Single Boson Production and Electroweak Processes at LHC with the ATLAS detector

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On behalf of the ATLAS Collaboration

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Overview

- $Z_p_T$ measurement
- $Z+$jets production
- High $m_{ll}$ Drell-Yan
- Low $m_{ll}$ Drell-Yan

\[
Z \rightarrow 4l
\]

- $Z$ production

- $Z$ rare decays

- $W+c / W+D$

\[
W \text{ production}
\]
The image contains a graph titled "Standard Model Production Cross Section Measurements" with a legend indicating various production channels such as W, Z, t̅t, t̅t-channel, WW, τγ, Wt, WZ, ZZ, t̅tγ, Wγ, Zy, Zj̅j. The graph compares cross sections for different LHC proton-proton center-of-mass energies, 7 TeV and 8 TeV, with data and theory points.

- Tests on perturbative QCD and EWK
- Constrain parton density functions of protons
- Background to Higgs and many New Physics phenomena
- Benchmark processes for detector calibration
Measurement of the $Z/\gamma^*$ transverse momentum

- Motivation → Measurement of $W$ mass
- Very clean signature and high cross section

Measurement in fiducial region
- $p_{T,l}>20$ GeV, $66<m_{ll}<116$, $|\eta|<2.4$
Measurement of the $Z/\gamma^*$ transverse momentum

- Measurement in fiducial region
  - $p_T, l > 20$ GeV, $66 < m_{ll} < 116$, $|\eta| < 2.4$

- 0.5% precision up to 30 GeV

- Break-down of the systematic uncertainties
Measurement of the $Z/\gamma^*$ transverse momentum

- Needed for MC tuning $\rightarrow W$ mass measurement

\[ \sqrt{s} = 7 \text{ TeV}; \int L = 4.7 \text{ fb}^{-1} \]

**PowhegPythia description of $p_T^Z$ after tuning**
Z+jets Production

- Measurement possible for high jet multiplicity and also for high energy regime
- Good agreement with BlackHat+Sherpa, Alpgen, Sherpa describe the data
- MC@NLO fails to predict the jet multiplicity

- Unfolded data compared to
  - BlackHat+Sherpa (NLO)
  - Alpgen+Herwig (up to 5 partons at ME level + PS, CTEQ6L PDF)
  - Sherpa (up to 5 partons at ME level +PS, CT10)
  - MC@NLO (1 additional parton + PS, CT10)
High $m_{ll}$ Drell-Yan Production

- Mass spectrum sensitive to PDFs (antiquarks at large $x$)
- Comparison with NNLO prediction from FEWZ
- Tension in low region but still compatible with data

**Graphs and Plots**

- ATLAS data comparing the mass spectrum with predictions from different PDF sets.
- Comparison of the data with the NNLO prediction from FEWZ, showing agreement in the tension region.

*Reference:
Low $m_{ll}$ Drell-Yan Production

- Low $m_{ll}$ Drell-Yan production dominated by electromagnetic coupling of $q\bar{q}$ to virtual photons

**Nominal analysis**
- 2011 data, 1.6 fb$^{-1}$ (trigger requirements), electron & muon channels
  - $26 < m_{ll} < 66$ GeV, $|\eta| < 2.4$, $p_T > 15/12$ GeV

**Extended analysis**
- 2010 data, 35 pb$^{-1}$, muon channel
  - $12 < m_{ll} < 66$ GeV, $|\eta| < 2.4$, $p_T > 9/6$ GeV

submitted to JHEP, arXiv:1404.1212
Low $m_{ll}$ Drell-Yan Production (2)

- Compared to FEWZ (N)NLO and Powheg (NLO+LL parton shower)
- Good description of data within theoretical uncertainties
Z→4l Cross Section Measurement

- **Z→4l** production cross section in \( m_{ll} > 5 \text{ GeV} \) and \( 80 < m_{4l} < 100 \text{ GeV} \)

<table>
<thead>
<tr>
<th>( 7 \text{ TeV} )</th>
<th>Cross section [fb]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measured</td>
<td>( 76 \pm 18 ) (stat) ( \pm 4 ) (syst) ( \pm 1.4 ) (lumi)</td>
</tr>
<tr>
<td>Theory</td>
<td>( 90.0 \pm 2.1 )</td>
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<table>
<thead>
<tr>
<th>( 8 \text{ TeV} )</th>
<th>Cross section [fb]</th>
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<tbody>
<tr>
<td>Measured</td>
<td>( 107 \pm 9 ) (stat) ( \pm 4 ) (syst) ( \pm 3.0 ) (lumi)</td>
</tr>
<tr>
<td>Theory</td>
<td>( 104.8 \pm 2.5 )</td>
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- Branching fraction for Z→4l

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<tr>
<td>Theory</td>
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Directly sensitive to $s$-quark PDF

Analysis looking for $W+c$ jet and $W+D^{(*)}$ mesons

(Opposite – Same) Sign pairs studied

Data better described with PDF with unsuppressed $s$-quark distribution (ATLAS-epW12, NNPDF2.3coll)
W+c / W+D(*) Production

- Charge asymmetry measured for the W+c jet and W+D(*) production

Data in good agreement of the prediction of aMC@NLO with different PDF sets
**W+c / W+D(*) Production**

- Differential cross section as a function of lepton pseudorapidity
- Use $W+c/W+D(*)$ data to fit the strange-to-down sea quark distributions
  - $s/sbar$-quark density suppressed compared to $d/ubar$-quark density for HERAPDF1.5
  - ATLAS data favour a symmetric light-quark density over the whole $x$-range of the measurement
Conclusions

- Measurements of W & Z production
  - Provide important tests of pQCD
  - Require excellent understanding of the detector performance
  - Can provide better handling of the backgrounds for many interesting measurements

- High precision of the data challenges the SM prediction

- Data useful to constrain the parton density distributions of the proton
BackUp
Z pt

ATLAS Preliminary

$Z \to e^+e^-$

Relative uncertainty (%)

- Stat. error
- Background
- Energy scale
- Energy resolution
- Efficiencies
- Charge id.
- Multiple scattering
- FSR model
- MC stat.
- Common syst.
- Total error

$\int L \, dt = 4.7 \, fb^{-1}; \sqrt{s} = 7 \, TeV$

Prediction / Data

Inclusive

- Data
- PYTHIA6-AMBT1
- POWHEG+PYTHIA6
- MC@NLO+HERWIG
- ALPGEN+HERWIG
- SHERPA

$\sqrt{s} = 7 \, TeV; \int L = 4.7 \, fb^{-1}$

Prediction/Data

- Data
- Total uncertainty
- POWHEG+PYTHIA6 $Z_{\phi^*}$-tuned
- POWHEG+PYTHIA6 $p_T$-tuned

ATLAS Preliminary
Z+jets

\[ \int L dt = 4.6 \text{ fb}^{-1} \]
anti-$k_t$, jets, $R = 0.4$
\[ p_T^{\text{jet}} > 30 \text{ GeV}, |y^{\text{jet}}| < 4.4 \]

\[ Z/\gamma^*(\rightarrow \gamma^{*} \rightarrow \pi^{+} \pi^{-}) + \text{jets} (l=e,\mu) \]

\[ (1/\alpha_{\gamma^*(\rightarrow \gamma^{*} \rightarrow \pi^{+} \pi^{-})} \text{ NLO} / \text{Data}) \]

\[ \text{MC} / \text{Data} \]

\[ N_{\text{jet}}+1/N_{\text{jet}} \]

\[ p_T^b \text{ [GeV]} \]

\[ \text{MC} @ \text{NLO} \]

\[ \text{ALPGEN} \]

\[ \text{SHERPA} \]

\[ \text{BLACKHAT + SHERPA} \]

\[ \text{Data 2011 (1s = 7 TeV)} \]

\[ \text{MC} @ \text{NLO} \]

\[ \text{ALPGEN} \]

\[ \text{SHERPA} \]

\[ \text{BLACKHAT + SHERPA} \]
High Mll DY

$\frac{d\sigma}{dm_{ee}}$ [pb/(GeV)] (dressed)

$\frac{d\sigma}{dm_{ee}}$ [pb/(GeV)]

ATLAS

Data

1.8 % luminosity uncertainty not included

MC/Data

PYTHIA 6.426 (MRSTMCa) $\times$ 1.23
MC@NLO 4.02 (CT10) $\times$ 1.08
SHERPA 1.3.1 (CTEQ6L1) $\times$ 1.39

$\sqrt{s} = 7$ TeV, $\int d\mathcal{L} = 4.9$ fb$^{-1}$
electron $p_t > 25$ GeV, $|y| < 2.5$

Dimitra Tsionou 02/06/14
Low m_{ll} extended

\[ \int L \, dt = 35 \text{ pb}^{-1} \]
\[ s = 7 \text{ TeV} \]

**ATLAS**

MSTW2008 68\% CL
\[ |\eta| < 2.4, p_T > 6 \& 9 \text{ GeV} \]
Z→4ℓ analysis selection

- **Electrons**
  - \( p_\text{T} > 7 \text{ GeV} \)
  - \(|\eta| < 2.47\)
  - Isolation \( E_\text{T}^{\text{cone20}}/p_\text{T} < 0.2 \) (0.3) for 8 (7) TeV
  - \( d_0/\sigma_{d0} < 6 \)

- **Muons**
  - \( p_\text{T} > 4 \text{ GeV} \)
  - \(|\eta| < 2.7\)
  - Isolation \( E_\text{T}^{\text{cone20}}/p_\text{T} < 0.3 \)
  - \( d_0/\sigma_{d0} < 3.5 \)

- **Leptons pairs**
  - 2 opposite sign, same flavour pairs
  - \( \Delta R > 0.1 \) for SF pairs, \( \Delta R > 0.2 \) for OF pairs
  - \( p_{T,1} > 20 \text{ GeV}, p_{T,2} > 15 \text{ GeV}, p_{T,3} > 10 \) (8) GeV for e (m)
  - \( m_{12} > 20 \text{ GeV}, m_{34} > 5 \text{ GeV} \)
  - \( 80 < m_{4\ell} < 100 \text{ GeV} \)
Z→bb analysis selection

![Graph showing ATLAS Simulation with POWHEG + Pythia 8 and aMC@NLO + Herwig++](image)

Fiducial to Total Cross Section Ratio

Z Boson $p_T$ [GeV]
W+b Production

- W+b cross section measured in exclusive 1jet, 2jet and 1+2 jet bins \((p_T^{bjet}>25 \text{ GeV}, |\eta^{bjet}|<2.1)\)

- Powheg, Alpgen: \(qq \rightarrow Wbb, qg \rightarrow Wbbq\) (4FNS)

- MCFM: Includes also \(bq \rightarrow Wbq, bg \rightarrow Wbqq\) (5FNS)

- Agreement with theoretical prediction
Z→bb Cross Section Measurement

- Cross section measured for
  - 2 b-jets with \( p_T > 40 \) GeV, \( |\eta| < 2.5 \)
  - Dijet system: \( \Delta R_{jj} < 1.2 \), \( p_T, jj > 200 \) GeV, \( 60 < m_{jj} < 160 \) GeV

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<thead>
<tr>
<th>Fiducial cross section [pb]</th>
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<tbody>
<tr>
<td>Measured</td>
</tr>
<tr>
<td>POWHEG</td>
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<tr>
<td>aMC@NLO</td>
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- In good agreement with the NLO +parton shower prediction
W+c/W+D(*) analysis selection

\[ \int_{\text{Ldt} = 4.6 \text{ fb}^{-1}} \text{wrt } \sqrt{s} = 7 \text{ TeV} \]

- Data
- Fit
- Signal
- Background

\[ \Delta m = m(D^*) - m(D^0) \text{ [MeV]} \]
**W+b analysis selection**

\[ \int L \, dt = 4.6 \, fb^{-1} \]
\[ s = 7 \, TeV \]
muon, Njet = 1

ATLAS

Data
W+b
W+c
W+light
Multijet
single top
Z
tf
WW + WZ

<table>
<thead>
<tr>
<th>Events / 5 GeV</th>
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<tbody>
<tr>
<td>5000</td>
</tr>
<tr>
<td>4000</td>
</tr>
<tr>
<td>3000</td>
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<tr>
<td>2000</td>
</tr>
<tr>
<td>1000</td>
</tr>
<tr>
<td>0</td>
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<table>
<thead>
<tr>
<th>( E_T^{\text{miss}} ) [GeV]</th>
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<tbody>
<tr>
<td>0</td>
</tr>
<tr>
<td>20</td>
</tr>
<tr>
<td>40</td>
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<tr>
<td>60</td>
</tr>
<tr>
<td>80</td>
</tr>
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<td>140</td>
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<tr>
<td>160</td>
</tr>
<tr>
<td>180</td>
</tr>
<tr>
<td>200</td>
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</table>

ATLAS
\[ \int L \, dt = 4.6 \, fb^{-1} \]
\[ e + \mu, \text{NJet} = 1 \]

<table>
<thead>
<tr>
<th>( d\sigma / dp_T^{b\text{-jet}} ) [pb/GeV]</th>
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<tbody>
<tr>
<td>1</td>
</tr>
<tr>
<td>0.1</td>
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<td>0.01</td>
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<table>
<thead>
<tr>
<th>Data / MCFM</th>
<th>Data / ALPGEN</th>
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<tbody>
<tr>
<td>Data / MCFM</td>
<td>theor. uncertainties</td>
</tr>
<tr>
<td>Data / ALPGEN</td>
<td></td>
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\( b\text{-jet} p_T \) [GeV]

25-30
30-40
40-60
60-140