W/Z Results From CMS

Jay Lawhorn (MIT/Caltech) on behalf of the CMS collaboration

QCD@LHC 2015
8 TeV W/Z Inclusive Cross Sections

Total cross section

\[ \sigma = \frac{N}{A \epsilon \int \mathcal{L} \, dt} \]

and fiducial

\[ A\sigma = \frac{N}{\epsilon \int \mathcal{L} \, dt} \]

- No theoretical uncertainties in fiducial measurement

18.2 pb\(^{-1}\) of 8 TeV low luminosity data for missing transverse energy resolution

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<table>
<thead>
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<tbody>
<tr>
<td>N</td>
<td>e</td>
<td>μ</td>
</tr>
<tr>
<td>Z(\rightarrow ll)</td>
<td>4793±69</td>
<td>5917±77</td>
</tr>
<tr>
<td>W(\rightarrow lv)</td>
<td>75051±287</td>
<td>81473±282</td>
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</tbody>
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W/Z Total and Fiducial Cross Sections

<table>
<thead>
<tr>
<th>Process</th>
<th>Total</th>
<th>Fiducial</th>
</tr>
</thead>
<tbody>
<tr>
<td>$W^+ \rightarrow l^+\nu$</td>
<td>$7.11 \pm 0.03_{\text{stat}} \pm 0.14_{\text{syst}} \pm 0.18_{\text{lum}} \text{ nb}$</td>
<td>$3.16 \pm 0.01_{\text{stat}} \pm 0.04_{\text{syst}} \pm 0.08_{\text{lum}} \text{ nb}$</td>
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<tr>
<td>$W^- \rightarrow l^-\nu$</td>
<td>$5.09 \pm 0.02_{\text{stat}} \pm 0.11_{\text{syst}} \pm 0.13_{\text{lum}} \text{ nb}$</td>
<td>$2.26 \pm 0.05_{\text{stat}} \pm 0.02_{\text{syst}} \pm 0.06_{\text{lum}} \text{ nb}$</td>
</tr>
<tr>
<td>$W \rightarrow l\nu$</td>
<td>$12.21 \pm 0.03_{\text{stat}} \pm 0.24_{\text{syst}} \pm 0.32_{\text{lum}} \text{ nb}$</td>
<td>$5.42 \pm 0.02_{\text{stat}} \pm 0.06_{\text{syst}} \pm 0.14_{\text{lum}} \text{ nb}$</td>
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<tr>
<td>$Z \rightarrow ll'$</td>
<td>$1.15 \pm 0.01_{\text{stat}} \pm 0.02_{\text{syst}} \pm 0.03_{\text{lum}} \text{ nb}$</td>
<td>$0.41 \pm 0.01_{\text{stat}} \pm 0.01_{\text{syst}} \pm 0.01_{\text{lum}} \text{ nb}$</td>
</tr>
<tr>
<td>$W^+ \rightarrow l^+\nu / W \rightarrow l^-\nu$</td>
<td>$1.39 \pm 0.01_{\text{stat}} \pm 0.02_{\text{syst}} \text{ nb}$</td>
<td>$1.40 \pm 0.01_{\text{stat}} \pm 0.02_{\text{syst}} \text{ nb}$</td>
</tr>
<tr>
<td>$W \rightarrow l\nu / Z \rightarrow ll'$</td>
<td>$10.63 \pm 0.11_{\text{stat}} \pm 0.25_{\text{syst}} \text{ nb}$</td>
<td>$13.26 \pm 0.15_{\text{stat}} \pm 0.21_{\text{syst}} \text{ nb}$</td>
</tr>
</tbody>
</table>

**luminosity, experimental, and theoretical uncertainties**

*Phys. Rev. Lett. 112 (2014) 191802*
Ratios of W/Z Inclusive Cross Sections

Drell-Yan Differential Cross Sections

**diagram**

**Text:**

**differential measurement in di-lepton mass:**

\[ 15 < m_{ll} < 2000 \text{ GeV} \]

sensitive to PDFs over wide range of \( Q^2 \)

Drell-Yan Double-Differential Cross Sections

double-differential measurements in rapidity and di-lepton mass

sensitive to $0.0003 < x_\pm < 1$, $600 < Q^2 < 750,000$ GeV$^2$ region of PDFs

Ratios of Drell-Yan Differential Cross Sections

\[ R \equiv \text{ratio of differential measurements in di-lepton mass at 7 and 8 TeV} \]

correlated theoretical uncertainties cancel in ratio of measurements at different center-of-mass energies

Ratios of Drell-Yan Double-Differential Cross Sections

\[ R_{\text{det}} \equiv \text{ratio of double-differential measurements in di-lepton mass and rapidity at 7 and 8 TeV} \]

\[ \text{low } m_{ll} \]

\[ \text{high } m_{ll} \]

\[ \text{Z peak} \]
differential measurement in di-lepton rapidity and transverse momentum at Z peak (81 < m_{ll} < 101 GeV)
Z Differential Cross Sections

sensitive to resummation at low $q_T$, higher order QCD effects at high $q_T$

\( \theta^* \), \( \phi^* \) are angles of negative lepton in the lepton pair rest frame
Z Boson Angular Coefficients

- Lepton angular distribution:

\[
\frac{d^2\sigma}{d\cos\theta^*d\phi^*} \propto (1 + \cos^2\theta^*) + \\
A_0 \frac{1}{2}(1 - 3\cos^2\theta^*) + A_1 \sin(2\theta^*) \cos\phi^* + A_2 \frac{1}{2}\sin^2\theta^* \cos(2\phi^*) + \\
A_3 \sin\theta^* \cos\phi^* + A_4 \cos\theta^* + \ldots
\]

**Z boson polarization**

- **First measurement of coefficients in proton-proton collisions**
- **Quark-antiquark production, but also qg Compton process**

*arXiv:1504.03512*
Z Boson Angular Coefficients

$|y|<1$

test of MadGraph (LO-QCD), POWHEG (NLO) and FEWZ (NNLO) predictions

arXiv:1504.03512
Drell-Yan Forward-Backward Asymmetry

Forward-backward asymmetry:

\[ A_{FB} = \frac{\sigma_F - \sigma_B}{\sigma_F + \sigma_B} \]

Includes electrons to \(|\eta| < 5.0\) using hadron forward calorimeter (no tracker coverage)
Drell-Yan Forward-Backward Asymmetry
Drell-Yan Forward-Backward Asymmetry

A_{FB} measurement in di-lepton rapidity and mass

Sensitive to new physics, weak quark couplings, mixing angles

CMS PAS SMP-14-004
Muon Charge Asymmetry

\[ A(\eta) = \frac{\frac{d\sigma}{d\eta}(W^+ \rightarrow \mu^+\nu) - \frac{d\sigma}{d\eta}(W^- \rightarrow \mu^-\nu)}{\frac{d\sigma}{d\eta}(W^+ \rightarrow \mu^+\nu) + \frac{d\sigma}{d\eta}(W^- \rightarrow \mu^-\nu)} \]
Muon Charge Asymmetry

**HERA only** and **HERA+CMS $A_W$ fits**

Constrains valence quark PDFs in range $10^{-3} < x < 10^{-1}$

**up valence quarks**

**down valence quarks**

*CMS PAS SMP-14-022*
Looking forward to our first W/Z results at 13 TeV
Summary

- W/Z inclusive, differential cross sections,
- DY forward-backward asymmetry
- W charge asymmetry
- Input for PDF fits
- Sensitivity to perturbative and soft QCD