INFN LNF
Istituto Nazionale di Fisica Nucleare

ATLAS EXPERIMENT

ATLAS

Abritta Costa Igor, Albicocco Pietro, Antonelli Mario, Arcangeletti Chiara, Battisti Marco, Beretta Matteo Mario, Buadze Beka, Capitolo Emilio, Chubinidze Zaza, Croce Antonio, Dané Emiliano, Gardini Alessia, Gargana Riccardo, Gongadze Levan, Ligi Carlo, Liedl Andrea, Mancini Giada, Pileggi Giuseppe, Ponzio Bruno, Pudzha Dennis, Rosatelli Filippo, Testa Marianna, Tinti Gemma, Vilucchi Elisabetta, Gianmario Cesarini

Si ringraziano i tecnici del servizio vuoto e della metrologia della DA, e tutti i tecnici e progettisti della DT

NSW Operation in ATLAS

M. Antonelli, G. Mancini, C. Arcangeletti
E. Capitolo, B. Ponzio, G. Pileggi

LNF still involved in operation and maintenance activity. Several responsibilities covered during the construction and installation phases

Micromegas HV status

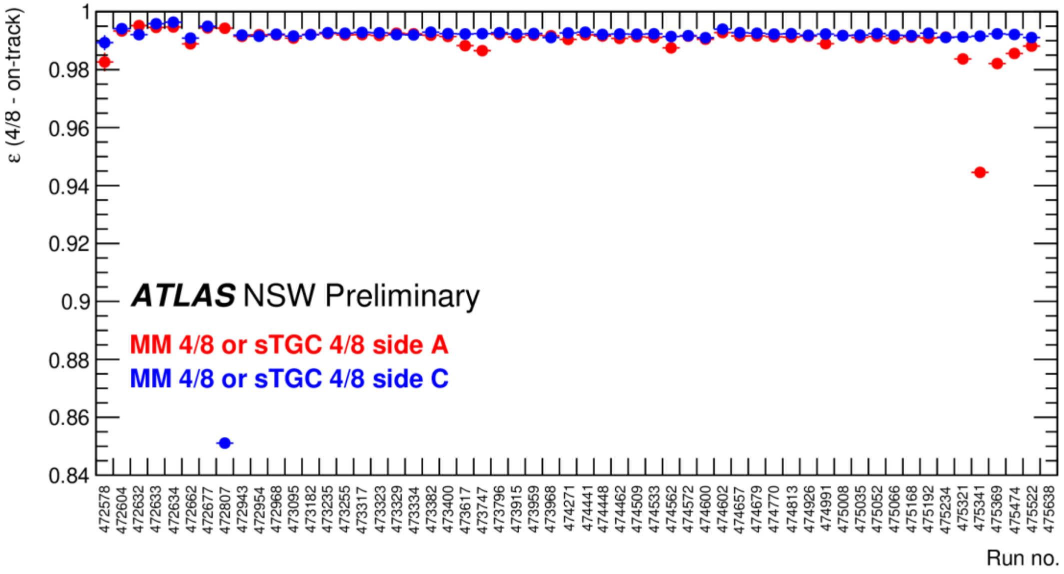
- Gas mixture with Isobutane → Only 1-2% channels are not working

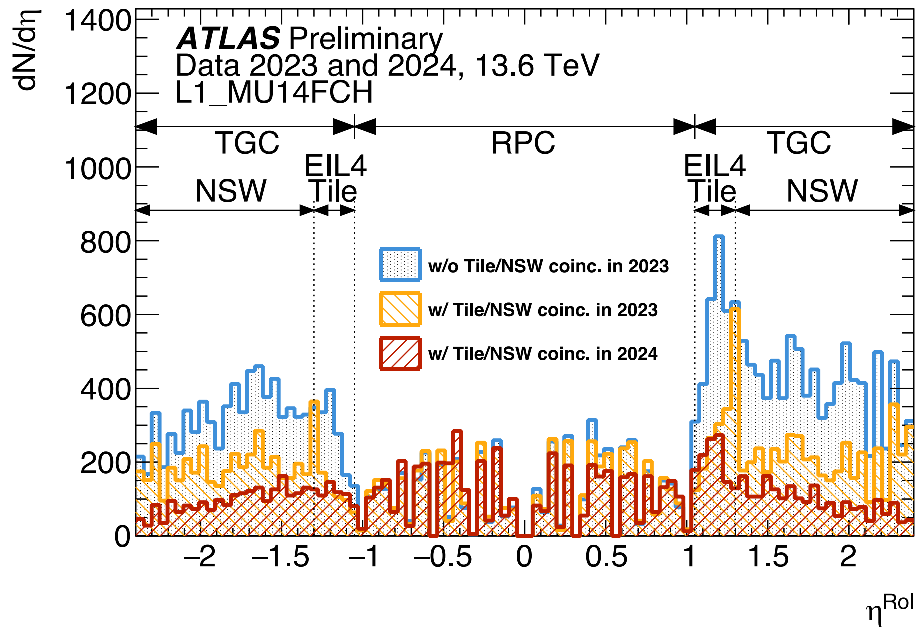
Data Taking & Performance

- DAQ stability very much improved: stable efficiency >95%
- Track reconstruction is >99%

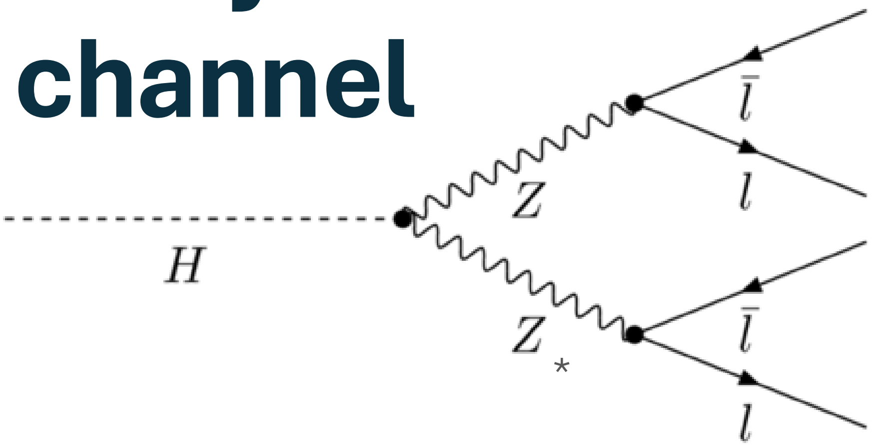
NSW in Level-1 Trigger chain included: all sTGC Pad and MM sectors in since May 28th 2024

Fakes rate rejection ~11 kHz and Tigger efficiency up to 98%

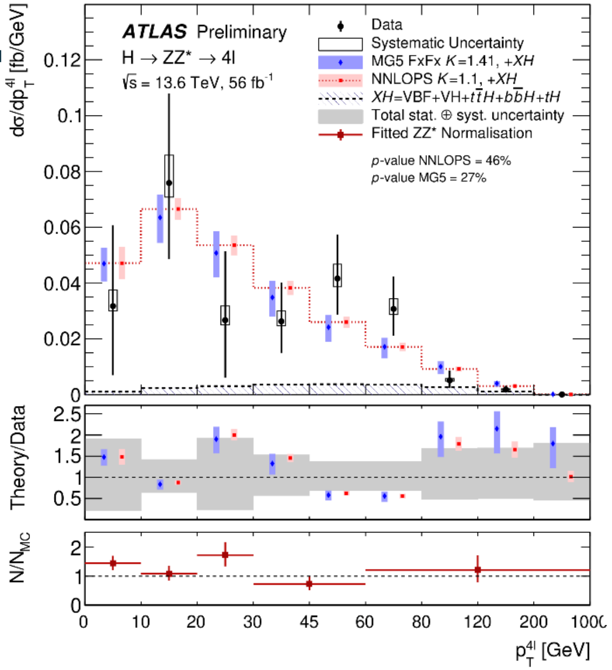


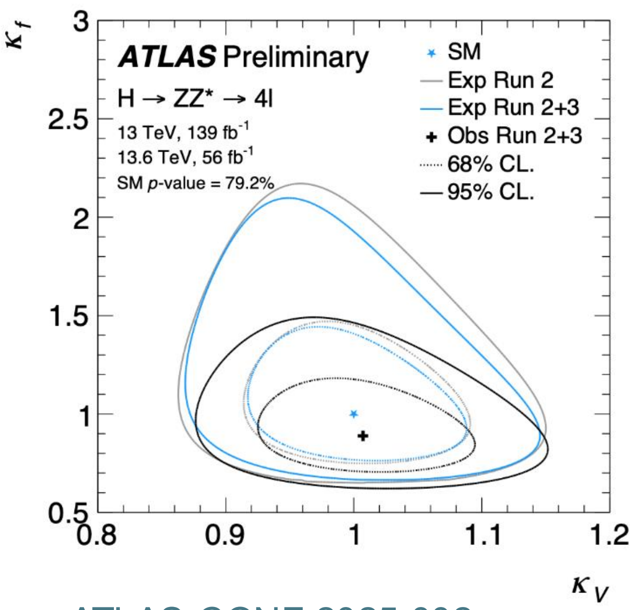


LNF activity on H→ZZ*→4l decay channel



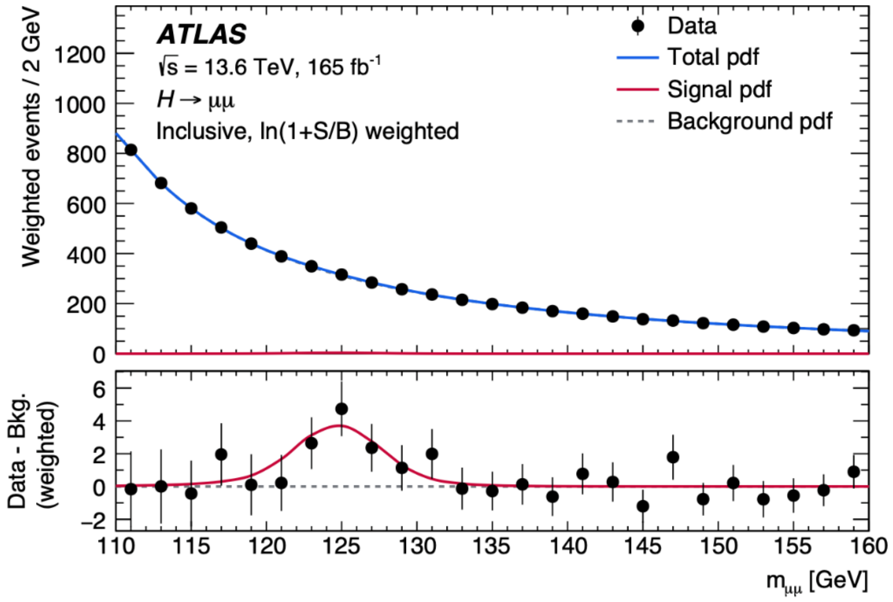
First Run2+Run3 combined result!





ATLAS-CONF-2025-002

H→μμ observed significance: 3.4σ (exp. 2.5σ)



2507.03595 (submitted to PRL)

LNF contribution

C. Arcangeletti, G. Mancini

- HZZ group convenership
  - Focusing on performing measurements of the Higgs boson properties in the H→ZZ* decay channel at 13.6 TeV
    - Differential and STXS measurements and BSM interpretation
  - First ATLAS evidence of the H→μμ decay channel!
  - Study of Quantum Entanglement in the Higgs decay in two vector bosons

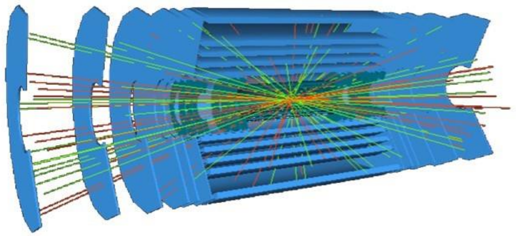
HL-LHC

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}

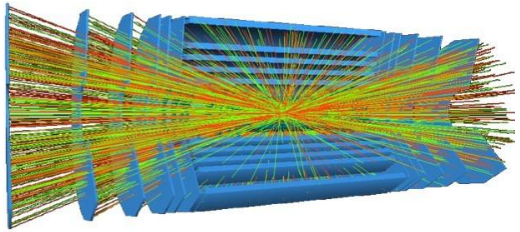
LHC: Inner Detector (ID) system, TRT (gas detector) + Strips + Pixels

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!

ATLAS ITk

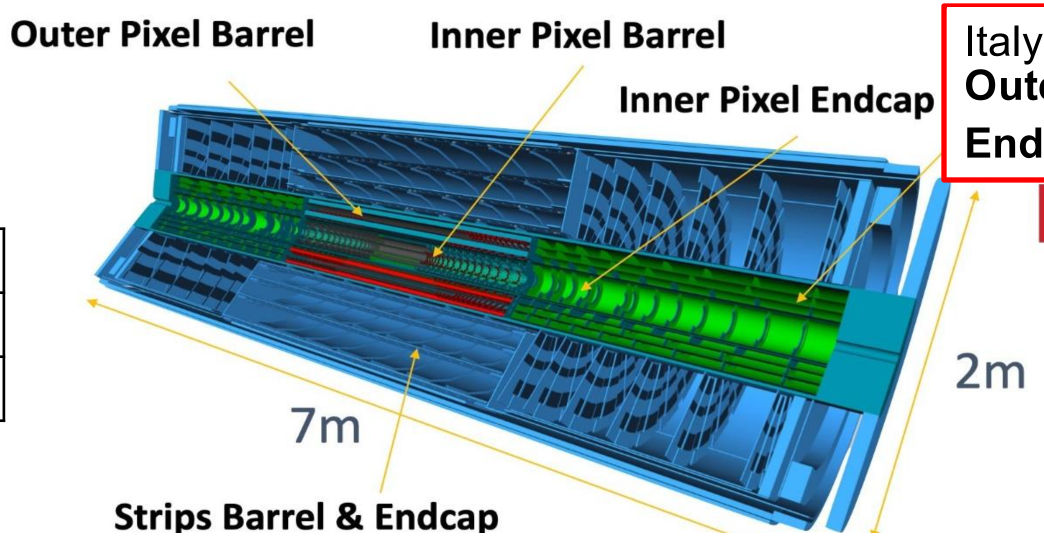
ITk : The New Inner Tracker

- **All-silicon** tracker

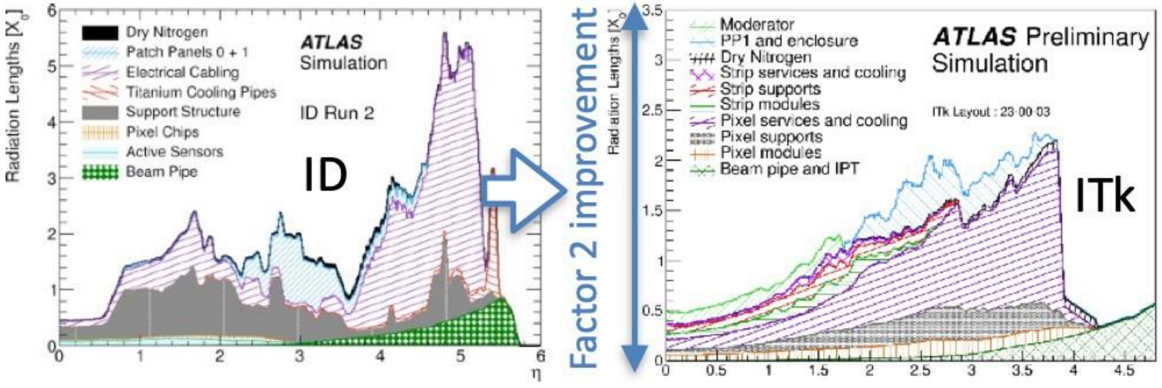
ITk (ID)	Area (m²)	# Modules	# Channels (M)
Pixels	13 (1.6)	9164 (2000)	5100 (92)
Strips	165 (61)	17888 (4088)	60 (6.3)

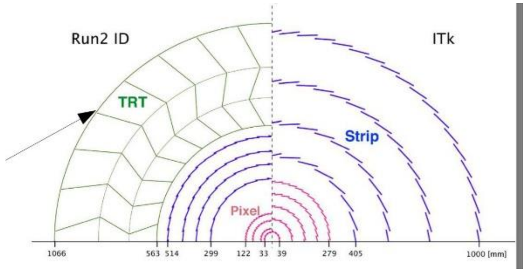
- **Improved tracking**
  - Coverage up to **|η|<4** (ITk) from |η|<2.5 (ID)
  - Finer **segmentation**:
    - 50x50μm² or 25x100μm²
    - ID: 50 × 400 μm² or 50 × 250 μm²
  - Reduced **material**: **Carbon Fibre** structures, **CO_2** cooling with thin Ti tubes walls, advanced **serial powering**, data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

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



Italy will build one **Outer Pixel Endcap**

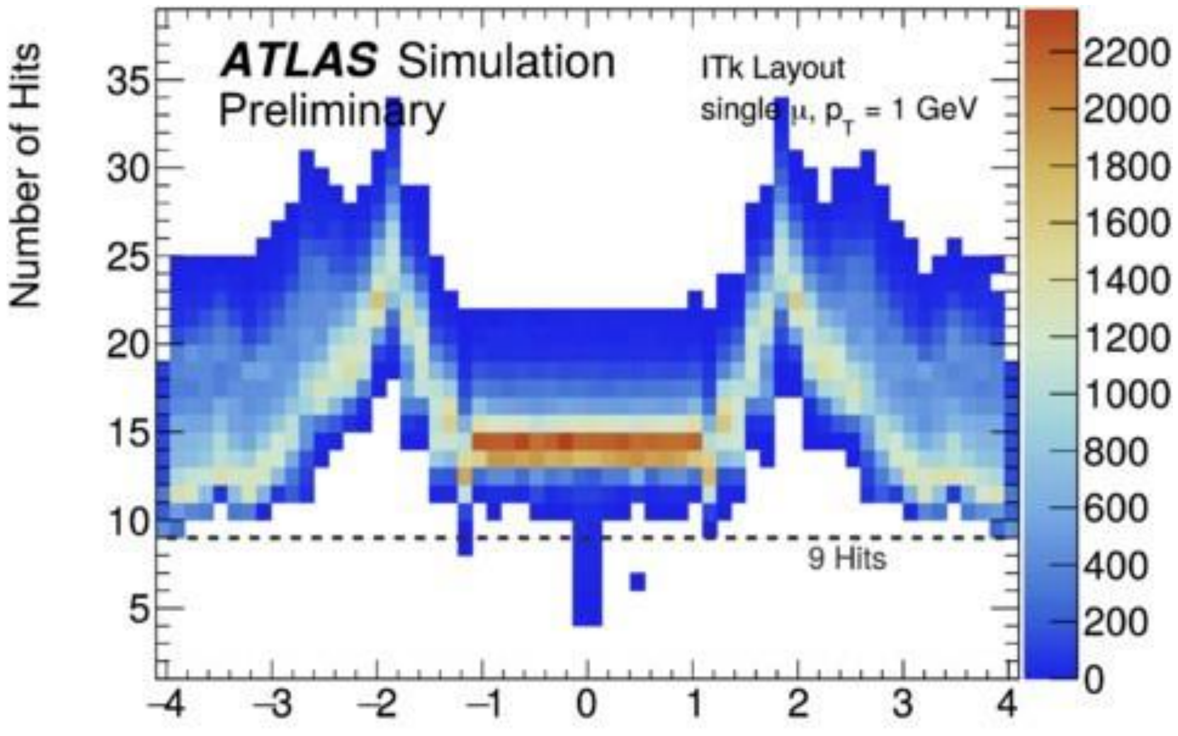




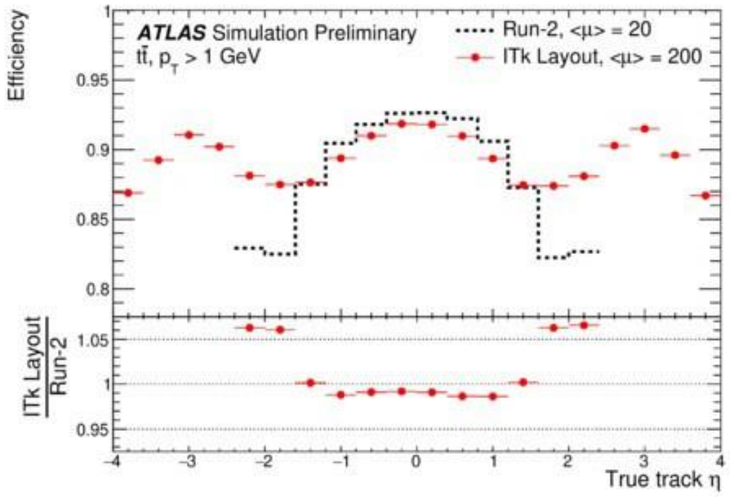
ITk Performances

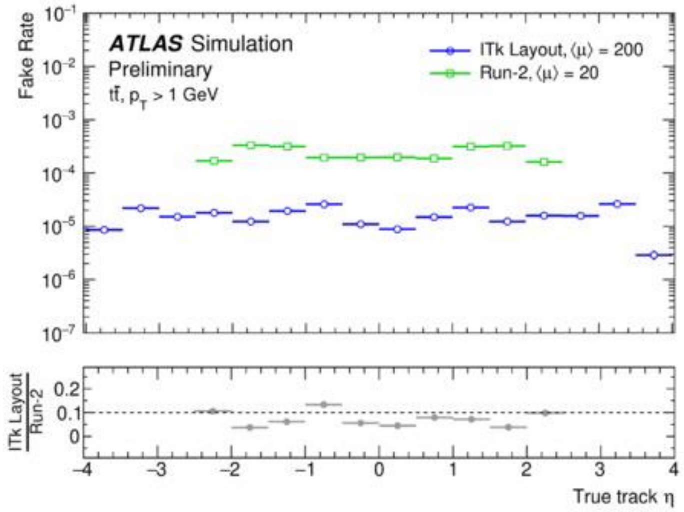
Important **LNF contribution** to design and simulation, for |η|<4 coverage and pixel size decision

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



>9 silicon hits per track

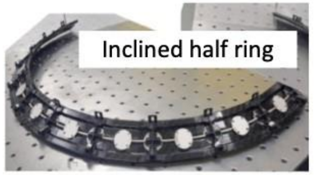


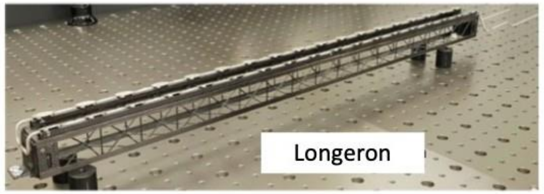


M.Testa

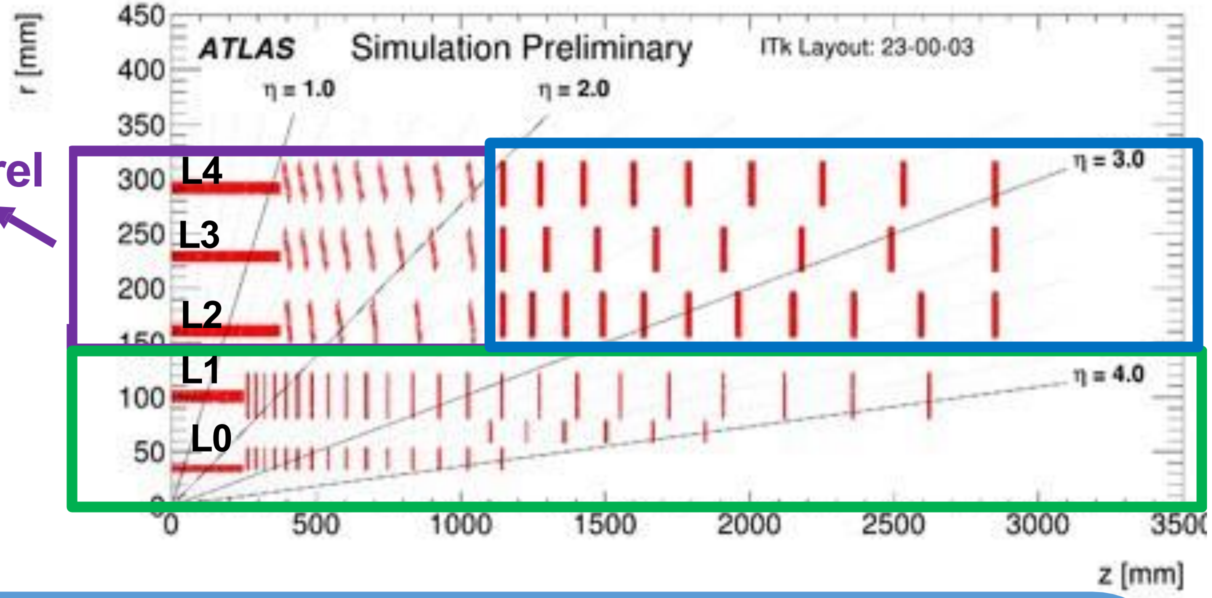
ITk Pixel Detector

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

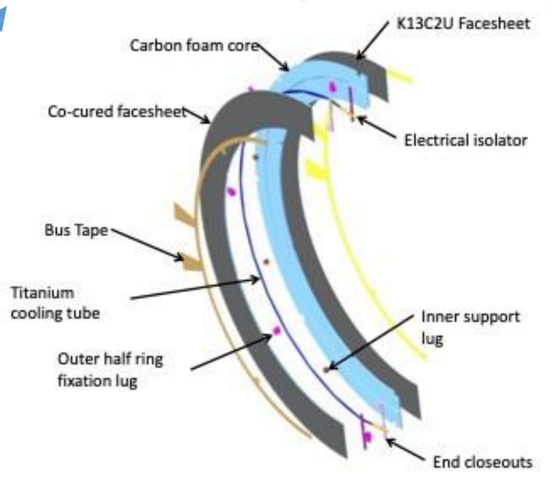




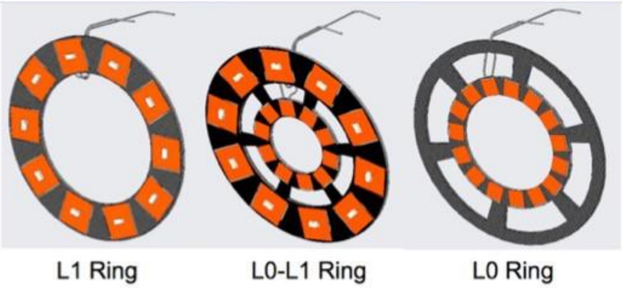
Outer Barrel



Outer Endcap



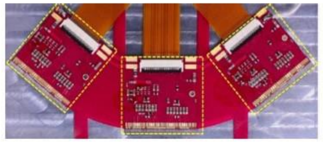
Inner System



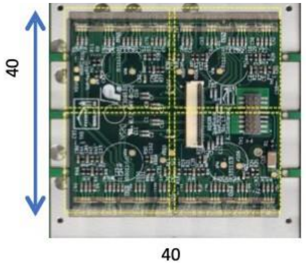
IS to be replaced after 2000fb^{-1} to reduce radiation damage.
L0 placed 34 mm from beam pipe.

Modules: two main module types, quad & triplet.

Triplet



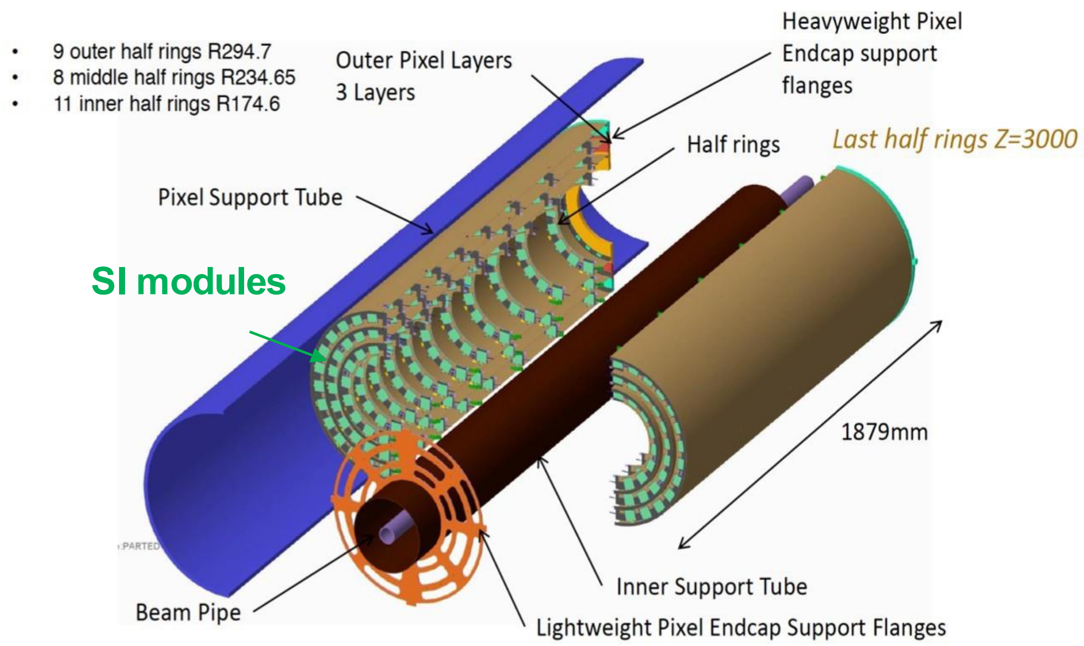
Quad

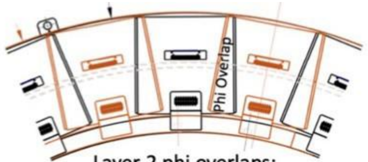


Layer	Module type	Sensor type	Sensor thickness [um]	Pixel size [um^2]
L0 barrel	Triplet	3D n-in-p	150	25x100
L0 rings	Triplet	3D n-in-p	150	50x50
L1	Quad	Planar n-in-p	100	50x50
L2-4	Quad	Planar n-in-p	150	50x50

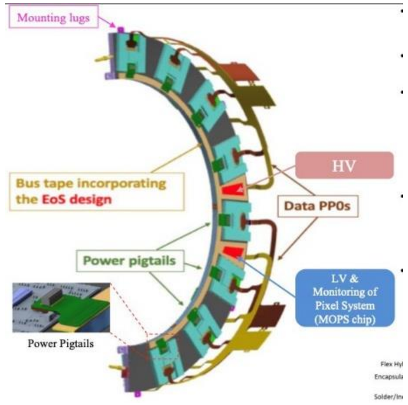
ITk Pixel Outer Endcap

- 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

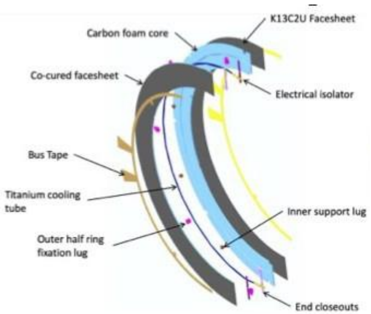




Layer-2 phi overlaps:
Black: front side modules
Orange: back side modules

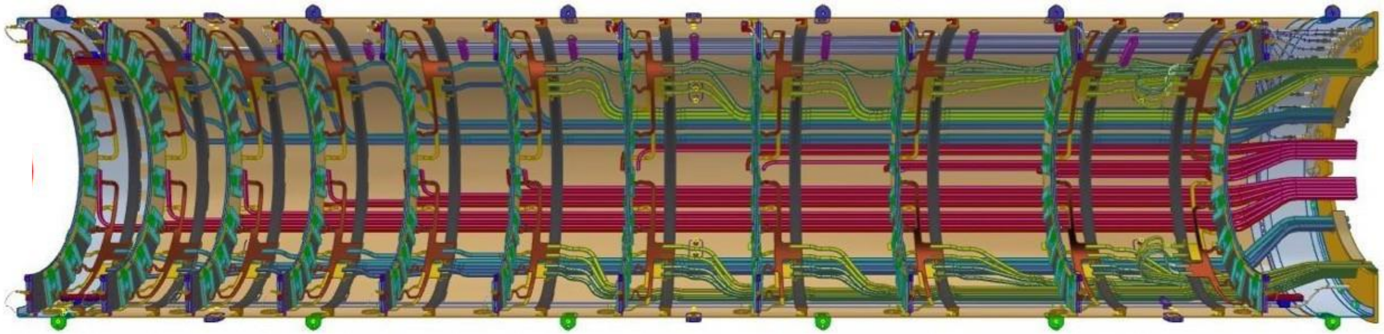


- Half-rings are C-foam / C-fibre “sandwiches” with embedded cooling pipe and fixation lugs



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

IP



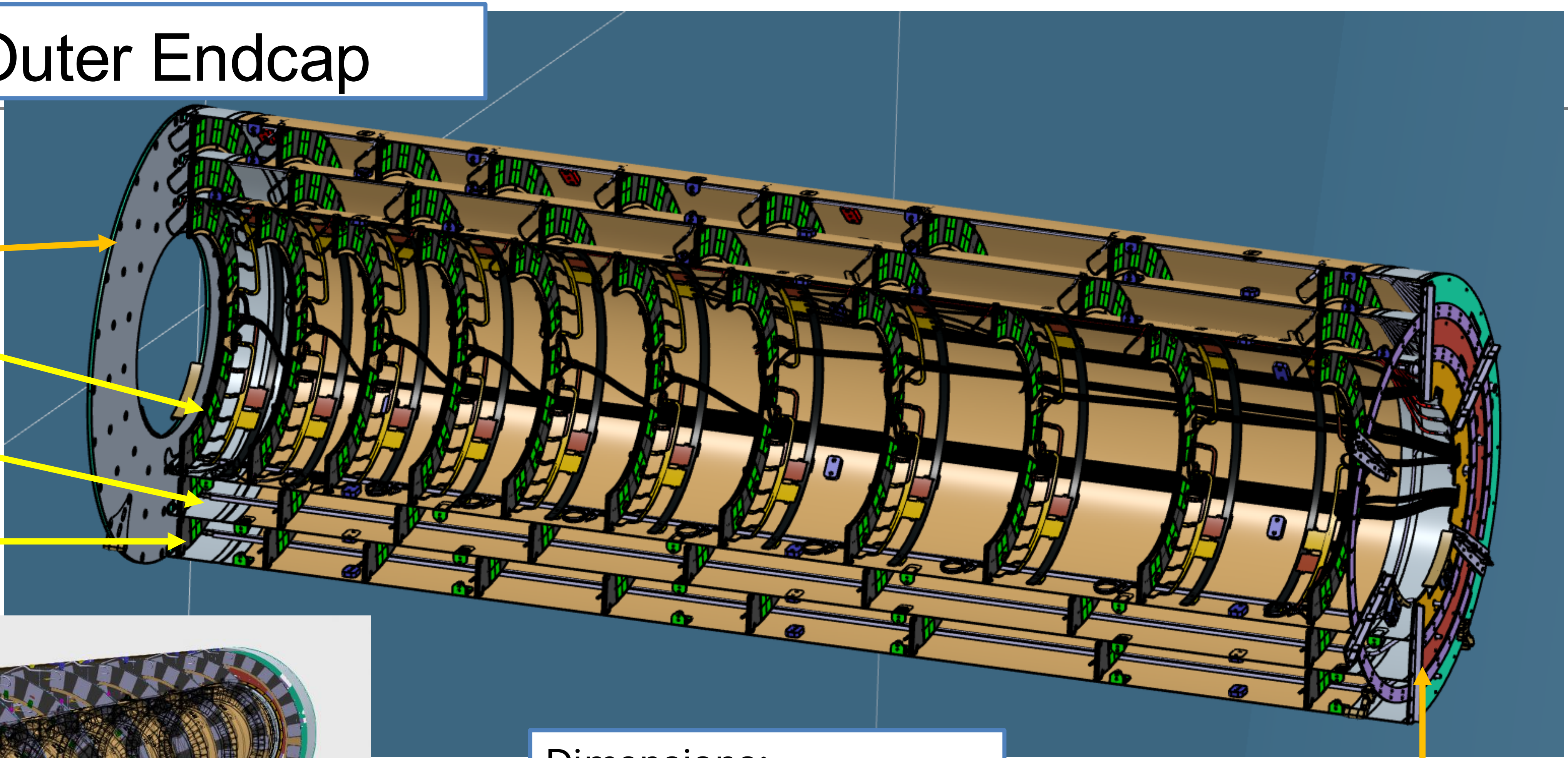
ITk Pixel Outer Endcap

IP FLANGE
(Low-z)

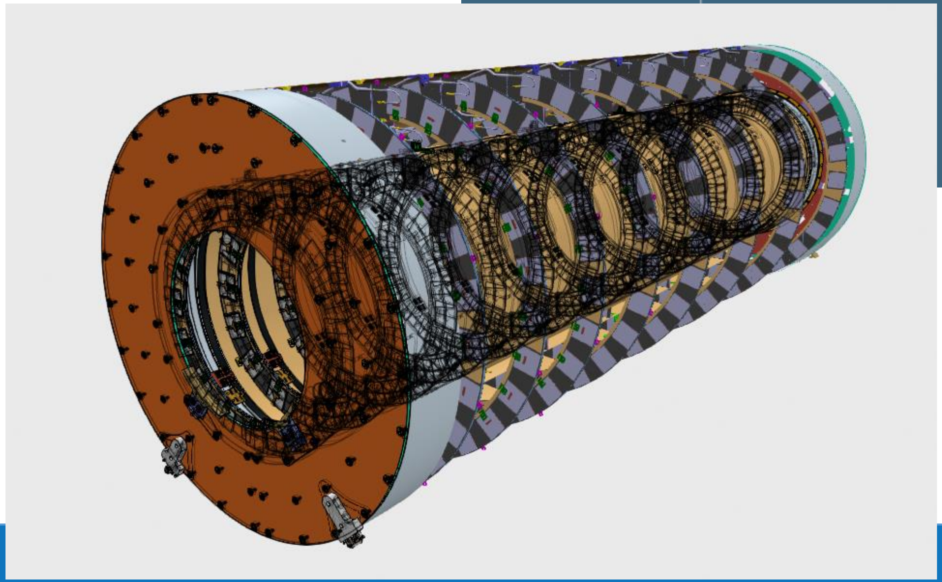
L2 HR: 11 per HS

L3 HR: 8 per HS

L4 HR: 9 per HS



SERVICE FLANGE
(High-z)

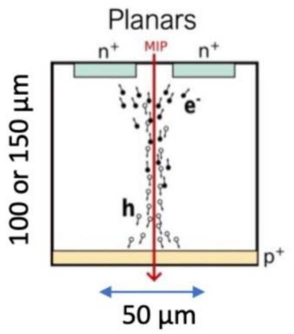


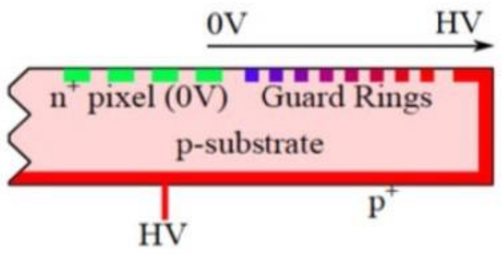
Dimensions:
L4 diam: 750,2 mm
L3 diam: 528.1 mm
L2 diam: 408 mm
Length: 1888 mm

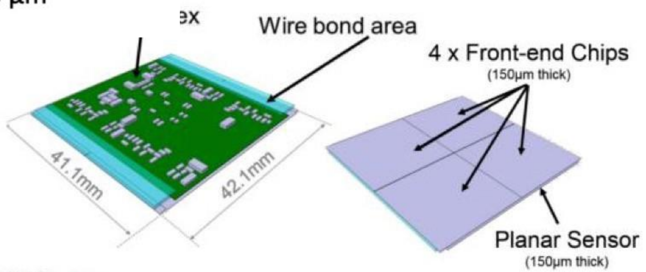
Sensor, Front-End Chip and Modules

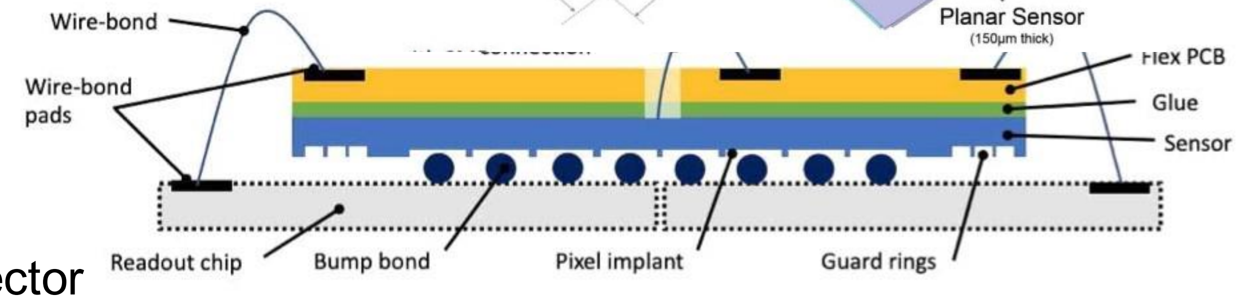
- **Planar Sensor n-in-p**

- **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,
    $50 \times 50\ \mu m^2$ pixels, $2.0 \times 2.1\ cm^2$
  - Shunt-LDO regulator for serial powering
  - **8912 data links** / endcap from modules to off-detector electronics



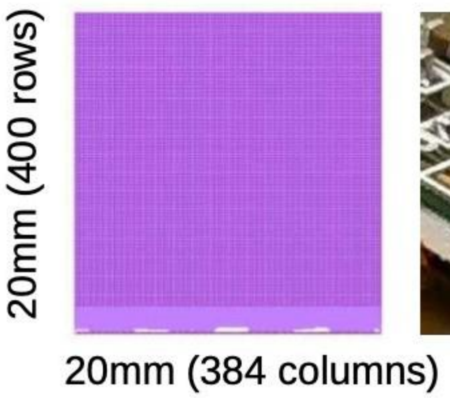


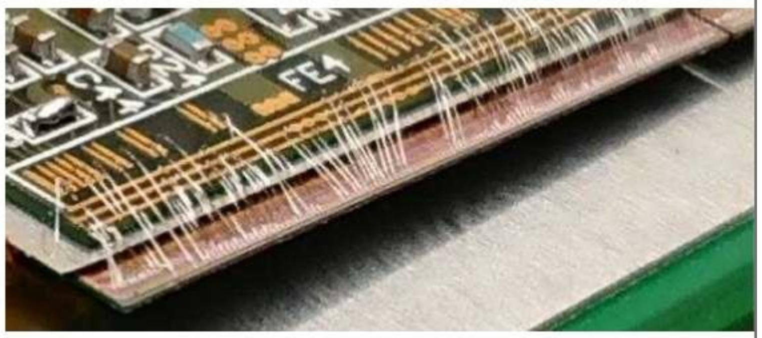




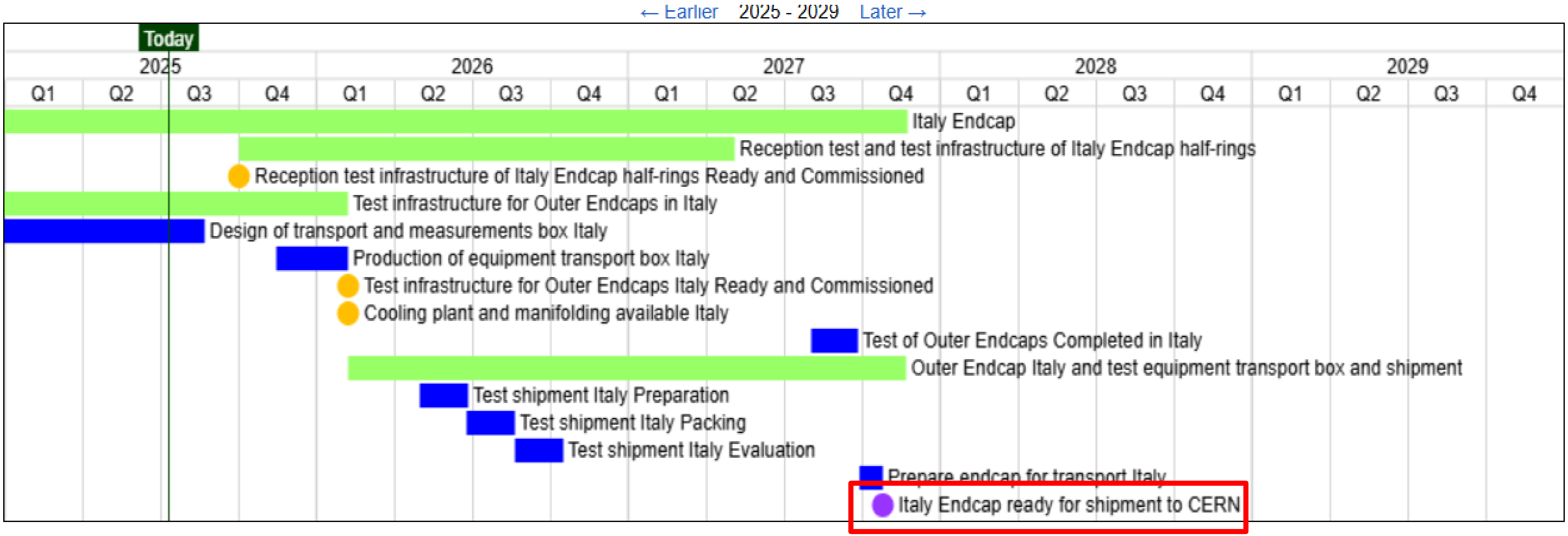
Modules: 4 FE chips bump-bonded to sensor

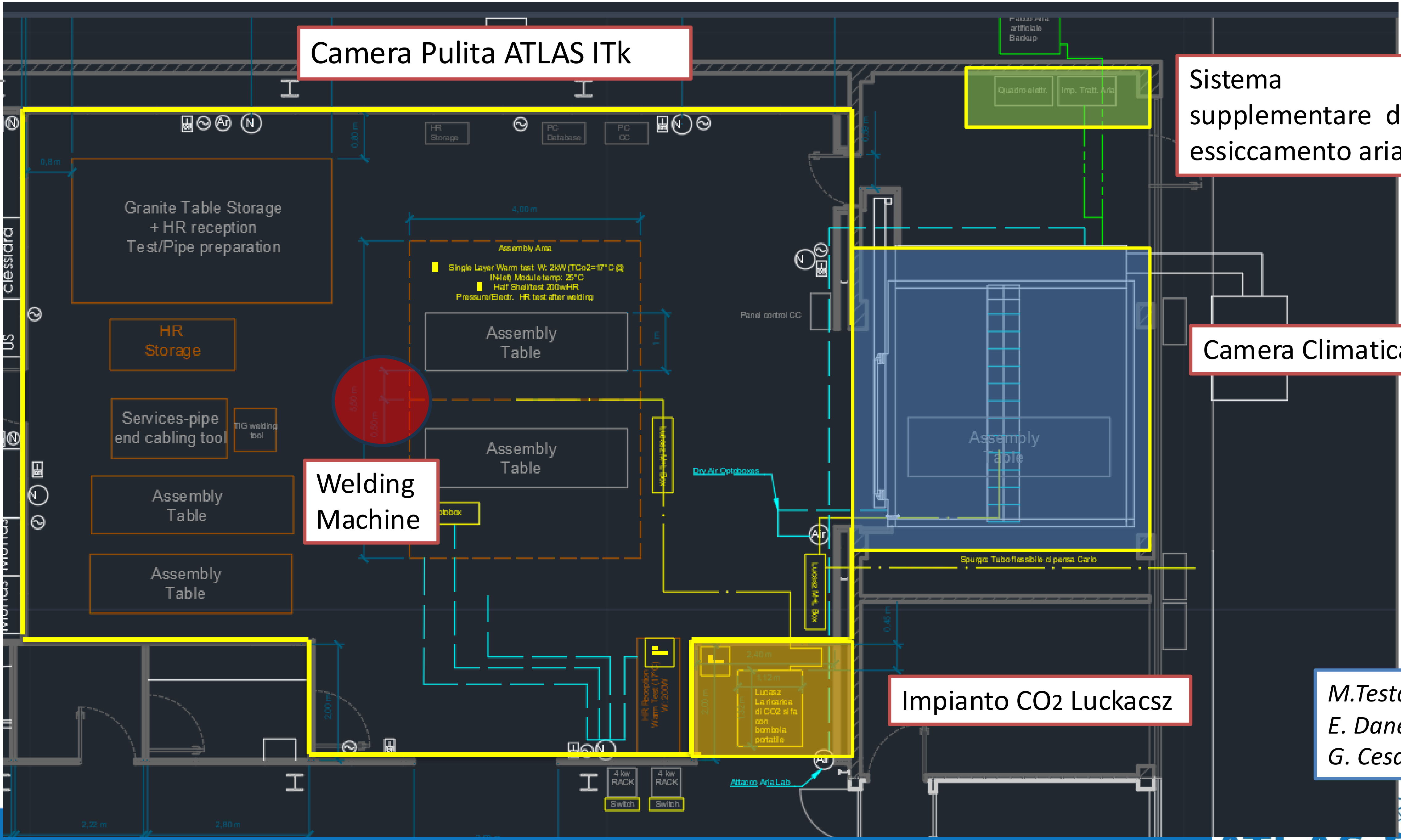
- Cu-Kapton flex hybrid glued to sensor
  for connection to power, slow controls and data distribution
  - Wire bonds connect the flex to the FE chip(s)
  - "pigtails" connecting modules to power / data
- **1172 modules/endcap**





Schedule from the last statusing





M.Testa
E. Dané
G. Cesarini

ATLAS ITk

CO_2 cooling LUCASZ
Light Use Cooling Appliance for Surfaces Zone

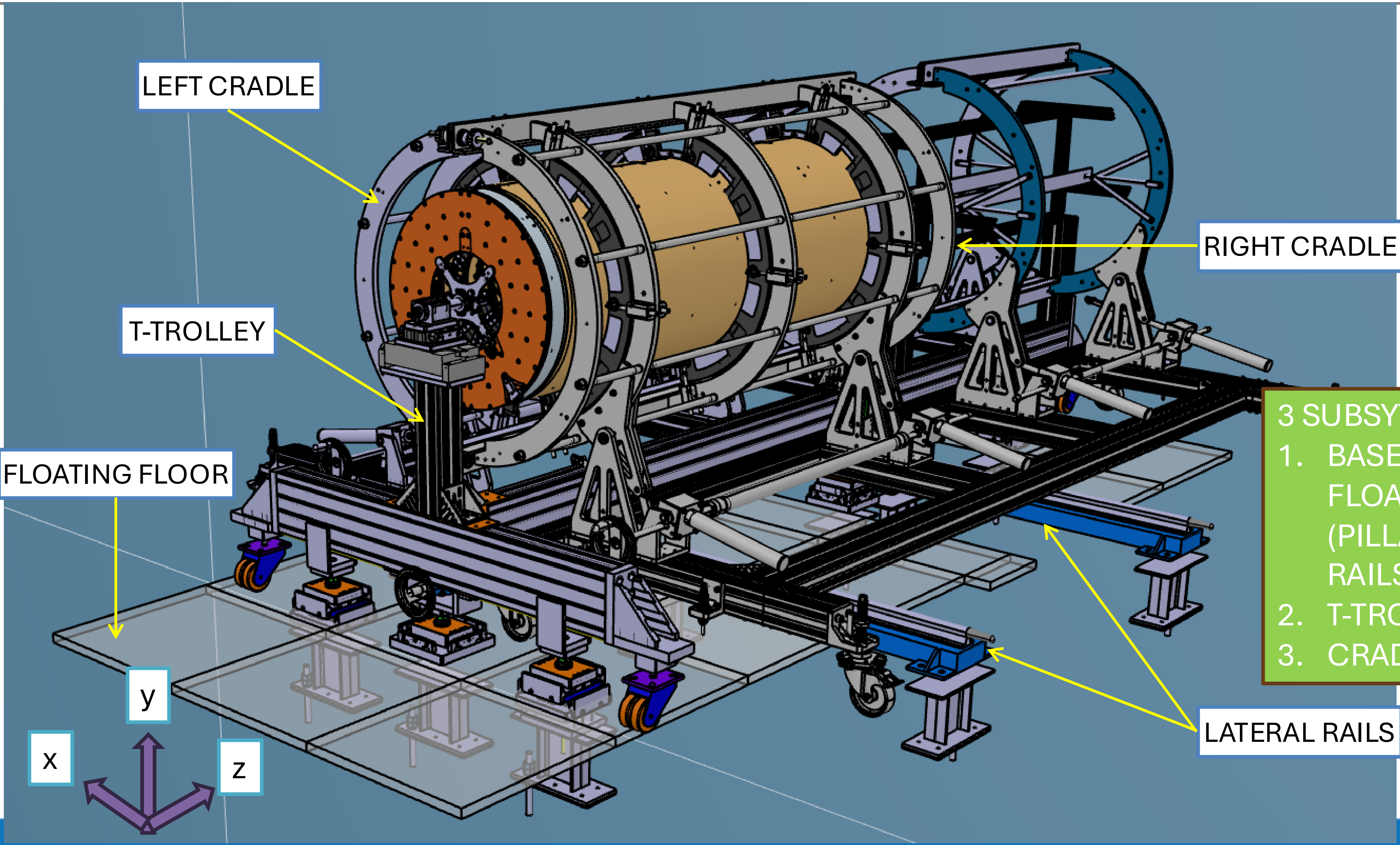
- Constructed and commissioned in 2021 at DESY
- Successful test with merging lines at LNF
- ➔ 20 g/s CO_2 flow
- Successful Integration with interlock system

Dry air with dew point down to -70°C

Climatic Chamber

Orbital Welding Machine

OVERVIEW OF THE SYSTEM



Filippo Rosatelli
Bruno Ponzio
Marco Battisti
Emilio Capitolo
Lorenzo Roscilli
Giuseppe Pileggi
Antonio Croce
Beka Buadze
Sandro Tomassini
Dario orecchini

3 SUBSYTEMS:

1. BASEMENT UNDER THE FLOATING FLOOR (PILLARS AND LATERAL RAILS)
2. T-TROLLEY
3. CRADLES

Material from Naples shipped to LNF, ready to be mounted

Missing the part of the service, the material is just arrived and some other parts are produced in LNF so we can start to add this part. The idea is to mount already closed the upper part of the cradle and then connect it to the bottom part. Missing the part of the connection between the cradles and carriages. Arriving these parts soon to perform some test.

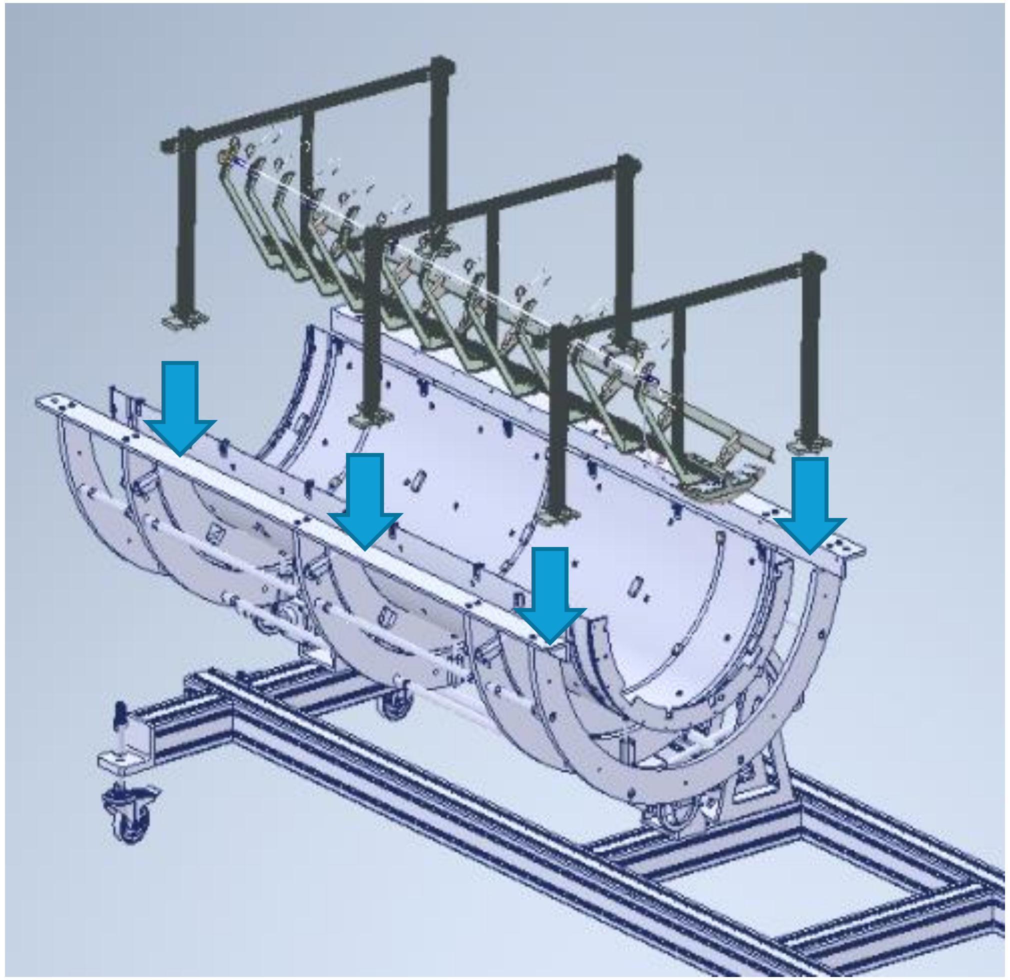
PIPE INSERTION TOOL

Assembly tool

Pipes

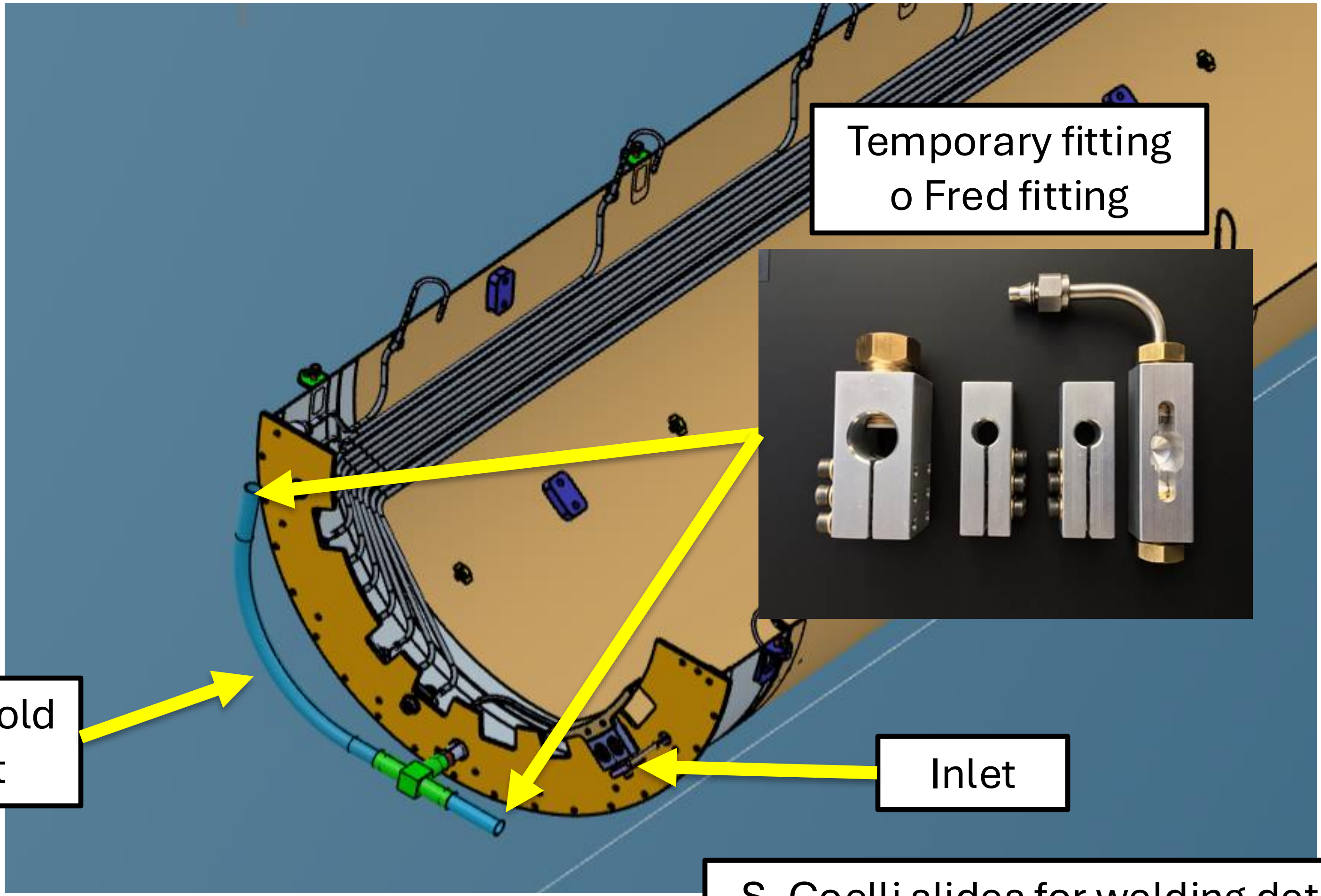
Detector Manifold

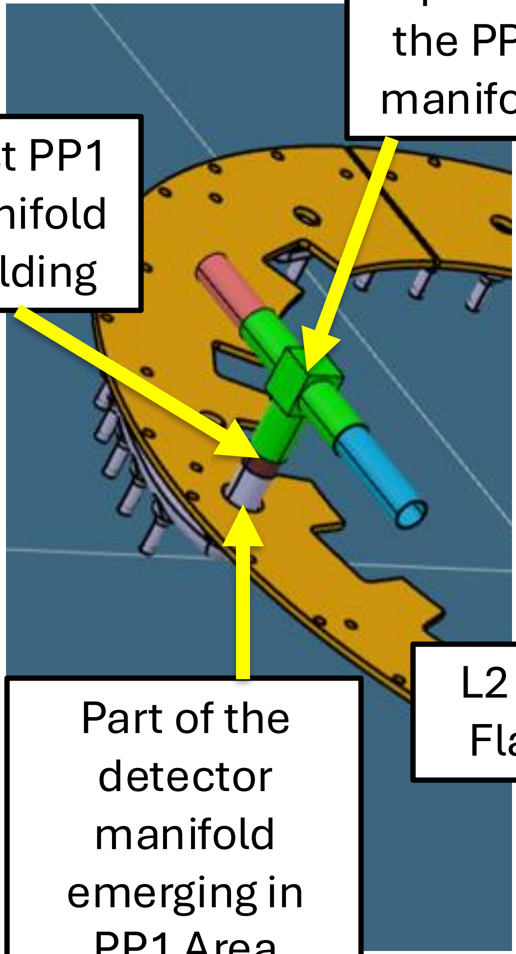
by Milan group



FIRST PP1 MANIFOLD WELDING

Once the pipes are in position the first welding for connecting the exhaust and inlet PP1 manifolds is performed





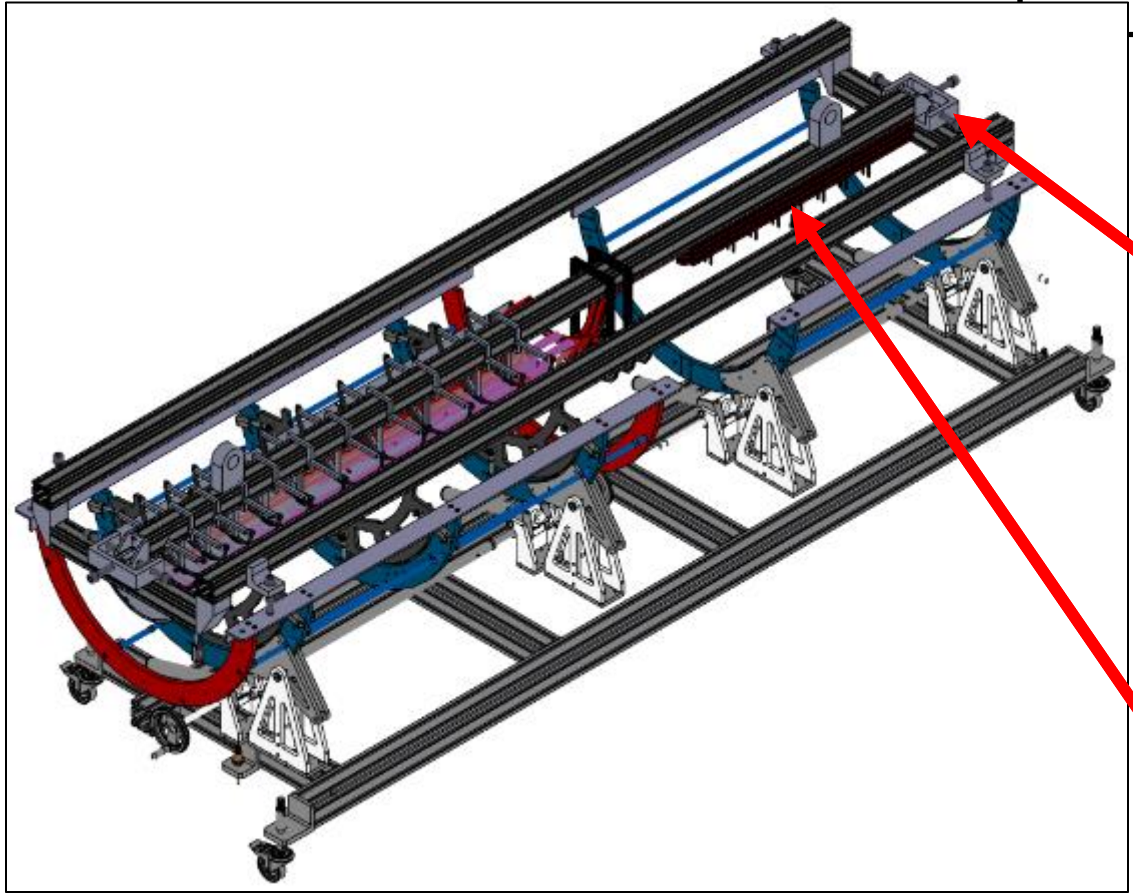
S. Coelli slides for welding details

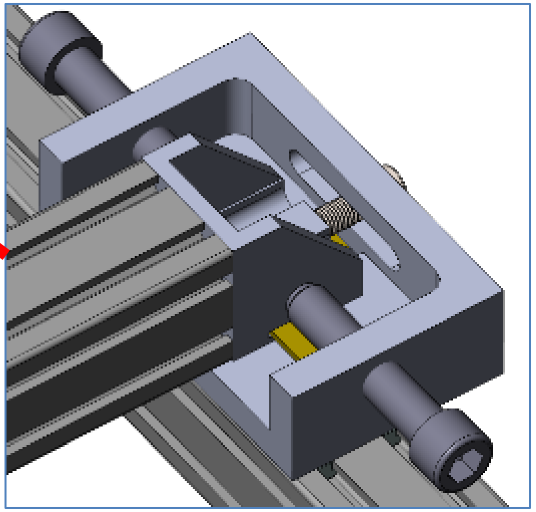
CABLE HARNESS INSERTION TOOL

by UK group

The position of the cable harness is adjustable on the cradle. The plate at either end can slide on a low-friction interface

Horizontal position is adjusted by screws

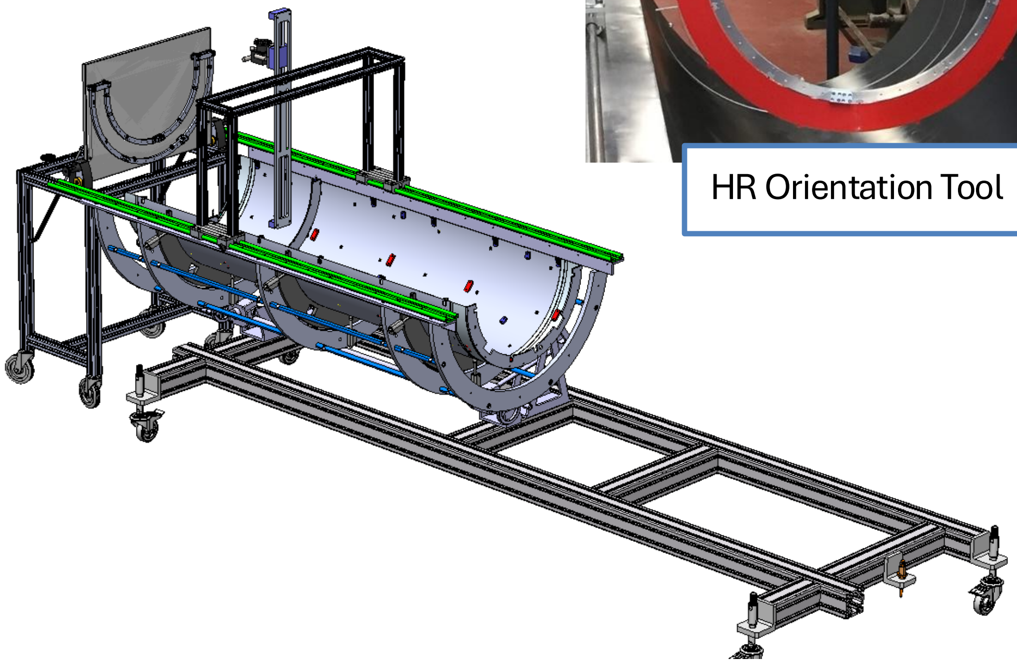


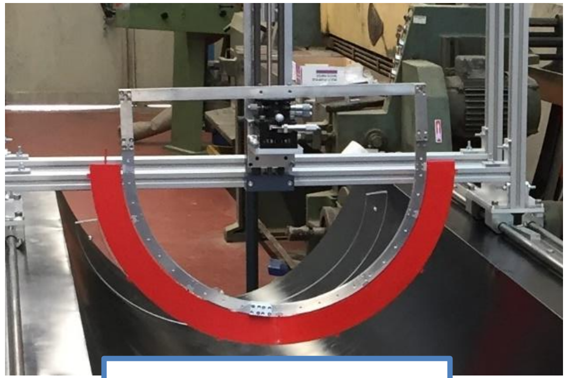


Support of cables in order to transfer to the integration tooling

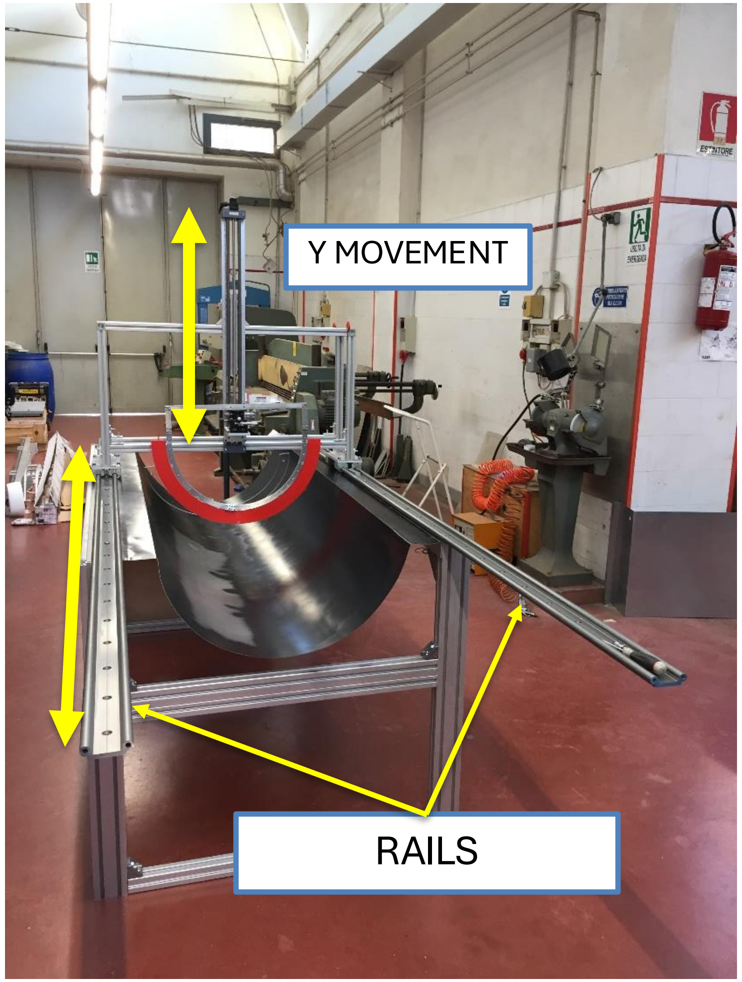
HALF RINGS INSERTION TOOL

Horizontal rails are positioned on the rotating cradle for movement along z axis. A vertical rail is devoted to move down the HR.





HR Orientation Tool

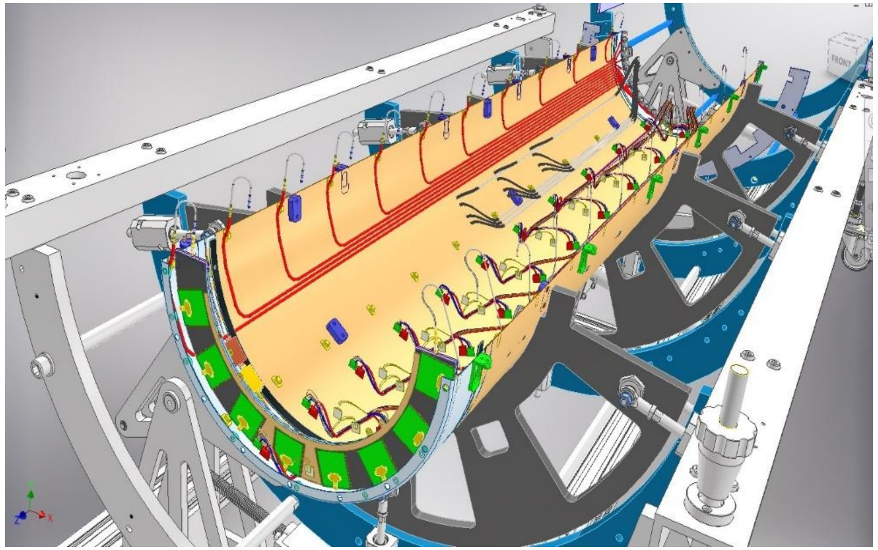


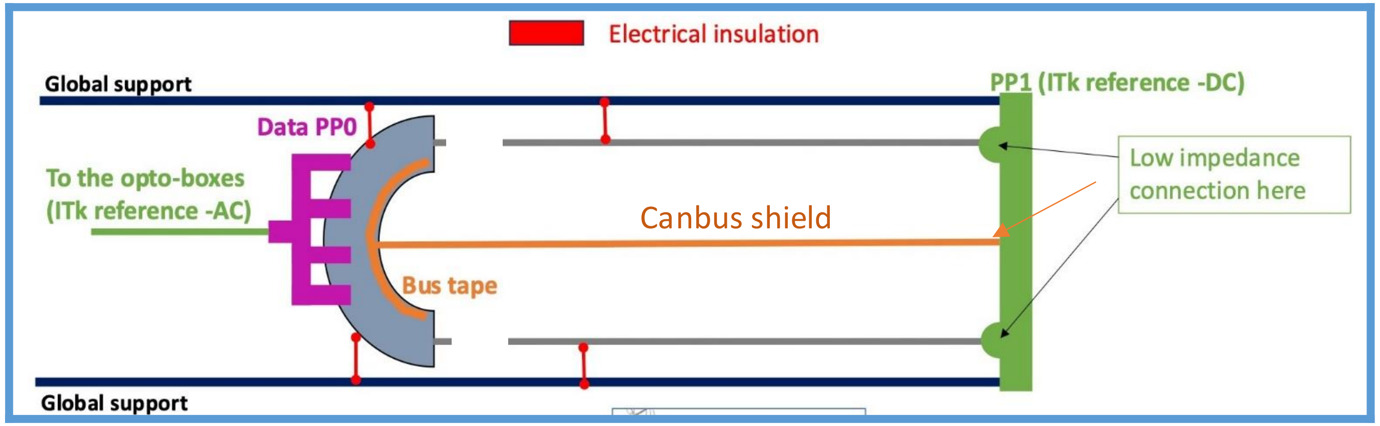
TILTING TABLE

by Lecce group

Half-ring test after insertion

- QC: measure the isolation resistance between the GND pad of bus-tape and the HS
- Connect HR to pwr and data type-1 cables
- Bus tape is grounded

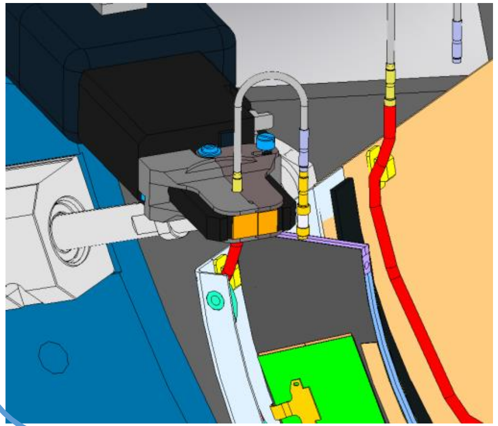




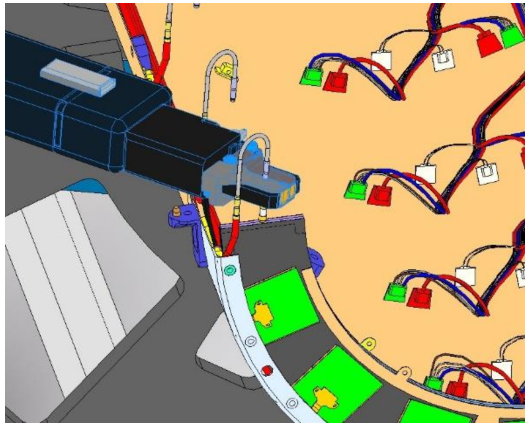
Half-ring welding

Three weldings per HR

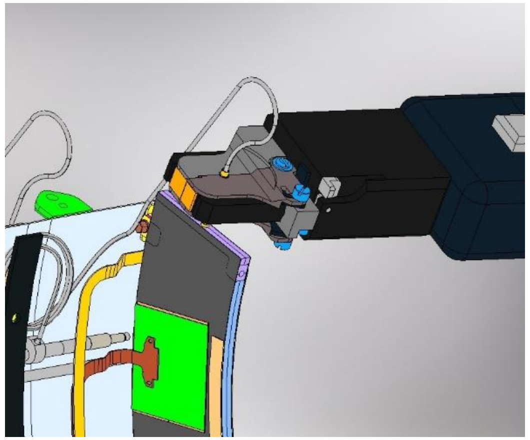
1° exhaust welding



2° exhaust welding

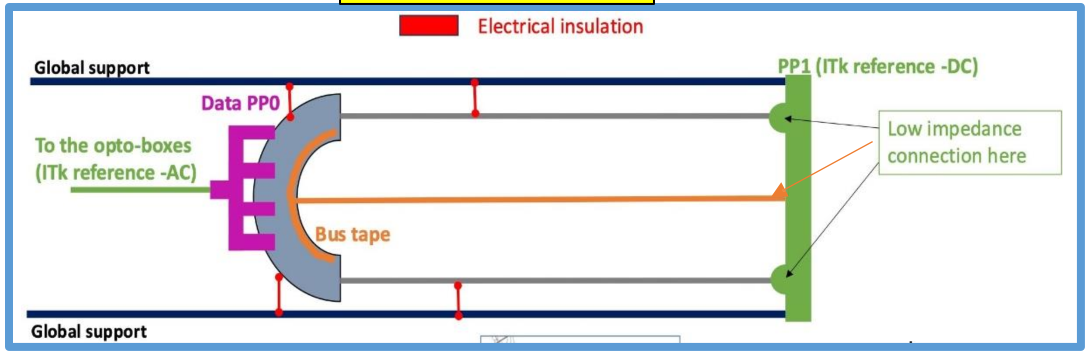


1° inlet welding



- Leak test, Pressure test 162 bar, Leak test
- Temporary ground the pipes nearby HR to protect modules
- Re-test connectivity one HR at the time after welding to check no damage to module or services

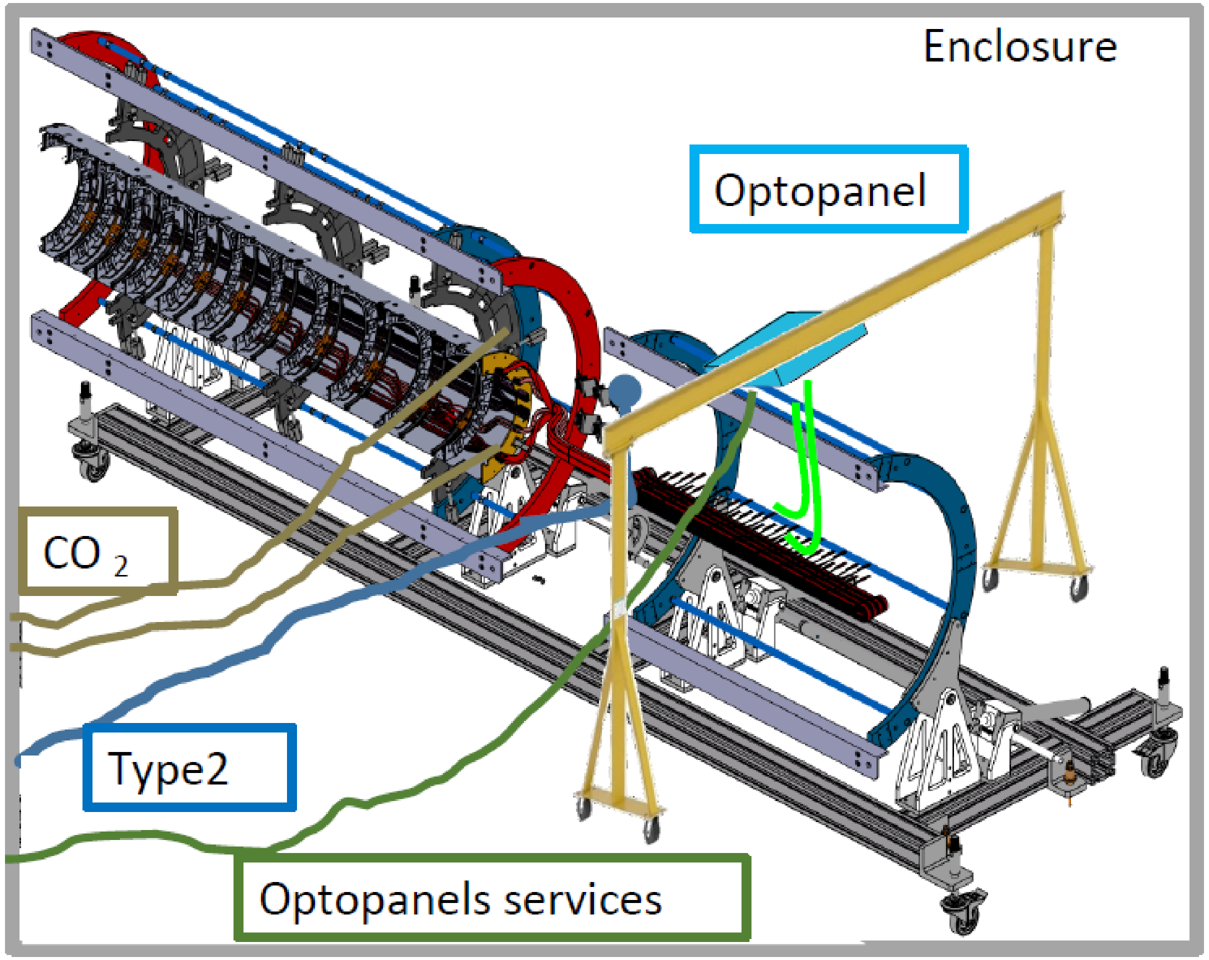
After welding



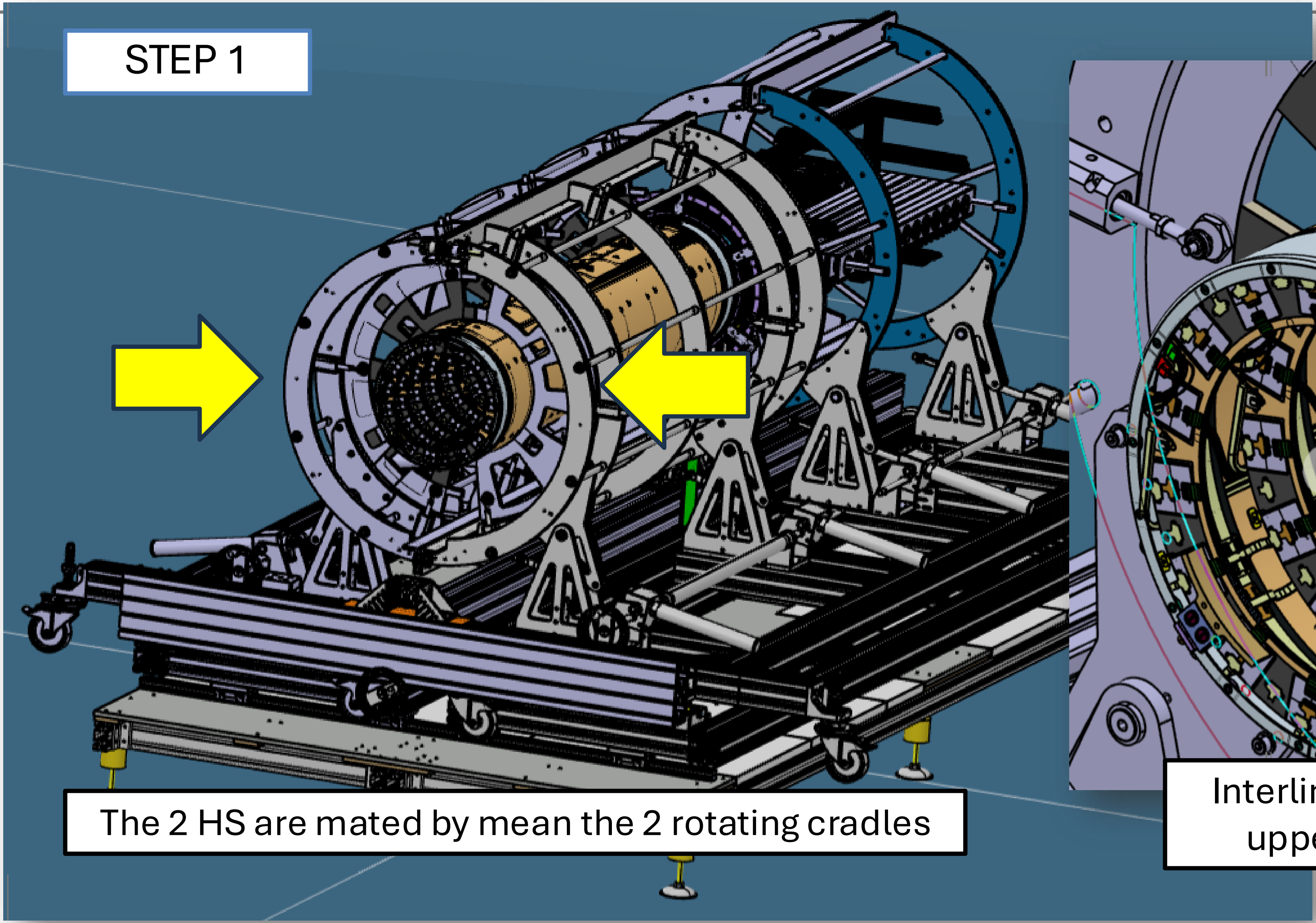
After welding LS is grounded through pipes

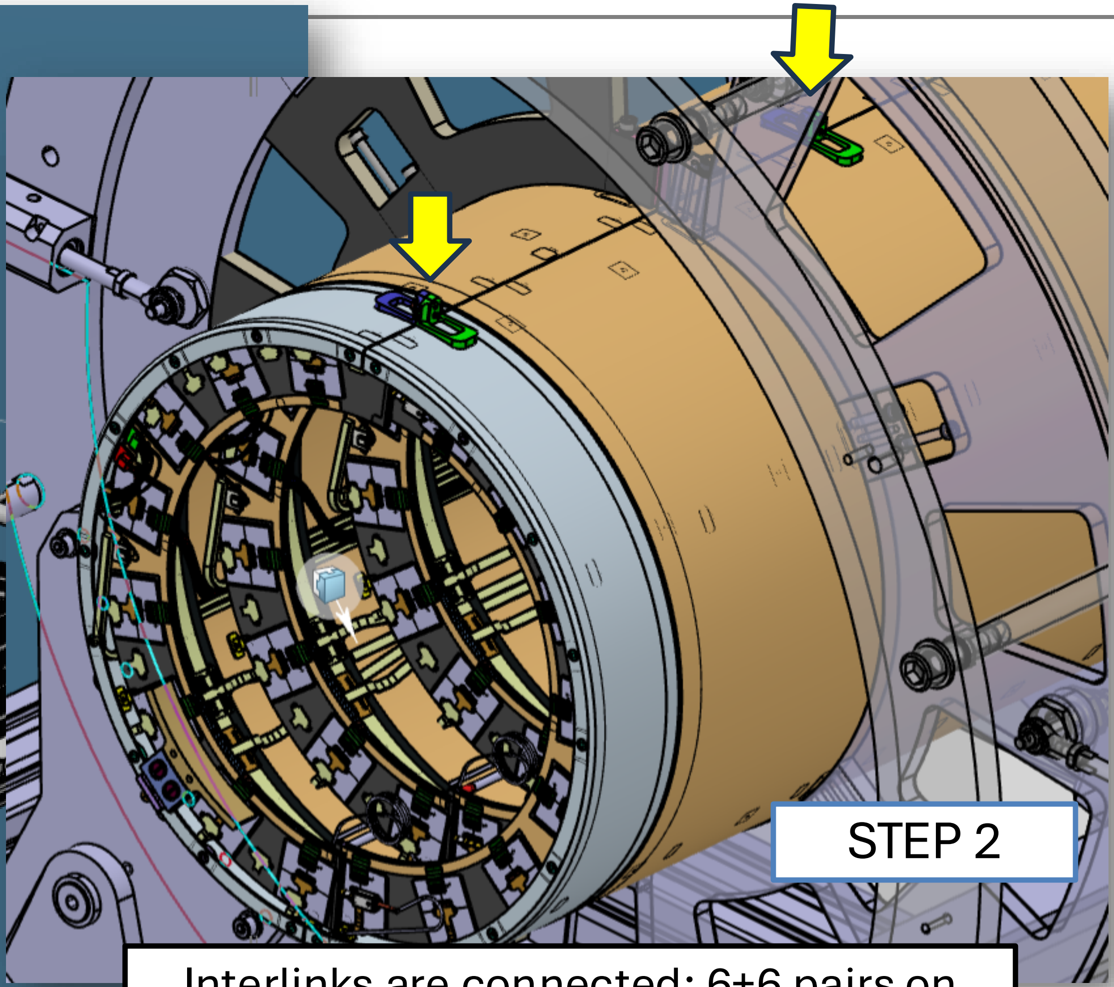
OEC Half-cylinder integration & test

- Move HS into climate chamber which serve also as test box
- Function cold test
  - Dew Point < -60 C
  - $T_{ev\ CO2}$ ~ -15 C
  - Normal powering mode
  - Digital, Analog, Threshold scan
    Disconnected bump-bond scan
- Thermal cycle [+40 – 45C]
  - Detector Off
  - All service can be kept inside (TBC)
- Repeat cold test



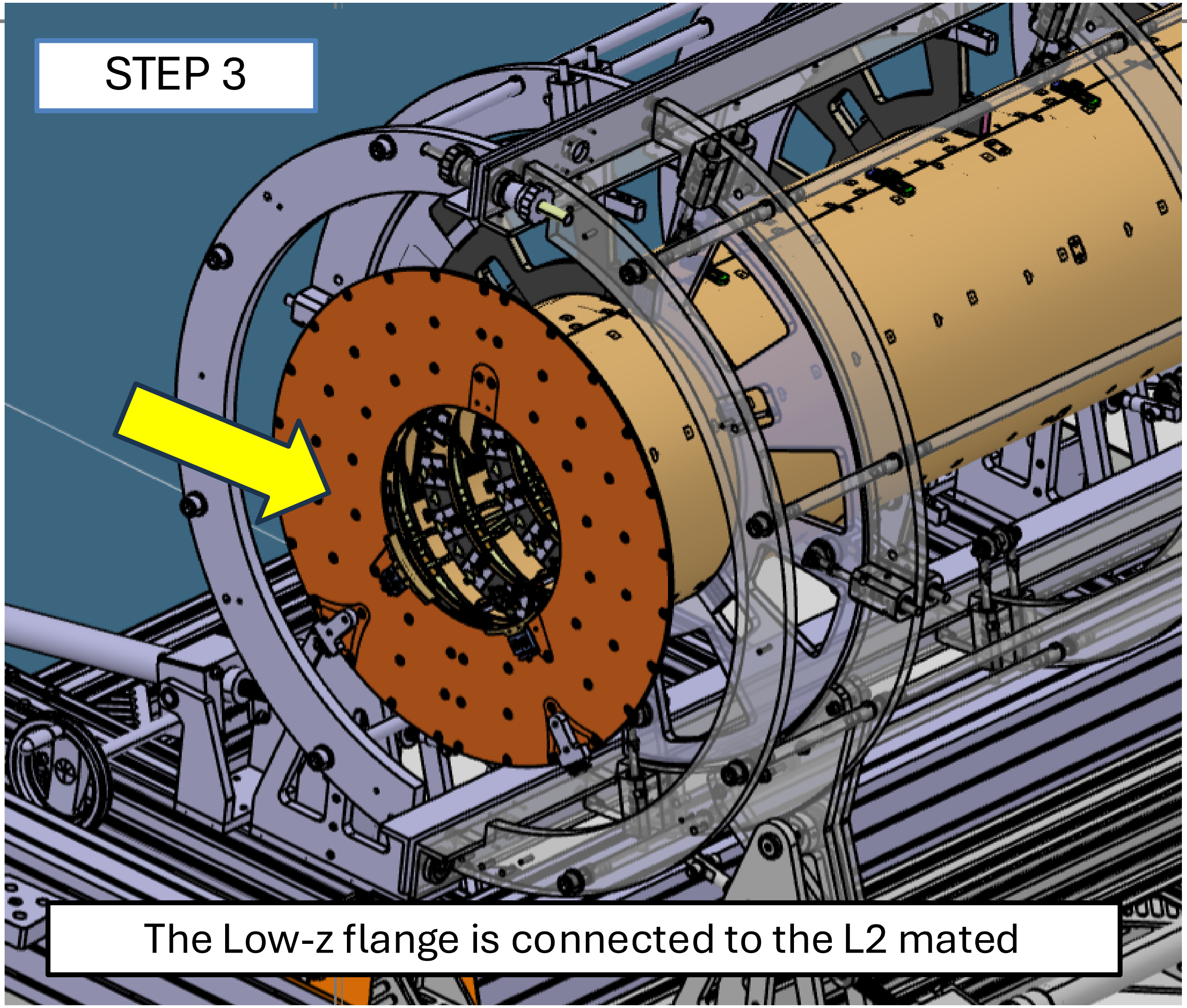
HALVES SHELLS MATING: ASSEMBLY PROCEDURE



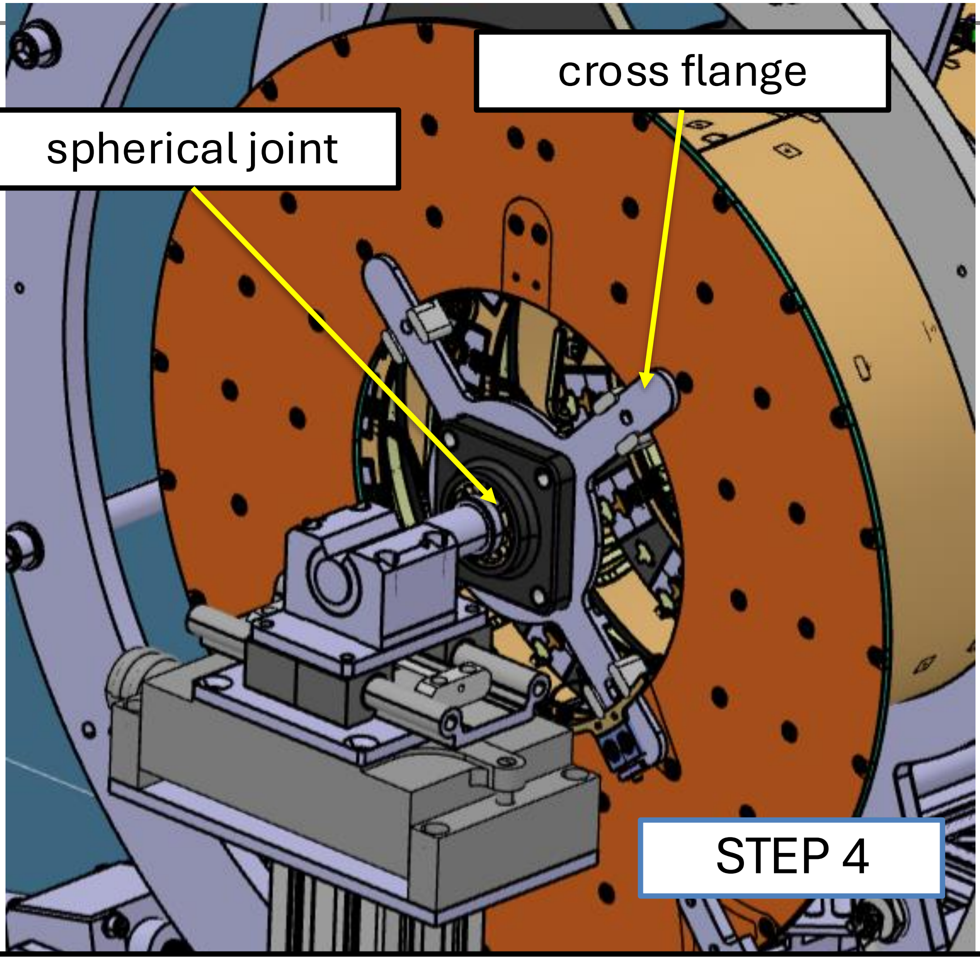


Interlinks are connected: 6+6 pairs on upper and bottom side of the HSs

HALVES SHELLS MATING: ASSEMBLY PROCEDURE

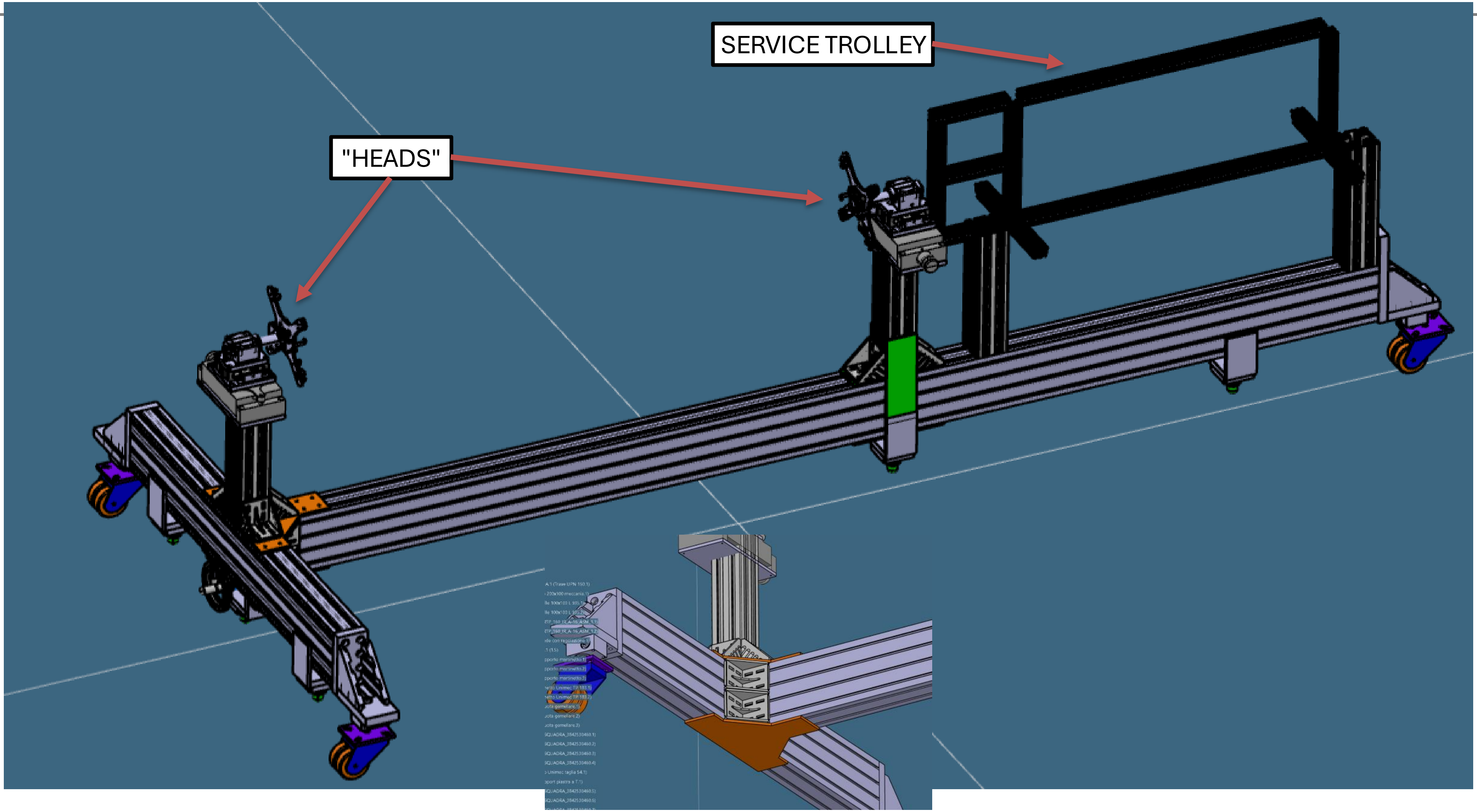


The Low-z flange is connected to the L2 mated



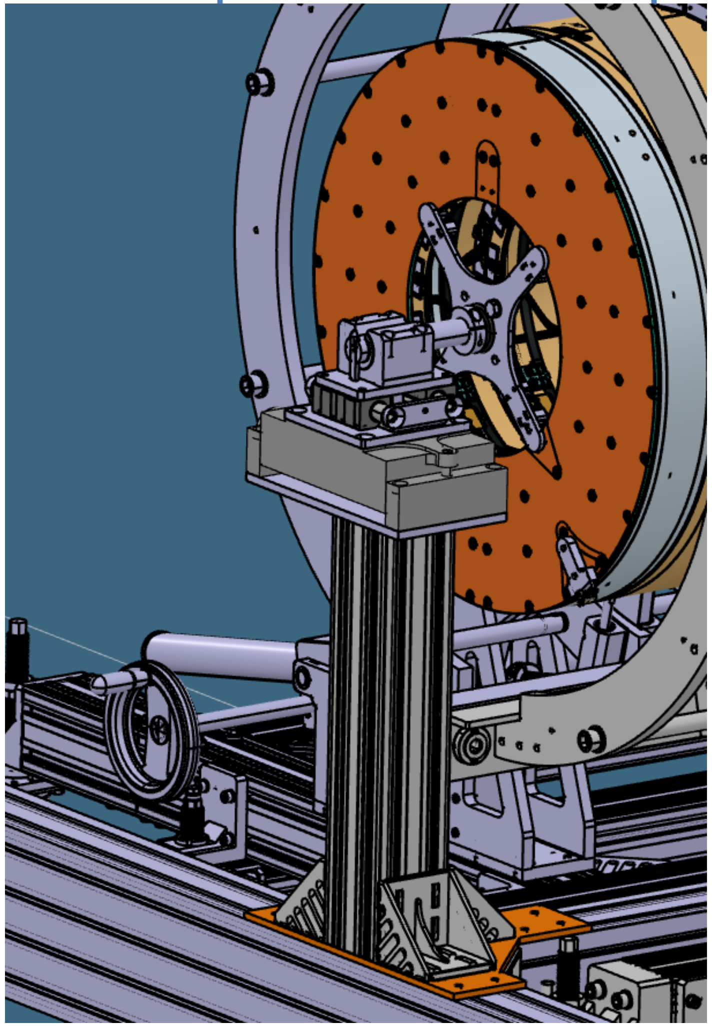
Exploiting the spherical joint and the linear stages the cross-flange is oriented and adapted to the low-z flange position

STATUS OF T-TROLLEY

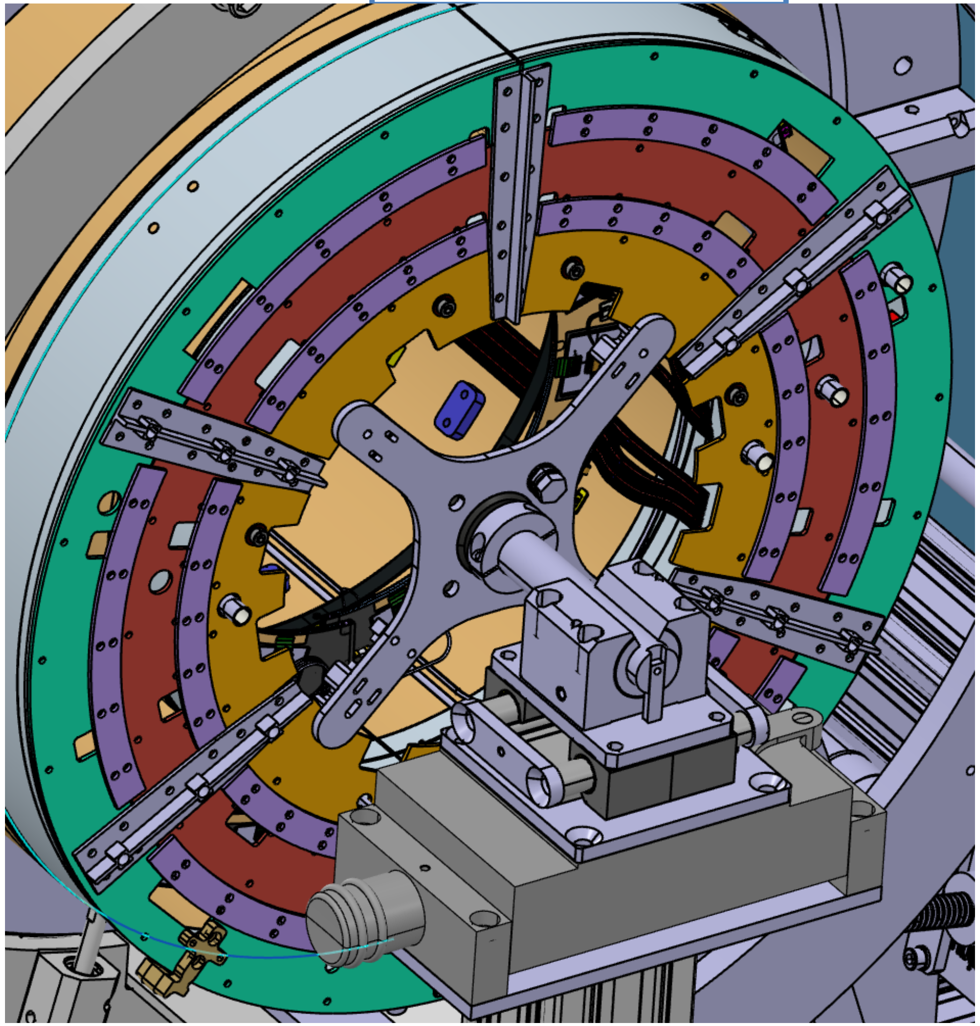


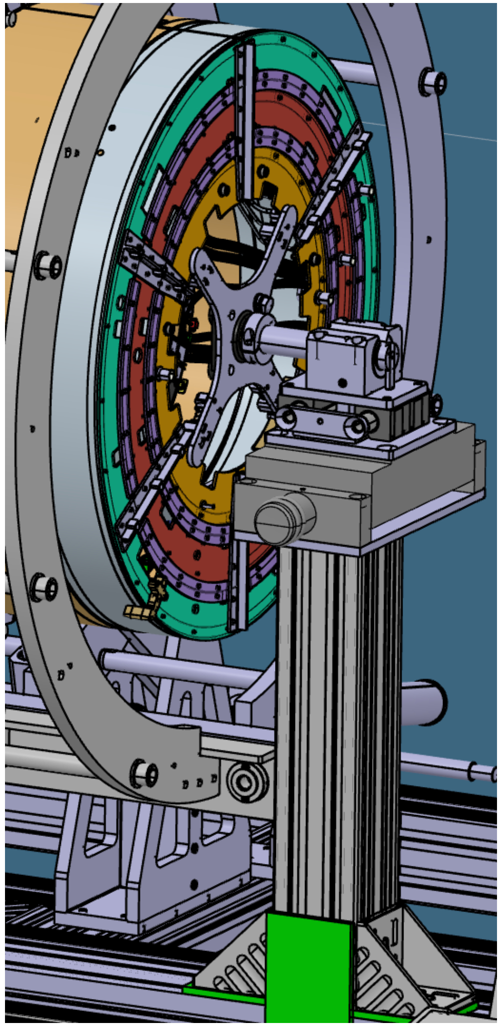
Integration Heads

Low Z flange (A)

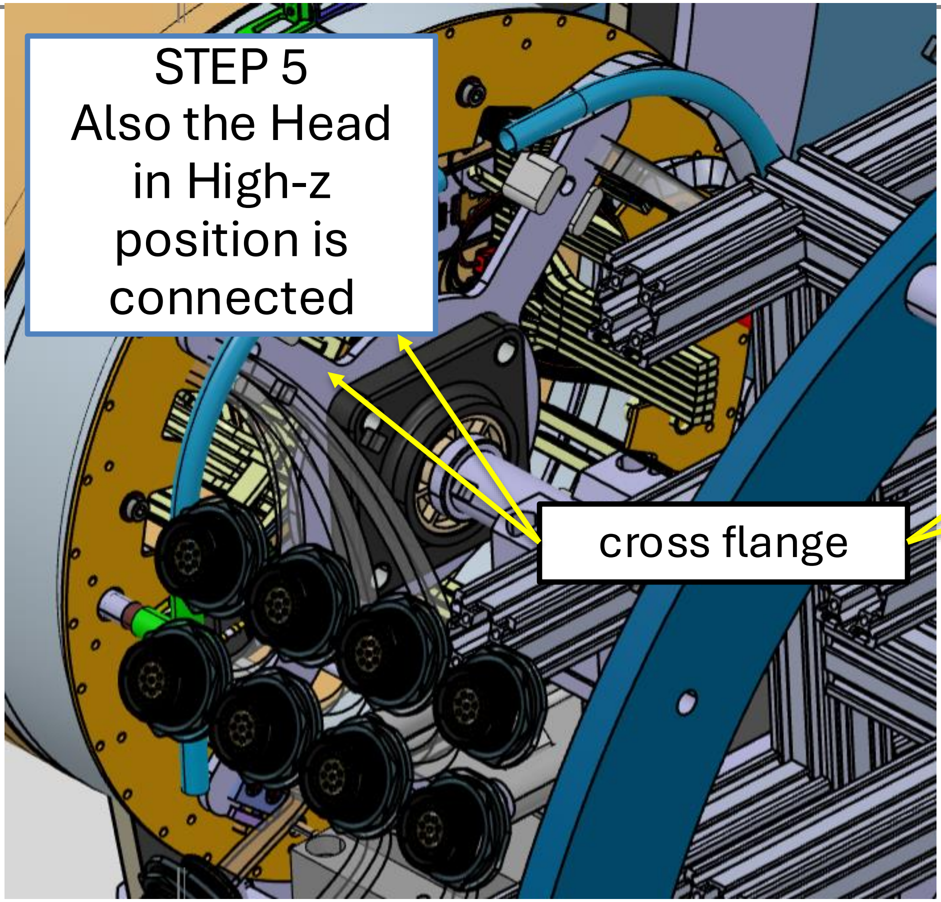


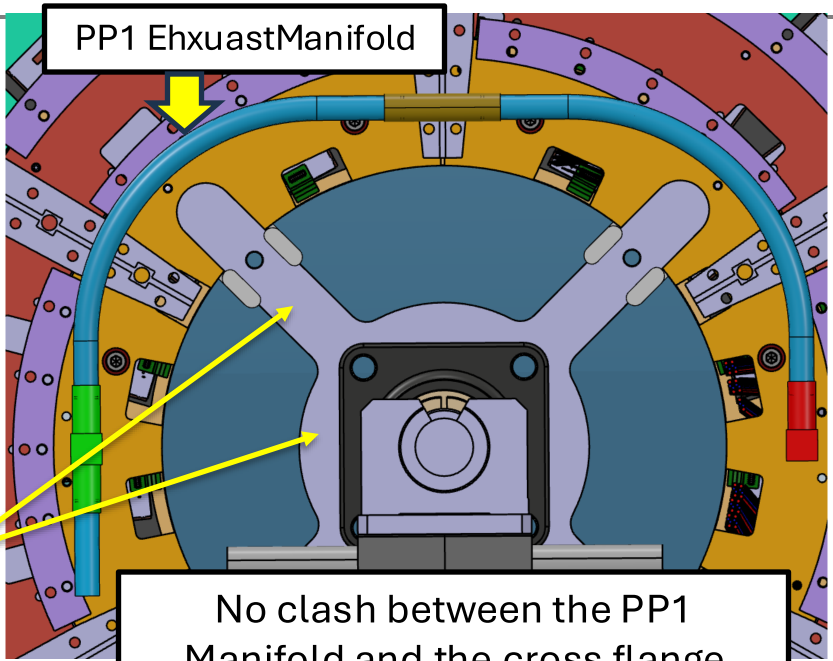
High Z flange (B)

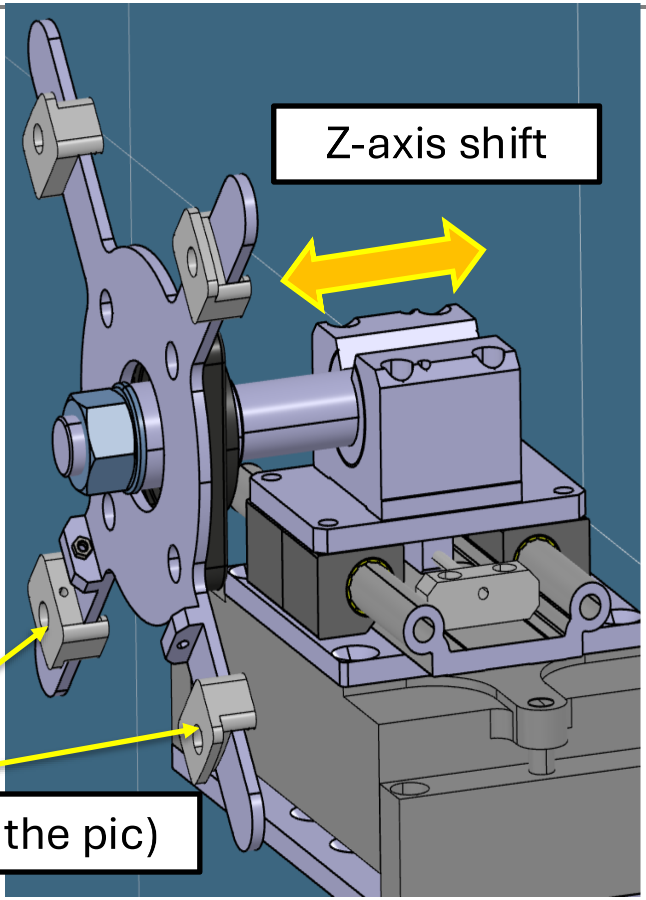




HALVES SHELLS MATING: ASSEMBLY PROCEDURE

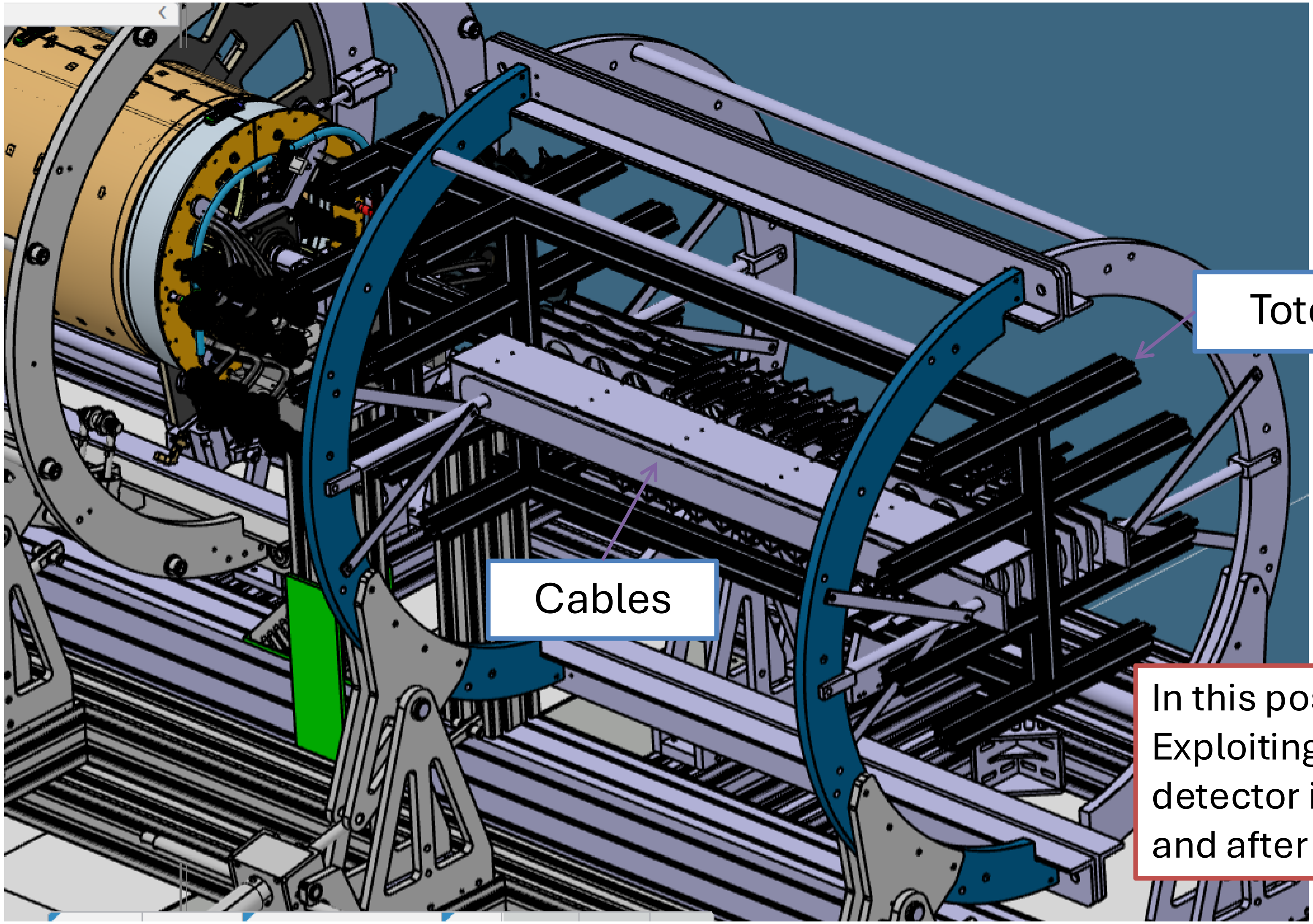






As can be seen in the figure there is no clash between the PP1 manifold and the detector support. By taking advantage of the 2 springs present in the lower arms of the cross-flange and the movement along the z axis allowed by the bearing, the detector support can be connected to the rear flange.

HALVES SHELLS MATING: ASSEMBLY PROCEDURE

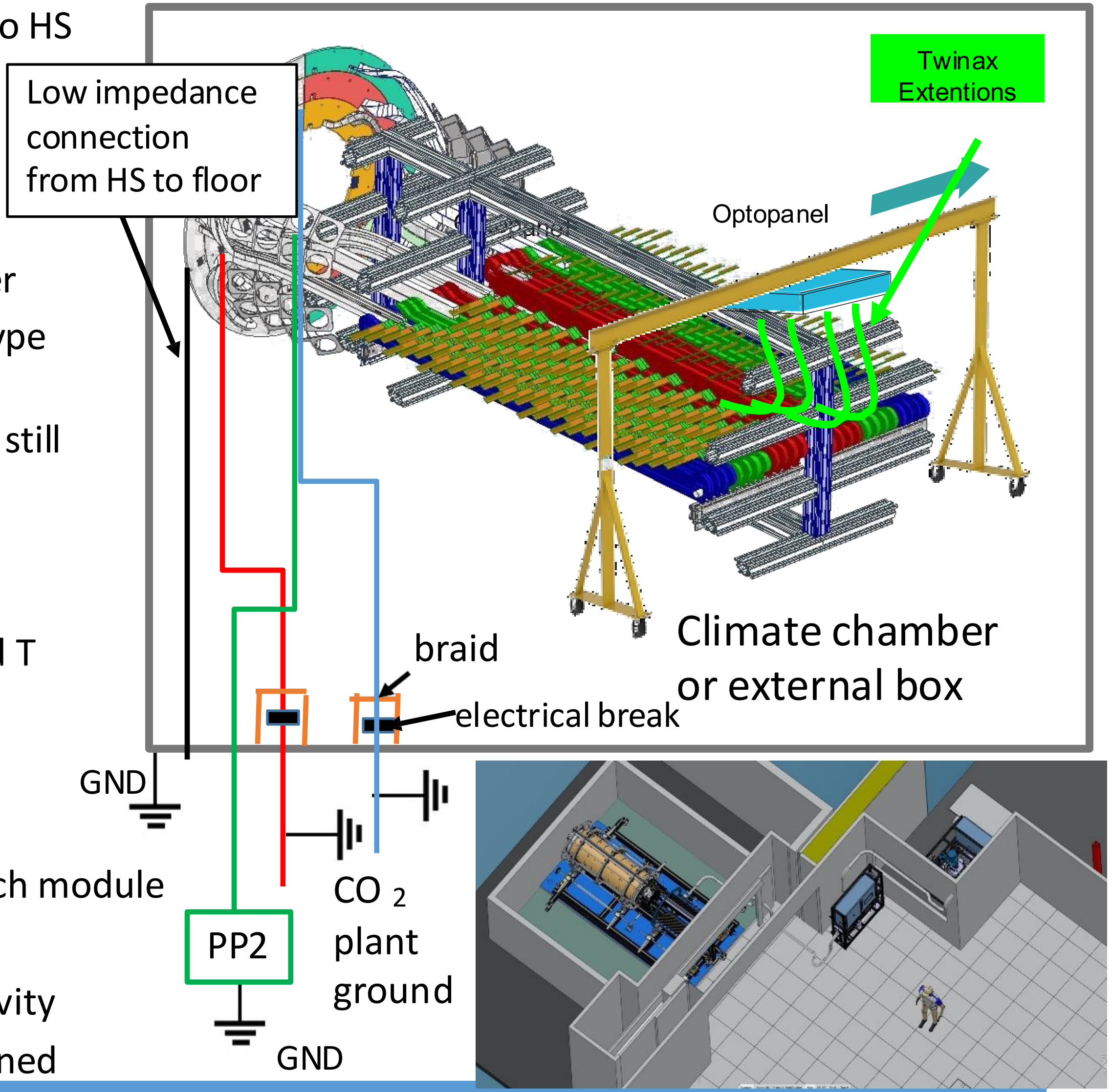


STEP 6
The part of the services is connected to the "Totem"

In this position the load is still on the cradles. Exploiting the spherical joints of the head the detector is the first load transferred to the T-trolley, and after the services.

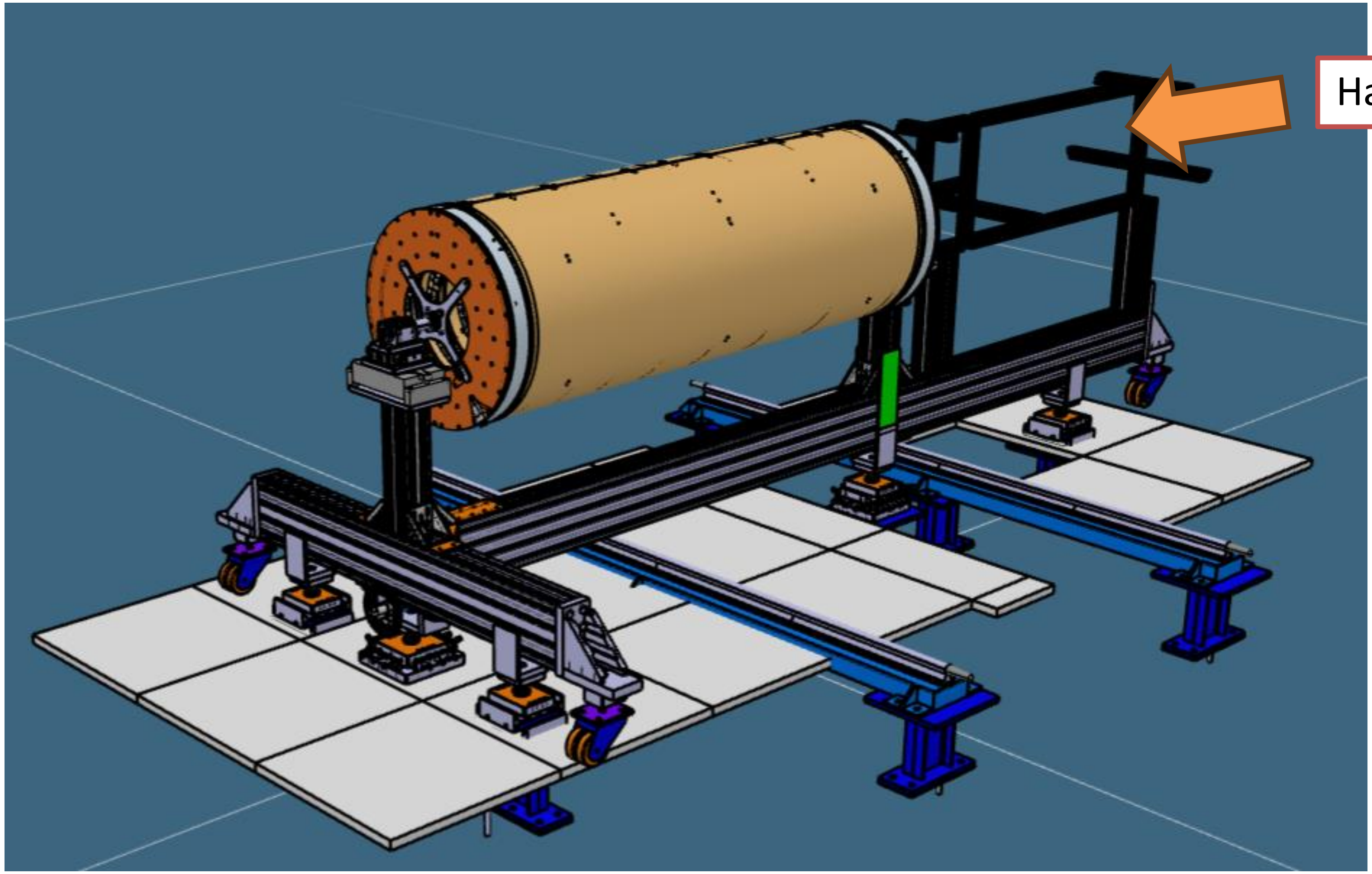
Test on complete Layer

- Low impedance connection of the two HS
- Ground layer to floor
- Connectivity Test for complete layer
  - Use Lowe Power mode
  - Cooling through climate chamber
    - Demonstrated with prototype with T_{air} ~ - 35 C (in bkp)
    - Helping with CO_2 cooling is still possible
- LV lines:
  - chip register reading
  - MOPS reading of module V and T
  - Tlock
- Data transmission:
  - Uplink: digital scan and BERT
  - Downlink: Configure a FE in each module
- HV lines:
  - PS will have not enough sensitivity
  - Open point: strategy to be defined



ATLAS ITk

Connectivity Test on full endcap pre-shipping

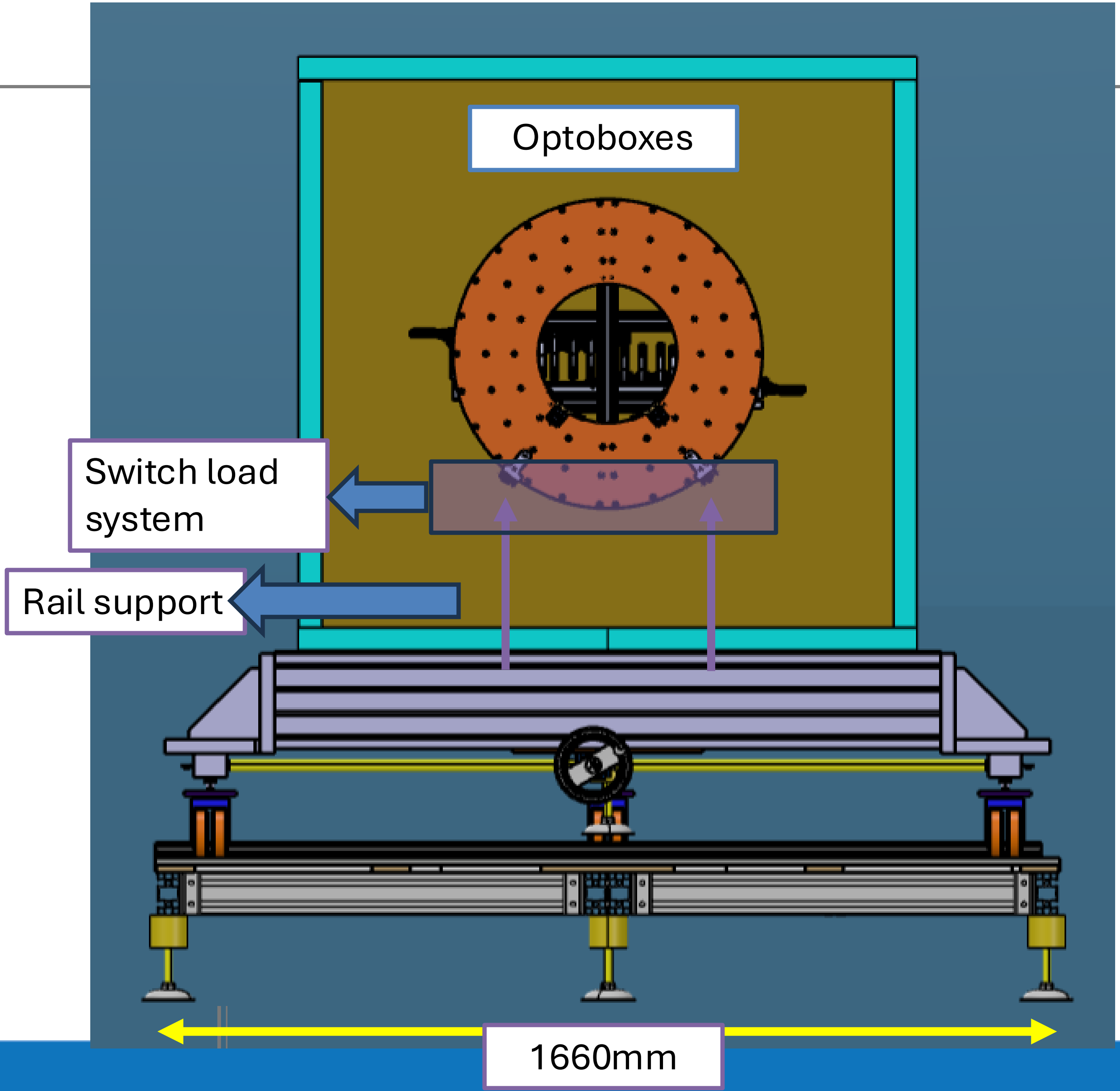


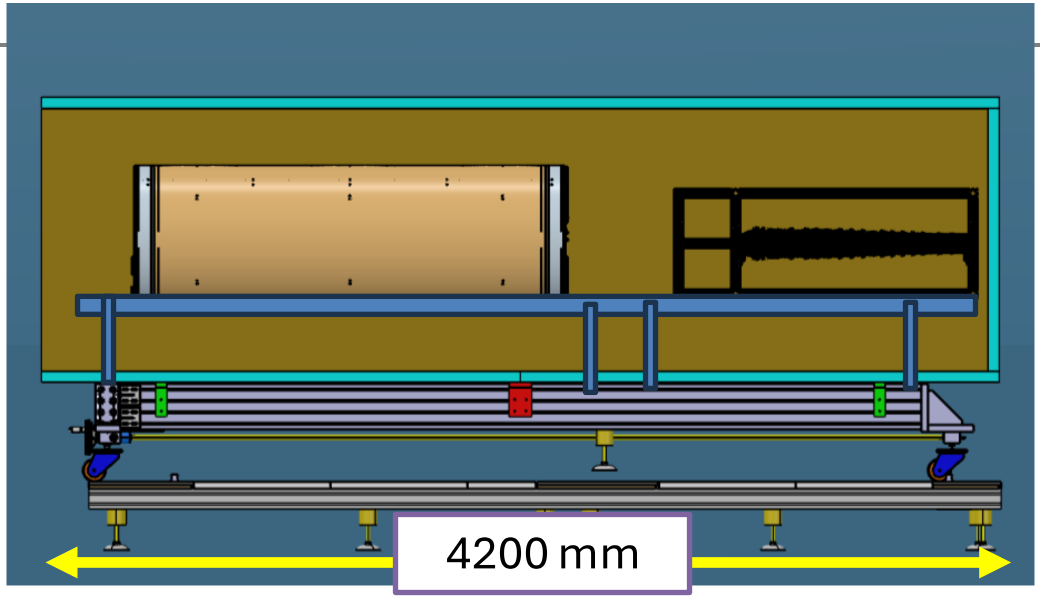
Harness not present in picture

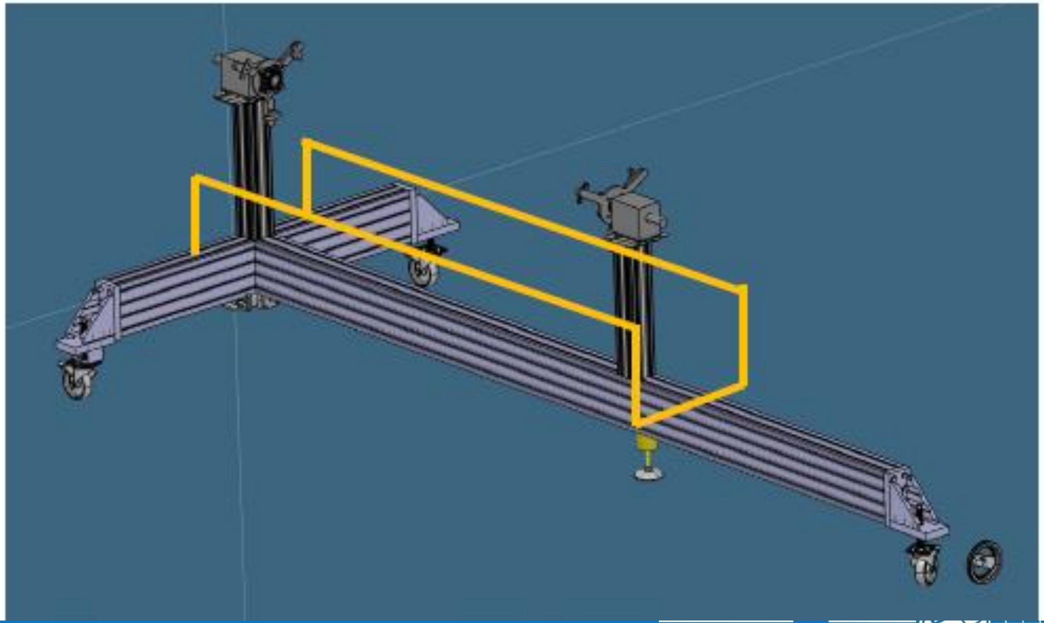
By mean the lifting system under the floating floor, the T-trolley is positioned on wheels and then can be moved into the Climatic Chamber for the final test.

- Final test in the climate chamber
  - Low power mode
  - Cooling demonstrated with prototype with Tair ~ - 35 °C
  - Helping with CO_2 cooling is still possible

Solution with a smaller box







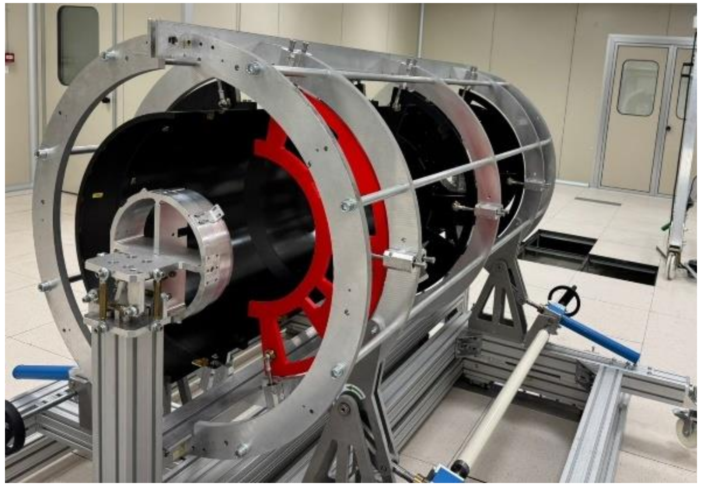
Prototypes

The idea is to have the whole detector in a prototype/mockup version in in order to test the mating (empty), then the insertion of the piping, the insertion of the cables and the Half Rings, and then the mating with the populated HS and the PP1 manifold (see tomorrow talk) for each layers. Some HRs could have the piping to perform some welding test.

What we have so far:

Half Shell: we have one Half L4 (from Liverpool) and 2 L2 (from Aviacompositi).
- Lugs: all printed in ULTEM (by Naples)
- In production the tool for the positioning the lugs of the HS (by Giuseppe Pileggi LNF)

Half rings: 2 HRs per type (6 in total) made in LNF (E. Paoletti, R. Tesauro)
Lz flange: already printed (ABS)
Hz flange: Printed for L2 (ABS)
"Spider" Flange: Produced (F. Rosatelli)



QA Tests are foreseen to check the functionalities of the system:

- Thermal Cycling on the HS connected to the rotating cradle
- Thermal Cycling and functional test on the HS equipped with HRs

Cradle with HS

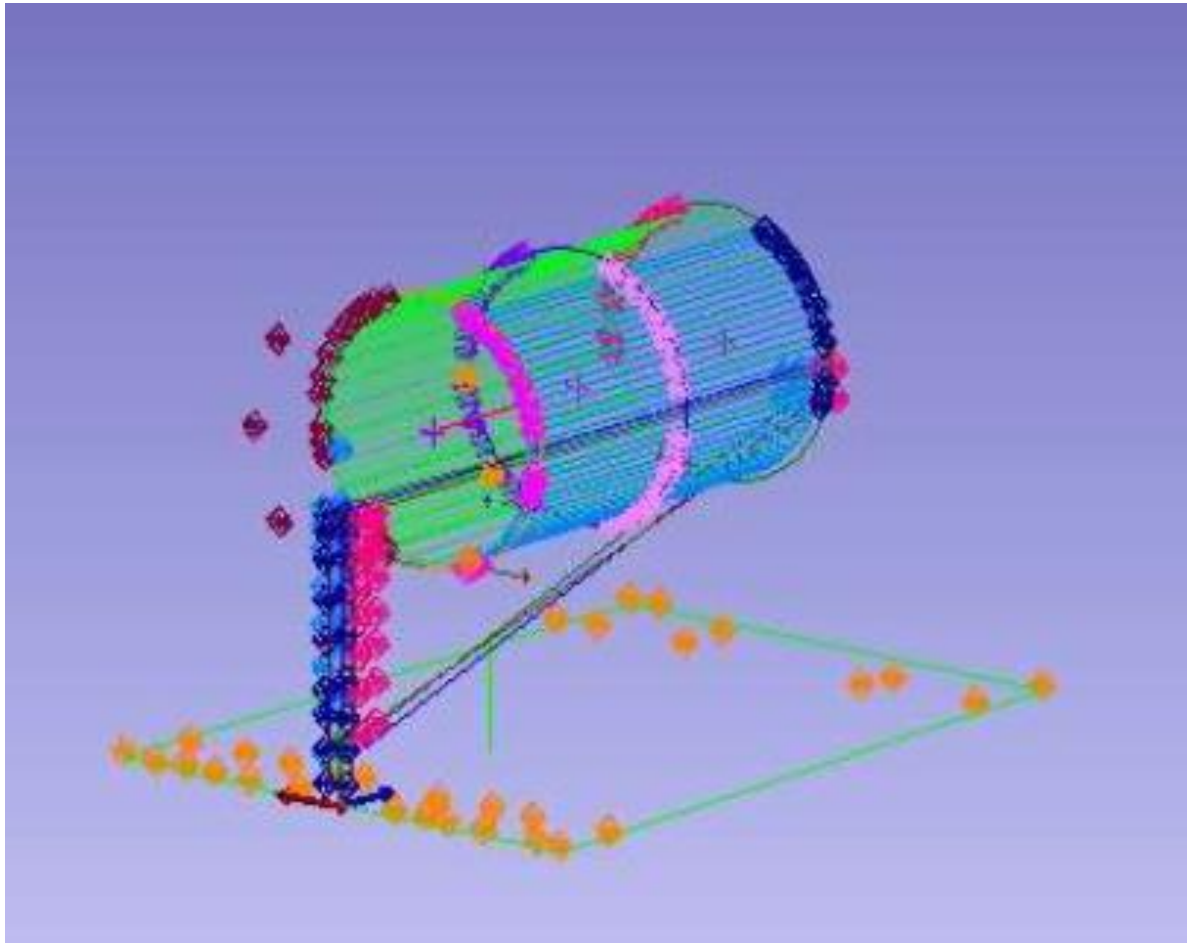
Climatic Chamber

Circle Relationship A::Cerchio1 sx	
Criteria	Measured
Diameter	839.95
Circularity	0.26
X	4.49
Y	1060.79
Z	437.96
RMS	0.09
Measurements	13

Alignment test are scheduled to prove the position precision of the system

Circle Relationship A::Cerchio1 dx	
Criteria	Measured
Diameter	839.20
Circularity	0.21
X	3.52
Y	1060.03
Z	437.60
RMS	0.07
Measurements	15

Circle Relationship A::Cerchio2 sx	
Criteria	Measured
Diameter	839.93
Circularity	0.21
X	3.37
Y	1059.88
Z	1107.99
RMS	0.06
Measurements	15



Circle Relationship A::Cerchio2 dx	
Criteria	Measured
Diameter	839.01
Circularity	0.19
X	1.85
Y	1060.08
Z	1107.56
RMS	0.06
Measurements	15

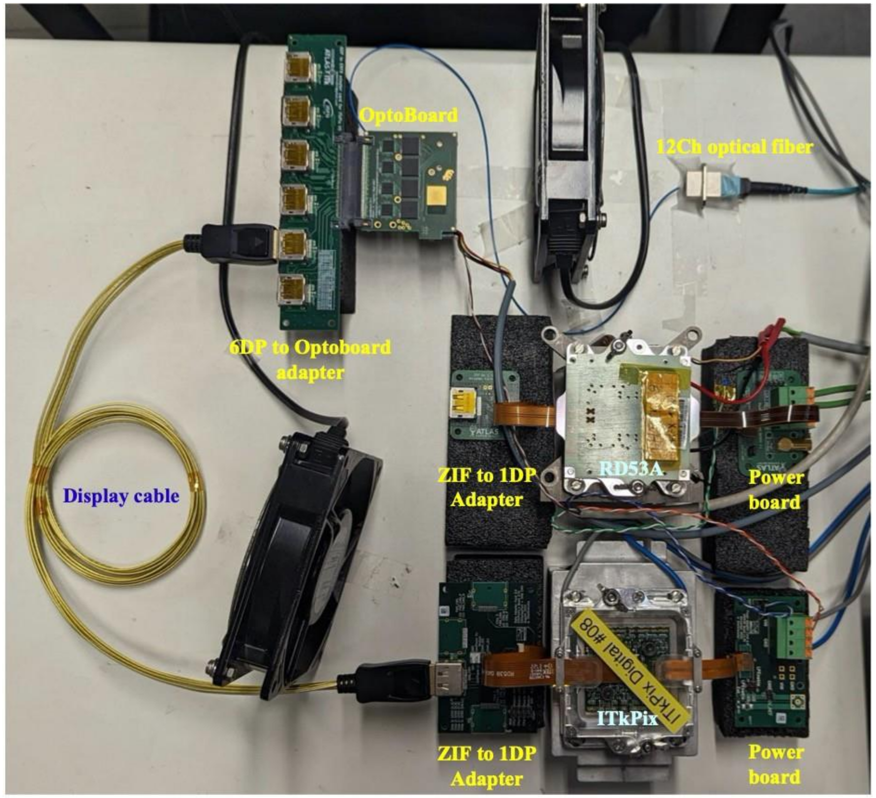
Circle Relationship A::Cerchio3 sx	
Criteria	Measured
Diameter	839.33
Circularity	0.15
X	2.55
Y	1059.88
Z	1778.25
RMS	0.05
Measurements	15

Circle Relationship A::Cerchio3 dx	
Criteria	Measured
Diameter	839.61
Circularity	0.17
X	1.10
Y	1060.74
Z	1777.88
RMS	0.05
Measurements	13

We performed some test for the mating of the cradles but problems raised up. Each part has not bad cylindrical shape but the mating of some part does'nt match, so we decide to simplify the system and check the alignment of the cradles once they are built. The rails now are one part instead being 2 parts in order to gurantee a better alignment.

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



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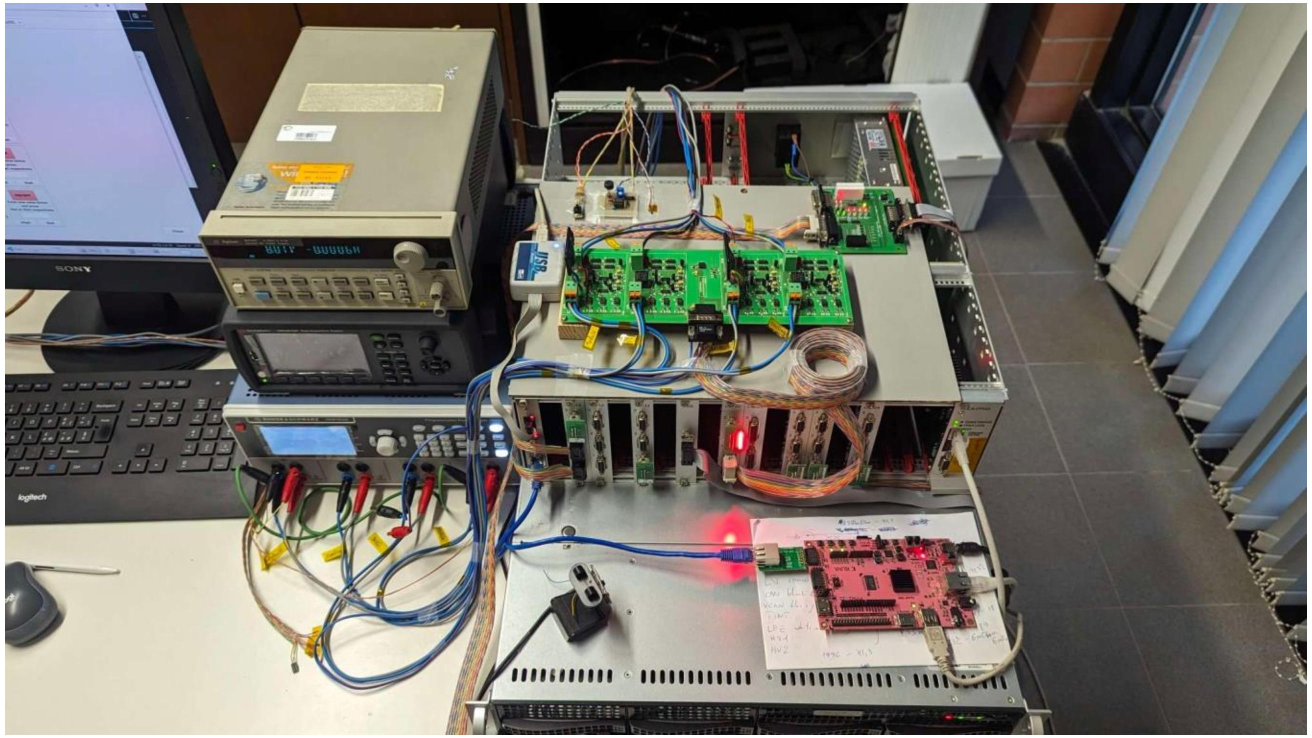
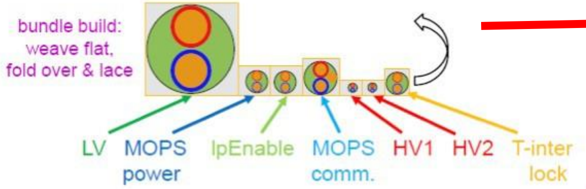
- Develop interlock logics
  - NTC, cooling, power, environmental sensors
- Develop of scalable DCS system

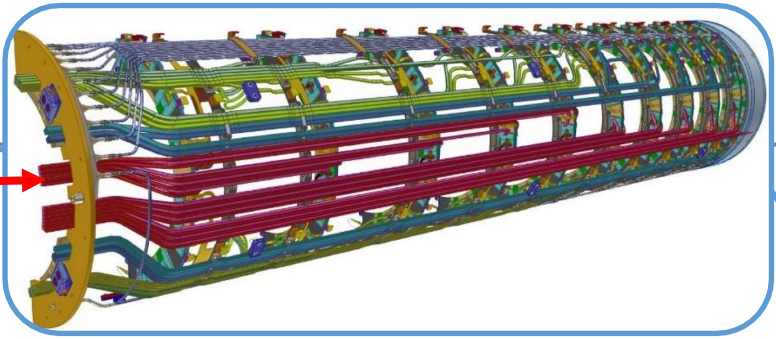


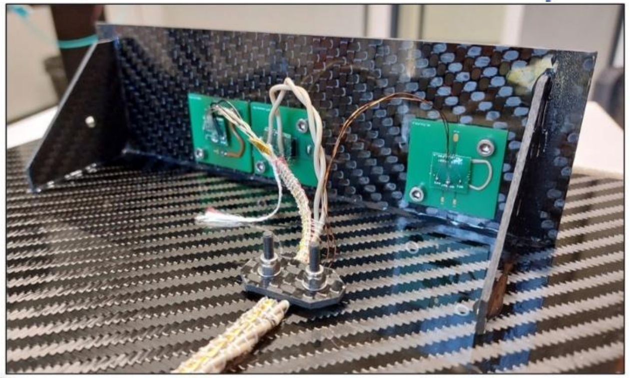
Z. Chubinidze

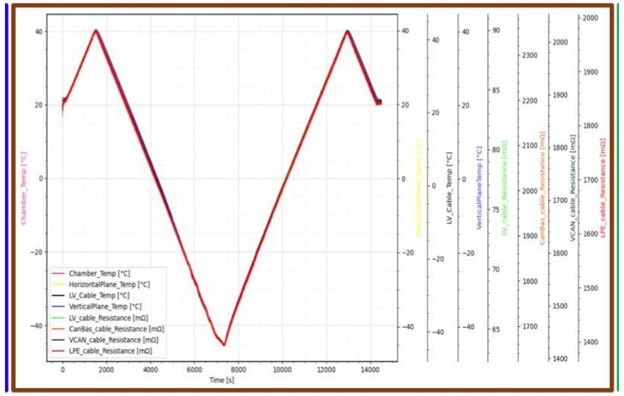
ITk Services

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

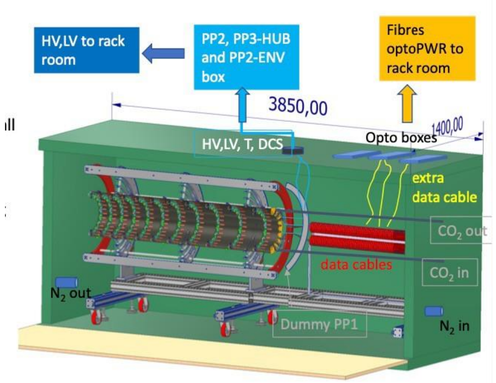


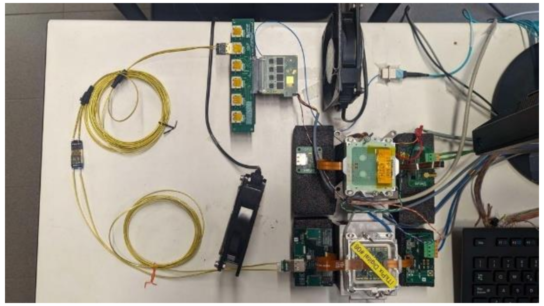


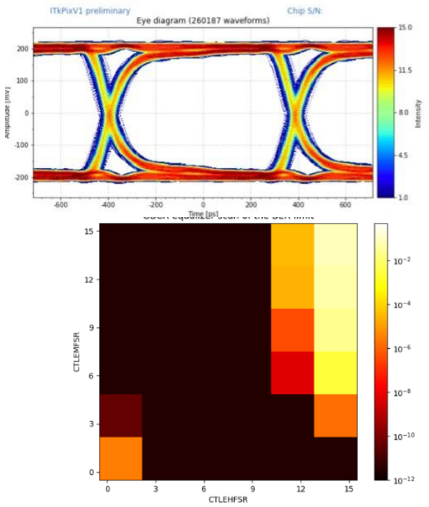




- Extension twinax data cables
  - Design Prototypes and Production
  - Data transmission test







P. Albicocco, M. Testa, Z. Chubinidze

Attività e assegnazioni CIF II Semestre 2025

Attività nel II semestre 2025:

- Finalizzazione dei disegni delle parti mancanti
- Finalizzazione del sistema di sollevamento
- Produzione di alcune parti del tool di assemblaggio
- Montaggio del tool di assemblaggio e test
- Progettazione del sistema di Trasporto

Servizio	Reparto	Assegnato (m.u.)
SEM	Progettazione	4,5
SEM	Costruzioni Meccaniche	10
Supporto Esperimenti	Support Unit	3
SPCM	Progettazione	0,5
SPCM	Meccanica	2

Richieste 2026

ATLAS FTE Totali: 11.25 (Fisici + Tecnologi)

		Richieste (kEUR)
apparati	ATLAS Tier-2	212
consumo	ATLAS	21
missioni	ATLAS	162
consumo	Phase II - ITk	34.5
apparati	Phase II - ITk core	563

Servizi	**Richieste stimate 2026 (person months)**
Electronics and Automation Service (DR)	12
Mechanics Service (DR)	8 months x 4 persons
Detector Development and Experimental Activities Support Service (DR)	10 months x 2 persons
Servizio Progettazione e Costruzioni Meccaniche (DT)	4
Cryogenic System (DA)	3
Vacuum (DA)	5