ATLAS ITk

Marianna Testa
on behalf of the LNF ITk group

Scientific Committee

8 November 2023

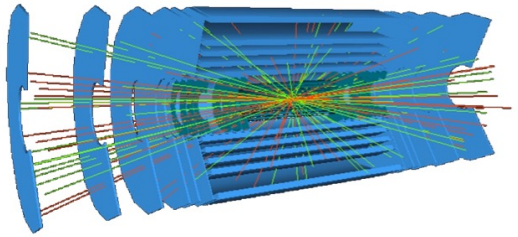
HL-LHC

The LHC will be upgraded to the High Luminosity-LHC (HL-LHC) to produce up to 4000 fb^{-1} of integrated luminosity until 2040

Luminosity
= 5-7.5 x 10^{34} cm^2 s^{-1}

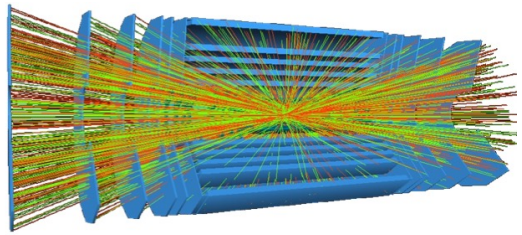
LHC: Inner Detector (ID) system, TRT (gas detector) + Strips + Pixels

HL-LHC: New all-silicon **Inner Tracker (ITk)**, Strips + Pixels



LHC:
19 – 55
pile up events

HL-LHC:
140 – 200
pile up events



Requirements for pixel detector at HL-LHC

Instantaneous conditions: pile-up, luminosity

- High trigger rate: 1 MHz
- High granularity: occupancy at 1 %

Integrated effects

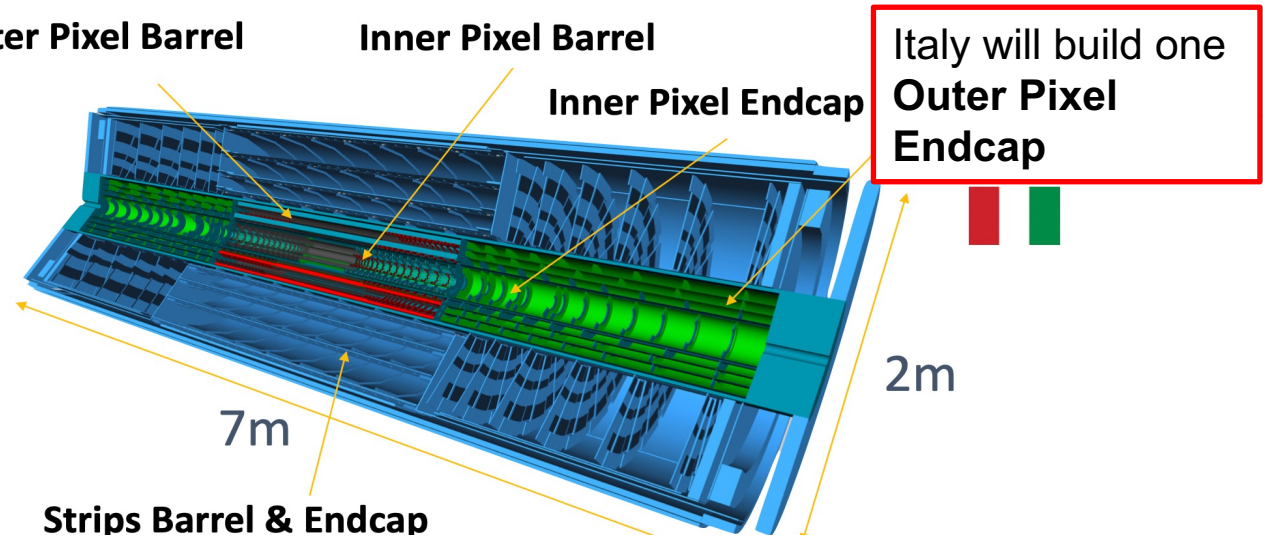
Integrated luminosity x10
→*Radiation hard technologies*
up to $2 \cdot 10^{16}$ neq/cm^2

A replacement of the current ID detector is by far not enough!

ITk : The New Inner Tracker

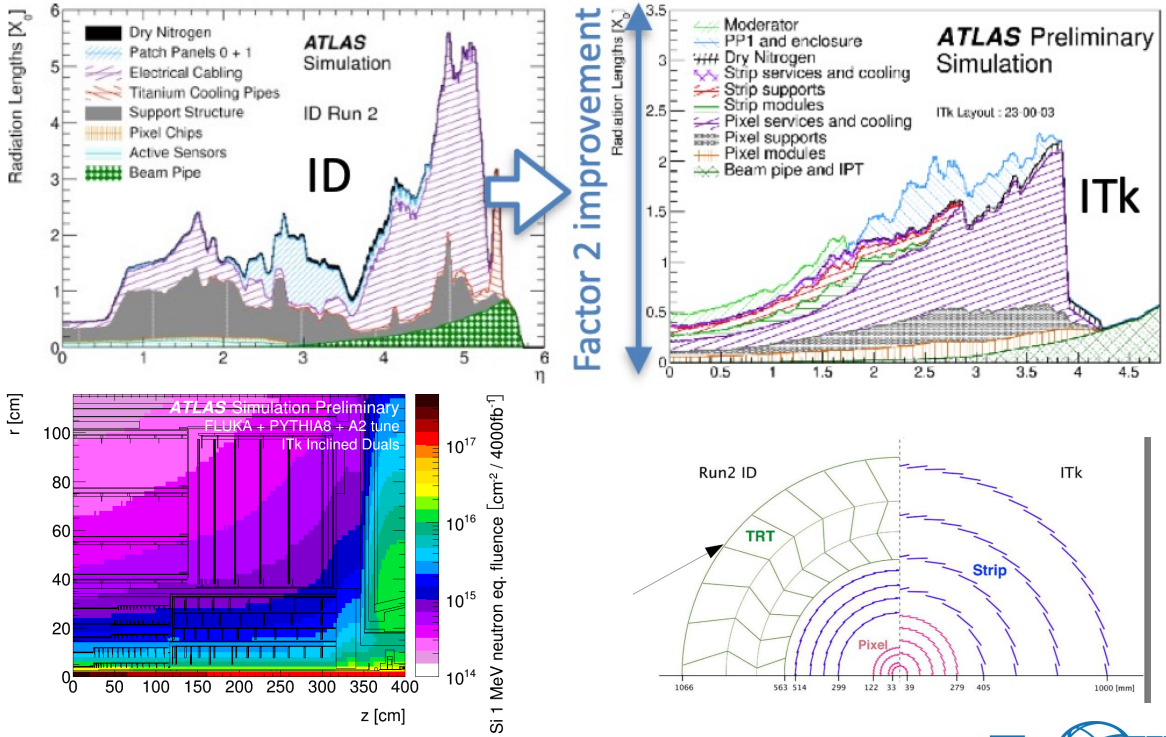
- **All-silicon** tracker

ITk (ID)	Area (m^2)	# Modules	# Channels (M)
Pixels	13 (1.6)	9164 (2000)	5100 (92)
Strips	165 (61)	17888 (4088)	60 (6.3)



- **Improved tracking**
  - Coverage up to **|η|<4** (ITk) from |η|<2.5 (ID)
  - Finer **segmentation**:
    - 50x50μm² or 25x100μm²
    - ID: 50 × 400 μm² or 50 × 250 μm²
  - Reduced **material**: **Carbon Fibre** structures, CO_2 cooling with thin Ti tubes walls, advanced **serial powering**, data link sharing

- **Radiation hardness**:
  - n-in-p pixel sensors (n-in-n for ID)
  - Thinner sensor 100-150 μm (200-250 μm in ID)

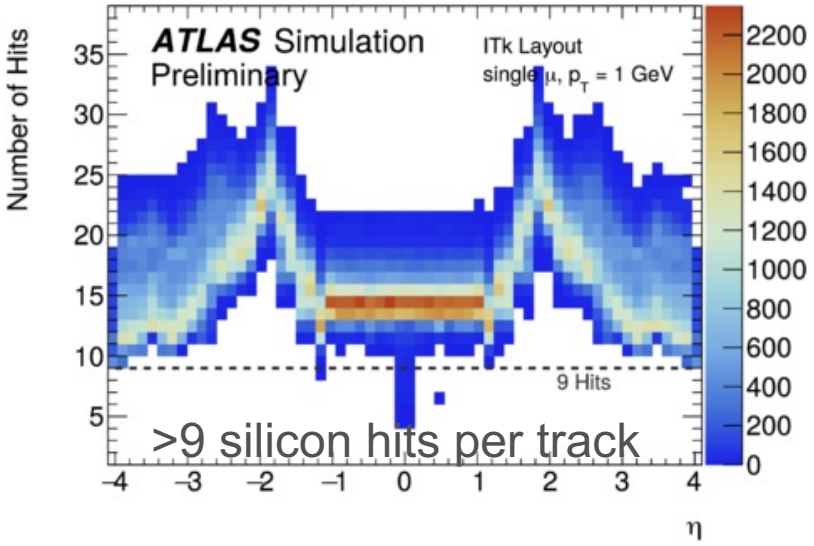


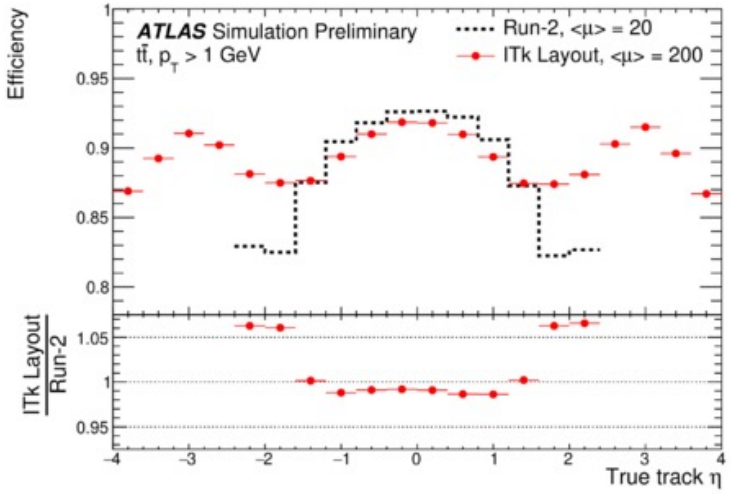
ITk Performances

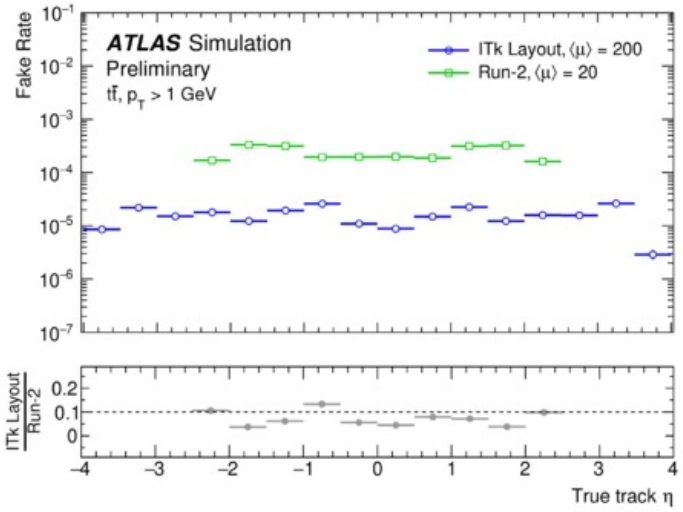
M. Testa

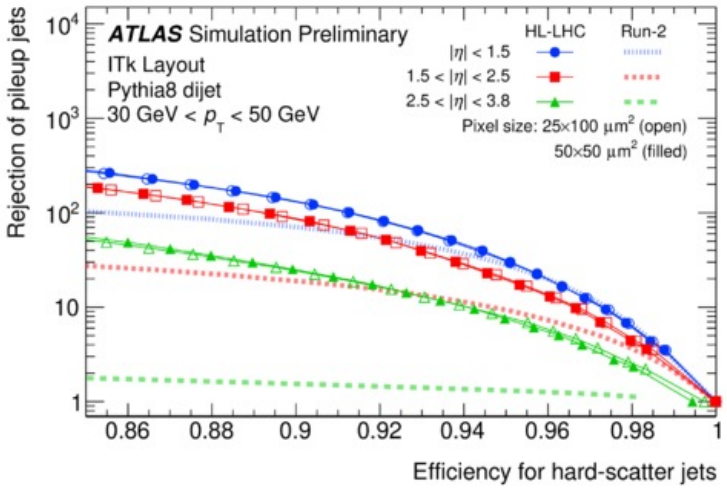
Important **LNF contribution** to design and simulation,
for |η|<4 coverage and pixel size decision

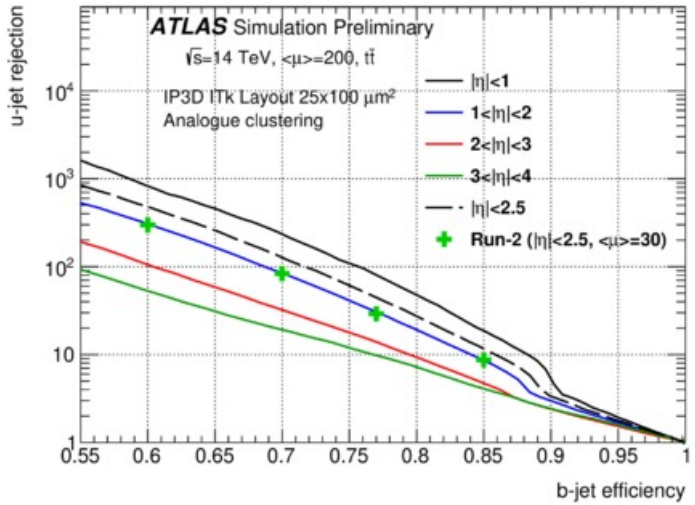
[ATL-PHYS-PUB-2019-014]
[ITk Pixel TDR]
[ITk Strip TDR]





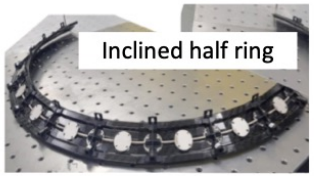


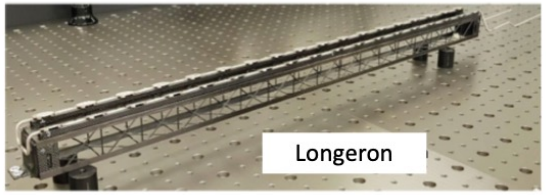




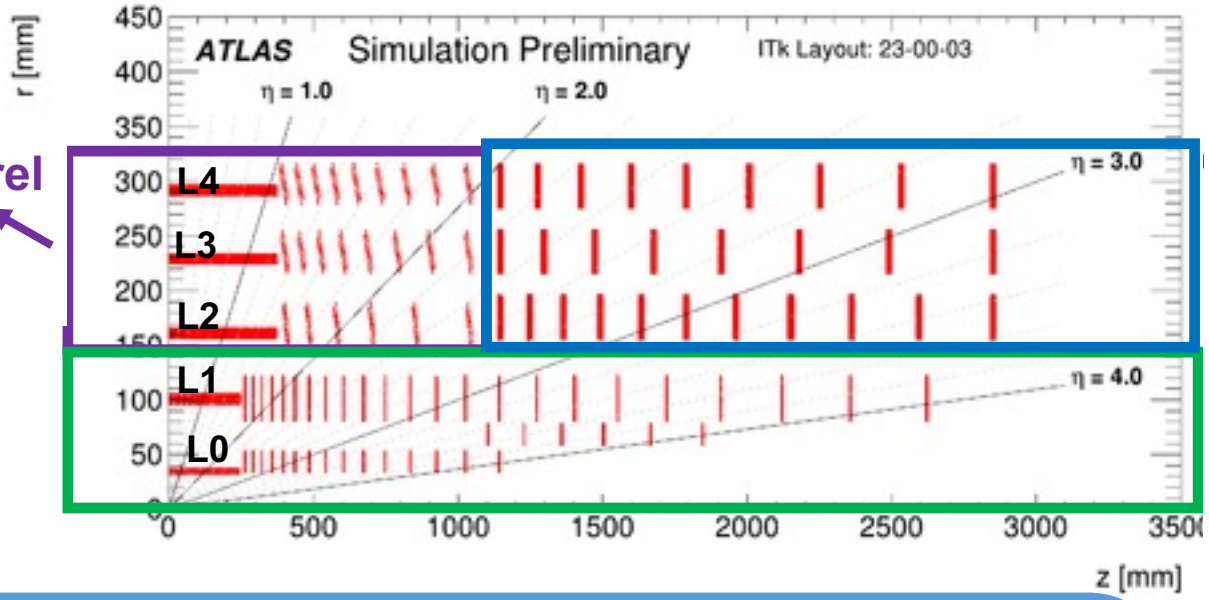
ITk Pixel Detector

Local supports: Different designs to support flat and inclined module mounting

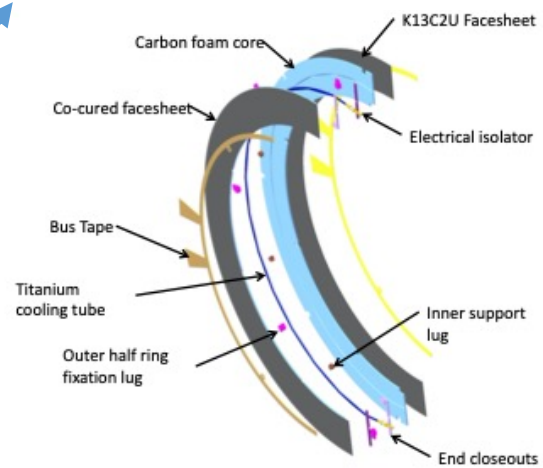




Outer Barrel



Outer Endcap

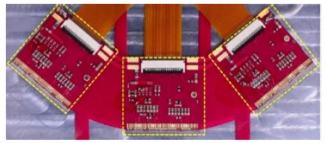


Inner System

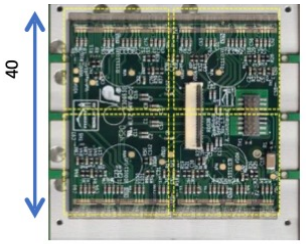
IS to be replaced after 2000fb^{-1} to reduce radiation damage.
L0 placed 34 mm from beam pipe.

Modules: two main module types, quad & triplet.

Triplet



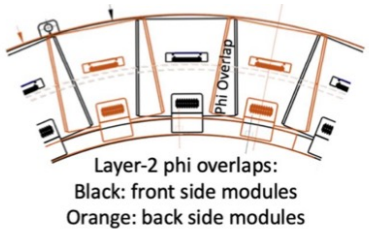
Quad

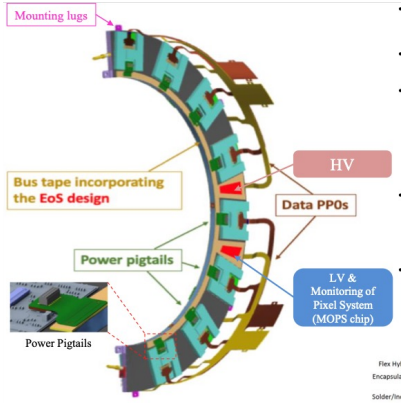


Layer	Module type	Sensor type	Sensor thickness [um]	Pixel size [um^2]
L0 barrel	Triplet	3D n-in-p	150	25x100
L0 rings	Triplet	3D n-in-p	150	50x50
L1	Quad	Planar n-in-p	100	50x50
L2-4	Quad	Planar n-in-p	150	50x50

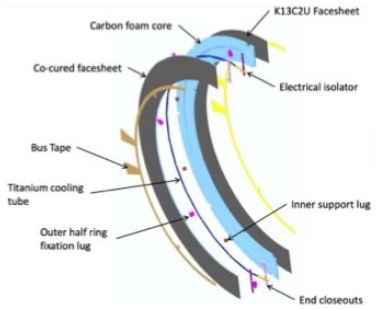
ITk Pixel Outer Endcap

- Three layers of half-rings (HR) loaded into carbon fibre half-cylinders
- HR are strategically placed in z to provide hermeticity in η
- Modules on both sides of HR ⊥ to beampipe → Φ hermeticity
  - >= 5 pixels overlap in φ.
- Each HR side holds one **serial-powering** chain:
  - 16/22/26 Modules for Layer2/3/4

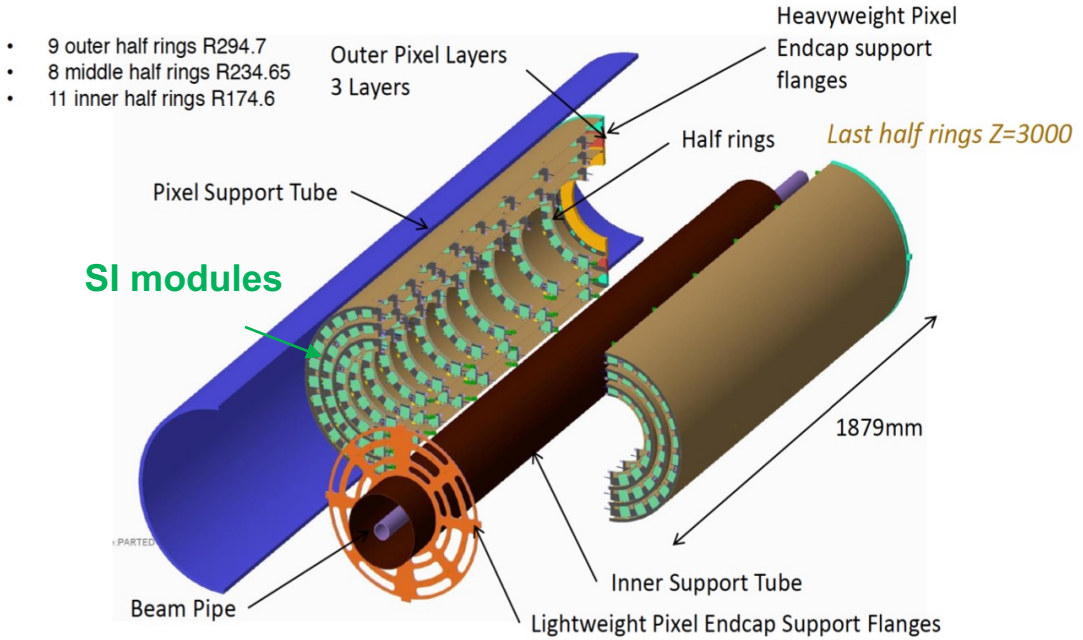




- Half-rings are C-foam / C-fibre “sandwiches” with embedded cooling pipe and fixation lugs

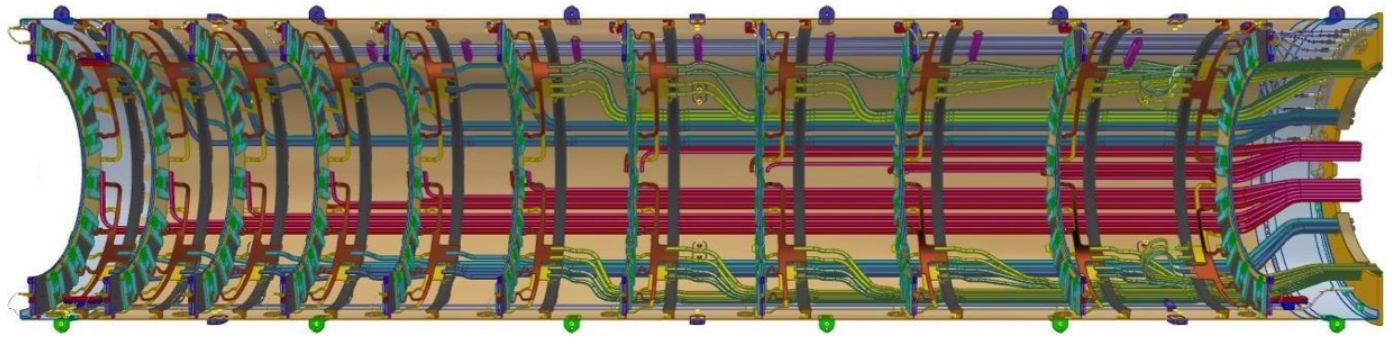


- 9 outer half rings R294.7
- 8 middle half rings R234.65
- 11 inner half rings R174.6



Cooling lines, data and electrical cables, run between outer rims of rings and inner surface of cylinder

IP

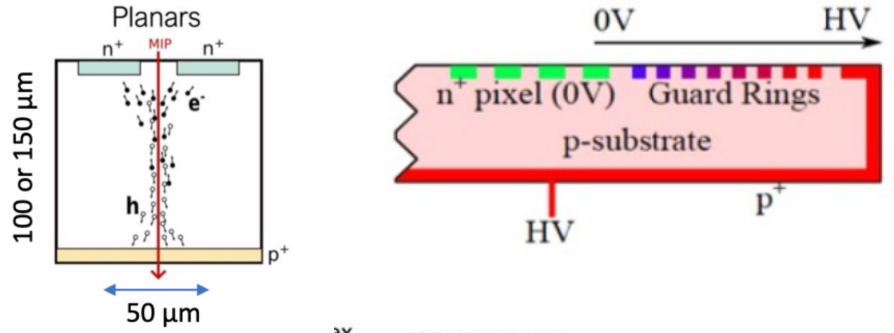


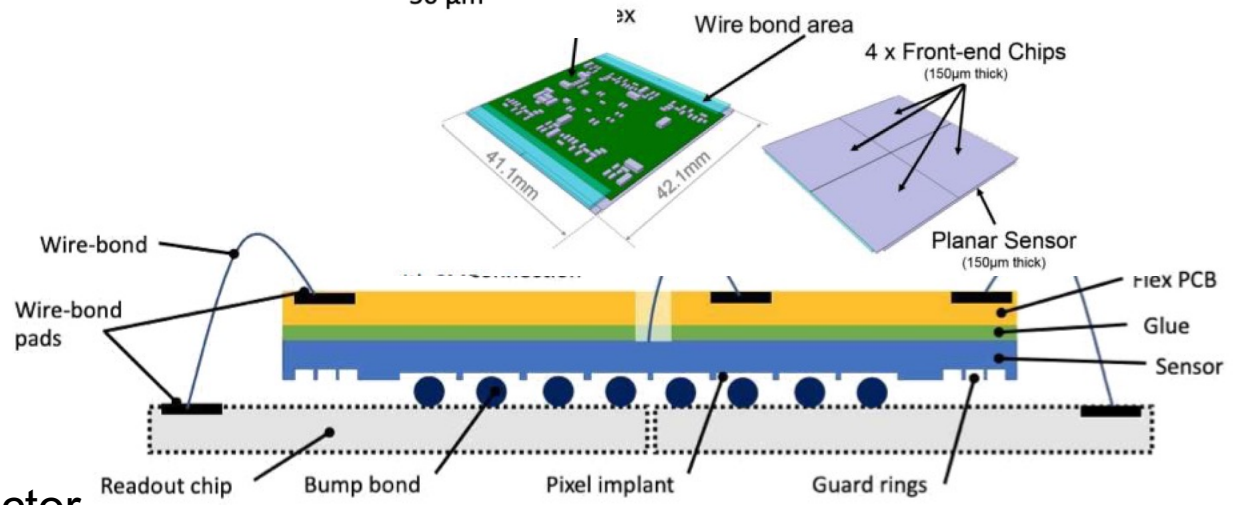
Sensor, Front-End Chip and Modules

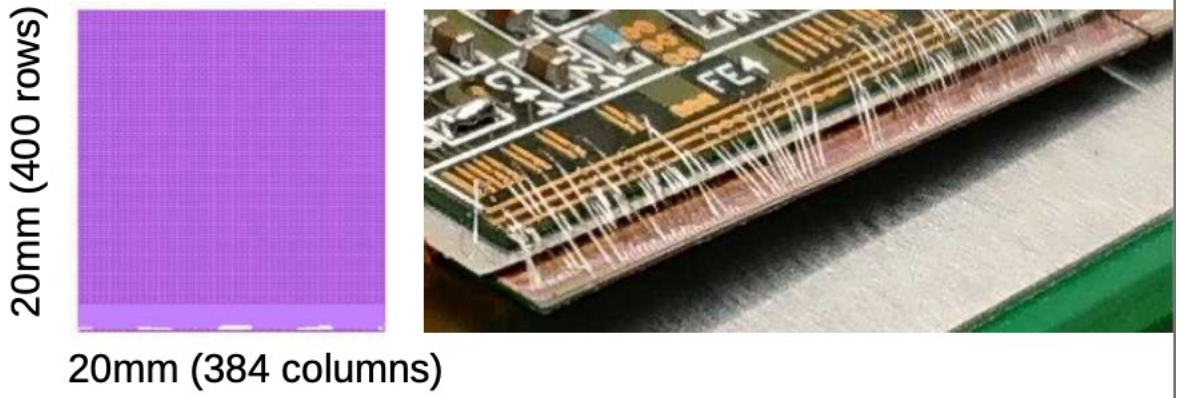
- **Planar Sensor n-in-p**

- **Front-End Chip** by RD53 collaboration
  - Read out trigger frequency at 1 MHz
  - 4 data lines at 1.28 Gbps
  - Uplink sharing
  - Rad-hard up to 500 MRad
  - 65nm technology
  - Chip size: 400 x 384,
    50x50 μm^2 pixels, 2.0 x 2.1 cm^2
  - Shunt-LDO regulator for serial powering
  - **8912 data links** / endcap from modules to off-detector electronics

Modules: 4 FE chips bump-bonded to sensor
- Cu-Kapton flex hybrid glued to sensor
  for connection to power, slow controls and data distribution
  - Wire bonds connect the flex to the FE chip(s)
  - "pigtails" connecting modules to power / data
- **1172 modules/endcap**







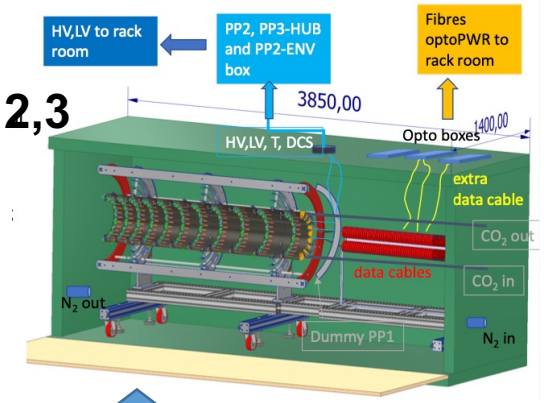
ITk Pixel Outer Endcap at LNF

Assembly and commissiong of one outer pixel endcap

0. Half-ring reception test
1. insertion of services – cooling lines, data/pwr cable - and half-ring with silicon modules
2. Testing functionality, cooling with CO_2
3. Thermo-cycles test with detector Off
4. Mating couple of half-shells to form a layer
5. Shipment to cern

0

2,3



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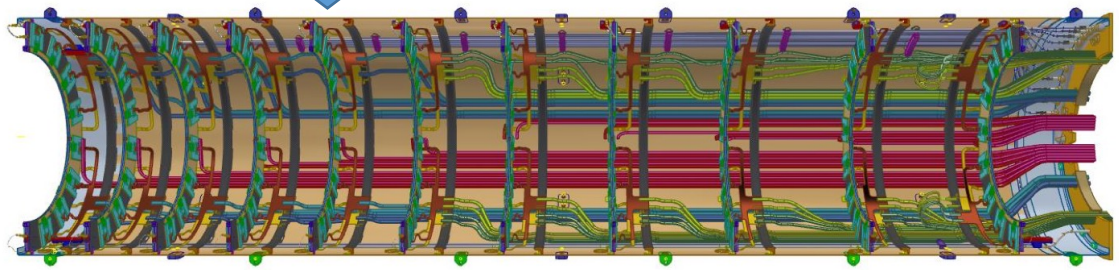

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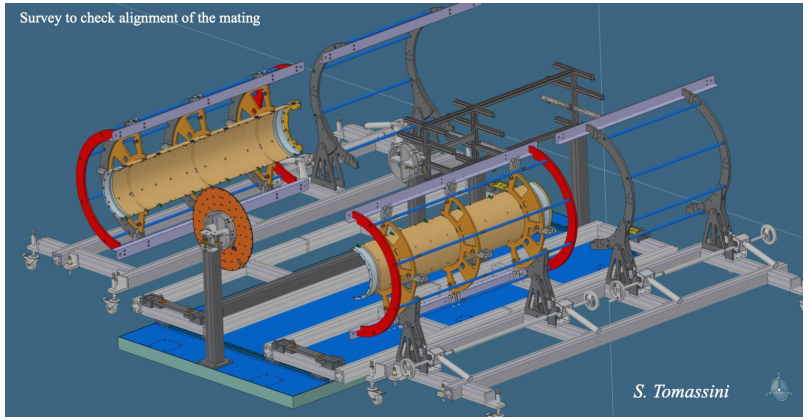

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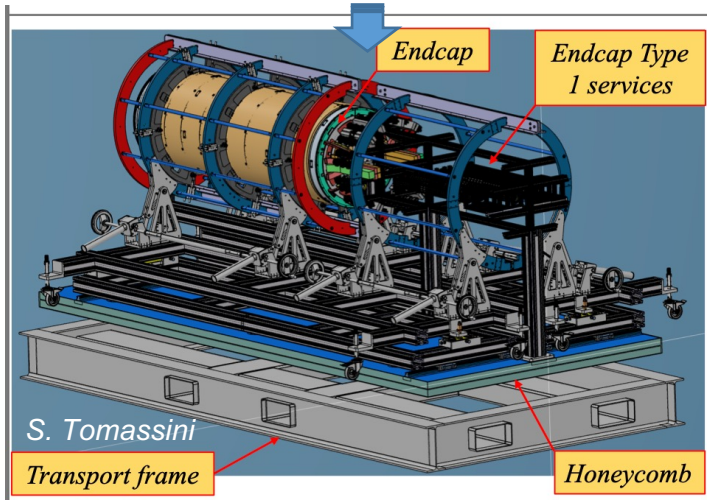
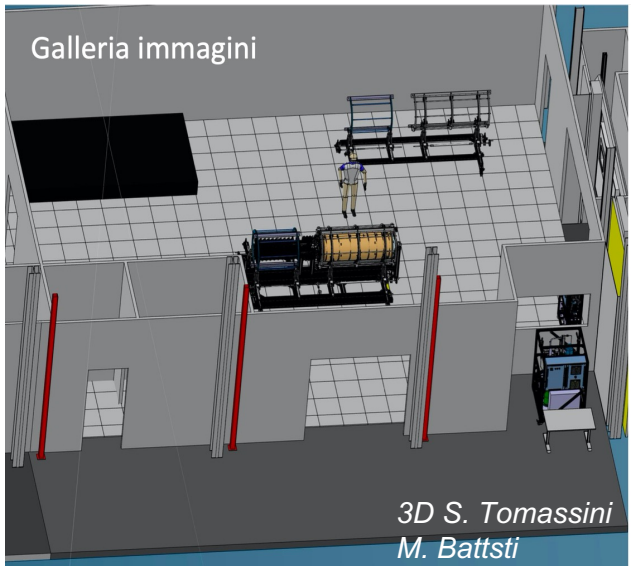


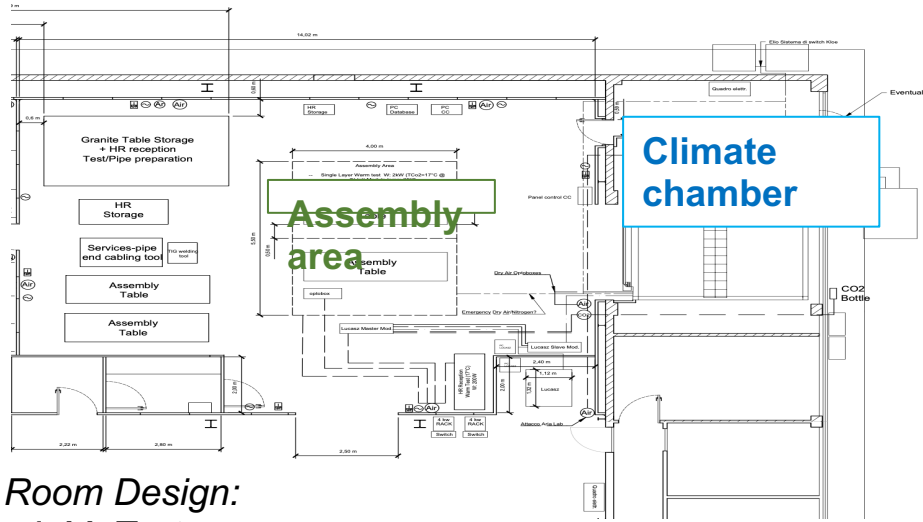
Clean room refurbishment at LNF per EC assembly

Large Clean room designed for:

- mechanical assembly, electical testing, cooling
- hosting climate chamber, transfer CO_2 cooling lines, dry air / N_2 distribution
- expected to be completed in Q1 2024

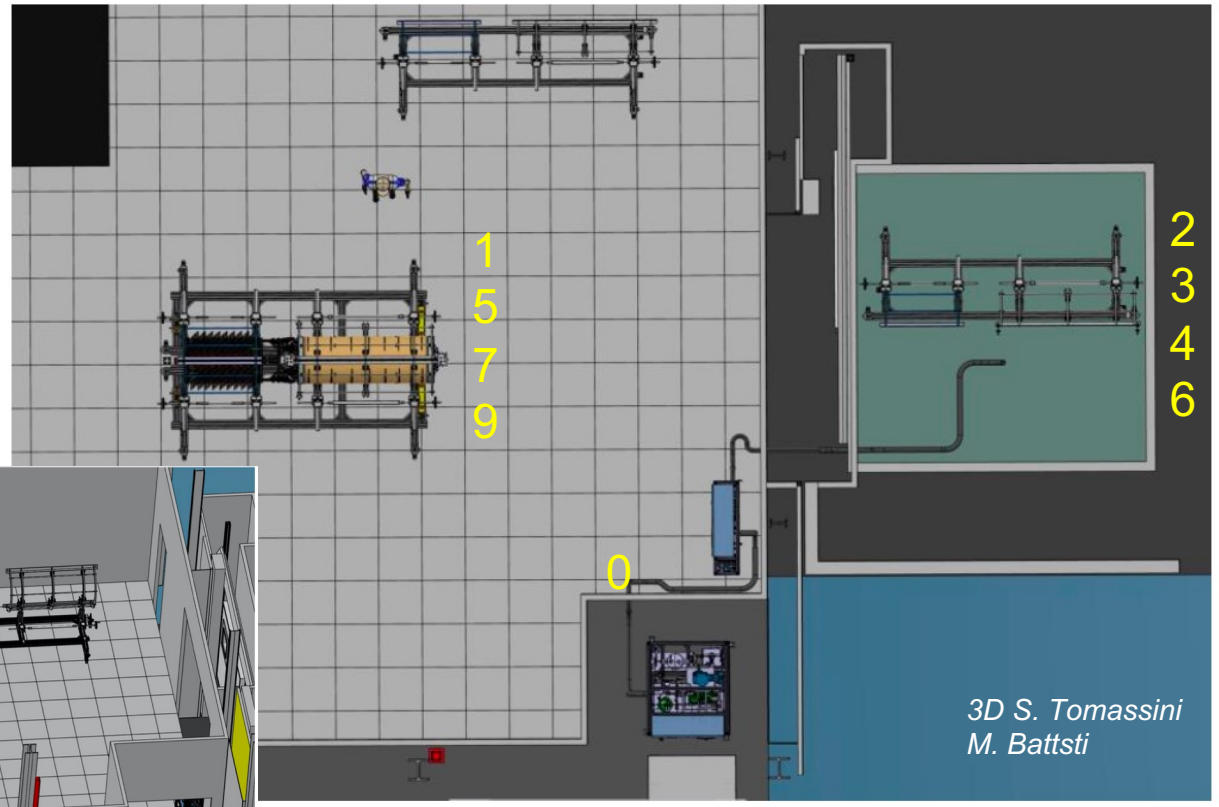


support platform, M. Battisti



Clean Room Design:
E. Dane', M. Testa

Pixel Outer Endcap: Testing during Integration



0. Half-ring reception test
1. insertion of services – cooling lines, data/pwr cable-and half-ring with silicon modules
2. Testing functionality cooling with CO_2
3. Thermo-clycles test with detector Off
4. Testing again functionality cooling with CO_2

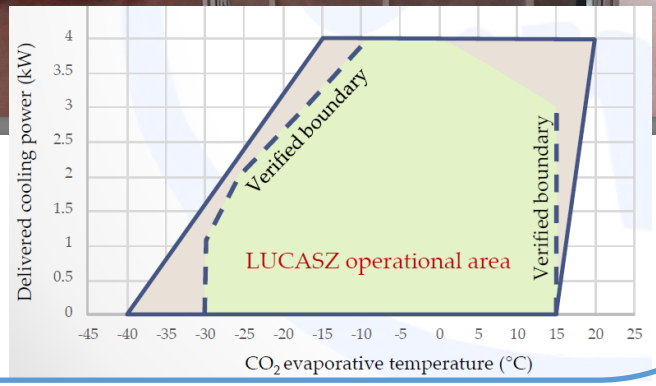
5. Mating couple of half-shells to form a layer
6. Testing functionality of complete layer cooling with CO_2
7. Bring layer on platform
8. Repeat for the three layers
9. Final test on tasport box

New Infrastructures

Dry air with dew point down to -70 C

Large Climate Chamber

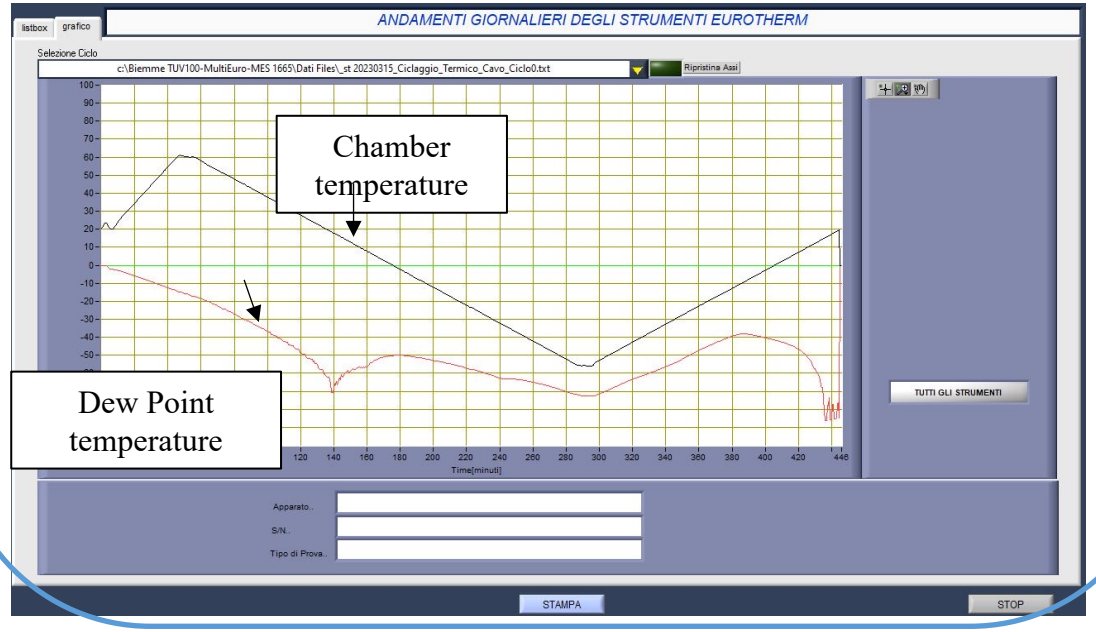
CO_2 cooling
LUCASZ =
Light **U**se **C**ooling **A**ppliance for **S**urfaces **Z**one



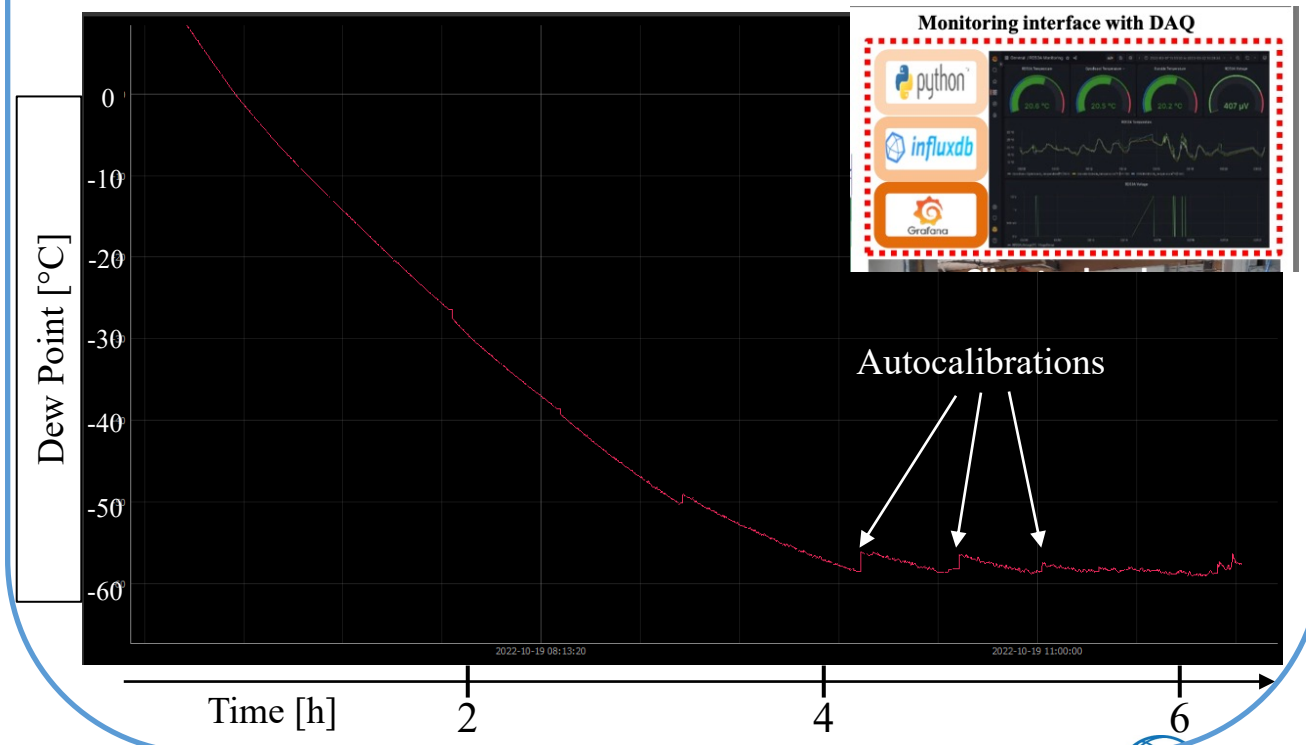
Climate Chamber commissioning

G. Cesarini, E. Dane', M. Testa, Z. Chubinidze

- **Thermal Cycle**
  - Aim: test services stability under thermo-mechanics stresses due to dfferent CTE of materials
  - Temperature: - 45C +40C (-55 C + 60C for prototypes)
  - Dew point < -10 C of T to avoid condensation
- **Commissioned**



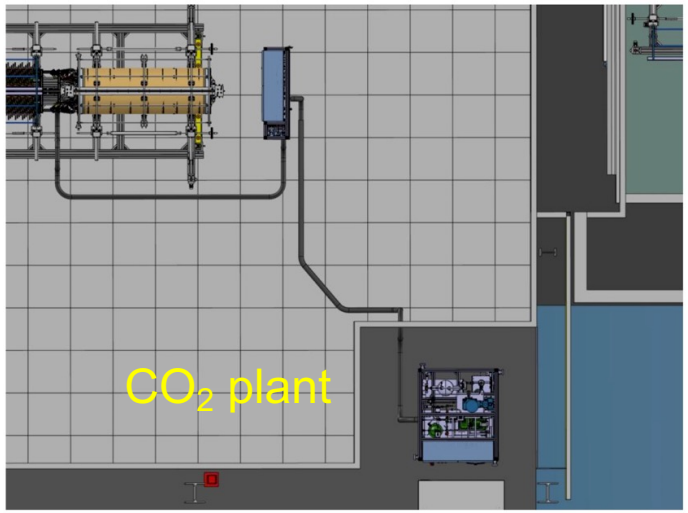
- **Functional test:**
- Aim: use climate chamber as testing box with CO_2 cooling and power on
  - T ~ +20-C
  - Dew point < - 60 C under CO_2 triple point
- **Commissioned**

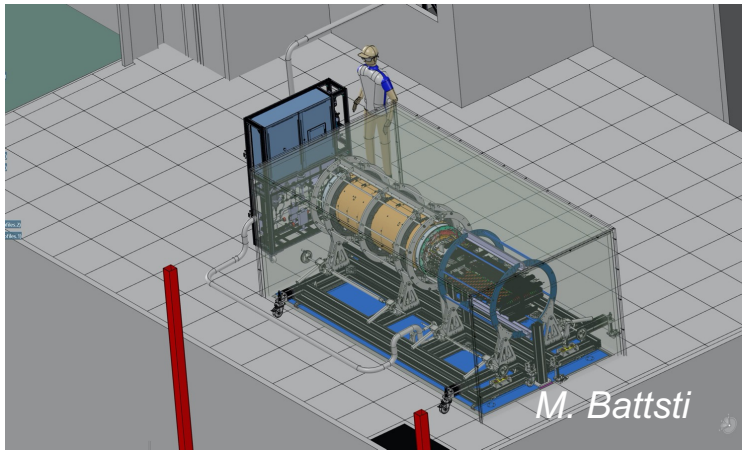


CO_2 cooling plant commissioning

C. Ligi, G. Cesarini

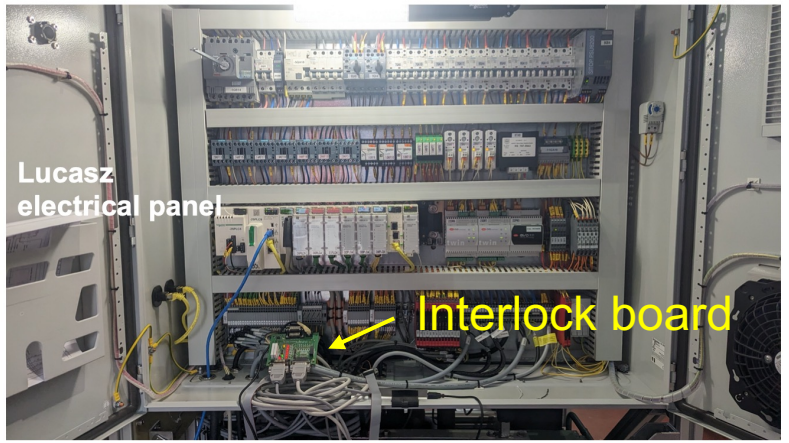
- Transfer lines design in clean room
- Installation in 2024





- Constructed and commissioned in 2021 at DESY
- Successful test with merging lines at LNF
- → 20 g/s CO_2 flow

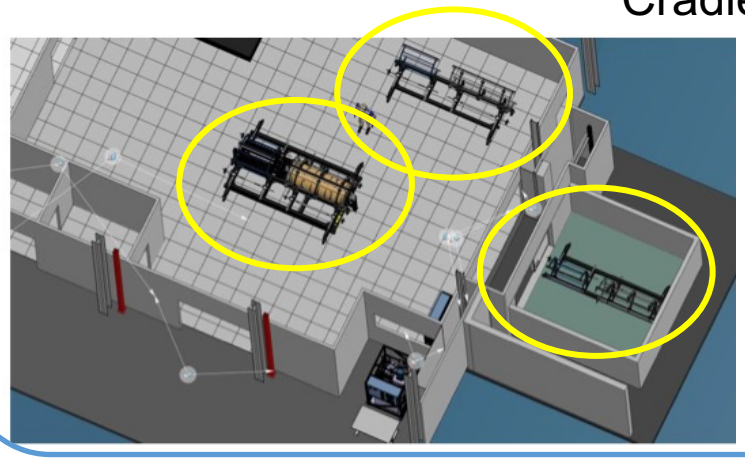
- Successful Integration with interlock system

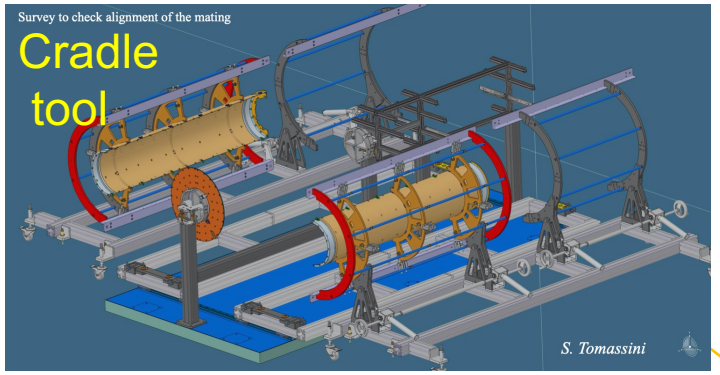


Z. Chubinidze

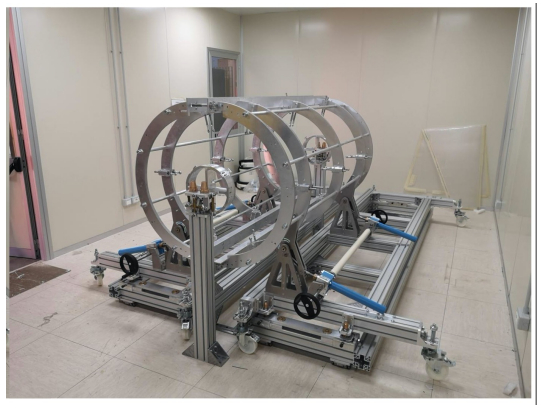
Tooling

Cradle tool: designed and prototype

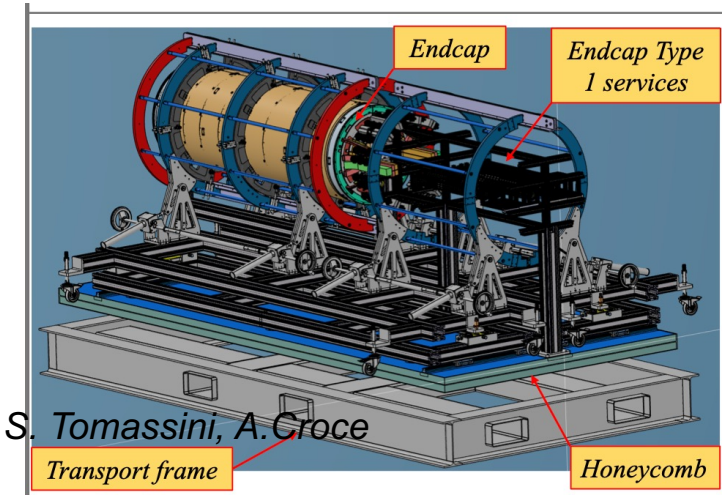




S. Tomassini, A.Croce

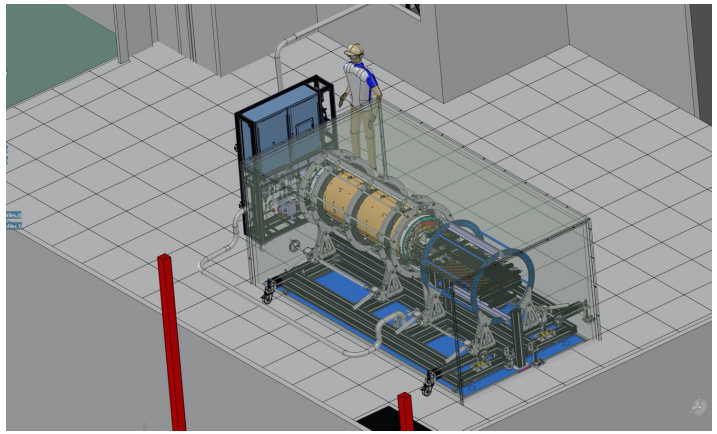


Transport Tooling: design in progress



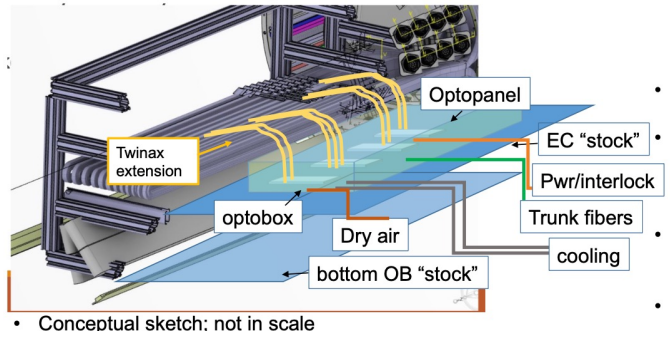
S. Tomassini, A.Croce

Transport/Test Box: design in progress



S. Tomassini, A.Croce

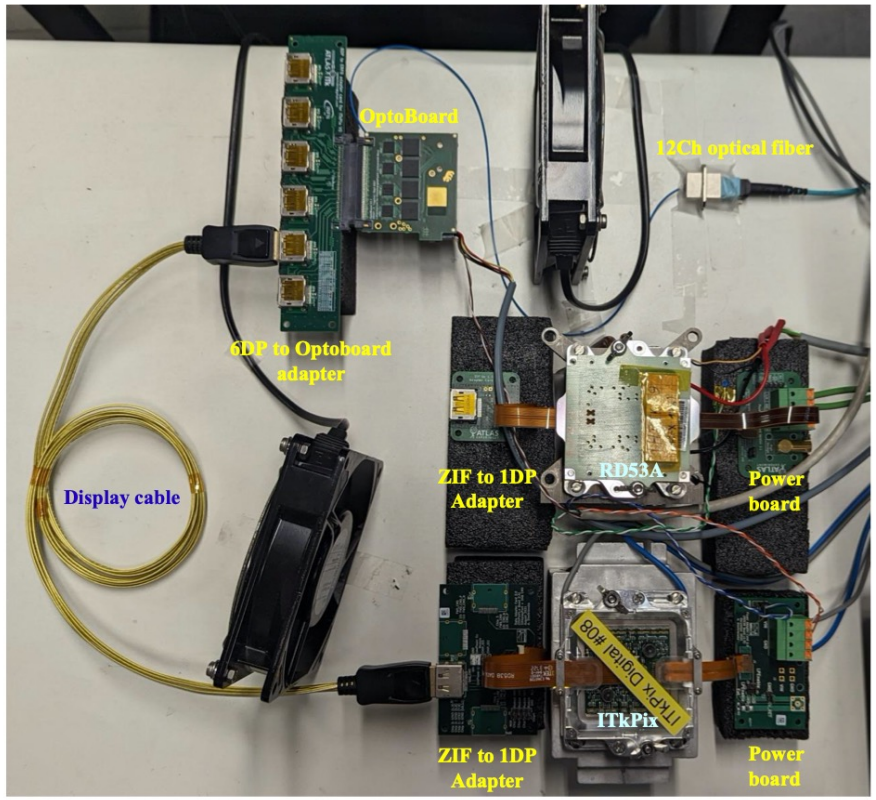
Services support: design in progress



B. Ponzio, E. Capitolo

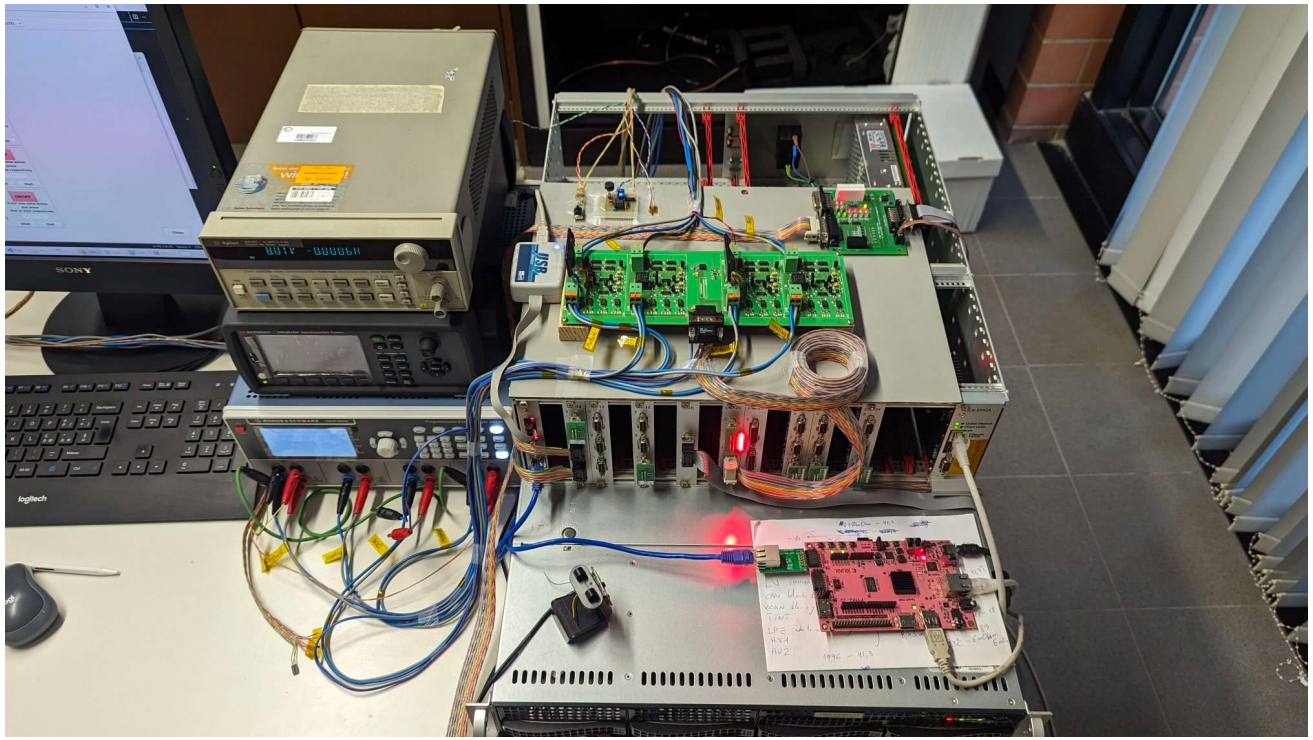
System Test

Single and multi-module setup
- High Speed data adapter board designed and produced for Pixel community
- DAQ with optical readout
- Data Transmission test



Z. Chubinidze, M. Gatta, M. Beretta, M. Testa

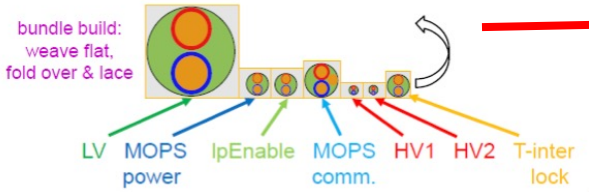
- Develop interlock logics
  - NTC, cooling, power, environmental sensors
- Develop of scalable DCS system

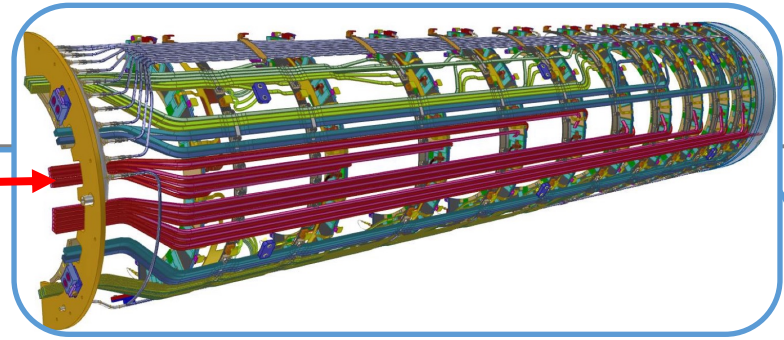


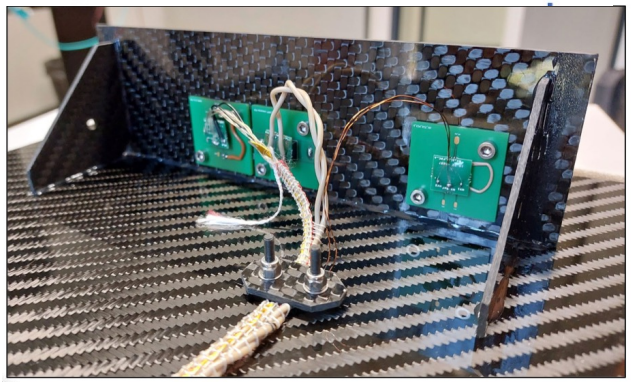
Z. Chubinidze

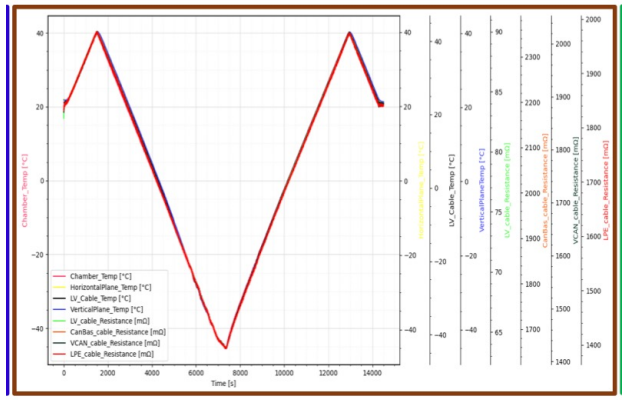
ITk Services

- Power/DCS cables:
- Design, Prototypes and Production
  - Quality Control
  - Thermo-mechanical cycles



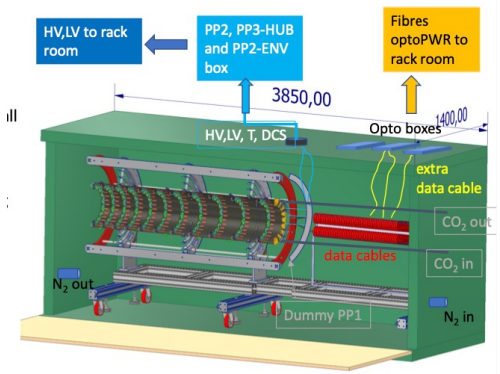


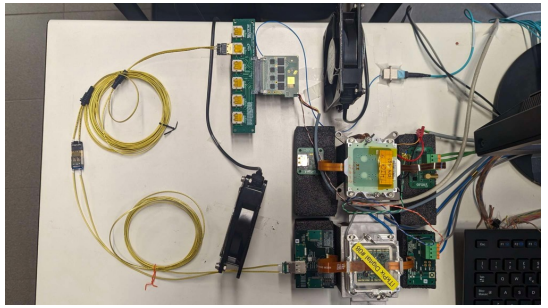


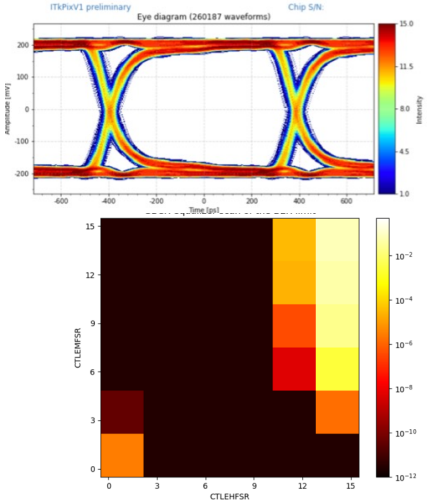


- Extension twinax data cables
  - Design Prototypes and Production
  - Data transmission test

P. Albicocco, M. Testa, Z. Chubinidze

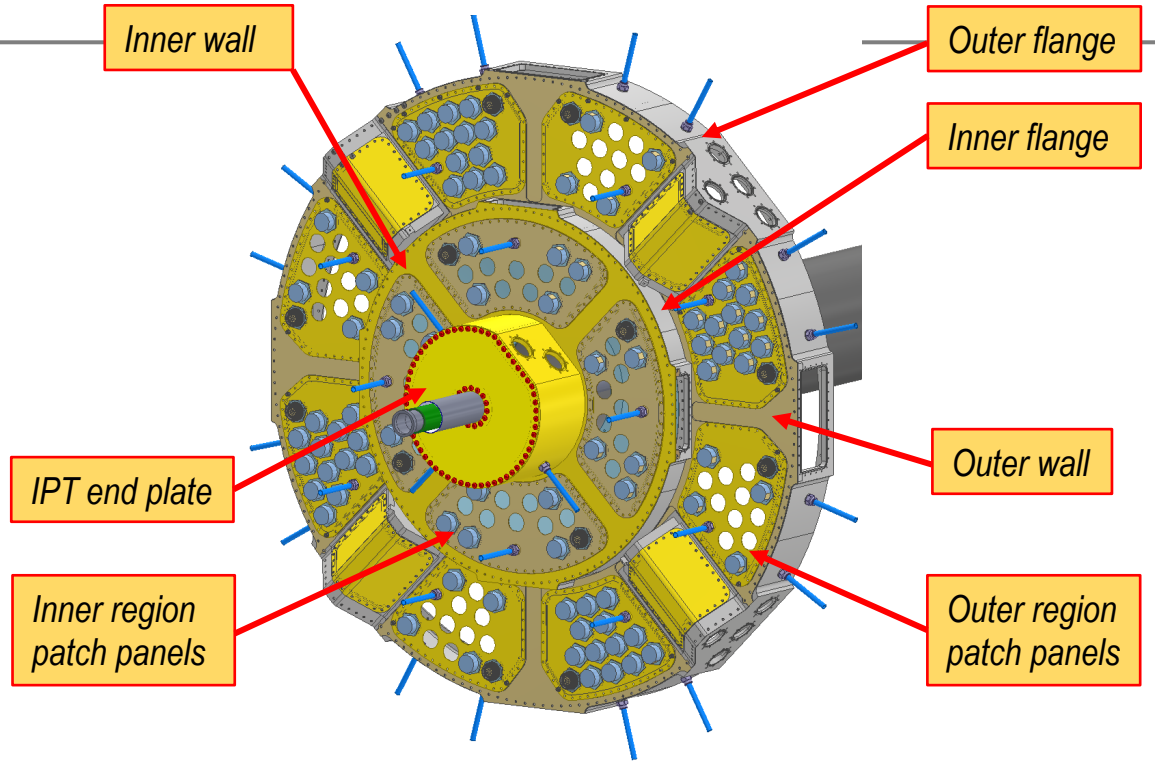






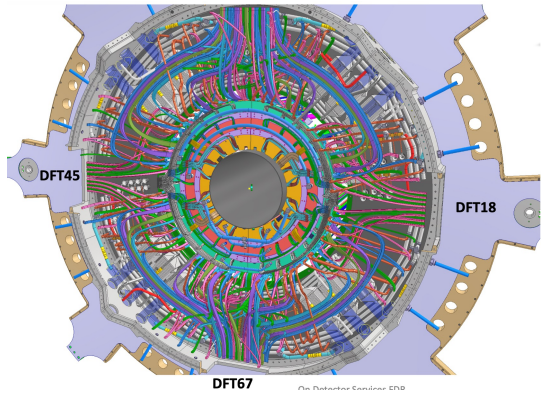
ITk Patch Panel 1

- Environmental gas sealing and Faraday cage closure of the detector volume.
- Feedthrough for **8488** twinax cable (OS)
  4604 twinax cable
- Cooling lines. 14 lines (OS)
  2 lines (IS)
- Power cables
- Inside N_2 overpressure 4mb
- Internal Dew point < - 60 C
- External Dew point < - 30 C
- Heaters to avoid surfaces



LNF responsabilities

- Mechanical structure: design and production
- Design and mockup of services routing:
  - Data and pwr cables, cooling lines and manifold
- Design and production of heaters

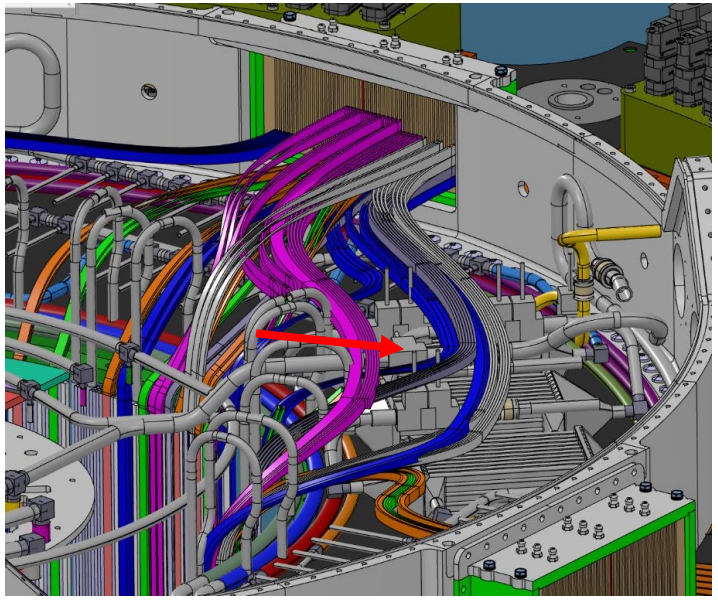


S. Tomassini, F. Rosatelli, E. Dane', B. Buadze, G. Cesarini, M. Beretta, B. Ponzio, E. Capitolo, S. Tomassini

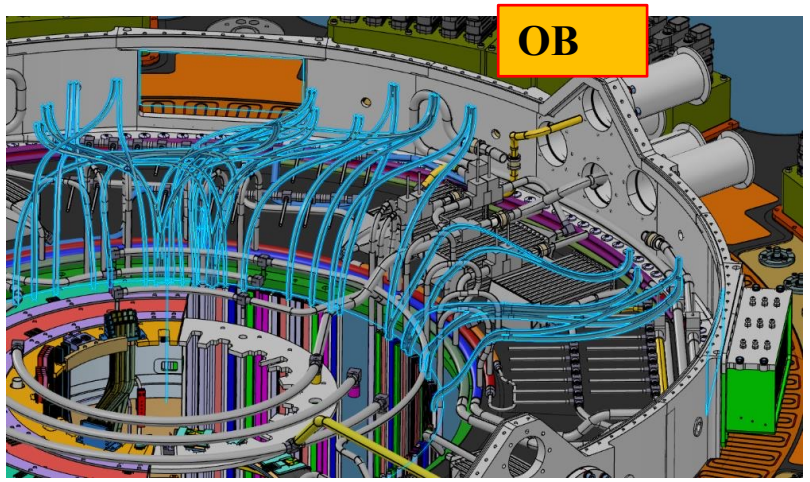
PP1 Activities: Cable Routing Design

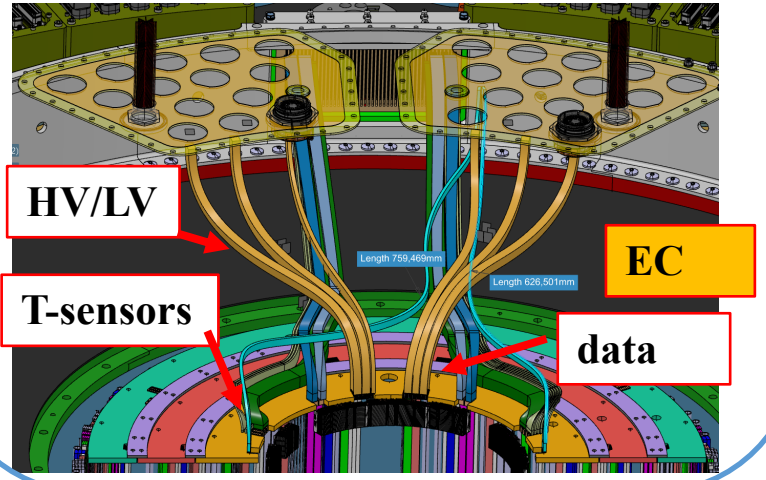
F. Rosatelli, E. Dane' , S. Tomassini

Data cables routing to the feedthrough

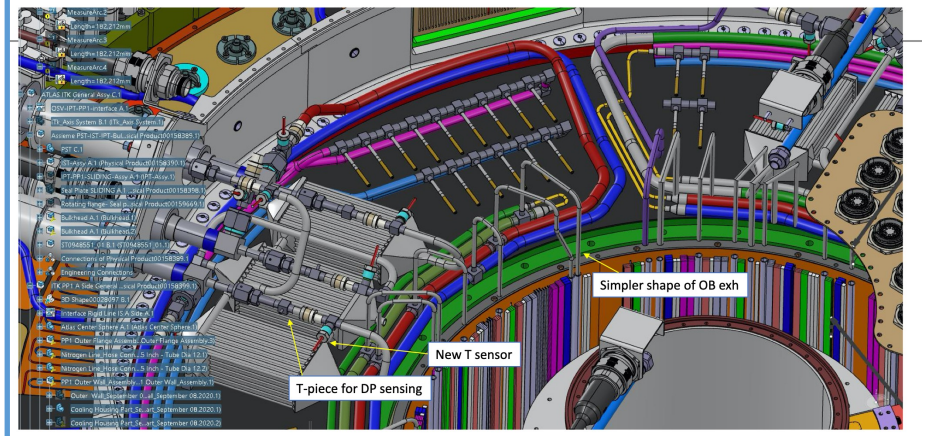


Pwr cables routing to connectors



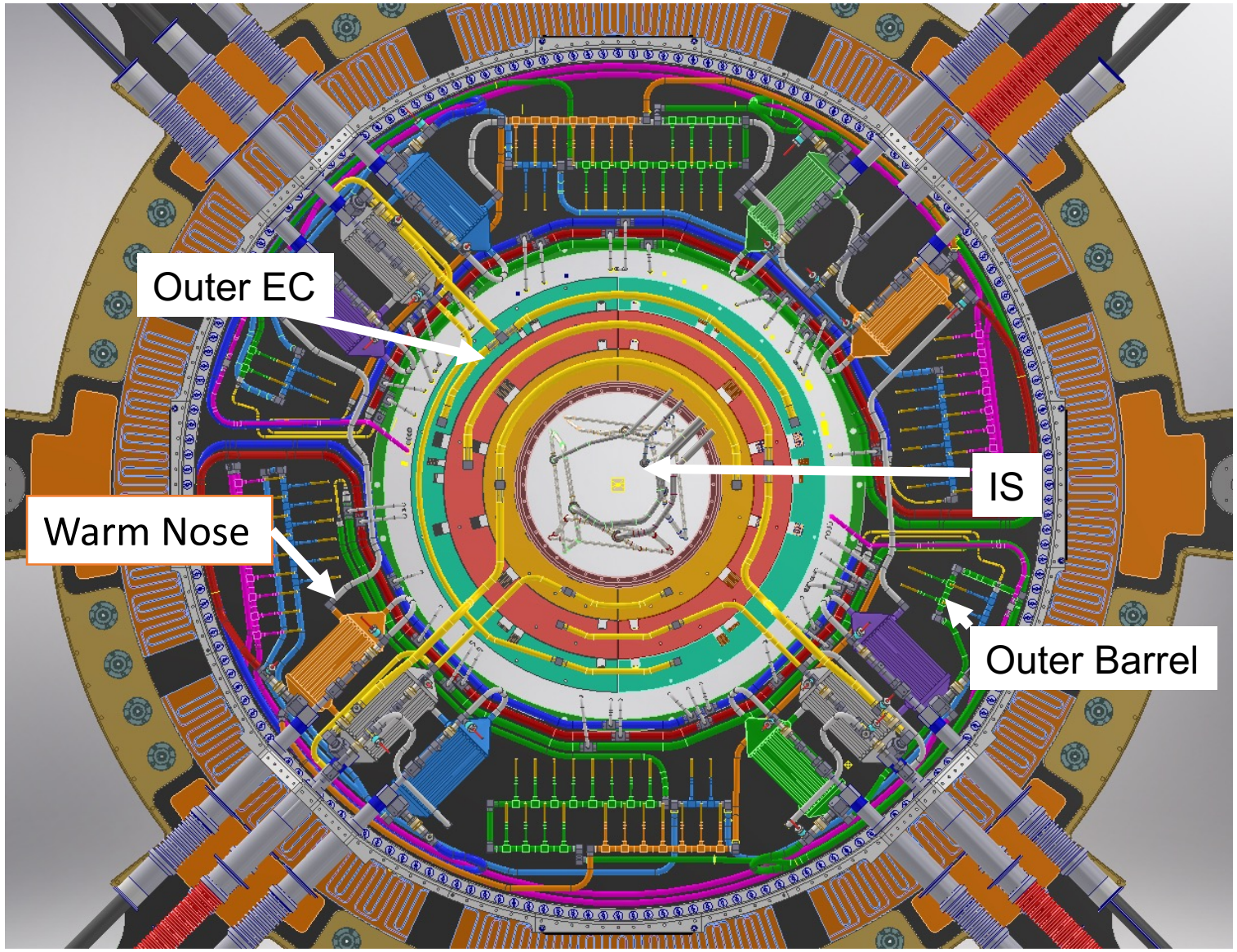


Cooling distribution



PP1 Activities: Cooling distribution design

E. Dane'

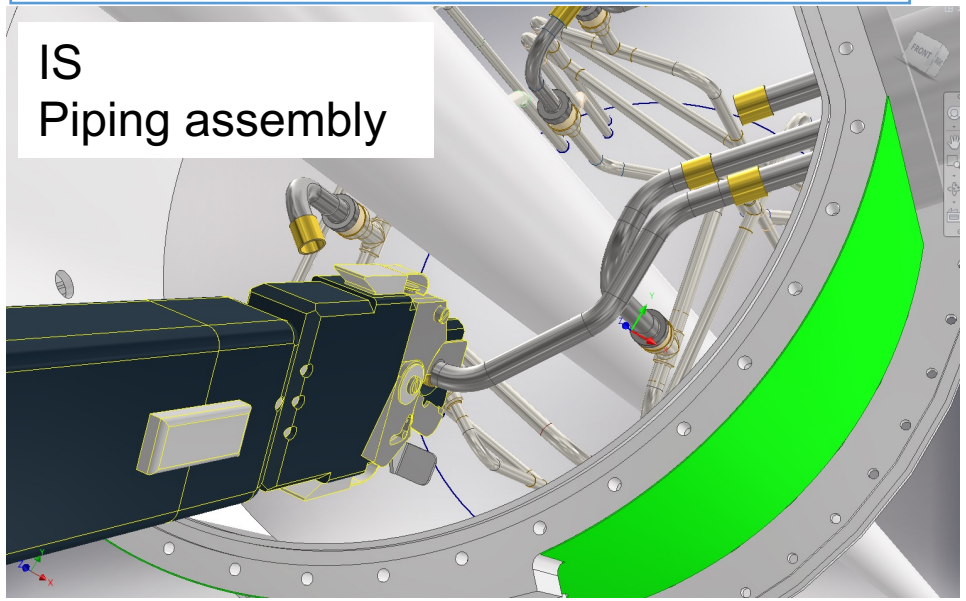


ITk PP1 piping

24 Inlets → 23 Exhausts

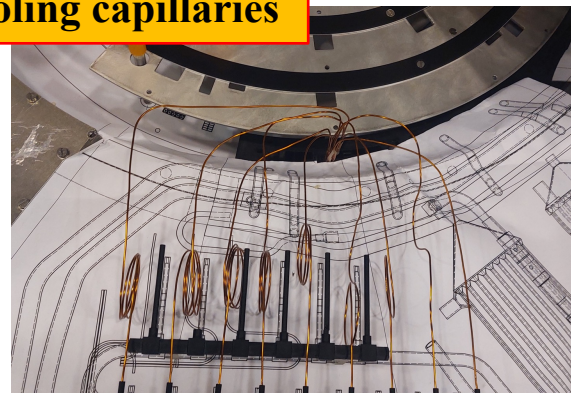
- Inner System: 3 loops
- Outer System: 11 loops
  - Outer Barrel: 8 loops
  - Outer Endcap: 3 loops
- Warm Nose: 2->1 loop

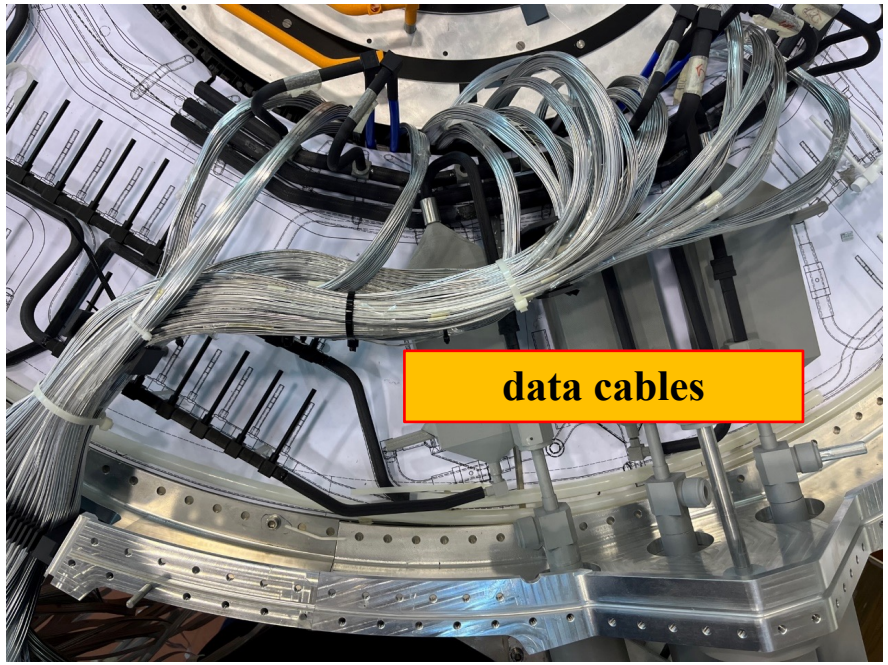
The piping design includes also the assembly sequence in SR1 and PIT



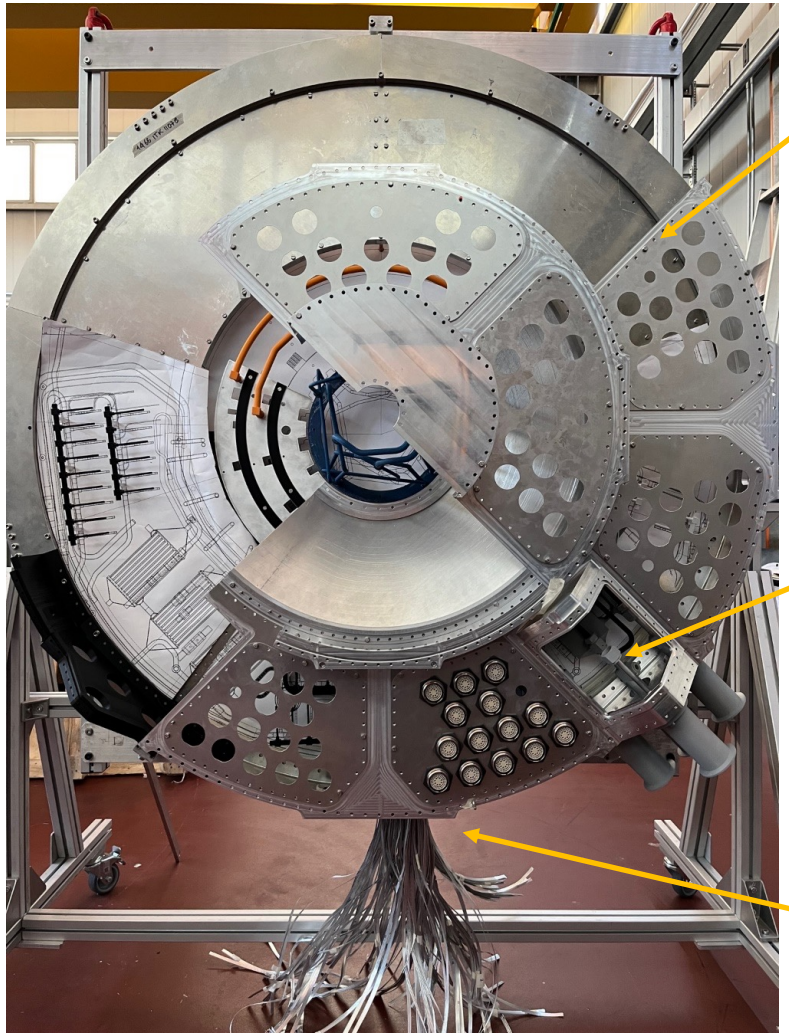
PP1 Activities: Mockup

Cooling capillaries

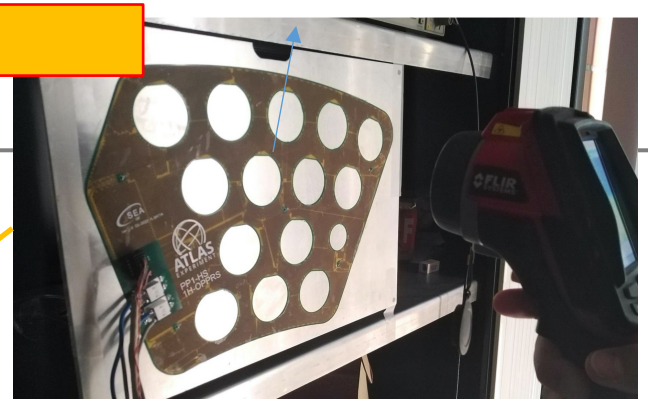




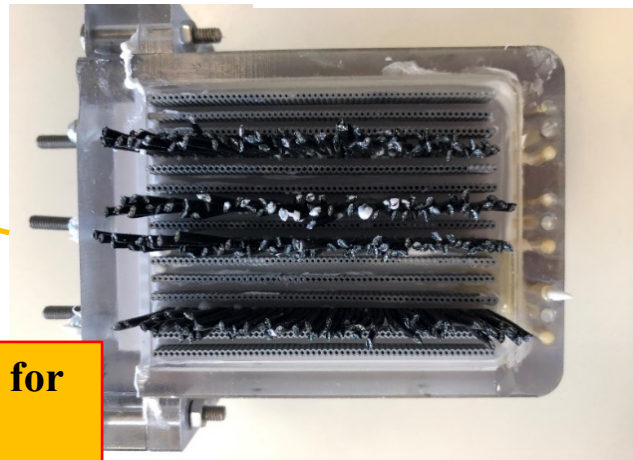
data cables



Heater



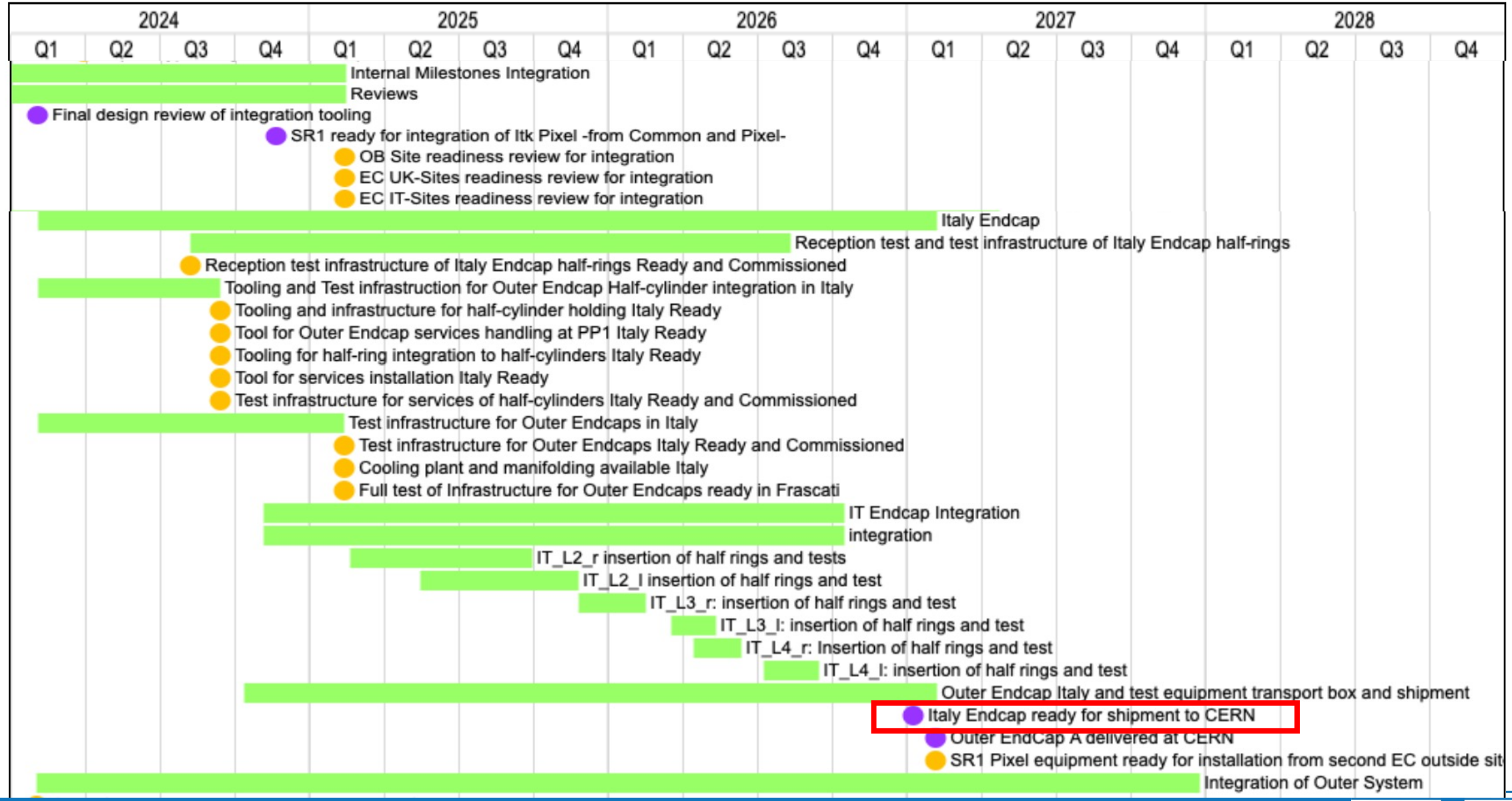
Shielding and grounding for cooling lines



Feedthrough prototype for data cables

F. Rosatelli, E. Dane', B. Buadze, G. Cesarini, M. Beretta, B. Ponzio, E. Capitolo, S. Tomassini + NA collegues

Schedule


2024
2025
2026
2027
2028
Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4
Internal Milestones Integration
Reviews
Final design review of integration tooling
SR1 ready for integration of Itk Pixel -from Common and Pixel-
OB Site readiness review for integration
EC UK-Sites readiness review for integration
EC IT-Sites readiness review for integration
Italy Endcap
Reception test and test infrastructure of Italy Endcap half-rings
Reception test infrastructure of Italy Endcap half-rings Ready and Commissioned
Tooling and Test infrastruction for Outer Endcap Half-cylinder integration in Italy
Tooling and infrastructure for half-cylinder holding Italy Ready
Tool for Outer Endcap services handling at PP1 Italy Ready
Tooling for half-ring integration to half-cylinders Italy Ready
Tool for services installation Italy Ready
Test infrastructure for services of half-cylinders Italy Ready and Commissioned
Test infrastructure for Outer Endcaps in Italy
Test infrastructure for Outer Endcaps Italy Ready and Commissioned
Cooling plant and manifolding available Italy
Full test of Infrastructure for Outer Endcaps ready in Frascati
IT Endcap Integration
integration
IT_L2_r insertion of half rings and tests
IT_L2_l insertion of half rings and test
IT_L3_r: insertion of half rings and test
IT_L3_l: insertion of half rings and test
IT_L4_r: Insertion of half rings and test
IT_L4_l: insertion of half rings and test
Outer Endcap Italy and test equipment transport box and shipment
Italy Endcap ready for shipment to CERN
Outer EndCap A delivered at CERN
SR1 Pixel equipment ready for installation from second EC outside sit
Integration of Outer System

Summary and Outlook

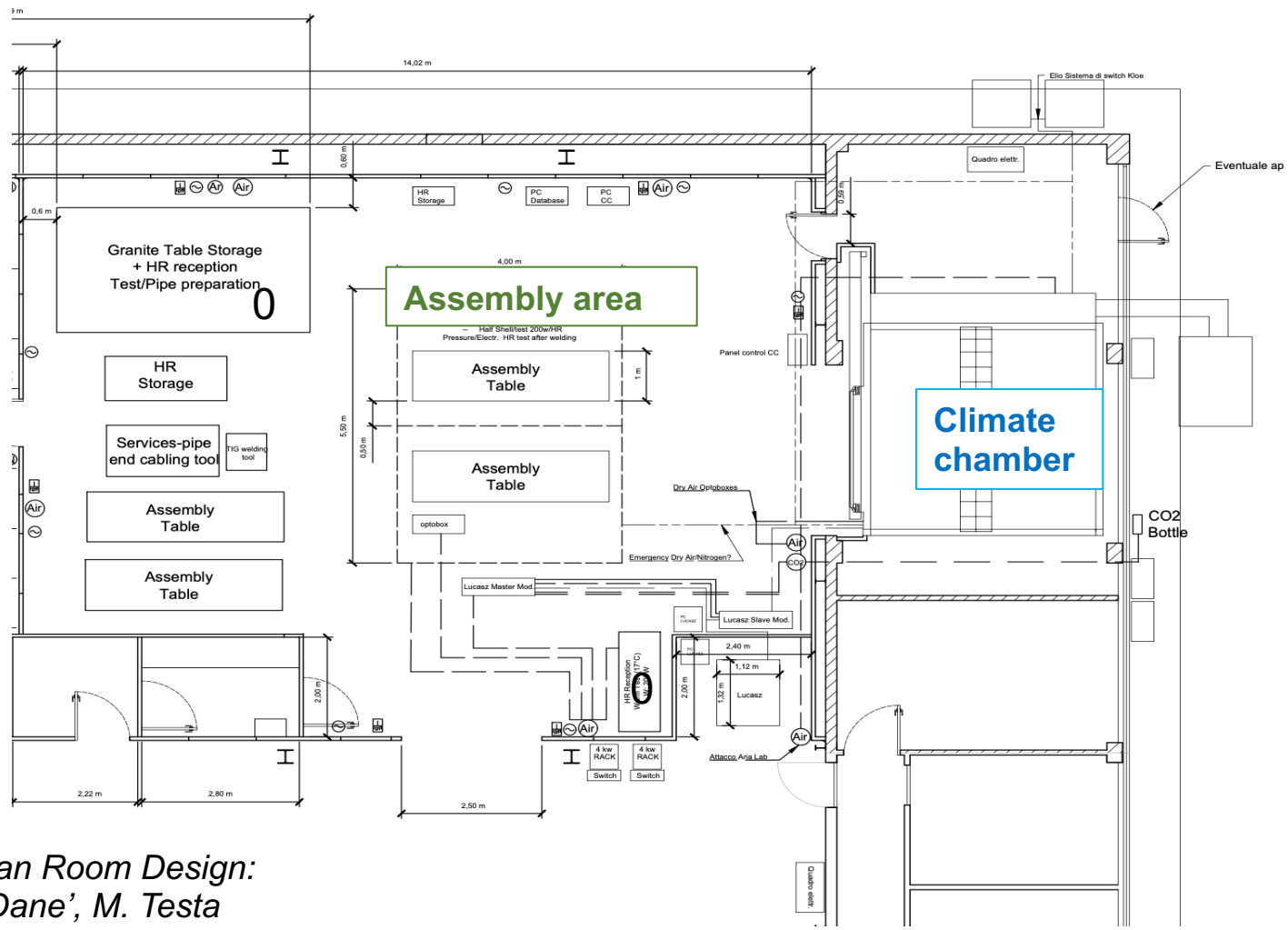
•The ATLAS ITk Pixel Detector will be at the centre of the new ATLAS tracker for HL-LHC Run 4

- Individual components verified in prototype runs during last two years and most passed final design reviews
- Sensors, FE-chips, Outer Barrel local supports in production
- Module hybridization and assembly, most services in pre-production
- Remaining activities planning final design reviews in next few months:
  - Global Mechanics and Integration Final Design Review, critical for LNF activities, in Q1 2024
- Completion scheduled for 2027

- Intense next years at **LNF** for
  - Design finalization and start production of **tooling** and **PP1**
  - Readiness of large **infrastructures**
  - Multi-module scalable testing setup: **DAQ**, **DCS**, **interlock**
  - **Assembly**
  - **Commissioning**

Backup slides

EC Testing during Integration



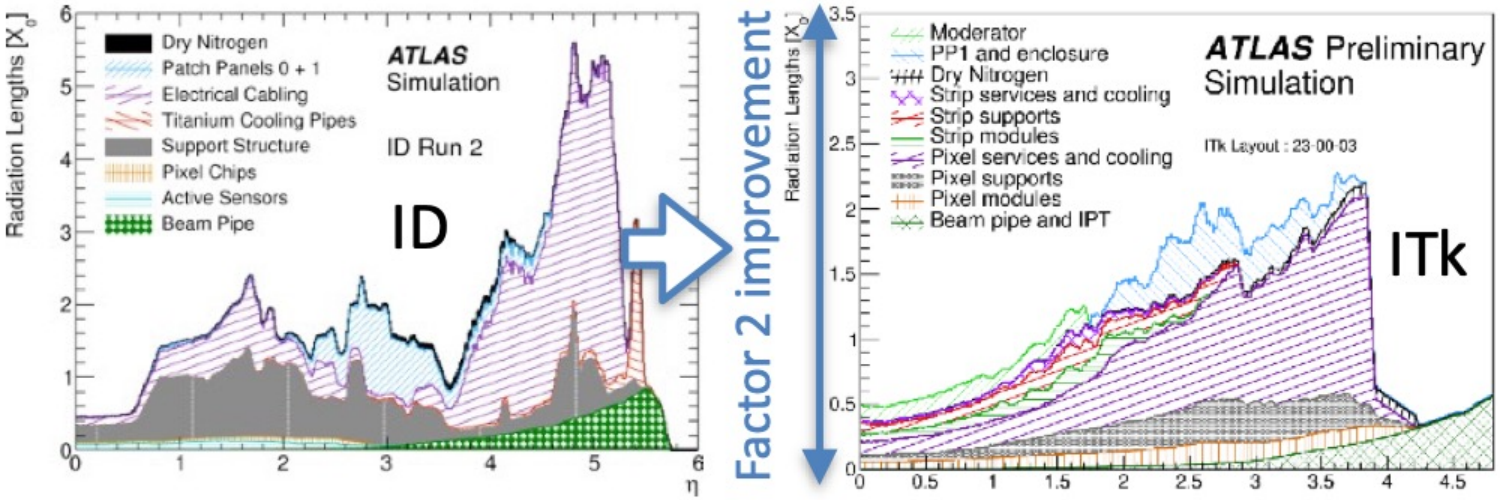
Clean Room Design:
E. Dane', M. Testa

0. Half-ring reception test
1. insertion of services – cooling lines, data/pwr cable-and half-ring with silicon modules
2. Testing functionality cooling with CO_2
3. Thermo-clycles test with detector Off
4. Testing again functionality cooling with CO_2

5. Mating couple of half-shells to form a layer
6. Testing functionality of complete layer cooling with CO_2
7. Bring layer on platform
8. Repeat for the three layers
9. Final test on tasport box

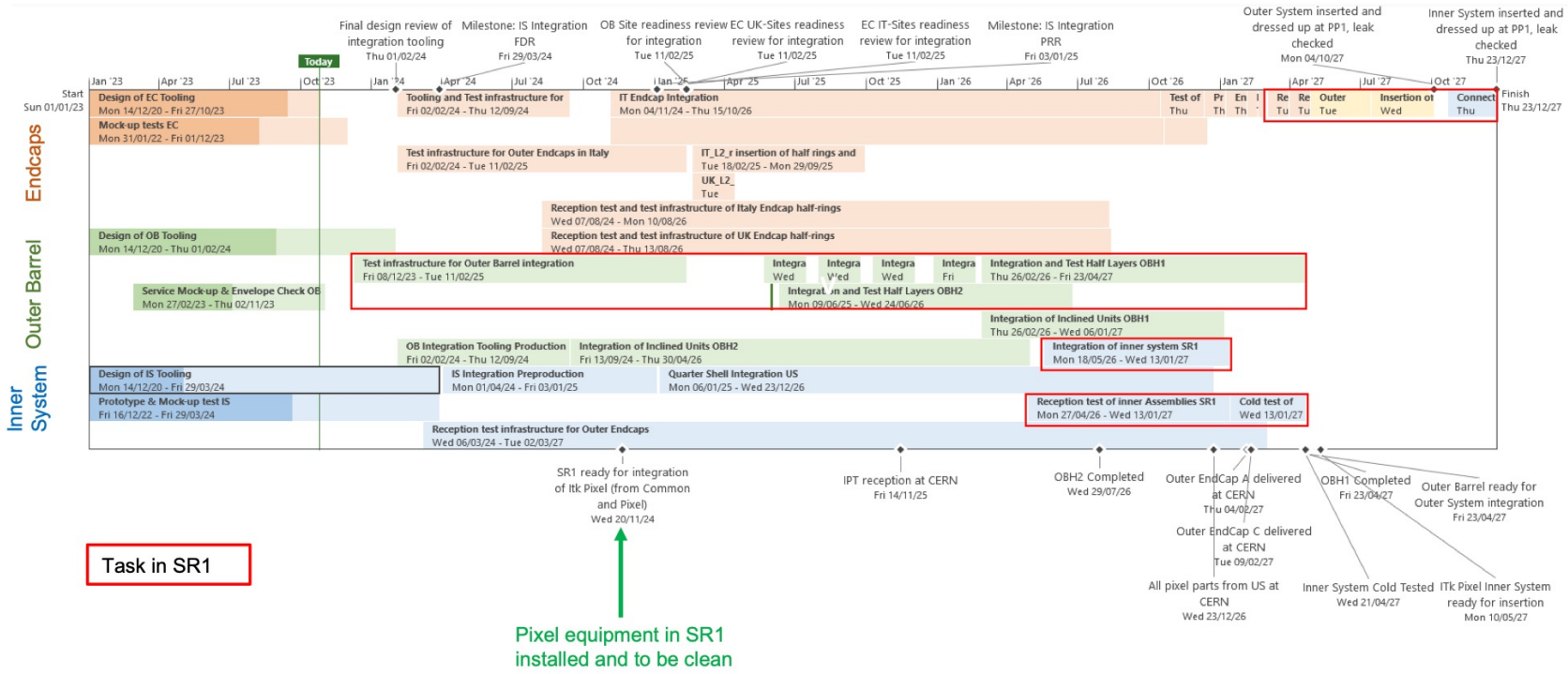
ITk Material

- Reduce of material using
  - CO_2 cooling with thin titanium pipes
  - Thin Si and FE- chips
  - Advanced powering: serial powering for pixels
  - Carbon Fibre structures for mechanical stability and mounting
  - Optimise number of readout cables using data link sharing



Schedule

WBS 2.1.7: Pixel Integration – Schedule Overview



- IST need date 01/02/2026
- IPT need date 27/04/2026

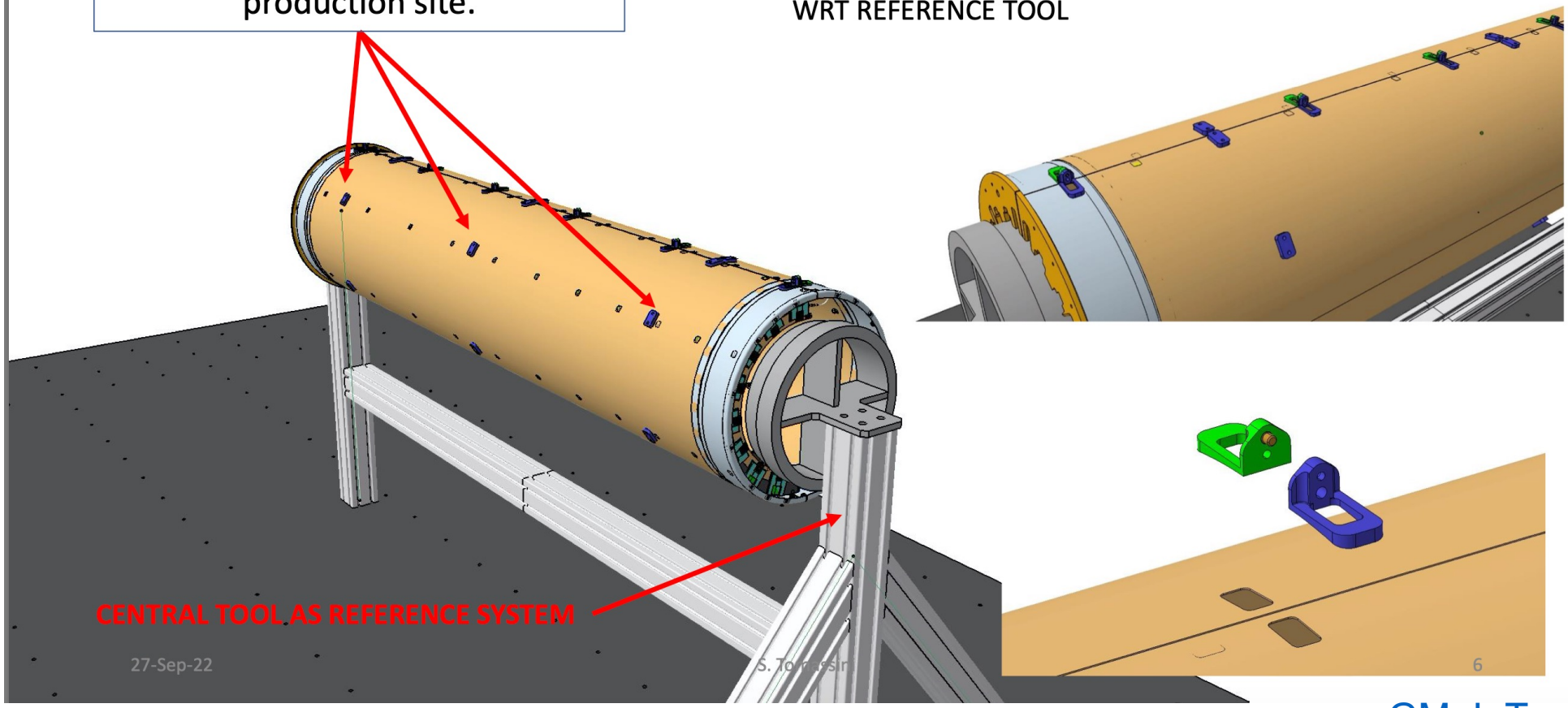
HS and tooling preparation - 1

Integration Sequence

L2_L3_L4 - Interface Plates (n.12)

already glued on CF shells at the production site.

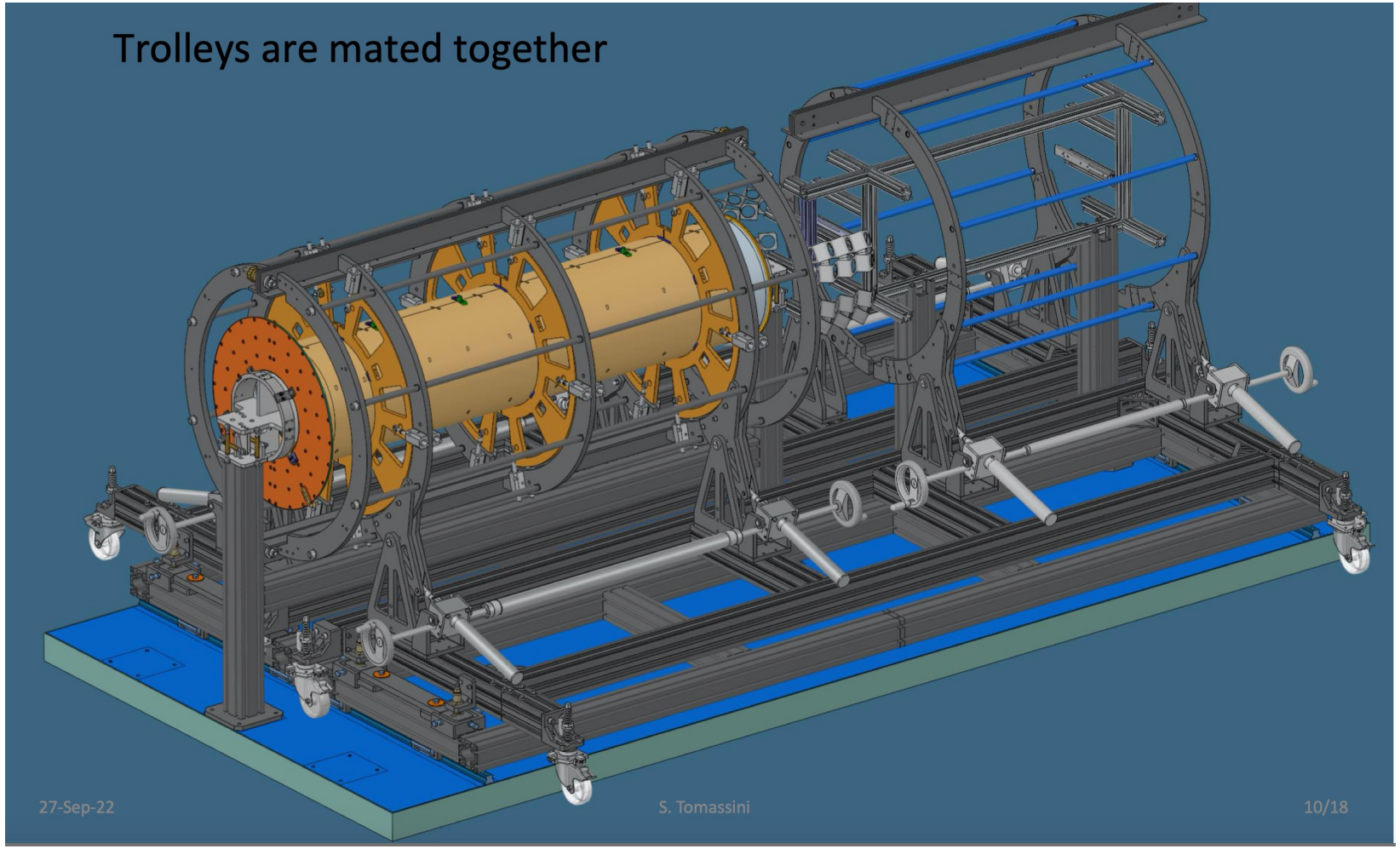
1. BARE SHELLS ARE INSTALLED AND CLAMPED ON THE REFERENCE TOOL
2. THE CILYNDER IS ALIGNED WRT REFERENCE TOOL



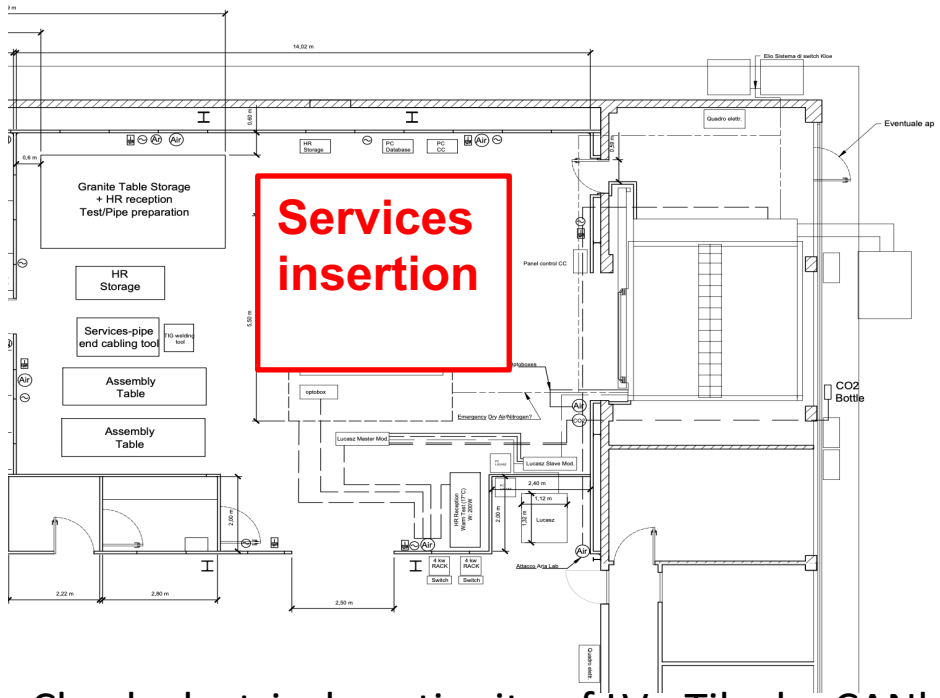
GM_I_Tomassini_27Nov2022 talk

HS and tooling preparation - 6

GM_I_Tomassini_27Nov2022 talk



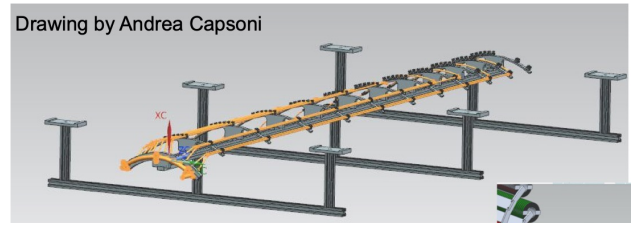
Insertion of type-1 services

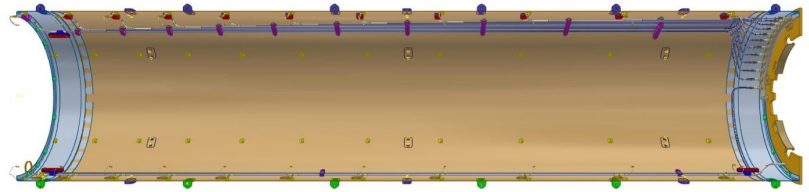


- Check electrical continuity of LV-, Tilock-, CANbus and VCAN-lines and data cables and env. bundles
- Where appropriate (e.g. the cooling manifolds), the resistance to the support structure will be measured and recorded to ensure compliance with the grounding and shielding including ground fault monitors, specifications

[ITkPixelIntegration-ElectrialEquipment-v10_docx_cpdf.pdf]

Insertion of cooling lines





Insertion of data/pwr harnesses and T sensors