Measurements of diboson production in lepton plus jets decays at the Tevatron

Thibault Guillemin,
Laboratoire de l’Accélérateur Linéaire d’Orsay
On behalf of the CDF and D0 collaborations

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Physics goals

- Diboson physics at hadron colliders ➔ interesting by itself: precise cross-section predictions in the SM (NLO), new physics search via TGC enhancement,…
  - $WW$, $WZ$ and $ZZ$ cross sections ➔ all measured in leptonic final states
  - In the last years, interest turned to the lepton+jets decays ➔ exact same topology as the Higgs boson associated production

In this presentation: focus only on the leptons+jets decays

Tevatron: $p\bar{p}$ Collisions collider

- $E_{\text{c.m.}} = 1.96$ TeV
- average luminosity: $\sim 1 - 1.5 \times 10^{32} \text{ cm}^{-2}\cdot\text{s}^{-1}$
- dataset: $\sim 8 \text{ fb}^{-1}$ available for analysis (expect $\sim 10 \text{ fb}^{-1}$ by end of September 2011)
3 published results

- Evidence of WW and WZ Production with lepton +jets Final States in $p\bar{p}$ Collisions at $\sqrt{s}=1.96$ TeV
  [Phys. Rev. Lett. 102, 161801 (2009)]
  
  $4.4 \sigma$ for WW+WZ

- First Observation of Vector Boson Pairs in a Hadronic Final State at the Tevatron Collider

  $5.3 \sigma$ for WW+WZ+ZZ

- Measurement of the WW+WZ Production Cross section using the Lepton+jets final state at CDF II

  $5.3 \sigma$ for WW+WZ
The ultimate low mass Higgs benchmark at the Tevatron

For $m_H=115$ GeV

$WH \rightarrow l \nu bb$: $\sigma = 26$ fb

$ZH \rightarrow \nu \nu bb$: $\sigma = 15$ fb

$ZH \rightarrow llbb$: $\sigma = 5$ fb

**Total VH**: 46 fb

For $l \nu$ and $ll$: $l = e/\mu$

Let's replace the Higgs boson by our well-known $Z$ boson

$WZ \rightarrow l \nu bb$: $\sigma = 105$ fb

$ZZ \rightarrow \nu \nu bb$: $\sigma = 81$ fb

$ZZ \rightarrow llbb$: $\sigma = 27$ fb

**Total VZ**: 213 fb

$\sigma(VZ \rightarrow \text{leptons}+bb) \sim 5 \sigma(VH[115] \rightarrow \text{leptons}+bb)$

But more challenging $WW$ background in the $Z$ case → dijet mass resolution too large to distinguish the hadronic decays of $W$ and $Z$

The observation of this process is the last milestone to demonstrate the Tevatron capability to observe the Higgs in the $bb$ channel
3 preliminary results

→ all these new results consider $b$-tagged jets in the final state

- **WZ+ZZ search in dilepton plus jets**
  Reference: CDF conference note 10601
  
  ![](image1)

  6.6 fb⁻¹

- **WW+WZ search in lepton-neutrino plus heavy-flavor jets**
  Reference: CDF conference note 10598
  
  ![](image2)

  7.5 fb⁻¹

- **WZ+ZZ search in missing transverse energy plus heavy-flavor jets**
  Reference: D0 conference note 6223
  
  ![](image3)

  8.4 fb⁻¹
Selection: 2 leptons (electron/muon, 20 GeV), 76<\(M_{ll}\)<106 GeV and at least 2 jets (20 GeV)

- Define three samples: a heavy-flavor tagged sample, a light-flavor tagged sample and an untagged sample
- Z+jets background shape adjusted using a modified jet energy scale for gluon jets (correction derived from the Z-jet \(p_T\) balance)

The final discriminant used is the dijet invariant mass: combination of three samples

- Distributions after a global fit of the background normalizations and of the systematic uncertainties
- Sensitivity not yet sufficient to observe the signal

\[ \text{expected limit: } 2.6 \sigma_{\text{SM}} \]
**WW+WZ search in lν + HF jets (1/2)**

**Selection:** 1 lepton (electron/muon, 20 GeV), MET>20 GeV and exactly 2 jets (20 GeV)

**Background models**

- Rejection of the multijet background using a multivariate discriminant
  - \( R_B \approx 90\% / \varepsilon_S \approx 95\% \)
- \( W + \text{LF jets}: \) normalization in the tagged samples from the pretag sample using mistag-rates derived from data
- Other backgrounds extracted directly from simulation

<table>
<thead>
<tr>
<th>Yields</th>
<th>1-tag</th>
<th>2-tag</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signal</td>
<td>215</td>
<td>11</td>
</tr>
<tr>
<td>Backg.</td>
<td>5514</td>
<td>396</td>
</tr>
<tr>
<td>S/\sqrt{B}</td>
<td>2.9</td>
<td>0.6</td>
</tr>
</tbody>
</table>

In 1-tag: \( WW \approx 74\% \) of the signal
In 2-tag: \( WZ \approx 88\% \) of the signal

Most of the sensitivity of this search comes from the \( W \) decay into a charm-strange quark pair
WW+WZ search in $l \nu + HF$ jets (2/2)

The final discriminant used is the dijet invariant mass

$\rightarrow$ combination of four samples: central leptons/non-central muon, 1-tag/2-tag

LLR for the B-only and S+B hypotheses

$WW+WZ \rightarrow l \nu + HF$ jets observed with a significance of 3.0 S.D. from the B-only hypothesis
Selection: high missing transverse energy (40 GeV) and exactly 2 jets acoplanar (20 GeV)
A lepton veto is applied to keep orthogonality with the similar search in the $lvbb$ channel but important $WZ$ contribution from events with a non-identified lepton

This analysis is a copy of the analogous low mass Higgs search in the same final state: the only difference is the signal used for the training of the final discriminant, $VZ$ instead of $VH$
Control samples are used to validate and improve the background modeling:

- multijet control sample (loosening of the MET cut)
- electroweak control sample (inversion of the isolated muon veto)

Example: validation of the trigger simulation and of the $b$-tagging algorithms in the electroweak control sample

Relatively loose tagging requirements to define the 1-tag/2-tag samples but full $b$-tag output injected in the final discriminant
WZ+ZZ search in MET + HF jets (3/3)

Yields | 1-tag | 2-tag |
---|---|---|
Signal | 252 | 77 |
Backg. | 18883 | 2725 |
S/√B | 1.8 | 1.5 |

Final discriminants in the 1-tag and 2-tag samples after a global fit to the data in the S+B hypothesis with marginalization of the systematic uncertainties.

Cross-section measurement:
\[ \sigma(WZ+ZZ)_{\text{mes}} = 6.9 \pm 2.2 \text{ pb} \]
\[ \sigma(WZ+ZZ)_{\text{th}} = 4.6 \text{ pb} \]
Summary and prospects

3 preliminary results presented

- **WZ+ZZ search in dilepton plus jets**
  - expected limit: $2.6 \sigma_{\text{SM}}$

- **WW+WZ search in lepton-neutrino plus heavy-flavor jets**
  - production observed with a significance of 3.0 S.D. from the B-only hypothesis

- **WZ+ZZ search in missing transverse energy plus heavy-flavor jets**
  - production observed with a significance of 2.8 S.D. from the B-only hypothesis

In preparation: a Tevatron combination for the **WZ+ZZ search in lepton plus heavy-flavor jets**