Low Mass Higgs Searches at the Tevatron

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For the CDF and DØ Collaborations

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Château Royal de Blois, 2011
Fits and Constraints

- Electroweak symmetry breaking is a cornerstone of the standard model
- Higgs mechanism provides mass for the W and Z
- A consequence of this is the Higgs boson
- Mass is not predicted

\[ M_H < 158 \text{ GeV (indirect constraints)} \]
\[ M_H < 185 \text{ GeV (include LEP search)} \]
Leave No Higgs Behind

This Talk

<table>
<thead>
<tr>
<th>Channel</th>
<th>DØ</th>
<th>CDF</th>
</tr>
</thead>
<tbody>
<tr>
<td>WH → lνb̄b</td>
<td>5.3 fb⁻¹</td>
<td>5.7 fb⁻¹</td>
</tr>
<tr>
<td>ZH → ννb̄b</td>
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</tr>
<tr>
<td>H → γγ</td>
<td>8.2 fb⁻¹</td>
<td>7.0 fb⁻¹</td>
</tr>
<tr>
<td>H+X → ττjj</td>
<td>5.4 fb⁻¹</td>
<td>6.0 fb⁻¹</td>
</tr>
</tbody>
</table>

Updated Since Moriond

- Comprehensive search program
- Look everywhere we can
- High mass searches contribute too

And H → WW → lνjj

And H → WW → lνlν

And same sign dilepton

And...
Signals and Backgrounds

Higgs Searches at the Tevatron

\[ \sigma \times BR \sim 470,000 \text{ fb} \]

\[ \sigma \times BR \sim 78,000 \text{ fb} \]
Signals and Backgrounds

Gluon initiated backgrounds
Even worse at LHC

σ×BR ~ 470,000 fb

σ×BR ~ 78,000 fb
Signals and Backgrounds

Gluon initiated backgrounds
Even worse at LHC

The Tevatron is still the place to look for $H \rightarrow b \bar{b}$

$\sigma \times BR \sim 470,000 \text{ fb}$

$\sigma \times BR \sim 78,000 \text{ fb}$
Associated Production Searches

- **ZH** → $ll\bar{b}\bar{b}$
- **WH** → $l\nu\bar{b}\bar{b}$
- **ZH** → $\nu\nu\bar{b}\bar{b}$

**Crucial ingredients**
- Maximize lepton acceptance
- Efficient $b$-tagging
- Multivariate discriminants
Leptons and Jets

- One or two high $p_T$ electrons or muons
- Infer neutrinos from $p_T$ imbalance (missing $E_T$)
- Two Jets
- At least one b-tag

Higgs Searches at the Tevatron
ZH → \nu\nu b\bar{b}

- Recovers events from WH
- Large missing $E_T$
- Two high $p_T$ jets
- At least one b-tag

Higgs Searches at the Tevatron
b-tagging

- Tag b-jets using
  - Impact parameter and
  - Reconstructed decay vertex
  - Soft leptons

<table>
<thead>
<tr>
<th></th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>b-jets</td>
<td>50%-70%</td>
</tr>
<tr>
<td>light jets</td>
<td>0.5%-4.5%</td>
</tr>
</tbody>
</table>
How to Get a Limit

- Train multivariate discriminants
- Exploit full distribution by doing counting experiment for each bin
- Combine by multiplying per bin likelihoods
- Track correlations of uncertainties across bins
- Combination of many channels becomes straightforward (in concept) – just add more bins
Results at $M_H = 115$ GeV

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<tr>
<td></td>
<td>Expected</td>
<td>Observed</td>
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<tr>
<td>WH $\rightarrow l\nu b\bar{b}$</td>
<td>4.8</td>
<td>4.5</td>
</tr>
<tr>
<td>ZH $\rightarrow \nu\nu b\bar{b}$</td>
<td>4.0</td>
<td>3.4</td>
</tr>
<tr>
<td>ZH $\rightarrow llb\bar{b}$</td>
<td>5.7</td>
<td>8.0</td>
</tr>
</tbody>
</table>

Combined limits @ 115 GeV:
Exp: $1.45 \times \sigma_{SM}$
Obs: $1.56 \times \sigma_{SM}$

Exclude $M_H < 109$ GeV
## More Recent Results

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*Updated since Moriond*
Searches in $\tau\tau$ plus jets channels

Selection:

One hadronic $\tau$
One electron or $\mu$
At least one jet
Searches in $\tau\tau$ plus jets channels

CDF Run II Preliminary

$\sigma$95% C.L. Limit/\sigma{(SM)} * BR(H -> \tau\tau)

Limit / \sigma{(H+X -> \tau\tau)}/\sigma{(SM)}

CDF Limits @ 115 GeV:
Exp: 15 × $\sigma_{SM}$
Obs: 35 × $\sigma_{SM}$

DØ Limits @ 115 GeV:
Exp: 13 × $\sigma_{SM}$
Obs: 33 × $\sigma_{SM}$
Diphoton final states

Simple event selection: two photons

Plots showing event selection and background estimation.

- Backgrounds from control samples and Monte Carlo
- Multivariate analysis to enhance sensitivity

Graphs showing event distributions and mass spectra for diphotons.

Background from sideband method

Extended selection: forward photons conversions
Diphoton final states

Tevatron Run II Preliminary \( H \rightarrow \gamma\gamma \) \( L \leq 8.2 \text{ fb}^{-1} \)

Limits @ 115 GeV:
Exp: \( 9.2 \times \sigma_{\text{SM}} \)
Obs: \( 12 \times \sigma_{\text{SM}} \)

95% CL Limit/SM

\[
\begin{array}{c}
10^2 \\
10 \\
1 \\
\end{array}
\]

\[
\begin{array}{c}
100 \\
110 \\
120 \\
130 \\
140 \\
150 \\
\end{array}
\]

\( m_H \) (GeV/c^2)

May 17, 2011

SM=1
Higgs Searches at the Tevatron

Projections

DZero×2 Preliminary Higgs Projection

- 95% CL Exclusion
- Improvement Potential
- No Detector Aging
- Three Sigma Evidence
- Improvement Potential
- No Detector Aging

Luminosity / Experiment

Already recorded almost 10 fb⁻¹

m_H (GeV)
Outlook

- All major channels will be updated for EPS
- Expect analyzed datasets of 8-9 fb\(^{-1}\)
- Will soon start pushing past the LEP lower bound
- Sensitivity across entire mass range by the winter conferences

http://www-d0.fnal.gov/Run2Physics/WWW/results/higgs.htm
http://www-cdf.fnal.gov/physics/new/hdg/hdg.html
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Production and Decay

- Use leptons to suppress backgrounds
- When $H \rightarrow b\bar{b}$ dominates, need associated W or Z
Associated Production Searches

Use specialized lepton ID to improve acceptance

$ZH \rightarrow ll\bar{b}\bar{b}$

$WH \rightarrow l\nu\bar{b}\bar{b}$

$ZH \rightarrow \nu\nu\bar{b}\bar{b}$
Resolving the Mass Peak

- For $H \rightarrow b\bar{b}$, dijet mass is the key variable
- Better mass resolution gives better sensitivity
- In llbb channels expect minimal missing $E_T$
  - Exploit to improve jet energy measurement