LHC Machine Status Report

Mike Lamont for the LHC team
Acknowledgements: Mirko Pojer, Matteo Solfaroli, Katy Foraz et al
CSCM (Copper Stabilizer Continuity Measurement)

Fully qualify magnet bypass = copper stabilizer of the bus-bar + diode + diode leads
Bypass contains about 3500 connections/joints per sector!

- Connect the two 6 kA/200 V power converters in series
- Stabilize the sector 20 K so the magnets and bus are not superconducting.
- Apply a current of a few 100 A to open the bypass diodes
- Apply a current pulse of 6.5 TeV equivalent and watch carefully
Conclusion:
• Voltages on the busbars behave as simulated, with a spread due to RRR and length differences. 😊
• There are no outliers! 😊
• All busbar segments (including joints and lyras) are qualified for 6.5 TeV! 😊
CSCM results so far

7 sectors completed

- RRR of the busbars as expected
- The main busbars, including the consolidated joints, behave as expected and are qualified for 6.5 TeV operation.
- The diodes behave as expected and are qualified for 6.5 TeV operation.
- The diode leads behave in a not-fully-understood, but rather predictive way, similar to the previous sectors, and are also qualified for 6.5 TeV operation.

Arjan Verweij, Hugues Thiesen and team
## Cool-down - status

<table>
<thead>
<tr>
<th>Sector</th>
<th>Temperature</th>
<th>CSCM Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sector 12</td>
<td>1.9 K</td>
<td>CSCM OK</td>
</tr>
<tr>
<td>Sector 23</td>
<td>5 K</td>
<td>CSCM OK</td>
</tr>
<tr>
<td>Sector 34</td>
<td>26 K</td>
<td></td>
</tr>
<tr>
<td>Sector 45</td>
<td>20 K</td>
<td>CSCM OK</td>
</tr>
<tr>
<td>Sector 56</td>
<td>1.9 K</td>
<td>CSCM OK</td>
</tr>
<tr>
<td>Sector 67</td>
<td>1.9 K</td>
<td>CSCM OK</td>
</tr>
<tr>
<td>Sector 78</td>
<td>5 K</td>
<td>CSCM OK</td>
</tr>
<tr>
<td>Sector 81</td>
<td>1.9 K</td>
<td>CSCM OK</td>
</tr>
</tbody>
</table>

Represents a major and successful effort by the cryogenics group
Before powering

Have to ensure that all circuits are safe to power, all protection functionality is sound. Small team – a lot of ground to cover

- Electrical quality assurance
  - Cable connection, 2.1 kV, 1.5 kV
- Quench protection system tests
  - Configuration, triggering, thresholds, heater discharge
  - Energy extraction checks
- Interlock tests
  - EE, PIC, permit, quench signal...

And address the inevitable on-conformities
QPS

• Major consolidation and upgrades to the Quench Protection system during LS1
  – First major system upgrade since introduction of the nQPS layer in 2009

• Essential debugging and testing of all:
  – Hardware
  – Firmware
  – Middle and high-level software

“Teething problems during initial exploitation phase to be expected (otherwise something is really wrong ...)” Reiner Denz
Operation “Yellow rack”

DQLPR
NEW

DQLCT
NEW

DQLCT
NEW

DQLCT
NEW

DQLCT
NEW

DQLPR
NEW

DQLIM

DQLPU type A

230 V power

Discharge

nGFS Trigger

MB signals

Trigger

DC power

Power cycle

230 V UPS F4

230 V UPS F3

MB

Signals & trigger

NEW

NEW

NEW

NEW

NEW

NEW

REFURBISHED

REFURBISHED

REFURBISHED

REFURBISHED

NEW

NEW

NEW

NEW

NEW

NEW

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NEW

NEW

NEW

NEW

NEW

NEW

World FP

Interlock

Interlock

DC power

MB signals
Main dipole protection rack type DYPB – components

- 1232 x DYPB (yellow rack)
  - 1 x DQLIM (interface module for local quench protection unit)
    - 2 x DQLPB (regulated low voltage power module)
    - 4 x DQCLT (current pulse measurement transformer)
  - 1 x DQLPU A (local protection unit)
    - 2 x DQQDL (quench detector)
    - 1 x DQHSU (quench heater supervision unit)
    - 1 x DQCSU (crate supervision unit)
    - 1 x DQAMC (acquisition & monitoring controller)
  - 4 x DQHDS (quench heater discharge power supply)

- 436 x DQLPUS (nQPS crate installed in DYPB B)
  - 5 x DQQBS (bus-bar splice protection systems)
  - 4 x DQQDS (aperture symmetric quench detection)
  - 3 x DQQDE (earth voltage feeler)
  - 1 x DQAMGS (acquisition & monitoring controller)

- 872 x power packs for DQLPUS (installed in DYPB B)

17248 items to be tested, 5880 circuit boards programmed!

6160 items to be tested, 5008 circuit boards programmed!
Powering tests

All circuits taken to nominal current level one by one
  – Rigorous checks of quench protection, energy extraction, interlocks, power converters...

• Phase 1
  – low current only – preliminary tests and measurements (QPS, energy extraction...)
  – 60 A, 120 A: low current correctors
  – 600 A: lattice correction circuits (sextupoles etc.)

• Phase 2
  – Full scale tests
  – IPQs: individually powered quadrupoles
  – IPDs: individually powered dipoles
  – ITs: inner triplets
  – MB, MQ (mains): dipoles, quadrupoles
Main dipoles

• 800 lb gorilla is the main dipoles
  – 100 or so quenches expected to get to 6.5 TeV
  – One so far in sector 67 at around 5.8 TeV
The first (re)training quench S67

- After the successful execution of the previous steps, the first ramp to nominal current was executed, leading to the first training quench at a current of 9779 A (corresponding to a bit less than 5.8 TeV)

- Secondary quenches were detected
  - A26L7 4248 A
  - C26L7 4235 A
  - A27L7 381 A

SM18 data for the first quenching magnet:

<table>
<thead>
<tr>
<th></th>
<th>Quench 1</th>
<th>Quench 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>I (A)</td>
<td>8391</td>
<td>12782</td>
</tr>
<tr>
<td>B (T)</td>
<td>5.93</td>
<td>8.96</td>
</tr>
<tr>
<td>E (TeV)</td>
<td>5.0</td>
<td>7.5</td>
</tr>
</tbody>
</table>
**Present status: sectors 12 to 45**

| S12          | • EIQA completed, powering tests in progress  
|             | • 60/120 A circuits tested  
|             | • 600 A start today  
|             | • Preparation of the mains started and progressing well |
| S23          | • On the way to 1.9 K |
| S34          | • Stable at 20 K  
|             | • **CSCM between 21\textsuperscript{st} November and 4\textsuperscript{th} December** |
| S45          | • **CSCM will finish today**  
|             | • Magnet alignment in progress  
|             | • Then EIQA and cool-down to 1.9 K |
Present status: sectors 56 to 81

<table>
<thead>
<tr>
<th>Sector</th>
<th>Status</th>
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<tbody>
<tr>
<td>S56</td>
<td>• EIQA will be completed mid next week</td>
</tr>
</tbody>
</table>
| S67    | • Powering tests up to first dipole quench  
       | • Cooling tower maintenance on-going  
       | • Powering will resume on Nov.24.  
       | • Training will resume at the beginning of December |
| S78    | • Cool-down in progress  
       | • EIQA in shadow of cooling tower maintenance  
       | • Powering in the New Year. |
| S81    | • **Powering**. Tests will be stopped at the end of this week - to be resumed in January - due to cooling tower maintenance  
       | • Powering tests well advanced for 60-120-600 A  
       | • Preparation of the mains well advanced |
**HWC - summary**

CSCM will be completed on all sectors within a couple of weeks

Major QPS upgrade - the debugging of the first sector was important and the result was evident in the following sectors...

ELQA, QPS prep. etc. mostly cleared by Christmas.

Experience on extensive training on one sector by Christmas – S12 – benchmark...

Opening the way to an intensive powering test campaign in the New Year.

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**Table:**

<table>
<thead>
<tr>
<th>Dec</th>
<th>Jan</th>
<th>Feb</th>
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<tbody>
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<td>5</td>
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<td>48</td>
<td>3</td>
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<td>51</td>
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<td>17/11</td>
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<td>26/1</td>
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<tr>
<td>8/12</td>
<td>26/1</td>
<td>2/2</td>
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<tr>
<td>15/12</td>
<td>2/2</td>
<td>9/2</td>
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</tbody>
</table>

**Legend:**

- Red: Powering tests
- Yellow: CSCM
- Green: ELQA etc.
- Pink: Cooling towers

**Big thanks due to a relatively small team:**

Machine Protection and Electrical Integrity (ELQA, machine protection, QPS, magnets), Power converters, MEF, Operations, Survey…

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Based on 4.1e - KF
From 7th November, 2014

MPE & LS1 resources loaded schedules

Courtesy Katy Foraz
Aside from the magnets

• Beam dumps
  – Reliability run ongoing

• Injection kickers
  – Conditioning, to be OP tested next weekend

• RF
  – Conditioning high-voltage, high-power, cavities, LLRF, hardware/controls...

• Dry runs
  – Full scale tests of: beam instrumentation, controls, timing, software, interlocks, RF synchronization etc. from CCC

  Plus: survey, vacuum, transverse feedback, collimators...
Transfer line tests this weekend

- Access system tests: 8/9 Nov.
- DSO tests: 15/16 Nov.
- Transfer line tests: 22/23 Nov.
### 2015 Q1/Q2

**First Beam**
- **9th March**

<table>
<thead>
<tr>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
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<td><strong>Mo</strong></td>
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<td>23</td>
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**March**
- **Sector test (S23)**
- **Sector test (S78)**
- **Machine checkout**
- **Recommissioning with beam**

### April
- **Recommissioning with beam**

### May
- **Special physics run**
- **TS1**

### June
- **Intensity ramp-up with 50 ns beam**

**Scrubbing**
- **For 50 ns**
- **For 25 ns**
### 2015 Q3/Q4

<table>
<thead>
<tr>
<th></th>
<th>July</th>
<th>Aug</th>
<th>Sep</th>
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<tbody>
<tr>
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<td>Su</td>
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**July 2015**
- **27th**: MD 1
- **28th**: Intensity ramp-up with 25 ns beam

**August 2015**
- **29th**: TS2
- **30th**: Special physicist run
- **31st**: MD 2

**September 2015**
- **1st**: Lower beta

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<table>
<thead>
<tr>
<th></th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wk</td>
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<td>41</td>
<td>42</td>
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<td>Mo</td>
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<tr>
<td>Su</td>
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</tbody>
</table>

**October 2015**
- **41st**: MD 3
- **42nd**: Floating MD

**November 2015**
- **43rd**: TS3
- **44th**: Ions setup
- **45th**: IONS
- **46th**: Technical stop

**December 2015**
- **47th**: Technical stop
- **48th**: Xmas

**End physics (08:00)**
<table>
<thead>
<tr>
<th>Phase</th>
<th>Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Commissioning</td>
<td>56</td>
</tr>
<tr>
<td>Scrubbing</td>
<td>23</td>
</tr>
<tr>
<td>Early special physics run (LHCf/VdM)</td>
<td>5</td>
</tr>
<tr>
<td>Proton physics 50 ns</td>
<td>$7 + 21$</td>
</tr>
<tr>
<td>Proton physics 25 ns – phase 1</td>
<td>44</td>
</tr>
<tr>
<td>Change in beta*</td>
<td>5</td>
</tr>
<tr>
<td>Proton physics phase 2 (including ramp-up)</td>
<td>44</td>
</tr>
<tr>
<td>Special physics runs (TOTEM/VdM)</td>
<td>7</td>
</tr>
<tr>
<td>Intermediate energy run - to be scheduled</td>
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</tr>
<tr>
<td>Machine development</td>
<td>19</td>
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<tr>
<td>Technical stops</td>
<td>15</td>
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<tr>
<td>Technical stop recovery</td>
<td>6</td>
</tr>
<tr>
<td>Ion setup/Ion run</td>
<td>$4 + 24$</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>280 (40 weeks)</strong></td>
</tr>
</tbody>
</table>
Conclusions

• Steady progress but little contingency left:
  – Cool-down has gone well
  – CSCM: additional overhead, but invaluable, 7/8 complete – excellent results
  – Important commissioning/debugging of other systems
  – Powering tests thus far have gone well

• Most of the preparation work will completed in 2014, opening the way to intensive powering test campaign in 2015
  – Experience with training in S12 will be the benchmark