Status of HLLHCV1.5

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WP2 Meeting 29/10/2019
# Optics And Layout versions

<table>
<thead>
<tr>
<th></th>
<th>Optics Files</th>
<th>Drawings</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>HLLHCV1.3</td>
<td>Apr. 2017</td>
<td>Apr 2017</td>
<td>Last approved layout drawings</td>
</tr>
<tr>
<td>HLLHCV1.4</td>
<td>Sep. 2018</td>
<td>Not released</td>
<td>Used in TDR, aperture calculations, DA studies, operational scenarios, ramp&amp;squeeze, LHCb upgrade studies</td>
</tr>
<tr>
<td><strong>Official release</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HLLHCV1.5rc0</td>
<td>Mar. 2019</td>
<td>Not released</td>
<td>Used for energy deposition studies new TAXN-Q4 area</td>
</tr>
<tr>
<td><strong>Pre-release</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HLLHCV1.5rc1</td>
<td>Jun. 2019</td>
<td>Not released</td>
<td>Used for energy deposition studies on rotated Q4</td>
</tr>
<tr>
<td><strong>Pre-release</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HLLHCV1.5</td>
<td>As soon as drawings are approved</td>
<td>Expected mid November</td>
<td>Released in 20/10/2019: in approval</td>
</tr>
<tr>
<td><strong>Official release</strong></td>
<td></td>
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</tbody>
</table>

The major aim of HLLHCV1.5 is to have optics in sync with drawings (essential to finalize the vacuum layout)
HLLHCV1.5 layout modifications

Point 1,5:
- **TAXS**: Changes due pre-existing non-conformities, area.
- **Q1-D1**: Small variation of positions of all elements (take into account thermal contraction)
- **CP**: Changes in position and magnetic lengths of HO correctors
- **D1**: Elongated beam screen + warm BPM new position (to be removed in 1.6)
- **TAXN-D2**: New positions TAXN-TCT/L-D2, D2 BPM relocation, TCTPV increased stroke
- **Crabs**: Changed position, different location between Point 1 and 5 due to internal cryostat differences between H(RFD) and V(DQW) cavities, new beam screen in non-crabbing pipe
- **Re-location for APWL and BTPX** (close to crab cavities, but not final yet)
- **Change of names for BPM, tertiary collimators and crab cavities.**
- **New position for TCT6** and small adjustments of other collimators.

Other points:
- **TCLD** in Point 2, 7. 11T, MQW in Point 7. TANB in Point 8.
MAD-X Sequence activities

- New layout database is deployed and allow multiple layout versions (e.g. LS2, LS3)
- Implementation changes have far reaching implications on the MAD-X sequence and interface with survey (very critical for installation work)
- LS2 sequence generated from layout database is being debugged. First working version generated on 23/10/2019, but still iterating…
- HL-LHC sequence generation is not ready yet, MAD-X sequence has to be generated manually
- Current layout drawings are the reference and are being finalized (new release is necessary to fix inconsistencies): crabs, MCBRD, BPM termal contraction need clarifications
- Present focus is the generation of survey files for 11 T installation.
- MAD-X, Geode, layout database software share similar data using different definitions and conventions: documentation effort on going

The new layout database brought new features, but considerable extra work. Complex workflow involves EN/ACE, BE/CO, BE/ABP, EN/SMM, TE/VSC.
Workflow today

ECR refer to Drawings

Checks MAD - X Sequence

Layout Database

Drawings MAD - X Vacuum Files

MAD-X Sequence MAD-X Vacuum Files

MAD-X Aperture Files

MAD-X Sequence MAD-X Optics files

Survey Files MAD-X Optics files

optics Model

Optics Files

Vacuum database generates after some manipulations HL-LHC specific

insert positions

used to determine bumps/fiducialization

manual editing

manual editing

inserted in manual editing

geodes for
Workflow issues

- Time consuming, involves many teams and 3 departments, not taken into account in the planning
- Layout database, optics models, geode use different conventions and duplicates some information, not always in consistent manner
  - Fiducialization rules are defined only in geode and not shared although they need to be used coherently in the layout database.
  - Layout database place objects differently from MAD-X in the presence of dipoles.
- The workflow never runs completely and lag behind installations (often does not complete)
- Last update of the LHC in geode in 2012. Many changes occurred in between not integrated and it is causing issues for the 11T.
On-going integration studies

Quantities still pending studies and decision
- Integration after removal of the BPM
- TAXN copper length and Y-chamber (latest proposal 3.492 m -> 2.8 m 22/10/2019)
- Position of APWL (wall current monitor) BTPX (BPM for experiments)
- Rotation of Q4

Integration proposed to implement this changes in 1.6
Optics repository

New optics repository containing official version
/afs/cern.ch/eng/lhc/HLLHCV1.5
Files not ready for production.

Kept for reference:
/afs/cern.ch/eng/lhc/HLLHCV1.5rc0: energy deposition studies
/afs/cern.ch/eng/lhc/HLLHCV1.5rc1: implementing Q4 rotations

We are in the process of restructuring the layout/optics repositories for all the machines https://cern.ch/acc-models: HL-LHC will also be available there.

Next steps:
• Complete cross check with drawings pending feedback from integration
• Re-match optics files
Back-up
TAXN – D2 Area

- TAXN moved by 68 cm towards D2
- Change of inter-distance of TAXN and collimators (discussed by WP8 and MME)
- Better radiation shielding (see F. Cerruti)
- Proposal to increase TCTPV stroke from 40 mm to 42 mm (discussed by MME) to equalize aperture margins between all tertiaries.

<table>
<thead>
<tr>
<th>Pos/Sep</th>
<th>HL1.4 [m/mm]</th>
<th>HL1.5 [m/mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1</td>
<td>77.782</td>
<td>77.534</td>
</tr>
<tr>
<td>TAXN</td>
<td>128.801 / 148-158</td>
<td>129.478 / 151-161</td>
</tr>
<tr>
<td>TCTPXV</td>
<td>131.949 / 162</td>
<td>132.495 / 165</td>
</tr>
<tr>
<td>TCTPXH</td>
<td>133.950 / 168</td>
<td>134.028 / 170</td>
</tr>
<tr>
<td>TCLPX</td>
<td>135.707 / 174</td>
<td>135.614 / 175</td>
</tr>
<tr>
<td>D2</td>
<td>142.513 / 188</td>
<td>142.095 / 188</td>
</tr>
<tr>
<td>BPMQBCZA</td>
<td>136.7955 / 180</td>
<td>151.8475 / 194</td>
</tr>
</tbody>
</table>

New specifications provided to WPs
Q4 options

- Changes in optics e.g. max crab angle but not expecting major impact.
- Changes in orbit corrector budget, but not expecting major impact.
- Gain in aperture in Q4.
- Loss of long. space for wire unless they could be put on the IP side...
On-going studies

- Alignment requirements for full remote alignment specifications
- Re-definitions of “mechanical” aperture tolerances
- Update of orbit corrector budget and BPM specifications
- Optics Optimization with/without MS10
- Ramp&squeeze scenarios, new flatCC scenario
- Increase beam size at the dump
- LS2 LHC sequence
- BGV location optimization
Transverse tolerances on Magnetic Fields

1. Orbit corrector budget assumes: quadrupole fields aligned to ±0.5 mm the “ideal” alignment line (blue in case of an IP shift).

2. Crab cavities will also need a small shear (from 0 to 0.8 mm) in the crossing plane depending on the available strength on the MCBRD and the chosen crossing angle.

3. Crab cavities should be aligned to the specified position to ±0.5 mm.

4. The alignment priorities are IP and crab cavities, quadrupole fields and beam screens.

Quantities to be reviewed from orbit correction studies for a consistent picture.
Alignment tolerances

Alignment tolerances are needed for WP2 to establish the maximum deviation from ideal alignment lines of magnetic fields and apertures.

Components:

<table>
<thead>
<tr>
<th>Components</th>
<th>WP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground motion from two alignment campaigns [ground motion]</td>
<td>15.4</td>
</tr>
<tr>
<td>Uncertainty of equipment fiducials to requested position [alignment error]</td>
<td>15.4</td>
</tr>
<tr>
<td>Uncertainty mechanical axis from fiducials [fiducialization]</td>
<td>15.4</td>
</tr>
<tr>
<td>Uncertainty magnetic/electric axis from mechanical axis [field error]</td>
<td>3/4/13</td>
</tr>
<tr>
<td>Uncertainty cold bore axis from mechanical axis [cold bore error]</td>
<td>3/4/8</td>
</tr>
<tr>
<td>Uncertainty beam screen position and shape from cold bore [b.s. errors]</td>
<td>12</td>
</tr>
</tbody>
</table>

Some of the quantities are already available, but not collected in a common sources.
WP2 and WP12 uses a mix LHC and HL-LHC quantities, but not the same mix.
Orbit correction and BPM error studies

The budget of orbit corrector strength and residual orbit accounts for operational knobs and orbit correction due to element imperfections and misalignments.

A new study has been started to include:

- orbit correction from BPMs under ground motion and alignment errors,
- stability of residual orbit after luminosity and crab leakage optimization during a fill,
- Realistic correction strategies.
- Alignment requirements, BPM specifications, knobs optimization to stay within the orbit residual and corrector strength budget.

Presentation from Joel and Davide 27/8/2019

[J. Andersson, D. Gamba]
Optimization without MS10

Studies have shown that:
- Baseline give always better DA
- Option without MS10 gives also worst DA

Mitigations:
- Cut MS14F and change vertical phase advances
- Cut MS14F&D and increase ATS factors
- [on going] Optimize IP1 to IP5 phase advance
- [on going] Optimize octupole families

New baseline phase

No MS10 equivalent to reduce increase $\beta^*$ to 21 cm for the same DA. [F. Plassard]

Work in progress to compare all options, to be presented on 27/8/2019 by Fabien.
IR6 Dump size optimization

- Increase spot size at the beam dump by relaxing MKD-TCT phase advance (not needed for round optics with V crossing in Point 5, or flat optics with H crossing in Point 5).

Status: spot size cannot be increased at injection due to aperture constraints, but can be done during ramp&squeeze.

Nominal ramp and squeeze for round optics.

<table>
<thead>
<tr>
<th>Requirements</th>
<th>V1.4 round</th>
<th>First iteration</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta_x$ [km]</td>
<td>&gt;4</td>
<td>6.3/5.0</td>
</tr>
<tr>
<td>$\beta_y$ [km]</td>
<td>&gt;3.2</td>
<td>3.8/7.8</td>
</tr>
<tr>
<td>$\sqrt{\beta_x\beta_y}$ [km]</td>
<td>&gt;4.5</td>
<td>4.6/6.2</td>
</tr>
</tbody>
</table>

Limits: non-conform mqtl11.r6b1, mqtl11.l6b2

First improvement 10% in beam size at the end of the squeeze [to be continued]
Conclusion

- HLLHCV1.5 optics should be released together with a new set of integration drawings
- Hardware integration is not completed yet
  - Last blocking point is Q4 rotation
  - Other modifications not involving magnets could be added in parallel with optics files generation
- This optics version aims at including an update of the aperture tolerance to refine aperture estimates.
- Several ongoing studies will be presented in August:
  - Orbit correction: strategy, corrector budget, BPM specifications
  - No MS10 studies
  - IR6 studies