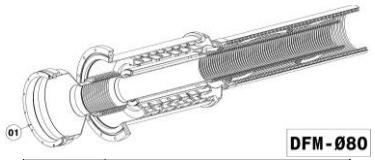
DFM engineering detailed design:
- interfaces
- assembly
- installation (DSHM handling and connection to DFM)
- maintenance

P. Schneider*, R. Betemps for WP6a

DFM detailed design review – 18.01.2022

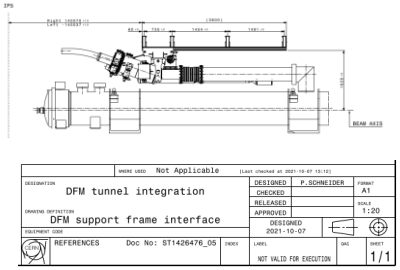
DFM external interfaces

DSHM interface LHCDSH_C0005

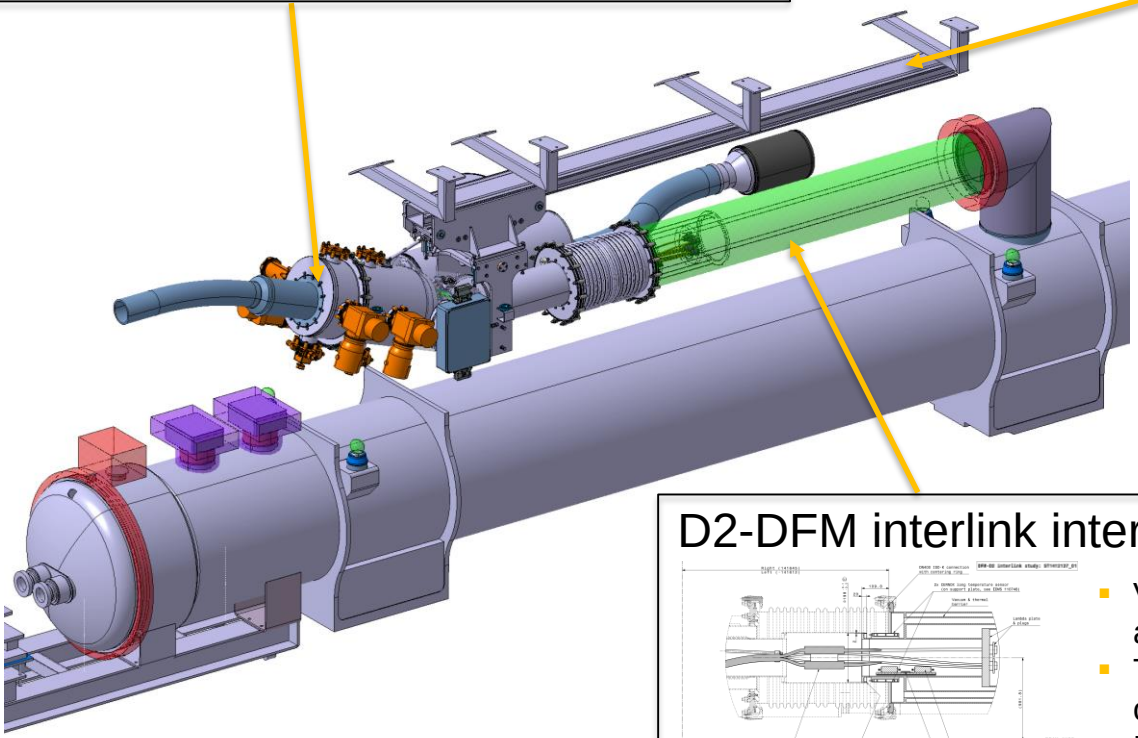


- DSHM He vessel weldable extremity
- Vacuum interface with floating flange

Tunnel interface LHCDFM_XXXX



- Different support frame for each of the four locations
- Study for IP5R is well advenced, to be done for other locations



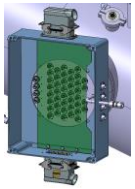
D2-DFM interlink interface LHCDFM_0010

- Vacuum & helium sleeves to access NbTi-NbTi splices
- Temperature sensors installed on the D2 Helium tube
- Heaters in the D2 Helium tube for WU

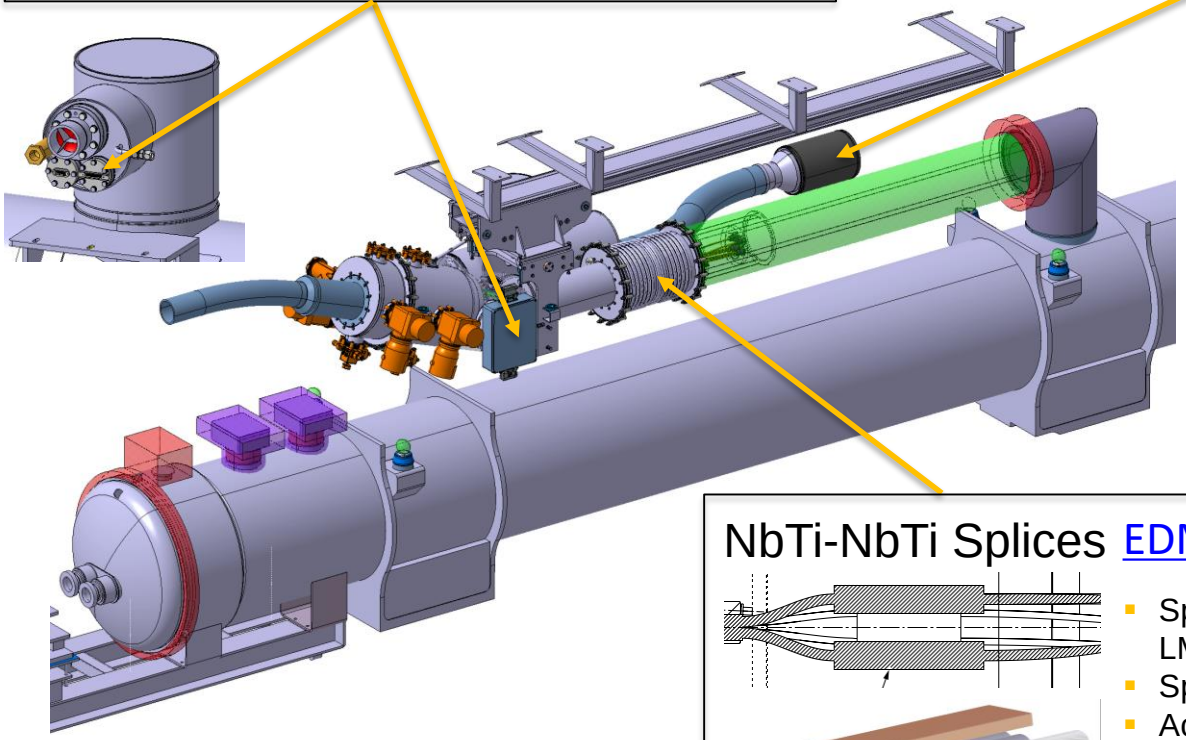
DFM external interfaces

IFS box & cryogenic instrumentation

See J. Fleiters presentation

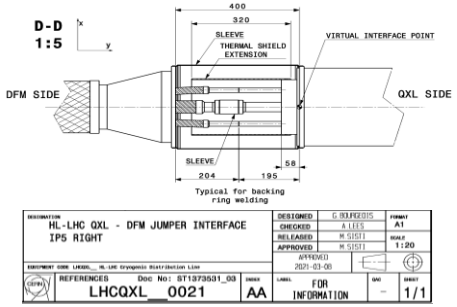


- Standard HL-LHC L-size IFS box
- Cryo instrumentation through boiler output



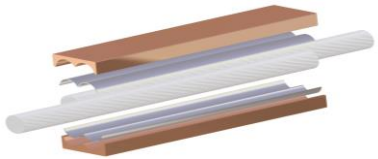
QXL jumper interface

LHCQXL__0021



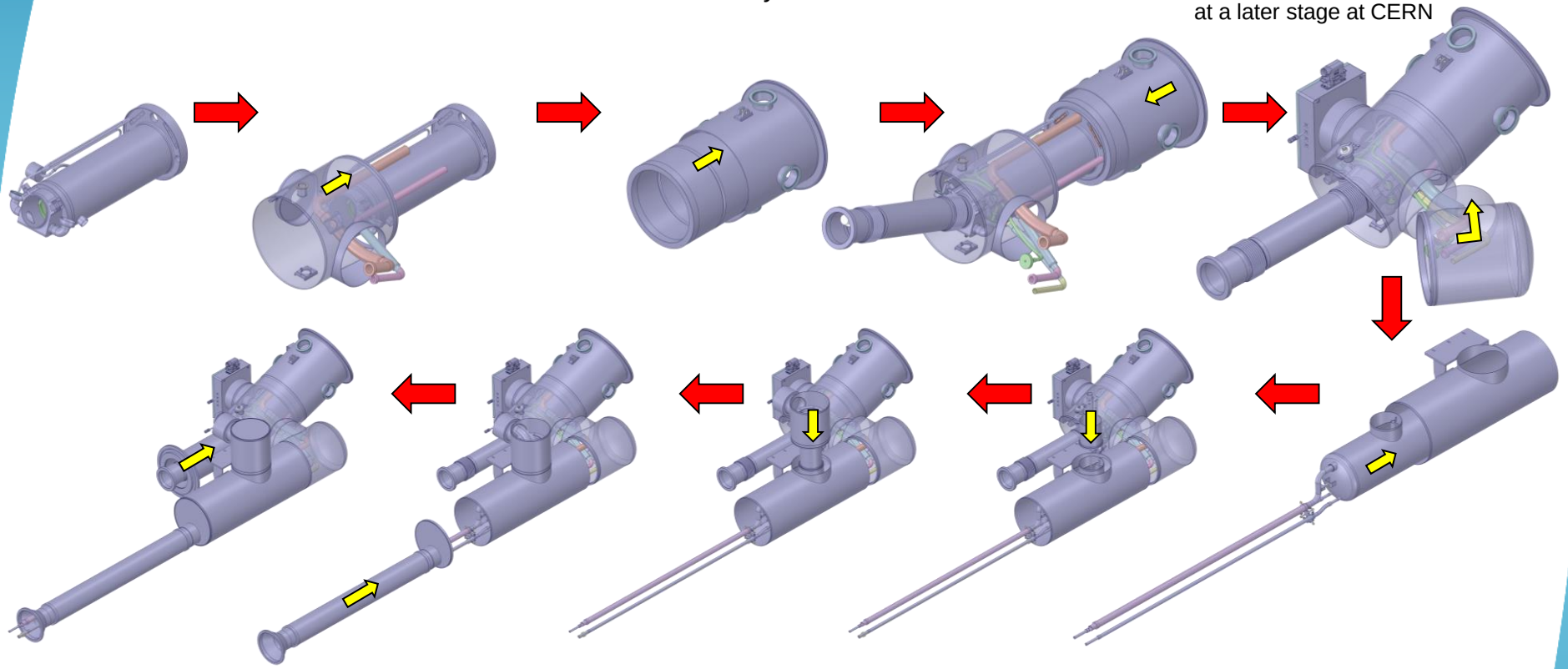
- Cryo-interconnections: He supply line, He discharge line, thermal shield line (heat exchanger in the boiler module)
- Vacuum sleeve to access the cryo-interconnexions

NbTi-NbTi Splices EDMS 2492410



- Splices developed by TE-MSC-LMF
- Splices as fixed point
- Access through vacuum bellows sleeve and welded He sleeve

DFM assembly summary

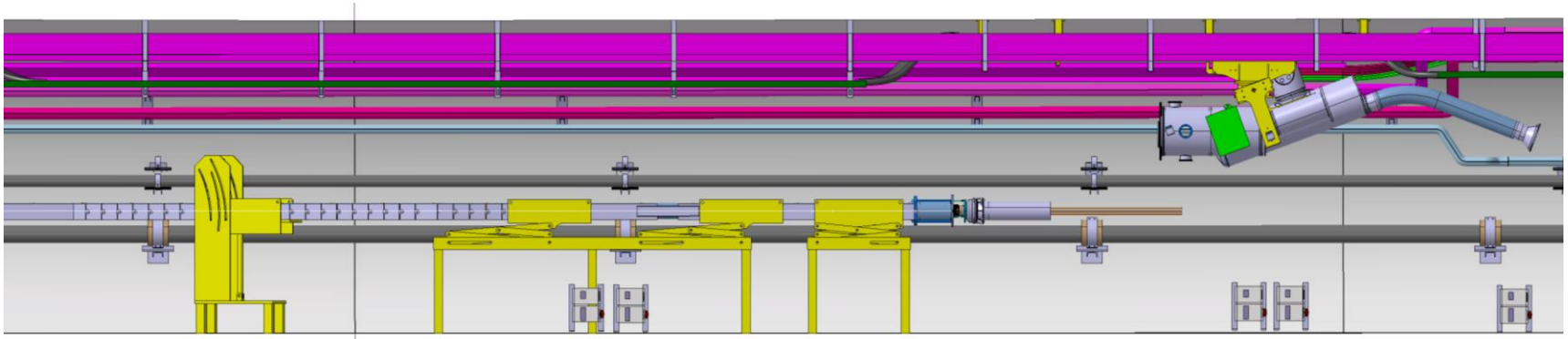


- Detailed assembly presentation with step-by-step sequence and welds available here: EDMS 2682158
- Special thank to Thibault Coiffet for his help with the optimization of this assembly sequence.

Courtesy of F. Di Ciocchis

DSHM-DFM installation Overview

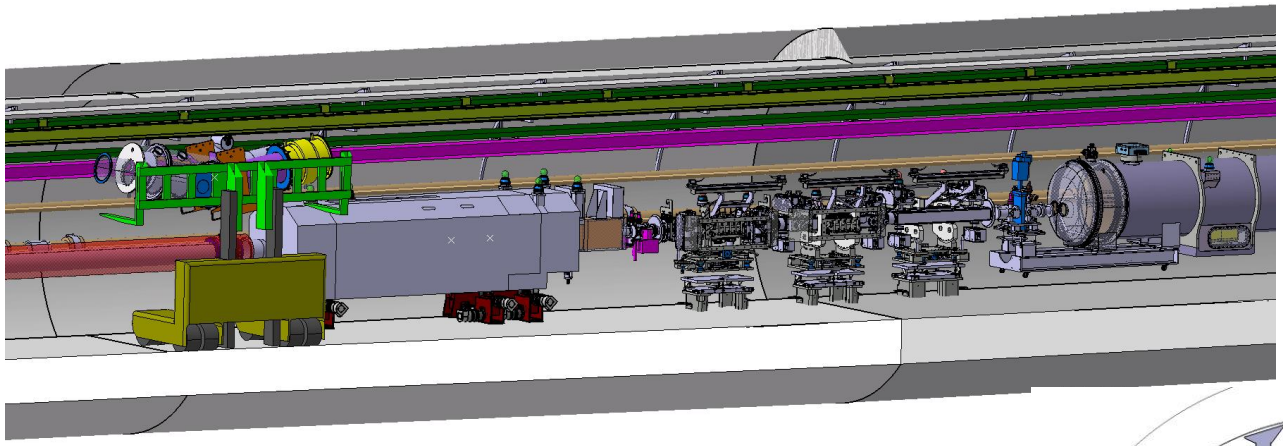
- Tunnel configuration (preferred)
  - DSHM installed before TAXN (preferred)
  - Collimators not installed (required)
  - D2 not installed (preferred)
- DSHM-DFM installation principle
  - DSHM located in cable chain final support
  - Cable chain support moved during operation



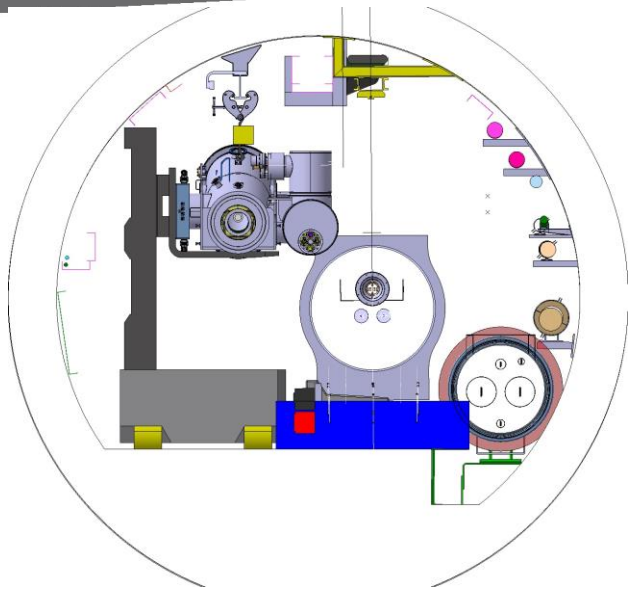
Side view from transport side: preferred tunnel configuration before DSHM-DFM insertion

DSHM-DFM installation Overview

- Transport of DFM

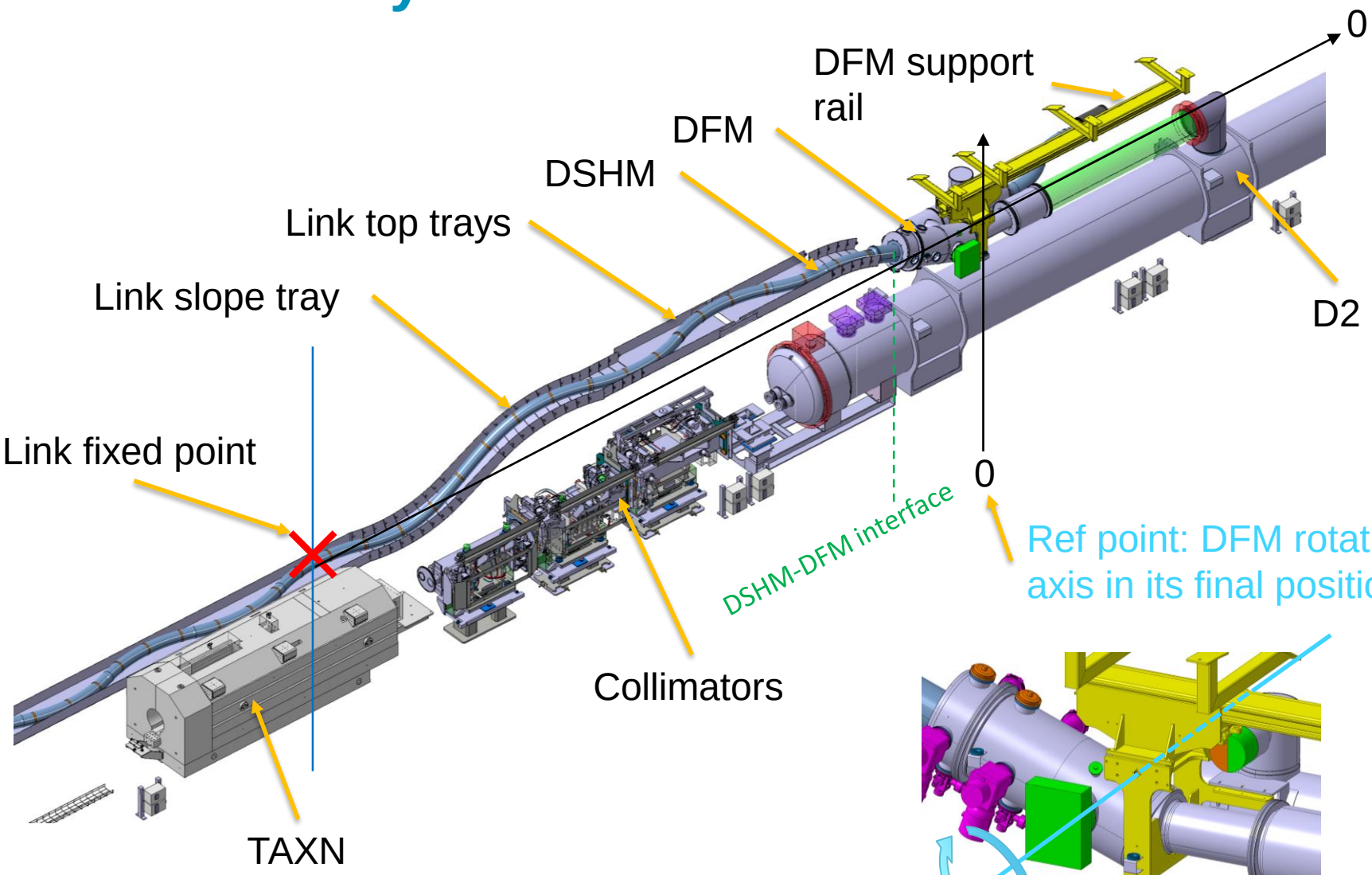


Courtesy of E. Richards

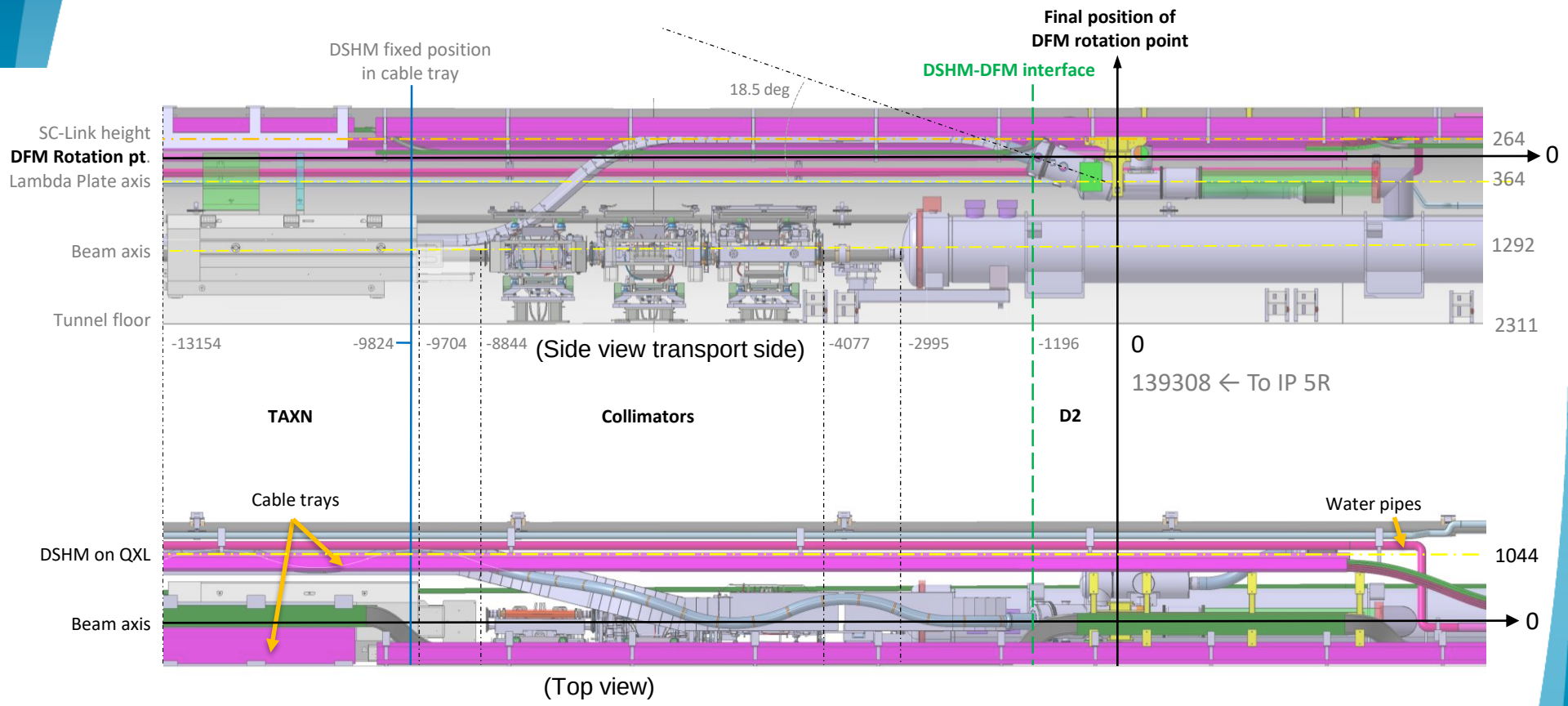


- Dedicated transport side loader forklift for DFX, DCM and DFM
- Transport up to rail support to fix the DFM in position
- Most critical situation in location 5R, DFM will be transported on chariot, then lifted by crane to be set in position with the forklift.

Key elements & referential

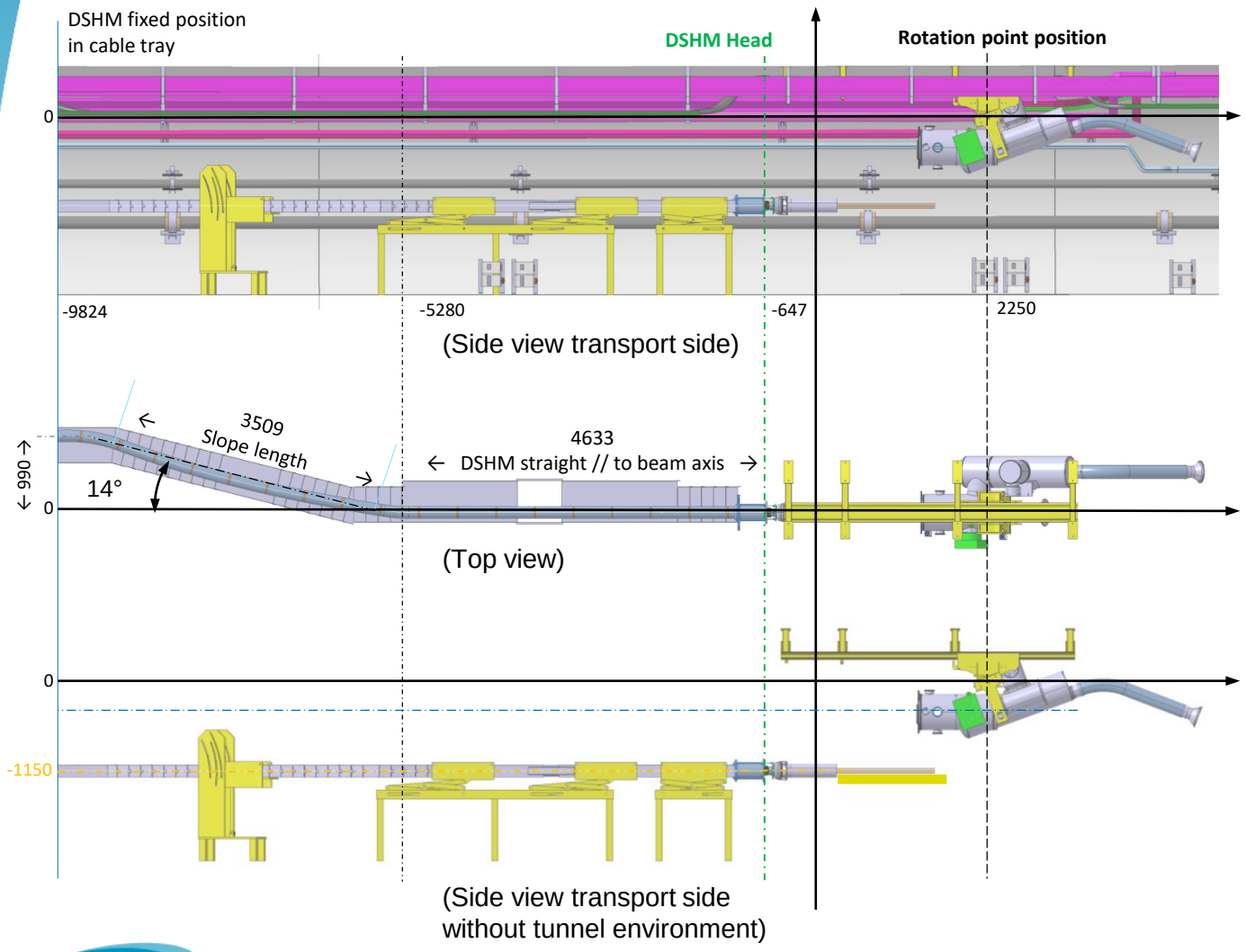


DSHM-DFM nominal configuration @ 5R



- **Referential** : Axis of rotation DFM frame / beam / Perpendicular to Beam
- **DSHm routing** : in tray over QXL, behind TAXN, ascending slope behind and over collimator reserved space, fixed on tunnel ceiling up to DFM

#1 : initial positions of DSHM and DFM



Tunnel configuration for installation :

- DSHM in place up to the fixed position in cable tray
- Collimators removed
- Absence of D2 preferred but not necessary

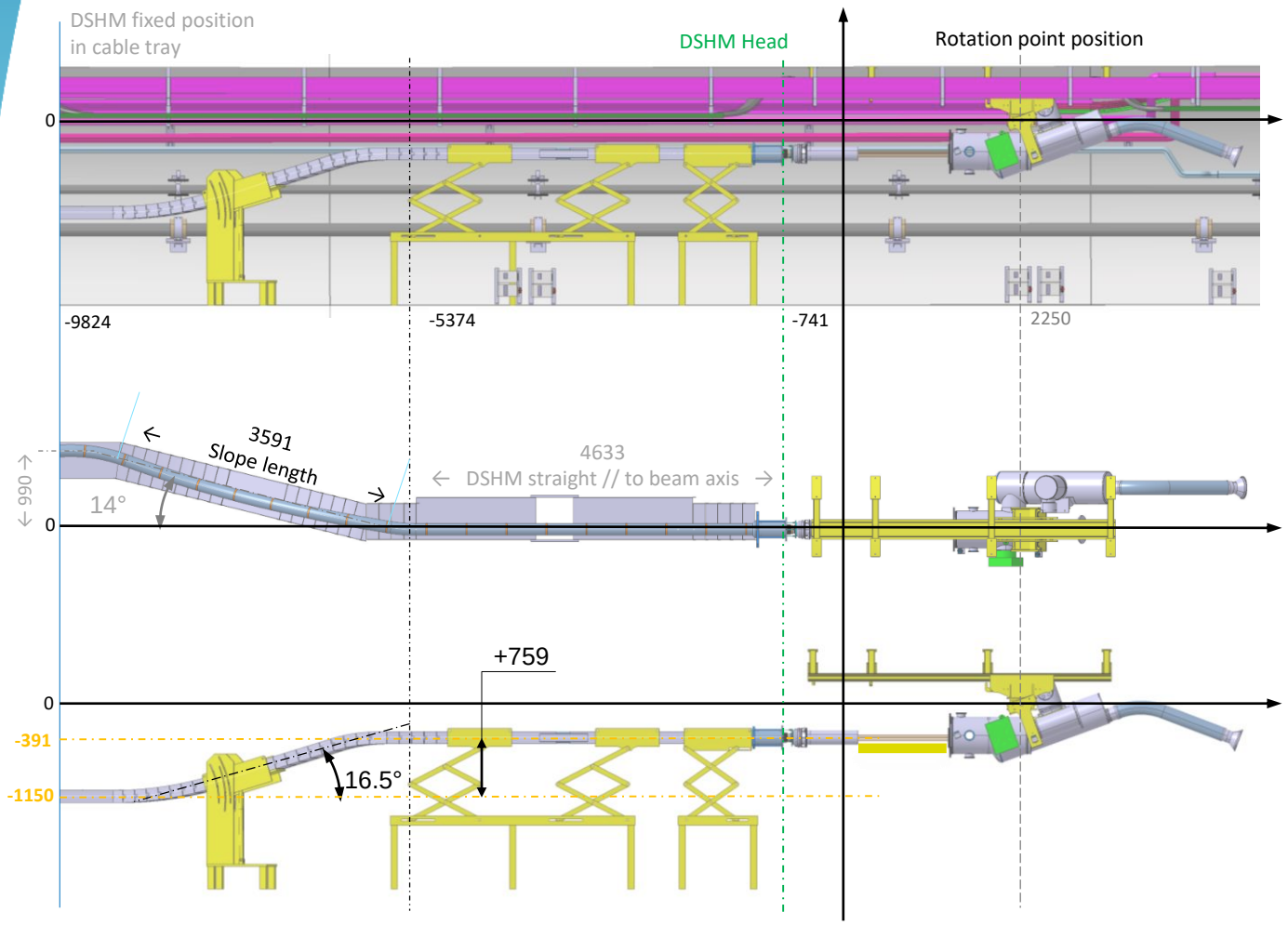
DFM:

- Inclined parallel to beam axis
- Slid 2.25m away from nominal position

DSHM:

- Parallel to beam axis
- 4.6 last meters in plane with beam axis & straight
- Equipped with head support tooling and alignment tool

#2 : Lift DSHM to intermediate position

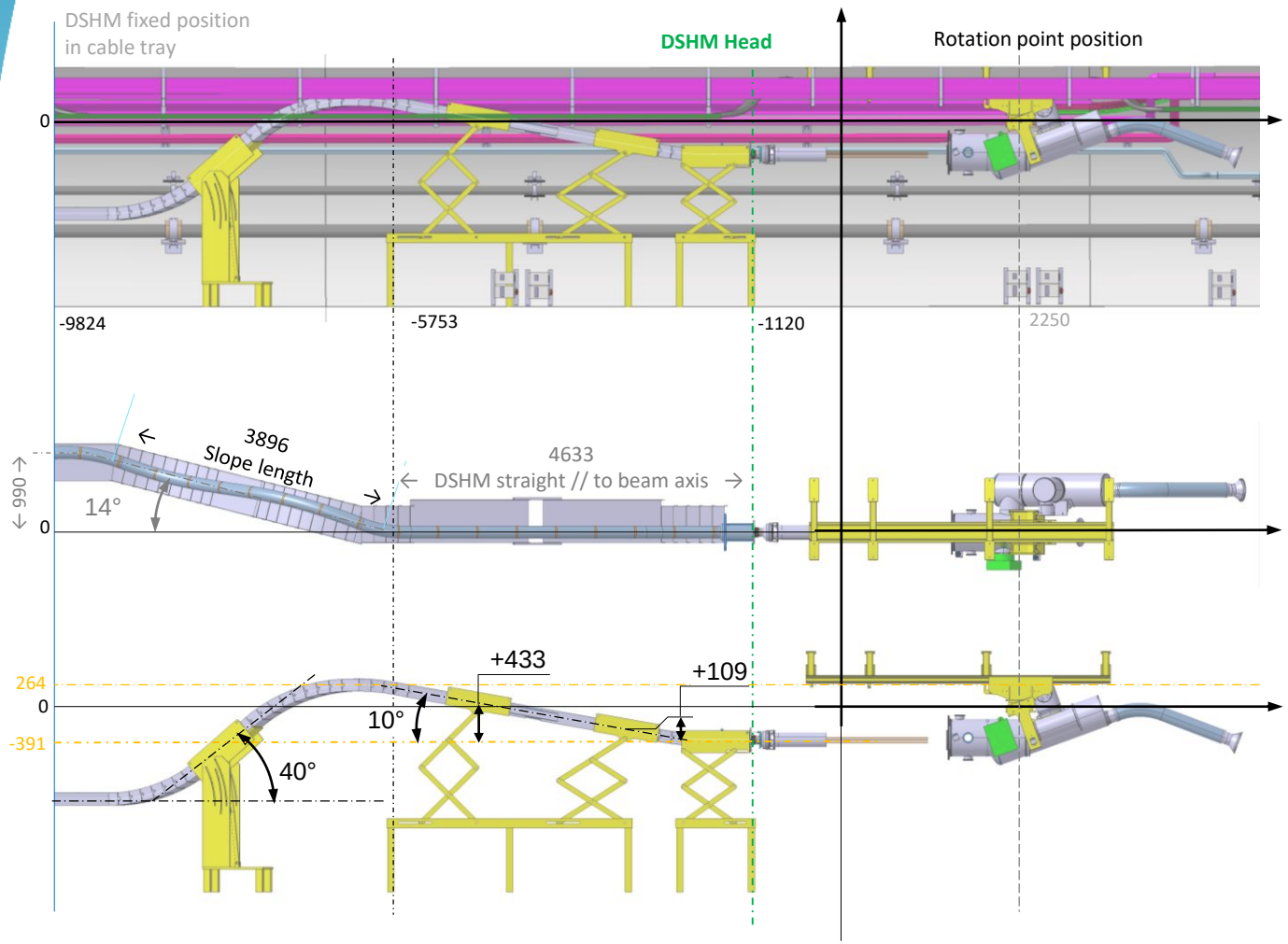


DFM: No action

DSHM:

- Rise simultaneously the 4 yellow supports
- Monitor:
  - Head displacement
  - Relative displacement tray/yellow support
  - Slope extension
- Slope extension of 82 mm for vertical translation of the top trays

#3 : Lift DSHM to insertion position

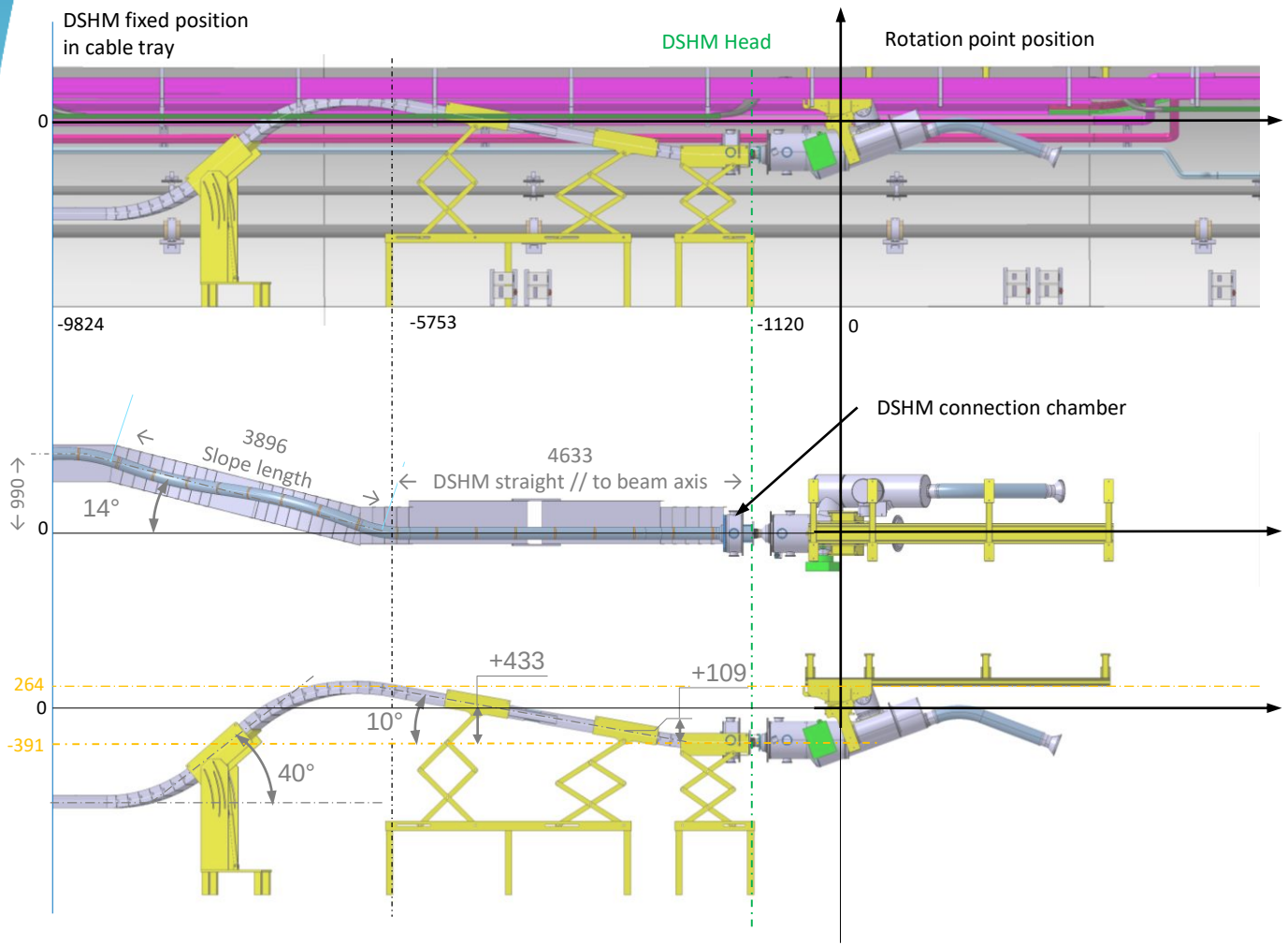


DFM: No action

DSHM:

- Rise simultaneously the 3 first yellow supports
- Monitor:
  - Head displacement
  - Relative displacement tray/yellow support
  - Slope extension
- Slope extension of 305 mm

#3 : Slide DFM to connection position



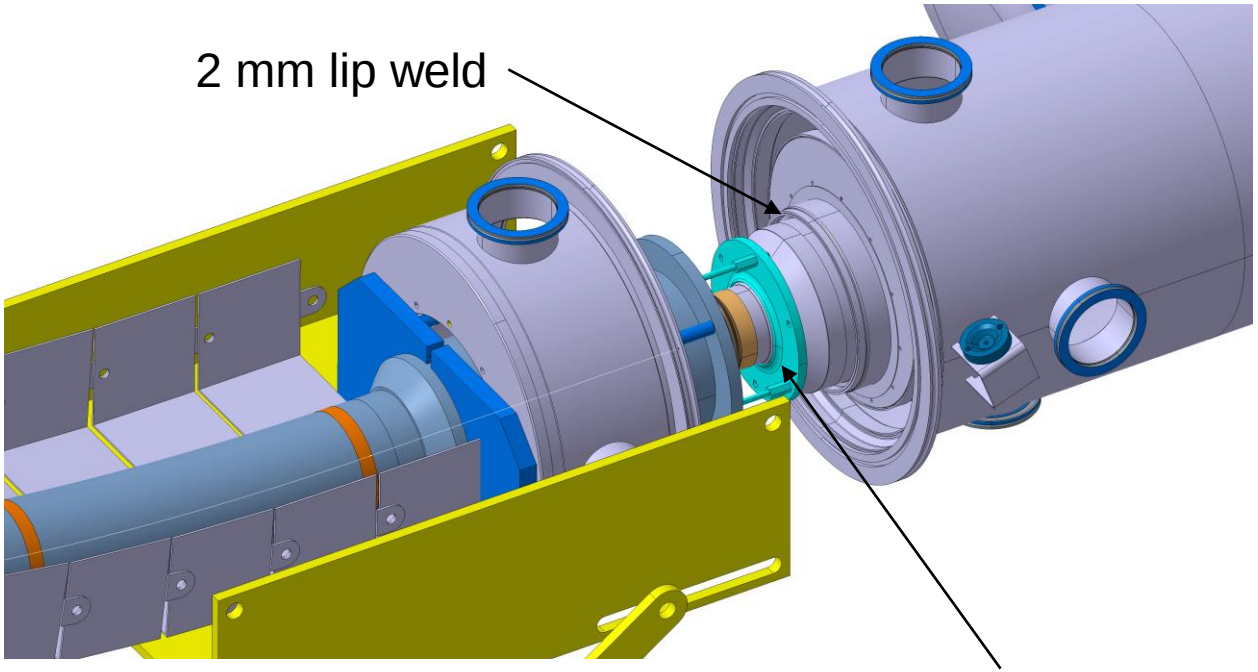
DFM:
- Install the connection chamber over link head
- Slide into connection position
- Lock in position

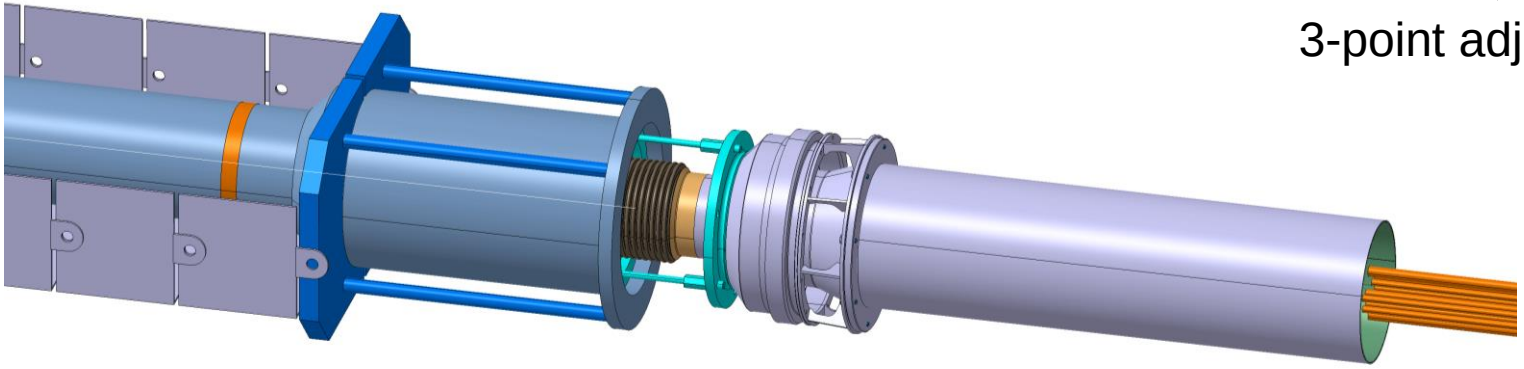
DSHM:
- Monitor and adjust splice protection sleeve during insertion into DFM

#4 : Connect DFM and DSHM

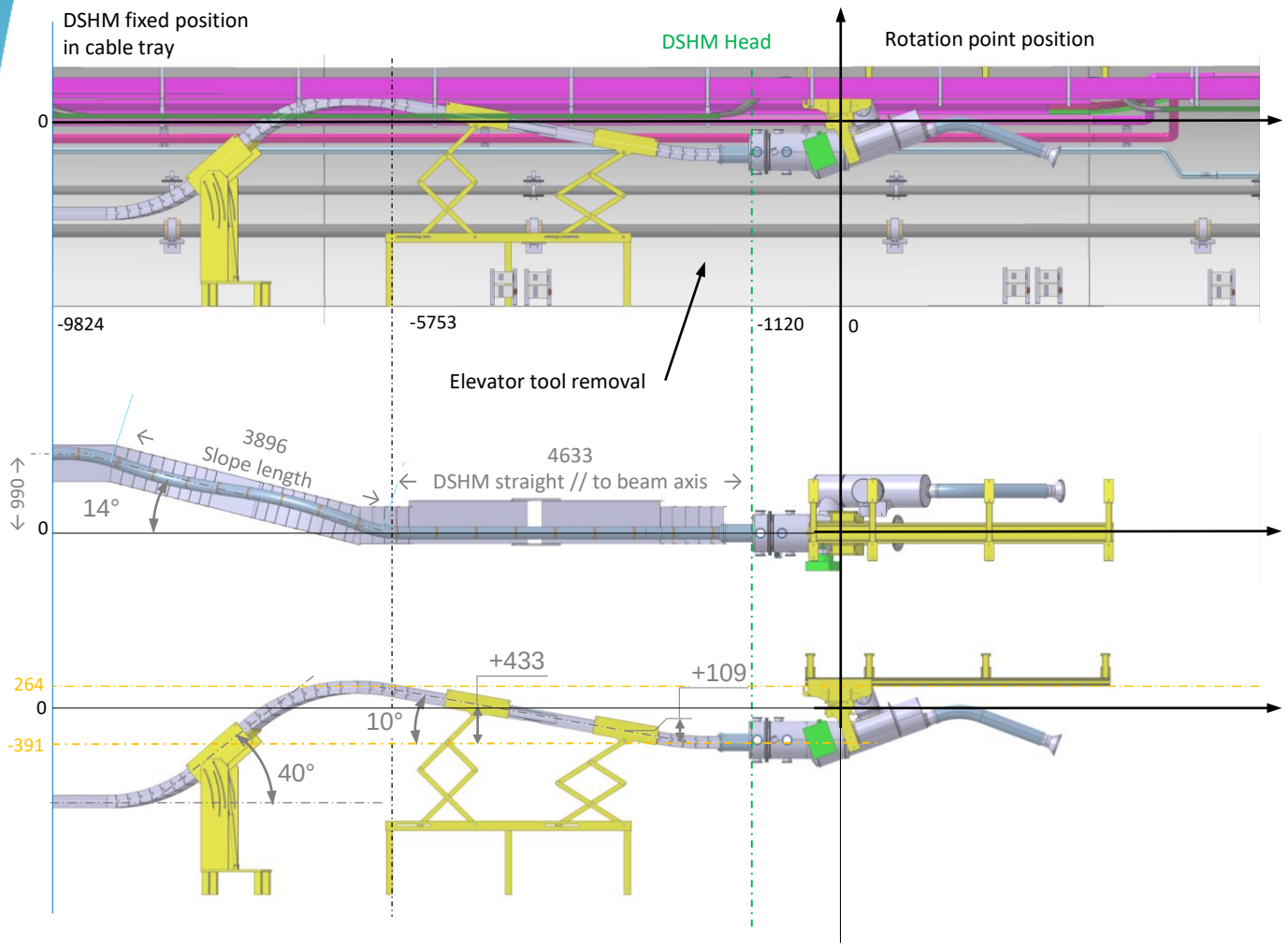
DFM: No action

DSHM:
- Adjust final position between the two flanges with the installed tooling
- Remove adjusting tool





#5 : Support tool removal

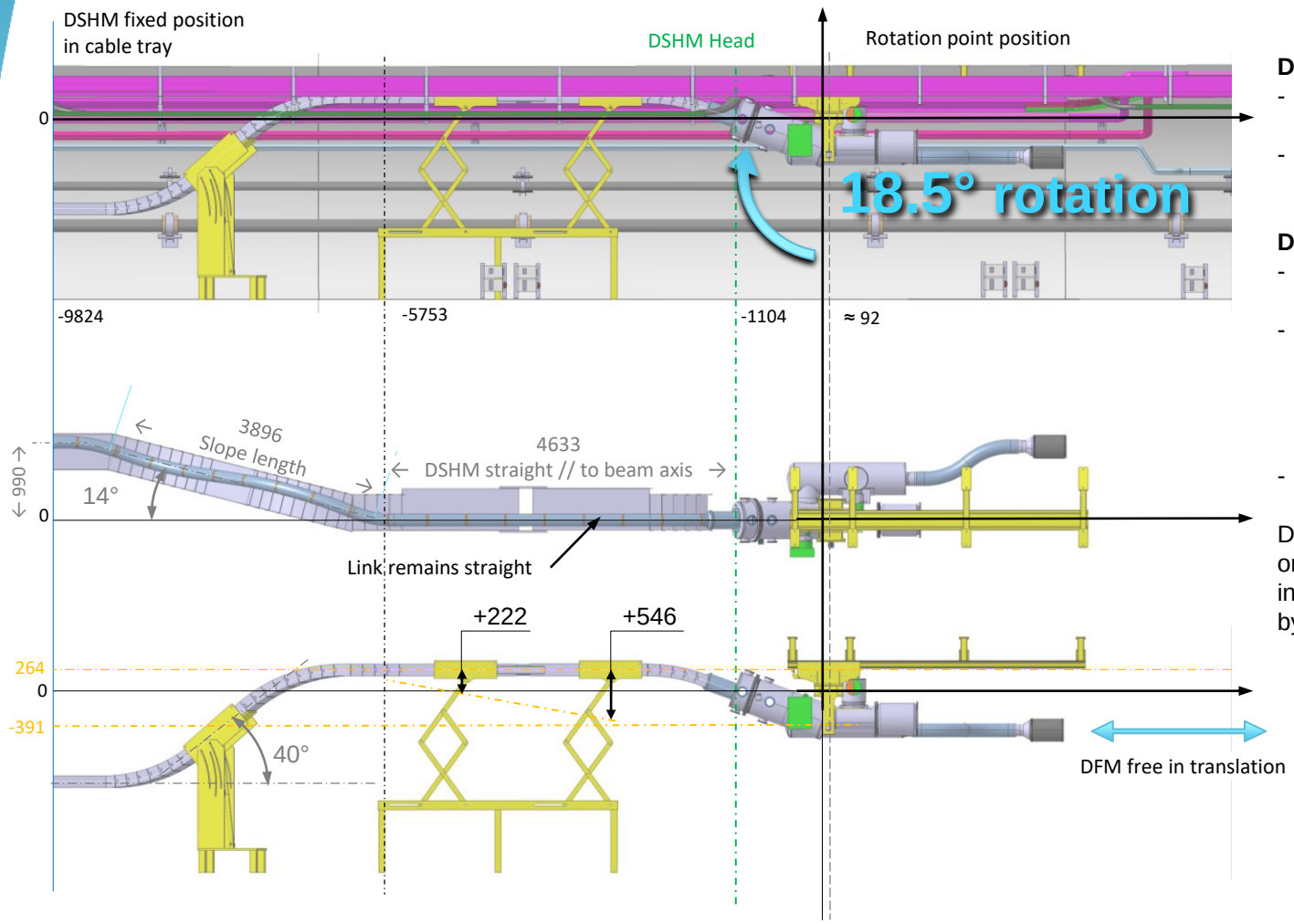


DFM: No action

DSHM:
- Remove head support tool

Remove front elevator tool.

#6 : Tilting of DFM and link

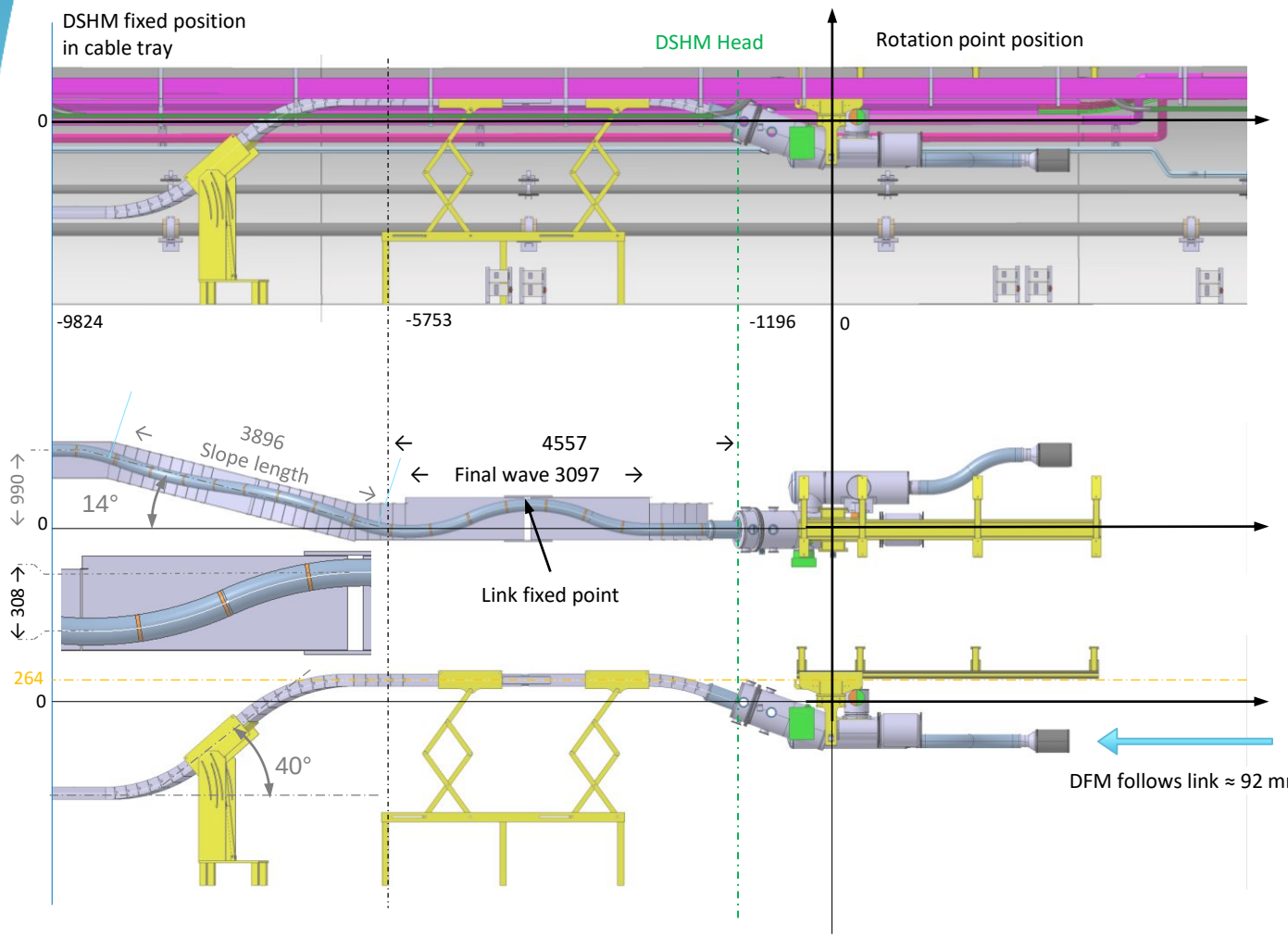


DFM:
- Unlock the DFM support in translation
- Rotate the DFM 18.5° with dedicated tool

DSHM:
- Rise simultaneously the 2 center yellow supports to top position
- Monitor:
  - Head displacement
  - Relative displacement tray/yellow support
  - Slope extension
- Link remains straight in upper tray

During rotation, to avoid any constraint on the link and splices, the DFM is free in translation and will move backwards by approx. 92 mm

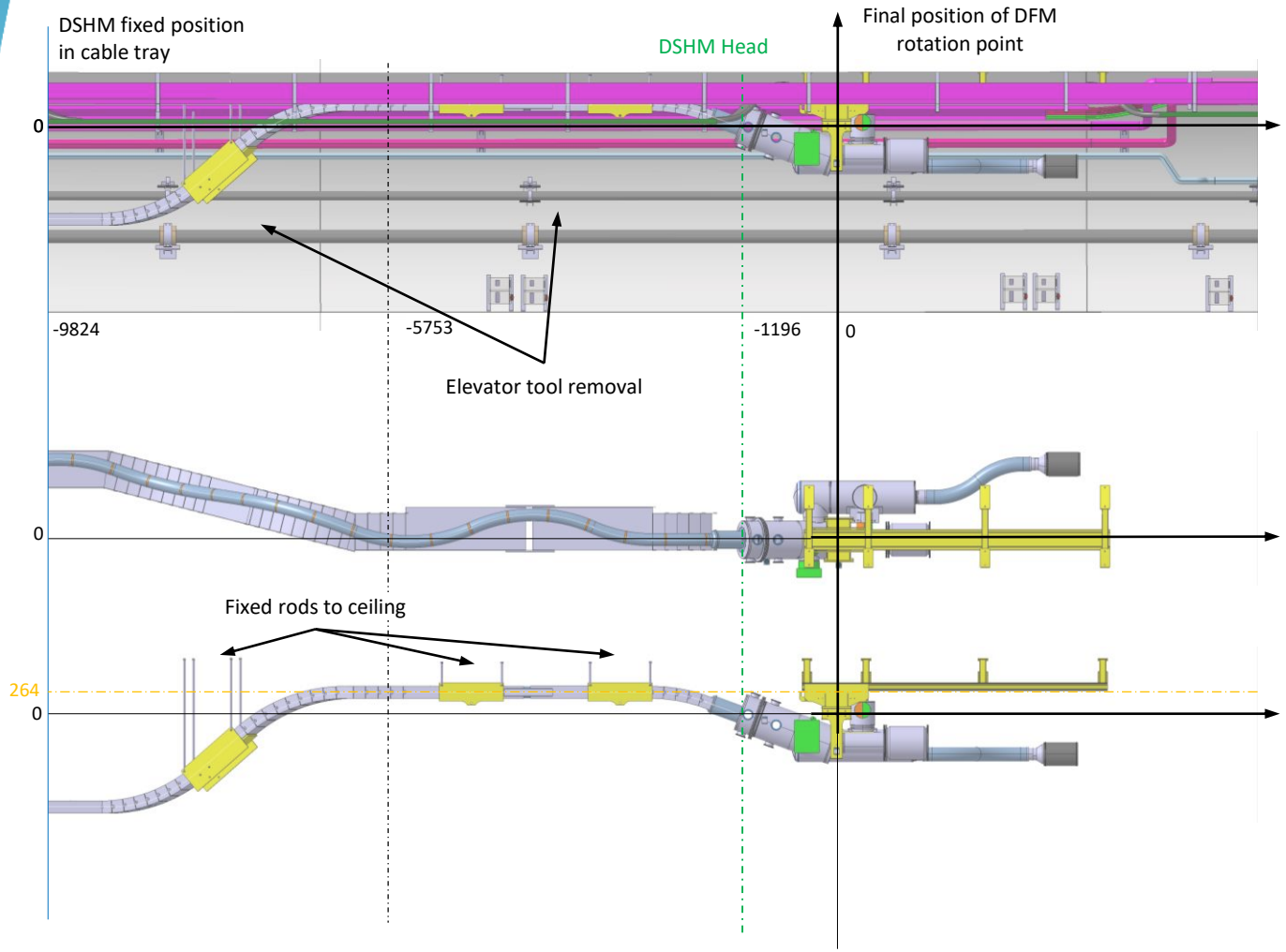
#7 : Forming of link wave



DFM:
- Free in translation, will follow the link displacement
- Lock the DFM in its nominal position

DSHM:
- Forming of the final wave in the top tray until the DFM reaches its nominal position
- Add the fix points

#8 : Mounting to tunnel ceiling with lifting supports



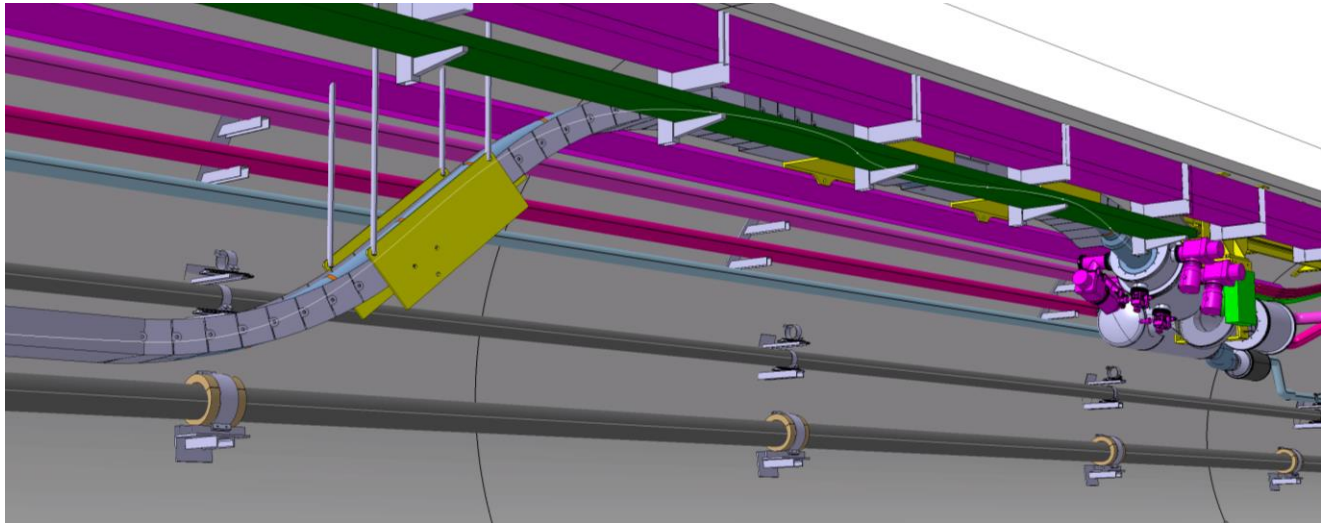
DFM: No action

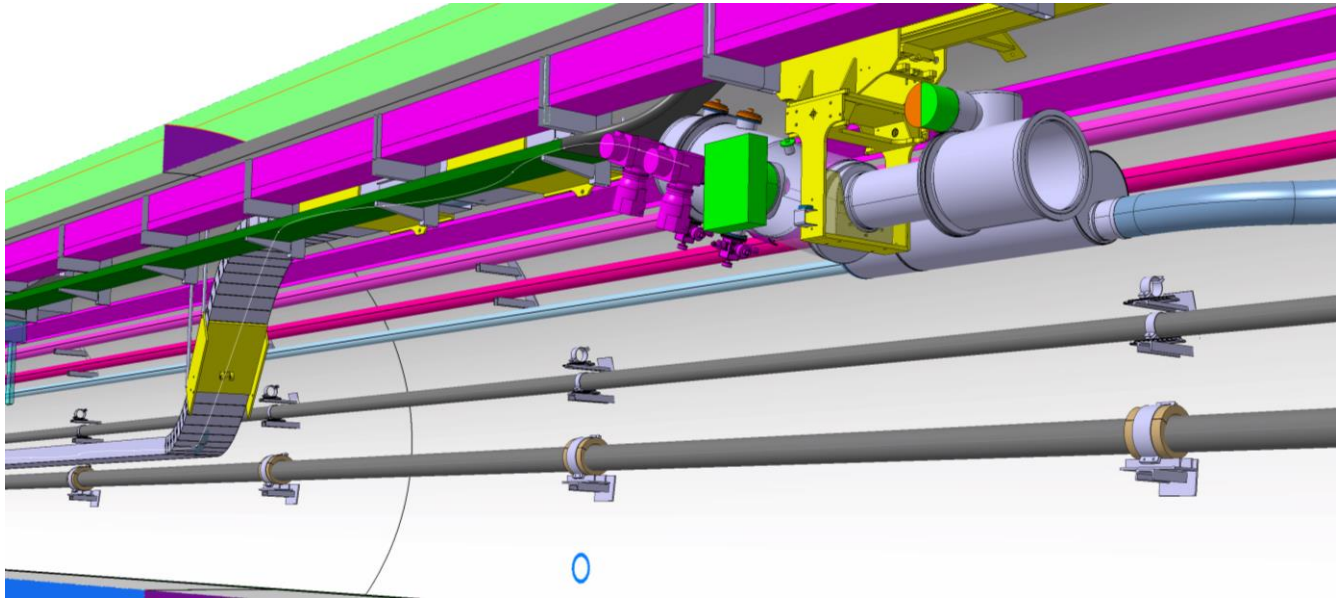
DSHM: No action

Fix the lifting support trays with pre-installed rods to the tunnel ceiling.

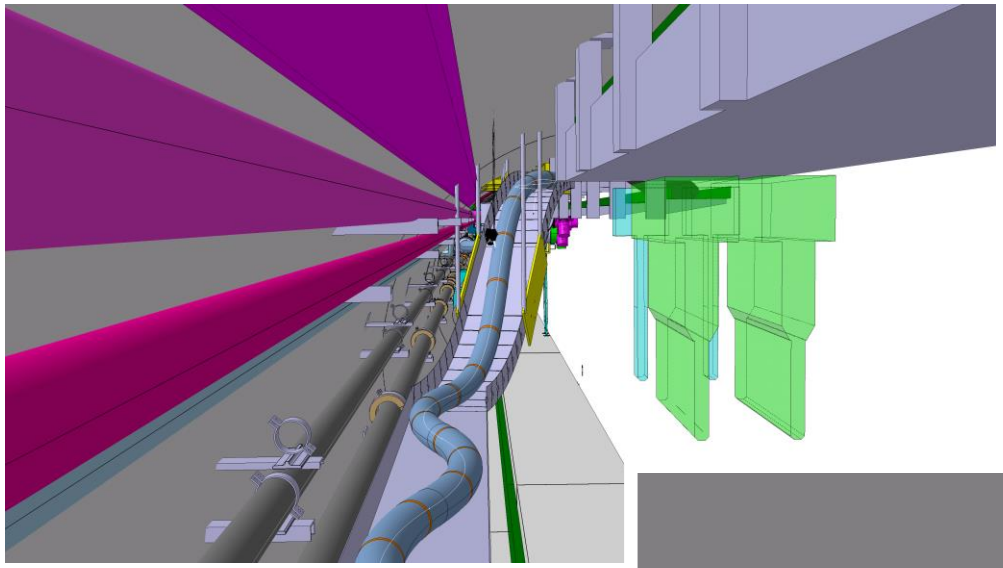
Detach and remove the elevator tools.

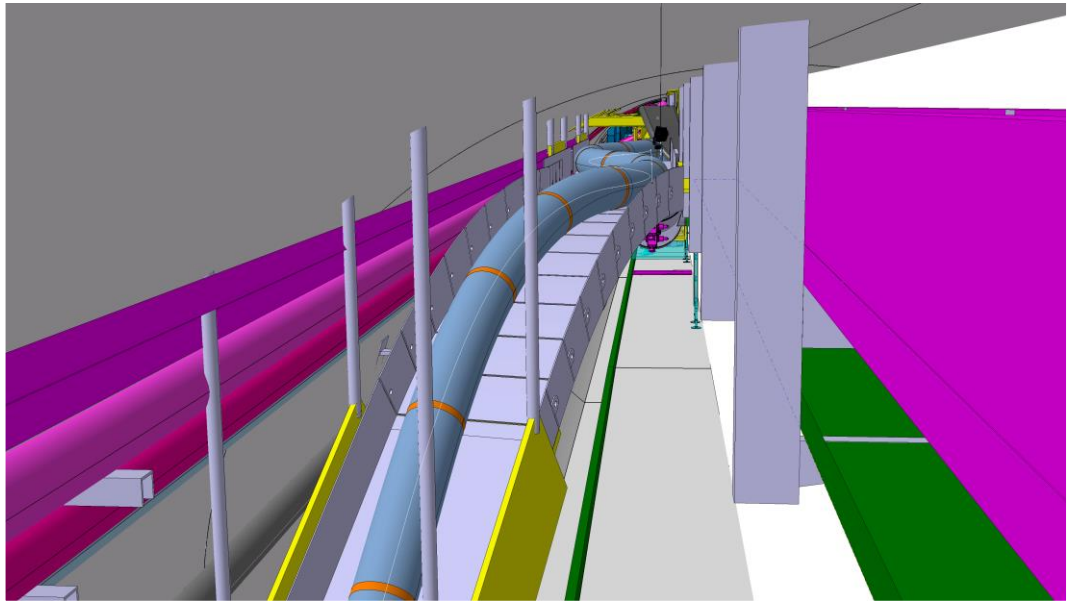
DSHM and DFM installed





DSHM and DFM installed

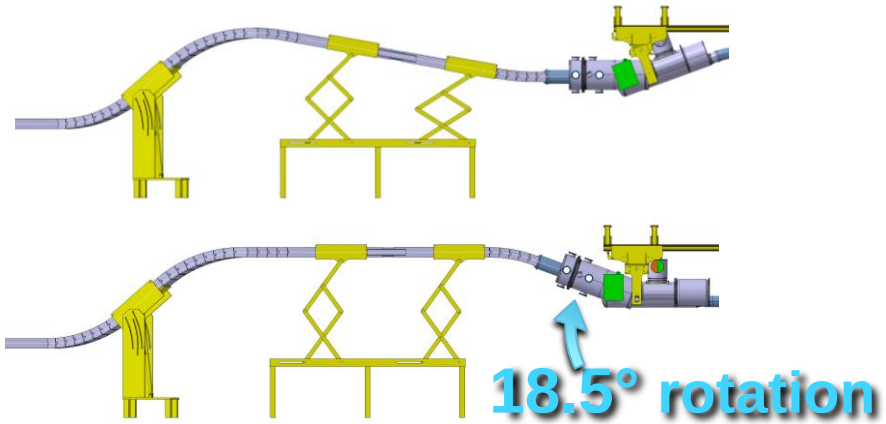


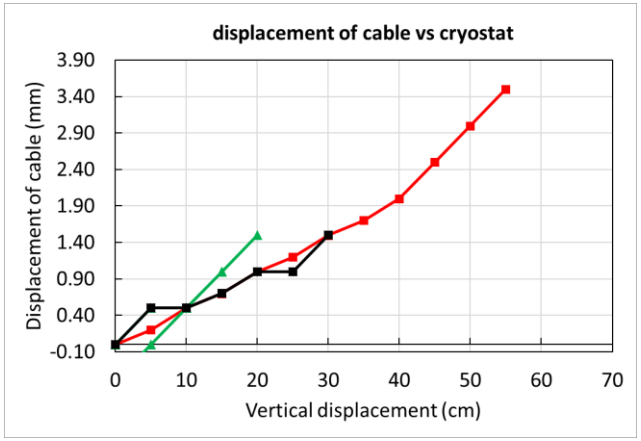


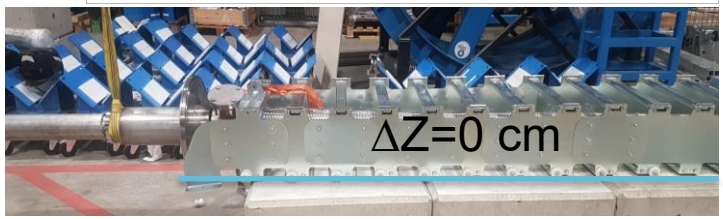
Mock-up for the measurement of displacement of MgB_2 cable during tilting of DFM cryostat

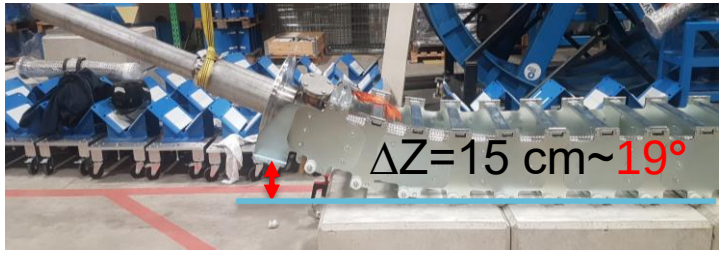
Courtesy of M. Careil, M. Curylo and J. Fleiter

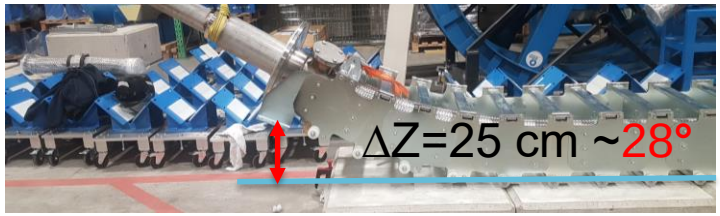
- A mock-up to measure the relative displacement of cable vs. cryostat built in 927
  - Prototype cryostat of DEMO IT system
  - Prototype cable of IT
- Mock-up allow for bending in only one direction with the cable chain of F2 test bench (Rmin=1.6 m)
- Cable was bent upwards, in a second mock-up it will be downward in a similar way as for the DFM







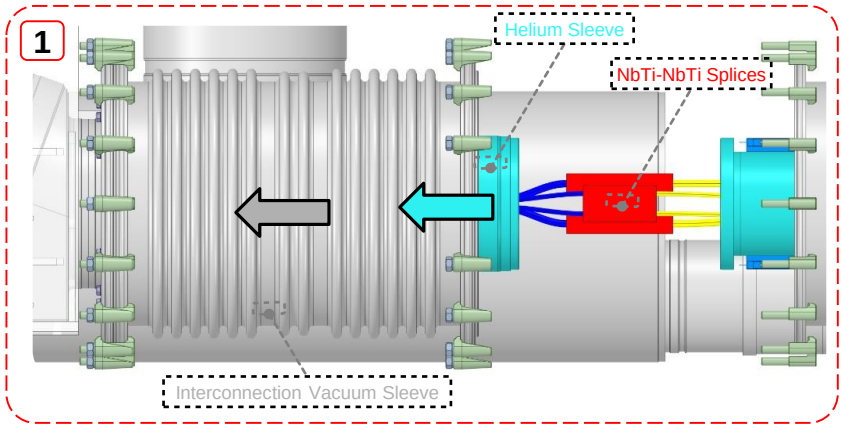


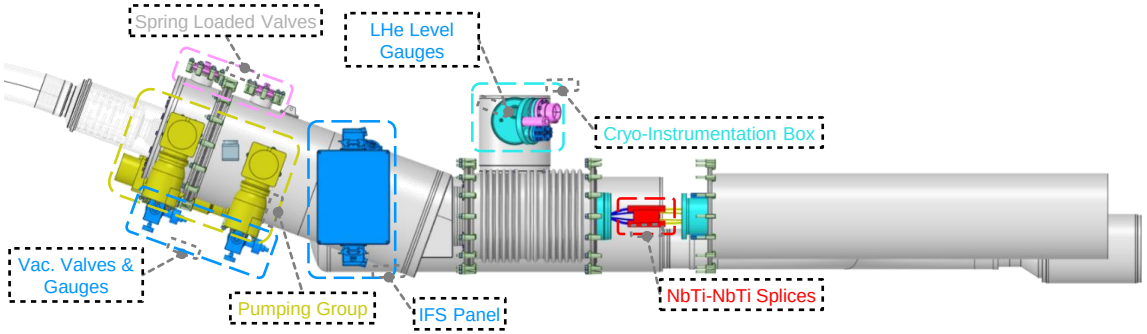


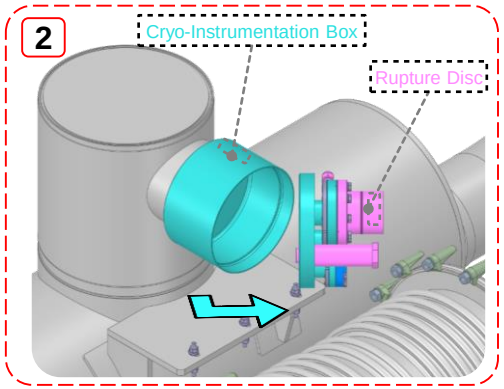
- **Cable displacement was about 0.9 mm for 15 cm vertical shift of cryostat**
- Advanced handling test with final tooling during DSHM / DFM prototype test in SM18

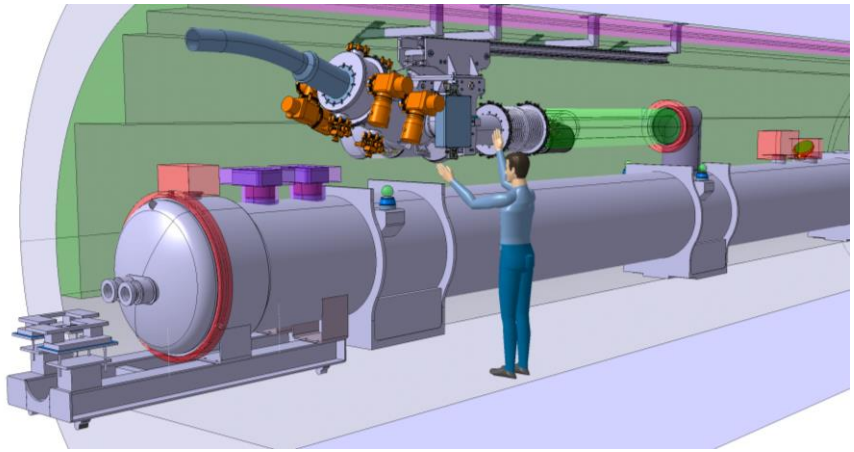
Maintenance

- **Preventive maintenance**
  - IFS & vacuum equipment & safety devices accessible from transport area
- **Unscheduled medium repair**
  1. LHC interconnection principle for repairing splices
     - Clamped vacuum bellow slid over vacuum vessel
     - Cut lip welds, slide He sleeve and access NbTi-NbTi splices
  2. Cryo-Instrumentations replacement (level gauges)
     - Cut lip weld, open Cryo-Instrumentation-Box and access wires
- **Unscheduled heavy repair**
  - Repairing MgB2-NbTi splices is considered as exceptional maintenance. Requires to put DFM back in connection position.









Courtesy of F. Di Ciocchis

Conclusions

- Mechanical Interfaces
  - Defined with QXL, D2, DSHM
  - Conceptual for support structure on tunnel vault
- Electrical interfaces
  - Defined for instrumentation
  - Design for splices by TE-MSC
- Assembly
  - All steps and welds defined in a detailed document
- DSHM-DFM installation
  - Transport has been studied for all four location with a dedicated tool
  - Conceptual sequence is proposed, feasibility being verified with practical tests in 927
  - Detailed study of the tooling to be continued
  - Will be finalized and validated during qualification of DSHM in SM18
- Maintenance
  - Preventive maintenance accessible from transport area
  - Repairing splices has been studied and is feasible in situ

Thank you for your attention

Credits:
All integration environment 3D models from Maria Amparo Gonzalez (CERN) – ATS-DO
Transport view of the DFM from Erik Richards – EN-HE
Drag chain test slide from M. Careil (CERN), M. Curylo and J. Fleiter(CERN) – TE-MSC
Maintenance and assembly slides from Franco Di Ciocchis (CERN) – TE-MSC

SPARE SLIDES

Extraordinary Maintenance

- Access to MgB2-NbTi splices for unlikely repair is feasible reversing the assembly sequence