LHC Commissioning and the ATLAS BCM

- Status of the LHC machine commissioning
- Plans for first beams
- The ATLAS BCM
- Commissioning Plans
- Beam abort scenarios

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The LHC Climate

http://hcc.web.cern.ch/hcc/field.php
Local Weather Forecasts

- Cool several sectors in parallel
- Sector cool-down becoming routine
Current experience with Cooldown

Presently two sectors are below 2K
The helium inventory in the LHC is 62 t
The Current Outlook for Cooldown
Commissioning the Power Circuits
Commissioning the Power Circuits

"The earliest that the machine could be ready for beam commissioning to 7 TeV is late August, without taking resources into account". ICC Feb’08
Commissioning the Power Circuits

- Sector 4-5 was the first to be cooled down
- Discovered fatal flaw with low-beta quads
- Last summer/fall it was commissioned to 7 TeV

- Clear it will take longer to commission to 7 TeV
- Decision has been taken to only run at 5 TeV in 2008
After the Machine is Powered?

- Once machine is turned over to operations

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>Ring factor</th>
<th>Total Time [days] both rings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Injection and first turn</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>Circulating beam</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>450 GeV - initial</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>450 GeV - detailed</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>450 GeV - two beams</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>Snapback - single beam</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>Ramp - single beam</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>8</td>
<td>Ramp - both beams</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>9</td>
<td>7 TeV - setup for physics</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>10</td>
<td>Physics un-squeezed</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>TOTAL to first collisions</td>
<td></td>
<td>30</td>
</tr>
<tr>
<td>11</td>
<td>Commission squeeze</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>12</td>
<td>Increase Intensity</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>13</td>
<td>Set-up physics - partially squeezed.</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>14</td>
<td>Pilot physics run</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Considering single-sector injection to expedite this phase
And then?

- When beam is circulating
- Step-by-step proton current increases
- Dictated by safe machine operation

<table>
<thead>
<tr>
<th>beta^* [m]</th>
<th>Bunch intensity</th>
<th>Luminosity [cm^-2 s^-1]</th>
<th>Event rate/cross</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 x 1</td>
<td>18</td>
<td>10^{10}</td>
<td>10^{27}</td>
</tr>
<tr>
<td>43 x 43</td>
<td>18</td>
<td>3 \times 10^{10}</td>
<td>3.8 \times 10^{29}</td>
</tr>
<tr>
<td>43 x 43</td>
<td>4</td>
<td>3 \times 10^{10}</td>
<td>1.7 \times 10^{30}</td>
</tr>
<tr>
<td>43 x 43</td>
<td>2</td>
<td>4 \times 10^{10}</td>
<td>6.1 \times 10^{30}</td>
</tr>
<tr>
<td>156 x 156</td>
<td>4</td>
<td>4 \times 10^{10}</td>
<td>1.1 \times 10^{31}</td>
</tr>
<tr>
<td>156 x 156</td>
<td>4</td>
<td>9 \times 10^{10}</td>
<td>5.6 \times 10^{31}</td>
</tr>
<tr>
<td>156 x 156</td>
<td>2</td>
<td>9 \times 10^{10}</td>
<td>1.1 \times 10^{32}</td>
</tr>
</tbody>
</table>

\[ L = \frac{N_b^2 n_b f_r \gamma}{4 \pi \varepsilon_n \beta^*} F \]

- $N_b$: number of particles per bunch
- $n_b$: number of bunches
- $f_r$: revolution frequency
- $\varepsilon_n$: normalised emittance
- $\beta^*$: beta value at Ip
- $F$: reduction factor due to crossing angle
ATLAS Beam Conditions Monitor

- **ATLAS** plans to use time of flight to distinguish beam collisions from background.
- Optimal separation is 4.1m.
- Ideal support in pixel space-frame 3.8m apart.
- Use CVD diamond sensors
  - 10x faster and 10x more radiation hard than silicon.
- Very fast, rad hard GaAs front end amplifier.
Mechanical Installation (January 2007)

- Cables connected this week
Testbeam Setup at CERN
Beam Profile and BCM Hit Efficiency

HIT MAP (sig>100.0), config2-T9 CH1 F403 @ -1000V, runs184-192

<table>
<thead>
<tr>
<th>Entries</th>
<th>20251</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean x</td>
<td>19.26</td>
</tr>
<tr>
<td>Mean y</td>
<td>-17.16</td>
</tr>
<tr>
<td>RMS x</td>
<td>1.82</td>
</tr>
<tr>
<td>RMS y</td>
<td>2.158</td>
</tr>
<tr>
<td>Integral</td>
<td>2.025e-04</td>
</tr>
<tr>
<td>Skewness x</td>
<td>nan</td>
</tr>
<tr>
<td>Skewness y</td>
<td>nan</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>20251</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Testbeam Signal Distributions

\begin{center}
\begin{tabular}{|c|c|}
\hline
F405@+1000V, T11 setup1 CH3, signal & \hline
\end{tabular}
\end{center}

\begin{center}
\begin{tabular}{|c|c|}
\hline
F405 T11 setup1, si & \hline
Entries & 8,361 \\
Mean & \hline
RMS & \hline
Underflow & \hline
Overflow & \hline
Integral & \hline
$\chi^2$/ndf & \hline
Prob & \hline
p0 & \hline
MPV & \hline
p2 & \hline
p3 & \hline
\end{tabular}
\end{center}

\begin{center}
\begin{tabular}{|c|c|}
\hline
Time diff. ch1-ch2, RUN=1029 & \hline
Entries & 9788 \\
Mean & 0.7883 \\
RMS & 0.6867 \\
\end{tabular}
\end{center}

\begin{center}
\includegraphics[width=\textwidth]{NINO.png}
\end{center}

\begin{center}
NINO
\end{center}

\begin{center}
Time res \sim 490\text{ps}
\end{center}
Digitisation Performance

- Using ALICE-TPC standard ADC (NINO) digitiser

- Results from 2007 testbeam
  - Median signal: 335 mV
  - Inferred noise: 31 mV
  - System S/N = 11:1
BCM Geometry in Simulation

- Full GEANT model of BCM module boxes and support brackets
  - In ATLAS ID simulation
- Study occupancies and arrival times in minbias collisions
- First look at showers of lost particles
Minimum Bias Collisions

Number of BCM Hits per Bunch Crossing

Entries: 1911
Mean: 1.481
RMS: 1.33

Entries: 518
Mean: 4.598
RMS: 1.875

Entries: 3428
Mean: 0.8474
RMS: 1.062

Number of A-C Coincidences per Bunch Crossing

Entries: 1911
Mean: 0.6599
RMS: 1.364

Entries: 518
Mean: 5.398
RMS: 4.591

Entries: 3428
Mean: 0.2684
RMS: 0.8214
Simulated 7 TeV Lost Proton
Beam Scraping Simulations

- Three injection loss scenarios
  1. Scraping on ATLAS pipe
  2. Scraping on incoming TAS
  3. Scraping on outgoing TAS

- Angular distribution of BCM hits
Predicting Abort rates

- Look for hits in 2 ns window
  - Early modules: $\equiv -6$ ns
  - In-time modules: $\equiv 6$ ns

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Early</th>
<th>In-time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noise-1</td>
<td>1</td>
<td>X</td>
</tr>
<tr>
<td>Noise-2</td>
<td>2</td>
<td>X</td>
</tr>
<tr>
<td>Lost p-1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Lost p-2</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

- $P_x$: Probability for single-$p$ collision
- $R_{1x}$: Rate in one year ($10^7$ s)
- $R_{2x}$: Rate in two successive crossings

<table>
<thead>
<tr>
<th></th>
<th>$\epsilon = 90%$</th>
<th>$\epsilon = 99%$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_{N1}$</td>
<td>$9 \times 10^{-9}$</td>
<td>$2 \times 10^{-4}$</td>
</tr>
<tr>
<td>$P_{N2}$</td>
<td>$3 \times 10^{-17}$</td>
<td>$1 \times 10^{-8}$</td>
</tr>
<tr>
<td>$P_{L1}$</td>
<td>$9 \times 10^{-17}$</td>
<td>$3 \times 10^{-8}$</td>
</tr>
<tr>
<td>$P_{L2}$</td>
<td>$1 \times 10^{-33}$</td>
<td>$1 \times 10^{-16}$</td>
</tr>
<tr>
<td>$R_{1N1}$</td>
<td>$1 \times 10^{7}$</td>
<td>$2 \times 10^{11}$</td>
</tr>
<tr>
<td>$R_{1N2}$</td>
<td>$4 \times 10^{-2}$</td>
<td>$1 \times 10^{7}$</td>
</tr>
<tr>
<td>$R_{1L1}$</td>
<td>$0.11$</td>
<td>$3 \times 10^{7}$</td>
</tr>
<tr>
<td>$R_{1L2}$</td>
<td>$1 \times 10^{-18}$</td>
<td>$0.16$</td>
</tr>
<tr>
<td>$R_{2N1}$</td>
<td>$0.11$</td>
<td>$3 \times 10^{7}$</td>
</tr>
<tr>
<td>$R_{2N2}$</td>
<td>$1 \times 10^{-18}$</td>
<td>$0.16$</td>
</tr>
<tr>
<td>$R_{2L1}$</td>
<td>$1 \times 10^{-17}$</td>
<td>1.2</td>
</tr>
<tr>
<td>$R_{2L2}$</td>
<td>$2 \times 10^{-51}$</td>
<td>$2 \times 10^{-17}$</td>
</tr>
</tbody>
</table>

- Study two BCM efficiencies
**Commissioning Plans**

- Four distinct periods
  1. Cabled (no beam): Now to June
  2. Single beams: June to September?
  3. First Collisions: September to end 2008
  4. Increasing luminosity/danger: 2009

- Simulations providing inspiration

- Developing FPGA algorithms; Develop trigger definitions later

- Test noise/signal performance in ATLAS

- No substitute for on-the-job experience with LHC beams
Summary of BCM Capabilities

- The BCM is only sensitive to charged particles
- The BCM will be always on
- Disentangle backgrounds using timing and spatial distributions
- Working with LHC to define warning signals and levels
- We are well suited to distinguish losses from A or C sides
- Will measure bunch-by-bunch luminosity variations
- Could measure luminosity variation on a time-scale of seconds
- 2.5 ns displaced bunches will be a challenge. 5 ns OK?
Summary

- Deterministic LHC commissioning proceeding on-schedule: Known-knowns
- A significant number of un-deterministic tasks remain: Known-unknowns
- Hopefully we won’t encounter any Unknown-unknowns

- Eight BCM modules installed in ATLAS June 2007
- First readout in pit March
- Now working on beam accident simulations
- Use simulations to guide design of beam abort logic
- Anticipate continuous operation by end of May