



# Status of D2 prototype cold mass

H. Prin, T. Bampton, N. Bourcey

Design Office:

Magnets:

Cryostat and cold tests interfaces :

Assembly procedures and tests :

Busbars and Splices:

Quality insurance and documentation:

Geometry:

Magnetic measurements:

O. Id Brahmane

A. Foussat, G. Kirby, A. Musso

A. Vande Craen, D. Duarte Ramos

T. Bampton, N. Bourcey, L. Grand-Clement, A. Milanese

R. Principe, L. Favier

R. Principe, O. Housiaux

P. Bestmann

L. Fiscarelli

WP3 meeting

<https://indico.cern.ch/event/1123666/>

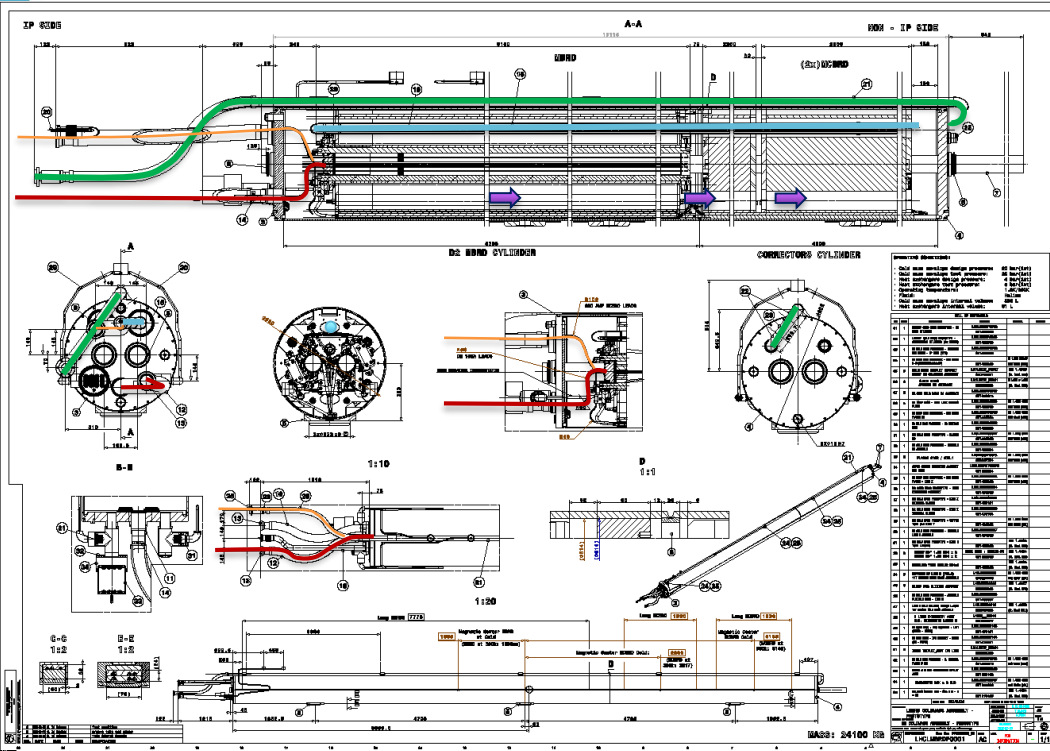
16/02/2022

# Outline

- Design Status
- Prototype Assembly Process & Status
- Tooling
- Documentation
- Proposed magnet improvements for the series
- Summary

# Introduction

In July 2021, a design update for the prototype was requested by the WPL to assess the MBRD prototype performance using the existing SM18 test station.



## Main changes with the series:

- Cryo-assembly turned by 180° on the test bench
- 13kA busses routing on the bottom to std position M3
- 600A busses routing on top to std position M2
- Helium feeding line (N) on top to the rear of the cold mass rather than inside
- Bayonet heat exchanger rather than multiple finger version
- Magnets longitudinal positions displaced by 100mm (proposed 200mm for the series)
- Soldering of 3<sup>rd</sup> lead to test each aperture individually

# Design Status

## Prototype Cold Mass

3D Model: [ST0796233\\_01](#)

Drawing Folder: [EDMS 2638369](#)

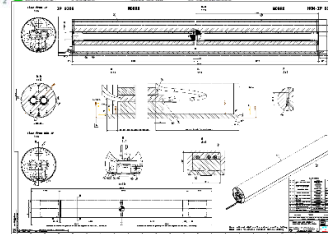
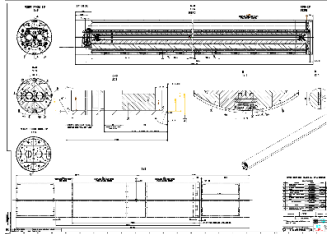
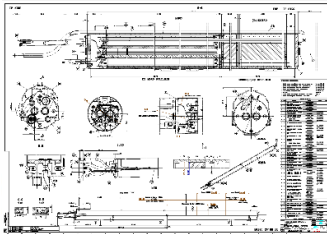
## Series Cold Masses

3D Model: [1232783\\_01](#)

Drawing Folder: [EDMS 2684106](#)

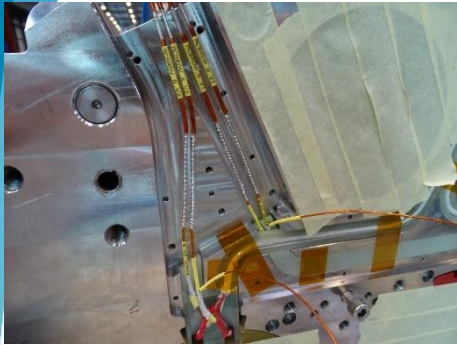
ID	Title	Status	Created on	Author
1	LHCLMBRD001 v1	Released	2022-02-09	O. Id Balthame
20	LHCLMBRD050 v0	Released	2021-07-30	O. Id Balthame
30	LHCLMQXF_0007 v0	Released	2018-06-01	A. Temporin
40	LHCLMBRD048 v0	Released	2019-03-01	O. Id Balthame
50	LHCLMBRD053 v0	Released	2019-03-01	O. Id Balthame
60	LHCLMBRD049 v0	Released	2019-03-01	O. Id Balthame
70	LHCLMBRD052 v0	Released	2019-03-01	O. Id Balthame
80	LHCLMQXF_0003 v0	Released	2019-03-01	O. Id Balthame
90	LHCLMQXF0750027 PLUMPING TIP	Ready For App.	2019-08-22	P. Perret
1	LHCLMBRD055 v0	Released	2019-03-01	O. Id Balthame
1	LHCLMBRD045 v0	Released	2021-06-18	O. Id Balthame
1	LHCLMBRD036 v0	Released	2021-07-18	O. Id Balthame
1	LHCLMBRD037 v0	Released	2021-07-18	O. Id Balthame
1	LHCLMQXF_0003 v0	Ready For App.	2019-10-15	A. Temporin
1	LHCLMQXF_0032 v0	Ready For App.	2020-02-05	V. Cauchon
1	LHCLMBRD054 v0	Released	2021-06-09	O. Id Balthame
1	LHCLMBRD057 v0	Released	2021-08-28	O. Id Balthame
1	LHCLMBRD046 v0	Released	2021-03-01	O. Id Balthame
1	LHCLMBRD040 v0	Released	2021-09-06	O. Id Balthame
1	LHCLMBRD040 v0	Ready For App.	2021-01-21	O. Id Balthame
2	LHCLMBRD009 v0	Released	2021-12-16	O. Id Balthame
2	LHCVSCSC0001 v0	Ready For App.	2020-11-06	F. Santangelo

ID	Title	Status	Created on	Author
1	LHCDQH_0002 vAA	Released	2021-08-17	
1	LHCLMBRD003 vAA	Released	2022-01-19	
1	LHCLMBRD013 vAA	Released	2022-01-19	
1	LHCLMBRD014 vAA	Released	2022-01-19	
1	LHCLMBRD015 vAA	Released	2022-01-31	
1	LHCLMBRD002 vAA	Released	2020-11-19	
1	LHCLMBRD010 vAA	In Work	2022-01-19	
1	LHCLMQXF_0011 v0	Released	2018-08-27	
1	LHCLMBRD029 vAA	Released	2022-01-19	
1	LHCDCCMA063 v0	Released	1999-04-26	
1	LHCLMBRD034 vAA	Released	2022-01-19	
1	LHCDCCMA025 v0	Released	1999-04-26	
1	LHCLMBRD026 vAA	Released	2022-01-19	
1	LHCLMBRD005 vAA	Released	2022-01-19	
1	LHCLMBRD027 vAA	Released	2022-01-19	
1	LHCLMBRD029 vAA	Released	2022-01-19	
1	LHCLMBRD026 vAA	Released	2022-01-19	
1	LHCLMBRD009 vAA	Released	2021-12-16	
1	LHCVSCSC0001 vAA	Ready For App.	2020-11-06	
1	LHCLMQXF_0007 v0	Released	2018-06-01	
1	LHCLMBRD040 vAA	Released	2022-01-19	
1	LHCLMBRD019 vAA	Released	2022-01-19	
1	LHCLMBRD014 vAA	Released	2022-01-19	
1	LHCLMQXF_0003 v0	Ready For App.	2019-10-15	

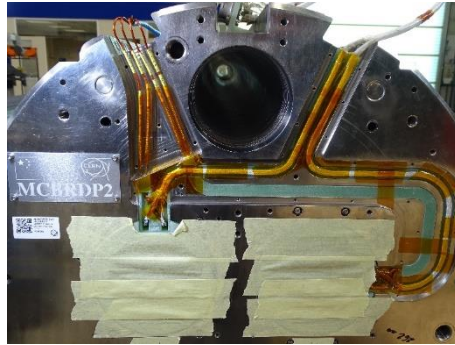


# Prototype Assembly Process & Status

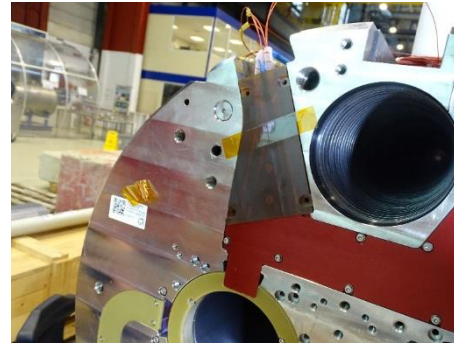
## HCLMBRDP003-CR000001 Corrector Cylinder 1/2



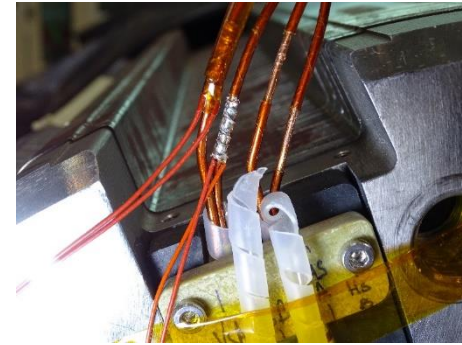
Busbars splicing to the leads



Busses and instrumentation routing



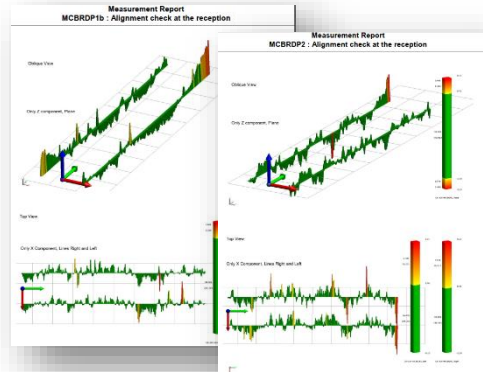
Insulation covers re-assembly



Additional V-Taps soldering



Alignment measurements



MCBDRP1b V[-0.07, +0.18]mm, H[-0.16, +0.14]mm  
 MCBDRP2 V[-0.13, +0.14]mm, H[-0.13, +0.14]



Backing strip welding



Transfer to the lower shell on the press conveyor

# Prototype Assembly Process & Status

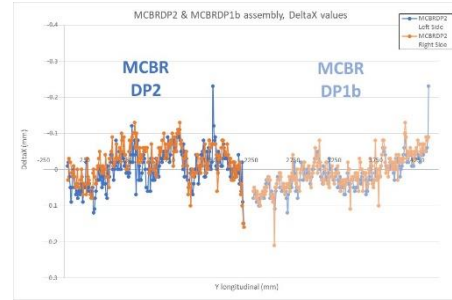
## HCLMBRDP003-CR00001 Corrector Cylinder 2/2



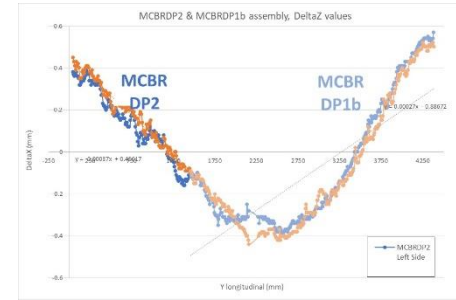
Transfer to the lower shell on the press conveyor (2nd trial)



Upper alignment cradles installation



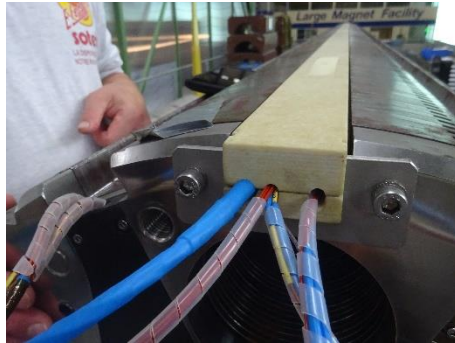
Horizontal Alignment  $\sim \pm 0.15\text{mm}$   
Yaw  $< 0.04\text{mrad}$



Total Vertical Alignment  $[-0.4, 0.6]\text{mm}$   
Pitch  $\sim 0.6\text{mrad}$   
Roll  $< 0.2\text{mrad}$



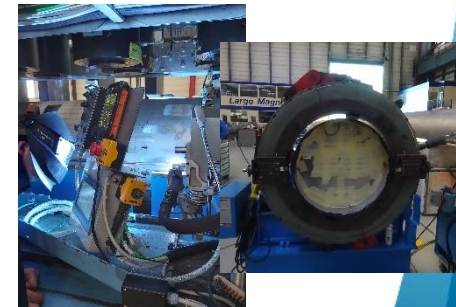
Aluminium restraint cylinders installation



Gutter installation, busses and instrumentation wires routing



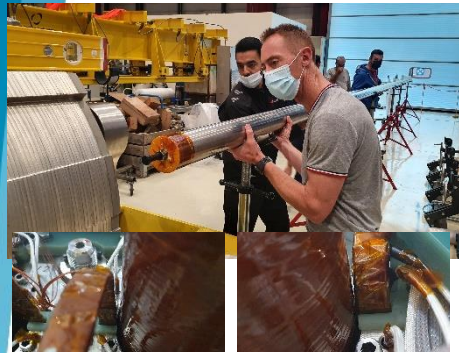
Upper shell installation



Shells longitudinal welding  
Cutting of the extremities

# Prototype Assembly Process & Status

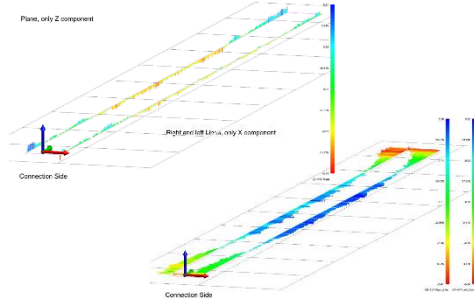
## HCLMBRDP002-CR000001 Separation dipole Cylinder 1/3



Cold bore tube insertion trial in both apertures



Alignment measurements



V alignment within  $[-0.13, +0.17]$ mm  
H alignment within  $[-0.6, +0.4]$ mm



Backing strip installation and welding



Transfer the magnet into the temporary shell



Gutter and cable puller installation  
Restraint alignment and welding



Install the shell on top



Transfer to rotating bench and turn the magnet upside down

# Prototype Assembly Process & Status

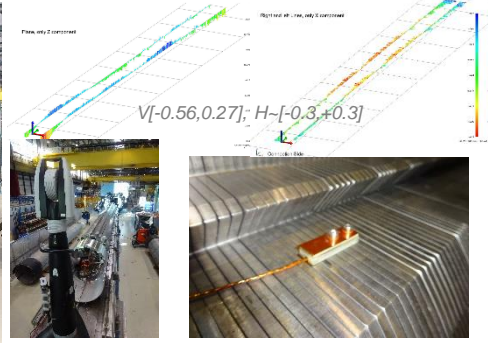
## HCLMBRDP002-CR000001 Separation dipole Cylinder 2/3



Remove upper shell  
Install radial restraints



Transfer the magnet and the lower  
shell to the press conveyor



Alignment measurements  
Temperature sensors installation



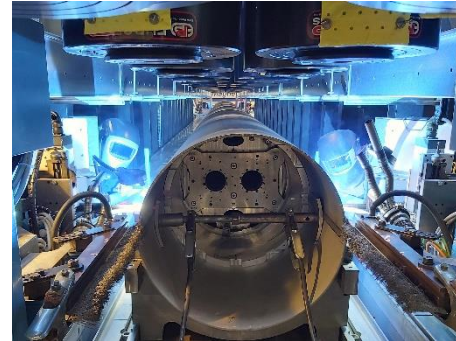
Backing strip to the shell weld and  
shims tack



Upper shell installation after developed  
length machining/adjustment



Gaps measurements



Longitudinal welding



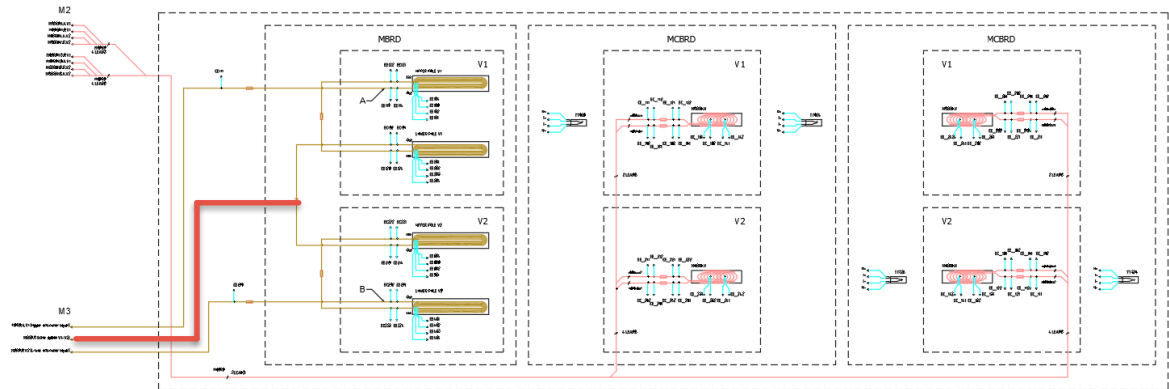
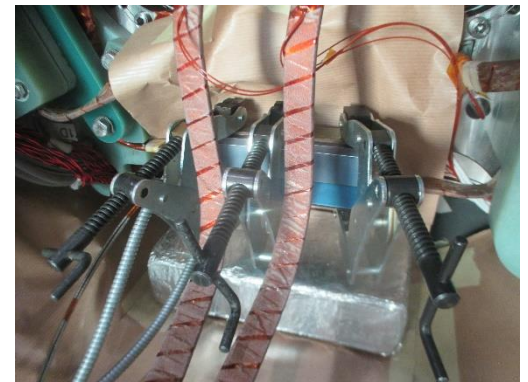
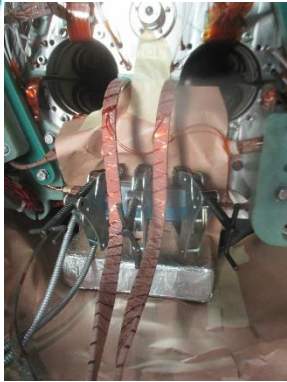
Cutting of the extremities  
and backing strip trimming



# Prototype Assembly Process & Status

## HCLMBRDP002-CR000001 Separation dipole Cylinder 3/3

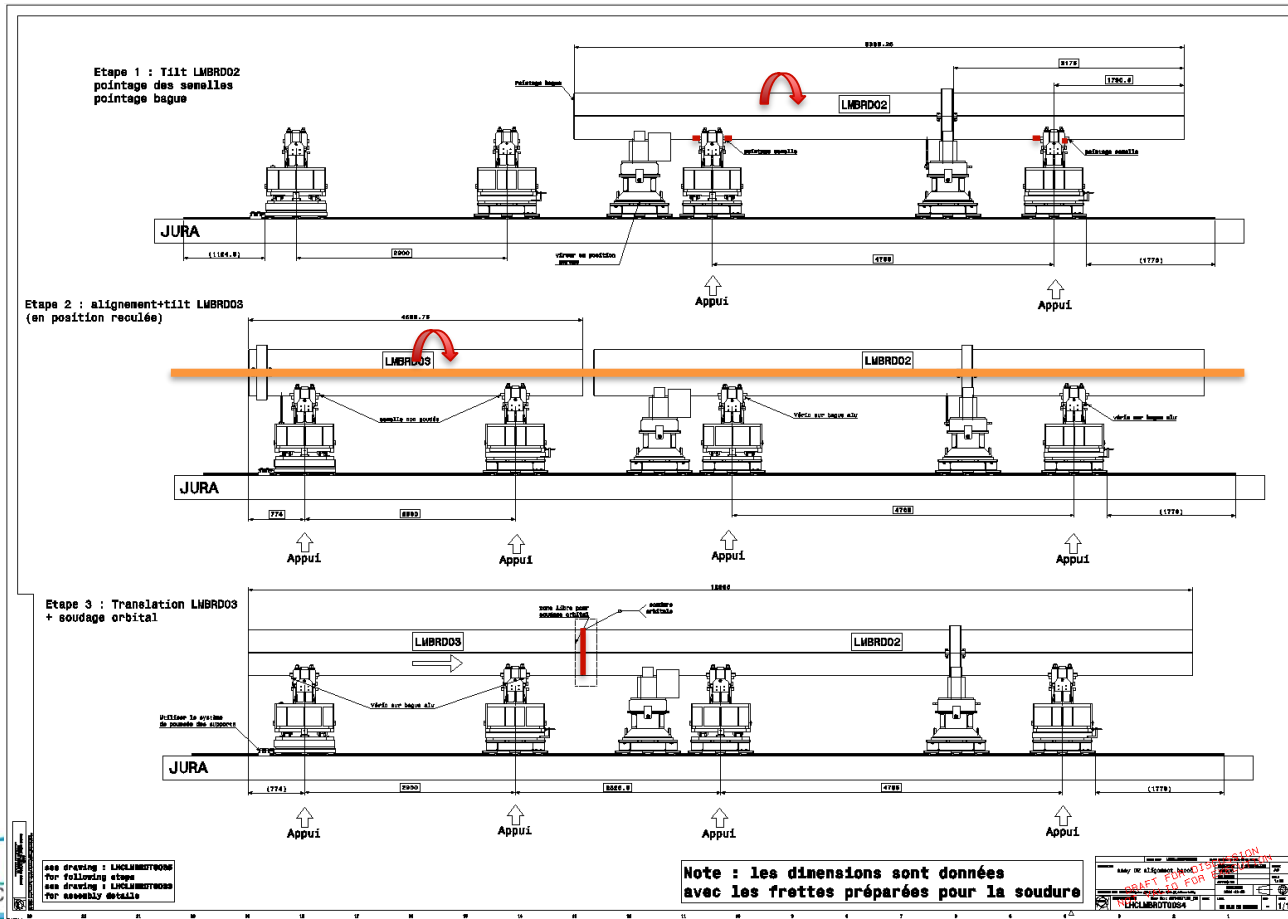
*Third lead soldering between the two apertures*



# Here we are today



# Next Steps

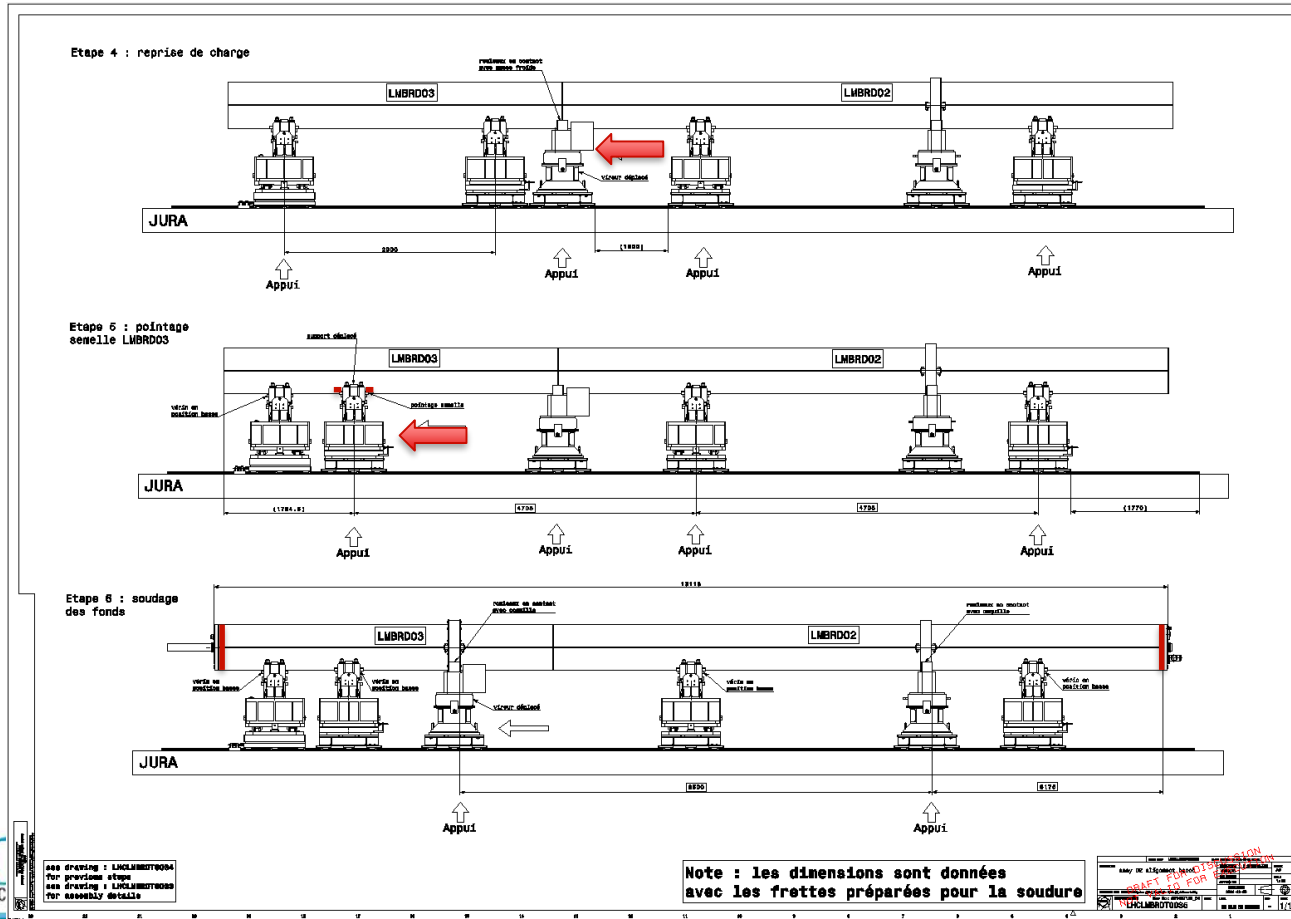


- Separation dipole cylinder tilt adjustment towards gravity
- Welding of supports
  
- Orbit correctors cylinder tilt adjustment towards gravity
- Cold bore Tubes insertion
- Geometrical measurements
  
- Orbital welding of the two cylinders

LHCLMBRD0034



# Next Steps



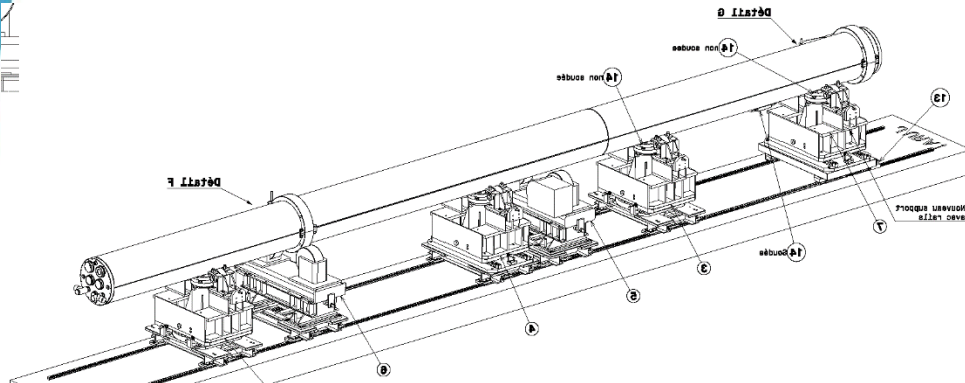
- Move the roller to support the welded cylinders

- Adjust the longitudinal position of the third support
- Weld the third support

- Welding of the two end covers

# Tooling

## Positioning and alignment of cylinders



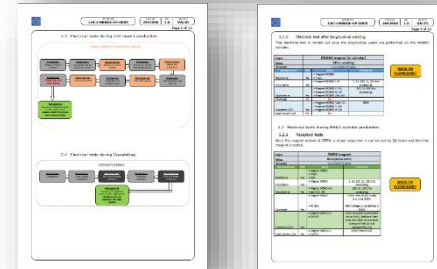
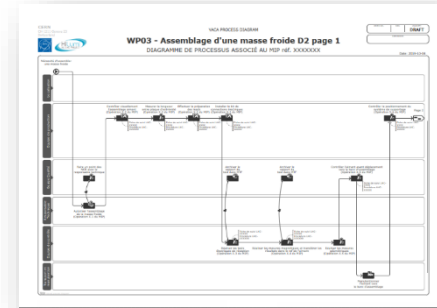
## Orbital welding



- After evaluation of the different welding options, it was concluded to stay with the initial proposal: orbital TIG
- DMOS completed
- QMOS in April then testing in accordance with PED
- QS in April

# Documentation 1/2



- [LHC-LMBRD-FP-0002](#): D2 Cold mass assembly flowchart **MIP under development** using the prototype assembly experience
  
- [LHC-LMBRDE-FP-0005](#): **Electrical test flowcharts** throughout the production
  
- [CERN-0000193764](#): **Control Procedures** (34 presently)
  - [LHC-MBRD-FP-0002](#): MBRD reception procedure
  - [LHC-MCBRD-FP-0013](#): MCBRD reception procedure
  - [LHC-LMBRDP-FR-0019](#): Longitudinal welding report



The screenshot displays a list of control procedures in a table format. The table has several columns: ID, Description, Status, and other details. The rows list various procedures, some with green status indicators and others with orange or blue ones. The table is organized in a structured manner, likely for tracking and management.




# Documentation 2/2


## ■ LHC-LMBRDP-FR-0015: LMBRDP001 Prototype cold mass assembly report


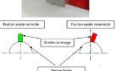


 CERN CH-1211 Geneva 23 Switzerland			EDMS NO. <b>2679760</b>	REV. <b>0.1</b>	VALIDITY <b>DRAFT</b>
 HiLumi at the LHC PROJECT			REFERENCE <b>LHC-LMBRDP-FR-0015</b>		
Date: 2021-09-27					
Production report HL-LHC / WP03					
<h3>Cylindre <u>Recombinaison dipole D2</u></h3>					
ABSTRACT:					
Ce document liste les opérations réalisées pour l'assemblage du cylindre D2 du D2 prototype (HCLMBRDP002-CR000001).					
Dans le dernier paragraphe, il liste aussi les actions correctives réalisées afin de mettre l'aimant (HCLMBRDP001-02000001) en conformité suite aux problèmes détectés lors de sa réception (voir rapport de réception EDMS <a href="#">2653213</a> ).					
DOCUMENT PREPARED BY: <b>O. HOUSTAUX (S145)</b>	DOCUMENT CHECKED BY: <b>H. PRIN (TE-MSC-LMF)</b> <b>T. SAMPTON (TE-MSC-LMF)</b> <b>N. BOURCEY (TE-MSC-LMF)</b> <b>R. PRINCIPE (TE-MSC-LMF)</b>	DOCUMENT APPROVED BY: <b>A. MILANESE (TE-MSC-LMF)</b> <b>A. FOUSSAT (TE-MSC-SMT)</b>			
DISTRIBUTION TO: <b>TE-MSC-LMF</b> <b>TE-MSC-SMT : A. FOUSSAT</b>					
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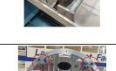


LHC-LMBRDP-FR-0015 2679760 0.1 DRAFT Page 12 of 46	
<b>5.1.3</b> Vérifier et placer les bornes au support de l'aimant. Respecter l'ordre des bornes et l'orientation des bornes. Lors des opérations de réassemblage.	
<b>5.1.3</b> Vérifier le câblage des bornes. Vérifier qu'il est correct et conforme aux plans.	

LHC-LMBRDP-FR-0015 2679760 0.1 DRAFT Page 13 of 46	
<b>5.1.4</b> Vérifier l'orientation des bornes. Lors des opérations de réassemblage.	
<b>5.1.4</b> Vérifier le câblage des bornes. Vérifier qu'il est correct et conforme aux plans.	
<b>5.1.6</b> Réception des sondes plates. A la réception des sondes plates, vérifier que les sondes sont conformes aux plans et qu'elles sont correctement étiquetées.	
<b>5.1.7</b> Réception des sondes plates. Vérifier la date.	

LHC-LMBRDP-FR-0015 2679760 0.1 DRAFT Page 14 of 46	
<b>5.1.8</b> Réception des sondes plates. Vérifier la date.	
<b>5.1.8</b> Préparation des sondes plates. Vérifier que les sondes plates sont conformes aux plans et qu'elles sont correctement étiquetées.	
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<b>5.1.8</b> Préparation des sondes plates. Vérifier que les sondes plates sont conformes aux plans et qu'elles sont correctement étiquetées.	

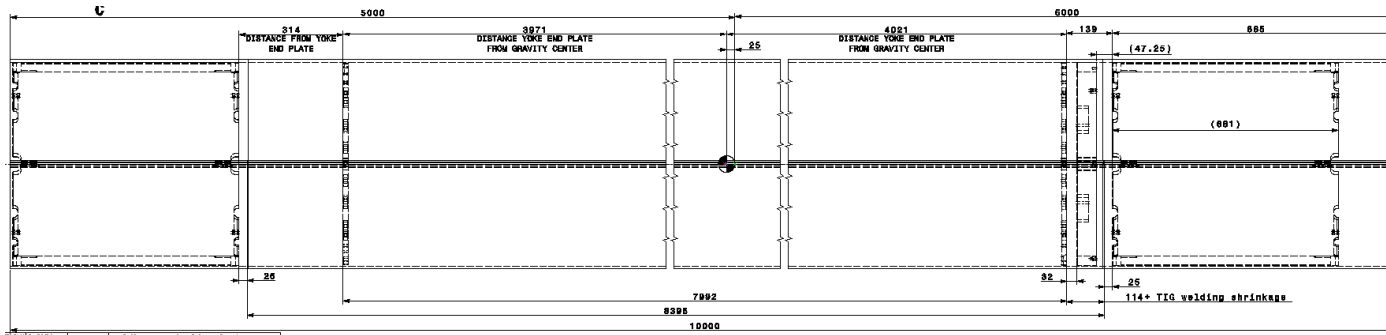
LHC-LMBRDP-FR-0015 2679760 0.1 DRAFT Page 15 of 46	
<b>4.1.1</b> Réception des sondes plates. Vérifier la date.	
<b>4.1.2</b> Réception des sondes plates. Vérifier la date.	
<b>4.1.3</b> Réception des sondes plates. Vérifier la date.	

LHC-LMBRDP-FR-0015 2679760 0.1 DRAFT Page 16 of 46	
<b>4.1.4</b> Réception des sondes plates. Vérifier la date.	
<b>4.1.4</b> Réception des sondes plates. Vérifier la date.	
<b>4.1.5</b> Réception des sondes plates. Vérifier la date.	
<b>4.1.6</b> Réception des sondes plates. Vérifier la date.	

LHC-LMBRDP-FR-0015 2679760 0.1 DRAFT Page 17 of 46	
<b>4.1.7</b> Réception des sondes plates. Vérifier la date.	
<b>4.1.8</b> Réception des sondes plates. Vérifier la date.	
<b>4.1.9</b> Réception des sondes plates. Vérifier la date.	
<b>4.1.9</b> Réception des sondes plates. Vérifier la date.	

# Welding report

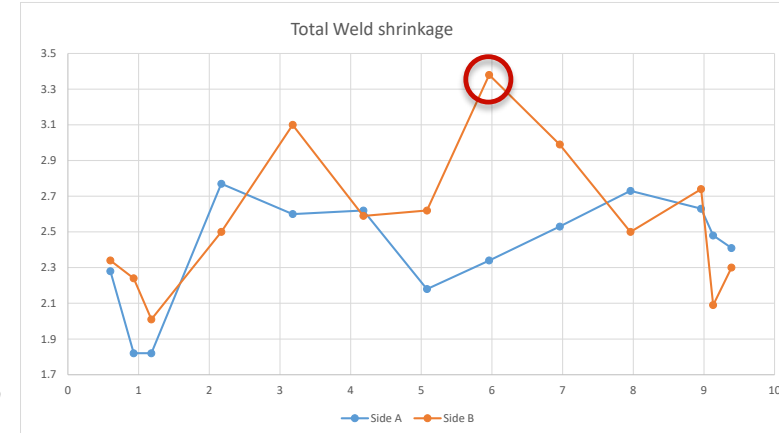
## EDMS: [LHC-LMBRDP-FR-0019](#)



Side A													Average	
Pos	0.6	0.93	1.18	2.17	3.18	4.18	5.08	5.96	6.96	7.96	8.96	9.13	9.39	
Shrinkage 1	0.69	1.04	1.16	1.63	1.46	1.13	1.21	1.32	1.3	1.5	1.21	0.92	0.96	1.19
Shrinkage 2	1	0.26	0.38	0.44	0.84	0.93	0.8	0.28	0.35	0.4	0.9	0.66	0.91	0.63
Shrinkage 3	0.59	0.52	0.28	0.7	0.3	0.56	0.17	0.74	0.88	0.83	0.52	0.9	0.54	0.58
Shrinkage Total	2.28	1.82	1.82	2.77	2.6	2.62	2.18	2.34	2.53	2.73	2.63	2.48	2.41	<b>2.40</b>

Side B													Average	
Pos	0.6	0.93	1.18	2.17	3.18	4.18	5.08	5.96	6.96	7.96	8.96	9.13	9.39	
Shrinkage 1	1.47	1.66	1.07	1.98	1.75	1.57	1.61	2.09	1.52	0.97	1.23	0.97	1.02	1.45
Shrinkage 2	0.33	0.11	0.64	0.21	0.67	0.2	0.51	0.35	0.35	0.63	0.43	0.64	0.57	0.43
Shrinkage 3	0.54	0.47	0.3	0.31	0.68	0.82	0.5	0.94	1.12	0.9	1.08	0.48	0.71	0.68
Shrinkage Total	2.34	2.24	2.01	2.5	3.1	2.59	2.62	3.38	2.99	2.5	2.74	2.09	2.3	<b>2.57</b>



- Average welding shrinkage between 2.4 and 2.6mm
- Half of the value given from the first TIG pass
- Measurement accuracy to be improved in the coming weeks thanks to ongoing developments



# Manufacturing and Test Folder (MTF)

**MTF**  
Equipment Management Folder

Home | Help | EDMS Portal | News | Login  
User: HPRIN

Actions: Show NCR Report Search: Equipment | Location | Slot | System

**Equipment Folder: Manufacturing Workflow**

Equipment Identifier: HCLMBRDP002-CR000001  
Other Identifier: None  
Description: Cold mass cylinder with separation dipole (prototype)

Workflow Diagram: No workflow diagram is defined for this equipment.

Step ID	R/E	Description	Status	Result	NC
5	(E)	Metrolgy on assembly bench	Done	Ok	
10	(E)	Aperture 1 cold bore insertion (*)	Done	Ok	
20	(E)	Electrical tests after A1 CBT insertion and after A1 CBT removal (*)	Done	Ok	
40	(E)	Aperture 2 cold bore insertion (*)	Pending		
50	(E)	Electrical tests after A2 CBT insertion and after A2 CBT removal (*)	Done	Ok	
55	(E)	Magnetic measurement	Done	Ok	
60	(E)	Geometrical measurement on the cradle (*)	Done	Ok	
62	(E)	Geom. meas. on the cradle after reversal (*)	Done	Ok	
70	(E)	Electrical tests before welding	Done	Ok	
80	(E)	Longitudinal weldings	Done	Ok	
90	(E)	Electrical tests after welding	Done	Ok	
100	(E)	Assembly report	Pending		

CERN - European Organization for Nuclear Research © CERN - 2022-02-11 19:12:46

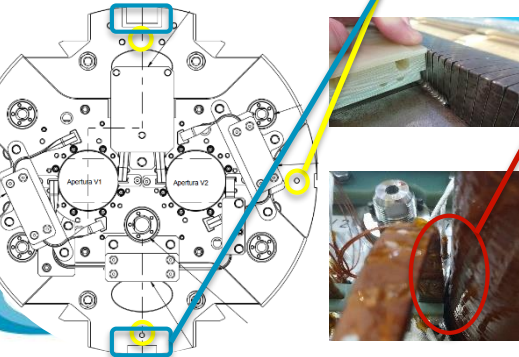
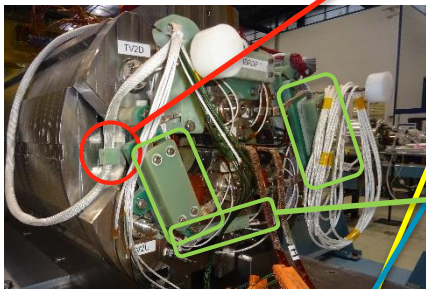
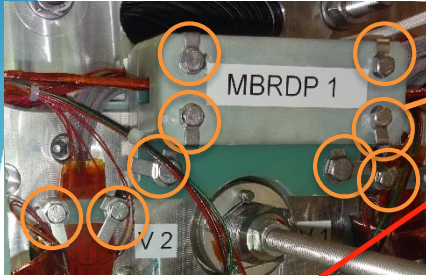
Parent and child attachment traceability

Manufacturing documentation including eventual NCR

Relevant manufacturing steps with their associated reports

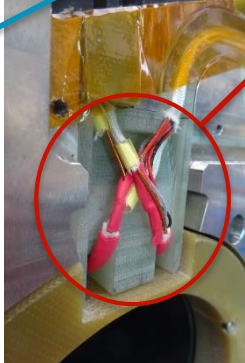
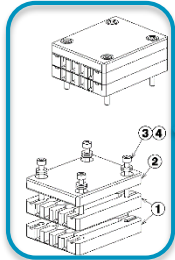
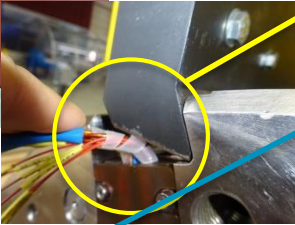
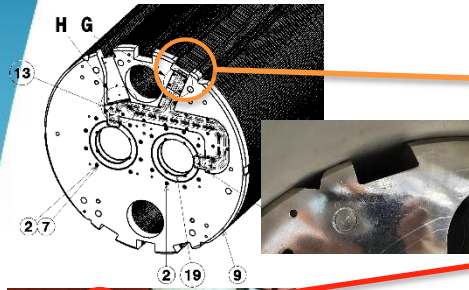
List of assets used to assemble the cold mass and its sub-components

# MBRD Magnets changes proposal for the series



- Screw restraints: use Nordlock rather than tab washers
- Instrumentation wires guiding pieces: not needed on the sides
- Fiducials: enlarge to  $\text{Ø}12\text{H}7$  with an additional one on top, radial positions to be revised
- Gutter for busses :
  - Enlarged slot on the connection side end plate, add two threaded holes
  - Ensure the key welding fillets are not protruding into the gutter area
- Splices shall be insulated with Kapton inside the boxes
- Voltage tap fibre glass sleeves shall be fixed immediately after the connection, this has to be soldered on the super conducting cable rather than copper stabilizer
- Leads/cold bore clearance must be maintained during coil fabrication
- Try to improve extremity plates parallelism during the assembly (up to 3mm difference measured during reception)
- Magnet Id engraving on both extremities, no stickers

# MCBRD Magnets changes proposal for the series



- End plates chamfer removal and diameter equal to the yoke to prevent shell deformation
- Nordlock rather than stycast
- Review insulation covers to prevent damage from the lifting beam jaws
- Comb boxes to house voltage-tap splices to be added on the magnet extremity plate (see drawing LHCLMBRDE0141)
- Consider a review of the voltage taps routing to prevent any short taking into consideration that machined G11 sharp edges are very abrasive
- Magnet Id engraving on both extremities rather than an additional plate

# Open Points in March 2021

## Open Points

- MBRD delivery state, date, shipping frame details?
- MBRD PVC tubes can be kept in the apertures?
- MCBRD extremity pieces?
- Alignment references magnetic or mechanical?
- Investigation and testing between the 3 orbital welding options.
- Supporting during the orbital welding?
- Can the tolerance range in the range in the TDR be relaxed?

### 8.6 Twist

After the completion of the cold mass assembly and welding, the geometric axes of the two cold bore tubes may not lie in a perfect plane. At any point along the arcs and the straight ends of the cold mass, the local twist shall be within  $\pm 3$  mrad relative to the plane containing the theoretical geometric axes V1 and V2. The average tilt shall stay inside  $\pm 1$  mrad.

### 8.7.1 Correctors MCBRD

The corrector MCBRD magnets shall be positioned with respect to the straight ends of the theoretical geometric axes to within  $\pm 0.3$  mm.



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WP3 meeting in 17/03/2021 <https://indico.cern.ch/event/1012677/>

- ✓ MBRDP was delivered in Oct the 21<sup>st</sup>, work on the cold mass started in Dec the 6<sup>th</sup> after NC correction, cold bore tube insertion trials, strain gauge measurements and issues with the overed crane solved in the facility.
- ✓ Yoke measurements to define the magnet geometry, no need for the PVC tubes
- ✓ Pieces procured by SMT
- ✓ Orbital TIG was chosen after investigation, welding qualification ongoing
- ✓ Tooling assembled and operational, procedures are defined, to be tested and fine-tuned
- ? First results after the cylinders welding, magnets alignment in the yoke can be improved.

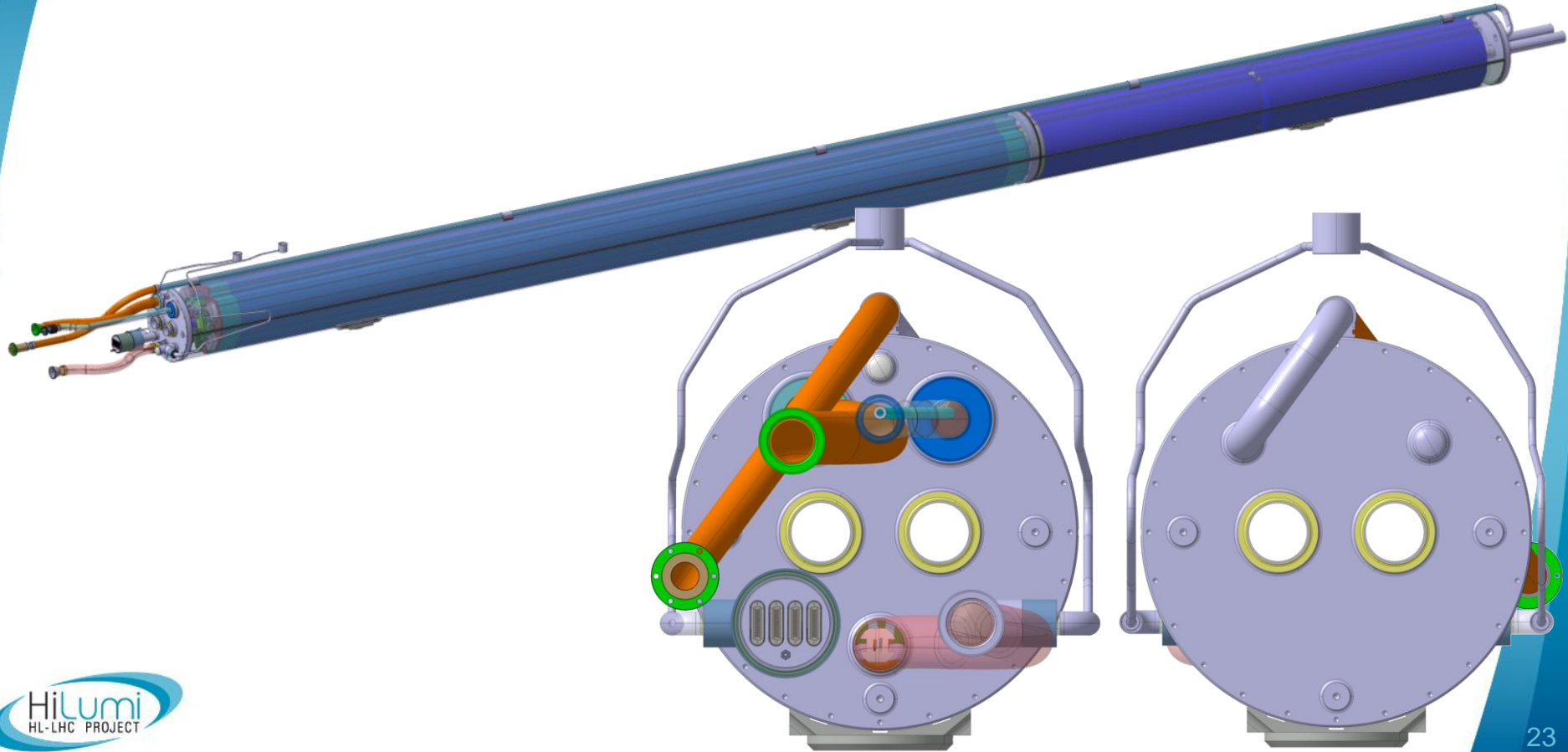
# Summary

- Cold mass design for prototype and series has been completed as well as fabrication and assembly drawings.
- Prototype cold mass design was reviewed to fit present cold test station in SM18 in order to test the MBRD prototype asap.
- Longitudinal welding process development to harmonize the WP3 cold masses in particular the Q2
- Assembly procedures and control steps were developed prior to the prototype assembly that is followed and documented day by day by LMF-QA.
- Components and tooling were prepared in advanced and are being proven.
- Assembly will be paused beginning of next week to solve issues with longitudinal loading ⇒ **Cold mass delivery for cryostating expected beginning of April**



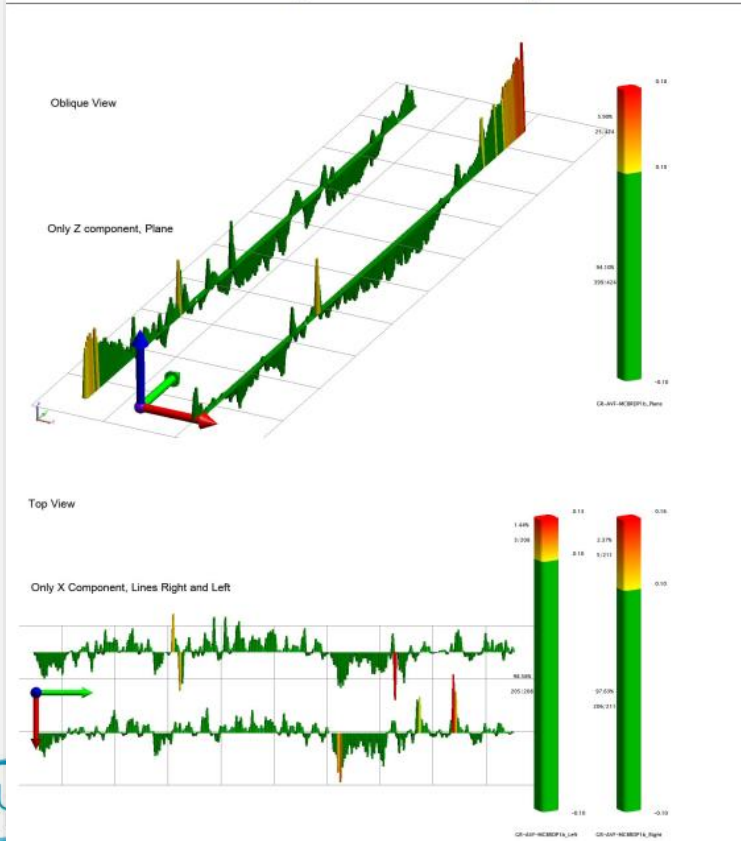
***Spare slides***

# LMBRDP D2 Prototype Cold Mass

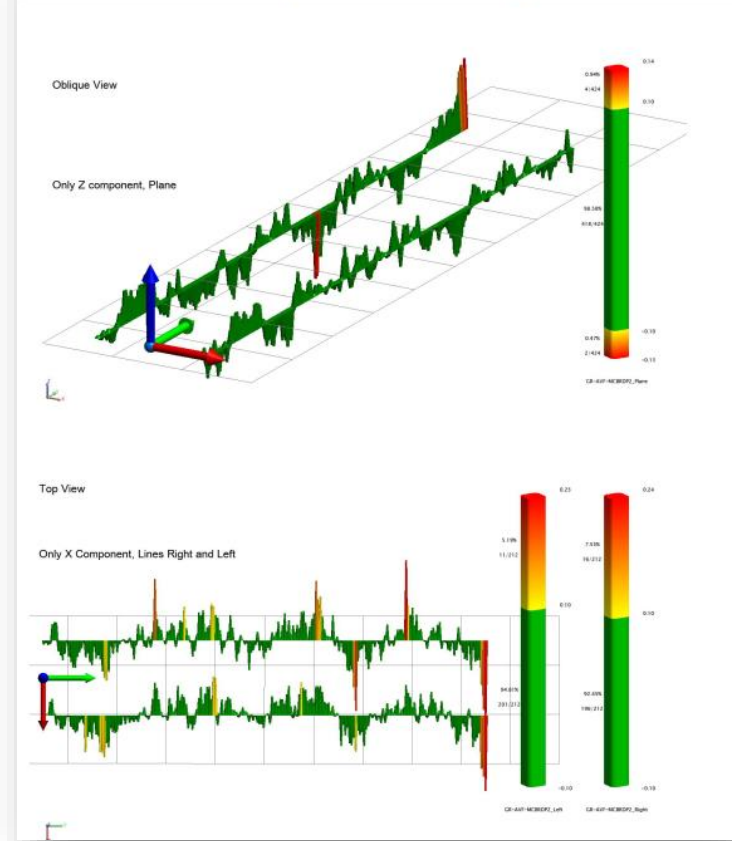


# MCBRD magnet at reception

Measurement Report  
MCBRDP1b : Alignment check at the reception

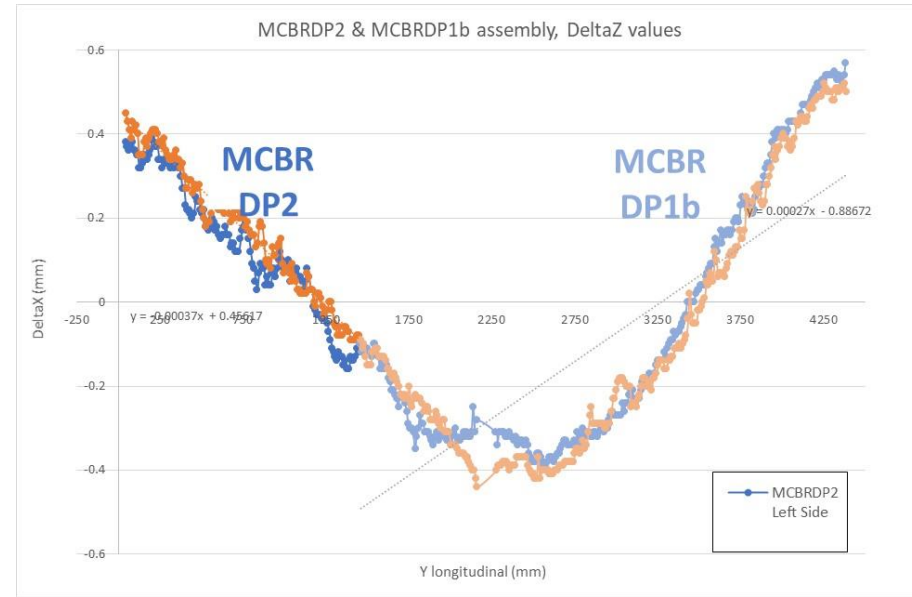
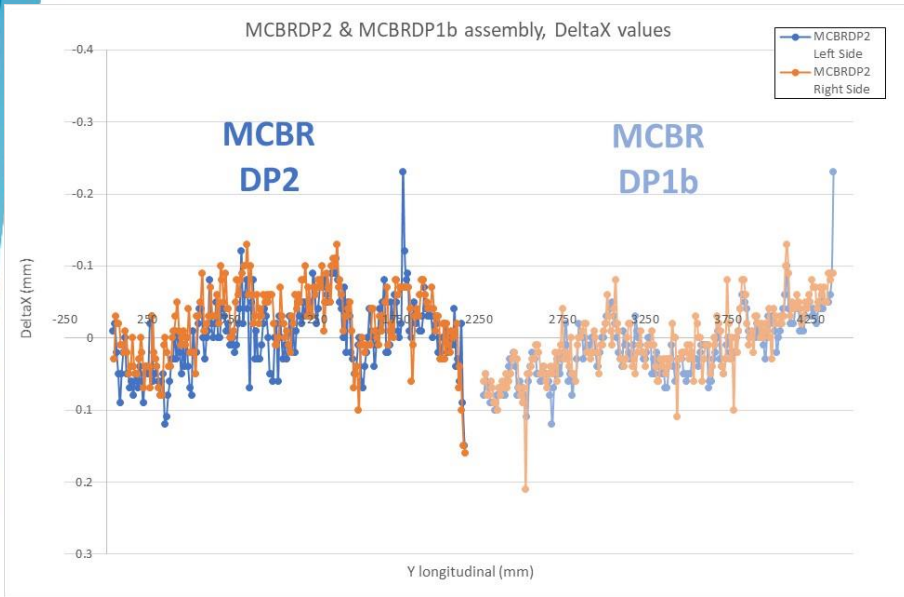


Measurement Report  
MCBRDP2 : Alignment check at the reception



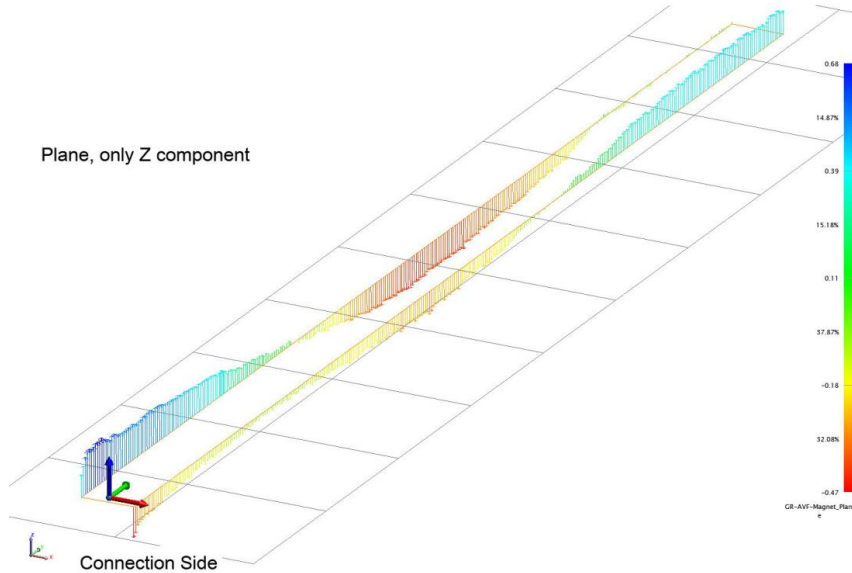


# MCBRD inside the shell

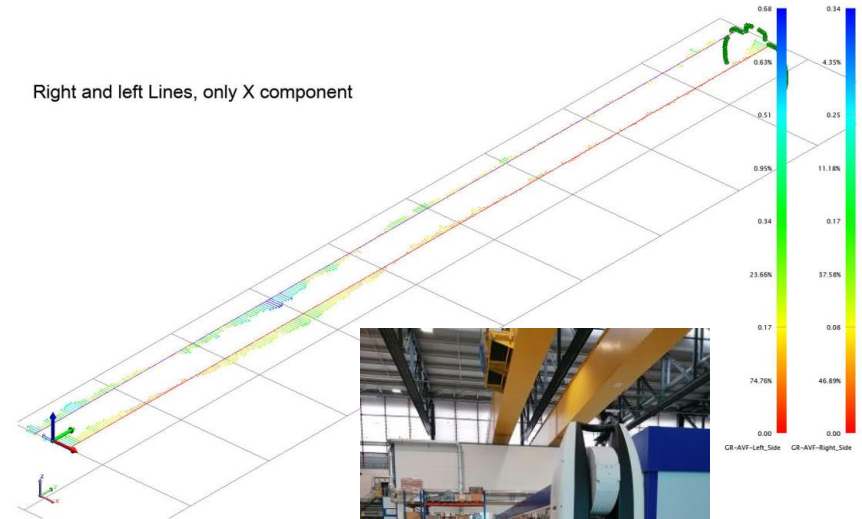


# MBRDP alignment on the transport frame at reception

Plane, only Z component

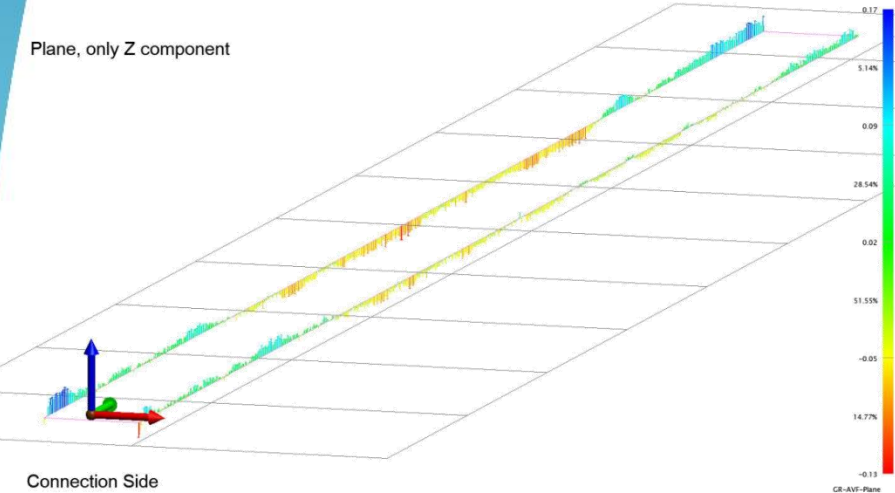


Right and left Lines, only X component

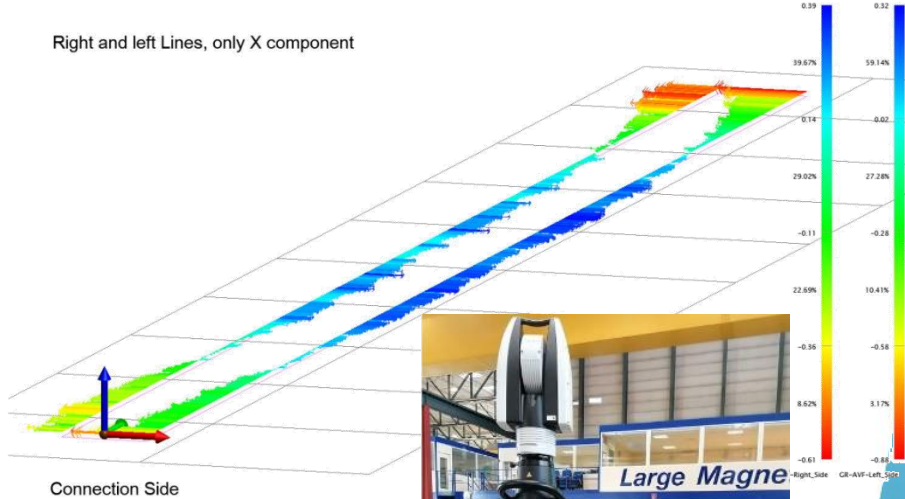


# MBRDP alignment on the assembly bench

Plane, only Z component

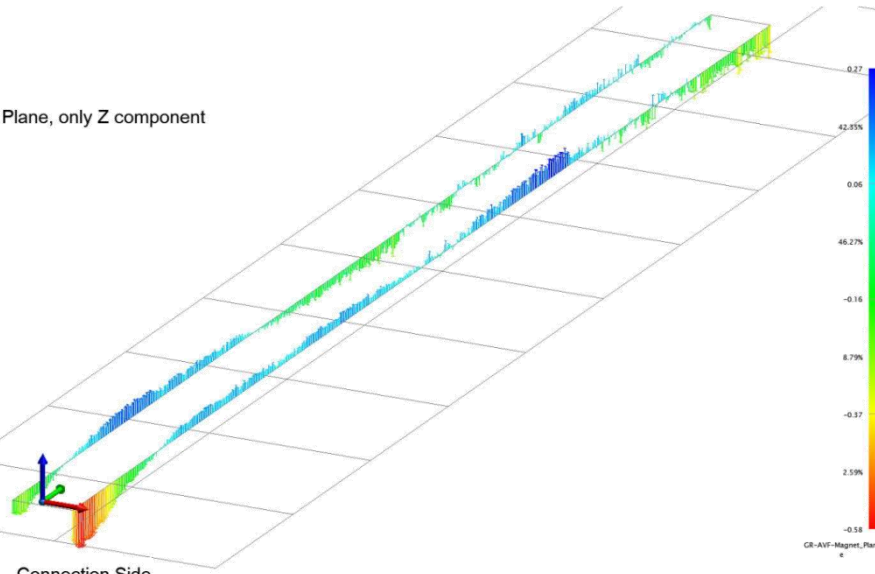


Right and left Lines, only X component



# MBRDP alignment inside the shell on the press conveyor

Plane, only Z component



Right and left Lines, only X component

