



Magnet installation and interconnection into the HL-LHC IT String

Sandrine Le Naour
On behalf of TE-MS C



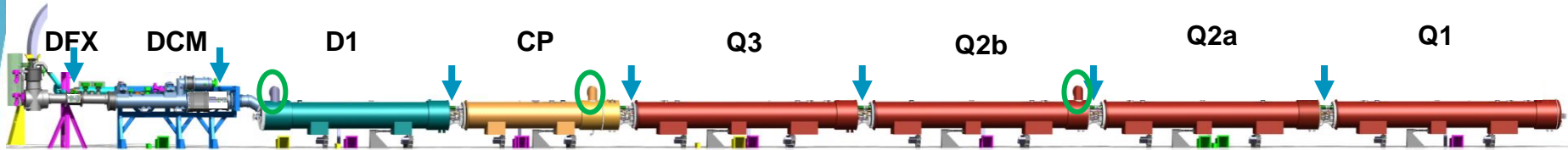
String Day, 27 Sept 2024

Outline

- ❑ IT String Contributions
- ❑ IT String Magnets Readiness
- ❑ Interconnection Sequence
 - Lines N insertion
 - Q1 to D1 connection
 - DCM connection
 - Jumper connection
- ❑ Activities follow-up
- ❑ Summary

HL-LHC IT string magnets connection

- The presentation concerns the magnet connection from the Q1 to the DFX (71C) and the jumper connexion to the SQXL (3 Jumpers).



- WP3 provides (see WP3 contribution to WP16 document : [EDMS 2188575](#))
 - the DCM and the cryo-magnets (proto or spare assemblies)
 - the jacks and the anchors, installed by EN-ACE
- WP6a installs the DFX (see WP6a contribution to WP16 document : [EDMS 2188577](#)). The DFX is in place prior the magnets installation
- TE-MS C is in charge of the cryo-magnets connection (see Summary of TE-MS C contribution to WP16 document : [EDMS 2755342](#))

HL-LHC IT string magnets readiness



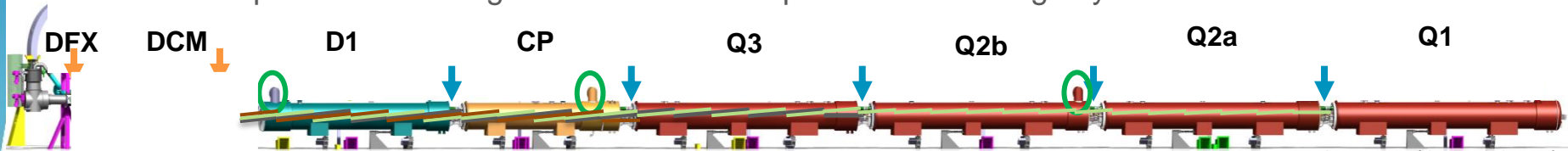
	D1	CP	Q3	Q2b	Q2a	Q1
Cryostating Phase 1	HCQBXF_S007-CR00001	HCQCXF_S006-CR00001	HCQQXF_SC002-FL00001	HCQQXF_SB014-CR00001	HCQQXF_SA008-CR00001	HCQQXF_SC002-FL00002
Cold test	Test report	Mg tested individually SM18 Test bench Oct → end Nov *			Test report	At FNAL
Cryostating Phase 2	HCQBXFC006-CR00001	HCQCXFC010-CR00001	Oct → Dec 2024 *	→ End Nov 2024 *	HCQQXFG005-CR00001	Reception at CERN Nov 2024 * for Phase 2
Critical nonconformities	-		QH issue NCR 2769128 NCR 2883868	Performance limitation NCR 2638374 NCR 2687264	QH issue NCR 3069797	 The delay of the Q1 do not prevent the connection of the other cryo-magnets and interlink (DCM).
ID card	EDMS 3117914				EDMS 3127310	
MAB	EDMS 31265			Performance limitation taken into account in the HWC parameters EDMS 2771118	EDMS 3164	

* According to [WP3 planning V46](#) (07/2024)

All cryo-magnets are available before the end of year 2024, but Q1.

Magnet interconnection sequence

The sequence of the magnet connection was presented in String day II & III review



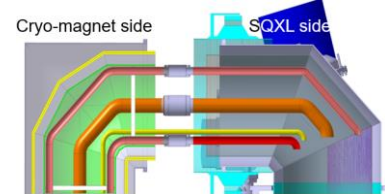
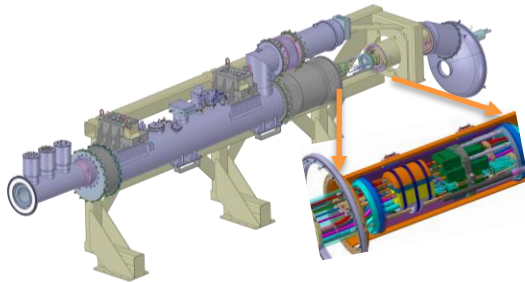
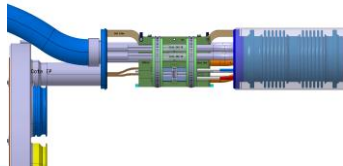
Cable N insertion
through D1 to Q2a

In case of long delay of the Q1, temporary plugs could be installed as mitigation measures to anticipate local leak test in the other interconnections.

Q1 to D1 connection

DCM installation and its connection

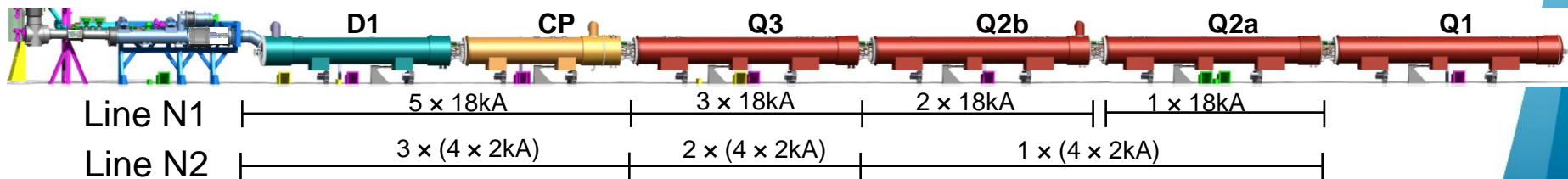
Jumper connection



Cable N insertion



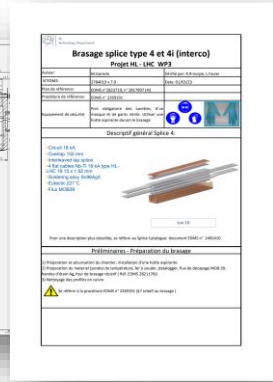
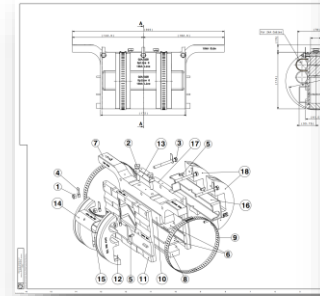
- 2 sets of busbar cable was received end of 2023 for 5 UL.
 - Cable N1 : $5 \times 18 \text{ kA}$ → outer diameter : 47 mm
 - Cable N2 : $3 \times (4 \times 2\text{kA})$ → outer diameter : 48 mm
- Insertion test of the 2 cables through a mock-up of 30 m long
 - Pull with a winch, the cables were inserted successfully through the lines
 - No damages observed on lines N1 and N2 after insertion
 - Insulation test passed.→ Control procedure in progress
- Preparation of the cables N for the IT string (Mid-Nov)
 - Preparation of extremities for soldering at the right position
 - Insulation test.



Q1 to D1 connection

Splice connection

- Splice qualification completed
 - Splice procedures available
- } see Rosario presentation at String day III : EDMS [2963029](#)
- Tooling development completed and in use
 - Fix point and splice components for IT string available
 - Splice soldering in real condition (mock-up) on going



Splice Quality Control

- Splice QC procedure in progress

Q1 to D1 connection



Interconnection
Drawings :

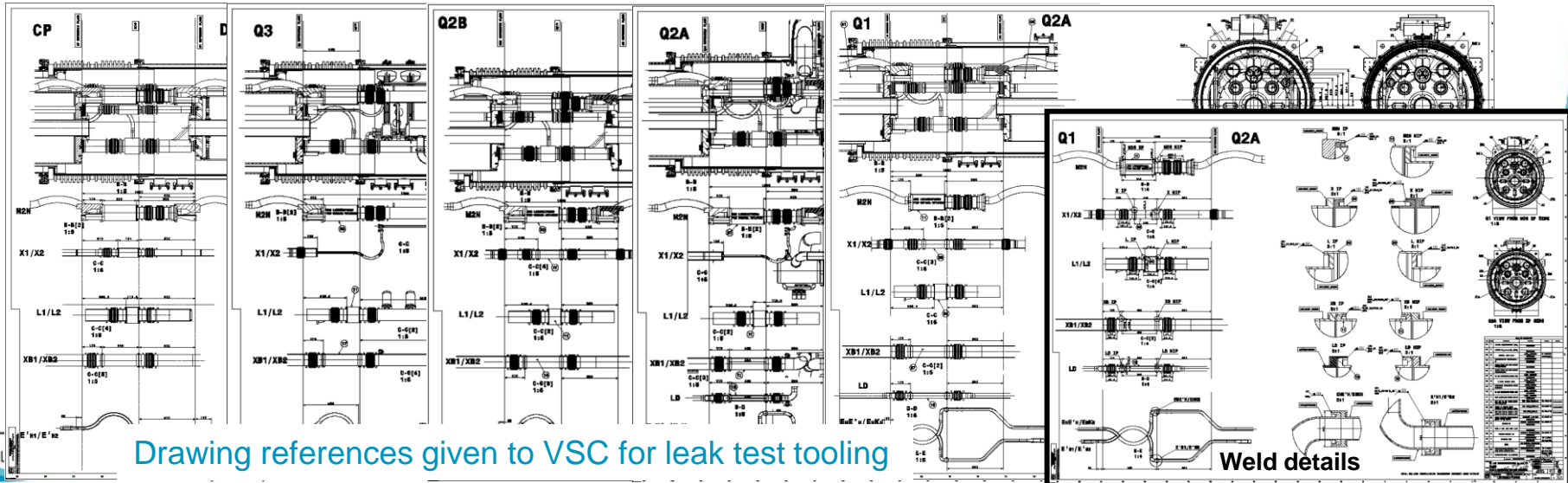
[LHCQCBIF0021](#)
[LHCQCBIF0022](#)

[LHCQQCIF0021](#)
[LHCQQCIF0022](#)

[LHCQQQIF0081](#)
[LHCQQQIF0022](#)

[LHCQQQIF0071](#)
[LHCQQQIF0072](#)

[LHCQQQIF0061](#)
[LHCQQQIF0062](#)



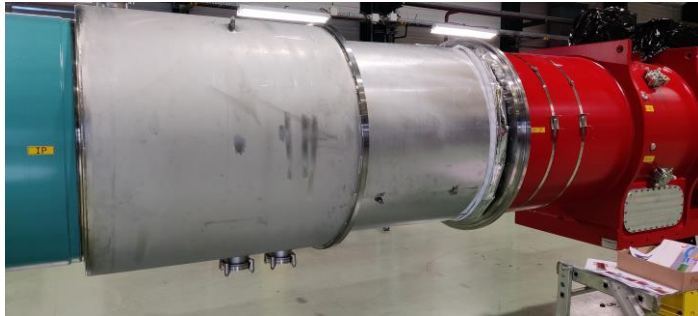
Drawing references given to VSC for leak test tooling

Weld details

Q1 to D1 connection

Thermal shield installation

- Installation of two cryo-magnets in SMI2 (Q2a and D1)
- Test in real condition of thermal shields and MLI
→ small adjustment to perform for an easier installation



DCM installation and its connection

DCM : 95% completed

- Diode connection done
- Final vacuum vessel assembly (Wk 40)
- Final test and DCM delivery : Mid Oct. 2024



Leak test in progress on the DCM

DCM connection

- Tooling and components available
- Splice soldering in real condition on going (mock-up)



Diode connection on SC busbar and NbTi-NbTi Splices (mock-up)

Next step : Installation procedure of the DCM and its module on the string

- Tooling development in progress
- Procedure ongoing



, 27 Sept 2024

Jumper connection

As agreed with WP16 and WP9 ([EDMS 2755342](#)), TE-MSC will proceed to the jumper connection between the cryo-magnets and the SQXL and to remove the temporary jumper sleeve installed for the SQXL commissioning.

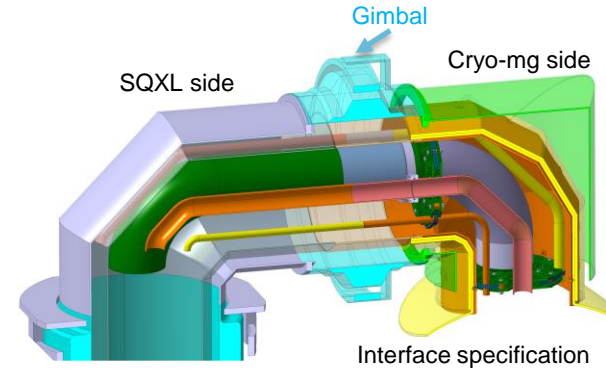
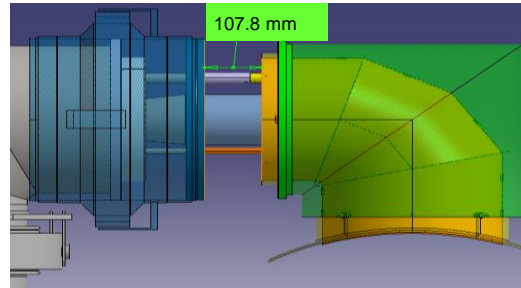


Observed on the three SQXL jumpers, the weld of the temporary sleeve on the jumper flange is not conform.

- No possibility to cut the sleeve without removing the flange

Moreover, the gimbals delivered are not conformed

- Inner diameter : 447mm (440 mm expected)
- Total length : 325 mm (295 mm expected)



Solution : New outer flange to manufacture and weld

Solution : Intermediate ring to weld on the gimbal to reduce the diameter on cryo-magnet side

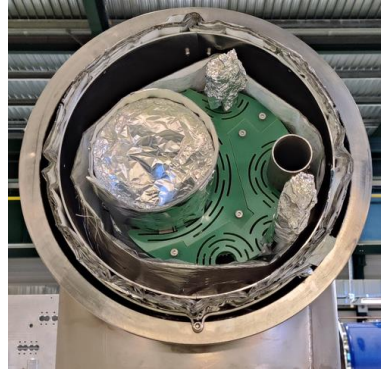
Consequence : Opening smaller than 11cm for the welding of the four inner pipes

Jumper connection

Due to the tight opening for the welding of the inner pipes, the two largest ones will be equipped with nested flanges and the small pipes will be butt welded.



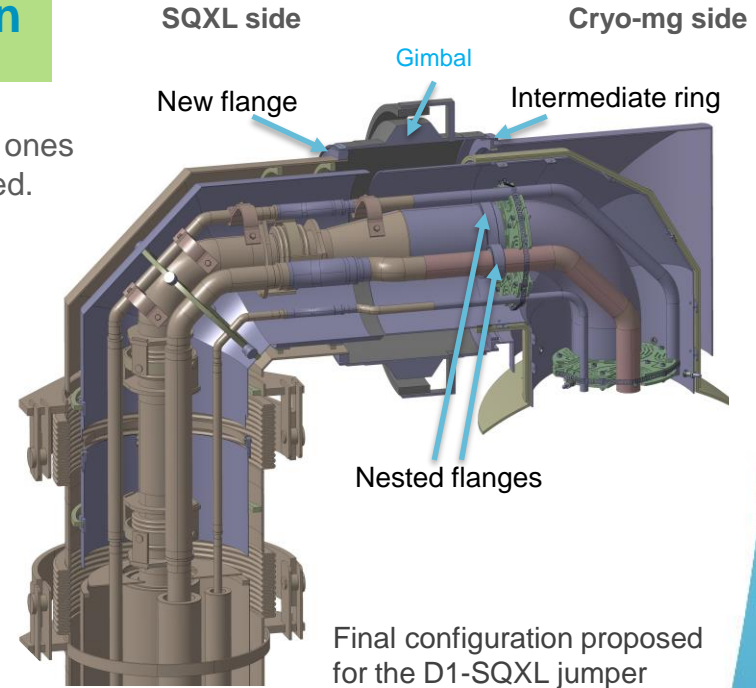
SQXL jumper



D1 jumper

Tooling for leak test will be developed to qualify the flanges welding.

A complete jumper connection for the D1 is proposed before cutting the CP and Q2b jumper extensions of the SQXL.




Final configuration proposed for the D1-SQXL jumper

Different configuration for the QXL in the tunnel : [LHC-QXL-EC-0001](#)

Activities follow-up

- For the follow-up of the activities, including Quality Control, a dedicated interface will be adapted for the IT string connection.
- The e-MIP (electronic version of the Manufacturing and Inspection Plan), currently used for the magnets manufacturing and the cryostating of HL-LHC magnets, was developed in close collaboration between TE-MS C and EN-IM.
- The tool was presented at the IT String technical meeting: [indico 1437961](#)

Example of an overview for a cryostating

 Infr EAM Reporting - Penzance - CMI QA
Equipment: HCQBRDP004-CR000001
Issued on 11/05/2022

Electronic MIP for HCQBRDP004-CR000001

A - Production Start-up (CMI)

	Document	Version	Executing Entity	Supplier	Client	3rd Party	Reports/NCRs	Comments
A.1 - Prod Start-Up Val. parts, calc. margins, assign parts to assembly	Assembly Procedure LHC QBRD-IP-0004	1.1	IN	JAMIL, RIZWAN			NCR: LHC-QBRDP-QN-0001	A. Seller digitally signed on behalf of R. Jamil initially due to access issues with EAM Light. R. Jamil has signed the paper copy. Now the access issue has been resolved and signed again by R. Jamil.

B - Cryostating (CMI)

	Document	Version	Executing Entity	Supplier	Client	3rd Party	Reports/NCRs	Comments
Production step B.1 - Installation of Locking Rings	Welding Book LHC-QBRD-NCR-0004	1	IN	BARLOW GRAEME	HOUSAIS DAVID		NCR: LHC-QBRDP-QN-0007	Seller signed on behalf of M. A. Theodor who performed the welder inspection on 11/05/2022
Procedures	LHCQBRD_2013 LHCQBRD_2013	0	IN	BARLOW GRAEME	HOUSAIS DAVID		19-JUL-22	16-MAY-22
	Assembly Procedure LHC QBRD-IP-0004	1.1						Signatures
B.2 - Installation of Upper Thermal Shield	Welding Book LHC-QBRD-NCR-0004	1	IN	SELLER ALISSAAR DOUGLAS	HOUSAIS DAVID		NCR: LHC-QBRDP-QN-0008	DH160522: Welding filler not used for welding upper thermal shield, approved by D RAMOS. DH170522: A SELLER signed in place of N. MAROUAN (Welder)
	LHCQBRD_2013 LHCQBRD_2013	0	IN	SELLER ALISSAAR DOUGLAS	HOUSAIS DAVID		17-MAR-22	17-MAY-22
	Assembly Procedure LHC QBRD-IP-0004	1.1						
B.3 - Cold Mass and Tooling are Ready for Cryostating	Assembly Procedure LHC QBRD-IP-0004	1.1	IN	BARLOW GRAEME	HOUSAIS DAVID		NCR: LHC-QBRDP-QN-0003	
	Assembly Procedure LHC QBRD-IP-0004	1.1	IN	BARLOW GRAEME	HOUSAIS DAVID			
	Assembly Procedure LHC QBRD-IP-0004	1.1	IN	BARLOW GRAEME	HOUSAIS DAVID			

The advantage of the e-MIP :

- Direct link of a step in EAMLIGHT (work orders)
- Direct link to procedure and its version applied
- Direct link to NCR or Reports (Check lists, pictures, ...)
- Digital signatures.

Summary

- The DCM and all cryo-magnets, but Q1 will be delivered to the IT string before the end of the year 2024. The interconnection of the magnets and the DCM can start once all magnets from Q2a to D1 are aligned.
- If the Q1 is not ready when the other magnets are connected and sleeves welded, temporary plugs could be installed on Q2a helium lines to proceed to the leak test and anticipate leak repair if any.
- No specific issues are expected for the cables N insertion and the magnets connection
 - Tests on mock-up were successful
 - All components are available
- Jumper interface is not conformed and requires serious modifications
 - Small room to weld inner pipes
 - Small room for leak test tooling
- A follow-up tool, based on e-MIP, will be adapted for IT string magnet connection activities

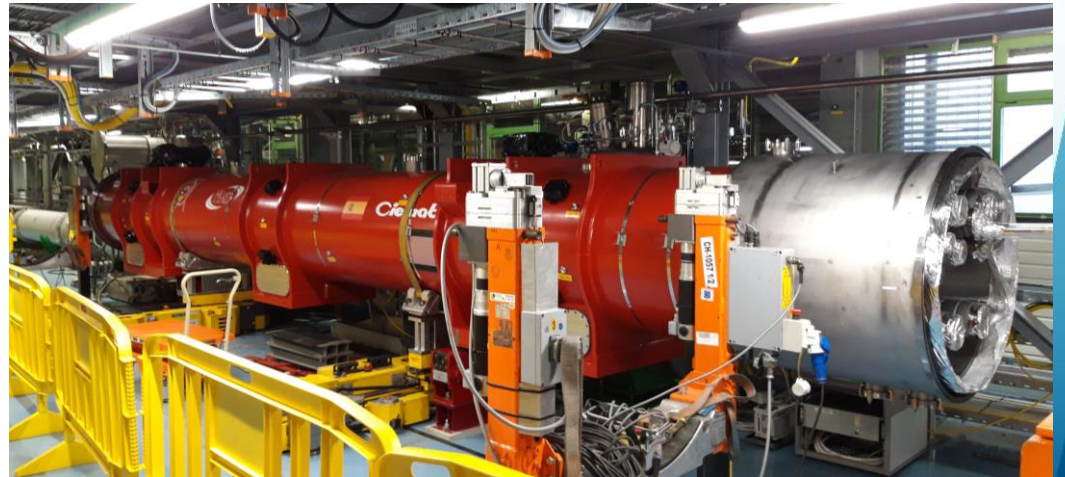


Thank you for your attention

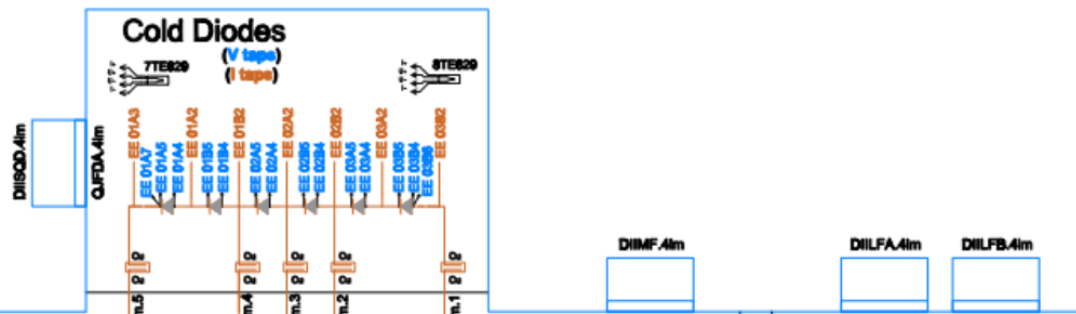
**Thanks for their
precious contribution**

Hervé Prin
Nicolas Bourcey
Tavis Bampton
Delio Duarte Ramos
Rosario Principe
Matthias Bonora

And many other colleagues



Cold Diodes



D1 - DCM Interconnect

DCM	PLUG	DFX							
EE A122	EE A121	NbTi	NbTi	EE A111	EBA101	EE A001	NbTi	NbTi	EE A001
EE B122	EE B121	NbTi	NbTi	EE B111	EEB101	EE B001	NbTi	NbTi	EE B001
EE Q121	NbTi	NbTi	EE G111	EEG101	EE G001	EE G001	NbTi	NbTi	EE G001
EE P121	NbTi	NbTi	EE F111	EEF101	EE F001	EE F001	NbTi	NbTi	EE F001
EE E121	NbTi	NbTi	EE E111	EEE101	EE E001	EE E001	NbTi	NbTi	EE E001
NbTi	NbTi	EE I111	EE I001	NbTi	NbTi	EE I001	NbTi	NbTi	EE I001
NbTi	NbTi	EE L111	EE L001	NbTi	NbTi	EE L001	NbTi	NbTi	EE L001
NbTi	NbTi	EE K111	EE K001	NbTi	NbTi	EE K001	NbTi	NbTi	EE K001
NbTi	NbTi	EE J111	EE J001	NbTi	NbTi	EE J001	NbTi	NbTi	EE J001
NbTi	NbTi	EE M111	EE M001	NbTi	NbTi	EE M001	NbTi	NbTi	EE M001
NbTi	NbTi	EE P111	EE P001	NbTi	NbTi	EE P001	NbTi	NbTi	EE P001
NbTi	NbTi	EE O111	EE O001	NbTi	NbTi	EE O001	NbTi	NbTi	EE O001
NbTi	NbTi	EE N111	EE N001	NbTi	NbTi	EE N001	NbTi	NbTi	EE N001
NbTi	NbTi	EE Q111	EE Q001	NbTi	NbTi	EE Q001	NbTi	NbTi	EE Q001
NbTi	NbTi	EE T111	EE T001	NbTi	NbTi	EE T001	NbTi	NbTi	EE T001
NbTi	NbTi	EE S111	EE S001	NbTi	NbTi	EE S001	NbTi	NbTi	EE S001
NbTi	NbTi	EE R111	EE R001	NbTi	NbTi	EE R001	NbTi	NbTi	EE R001
EE C121	NbTi	NbTi	EE C001	NbTi	NbTi	EE C001	NbTi	NbTi	EE C001
EE D121	NbTi	NbTi	EE D001	NbTi	NbTi	EE D001	NbTi	NbTi	EE D001

NbTi -> NbTi splices done in the tunnel
(for D1, crossing of the busbars on the LaR IP side)

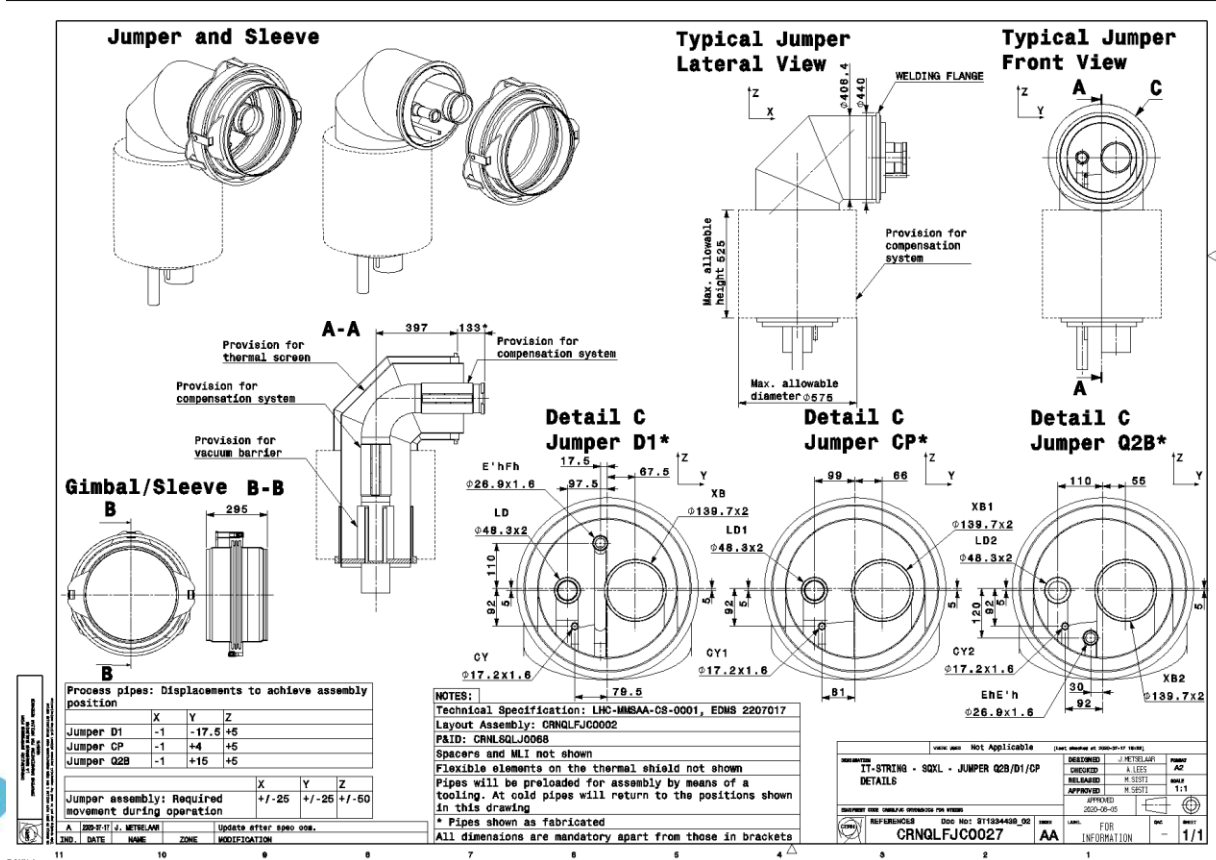
NbTi -> Cu splices done on surface

NbTi -> NbTi splices done in the tunnel



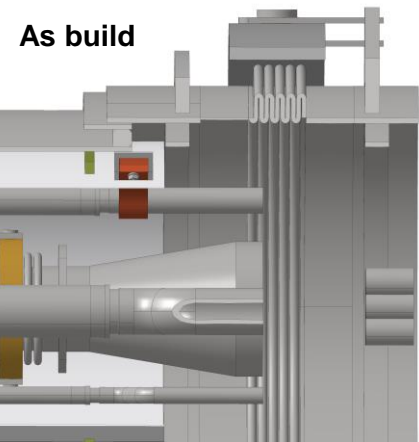
SQXL jumper configuration

- IT string SQXL Jumper Q2B/D1/CP details : [EDMS 2379806](#) - CRNQLFJC0027

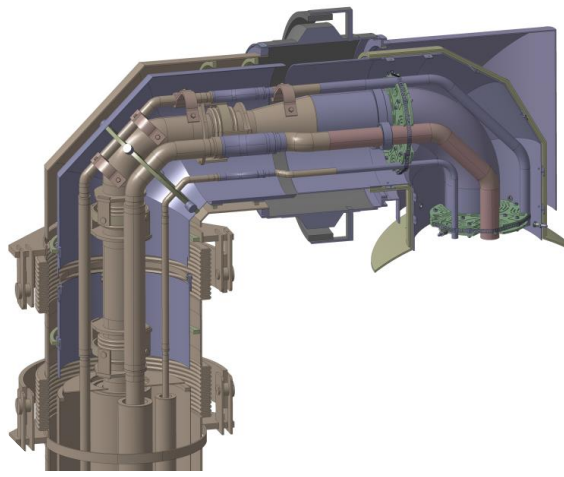
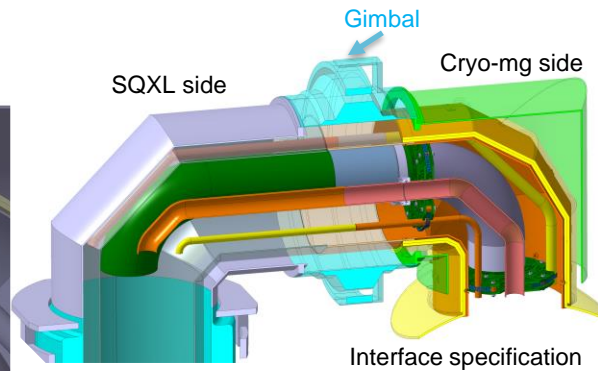
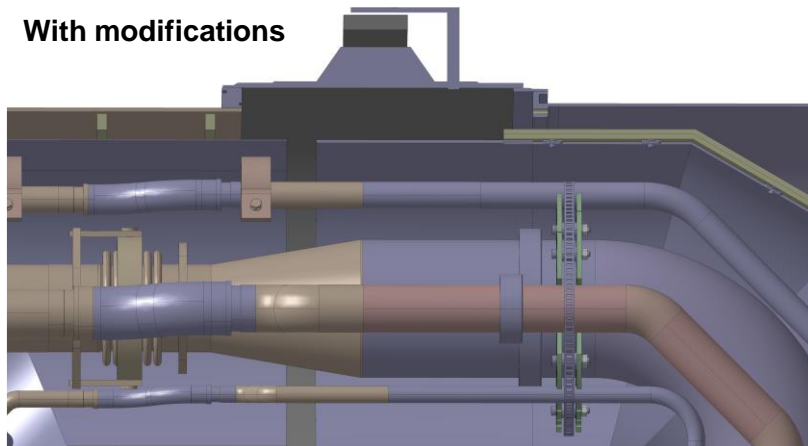


Jumper connection

As build

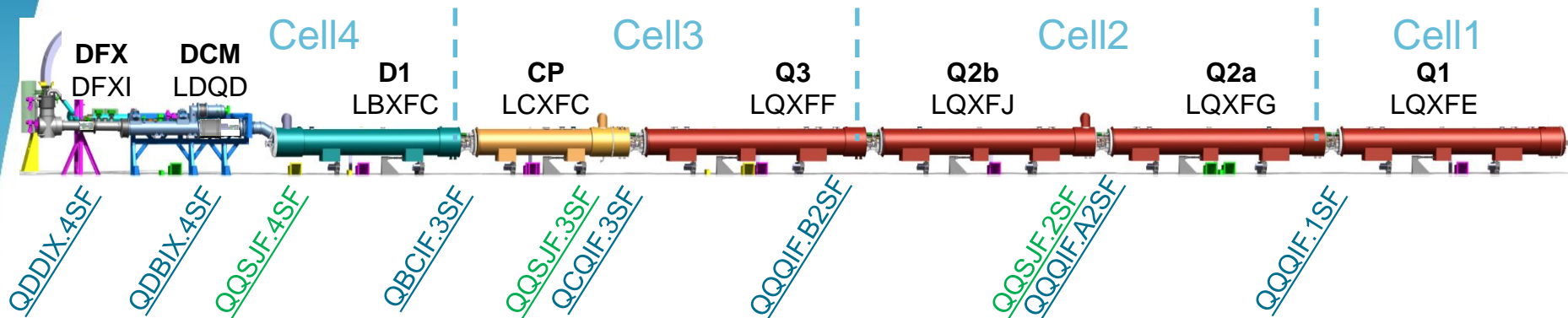


With modifications



String Day, 27 Sept 2024

Activities and QC follow-up



- The activities and the QC steps will be followed up directly in EAM with predefined work orders for each IC and jumpers.
- A new interface, similar to the eMIP, is in development by MSC (M. Bonora) in collaboration with EN-IM

String Installation: CP-Q3 interconnection

ELQA green light	No Checklists to fill	
PIM installation	No Checklists to fill	
Splice polarity	<input checked="" type="checkbox"/> Splice polarity (2/2)	Fixed point <input checked="" type="checkbox"/> Fixed point (0/3 done)
Splicing work 18kA	<input checked="" type="checkbox"/> #5 low splice (0/5 done)	
	<input checked="" type="checkbox"/> #5 high splice (0/5 done)	
	<input type="checkbox"/> Splice solderi <input type="checkbox"/> Visual inspec <input type="checkbox"/> Electrical che <input type="checkbox"/> Insulation <input type="checkbox"/> Insulation ins	Cryolines welding <input checked="" type="checkbox"/> Welding (0/7 done)
		<input type="checkbox"/> L1 weldings <input type="checkbox"/> L2 weldings <input type="checkbox"/> X1 weldings <input type="checkbox"/> X2 weldings <input type="checkbox"/> M2N weldings <input type="checkbox"/> Xb1 weldings <input type="checkbox"/> Xb2 weldings
		<input checked="" type="checkbox"/> Visual Inspection (0/7 done)

Quality assurance

During the interconnection of cryo-magnets, holding point for Quality Control (QC) steps are included.

- Regular EIQA test to ensure the electrical integrity of the connection, with mandatory test after the lines N insertion and before the M2N line closure.
- Electrical resistance test at RT and visual inspection for each splice.
- Visual inspection of the M2N line closure.
- Visual inspection by EN-MME and helium local leak test for each weld. In addition, X-ray for each butt weld.
- Visual inspection and document verification before W closing
- Global leak test after W closure.

