



## Recap on DFM Integration in the LHC tunnel

- **Activities completed,**
- **On-going studies,**
- **Next steps**

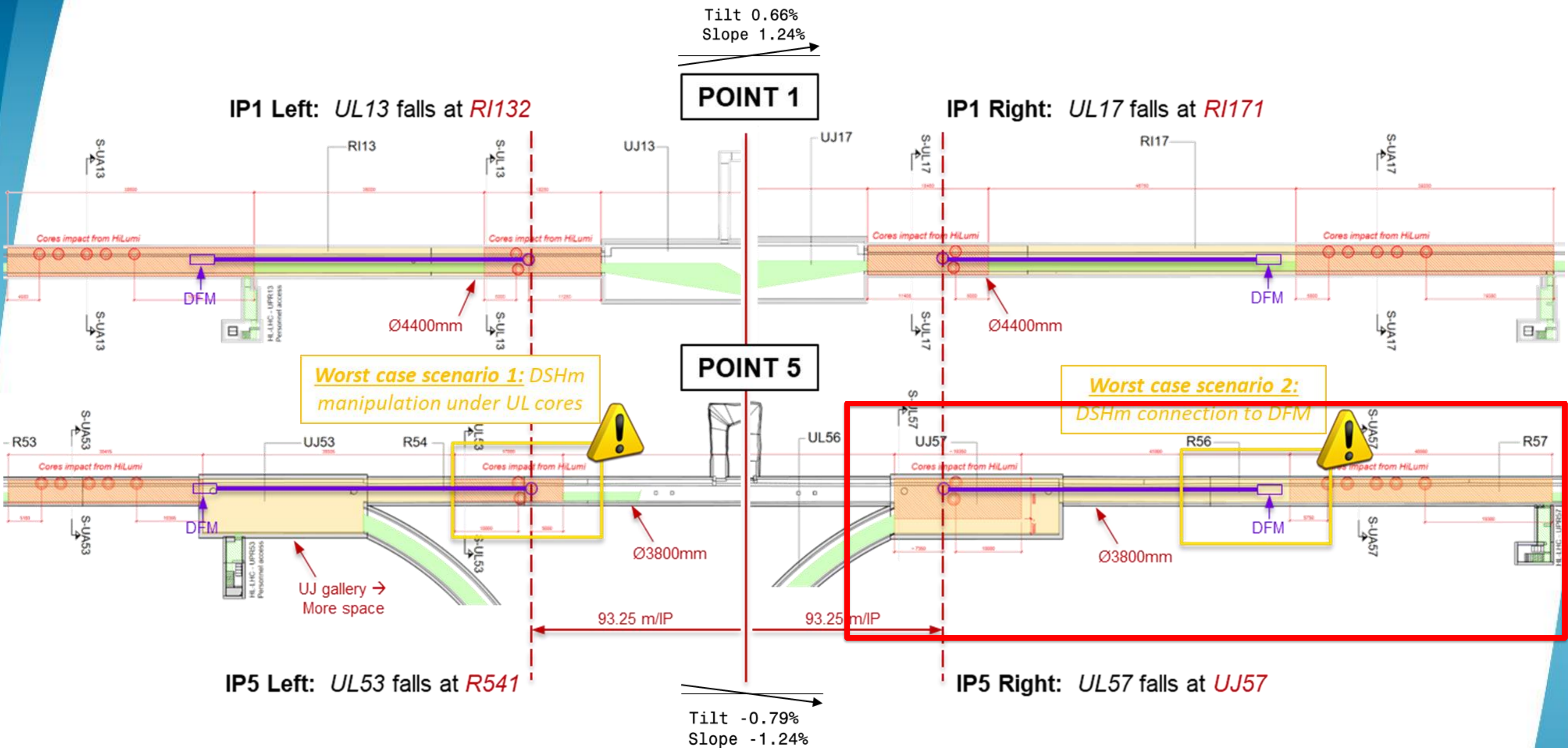
M. Gonzalez, G. Aparicio

# Outline

- **Recall on the boundary conditions in the existing LHC tunnels for P1 and P5**
- **Follow-up on the DFM and cryo-line Integration in the LHC tunnel**
  - Completed activities
  - On going studies
  - Pending points/ Next Steps
- **Summary table**
- **Conclusions**



# LHC tunnels dimensions at IP1 and IP5 (top view)



- Different QXL elevation in IP5 and IP1
- Different shape and dimension of the LHC tunnels
- Different Slope and Tilt

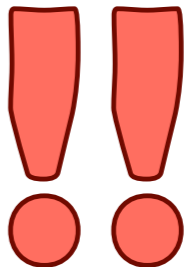
## WARNING!

→ Detailed integration has been performed in 5R → considered the **worst-case scenario**. The other 3 locations have been analysed copying and mirroring the provided models.

→ While we are confident that the main issues have been identified and dealt, the 4 specific integration studies could not be carried out at this point → it is a possible source of uncertainties.

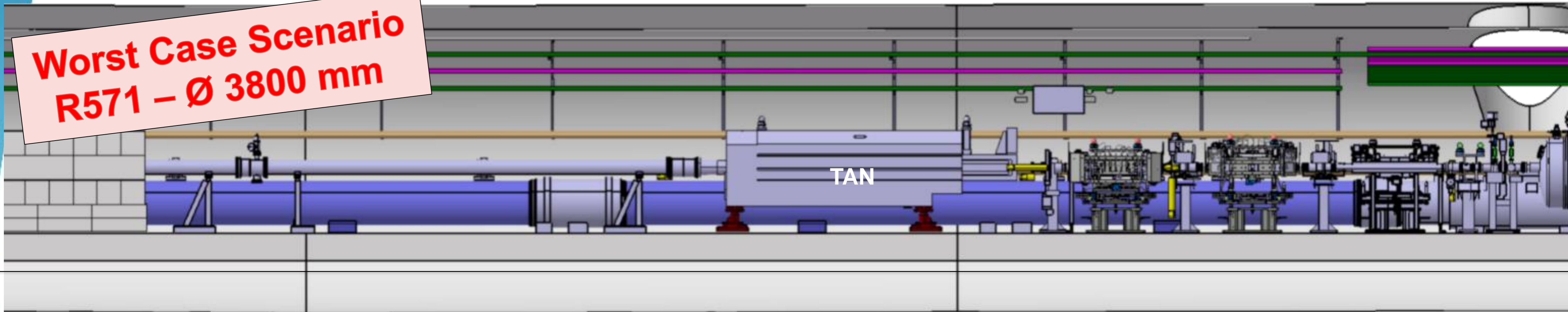


# MACHINE LAYOUT: IP5 RIGHT ZONE



LHC

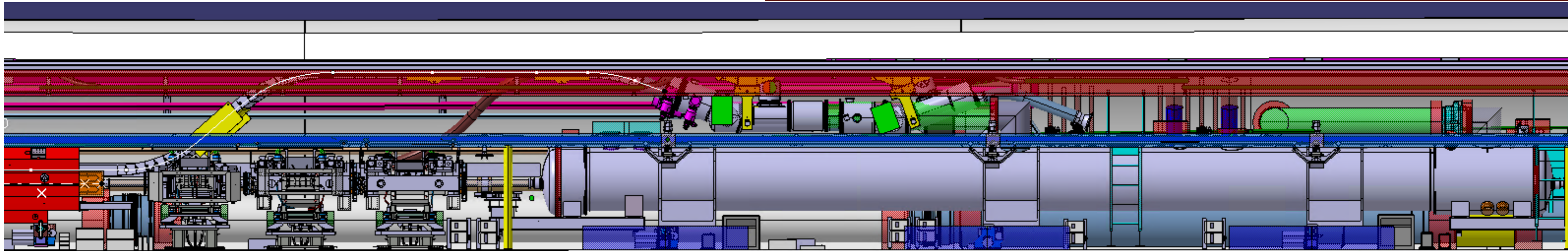
**Worst Case Scenario  
R571 - Ø 3800 mm**



132 134 136 138 140 142 144 146 148 150 152

No major changes for HL-LHC v.1.6

HL\_LHC v.1.5



30000 132000 mm 134000 136000 138000 140000 142000 144000 146000 148000 150000 152000



# MACHINE LAYOUT: IP5 LEFT ZONE

LHC

UJ53

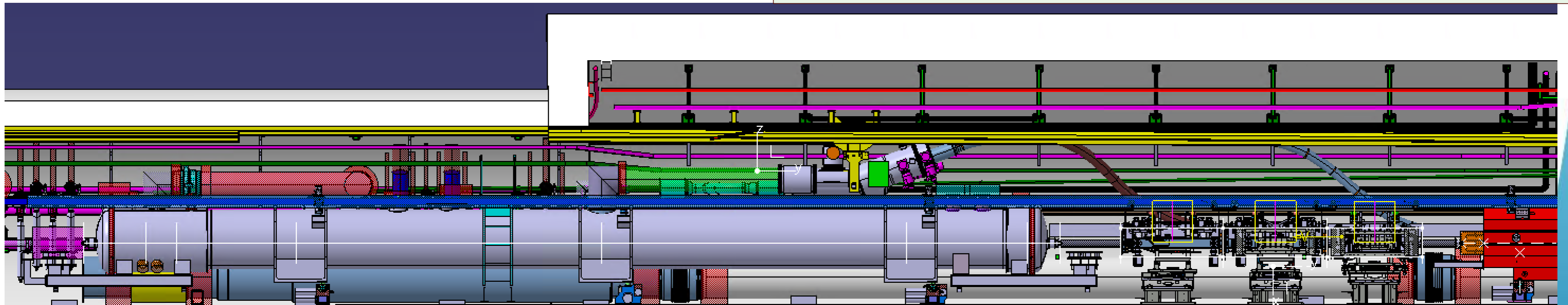
R532

TAN

-152 -150 -148 m -146 -144 -142 -140 -138 -136 -134 -132 -130

HL\_LHC v.1.5

No major changes for HL-LHC v.1.6

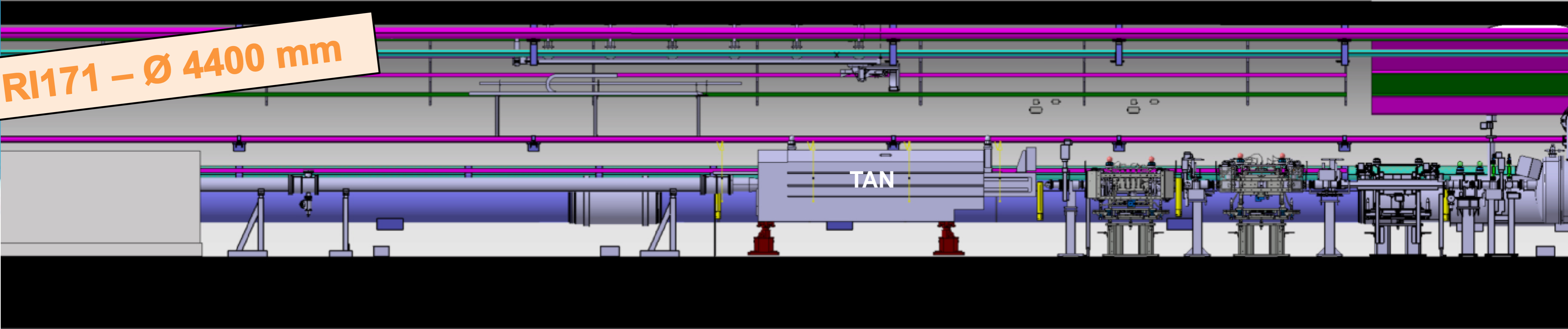


-152000 mm -150000 -148000 -146000 -144000 -142000 -140000 -138000 -136000 -134000 -132000 -130000

# MACHINE LAYOUT: IP1 RIGHT ZONE

LHC

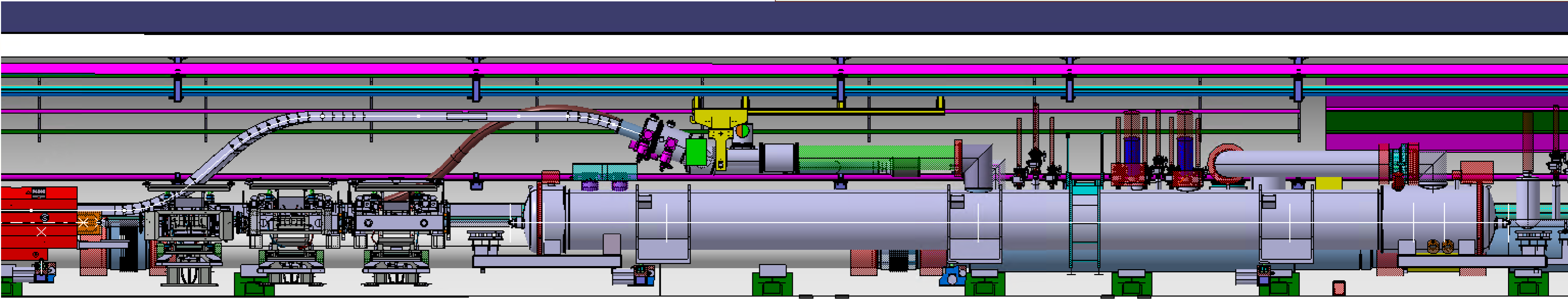
RI171 - Ø 4400 mm



130 132 134 136 138 140 142 144 146 148 150 152

HL\_LHC v.1.5

No major changes for HL-LHC v.1.6



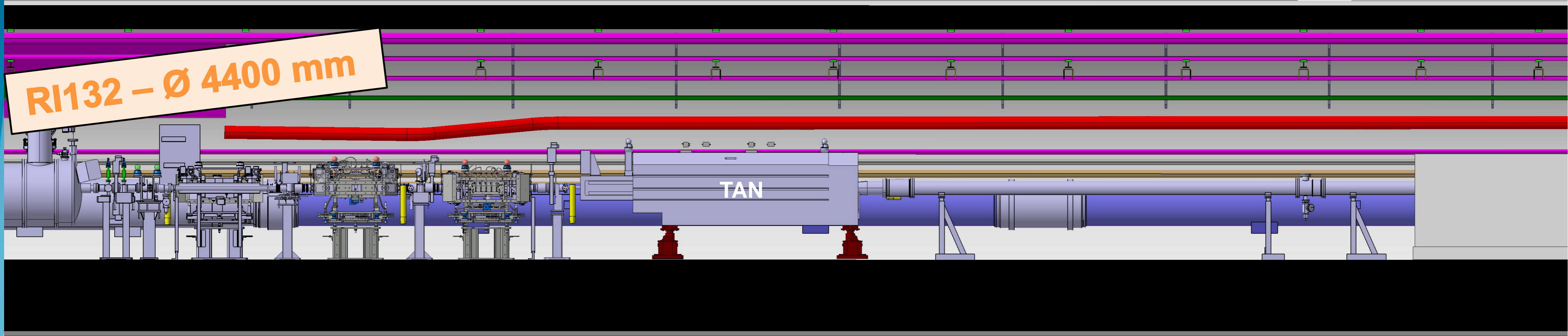
130000 132000 mm 134000 136000 138000 140000 142000 144000 146000 148000 150000 152000



# MACHINE LAYOUT: IP1 LEFT ZONE

LHC

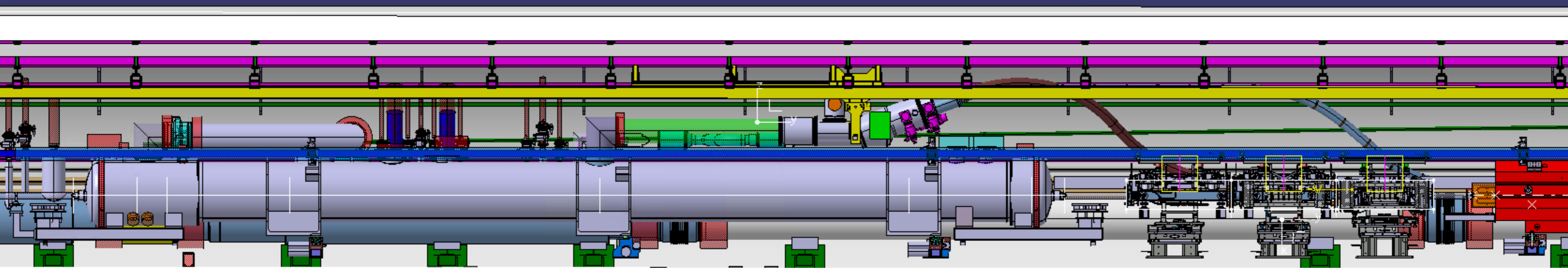
RI132 – Ø 4400 mm



-152      -150      -148      m      -146      -144      -142      -140      -138      -136      -134      -132      -130

HL\_LHC v.1.5

No major changes for HL-LHC v.1.6



-152000      -150000      -148000      mm      -146000      -144000      -142000      -140000      -138000      -136000      -134000      -132000      -130000



# DFM Integration

## DFM Integration

### ➤ Completed activities

- WP6a • 3D Simplified models: only provided for **5R**.
- WP15 • Temporary solution for 5L, 1R and 1L
- WP15 • Study of **boundary conditions** in the LHC tunnel

### ➤ On going studies

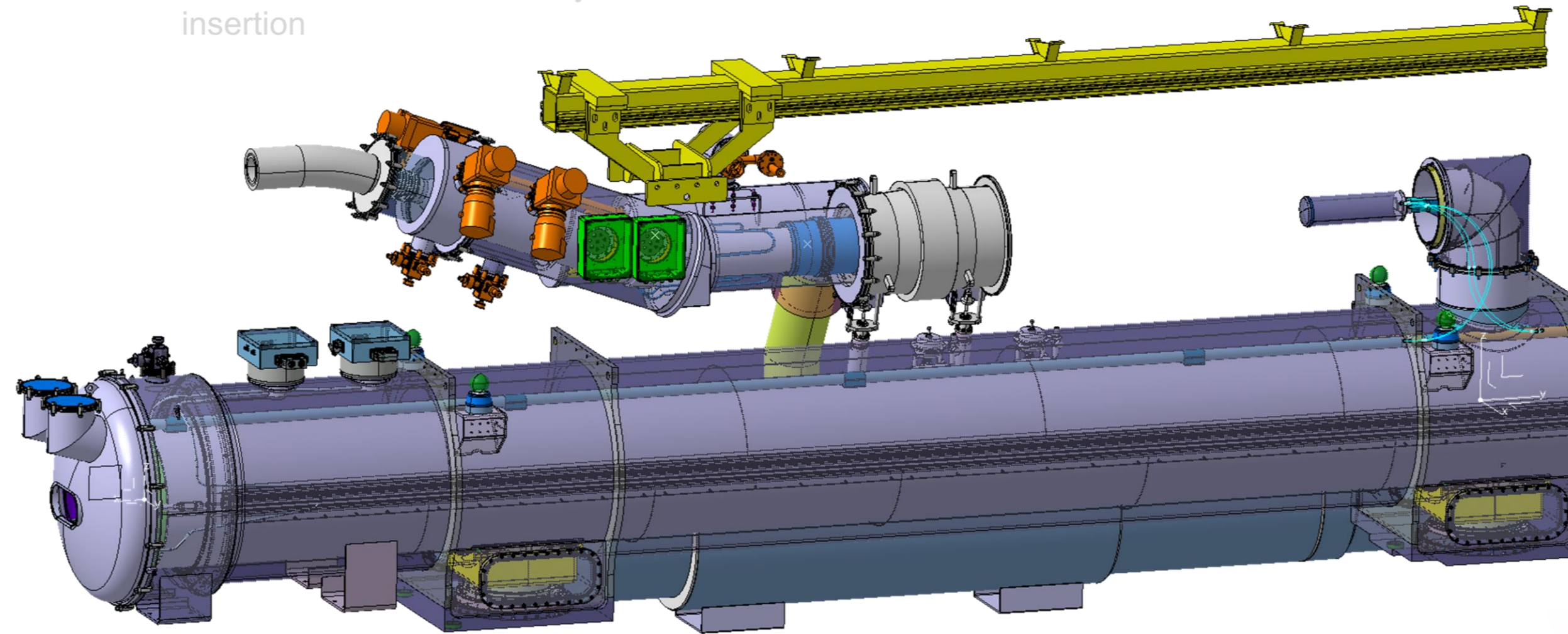
- All WP • Design of new **HL-LHC services** in the tunnel (5R)
- WP6a • Definition of **cryo-line flexible extension design / DFM integration solution**
- WP6a|15 • Definition of **reference points** in the LHC tunnel

### ➤ Pending points/ Next Steps

- WP6a • **Finalise DFM design** (including expected inclination of the cryostat, shorten the beam by 20cm)
- WP6a • Provide 3D simplified models for **5L, 1R and 1L**, and corresponding supporting solutions.
- WP6a • Consider ancillaries below D2
- Consider QXL current design is **NOT** the final design

Latest version includes the DFM in 3 different positions:

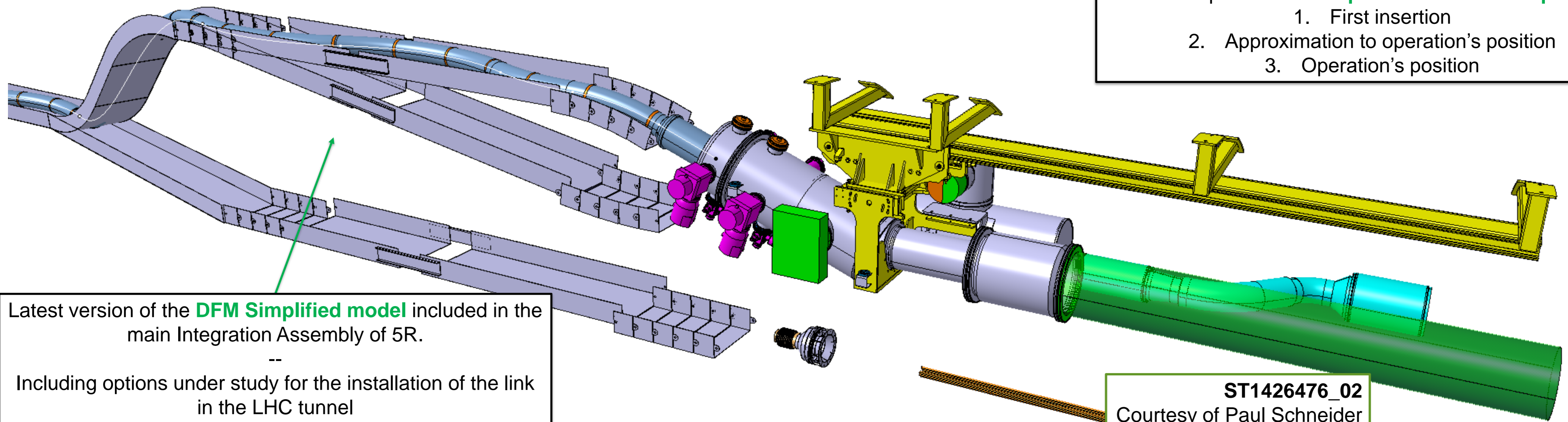
- DFM position in operation
- DFM tilted for splice connection
- DFM tilted and translated by 2250 mm for cable insertion



From **Integration point of view**:

Reserved space → **envelope of the 3 different positions**:

1. First insertion
2. Approximation to operation's position
3. Operation's position



Latest version of the **DFM Simplified model** included in the main Integration Assembly of 5R.

--  
Including options under study for the installation of the link in the LHC tunnel

ST1426476\_02  
Courtesy of Paul Schneider



# DFM Integration

## DFM Integration

### ➤ Completed activities

- WP6a • 3D Simplified models: only provided for **5R**.
- WP15 • Temporary solution for 5L, 1R and 1L
- WP15 • Study of **boundary conditions** in the LHC tunnel

### ➤ On going studies

- All WP • Design of new **HL-LHC services** in the tunnel (5R)
- WP6a • Definition of **cryo-line flexible extension design / DFM integration solution**

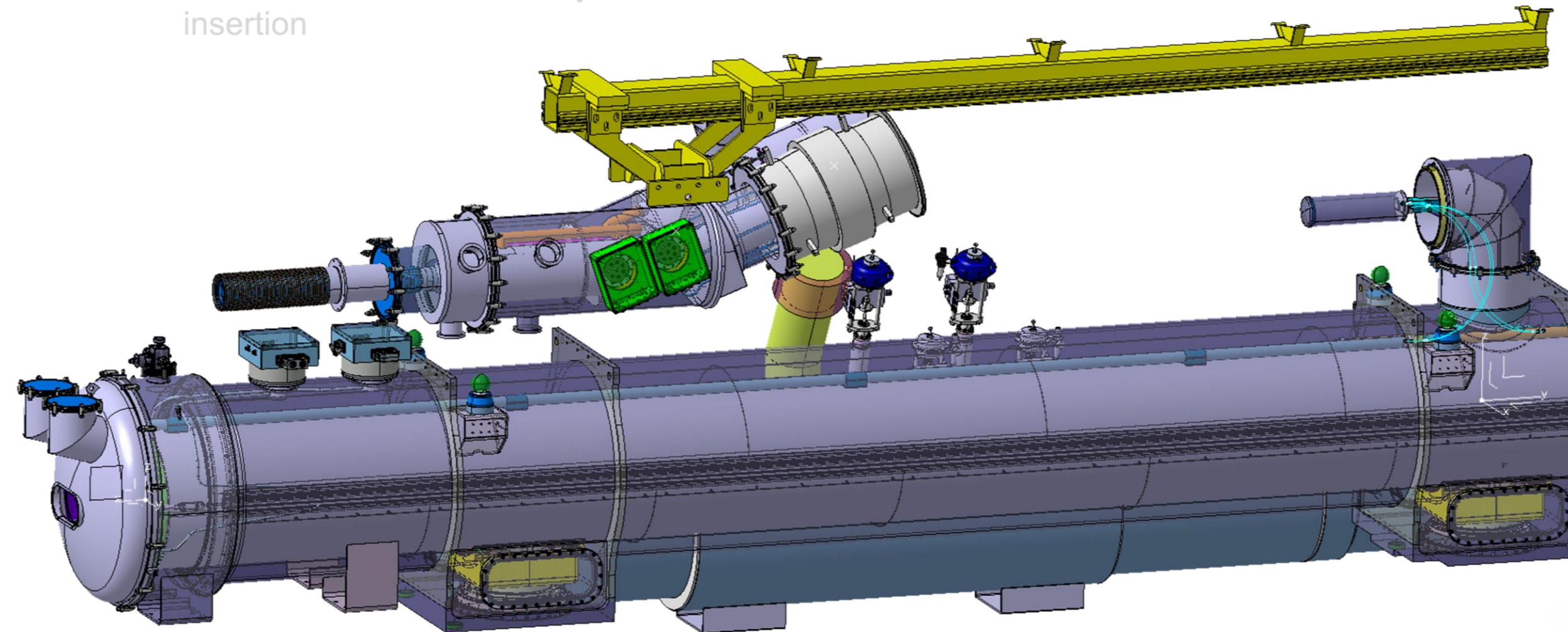
- WP6a|15 • Definition of **reference points** in the LHC tunnel

### ➤ Pending points/ Next Steps

- WP6a • **Finalise DFM design** (including expected inclination of the cryostat, shorten the beam by 20cm)
- WP6a • Provide 3D simplified models for **5L, 1R and 1L**, and corresponding supporting solutions.
- WP6a • Consider ancillaries below D2
- WP6a • Consider QXL current design is **NOT** the final design

Latest version includes the DFM in 3 different positions:

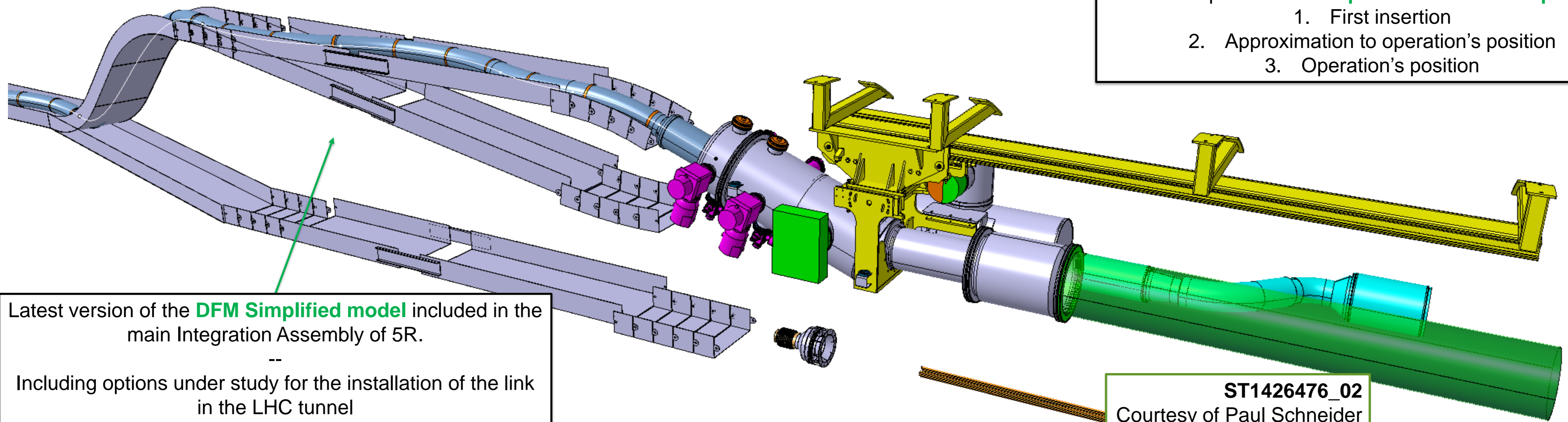
- DFM position in operation
- DFM tilted for splice connection
- DFM tilted and translated by 2250 mm for cable insertion



From **Integration point of view**:

Reserved space → **envelope of the 3 different positions**:

1. First insertion
2. Approximation to operation's position
3. Operation's position



Latest version of the **DFM Simplified model** included in the main Integration Assembly of 5R.

--  
Including options under study for the installation of the link in the LHC tunnel

**ST1426476\_02**  
Courtesy of Paul Schneider



# DFM Integration

## DFM Integration

### ➤ Completed activities

- WP6a • 3D Simplified models: only provided for **5R**.
- WP15 • Temporary solution for 5L, 1R and 1L
- WP15 • Study of **boundary conditions** in the LHC tunnel

### ➤ On going studies

- All WP • Design of new **HL-LHC services** in the tunnel (5R)
- WP6a • Definition of **cryo-line flexible extension design / DFM integration solution**

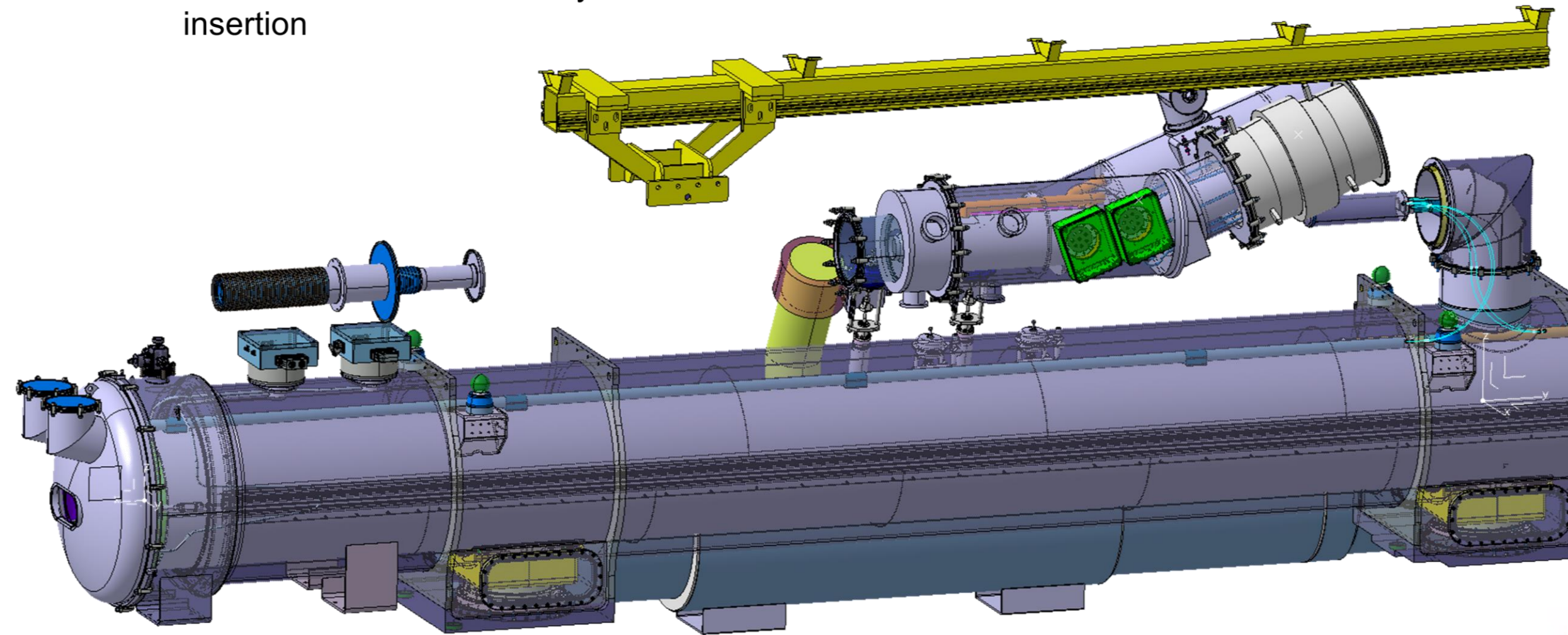
- WP6a|15 • Definition of **reference points** in the LHC tunnel

### ➤ Pending points/ Next Steps

- WP6a • **Finalise DFM design** (including expected inclination of the cryostat, shorten the beam by 20cm)
- WP6a • Provide 3D simplified models for **5L, 1R and 1L**, and corresponding supporting solutions.
- WP6a • Consider ancillaries below D2
- WP6a • Consider QXL current design is **NOT** the final design

Latest version includes the DFM in 3 different positions:

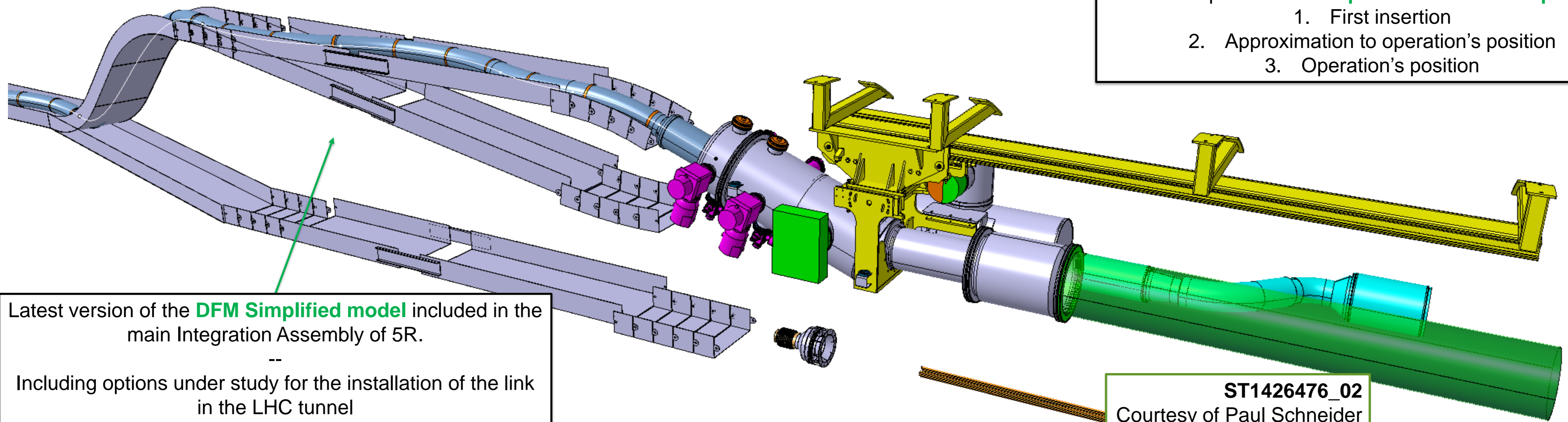
- DFM position in operation
- DFM tilted for splice connection
- DFM tilted and translated by 2250 mm for cable insertion



From **Integration point of view**:

Reserved space → **envelope of the 3 different positions**:

1. First insertion
2. Approximation to operation's position
3. Operation's position



Latest version of the **DFM Simplified model** included in the main Integration Assembly of 5R.

--  
Including options under study for the installation of the link in the LHC tunnel

ST1426476\_02  
Courtesy of Paul Schneider



# DFM Integration

## DFM Integration

### Completed activities

- WP6a • 3D Simplified models: only provided for 5R.
- WP15 • Temporary solution for 5L, 1R and 1L
- WP15 • Study of **boundary conditions** in the LHC tunnel

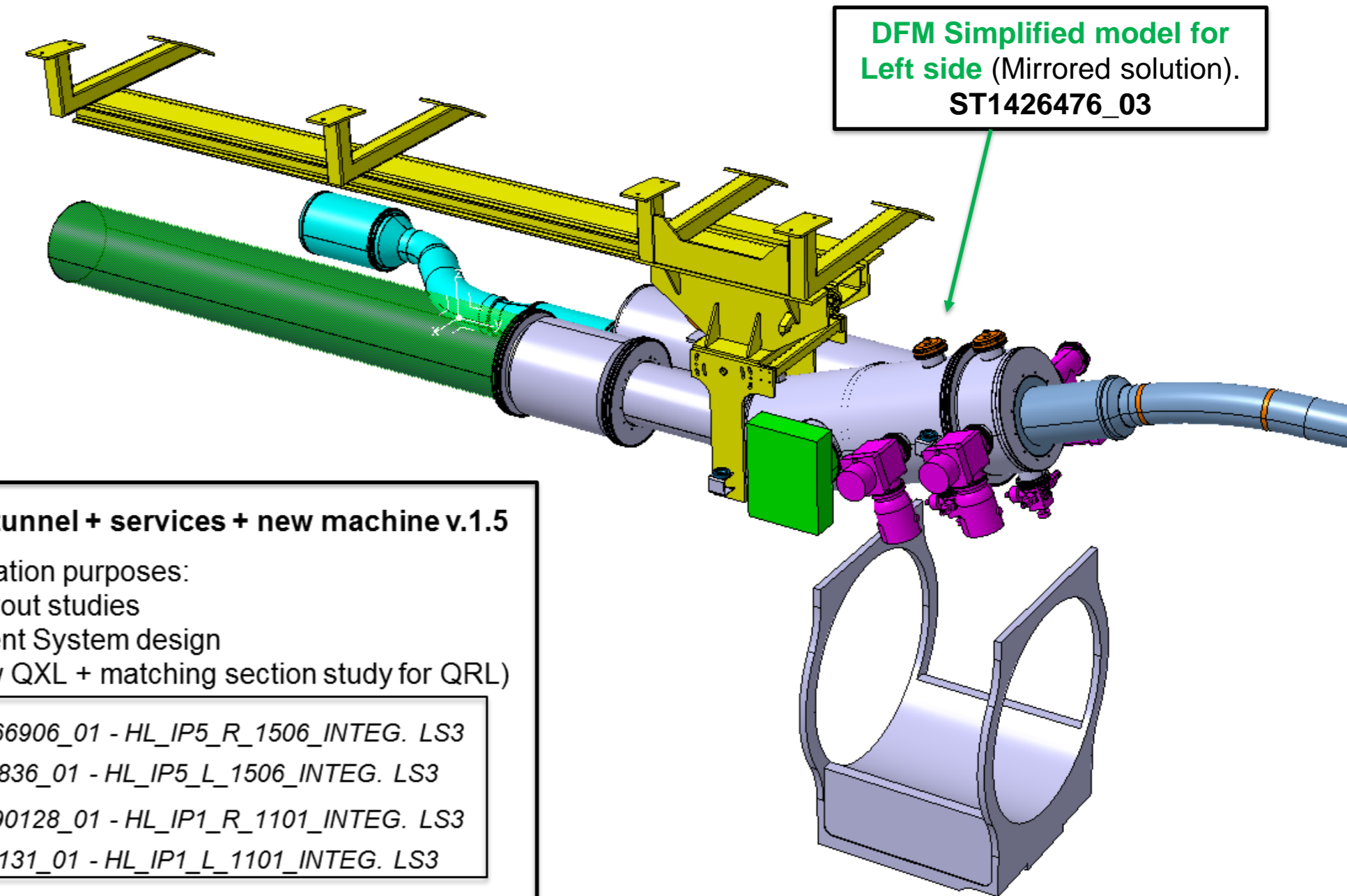
### On going studies

- All WP • Design of new HL-LHC services in the tunnel (5R)
- WP6a • Definition of cryo-line flexible extension design / DFM integration solution

- WP6a|15 • Definition of **reference points** in the LHC tunnel

### Pending points/ Next Steps

- WP6a • **Finalise DFM design** (including expected inclination of the cryostat, shorten the beam by 20cm)
- WP6a • Provide 3D simplified models for 5L, 1R and 1L, and corresponding supporting solutions.
- WP6a • Consider ancillaries below D2
- WP6a • Consider QXL current design is **NOT** the final design



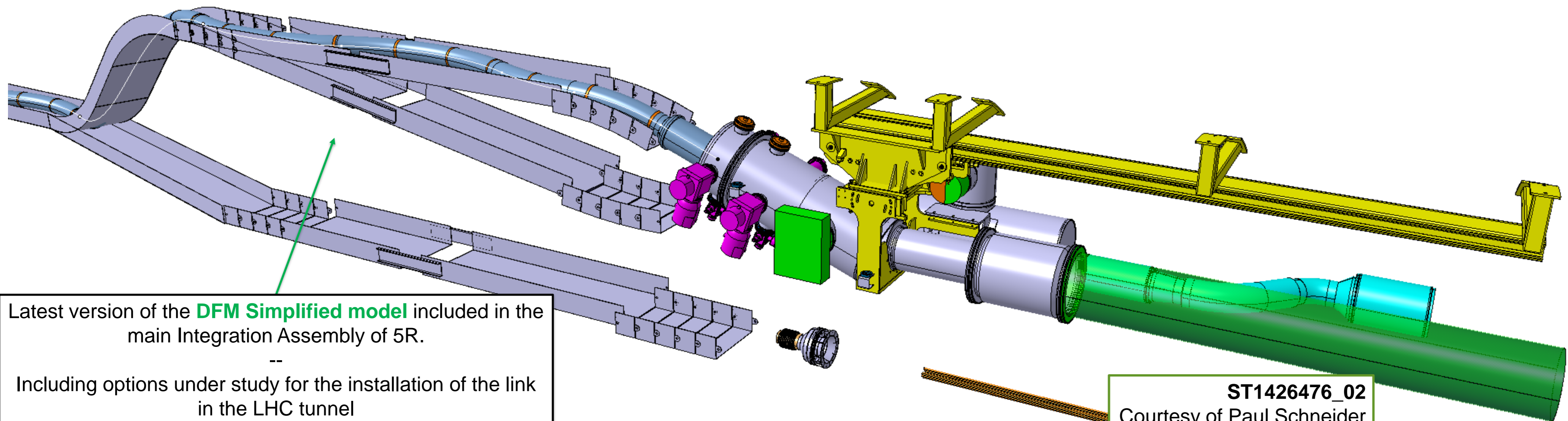
DFM Simplified model for Left side (Mirrored solution). ST1426476\_03

### Boundary Conditions

#### Full LSS (from Q1 till Q7): tunnel + services + new machine v.1.5

- Used for general integration purposes:
- HL-LHC machine layout studies
  - Full Remote Alignment System design
  - Cryoline design (new QXL + matching section study for QRL)

- IP5 Right: ST0966906\_01 - HL\_IP5\_R\_1506\_INTEG. LS3
- IP5 Left: ST0968836\_01 - HL\_IP5\_L\_1506\_INTEG. LS3
- IP1 Right: ST0990128\_01 - HL\_IP1\_R\_1101\_INTEG. LS3
- IP1 Left: ST0990131\_01 - HL\_IP1\_L\_1101\_INTEG. LS3



Latest version of the **DFM Simplified model** included in the main Integration Assembly of 5R.

--  
Including options under study for the installation of the link in the LHC tunnel

ST1426476\_02  
Courtesy of Paul Schneider



# DFM Integration

## DFM Integration

### ➤ Completed activities

- WP6a • 3D Simplified models: only provided for 5R.
- WP15 • Temporary solution for 5L, 1R and 1L
- WP15 • Study of **boundary conditions** in the LHC tunnel

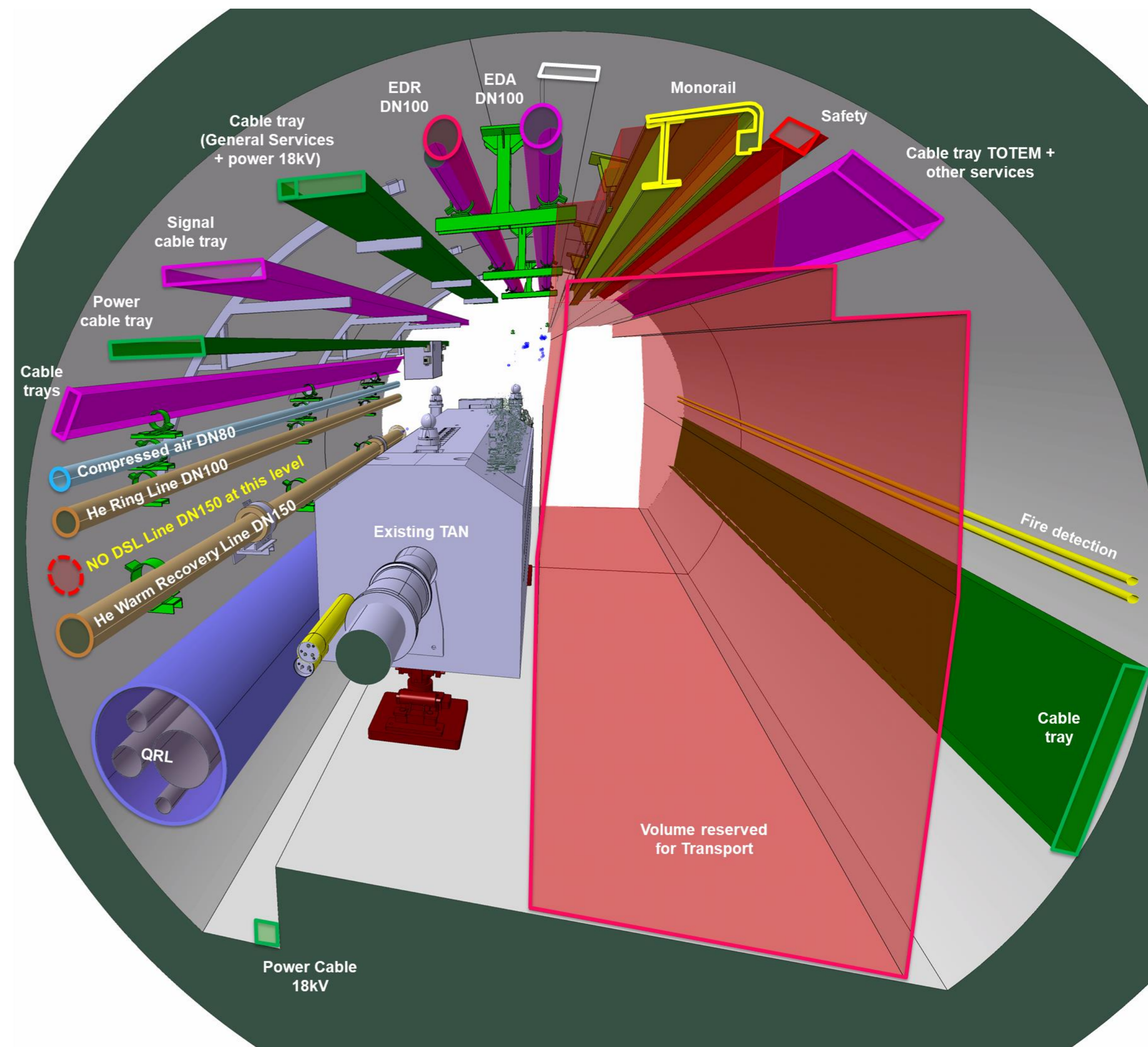
### ➤ On going studies

- All WP • Design of **new HL-LHC services** in the tunnel (5R)
- WP6a • Definition of **cryo-line flexible extension design / DFM integration solution**
- WP6a|15 • Definition of **reference points** in the LHC tunnel

### ➤ Pending points/ Next Steps

- WP6a • **Finalise DFM design** (including expected inclination of the cryostat, shorten the beam by 20cm)
- WP6a • Provide 3D simplified models for 5L, 1R and 1L, and corresponding supporting solutions.
- WP6a • Consider ancillaries below D2
  - Consider QXL current design is **NOT** the final design

## Existing LHC Services





# DFM Integration

## DFM Integration

### ➤ Completed activities

- WP6a • 3D Simplified models: only provided for 5R.
- WP15 • Temporary solution for 5L, 1R and 1L
- WP15 • Study of boundary conditions in the LHC tunnel

### ➤ On going studies

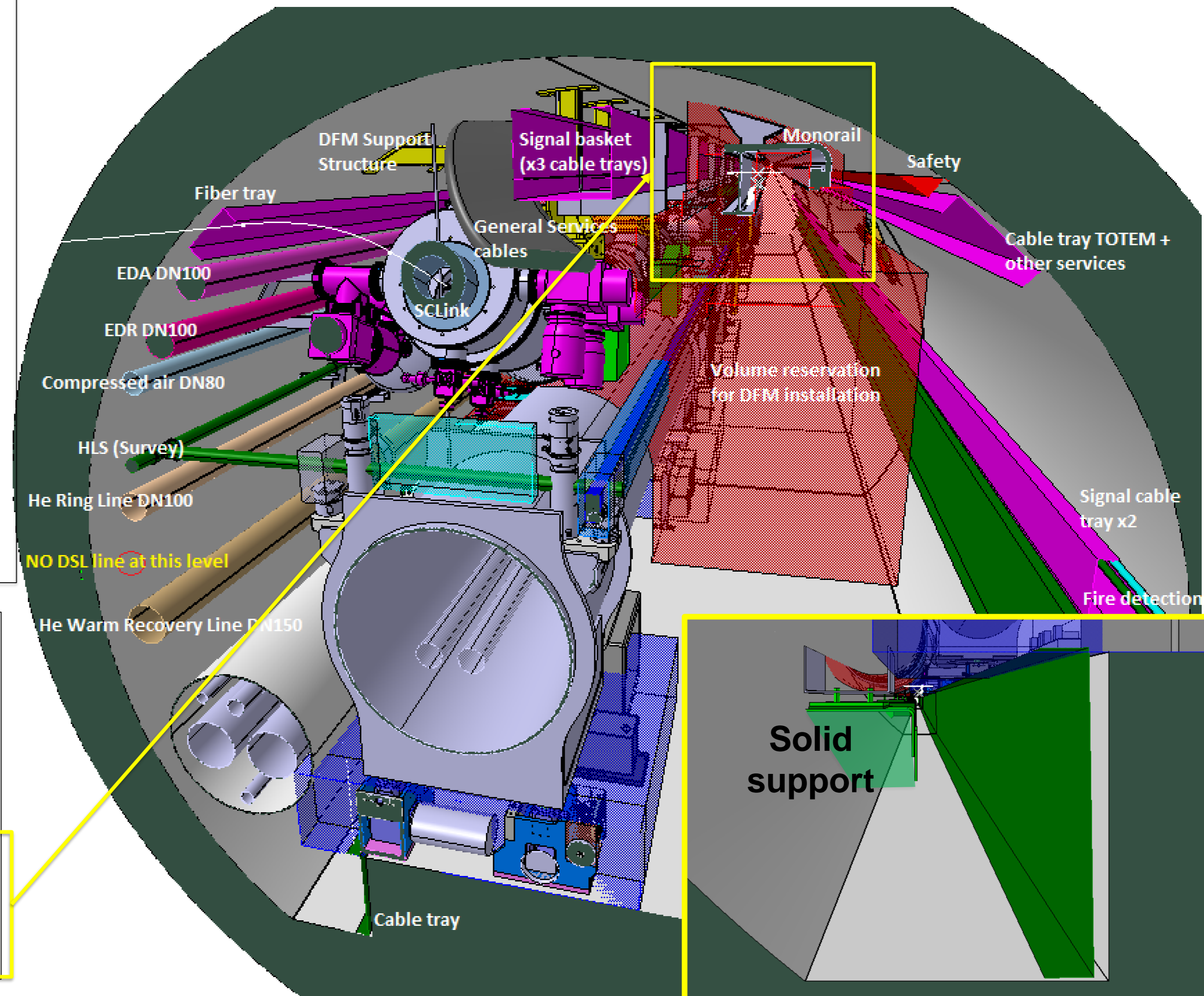
- All WP • Design of **new HL-LHC services** in the tunnel (5R)
  - WP6a • Definition of cryo-line flexible extension design / DFM integration solution
  - WP6a|15 • Definition of reference points in the LHC tunnel
- ### ➤ Pending points/ Next Steps
- WP6a • **Finalise DFM design** (including expected inclination of the cryostat, shorten the beam by 20cm)
  - WP6a • Provide 3D simplified models for 5L, 1R and 1L, and corresponding supporting solutions.
  - WP6a • Consider ancillaries below D2
    - Consider QXL current design is **NOT** the final design

Cable tray strategy → **ONGOING**

**Cable tray strategy is being reviewed by EN/EL and could change in the next couple of months**

Volume required for handling and installation has been counted in integration and it is being taken into account for the optimisation of all the services

## Proposed HL-LHC Services (at the present moment)





# DFM Integration

## DFM Integration

### Completed activities

- WP6a • 3D Simplified models: only provided for 5R.
- WP15 • Temporary solution for 5L, 1R and 1L
- WP15 • Study of boundary conditions in the LHC tunnel

### On going studies

- All WP • Design of **new HL-LHC services** in the tunnel (5R)
- WP6a • Definition of **cryo-line flexible extension design / DFM integration solution**

- WP6a|15 • Definition of reference points in the LHC tunnel

### Pending points/ Next Steps

- WP6a • Finalise DFM design (including expected inclination of the cryostat, shorten the beam by 20cm)
- WP6a • Provide 3D simplified models for 5L, 1R and 1L, and corresponding supporting solutions.
- WP6a • Consider ancillaries below D2
- Consider QXL current design is **NOT** the final design

Design of **new HL-LHC services** in the tunnel is currently under development: **cables trays** routing, **piping** routing...

**Old picture:** several problems have been sorted out

We will ask to represent the cable trays in drapeau, then it must be verified if still interfering

Supporting frame needs optimisation. Plus, the amount of cables will increased for HL era.

Proximity to main water lines (30mm)

**Current situation:** final number of bypass, gauges and pumping groups **to be confirmed**

**NO POSSIBILITY TO FURTHER RESTRICT THE RELOCATION OF THE NEW HL-LHC SERVICES**



# DFM Integration

## DFM Integration

### ➤ Completed activities

- WP6a • 3D Simplified models: only provided for 5R.
- WP15 • Temporary solution for 5L, 1R and 1L
- WP15 • Study of **boundary conditions** in the LHC tunnel

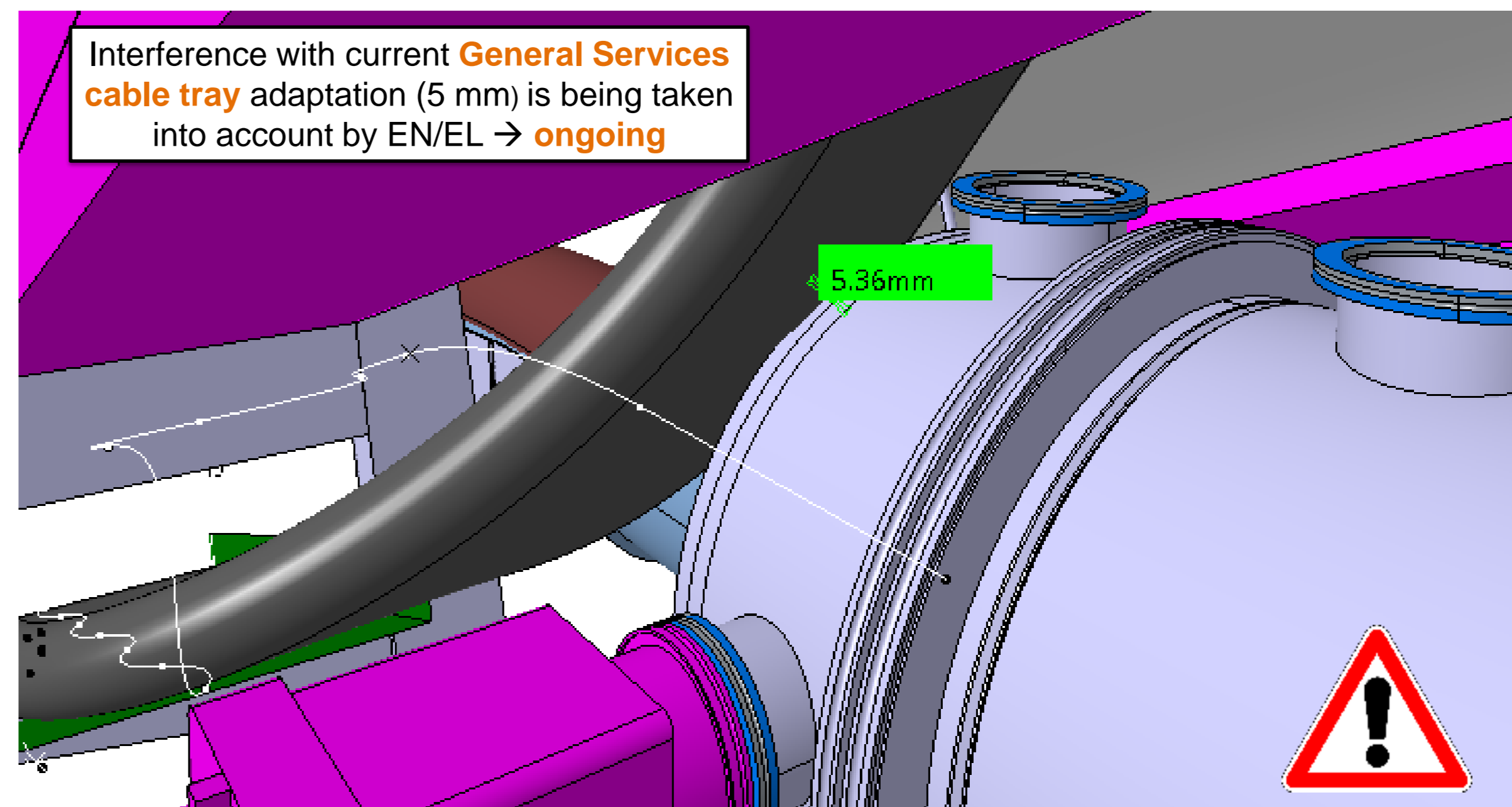
### ➤ On going studies

- All WP • Design of **new HL-LHC services** in the tunnel (5R)
- WP6a • Definition of **cryo-line flexible extension design / DFM integration solution**

- WP6a|15 • Definition of **reference points** in the LHC tunnel

### ➤ Pending points/ Next Steps

- WP6a • **Finalise DFM design** (including expected inclination of the cryostat, shorten the beam by 20cm)
- WP6a • Provide 3D simplified models for **5L, 1R and 1L**, and corresponding supporting solutions.
- WP6a • Consider ancillaries below D2
- Consider QXL current design is **NOT** the final design



Design of **new HL-LHC services** in the tunnel is currently under development: **cables trays routing, piping routing...**

**NO POSSIBILITY TO FURTHER RESTRICT THE RELOCATION OF THE NEW HL-LHC SERVICES**



# DFM Integration

## DFM Integration

### ➤ Completed activities

- WP6a • 3D Simplified models: only provided for 5R.
- WP15 • Temporary solution for 5L, 1R and 1L
- WP15 • Study of **boundary conditions** in the LHC tunnel

### ➤ On going studies

- All WP • Design of **new HL-LHC services** in the tunnel (5R)
- WP6a • Definition of **cryo-line flexible extension design / DFM integration solution**

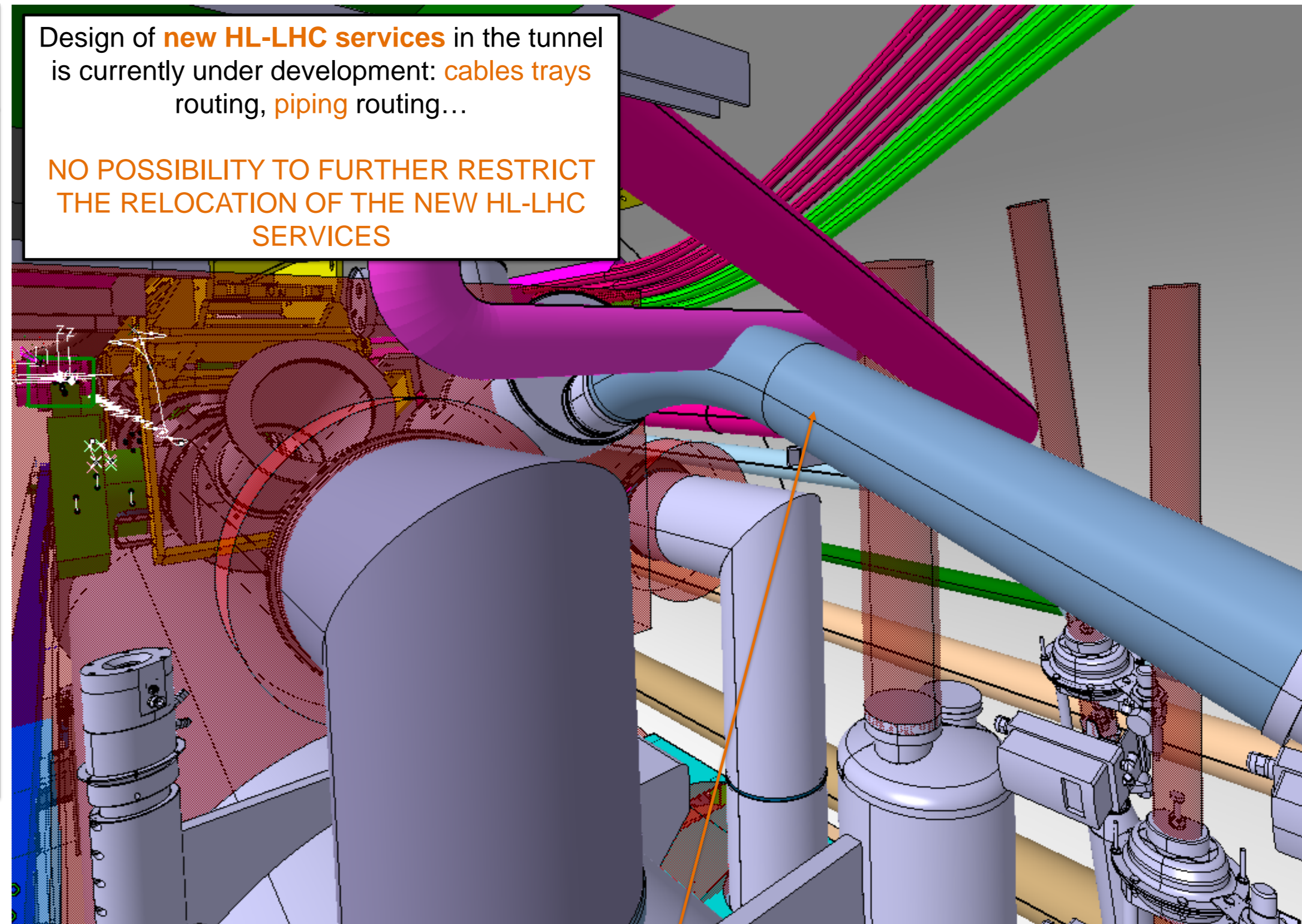
- WP6a|15 • Definition of **reference points** in the LHC tunnel

### ➤ Pending points/ Next Steps

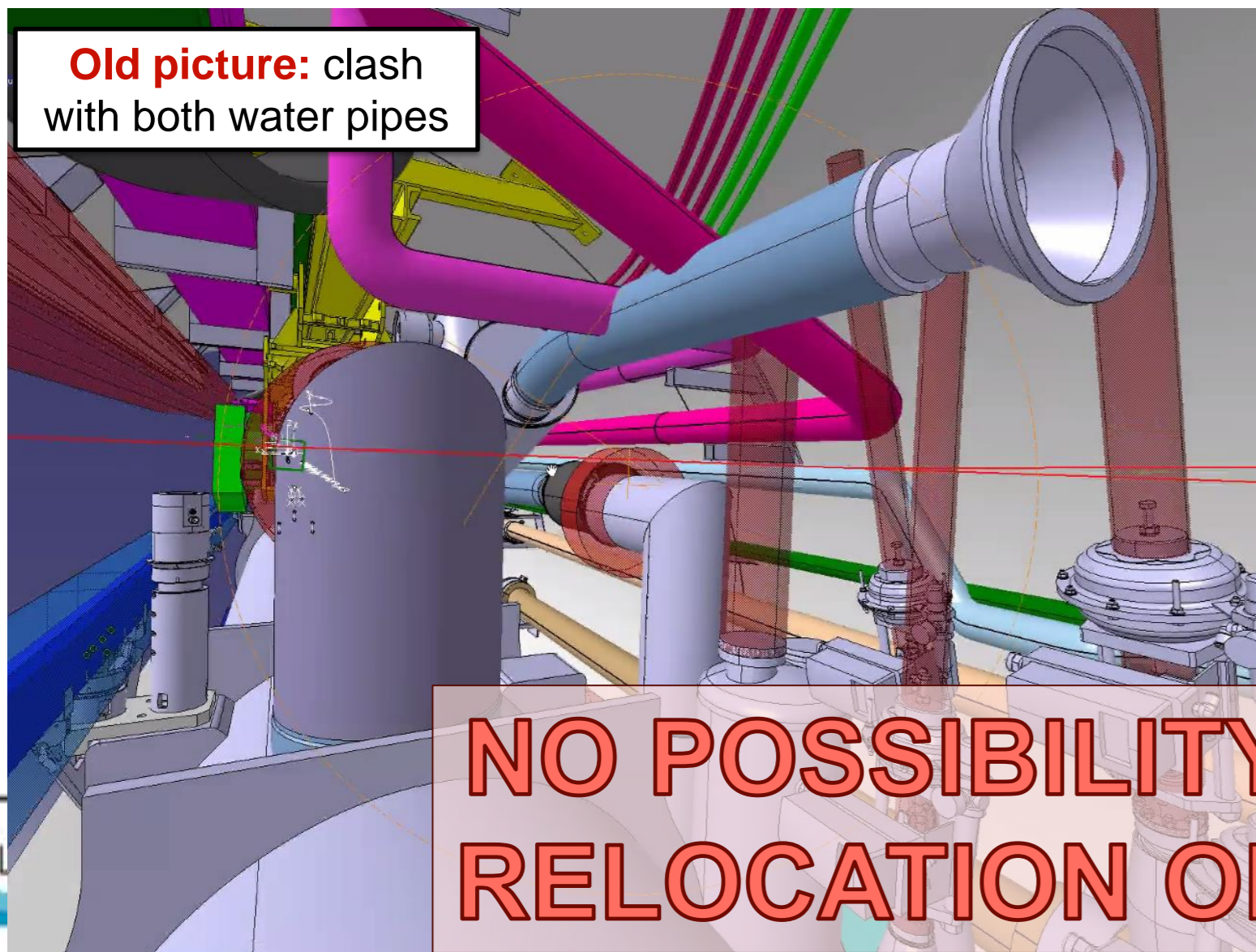
- WP6a • **Finalise DFM design** (including expected inclination of the cryostat, shorten the beam by 20cm)
- WP6a • Provide 3D simplified models for **5L, 1R and 1L**, and corresponding supporting solutions.
- WP6a • Consider ancillaries below D2
- Consider QXL current design is **NOT** the final design

Design of **new HL-LHC services** in the tunnel is currently under development: **cables trays routing, piping routing...**

**NO POSSIBILITY TO FURTHER RESTRICT THE RELOCATION OF THE NEW HL-LHC SERVICES**



**Old picture:** clash with both water pipes



Problem: Interference between **flexible extension for the connection to the cryo-line** and **water piping**

Possible solution on-going:

Increase the **flexibility of the extension** → extension below piping

**NO POSSIBILITY TO FURTHER RESTRICT THE RELOCATION OF THE NEW HL-LHC SERVICES**





# DFM Integration

## DFM Integration

### Completed activities

- WP6a • 3D Simplified models: only provided for 5R.
- WP15 • Temporary solution for 5L, 1R and 1L
- WP15 • Study of boundary conditions in the LHC tunnel

### On going studies

- All WP • Design of new HL-LHC services in the tunnel (5R)
- WP6a • Definition of cryo-line flexible extension design / DFM integration solution
- WP6a/15 • Definition of **reference points** in the LHC tunnel

### Pending points/ Next Steps

- WP6a • Finalise DFM design (including expected inclination of the cryostat, shorten the beam by 20cm)
- WP6a • Provide 3D simplified models for 5L, 1R and 1L, and corresponding supporting solutions.
- WP6a • Consider ancillaries below D2
- WP6a • Consider QXL current design is **NOT** the final design

All WP

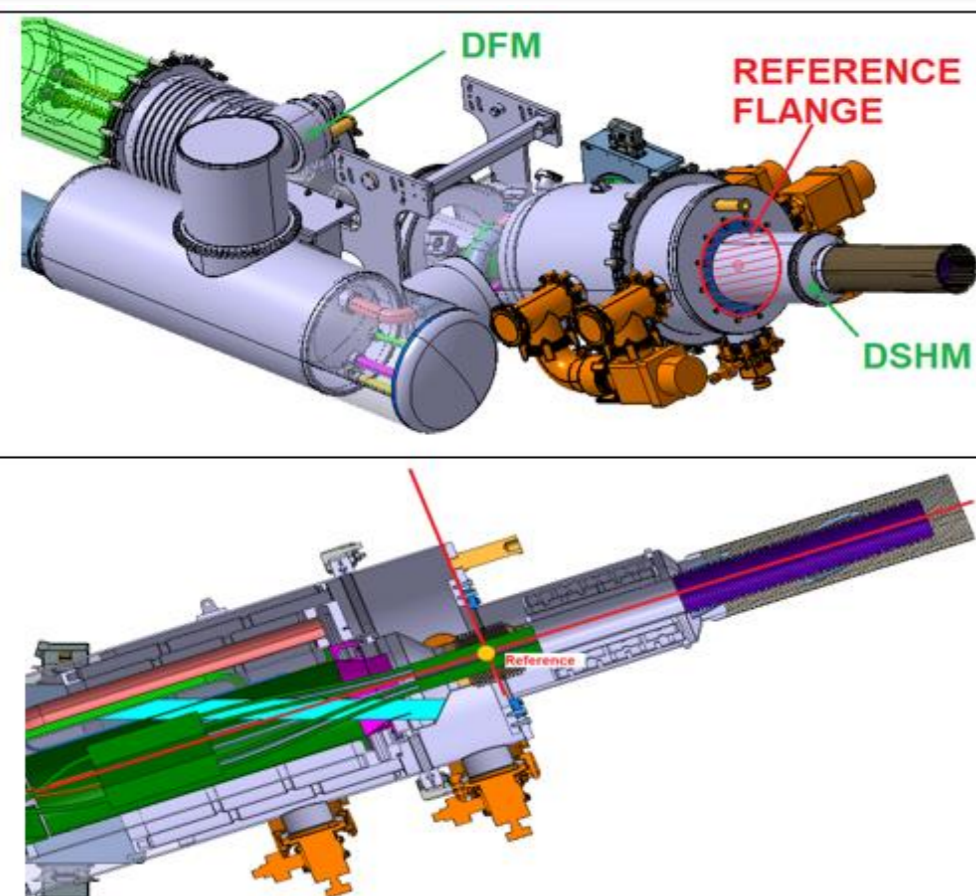


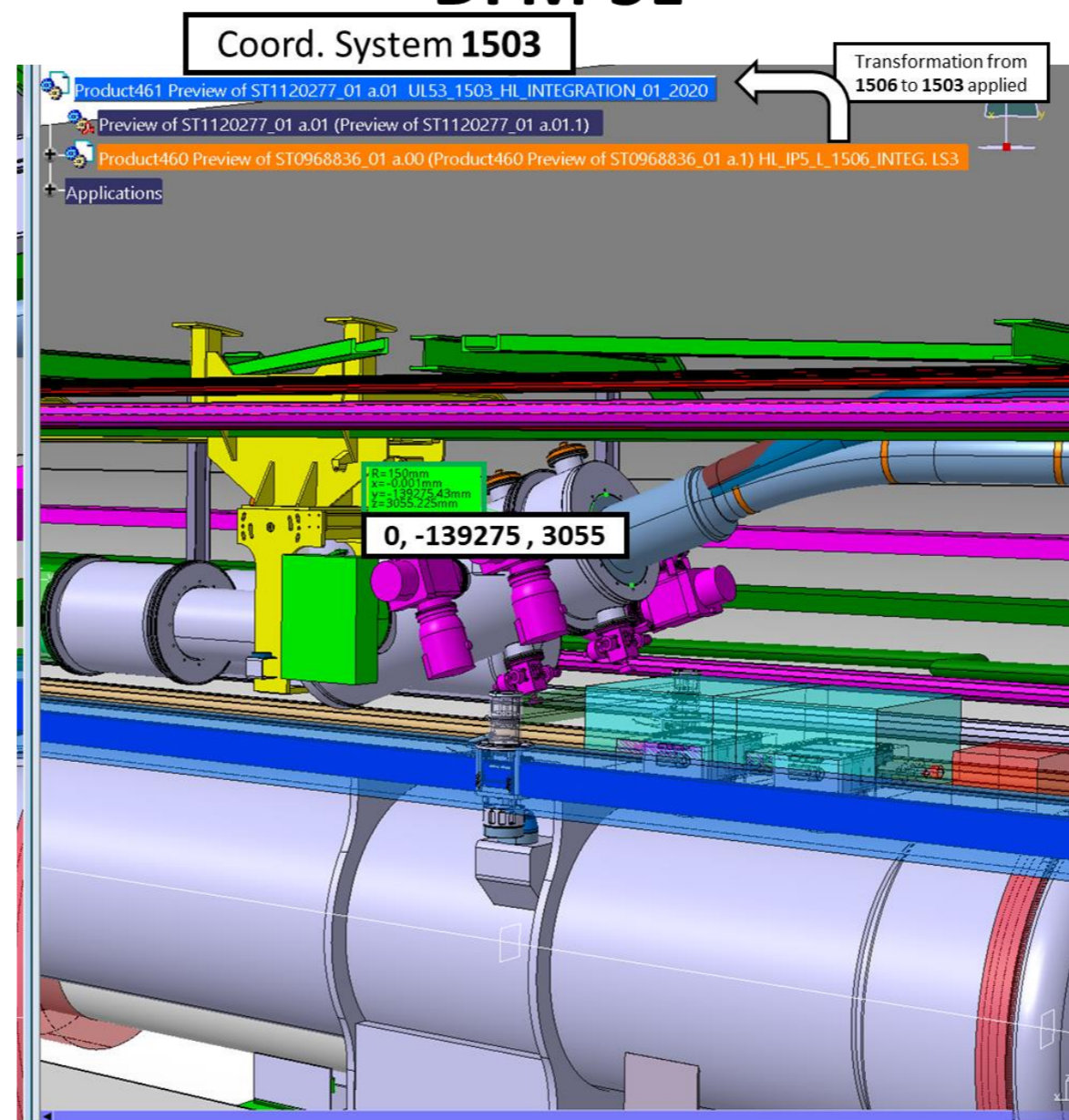
Fig. 7 DFM interface flange layout: on the top general view, below cross section through central axis in termination area

Table 3. Reference position of DFM system.

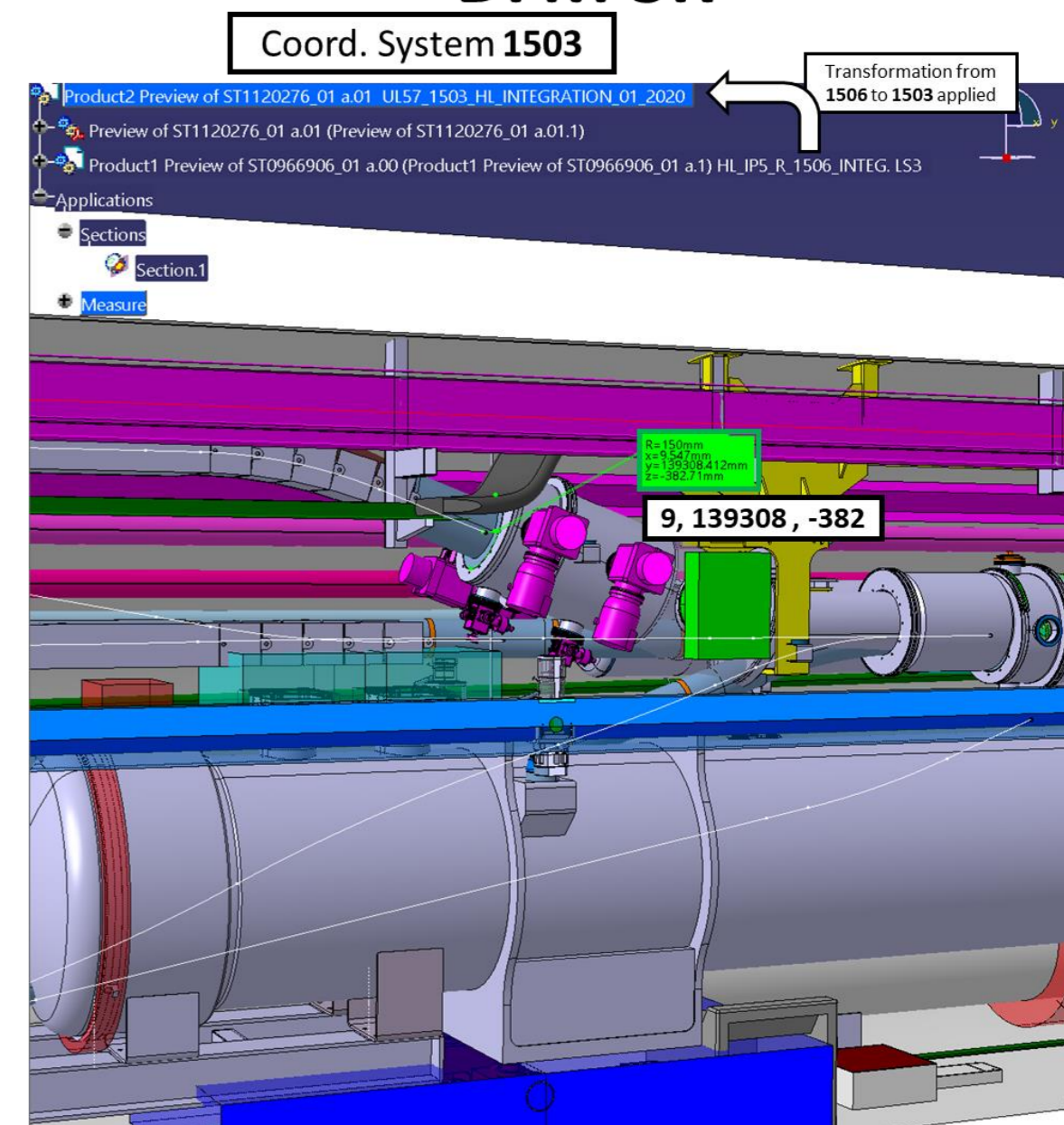
IP # - #: AXIS SYSTEM	SIDE (L) [X, Y, Z]	SIDE (R) [X, Y, Z]
IP 1 - DFM: CERN 1102	0, -139308, -385	0, 139275, 3058
IP 5 - DFM: CERN 1503	0, -139275, 3055	0, 139308, -382

**Reference points** provided in the reference system requested by WP6a were taken from the four Integration Assemblies (5R, 5L, 1R, 1L).

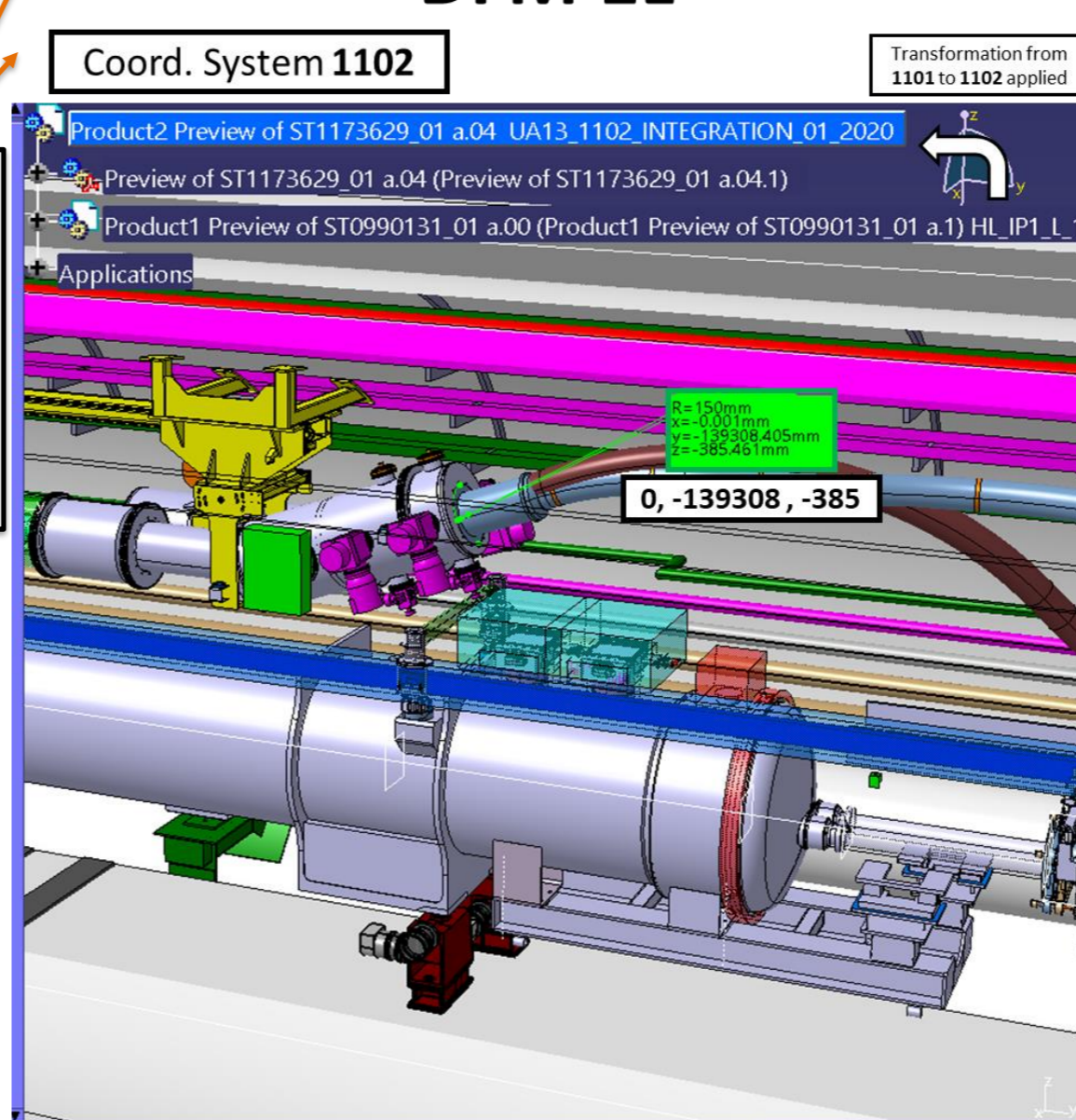
### DFM 5L



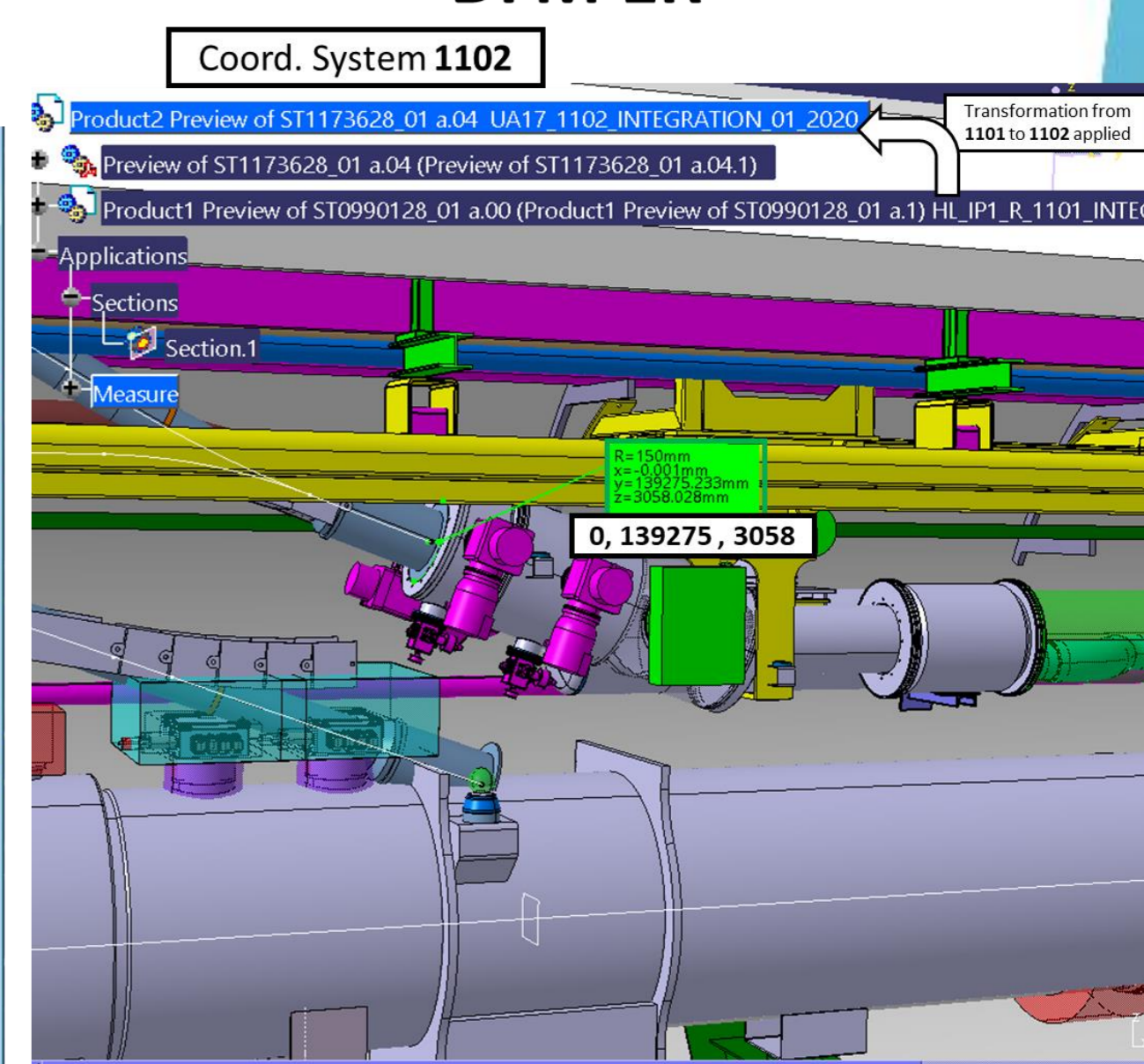
### DFM 5R



### DFM 1L



### DFM 1R





# DFM Integration

## DFM Integration

### ➤ Completed activities

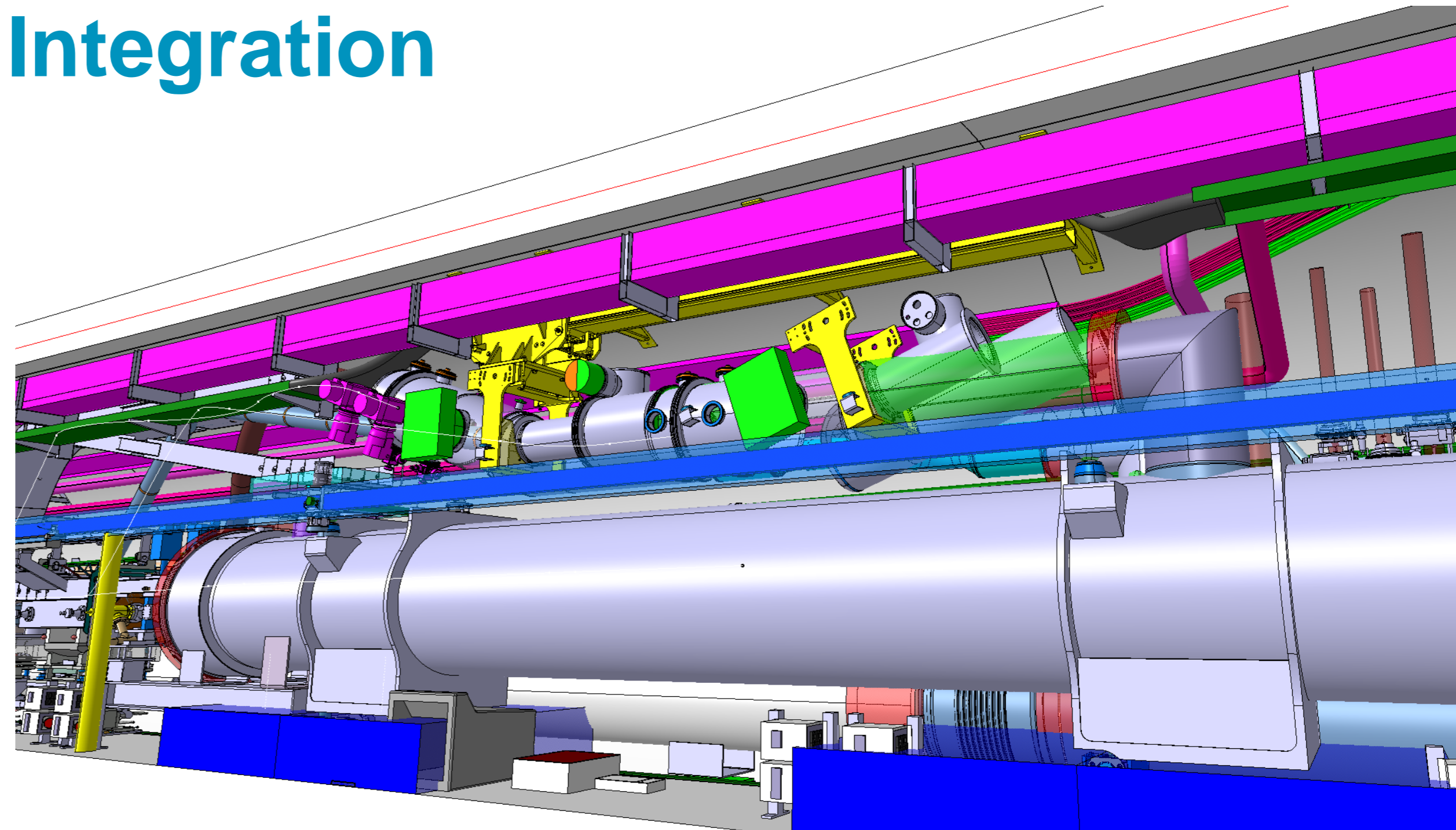
- WP6a • 3D Simplified models: only provided for 5R.
- WP15 • Temporary solution for 5L, 1R and 1L
- WP15 • Study of **boundary conditions** in the LHC tunnel

### ➤ On going studies

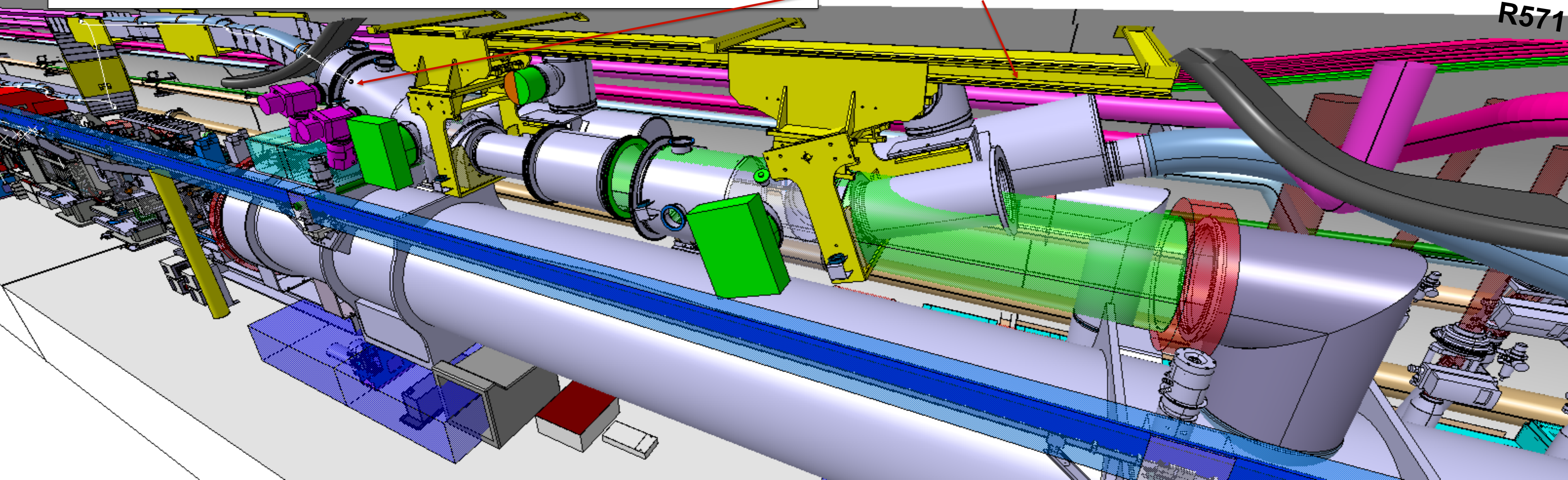
- All WP • Design of new HL-LHC services in the tunnel (5R)
- WP6a • Definition of **cryo-line flexible extension design / DFM integration solution**
- WP6a|15 • Definition of **reference points** in the LHC tunnel

### ➤ Pending points/ Next Steps

- WP6a • **Finalise DFM design** (including expected **inclination** of the cryostat, **shorten the beam** by 20cm)
- WP6a • Provide 3D simplified models for 5L, 1R and 1L, and corresponding supporting solutions.
- WP6a • Consider ancillaries below D2
  - Consider QXL current design is **NOT** the final design



In the DFM design there are still points that have to be finalised and optimised as: inclination of the cryostat, shorten the length of the supporting beam, possible final reduction in the number of pumping ports (worst-case scenario considered)...





# DFM Integration

## DFM Integration

### ➤ Completed activities

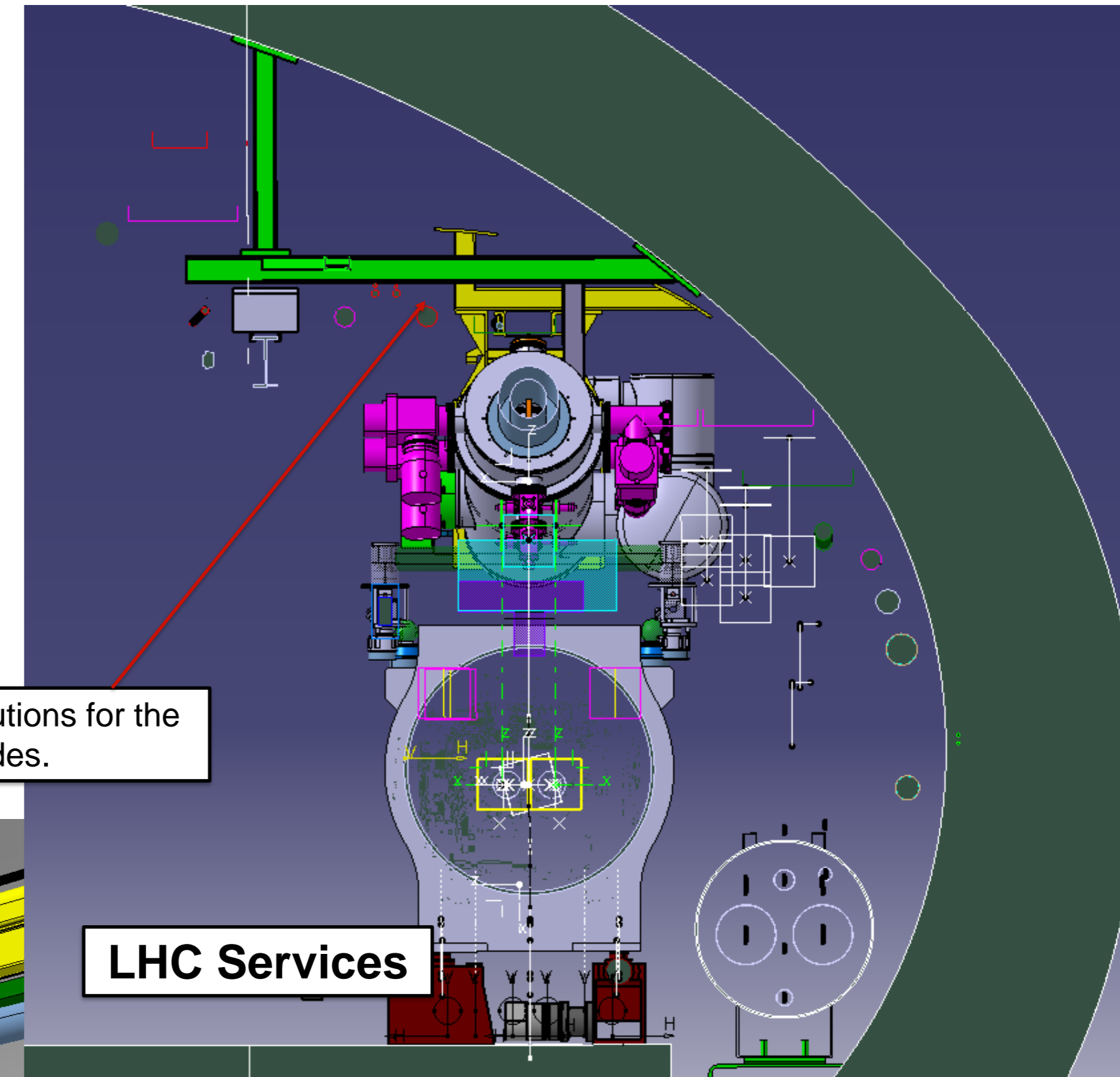
- WP6a • 3D Simplified models: only provided for 5R.
- WP15 • Temporary solution for 5L, 1R and 1L
- WP15 • Study of **boundary conditions** in the LHC tunnel

### ➤ On going studies

- All WP • Design of new HL-LHC services in the tunnel (5R)
- WP6a • Definition of **cryo-line flexible extension design / DFM integration solution**
- WP6a|15 • Definition of **reference points** in the LHC tunnel

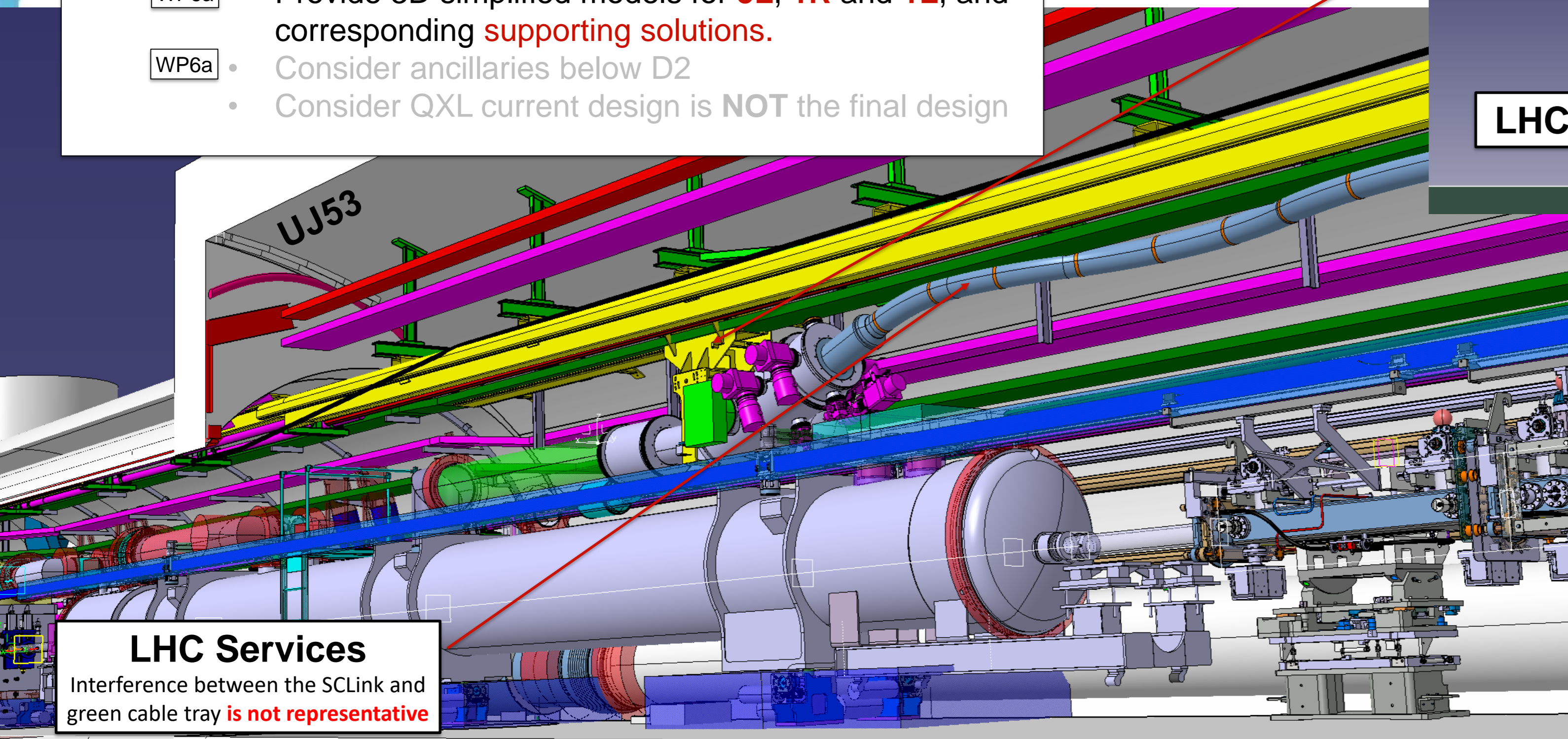
### ➤ Pending points/ Next Steps

- WP6a • **Finalise DFM design** (including expected inclination of the cryostat, shorten the beam by 20cm)
- WP6a • Provide 3D simplified models for **5L, 1R and 1L**, and corresponding **supporting solutions**.
- WP6a • Consider ancillaries below D2
- Consider QXL current design is **NOT** the final design



**Support frame** solutions for the other IP sides.

**LHC Services**



**LHC Services**

Interference between the SCLink and green cable tray **is not representative**

It is **NOT FORESEEN** to **MODIFY** the **GREEN STRUCTURE** in **UJ53**





# DFM Integration

## DFM Integration

### ➤ Completed activities

- WP6a • 3D Simplified models: only provided for 5R.
- WP15 • Temporary solution for 5L, 1R and 1L
- WP15 • Study of **boundary conditions** in the LHC tunnel

### ➤ On going studies

- All WP • Design of new **HL-LHC services** in the tunnel (5R)
- WP6a • Definition of **cryo-line flexible extension design / DFM integration solution**
- WP6a|15 • Definition of **reference points** in the LHC tunnel

### ➤ Pending points/ Next Steps

- WP6a • **Finalise DFM design** (including expected inclination of the cryostat, shorten the beam by 20cm)
- WP6a • Provide 3D simplified models for **5L, 1R and 1L**, and corresponding supporting solutions.
- WP6a • **Consider ancillaries below D2**
  - Consider QXL current design is **NOT** the final design

## **Ancillaires distribution currently under study!**

**Already integrated** in 3D integration models:

### **D2 ancillaries:**

- *Jacks + reserved space*
- *Motors Patch panel + Fiber terminal box + Inclinator*
- *Primary pump + Vacuum minirack*
- *Mobile pumping group (trolley)*
- *Survey electrical boxes*
- *Electrical plugs*

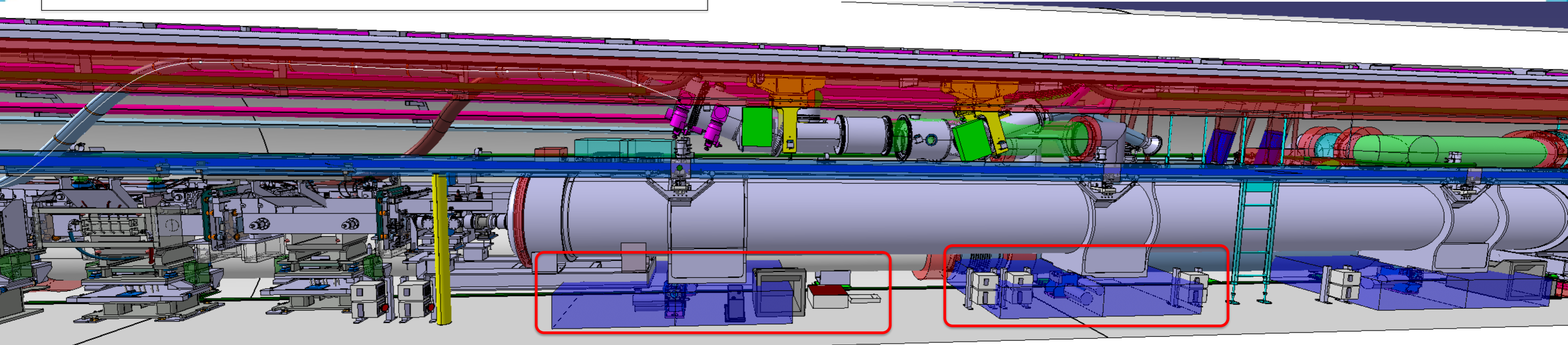
**DFM equipment (redundant, simplification would be important to ease installation and integration):**

- 2 bypass at QXL side
- 2 gauges at the bottom

**To be integrated** in 3D integration models:

### **DFM ancillaries:**

- 2 mobile pumping groups at transport side → 1 extra Trolley needed





# DFM Integration

## DFM Integration

### ➤ Completed activities

- WP6a • 3D Simplified models: only provided for 5R.
- WP15 • Temporary solution for 5L, 1R and 1L
- WP15 • Study of **boundary conditions** in the LHC tunnel

### ➤ On going studies

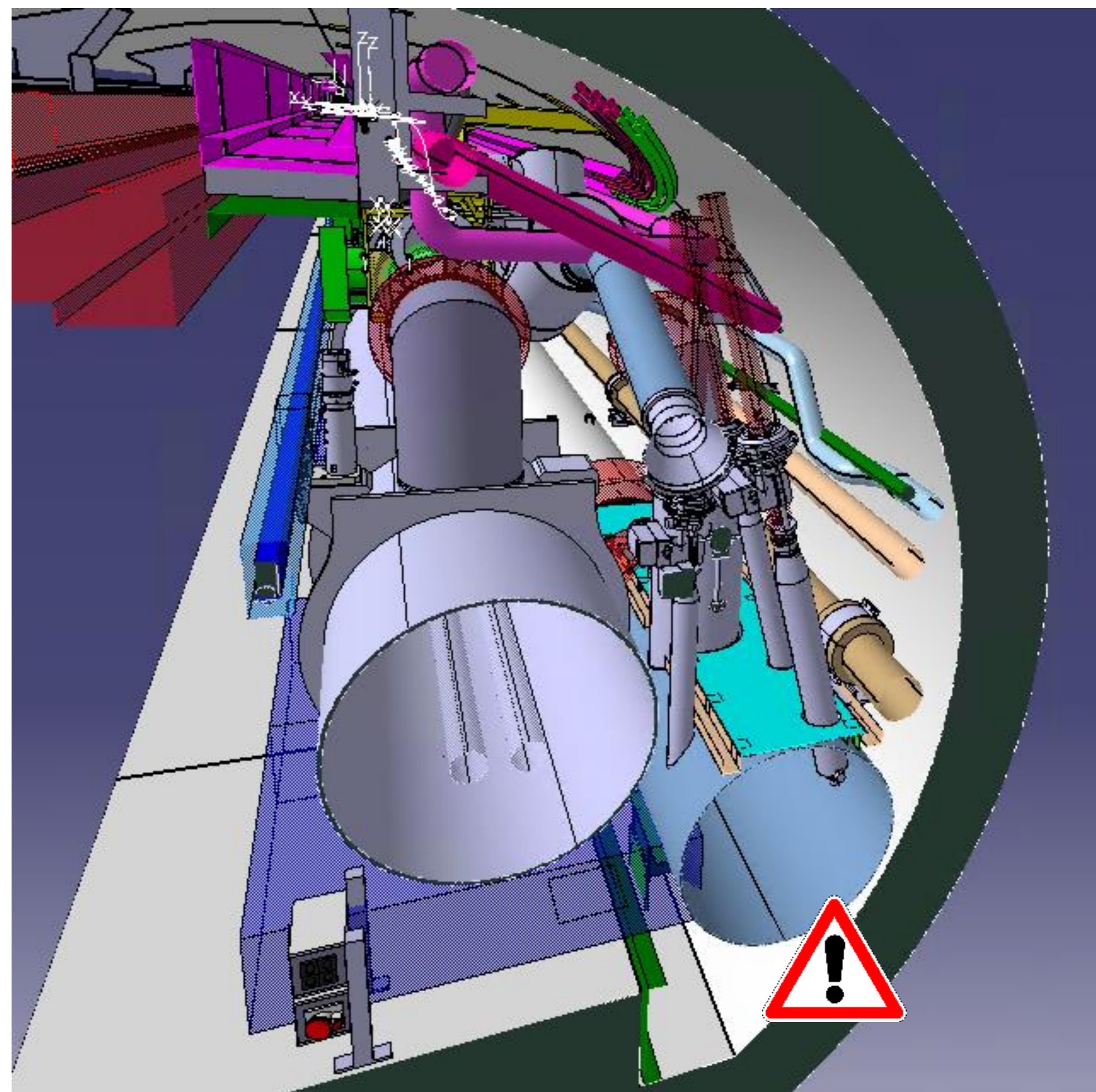
- All WP • Design of new **HL-LHC services** in the tunnel (5R)
- WP6a • Definition of **cryo-line flexible extension design / DFM integration solution**
- WP6a|15 • Definition of **reference points** in the LHC tunnel

### ➤ Pending points/ Next Steps

- WP6a • **Finalise DFM design** (including expected inclination of the cryostat, shorten the beam by 20cm)
- WP6a • Provide 3D simplified models for **5L, 1R and 1L**, and corresponding supporting solutions.
- WP6a • Consider ancillaries below D2
  - Consider **QXL current design** is **NOT** the final design

The **position of the DFM jumper** on the QXL has been slightly **shifted towards the IP**, according to the latest version recently provided TE-CRG (which incorporates 1 extra valve in the service module)

Final QXL → **waiting SUPPLIER DESIGN**





# Summary table

## DFM Integration

### ➤ Completed activities

- WP6a • 3D Simplified models: only provided for **5R**.
- WP15 • Temporary solution for **5L**, **1R** and **1L**
- WP15 • Study of **boundary conditions** in the LHC tunnel

### ➤ On going studies

- All WP • Design of **new HL-LHC services** in the tunnel (5R)
- WP6a • Definition of **cryo-line flexible extension design / DFM integration solution**
- WP6a|15 • Definition of **reference points** in the LHC tunnel

### ➤ Pending points/ Next Steps

- WP6a • **Finalise DFM design** (including expected **inclination** of the cryostat, **shorten the beam** by 20cm)
- WP6a • Provide 3D simplified models for **5L**, **1R** and **1L**, and corresponding **supporting solutions**.
- WP6a • Consider ancillaries below D2
  - Consider **QXL current design** is **NOT** the final design

## ST 3D models

### Full LSS (from Q1 till Q7): tunnel + services + new machine v.1.5

Used for general integration purposes:

- HL-LHC machine layout studies
- Full Remote Alignment System design
- Cryoline design (new QXL + matching section study for QRL)

**IP5 Right:** ST0966906\_01 - HL\_IP5\_R\_1506\_INTEG. LS3

**IP5 Left:** ST0968836\_01 - HL\_IP5\_L\_1506\_INTEG. LS3

**IP1 Right:** ST0990128\_01 - HL\_IP1\_R\_1101\_INTEG. LS3

**IP1 Left:** ST0990131\_01 - HL\_IP1\_L\_1101\_INTEG. LS3

### DFM simplified design:

**IP5 Right:** ST1426476\_02

**IP5 Left:** (temporary 5R mirrored solution) ST1426476\_03

**IP1 Right:** (temporary 5R solution) ST1426476\_02

**IP1 Left:** (temporary 5R mirrored solution) ST1426476\_03



# Conclusions

- The DFM integration is one of the most challenging, if not the most challenging, of HL-LHC. The adopted assembly solution requires to take into account the envelope of the system in 3 different positions creating more constraints to the systems around. At the moment the major issues seems to be tackled but the installation and handling gaps are very limited leading to two considerations.
  - Minor changes in the surrounding system, or the DFM itself, (that cannot be excluded) could lead to create interferences.
  - On site alignment of the supporting system and its adjustment capabilities are important in order to make possible the assembly.
- DFM final design is almost finalised with no major changes foreseen → possible final reduction in the number of bypass, gauges and pumping ports to be confirmed.
- Supporting structure to be shortened by 20 cm and more generally optimised DFM supporting structure designs to be provided at points IP5L, IP1R and IP1L.
- WP15 cannot provide more space around DFM → services still under design.
- Keep in mind QXL design is not definitive → waiting for the supplier's final design (interfaces and max. envelope are part of the tech specification being issued by WP9).