STT prototype construction and assembly

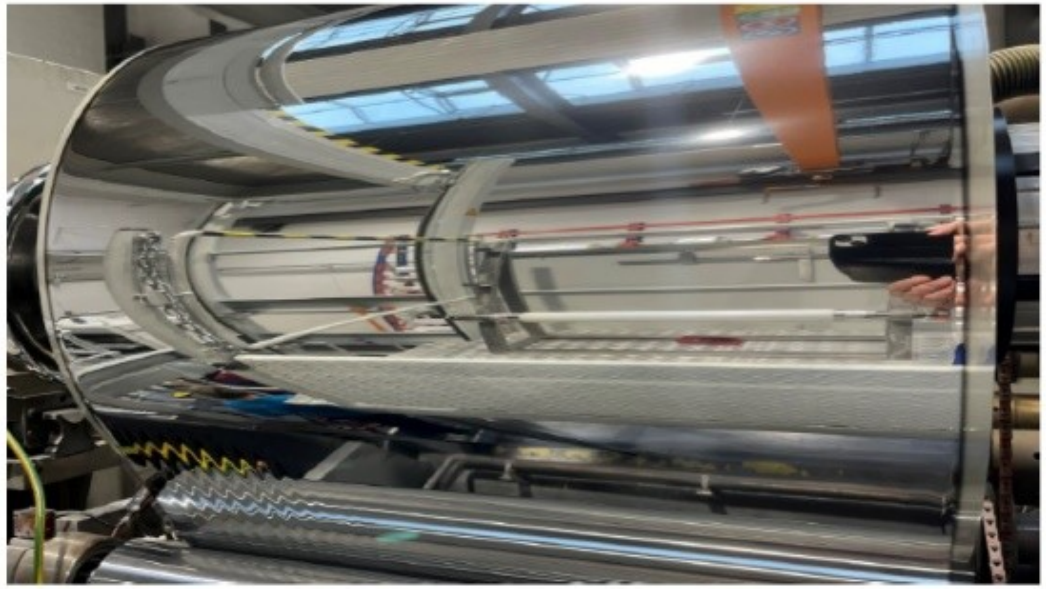
Fabrizio Raffaelli
INFN Pisa

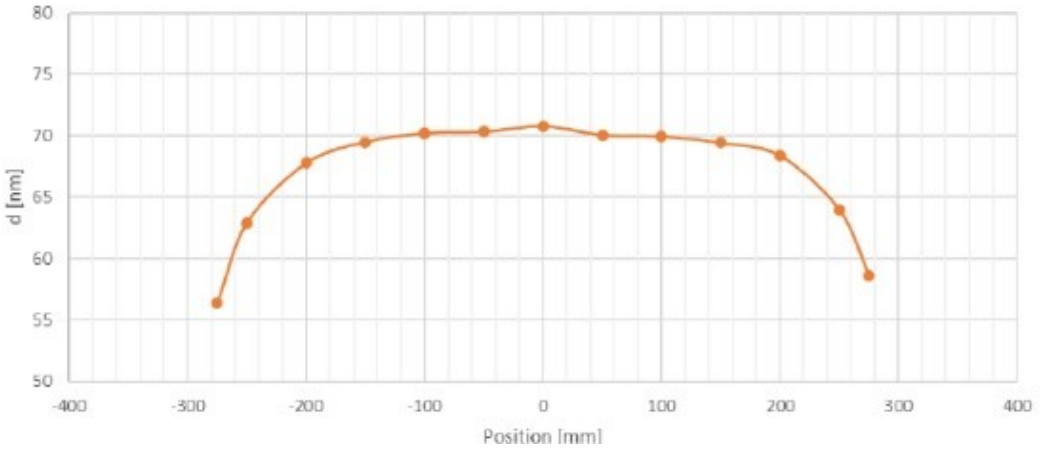
SAND CSN1 review
Frascati, July 12, 2024

Outline

- Prototypes construction
- Future design validation
- Summary

Components of straw tube tracker: the film





Straw tubes are made of a film of 19 μm with double side Aluminum of 70 nm.

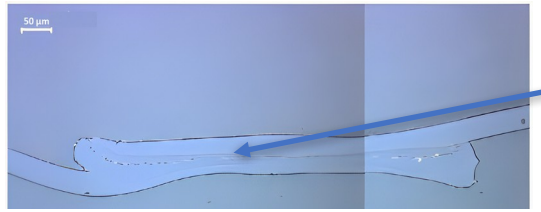
Hostaphan® RNK is an highly transparent, biaxially oriented coextruded film made of polyethylene terephthalate (PET)).

The double side

The double side Aluminum metaliza

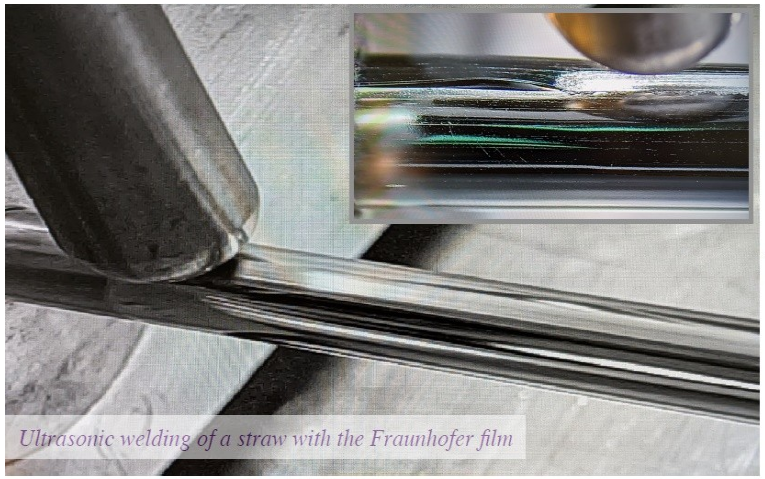
Aluminum metalization improves straw tightness.

Components of straw tube tracker: the tubes.



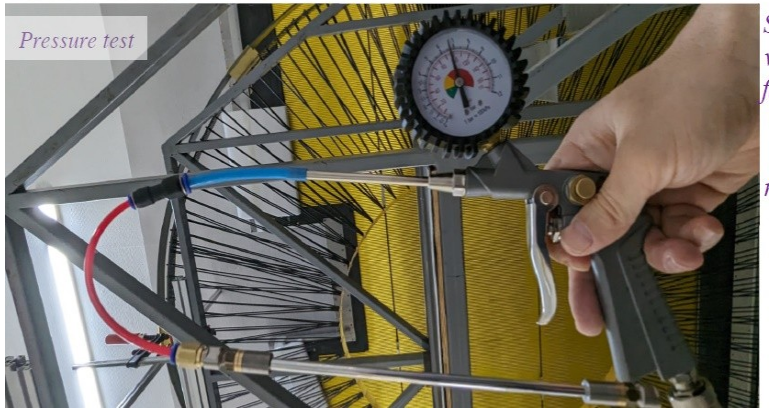
Welded seam

STRAW PRODUCTION WITH FINAL FILM



Ultrasonic welding of a straw with the Fraunhofer film

Production of 5m straws with Fraunhofer film and ultrasonic welding



Pressure test

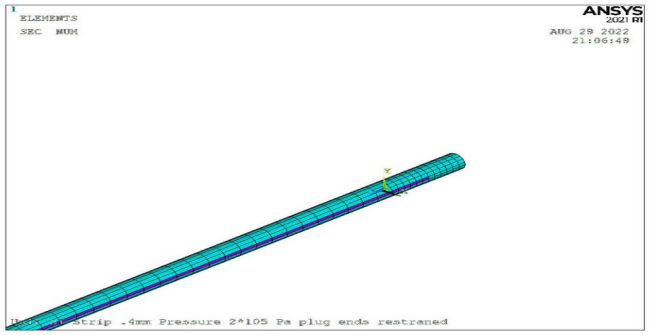
Straws produced with Fraunhofer film passed high-pressure test up to 7 bar relative pressure

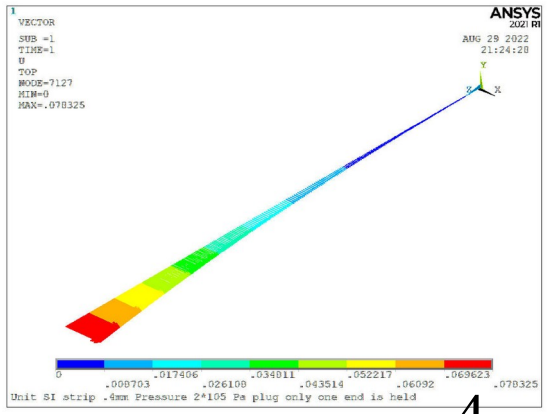
5m STT straws with Fraunhofer film

Straw tubes with 5 mm diameter are built from the film using ultrasonic welding.

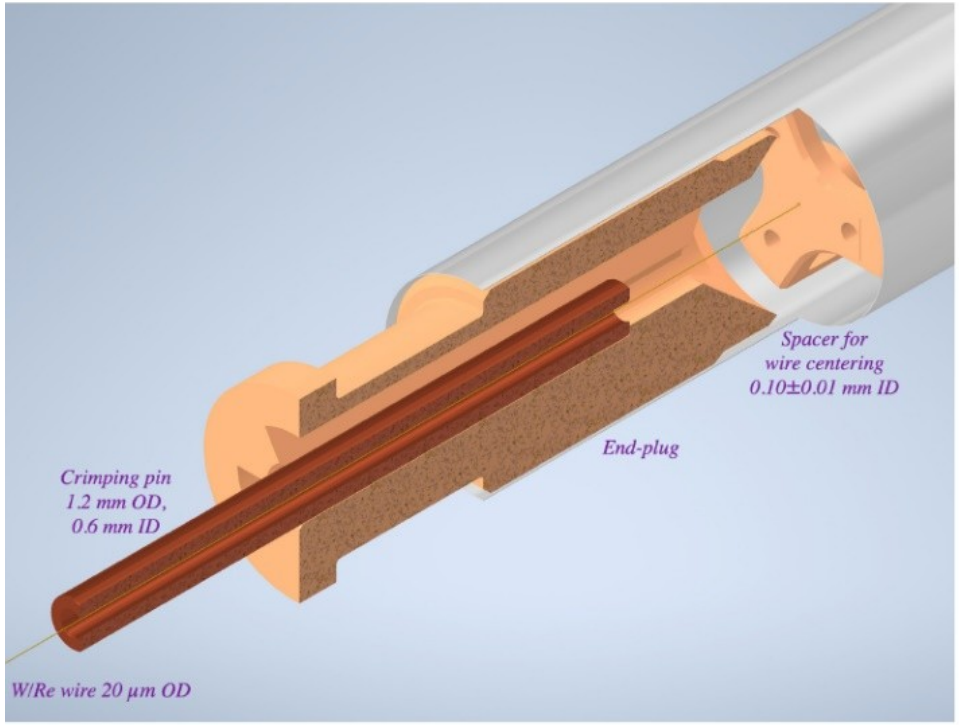
Visual and overpressure checks are performed to accept the straws.

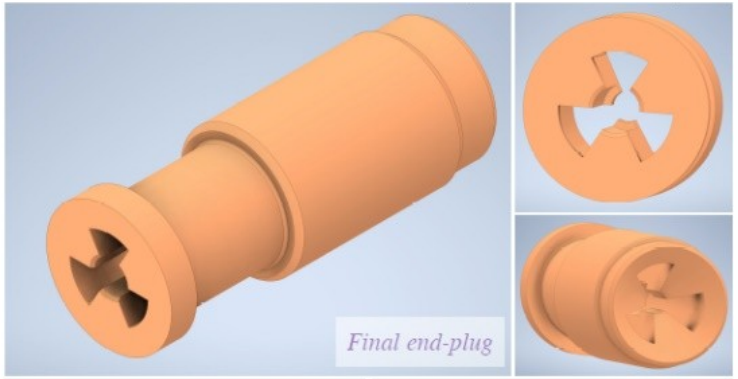
A detailed mechanical analysis has been performed. Results have been validated by the experimental tests.

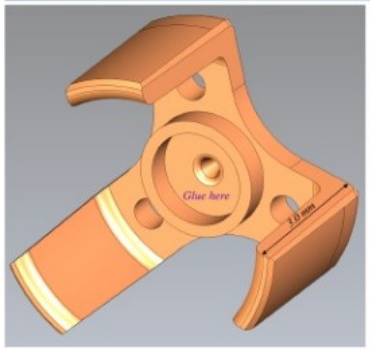


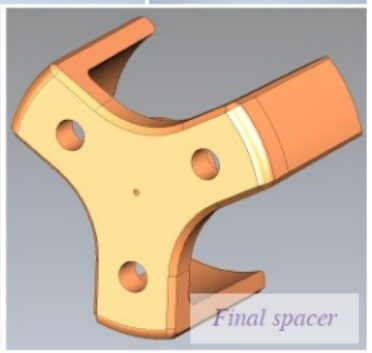


Components of straw tube tracker: wire, spacers and endplugs.









A gold tungsten rhenium of 20 µm is inserted in the straw and stretched using the crimping pins inserted in the end plugs.

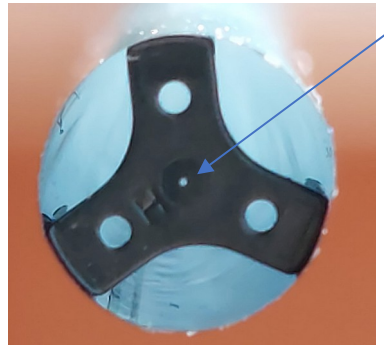
The wire is kept in position by some spacers.

- *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.*

End plugs are glued to the straw tube.

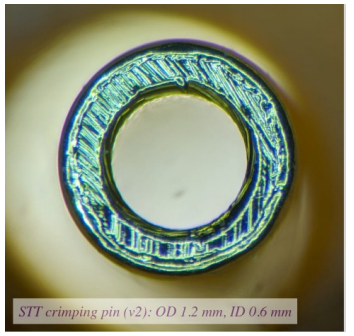
Spacers and end plugs are made in polycarbonate using injection molding ensuring very smooth surface (roughness 0.25 µm) at low cost for a large production.

100 µm hole



Components of straw tube tracker: crimping pins

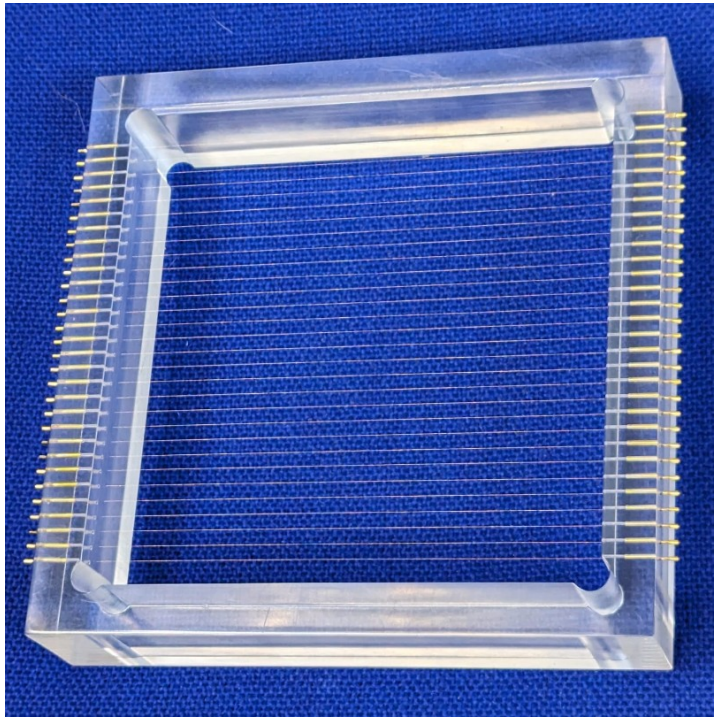
The wire is stretched and crimped to the gold plated cooper pins.

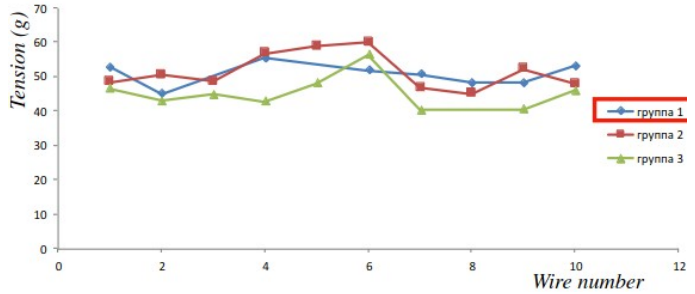


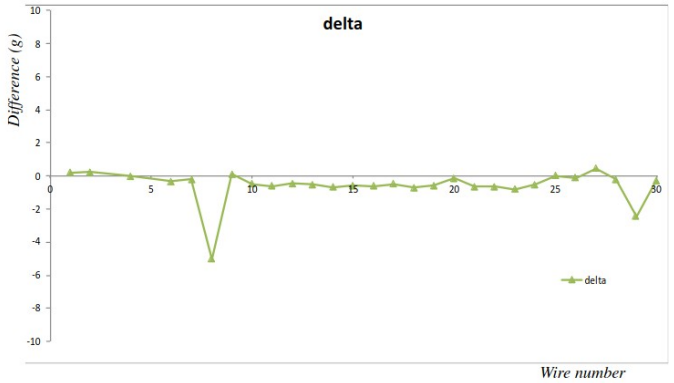
Use 20 μm wire from LUMA and crimping tool from ATLAS TRT 2

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

Crimping test: variation of nominal tension (50g) after 2 weeks







Components of straw tube tracker: supporting structure requirements

The alignment and stability of the straw tube tracker is ensured by a rigid frame where the straws are glued.

Straws will be filled with a mixture of argon/CO_2 (70/30) and operated at 2 bar absolute pressure.

During the assembly straw tubes will be pressurized at 3 bar of absolute pressure to be safely handled and glued to the supporting structure.

The key requirements for this structure are:

- Straw alignment accuracy: 100 μm;
- withstand a gas pressure of 2 bar with an appropriate safety factor;
- gas tightness (better than straws);
- No straw compression during construction, handling, and transportation;
- ensure minimum required tension on the wires;
- Fit in calorimeter inner volume (including the external mechanical structure);
- Ensure an average tracker density (without targets) of 0.005 +/- 5% kg/m^3

Components of straw tube tracker: carbon fiber frame

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 v	55	%
Young's Modulus E_1	218	GPa
Young's Modulus E_2	7.23	GPa
Poisson's ratio v_{12}	0,3	
Poisson's ratio v_{23}	0.35	
Shear Modulus G_{12}	4.09	GPa

Physical properties of the lamina

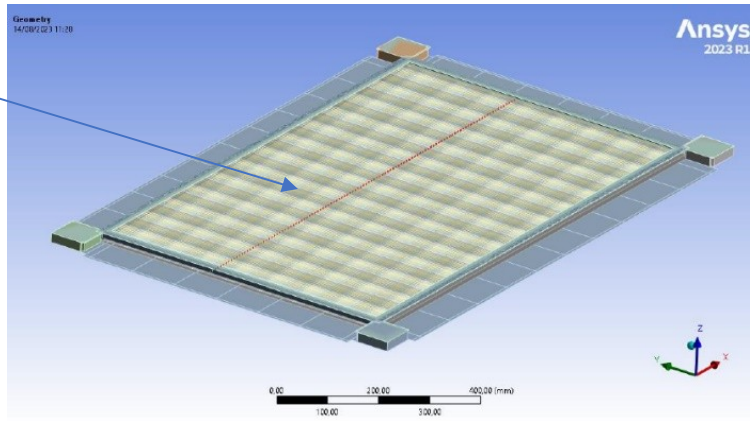
Parameter	Value	Unit
X_{et}	0.784	%
Y_{et}	0.357	%
X_{ec}	0.401	%
Y_{ec}	2.614	%
S_e	1.687	%

First failure strains

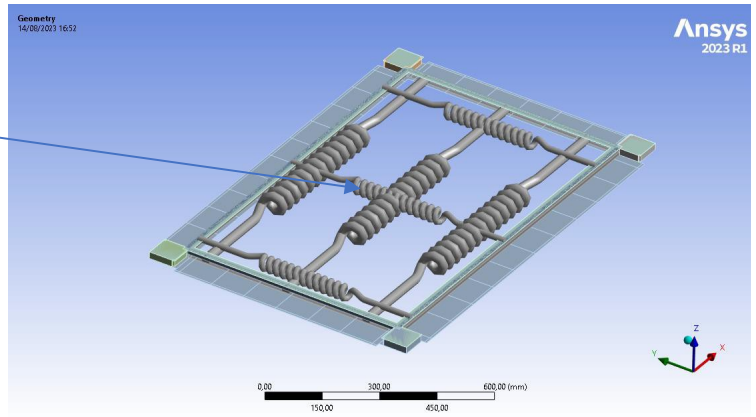
The frame structure is made by 18 plies 0/90.

Internal beam elements

Pre-stressed



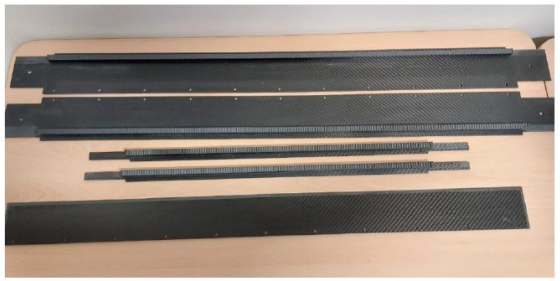
Internal spring elements pre-stressed



Mechanical simulations and the construction of the first prototype have validated the design

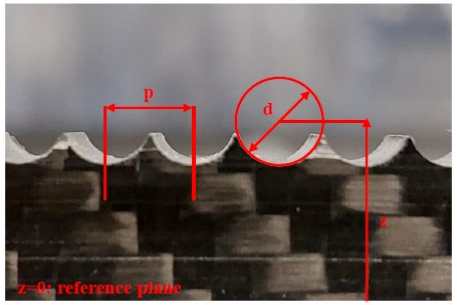
Components of straw tube tracker: carbon fiber frame characterization

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



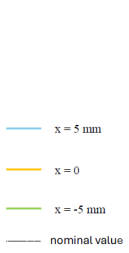
x = 5 mm

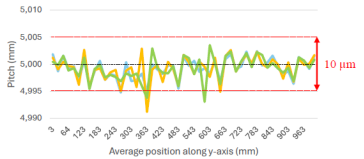
x = 0

x = -5 mm

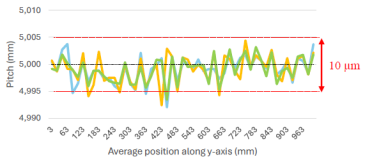
RMS measurement results:
- pitch: < CMM resolution
- diameter: 20 µm
- height: 30µm

Measurements: long piece pitch (1/2)



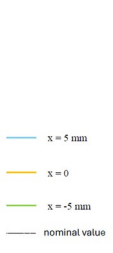


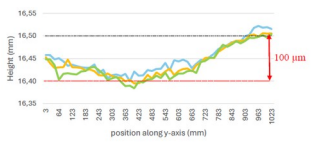
1° slab	mean	RMS
1	4,999	0,002
2	4,999	0,002
3	4,999	0,002



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

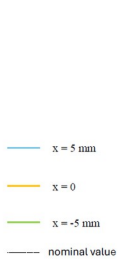
Measurements: long piece height (1/2)



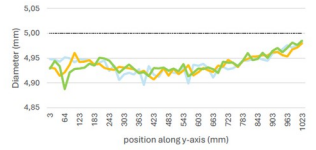


1° slab	mean	RMS
1	16,449	0,033
2	16,440	0,034
3	16,435	0,035

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)

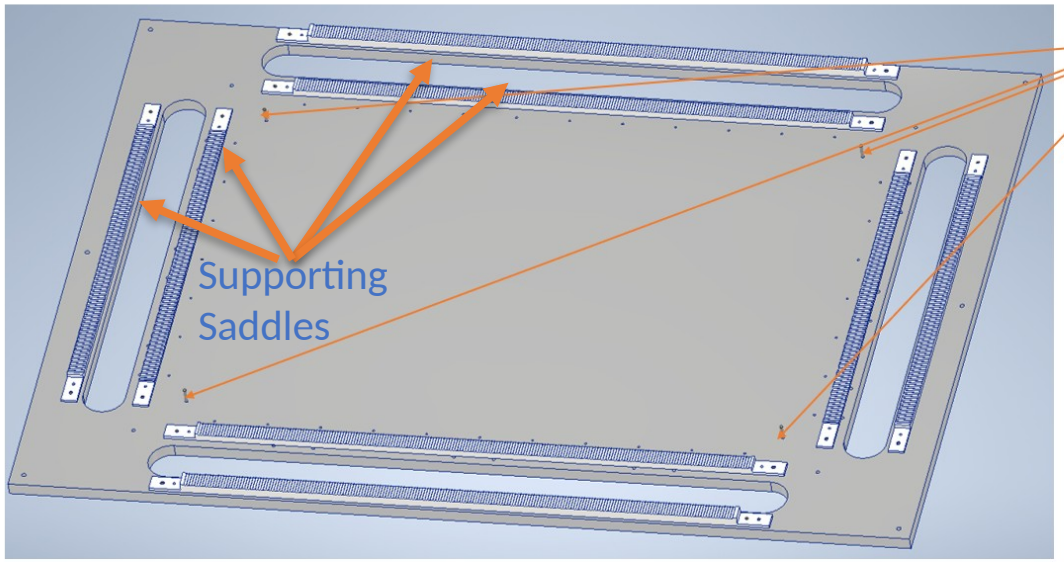


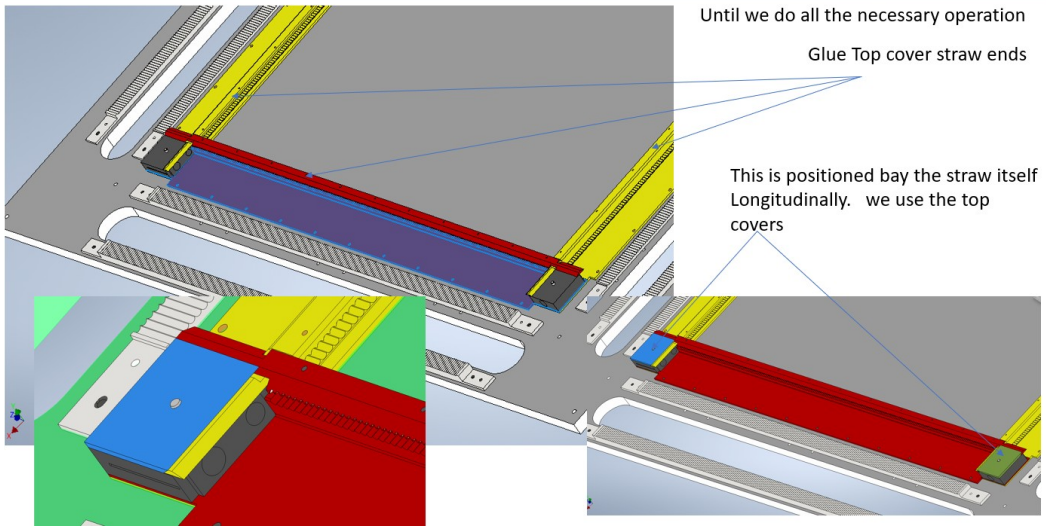
1° slab	mean	RMS
1	4,938	0,019
2	4,937	0,017
3	4,938	0,019

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

Components of straw tube tracker: the mounting table

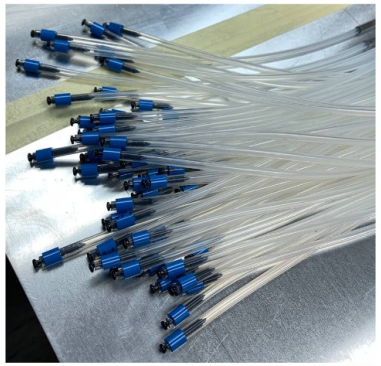
A mounting table has been used to accurately align the carbon fiber frame parts and the straws for the construction of the 120x80 cm prototypes.

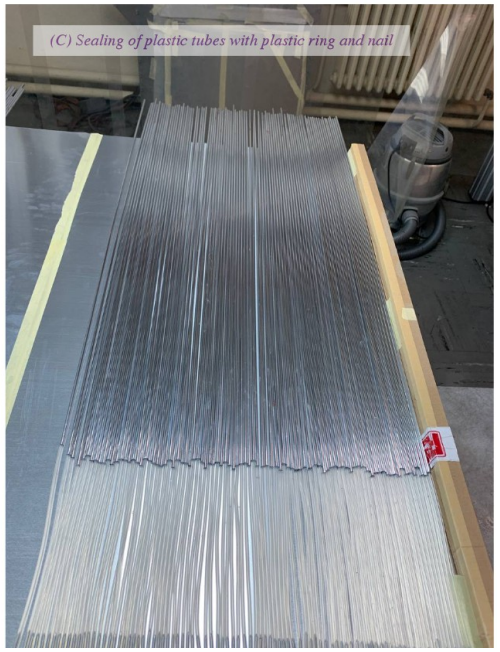


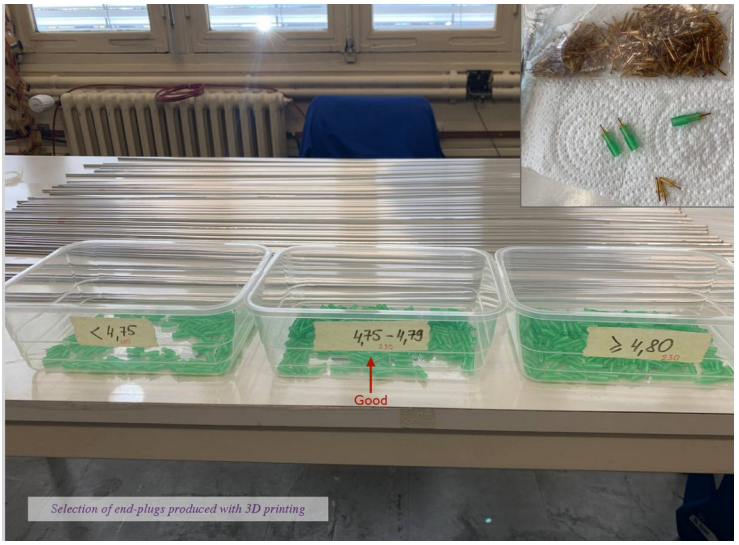


The table can be easily moved, together with the straw module, thanks to an ad-hoc rotating supporting structure

80x120 cm Cern prototype: straw tube preparation





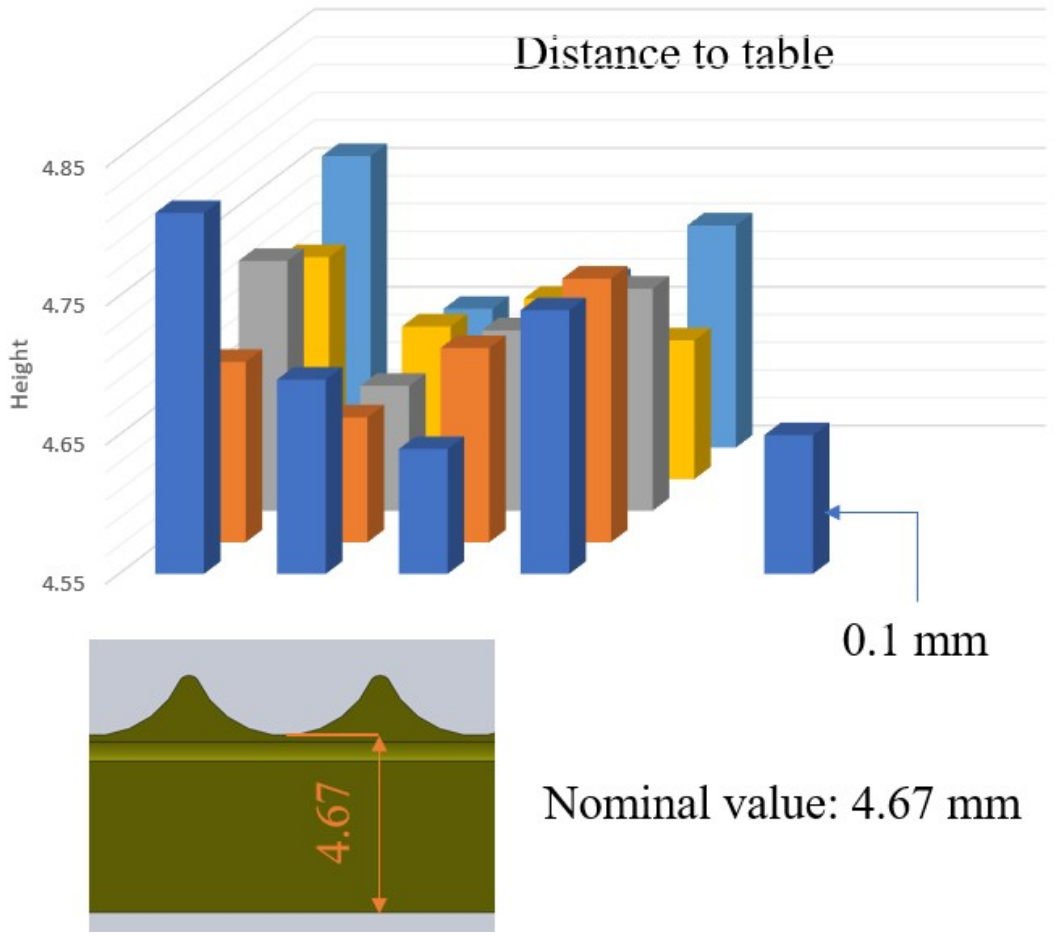


Sealing individual straws with temporary solid plug and flexible plastic tube to be connected to pressurized Ar gas

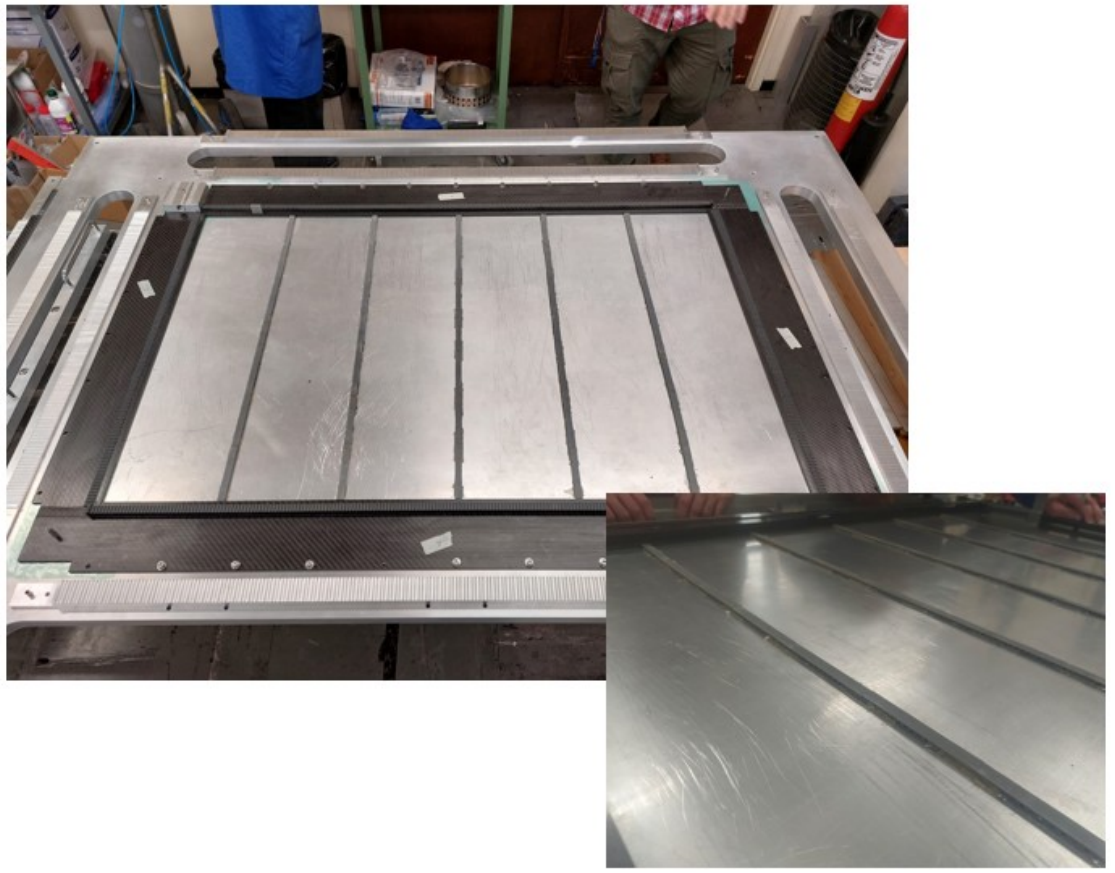
Gluing of plugs and tubes in vertical position within rack

80x120 cm Cern prototype: planarity checks and fixes

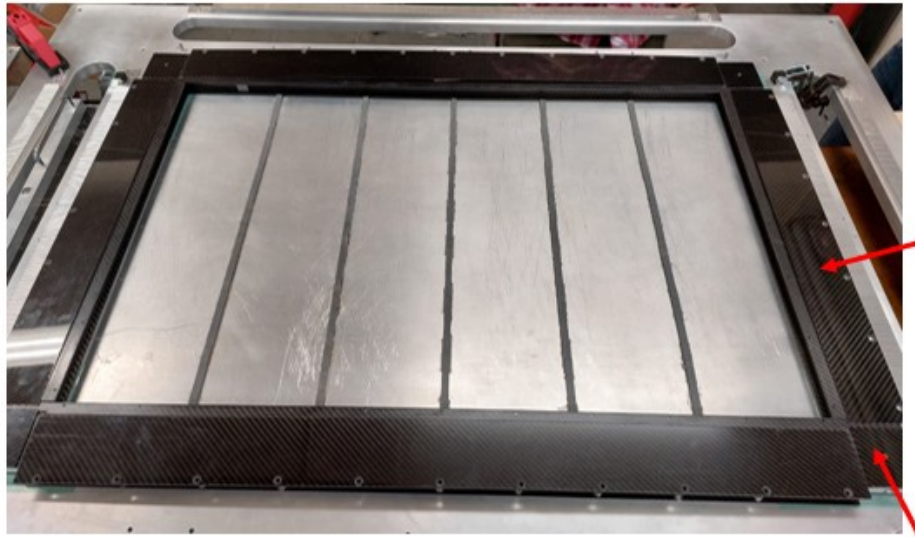
Problem: gravitational sag of straw tubes
Previous solution (aluminum spacers) didn't guarantee adequate accuracy

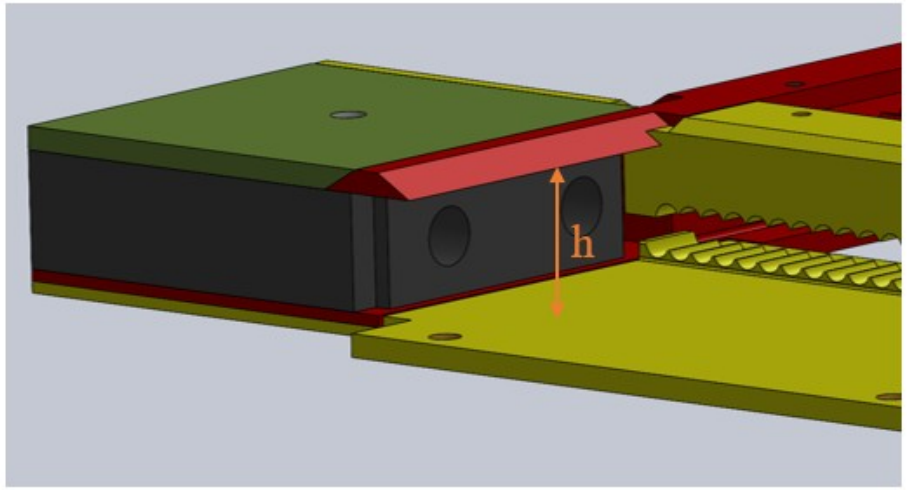


Nominal value: 4.67 mm



80x120 cm Cern prototype: calibration of top cover position

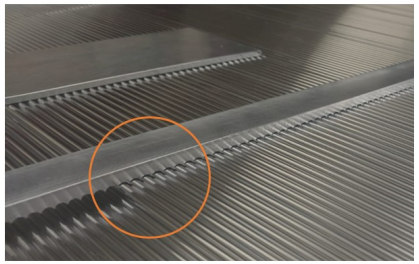




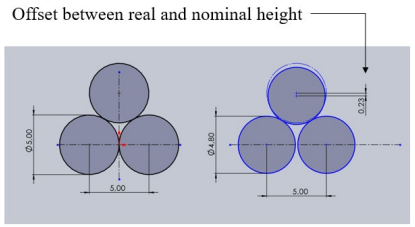
We need to check:

- height h for sealing
- position of the straw tubes

Lessons learnt (1/2)

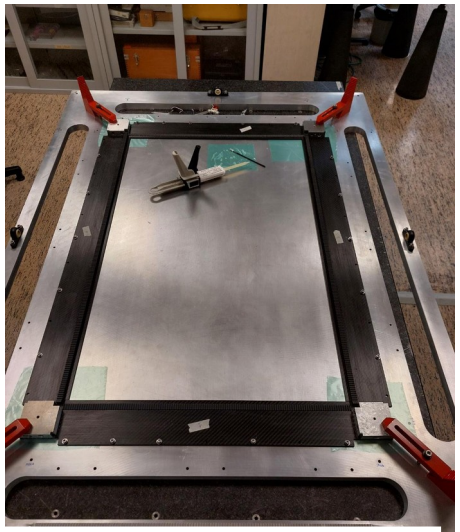


gap

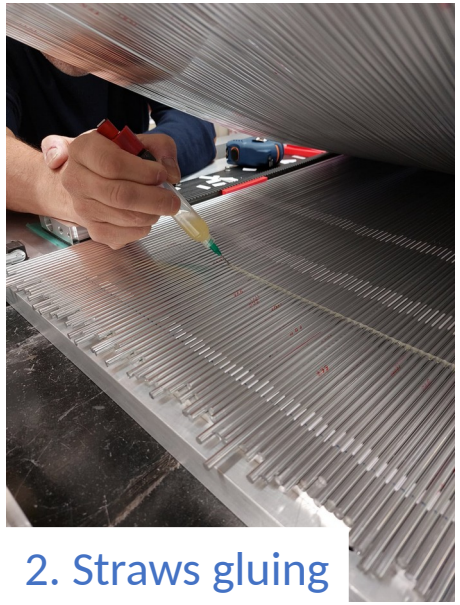


influence of diameter value on center height
(pitch value is given by the frame)

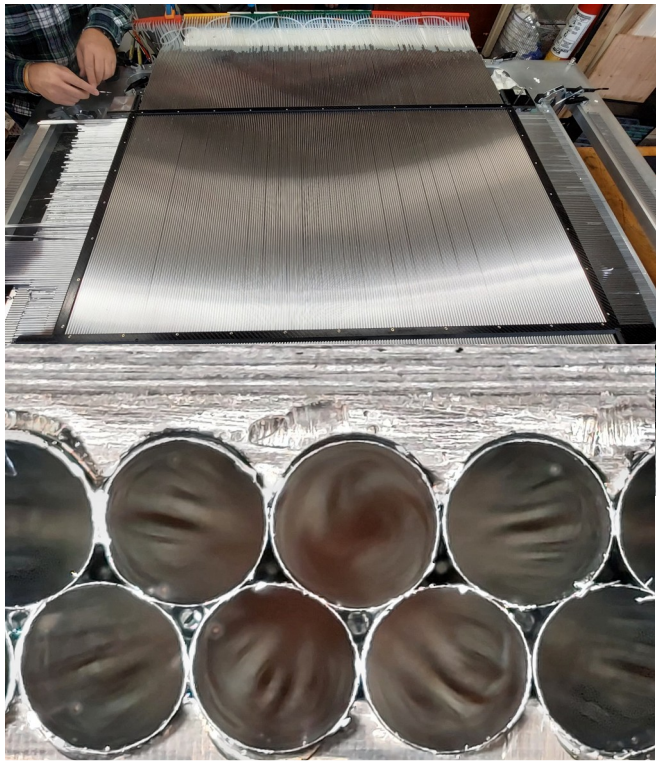
80x120 cm Cern prototype: assembly procedure



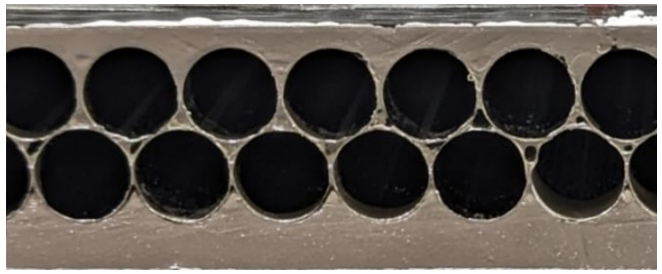
1. Frame parts gluing



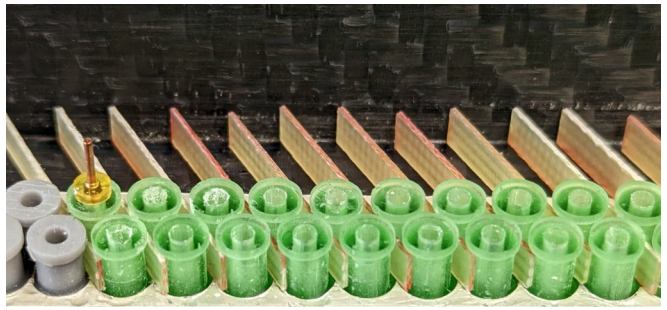
2. Straws gluing



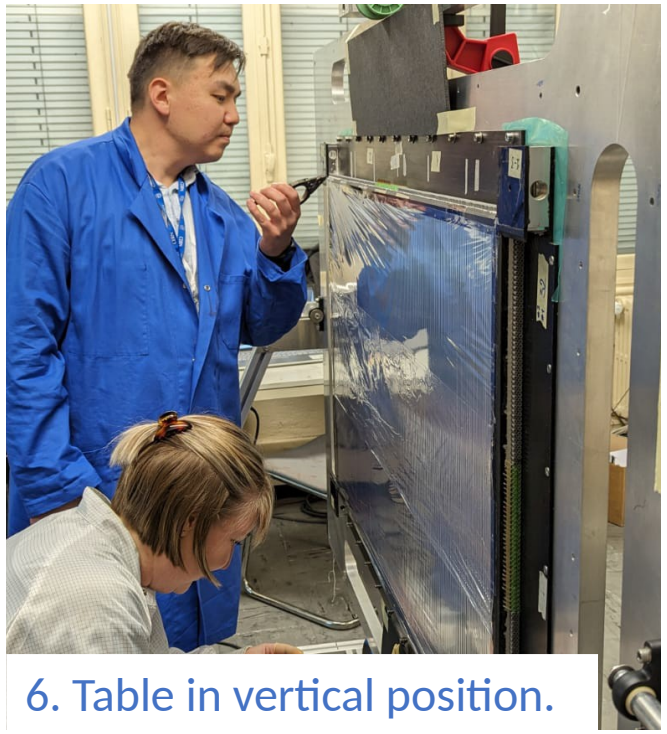
3. Straw cutting to frame end



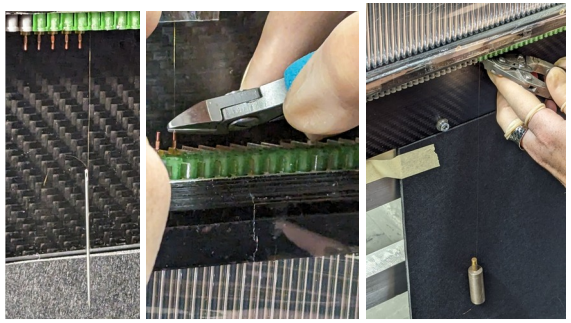
4. Conductive paint covering



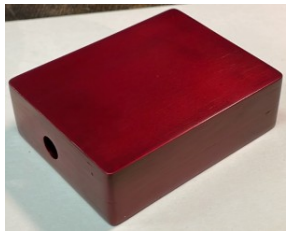
5. End plugs insertion and temporary blocking



6. Table in vertical position.

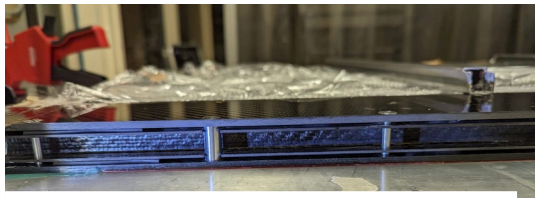


7. Wiring and crimping (T=50g)



8. Resistance and Tension check

9. Endplugs sealing



10. Final frame closing

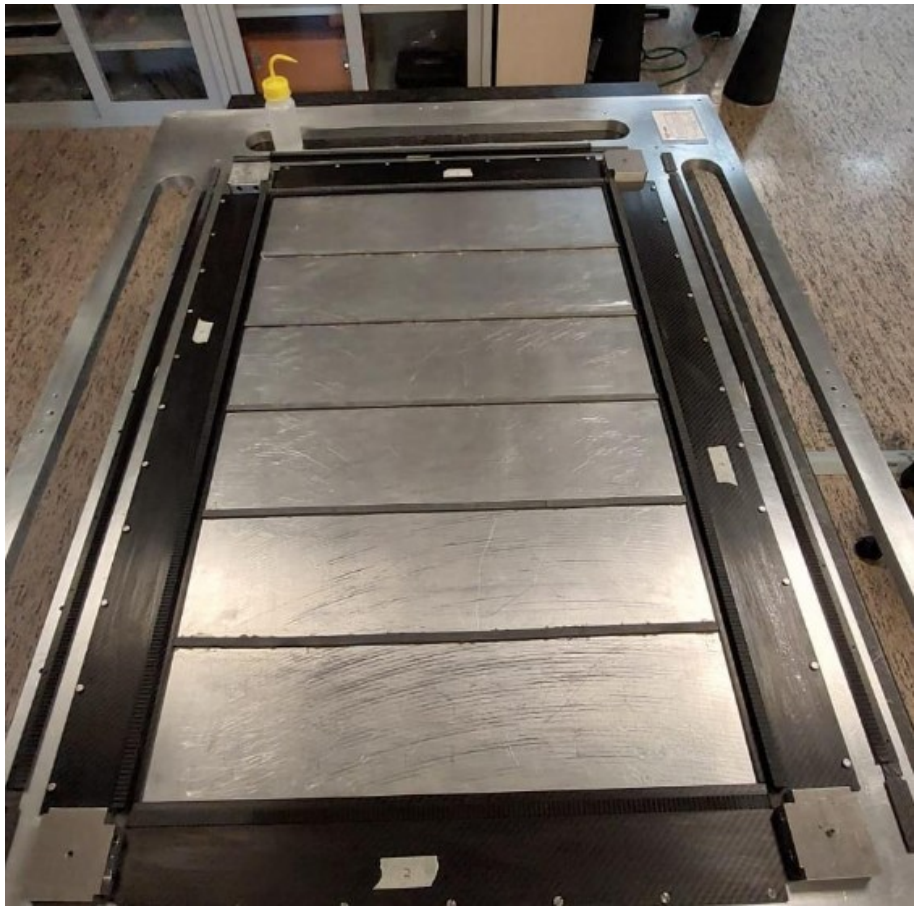
80x120 cm Cern prototype: lessons learned

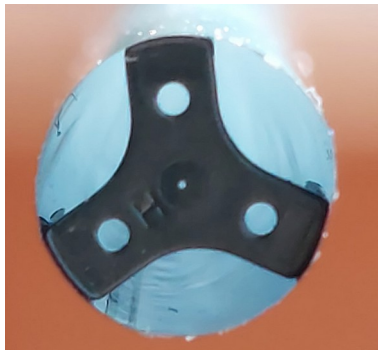
First prototype at CERN

- Straw tubes, produced by GTU, arrived to Cern in August
- A month has been needed to prepare the straw tubes (valve tests, connection to collector, pressure tests).
- The month of September has not be used (waiting for Carbon Fiber frame)
- In October we have preformed two dry runs fixing the alignment of the mounting table and the straw layers, developing additional mounting tools.
- Gluing and wiring has been done in November. Involving 5 people for gluing and 2 for wiring. (only 64 (XX)+64 (YY) straws have been wired).
- We can estimate that, **having all material ready and tested** (and excluding the need to develop new mounting tools), **4 people** continuously working for **4 weeks** can assembly and test **a module of this size** (functional tests and burn in not included)

80x120 cm Pisa prototype: goals

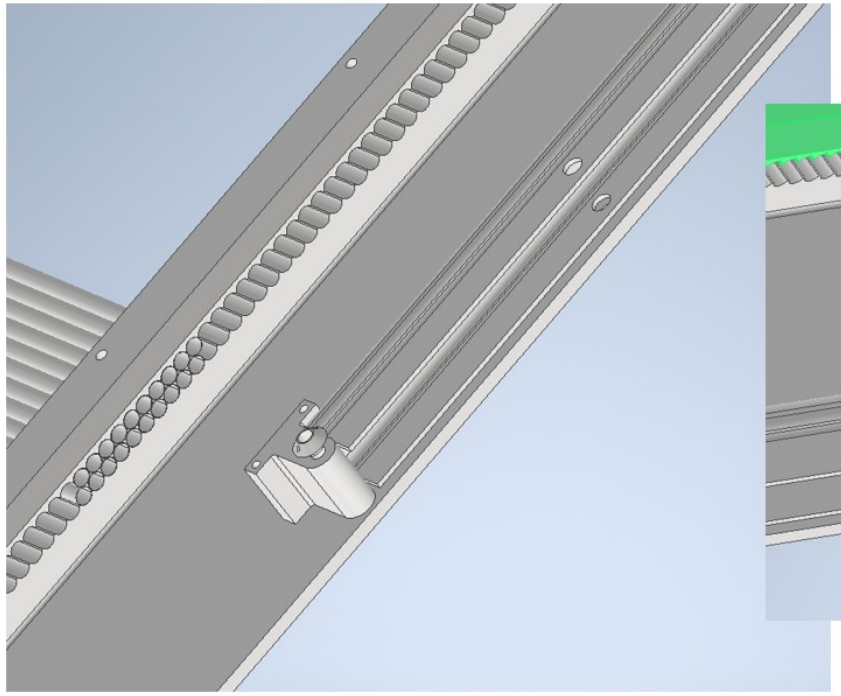
A new 80x120 cm prototype will be assembled in Pisa in September to test the final endplugs, pins and spacers. Straws built using the new Fraunhofer film will be used.





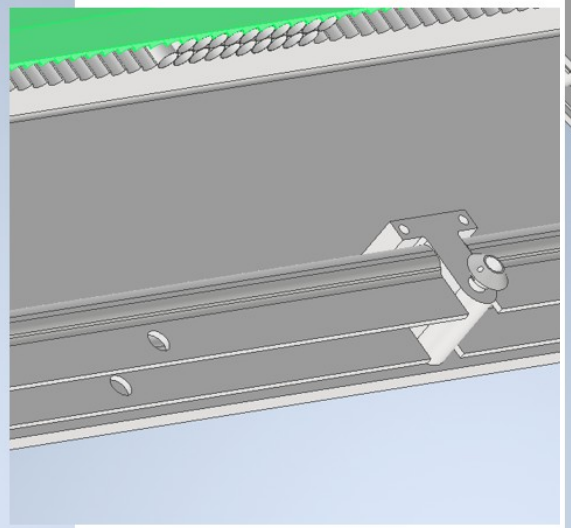
Full scale module studies

The full scale prototype (3800X3200mm) is the final step for the straw tracker design validation. This can allow us to estimate in detail the required time and to face and solve all the technical issues. However this prototype needs an investment in term of man power and tooling much larger than the previous prototype. We started to extend the design to a full scale module and to study the integration of the straw layers with radiator and graphite layers.

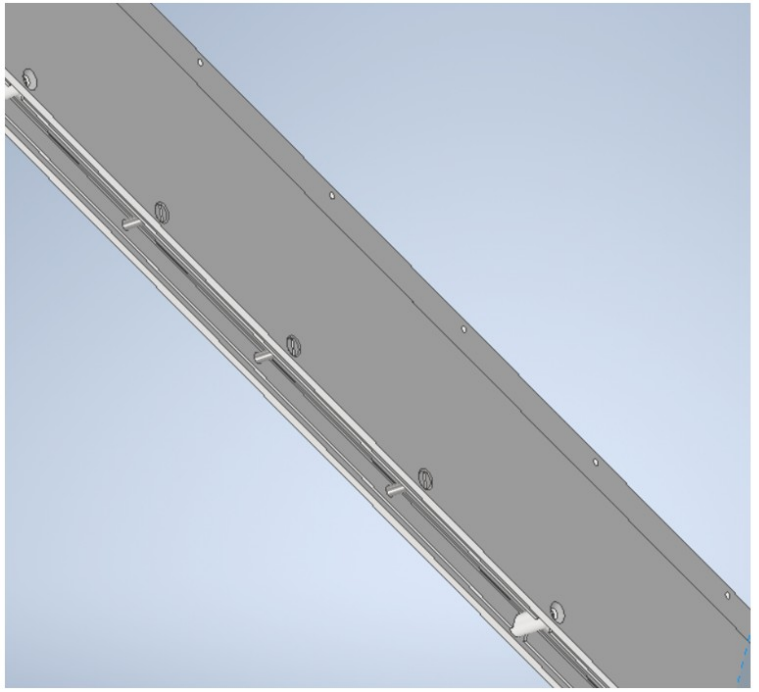


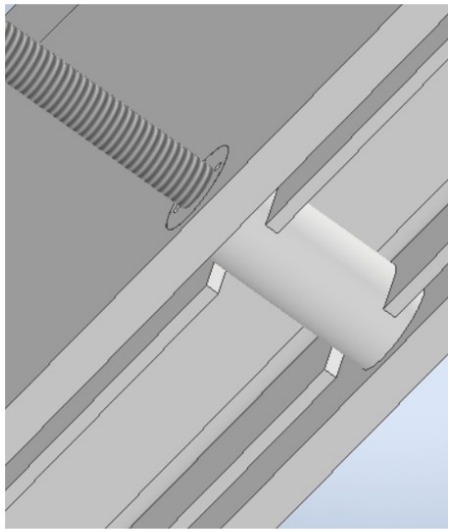
Central support for omega made in two parts to reduce the size.

Module Design 3800X3200mm



Improvement of Carbon frame design

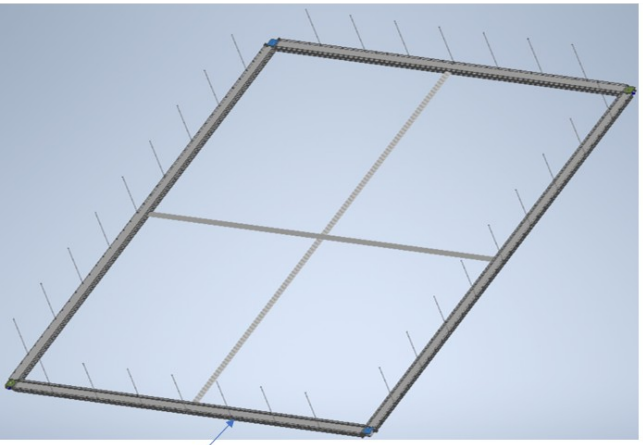




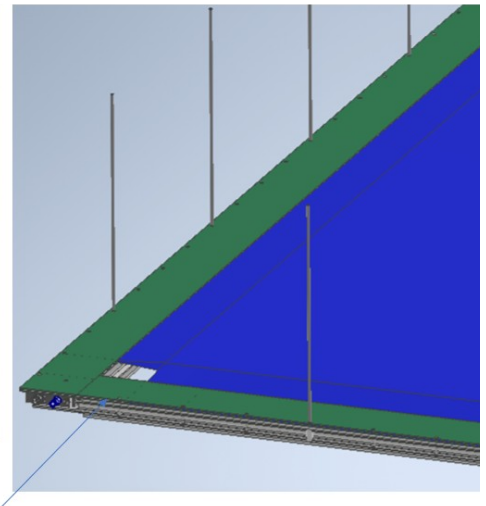
Thread rod conection

Target integration and supermodules

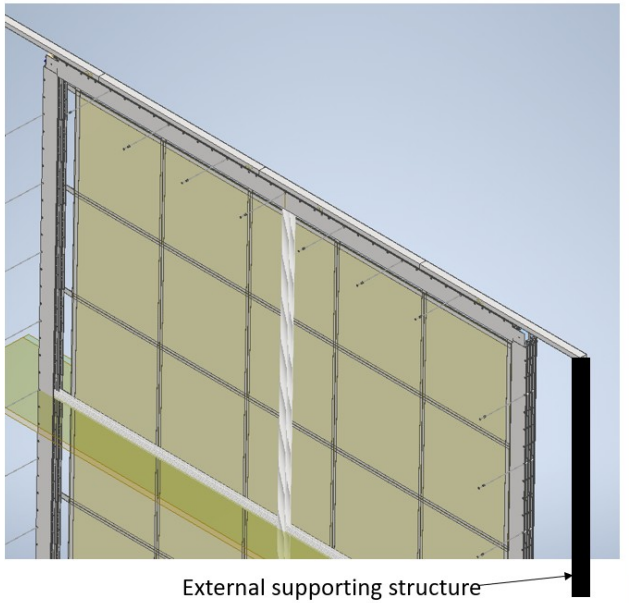
The assembly of the module is made in vertical position supporting the each straw panel from an external frame structure.



Straw frame with thread rod

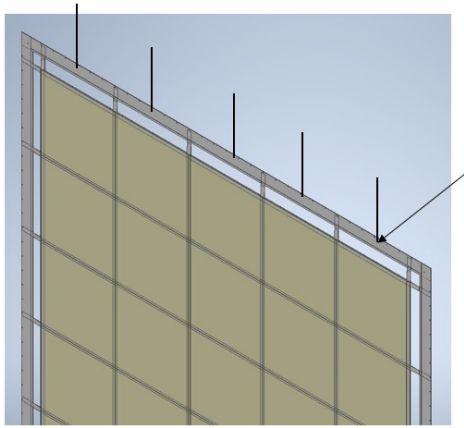


Radiator

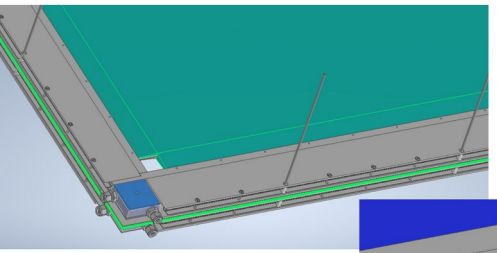


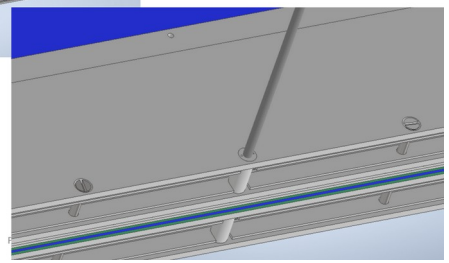
External supporting structure

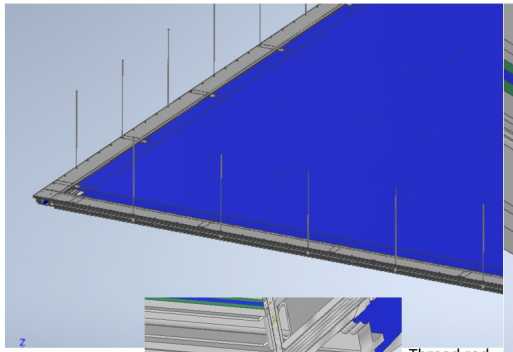
- The mounting sequence can occur using a cart to bring the panels in position.
- Proper clearance must be address in the design to allow the mounting.

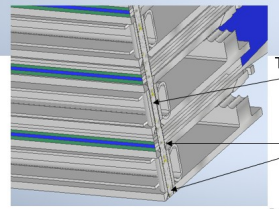


Tread insert for holding with strip the panel in vertical position.



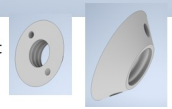


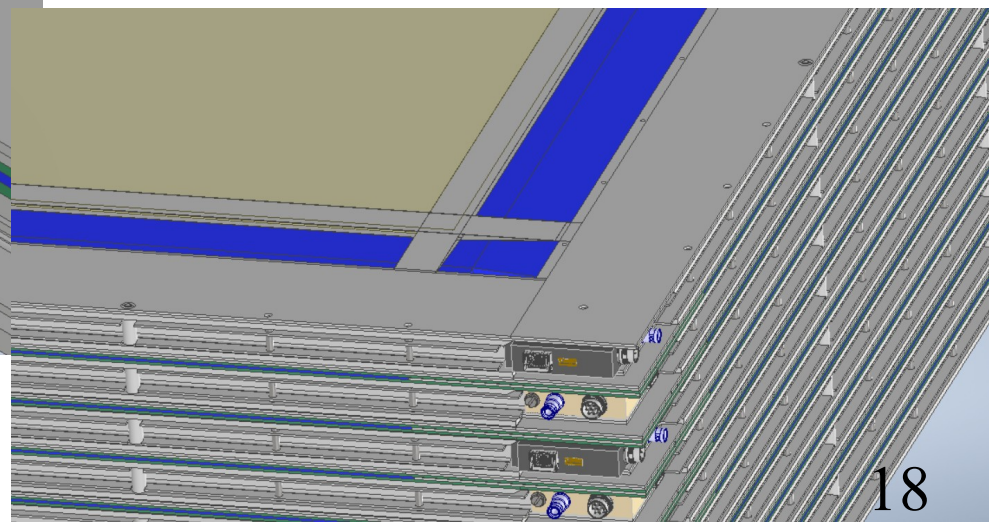




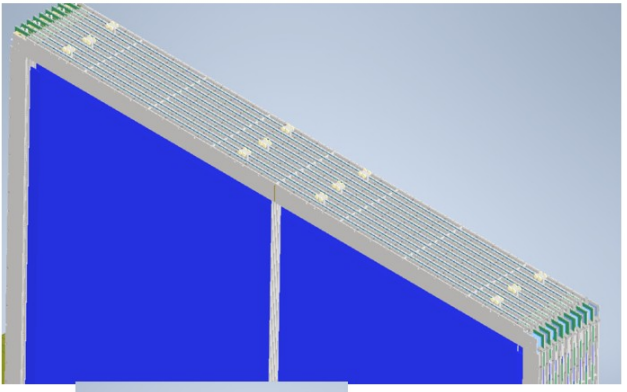
Thread rod

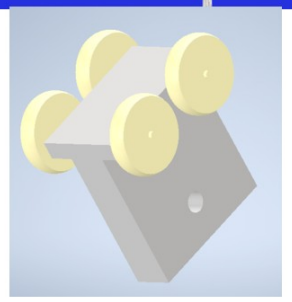
Special Nut

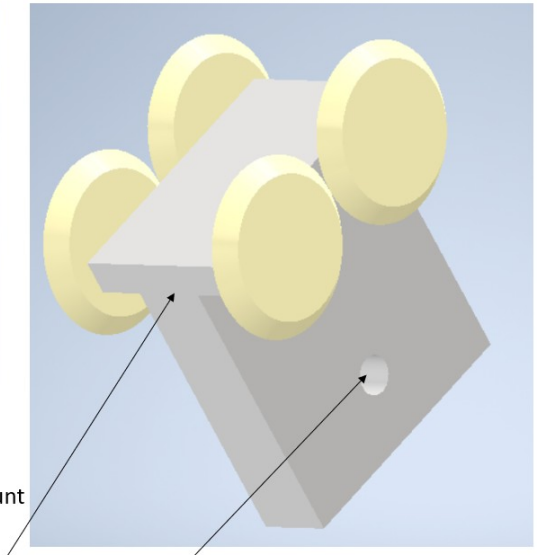




External mechanical support

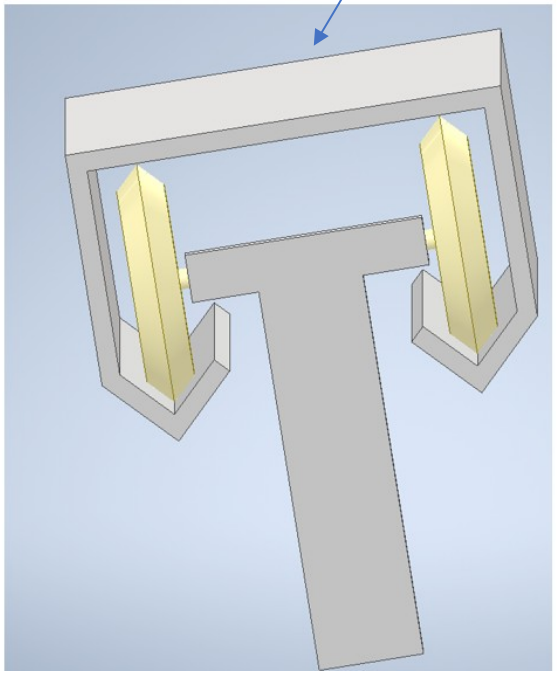




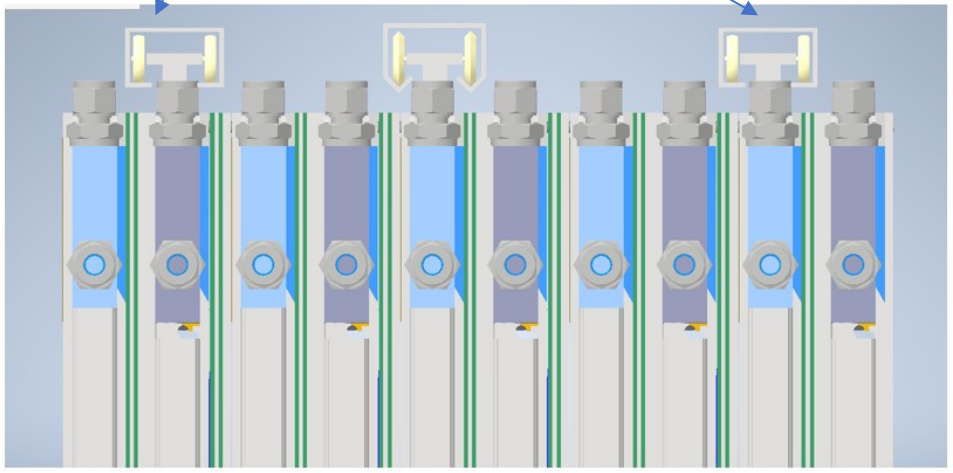


An external frame will hold the super module in vertical position while mounting, transporting, inserting, and extracting it inside SAND. More work needed (lack of man power) to verify with FEA that the deformation is compatible with our requirements.

Guiding rolling



Simple elastic support self align



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

Summary

- We consider the construction of the second 80x120cm prototype in Pisa as an important step to test the final design: various “final” components (end plugs, spacer, crimping pins, straws) will be used and the assembly procedure will be further developed.
-
- The new prototype could also be used to validate the gas flow and cooling and a preliminary version of the readout electronics.

- The full scale design of a super module requires more engineering work. An important effort is required to finalize a design that integrates all the components and the mechanical interface with the rest of the SAND detector. Additional work and man power is needed to design the tools necessary for constructing, handling and mounting a full scale module.

- The construction of a full scale prototype would be crucial to validate the proposed design and the assembly procedure of the full detector.

BACKUP

Tools for assembling a 4 m module

The mounting table, glue dispenser and wiring tools, already used to build the COMPASS straw tracker, are available


Wiring of straws in vertical position


Glue dispenser and robotic arm for automatic gluing


Assembly table for 4m modules