



Experience on NCRs and future expectations

Julien DEBEUX (CERN) on behalf of HL-LHC WP4

14th HL-LHC Collaboration Meeting – Genoa (Italy) – 08/10/2024

Introduction

■ Outline

- Brief reminder on NCRs for HL-LHC WP4
- NCRs spotted during RFD-SPS CM fabrication, assembly and reception
- Conclusions + few words about LHC Series

■ Not part of this presentation

- Manufacturing of CRAB cavities
- NCRs linked to FPCs


Talk of E. Jordan: “RFD NCRs & future mitigation”



*Talk of J. Swieszek and S. Barriere:
“RFD-CM Repair overview and highlight”*

NCRs for HL-LHC WP4

- **Nonconformity** → Non fulfilment of a *requirement*
 - *Requirements are specified in Engineering specifications, drawings, procedures, standards, etc.*

Courtesy of H. Garcia Gavela: [EDMS 2894857](https://cds.cern.ch/record/2894857)

		EDMS NO. 2093032	REV. 1.0	VALIDITY VALID
REFERENCE : LHC-ACFQC-ES-0001				
ENGINEERING SPECIFICATION				
HL-LHC LHC CRAB CAVITIES CRYOMODULE CRYOGENIC LINES				
Abstract The present document concerns the engineering specifications of the cryogenic lines to be installed in the Crab Cavities cryomodules intended to host the superconducting niobium radio-frequency crab cavities (two types: DQW and RFD) installed in the LHC ring for the HL-LHC project.				
TRACEABILITY				
Prepared by: L. Dassa (EN-MME), H. Garcia Gavela (ATS-DO)			Date: 13-05-2020	
Verified by: I. Aviles Santillana (EN-MME), K. Brodzinski (TE-CRG), T. Capelli (EN-MME), T. Demaziere (EN-MME), C. Gaignant (HL-DPSO), M. Garlaschi (EN-MME), T. Jones (STFC), R. Lardat (Triumph), Th. Otto (HL-PSO)			Date: 27-11-2020	
Approved by: R. Calaga (BE-RF-BR WP4 leader), O. Capatina (EN-MME EDM)			Date: 16-02-2021	
Distribution: J. Gascon (HSE-OHS), O. Williams (HSE-OHS), S. Marsh (HSE-OHS)				
Rev. No.	Date	Description of Changes (major changes only, minor changes in EDM5)		
0.1		First draft for discussion		
0.2	02/09/2019	Second draft for discussion: rearrangement of the content + clarification on materials and bellows requirements		
0.3	04/03/2020	3rd draft for discussion: general revision. Few chapters (i.e. Marking) added. List of SPS DQW drawings replaced with list of EDM5 folders		
0.91	13/05/2020	Comments provided by M. Garlaschi included		
0.92	09/11/2020	Comments provided by K. Brodzinski included		
1.0	02/02/2021	Comments provided by O. Capatina included. Filler material modified. Document status changed to 'Valid'		
Page 1 of 23		Template EDM5 No.: 1372609		

NOTE : NON RIGID ASSEMBLY : THE CONDITIONS OF RESTRAIN TO MEET THE DRAWING REQUIREMENTS ARE DESCRIBED IN THE DOCUMENT EDM5 2956687					
BILL OF MATERIALS					
POS	QTY	DESIGNATION	REFERENCE	MATERIAL	EDM5 CODE
01	1	UPPER CRYO LINE JUMPER CONNECTION	LHCACFQC0580 ST1790616		
02	1	BI-PHASE BOX 1	LHCACFQC0243 ST1358658		
03	1	LHC RFD SAFETY EXTENSION PORT	LHCACFQC0495 ST1647275		
04	1	BI-PHASE BOX 2	LHCACFQC0244 ST1330942		
EDMS SPECIFICATIONS					
No	TITLE			EDMS REFERENCE	
1	Engineering Specifications: cryolines for Crab cavities			2093032 v.1.0	
ISO STANDARDS					
ISO 13920 A-E		ISO 10579-NR			
WHERE USED: Not Applicable [Last checked at 2023-10-26 10:26]					
DESIGNATION		DESIGNED	J. DEQUAIRE	FORMAT	
LHC UPPER CRYO LINE		CHECKED	T. CAPELLI	A0	
		RELEASED	L. DELPRAT	SCALE	
		APPROVED		1:4	
		RELEASED 2024-01-10			
EQUIPMENT CODE	LHCACFQC HL-LHC - deflecting (Crab) Cavities - Cryogenic Circuits		INDEX	FOR INFORMATION	SHEET
	REFERENCES	Doc No: ST1633544_02	AA	GAC	1/1
	LHCACFQC0494				

NCRs for HL-LHC WP4

■ Useful links and documents:

- HL QA training for WP4 (H. Garcia Gavela): [EDMS 2894857](#)
- NCR Process: [EDMS 1499015](#)
- NCR Process for Collaborations: [EDMS 2149457](#)
- NCR Template: [EDMS 1501109](#)
- Launching NCR using EDMS: [EDMS 1908145](#)

■ Main contacts:

- HL-Quality contact for WP4: G. Prica, H. Garcia Gavela
- Standards and specifications: L. Dassa
- Manufacturing quality / Welding activities: J. Debeux, M. Benahmed

NCRs for HL-LHC WP4

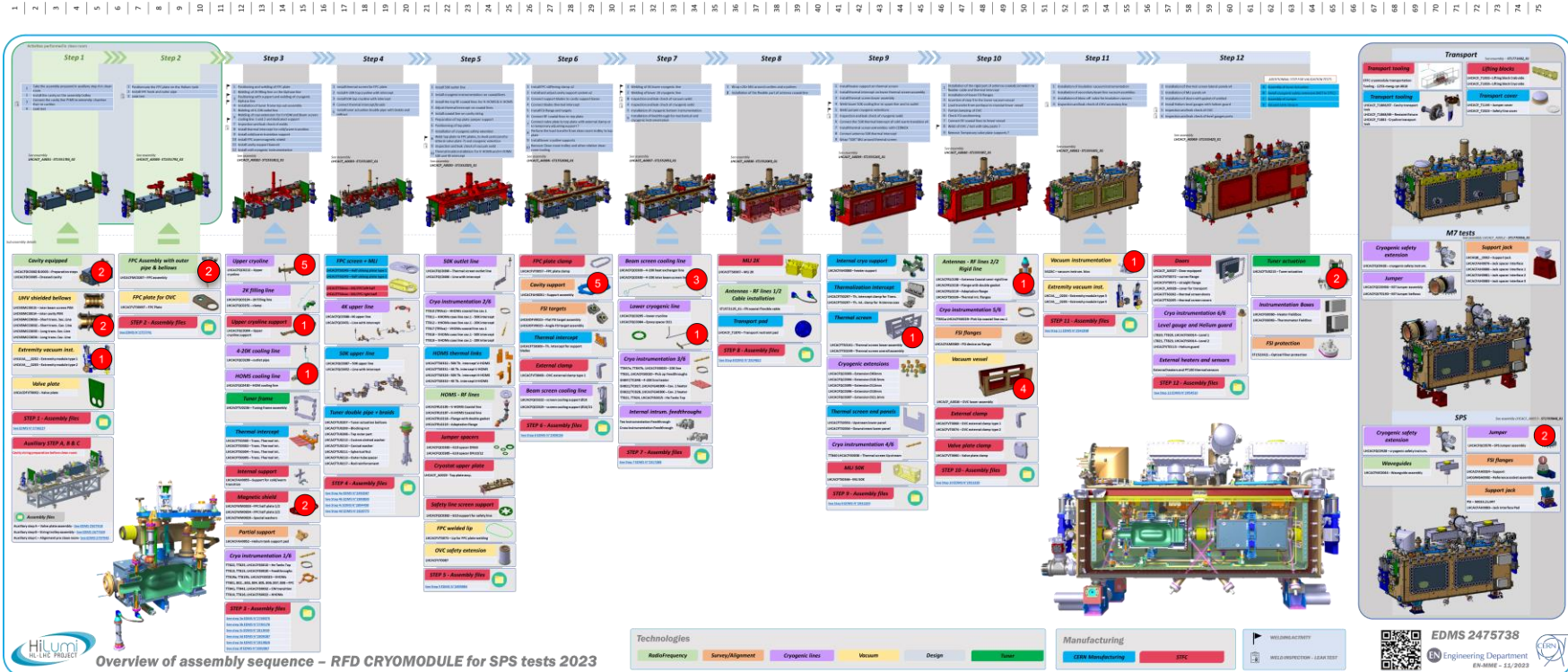
- Persons to be contacted in case of Nonconformity on the HL-LHC WP4 Cryomodule

[EDMS 3014549](#)

Who (from CERN) should sign the NC will depend on the component/system/domain and the level

	Non-critical		Critical
	1 or 2	3	4 or 5
Standards and specifications	L. Dassa		O. Capatina
Transport engineering and Tuner	K. Artoos		O. Capatina
General Design - Test - RF compliance	N. Valverde		R. Calaga
General Design - Design & calculations	T. Capelli		O. Capatina
Manufacturing & assembly & Welding & Logistics	J. Debeux / S. Barriere	M. Garlasche	
Materials	C. Santos Maldonado	I. Aviles	S. Sgobba
Survey	V. Rude	M. Sosin	H. Mainaud
Vacuum compliance	G. Bregliozzi		
Cryogenic compliance	L. Delprat/K. Brodzinski		
Cleanroom & RF cavity compliance	N. Valverde		R. Calaga
RF Tests	K. Turaj		R. Calaga
Low level RF	G. Hagmann		R. Calaga
RF Controls	A. Butterworth		R. Calaga
RF Power compliance	E. Montesinos		
Beam dynamics compliance	N. Mounet	R. Tomas	
HL Quality	G. Prica	H. Garcia Gavela	
Integration, installation	G. Cipolla	P. Fessia/M. Modena	
HL safety	C. Gaignant		T. Otto
Transport and handling on site	M. Perez Ornedo	C. Bertone	
Safety conformity	D. Tshilumba/L. Dassa		S. Marsh
Configuration	M. Zerlauth		

Overview of NCRs for RFD SPS



Between 30 to 35 NCRs reported on EDMS
12 main steps of assembly, ~1300 items (~900 drawings), etc.

NCRs during RFD-SPS CM fabrication, assembly and reception

Bellows and base materials

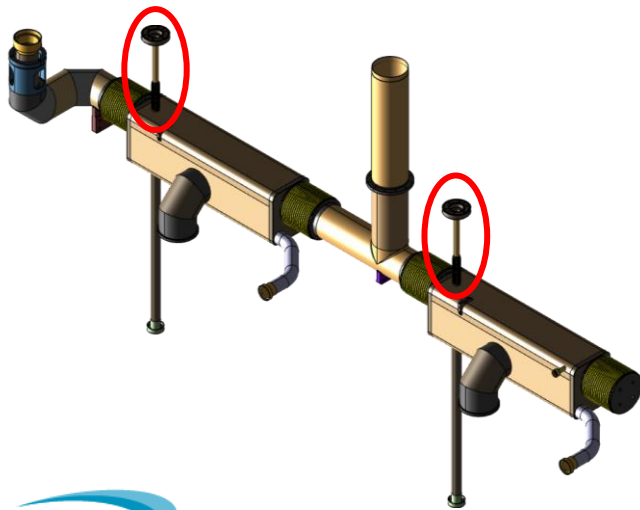
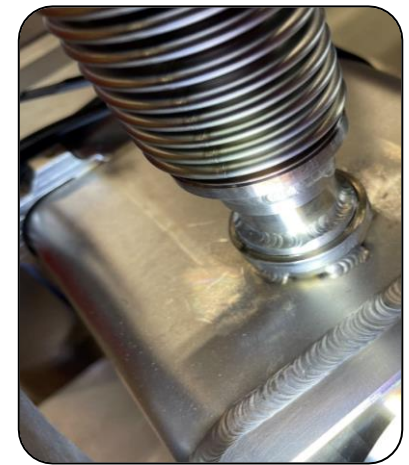
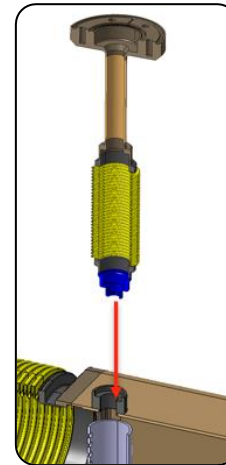
NCRs spotted during RFD-SPS CM Components fabrication

Bellows ~10 NCRs in total

- The NCRs are linked to:
 - **2-ply bellows**
 - Design and Test Pressure
 - Dents
 - Base material
 - Dimensional aspect

Biphase boxes – Level Port Bellows

- *Bellows proposal from subcontractor*
- *Approval focused on dimensions and base material*
- *Essentially discussed / approved by mail*
- *Info on «2-ply» missed during discussions*



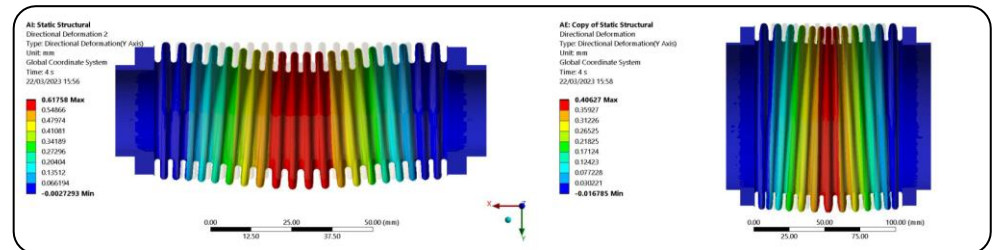
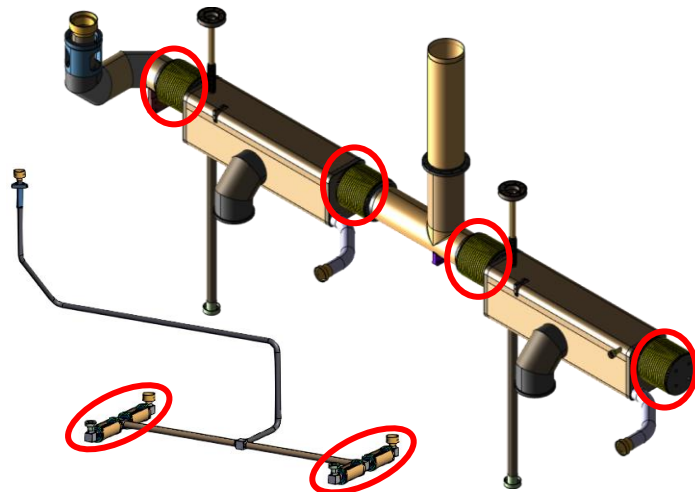
NCRs spotted during RFD-SPS CM Components fabrication

Bellows ~10 NCRs in total

- The NCRs are linked to:
 - 2-ply bellows
 - Design and Test Pressure
 - Dents
 - Base material
 - Dimensional aspect

Bellows for cryogenic lines

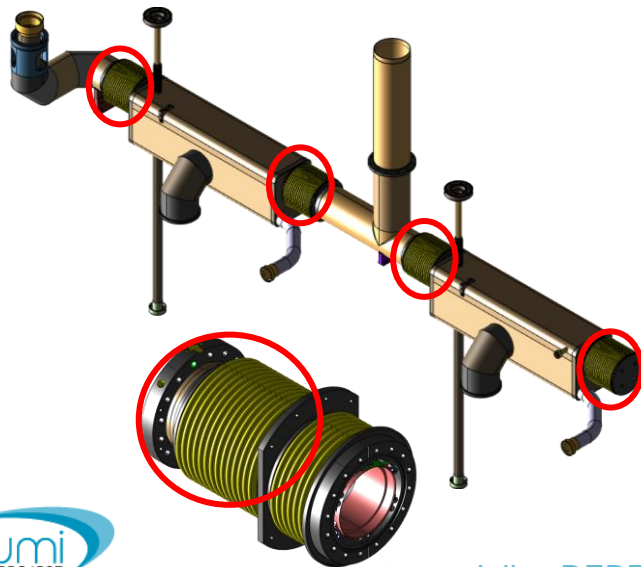
- Design pressure is **2.1 barg** and test pressure is **2.7 barg**.
- The supplier used a design pressure of **1.8 barg** based on test pressure **2.7 barg + coefficient of 1.5** ; while the actual coefficient in **CERN Specification is 1.25**.



NCRs spotted during RFD-SPS CM Components fabrication

Bellows ~10 NCRs in total

- The NCRs are linked to:
 - 2-ply bellows
 - Design and Test Pressure
 - **Dents**
 - Base material
 - Dimensional aspect



Bellows for cryogenic lines and CWT

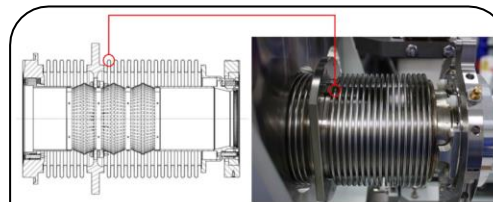
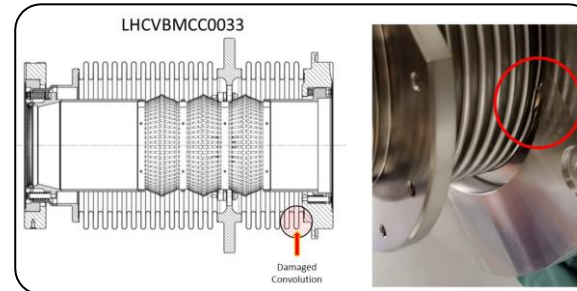
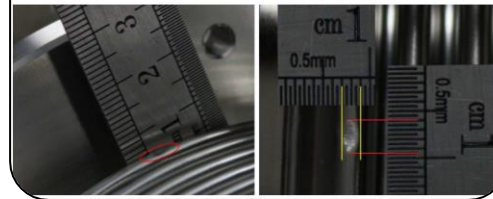
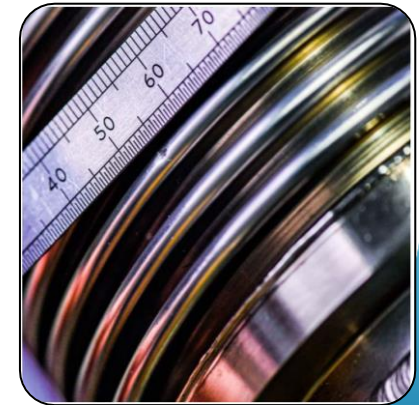


Figure 1: Short CW Transition (Secondary Line) dent.



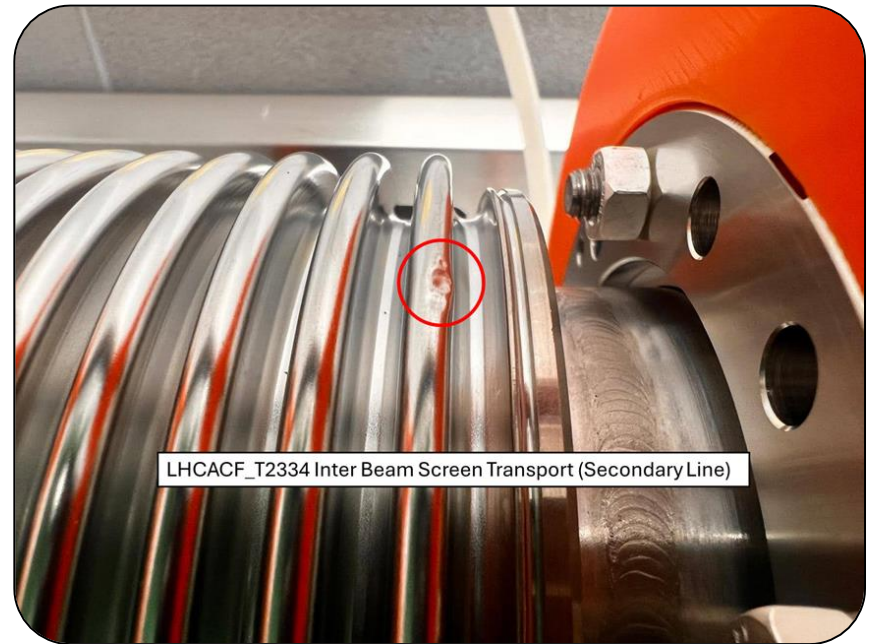
Damaged Convolution



NCRs spotted during RFD-SPS CM Components fabrication



Parallel with LHC Series (RFD Biphasé & DQW PIMs)



NCRs spotted during RFD-SPS CM Components fabrication

Bellows ~10 NCRs in total

- The NCRs are linked to:
 - 2-ply bellows
 - Design and Test Pressure
 - Dents
 - **Base material**
 - Dimensional aspect

Cryogenic lines bellows, blade support and tuner bellows

- *Collars in EN 1.4429 2D Forged instead of 3D Forged*
- *Convolutions in EN 1.4404 (EN 10088-2) instead of EN 1.4435 (EN 10028-7)*
- *Missing Cobalt assessment or Cobalt content >0.3%*
- *No magnetic permeability values given*
- *No inclusion content reported*

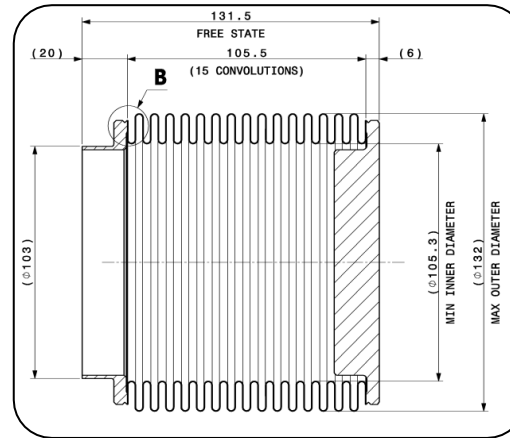
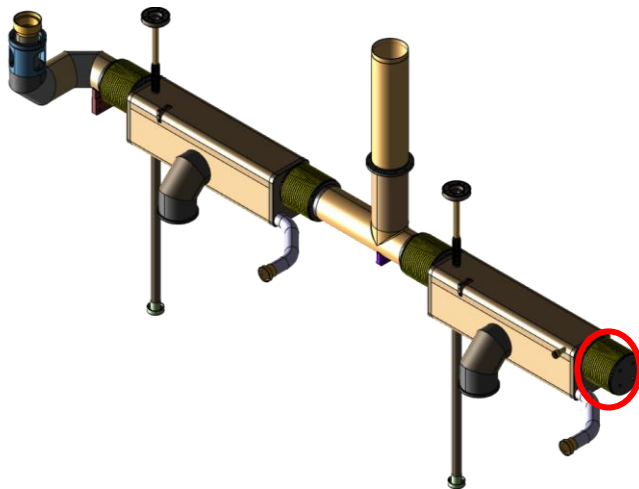
NCRs spotted during RFD-SPS CM Components fabrication

Bellows ~10 NCRs in total

- The NCRs are linked to:
 - 2-ply bellows
 - Design and Test Pressure
 - Dents
 - Base material
 - **Dimensional aspect**

Cryogenic line bellows (extremity bellows)

- *The total length of the bellows is shorter than required (118.6mm instead of 131.5mm)*
- *The number of convolutions is lower than mentioned on drawing*
- *Holes of blank extremity collar not perpendicular*



NCRs spotted during RFD-SPS CM Components fabrication

Bellows ~10 NCRs in total

- The NCRs are linked to:
 - 2-ply bellows
 - Design and Test Pressure
 - Dents
 - Base material
 - Dimensional aspect



LHC SERIES

- Update of Engineering specifications
- Single sourcing for each type of bellows, then dispatched to the collaborations:
 - Cryogenic bellows: KOMPAFLEX AG
 - Tuner and blade support bellows: MEWASA AG



NCRs spotted during RFD-SPS CM Components fabrication

Base material ~8 NCRs in total

- The NCRs are linked to:
 - Material standard
 - ASME / ASTM vs EN standards → Evaluation thanks to PMA
 - EN standards for pressure applications (PED harmonized)
 - Material grades or properties
 - Grade of austenitic stainless steels (EN 1.4429) → Evaluation by experts
 - Welding filler material (W Z 18 16 5 NL) → Evaluation with destructive testing
 - Magnetic permeability → Non-destructive measurements
 - Cobalt content
 - Cobalt content not mentioned in the certificates → Measurements at CERN
 - Values are above the limit → Tracking in [EDMS 2798791](#)

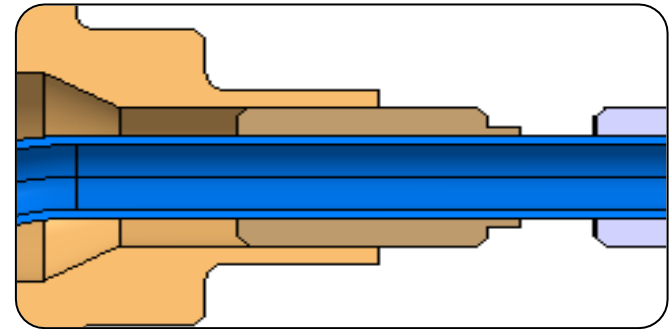
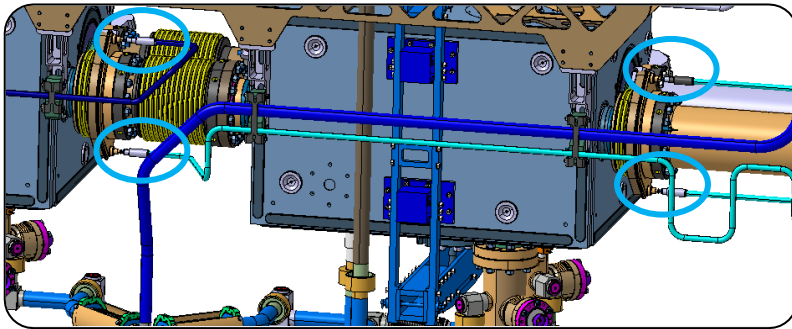
→ **For LHC Series:** Update of specs and drawings, procurement strategy, improvement of QA/QC

NCRs during RFD-SPS CM assembly

Welding

NCRs during RFD-SPS CM assembly

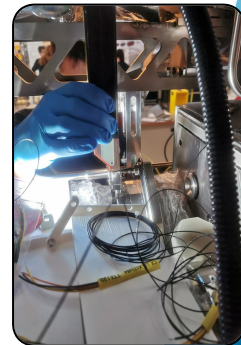
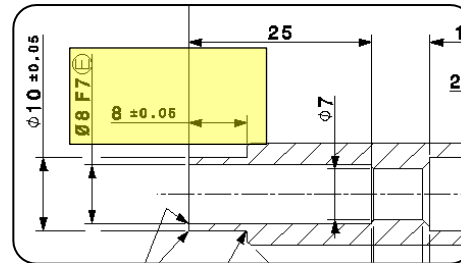
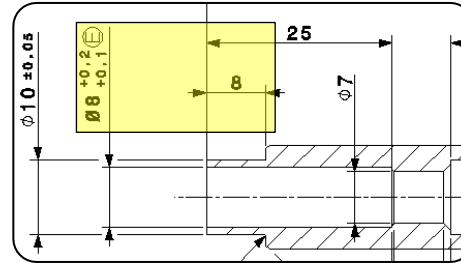
Orbital welds on beam screen lines



NCRs during RFD-SPS CM assembly

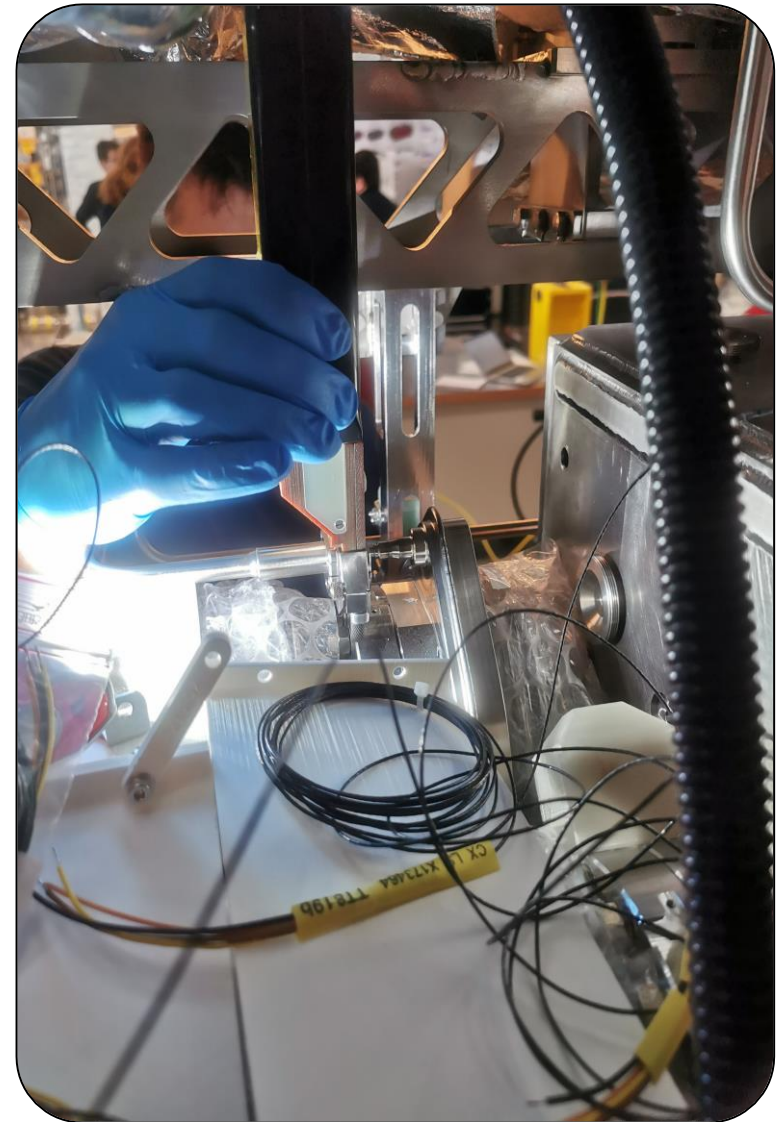


Orbital welds on beam screen lines



- Potential root causes:
 - Tolerances of the parts
 - Limited access
 - Difficulty of execution
 - Backing gas set-up
- Actions:
 - STFC and CERN performed together the repair
 - Knowledge transfer between the teams
 - Modifications of the design drawing
 - Qualification of the welder for repair operation

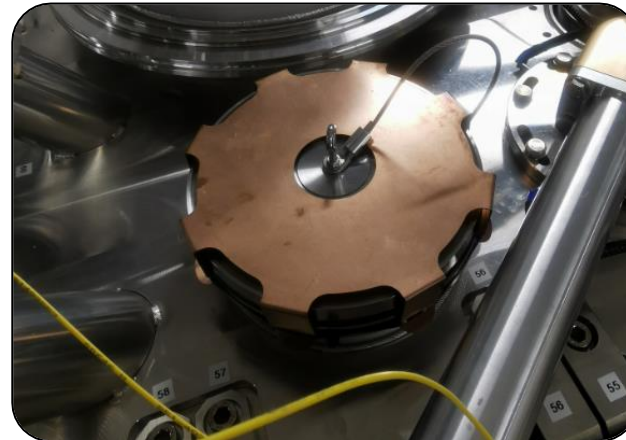
NCRs during RFD-SPS CM assembly



NCRs during RFD-SPS CM assembly

Other NCRs

- Dimensional control (Blade support assy, OVV, WMS, biphasic line, etc.)
- Clash / Matching during assembly (HOM Cooling line, RF Coax line, etc.)
- Blow-off valve (insulation vacuum)

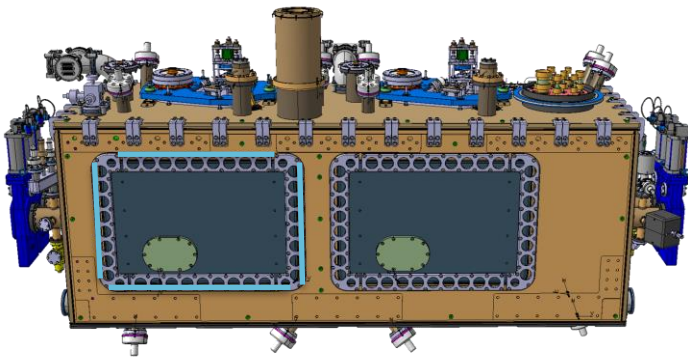


➔ Evolution of assembly procedure, Engineering Specs, safety components, etc.

NCRs during RFD-SPS CM Reception

Other NCRs

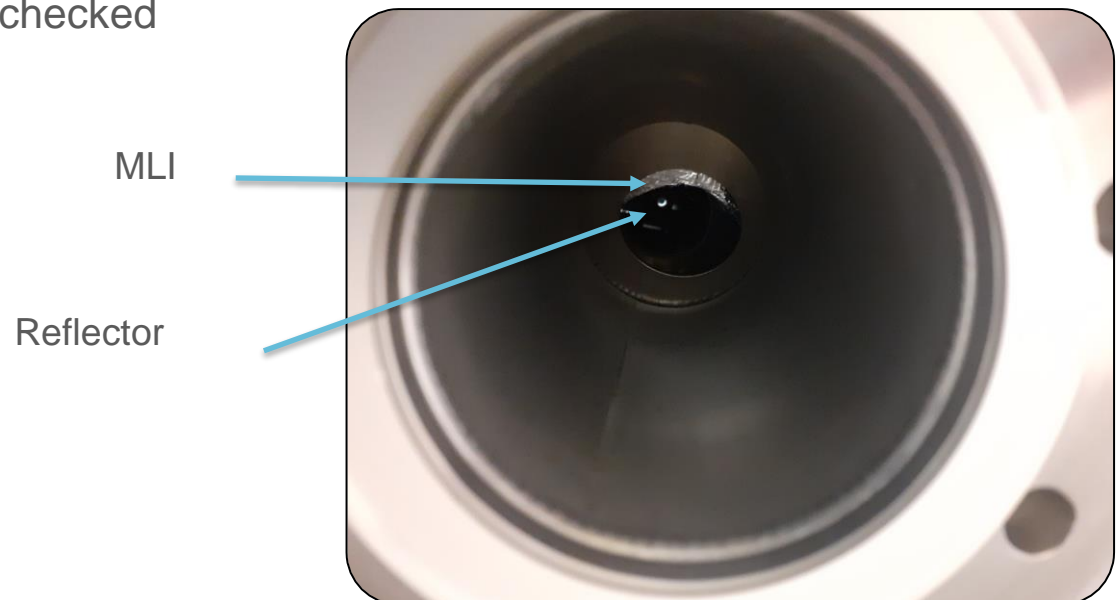
- Tightening checks:
 - Lateral doors: 1 door not OK (1/4 of a turn missing)
 - Cavity support system:
 - 1 FPC connection **partially OK**
 - Top blade connection: locking screws **not OK**
 - Cryogenic transport lock: **Loose**
 - Tuner Thermal Intercept: Connexion to double pipes or braids **partially OK**



NCRs during RFD-SPS CM Reception

Other NCRs

- FSI checks:
 - 4 lower FSI were obstructed by MLI
- Cryo instrumentation:
 - Labels removed / replaced
 - Heaters not installed / checked



Courtesy of T. CAPELLI

Conclusions and perspectives

- RFD-SPS Prototype:
 - This prototype phase was highly instructive, also for QA-QC activities.
 - Some difficulties to deliver and review quality and manufacturing documents in time, with a rigorous respect of approval process.
- Concerning requirements:
 - To prepare LHC Series, the Eng. Spec and drawings were updated.
→ Few Deviation Permit Requests have been already prepared.
- Concerning NCRs:
 - Important step during drafting NCRs: Root causes, preventive and corrective actions and implications

→ For LHC Series:

All the requirements shall be respected, any deviation must be **traced** and **approved before continuing the production.**

Conclusions and perspectives

- CERN:
 - A new welding and quality engineer hired in April 2024 (Myriam Benahmed)
- Collaborations with STFC / TRIUMF:
 - Good use of HL QA tools
 - Efficient raw material procurement strategy
 - Transparency, respect of reviewing processes (from the procurement specification drafting)
 - Some QA tools have been implemented

UPPER CRYOLINE (LHCACFQC0357)						
EDMS Link	Document title	Status	responsible of on-going action	Actions	Priority	
The documents shall be attached to the rights MTF asset						
	Traceability and material certificates					
https://edms.cern.ch/document/1314537/	IME	In work	STFC	Revisions requested from Hyds following CERN comments: 2024 16/9	0	
https://edms.cern.ch/document/1314604/	Weld books (weld traceability reports)	In work	STFC	Revisions requested from Hyds following Julia's comments on 6/9	0	
https://edms.cern.ch/document/13149234/	Weld production schedules	HL Engineering Check	STFC	Andy to clarify with Hyds where some of JDB's comments not taken into account	0	
https://edms.cern.ch/document/13144603/	WPSs	In work	STFC	Andy to upload updates with CERN feedback soon by email 6/9 after weld tests	0	
https://edms.cern.ch/document/1314555/	WPOs	In work	STFC		0	
https://edms.cern.ch/document/1314545/	WPOs	In work	STFC	Ready to upload after weld tests	0	
https://edms.cern.ch/document/1314545/	Welding filler	Released	STFC	Hyds to process approved welding filler	0	
https://edms.cern.ch/document/13126037/	NDT qualifications	HL Engineering Check	STFC	Prepare deviation request with Hyds to demonstrate the equivalence / the differences between their certifications and our requirement EN ISO 9712. Ref JDB's comments: 16/9 (email and EDMS)	1	
https://edms.cern.ch/document/13156653/	Biphase box production drawings	Draft for Discussion	STFC	To be updated following test results	1	
https://edms.cern.ch/document/13149637/	Biphase line cleaning procedures	In work	STFC	Flow chart to be added	0	
https://edms.cern.ch/document/13156545/	Biphase line cleaning procedures at Hyds	Under Approval	CERN	To be approved/accepted by JDB: 10-Sept)	1	
https://edms.cern.ch/document/13156718/	Biphase line cleaning procedures at STFC	In work	STFC	To be provided by vac lab	0	
https://edms.cern.ch/document/13162020/	Biphase line leak test procedure	In work	STFC	To be provided by Hyds	1	
https://edms.cern.ch/document/13162020/	Biphase line leak pressure procedure	In work	STFC	To be provided by Hyds	1	
https://edms.cern.ch/document/13162020/	Biphase line leak test reports	In work	STFC	To be provided by Hyds	2	
https://edms.cern.ch/document/13162024/	Biphase line leak pressure reports	In work	STFC	To be provided by Hyds	2	
https://edms.cern.ch/document/13162025/	Biphase line metrology	In work	STFC	To be provided by Hyds	2	
	Bellows reports					
LOWER CRYOLINES						
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The documents shall be attached to the rights MTF asset						
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	WPSs	In work	STFC	FE to send to STFC	0	
	WPOs	In work	STFC	FE to send to STFC	0	
https://edms.cern.ch/document/13162031/	WPOs	In work	STFC	FE to send to STFC	0	
	Welding filler					
	NDT qualifications	In work	STFC	FE to send to STFC	0	
https://edms.cern.ch/document/13162965/	Cryolines cleaning procedure	In work	STFC	FE to send to STFC (updated following CERN feedback)	1	
	Cryolines leak test procedure					
	Cryolines pressure test procedure					
https://edms.cern.ch/document/1315517/	Cryolines leak test reports	Draft for Discussion	CERN	CERN to approve templates	1	
https://edms.cern.ch/document/13155653/	Cryolines pressure test reports	Draft for Discussion	CERN	CERN to approve templates	1	
	Cryolines metrology					

Page 1



Thank you !

Any questions ?



Back-up slides

Back-up slides

