Conceptual study of the cryostats for the cold powering system for the triplets of the High Luminosity LHC

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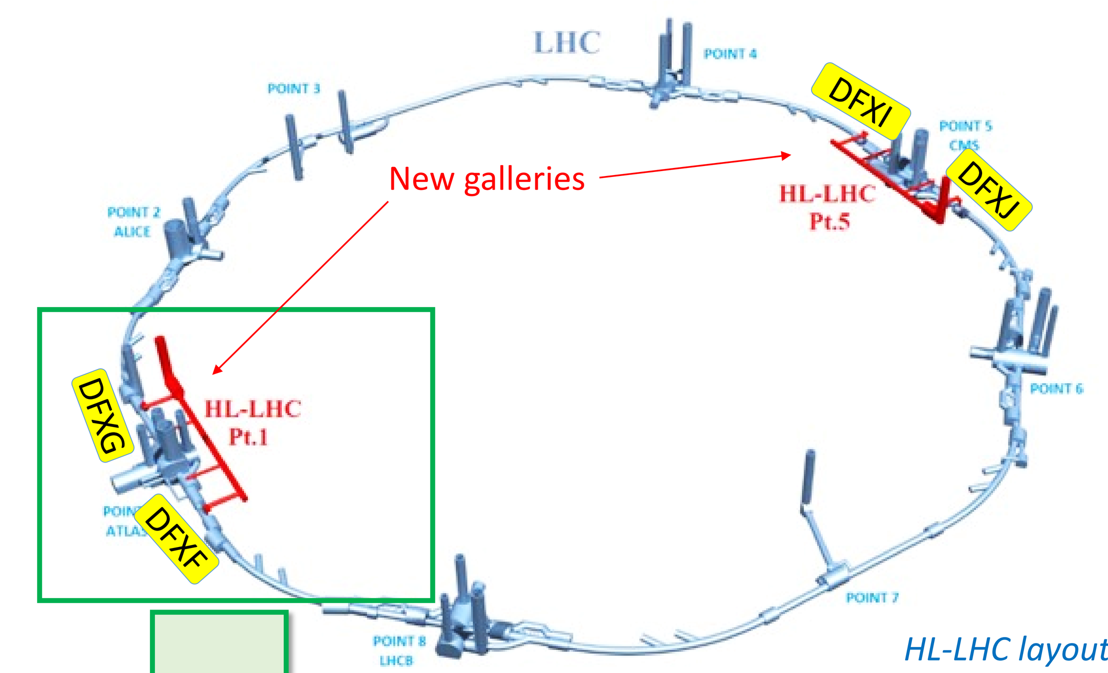
Abstract. The High Luminosity LHC (HL-LHC) is a project aiming to upgrade the LHC collider after 2020-2025 in order to increase the integrated luminosity by about one order of magnitude and extend the operational capabilities until 2035. The upgrade of the focusing triplet insertions for the Atlas and CMS experiments foresees using superconducting magnets operating in a pressurised superfluid helium bath at 1.9 K. The increased radiation levels from the particle debris produced by particle collisions in the experiments require that the power converters are placed in radiation shielded zones located in a service gallery adjacent to main tunnel. The powering of the magnets from the gallery is achieved by means of MgB_2 superconducting cables in a 100-m long flexible cryostat transfer line, actively cooled by 4.5 K to 20 K gaseous helium generated close to the magnets. At the highest temperature end the helium flow cools the HTS current leads before being recovered at room temperature. At the magnet connection side, a dedicated connection box allows connection to the magnets and a controlled boil-off production of helium for the cooling needs of the powering system. This paper presents the overall concept of the cryostat system, from the magnet connection boxes, through the flexible cryostat transfer line, to the connection box of the current leads.

Context

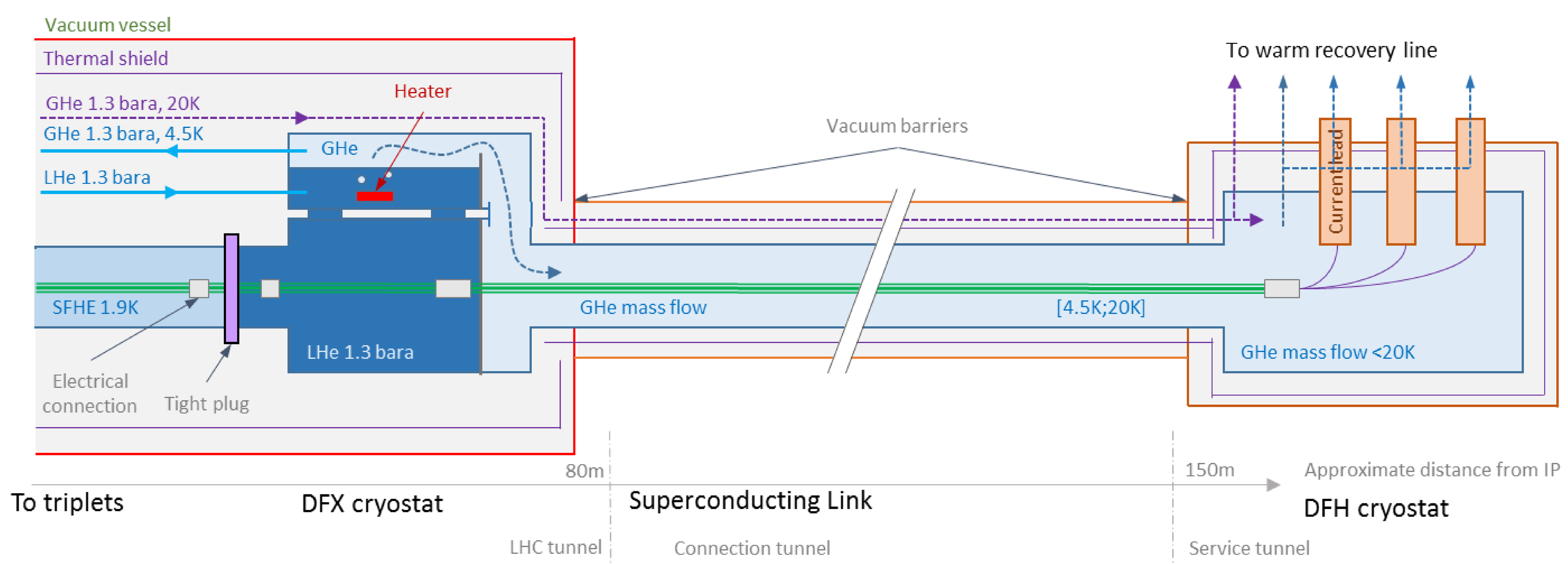
- The High Luminosity LHC project requires the installation of new triplet insertions focusing the beam at each side of the 2 interaction points.
  - ➔ Increase of intensity and luminosity
  - ➔ Higher levels of radiation
  - ➔ Shield power converters by installing them in newly dug 400 meters long parallel galleries
- Installation of power converters and cold powering system is planned in 2024-2025 and operation from mid-2026.



HL-LHC layout

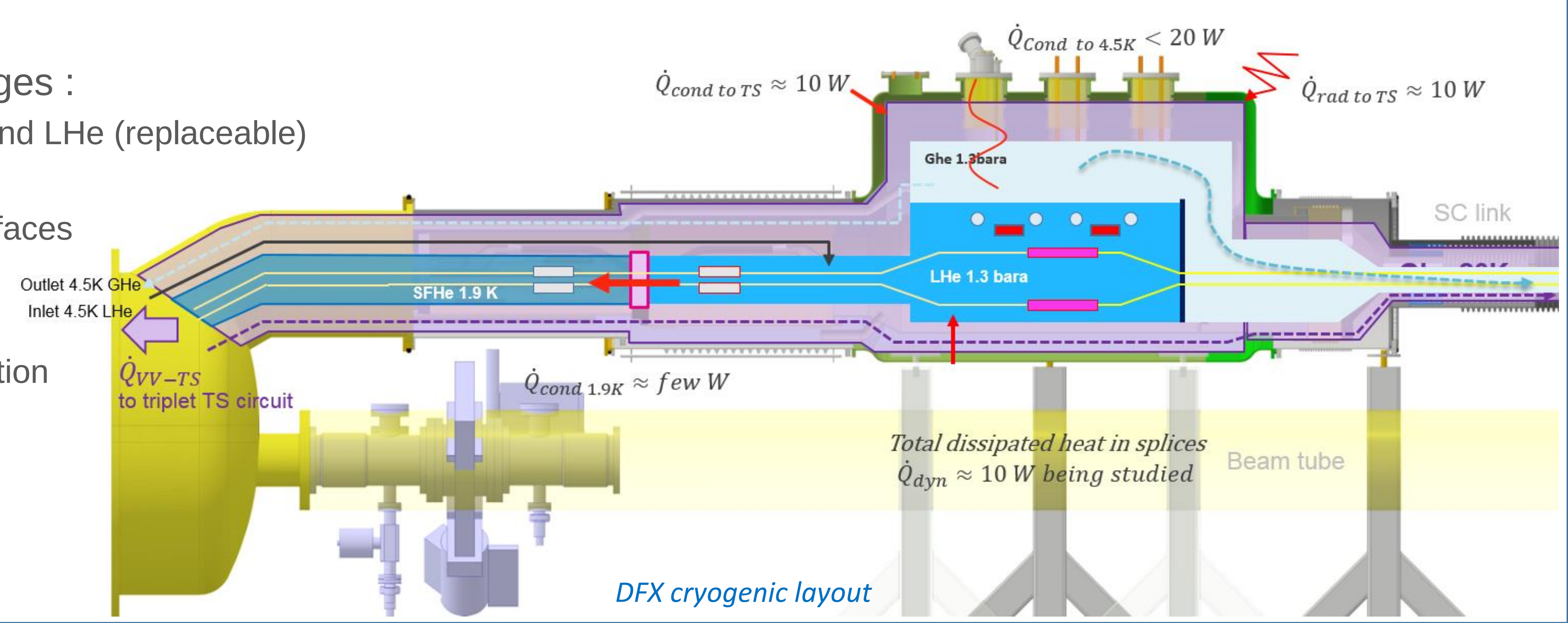
Cryogenics layout

- Principle:
  - A tight interface, called plug, separates the superfluid helium volume of the triplets and the saturated liquid helium bath of the DFX.
  - The plug presents soldered electrical connections on each side.
  - Heaters vaporizes liquid forcing the gaseous mass flow from 4.5 K through the SCLink
  - The gas cooling the current leads, is recuperated at the warm end and returned to the recovery line
- Operational temperature ranges for the superconductors in the chain of cryostats:
  - Max T(Nb-Ti) < 5.5 K
  - Max T(MgB_2) < 20 K
  - Max T(HTS) < 50 K
- The mass flow is guided by the needs of the current leads ≈ 5 g/s
- Superconducting heat loads estimations
  - To the thermal shield ≈ 250 W
  - To the helium volume < 20 W



Simplified layout of the cryogenic supply of the cold powering system

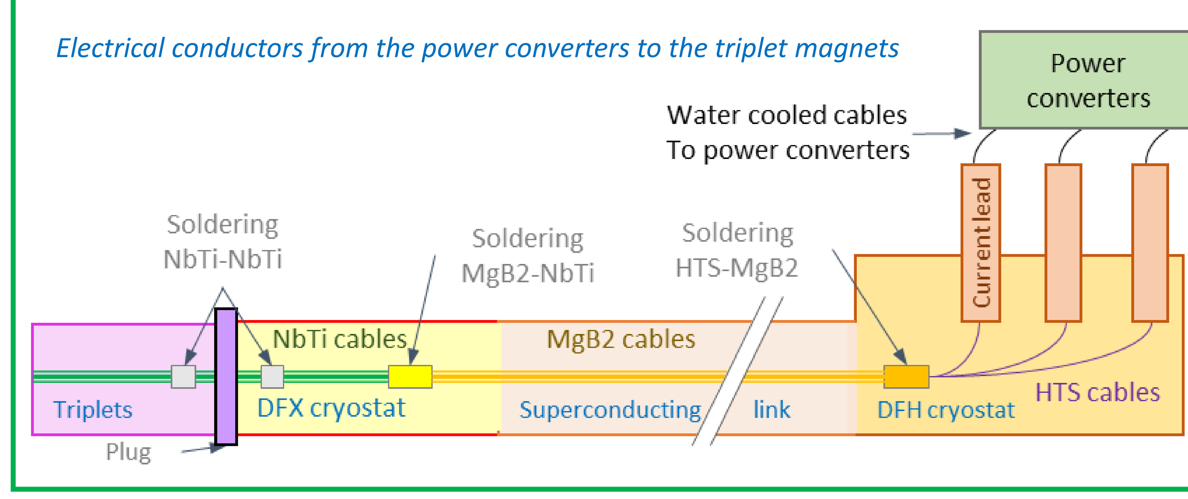
- DFX cryogenic details
  - Static heat loads to Thermal shield < 20 W
  - Static heat loads to 4.5 K bath < 20 W
  - Dynamic heat loads due to splices resistivity < 10 W, being studied.
- Key technical challenges :
  - Plug between SFHE and LHe (replaceable)
  - Lhe-Ghe interface
  - Integration of the interfaces
  - Instrumentation policy
  - Heaters technology
  - Splice resistivity definition

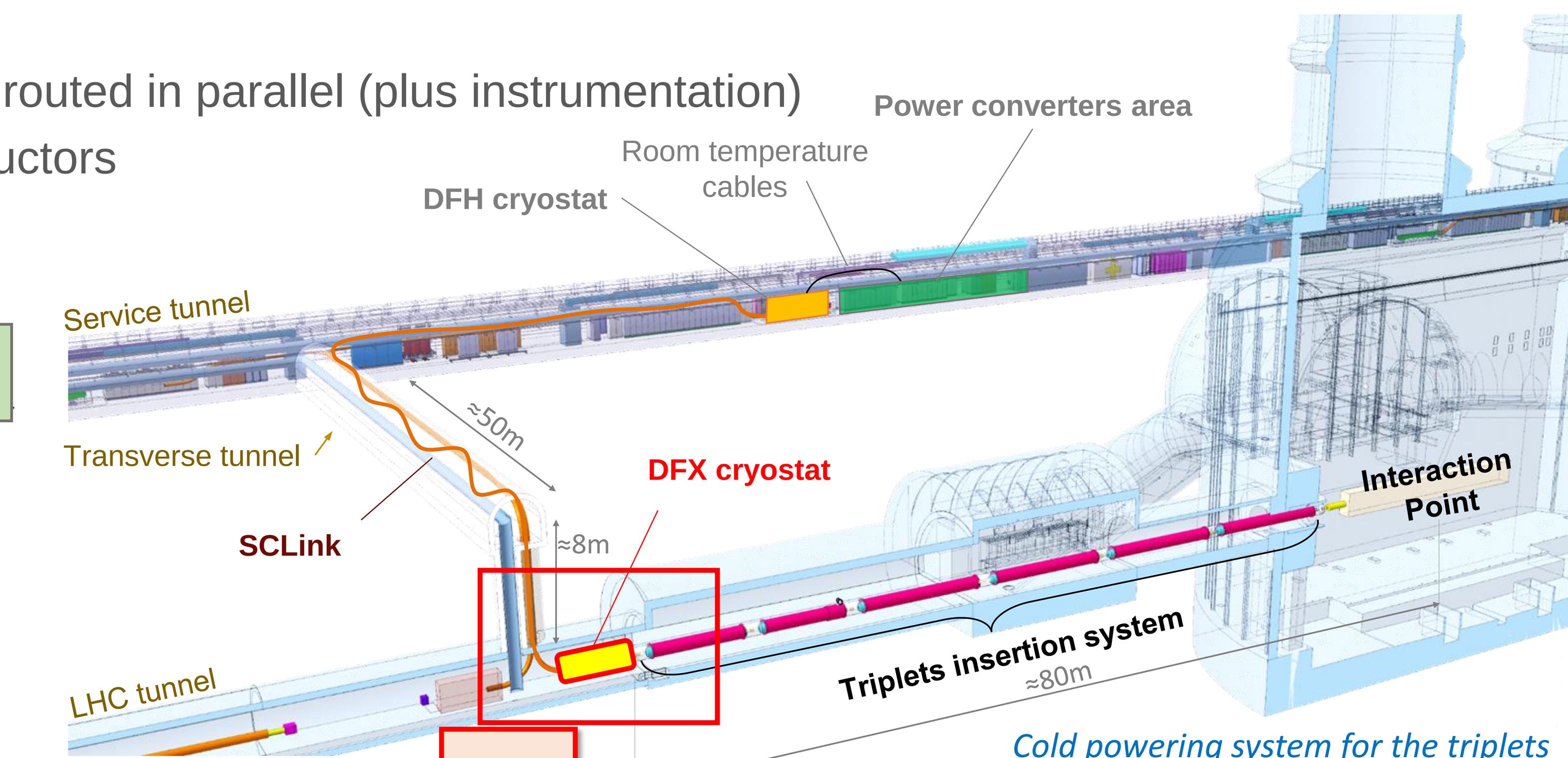


DFX cryogenic layout

Superconducting link and connection boxes

- Each interaction point sides is equipped with a cold powering chains of cryostats to power the triplet magnets and correctors.
- Power converters, located about 100 metres away, are electrically connected to the superconducting magnets via circuits made of conventional and superconducting cables
- Circuits are rated from 120 A to 18 kA, 37 cables are routed in parallel (plus instrumentation)
- Up to 220 electrical connections between superconductors

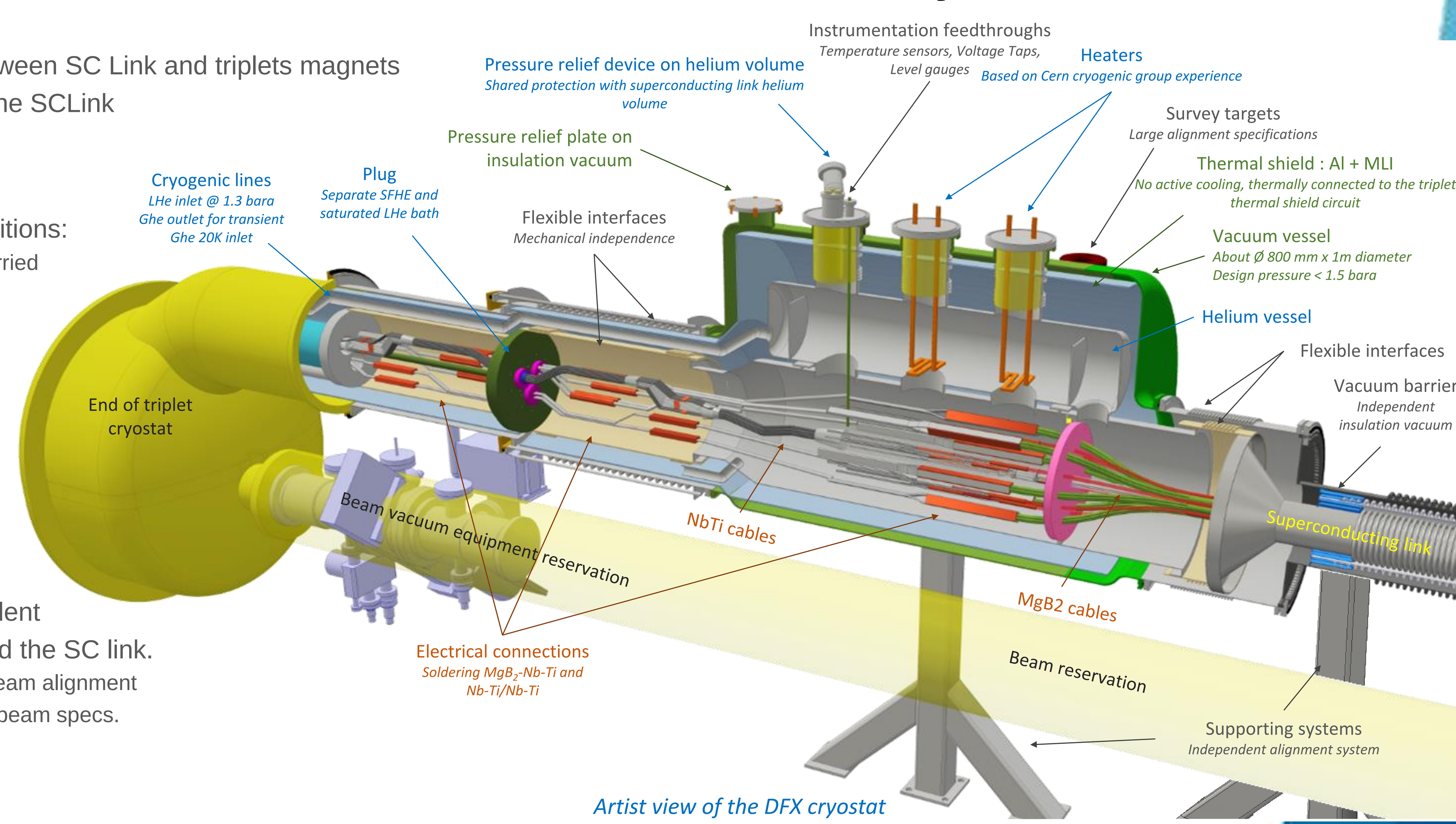




Cold powering system for the triplets

DFX : electrical connection box cryostat

- DFX basic functions:
  - Electrical interface between SC Link and triplets magnets
  - Supply cryogenics to the SCLink
- Key concepts:
  - Design boundary conditions:
    - Future maintenance carried out in an activated zone
    - Interferences with the beam tube shall be minimised
  - Mechanically independent from the beam tube and the SC link.
    - ➔ No perturbation to beam alignment
    - ➔ No constraints from beam specs.



Artist view of the DFX cryostat