Detector integration in the interaction region

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on behalf of

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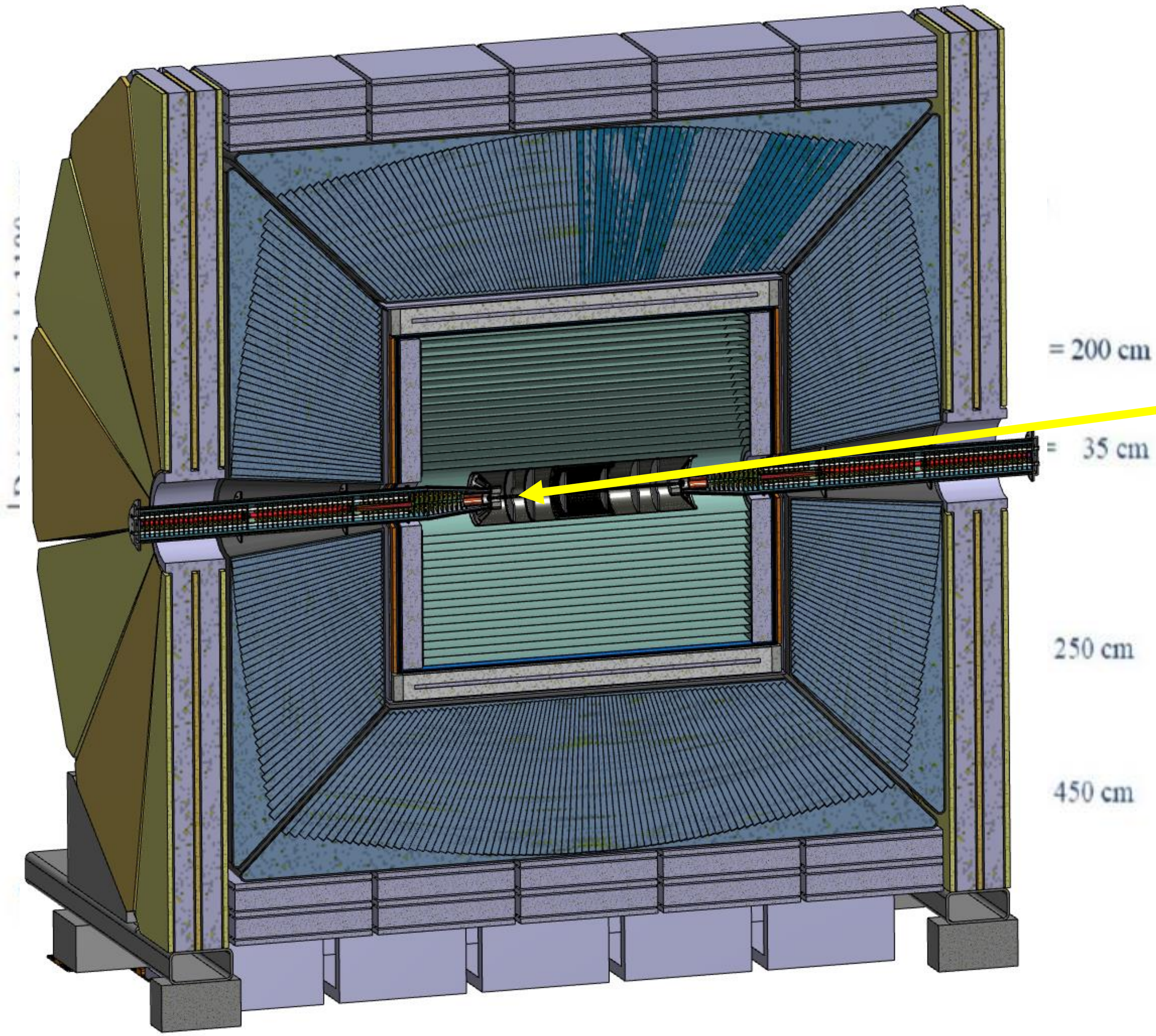
(*) Thanks to M. Dam (NBI, Copenhagen) for the part on Lumical



- 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)
  - Support structure should house the luminometer
  - The mounting of the vertex and the outer tracker must be done inside the support tube
  - Minimize the radiation lengths

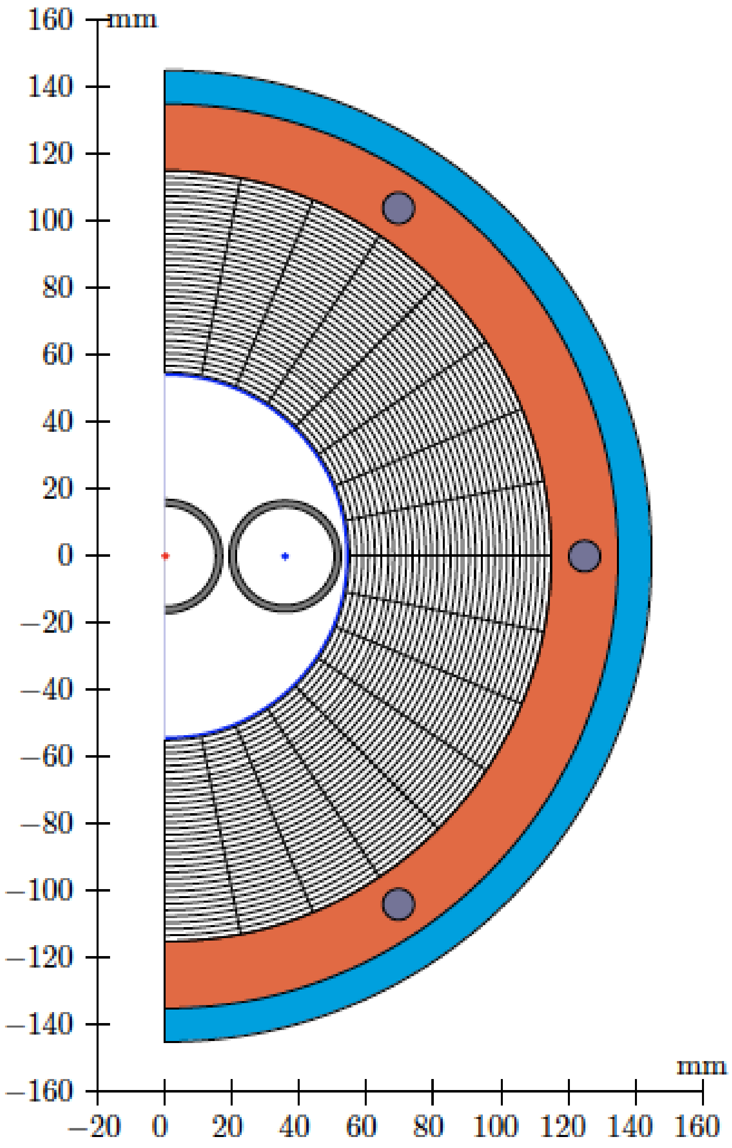
CDR LumiCal Design

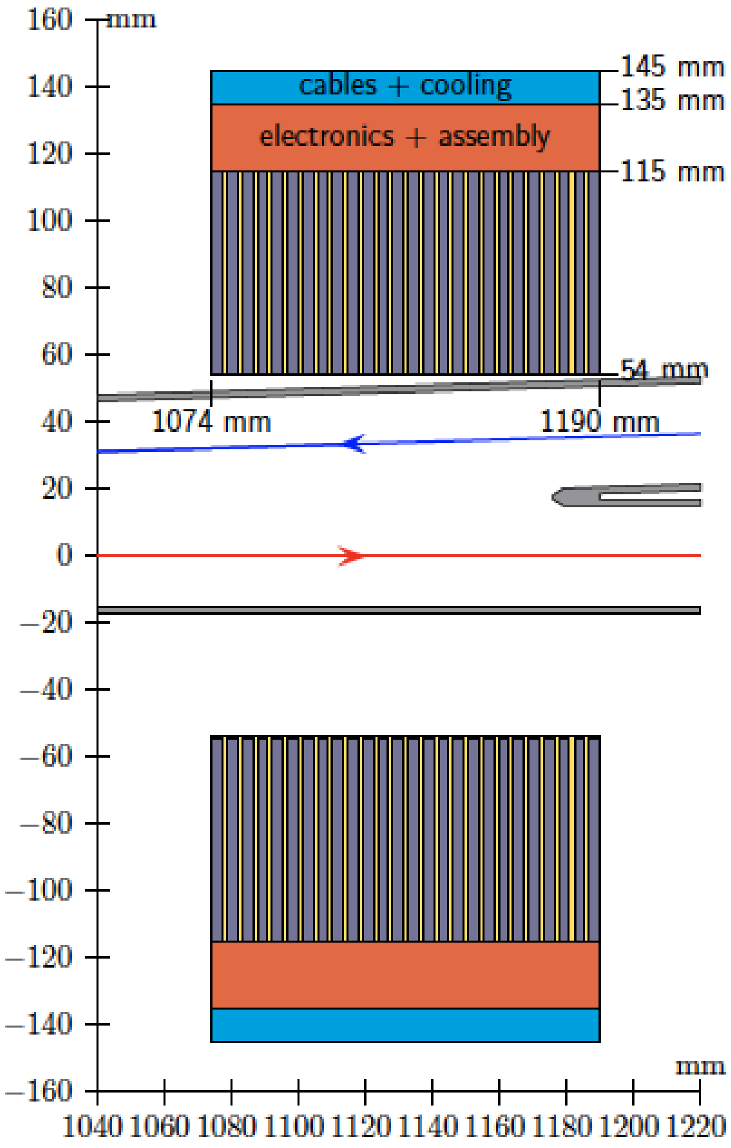
Design considerations:

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

Multilayer barrels where all layes have identical circular geometry

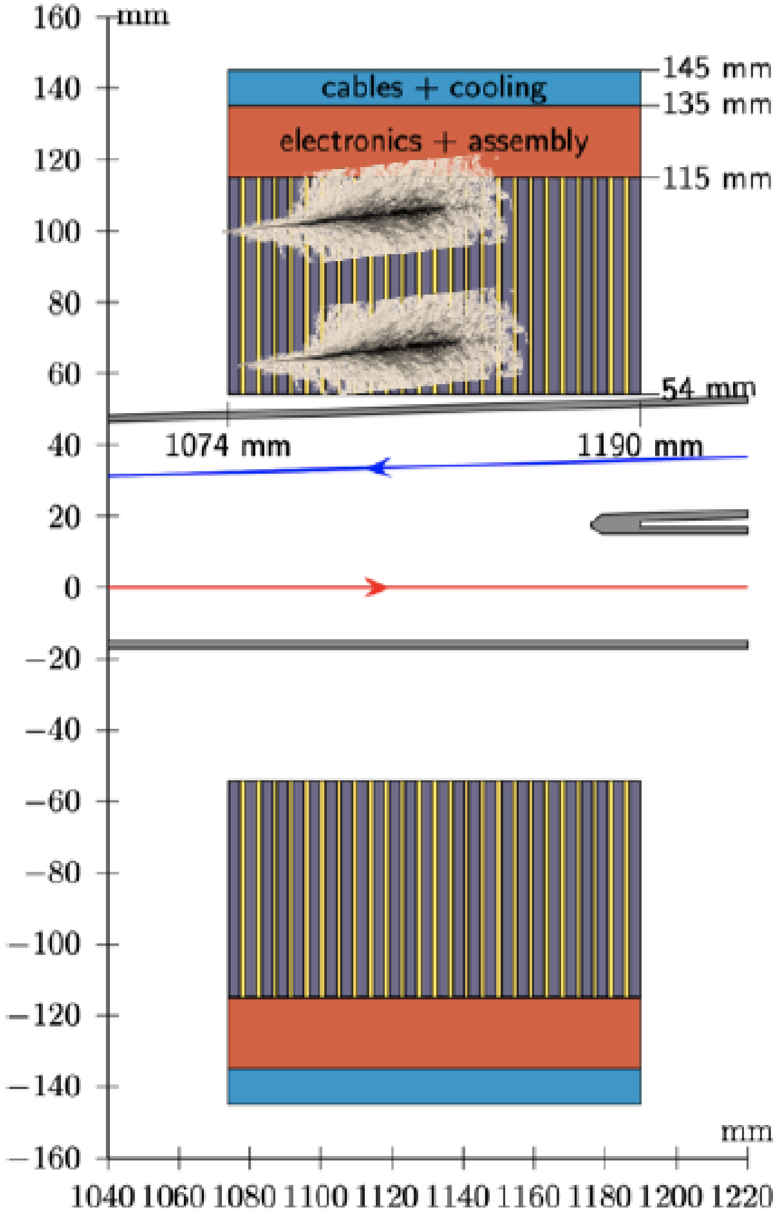
- 25 layer SiW sandwich
  - 3.5 mm W (1 X_0) + 1.0 mm gap for Si pads
- Physical dimensions
  - Sensitive region: r = 54-115 mm
  - Region for "services": 115-145 mm
  - Calorimeter face at x = 1074 mm
- Proposed segmentation
  - 32x32 pads/layer (1.9 x 10-22 mm² pads)
  - 25,600 channels per LumiCal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



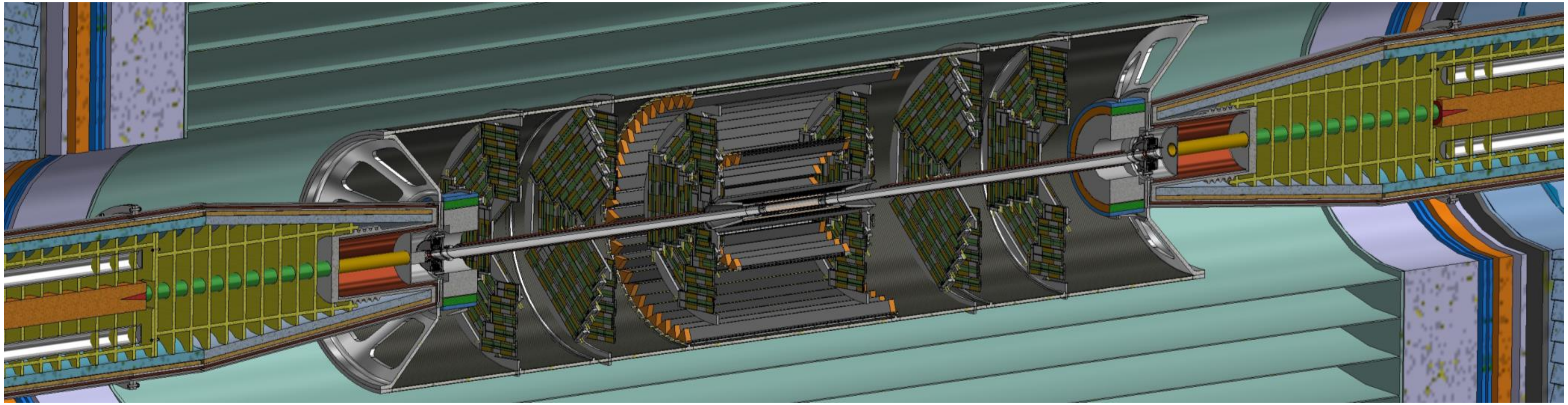


Acceptance and tolerances

- 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 (2 barrel layers 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

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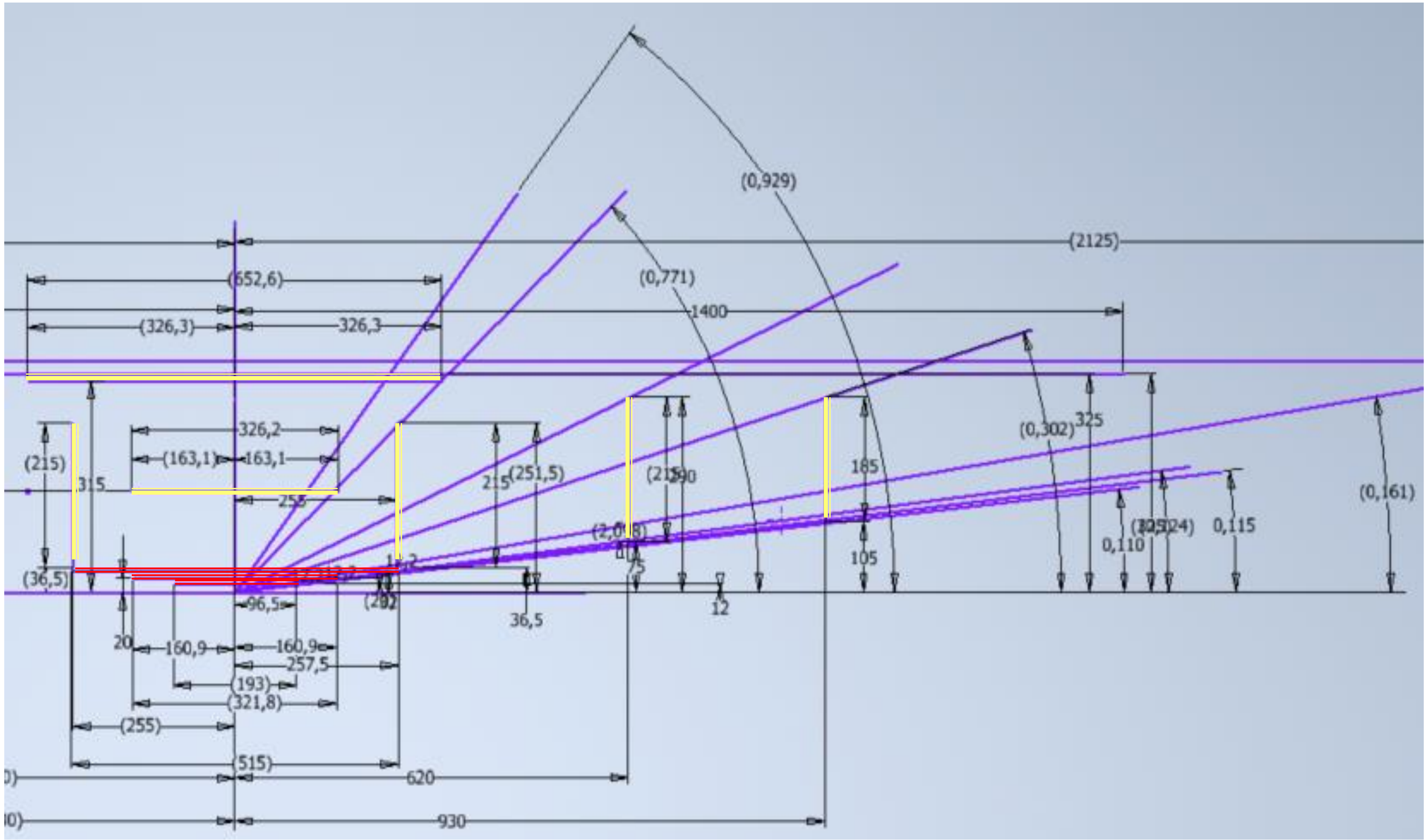
Conceptual layout



Outer tracker:

Modules of $50 \times 150\ \mu m^2$ pixel size

- Intermediate barrel at 15 cm radius (improved reconstruction for $p_T > 45$ MeV tracks)
- Outer barrel at 31.5 cm radius
- 3 disks per side

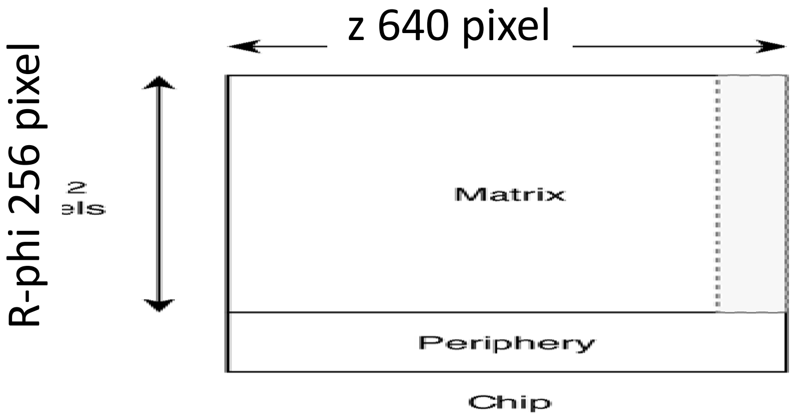
Vertex detector:

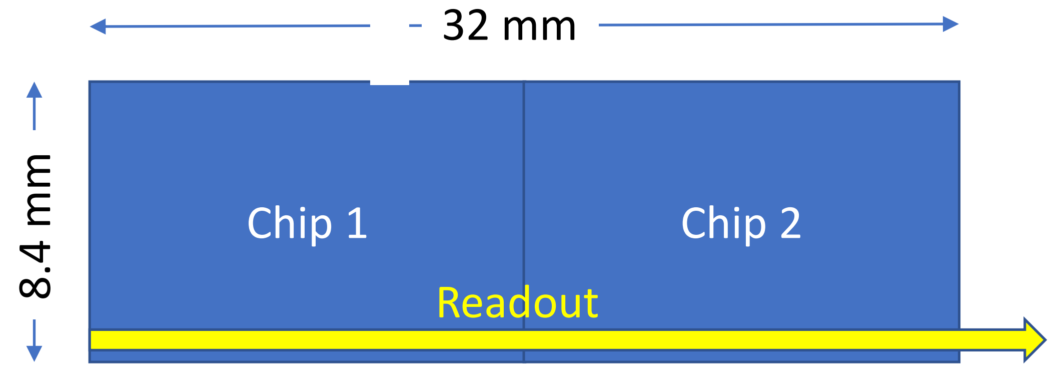
Modules of $25 \times 25\ \mu m^2$ pixel size

3 barrel layers at
- 12, 20 and 31 mm radius

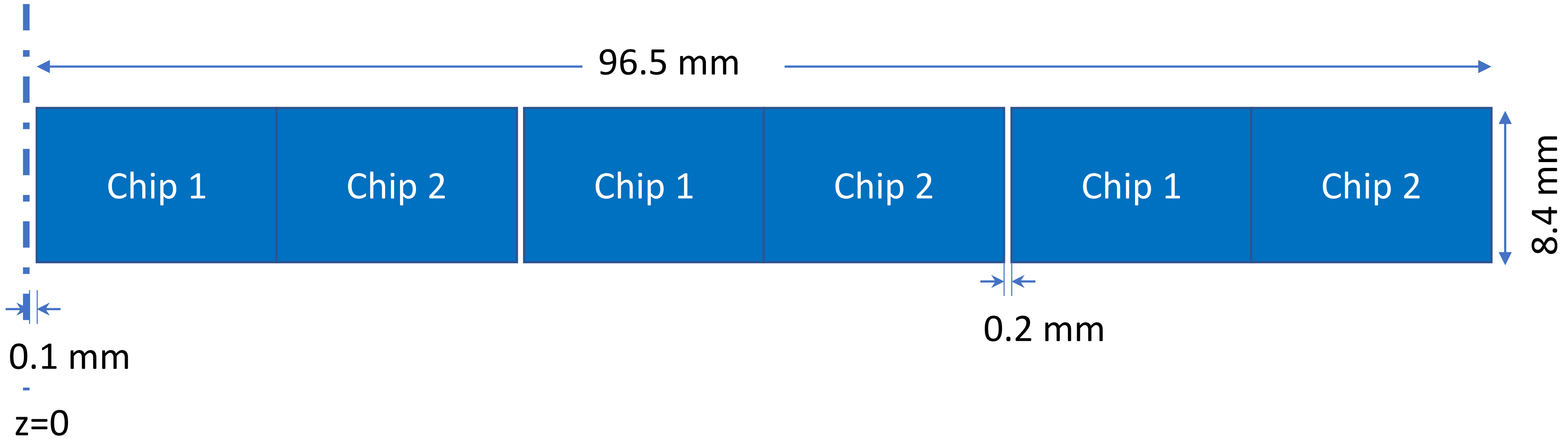
Vertex detector modules

- 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 $50\ \mathrm{mW/cm^2}$



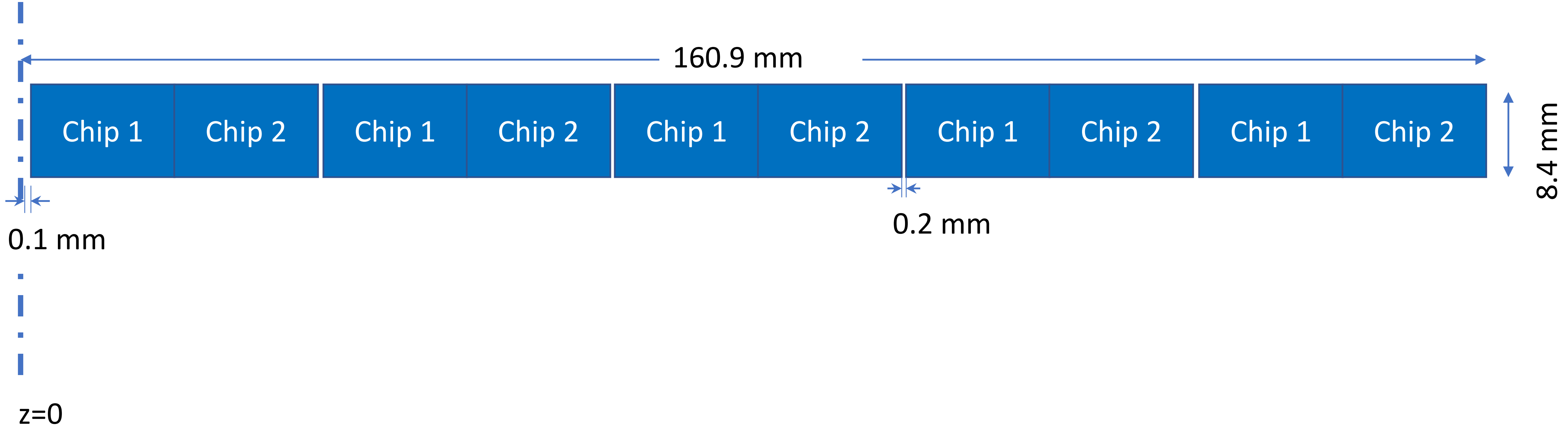


Half-ladder layout – layer 1



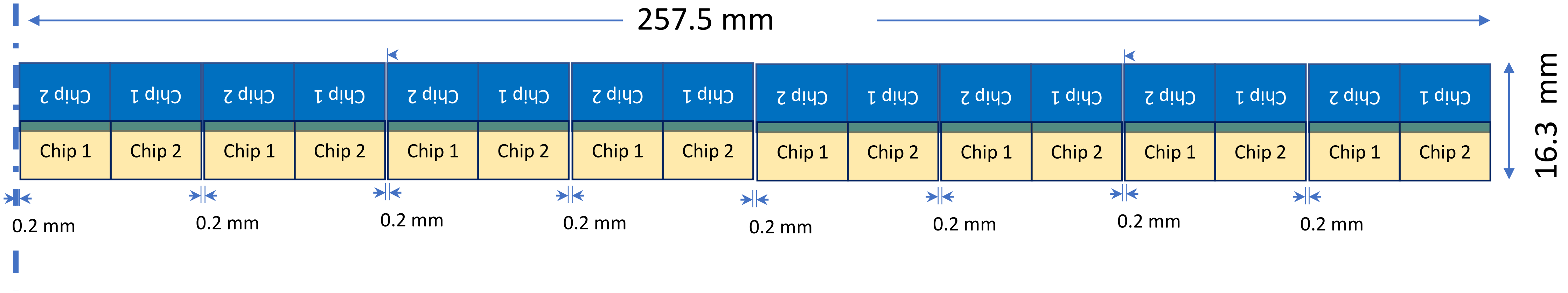
Layer 1 ladders are placed at 12 mm radius

Half-ladder layout – layer 2



Layer 2 ladders are placed at 20 mm radius

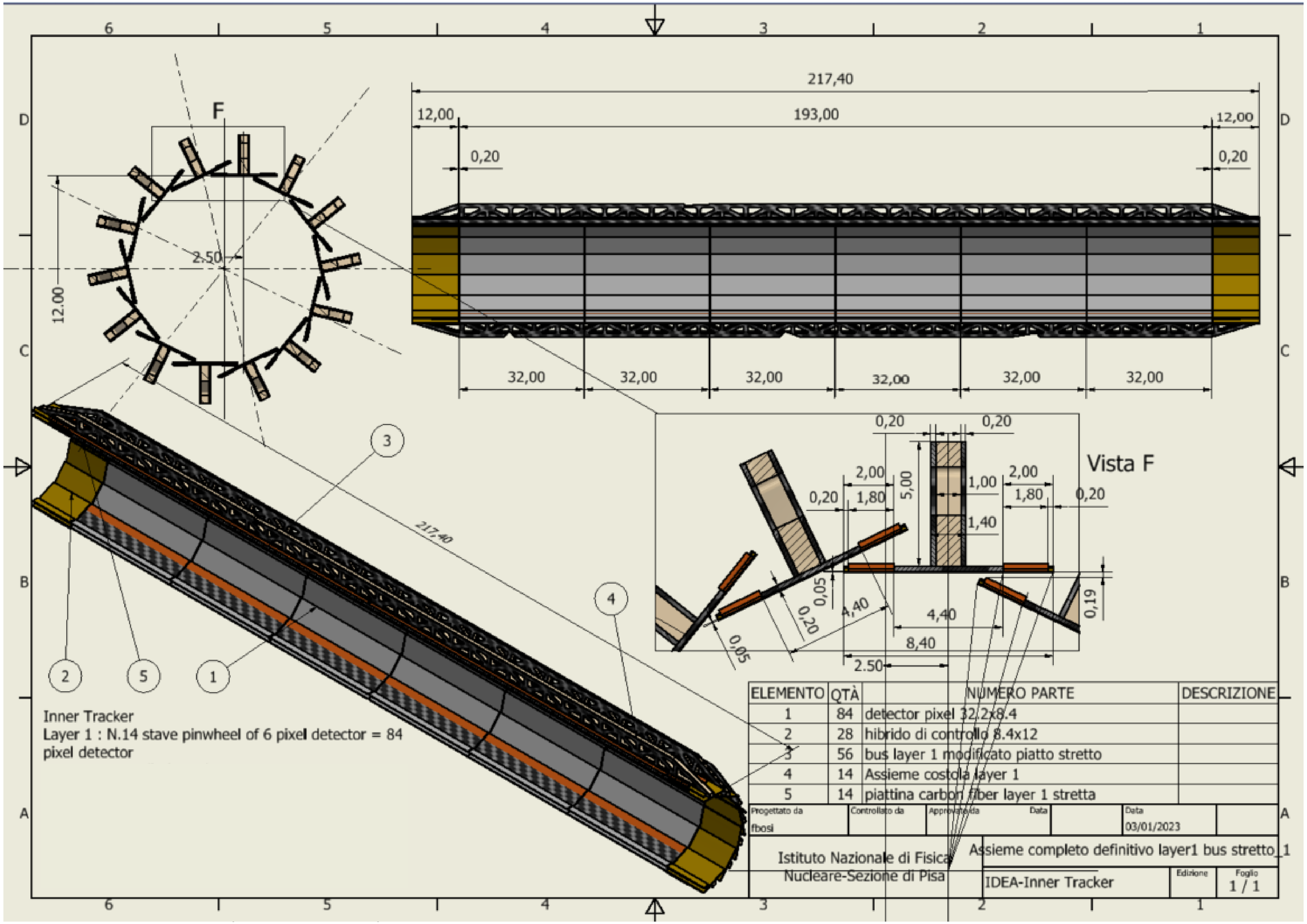
Half ladder layout – layer 3



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 between 30.5 and 31.05 mm radius



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Layer 1

14 overlapping staves of 6 modules each

Pinwheel geometry: all modules at the same (smallest) radius

Power budget ~11 W

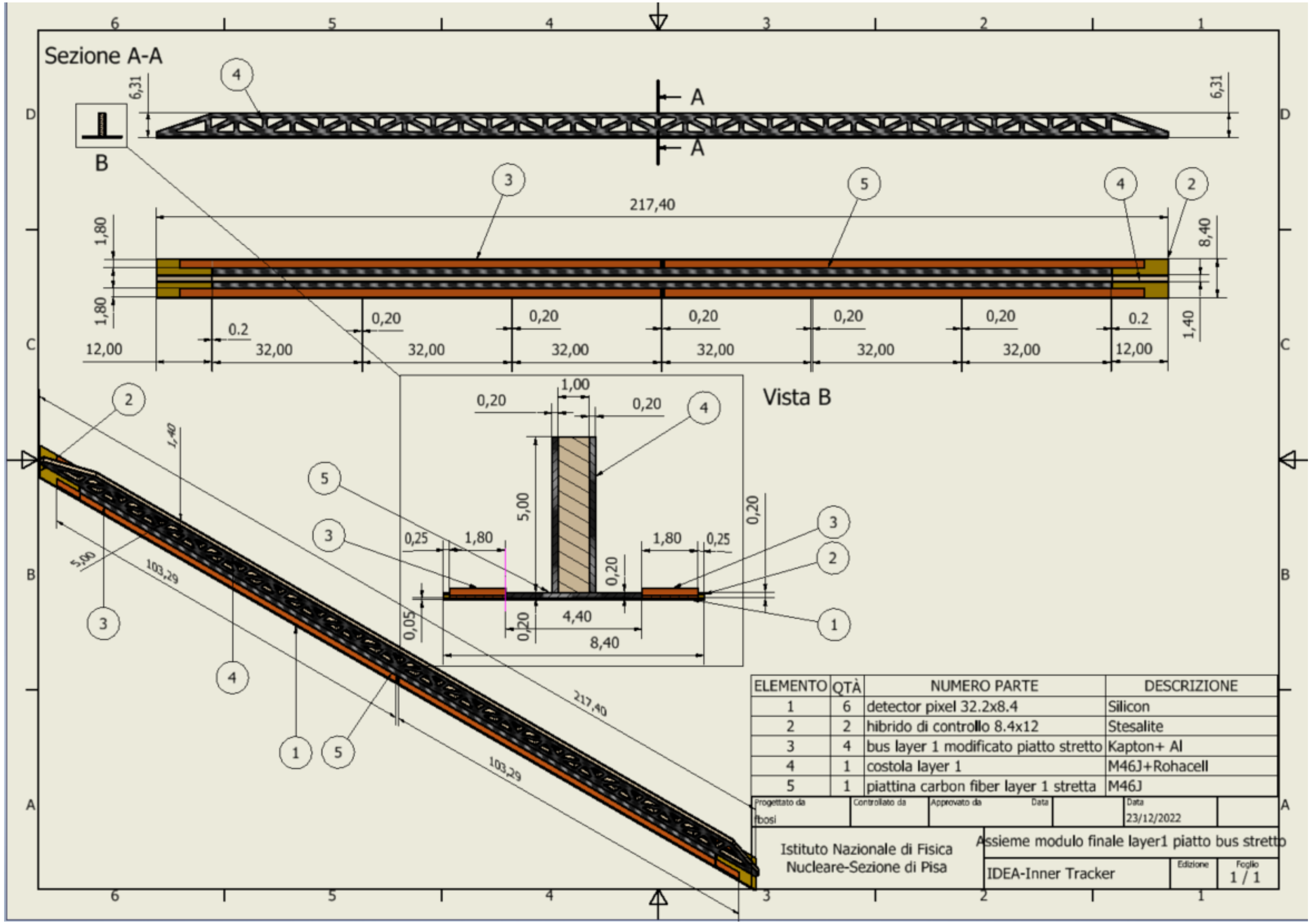
DISCLAIMER:

Mechanical supports very preliminary, mainly for MDI integration at this stage (for all layers)

Mechanical supports are being optimised for material budget

Power and signal distribution yet to be fully engineered

Layer 1 stave detail



Reticular lightweight support to provide stiffness

- Thin carbon fiber walls interleaved with Rohacell
- 2 buses (data and power) 1.8 mm wide each per side.

Sensors facing interaction point w/o any other material in front

Readout chips either sides

Air cooled

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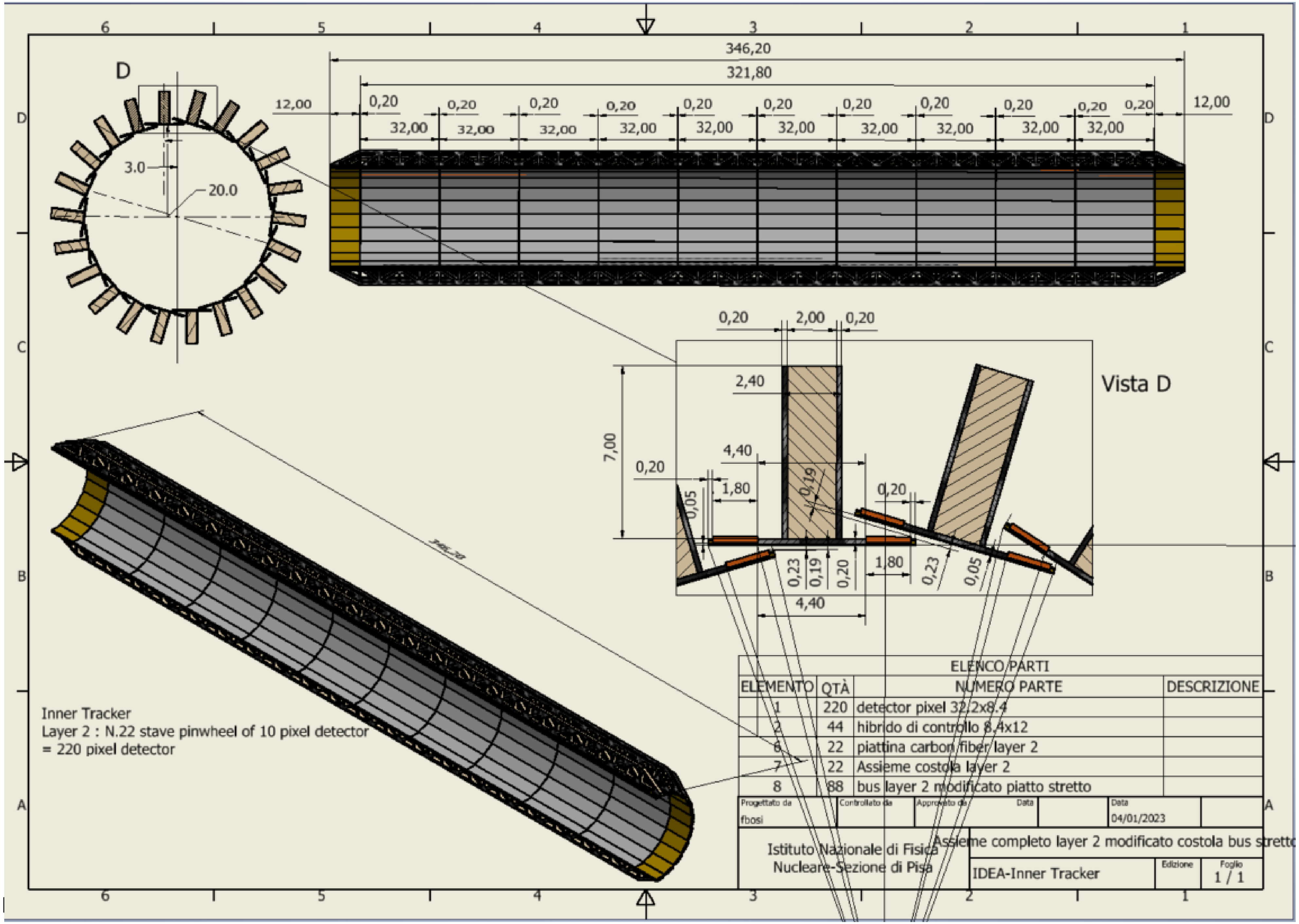

Layer 2

22 overlapping staves of 10 modules each

Pinwheel geometry Counter-rotated wrt layer 1 to mitigate charge-asymmetry effects in track reconstruction

Power budget ~30 W

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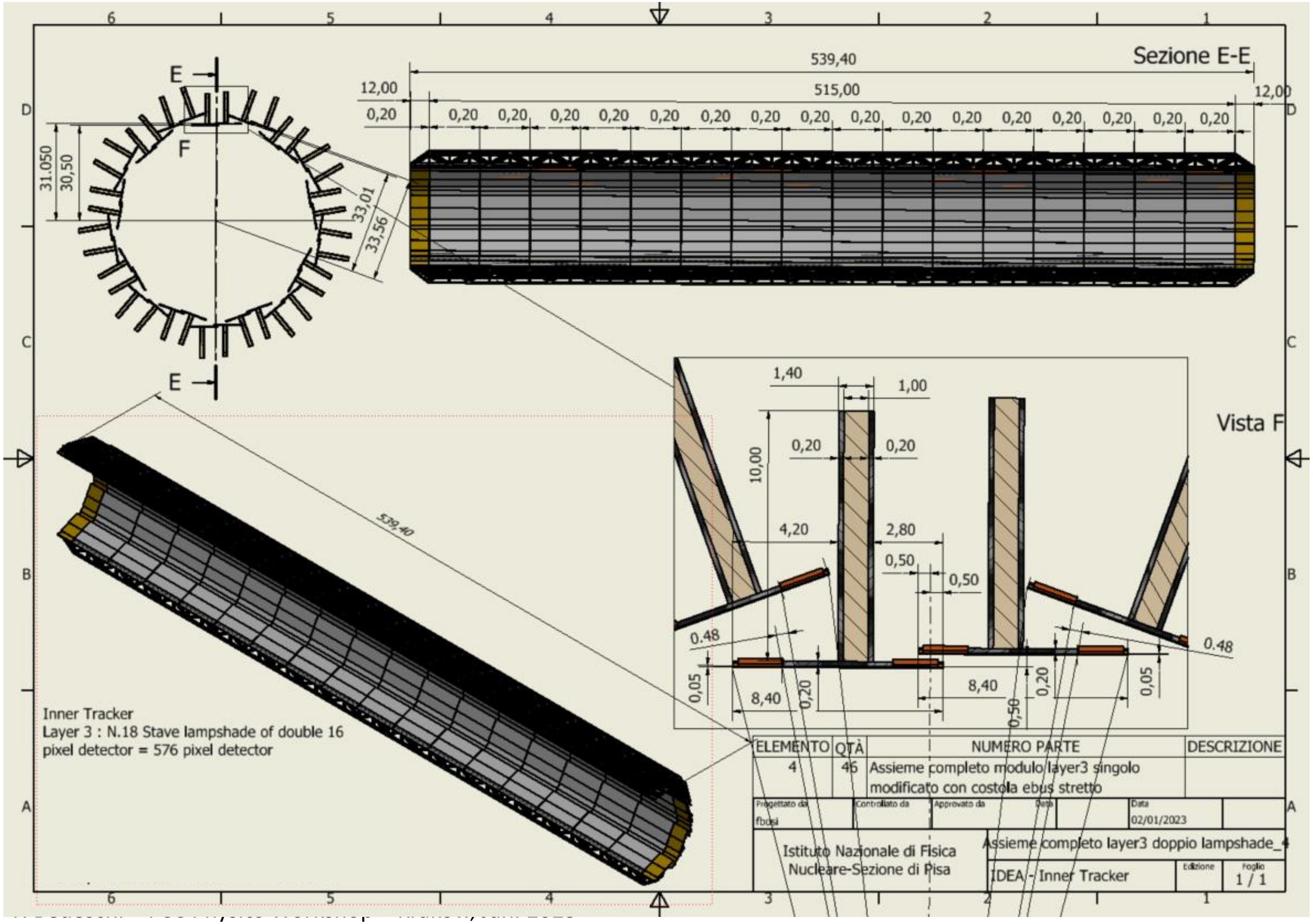


Layer 3

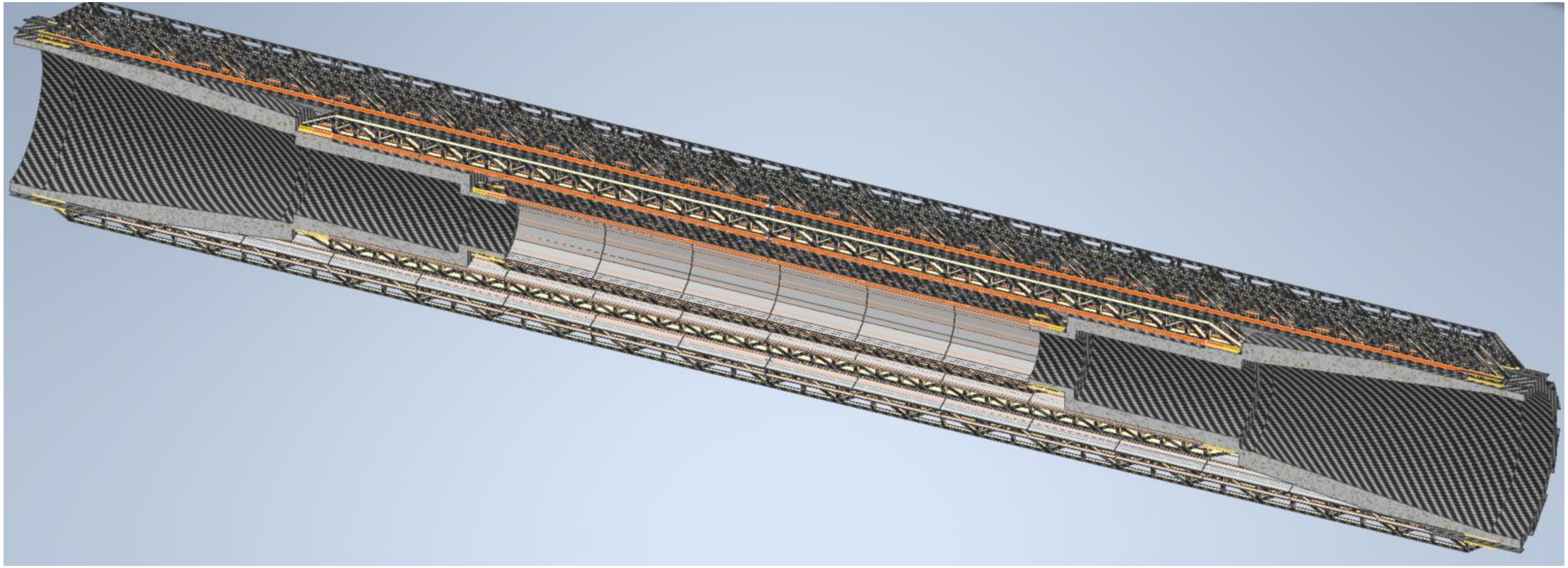
18 overlapping staves of double 16 modules each

Lampshade geometry. Charge symmetric track reconstruction

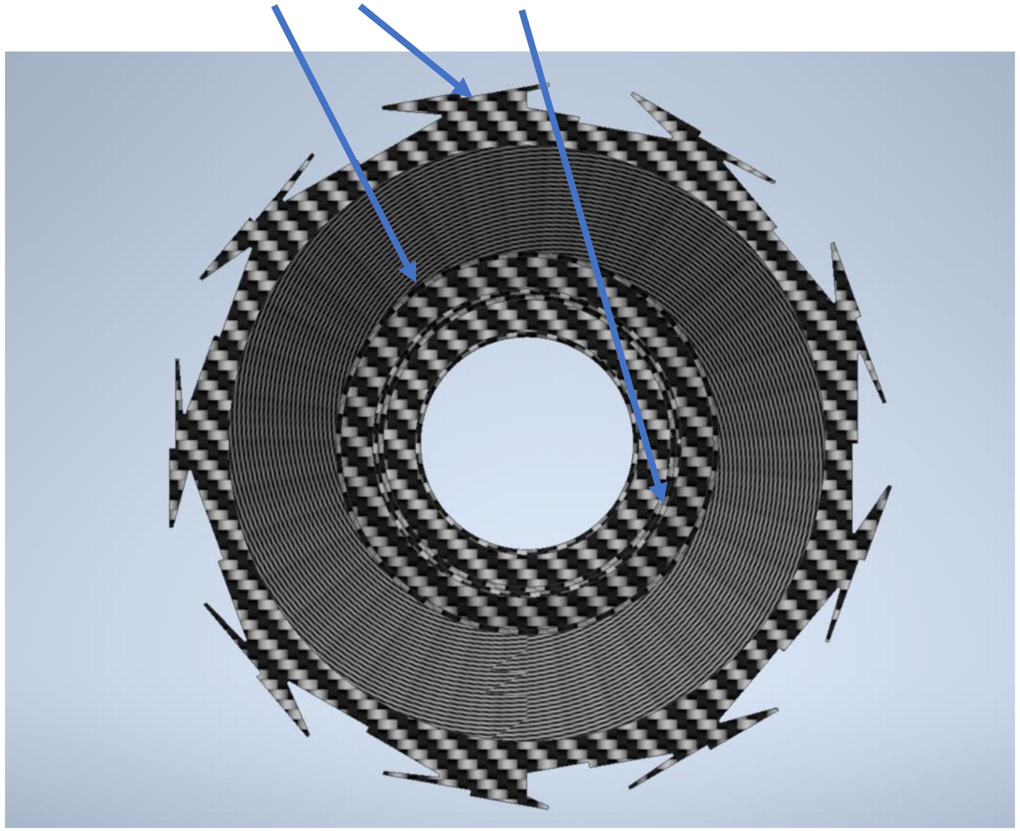
Power budget ~77 W

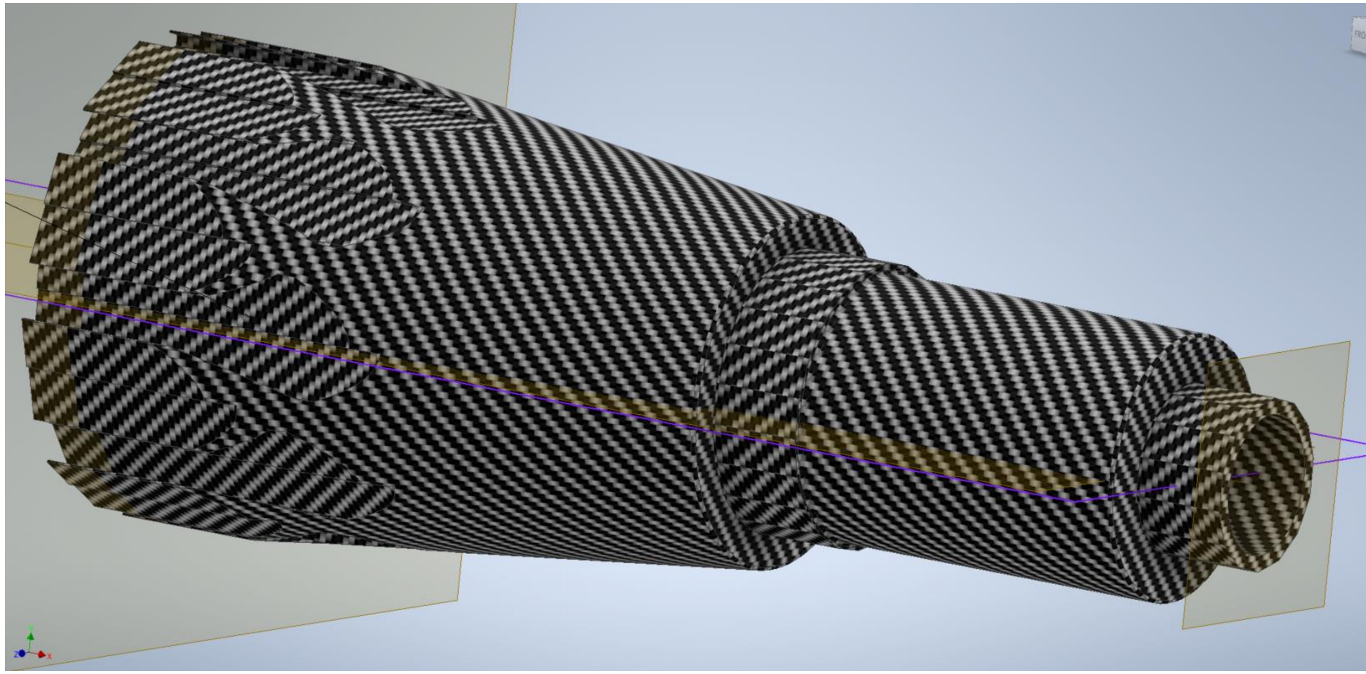
Vertex layer supports

- Conical carbon fibre shaped structure, held by the beam pipe



Carbon fibre support details





Being engineered.
It will also bring air ducts for refrigeration

Air cooling for Belle-II upgrade

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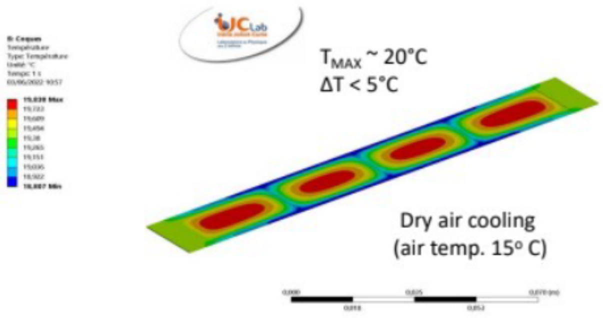
AIDA innova

WP10.2

Integrated micro-channels

Thin multi-CMOS-chip Silicon structures for Belle 2 upgrade Thermo-mechanical demonstrator submitted to IZM by Valencia and Bonn, thermal simulations in IJCLab Paris



CSIC

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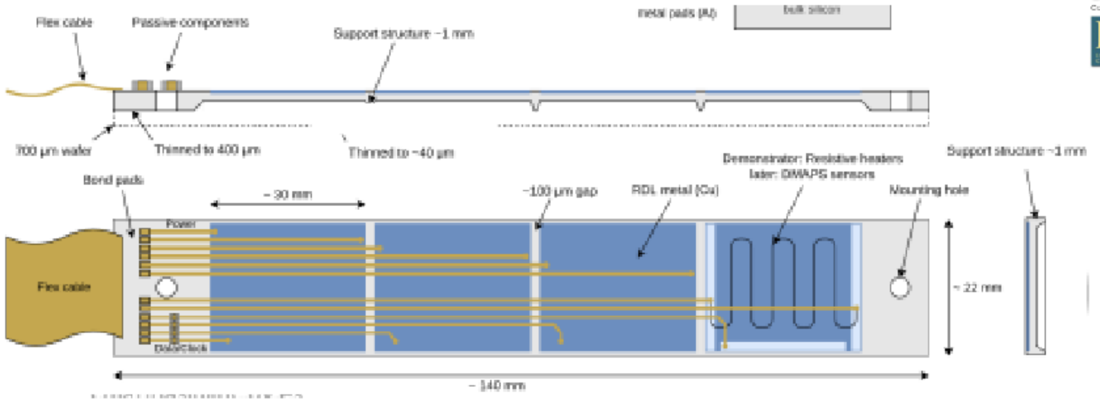
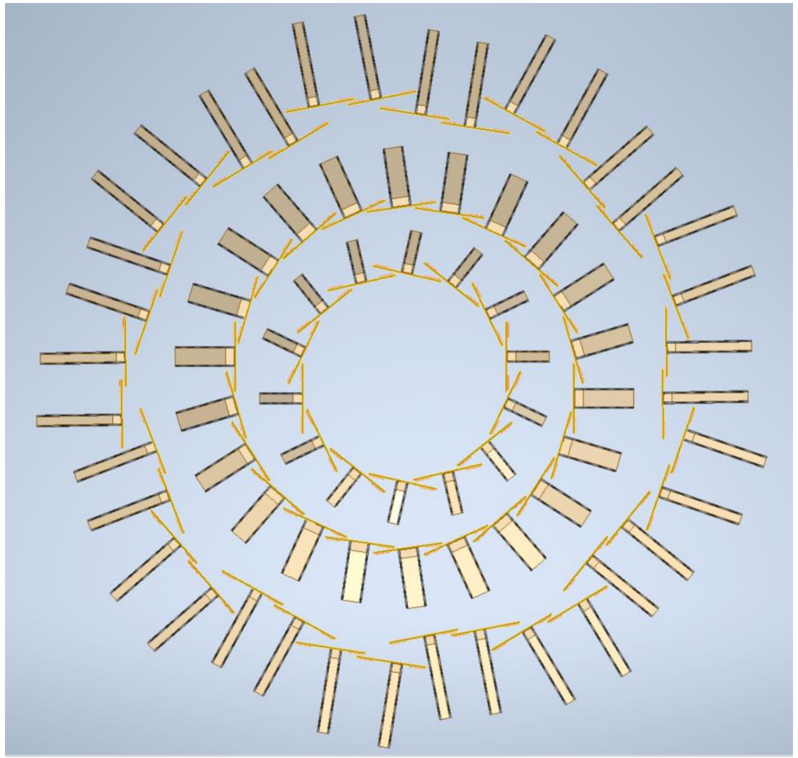
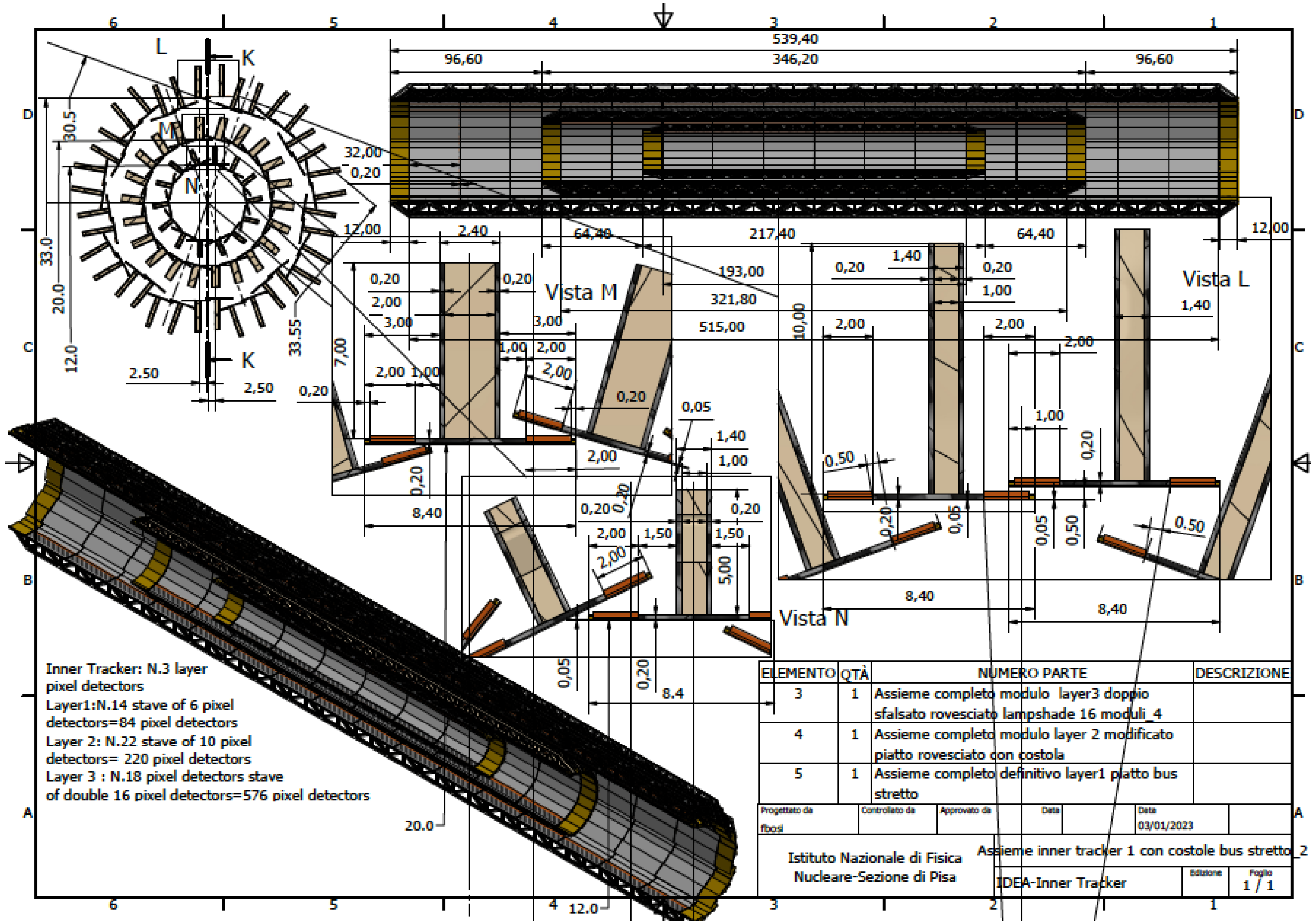


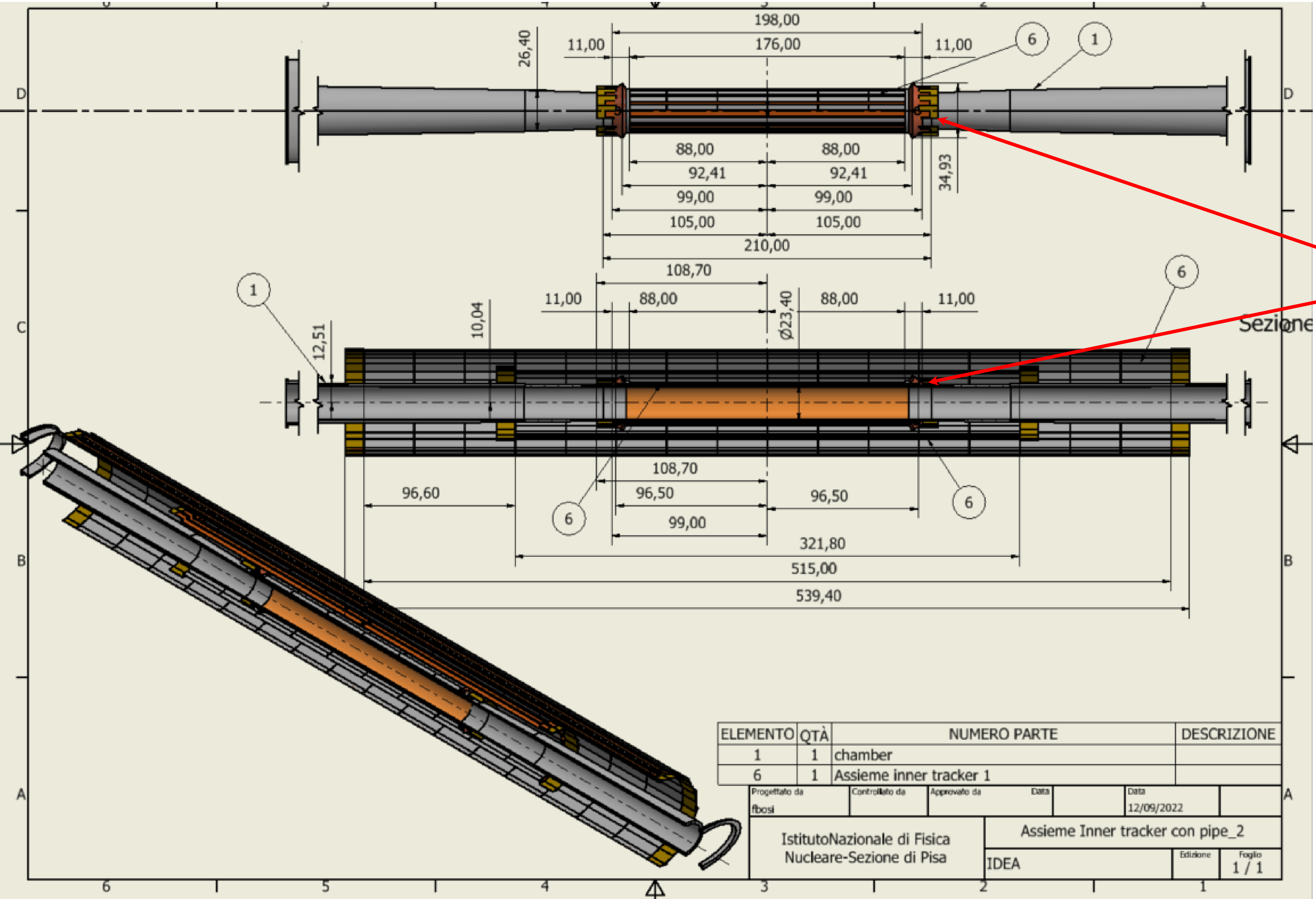
Overall Vertex layout



Layer 3 is lampshaded
Layer 1 and 2 are pinwheel



Total power ~120 W – Air cooled



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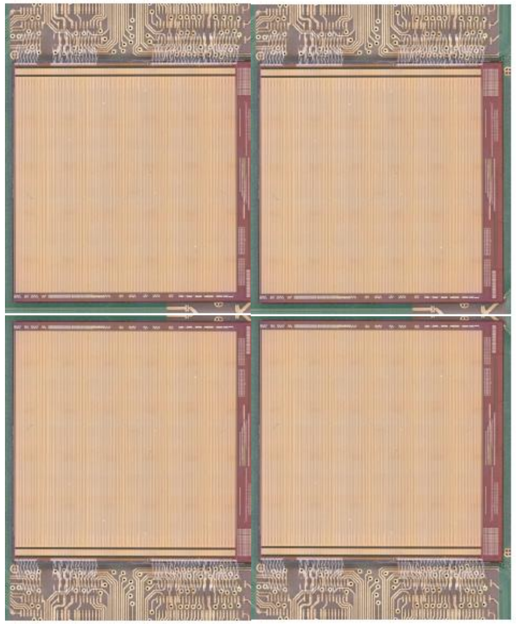
Mounting 2 halves (in φ) on the beam pipe cooling manifolds

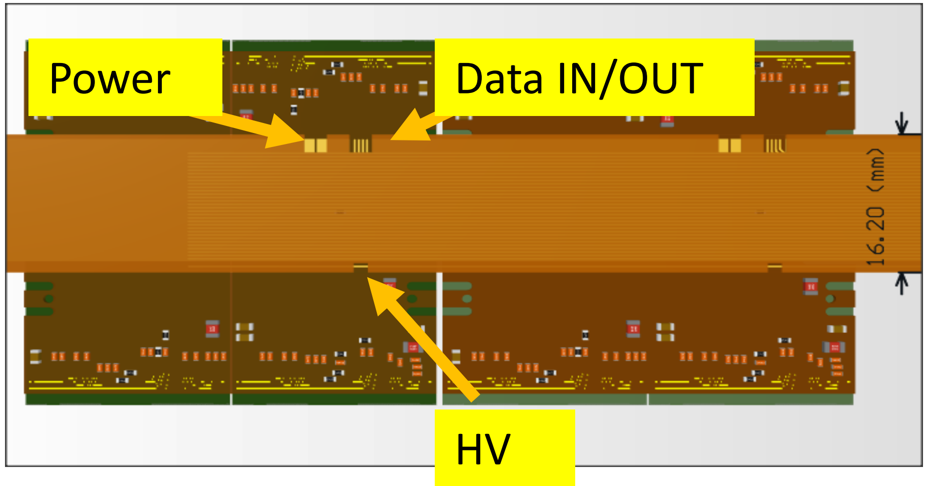
Outer layers modules

- Based on ATLASPIX3 R&D
  - 50 x 150 μm^2
  - 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 $100\ mW/cm^2$





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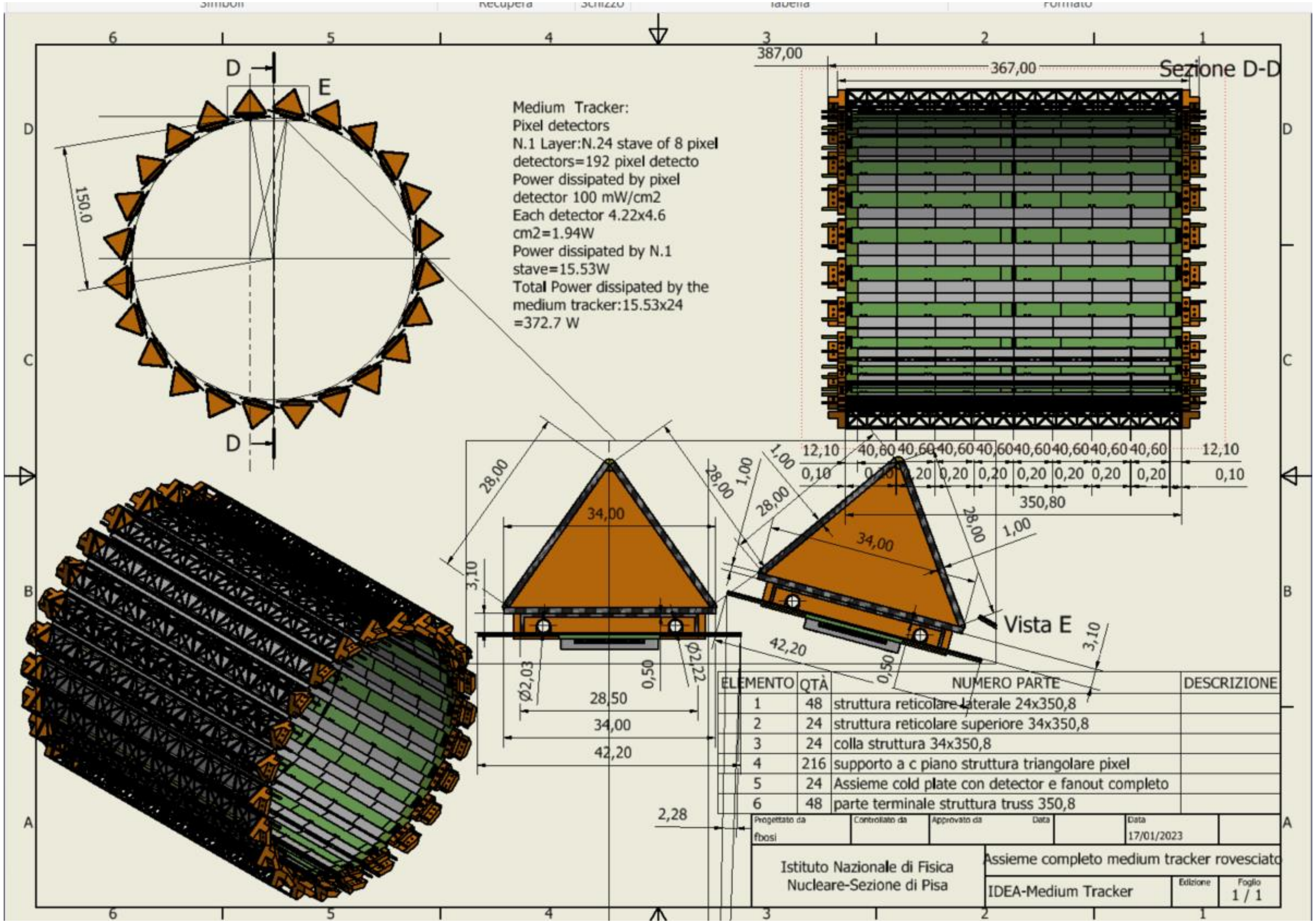

Intermediate Tracker Barrel

At 15 cm radius

24 staves of 8 modules each.

Lightweight reticular support structure (ALICE/Belle-II like)

Readout chips either side

Power budget

~370 W

Water cooled (2 pipes of 2 mm diameter)

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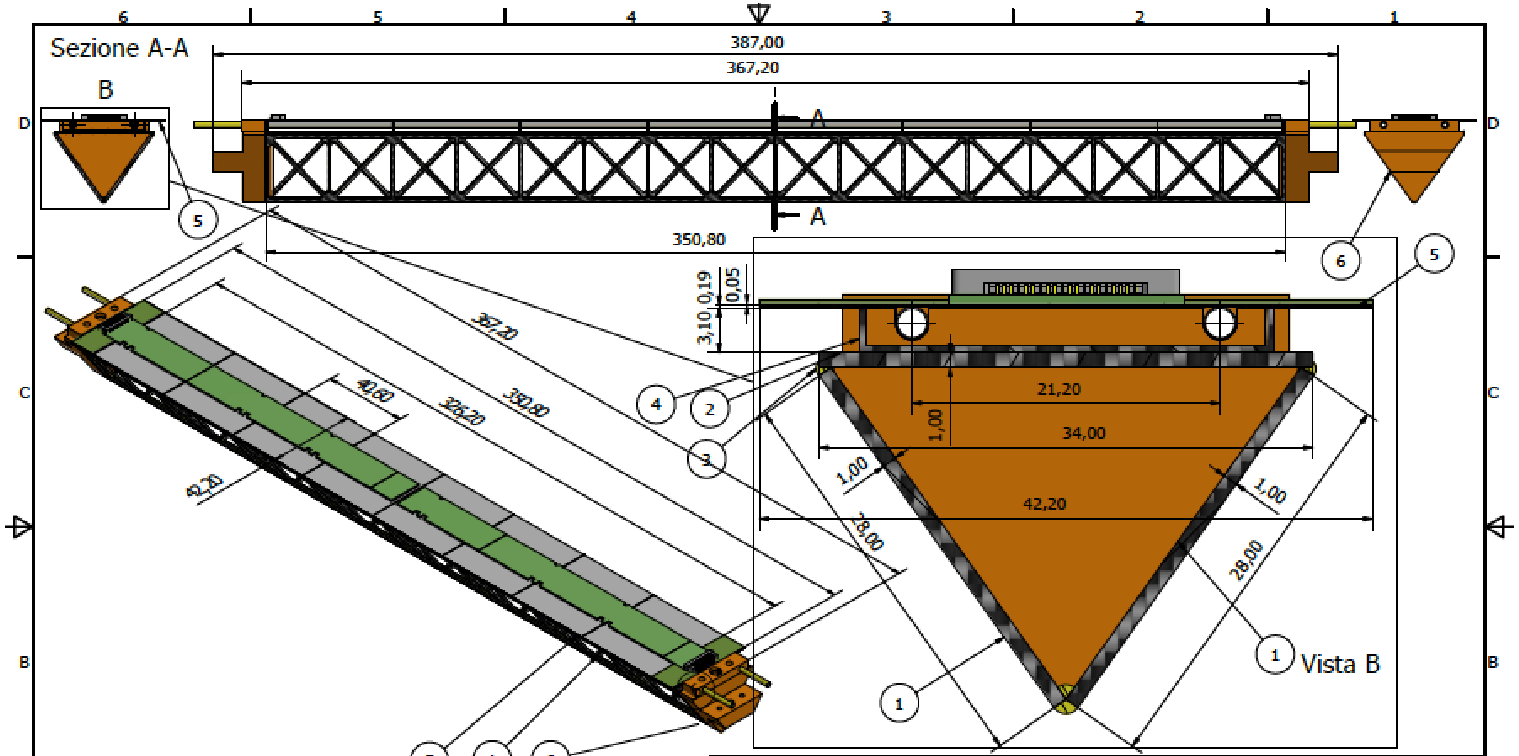
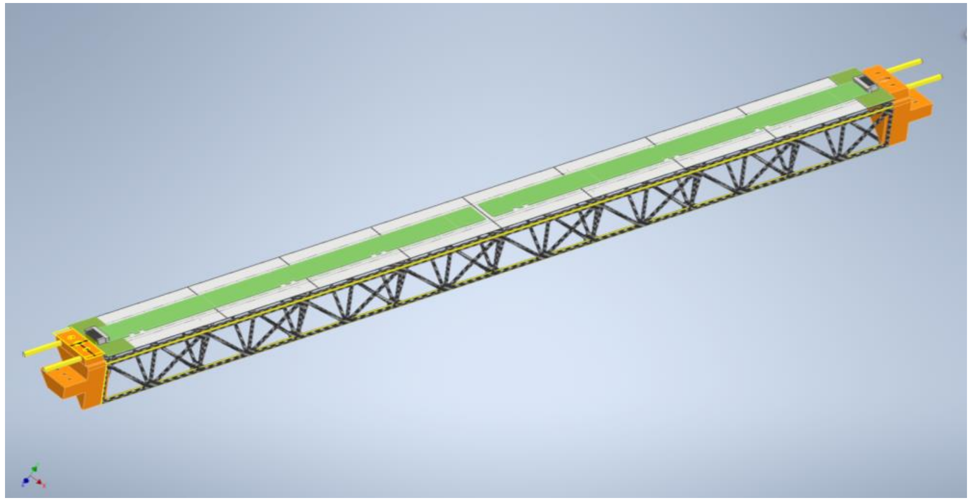
Stave detail



ELEMENTO	QTÀ	NUMERO PARTE	DESCRIZIONE
1	2	struttura reticolare laterale 24x350,8 medium tracker	
2	1	struttura reticolare superiore 34x350,8 medium tracker	
3	1	colla struttura 34x350,8	
4	9	supporto a c piano struttura triangolare pixel medium tracker	
5	1	Assieme cold plate con detector e fanout completo medium tracker	
6	2	parte terminale struttura truss 350,8	

Progettato da	Controllato da	Approvato da	Data	Data
fbosi				17/01/2023

Istituto Nazionale di Fisica Nucleare-Sezione di Pisa	Assieme completo stave medium tracker		
	IDEA-Medium Tracker	Edizione	Foglio 1 / 1



- Similar structure of Belle-II **oVTX L5**

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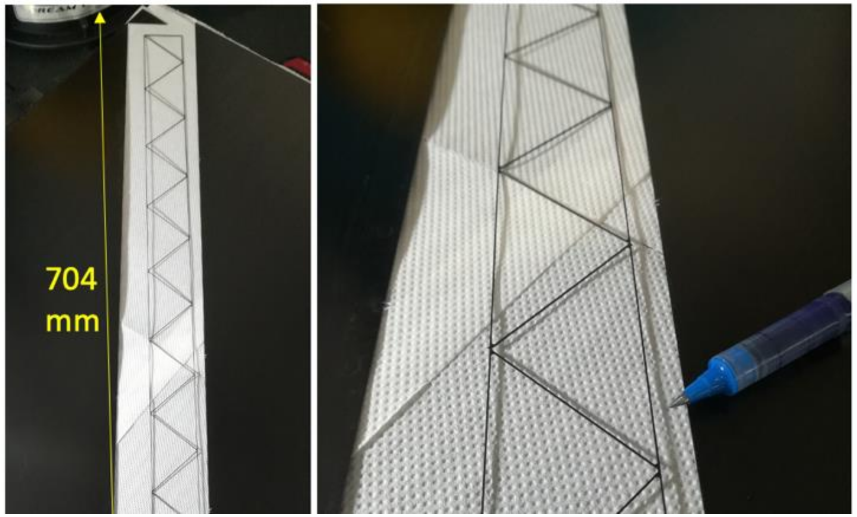
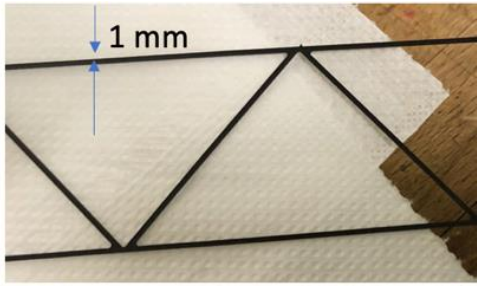
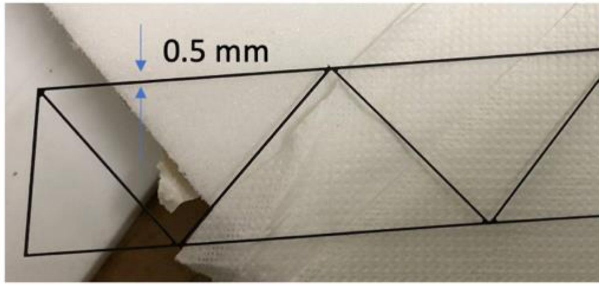
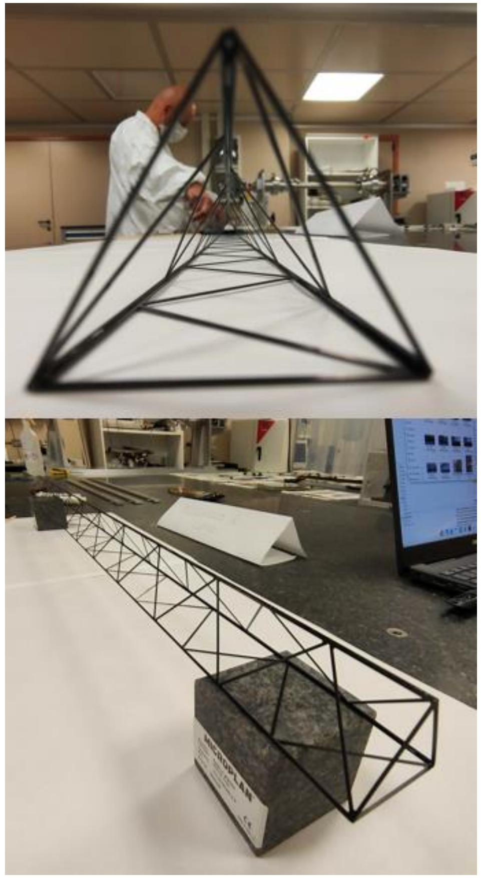
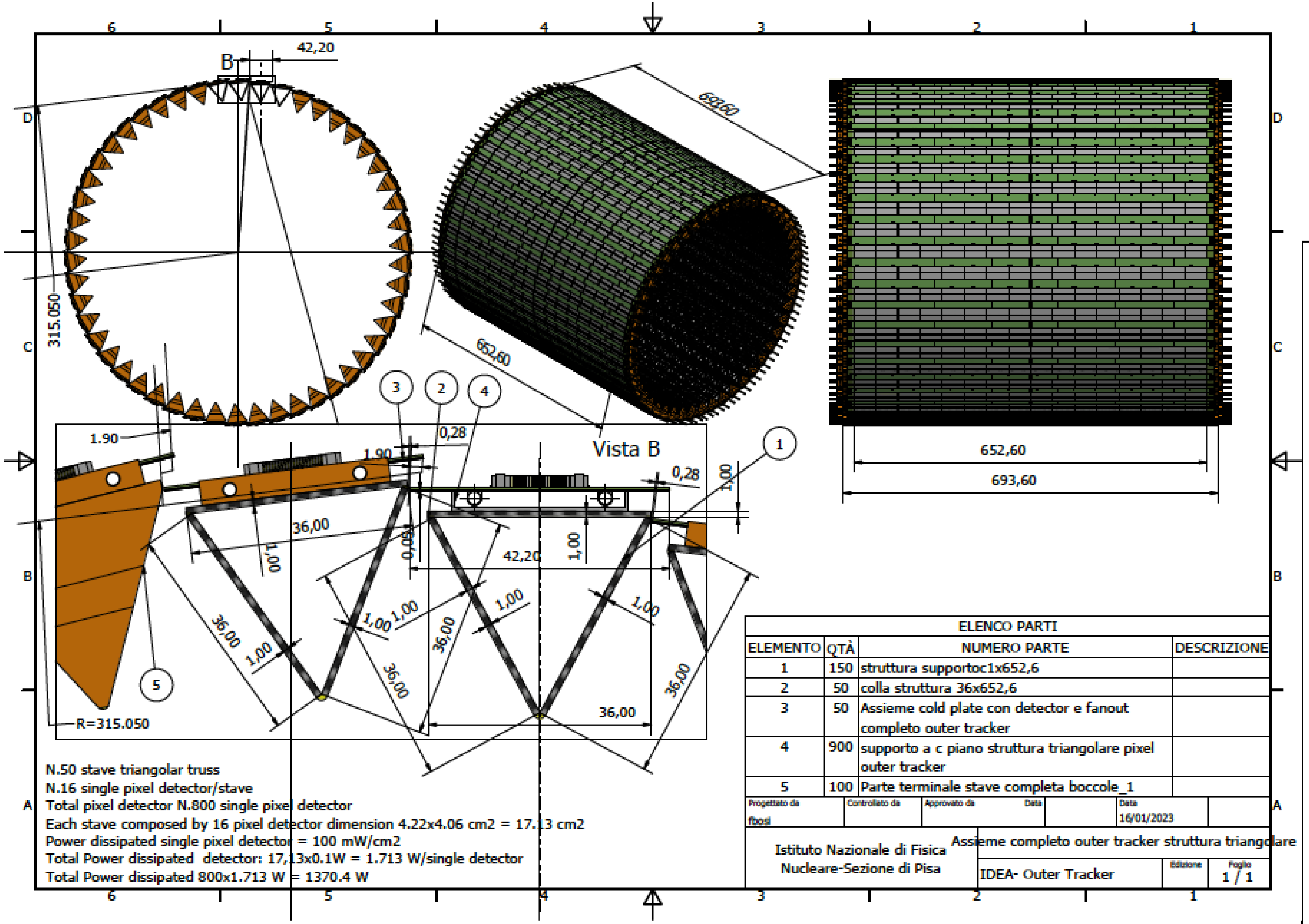
CF water-jet cut (by WatAJet Company)











ELEMENTO	QTÀ	NUMERO PARTE	DESCRIZIONE
1	150	struttura supportoc1x652,6	
2	50	colla struttura 36x652,6	
3	50	Assieme cold plate con detector e fanout completo outer tracker	
4	900	supporto a c piano struttura triangolare pixel outer tracker	
5	100	Parte terminale stave completa boccole_1	

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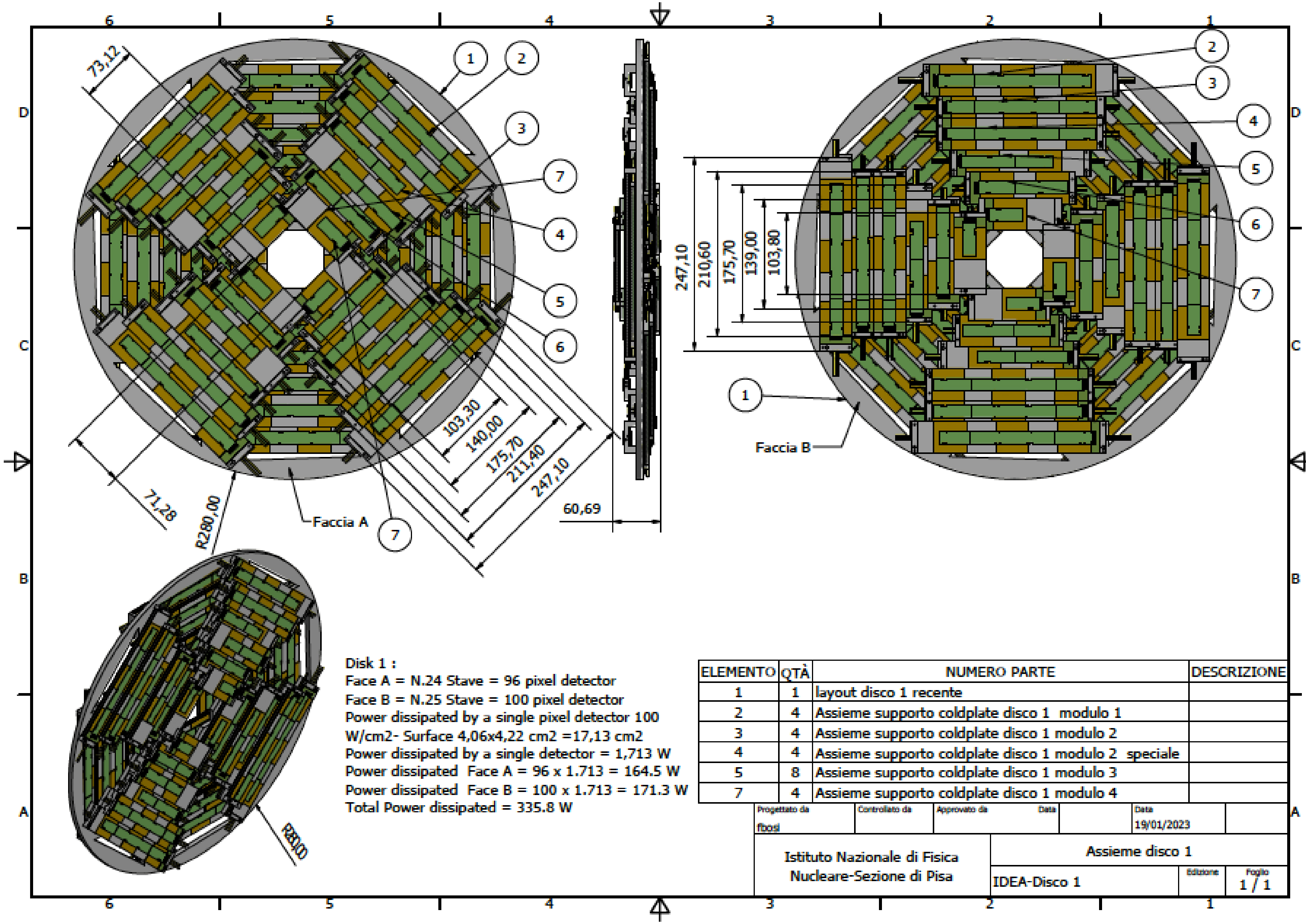
Outer Tracker Barrel
At 31.5 cm radius

50 staves of 16 modules each

Lightweight reticular support structure (ALICE/Belle-II like)

Readout chips either side
Power budget
~1370 W

Water cooled (2 pipes of 2 mm diameter)



ELEMENTO	QTÀ	NUMERO PARTE	DESCRIZIONE
1	1	layout disco 1 recente	
2	4	Assieme supporto coldplate disco 1 modulo 1	
3	4	Assieme supporto coldplate disco 1 modulo 2	
4	4	Assieme supporto coldplate disco 1 modulo 2 speciale	
5	8	Assieme supporto coldplate disco 1 modulo 3	
7	4	Assieme supporto coldplate disco 1 modulo 4	

Outer Tracker Disk 1

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

One petal is made of different staves of overlapping modules

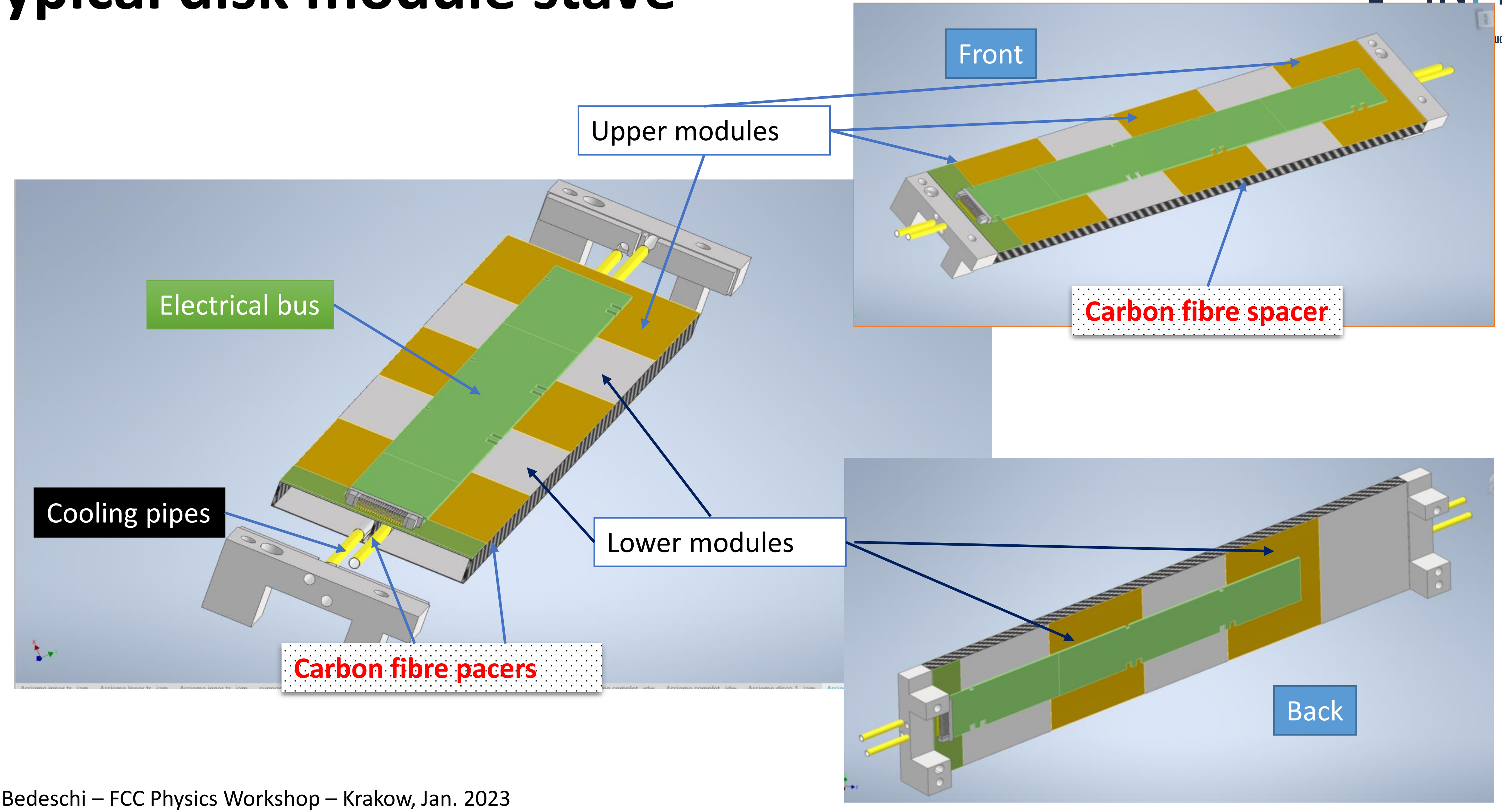
Total modules per disk: 196

Power budget ~335 W

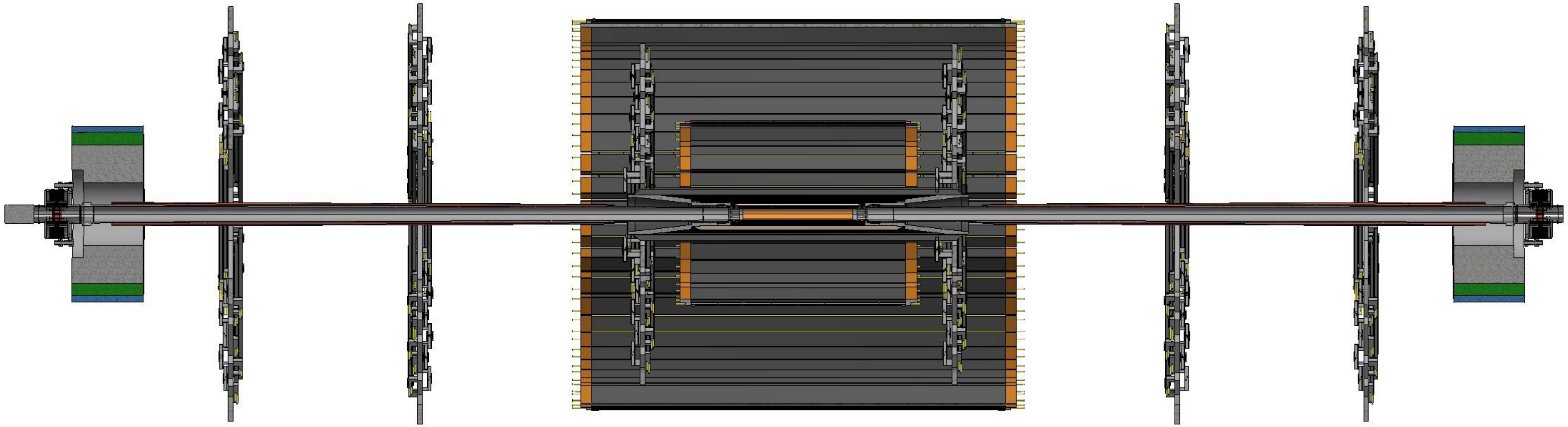
Cooling using 1 water pipe (2 mm diameter)

Similar geometry for the other two disks (only change the inner radius)

Typical disk module stave

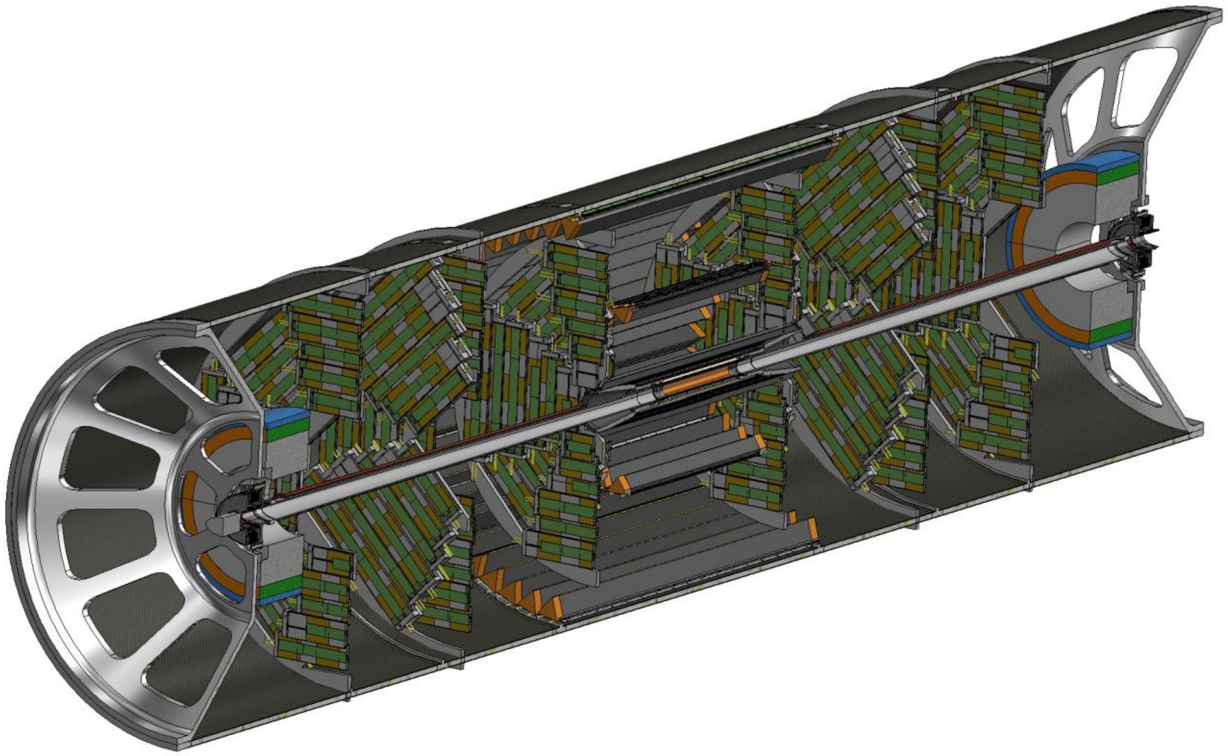


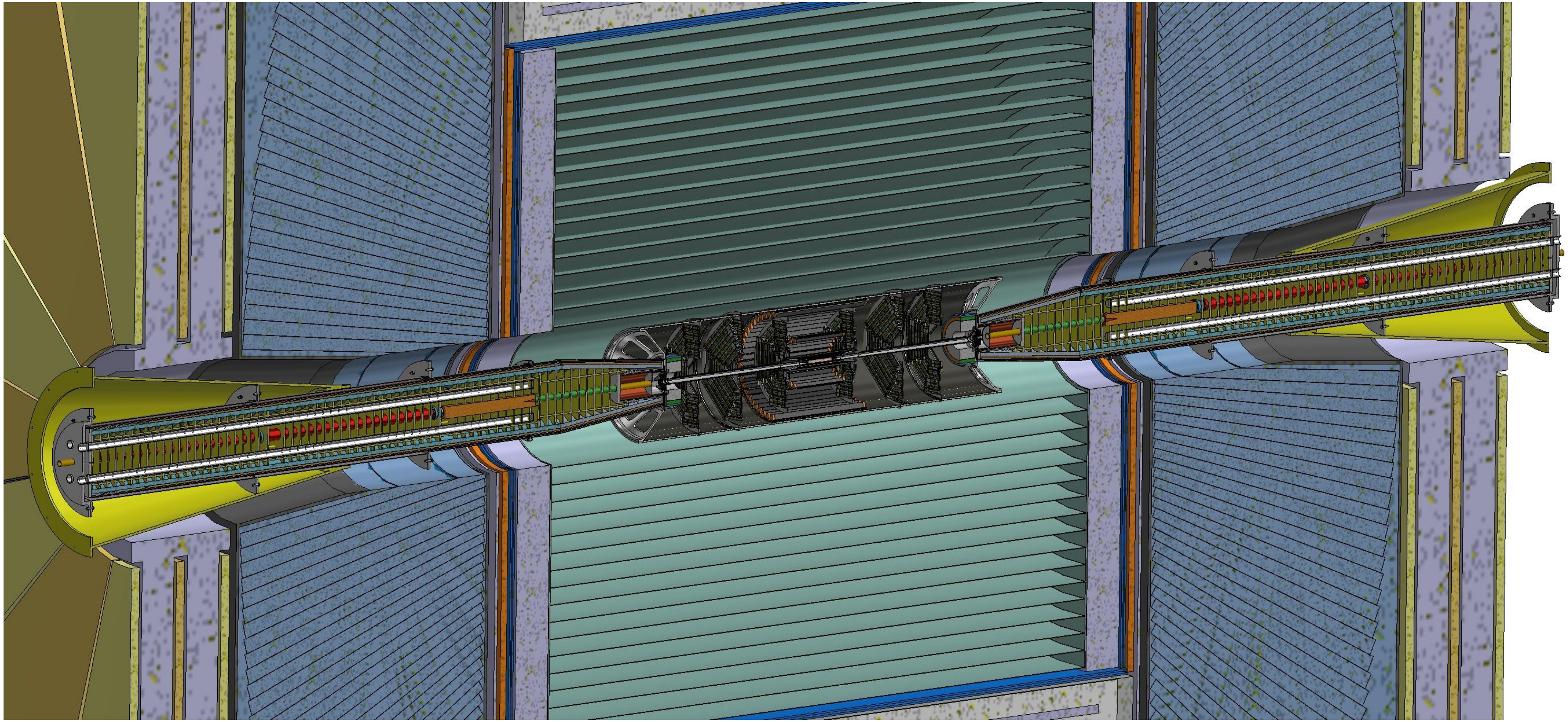
Overall layout



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





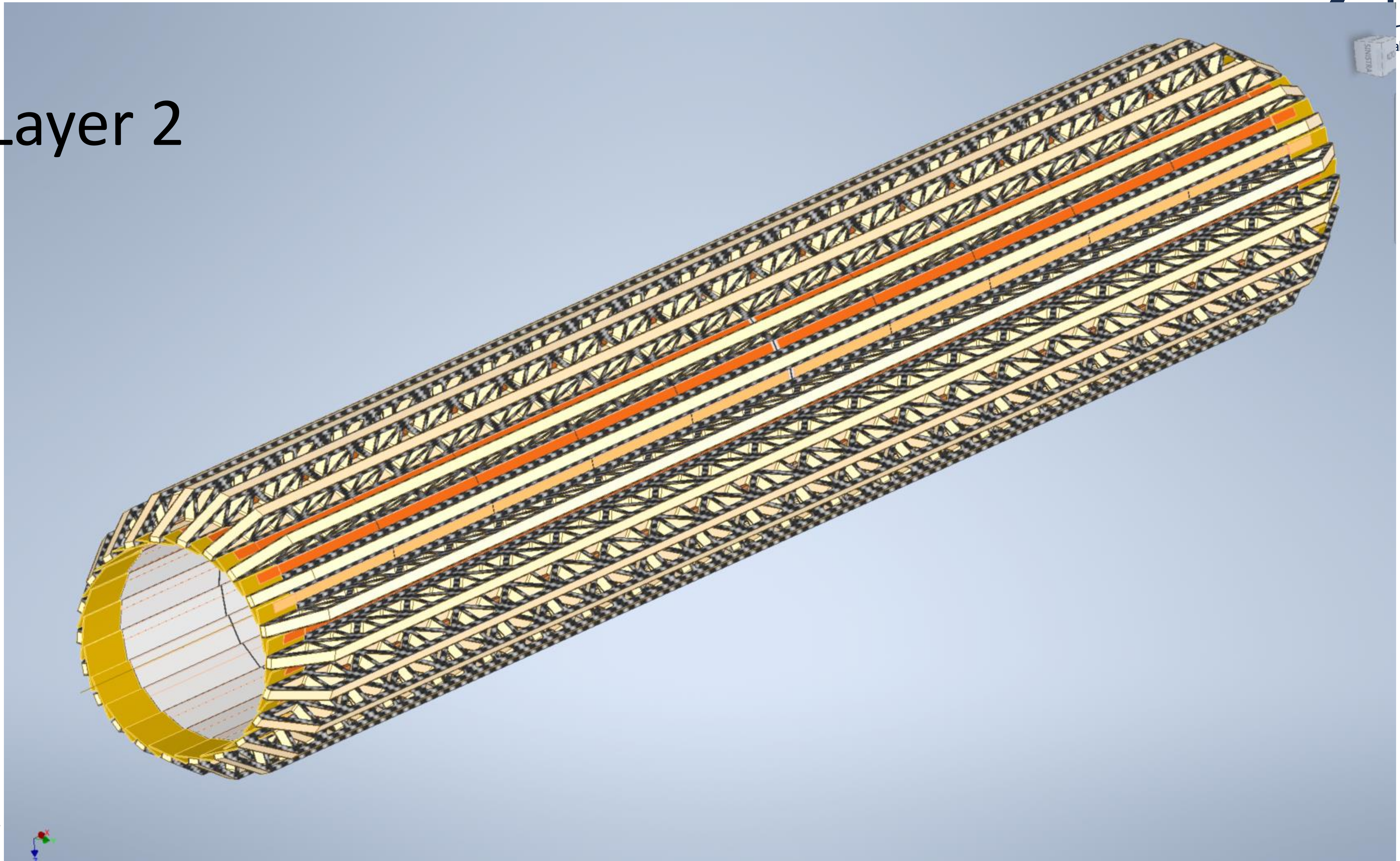
Conclusions

- 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
    - Optimise the support mechanics
    - Evaluate material budget
    - Study the routing of the services (readout and power cables)
    - Dimensioning the air cooling system
  - Outer Tracker
    - Study the routing of the services (readout and power cables, cooling manifolds)
  - Lumical
    - Engineering and assembly
  - Simulation
    - DELPHES geometry updated, material still to be revised
    - Geant4 geometry update on-going (see Armin Ilg talk on Wednesday) Joint Detector/Software session

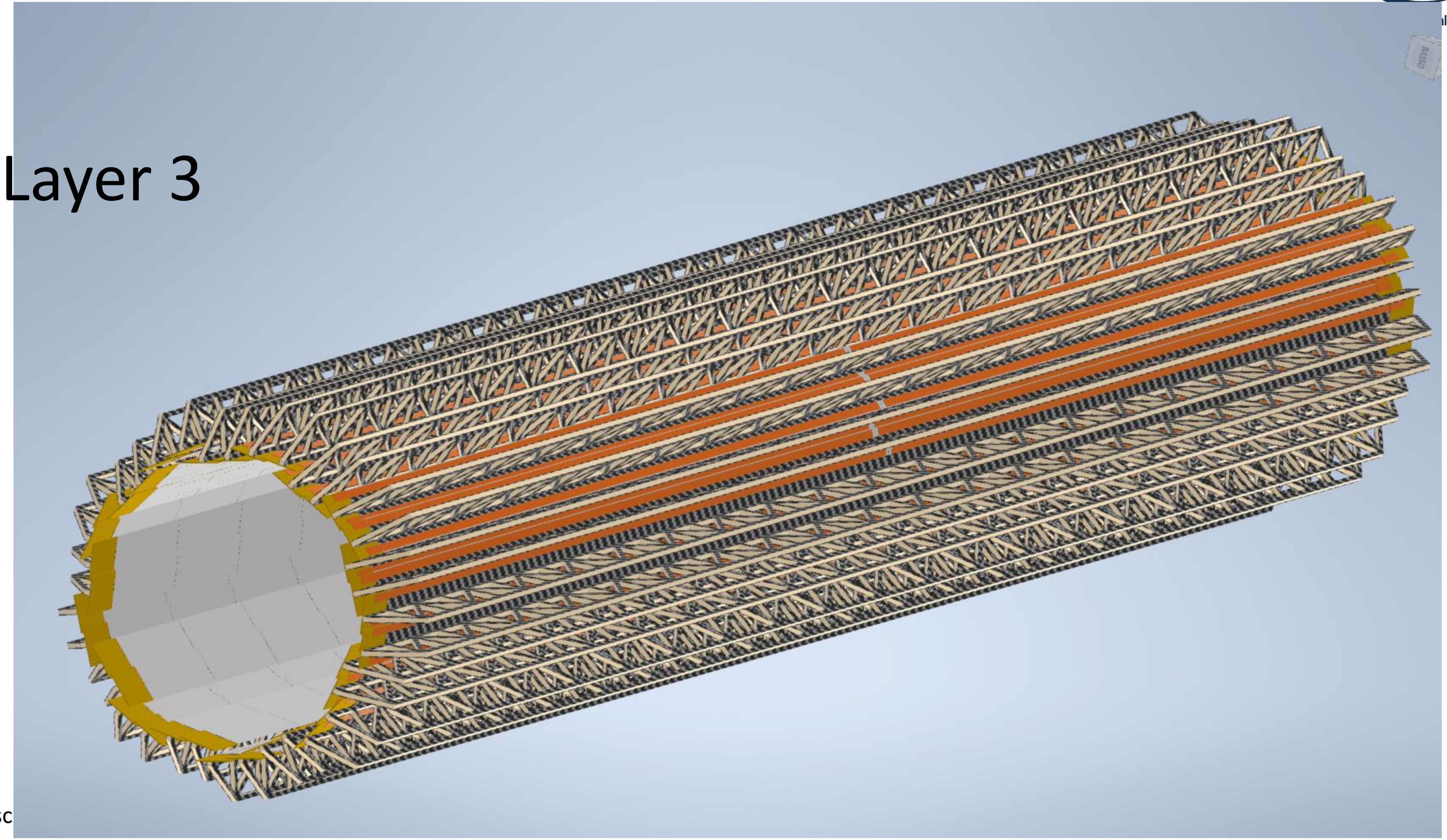
Backup

Layer 1

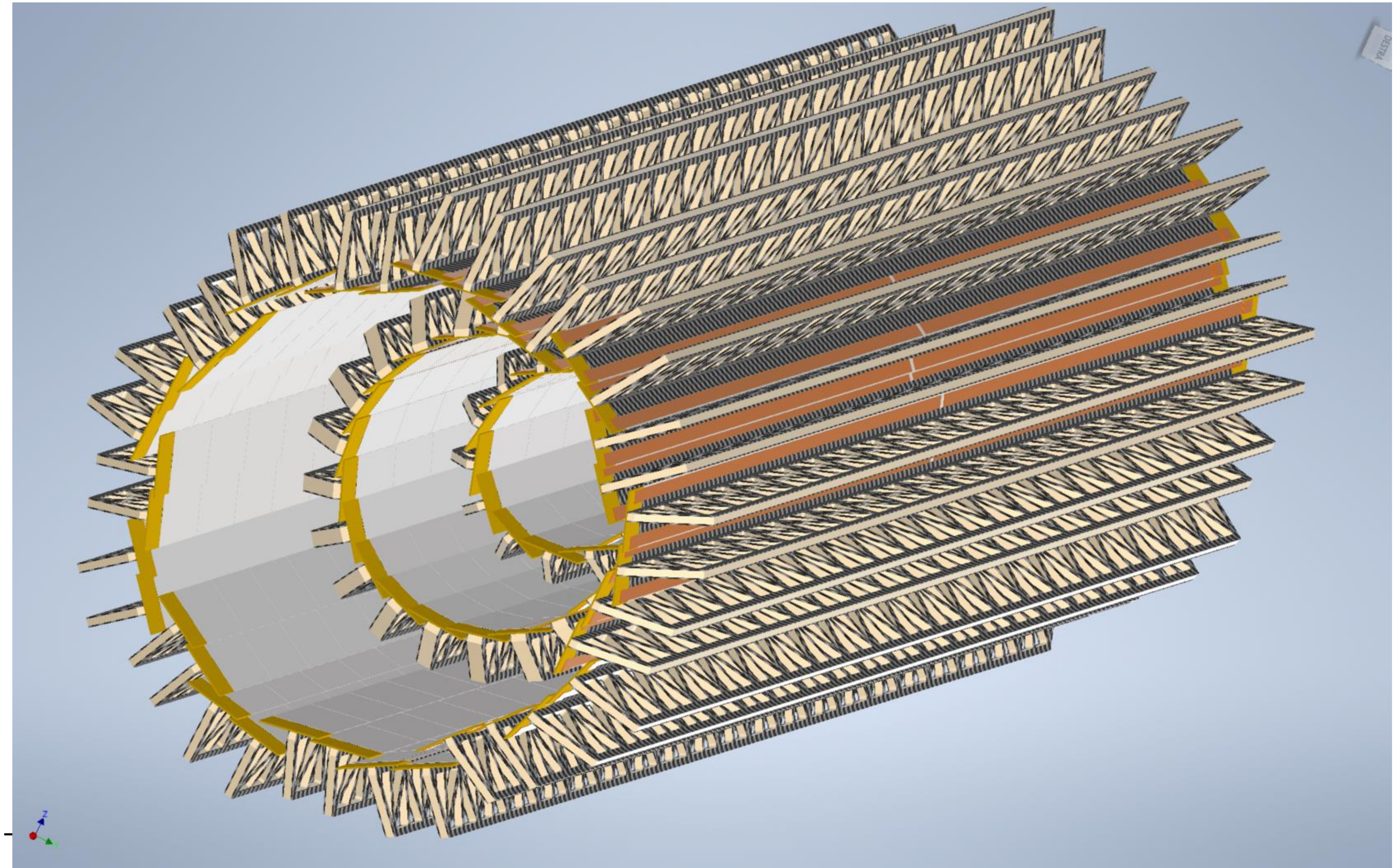
Layer 2



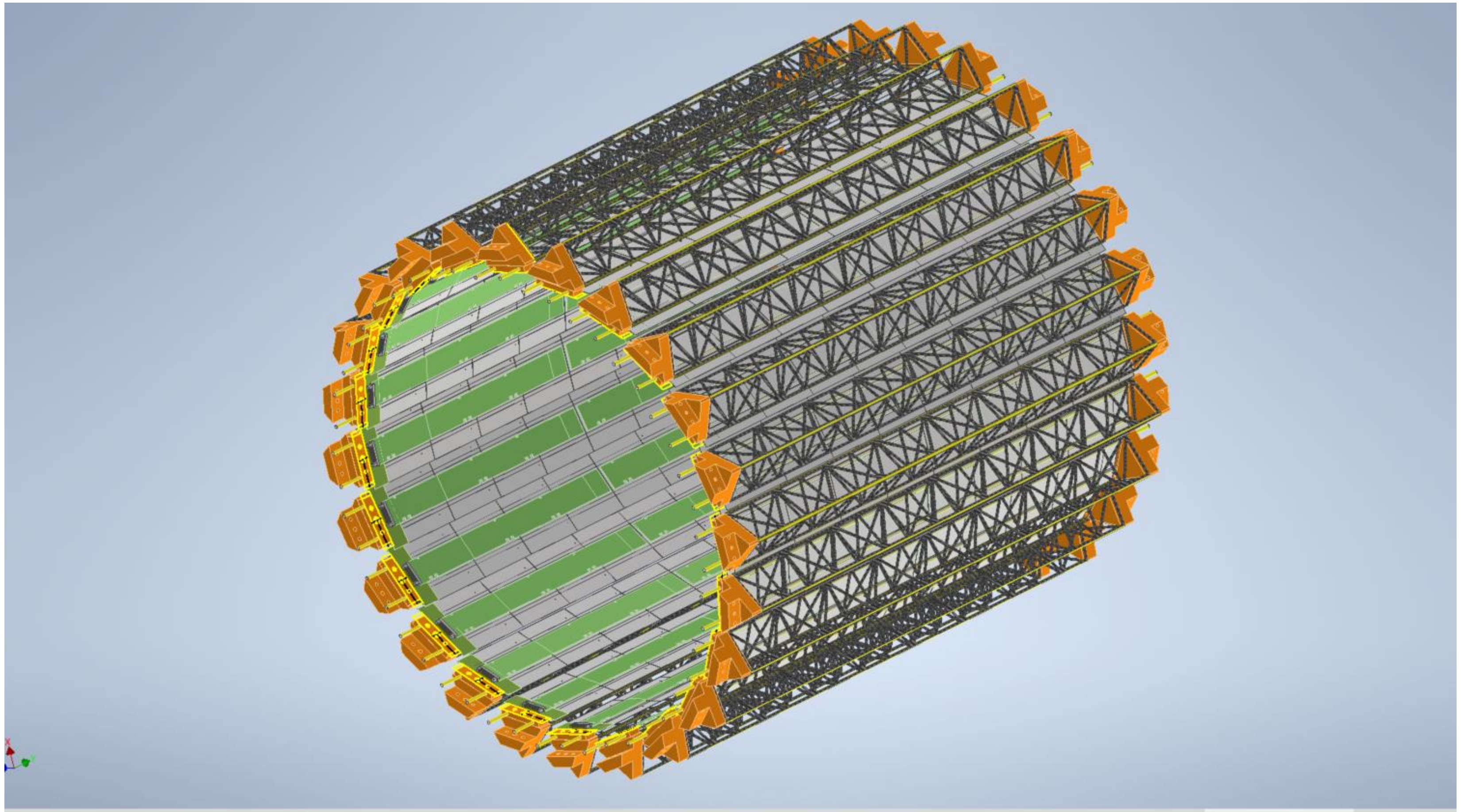
Layer 3



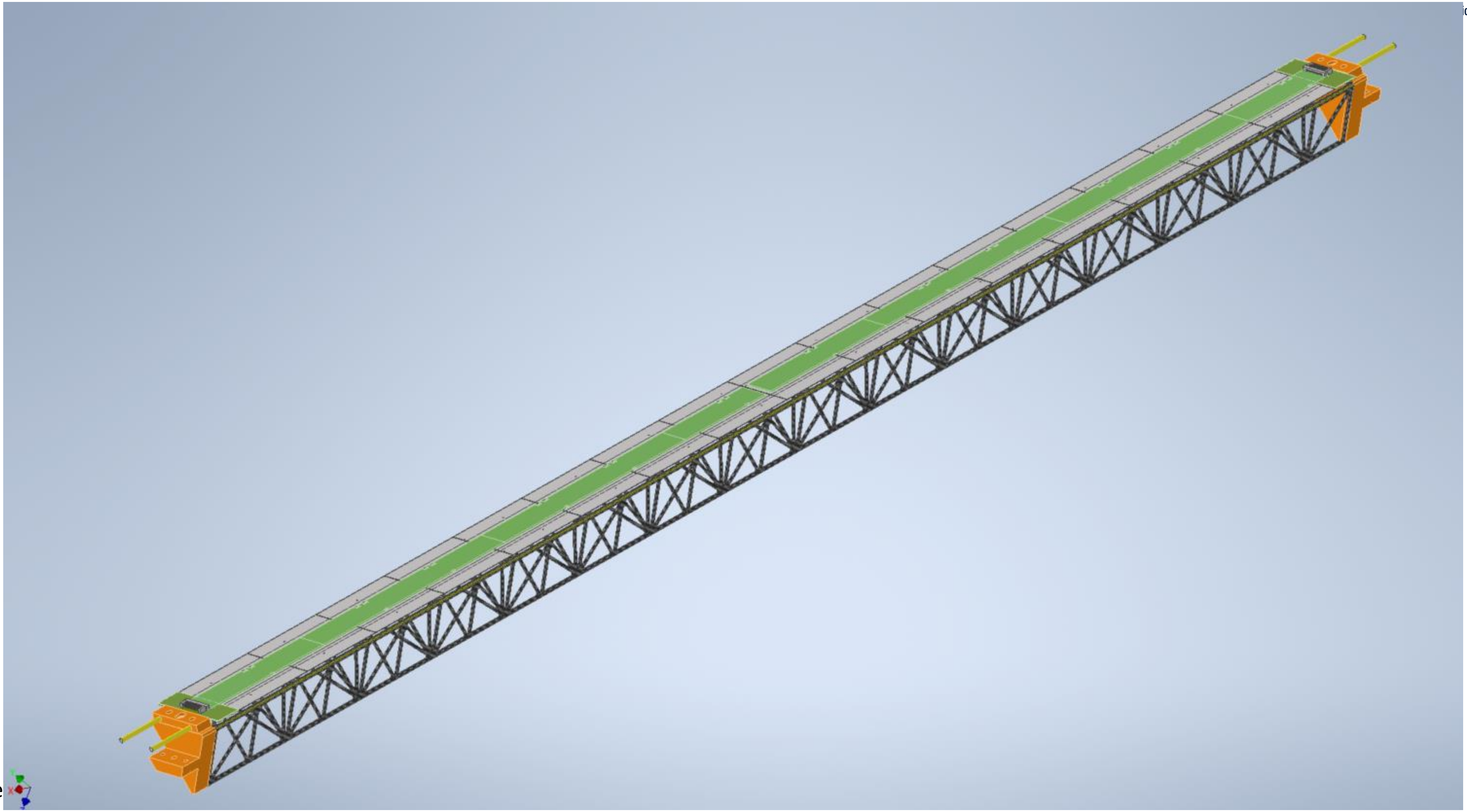
Inner tracker



Medium Tracker

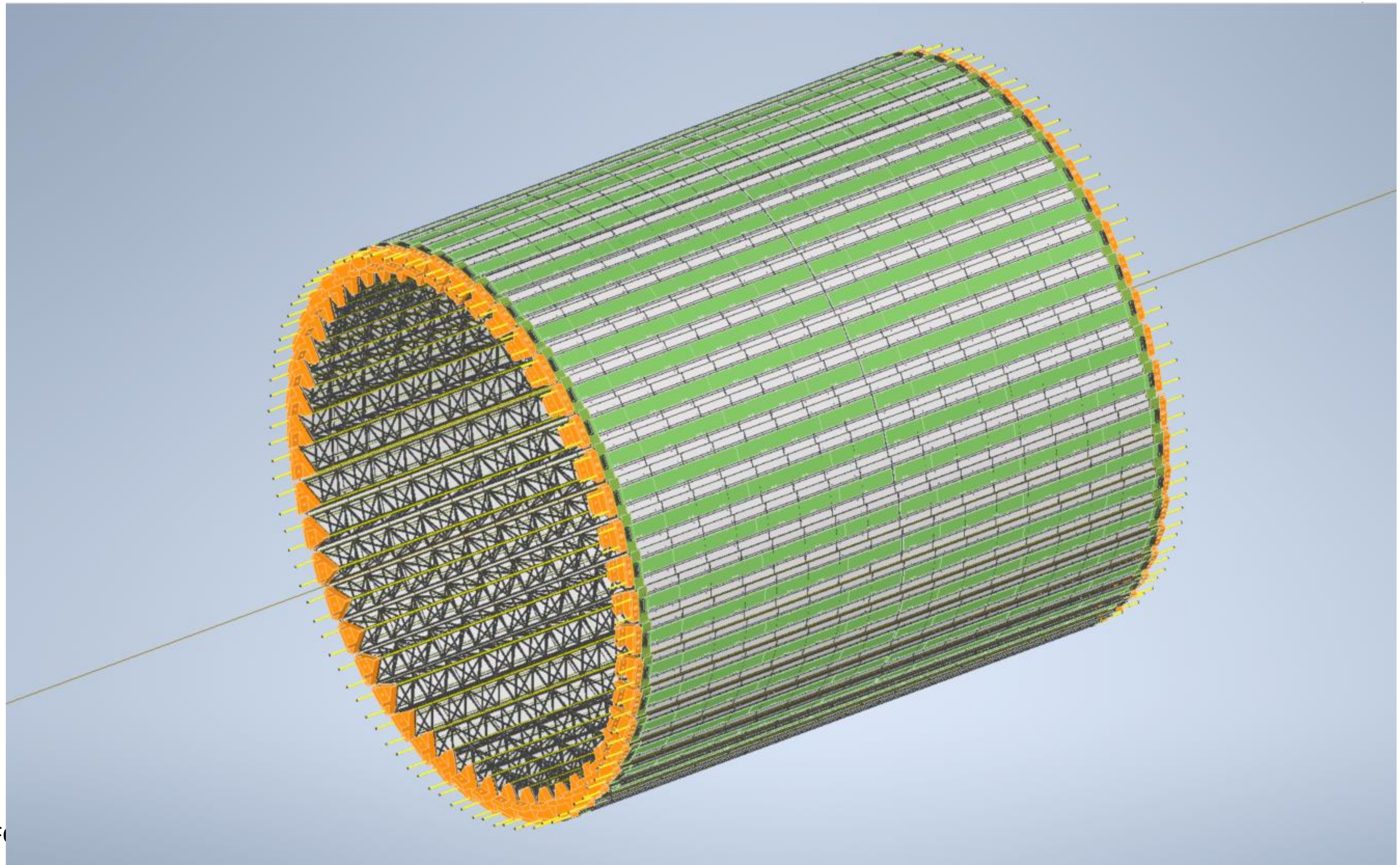


Stave outer tracker

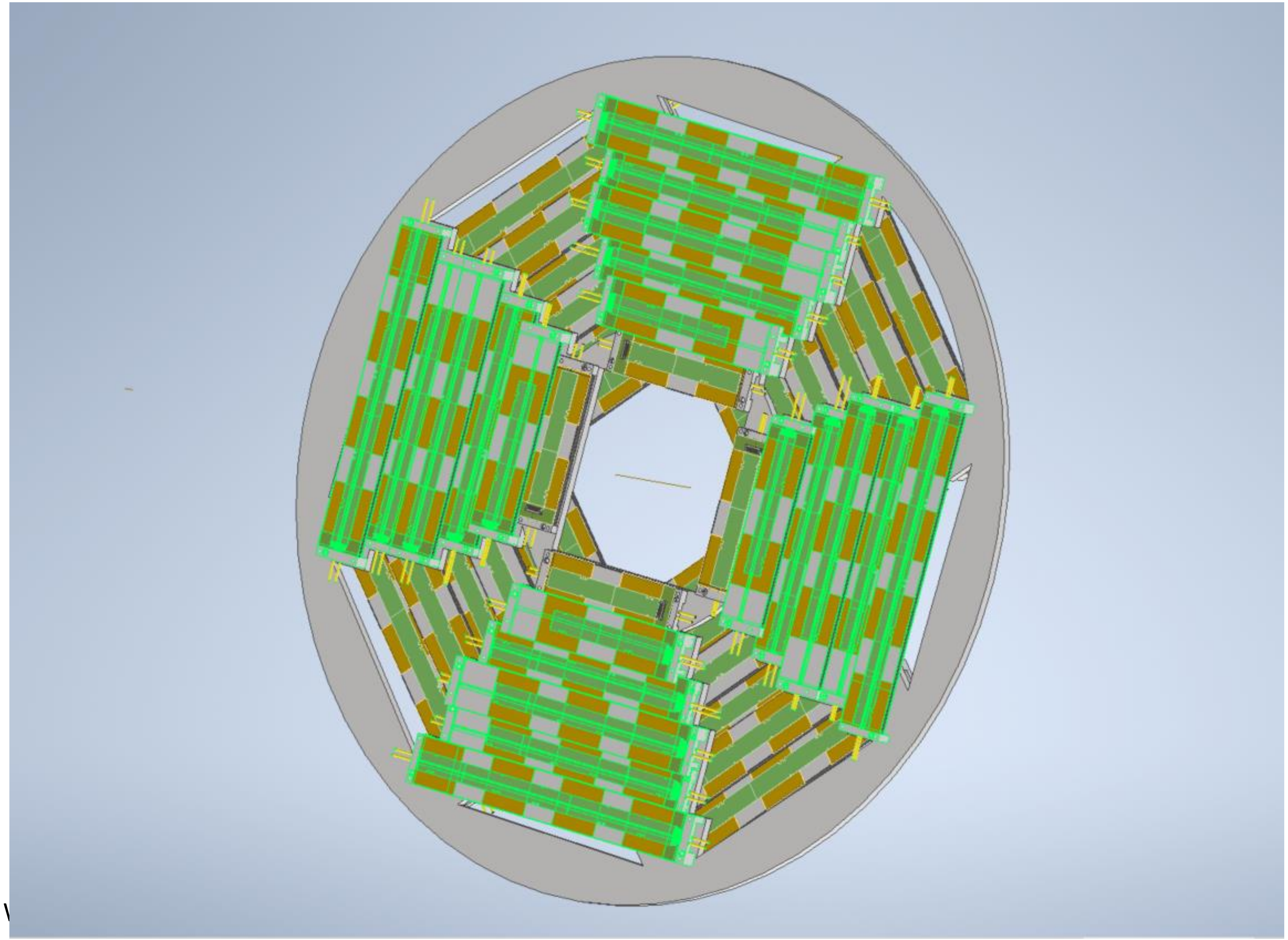


F. Bede

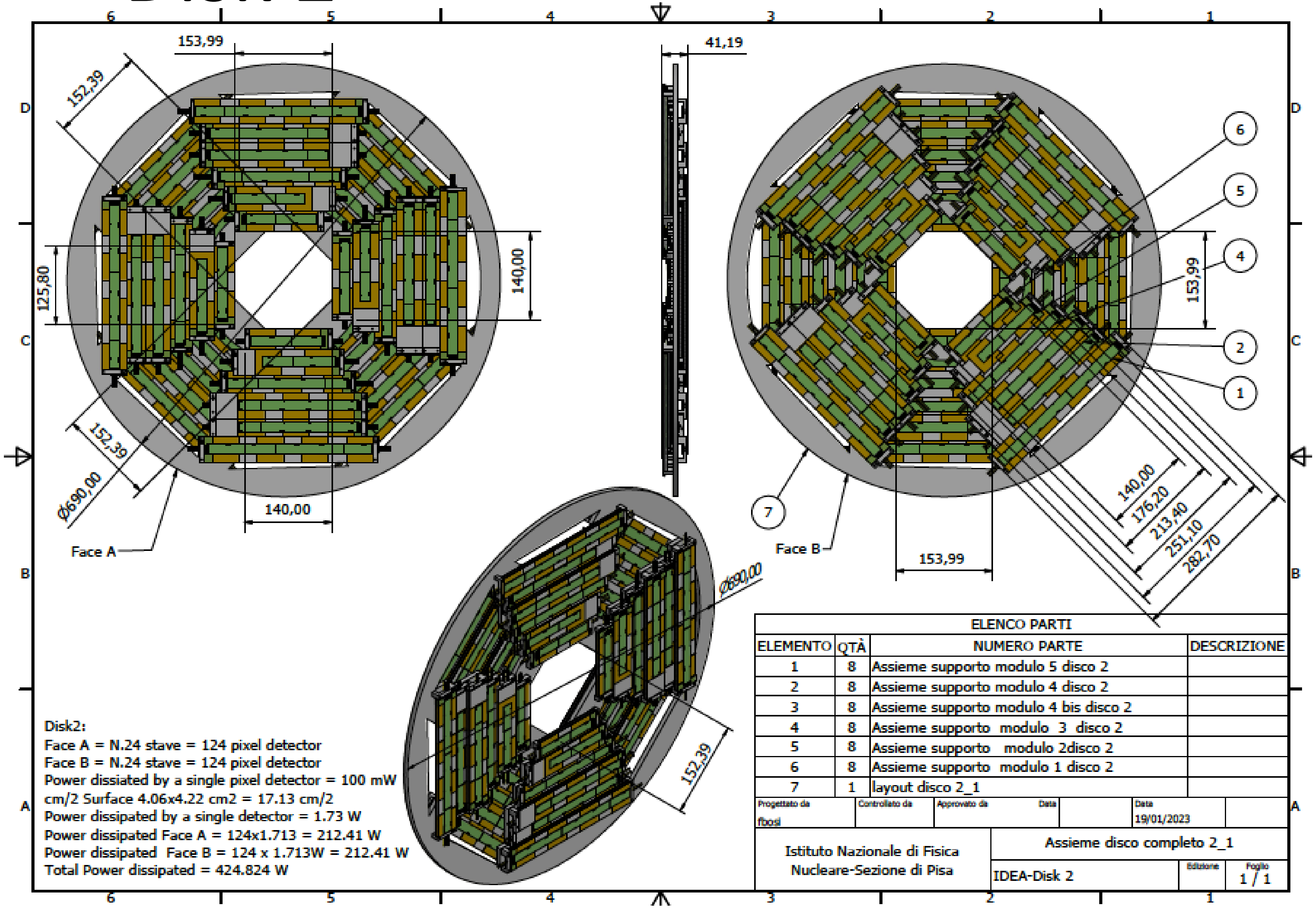
Outer tracker



Disk 2



Disk 2



ELENCO PARTI

ELEMENTO	QTÀ	NUMERO PARTE	DESCRIZIONE
1	8	Assieme supporto modulo 5 disco 2	
2	8	Assieme supporto modulo 4 disco 2	
3	8	Assieme supporto modulo 4 bis disco 2	
4	8	Assieme supporto modulo 3 disco 2	
5	8	Assieme supporto modulo 2disco 2	
6	8	Assieme supporto modulo 1 disco 2	
7	1	layout disco 2_1	

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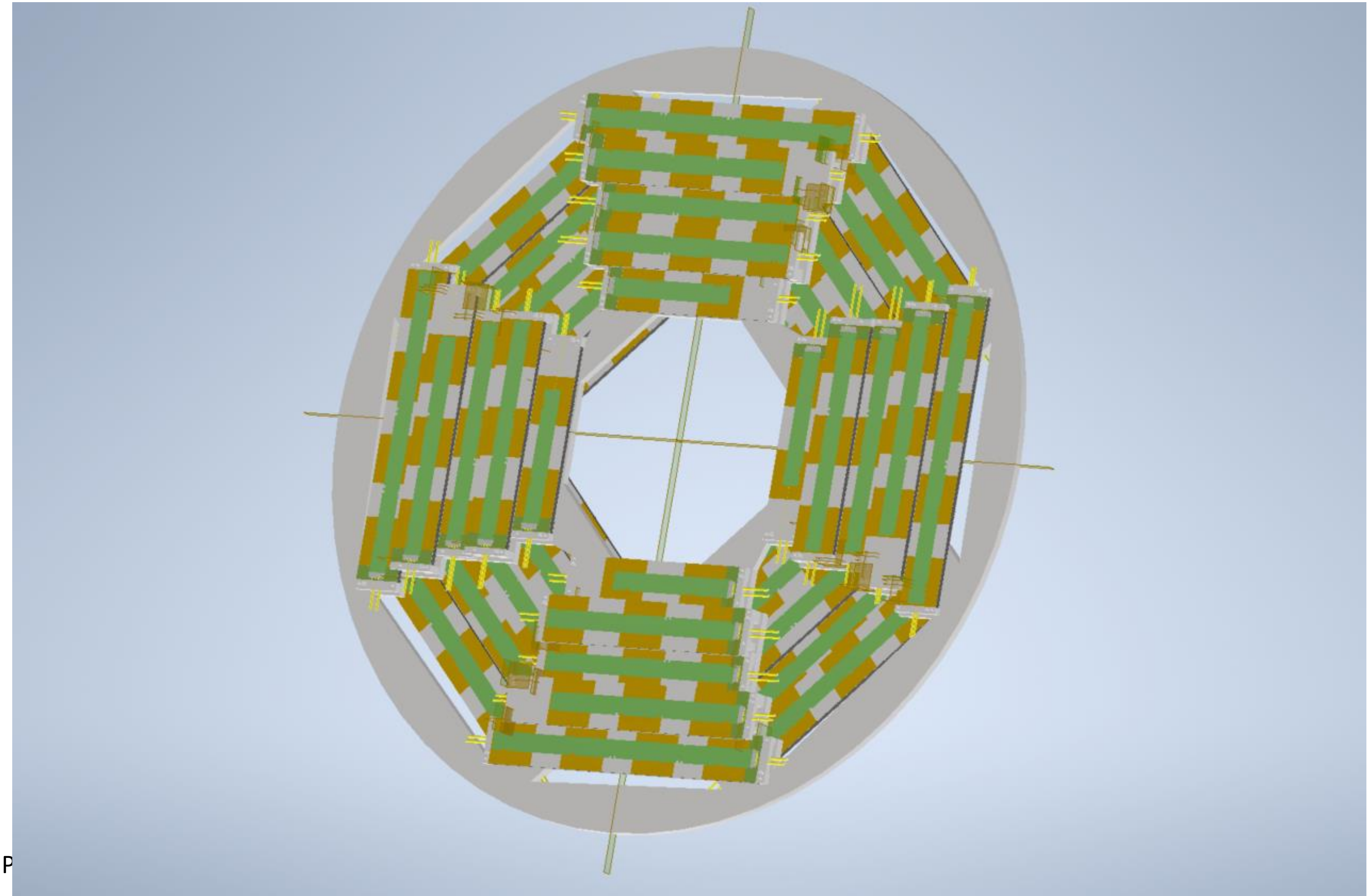
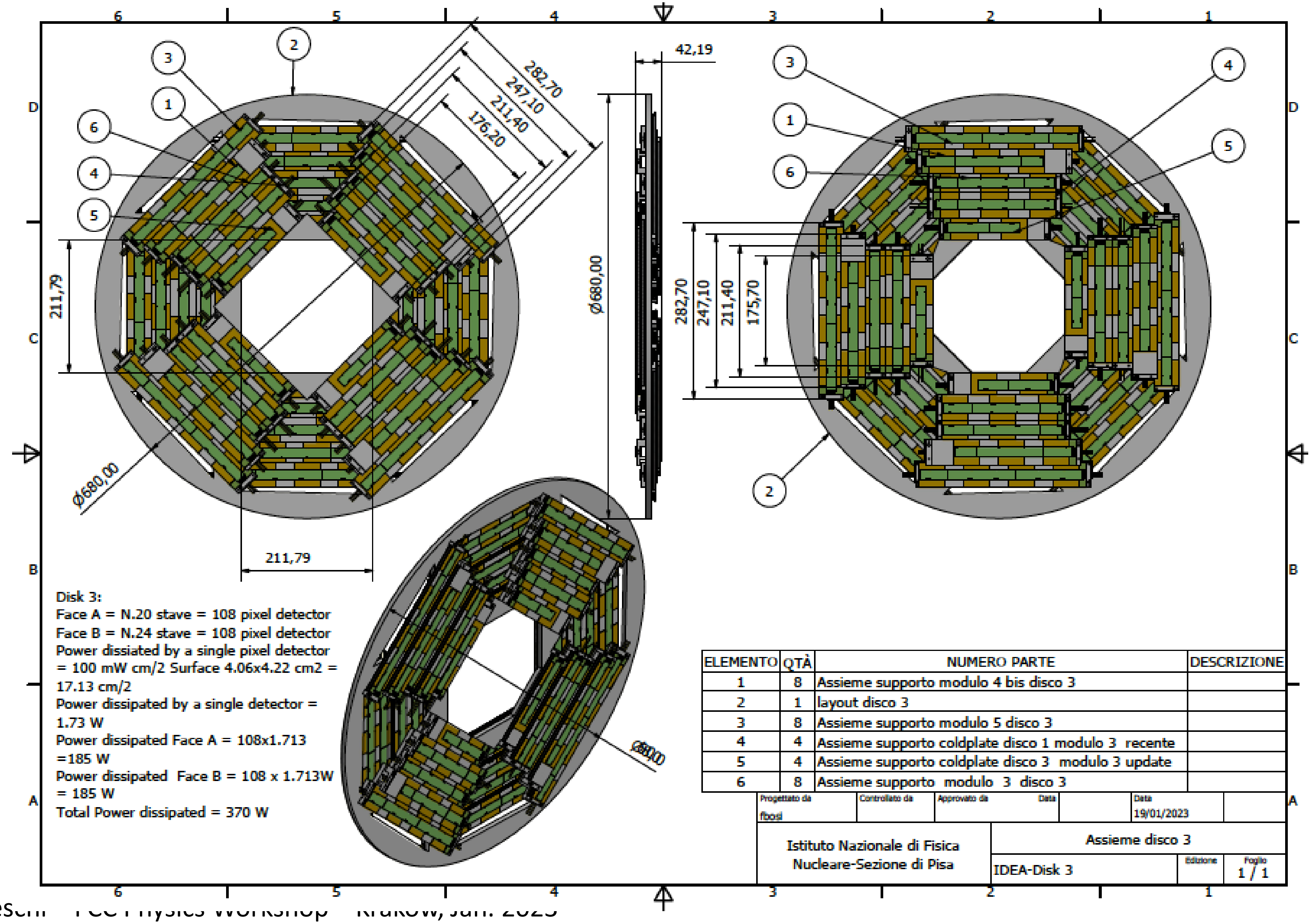
Disk 3



Disk 3



Disk 3:
Face A = N.20 stave = 108 pixel detector
Face B = N.24 stave = 108 pixel detector
Power dissiated by a single pixel detector = 100 mW cm/2 Surface 4.06x4.22 cm2 = 17.13 cm/2
Power dissipated by a single detector = 1.73 W
Power dissipated Face A = 108x1.713 =185 W
Power dissipated Face B = 108 x 1.713W = 185 W
Total Power dissipated = 370 W

ELEMENTO	QTÀ	NUMERO PARTE	DESCRIZIONE
1	8	Assieme supporto modulo 4 bis disco 3	
2	1	layout disco 3	
3	8	Assieme supporto modulo 5 disco 3	
4	4	Assieme supporto coldplate disco 1 modulo 3 recente	
5	4	Assieme supporto coldplate disco 3 modulo 3 update	
6	8	Assieme supporto modulo 3 disco 3	

Progettato da: fbosi — Controllato da — Approvato da — Data — Data: 19/01/2023

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Assieme disco 3

IDEA-Disk 3 — Edizione — Foglio 1 / 1

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