Status of the tungsten shielded BPM design for the inner triplets
HL-LHC WP13

C. Boccard, M. Krupa, T. Lefevre, G. Schneider, M. Wendt

8th HL-LHC Collaboration Meeting – CERN – 18/10/2018
Prototype manufacturing started by EN/MME – driven by String Test

Design to be started

Predesign done

Same as in the LHC
New BPMs per HL-LHC IP side

1x **BPMSQTA**  cryogenic directional coupler, aperture A (small)

5x **BPMSQTB**  cryogenic tungsten-shielded directional coupler, aperture B (large)

1x **BPMSWQ**  warm directional coupler

2x **BPMWQ**  warm or cold (non-directional) button

**In total:**

9 BPMs x 2 IPs x 2 sides = 36 new BPMs to be installed
Cryogenic directional coupler challenges

- Both beams in a single vacuum chamber
- Octagonal vacuum chamber
- Cryogenic BPMs installed in vacuum
- Heat load due to electron cloud
- Tungsten blocks at H and V planes to absorb collision debris
- Very complicated integration
Directional coupler – RF design

- RF design optimised with 3D EM simulations
  - Achieved very good directivity
- Electrode **prototyping started** with EN/MME
- Purchasing of 400 RF coaxial feedthroughs to be started soon
  - Technical specification ready
- Impedance being validated by WP2
Cryogenics - heat load and cooling

- Heat load contributions:
  - 2.5 W (45%) – collision debris
  - 2 W (35%) – electron cloud
  - 1 W (20%) – beam and cabling
- Amorphous carbon coating
  - Electron cloud effects lower by a factor of 40
- Active cooling with liquid helium required
  - Same technical solution as designed for the beam screen
  - Simulations performed by M. Pasquali (EN/MME)
Collision debris – tungsten absorbers

- Tungsten absorbers installed at H and V plane
  - 15% lower dose on the Q2B magnet
  - BPM electrodes installed at 45°
- Tungsten block alignment specification discussed with WP10
  - Manufacturing tolerances seem adequate
  - Simulations performed by F. Cerutti, M. Sabate Gilarte, A. Tsinganis (EN/STI)
- Procurement of 100 absorbers in collaboration with WP12
  - Same contract handled by TE/VSC
Integration in the interconnect

- Major collaboration of multiple WPs to advance integration of the IT interconnect regions
  - Work coordinated by D. Duarte Ramos (TE/MSC)
- Extremely busy region with multiple important stakeholders
  - Alignment
  - Welding and cutting machines
  - Cable routing
- Mock-ups planned
  - Details under discussion
String Test preparation

- IP5L configuration
- **2 BPMs needed by 2021** – prototype manufacturing launched with EN/MME
- BPM test program presented at the HL-LHC Inner Triplet String Test Day (05/10/2018)
HL-LHC IT BPM conceptual design review

- Organised by WP13 and held on 17 May 2018
- With input from HL-PO, WP3, WP10, WP12, WP16, EN/MME
- Identified **4 recommendations** and **20 actions**
  - 4 recommendations followed
  - 13 actions completed
  - 3 actions being addressed
  - 4 actions to be addressed
- Summary to be presented at the TCC
D2 BPM – from warm to cold

- Recent request to study moving the D2 BPM into the cryostat
  - Motivated by full remote alignment
- **Preliminary design done**
  - No showstoppers identified
  - Huge thanks to N. Chritin and A. Demougeot (EN/MME)
- Detailed design and integration study to follow
Conclusions and outlook

- Development of new HL-LHC BPMs on track
  - Collaboration and common designs with other WPs
- Project priorities driven by the String Test
  - Prototype manufacturing started by EN/MME
  - Tests on mock-ups planned before the String Test
- Purchasing planned and on schedule
  - Tungsten absorbers with TE/VSC
  - RF coaxial feedthroughs ready to start
- Conceptual design review held in May
  - All recommendations followed
  - Most actions already completed or being addressed
  - Remaining actions to be addressed soon
Thank you for your attention!

Acknowledgements: F. Cerutti, N. Chritin, A. Demougeot, D. Duarte Ramos, G. Iadarola, R. Jones, M. Pasquali, A. Tsinganis
Back up: design priorities

- Main focus on the cryogenic directional couplers BPMSQTA and BPMSQTB which are required for string test in 2020
- Minimising differences between the two designs
- Studying possibilities of reusing parts of the design for the non-cryogenic BPMSWQ
3D printing of the 2016 electrode very challenging
Major effort made to simplify the electrode’s shape in 2017
Additional performance improvements achieved
Goal: electrode impedance stable at $50 \pm 0.5 \, \Omega$
Back up: directivity

**Ideal World**

**Real World**
Back up: directivity

Dream: 30+ dB directivity → 0.0316 downstream ratio
Back up: temporal separation

Optimisation: temporal bunch separation at BPM locations
Back up: passive cooling

BPM 220 K above beam screen’s temperature
Back up: active cooling

Cooling inspired by the beam screen solution
Electrodes 5 K above beam screen’s temperature

Temperature 2
Type: Temperature
Unit: K
Time: 1
10/11/2017 14:08

85.338 Max
84.74
84.143
83.546
82.948
82.351
81.754
81.157
80.559
79.962 Min

Courtesy: M. Pasquali
Back up: Tungsten shielding

Peak dose profile in the inner coils ($L_{int} = 3000$ fb$^{-1}$)
HL–LHCV1.2 Round horizontal 295 $\mu$rad

No IC shielding
7cm Inermet
7cm Inermet + BPM shielding

Q1 Q2A Q2B Q3 CP D1

Peak dose [MGy/3000 fb$^{-1}$]

Distance from IP [m]

20 25 30 35 40 45 50 55 60 65 70 75 80 85

Courtesy: A. Tsinganis
F. Cerutti
Back up: Heat load

![Graph showing heat load vs SEY](image)

Courtesy: G. Iadarola
# Back up: Locations

<table>
<thead>
<tr>
<th>Number</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
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<tbody>
<tr>
<td>Type</td>
<td>BPMSTQA</td>
<td>BPMSTQB</td>
<td>BPMSTQB</td>
<td>BPMSTQB</td>
<td>BPMSTQB</td>
<td>BPMSTQB</td>
<td>BPMSQW</td>
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<tr>
<td>Distance from IP [mm]</td>
<td>21853</td>
<td>33073</td>
<td>43858</td>
<td>54643</td>
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<td>73697</td>
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<tr>
<td>Location comments</td>
<td>Between TAXS and Q1A</td>
<td>Between Q1B and Q2A</td>
<td>Between Q2A and Q2B</td>
<td>Between Q2B and Q3A</td>
<td>Between Q3B and CP</td>
<td>Between CP and D1</td>
<td>After D1, WARM</td>
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<tr>
<td>N</td>
<td>5.34</td>
<td>8.34</td>
<td>11.23</td>
<td>14.11</td>
<td>17.08</td>
<td>19.21</td>
<td>22.72</td>
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<td>Periodicity number</td>
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<td>Preceding ideal position [mm]</td>
<td>20,570</td>
<td>31,790</td>
<td>43,010</td>
<td>54,230</td>
<td>65,450</td>
<td>72,930</td>
<td>84,150</td>
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<td>Succeeding ideal position [mm]</td>
<td>24,310</td>
<td>35,530</td>
<td>46,750</td>
<td>57,970</td>
<td>69,190</td>
<td>76,670</td>
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<tr>
<td>Distance from ideal position [mm]</td>
<td>-1,283</td>
<td>-1,283</td>
<td>-848</td>
<td>-413</td>
<td>-293</td>
<td>-767</td>
<td>1,044</td>
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<td>TOF from ideal position [ns]</td>
<td>-4.28</td>
<td>-4.28</td>
<td>-2.83</td>
<td>-1.38</td>
<td>-0.98</td>
<td>-2.56</td>
<td>3.48</td>
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<td>Bunch arrival time difference [ns]</td>
<td>3.92</td>
<td>3.92</td>
<td>6.82</td>
<td>9.72</td>
<td>10.52</td>
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Back up: LHC electrodes

Courtesy: C. Boccard, P. Clergue