MDI Summary – Detectors integration in the interaction region

Fabrizio Palla - INFN Pisa

On behalf of

M. Boscolo, A. Ciarma, F. Fransesini, S. Lauciani, and L. Pellegrino – INFN Frascati

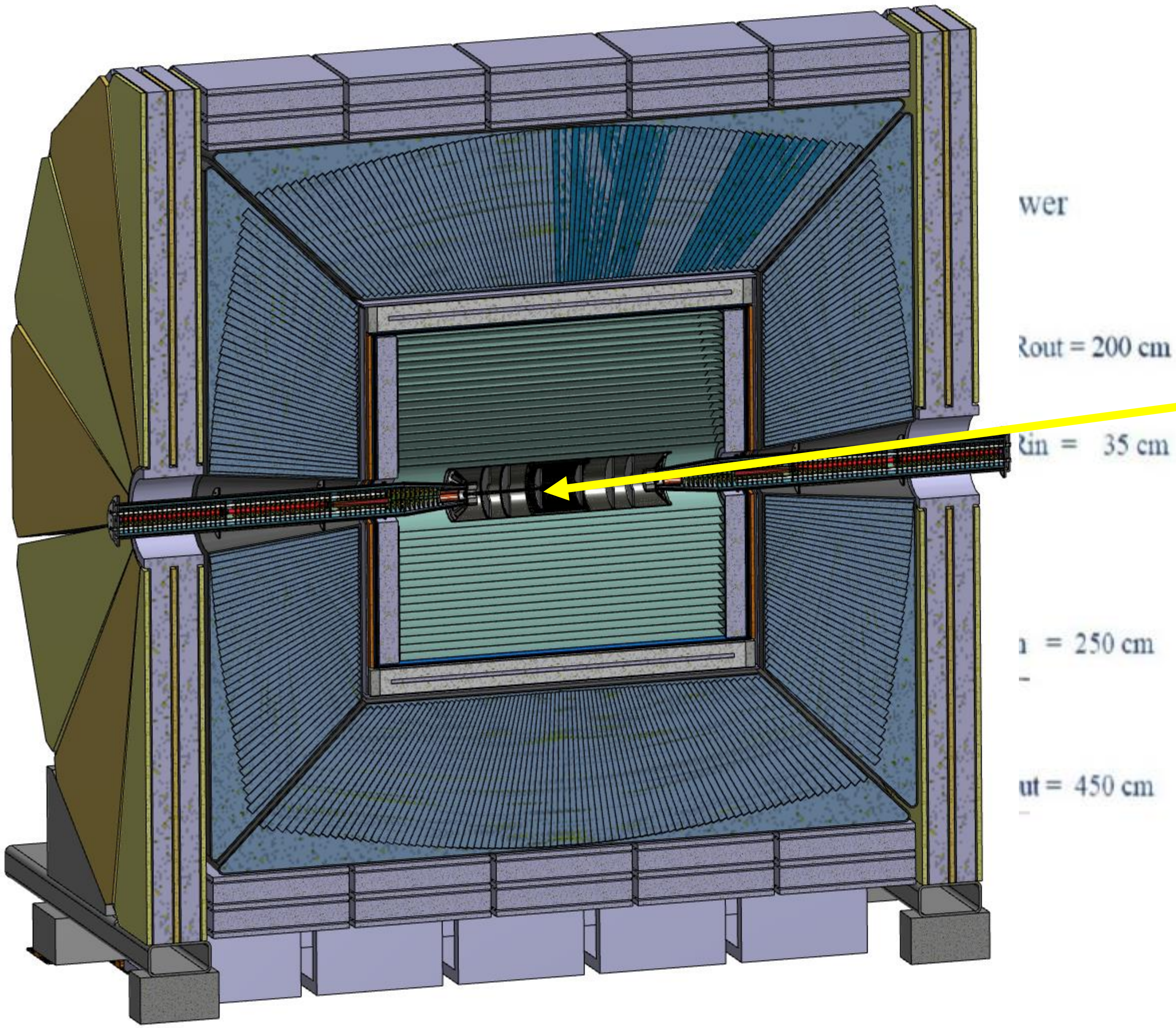
F. Bosi – INFN Pisa

M. Dams – NBI Copenhagen

Detector Concept Meeting

CERN – 7 November 2022

Istituto Nazionale di Fisica Nucleare



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- Central tracking device:
  - light Drift CHamber
- **Silicon detectors for precision measurements**
  - **vertex detector**
  - **silicon internal tracker**
  - **silicon wrapper**
- Thin solenoid with 2T field (according to MDI limits)
- Dual readout calorimeter
  - supplemented by a pre-shower detector
- Muon chambers in the solenoid return yoke

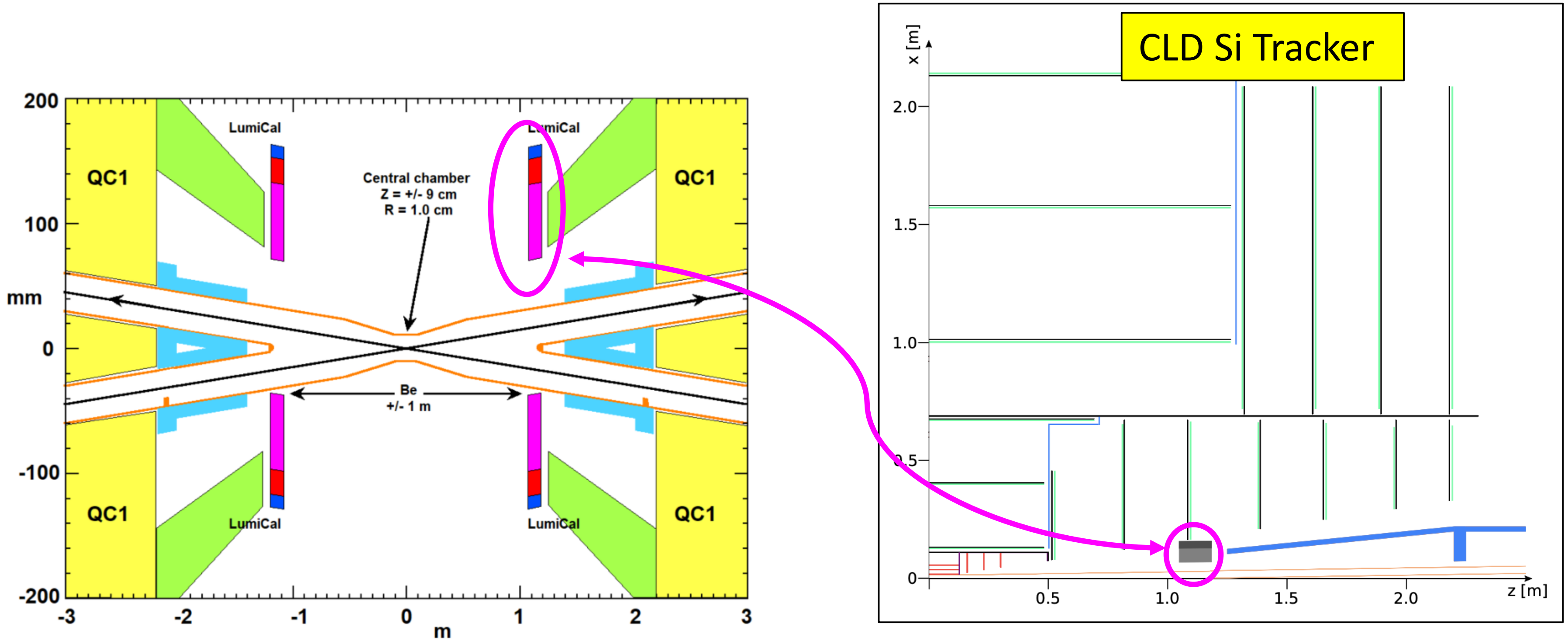
Requirements

- Interaction region detectors must be integrated with the beam pipe
  - The vertex detector innermost radius should profit of the reduced beam pipe diameter (2 cm) and should cover $|cos\theta| < 0.99$
  - Must not interefere with the Luminosity Calorimeter (clearance of ~120 mrad)
  - The mounting of the vertex and the outer tracker must be done inside the support tube
  - Minimize the radiation lengths

LumiCals

Challenge:

- MDI region is very busy, LumiCals pushed far inside detector volume



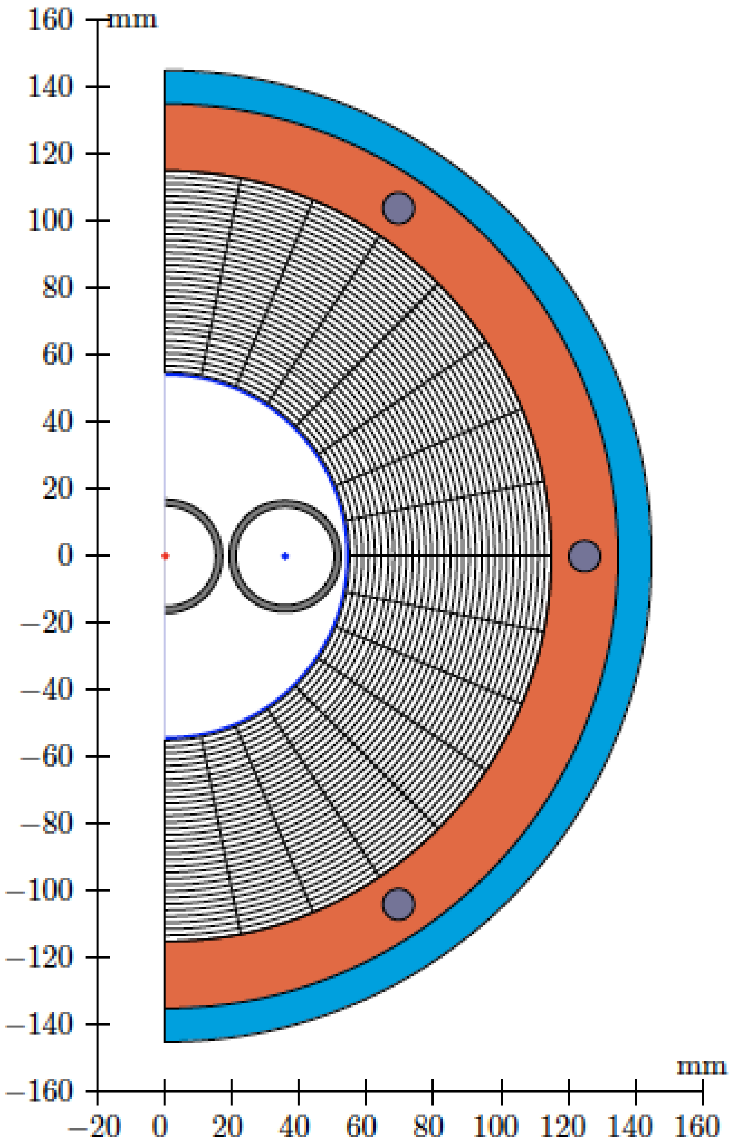
CDR LumiCal Design

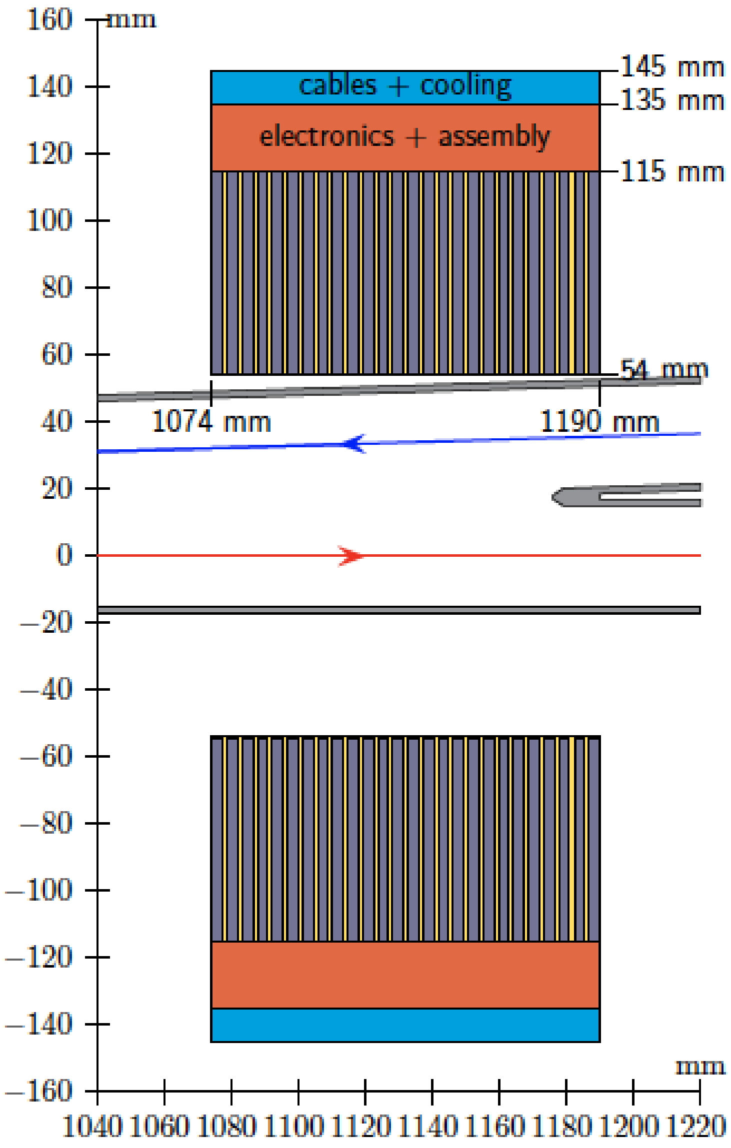
Design considerations:

- Need to control geometry to a precision of $\mathcal{O}$(1 μm)
  - Keep geometry as simple as at all possible

  Multilayer barrels where all layes have identical circular geometry

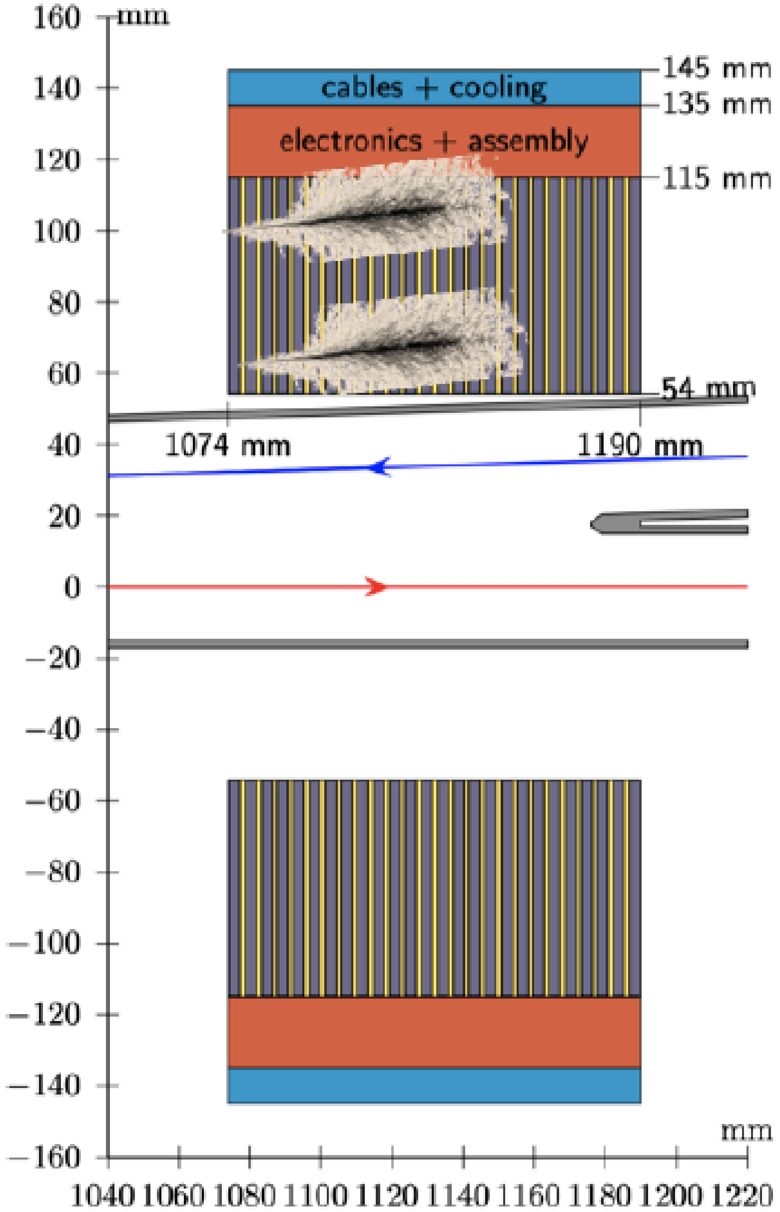
- 25 layer SiW sandwich
  - 3.5 mm W (1 X_0) + 1.0 mm gap for Si pads
- Physical dimensions
  - Sensitive region: r = 54-115 mm
  - Region for "services": 115-145 mm
  - Calorimeter face at x = 1074 mm
- Proposed segmentation
  - 32x32 pads/layer (1.9 x 10-22 mm² pads)
  - 25,600 channels per LumiCal
- Weight
  - About 65 kg per LumiCal



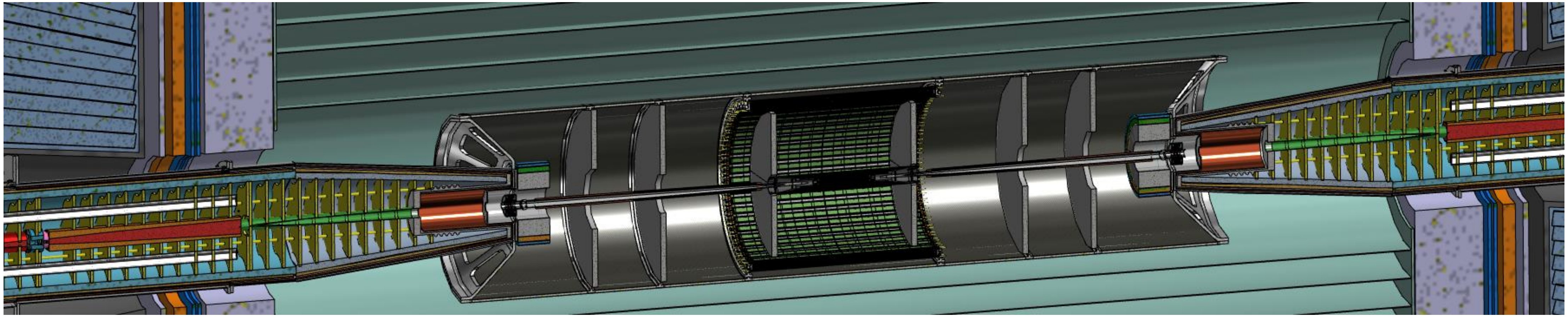


Acceptance and tolerances

- Effective Moliere radius of W-Si sandwich: **~15 mm**
- Stay 1 Moliere radius away from both inner radius and somewhat more at outer radius
    - To be optimised
- => **Wide acceptance:** **62 – 88 mrad**
- Slightly smaller **narrow acceptance**: **64 – 86 mrad**
    - **Bhabha cross section: 14 nb**
        - Compared to 30 nb multihadronic Z decays at peak
- Geometrical tolerances for shift in acceptance of 10^{-4}:
    - **Inner border: $\delta\Theta_{min}$ = ± 1.3 μrad ; δR_{min} = ± 1.5 μm**
    - **Outer border: $\delta\Theta_{max}$ = ± 3.0 μrad ; δR_{max} = ± 3.3 μm**
    - **Half distance between two calorimeters: δZ = ± 55 μm**



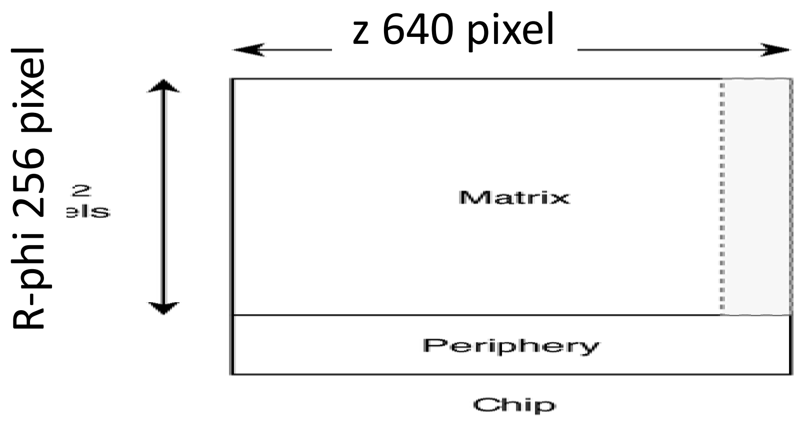
Vertex and Outer Trackers



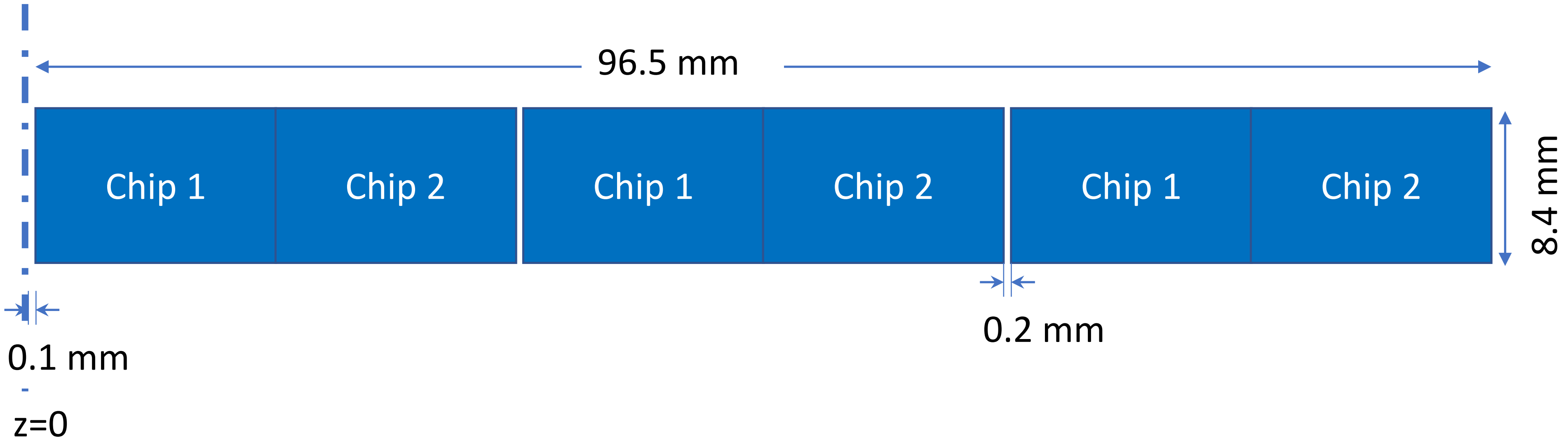
- Inside the same volume of the support tube that holds also the LumiCal
  - Vertex detector supported by the beam pipe
  - Outer Tracker (1 barrel and 6 disks) fixed to the support tube
- Minimal number of detector module variants
  - One module type only for the Vertex
  - One module type only for the Outer barrel and disks

Vertex detector modules

- Module concept inspired by ARCADIA INFN R&D
  - Pixel size 25x25 μm^2
  - Active area 640 pixel (16 mm) in z and 256 pixels (6.4 mm) in $r-\varphi$
  - Chip periphery plus an inactive zone: total 2 mm in $r-\varphi$
  - Chips are side-abuttable in z
  - Assume total thickness of 50 µm
- Composed of 2 pixelated parts: total of 8.4 mm $(r-\varphi)\ \times$ 32 mm (z)
  - Power budget not established yet: assume (conservatively) $100\ mW/cm^2$

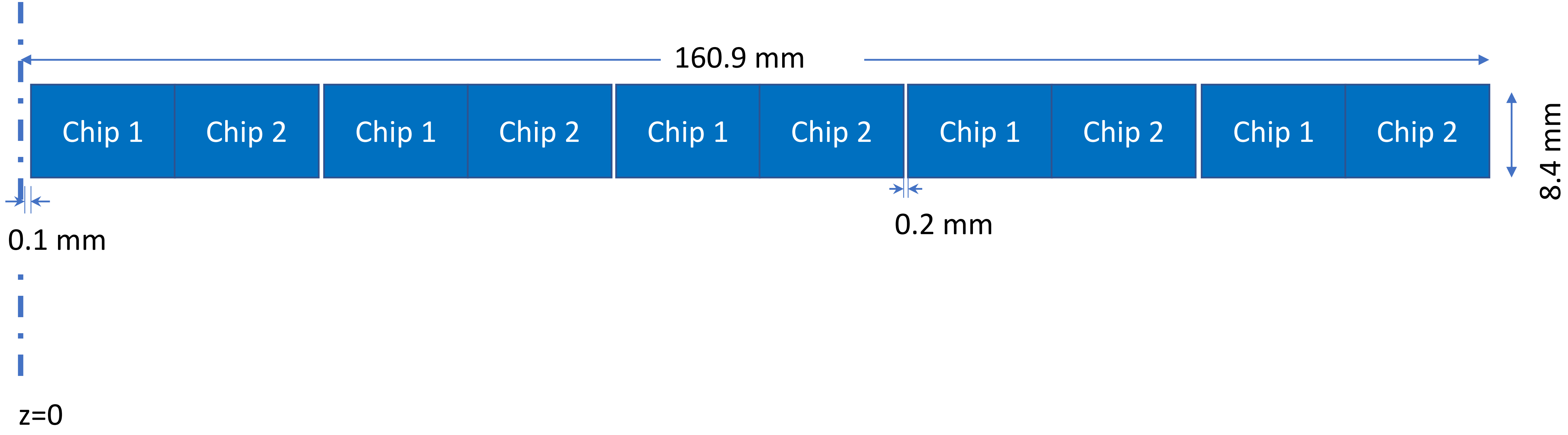


Half-ladder layout – layer 1



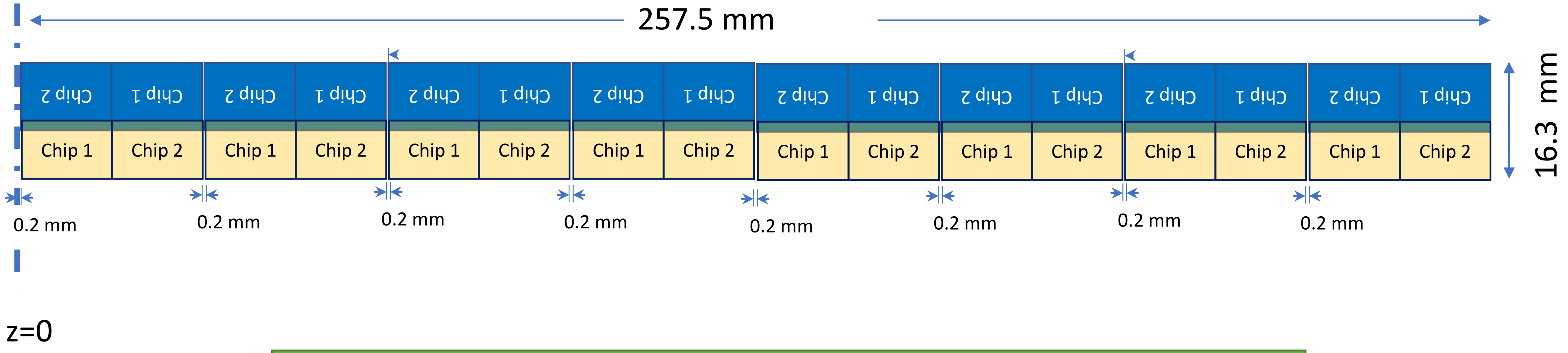
Layer 1 ladders are placed at 12 mm radius

Half-ladder layout – layer 2



Layer 2 ladders are placed at 20 mm radius

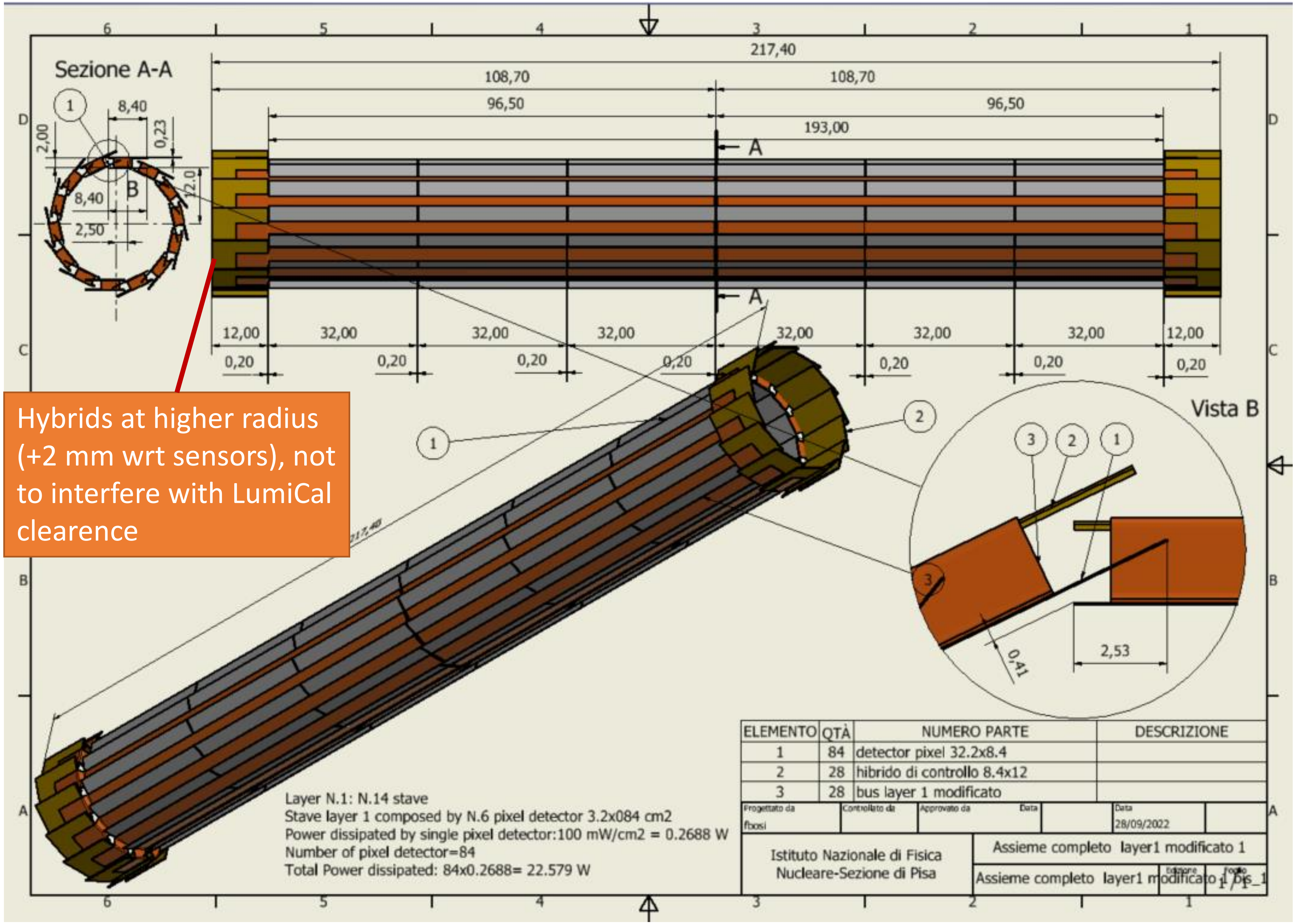
Half ladder layout – layer 3



Overlapping in $r - \varphi$:2 parallel ladders separated by 500 µm
- see engineering drawings later

Passive parts on the sides

Layer 3 ladders are placed at 32 mm radius



Hybrids at higher radius (+2 mm wrt sensors), not to interfere with LumiCal clearence

Layer 1

14 overlapping staves of 6 modules each

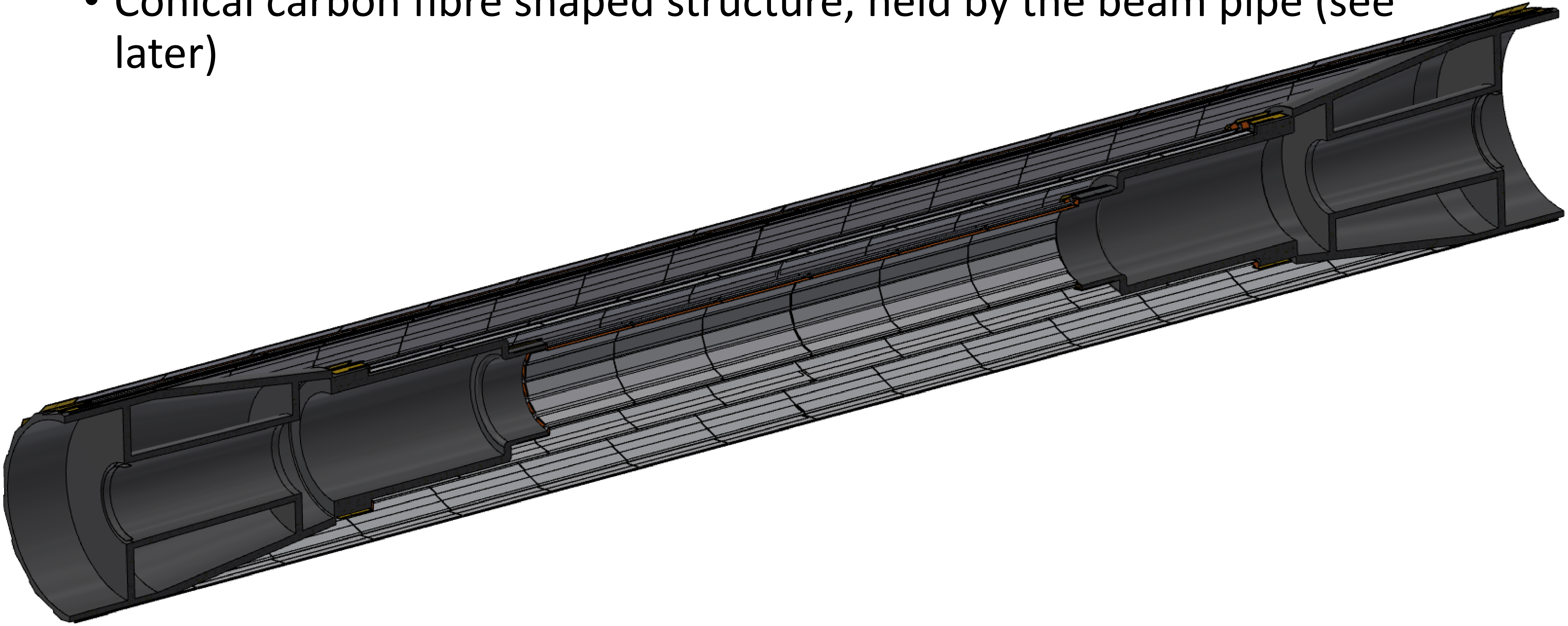
Power budget of the modules (only) ~23 W

Disclaimer

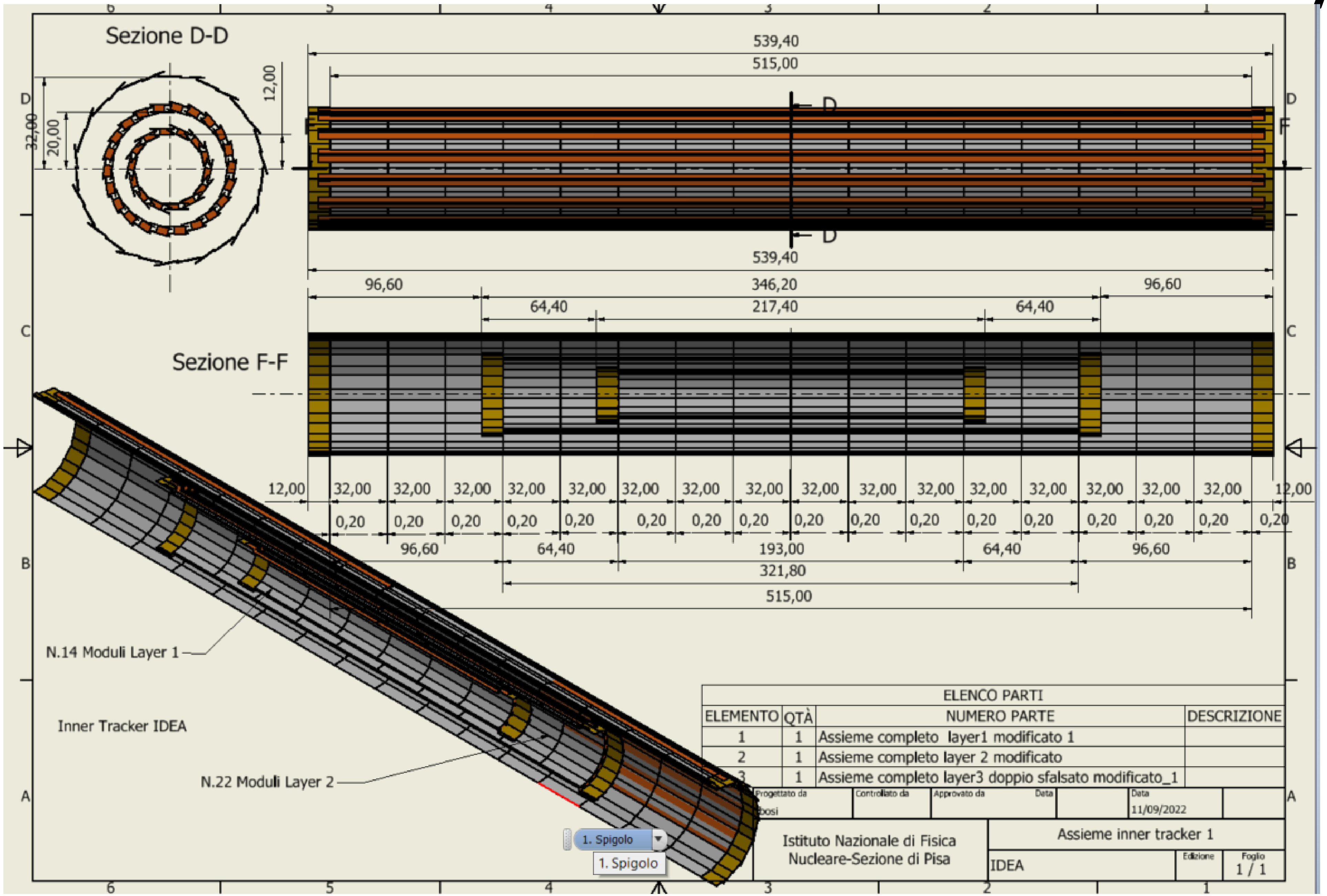
In this and the following we have made a study of a ***realistic mechanical geometrical layout***, including hybrids and readout bus, but ***still missing*** the final module frame mechanical support

Vertex layer supports

- Conical carbon fibre shaped structure, held by the beam pipe (see later)

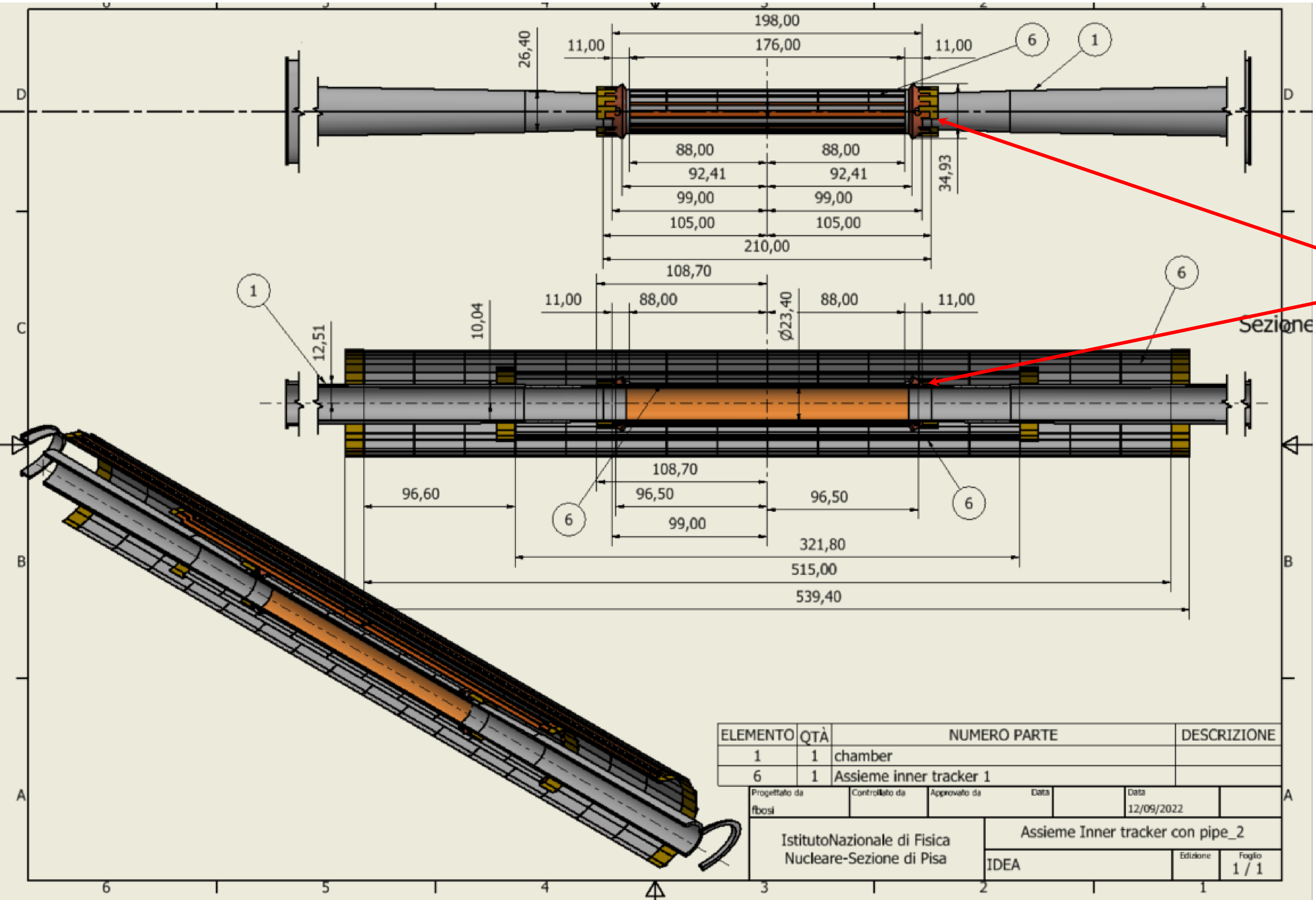


Vertex overall assembly



Total weight to be estimated, but far **less than 100 grams**

Air cooled



Mounting 2 halves (in φ) on the beam pipe cooling manifolds

Outer layers modules

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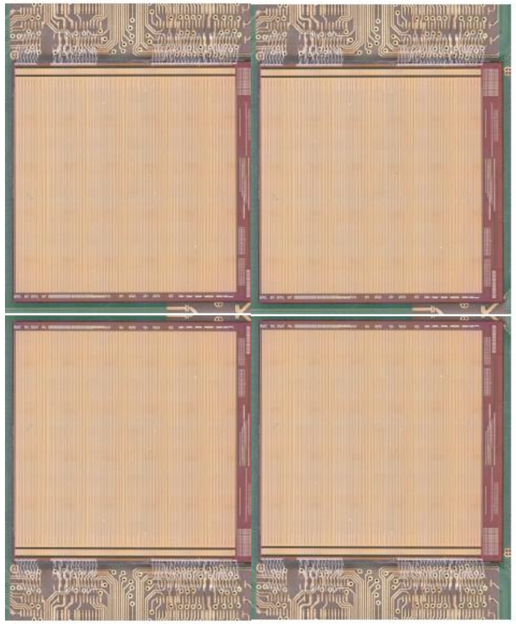
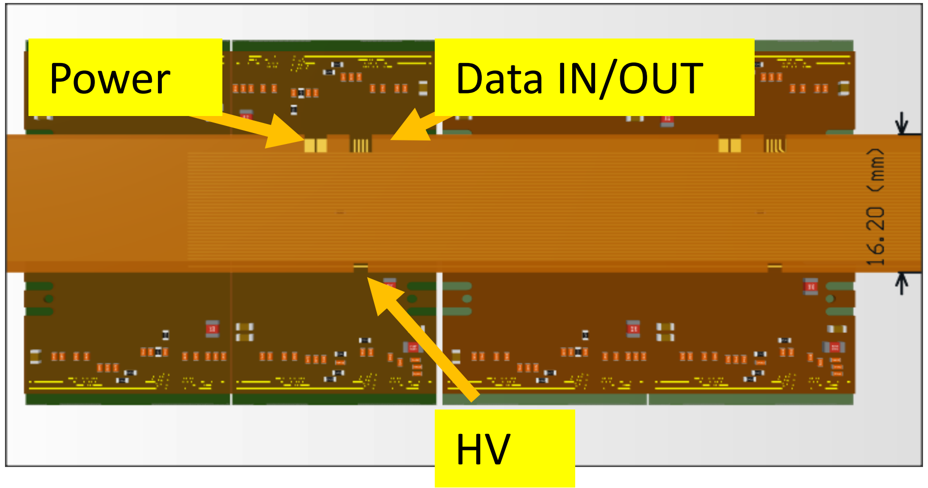
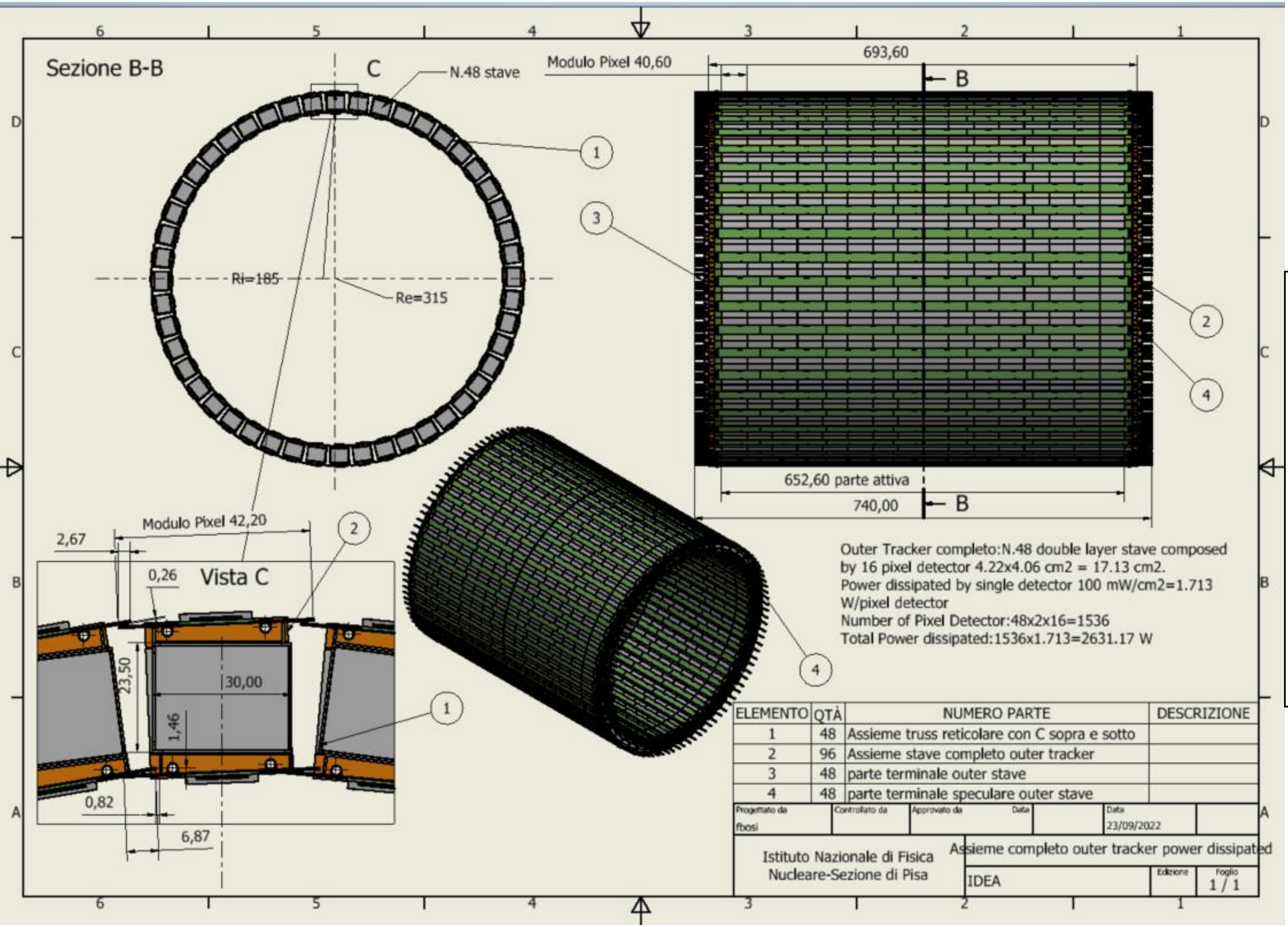
- Based on ATLASPIX3 R&D
  - 50 x 150 µm
  - Up to 1.28 Gb/s downlink
  - TSI 180 nm process
  - 132 columns of 372 pixels

  - Active (total) length (r-phi x z)
    - 18.6 (21) mm x 19.8 (20.2) mm
  - Module is made of 2x2 chips – total length:
    - size 42.2 mm x 40.6 mm

  - Power budget not established yet:
    assume $100\ \mathrm{mW/cm^2}$







ELEMENTO	QTÀ	NUMERO PARTE	DESCRIZIONE
1	48	Assieme truss reticolare con C sopra e sotto	
2	96	Assieme stave completo outer tracker	
3	48	parte terminale outer stave	
4	48	parte terminale speculare outer stave	

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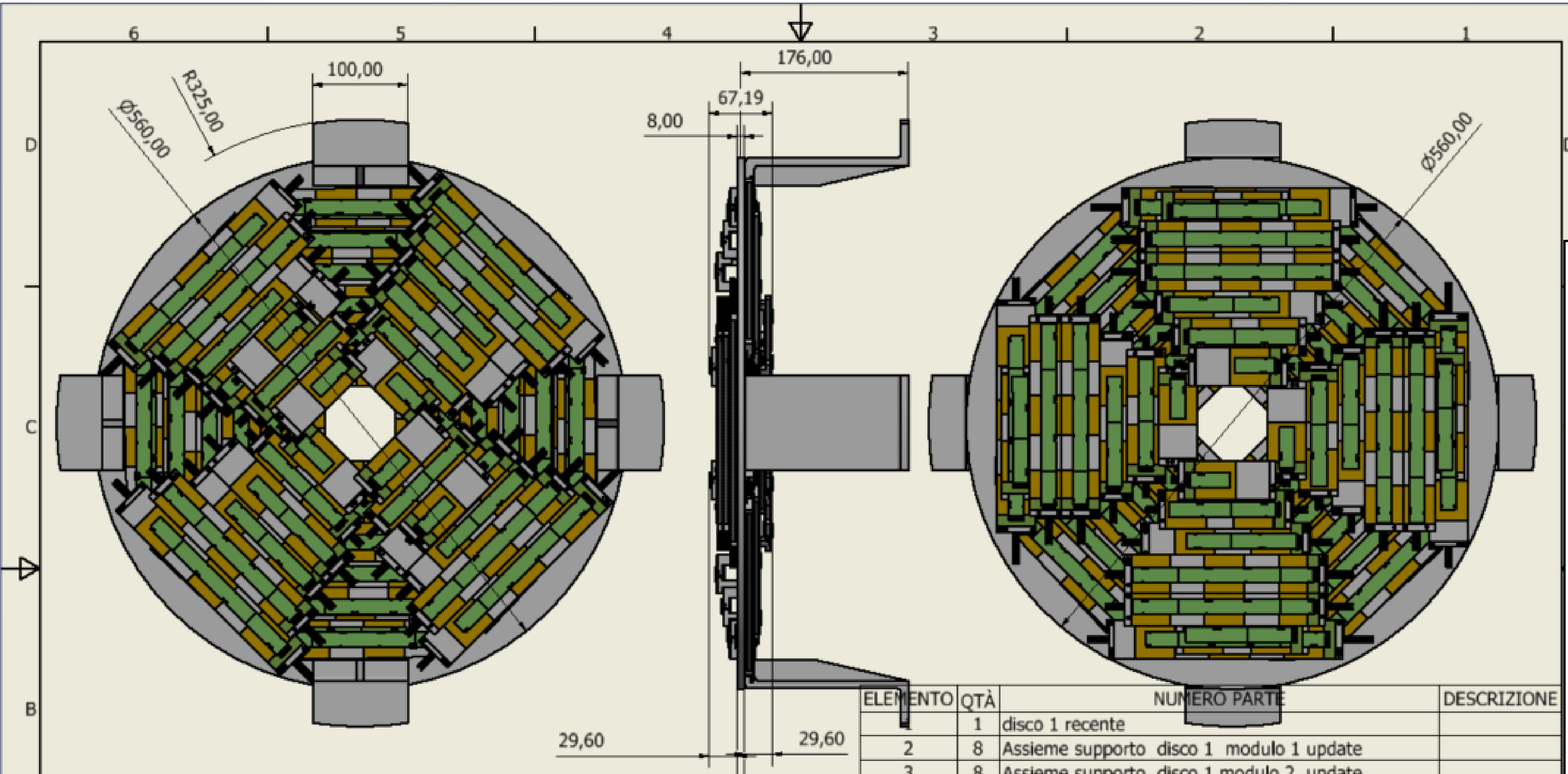
Outer Tracker Barrel

48 staves of 32 modules each (at different radii)

Power budget ~2.63 kW

Cooling using water 4 pipes (2 mm diameter) per stave



Disk1 completed:N.48 stave composed by 196 pixel detector 4.22x4.06 cm2 = 17.13 cm2.
Power dissipated by single detector 100 mW/cm2=1.713 W/pixel detector
Number of Pixel Detector:100+96
Total Power dissipated Disk 1:196x1.713=335.8 W

ELEMENTO	QTÀ	NUMERO PARTE	DESCRIZIONE
1	1	disco 1 recente	
2	8	Assieme supporto disco 1 modulo 1 update	
3	8	Assieme supporto disco 1 modulo 2 update	
4	4	Assieme supporto disco 1 modulo 2 speciale update	
5	8	Assieme supporto disco 1 modulo 3 update	
6	4	Assieme supporto disco 1 modulo 3 speciale update	
7	8	Assieme supporto disco 1 modulo 4 update	
8	4	Assieme supporto disco 1 modulo 4 speciale update	
9	4	Assieme supporto disco 1 modulo 5 update	
10	6	Assieme supporto disco 1 modulo 5 speciale update	
11	4	staffa di supporto	

Progettato da	Controllato da	Approvato da	Data	Data
fbosi				23/10/2022

Istituto Nazionale di Fisica Nuclere-Sezione di Pisa	Assieme disco 1		
	IDEA	Edizione	Foglio 1 / 1

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Outer Tracker Disk 1

2 sides (front and back) each with 4 petals.

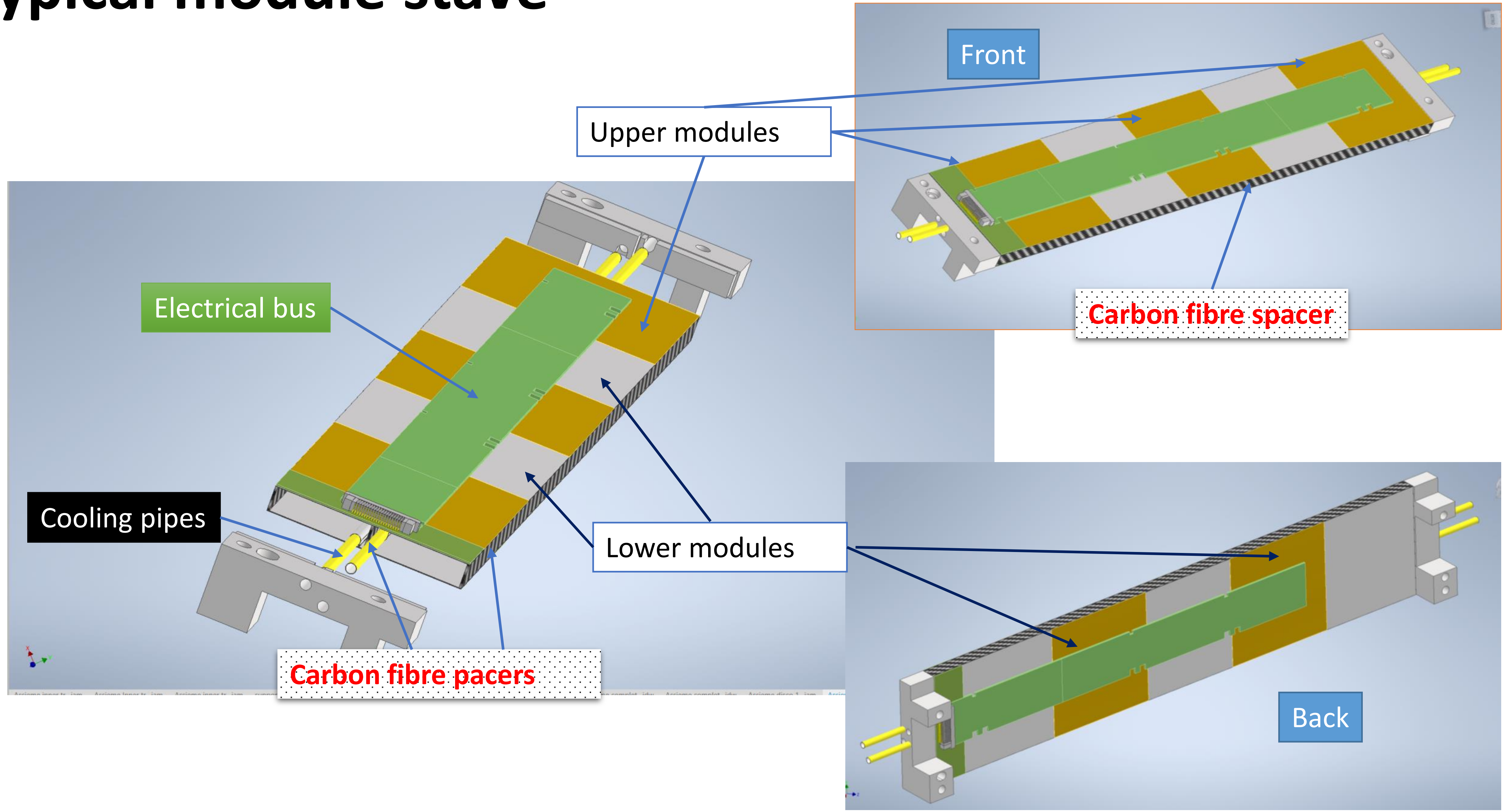
One petal is made of different staves of overlapping modules in z.

Total modules per disk: 196

Power budget ~340 W

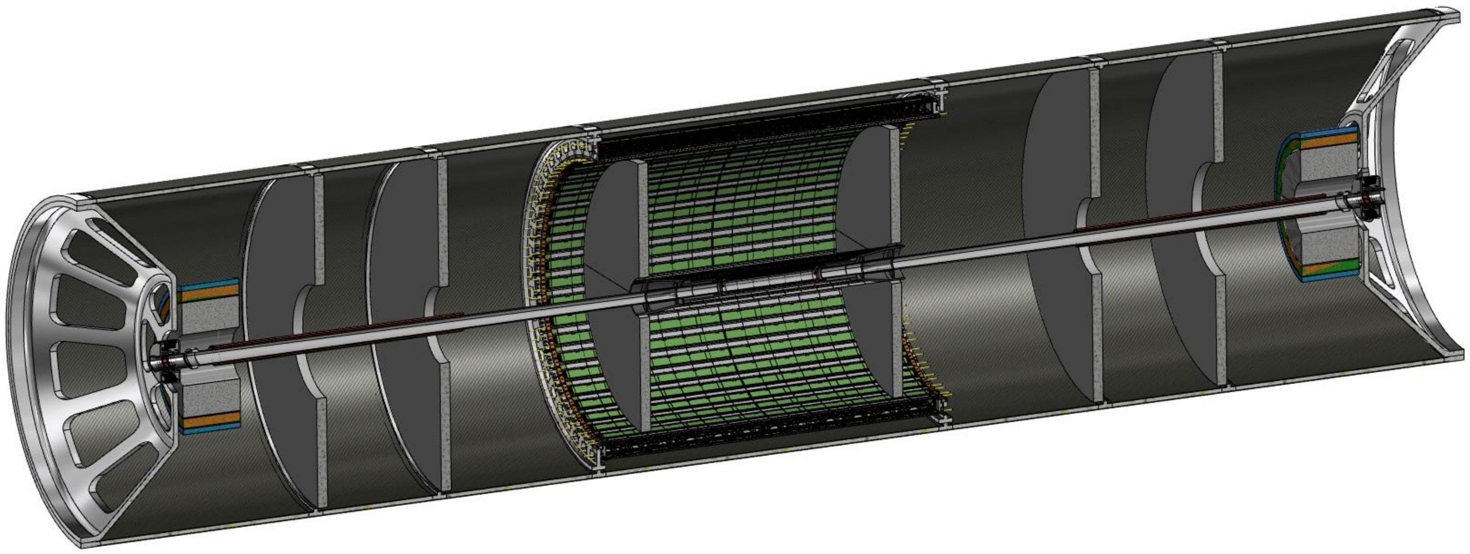
Cooling using 1 water pipe (2 mm diameter)

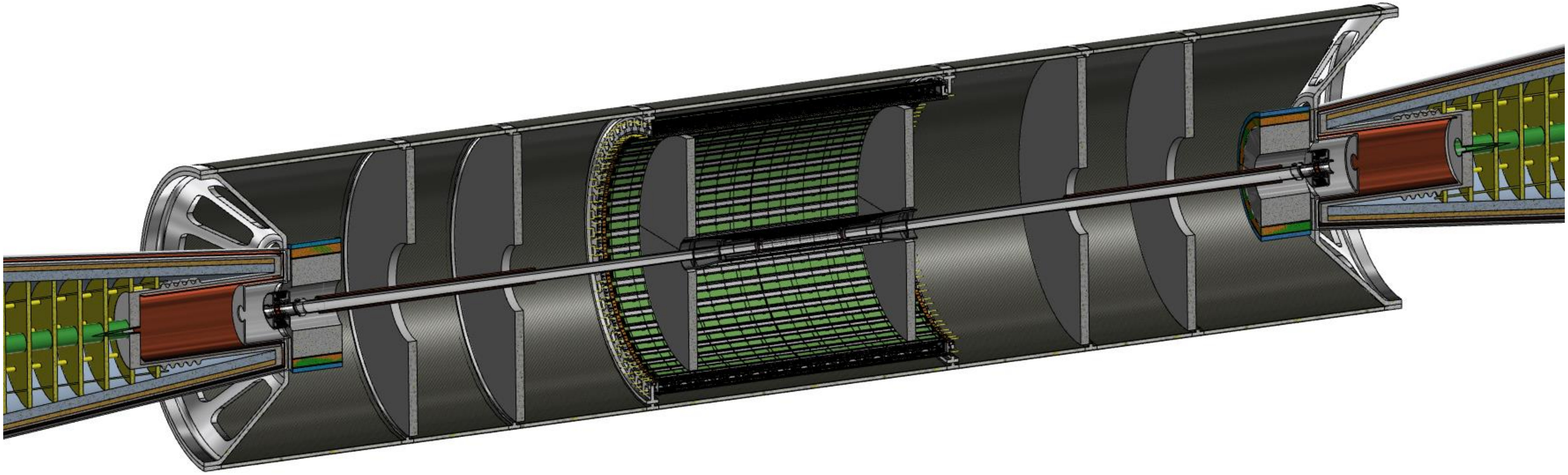
Typical module stave



Support cylinder

- All elements in the interaction region (vertex, Tracker and LumiCal) are mounted rigidly on a support cylinder that guarantees mechanical stability and alignment
  - Once the structure is assembled it is slided inside the rest of the detector





Cylinder material and structure

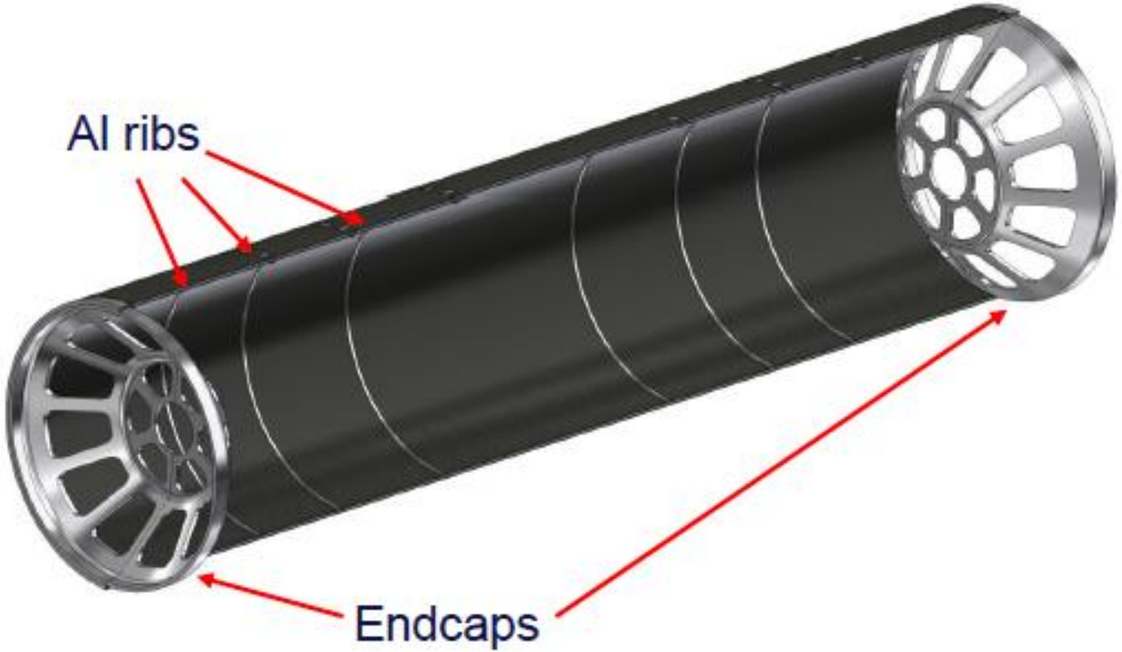
Sandwich structure:

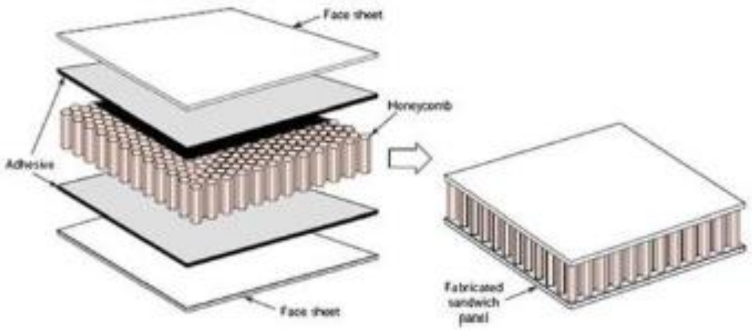
- Carbon fiber 1mm
- Honeycomb or rigid foam structure (Rohacell) 8mm
- Carbon fiber 1mm

Cylinder splitted in two halves

Alumin ribs to fix detector

Endcaps for supporting Lumical and beampipe



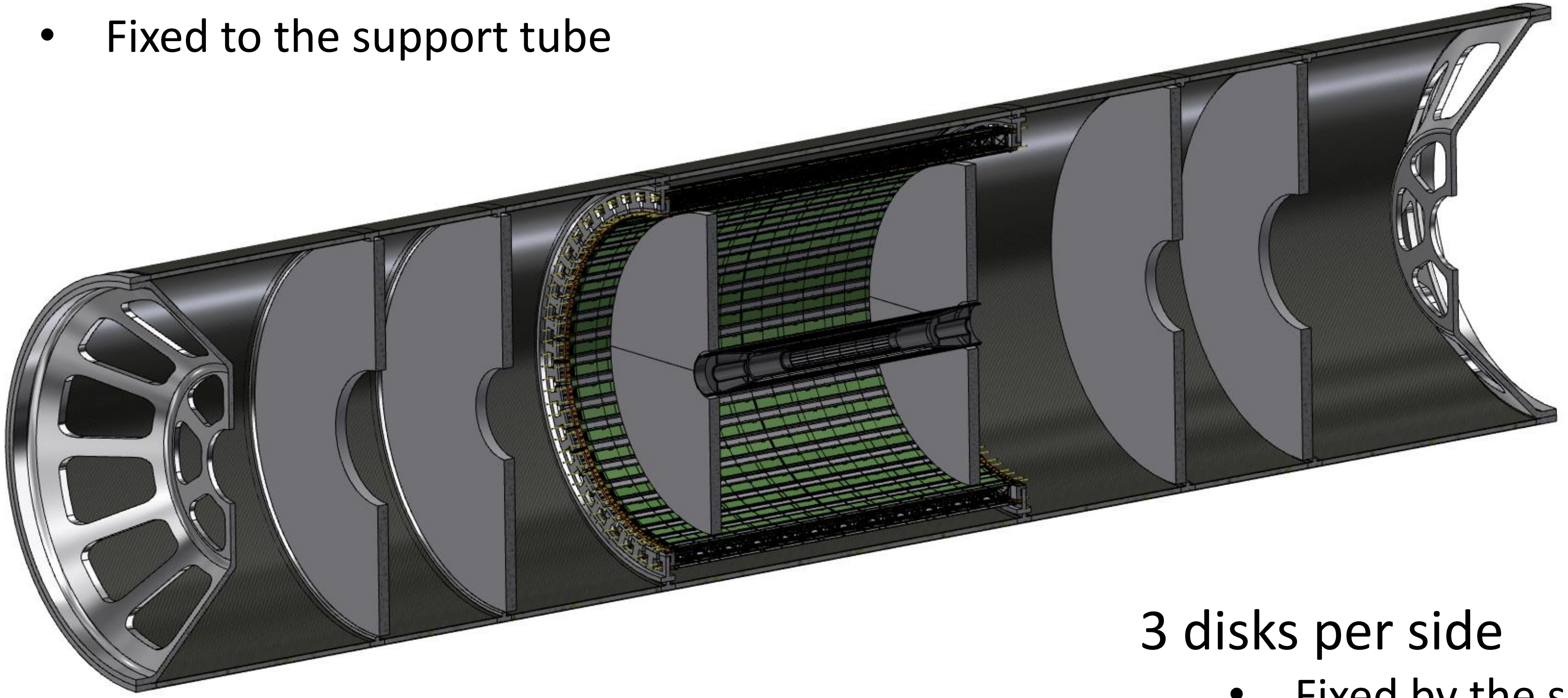


Honeycomb (fiberglass, aluminum, nomex/Kevlar)

Rohacell (polymethacrylimide)

Outer barrel and disks

- Barrel:
  - a truss structure with 2 layers of modules (at radii of 31.5 cm and 28.5 cm)
  - Fixed to the support tube



3 disks per side

- Fixed by the support tube

Overal

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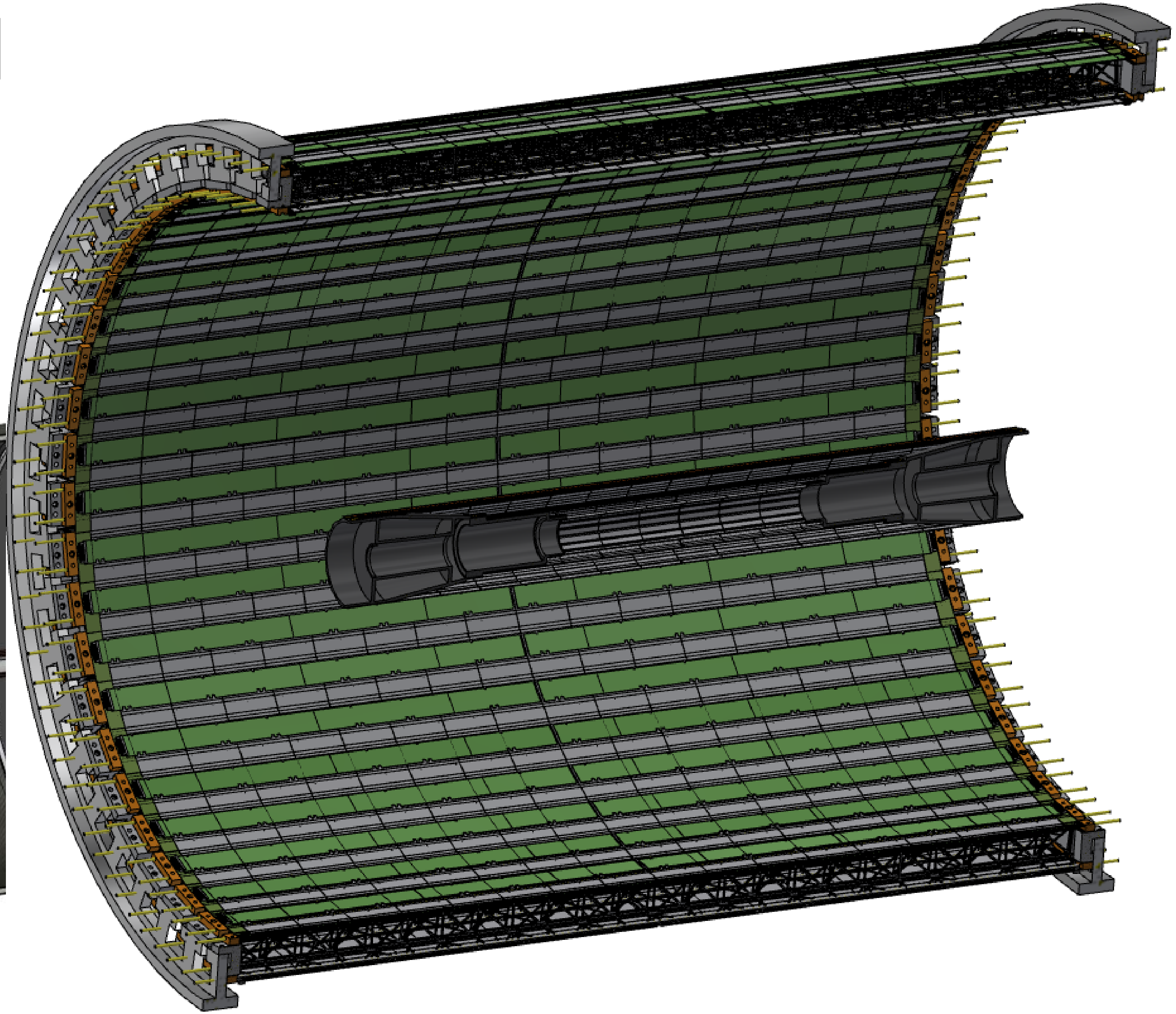
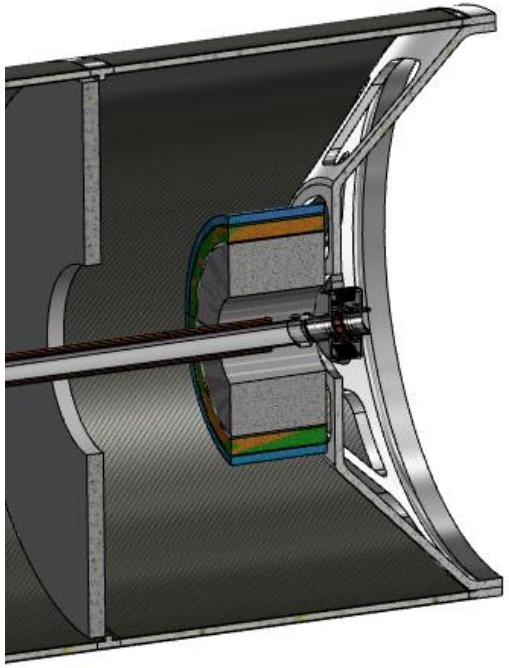




Is it feasible?

- Mechanical stability of the support cylinder is not an issue

Preliminary simulation on supporting Cylinder (1)

Materials

1) Cylinder structure (10mm)

- 1mm CF
- 8mm HC
- 1mm CF

Flanges:

- 10mm Aluminium

2) Cylinder structure (7mm)

- 1mm CF
- 5mm HC
- 1mm CF

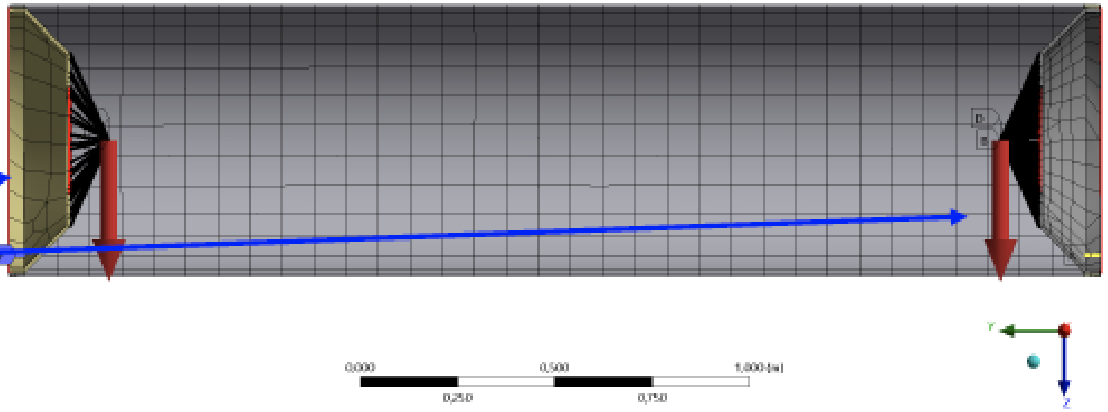
Flanges:

- 10mm Aluminium

Layer	Material	Thickness (m)	Angle (°)
(+Z)			
5	Epoxy Carbon Woven (230 GPa) Wet	0,0005	45
4	Epoxy Carbon Woven (230 GPa) Wet	0,0005	-45
3	Honeycomb	0,008	0
2	Epoxy Carbon Woven (230 GPa) Wet	0,0005	-45
1	Epoxy Carbon Woven (230 GPa) Wet	0,0005	45
(-Z)			

Loads

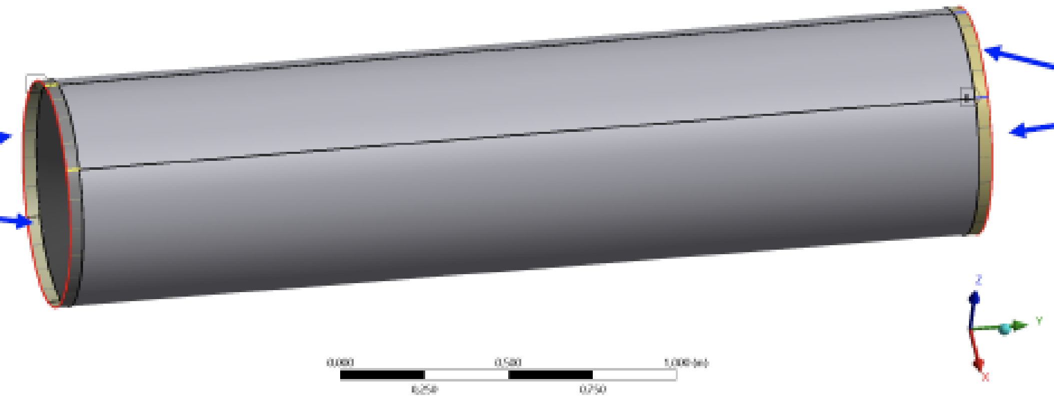
- 70 Kg on each flanges



Constraints

- Simply supported in order to simulate rail supports

Fixed

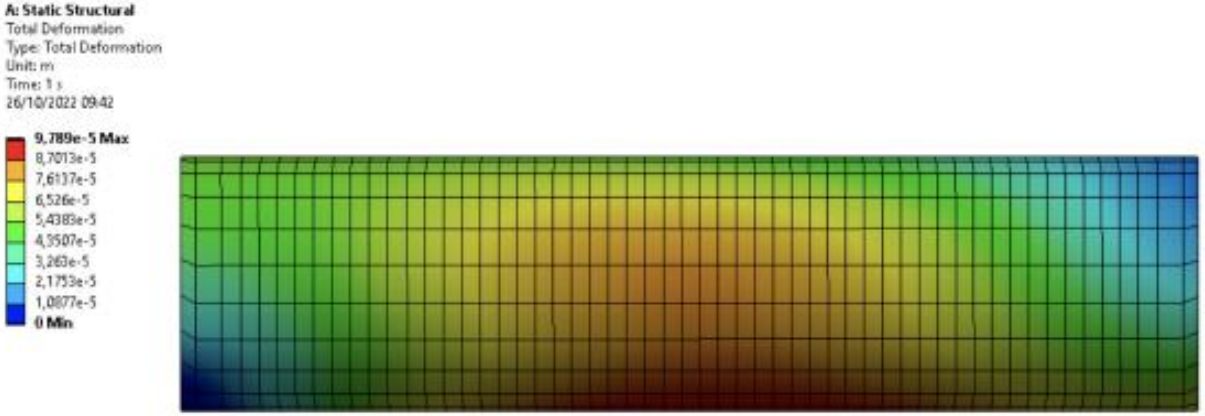


Free to move in longitudinal direction

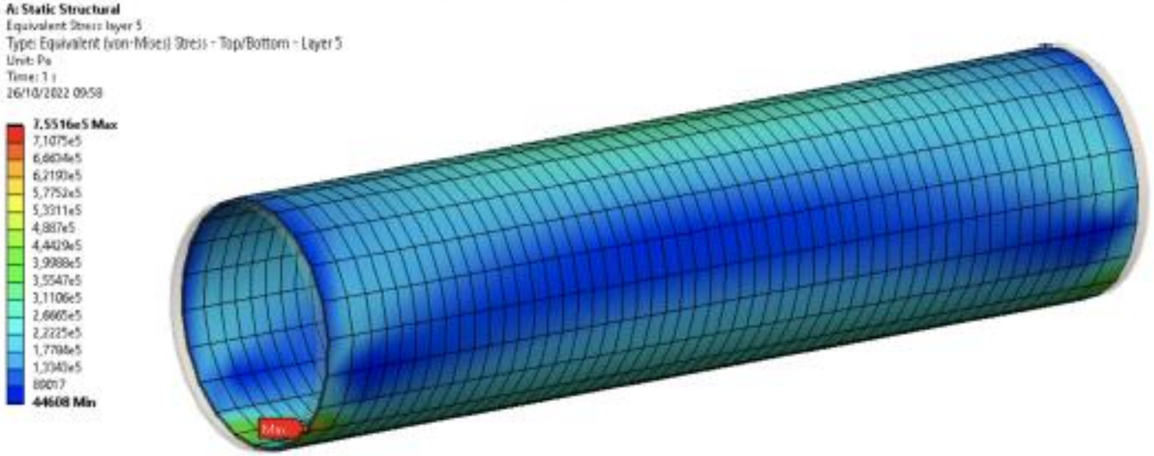
CF=carbon fiber
HC=honeycomb

Results

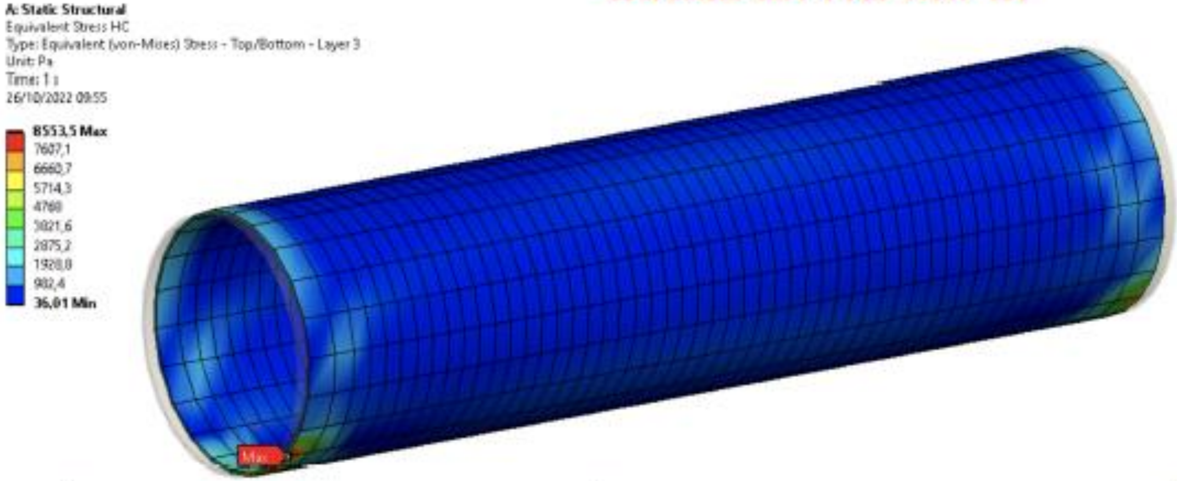
Deformation



Stress on CF



Stress on HC [MPa]



	Maximum deformation [mm]	Maximum stress on CF [MPa] Layer 1	Maximum stress on HC [MPa] Layer 3	First failure stress for CF [Mpa]
8mm HC	0,098	0,7	0,085	275
5mm HC	0,11	0,7	0,094	275

Is it feasible?

- Mechanical stability of the support cylinder is not an issue
- Vertex detector weight (<< 100 grams) on the beam pipe is well supported

Study of the influence of the VTX detector first layer weight over the chamber

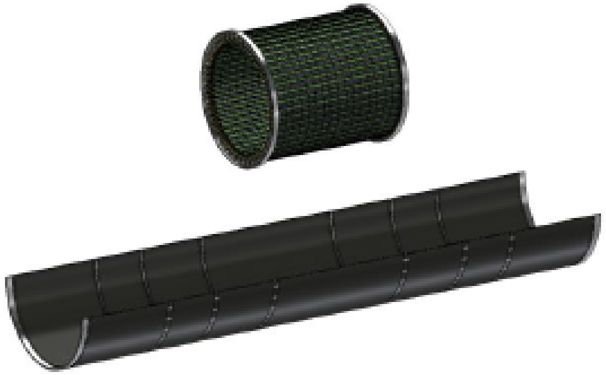
- To understand the behavior of the chamber under a load due to the weight of the VTX first layers, is useful to create a table.
- This table is created performing a Parametric design with Ansys, augmenting the weight of the layers and evaluating the central chamber stress and strain.

Configuration	VTX load [kg]	Maximum stress [Mpa]	Maximum displacement [mm]	Safety factor
1	0,5	46,8	9,56E-02	5,9
2	1,0	47,4	1,15E-01	5,7
3	2,0	48,4	1,47E-01	5,3
4	3,0	49,4	1,80E-01	5,0
5	4,0	50,0	2,03E-01	4,8
6	5,0	50,7	2,27E-01	4,5
7	6,0	51,6	2,62E-01	4,3

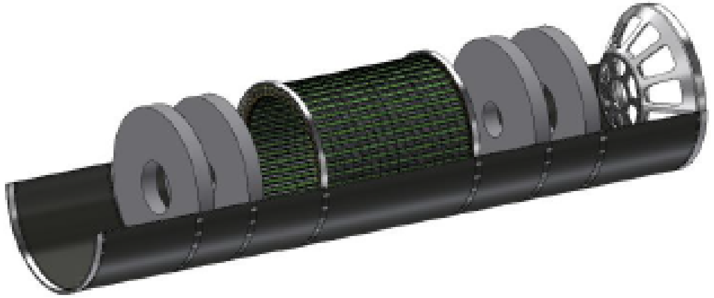
Is it feasible?

- Mechanical stability of the support cylinder is not an issue
- Vertex detector weight (<< 100 grams) on the beam pipe is well supported
- Integration of the detectors is doable

Conceptual assembly strategy

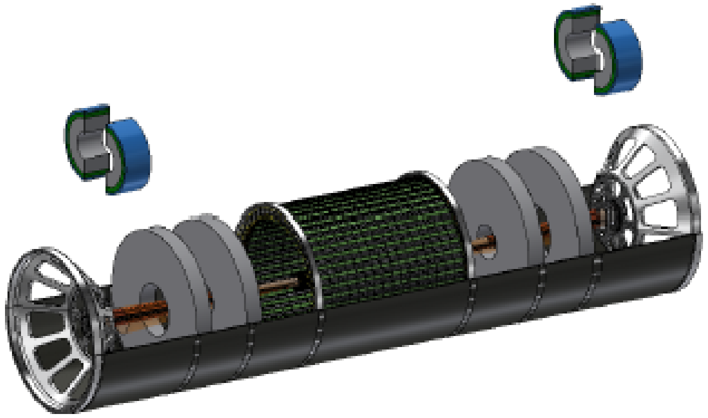


1) Outer tracker is assembled and laid down and fixed on half cylinder

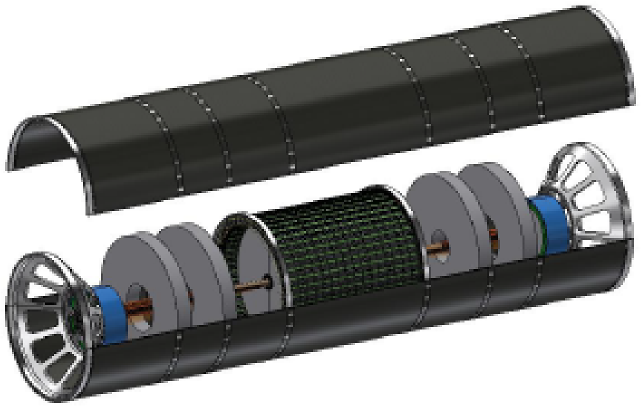


2) Detector disc and one endcap fixed to the half cylinder

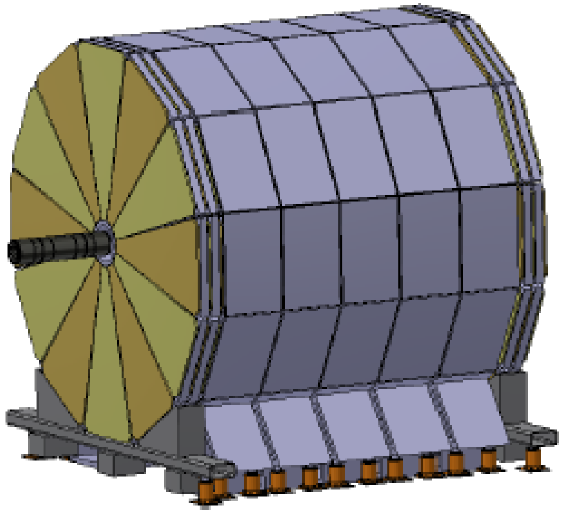
3) Beam pipe with vertex detector is inserted with a dedicated tool inside discs and outer tracker, then fixed to both endcaps



4) Lumicals are coupled to endcaps



5) The whole cylinder can be composed

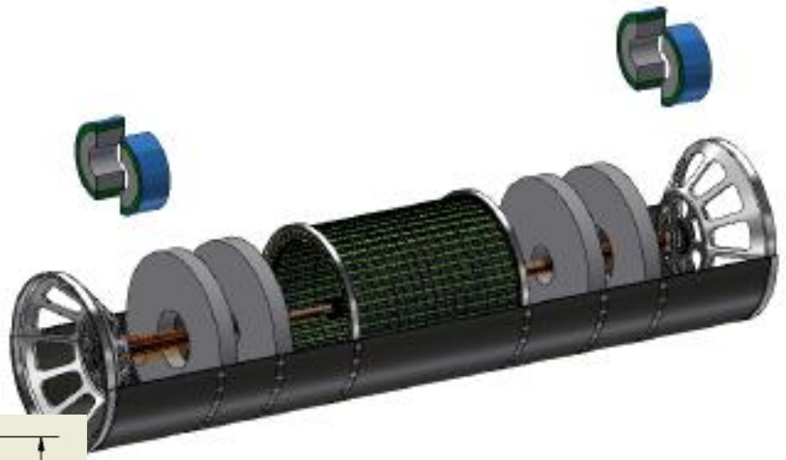


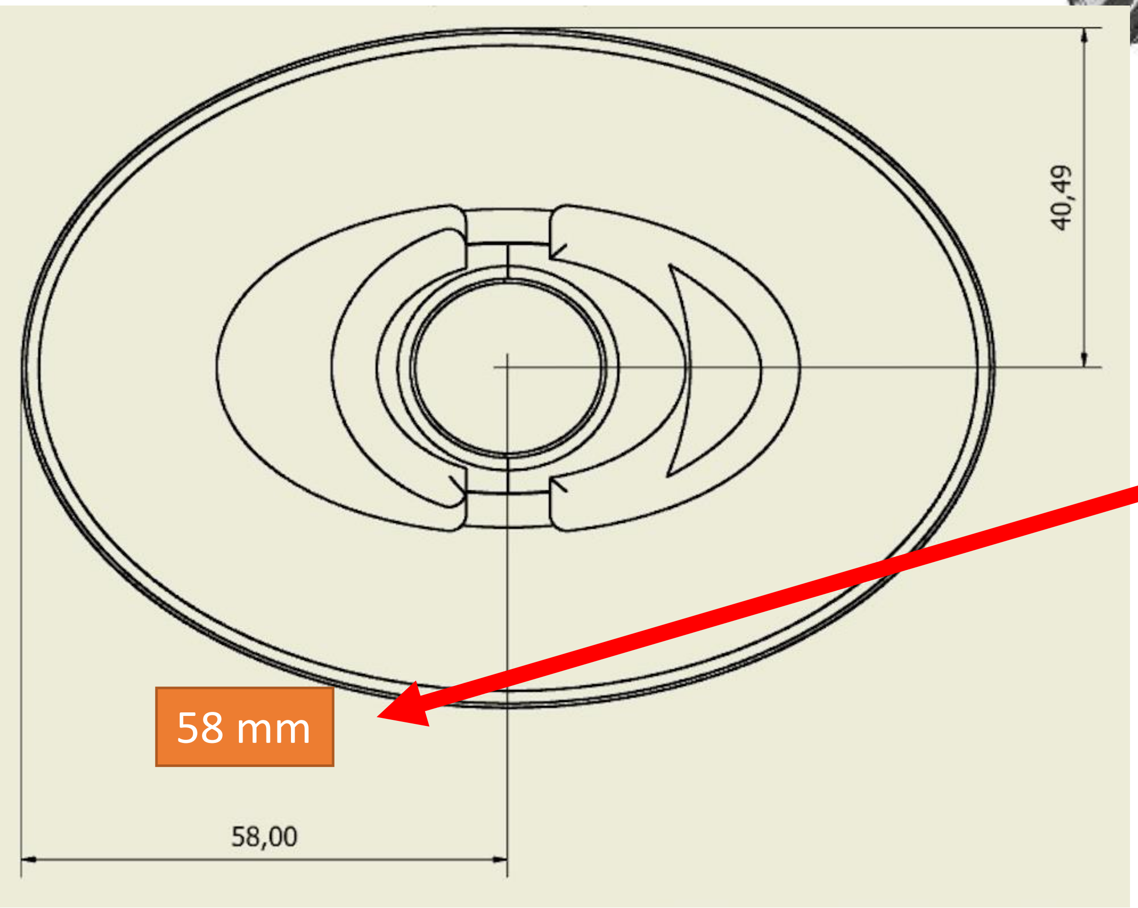
6) Cylinder can be inserted inside the detector using a rail system

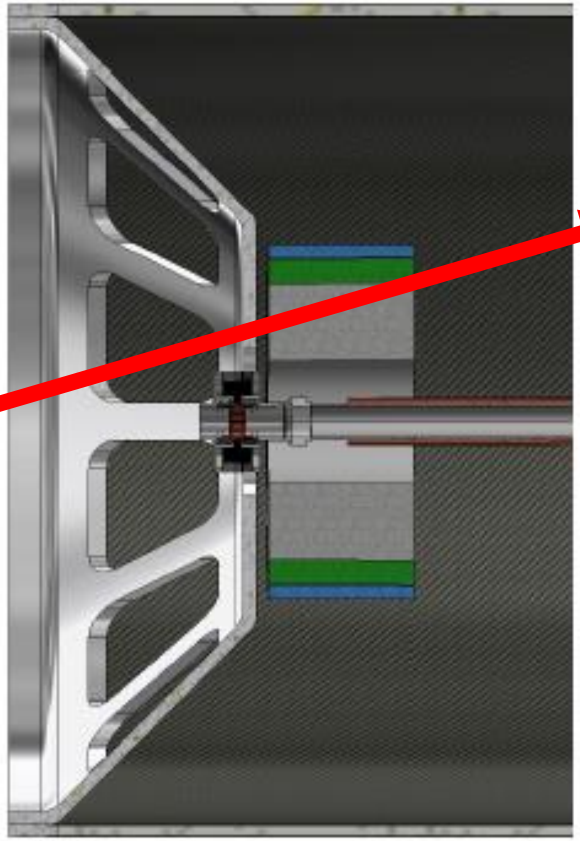
Is it feasible?

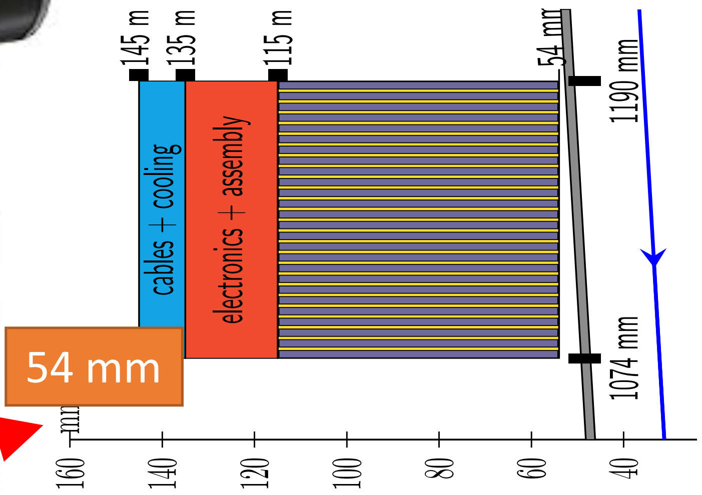
- Mechanical stability of the support cylinder is not an issue
- Vertex detector weight (<< 100 grams) on the beam pipe is well supported
- Integration of the detectors is doable
  - Open remaining issue to be investigated is whether or not LumiCal can be inserted as unique assembled structure or must be splitted due to 4 mm difference between the bellow and the inner LumiCal radius
    - Ongoing design effort to reduce the bellow size

Needs tuning of the bellow size.
Study ongoing









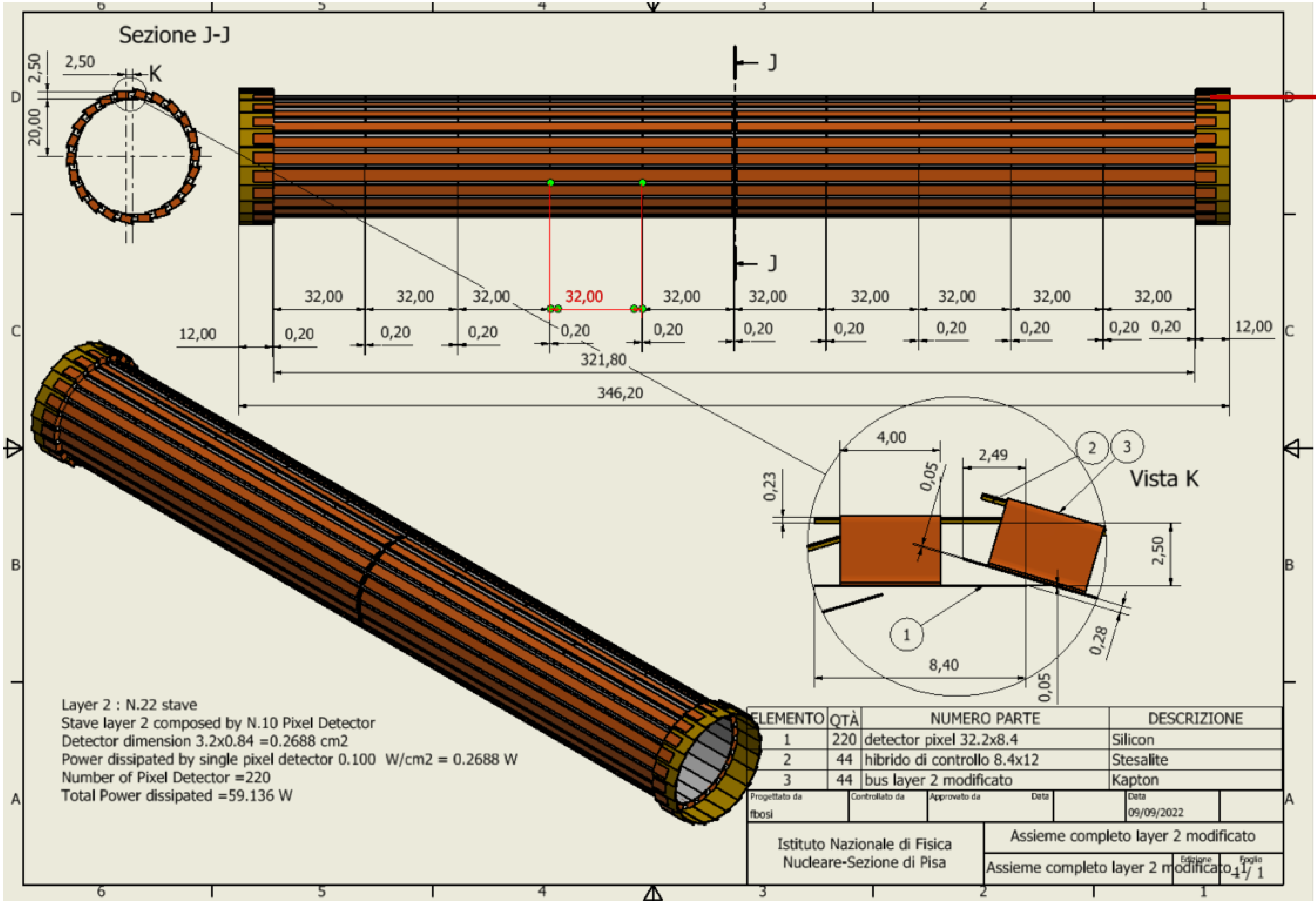
Conclusions

- A preliminary layout of the interaction region with LumiCal, vertex and outer tracker of the IDEA detector is being engineered
  - Feasibility studies of vertex and track integration successfully made
  - LumiCal conceptual integration done
- Next steps:
  - Vertex detector
    - Ladders mechanical support design
    - Study the feasibility of air cooling
    - Study the routing of the services (readout and power cables)
  - Outer Tracker
    - Study the routing of the services (readout and power cables, cooling manifolds)
  - Lumical
    - Engineering and assembly
  - Finalize detector assembly and its maintenance
  - Insert the layout in the GEANT simulation

Thank you for the attention

- Fabrizio.Palla@cern.ch

Backup

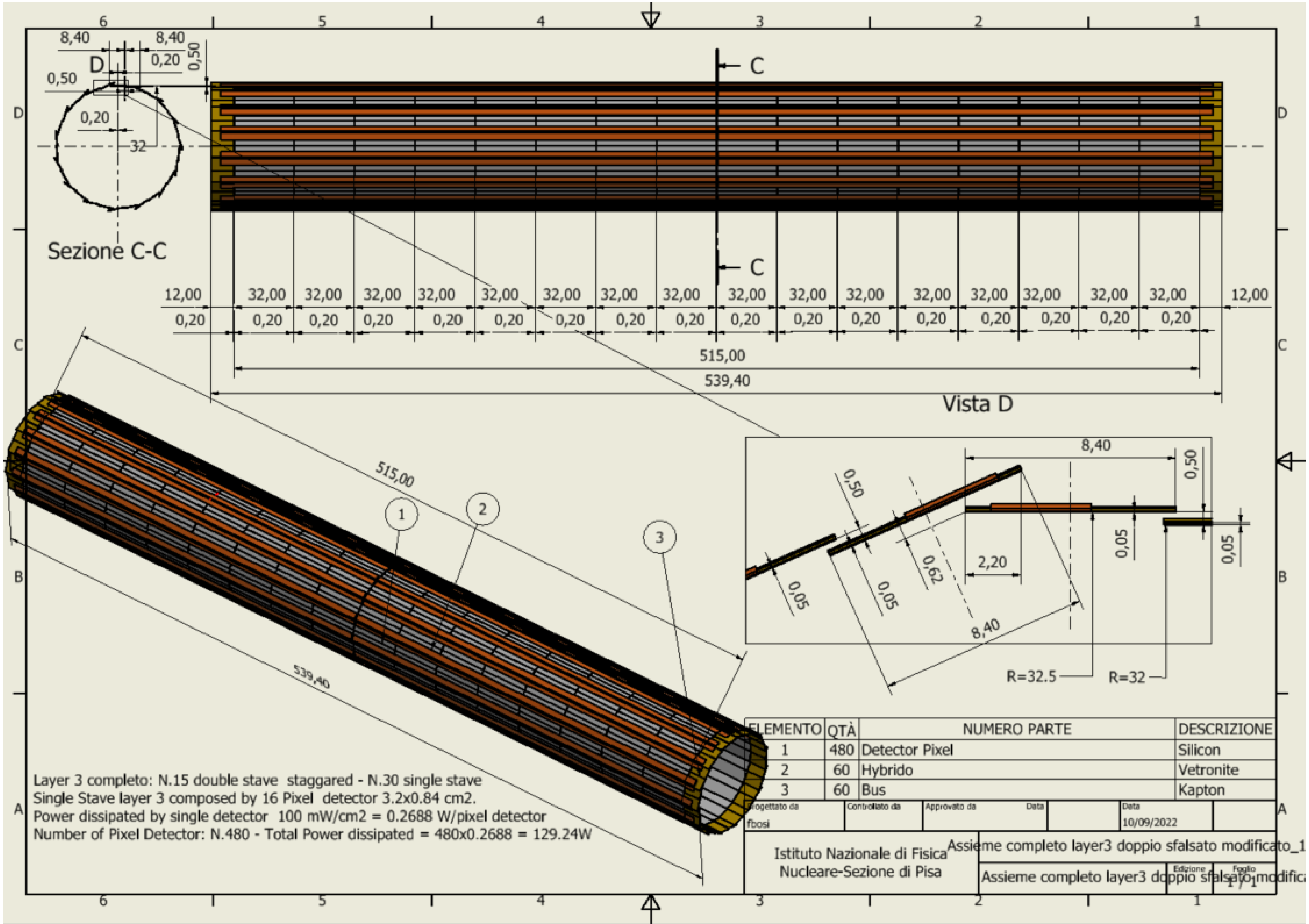


Hybrids at higher radius (+2.5 mm wrt sensors), not to interfere with LumiCal clearence

Layer 2

22 overlapping staves of 10 modules each

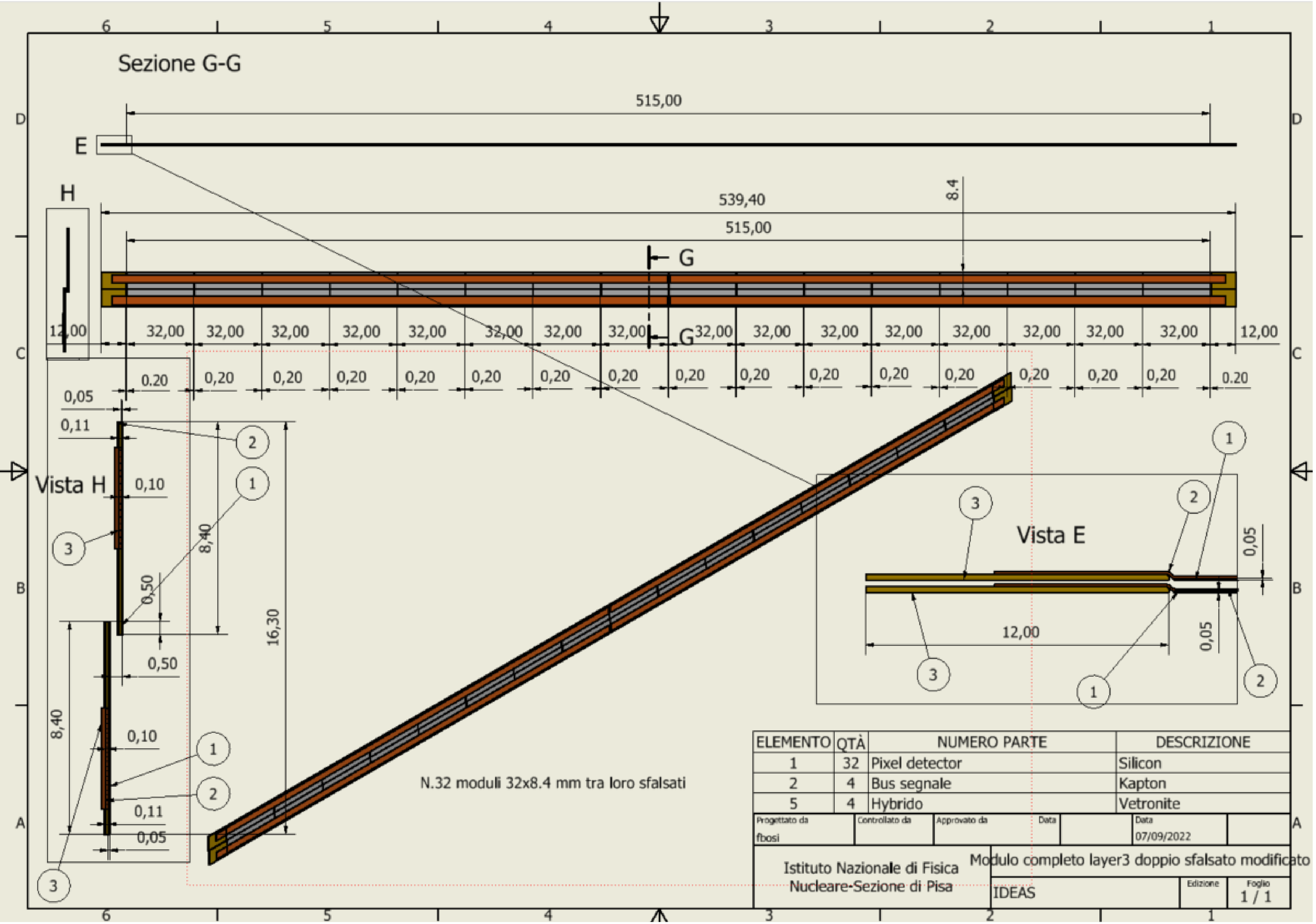
Power budget of the modules (only) ~59 W



Staves staggered by 500 μm wrt to the previous to profit of ϕ overlap

Layer 3
15 overlapping double staves of 32 modules each

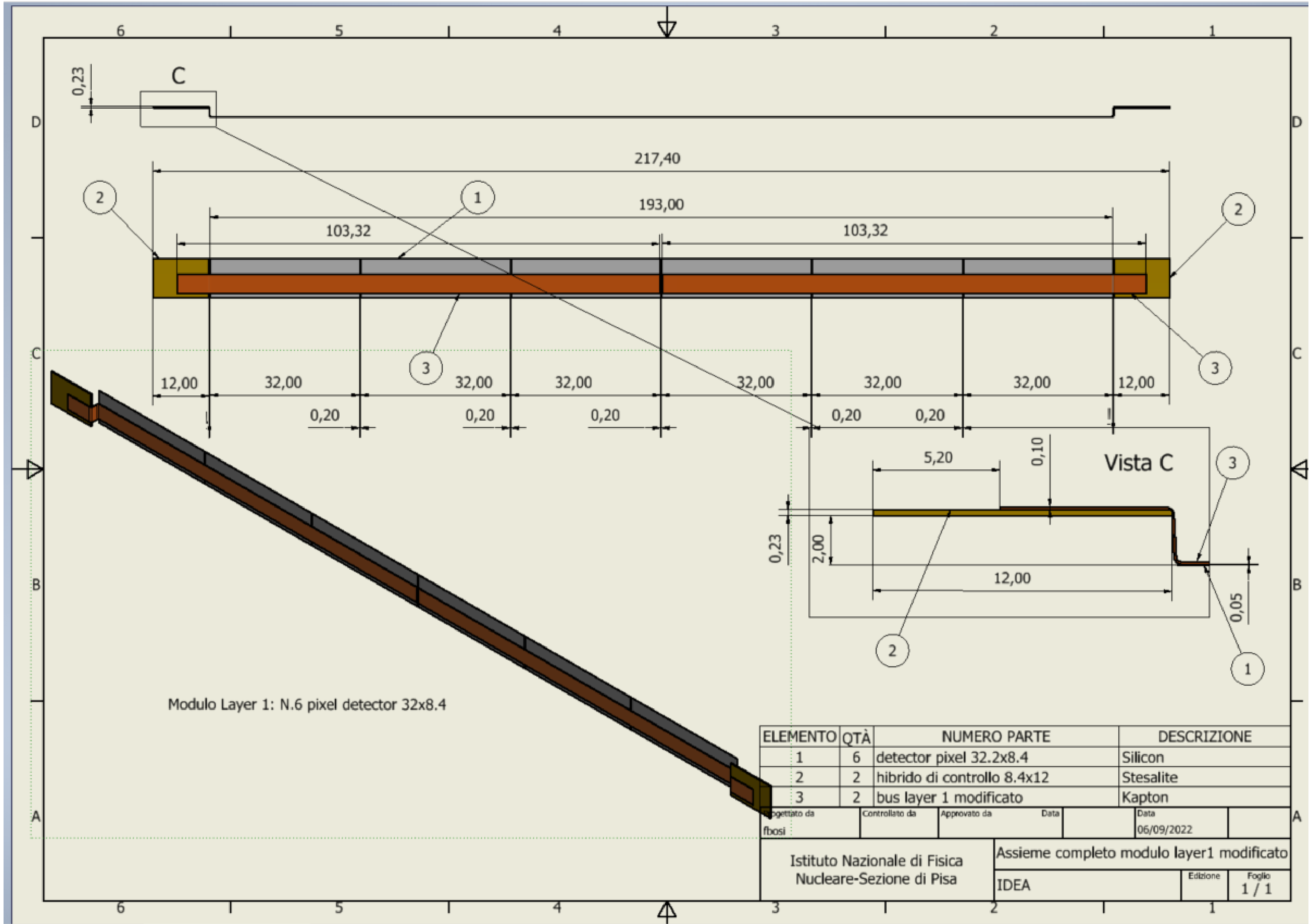
Power budget of the modules (only) ~130 W



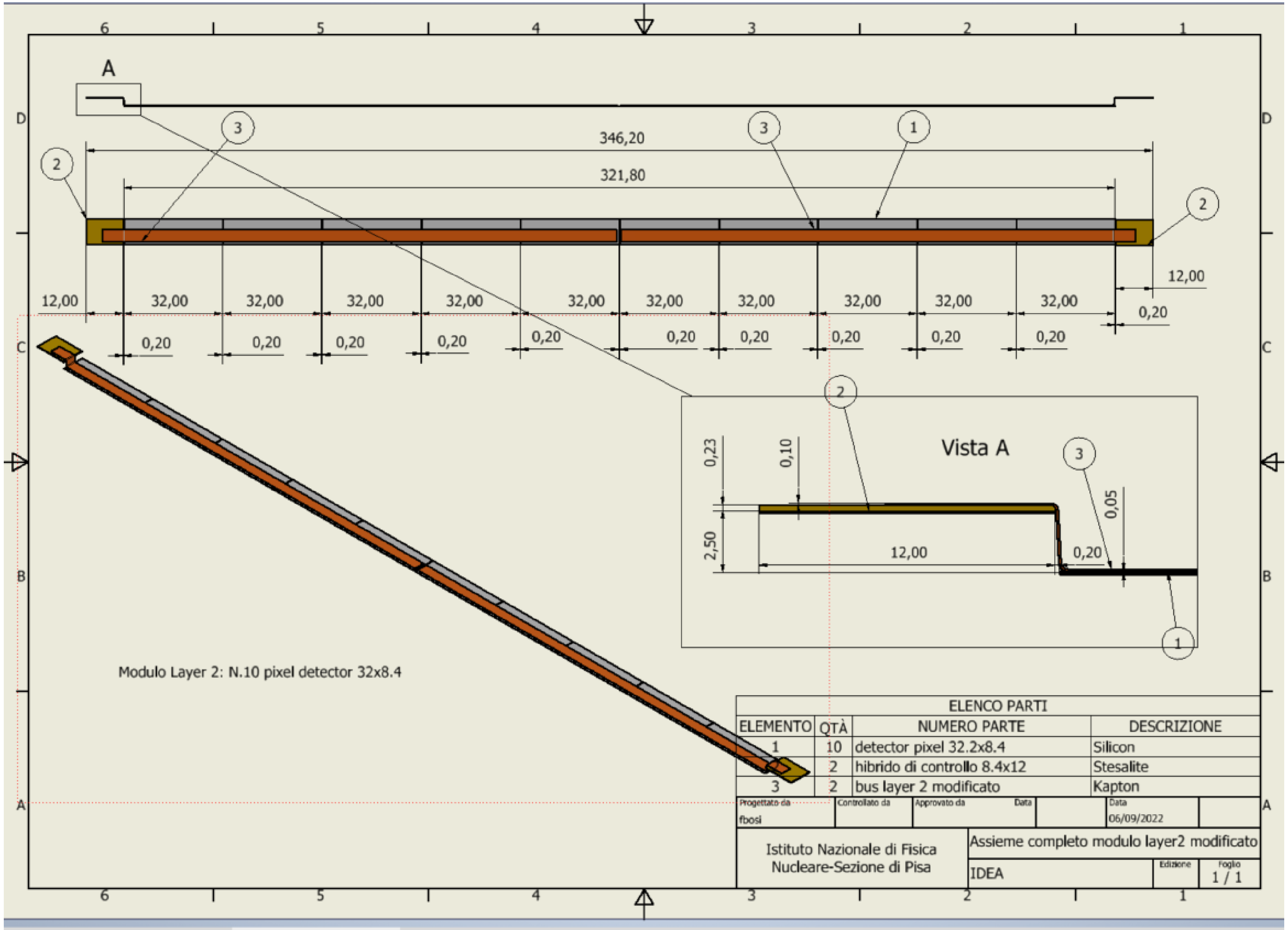
Double stave

2 parallel strings of detectors overlapped by 500 µm

Stave Layer 1



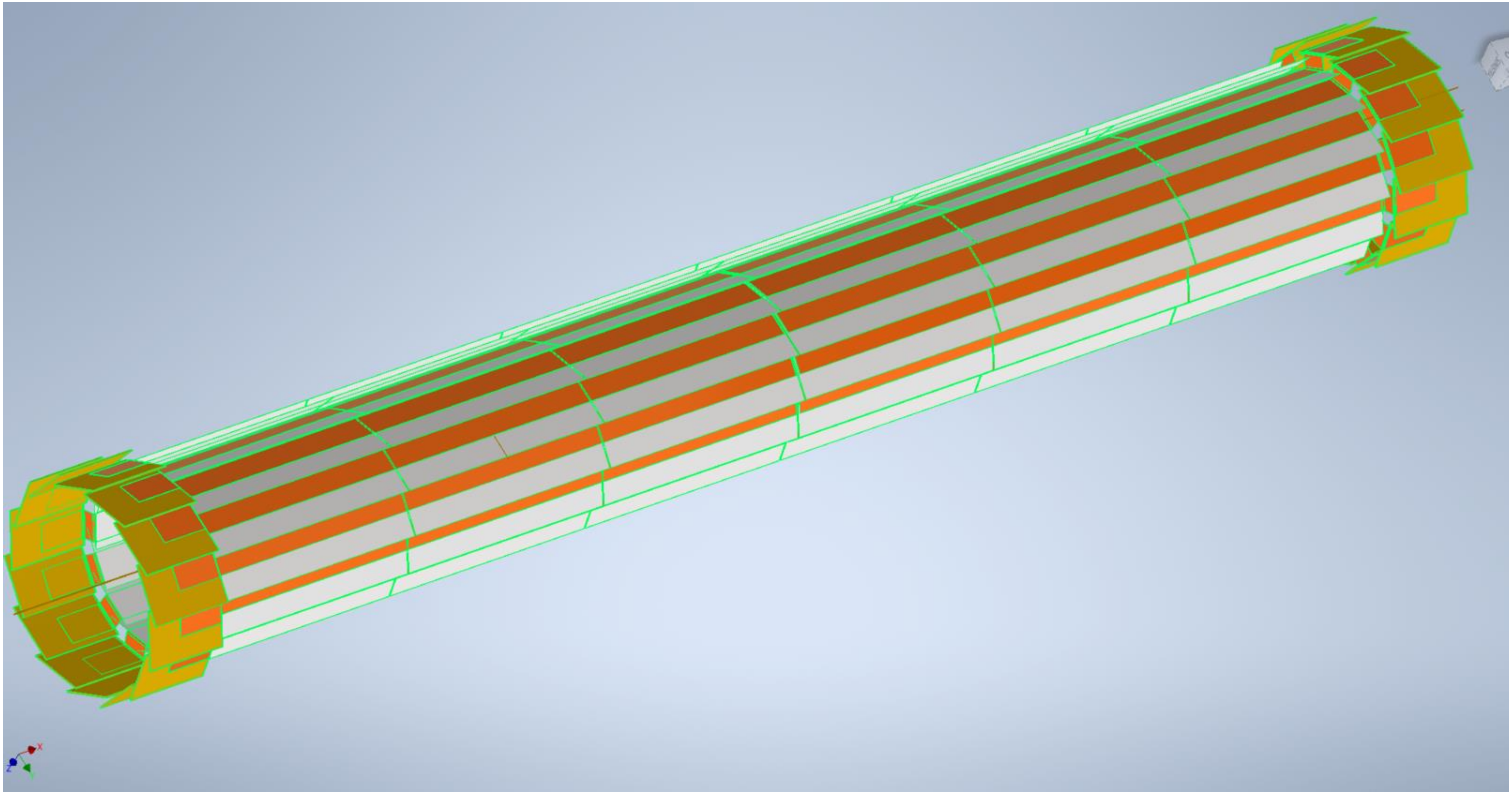
Stave Layer 2



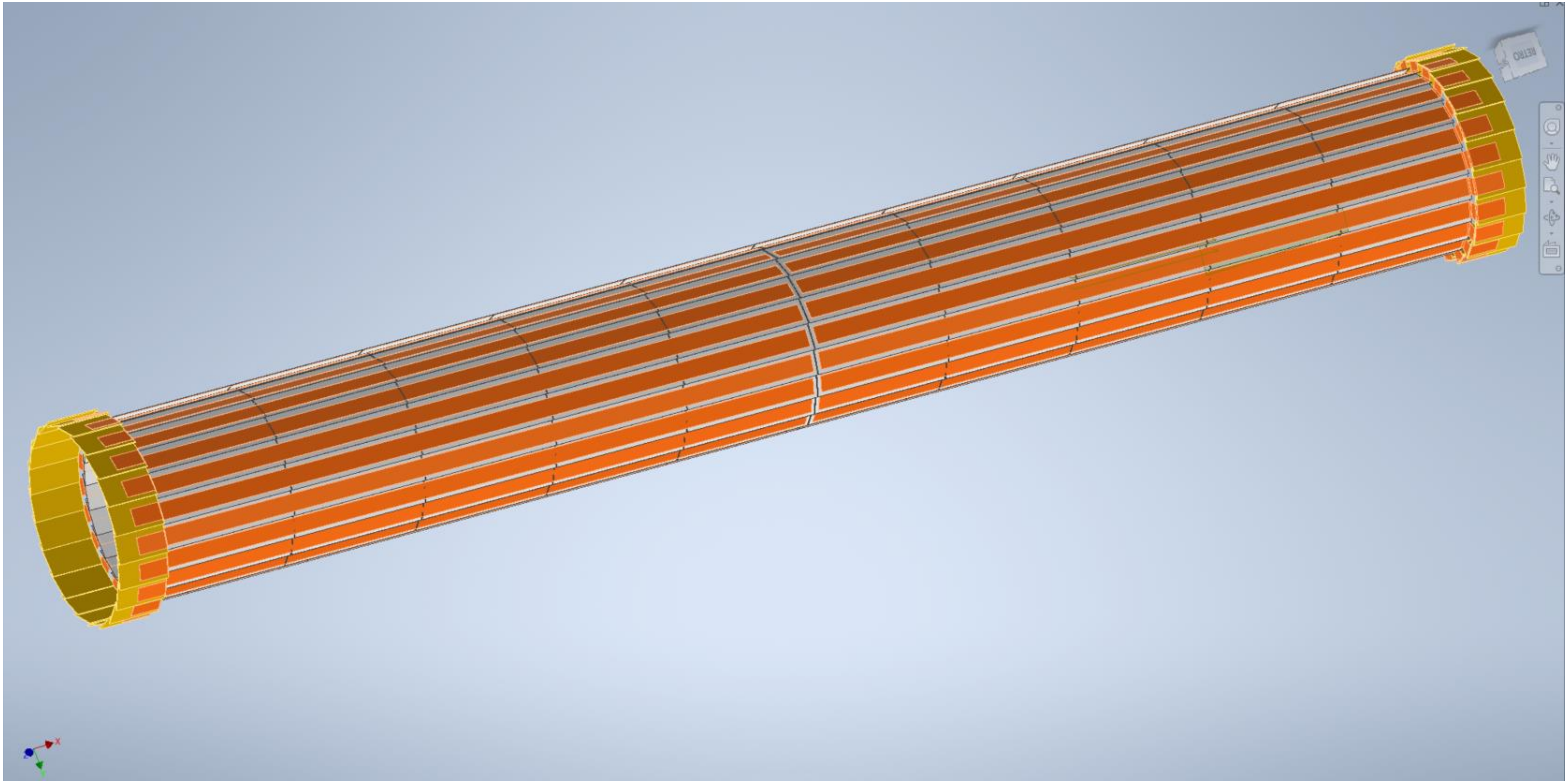
ELENCO PARTI

ELEMENTO	QTÀ	NUMERO PARTE	DESCRIZIONE
1	10	detector pixel 32.2x8.4	Silicon
2	2	hibrido di controllo 8.4x12	Stesalite
3	2	bus layer 2 modificato	Kapton

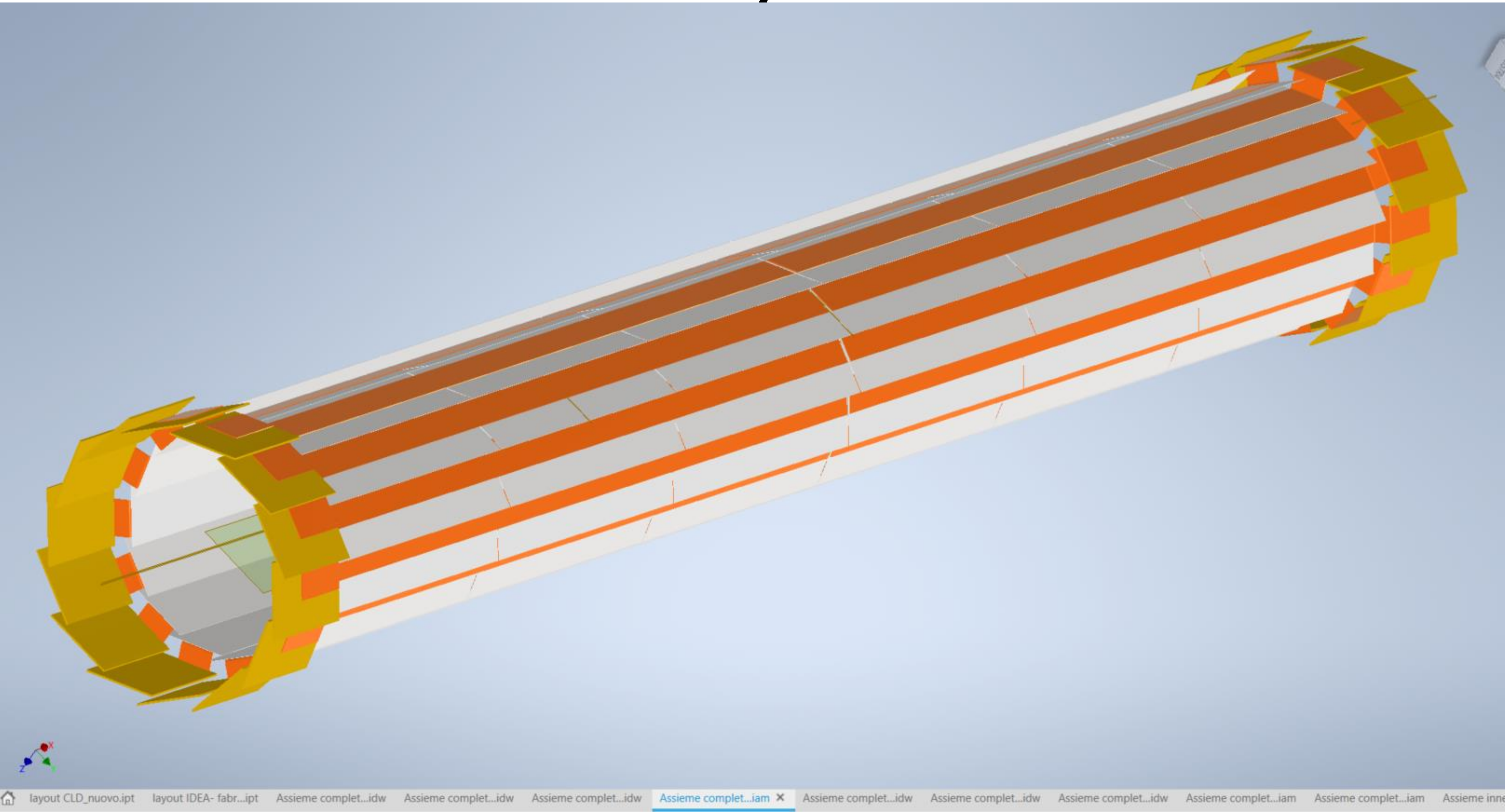
Layer 1



Layer 2



Layer 3


layout CLD_nuovo.ipt
layout IDEA- fabr...ipt
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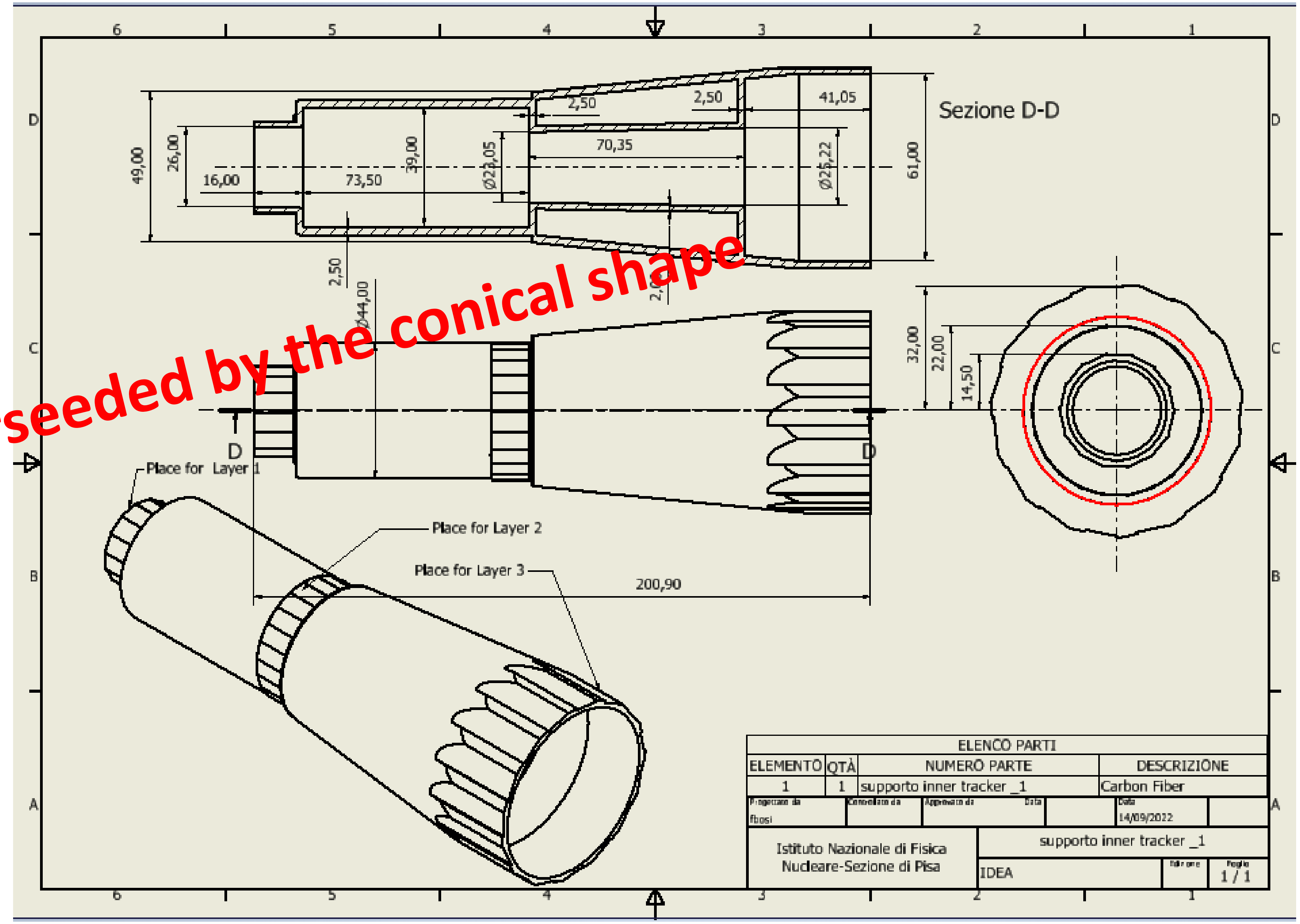
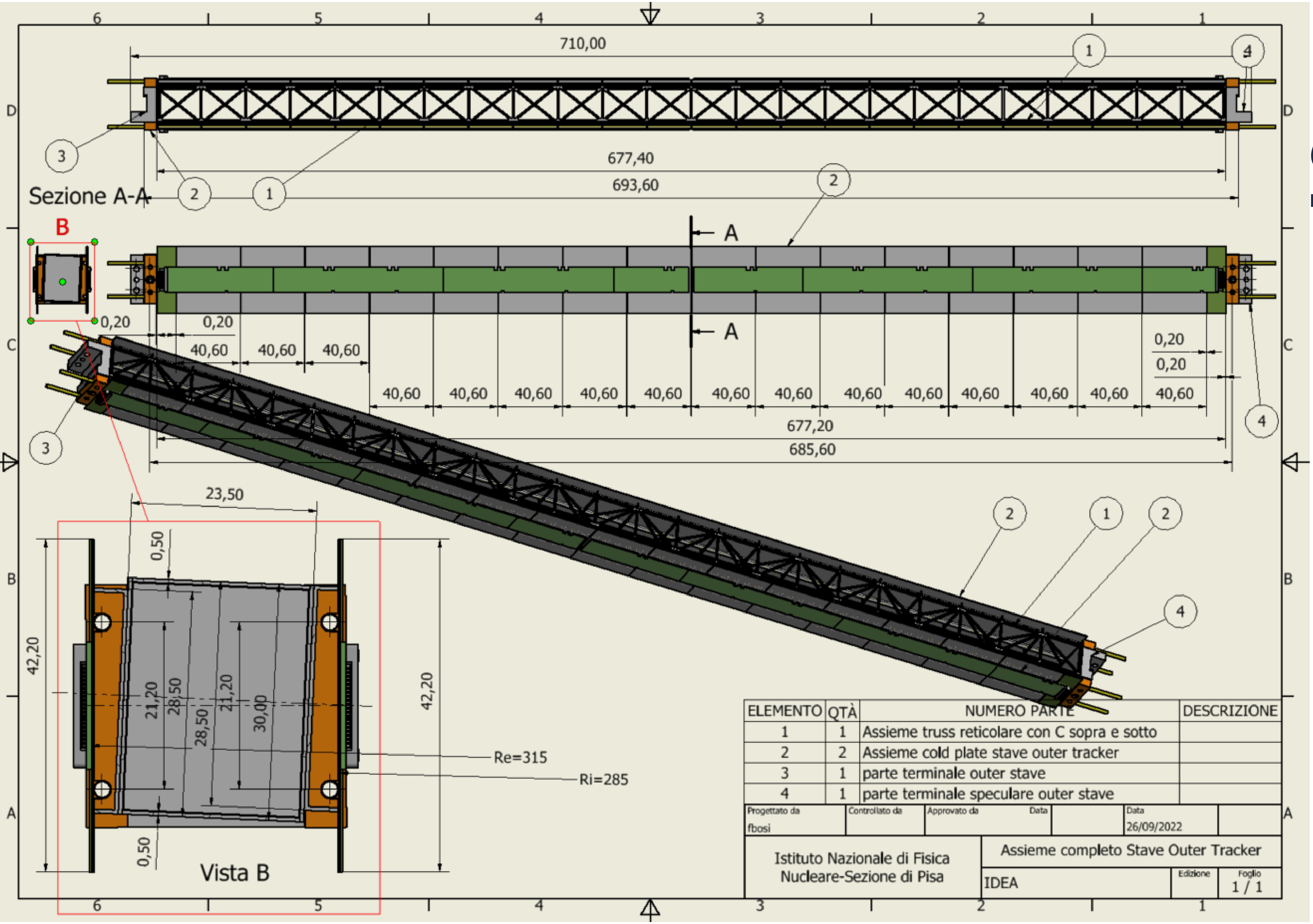
Support Carbon Fiber



Superseeded by the conical shape



ELEMENTO	QTÀ	NUMERO PARTE	DESCRIZIONE
1	1	Assieme truss reticolare con C sopra e sotto	
2	2	Assieme cold plate stave outer tracker	
3	1	parte terminale outer stave	
4	1	parte terminale speculare outer stave	

Progettato da	Controllato da	Approvato da	Data	Data
fbosi				26/09/2022

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Assieme completo Stave Outer Tracker

IDEA

Edizione

Foglio 1 / 1

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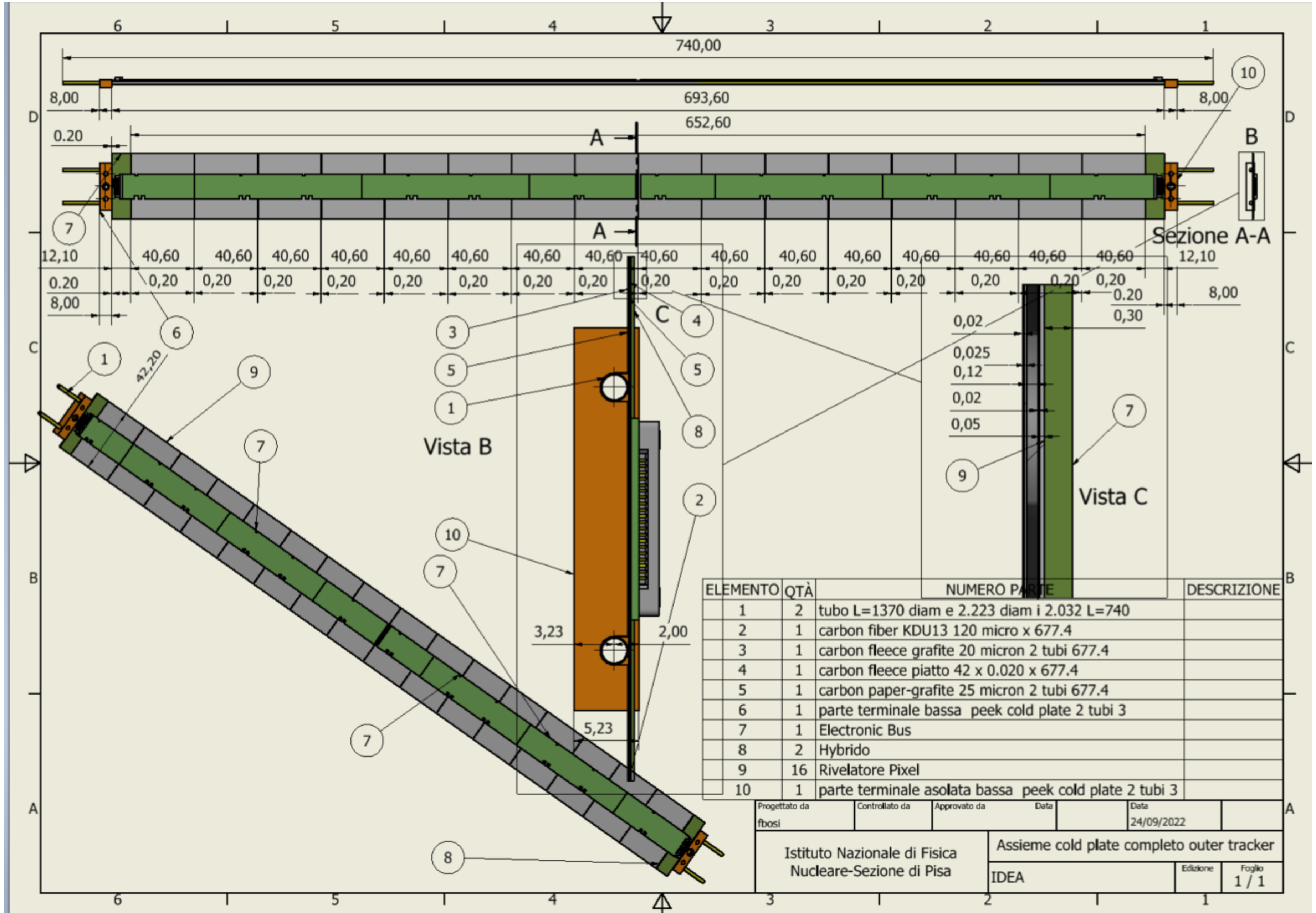
Cold stave



ELEMENTO	QTÀ	NUMERO PARTE	DESCRIZIONE
1	2	tubo L=1370 diam e 2.223 diam i 2.032 L=740	
2	1	carbon fiber KDU13 120 micro x 677.4	
3	1	carbon fleece grafite 20 micron 2 tubi 677.4	
4	1	carbon fleece piatto 42 x 0.020 x 677.4	
5	1	carbon paper-grafite 25 micron 2 tubi 677.4	
6	1	parte terminale bassa peek cold plate 2 tubi 3	
7	1	Electronic Bus	
8	2	Hybrido	
9	16	Rivelatore Pixel	
10	1	parte terminale asolata bassa peek cold plate 2 tubi 3	

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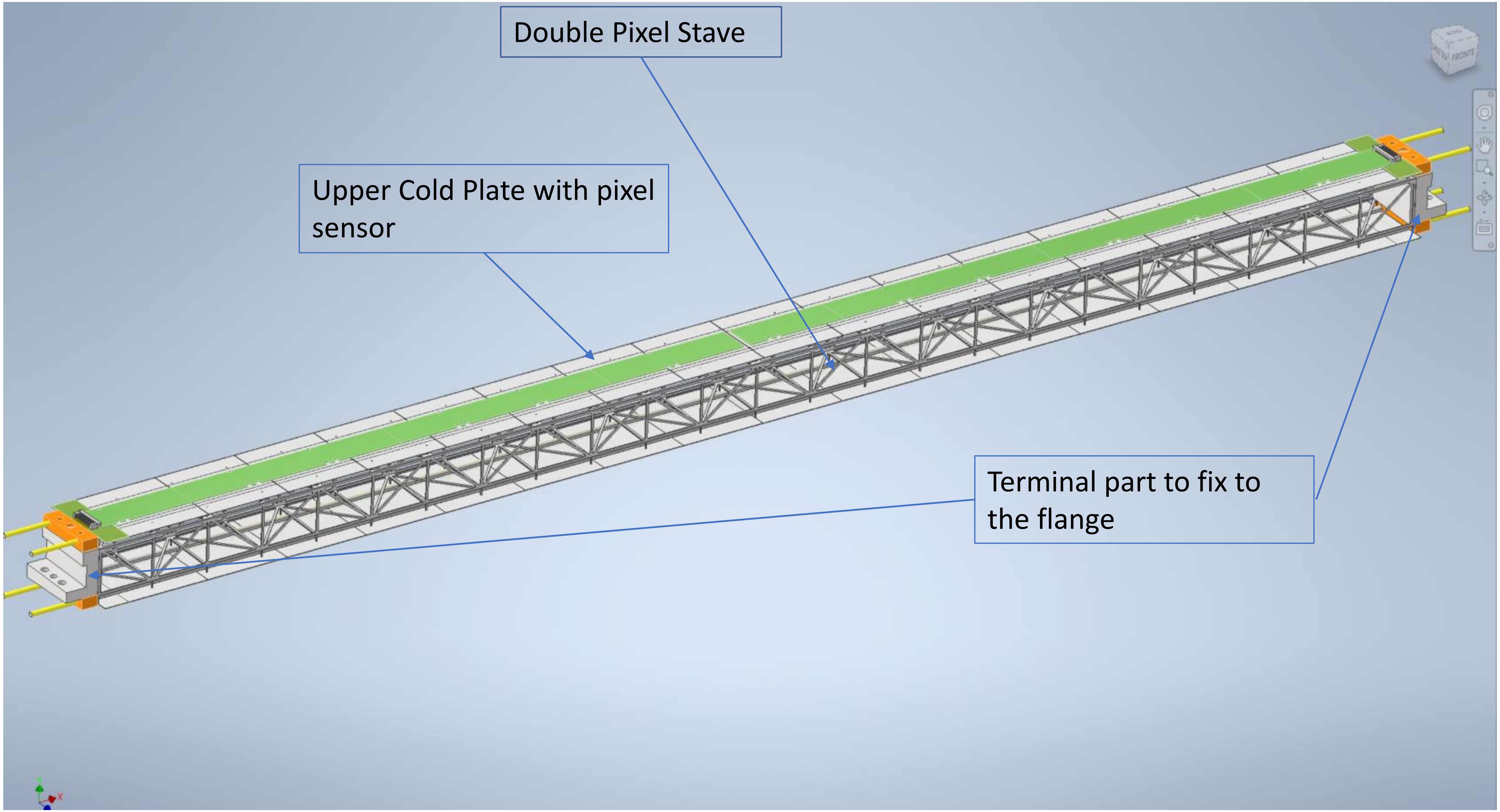
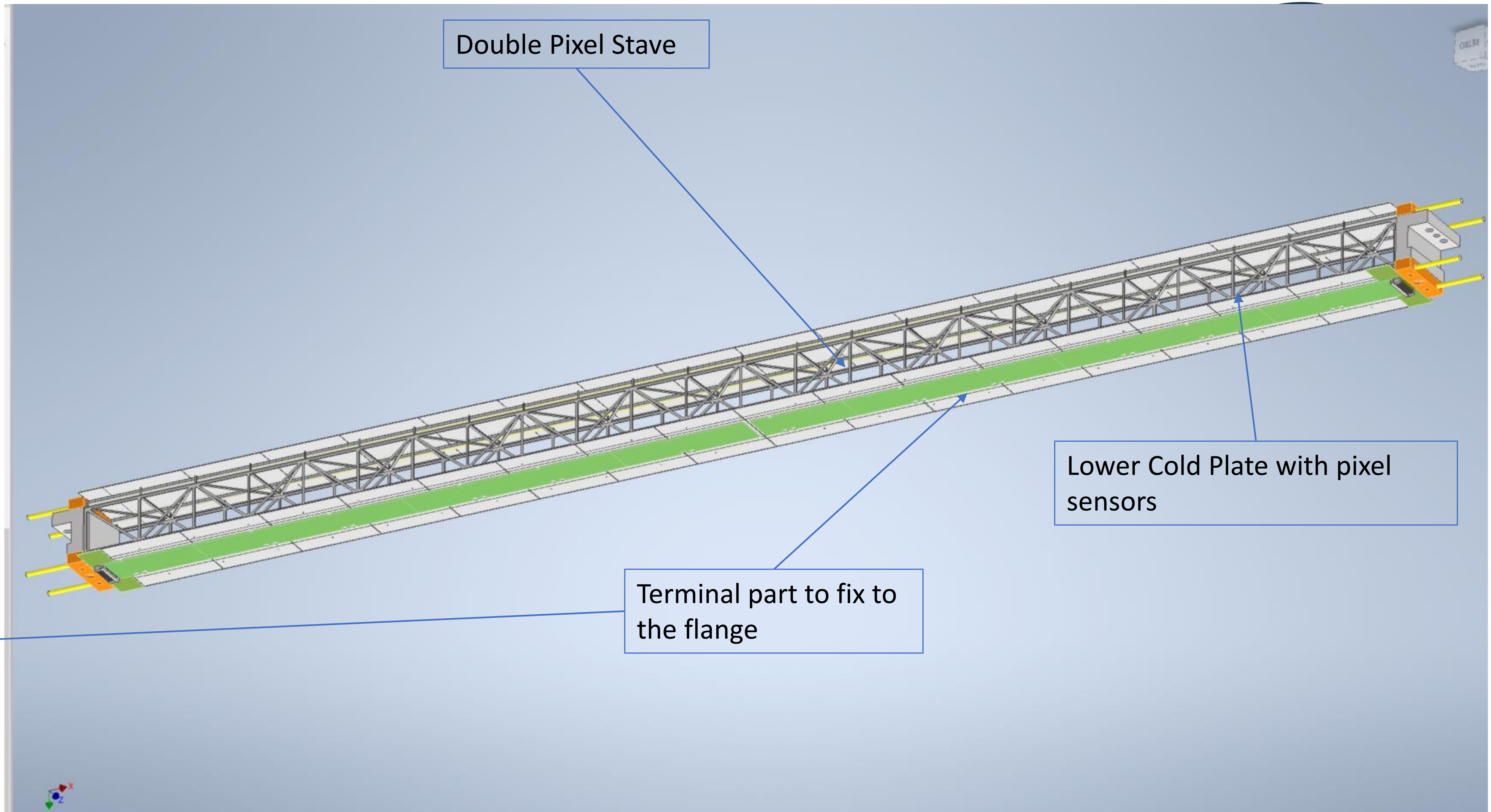
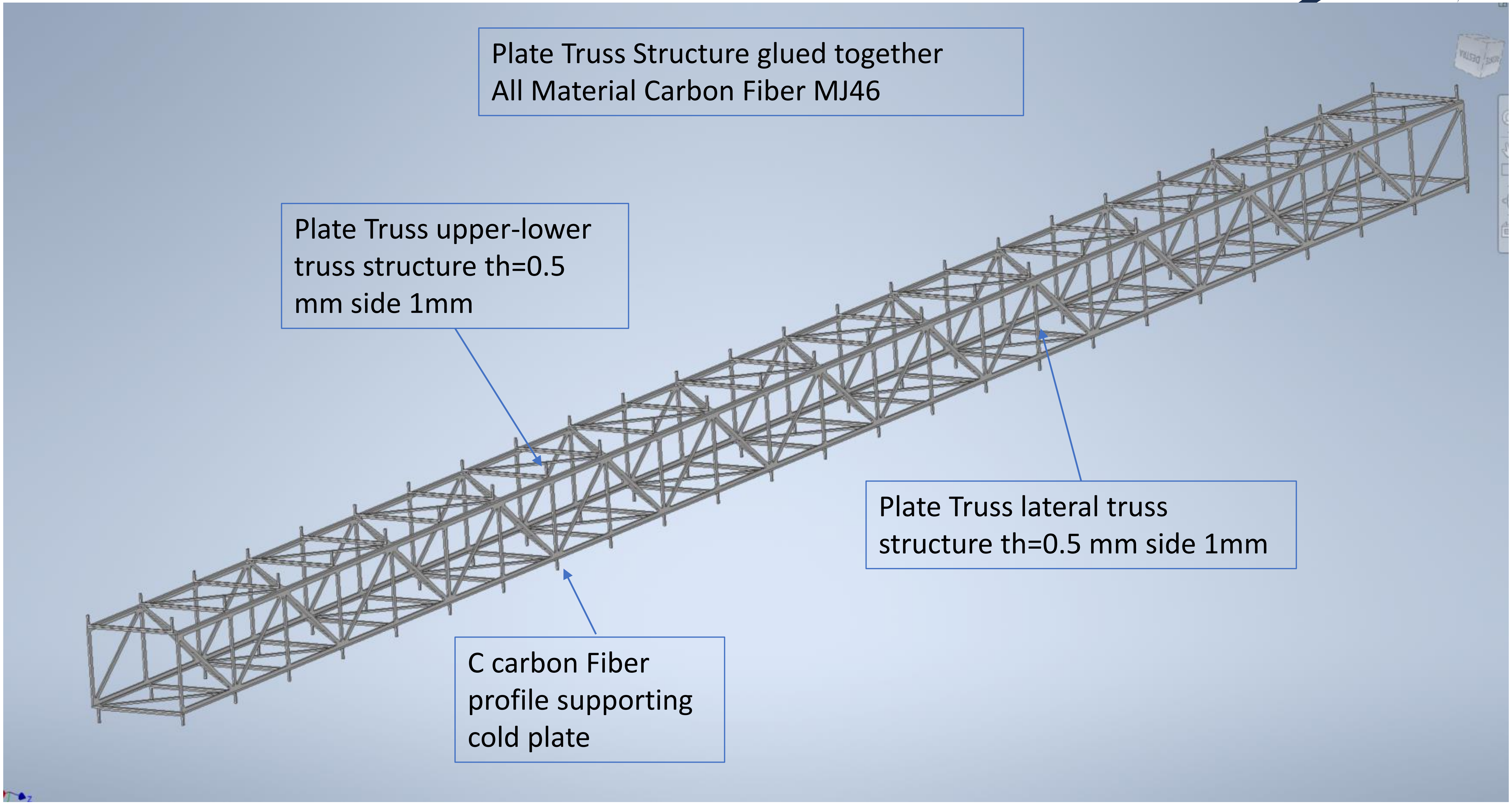
Stave Outer Tracker



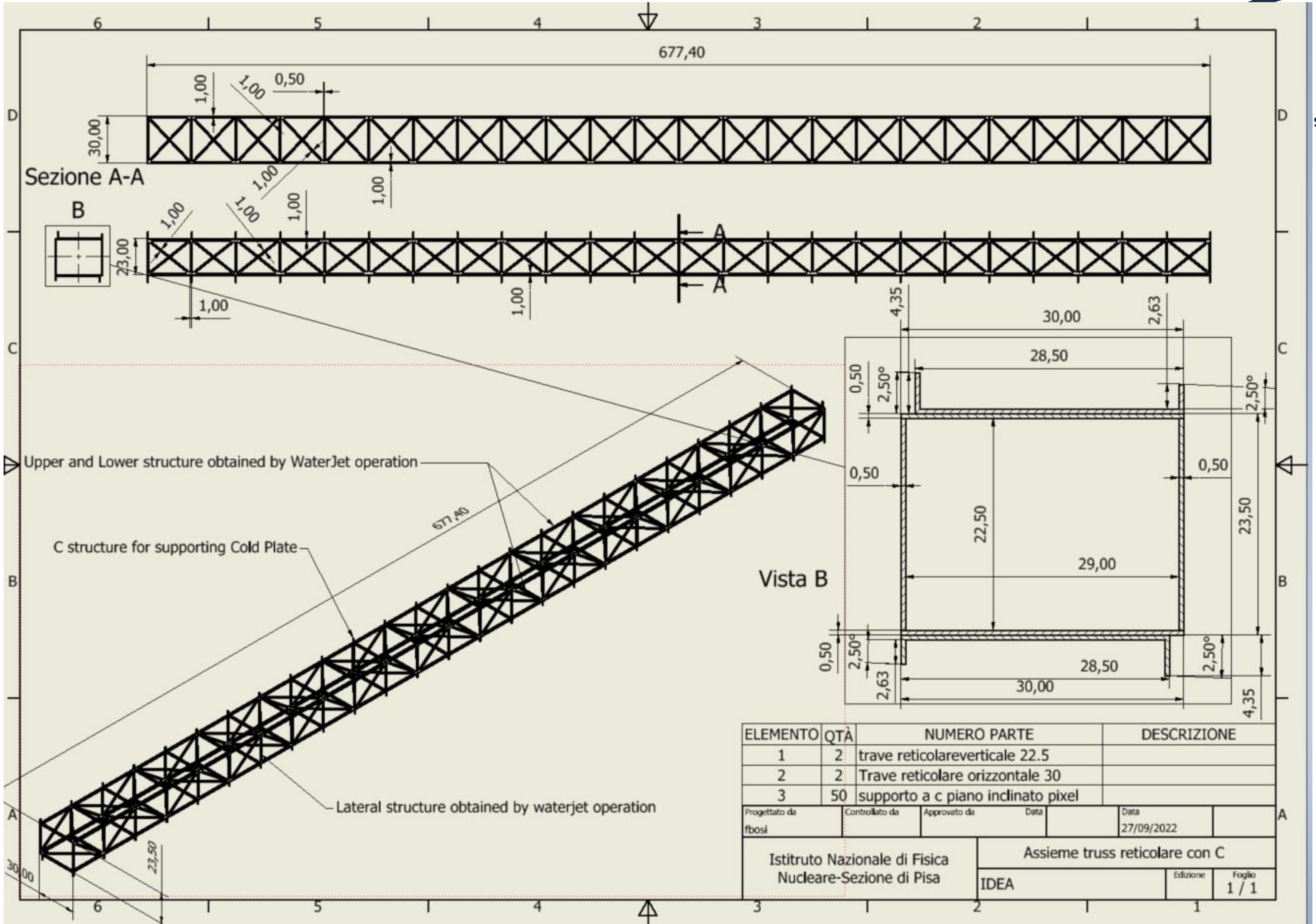
Stave Outer Tracker



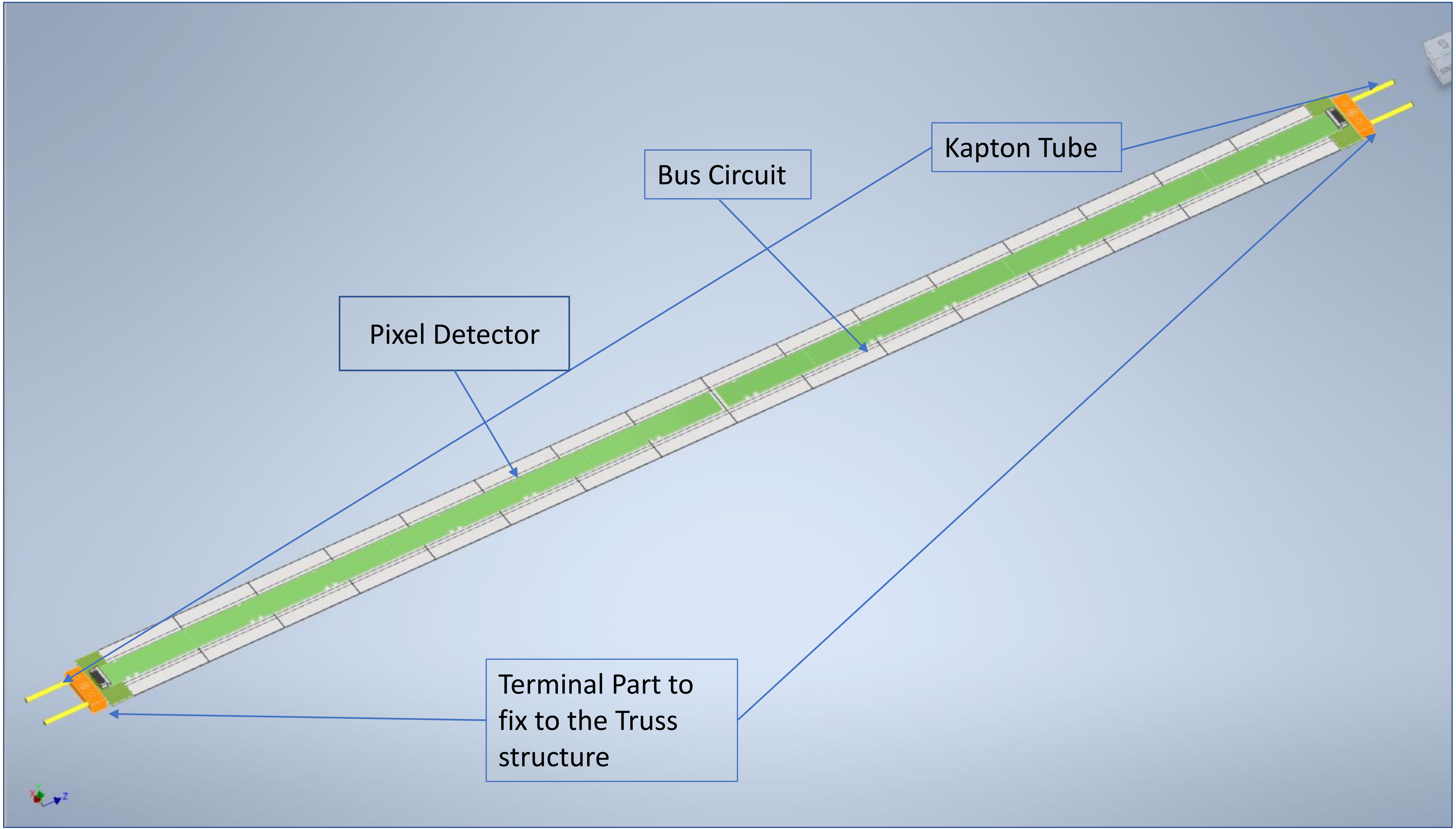
Truss Structure



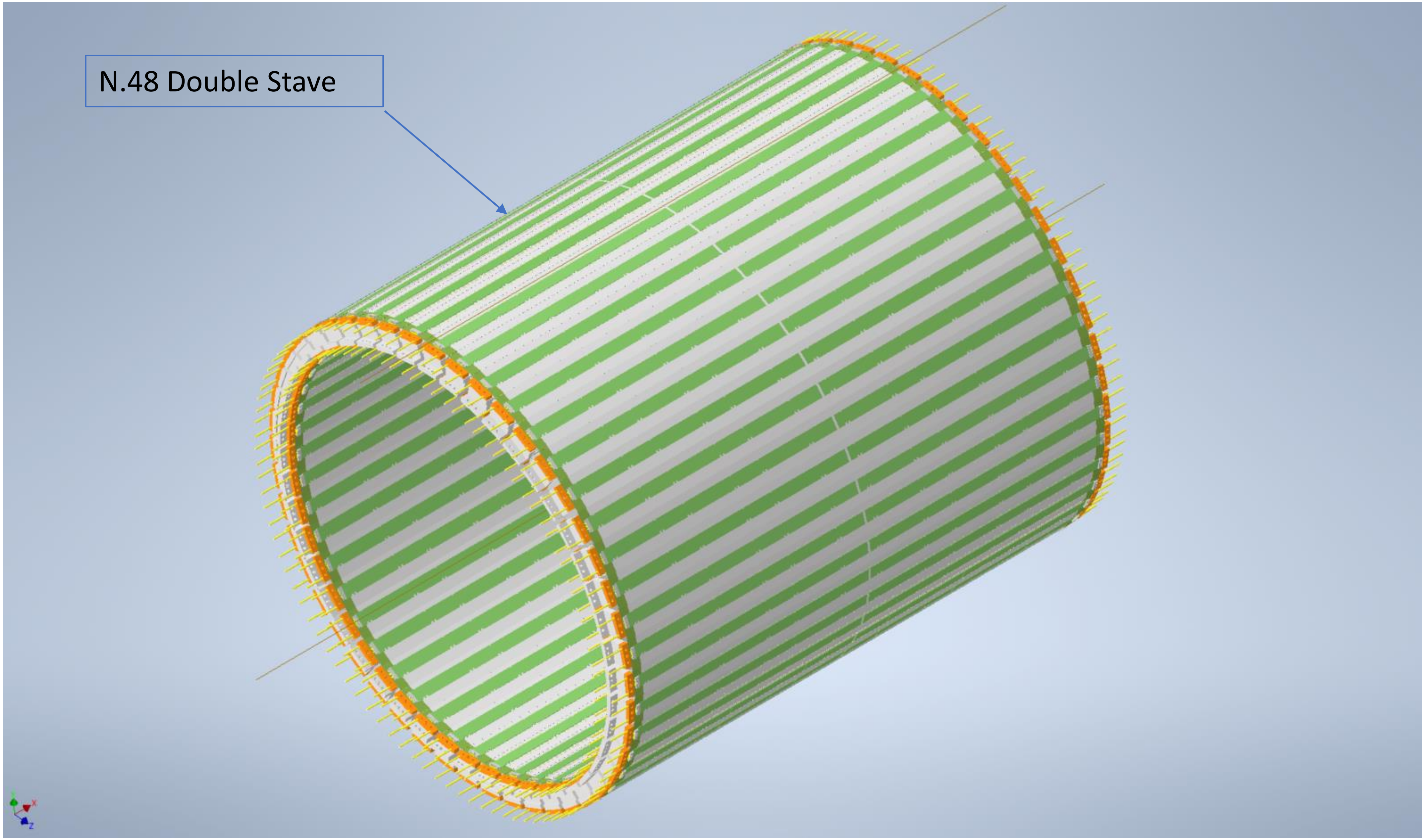
Truss Structure



Cold Stave


Kapton Tube
Bus Circuit
Pixel Detector
Terminal Part to
fix to the Truss
structure

Outer Tracker



Inner disk with conceptual mechanical support structure

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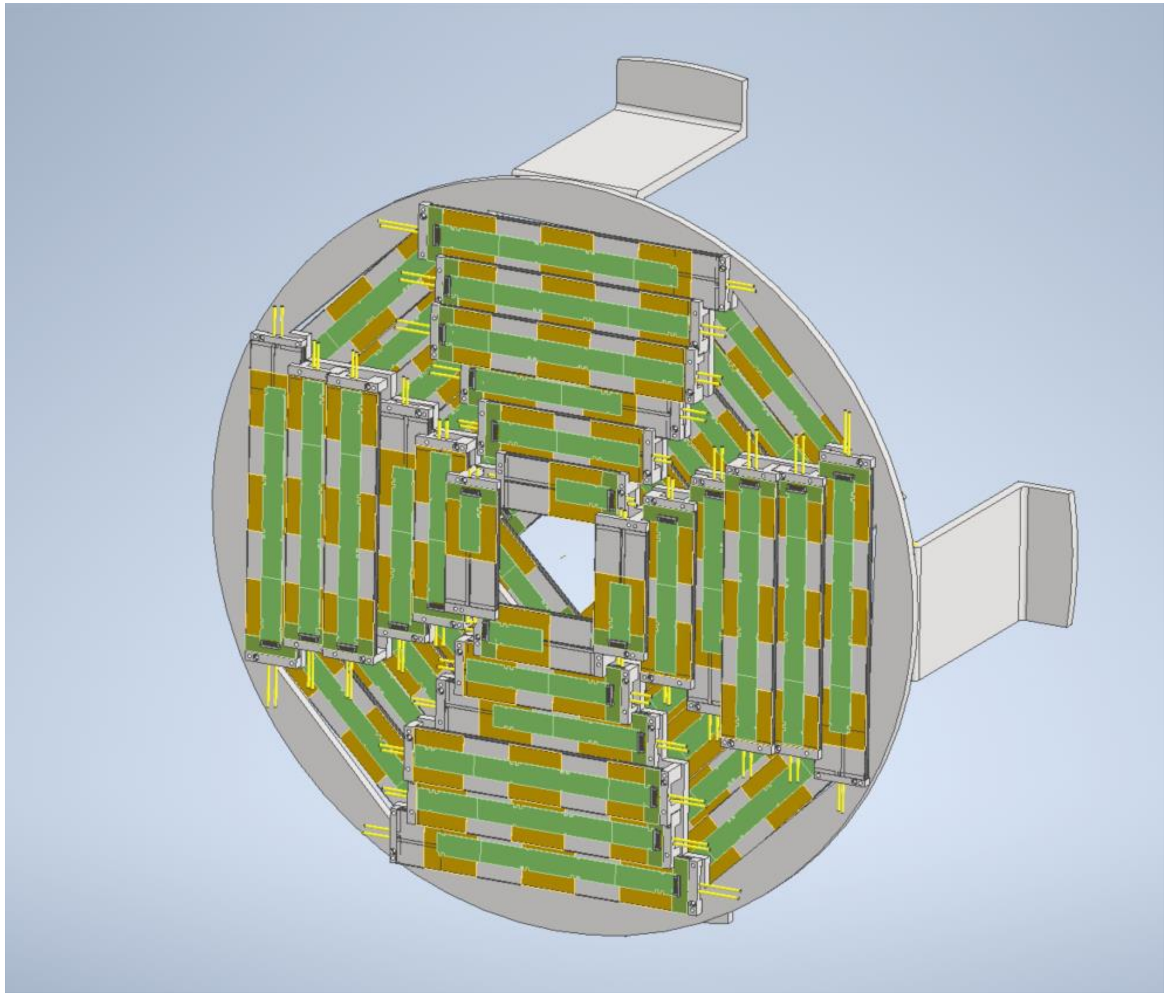

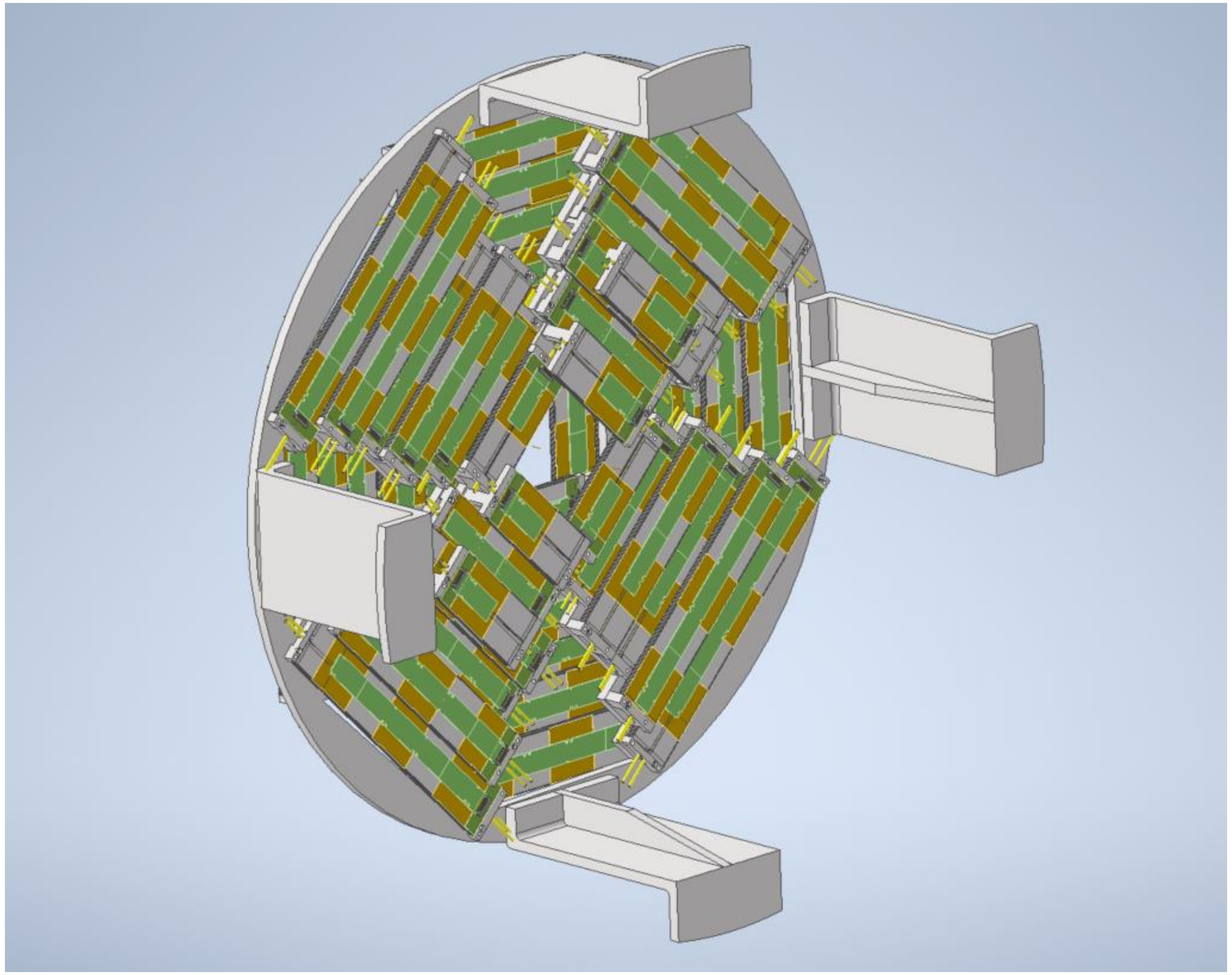

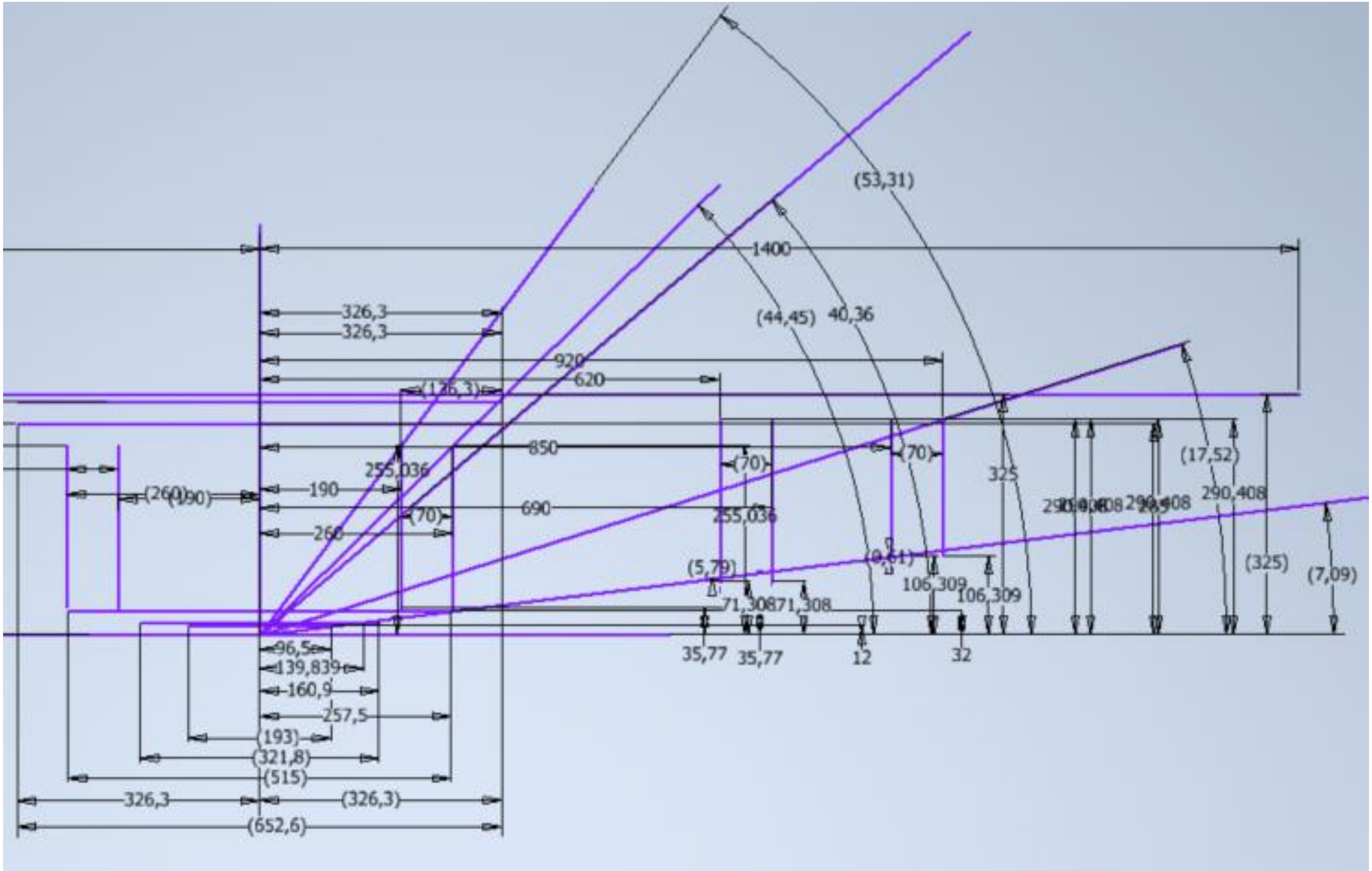

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