Internal review of the D1-DFX connection module follow-up

Y. Leclercq, S. Spathopoulos, J-B. Deschamps, F. Crisci, J. Dequaire, R. Abdennour, G. D’Angelo

*Engineering Design Review of the D1-DFX connection module (DCM) 24.06.2021*
## Recommendations follow-up overview

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Actions</th>
<th>Status</th>
<th>Comment</th>
<th>Due by</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Verify compliancy of design/requirements with HSE (and HL-SO)</td>
<td>Iterate with HSE</td>
<td>✔</td>
<td>Strategy agreed</td>
<td>06.21</td>
</tr>
<tr>
<td>2.A Check thermo-mechanic behaviour of the system</td>
<td>Study off nominal scenarios</td>
<td>In progress</td>
<td>Scenarios identified, calculations pending</td>
<td>06.21</td>
</tr>
<tr>
<td>2.B Check DCM cooling time</td>
<td>Estimate CD time</td>
<td>95%</td>
<td>Study completed, assessment to be endorsed</td>
<td>07.21</td>
</tr>
<tr>
<td>3 Check with FRAS design team wrt DCM-D1 displacement</td>
<td>Iterate with FRAS team</td>
<td>95%</td>
<td>Monitor D1 integrated displacement</td>
<td>12.21</td>
</tr>
<tr>
<td>4 Test installation procedure of diodes stack in the tunnel</td>
<td>Mock-up, dvlp tooling</td>
<td>In progress</td>
<td>No showstoppers identified so far</td>
<td>12.21</td>
</tr>
<tr>
<td>5 Harmonise lip weld dimensions</td>
<td>Qualification wise Tooling wise</td>
<td>✔</td>
<td>Actions defined</td>
<td>06.21</td>
</tr>
<tr>
<td>6.A Cu-Cu busbars splices review</td>
<td>Iterate with LMF</td>
<td>In progress</td>
<td>Under BB review</td>
<td>07.21</td>
</tr>
<tr>
<td>6.B Develop detail design of BB guides</td>
<td>Cu BB : in progress NbTi: solutions from IT</td>
<td>In progress Pending</td>
<td>Iterative process Use of LMF experience</td>
<td>09.21</td>
</tr>
<tr>
<td>6.C Implement spare CERNOX at LP</td>
<td>Integrate for redundancy</td>
<td>✔</td>
<td>Done for IFS &amp; interface</td>
<td>05.21</td>
</tr>
<tr>
<td>7.A Check R-L symmetry wrt interfaces &amp; unique design</td>
<td>Study R/L layouts</td>
<td>In progress</td>
<td>Being finalized</td>
<td>09.21</td>
</tr>
<tr>
<td>7.B Check R-L symmetry wrt electrical aspect (with M.Pojer)</td>
<td>Study R/L layouts</td>
<td>In progress</td>
<td>Being studied</td>
<td>11.21</td>
</tr>
<tr>
<td>8 Define Vacuum Relief Plate layout in IT area</td>
<td>Iterate with HL-SO / WP3</td>
<td>In progress</td>
<td>Study being started under MSC-WP3</td>
<td>12.21</td>
</tr>
<tr>
<td>9 Envisage DCM 1st series assembly post string test</td>
<td>Evaluate pros &amp; cons</td>
<td>✔</td>
<td>Compromise : after String installation</td>
<td>06.21</td>
</tr>
<tr>
<td>10.A/B Electrical Design Criteria document for DCM (with M.Pojer)</td>
<td>Produce document</td>
<td>In progress</td>
<td></td>
<td>08.21</td>
</tr>
<tr>
<td>10.C/D Impose CERN Spec for Stainless steel material</td>
<td>Study consequences</td>
<td>✔</td>
<td>Compromise in place</td>
<td>06.21</td>
</tr>
<tr>
<td>10.E Profit from C.Garion’s experience for bellows design/proc.</td>
<td>iteration</td>
<td>✔</td>
<td>Constructive and improving system margin</td>
<td>05.21</td>
</tr>
<tr>
<td>10.F Extended qualification CD test on full DCM</td>
<td>List objectives &amp; benefit</td>
<td>In progress</td>
<td>Under consideration</td>
<td>10.21</td>
</tr>
</tbody>
</table>
Recommendation #1

Verify with HSE (and HL-SO) the complying of the design and requirements with CERN and PED standards.

Actions:
Strategy discussed and agreed with HSE
- Design assessment:
  - Strategy presented at the review agreed with HSE
  - Calculation report acc. to standards in progress, to be validated
- Manufacturing:
  - Iterations with HSE converged to HV technical specifications in agreement with PED standards (cat. IV for the HV) for what concerns materials, manufacturing and tests procedures
  - To be released and approved
- DCM assembly:
  - “Modified Approach” applies

Next:
- Finalise the Lambda Plate test qualification report and share with HSE for approval
- Write the Modified Approach Request & submit to HSE for manufacturing/assembly
Recommendation #2

A. Check thermo-mechanic behaviour of the system (e.g. differential thermal expansion/contraction) for all working scenarios.

Actions performed:
- Defined 5 additional working scenarios covering independent CD/WU of DFX/D1 (added to the 11 scenarios already verified)

Future actions:
- Analytical & Thermo-mechanic FEA simulations to confirm:
  - Gaps between structures are sufficient wrt to all scenarios
  - Stress levels are compliant with standards requirements
  - Dimensional controls are foreseen during assembly to ensure gaps and margins.

Additional scenarios for independent DFX/D1 CD & WU

<table>
<thead>
<tr>
<th>Configurations</th>
<th>DFX volumes</th>
<th>DCM volumes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Insulation vacuum</td>
<td>Helium vessel</td>
</tr>
<tr>
<td></td>
<td>bara</td>
<td>K</td>
</tr>
<tr>
<td>1 DFX warm and D1 cold</td>
<td>1</td>
<td>300</td>
</tr>
<tr>
<td>2 DFX cold and D1 warm</td>
<td>0</td>
<td>300</td>
</tr>
<tr>
<td>3 DFX cold, cooling circuit TS cold and D1 warm</td>
<td>0</td>
<td>300</td>
</tr>
<tr>
<td>4 Cooling circuit cold, DFX and D1 warm</td>
<td>0</td>
<td>300</td>
</tr>
<tr>
<td>5 D1 and DFX cold, cooling circuit warm</td>
<td>0</td>
<td>300</td>
</tr>
</tbody>
</table>
Recommendation #2

B. Evaluate the module extremity (on the lambda plate site) cooling time vs. D1 cooling time. If the evaluated delay is considered too long this will be a lost time for the machine operation (i.e. integrated luminosity). In that case the possibility to add a small cool down/warm up He line routed from the D1 jumper should be addressed and implemented.

INPUTS:
Cool Down profiles:
- IT Side: bilinear curve
  - 7 days: 300 K to 80 K
  - 10 days: 80 K to 1.9 K
- DFX side: Linear curve
  - 300 K to 4.5 K in 4 days
  - 3 m away from LP
Model: Based on 84 mm² copper RRR100

Outcome:
- After 100h, $T_{NbTi}\ BB \leq T_{D1}\ BB$
- (=BB in DCM are cooled by DFX)
- $\Rightarrow$ addition of DN10 cooling line would not speed up the NbTi BB CD
Recommendation #2

B. Evaluate the module extremity (on the lambda plate site) cooling time vs. D1 cooling time. If the evaluated delay is considered too long this will be a lost time for the machine operation (i.e. integrated luminosity). In that case the possibility to add a small cool down/warm up He line routed from the D1 jumper should be addressed and implemented.

Consideration of Diodes stack:
- Addition of Diodes stack represented by a 40 kg bulk copper (RRR100) cylinder
- Same CD profiles
- As for LHC, the diodes are conductively CD by BB (>100K)

Outcome:
- Diodes CD delayed wrt NbTi BB (e.g. @ 80K, delay of ~60h)
- Add He line @ LP would not speed up CD
- Integrating He line @ diodes is hardly feasible
- Is the scenario different from LHC?
- no changes foreseen
Recommendation #2

Copper BB

Diode stack

DFX side

D1 side

Internal review of the D1-DFX connection module follow-up – 24.06.2021
**Recommendation #3**

Check with FRAS design team (Survey-BE/GM) if any design/control consideration shall be bring following the FRAS requirements impacting on D1 position

**Actions performed:**
- Meeting with FRAS design team 10.05.2021 (Helene Mainaud Durand and Andreas Herty)
- Maximum re-alignment of D1 is +/- 2.5 mm (= range of remote system)
  - If re-alignment of this order is needed it is performed at the beginning of Run3, before activation
  - Max expected ground motion is +/- 2.5mm (even if D1 and DCM proximity reduces significantly this value)
- → Maximum conservative displacement range is +/- 5 mm
- → Maximum displacement allowed by current DCM design +/- 10 mm

**Future actions:**
- Set up a monitoring of integrated D1 movements over lifetime to trigger warning if boundaries are reached
- Due by: 12.2021
Recommendation #4

Test the installation procedure of pre-assembled diode-cryostat on a fully representative mock-up, including the development of all needed tooling, also the tools necessary for the activities in the LHC Tunnel environment (limited space, ALARA requirements, etc.).

**Actions:**

- **Mock-up:**
  - Main parts manufactured, some to be reworked
  - Focus is now on electrical aspects
  - Mock-up can be used for future confirmation of feasibility
- Meeting with the Handling Engineering (HE) Group to study the replacement in the tunnel:
  - no showstoppers identified
  - EN-HE shall return shortly with conceptual proposal

**Future actions:**

- Test EN-HE proposal
- Develop tooling
- Due by: 12.2021
Recommendation #5

Harmonise as much as possible the dimensions of the elements for the edge welds (lip welds) in order to profit from the development of similar LHC welding tools as well as the welding and testing procedures.

Actions performed:

- Summarized all the dimensions of the lip welds requiring specific qualification (non-standard wrt PED) in a table and shared with EN/MME group for feedback
- All the lip welds with parts thickness = 1 mm or 2 mm are already qualified
  - The burst test has been done on a larger diameter, with a flat end and the obtained burst pressure is at least 110 bars, >5*20bars
- Lip welds with part thickness = 3 mm can rely on the burst test foreseen for DFHX
  - Ø600-thickness 3mm
  - if the burst pressure will be >5*20 bars

Future actions:

- Feedback from EN/MME pending on geometries
- Complete the same table also for butt and fillet welds
- Waiting for on the burst test foreseen for DFHX (Ø600-thickness 3mm)
**Recommendation #6**

A. Consider to revise the Diode stack BB connection adding to the design a clamping concept/elements. Alternatively, reconsider a well-designed bolted connection.

- This recommendation is being assessed under the Busbar review
- Status : 3 splice designs are under considerations
- Next steps:
  - DCM team performs Integration studies to list consequences
    - Redefine need to shape diodes busbars
    - Re-routing of BB
  - Test on the mock-up

---

**R12 Design electric joint 8**

*Re-design splice type 8 based on bolted connections*

- OFE Cu due joint to the diode bus
- Bushing section 10 X 3 mm
- Soft soldering alloy Sn95Ag5
- Endothermic 221°C

To be considered:
- Electromechanical, ALARA
- Integration
- 3 solutions studied:
  1. Simple soldering
  2. U profile + wedge soldered + transversal pin
  3. Screwed solution + fabric list

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**Electric joint 8 – Solution 2**

2. U profile + wedge soldered + transversal pin
- OFE Cu for the components
- U profile and wedge 70 mm
- Transversal pin (small effect)
- Soft soldering alloy Sn95Ag5
- Soldered in one go (3 mins + soldering machine positioning).
- Manual feeding at the pin level

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**Electric joint 8 – Solution 3**

3. Screwed solution + indium foil
- 2 x clamping plate (stainless steel)
- Belleville springs (thermal contraction)
- Indium foil (improve contact)
- Tightening torque 5 Nm (tested)

*Courtesy R. Principe BB review follow up*
Recommendation #6

B. Develop a detail design for all the BB guides with main attention to diode elbow and flexible hose regions. Try to push for standardization of these elements.

- **Actions:**
  - Copper busbars:
    - Re-use of LHC technology for insulation and guiding parts
    - Status: in progress
  - NbTi busbars:
    - Import technical solutions applied to BB in IT
    - Status: pending
Recommendation #6

C. Implement a spare Cernox sensor close to the lambda plate.

- Interface for Immersed CERNOX integrated
- Instrumentation wires included in IFS capillary and flange
Recommendation #7

A. Check that the R-L symmetry of the installation and interfacing of other elements is fully compatible with a unique DCM design.
B. Put in the loop M. Pojer in this analysis and for any aspect linked with the BB routing, polarity check, etc

Work in progress

- Diodes Stack is a unique design
- 5 Cu BB routing being optimised with Giorgio D’Angelo
- 1st meeting with M. Pojer to clarify the polarity change between L and R configuration ➔ iterations in progress
- Polarity change in D1 being assessed under HL-MCF
Recommendation #7

C. Check carefully with WP15 Integration the specificity of the different installations wrt the support design and if some fixation points to the tunnel vault could be an advantage (exceptional maintenance tooling fixation, etc.).

- Integration at 4 locations: pending

- The possibility of adding fixation points to tunnel vault has been discussed with EN-HE. (for both DCM installation & Diodes stack replacement)

- ➔ No need identified so far: In progress
Recommendation #8

The He and vacuum vessels design must be completed (urgently) as concerning the safety devices. The positions of the quench relief valve and the vacuum volume relief plate should be optimized for the entire assembly D1-DCM-DFX. This work has to be done together with the CRG-SO, HL-SO and HSE.

- **Actions**: exchanges held with T.Otto and S.Claudet.
- **Status QRV**: completed
  - DCM considered in CRG calculations see EDMS2364300
  - DCM calculations match requirements as presented in Review
  - ➔ No issue with QRV

- **Status VV Relief Plate**: starting
  - Exchanges converged to the need for identification of a MSC-WP3 responsible to coordinate the study
  - CRG offering help to check the impedance through the vacuum vol.
**Recommendation #9**

Envisage the possibility to wait for the results of the prototype test in the String Facility before to launch the assembly of the series units (in case of possible necessity of minor modifications).

- **Actions**: schedule updated with assumed date of cable availability
- Waiting for the outcome of the STRING test would imply:
  - 2 years between end of prototype and start of 1st Serie ➔ loss of know-how
  - Availability of the 5 units when Installation in tunnel starts
  - (Review of resources and layout organization)
- ➔ Waiting for the STRING result does not appear appropriate with today’s overall planning.
- ➔ However, experience from String Installation will come only 3-4 w after DCM #1 assembly start, offering flexibility for rework, if needed

<table>
<thead>
<tr>
<th>2021</th>
<th>2022</th>
<th>2023</th>
<th>2024</th>
</tr>
</thead>
<tbody>
<tr>
<td>DCM Availability</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Cable procurement</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Plugs assemblies AX</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Main Stream assembly</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Periscope Assembly</td>
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<tr>
<td>Diodes cryo at assembly</td>
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<td></td>
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<tr>
<td>Diodes to Main Stream Assembly</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D1 Module assembly</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Results from String**: Q3-2024 ➔ Inst. Tunnel Q2-2026 ➔
**Recommendation #10**

A. Provide a document that covers all electrical functional qualification and testing aspects for the DCM (similar documents exist for the other main elements of the Cold Powering systems).

B. As already mentioned, put M. Pojer in the loop for an external checks of the electrical routing and for finalization of documentation.

### Electrical Design Criteria document: in progress
- Discussion started with M. Bednarek to set actions
- **Next:** DCM team prepares proposal (due by 08.21)

### Polarities & Electrical routing in DCM: in progress
- Discussions with M. Pojer, MCF, G. D’Angelo, R. Principe
- Identification of actions
- **1st** MCF topical meeting 7.6.21
- **Next:** DCM presents proposal R/L (due by 08.21)

<table>
<thead>
<tr>
<th>Test ID</th>
<th>Component</th>
<th>Conditions</th>
<th>DC Test Voltage</th>
<th>Voltage Ramp Rate (V/s)</th>
<th>Leakage Current Requirement (μA)</th>
<th>Testing time at DC test voltage (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>IFS wire</td>
<td>IFS wire after tube, shaping, thermal shock in UN2 and pressure tests (RT, air, 1 bara)</td>
<td>10 kV for VT and RH conductors, 200 V for TT conductors</td>
<td>200 for VT and RH, 10 for TT</td>
<td>&lt;10 for VT and RH, &lt;5 for TT</td>
<td>60</td>
</tr>
<tr>
<td>2</td>
<td>IFS flange</td>
<td>IFS flange, before connection to wiring (RT, air, 1 bara)</td>
<td>5 kV for VT and RH conductors, 100 V for TT conductors</td>
<td>200 for VT and RH, 10 for TT</td>
<td>&lt;10</td>
<td>60</td>
</tr>
<tr>
<td>3</td>
<td>IFS flange</td>
<td>IFS flange, before connection to wiring (RT, GHe, 1 bara)</td>
<td>3.1 kV for VT and RH conductors, 100 V for TT conductors</td>
<td>200 for VT and RH, 10 for TT</td>
<td>&lt;10</td>
<td>60</td>
</tr>
<tr>
<td>4</td>
<td>PCB card</td>
<td>PCB card equipped with connectors, (RT, air, 1 bara)</td>
<td>5 kV for VT and RH conductors</td>
<td>100</td>
<td>&lt;10</td>
<td>60</td>
</tr>
<tr>
<td>5</td>
<td>Diodes stack</td>
<td>Diodes stack after diodes stack assembly</td>
<td>Test condition</td>
<td>Test condition</td>
<td>Test condition</td>
<td>Test condition</td>
</tr>
<tr>
<td>6</td>
<td>Diodes stack</td>
<td>Diodes stack</td>
<td>Test condition</td>
<td>Test condition</td>
<td>Test condition</td>
<td>Test condition</td>
</tr>
<tr>
<td>7</td>
<td>IFS system</td>
<td>IFS system, after welding, before welding</td>
<td>Test condition</td>
<td>Test condition</td>
<td>Test condition</td>
<td>Test condition</td>
</tr>
<tr>
<td>8</td>
<td>IFS system</td>
<td>IFS system, after welding, after welding, before welding</td>
<td>Test condition</td>
<td>Test condition</td>
<td>Test condition</td>
<td>Test condition</td>
</tr>
</tbody>
</table>

**Support table for HV test definition**

**Internal review of the D1-DFX connection module follow-up – 24.06.2021**
Recommendation #10

C. Procurement of Austenitic SS components must be done imposing the respect of the CERN specification for such materials.
D. Similar problem (as evidenced for the DFX and DFM procurement) concerns the Cobalt content in the SS. Face this aspect following a coherent approach and in close contact with HL-SO and HSE.

Context & Inputs:

- Material requirements purposes:
  - Compliancy with HSE requirements
    - e.g: RP & PED / Defined by HSE
  - Machine performance
    - e.g: UHV, Cryogenics, Corrosion resistance, Permeability / Defined by PE

- CERN Specifications:
  - Compliant with (almost) all usual application at CERN (HSE & Performance)
  - Define element contents, metallographic properties, production process specifically for tubes, sheets, bars, forged products
  - Note: it is not possible to produce various tubes, bars, sheets from a unique heat.
Recommendation #10

C. Procurement of Austenitic SS components must be done imposing the respect of the CERN specification for such materials.
D. Similar problem (as evidenced for the DFX and DFM procurement) concerns the Cobalt content in the SS. Face this aspect following a coherent approach and in close contact with HL-SO and HSE.

Experience & figures
- Raw material procurement under CERN spec : Delay & minimum quantity

<table>
<thead>
<tr>
<th>Product Type</th>
<th>Minimum Order Quantity</th>
<th>Announced Delay</th>
<th>Examples for illustration (Effective delays &amp; costs)</th>
<th>CERN store</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tubes</td>
<td>60/120 m (small suppliers) 3 to 5 tons (big suppliers)</td>
<td>10-16 w 10-16 w</td>
<td>Ø58x2: delay 22 weeks Ø508x5mm : Delay 10 w (vs 2d) Cost/m : + 25 % : Cost/unit : + 350 %</td>
<td>Few dimensions available Procure big quantities if future needs</td>
</tr>
<tr>
<td>Metal sheets</td>
<td>3 to 5 tons</td>
<td>30-46 w</td>
<td>Many references available, no CERN SPEC for &lt; t=6mm</td>
<td></td>
</tr>
<tr>
<td>Forged products</td>
<td>No low limitation</td>
<td>10-16 w</td>
<td>Ø500 to 900 mm rolled rings: Delay : 3 months / Cost : 40 kCHF for 30 Rings</td>
<td>Easily bought custom to flexible suppliers Store has contracts of several tens of tons</td>
</tr>
</tbody>
</table>

Sub-contract small orders with CERN Specifications
- CERN usually supplies raw material
- Different material properties ➔ process adaptation
  - Imply costs for suppliers & risks
  - ➔ less bidders & difficult contracts
- ➔ Emergency solutions
  - Meaning lower quality + extra costs (kCHF & resources)

Example : Bypass cryostat Universal Expansion Joints : 1.4441 grade supplied (lower Elongation than 1.4404)
**Recommendation #10**

C. Procurement of Austenitic SS components **must be done** imposing the respect of the CERN specification for such materials.

D. Similar problem (as evidenced for the DFX and DFM procurement) concerns the Cobalt content in the SS. Face this aspect following a coherent approach and in close contact with HL-SO and HSE.

**Strategy for raw material procurement:**
- Ensure PED and performance requirements
- Use CERN specification whenever available in CERN store

**Cobalt content:** request for derogation being written
- <0.1% for parts from CERN store
- Measure content for supplied parts/raw material

**External supply:**
- Qualify material:
  - e.g Ø508mm / 1m sample under test (chemical compo, X-ray & Leak test at reception)
  - Co content 0.22%
- Outcome:

<table>
<thead>
<tr>
<th>Material</th>
<th>Specification</th>
<th>Cobalt Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sheet: CERN Store</td>
<td>CERN Spec &lt;0.1% Co</td>
<td>TBD</td>
</tr>
<tr>
<td>Manuf. Ext: Standard Co</td>
<td>Standard Co TBM</td>
<td>TBD</td>
</tr>
<tr>
<td>Tubes: Standard Co</td>
<td>Standard Co TBM</td>
<td>TBD</td>
</tr>
<tr>
<td>Sheet: CERN Store</td>
<td>CERN Spec &lt;0.1% Co</td>
<td>TBD</td>
</tr>
<tr>
<td>Tubes: Standard Co</td>
<td>Standard Co TBM</td>
<td>TBD</td>
</tr>
</tbody>
</table>

- Procure from CERN store under CERN Spec
- Procure externally under CERN Spec

Is the part manufactured at CERN?
- YES
- NO

Is the raw material available in CERN store?
- YES
- NO

Is the raw material available on the market under CERN Spec at reasonable delay & cost?
- YES
- NO

PED requirements if any
- Manufacturing process requirements
- Specify properties based on needs

Cobalt Content Measurement
- Specific Reception test

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Recommendation #10

E. For the bellow design and procurement profit from the expertise of C. Garion.

- Meeting with C. Garion to validate bellows tech spec
  
  **Outcome:**
  - Confirmation of approach and design
  - Discussion on raw material
  - Suggestion to implement a banana buckling limiter on Helium tube

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**Outcome:**

- Confirmation of approach and design
- Discussion on raw material
- Suggestion to implement a banana buckling limiter on Helium tube

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**4-points adjustable anti-banana buckling system**

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**Example of banana buckling**
Recommendation #10

G. A pressure test of DCM unit is planned as a type test. Before the prototype installation in the String it is recommended to add an 80K thermal cycle test with continuous electrical monitoring of BB dielectric insulation followed by He leak tightness test.

冷测试目标

<table>
<thead>
<tr>
<th>Objective</th>
<th>Source</th>
<th>Detection</th>
</tr>
</thead>
</table>
| #1: Identify Electrical short cut | Physical contact between non insulated parts due to thermal contraction | - Apply thermal contraction differences  
- Monitor BB dielectric |
| #2: Identify source of insulation degradation | Repeated friction between insulation and sharp edge/swarf | - Reproduce relative displacements due to thermal contractions & electric quenches under nominal conditions (material properties at 1.9K, gravity axis) |
| #3: Identify thermal short cuts | Physical contact after thermal contractions | - Apply nominal structural layout at 1.9 K  
- Detect cold surfaces / temperature layout |
| #4: Identify cold leak | Inclusion/porosity opening in stainless steel under deformation induced by cold configuration | - Apply deformation/stresses equivalent to 1.9K thermal configuration |

测试限制
- DCM presents 2 independent modules without NbTi-NbTi splices ➔ simulate a representative fixing system for BB
- To be representative of physical contacts, the DCM shall be installed in nominal config ➔ find how to CD to LN2
- DCM presents BB extensions of high conductivity ➔ need specific tooling to insulate
- Temperature instrumentation is limited

状态:
- A relevant 80K test with GN2 evacuation is not straight forward
- A test at 4.5K would require significant tooling development
- ➔ Work in progress to identify useful specific qualification tests
Observations

- Parallel activities in progress
- Actions identified and being scheduled
- Some recommendations only partially implemented after in-depth analysis
- Work in progress, some recommendations still to be assessed