DFX Functional Specification

Y.Leclercq on behalf of the DF development team WP6a
31 Jan. 2019

Conceptual design review of the DFX

DFX in Cold Powering System

Each IP1 and IP5 sides equipped with a cold powering chains of cryostats

- Triplet insertion : DFHx – SC Link (DSH) – **DFX**

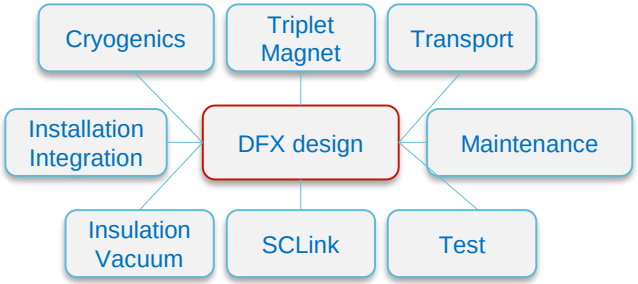
DFX basic functions:

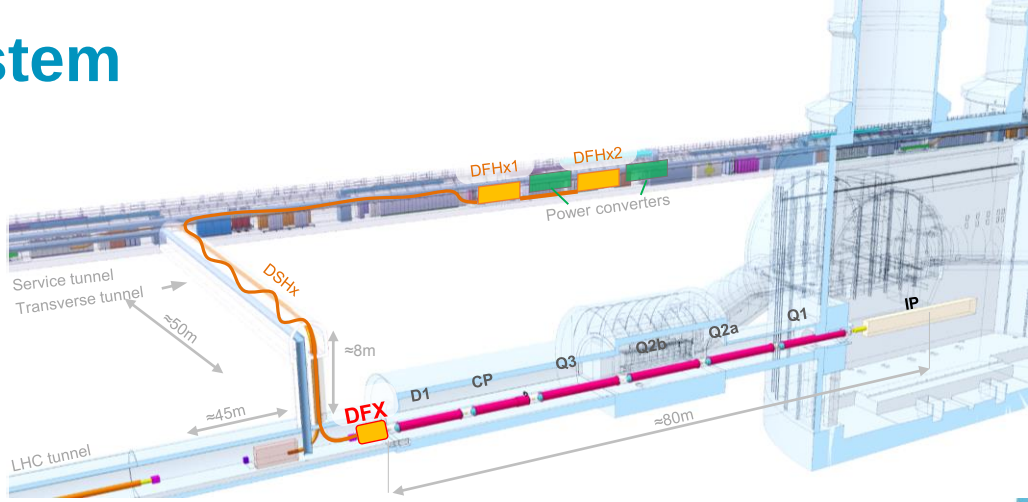
- Electrical interface between SC Link and superconducting magnets
- Supply cryogenics to the SCLink

System Interfaces

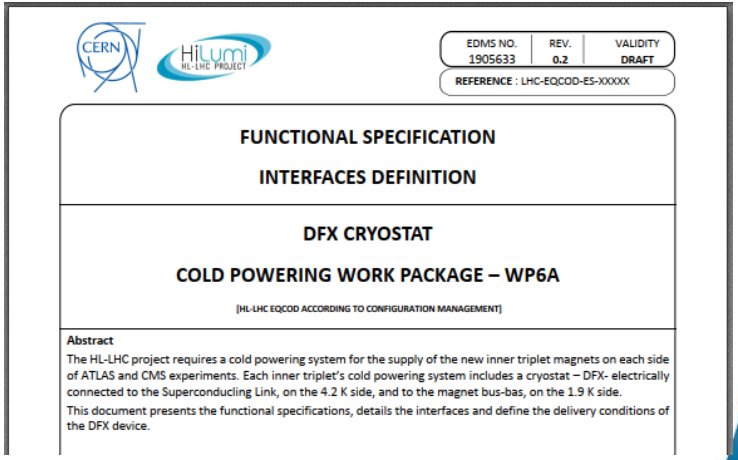
DFX functional specification and interface definition EDMS1905633

DF system interfaces





DFX functional specification EDMS 1905633



EDMS NO. 1905633 | REV. 0.2 | VALIDITY DRAFT

REFERENCE : LHC-EQCOD-ES-XXXXX

FUNCTIONAL SPECIFICATION

INTERFACES DEFINITION

DFX CRYOSTAT

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 magnets on each side of ATLAS and CMS experiments. Each inner triplet's cold powering system includes a cryostat – DFX- electrically connected to the Superconducting Link, on the 4.2 K side, and to the magnet bus-bas, on the 1.9 K side.

This document presents the functional specifications, details the interfaces and define the delivery conditions of the DFX device.

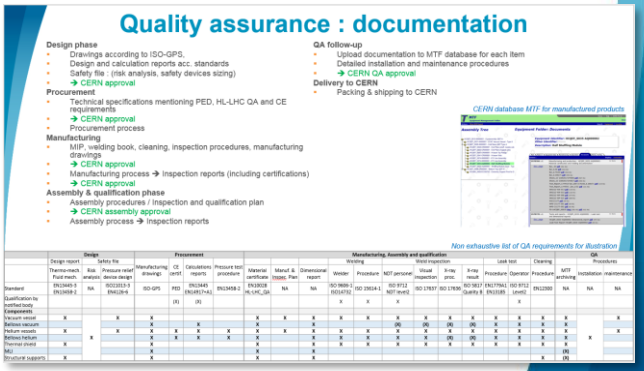
General requirements

- DFX installed in LHC machine
  - ➔ Comply with CERN rules
    - CERN Safety Rules
    - GSI-M-4 - Cryogenic equipment :

GSI-M4: “The manufacture […] by collaborating institutions, of all new cryogenic equipment shall comply with the applicable CERN Safety Rules, European directives and harmonised standards”.

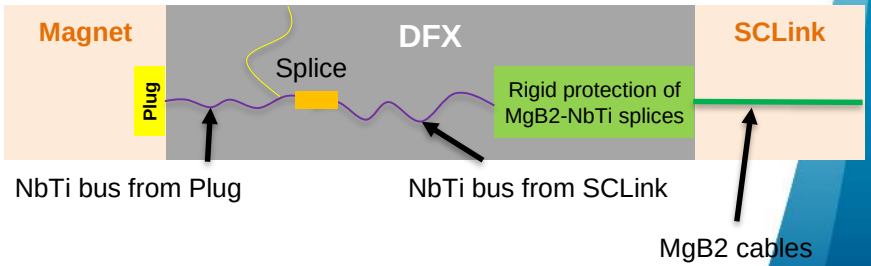
  - ➔ European directives
    - Pressure Equipment Directive 2014-68-EU
  - ➔ HL-LHC QA requirements
    - ALARA principle
    - Material requirements
    - Documentation & MTF

HL-LHC documentation requirements
Details in spare slide



Electrical main specifications

- DFX shall ensure the electrical connectivity between the SCLink and triplet cables
- SCLink cables layout:
  - 19 MgB2 conductors in SCLink
  - NbTi extensions soldered to MgB2 in protective rigid cylinder
  - Only NbTi extensions are accessible in DFX
- Magnet cables layout: 19 NbTi conductors from magnet side
  - (details on bus bars, see dedicated talk)
- The NbTi extensions shall be routed and connected to the NbTi bus coming out of from the plug
- Instrumentation shall be routed to feedthroughs on a dedicated patch panel at the level of the vacuum vessel interface (no cold feedthroughs)

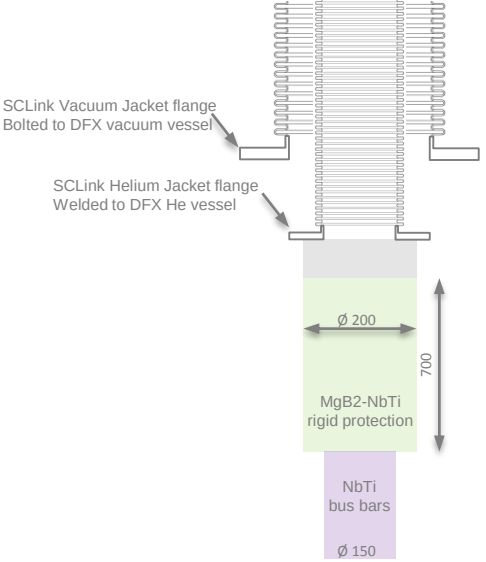


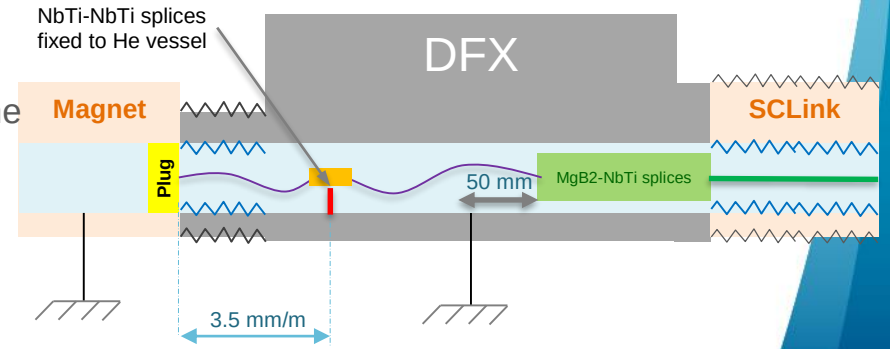
Mechanical interfaces

- SCLink mechanical interface
  - Two independent flexible when installed
  - Vacuum & helium jacket flanges fixed to DFX
  - MgB2-NbTi splices contained in rigid protection fixed to He jacket flange
  - Only NbTi extensions access the DFX He volume

- Magnet mechanical interface
  - Plug fixed to ground
  - DFX fixed to He/vacuum interfaces with bellows
  - Access to NbTi-NbTi splices granted during installation and maintenance

- Cables thermal contractions
  - NbTi-NbTi splices fixed to DFX He vessel
  - DFX covers internal contractions 3.5 mm/m
  - DFX shall allow NbTi extensions to move 50 mm into the splices protection





Cryogenics requirements

Dedicated presentations on Cryogenic scheme, operation, safety

Layout:
- Hydraulic plug separates triplet magnet & DFX-SCLink He volumes
- Dedicated DFX jumper

Electrical performance:
- NbTi cables & MgB2-NbTi splices immersed in LHe

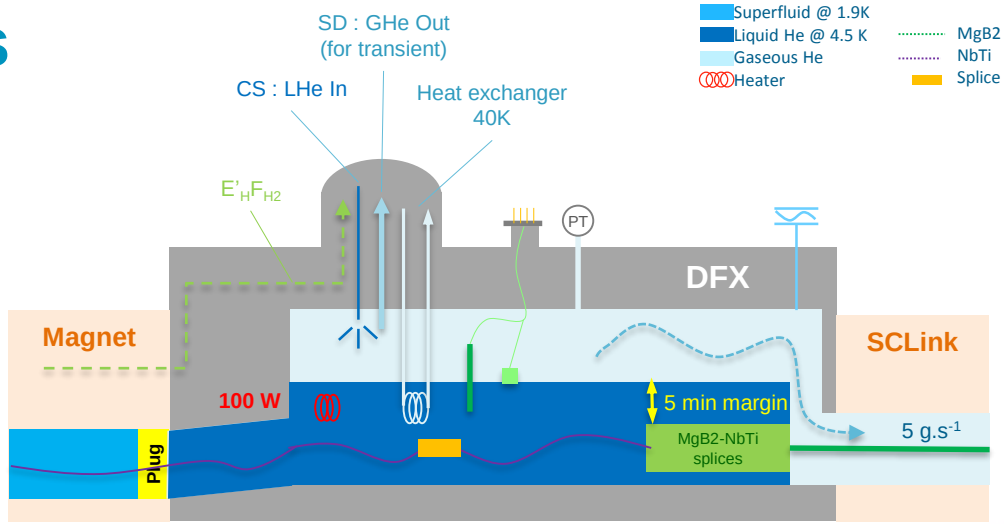
Cryogenic lines:
- LHe in, Ghe out, Outlet Magnet line, heat exchanger

Operation configuration
- Heaters (electrical & heat exchanger) vaporises helium
  - Nominal : 5 g.s^{-1} , design 10 g.s^{-1}
- Ghe gaseous mass flow through the SCLink

Instrumentation:
- Level gauges, Temperature sensors, Pressure gauge

Design requirements:
- Heat loads to LHe < 20 W
- No condensation on external surfaces and feedthroughs
- > 5 min of nominal supply GHE in case of liquid supply stop
- Constant slope between coldest point and LHE-GHE interface
- Safety relief devices to protect DFX+SCLink

Access to safety relief devices, instrumentation interfaces shall be granted for inspection and maintenance



DFX nominal configuration

DFX functional specification

Table 2: Cryogenic parameters and equipment design pressures [9]

Description	Ref:	Inlet outlet	DN [mm]	Fluid	Nominal pressure [bara]	Design pressure [bara]	Temperature range [K]
Inlet Liquid helium	CS	From line C	DN12 TBC	Mix liquid-gas helium	1.3	3.5	[4.5;300]
Return gas helium for transient phases	SD	To line D	DN40 TBC	Gaseous helium	1.3	3.5	[4.5;300]
DFX helium volume	S	From line CS To DSHx	TBD	Saturated liquid helium bath	1.3	3.5	[4.5;300]
Outlet thermal shield	E'$_H$F$_{H2}$	From D1 side To DFX jumper	TBD	Gaseous helium	24	25	[60;300]
Inlet coil warm up	TBD	From E'$_H$F$_H$	DN4	Gaseous helium	24	25	[40;300]
Outlet coil warm up	TBD	To jumper	DN4	Gaseous helium	24	25	[40;300]

Insulation vacuum

- The DFX insulation vacuum shall be compatible with the General WP6a insulation vacuum layout EDMS 2048016

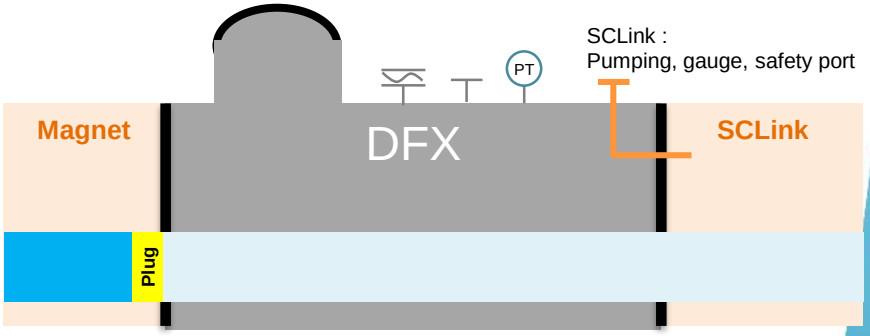
- The DFX insulation vacuum is independent to:
  - Allow local maintenance & leak detection
  - Minimise inter-dependence between helium volumes

- ➔ DFX presents vacuum barriers with:
  - The cryolines (not part of DFX)
  - The SCLink (part of the DFX)
  - The triplet cryostat (not part of SCLink)

- Interfaces:
  - Standard type flanges with elastomer seal
  - Ports for pumps and instrumentation for both DFX & SCLink
  - Pressure relief plate

Table1 : Insulation vacuum requirements for WP6a components

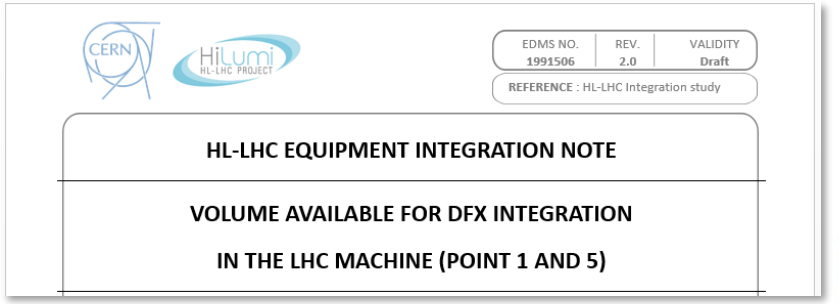
Unit	Value
Insulation vacuum pressure level at ambient temperature	$< 1.10^{-4}$ mbar
Insulation vacuum pressure level in nominal operation	$< 1.10^{-5}$ mbar
Maximum allowed overall leak rate in nominal operation	$< 2.10^{-8}$ mbar.l.s^{-1}

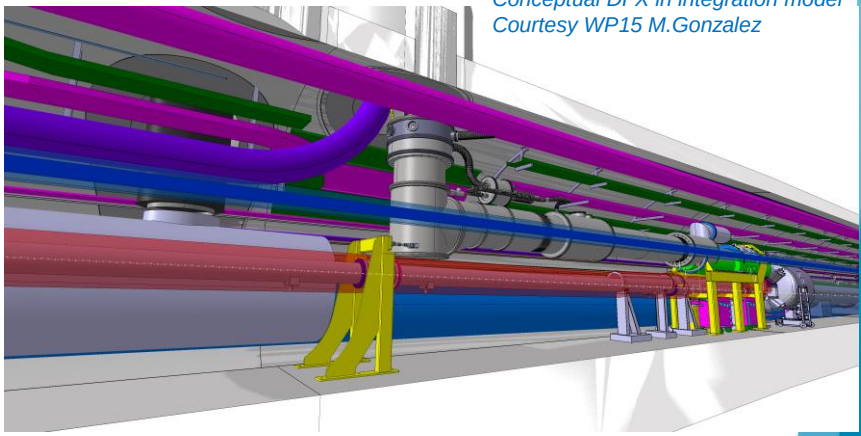


Integration specification

EDMS 1991506

- Tunnel integration
  - Dedicated talk from HL-LHC WP15 on volumes, environment.
  - Notes:
    - The vertical position of the DFX shall be adjustable
    - Tunnel slope shall be considered
    - Accesses during installation and inspections shall be granted

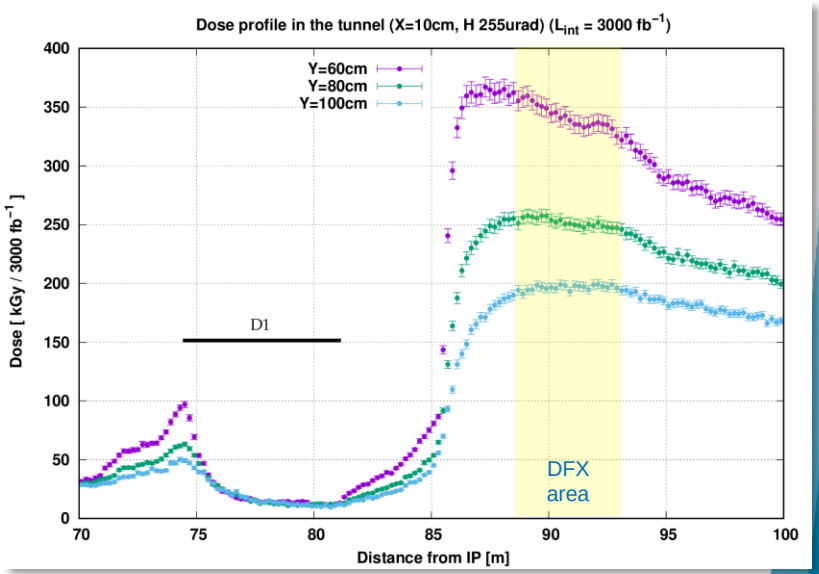




Conceptual DFX in integration model
Courtesy WP15 M.Gonzalez

Preventive maintenance and repairs

- All operations shall be designed from the ALARA point of view:
  - Minimise intervention time (access, automatic operation)
- Interventions
  - Unscheduled interventions for inspections and light work during Technical Stops (e.g. for electrical checks on patch panel)
  - Planned interventions for routine maintenance requiring warm up during YETS (e.g. replacement of burst disks)
  - Unscheduled medium repair work interventions requiring warm up during YETS (e.g. Nb-Ti/Nb-Ti repair)
  - Unscheduled heavy repair work interventions requiring warm up during EYETS or unscheduled extended machine stop (e.g. MgB2/Nb-Ti repair, plug replacement)



See : R.Garcia : LHC and HL-LHC: Present and future radiation environment in the high-luminosity collision points and RHA implications

Manufacturing & Inspections

- Manufacturing & Inspections according to
  - Pressure Equipment Directive (PED)
  - HL-LHC QA requirements (see spec)

    - *Materials specific requirements:*
      - *Compatible with Dose level over HL-LHC project period:*
      - *Cobalt content for stainless steel < 0.1%*
      - *Polymers according to IS41 EDMS335806*

    - *Inspections and certifications*
      - *Welding and welders*
      - *Leak tightness level, procedure and operators*
      - *Pressure testing according to PED*

    - *Documentation*
      - *Manufacturing procedures & qualifications*
      - *Inspection reports*
      - *CE certification*
      - *Upload into CERN database MTF*

INSTRUCTION DE SÉCURITÉ
SAFETY INSTRUCTION
Mandatory as defined in SAPOCO/42

IS41 Rev. 1

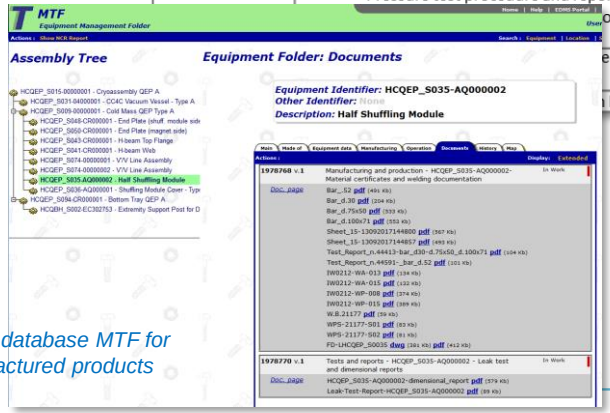
Issued by: SC-GS

Date of revision: November 2005
Original: English

The Use of Plastic* and other Non-Metallic Materials at CERN with respect to Fire Safety and Radiation Resistance

Table 4: Documentation

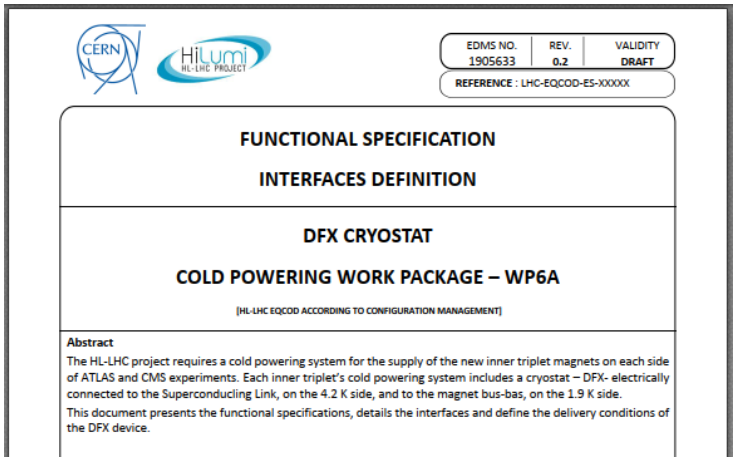
Phase	Requirements
Design	- Specification drawings according to ISO-GPS; - Design and calculation reports according to applicable standards; - Safety file as defined in [2];
Procurement	- Technical specifications with certification requirements;
Manufacturing	- Manufacturing drawings to ISO-GPS standards; - Manufacturing and Inspection plan; - Welding book - Welder certifications (ISO9606-1) - Weld qualification (ISO 15614-1) - Welds visual and radiographic inspection reports (ISO 17637, ISO 17636-1) - NDT operator certification (ISO 9712 NDT level2) - Cleaning procedure and reports - Pressure test procedure and reports - …onnel certification (ISO 9712); …edures; … MTF, CERN database;



CERN database MTF for manufactured products

Summary

- Functional specifications and interfaces are defined and gathered in EDMS1905633



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[1] L.Rossi et al. "High-Luminosity Large Hadron Collider (HL-LHC): Technical Design Report V. 0.1", EDMS 1833445.

[2] CERN HSE department "GSI-M-4 – Cryogenic equipment", EDMS 1327191.

[3] CERN HSE department "CERN Safety rules", https://hse.cern/content/safety-rules

[4] European Parliament "Pressure European Directive 2014/68/EU", https://eur-lex.europa.eu/homepage.html , direct link PED2014/68/EU

[5] CERN HSE department "Safety Instruction : The Use of Plastic and other Non-Metallic Materials at CERN with respect to Fire Safety and Radiation Resistance", EDMS 335806

[6] GS-IS & EN-MME CERN groups "Material Specification, Welded and seamless stainless steel tubes", EDMS 1380627

[7] R.Garcia, presentation at HL-MCF meeting, https://indico.cern.ch/category/8387/

[8] D.Berkowitz "Process flow diagram of HL-LHC IT.R5 (Inner Triplet) including SC link and DFX box.", EDMS1736906

[9] D.Berkowitz "Preliminary naming, operational parameters and flow diagrams of the cryogenic distribution lines for HL-LHC", EDMS1573115.

[10] Ch.Balle "Installation guide for LHC cryogenic thermometers", EDMS 110748

[11] A.Vidal et al. "Specification for mechanical assemblies or sub-assemblies exposed to insulation vacuum" EDMS 1584250.

[12] M.Mendes "Volume available for DFX integration in the LHC machine (point1 and point5)", EDMS 1991506.

[13] Y. Leclercq, J. Fleiter, Y.Yang "Insulation Vacuum Proposal for the Cold Powering Chain of Cryostats", EDMS2048016

[14] A. Ballarino "Cold powering: Updated baseline and results from Demo1 construction", 8th HL-LHC collaboration meeting. Indico event 742082.

[15] A. Ballarino, Y. Leclercq "Conceptual study of the cryostats for the cold powering system for the triplets of the High Luminosity LHC", CEC 2017 CDS.

Spare slides

Quality assurance : documentation

Design phase
- Drawings according to ISO-GPS,
- Design and calculation reports acc. standards
- Safety file : (risk analysis, safety devices sizing)
- ➔ CERN approval

Procurement
- Technical specifications mentioning PED, HL-LHC QA and CE requirements
- ➔ CERN approval
- Procurement process

Manufacturing
- MIP, welding book, cleaning, inspection procedures, manufacturing drawings
- ➔ CERN approval
- Manufacturing process ➔ Inspection reports (including certifications)
- ➔ CERN approval

Assembly & qualification phase
- Assembly procedures / Inspection and qualification plan
- ➔ CERN assembly approval
- Assembly process ➔ Inspection reports

QA follow-up
- Upload documentation to MTF database for each item
- Detailed installation and maintenance procedures
- ➔ CERN QA approval

Delivery to CERN
- Packing & shipping to CERN

CERN database MTF for manufactured products

Non exhaustive list of QA requirements for illustration

	Design			Procurement				Manufacturing, Assembly and qualification												QA		
	Design report	Safety file									Welding		Weld inspection				Leak test		Cleaning		Procedures	
	Thermo-mech. Fluid mech.	Risk analysis	Pressure relief device design	Manufacturing drawings	CE certif.	Calculations reports	Pressure test procedure	Material certificate	Manuf. & Inspec. Plan	Dimensional report	Welder	Procedure	NDT personel	Visual inspection	X-ray proc.	X-ray result	Procedure	Operator	Procedure	MTF archiving	Installation	maintenance
Standard	EN13445-3 EN13458-2	NA	ISO21013-3 EN4126-6	ISO-GPS	PED	EN13445 EN14917+A1	EN13458-2	EN10028 HL-LHC_QA	NA	NA	ISO 9606-1 ISO14732	ISO 15614-1	ISO 9712 NDT level2	ISO 17637	ISO 17636	ISO 5817 Quality B	EN1779A1 EN13185	ISO 9712 Level2	EN12300	NA	NA	NA
Qualification by notified body					(X)	(X)					X	X	X					X				
Components																						
Vacuum vessel	X		X	X				X	X	X	X	X	X	X	X	X	X	X	X	X		X
Bellows vacuum				X		X		X		X			(X)	(X)	(X)	(X)	X	X	X	X		
Helium vessels	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X
Bellows helium		X		X	X	X	X	X		X	X	X	X	X	(X)	(X)	X	X	X	X	X	
Thermal shield	X			X				X		X	X	X	X	X	X	X	X	X	X	X		
MLI				X				X		X										(X)		
Structural supports	X			X				X		X									X	(X)		

Cold powering system basic principle