Outline

• Objectives for 2016
• Changes w.r.t. 2015
• Summary of the machines commissioning
• Status of the operation
• Plan for 2016
Objectives for 2016

• 2015 has been a recommissioning year after LS1
• 2016 will be the first production year of run 2
  • Increase the total number of bunches (288b trains)
  • Reduce the beam size at the IPs (beta* 40cm)
  • Shorter and faster intensity ramp-up (more luminosity)
• 2015: ~4 fb^{-1} integrated luminosity
• 2016: target is 25 fb^{-1} integrated luminosity
LHC schedule for 2016

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<th>Week</th>
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<th>Feb</th>
<th>Mar</th>
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- **Year end technical stop**
- **Powering tests**
- **Machine checkout**
- **Machine development**

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- **Recommissioning with beam**
- **Beta* 2.5 km dev.**
- **Vacuum runs**
- **Intensity ramp-up**
- **Scrubbing as required**

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- **Beta* 2.5 km data taking**
- **Ion run (p-Pb)**
- **Jeune G**
- **Extended year end technical stop**
- **Lab closed**

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- **Ion setup**
- **Extended year end technical stop**

150 days p-p physics
24 days p-Pb physics
8 days special physics + VdM
Main changes w.r.t. 2015

- Smaller beta* from 80cm to 40cm → Higher luminosity
- New combined ramp & squeeze → Shorter squeeze
- Better handling of e-cloud effects → Mitigate transients, reduced movement of triplet in IR8
- New TDIs → more bunches per injection from SPS → more bunches in the machine
- Changed BLM thresholds → Minimise dumps due to UFOs
Smaller beta\(^*\)

\[ L \propto \frac{1}{\beta^*} \]

- Beta\(^*\) limited by aperture in the focusing triplets
  - 40cm is the lower limit for a long range beam-beam separation of 11 sigma
- Increase in squeeze time
  - Compensated by combined ramp & squeeze
- Tighter collimators setting
  - Modified phase advance between IP6 and TCTs IP1&5
TDIs replacement

- Damaged BN ceramic tiles replaced with Cu coated graphite
- New TDI can cope with the injection of trains of 288 bunches
Commissioning milestones

- **YETS - Many interventions on many systems**: Ended on March 4
- **Powering tests**: Start March 4, End March 21
- **HW check out**: BIS loop closed March 23
- **Low intensity injection**: First beam March 25
- **Low intensity combined ramp and squeeze**: First CR&S March 26
- **Low intensity squeeze**: First squeeze March 26
- **Corrections of Optics, Q, Q`, C-**

**Nominal intensity**

- **Injection**
- **Combined ramp and squeeze**
- **Squeeze**
- **First collisions**
- **Collimators setup**
- **First stable beams**
- **Bunch trains injection**

**Physics**

- **Intensity ramp-up**

**Started operation with nominals March 29**

- **CR&S on April 6**
- **First collisions April 8**
- **April 23 3b+3b**
- **April 24 12b+12b**
- **72b April 21**
- **1177b May 18**

**Included special bump in IP5 to increase dispersion in TOTEM**
Powering tests

Early debugging in S45 on 1st March

Powering tests started on March 4

S34, 45, 78 and 81 available
S12 and 23 available
S56 and 67 available

1572 Systems
8592 Tests
8467 Successes (98%)

March 16

The 10% effect
Successful completion of cold checkout
25 March Morning

LHC is ready for beam
Injection & Threading

25 March Morning

10:13 B1 Injected

10:34 B1 Circulating

12:22 B1 and B2 circulating and orbit corrected
Combined Ramp & Squeeze

Graph showing the combined ramp and squeeze for different distances (11m, 10m, 6m, 3m, 40cm) with shaded areas for CR&S and Squeeze phases. The graph also indicates time intervals from 01:00 to 03:00 with specific distances marked as x-axis.

In the graph:
- CR&S is represented by red shading.
- Squeeze is represented by blue shading.
- The distances 11m, 10m, 6m, 3m, and 40cm are marked on the y-axis.
- The x-axis represents time from 01:00 to 03:00.

Graph key:
- ATLAS & CMS
- LHCb
- ALICE
Optics corrections at 450 GeV

B1 Before

B2 Before

B1 After

B2 After

LHCb1 450 GeV

LHCb2 450 GeV

IR2 IR3 IR4 IR5 IR6 IR7 IR8 IR1

IR8 IR1 IR2 IR3 IR4 IR5 IR6 IR7

0 5000 10000 15000 20000 25000

0 5000 10000 15000 20000 25000

0 5000 10000 15000 20000 25000

0 5000 10000 15000 20000 25000

Δβ/β

Δβ/β

Δβ/β

Δβ/β

10-4-2015 26-03-2016

2015 2016
Optics corrections

Squeeze: 40cm, Beam 2

\[ \frac{\Delta \beta_x}{\beta_x} \]

\[ \frac{\Delta \beta_y}{\beta_y} \]

Longitudinal location (m)

rms 1.6%

rms 1.6%
Loss maps

Loss maps need to be performed for all different cycles!

Refinement of HW and tool has reduced the time from days to hours
Special cycles

- Van der Meer scans for luminosity calibration
  - Scheduled early in the run
  - Completed for ATLAS, ALICE and LHCb
  - Need to be completed/repeated for CMS
- Large beta* run
  - Scheduled later in the year
- Proton-Lead physics
Possible performance limitations

• Unidentified laying object (ULO)
  • Reduces available aperture

• Unidentified falling objects (UFO)
  • Trigger beam dumps and magnet quenches

• Electron cloud
  • Limits number of bunches and degrades beam quality

• Hardware faults rate
  • Fault tracking tools (identify critical systems)
  • Consolidations (using fault tracking as input)
  • R2E project (SEU almost gone)
ULO in 15R8

The unidentified laying object in cell 15R8 causes an aperture restriction.

A scan was performed early on during commissioning and the restriction was found to be similar to 2015.
UFOs

• In 2015 14 UFO-related beam dumps
  • 3 UFO-induced quenches (BLM could not prevent)
  • 9 BLM trigger after UFO event already over.
  • 1 BLM trigger may have shortened the UFO but there was no risk of quenching.
  • 1 BLM trigger potentially avoided a quench.

• Decided to increase threshold of BLM for 2016
  • Number of UFO-induced quenches slightly higher (in 2015 +1)
  • Number of unnecessary dumps decreased (in 2015 -10)
UFO conditioning in 2015

For 2016

- Statistics and intensity still low, too early to quantify the situation
- For the time being one event of UFO-induced quench
Present e-cloud status

No dedicated scrubbing time, will happen during physics
Long faults

- SPS dump (TIDVG) developed a small leak in the vacuum vessel
  - Limit bunch trains to 72b to prevent increase of leak
  - Spare being prepared
- 66kV transformer fault caused by small animal
  - 6 days of down time
- PS main power supply
  - Back-up system failed while main system under repaired. 5 days downtime
LHC schedule for 2016

14 days lost already due to long faults
136 days p-p physics
24 days p-Pb physics
Advancement with luminosity production
Record length fill 21.05

35h28m stable beams - integrated luminosity ~270 pb⁻¹!

- Luminosity performance looks good
- Excellent luminosity lifetime
- Long fills
- Availability hit by the extended stops.
Projection for 2016

2016 Integrated Luminosity Projection (40 cm $\beta^*$ 2100 bunches

- Projection
- Actual

Integrated luminosity [fb$^{-1}$]

Conclusions

• The work done during LS1 to improve hardware and tools has allowed for a very efficient startup and commissioning

• LHC in good shape

• Optics and orbit have never been corrected so well

• Significant downtime from important faults in injectors and infrastructure
  • lost around two weeks
  • impact on peak performance from SPS beam dump limitations

• Still early days - 2016 has the potential to be a productive year!
The End