Higgs Search at DØ

DoE Site Visit, UTA
Nov. 13 - 14, 2001
Jae Yu

Outline

1. Introduction
2. Search channels at DØ
3. Current Status on Higgs search
4. Conclusions
Introduction

- Standard Model has been extremely successful → EW sector tested very rigorously
- Yet, there are outstanding issues still remaining
  - Neutrino masses ← Neutrino oscillations
  - Electroweak symmetry breaking → Origin of masses
  - CP violations ← kTeV and other experiments
- TeVatron collider Run II can contribute to resolve two of the three issues in SM
- Based on EW precision fits → Higgs could be just around the corner, at the mass of ~120GeV
- If lower mass, TeVatron will see Higgs (I personally hope more intriguing scenario with SUSY)
The Standard Model works at the $10^{-3} \sim 10^{-6}$ level.

All observations are consistent with a single light SM Higgs, though no such beast has yet been observed.

- Best fit $m_H = 88$ GeV (LEP) and $m_H < 198$ GeV (Global SM fit)
Tevatron Run I Results

- Run I limits are not very stringent

<table>
<thead>
<tr>
<th>Channel</th>
<th>DØ (95% CL)</th>
<th>CDF(95% CL)</th>
<th>Theory</th>
</tr>
</thead>
<tbody>
<tr>
<td>WH → l ν bb</td>
<td>&lt;28 pb</td>
<td>&lt;27 pb</td>
<td>0.07</td>
</tr>
<tr>
<td>ZH → ν ν bb</td>
<td>&lt;8 pb</td>
<td>0.10</td>
<td></td>
</tr>
<tr>
<td>ZH → ll bb</td>
<td>&lt;7.5 pb</td>
<td>0.11</td>
<td></td>
</tr>
</tbody>
</table>

No real mass limit here…
Tevatron Run II Higgs Physics

- $\sigma \times \text{BR} @ 2 \text{ TeV}$
  - Use associated H+W/Z production
    - $H \to b \overline{b}$

### Backgrounds

<table>
<thead>
<tr>
<th>Process</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZZ</td>
<td>4.4</td>
</tr>
<tr>
<td>Wbb+Zbb</td>
<td>14</td>
</tr>
<tr>
<td>$tt$</td>
<td>7.5</td>
</tr>
<tr>
<td>$tb+tq_{tbq}$</td>
<td>3.4</td>
</tr>
<tr>
<td>QCD</td>
<td>$O(10^6)$ dijet $O(10^5)$ 4jet</td>
</tr>
<tr>
<td>$W \to e\nu$</td>
<td>2800</td>
</tr>
</tbody>
</table>

$\sigma (\text{pb})$ for $M_H=100$ GeV

<table>
<thead>
<tr>
<th>Process</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$gg \to H$</td>
<td>1.17</td>
</tr>
<tr>
<td>$qq,gg \to WH$</td>
<td>0.31</td>
</tr>
<tr>
<td>$qq,gg \to ZH$</td>
<td>0.17</td>
</tr>
<tr>
<td>$qq,gg \to H+2\text{jets}$</td>
<td>0.12</td>
</tr>
<tr>
<td>All others</td>
<td>$&lt;0.02$</td>
</tr>
</tbody>
</table>
Run II Higgs S/N

- $H \rightarrow b \overline{b}$
  - S/N drops as $M_H$ increases
  - Run out of events....
  - Ultimately limits Run II reach

- $H \rightarrow WW/ZZ$ (virtual)
  - Definite gains, depends on di-jet mass resolution
  - $1 \text{ fb}^{-1}$ delivered

![Graph showing S/B ratio vs. $M_H$ (GeV)]
For $M_H < \sim 135$, $H \to b \bar{b}$ dominates

- FNAL Tevatron:
  - look for $H \to b\bar{b}$ $M_H < \sim 135$ GeV
    - Note $H \to WW$ possible down to $M_H \sim 110$ GeV
  - Maybe $H \to WW/ZZ$ $M_H > \sim 135$ GeV
- CERN LHC: look for $H \to WW$ or $ZZ$
  - Depending on what is found at FNAL Run II
\( m_H < 130-140 \, \text{GeV} \)

- \( WH \rightarrow lv b \, \bar{b} \) backgrounds \( Wb \, \bar{b}, \) \( WZ, t \, \bar{t}, \) single \( t \)
  - factor ~ 1.3 improvement in S/B with neural network
  - possibility to exploit angular distributions (\( WH \) vs. \( Wbb \))
  - Parke and Veseli, hep-ph/9903231

- \( WH \rightarrow qq b \, \bar{b} \) overwhelmed by QCD background

- \( ZH \rightarrow l \, \bar{l} \, b \, \bar{b} \) backgrounds \( Zb \, \bar{b}, ZZ, t \, \bar{t} \)

- \( ZH \rightarrow v \, \bar{v} \, b \, \bar{b} \) backgrounds QCD, \( Zb \, \bar{b}, ZZ, t \, \bar{t} \)
  - requires relatively soft missing \( E_T \) trigger (35 GeV?)
$m_H > 130-140$ GeV

- $gg \rightarrow H \rightarrow WW^*$ backgrounds Drell-Yan, WW, WZ, ZZ, $t\bar{t}$, $tW$, $\tau\tau$
  
  signal:background ratio $\sim 7 \times 10^{-3}$!

  - Angular cuts to separate signal from “irreducible” WW background
- LEP limit $M_H > 113.3$ GeV already
- $2 \text{ fb}^{-1}$ per DØ/CDF not enough
- Can have up to $15 \text{ fb}^{-1}/\text{exp}$ by 2007 ➔ Good to reach $3\sigma$ discovery up to $M_H \sim 180$ GeV

Run II Expectation

![Graph showing the expected integrated luminosity vs. Higgs mass, with thresholds and limits indicated.](image)

Ruled out by LEP
Higgs Signal Event Characteristics

\[ \overline{p}p \rightarrow WH \rightarrow \overline{b}b \rightarrow e\nu \]

- Missing \( E_T \)
- EM cluster
- Electron Track
- Hits in Silicon Tracker (for b-tagging)
- Calorimeter Towers
- Two b-jets from Higgs decay
Z → ee candidates

Initial Calorimeter performance

2 EM objects, $E_T > 20$ GeV, isolation and shower shape cuts

(uncalibrated energy scale)

Calibration: shift to Z mass

Jae Yu, Higgs Search at DØ
DoE Site Visit, 11/14/01
• Two muons recoiling against a jet
W → eν candidates

EM cluster with track

Need to understand missing E_T

m_T(e,ν) ~ 0.1pb^{-1}
WH Candidate????

DØ W + 2 jet (Higgs!) candidate, October 2001

All ingredients needed for “high \(P_T\)“ physics

Electron

Jet 1
\[E_T^{\text{raw}} = 17 \text{ GeV}*\]

Jet 2
\[E_T^{\text{raw}} = 13 \text{ GeV}*\]
Conclusions

- Higgs could be just around the corner
- Extremely important to carry out RunII successfully
- Must have $15 \text{ fb}^{-1}/\text{exp}$ for extended reach
- Best chance with WH or ZH associated production
- Have been working with W/Z + Jets events
- DØ Starts accumulating W and Z events in e and $\mu$
- Crucial to understand the detector with the full tracking systems ASAP
- Exploit local computing system for analysis for expedited results