FERMILAB-CONF-08-684-E

Search for the Standard Model Higgs with $m_h > 130 - 200$ GeV at the Tevatron

Daniel Whiteson
University of California, Irvine
Irvine, CA 92607
On behalf of the CDF and D0 collaborations

Abstract

We present the latest results in searches for the Standard Model Higgs boson in the range $m_h > 130 - 200$ GeV. No evidence of Higgs production is observed, and limits on its cross section approach the Standard Model prediction near $m_h = 160$ GeV.

1 Introduction

The Standard Model requires a Higgs boson to explain the origins of Electro-Weak symmetry breaking and to regulate strong WW scattering.

The most senstive direct searches for the Higgs boson have been performed with the detectors at LEP, which give a limit of $m_h > 114.1$ GeV [1]. However, the current energy and luminosity frontier is at the FermiLab Tevatron, a 1.96 TeV center-of-mass accelerator which collides protons and anti-protons at the center of two detectors, CDF and D0.

The primary Higgs production mechanism at the Tevatron is $gg \to h$. Cross sections for associated production $p\bar{p} \to Wh$, $p\bar{p} \to Zh$ are lower by an order of magnitude.

The primary decay mode below Higgs mass of 130 GeV is $h \to bb$, while above 130 GeV the Higgs decays predominantly as $h \to WW$. In the lower mass region, production by gluon fusion is nearly impossible to observe due to the large backgrounds to the primary decay mode to b pairs. Analysis of the associated production modes is challenging but possible.

In the high mass region, however, the decay to W pairs makes a search for $gg \to h$ feasible. The associated production $p\bar{p} \to Vh \to VWW$ where $V = Z, W$ gives additional sensitivity. This note presents results of searches by CDF and D0 in the high mass region, $m_h = 130 - 200$ GeV using datasets with integrated luminosity of up to 2 fb^{-1}.

2 Final State Objects

In the high mass searches, the most sensitive searches for both production mechansisms $gg \to h \to WW$ and $p\bar{b} \to VH \to VWW$ involve final states with leptons. Leptonic W decay gives a powerful rejection of the QCD background in the hadronic environment.

For the WW final state, the signature is two opposite-signed leptons and missing transverse energy. The major backgrounds are discussed below.

For the VWW final state, the greatest power comes from the final state which includes two same-signed leptons. Backgrounds are described below.

The power of the analysis is closely tied to the ability to observe the final state leptons. To boost the sensitivity of the analyses, significant work has been done to extend the leptonic acceptence of the CDF and D0 detectors, by loosening the identification requirements and adding new categories of identified leptons based on charged tracks rather than electromagnetic deposits or tracks in muon systems.

3 $h \to WW$

Searches at D0 and CDF for $h \to WW$ require observation of two opposite sign high p_T electrons or muons as well as significant missing transverse energy due to the escaping neutrinos [2, 3].

Major backgrounds come from diboson (WW, WZ, ZZ), where additional leptons are lost to give missing energy; dilepton top quark events, which can be suppressed due to their jet production; Drell-Yan events ($Z \to ll$), which are highly suppressed by requiring missing energy; and $W\gamma$ events, in which the photon can give a final state electron.

The analysis at CDF calculates an event probability, by convoluting the matrix element for higgs or background processes with detector resolution functions and numerically integrating over unknown parton-level quantities. Some assumptions are made to retain computational tractability, but the event probability is a powerful discriminator.

Both CDF and D0 use a neural network as their final stage of analysis; at CDF the event probabilities are used as inputs to the neural network. To validate the simulation of the data, many adjacent control regions are checked and good agreement is seen, see Fig. 1.

The two experiments have sensitivity such that they expect to set an upper limit on the production cross-section which is 2.8 times the SM prediction. CDF's observed limit is 1.6, and D0's is 2.4 times the SM prediction.

4 $Vh \to VWW$

While the production cross section for Vh is significantly smaller than for $gg \to h$, the final state of VWW has a striking signature of like-signed leptons, for which the Standard Model backgrounds are small.

Dominant backgrounds at CDF and D0 are diboson production ($ZZ, Z\gamma, W\gamma$) in which some of the leptons are lost, and misidentified leptons from jets. The backgrounds are described using a combination of Monte Carlo and data-driven techniques.

CDF and D0's limits are shown in Figure 2.

5 Combination

The results from all channels at both CDF and D0 have been combined for maximum sensitivity [6]. At the most sensitive Higgs mass, $m_h = 160$ GeV, the combined analysis expects to set an upper limit on the production cross section at 1.9 times the SM prediction. The observed limit is 1.4 times larger than the SM rate.

6 Conclusions

CDF and D0 have presented their analyses of data in searches for the Higgs boson with masses between 130 and 200 GeV. No evidence of a Higgs signal is seen, but upper limits on the cross section are rapidly approaching the predictions of the Standard Model around $m_h = 160$ GeV.

Additional improvements currently being developed, including consideration of contributions from vector boson fusion, should yield important increases in sensitivity.

References

1. LEP higgs result
2. `http://www-cdf.fnal.gov/physics/new/hdg/results/hwwmenn_080229/WW_2fb_public_note.ps`
3. `http://www-d0.fnal.gov/Run2Physics/WWW/results/prelim/HIGGS/H45/H45.pdf`
4. `http://www-cdf.fnal.gov/physics/exotic/r2a/20041014.lsdilep_whwww/note_7307.pdf`
5. `http://www-d0.fnal.gov/Run2Physics/WWW/results/prelim/HIGGS/H37/H37.pdf`
6. Tevatron New Phenomena And Higgs Working Group, hep-ex/0712.2383

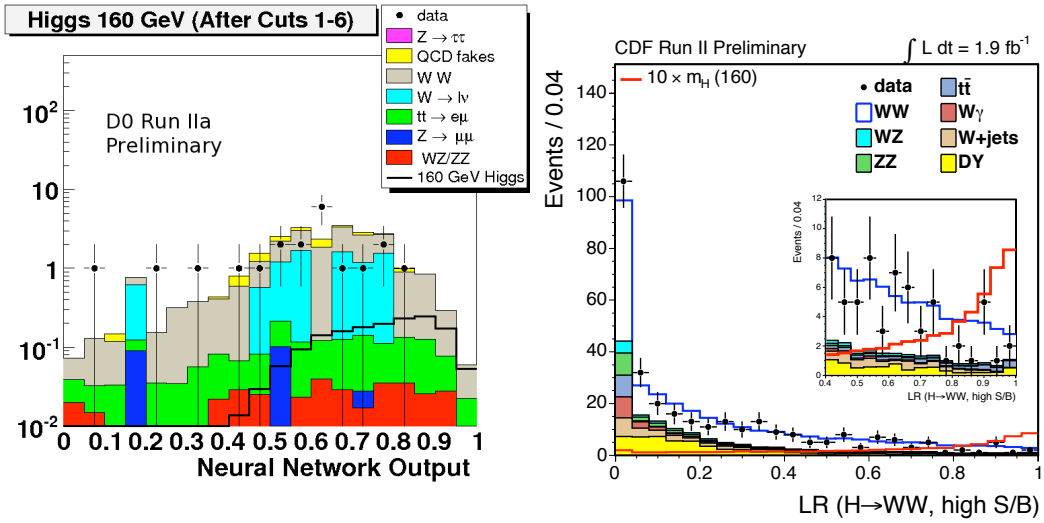

Figure 1: *Higgs and backgrounds predictions in the $h \to WW$ analyses at D0 (left) and CDF (right), compared to observed data.*

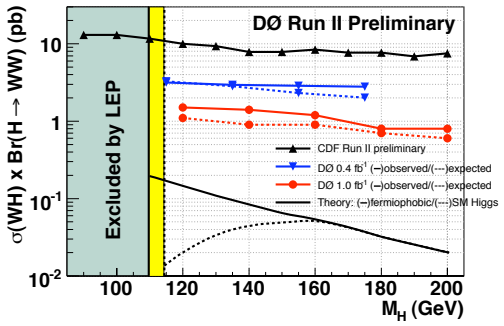

Figure 2: *Upper limits on Standard Model Higgs production from searches for* $Vh \rightarrow VWW$ *with same-signed leptons.*

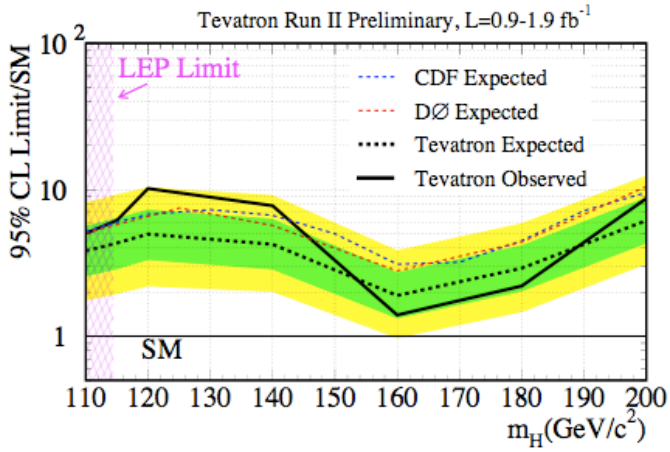

Figure 3: *Combined results from CDF and D0 higgs searches.*