Search for Associated Higgs Boson Production at DØ

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on behalf of the DØ collaboration
Introduction

- The SM parameters fit to EW precision data prefers a light Higgs boson.
- The most sensitive search channels for $114 < m_H < \sim 135$ GeV at the Tevatron is associated Higgs production.
- Leptonically decaying $W$ or $Z$ boson allows for rejection of multijet background.

- DØ results for the summer are still in internal review, no updated results in this talk.
  - Typical $\mathcal{L} \approx 1 \, \text{fb}^{-1}$.
  - No RunIIb data (2006-2007 data).
- Try to give an idea of what to expect for the Lepton-Photon conference (LP07).
The DØ Detector

- Liquid Ar and U calorimeter.
- Three-layer Muon system with coverage out to $|\eta| < 2$.
- Magnetic fields provided by a 2 T solenoid and a 1.8-2 T toroid.

- Si and Fiber Tracking detectors.
- New innermost layer of the silicon detector installed in spring 2006.
  - Will be used in updated results shown at LP07.
Higgs Production at the Tevatron

- Expected cross section $\sigma(VH)$ of the order of 0.1 pb.
- With $BR(W \rightarrow \ell\nu) \sim 0.1$ and typical event selection efficiency of $\sim 10\%$, expect about 2 event/fb$^{-1}$ of data (per lepton type).
Higgs Decay and $b$-tagging

- For $114 < m_H < \sim 135$ GeV, the decay $H \rightarrow b\bar{b}$ dominates.
- For $m_H \gtrsim 135$ GeV the $H \rightarrow WW$ decay is more sensitive.
- Decays of $b$-hadrons produce displaced tracks and vertices.
- All analyses use a NN-based $b$-tagging algorithm.
  - High I.P. tracks, SVX ...
WH - Cut Based Analysis

- $WH$ is the most sensitive channel for a Higgs with $m_H < 135$ GeV.
- Expected $\sigma(WH) \times Br(H \rightarrow b\bar{b}) = 0.13$ pb for $m_H = 115$ GeV.
- 1 fb\(^{-1}\) of data analyzed in the $e$+jets and the $\mu$+jets channels.
- Event Selections:
  - Equal to two jets with $p_T > 20$ GeV and $|\eta| < 2.5$.
  - An electron or a muon with $p_T > 20$ GeV.
  - A well reconstructed primary vertex with $> 2$ tracks.
  - $E_T > 20$ GeV.
  - Either two loose NN $b$-tagged jets ($70\% b$, $4.5\% l$-tag eff.) . . .
  - . . . or one tight NN $b$-tagged jet ($48\% b$, $0.5\% l$-tag eff.).
Sample before $b$-tagging

- Multijet (QCD) background estimated from data, other backgrounds estimated from simulated samples. Relatively pure $W$+jets sample.
Limit on $\sigma(WH) \times Br(H \rightarrow b\bar{b})$ derived from the invariant mass distribution of the jets. Expected 3.6 signal events ($m_H = 115$ GeV).
WH - Using Matrix Element (ME) Discriminant

- Using LO ME to compute $WH$ probability:

$$D(\vec{x}) = \frac{P_{WH}(\vec{x})}{P_{WH}(\vec{x}) + \sum_i c_i P_{B;i}(\vec{x})}$$

- Code imported from single top analysis.
  - Selections still to be optimized for $WH$.
- 900 pb$^{-1}$ analyzed.
- Around $2\sigma$ excess of events in double tags.
  - Low statistics.
  - Not seen for ST.
Dominant syst. uncertainties JES, $b$-tagging and $W$+h.f. content.

Updated result using 1.5 fb$^{-1}$ and NN discriminant for LP07.
$ZH \rightarrow \ell\ell bb$ Analysis

- $ZH$ with $Z \rightarrow \ell^+\ell^-$ is one of the more sensitive channels.
- Small production rate, $\sigma(ZH) \times Br(H \rightarrow b\bar{b}) = 0.085-0.02$ pb.
- 920 (840) pb$^{-1}$ of data analyzed in the $ee$ ($\mu\mu$) channel.

- Event Selections:
  - At least two jets with $p_T > 15$ GeV and $|\eta| < 2.5$.
  - Two electrons or two muons with $p_T > 15$ GeV.
  - The $\ell\ell$ invariant mass within $65 < M_{\ell\ell} < 115$ GeV ($ee$) or $70 < M_{\ell\ell} < 110$ GeV ($\mu\mu$).
  - The reconstructed $Z$ $p_T > 20$ GeV in the $\mu\mu$ channel.
  - A well reconstructed primary vertex with $> 2$ tracks.
  - 2 jets $b$-tagged with a NN-based tagger (72% $b$, 6% $l$-tag eff.).
ZH → ℓℓbb Data Sample Before $b$-tagging

- Dominant background is $Z$+jets.
- Simulated $Z$+jets samples are scaled to the yield in the $Z$ peak.
- Reconstructed $Z$ gives good rejection against multijet events.

- The $Z$ $p_T$ distribution poorly simulated in the $Z$+light jets sample.
  - Events are reweighted before $b$-tagging to correct this.
- Reweighted distribution shown.
• Look for mass peak in $M_{jj}$ after $b$-tagging has been applied.

• For $m_H = 105-155$ GeV, look for excess in mass window $m_H - 1.5w < M_{jj} < m_H + 1.5w$ (ee)
  $m_H - 1w < M_{jj} < m_H + 2w$ (μμ)
  where $w$ is exp. width of $M_{jj}$.

• Dominant syst. uncertainties:
  - Jet energy scale.
  - $b$-tagging efficiency.
  - $Z$+heavy flavor cross sections.

• Work ongoing to update the result using a NN discriminant.
ZH → ννbb Analysis

- $BR(Z \rightarrow \nu\nu) \approx 20\%$ in contrast with $BR(Z \rightarrow ee/\mu\mu) \approx 3.34\%$.
- No visible leptons to trigger on, also harder to reject multijet events.
- 930 pb$^{-1}$ of data analyzed.
- Event Selections:
  - At least two jets with $p_T > 20$ GeV and $|\eta| < 2.5$.
  - No isolated leptons.
  - $\Delta\phi(jet_1, jet_2) < 165^\circ$.
  - $H_T < 240$ GeV.
  - A well reconstructed primary vertex with $> 2$ tracks.
  - One tight NN $b$-tagged jet (43% $b$, 0.3% $l$-tag eff.).
  - One loose NN $b$-tagged jet (72% $b$, 6% $l$-tag eff.).
  - Selections to remove multijet:
    $min\Delta\phi(E_T, jets)$
    $\Delta\phi(E_T, p_T^{neg.\, trk.})$
    $Asym(E_T, H_T)$
**ZH → ννbb Cross Section Limit**

- Expect 1.4 $ZH$ events after $b$-tagging with an expected background of 63.3 events.
- Limit on $\sigma(ZH) \times BR(H \rightarrow b\bar{b})$ extracted from the the $M_{jj}$ distribution.

- Limit ranges from 2.7 to 1.6 pb for $m_H = 105$-$135$ GeV.
- Overall syst. uncertainty 15% (14%) for signal (background).
- Expect updated result using 1.5 fb$^{-1}$ for the LP07 conference.
Conclusions and Outlook

- Limits on the $\sigma(VH) \times Br(H \rightarrow b\bar{b})$ production rate for $m_H = 115$ GeV:

<table>
<thead>
<tr>
<th>Channel ($\mathcal{L} \approx 1$ fb$^{-1}$)</th>
<th>Exp. Limit</th>
<th>Obs. Limit</th>
<th>SM Exp.</th>
</tr>
</thead>
<tbody>
<tr>
<td>$WH$ cut based</td>
<td>1.1</td>
<td>1.3</td>
<td>0.13</td>
</tr>
<tr>
<td>$WH$ ME discriminant</td>
<td>1.2</td>
<td>1.7</td>
<td>0.13</td>
</tr>
<tr>
<td>$Z(\rightarrow \ell\ell)H$</td>
<td>2.8</td>
<td>2.7</td>
<td>0.08</td>
</tr>
<tr>
<td>$Z(\rightarrow \nu\nu)H$</td>
<td>1.9</td>
<td>2.5</td>
<td>0.08</td>
</tr>
</tbody>
</table>

- Expect updated results with 1-1.5 pb$^{-1}$ for LP07. Besides increased data set, several improvements are envisioned for these analyses:
  - Trigger selections, NN, event selections, $WH \rightarrow WWW \ldots$

- Combined with CDF, we will soon start probing the expected standard model production rates. Stay tuned!