

SM18 tests and test benches for magnets and SC-link

Status update

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TE-TM 3 June 2024

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With many thanks to FSU support and all other teams involved.

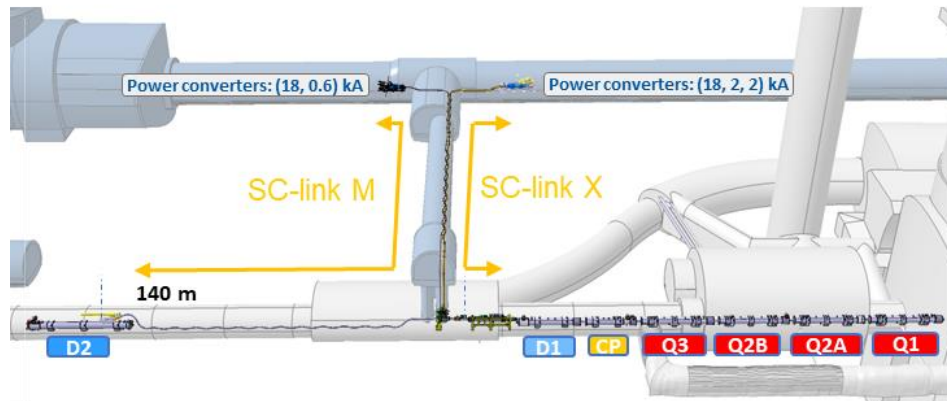
Overview test of full assemblies in SM18

1-Jun-2024

Dashboard horizontal magnets/SCLinks to be tested in SM18 for HL-LHC

Object	Test completed	In test	To be tested
Q2a/b	P3 04	P2	03 05 06 07 08 09 10 02b
D2	P1		1 2 3 4 5 6
D1	P1		1 2 3 4 5 6
CP			01 02 03 04 05
Q1/Q3		01	04
Q10			1 2 3 4
SC-link type X	P		1 2 3 4
SC-link type M			P 1 2 3 4

* Magnets and SC-link for the String are high lighted in blue cells.



Main focus in the coming months is to test magnets and the SC-link for the IT-String test facility.

- Tests are completed for SC-link type X, D1 and Q2a
- Q3 is ready for test now, Q2b cooldown foreseen within 2 weeks
- The Corrector Package test (CP) is foreseen to complete in September

The Q3 has already been qualified at Fermilab, at CERN we perform a verification test after transport. *The Q1 and Q3 cryo-assemblies will normally only be qualified in the US as part of the UAP contribution. The table focusses on the tests in SM18.*

Qualification test overview in SM18 for Magnets/SCLink

1-Jun-2024

Dashboard horizontal magnets/SCLinks to be tested in SM18 for HL-LHC			
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D2	P1		1 2 3 4 5 6
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Q1/Q3		01	04
Q10			1 2 3 4
SC-link type X	P		1 2 3 4
SC-link type M			P 1 2 3 4

* Magnets and SC-link for the String are high lighted in blue cells.

3-Jun-2024

Dashboard Vertical magnets to be tested for HL-LHC			
Object	Test completed	In test	To be tested
MCBXFA	P1		1 2 3 4 5 6
MCBXFB	P1 P2 01 02 03 04	05	06 07 08 09 10 11 12
MCBRD	P1 P3 P4 01 02 P2c 12 04		11 03 05 06 07 08 09 10
MQML	42		41 3 4 5
MSCB	1		2 3 4
IT-diode stack	P1		1 2 3 4 5

Test benches

Assembly	Bench	Status
Q2a/Q2b	F1	OK
SC-link	F2	OK
Q1/Q3/CP	A2	OK
D2	C2	08/24
D1	B2	09/24

Today's content:

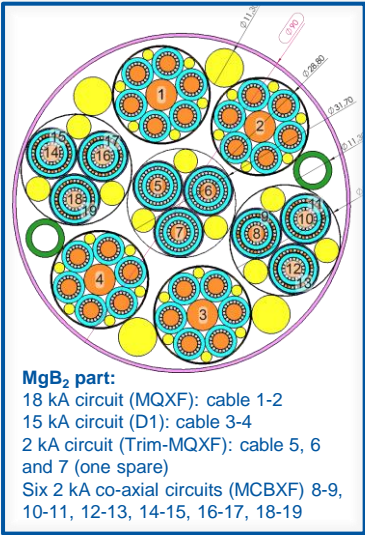
- SC-link X prototype and bench F2
- Q3 and bench A2
- Q2b-04 results
- MCBXFB05 results
- Upgrade status

Content

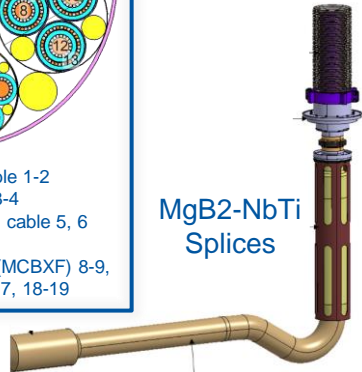
- SC-link X prototype on bench F2
- Q3 on bench A2
- MQXFB04 full series Q2 cryo magnet assembly
- MCBXFB05 qualification test in Cluster D
- Bench upgrades



SC-link X prototype – focus on electrical circuits test



NbTi-NbTi splices
 (In SM18 a short-circuit is made, but connection to magnets in the tunnel)



DSHX, Sc link 74.5 m
 MgB₂

GHe cooled
 LHe cooled

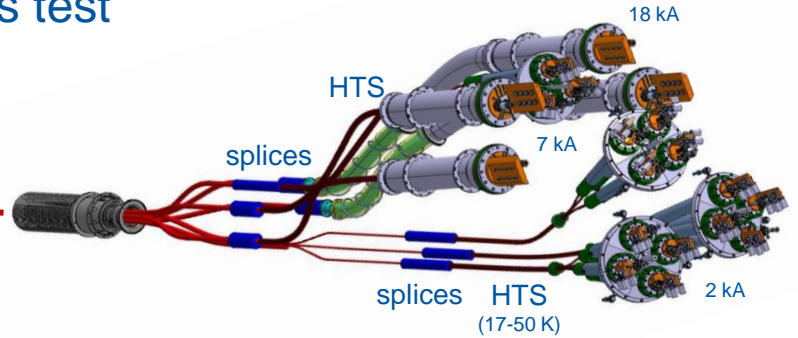


Image courtesy WP6a, Yann Leclerc
<https://indico.cern.ch/event/1293138/contributions/5476194/>

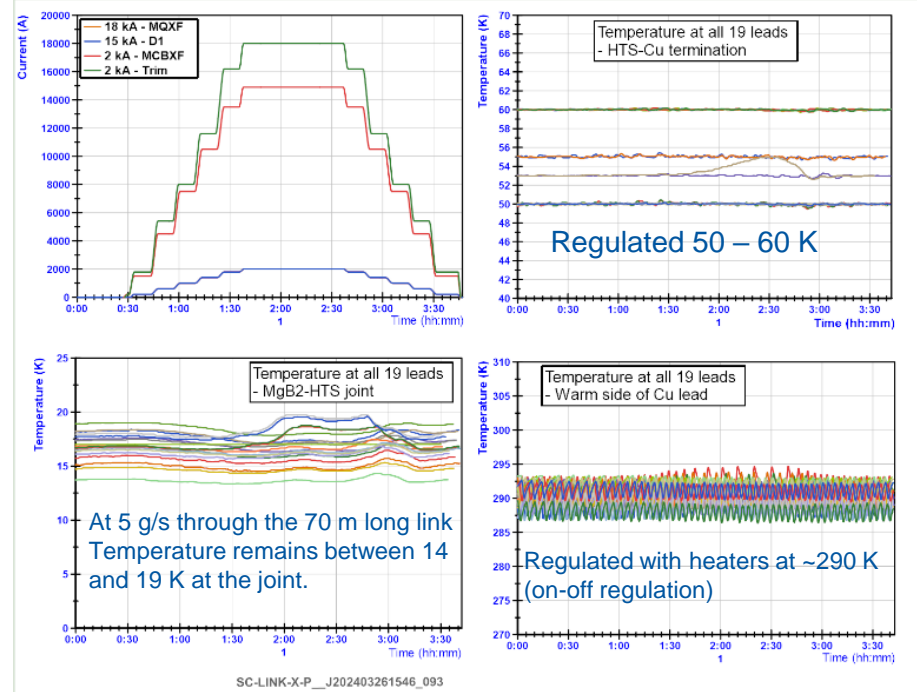
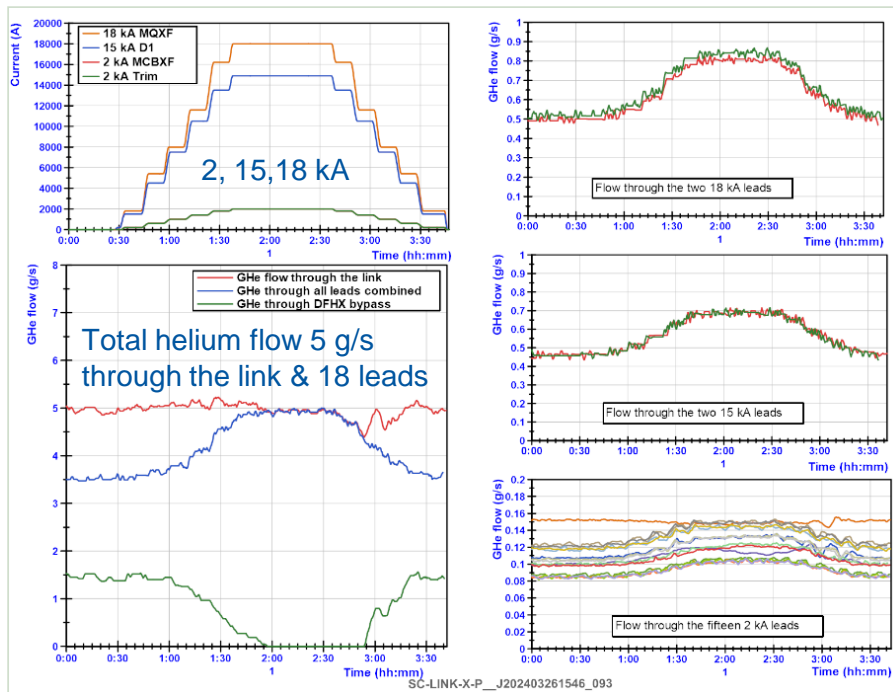
From February to April the tests of the first SC-link type X prototype were successfully performed.

- Complex system with 19 circuits between 2 and 18 K composed of
- NbTi part at 4.5 K (He liquid)
 - 70 meter of MgB₂ from 4.5 to 17 K (gas cooled, 5 g/s)
 - HTS from 17 to ~ 50 K (gas cooled, 5 g/s)
 - Cu leads from ~ 50 to 300 K (gas cooled, 5 g/s combined)

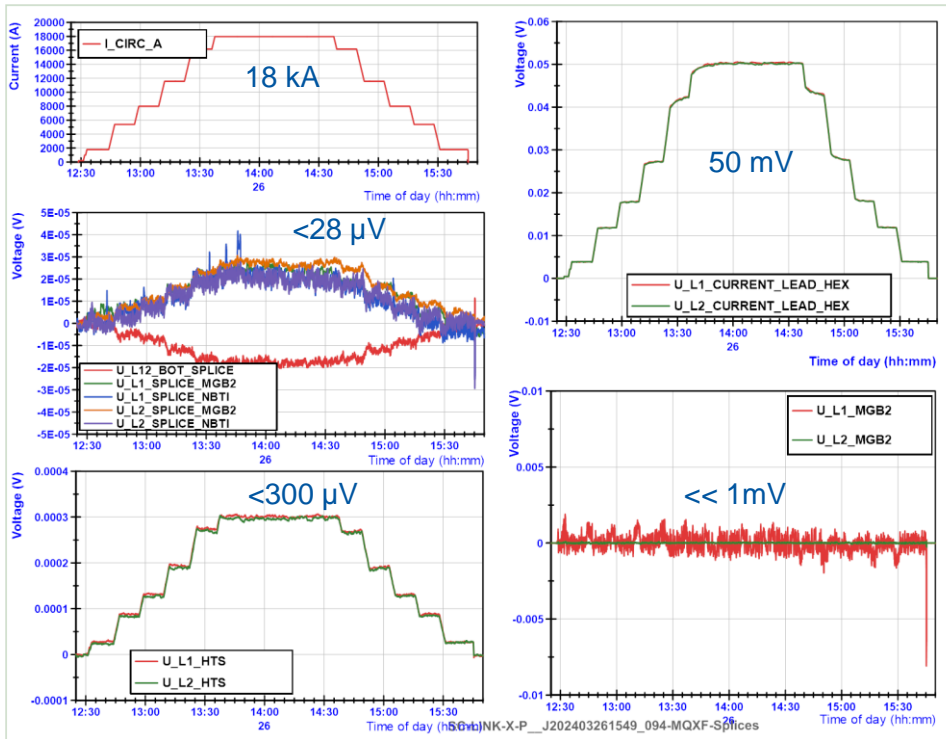
Maximum combined transport current during test: 94 kA
 Maximum current during HL-LHC operation: 76.8 kA

Powering results summary

Tests performed up to ultimate current in eighteen circuits combined (18 kA, 15 kA, 2 kA, 2 kA).
 Tests performed at minimum flow of 5 g/s gives a temperature at the joint between 14 and 19 K.
 All thermal behavior very stable for all circuits and smooth regulation.



Powering results summary – Voltages measured with as example the 18 kA circuit.



Splice/resistance measurements at minimum gas flow

- Cu lead resistance: 50 mV at 18 kA, stable.
- HTS-Cu connections: 300 μ V (17 n Ω), stable
- NbTi-MgB₂ splices: 20-28 μ V (1.1-1.6 n Ω), stable
- Voltage on 70 meter MgB₂ << 1 mV, also including inductive components during ramp.
- Noise depends strongly on position of cable compared to voltage tap wire.

uQDS system used for quench detection. Cross talk between circuits has been measured. Quench detection were settings updated during the test.

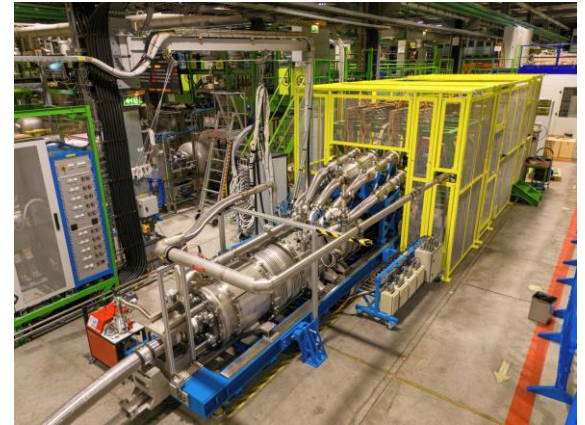
More detailed test report soon in EDMS 3077607

SC-link X prototype test summary

- Insulation tests OK
- Smooth cryo control
- All powering tests OK during two cool downs, including stable for 8 hours at maximum current
- All splices and resistances showed very uniform behavior

Cold tests were successful. Next stage will be installation by WP6a in the String.

The test team thanks WP6a (Amalia Ballarino, Yann Leclercq, Christian Barth and all) and TE-CRG (Vanessa Gahier, Remi Mauny and all) for the nice collaborative efforts, making the tests going smooth.



Photos Mike Struik, <https://cds.cern.ch/record/2895375>

Content

- SC-link X prototype on bench F2
- **Q3 on bench A2**
- MQXFB04 full series Q2 cryo magnet assembly
- MCBXFB05 qualification test in Cluster D
- Bench upgrades

Q3 cryo assembly on bench A2

Bench A2

- Large upgrade work performed since November
 - CFB modified, new shuffling module, test station fully recabled, protection and detection circuits upgraded, New 2 kA power converters, new 2 kA leads, new Energy Extraction.
- Main upgrade work completed end of April.

Q3 (composed of two MQXFA magnets)

- All standard qualification tests performed at Fermilab.
- Received at CERN in 2023
- Waited at CERN for bench A2 upgrade to be completed.

Q3 on the bench ready for cool down since Friday.

Cool down is pending installation of an additional vacuum pump due to a leak found on Friday



Reception ceremony of first final cryostat assembly from UAP at CERN in December 2023. <https://cds.cern.ch/record/2884216>



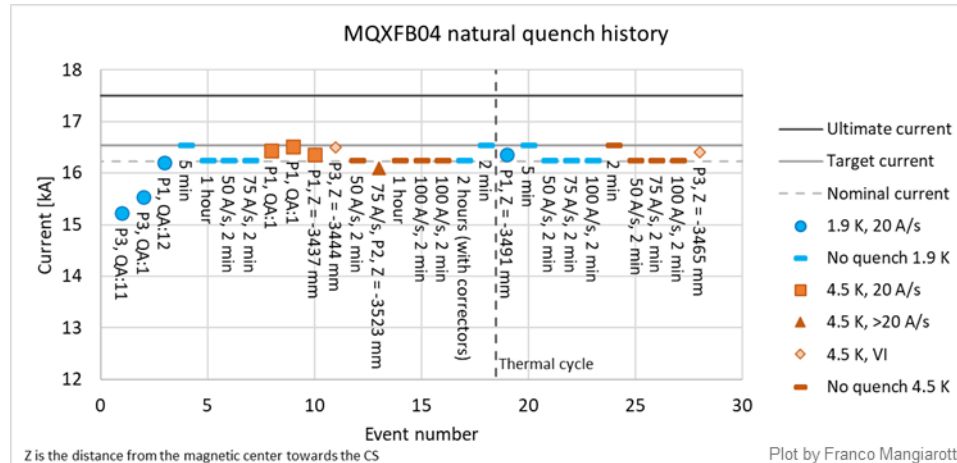
Q3 magnet on the test bench.

Content

- SC-link X prototype on bench F2
- Q3 on bench A2
- **MQXFB04 full series Q2 cryo magnet assembly**
- MCBXFB05 qualification test in Cluster D
- Bench upgrades

Q2b 04 on bench F1 – Test results

- MQXFB04 is the first virgin MQXFB magnet assembled with a corrector in a Q2 cold mass.
- MQXFB04 is the second magnet (after MQXFB03) following the changes in production procedures.
- Test with two cooldowns completed in April and May.



MQXFB04 in Q2b

- Three training quenches to $I_{nom} + 300$ A in cool down 1.
- Single training quench above nominal current in cool down 2.
- Reaching target current at 4.5 K
- No measurable voltage during the V-I measurements at 4.5 K
- MCBXFB corrector magnets successful without quench.
- Insulation tests successful

Cold qualification tests successful. Magnet removed from bench today. Ready for final preparation for installation in the HL-LHC.

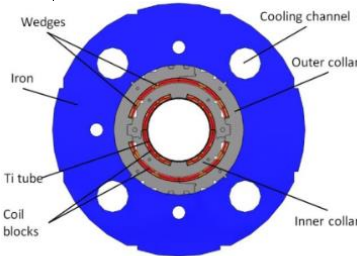
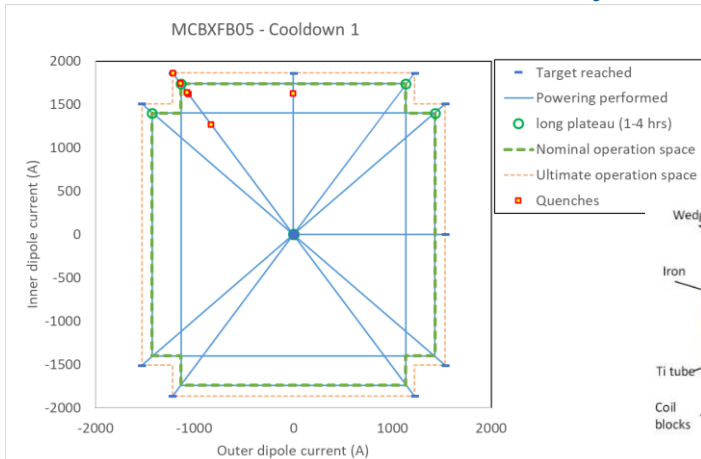


Content

- SC-link X prototype on bench F2
- Q3 on bench A2
- MQXFB04 full series Q2 cryo magnet assembly
- **MCBXF05 qualification test in Cluster D**
- Bench upgrades

Qualification test MCBXFB05, nested dipole corrector for Q2 assembly.

- First magnet following change of production facility.
- Completed end of May, already in test since last week. Thermal cycle ongoing.
 - First powering results are promising, stable behavior after six initial training quenches.
 - Final validation in second cool down this week including magnetic measurements.



MCBXF [F. Toral, et al.]

2024 updated 03 June 2024

2024	Jan					Feb				Mar				Apr				May				Jun				Jul				Aug				Sep				Oct				Nov				Dec										
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52				
No Helium																																																								
MCBRD in Cluster D																																																								
MCBXF in Cluster D																																																								
MQML in Cluster D																																																								

Ramp up in number of tests for MCBXF magnets expected to ramp up after summer technical stop. Cluster D test HL-LHC test schedule will be challenging in number of magnets, depending on given priority and cryo availability.



Content

- SC-link X prototype on bench F2
- Q3 on bench A2
- MQXFB04 full series Q2 cryo magnet assembly
- MCBXFB05 qualification test in Cluster D
- **Bench upgrades**

Upgrade work	F1 (Q2)	F2 (SC-link)	A2 (Q3 and CP)	C2 (D2)	B2 (D1)
CFB modifications, hardware and controls	X	X	X	X	X
Shuffling module installation	X	X	X	X	X
2 kA leads in CFB	X		X		
Powering circuit change (new PC, EE)	X	X	X		
PPI shuffling module		X			
Full UQDS, used as DAQ, communication software, data storage/transfer and analysis.	X	X			
New anti-cryostats	X		X	X	X
Full recabling, modification of electronics racks and PLC changes	X	X	X		
Cold commissioning completed First full assembly test	08-2023 10-2023	02-2024	05-2024 06-2024 (Q3) 08-2024 (CP)	08-2024 03-2025	09-2024 03-2025

The largest upgrades were for bench F1 and F2. Bench A2 still had large modifications also on the electronic and powering systems. These 3 benches are now completed and fully operational.

The main work remains on the shuffling modules for cluster B2 and C2, profiting from the learning curve on F1 and A2.

Ready well in time for the magnet to test.

Acknowledgements to all teams involved in the upgrades over the last years MPE-PE, MP SB-EPC, TE-CRG, TE-MS-CMI, TE-MS-LMF, etc.

Special thanks to Marco Buzio, Frédéric Savary, Jens Steckert and Olivier Pirotte.

Summary slide and outlook

- Good results for Q2b 04 (MQXFB04), SC-link, MCBXF05
 - Q3 and Q2b tests ongoing with test completion foreseen before summer technical stop in SM18.
 - CP test foreseen to be completed in September as last CERN magnet assembly for the IT-String test.
-
- Upgrades completed for bench F1, F2 and A2!
 - Upgrades C2 and B2 less complex, profiting of learning curve from F1 and A2 and advancing well. Large margin to magnet arrival to test.

2024 updated 03 June 2024

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MB spare																																																												

Global planning for horizontal benches. Cold phase in blue, thermal cycle in light blue, salmon is for a magnet on the bench in preparation.