MCBXF magnet assembly and powering tests results at CERN

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On behalf of MCBXF team.
Acknowledgments to people who contributed to this presentation.

14th HL-LHC Collaboration Meeting - Genoa

7-10 October 2024

https://indico.cern.ch/event/1421594/overview

Outline

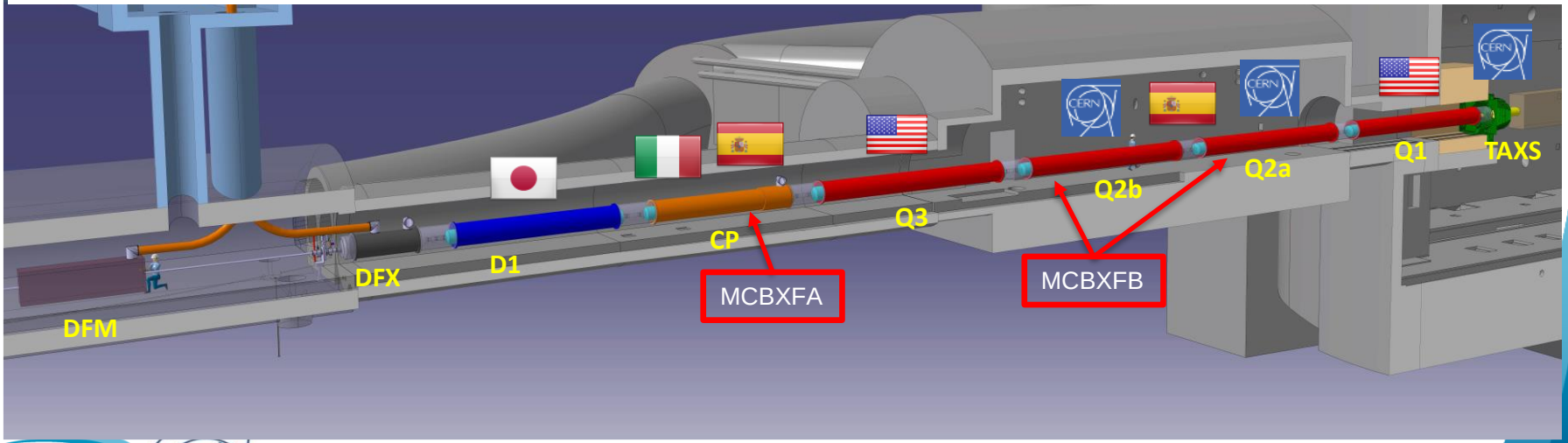
- MCBXF: Spanish in-kind contribution for HL-LHC
- Series magnet production status in October 2023
- Remaining magnets production at CERN
- Summary

Spanish in-kind contribution for HL-LHC

CIEMAT and CDTI signed a contract in March 2021 with ELYTT Energy (Spain) to produce the series magnets:

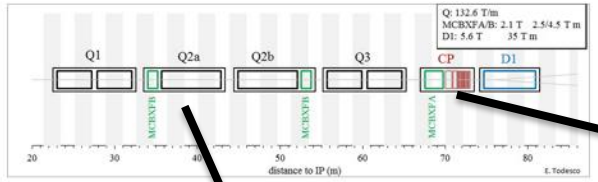
- 6 MCBXFA
- 11 MCBXFB

During the prototyping phase, 2 MCBXFB and 1 MCBXFA prototypes, as well as the first MCBXFB for the series, were built within a collaboration between CIEMAT and CERN.

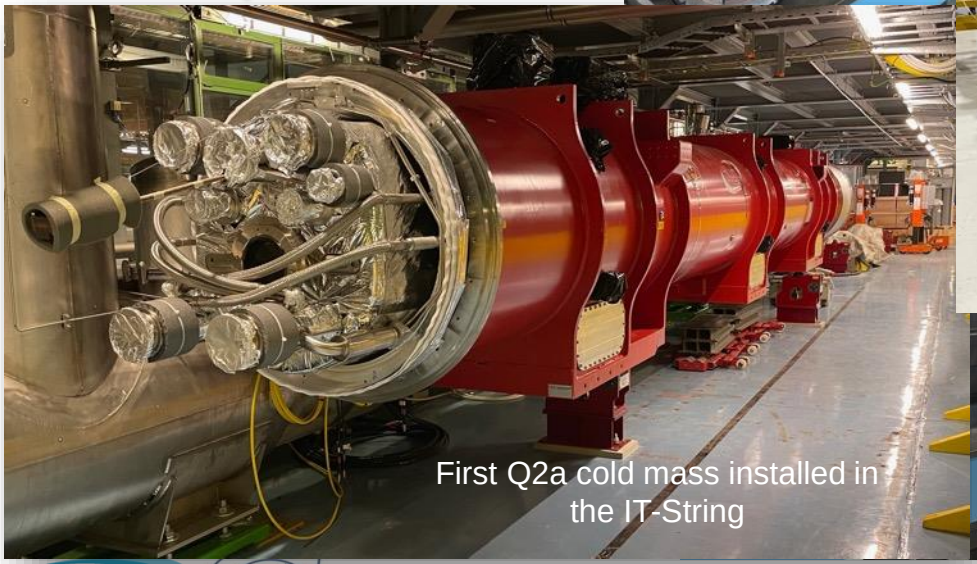


MCBXF combined dipole orbit correctors for HL-LHC

Insertion Region Layout



First CP cold mass waiting in SMS18 for cold powering tests


First Q2a cold mass installed in the IT-String

MCBXF series magnet production

- From March 2021 until September 2023 ELYTT Energy delivered to CERN 3 MCBXFB magnets
- The series production contract was stopped in September 2023 by mutual agreement between CIEMAT, CDTI and ELYTT.

The situation was:

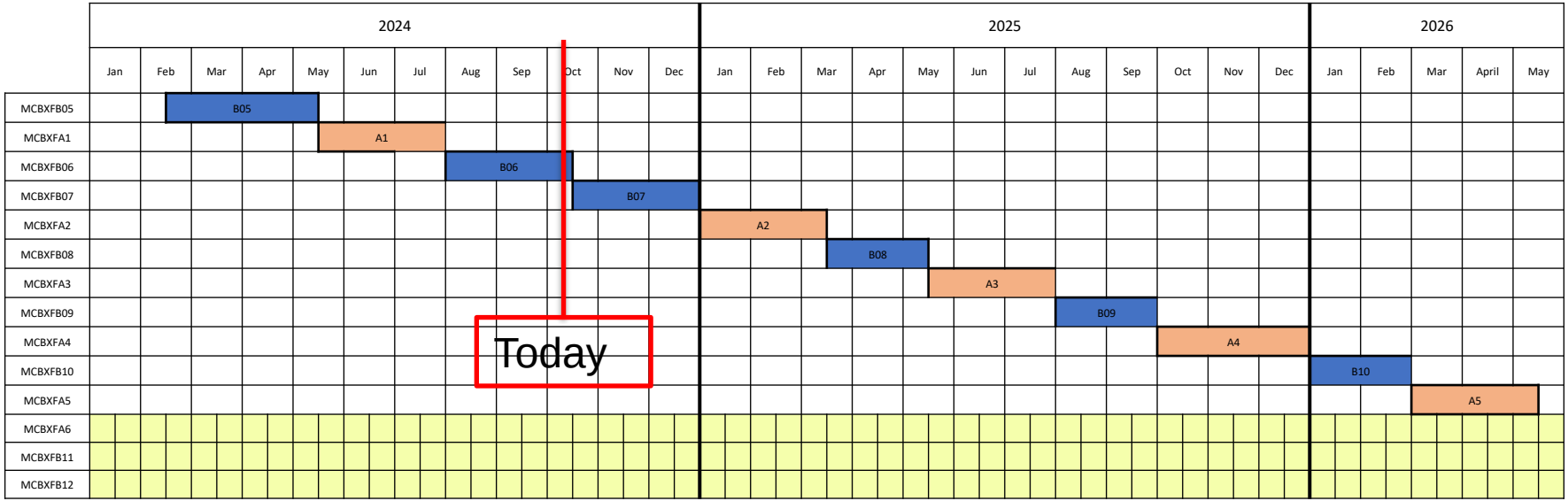
- 4 MCBXFB (1 made by CIEMAT & CERN) magnets over the 18 foreseen to be built by ELYTT were delivered
- 33 Coils still to be produced:
  - 16 MCBXFB
  - 17 MCBXFA
- No MCBXFA assembled at ELYTT
- 14 Magnets still to be assembled at CERN:
  - 8 MCBXFB
  - 6 MCBXFA

A strategy to complete the remaining magnet production, on schedule, was presented in October 2023.

The idea was to split the manufacturing into two separate sites:

- CIEMAT to produce the missing coils in its new laboratory in Madrid and will oversee the production of the remaining components
- CERN to be responsible for assembling the magnets in its facilities in Geneva

Magnet production planning presented in January 2024



The initial planning accounts for a delivery rate of 1 magnet every 2.5 months, exception for the first magnet (B05), with an assembly time of 3 months (used for knowledge transfer and production line set-up) to cope with WP3 master plan.

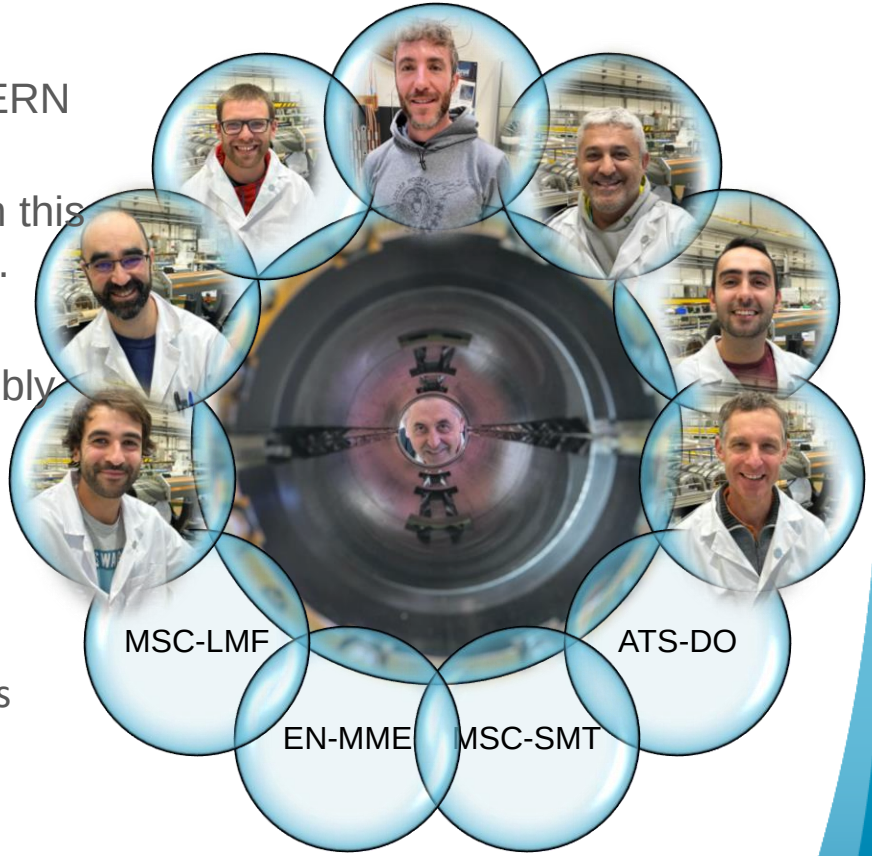
The team

All prototypes were developed and assembled at CERN in close collaboration with CIEMAT until fall 2021.

CERN's team has the required know-how to perform this task, but a series production approach was required.

A small, fully dedicated core team to MCBXF assembly activities has been formed.

- WP3 Project engineer
- 1 engineer for production follow-up
- Magnet assembly activities:
  - 1 trained engineer for assembly
  - 1 CERN trained technician to teach the newcomers (during first assembly)
  - 3 technicians for assembly
- 1 technician part time for electrical measurements
- Punctual support from MSC-LMF, MSC- SMT , EN-MME and ATS-DO is provided



Magnet assembly life cycle

Magnet storage in 180 waiting for assembly in a cold mass

To 180

Cold powering tests in SM18

To SM18

Electrical connections

WMM in 180

Yoke assembly in 180

Outer dipole WMM in 180

To 180

Outer Dipole collaring in 927

Outer Dipole assembly in 180

To 927

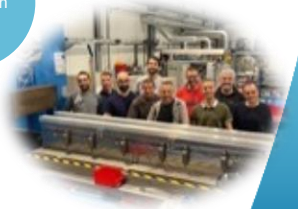
Inner Dipole WMM in 180

Inner Dipole collaring in 927

180

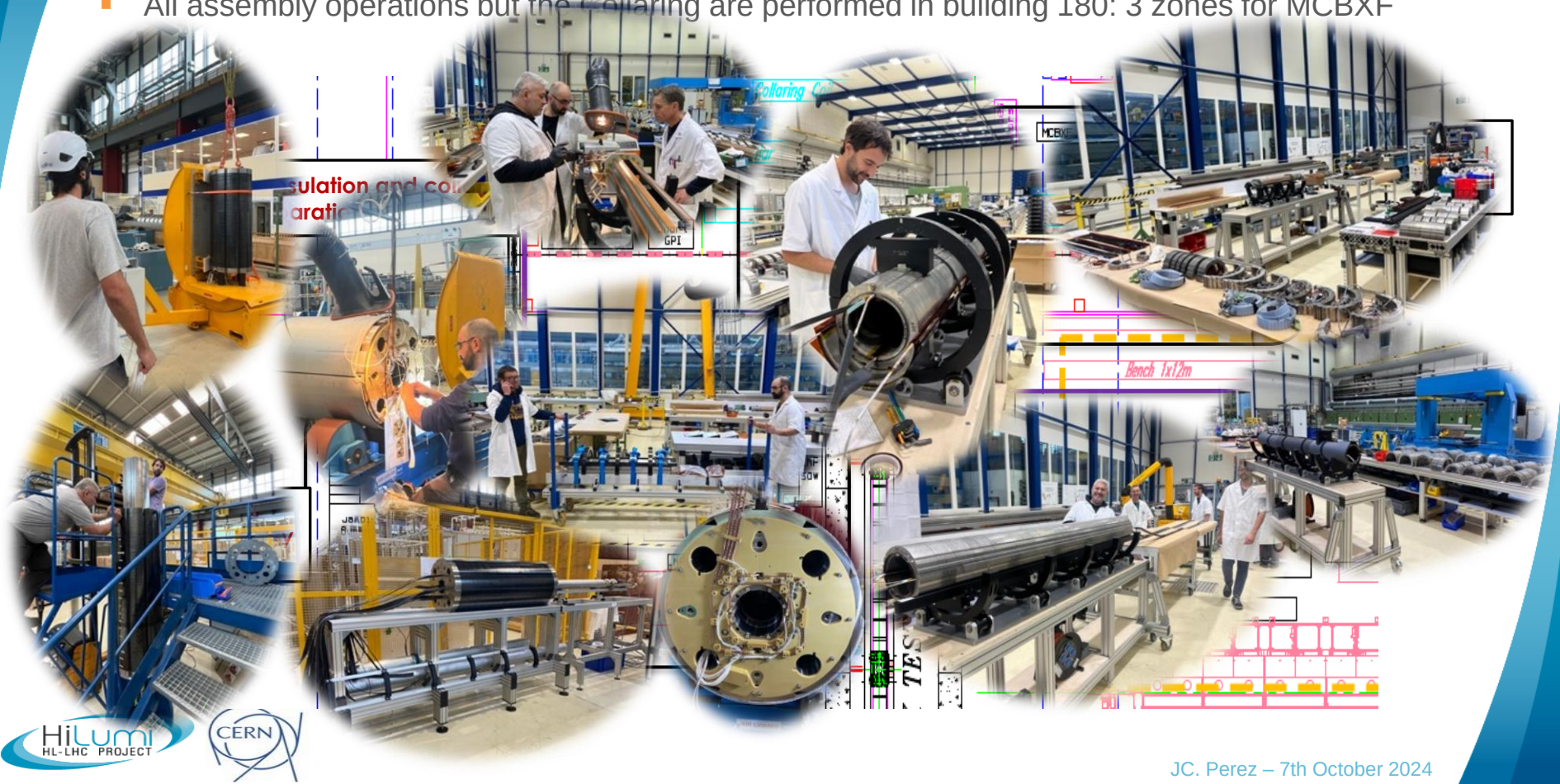
Inner Dipole assembly in 180

To 927



Set up of the assembly line at CERN: Building 180

- All assembly operations but the Collaring are performed in building 180: 3 zones for MCBXF

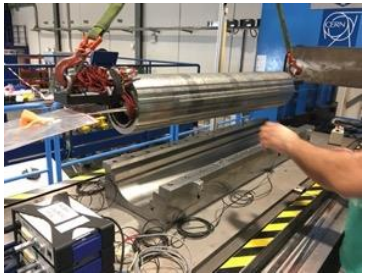


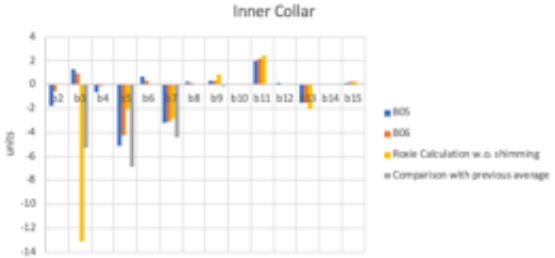
Set up of the assembly at CERN: Building 927

Quality Control Measurements

MAGNETIC

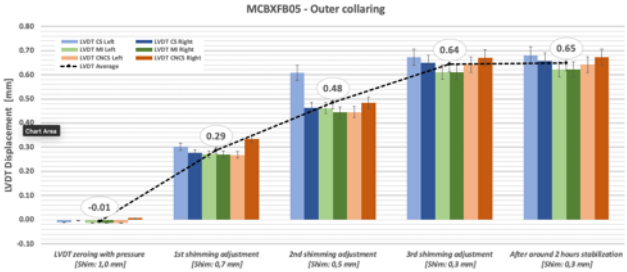
		INNER at 1740A		INNER at 0A		INNER at 1740A		INNER at 1400A	
		OUTER at 0A		OUTER at 1430A		OUTER at 1135A		OUTER at 1430A	
Norm. TF	Tm/kA	-1.4593				-1.4345		-1.4201	
Skew TF				1.772		1.7558		1.7488	
Multipoles	n	bn	an	bn	an	bn	an	bn	an
	2	3.58	1.25	0.11	-2.68	4.76	-0.63	4.37	-1.56
	3	2.72	1.09	-0.36	3.15	-14.55	-10.93	-21.80	-10.25
	4	0.61	0.66	-0.02	0.20	0.53	0.40	0.27	0.26
	5	3.97	0.69	0.08	0.49	2.41	1.79	1.80	2.19
	6	-0.02	0.59	0.13	0.31	0.02	0.89	0.05	0.80
	7	2.78	0.32	0.23	-2.51	3.12	-1.74	2.59	-2.24
	8	0.16	0.20	0.04	-0.19	0.30	0.14	0.37	0.18
	9	-0.22	-0.10	-0.06	0.51	-0.25	0.36	-0.19	0.42
	10	0.51	-0.14	0.02	-0.04	0.50	0.04	0.35	0.12
	11	-1.80	-0.41	-0.08	0.05	-1.81	-0.51	-1.36	-0.56



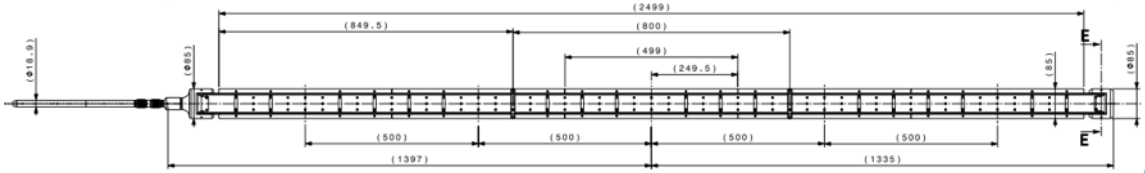


Support by TE-MSC and EN-MME
WMM data analysis by CIEMAT

MECHANICAL



Performed in 927, 180 and SM18

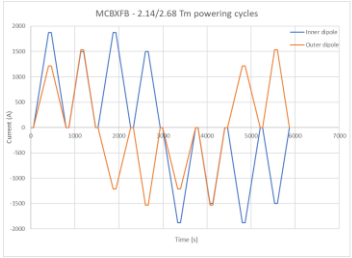


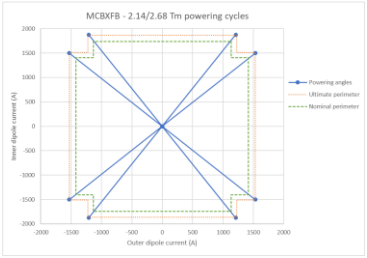
ELECTRICAL

Test name			CIDBC_hall	CIDBC	CIDBC 2	CIDBC 3	CIDBC 4	CIDAC	CIDBC	CIDBC_bis		CODAC	ALL	FINAL
Data				23.05.24	29.05.24	31.05.24	03.06.24	04.06.24	11.06.24	12.06.24	12.06.24	13.06.24	28.06.24	01.08.24
Operator name				Jeremy FECHINEY	Jeremy FECHINEY	Jeremy FECHINEY	PA Contat	PA Contat	Franck Evrard	PA Contat	PA Contat	Jeremy FECHINEY	Franck Evrard	
T_{amb} [°C]				22.7	23.1	22.8	22.3	21	23	20.7	22.5	20.5	24.7	27.5
Humidity [%]				50.4	48	43.3	57.4	58.8	46	43.7	36.7	41.1	71.2	65.5
Insulation resistance	U[test]	time	measured	measured	measured	measured	measured	measured	measured	measured	measured	measured	measured	measured	nominal
	[V]	[s]	[GΩ]	[GΩ]	[GΩ]	[GΩ]	[GΩ]	[GΩ]	[GΩ]	[GΩ]	[GΩ]	[GΩ]	[GΩ]	[GΩ]	[GΩ]
coil ICAS01 --> Ground	2000	30		166.3	168.5	224.0	98.2	39.0	50.0	48.5	172.4	117.4	6.1	X	>1
coil ICAS02 --> Ground	2000	30		100.3	159.1	166.4	107.5	54.7	19.4	103.9	206	101.5	12.7	X	>1
coil ICAS01 --> coil ICAS02	1000	30		155	972	134	707	60	31.4	250	289	192.5	15	X	>1
coil OCAS02 --> Ground	500	30	X	X	X	X	X	X	X	X	X	X	X	X	>1
coil OCAS02 --> Ground	2000	30	X	X	X	X	X	X		52.1	58.2	54.5	9.7	X	>1
coil OCAS05 --> Ground	500	30	X	X	X	X	X	X	X	X	X	X	X	X	>1
coil OCAS05 --> Ground	2000	30	X	X	X	X	X	X		29.4	33.0	48.4	11.0	X	>1
coil OCAS02 --> coil OCAS05	200	30	X	X	X	X	X	X	X	X	X	X	X	X	>1
coil OCAS02 --> coil OCAS05	1000	30	X	X	X	X	X	X		67.6	147.1	62.6	18.9	X	>1
coils ICAS01-ICAS02 --> Ground	500	30	X	X	X	X	X	X	X	X	X	X	X	X	>1
coils ICAS01-ICAS02 --> Ground	2000	30	X	X	X	X	X	X	X	X	X	X	X	4.2	>1
coils OCAS02-OCAS05 --> Ground	500	30	X	X	X	X	X	X	X	X	X	X	X	X	>1
coils OCAS02-OCAS05 --> Ground	2000	30	X	X	X	X	X	X	X	X	X	X	X	2.6	>1
coils ICAS01-ICAS02 --> coils OCAS02-OCAS05	500	30	X	X	X	X	X	X	X	X	X	X	X	X	>1
coils ICAS01-ICAS02 --> coils OCAS02-OCAS05	2000	30	X	X	X	X	X	X	X	X	X	X	X	2.7	>1
All coils --> inner + outer collar	2000	30	X	X	X	X	X	X	X	X	X	X	X	X	>1

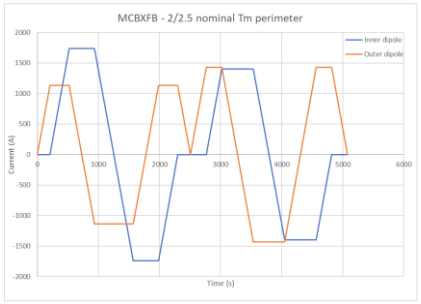
MCBXF Cold Powering

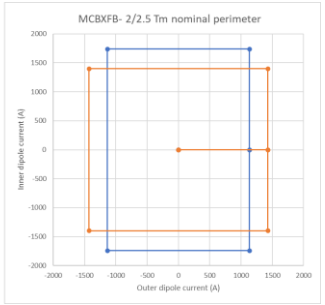
- Each dipole is tested in standalone mode up to its ultimate current
- Then the magnet is trained in combined powering up to its ultimate field

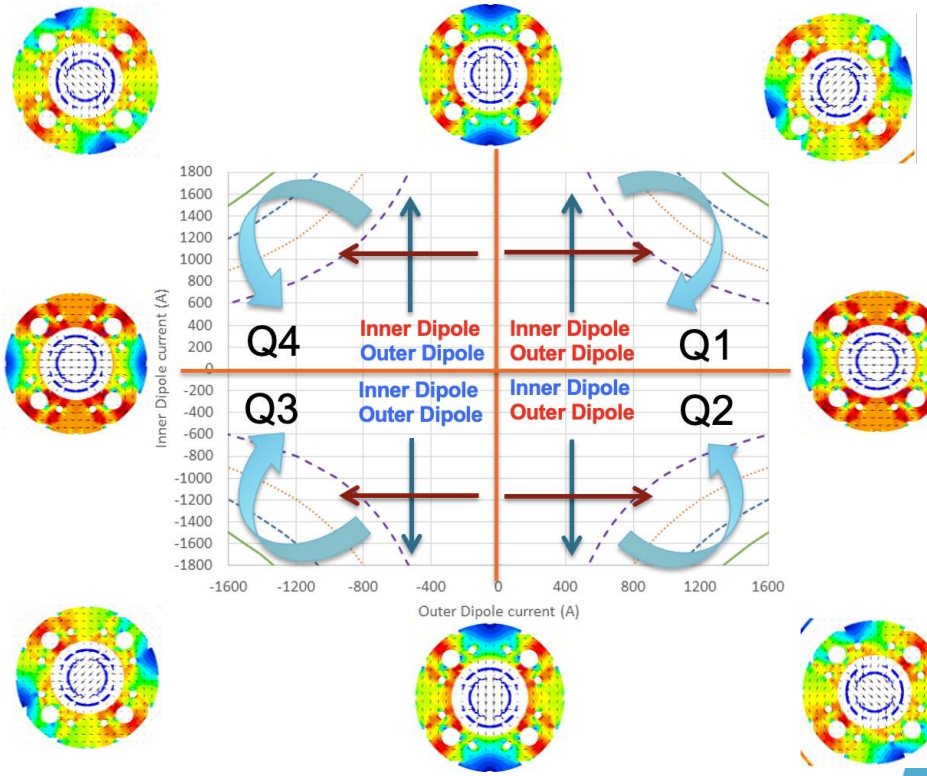




- Then the magnet is powered around its nominal perimeter by performing two rectangular powering cycles



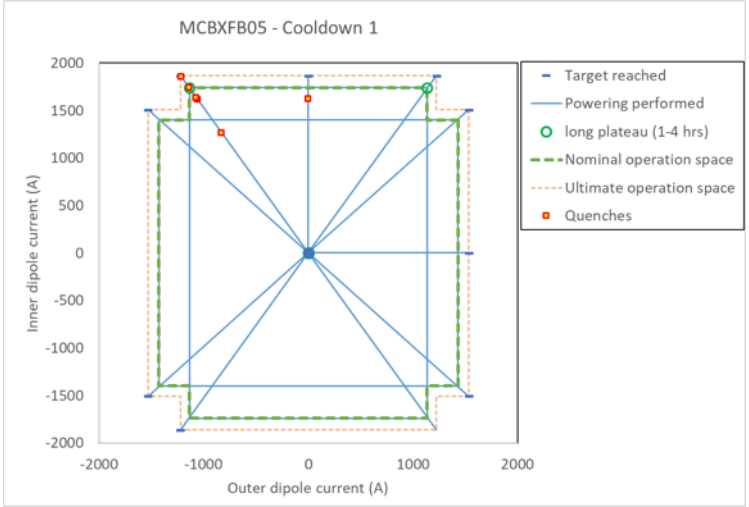




Nominal torque per unit length at straight section is very high: 147 kNm/m, about 84 MPa at the inner dipole coil.

MCBXFB05 powering test results

- Cold test (1st thermal cycle)
  - Single powering:
    - 1 quench while powering the inner dipole on standalone configuration
    - No quench for the outer dipole
  - Combined powering:
    - No quenches in the first quadrant, but 5 quenches in the second quadrant to reach ultimate.
    - We then went through all quadrants without further quenches (see the five markings in the current vs time plot).
- Cold test (2nd thermal cycle)
  - Single powering:
    - No quench
  - Combined powering:
    - No quench
- Documentation and EDMS status:
  - Documentation is up to date. NCRs are closed

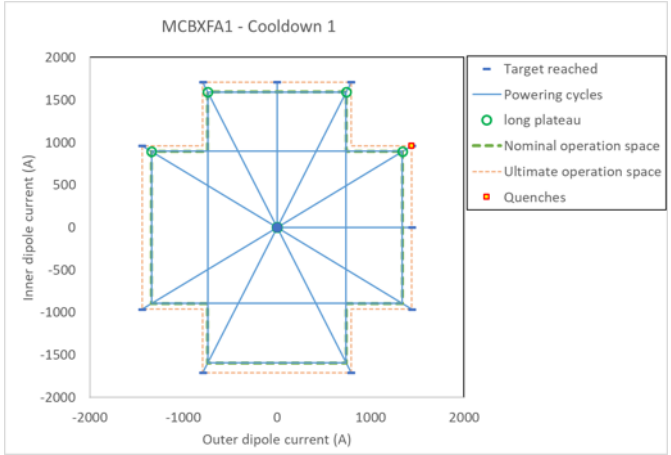


MCBXFB05 is the first magnet tested after the restart of assembly activities by CERN at CERN.

Courtesy of G. Willering

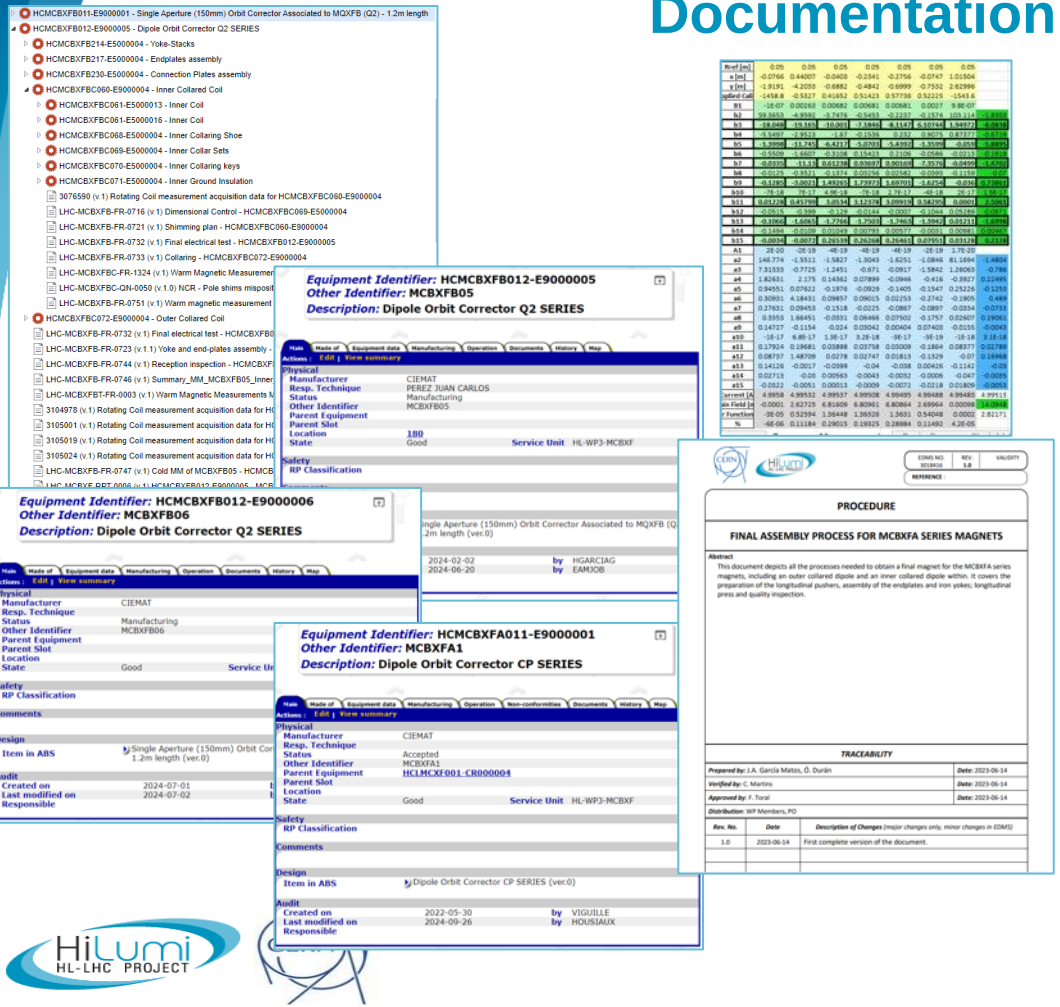
MCBXFA1 powering test results

- Cold test (1st thermal cycle)
  - Single powering:
    - No quench for the inner dipole
    - No quench for the outer dipole
  - Combined powering:
    - 1 quench in the first quadrant at almost ultimate current.
    - We then went through all quadrants without further quenches.
- Cold test (2nd thermal cycle)
  - Single powering:
    - No quench
  - Combined powering:
    - No quench
- Documentation and EDMS status:
  - Documentation is up to date. NCRs are closed



Courtesy of G. Willering

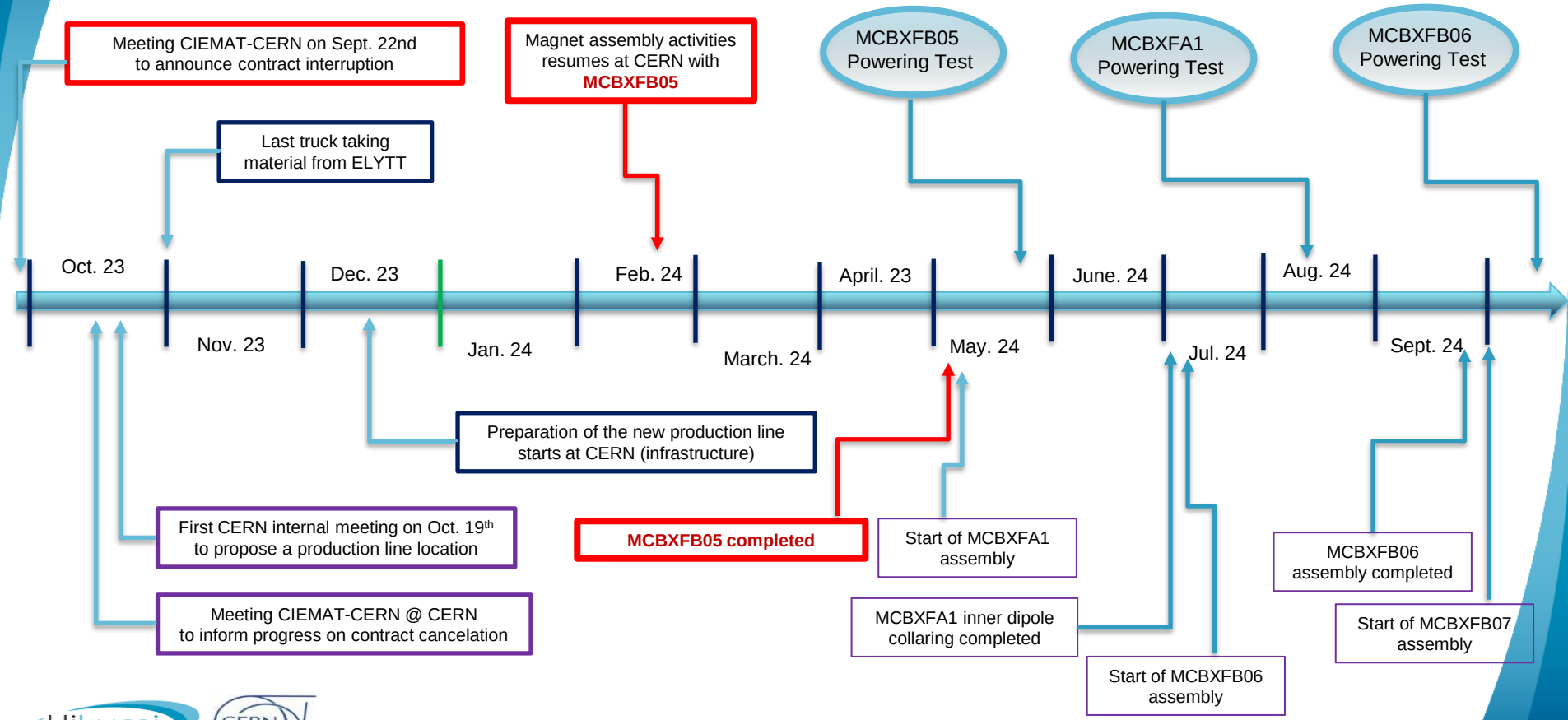
Documentation status



- MTF Assets (Coils/Magnets) modified to represent the new production scheme
- Results from the incoming inspections on the materials used from previous production are available
- NCRs from previous production are being closed
- Manufacturing and assembly procedures issued
- All updated drawings uploaded to PLM
- Documentation systematically upload by both teams to MTF
- NCRs from assembly at CERN well documented (root cause identification, corrective and preventive actions)

Courtesy of H. Garcia

CERN assembly activities timeline



Summary

Today we have:

- MCBXFB05 and MCBXFA01 have been assembled and successfully tested
- MCBXFB06 is waiting for cold powering tests
- MCBXFB07 assembly has started

- The provisional schedule presented at the beginning of the year is being perfectly followed and is in line with the requirements of the general WP3 schedule
- Less than a year ago, we were in a crisis situation following the closure of a contract for the manufacturing of the series for the combined orbit corrector magnets
- The necessary infrastructure to cover the assembly activities was set up in record time
- Today, we are in a stable situation with an assembly pace aligned with the forecasts made at the beginning of the year
- We are confident about the continuation of operations thanks to the establishment of a dedicated and stable team
- The results achieved so far, despite the unexpected challenges caused by the decision to close the contract signed with ELYTT, would not have been possible without the support of many individuals who may not always be visible at the forefront
- My sincerest thanks to all of them for their contribution

It is much easier to achieve ambitious goals with a cheerful and motivated team.

Thank you guys !!!!

Thank you for your attention

Acknowledgements to:

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Steve Becle, Nicolas Bourcey, Federico Ben el Caid, Pierre-Antoine Contat, Nicolas Eyraud, josé Ferradas, Lucio Fiscarelli, Bertrand Fornes, Hector Garcia, Ludovic Grand-Clement, Victor Guillen, Jean-Luc Guyon, Hector Garcia, Gonzalo Hernando, Olivier Housiaux, Michael Guinchard, Susana Izquierdo, Karim Kallat, Nicholas Lusa, Sebastien Luzieux, Franco Mangiarotti, Gregory Maury, Sabine Menu, Attilio Milanese, Sylvain Mugnier, Nicolas Peray, Francois-Olivier Pincot, Hervé Prin, Pietro Rizzo, Piotr Rogacki, Frederic Rougemeont, Ezio Todesco, Yanick Thuau, Patrick Viret, Gerard Willering from CERN…
and many others that I certainly forgot to mention.