

IDEA VERTEX DETECTOR INTEGRATION

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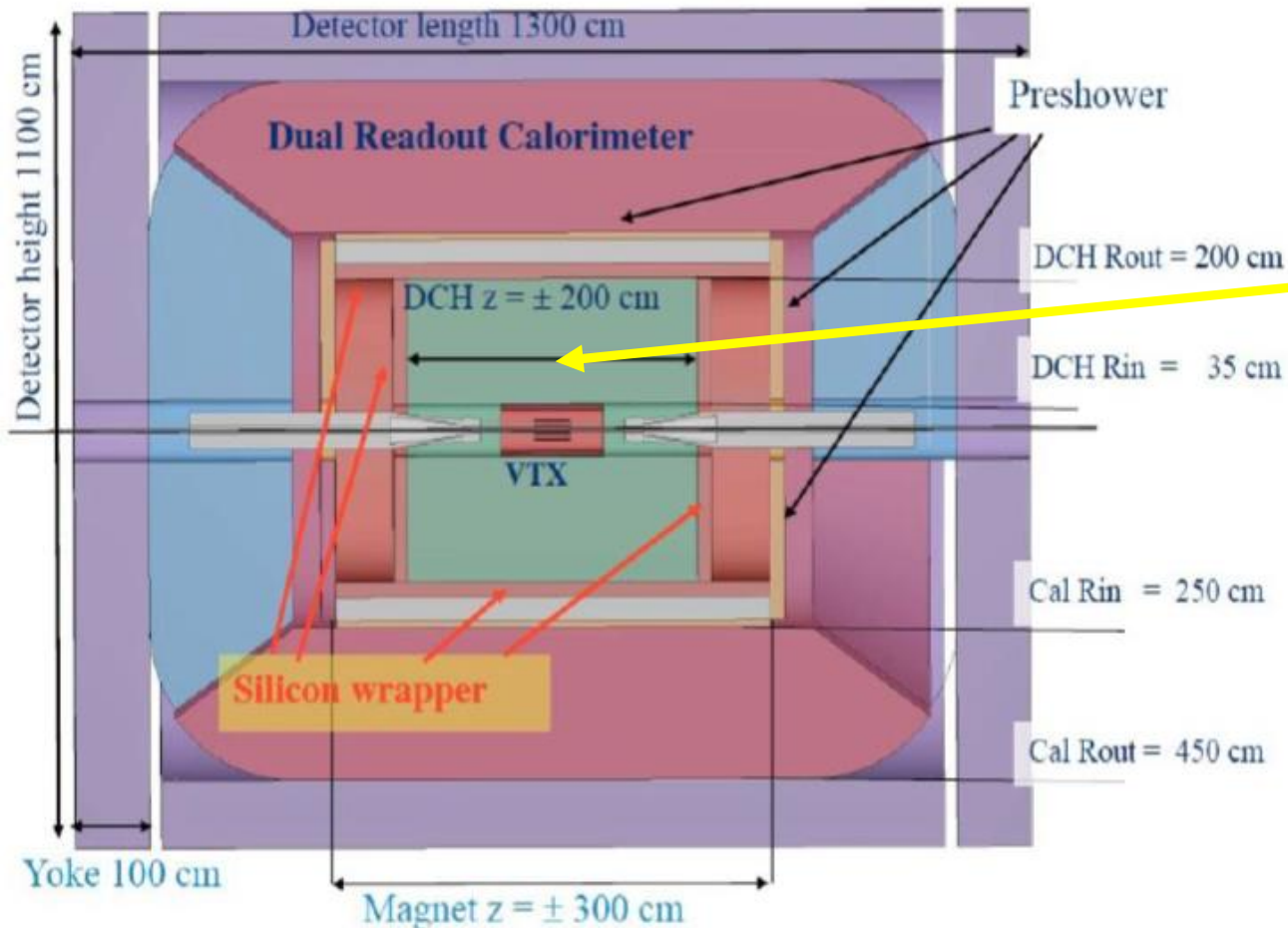
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The 2024 European Edition of the International Workshop on the Circular Electron-Positron Collider (CEPC)

Marseille (France)

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The IDEA Concept

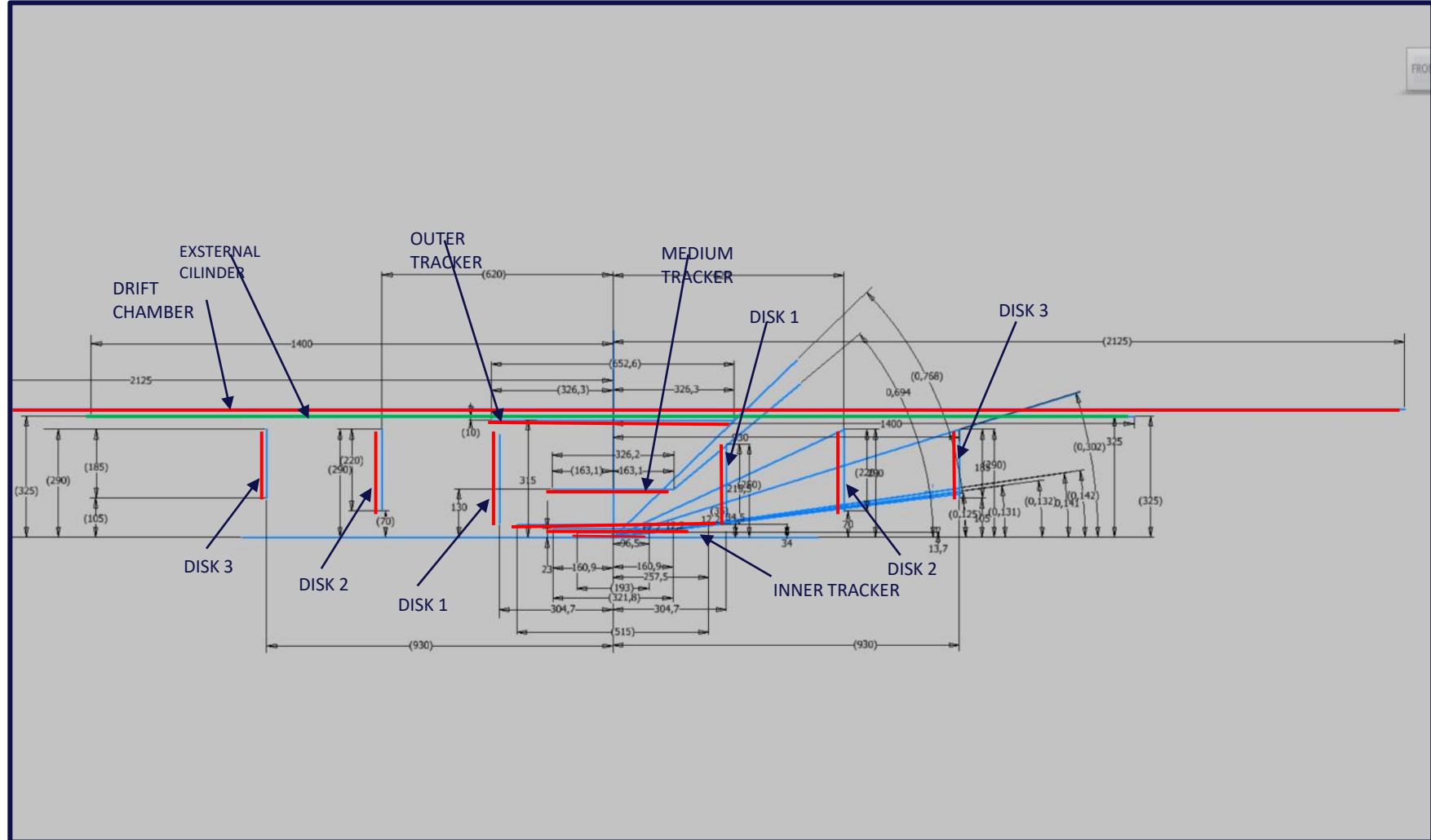


- Central tracking device:
 - light Drift CHamber
- **Silicon detectors for precision measurements**
 - vertex detector
 - silicon internal tracker
 - silicon wrapper
- Thin solenoid with 2T field (according to MDI limits)
- Dual readout calorimeter
 - supplemented by a pre-shower detector
- Muon chambers 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 interfere with the Luminosity Calorimeter (clearance of ~120 mrad)**
- **The mounting of the vertex tracker must be done inside the support tube**
- Minimize the radiation lengths



Outer vertex tracker:

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

- Intermediate barrel at 13 cm radius (improved reconstruction for $p_T > 40 \text{ MeV}$ tracks)
- Outer barrel at 31.5 cm radius
- 3 disks per side

Inner Vertex detector:

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

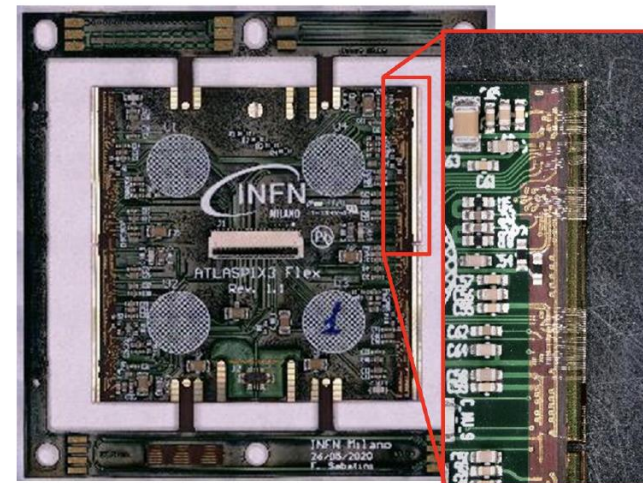
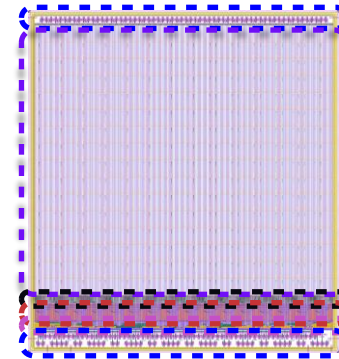
3 barrel layers at

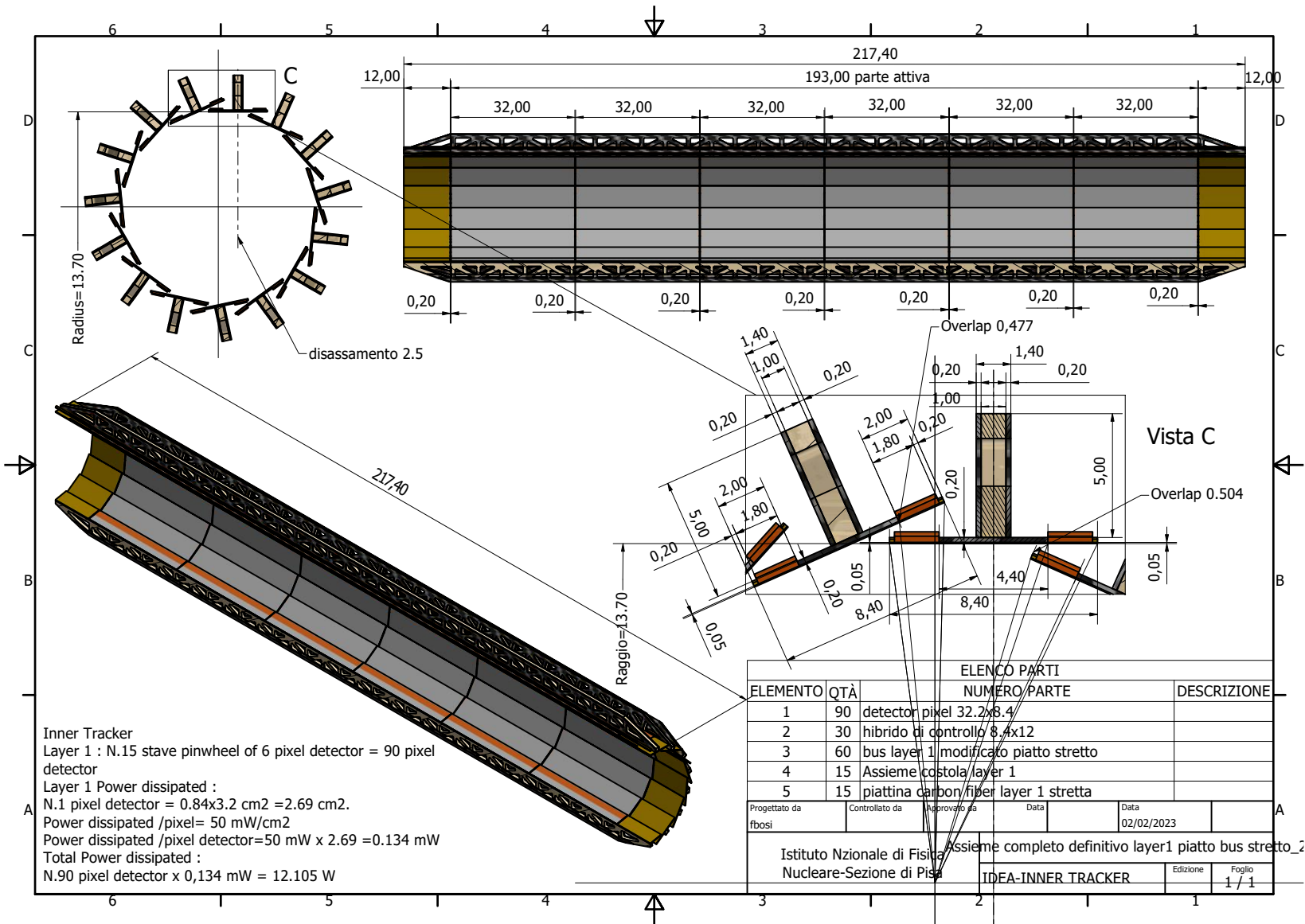
- 13.7, 22.7 and 34.8 mm radius

Sensors technology and dimensions

Depleted Monolithic Active Pixel Detectors

- **Inner Vertex (inspired to ARCADIA):**
 - Lfoundry 110 nm process
 - *50 μm thick, 25 μm x 25 μm*
 - Module dimensions: $8.4 \times 32 \text{ mm}^2$
 - **Power density 50 mW/cm^2** (core 30 mW/cm^2)
 - **Current at 100 MHz/cm²**
- **Outer Vertex and disks (inspired to ATLASPIX3)**
 - TSI 180 nm process
 - *50 μm thick (50 μm x 150 μm)*
 - Module dimensions: $42.2 \times 40.6 \text{ mm}^2$
 - **Power density: assume 100 mW/cm^2**
 - **Up to 1.28 Gb/s downlink**



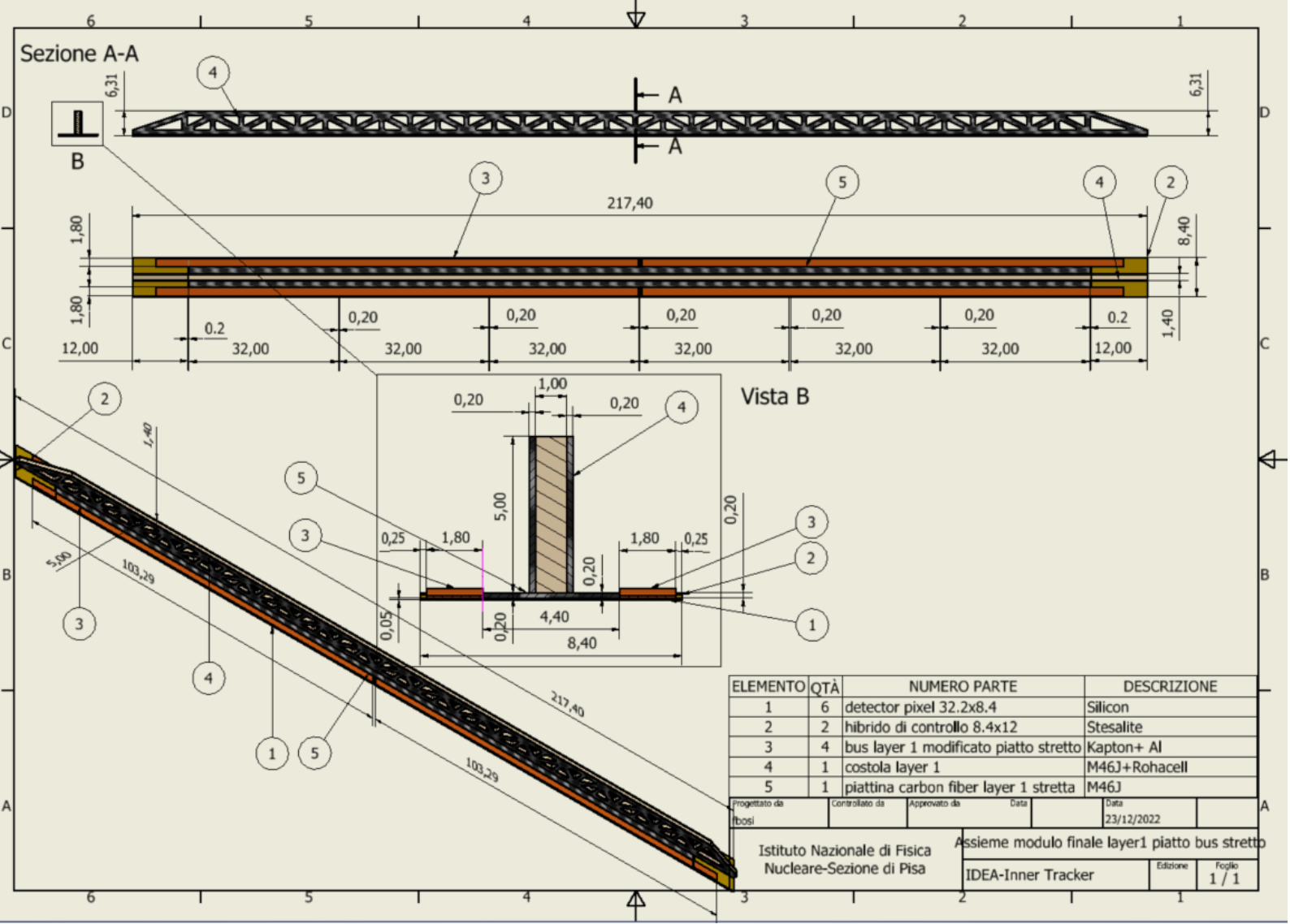


Inner Tracker
 Layer 1 : N.15 stave pinwheel of 6 pixel detector = 90 pixel detector
 Layer 1 Power dissipated :
 N.1 pixel detector = 0.84x3.2 cm2 = 2.69 cm2.
 Power dissipated /pixel= 50 mW/cm2
 Power dissipated /pixel detector=50 mW x 2.69 =0.134 mW
 Total Power dissipated :
 N.90 pixel detector x 0,134 mW = 12.105 W

Layer 1
 15 overlapping staves of 6 modules each
 Overlap to allow alignment ~500 μm
 Pinwheel geometry: all modules at the same (smallest) radius
 Power budget ~12 W
 Total weight ~22 grams
 Total thickness 0.25% X₀
 Silicon: 0.053% X₀
 Power and readout bus: 0.056% X₀

Progettato da	Controllato da	Approvato da	Data
fbosi			02/02/2023
Istituto Nazionale di Fisica Nucleare-Sezione di Pisa			
Assieme completo definitivo layer1 piatto bus stretto_2		Edizione	Foglio
		1	1

Layer 1 stave detail



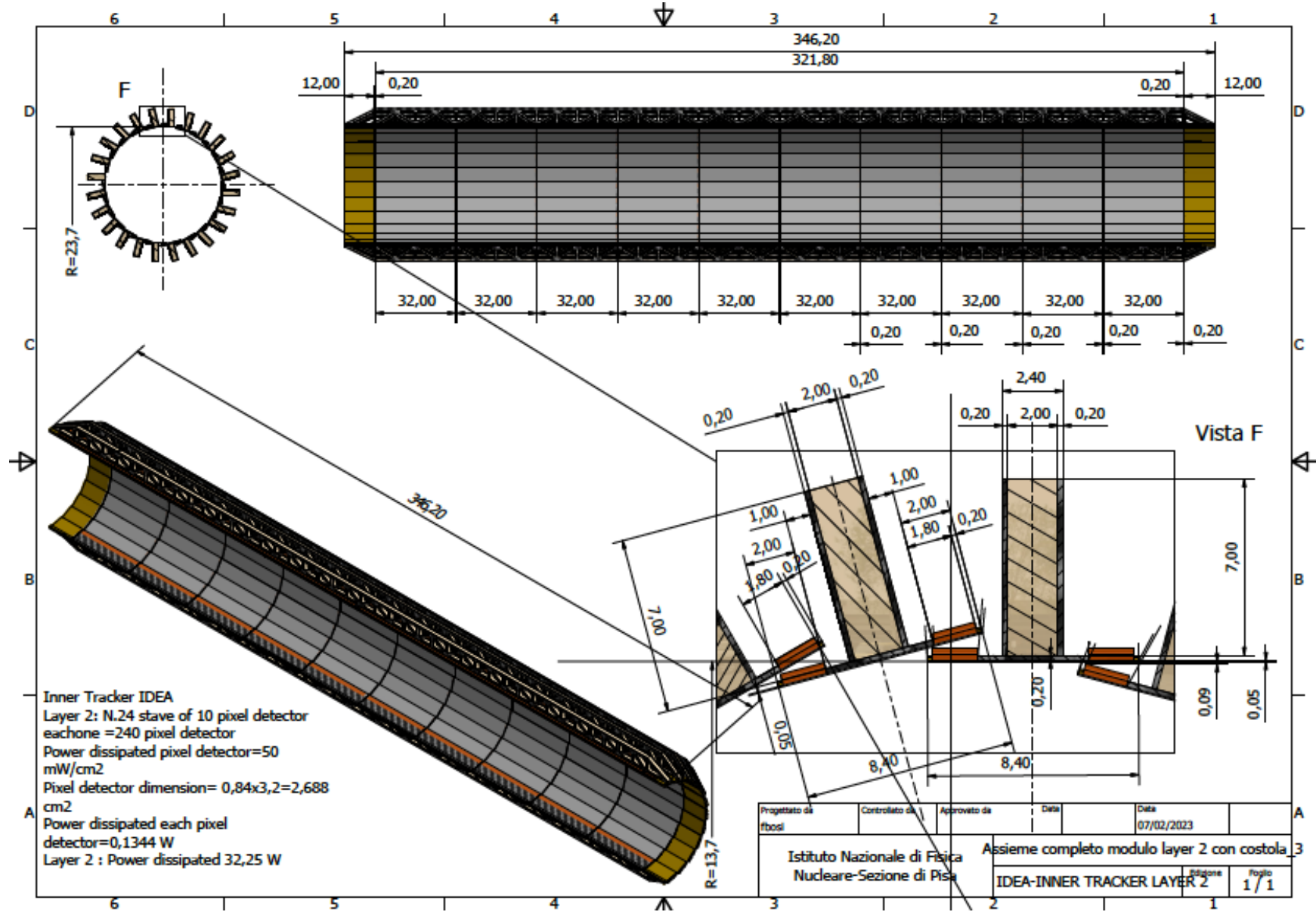
Reticular lightweight support to provide stiffness

- Thin carbon fiber walls interleaved with Rohacell
- 2 buses (data and power) 1.8 mm wide and 250 µm thick (50 µm Al, 200 µm kapton) per side
 - Inspired to low mass hybrid R&D

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

Readout chips either sides

Air cooled



Inner Tracker IDEA
 Layer 2: N.24 stave of 10 pixel detector
 eachone =240 pixel detector
 Power dissipated pixel detector=50
 mW/cm2
 Pixel detector dimension= 0,84x3,2=2,688
 cm2
 Power dissipated each pixel
 detector=0,1344 W
 Layer 2 : Power dissipated 32,25 W

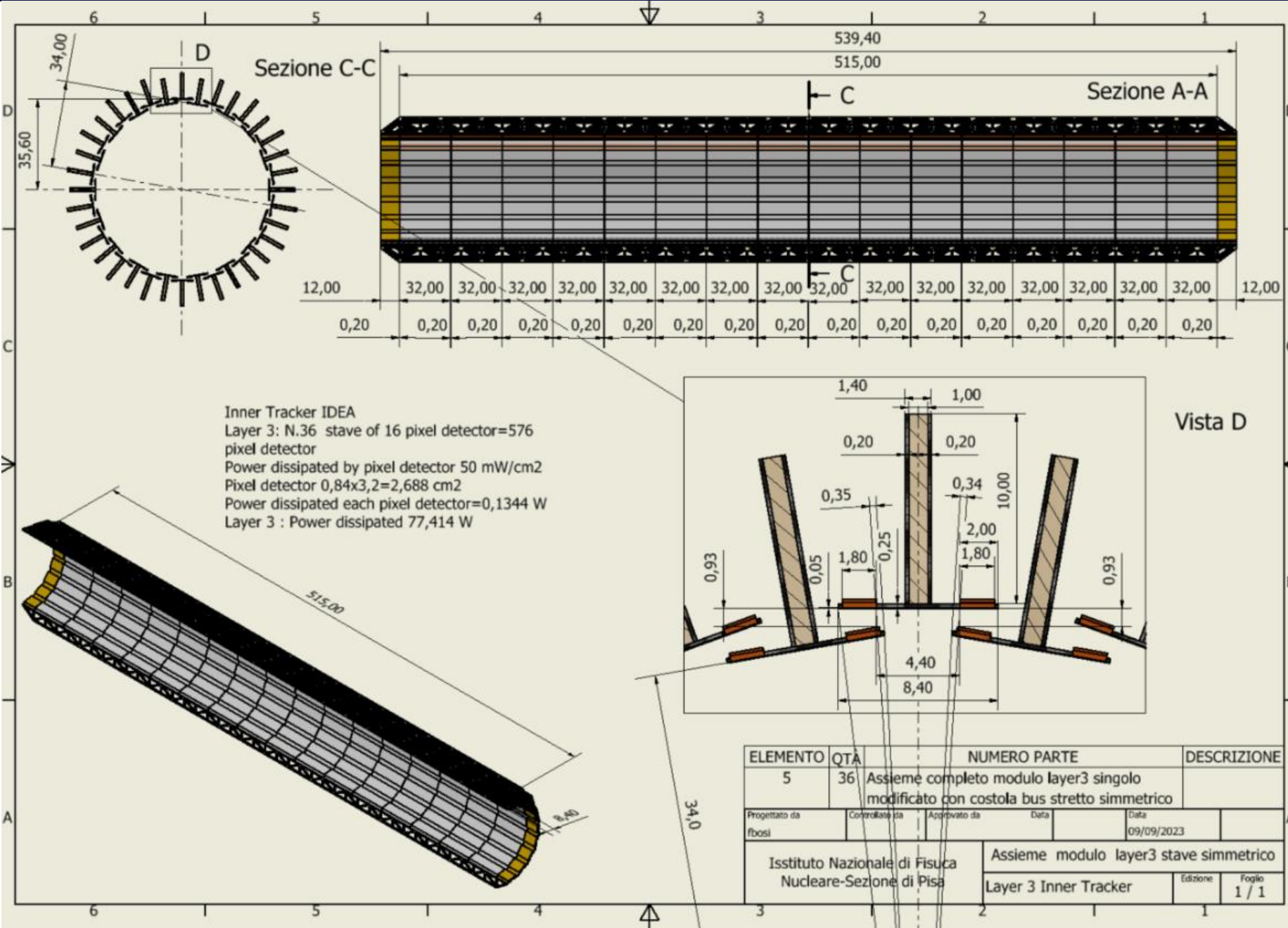
Layer 2
 24 overlapping staves of
 10 modules each

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

Power budget
 ~32 W

Total weight ~63 grams

Total thickness 0.25% X₀



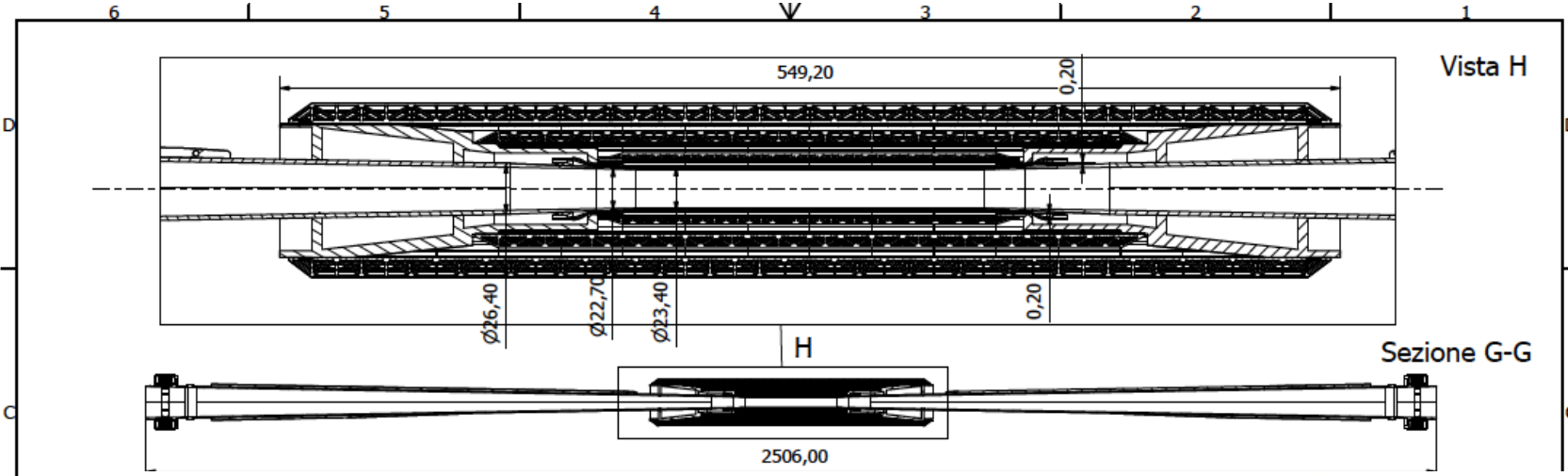
Layer 3
 36 staves of 16 modules each

Lampshade geometry.
 Charge symmetric track reconstruction

Total weight ~150 grams

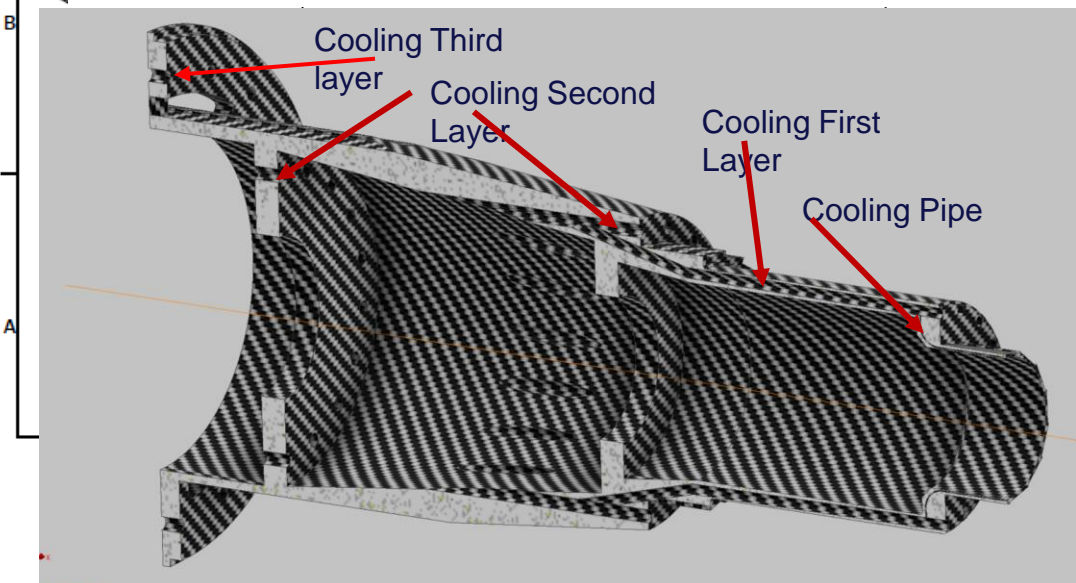
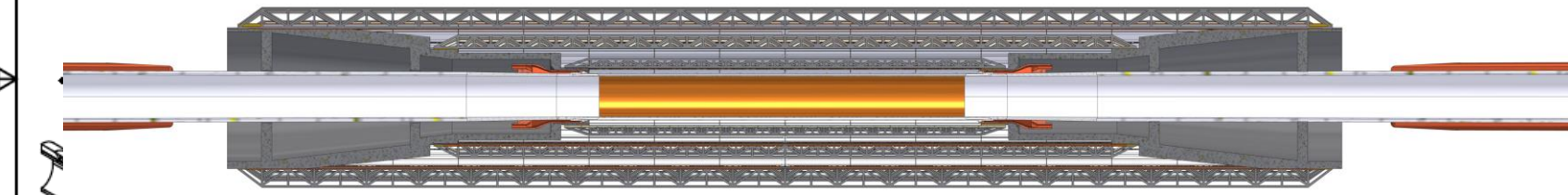
Total thickness 0.25% X₀

Power budget
 ~77 W



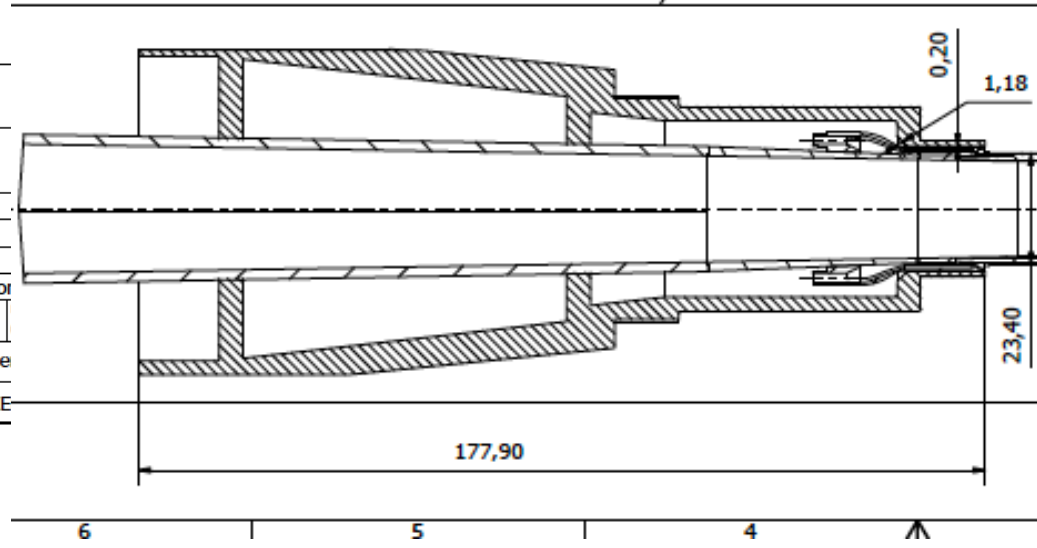
Inner vertex detector supporting conical structures on elliptical chamber
~450 grams

Engineered for air ducts and thermal isolation from the beam pipe during bakeout



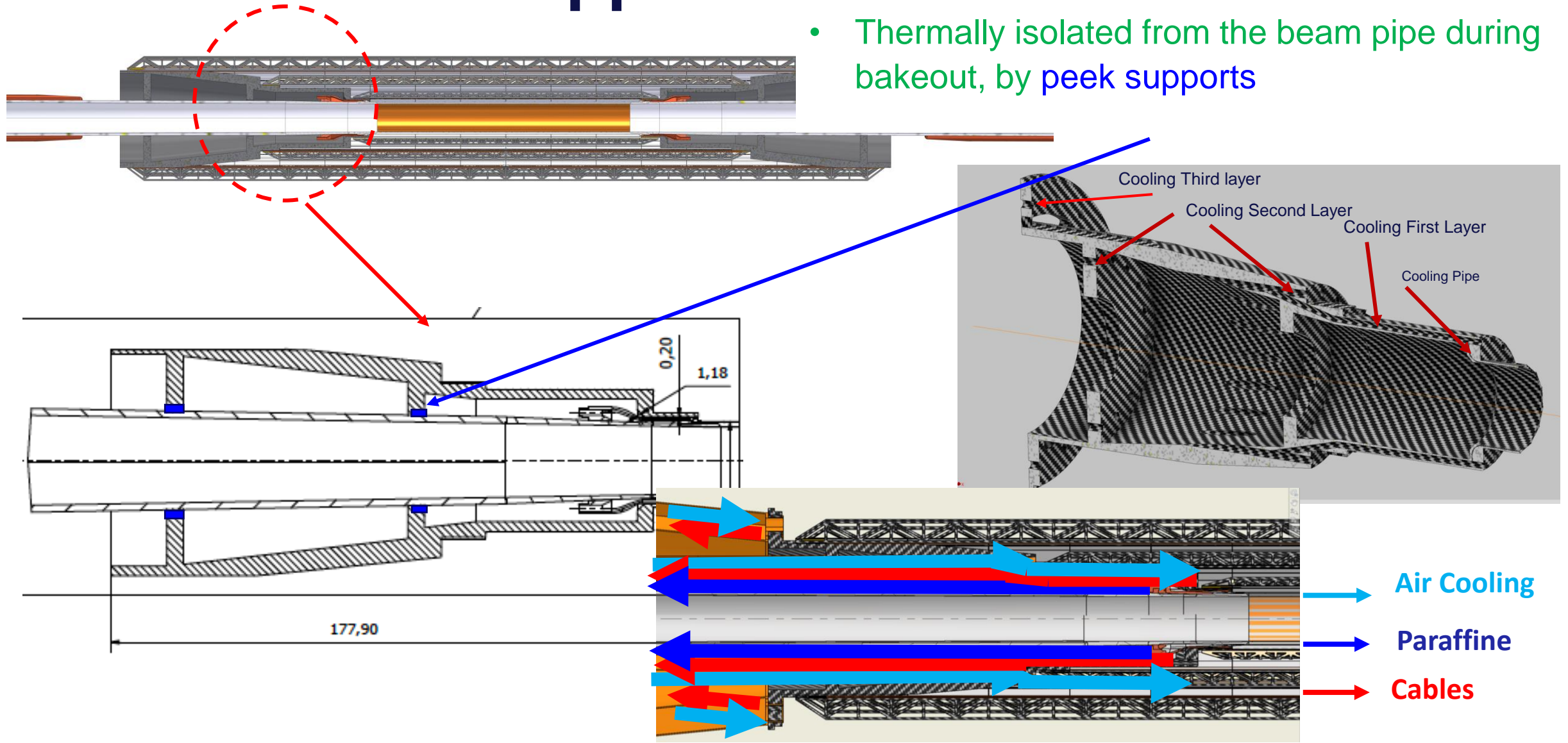
978,40

ELENCO PARTI		
NUMERO PARTE		
chamber_27012023		
Assieme inner tracker con supporti carboni		
Controllato da	Approvato da	Data
chamber_27012023+inne		
IDEA-INNER TRACKE		

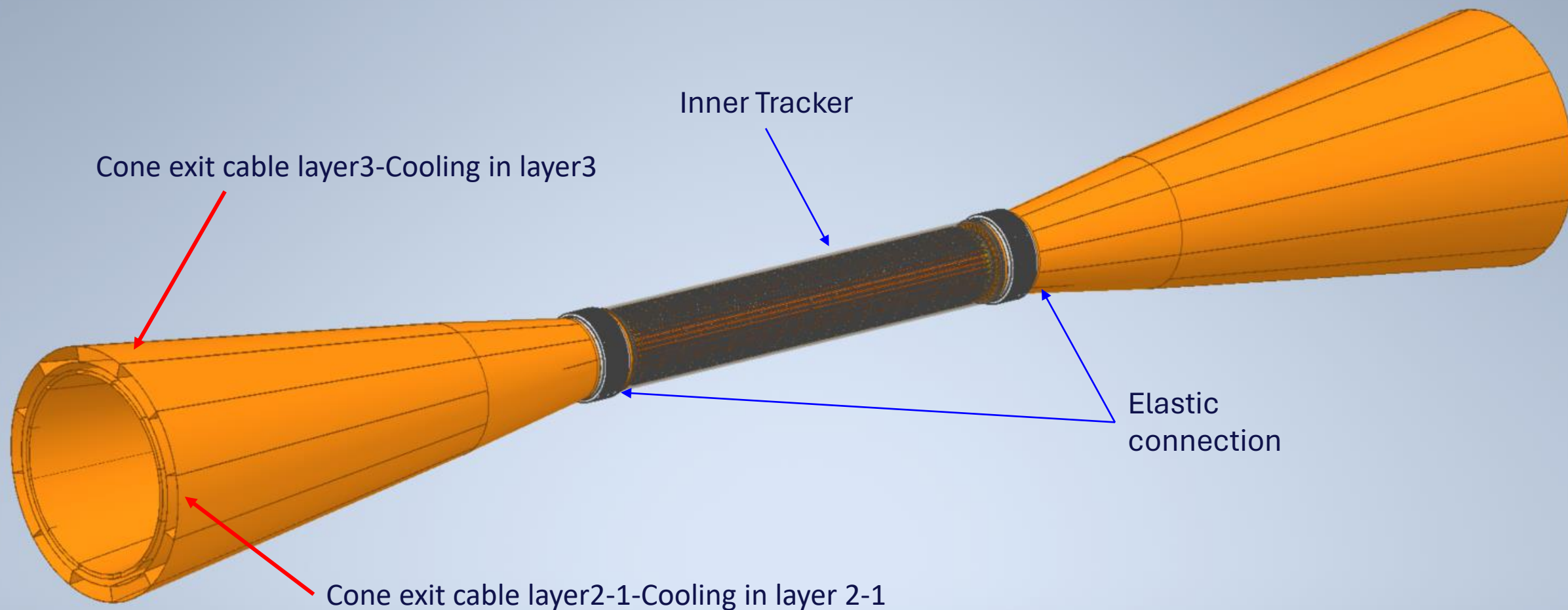


Inner Vertex support

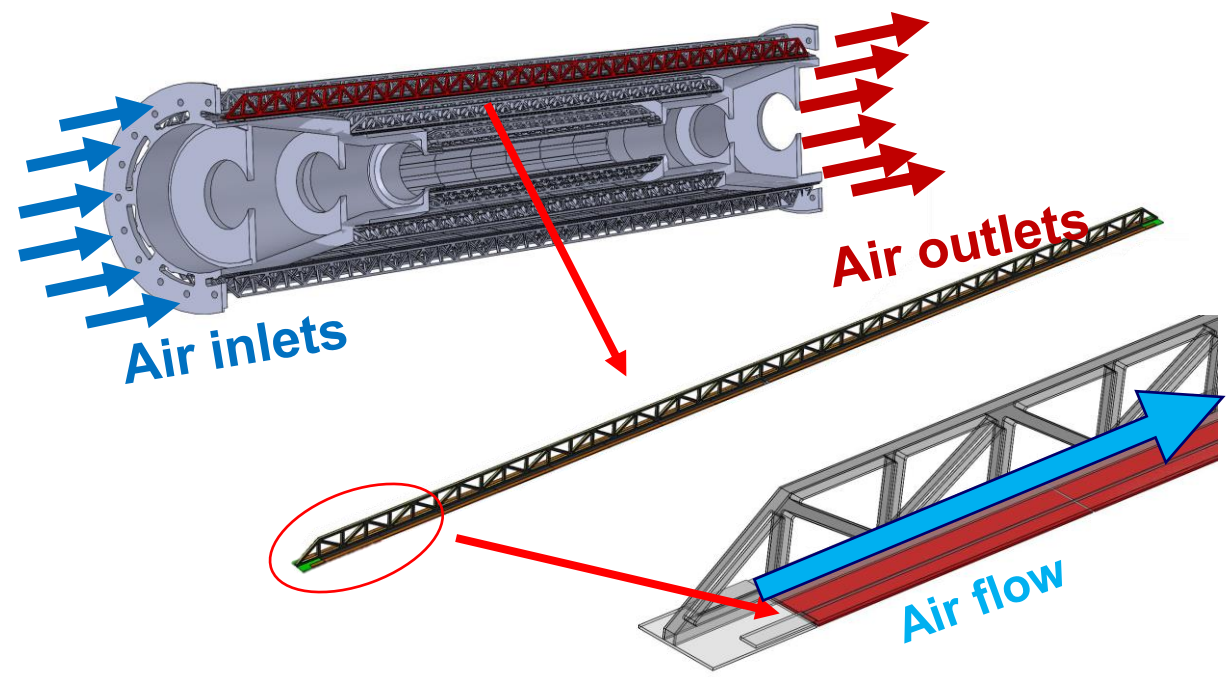
- Anchored to the conical chamber
- Air cooled
- Thermally isolated from the beam pipe during bakeout, by peek supports



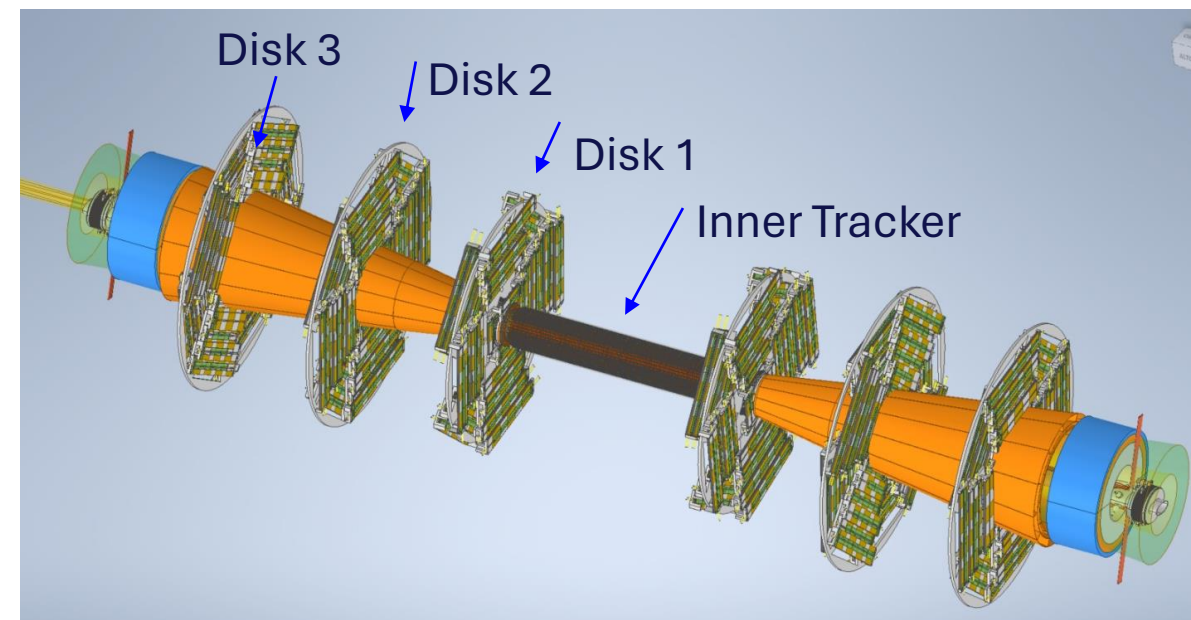
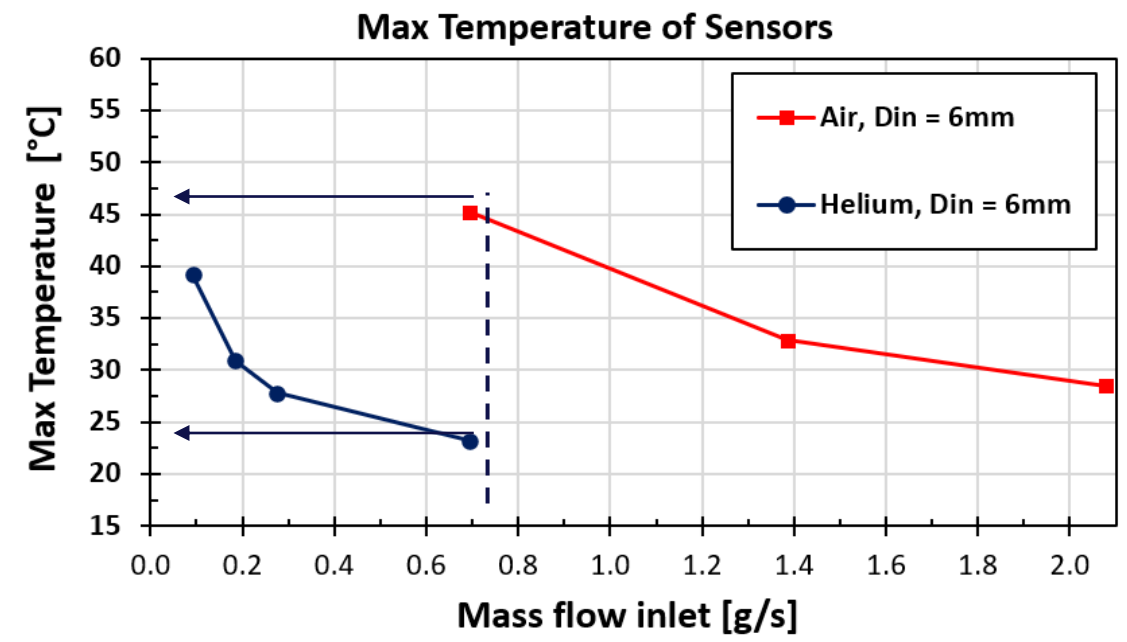
Service cones for cooling and cables

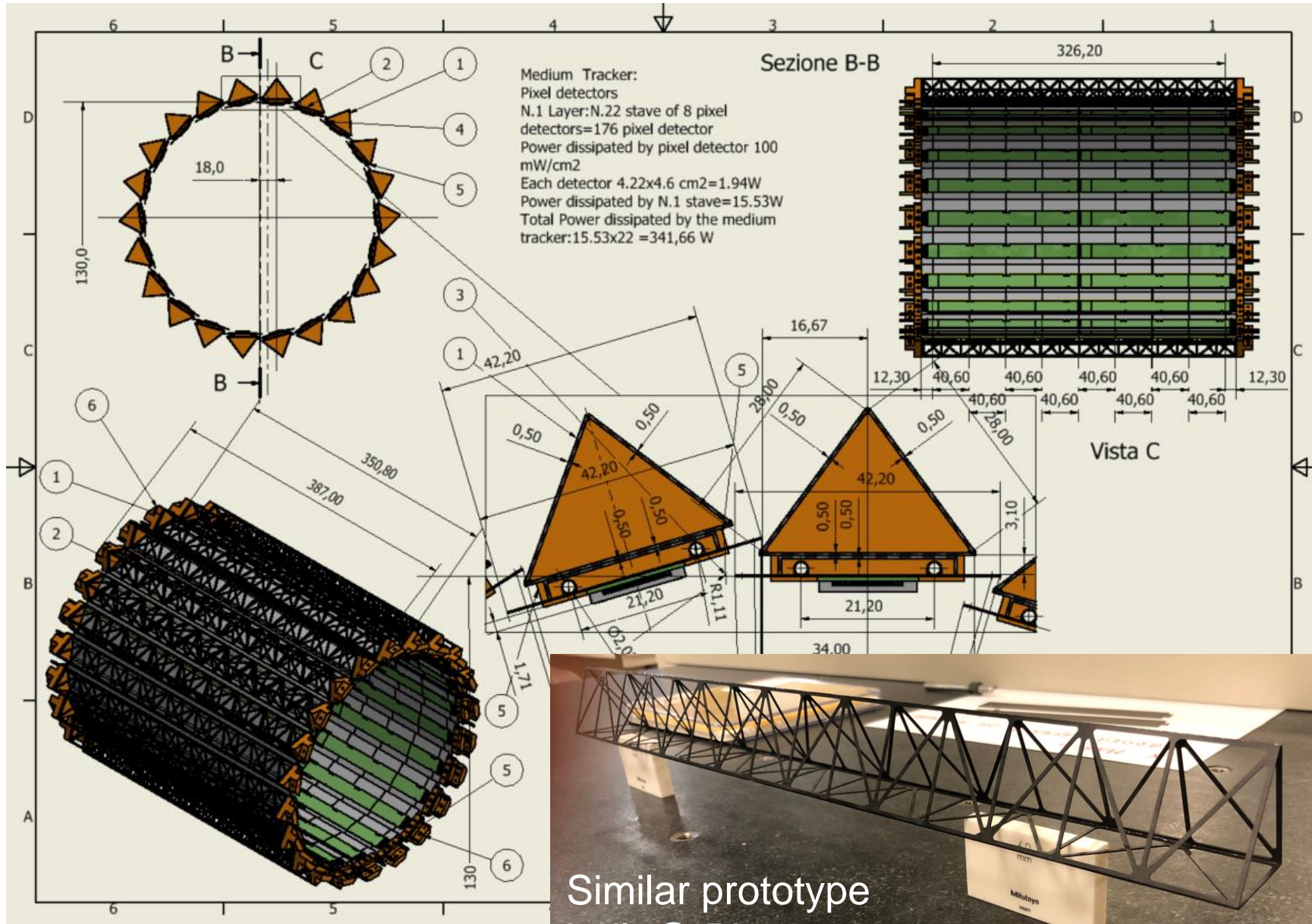


Air cooling (simulations)



- Cooling with air/He flow along the detector.
 - Air temperature: $T_{air} = 15^{\circ}C$
 - Max sensor temp on layer 3 (hottest one) $\sim 25/30^{\circ}C$ with He/Air.
 - Vibrations studies ongoing





Middle Barrel
At 13 cm radius

22 staves of 8 modules each.

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

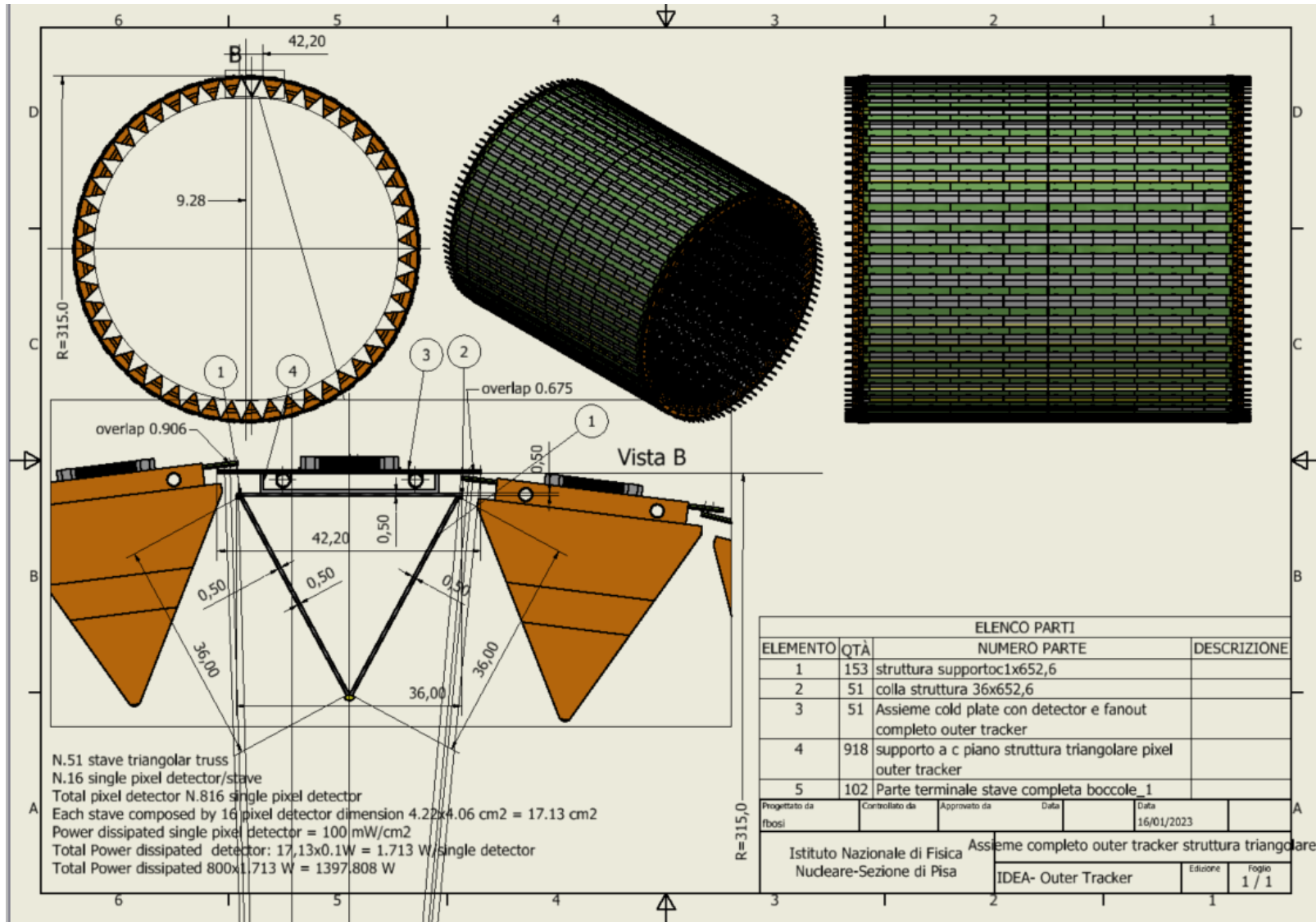
Readout chips either side
Power budget ~342 W

Total weight ~1 kg
 Water cooled (2 pipes of 2 mm diameter)



Similar prototype built @ Pisa

Outer barrel is similar but longer (see backup)



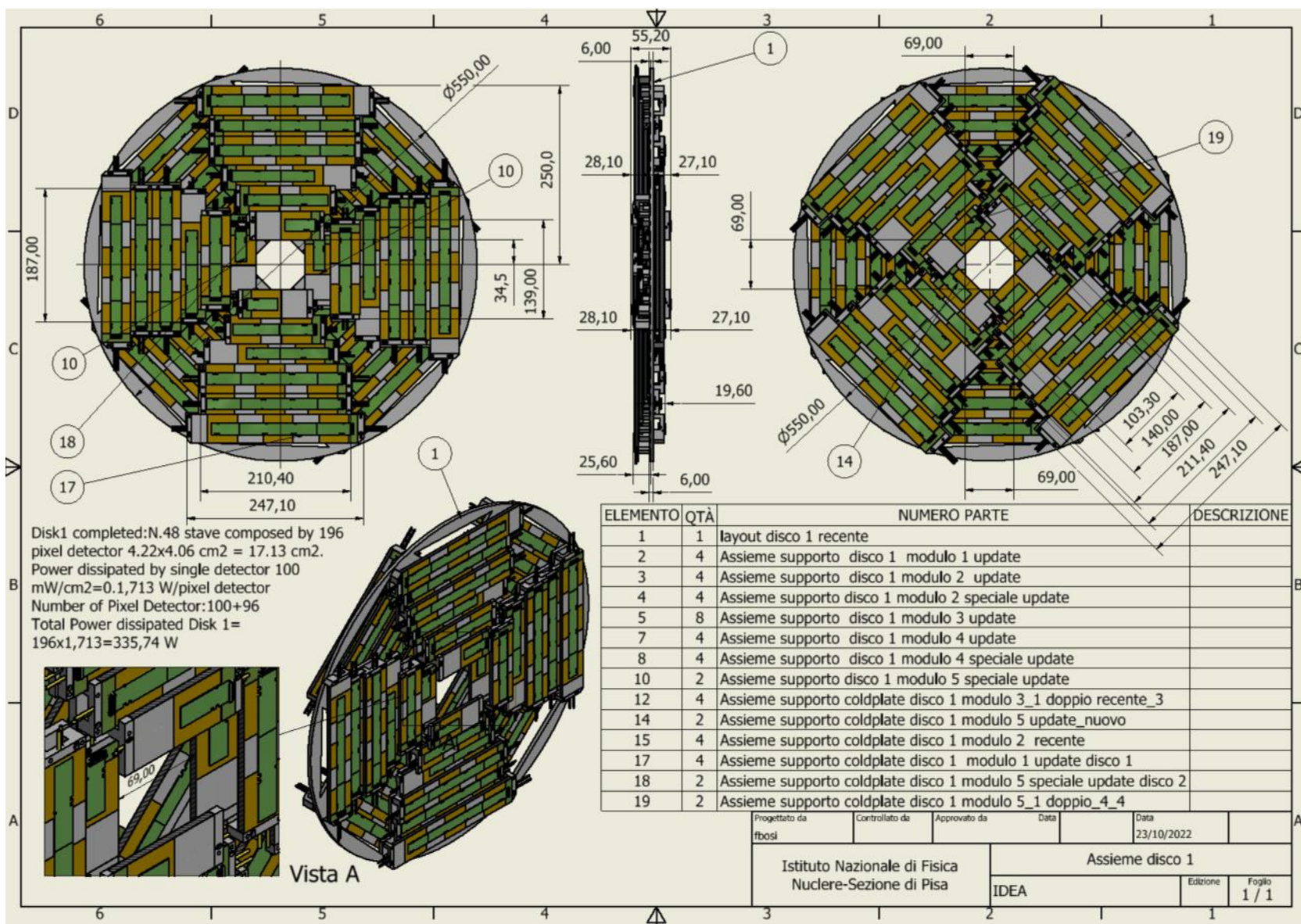
Outer Vertex Tracker Barrel
At 31.5 cm radius

51 staves of 16 modules each

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

Total weight ~3.7 kg
 Readout chips either side
Power budget ~1400 W

Water cooled (2 pipes of 2 mm diameter)



Outer Vertex Tracker Disk 1
 2 sides (front and back) each with 4 petals.

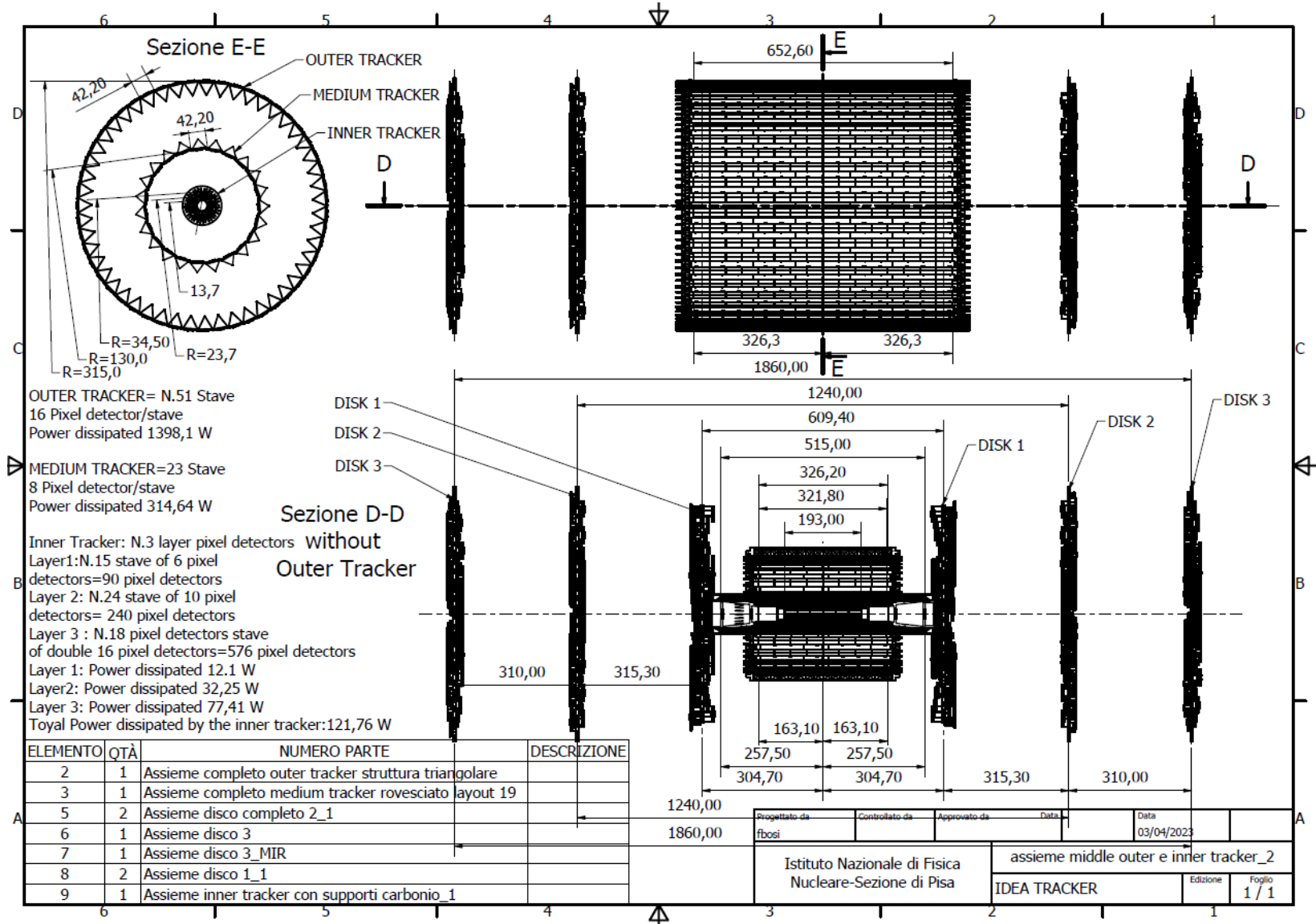
One petal is made of different staves of overlapping modules

Total modules per disk: 196
 Total weight ~850 grams
 Power budget ~ 336 W

Cooling using 1 water pipe (2 mm diameter)

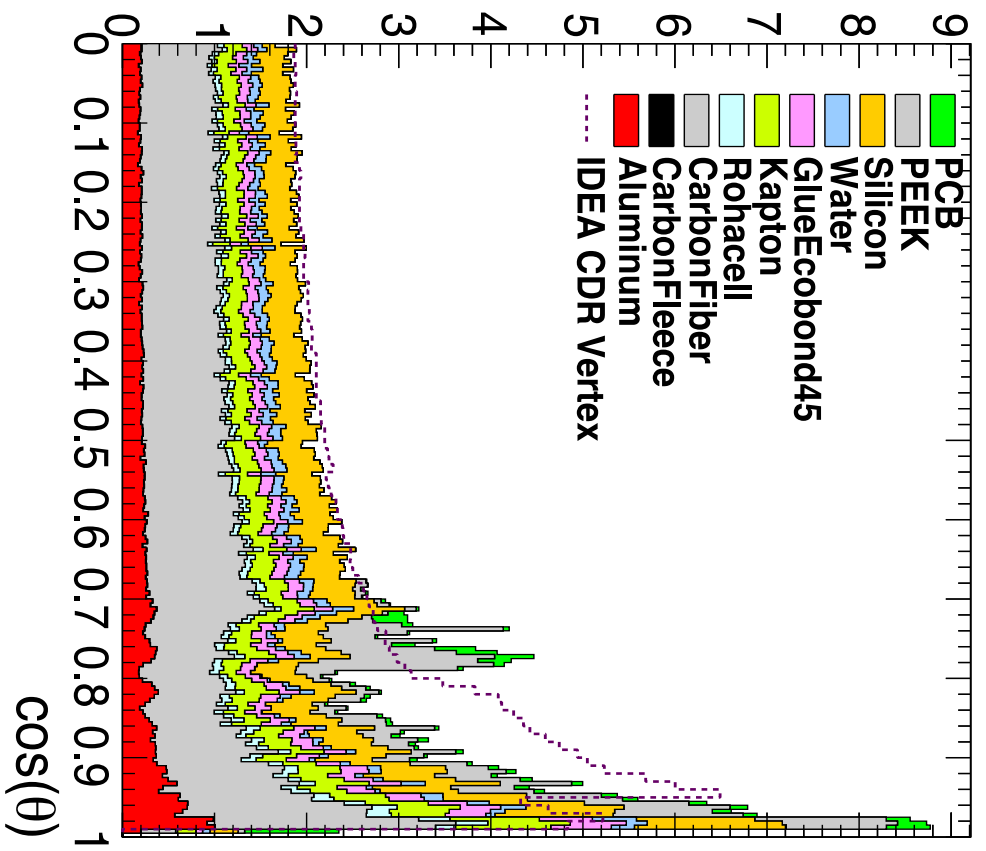
Similar geometry for the other two disks

Overall layout and dimensions

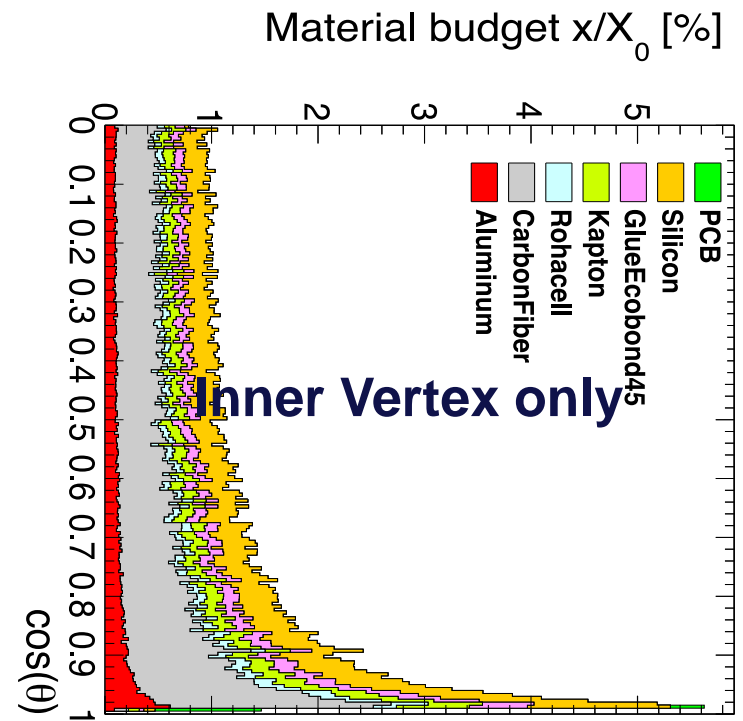
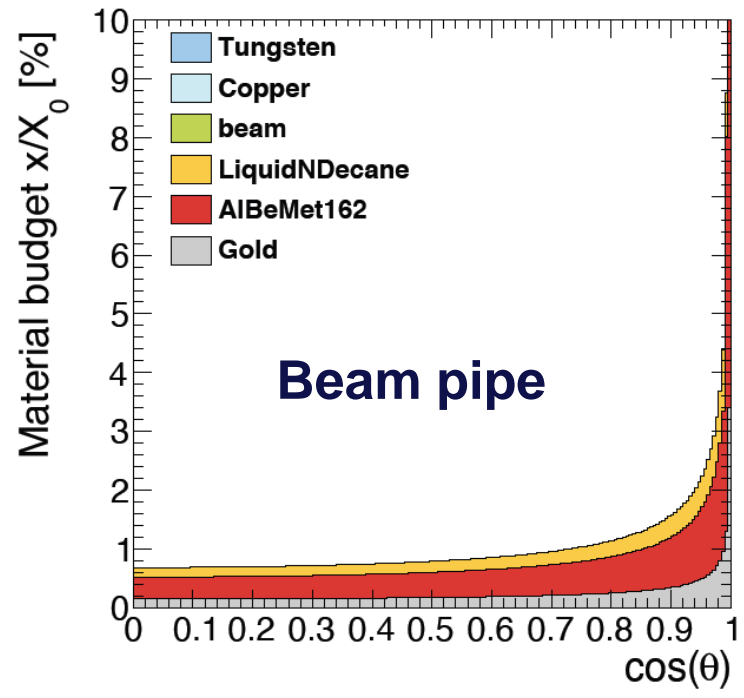


Simulated material budget

Material budget x/X_0 [%]



In agreement with CAD estimates
 Smaller X/X_0 wrt IDEA CDR estimates even including power and readout cables in the sensitive region
 Silicon only ~15% of the total

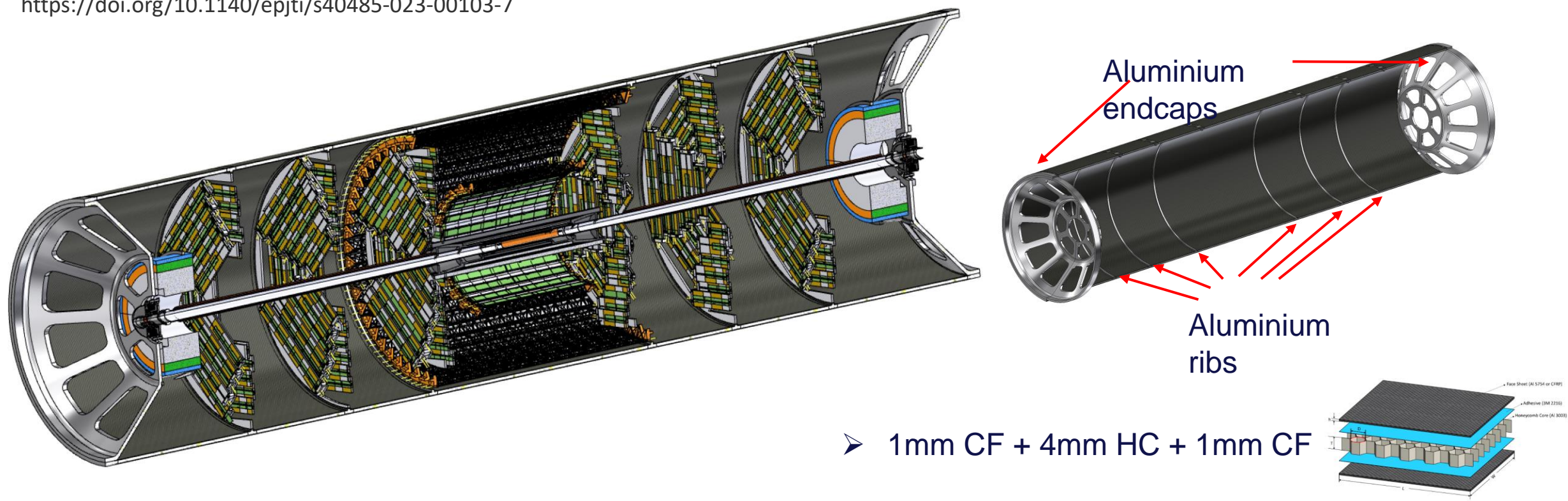


Support cylinder

All elements in the interaction region (Vertex and LumiCal) are mounted rigidly on a support cylinder that guarantees mechanical stability and alignment

- Once the structure is assembled it is slid inside the rest of the detector

*M. Boscolo, F. Palla, F. Franesini, F. Bosi and S. Lauciani, Mechanical model for the FCC-ee MDI, EPJ Techn Instrum 10, 16 (2023).
<https://doi.org/10.1140/epjti/s40485-023-00103-7>*



➤ 1mm CF + 4mm HC + 1mm CF

Conclusions



- **A Vertex Detector layout for IDEA detector concept has been engineered**
 - Uses low power, thin (50 μm) DMAPS technology
 - Integration with the machine detector elements developed
 - Services integration and cooling being finalised
 - Material budget kept at the level of 0.25 % X/X_0 per layer
- Documented in
 - *M. Boscolo, F. Palla, F. Franesini, F. Bosi and S. Lauciani, Mechanical model for the FCC-ee MDI, EPJ Techn Instrum* **10**, 16 (2023). <https://doi.org/10.1140/epiti/s40485-023-00103-7>

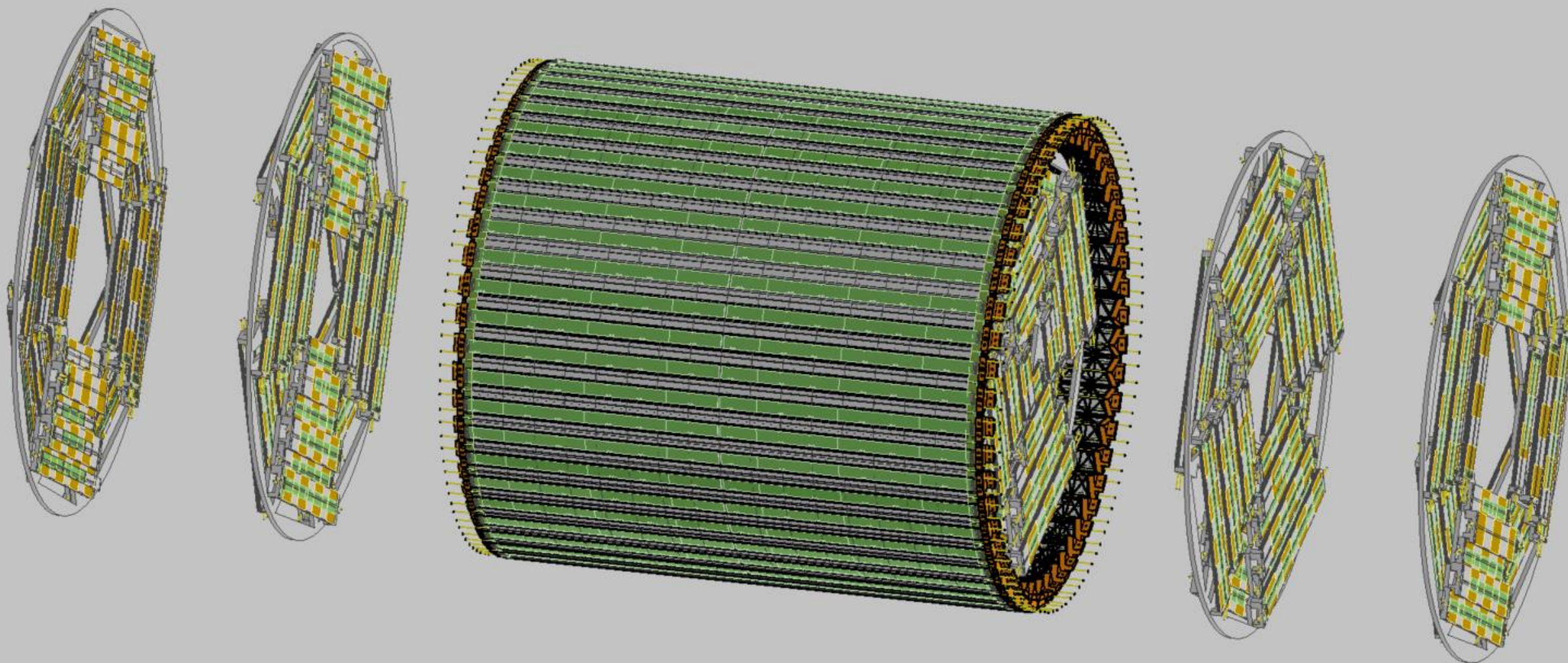


Thank you
for your attention.
感谢您的关注

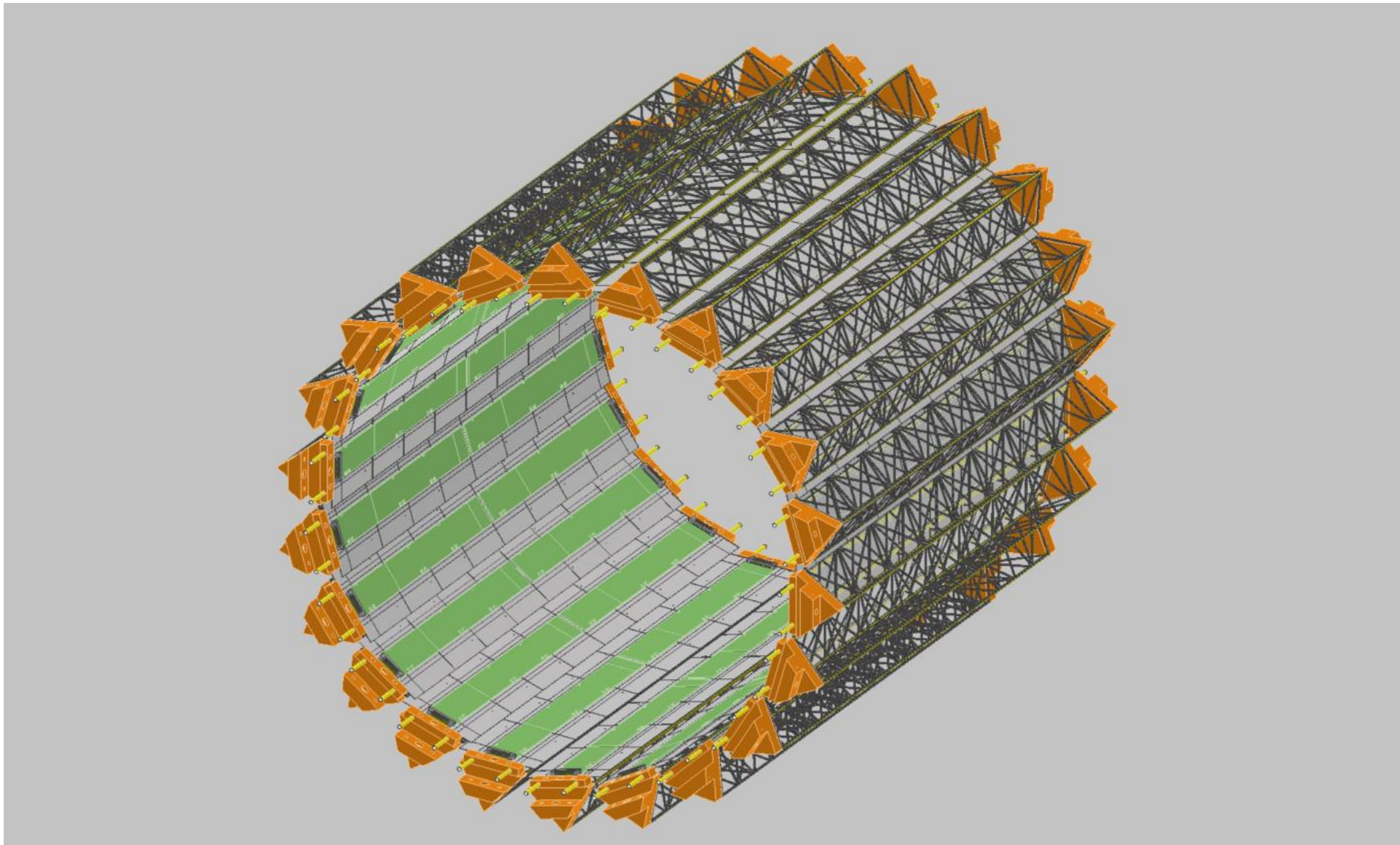


Backup

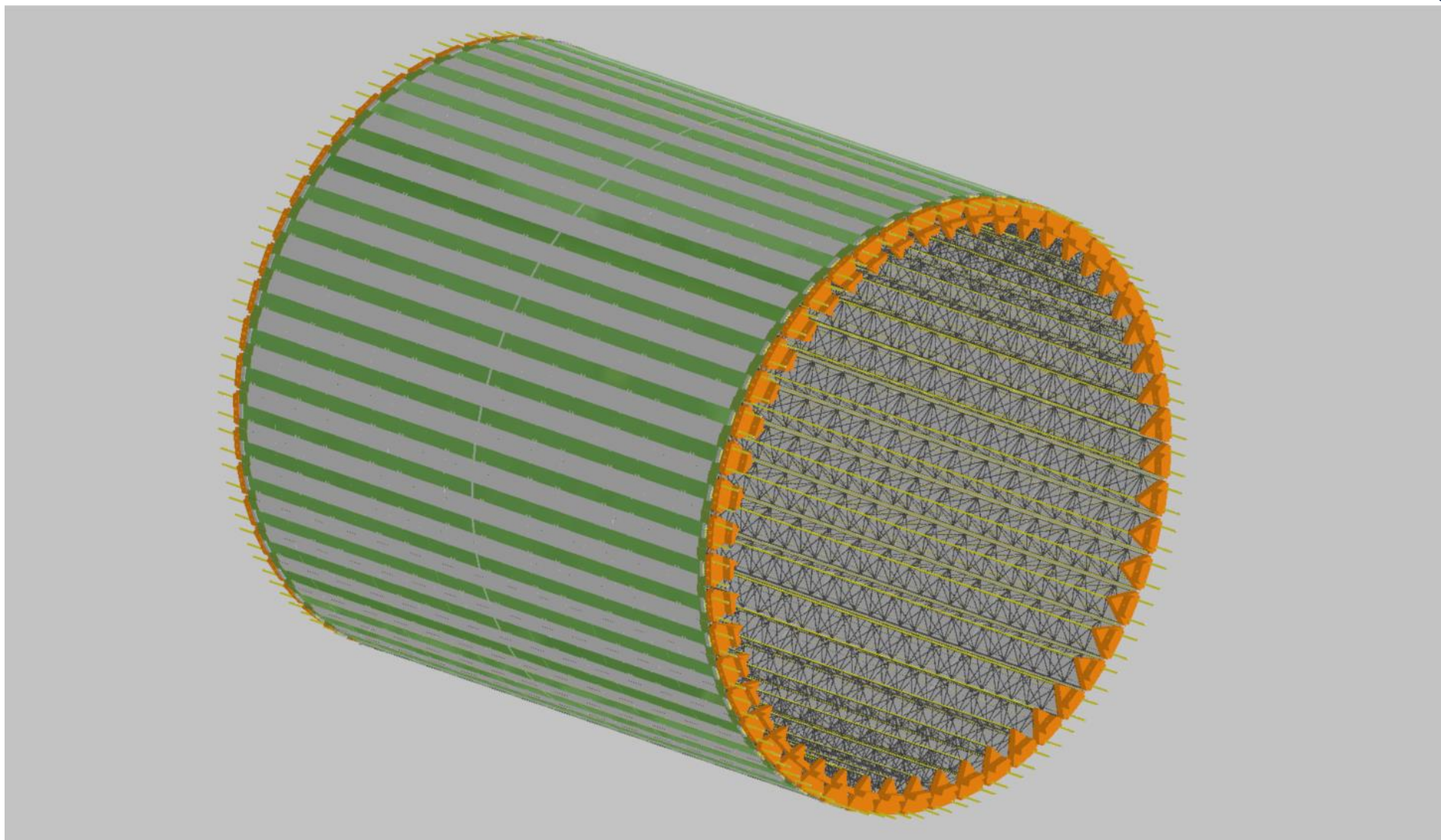
Outer Tracker and Disks



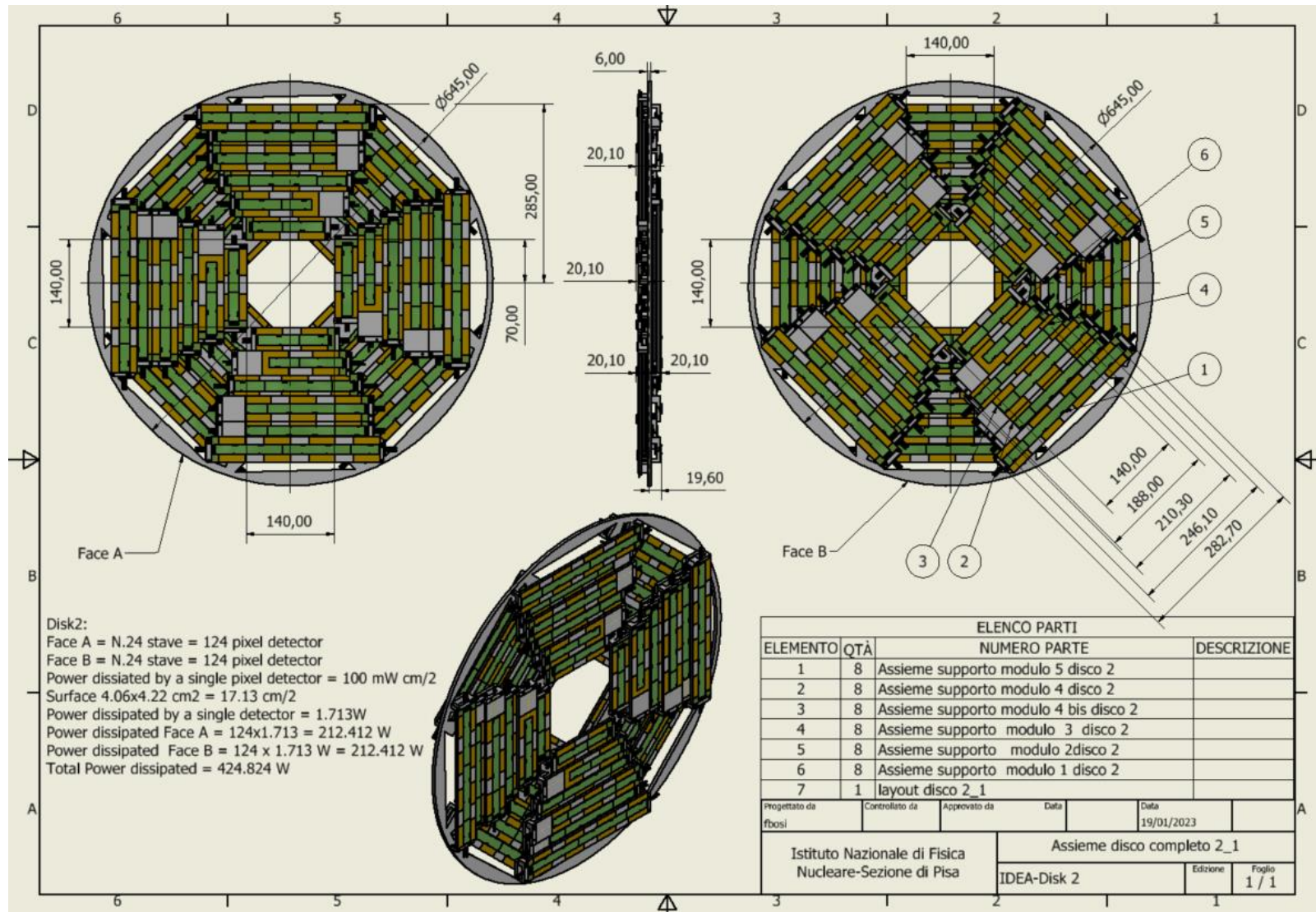
MIDDLE TRACKER



OUTER TRACKER



DISK 2



DISK 3

