Part I:
W/Z + Jets results from CMS

Lukas Vanelderen (Universiteit Gent)
on behalf of the CMS Collaboration

April 13, 2011
introduction

W/Z + jets

- clean environment to probe QCD
- important bkg to searches

studies on the 36pb$^{-1}$ from 2010 presented here:
- W/Z + jets
- Z+b
- boosted W polarization
W/Z + Jets

- combination of QCD and EWK
- interesting topology
  - jets
  - leptons
  - MET
- ⇒ important BKG in searches

- how well are these processes understood?
- how much can we rely on simulation?
**W/Z + Jets**

**ME + PS simulation:**
- tree level only
- includes non-perturbative corrections
- most common method

**NLO calculations:**
- recent development
- not yet widely used

**Tevatron results:**
- can we do better? (shown: W + jets)
W/Z candidate selection

single electron or muon trigger

**first lepton**

electron / muon

▶ tight selection
▶ high purity
▶ caused trigger

**second lepton**

same flavor

▶ loose selection
▶ high efficiency

1 lepton ⇒ W candidate
2 leptons ⇒ Z candidate
electron selection

- **single electron trigger** (threshold below 17 GeV)
  - **find first electron**
    - $p_T > 20 \text{GeV}$, $|\eta| < 2.5$, $1.44 < |\eta| < 1.57$ excluded
    - matches trigger primitive
    - tight isolation, ID, conversion rejection (80% efficiency)
  - **search second electron**
    - $p_T > 10 \text{GeV}$, $|\eta| < 2.5$, $1.44 < |\eta| < 1.57$ excluded
    - $60 < M_{ee} < 120 \text{GeV}$
  - **W candidates**
    - no muon with $p_T > 10 \text{GeV}$ (top veto)
electron selection

- **single electron trigger** (threshold below 17 GeV)
  - find first electron
    - $p_T > 20\text{GeV}$, $|\eta| < 2.5$, $1.44 < |\eta| < 1.57$ excluded
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  - search second electron
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- **W candidates**
  - no muon with $p_T > 10\text{GeV}$ (top veto)

results are quoted in this acceptance
muon selection

- **single muon trigger** (threshold below 15 GeV)
- **find first muon**
  - $p_T > 20\text{GeV}$, $|\eta| < 2.1$
  - matches trigger primitive
  - tight isolation, ID
- **search second muon**
  - $p_T > 10\text{GeV}$, $|\eta| < 2.4$
  - $60 < M_{\mu\mu} < 120\text{GeV}$

results are quoted in this acceptance
muon selection

- **single muon trigger** (threshold below 15 GeV)
- **find first muon**
  - $p_T > 20\text{GeV}, \abs{\eta} < 2.1$
  - matches trigger primitive
  - tight isolation, ID
- **search second muon**
  - $p_T > 10\text{GeV}, \abs{\eta} < 2.4$
  - $60 < M_{ee} < 120\text{GeV}$

results are quoted in this acceptance
cluster “Particle Flow” objects, Anti-kt, $\Delta R = 0.5$

- $|\eta| < 2.4$ (tracker acceptance), $E_T > 30$GeV
- data driven jet energy calibration
- pile-up removal with FastJet
- muons from W/Z candidates: removed from particle list before clustering
- electrons from W/Z candidates: veto jets within $\Delta R < 0.3$
Jets: data vs MC

- 

CMS preliminary

36 pb$^{-1}$ at $\sqrt{s} = 7$ TeV

$M_{T} > 50$ GeV

- 

CMS preliminary

$M_{T} > 50$ GeV

- 

CMS preliminary

$M_{T} > 50$ GeV

- 

CMS preliminary

$M_{T} > 50$ GeV
Jets: data vs MC

CMS preliminary

$36 \text{ pb}^{-1}$ at $\sqrt{s} = 7 \text{ TeV}$

$E_{\text{jet}} > 30 \text{ GeV}$

number of events

- $\nu_e \rightarrow W$, $\nu_\mu \rightarrow W$
- $Z$, $\mu\mu$
- Other backgrounds

CMS preliminary

$36 \text{ pb}^{-1}$ at $\sqrt{s} = 7 \text{ TeV}$

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CMS preliminary

$36 \text{ pb}^{-1}$ at $\sqrt{s} = 7 \text{ TeV}$

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number of events

- $Z \rightarrow ee$, $Z \rightarrow \mu\mu$
- Other backgrounds

CMS preliminary

$36 \text{ pb}^{-1}$ at $\sqrt{s} = 7 \text{ TeV}$

$E_{\text{jet}} > 30 \text{ GeV}$

number of events

- $Z \rightarrow ee$, $Z \rightarrow \mu\mu$
- Other backgrounds
signal extraction: $Z$

**Unbinned Maximum Likelihood (UML) Fit on $M_{ll}$**

- functional forms
- parametrization in events with 0, 1, 2, 3 and $\geq 4$ jets
- BKG params floated
- signal params floated, kept equal for all jet multiplicities

![Graph showing $Z \rightarrow ee + \geq 1$-jet events](image)
signal extraction: W

**UML Fit on** $m_T$ and $n_{b-tagged}^j$

- functional forms
- parametrization in events with 0, 1, 2, 3 and $\geq 4$ jets

**signal vs QCD**

- $m_T = \sqrt{2p_T^l \cdot MET \cos(\Delta \Phi(l, MET))}$
- MET from “Particle Flow” objects
- fit in range $20 < m_T < 150$
- 0 jets: high stats, important parameters floated
  ...
- 4 jets: low stats, few params floated (electron/muon)
signal extraction: $W$

36 pb$^{-1}$ at $\sqrt{s} = 7$ TeV

$W \rightarrow e\nu + \geq 1$-jet

$W \rightarrow \mu\nu + \geq 1$-jet

$W \rightarrow e\nu + \geq 3$-jets

$W \rightarrow \mu\nu + \geq 3$-jets
**signal extraction: W**

**signal vs top**

- $\mathbb{N}^{b-tagged}_{jet}$
- b-tag and mistag eff measured in control samples
- top contribution floated!

---

**Graphs:**

- **CMS preliminary**
- 36 pb$^{-1}$ at $\sqrt{s} = 7$ TeV
- $W \rightarrow e\nu + \geq 3$-jets

- **Graphs:**
- CMS preliminary
- 36 pb$^{-1}$ at $\sqrt{s} = 7$ TeV
- $W \rightarrow \mu\nu + \geq 3$-jets
corrections

lepton efficiency
measured with tag and probe on Z events, factorizes as:

- reconstruction
  (cluster $\rightarrow$ electron, track $\rightarrow$ muon)
- selection
  (differs between 1st and 2nd lepton, $n_{jet}$ dependence)
- trigger (only for 1st lepton)

fit range, $m_T > 20$
from MC, verified on data in Z events

unfolding jet multiplicity spectrum
- extract migration matrix $R(n^{RECO}, n^{GEN})$ from MC
- singular value decomposition (SVD) to "unsmear" $n_{jet}$ distribution
corrections

measure ratios

\[
\frac{\sigma(V + \geq njets)}{\sigma(V + \geq 0jets)} \quad \quad \frac{\sigma(V + \geq njets)}{\sigma(V + \geq (n-1)jets)}
\]

⇒ reduce systematics
  - partial cancelation JES
  - full cancelation luminosity
  - only lepton efficiency vs \(n_{jets}\)
  ...

results for $W$

$p_T > 30\text{GeV}$

- very good agreement with predictions from ME+PS
- negligible difference between tunes for $p_T > 30\text{GeV}$
- PS alone starts to fail for $n_{jet} \geq 2$
results for $Z$

$p_T > 30$GeV

- excellent agreement with expectations from ME+PS
- PS alone is also compatible with data
Berends-Giele scaling

- test scaling by fitting $C_n = \frac{\sigma_n}{\sigma_{n+1}} = \alpha + \beta n$
- take into account correlations between $\sigma_n$
- take into account migration between jet bins

\[ W \]

![Graph showing CMS preliminary results and 36 pb$^{-1}$ at $\sqrt{s} = 7$ TeV]
Berends-Giele scaling

\[ \frac{\sigma(Z + \geq n\text{-jets})}{\sigma(Z + \geq (n+1)\text{-jets})} = \alpha + \beta \times n \]

CMS preliminary

\[ Z \rightarrow ee \]

- data
- MadGraph

stat. only 68% C.L. contours

uncertainties:
- electron efficiency

\[ Z \rightarrow \mu\mu \]

- data
- MadGraph

stat. only 68% C.L. contours

uncertainties:
- jet energy scale

36 pb\(^{-1}\) at \( \sqrt{s} = 7 \text{ TeV} \)

reasonable agreement between ME + PS expectation
Z + b-jets

- benchmark channel for MSSM Higgs searches
- fixed vs variable flavour number schemes (LO only)

**selection**

- At least one Z
- At least one $>25\text{GeV}$ jet
- $\geq 1$ secondary vertex in jet
- $\text{MET} < 40\text{GeV}$ (top rejection)

**2 ways of b-tagging**

- high purity
- high efficiency
Z + b-jets

- Good agreement data vs ME+PS
- no distinction between schemes
- low stats were schemes disagree
Z+b/Z+jet ratio

- Z+b purity extracted from fit on secondary vertex mass
- results compatible with MadGraph(*) and MCFM NLO calculations
- (*) Z+b and Z+c with $p_T,\text{jet} > 15$ GeV scaled to corresponding MCFM x-sec

\[
\mathcal{R}(\text{Z} \rightarrow \text{ee}) = \frac{\sigma(pp \rightarrow \text{Z}+\text{b}+X)}{\sigma(pp \rightarrow \text{Z}+\text{j}+X)}
\]

<table>
<thead>
<tr>
<th>Sample</th>
<th>$\mathcal{R}(\text{Z} \rightarrow \text{ee})$ (%)</th>
<th>$\mathcal{R}(\text{Z} \rightarrow \text{\mu\mu})$ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$p_T^e &gt; 25$ GeV, $</td>
<td>\eta^e</td>
</tr>
<tr>
<td>Data HE</td>
<td>$4.3 \pm 0.6(\text{stat}) \pm 1.1(\text{syst})$</td>
<td>$5.1 \pm 0.6(\text{stat}) \pm 1.3(\text{syst})$</td>
</tr>
<tr>
<td>Data HP</td>
<td>$5.4 \pm 1.0(\text{stat}) \pm 1.2(\text{syst})$</td>
<td>$4.6 \pm 0.8(\text{stat}) \pm 1.1(\text{syst})$</td>
</tr>
<tr>
<td>MADGRAPH</td>
<td>$5.1 \pm 0.2(\text{stat}) \pm 0.2(\text{syst}) \pm 0.6(\text{th.})$</td>
<td>$5.3 \pm 0.1(\text{stat}) \pm 0.2(\text{syst}) \pm 0.6(\text{th.})$</td>
</tr>
<tr>
<td>MCFM</td>
<td>$4.3 \pm 0.5(\text{th.})$</td>
<td>$4.7 \pm 0.5(\text{th.})$</td>
</tr>
</tbody>
</table>

Data HE: $L = 36$ pb$^{-1}$ at $\sqrt{s} = 7$ TeV with high efficiency b-tagging.
boosted W polarization

production of high $p_T$ W bosons ($p_T > 50$GeV)

Production of high $p_T$ W-bosons ($p_T > 50$ GeV)

- 7 TeV+high $p_T$ dominant production valence quark w/gluon
  - **Strong polarization effects in transverse plane**
  - SM: Predominant left handedness for + and -
  - Unlike tevatron ($p\bar{p}$)
    - No CP counterparts
    - Cause for left handedness
  - Robust over jet multiplicity

Expect left right polarization asymmetry in a pp collider
boosted W polarization

- z component $\nu$ not measured
  $\theta^*$ not available
- use instead

$$L_P = \frac{\vec{p}_T(l) \cdot \vec{p}_T(W)}{|\vec{p}_T(W)|^2}$$

$$\approx 0.5 \cos(\theta^*) + 0.5$$

- template fit to extract polarization
boosted W polarization results

- systematics dominated by MET uncertainty
- \( f_L - f_R > 0 \) \( \Rightarrow \) mostly left-handed

<table>
<thead>
<tr>
<th></th>
<th>Combined Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>((f_L - f_R)^-)</td>
<td>0.226 (\pm) 0.031 (stat) (\pm) 0.050 (syst)</td>
</tr>
<tr>
<td>(f_0^-)</td>
<td>0.162 (\pm) 0.078 (stat) (\pm) 0.136 (syst)</td>
</tr>
<tr>
<td>((f_L - f_R)^+)</td>
<td>0.300 (\pm) 0.031 (stat) (\pm) 0.034 (syst)</td>
</tr>
<tr>
<td>(f_0^+)</td>
<td>0.192 (\pm) 0.075 (stat) (\pm) 0.089 (syst)</td>
</tr>
</tbody>
</table>
Summary

- Comprehensive set of measurements on full 2010 data (36 pb$^{-1}$)
- Jet rates for $E_t > 30$ GeV in agreement with ME+PS
- Direct measurement of Berends-Giele scaling agrees with expectations
- Observation of $Z + b$ and ratio $Z + b / Z +$ jets agrees well with NLO calculation
- Measured significant polarization of boosted $W$
PART II: V+jets as bkg in searches in CMS

Lukas Vanelderen (Universiteit Gent)
on behalf of the CMS collaboration

April 7, 2011
CMS has developed and uses a large variety of methods to estimate $V + \text{jets}$ bkg in searches

picking out a few of the most interesting examples from

- “razor” analysis
- multi jet + MET analysis
- single lepton + jets + MET analysis
Razor Analysis

inclusive search for heavy squark pair production based on 2 variables (arXiv:1006.2727):

- \( M_R \): “search variable”
  \[ \sim \text{per event estimate for } \frac{M_R^2 - \tilde{M}_\chi^2}{\tilde{M}_q} \]
- \( R \): cleans up bulk of QCD related to mass scale for signal, and to MET [0, \sim 1], low value \( \rightarrow \) fake/low MET

hadronic box, \( R > 0.50 \)

muon box, \( R > 0.45 \)
Razor Analysis

? shape W + jets given cut on R ?

- \( W \rightarrow \nu \) from “lepton boxes”
- bkg dominated: low \( R \), \( M_R \) region
- fit 2 exponentials
  - exponential parameters from fit
  - contributions from fit

- slopes are linear function of \( R^2 \)
- \( \rightarrow \) parameters \( a, b \)
  for 1st and 2nd slope
Razor Analysis

- $W \rightarrow l\nu$ with $l$ in acceptance OK
- $?W \rightarrow l\nu$ with $l$ out acceptance?
  
  calculate a $MC \rightarrow data$ conversion factor in “lepton box”

\[
\rho(a)^{DATA/MC} = 0.97 \pm 0.02 \\
\rho(b)^{DATA/MC} = 0.97 \pm 0.02
\]

- $?Z \rightarrow \nu\nu$?

Correct slopes in MC to slopes measured in “lepton box” with lepton treated as neutrino
multi jet + MET analysis

- $\geq 3$ jets ($p_T > 50\text{GeV}, \ |\eta| < 2.5$)
- $HT > 300\text{GeV}$
  scalar sum jet $p_T$
- $MHT > 150\text{GeV}$
  magnitude vectorial sum jets,
  $p_T > 30\text{GeV}, \ |\eta| < 5$
- muon and electron veto

V+jets bkg

- $Z \rightarrow \nu\nu$
- $W \rightarrow e\nu, \ W \rightarrow \mu\nu, \ W \rightarrow \tau\nu \rightarrow l\nu\nu$
  with leptons out of acceptance
- $W \rightarrow \tau\nu \rightarrow \text{had} + \nu\nu$
multi jet + MET analysis

$Z \rightarrow \nu\nu$

clean, but low statistics

- nominal selection + lepton id + $60 \text{GeV} < M_{ll} < 120 \text{GeV}$
- observed 1(2) events, muons(electrons)
- too few statistics
multi jet + MET analysis

$Z \rightarrow \nu\nu$

**from $\gamma +$ jets**

$Z$ and $\gamma$ production similar in many ways for high boson $p_T$

- measure $\gamma +$ jets
  nominal selection + hard isolated photon
- derive $\gamma$ to $Z$ conversion factor
  - $Z/\gamma$ correction
    MADGRAPH $\gamma +$ jets and $Z +$ jets
    uncertainty: LO vs NLO MC
  - fragmentation
    contribution strongly suppressed by $\gamma$ isolation
    remainder calculated with NLO JETPHOX
- secondary photons (neutral pions and $\eta$ meson) data driven
multi jet + MET analysis

$Z \rightarrow \nu\nu$

from $\gamma + \text{jets}$

$Z$ and $\gamma$ production similar in many ways for high boson $p_T$

- measure $\gamma + \text{jets}$
- derive $\gamma$ to $Z$ conversion factor

<table>
<thead>
<tr>
<th></th>
<th>Baseline selection</th>
<th>High-MHT selection</th>
<th>High-HT selection</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Z/\gamma$ correction</td>
<td>$0.41 \pm 6%$</td>
<td>$0.48 \pm 6%$</td>
<td>$0.44 \pm 4%$</td>
</tr>
<tr>
<td>$\pm$ theory</td>
<td>$\pm 5%$</td>
<td>$\pm 5%$</td>
<td>$\pm 5%$</td>
</tr>
<tr>
<td>$\pm$ acceptance</td>
<td>$\pm 7%$</td>
<td>$\pm 13%$</td>
<td>$\pm 13%$</td>
</tr>
<tr>
<td>$\pm$ MC stat</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fragmentation</td>
<td>$0.95 \pm 1%$</td>
<td>$0.95 \pm 1%$</td>
<td>$0.95 \pm 1%$</td>
</tr>
<tr>
<td>Secondary photons</td>
<td>$0.94 \pm 9%$</td>
<td>$0.97 \pm 10%$</td>
<td>$0.90 \pm 9%$</td>
</tr>
<tr>
<td>Photon mistag</td>
<td>$1.00 \pm 1%$</td>
<td>$1.00 \pm 1%$</td>
<td>$1.00 \pm 1%$</td>
</tr>
<tr>
<td>ID data/MC ratio</td>
<td>$1.01 \pm 2%$</td>
<td>$1.01 \pm 2%$</td>
<td>$1.01 \pm 2%$</td>
</tr>
<tr>
<td>Total correction</td>
<td>$0.37 \pm 14%$</td>
<td>$0.45 \pm 18%$</td>
<td>$0.38 \pm 17%$</td>
</tr>
</tbody>
</table>
multi jet + MET analysis

\( Z \rightarrow \nu \nu \)

from \( \gamma + \text{jets} \)

\( Z \) and \( \gamma \) production similar in many ways for high boson \( p_T \)

- measure \( \gamma + \text{jets} \)
- derive \( \gamma \) to \( Z \) conversion factor

<table>
<thead>
<tr>
<th>Selection</th>
<th># events in ( \gamma + \text{jets} ) data sample</th>
<th># ( Z \rightarrow \nu \nu ) events predicted</th>
<th># ( Z \rightarrow \nu \nu ) events from simulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline selection</td>
<td>72</td>
<td>26.3 ± 3.2(stat.) ± 3.6(syst.)</td>
<td>21.2 ± 1.4</td>
</tr>
<tr>
<td>High-MHT selection</td>
<td>16</td>
<td>7.1 ± 1.8(stat.) ± 1.3(syst.)</td>
<td>6.3 ± 0.8</td>
</tr>
<tr>
<td>High-HT selection</td>
<td>22</td>
<td>8.4 ± 1.8(stat.) ± 1.4(syst.)</td>
<td>5.8 ± 0.7</td>
</tr>
</tbody>
</table>
multi jet + MET analysis

$W \rightarrow e\nu, W \rightarrow \mu\nu, W \rightarrow \tau\nu \rightarrow l\nu\nu$

treated together with bkg from top

some leptons pass veto

- outside acceptance
- fail trigger
- fail reconstruction, iso, ID

- nominal selection + $\mu$, Control Selection (CS)
- reweight to events with “lost lepton”
multi jet + MET analysis

\[ W \to e\nu, \; W \to \mu\nu, \; W \to \tau\nu \to l\nu\nu \]

- Identified electrons/muons failing isolation
  
  \[ \text{ISO}^{e,\mu} = CS \cdot \frac{1 - \epsilon^{e,\mu}_{\text{ISO}}}{\epsilon^{e,\mu}_{\text{ISO}}} \]

  from TnP on Z,

- Electrons or muons in acceptance, failing ID
  
  \[ \text{ID}^{e,\mu} = CS \cdot \frac{1}{\epsilon^{e,\mu}_{\text{ISO}}} \frac{1 - \epsilon^{e,\mu}_{\text{ID}}}{\epsilon^{e,\mu}_{\text{ID}}} \]

- \( \epsilon^{e,\mu}_{\text{ISO}} \) and \( \epsilon^{e,\mu}_{\text{ID}} \) from TnP on Z

  \( \epsilon^{e,\mu}_{\text{ISO}} \) vs \( p_T^{e,\mu} \) and \( \eta^{e,\mu} \)

  \( \epsilon^{e,\mu}_{\text{ID}} \) vs \( p_T^{e,\mu} \) and \( \Delta R(jet)^{e,\mu} \)

  impact other differences in \( \eta \) and \( p_T \) spectrum small evaluated on MC, \( \to \) systematics

- Muon or electrons outside acceptance

  ratio \( R_{\text{accept}} \) from MC

  same control sample corrected for isolation and ID eff
multi jet + MET analysis

$W \rightarrow e\nu, \ W \rightarrow \mu\nu, \ W \rightarrow \tau\nu \rightarrow l\nu\nu$

events / 100 GeV

Simulation
Estimate from simulation
Total statistical uncertainty

T

L=36 pb$^{-1}, \sqrt{s}=7$ TeV

Simulation
Estimate from simulation
Total statistical uncertainty

T

L=36 pb$^{-1}, \sqrt{s}=7$ TeV

good closure, estimated bkg higher than expected from MC

not so far off within uncertainties

<table>
<thead>
<tr>
<th>Method</th>
<th>Baseline selection (stat.)</th>
<th>Baseline selection (syst.)</th>
<th>High-MHT selection</th>
<th>High-MHT selection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimate from data</td>
<td>33.0 ±5.5</td>
<td>+6.0 −5.7</td>
<td>4.8 ±1.8 +0.8 −0.6</td>
<td>10.9 ±3.0 +1.7 −1.7</td>
</tr>
<tr>
<td>Estimate (PYTHIA)</td>
<td>22.9 ±1.3</td>
<td>+2.7 −2.6</td>
<td>3.2 ±0.4 +0.5 −0.5</td>
<td>7.2 ±0.7 +1.1 −1.1</td>
</tr>
<tr>
<td>MC Truth (PYTHIA)</td>
<td>23.6 ±1.0</td>
<td></td>
<td>3.6 ±0.3</td>
<td>7.8 ±0.5</td>
</tr>
<tr>
<td>Estimate (MADGRAPH)</td>
<td>20.4 ±1.5</td>
<td>+2.6 −2.5</td>
<td>2.4 ±0.3 +0.3 −0.3</td>
<td>4.8 ±0.4 +0.6 −0.5</td>
</tr>
<tr>
<td>MC Truth (MADGRAPH)</td>
<td>21.4 ±0.7</td>
<td></td>
<td>3.0 ±0.3</td>
<td>5.9 ±0.4</td>
</tr>
</tbody>
</table>
multi jet + MET analysis

$W \rightarrow e\nu$, $W \rightarrow \mu\nu$, $W \rightarrow \tau\nu \rightarrow l\nu\nu$

uncertainties dominated by statistics

<table>
<thead>
<tr>
<th>Source of Uncertainty</th>
<th>Relative size</th>
<th># events</th>
</tr>
</thead>
<tbody>
<tr>
<td>Statistics of control-sample</td>
<td>$-17%$</td>
<td>$5.5$</td>
</tr>
<tr>
<td>Iso- &amp; id- efficiencies (statistical)</td>
<td>$-13%$</td>
<td>$4.1$</td>
</tr>
<tr>
<td>Kinematic differences $t\bar{t}$, $W$, $Z$-samples</td>
<td>$-10%$</td>
<td>$3.3$</td>
</tr>
<tr>
<td>SM background in control-region</td>
<td>$-3%$</td>
<td>$1.0$</td>
</tr>
<tr>
<td>MC use for acceptance calculation</td>
<td>$-5%$</td>
<td>$1.7$</td>
</tr>
<tr>
<td>Total</td>
<td>$-24%$</td>
<td>$7.9$</td>
</tr>
</tbody>
</table>
multi jet + MET analysis

$W \rightarrow \tau \nu \rightarrow \text{had} + \nu \nu$

treated together with bkg from top

- same muon control sample
- replace muon by simulated tau jet

**corrections**

- kinematic and geometrical acceptance
  apply procedure on MC with and without muon selection
- muon trigger, reconstruction and isolation eff
  same procedure as for “lost leptons” method
- relative branching ratio
  $W \rightarrow \mu \nu$ vs $W \rightarrow \tau \nu \rightarrow \text{had} + \nu \nu$
multi jet + MET analysis

$W \rightarrow \tau \nu \rightarrow \text{had} + \nu \nu$

Systematic uncertainties

<table>
<thead>
<tr>
<th></th>
<th>Baseline selection</th>
<th>High-MHT selection</th>
<th>High-HT selection</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\tau$ response template</td>
<td>2%</td>
<td>2%</td>
<td>2%</td>
</tr>
<tr>
<td>Acceptance</td>
<td>+6%,-5%</td>
<td>+6%,-5%</td>
<td>+6%,-5%</td>
</tr>
<tr>
<td>Muon efficiency on data</td>
<td>1%</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td>SM backgr. subtraction</td>
<td>5%</td>
<td>5%</td>
<td>5%</td>
</tr>
</tbody>
</table>

Results

<table>
<thead>
<tr>
<th></th>
<th>Predicted $W / t \bar{t} \rightarrow \tau_{\text{hadr}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline selection</td>
<td>22.3 $\pm$ 4.0 (stat.) $\pm$ 2.2 (syst.)</td>
</tr>
<tr>
<td>High-MHT selection</td>
<td>6.7 $\pm$ 2.1 (stat.) $\pm$ 0.5 (syst.)</td>
</tr>
<tr>
<td>High-HT selection</td>
<td>8.5 $\pm$ 2.5 (stat.) $\pm$ 0.7 (syst.)</td>
</tr>
</tbody>
</table>

uncertainties dominated by statistics
single lepton + jets + MET analysis

- main bkg: V+jets and top
- 2 uncorrelated variables: $S_{MET} = MET / \sqrt{H_T}$ and $H_T$
- predict bkg in signal region with ABCD method

MC: total SM in $\mu$ channel

Data: $\mu$ channel

correlation effects studied in MC, non observed, systematic
Summary

- wide diversity of methods
- wherever possible based on measurements
- quantities measured in control region converted to signal region
  - conversion factors from measurements
  - conversion factors from MC
- predictions from MC scaled
  - scaling factors from data

assumptions based on MC, taken into account in systematics
uncertainty in methods still dominated by statistics