Qualification and NCRs from UK during Cryomodule Assembly

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Experience from RFD CM tests at CERN I – Indico 1414262 – 18/06/2024

Introduction

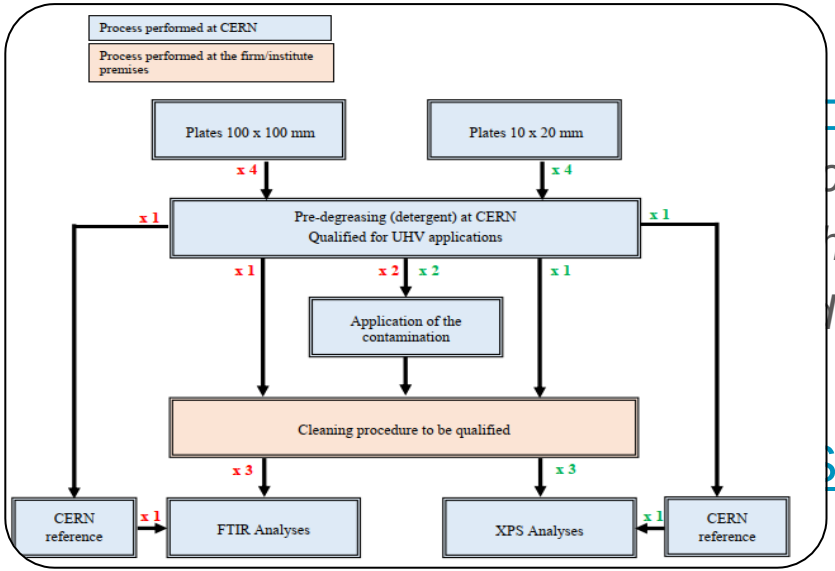
- **Welding and Manufacturing Quality activities**
  - 3 years working at Main Workshop as Welding Engineer for various projects
  - Working for WP4 since November 2022
  - Since April 2024: Myriam Benahmed has joined the WP4 team as Welding Engineer

- **Topics**
  - Qualifications passed by UKRI during RFD-SPS CM Assembly
  - NCRs spotted during RFD-SPS components fabrication and assembly in UK
  - NCRs spotted during RFD-SPS assembly and reception at CERN

Qualification passed by UKRI during CM Assembly

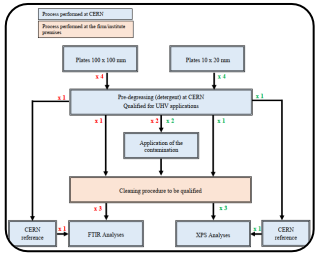
Qualification passed by UKRI during CM Assembly

- **UHV Cleaning procedure qualification**
  - Procedure for qualification: EDMS 1726970



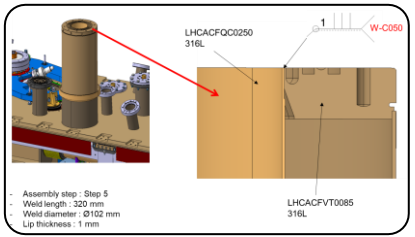
Qualification passed by UKRI during CM Assembly

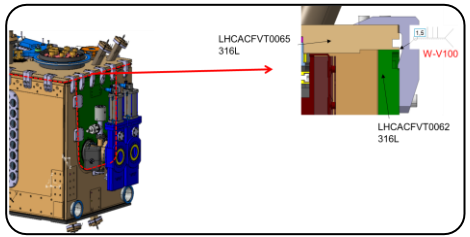
- **UHV Cleaning procedure qualification**
  - Procedure for qualification: EDMS 1726970
  - First attempt: NOK, see NCR LHC-ACF_A-QN-0004
    - *Qualification process not respected*
    - *Cleanliness requirements not shared with technicians*
    - *6 months between cleaning and CERN analysis*
  - Second attempt: OK, see EDMS 2888023

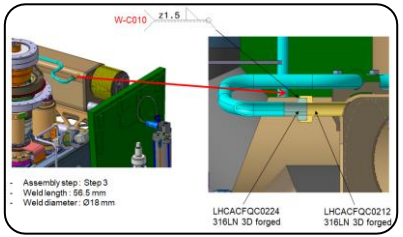


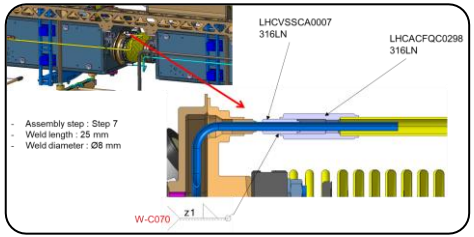
Qualification passed by UKRI during CM Assembly

- **Welding activity during CM Assembly**
  - List of weld to be performed during CM Assembly: EDMS 2678641
  - 4 main configurations:



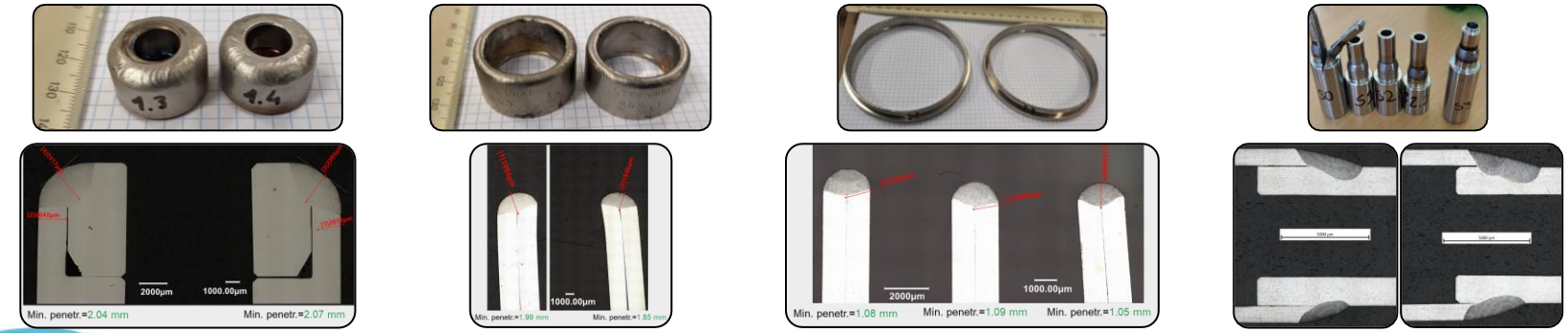






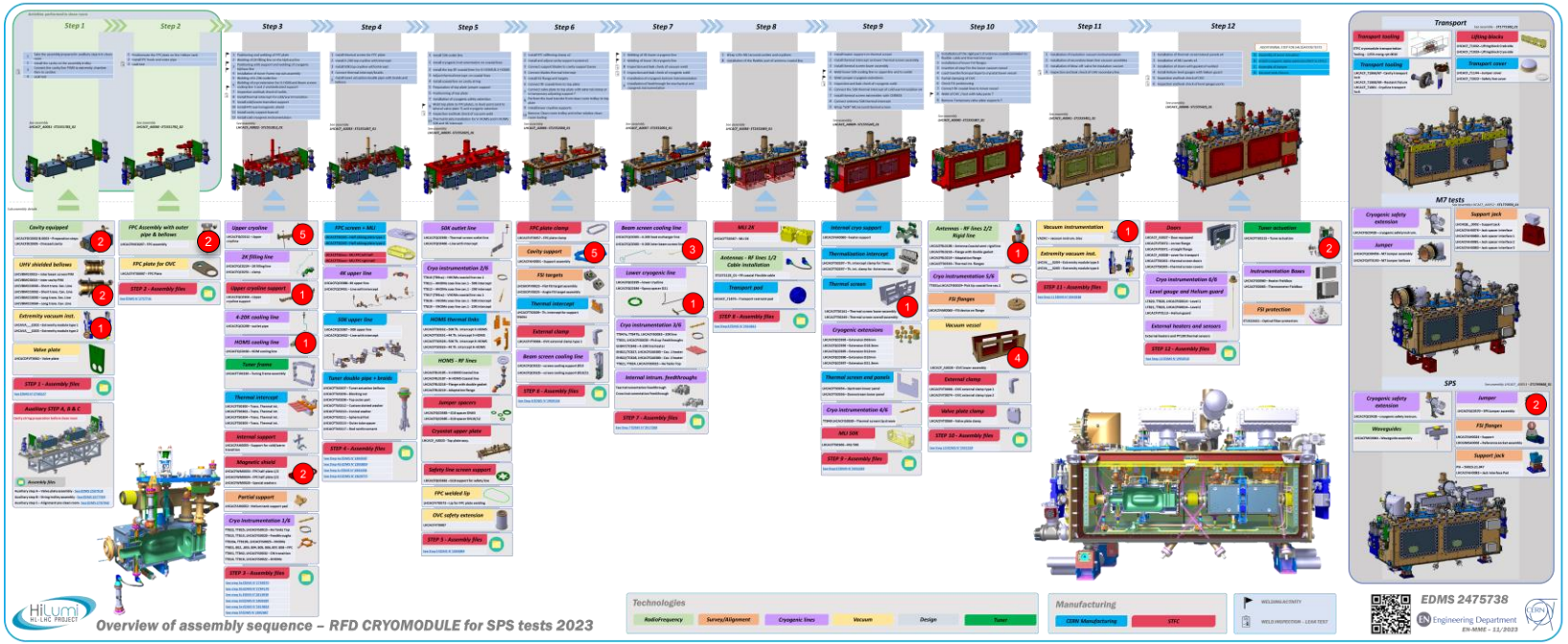
Qualification passed by UKRI during CM Assembly

- **Welding activity during CM Assembly**
  - Dedicated specification edited for qualification, fabrication, inspection and acceptance criteria: EDMS 2706475
    - WPQR required for the 4 configurations
    - Welder and Welding Operators Qualifications required
    - Witness samples sent to CERN for examination (VT + PT + Metallography)



NCRs during RFD-SPS CM fabrication, assembly and reception

Overview of NCRs for RFD SPS



Between 30 to 35 NCRs

Difficult to count due to approximative metadata / EDMS Context / Release Procedure / Assets / etc.

NCRs during RFD-SPS CM fabrication, assembly and reception

Bellows and base materials

NCRs spotted during RFD-SPS CM Components fabrication

Bellows

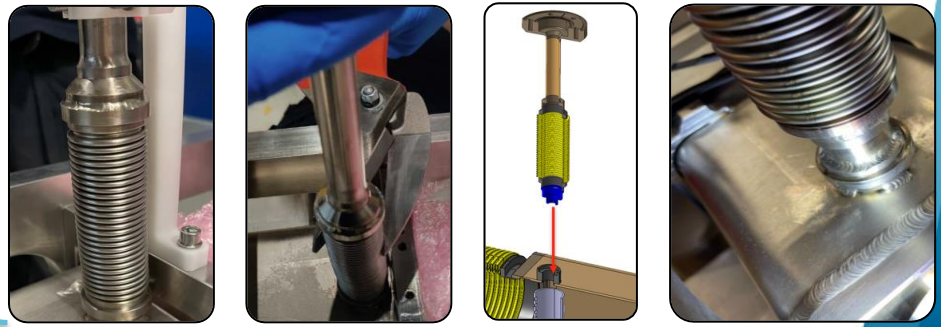
- The NCR are linked to:
  - 2-ply bellows
  - Design and Test Pressure
  - Dents
  - Base material
  - Dimensional aspect

1 NCR

Biphase boxes – Level Port Bellows

- *Difficulties to source bellows as per CERN drawings, so stock bellows were proposed.*
- *No NCR / Deviation request prepared in time with full review*
- *Info on «2-ply» missed during discussions*

➔ *Replacement with an adapted CERN LOWER CRYOLINE BELLOWS*



NCRs spotted during RFD-SPS CM Components fabrication

Bellows

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

Bellows for cryogenic lines

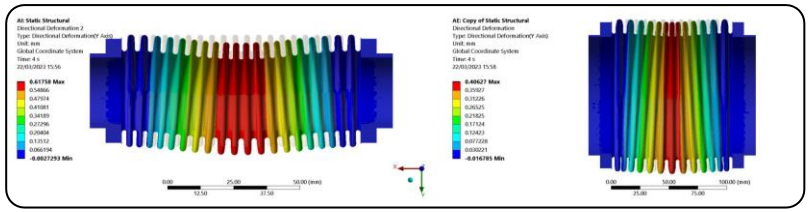
- *Design pressure is **2.1 barg** and test pressure is 2.7 barg.*
- *The supplier used a design pressure of **1.8 barg** based on test pressure 2.7 barg + **coefficient of 1.5** ; while the actual coefficient in CERN Specification is **1.25**.*

➔ *The bellows were welded before acceptance of the documentation.*

➔ *New calculations and simulations were performed*

➔ *Pressure test passed*

➔ *Clarification done in Engineering Specification*



2 NCRs

NCRs spotted during RFD-SPS CM Components fabrication

Bellows

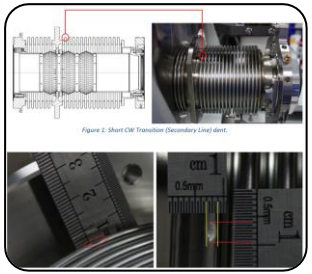
- The NCR are linked to:
  - 2-ply bellows
  - Design and Test Pressure
  - Dents
  - Base material
  - Dimensional aspect

Bellows for cryogenic lines and CWT

- *Protection during transport or manufacturing*
- *Deviation during assembly procedure*

➔ *Bellows must be always protected*

➔ *Dedicated leak tests and pressure tests of the components with evaluation of the geometries before, during and after.*



2 NCRs

NCRs spotted during RFD-SPS CM Components fabrication

Bellows

- The NCR 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*

➔ *PMA (Particular Material Appraisal) prepared*

➔ *Additional tests performed on spare bellows (metallography, 3D Computed microtomography, Helium leak test)*

➔ *Cobalt content assessment (EN-MME-MM)*

➔ *Update of Engineering Specification and drawings to be more precise and relevant in the requirements*

3-4 NCRs

NCRs spotted during RFD-SPS CM Components fabrication

Bellows

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

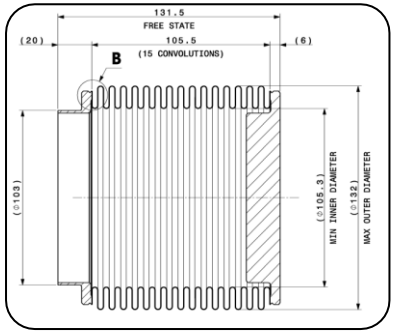
Cryogenic line bellows (extremity bellows)

- *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*

➔ *Spacers installed to compensate*

➔ *Second pattern of holes machined*

➔ *Quality controls requirements increased*



2 NCRs

NCRs spotted during RFD-SPS CM Components fabrication

Bellows

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

Main preventive actions for LHC Series:

- *The Engineering specification have been reworked*
- *CERN is providing the bellows (vacuum and cryogenic) to the collaborations*
  - *Cryogenic bellows: KOMPAFLEX AG*
  - *Tuner and blade support bellows: MEWASA AG*

~10 NCRs in total

NCRs spotted during RFD-SPS CM Components fabrication

Base materials

8 NCRs

- The NCR are linked to:
  - Material standard
    - *ASME / ASTM vs EN standards*
    - *EN standards for pressure applications (PED harmonized)*

    → *Evaluation thanks to PMA*

  - Material grades or properties
    - *Grade of austenitic stainless steels (EN 1.4429)*
    - *Welding filler material (W Z 18 16 5 NL)*
    - *Magnetic permeability*

    → *Evaluation by experts*
    Evaluation with destructive testing
    Non-destructive measurements

  - Cobalt content
    - *Cobalt content not mentioned in the certificates*
    - *Values are above the limit*

    → *Measurements at CERN*
    Tracking in EDMS 2798791

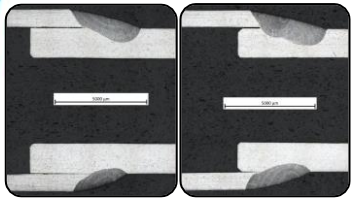
→ ***For LHC Series:*** *Update of specs and drawings, free-issued parts, improvement of QA/QC*

NCRs during RFD-SPS CM fabrication, assembly and reception

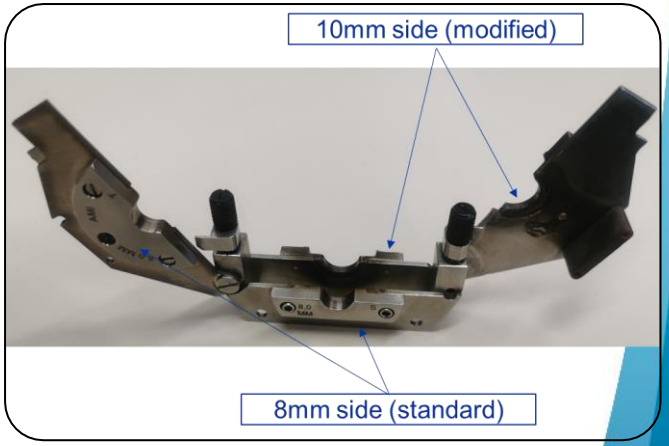
Welding

NCRs spotted during RFD-SPS CM Components assembly

- **Orbital welds of beam screens**

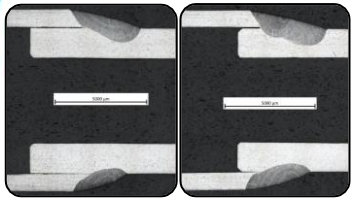


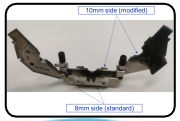
See [EDMS 2758225]



NCRs spotted during RFD-SPS CM Components assembly

- **Orbital welds of beam screens**





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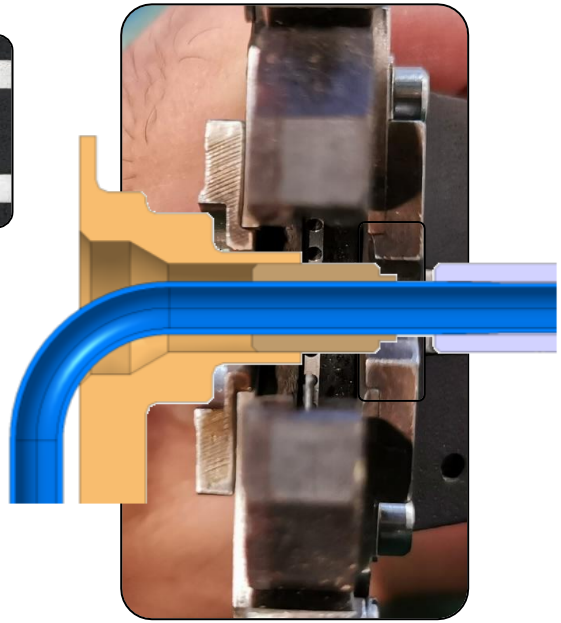
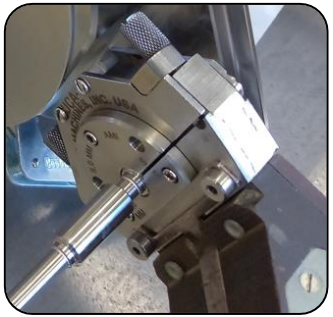
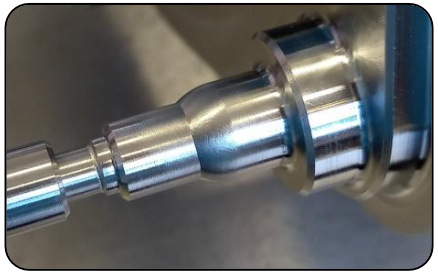




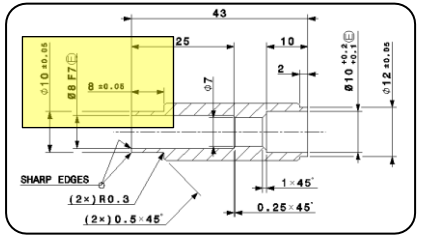


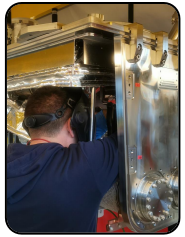
NCRs spotted during RFD-SPS CM Components assembly

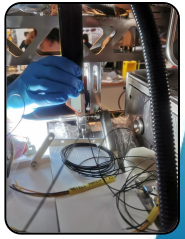
Orbital welds of beam screens

- The NCR is linked to:
  - *Tolerances of the parts*
  - *Experience of the welder*
  - *Limited access*
  - *Difficulty of execution*
  - *Difference between sample work and in-situ assembly*

- Actions:
  - *CERN performed the repair*
  - *Knowledge transfer between welders*
  - *Modifications of the design drawings*







NCRs spotted during RFD-SPS CM Components assembly

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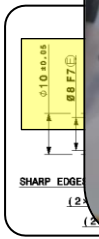
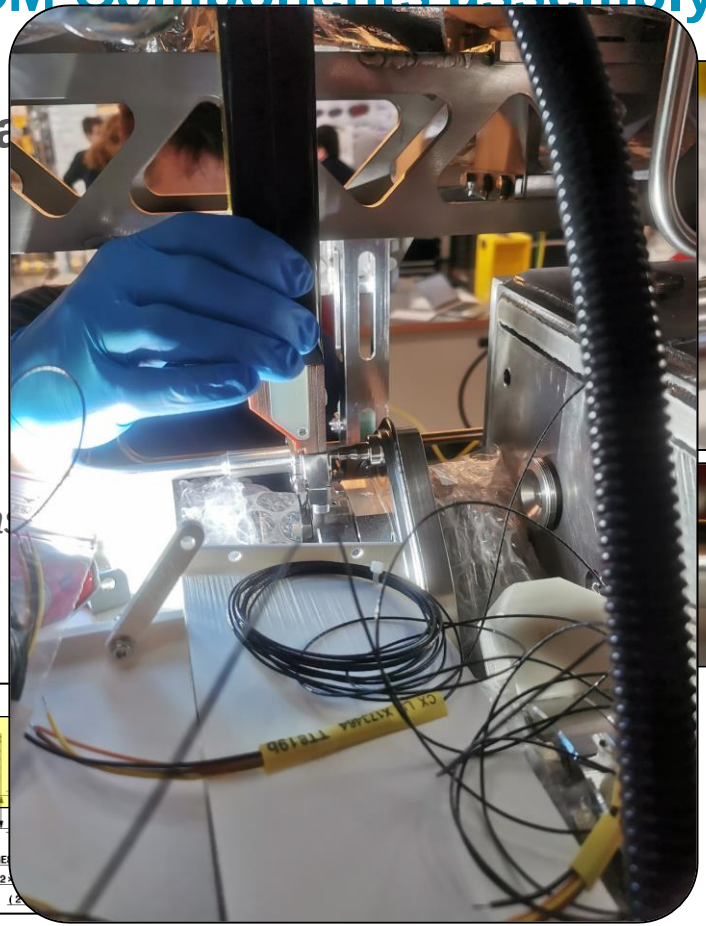
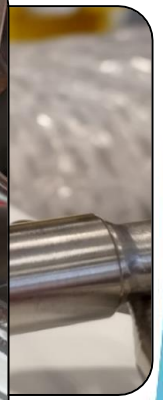




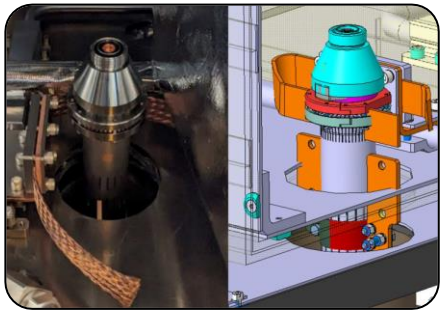


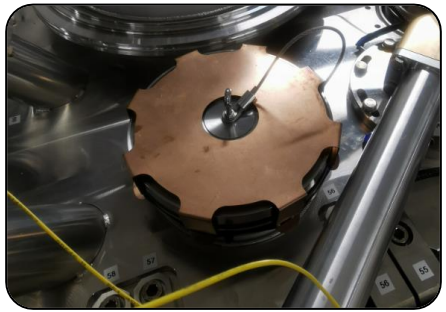
NCRs spotted during RFD-SPS CM Components assembly

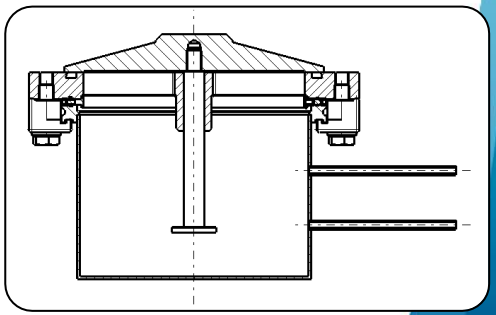
Other NCRs

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

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



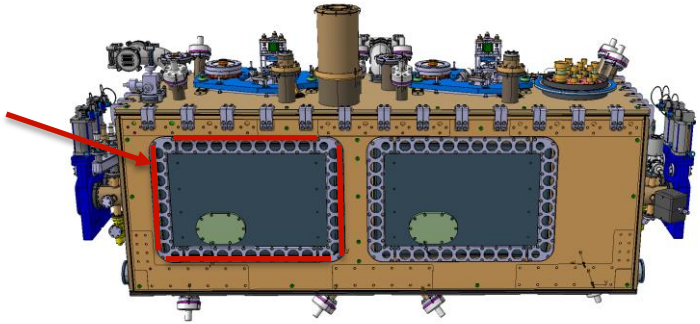




NCRs spotted during RFD-SPS CM Reception and Testing

These NCRs are not always documented on EDMS

- *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*

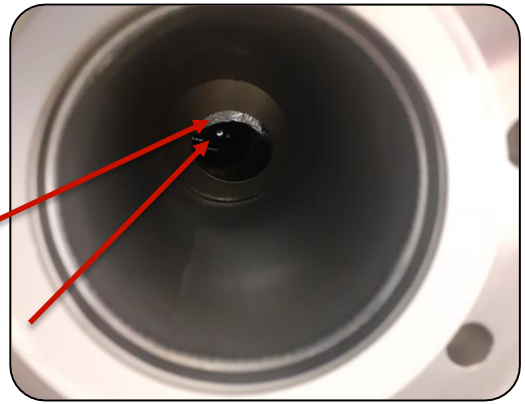


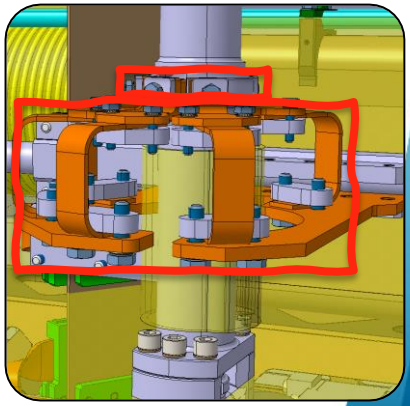
Courtesy of T. CAPELLI

NCRs spotted during RFD-SPS CM Reception and Testing

These NCRs are not always documented on EDMS

- *Tightening checks:*
  - *Cryogenic transport lock: Completely loose*
  - *Tuner Thermal Intercept: Connexion to double pipes or braids partially OK*
- *FSI checks:*
  - *4 lower FSI were obstructed by MLI*
- *Cryo instrumentation:*
  - *Labels removed / replaced*
  - *Heaters not installed / checked*
  - *Etc.*





Courtesy of T. CAPELLI

Conclusions

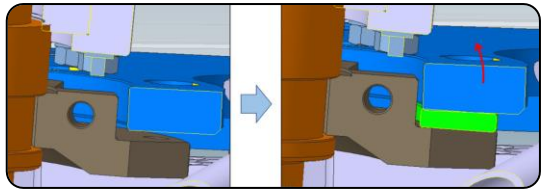
Importance of NCR Evaluation, Decision and Actions

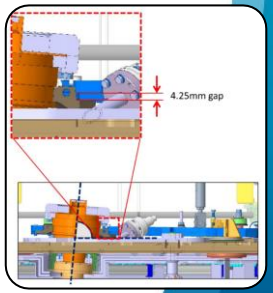
Non-exhaustive list of guidelines

- In case of NCR:
  - *Stop the work and contact ALL the WP4 experts concerned: EDMS 3014549*
  - *In parallel, prepare and launch the NCR according to the HL Procedure: EDMS 1499015*
  - *It is important to mind about **preventive and corrective actions***
  - ***Root cause analysis** and **implications** shall be evaluated too, especially when integration is concerned*

➔ *Hector GARCIA GAVELA and Gorana PRICA can help you in the process*

- Example of (potential) link between NCRs / Critical Components / Steps:
  - ***RFD-SPS Biphase line:** NCRs on bellows > New Pressure Test > NCR due to Plastic deformation of bellows*
  - ***Cavity Support Plate Integration:** Is this issue linked to the critical NCR on FPC1 ?*
    - *LHC-ACFAH-QN-0005*
    - *LHC-ACF-QN-0005*





➔ *See talk of T. CAPELLI (NCR and Repair actions : Leak cav2 and FPC cav1)*

Importance of NCR Evaluation, Decision and Actions

LHC Series

- CERN:
  - *Following RFD-SPS, a huge work done on Eng. Spec. and drawings*
  - *A new welding and quality engineer hired early 2024*
  - *A close-knit, transparent and responsive team*

- STFC / UKRI:
  - *The RFD-SPS Prototype phase was highly instructive*
  - *The team seems now OK with HL Procedure and WP4 Eng. Spec. requirements*

- TRIUMF:
  - *Relevant questions and discussions on WP4 components requirements*
  - *HL Quality trainings seems to have a good impact*
  - *Some of the critical components (e.g.: cryogenic lines) are manufactured at CERN*
  - *During manufacturing steps, probable discussions or NCR linked to standards (ASTM /ASME vs EN ISO)*
  - *At that time, Cleaning and Welding qualifications have not yet begun…*

Thank you !