LHC Machine Status Report

LHCC, November 2010
Roger Bailey
LHC Operations

On behalf of the LHC commissioning team and drawing on material from many sources

LHC Machine Status Report

The problem and fixing it
Understanding the problem

150ns operation
50ns running

Ions

First 3 weeks of September (covered at last LHCC)

Key things addressed (then or later)

- Operation with crossing angles all through the cycle
- Injection of multiple bunches
- Operation with higher beam intensities
- Implications for beam instrumentation
- Implications for beam protection devices
- Implications for multiple bunches
- Technical stop of week 44 advanced to week 42

- Strategy (all with nominal bunch intensities)
- Started with 24 on 24 (September 22)
- Moved to 56 on 56 after 1 fill (September 23)
- Started with 24 on 24 (September 22)
- Stripped (all with nominal bunch intensities)

150ns bunch train running, 22/09 to 29/10

Bunch train commissioning - reminder

11/18/2010
24
56
104

11/18/2010
24
56
104
Increased losses observed in P2: started Oct 8th

RF inserts between MSIA and MSIB septa

Beam B1

- At first able to steer around aperture restriction
- Eventually ran out of margin – badly aligned insert

Intervened October 19th (technical stop early)

150ns bunch train performance, 22/09 to 29/10

<table>
<thead>
<tr>
<th>Energy</th>
<th>Bunch intensity</th>
<th>Bunches per beam</th>
<th>Colliding in</th>
<th>Emittance (μm m^2)</th>
<th>Luminosity (cm^-2 s^-1)</th>
<th>Event rate / Xing Hz</th>
<th>BBTS / Xing</th>
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<tbody>
<tr>
<td>TeV 3.50</td>
<td>1.E+10</td>
<td>24</td>
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<td>% nominal</td>
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<td>0.7</td>
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Intervened October 25th (technical stop early)

Increased losses observed in P2: stared Oct 8th
Luminosity evolution 2010

11/18/2010

5 orders of magnitude in ~200 days

$10^{30}$ cm$^{-2}$ s$^{-1}$

Bunch train commissioning

~50 pb$^{-1}$ delivered, half of it in the last week!

LHC now on its own in terms of stored energy

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Achievements

- Bunch intensities ~ nominal throughout
- Can collide small emittance bunches
- Carefully increased number of bunches from 24 to 368
- Inject, ramp, squeeze, collide and all that this entails
- Stable beam operation with 25MJ per beam
- Beam-beam effects with crossing angles
- Food for thought for 2011+

- Beam-beam effects with crossing angles
- Did we reach an intensity limit?
- How evolved of the vacuum system?
- Beam-beam effects with crossing angles

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Key points

- Both head-on and long-range beam-beam interactions
- Head-on tune shifts depend (mostly) on:
  - Number of particles per bunch
  - Normalised emittance
- Long-range tune shifts depend (mostly) on:
  - Number of particles per bunch
  - Head-on tune shifts depend (mostly) on:
  - Crossing angles
  - Beam-beam effects with crossing angles

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LHC beam momentum (GeV/c)

Stored energy (MHz)

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LHC now is own in terms of stored energy

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Luminosity evolution 2010
Clear differences between different bunches/beams correlates with number of collisions; analysis ongoing.

Vacuum - Fill 1381 (First fill with 152 bunches)

Gradual degradation seen with the benefit of hindsight from Friday September 29th:

- In the LSS (Long Straight Sections)
  - Pressure rises in the pipes with 1 circulating beam explained by Synchrotron Radiation
  - Dependent only from the energy and total intensity
  - Pressure rises in the pipes with 2 circulating beams cumulates different effects:
    - SR induced by D1 or D2 bending magnets
    - HOM effects linked to the bunch length variations during the ramp
    - Electron stimulated desorption (Electron cloud) – Threshold effect
    - Bigger effects observed in the Cold/Warm transition of the Inner triplets on Q3/DFBX side for ATLAS and D1 side for Alice and LHCb

- Nothing in CMS, could be explained by the wake fields from the solenoid

- Vacuum cleaning will be very effective to reduce the pressure rise

- Temperature diagnostics and solenoids installed (IR1)

Vacuum - Fill 1427 - beam 1 - 312 bu/ring

Note spikes during injection tests when B1 AND B2 are injected

Vacuum - summary of observations

Vacuum - Bunch trains and vacuum around IR1

Bunch intensity loss evolution through the fill
Mitigated by change of BLM threshold

UFO - Unidentified Falling Object (fast local loss)

- Working explanation: dust particles falling into beam creating scatter losses and showers propagating downstream
- No quench with UFOs.
- 2 UFOs since threshold change:
  - UFO near LHCb leading to dump by LHCb – not the LHC BLMs.
  - Ultra-fast and somehow non-standard UFO at BSRT.

- Even though the UFO rate seems to be under control now UFOs will become a problem if we ever increase the energies since the quench and BLM thresholds will come down again (factor 2-3).
- No quench, but preventive beam dump
- Rise time on the ms scale
- Ultra-fast local losses
- UFO dump rate has gone down significantly since we increased the threshold by a factor 3.

- UFO Worrying trend through the summer
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Vacuum - effect of solenoids on pressure IR1

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Vacuum - effect of solenoids on pressure IR1
LHC Machine Status Report

Physic fill with 9 x 12 bunches

50ns run (29/10 to 04/11)

Motivation (in view of effects seen during 150ns operation)

Dependence on bunch intensity

Dependence on bunch train length

Dependence on bunch train spacing

Measurements for the characterization of the scrubbing

Behaviours of vacuum system

Behaviours of instrumentation and its impact on commissioning

Influence on reliability and efficiency

Evolution of physical conditions with time scaling

In order to reach the intensity limit for 50ns operation

To be followed...
Vacuum Interlock due to pressure increase on the Penning gauges VGPB.773.6L7.R on the cold-warm transition of the Q6L7.R. Beams circulating in different vacuum chambers are expected to cause instabilities and emittance blow-up along the trains. Pressure rises with trains of 24 bunches spaced by 1.85 ms.

Beams circulating in different vacuum chambers at injection dependence on bunch intensity and train length.

Threshold effect starts between 8, 10, and 12,10^11 protons per bunch. Threshold effect starts between 8 and 12,10^11 protons per bunch. There is no threshold for trains of 12, not for trains of 24, worse for trains of 36. Measurement made with 2 trains of 24 bunches spaced by 1.85 ms.
Scrubbing in the LSS

Can hope to gain 2 orders of magnitude in ~16h

11/18/2010

Observed temperature increases on the beam screens in all the arcs in correspondence with 50 ns beam injection

Heat load on beam screens

Heat load on beam screens in 33L6

I beam

Heat load dominated by sources other than Synch. Light and Image Currents on the beam screens

Electron-Cloud

LHC Machine Status Report

The problem and fixing it

Understanding the problem

150 ns operation

50 ns running

Ions running

2011

Ions
Ion Commissioning: First 24h from Nov 4th!

Optics comparison at 3.5 GeV 3.5 m

Collimation checks (loss maps)

Pb orbit compared to p orbit – no steering!

Losses in predicted locations, namely the dispersion suppressors

Expected (ion fragmentation and dissociation)

Lose about a factor 50-100 in cleaning efficiency for ions cf protons

Main losses in predicted locations, namely the dispersion suppressors

Collimation checks (loss maps) to DS
First stable beams (2 bunches per beam)

Luminosity evolution (not quite up to date)

Single Event Upset (SEU)

Primary ion beam losses are intercepted at the collimators.

Effects are clearly seen in Radmon monitors.

- Beam lifetime shorter than for proton beams
- Nuclear physics: Ion dissociation and fragmentation reduce cleaning efficiency by factor ~100 when compared to protons (predicted since years, now confirmed).

Collimation upgrade (DS collimators) will solve this.

Ion beam lifetimes factor ~3-6 lower than for proton beams

- Not yet understood
- Several features contribute to more severe ion loss problems.

Primary ion beam losses are intercepted at the collimators.

Primary ion beam losses are intercepted at the collimators.

Effects are clearly seen in Radmon monitors.

And in the equipment:

- Significant IBS growth and debunching at injection, seems to be in reasonable agreement with theory.
- Emittances at injection around 1-2 μm
- Emittances on flat top 1.5-3 μm
- Emittance blow-up in physics is not too bad, but mostly not IBS.

Characteristics and Evolution

<table>
<thead>
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<th>Luminosity</th>
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<td>2</td>
<td>13</td>
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<tr>
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150ns operation
50ns running

Ultimate Reach

-200 days proton physics
2011: “reasonable” numbers

12/11/10 LHC status
Usual warnings particularly apply – see problems, problems above

2011
Ions
50ns running
150ns operation
Bunch train operation with 150ns was a big success
- Bunch intensity ~ nominal
- Normalised emittance/g in collision ~ 2.5 μm
- Maximum bunches/colliding 1 & 5: 368/348
- Peak luminosity ~ $2 \times 10^{32}$ cm$^{-2}$s$^{-1}$
- Delivered luminosity ~ 50 pb$^{-1}$
- Plenty of interesting data
- A few interesting (intensity-related) effects

50ns run
- Ion run
- Should allow definition of strategies for 2011 (together with ongoing studies)
  - Very useful few days
  - Very useful few days

Full debriefing and more at forthcoming workshops
- Quick return to normal performance for 2010
- Very fast switch from p to Pb

Ion run
- A few interesting (intensity-related) effects
  - Plenty of interesting data
  - Delivered luminosity
  - Peak luminosity
  - Number of collisions in target
  - Number of collisions in target
  - Bunch intensity

Summary