Status of nested corrector activities at CIEMAT

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12th HL-LHC Collaboration Meeting – 19th Sept 2022

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- Series production
- Reassembly of second short prototype: MCBXFBP2c
- First long prototype magnet MCBXFAP1
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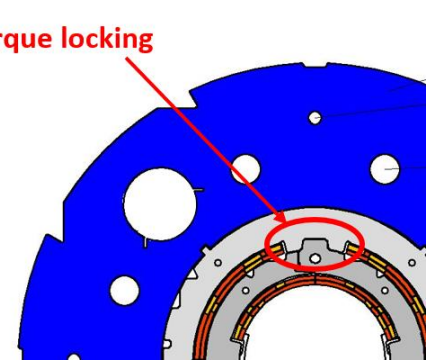
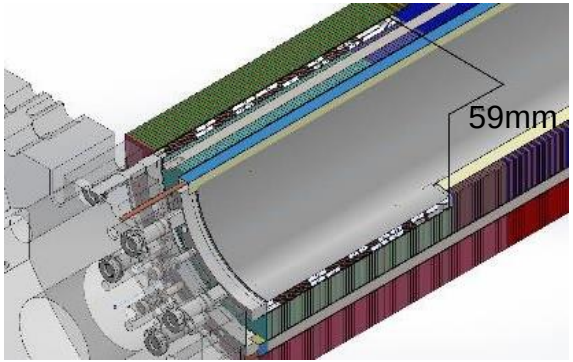
One year ago: executive summary

- After a fine-tuning of the design, the first series B-type magnet (MCBXFB01) was the first one to **fulfil all the specifications**.
- The **series contract** was awarded to **Elytt Energy**. The first B-type coil was produced in September 2021.
- The winding of the **first A-type coil** had just started at CIEMAT.

Reminder: design fine-tuning (MCBXFB01)

- Torque locking is only possible along the OD pole window (828 mm long). ID pole window of magnet prototypes was 946 mm long => 59 mm at each side **without torque locking.**
- MCBXFB01 inner coil length was **shortened by 118 mm** to **reduce the unlocked length** at coil ends.
- In addition, **endspacers** legs were enlarged to increase the rigidity at the transition from the straight section to the coil heads.





MCBXF production strategy

Based on MCBXFB01 results, it was decided to:

- Manufacture the rest of the **B-type magnets** for the series in Elytt according to the same fine-tuning of the design.
- Reassemble the second prototype with new shorter inner coils produced by Elytt: **MCBXFBP2c**.
- Apply the design fine-tuning to the **A-type magnets**, starting with the prototype being developed at CIEMAT.
- Implement some improvements to ease the **magnet assembly**:
  - New distribution of collar packages
  - Re-design endplates

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MCBXF series contract

- Contract signed with **Elytt Energy** at **March 2021**: delivery of 6 long (A) and 11 short (B) MCBXF magnets.
- All **documents** and **templates** (technical specification, acceptance criteria, manufacturing and inspection plan, quality documentation…) have been agreed with CERN.
- CIEMAT has prepared detailed **procedures** with pictures for each step of production.
- **CIEMAT staff** has been at Elytt premises during six months for know-how transfer on coil production. Daily support for production follow-up, questions and incident solving. **CERN and CIEMAT staff** has supported the first magnet assembly.
- CIEMAT is supporting Elytt to contact **suppliers** for components, tooling and materials.
- **In-kind contribution** of some components: end-spacers, collars (CIEMAT), cable, steel for collars, iron plates, magnetic test bench and magnet lifting tooling (CERN).

MCBXF series: quality assurance

- **Quality controls** of each step of production are defined in the manufacturing and inspection plan (MIP).
- **Traceability** is guaranteed thanks to documentation stored in MTF.

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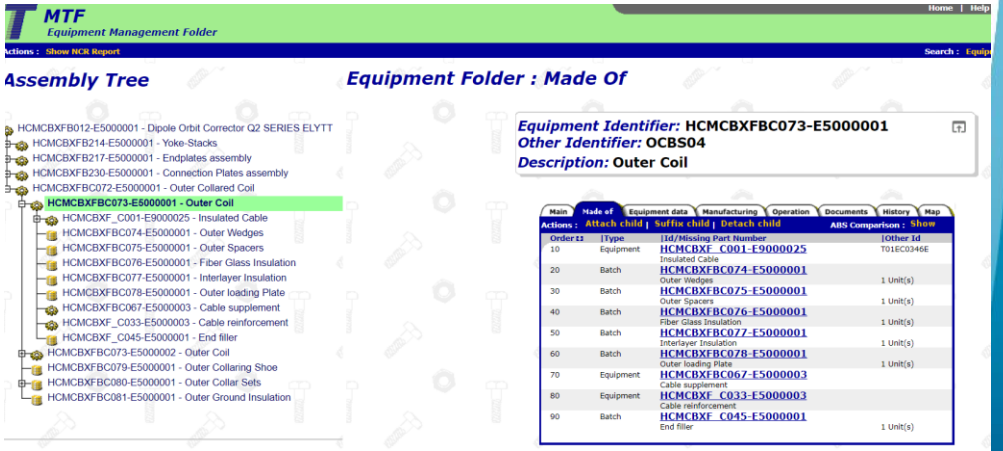
EDMS NO.	REV.	VALIDITY
2335157	0.0	DRAFT

REFERENCE: LHC-MCBXFB-FP-0001

HL-HC: Quality
Manufacturing and Inspection Plan – MCBXFB Coil

Prepared by: R. Diaz Vez, J.C. Perez (CERN) **Date:** 24/02/2020	**Project:** HL-LHC	**Executing Entity:** TBC **Supplier:** CIEMAT	**Item Eq. Code:** HCMCBXFBC002 HCMCBXFBC006	**Asset Code (LHC Part Identifier):** **HCMCBXFBC002-E90000 _ _** **HCMCBXFBC006-E90000 _ _**
Verified by: _____ **Date:** _____				
Approved by: _____ **Date:** _____	**Work Package:** WP03	**Client:** CERN (HL-LHC WP03)	**Item description:** MCBXFB OUTER COIL OCBS11 (HCMCBXFBC073-E5000009)	**EDMS Report No:**

No	ACTIVITY / OPÉRATION	APPL. STANDARDS / NORMES APPL.	APPLICABLE DOCUMENTS / DOCUMENTS APPLICABLES	REV. DOC.	INSPECTION / CONTRÔLE								NOTES / COMMENTAIRES / REPORTS
					EXECUTING ENTITY		SUPPLIER		CLIENT		3RD PARTY / SURVEILLANCE		
					Code	Signature/Date	Code	Signature/Date	Code	Signature/Date	Code	Signature/Date	
A	PRODUCTION START-UP												
A.1	Magnet Procedures version verification		All Magnet procedures		IN	15-06-2022							Check if all applicable procedures are in the last version available
A.2	Production start-up				IH	15-06-2022	H	28-06-2022	N				Notification by email



MCBXF series: Elytt Energy facilities

- Two closed **clean areas** with controlled humidity and temperature:
  - **Coil production**: two lines (winding machine + binder mould + impregnation), component preparation (preforming ground insulation and collaring shoes, collar package assembly, collared coil assembly).
  - **Magnet assembly**: collaring press, yoke assembly, magnetic measurements and final electrical measurements.

Hall with two clean areas: coils (left) and magnets (right)

Coil production area

Magnet assembly area

Courtesy: Elytt Energy

MCBXF series: coil production

- Delicate production process with a **long learning curve**.
- Three inner coils and one outer coil are in quarantine because of **faulty impregnation**.
- Two inner coils were used for reassembly of second prototype (MCBXFBP2c) to **validate** the production techniques.
- Only B-type coils up to now. **A-type coil** production is being set-up.

Courtesy: Elytt Energy

Coil winding

Binder curing

Impregnation mould assembly

MCBXF series: first magnet assembly MCBXFB02

- CERN and CIEMAT staff have provided in-site support for the assembly of the first B-type magnet (Summer 2022).

Current lead routing

Courtesy: Elytt Energy

Magnet with iron yoke

More info at parallel session next Wednesday morning (F. Toral)

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Reassembly of second short prototype: MCBXFBP2c

- The performance of the second prototype in combined powering was not so good as expected (Summer 2020).
- It was decided to replace the inner coils with ones with shorter pole window and extended endspacer legs (same design than MCBXFB01).
- The **objective** is three-fold:
  - To **improve P2** magnet performance
  - To confirm the effectiveness of the **design fine-tuning**
  - As the two **inner coils** have been produced at Elytt, its assembly will provide an “early” qualification of the **series coil fabrication process**
- The same outer coils used during MCBXFBP2b assembly have been assembled in MCBXFBP2c.

Magnet reassembly at CERN (927 lab)

- Some **improvements** are implemented to ease the **magnet assembly:**
  - **Yoke rods** assembled with nuts embedded in end plate
  - **Collar packages** redistributed to optimise collaring assembly transitions
- **New parts** necessary for the reassembly were produced at Ciemat: ground insulation, collaring shoes, support structure (endplates, pushers..):

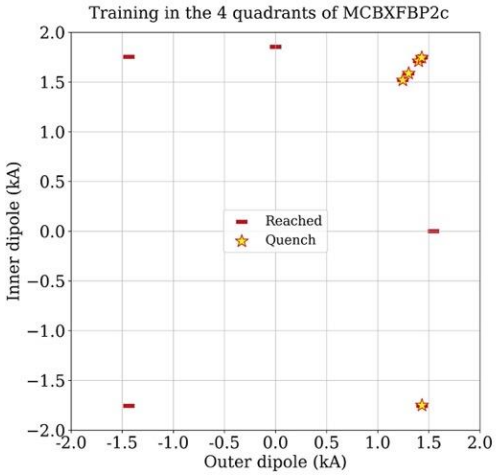
Collaring shoes assembly

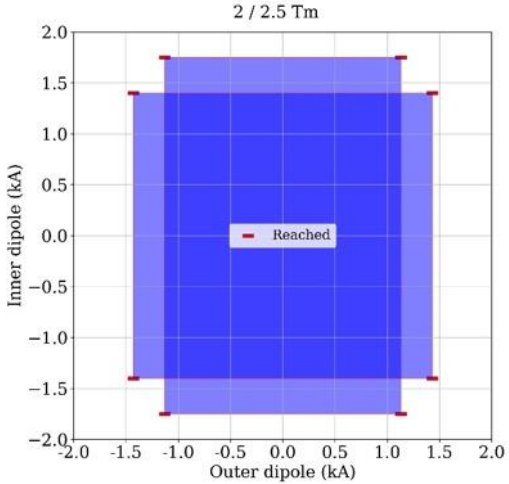
Inner dipole at collaring press

Problem with threaded rods in MCBXFB01

Test results

- No quenches in **standalone** powering up to ultimate current.
- **Only 5 quenches** in the whole campaign vs. **85** in the previous assembly MCBXFBP2b.
- No quenches after the **thermal cycle**, even with 250 cycles as a first **endurance** test.
- Magnetic **field quality** is within requirements.
- Specifications are fulfilled: **spectacular improvement**.





Required operational range at 7 TeV

MCBXBP2c at SM18

More info at parallel session next Wednesday morning (J. C. Pérez)

Courtesy: S. Ferradas

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MCBXFA prototype

- This is the **longest** magnet ever produced at CIEMAT.
- The coil production **tooling** was modified to produce inner coils with shorter pole window, like B-type magnets.
- We use the same **fabrication techniques** that are being used for the B-type coils.
- The prototype **components** are being produced at CIEMAT:
  - Three finished inner coils.
  - First outer coil impregnated. Outer layer of second coil is being wound.
  - Ground insulation preforming, collaring shoes and collar packages ongoing.
  - Tooling: only the assembly magnet tooling is not finished yet.
  - Iron yoke close to be finished.
  - Endplates and connection plate finished.
- **Assembly** and **tests** will be done at CERN in November.

MCBXFA prototype: inner dipole coils (I)

Inner layer winding

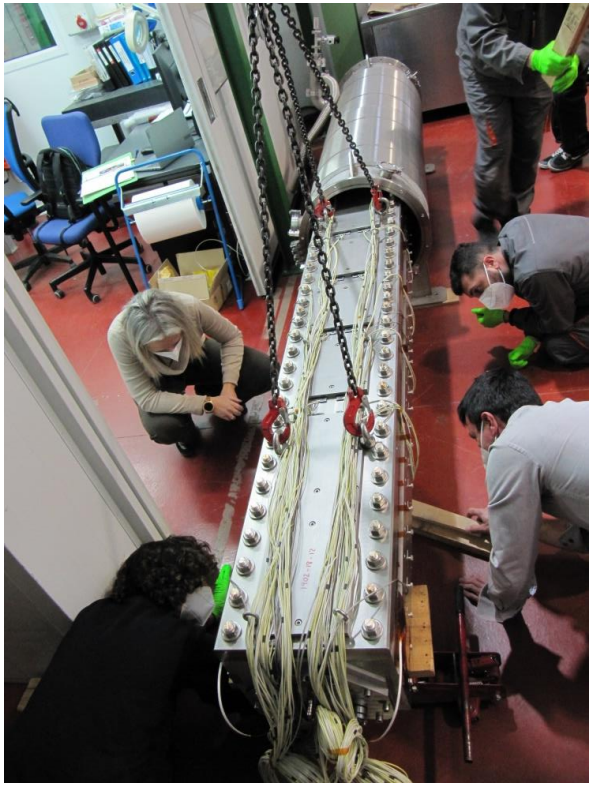
Binder mould assembly

- No significant difficulties for winding.
- Assembly of binder mould in one day is challenging.

MCBXFA prototype: inner dipole coils (II)

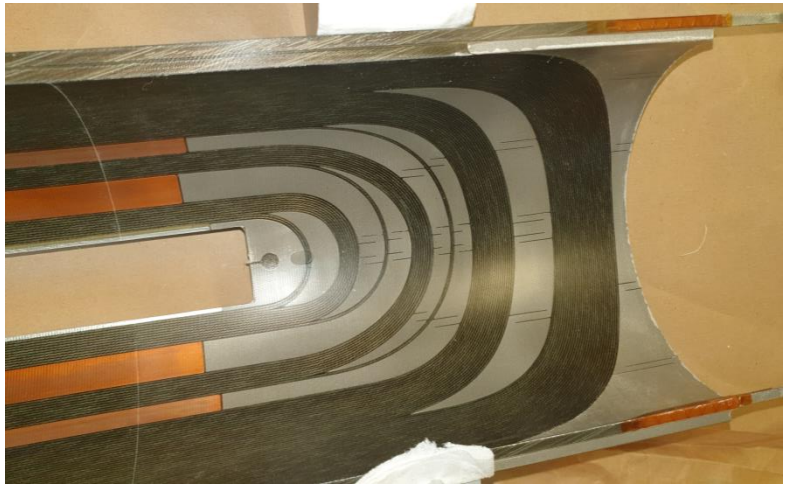
Inner coil impregnation

- Assembly of impregnation mould is delicate because of the tight tolerances for such a long coil.
- Long time for resin injection. Ongoing improvements.



Introduction of impregnation mould into vacuum chamber

MCBXFA prototype: inner dipole coils (III)



First finished inner coil

MCBXFA prototype: outer dipole coils

First layer winding

Impregnation mould assembly

- Difficult winding of inner layer (105 turns).
- Challenging assembly of impregnation mould.
- Very slow injection of resin.

Conclusions

- A fine-tuning of the design was **successfully** implemented in the first series short magnet MCBXFB01.
- **Series** fabrication contract was awarded to **Elytt Energy**.
- This design fine-tuning was implemented to **reassemble** the second prototype with inner dipole coils produced by Elytt. Powering testS validated the fine-tuning and Elytt coils.
- The components of the **long prototype** MCBXFAP1 are being manufactured at CIEMAT. The magnet assembly will be done at CERN in November.

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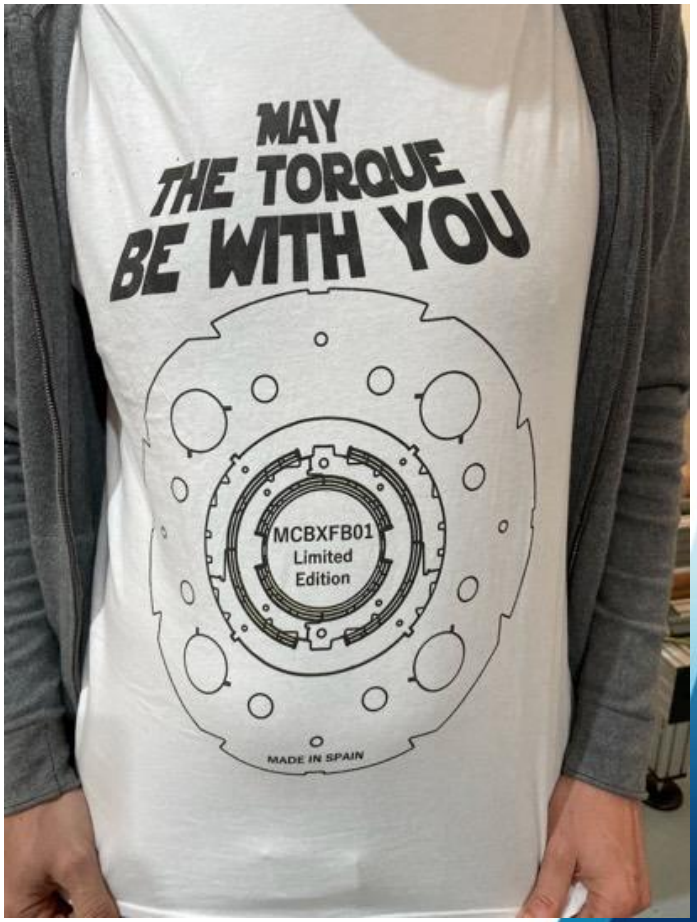

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