LHC Machine Status
RRB
Frédérick Bordry
29th October 2018
LHC 2018: Performance

- Full machine (2556 bunches) reached on May 5th
- Four “16L2 storms” encountered with successful recovery
- Bunch intensity is not really pushed to avoid issues with 16L2
- Steadily close to \( \sim2\times10^{34} \text{ cm}^{-2}\text{s}^{-1} \) (twice the LHC design value)
## LHC Beam parameters achieved

<table>
<thead>
<tr>
<th>Parameter</th>
<th>2018</th>
<th>Design</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Energy [TeV]</strong></td>
<td>6.5</td>
<td>7.0</td>
</tr>
<tr>
<td><strong>No. of bunches</strong></td>
<td>2556</td>
<td>2808</td>
</tr>
<tr>
<td><strong>Max. stored energy per beam (MJ)</strong></td>
<td>312</td>
<td>362</td>
</tr>
<tr>
<td><strong>$\beta^*$ [cm]</strong></td>
<td>30→25</td>
<td>55</td>
</tr>
<tr>
<td><strong>p/bunch (typical value) [10^{11}]</strong></td>
<td>1.1</td>
<td>1.15</td>
</tr>
<tr>
<td><strong>Typical normalized emittance [μm]</strong></td>
<td>~1.8</td>
<td>3.75</td>
</tr>
<tr>
<td><strong>Peak luminosity [10^{34} cm^{-2}s^{-1}]</strong></td>
<td>2.1</td>
<td>1.0</td>
</tr>
</tbody>
</table>
LHC 2018: Beam Availability and Performance

Fault / Downtime: 31%
Operations: 16%
Pre-cycle: 2%
Stable beams: 51%

Integrated Luminosity [fb⁻¹]

LHCb: 2.46 fb⁻¹
ATLAS: 65.1 fb⁻¹
CMS: 66.9 fb⁻¹

LHC Machine Status
RRB
Frédérick Bordry
29th October 2018
LHC 2018: last week of p-p-p operation!

Availability
88.4%

Stable beams
70.6%

Fault vs Operation Time Distribution

Stable Beams
Operations
Fault
Pre-Cycle

Energy
Beam 1 intensity
Beam 2 intensity

18. Oct
19. Oct
20. Oct
21. Oct
22. Oct
23. Oct
24. Oct

8.0 TeV
6.0 TeV
4.0 TeV
2.0 TeV
0.0 TeV

3.0e+14
2.4e+14
1.8e+14
1.2e+14
6.0e+13
0.0e+0

LHC Machine Status
RRB
Frédérick Bordry
29th October 2018
LHC cryogenics availability summary from Run 1 to Run2

LHC CRYO AVAILABILITY SUMMARY FROM RUN 1 TO RUN 2

PRELIMINARY
Run 1 + Run 2: Luminosity Production

<table>
<thead>
<tr>
<th>Period</th>
<th>Int. Luminosity [fb⁻¹]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run 1</td>
<td>29.2</td>
</tr>
<tr>
<td>Run 2: 2015</td>
<td>4.2</td>
</tr>
<tr>
<td>Run 2: 2016</td>
<td>39.7</td>
</tr>
<tr>
<td>Run 2: 2017</td>
<td>50.2</td>
</tr>
<tr>
<td>Run 2: 2018</td>
<td>66.0</td>
</tr>
<tr>
<td>Total Run1 + Run 2</td>
<td>189.3</td>
</tr>
</tbody>
</table>

Run 2 at 13 TeV
160.1 fb⁻¹
# LHC: outlook on rest of 2018

<table>
<thead>
<tr>
<th>July</th>
<th>Aug</th>
<th>Sep</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mo</td>
<td>β = 90 m run</td>
<td></td>
</tr>
<tr>
<td>Tu</td>
<td></td>
<td></td>
</tr>
<tr>
<td>We</td>
<td>MD 2</td>
<td></td>
</tr>
<tr>
<td>Th</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fr</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sa</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Su</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mo</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tu</td>
<td></td>
<td></td>
</tr>
<tr>
<td>We</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Th</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fr</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sa</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Su</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**End of run (06:00)**

- **Low energy high beta run 900 GeV**
- **Magnet training tests to aiming for 7 TeV after LS2**
The Long Shutdown 2 (LS2)

- Perform major **Maintenance and Consolidations**
- Increase intensity/brightness in the injectors to match HL-LHC requirements (**LIU Project**)  
- Increase **injector reliability and lifetime** to cover HL-LHC run (until ~2035) closely related to consolidation programs (in synergy with LIU Project)  
- Anticipate **HL-LHC work**
LS2 (2019-2020 period): coordination of multi projects

Consolidation & upgrades

The main projects during LS2

- LIU (incl. L4 connection)
- AWAKE
- HL-LHC
- DISMAC
- ELENA
- Consolidation
- LHC experiments upgrade
- SPS Access
- SPS Fire Safety
- East Area consolidation
Master Schedule of the Long Shutdown 2 (2019-2020)

LHC Machine Status
RRB
Frédérick Bordry
29th October 2018
LHC Machine Status
RRB
Frédéric Bordry
29th October 2018

LHC: LS2 planning (version October 2018)
HL-LHC: Civil Engineering Pt 1 and Pt5 has started
HL-LHC first stone ceremony, 15th June 2018
FRESCA2 dipole: the first project as R&D for HL-LHC

Nb$_3$Sn dipole for cable test facility.

Nominal design field 13 T (ultimate 15 T): reached 14.6 T, few quenches!
11T First Nb$_3$Sn prototype magnet on test stand

Models 2017

Quench current (A)

nominal

Quench number

LHC Machine Status
RRB
Frédérick Bordry
29th October 2018
New Model (SP 107) model training

4 quenches to nominal
10 quenches to ultimate
2 quenches to ultimate after thermal cycle

Excellent result!
11T magnet production (LS2 installation)
Quadrupole Model tests

All MXQF magnets have exceptional memory (no low current quench after thermal cycle)

MXQXF4: Best HF magnet ever tested in terms of behaviour - Final conductor and final pre-stress procedure

Ultimate with no quench after TC

MQXFS4
Run 3 outlook

\[ \sum (\text{Run1} + \text{Run2} + \text{Run 3}) > 300 \text{ fb}^{-1} \]

<table>
<thead>
<tr>
<th></th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
<th>2023</th>
</tr>
</thead>
<tbody>
<tr>
<td>JFMAMJASOND</td>
<td>JFMAMJASOND</td>
<td>JFMAMJASOND</td>
<td>JFMAMJASOND</td>
<td>JFMAMJASOND</td>
<td>JFMAMJASOND</td>
</tr>
<tr>
<td>LS2</td>
<td>10-15 fb^{-1}</td>
<td>~75-80 fb^{-1}</td>
<td>~75-80 fb^{-1}</td>
<td>~75-80 fb^{-1}</td>
<td>~75-80 fb^{-1}</td>
</tr>
</tbody>
</table>

2021: beam commissioning in the injectors after LIU upgrade
LHC 14 TeV commissioning and operation

2022-2023: production years at 14 TeV;
Lpeak \sim 2.0-2.2 \times 10^{34} \text { cm}^{-2}\text{s}^{-1} ; \text{luminosity levelling}

>350 fb^{-1}
Successful Run 1 and Run 2: > 189 fb⁻¹
Solid preparation for LS2 activities. In full swing to start less of 1.5 months LIU ready for installation and successful MD in 2018
HL-LHC Civil Engineering: a good start - HL-LHC machine in schedule

Run 3 at 14 TeV
End of 2023: ~350 fb⁻¹ => HL-LHC installation during LS3 (2024-2025)

Thanks for your attention