Summary

- Status of STT mechanical Design.
- Pisa Prototype 1200x800mm.
- Resources for development of STT design.
- Conclusions.

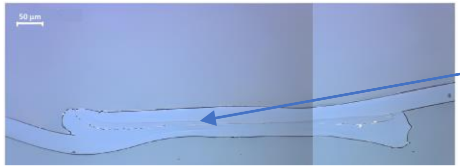
Status of STT mechanical Design.

- Some STT components have been produced and qualified.
- The construction and an assembly method have been study and validated by mechanical analysis.
- Mechanical validation of the specifications was done through analytical and FEM analysis. The analysis of the final supporting system of the super module is not yet done.
- The necessary tooling for the STT construction are at level of conceptual design.
- The mechanical system of handling and insertion in Sand it is at the level of conceptual design.
- The design of service integration is not present.
- A prototype 1200x800 mm has been completed at CERN a second prototype 1200x800 mm is in construction in Pisa.
- The Pisa prototype is going to use some final STT components (spacer, pins, E.P).
- A design of a prototype 3800X3200mm module has been completed.

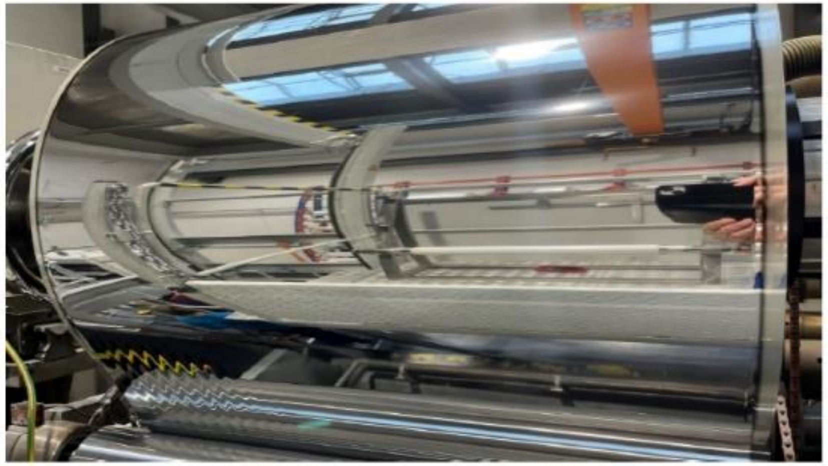
Components Overview of straw tube detectors.

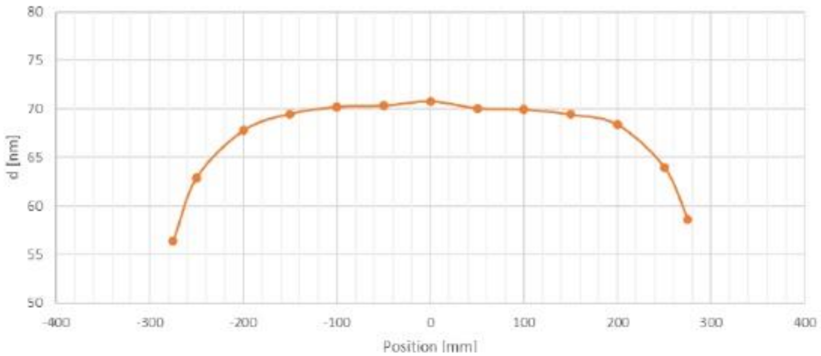
Straw tube are made starting for a film of 19 μm with double side Aluminum of 70 nm (Hostaphan® RNK is a highly transparent, biaxially oriented coextruded film made of polyethylene terephthalate (PET)). An inner wire of gold tungsten rhenium of 20 μm is inserted inside stretched. Straws are filled with a mixture of argon/CO_2 (70/30) at 2 bar maximum absolute pressure.

The double side Aluminum improve the tightness if the straw.

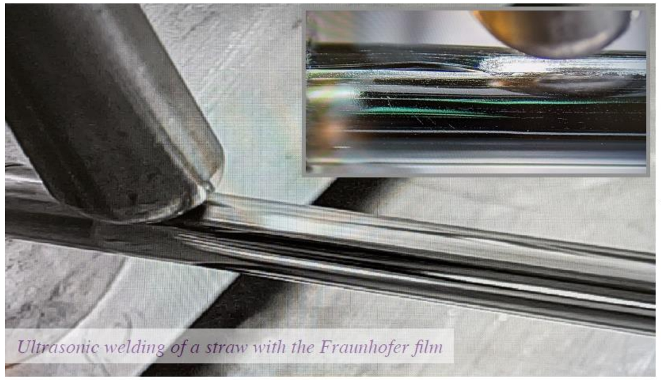


Welded seam

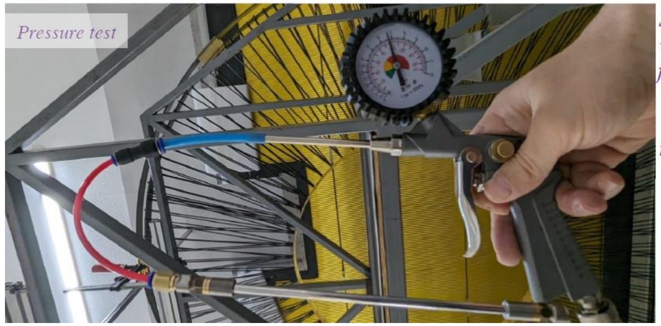




STRAW PRODUCTION WITH FINAL FILM



Production of 5m straws with Fraunhofer film and ultrasonic welding



Straws produced with Fraunhofer film passed high-pressure test up to 7 bar relative pressure

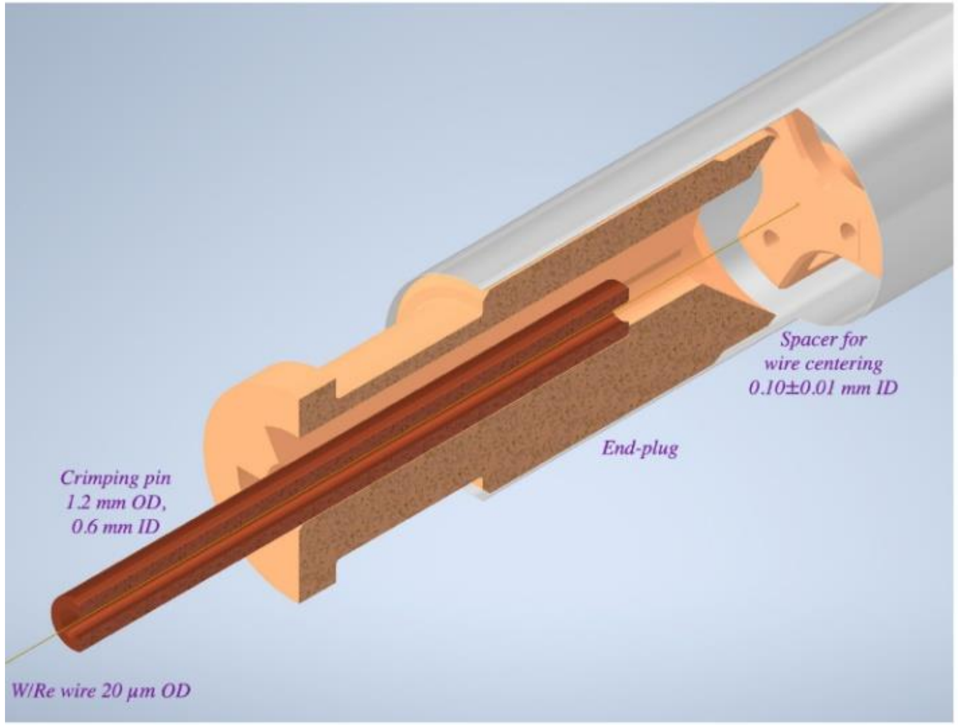
The straw tube are pressurized at 3 bar of absolute pressure to be handle it and glue it to the supporting structure.
Mechanical detail analysis has been done and verify by experimental test.

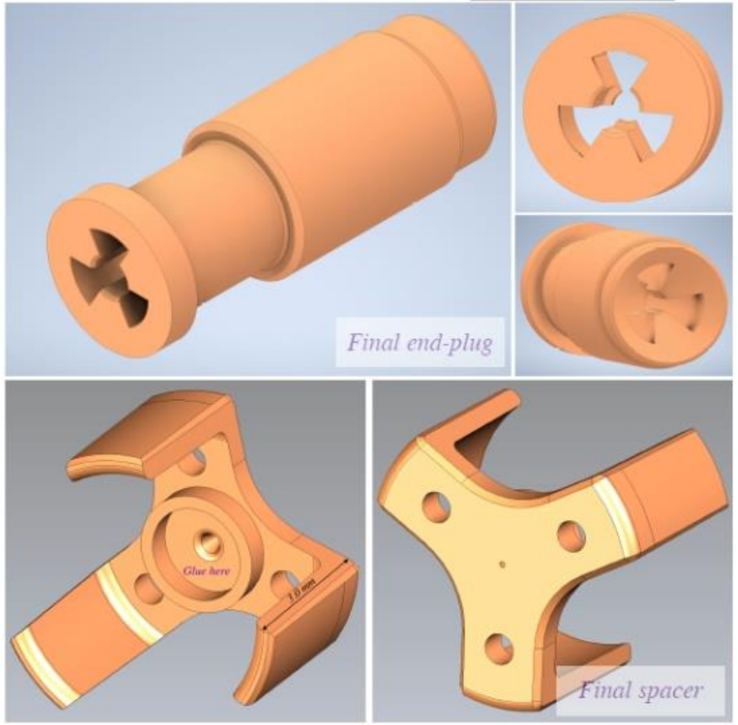
Components of straw tube detectors.

The spacer and end plug are made in polycarbonate with injection mold. This technology allows a production a low cost and large production. The end plug are glue to the straw tube. The wire is stretched and crimped to the gold plated cooper pins.

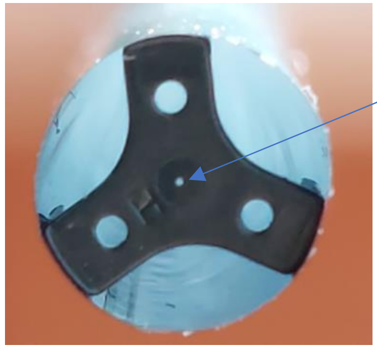
CRIMPING PIN, ENDPLUG, & SPACER

RP (USC)





Holes 70-80 μm



Crimping test

Use 20 μm wire from LUMA and crimping tool from ATLAS TRT

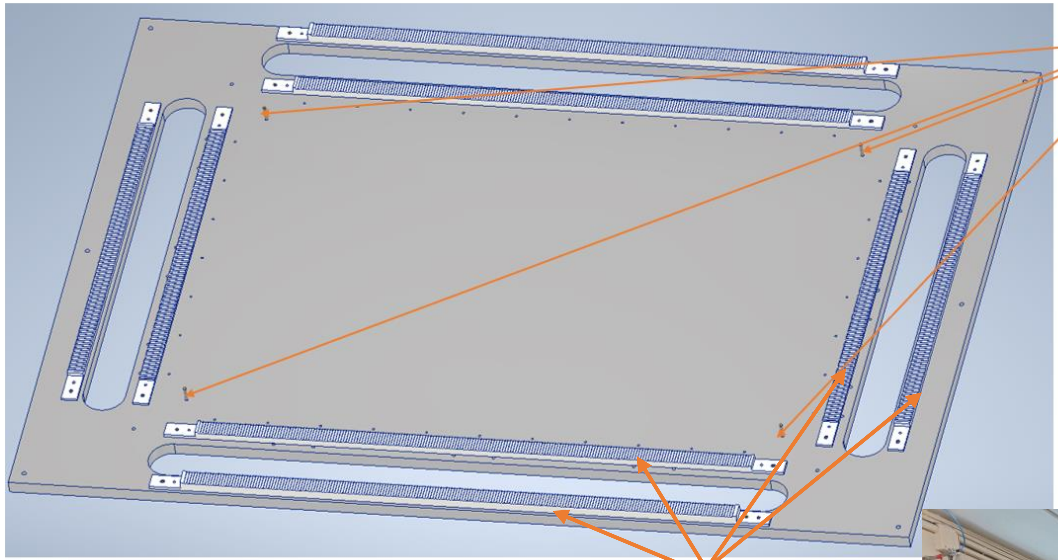
2

Evaluate effect of different crimping points along the pin and long term stability of wire tension after crimping

- *Larger crimping pins to fix the wire* + *extra spacer for wire centering:*
  - *Reduced costs (~$1.1M savings) and easier supply of pins;*
  - *Simplified assembly procedure: self-centering of wires with glued spacers insensitive to endplug/pin misalignments.*
- *Final design of pins validated, final design of end-plugs and spacers in production with injection molding*

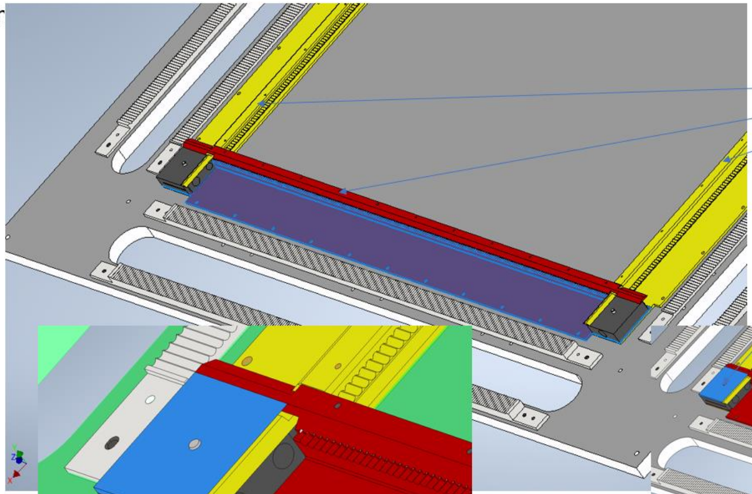
We need to have a mounting table with reference feature to build carbon fiber frame and the straw detector. It is very important to start with first straw layer aligned very well.

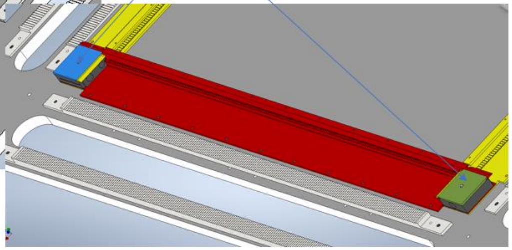
Step1



Pins with threated er
Diameter 6mm

Supporting Saddles



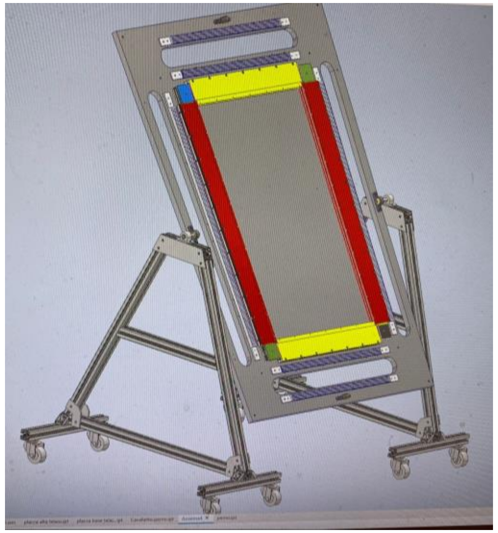


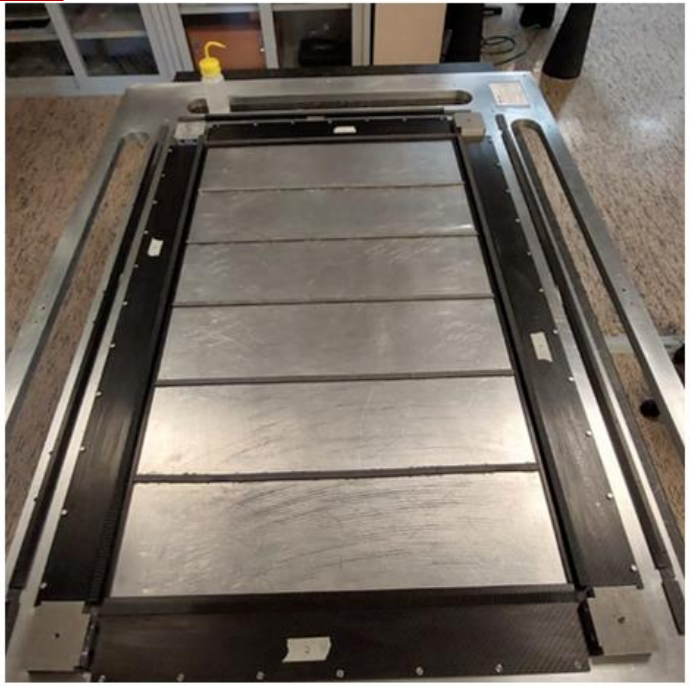
Until we do all the necessary operation

Glue Top cover straw ends

This is positioned bay the straw itself Longitudinally. we use the top covers

We setup the plate on a table and we insert four pins.

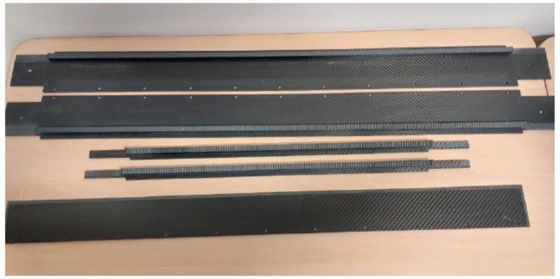


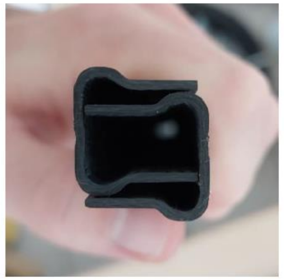


Components of straw tube detectors.

Carbon fiber Frame

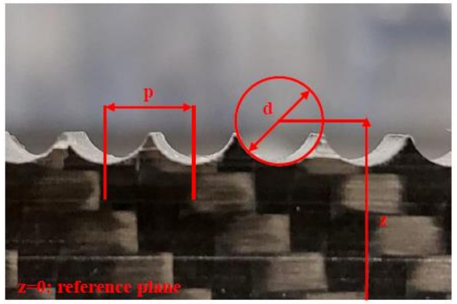
Carbon fiber frame

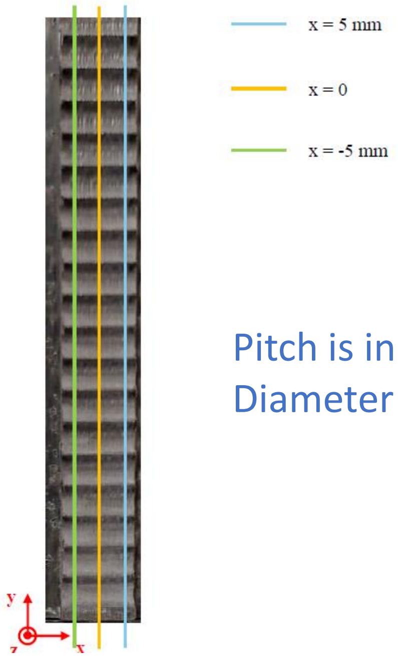




Measurement procedure

1. Place the component under a CMM
2. We measure pitch (p), diameter (d) and center height from reference plane (z) as function of the longitudinal coordinate (y)
3. Each measurement is repeated at three different x-coordinates: -5 mm, 0, 5 mm





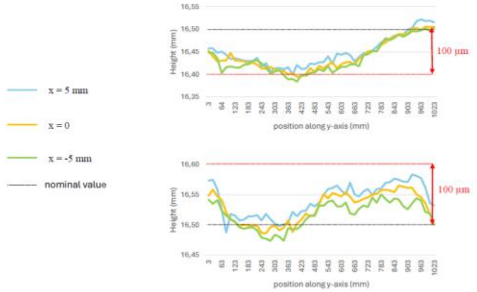
Pitch is in the order of CMM accuracy.
Diameter RMS 20 μm height 30μm

Measurements: long piece pitch (1/2)

1° slab	mean	RMS
1	4,999	0,002
2	4,999	0,002
3	4,999	0,002

3° slab	mean	RMS
1	4,999	0,002
2	4,999	0,003
3	4,999	0,002

Measurements: long piece height (1/2)



1° slab	mean	RMS
1	16,449	0,033
2	16,440	0,034
3	16,435	0,035

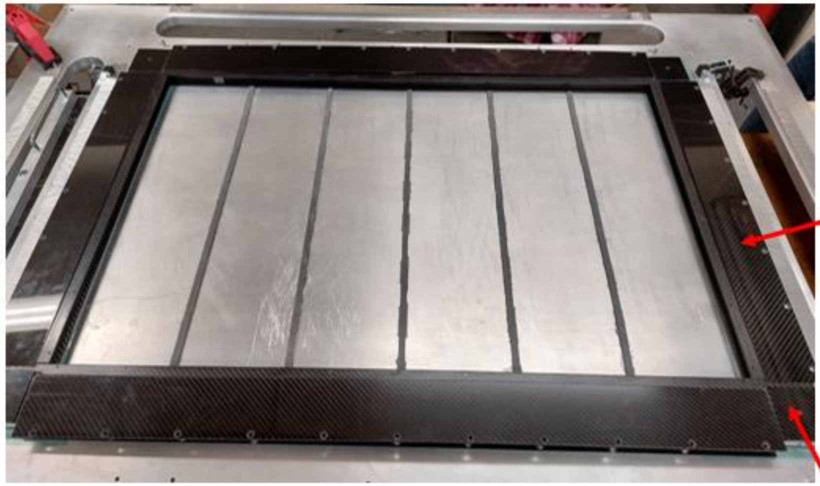
3° slab	mean	RMS
1	16,541	0,027
2	16,530	0,025
3	16,518	0,022

Measurements: long piece diameter (1/2)

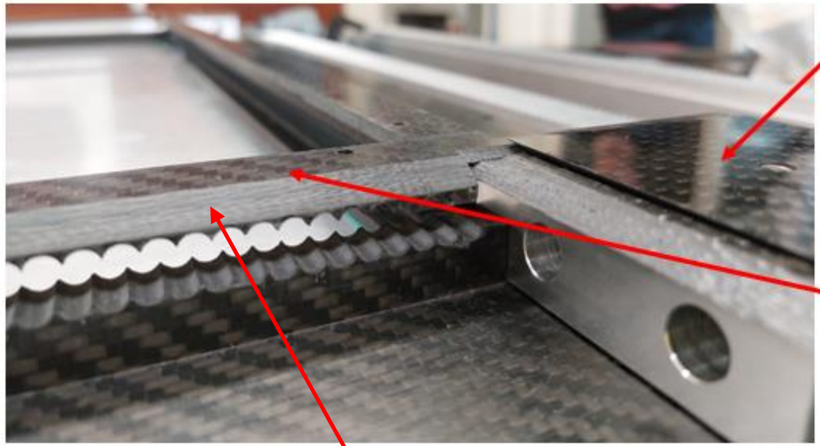
1° slab	mean	RMS
1	4,938	0,019
2	4,937	0,017
3	4,938	0,019

3° slab	mean	RMS
1	5,093	0,026
2	5,094	0,021
3	5,087	0,019

Mechanical integration of top cover

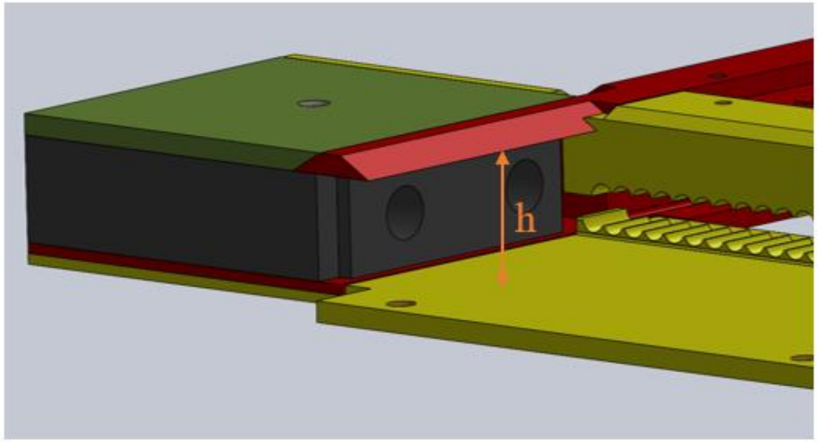


cover (4)



CF corners (4)

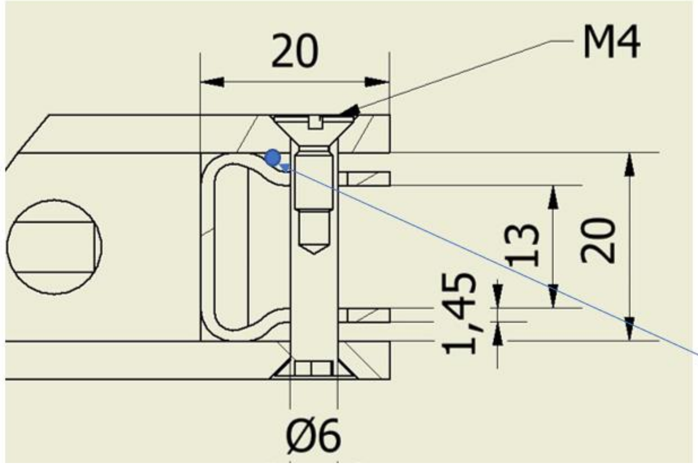
Top holder



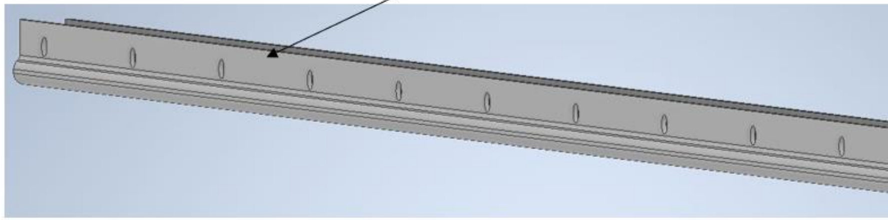
We need to check:

- height h for sealing

Lid omega design and sealing



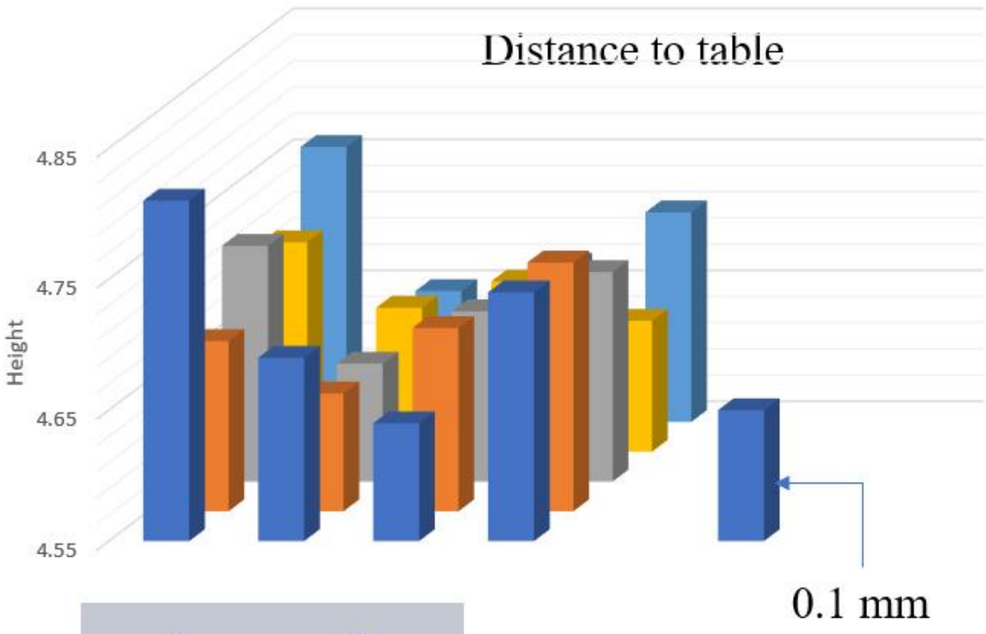
CF omega lid

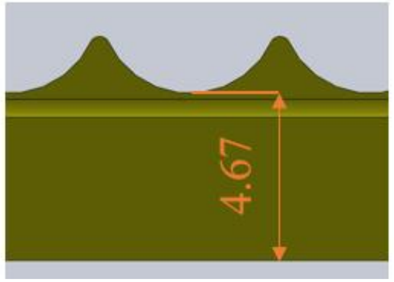


Removable sealing Threebond 1530 1nd 1212 compound /or rubber or o-ring 3mm with an attritional part.

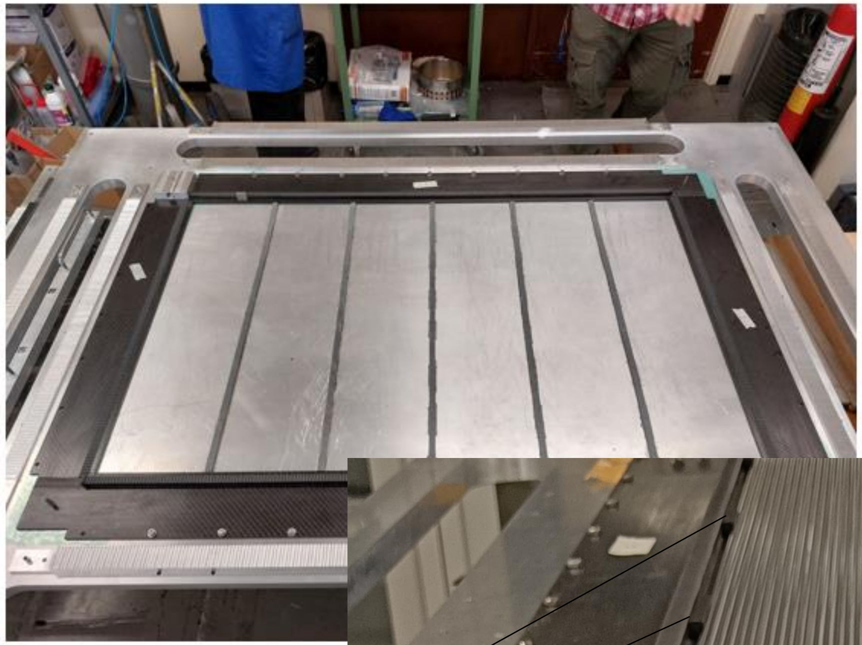
Dry test: new spacers

Problem: gravitational sag of straw tubes
Previous solution (aluminum spacers) didn't guarantee adequate accuracy





Nominal value: 4.67 mm



Restrain against the CF frame is necessary

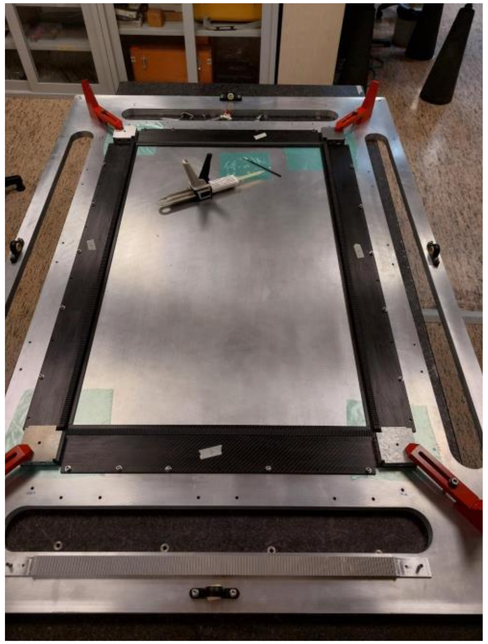
Main steps of the mounting procedure

1. ...
2. cutting of straw tubes (rough cut and finish cut)
3. wiring in vertical/horizontal position + wire tension checks
4. applying conductive paint
5. sealing with Stycast
6. installing electronic boards
7. performing verification checks with temporary covers
8. gluing top covers
9. closing the frame with sealed lid
10. final checks

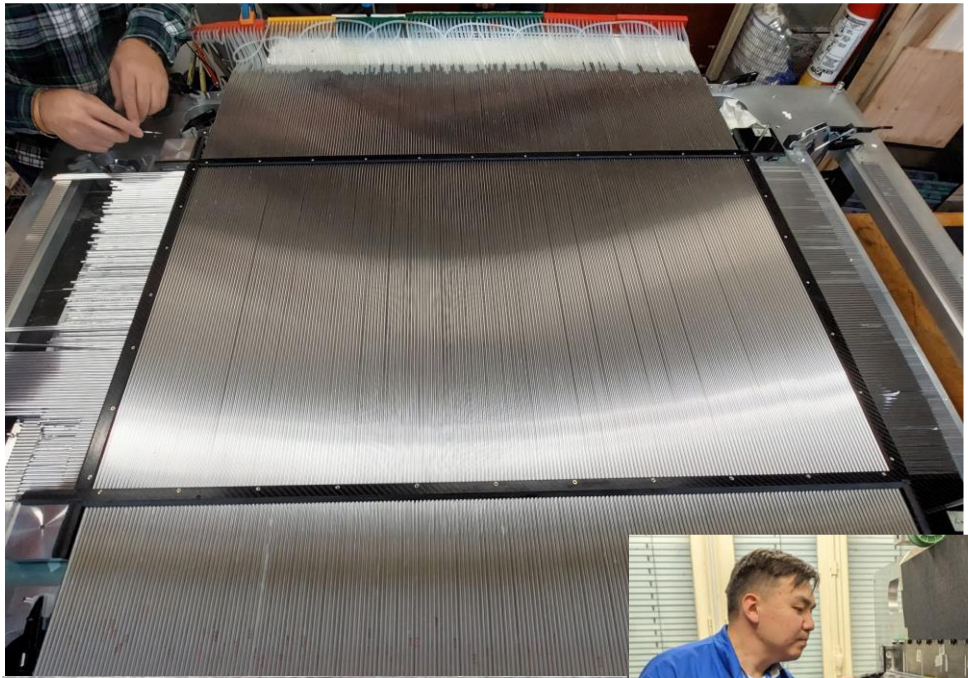
$\Rightarrow$ regardless of the wiring process, the frame must be placed in a vertical position for Stycast pouring

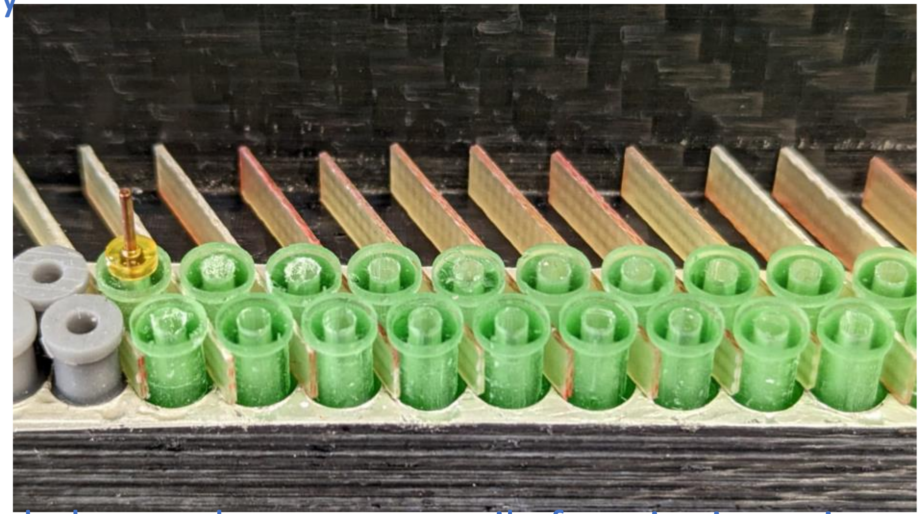
6. Construction phases of a prototype 1200x800mm

3 bar of absolute pressure are used for the straw assembly

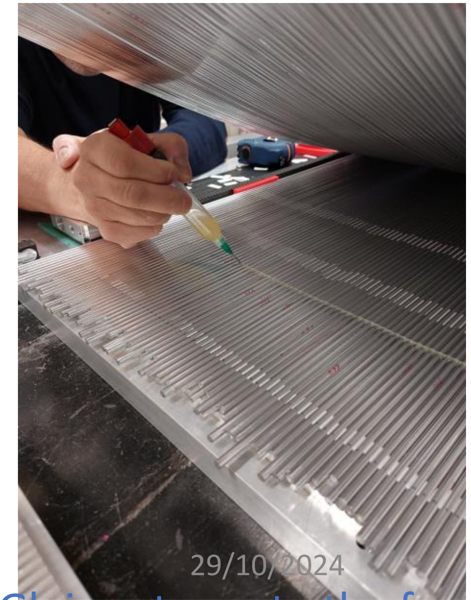


Gluing a Supporting frame



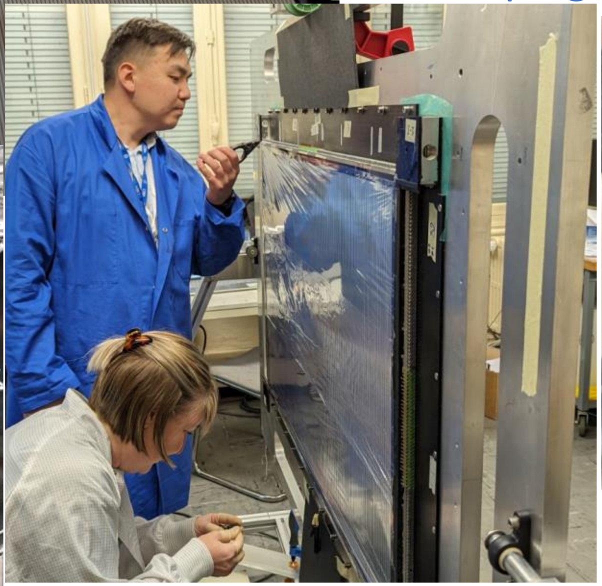


End plug are kept temporarily for wire insertion.

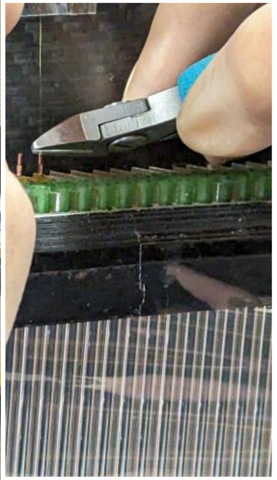


Gluing straws to the frame

Straw are cut at the end of the CF frame



Wiring of the short straws with the table in the vertical position.



Final sealing with stycast glue poured around the neck of the end-plugs with the module in vertical position.

The mechanical validation of the CF supporting frame is based on these assumptions:

1) The CF frame is screwed to a precision mounting table until is the frame is completed. In case we need to remove it from the table, an additional bracing system is envisaged.
2) The straw are pressurized at 3 bar absolute pressure to be glued to the CF frame.
3) The straw are kept in position using additional external features. This is due to the fact that the straw are no straight. The necessary forces to realign the straw are minimal.
4) An external bracing system allows to release a straw tracker unit from the assemble table and glue the covers and connect the lid omegas.
5) We design several attachment points are built on the perimeter. These are used to build the super module, support the module under gravity and connected the super module to a rolling system in sand.

5. Straw supporting structure requirements.

The alignment and stability of the straw tubes is ensured by a rigid frame where the straws are glued. Detailed simulations, together with the insights gained from previous experiments, have been conducted to establish the key requirements for this structure:

- the frame must ensure precise alignment of straws with an accuracy of 100 μm;
- the frame should possess the capacity to withstand to a maximum absolute pressure of 2 bar while ensuring an appropriate safety factor;
- the frame gas tightness must be lower than or comparable to the straw leak rate;
- the frame must prevent straw compression throughout all phases, including construction, handling, and transportation;
- ensuring the minimum required stress on the electric wire is a crucial aspect of the frame functionality;
- structure within the calorimeter; the average density of the tracker, without the target layers, should fall within the range of 0.005 +/- 5% kg/m3

Frame material properties (1/2)

Ply (M46J)

Parameter	Value	Unit
X_t	1709	MPa
Y_t	25.8	Mpa
X_c	875	Mpa
Y_c	189	Mpa
S	69	MPa

First failure stress

Property	Value	Unit
Thickness t	~ 0.2	mm
Density ρ	1561	kg/m^3
Fibre volume fraction ν	55	%
Young's Modulus E_1	218	GPa
Young's Modulus E_2	7.23	GPa
Poisson's ratio ν_{12}	0,3	
Poisson's ratio ν_{23}	0.35	
Shear Modulus G_{12}	4.09	GPa

Physical properties of the lamina

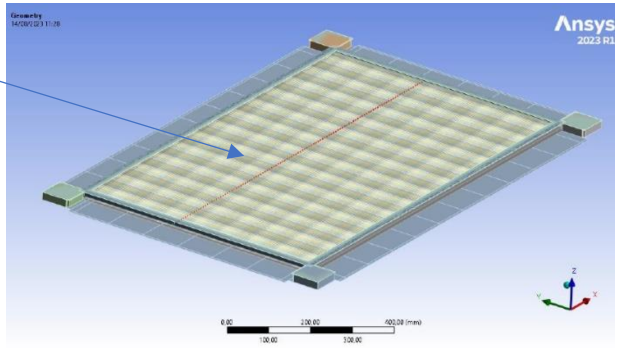
Parameter	Value	Unit
$X_{\varepsilon t}$	0.784	%
$Y_{\varepsilon t}$	0.357	%
$X_{\varepsilon c}$	0.401	%
$Y_{\varepsilon c}$	2.614	%
S_{ε}	1.687	%

First failure strains

The frame structure is made by 18 plies 0/90.

Internal beam elements

Pre-stressed



The mechanical requirement ahs been analyzed with analytical and FEM analysis.

Analytical, FEM analysis and test on straw has been done before analyzed the CF frame.

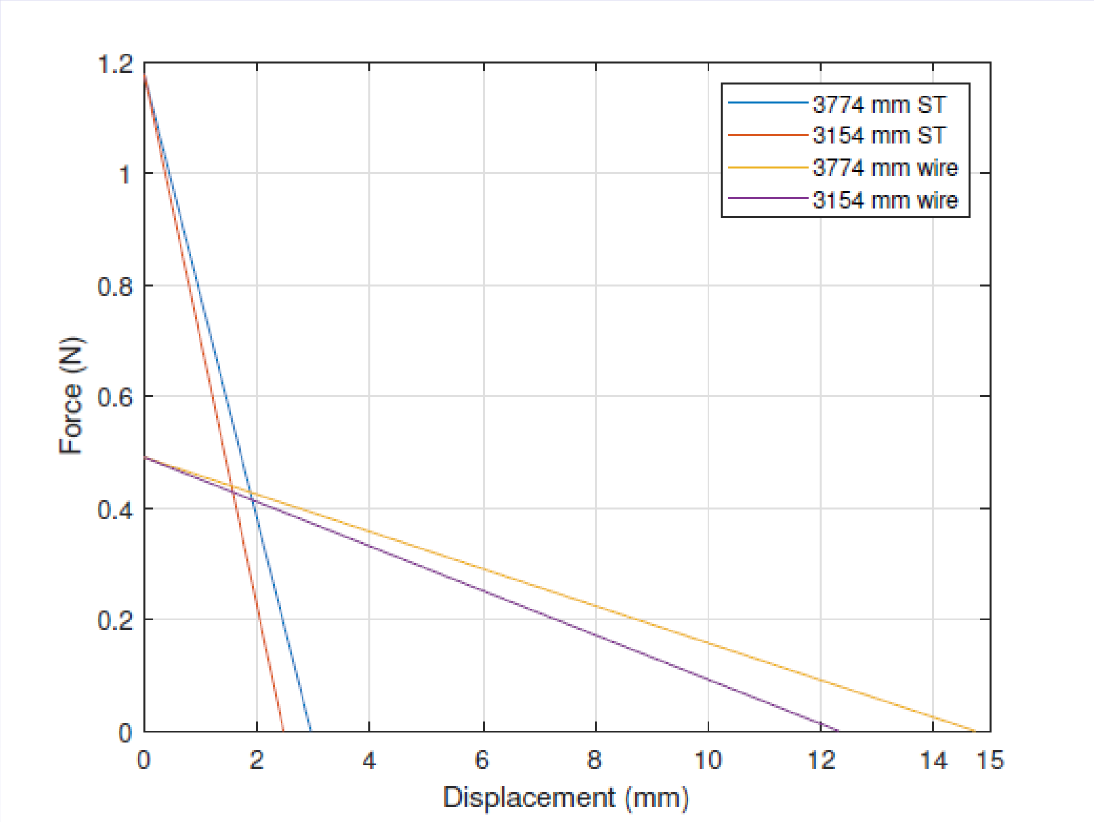
Straws are pressurized at 2 bar to be glued and handled. Initially they are stretched when the pressure is released they transfer a force to the supporting frame. The minimum tension on the tungsten wire is 50 gr.

The stiffness of the frame must be guarantee:

1) that the straw tube never be compressed.
2) The minimum tungsten wire tension. (the initial tension of the wire is greater the minimal one)
3) The frame must withstand to 2 bar of internal pressure.

This requirement that can be removed after a test. The worry that a small compression can damage the weld seal.

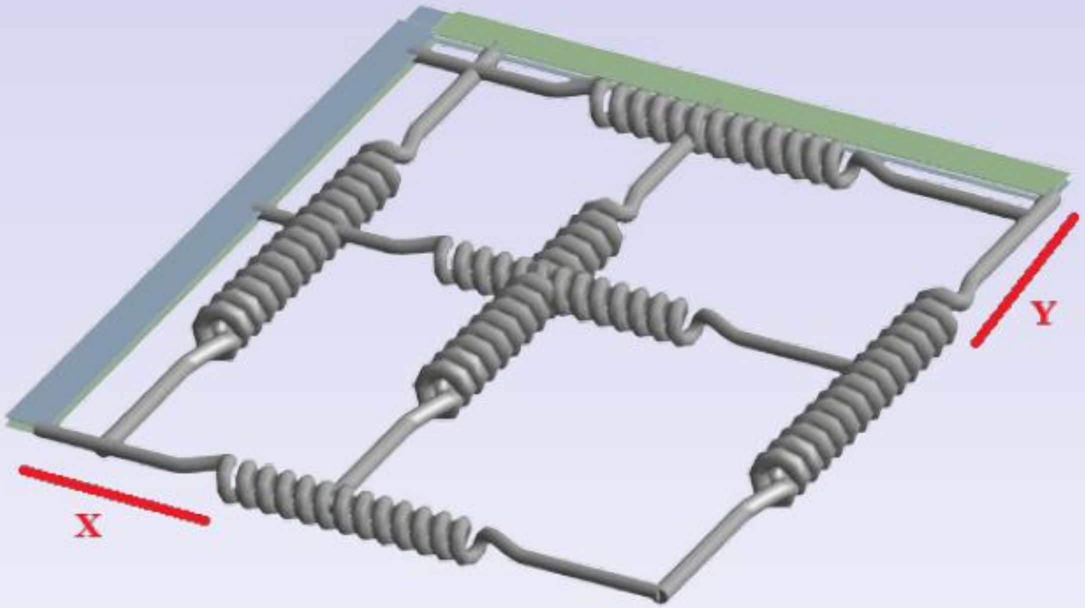
Straw and wire Force and displacements



- the initial ST force is independent of the straw tube length
- the initial ST force depends on material properties (E, ν), and geometrical parameters (A, t)
- the force reduces to zero when both straw tube and wire recover their initial displacements

Initial straw tube elongation (2 relative bar): 2.95 mm (long) and 2.47 mm (short)
Initial wire elongation (50 gr): 14.7 mm (long) and 12.3 mm (short)

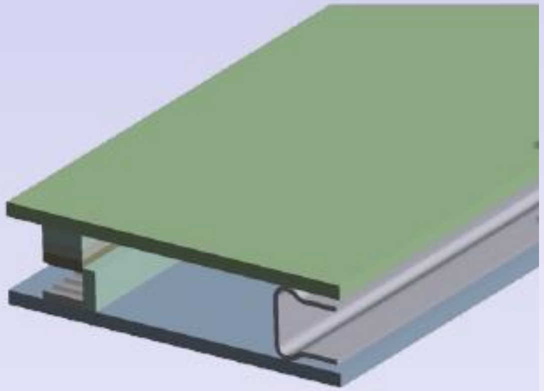
Release the frame from the table after gluing the top covers

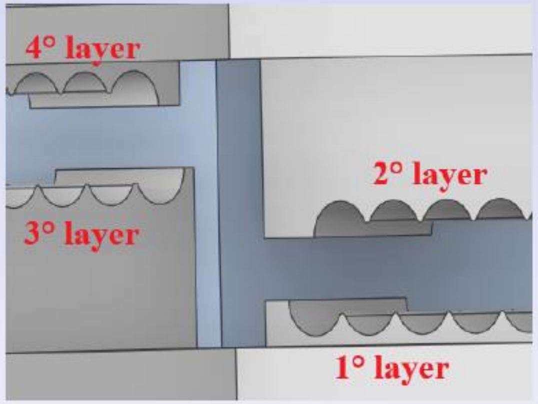


- full frame (4m $\times$ 3.3m) model
- a quarter model using symmetry to reduce size
- spring (rope) behavior for both straw tubes and wires
- frame attached to the plane (no twisting effect)
- pre-load on each straw tube: 1.2 N
- pre-load on each wire: 0.49 N (50 gr)

Total force on x-direction due to straw tubes: 1794 N (183 kg)
Total force on y-direction due to straw tubes: 1496 N (152 kg)
Total force on x-direction due to wires: 733 N (75 kg)
Total force on y-direction due to wires: 611 N (62 kg)

Release the frame from the external frame after closing it with the lids





Parameters and constrains as before

Layer	Force (N)
1°	0.26
2°	0.26
3°	0
4°	0

Table: Load on straw tubes

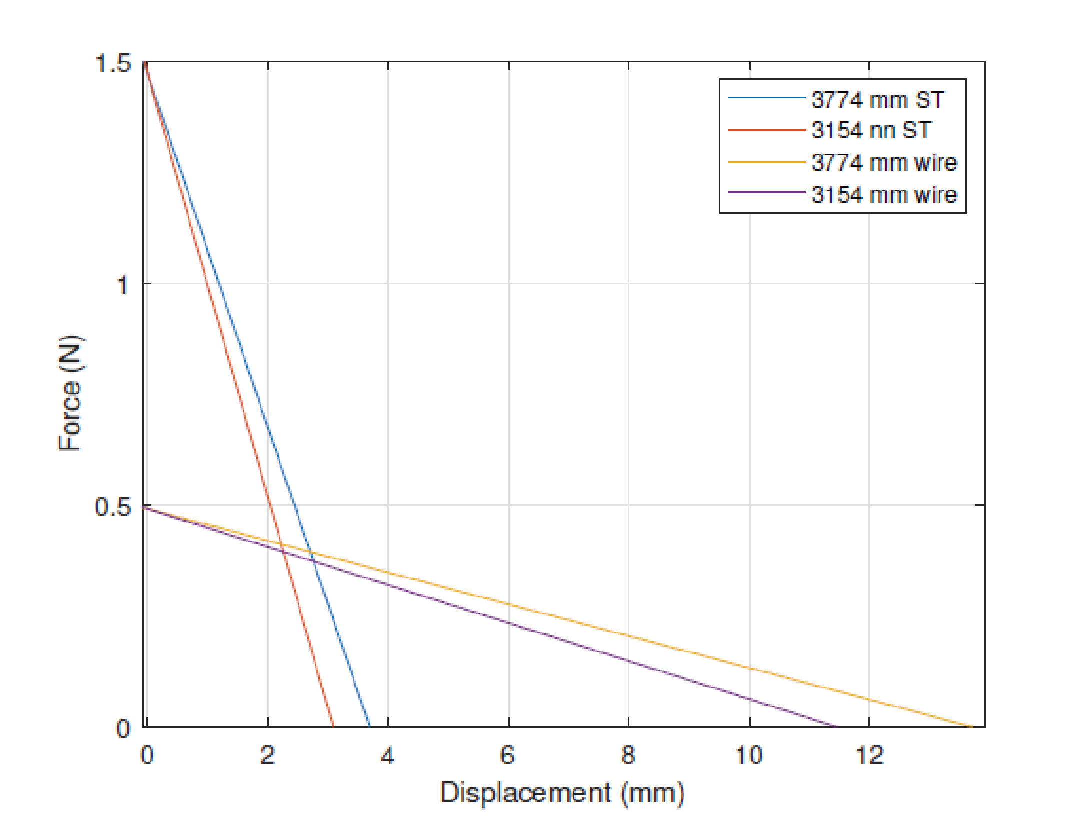
Layer	Force (gr)
1°	41.9
2°	41.9
3°	38.1
4°	38.1

Table: Load on wires

⇒ straw tubes are still compressed
⇒ one possible solution is to increase the inertia of the cross section

Increasing the mounting pressure to 2.5 bar

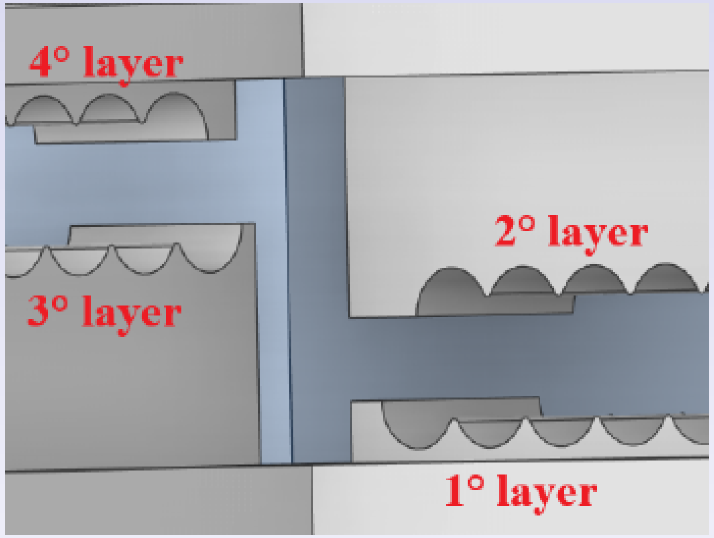
- mounting initial pressure: 2.5 bar
- Re-W elastic properties



Initial straw tube elongation (2.5 relative bar): 3.69 mm (long) and 3.09 mm (short)
Initial wire elongation (50 gr): 13.7 mm (long) and 11.5 mm (short)

Increasing the mounting pressure to 2.5 bar

Results: straw tubes and wires

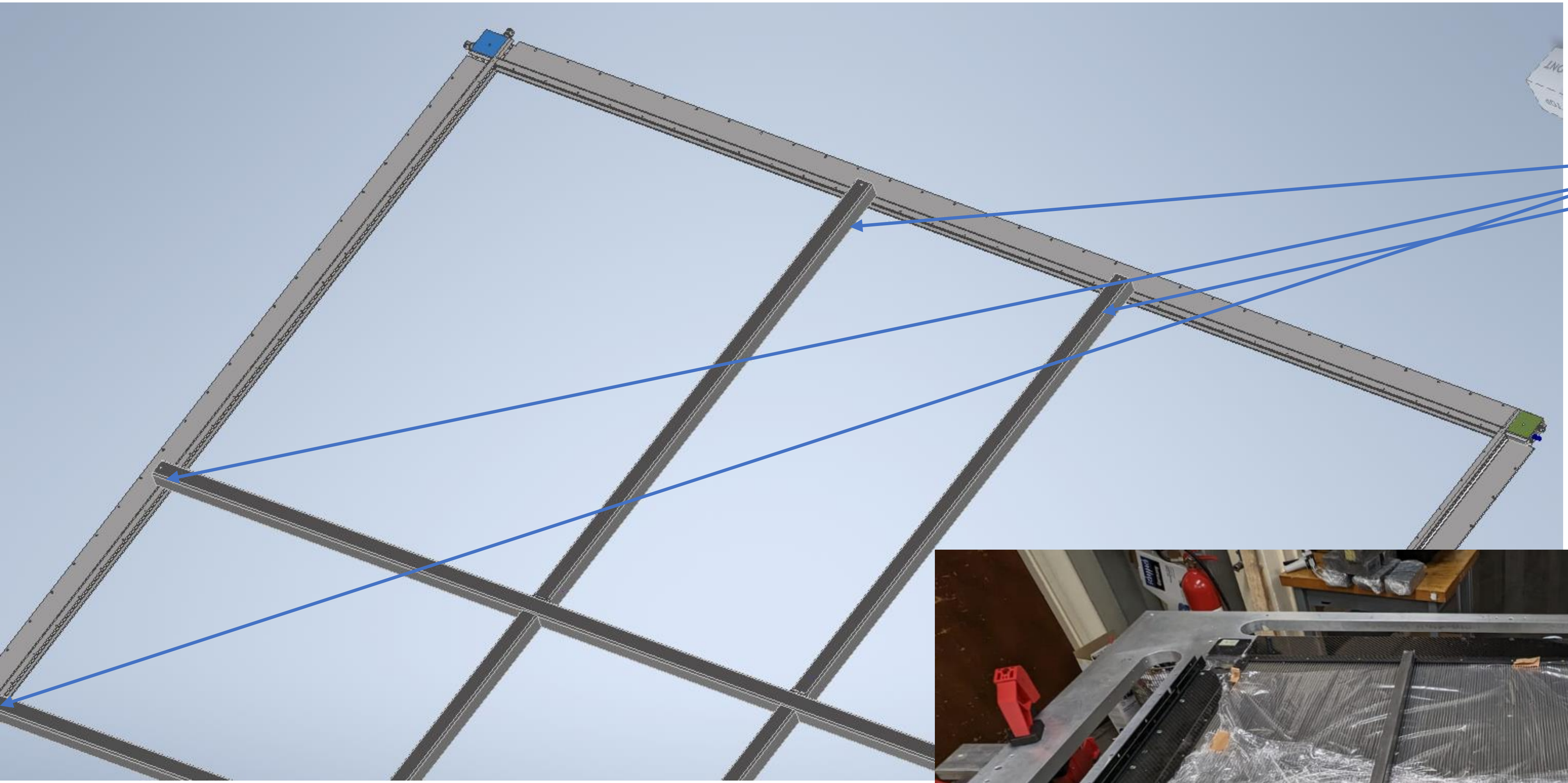


Layer	Displacement (mm)
1°	2.75
2°	2.75
3°	3.25
4°	3.25

Table: Maximum displacement on straw tubes

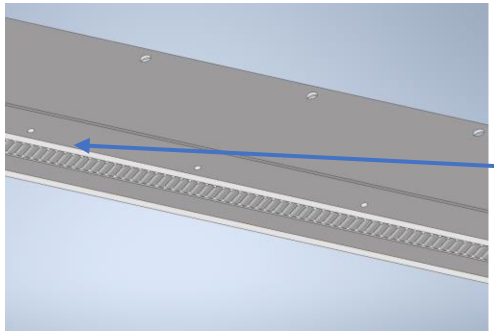
Layer	Force (gr)
1°	39.9
2°	39.9
3°	35.7
4°	35.7

Table: Minimum residual load on wires

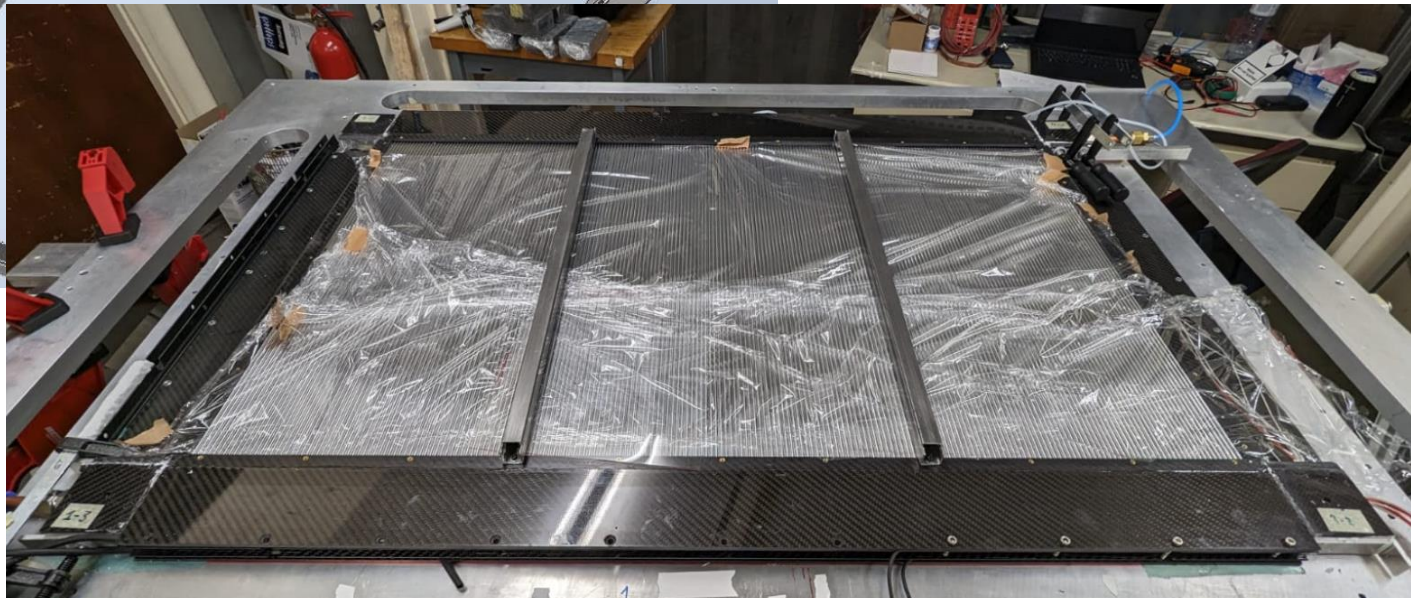


Bracing system to remove the CF from the mounting table.

This is necessary to seal with staycast and/or for the wiring.

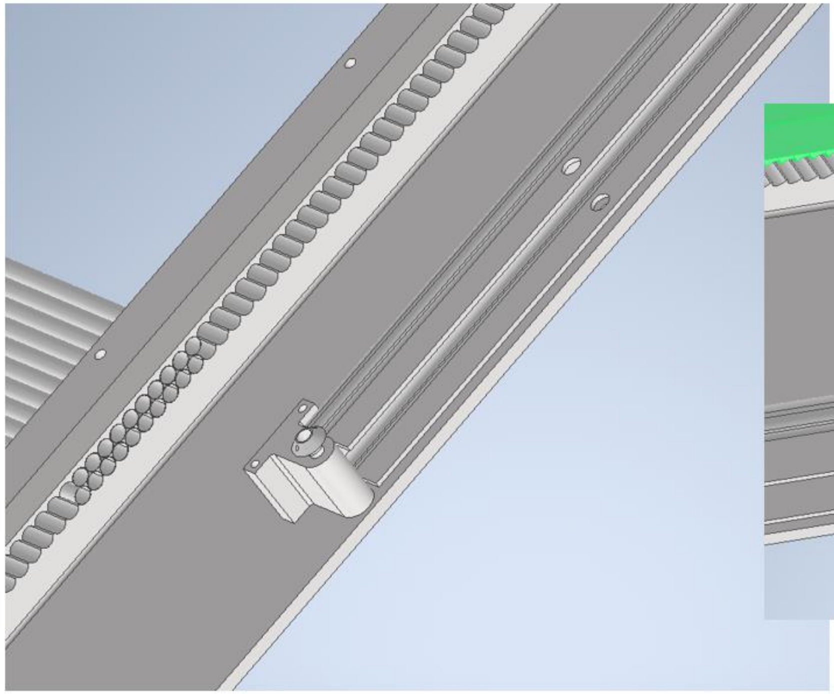


We increase the size of the top holder and we set M5 thread inserts.



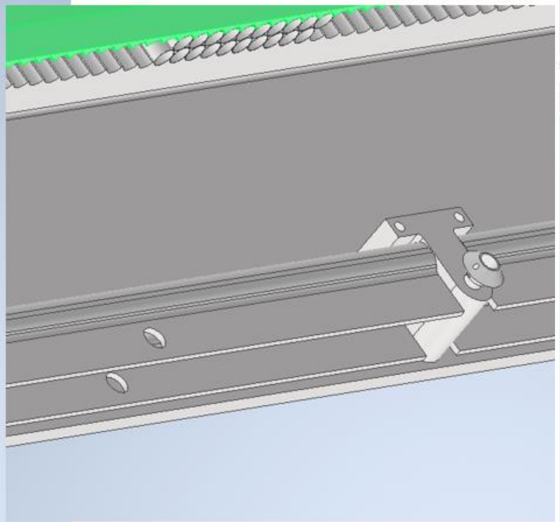
Future design validation.

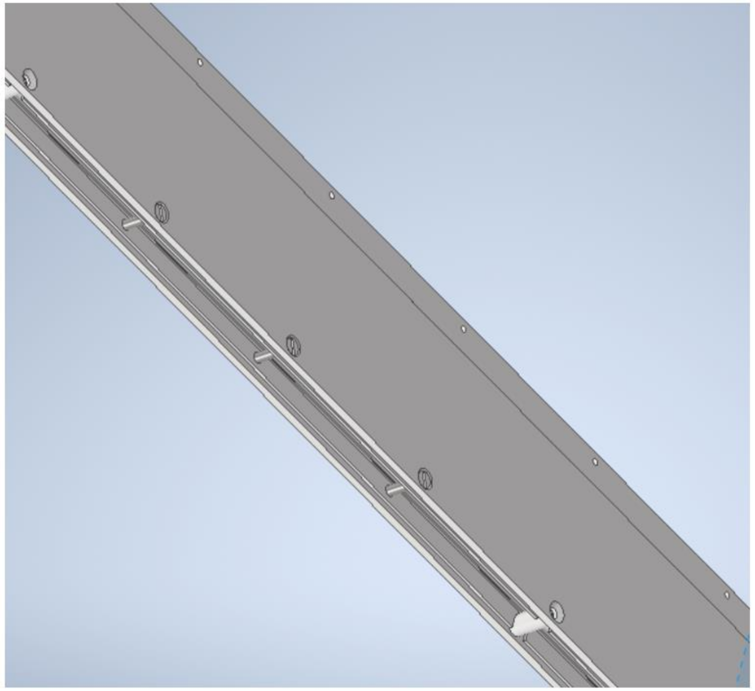
The full scale prototype (3800X3200mm) is the final step for the straw construction validation. This can allow us to estimate in detail the required time and solve all the technical issues. However this prototype needs an investment in term of man power and tooling much larger that the previous prototype. We started to expand al the level of conceptual design the large prototype and the integration with radiator and graphite sheet. Some examples are reported.

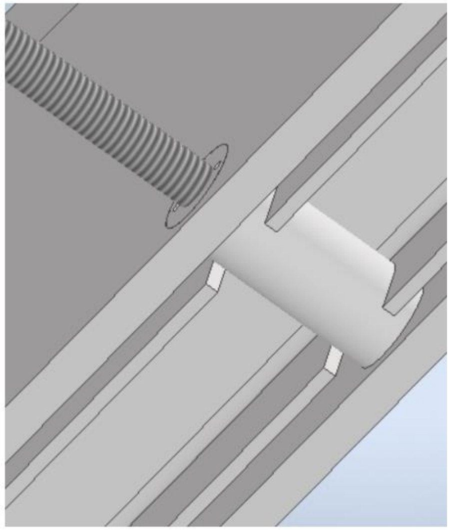


Central support for omega made in two parts to reduce the size.

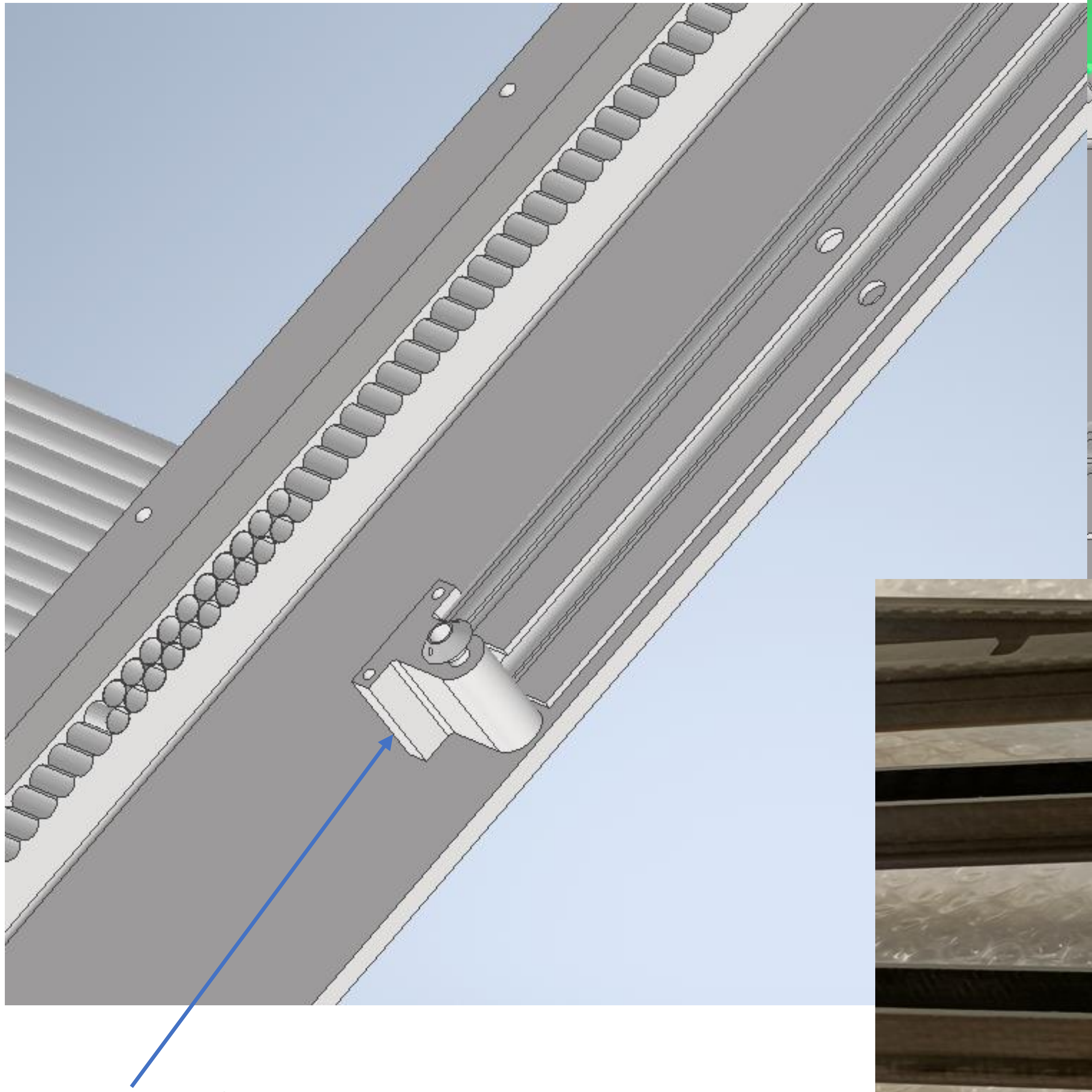
Module Design 3800X3200mm



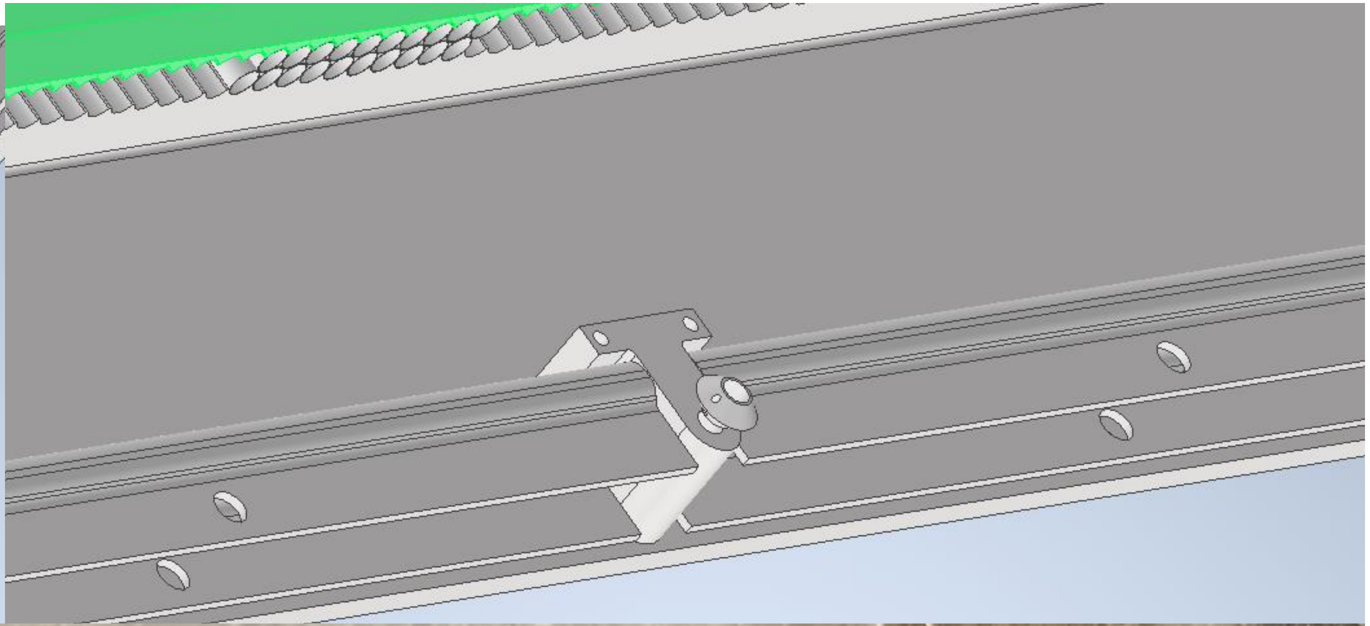




Thread rod conection

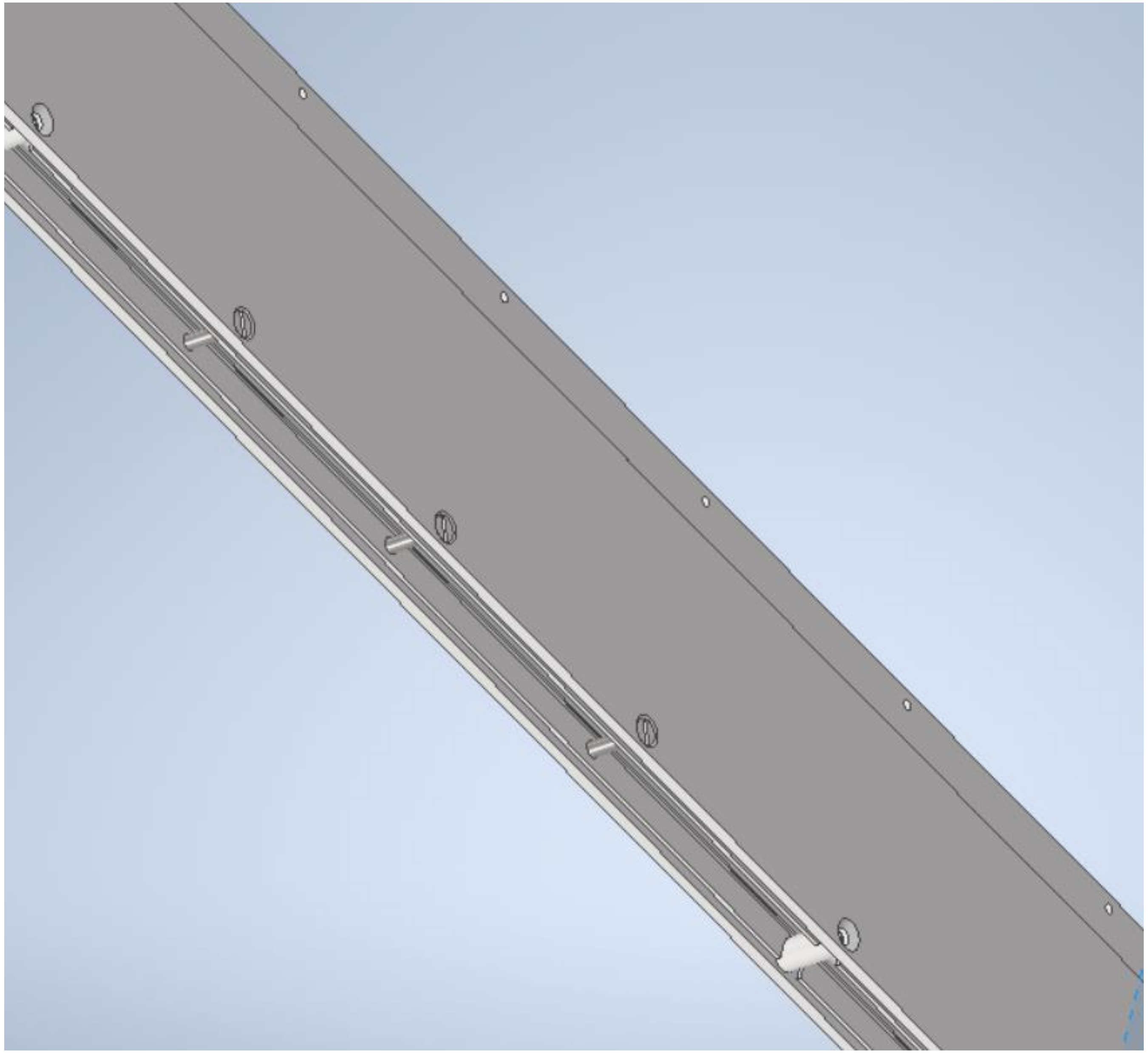


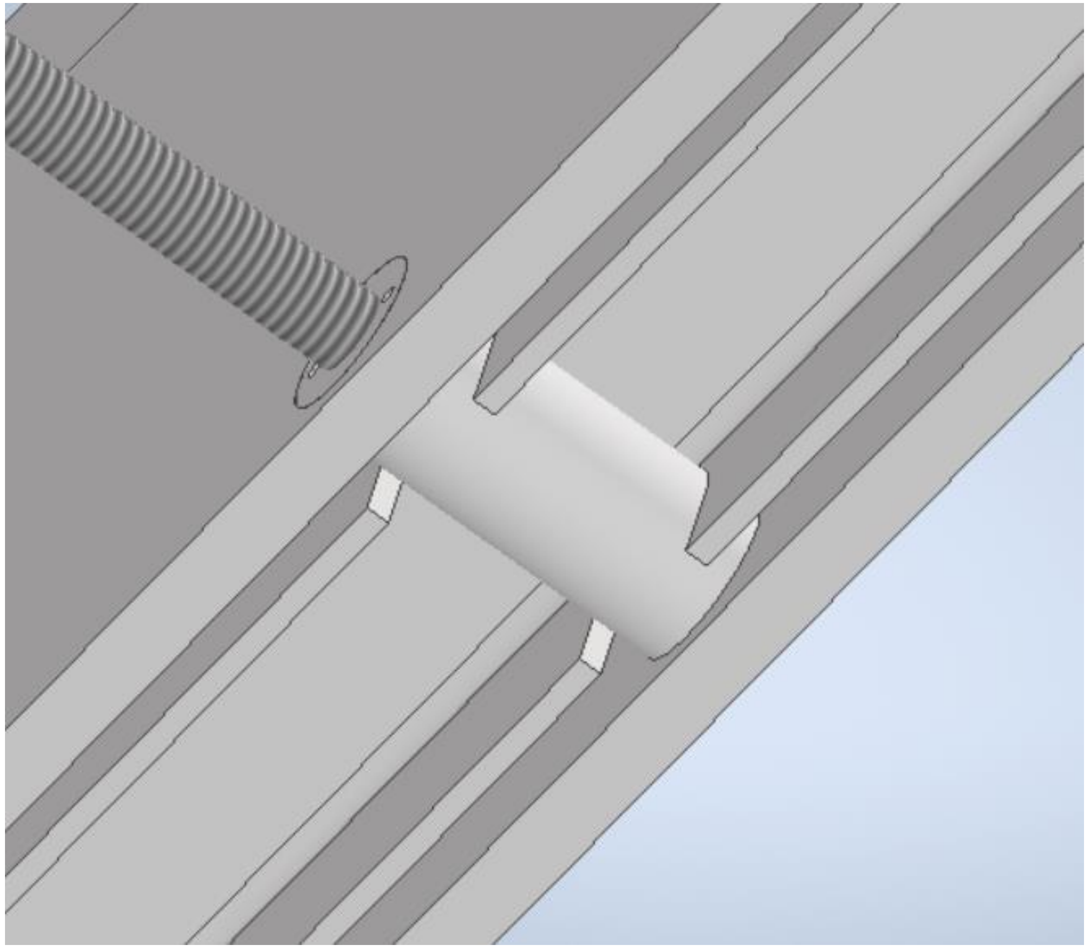
Central support omega

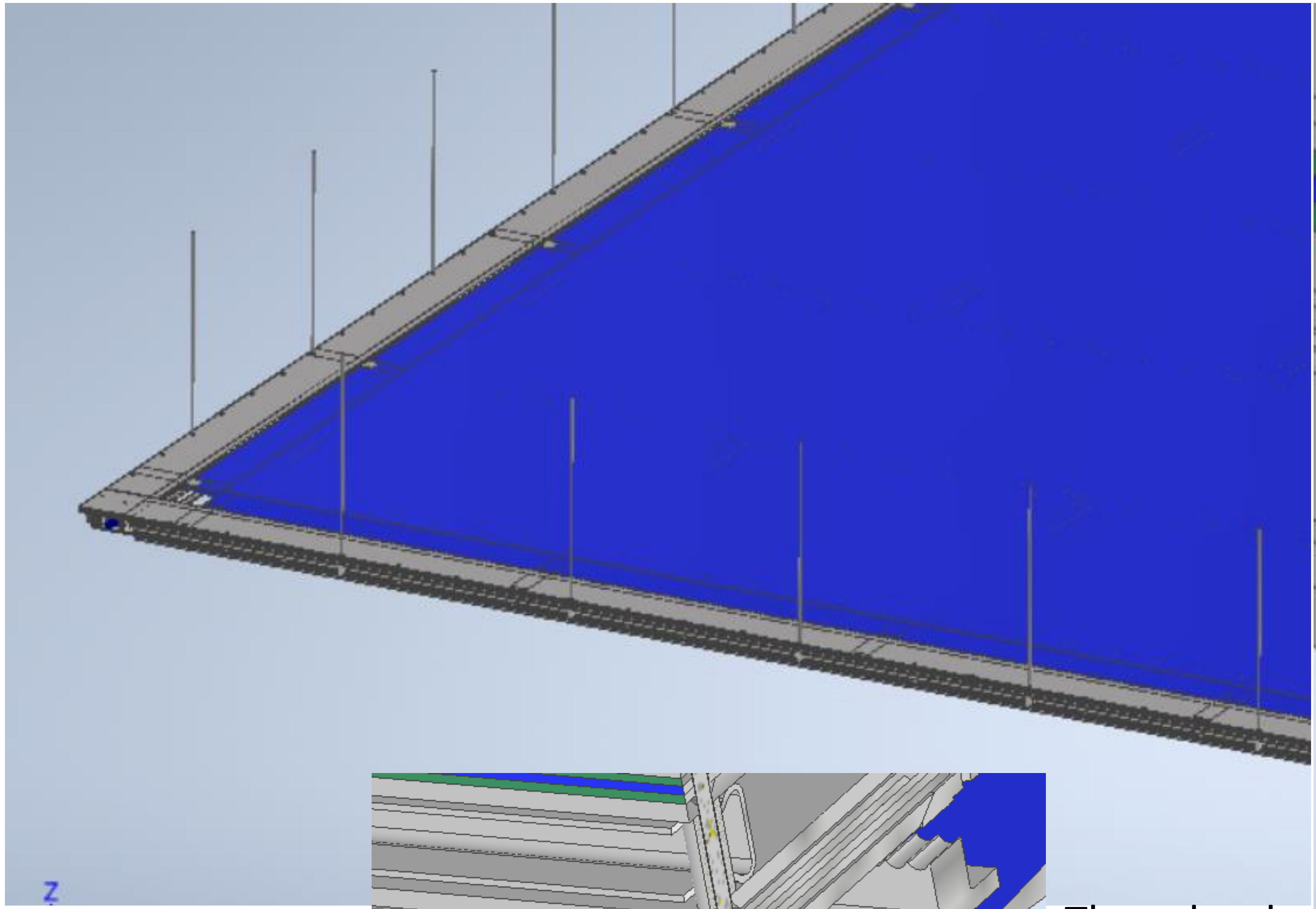


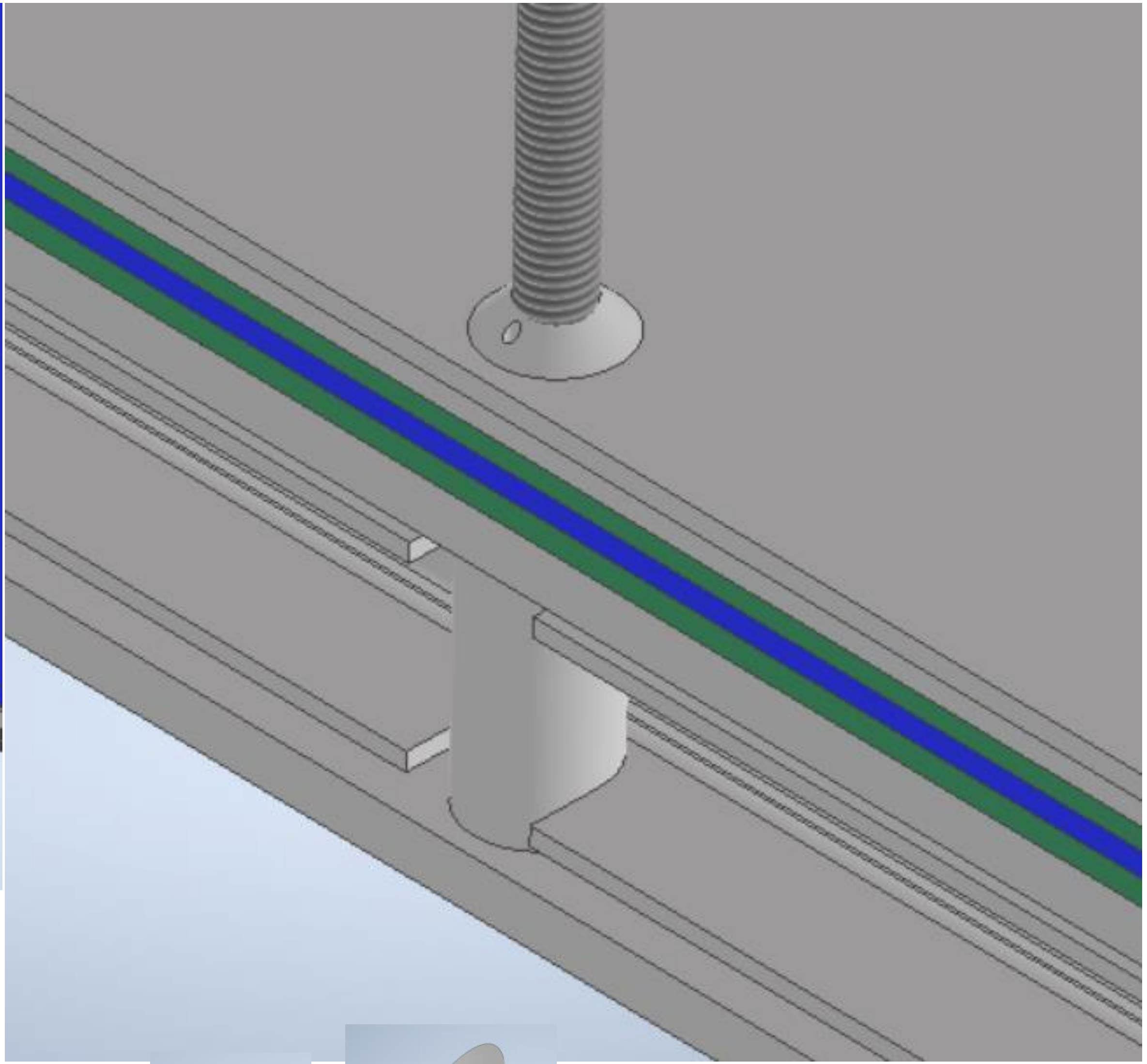
The omega to close the gas volume has been made in three elements per sides.

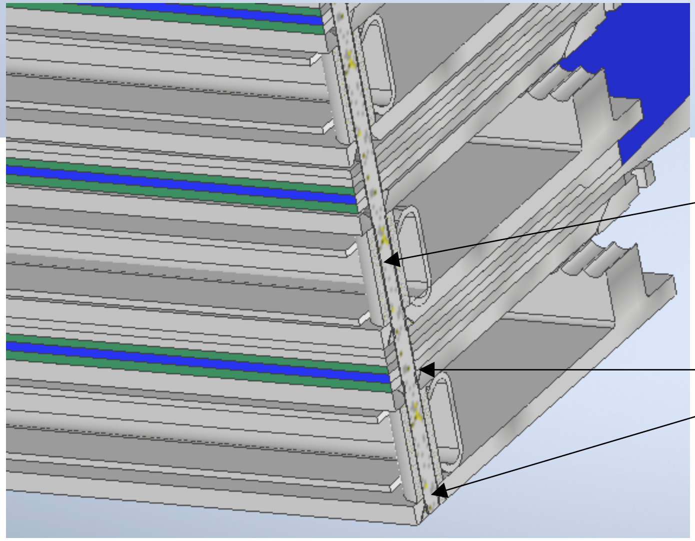
We can have access inside to the electronic each about 1.2 meter





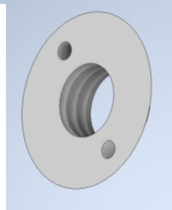


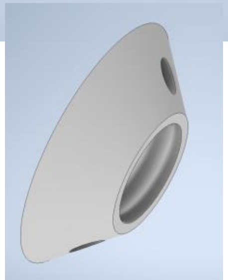


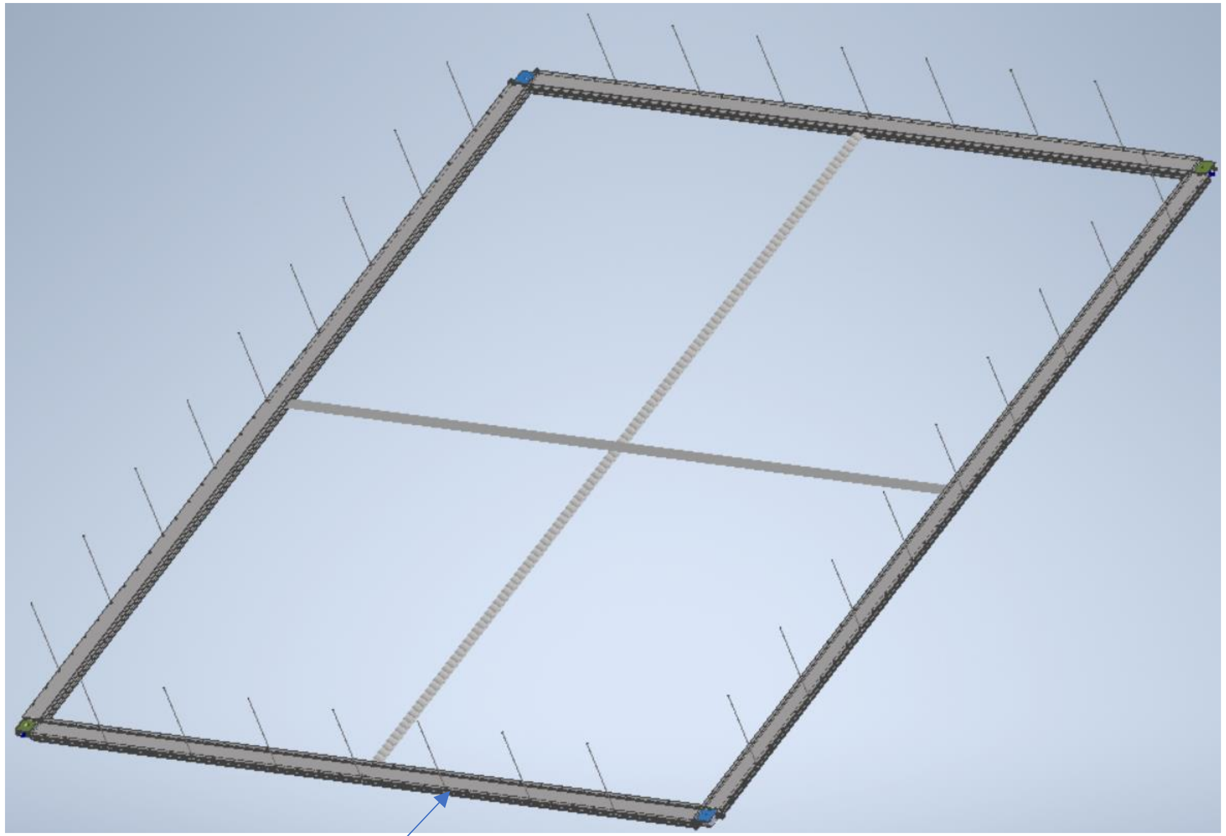


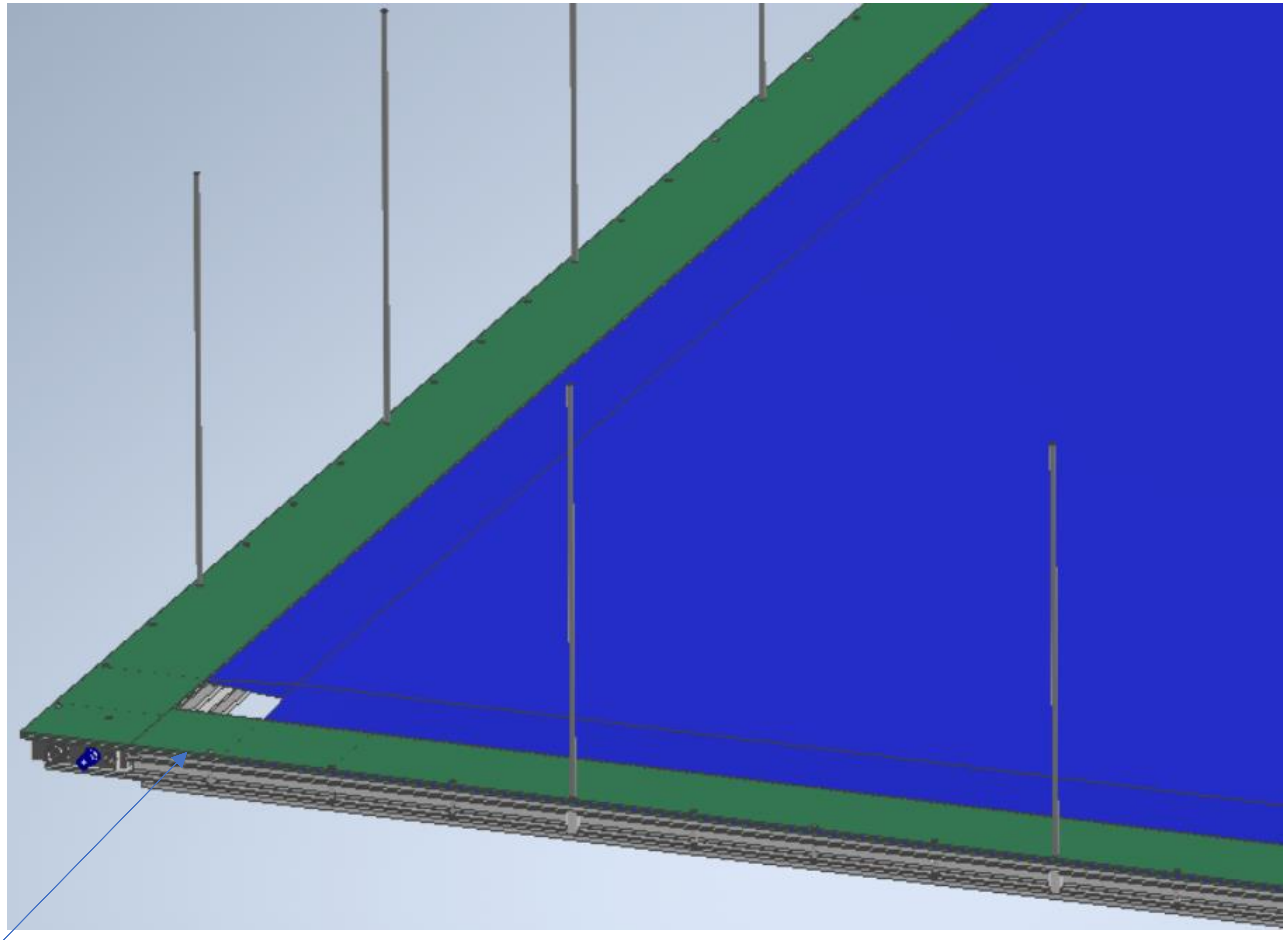
Thread rod

Special Nut





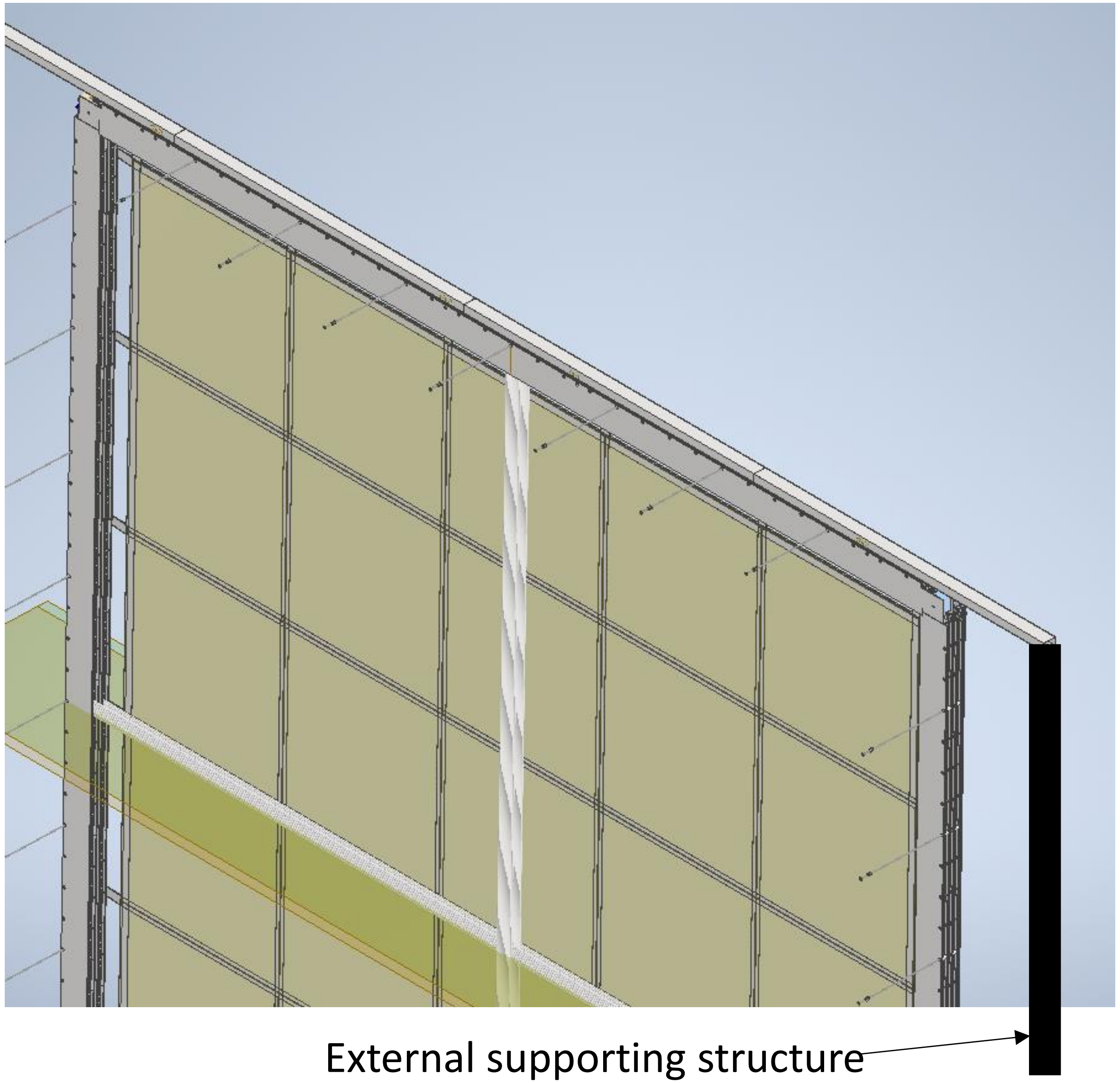




Straw frame with thread rod

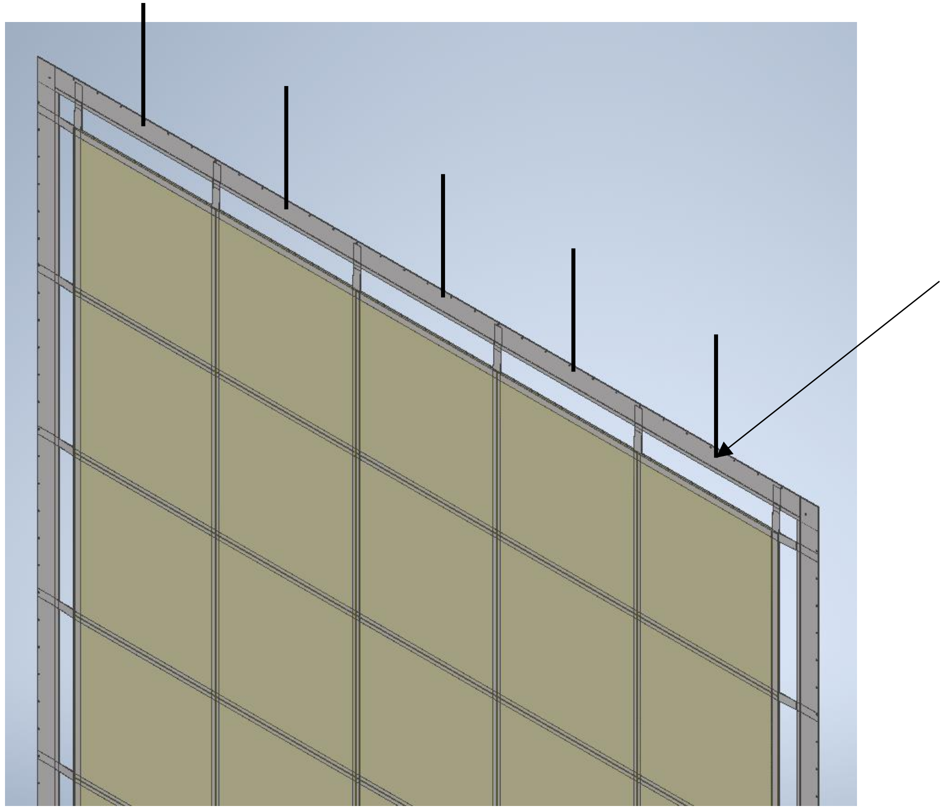
Radiator

The assembly of the module is made in vertical position supporting the each straw panel from an external frame structure.

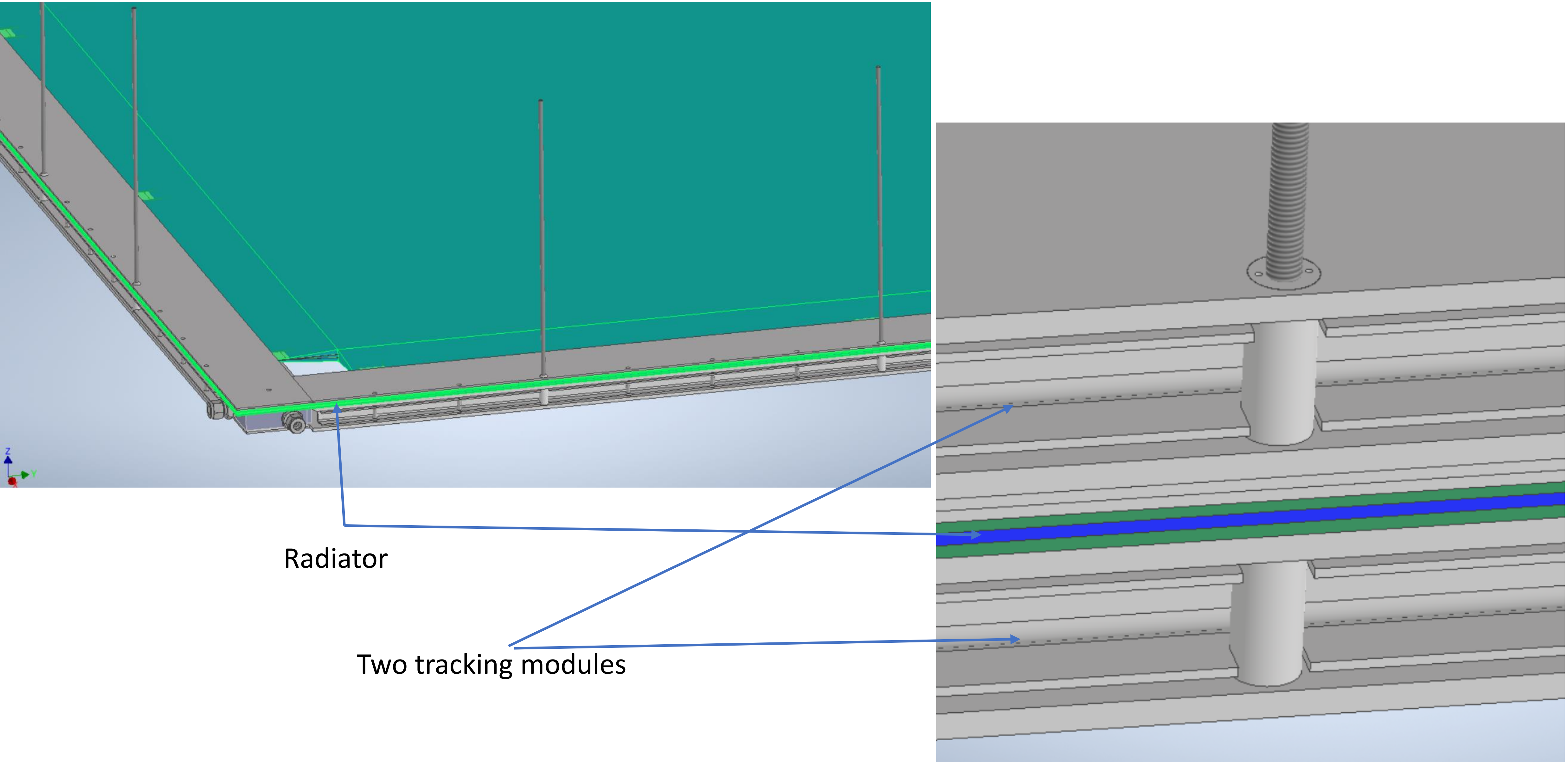


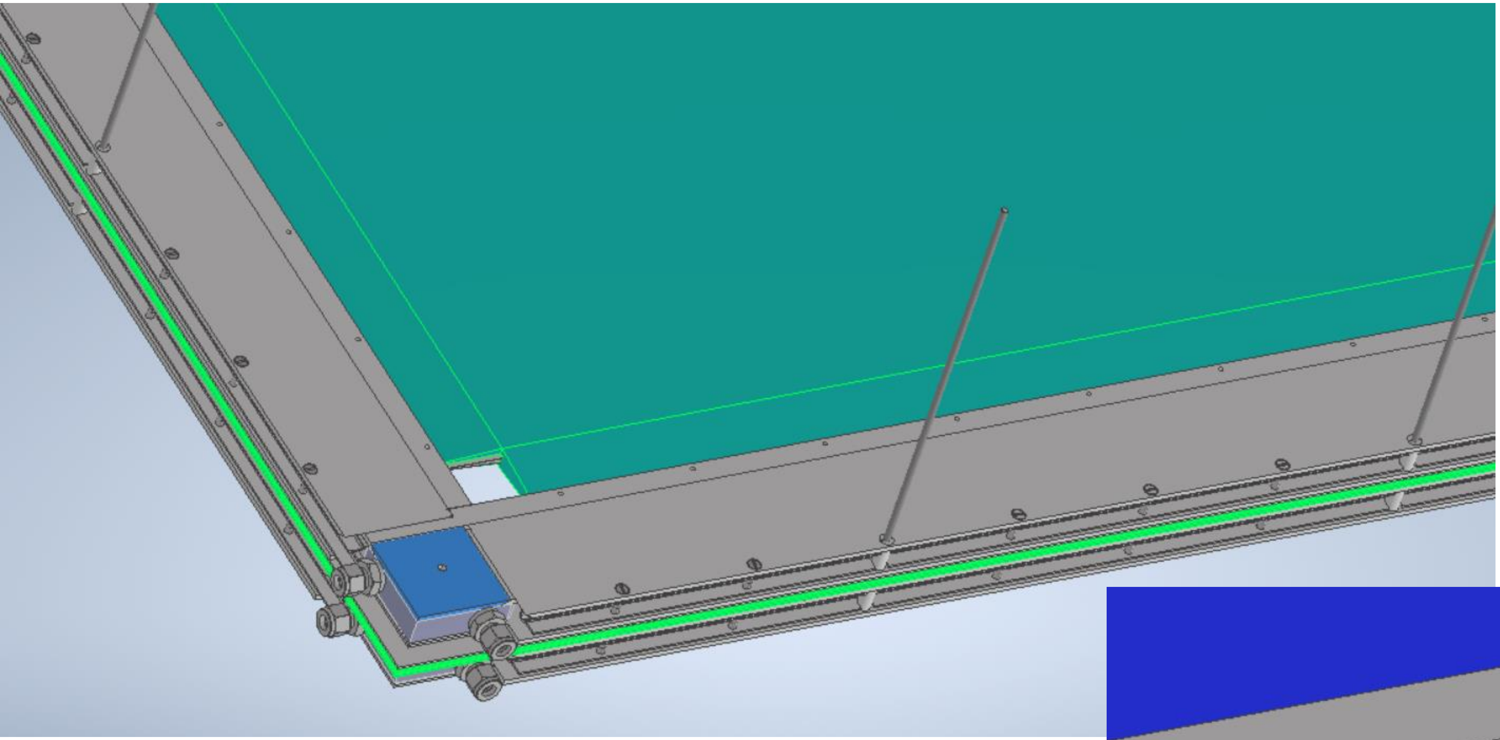
- The mounting sequence can occur using a cart to bring the panels in position.
- Proper clearance must be address in the design to allow the mounting.

External supporting structure

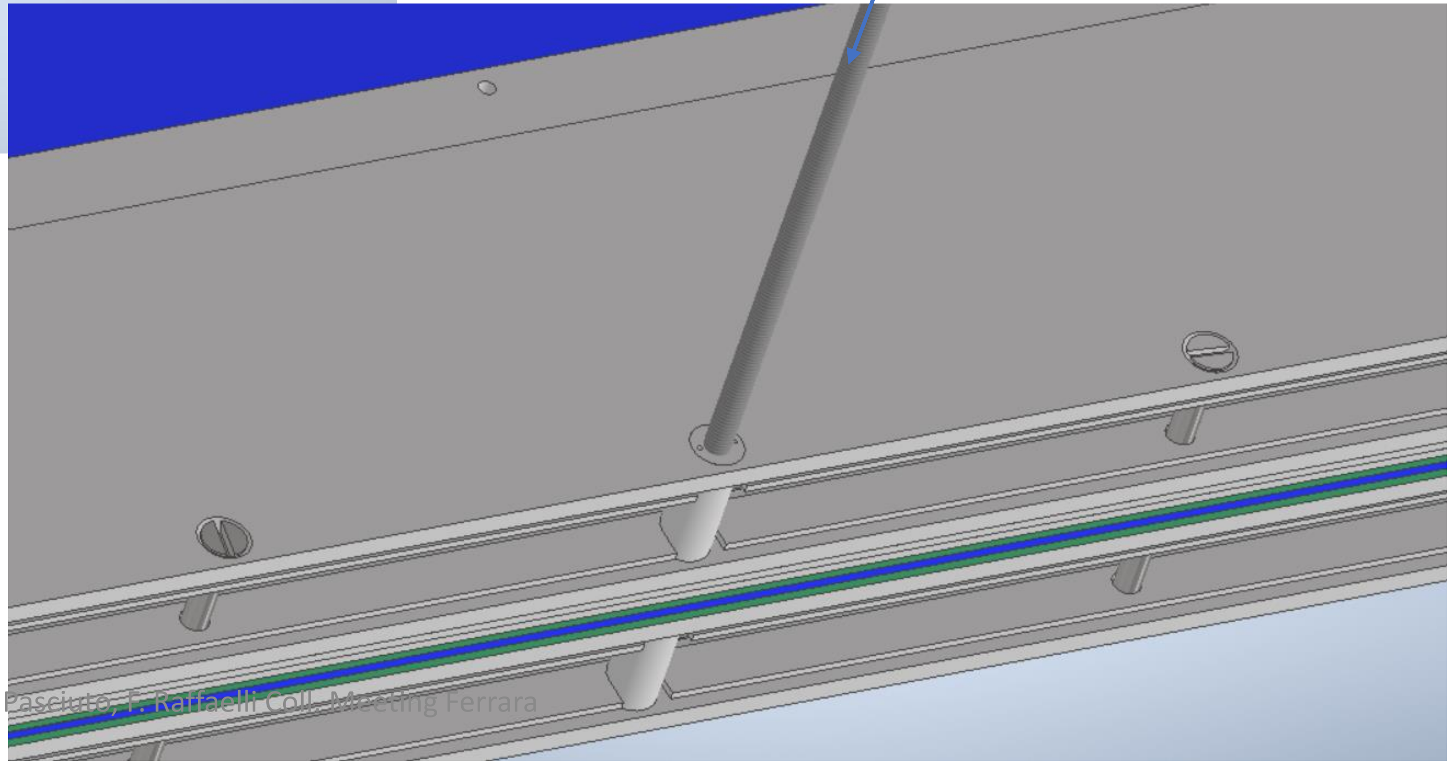


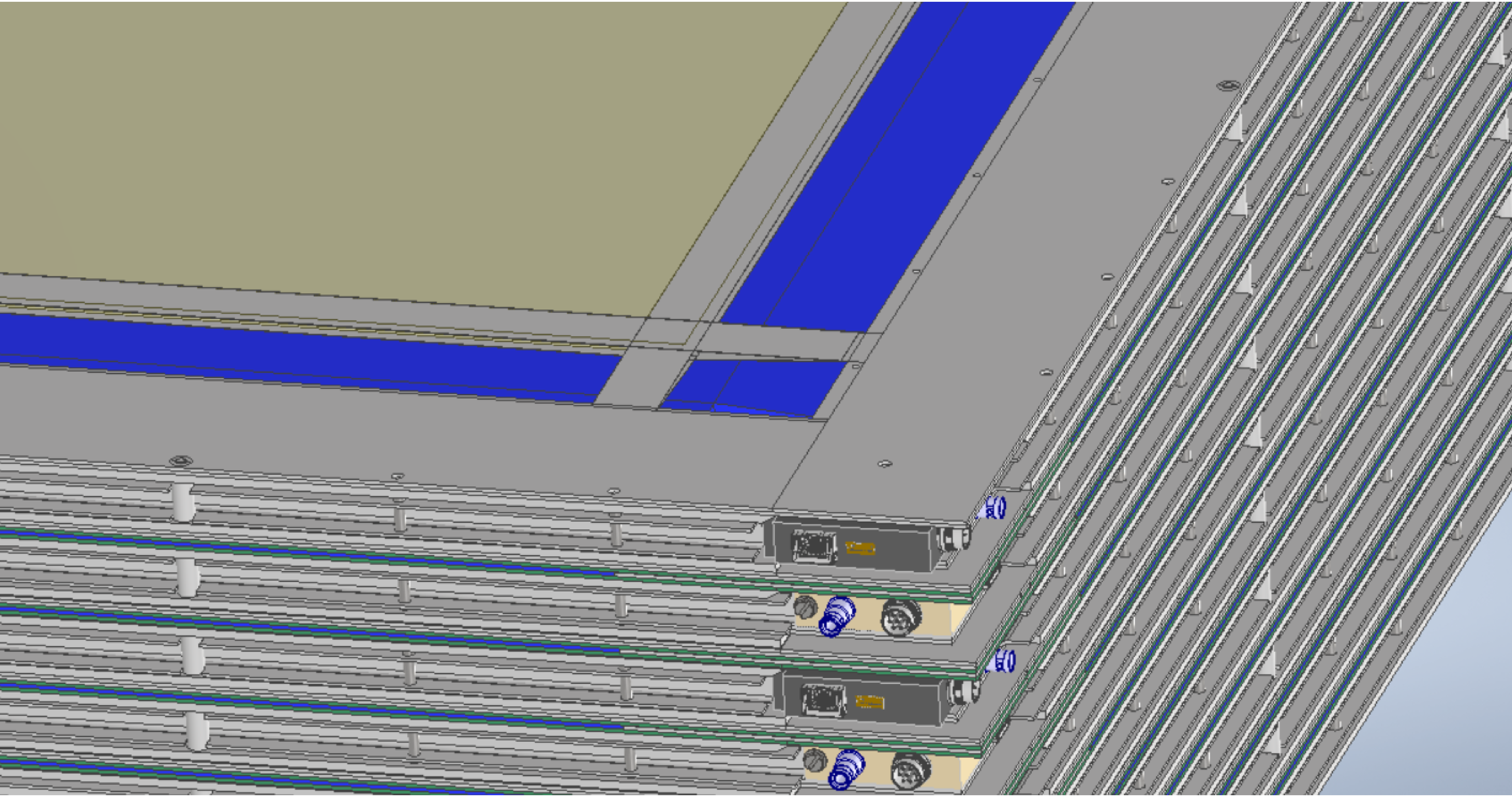
Tread insert for holding with strip the panel in vertical position.

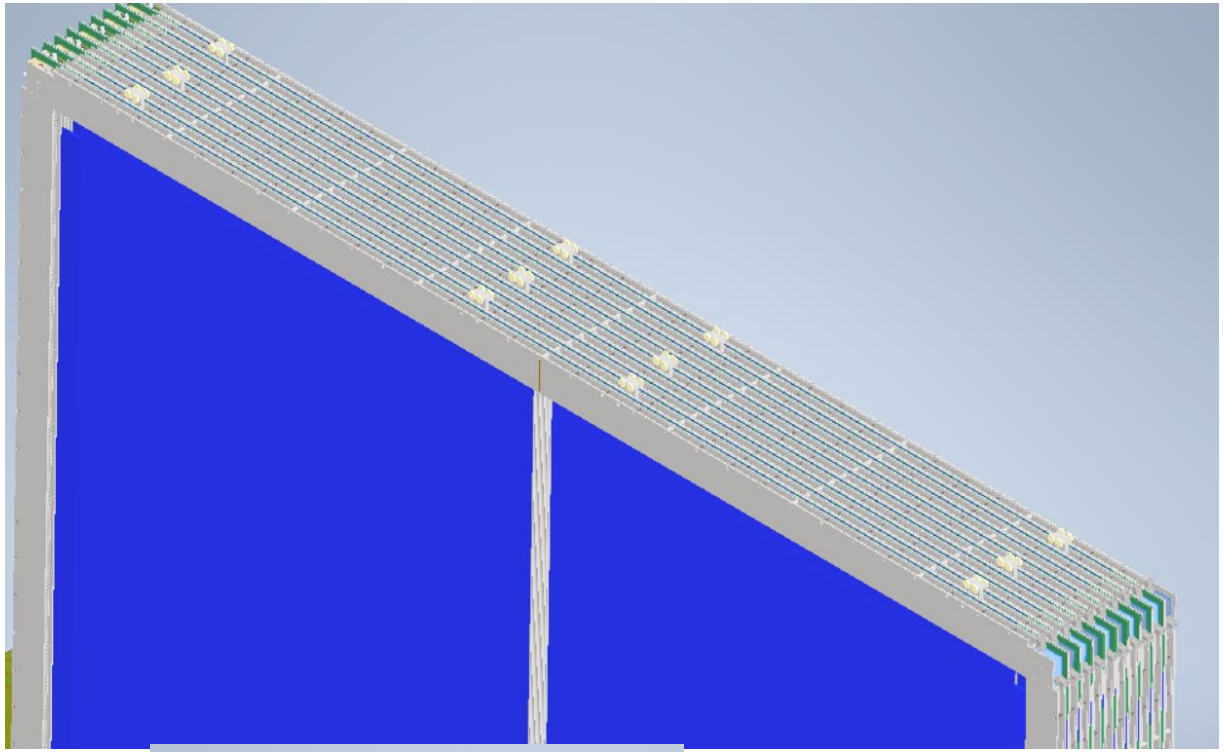

Radiator
Two tracking modules

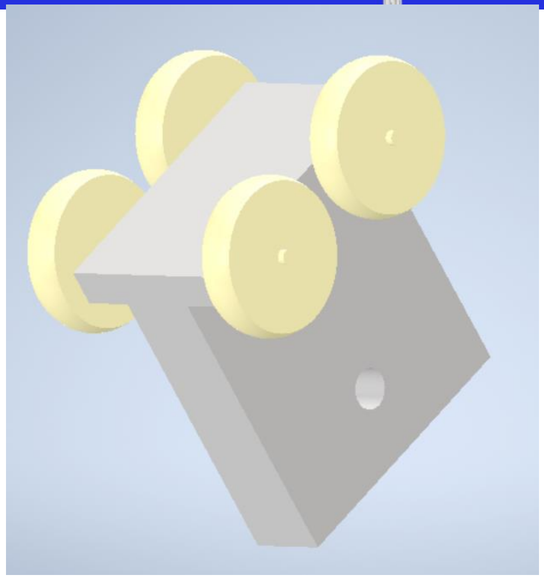


Thread rod can have a breaks on the Thread.

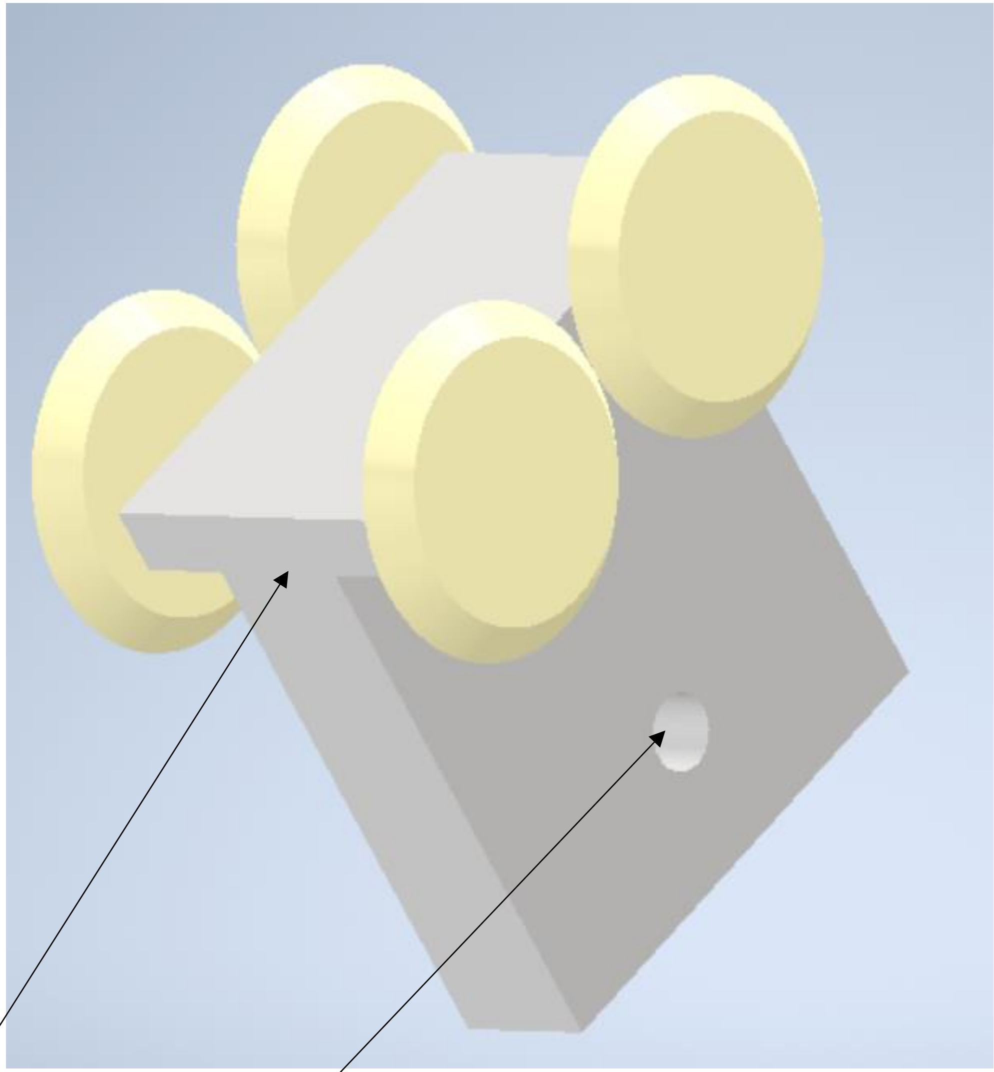








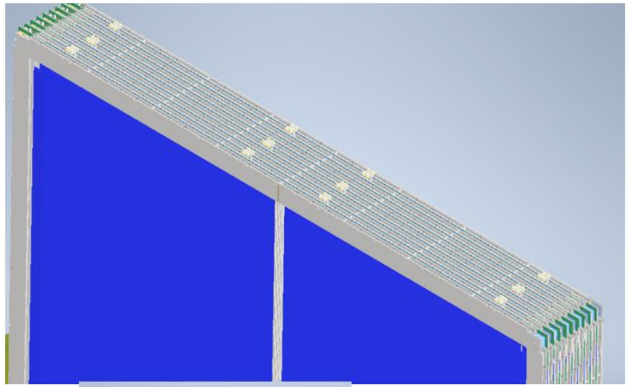
Elastic self alignments mount

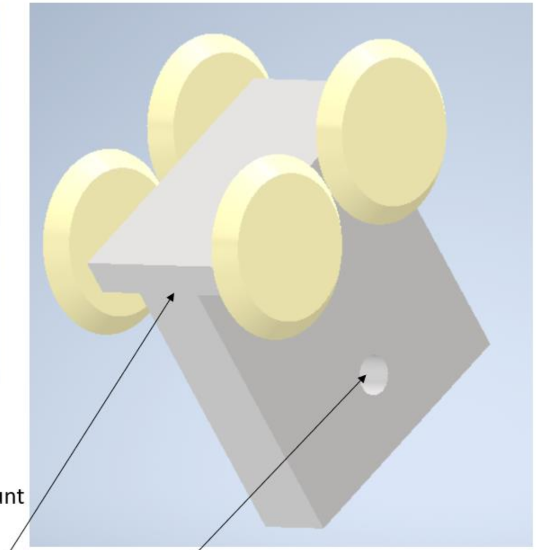


Vertical elastic mounting

Elastic pivot mounting

An external frame will hold of the super module in vertical position for mounting transportation and insertion and extraction inside SAND. Number of support need to analyzed with FEA analysis to verify that the deformation are compatible with our requirements.





Elastic self alignments mount

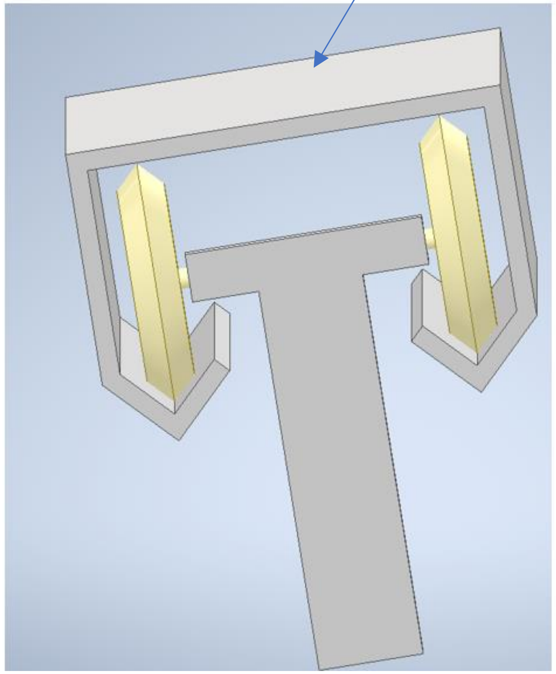
Vertical elastic mounting

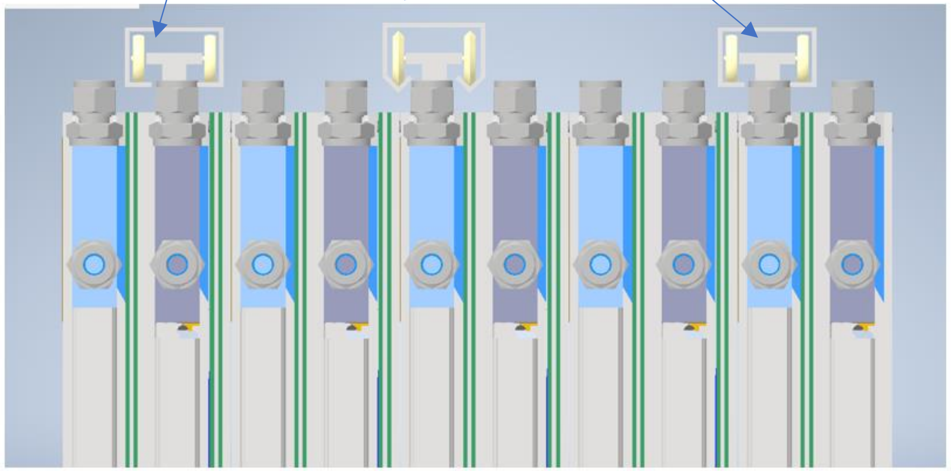
Elastic

Simple elastic support self align

Guiding rolling

Upper part





The lower part will be a simple elastic vertical support to minimize the deflection of the lower part.

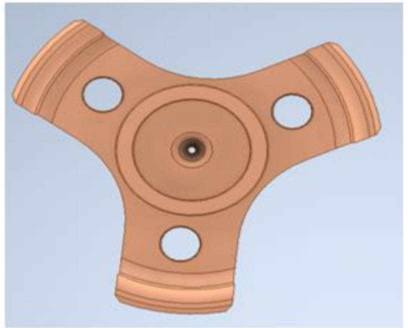
Pisa Prototype 1200x800mm

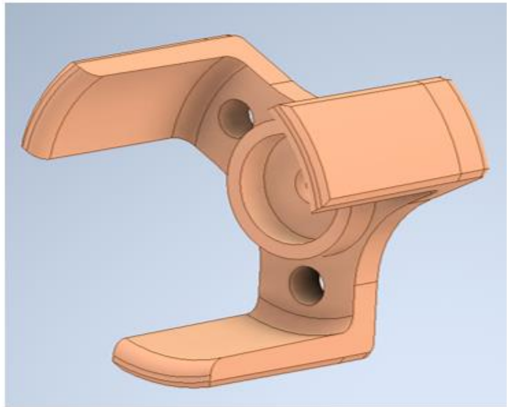
In the first prototype made at CERN has a gap of 100 μm between straw. We have to fill the gap with paper foil to control the straw position. The new straw have a larger diameter than the previous one. We increase 50 μm on the diameter to fill the gap. Check the release from the mounting table.

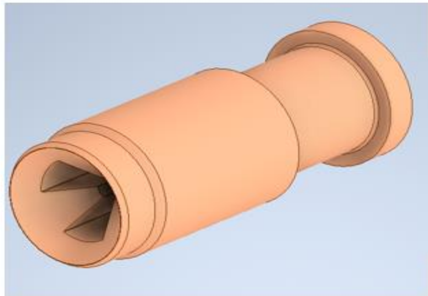
Goals for the new prototype in Pisa (1200x800mm)

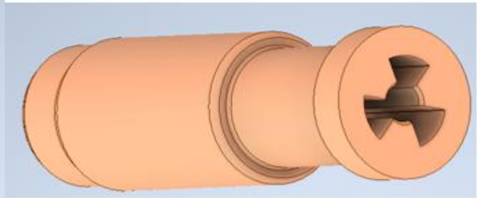
In the new prototype we would like to test the insertion of the wire spacer.
This operation it was not tested yet in real condition in which the straw are pre-tensioned.
This time we are trying to have all materials in advance to be able to do the necessary adjustments.
New pin and end plug are going to be tested.

Spacer









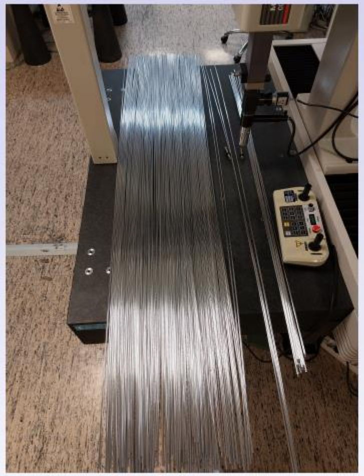
End Plug

Inner diameter 100 μm,
Outer diameter 600 μm

Spacer procurement

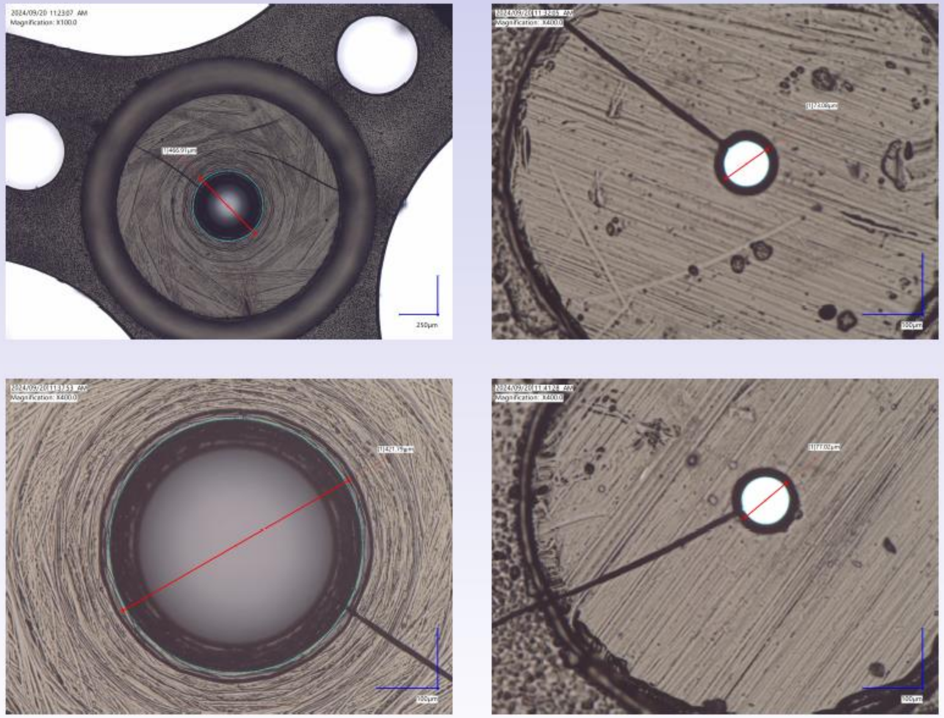
- 70 spacers each pack
- we have taken 6 packs for the prototype
- trials on inserting three spacers in a straw tube in vertical position

Straw tubes



We have enough one-side metallization straw tubes for only first layer
8 straw tubes have metallization in both sides

Spacer survey

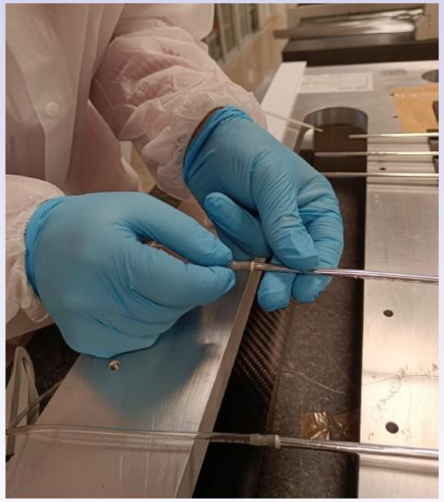


Wire hole is in the range 70 μm $\leq \Phi \leq$ 80 μm

Preparation for the prototype assembly in Pisa

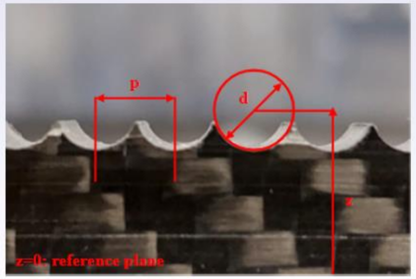
Straw tube preparation

Figure: Plugs and feedings for straw pressurization

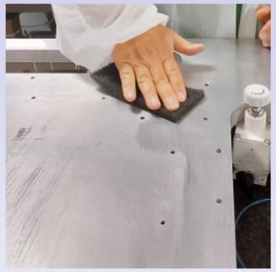


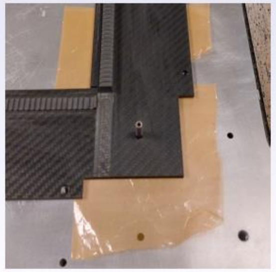
Carbon fiber frame survey

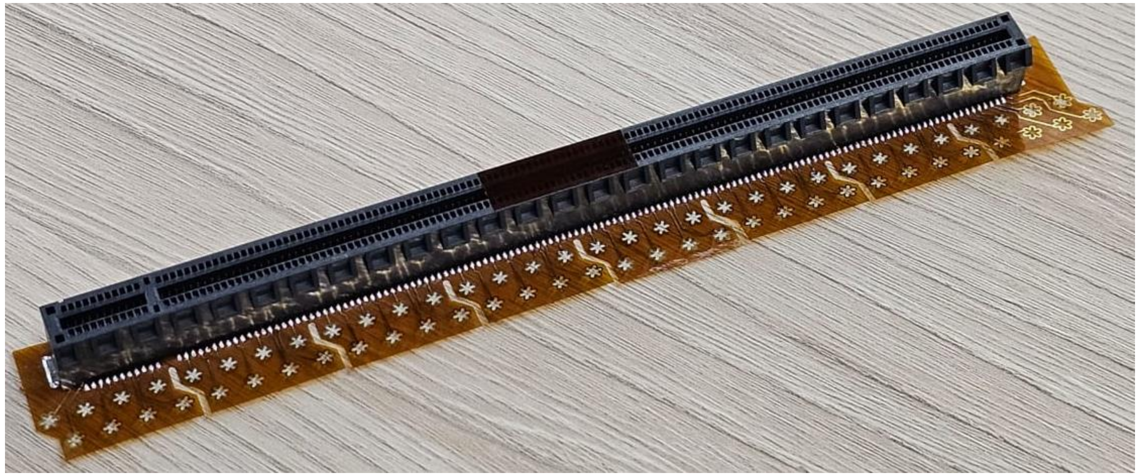
- we have sent back the frame to the technician to make some adjustments. We received it and checked again.
- we measured pitch, diameter and center height as function of the longitudinal coordinate (y)
- each measurement is repeated at three different x-coordinates: -5 mm, 0 and 5 mm



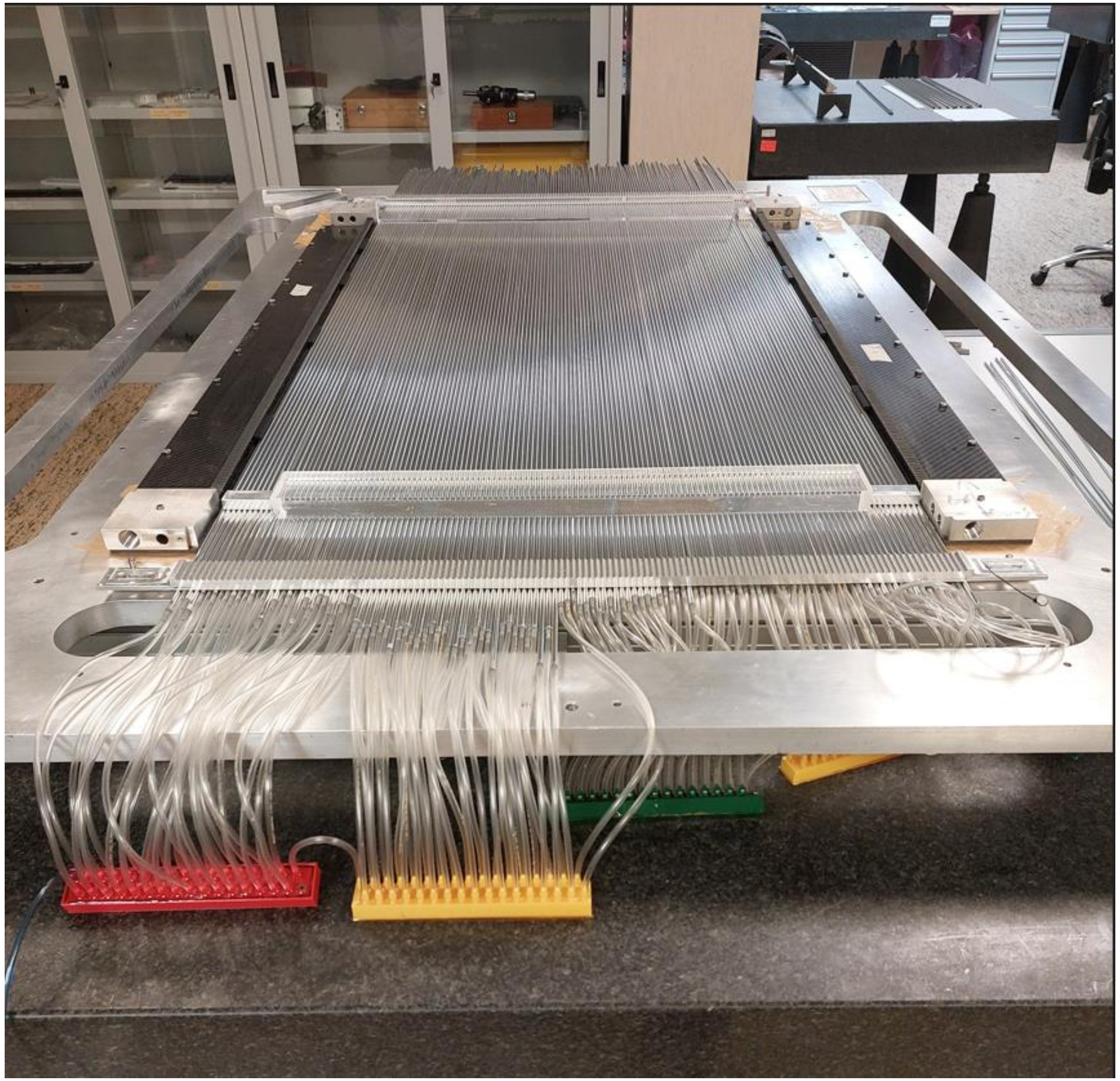
Next step: gluing the frame

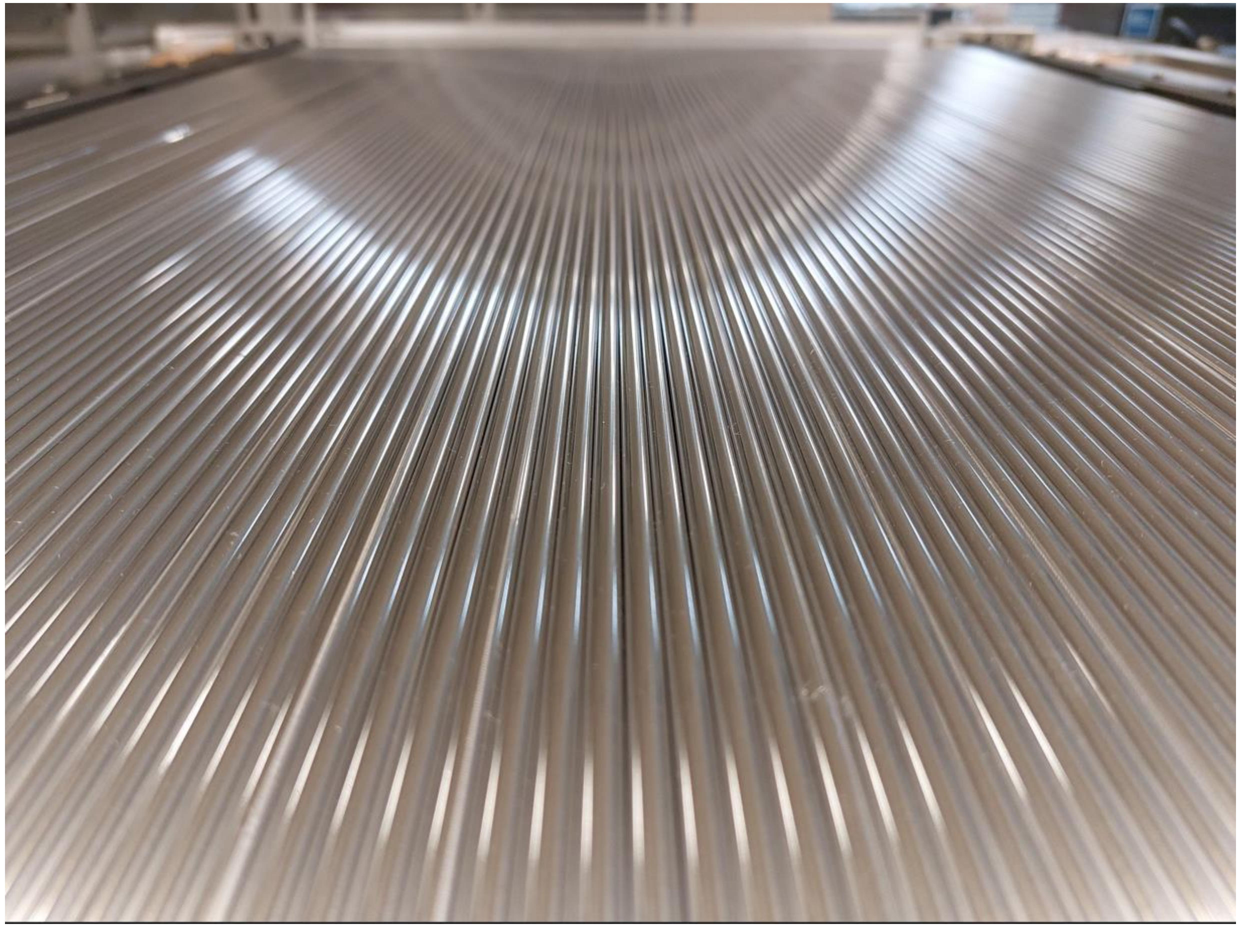






Straw connecting cable





Straw components inventory.

We expect to have the straw necessary to complete the prototype in January 2025 from Georgia group.

Componentistica	Qt. necessaria	Qt. in possesso	Status	Note
3M 2216	1	2	✓	
Anellini per tappo	≥ 1340	/	✓	risolto modificando il design
Araldite 2011	~ 5	2	🕓	ordinate 8
Colla per tappo	/	/	✓	stampati 3D
Collettori	21	26	✓	
Connettore elettronica	2	10	✓	
Connettore gas	4	4	✓	
Connettore HV	2	2	✓	
Corner block	4	6	✓	
Dispenser pneumatico	1	1	✓	chiedere a Ceccanti
Distanziali laterali	≥ 16	16	✓	
Distanziali sul piano	~ 30	/	✓	riutilizzati quelli precedenti
End-plugs	670 + 670	600 + /	✗	
Filo	~ 200 m		🕓	ritirare al Cern
Inserti polistirolo per taglio	~ 200	/	✗	filtri utra-slim per sigarette sono ok
Miscelatori	~ 10	100	✓	
Piastra alluminio	1	1	✓	
Pin di crimpaggio	128	q.b.	✓	
Pinsa crimpaggio	1	/	✗	
Profili in teflon	4	4	✓	
Riduttore pressione	1	2	✓	P max 4 e 12 bar
Sedi alloggiamento	8	8	✓	
Spacer per filo		420	✓	
Spine	≥ 12	q.b.	✓	
Straw tubes	≥ 670	8	✗	
Stycast nero	?	1	✓	
Tasselli omega	8		?	controllare al Cern
Telaio	1	1	✓	
Threebond 1212, 1530	1+1	2+2	✓	
Tubo di silicone	~200 m	>150 m	🕓	da ricontrollare (15 m ogni scatola)
Valvole, adattatori	q.b.	q.b	✓	
Vernice contatto	1	1	✓	
Viti per omega	30	40	🕓	da tornire
Viti speciali ribassate	14	14	✓	

Resources for future development of STT design.

The current situation of the manpower for the development of STT project is:
F. Raffaelli 30% Eng., A. Soldani 20% draftsman.
Saverio Mameli is working on the project unofficially.

- We need to identify Tasks and the adequate resources to finalized the STT mechanical design.
- The design process that allows to complete the straw tracker is related to the prototype construction. We cannot finalized the mechanical design without participating to the construction process of the prototype. We feel uncomfortable to design a prototype whiteout participate to the construction.

Conclusions.

- We consider the second prototype in Pisa very important step to test the STT design. We can test the mechanical design of various “final” components as straw, plugs, spacer, crimping pins, (procured at a reasonable price). This prototype should be ready in the spring 2025.
- With this prototype we will test the performance of the detector validating the gas distribution, the cooling of electronic and the physical performance.
- The design of the full scale STT module prototype has been done.
- A full scale design of super module requires a more engineering efforts and time. We need a lot of work to make a STT design that integrates all components and that have the right features to be compatible with the tooling for its construction handling and mounting.
- We need a full scale prototype to test the solutions adopted, this is necessary step to launch the final straw detector production.