W & Z boson Production @ CMS

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on behalf of the CMS Collaboration

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CMS Data taking

- Total 29.4/fb delivered to CMS detector
- 7 TeV analysis
  - New result from Muon Q Asymm. 4.7/fb full data 2011
  - DY differential: 4.5(Mu), 4.8(Ele)/fb full 2011 data
  - Electron Q Asymm. 840/pb data 2011
- Low Pile Up (Av. 3 bunch crossing) 8 TeV Special run:
  - 19/pb in the beginning of 2012 data taking
  - W/Z cross section
  - DY (muon) pT differential cross section
Measurement of the Muon Charge Asymmetry in inclusive W production at 7 TeV
Motivation

- Overall excess of W+ over W- due to the presence of two valence u-quarks in the proton
- Muon Charge Asymmetry on eta
  - High precision than boson
- Full 2011 7 TeV dataset amount to 4.7/fb
  - Measurement with 20 M W bosons
- high precision than previous measurement

**Electron Charge Asymmetry**

- PRL 109 (2012) 111806
- 840/pb at 7 TeV
- pT >35 GeV/c, 11 Bins of |η|<2.4
- very precise (4-5%) to theory predictions
Muon Q Analysis

- For better resolution for MET distributions, several correction techniques are applied
- **Muon momentum scale correction:**
  - Due to misalignment and mis-modeling of magnetic field
  - The correction is derived from $<1/pT>$ in $(\eta, \phi, Q)$ using Z events
  - Effect on: acceptance region, missing transverse energy (MET)
  - Corrections applied to data and MC
- Drell-Yan sample Normalization correction
  - Mass dependent k-factor derived to match data normalization in DY control region
Define **Hadronic Recoil** to study MET taking advantage of well defined lepton

\[ u = -MET - \sum p_T \]

- **Φ modulation correction** in data and MC
  - Caused by deviation b.t.w. interaction point and detector coordinates
  - To make **Φ (MET) flat**
  - Fit on \( u_{\parallel} \) and \( u_{\perp} \) with \( A(n)\cos(\phi - \phi_0(n)) \)

- **Hadronic Recoil correction** in MC
  - To match recoil and resolution to data
  - Parallel recoil estimated for each of 4 \(|\eta|\) bins from a leading jet
  - Parallel & Perpendicular resolution in each n-vertices

Parameterization, for recoil w/ 1st order, for resolution w/ sqrt ftn

\[-u_{\parallel}(q_T) = (c_0 + c_1 q_T) \left( 1 + erf(\alpha q_T^\beta) \right)\]

\[\sigma(q_T; n) = \sqrt{N_R^2 + S_R^2 q_T}\]

CMS-PAS-SMP-12-021
Fitting MET distributions

- Binned Maximum likelihood for 11 bins, $|\eta| < 2.4$
- MC templates used
- Floating: Number of $W$ and QCD events
- Fixing:
  - Ratio of QCD+ and QCD- to control region (CR) value
  - DY and t\bar{t} normalization (+corrections to CR)
  - $W\rightarrow\tau\nu$ normalized to $W\rightarrow\mu\nu$

True charge asymmetry applying the charge dependent efficiency ratio ($r_{W+/W-}$)

- Muon efficiency from Tag-and-Probe technique with Z control sample

\[
A_{true} = A_{raw} - \frac{1 - (A_{raw})^2}{2} \left( r_{W+/W-} - 1 \right)
\]
Muon Charge Asymmetry

- Measurement precision 0.2-0.4 % per bin
- Dominant systematics:
  - Efficiency ratio $\epsilon^+/\epsilon^-$
  - QCD Normalization
  - Muon Scale (for $p_T>35$ analysis)

- Good agreement with CT10, NNPDF and HERA, worse with MSTW
- New MSTW shows significant improvement
  - Flexible input parameterisation
  - Deuteron correction
- Data uncertainty is much smaller than the PDF one

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CMS preliminary
$\sqrt{s} = 7$ TeV, 4.7 fb$^{-1}$

Charge asymmetry

- $p_T>25$ GeV
- $p_T>35$ GeV

Data

CMS-PAS-SMP-12-021
Comparison to Electron channel

- In good agreement
- Electron and current muon results are largely independent (common systematics are negligible)
  - Complementary input for global PDF analysis
- Can make significant contribution to global PDF analysis
Measurements of Differential and Double Differential Drell-Yan Cross Sections in PP collisions at 7 TeV
\[ \sigma = \frac{N}{A \cdot \epsilon \cdot \rho \cdot L} \]

- **Muon Channel**
  - **Muon** in fiducial volume: \( p_T > 14, 9 \text{ GeV}/c, |\eta| < 2.4 \)
  - Dominant backgrounds are estimated in data-driven ways, Top (e-\(\mu\)), QCD (ABCD), others from MC
  - Muon momentum scale & resolution applied to data and MC
- **Electron Channel**
  - **Electron** in fiducial volume: \( p_T > 20, 10 \text{ GeV}/c, |\eta| < 2.5 \)
  - All Electron channel background from data-driven ways: QCD and W+Jets from fake rate, others from e-\(\mu\)
  - Electron energy scale applied to \( E_t \) and smearing to MC
- **Efficiency correction using MC**
  - Take into account the difference between data and MC using tag-and-probe method
- **Correction for detector resolution and FSR effects:**
  - Unfolding with matrix inversion technique

CMS-PAS-SMP-13-003
dσ/dM Results

• With full phase and within detector acceptance, at pre(post)-FSR
  ➔ 40 mass bins (15-1500 GeV/c^2) taking advantage of the CMS detector
  ➔ Test significant NNLO contribution below 40 GeV

• Combined (BLUE) DY invariant mass spectrum in full phase space

• Cross section normalized to the Z peak (60<Inv.M<120 GeV/c^2)
  ➔ Cancel/reduce systematic uncertainties

• Statistical uncertainty: <2%, systematic uncertainty: <12% up to 200 GeV/c^2

• Dimuon and dielectron are compatible within uncertainties: χ^2/ndof = 1.1

• Good agreement with FEWZ NNLO expectation of CT10 PDF

CMS Preliminary

FEWZ calculation with stat+PDF (blue), + EWK correction uncer. (green)

CMS-PAS-SMP-13-003
**dσ^2/dMdY**

- **Within the detector acceptance** to reduce the model dependence using \(6 \times 24 = 132\) mass-rapidity bins
- Interesting for PDF constraints, especially d quark and antiquark
- Good agreement with most of PDFs but deviations shown at low and high mass regions
  - Potential constraint to PDFs expected from the results

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**All of the existing NNLO PDFs**
W and Z Cross Section at 8 TeV
Introduction

- Update to previous measurement with 36/pb at 7 TeV
- Using **special run with low pileup** amount to 18.7±0.9/pb
  - Un-prescaled trigger with low pT thr.
  - Suitable MET resolution for data-driven QCD estimation
- Fiducial volume: pT > 25 GeV, |η|<2.1(mu), 2.5(e)
- Using Tag-and-Probe in Z sample for efficiency
- Electron energy, Muon momentum scale corrections
- Recoil method to correct for the MET
- Z→μμ(ee) boson yield extraction:
  - 4 categories from each muon (electron) ID
  - Add events from categories
- W boson extraction: template fitting
  - QCD template from QCD dominant region
- Acceptance: POWHEG NLO MC

\[ \sigma = \frac{N}{A \cdot \epsilon \cdot \rho \cdot L} \]
• Theory uncertainty interpreted as a 68% CL
• $Z$ cross section is limited to a dilepton mass range of 60 to 120 GeV/c$^2$
• Measurements are consistent between the electron and muon channels, and in agreement with NNLO cross section calculations
• Inclusive electron, muon, and combined cross section
• Theoretical prediction w/ FEWZ MSTW NNLO PDF

Stat. (back) + Syst. (red) + lum (green)

CMS-PAS-SMP-13-003
Results (cont’d)

- $W$ vs. $Z$ x-sec.: ellipses illustrate the 68% coverage for total uncertainties
- $W^+$ vs. $W^-$ x-sec in agreement to theory within $1\sigma$
- Cross section comparison to previous results from CMS and other experiment
  - Good agreement with theory predictions at NNLO for both at 7 and 8 TeV

![Graph showing cross sections and comparisons](image-url)
Measurement of the **Transverse Momentum distribution of Z bosons**

decaying to **dimuons** in pp collisions

at $\sqrt{s} = 8$ TeV
Z pT differential cross-section

- Transverse momentum $q_T$ of dimuon system has important role
  - **Non perturbative** prediction of soft gluon emission in low $q_T$
  - **Perturbative QCD prediction** for hard gluon radiation in the initial state in the **high $q_T$** range

- Low PU data sample of pp collisions at 8 TeV in 2012, similar PU condition to 2010 analysis
- Similar methods used as DY $d\sigma/dM$
  - $e-\mu$ method, fake muon ratio from QCD
- Resolution & FSR Unfolding with inverse matrix technique
- Several **Pythia tunes tested** for the underlying events in the low $q_T$

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CMS-PAS-SMP-12-025
W & Z production Summary

- Presented
  - The first release of **W Muon Charge Asymmetry** at 7 TeV with **4.7/fb full data** 2011 with high precision results 0.2-0.4 % per bin
  - W Electron Charge Asymmetry at 7TeV with 840/pb partial data 2011
  - DY mass, mass and rapidity differential cross section at 7 TeV with 4.5(Mu), 4.8(Ele)/fb full 2011 data
  - W/Z cross section at 8 TeV with 19/pb
  - DY (muon) pT differential cross section at 8 TeV with 19/pb
- With high precision, in good agreement to theory prediction within error.
  - high precision results contribute to theory calculations
- We are planning to get better results at 8 TeV data with more data 20/fb taken in 2012, cf. 5/fb in 2011
Back-UP Slides
Measurement of the Electron Charge Asymmetry in Inclusive W Production in pp Collision at $\sqrt{s} = 7$ TeV
- 840/pb partially collected in 2011
- Electron $p_T > 35$ GeV/c, 11 bin of $|\eta| < 2.4$
- Electron with same charges with three different algorithm to suppress systematic from mi-charge measurement
- corrections on Hadronic Recoil, energy scale and resolution
- Signal Extraction by Ext. binned Max. Likelihood fit with templates floating $N(QCD)$ and $N(Sig + EWK)$
- QCD template from Anti-Selection of Data
- Charge misid($w$) measured in data from same-sign/opposite-sign Z boson yield
- Relative efficiency from Tag-and-Probe using Z sample

\[ A_R = \frac{1}{1 - 2\omega} \frac{\mathcal{A}_M(R + 1) - (R - 1)}{\mathcal{A}_M(R + 1) - \mathcal{A}_M(R - 1)} \approx \frac{1}{1 - 2\omega} \left( \mathcal{A}_M - \frac{(R - 1)(1 - A_M^2)}{2} \right) \]
Results

- 11 bins result with factor 2 precision than previous 6 bins, error with stat.+syst
- PDF uncertainty using PDF reweighting technique corresponding 68% CL
- 4 PDFs interfaced to MCFM (NLO)
  - data are in good agreement with HeraPDF, CTEQ, and NNPDF while MSTW is systematically lower
- Very precise (4-5%) theory predictions
- Systematic errors from Efficiency ratio, Signal MET shape (CTEQ6.6), recoil corrections
- PU insensitive for using of data-driven MET templates

<table>
<thead>
<tr>
<th>(10^{-3})</th>
<th>Signal Yield</th>
<th>Energy Scale and Res.</th>
<th>Charge Misld.</th>
<th>Efficiency Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 &lt; (</td>
<td>\eta</td>
<td>) &lt; 0.2</td>
<td>1.8</td>
<td>0.6</td>
</tr>
<tr>
<td>0.2 &lt; (</td>
<td>\eta</td>
<td>) &lt; 0.4</td>
<td>2.5</td>
<td>0.6</td>
</tr>
<tr>
<td>0.4 &lt; (</td>
<td>\eta</td>
<td>) &lt; 0.6</td>
<td>2.7</td>
<td>0.3</td>
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<td>\eta</td>
<td>) &lt; 0.8</td>
<td>2.5</td>
<td>0.3</td>
</tr>
<tr>
<td>0.8 &lt; (</td>
<td>\eta</td>
<td>) &lt; 1.0</td>
<td>1.9</td>
<td>0.6</td>
</tr>
<tr>
<td>1.0 &lt; (</td>
<td>\eta</td>
<td>) &lt; 1.2</td>
<td>2.4</td>
<td>1.0</td>
</tr>
<tr>
<td>1.2 &lt; (</td>
<td>\eta</td>
<td>) &lt; 1.4</td>
<td>2.6</td>
<td>0.8</td>
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<td>1.6 &lt; (</td>
<td>\eta</td>
<td>) &lt; 1.8</td>
<td>3.1</td>
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<tr>
<td>1.8 &lt; (</td>
<td>\eta</td>
<td>) &lt; 2.0</td>
<td>2.0</td>
<td>1.6</td>
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<tr>
<td>2.0 &lt; (</td>
<td>\eta</td>
<td>) &lt; 2.2</td>
<td>2.0</td>
<td>2.6</td>
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<tr>
<td>2.2 &lt; (</td>
<td>\eta</td>
<td>) &lt; 2.4</td>
<td>2.9</td>
<td>2.4</td>
</tr>
</tbody>
</table>

\(p_T(e) > 35 \text{ GeV}\)

\(W \rightarrow e\nu\)

CMS 840 pb\(^{-1}\) at \(\sqrt{s} = 7 \text{ TeV}\)
### Muon Charge Asymm. Syst. Err

- **Units in Percent**

<table>
<thead>
<tr>
<th>$\eta$</th>
<th>$0.0$-$0.2$</th>
<th>$0.2$-$0.4$</th>
<th>$0.4$-$0.6$</th>
<th>$0.6$-$0.8$</th>
<th>$0.8$-$1.0$</th>
<th>$1.0$-$1.2$</th>
<th>$1.2$-$1.4$</th>
<th>$1.4$-$1.6$</th>
<th>$1.6$-$1.85$</th>
<th>$1.85$-$2.1$</th>
<th>$2.1$-$2.4$</th>
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<tbody>
<tr>
<td>$p_T &gt; 25$ GeV</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stat. err.</td>
<td>0.096</td>
<td>0.098</td>
<td>0.094</td>
<td>0.093</td>
<td>0.098</td>
<td>0.099</td>
<td>0.099</td>
<td>0.099</td>
<td>0.099</td>
<td>0.093</td>
<td>0.094</td>
</tr>
<tr>
<td>Eff.</td>
<td>0.111</td>
<td>0.133</td>
<td>0.121</td>
<td>0.122</td>
<td>0.170</td>
<td>0.175</td>
<td>0.170</td>
<td>0.168</td>
<td>0.165</td>
<td>0.175</td>
<td>0.268</td>
</tr>
<tr>
<td>QCD +/-</td>
<td>0.120</td>
<td>0.113</td>
<td>0.110</td>
<td>0.105</td>
<td>0.102</td>
<td>0.103</td>
<td>0.097</td>
<td>0.104</td>
<td>0.108</td>
<td>0.094</td>
<td>0.183</td>
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<tr>
<td>QCD shape</td>
<td>0.070</td>
<td>0.065</td>
<td>0.065</td>
<td>0.067</td>
<td>0.068</td>
<td>0.069</td>
<td>0.078</td>
<td>0.082</td>
<td>0.092</td>
<td>0.083</td>
<td>0.087</td>
</tr>
<tr>
<td>Muon scale</td>
<td>0.045</td>
<td>0.050</td>
<td>0.050</td>
<td>0.049</td>
<td>0.051</td>
<td>0.054</td>
<td>0.054</td>
<td>0.058</td>
<td>0.054</td>
<td>0.054</td>
<td>0.055</td>
</tr>
<tr>
<td>PDF</td>
<td>0.028</td>
<td>0.026</td>
<td>0.023</td>
<td>0.025</td>
<td>0.018</td>
<td>0.020</td>
<td>0.027</td>
<td>0.031</td>
<td>0.042</td>
<td>0.050</td>
<td>0.069</td>
</tr>
<tr>
<td>Drell-Yan bkg.</td>
<td>0.002</td>
<td>0.001</td>
<td>0.002</td>
<td>0.003</td>
<td>0.000</td>
<td>0.007</td>
<td>0.001</td>
<td>0.013</td>
<td>0.019</td>
<td>0.038</td>
<td>0.046</td>
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<tr>
<td>$E_T \Phi$ modul.</td>
<td>0.011</td>
<td>0.009</td>
<td>0.033</td>
<td>0.012</td>
<td>0.029</td>
<td>0.034</td>
<td>0.044</td>
<td>0.045</td>
<td>0.055</td>
<td>0.049</td>
<td>0.038</td>
</tr>
<tr>
<td>Recoil</td>
<td>0.003</td>
<td>0.003</td>
<td>0.003</td>
<td>0.003</td>
<td>0.003</td>
<td>0.003</td>
<td>0.003</td>
<td>0.003</td>
<td>0.003</td>
<td>0.003</td>
<td>0.003</td>
</tr>
<tr>
<td>PU</td>
<td>0.017</td>
<td>0.013</td>
<td>0.011</td>
<td>0.005</td>
<td>0.014</td>
<td>0.025</td>
<td>0.022</td>
<td>0.031</td>
<td>0.019</td>
<td>0.028</td>
<td>0.000</td>
</tr>
<tr>
<td>Luminosity</td>
<td>0.002</td>
<td>0.003</td>
<td>0.004</td>
<td>0.004</td>
<td>0.006</td>
<td>0.009</td>
<td>0.012</td>
<td>0.017</td>
<td>0.024</td>
<td>0.033</td>
<td>0.040</td>
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<tr>
<td>$t\bar{t}$ bkg.</td>
<td>0.012</td>
<td>0.013</td>
<td>0.012</td>
<td>0.011</td>
<td>0.012</td>
<td>0.011</td>
<td>0.010</td>
<td>0.009</td>
<td>0.008</td>
<td>0.007</td>
<td>0.005</td>
</tr>
<tr>
<td>$W \rightarrow \tau\nu$ bkg.</td>
<td>0.026</td>
<td>0.026</td>
<td>0.026</td>
<td>0.026</td>
<td>0.026</td>
<td>0.025</td>
<td>0.025</td>
<td>0.025</td>
<td>0.025</td>
<td>0.025</td>
<td>0.024</td>
</tr>
<tr>
<td>$W q_T$</td>
<td>0.003</td>
<td>0.004</td>
<td>0.004</td>
<td>0.005</td>
<td>0.008</td>
<td>0.011</td>
<td>0.008</td>
<td>0.009</td>
<td>0.006</td>
<td>0.003</td>
<td>0.000</td>
</tr>
<tr>
<td>Tot. sys.</td>
<td>0.189</td>
<td>0.197</td>
<td>0.190</td>
<td>0.186</td>
<td>0.221</td>
<td>0.229</td>
<td>0.227</td>
<td>0.233</td>
<td>0.239</td>
<td>0.241</td>
<td>0.355</td>
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<tr>
<td>Tot. err.</td>
<td>0.212</td>
<td>0.220</td>
<td>0.212</td>
<td>0.208</td>
<td>0.242</td>
<td>0.249</td>
<td>0.248</td>
<td>0.253</td>
<td>0.256</td>
<td>0.259</td>
<td>0.371</td>
</tr>
</tbody>
</table>

<p>| $p_T &gt; 35$ GeV |
| Stat.err. | 0.116 | 0.119 | 0.114 | 0.114 | 0.124 | 0.121 | 0.123 | 0.123 | 0.118 | 0.123 | 0.141 |
| Eff. | 0.120 | 0.138 | 0.116 | 0.107 | 0.159 | 0.164 | 0.171 | 0.176 | 0.186 | 0.194 | 0.325 |
| QCD +/- | 0.151 | 0.138 | 0.135 | 0.128 | 0.133 | 0.118 | 0.116 | 0.122 | 0.137 | 0.120 | 0.168 |
| QCD shape | 0.030 | 0.025 | 0.017 | 0.023 | 0.024 | 0.022 | 0.018 | 0.017 | 0.031 | 0.031 | 0.037 |
| Muon scale | 0.122 | 0.135 | 0.134 | 0.141 | 0.146 | 0.154 | 0.162 | 0.170 | 0.161 | 0.172 | 0.189 |
| PDF | 0.008 | 0.008 | 0.007 | 0.011 | 0.012 | 0.010 | 0.017 | 0.022 | 0.031 | 0.040 | 0.058 |
| Drell-Yan bkg. | 0.010 | 0.009 | 0.009 | 0.003 | 0.006 | 0.010 | 0.008 | 0.009 | 0.009 | 0.020 | 0.040 |
| $E_T \Phi$ modul. | 0.002 | 0.009 | 0.010 | 0.003 | 0.008 | 0.028 | 0.037 | 0.035 | 0.022 | 0.022 | 0.001 |
| Recoil | 0.005 | 0.006 | 0.005 | 0.004 | 0.005 | 0.004 | 0.005 | 0.004 | 0.004 | 0.006 | 0.008 |
| PU | 0.015 | 0.003 | 0.005 | 0.018 | 0.019 | 0.002 | 0.007 | 0.003 | 0.013 | 0.014 | 0.032 |
| Luminosity | 0.001 | 0.002 | 0.000 | 0.000 | 0.000 | 0.001 | 0.004 | 0.010 | 0.016 | 0.025 | 0.039 |
| $t\bar{t}$ bkg. | 0.011 | 0.013 | 0.012 | 0.011 | 0.011 | 0.010 | 0.010 | 0.009 | 0.007 | 0.006 | 0.005 |
| $W \rightarrow \tau\nu$ bkg. | 0.013 | 0.012 | 0.013 | 0.012 | 0.012 | 0.012 | 0.011 | 0.012 | 0.011 | 0.011 | 0.011 |
| $W q_T$ | 0.004 | 0.002 | 0.004 | 0.004 | 0.007 | 0.005 | 0.006 | 0.009 | 0.009 | 0.001 | 0.014 |
| Tot. sys. | 0.232 | 0.240 | 0.225 | 0.221 | 0.257 | 0.258 | 0.267 | 0.277 | 0.287 | 0.294 | 0.423 |
| Tot. err. | 0.260 | 0.268 | 0.252 | 0.248 | 0.285 | 0.285 | 0.294 | 0.303 | 0.311 | 0.318 | 0.446 |</p>
<table>
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<tr>
<th>unit (%)</th>
<th>Low mass</th>
<th>Peak region</th>
<th>High mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luminosity</td>
<td>2.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy Scale corr.</td>
<td>--</td>
<td>&lt;2.5</td>
<td>--</td>
</tr>
<tr>
<td>Backgrounds</td>
<td>&lt;4</td>
<td>&lt;7</td>
<td>0.1</td>
</tr>
<tr>
<td>Unfolding</td>
<td>&lt;0.5</td>
<td>2-3</td>
<td>3</td>
</tr>
<tr>
<td>Efficiency scale</td>
<td>2</td>
<td>2</td>
<td>&lt;1.5</td>
</tr>
<tr>
<td>FSR correction</td>
<td>0.5</td>
<td>&lt;3</td>
<td>1.5</td>
</tr>
<tr>
<td>Modeling(MC NNLO rew.)</td>
<td>10</td>
<td>&lt;0.5</td>
<td></td>
</tr>
<tr>
<td>PDF</td>
<td>2.5-3</td>
<td>2-3</td>
<td>2-2.5</td>
</tr>
</tbody>
</table>
DY $1/\sigma \frac{d^2\sigma}{dMdY}$ Systematic Err

- Backgrounds
  - 4-5% off the Z-peak, increasing up to 15% in the last mass bin
- Momentum scale correction and unfolding
  - within 1%
- Efficiency scale factors
  - 1.5-3%, up to 10% in the first mass bin
- FSR correction
  - within 1%, 2-6% in the FSR region growing at high rapidity
W/Z cross section Uncertainties

- **Theory Uncertainty**
  - determined as function of W boson pT, following the strength of the strong coupling: Non-perturbative, Resummed, Perturbative

- **Affect of higher order perturbative terms**
  - Calculate FEWZ (NNLO) Acceptance

- **Affect of NNLO+higher order resummed terms**
  - Compare Acc. difference for Resbos vs. Powheg
  - Resbos is an NNLO+NNNLL calculation

- **PDF uncertainties comparing NNPDF/MSTW/CTEQ: dominant theoretical uncertainty**

- **FSR uncertainties+O(α) EWK uncertainties**
  - Compare Horace w/ and w/o O(α) EWK corrections
  - Compare Horace FSR w/ Pythia FSR

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### Source Table

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<tr>
<th>Source</th>
<th>W^+</th>
<th>W^-</th>
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<th>W^+ / W^-</th>
<th>Z</th>
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### Source Table (continued)

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DY pT differential xsection Error

CMS Preliminary

\[ \int 18.4 \text{ pb}^{-1} \text{ at } \sqrt{s} = 8 \text{ TeV} \]

- **Dotted line**: Statistical uncertainty
- **Red line**: Systematic uncertainty

![Graph showing relative error on differential xsection vs. qT](image)