The ATLAS detector: status and performance in Run-II

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The ability of collider experiments to perform physics depends on:

- Performance of the accelerator (LHC)
- Detector used to observe the collisions (ATLAS detector)
- Capability to record interesting events (trigger/operation)
- Strength of the object reconstruction and performance
- Techniques used in physics searches and measurements

\[ \sqrt{s} = 8 \rightarrow 13 \text{ TeV}, \text{ large increase to the sensitivity to rare processes} \]

Higher luminosity is on the way \( \Rightarrow \) much more data in coming years

ATLAS physics potential has expanded considerably since 2012

We've been hard at work improving all of the other points

Note: Run-I is 2010-2012, Run-II starts with 2015
The ATLAS detector in Run-I

LHC → ATLAS detector → trigger/operation → reconstruction/performance → physics

- Large general-purpose detector
  - Three levels of high precision tracking subdetectors
  - Fine granularity segmented calorimetry out to $|\eta| < 4.9$
  - Both rapid (triggering) and precision muon spectrometers
Many detector repairs and upgrades
- Improved detector support services (such as cryogenics)
- Replaced/upgraded pixel modules and calorimeter electronics
- Completed installation of muon systems (much improved coverage)
Beyond repairs and upgrades, one major addition: the IBL

- Insertable B-Layer: new tracking detector 3.3 cm from the beam
  - Lies within the previously innermost tracking detector
  - Required a new (smaller) beam pipe to fit

IBL significantly improves tracking performance, shown later
Trigger upgrades and commissioning

- LHC beams currently collide at ATLAS every 25 ns (40 MHz)
- Can only write out data at up to $\sim 3$ GB/s (events at $\sim 1$ kHz)
- ATLAS multi-level trigger decides which events to record
  - Trigger system and architecture updated to cope with this data rate
- Trigger turn-on curves well understood [$e/\gamma$, $\mu$, $\tau$, jet, $b$-jet, $E_T^{\text{miss}}$]
More than $2.4 \text{ fb}^{-1}$ of data has been recorded

- $\mathcal{O}(100 \text{ pb}^{-1})$ of 50 ns bunch spacing at the start, 25 ns for the rest
- Not all of the recorded data is usable (detector defects, etc)
- In general, ATLAS detector is performing well in 2015
Track and vertex reconstruction

- Early data used for alignment and updating MC detector description
- After updates, basic track properties well-described in simulation
  - Includes tracks in jets, important to both jet calibration and $b$-tagging

Early data used for alignment and updating MC detector description
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Includes tracks in jets, important to both jet calibration and $b$-tagging
• IBL significantly improves impact parameter resolution
  • More or less a factor of 2 gain in performance
  • Proximity of IBL to interaction point is the reason for the large gain
Muon reconstruction performance

- $Z \rightarrow \mu\mu$ and $J/\psi$ used to measure reco. efficiency, scale, resolution
- Excellent data/MC agreement
- Reconstruction efficiency above 99% from 7 GeV

ATL-PHYS-PUB-2015-037
Electron/photon reconstruction performance
LHC → ATLAS detector → trigger/operation → reconstruction/performance → physics

- Photon reconstruction efficiency measured in MC
- Electron efficiency measured with $Z \rightarrow ee$ events in data and MC
  - Identification based on likelihood (shower shapes + tracking info)
  - Differences consistent with Run-I, comes from shower shape modelling
  - Accounted for using scale factors
- Electron scale/resolution probed via $Z \rightarrow ee$, cross-checked with $J/\psi$

ATL-PHYS-PUB-2015-041
Jet reconstruction performance
LHC → ATLAS detector → trigger/operation → reconstruction/performance → physics

- Updated jet cleaning procedure is >99% efficient by ∼30 GeV
- Jet calibration updated to obtain performance similar to Run-I
- Jet uncertainties extrapolated from Run-I to Run-II conditions
  - Detector and reconstruction changes taken as additional uncertainties

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ATLAS-CONF-2015-029

ATLAS Preliminary

$\sqrt{s} = 13$ TeV, 25 ns
antik, EM+JES + in situ, R = 0.4
$\eta = 0.0$

Fractional JES uncertainty

ATL-PHYS-PUB-2015-015

$P_T^{\text{jet}}$ [GeV]
**b-jet identification performance**

LHC → ATLAS detector → trigger/operation → reconstruction/performance → physics

- New $b$-tagging algorithm well described in $t\bar{t}$ data/MC events
- Major improvement from addition of the IBL and improved algorithms
  - Most common used scenario of 70% $b$-jet efficiency:
    factor of 4 (1.75) gain in light-flavour (charm) jet rejection
Large-$R$ jet reconstruction performance
LHC→ATLAS detector→trigger/operation→reconstruction/performance→physics

- Large-$R$ (radius) jets are becoming increasingly important
  - Decays of energetic massive particles ($W$, $Z$, $H$, top) are collimated
  - Reconstructing as a single jet allows for tagging the decay
- QCD rejection factor for $W/Z$ tagging is $40$ ($200$) for $50\%$ ($25\%$) eff.
- $H\rightarrow bb$ tagging rejection factor of $5$ ($10^5$) for bb-jets (light-jets)
• New algorithm **TST** (Track Soft Term) replaces old method (CST)
  • Fully calibrated hard objects, tracks for soft activity
• Reduces pileup sensitivity, improves resolution without sacrificing scale
• Good TST data/MC agreement in first data (ATL-PHYS-PUB-2015-027)

\[ \sqrt{s} = 13 \text{ TeV} \]
\[ Z \to \mu\mu \quad 25\text{ ns} \]
\[ \text{all jets} \]
Luminosity uncertainty dominates for early data measurements
- Neglecting lumi, experimental uncertainty at the same level as theory
- Ratios cancel the lumi uncertainty, stat uncertainty already negligible
  - Already $O(10^6)$ W and $O(10^5)$ Z candidates in the first 85 pb$^{-1}$
- W/Z cross-sections and ratios thereof agree with predictions

![Graph showing W/Z cross-section measurements](image)

**ATLAS** Preliminary
13 TeV, 85 pb$^{-1}$

$R_{W/Z} = \frac{\sigma_{W}^{\text{fid}}}{\sigma_{Z}^{\text{fid}}}$
No significant deviations observed search for dijet resonances
- Mostly sensitive to black holes with $O(100 \text{ pb}^{-1})$ of data
- Sensitivity to many other models requires $O(1 \text{ fb}^{-1})$ of data
Summary

- LHC upgrades: higher energy and instantaneous luminosity
- Several parts of the ATLAS detector have been upgraded
  - Insertable B-Layer added as the new innermost tracking detector
  - Trigger systems/architecture updated for increased data throughput
- The ATLAS detector has recorded more than 2.4 fb$^{-1}$ of data
  - Object reconstruction and performance already well understood
- First measurements are already probing theory uncertainties
- First searches are complete, and are eagerly awaiting more data
- Only a small portion of the $O(60)$ public documents from this summer
- ATLAS is ready for an exciting Run-II physics program!
A high energy dijet event ($m_{jj} = 5.2 \text{ TeV}$)