Search for dilepton and lepton+$E_{T\text{miss}}$ resonances at high mass with ATLAS

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Motivation

- The unification of fundamental interactions as well as some SM deficiencies have motivated the introduction of extended gauge symmetries, featured by several possible extensions of the SM:
  - GUTs
  - Superstring-inspired E6 models
  - Kaluza-Klein model
  - etc...
- $Z'$ and $W'$ are the generic names of the new heavy gauge bosons introduced in those extensions
- ATLAS has studied the dilepton and lepton+$E_{T\text{miss}}$ signatures to search for these particles
ATLAS Detector

- High energy electrons are detected by LAr calorimeter, and identified using shower shapes, track matching, etc...
  - See talk by O. Arnaez

- Muons are detected by the Muon System, and their momenta obtained by a combination with the Inner Detector information
  - See talk by D. Lopez Mateos

- Expected electron energy resolution is
  - ~0.6% for E=500GeV
  - ~0.5% for E=1000GeV

- Muon transverse momentum ($p_T$) resolution is:
  - ~6% for $p_T=500GeV$
  - ~11% for $p_T=1000GeV$
Dileptons
Introduction

- The dominant $Z'$ production process is $q\bar{q} \rightarrow Z'$
- The neutral gauge bosons are produced via the Drell-Yan process: $pp \rightarrow Z' \rightarrow l^+l^- (l=e, \mu)$, clean signature
- The differential cross-section for the lepton-pair production depends on:
  - Center of mass energy ($\sqrt{s'}$)
  - $Z'$ couplings
  - $Z'$ Invariant mass $M$, its rapidity $y$
  - The c.m. angle $\theta^*$
- If a $Z'$ is discovered we will be able to measure:
  - Its mass $M_{Z'}$, decay width $\Gamma_{Z'}$
  - The total cross-section $\sigma_{Z'}$
  - Its spin and its branching ratios

\[ \frac{d\sigma}{dMdyd(\cos\theta^*)} = \frac{Mx_Ax_B}{48\pi} \left[ \sum_q \left[ f_q^A(x_A)f_{\bar{q}}^B(x_B) + f_q^A(x_A)f_{\bar{q}}^B(x_B) \right] S_q(1 + \cos^2\theta^*) \right. \]
\[ \left. + \sum_q \left[ f_q^A(x_A)f_{\bar{q}}^B(x_B) - f_q^A(x_A)f_{\bar{q}}^B(x_B) \right] 2A_q \cos\theta^* \right] \]

- $S_q$ and $A_q$ symmetric and antisymmetric contributions to the cross-section in $\cos\theta^*$ ($\theta^*$ is the c.m. angle between negative lepton with respect to the quark direction)
- $f^A$ and $f^B$ are parton densities depending on the momentum fractions of the quarks

Lepton Identification

- Efficiency of electron identification at 1 TeV $Z' \rightarrow e^+e^-$ for clusters with $p_T > 50$ GeV and $|\eta| < 2.5$
  - loose selection: very high efficiency (~80%)
  - medium selection: better rejections against neutral pions (~63%)

- Muon reconstruction efficiency at 1 TeV $Z'$ is $(95 \pm 0.2)$% requiring $p_T > 30$ GeV and $|\eta| < 2.5$
Backgrounds

- Background contribution before and after the selection criteria to the $e^+e^-$ invariant mass:
  - $|\eta|<2.5$, at least 1 electron with $p_T>65\text{GeV}$
  - Rejection factor $R_{e\text{-jet}}=10^4$($R_{e\text{-}\gamma}=10$) was applied for each electron-candidate leg from jet (photon)

- The rejection factors in the case of muons are higher than the electrons and the reducible backgrounds are lower

- After selection, Drell-Yan is the main background
Several benchmark $Z'\rightarrow l^+l^-$ models have been analyzed in ATLAS.

- Electron channel:
  - Two "loose" electrons with $|\eta|<2.5$ and at least one electron with $p_T>65\text{GeV}$
  - Event triggered, opposite charges
  - $K$-factor $\approx 1.26$ is applying to signal and Drell-Yan background as well.
  - Uncertainties: energy resolution (5% effect on the luminosity for $5\sigma$) and electron energy scale (2.5%)

- Muon channel:
  - Two combined muons (inner detector and muon spectrometer), at least one with $p_T>30\text{GeV}$ and $|\eta|<2.5$
  - Event triggered, opposite charges
  - Main uncertainty comes from misalignment of the muon spectrometer (5%)

- Theoretical uncertainties (Renormalization/factorization scales, PDF's, non perturbative form factor): $\pm 8.5\%$ at $1\text{TeV} \ Z'$ and $\pm 14\%$ at $3\text{TeV} \ Z'$
$Z' \rightarrow \tau\tau$

- $Z' \rightarrow \tau\tau$ combining all 3 final states: hadron-hadron, lepton-hadron and lepton-lepton
  - Events selected using a combined tau and missing $E_T$ trigger
  - Collinear approximation: $m_{\text{col}} = m_{\tau\tau}^{\text{vis}} / (x_{\tau_1} \cdot x_{\tau_2})^{\frac{1}{2}}$
    - $m_{\tau\tau}^{\text{vis}}$: inv. mass of the 2 tau visible decay products
    - $x_{\tau_1}$ and $x_{\tau_2}$ are the fractions of the tau momenta carried by the visible decay daughters
  - Backgrounds: Drell-Yan, Z+jets, ttbar and QCD
If a high-mass dilepton resonance is discovered, then we will be able to measure its spin in order to distinguish if it is a $Z'$ (spin 1) or Graviton (spin 2).

- 1TeV graviton and coupling constant $k/M_{pl} = 0.02$ (k curvature scale)
  - $p_T > 65\text{GeV}$, back-to-back loose electrons, no charge requirement
  - K-factors $\simeq 1.6$ is taking into account for both signal and Drell-Yan background
  - Drell-Yan Background fitted by exponential function
ATLAS Discovery potential at 14TeV

- 5σ luminosities for the $Z'$ models in the electron channel as a function of its true mass:
  
  - Less than 100pb$^{-1}$ are needed to discover a 1TeV $Z'$

- Systematic uncertainties included for $Z'_{\chi}$

CDF exclusion limits at 95% C.L. on $Z'$ Sequential Standard Model (SSM) in electron channel:

$$M_{Z'}^{(SSM)} < 966\text{GeV}, \text{ arXiv: hep-ph/0810.2059v2}$$
ATLAS Discovery potential at 14TeV

- The 1-CL$_b$ as a function of int. luminosity for 1TeV Z$'_\text{SSM}$ in the muon channel:
  - 5σ luminosity between 15pb$^{-1}$ and 25pb$^{-1}$

- Largest systematic uncertainty: misalignment of the muon spectrometer

- The significance as a function of int. luminosity for 3TeV Z$'_\text{SSM}$ $\rightarrow \mu^+\mu^-$
  - With a 3.4 fb$^{-1}$ ATLAS can reach 3TeV Z$'$

CDF is excluding Z$'_\text{SSM}$ $\rightarrow \mu^+\mu^-$ masses below 1030GeV, arXiv: hep-ph/0811.0053v1
ATLAS Discovery potential at 14TeV

- The Z' in tau channel, the luminosity required for 3σ evidence or 5σ discovery (combining all the channels) as a function of the true Z' mass including 20% of uncertainty
  - The most dominant systematic uncertainties on the signal are coming from the uncertainty on the luminosity (±18%) and the second is the hadronic tau energy scale (the lowest mass energy is affected by ±10%)
  - With 100pb⁻¹ ATLAS could observe it in a relatively low mass region
The 5σ discovery and 3σ evidence reach in cross-section and $k/M_{Pl}$ coupling constant as a function of graviton mass.

With $1fb^{-1}$ of data, a graviton with $900GeV$ and $k/M_{Pl}=0.01$ can be discovered.

- Systematic uncertainties (luminosity, energy scale, energy resolution, electron identification efficiency and Drell-Yan background uncertainties): between ±10% and 15%
Lepton + Etmiss
Introduction

- Right-handed charged heavy boson corresponds to a symmetry spontaneously broken down to the left-right symmetry

- The differential cross-section of $W'$ depends on:
  - Center of mass energy ($\sqrt{s}$)
  - Its couplings, its mass
  - Its rapidity and c.m. angle $\theta$

- The observation of the $W'$ is based on the detection of an excess of a single lepton at high $p_T$ above background, with a sharp upper edge (transverse mass)

\[
\frac{d\sigma}{d\tau dy dz} = K \frac{G_F^2 M_W^4}{48\pi} \sum_{qq'} |V_{qq'}|^2 \left[ S G_{qq'}^+ (1 + z^2) + 2 A G_{qq'}^- z \right]
\]

T. G. Rizzo, JHEP 0705 (2007)

- The coupling strengths for leptons and quarks, the helicity factors and the square of the total collision energy are implicitly in $S$ and $A$
- $V_{qq'}$ is the CKM(unit) matrix; $q(q')$ is a $u(d)$-type quark
- $G_{qq'}^{\pm}$ are the combinations of the parton distribution functions.
- $z$ in the $\cos\theta$, the scattering angle in the c.m. frame defined as that between the incoming $u$-type quark and the outgoing neutrino.
- $\tau = M^2/s$, where $M^2$ lepton-pair invariant mass and $\sqrt{s}=cme$
Muon Reconstruction

- Efficiency of the muon reconstruction as a function of $p_T$ from fully simulated $W'$
  - 93.6% is the reconstruction efficiency for 1TeV $W'$ and 92.4% for 2TeV $W'$
  - Systematic errors on the momentum scale of the muons can arise for instance due to the non-perfect knowledge of the magnetic field, to take into account such effect, a variation of $\pm 1\%$ is applied to the $p_T$ of the reconstructed

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Missing Energy Resolution

- Since the final state of the $W'$ includes a neutrino, it is necessary to understand the Missing Transverse Energy (MET)

- The (average) resolutions of MET for 1TeV and 2TeV $W'$ events that contain one high $p_T$ muon are 18GeV and 25GeV, respectively

- For the electron-neutrino case, 10GeV for 1TeV $W'$ and 14GeV for 2TeV $W'$

\[ W'\rightarrow \mu \nu \]

\[ W'\rightarrow e\nu \]
Transverse Mass

\[ m_T = \sqrt{2p_T E_T (1 - \cos(\Delta \phi_l, E_T))} \]

- **Event selection:**
  - Preselection: \( p_T > 50 \text{GeV}, |\eta| < 2.5 \) and MET > 50 GeV
  - Isolation:
    - Tracking: Sum \( p_T \) track in \( \Delta R \) cone around the lepton
  - Lepton fraction: fraction of the energy that can be attributed to leptons in an event

- **Systematic uncertainties:**
  - Theoretical uncertainties (Renormalization/factorization scales and PDF's): ±8% uncertainty on K-factor (1.37) for all true W' masses
  - Experimental uncertainties (lepton reconstruction, jet reconstruction and missing energy): ±3% the luminosity for 5σ is affected for 1TeV W' in electron and muon channel

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ATLAS discovery potential at 14TeV

- Integrated luminosity needed to have a $5\sigma$ discovery as a function of the $W'$ mass
- With 10pb$^{-1}$ of data in ATLAS it would be possible to discover this type of boson if its mass is not far above the current limit
- With 1fb$^{-1}$, a 3TeV $W'$ can be reached in ATLAS

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\textit{D0 is excluding at 95\%C.L. $W'_{SSM} \rightarrow ev$ masses below 1TeV,}

\textit{The D0 Collaboration, Phys. Rev. Lett. 100, (2008)}
Summary

- The data in LHC is coming soon and ATLAS is ready to explore and discover the new physics behind it.
- In this talk we presented the discovery potential of searches for dilepton and lepton+Jetmiss signatures.
- Several values of the masses for new particles from benchmark models were studied.
- Particles predicted in several models would be within reach for luminosities as low as O(10/pb). LHC is expected to deliver 200-300pb\(^1\) at 10TeV in 2010.
BACKUP
Z': Estimation from the theorists

- 5σ discovery as a function of the integrated luminosity for Z' models at 10TeV LHC center of mass energy:

CDF Limits

CDF Limits

- Present limits on Z' Sequential Standard Model (SSM) searches at 95% C.L.:
  - $Z'\rightarrow\mu^+\mu^-$: $M_{Z'(SSM)}>1030\text{GeV}$ \textit{arXiv:hep-ph/0811.0053v1}
$Z'_\chi \rightarrow ee$

- Integrated luminosity needed for a $5\sigma$ discovery combining all systematic uncertainties that we have mentioned

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**Figure**: Integrated luminosity ($L$) in units of $fb^{-1}$ as a function of the mass ($M_{Z'}$) in GeV. The green line represents the systematic uncertainty, while the red line indicates the expected signal. The data is from the ATLAS experiment. The graph shows a logarithmic scale for both the luminosity and the mass, with a linear increase in luminosity with mass.
**Z’: Results**

**Z’->e^+e^- analysis: Cross-section in fb^{-1}**

<table>
<thead>
<tr>
<th>Selection</th>
<th>Signal at 1 TeV</th>
<th>DY at 1 TeV</th>
<th>Signal at 2 TeV</th>
<th>DY at 2 TeV</th>
<th>Signal at 3 TeV</th>
<th>DY at 3 TeV</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 generated e^\pm,</td>
<td>\eta</td>
<td>&lt; 2.5</td>
<td>347.</td>
<td>3.56</td>
<td>14.7</td>
<td>0.16</td>
</tr>
<tr>
<td>2 clusters with a track</td>
<td>201.</td>
<td>2.06</td>
<td>8.0</td>
<td>0.09</td>
<td>0.62</td>
<td>0.009</td>
</tr>
<tr>
<td>2 loose electrons</td>
<td>190.</td>
<td>1.96</td>
<td>7.2</td>
<td>0.08</td>
<td>0.52</td>
<td>0.008</td>
</tr>
<tr>
<td>At least one $p_T &gt; 65$ GeV</td>
<td>190.</td>
<td>1.96</td>
<td>7.2</td>
<td>0.08</td>
<td>0.52</td>
<td>0.008</td>
</tr>
<tr>
<td>Event triggered</td>
<td>173.</td>
<td>1.77</td>
<td>6.6</td>
<td>0.07</td>
<td>0.47</td>
<td>0.007</td>
</tr>
<tr>
<td>2 opposite charges</td>
<td>166.</td>
<td>1.70</td>
<td>6.2</td>
<td>0.07</td>
<td>0.43</td>
<td>0.007</td>
</tr>
</tbody>
</table>

**Z’->μ^+μ^- analysis: Cross-section in fb^{-1}**

<table>
<thead>
<tr>
<th>Sample</th>
<th>$Z_SSM$ (1 TeV)</th>
<th>$Z_X$ (1 TeV)</th>
<th>Drell-Yan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generated</td>
<td>508.6</td>
<td>380.6</td>
<td>13.5</td>
</tr>
<tr>
<td>$</td>
<td>\eta</td>
<td>\leq 2.5$</td>
<td>366.8</td>
</tr>
<tr>
<td>$p_T \geq 30$ GeV</td>
<td>364.0</td>
<td>270.1</td>
<td>10.7</td>
</tr>
<tr>
<td>Muon identification</td>
<td>342.3</td>
<td>256.0</td>
<td>10.0</td>
</tr>
<tr>
<td>Trigger</td>
<td>325.2</td>
<td>243.2</td>
<td>9.5</td>
</tr>
<tr>
<td>Opposite charge</td>
<td>324.8</td>
<td>243.0</td>
<td>9.5</td>
</tr>
</tbody>
</table>
Graviton

G→ee: natural width ($\Gamma_G$), Gaussian width after detector effects ($\sigma_m$) and leading order cross-section.

<table>
<thead>
<tr>
<th>Model Parameters</th>
<th>$\Gamma_G$ [GeV]</th>
<th>$\sigma_m$ [GeV]</th>
<th>$\sigma \cdot BR(G \rightarrow e^+e^-)$ [fb]</th>
</tr>
</thead>
<tbody>
<tr>
<td>$m_G$ 500 GeV</td>
<td>0.08</td>
<td>4.6</td>
<td>187.4</td>
</tr>
<tr>
<td>$m_G$ 750 GeV</td>
<td>0.10</td>
<td>6.4</td>
<td>27.7</td>
</tr>
<tr>
<td>$m_G$ 1.0 TeV</td>
<td>0.57</td>
<td>7.9</td>
<td>26.0</td>
</tr>
<tr>
<td>$m_G$ 1.2 TeV</td>
<td>1.62</td>
<td>10.3</td>
<td>22.4</td>
</tr>
<tr>
<td>$m_G$ 1.3 TeV</td>
<td>2.98</td>
<td>11.4</td>
<td>25.3</td>
</tr>
<tr>
<td>$m_G$ 1.4 TeV</td>
<td>5.02</td>
<td>13.1</td>
<td>26.8</td>
</tr>
</tbody>
</table>

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Z': NLO Corrections

- NLO electroweak corrections in the high-mass region for Standard Model electron and muon pair production at the LHC

- Mass (left) and transverse-momentum (right) spectra after matching the NLO corrections to join resummation with CTQ6M (full) and MRST 2004 NLO (dashed) parton densities
W'->e\nu: D0 Limits

- Limits at 95% C.L. on W' search:
  - D0: $M_{W'}^{SSM} > 1$TeV, *The D0 Collaboration, Phys. Rev. Lett. 100, (2008)*

\[
\sigma_{W'} \times B(W' \rightarrow e\nu) [fb] \text{ at 95% CL}
\]

D0, 1 fb$^{-1}$
### MC samples used for \( W' \) analysis at 14TeV

<table>
<thead>
<tr>
<th>Process</th>
<th>Generator</th>
<th>( \sigma \times BR ) [fb]</th>
<th>Comments</th>
<th>Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 TeV ( W' \to \ell \nu )</td>
<td>PYTHIA</td>
<td>9430</td>
<td>( \sqrt{s'} &gt; 300 ) GeV</td>
<td>30K</td>
</tr>
<tr>
<td>2 TeV ( W' \to \ell \nu )</td>
<td>PYTHIA</td>
<td>437</td>
<td>( \sqrt{s'} &gt; 300 ) GeV</td>
<td>30K</td>
</tr>
<tr>
<td>3 TeV ( W' \to \ell \nu )</td>
<td>PYTHIA</td>
<td>54</td>
<td>( \sqrt{s'} &gt; 300 ) GeV</td>
<td>10K</td>
</tr>
<tr>
<td>Standard Model ( W \to \ell \nu )</td>
<td>PYTHIA</td>
<td>18721.1</td>
<td>200 GeV &lt; ( m_W ) &lt; 500 GeV</td>
<td>20K</td>
</tr>
<tr>
<td>Standard Model ( W \to \ell \nu )</td>
<td>PYTHIA</td>
<td>708.26</td>
<td>( m_W &gt; 500 ) GeV</td>
<td>20K</td>
</tr>
<tr>
<td>( t\bar{t} )</td>
<td>MC@NLO</td>
<td>452000</td>
<td></td>
<td>340K</td>
</tr>
<tr>
<td>Dijet J0</td>
<td>PYTHIA</td>
<td>( 1.76 \times 10^{13} )</td>
<td>( p_T = 8 ) – ( 17 ) GeV</td>
<td>380K</td>
</tr>
<tr>
<td>Dijet J1</td>
<td>PYTHIA</td>
<td>( 1.38 \times 10^{12} )</td>
<td>( p_T = 17 ) – ( 35 ) GeV</td>
<td>380K</td>
</tr>
<tr>
<td>Dijet J2</td>
<td>PYTHIA</td>
<td>( 9.33 \times 10^{10} )</td>
<td>( p_T = 35 ) – ( 70 ) GeV</td>
<td>390K</td>
</tr>
<tr>
<td>Dijet J3</td>
<td>PYTHIA</td>
<td>( 5.88 \times 10^{9} )</td>
<td>( p_T = 70 ) – ( 140 ) GeV</td>
<td>380K</td>
</tr>
<tr>
<td>Dijet J4</td>
<td>PYTHIA</td>
<td>( 3.08 \times 10^{8} )</td>
<td>( p_T = 140 ) – ( 280 ) GeV</td>
<td>390K</td>
</tr>
<tr>
<td>Dijet J5</td>
<td>PYTHIA</td>
<td>( 1.25 \times 10^{7} )</td>
<td>( p_T = 280 ) – ( 560 ) GeV</td>
<td>370K</td>
</tr>
<tr>
<td>Dijet J6</td>
<td>PYTHIA</td>
<td>( 3.60 \times 10^{5} )</td>
<td>( p_T = 560 ) – ( 1120 ) GeV</td>
<td>380K</td>
</tr>
<tr>
<td>Dijet J7</td>
<td>PYTHIA</td>
<td>( 5.71 \times 10^{3} )</td>
<td>( p_T = 1120 ) – ( 2240 ) GeV</td>
<td>430K</td>
</tr>
</tbody>
</table>
Cross-section for signal and background: electron mode

<table>
<thead>
<tr>
<th>Requirement</th>
<th>$\sigma$ [pb]</th>
<th>$W'$ (1 TeV)</th>
<th>$W'$ (2 TeV)</th>
<th>$W_{tail}$</th>
<th>$\tilde{t}\tilde{t}$</th>
<th>Dijets[1-7]</th>
</tr>
</thead>
<tbody>
<tr>
<td>(No requirement)</td>
<td>4.99</td>
<td>0.231</td>
<td>10.28</td>
<td>452</td>
<td>$1.91 \times 10^{10}$</td>
<td></td>
</tr>
<tr>
<td>Preselection</td>
<td>3.67±0.04</td>
<td>0.160±0.002</td>
<td>6.80±0.06</td>
<td>150.57±0.40</td>
<td>$(13.6±0.2) \times 10^{6}$</td>
<td></td>
</tr>
<tr>
<td>$p_T &gt; 50$ GeV</td>
<td>3.43±0.04</td>
<td>0.150±0.002</td>
<td>5.53±0.05</td>
<td>51.13±0.23</td>
<td>$(7.23±0.6) \times 10^{3}$</td>
<td></td>
</tr>
<tr>
<td>$\slashed{E}_T &gt; 50$ GeV</td>
<td>3.40±0.04</td>
<td>0.149±0.002</td>
<td>5.19±0.05</td>
<td>25.78±0.16</td>
<td>45.33±16.65</td>
<td></td>
</tr>
<tr>
<td>Isolation</td>
<td>3.36±0.04</td>
<td>0.148±0.002</td>
<td>5.01±0.05</td>
<td>23.30±0.16</td>
<td>0.65±0.13</td>
<td></td>
</tr>
<tr>
<td>Lepton fraction</td>
<td>3.25±0.04</td>
<td>0.145±0.002</td>
<td>4.10±0.04</td>
<td>0.50±0.02</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>$m_T &gt; 700$ GeV</td>
<td>1.86±0.03</td>
<td>0.0317±0.0008</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>$m_T &gt; 1400$ GeV</td>
<td>0.0740±0.001</td>
<td>0.0014±0.0002</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Cross-section for signal and background: muon mode

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<tr>
<th>Requirement</th>
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<th>$W'$ (1 TeV)</th>
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<th>$\tilde{t}\tilde{t}$</th>
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<td>0.231</td>
<td>10.28</td>
<td>452</td>
<td>$1.91 \times 10^{10}$</td>
<td></td>
</tr>
<tr>
<td>Preselection</td>
<td>4.28±0.05</td>
<td>0.199±0.002</td>
<td>7.77±0.06</td>
<td>205.30±0.46</td>
<td>$(11.2±0.19) \times 10^{6}$</td>
<td></td>
</tr>
<tr>
<td>$p_T &gt; 50$ GeV</td>
<td>4.03±0.04</td>
<td>0.187±0.002</td>
<td>6.40±0.06</td>
<td>61.71±0.25</td>
<td>$(1.24±0.26) \times 10^{3}$</td>
<td></td>
</tr>
<tr>
<td>$\slashed{E}_T &gt; 50$ GeV</td>
<td>4.00±0.04</td>
<td>0.186±0.002</td>
<td>6.04±0.05</td>
<td>31.34±0.18</td>
<td>74.32±23.28</td>
<td></td>
</tr>
<tr>
<td>Isolation</td>
<td>3.95±0.04</td>
<td>0.185±0.002</td>
<td>5.99±0.05</td>
<td>28.70±0.17</td>
<td>1.00±0.82</td>
<td></td>
</tr>
<tr>
<td>Lepton fraction</td>
<td>3.81±0.04</td>
<td>0.181±0.002</td>
<td>4.85±0.05</td>
<td>0.64±0.03</td>
<td>$(1.96±1.38) \times 10^{-3}$</td>
<td></td>
</tr>
<tr>
<td>$m_T &gt; 700$ GeV</td>
<td>2.20±0.03</td>
<td>0.043±0.002</td>
<td>0.007±0.003</td>
<td>0.001±0.001</td>
<td>0.001±0.001</td>
<td></td>
</tr>
<tr>
<td>$m_T &gt; 1400$ GeV</td>
<td>0.094±0.0001</td>
<td>0.0031±0.0006</td>
<td>0.001±0.001</td>
<td>0.001±0.001</td>
<td>0.001±0.001</td>
<td></td>
</tr>
</tbody>
</table>
W': NLO Corrections

Integrated W' boson and W boson tail cross-section for Pythia and MC@NLO with common scale factor S=1. Integral is over the full $\eta$ range $-2.5<\eta<2.5$. The listed K-factors are the ratios of the integrated MC@NLO and Pythia cross-sections. The last two columns give the change in the MC@NLO cross-section when the common scale factor is changed by a factor of two. The statistical error in the last digit of each calculated quantity is shown in parentheses.

![Cross-section table]

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