Luminosity Monitoring in ATLAS with MPX Detectors

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on behalf of the ATLAS and Medipix2 Collaborations

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Outline

• Introduction
• Luminosity from Hit Counting
• Luminosity from Thermal Neutron Counting
• van der Meer Scans
• Conclusions
Focus on MPX network 2012 data from 8 TeV proton-proton collisions

- 16 Medipix2 (MPX) pixel detectors operating in ATLAS from 2008 to Feb. 2013, acquisition time 0.1ms-600s.
- For luminosity measurements usage as 65536 (256x256) independent counting detectors.
- Measure the particle fluxes originating from the LHC proton-proton collisions.

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The ATLAS detector
MPX detectors for luminosity determination: MPX01-MPX13 used
MPX locations and particle (cluster) fluences in the ATLAS detector

<table>
<thead>
<tr>
<th>Device</th>
<th>Z [m]</th>
<th>R [m]</th>
<th>Measured MPX clusters per sensor area and per unit luminosity [cm(^{-2})/nb(^{-1})]</th>
<th>Used for neutron counting</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPX01</td>
<td>3.42</td>
<td>0.77</td>
<td>55000</td>
<td>No</td>
</tr>
<tr>
<td>MPX13</td>
<td>-3.42</td>
<td>2.44</td>
<td>380</td>
<td>No</td>
</tr>
<tr>
<td>MPX02</td>
<td>3.42</td>
<td>2.50</td>
<td>230</td>
<td>No</td>
</tr>
<tr>
<td>MPX03</td>
<td>2.94</td>
<td>3.57</td>
<td>31</td>
<td>No</td>
</tr>
<tr>
<td>MPX06</td>
<td>7.20</td>
<td>3.36</td>
<td>20</td>
<td>Yes</td>
</tr>
<tr>
<td>MPX05</td>
<td>7.20</td>
<td>2.36</td>
<td>47</td>
<td>No</td>
</tr>
<tr>
<td>MPX08</td>
<td>4.02</td>
<td>4.40</td>
<td>1.2</td>
<td>Yes</td>
</tr>
<tr>
<td>MPX07</td>
<td>0.35</td>
<td>4.59</td>
<td>0.45</td>
<td>Yes</td>
</tr>
<tr>
<td>MPX04</td>
<td>7.12</td>
<td>1.30</td>
<td>110</td>
<td>No</td>
</tr>
<tr>
<td>MPX09</td>
<td>15.39</td>
<td>1.56</td>
<td>5.8</td>
<td>Yes</td>
</tr>
<tr>
<td>MPX12</td>
<td>7.23</td>
<td>6.25</td>
<td>3.9</td>
<td>Yes</td>
</tr>
<tr>
<td>MPX10</td>
<td>22.88</td>
<td>5.19</td>
<td>1.0</td>
<td>Yes</td>
</tr>
<tr>
<td>MPX11</td>
<td>4.86</td>
<td>16.69</td>
<td>0.30</td>
<td>Yes</td>
</tr>
</tbody>
</table>

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Method of luminosity monitoring with hit counting

• Measure number of counts by 13 independent MPX devices during collision periods.

• Apply three different methods to remove noisy pixels from the hit counting.

• Normalize MPX hit rate/luminosity with the ATLAS BCM luminosity detector for the data taking on 21 May 2012.

• Study the MPX/BCM luminosity ratio as a function of time for all 2012 data.
MPX luminosity

\[ \sqrt{s} = 8 \text{ TeV} \]
\[ \text{LHC Fill 2649} \]
MPX/BCM luminosity ratio

\[ \sqrt{s} = 8 \text{ TeV} \]
LHC Fill 2649

ATLAS Preliminary

Hour on 21 May 2012
MPX01 hit luminosity vs. bunch-averaged interactions per crossing

\[ \text{ATLAS Preliminary} \]

\[ \sqrt{s} = 8 \text{ TeV} \]

LHC Fill 2872

\[ \langle \mu \rangle \]

BCMV_EventOR

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Fractional deviation in luminosity (hit counting mode)

\[ \frac{L_{MPX}}{L_{BCM}} \]

\( \sqrt{s} = 8 \text{ TeV} \)

ATLAS Preliminary

Day in 2012
Method of luminosity monitoring with thermal neutron counting

- Thermal neutrons detected by MPX devices via $^6\text{Li}(n,\alpha)^3\text{H}$ reactions in a $^6\text{LiF}$ converter layer.
- Resulting tritons and alpha particles are registered as “heavy blobs” (large round-shaped pixel clusters).
- Typical detection efficiency of thermal neutrons 1%.
- Normalize MPX thermal neutron rate/luminosity with the BCM ATLAS luminosity detector for the data taking on 21 May 2012.
- Study the MPX/BCM luminosity ratio as a function of time for 2012 data.
Number of heavy blobs per frame

MPX12 number of heavy blobs (thermal neutrons) per frame

ATLAS Preliminary
2012 $\sqrt{s} = 8$ TeV

MPX12 data
Poisson fit
Fractional deviation in luminosity (thermal neutron counting mode)
Fractional deviation in the number of interactions per bunch crossing

Data 2012 - $\sqrt{s} = 8$ TeV
Reference LHC Fill 3228 - Oct 27, 2012

ATLAS Preliminary

- $\langle \mu \rangle_{\text{algorithm}}$
- $\langle \mu \rangle_{\text{BCM V EventOR}}$

- MPX11 hits
- MPX02 hits
- MPX06-MPX12 neutrons

Day in 2012

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van der Meer scan peak (last horizontal scan in November 2012)

- At LHC, van der Meer scans (vdM) are used for absolute luminosity calibration.
- This study focuses on comparisons of the ratio of MPX versus the BCM luminosity measurements in order to quantify the relative stability of the BCM and MPX luminosity calibrations.
van der Meer scan: linearity
MPX01 hit vs. BCM luminosities

ATLAS Preliminary
Data 2012 - $\sqrt{s} = 8$ TeV
LHC Fill 3316 - Nov 24, 2012
Conclusions

- Sufficiently radiation hard for the 2012 high-luminosity.
- MPX network has an internal consistency of about 2% using different detectors and techniques for hit counting and heavy blob (thermal neutron) counting as measures of luminosity.
- This precision is comparable to other luminosity detectors in ATLAS in the same 2012 time period.
- MPX 2012 van der Meer scan luminosity four orders of magnitude lower than routine physics data-taking: MPX has wide dynamic range \(\sim 0.5-7000 \times 10^{30} \text{ cm}^{-2}\text{s}^{-1}\).
References


