LHC machine status report

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Operation Group
On behalf of the LHC team
Outline

- Status of powering tests
- Machine check-out
- Overview of 2022 operation
Global Schedule on 17.11.2021 @LHCC

Machine checkout start:
Monday 21st February 2022

Finalize the powering tests and magnet training in S23 and S78 after repair

Today

YETS

Finalize the powering tests and magnet training in S23 and S78 after repair
• **Sector 78**: Powering tests completion (including training) after the beam test, quicker than foreseen

• **Sector 23**: Schedule to be re-worked, following the discovery of bent RF finger in cell 21L3 ➔ warm-up needed

**YETS**

Today

**DSO tests: 25th March**

**Machine checkout start: 26th March**
Powering tests

7983 tests to be performed for the superconducting circuits to be ready for beam in a very short time

For all sectors (but S23)

For S23

ex. for main dipole circuits

A similar table exists for every circuit type

LHC status – LHCC - 09.03.2022
Powering tests progress

* besides very few NCs to be fixed, all sectors but S23 are ready for beams up to 6.8 TeV
Main dipoles training

- **Dipole training** in sector 23 is expected to start beginning of next week
- **Excellent memory** seen in S78 (22 quenches to 6.8 TeV, instead of 69) is encouraging, BUT S23 undertook **2 thermal cycles**

<table>
<thead>
<tr>
<th>Circuit</th>
<th># circuit quenches in 2022 campaign (2021 campaign)</th>
<th>Max E reached</th>
</tr>
</thead>
<tbody>
<tr>
<td>RB.A12</td>
<td>0 (77)</td>
<td>7 TeV</td>
</tr>
<tr>
<td></td>
<td></td>
<td>COMMISSIONED @7 TeV</td>
</tr>
<tr>
<td>RB.A23</td>
<td>- (29, 3)</td>
<td>6.8 TeV</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Training to be re-done (~20 quenches estimated)</td>
</tr>
<tr>
<td>RB.A34</td>
<td>0 (70)</td>
<td>7 TeV</td>
</tr>
<tr>
<td></td>
<td></td>
<td>COMMISSIONED @7 TeV</td>
</tr>
<tr>
<td>RB.A45</td>
<td>0 (87)</td>
<td>7 TeV</td>
</tr>
<tr>
<td></td>
<td></td>
<td>COMMISSIONED @6.8 TeV</td>
</tr>
<tr>
<td>RB.A56</td>
<td>1 (75)</td>
<td>6.8 TeV</td>
</tr>
<tr>
<td></td>
<td></td>
<td>COMMISSIONED @6.8 TeV</td>
</tr>
<tr>
<td>RB.A67</td>
<td>0 (62)</td>
<td>6.8 TeV</td>
</tr>
<tr>
<td></td>
<td></td>
<td>COMMISSIONED @6.8 TeV</td>
</tr>
<tr>
<td>RB.A78</td>
<td>0 (69, 22)</td>
<td>6.8 TeV</td>
</tr>
<tr>
<td></td>
<td></td>
<td>COMMISSIONED @6.8 TeV</td>
</tr>
<tr>
<td>RB.A81</td>
<td>1 (55)</td>
<td>6.8 TeV</td>
</tr>
<tr>
<td></td>
<td></td>
<td>COMMISSIONED @6.8 TeV</td>
</tr>
</tbody>
</table>

**NB:** for each circuit quench event, there could be other magnets quenching, following the primary quench

- Quenches occurred also at flat-top → **additional plateaus** at operational current (11.5 kA) being performed to ensure reliability
- Main dipoles circuits in S12, S34, S45 reached 7 TeV

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LHC operation schedule

Starting Machine Check-out on **26th March**

- **2 wks** of Machine Checkout (interleaved with S23 training)
- **4 days** of full Machine Checkout
- **~9 wks** of Beam Commissioning, including:
  - **8 days** of scrubbing (+2)
  - **4x1 day** of Machine Development
- **~7 wks** of intensity ramp-up

Closure of tunnel and experimental caverns:

- **25.03** for DSO tests
- **wk13 machine closed** (with some exceptions)
- **wk14** access partially possible
- **08.04** onwards machine closed

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LHC status – LHCC - 09.03.2022
Machine Check-out

- Machine check-out is meant to ensure that all systems work together in the correct way and communicate with each other as expected!
- Because of the limited intensity, most of the systems were not or only partially used/tested for the pilot beam test

Checklist to be completed:
- Machine Protection tests
- Powering tests (including global)
- Individual System Tests
- LBDS BETS tests
- Vacuum interlock
- Collimation system setup
- Sequences dry-run
- Settings check
- ...and many many others!!

- Seven out of eight sectors are ready → possibility to interleave some powering and MC tests
- S23 is not included in the Beam Energy Tracking System configuration -> possibility to perform BIS-LBDS tests, while training S23
  - Disabling some interlock in S23
  - Strap of interlocks from access system
  - Not an easy operation, but some activities can be done
Beam commissioning

Main goal is to prepare the machine for first physics fill, followed by intensity ramp-up:

- **Commission with beam** the key accelerator systems (feedbacks, RF, ADT, injection, dump, collimation, instrumentation,…), with particular emphasis at LS2 changes
- Test all **Machine Protection** systems and functionalities
- Establish and validate the **machine configuration**

Pre-commissioning of **special cycles** (VdM, 90 m,…) is foreseen as bonus:

- Proved in the past to be an efficient strategy
- Very fast way into the cycle when dedicated period for operation -> **high efficiency**
- Allows to have other options in the pocket to establish collisions, **in case of needs**
Intensity ramp-up

Intensity ramp-up is designed to:
- Validate machine configuration and optics
- Spot potential issues in machine protection system
- Identify issues related to increased beam intensity

**STRATEGY:** First increase of N of bunches then push bunch intensity

**Proposal for bunch number increase**
3/12-75-300-600-900-1200-1800-2400-2700
Beam commissioning

Preliminary detailed planning (with margin for access & problems) indicates 49 days (7 weeks) until first stable beams.

2015 commissioning was done in ~8 weeks
• but:
  • Energy increase 4TeV -> 6.5 TeV
  • 25 ns beam setup, after commissioning with 50 ns
  • Fight with ULO in 15R8 (investigation and quench recovery)
• However:
  • More complex cycle wrt 2015 requires longer setup
  • Variety of leveling strategies to be commissioned

(almost) everything will have to be redone!

What we gained with the beam test is the confidence in the systems and knowledge that NO major problem is present.
The 2022 operational cycle

1. Injection @450 GeV
2. CRS to 1.3m (IP1/5), 2m (IP8), 10m (IP2) @6.8 TeV
3. Squeeze to 60 cm (IP1/IP5)
4. Collisions
5. Levelling to 30 cm (Xing angle fixed)

LHCb Xing angle rotation test
Levelling

What was done in Run 2

• Separation levelling in IP2/8
• 2017 onwards: crossing angle levelling with intensity
• 2018: operational $\beta^*$ levelling @end-of-fill (30cm -> 27cm -> 25cm)
• Levelling mechanics & procedures well established

Run3 $\beta^*$ levelling is nothing fundamentally new!!
• larger levelling range - some additional requirements

• Pre-matched optics $\Rightarrow$ fixed steps
• Small and regular steps
• Max. 5% lumi/pile-up jump
# Beam and optics parameters for 2022

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value @inj</th>
<th>Value @FT</th>
<th>Value @coll</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy [TeV]</td>
<td>0.45</td>
<td>6.8</td>
<td>6.8</td>
</tr>
<tr>
<td>$\beta^* (1/2/5/8) [m]$</td>
<td>11/10/11/10</td>
<td>1.3/10/1.3/2</td>
<td>0.6/10/0.6/2 down to 0.3/10/0.3/2</td>
</tr>
<tr>
<td>(half) Xing angle [urad] IP1(V)/IP2(V)/IP5(H)/IP8(H)</td>
<td>-170/170/170/-170</td>
<td>-160/200/160/-200</td>
<td></td>
</tr>
<tr>
<td>Sep (1/2/5/8) [mm]</td>
<td>-2/3.5/2/-3.5</td>
<td>-0.55/1/0.55/-1</td>
<td></td>
</tr>
<tr>
<td>Tune (H/V)</td>
<td>.27/.295 (to be verified)</td>
<td>.28/.31</td>
<td>.31/.32</td>
</tr>
<tr>
<td>Emittance (BCMS standard) [um]</td>
<td>1.3</td>
<td>1.8</td>
<td>1.8 -&gt; 2.5</td>
</tr>
<tr>
<td>Bunch intensity [p]</td>
<td>1.1E11 to start, towards 1.4E11 later</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bunch length [ns]</td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
</tr>
<tr>
<td>COLL (TCP/TCSG/TCSP) [$\sigma$]</td>
<td>5.7/6.7/7.5</td>
<td>5.0/6.5/7.3</td>
<td>5.0/6.5/7.3</td>
</tr>
</tbody>
</table>
Conclusions

➢ Powering tests are proceeding as expected
  • All sectors, with exception of sector 23 are ready for beam up to 6.8 TeV
  • Sector 23
    • Re-commissioning after thermal cycle is proceeding smoothly
    • Main dipole training will start sometimes at the beginning of next week

➢ NO showstopper identified. The LHC activities are following the schedule:
  • Machine check-out is planned to start at the end of week 12
  • Beam commissioning is expected to start sometimes in the week leading to the Easter weekend