Cold mass development CERN

H. Prin

Summary of the work achieved with:

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9th HL-LHC Collaboration Meeting
Fermilab, USA – 14-16 October 2019

Ouline

LMQXFB cold mass for the Q2A and B

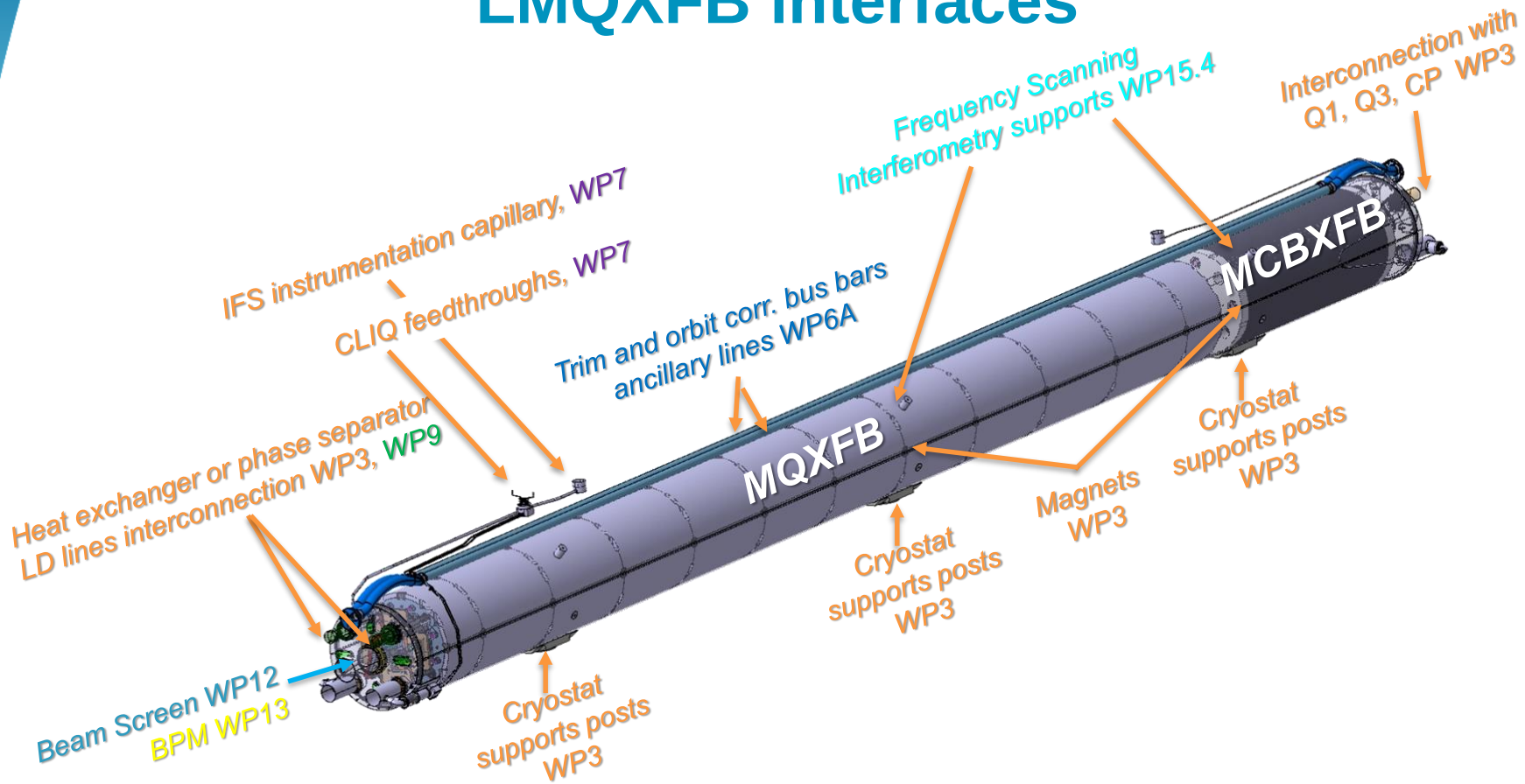
- Interfaces
- Design
- Main Components Status
- Documentation

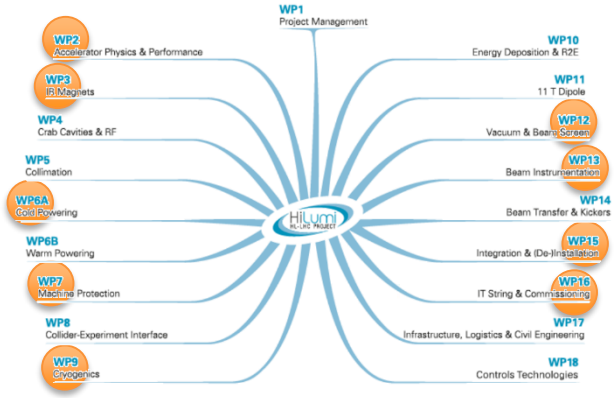
LMQXFBT cold mass to test the prototype MQXFB

- Review of the Ongoing Assembly
- First Results

Summary

LMQXFB interfaces

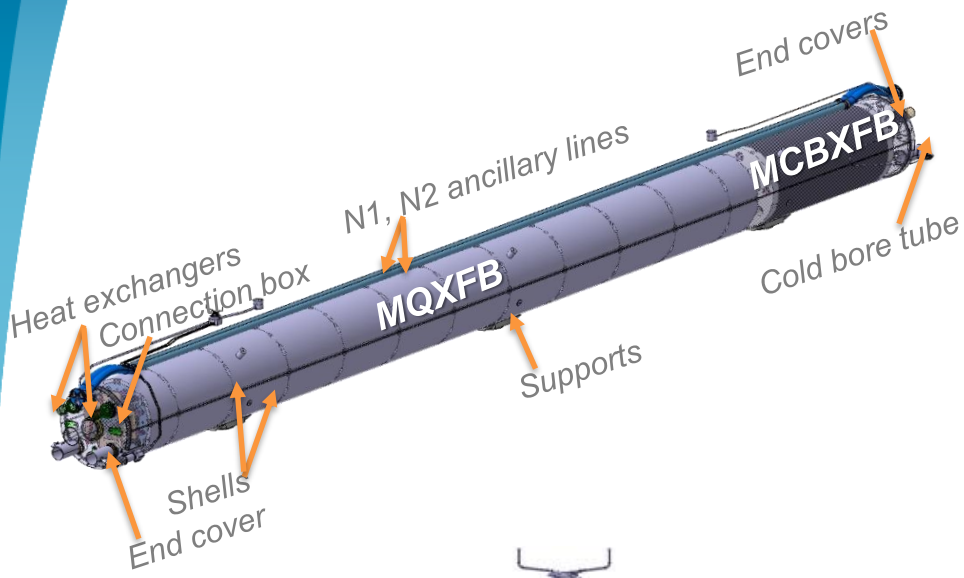




Close collaboration with many other work packages:

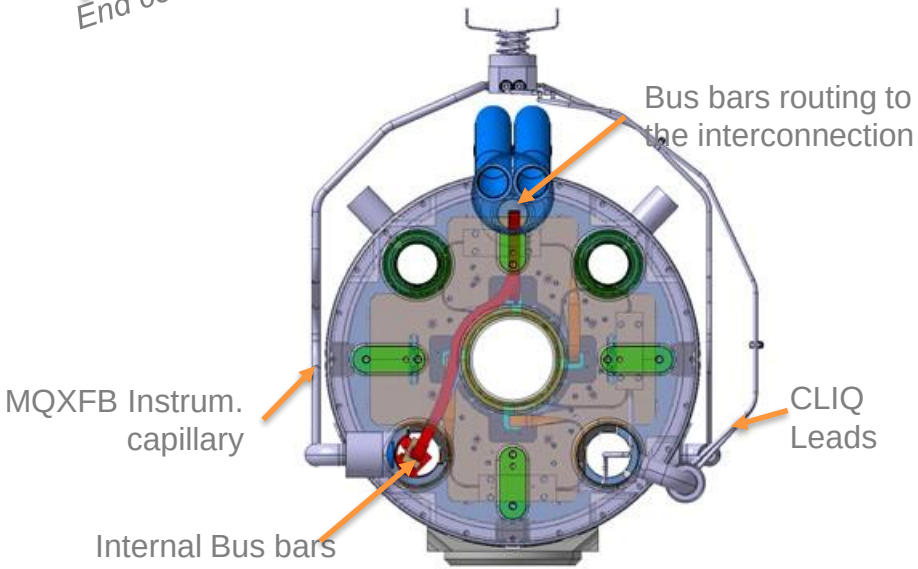
- WP3: weekly meeting at CERN, video-conferences with US-LARP almost once every three weeks
- WP6A, WP7: Magnet Circuit Forum (MCF) once every two weeks
- WP9, WP12, WP13: Informal meetings when necessary
- WP2, 15: HL-LHC Integration meeting , WGA…

LMQXFB design

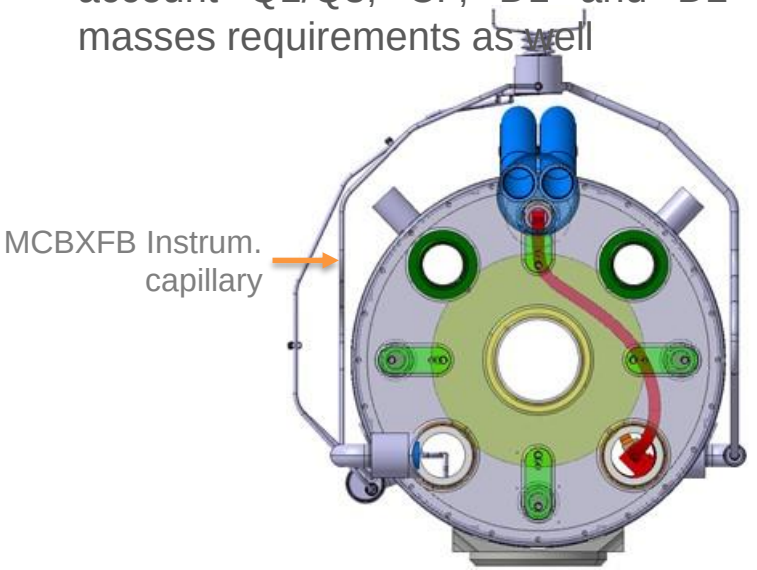


Common design to accommodate Q2A and Q2B slots in the IR1&5

- Spare policy efficiency
- Envelop and interfaces symmetry to the longitudinal vertical plane
- Envelop and interfaces symmetry to the transverse vertical plane to accommodate a single vacuum vessel design
- Components standardization taking into account Q1/Q3, CP, D1 and D2 cold masses requirements as well



LMQXFB seen from the MQXFB quadrupole connection side

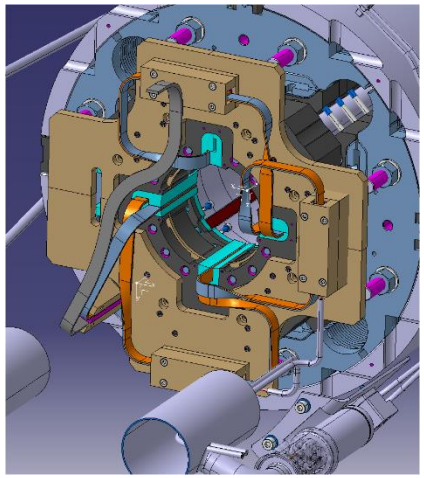


LMQXFB seen from the MCBXFB corrector connection side

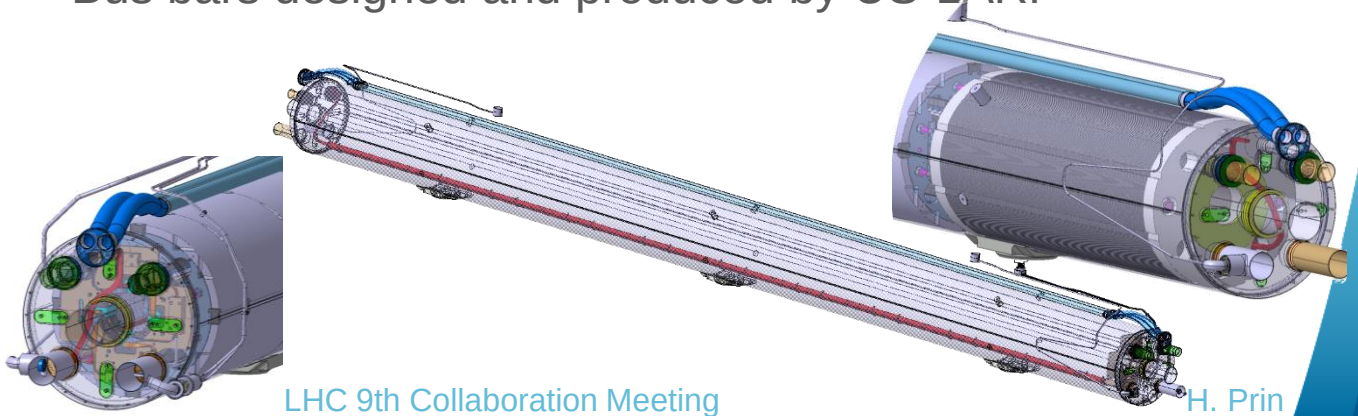
Latest and Ongoing Design Progresses 1/2

- Pole order engineering change request LHC-LMQXFE-EC-0001 now merged with additional ECRs in a common document to provide a single reference to the modifications and to make it compatible with TDR1.0 *(see Felix's talk)*
- Protection scheme and V-Taps distribution according to discussions with WP7, MPE, MP3 and the MCF
- Cryogenics instrumentation distribution in the triplet string in collaboration with WP9

⇨ *Summarised in drawing **LHCLMQXF_E0001** from Q1 to Q3*

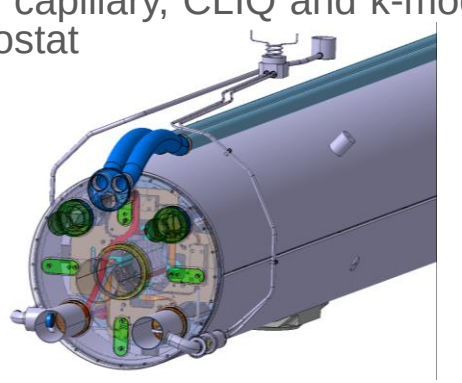


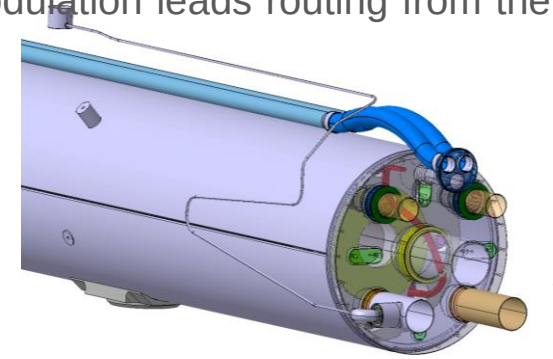
- Splice box redesign to standardise tooling and procedures (see slide 10 on LMQXFBT)
- Bus bars designed and produced by US-LARP



Latest and Ongoing Design Progresses 2/2

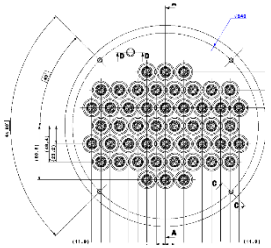
- IFS capillary, CLIQ and k-modulation leads routing from the cold mass interface outside the cryostat



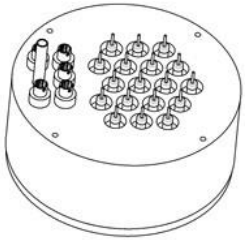


See Delio's talk for the routing inside the cryostat

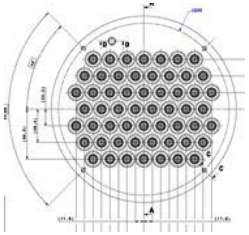
- IFS boxes design and standardisation with the CP, D1 and D2 cold masses



48 pins + Temp
Q1/Q3
Q2 quads
D2 dipole

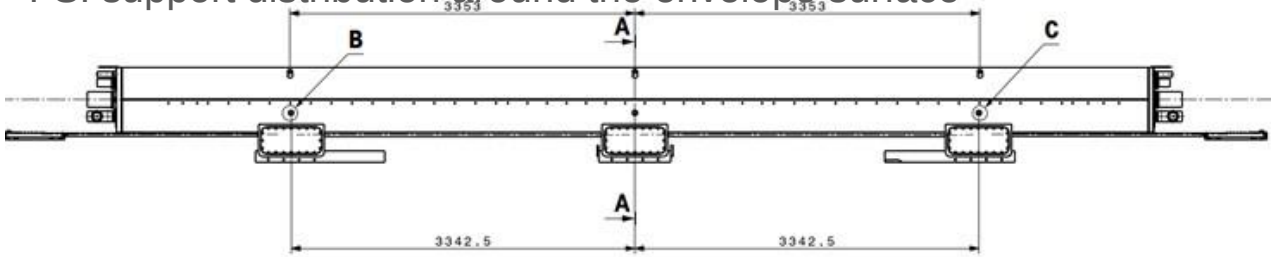


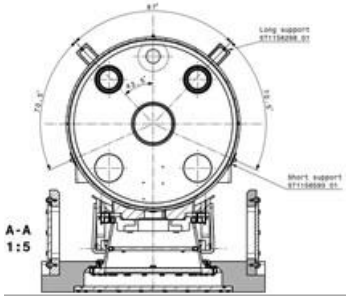
20 pins + Temp
Q2 corr.
D1



56 pins
D2 corr.

- FSI support distribution around the envelope surface





- Interfaces tolerance drawing based on ISO standards
- Ongoing work on the sc cable splicing (flat/flat and flat/round)

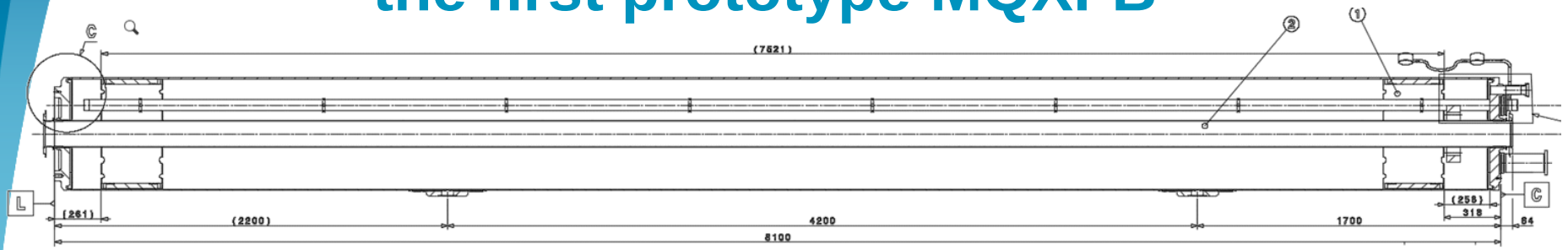
HL-LHC Cold Masses
Main Components Status

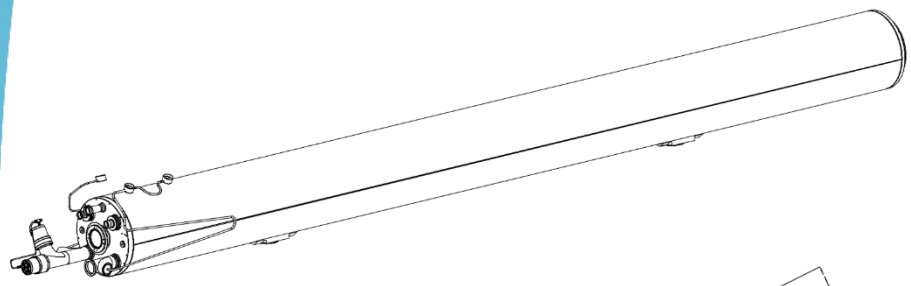
	Drawing Nb	Ordered Qtty	Delivered Qtty	Remarks
Plates	1.4 x 11m Q1/Q3 1.4 x 10m Q2, D2Dip 1.4 x 6.5m CP, D2Corr	26 10+39 38	**26** **10**	 Mar 20 Mar 20
Shells	LHCLMQXF_S0001 Q2, D2D LHCLMCXF_S0001 CP, D2C	10+37 32	**10**	First shell 4 month after plates delivery :Last shells 3 years later
End covers	LHCLMQXF_S0002 Q+CP LHCLMBXF_S0002 D1 LHCLMBRDS0002 D2 CS LHCLMBRDS0004 D2 LS	4+2+21+39 7+7 1+6 1+6	4	2 pairs for the Q1 and Q2 first cold masses Nov 19 Jun 20 Oct 20
Supports	LHCLMQXF_S0007	84	84	
Heat exchanger tubes	LHCLMQXF_S0008 Q2 LHCLMQXF_S0022 Q1/3 LHCLMCXF_S0008 CP LHCLMBXF_S0008 D1	30 30 12 14	**30** **30** **12** **14**	SST/Cu transitions machined, Soldering starting on week 42, BE welding to the tubes will follow
Cold bore tubes	LHCLMQXF_S0009 Q2 LHCLMQXF_S0025 Q1/3 LHCLMCXF_S0008 CP LHCLMBXF_S0008 D1	13 15 8 8	**2** **2** **1**	Tubes will be delivered in 6 batches from Nov. 19 till Nov. 21 To be insulated at CERN by the LMF busbars team
Bellows	LHCLMQXF_S0014 Quads LHCLMCXF_S0010 CP-D1 8 references	12 X int 6 X int 500		16 units in Nov 19 (for cold masses used in the string) 6 units in Nov 19 34 units in Mar 20 (see Delio's presentation) 116 units in July 20 350 units in Nov 20
Cover Flanges (IFS feedthroughs)	LHCLMQXF_E0020 20pins LHCLMBRDE0078 48pins LHCLMBRDE0031 56pins	23 40 7		**To be launched** MS in Nov 19 for a FC in Jun 20 Estimated delivery time ~32w

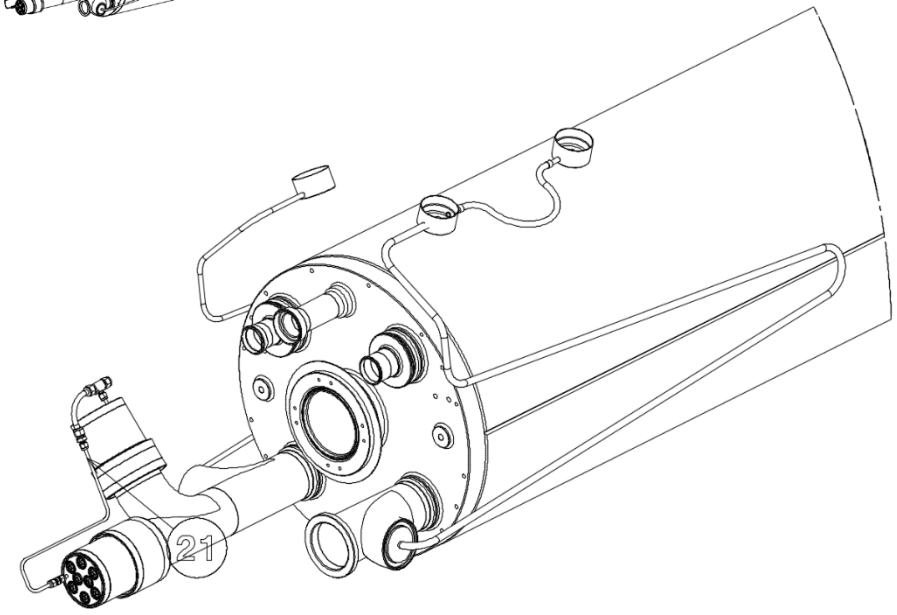
LMQXFB Documentation

- **Flowchart** diagram drafted and presented to the Working Group on Alignment (WGA).
- Associated **MIP** (Manufacturing and Inspection Plane) under construction.
- Many **Assembly Procedures** can be adapted from other cold masses assembly (main dipole, insertion quad. CM, 11T CM…).
- Most of the specific **Assembly Procedures** are establish and developed during the LMQXFBT assembly. This cold mass is only equipped with the quadrupole magnet. The MCBXFB orbit corrector relative alignment cannot be assessed now.
- **MTF** (Manufacturing and Test Folder) chosen tool to **store** and **distribute** the control reports

LMQXBT cold mass to test the first prototype MQXFB



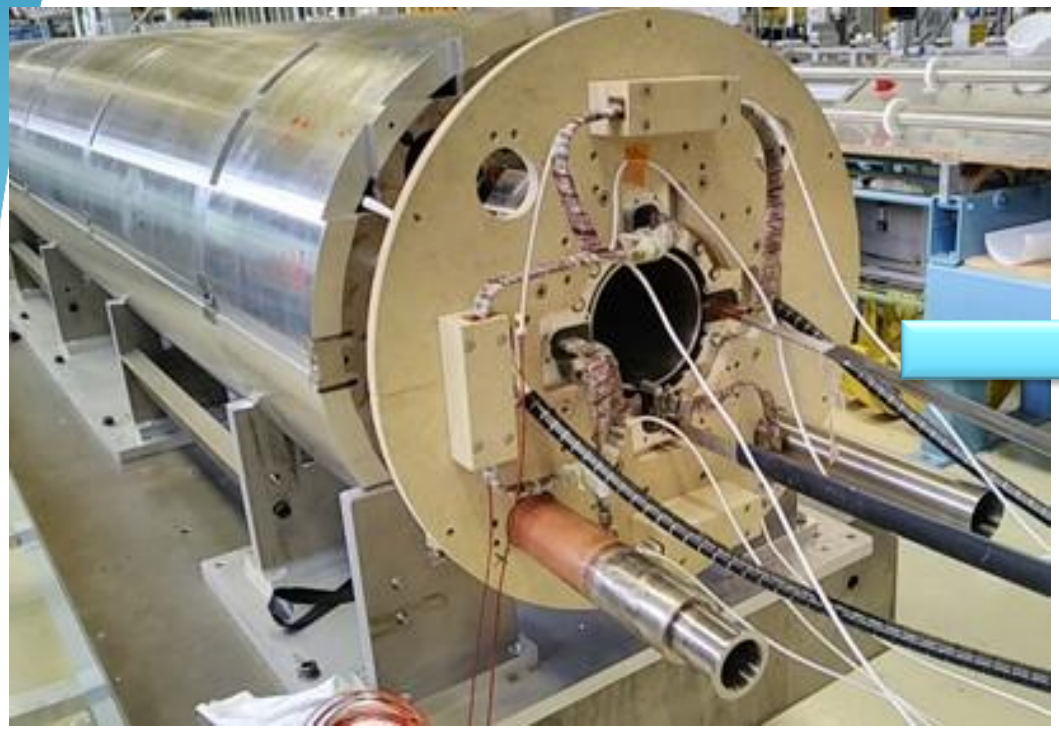


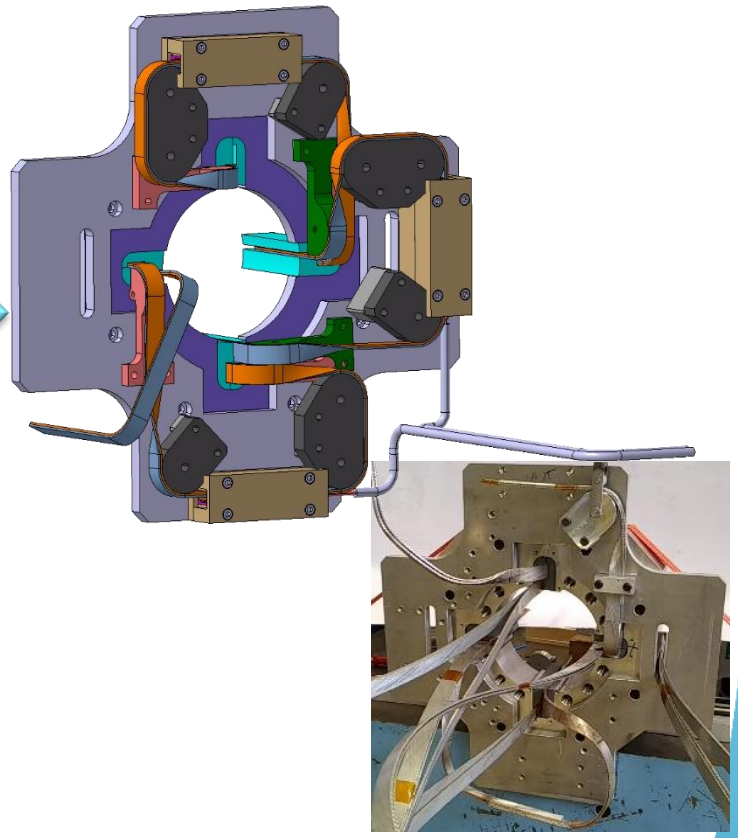


Scope of the project:

- Providing a leak tight envelope surrounding the MQXFB prototype magnet to perform **cold test horizontally**.
- Providing **mechanical inertia**, rigidity and alignment in between aluminium shells,
- Fitting and integrating inside an **existing spare vacuum vessel.**
- Connecting to the **existing test bench in SM18.**
- Enabling **magnetic measurements** at cold, eventually with **beam screen** inserted.
- Housing **electrical protection and mechanical instrumentation** and provide interfaces to route the signals from 1.9K to RT.

LMQXFBT Cold Mass Assembly
MQXFB splicing





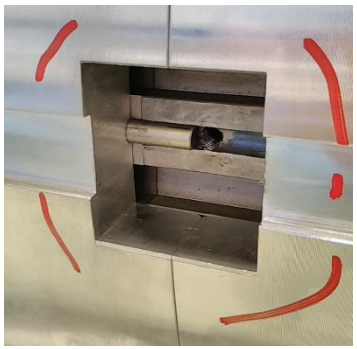
Procedure, tooling and components used for the MQXFS

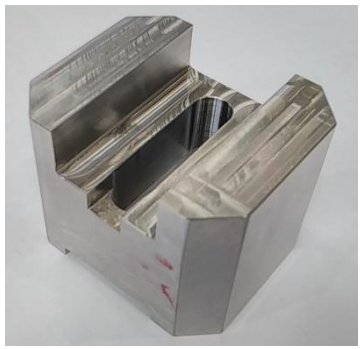
Ongoing work to:

- Increase the distance between the cables
- Increase the distance to the HX tubes
- Increase the stiffness along the routing
- Standardize the tooling and procedures

LMQXFBT Cold Mass Assembly

Alignment blocks and backing strip assembly





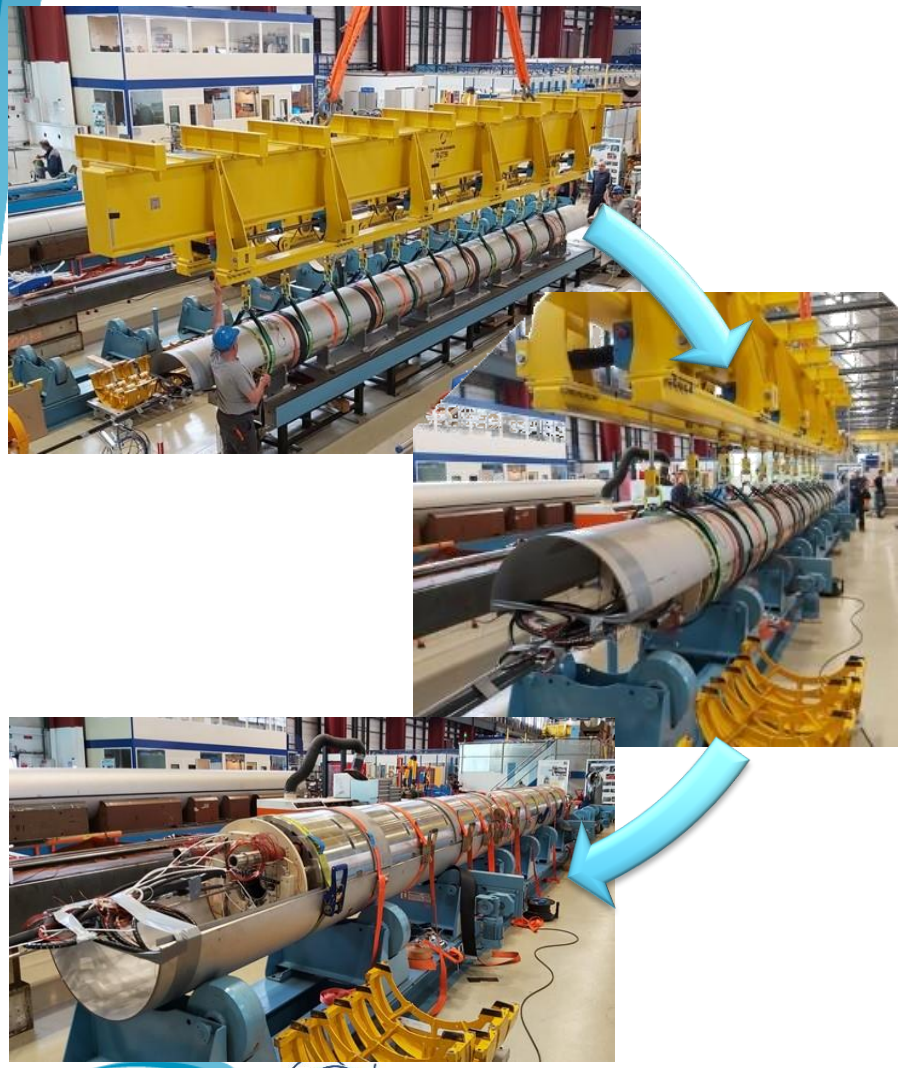
One issue over the full length, a pin was not properly inserted ⇨ the block had to be machined to fit the default.

Upper shell installation and tack welding to the alignment blocks

n x 30 x 228

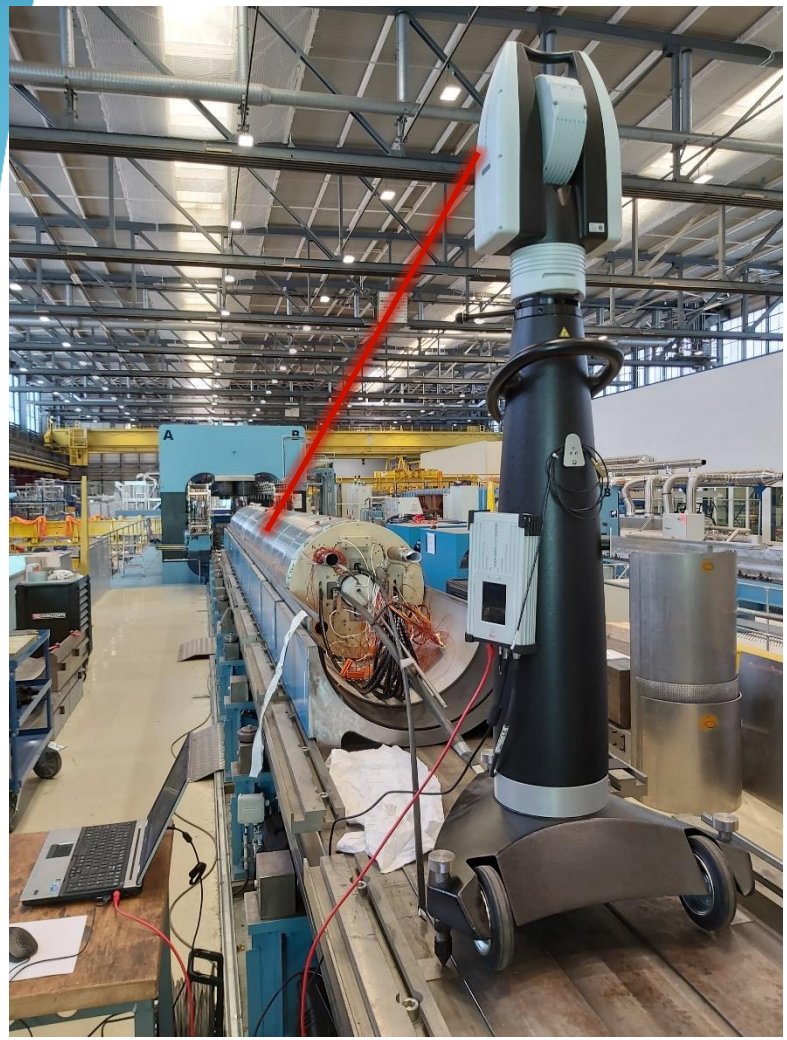
LMQXFBT Cold Mass Assembly

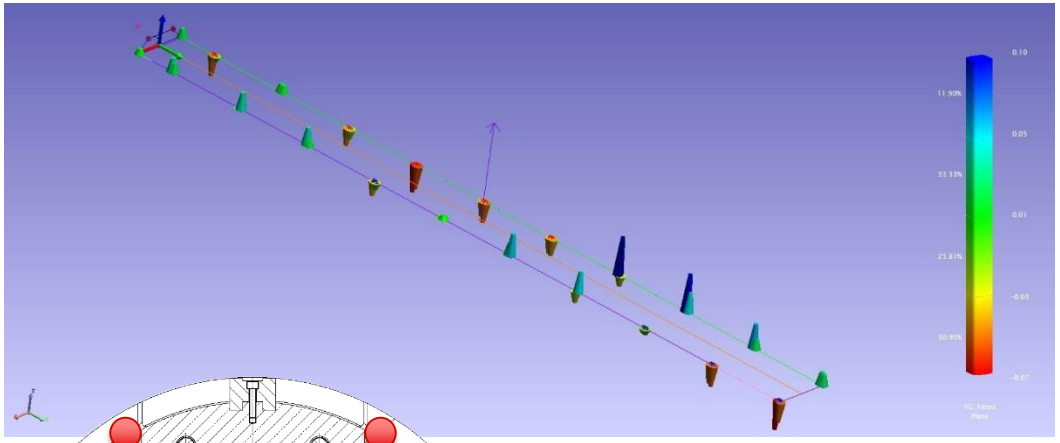
Transfer to the rotation bench and rollover

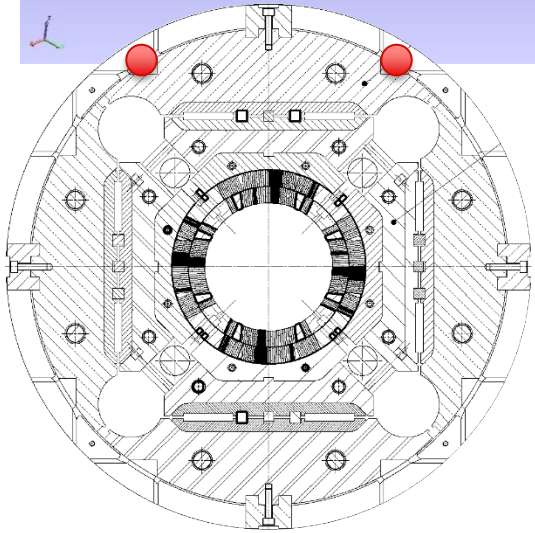


Transfer to the welding press conveyor

LMQXFBT Cold Mass Assembly
Geometrical and alignment measurements







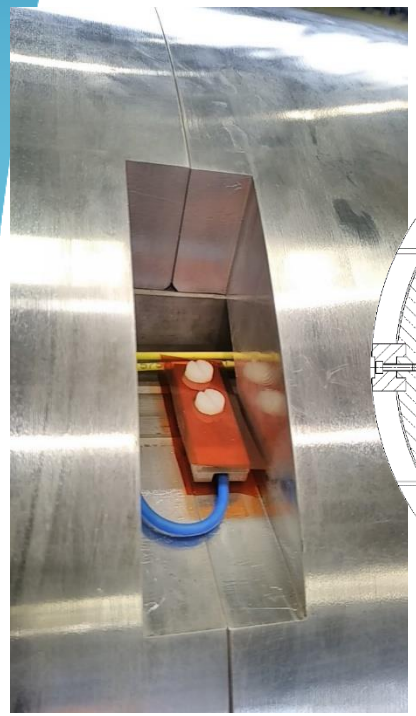
All Vectors Summary: Vector Group Analysis::VG: Fitted Plane			
Statistic	dX (mm)	dZ (mm)	MagXZ (mm)
Min	-0.00	-0.07	-0.07
Max	0.00	0.10	0.10
Average	0.00	-0.00	-0.00
StdDev from Avg	0.00	0.04	0.04
StdDev from Zero	0.00	0.04	0.04
RMS	0.00	0.04	0.04
Tol Range			-0.10
			0.10
In Tol			42 (100.0%)
Out Tol			0 (0.0%)
Count	42		
Projection mode: Surface to Offset Point			

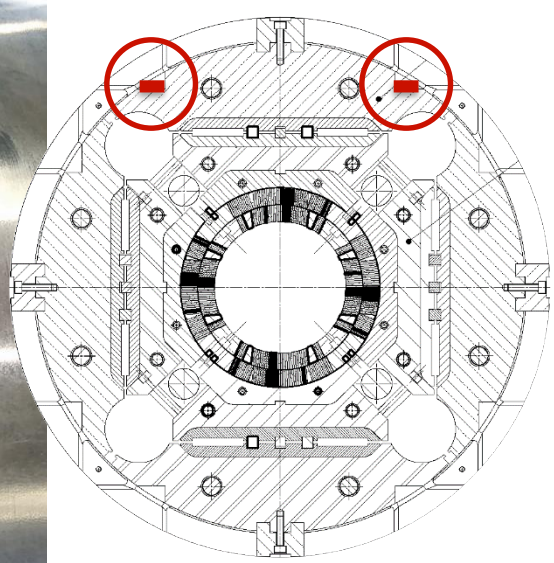
Excellent alignment kept from the initial assembly bench up to the press conveyor cradles

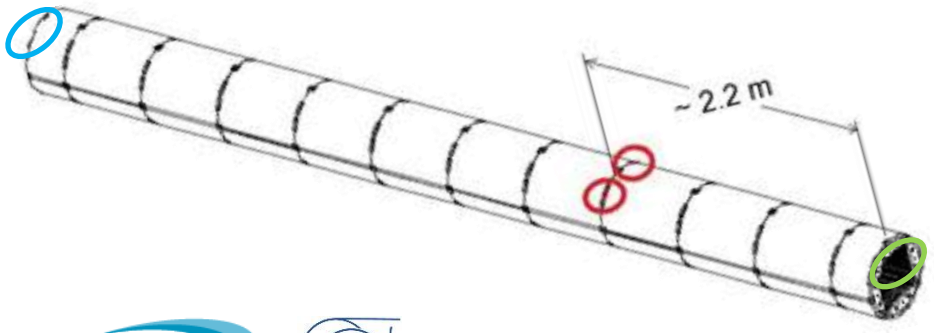
⇨ the shell inertia is transmitted to the magnet, it prevents twist and longitudinal misalignment

LMQXFBT Cold Mass Assembly
Thermometers and Cryo-Heaters Installation

On the magnet surface series like



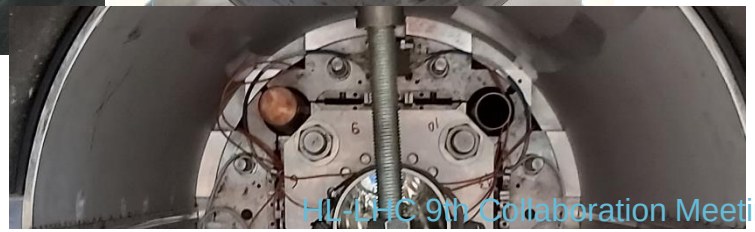




On the magnet surface thermalized in the extremities (for cold test)

Inside the end cover (series like)

LMQXFBT Cold Mass Assembly
Upper shell installation, alignment and tack welding

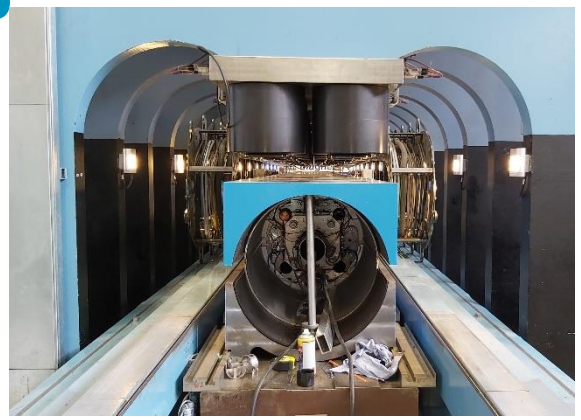


Restrains in the extremities to contain the welding shrinkage need to be improved. Spare aluminum shells with sharp corners will be adapted and used.

Molykote?

Excellent fitting between the stainless steel shells and the aluminum one

LMQXFBT Cold Mass Assembly Longitudinal Welding



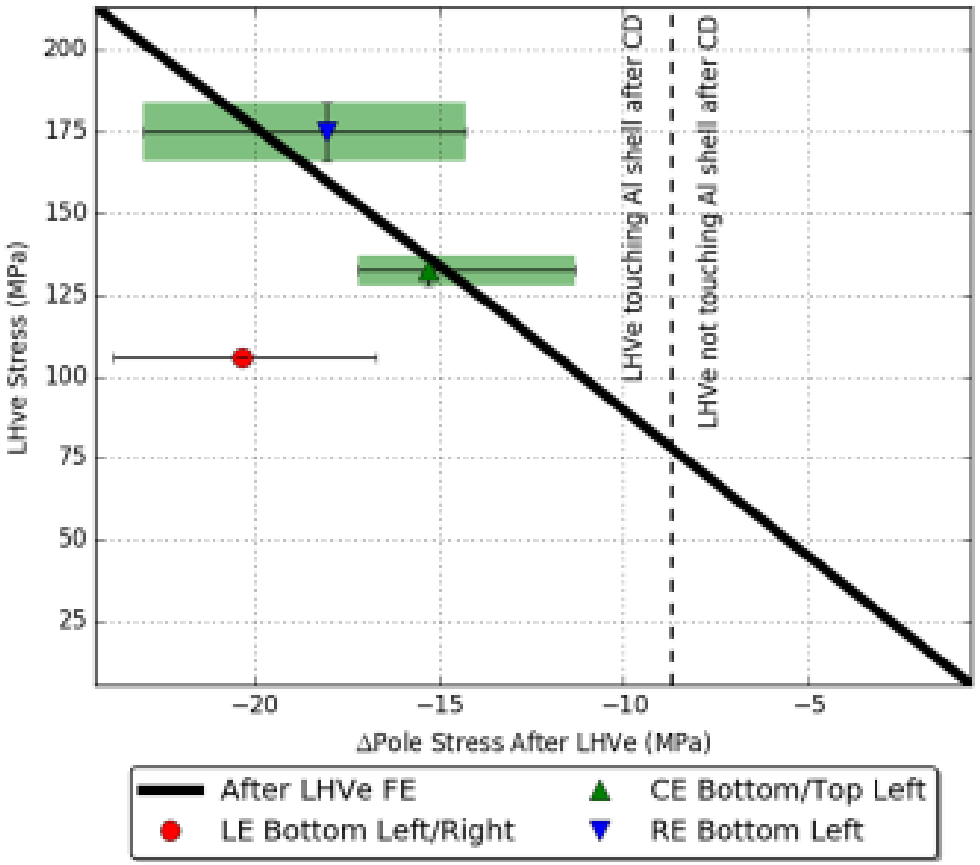
Welding without additional pressure than the one given by the cradles weight

ROOT GAP	B	START	TIG	MIG		SHRINK
	POSITION		1	1	2	
2.2	1	40.3	39.7	39.47	39.45	0.85
3	2	35	34.37	34.09	33.85	1.15
2.8	3	31.5	30.94	30.45	30.21	1.29
2.2	4	33.6	33.25	32.91	32.73	0.87
1.6	5	37.5	36.63	35.95	35.76	1.74
ROOT GAP	A	START	TIG	MIG		SHRINK
	POSITION		1	1	2	
2.5	1	41.3	40.3	39.9	39.84	1.46
2.9	2	37.7	36.92	36.88	36.41	1.29
3.3	3	35.8	35.23	34.88	34.7	1.1
3.8	4	36.8	36.31	36.08	35.8	1
2.6	5	34	33.34	32.68	32.3	1.7

Shell Azimuthal and Coils Induced Stress after Welding

Shell welding

- The measured LHVe stress after welding ranging between 110 Mpa-175 Mpa
  - Only 5 out of 12 measuring points
- The measured delta coil pole stress is around -18 Mpa
  - Consistent with the computation
- According to the model during cooldown around 80 Mpa is lost from the LHVe
  - The LHVe should be in contact if one has more than that -> contact ensured

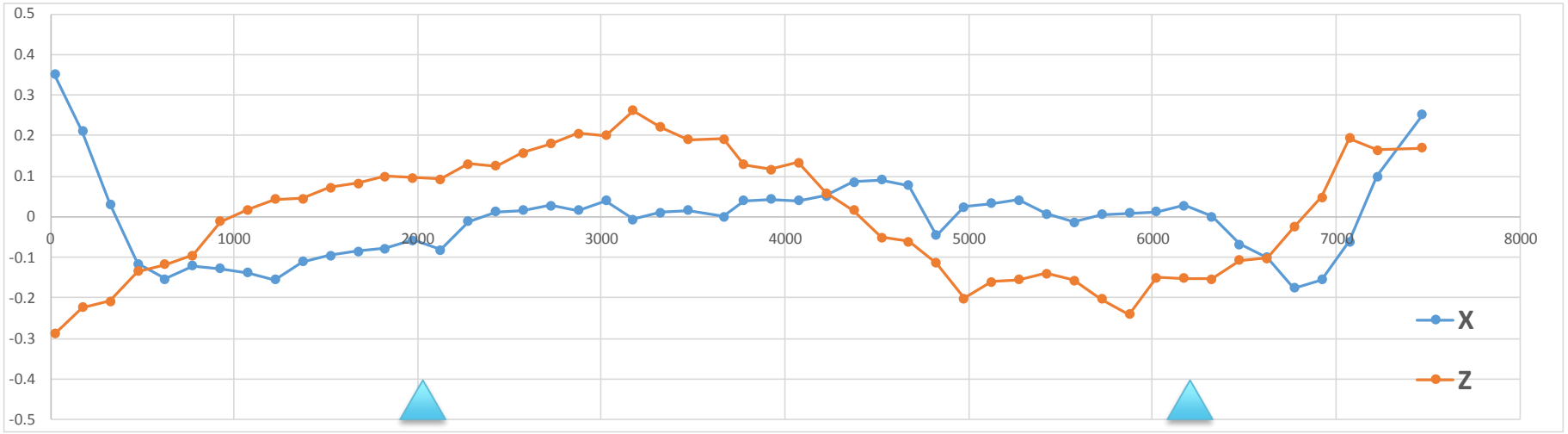


Courtesy of EelisTapani Talaka

Cold Mass after longitudinal welding
Transfer to the “finishing area”, Geom Measurements

Software developments and debugging between LabVIEW and Spatial Analyser.
Cold mass automatic generation of the travellers according to the measured values.

LMQXFBT Cold Mass Assembly Geometrical Measurements



Where the cold bore tube is supported by the “pions”:

$X \epsilon [-0.17 , 0.09]$ $\sigma_x = 0.068mm$

$Z \epsilon [-0.24 , 0.26]$ $\sigma_z = 0.140mm$

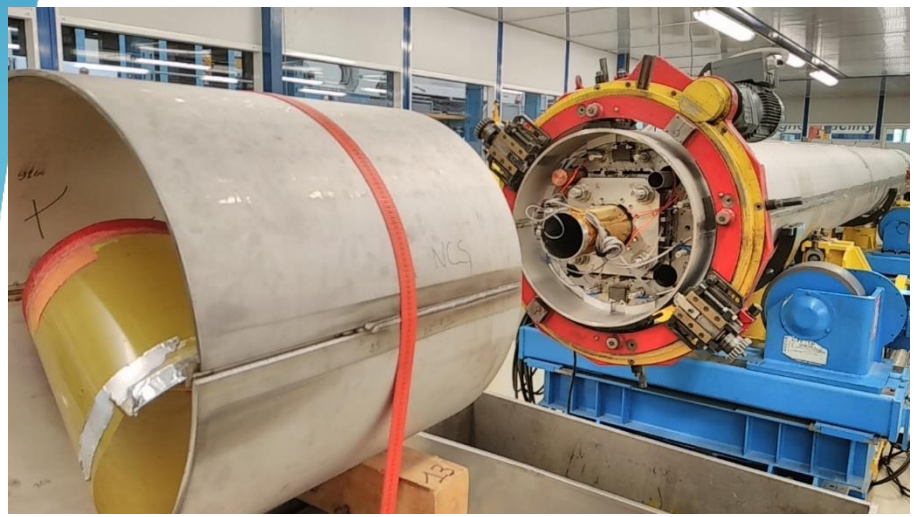
Extremities will be aligned towards the main axis after the end covers have been welded

Compared to LHC magnets, the stiffness increased due to:

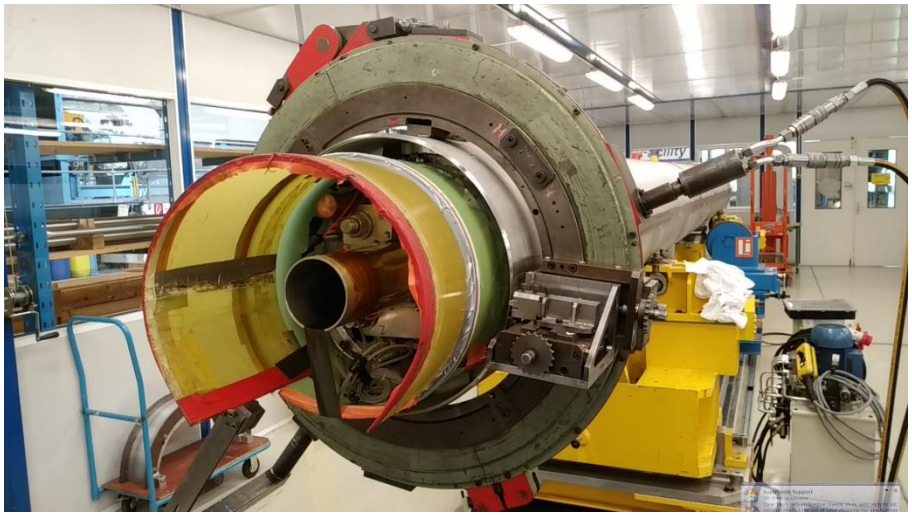
- ⇨ Cold bore tube dimensions (diameter and thickness)
- ⇨ Aluminium shells inertia

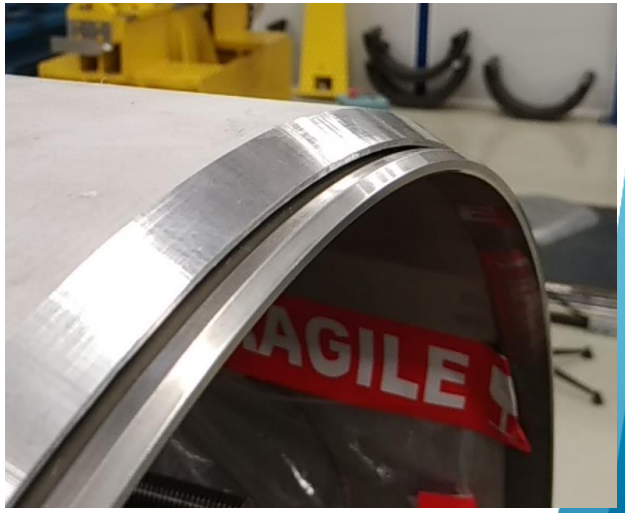
LMQXFBT Cold Mass Assembly

Extremities cutting

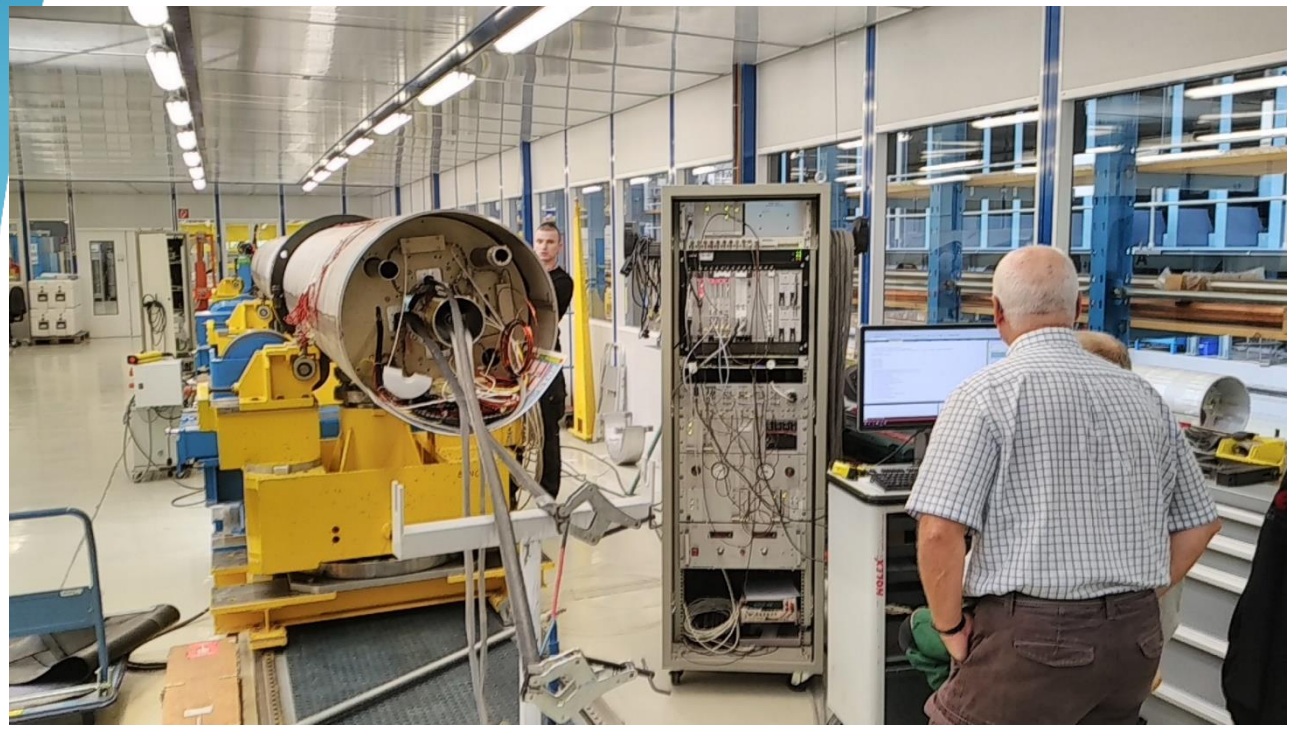


Welding preparation machining





LMQXFT Magnetic axis measurements
Alignment to gravity

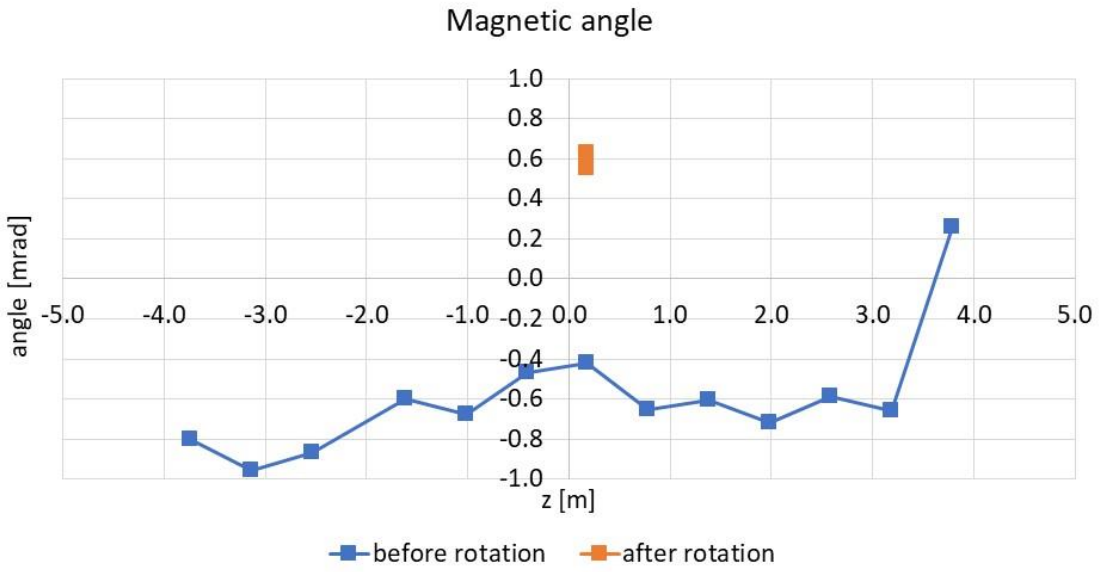


~0.4 mrad alignment reached after one trial

Tooling to be enhanced to improve angular adjustment

- ⇨ *Minimizing friction and effects*
- ⇨ *Improving tooling alignment from one vertical position to the other*

MQXFB Cold Mass Assembly
Magnetic Measurements



- Magnetic angle measured after shell welding

  Two different instruments
  - Rotating coil scanner
  - Stretched wire in AC mode

  The initial angle was -0.55 mrad

  Before welding the feet we rotated the cold mass in order to correct the small deviation

  We rotated too much
  - +0.6 mrad measured by using the rotating coil at the center (z = 0)
  - +0.4 measured by using the stretched wire as integral along the whole magnet
- We think that we can improve the correction before welding the feet

Courtesy of Lucio Fiscarelli

Next Steps

For LMQXFBT001 cold mass

- 18kA leads routing and CLIQ leads extensions (ongoing)
- Cold mass closure aligning the various components
- Final magnetic measurements
- Pressure/leak test
  - ⇨ Cryostating and cold tests

In view of the series production

- Connection box improvement
- QH and V-taps wires routing and fixation
- “Light” tooling improvements
- Orbit corrector alignment bench in line with the MQXFB one
- Busbars installation procedure to be defined
- Welding procedures qualification
- …

Q2 cold masses tooling and assembly benches

❼ Finishing area

❽ Pressure/leak tests bench

❻ Welding press

Ø630mm cradles

❹ MCBXFB alignment and prep bench
(reception and preparation of the orbit corrector magnet, not yet in place)

❸ MQXFB alignment and prep bench
(reception, electrical tests, geometrical measurements, pole splicing, cbt and heat exchanger pipes insertion, V-Taps and instrumentation connections, thermometers installation, tack blocks, backing strip …)

❶ MQXFB Coil pack insertion bench
(coil pack insertion, electrical tests, bladders and keys insertions, magnetic measurements)

11T then CP assy bench

❷ Pipes preparation bench
(Cold bore tube, heat exchangers, instrumentation wires preparation)

D2 assy bench

❺ Shell and cold mass turning bench
(Shell preparation and rotation around its axis, cold mass rotation after tack welding the first shell)

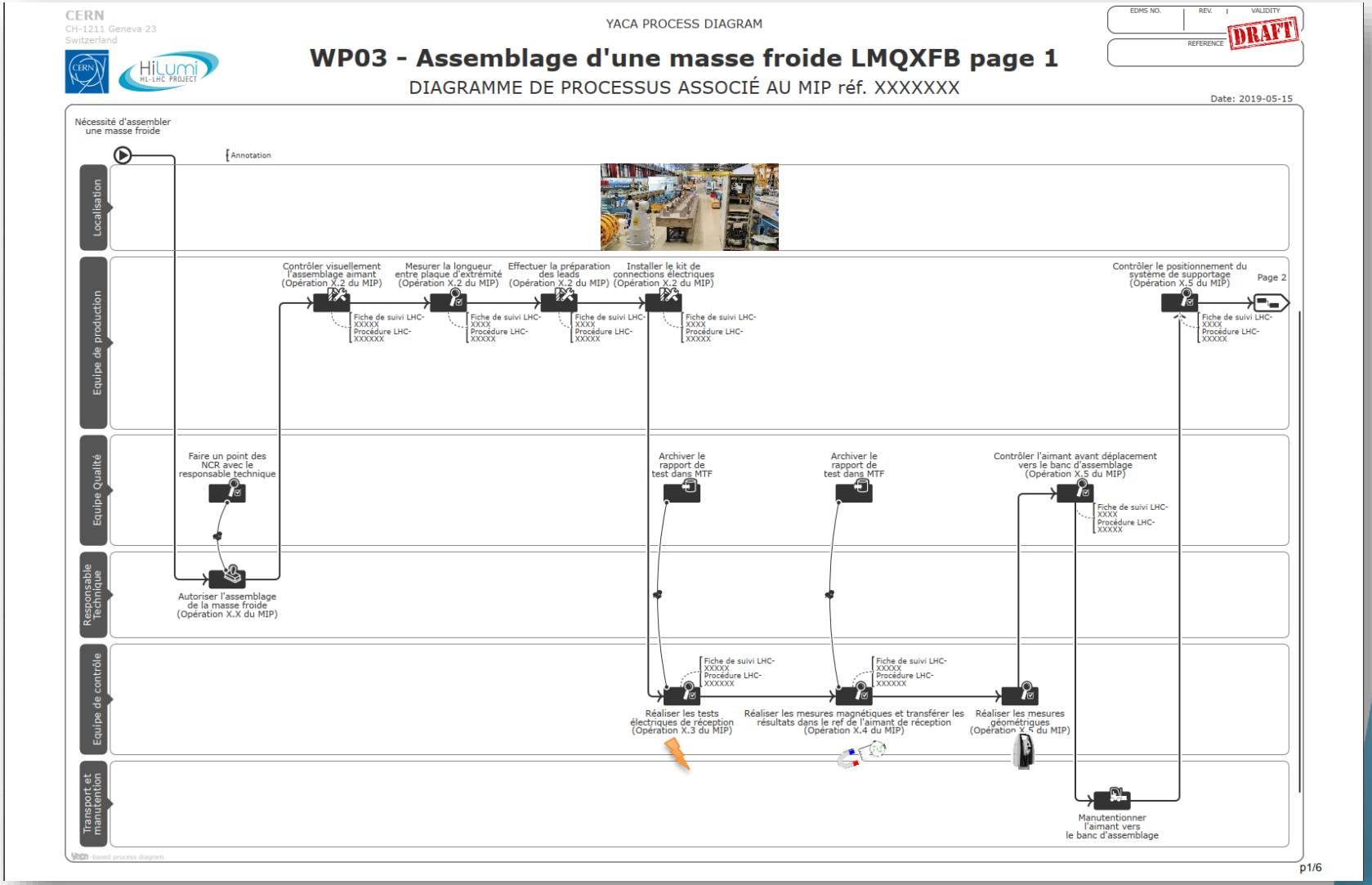
Summary

- Many interfaces with various partners, collaborations and WPs, regular productive meetings and exchanges with close cooperation.
- Q2 cold mass design close to completion. Single version intended for the two variants A and B sharing numerous components with the Q1, CP, D1 and D2 cold masses for HL-LHC.
- Main components delivery schedule fits the requirements but cover flanges with instrumentation feedthrough could be an issue for the very first cold masses.
- Procedures and documentation is being drafted thanks to the LMQXFBT prototype.
- Very promising achievements in terms of geometrical and magnetic alignment proving processes and large tooling foreseen for the series production.
- Light production tooling and procedures will be refined before the next prototype assembly. Orbit corrector and busbars integration will be validated then.
- CERN Large Magnet Facility ensures an adequate infrastructure to meet the Q2, CP and D2 cold masses production purposes.

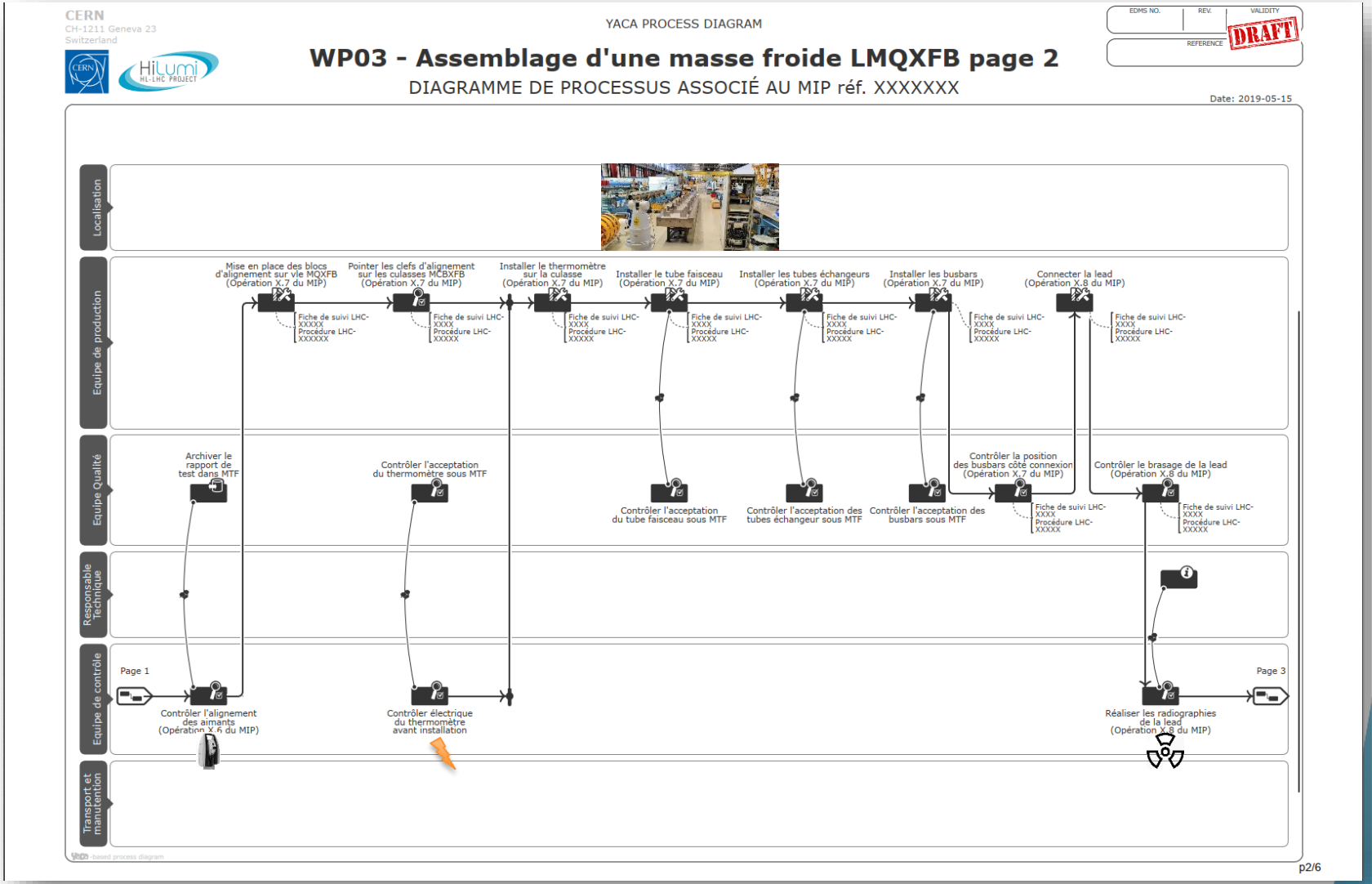
Thank you for your attention

Spare Slides

LMQXFB Flowchart P.1



LMQXFB Flowchart P.2



LMQXFB Flowchart P.3

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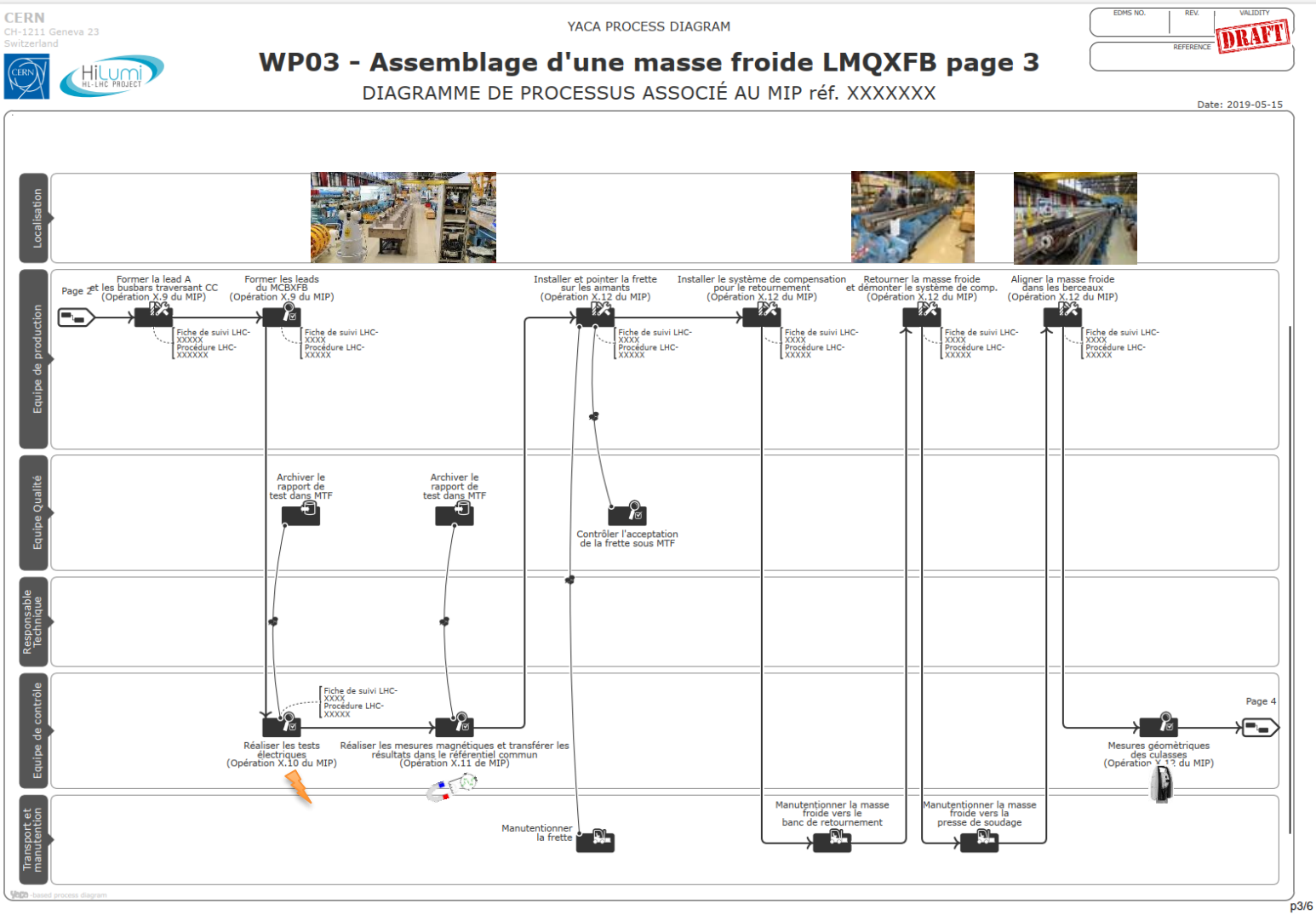
YACA PROCESS DIAGRAM

EDMS NO. | REV. | VALIDITY | DRAFT
REFERENCE

WP03 - Assemblage d'une masse froide LMQXFB page 3

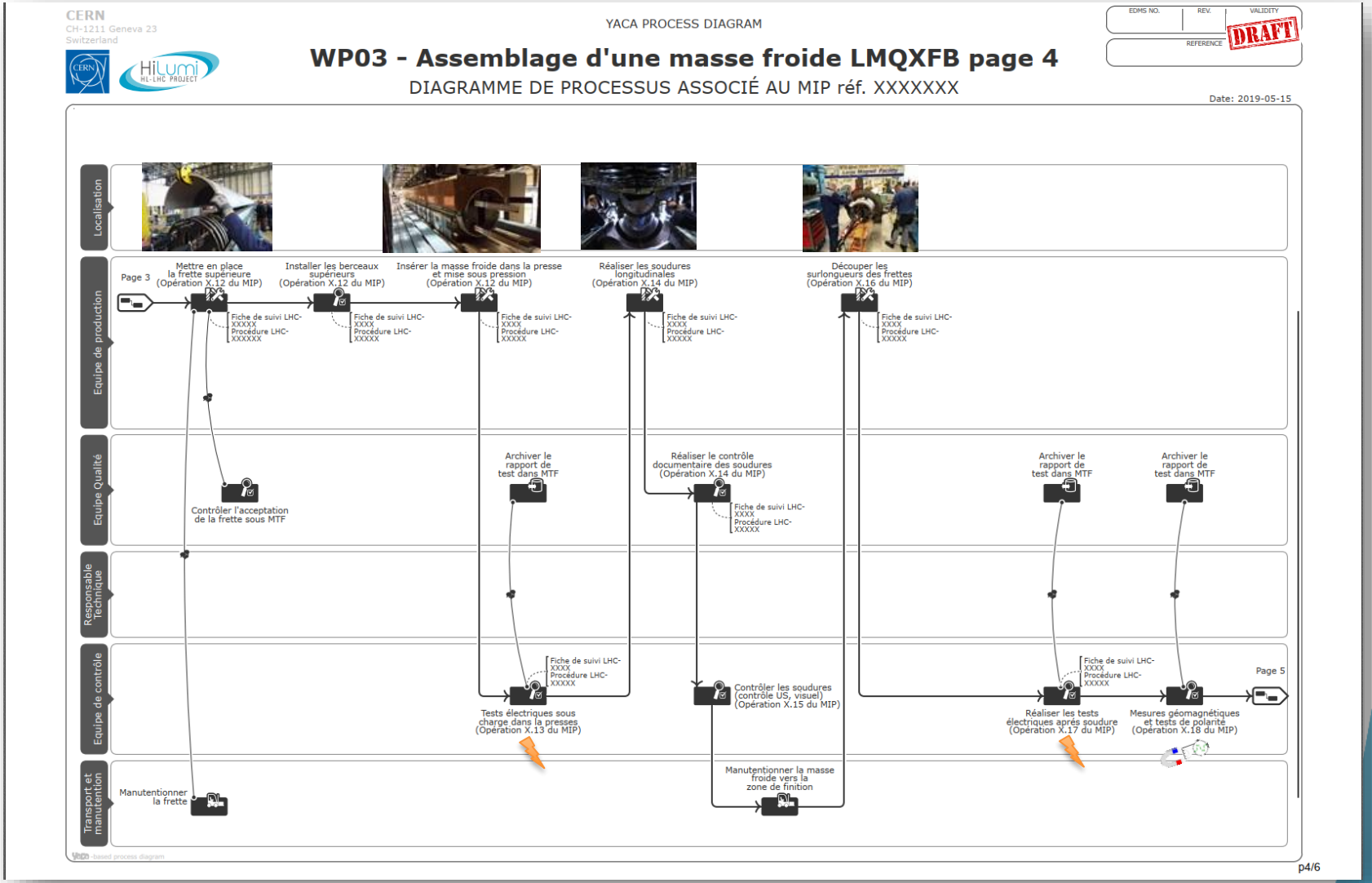
DIAGRAMME DE PROCESSUS ASSOCIÉ AU MIP réf. XXXXXXX

Date: 2019-05-15



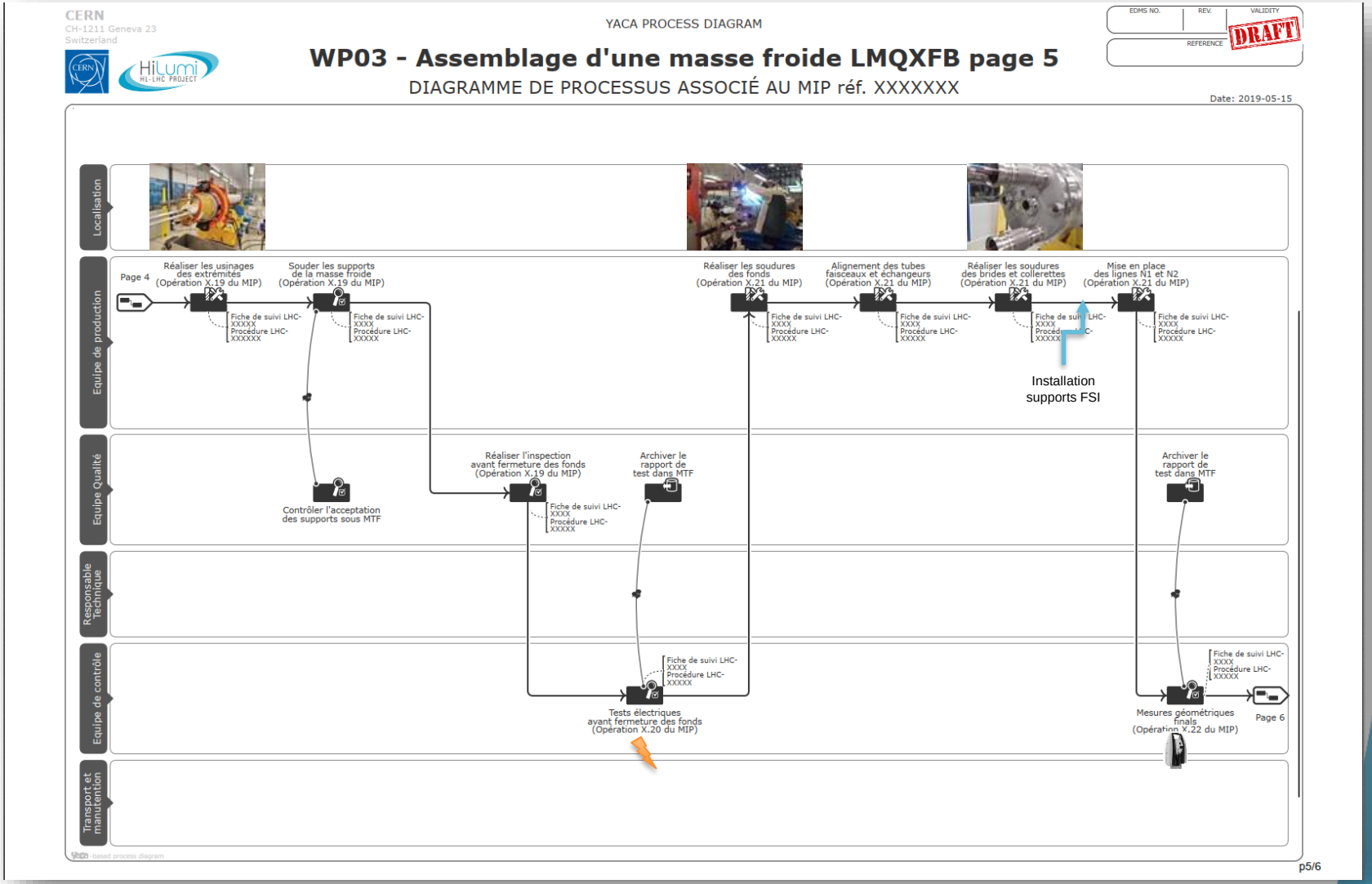
LMQXFB Flowchart P.4

4. Longitudinal Welding

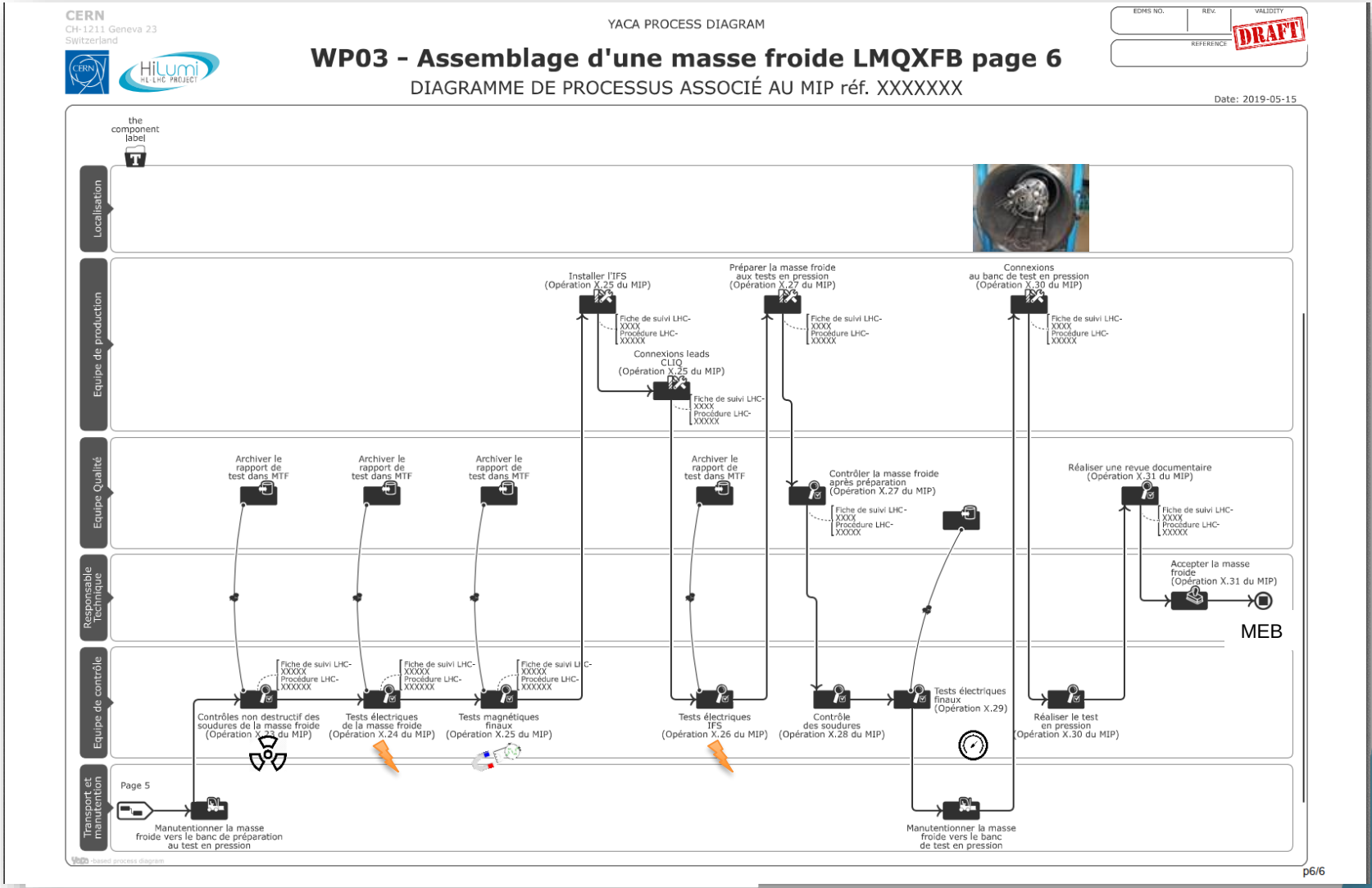


LMQXFB Flowchart P.5

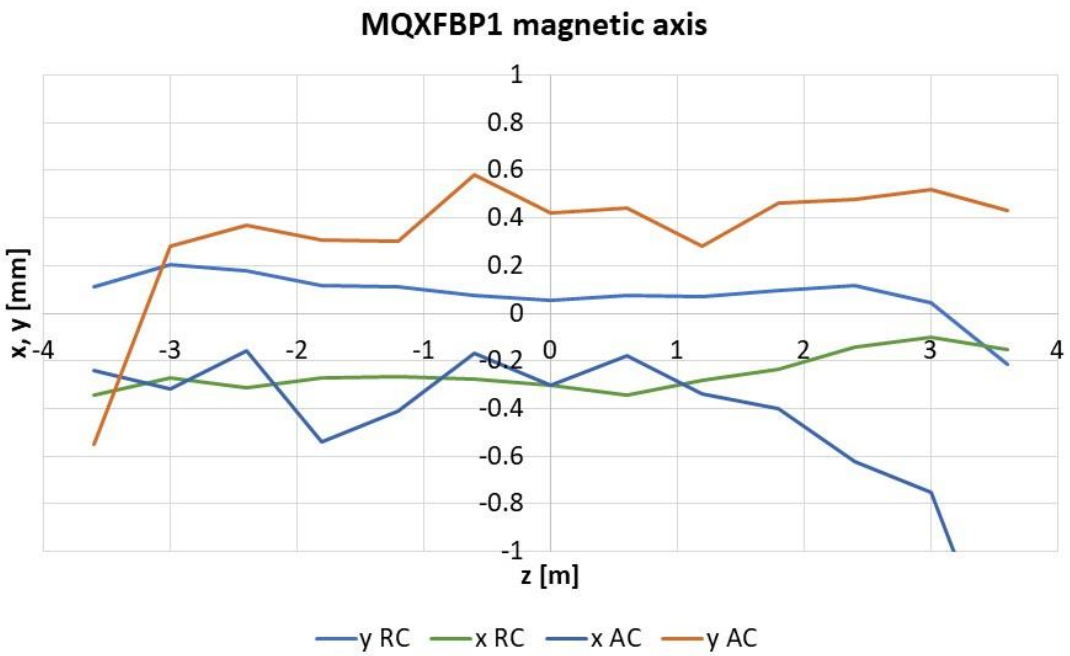
5. Cold Mass Finishing



LMQXFB Flowchart P.6



MQXFB Cold Mass Assembly
Magnetic Measurements



- Measurement of the offset of the magnetic axis with respect to the mechanical axis
- Two different instruments
  - Newly developed rotating coil scanner (RC)
  - Legacy AC mole (AC)
- New system is more accurate
  - Better than 0.1 mm
- The magnetic axis is within ±0.3 mm the mechanical axis

Courtesy of Lucio Fiscarelli