



# Assembly & tests results on MCBXFB prototypes at CERN

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On behalf of MCBXF CERN-CIEMAT team

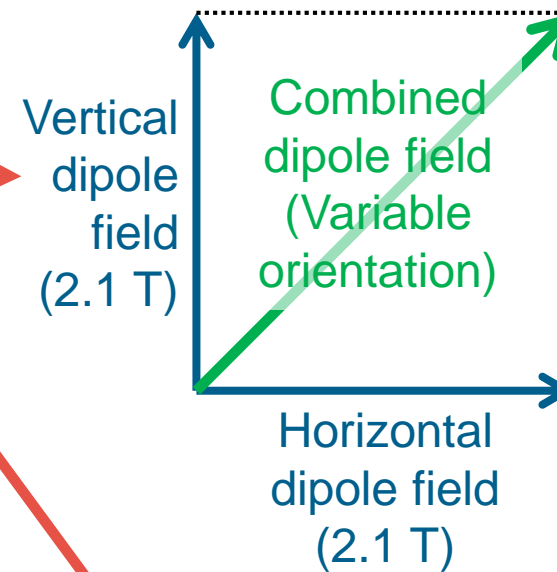
Kick-off meeting for MCBXF series production – CERN 23<sup>rd</sup> April 2021



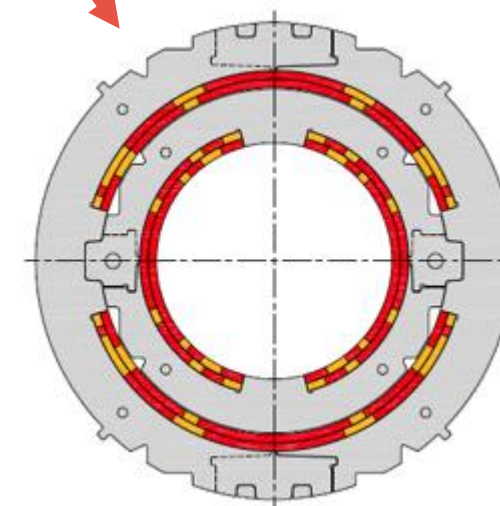
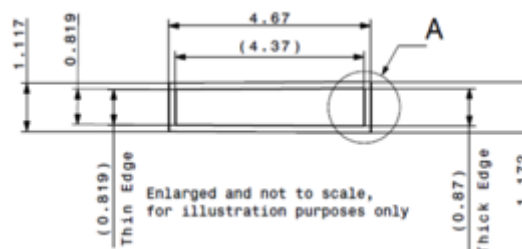
# Magnet and cable specifications

## MCBXFB Technical specifications

<b>Magnet configuration</b>	Combined dipole (Operation in X-Y square)
<b>Integrated field</b>	2.5 Tm
<b>Minimum free aperture</b>	150 mm
<b>Nominal current</b>	< 2500 A
<b>Radiation resistance</b>	35 MGy
<b>Physical length</b>	< 1.505 m
<b>Working temperature</b>	1.9 K
<b>Iron geometry</b>	MQXF iron holes
<b>Field quality</b>	< 5 units (1E-4) ( $b_3 < 20$ )
<b>Fringe field</b>	< 40 mT (Out of the Cryostat)



Cable Parameters	
<b>No. of strands</b>	18
<b>Strand diameter</b>	0.48 mm
<b>Cable thickness</b>	0.845 mm
<b>Cable width</b>	4.37 mm
<b>Key-stone angle</b>	0.67°
<b>Cu:Sc</b>	1.75



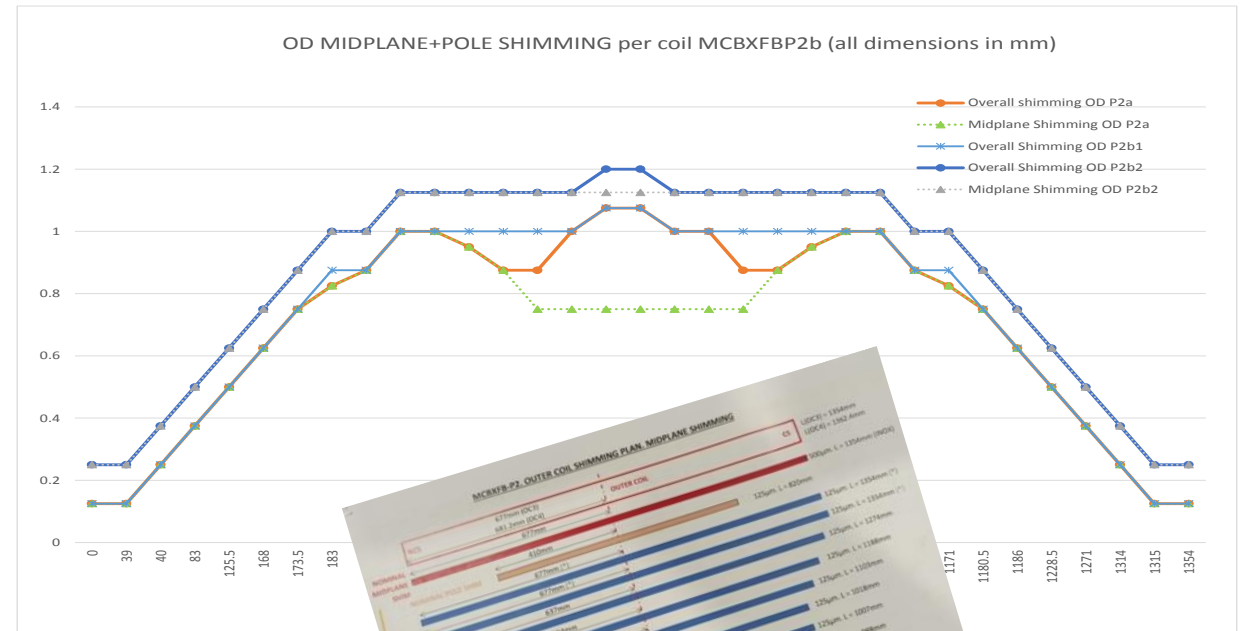
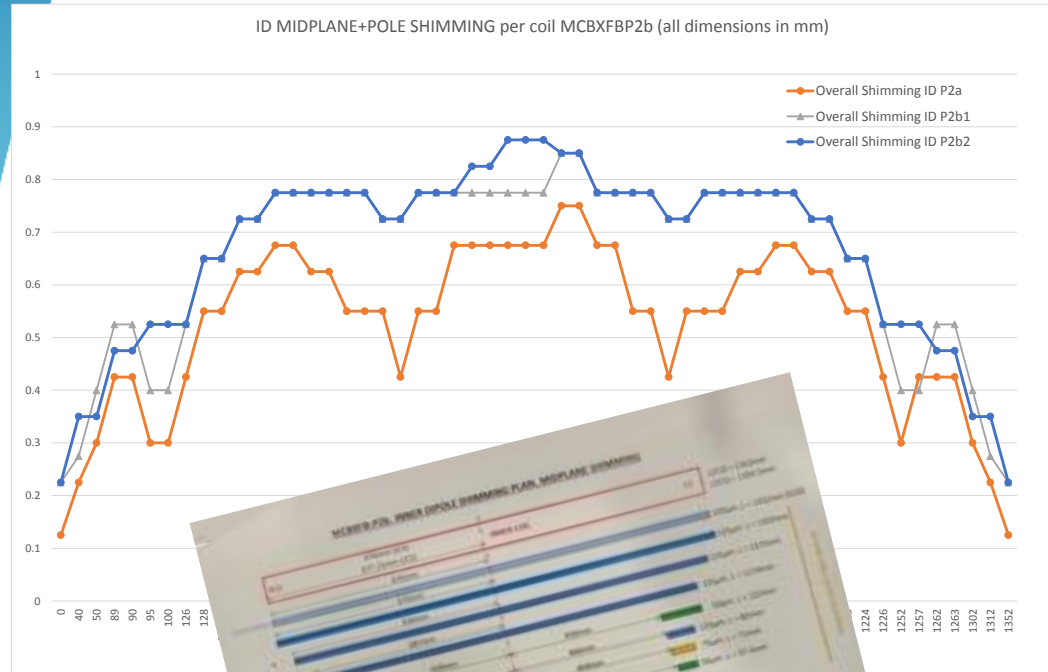
# Magnet coils & components delivery to CERN



- The coils are wound at CEDEX (see Carla's presentation)
- All magnet components are delivered by CIEMAT

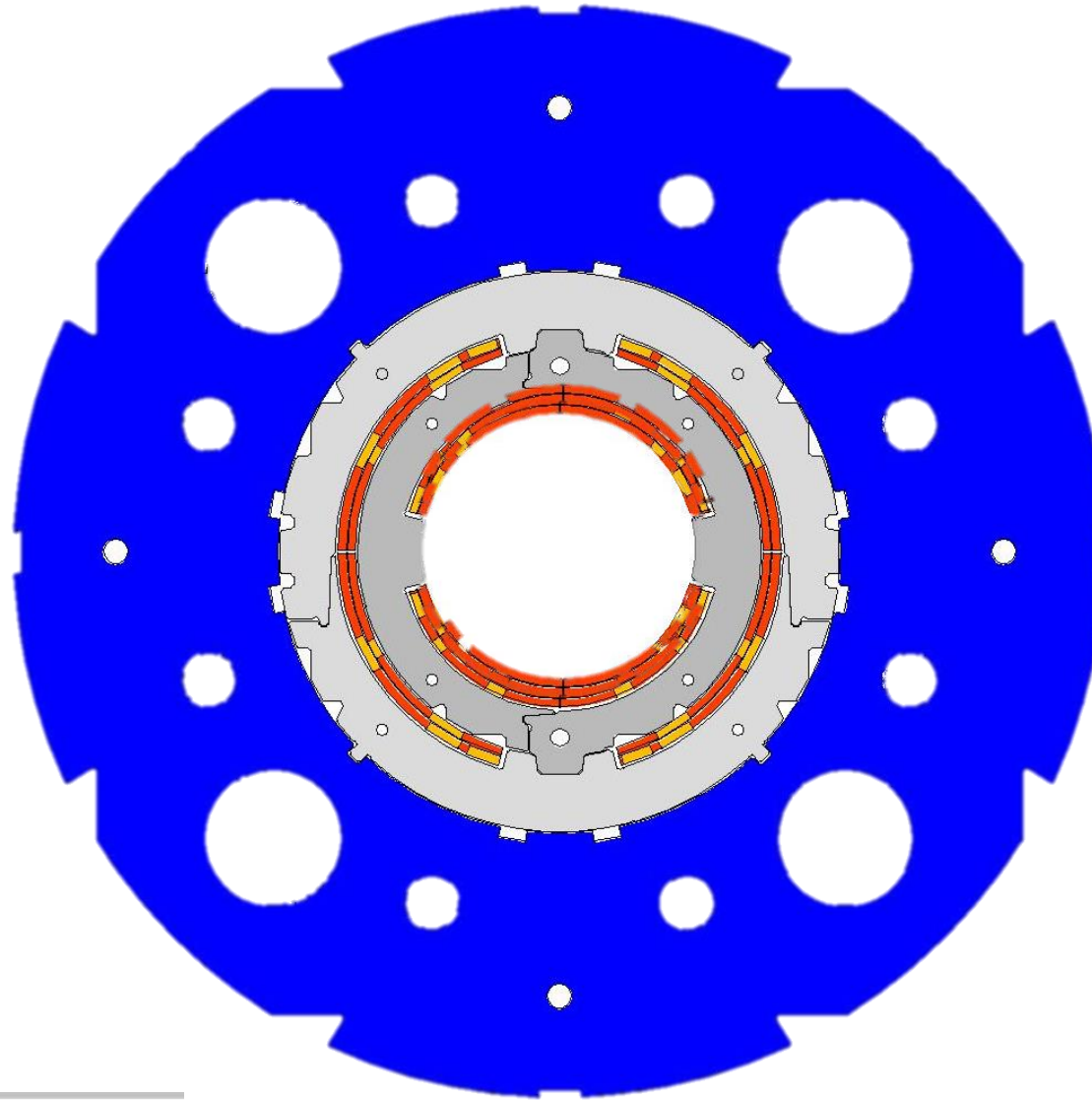


# Coils geometry and shimming plan



- Each coil is measured using a CMM measuring system.
- A shimming plan is defined by CIEMAT's crew to compensate the cross-section deviation from nominal design value and to achieve the required coil compression values during magnet operation.

# MCBXF magnet assembly sequence





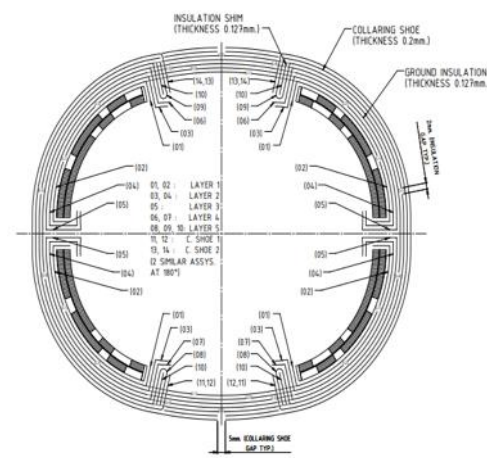
# Inner dipole assembly



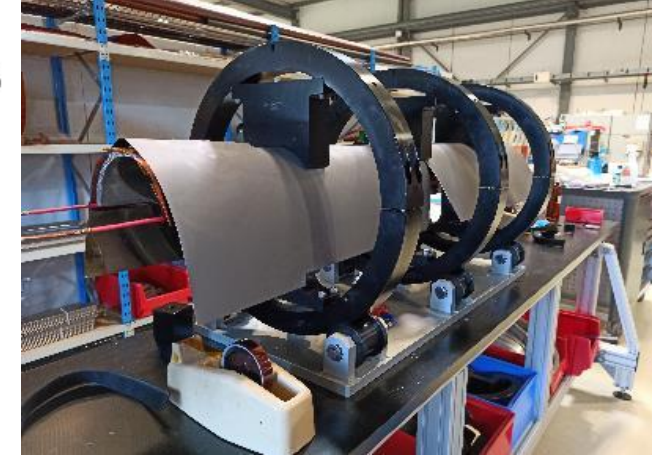
Ground insulation assembly



Stepped shimming preparation



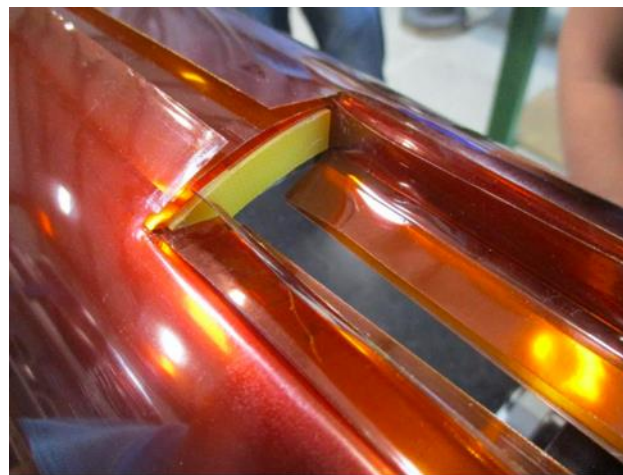
Ground insulation scheme



Collaring shoe assembly



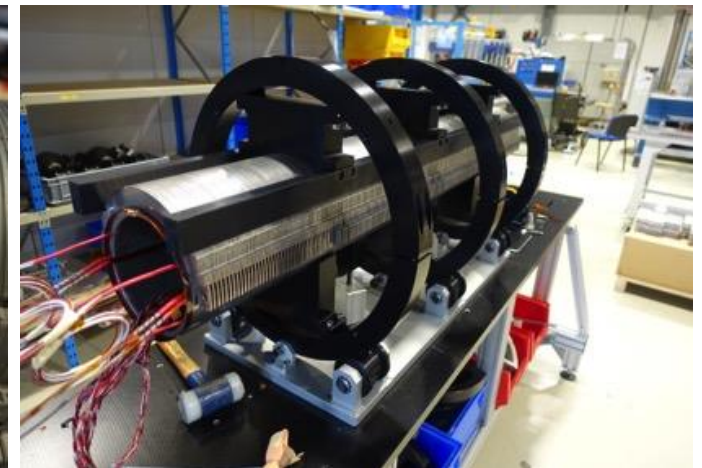
Transfer of second inner coil



Ground insulation



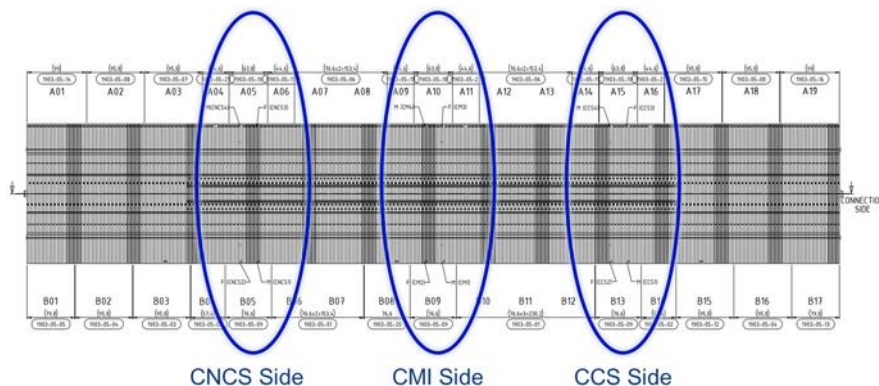
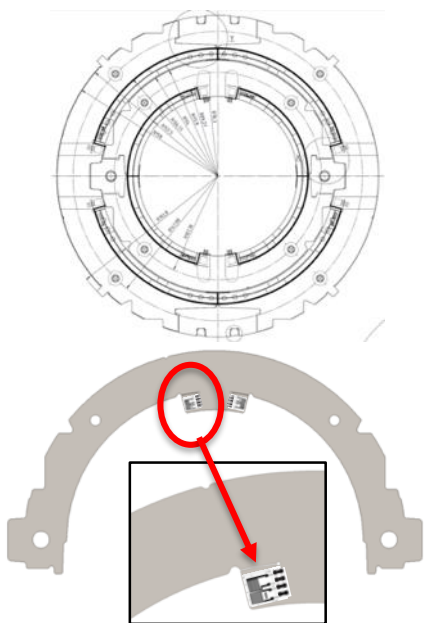
Collar pack assembly



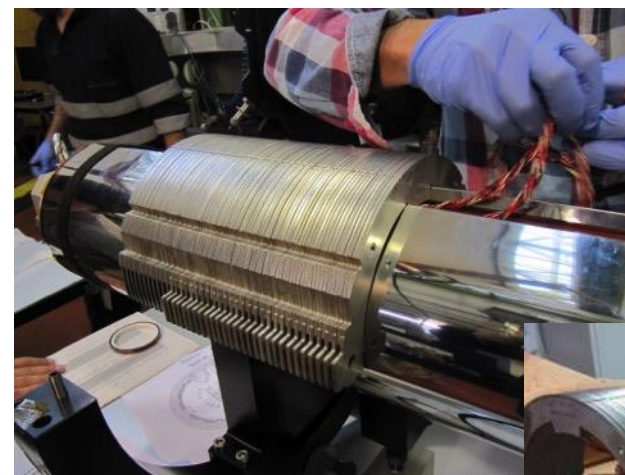


# Mechanical measurements during assembly process

- Collar packs equipped with strain gauges are used during the assembly process for azimuthal strain measurements
  - 12 instrumented collars
  - 3 magnet sections equipped
  - Instrumented collars equipped for temperature and magnetic field compensation for the prototypes



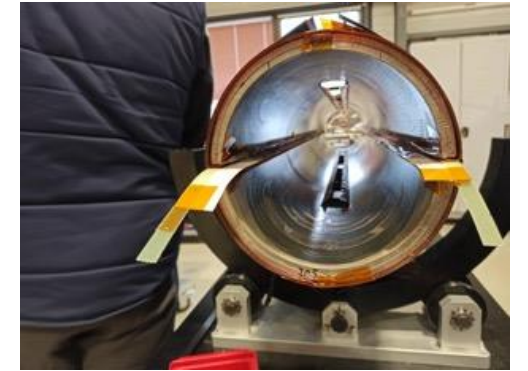
Collars Location



The targeted strain will be validated under the collaring press and the instrumented collars will be removed during series production



# Inner dipole collars assembly



Strain sensitive Fuji paper is inserted in the mid-plane to confirm a homogenous contact over the full coil length.

The inner dipole is assembled using temporary instrumented collar-packs



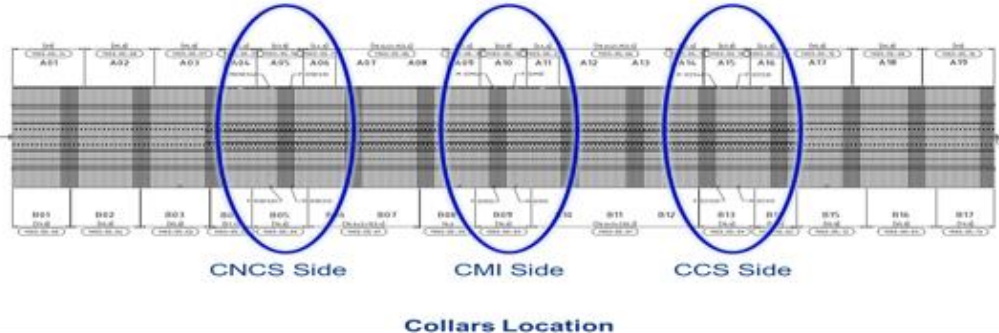
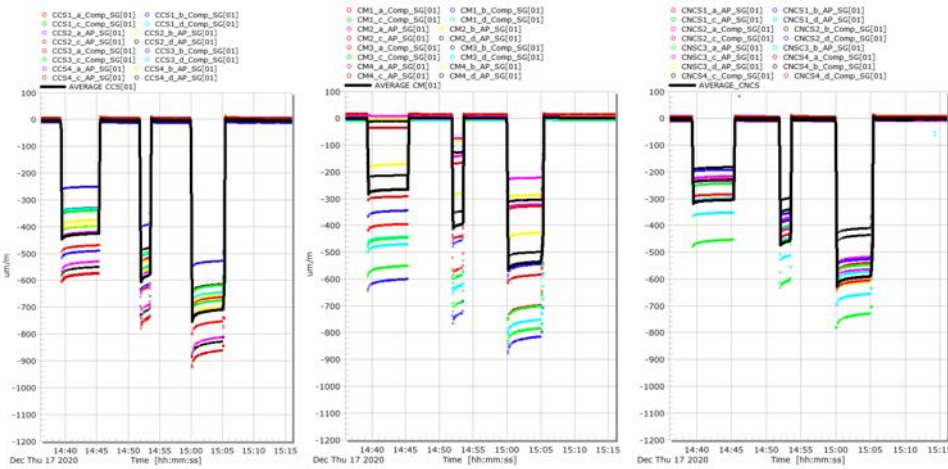
The relative displacement of the collaring tool is controlled and limited using different sets of shim thickness and monitored by 6 LVDTs.



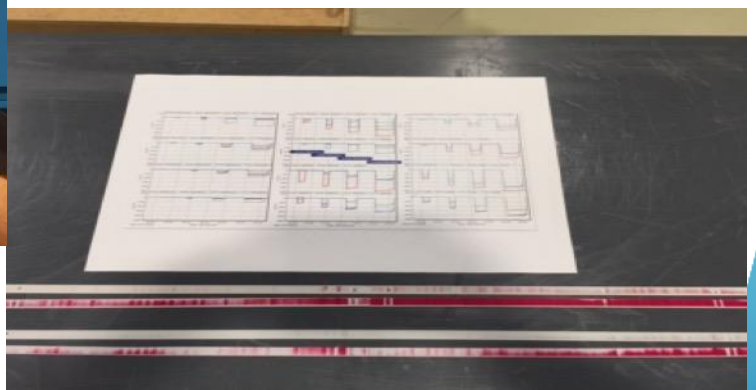
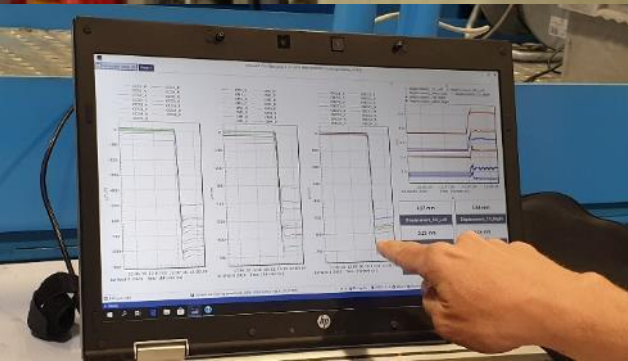
The inner dipole is mounted into the collaring tool and inserted in the collaring press



# Inner dipole pre-collaring

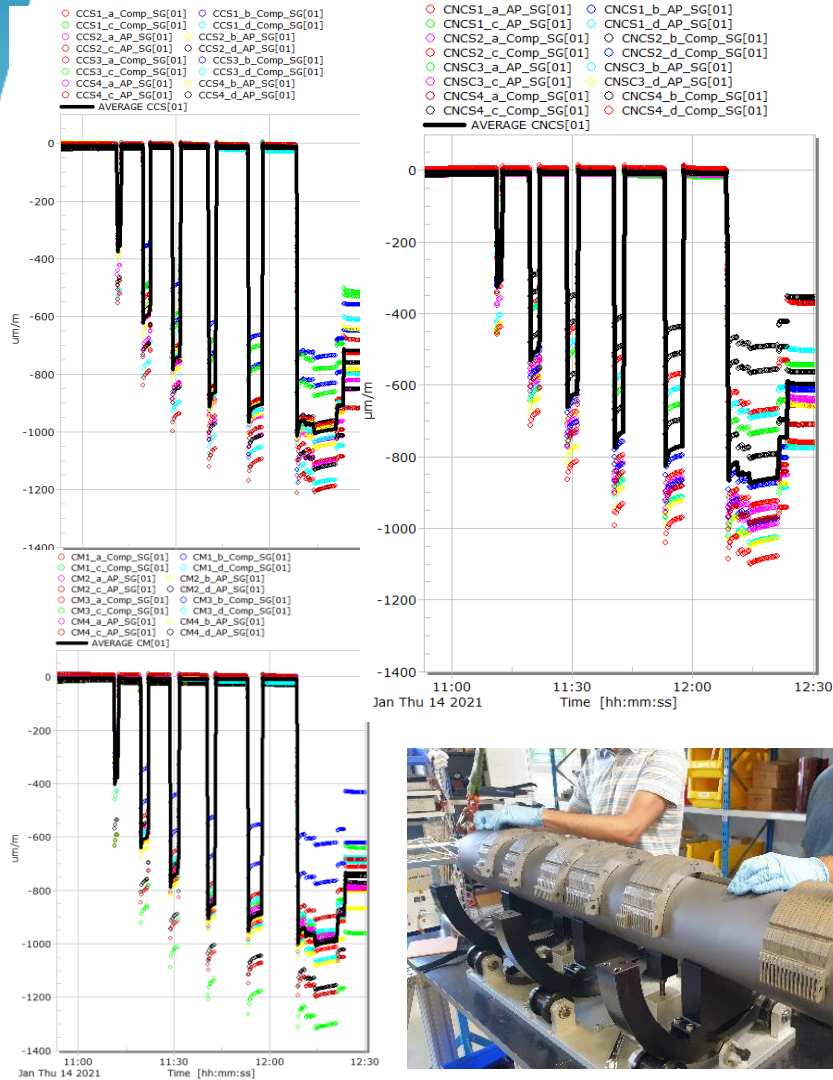


Gap	cs	cm	cncs	mean	prediction	max	min
1	85	53	53	64		119	2
0.8	114	78	82	91	98	145	15
0.6	139	105	108	117	133	168	43

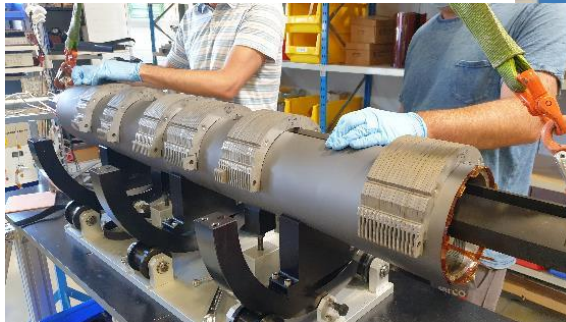
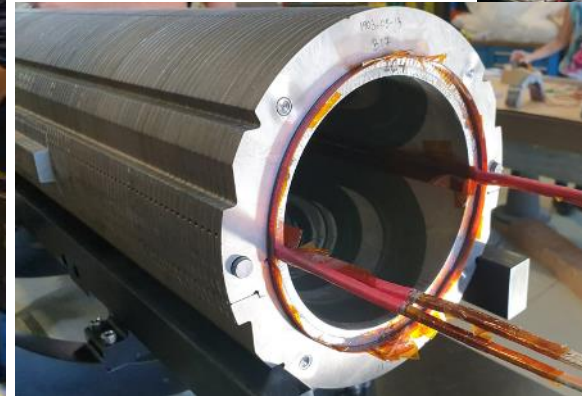
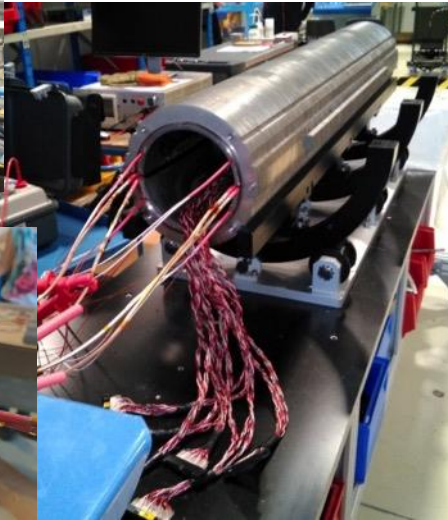


The strain values are monitored and compared with expected values. The coils contact at mid-plane is validated before proceeding with final collaring operation.

# Inner dipole final collaring operation

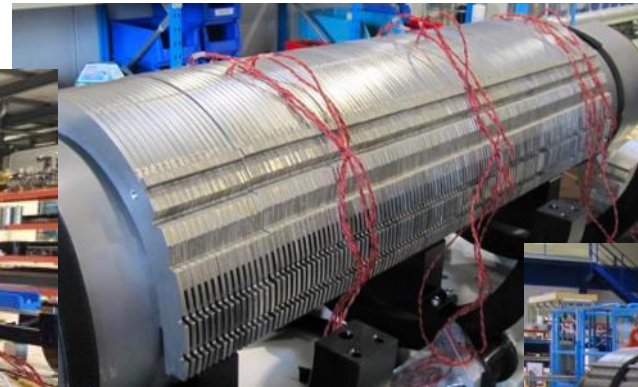
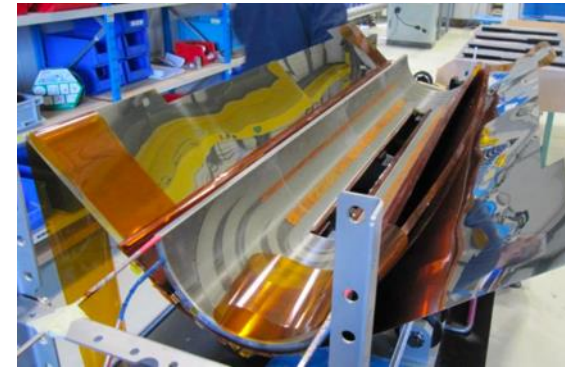
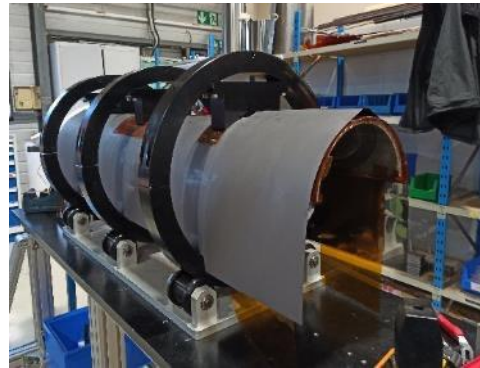
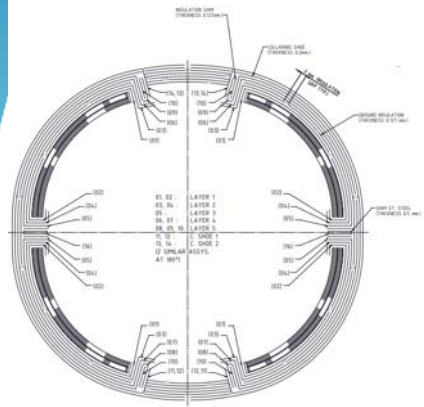


Gap	CS	CM	CNCS	Mean	Prediction	Max	Min
1	69	74	60	68	92	116	30
0.7	116	118	99	111	125	169	57
0.5	144	144	122	137	147	198	68
0.3	168	166	143	159	158	221	80
0.2	177	174	150	167	169	230	85
0.1	192	188	163	181	180	246	93





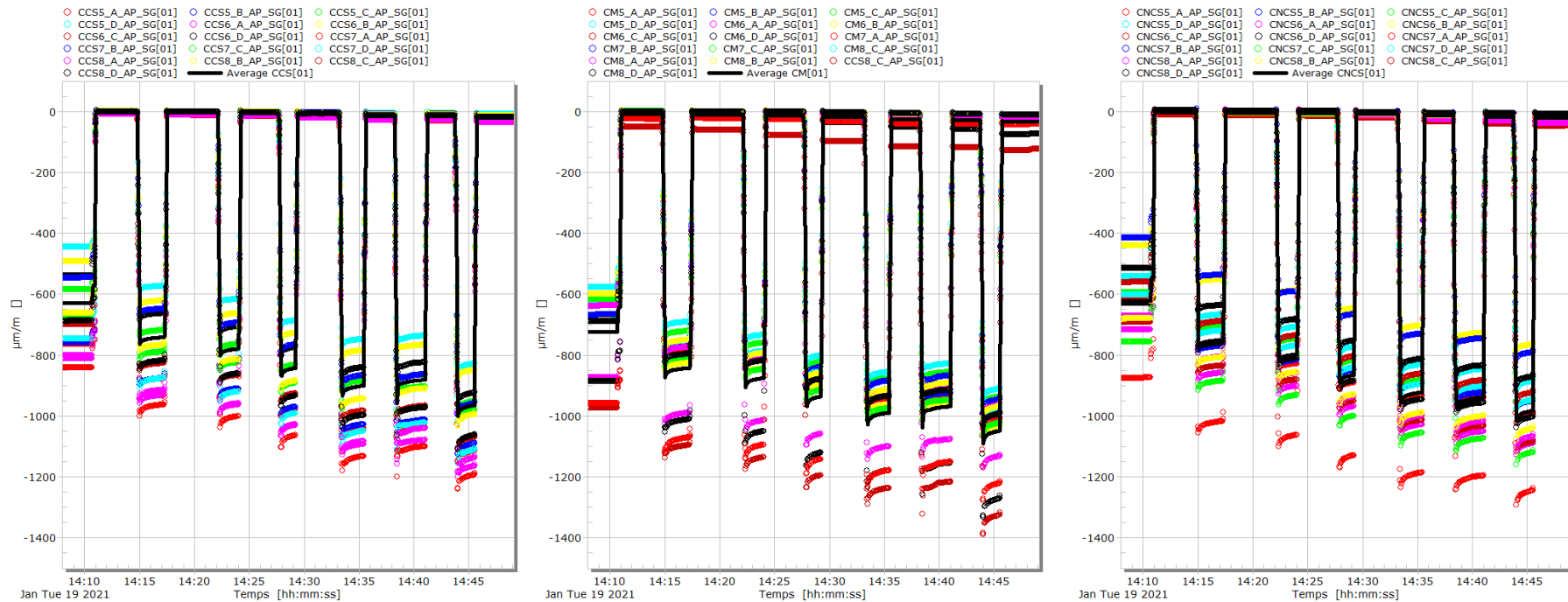
# Outer dipole assembly



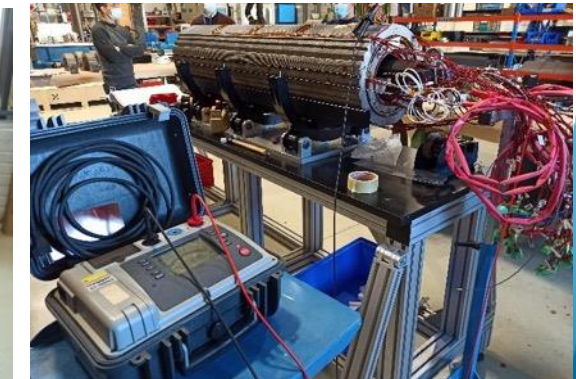
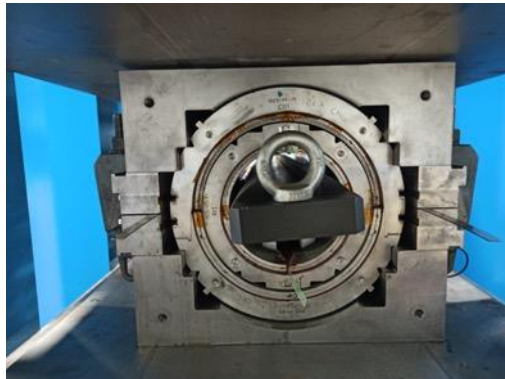
The same assembly sequence used for the inner dipole is applied while assembling the outer dipole



# Outer dipole collaring

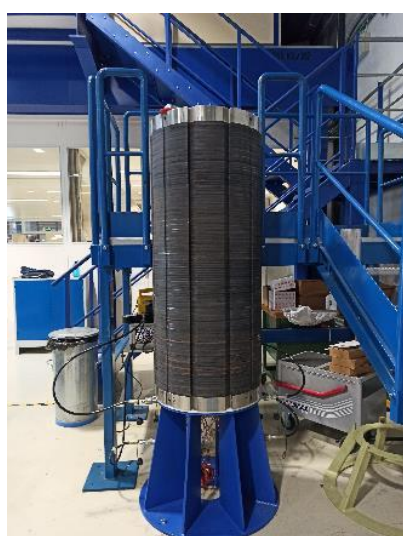
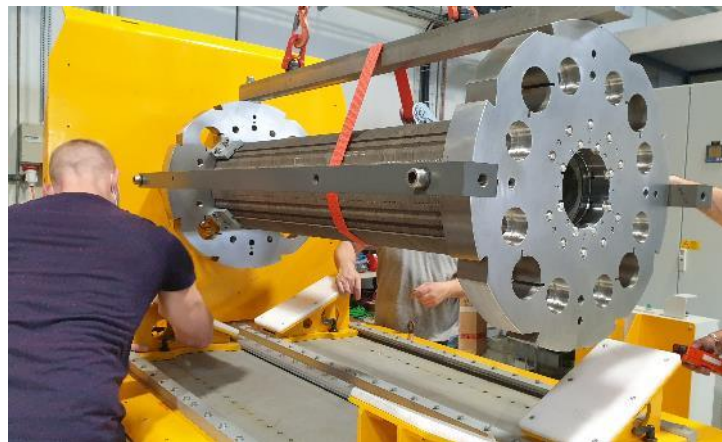


The instrumented outer collars were removed before the final collaring operation



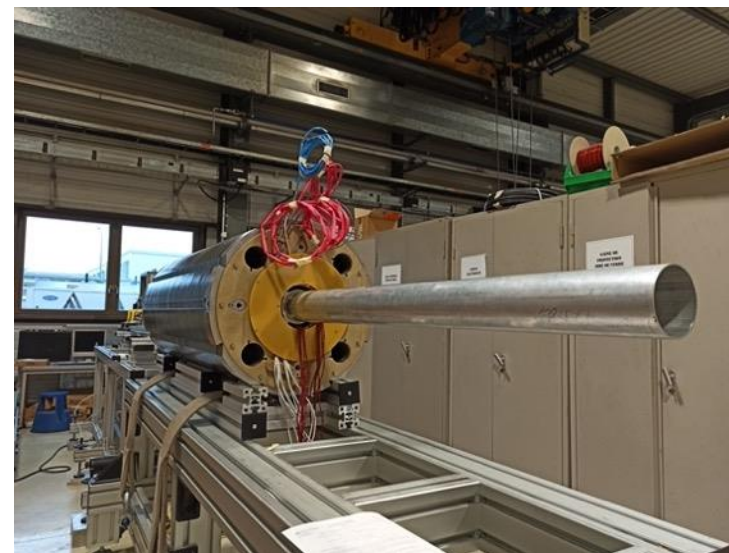
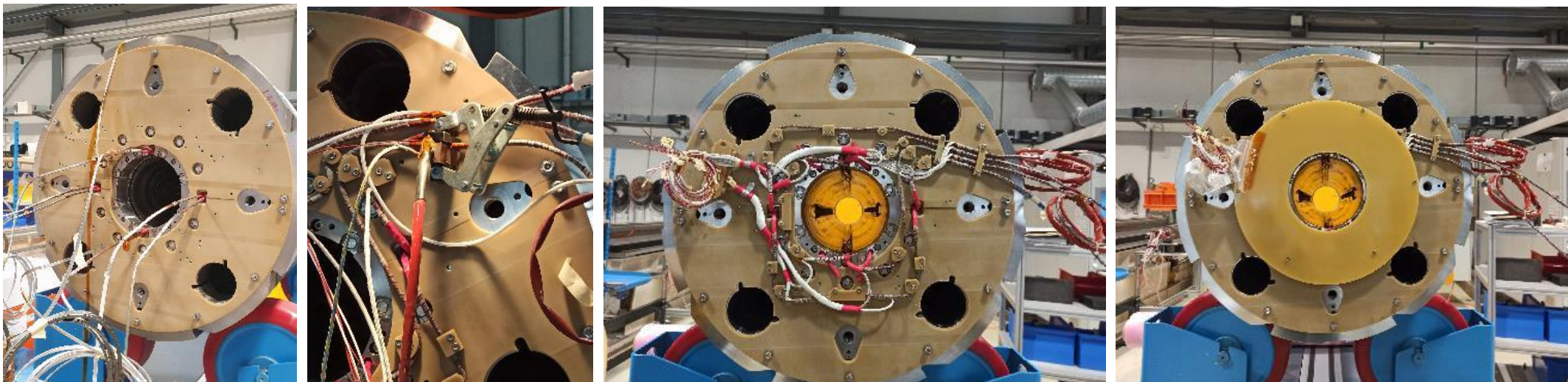


# Magnetic yoke assembly



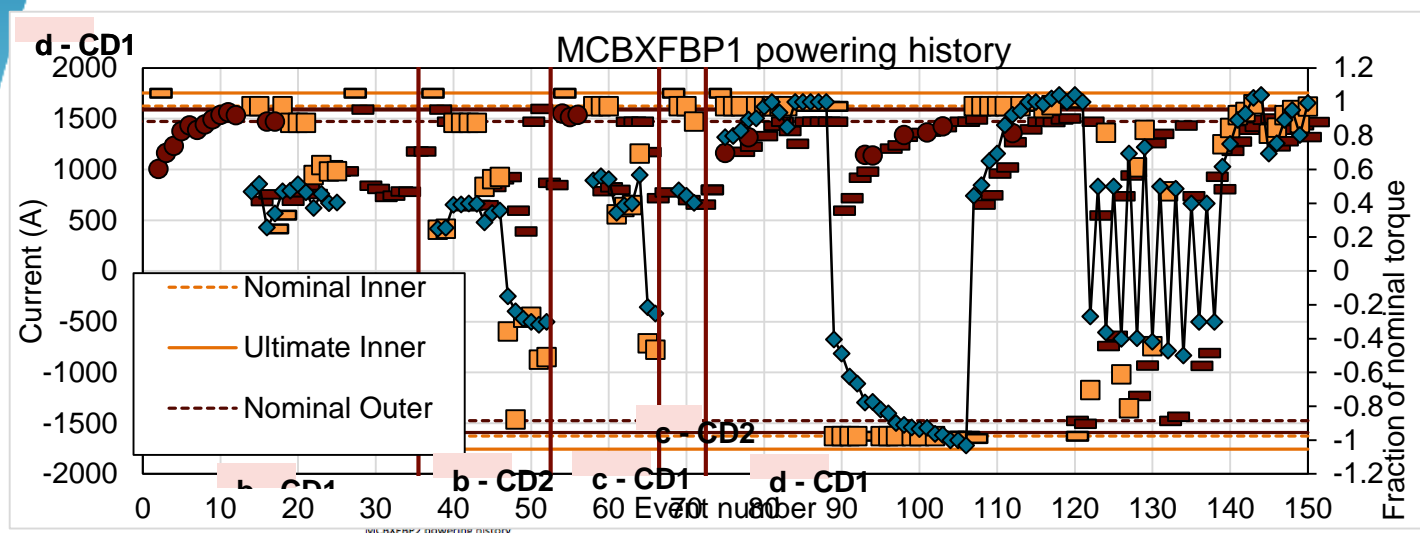


# Electrical Connections & Warm Magnetic Measurements

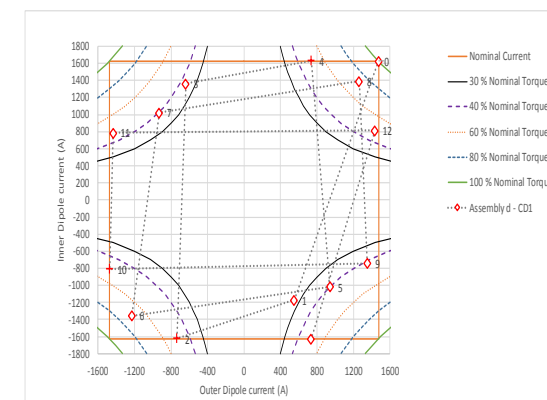
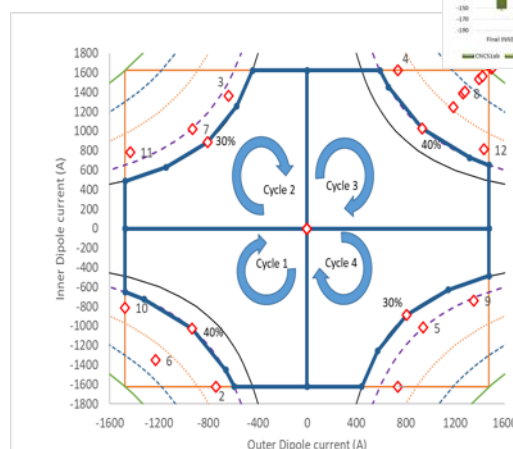
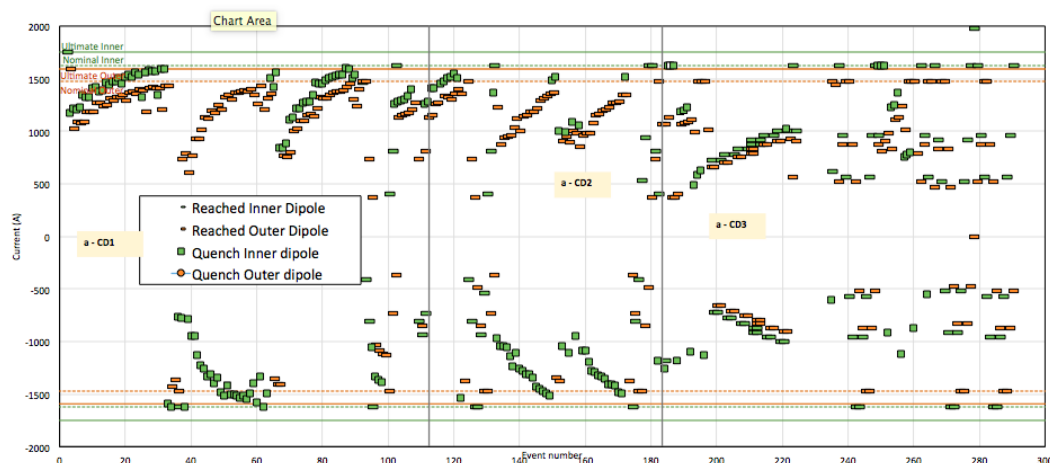




# MCBFBs prototypes powering campaign



## Mechanical measurements



Intensive powering tests campaign: several thermal cycles, around 600 events and more than 300 quenches.

# Documentation

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- Publications WP3
- MCBXFB Short Mechanical Model
- MCBXFA Prototype
- MCBXFB Prototype
- MCBXFA Series
- MCBXFB Series
- LHC-MCBXF-NOT-0004 (v.0.1) CIEMAT MCBXF Documentation Status

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**Functional drawings & models**

- MCBXFB Prototype Drawings
  - LHC-MCBXFB-DF-0002 (v.3) 1601 - MCBXFB PROTOTYPE 1
  - LHC-MCBXFB-DF-0003 (v.1) 1903 - MCBXFB PROTOTYPE 2
  - LHC-MCBXFB-DF-0004 (v.1) 1907 - MCBXFBP1e for the String
- MCBXFB Tooling Drawings
  - 1855359 (v.1) 1603-00 - Pay-off Machine
  - 1855361 (v.1) 1604-00 - Take-up Machine
  - 1855364 (v.2) 1605 - MCBXFB Tooling
  - 2455106 (v.1) 1503-03 - MCBXFB Tooling - Tubular Rivet Crimping Tool
  - 2455119 (v.1) 1605-34 - MCBXFB Tooling - ASSEMBLY AND ROTATION TOOL

**HL-LHC Nonconformity Report**  
Chopping of Resin in Inner and Outer Coils

Work Package: WP3 MCBXF2 Equipment: MCBXFBP1e (v.3) 1601 - MCBXFB PROTOTYPE 1

Calibration: CIEMAT Person: Inspector

During visual inspection to the coils before starting the magnet assembly some chopping of the resin was detected in several coils (ICL, ICA, OCA and OCC) in different areas. Below some examples:

Figure 1.001 in ICA OCA

Figure 1.002 in ICA OCA

- QA/QC structure is ready in EDMS. All drawings and fabrication records from the prototypes are accessible
- Detailed assembly procedures optimised during the prototype construction phase as well as hundreds of pictures are available
- MIP document ready



# Lessons learned and Conclusion

- The final coil geometry needs to be precisely measured to provide the required inputs for shimming calculation.
- The fabrication quality and accuracy of the shims is a key point for final magnet performance and field quality.
- The validation of the contact surface between coils using FUJI sensitive paper is a crucial step during assembly.
- Coil preload at room temperature needs to be validated by strain gauge measurements.
- The fabrication and test of 2 MCBXFB prototypes has proved a reproducibility of the magnet performance.
- Both prototypes were assembled several times to optimise their performance.
- Field quality is under control and does not pose significant challenges.
- Both prototypes went through more than 150 quenches each, proving the robustness of the magnet design.
- A fine tuning of the inner coils geometry will be implemented on the next assembly to try to improve magnet performance when changing the torque orientation (see Ezio's presentation).
- QA/QC, MOP, MIP documentation ready.
- Many pictures illustrating each fabrication step are available.
- The assembly of the next MCBXFB01 at CERN will be an unique occasion for ELYTT crew to get trained with a real magnet.
- I encourage ELYTT management to organise a visit to our laboratory for one of their technical staff during the assembly of the next magnet foreseen from last week of May onwards.



## Acknowledgements to:

Pablo Abramian, Cristóbal Alcázar, Jesús Calero, Manuel Domínguez, Jesus Angel García Matos, Luis Garcia-Tabarés, Luis González, Pablo Gómez, Jesús Jiménez, Teresa Martínez, Carla Martins, Javier Munilla, José Antonio Pardo, José Manuel Pérez, Víctor Sanz, Sebastián Soto, Pablo Sobrino, Fernando Toral from CIEMAT  
Beatriz Almeida, Marta Bajko, Isabel Bejar, Nicolas Bourcey, Raphael Bouvier, Cristina Castro, Ruth Diaz, Hugues Dupont, Nicolas Eyraud, Elena Fernandez, Salvador Ferradas, Paolo Fessia, Bertrand Fornes, Jean-Luc Guyon, Hector Garcia, Michael Guinchard, Lucio Fiscarelli. Gregory Maury, Jacky Mazet, Sylvain Mugnier, Francois-Olivier Pincot, Ezio Todesco, Gerard Willering from CERN ..... & many others

## Thank you for your attention.

