

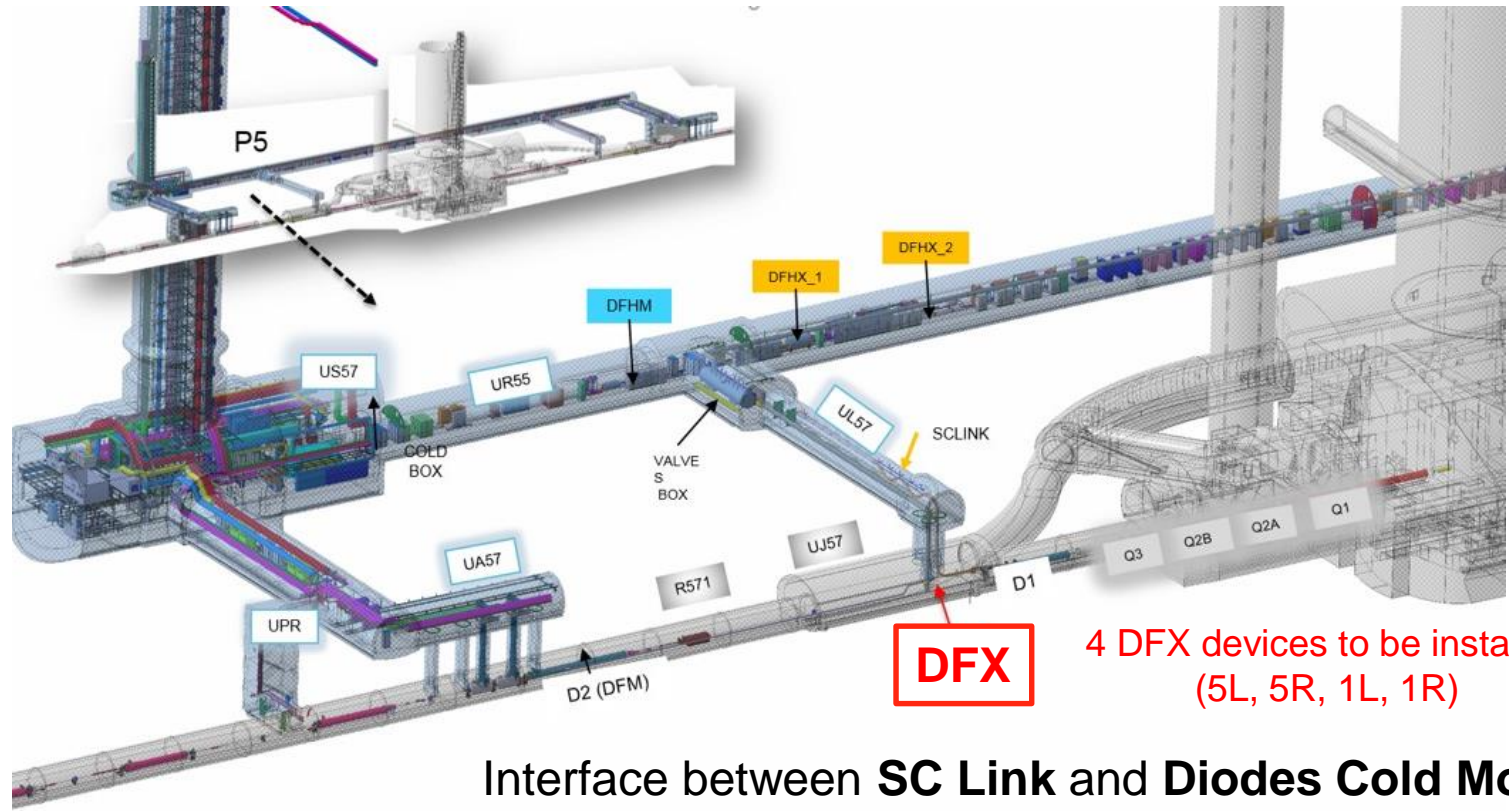


Description of the DFX device, scope & interfaces

P. Cruikshank on behalf of the WP6a team
3 March 2020

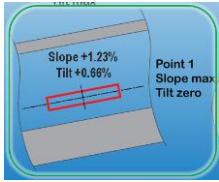
Production Readiness Review of the DFX

WP6a - DFX



Interface between **SC Link** and **Diodes Cold Module**
of the **HL-LHC Inner Triplets**

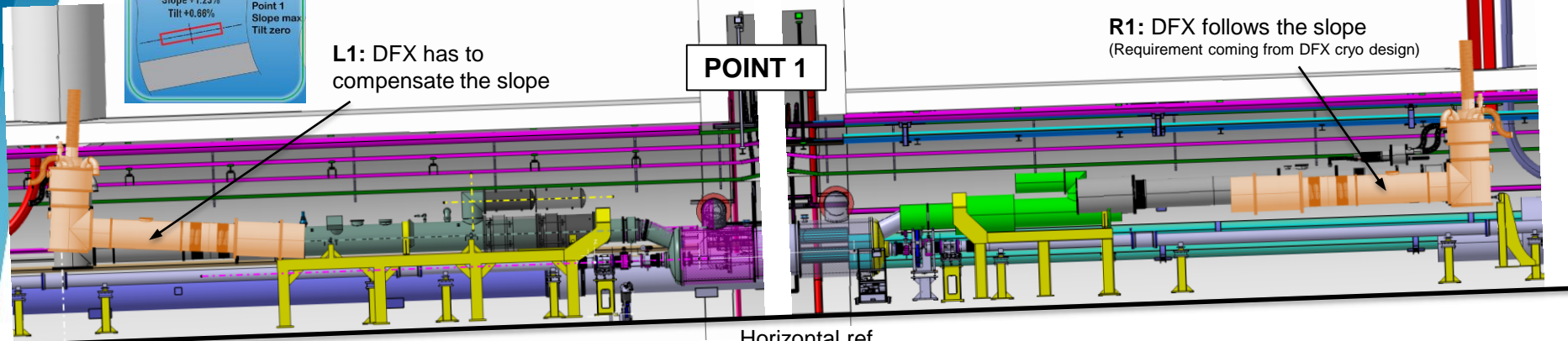
1. INTRODUCTION: Direction of the slope P1 vs P5



L1: DFX has to compensate the slope

POINT 1

R1: DFX follows the slope
(Requirement coming from DFX cryo design)



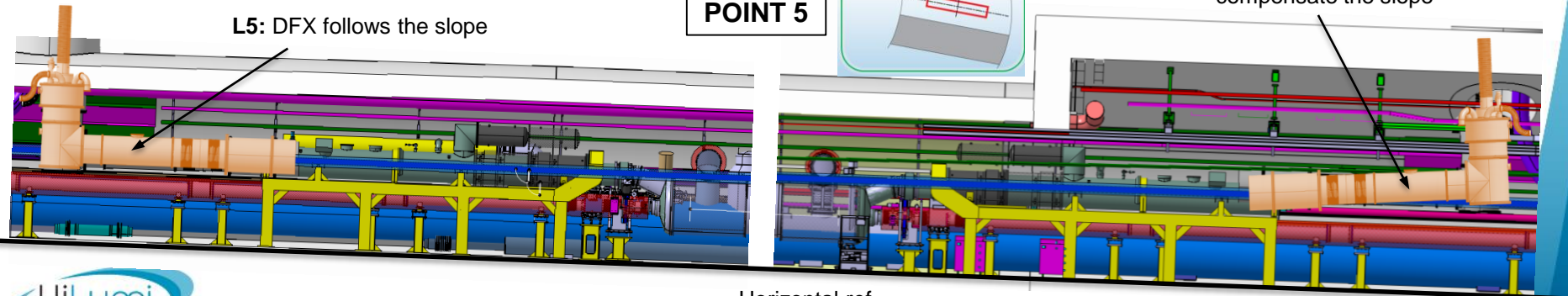
Horizontal ref

Extract from DFX integration review June 2019

L5: DFX follows the slope

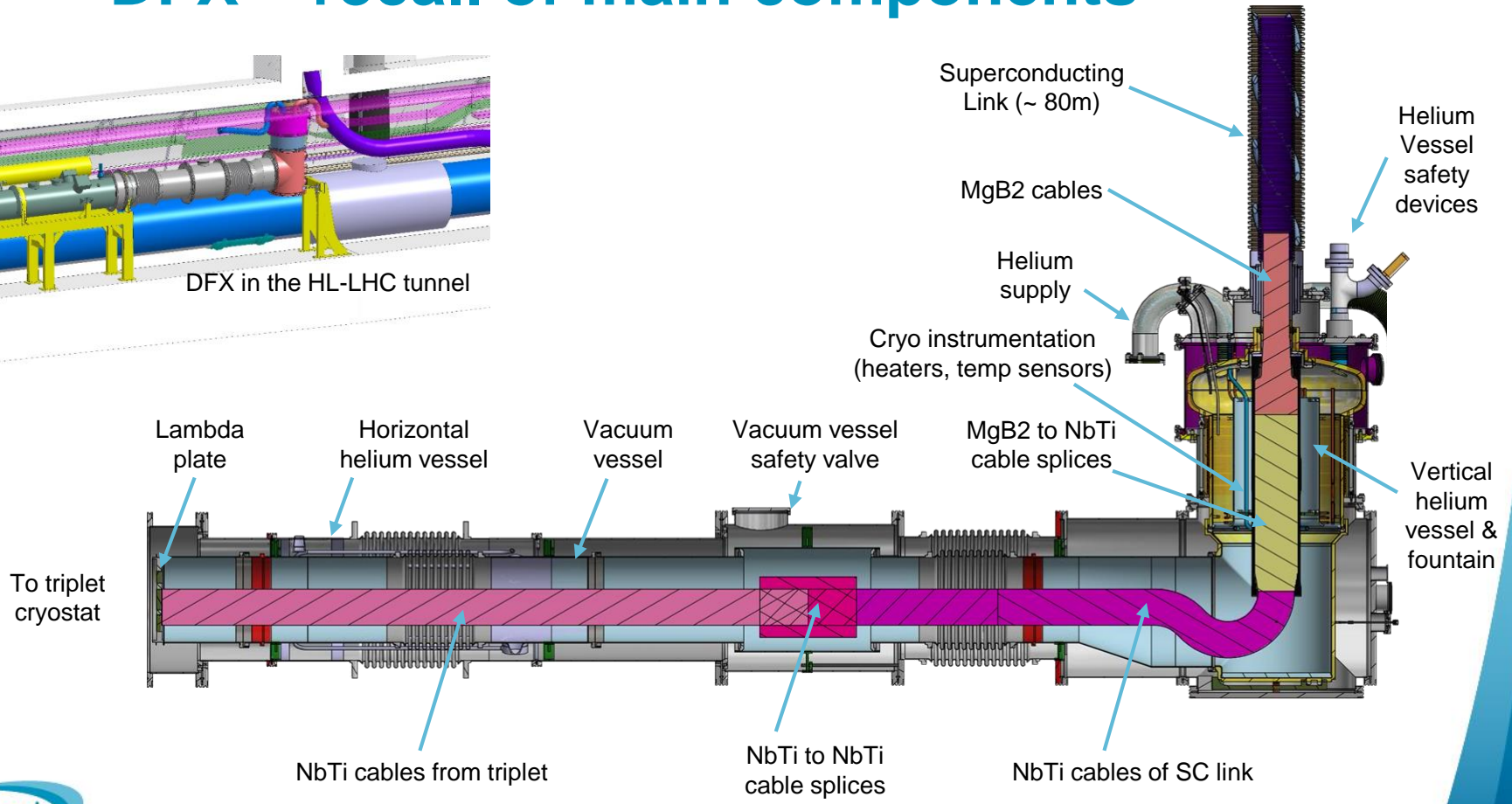
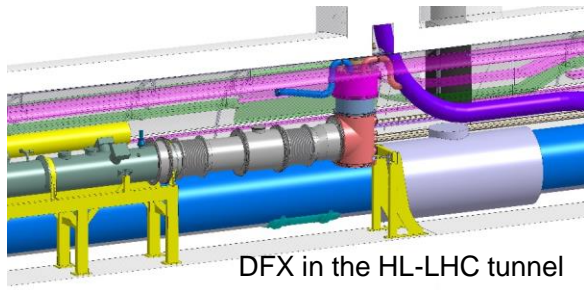
POINT 5

compensate the slope

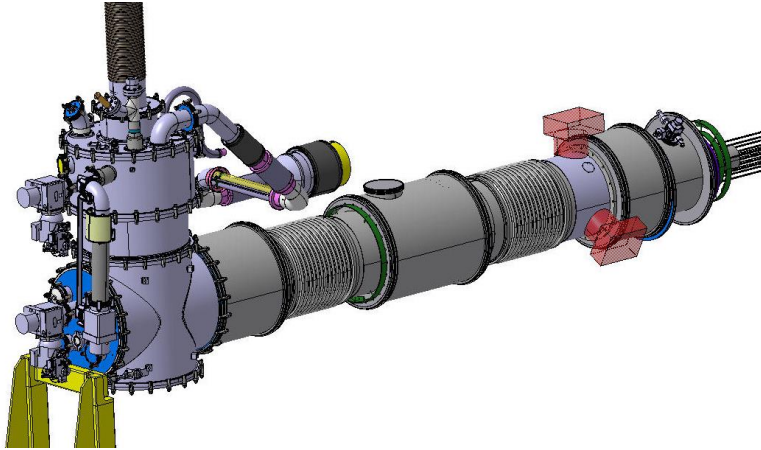


Horizontal ref

DFX – recall of main components



DFX - WP6a



DFX CDR - xxxx

DFX DDR - xxxx

5 DFX & 5 DFM cryostats required:

- Connection of MgB₂ SC link to NbTi leads of cryomagnets in LHC tunnel
- In-kind contribution from UK via collaboration with Southampton University (design & manufacture).
- Supply of DFX prototype within UK1
- 4 DFX series & 5 DFM series in UK2 (not yet signed)

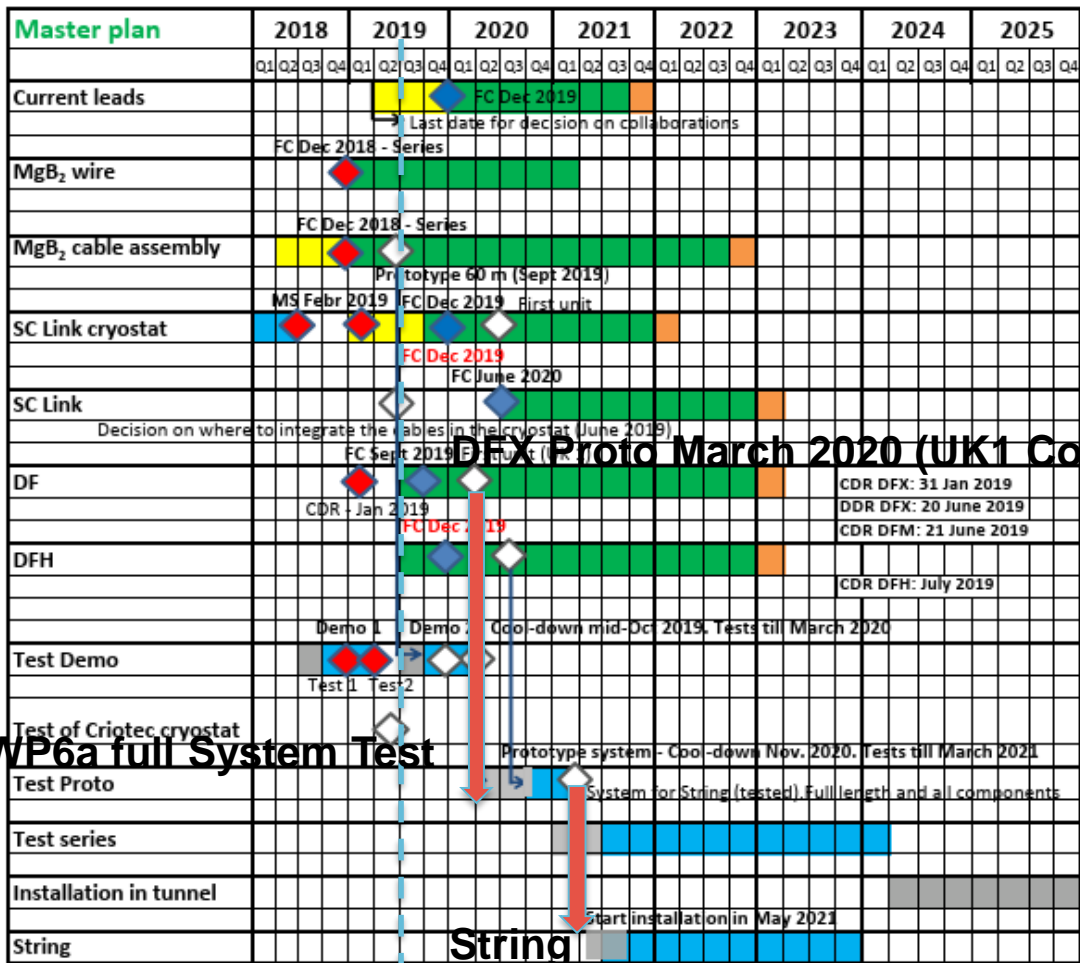
DFX prototype usage at Cern:

- Prototype test of cold power system (SC link, DFHX)
- HL String
- Stored as HL operational spare.

Design & Manufacturing:

- According to harmonized standards EN 13445
- Compliance with PED 2014/68/EU.
- CE marking (not 'modified approach' cf HSE advice)
- All quality records to be put in MTF

DFX planning – get latest from Amalia



- Tendering
- Manufacturing
- Tests
- Installation
- Spares
- ◆ Achieved milestone
- ◇ Future milestone
- ◆ FC dates

DFX Proto March 2020 (UK1 Contr., SOTON)

Proto WP6a full System Test

String



DFX documentation for PRR

The screenshot displays a document management system interface. On the left, a navigation pane shows a tree structure with folders: 'Tunnel Interconnection Cryostats Inner Triplets [DFX]', 'DFX Meetings', 'Engineering Drafts & Notes', and 'Fabrication, Assembly & Verification Drafts & Notes'. The main area is titled 'Info' and 'More info'. Below this, there are tabs for 'Documents', 'Structure', 'Used in', 'Access rights', and 'History'. A toolbar contains buttons for 'Create new document', 'Attach document', 'Detach', 'Auto Link', 'Export to Excel', 'Request access', 'Add all to Caddie', and 'Edit Tag'. The main content is a table of documents:

#...	Id	Title	Files	Status	Created on	Author	Document type	Tags
30	2040676 v.1	DFX prototype acceptance criteria		In Work	2018-10-20	Vittorio PARMA	Report	
40	1905382 v.0.1	Demonstrator DFX functional speci...	2	In Work	2018-02-15	Yann Leclercq, Ioli	Note	
80	LHC-DFX-ES-0001 v.	DFX Functional Specification	2	Under Approv	2020-02-27	YANN LECLERCQ	Engineering S...	
90	2157597 v.0.1	DFX Interfaces	1	In Work	2019-05-24	Yann Leclercq	Note	
1...	LHC-DFX-ES-0004 v.	DFX Technical Specification	2	HL Engineerin	2020-02-27	Yann Leclercq	Engineering S...	
1...	2224370 v.1.1	DFX loads to tunnel vault	2	Released	2019-12-16	Yann Leclercq	Report	
1...	2317283 v.0.1	Estimation of DFX NbTi-NbTi Splic...	1	HL Engineerin	2020-01-29	J. Fleiter, J. Hurte,	Report	
1...	2230929 v.1	DFX drawings		In Work	2019-09-18	JULIEN PASCAL I	Drawing Folder	
1...	LHC-D-ES-0011 v.1.0	Draft Conceptual Specification HL -...	2	Released	2018-04-05	WPL:A. Ballarino'	Engineering S...	
1...	LHC-D-ES-0012 v.1.0	Draft Conceptual Specification HL -...	2	Released	2018-04-05	WPL:A. Ballarino \	Engineering S...	
2...	2337455 v.1	Visit Report Lti Metaltech 2019-12-19	2	Released	2020-02-26	Paul Cruikshank	Report	

At the bottom of the table, there is a pagination control showing 'Page 1 of 1'.

All items shall be released prior to start of production

Interfaces overview

Tunnel, supports & Beam

SCLink interface

- Leads + Instru
- Jackets flanges

DCM interface

- Leads + Instru
- Jackets flanges

QXL interface

- Vacuum jacket flange
- Cryogenic lines

Instrumentation

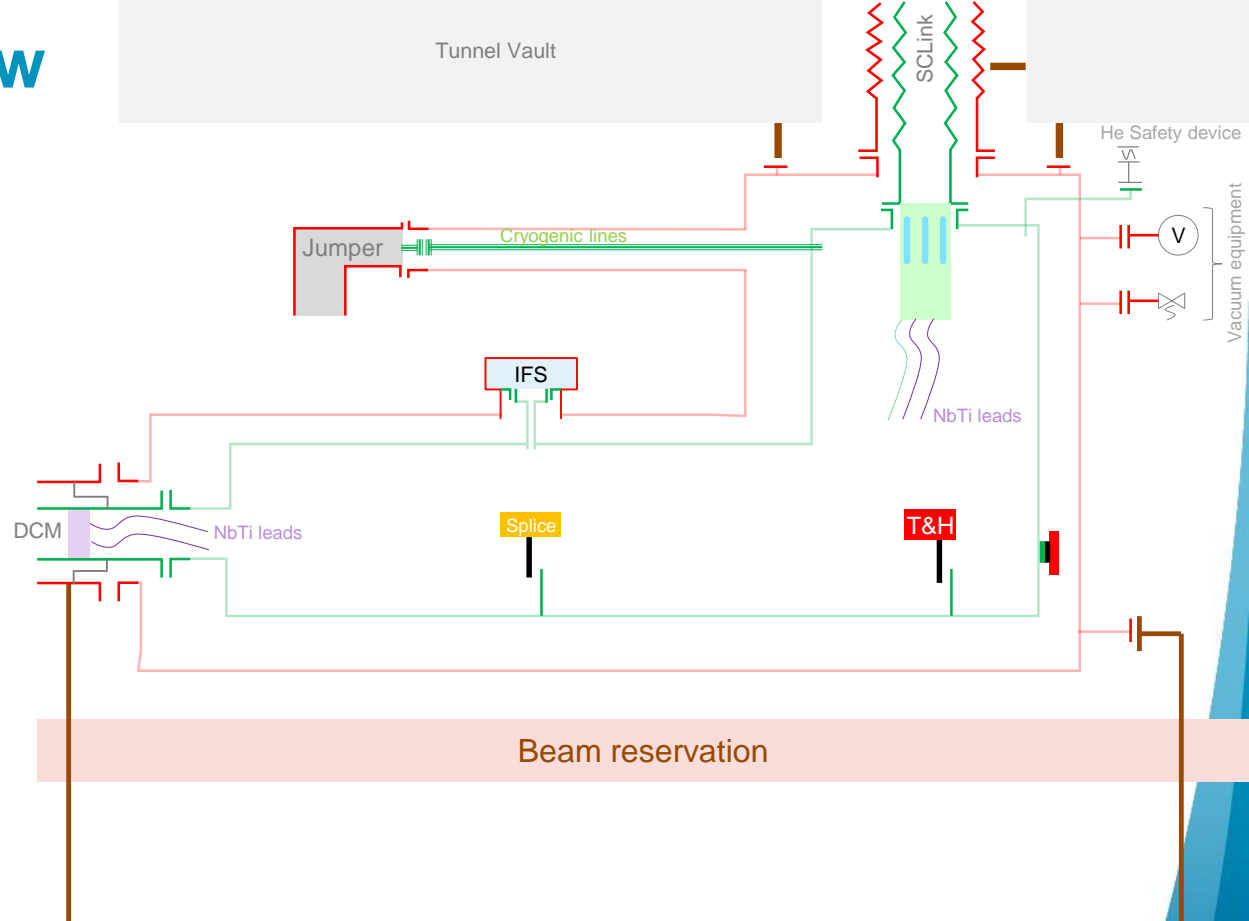
- Sensors supports + IFS
- Splices + bus bars support

External services

- Vacuum equipment
- Pressure relief devices

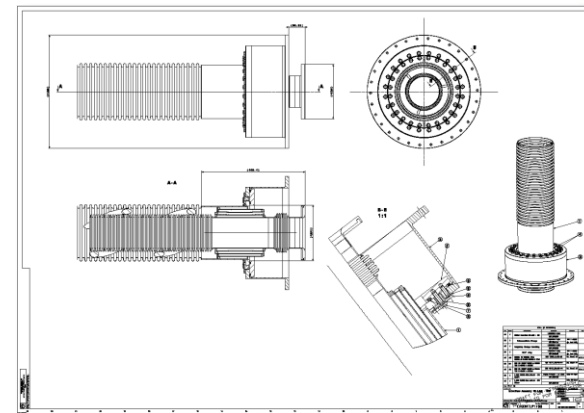
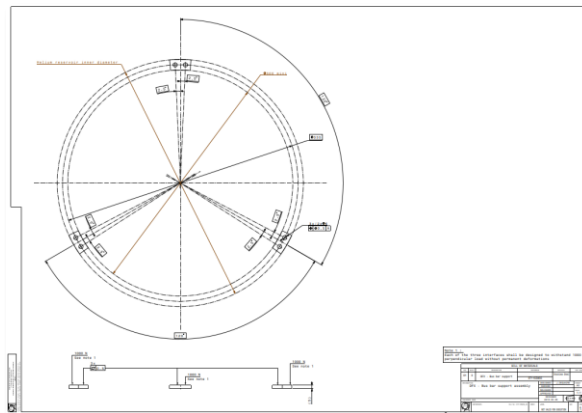
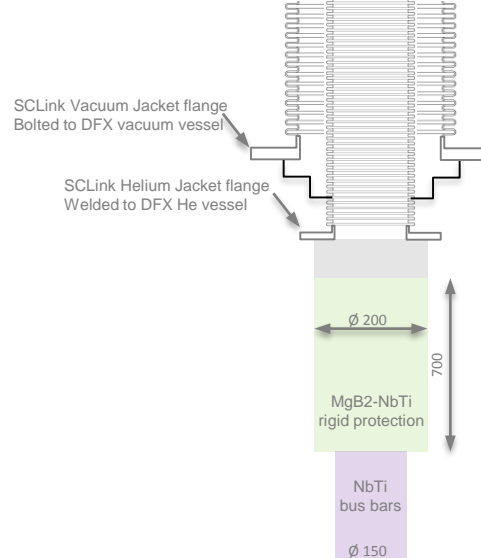
DFX interfaces

- Outer & Inner jackets
- Cryogenics
- Supports
- External accessories
- Instrumentation & cables/splices



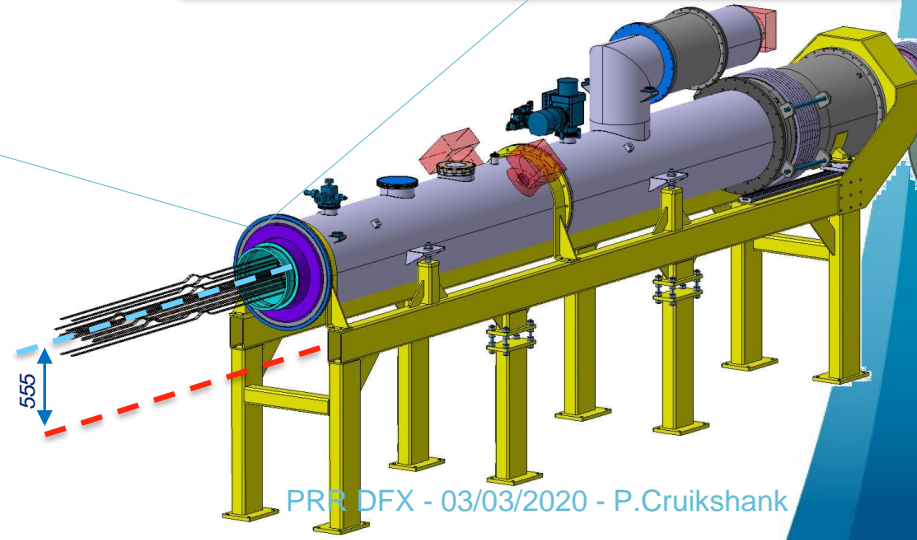
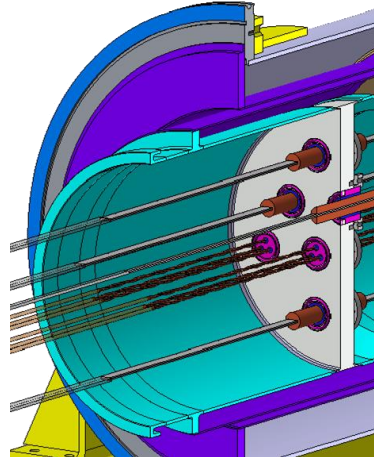
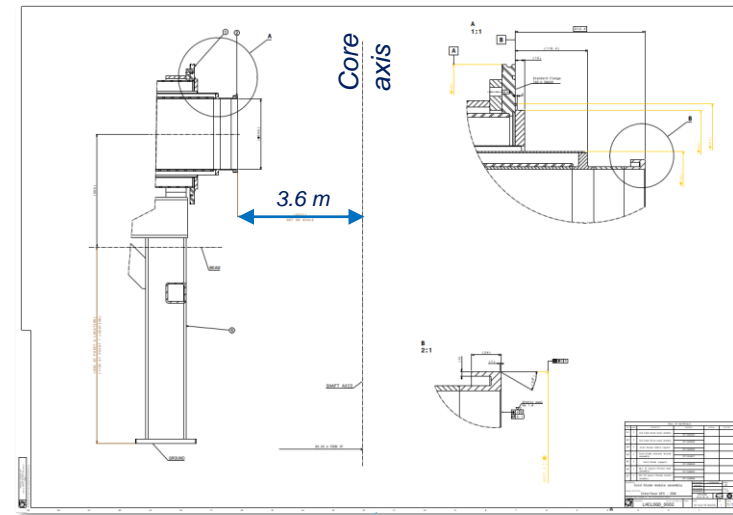
SCLink interfaces

- Vacuum & Helium jackets
 - LHCDHTLP1190
- Helium jacket end
 - $\varnothing 200$ x 700 mm + NbTi bus bars
- Bus bars
 - Design of supports between bus bars de-scoped from prototype deliverables
 - DFX shall present mechanical interfaces in helium vessel
 - LHCLDQD_0003
- NbTi-NbTi splices
 - Fixed to helium vessel
 - LHCLDQD_0003



DCM interface

- D1-DFX Connection Module (DCM)
- Vacuum & Helium Jackets
 - ISOK-DN630 with standard O-ring
 - Lip weld
 - Interface Drawing: LHCLDQD_0002
- Bus bars
 - De-scoped from prototype



DCM interface : Lambda Plate

- Bus bars overview (see dedicated talk)
- Λ -Plate design based on LHC experience:

- $\Delta P=20$ bar
- Nominal operation 1.9K
- Thermal cycle : 50
- Insulation @ RT : 4.6 kV
- Overall leak rate @ RT : 1.10^{-4} mbar.l.s $^{-1}$

- R&D activities:

- Demonstrator completed
 - 6 kA type plug manufacturing R&D complete
 - 18 kA similar type plug being qualified
- Plug Lab complete
 - Plasma treatment machine
 - Soldering post

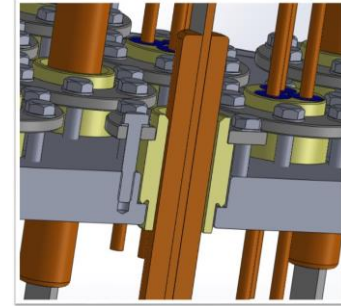
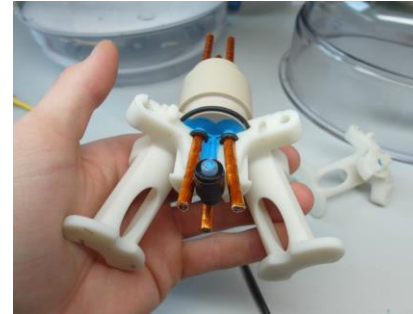
- Thermo-mechanical results

- 100% 6 kA plugs @ 1.10^{-10} mbar.l.s $^{-1}$ after 10 Thermal cycle and Pressure test (electrical qualification pending)
- 80% 18 kA demo plug @ 1.10^{-10} mbar.l.s $^{-1}$ after 5 Thermal cycles

- Final configuration in progress

- 6 kA manufacturing procedure complete
- MQXF cable plug being developed
- Manufacturing & qualification procedures being finalised
- Final qualification with current during System test 2020

	Cable type				
	I_{cable} [kA]	N_{cables}	Triplet side	Plug	DFX side
MQXF	18	2	18 kA Nb-Ti round	2 x MQXF leads	See J.Fleiter talk Round
MBXF (D1)	18	2	13 kA Nb-Ti flat		
Trims	7	3	18 kA Nb-Ti round	LHC 6 kA	See J.Fleiter talk Round
MCBXF%	2	12	6 kA Nb-Ti round		



PRR DFX - 03/03/2020 - P. Cruikshank

Courtesy S.Donche & E.Andrews

DCM interface : Lambda Plate

Cable opening
Cleaning
Plasma treatment



Injection (800 mbar)
under vacuum (<1mbar)
of pre-heated parts (40°C)

Status:

- Plug prototype production is up and running (procedures, tooling & equipment)
- Integration constraints shall now be studied
 - Up to 6m long leads
 - MQXF cable (proto with 13 kA LHC cable)
- Qualification procedures for series to be finalised
 - Individual follow-up & results archiving in place
 - Manufacturing procedures uploaded to EDMS

Production Plan

- Prototype expected by end of 2019
- Injection moulds, Peek & SS parts sub-contracted
- Assembly & qualification (thermo-mechanical + insulation) at CERN



Traceability

Leak test
<1.10⁻⁸mbar.l.s⁻¹

Pressure test
1 h at 30 bara

Thermal cycles
X10 to 77K



Demoulding

Cryogenics interfaces

Jumper interfaces

- Cryogenic lines defined for DFX
- Still discussions on DCM new module TS line
- Jumper location above the QXL
- DN250, longitudinal position TBC

Temperature sensors supports

- Interface long CERNOX

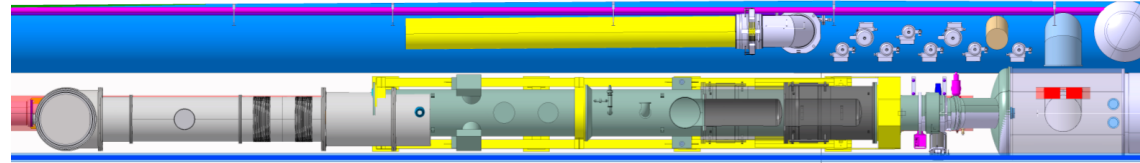
Heaters Vishay® RH100 interfaces

Level gauges interfaces

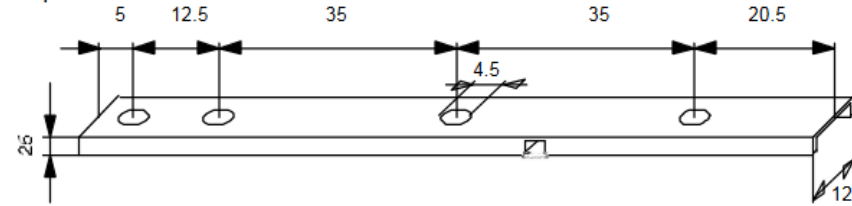
DeltaP gauge pneumatic fittings to be agreed

Pressure relief devices

- See safety dedicated talk

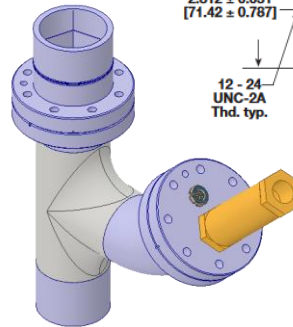
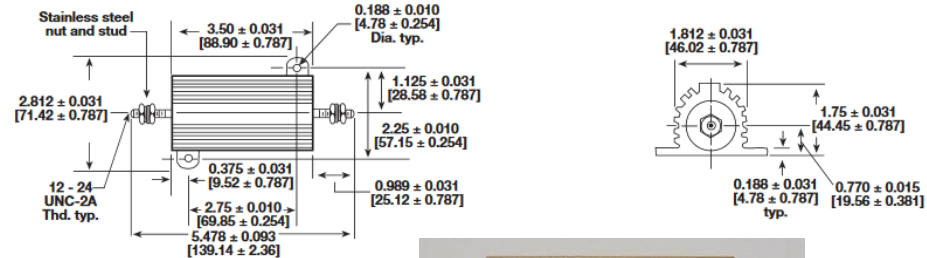


On going work for Jumper location



DIMENSIONS in inches [millimeters]

RH100, NH100



PRR DFX - 03/03/2020 - P.Cruikshank

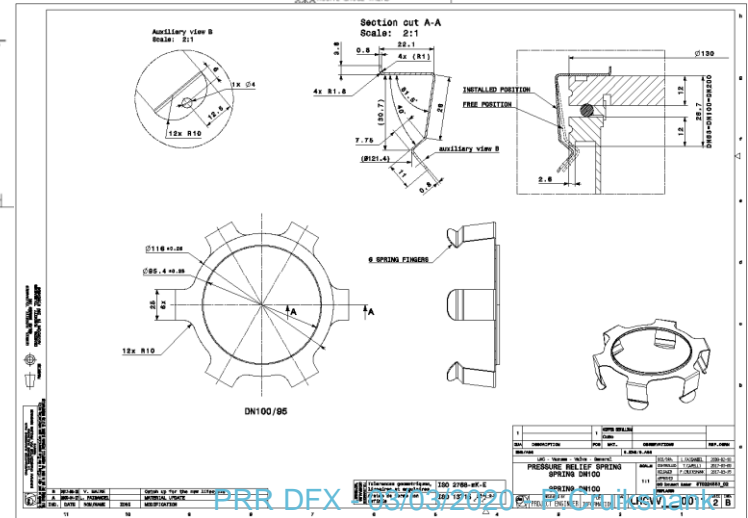
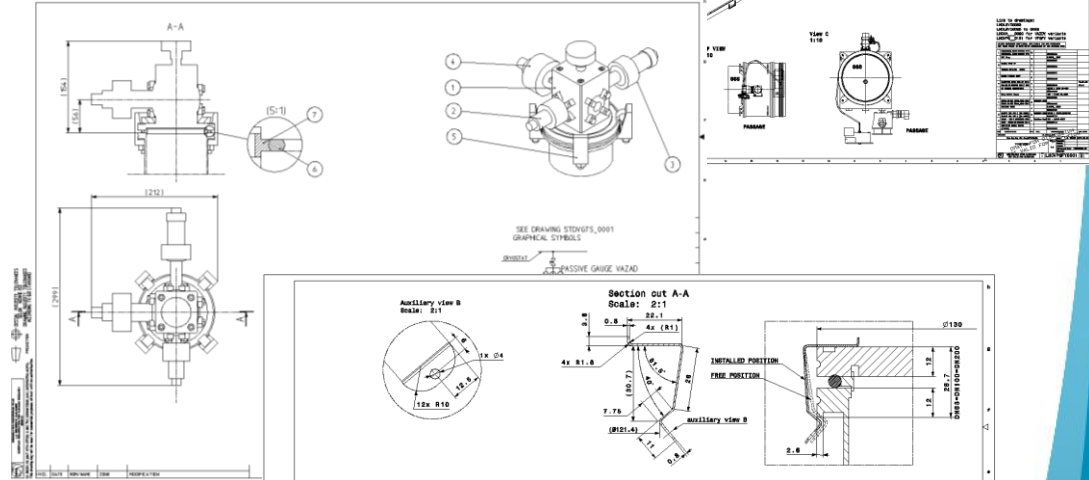
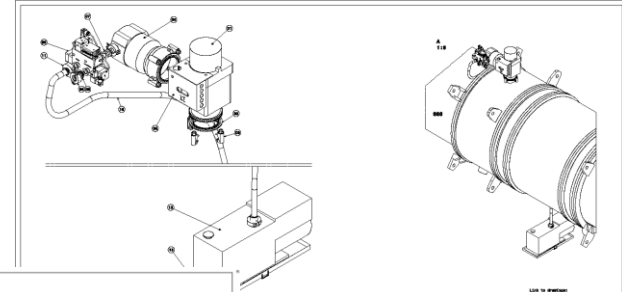
Insulation vacuum interface

SCLink insulation vacuum volume

- Pumping equipment :
 - valve + turbopump + primary pump
 - LHCVPGFY0001
- Gauges interface
 - 3 gauges on one ISO DN100
 - LHCVA___0076
- Relief plate interface
 - ISO-K DN100
 - LHCVV___0011

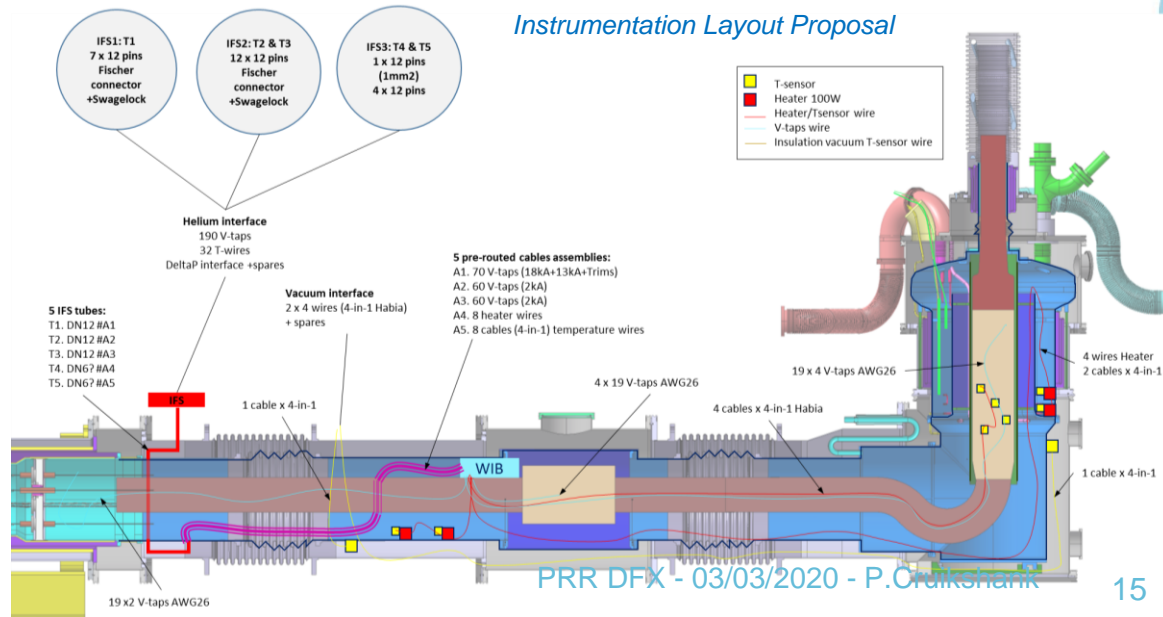
DFX insulation vacuum volume

- Pumping equipment
 - Valve + Turbopump + Primary Pump
 - LHCVPGFY0001
- Gauges interface
 - 3 gauges pn pne DN100
 - LHCVA___0076
- Relief plate interface
 - ISO-K DN200
 - ST0705009_01



Instrumentation interface

- Mechanical supports
- Wire Instrumentation Box (WIB)
- IFS
 - (CERN design & supply)
 - 3 Flanges
 - 5 tubes sorted by functions
 - 190 V-taps
 - 32 T-wires
 - 8 power wires
- Vacuum instrumentation feedthrough ISO DN100



Instrumentation Layout Schematic Edms xxxxxx,

All instrumentation is provided by Cern.

- IFS1:** 8 x 12 pins Fischer connector +Swagelock
- IFS2:** T2 & T3 12 x 12 pins Fischer connector +Swagelock
- IFS3:** T4 & T5 1 x 12 pins (1mm²) 4 x 12 pins

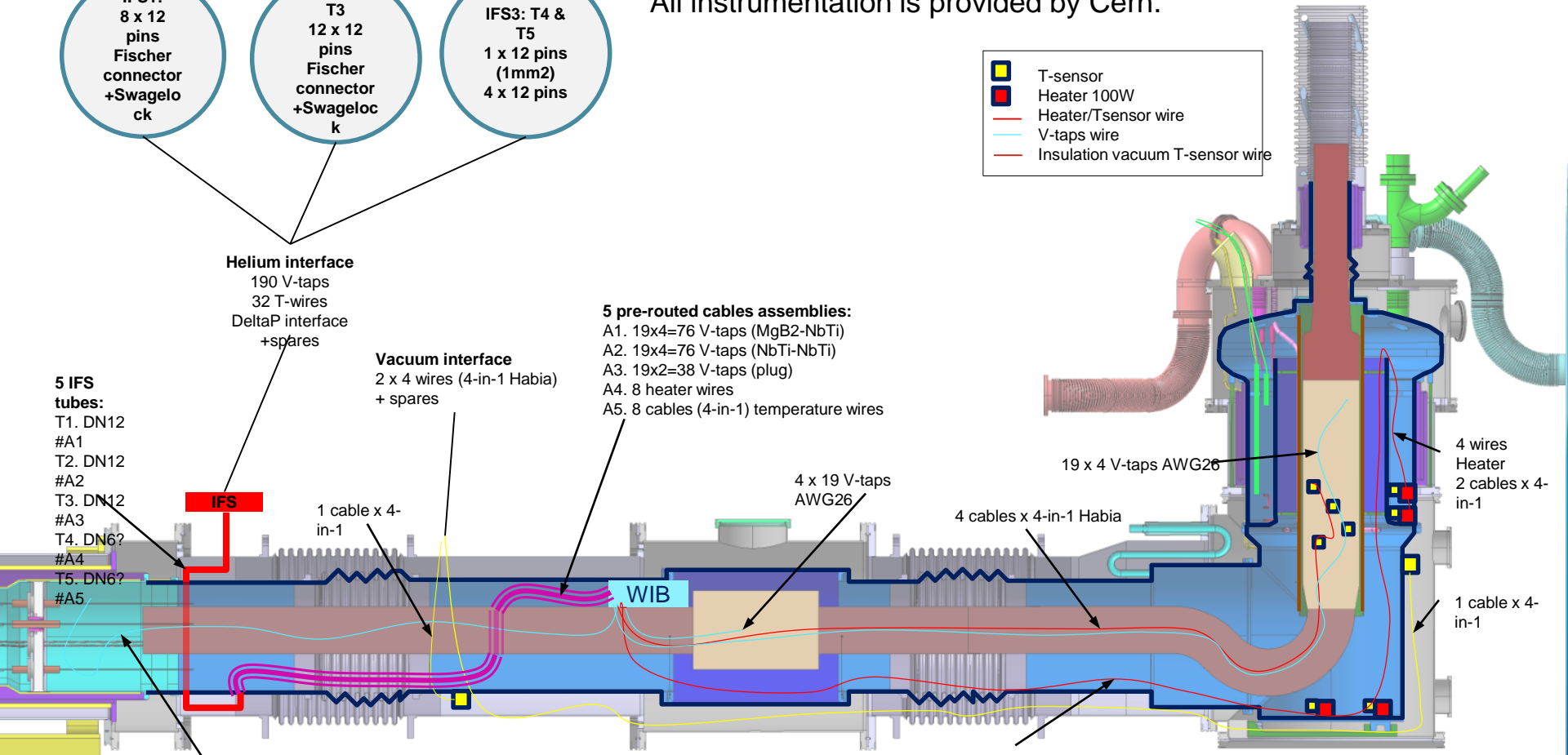
■	T-sensor
■	Heater 100W
—	Heater/Tsensor wire
—	V-taps wire
—	Insulation vacuum T-sensor wire

Helium interface
190 V-taps
32 T-wires
DeltaP interface
+spares

Vacuum interface
2 x 4 wires (4-in-1 Habia)
+ spares

5 pre-routed cables assemblies:
A1. 19x4=76 V-taps (MgB2-NbTi)
A2. 19x4=76 V-taps (NbTi-NbTi)
A3. 19x2=38 V-taps (plug)
A4. 8 heater wires
A5. 8 cables (4-in-1) temperature wires

5 IFS tubes:
T1. DN12 #A1
T2. DN12 #A2
T3. DN12 #A3
T4. DN6? #A4
T5. DN6? #A5



19 x 2 V-taps AWG26

4 x 19 V-taps AWG26

4 cables x 4-in-1 Habia

19 x 4 V-taps AWG26

4 wires Heater
2 cables x 4-in-1

1 cable x 4-in-1

4 cables heaters + 4 x 4-in-1 Habia

Civil Engineering & Transport Interfaces

CERN responsible for supports design to ground/ceiling in the tunnel

Conceptual proposal to ceiling and ground being discussed at CERN

DFX interfaces

- Civil engineering : threaded blocks
- Transport : adequate lifting points compliant with design
- Tooling not defined today

Forces distribution DFX to tunnel

- Configuration:
 - Rigid outer DFX + supports + ring fixed to tunnel vault
 - Bi-lateral lower support transferring longitudinal loads to ground
- Constraints transferred to tunnel walls through red surfaces

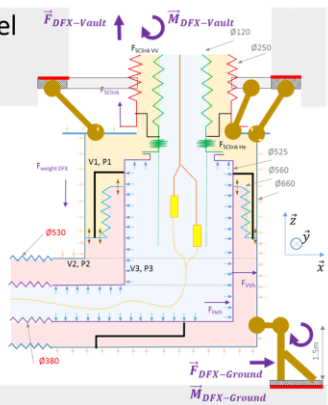
Configurations

Phases	Pressures				Weight	Vacuum induced loads		He V induced loads	
	Atm	P1	P2	P3		DSH-DFX	DCM-DFX	DSH-DFX	DCM-DFX
Neutral	1	1	1	1	20	10	0	0	0
Purging	1	1	1	0	20	10	0	0	12
Dist vacuum	1	0	1	1	20	10	5	0	-2
Dist vacuum / purge	1	0	1	0	20	10	5	0	12
DFX vacuum	1	1	0	1	20	10	-15	-22	12
DFX vacuum / purge	1	1	0	0	20	10	-15	-22	0
Nominal	1	0	0	1.5	20	10	5	-22	-2
Unspooled magnet	1	0	0	2.5	20	10	5	-22	-3
Design pressure	1	1	1	2.5	20	10	0	0	-2

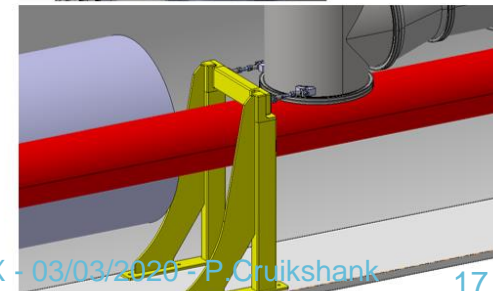
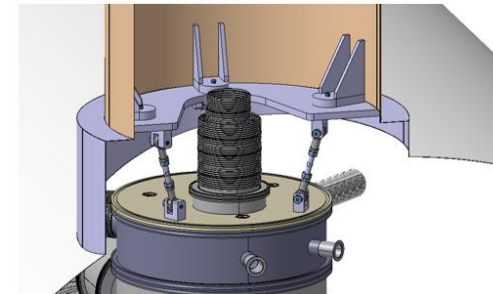
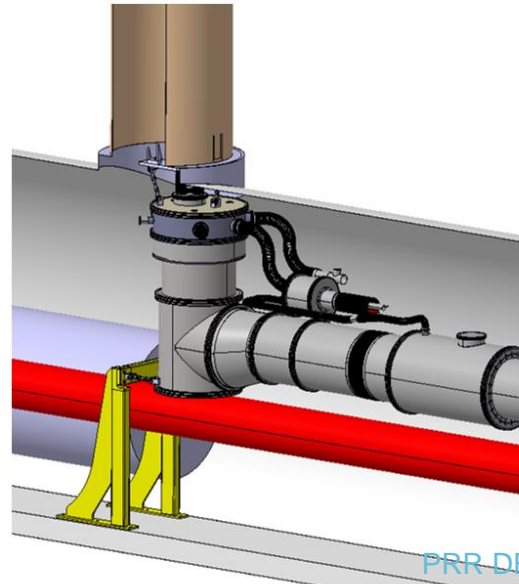
Maximum transferred loads

$$\begin{aligned} \bar{x} &< 1 \text{ kN} & \bar{z} &< 1 \text{ kN.m} \\ \bar{F}_{DFX-vault-y} &< 1 \text{ kN} & \bar{M}_{DFX-vault-z} &= \pm 10 \text{ kN.m} \\ \bar{z} &[-20; +5] \text{ kN} & \bar{z} &< 1 \text{ kN.m} \end{aligned}$$

$$\begin{aligned} \bar{x} &\pm 25 \text{ kN} & \bar{z} &< 1 \text{ kN.m} \\ \bar{F}_{DFX-ground-y} &< 1 \text{ kN} & \bar{M}_{DFX-ground-z} &= \pm 25 \text{ kN.m} \\ \bar{z} &< 1 \text{ kN} & \bar{z} &\pm 10 \text{ kN.m} \end{aligned}$$

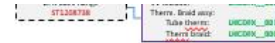
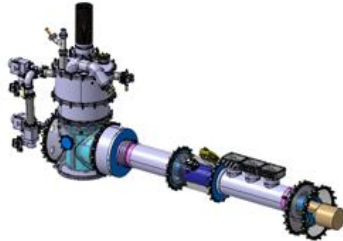


On going studies for load transfer to civil engineering



Assembly and P.Test configurations

- Need latest images/x-sections



- System fully assembled in UK to validate assimilability perform pressure test and all pressure configurations.
- To avoid welding/cutting operations at lip welds in UK, the design permits the closing of the helium vessel with elastomer seals prior to cable integration at Cern.
- CE marking is removed at Cern prior to the welding.

Summary