Instrumentation in the DFX: Requirements and Routing

Electrical Protection and Cryogenic Sensors

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Internal Review of DFX Detailed Design, 20th June 2019 (Indico 821876)

Outline

- Cold Powering Instrumentation Specification
- DFX Instrumentation:
  - Electrical Protection of Circuits
  - Cryogenics
  - Feedthroughs
  - Vacuum

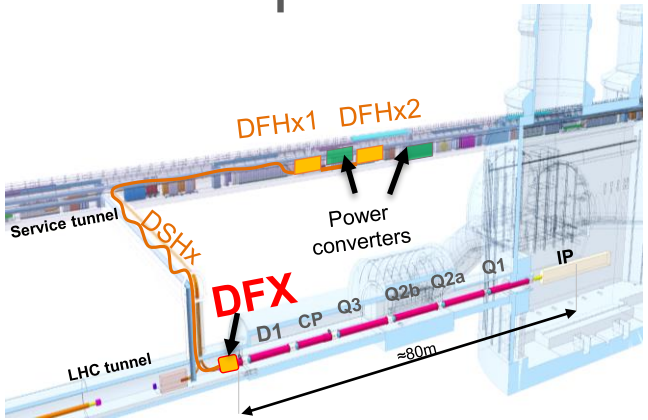
Specification

- A functional specification documenting the instrumentation requirements of the Cold Powering System of the Inner Triplets has been discussed and prepared [1]
  - DFX instrumentation represents a subset of that specification
- A draft DFX instrumentation list was presented at the DFX conceptual design review, 31st Jan 2019 [2]. Since then:
  - No change to the voltage taps
  - **Addition of two heaters for the warm-up phase and four temperature sensors for monitoring the heaters**
  - **Addition of ΔP LHe level gauge** for level monitoring in LHe fountain

[1] J. Fleiter, EDMS 2087413
[2] J. Fleiter, DFX Instrumentation Requirements, Indico 783116

Overview of Electrical Circuits

- The cold powering system of the inner triplets consists of:
  - 2 × **18 kA** **MQXF main circuit**
  - 3 × **7 kA** **MQXF trims**
  - 2 × **13 kA** **D1 circuit**
  - 12 × **2 kA** **MCBXF circuit**



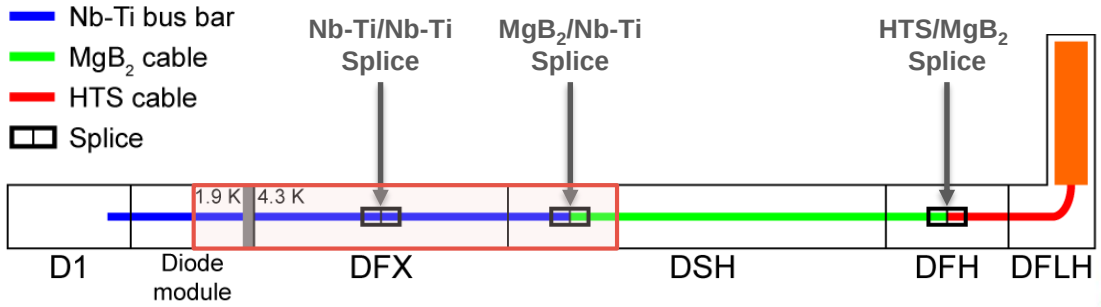
- A total of 19 circuit branches will be routed through the DFX:
  - The DFX hosts Nb-Ti/Nb-Ti splices between Nb-Ti bus bars and the Nb-Ti extensions of the SC Link.

Overview of Electrical Circuits

- Each circuit branch consists of:
  - **SC cables**

Present Scope

    - **Nb-Ti bus bar passing through the plug (~3.5m in DFX)**
    - **Nb-Ti bus bar extension connected at the surface to the MgB_2 cables (~1.5 m)**
    - MgB_2 cable (~100 m long)
    - HTS cable (~3-5 m long)
  - **Splices**
    - **Nb-Ti/Nb-Ti**
    - **MgB_2/Nb-Ti**
    - HTS/MgB_2



Electrical Protection Requirements

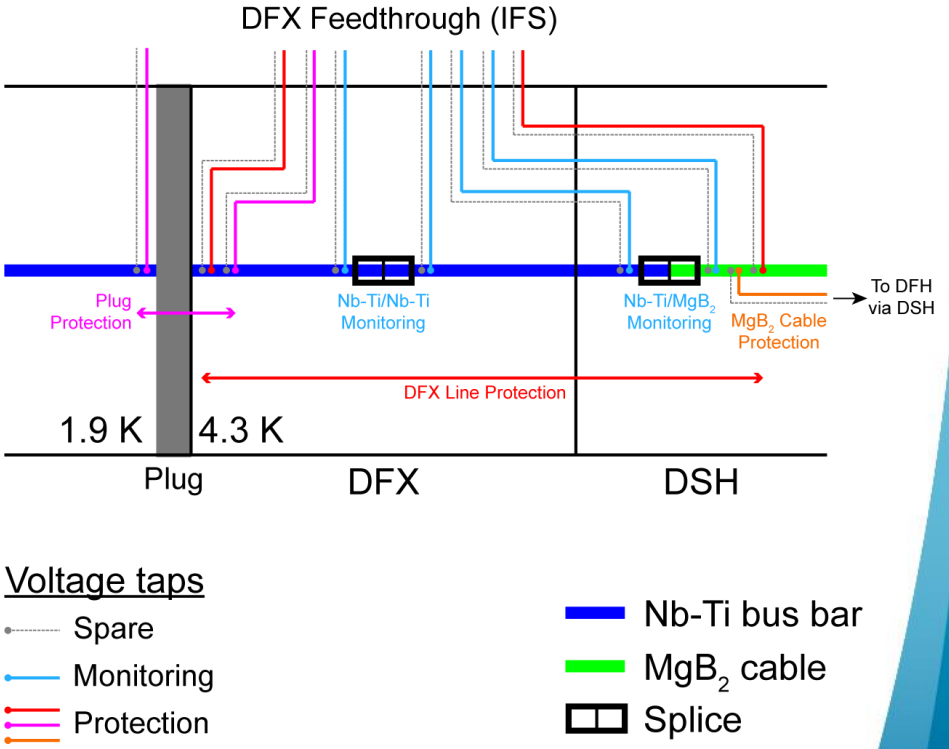
- Requirements for circuit protection were presented in the cold powering review, July 2017 [1]:
  - **Active protection** of SC cables and current leads.
  - **Monitoring** of individual splices:
    - MgB_2/HTS, MgB_2/Nb-Ti and Nb-Ti/Nb-Ti.
  - Redundancy of voltage taps.
- Active protection shall be implemented with a dedicated Quench Detection/Protection System that:
  - Detects any quench or detached voltage taps, and
  - Triggers the discharge of the circuit.

[1] A. Ballarino, Requirements for the protection of the SC links components, Indico 643197

Instrumentation for Circuit Protection

- Each circuit branch will be equipped with voltage taps:
  - 1 pair within the DFX cold mass to monitor the Nb-Ti/Nb-Ti splice
  - 1 pair routed via the DFX to monitor the Nb-Ti/MgB_2 splice
  - 1 pair to protect the line inside the DFX
  - 1 pair to protect the Nb-Ti bus through the plug (1 wire from the DFX, 1 from the cold diode module)
  - One spare for each of the above

  →14 wires per circuit branch to route out from the DFX
- Wire for voltage taps:
  - Polyimide insulated Cu wire, AWG 26 (used for magnet instrumentation) [1]



[1] Axon HH2619, EDMS 2030599

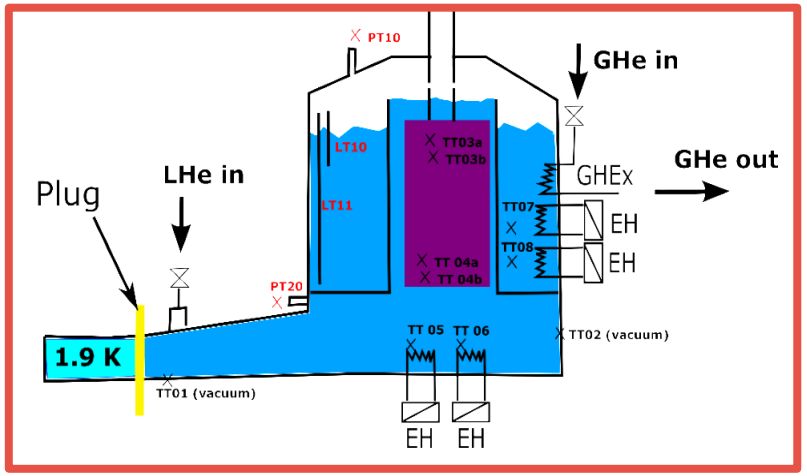
Enlarge

Cryogenic Requirements of the DFX

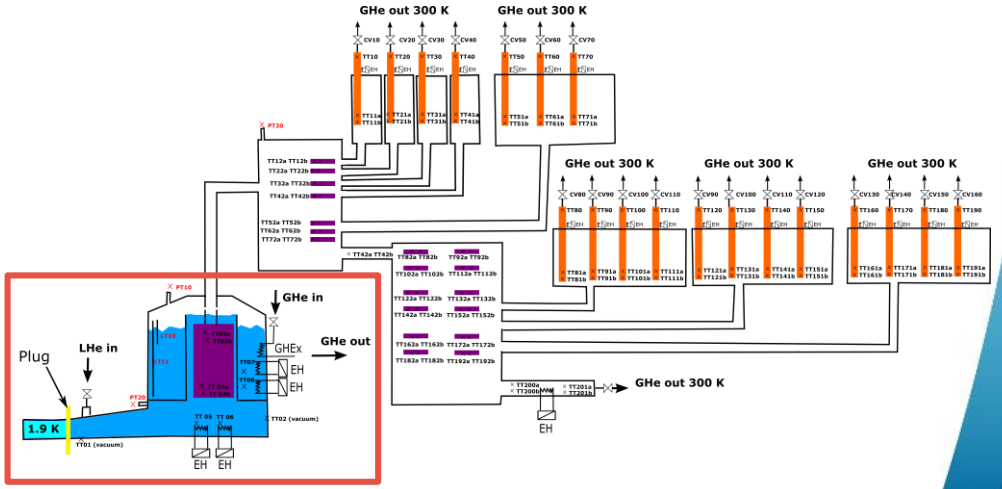
- **Immersion** of Nb-Ti/MgB_2 splices and Nb-Ti bus bars in saturated **LHe bath at 1.3 bar**:
  - LHe level regulation required
- Generate a GHe mass flow from the LHe bath to:
  - Maintain the **MgB_2 cable assembly** within the SC Link at **below 17 K**
  - Maintain all the **MgB_2/HTS splices** (DFH box) **below 17 K**
  - Thermalize the cold terminal of the **heat exchanger** of each **current lead** to **50 K**

General Cryogenic Layout of the SC Link for the Triplets

- General cryogenic instrumentation layout of SC Link elaborated with S. Claudet
- Wiring of cryo instrumentation of DFX routed via the DFX feedthrough
- No routing of cryo instrumentation of DFH and current leads via the DFX

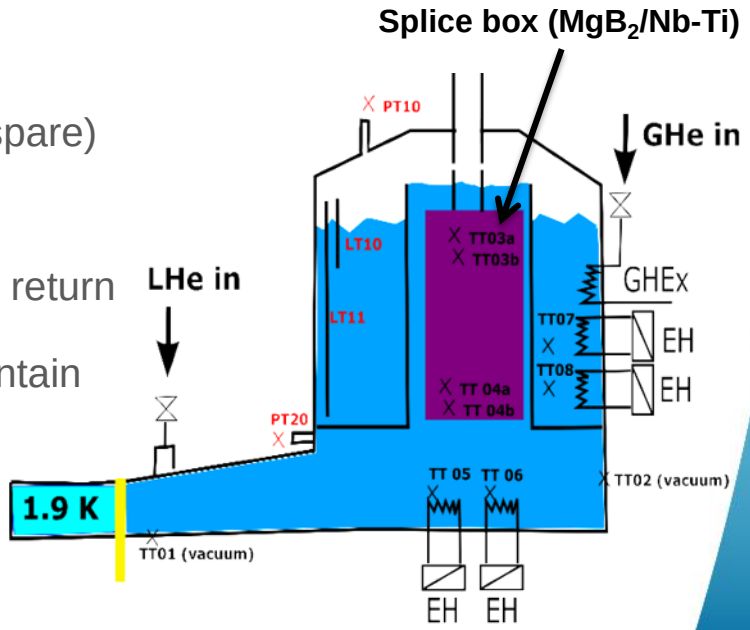


➔ **Focus on DFX in this presentation**



Cryogenic Instrumentation of the DFX

- 10 temperature transducers (TT):
  - Two in vacuum attached to He tank (Cernox): mutual spares
  - 4 in the splice box (He tank) (Cernox)
  - 4 temperature sensors attached to the resistive heaters
- 4 resistive heaters and 1 heat exchanger:
  - 1 GHe/LHe heat exchanger
  - 2 resistive heaters in external bath (includes 1 spare)
  - 2 resistive heater in the lower bath
- 2 pressure gauges:
  - 1 He pressure gauge located on the helium gas return line in the QXL
  - 1 ΔP gauge to measure level of liquid in the fountain
- 2 LHe level transducers
- Cryo valves: part of cryo jumper



Cryogenic Instrumentation of the DFX

- Temperature transducer wiring:
  - 4 wires per probe
  - 2 probes in vacuum → 8 wires at vacuum feedthrough:
    - >1 m long wires, no thermalization required
    - Manganin wires, AWG 36 [1]
  - 8 probes in LHe → 32 wires at DFX cold mass instrumentation feedthrough:
    - Cu wires, AWG 32 [1]
- LHe level transducer:
  - 2 probes (wires part of the probe)
    - Easily replaceable for unscheduled repair work interventions (by design of DFX)
- Electrical heater wiring:
  - 2 wires per heater → 8 wires (Cu, cross-sectional area to be confirmed)

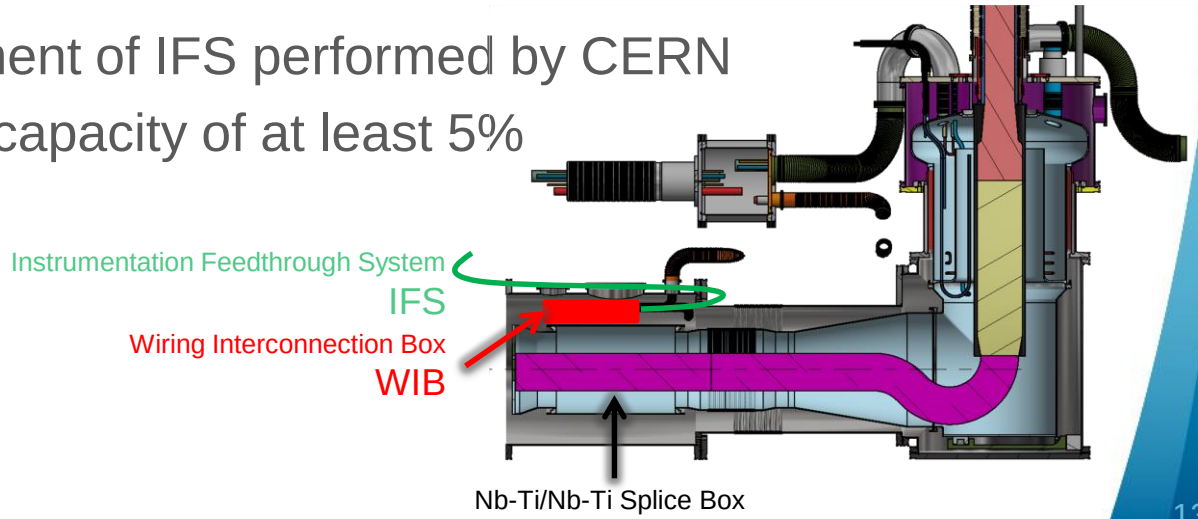
[1] LHC-Q-GN-0009, EDMS 320597

Feedthroughs for DFX Voltage Taps and Cryogenic Instrumentation (1)

- Two types of feedthrough for instrumentation installed in DFX cold mass:
  - Voltage taps (at least two units)
    - Must meet insulation voltage requirements, to ground and between circuits, during acceptance tests of components, insulation tests of the system and operation
    - Instrumentation wires grouped by circuit, considering voltage ratings
  - Temperature probes and resistance heaters (one unit)
- Feedthrough based on the concept of the Instrumentation Feedthrough System (IFS) of LHC cryo magnets
  - IFS constructed as components tested on the surface and then assembled in the DFX

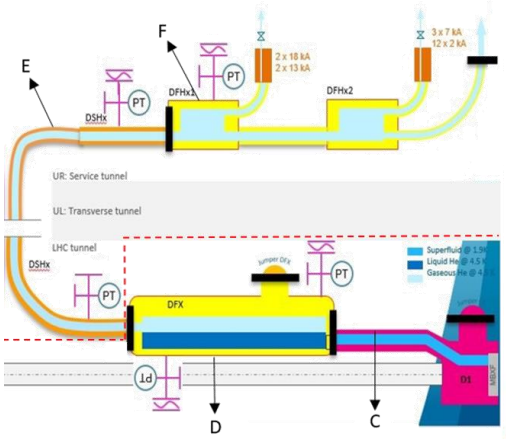
Feedthroughs for DFX Voltage Taps and Cryogenic Instrumentation (2)

- Cold mass instrumentation wiring (voltage taps, temperature, heater) connected to IFS wiring in a Wiring Interconnection Box (WIB)
- WIB located next to Nb-Ti/Nb-Ti splice box to allow access for repairs
- Design and procurement of IFS performed by CERN
- IFS to provide spare capacity of at least 5%



Vacuum Instrumentation of the DFX

- The cold powering chain of the inner triplet comprises three vacuum volumes [1]:
  - **DFX**, **DSH** and **DFH**
- The DFX vacuum vessel will be equipped with ports to connect pumping units and vacuum instrumentation [2]
- All the vacuum instrumentation (Pirani, Penning and membrane gauge) will be external to the DFX vacuum vessel
  → **no wiring is required in the vessel for vacuum instrumentation**



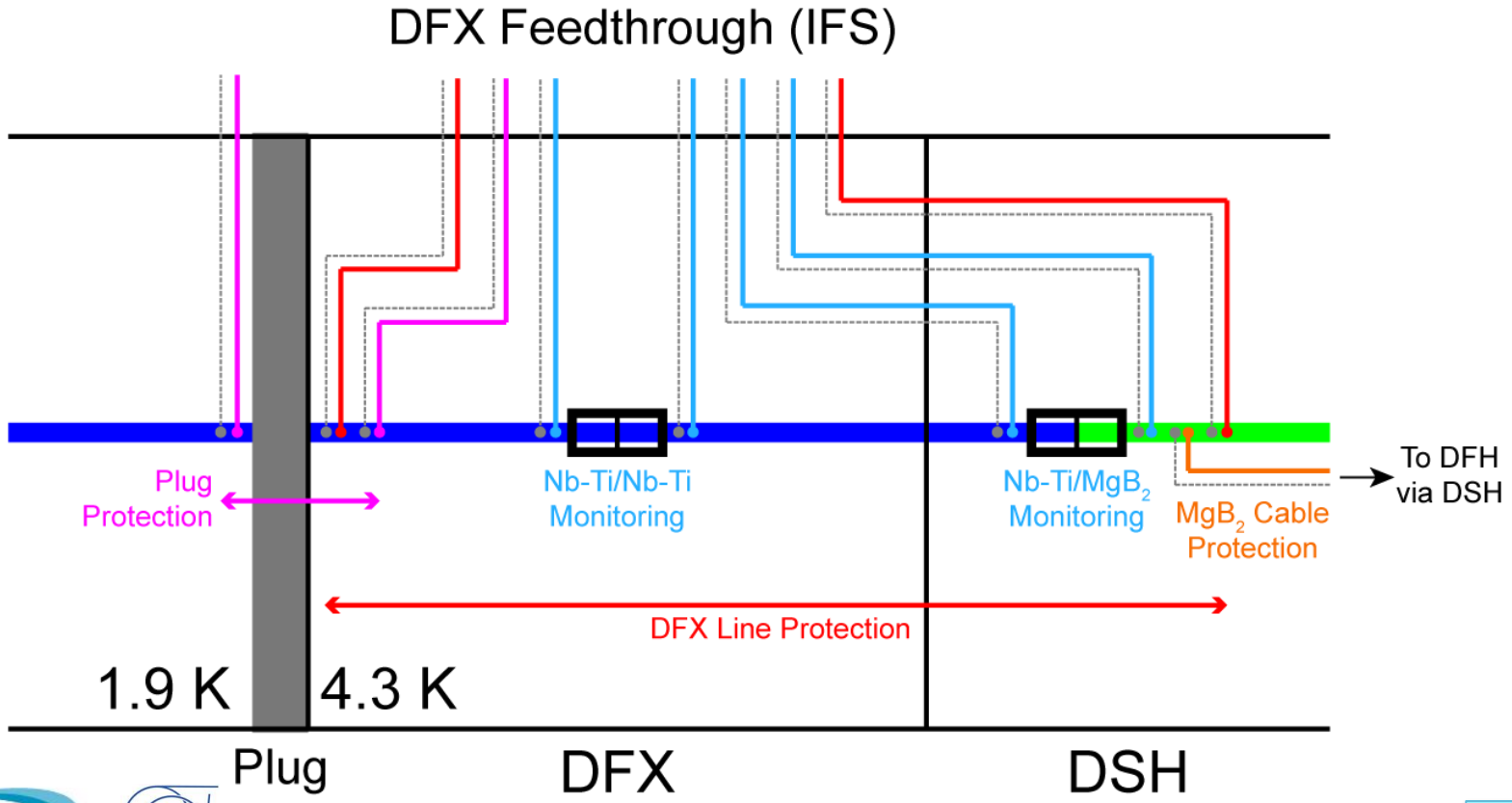
[1] G. Riddone et al., EDMS 1824906; Y. Leclercq, EDMS 2019348
[2] Y. Leclercq, DFX Interfaces, EDMS 2157597

Summary

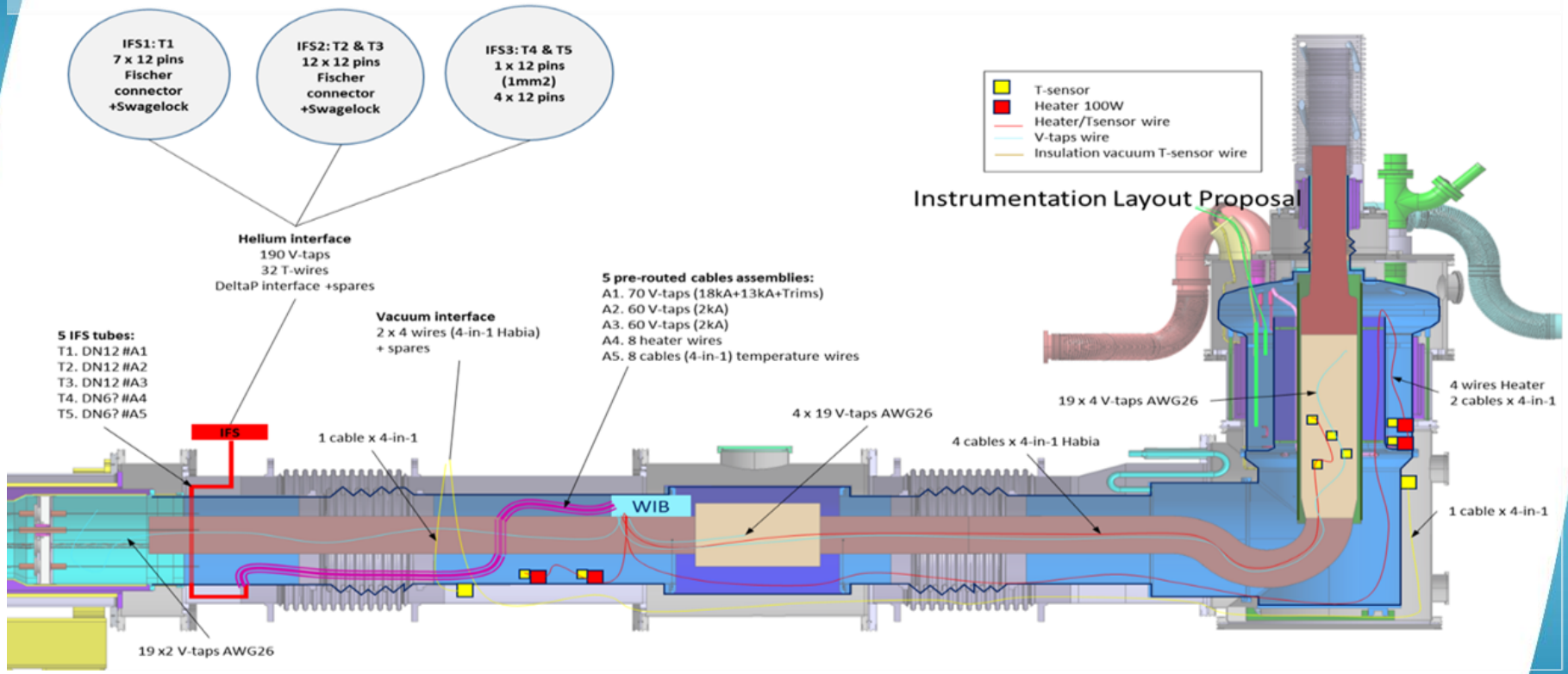
- Instrumentation in the DFX:
  - Protection:
    - Electrical protection requirements implemented using ~200 voltage taps over the 19 circuit branches for monitoring and protection
  - Cryogenics:
    - 8 temperature probes, + 2 in vacuum *
    - 2 level gauges *,
    - 2 pressure gauges,
    - 1 GHe/LHe heat exchanger,
    - 4 resistive heaters
  - Vacuum: no vacuum instrumentation routed in the vessel
- Instrumentation wires routed to room temperature via Instrumentation Feedthrough Systems (IFS) on the DFX
  (except those marked * above)

Extra Slides

Enlargement of Voltage Tap Configuration



DFX Instrumentation Layout Proposal



Sketch from Y. Leclercq