CHALLENGES OF THE IDEA VERTEX DETECTOR INTEGRATION

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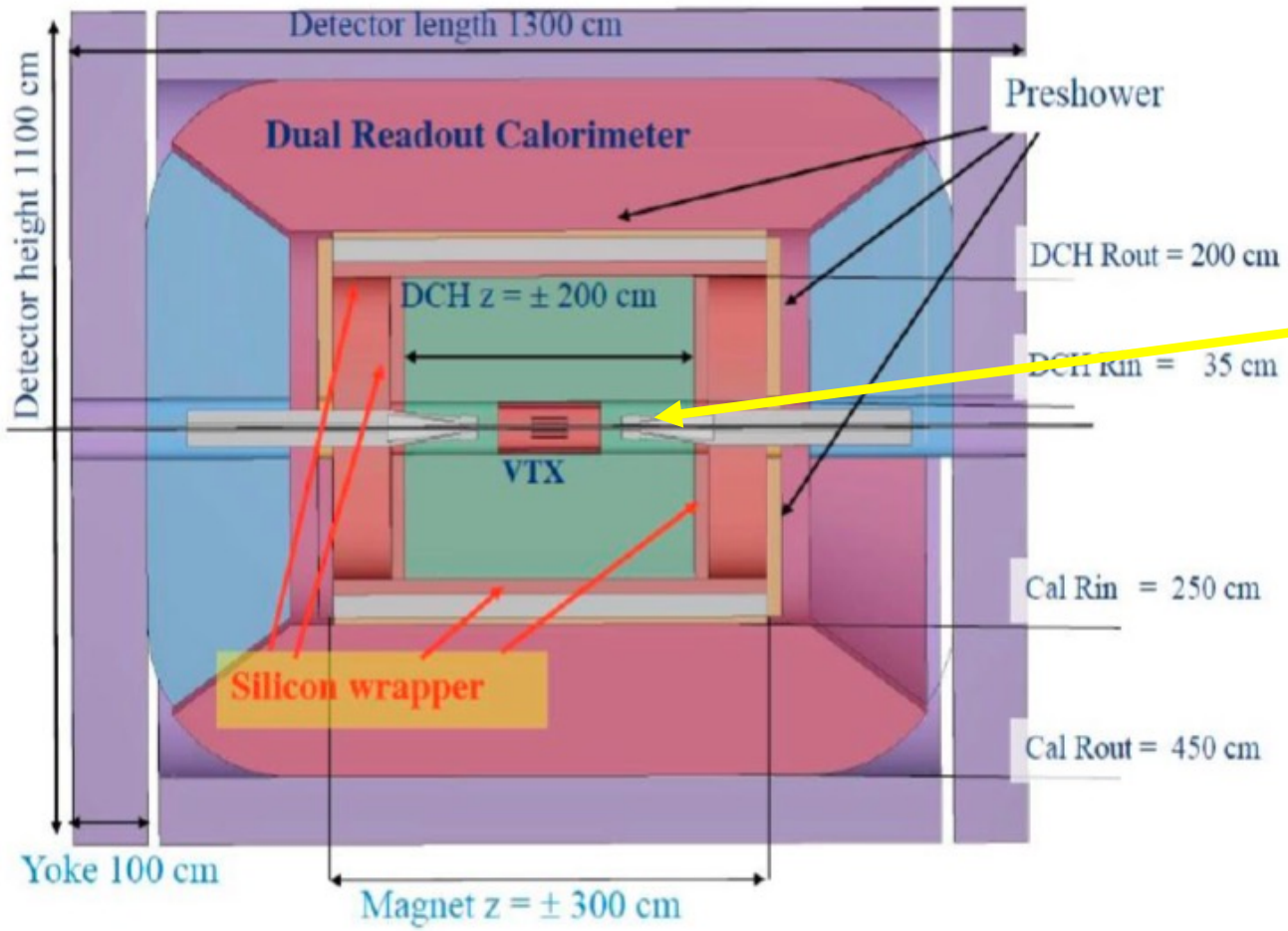
The IDEA Concept



- 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

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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 tracker must be done inside the support tube
- Minimize the radiation lengths

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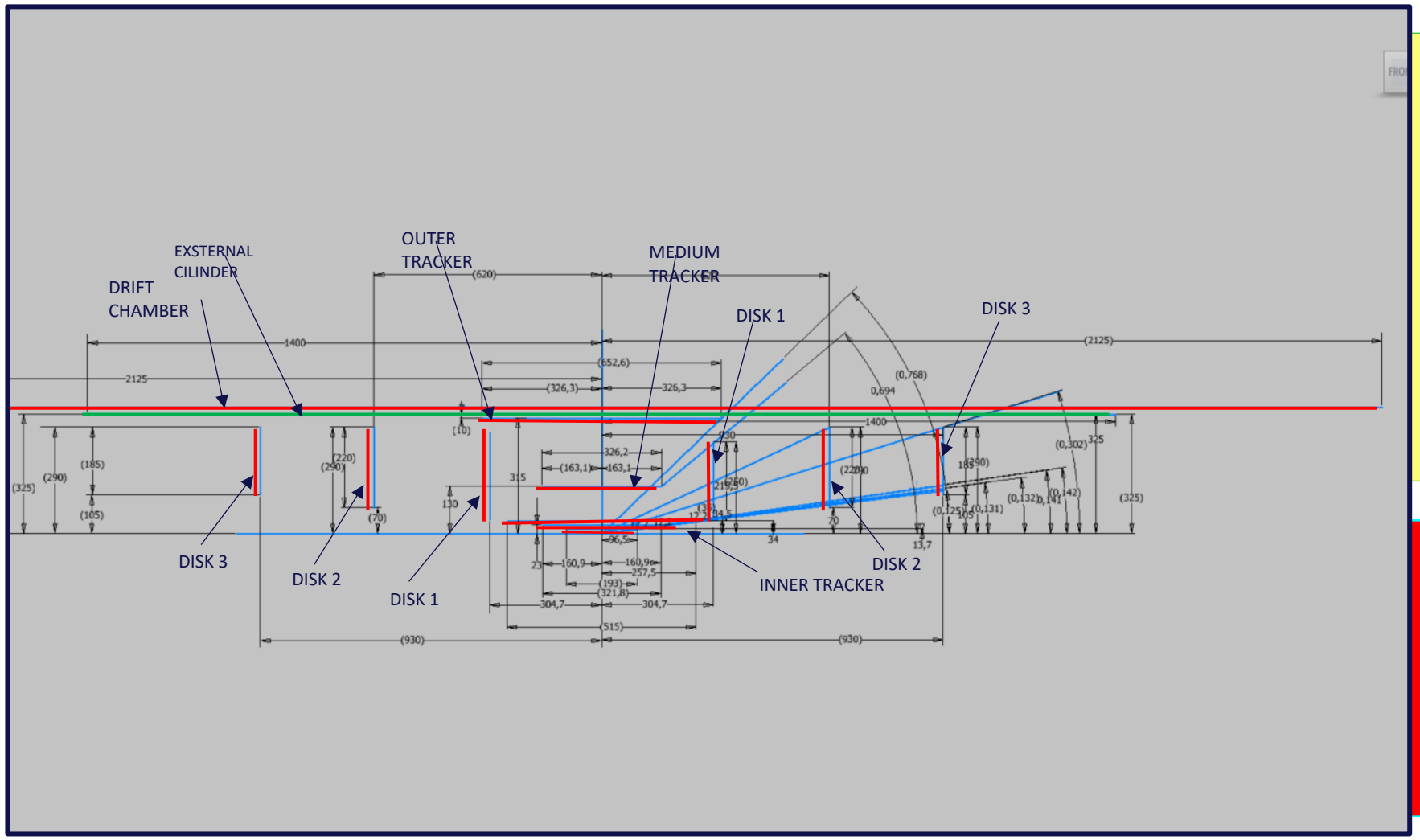

Outer vertex tracker:

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

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

Inner Vertex detector:

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

3 barrel layers at
- 13.7, 22.7 and 34.8 mm radius

Sensors technology

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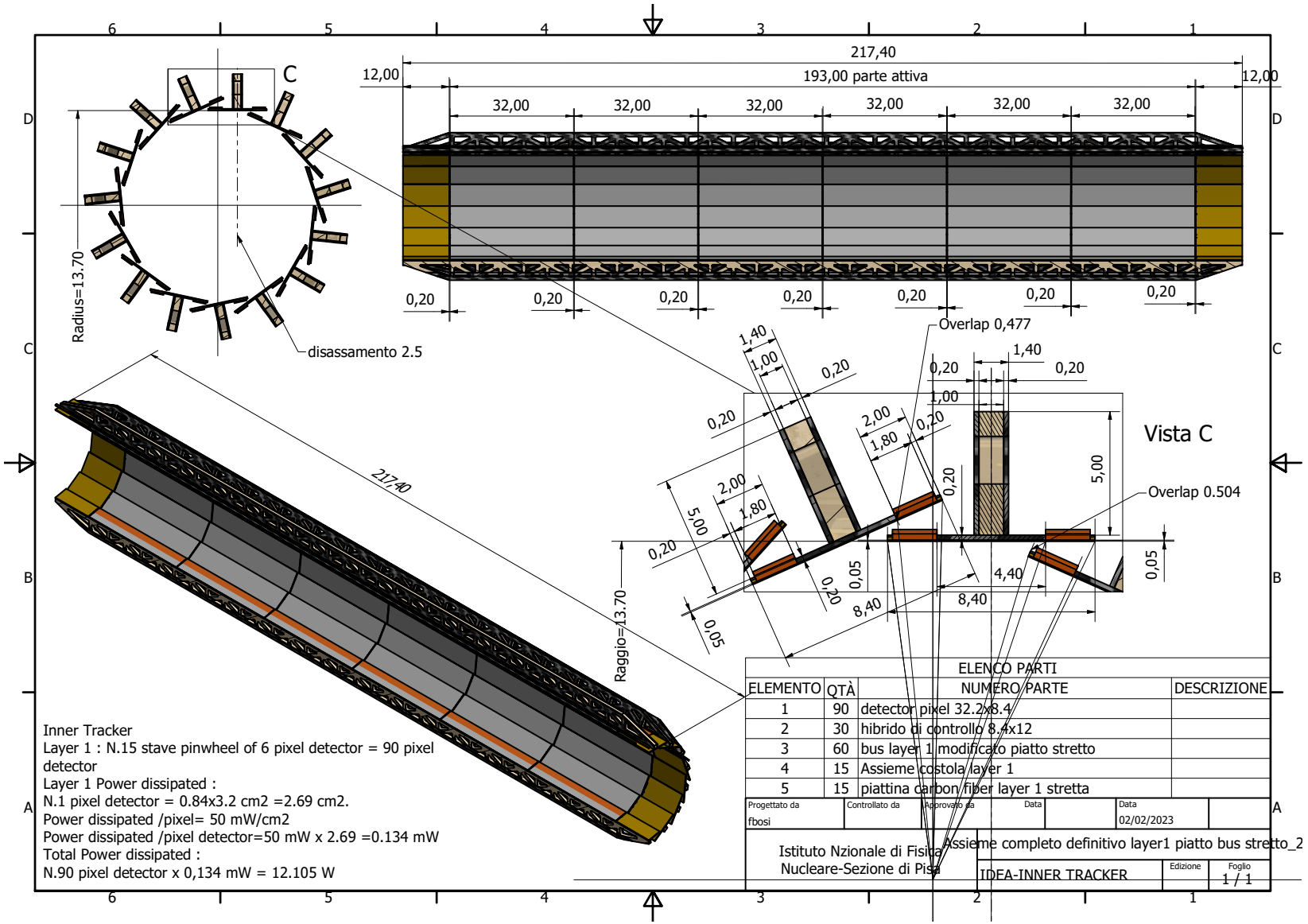
Depleted Monolithic Active Pixel Detectors

- Vertex:
  - Technology: LF11is 110 nm CMOS node, high-resistivity bulk
  - Pixel size 25x25 μm^2 , 50 µm thick, 50 mW/cm2
  - Active area 640 pixel (16 mm) in z and 256 pixels (6.4 mm) in $r - \varphi$
  - Chip periphery plus an inactive zone: total of 2 mm in $r - \varphi$
  - See talk by D. Falchieri
- Outer Vertex and disks
  - TSI 180 nm process
  - Based on ATLASPIX3 R&D
  - 50 µm thick, 50 x 150 μm^2,132 columns of 372 pixels, 4 chip module
  - See talk by R. Zanzottera



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

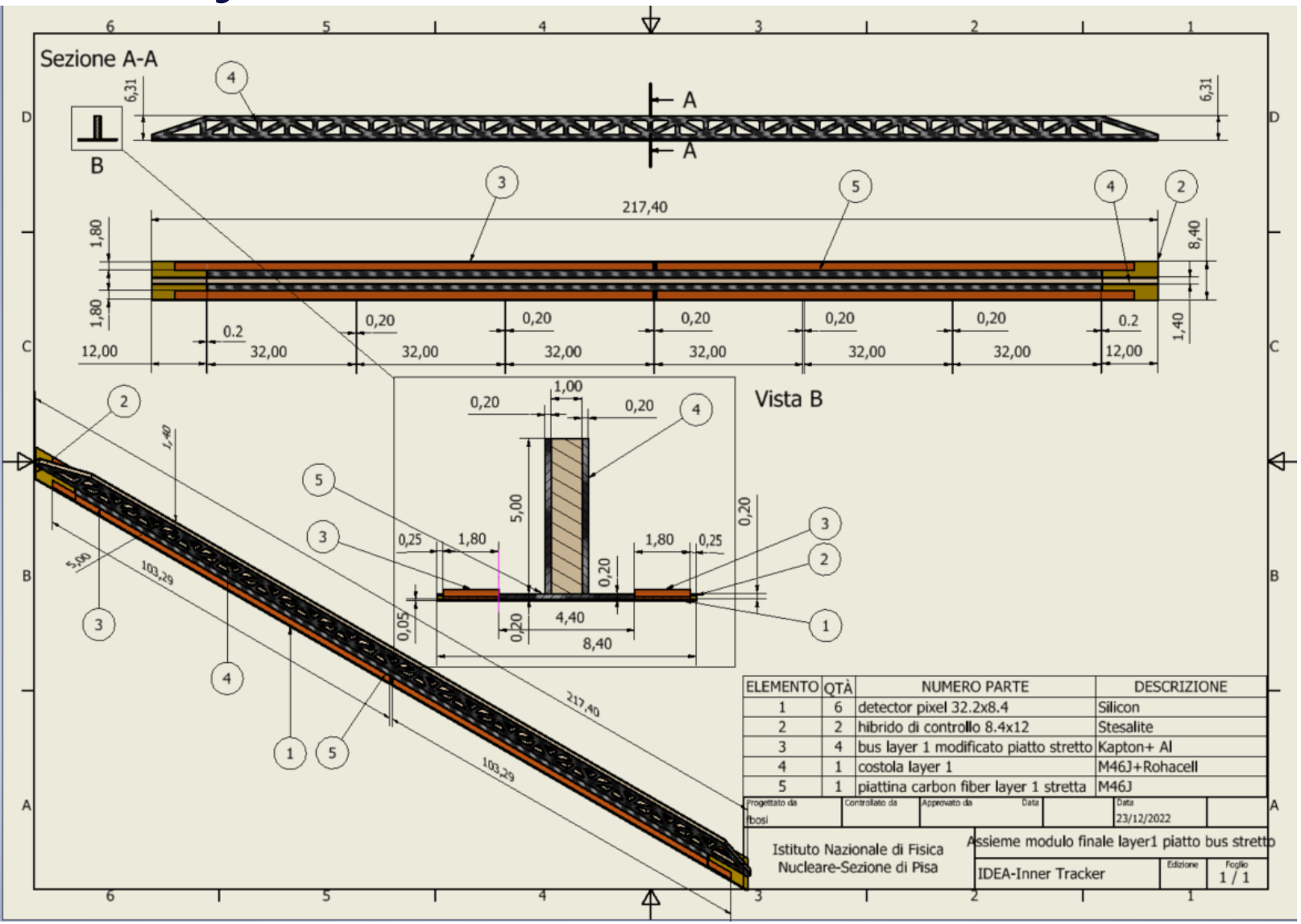
Total weight ~22 grams

Total thickness 0.25% X_0

Silicon: 0.053% X_0

Power and readout bus: 0.056% X_0

Layer 1 stave detail



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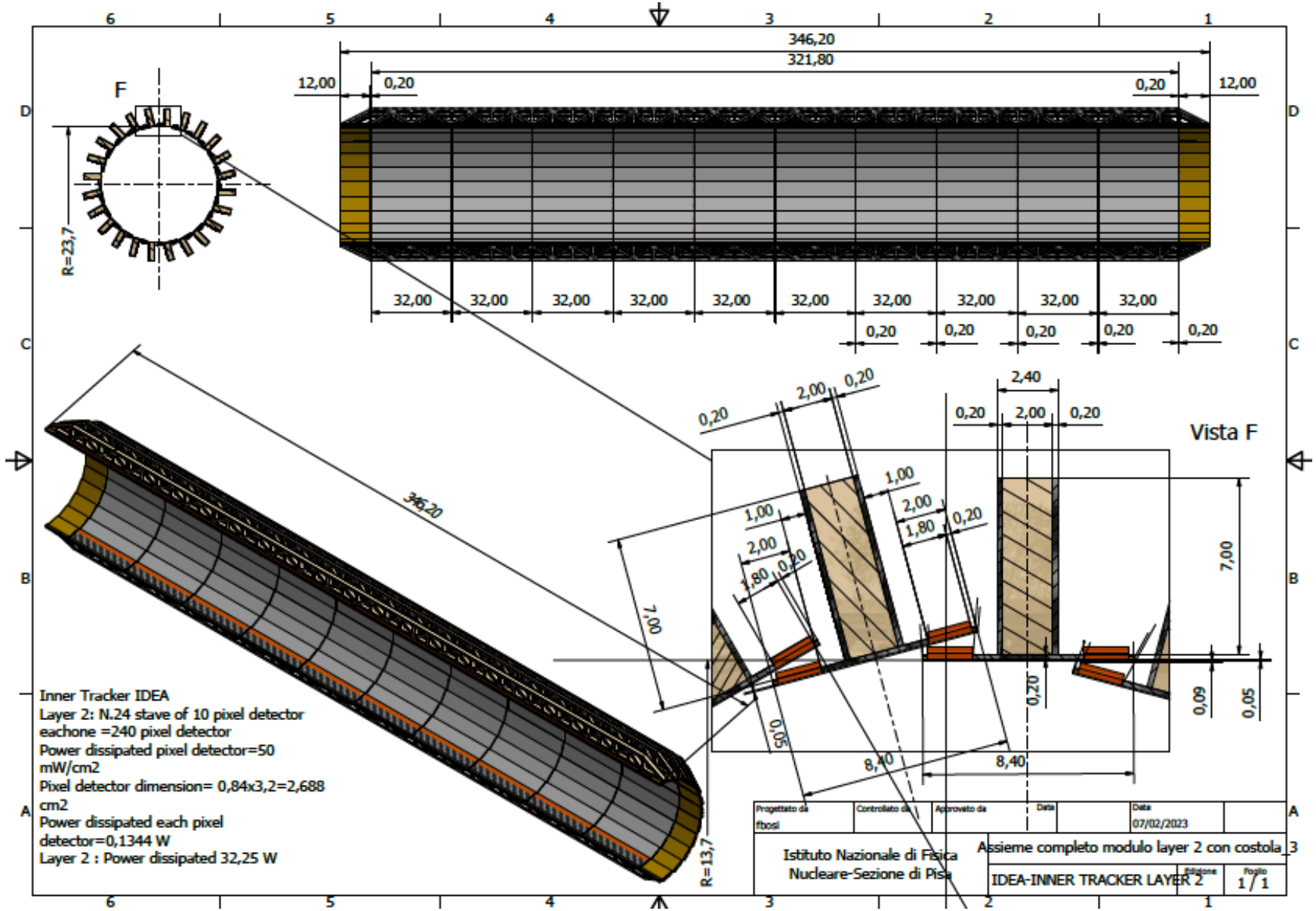
Reticular lightweight support to provide stiffness

- 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



Layer 2

24 overlapping staves of 10 modules each

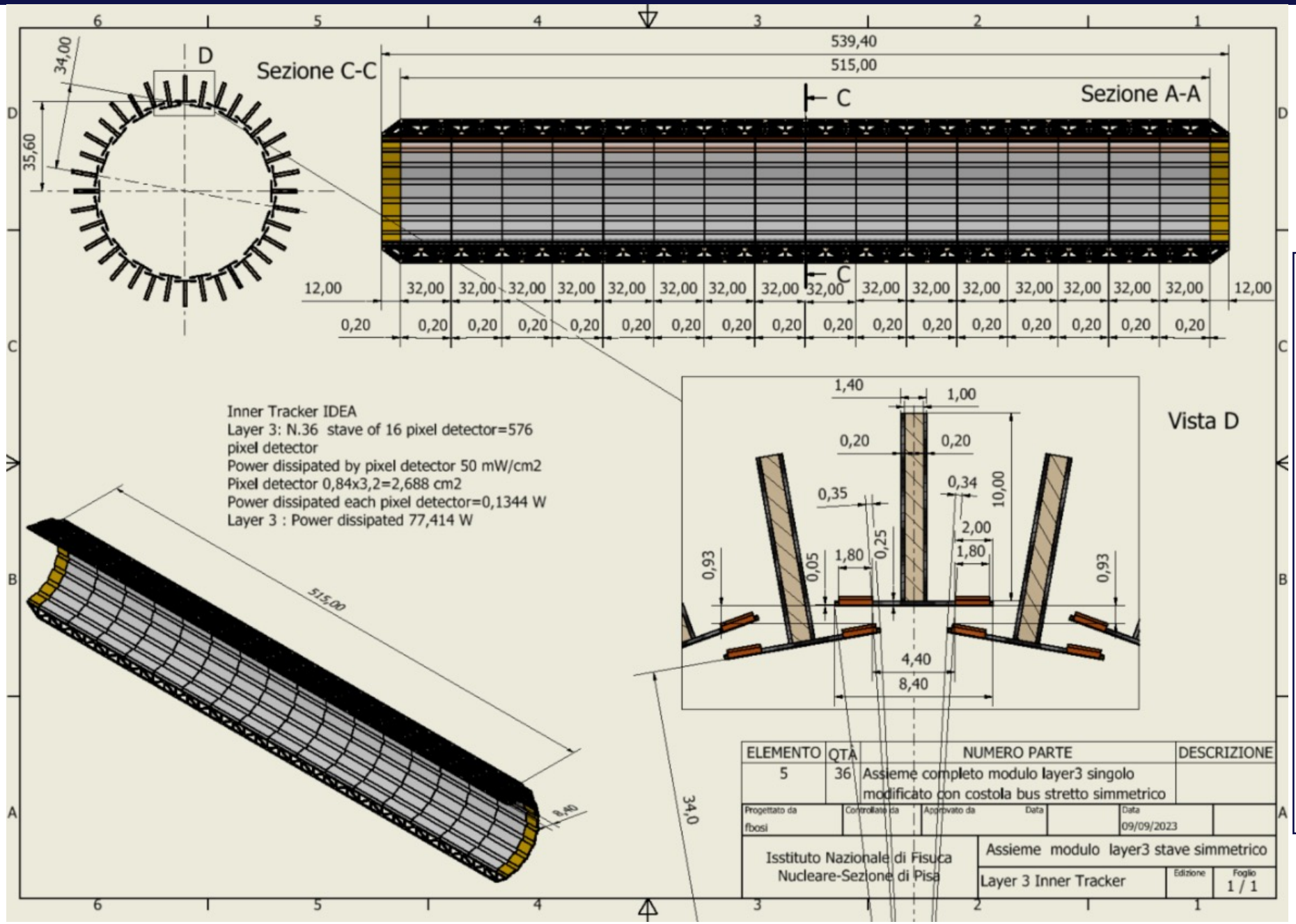
Pinwheel geometry

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% X_0



Layer 3

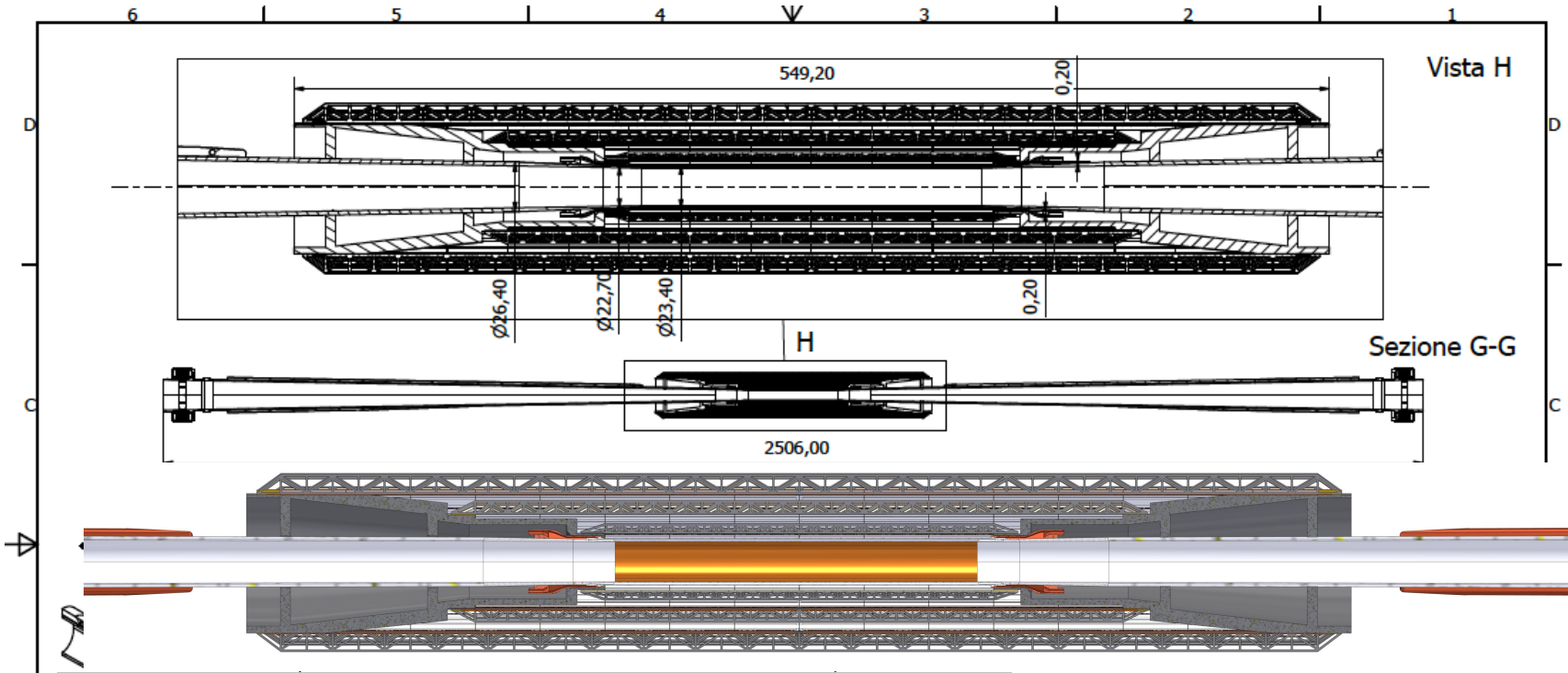
36 staves of 16 modules each

Lampshade geometry.
Charge symmetric track reconstruction

Total weight ~150 grams

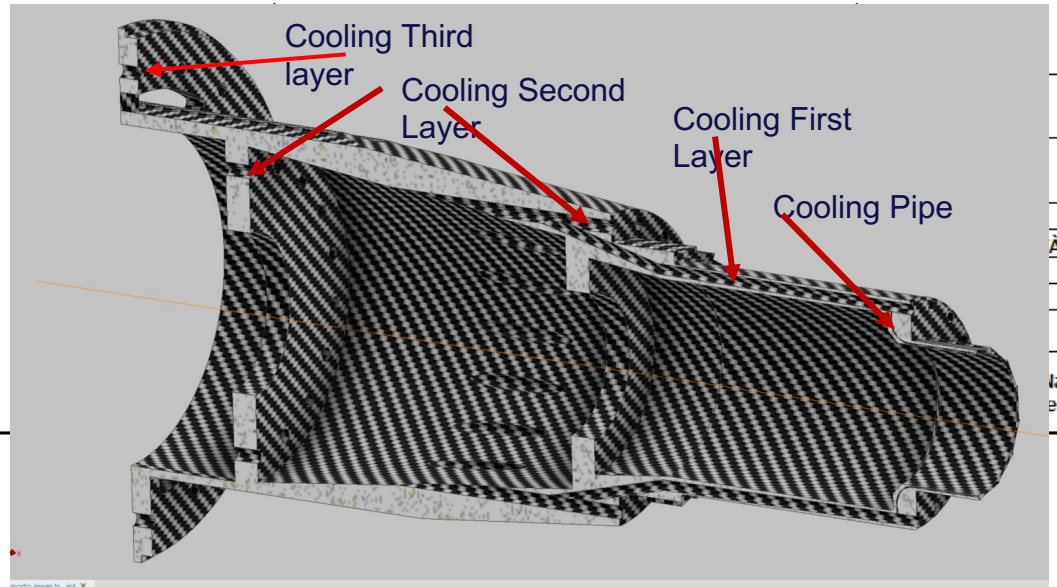
Total thickness 0.25% X_0

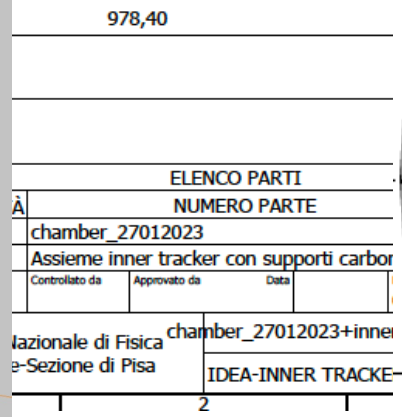
Power budget
~77 W

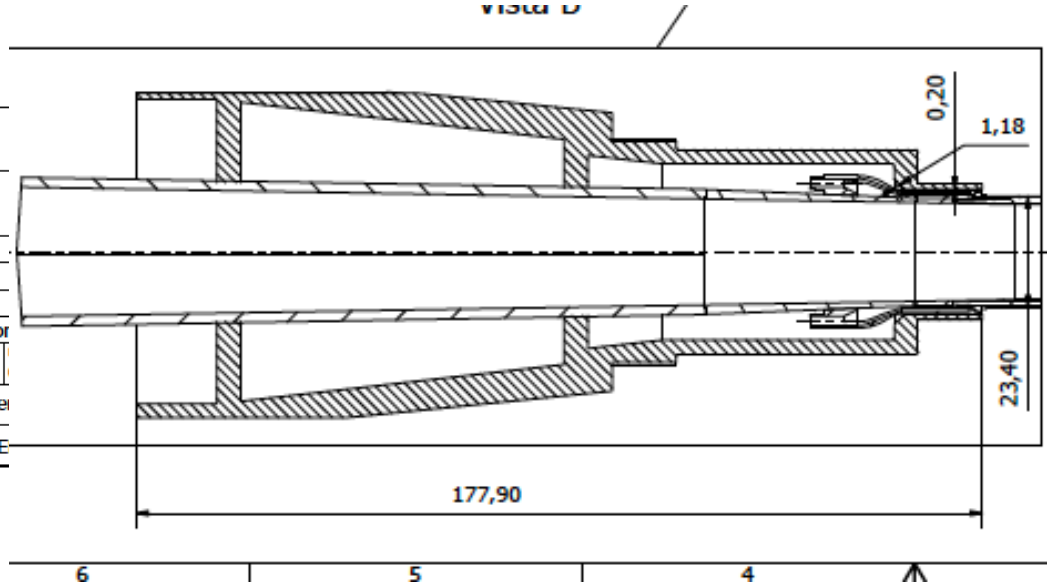


Inner vertex detector supporting conical structures on elliptical chamber
~450 grams

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





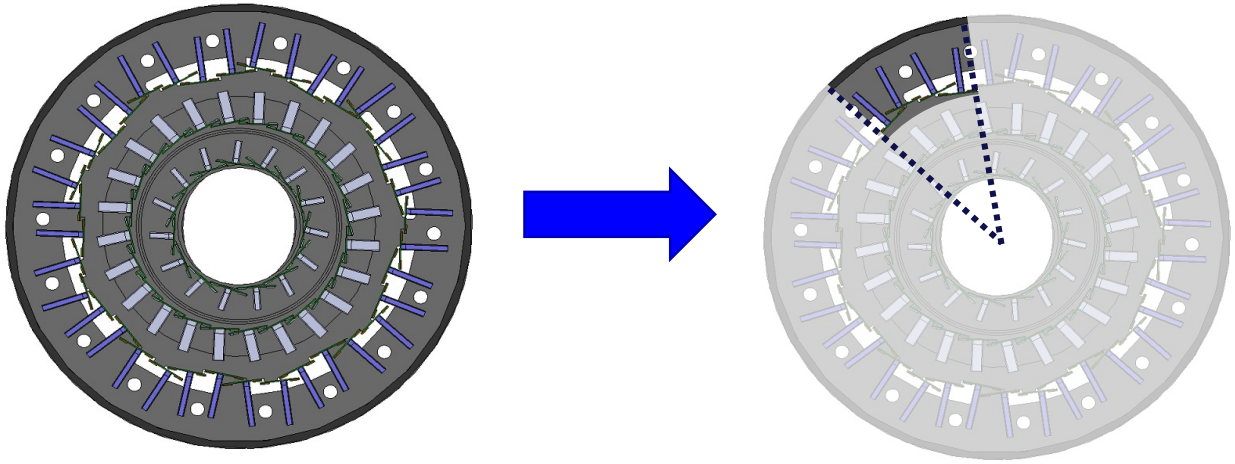


Thermal simulation in progress

INFN Perugia

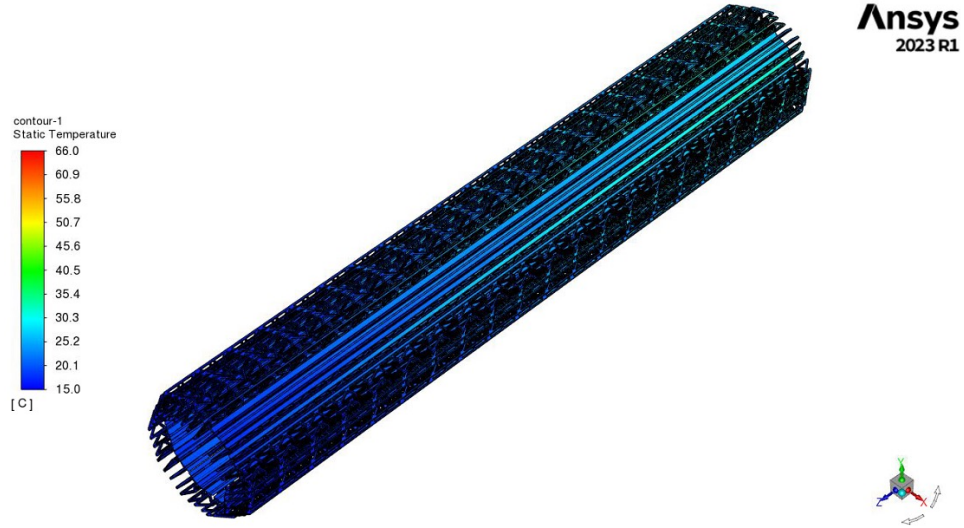
G. Baldinelli, F. Bianchi, C. Turrioni

Start from a radial sector of layer 3 (relying on periodic symmetry) and import in ANSYS FEA. Then move to all other layers
Layer 3 is the toughest in power dissipation and length

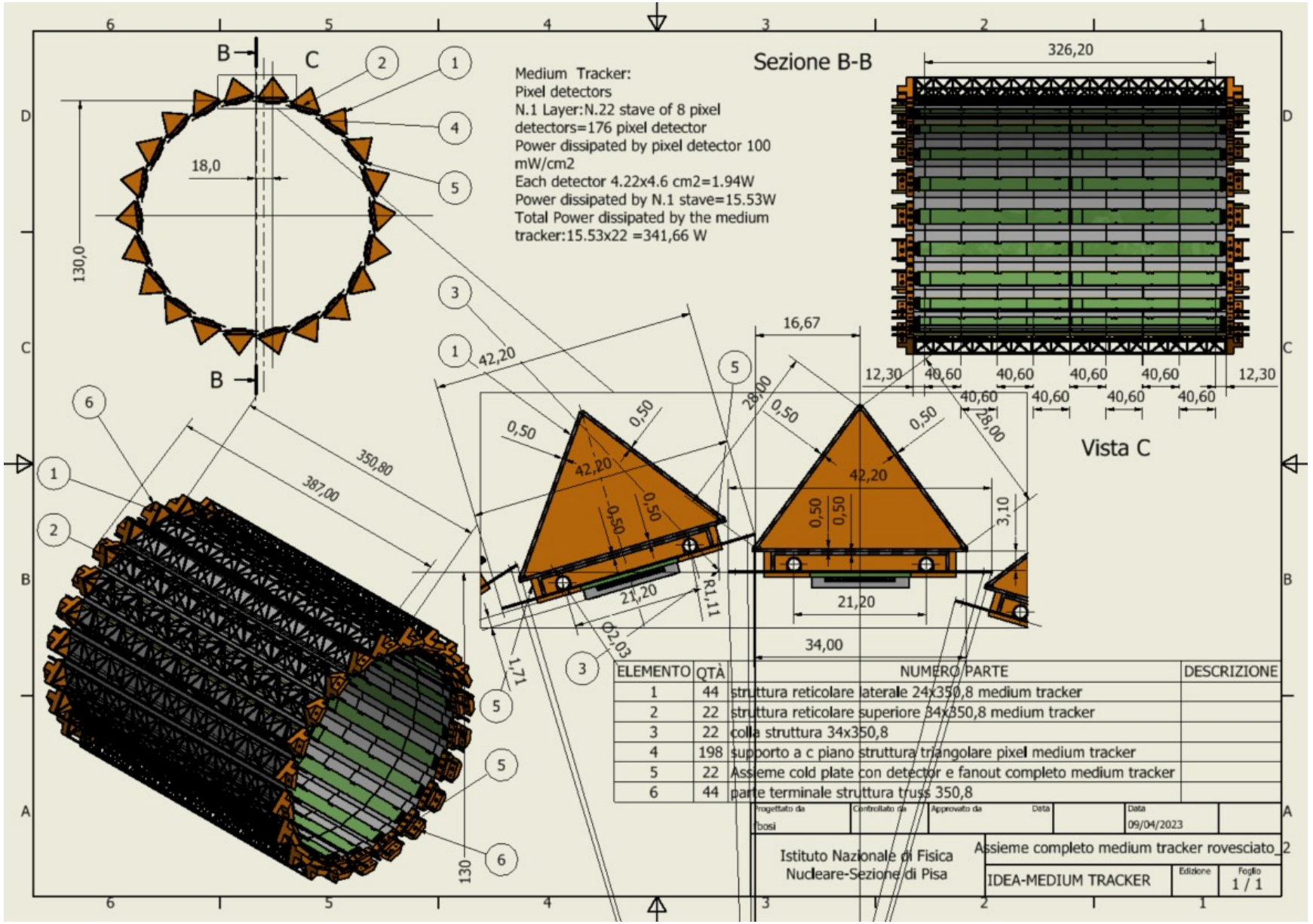


Full model

Extraction of a radial sector for layer 3



- Optimisation of the system ongoing: (speed and T of air, direction of the inlet flow, connection with the other layers, etc…)
- A mechanical vibrational analysis will be performed
- Experimental validation of the simulations foreseen



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Middle Vertex Barrel
At 13 cm radius

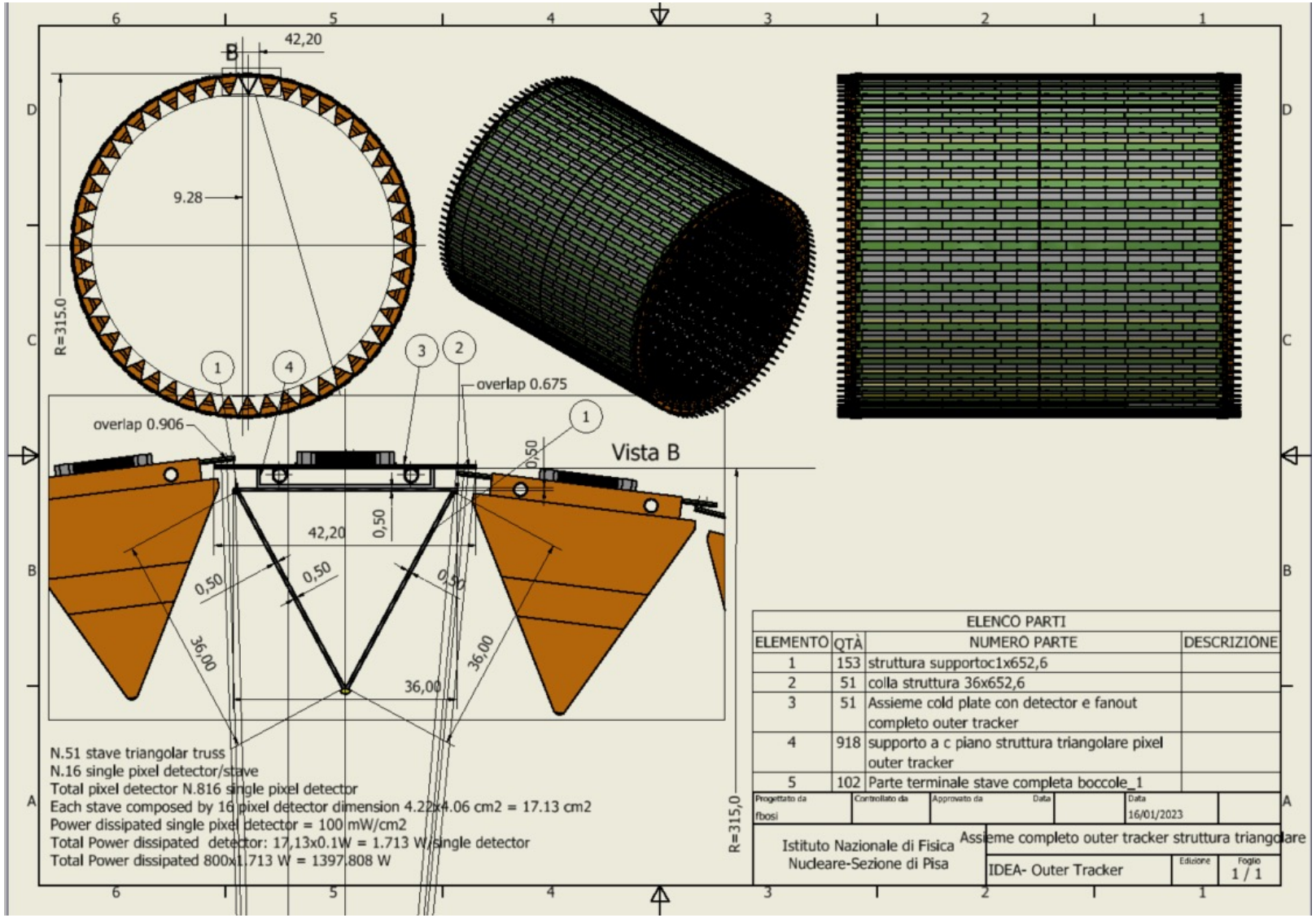
22 staves of 8 modules each.

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

See talk by H. Fox

Readout chips either side
Power budget
~342 W

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



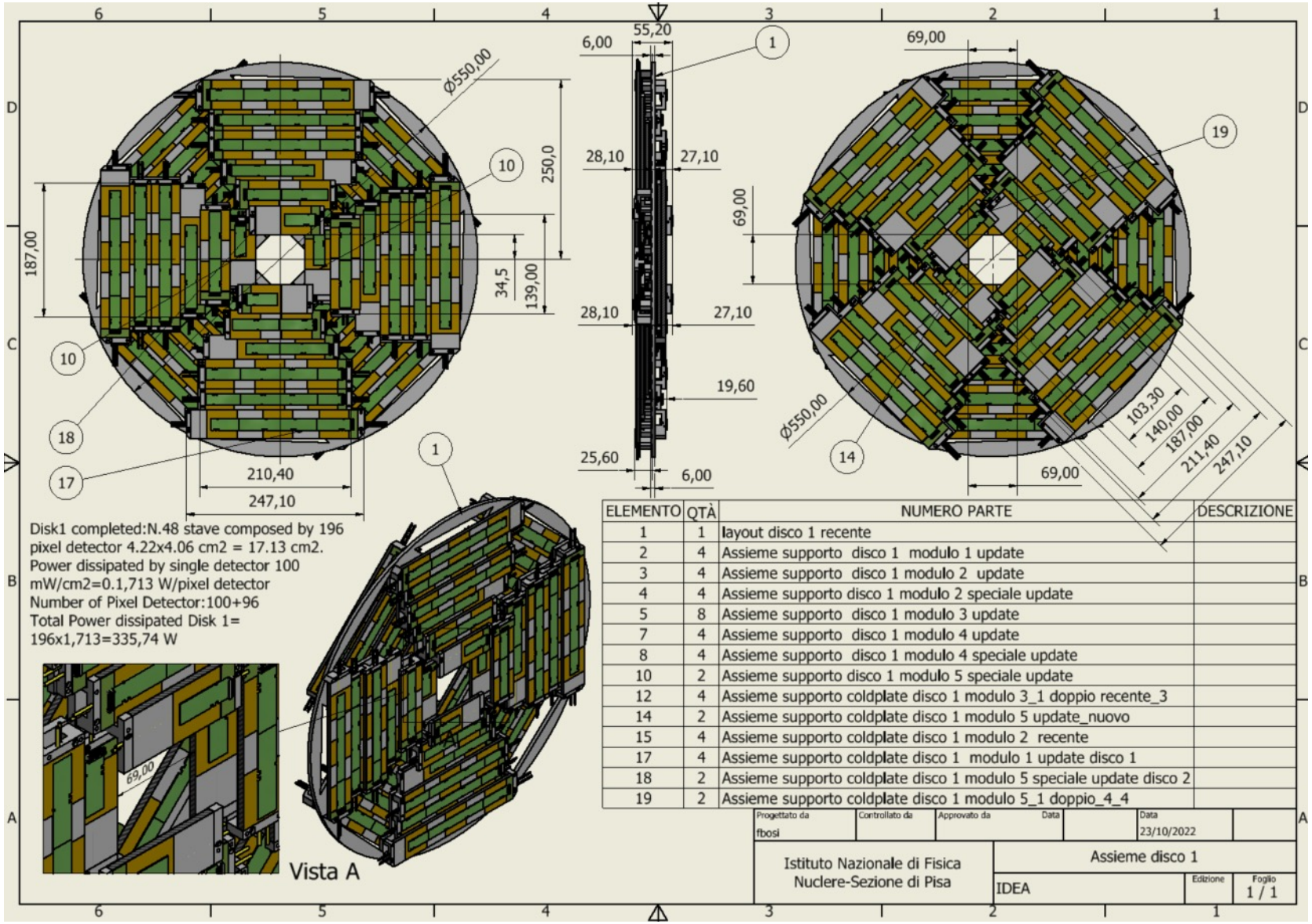
Outer Vertex Tracker Barrel
At 31.5 cm radius

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)



ELEMENTO	QTÀ	NUMERO PARTE	DESCRIZIONE
1	1	layout disco 1 recente	
2	4	Assieme supporto disco 1 modulo 1 update	
3	4	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	
7	4	Assieme supporto disco 1 modulo 4 update	
8	4	Assieme supporto disco 1 modulo 4 speciale update	
10	2	Assieme supporto disco 1 modulo 5 speciale update	
12	4	Assieme supporto coldplate disco 1 modulo 3_1 doppio recente_3	
14	2	Assieme supporto coldplate disco 1 modulo 5 update_nuovo	
15	4	Assieme supporto coldplate disco 1 modulo 2 recente	
17	4	Assieme supporto coldplate disco 1 modulo 1 update disco 1	
18	2	Assieme supporto coldplate disco 1 modulo 5 speciale update disco 2	
19	2	Assieme supporto coldplate disco 1 modulo 5_1 doppio_4_4	

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

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Outer Vertex Tracker Disk 1

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

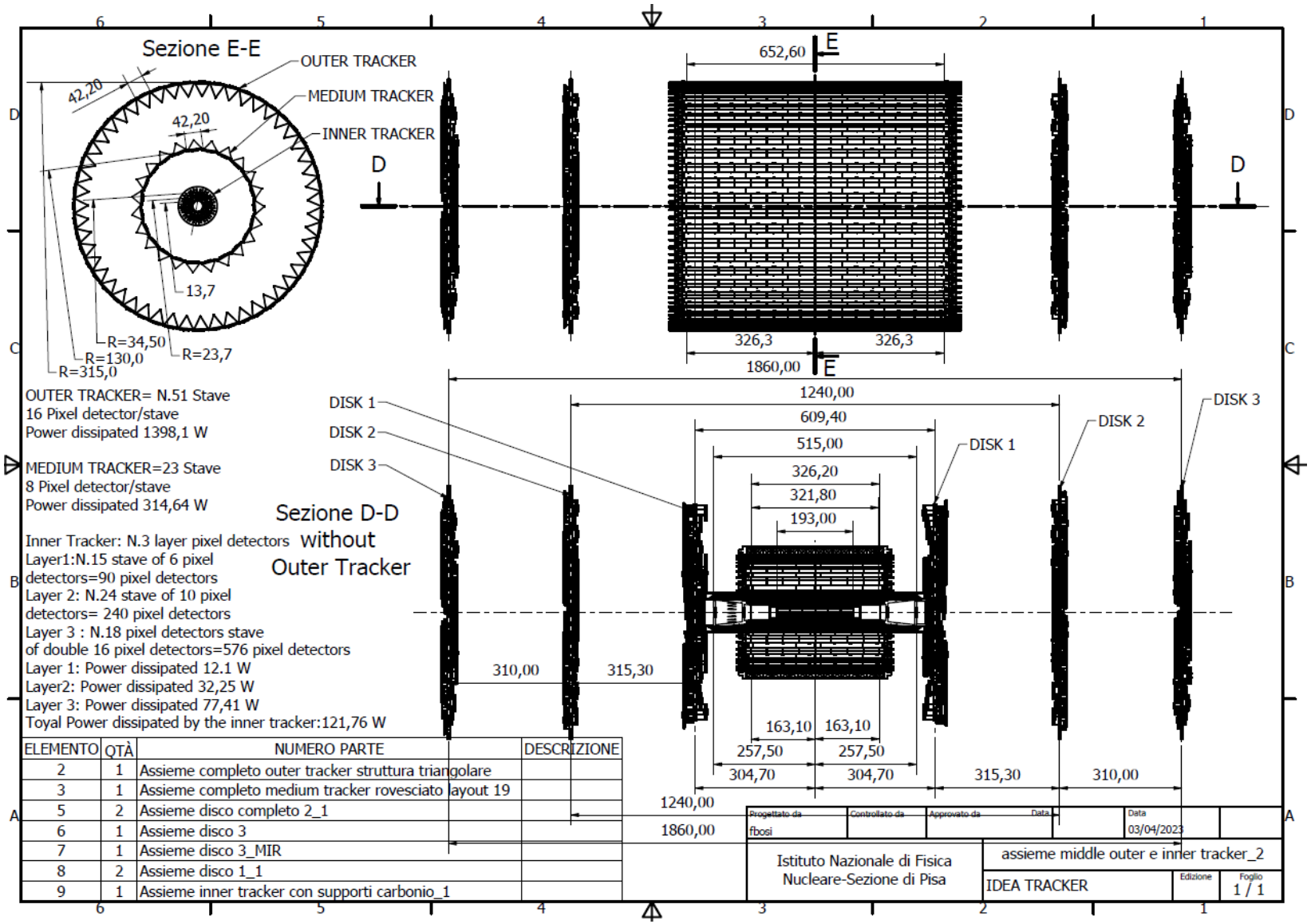
One petal is made of different staves of overlapping modules

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

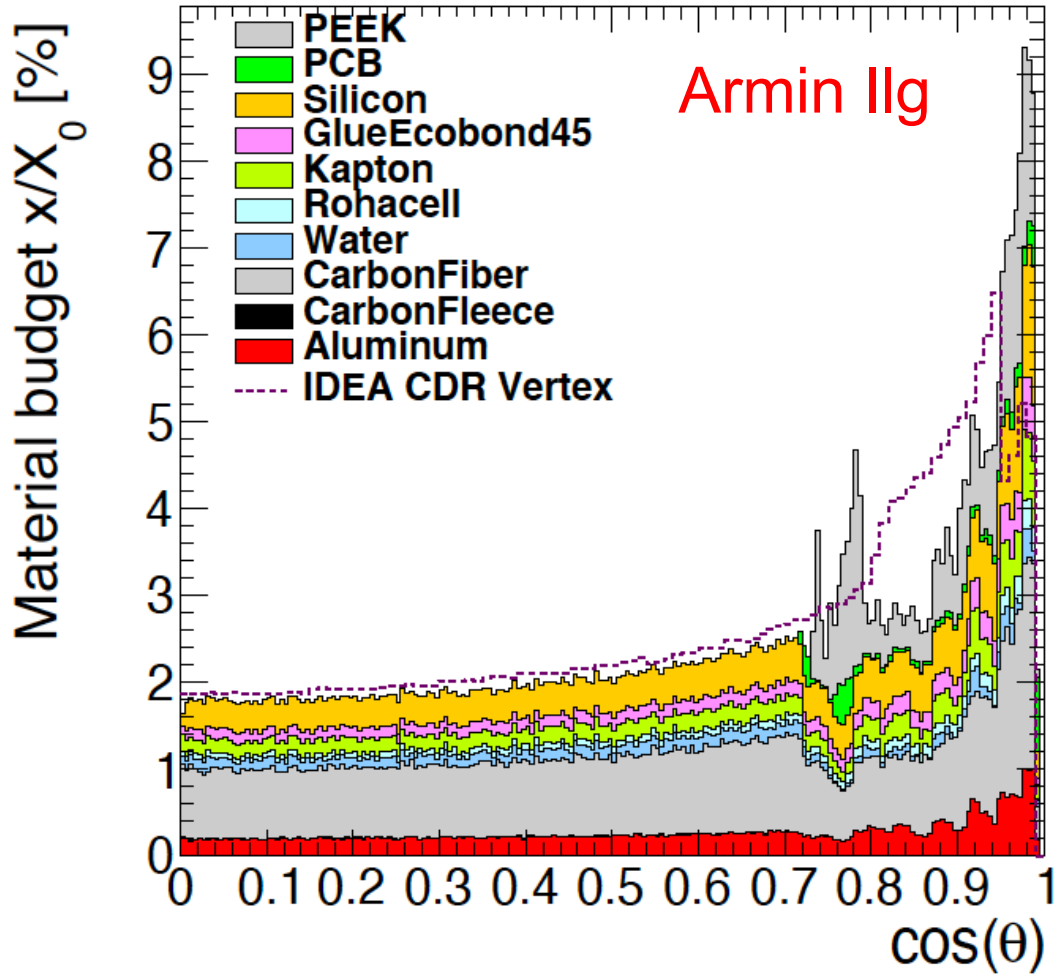
Cooling using 1 water pipe (2 mm diameter)

Similar geometry for the other two disks

Overall layout and dimensions



Simulated material budget



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

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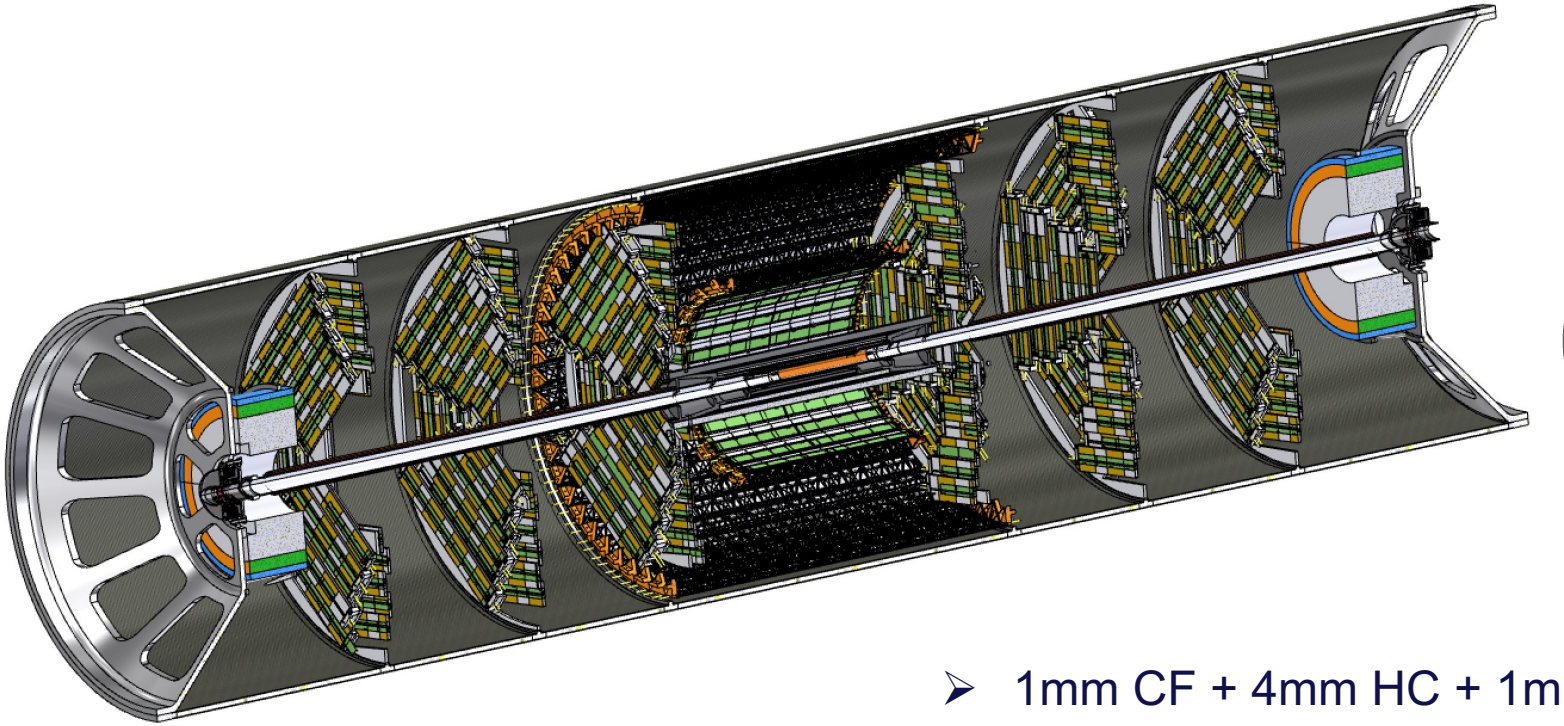
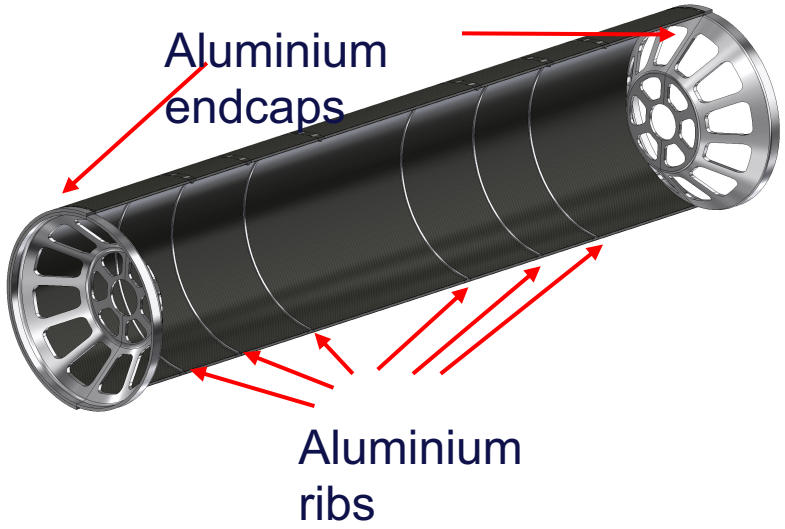
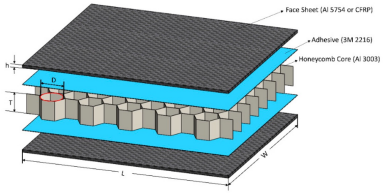
All elements in the interaction region (Vertex and LumiCal) are mounted rigidly on a support cylinder that guarantees mechanical stability and alignment

- Once the structure is assembled it is slided inside the rest of the detector
- Studies on-going where to anchor it (most likely to the Calorimeter)

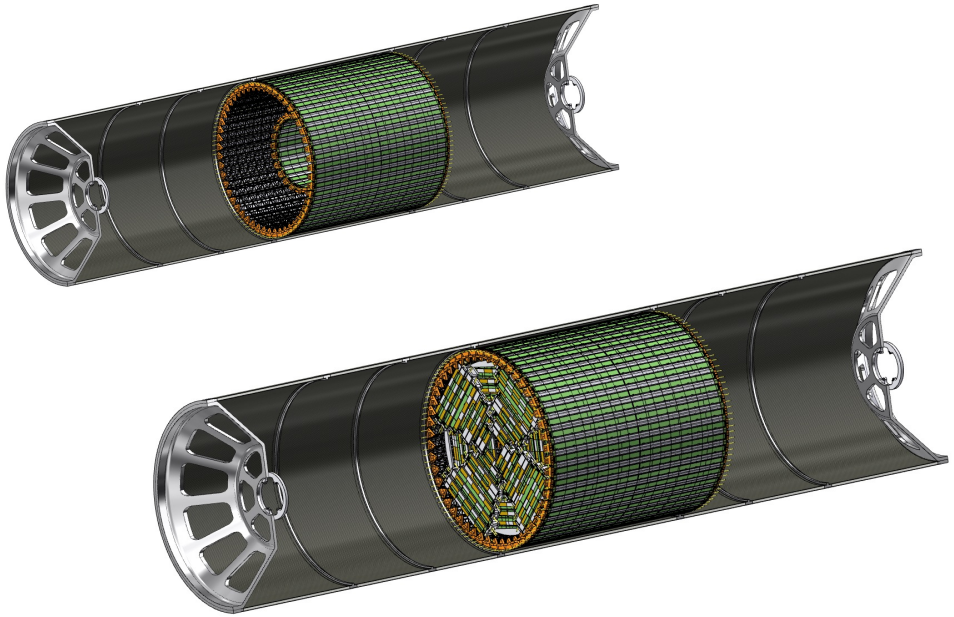




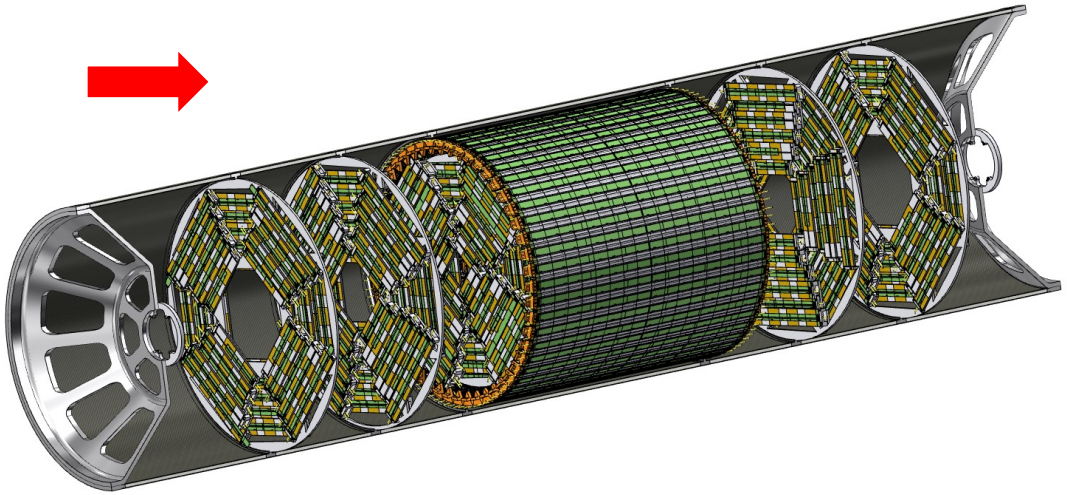
➢ 1mm CF + 4mm HC + 1mm CF



Assembly procedure – I

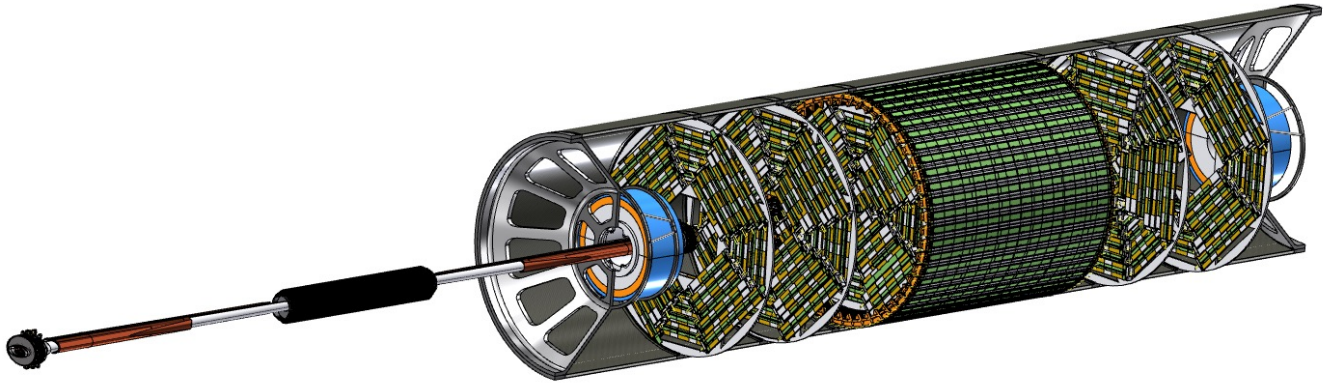


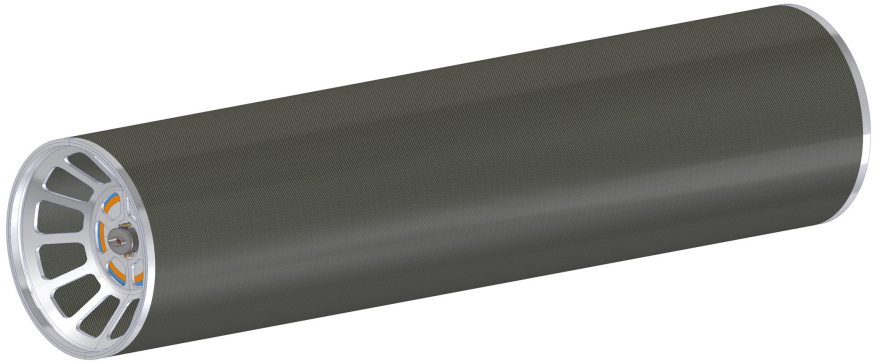
1) Outer vertx tracker, middle vertex tracker and disks 1 are installed as a rigid structure inside the support tube



2) Disks 2 and 3 are installed inside the support tube

Assembly procedure – II

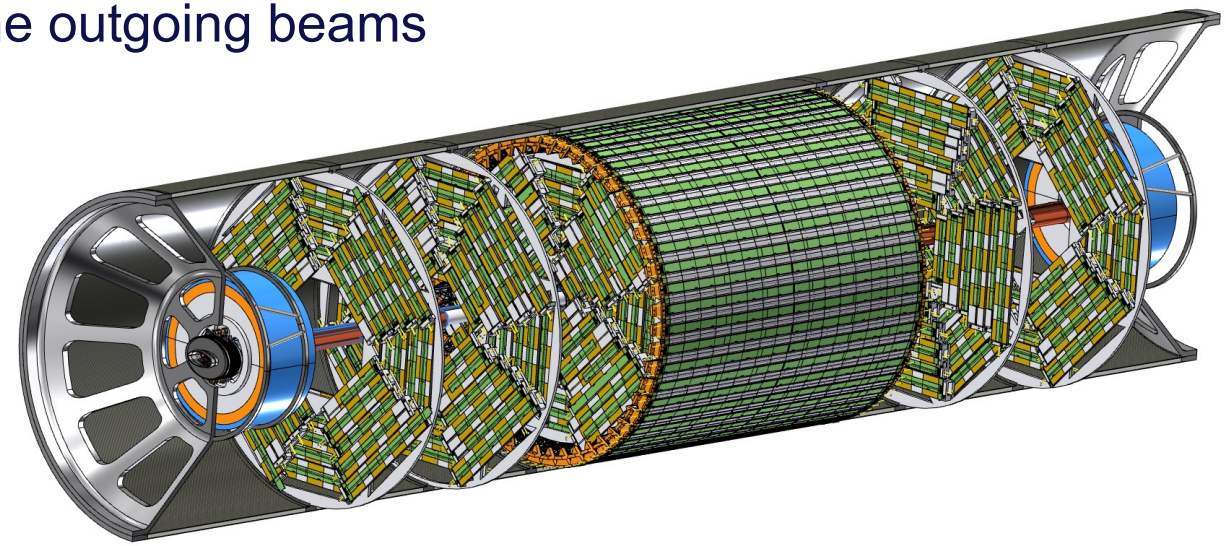




3) LumiCal is installed in centered position, then beam pipe with inner vertex detector is inserted with a dedicated tool inside disks and outer vertex tracker, then fixed to both endcaps

4) LumiCal can be aligned in the correct position on the outgoing beams

5) Support tube can be closed



General integration

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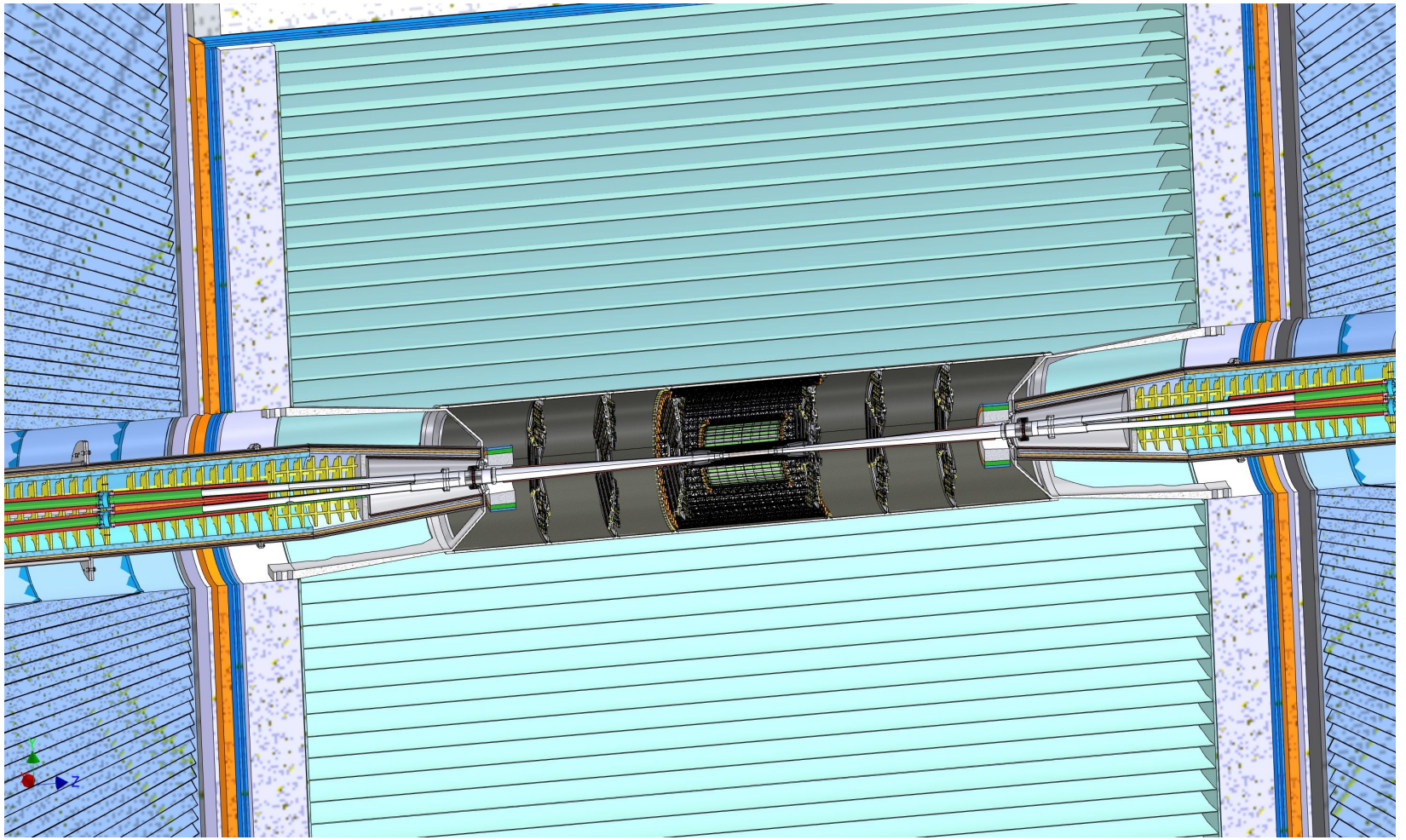

Conclusions

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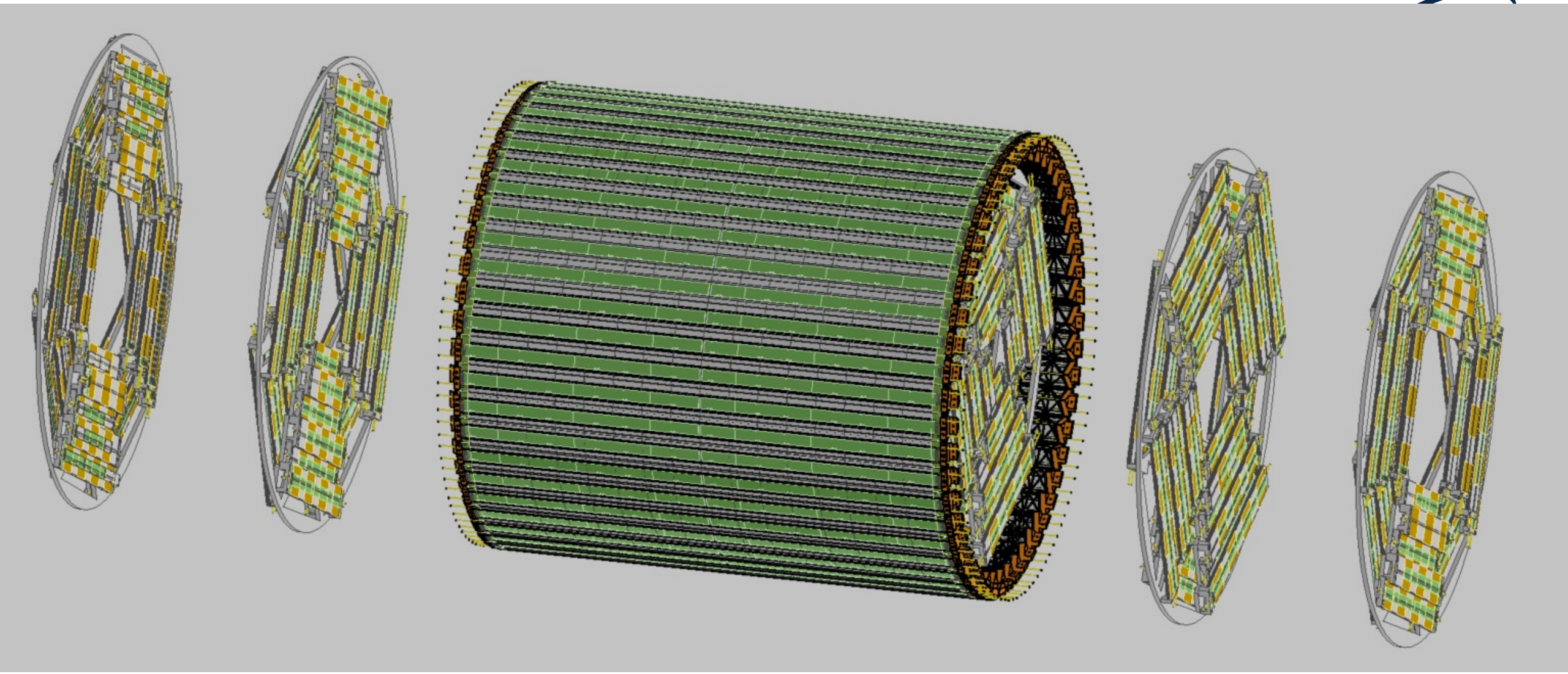
A layout of the interaction region (with LumiCal) of the vertex trackers of the IDEA detector has been engineered

- Feasibility studies of integration successfully done including mounting sequence

- Documented in
  - *M. Boscolo, F. Palla, F. Fransesini, 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

Thank you
for your attention.
感谢您的关注

Backup



MIDDLE TRACKER

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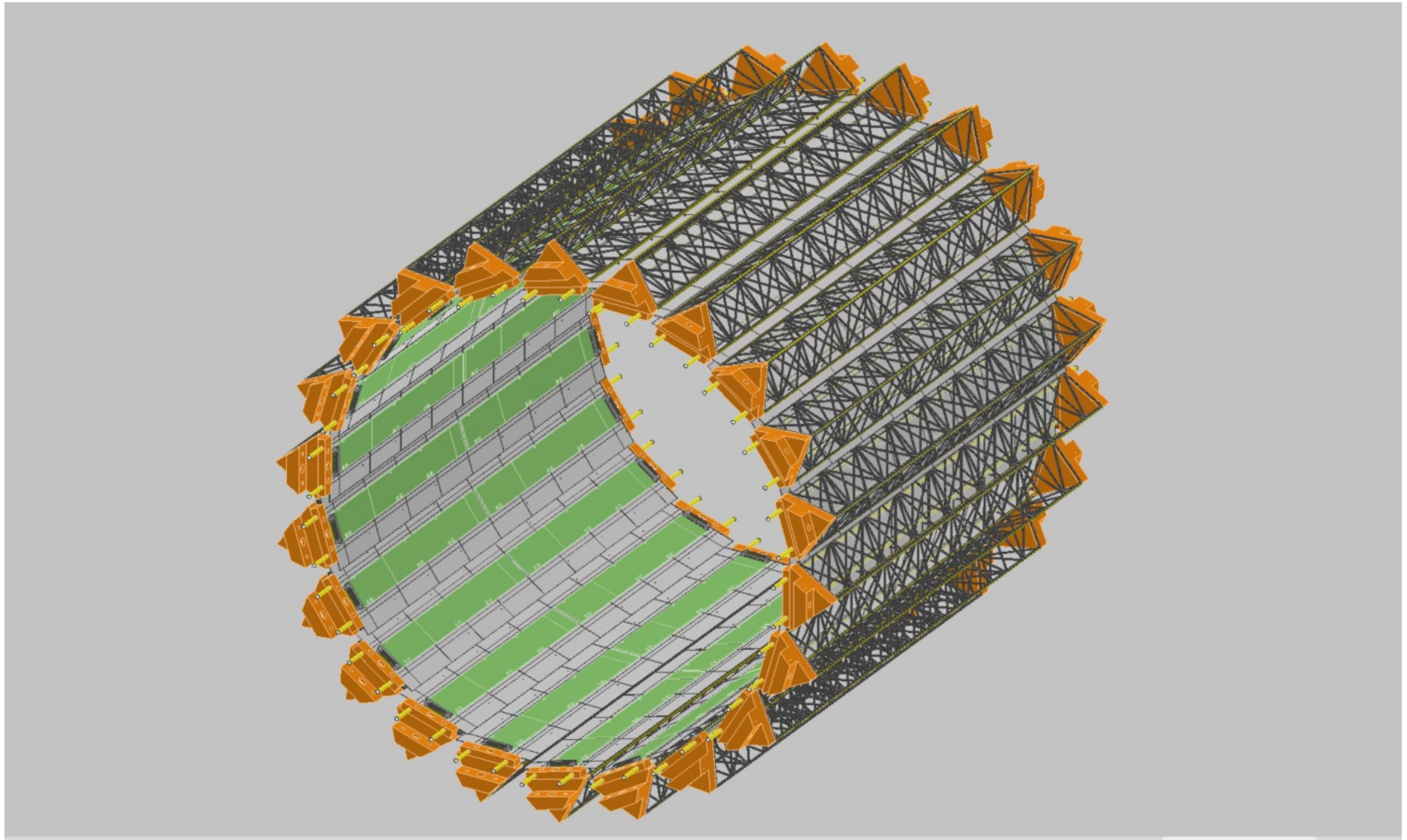
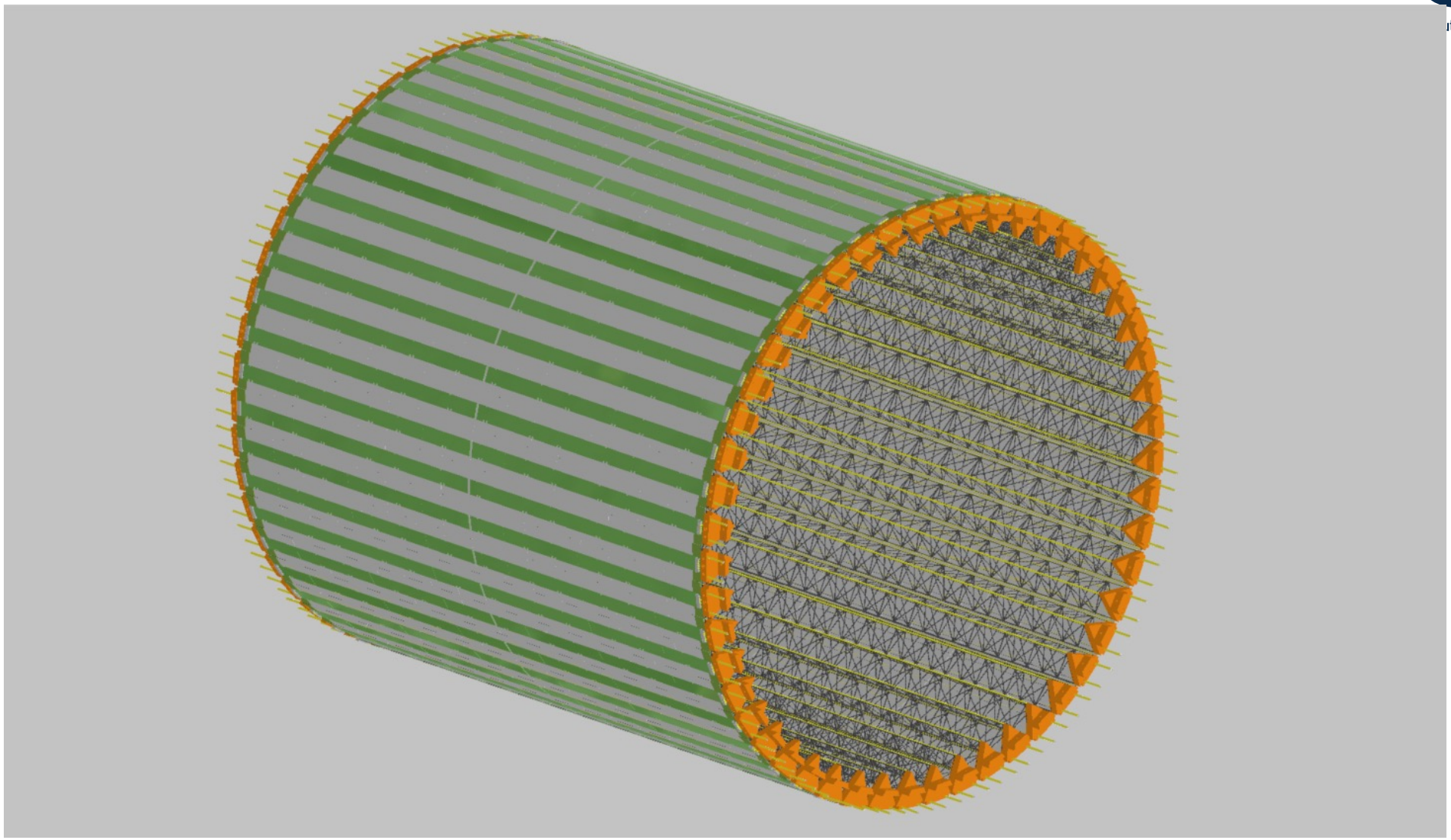
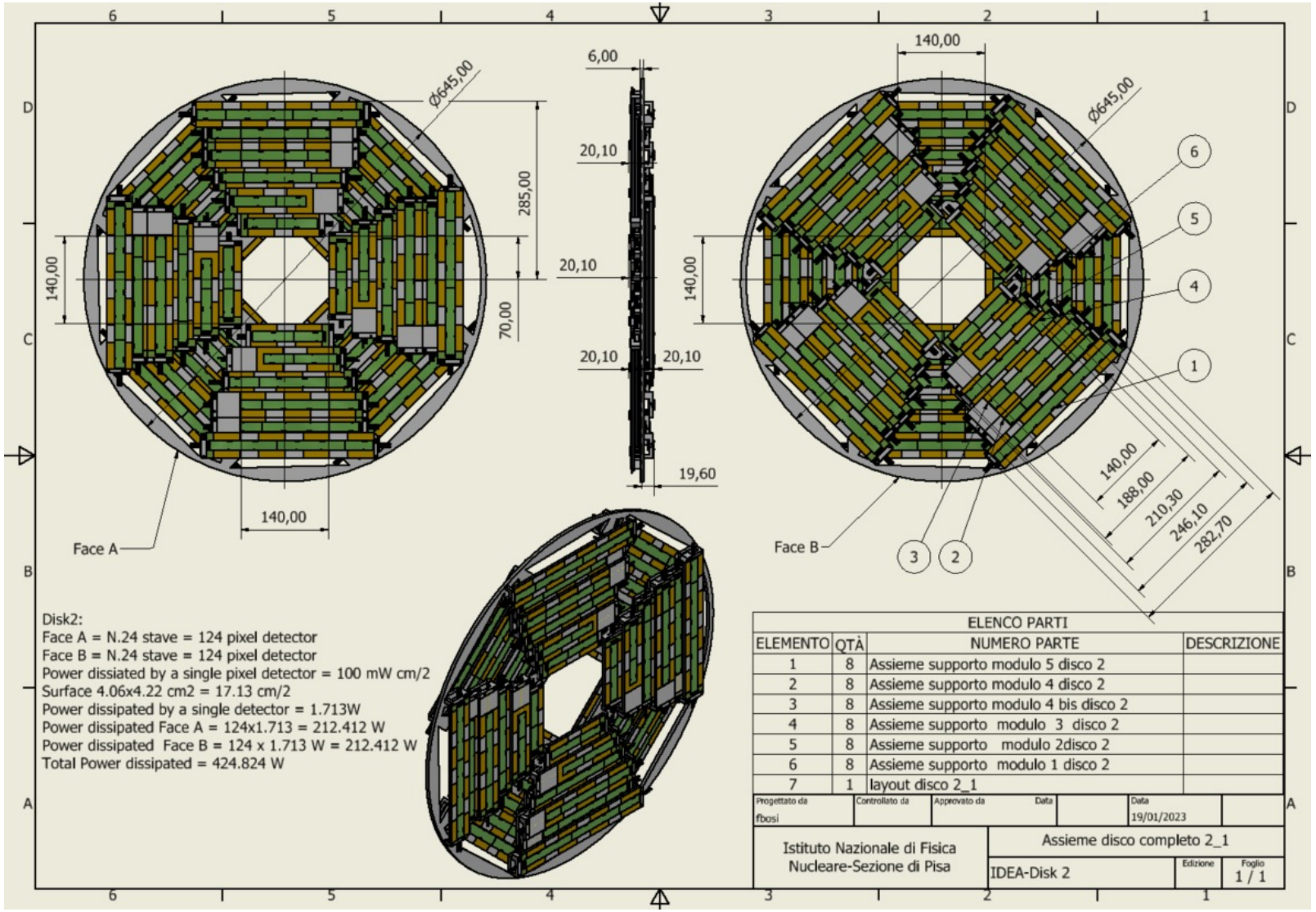


OUTER TRACKER



DISK 2


Ø645,00
285,00
140,00
70,00
6,00
20,10
20,10
20,10
20,10
19,60
140,00
Face A
Face B
140,00
188,00
210,30
246,10
282,70
Disk2:
Face A = N.24 stave = 124 pixel detector
Face B = N.24 stave = 124 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 = 1.713W
Power dissipated Face A = 124x1.713 = 212.412 W
Power dissipated Face B = 124 x 1.713 W = 212.412 W
Total Power dissipated = 424.824 W
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
Progettato da fbosi
Controllato da
Approvato da
Data
Data 19/01/2023
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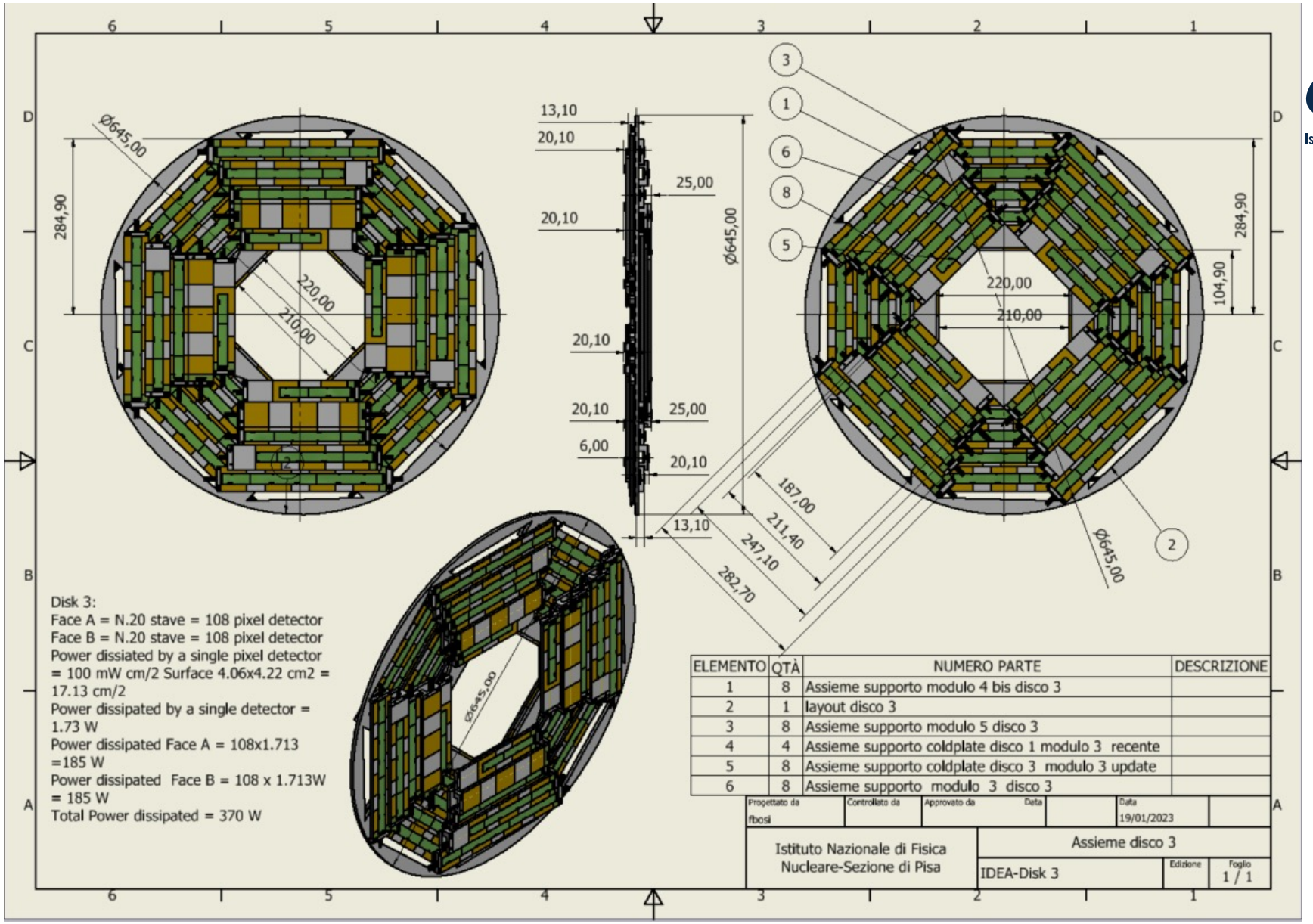
Assieme disco completo 2_1
IDEA-Disk 2
Edizione
Foglio 1 / 1

DISK 3


Ø645,00
284,90
220,00
210,00
13,10
20,10
25,00
20,10
20,10
20,10
25,00
6,00
20,10
13,10
Ø645,00
187,00
211,40
247,10
282,70
284,90
104,90
220,00
210,00
Ø645,00
Disk 3:
Face A = N.20 stave = 108 pixel detector
Face B = N.20 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
Ø645,00
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 | 8 | 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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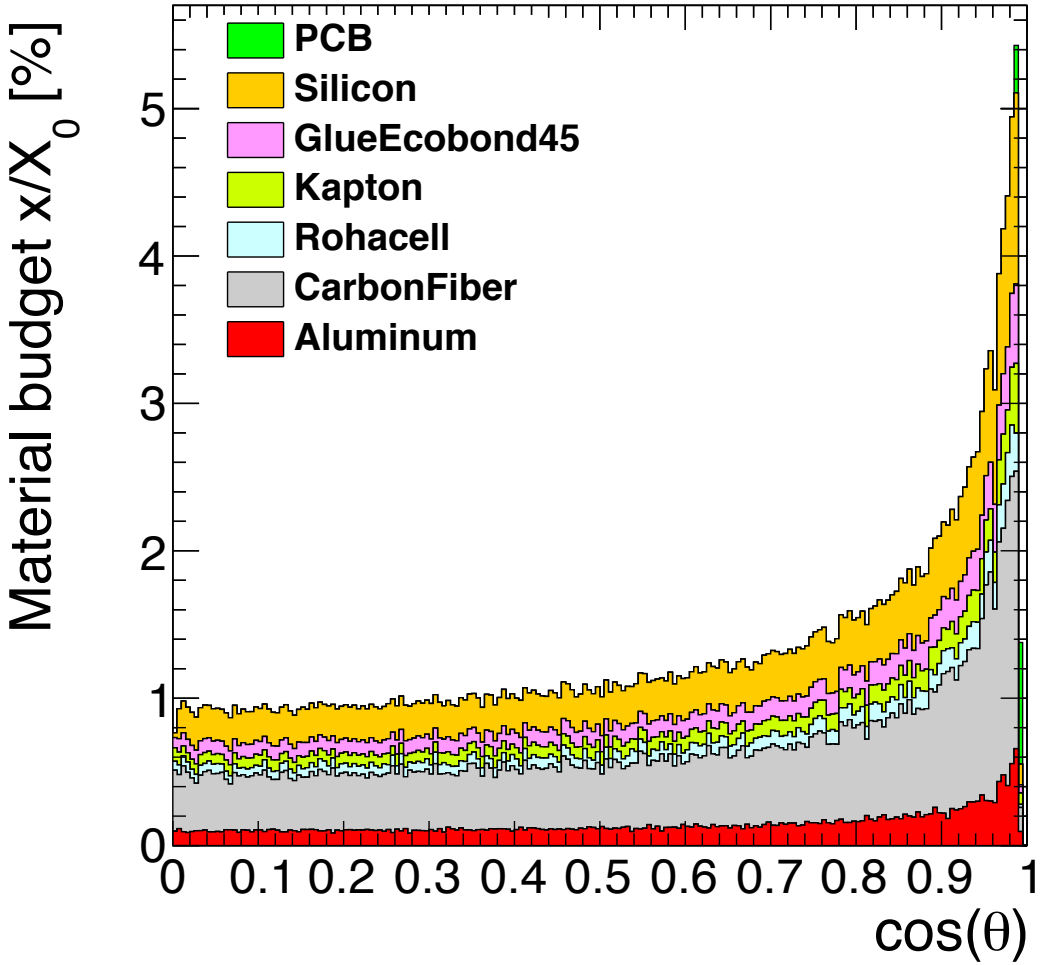
Assieme disco 3
IDEA-Disk 3
Edizione
Foglio 1 / 1

Inner vertex (all 3 layers)



A. Ilg

Middle and Outer vertex

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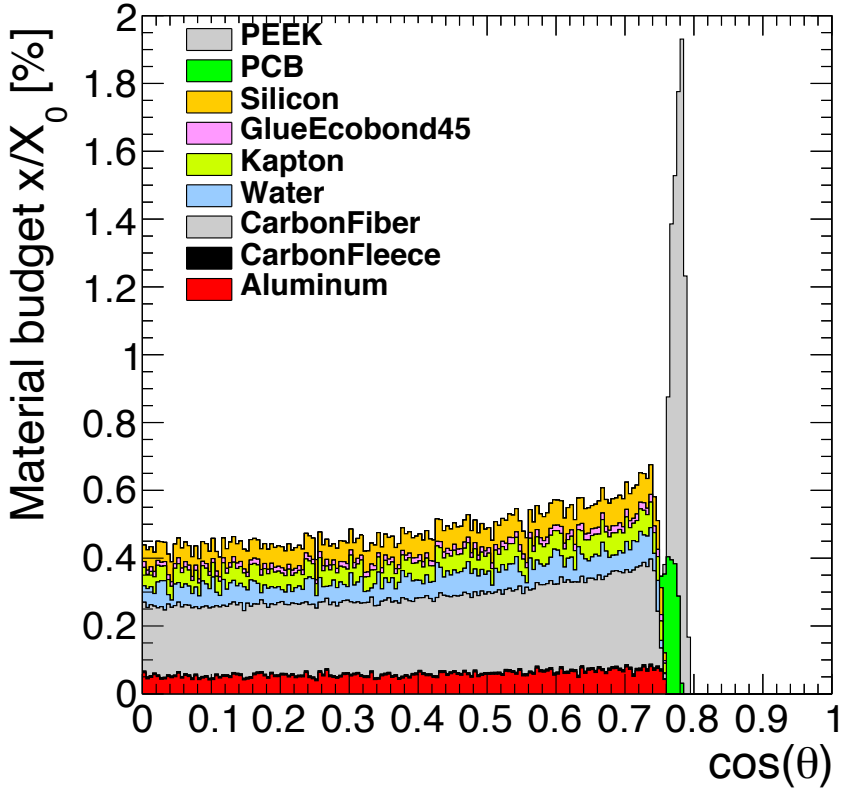
Middle



A. Ilg

Outer