The upgraded Pixel detector and the commissioning of the Inner Detector tracking of the ATLAS experiment for Run-2 at the Large Hadron collider

Karolos Potamianos
On behalf of the ATLAS Collaboration

EPS-HEP 2015
July 22-29 2015
The ATLAS Detector
The ATLAS Inner Detector (ID) for Run-2

- New Insertable-B-Layer (IBL)
- Silicon Pixel detector (Pixels)
- Silicon Tracker (SCT)
- Transition Radiation Tracker (TRT)
- 2T axial B-field
- Reconstruction of charged particles within $|\eta| < 2.5$
Major upgrade to ATLAS during LHC Long Shutdown 1

- Pixel: new services, new optical links (accessible when ATLAS open)
- New Diamond Beam Monitor (DBM) installed in the Pixel volume
- New Insertable B-Layer (IBL) around the beam pipe (smaller diameter than Run-1) on the surface and insertion in ATLAS
Many improvements to ID tracking code:
- Simplified Event Data Model
- Using new solver (EIGEN)
- Reconstruction in ID 4× faster than in Run-1
- Improved tracking in dense environments (TIDE)

**ATLAS Preliminary**
Simulation, $\sqrt{s}=13$ TeV, $Z'(3$ TeV)

- **TIDE**
- **Baseline**

**ATLAS Preliminary**
Simulation, $\tau\rightarrow\nu,3\pi^{\pm}$
≤ 2 Shared SCT Clusters
No Secondaries

Details: ATL-PHYS-PUB-2015-006
The Insertable B-Layer (IBL) – 4th Pixel Layer

- 14 staves with 130 nm CMOS modules using two different sensor technologies: 12 planar and 2 × 4 3D modules
- Preserves tracking performance with increased luminosity and improves vertexing and b-Tagging
- New readout system, to be used for Pixel bandwidth upgrade in Run-2

Details: ATL-INDET-PUB-2014-006 & IDTR-2015-007
An Improved Pixel Detector

- **Pixel:** 3% of modules recovered since Run-1 (now 98% of modules active)
- **New IBL:** 99.5% of modules active for Run-2

---

**ATLAS Pixel Preliminary**

<table>
<thead>
<tr>
<th>Layer</th>
<th>End of Run 1</th>
<th>After Re-installation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disk</td>
<td>4.5%</td>
<td>3.5%</td>
</tr>
<tr>
<td>Layer 2</td>
<td>7.0%</td>
<td>1.9%</td>
</tr>
<tr>
<td>Layer 1</td>
<td>2.0%</td>
<td>1.2%</td>
</tr>
<tr>
<td>Layer 0</td>
<td>6.3%</td>
<td>1.4%</td>
</tr>
</tbody>
</table>

---

Pixel Layer 0

- **December 2012**
- **May 2015**
First Run-2 Collisions With a 4-Layer Pixel Detector

Run Number: 266904, Event Number: 25884805
Date: 2015-06-03 13:41:54 CEST
The pixel and IBL detectors perform very well so far, providing lots of interesting data to study.

However, different coefficients of thermal expansion of the stave flex and carbon foam cause a distortion of the shape of the IBL from the design geometry.

Local X displacement magnitude: \( \frac{dM}{dT} = -10.6 \pm 0.7 [\mu m/K] \)

Effect under control when keeping the temperature constant (within 0.2 K): no degradation in the precision of position measurements of charged particle tracks with the IBL.
ID Alignment

- **Initial 13 TeV \( pp \) collisions data used to align the ATLAS ID using a track-based algorithm, with special focus on the IBL**
- Aligned big structures, as well as individual modules
- Good stability of alignment constants

Details: ATL-PHYS-PUB-2015-031
ID Tracking Commissioning with Early 13 TeV Data

- Good agreement between Monte Carlo (MC) simulation and data
- Number of shared IBL hits well reproduced in simulation

ATLAS Preliminary
\( \sqrt{s} = 13 \text{ TeV} \)

Details: ATL-PHYS-PUB-2015-018
ID Material Studies with Early 13 TeV Data

- Using **hadronic interactions** and photon conversions to study ID material
- Agreement with simulation within a few percent

Vertex efficiency and position resolution in **reasonable agreement** between simulation and data **given the current status of the alignment and material description**

Details: ATL-PHYS-PUB-2015-026
**b-Tagging Performance Enhancements**

- **Significant improvement to b-Tagging for Run-2**
- Improved light-flavour jet rejection due to IBL and algorithmic improvements (new multivariate tagger MV2, tracking, esp. TIDE)

**Details:** ATL-PHYS-PUB-2015-022

K. Potamianos (LBNL)
ATLAS Preliminary
\( \sqrt{s} = 13 \text{ TeV}, 290 \mu \text{b}^{-1} \)

Details: IDTR-2015-006
Summary and Outlook

- **Improved pixel detector for Run-2**
  - Improved services and optical links for high occupancy
  - Recovered about 3% of the 3-layer pixel
  - The new innermost layer (IBL) is well under control, and still under performance optimization
  - New read-out system for IBL to be used for Pixel bandwidth upgrade

- **Many improvements to the inner detector tracking software**
  - Reduced processing time over a factor of 4
  - Improved tracking in dense environments (TIDE)
  - Alignment approaching Run-1 precision
  - Improved vertexing and $b$-Tagging
  - Good agreement with simulation

We look forward to a very successful Run-2
Related Talks and Posters at EPS-HEP 2015

QCD and Hadronic Physics
- A. Morley, "Charged-particle multiplicities at different pp interaction centre-of-mass energies measured with the ATLAS detector at the LHC", July 23

Posters
- H. Oide, "Improvements to ATLAS track reconstruction for Run-2"
- T. Calvet, "b-tagging performance for ATLAS in LHC Run II"
Backup Slides
References


- ATL-PHYS-PUB-2015-018: "Track Reconstruction Performance of the ATLAS Inner Detector at $\sqrt{s} = 13$ TeV"


- ATL-PHYS-PUB-2015-031: "Alignment of the ATLAS Inner Detector with the initial LHC data at $\sqrt{s} = 13$ TeV"

- ATL-PHYS-PUB-2015-026: "Vertex Reconstruction Performance of the ATLAS Detector at $\sqrt{s} = 13$ TeV"

- ATL-PHYS-PUB-2015-022: "Expected performance of the ATLAS $b$-tagging algorithms in Run-2"

The 40 Mbit readout of Layer 2 will be a bottleneck when running at Run-2 luminosities.
Therefore, we need to increase the read-out bandwidth.
Will use the IBL ROD and BOC cards to communicate with pixel modules.

<table>
<thead>
<tr>
<th></th>
<th>Link occupancy at 100 kHz L1 trigger rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\mu$</td>
</tr>
<tr>
<td>50 ns</td>
<td>37</td>
</tr>
<tr>
<td>25 ns ; 13 TeV</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>51</td>
</tr>
<tr>
<td></td>
<td>76</td>
</tr>
</tbody>
</table>
IBL Mechanical Stability

\[ f(z) = B - M \left( \frac{z^2}{z_0^2} \right) \]

**ATLAS Preliminary**

After Alignment
IBL
Cosmic ray data
March 2015

\[ T_{\text{set}} = -20 \, ^\circ \text{C} \]
\[ T_{\text{set}} = -15 \, ^\circ \text{C} \]
\[ T_{\text{set}} = -10 \, ^\circ \text{C} \]
\[ T_{\text{set}} = 0 \, ^\circ \text{C} \]
\[ T_{\text{set}} = +7 \, ^\circ \text{C} \]
\[ T_{\text{set}} = +15 \, ^\circ \text{C} \]