Comparison of ATLAS and CMS Luminosities

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on behalf of ATLAS and CMS

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Delivered Luminosity in 2010

- **ATLAS:** 48.9 pb\(^{-1}\)
  - 48.1 pb\(^{-1}\) during stable beam until end-of-fill handshake
  - 0.8 pb\(^{-1}\) delivered after handshake with stable beam flag set
- **CMS:** 47.0 pb\(^{-1}\)
  - During stable beams
- 4% more luminosity reported by ATLAS
  - May also be partially due to detector downtime etc.
Luminosity Determination: ATLAS vs CMS

• Both experiments use the Van-der-Meer scans from April and May 2010 (see previous talks)

• **ATLAS uses event counting**
  – main method counts events with at least one hit on either side of LUCID (LUCID EVENT OR)
    • Many other methods studied and yield consistent results to within <2%
  – This is sensitive to pileup but corrected for
    • E.g. at μ=3.0 the correction is 54%
    • Residual non-linearity is <0.5%

• **CMS uses hit counting**
  – Main method counts total number of channels with 0-hits in HF (on either side)
  – This is also sensitive to pileup and corrected for
    • Residual non-linearity <1%
### Systematic Uncertainties from Spring scans

<table>
<thead>
<tr>
<th></th>
<th>ATLAS</th>
<th>CMS</th>
<th>Uncorrelated part per experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam current</td>
<td>10%</td>
<td>10%</td>
<td>0%</td>
</tr>
<tr>
<td>Length scale</td>
<td>2%</td>
<td>2%</td>
<td>2%</td>
</tr>
<tr>
<td>Beam centering</td>
<td>2%</td>
<td>2%</td>
<td>2%</td>
</tr>
<tr>
<td>Background</td>
<td>negligible</td>
<td>0.1%</td>
<td>0.1%</td>
</tr>
<tr>
<td>μ dependence</td>
<td>2%</td>
<td>n.a.</td>
<td>2%</td>
</tr>
<tr>
<td>reproducibility</td>
<td>3%</td>
<td>3%</td>
<td>3%</td>
</tr>
<tr>
<td>Fit model</td>
<td>1%</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td>total</td>
<td>11%</td>
<td>11%</td>
<td>CMS: 4.2%, ATLAS: 4.7%</td>
</tr>
</tbody>
</table>

• The uncorrelated systematic uncertainty on ratio of ATLAS to CMS luminosity is 6.3%
  – This does not change with new beam current uncertainty
• Deviations of ~6% are thus easily expected on the ratio of ATLAS to CMS luminosity
Comparison of Luminosity for typical fills

- CMS and ATLAS provide luminosity online to Massi Ferro-Luzzi via ascii files
- Available at https://lpc-afs.web.cern.ch/lpc-afs/cgi-bin/webpage.sh
- Comparison made of ATLAS vs CMS values by both experiments
  - Will show here just some example fills
Comparison per Fill: e.g. 1418

- 2% higher luminosity for ATLAS
- Ratio constant in time in this fill
More LHC fills: ratio of ATLAS to CMS

• Some observations:
  – ATLAS Luminosity generally ~2% larger than CMS luminosity
  – Usually 2% but sometimes up to 6%
  – Sometimes strong time-dependence within fill

• 2% difference well within uncertainty of ATLAS and CMS luminosity measurements

• Would be nice to understand why sometimes difference larger
  – Not obviously correlated with anything (e.g. not with peak luminosity or bunch setup)
Physics Rates and Cross Sections

• Luminosity delivered by LHC to ATLAS and CMS may of course be different
  – Although ATLAS and CMS reported values agree usually to within uncorrelated experimental uncertainty on luminosity measurement

• Physics cross section should, however, be the same
  => compare
  – W and Z Cross Sections
  – Rate of MinBias events in common acceptance region
W and Z cross section

- ATLAS and CMS have both measured the W and Z boson cross sections in e and \( \mu \) decay channels.
- CMS (arXiv: 1012.2466) using 2.9 pb\(^{-1}\)
  - W: \( 9.95 \pm 0.29 \) (stat.+syst.) \( \pm 1.09 \) (lumi) nb
  - Z: \( 0.931 \pm 0.035 \) (stat.+syst.) \( \pm 0.102 \) (lumi) nb
- ATLAS (arXiv: 1010.2130) using 0.3 pb\(^{-1}\)
  - W: \( 9.96 \pm 0.55 \) (stat.+syst.) \( \pm 1.10 \) (lumi) nb
  - Z: \( 0.82 \pm 0.08 \) (stat.+syst.) \( \pm 0.09 \) (lumi) nb
- W cross section ratio ATLAS/CMS:
  - \( 1.00 \pm 0.06 \) (stat.+syst.)\( \pm 0.06 \) (unc. Lumi)
- Excellent agreement between experiments
  - Indicates that luminosity is the same within uncorrelated errors
  - Will be very interesting with full data statistics (40 pb\(^{-1}\))
Event Rate in MinBias Events

- Selected common acceptance region:
  - Events with at least one prompt charged particle with $p_T>0.5$ GeV and $|\eta|<0.8$ for ATLAS, CMS and ALICE
    - Spin-off of Minimum Bias analysis
- Measure cross section for such events
  - Corrected for any experimental effects
    - Tracking efficiency, fake tracks, vertex efficiency, trigger, deadtime, pileup,…
- Compare between experiments for one LHC fill
  - Rate of these events versus time
  - Cross section of these events versus time
- Comparison done for fill 1089
  - This is the May van-der-Meer-scan fill where both ATLAS and CMS scans took place
  - Can hopefully be extended to more fills (maybe even all)
    - E.g. for other VdM scan fills or for e.g. 1397 where 6% difference between CMS and ATLAS lumi is seen
Charged Particle Event Rate for Fill 1089

- Gaps in rate due to ongoing VdM scan or due to interruptions in data taking
- Overall analysis corrections about 10%
  - About 5% due to reconstruction, trigger etc.
  - About 5% at start and 3% at end due to pileup
• Rates are nicely fit by exponential + constant
• Ratio of ATLAS over CMS rate:
  – Differs by ~5% at start and ~3% at end of fill
• This should correlate with luminosity => check cross section
Charged Particle Cross Section for fill 1089

- **ATLAS**: $42.3 \pm 0.7\text{ mb}$, **CMS**: $43.99 \pm 0.62\text{ mb}$
  - Systematic errors quoted do not include luminosity uncertainty
- $\sigma_{\text{CMS}}/\sigma_{\text{ATLAS}} = 1.040 \pm 0.022 (\text{stat+syst}) \pm 0.063 (\text{unc. lumi})$
  - Difference corresponds to $1.8\sigma$ (stat. + syst) and $0.6\sigma$ (stat+syst+lumi)
Conclusions and Outlook

• ATLAS than CMS luminosities usually differ by 2%
  – Sometimes bigger differences reason not yet understood
  – Integrated luminosity in all of 2010 differs by 4%

• The observed differences are within the experimental systematic associated to the analyses of the spring VdM scans
  – Uncertainties will get reduced with new scan => check again

• Physics cross sections comparable within uncorrelated systematic uncertainties (stat.+syst. And luminosity):
  – W cross section: ratio (CMS/ATLAS)=1.00± 0.06±0.06
  – Charged particle event cross section: ratio(CMS/ATLAS)=1.040 ± 0.022±0.063

• Higher precision statements soon possible
  – W cross sections with full 2010 dataset
  – New VdM scan from October will have much smaller uncertainty
  – Charged particle event rate can be compared in more fills and also with new luminosity normalization from new scans