Beyond the Standard Model
neutral Higgs searches
at the Tevatron

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on behalf of the CDF and D0 collaborations
Higgs beyond the SM

• most efforts centered on finding a standard model Higgs
  ‣ however standard model incomplete
• most SM extensions predict Higgs bosons as well
  ‣ often similar to SM Higgs, but different couplings

• fermiophobic Higgs (part I)
  ‣ Higgs only (mostly) couples to bosons
  ‣ Higgs decays predominantly into $\gamma\gamma$ or $WW$ (depending on Higgs mass)
  ‣ most searches double as standard model searches
• MSSM Higgs (part II)
  ‣ predicts 5 Higgs bosons: $h, H, A, H^\pm$
  ‣ $h, H, A$ similar to SM Higgs
  ‣ couplings different enough to warrant special searches
• searching for $WH \rightarrow WWW$
  ▷ less backgrounds than $H \rightarrow WW$
• looking for two like-sign leptons
  ▷ veto on third lepton
• set mass dependent limit

![Graphs showing results of D0: WWW search](image-url)
CDF: WWW search

- looking for exactly two same charge leptons
- split sample by lepton types
- simple counting experiment
- extract limits as function of $m_H$

<table>
<thead>
<tr>
<th>$m_H$ (GeV/c$^2$)</th>
<th>Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>110</td>
<td>141.7±9.2</td>
</tr>
<tr>
<td>160</td>
<td>0.272±0.016</td>
</tr>
<tr>
<td>134 data</td>
<td></td>
</tr>
</tbody>
</table>
D0: γγ search

• using neural network to distinguish photons from jets
• searching for excess in di-photon mass

- setting limit as a function of the Higgs mass
- new results coming soon
• assume $h_fVV$ is suppressed
  ‣ use $h_fVH$ vertex instead
  ‣ $W^* \rightarrow h_fh \rightarrow h_fh_fW \rightarrow \gamma\gamma\gamma(\gamma)+X$
• look for excess at high transverse momentum of tri-photon system
• setting model depending limits

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{distribution.png}
\caption{Distribution of 3-body transverse momentum}
\end{figure}

<table>
<thead>
<tr>
<th>$H_T$</th>
<th>30</th>
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<tbody>
<tr>
<td>SM</td>
<td>1.1</td>
</tr>
<tr>
<td>bkg</td>
<td>$\pm 0.2$</td>
</tr>
<tr>
<td>data</td>
<td>0</td>
</tr>
</tbody>
</table>
MSSM Higgs

- Processes involving bottom quarks (down-type) can be enhanced (goes like $\tan^2\beta$)
- Boost from femtobarns to picobarns
- Dominant decays to $bb$ (90%) and $\tau\tau$ (10%)
- $\tau\tau$ has much lower backgrounds
bbb search

- at high $\tan\beta$ predominant decay is to $bb$ (BR=90%)
- direct search for $H \rightarrow bb$ is hard
  - lots of QCD background

- $b$ quark $p_T > 20$ GeV/c, $|\eta| < 2$

- search for $bH \rightarrow bbb$ instead
  - best signal to background

Dawson, Jackson, Reina, Wackeroth hep-ph/0603112
• fitting two and three tag distributions to obtain signal and background contributions
• extract cross section limit from signal fit
• convert cross section limit to $\tan\beta$ limit
D0: bbb search

- split signal into 3, 4, 5 jet bins
- fit two and three tag distributions to obtain signal and background rates
- extract tanβ, mA limits for several points in parameter space

**D0 Preliminary, L=2.6 fb⁻¹**

\[ gb \rightarrow b\phi \]
**CDF: \(\tau\tau\) search**

- split sample according to \(\tau\) decay mode
- fit signal template to visible di-tau mass spectrum
- extract limits in \(\tan\beta\) and \(m_A\)

**MSSM Higgs → \(\tau\tau\) Search, 95% CL Exclusion**

CDF Run II Preliminary, 1.8 fb\(^{-1}\)

**MSSM Higgs → \(\tau\tau\) Search, 95% CL Exclusion**

CDF Run II Preliminary, 1.8 fb\(^{-1}\)

- observed
- \(A \rightarrow \tau\tau\)
- \(Z/\gamma^* \rightarrow \tau\tau\)
- other EW, \(t\bar{t}\)
- jet fake

**LEP 2**

- \(m_h^\text{max}\)
- no mixing

- \(\mu<0\)

- \(\mu>0\)
D0: τττ search

• split sample by τ decay mode and run period
• fit signal template to visible mass
• extract limits in $\tan \beta$ and $m_A$

$\tan \beta$, $\mu = +200$ GeV

$D0$ prel., 1-2.2 fb$^{-1}$

$M_A$ (GeV)

Observed limit
Expected limit
LEP 2

No-mixing, $\mu = +200$ GeV

$D0$ prel., 1-2.2 fb$^{-1}$

$M_A$ (GeV)

Observed limit
Expected limit
LEP 2
D0: bττ search

- analogous to bbb search
  - looking for ττ + b
- one τ decays to μ, one to hadrons (T_h)
- split sample by T_h decay type
- perform counting experiment
- extract tan β, m_A limits
- improved analysis on the way

<table>
<thead>
<tr>
<th>T_h type</th>
<th>I</th>
<th>II</th>
<th>III</th>
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</thead>
<tbody>
<tr>
<td>bkg</td>
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<tr>
<td>data</td>
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<td>2</td>
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Summary & Outlook

- CDF and D0 are looking actively for Higgs in the context of new physics models
- Lots of parameter space and models to cover
- Many standard model searches can double as BSM searches
- So far no sign of the Higgs

- More results which are to be released soon
- Still lots of data to come
- Working on combining these results into overall limits

- Still chance that some day we will do more than set limits

- **D0**: [http://www-d0.fnal.gov/Run2Physics/WWW/results/higgs.htm](http://www-d0.fnal.gov/Run2Physics/WWW/results/higgs.htm)