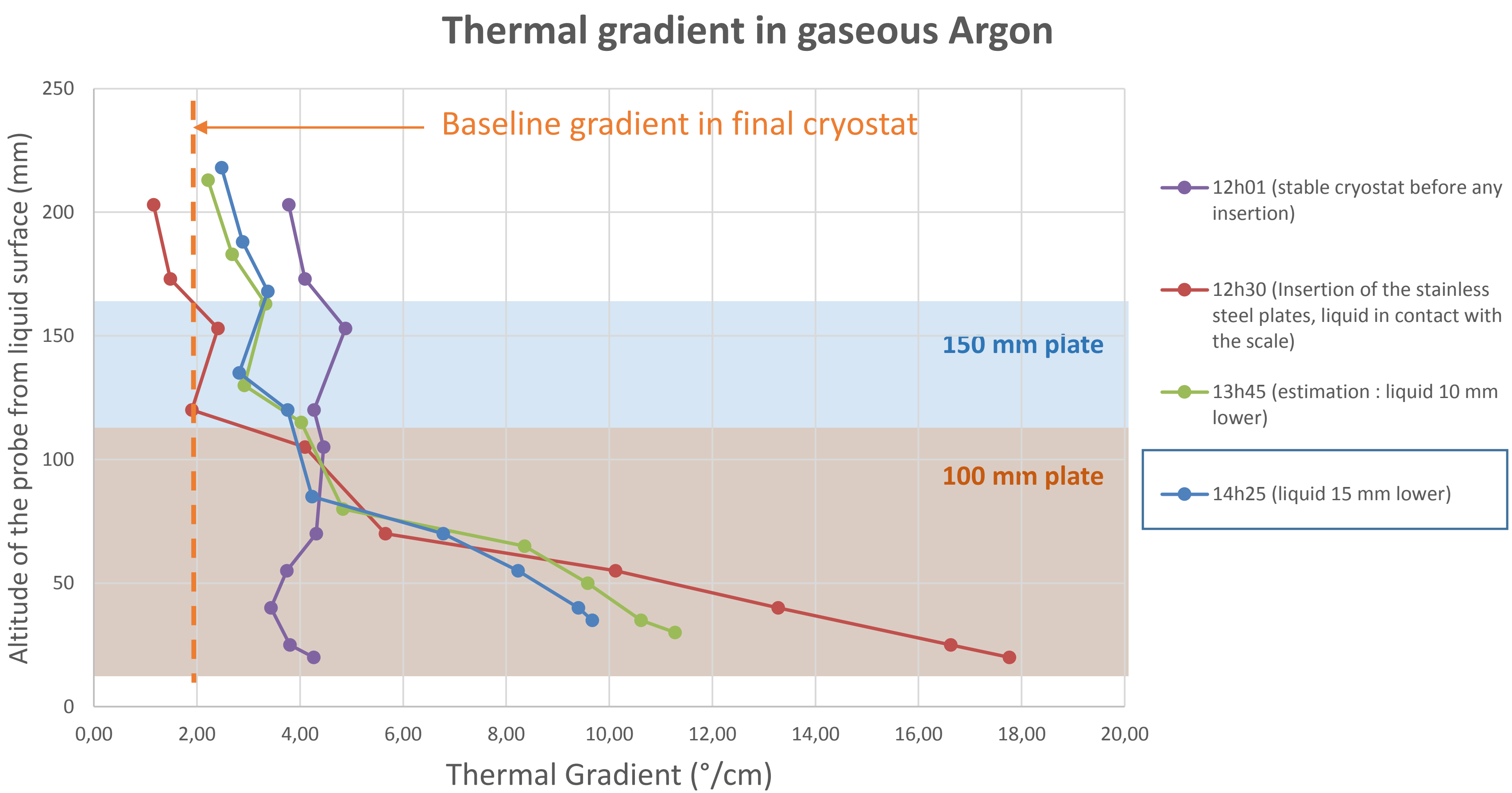
- ***100 mm plate*** **:** *Bottom = -163°C, Top = -98°C* , *ΔT : 65° (GAr)*
- ***150 mm plate :*** *Bottom = -163°C, Top = -84°C* , *ΔT : 79° (GAr)*



Thermal shrinkage *Thermal gradient in gaseous Argon*

Thermal gradient **in gaseous Argon** around the plates (@14h25):

- ***100 mm plate :*** *4 - 10 °/cm (in GAr)*
- ***150 mm plate :*** *3 - 10 °/cm (in GAr)*

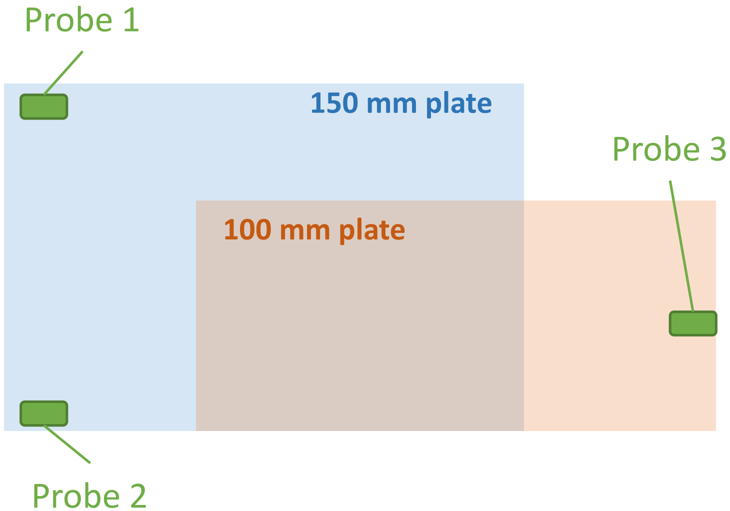


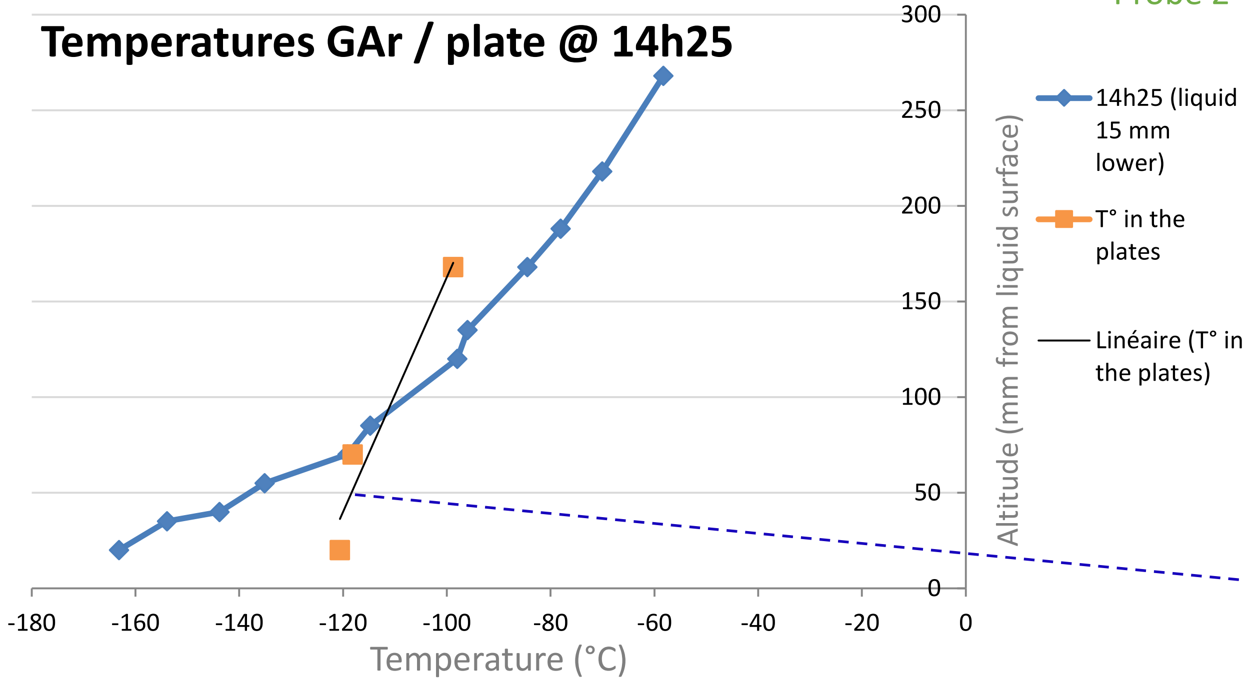
Thermal gradient in the plates

Temperatures **in the plates** (@14h25) :

(*With three PT100 probes)*

- ***Probe 1 :*** *-98,75°C*
- ***Probe 2 :*** *-120,6°C*
- ***Probe 3 :*** *-118,10°C*



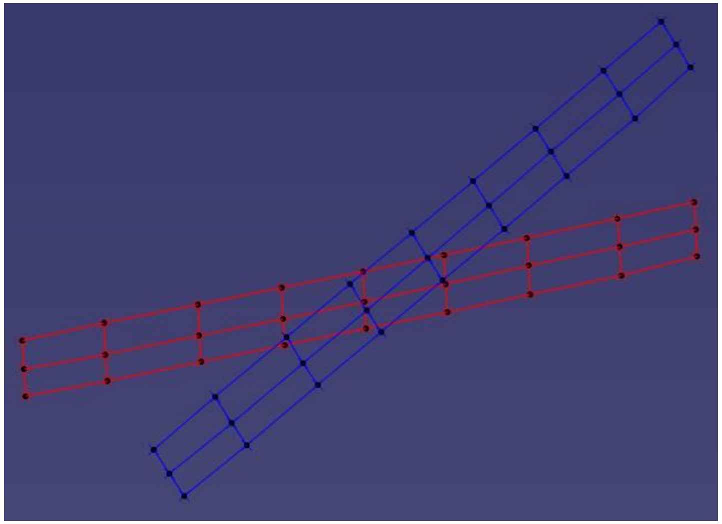


Remarks :

- Temperatures measured **on the surface of the plate**
- No special care taken to insure probe quality measurements (glueing?)

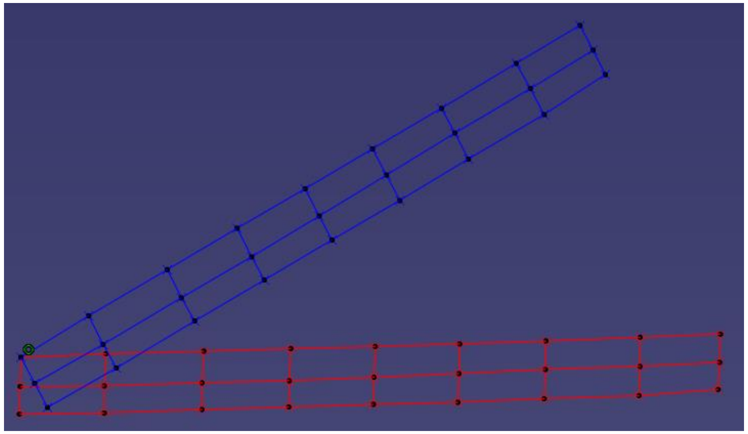
- *Average gradient in the plate : ~ 1,5°/cm*

Thermal shrinking : Photogrammetry results – Model constraints



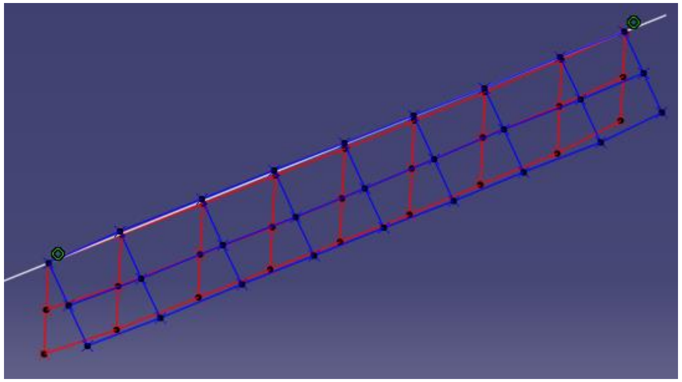
- Photogrammetry provides two clouds of points
- How to superpose clouds for measurements ?

➢ Red (warm measurement) is the reference.

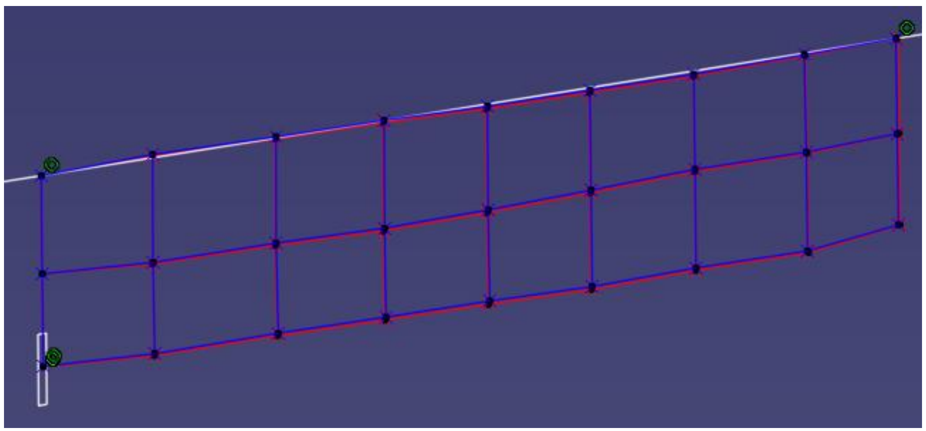


- First, a corner is fixed.

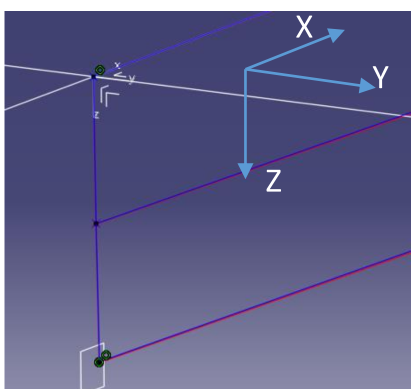
Thermal shrinking : Photogrammetry results – Model constraints



- Then, a line between upper corners

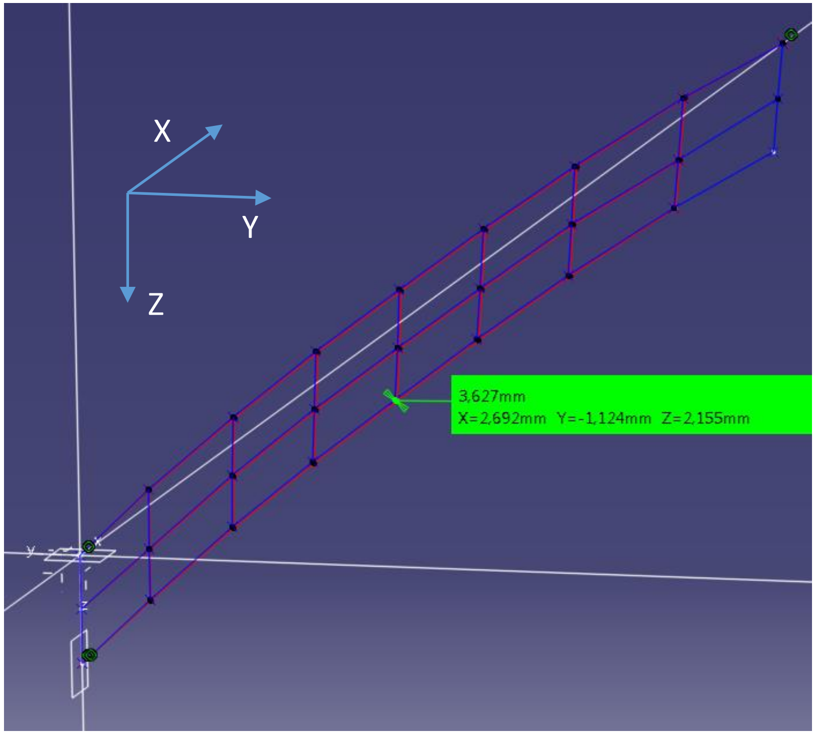


- Finally, the rotation is locked by a third point on a plane
  - *(plane defined by previous line + bottom corner point)*



- Results are given in this coordinate system

Thermal shrinking : Photogrammetry results – Large plate 150 mm



- First : The plate is bended
- Displacements from warm to cold, (at the middle bottom point) :
  - *ΔX = 2,69 mm*
  - *ΔY = - 1,124 mm*
  - *ΔZ = 2,155 mm*

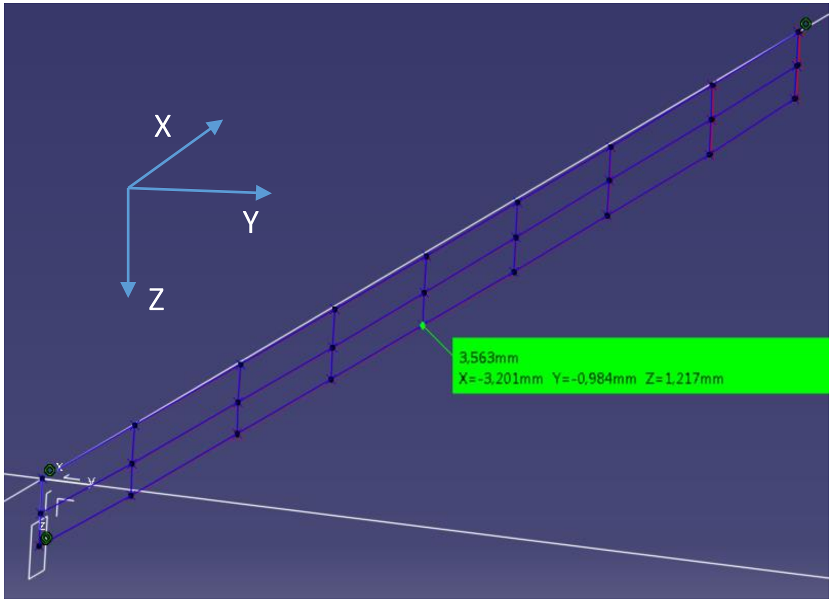
More than 4x the spec

Photogrammetry precision :
+/-0,1 @ one sigma along X
+/-0,05 @ one sigma along YZ

- *ΔX comes from the longitudinal contraction of Stainless Steel => OK **with NIST***
- *ΔY comes from a bending amplification => Unknown gas flow? radiation?*
- *ΔZ comes from thermal gradient in the structure => Ok but less than expected*

⚠

Thermal shrinking : Photogrammetry results – Small plate 100 mm



- The plate is slightly bended
- Displacements from warm to cold, (at the middle bottom point) :
  - *ΔX = 3,201 mm*
  - *ΔY = - 0,98 mm*
  - *ΔZ = 1,217 mm*

More than 2x the spec

Photogrammetry precision :
+/-0,1 @ one sigma along X
+/-0,05 @ one sigma along YZ

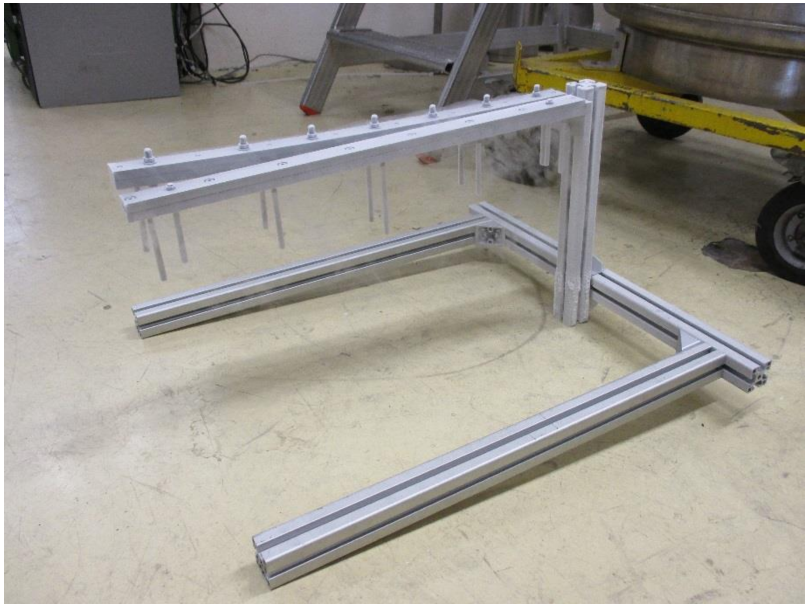
- *ΔX comes from the longitudinal contraction of Stainless Steel => OK **with NIST***
- *ΔY comes from a bending amplification => Unknown gas flow? radiation?*
- *ΔZ comes from thermal gradient in the structure => Ok but less than expected*

Invar oxydation studies

INVAR part

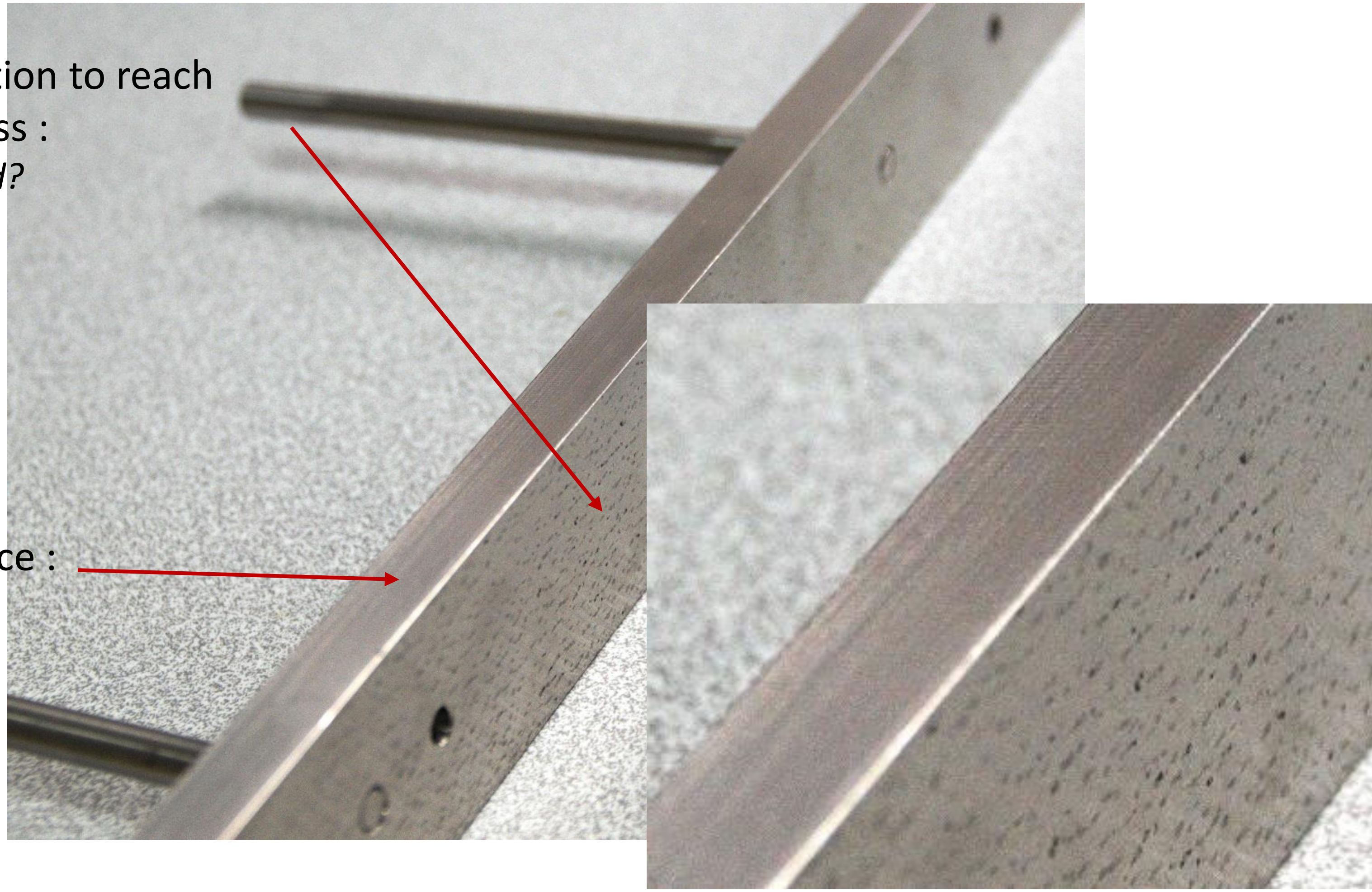
INVAR part from cryo decoupling test

- *Two thermal cycles in liquid Argon/Nitrogen*
- *No storage precaution*
- *Stored for 6 months*



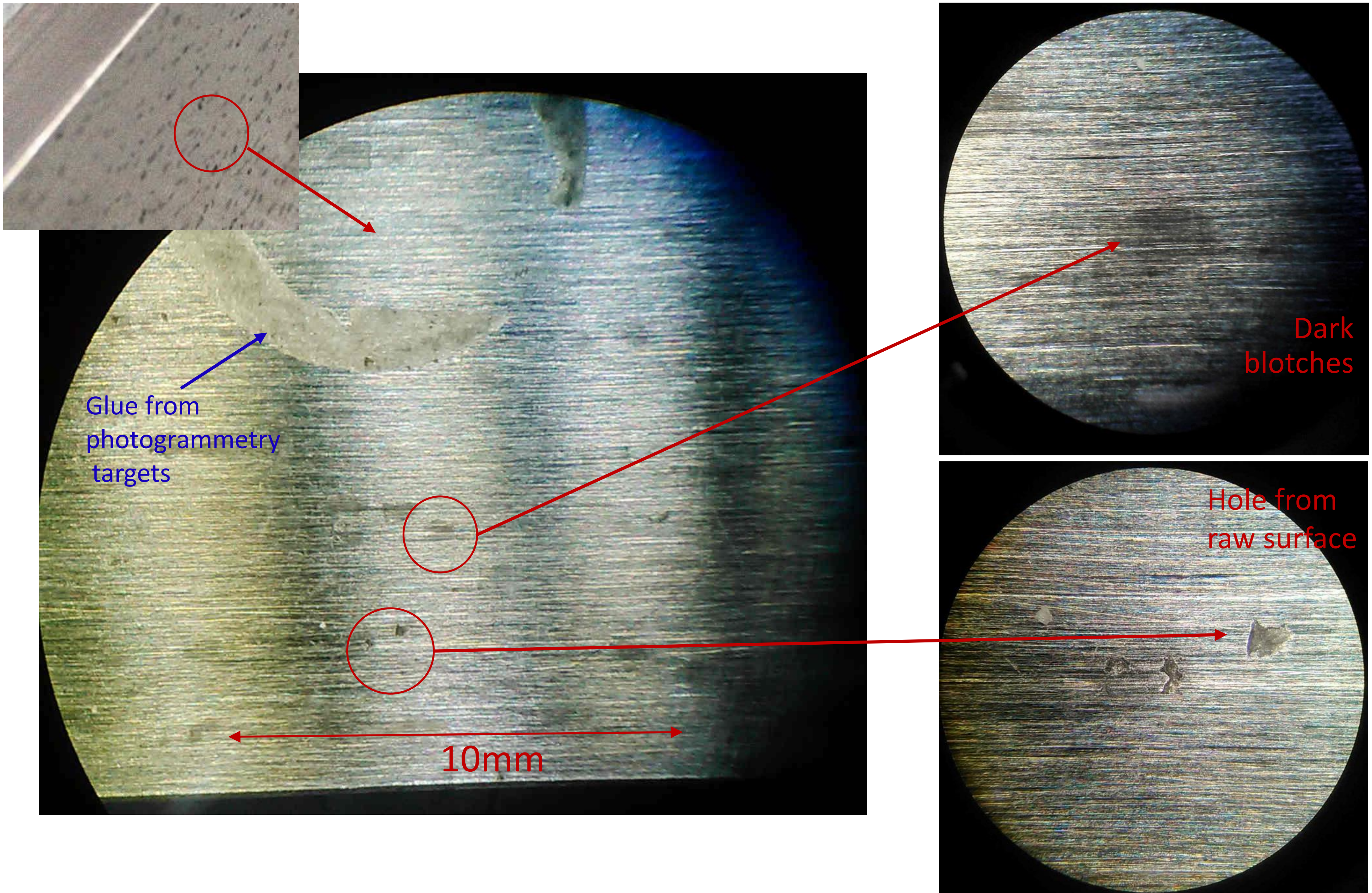
Design overview

Slight rectification to reach 10mm thickness :
Slightly oxydated?



Machined face :
No oxydation

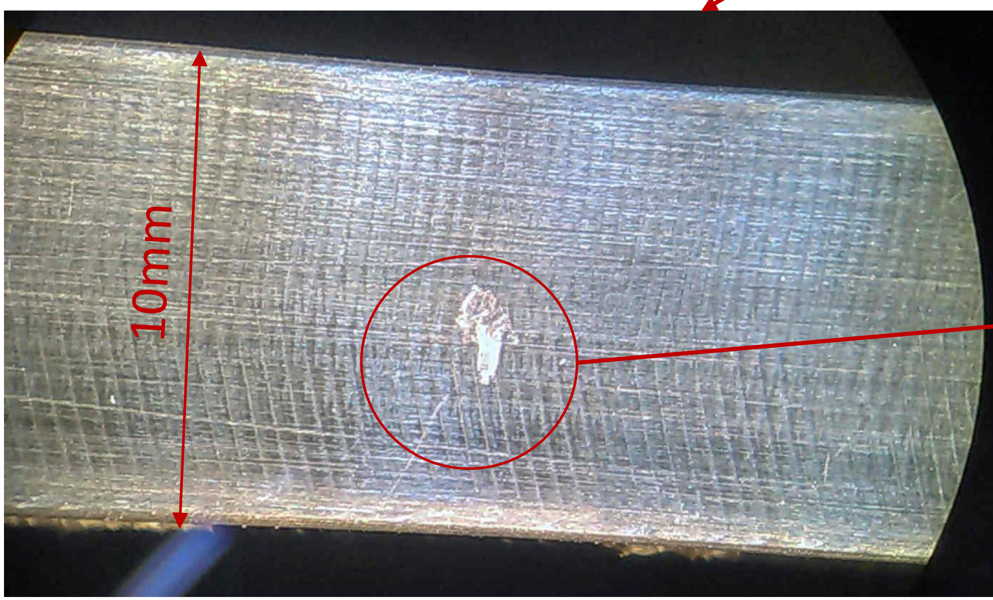
Rectified face (from a block, not from a plate)

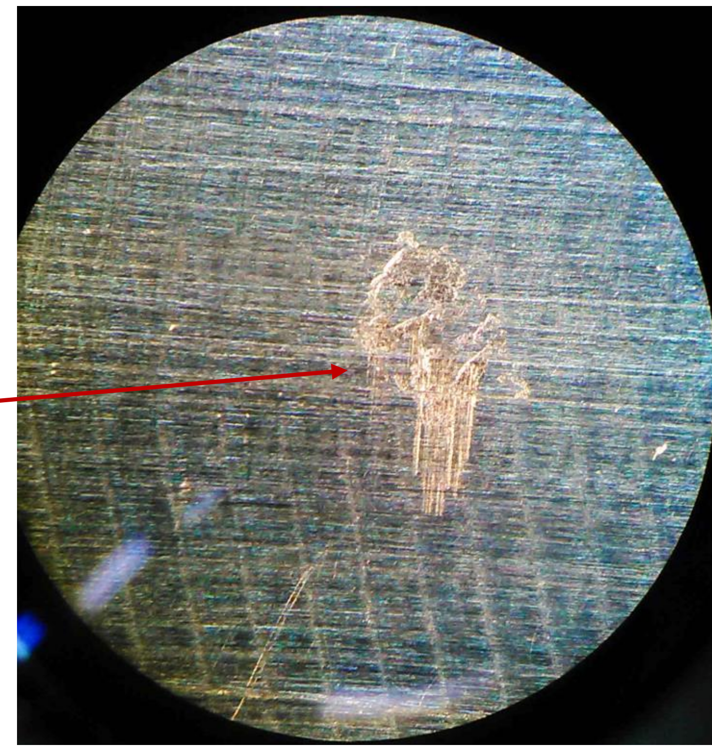


Machined face (from a block, not from a plate)

No trace of oxydation noticed on the machined face

- *Even no oxydation in the scratches*





Machined face (from a block, not from a plate)

- Invar frame will be made from rectified plates
  - shallower « holes » on the surface, and deeper rectifying than previous test

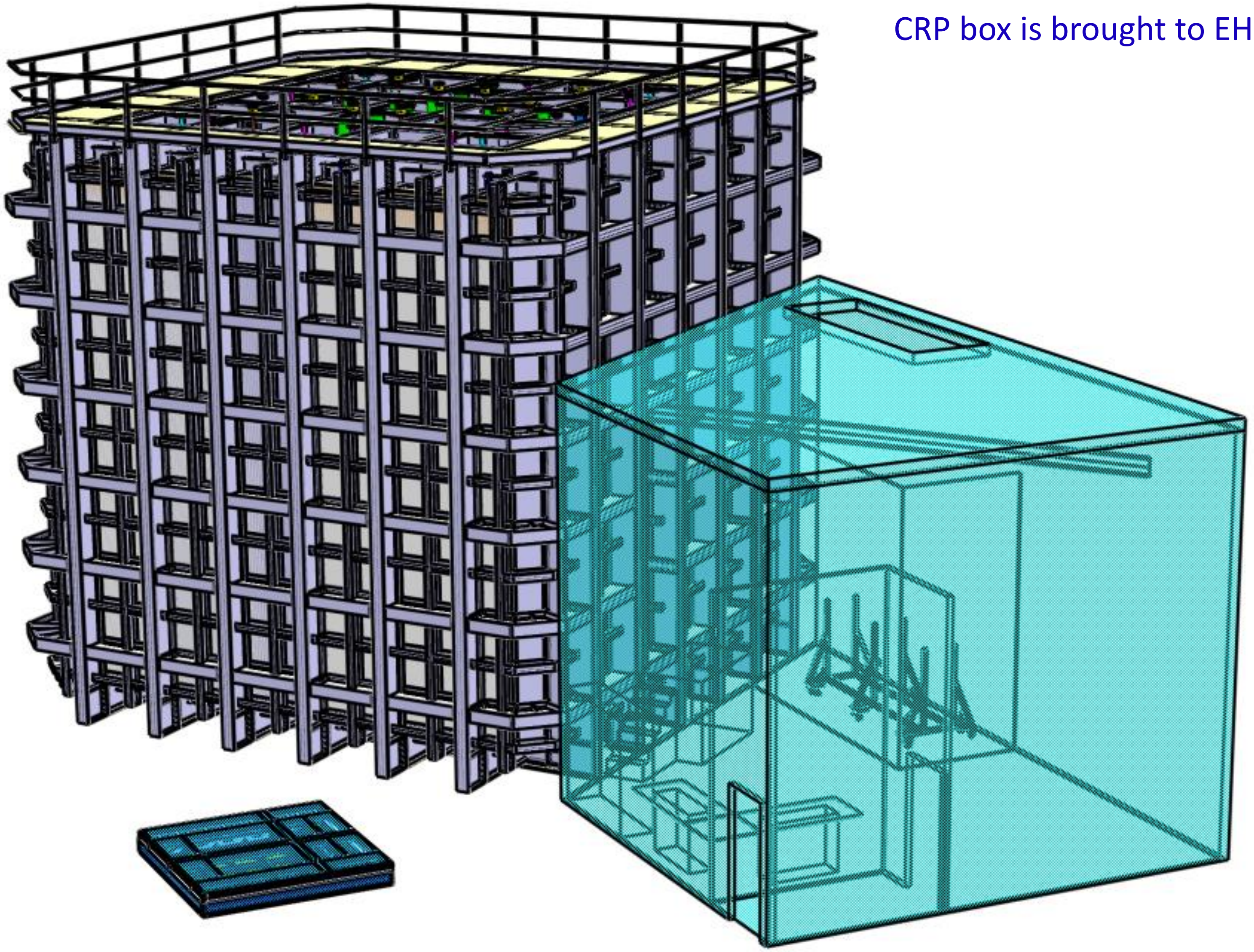
- Even with no precaution storage, no special oxydation observed.

- Final frame will be rectified, assembled, welded, washed and stored in special plastic cover with dessicant to absorb humidity and avoid oxydation.

CR185 Installation

Cryostat insertion

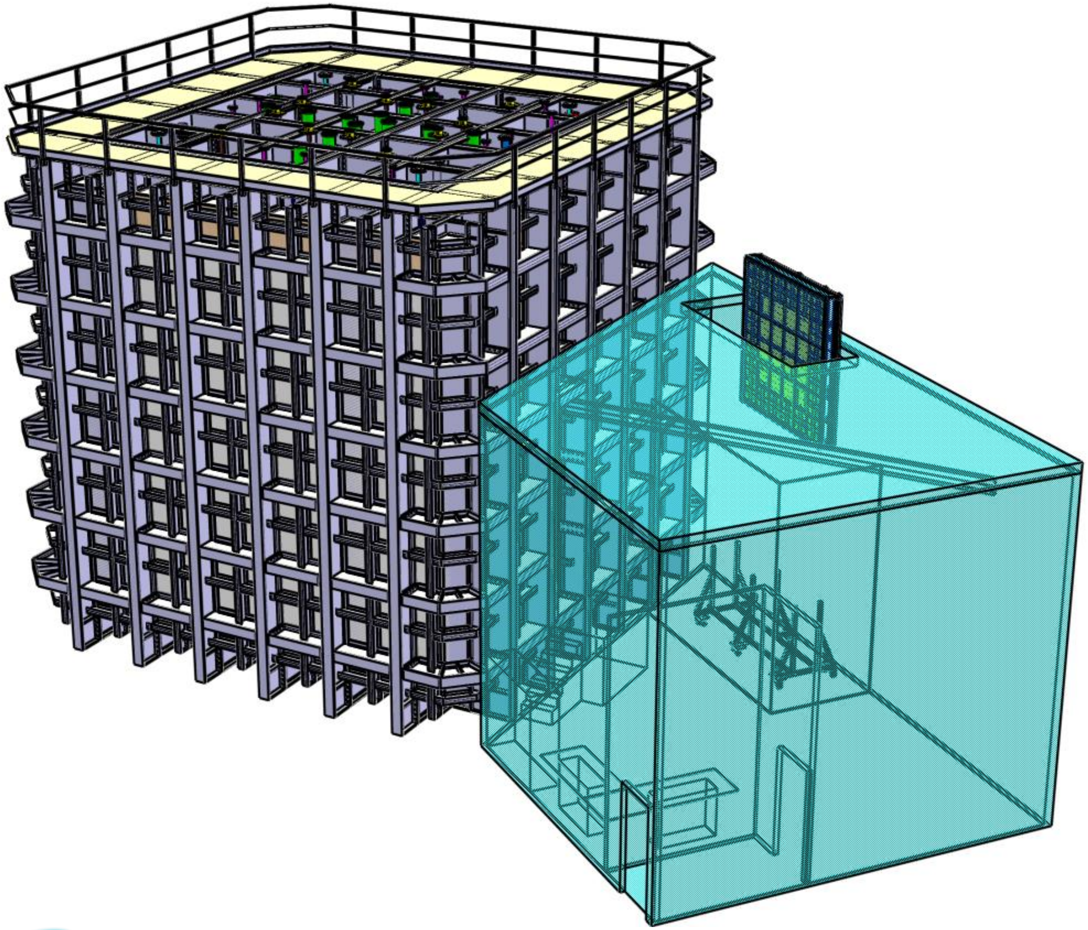
CRP box is brought to EHN1 from CR185



Cryostat insertion

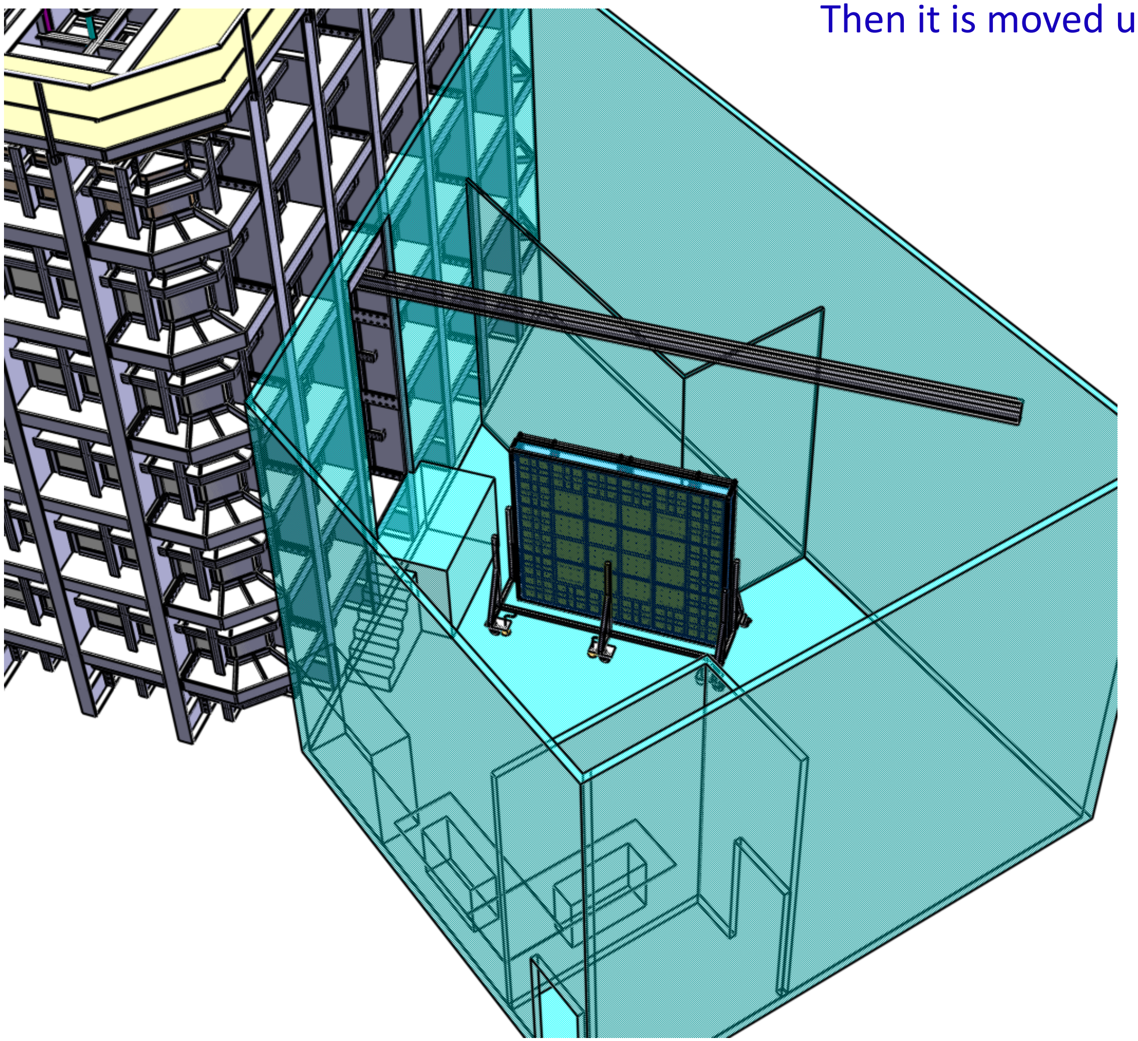
The box is inserted in the CRB thanks to the Hall's crane

- *The box is suspended by a special handling IPE stiffener*



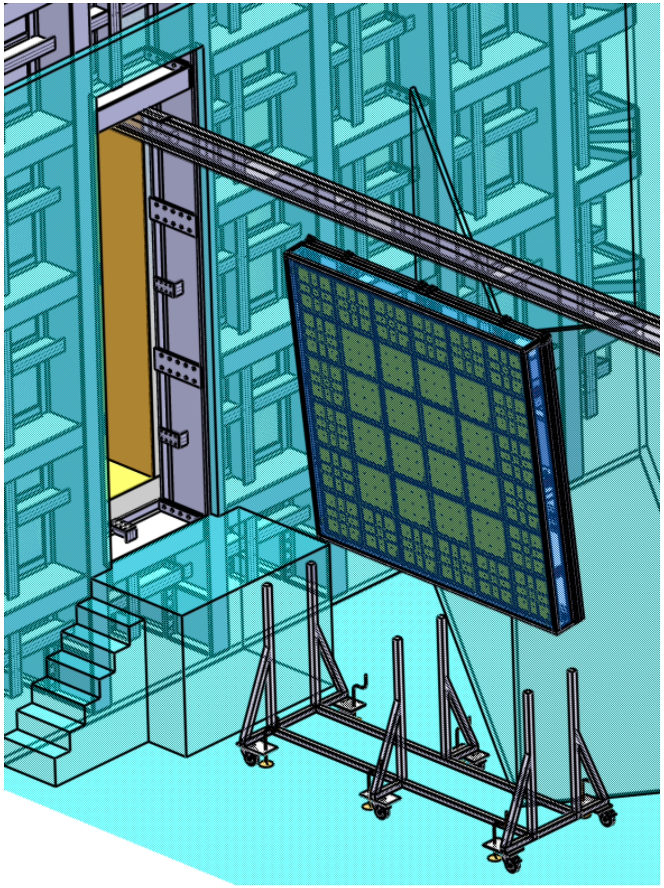
Cryostat insertion

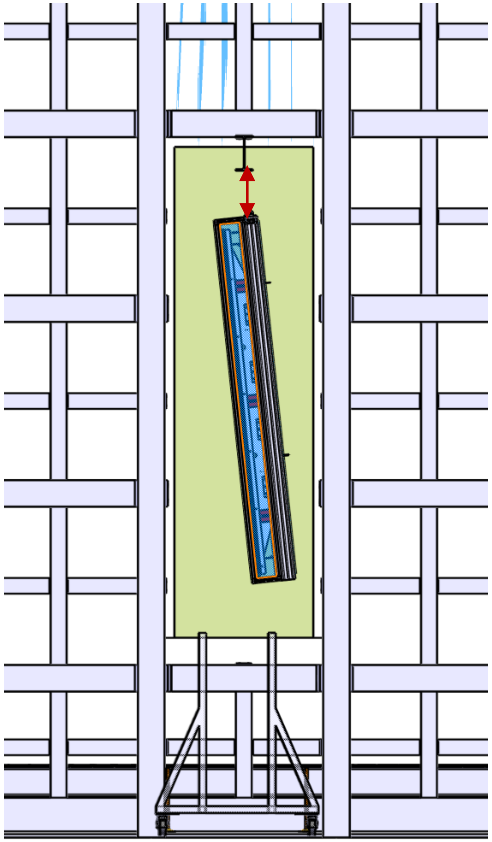
The box is unwrapped to preserve CRB cleanness
Then it is moved under the rail to be lifted



Cryostat insertion

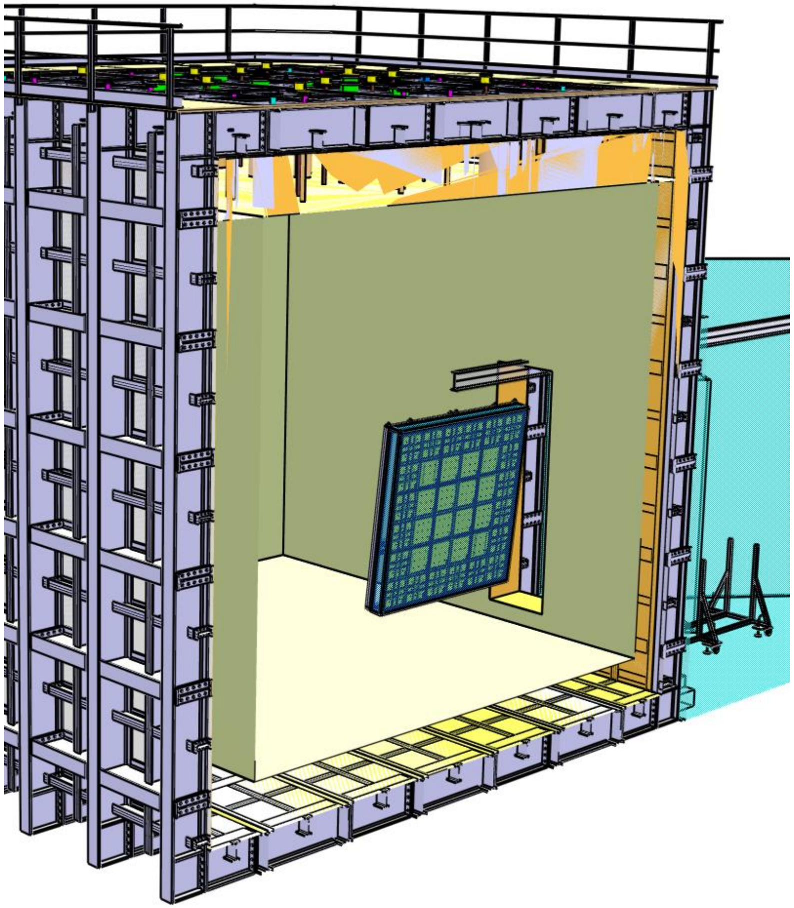
The box is lifted under the rail

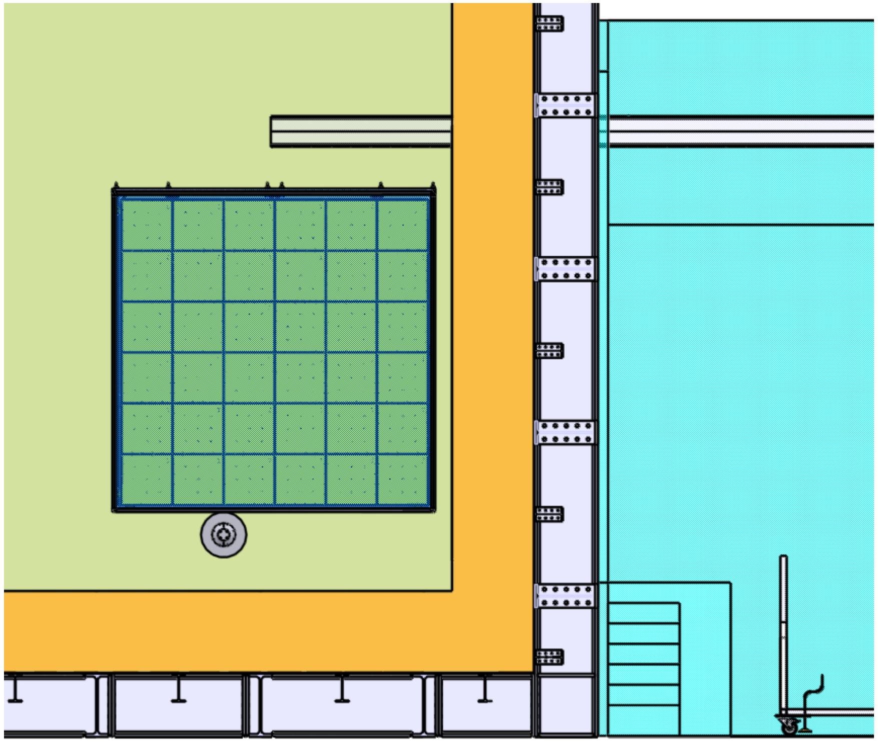




Cryostat insertion

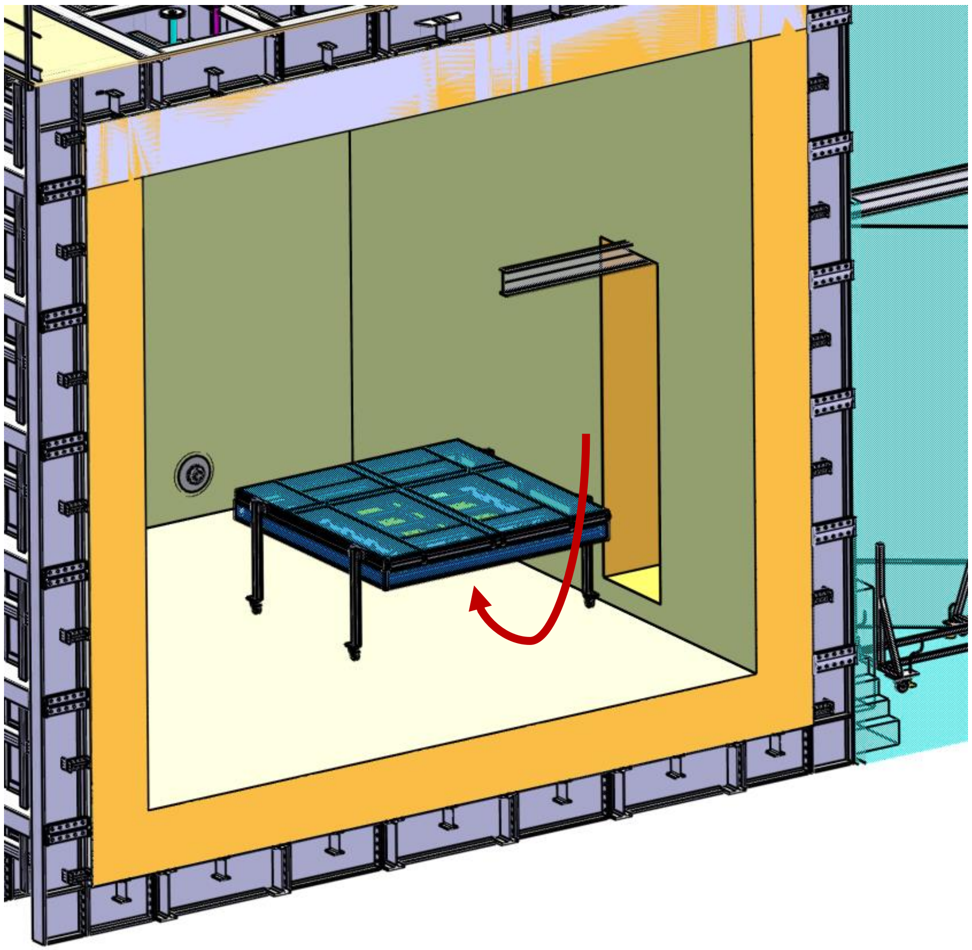
The box is inserted inside the cryostat through the rail





Cryostat insertion

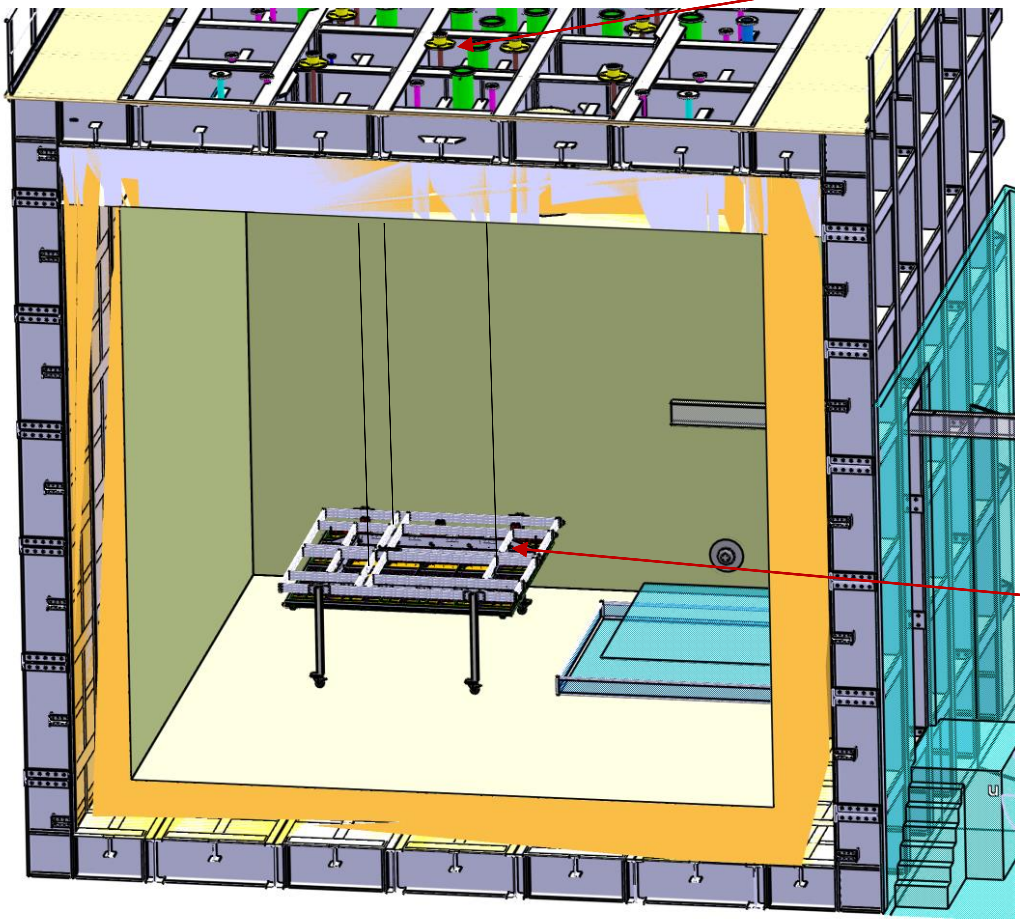
The feet of the box are replaced, the box is lowered and rotated, then placed on its wheels

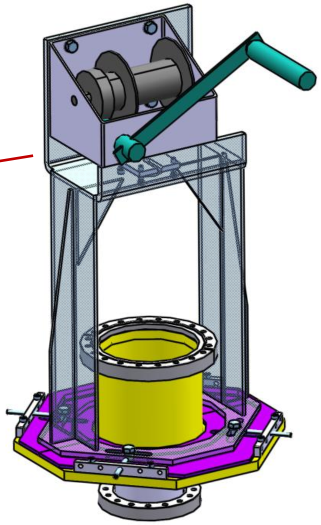


Feet will be mounted as short as possible to ease the rotation operation

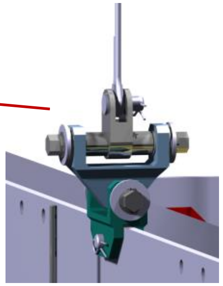
Cryostat insertion

The box is placed below its SPFT chimneys
The top and the bottom of the box are removed
Cables from the SPFT are connected to the module





SPFTs are equiped with special winches at this time



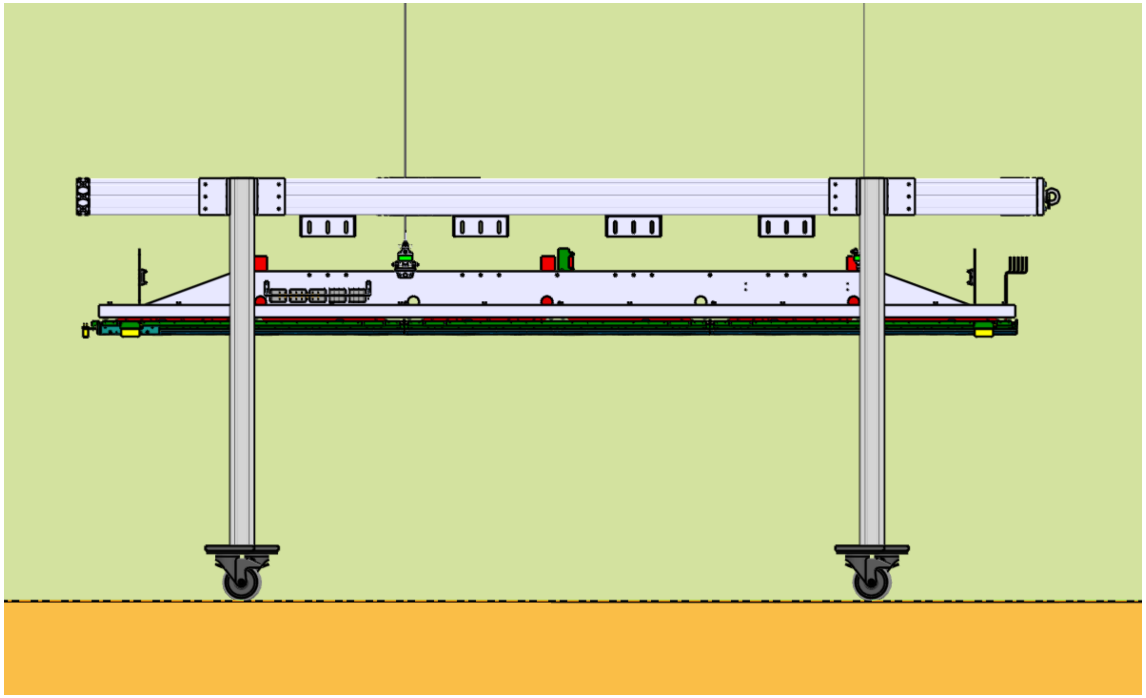
CRP suspension systems

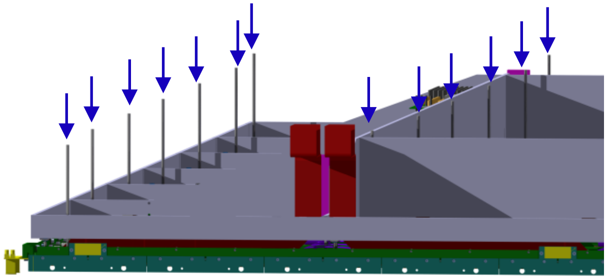
Cryostat insertion

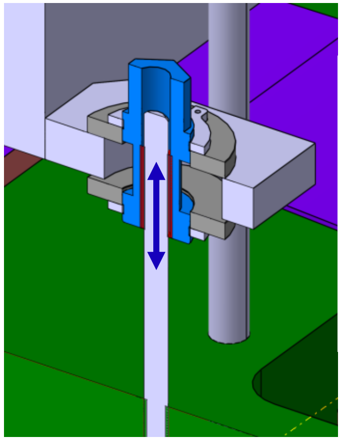
Once the module is suspended, it can be detached from the structure

All the supporting squares for transport are removed

The planarity is checked thanks to laser-tracker or optical level

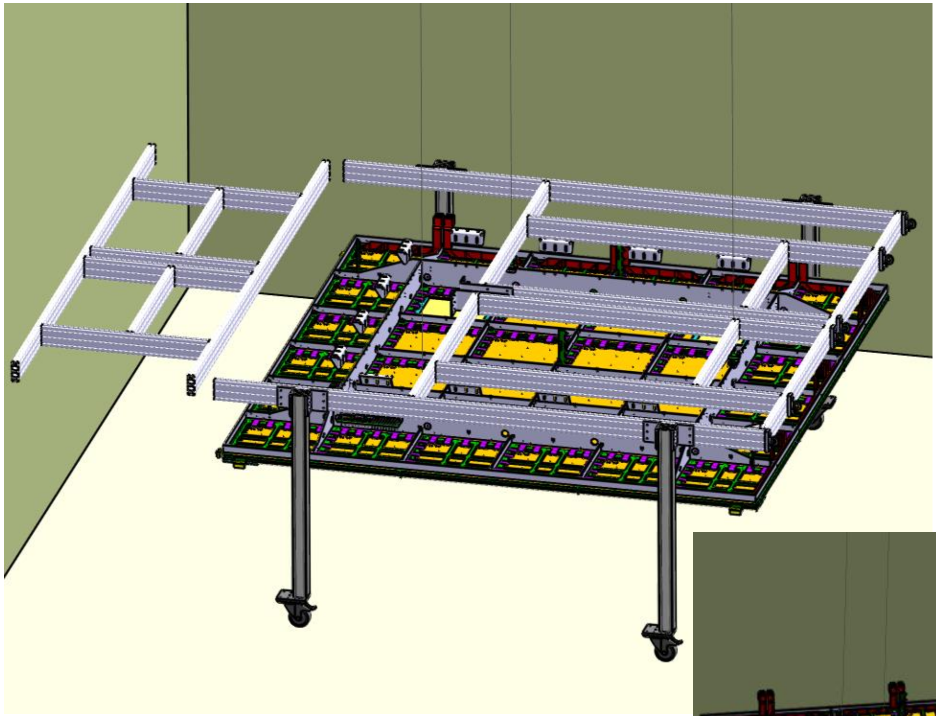


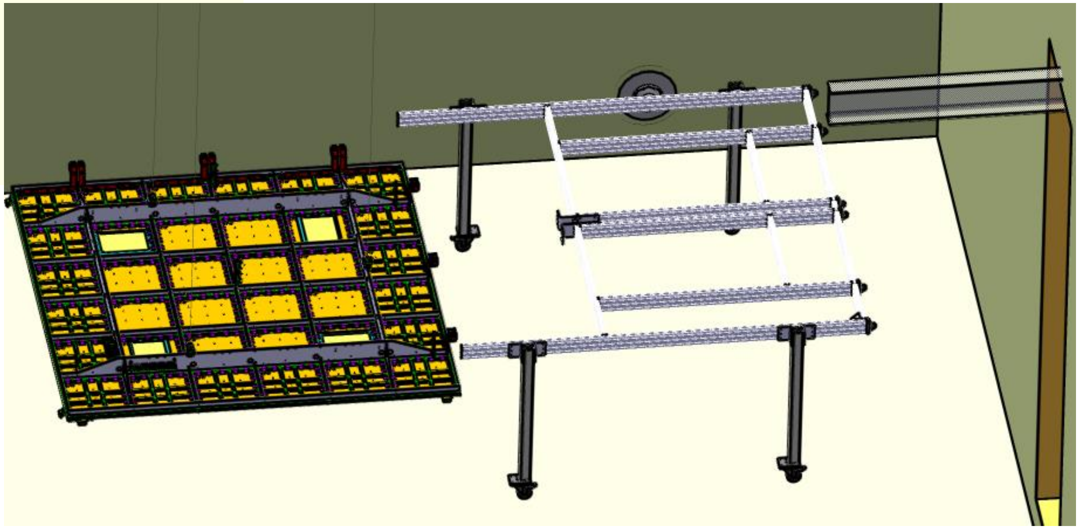




Cryostat insertion

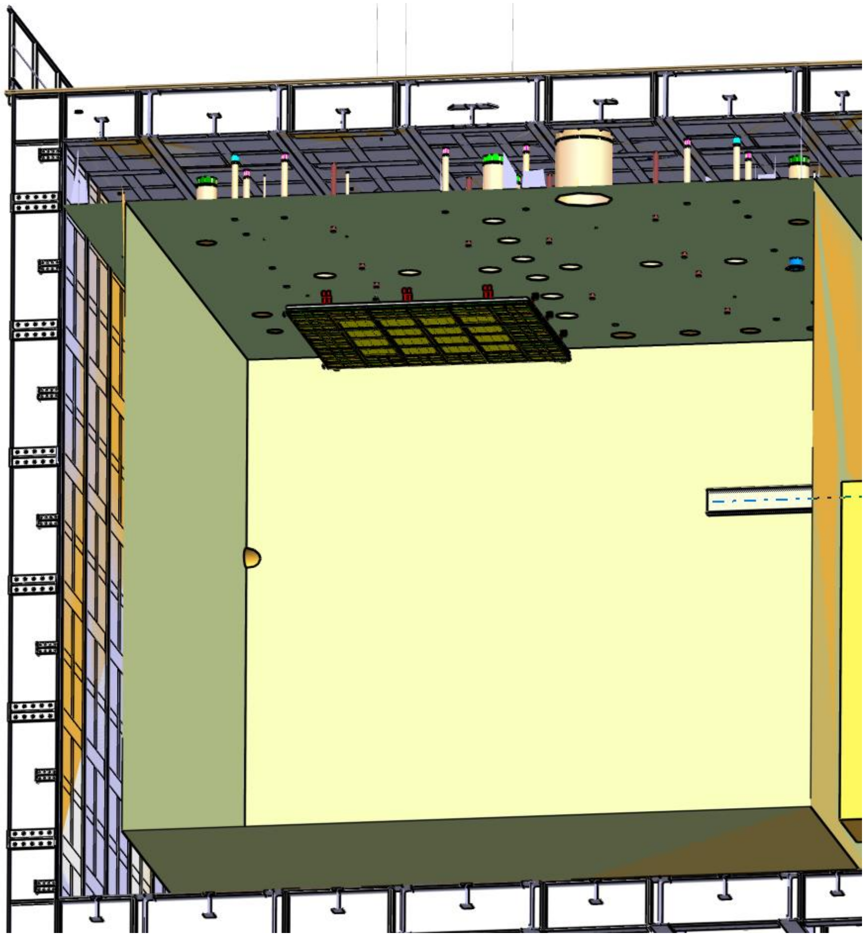
The structure is then removed in two parts

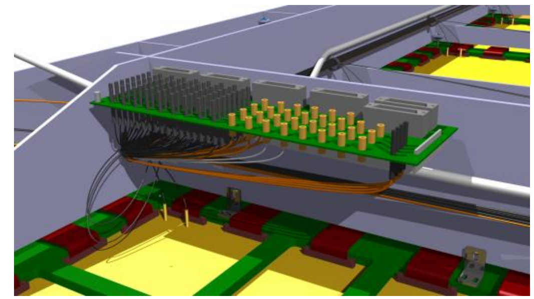


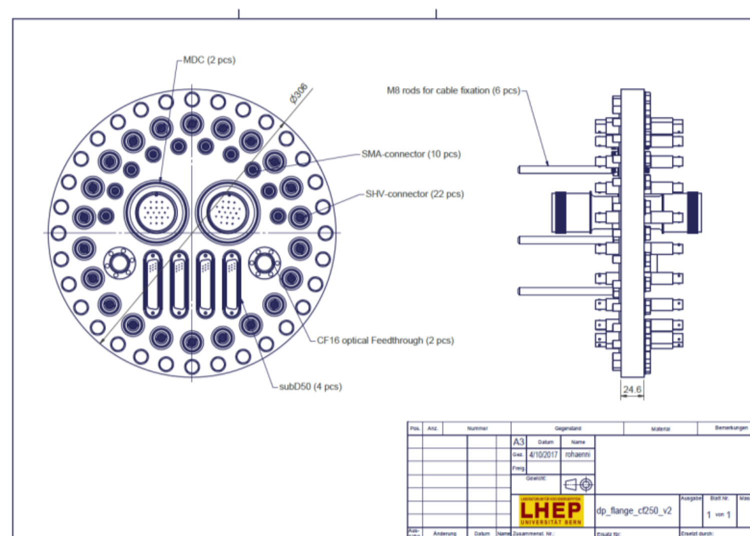


Cryostat insertion

- The module is lifted to the roof, and connected to chimneys (signal, HV, control…)
- Metrology operation is foreseen to control lateral position of the module

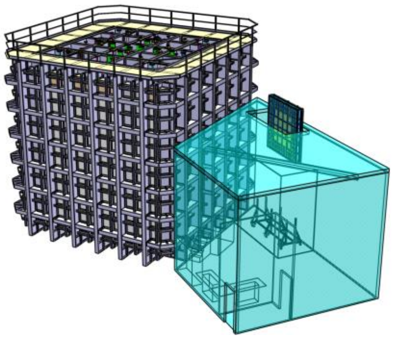
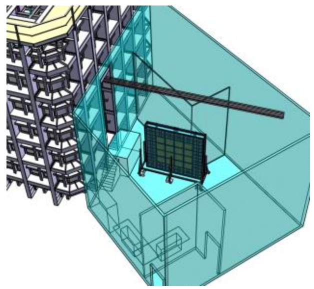
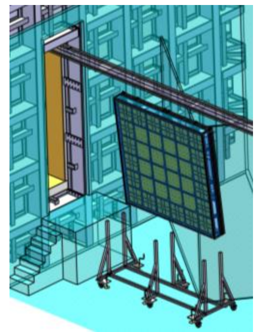
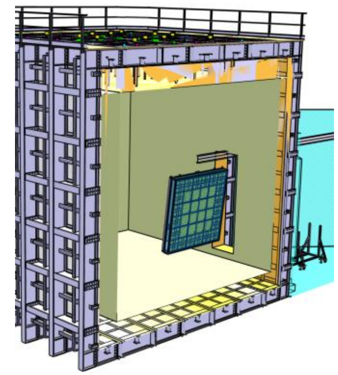
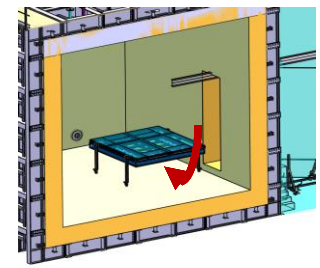


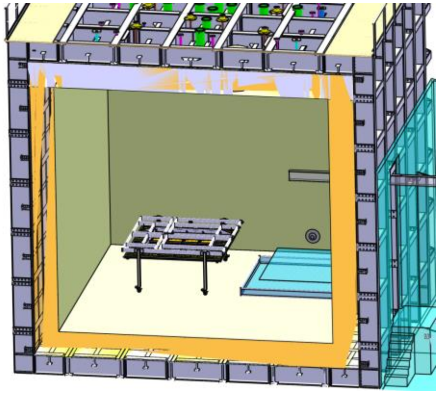
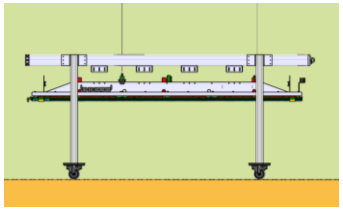
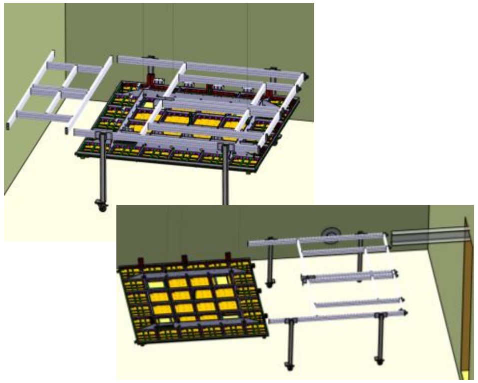
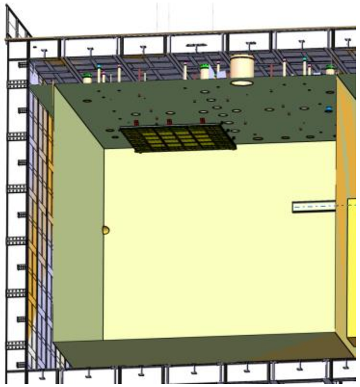




Cryostat insertion

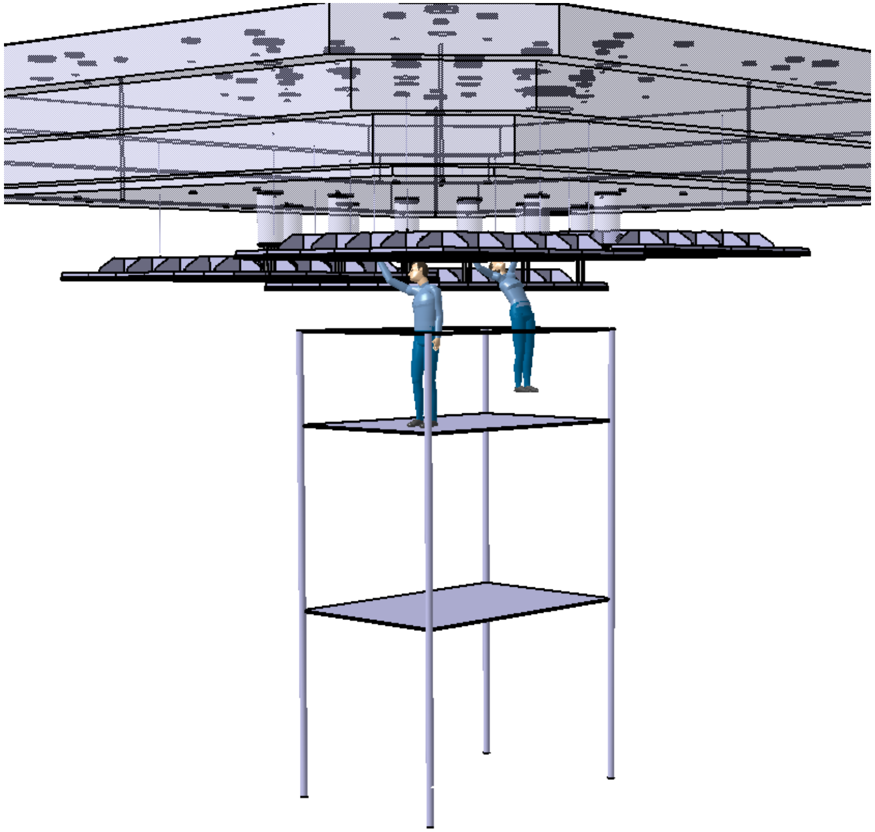
The operation is then repeated to insert the other modules …

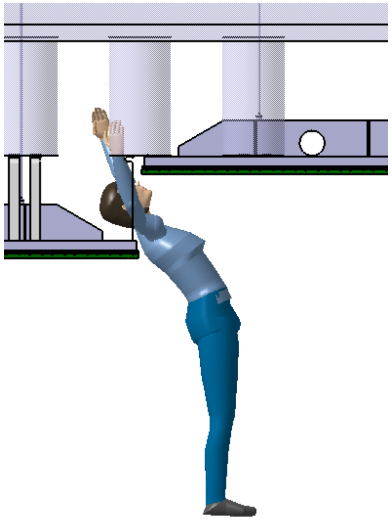






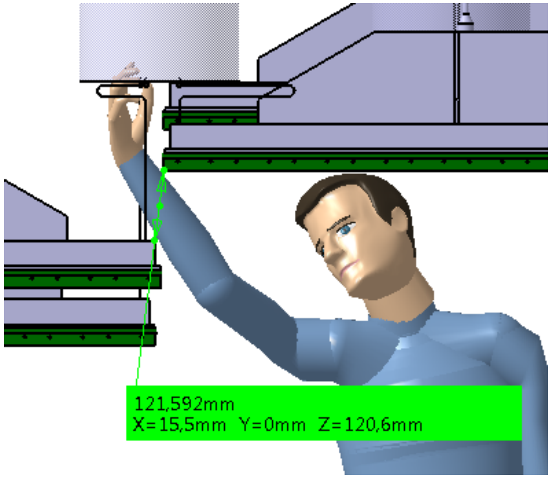





Cryostat insertion

To connect plugs between modules, the modules are vertically shifted







Cryostat insertion

Modules' alignement is made from the roof

- *Distance-Meters to get information on relative position*
- *SPFT system to translate modules*
- *Intervention with metrology team*