DFH Functional and Technical requirements

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DDR DFH 16 June 2020

Outline

- System reminder and Applicable Code and standards
- Main functions
- Cryogenic requirement :
  - PFD and interface
  - Pressure map
  - Operating cases
  - Helium flow requirement and thermal design
  - Cryo instrumentation

System reminder

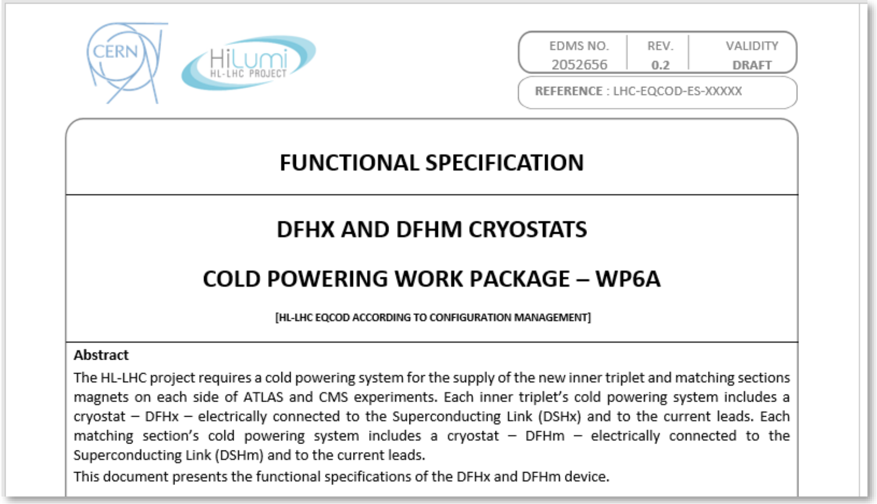
- Functional spec EDMS [2052656]
- DFH located in the Service Gallery

→ Radiation-free and magnetic field-free area

- Lifetime : 20 years
- Applicable codes:

→ CERN GSI-M4 → The Pressure Equipment Directive (PED) 2014-68-EU

→ CERN Code C1 → Electrical Installations for Buildings : IEC 60364



EDMS NO.	REV.	VALIDITY
2052656	0.2	DRAFT

REFERENCE : LHC-EQCOD-ES-XXXXX

FUNCTIONAL SPECIFICATION

DFHX AND DFHM CRYOSTATS

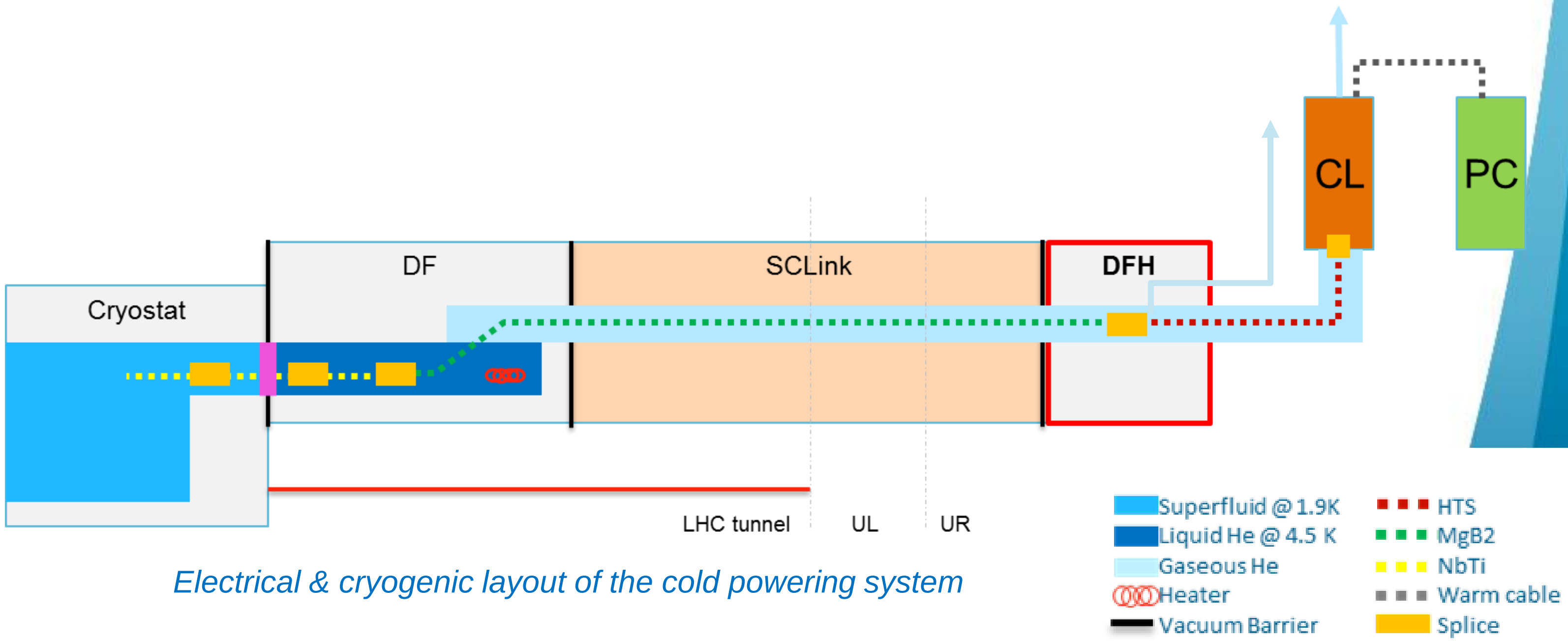
COLD POWERING WORK PACKAGE – WP6A

[HL-LHC EQCOD ACCORDING TO CONFIGURATION MANAGEMENT]

Abstract

The HL-LHC project requires a cold powering system for the supply of the new inner triplet and matching sections magnets on each side of ATLAS and CMS experiments. Each inner triplet's cold powering system includes a cryostat – DFHx – electrically connected to the Superconducting Link (DSHx) and to the current leads. Each matching section's cold powering system includes a cryostat – DFHm – electrically connected to the Superconducting Link (DSHm) and to the current leads.

This document presents the functional specifications of the DFHx and DFHm device.



Electrical & cryogenic layout of the cold powering system

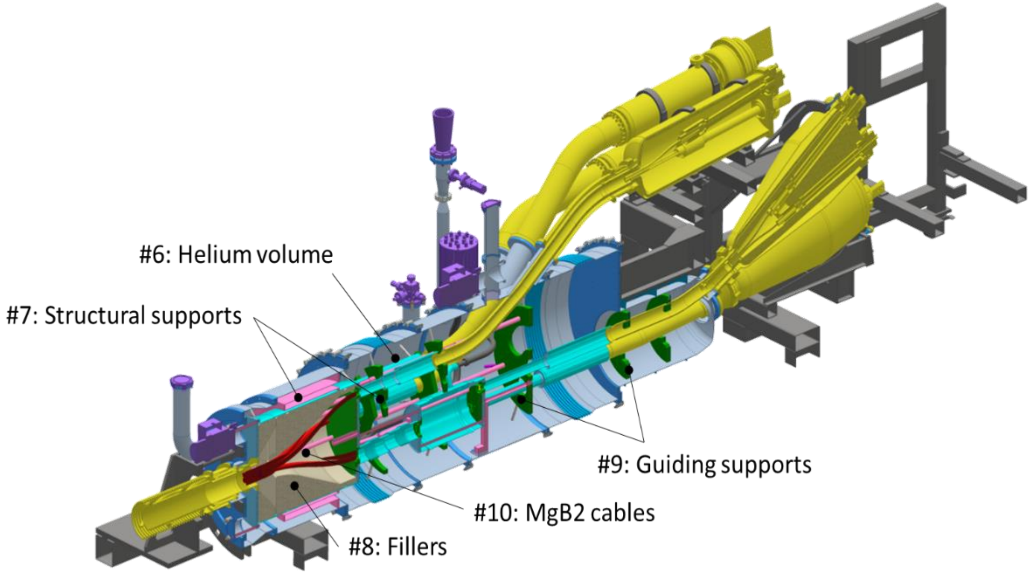
Main requirements and interfaces

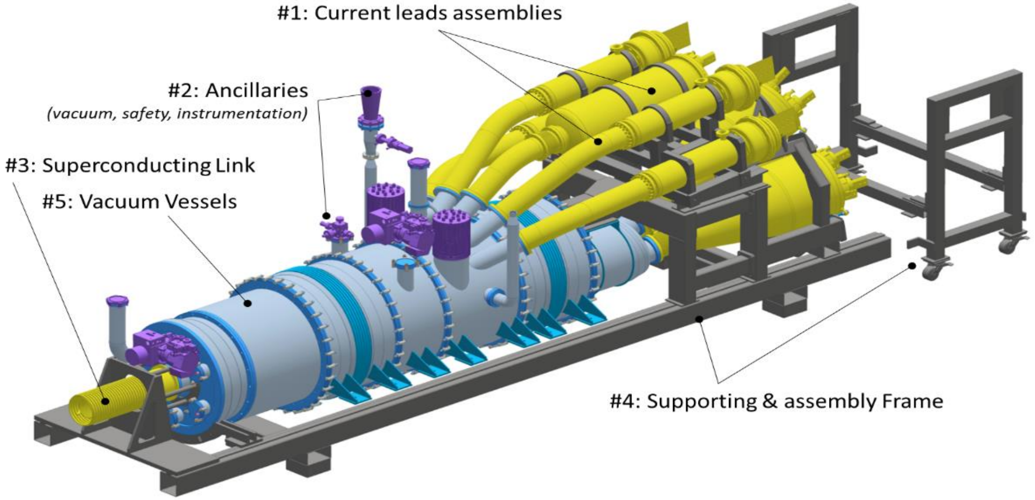
- **Electrical requirements**
  - Electrical performance of the SC link MgB_2 to current leads HTS cables electrical connections
  - Routing, support and thermal contraction of conductors
  - Access to do and repair the splices
  - Will be covered in more details DFH cable, splices talk.

- **Insulation vacuum specifications**
  - Independent SC Link – DFH+CL volumes
  - Use of CERN standard equipment & design rules
  - Usual CERN leak rate levels for cryogenic equipment

- **Integration & Maintainability**
  - Comply with UR and interfaces requirements
  - See dedicated talks

- **Cryogenic interface**
  - Ensure heat extraction from MgB2/HTS splice by gaseous helium forced convection transfer
  - Ensure the transfer of required gaseous helium to the current leads





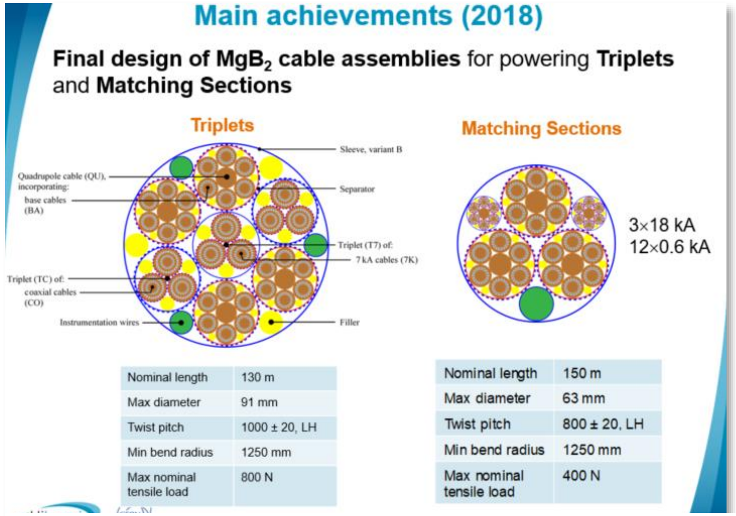
3D images courtesy F.Pillon & EN-MME

Electrical specifications

- **Electrical interface**
  - Electrical performance of the SC link MgB_2 to current leads HTS cables electrical connections
  - Routing, support and thermal contraction of conductors
  - Access to do and repair the splices
  - Current leads are organised as follow:
    - 13-18 kA : one conductor per cryostat
    - 2 kA – 0.6 kA : 4 conductors per cryostat
    - Trim : 3 conductors per cryostat

Splice type	Resistance	Volume
[-]	[nΩ]	[mm]
18 kA	2.5*	70 x 60 x 300
13 kA	2.5*	70 x 60 x 300
2 kA	15	20 x 30 x 650
2 kA Trim	7.5	20 x 45 x 300

* Equivalent resistance



Main achievements (2018)

Final design of MgB_2 cable assemblies for powering **Triplets** and **Matching Sections**

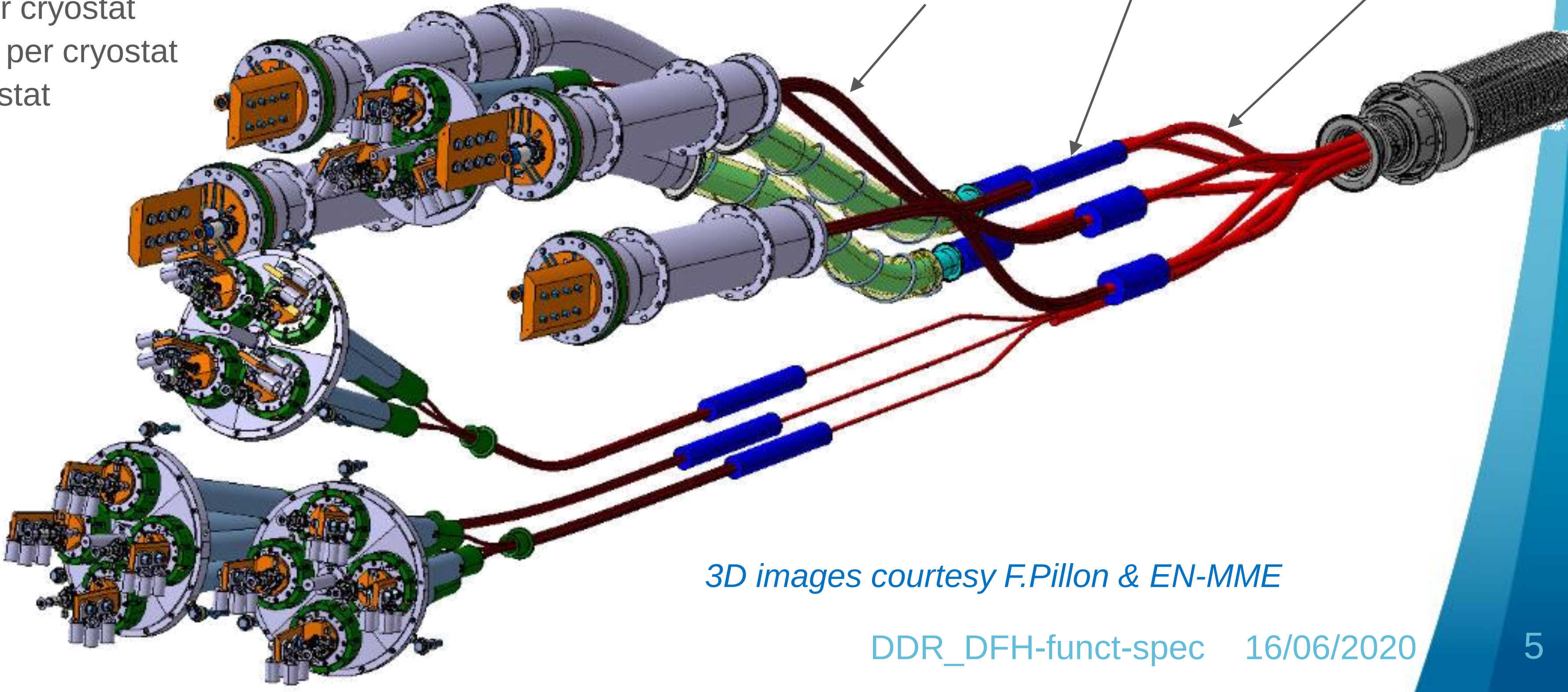
Triplets:

Nominal length	130 m
Max diameter	91 mm
Twist pitch	1000 ± 20, LH
Min bend radius	1250 mm
Max nominal tensile load	800 N

Matching Sections:

Nominal length	150 m
Max diameter	63 mm
Twist pitch	800 ± 20, LH
Min bend radius	1250 mm
Max nominal tensile load	400 N

MgB2 cable Spec :
courtesy A.ballarino 8th HL LHC collaboration meeting



3D images courtesy F.Pillon & EN-MME

Cryogenic requirement :
Process Flow Diagram and interface

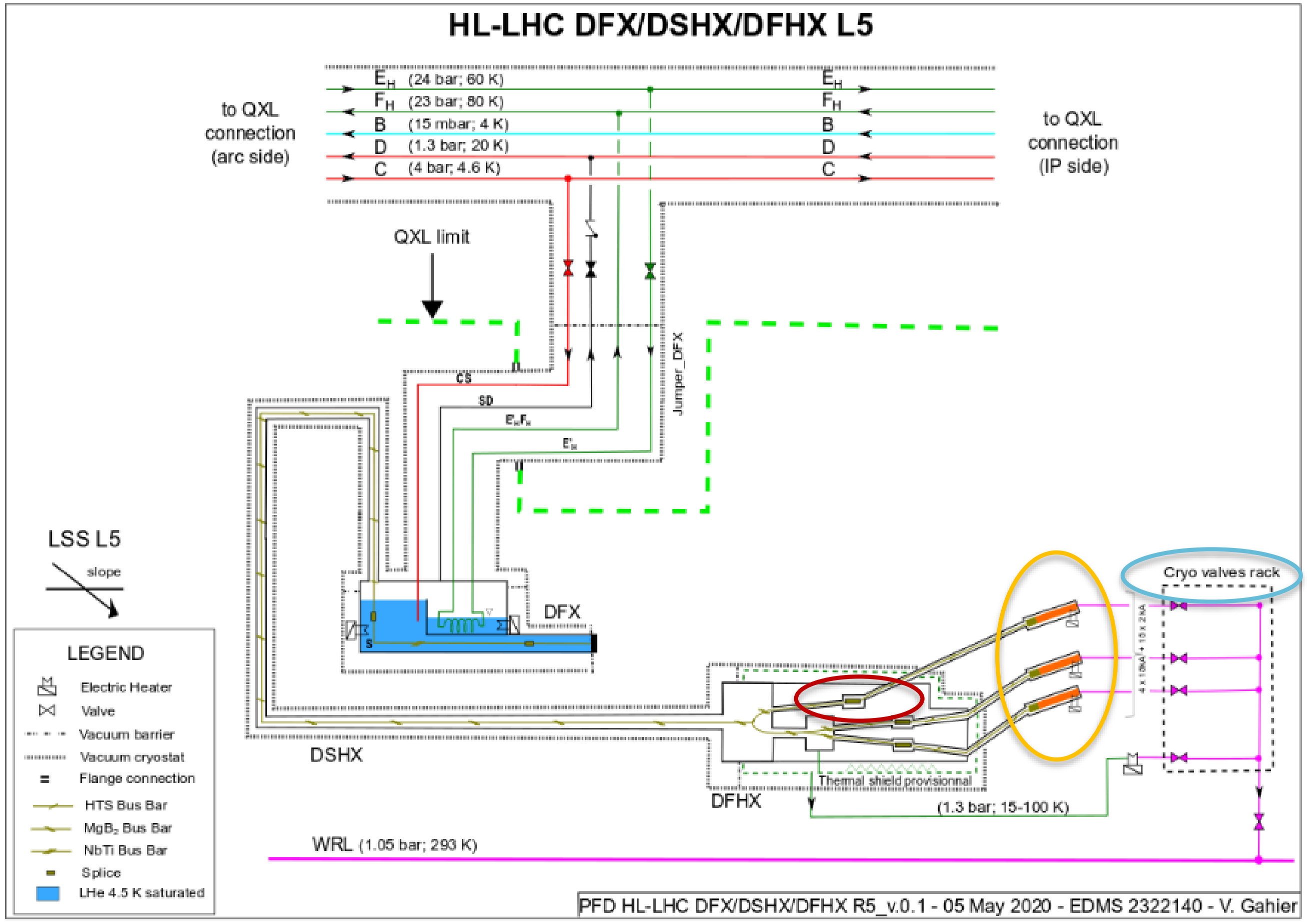
MgB2-HTS splice
< 20 K by forced gaseous circulation

Current lead
HTS-copper transition < 50 K by helium circulation. Controlled by flow control at warm end of the current lead
Warm end of current lead to be maintained at 300 K to avoid water/ice condensation (heater installed)

19 currents leads for DFHX
- 4 x 18 kA type
- 15 x 2 kA type

10 currents leads for DFHM
- 2 x 18 kA type
- 8 x 0.6 kA type

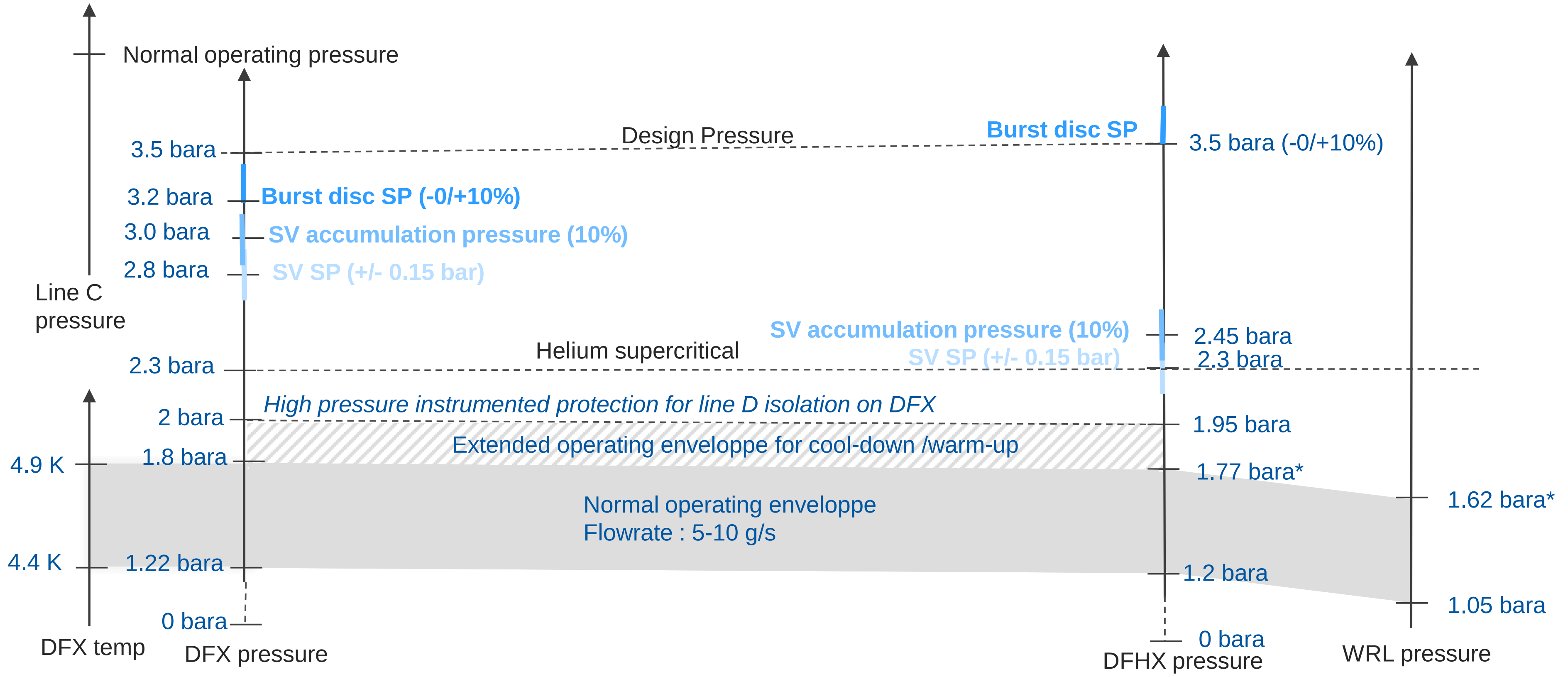
Valve rack
Part of WP6a but engineered and procured by CRG
19 currents leads valves (baseline type Burkert as per LHC) for DFHX (**10** for DFHM)
1 bypass valve and one heater to control a priori pressure in DFH



- PFD for Inner triplet cold powering presented above EDMS 2322140
- PFD for Matching section cold powering refer to EDMS 2373843

Cryogenic safety

- All Cold powering system designed at 3.5 bara
- Staggered safety protection system to ensure release of helium at safe location
- More details available in Safety talk



* Considering minimized pressure drop

Operating modes

Cool down
- Circuit **Purging ; Flushing**
- **Cool down** from 300 K to 4.5 K
- Re cool down after unplanned stop

Planned Operation
- **Standby** no current during normal operation
- **Nominal full current** (ultimate and nominal)
- Standby mode during **Technical Stop**

Unplanned Operation
- Power cut (with blocked outlet)
- Quench / electrical short circuit…
- Degraded performance (SC link; current lead…)

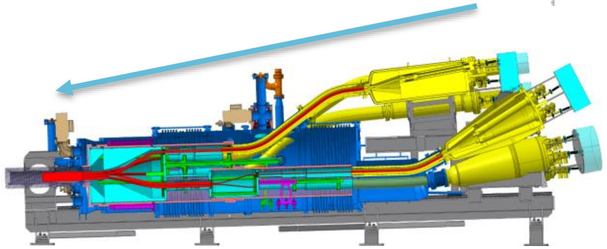
Warm up
- **Warm up** to 300 K

Configuration	Helium Volume		SC Link Insulation Vacuum		DFH and CL Insulation vacuum	
	[bara]	*[K]*	*[bara]*	*[K]*	*[bara]*	*[K]*
After assembly	1	300	1	300	1	300
Pumping						
Pumping insulation vacuum SC Link	1	300	0	300*	1	300
Pumping insulation vacuum DFH	1	300	1	300	0	300*
Cryogenic circuit purging						
Purge of cryogenic circuit without vacuum	0	300	1	300	1	300*
Purge of cryogenic circuit with SC Link vacuum	0	300	0	300*	1	300*
Purge of cryogenic circuit with DFH vacuum	0	300	1	300	0	300
Pressure test	5.0	300	0	300*	0	300
Thermal cycle						
DFH Cool down	2.0	-	0	300*	0	300*
Nominal	1.3	17	0	300*	0	300*
DESIGN	3.5	17	0	300*	0	300*
DFH warm up	2.0	-	0	300*	0	300*
Non nominal events						
Vacuum break SC Link	3.5	17	1.5	300	0	300*
Vacuum break DFH	3.5	17	0	300*	1.5	300

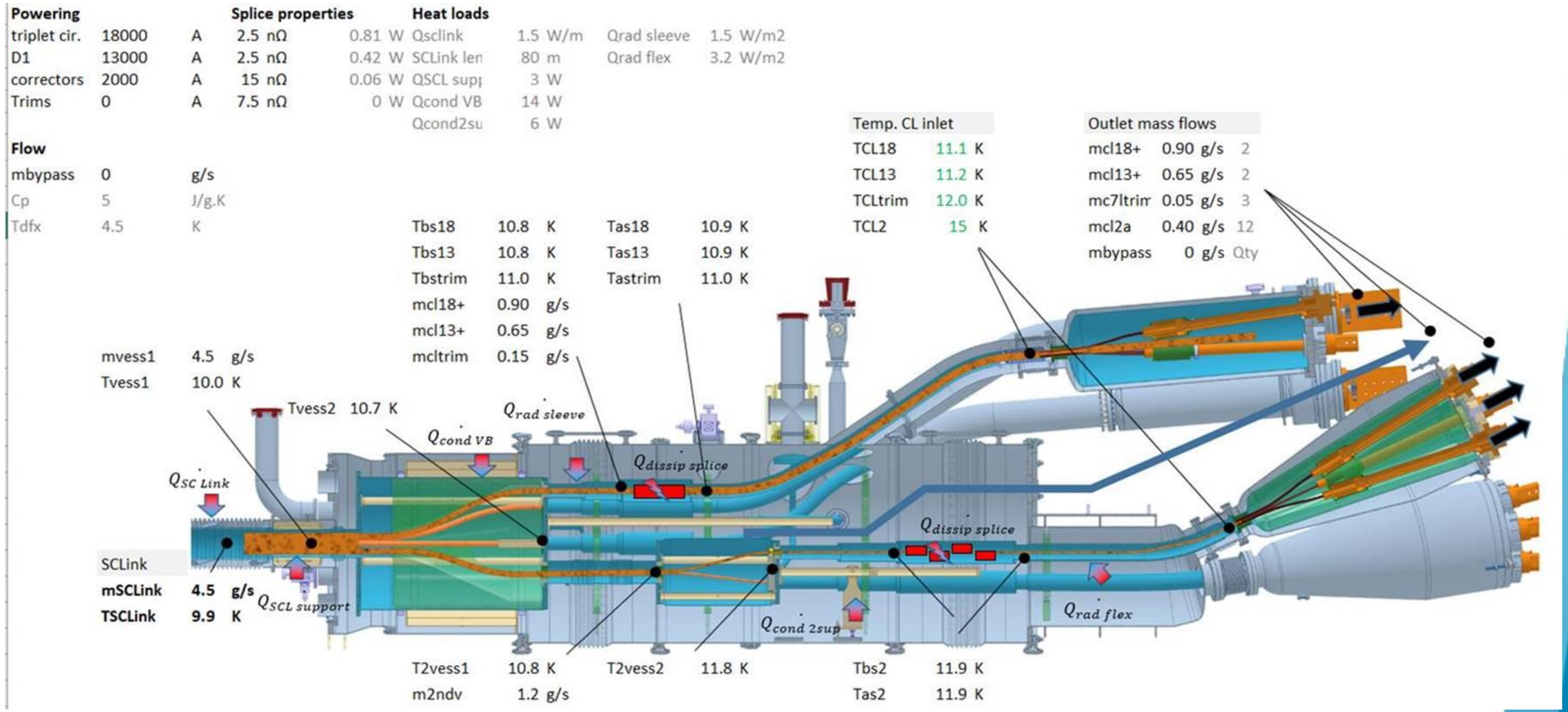
More details available in Mechanical talk for thermo- mechanical calculation

Helium flow requirement and thermal design DFHX

- Gaseous helium feeding DFHX from SC link available at 10-14 K
- DFHX designed for:
- Nominal : 5 g/s (Ultimate current)
- Design : 10 g/s
- Total Heat load < 30 W
- No condensation on external surface and feedthrough
- Thermal shield not required
- 1% slope between cold point and ambient interface on helium circuit taking into account the tunnel configuration



DFHX : Ultimate current

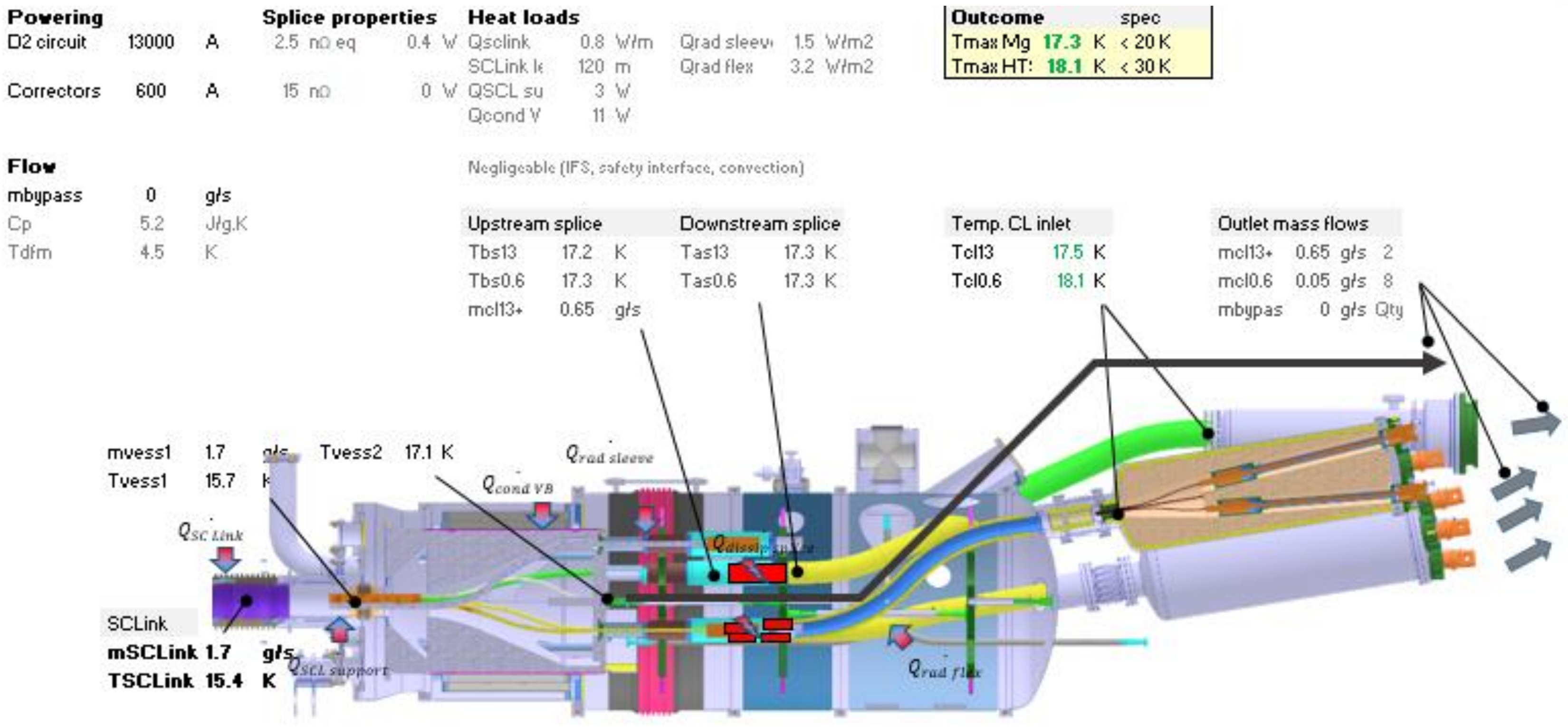


More details available in Mechanical talk

Helium flow requirement and thermal design DFHM

DFHM : Ultimate current

- Gaseous helium feeding DFHM from SC link available at 18 K
- DFHM designed for:
- Nominal : 2 g/s (Ultimate current)
- Design : 3 g/s
- Total Heat load < 30 W
- No condensation on external surface and feedthrough
- Thermal shield not required

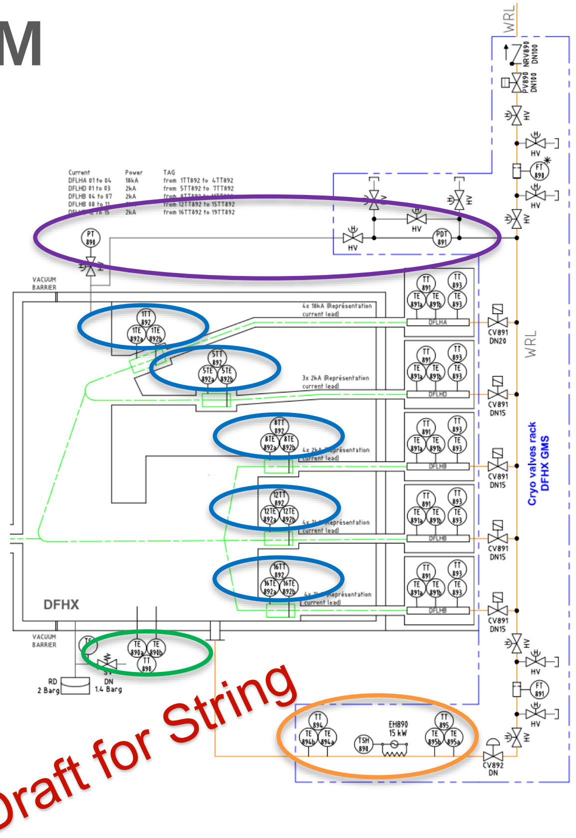


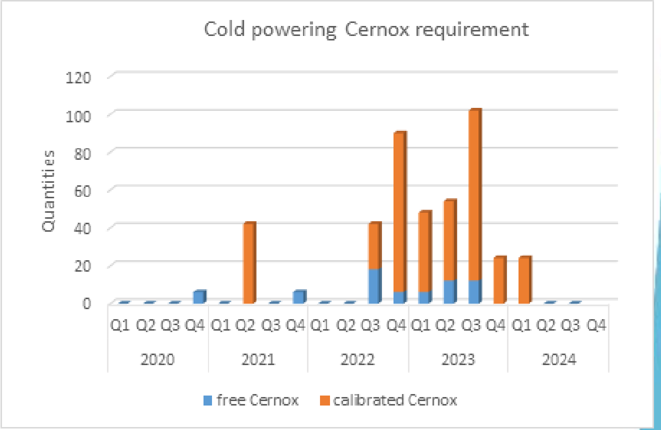
More details available in Mechanical talk

Cryo Instrumentation provided by CRG

DFHX example – same concept for DFHM

Number	Instrumentation	Operating Range	Application (for thermometer)	Range	accuracy
38 (19+19S)	TT on splices	10-20 K	Immersed Monitoring Cernox calibrated	3-325 K	+/- 0.5 K (TBC)
2 (1+1S)	TT in DFH (at inlet)	10-20K	Immersed Control Cernox calibrated	3-325 K	+/- 0.5 K (TBC)
1	Electric Heater	0-1500 W	NA	0-15000 W	1 W
2 (1+1S)	TT at bypass inlet	10-20K	Immersed or finger Cernox calibrated	3-325 K	+/- 0.5 K (TBC)
2	Temperature transmitter	ambient	PT-100	3-325 K	+/- 5 K
1	Pressure transmitter	1.05-2 bara	NA	0-4 bar	0.01 bar
1	DPT	0-100 mbar	NA	0-300 mbar	1 mbar





- Total of 438 Cernox required→ 372 Cernox for DFH
- IFS connector to be defined

More details for Instrumentation in J. Fleiter talk

After confirmation by prototype, potential engineering value by removal on Thermometer on splice if helium flow can be controlled with cold end of current lead.

Observations

- The requirements for the DFHx and DFHm have been assessed and gathered in a document used to perform the detailed design

- Key operating values are defined and shall be validated/corrected following the analysis of Demo2’s data

Spare slides

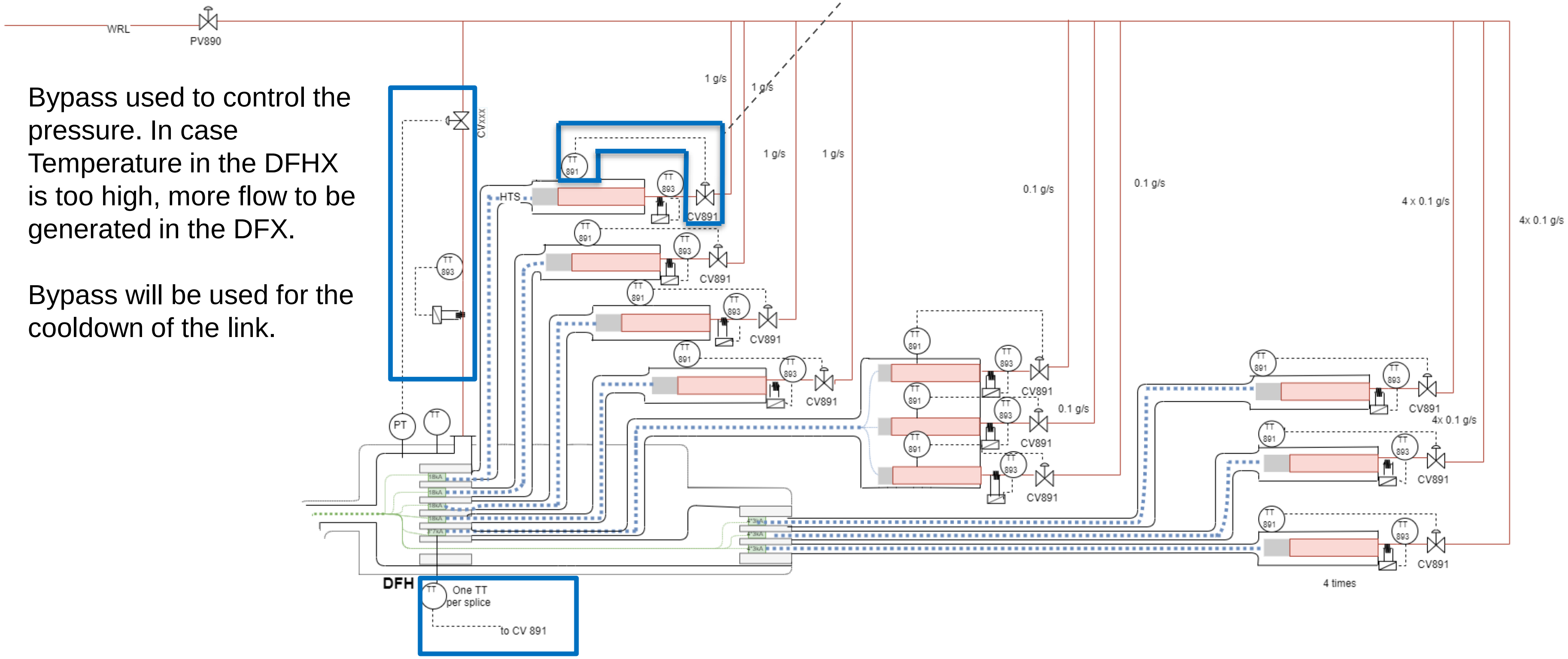
Control strategy : DFHx example

Case	From SC link flow	bypass flow	Current lead flow
Nominal (current)	5 g/s	0 g/s	5 g/s
Nominal (no current)	2.5-5 g/s	0-2.5 g/s	2.5 g/s
Cooldown	TBC	TBC	TBC

Temperature of the HTS transition controlled at 50 K (flow to current lead)

Bypass used to control the pressure. In case Temperature in the DFHX is too high, more flow to be generated in the DFX.

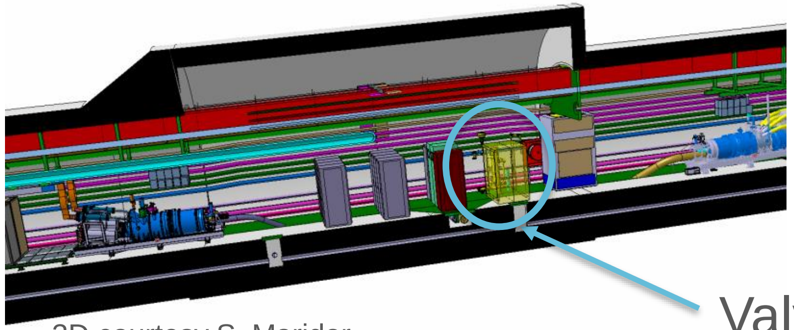
Bypass will be used for the cooldown of the link.



Temperature of the HTS splice monitored at 20 K

Current lead control valve

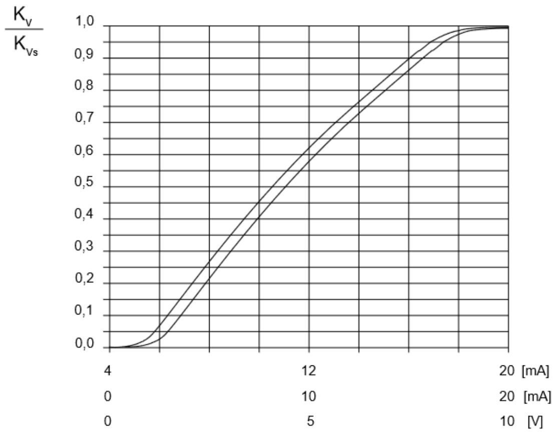
- Installed current lead control valve in LHC tunnel : Burkert flow solenoid control valve
- Valve rack design in progress for WP16. Similar concept will be adopted for Tunnel configuration



3D courtesy S. Maridor

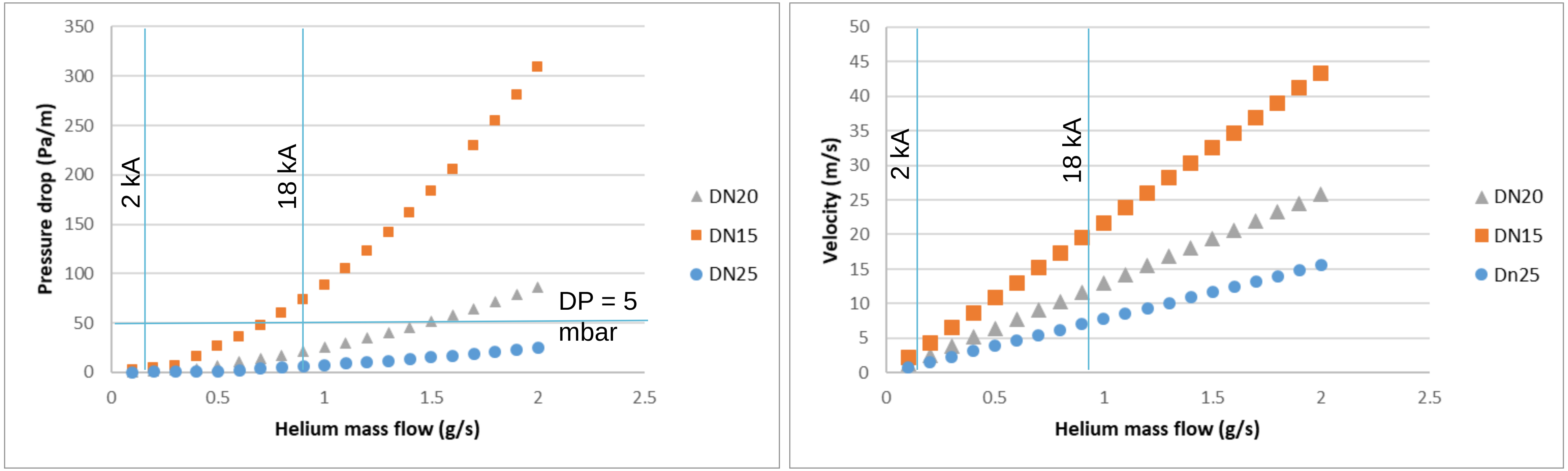
Valve rack

HTS	VANNES				CONSOMMATION (W)
	Type	Size	Ref CERN	Ref BURKERT	
120 A (8 amenees)	2832	4	HCQIVECB14-BTXXXXXX	200968	8
120 A (4 amenees)	2832	3	HCQIVECB13-BTXXXXXX	166284	8
600 A	2832	3	HCQIVECB13-BTXXXXXX	166284	8
6 kA	6023	2	HCQIVECB12-BTXXXXXX	166286	15
13 kA	6023	1	HCQIVECB11-BUXXXXXX	166285	15



	Solenoid control valve
Compactness	High
Positionner	No
Instrument air	No
Min DP	<50 mbar
Reference on same service	Yes (> 1000 valves in tunnel)
Price per valve (order of magnitude)	CHF 1000
Potential vendors	Burkert Shirokuma (labo) Asco ?

Current lead line sizing - DFHX



- Velocity and pressure drop calculated at 1.1 bara.
- 20 m line considered from the DFHX to the control valve rack
- For 18 kA : DN 20 or above to avoid high velocity in the line
- For 2 kA : DN 15 or above to avoid high velocity in the line

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