DFX functional specifications

DFX concept meeting : Collaboration meeting SOTON-CERN

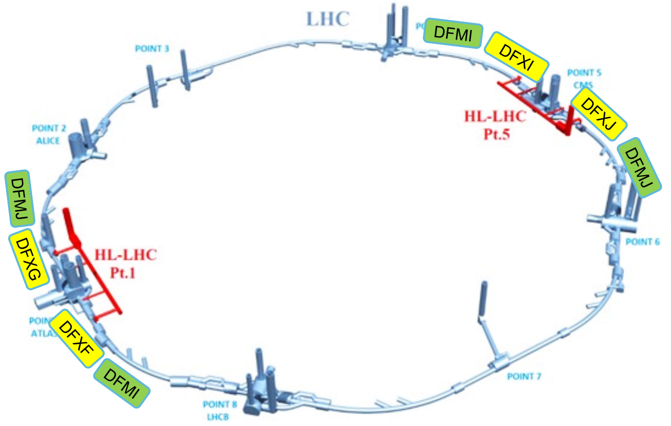
21 June 2018

Y.Leclercq on behalf of the DF cryostats design team (WP6a)
WP6a workpackage leader : A. Ballarino / Deputy : V. Parma

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



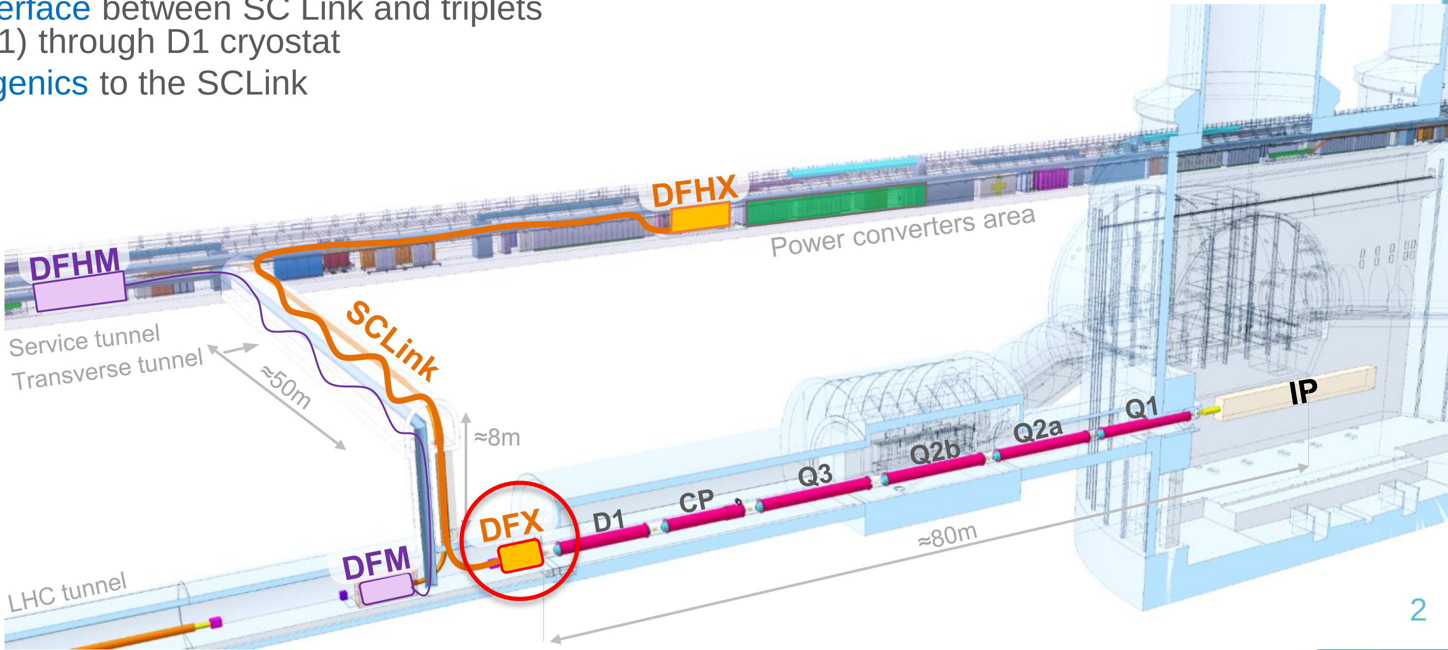


Illustration of the position of the DFX (not latest version for details)

DFX environment

DFX boxes:

- Shall be identical in all locations
- Prototype shall be used as spare

Resistance to radiation:

- The DFX shall be designed to withstand the total integrated dose over the HL-LHC life time, [2] :
  - 100kGy @ 1.6m
  - 1.2 MGy @ 30cm distance
- ALARA principle as key argument for the design.

DFX boundaries:

- Cold diodes module interface
- SCLink interface
- Cryogenic interface
- Supporting system

From [2] : R. Garcia Alia

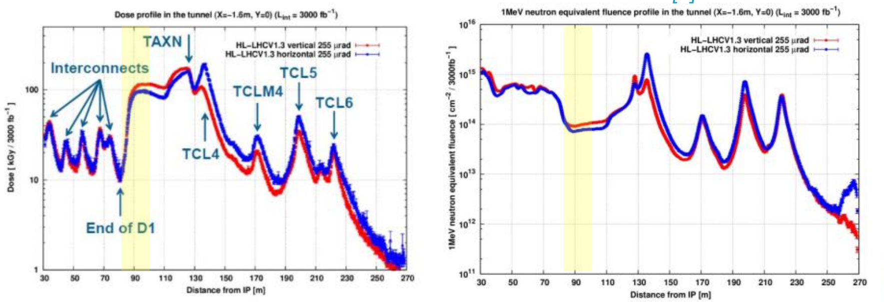
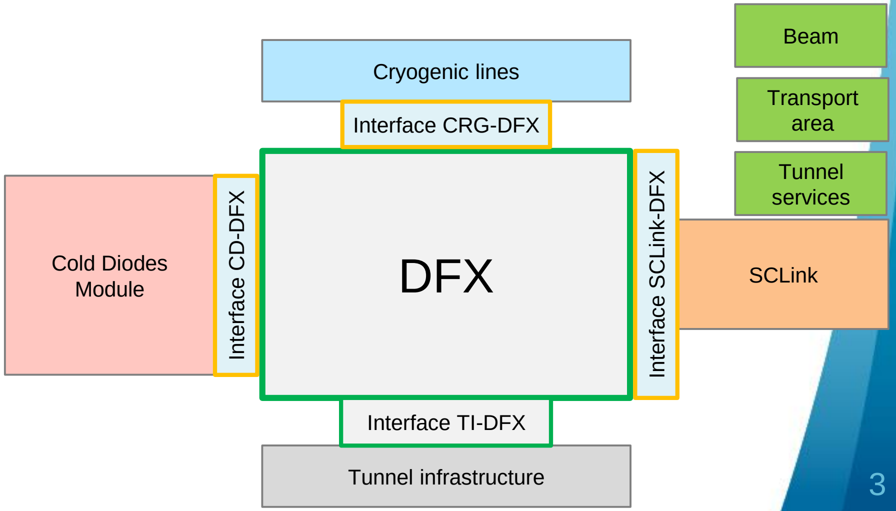


Fig. 10. Calculated dose in air and 1-MeV n_{eq} profile in the HL-LHC tunnel at beam height and 1.6 m from the beam, for the full 3000-3000-fb^{-1} expected lifetime. Simulations include both horizontal (IP5) and vertical (IP1) beam crossing, a crossing angle of 255 μrad and optics version 1.3. The TAXN corresponds to an absorber for neutral collision debris.

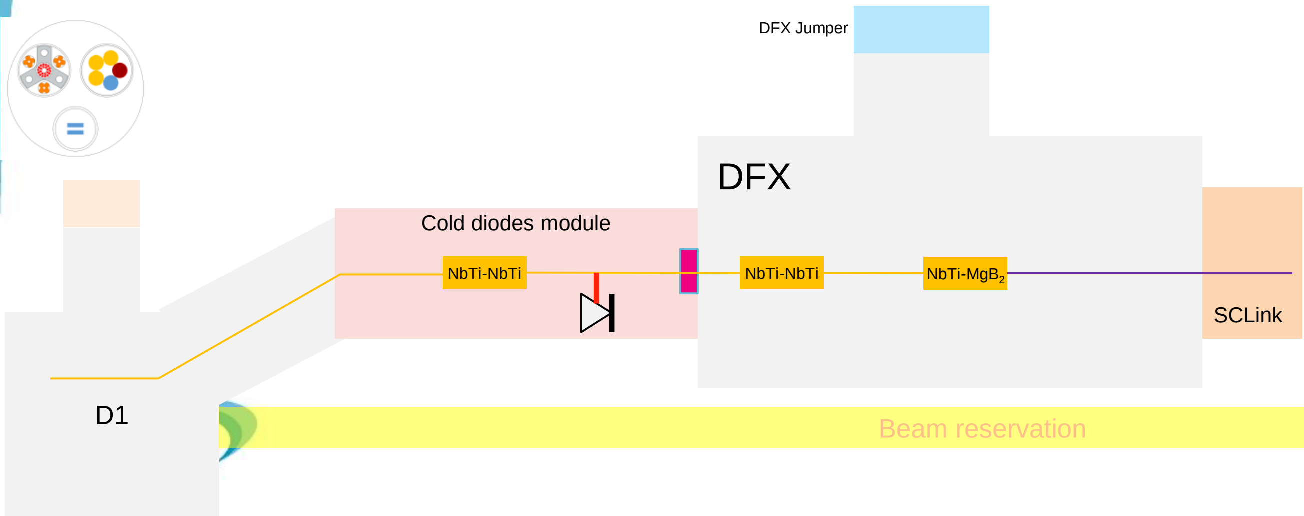
Preliminary estimations	y = 30cm	y = 60cm
z = 80m	30 kGy, 2×10^{15} n/cm²	15 kGy, 10^{15} n/cm²
z = 85m	240 kGy, 6×10^{14} n/cm²	120 kGy, 3×10^{14} n/cm²
z = 90m	1.2 MGy, 6×10^{14} n/cm²	600 kGy, 3×10^{14} n/cm²



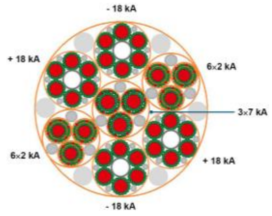
Electrical functional specifications

- The DFX shall:
  - Ensure the continuity of electrical circuits between triplets and SCLink leads
  - Ensure the integrity of cables and insulation.
  - Ensure access for NbTi-NbTi splicing during installation and maintenance

Cables / see [3] for details	
MgB_2 Cable rating [kA]	Nb leads [-]
18	4
7	3
2	12
0.2	*2*
0.12	*16*



Courtesy A. Ballarino

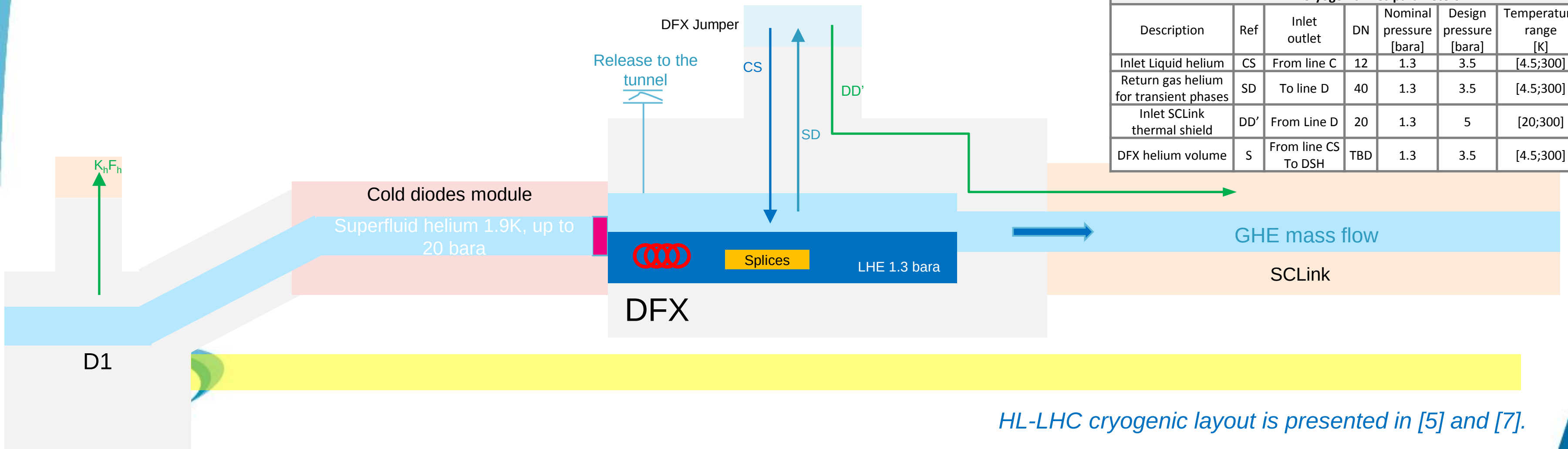


Cryogenics functional specifications

- ALARA principle: ➔ simplification of layouts and time optimisation for future interventions
- Temperature of splices maintained by immersion in liquid helium
- Supply of gaseous mass flow to SCLink by vaporisation of the liquid
- Safety : helium pressure relief device covers DFX + SCLink helium volume
- Instrumentation principle:
  - Free of cryogenic valves
  - Monitoring and controlled loop with Temperature, Pressure and liquid level sensors
- DFX heat transfer design focused on condensation limitation on the outer vessel

Cryogenic lines parameters

Description	Ref	Inlet outlet	DN	Nominal pressure [bara]	Design pressure [bara]	Temperature range [K]	Mass flow [g/s]
Inlet Liquid helium	CS	From line C	12	1.3	3.5	[4.5;300]	[0;10]
Return gas helium for transient phases	SD	To line D	40	1.3	3.5	[4.5;300]	[0;10]
Inlet SCLink thermal shield	DD'	From Line D	20	1.3	5	[20;300]	[0;10]
DFX helium volume	S	From line CS To DSH	TBD	1.3	3.5	[4.5;300]	NA



HL-LHC cryogenic layout is presented in [5] and [7].

Integration functional specifications

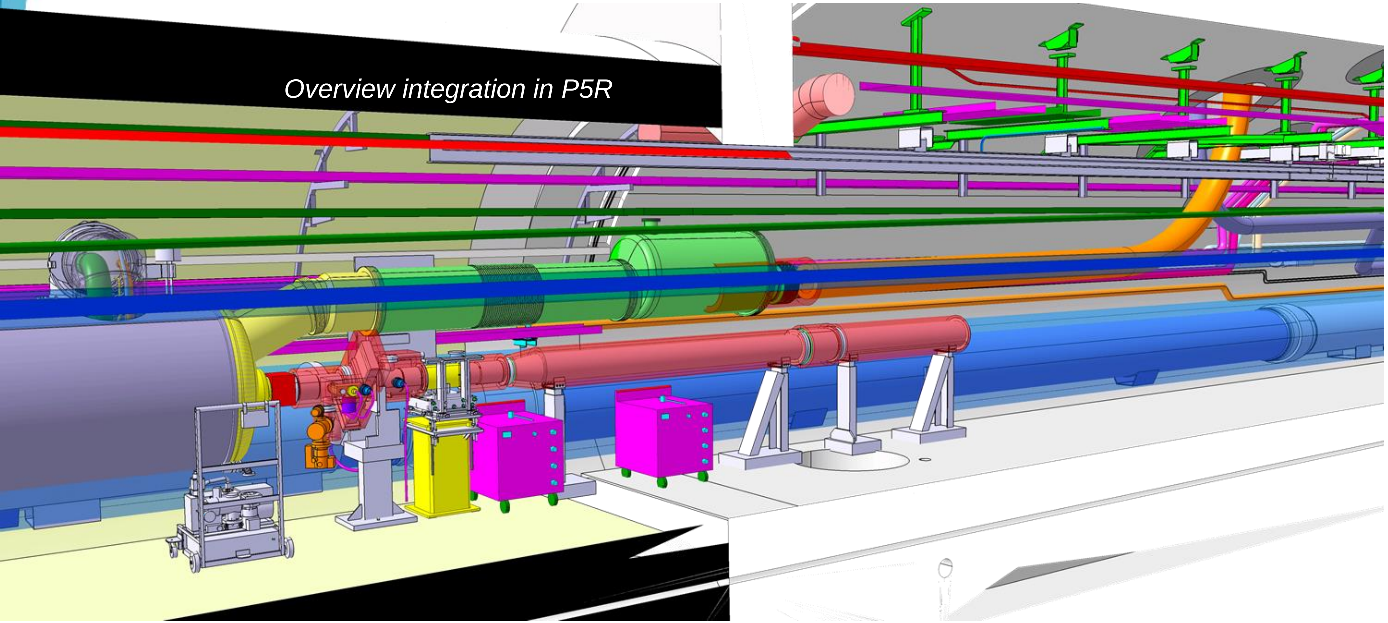
- DFX available envelope : defined by WP15 / EDMS1991506
- Interferences or additional requests can be addressed and will be discussed

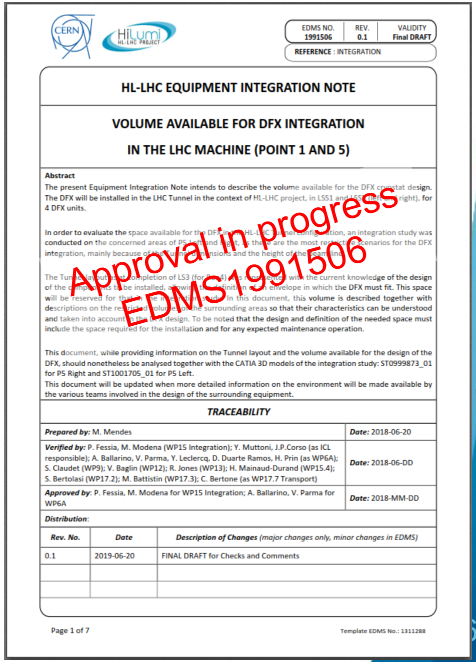
WP15 EDMS dedicated document for DFX integration

References of Smarteam DFX integration model

*Point 5 – Right P5R: HL_5R_1506_DFX INTEG. STUDY LS3 - **ST0999873_01***

*Point 5 – Left P5L: HL_5L_1506_DFX INTEG. STUDY LS3 - **ST1001705_01***





CERN HiLumi HL-LHC PROJECT

EDMS NO.	REV.	VALIDITY
1991506	0.1	Final DRAFT

REFERENCE : INTEGRATION

HL-LHC EQUIPMENT INTEGRATION NOTE

VOLUME AVAILABLE FOR DFX INTEGRATION

IN THE LHC MACHINE (POINT 1 AND 5)

Approval in progress
EDMS1991506

Abstract

The present Equipment Integration Note intends to describe the volume available for the DFX cryostat design. The DFX will be installed in the LHC Tunnel in the context of HL-LHC project, in LSS1 and LSS5 (left and right), for 4 DFX units.

In order to evaluate the space available for the DFX in the HL-LHC Tunnel configuration, an integration study was conducted on the concerned areas of P5 Left and Right, as these are the most restrictive scenarios for the DFX integration, mainly because of the Tunnel dimensions and the height of the beamline.

The Tunnel layout as at completion of LS3 (for Run4) was represented with the current knowledge of the design of the components to be installed, allowing the definition of an envelope in which the DFX must fit. This space will be reserved for that in the integration study. In this document, this volume is described together with descriptions on the restricted volumes of the surrounding areas so that their characteristics can be understood and taken into account in the DFX design. To be noted that the design and definition of the needed space must include the space required for the installation and for any expected maintenance operation.

This document, while providing information on the Tunnel layout and the volume available for the design of the DFX, should nonetheless be analysed together with the CATIA 3D models of the integration study: ST0999873_01 for P5 Right and ST1001705_01 for P5 Left.
This document will be updated when more detailed information on the environment will be made available by the various teams involved in the design of the surrounding equipment.

TRACEABILITY

Prepared by: M. Mendes	***Date:*** 2018-06-20
Verified by: P. Fessia, M. Modena (WP15 Integration); Y. Muttoni, J.P.Corso (as ICL responsible); A. Ballarino, V. Parma, Y. Leclercq, D. Duarte Ramos, H. Prin (as WP6A); S. Claudet (WP9); V. Baglin (WP12); R. Jones (WP13); H. Mainaud-Durand (WP15.4); S. Bertolasi (WP17.2); M. Battistin (WP17.3); C. Bertone (as WP17.7 Transport)	***Date:*** 2018-06-DD
Approved by: P. Fessia, M. Modena for WP15 Integration; A. Ballarino, V. Parma for WP6A	***Date:*** 2018-MM-DD
Distribution:	

Rev. No.	***Date***	***Description of Changes*** *(major changes only, minor changes in EDMS)*
0.1	2019-06-20	FINAL DRAFT for Checks and Comments

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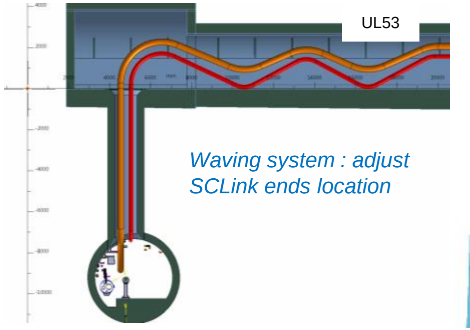
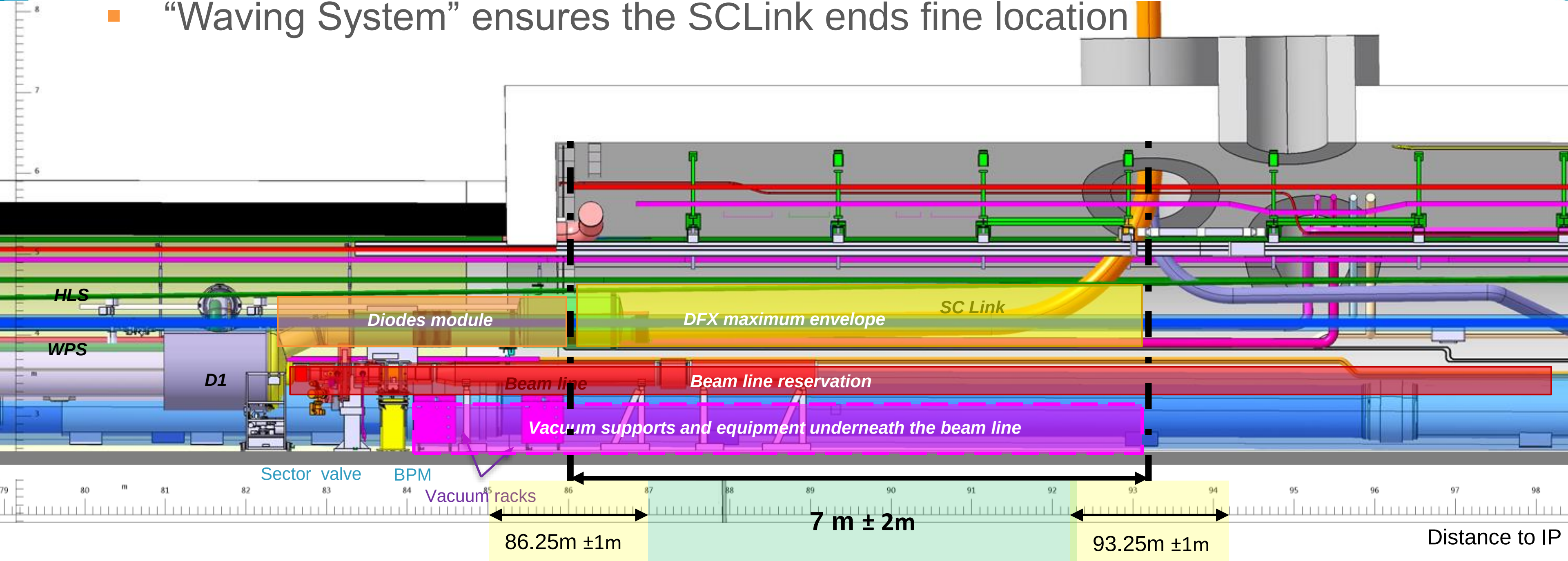
Integration functional specifications

- DFX environment design is in progress and evolves
  - ➔ The DFX design shall adapt without physical change to position of diodes module and pit interfaces tolerances
  - ➔ Distance between CDM and SCLink interfaces shall be fixed and identical for all DFX
- "Waving System" ensures the SCLink ends fine location

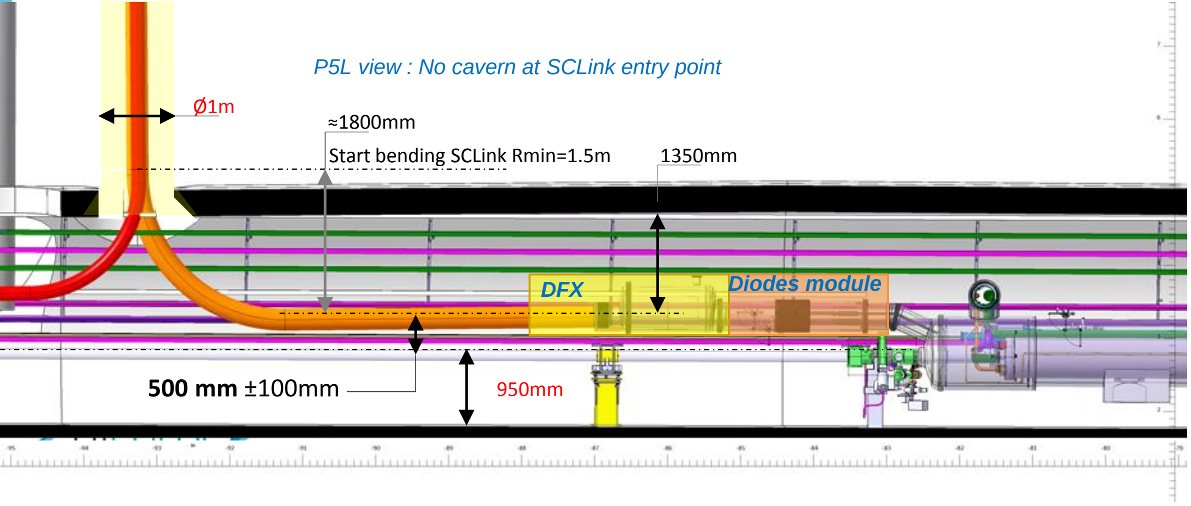




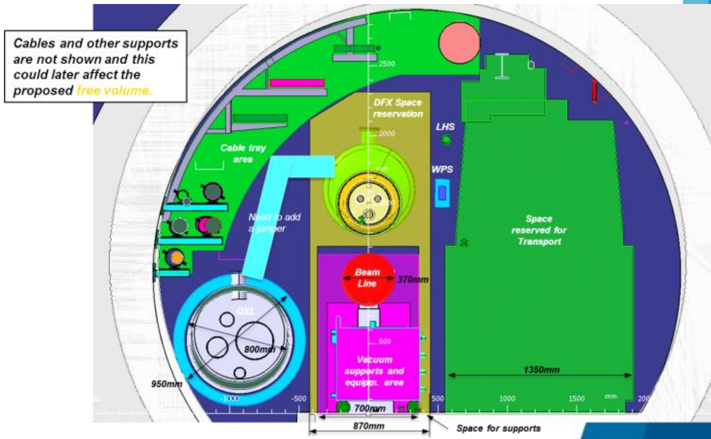
Integration functional specifications

- Installation sequence:
  - Same tooling for all (identical) DFX
  - Flexibility defined in EDMS1991506
  - Not fixed yet, open to discussion
  - LHS, WPS, transport reservations can be used for installation
  - Vacuum and beam line reservations may be used during installation upon request and discussions

P5L view : No cavern at SCLink entry point

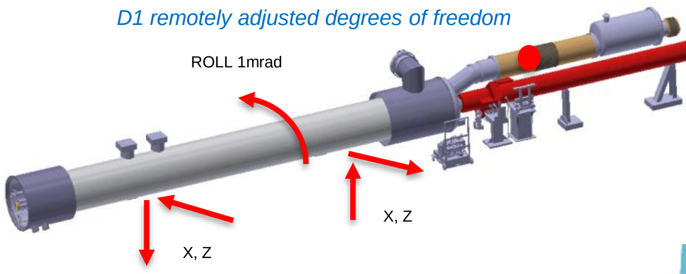


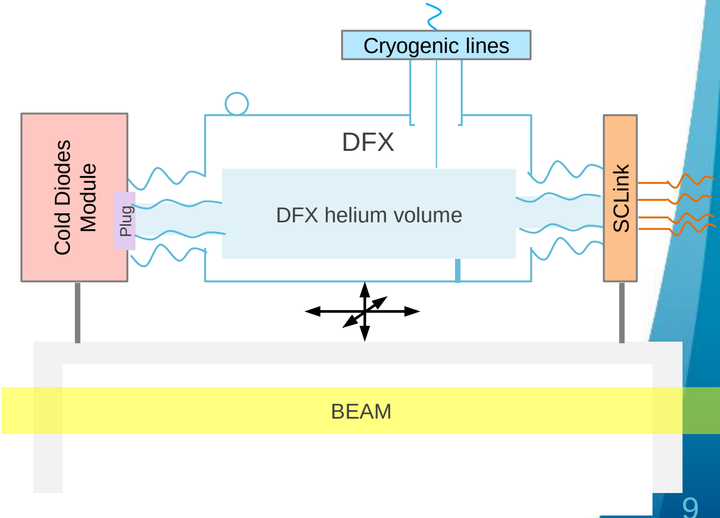
Tunnel integration section view as defined in EDMSXXXX



Mechanical functional specifications

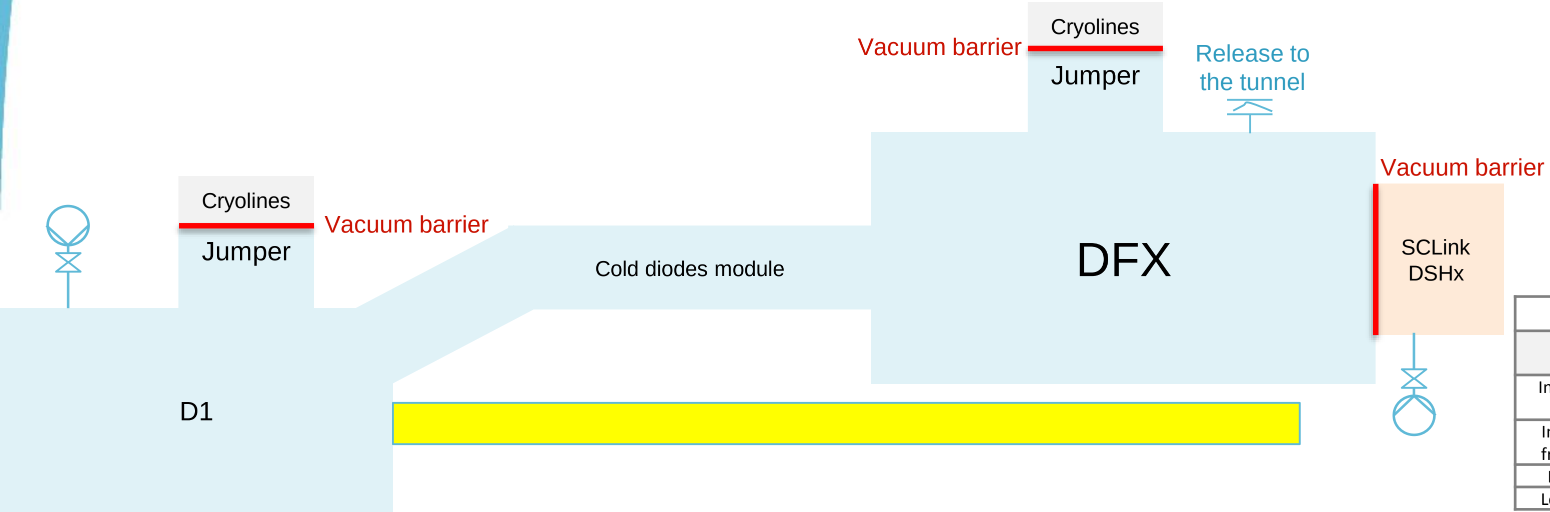
- The DFX shall :
  - Be externally static during transient and pressure fluctuation
  - Be independent from yearly triplet re-alignment (ALARA)
  - Minimise loads and vibration transfer to magnets
  - ➔ present flexibility toward diodes module
  - ➔ be fixed, monitored and adjustable to ground (±20mm)
  - Minimise mechanical solicitations to the cables passing through the plug
  - Present flexibility toward SCLink to ensure interfacing
  - Co-design a fixed point for the MgB_2 cable bundle at the SCLink-DFX interface





Insulation vacuum functional specifications

- The DFX :
  - Shares the insulation vacuum of the triplet magnets (ALARA)
  - Shall present surface finish, leak tight design and cleaning processes adapted to vacuum level
- Vacuum barriers:
  - of the jumper is not part of the DFX
  - at the SCLink interface shall result from co-design for its integration



Specifications + see [9]		
	Unit	Max value
Insulation vacuum level	[mbar]	1.10^{-5}
Independent leak from atmosphere	[mbar.l.$^{-1}$]	2.10^{-8}
Design pressure	[bara]	1.5
Leak tight closure	[-]	ISO flange

Maintainability functional specifications

- All inspections and maintenance operations must be designed under the ALARA principle (time, waste)
- ➔ optimise access for inspection and maintenance
- ➔ minimise number of operations
- ➔ prefer automated tools, light parts

- The DFX shall :
  - Optimised inspections for the instrumentation interfaces
  - Optimise safety relief devices regular maintenance (pumps if applicable)
  - Allow in-situ replacement of the plug
  - Allow in-situ replacement of the heater
  - Allow repair of NbTi splices around the plug

- In situ repair of MgB_2-NbTi splices shall be evaluated and discussed.

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Quality assurance : overview

- DFX design, manufacturing, qualification shall comply with:
  - CERN safety rules : GSI-M4 [10]
    - “The manufacture […] by collaborating institutions, of all new cryogenic equipment shall comply with the applicable CERN Safety Rules, European directives and harmonised standards”
  - Pressure European Directive 2014/68/EU (PED)
  - Relevant standards on European standard for electrical devices
  - HL-LHC QA specific requirements:
    - Material (inclusion and content)
    - Manufacturing and inspection process (specific inspections)
    - Archiving in MTF database

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)		

References

- [2] : R.Garcia et al. “LHC and HL-LHC: Present and Future Radiation Environment in the High-Luminosity Collision Points and RHA Implications”, NSREC2017
- [3] : A.Ballarino, S.Yammine “Number of components and current rating of the current leads and superconducting cables feeding the HL-LHC triplets and D1”, EDMS1821907.
- [5] : D.Berkowitz “Process flow diagram of HL-LHC IT.R5 (Inner Triplet) including SC link and DFX box.”, EDMS1736906
- [6] : I.Bejar Alonso, L.Rossi “HiLumi LHC Technical Design Report”, CERN-ACC-2015-0140,
- [7] : D.Berkowitz “Preliminary naming, operational parameers and flow diagrams of the cryogenic distribution lines for HL-LHC”, EDMS1573115.
- [9] : J.Hansen et al. “Specification for mechanical assemblies or sub-assemblies exposed to insulation vacuum”, EDMS1585240.
- [10] : CERN rules : HSE department : GSI-M-4 Cryogenic equipment https://espace.cern.ch/safety-rules-regulations/

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List of items supplied by CERN

- Instrumentation layout proposed by SOTO, approved by CERN

- QA procedures (pin layout, test procedures, inspection steps, travellers) supplied by CERN

- Components supplied by CERN, installed and tested by SOTON:
  - Instrumentation & Hardware
    - Wired level gauges
    - Pressure transducers
    - Wired calibrated temperature sensors mounted on CERN type supports
    - Heaters (controls ?)
  - Fully qualified plug equipped with bus bars if needed
  - Cryogenic safety pressure relief devices (based on SOTON sizing and risk analysis)
  - Survey targets to be installed on vacuum vessels