



Magnet installation and interconnection into the HL-LHC IT String

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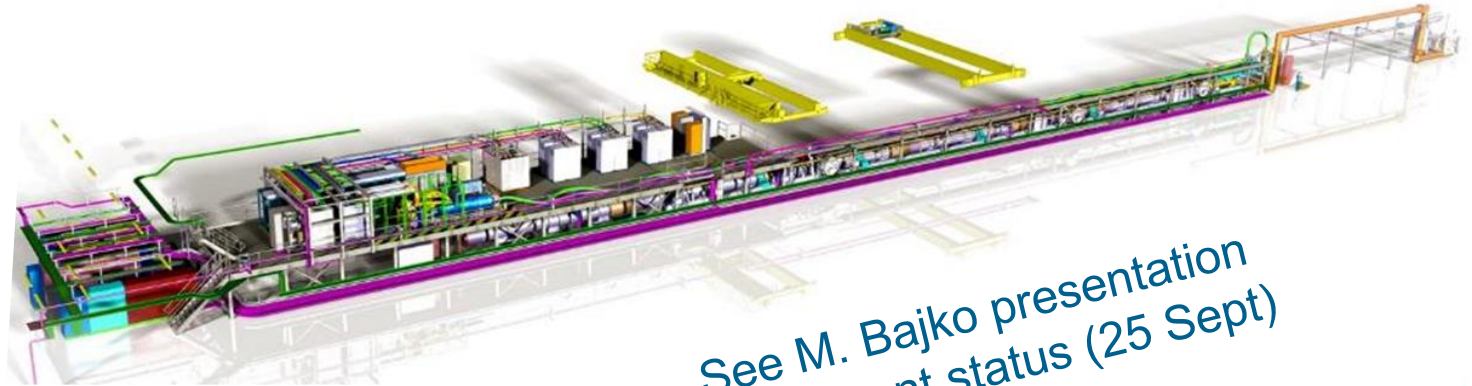


13th HL-LHC Collaboration Meeting, Vancouver (Canada), 25-28 Sept 2023

HL-LHC IT String

The IT String is a test bench to simulate a part of the IT region for the High Luminosity project. The scope is :

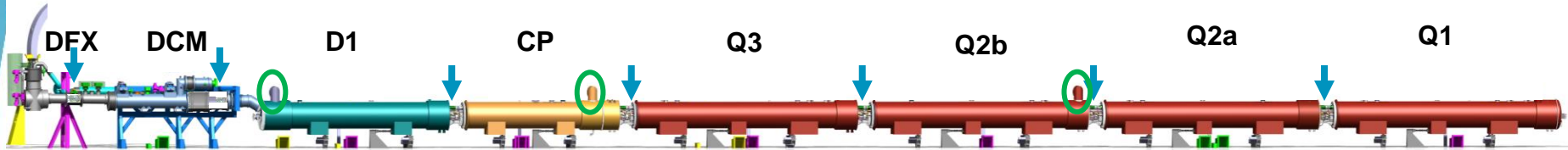
- To develop and validate the installation sequences and procedures
- To validate the collective behaviour of the powering system before the installation in the LHC



See M. Bajko presentation
on present status (25 Sept)

HL-LHC IT string magnets connection

- The presentation will concern the magnet connection from the Q1 to the DFX (7IC) and the jumper connexion to the SQXL (3 Jumpers).



- WP3 will provide (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 will assemble and install the DFX (see WP6a contribution to WP16 document : [EDMS 2188577](#)). The DFX is in place prior the magnets installation
- TE-MS C will be in charge of the cryo-magnets connection (see Summary of TE-MS contribution to WP16 document : [EDMS 2755342](#))

Cryo-magnets for the IT String

The cryo-assemblies considered for the IT string are :

- Q1 cryo-assembly with MQXFA05 and MQXFA06 (spare assembly)
- Q2a cryo-assembly with MQXFBP3 and MCBXFBP2b (prototype assembly)
- Q2b cryo-assembly with MQXFBP2b* and MCBXFBP1d** (prototype assembly)
Quench performance limitation : *[NCR 2638374](#), **[NCR 2687264](#)
- Q3 cryo-assembly with MQXFA03*** and MQXFA04 (QH NCR: ***[EDMS 2769128](#); ***[EDMS 2883868](#))
- Corrector package cryo-assembly with MCBXFAP1 and 9 High Order Correctors- (spare assembly)
- D1 cryo-assembly with MBXFP1 (spare assembly)
- DCM (D1-DFX Connection Module (spare assembly)

All magnets will be tested at 1.9K before the installation to the IT string. The Q3 cryo-assembly will be tested twice, at FNAL and at CERN for cross-checking.

After the test at cold and before the installation to the IT String, the MAB (Magnet Assessment Board) gives a cryo-magnet evaluation and recommendation if specific issues. According to WP3 schedule ([EDMS 2645484](#)), all cryo-magnets but CP are measured at 1.9K by spring 2024.

Cryo-magnets installation - support

All supports for the cryo-magnets and the DCM are at CERN or in production.

The support will be installed by EN-ACE and the integration drawing is available : [LHCLJXS_001](#)

The installation procedure is given in [EDMS 2757081](#)

- Jacks : [LHCHQHL_0001](#), [LHCHQH C_0001](#)
- Bridge over the gallery below Q3 : [LHCLJXS_0034](#)
- Shims (String height adjustment): [LHCLJXS_0028](#)
- Anchors for IT String (no shim) : [LHCHQFXM0014](#)
- DCM Frame (no shim) : [LHCLDQD_0367](#)

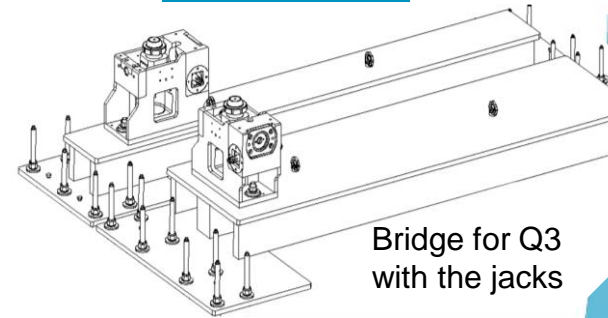
Received

In production

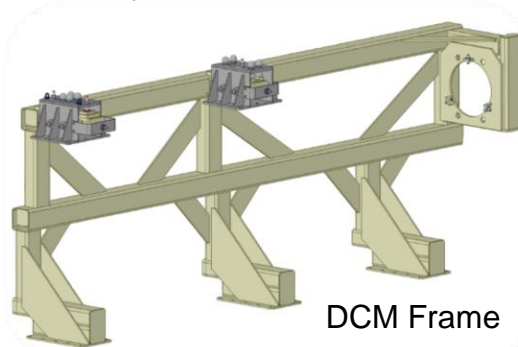
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In production

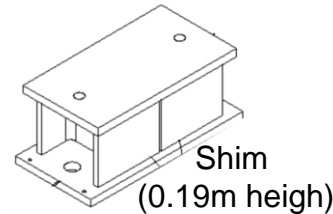
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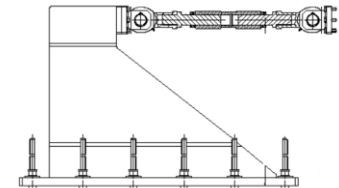
Bridge for Q3
with the jacks



DCM Frame



Shim
(0.19m height)

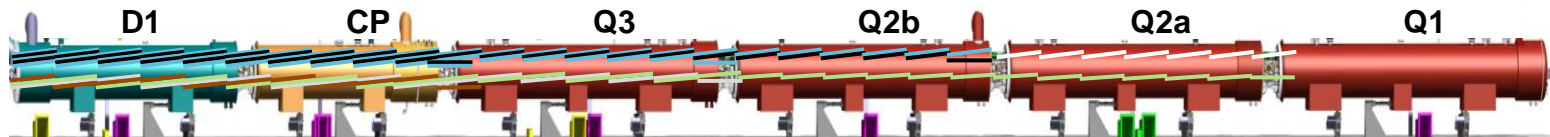


Anchor for IT String

Cryo-magnets installation - Busbar

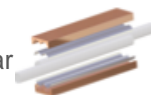
DFX

DCM not in place



18kA busbar:	5 cables	/	3 cables	/	2 cables	/	1 cable	/
2kA busbar	3 sets of 4 cables	/	2 sets of 4 cables	/	1 set of 4 cables	/		/

- Connected to the power converters via the SC link, seven 18kA cables and twelve 2kA cables arrive in the DCM to power the main magnets from Q1 to D1 and the MCBXF correctors.
- Busbars must be installed before the magnet connection
 - **All magnets from D1 to Q2a must be installed and aligned**
 - DCM not in place for the insertion of the lines N (N1 and N2)
 - N1 is a set of **5** cables for 18 kA supply (45 m long)
 - 2 connections in CP – Q3
 - 1 connection in Q3 – Q2b
 - 2 connections in Q2b – Q2a → One splice to end of Q1 busbar
 - N2 is **3** sets of **4** cables for 2 kA supply (55 m long)
 - 4 connections in CP – Q3
 - 4 connections in Q3 – Q2b
 - 4 connections in Q2a – Q1



Line N procurement

➤ 18 kA Busbar Cable

- Issue on cable rigidity in 2022, fixed in Jan 2023 (wrapping load reduction of polyimide tape)
- Reception of 300m of cable in Feb 2023 with a correct flexibility
- 200m of cable given for the DCM assembly
- Production of the set of 5 cables (Line N1) by TRATOS (amendment in Mar 23)
 - **Delivery of 1 set in Oct 2023 !**
 - Total production of 6 sets of cables (one spare only)
 - **Up to now no insertion test with SC cables, only with Cu cables on a short length mock-up (10m)**

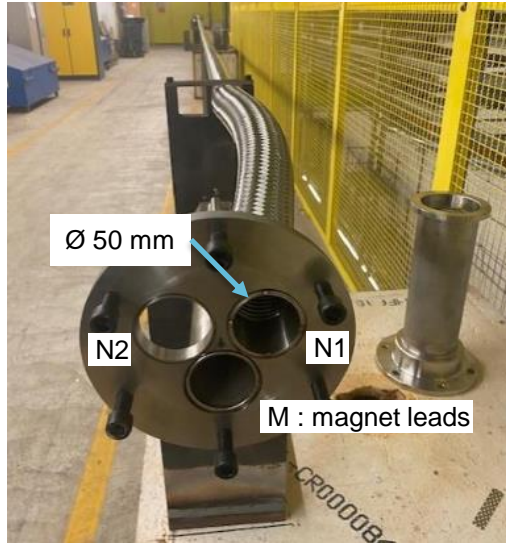
➤ 2 kA Busbar Cable

- Reception of 70 m of 1 set of 4 cables, end of May 2023 with an unexpected diameter (21.6mm)
- 60 m of the cables set given for the DCM assembly
- Production of single set of 4 cables by TRATOS
 - **Delivery Oct 2023 !**
 - Line N2 assembly made at CERN
 - **Up to now no test insertion done with SC cables !**

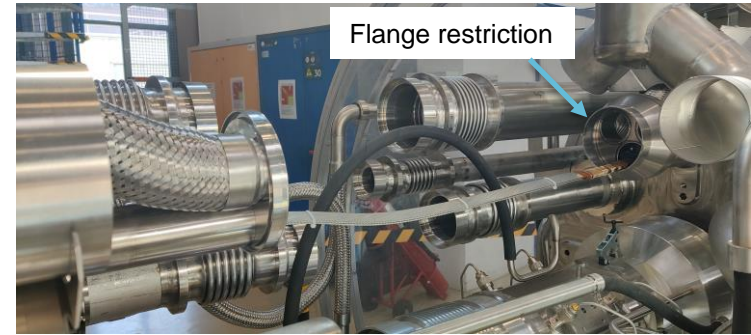


Line N insertion

- Each line N is inserted in an aperture of $\text{Ø } 50 \text{ mm}$ and in a flexible to run along the magnet
 - Expected diam of N1 (18kA) : 45 mm (set of 5 cables)
 - Expected diam of N2 (2kA) : 48 mm (3 sets of 4 cables)



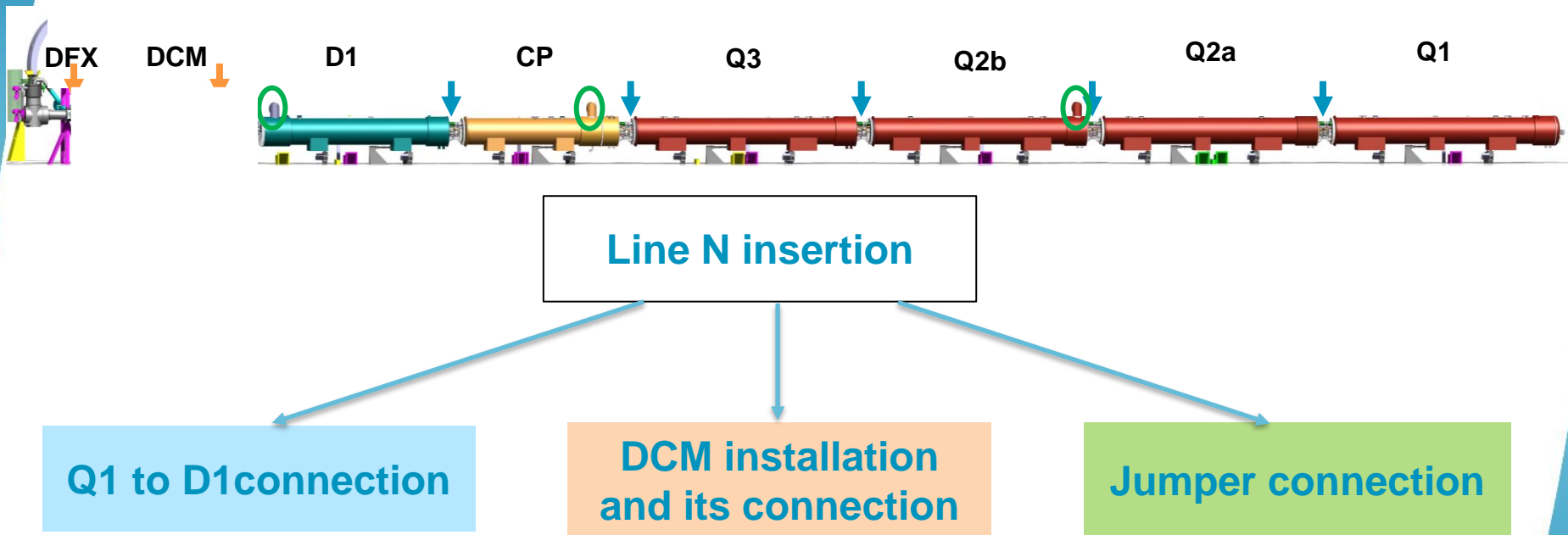
Line N mock-up (TT2A)



Interconnection mock-up (bld 180)

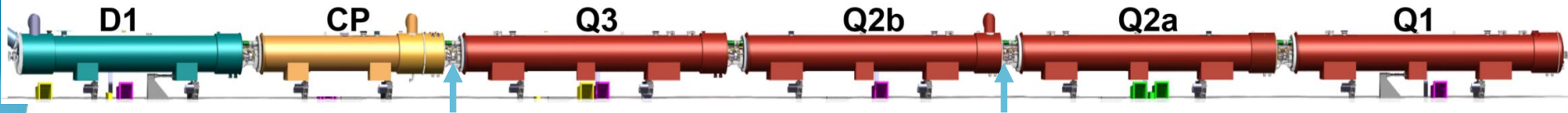
- Significant friction are expected along the tubes
- In addition, a flange restriction appears in the interconnection
- Once the cables are received at CERN, we are ready for insertion test with a long mock-up (30m long)

Magnet interconnection sequence

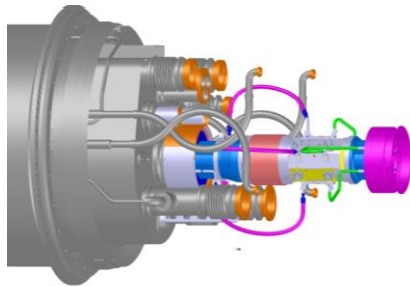


Interconnection sequence was detailed in String day II review in sept 2022, only main steps are described in this presentation

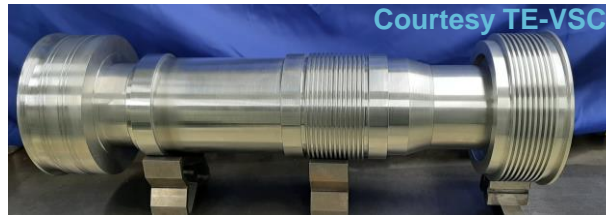
Q1 to D1 connection : PIM installation



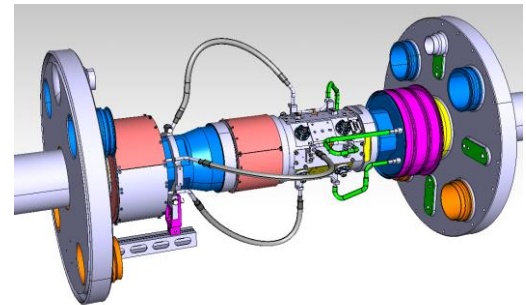
For the IT String, it was decided to not install beam screens, BPMs and PIMs, but they take a big volume in the interconnections.



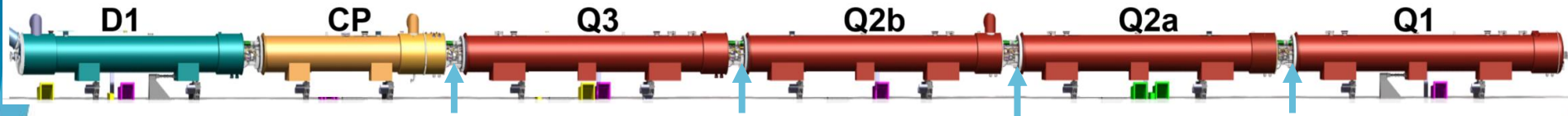
To be as closed as possible to the conditions for the HL-LHC project magnet connection , we propose to install in 2 IC (CP-Q3 and Q2a-Q2b), dummy PIM-BPMs assembly. The assemblies will be fixed to the magnet cold bores. A system of sliding tubes with gimbals will allow thermal contraction and alignment movements. *These dummy assemblies are provided by TE-VSC.*



Core part of the dummy PIM-BPM assembly

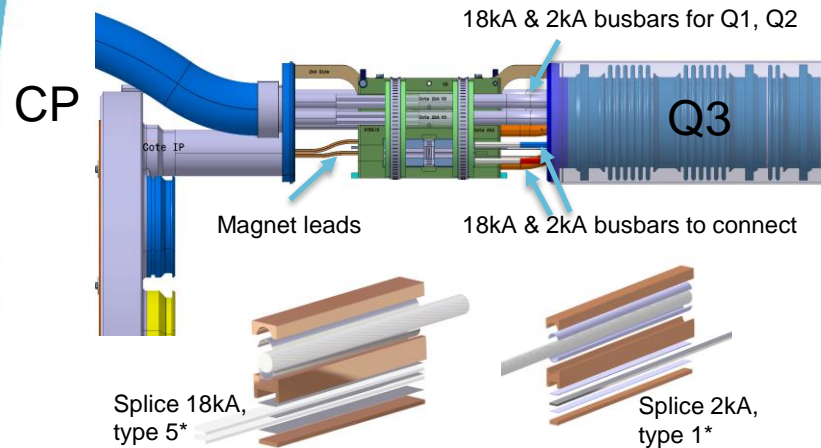


Q1 to D1 connection : Splicing work



After the PIM installation, the next step is the M2N line connection with the splices soldering and the installation of insulation and fixe point components.

- ✓ All splice soldering procedure are approved
 - Ex: EDMS 2784612, EDMS 2784119 for splices type 1 and 5
- ✓ All splice types are qualified.
 - Electrical resistance at room and cryogenics temperature
 - Mechanical test by EN-MME
- ✓ Tools for soldering are available but need to be tested in real condition

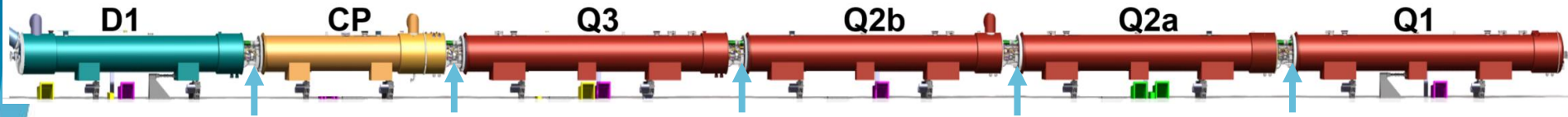


* Splice type from splice catalogue [EDMS 2492410](#)

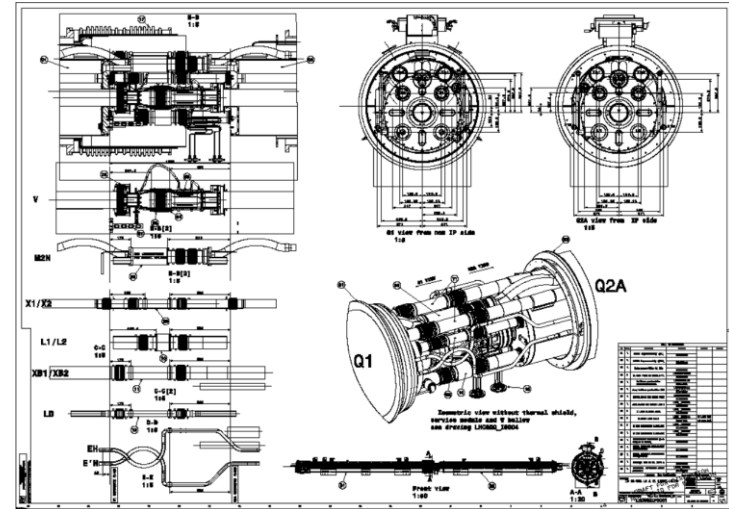
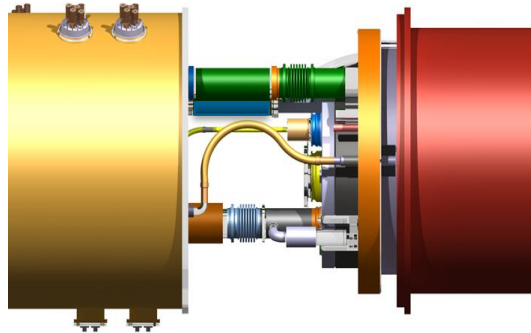
To-do list

- Installation procedures after test of lines N insertion and splicing exercise in real conditions
- Finalising the tooling design and construction
- Finalising the design of the insulation and fixe point components.
- Production of the components

Q1 to D1 connection : Cryo-lines welding



After the qualification of the splices and the visual inspection of the connection, the M2N line can be welded as well as all the cryogenics lines

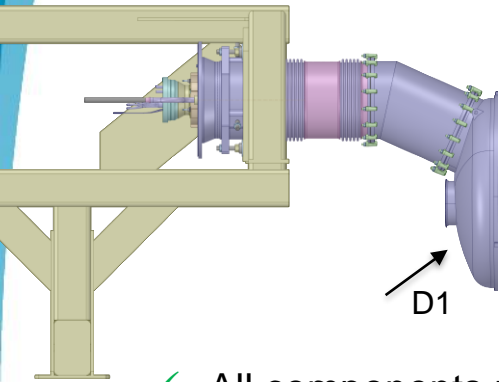


Drawings of a first interconnection is done and in validation.
Drawings of the others IC are following

→ Launch the sleeves production before end of the year.

DCM installation

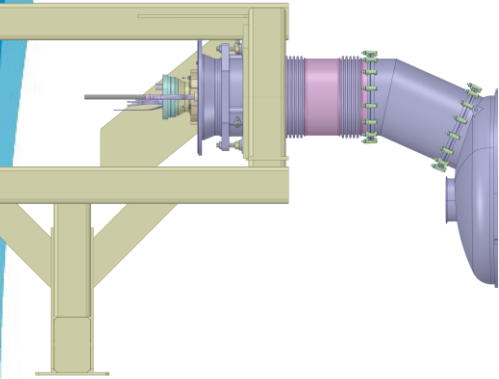
Installation of the DCM frame
and the D1 module



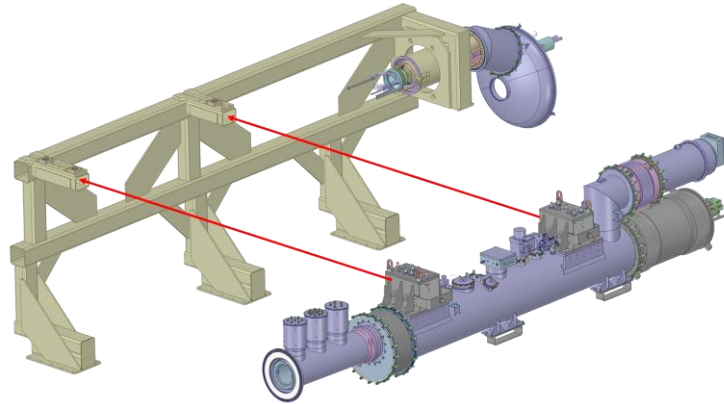
- ✓ All components received
- ❑ Installation procedure will follow the DCM manufacturing

DCM installation

Installation of the DCM frame
and the D1 module

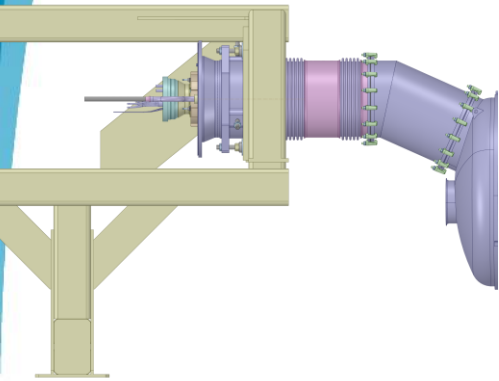


Installation of the DCM

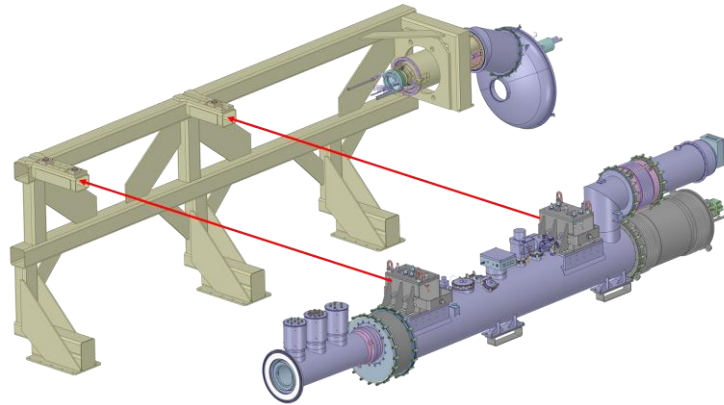


DCM installation

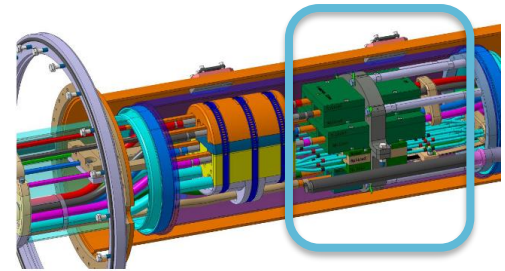
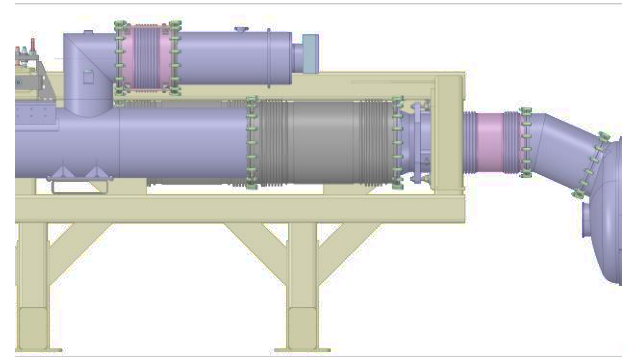
Installation of the DCM frame and the D1 module



Installation of the DCM



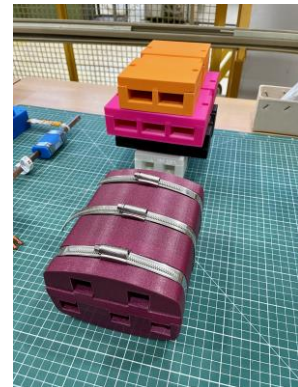
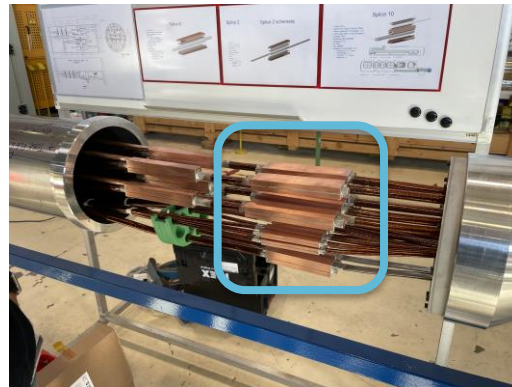
Connection of the DCM



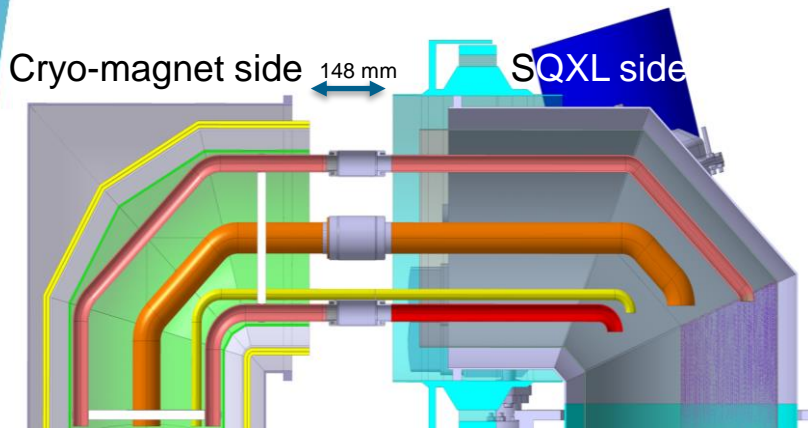
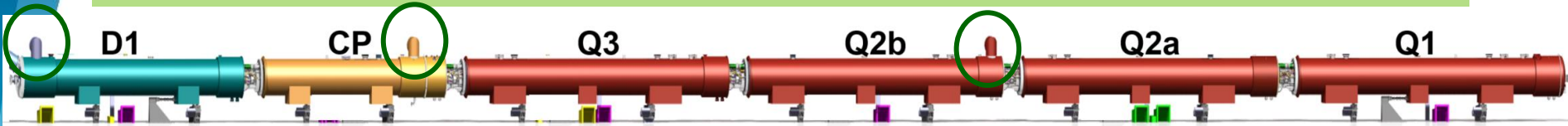
DCM connection



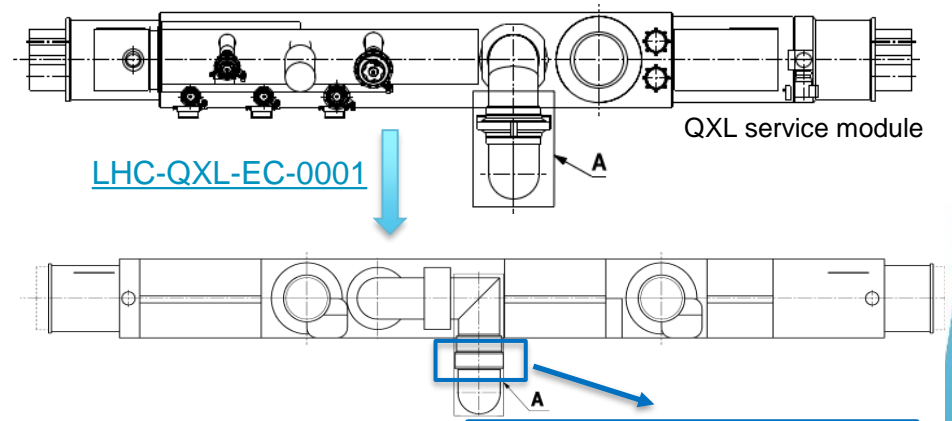
DCM interconnection mock-up
Progress of a splicing exercise



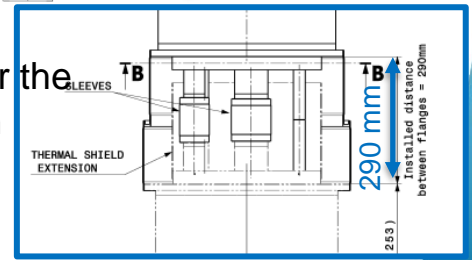
Jumper connection



Base line configuration in SM18 but not feasible → no access to the flanges

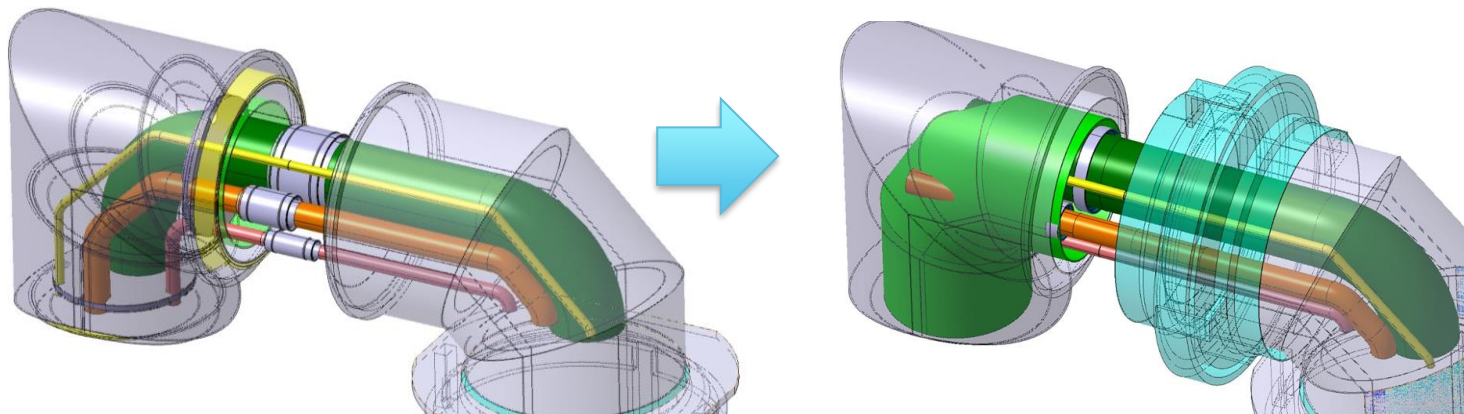


More room given for the tunnel configuration



Jumper connection

We propose to change the IT string configuration, either with butt welds or with lip welds with flanges installed as close as possible to the magnet thermal shield



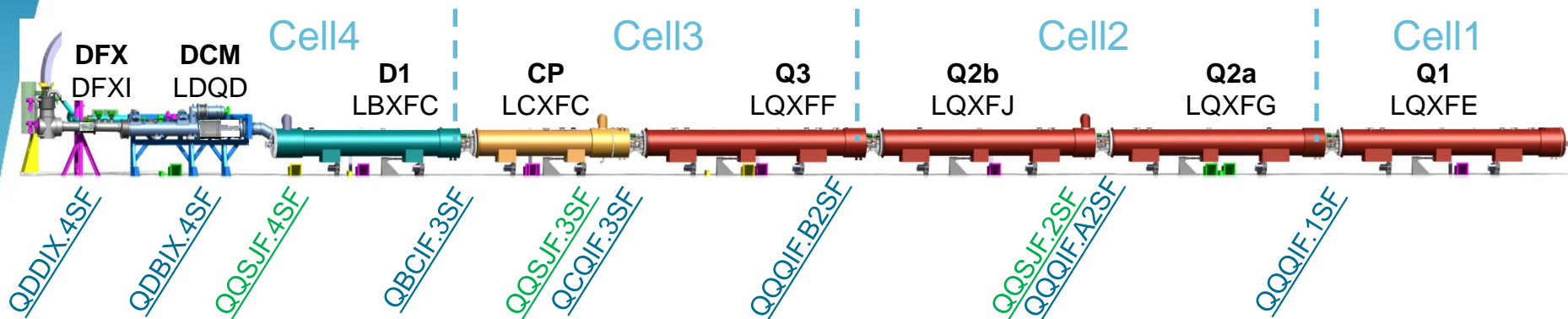
A mock-up of the jumper configuration was recently built to test the welding feasibility of the inner pipes

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 integration 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.

Activities and QC follow-up



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

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 inspect <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)

Summary

- Sequence of the magnet installation and connection for the IT String have been developed
 - For the support of the DCM and cryo-magnets, all components are available by the end of the year. Q1 2024 for the anchors.
 - The delivery of the cryo-magnets for WP16 is followed-up by WP3 ([EDMS 2645484](#)). The MAB will give assessment and recommendation for each cryo-assembly after the magnet test on the horizontal test bench.
- For the magnet connection, the procurement of the busbar cables is planned for Oct 2023. Due to the delay, insertion test with final cables is not yet done, delaying also the finalisation of the tooling and component design.
- The splice soldering procedures are approved, and all splice types are qualified.
- Interconnection drawings are in progress. Sleeves production launch by the end of 2023.
- Procurement of the interconnection components should be completed in Q1 2024.
- Jumper connection procedure is in study, and welding test is being performed on a mock-up.
- Web Interface tool is in development to follow-up the activities and QC of the interconnection.
- Still lots of work to do, and a good progress was made this year. A first version of the installation procedures is expected in Q2 2024.



Thank you for your attention

Special Thanks to

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 - ***Delio Duarte Ramos***
 - ***Federico Crisci***
 - ***Nicolas Bourcey***
 - ***Matthias Bonora***
- for their precious help***

