ATLAS Status and First Results

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On behalf of the ATLAS Collaboration
Outline

- Introduction
- Performance of the ATLAS Detector
  - Inner Detector
  - Calorimeters
  - Muons
- First Physics Results
  - Soft QCD
  - Jet Cross Section
  - W/Z Production
- Conclusions and Outlook
The Start of an Era!

• After 15 years of planning, the LHC physics program now underway
• Tremendous excitement within collaboration
• First steps in physics programme:
  – Study performance of ATLAS with pp collision data and validate simulation
  – Characterize pp interactions and test predictions of event generators
  – Rediscover Standard Model: Study Jets, W/Z bosons, Top
  – Characterize potential backgrounds to new physics
  – Keep our eyes open for any deviates from expectations
Data Collection To Data (7 TeV)

- Integrated luminosity:
  - $209 \text{ nb}^{-1}$
- Record instantaneous luminosity:
  - $1.44 \times 10^{30} \text{ cm}^{-2} \text{ s}^{-1}$
- Data-collection efficiency:
  - $\sim 90\%$
    - Up time for all subsystems $\geq 95\%$ during 2010 stable beam ops

- Systematic uncertainty on luminosity: 11%
  - Determined from van der Meer beam separation scans
  - Dominant uncertainty: LHC beam current measurement
ATLAS Detector

- Length: ~46 m
- Radius: ~12 m
- Weight: ~7000 tons
- ~10^8 electronic channels
- ~3000 km of cables
Inner Detector

- 2 T Magnetic Field
- Pixel Detector
  - 3 barrel layers, 2x3 disks
  - $\sigma(r\phi) = 10 \, \mu m$, $\sigma(z) = 115 \, \mu m$
- Silicon Strip Detector
  - 4 barrel layers, 2x9 disks
  - Pairs of single-sided sensors
  - $\sigma(r\phi) = 17 \, \mu m$, $\sigma(z) = 580 \, \mu m$
- Transition Radiation Tracker
  - 73 barrel, 2x160 Endcap layers
  - $\sigma(r\phi) = 130 \, \mu m$

Nominal Resolution:

\[
\sigma \left( \frac{p_T}{p_T} \right) \approx 3.4 \times 10^{-4} \left( \frac{p_T}{\text{GeV}} \right) \oplus 0.015
\]

\[
\sigma(d_0) \approx 10 \, \mu m \oplus \frac{140 \, \mu m}{\left( \frac{p_T}{\text{GeV}} \right)}
\]
### Tracking Performance: Reconstruction of Resonances

#### ATLAS mass (MeV) (stat errors only)

<table>
<thead>
<tr>
<th>Species</th>
<th>ATLAS mass (MeV)</th>
<th>PDG Mass (MeV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ξ</td>
<td>1322.22 ± 0.07</td>
<td>1321.71 ± 0.07</td>
</tr>
<tr>
<td>Ω</td>
<td>1672.78 ± 0.332</td>
<td>1672.45 ± 0.29</td>
</tr>
<tr>
<td>K*</td>
<td>892 ± 0.7</td>
<td>891.66 ± 0.26</td>
</tr>
<tr>
<td>K_s</td>
<td>497.427 ± 0.006</td>
<td>497.614 ± 0.024</td>
</tr>
<tr>
<td>Λ</td>
<td>1115.73 ± 0.01</td>
<td>1115.683 ± 0.0006</td>
</tr>
</tbody>
</table>

#### ATLAS Preliminary

- Correct charge comb.
- Wrong charge comb.

Gaussian+polynomial fit

- $\mu = 1672.8 ± 0.3$(stat.) MeV
- $\sigma = 4.0 ± 0.3$(stat.) MeV

Minimum Bias Stream, Data 2010 ($\sqrt{s} = 7$ TeV)

### $\Lambda \rightarrow p\pi$

- Data
- Double Gauss + poly fit
- Pythia MC09 signal
- Pythia MC09 background

Minimum Bias Stream, Data 2010 ($\sqrt{s} = 7$ TeV)

- $\Xi(1320) \rightarrow \Lambda\pi$
- $\sigma = 3.8 ± 0.06$(stat.) MeV

- $\Xi_{(1370)} \rightarrow \Lambda\pi$
- $\sigma = 3.0 ± 0.07$(stat.) MeV
Tracking Performance: Efficiencies and MC Modeling

- Tracking and reconstruction well understood
- ID alignment good enough for first physics
Tracking Performance: B-Tagging

Secondary Vertex Tagging

- Several taggers available:
  - Impact Parameter, jet probability, secondary vertex
  - Reasonable agreement between data and MC
  - Excess for positive decay length
    - Vertex mass consistent with expectations for heavy flavor

Impact Parameter Tagging

ATLAS Preliminary

- Data 2010
  - $\sqrt{s} = 7$ TeV, $L = 0.4$ nb$^{-1}$
- Simulation
  - b jets
  - c jets
  - light jets

$\Delta s / \sigma(\Delta s) > 7$

Vertex Mass: $L/\sigma > 7$

$\Delta_0$ Significance

07/16/10

Marjorie Shapiro (LBNL) Blois-2010
Calorimeters

**EM Calo:** LAr/Pb  
|η|<3.2  
σ(E)/E (e/γ)≈10%/√E±0.7%

**Hadronic barrel:** Scin/Fe  
|η|<1.7  
σ(E)/E (jet)≈50%/√E±3%

**Hadronic endcap:** LAr/Cu  
1.5<|η|<3.2  
σ(E)/E (jet)≈50%/√E±3%

**Hadronic Forward:** LAr/Cu,W  
3.1<|η|<4.9  
σ(E)/E (jet)≈100%/√E±10%
**EM Calorimeter Performance: Electrons and Photons**

- \( E_T(\gamma) > 400 \text{ MeV} \)
- \( E_T(\gamma\gamma) > 900 \text{ MeV} \)
- \( M_{\gamma\gamma} = 135.04 \pm 0.04 \text{ MeV} \) (PDG: 134.977 MeV)
- Systematic uncertainty
  - 1% on mass
  - 10% on width

- 2 electrons: \( p_T > 2.4 \text{ GeV} \)
- Shower shape and track quality cuts
- Mass calculated from tracks: no bremsstrahlung recovery yet
Calorimeter Performance: Jet Energy Scale

- **Input to Jet reco:**
  - 3D Topological clusters
- **Baseline calibration:**
  - EM scale
- **Corrections necessary for:**
  - Lower response to hadrons
  - Energy loss in dead material
  - Leakage outside clusters
- **Systematic uncertainties:**
  - Momentum spectrum of particles in the jets
  - Uncertainties in hadron response
  - Cluster Thresholds
- **Jet fragmentation compared to MC**
- **In-situ responds to single hadrons measured**

7% JES uncertainty for central jets with $p_T > 60$ GeV
Calorimeter Performance: Missing $E_T$

- Essential for new physics searches
- Reduce sensitivity to noise:
  - Use only cells belonging to 3D calorimeter “topo-clusters”
- “Refined” algorithms to correct for $e, \mu, \tau$ exist and under study
- Excellent agreement between data and MC over 6 orders of magnitude
Muon Spectrometer

- Coverage $|\eta| < 2.7$
- Trigger Chambers: RPC/TGC
- Precision Chambers: MDT/CSC
- Magnetic Field $\sim 0.5$ T
- Bending Power: $\sim 2-5$ Tm

- Stand-alone resolution: $\Delta p_T/p_T < 10\%$ up to 1 TeV
- Combined muon/ID tracking for optimal performance over full $p_T$ range
Muon Spectrometer + ID Performance

- Muon reconstruction working well, both standalone and in combination with ID
- Performance well modeled in simulation
- Measurements of trigger efficiencies using data in progress (tag-and-probe)

Trigger $\varepsilon$ Relative to Offline

$J/\psi \rightarrow \mu^+\mu^-$

$\mu$ Rate vs $\eta$

$\int_{L=0.6 \text{ nb}^{-1}} L_{s=7 \text{ TeV}} \text{ ATLAS Preliminary Chain1 (p_T>4 GeV)}$

$\int_{L=6.4 \text{ nb}^{-1}} \text{ ATLAS Preliminary}$
First Physics: Particle Production in Min Bias Events

- Charged-particle multiplicities with:
  - $|\eta| < 2.5$, $p_T > 100$ and 500 MeV
  - Standard analysis requires $n_{ch} \geq 1$
- Study $n_{ch} \geq 6$ to reduce sensitivity to diffractive component
  - First tuning of PYTHIA6 to LHC data at 900 GeV and 7 TeV (“AMBT1”)
    - Good agreement with 500 MeV cut
    - Poor for 100 MeV cut
    - Lower $p_T$: larger diffractive component

Details in talk by Remi Zaidan
Soft QCD: Description of Underlying Event

- Ambient level of particles in events with a hard scatter not predicted by pQCD
  - Phenomenological models implemented in MC generators
- Description of UE necessary,
  - eg for predicting lepton isolation
- Study UE via distributions of tracks transverse to leading track in event
- Not well modeled w/ default generator tunes:
  - Used as input to ATLAS tunes

See talk by Gabriel Hare
Jet Production: First Tests of pQCD at LHC

- Requirements on jet finding algorithm:
  - Theoretical:
    - Infrared safe
  - Experiment:
    - Performs well in presence of UE and pileup
    - Well defined shape (pileup corrections)
- ATLAS Baseline: Anti-Kt
  Cacciari, G. Salam, and G. Soyez
  JHEP 0803 (2008)

- Anti-Kt algorithm has one free parameter: $R$
  - For each input $i$, construct:
    
    \[
    d_{ij} = \min\left(k_{ti}^{-2}, k_{tj}^{-2}\right) \frac{(\Delta R)_{ij}^2}{R^2}
    \]

    \[
    d_{iB} = k_{ti}^{-2}
    \]

    \[
    (\Delta R)_{ij}^2 = (y_i - y_j)^2 + (\phi_i - \phi_j)^2
    \]

    - When $d_{ij} < d_B$ combine $i & j$
    - When $d_{ij} > d_B$ jet complete
  - Recalculate until stable

- Experimental results can be compared to:
  - Same algorithm run on MC truth particles OR
  - NLO pQCD
Inclusive cross section compared to NLO QCD calculation
- Non-perturbative corrections from leading-log partonic showering MC

Systematic Uncertainties:
- 7% Jet Energy Scale for central jets with $p_T > 60$ GeV ($<9\%$ for all $P_T$)
- Response vs $\eta$ modeled to better than 5%
- Luminosity: 11%

$R=0.6$ shows similar level of agreement

See talk by Zachary Marshall
PQCD: Dijet Cross Section and Angular Distribution

- Study cross section is function of dijet invariant mass and rapidity section
- Also measure angular distribution
- Good agreement between data and pQCD (NLOJET++ 4.1.2)

\[ \chi = \frac{1 + \cos \theta}{1 - \cos \theta} \]
Electroweak $W^\pm$ Production at 7 TeV

$W \to e\nu$ ($L_{\text{int}} = 6.7\,\text{nb}^{-1} \pm 20\%$)
- Track pointing to EM cluster
- $E_T > 20$ GeV
- Shower shape & leakage cuts
- TRT $e^\pm$ probability > 90%

$W \to \mu\nu$ ($L_{\text{int}} = 6.4\,\text{nb}^{-1} \pm 20\%$)
- Isolated combined track (ID-MS)
- $p_T > 20$ GeV

- With cuts on $E_T^{\text{miss}} > 25$ GeV and $M_T > 40$ GeV
  - (both $e$ and $\mu$ channel):

<table>
<thead>
<tr>
<th>Channel</th>
<th>Observed</th>
<th>Expected</th>
<th>Signal</th>
<th>Bkg</th>
</tr>
</thead>
<tbody>
<tr>
<td>$W \to e\nu$</td>
<td>17</td>
<td>23.1 ± 1.2(stat) ± 1.7(syst) ± 4.6(lumi)</td>
<td>20.7 ± 1.7(syst) ± 4.1(lumi)</td>
<td>2.4 ± 1.2(stat) ± 0.4(syst) ± 0.5(lumi)</td>
</tr>
<tr>
<td>$W \to \mu\nu$</td>
<td>40</td>
<td>28.7 ± 0.5(stat) ± 3.9(syst) ± 5.7(lumi)</td>
<td>25.9 ± 3.6(syst) ± 5.2(lumi)</td>
<td>2.8 ± 0.5(stat) ± 0.8(syst) ± 0.6(lumi)</td>
</tr>
</tbody>
</table>

1st Cross Section Measurement With Improved Statistics Expected for ICHEP

See talk by Kristin Lohwasser
Electroweak Z Production at 7 TeV

\[ Z \rightarrow ee \quad (L_{\text{int}} = 6.7\text{nb}^{-1} \pm 20\%) \]
- 2 tracks with opposite charge pointing to EM clusters
- \( E_T > 20 \text{ GeV} \)
- Shower shape & leakage cuts
- \( 80 \text{ GeV} < m_{ee} < 100 \text{ GeV} \)
  - **Observed 1, expected 1.6 ± 0.3**
  - Reconstructed mass: 91.4 GeV

\[ Z \rightarrow \mu\mu \quad (L_{\text{int}} = 7.9\text{nb}^{-1} \pm 20\%) \]
- 2 isolated combined track (ID-MS) with opposite charge
- \( p_{T1} > 20 \text{ GeV}, p_{T2} > 15 \text{ GeV} \)
  - \( 80 \text{ GeV} < m_{\mu\mu} < 100 \text{ GeV} \)
  - **Observed 2, expected 3.2 ± 0.9**
  - Reconstructed mass: 87.6, 80.2 GeV

See talk by Kristin Lohwasser
Conclusions

• After 15 years of preparation, ATLAS is performing beautifully
  – All subsystems operating within specifications
  – Data collection efficiency > 90%
  – Detector response well modeled by simulation
• First physics results now available
  – Studies of soft QCD processed: min bias, UE
  – First measurements of Jet Cross Section
    • Excellent agreement with pQCD
  – Observation of W/Z
• With increased luminosity expected soon
  – High statistics studies of SM processes
  – First searches for (and perhaps discovery of) BSM Physics

Exciting times ahead!
Backup Slides
**Z → μμ Candidate Event**

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**Z→μμ candidate**

- 7 TeV collisions
- Run Number: 154822
- Event Number: 14321500

**Z:** 
- 

**Minv = 87 GeV, Pt = 26 GeV**
- Pt(μ+) = 45 GeV, \( \eta = 2.2 \)
- Pt(μ -) = 27 GeV, \( \eta = 0.7 \)