Mechanical design aspects of the HL-LHC jumper interfaces

F. Merli, TE-CRG
with the contribution of A. Lees, M. Sisti, A. Perin
Outline

- Current status
- HL-LHC jumpers interfaces
- Design
- Installation
- Conclusions
Current status of jumpers interfaces design

Position ✔ → Layout drawings – Project version (LHCQXL_G0001 / 0002 / 0003 / 0004)
– Tender version (LHCQXL_G0009 / 0010 / 0011 / 0012)

Configurations ✔ → Interface drawings – Project version (LHCQXL__20 - 54)
– Tender version (LHCQXL__55 - 90)

Design requirements (main) ✔ → Technical Specification (IT-4630)

Design requirements (full list)

Installation requirements

Assembly methods

Interconnection parts
Contents of interface specification

**HL-LHC JUMPER INTERFACES**
- Configurations *
- List *
- Position *

**DESIGN**
- Design Functions *
- Design Requirements *

**INSTALLATION**
- Installation sequence
- Installation tolerances *
- Tooling

**INTERCONNECTION**
- Assembly methods
- Interface Interconnection Kit *
- Tooling

* To be included in the first release of the Interface Specification
Proposed schedule of interface specification

HL-LHC Jumpers Interface Specification

HL-LHC WP9

HL-LHC WP16

Version 1

QXL Technical specification release

SQXL installation

31.03.2022

Version 2

QXL Procurement Contract release

Version 3

Version 4

SQXL interconnection
HL-LHC Jumpers Interfaces
Types of Jumpers Interfaces

**Type 1**
QXL/QRL flexible jumper to user

**Type 2**
Jumper extension to QXL/QRL

**Type 3**
Jumper extension to user

**Type 4**
QXL/QRL rigid jumper to user

Q2B, CP, D1, Q4

D2, CC-B1, CC-B2, Q4

DFX, DFM
# Variants of Jumpers Interfaces

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<tr>
<th>Type 1</th>
<th>Type 2 &amp; 3</th>
<th>Type 4</th>
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<th>Butt welds</th>
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## Variants of Jumpers Interfaces

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Position of Jumpers Interfaces

### Table: Position of Jumpers Interfaces

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### Diagram: Position of Jumpers Interfaces

- QRL axis: 530 mm
- COL axis: 530 mm
- COL x: 440 mm
- Beam axis: 1100 mm

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F. Merli, TE-CRG-ME, 04.03.2022 - Mechanical design aspects of HL-LHC jumper interfaces
Design functions

DF1 – Continuity of insulation vacuum
DF2 – Continuity of thermal shield
DF3 – Continuity of cryogenic lines
DF4 – Accessibility for installation activities
DF5 – Allowance for repair activities (3x)
DF6 – Capability to fulfill installation requirements
DF7 – Weldability without inert gas inside the pipes
DF8 – Easy running fits matching welding alignment requirements
Design requirements

DF1 – Continuity of insulation vacuum

DR1.1 – Leak rate ≤ $10^8$ mbar l/s

DR1.2 – Accommodate relative offsets of jumpers without exceeding allowable loads

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<th>Jumper</th>
<th>Global displacement of users [mm]</th>
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Including:
1. Manufacturing tolerances, $\Delta_{MAN}$
2. Installation tolerances, $\Delta_{INST}$
3. Installation measurement accuracy, $\Delta_{MEAS}$
4. Pipes interconnection allowance, $\Delta_{INT}$
5. Pipes nominal thermal contraction, $\Delta_{TH}$
6. Remote alignment allowance, $\Delta_{RA}$
7. Loss of Insulation Vacuum allowance, $\Delta_{LIV}$

Maximum allowable force [N] | Maximum allowable moment [Nm]
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Description of input and assumptions of global displacements evaluation

Jumper stiffness analysis

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F. Merli, TE-CRG-ME, 04.03.2022 - Mechanical design aspects of HL-LHC jumper interfaces

S. Dutta, 2004
Design requirements

DF2 – Continuity of thermal shield
DR2.1 – Heat Load < 1 W/m²
DR2.2 – Accommodation of relative offsets of jumper interfaces

DF3 – Continuity of cryogenic lines
DR3.1 – Design pressure as for pipes (Header B=4 bar, C=20 bar, D=20 bar, E=25 bar, F=25 bar)
DR3.2 – Leak rate ≤ 10⁻⁹ mbar l/s
DR3.3 – Load < 0.1 W/m²
DR3.4 – Negligible pressure loss
DR3.5 – Accommodate relative offsets of jumpers without exceeding allowable loads

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<th>Additional displacement of Process Piping [mm]</th>
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Weld flange structural analysis

EDMS 1896504
Diode Box covers weld assessment

Jumper stiffness analysis
Design requirements

DF4 – Accessibility for installation activities
DR4.1 – Minimum access opening
DR4.2 – Reservation volumes for installation tooling
DR4.3 – Reservation volumes for cutting tools to remove end caps

DF5 – Allowance for repair activities (3x)
DR5.1 – Weld flanges length ≥ 9 mm
DR5.2 – Reservation volume for installation tooling in worst case scenario

Interface layout review
Interface interconnection mock-up
Design requirements

DF6 – Capability to fulfil installation requirements

DR6.1 – Manufacturing tolerance on key Service Module dimensions

DR6.2 – Temporary end cap design equipped with temporary fiducial linked to V.I.P.
Design requirements

DF7 – Weldability without inert gas inside the pipes
DR7.1 – Butt weld with backing ring for D<30 mm
DR7.2 – Weldable flange with sliding sleeve connection for D>30 mm

DF8 – Easy running fits matching welding alignment requirements
DR8.1 – Manufacturing tolerance on backing ring outer diameter
DR8.2 – Manufacturing tolerance on pipe flanges outer diameter and sleeve inner diameter
DR8.3 – Manufacturing tolerance on vacuum jacket flanges outer diameter and sleeve inner diameter

Flanges
Sleeve

LHC-QRL-NOT-2006

Welding technique: Orbital TIG welding
Maximum radial gap: 0.8 mm

Line M Tacking Procedure
## Design requirements

<table>
<thead>
<tr>
<th>Design Function</th>
<th>Design Requirement</th>
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| **DF1** Continuity of insulation vacuum | DR1.1 Leak rate ≤ $10^{-8}$ mbar l/s  
DR1.2 Accommodate relative offsets of jumpers without exceeding allowable loads |
| **DF2** Continuity of thermal shield | DR2.1 Heat Load < 1 W/m²  
DR2.2 Accommodate relative offsets of jumpers |
| **DF3** Continuity of cryogenic lines | DR3.1 Design pressure as for pipes  
DR3.2 Leak rate ≤ $10^{-9}$ mbar l/s  
DR3.3 Heat load < 0.1 W/m²  
DR3.4 Negligible pressure loss  
DR3.5 Accommodate relative offsets of jumpers without exceeding allowable loads |
| **DF4** Accessibility for installation activities | DR4.1 Minimum access opening  
DR4.2 Reservation volumes for installation tooling  
DR4.3 Reservation volumes for cutting tools to remove end caps |
| **DF5** Allowance for repair activities (3x) | DR5.1 Weld flanges length ≥ 9 mm  
DR5.2 Reservation volume for installation tooling for worst case scenario |
| **DF6** Capability to fulfil installation requirements | DR6.1 Manufacturing tolerance on key Service Module dimensions  
DR6.2 Temporary end cap design equipped with temporary fiducial linked to V.I.P. |
| **DF7** Weldability without inert gas inside the pipes | DR7.1 Butt weld with backing ring for D<30 mm  
DR7.2 Weldable flange with sliding sleeve connection for D>30 mm |
| **DF8** Easy running fits matching welding alignment requirements | DR8.1 Manufacturing tolerance on backing ring outer diameter  
DR8.2 Manufacturing tolerance on flanges outer diameter and sleeve inner diameter  
DR8.3 Manufacturing tolerance on flanges outer diameter and sleeve inner diameter |
Installation sequence

1. QXL/QRL INSTALLATION

- **Installation tolerance:** ± 3 mm
- **Measurement accuracy** <= 0.3 mm

1.1 ADJUSTMENT IN Y
1.2 ADJUSTMENT IN X AND Z
1.3 ADJUSTMENT OF TILTING ANGLE

Similar to QRL procedure C1105-PO-088(5)
Installation sequence

1. QXL/QRL INSTALLATION

2. QXL/QRL INTERFACE PREPARATION FOR INTERCONNECTION

2.1 OPENING OF VACUUM JACKET VALVES

2.2 CUTTING OF VACUUM JACKET ENDCAP

2.3 CUTTING OF PIPES OVERLENGTH

2.4 REMOVAL OF PIPES PROTECTION CAPS

2.5 REMOVAL OF PIPING INTERNAL SUPPORT

2.6 POSITIONING OF VACUUM JACKET SLEEVE

2.7 CLEANING
Installation sequence

1. QXL/QRL INSTALLATION

2. QXL/QRL INTERFACE PREPARATION FOR INTERCONNECTION

3. USER INSTALLATION

Installation tolerance: ± 3 mm
Measurement accuracy ≤ 0.3 mm
Installation sequence

1. QXL/QRL INSTALLATION
2. QXL/QRL INTERFACE PREPARATION FOR INTERCONNECTION
3. USER INSTALLATION
4. JUMPER EXTENSION INSTALLATION
5. INTERFACE TO USER ALIGNMENT

5.1 ADJUSTMENT IN X
5.2 ADJUSTMENT IN Y AND Z
Installation sequence

1. QXL/QRL INSTALLATION
2. QXL/QRL INTERFACE PREPARATION FOR INTERCONNECTION
3. USER INSTALLATION
4. JUMPER EXTENSION INSTALLATION
5. INTERFACE TO USER ALIGNMENT
6. INTERFACE TO USER INTERCONNECTION
7. QXL/QRL INTERNAL INTERFACE INTERCONNECTION

6.1. WELDING OF PROCESS PIPES
6.2. REMOUNTING OF PIPING INTERNAL SUPPORT
6.3. CLEANING
6.4. MOUNTING OF PIPES RADIATIVE INSULATION
6.5. MOUNTING OF THERMAL SHIELD EXTENSION
6.6. WELDING OF VACUUM JACKET SLEEVE
6.7. MOUNTING OF POSITION MONITORING DEVICE
6.8. REMOVAL OF VERTICAL BELLOWS FIXTURE
Conclusions

• Baseline for jumper interfaces is specified in the issued documentation (layout drawings, interface drawings, technical specification IT-4630).

• To complete the definition of the requirements needed for the tender a first release of the Interface specification is under preparation.

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• To finalize the definition of the requirements several detailed investigations will be launched:
  • Weld flange analysis
  • Jumper stiffness analysis
  • Interface layout review
  • Interface interconnection mock-up
  • Alignment strategy definition
  • Assembly methods definition