The Search for the Higgs through the decay channel

$H \rightarrow WW \rightarrow e\nu + jj$

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- Motivation
  - theoretical overview

- Analysis
  - BDT method

- Obtain Limits with Collie

- Summary
• All particles fall into 1 of 2 categories; fermions and bosons

• According to the SM, all particles are necessarily mass-less
The Tevatron

- proton/anti-proton collider
- 6.3km radius

- The tevatron is a synchrotron

- The acceleration can impart up to 980GeV center of mass energy to the particles resulting maximum of around 1.96 TeV for the collision

- The beams, consisting of bunches of around 10 billion particles each cross each other at the center of the 5000-ton DZero detector located inside the Tevatron tunnel, creating thousands of new particles.
The D0 Detector

Muon System

DØ Detector in Collision Hall, January 2001
The D0 detector consists of a silicon micro strip vertex detector and fiber tracker both located within a 2 T superconducting solenoidal magnet.

There is also a liquid argon and uranium sampling calorimeter, housed in three cryostats.

The calorimeter is segmented longitudinally into four electromagnetic and up to five hadronic layers.

Additional shower sampling is provided by scintillating tiles located at the boundaries between cryostats. Beyond the calorimeter are the muon detectors.
Reconstruction

Analysis software reconstructs actual physical objects from the info in the detector. For example, we can start with a cluster in the calorimeter, match a track to it, and if the shower shape in the calorimeter corresponds to that expected from an electron, we identify that object as an electron. In the image below, the red column represents an EM cluster corresponding to an electron.
The cross section is related to the probability of H production.

The dominant H production process is gluon fusion.

Decay into vector boson pairs is most common for high Higgs mass.
Unfortunately, it’s only possible to detect the Higgs indirectly through its decay products because its lifetime is so short.

Heavier Higgs ( \textgreater; 140 GeV) generally decay into boson pairs, which then decay further. Most experiments until now have focused on channels or modes where two W’s decay into leptons when \( m(H) = 2m(W) \). This summer we’ve been searching the semi-leptonic mode, \( H \rightarrow WW \rightarrow ev jj \).
Overview of Analysis

- Our data was collected between August 2002 and February 2006 in D0 run Iia. The luminosity was $1.03 \text{ fb}^{-1}$.

- Higgs signal and background samples have been produced with Monte Carlo event generators. The MC samples were then passed through detector simulation and reconstruction because we intended to analyze them as if they were data and compare them to the actual data.

- Input files (data, sig and back) formatted as trees, were processed and a set of kinematic and angular variables that can distinguish between signal and background were obtained.
The Analysis Process, cont.

- Feed the to the classification program “toolkit for multivariate analysis” or tmva and run it using the Boosted Decision Tree technique.

- Read the output to histograms and Check for Background/Data agreement.

- Feed the histograms to the program “Collie” which, among other things, sets a lower exclusion limit on the cross section of Higgs production at a certain mass.
Event Selection

- **Electron:**
  - $p_T > 20$ GeV
  - $|\eta_e| < 1.1$ (Central Calorimeter)

- **At least 2 jets - most central:**
  - Leading $p_T > 30$ GeV
  - Second $p_T > 20$ GeV

- **MET > 20 GeV**

- **W → ev selection:**
  - $40$ GeV $< m_{TR} < 200$ GeV (transverse mass)

- **W → jj selection:**
  - $10$ GeV $< m_{jj} < 300$ GeV (jet-jet mass)
Data/MC Agreement

We add MC background samples on top of each other. The total solid histogram should agree with the black data points. The signal is scaled for visibility.

MC: WW, WZ, ZZ     W+jets     Wcc, Wbb     tt, single t     QCD     H->WW     data
Variable Correlations

The variables distinguish signal from background better the less correlated they are.
Toolkit for Multivariate Analysis

- The program runs in two phases; training and application
- Makes use of multivariate classifiers, specifically BDT
Boosted Decision Tree

N=5814.100000
S/(S+B)=0.519
wlep_pt< 49.1

N=1641.680000
S/(S+B)=0.208
ww_pt> 18.1

N=812.577000
S/(S+B)=0.357
wlep_pt< 91.0

N=4172.420000
S/(S+B)=0.641
ww_mass> 153

N=345710040
S/(S+B)=0.767
sumPt> 154
Classifier Output Distribution

$m_H = 160$ GeV \quad m_H = 180$ GeV

Histograms with vertical axis = # of events
Signal and Background efficiencies

- The ratio of $S/\sqrt{S+B}$ is an indicator of how close we are to detecting the Higgs.

- Our value for the ratio is 0.1035.

- On this scale, 5 would mean discovery!

$m_H = 160$ GeV
Because $S/\sqrt{S+B} << 1$, we can only set limits on the Higgs.

Collie uses as inputs the results from tmva.

It produces the ratio of excluded cross section to predicted SM cross section.
Collie exclusion curves

- This curve represents the lower exclusion limit of Higgs cross section.

- Calculated as the ratio of excluded expected and observed cross sections to SM cross section.

Graph: X axis: Mass
Y axis: Excluded Cross Section in SM units

- D0 Preliminary, L=1.03 fb⁻¹

H→W⁺W⁻→eνjj

Standard Model = 1.0
Collie Exclusion

- Mass: 155, exp: 23.95, obs: 29.42
- Mass: 170, exp: 17.06, obs: 29.68
- Mass: 175, exp: 19.03, obs: 23.82
- Mass: 180, exp: 20.74, obs: 20.92
- Mass: 185, exp: 24.05, obs: 26.69
- Mass: 190, exp: 27.18, obs: 14.45
- Mass: 195, exp: 27.55, obs: 18.16
- Mass: 200, exp: 34.07, obs: 20.98

The obs/exp values correspond to the multiple of SM cross section that is excluded for each mass
Conclusions

- We performed the search for the Higgs Boson through the channel $H \rightarrow WW \rightarrow e\nu+jj$ with the data collected by the D0 detector.

- BDT was used to separate signal from background events.

- Collie was used to set limits on the SM Higgs production.

- For $m(H) = 160$, we can exclude cross sections above $16.67 \times \text{SM cross sec}$, while we expected to exclude above $15.71 \times \text{SM cross sec}$.
Acknowledgements

- The Nevis Laboratory including:
  - Lidija Zivkovic
  - John Parsons
  - Gustaaf Brooijmans

- The REU program
Cross Section