Laser interferometer for cold mass displacement

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On behalf of Mateusz Sosin and Vivien Rude

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Alignment systems for HL-LHC

To determine the position of the cryostats
- Wire Positioning Sensors (WPS)
- Hydrostatic Levelling Sensors (HLS) (or rad-hard inclinometers)
- Sensors for the longitudinal position

To adjust the position of the cryostats
- Motorized jacks
To monitor the position of the cold mass inside the Inner Triplet cryostat
Why a system to monitor the cold mass displacement?

- From the LHC experience: we know at the micron level the position of the cryostat, but not what happens inside → difficult to correlate with beam.
- Displacements up to ± 0.5 mm (3σ) seen on the LHC dipoles after transport (EDMS 677511)
- Strong interest from WP2 to know more accurately than in the LHC the longitudinal position of the cold mass

- Decision to include in the baseline the internal monitoring of the inner triplet cold masses using laser interferometer (less «invasive» solution)
- Validation of the commercial solution based on Frequency Scanning Interferometry (FSI), providing absolute distance measurements
Introduction to laser interferometer

- FSI = Frequency Scanning Interferometry
  = absolute distance measurement

\[ \Delta \text{Phase (meas.)} = \frac{2\pi}{c} \cdot L_M \cdot \Delta \nu \]
\[ \Delta \text{Phase (ref.)} = \frac{2\pi}{c} \cdot L_R \cdot \Delta \nu \]

Accuracy: 0.5 µm per meter
Outlook

- Qualification tests
  - Validation on independent benches
    Performance of one line FSI & study of an alternative
    - Irradiation tests
    - Thermal tests
    - Precision, accuracy,…
  - Validation on Crab cavities in SM18 & SPS
    Performance target at warm, vacuum, cold, and cross-comparison with other systems
  - Validation on a test magnet (Dipole)
    Validation of performance
    - Accuracy and precision
    - Long term stability
    - Cryo-condensation issues

- Cryo-condensation issue
- Next steps and summary
Pre-test achieved on FSI

- Validation of targets through irradiation and cold tests
  
  **Liquid nitrogen test:**
  - No damage of targets
  - No loss of performance

  **Radiation tests of BMRs:**
  - Ceramic BMRs and collimators validated with TID of 10MGy
  - BMR mirror centricity lost ~20µm

- Validation of meas. chain (vacuum & cold tests)
  
  **Liquid nitrogen test:**
  - No visible deformation of the feethrough
  - Decrease of intensity but no impact on the measurements
  - Comparison with AT401 measurements within 20 µm
Crab cavities case

Alignment requirements (3σ):
• The cavities axes have to be included in a 0.5 mm diameter cylinder w.r.t. the cryostat axis,
• The cavities roll (Rz) w.r.t. the cryostat axis has to be lower than 5 mrad,
• The cavities pitch and yaw (Rx, Ry) w.r.t. the cryostat axis has to be lower than 1 mrad.

HL-LHC environmental conditions:
• Radiation → 10 MGy (beam pipe), 1 MGy (cryostat surface)
• Insulation vacuum: 10^{-6} mbar
• Temperature: 2 K
Crab cavities results

- Pressure: ambient
- Temperature: ambient

Isolation vacuum
- Temperature: 2 K
Crab cavities results

- Successful cross-comparison with other systems at warm, at cold, under vacuum
- Accuracy of the absolute position of crab cavities using FSI: ±0.05 mm
- Relative position: a few micrometers
Configuration for IT cold masses

3 x 4 FSI heads for each cold mass

Cold mass position monitoring (FSI)

Courtesy D. Duarte Ramos
Validation on a dipole test
Cryo-condensation issue
Cryo-condensation issue

How can we achieve a “heating” of the probes up to ~200K?

Permanent heating – by making sure that the probe stays at \( \geq 200\text{K} \), no cryo-condensation should ever take place in principle. This could be achieved using the power radiated from the vacuum vessel (which is 300K “hot”).

![Diagram of cryo-condensation system](image)

- Vacuum vessel – 300K heat sink
- Thermal shield – ~60K heat sink
- Reflective prism
- Radiation interception plate
- Insulator support
- Cold mass – 1.9K heat sink

Courtesy F. Micolon
Thermal dissipation

The FSI system is fitted with 12 holes per magnet – 48 holes per triplet: 
→ 48*0.116=5.57W (for TS holes Φ40mm)

Thermal in-leaks additional operating cost is 
~ 28kCHF for 10 years operation per triplet string

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<th>Power (mW)</th>
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<tr>
<td>Residual opening</td>
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<td>Heat conducted by support</td>
<td>56</td>
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<tr>
<td><strong>Total heat to CM</strong></td>
<td><strong>116</strong></td>
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</table>

FSI thermal load budget discussed with WP9 and assessed as acceptable

Courtesy F. Micolon
Cryo-condensation issue

- Next step: design of a more robust support, made of another material (Acurra Blue stone and then Accura 48).
- Installation and validation on the dipole (all viewports configuration)
Successful test at 4 K of the new support of targets! Cryo-condensation issue solved!
Summary

- All tests of validation of FSI system successful: individually, in the crab cavities, inside a dirty dipole.
- Issue of cryo-condensation solved by the development of a new support of target, made of Accura 48, allowing the target to be at 200 K with an acceptable thermal dissipation.
- Tests still under way to decide on the targets and the configuration of feedthrough/viewport before the end of the year.
- Final validation will take place on the string test.
Thank you very much
### Latest results per section

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<td>Z (mm)</td>
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### Residuals

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<td>Col B</td>
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<tr>
<td>Col C</td>
<td>36</td>
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<tr>
<td>Col D</td>
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Scale factor: 0.996920

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<td>Col J</td>
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<tr>
<td>Col K</td>
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<td>Col L</td>
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Scale factor: 0.997129

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Scale factor: 0.996903