DFM Conceptual Design

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CDR DFM 21 June 2019

Cold Powering of the D2 cryostat

Chain of cryostats :
DFHM-DSHM-DFM-Interlink D2/DFM-D2

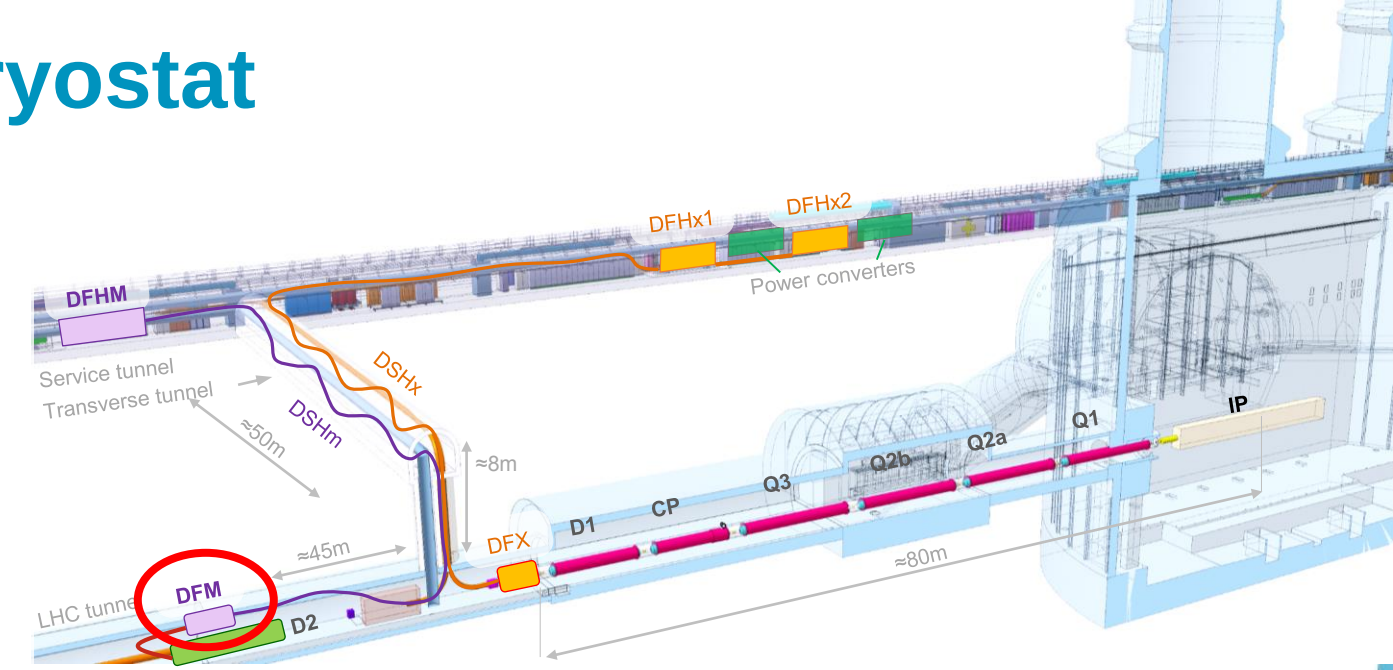
D2 cryostat

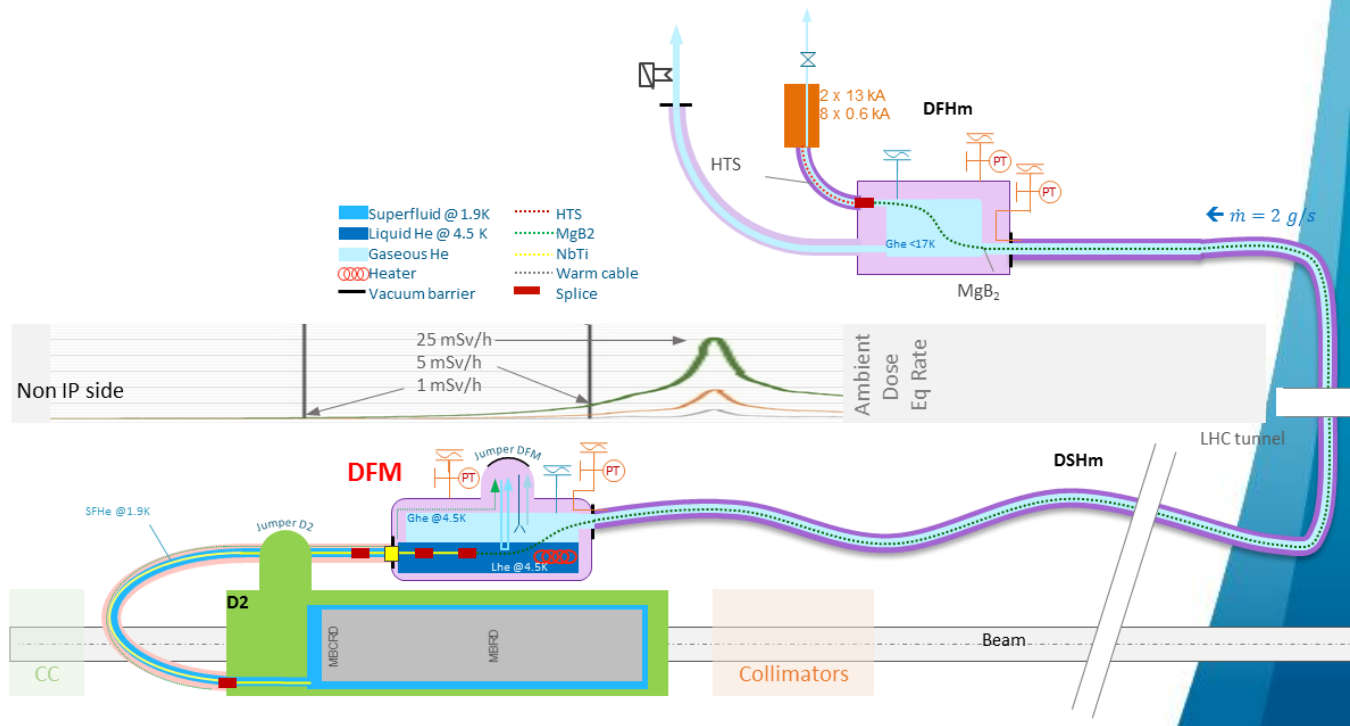
- 5 Magnets : MBRD + 4 x MCBRD
- Superfluid helium @ 20 bar design pressure

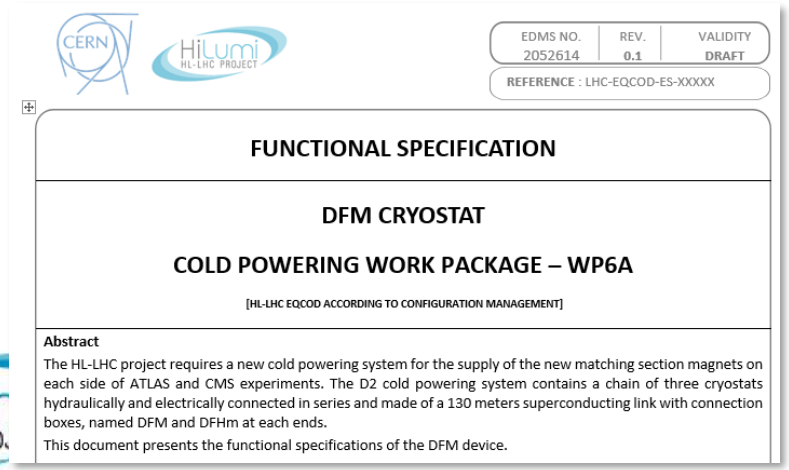
DFM basic functions:

- Electrical interface between SC Link and superconducting magnets
- Supply cryogenics to the SCLink

DFM conceptual design based functional specification EDMS 2052614







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REFERENCE : LHC-EQCOD-ES-XXXXX

FUNCTIONAL SPECIFICATION

DFM CRYOSTAT

COLD POWERING WORK PACKAGE – WP6A

[HL-LHC EQCOD ACCORDING TO CONFIGURATION MANAGEMENT]

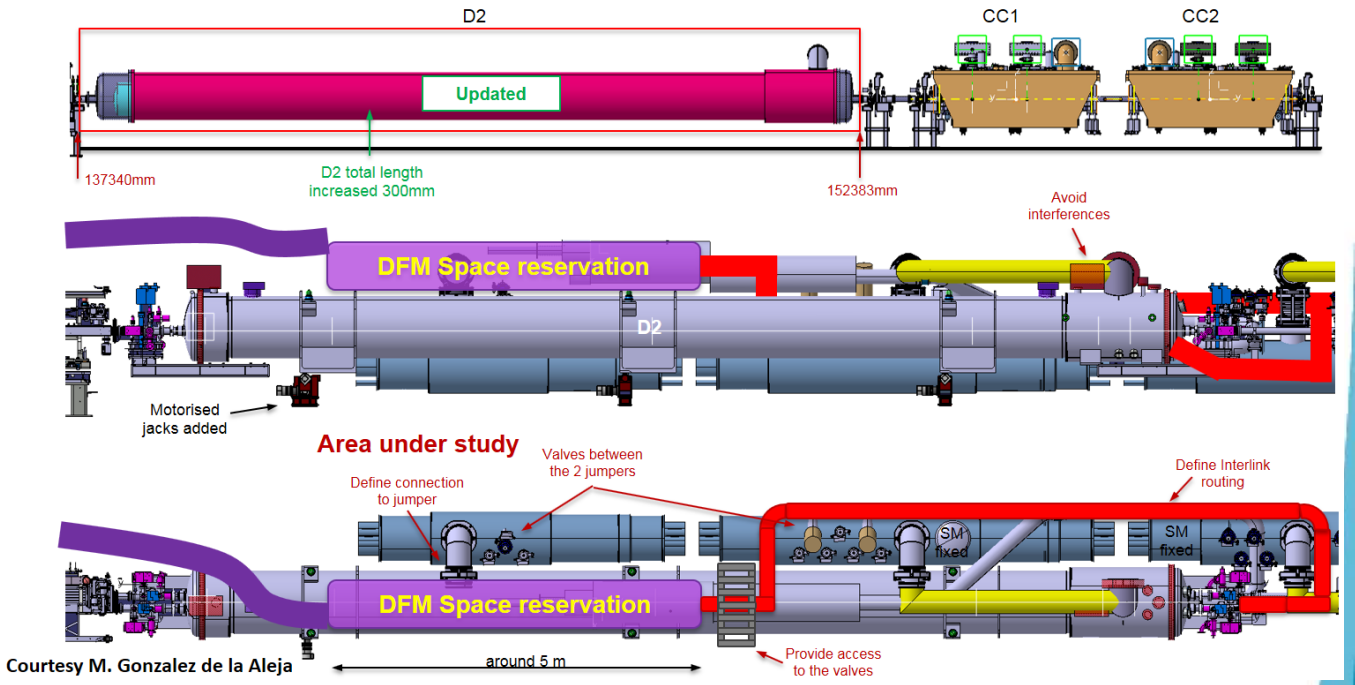
Abstract

The HL-LHC project requires a new cold powering system for the supply of the new matching section magnets on each side of ATLAS and CMS experiments. The D2 cold powering system contains a chain of three cryostats hydraulically and electrically connected in series and made of a 130 meters superconducting link with connection boxes, named DFM and DFHm at each ends.

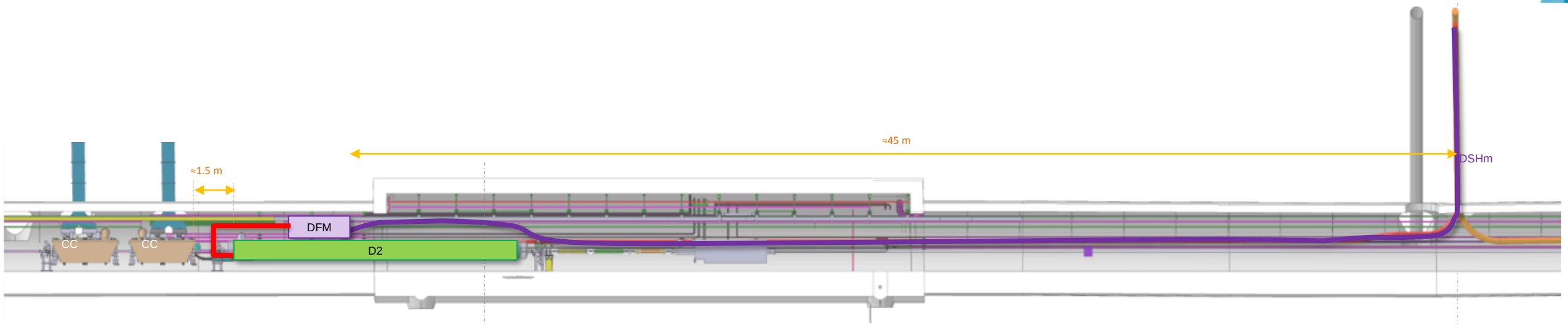
This document presents the functional specifications of the DFM device.

Environment overview

- D2 located between Crab Cryomodules and Collimators
- Connect to D2 via Interlink
- Connect to cryogenic lines with dedicated jumper
- DFM located above D2

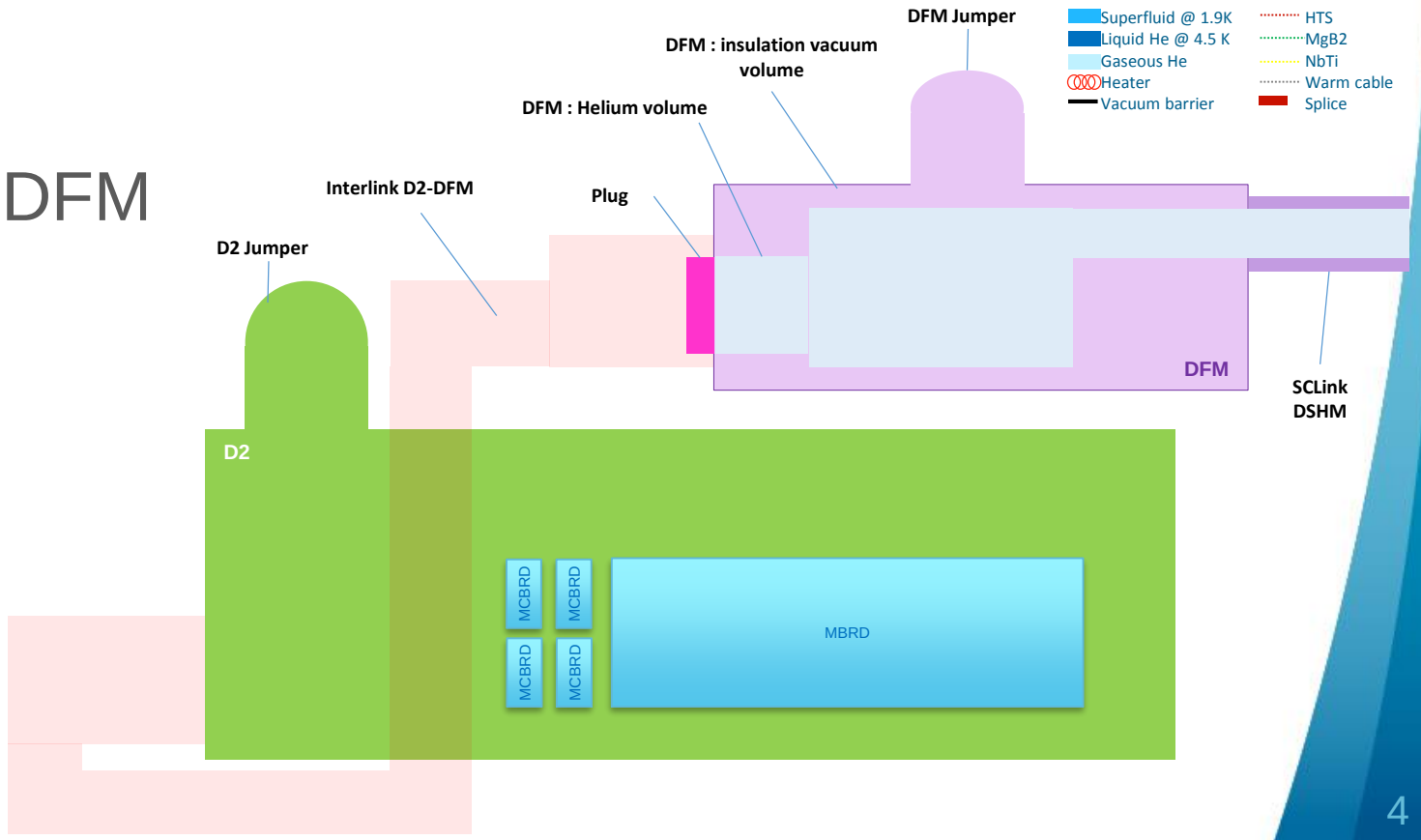


Courtesy M. Gonzalez de la Aleja



Concept : key items

- Items
  - D2 cryostat :
    - MBDR + 4 x MCBDR magnets
  - Interlink D2-DFM equipped with plug
  - DFM : insulation vacuum and helium volumes
  - SCLink – DSHM
  - Jumpers : 1 for D2 + 1 for DFM



Concept : DFM Cryogenic layout

- Cryogenics
  - Superfluid helium phase up to the plug
  - Superfluid volume actively shielded (return line through DFM Jumper)
  - Saturated liquid @ 1.3 bara in DFM (nominal)
  - GHE from 4.5K to 17K in SCLink
  - Hardware + Instrumentation
    - Operation device doubled
    - Heater for operation and liquid vaporisation during WU
  - Pressure relief devices
    - One burst disc (safety relief device)
    - One pressure relief device sized to static heat loads

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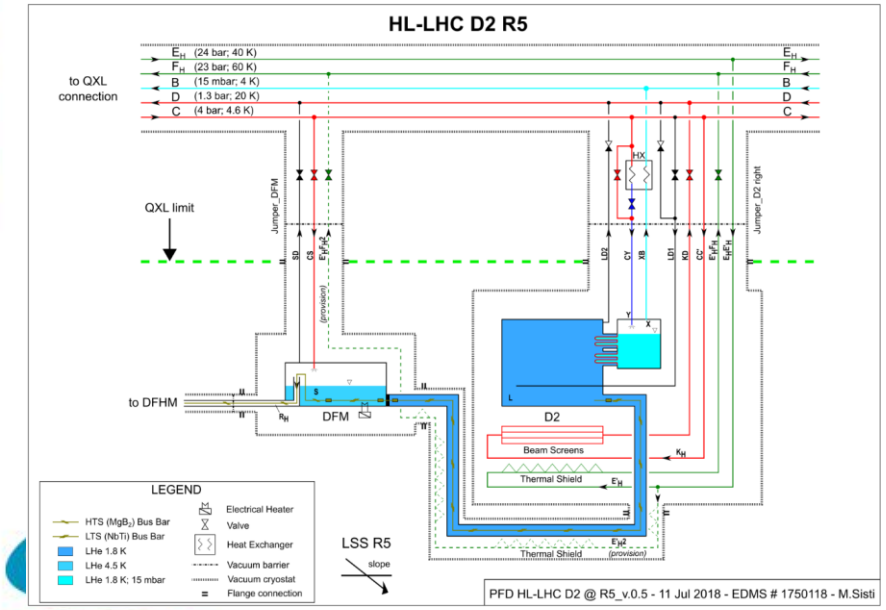
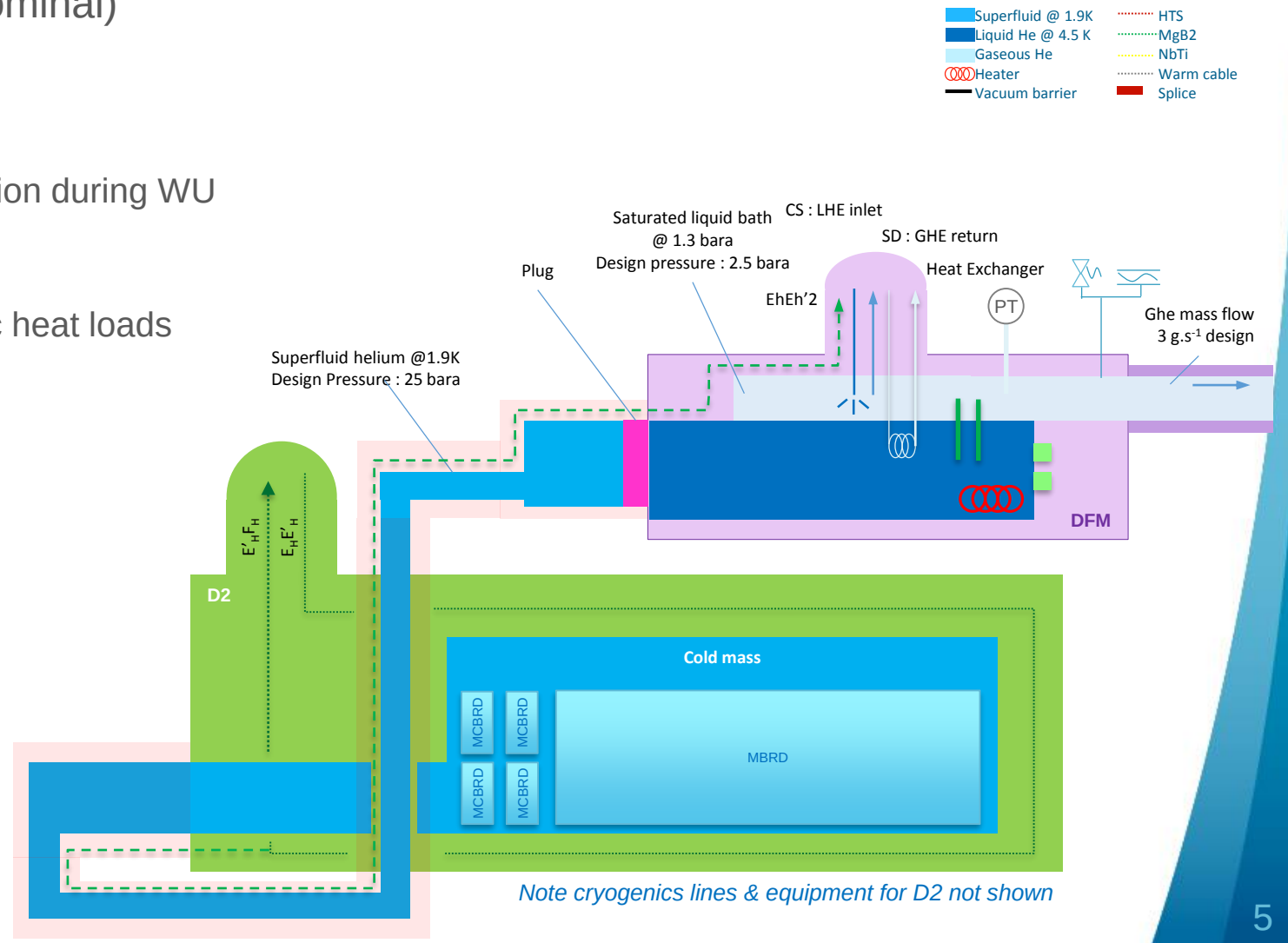
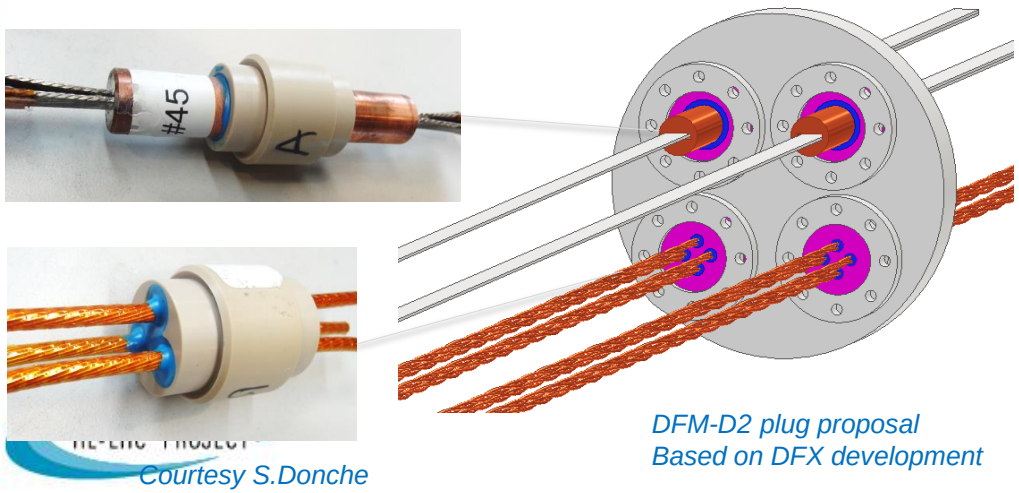




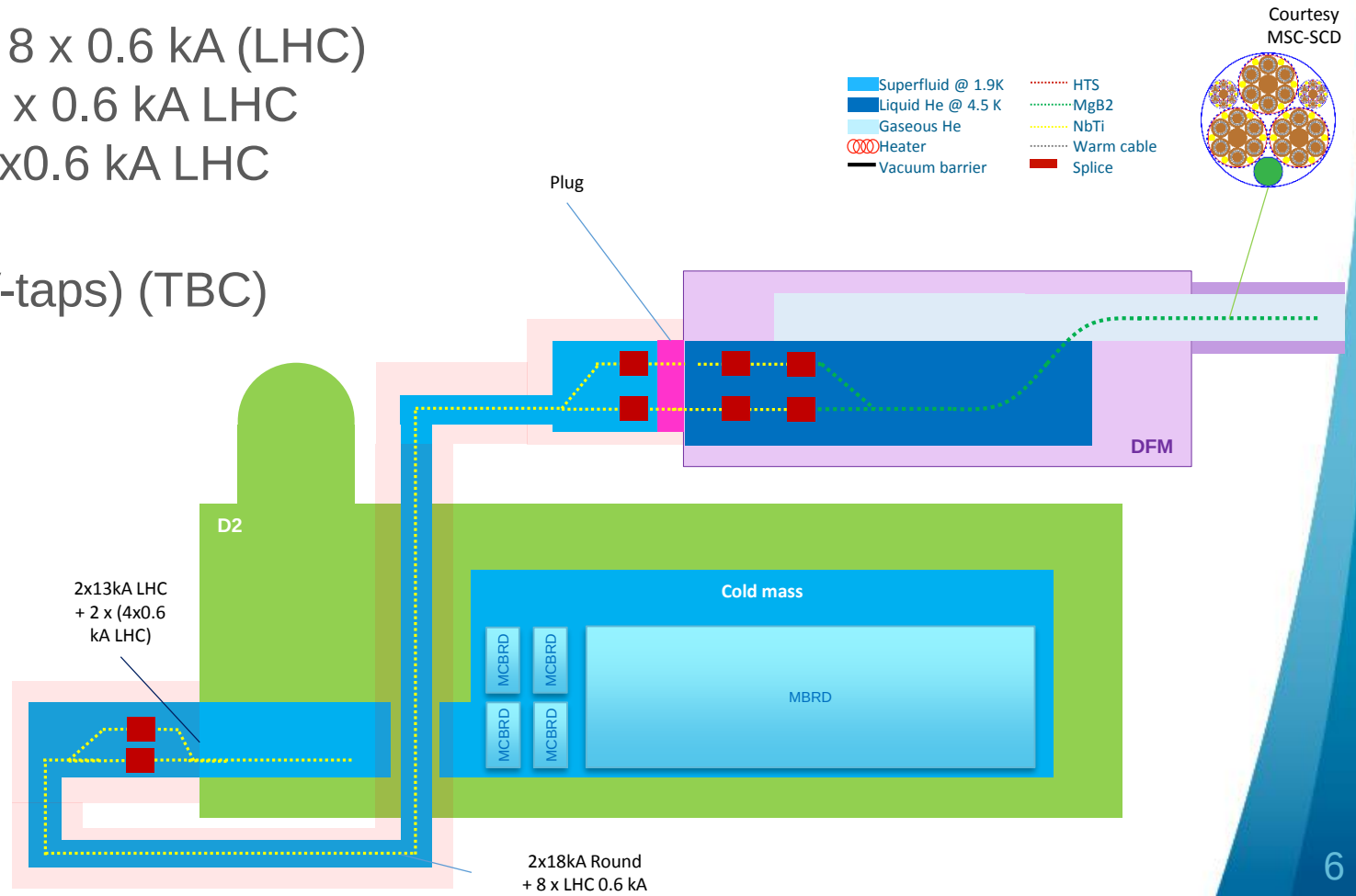
Concept : Electrical

- Leads requirements in DFM
  - Splices & NbTi leads immersed in liquid
- Leads characteristics
  - SCLink : MgB_2 : 3 x 18 kA + 12 x 0.6 kA
  - SCLink extensions : NbTi : TBD
  - Plug leads : NbTi : 2 x (2xMQXF) + 8 x 0.6 kA (LHC)
  - Interlink : NbTi : 2 x 18kA round + 8 x 0.6 kA LHC
  - D2 cryostat : 2 x 13 kA LHC + 2 x 4x0.6 kA LHC
- Circuit protection proposal in DFM
  - As for DFX (10 V-taps/lead = 100 V-taps) (TBC)



Courtesy S.Donche

DFM-D2 plug proposal
Based on DFX development

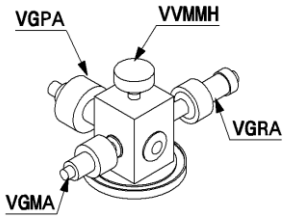


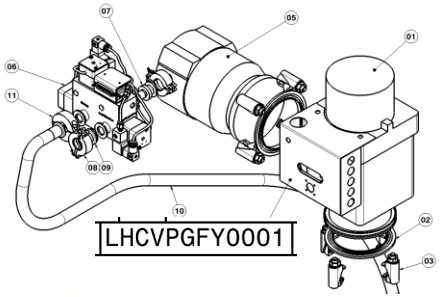
Concept : Insulation vacuum DFM

- Vacuum barrier layout EDMS 2048016
- Interlink insulation vacuum shared with D2
- Pumping & instrumentation interfaces on DFM + SCLink volumes (ISODN100)
- Pressure relief plate (ISODN100)

CERN standard models (gauges/pumps/ISO100 spring) : proposal

VAZAC





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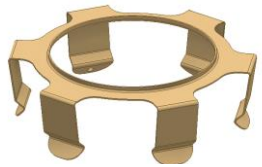
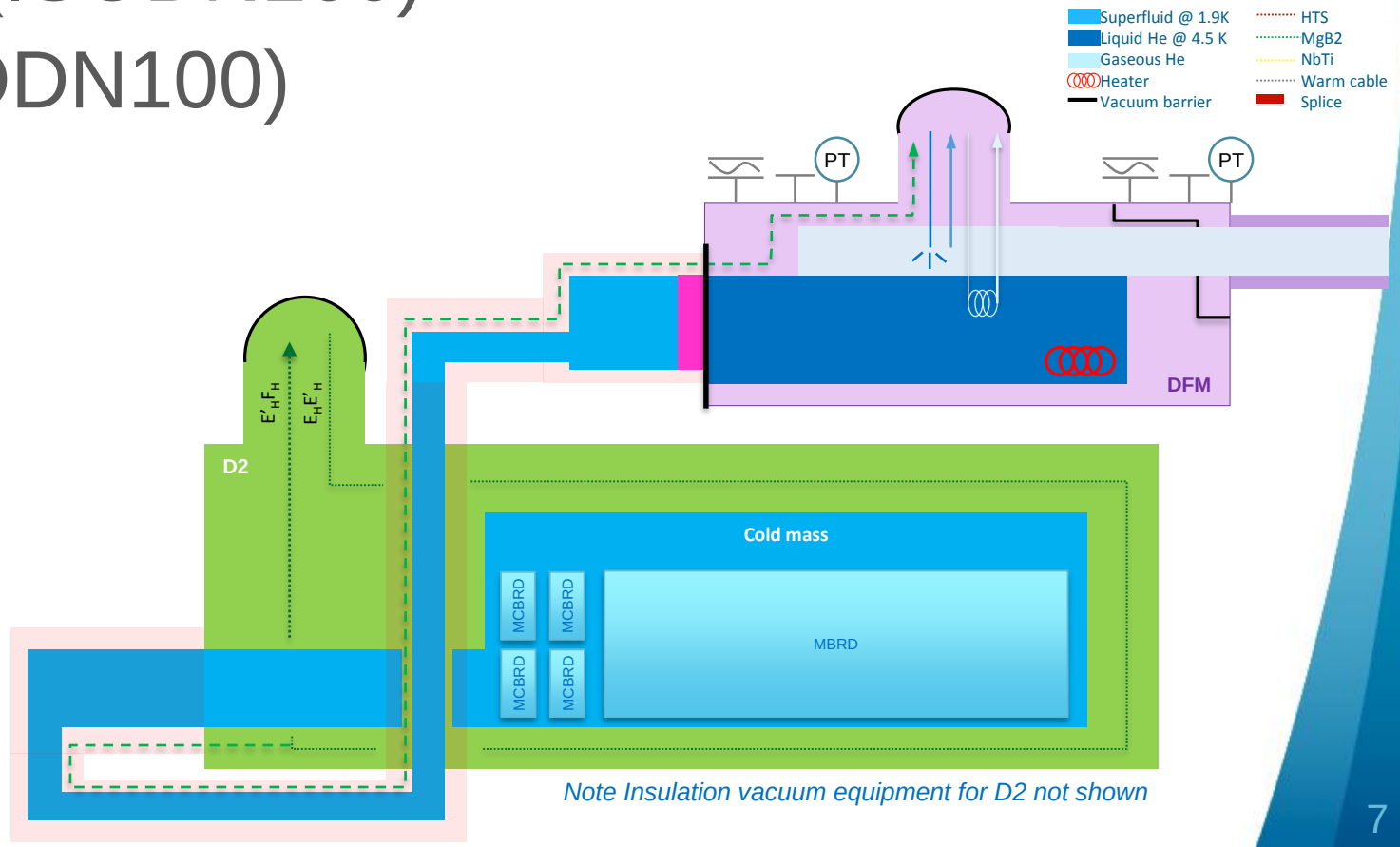
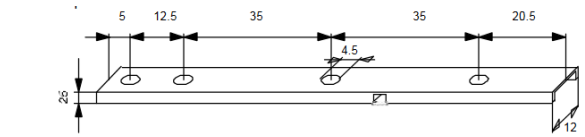


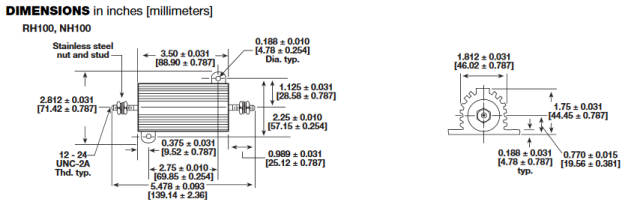


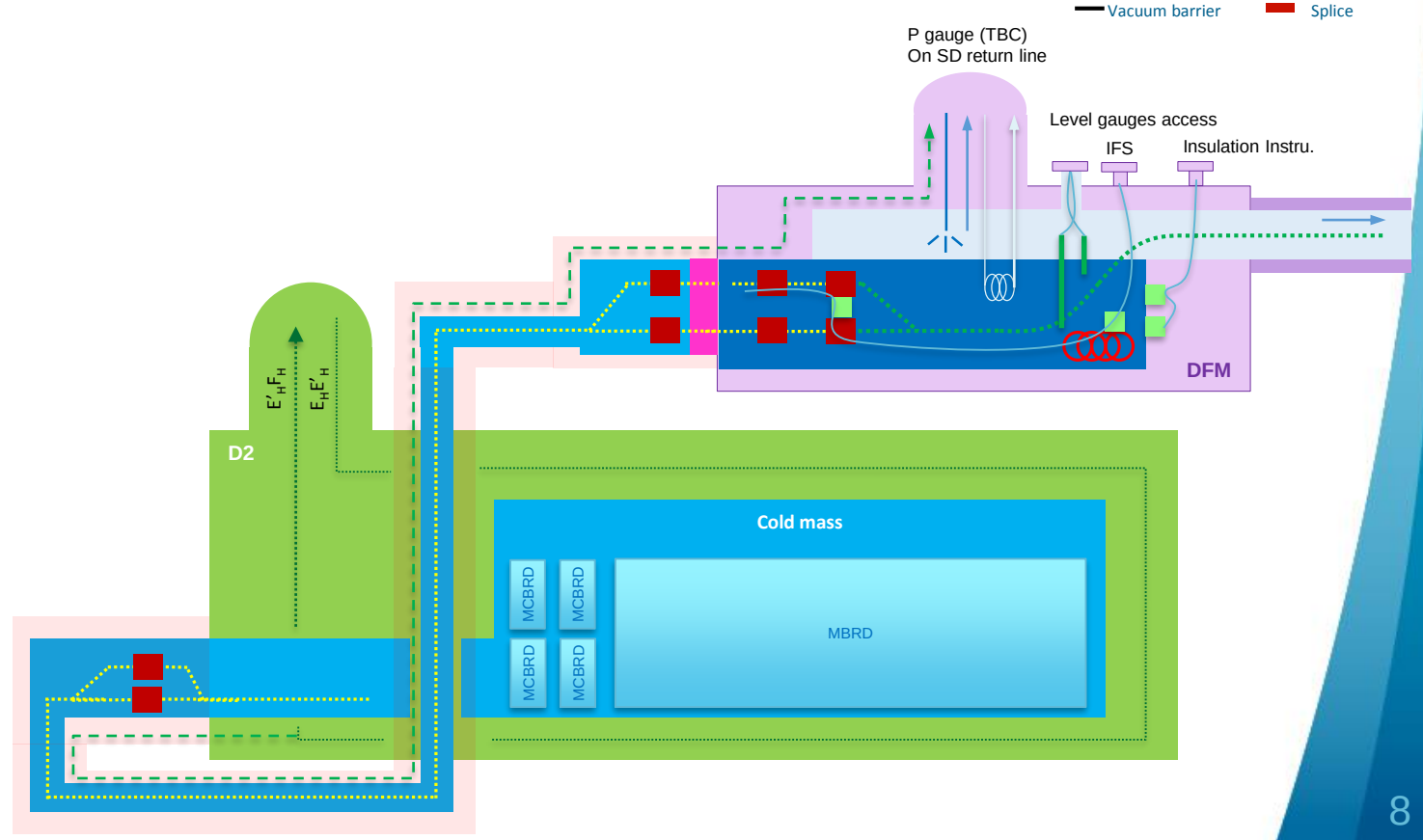
Note Insulation vacuum equipment for D2 not shown

Concept : Instrumentation & Hardware layout

- Heaters:
  - For operation & transient
  - 2 x 100 W (RH100)
  - Protected by T-sensor (TBC)
- Level gauges:
  - CERN standard type
  - Replaceable
  - Radiation resistant wires
  - 1 long over filling height
  - 1 short gauge around nominal range
- Temperature sensors
  - CERNOX for He vessel temperature monitoring
  - CERNOX for MgB_2-NbTi splices monitoring
  - TBD for heaters
- V-Taps (TBD)
- Interfaces:
  - One insulation vacuum feedthrough
  - One IFS with separated tubes by functions (T-signals / power)
- Note: Interlink requirements TBD

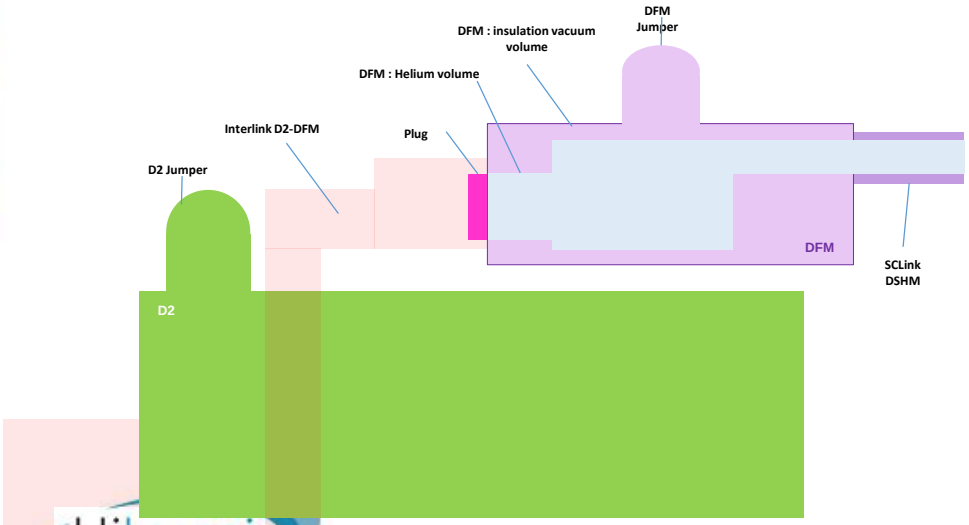


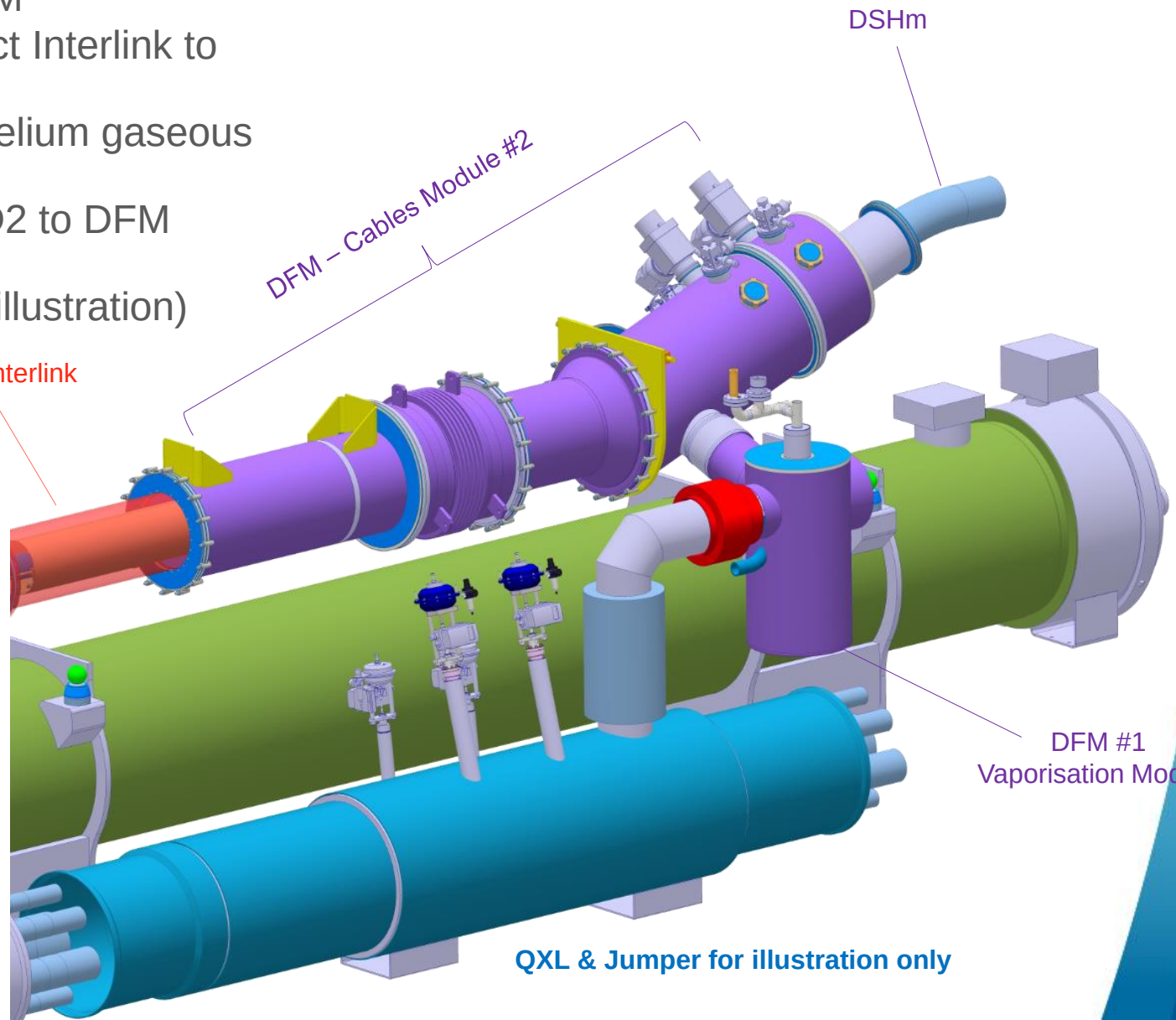




Proposal overview

- Key components denomination and interfaces
  - DSHm (SCLink D2): from DFHM to DFM
  - DFM cables module: electrically connect Interlink to SCLink
  - DFM vaporisation module: create the helium gaseous mass flow
  - D2-DFM interlink: connect leads from D2 to DFM leads
  - DFM Jumper: connect to cryolines (for illustration)

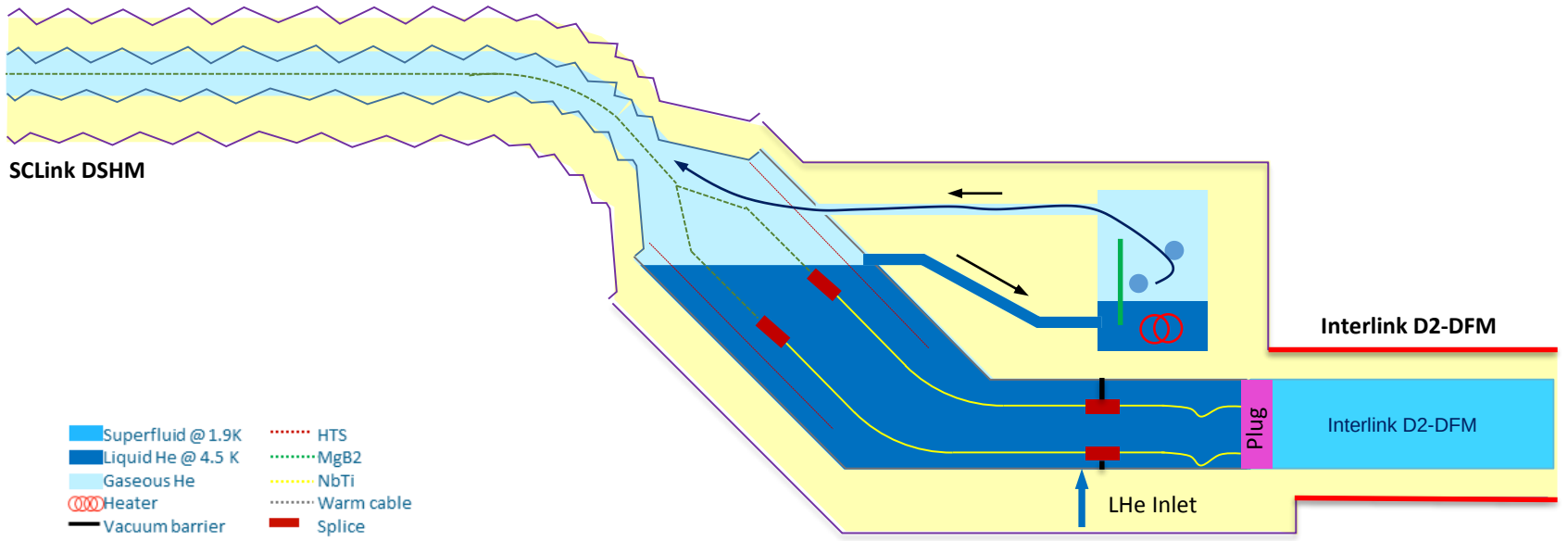




DFM concept

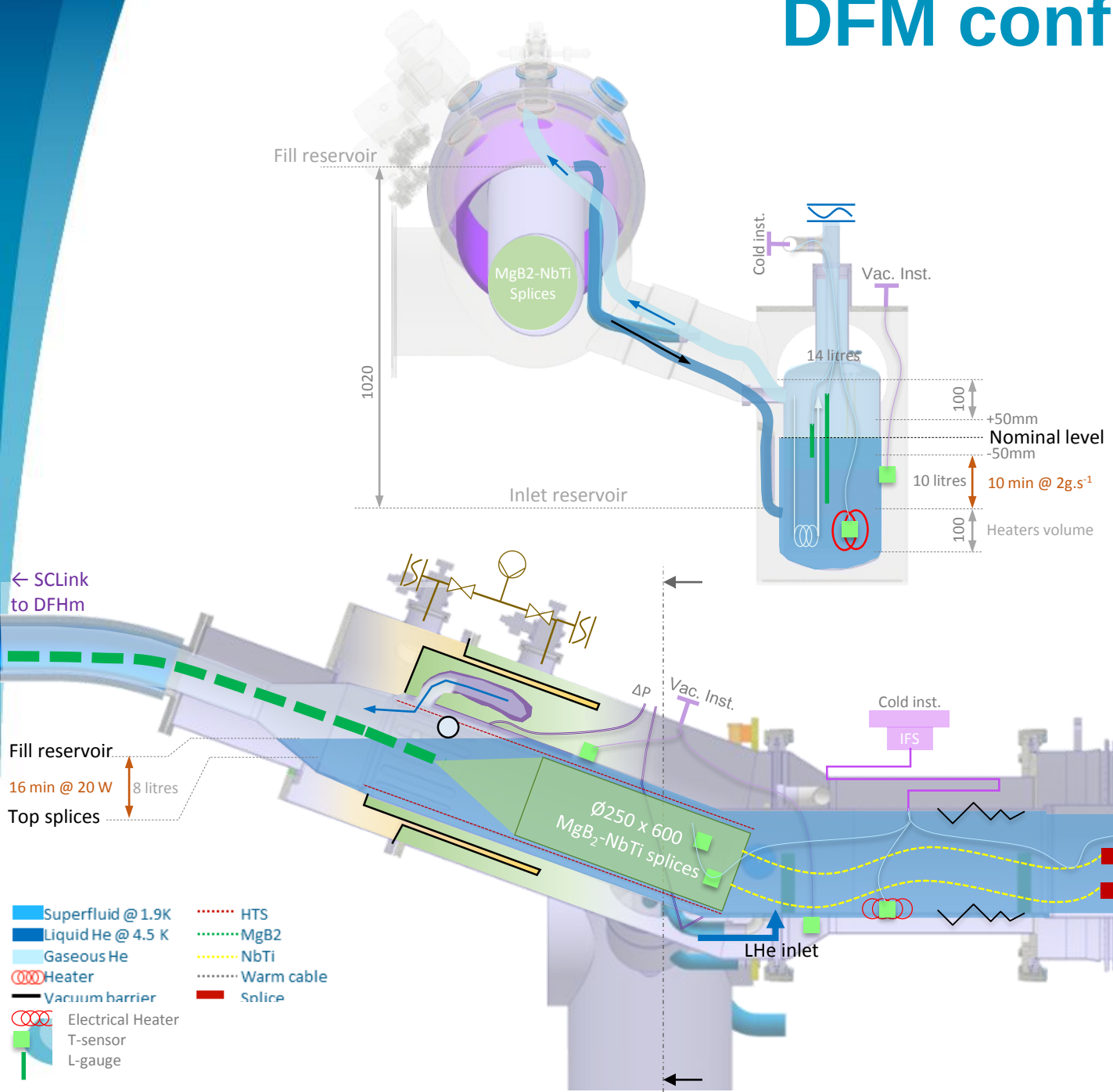
- Key design features
  - Inclined design to perform Liquid – Gas separation
  - Dedicated vessel for vaporising LHE (allow to control the nominal level with more margin) :
  - ➔ DFM Vaporisation module
- Basic concept

1. Lhe injection in splice volume
2. Level flows in side reservoir by gravity
3. Heater vaporises liquid (based on DFHm needs)
4. Level gauge control LHE inlet to ensure level



D2

DFM configuration



Electrical:

- MgB_2-NbTi Splices protected
- NbTi-NbTi splices on either side of plug

Cryogenics:

- Superfluid in interlink
- Splices immersed in LHE
- Fountain principle
- 10 min buffer at nominal conditions

Insulation vacuum

- Vacuum barrier in DFM
- Vacuum barrier at plug level

Thermal contraction proposal

- Main vessel : 1 fixed point
- Side vessel : suspended from 300K top

Instrumentation layout proposal

- Level gauges + V-taps + T-sensors + heaters + P gauges

Nominal configuration proposal

Electrical

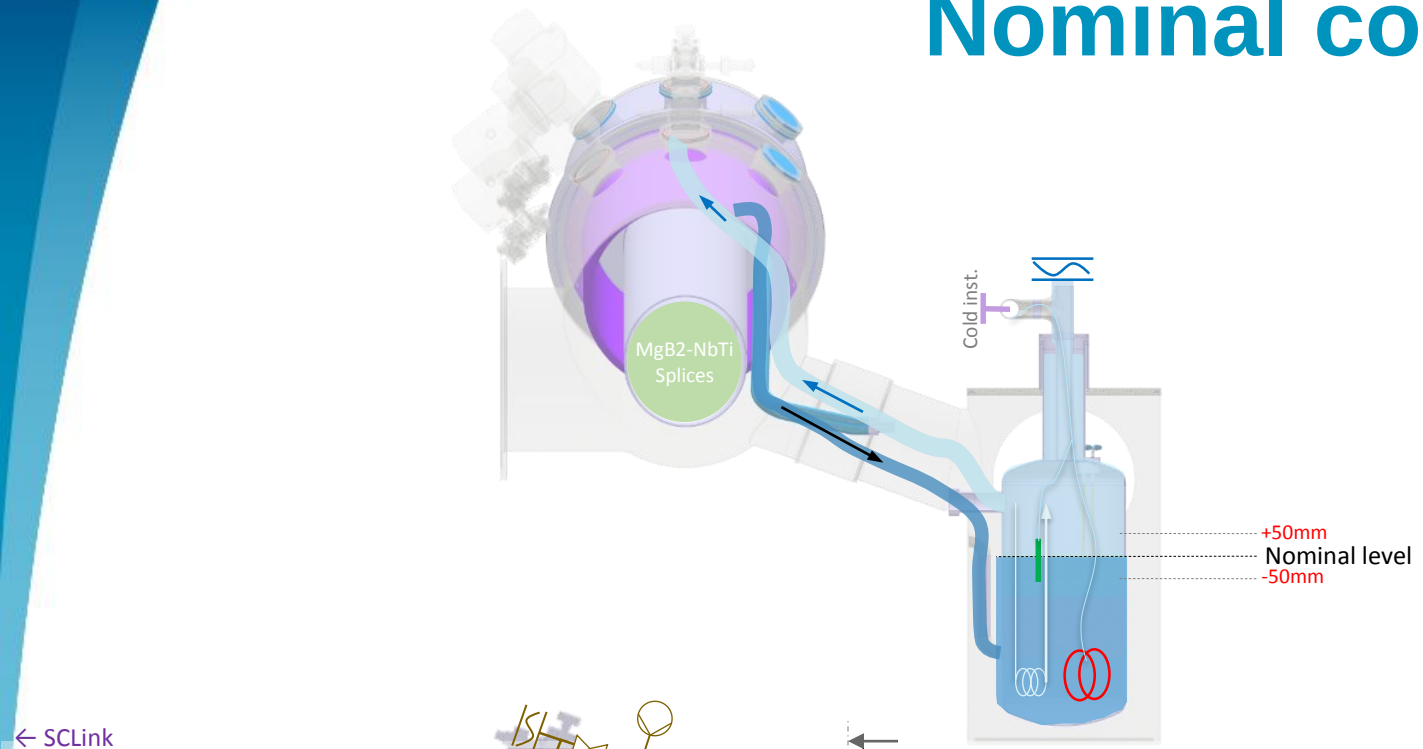
- Monitored by V-taps
- Bus-bars supported together toward Lorentz forces

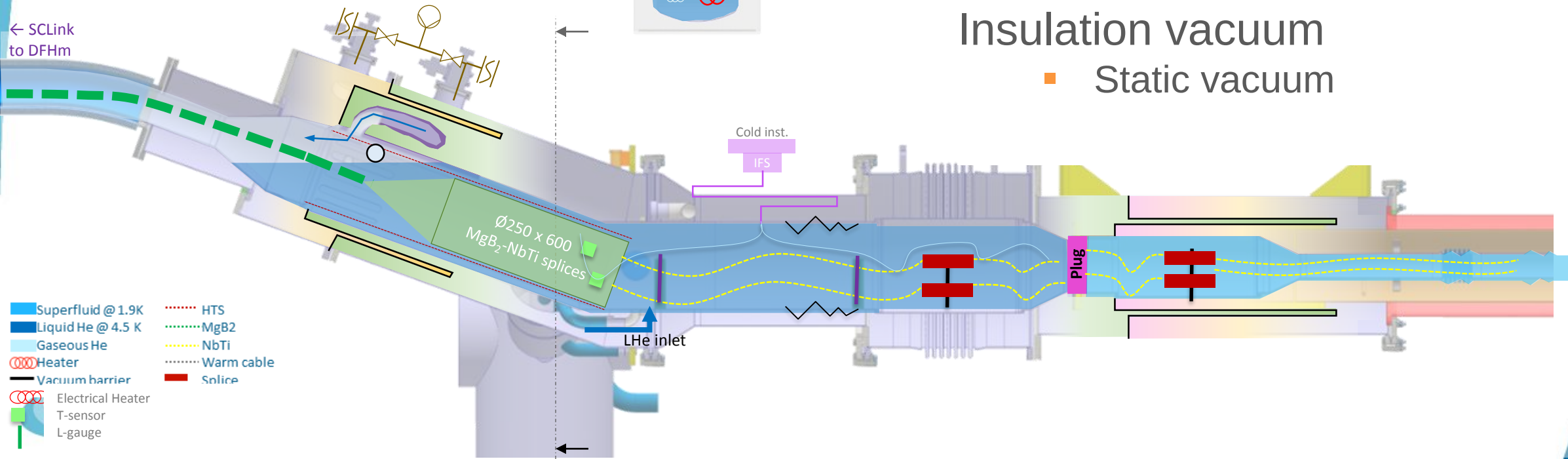
Cryogenics operating proposal:

- DFH (inlet Gas, Splice) & Current leads controls power dissipated in the heaters
- Level gauge controls inlet valve

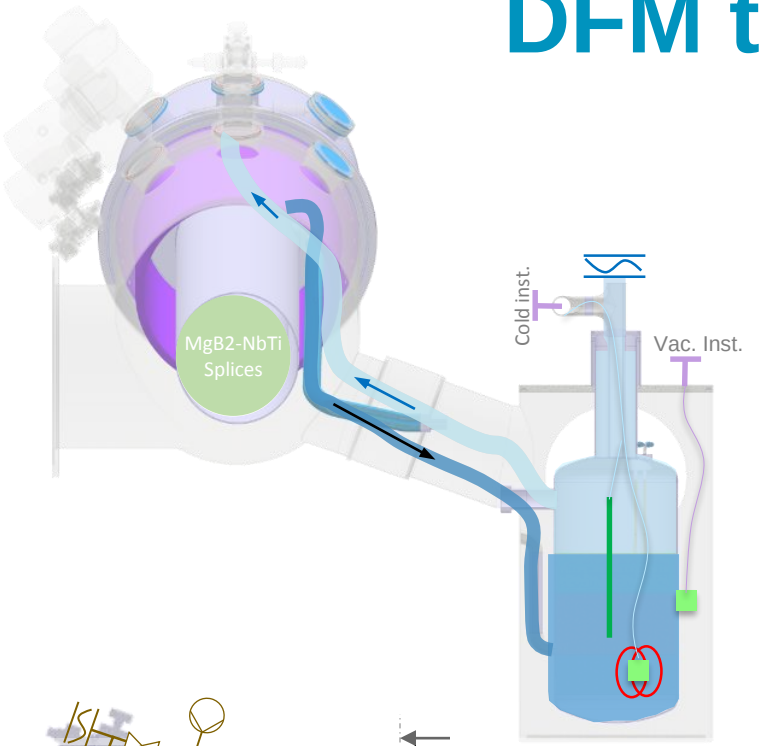
Insulation vacuum

- Static vacuum





DFM transient configuration



Cool down

- Inject through LHE inlet
- Monitored by T-sensors to 4.5K
- Thermal contractions covered by bellows and lyras
- Filling up monitored by ΔP and long level gauge

Warm Up

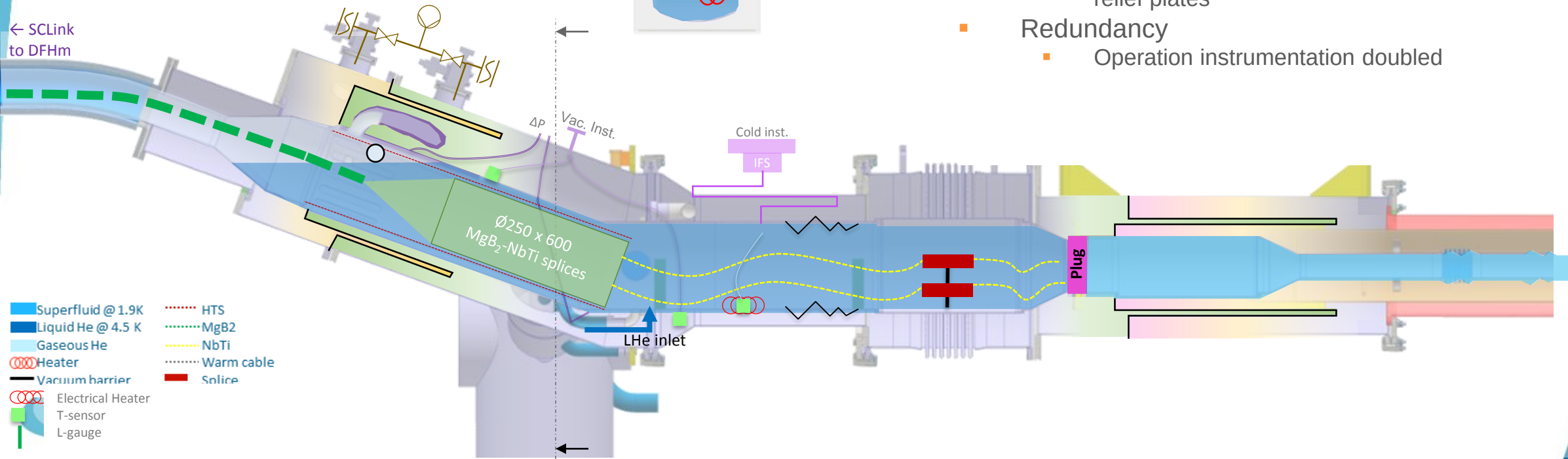
- Liquid vaporisation with electrical heaters (both volumes)
- Monitoring with ΔP and long level gauge
- Warm up to ambient with static heat loads

Unexpected events

- Heaters temperature monitored by T-sensors (TBC)
- Helium vessel over pressure relieved through burst disc + relief pressure
- Helium envelope rupture protected by Vacuum vessel relief plates

Redundancy

- Operation instrumentation doubled



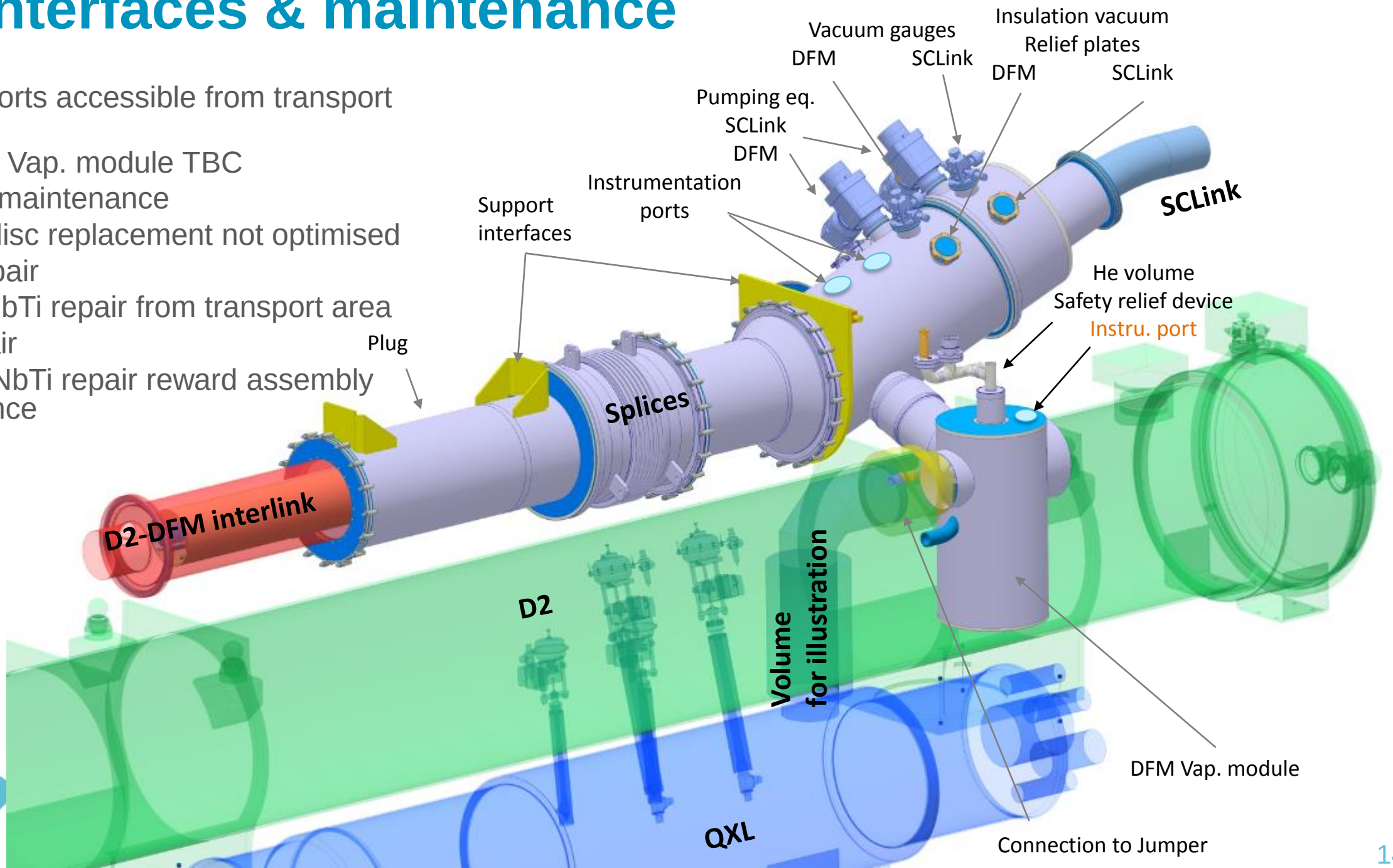
DFM Interfaces & maintenance

Inspection
- Instr. ports accessible from transport area
- Except Vap. module TBC

Preventive maintenance
- Burst disc replacement not optimised

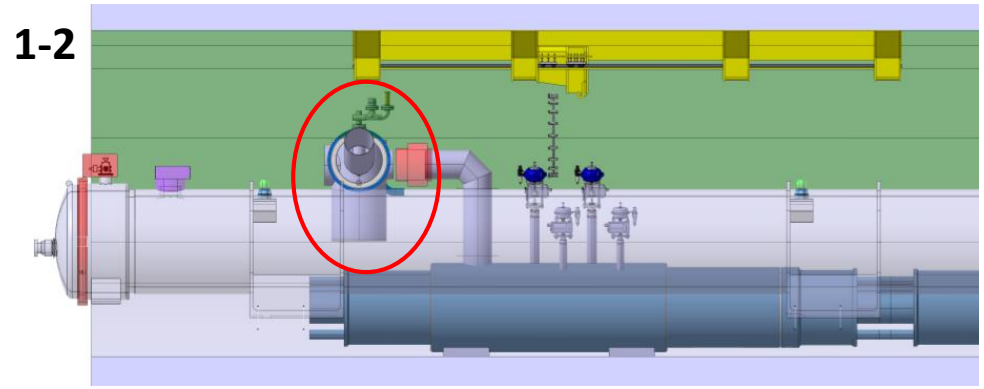
Medium repair
- NbTi-NbTi repair from transport area

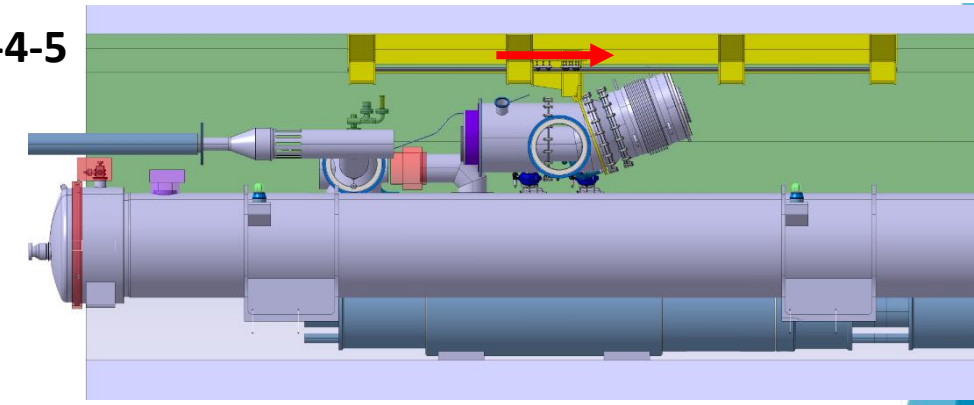
Heavy repair
- MgB_2-NbTi repair reward assembly sequence

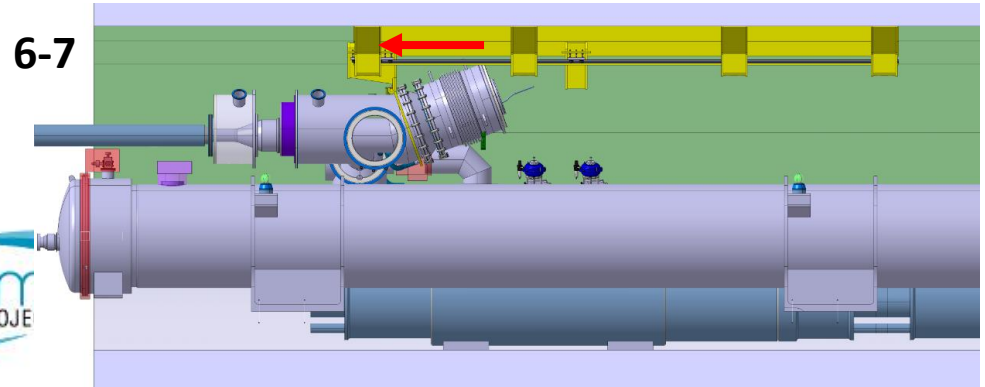


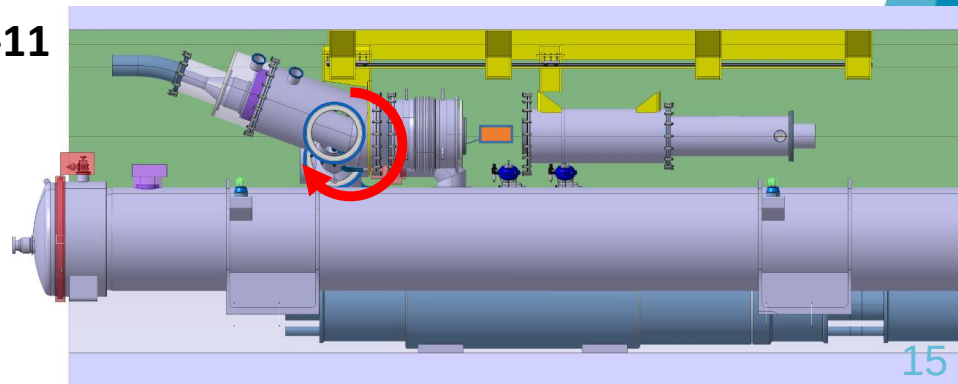
Preliminary assembly sequence

1. Initial configuration:
   - Services, tooling, QXL, D2 installed
   - D2-DFM interlink partly installed
2. DFM vaporisation module #1 to jumper connection and test
3. DFM transported above D2
4. DFM cables module #2 located toward non IP
5. SCLink horizontal
6. DFM #2 slided around SCLink
7. SCLink to DFM connections & test
8. DFM #2 rotated
9. DFM #1 to DFM#2 connection and test
10. D2-DFM interlink connected and test
11. Splices operation and sleeves closure and qualification





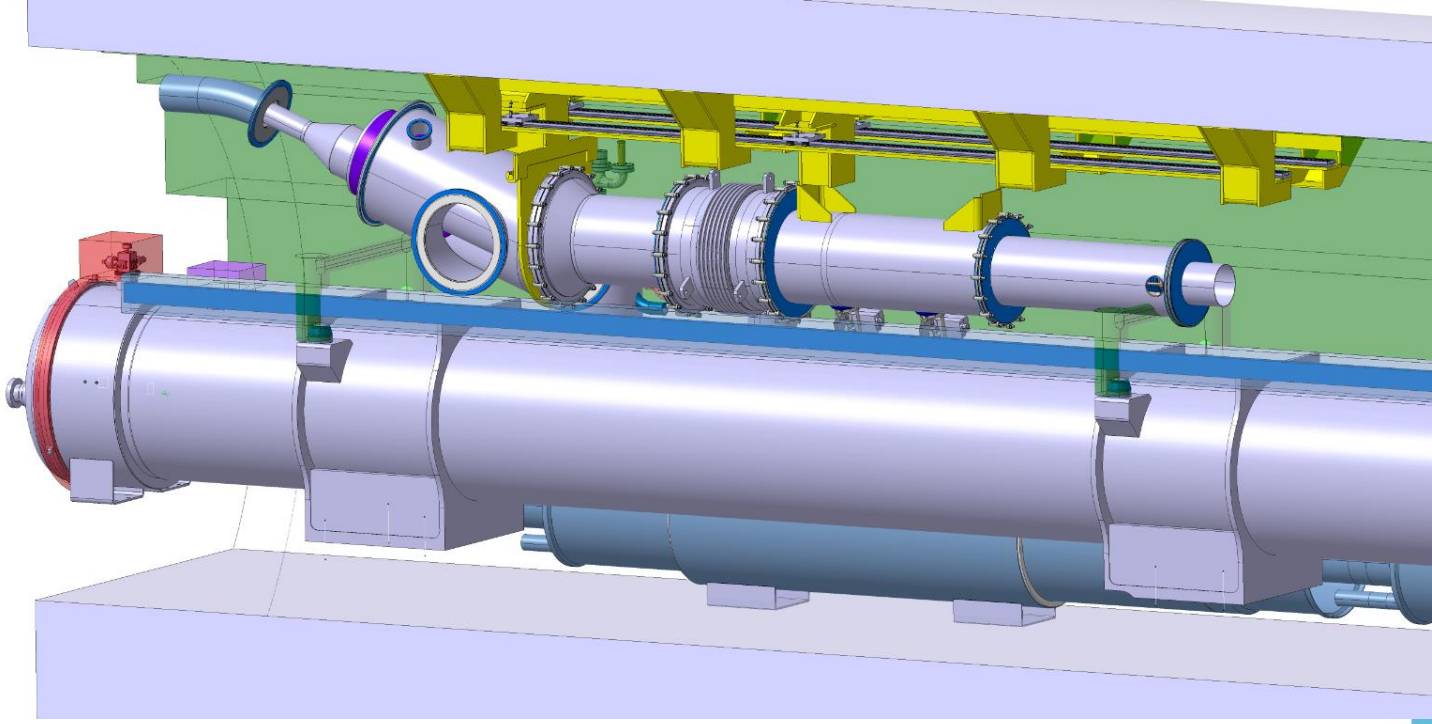


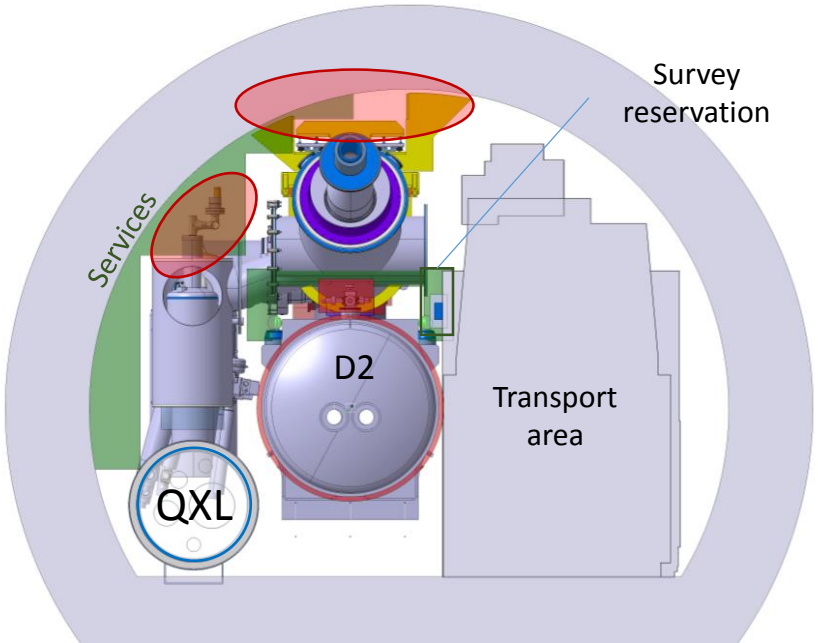


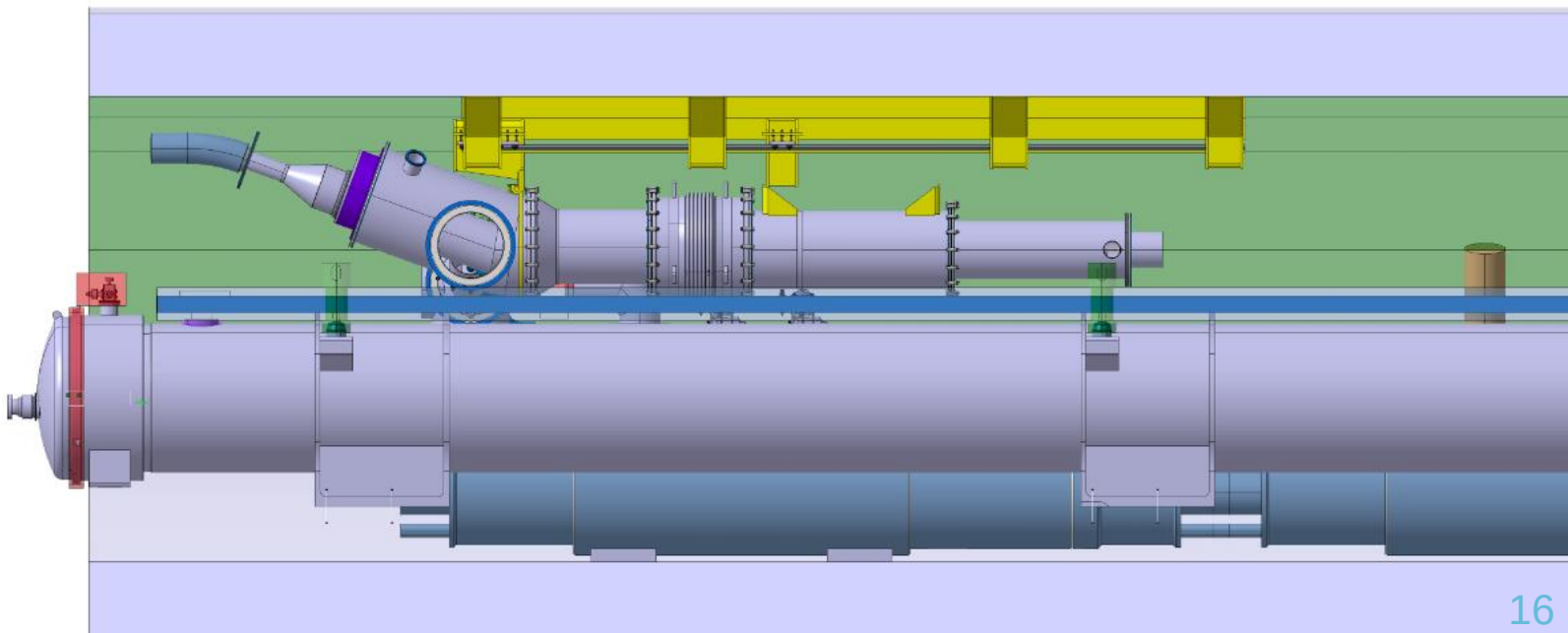
Pre-integration study

- Preliminary interference study with basic DFX environment on going
  - Service, , Transport, QXL
  - Tunnel infrastructure (model)
  - Interferences already detected to be studied

- Integration study to be led
  - Services, Survey, Transport, SCLink, Interlink, D2 installation, close services maintenance







Transport and Installation

- Transport:
  - Dimensions need to be verified
  - Transition from transport area to final configuration may present interferences
  - ➔ work starting
- Installation specifications
  - Shall be independent from D2 Assembly-Disassembly
  - Shall minimise the SCLink handling
  - Shall comply with reserved volumes (survey, transport, services)
- Work in progress
  - List of actions:
    - Interferences identification
    - Iterations with transport within WP15
    - Iterations with survey, services interfaces (under WP15 supervision)
  - Weekly meeting under WP15 started (Friday 10 am)

Functional spec:

Electrical requirements:	
Route NbTi leads from SCLink to splice with Rmin>125mm	✓
Route Plug leads to splice	✓
Provide access for splices performance	✓
Provide supports to splices and leads in He vessel	Pending
Cryogenics aspects:	
Immerse splices and NbTi leads	✓
Produce 3 $g.s^{-1}$ GHE mass flow to SCLink	✓
Connect to cryogenic lines	In progress
Release over pressure	✓
Limit heat loads to 20 W	✓
Slope from coldest point to LHE-Ghe interface	✓
Respect instrumentation requirements	TBC
Respect levels, volumes	✓
Insulation vacuum	
Provide required interfaces	✓
Thermo-mechanical aspects:	
Allow thermal-contractions (500 cycles)	✓
Integration	
Connect to Jumper	In progress
Respect reservations	TBC
Installation	
Do not impose bending radius to SCLink < 1.5m	✓
Be independent from D2 installation	TBC
Transport	Pending
Unexpected events	
10 min nominal operation in case of LHE supply stop	✓
Energy deposition in LHE volume	✓
He envelope rupture to insulation vacuum	✓
Maintenance	
Vacuum equipment access	TBC
Valves & instrumentation access	TBC
Safety relief devices access	TBC
NbTi-NbTi repair	✓
MgB_2-NbTi splices extraordinary repair	TBC

Summary

- A conceptual design proposal has been developed
- Some upcoming work on cryogenics and integration interfaces expected
- Iterations with interfaces have started (under WP15)
- Detailed design to be started in parallel

Spare slides

Cold Powering of the D2 cryostat

D2 cryostat:

- 5 Magnets : MBRD + 4 x MCBRD

DFM basic functions:

- Electrical interface between SC Link and superconducting magnets
- Supply cryogenics to the SCLink

DFM functional specification and interface definition
EDMS 2052614