W/Z and top at the LHC

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LHC experiments have been built for discovery

- New physics = measurement – standard model physics (background)
  - Need re-discovery of the standard model particles at the first stage of the experiment

- $W/Z$ and top are the heavy particles in the standard model
  - Measurements of these particles are good exercise for discovery
    - yesterday’s signal is today’s control sample and tomorrow’s background, in other word, bridge to New Physics
  - Let’s start with $W/Z$ and top as today’s signal

- K. Hanagaki: Higgs searches at the LHC
- A. Ishikawa: BSM physics at the LHC
• **ATLAS/CMS detectors**

• *W/Z at LHC*
  - *W → lν*: $E_T^{\text{miss}}$, $M_T$
  - *Z → ll*: invariant mass
  - *W → lν, Z → ll*: cross sections
  - *W/Z to τ*
  - *W/Z distributions with full 2010 data*
  - *W/Z + jets*

• **top at LHC**
  - top control plots
  - top cross sections

• summary
ATLAS detector overview

- length: $\sim45$ m
- diameter: $\sim22$ m
- weight: $\sim7,000$ tons
- 2 T solenoid and air-core toroids

CMS detector overview

- length: 21.6 m
- diameter: 15 m
- weight: 12,500 tons
- 3.8 T solenoid and iron return york
ATLAS detector layout

- Tracker
  - silicon tracker (pixel + strip), transition radiation tracker
- Calorimeter
  - EM: lead/LAr, HAD: steel/scintillator, copper/LAr
- Muon system
  - drift tube, cathod strip chamber, thin-gap chamber, resistive plate chamber

CMS detector layout

- Tracker
  - silicon tracker (pixel + strip)
- Calorimeter
  - EM: lead tungsten crystal, HAD: brass/steel and scintillator
- Muon system
  - drift tube, cathod strip chamber, resistive plate chamber
• ATLAS/CMS detectors

• **$W/Z$ at LHC**
  - $W \rightarrow l\nu$: $E_T^{\text{miss}}$, $M_T$
  - $Z \rightarrow ll$: invariant mass
  - $W \rightarrow l\nu$, $Z \rightarrow ll$: cross sections
  - $W/Z$ to $\tau$
  - $W/Z$ distributions with full 2010 data
  - $W/Z + \text{jets}$

• top at LHC
  - top control plots
  - top cross sections

• summary
**W/Z at LHC**

**W/Z are important for:**

- detector performance study with high-$p_T$ objects
  - lepton identification
  - $E_T^{\text{miss}}$
- test of the SM at 7 TeV
  - cross section known at NNLO
    
    \[
    \frac{\sigma_{W \rightarrow l \nu}^{\text{NNLO}}}{\sigma_{Z/\gamma^* \rightarrow ll}^{\text{NNLO}}} = 10.5 \pm 0.5 \text{ nb} \\
    \frac{\sigma_{Z/\gamma^* \rightarrow ll}^{\text{NNLO}}}{\sigma_{W \rightarrow l \nu}^{\text{NNLO}}} = 1.0 \pm 0.1 \text{ nb}
    \]
- background study for new physics searches

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**Proton - (anti)proton cross sections**

- $\sigma_{W}$
- $\sigma_{Z}$
- $\sigma_{\text{jet}}(E_T^{\text{jet}} > \sqrt{s}/20)$
- $\sigma_{\text{jet}}(E_T^{\text{jet}} > 100 \text{ GeV})$
- $\sigma_{\text{jet}}(E_T^{\text{jet}} > \sqrt{s}/4)$
- $\sigma_{\text{Higgs}}(M_H = 150 \text{ GeV})$
- $\sigma_{\text{Higgs}}(M_H = 500 \text{ GeV})$

- Tevatron
- LHC

**Events/Sec for $L = 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$**

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2011-01-06  |  **W/Z and top at the LHC**  |  T. Matsushita (Kobe)
$W \rightarrow l\nu$ event topology

- High-$p_T$ lepton
  - Cluster of energy deposit in electro-magnetic calorimeter
  - Track in muon spectrometer
- $E_T^{\text{miss}}$
- Characterised by transverse mass
  
  \[
  M_T = \sqrt{2E_T\nu E_{Tl} - 2p_{T\nu} \cdot p_{Tl}}
  \]

$Z \rightarrow ll$ event topology

- Two high-$p_T$ leptons
  - Cluster of energy deposit in electro-magnetic calorimeter
  - Track in muon spectrometer
- Characterised by invariant mass of di-lepton
• ATLAS/CMS detectors
• $W/Z$ at LHC
  • $W \rightarrow l\nu$: $E_T^{\text{miss}}$, $M_T$
  • $Z \rightarrow ll$: invariant mass
  • $W \rightarrow l\nu$, $Z \rightarrow ll$: cross sections
  • $W/Z$ to $\tau$
  • $W/Z$ distributions with full 2010 data
  • $W/Z +$ jets
• top at LHC
  • top control plots
  • top cross sections
• summary
$W \rightarrow e\nu$ candidate

CMS

CMS Experiment at LHC, CERN
Run 133874, Event 21466935
Lumi section: 301
Sat Apr 24 2010, 05:19:21 CEST

Electron $p_T = 35.6$ GeV/c
$M_{E_T} = 36.9$ GeV
$M_T = 71.1$ GeV/$c^2$
$W \rightarrow l\nu$

CMS: 2.9 pb$^{-1}$

**electron channel**

- $p_T > 20$ GeV, $|\eta| < 1.44$ or $1.57 < |\eta| < 2.5$
- unbinned likelihood fit:
  - QCD background modelled with a modified Rayleigh distribution
- fit distribution describes data well

**muon channel**

- $p_T > 20$ GeV, $|\eta| < 2.1$
- binned likelihood fit:
  - QCD background shape from data
- fit distribution describes data well
$W \rightarrow l\nu$

ATLAS: 0.3 pb$^{-1}$

electron channel

- $p_T > 20$ GeV, $|\eta| < 1.37$ or $1.52 < |\eta| < 2.47$
- $W$ MC populates in high-$E_T^{\text{miss}}$ region

muon channel

- $p_T > 20$ GeV, $|\eta| < 2.47$
- $W$ MC gives Jacobian peak in $M_T$ distribution

- without $E_T^{\text{miss}} > 25$ GeV and $M_T > 40$ GeV cuts
• ATLAS/CMS detectors

• $W/Z$ at LHC
  • $W \rightarrow l\nu$: $E_T^{\text{miss}}, M_T$
  • $Z \rightarrow ll$: invariant mass
  • $W \rightarrow l\nu, Z \rightarrow ll$: cross sections
  • $W/Z$ to $\tau$
  • $W/Z$ distributions with full 2010 data
  • $W/Z +$ jets

• top at LHC
  • top control plots
  • top cross sections

• summary
$Z \rightarrow \mu\mu$ candidate

ATLAS
Z → ll
ATLAS: 0.3 pb⁻¹

**electron channel**

- \( p_T > 20 \text{ GeV}, |\eta| < 1.37 \text{ or } 1.52 < |\eta| < 2.47 \)

**muon channel**

- \( p_T > 20 \text{ GeV}, |\eta| < 2.4 \)
- worse resolution in data taken into account in the systematics

- backgrounds are negligible and not shown
$Z \rightarrow ll$

CMS: 2.9 pb$^{-1}$

**electron channel**

- $p_T > 20$ GeV, $|\eta| < 1.44$ or 1.57
- $|\eta| < 2.5$

- backgrounds are negligible and not shown

**muon channel**

- $p_T > 20$ GeV,
- $|\eta| < 2.1$
• ATLAS/CMS detectors

• $W/Z$ at LHC
  • $W \rightarrow l\nu$: $E_T^{\text{miss}}, M_T$
  • $Z \rightarrow ll$: invariant mass
  • $W \rightarrow l\nu, Z \rightarrow ll$: cross sections
  • $W/Z$ to $\tau$
  • $W/Z$ distributions with full 2010 data
  • $W/Z + \text{jets}$

• top at LHC
  • top control plots
  • top cross sections

• summary
$W/Z$ cross sections

**ATLAS: 0.3 pb$^{-1}$**

- Measured cross sections agree with the prediction within errors (stat. + syst. + lumi.) (Theory: FEWZ with MSTW 08 NNLO PDF)
- Expected asymmetry between $W^+$ and $W^-$ confirmed
### $W/Z$ cross sections: systematics

**ATLAS: 0.3 pb$^{-1}$**

<table>
<thead>
<tr>
<th></th>
<th>$W \rightarrow e\nu$</th>
<th>$Z \rightarrow ee$</th>
<th>$W \rightarrow \mu\nu$</th>
<th>$Z \rightarrow \mu\mu$</th>
</tr>
</thead>
<tbody>
<tr>
<td>trigger eff.</td>
<td>$&lt; 0.2$</td>
<td>$&lt; 0.2$</td>
<td>1.9</td>
<td>0.7</td>
</tr>
<tr>
<td>material/reco./id</td>
<td>5.6</td>
<td>8.8</td>
<td>2.5</td>
<td>5.0</td>
</tr>
<tr>
<td>$E$ scale/res.</td>
<td>3.3</td>
<td>1.9</td>
<td>1.2</td>
<td>0.5</td>
</tr>
<tr>
<td>$E_T^{\text{miss}}$ scale/res.</td>
<td>2.0</td>
<td>-</td>
<td>2.0</td>
<td>-</td>
</tr>
<tr>
<td>problematic calo. region</td>
<td>1.4</td>
<td>2.7</td>
<td>1.0</td>
<td>2.0</td>
</tr>
<tr>
<td>pile-up</td>
<td>0.5</td>
<td>0.2</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>charge mis-id</td>
<td>0.5</td>
<td>0.5</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>FSR modelling</td>
<td>0.3</td>
<td>0.3</td>
<td>4.0</td>
<td>5.5</td>
</tr>
<tr>
<td>PDF</td>
<td>0.3</td>
<td>0.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>total</td>
<td>7.0</td>
<td>9.4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- electron have larger uncertainties due to higher sensitivity to the material effects in the inner detector.
$W/Z$ cross sections
CMS: 2.9 pb$^{-1}$

• measured cross sections agrees with the prediction within errors (stat. + syst. + lumi.) (Theory: FEWZ with MSTW 08 NNLO PDF)
• expected asymmetry between $W^+$ and $W^-$ confirmed
### $W/Z$ cross sections: systematics

CMS: $2.9 \text{ pb}^{-1}$

<table>
<thead>
<tr>
<th>Source of Uncertainty</th>
<th>$W \rightarrow e\nu$</th>
<th>$Z \rightarrow ee$</th>
<th>$W \rightarrow \mu\nu$</th>
<th>$Z \rightarrow \mu\mu$</th>
</tr>
</thead>
<tbody>
<tr>
<td>reco. &amp; id. eff.</td>
<td>3.9</td>
<td>5.9</td>
<td>1.5</td>
<td>0.5</td>
</tr>
<tr>
<td>momentum scale/res.</td>
<td>2.0</td>
<td>0.6</td>
<td>0.3</td>
<td>0.2</td>
</tr>
<tr>
<td>$E_T^{\text{miss}}$ scale/res.</td>
<td>1.8</td>
<td>-</td>
<td>0.4</td>
<td>-</td>
</tr>
<tr>
<td>bg subtraction &amp; modelling</td>
<td>1.3</td>
<td>0.1</td>
<td>2.0</td>
<td>0.2</td>
</tr>
<tr>
<td>PDF</td>
<td>0.8</td>
<td>1.1</td>
<td>1.1</td>
<td>1.2</td>
</tr>
<tr>
<td>ISR/FSR/norm. &amp; fact. scale</td>
<td>1.3</td>
<td>1.3</td>
<td>1.4</td>
<td>1.6</td>
</tr>
<tr>
<td>total</td>
<td>5.1</td>
<td>6.2</td>
<td>3.1</td>
<td>2.3</td>
</tr>
</tbody>
</table>
$W/Z$ cross section ratio

ATLAS: $0.3 \text{ pb}^{-1}$, CMS: $2.9 \text{ pb}^{-1}$

- Theory: FEWZ with the MSTW 08 NNLO PDF
- Uncertainty on luminosity cancels out
- Measured ratio are consistent with the predictions
  - ATLAS electron channel slightly higher than prediction due to slightly low observed $Z \rightarrow ee$ cross section
$W/Z$ cross sections
ATLAS: 0.3 pb$^{-1}$, CMS: 2.9 pb$^{-1}$

- theoretical predictions are in good agreement with all measurements
- energy dependence of the $W$ and $Z$ production cross sections is well described
• ATLAS/CMS detectors
• $W/Z$ at LHC
  • $W \rightarrow l\nu$: $E_T^{\text{miss}}, M_T$
  • $Z \rightarrow ll$: invariant mass
  • $W \rightarrow l\nu, Z \rightarrow ll$: cross sections
  • $W/Z$ to $\tau$
  • $W/Z$ distributions with full 2010 data
  • $W/Z$ + jets
• top at LHC
  • top control plots
  • top cross sections
• summary
$W/Z$ to $\tau$

$W \rightarrow \tau \nu$ candidate in 7 TeV collisions

$\frac{p_T(\tau)}{} = 29$ GeV 
$E_T^{\text{miss}} = 39$ GeV 
$\Delta \phi(\tau, E_T^{\text{miss}}) = 3.1$ 
$m_\tau = 68$ GeV

Run 155697, Event 6769403 
Time 2010-05-24, 17:38 CEST
$W/Z$ to $\tau$

Visible mass $= 73$ GeV

$p_T(\tau) = 36.8$ GeV
• ATLAS/CMS detectors
• W/Z at LHC
  • \( W \rightarrow l\nu: E_T^{\text{miss}}, M_T \)
  • \( Z \rightarrow ll: \) invariant mass
  • \( W \rightarrow l\nu, Z \rightarrow ll: \) cross sections
  • \( W/Z \) to \( \tau \)
• \( W/Z \) distributions with full 2010 data
• \( W/Z + \text{jets} \)
• top at LHC
  • top control plots
  • top cross sections
• summary
$W/Z$ distributions with full 2010 data

- good agreement between data and MC
- ATLAS $m_Z$ distribution closer to prediction with improved understanding of detector alignment

<table>
<thead>
<tr>
<th>$W$ candidates</th>
<th>$Z$ candidates</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMS</td>
<td>305 k</td>
</tr>
<tr>
<td>ATLAS</td>
<td>250 k</td>
</tr>
<tr>
<td>CMS</td>
<td>20 k</td>
</tr>
<tr>
<td>ATLAS</td>
<td>23 k</td>
</tr>
</tbody>
</table>

- good control sample for understanding the detectors
**W/Z distributions with full 2010 data**

- differential distributions are important for
  - test of QCD
  - constraining PDF
  - $M_W$ measurement

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**ATLAS Preliminary**

$\int L \, dt = 37 \, \text{pb}^{-1}$

$\int L \, dt = 35 \, \text{pb}^{-1}$

- Data 2010 ($\sqrt{s} = 7 \, \text{TeV}$)
- $Z \rightarrow \text{ee}$

Events / 5 GeV

- Statistical Errors Only
- MC normalised to data
- $N_{jets} \geq 1$
• ATLAS/CMS detectors
• $W/Z$ at LHC
  • $W \rightarrow l\nu$: $E_T^{\text{miss}}, M_T$
  • $Z \rightarrow ll$: invariant mass
  • $W \rightarrow l\nu, Z \rightarrow ll$: cross sections
  • $W/Z$ to $\tau$
  • $W/Z$ distributions with full 2010 data

• $W/Z + \text{jets}$

• top at LHC
  • top control plots
  • top cross sections

• summary
**Z + jets**

detector-level distributions

- anti-$k_T$: $R = 0.4$, $|\eta| < 2.8$, $p_T > 20$ GeV
- jet multiplicity and $p_T$ of leading jets
- predictions normalised to data
- ME + PS simulation (Alpgen + Herwig) describes data well

**electron channel**

**muon channel**
**W + jets**

detector-level distributions

- anti-$k_T$: $R = 0.4$, $|\eta| < 2.8$, $p_T > 20$ GeV
- $p_T$ of leading jets and jet multiplicity
- predictions normalised to data
- ME + PS simulation (Alpgen + Herwig) describes data well

**electron channel**

<table>
<thead>
<tr>
<th>Leading Jet $p_T$ [GeV]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Events / 5 GeV</td>
</tr>
<tr>
<td>10^5</td>
</tr>
<tr>
<td>10^4</td>
</tr>
<tr>
<td>10^3</td>
</tr>
<tr>
<td>10^2</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td>1</td>
</tr>
</tbody>
</table>

ATLAS Preliminary

Data 2010 ($\sqrt{s}$ = 7 TeV)

Njets $\geq 1$

$\int L dt = 36$ pb$^{-1}$

MC normalised to data

Statistical Errors Only

**muon channel**

<table>
<thead>
<tr>
<th>Inclusive Jet Multiplicity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Events</td>
</tr>
<tr>
<td>$\geq 0$</td>
</tr>
<tr>
<td>$\geq 1$</td>
</tr>
<tr>
<td>$\geq 2$</td>
</tr>
<tr>
<td>$\geq 3$</td>
</tr>
<tr>
<td>$\geq 4$</td>
</tr>
<tr>
<td>$\geq 5$</td>
</tr>
<tr>
<td>$\geq 6$</td>
</tr>
</tbody>
</table>

$\int L dt = 35$ pb$^{-1}$

Data 2010 ($\sqrt{s}$ = 7 TeV)

W$\rightarrow$$\mu$ + jets (Alpgen)

QCD

Z$\rightarrow$$\mu$$\mu$ + jets

W$\rightarrow$$\tau$$\nu$ + jets

t$\bar{t}$

MC normalised to data

Statistical Errors Only

2011-01-06 W / Z and top at the LHC T. Matsushita (Kobe) 32/45
• Good agreement between the measured cross sections in terms of two leading jets in event and NLO predictions from MCFM
• Good agreement between the measured cross sections in terms of jet multiplicity and NLO ($\leq 2$ jets) and LO (jet = 3) predictions from MCFM
• JES is the dominant systematics

**electron channel**

**muon channel**
• ATLAS/CMS detectors
• \( W/Z \) at LHC
  • \( W \rightarrow l\nu: E_{T}^{\text{miss}}, M_{T} \)
  • \( Z \rightarrow ll: \) invariant mass
  • \( W \rightarrow l\nu, Z \rightarrow ll: \) cross sections
  • \( W/Z \) to \( \tau \)
  • \( W/Z \) distributions with full 2010 data
  • \( W/Z + \text{jets} \)

• **top at LHC**
  • top control plots
  • top cross sections

• summary
**top at LHC**

- **top quark**
  - The heaviest known elementary particle, \( m_t = 173.3 \pm 1.1 \) GeV
  - \( \tau_t = 5 \cdot 10^{-25} \) s \( \ll \tau_{\text{hadr.}} \). no bound states
  - \( V_{tb} \sim 0.999 \). almost always \( t \rightarrow bW \)

- **main production modes are gluon fusion (85%)**

- **remaining mode is \( q\bar{q} \) annihilation**

- **\( \sigma_{t\bar{t}}(\text{theory}) = 164^{+11.4}_{-15.7} \) pb**
  - assuming \( m_t = 172.5 \) GeV
  - 20 * \( \sigma_{t\bar{t}} \) (Tevatron)

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**proton - (anti)proton cross sections**

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2011-01-06  W / Z and top at the LHC  T. Matsushita (Kobe)
top at LHC

- at early stage
  - re-discovery of top
    - first cross-section measurement
  - detector performance
    - leptons, jets, $E_T^{\text{miss}}$
- decay modes$^a$
  - di-lepton (6.5%)
    - $l^+ l^- \nu \nu bb$
  - lepton + jets (38%)
    - $l \nu qqbb$
  - all hadronic (55.5%)
    - $qqqqbb$
  - additional jets come from ISR/FSR

$^a$include tau decays
$\bar{t}t \rightarrow \text{lepton + jets candidate}$

$\mu + 4 \text{ jets}$

Jet $p_T = 56.6 \text{ GeV/c}$, $\eta = 0.389$, $\varphi = 2.38$

Jet $p_T = 82.2 \text{ GeV/c}$, $\eta = -1.79$, $\varphi = 1.03$

Jet $p_T = 152.2 \text{ GeV/c}$, $\eta = 0.354$, $\varphi = -2.75$

Jet $p_T = 43.4 \text{ GeV/c}$, $\eta = 0.827$, $\varphi = -0.587$

Muon $p_T = 30.6 \text{ GeV/c}$, $\eta = -1.67$, $\varphi = -2.06$

$\mathcal{E}_T = 119.0 \text{ GeV}$, $\varphi = 0.010$

$W/Z$ and top at the LHC

T. Matsushita (Kobe)
\( \bar{t} t \rightarrow \text{di-lepton candidate} \)

\( e - \mu \) with two \( b \)-tagged jets

\[ p_T(\mu) = 51 \text{ GeV}, \quad p_T(e) = 66 \text{ GeV}, \quad p_T(b\text{-tag jets}) = 175, 45 \text{ GeV}, \quad E_T^{\text{miss}} = 113 \text{ GeV}. \]
Event selection for $\sigma_{tt}$ measurement

ATLAS analysis

- lepton
  - electron or muon
  - $p_T > 20$ GeV, $|\eta| < 2.5$, isolated
- jet
  - anti-$k_T$: $R = 0.4$, $|\eta| < 2.4$

lepton + jets

- one lepton
- $\geq 4$ jets with $p_T > 25$ GeV
- $\geq 1$ jet(s) with $b$-tag at 50% efficiency working point
- $E_T^{\text{miss}} > 20$ GeV
- $E_T^{\text{miss}} + m_T(W) > 60$ GeV

CMS uses similar analysis

di-lepton

- two leptons with opposite charge
- $\geq 2$ jets with $p_T > 20$ GeV, no $b$-tag
- $ee$: $|M_{ee} - M_Z| > 5$ GeV, $E_T^{\text{miss}} > 40$ GeV
- $\mu\mu$: $|M_{\mu\mu} - M_Z| > 10$ GeV, $E_T^{\text{miss}} > 30$ GeV
- $e\mu$: $H_T^a > 150$ GeV

$a$: scaler sum of $p_T$ of leptons and selected jets
\( \bar{t}t \rightarrow \text{lepton} + \text{jets}: \text{control plots} \)

ATLAS: 2.9 pb\(^{-1}\)

- \( \mu + \text{jets} \)
- \( e + \text{jets} \)

- \( \mu \) channel without \( E_T^{\text{miss}}, M_T \) cut
- QCD multi-jet estimation is data driven
- Acceptable agreement between data and prediction
\( \bar{t}t \rightarrow \text{lepton + jets} \)

**ATLAS: 2.9 pb\(^{-1}\)**

- **Data**
  - \( \bar{t}t \) single top
  - \( Z + \text{jets} \)
  - \( W + \text{jets} \)
  - \( \text{QCD} \)
  - Uncertainty

**Events**

<table>
<thead>
<tr>
<th>Number of jets</th>
<th>( \bar{t}t ) (MC)</th>
<th>Single t (MC)</th>
<th>Z+jets (MC)</th>
<th>W+jets (DD)</th>
<th>QCD (DD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>14.9±3.5</td>
<td>0.7±0.2</td>
<td>0.2±0.1</td>
<td>1.9±1.1</td>
<td>4.8±3.1</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td>3.2±1.7</td>
<td>0.8±0.5</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Total BG**

<table>
<thead>
<tr>
<th></th>
<th>( e+\text{jets} )</th>
<th>( \mu+\text{jets} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \bar{t}t ) (MC)</td>
<td>7.2±3.4</td>
<td>3.3±1.7</td>
</tr>
</tbody>
</table>

**Clear excess of top like events with \( \geq 4 \) jets**
$\bar{t}t \rightarrow \text{di-lepton: control plots}$

ATLAS: $2.9\text{ pb}^{-1}$, CMS: $3.1\text{ pb}^{-1}$

- **ATLAS**
  - $\int L = 2.9\text{ pb}^{-1}$
  - Control region
  - Events vs. number of jets

- **CMS**
  - Events vs. number of jets
  - Data
  - Single top
  - $Z + \text{jets}$
  - Diboson
  - Fake leptons
  - Uncertainty

- Good agreement between data and prediction

- Dominant background
### ATLAS

<table>
<thead>
<tr>
<th>Category</th>
<th>ee</th>
<th>$\mu\mu$</th>
<th>$e\mu$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Z+$jets (DD)</td>
<td>0.25±0.18</td>
<td>0.67±0.38</td>
<td>-</td>
</tr>
<tr>
<td>$Z \rightarrow \tau\tau+$jets (MC)</td>
<td>0.07±0.04</td>
<td>0.14±0.07</td>
<td>0.13±0.06</td>
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<tr>
<td>non-$Z$ leptons (DD)</td>
<td>0.16±0.18</td>
<td>-0.08±0.07</td>
<td>0.47±0.28</td>
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<tr>
<td>single $t$ (MC)</td>
<td>0.08±0.02</td>
<td>0.07±0.03</td>
<td>0.22±0.04</td>
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<tr>
<td>dibosons (MC)</td>
<td>0.04±0.02</td>
<td>0.07±0.03</td>
<td>0.15±0.05</td>
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<tr>
<td>Total BG</td>
<td>0.60±0.27</td>
<td>0.88±0.40</td>
<td>0.97±0.30</td>
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<tr>
<td>$t\bar{t}$ (MC)</td>
<td>1.19±0.19</td>
<td>1.87±0.26</td>
<td>3.85±0.51</td>
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### CMS

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<th>Category</th>
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<tr>
<td>$Z+$jets (DD)</td>
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<tr>
<td>$Z \rightarrow \tau\tau+$jets (MC)</td>
<td>0.18±0.09</td>
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<tr>
<td>non-$W/Z$ (DD)</td>
<td>0.1±0.5</td>
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<tr>
<td>single $t$ (MC)</td>
<td>0.25±0.13</td>
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<td>dibosons (MC)</td>
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<tr>
<td>Total BG</td>
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<tr>
<td>$t\bar{t}$ (MC)</td>
<td>7.7±1.5</td>
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### ATLAS

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<th>di-lepton</th>
<th>combined</th>
<th>approx. NNLO</th>
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<tbody>
<tr>
<td></td>
<td>$142 \pm 34$</td>
<td>$151 +78\ ^{+37}_{-62}$</td>
<td>$145 \pm 31$</td>
<td>$164^{+11.4}_{-15.7}$</td>
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### CMS

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<th>NLO</th>
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<tbody>
<tr>
<td></td>
<td>$194 \pm 72 \pm 24$</td>
<td>$158^{+23}_{-24}$</td>
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</table>

- dominant systematics are due to statistical uncertainties in data-driven measurements, jet energy reconstruction
- measured cross sections agree with theoretical predictions within errors
Summary & Outlook

- $W/Z$ cross sections measured and the results are in good agreement with NNLO predictions
- Measurements are being updated with full statistics of 2010
- Differential measurements in preparation
- Cross section measurements of $W \rightarrow \tau \nu$ and $Z \rightarrow \tau \tau$ underway

- Top cross section measured and the results are in good agreement with theoretical predictions
- Measurements are being updated with full statistics of 2010

- Re-discovery of $W/Z$ and top have been performed
- Understanding of detectors and backgrounds continues for discovery
- This year will be an exciting year