Status of design and production of LEP connection cryostat

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CERN

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Summary

- Introduction
- Design
- Production
- Conclusion
Reminder

- Connection cryostat
  - To be used with “standard” cryo-bypass
  - Guarantee continuity of the cryogenic and electrical distribution
Introduction

- Build to print design
- Use of standard LHC components when possible
- New concepts to:
  - Ease assembly
  - Limit welding work
  - Avoid deformation during fabrication and life cycle
Requirements

- LHC equipment requirements for pressure, temperature and leak tightness
- LE requirements: LHC-LE-ES-0001

Beam line alignment as Golden Class magnet (LHC project report 1007)

Maximum temperature of cold bore: 2.7 K

Extremity compatible with the HL-LHC bypass cryostat (LEN)
Specific requirements

- Golden class magnet (most stringent)

- Tolerances distribution

<table>
<thead>
<tr>
<th>Source</th>
<th>+/- Vertical [mm]</th>
<th>+/- Horizontal [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geometry (sag)</td>
<td>0.015</td>
<td>0</td>
</tr>
<tr>
<td><strong>Geometry (straightness)</strong></td>
<td><strong>0.2</strong></td>
<td><strong>0.2</strong></td>
</tr>
<tr>
<td>Play in V/V' assembly</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Play in alignment system</td>
<td>0.1</td>
<td>0.35</td>
</tr>
<tr>
<td><strong>Alignment tolerance</strong></td>
<td><strong>0.05</strong></td>
<td><strong>0.05</strong></td>
</tr>
<tr>
<td>Stability over time</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>0.465</strong></td>
<td><strong>0.7</strong></td>
</tr>
<tr>
<td>Maximum</td>
<td>0.5</td>
<td>0.8</td>
</tr>
</tbody>
</table>

Centre of theoretical beam axis (drawn from position of cold bore at extremities)
Concept

<table>
<thead>
<tr>
<th>Concept</th>
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<tbody>
<tr>
<td>Cold bore in helium vessel</td>
</tr>
<tr>
<td>Pipes in continuity of standard interconnection lines</td>
</tr>
<tr>
<td>Shuffling module at LEN extremity</td>
</tr>
<tr>
<td>Bolted supporting structure</td>
</tr>
<tr>
<td>LEP-A mirror of LEP-B</td>
</tr>
</tbody>
</table>
LEP vs LE

- Pipe fixed point
- Busbar fixed point
Cold bore cooling

- **Goal**
  - Beam line heat load = 0.65 W/m (LHC-LE-ES-0001)
  - Warmest point bellow 2.7 K

- **Solution**
  - Addition of a V’ line around cold bores
    - Filled with superfluid helium
    - Connected to shuffling module
    - Cooling by conduction through superfluid helium

$T \sim 1.901 \text{ K}$

$Q = 0.65 \text{ W/m}$

$T = 1.9 \text{ K}$
Cold bore/V’ supporting

- **Goal**
  - V’ for cooling of cold bore with helium
  - Insure positioning of cold bore inside V’ lines (play ~ 0 mm)
  - No deformation of cold bore

- **Solution**
  - Local “Punching” of V’ line to make contact with cold bore
  - 3 deformation at 120°
V/V’ support

- Tooling: lathe chuck

- Development campaign to find correct procedure
  - Zero gap between tubes
  - No deformation of cold bore
Cold bore alignment system

- **Goal**
  - Align beam lines within tight tolerances

- **Solution**
  - Sleeve on V’ (tack welded) to improve pipe geometry
  - Brass/Stainless steel contact to avoid seizing
  - X-Y table for positioning

<table>
<thead>
<tr>
<th>Source</th>
<th>Requirement</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>V’/support</td>
<td>+/- 0.1 (V)</td>
<td>+/- 0.05</td>
</tr>
<tr>
<td></td>
<td>+/- 0.35 (H)</td>
<td></td>
</tr>
<tr>
<td>Play in alignment system</td>
<td></td>
<td>&lt; +/- 0.05</td>
</tr>
</tbody>
</table>
- Ease access during assembly
- No structural welds
  - No deformation/stresses
  - Mechanical assembly for cold mass alignment
- Tight tolerances easy to achieve
  - Machined plates $\Rightarrow$ flatness = 0.2 mm/m
  - Stress relieving $\Rightarrow$ no later deformation due to stress relaxation
- Light cold mass (~ 2 tons)
- Lower mechanical rigidity than closed profile
H-beam cooling

- **Goal**
  - Uniform cool-down of the cold mass (no hot spot, no deformation)
  - Cooling of the cold mass from 300 to 80 K < 1 week (on test bench)

- **Solution**
  - Copper clamps on M1 and M2 lines → vertical symmetry
  - Copper plates on H-beam for heat distribution
  - Copper braids to connect clamps to plates
  - All bolted solution

Cooling time 300 → 80 K ~6 days (conservative assumption)
Flexible M lines

- Tolerances and forces in interconnection
  - +/- 5 mm on each line (LHC-LI-ES-0001)
  - Forces ~ 3310 N in interconnection (EDMS 346011)
  - Lift cold mass if not fixed
  - Deform cold mass if properly fixed (~ 1.3 mm)

- Solution: reduce interconnection forces
  - > 90% due to M lines bellows
  - Stability over time (+/- 0.1 mm allowed)

Reduced interconnection forces
- Free radial movement
- 90 N for 5 mm displacement

Bellows
- Only for longitudinal movement
- Pre-compressed during installation

Interconnection Bellows blocking
- Longitudinal + Radial
- In compressed state
- Keep standard interconnection

Pipe guiding
- Allow longitudinal movement
- Increase buckling resistance

Negligible deformation of cold mass
("0.1 mm deformation due to weight"
(See M. Moretti’s presentation)
Flexible line prototype

Test:
• 5 mm vertical offset
• 25 bar (water)
• External radial excitation

Results:
• Small line displacements
  • $V = 0.07$ mm
  • $H = 0.1$ mm
• No buckling
Shuffling module

- **Goal**
  - Create space for busbars lyras
  - Transition between position of lines in standard interconnection and LEN
  - House bayonet heat exchanger

- **Solutions**
  - 2 welded stainless steel dished ends with nozzles
  - 12 mm thick for deformations ~0.12 mm @ 20 bar
Procurement strategy

- Collaboration with EN-MME for machined components

- Busbars and associated components procured by TE-MSC-LMF

- TE-MSC-CMI specification and contract follow-up
  - Welded pressure components (shuffling module, bellows);
  - MLI;
  - Vacuum vessel;
  - Bottom tray;
  - Standard components.
Production status

- Vacuum vessel and bottom tray
  - Being fabricated
  - Delivery from December 2017

- Cold mass
  - Being manufactured
  - Delivery of components starting from November 2017
Conclusion

- Design reviewed and approved
- Fabrication on going
- Assembly of first unit starting from November
Thank you!