CRP mechanical design status

DUNE Vertical Drift CDR

04/2021

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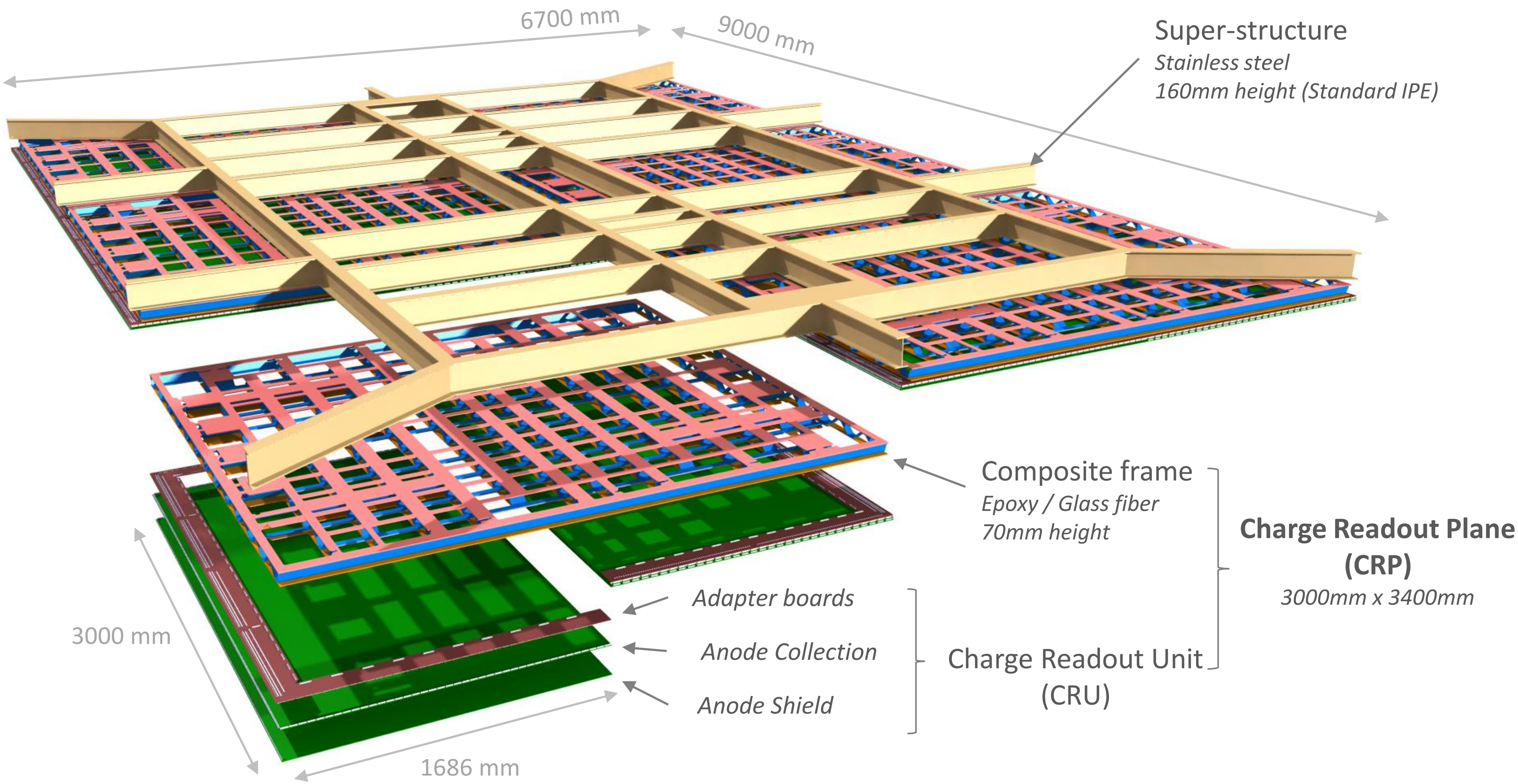
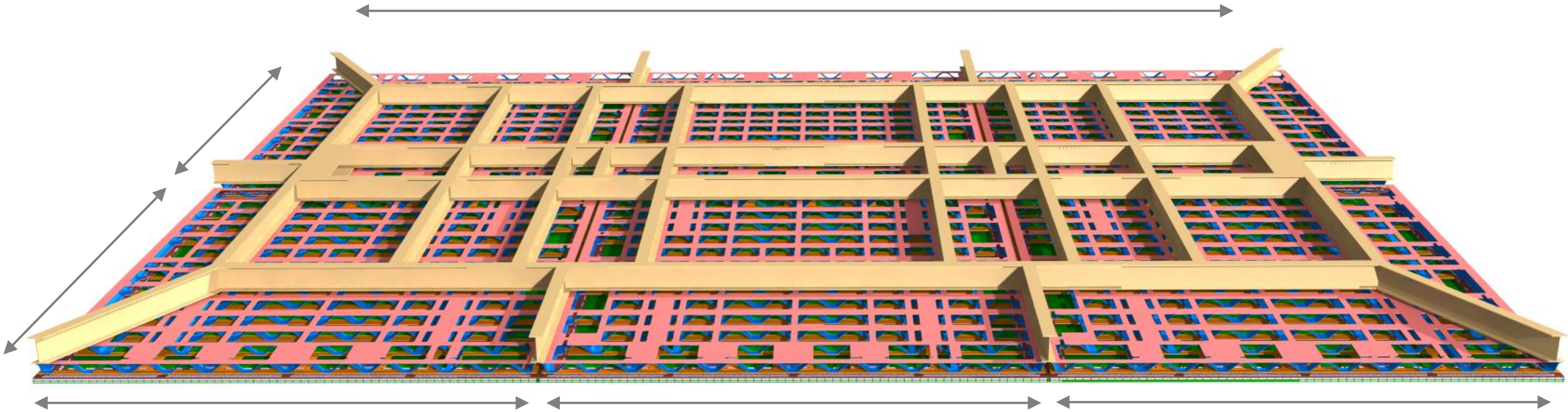
Super-CRP for DUNE-VD



6 CRP by Super-Structure

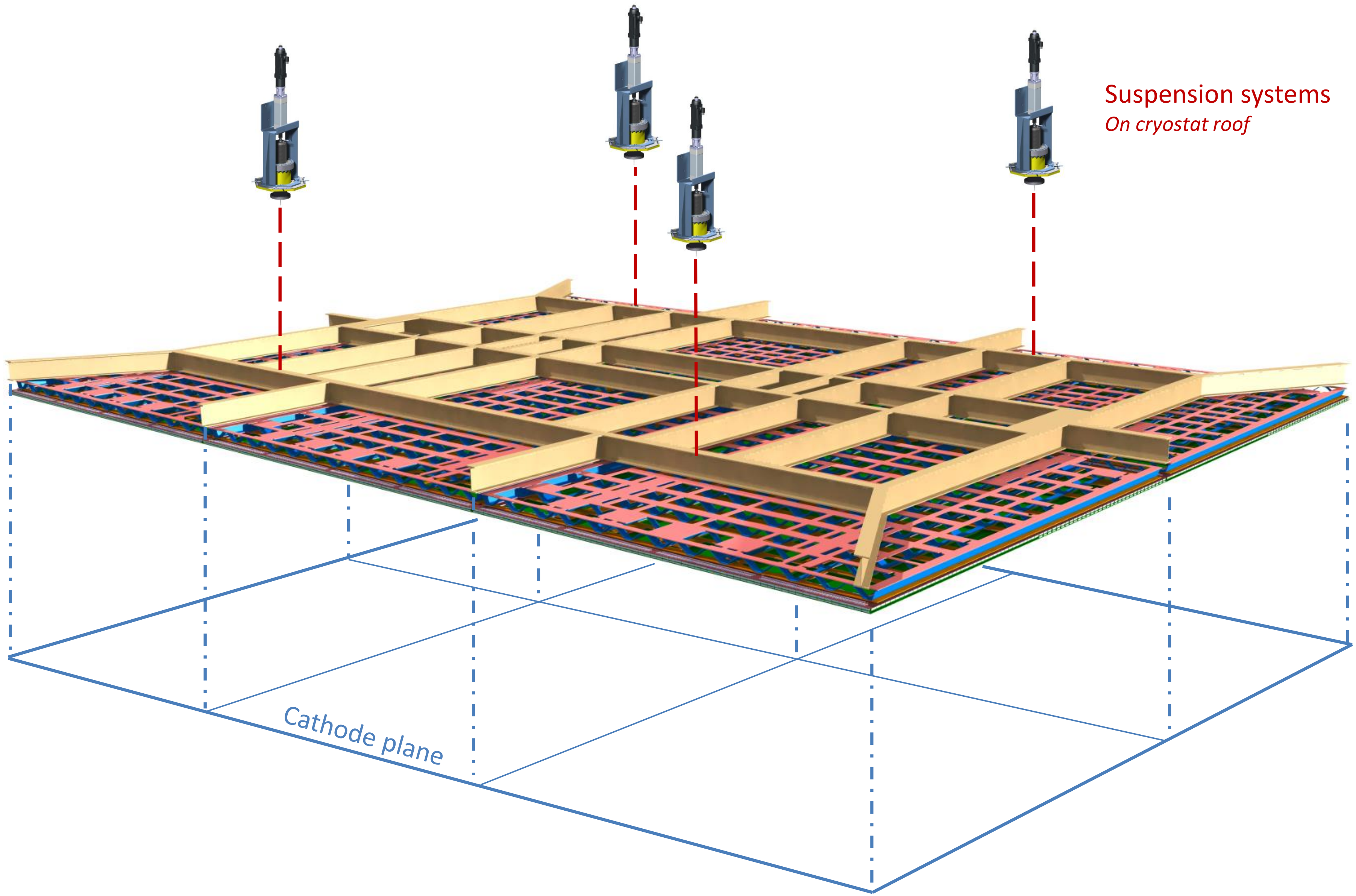
Metallic frame
Brings general stiffness
*Thermal shrinkage : **25mm** over 200°K and 9 meters*



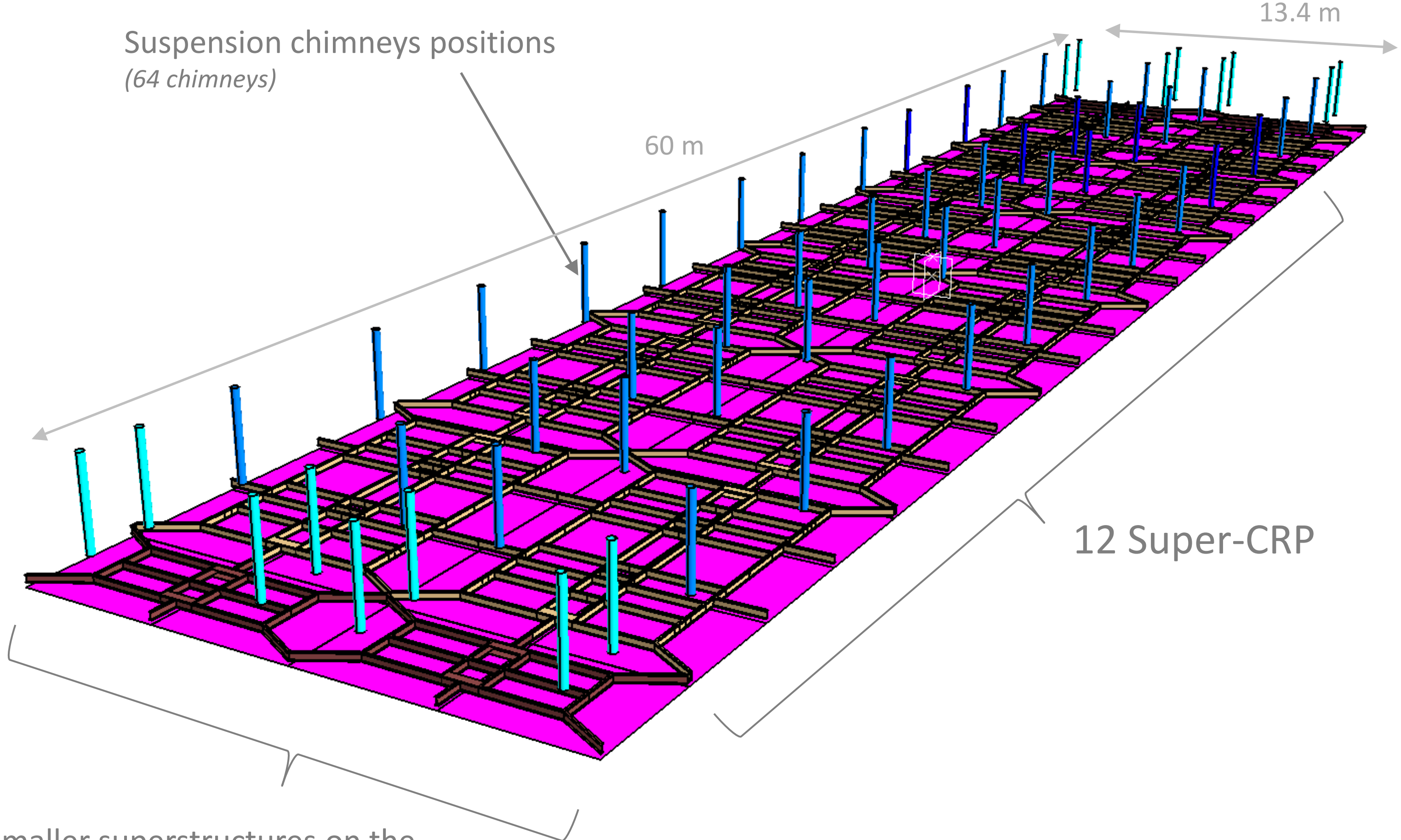
Composite frames
Brings primary stiffness to electronic PCB
Thermo-mechanical behaviour close to PCB
*Thermal shrinkage : **5,5mm** over 200°K and 3 meters*

Anodes
*Thermal shrinkage : **6mm** over 200°K and 3 meters*

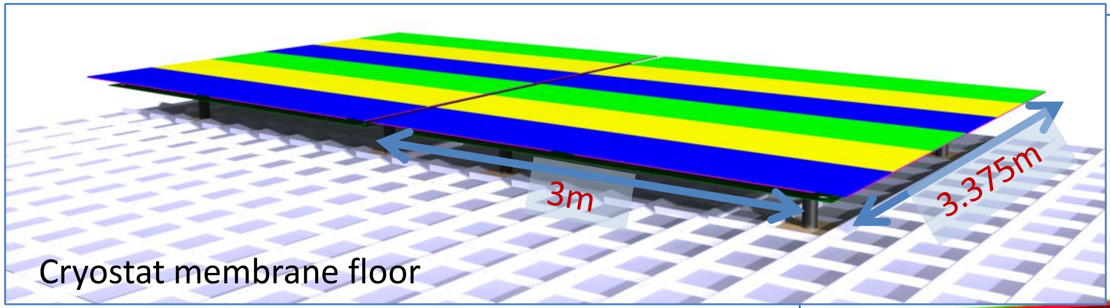
- Differential thermal shrinkage must be studied and handled properly to insure planarity
  - *Decoupling system is foreseen between metallic and composite frames to allow sliding and positioning*

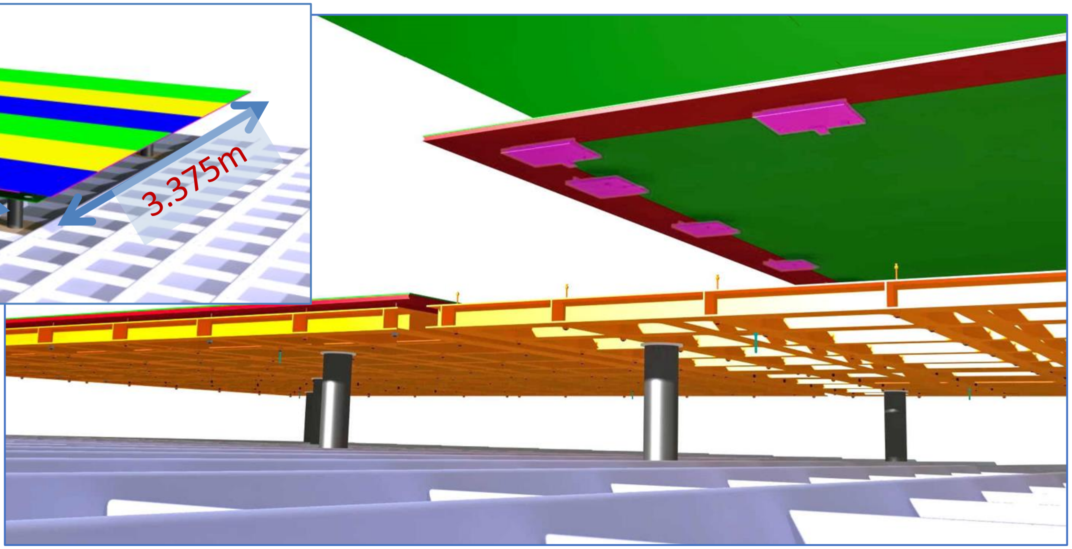

Suspension systems
On cryostat roof
Cathode plane

DUNE-VD Top plane layout



4 smaller superstructures on the sides (1 x 2 CRP each)



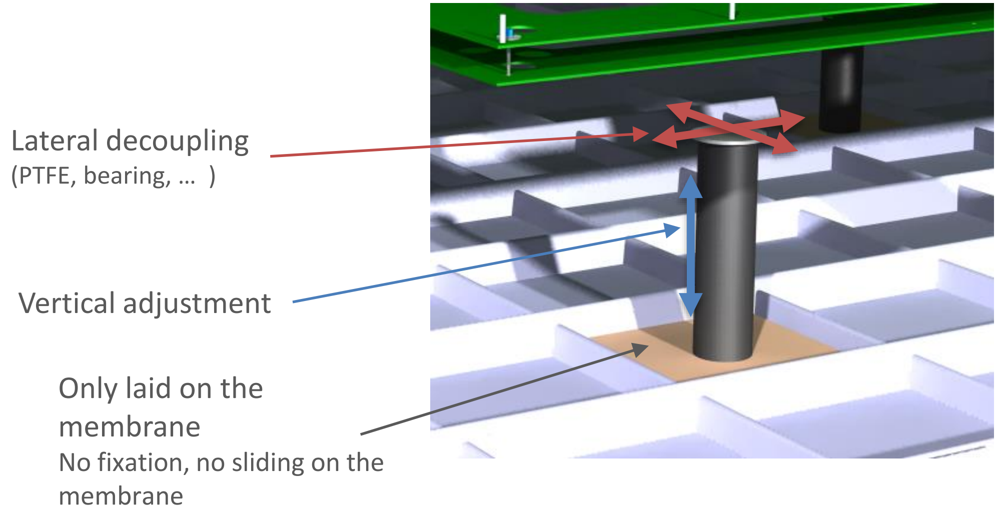


Design of the bottom CRP frame:

having the bottom CE boxes attached below the anode plane +
planarity can be controled by the suporting feet to keep each anode plane within the 5 mm deformation range

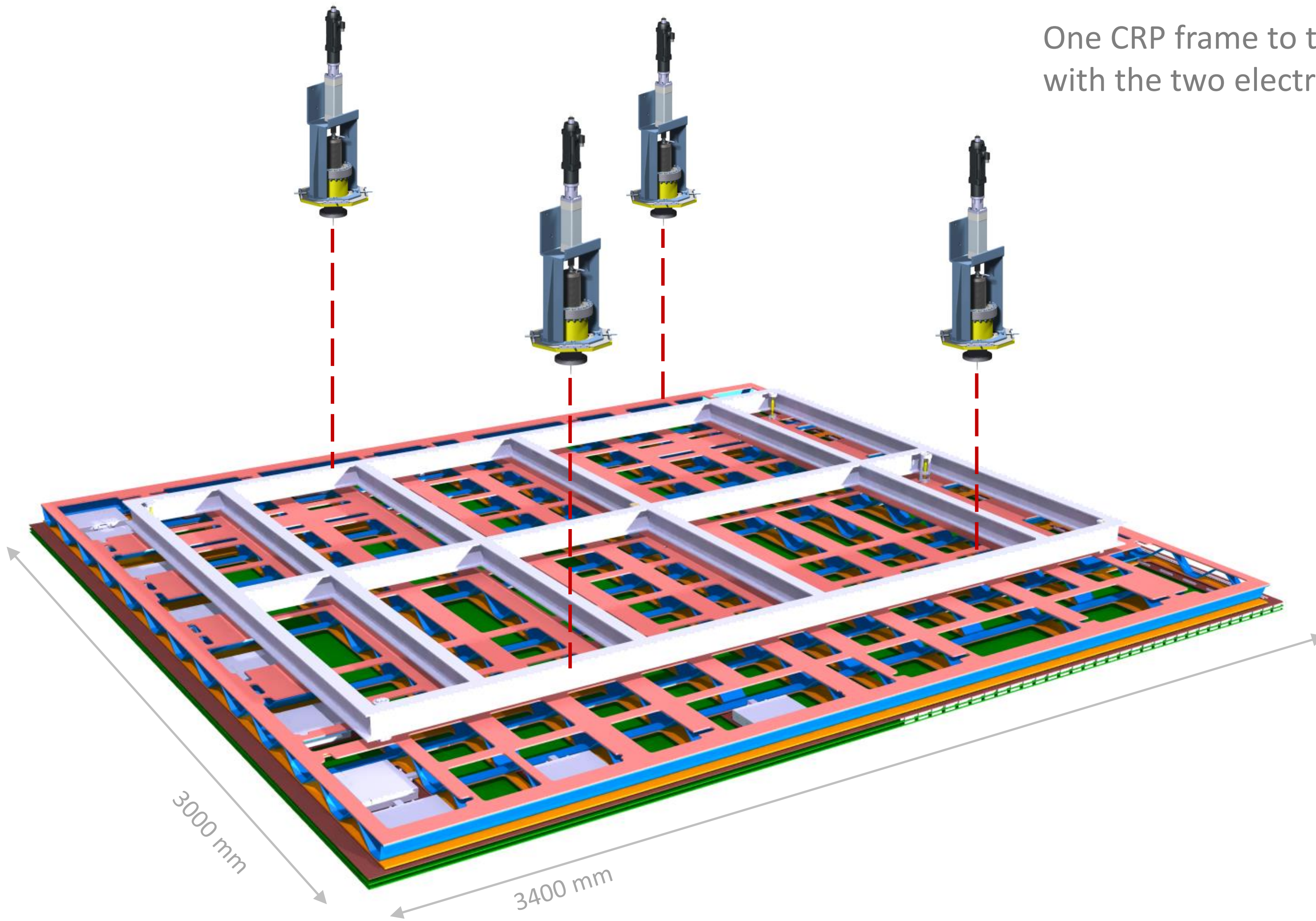
⇒ More transparent (with a design goal close to 75%) and
⇒ Lighter frame thanks to the adaptable supporting feet distribution

The bottom CRPs will be positionned on adjustable feet

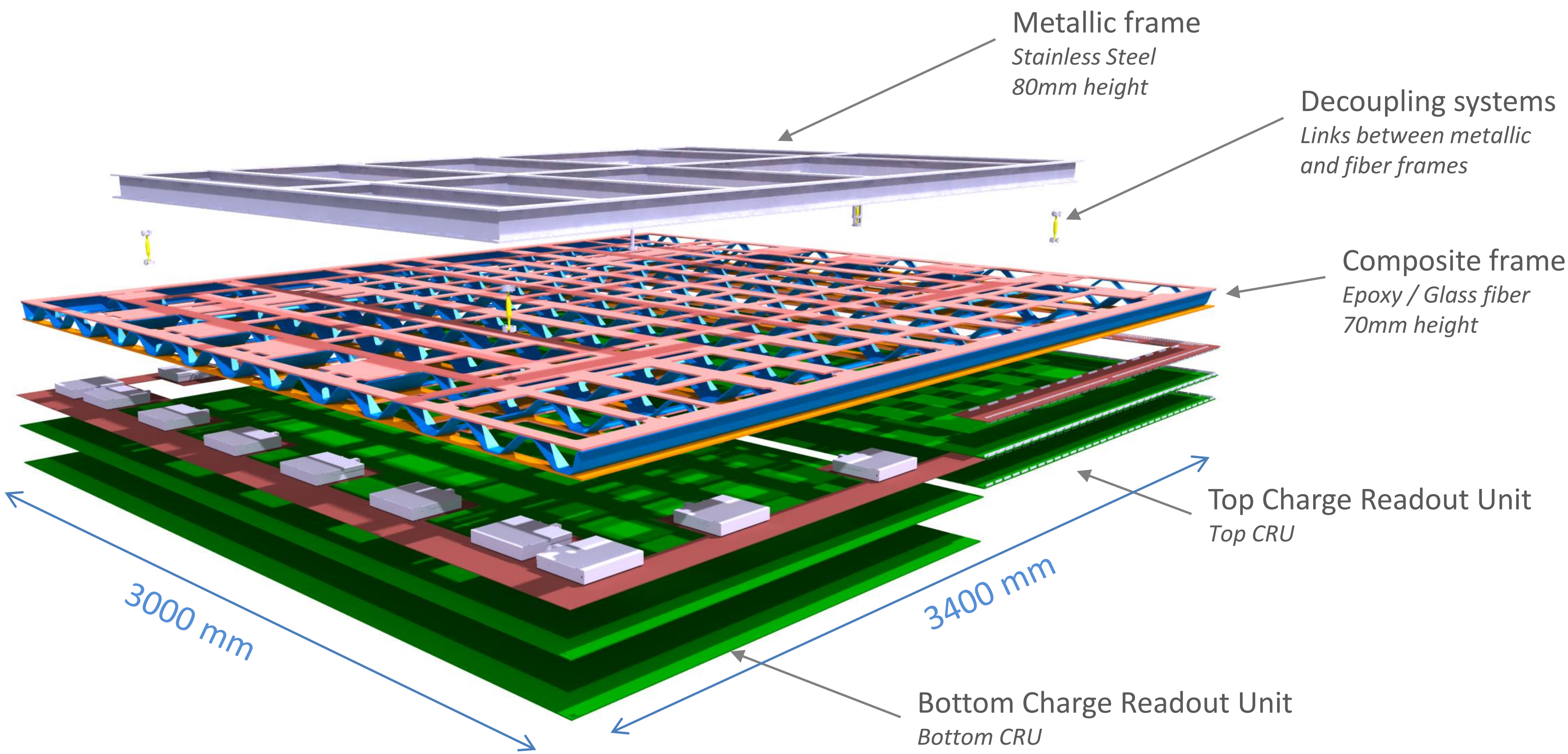


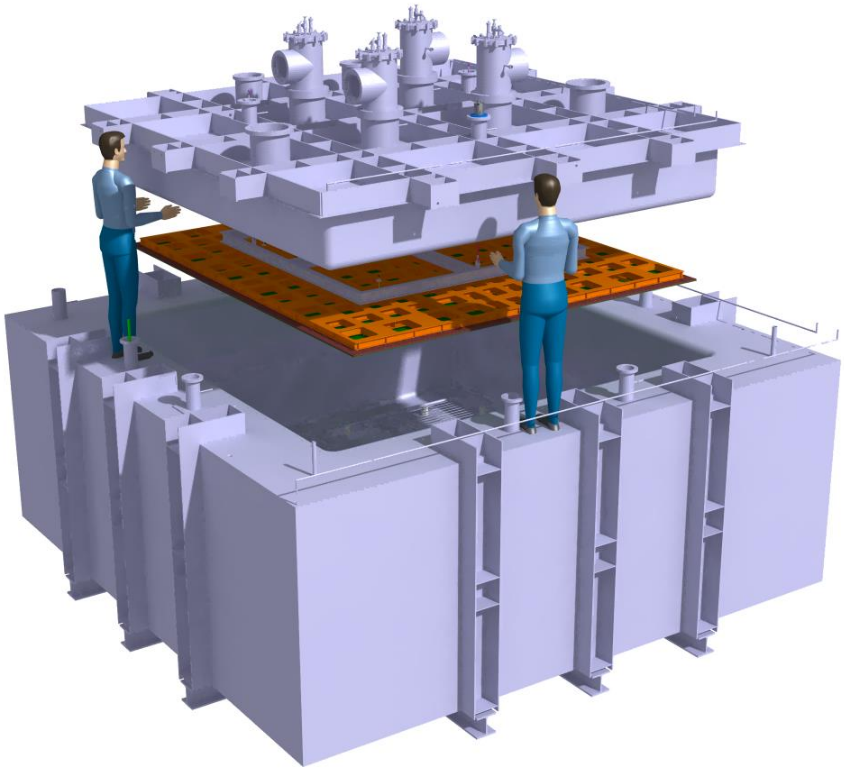
Single CRP for Coldbox Test in 2021

One CRP frame to test anodes with the two electronics types



Single CRP for Coldbox Test

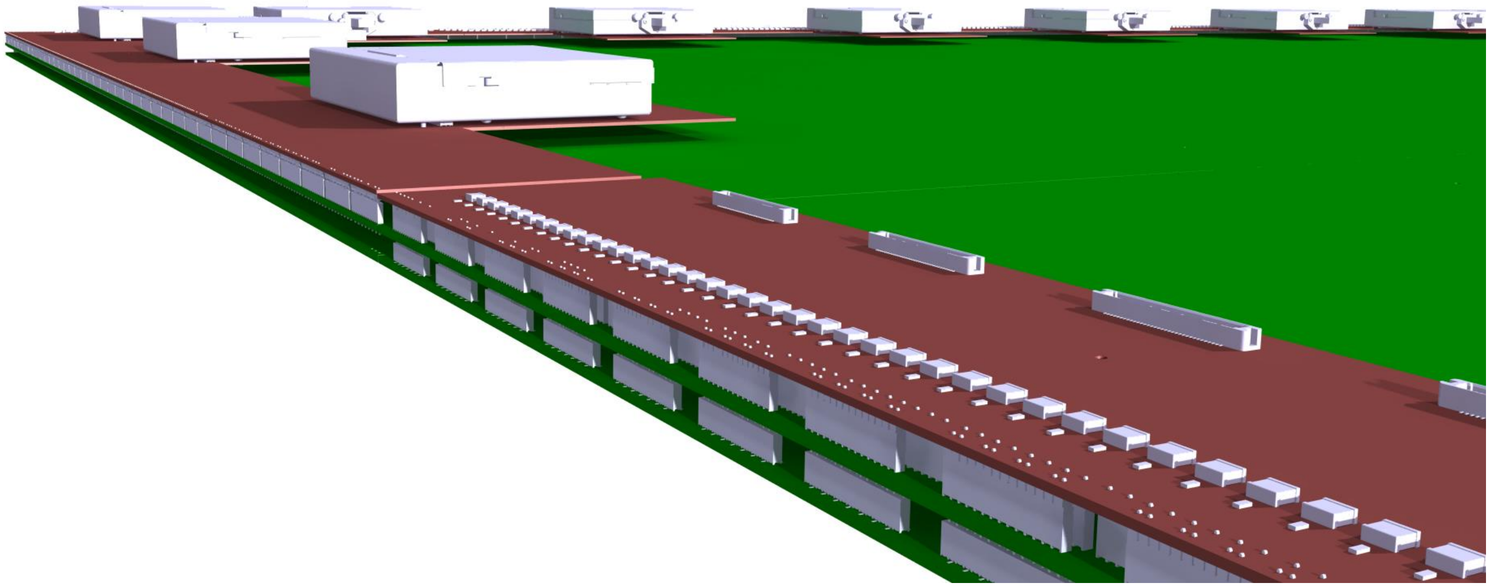




Anodes

Material properties for mechanical simulation

Assembly design



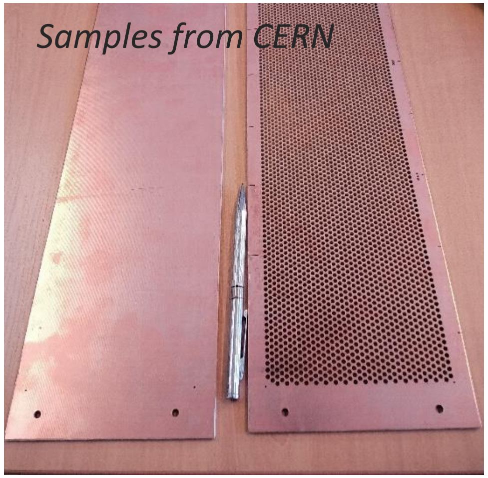
Full and drilled PCB : copper plated glass fiber - 3,2mm/2x35µm

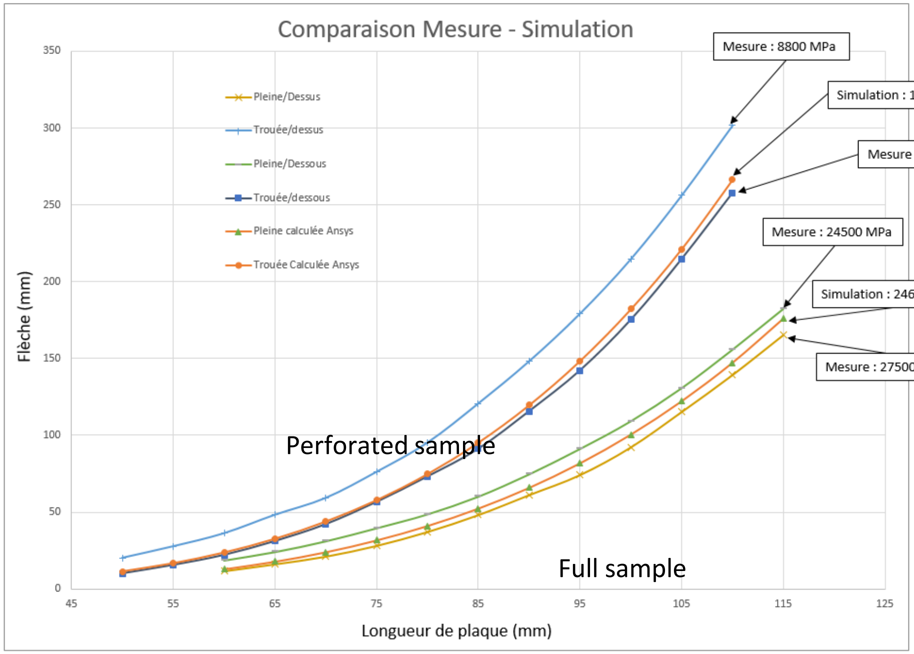
Length variation / Deflection measurement

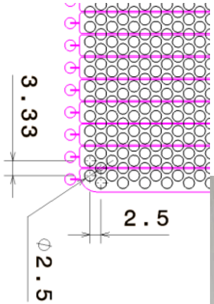
From measurements : Reference equivalent Young modulus for simulations :

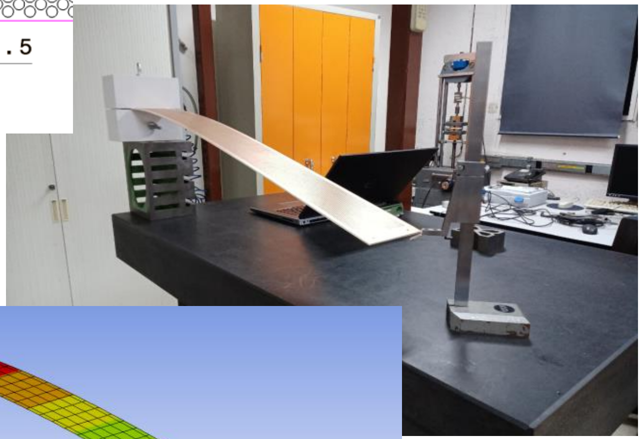
Full Plate : 24600 MPa *(24500-27500 MPa)*

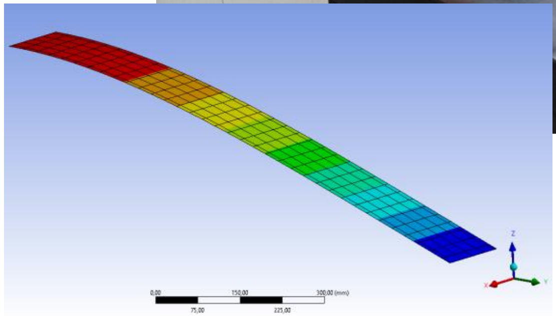
Drilled Plate : 10000 MPa *(8800-11700 MPa)*



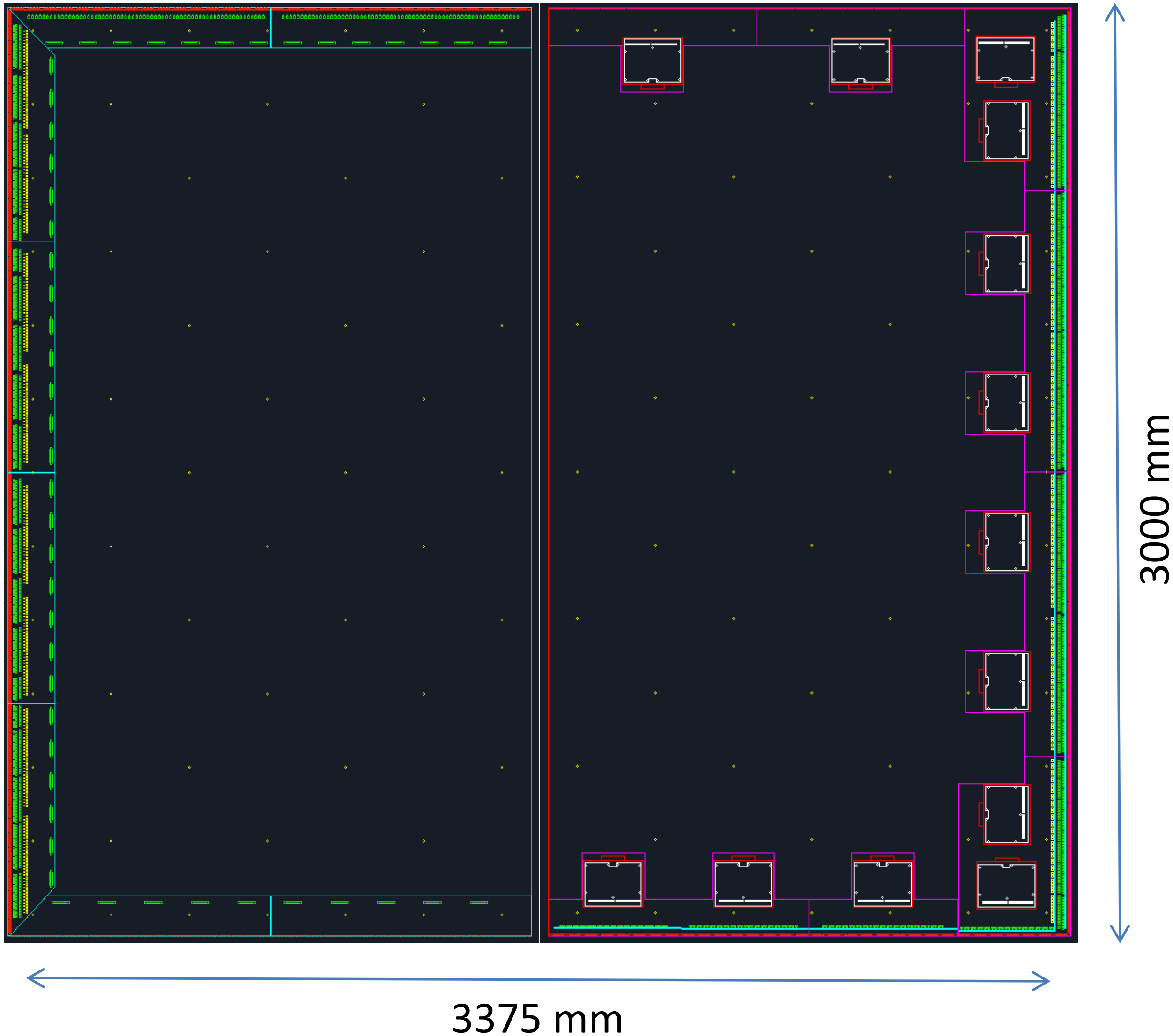






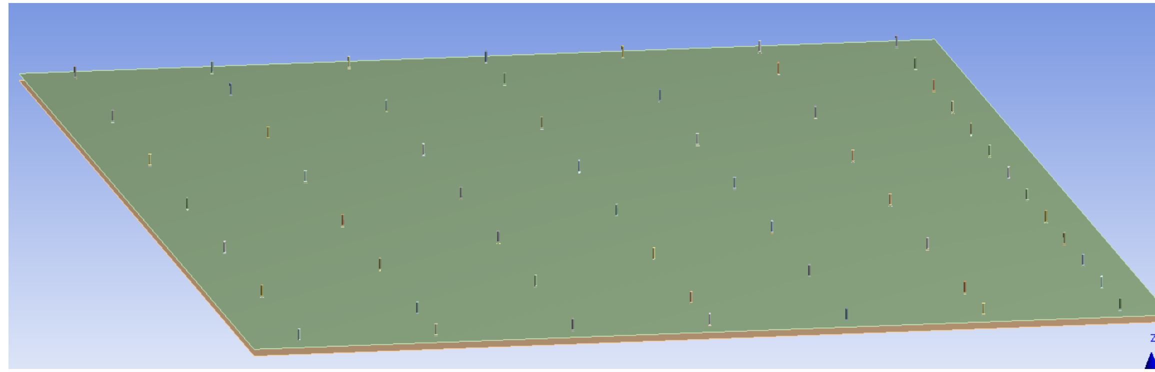


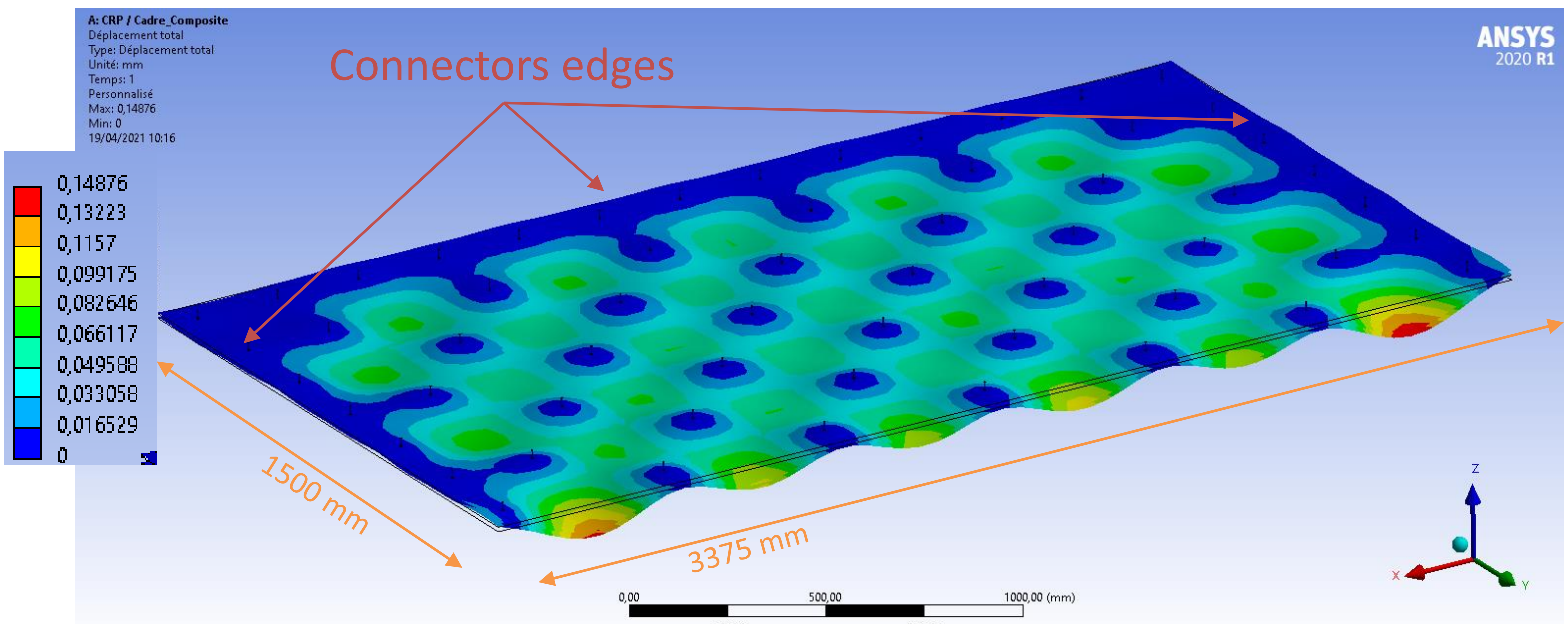
58 supporting points by CRU

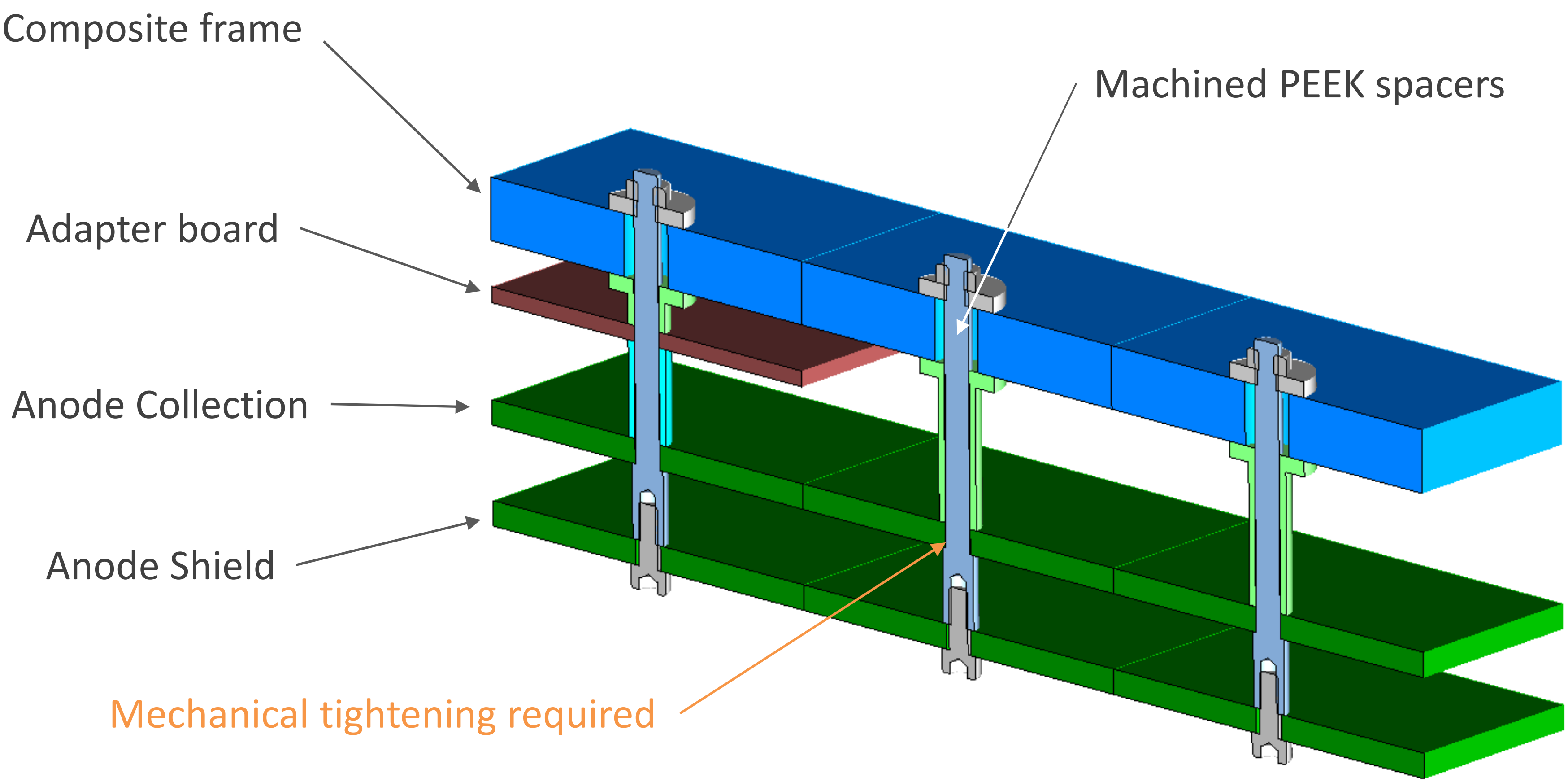


Positions optimized by FE simulation to minimize deformations

Especially on edges including connectors

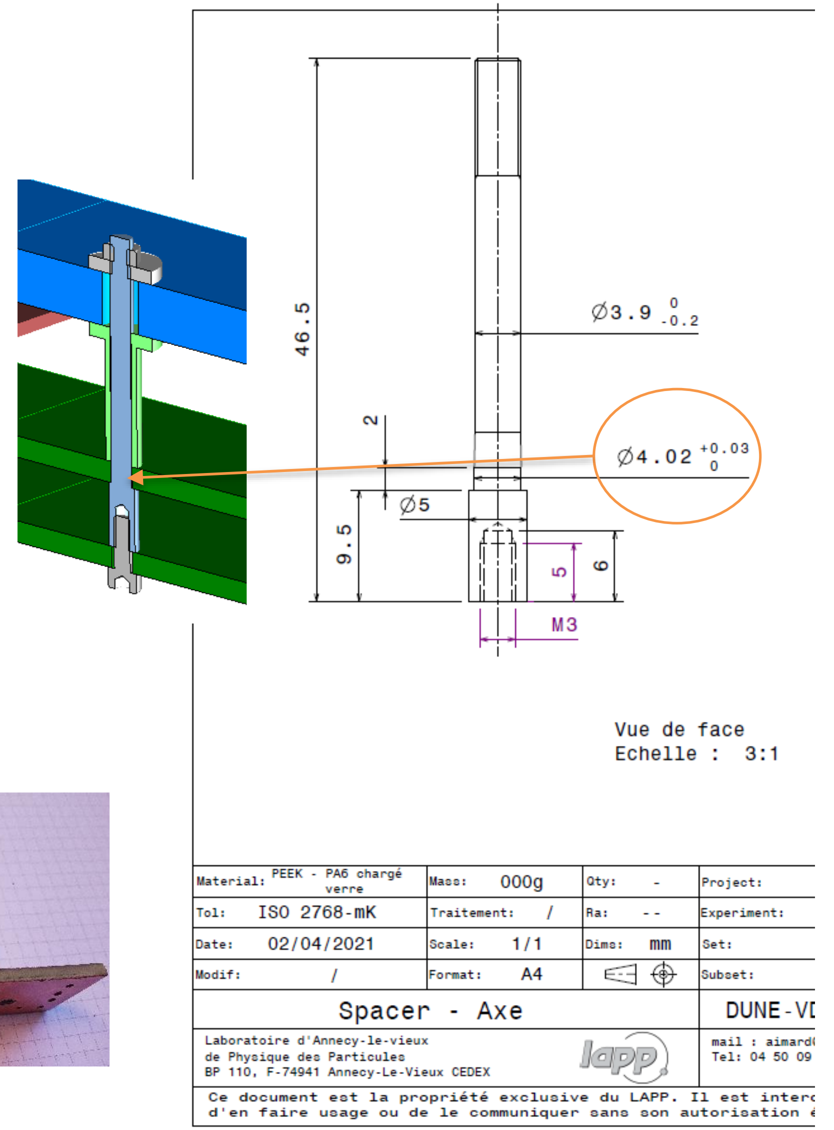


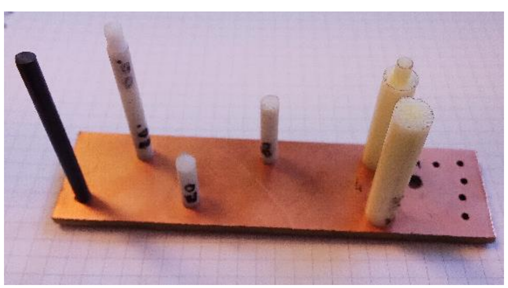


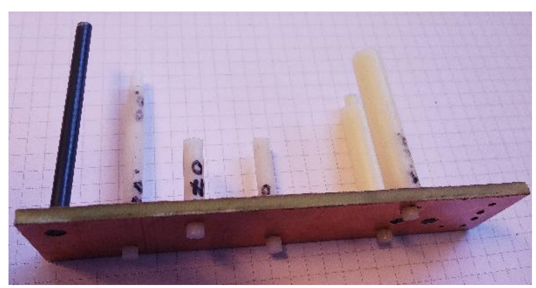


- Specific Spacer design allows quick, accurate and clean assembly (no glue)

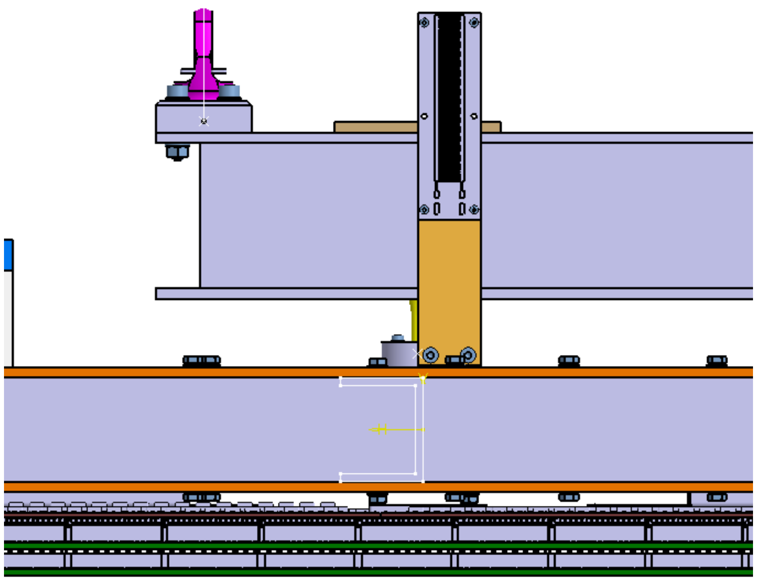
- Optimal tightening : 30 – 50 µm
  - *Tests shows that 15µm to 80µm are suitable*
- Manual assembly, in force or with cold
  - *Liquid Ar/N cooling of the pin induces a -40µm contraction on the PEEK diameter*
  - *Eltos insures +/-10 µm tolerances on anodes holes*
- Real size tests in progress

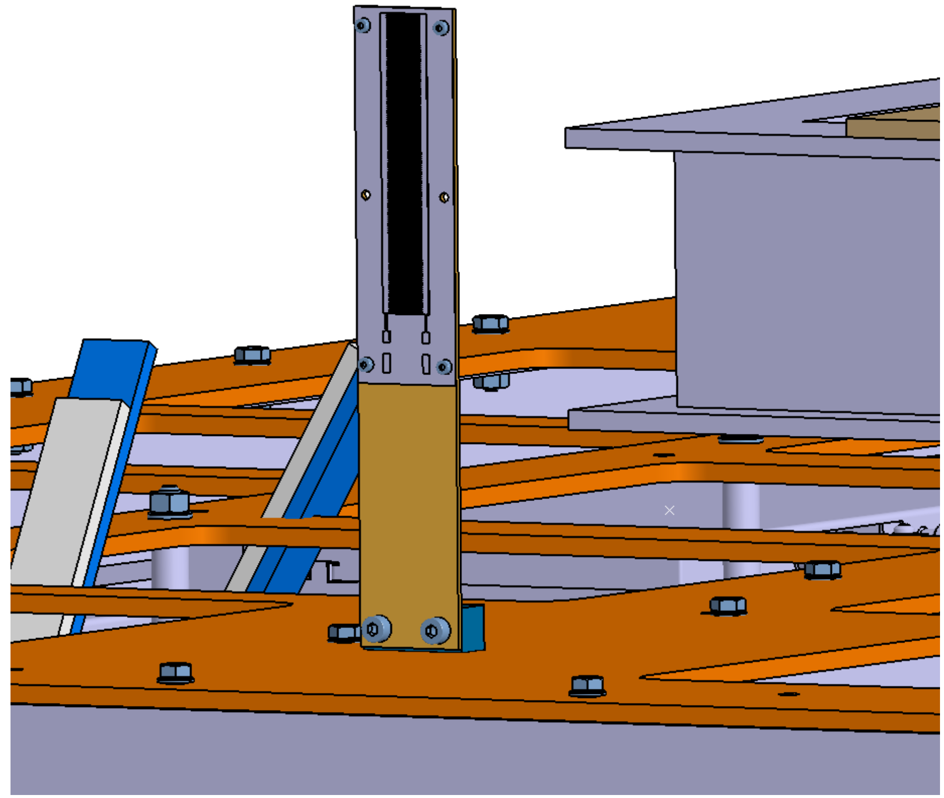






Capacitive levelmeters developed by LPSC team
Height adjusted to nominal liquid level





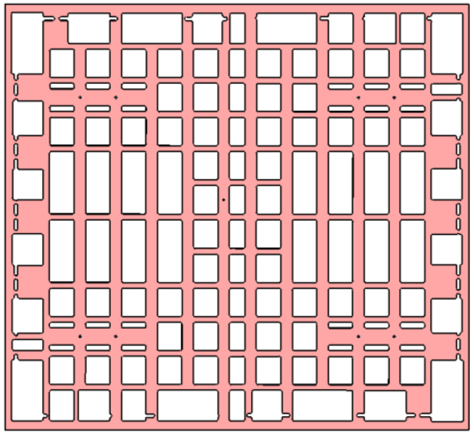
Composite frame

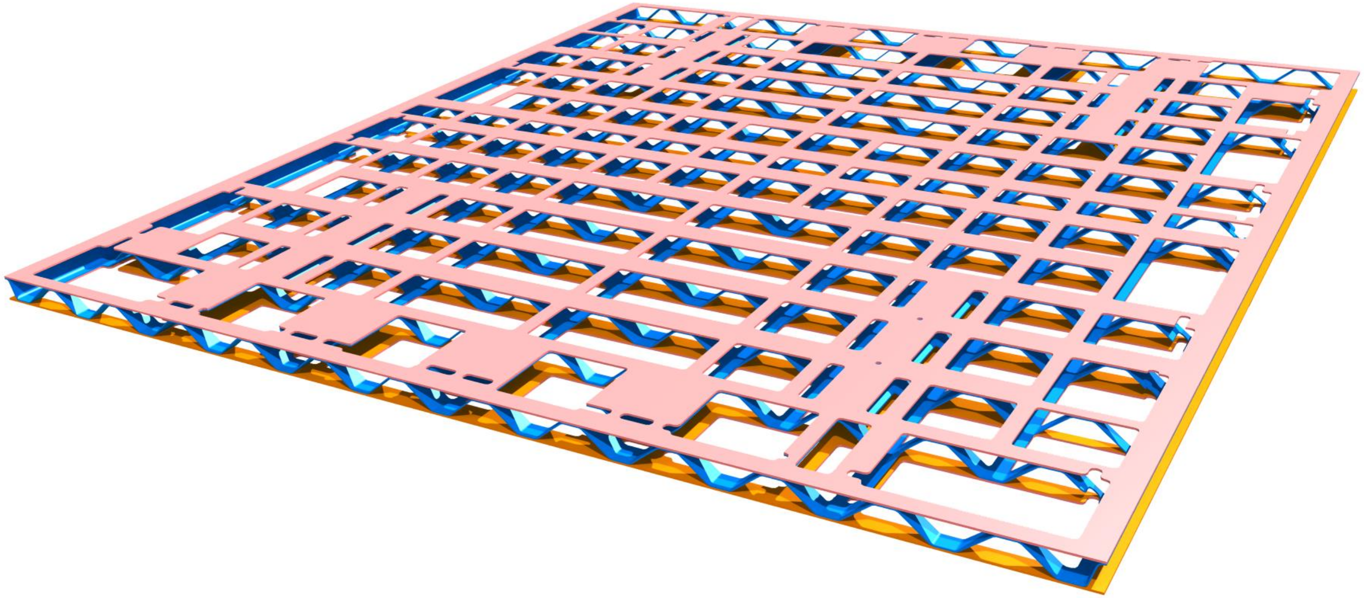
Design

Decoupling systems

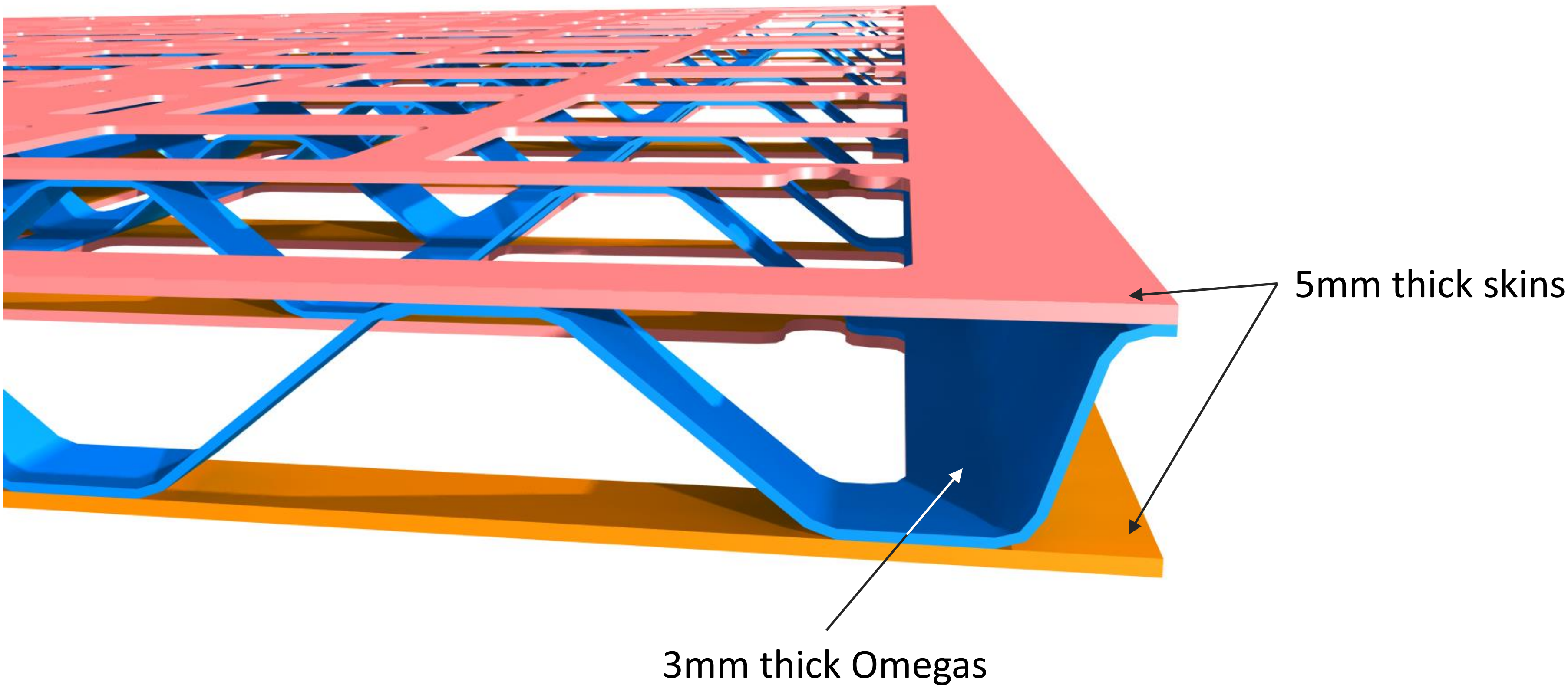
Coldbox test : Hybrid solution to combine the 2 types of readout electronics in a suspended CRP configuration

Thickness : 70mm
Transparency : 50% *(for vertical Argon flow)*
Mass : 103kg
Material : Epoxy / Glass fiber
Cost : under 30k€ for prototype, 15-20k€ target for DUNE
Last optimization in progress before production start



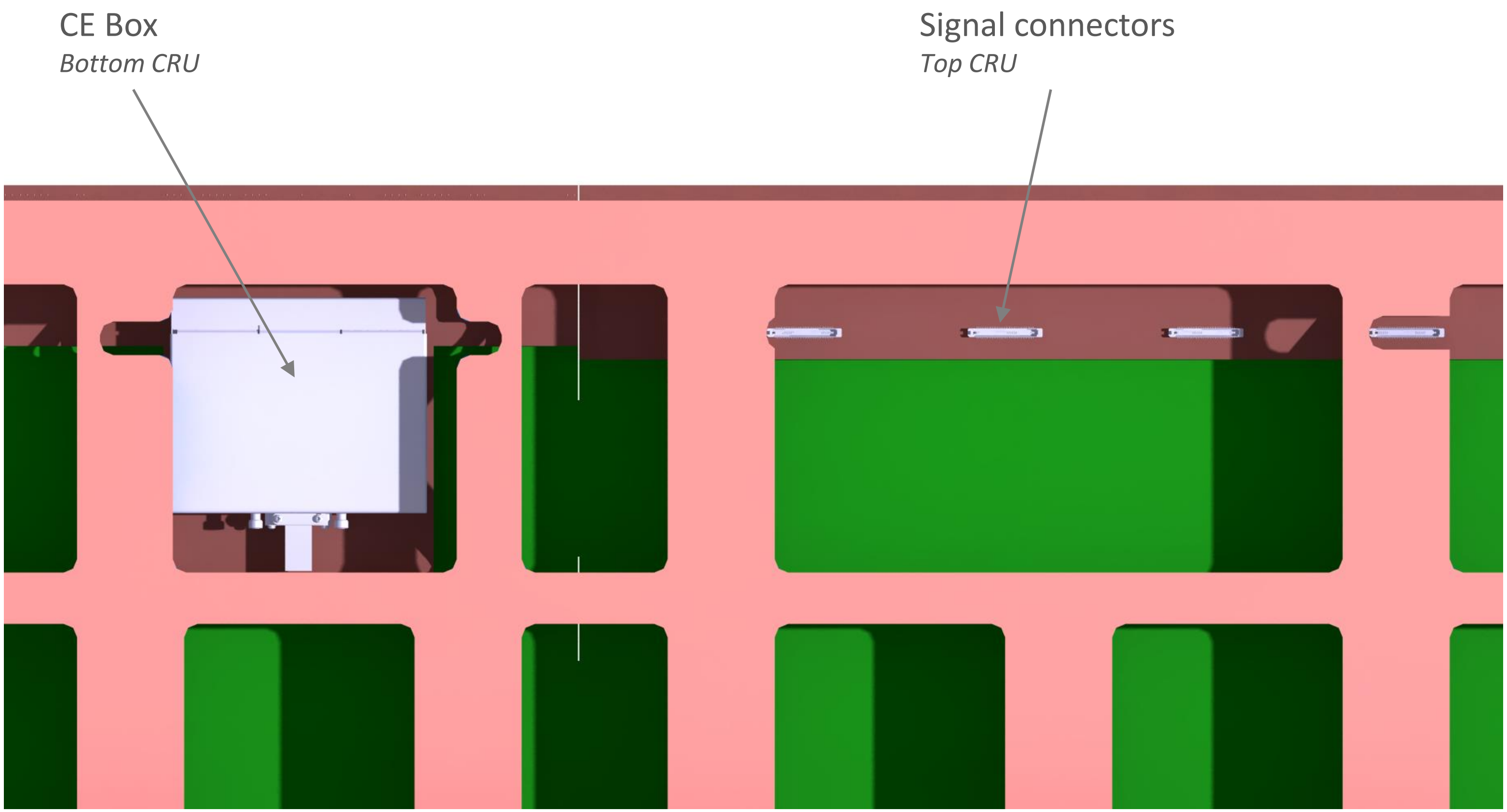


- Various solutions & configs have been investigated (Omega or IPE)
- Molded omega-structure used for high Stiffness/Mass ratio
- Openings are CNC machined
- Assembled in 3 parts for Colbox test, probably two for DUNE



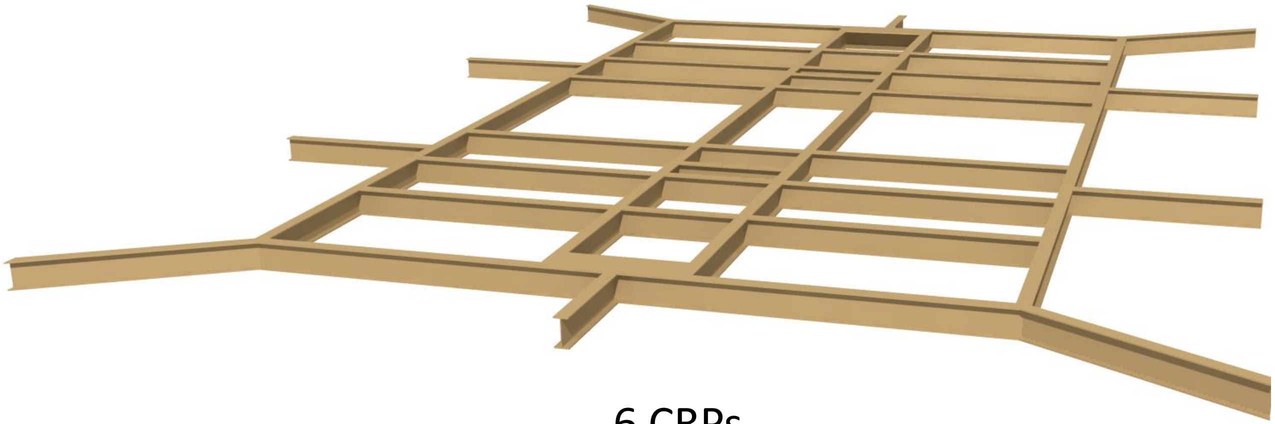
Coldbox Test version designed to support both Top and Bottom electronics

DUNE-VD versions will be specific to electronics to support, design will be optimized specifically for Top and Bottom planes



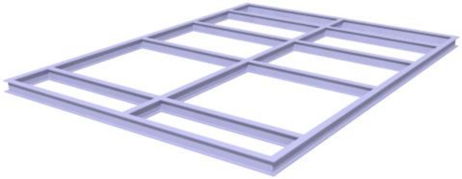
Metallic frames

Super-structure for DUNE-VD



6 CRPs

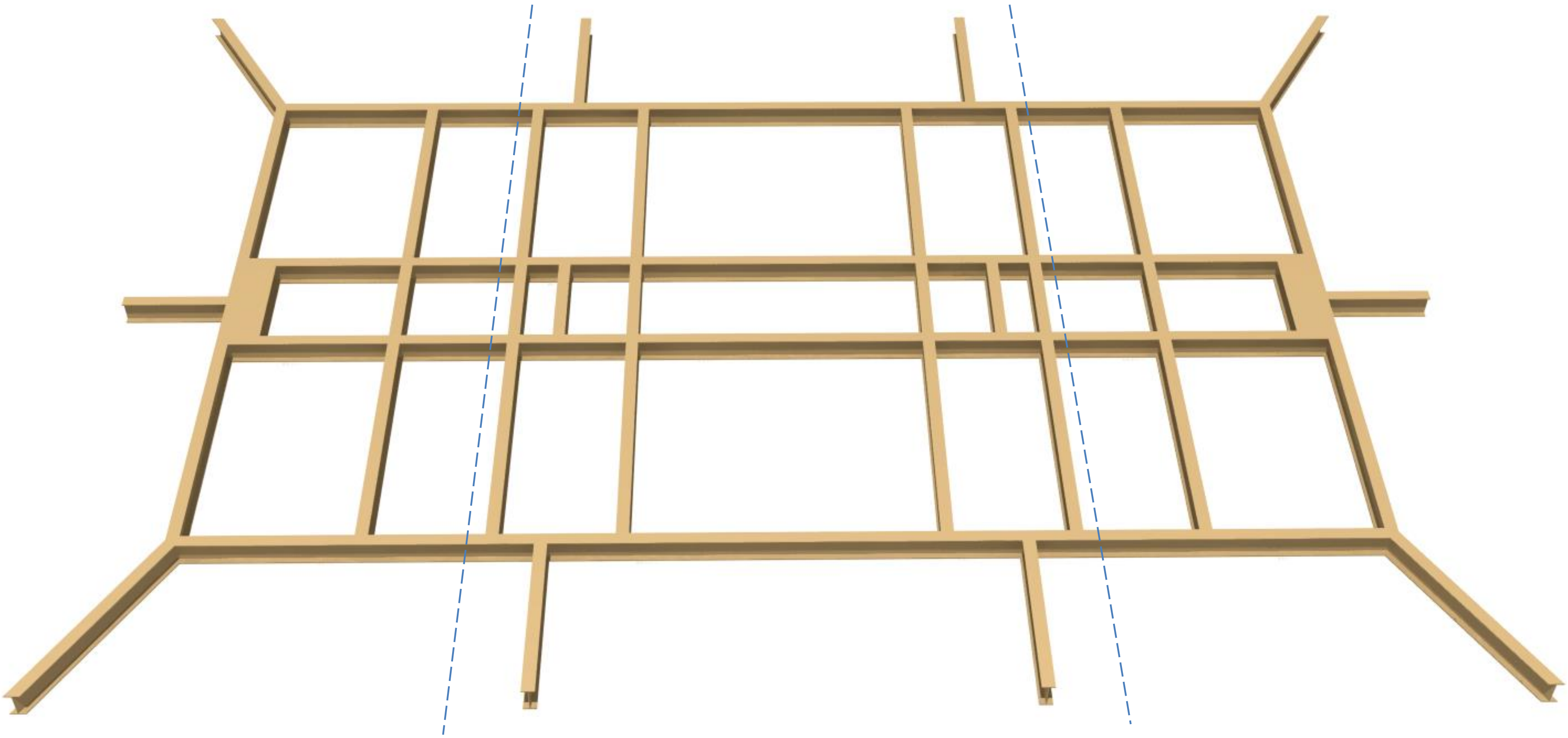
Test frame for the ColdboxTest



1 CRP

Metallic frame for DUNE-VD

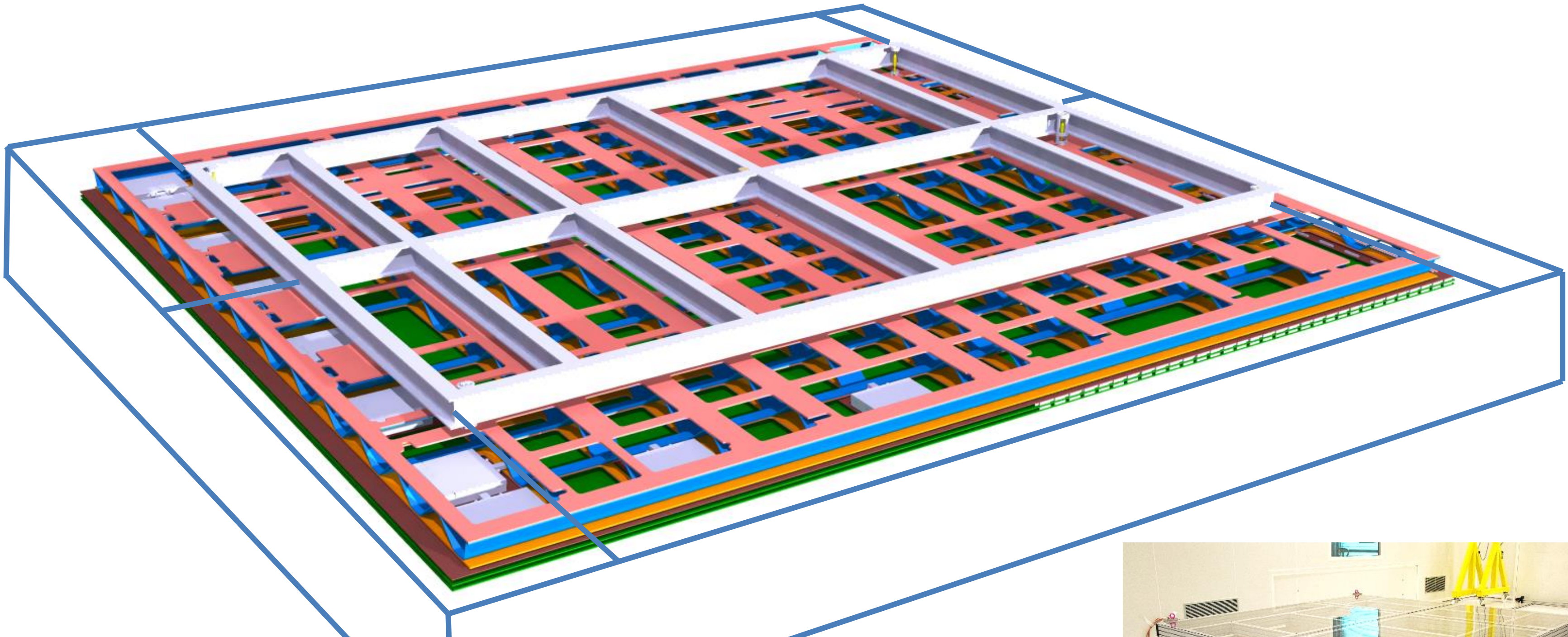
- Stainless steel frame, done in three part, transported separately and re-assembled in the cryostat
- Also supports the cathode



Metallic frame for coldtest

- Stainless steel frame, done in one part, welded
- Extension design in progress, for assembly tooling and transport box

Concept validated with ProtoDUNE-DP



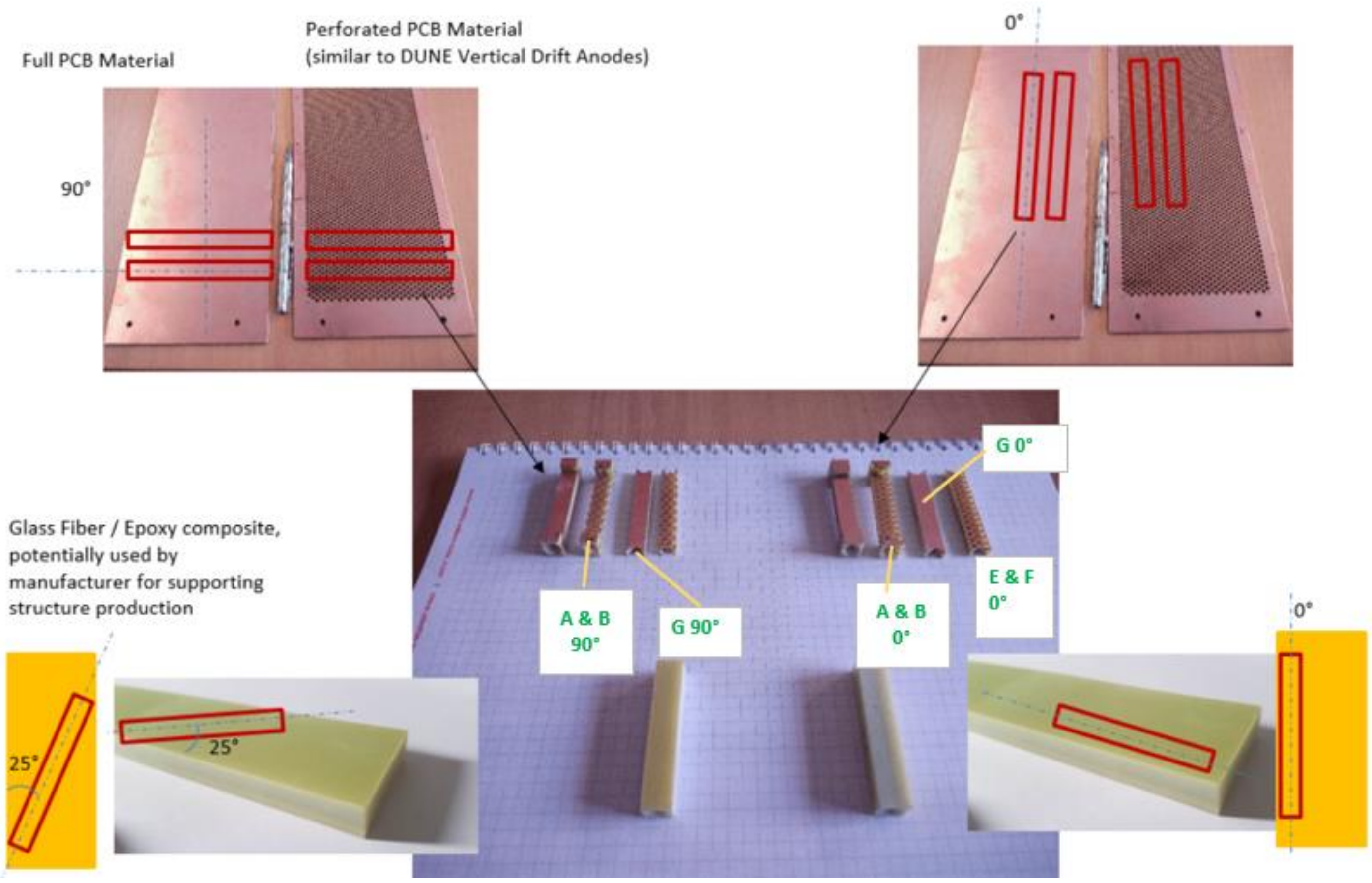
ProtoDUNE-DP (3mx3m CRP)

Thermal shrinkage

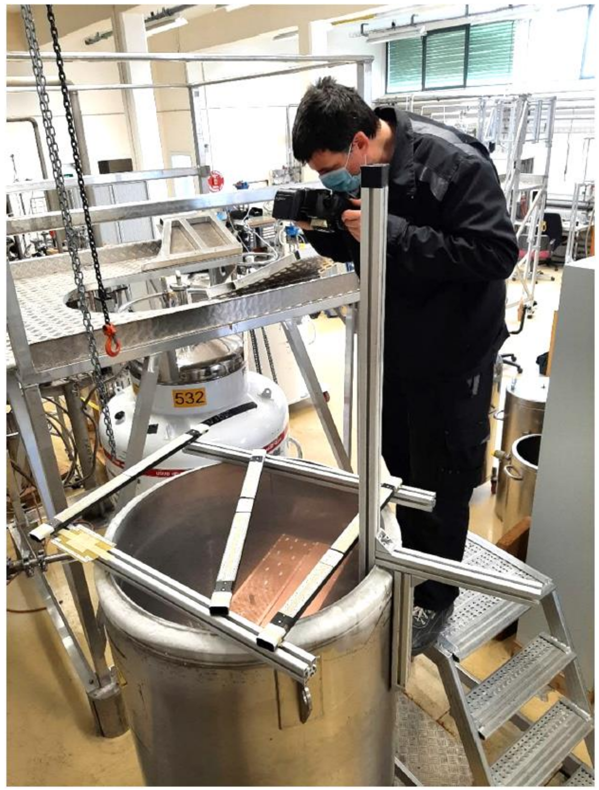
Material properties & assembly design

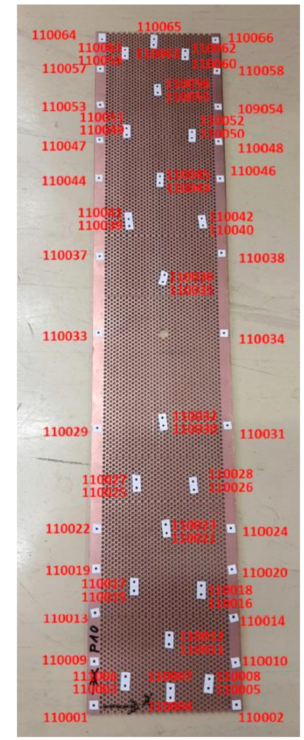
Coefficients of Thermal Expansions (CTE) measured by Cryolab (CERN)

- on **Anode material** and **Glass fiber** from manufacturer,
- along **two orthogonal directions**



CTE for Anode material measured by photogrammetry by CERN metrology team.





CTE measurements results

Direction : 0°	**PCB Perforated**	**11,31**	$e^{-6}K^{-1}$
	Cryolab	*11,39*	$e^{-6}K^{-1}$
	Cryolab	*11,65*	$e^{-6}K^{-1}$
	Photogrammetry	*10,90*	$e^{-6}K^{-1}$
	PCB Non-perforated	**11,29**	$e^{-6}K^{-1}$
	Cryolab	*11,38*	$e^{-6}K^{-1}$
	Photogrammetry	*11,20*	$e^{-6}K^{-1}$

Direction 90°	**PCB Perforated**	**9,97**	$e^{-6}K^{-1}$
	Cryolab	*9,98*	$e^{-6}K^{-1}$
	Cryolab	*9,74*	$e^{-6}K^{-1}$
	Photogrammetry	*10,20*	$e^{-6}K^{-1}$
	PCB Non-perforated	**9,73**	$e^{-6}K^{-1}$
	Cryolab	*9,56*	$e^{-6}K^{-1}$
	Photogrammetry	*9,90*	$e^{-6}K^{-1}$

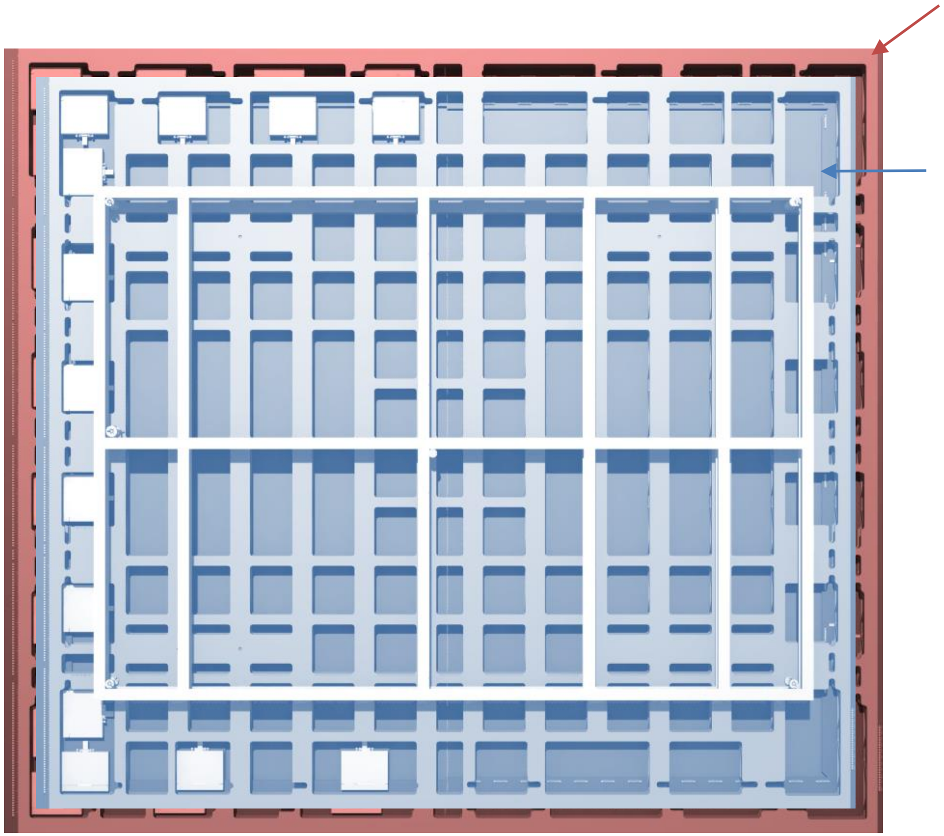
	Glass-Fiber		
0°	*Measured*	**8,82**	$e^{-6}K^{-1}$
25°	*Measured*	**8,89**	$e^{-6}K^{-1}$
90°	*Estimation*	**9,08**	$e^{-6}K^{-1}$

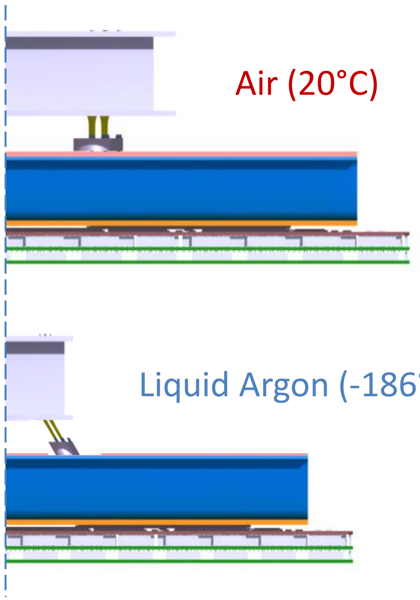
- PCB perforation has negligible effect on CTE
- Glass-Fiber, as built from the manufacturer, is almost isotropic in plane

Note : A difference of 0,2 $e^{-6}K^{-1}$ over 3 meters and 200°K induces a 0,12 mm shrinkage

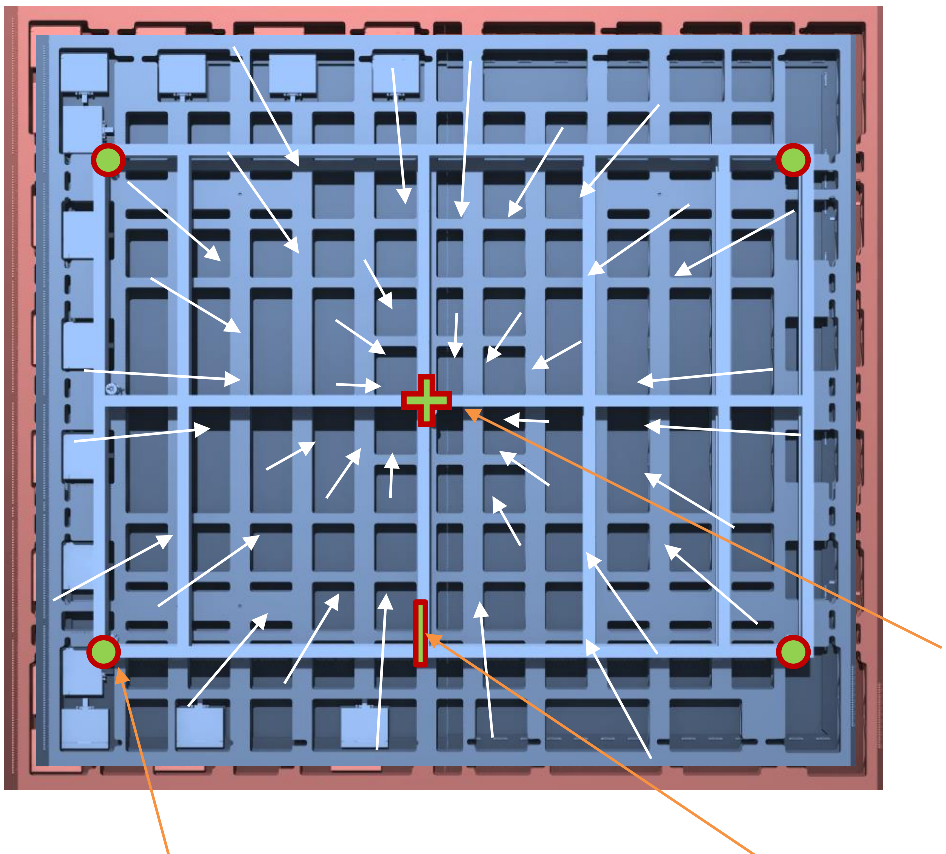
- Those properties are included in FE analysis and impacts on stress and planarity are evaluated

- Thermal shrinkage of Stainless Steel and Glass-Fiber are different
- Links between frames must allow a sliding : the decoupling systems
- Sliding should be handled specifically

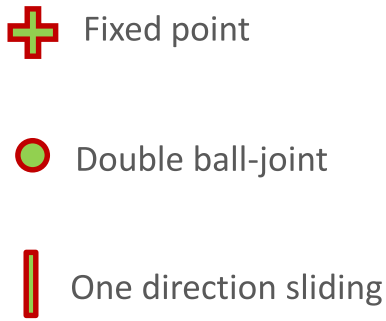




Thermal shrinkage focused toward fixed point :



Links between metallic and composite frames :



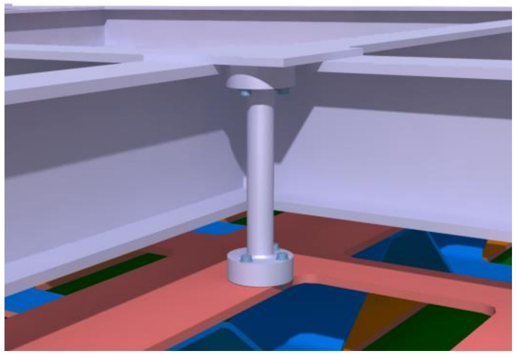
Fixed point, to control the lateral position of the panel

Double ball-joints, to insure vertical position while allowing lateral sliding

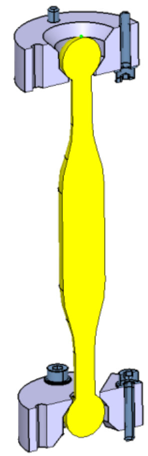
One direction sliding, to avoid panel rotation

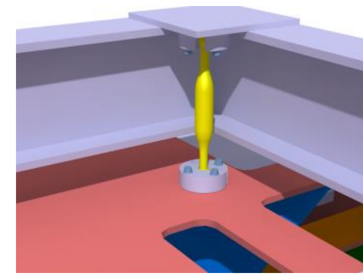
Stainless Steel links between metallic and composite frames :

Fixed point

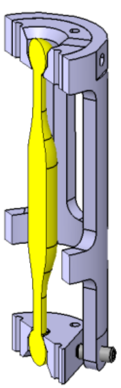


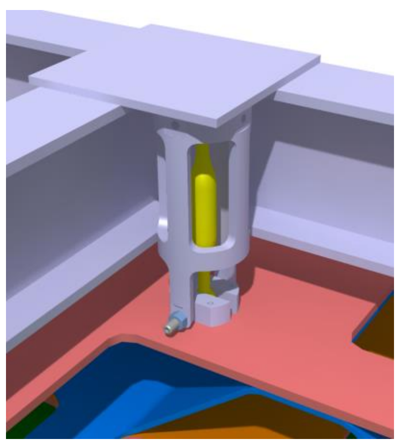
Double ball-joint





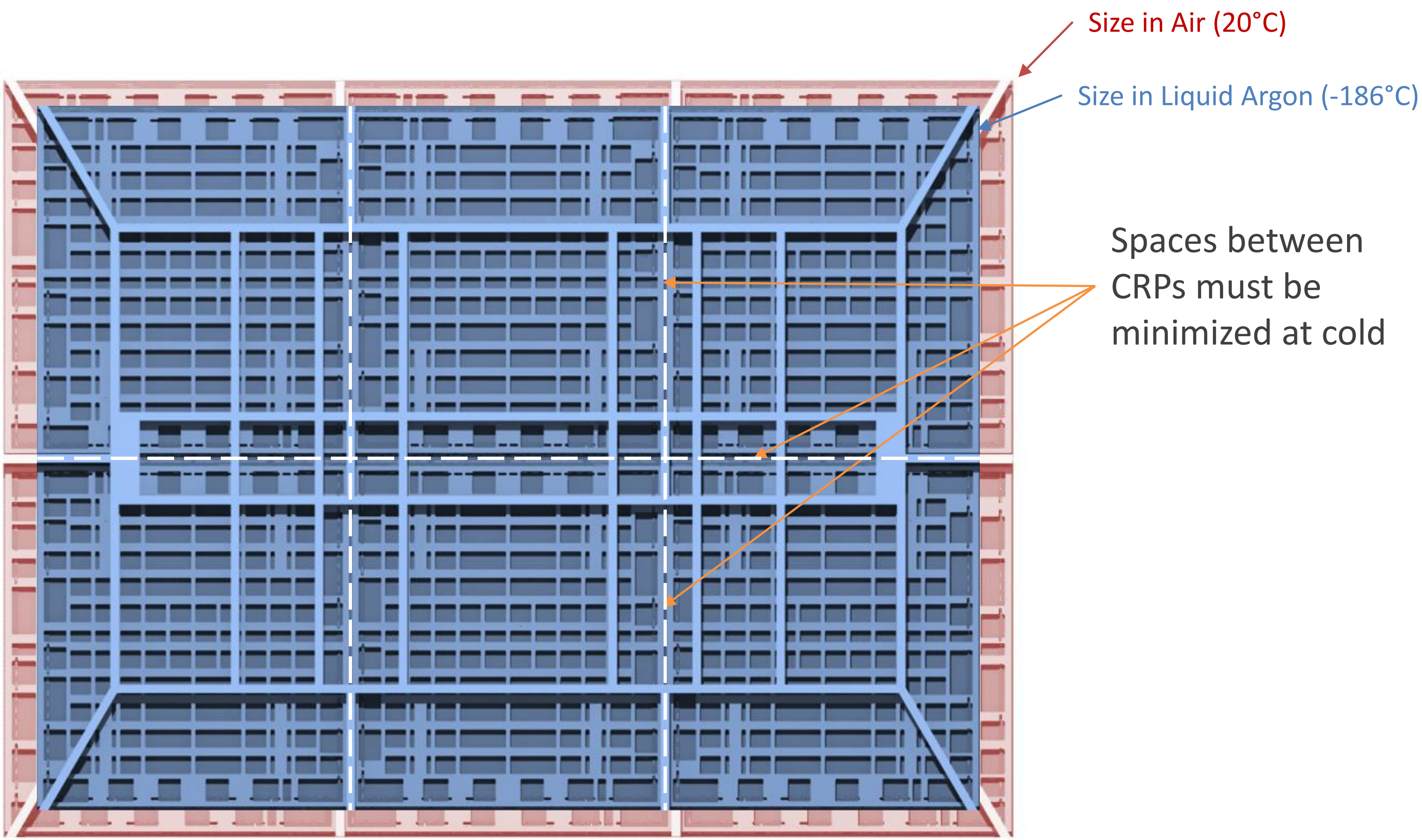
One direction sliding



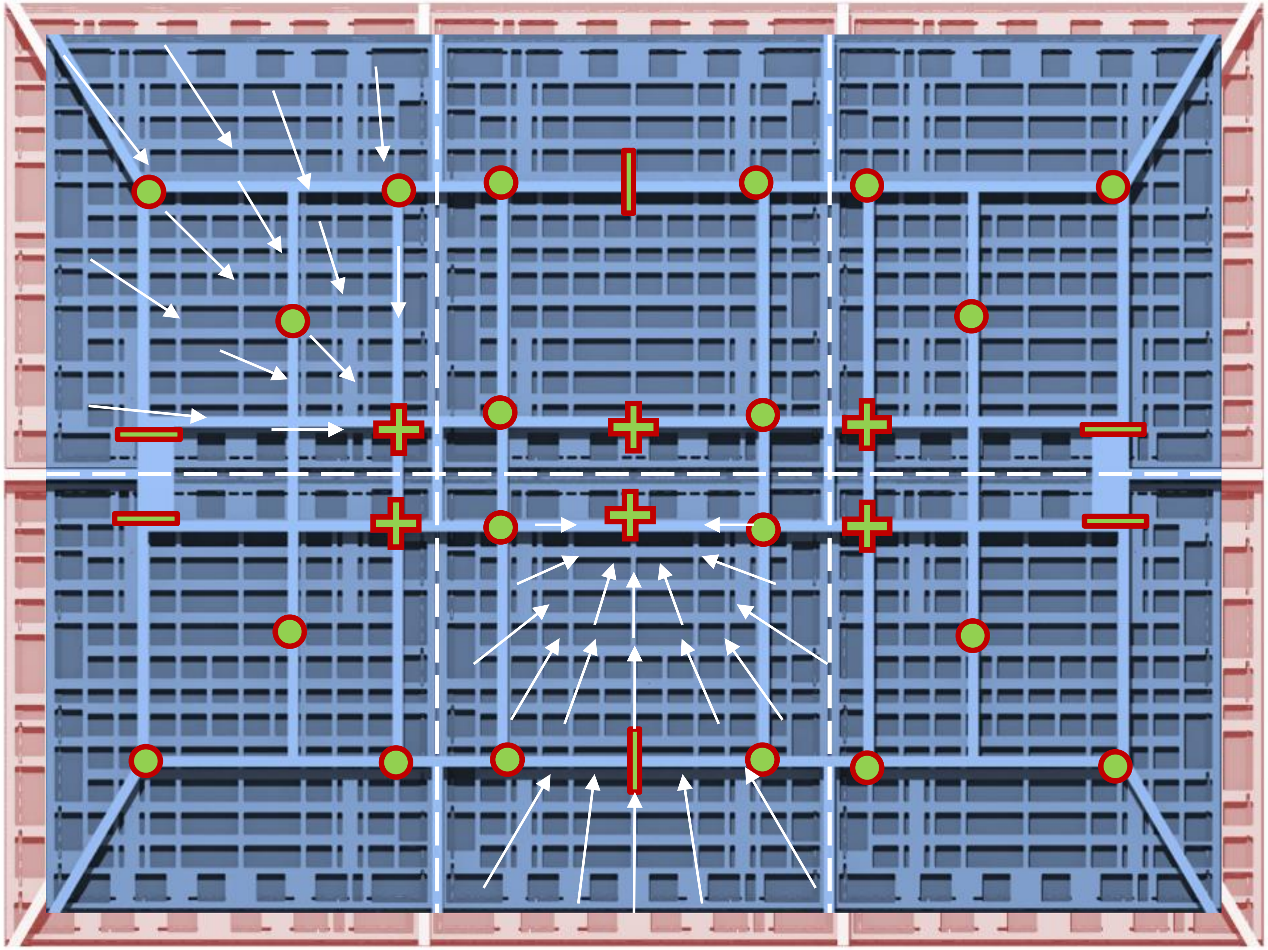


- Those parts will be machined at LAPP by the end of April
- Tests in Liquid Argon and fine tuning are foreseen

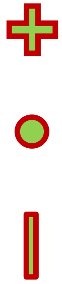
DUNE-VD : Thermal shrinkage pattern



DUNE-VD : Thermal shrinkage pattern



Links between metallic and composite frames :



- Differential thermal shrinkage is oriented toward SuperCRP center to minimize dead spaces

Mechanical simulations

Single CRP for Coldbox Test

Super-Structure for DUNE-VD

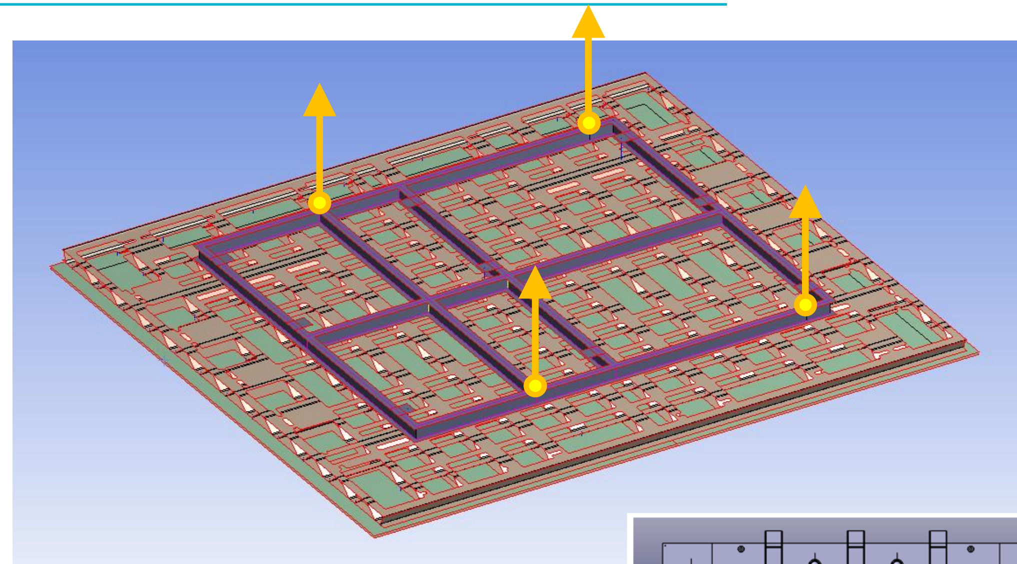
Model :

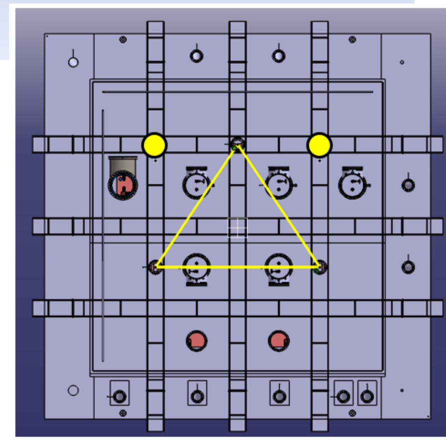
- *Metallic/composite frame, anodes, CE-boxes*
- *Fours suspension cables (off-centered)*

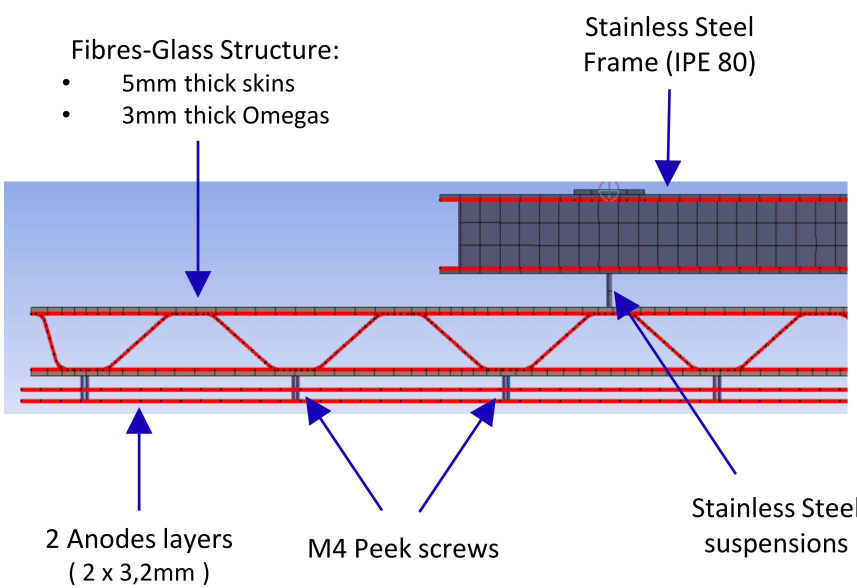
Boundary conditions :

- *Gravity (in Air/in Argon)*
- *Thermal loads*

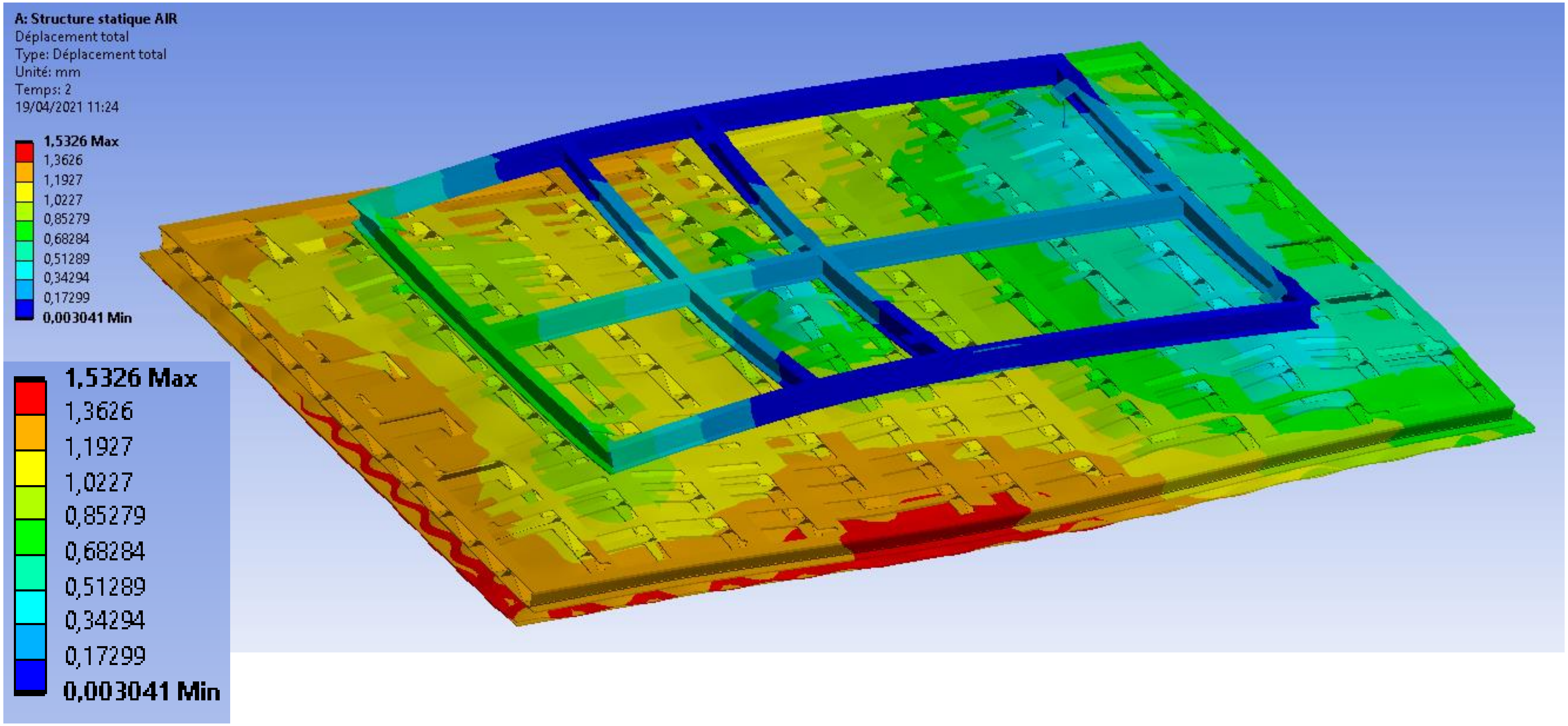
- $\alpha_{\text{Stainless Steel}}$ = 13,2 . 10^{-6} K^{-1}
- $\alpha_{\text{FG composite structure}}$ = 8,9 . 10^{-6} K^{-1}
- α_{Anodes} = 11,0 . 10^{-6} K^{-1}





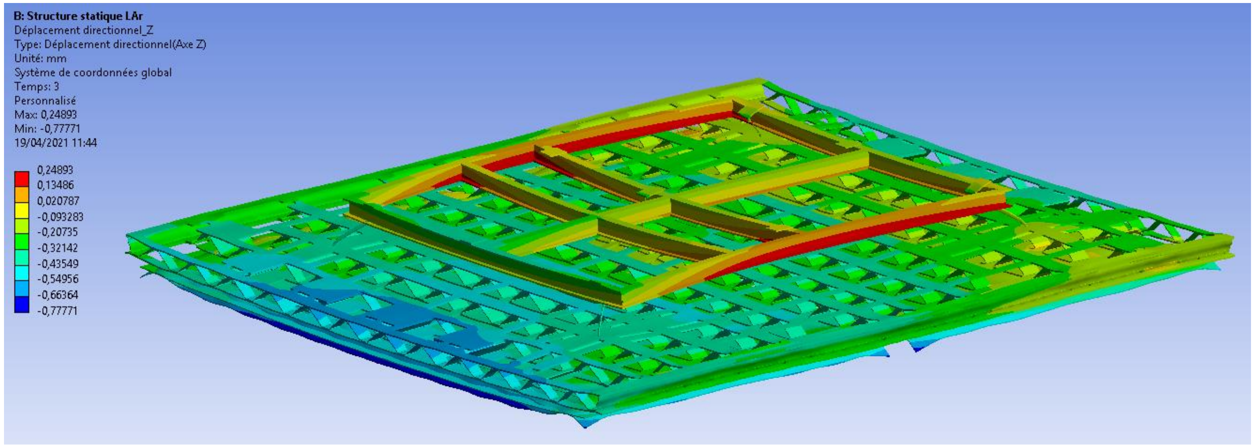


Vertical displacements in **Air :**



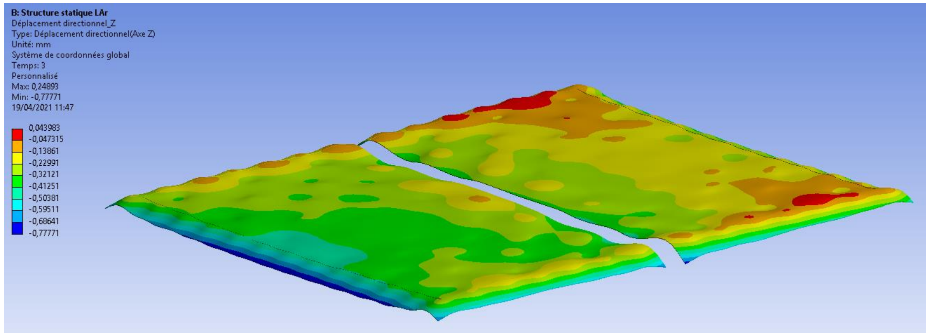
Note : Manufacturing and assembly defects not included

Vertical displacements in
Liquid Argon (-186°C) :



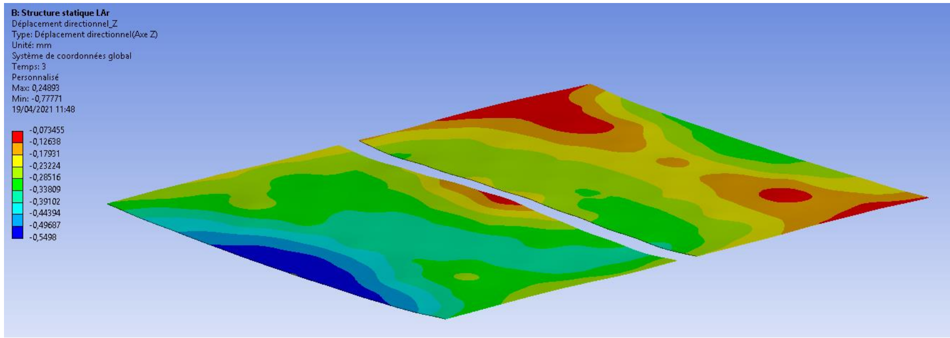
Z-displacements on Anode with shield :

$\Delta z_{\text{Anode S}}$ = 0,82mm



Z-displacements on Anode with collection :

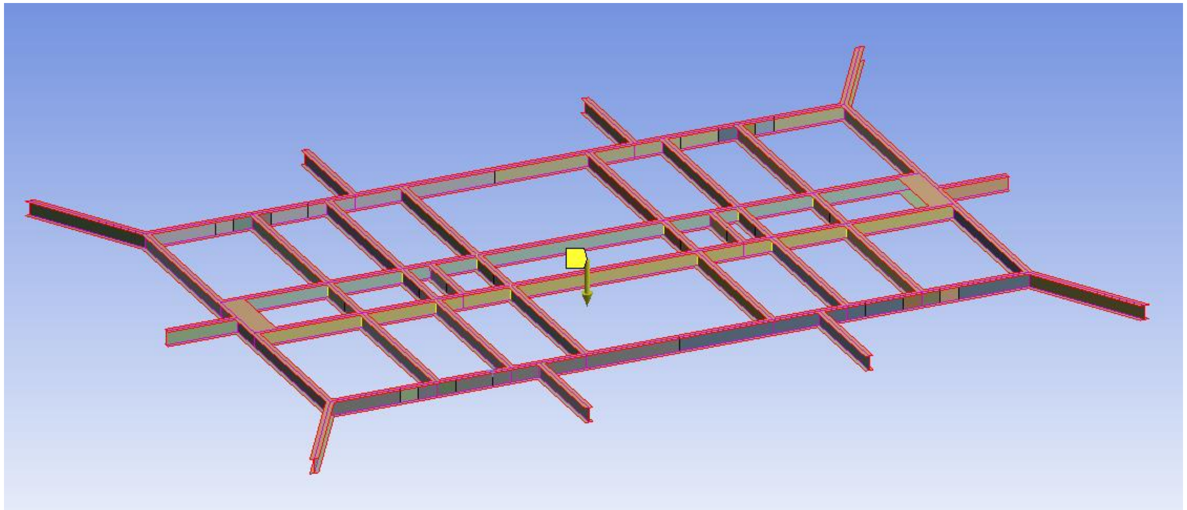
$\Delta z_{\text{Anode C}}$ = 0,62mm

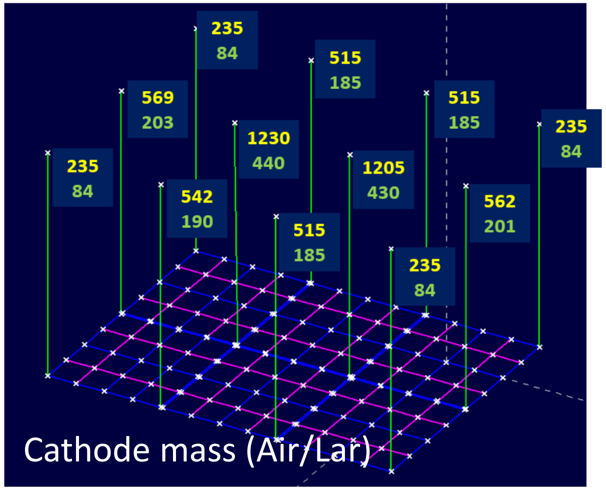


- Max local relative displacement between anodes : 0,3mm

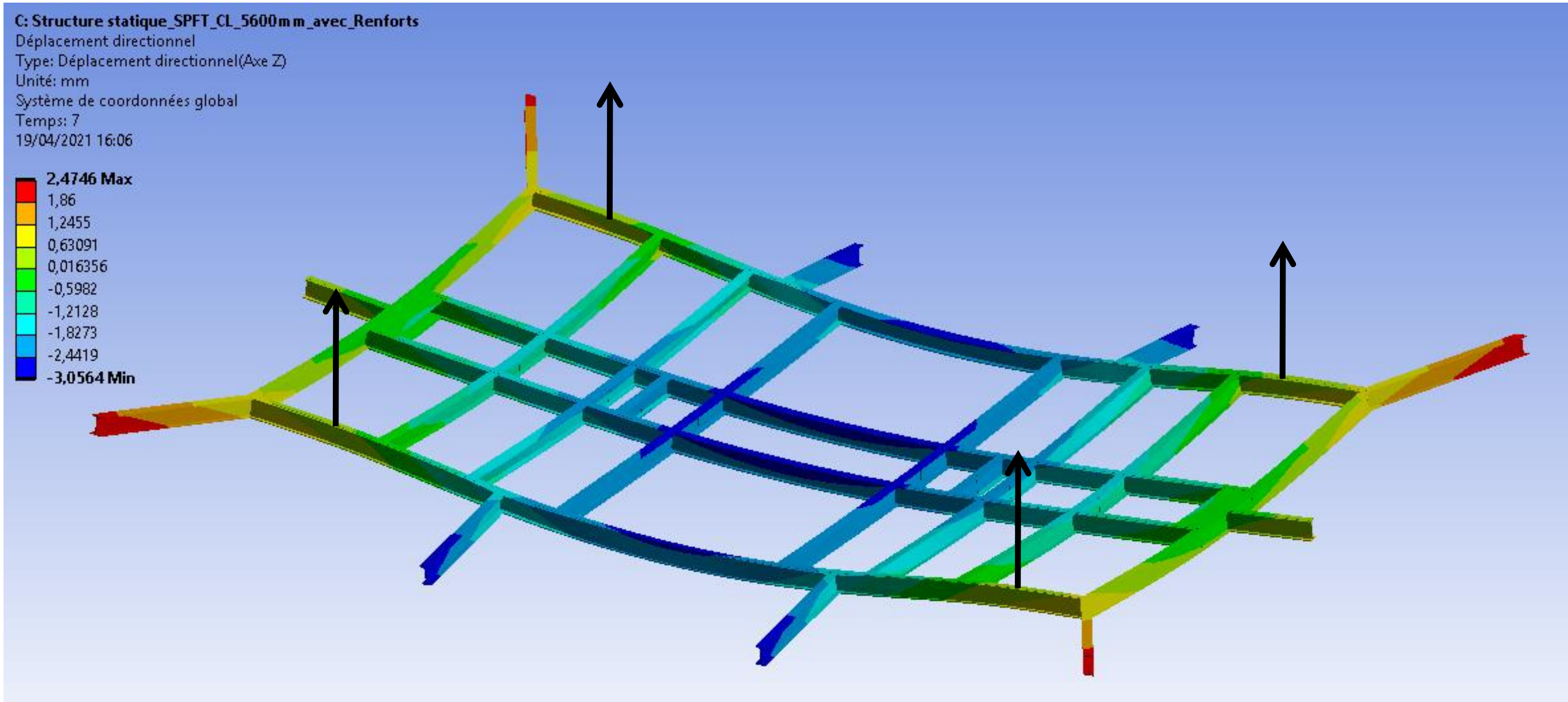
DUNE-VD Super-Structure mechanical simulation

Step 1 : Gravity on SuperStructure alone	(1230 kg)	AIR
Step 2 : same + 6 CRPs mass	(208 kg on four points)	AIR
Step 3 : same + cathode mass	(660 kg on 12 points)	AIR
Step 4 : Gravity on SuperStructure alone in LAr	(1000 kg)	LAr
Step 5 : same + 6 CRPs mass in Lar	(68 kg on four points)	LAr
Step 6 : same + cathode mass in LAr	(236 kg on 12 points)	LAr
Step 7 : same + Thermal shrinking	(22°C → -186°C)	LAr





DUNE-VD Super-Structure mechanical simulation



	Temps [s]	Minimum [mm]	Maximum [mm]
Entire structure in AIR	1.	-2,0875	1,5894
	2.	-4,5314	3,7174
	3.	-6,8956	3,8981
	4.	-1,7118	1,3033
	5.	-2,5107	1,999
Entire structure in LAr	6.	-3,057	2,055
	7.	-3,0564	2,4746

Δz_{Air} = 10,8 mm

Δz_{LAr} = 5,53 mm…

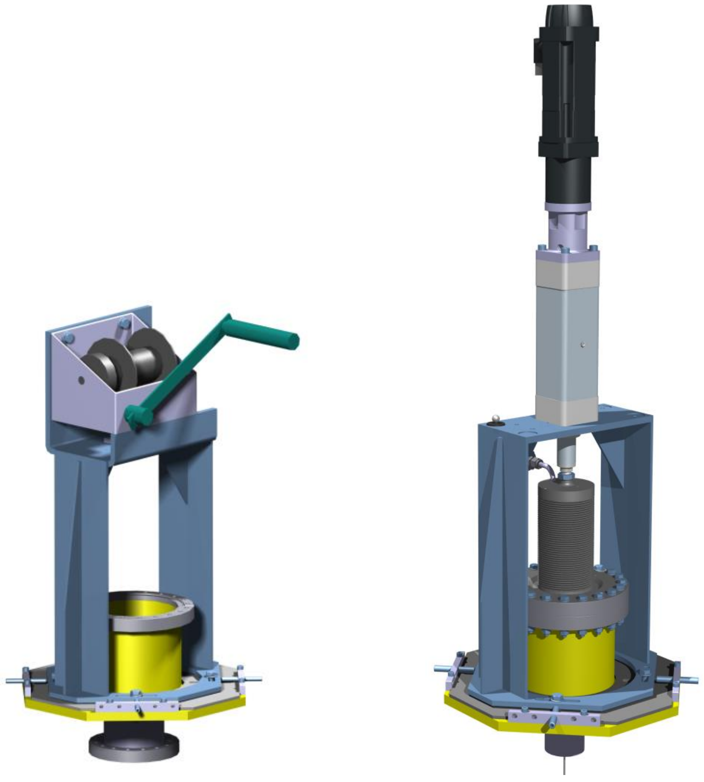
Force de réaction (Total) [N]
12334
24814
31407
10114
14194
16549

31407 → 785 kg per suspension cable

16549 → 414 kg per suspension cable

Suspension system

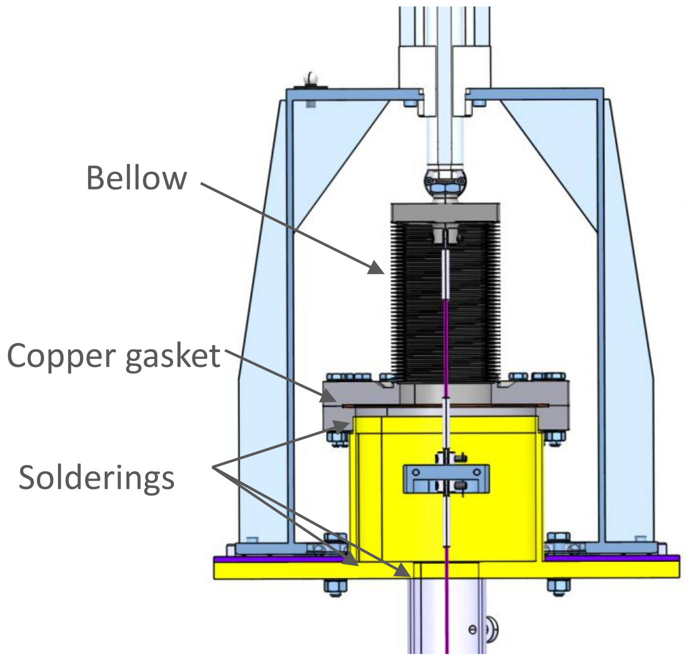
Tested and validated with ProtoDUNE-DP

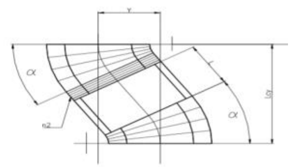


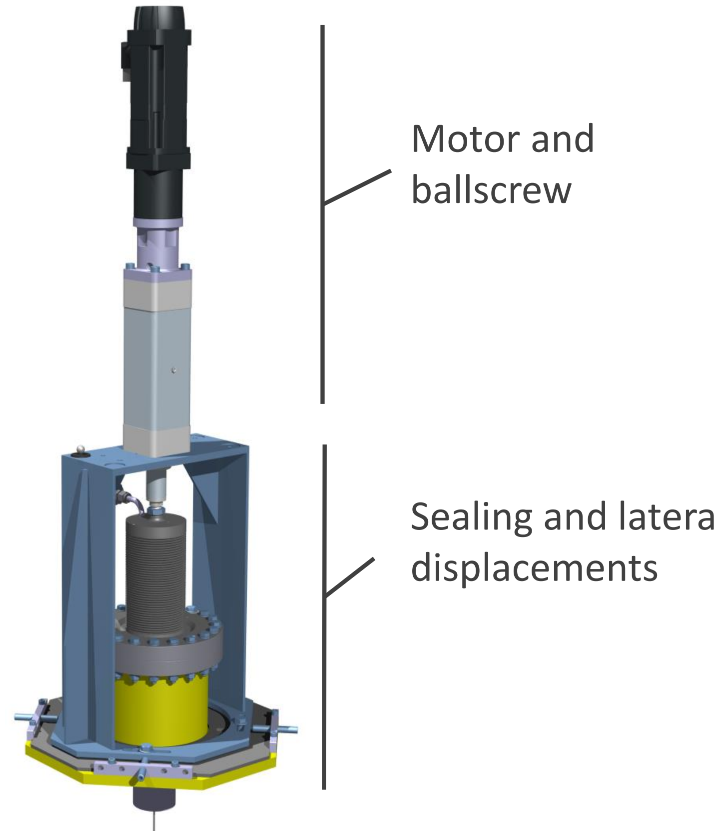
GAr volume completely closed

- no sliding parts,
- no moving sealing

Lateral movement absorbed by lateral deformation of the bellow

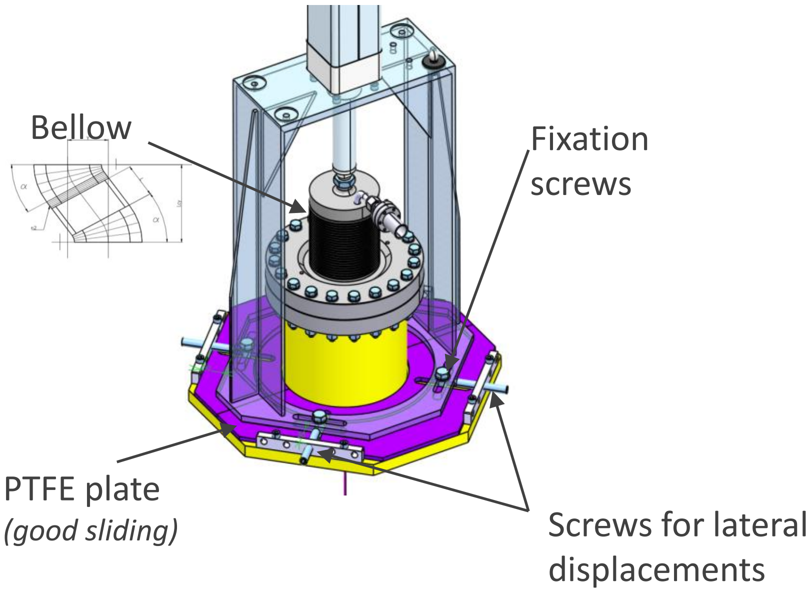




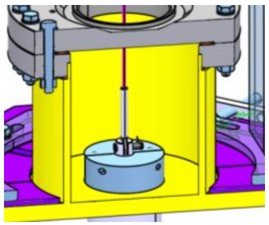


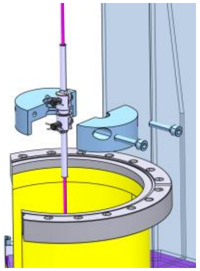
Suspensions from ProtoDUNE-DP

- Vertical stroke : **98mm**
- Lateral stroke : **+/- 26mm**

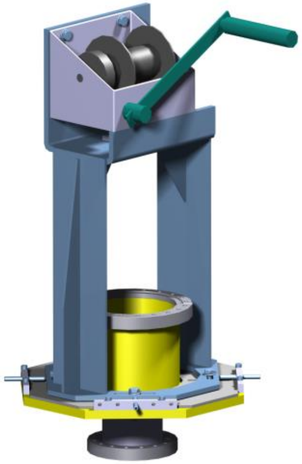


- Mechanical stop and chimney simple obstruction for maintenance or bellow replacement





- Winch config, to raise manually the CRPs



➢ Actual system is motorized, manual system design in progress

CRP assembly

From raw parts to packed CRP, ready for transport

The tasks are being defined and detailed for the first CRP construction in 2021
=> Input to the CRP factories task definition and optimization (cf: Matt's talk)

Overview of the ProtoDUNE Dual Phase CRPs is available here :

https://lapp-owncloud.in2p3.fr/s/fPC2Sb8KfesLMoS

Clean room dimensions : 20m x 6m x 5m

Clean room 185 tooling

CRP assembly for ColdTest is done in Clean Room 185 at CERN

Optical table

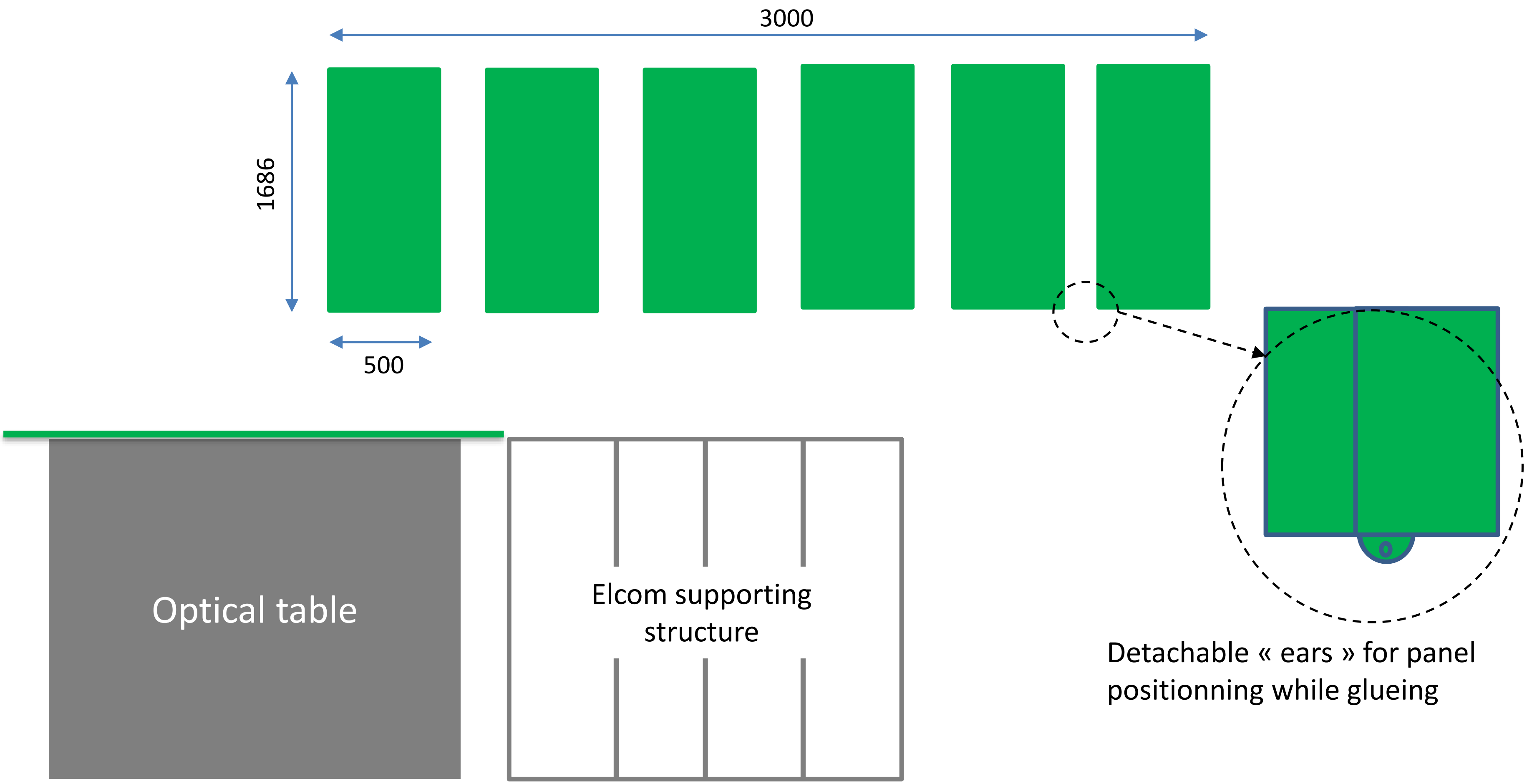
Good surface and flatness

Elcom structure

Access from below

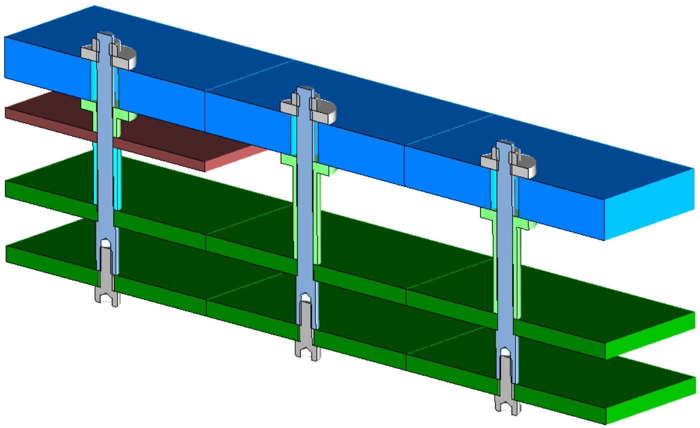
Anode panels are glued together on the optical table (in a vacuum bag)
Connections are printed

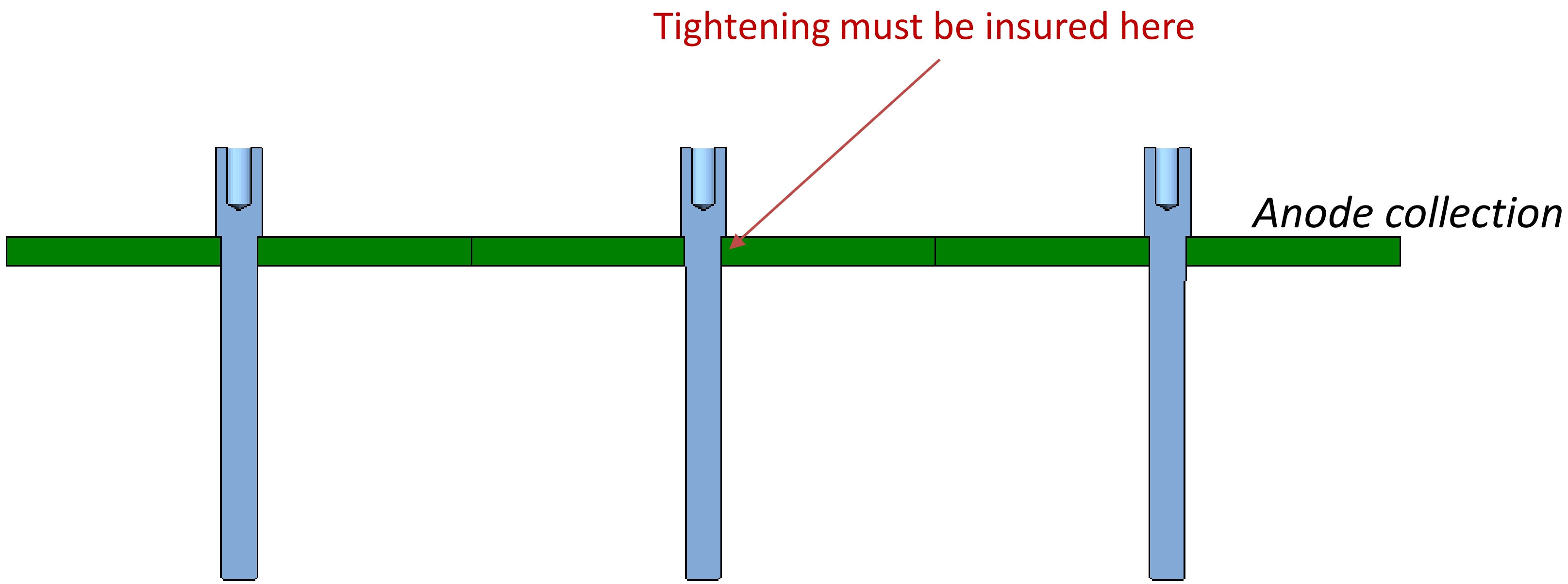
- Once glued, panels can be safely moved and fliped by hand by 4 persons



The 58 plastic spacers are placed in the panel

- *Performed on Elcom structure to access from below*
- *Pins are gently inserted with a mallet, or cooled down in liquid argon / nitrogen, tests in progress*

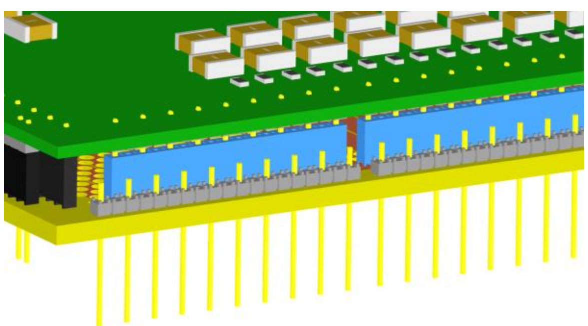


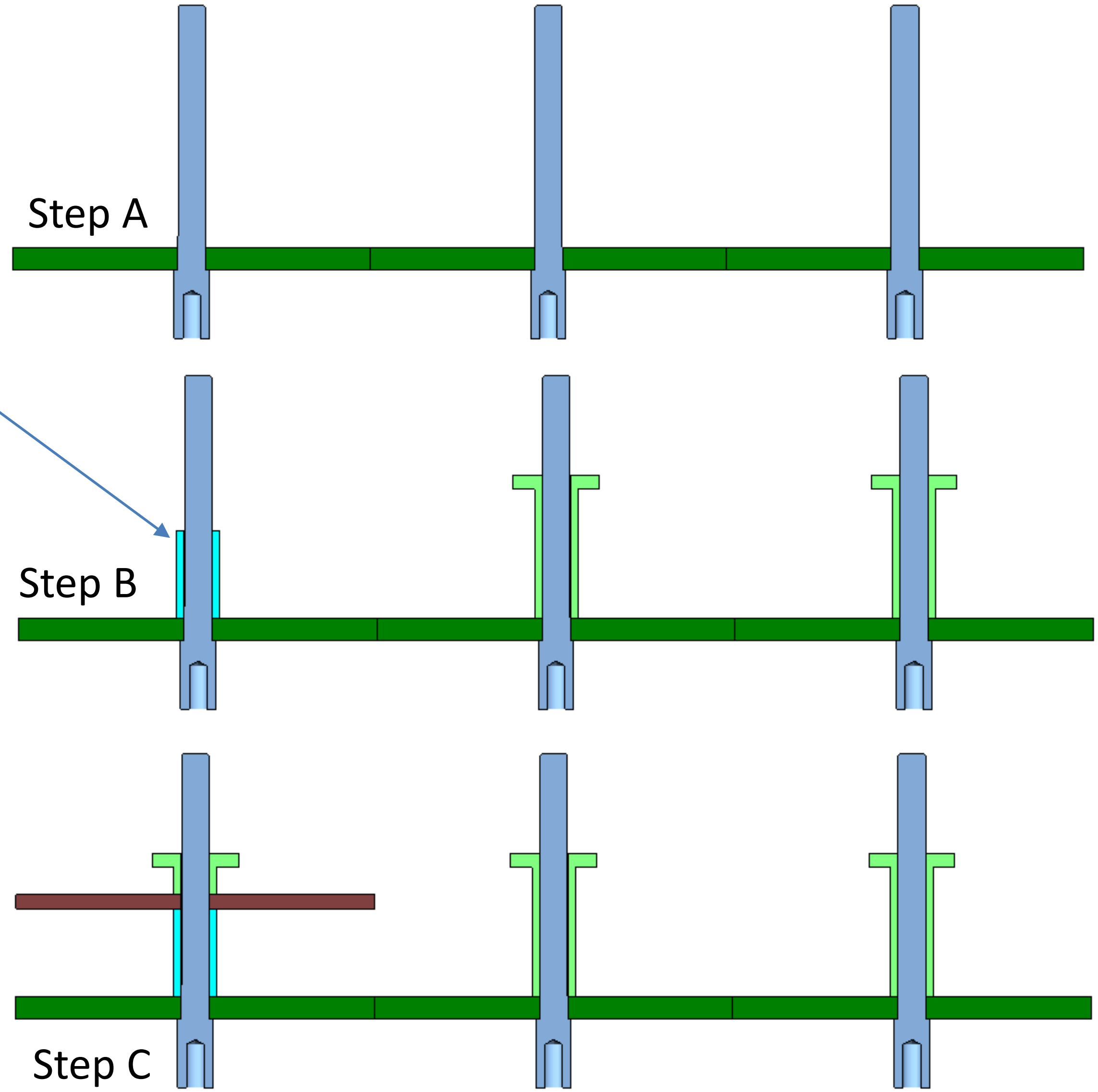


Panel is then flipped back :

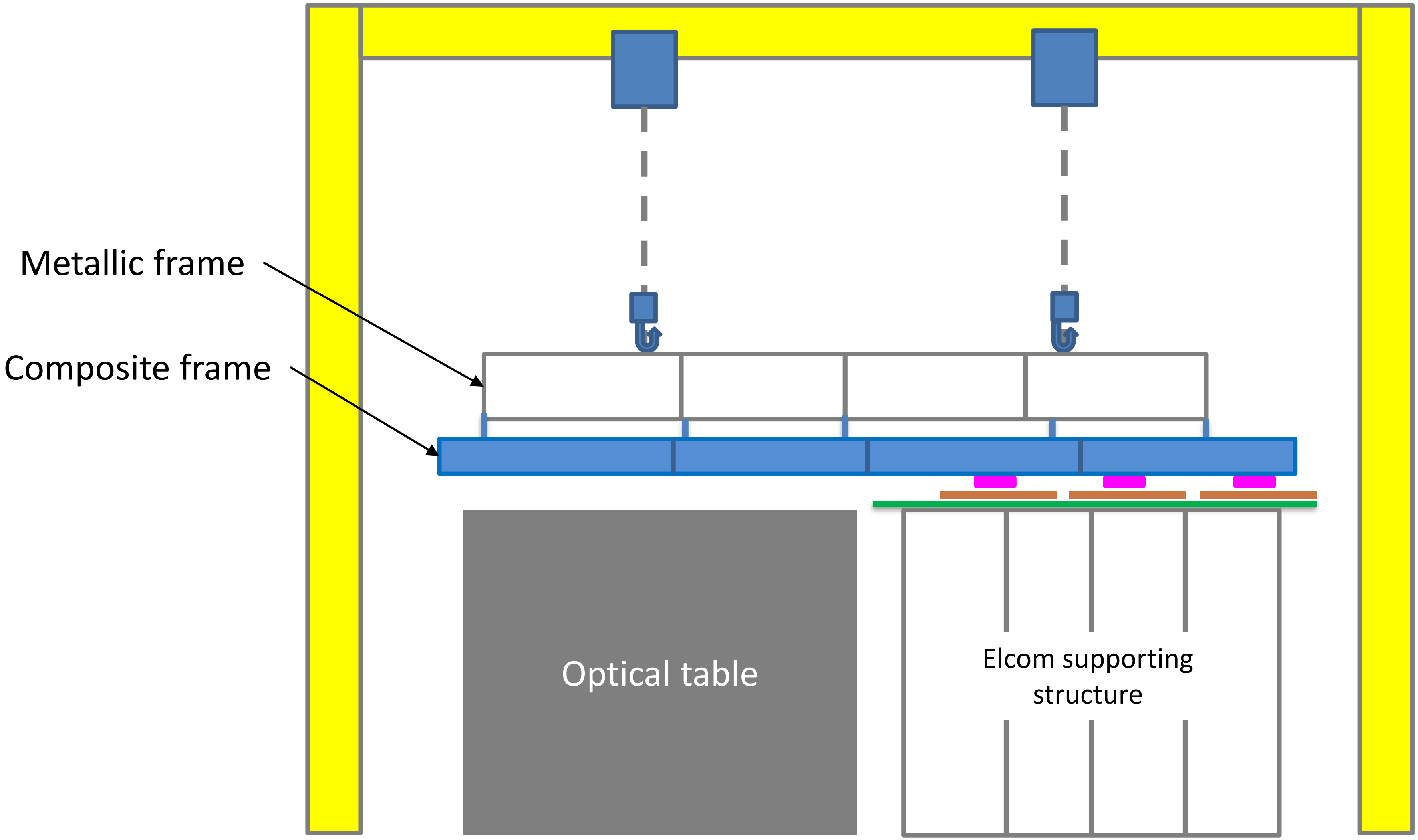
Spacers insertions

Electrical connections +
Adapter boards mounting
by CERN team
See Bo's slides

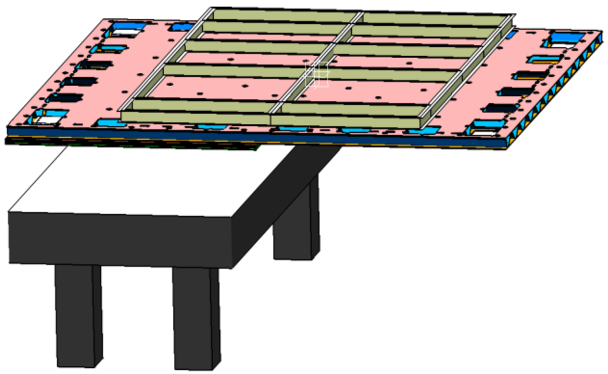


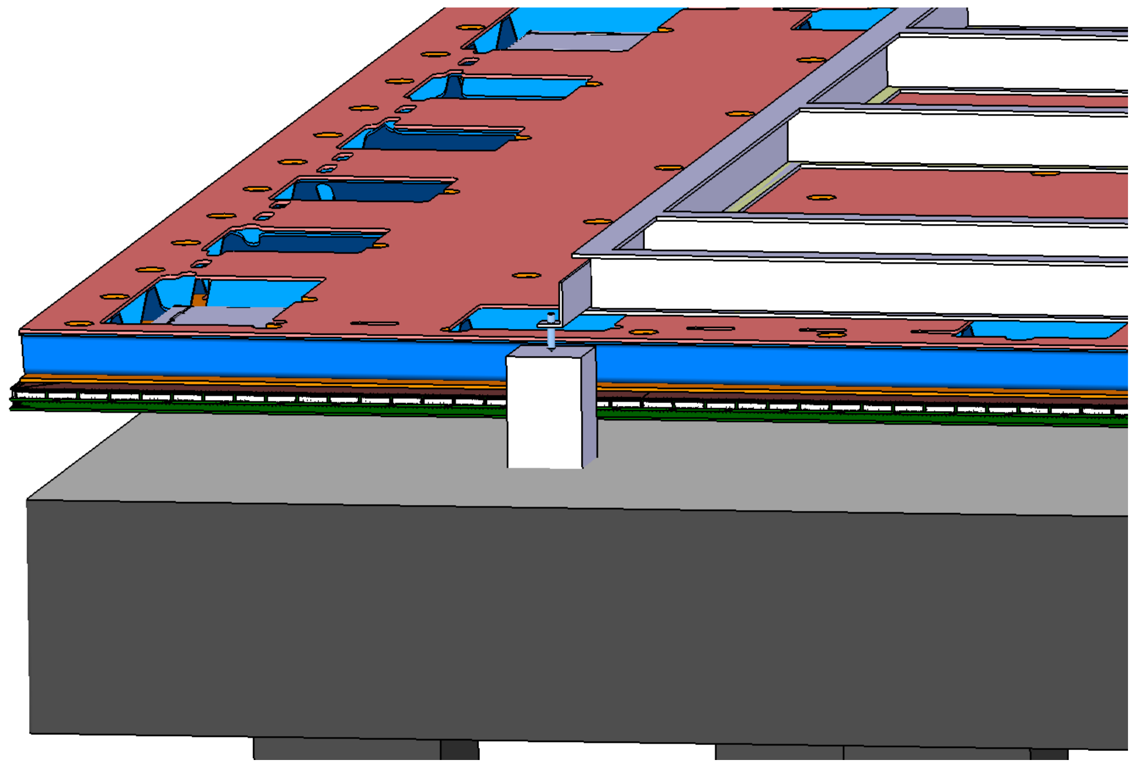


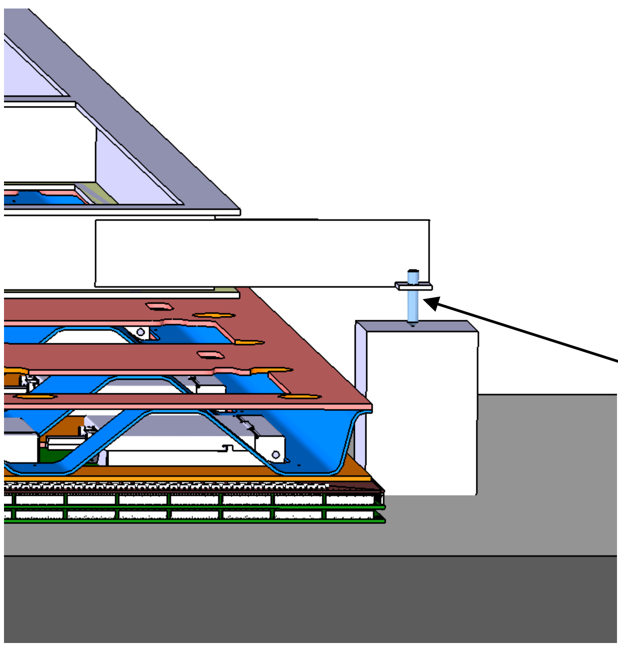
Composite frame mounted on metallic frame + crane are brought above panel assembly :



Composite frame – Anodes connection





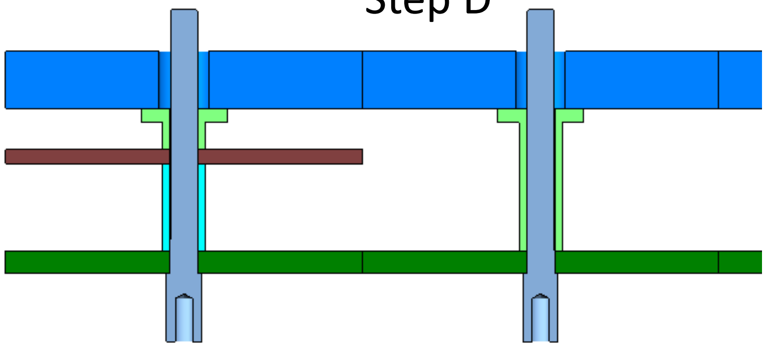


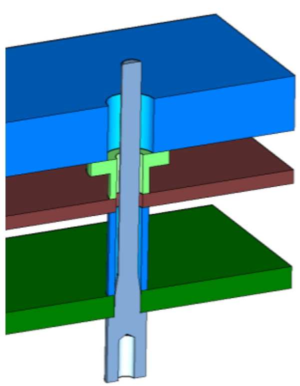
Composite frame is brought above anode with the crane, then laid on adjustment arms

Precise vertical positionning thanks to ball-screws

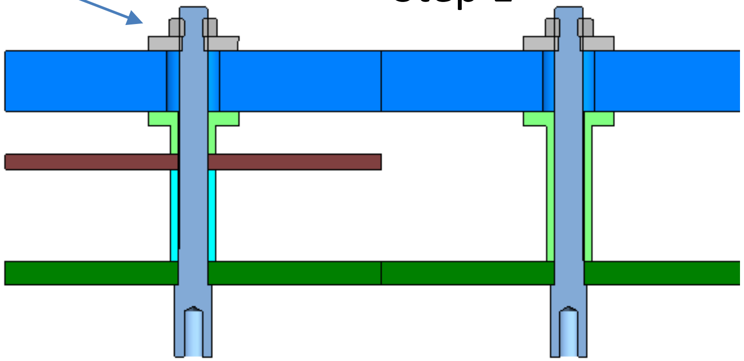
Special tooling is used to access the top of the composite frame (even the middle) and place the washers + nuts

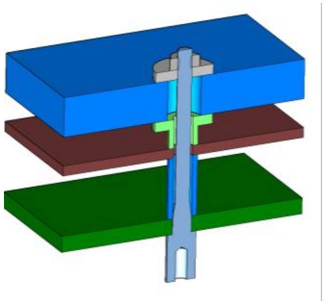
Step D



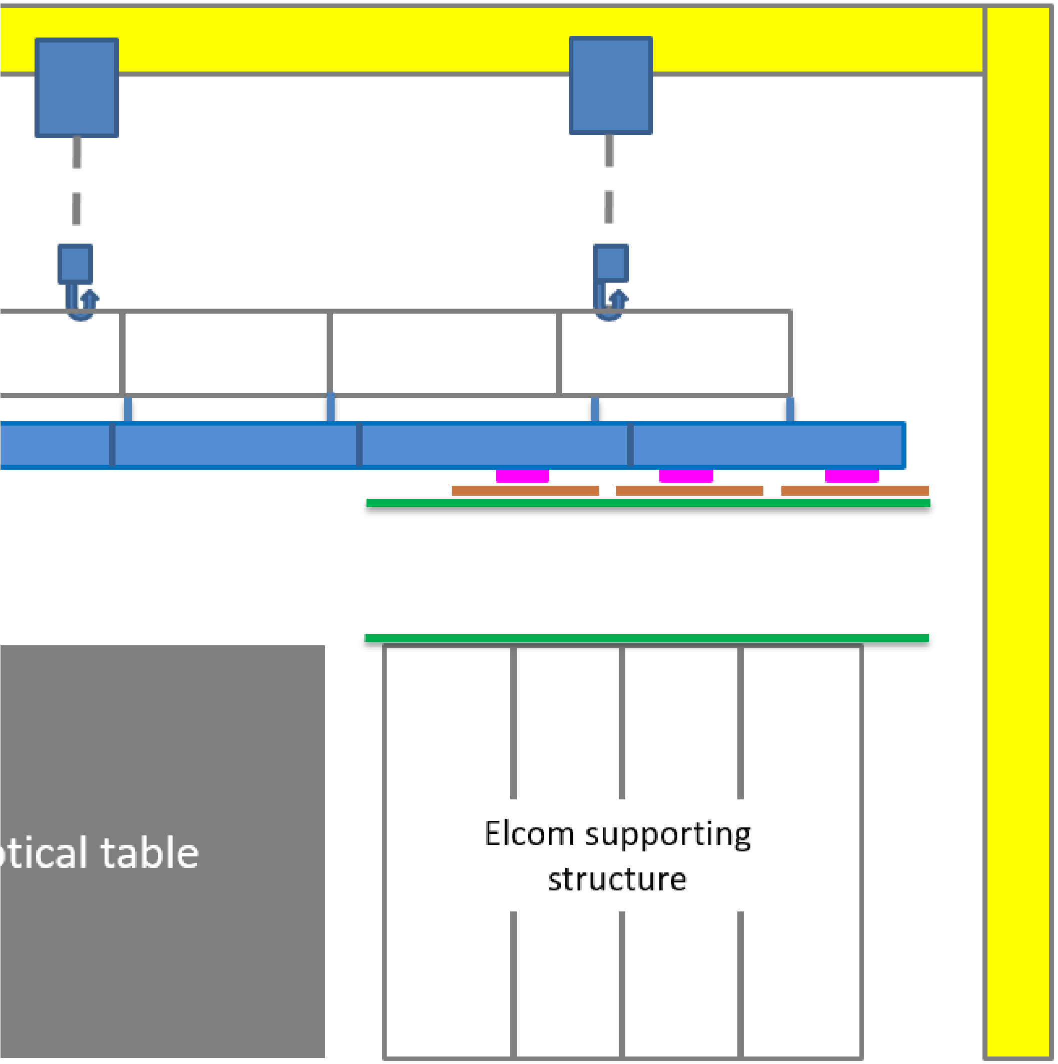


Step E

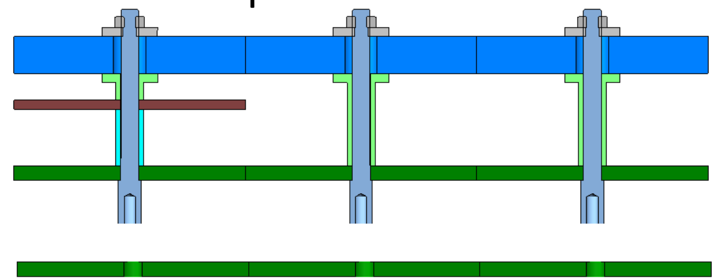


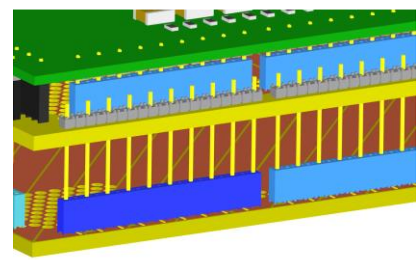


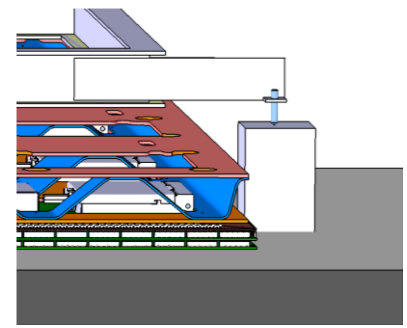
Anode : Shield layer connection



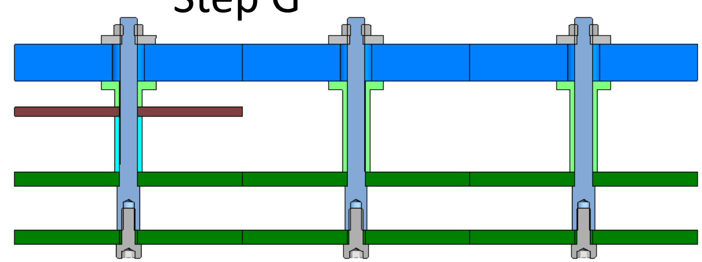
Step F



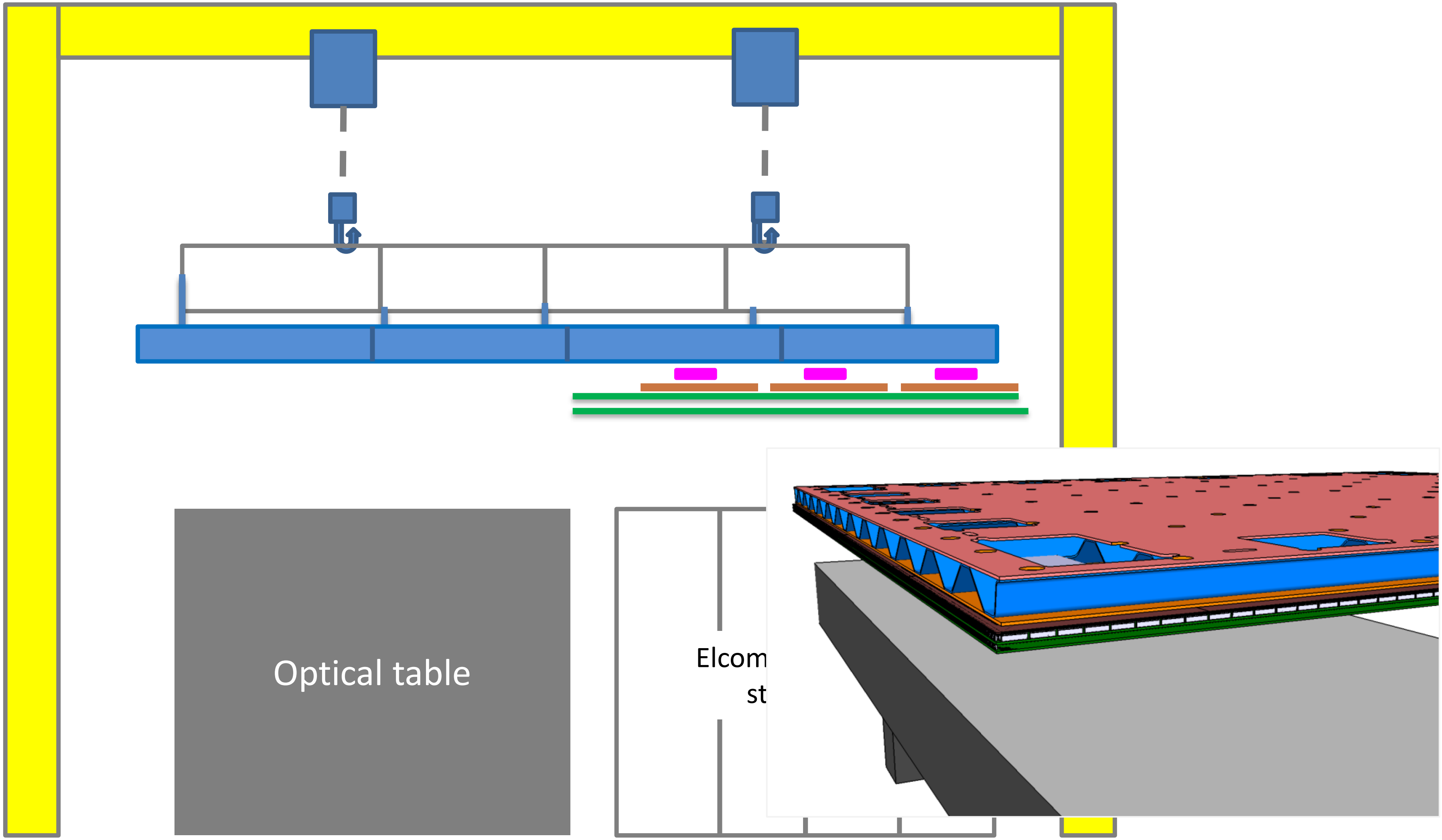




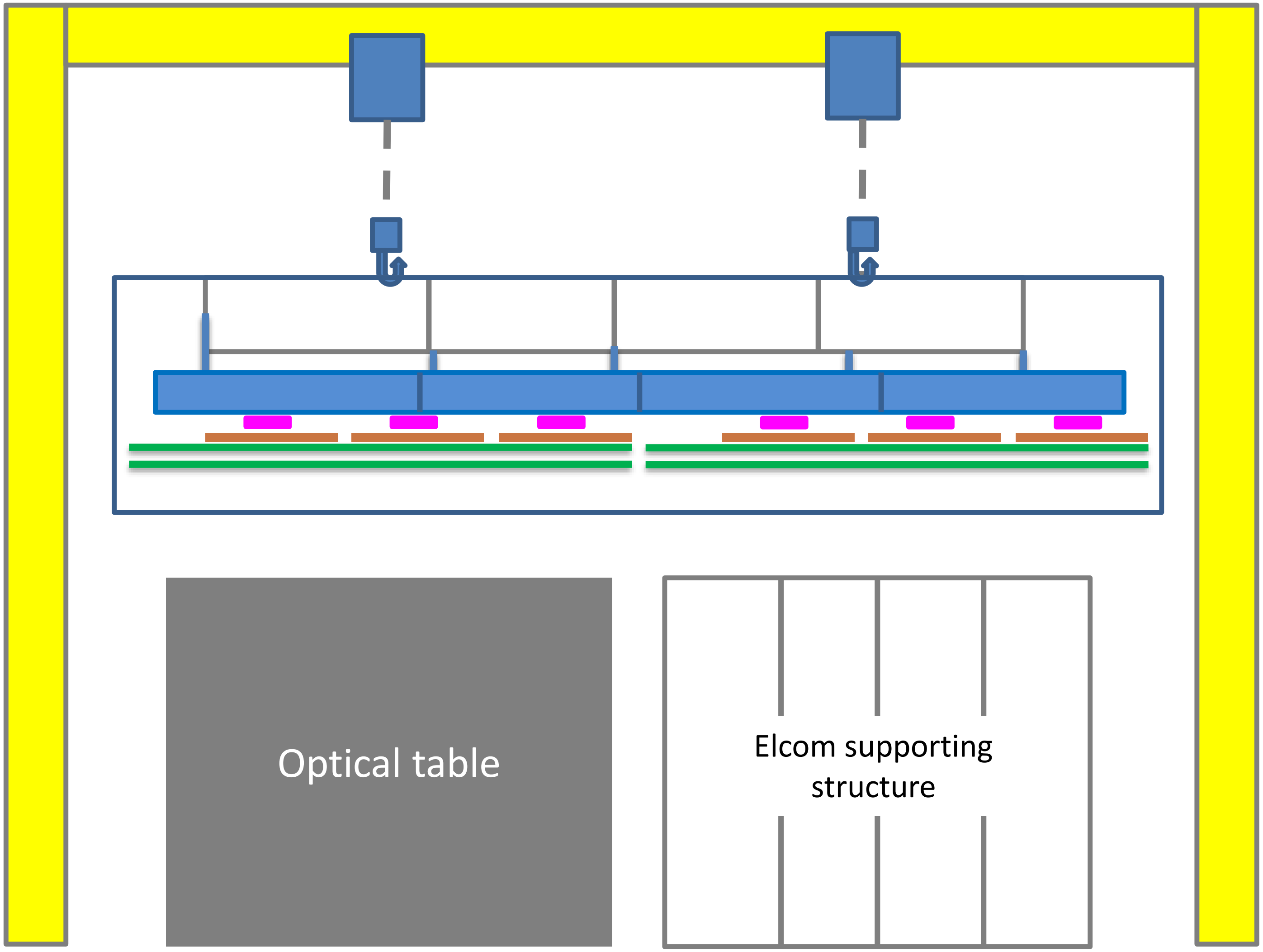
Step G



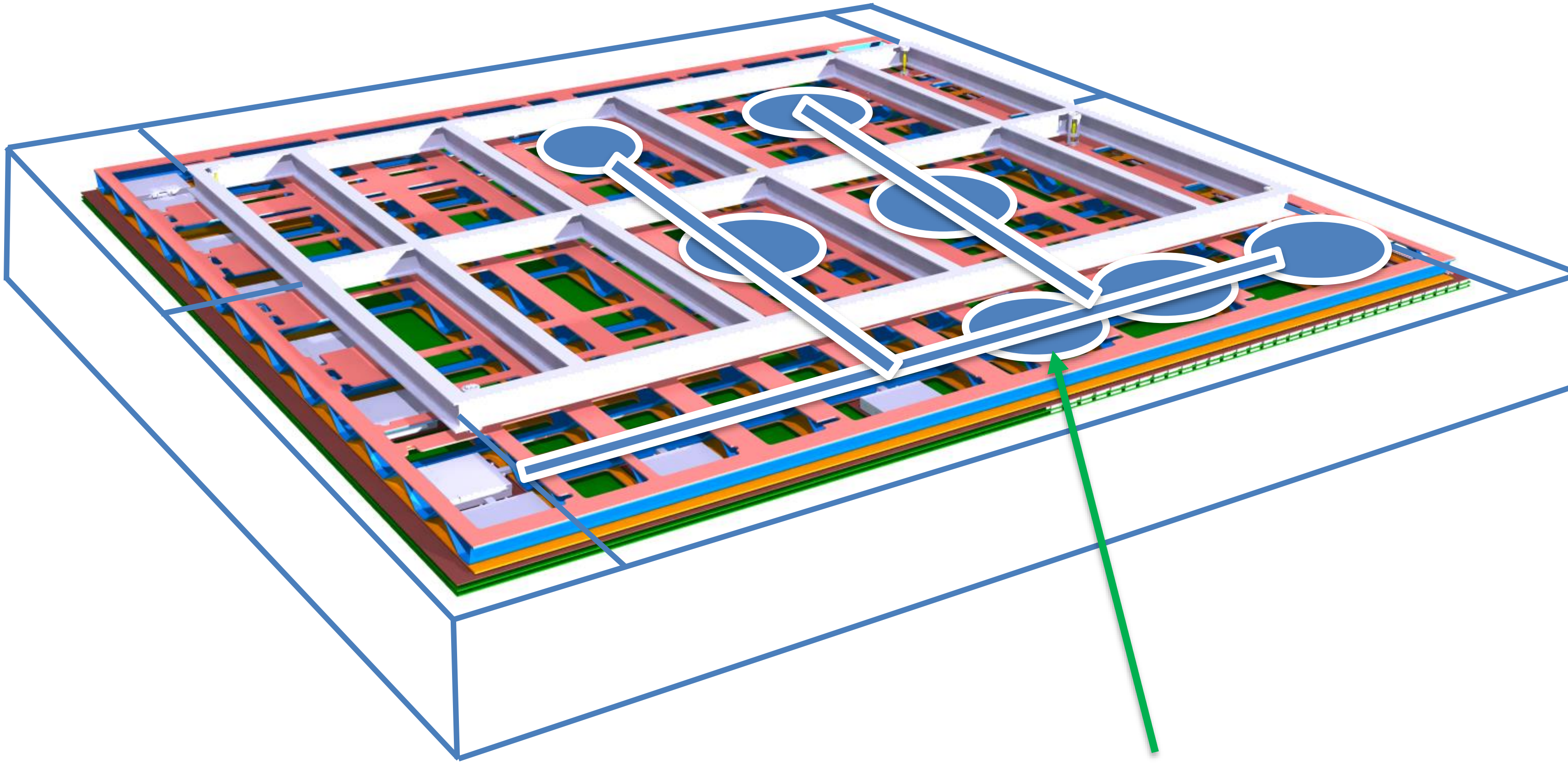
Anode : Shield layer connection



Second half assembly - Packing

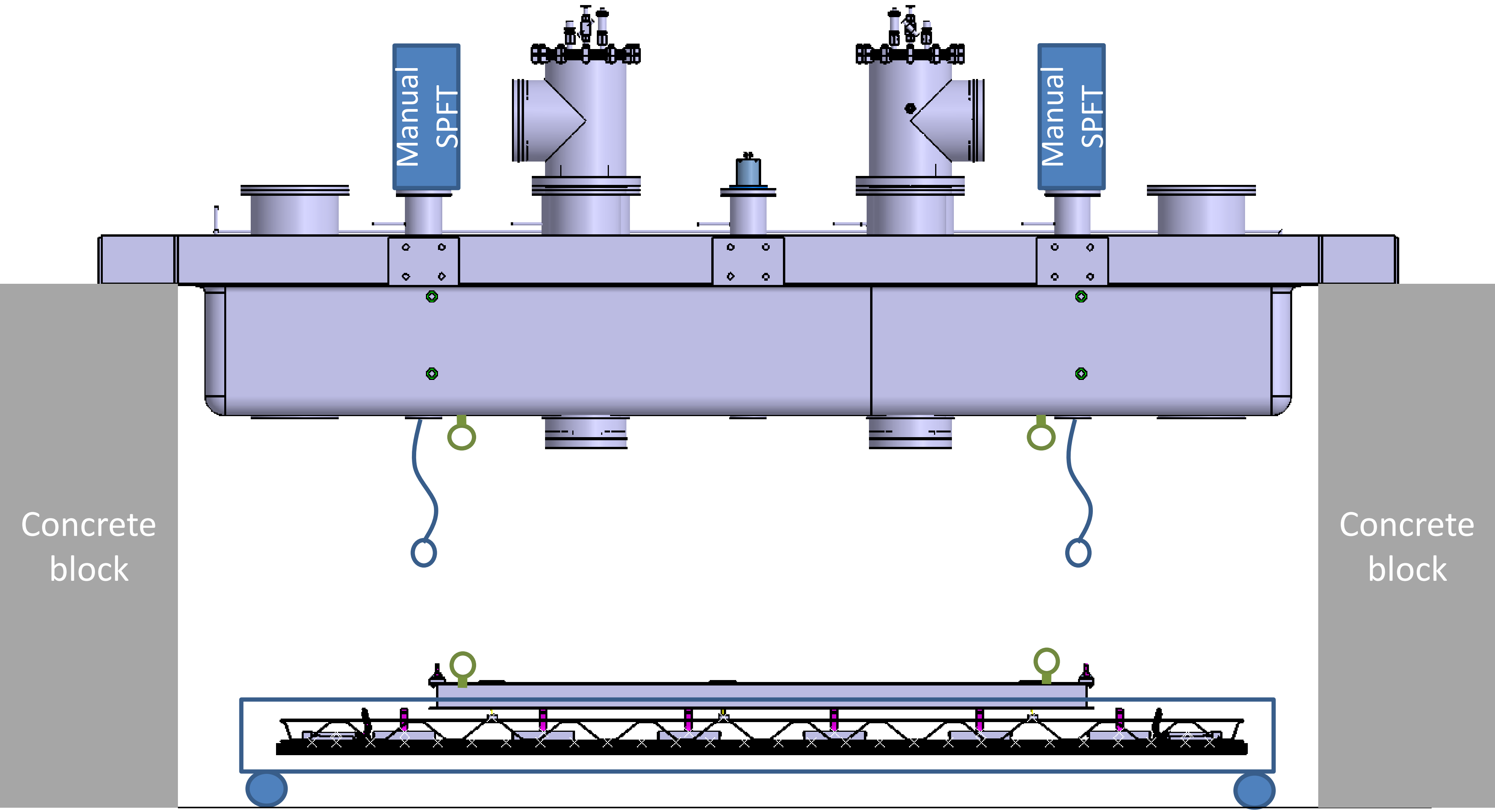


Scenario 2 : Cables during transport

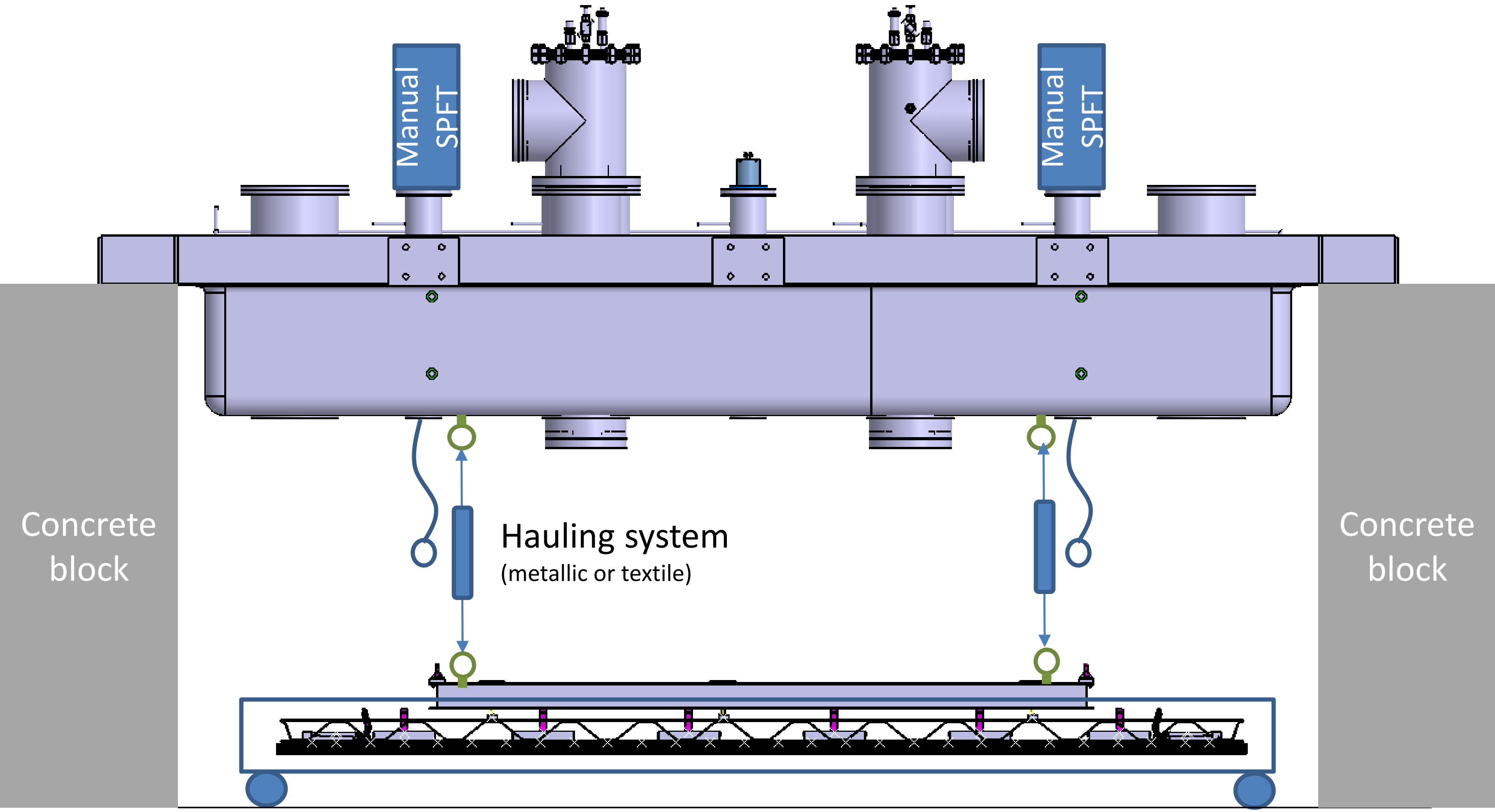


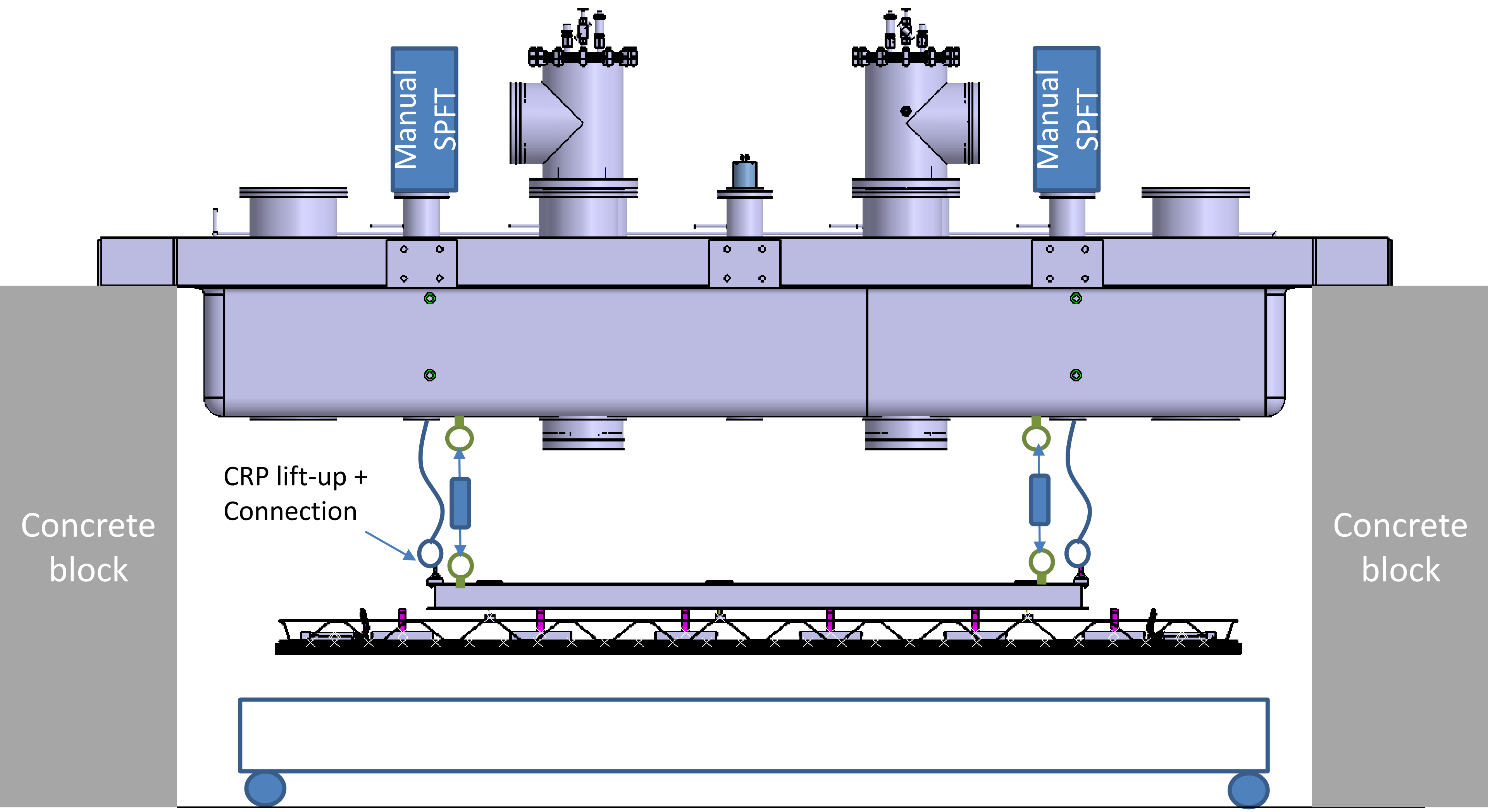
Cables attached to composite frame during transport, distributed on the plane, on « Top plane » side, thanks to cable ties.

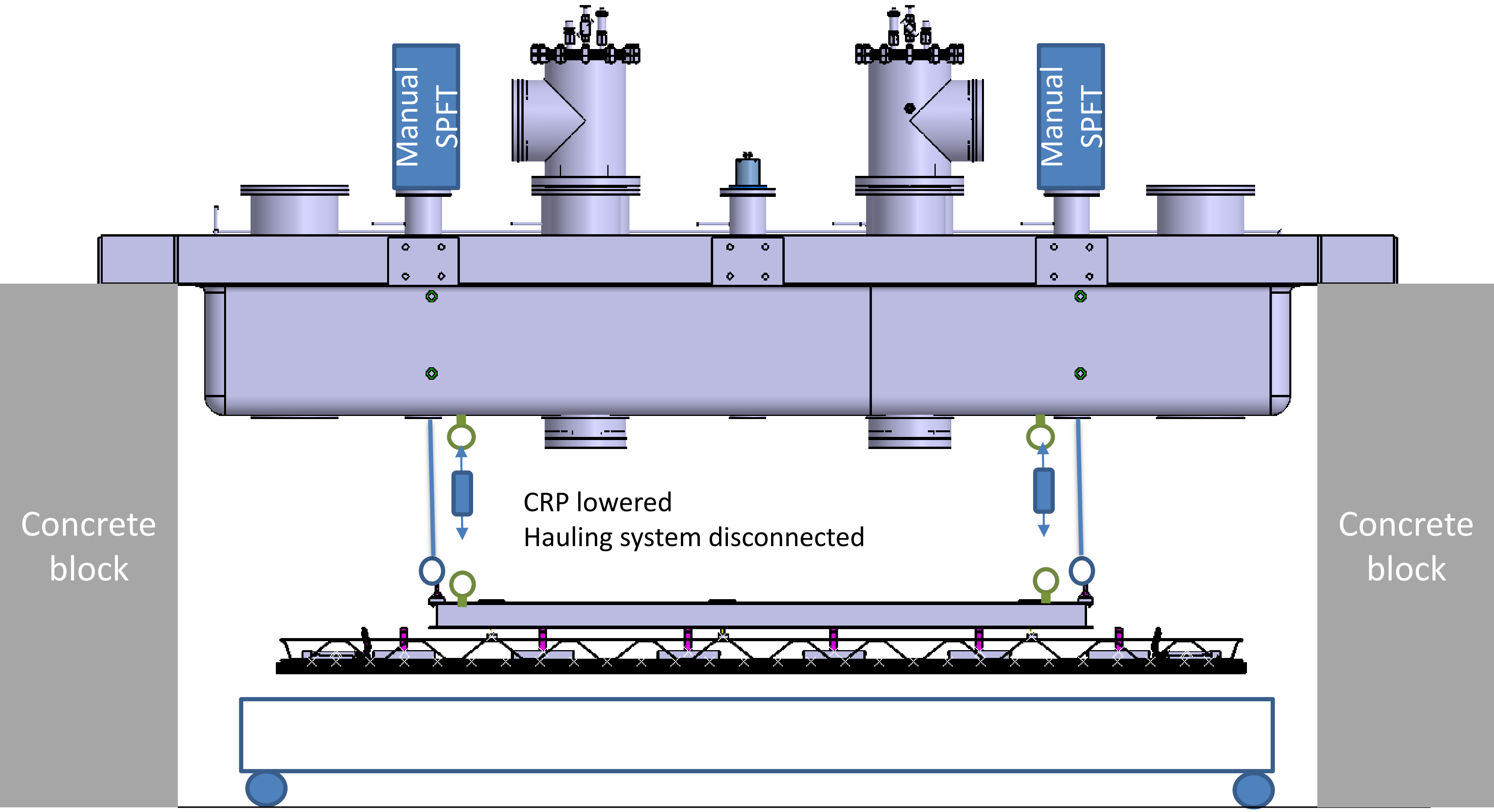
Once bellow topcap, cable are tied in cable trays, fixed bellow topcap

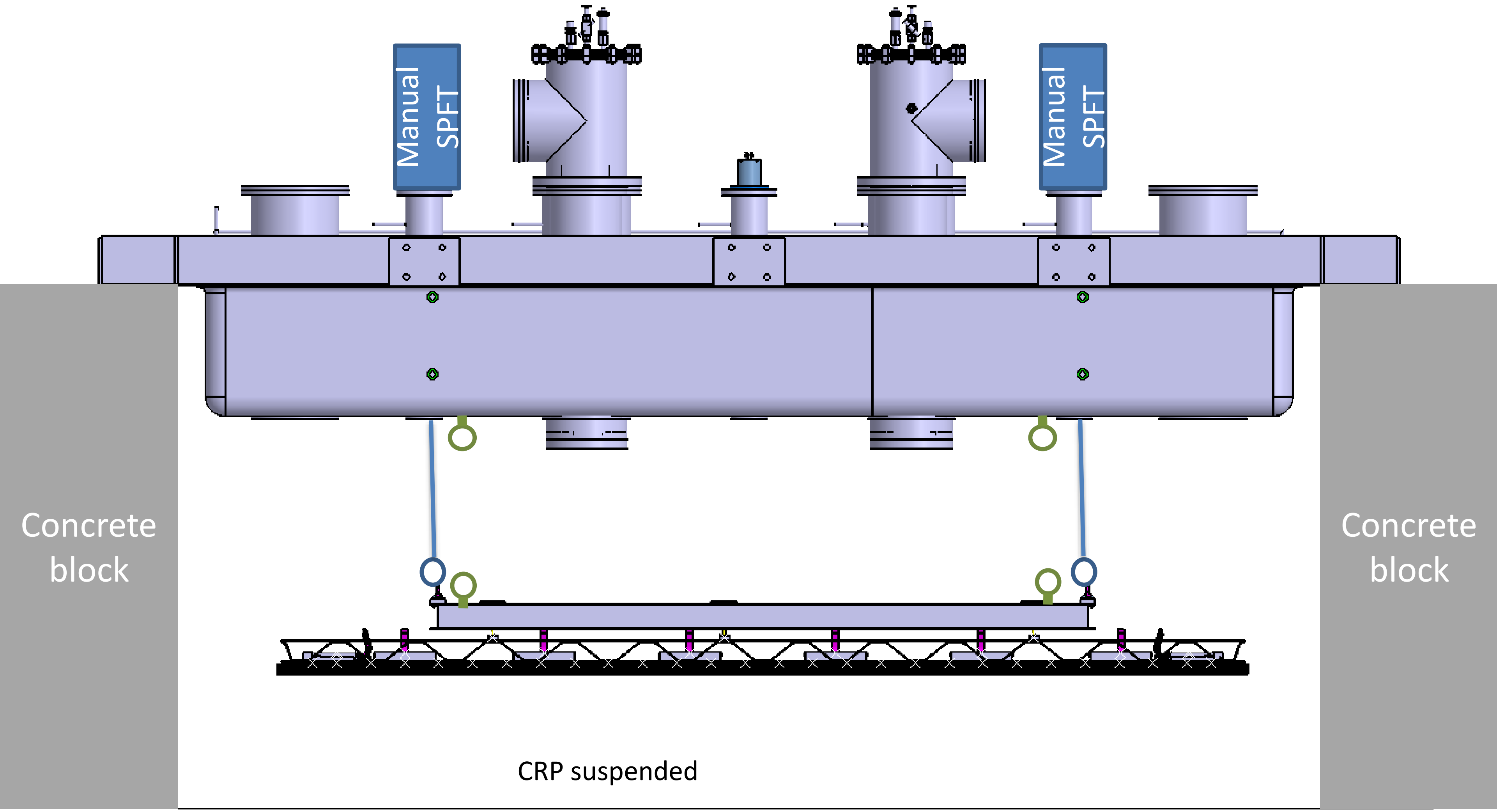

Manual SPFT
Manual SPFT
Concrete block
Concrete block

Once suspended to hauling system, CRP is detached from transport box

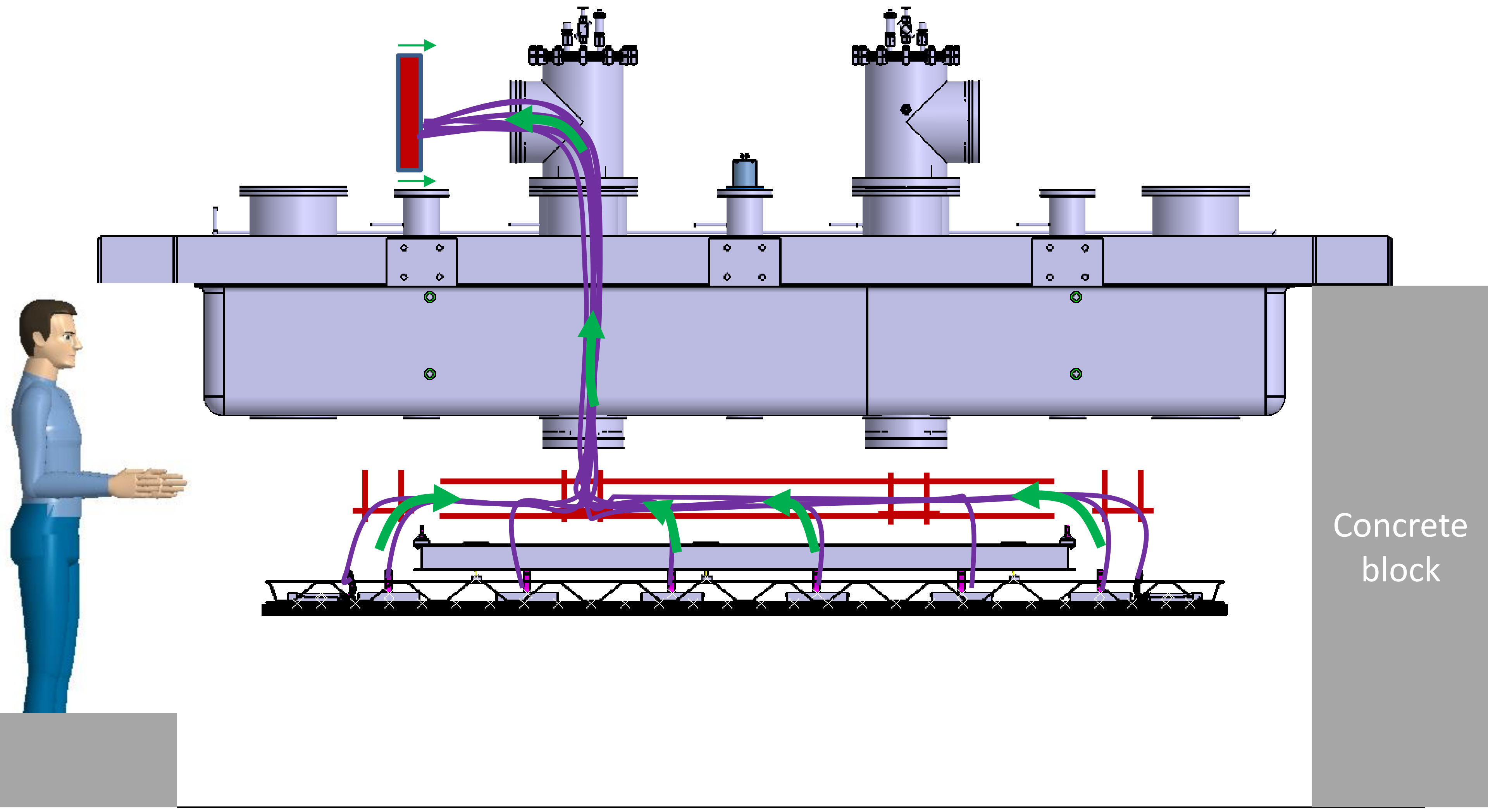



Manual
SPFT
Manual
SPFT
CRP lift-up +
Connection
Concrete
block
Concrete
block


Manual SPFT
Manual SPFT
Concrete block
Concrete block
CRP lowered
Hauling system disconnected


Manual
SPFT
Manual
SPFT
Concrete
block
Concrete
block
CRP suspended

Connection from CRP to cable trays, through chimney to flange



Power supply
- 7 meters
- ~1kg

Signal
- 7 meters
- ~1.1kg

In total, 13 CEbox, 26kg cables.

Thanks for your attention