LHC Machine Status Report

Steve Myers

For the LHC team
Maximizing the Luminosity

Luminosity (round beams):

\[
L = \frac{n_b \cdot N_{\text{bunch}_1} \cdot N_{\text{bunch}_2} \cdot f_{\text{rev}} \cdot R(\phi, \beta^*, \varepsilon_n, \sigma_s)}{4\pi \cdot \beta^* \cdot \varepsilon_n}
\]

1. maximize bunch brightness \([N_{\text{bunch}}/\varepsilon_n]\) beam-beam limit and injector complex performance
2. minimize beam size \([\beta^*]\) (constant beam power)
3. maximize number of bunches (beam power limit)
4. compensate for ‘R’
Reminder of 2012 Priorities

1. The LHC machine must produce enough integrated luminosity to allow ATLAS and CMS to independently discover the Higgs before the start of LS1.

2. We must also prepare for the proton-lead ion run at the end of the year.

3. We must (in 2012) do the necessary machine experiments to allow high energy, useful high luminosity running after LS1.
Integrated luminosity needed for Discovery of Higgs

<table>
<thead>
<tr>
<th>Year</th>
<th>fb-1</th>
<th>signal (in $\sigma$)</th>
<th>Beam Energy</th>
<th>Year</th>
<th>fb-1</th>
<th>signal (in $\sigma$)</th>
<th>Beam Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>5</td>
<td>2.5</td>
<td>3.5</td>
<td>2011</td>
<td>5</td>
<td>2.5</td>
<td>3.5</td>
</tr>
<tr>
<td>2012</td>
<td>15</td>
<td>5</td>
<td>3.5</td>
<td>2012</td>
<td>11.5</td>
<td>5</td>
<td>4.0</td>
</tr>
<tr>
<td>2012</td>
<td>11.5</td>
<td>5</td>
<td>3.5</td>
<td>2012</td>
<td>13.3</td>
<td>5</td>
<td>4.0</td>
</tr>
</tbody>
</table>

**Needed**

*additional 15% for pile up and margin*
Reminder 2012 run configuration

- Energy – 4 TeV
- Bunch spacing – 50 ns
- Collimator settings – tight
- Atlas and CMS beta* - 60 cm
- Alice and LHCb beta* - 3 m
  - Natural satellites versus main bunches in Alice

Real Challenge
- 2 high luminosity experiments (ATLAS, CMS)
- 1 mid-luminosity (LHCb) x20 lower
- 1 low-luminosity (ALICE) x10,000
- Non colliding bunches to monitor background
- Also TOTEM and ALFA
First (most critical) Break-point

Second Break-point

Predicted peak 5.8E33

Check if we are on track to produce sufficient integrated luminosity for the Higgs

If needed we can delay the start of LS1 by up to 2 months
Present Performance
Peak Luminosity

ATLAS Online Luminosity \( \sqrt{s} = 8 \text{ TeV} \)

- LHC Stable Beams
- Peak Lumi: \( 6.76 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1} \)

Estimated for 2012
7 Days of production $(1.133 fb^{-1})$ (June 4—11)

Intensity per bunch: $\sim 1.5 \times 10^{11}$ p/b

Initial $L$: $6.2 - 6.7 \times 10^{33}$ cm$^{-2}$s$^{-1}$

LHC 8:30 meeting

6/13/2012

Luminosity

LBDS

TSU

Access, PSB RF

Intensity per bunch: $\sim 1.5 \times 10^{11}$ p/b

Initial $L$: $6.2 - 6.7 \times 10^{33}$ cm$^{-2}$s$^{-1}$

CERN Accelerator Complex

LHC Efficiency - last 7 days

Mode: Proton Physics
Number of Fills: 28
Time in SB: 4 days 19 hrs 10 mins

52%
Saturday 2\textsuperscript{nd} June
Fill 2692 (238pb-1 in 23 hours)

Integral of all of 2010 now 2.5 hours
Integrated from ATLAS

ATLAS Online Luminosity \( \sqrt{s} = 8 \text{ TeV} \)

- Light grey: LHC Delivered All
- Yellow: LHC Delivered Stable
- Dark grey: ATLAS Ready Recorded

Day in 2012

Total Integrated Luminosity \( [\text{fb}^{-1}] \)
With Respect to estimates (as of Tuesday June 12)

2012 Measured vs Predicted Integrated Luminosity

- Integrated Lumi 50 (pb-1)
- Measured 50ns (pb-1)
## Last 24 hours

**13-Jun-2012 07:37:26**  
**Fill #: 2727**  
**Energy: 59 GeV**  
**L(B1): 0.00e+00**  
**L(B2): 0.00e+00**

<table>
<thead>
<tr>
<th>Experiment Status</th>
<th>ATLAS</th>
<th>ALICE</th>
<th>CMS</th>
<th>LHCb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instantaneous Lumi (/ub.s)^{-1}</td>
<td>0.0</td>
<td>0.000</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>BRAN Luminosity (/ub.s)^{-1}</td>
<td>0.8</td>
<td>0.000</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Fill Luminosity (nb)^{-1}</td>
<td>1.422282</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
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<tr>
<td>BKGD 1</td>
<td>0.003</td>
<td>0.163</td>
<td>0.001</td>
<td>0.141</td>
</tr>
<tr>
<td>BKGD 2</td>
<td>0.000</td>
<td>0.000</td>
<td>0.002</td>
<td>0.000</td>
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<tr>
<td>BKGD 3</td>
<td>0.348</td>
<td>1.654</td>
<td>0.434</td>
<td>0.056</td>
</tr>
</tbody>
</table>

**LHCb VELO Position**: OUT  
**Gap**: 58.0 mm  
**Performance over the last 24 Hrs**

### Background 1

**Updated: 07:37:25**

### Background 2

**Updated: 07:37:25**
## Records

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value</th>
<th>Fill</th>
<th>Date/Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Stable Luminosity Delivered</td>
<td>$6.76 \times 10^{33}$ cm$^{-2}$s$^{-1}$</td>
<td>2710</td>
<td>12/06/06, 15:52</td>
</tr>
<tr>
<td>Maximum Luminosity Delivered in one fill</td>
<td>237.32 pb$^{-1}$</td>
<td>2692</td>
<td>12/06/02, 01:55</td>
</tr>
<tr>
<td>Maximum Luminosity Delivered in one day</td>
<td>228.55 pb$^{-1}$</td>
<td></td>
<td>Saturday 02 June, 2012</td>
</tr>
<tr>
<td>Maximum Luminosity Delivered in 7 days</td>
<td>1133.3 pb$^{-1}$</td>
<td></td>
<td>Monday 04 June, 2012 - Sunday 10 June, 2012</td>
</tr>
<tr>
<td>Maximum Colliding Bunches</td>
<td>1380</td>
<td>2660</td>
<td>12/05/24, 13:17</td>
</tr>
<tr>
<td>Maximum Peak Events per Bunch Crossing</td>
<td>43.81</td>
<td>2479</td>
<td>12/04/06, 10:22</td>
</tr>
<tr>
<td>Maximum Average Events per Bunch Crossing</td>
<td>31.87</td>
<td>2710</td>
<td>12/06/06, 15:52</td>
</tr>
<tr>
<td>Longest Time in Stable Beams for one fill</td>
<td>22.8 hours</td>
<td>2692</td>
<td>12/06/02, 05:10</td>
</tr>
<tr>
<td>Longest Time in Stable Beams for one day</td>
<td>20.5 hours (85.6%)</td>
<td></td>
<td>Saturday 02 June, 2012</td>
</tr>
<tr>
<td>Longest Time in Stable Beams for 7 days</td>
<td>79.0 hours (47.0%)</td>
<td></td>
<td>Monday 04 June, 2012 - Sunday 10 June, 2012</td>
</tr>
<tr>
<td>Fastest Turnaround to Stable Beams</td>
<td>2.13 hours</td>
<td>2472</td>
<td>12/04/05, 15:46</td>
</tr>
</tbody>
</table>
Don’t get the idea that it’s easy!(1)

- Beam-beam
  - luminosity levelling by transverse separation,
  - crossing angle and separation schemes
  - bunches with a range of betatron tunes,
- Instabilities (TMCI, Head-tail, coherent instabilities, electron cloud) Collimators very close to beam
  - Transverse Damping
  - Landau damping octupoles,
  - Beam-beam stabilization
  - Solenoidal fields in warm regions
- Beam Induced Heating
Don’t get the idea that it’s easy!(2)

• Magnet measurement system (snapback, persistent currents..)

• Machine protection
  – Injection (protection devices, BLMS, injection interlocks..)
  – Ramp and squeeze (collimators, BLMS, orbit control...)
  – Collisions (idem, FCMM, UFOs...) electrical storms

• Emittance Control (longitudinal and transverse)

• Aperture
Don’t get the idea that it’s easy!(3)

- UFOs... dust particles
- R2E and Single Event Upsets (SEUs)
- Abort gap cleaning and Beam dump
- Beam feedback; orbit, tune, chromaticity
- Vacuum and electron cloud
Recent Example

Bunches used for background monitoring (only interact in LHCb) get lost and trigger the machine protection system to dump the beam.
Summary

• A very successful first period in 2012

• However, we must remain extremely vigilant with respect to the protection of the machine (120MJ of stored energy) and hope that there are no “new” old “unexploded bombs” in the hardware!!

• In the absence of any major technical failure, the LHC machine WILL produce enough integrated luminosity in 2012 to allow the detectors to discover or exclude the Higgs Boson. EITHER DISCOVERY OR EXCLUSION WILL BE A MAJOR DISCOVERY!
Near Miss!
Preparing for a review on “LBDS powering” on 20 June … (triggered by asynch. dump)
Identified an error source on the test bed which would (if this error would occur) render the LBDS inoperable (→ NO dump when requested)
Trigger Synchronization Units (redundant TSUs, powered by redundant PS) in one crate
Loss of +12 V, e.g. by short circuit on a card, would make all output stages unusable
Power failure will be detected but, due to the loss of 12 V, not be transmitted further down into the LBDS (power triggers/pulse generators)

Disaster, nightmare, Armageddon ....
Summary

• A very successful first period in 2012

• However, we must remain extremely vigilant with respect to the protection of the machine (120MJ of stored energy). There are no “new” old “unexploded bombs”!!

• In the absence of any major technical failure, the LHC machine WILL produce enough integrated luminosity for the detectors to discover or exclude the Higgs Boson. EITHER DISCOVERY OR EXCLUSION WILL BE A MAJOR DISCOVERY!
Thank you for your attention
Main LS1 Work

- Repair defectuous interconnects
- Consolidate all interconnects with new design
- Finish off pressure release valves (DN200)
- Bring all necessary equipment up to the level needed for 7TeV/beam
LHC MB circuit splice consolidation proposal

Phase I
Surfacing of bus bar and installation of redundant shunts by soldering

Phase II
Application of clamp and reinforcement of nearby bus bar insulation

Phase III
Insulation between bus bar and to ground, Lorentz force clamping
7 Days of production (1.133 fb⁻¹) (June 4—11)