Interconnection boxes : DFX

International Review of the Conceptual Design of the Cold Powering System for the HL-LHC Superconducting Magnets : 3-4 July 2017

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Outline

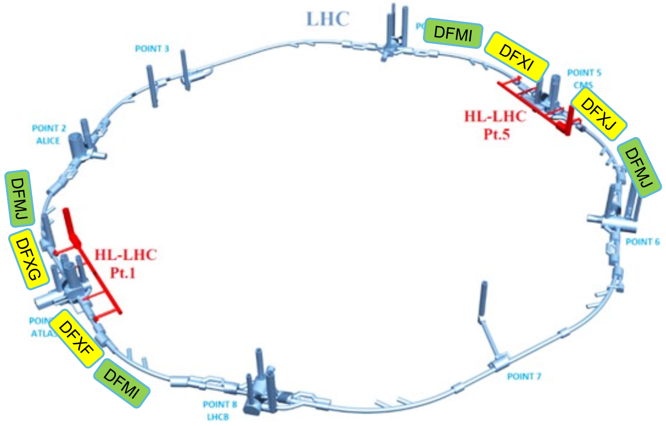
- Context : DFH-SCLink-DFX cryostat
- Planning and milestones
- DFX design
  - Conceptual layouts
  - Detailed design overview
  - Identified key technical challenges
- Next steps

Note: 3D models are illustrative, the detailed design of the DFX is not started yet.

Context

- Each IP1 and IP5 sides equipped with 2 cold powering chains of cryostats
  - Triplet insertion : **DFH – SC Link (DSH) – DFX**
  - Matching sections : DFH – SC Link - DFM

- DFX basic functions:
  - Electrical interface between SC Link and triplets string (Q1-D1) through D1 cryostat
  - Supply cryogenics to the SCLink



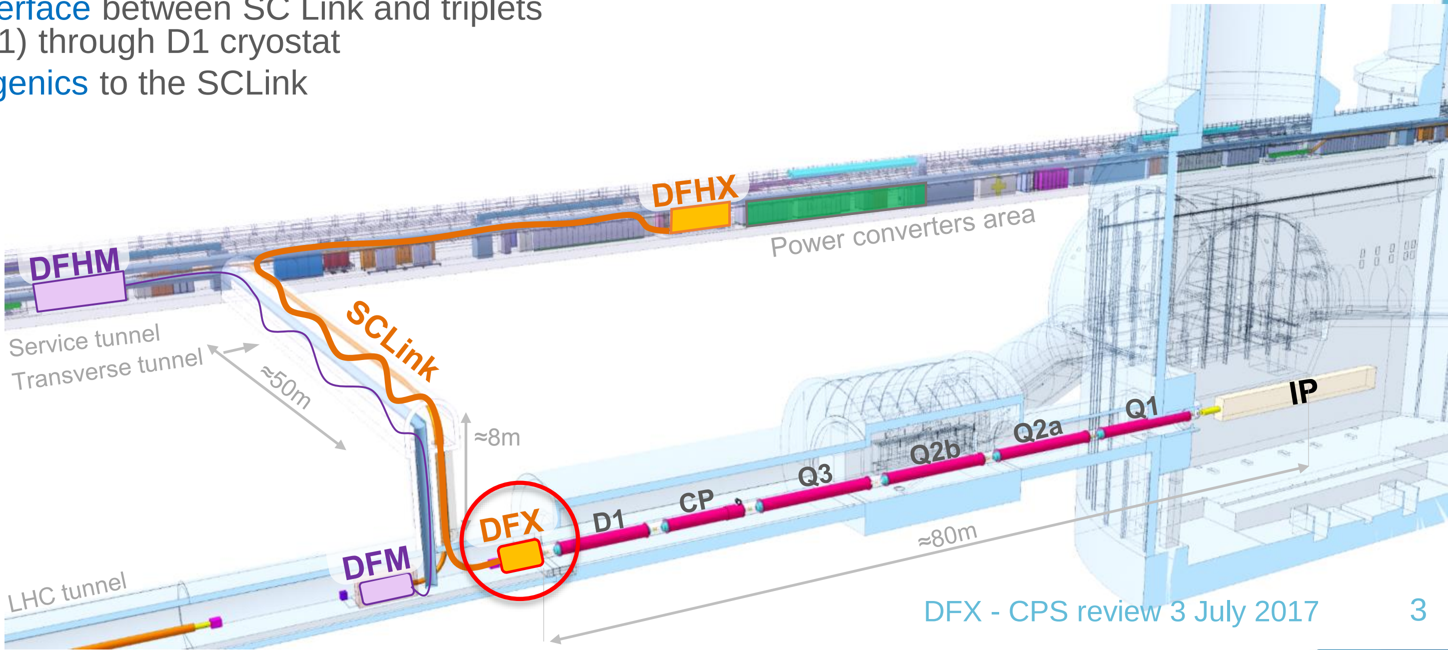
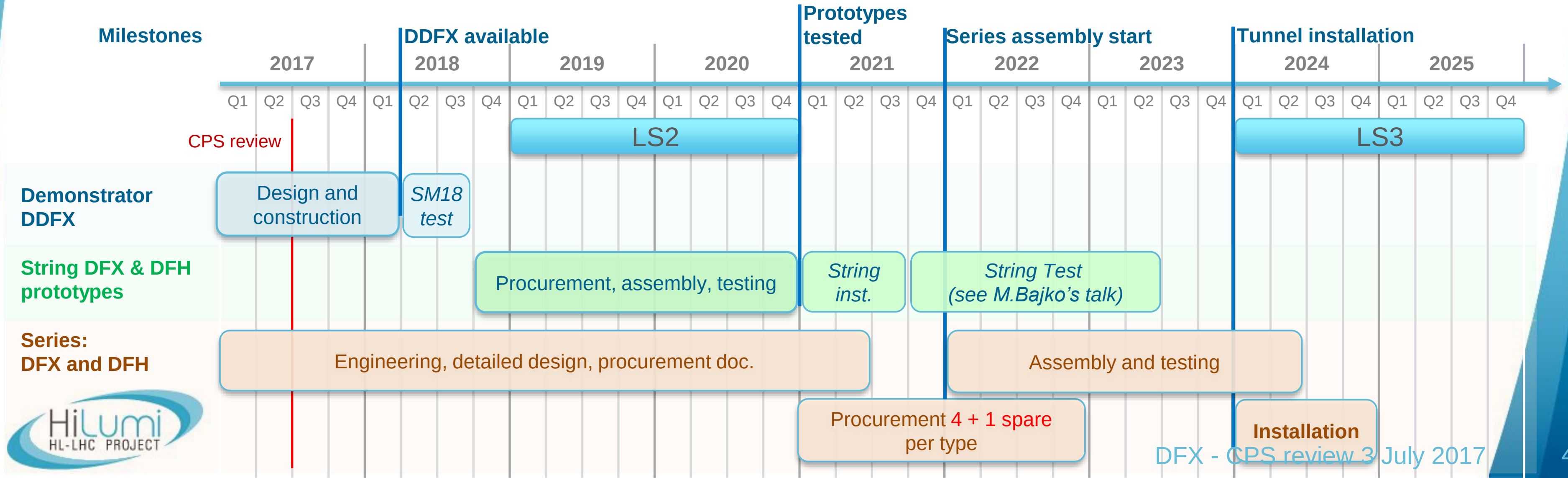


Illustration of the position of the DFX (not latest version for details)

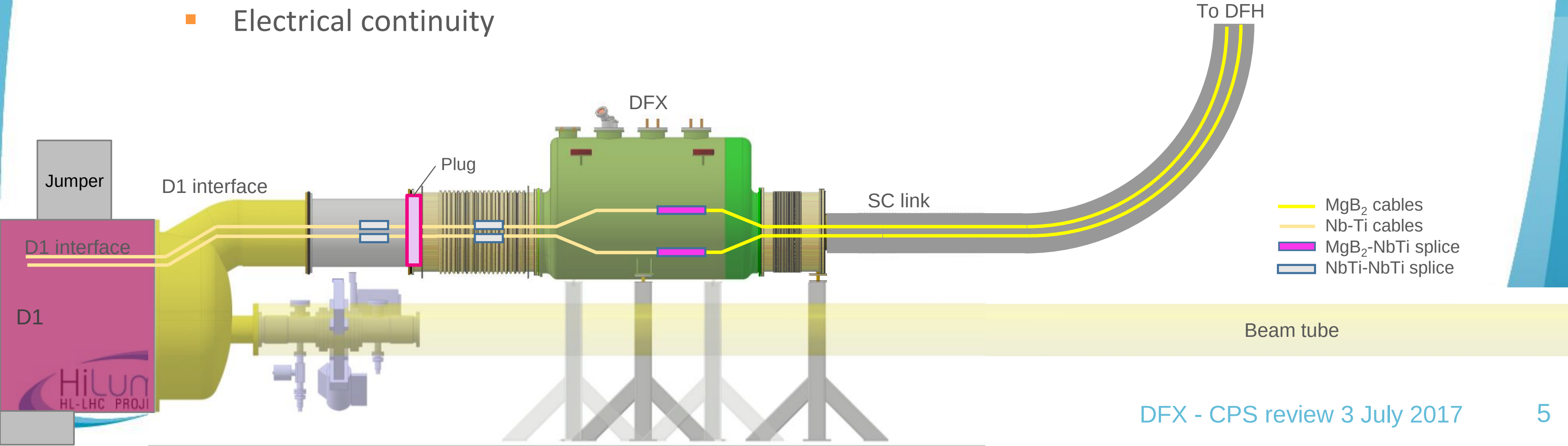
Planning – DFX & DFH cryostats key dates

- Strategy: Design of DFX-DFH cryostats series
  - In parallel with demonstrator to validate choices
  - Prototypes to be tested in string



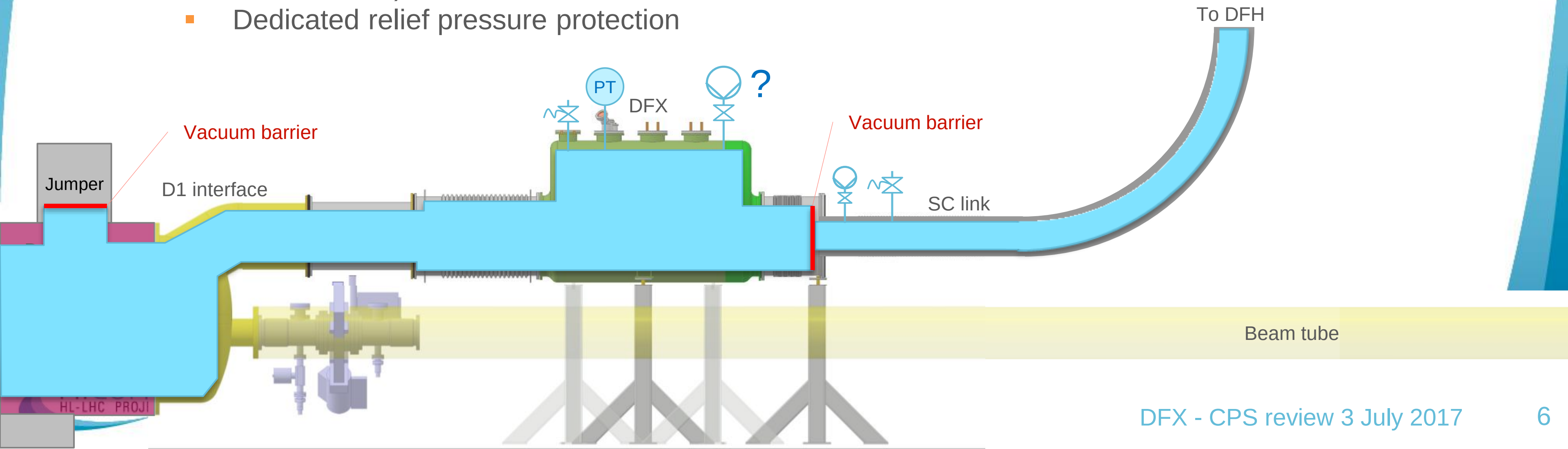
DFX concept

- Key concepts:
  - Main boundary conditions for the design:
    - Future maintenance carried out in an activated zone ➔ to be limited and optimised
    - Interferences with the beam tube shall be minimised
  - Mechanically independent from the beam tube and the SC link.
    - ➔ No perturbation to beam alignment (↘ vacuum loads, thermal contraction loads, SC link loads, cryogenic pressure fluctuations)
    - ➔ No constraints from beam specs.
  - Electrical continuity



Insulation vacuum layout

- DFX insulation vacuum shared with triplet insulation vacuum
- SCLink has independent vacuum volume and equipment.
- Figures:
  - Target value : 1.10^{-5} mbar
  - Design pressure of vacuum vessels PS < 1.5 bara
- Objective :
  - adapt conductance at D1-DFX to avoid additional pumping equipment (and associated maintenance).
  - Dedicated relief pressure protection

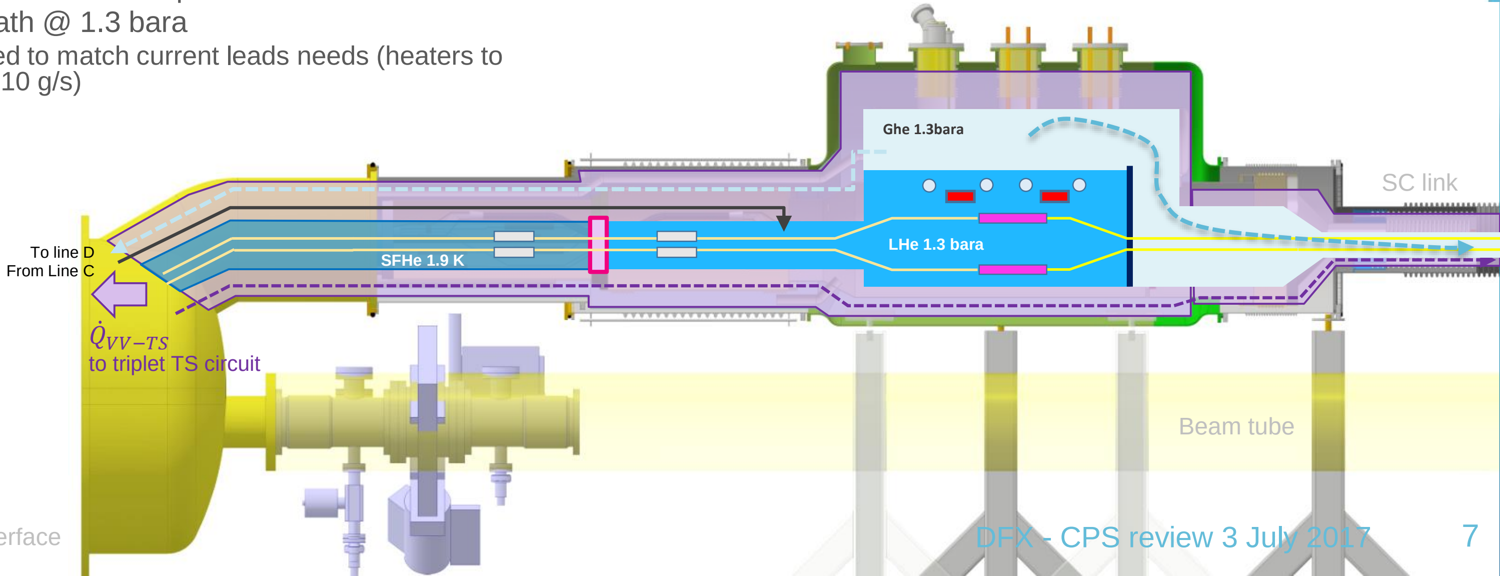


Cryogenics layout

General layout : see Serge Claudet's talk

- Thermal shielding :
  - Conduction cooled from triplets circuit : Tmax < 95 K
  - Line for SCLink thermal shield active cooling 20 K
- Tmax of superconductors in DFX:
  - T(Nb-Ti) < 5.5 K
  - T(MgB_2) < 20 K
- Superfluid helium volume from triplets
- Saturated helium bath @ 1.3 bara
  - Vapor produced to match current leads needs (heaters to produce up to 10 g/s)

- Principle:
  - Heaters (designed up to 200W) vaporizes liquid forcing the gaseous mass flow through the SCLink
- Key technical challenges :
  - Plug between SFHE and LHe (replaceable)
  - Lhe-Ghe interface
  - Interfaces to D1, to SCLink
  - Instrumentation redundancy policy
  - Heaters technology
  - Splice resistivity definition



D1 interface

Heat loads preliminary estimations

To the 40-60K Triplets TS circuit : ≈ 20 W

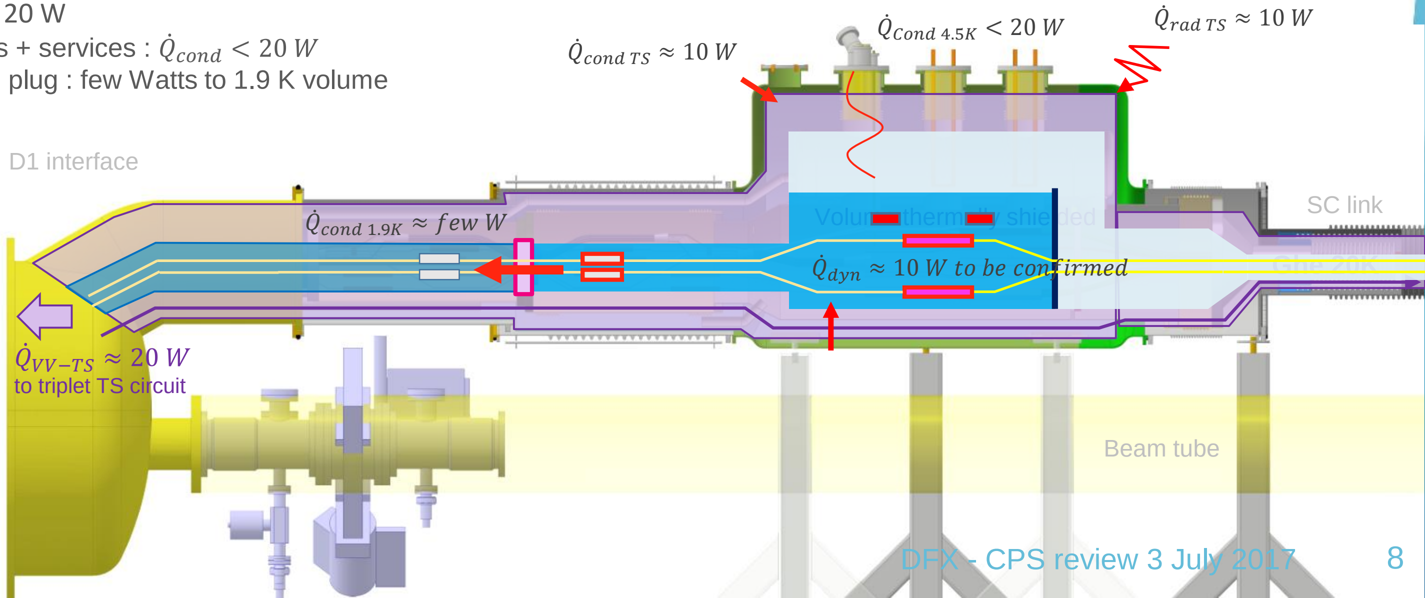
- Radiative heat exchange : Thermal shield equipped with MLI :$\dot{Q}_{rad} \approx 10\ W$
- Conduction heat exchange : supports : $\dot{Q}_{Cond} \approx 10\ W$

To the 4.5 K saturated bath:

- Dynamic loads :
  - Nb-Ti/Nb-Ti : LHC experience R<1.5 nΩ @ 3σ
  - MgB_2/Nb-Ti : R≈10 nΩ starting point, studies on-going
  - ➔ Total splices heat dissipation < 10 W (Iult)

To the 4.5 K saturated bath:

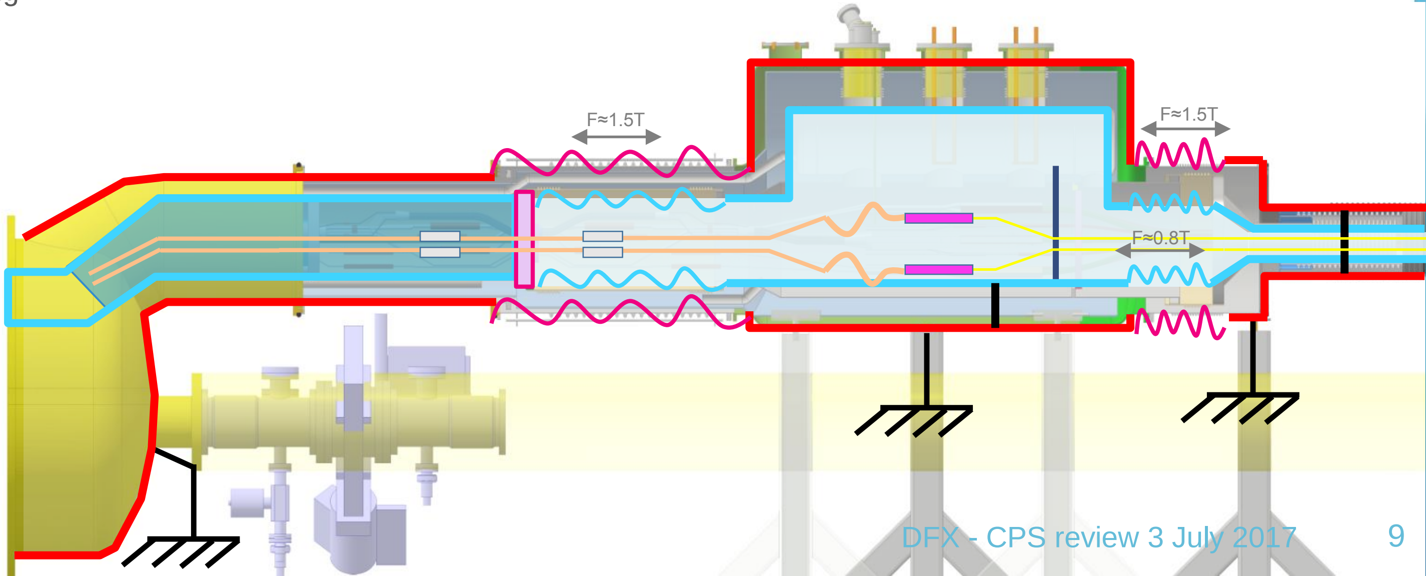
- Static loads : < 20 W
  - Supports + services : $\dot{Q}_{cond} < 20\ W$
  - Through plug : few Watts to 1.9 K volume



Mechanical layout

- Fixed points
  - Vacuum envelopes :
    - SC Link, DFX, independent from D1-Beam tube
  - Helium vessels
    - SC Link, DFX, independent from D1-Beam tube
  - Cables fixed points :
    - SC Link, Plug

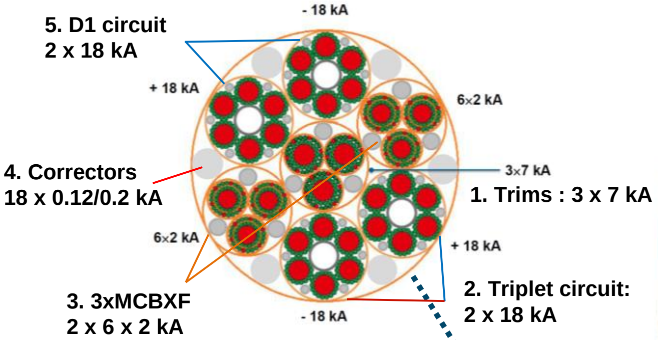
- Thermal contraction
  - MgB_2 cables in SC Link (see P. Retz' presentation)
  - DFX cables : locally
  - D1 interface cables: to be studied
- Challenges
  - Interface D1
  - Installation (see V. Parma's presentation)

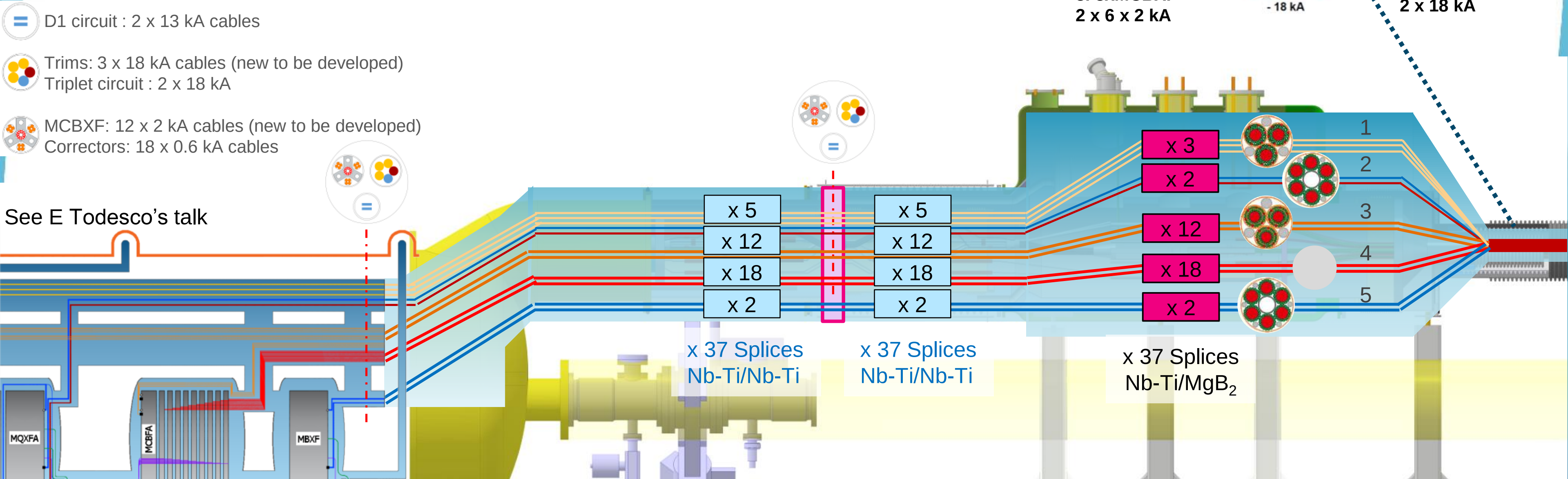


Electrical layout

See K. Konstantopolou and A. Ballarino's talks

- Clear configurations at both ends
- Key challenges for the DFX
  - Integrate splices for accesses, maintenance
  - Prepare SCLink end before installation
  - New cables to be developed ➔ new splices, new tooling, new integration

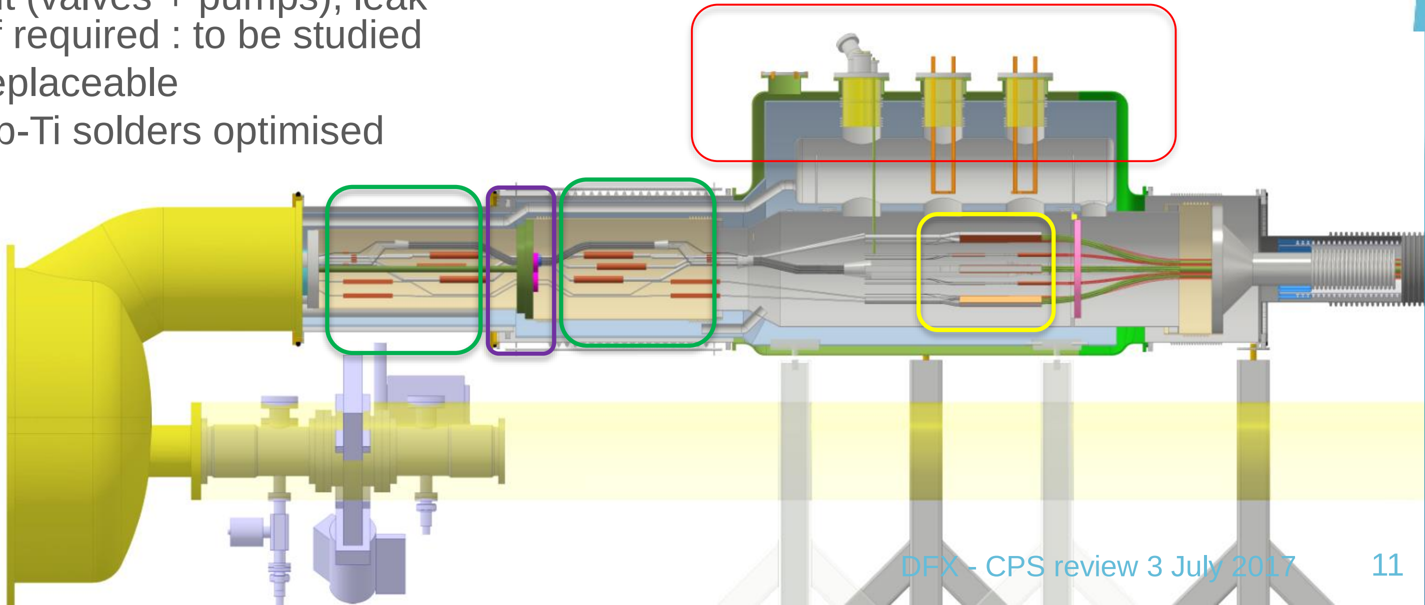




Maintainability

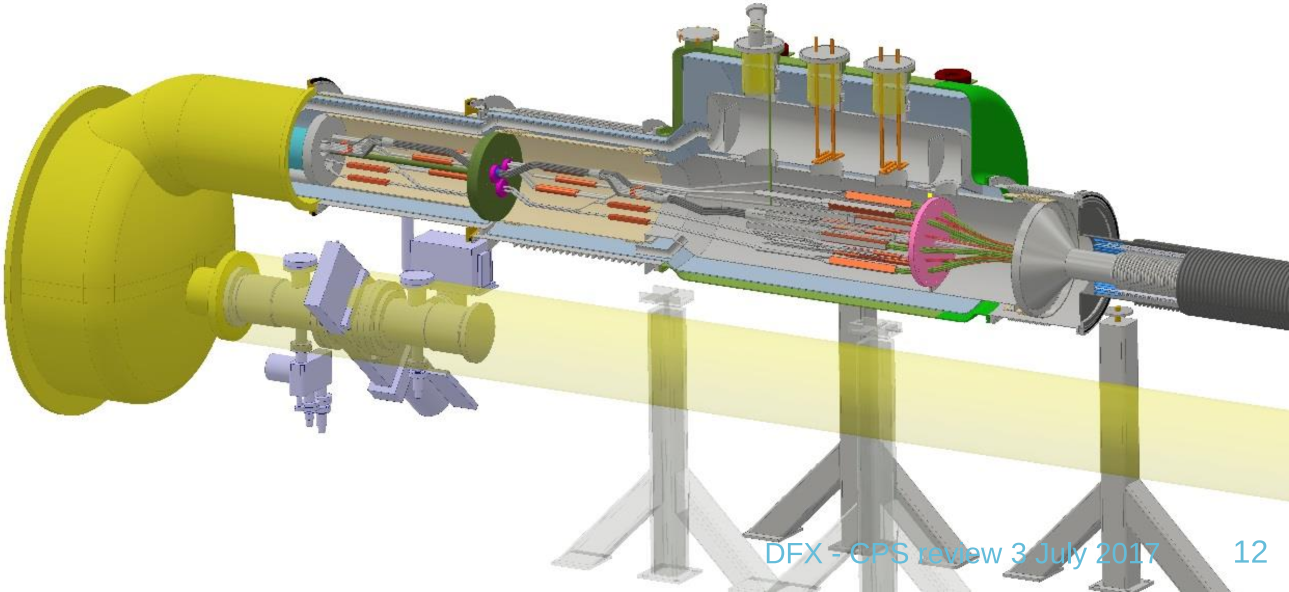
- Instrumentation ➔ redundancy being evaluated
  - T-sensors
  - V-taps
  - Level gauges
  - Heaters
- Safety devices ➔ access optimised
- Vacuum equipment (valves + pumps), leak detection access if required : to be studied
- Plug is foreseen replaceable
- Access to Nb-Ti/Nb-Ti solders optimised

- Maintenance of MgB_2-NbTi solders may require :
  - Disconnection of Nb-Ti solders
  - Disassembly of SCLink-DFX
  - No spare MgB_2 cables
- All maintenance operations to be performed in radioactive environment



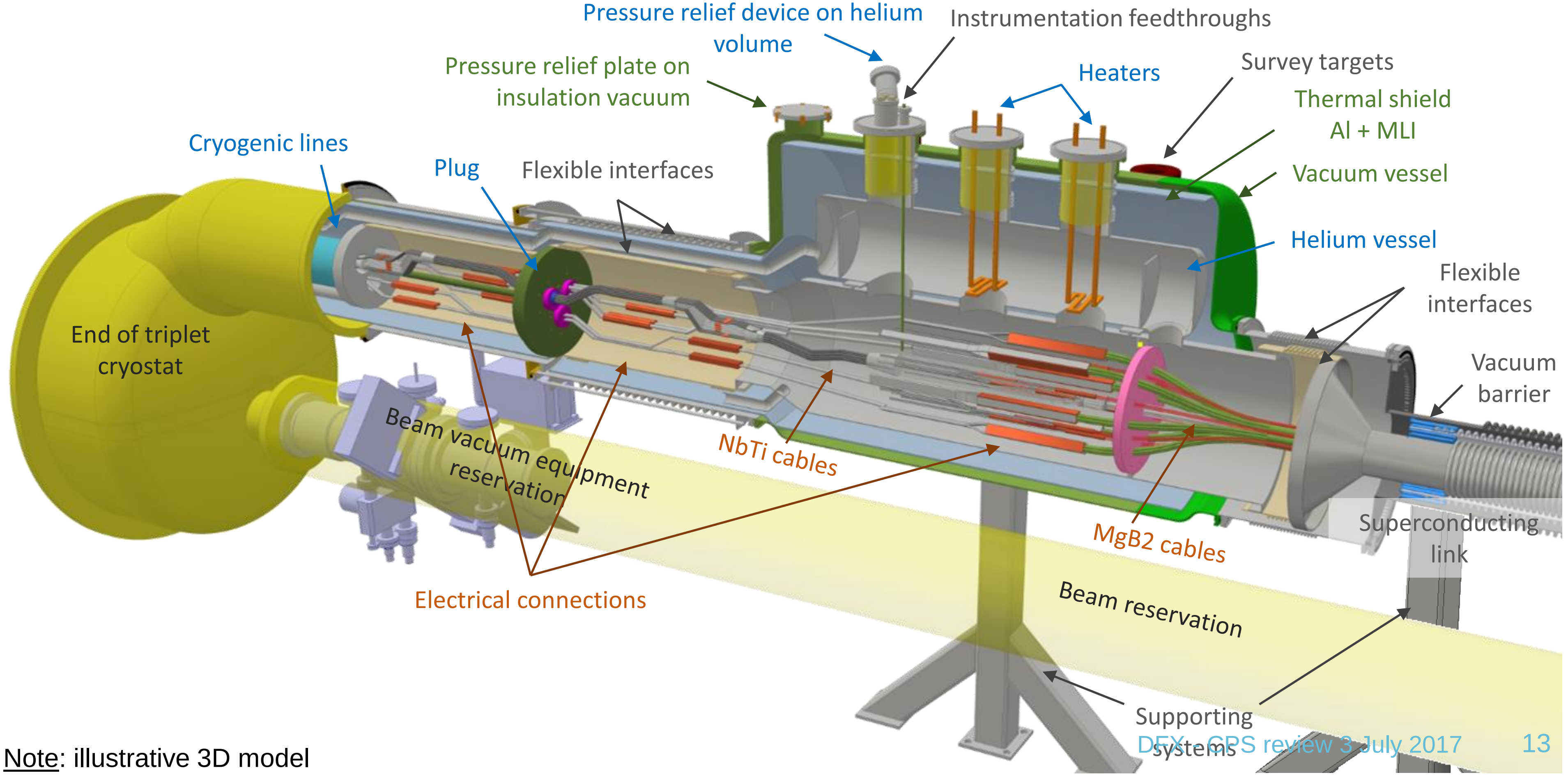
Installation sequence

- D1 and electrical connection up to plug pre-installed
- Installation DFX + SCLink (see V. Parma's presentation)
- Welding Helium volumes DFX-SCLink
- Insulation vacuum interface DFX-SCLink
- Electrical connection Nb-Ti / Nb-Ti
- Closure Helium volume
- Thermal shield
- Vacuum vessel sleeve



Note: illustrative 3D model

DFX design : 3D Model



Note: illustrative 3D model

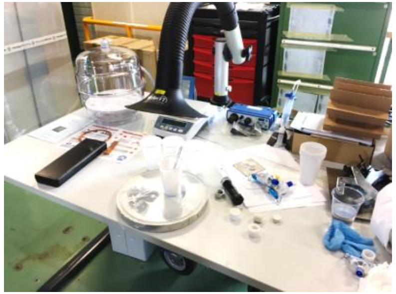
Identified key challenges

Work on identified technical challenges

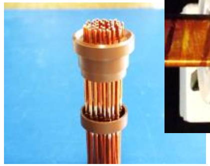
- Plug : activity starting (resources available from October)
  - State of the art studied
  - Dedicated lab being set-up
  - Be able to reproduce existing plugs used in LHC
  - ➔ Adapt to new cables, new specifications
- Heaters technology : well advanced
  - Specs. of needs and state the of art studied ➔ report soon in EDMS (I. Falorio)
  - Technical solution based on CERN cryogenic group's experience
- LHe-Ghe barrier : being studied
- Splices resistivity:
  - NbTi-NbTi : based on LHC measurements campaign measure as basis (March 2012)
  - MgB2-Nb-Ti : studies on going
- Splices integration : in progress
  - Mock-up in SMI2 for real visualisation and future access testing
  - 3D study in parallel
  - ➔ define overall integration
  - ➔ define conductance with D1 and pumping equipment needs
- Mechanical interfaces with D1 : being studied
  - D1 : cryogenic integration, fixed points for piping, cables.
- Mechanical interfaces with SCLink : studies in progress
  - Installation (see V. Parma's presentation), detailed design,

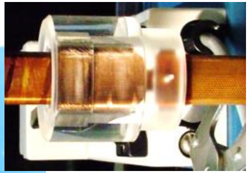
➔ Focusing resources on technical challenges

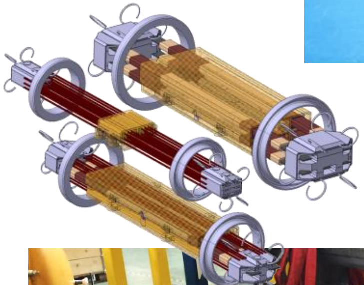
DFX plug laboratory (SMI2)



LHC experience







Conceptual 3D modelling

Splices layout mock-up

Conclusions

- The DFX design is well advanced within limits of today's knowledge
  - Needs are clear and detailed specs are in progress (first-order values defined)
  - Engineering concepts defined and feasible (most from LHC experience)
  - Key challenges identified (e.g. plugs, splices) and *ad-hoc* actions being implemented
  - Several technical challenges ahead but no showstoppers identified
  - The engineering and detailed design workload remaining is heavy, especially considering parallelism on various working fronts

- Forthcoming activities:
  - Design of SC link extremity and integration of SC link cable (MgB2-NbTi extensions geometry)
  - Design/construction of a DFX demonstrator (DDFX), a focused prototype to validate the DFX main concepts for a system test from April 2018
  - The DFH: start conceptual design, aiming at an overall concept towards end 2017
  - 2018 should be dedicated to detailed design and drawings for procurement of DFX and DFH prototypes for a procurement to start in Q4 2018