Tracking performance in ATLAS for Run-2

Alejandro Alonso (Niels Bohr Institute) on behalf of the ATLAS Collaboration

LHCP2015
31 August - 5 September 2015
The ATLAS Detector

- Muon chambers
- Solenoid magnet
- Transition radiation tracker
- Semiconductor tracker
- Pixel detector
- LAr electromagnetic calorimeters
- LAr hadronic end-cap and forward calorimeters
- Tile calorimeters
- Toroid magnets

Dimensions:
- 44m
- 25m
The Inner Detector (ID)

- Reconstruction of charged particles with $|\eta| < 2.5$
  - New Insertable-B layer (IBL)
    - 6.02 M channels
    - Resolution: 8x40 $\mu$m (pixel size 50x250 $\mu$m)
  - Silicon Pixel detector (Pixel)
    - ~80M channels
    - Resolution: 10x115 $\mu$m (pixel size 50x400 $\mu$m)
  - Semiconductor tracker (SCT)
    - Silicon microstrip
    - 6M channels
    - Resolution: 17x580 $\mu$m
  - Transition Radiation Tracker (TRT)
    - 2mm radius drift tubes + Transition radiation
    - ~350k channels
    - Resolution ~130 $\mu$m
  - 2T axial B-field
ID Upgrades

New insertable B-layer (IBL)
- Inner most additional pixel layer (4th) at radius 33 mm from the beam line
- New beampipe
- Preserve tracking with increased luminosity
- Improves vertexing, impact parameter resolution and b-tagging
- 14 staves overlapping in the r - \(\phi\) plane of length 332 mm with 130nm CMOS modules with 2 technologies:
  - 12 planar and 2 x 4 3D modules

Triggers (TRT):
- Gas leaks for the end-caps repaired, new firmware to operate at 100kHz, validity gate, PID optimised

Software:
- Simplified data model, use of EIGEN. Speed up: 4x Run-1

New Diamond Beam monitors (DBM) installed in the Pixel volume
Alignment

- **Track based algorithm**
- **March alignment:** Correct relative movement of big structures
- **June alignment:** Very close to expected performance
  - Beam-spot constraint
  - Improve impact parameter resolution
  - Focused on IBL and Pixel alignment
- **Future plans:**
  - Study weak modes using resonances

ATLAS Preliminary

**IBL Planar sensors**

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

**Pixel Barrel**

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

**SCT barrel**

\( \sqrt{s} = 13 \text{ TeV} \)
ID performance

✦ IBL simulation in good agreement with data
✦ Pixel, SCT and TRT also in great agreement
Methods:

- **SCT extension Efficiency:**
  Material between SCT and Pixel

- **Photon conversions**
  Sensitive to radiation lengths

- **Hadronic interactions**
  Sensitive to interaction lengths

  Very good position resolution

Studies are progressing rapidly to provide a new detector geometry

IDTR-2015-003  IDTR-2015-004
Impact parameter resolution

- $D_0$ and $Z_0$ resolution improved:
  - New IBL
  - Material reduction in the pixel boundaries

- Improved discrimination between primary and secondaries
  - See Minimum Bias results:

The impact parameter resolution has been unfolded to remove the contribution from the vertex resolution.
Vertex efficiency

- Ratio between events with a reconstructed vertex and events with at least 2 tracks
- Beam-induced-background extracted
Vertex resolution

- Estimated by Data/MC studies, differences due to:
  - Description of the sub-detector hit errors
  - Multiple scattering, ionization energy losses
  - Residual misalignment

Primary vertex resolution ($x$-direction)

Primary vertex resolution ($z$-direction)

ATLAS Preliminary

$\sqrt{s} = 13$ TeV, 216.9 $\mu$b$^{-1}$

Data 15, low-$\mu$

Monte Carlo

ATL-PHYS-PUB-2015-026

IDTR-2015-005
Tracking inside jets

- **Improved during LS1:** tracking in dense environments
- **Neural network** to identify clusters *shared* by more than 1 particle, split them and estimate the position of each one
  - NN introduced in run-1, in run-2 use of NN information use was optimised
- Promising data/MC agreement
- *b*-tagging and $\tau$ reconstruction
b-tagging improvements

New multivariate tagger (MV2)

- BDT to combine:
  - Impact parameter
  - Secondary vertex finding algorithm
  - Decay chain multivertex

Better light and c-flavour rejection:

- Low $p_T$: IBL
- High $p_T$:
  - Improved reconstruction inside jets
  - b-tagging algorithms optimization

| MV2c20: | Run-2 BDT |
| MV1c:   | Run-1 NN   |
| Both trained with: |
| signal:  | b-jets     |
| background: | 80% light jets |
|          | 20% c-jets |

**ATL-PHYS-PUB-2015-022**

Alejandro Alonso (Niels Bohr Institute)
b-tagging in early data

- Commissioning ongoing with early Run-2 data.
- The modelling of the b-tagging is cross-checked in e-μ ttbar events, with ~70% b-jet purity.
- Jet selection: \( p_T > 20 \text{ GeV}, |\eta| < 2.5 \), leading two jets
- Quite good control of our modelling, so our expectations are close to the reality.

ATL-PHYS-PUB-2015-039/
The Muon Spectrometer

Detect muons with $|\eta| < 2.7$

- Momentum measurement: 3% resolution over a wide $p_T$ range, up to 10% at $p_T \sim 1$ TeV.
- Muon Drift Chambers (MDT) 80 µm, Cathode Strip Chambers (CSC) 60 µm
- Triggering capabilities and 5-10 mm position resolution:
  - Resistive Plate chambers (RPC), Thin Gap Chambers (TGC)

Improvements for Run-2

- Completion and extension of initial design:
  - Added last missing MDTs in transition region: $1.0 < |\eta| < 1.4$
  - 4 supplementary MDT chambers equipped with RPCs to close coverage holes at the bottom of the detector.
- Software:
  - More robust against fakes, better background rejection early in the pattern recognition
  - Improved energy loss calculation in the calorimeters:
    Detailed geometry and improved tune
    20-30 MeV for muons with $p_T$ of 50 GeV.
Muon efficiency

- Muon medium identification algorithm
  - Efficiency over 99%.
  - Excellent agreement with simulation.
  - To be updated with increased statistics

![Graphs showing efficiency and reconstruction efficiency with ATLAS Preliminary data and MC predictions.](image-url)
Muon resolution

MC: detailed material and geometry description. Second order effect corrections for momentum are applied (Derived in Run I and corrected Run 2)

Mass spectrum modelled by a Crystal-Ball convoluted with a Breit-Wigner:

✦ Gaussian component: Detector resolution
✦ Exponential component: Energy loss
✦ Breit-Wigner component: Width of the Z boson

Maximum Likelihood to estimate the mean (scale) and the resolution

ATL-PHYS-PUB-2015-037
Summary and Outlook

✧ IBL:
  ✧ Successfully installed, commissioned and great agreement with expectations

✧ ID Tracking:
  ✧ Improved track reconstruction in dense environments
  ✧ Improved impact parameter resolution
  ✧ Improved vertexing

✧ Flavour tagging:
  ✧ Improved b-tagging performance

✧ Muons:
  ✧ Very high efficiency. Resolution and scale well under control

✧ Detector understanding:
  ✧ Very good agreement in all areas for data and Monte Carlo
Related talks and poster at LCHP

✦ Poster Session:

✦ Yulia Rodina:
  b-tagging performance during LHC Run-II
  with the Insertable B-layer (IBL)

✦ Session SM - QCD - 3:

✦ Stewart Martin-Haugh:
  ATLAS soft QCD
Event Displays
Event display
Event display

First Stable Beams at 13 TeV
Event display
Event display

First Stable Beams at 13 TeV

Run: 266904
Event: 9886561
2015-06-03 10:49:54 CEST
Backup
The Insertable b-layer (IBL)
ID and MS status for Run-2

<table>
<thead>
<tr>
<th>Component</th>
<th>Run-2</th>
<th>Run-1</th>
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<tr>
<td>TGC</td>
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Approved Plots ATLAS Detector
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- **Future plans**:
  - Study weak modes using resonances
♦ D₀ and Z₀ resolution improved:
  ♦ New IBL
  ♦ Material reduction in the pixel boundaries

♦ Improved discrimination between primary and secondaries
  ♦ See Minimum Bias results:
    ATLAS-CONF-2015-028

♦ Discrepancies:
  ♦ Low p_T: IBL Material description
  ♦ High p_T: misalignments
  ♦ Resolution of individual measurements in the pixel:
    ♦ Longitudinal resolution in MC is superior due to the use of simplified energy deposit model
Vertex reconstruction

- Data recorded 3rd and 4th June 2015.
- ID fully operation
- Solenoid field on
- MBTS trigger used for low mu \((13.8 \text{ nb}^{-1})\)
- Random trigger for high mu \((177.4 \text{ nb}^{-1})\)
- Tracks:
  - \(p_T > 500 \text{ MeV}\)
  - \(|\eta| < 2.5\)
  - Nsilicon hits: 9 if \(|\eta| < 1.65\) or 11 if larger
  - IBL + B-layer hits > 0
  - Pixel holes = 0
  - SCT holes = 0
- 2 Tracks are required to form a vertex candidate

ATL-PHYS-PUB-2015-026
b-tagging improvements

Improved tracking in dense environments

New multivariate tagger (MV2)

- **BDT** to combine:
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Better light and c-flavour rejection:

- **IBL**

- Improved reconstruction inside jets

**MV2c20:**

- Run-2 BDT
- Trained:
  - signal: b-jets,
  - bkg: 80% light jets, 20% c-jets

**MV1c:**

- Run-1 NN algorithm

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