PROCEEDINGS OF SCIENCE

Higgs boson at 160 GeV at the Tevatron

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On behalf of the CDF and DØ Collaborations

We are presenting results from searches for a Standard Model (SM) Higgs boson that are sensitive to a high mass Higgs. These results are based on 1-3fb^{-1} of data collected with the CDF and DØ detectors. We exclude at the 95% confidence level (CL) the production of a SM Higgs boson with a mass of 170 GeV/c^2.

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1. Higgs Production and Decay

SM Higgs production at the Tevatron is dominated by the gluon fusion process (Fig. 1). Additional gains in sensitivity for Higgs searches are possible by including Higgs production via W/Z associated production (*Higgs Strahlung*), and vector boson fusion (VBF). Requiring subsequent decays of the Higgs boson into W pairs enhances search sensitivities for larger Higgs masses, centered around the energy for on-shell W pair production (Fig. 2).

In order to suppress multijet background events (*QCD*), results presented here focus on final states originating from leptonically decaying W bosons, $W \to l\nu$ $(l = e, \mu)$.

Our results are based on 1-3fb^{-1} of data collected with the CDF and DØ detectors ([1], [2]).

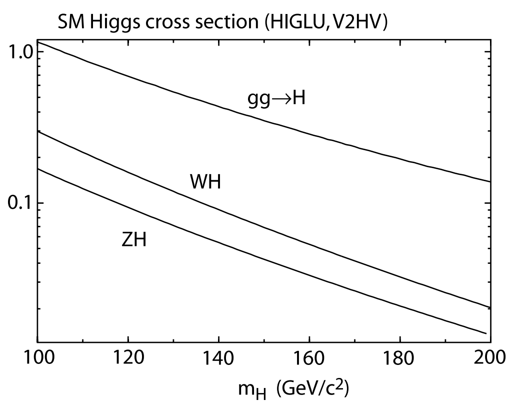

Figure 1: SM Higgs boson production cross sections at the Tevatron.

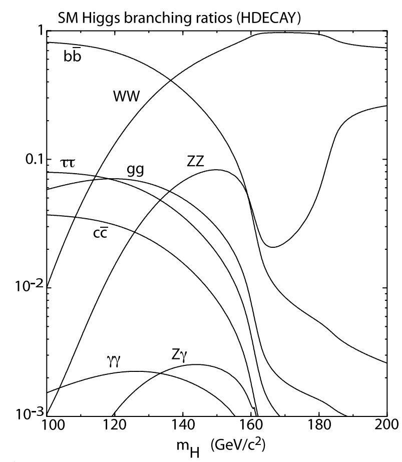

Figure 2: SM Higgs boson branching fractions.

2. $H \to WW \to l\nu l\nu$ $(l = e, \mu)$

The $H \to WW \to l\nu l\nu$ $(l = e, \mu)$ channel represents the most sensitive Higgs search channel at the Tevatron where both CDF and DØ are approaching SM sensitivity ([3], [4]). Results presented here take into account Higgs bosons produced via gluon fusion, VBF, and Higgs Strahlung. In the final state two high p_T leptons and missing transverse energy ($\not{E}_T$) from neutrinos are selected as signal signatures. Main backgrounds are due to diboson (WW), top quark, $Z \to ll$, and $W+$ Jets production. Both CDF and DØ analyses use 3fb^{-1} of data. Final signal-background discriminants are based on neural network (NN) outputs and Matrix Element (ME) likelihoods.

The following paragraph describes the DØ analysis.

After a loose preselection the following analysis cuts are applied (final state leptons in parenthesis):

- $\not{E}_T$(GeV/c^2): $> 20(e\mu)$, $> 20(ee)$, $> 20(\mu\mu)$
- $\not{E}_T^{scaled}$: $> 7(e\mu)$, $> 6(ee)$, $> 5(\mu\mu)$
- $M_T^{min}(l, \not{E}_T)(GeV/c^2)$: $> 20(e\mu)$, $> 30(ee)$, $> 20(\mu\mu)$
- $\Delta\Phi(l,l)$: $< 2.0(e\mu)$, $< 2.0(ee)$, $< 2.5(\mu\mu)$

$\not{E}_T^{scaled}$ is a parameter designed to remove events if $\not{E}_T$ could have been produced by a mis-measurement of jet energies. It is defined as:

$$\not{E}_T^{scaled} = \frac{\not{E}_T}{\sqrt{\sum_{jets}(\Delta E^{jet} \cdot sin\theta^{jet} \cdot cos\Delta\Phi(jet, \not{E}_T))^2}} \tag{2.1}$$

Minimal transverse mass ($M_t^{min}(l, \not{E}_T)$) is the lesser transverse mass (M_T) built out of either of the two leptons and $\not{E}_T$, with M_T defined as

$$M_T(l, \not{E}_T) = \sqrt{2p_T^l \not{E}_T(1 - cos\Delta\Phi(l, \not{E}_T))} \tag{2.2}$$

The opening angle $\Delta\Phi(l,l)$ is used to reject Z/γ^* boson and multi-jet events, since most of the background decays are back-to-back.

A NN is used as the final discriminant. A separate NN is trained for each Higgs mass in 5 GeV/c^2 steps for each of the final states ($e\mu$, ee, $\mu\mu$). The NN output distributions are then used to set limits. Using a NN based approach as opposed to a simple cut-based approach results in a gain of approx. 30% in overall sensitivity. Figures 3, 4, and 5 show the NN output distributions for the $e\mu$, ee, and $\mu\mu$ channels, respectively.

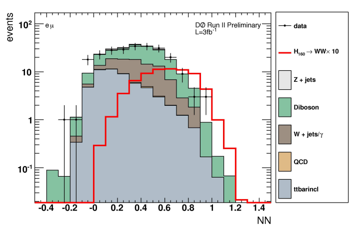

Figure 3: NN output for $e\mu$.

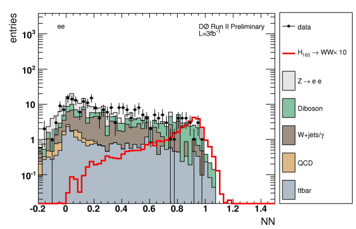

Figure 4: NN output for ee.

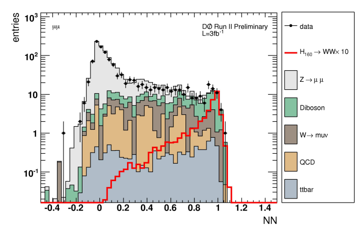

Figure 5: NN output for $\mu\mu$.

The following paragraph describes the CDF analysis.

Final states are separated according to jet multiplicities. The 0-jet sub-sample is only sensitive to Higgs production via the gluon fusion process. The 1-jet and $\geq$2-jet sub-samples add Higgs Strahlung and VBF as production modes (Higgs Strahlung and VBF contributions add approx. 20% of signal to the 1-jet sub-sample, and approx. 60% to the $\geq$2-jet sub-sample).

Events are selected based on the following criteria:

- p_T(lepton 1) $>$ 20 GeV/c^2, p_T(lepton 2) $>$ 10 GeV/c^2
- Oppositely charged leptons
- $M_{ll} > 16$ GeV/c^2
- p_T(jet) $>$ 15 GeV/c^2
- $\not{E}_{T\,spec} > 25$ GeV/c^2 (ee, $\mu\mu$), $\not{E}_{T\,spec} > 15$ GeV/c^2 ($e\mu$)

$\not{E}_{T\,spec}$ is used to suppress the Drell-Yan background, and is defined to be:

$$\not{E}_{T\,spec} = \begin{cases} \not{E}_T & \text{if } \Delta\Phi(\not{E}_T, lepton, jet) > \frac{\pi}{2} \\ \not{E}_T sin(\Delta\Phi(\not{E}_T, lepton, jet)) & \text{if } \Delta\Phi(\not{E}_T, lepton, jet) < \frac{\pi}{2} \end{cases} \tag{2.3}$$

Figures 6, 7, and 8 show the NN output distributions for the 0-jet, 1-jet, and ≥2-jet channels, respectively.

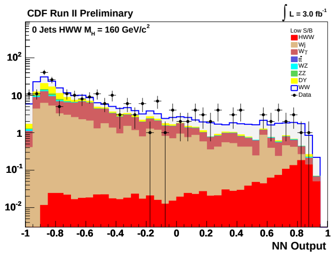

Figure 6: NN output for 0j.

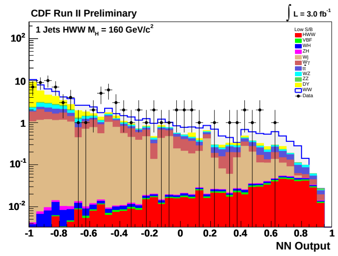

Figure 7: NN output for 1j.

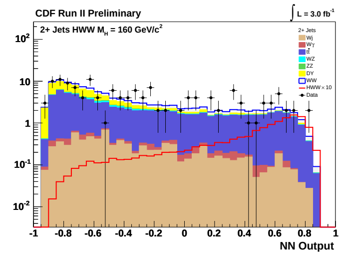

Figure 8: NN output for 2j.

3. $W^{\pm}H \to W^{\pm}W^{*}W^{*} \to l^{\pm}l^{\pm} + X \ (l = e, \mu)$

The tri-boson channel is added to gain additional sensitivity ([5], [6]). The CDF (DØ) analysis uses 1.9 fb^{-1} (1.0 fb^{-1}) of data. To get the minimized expected upper limit on the production cross section times branching fraction, CDF uses a 2-dimensional cut (second lepton p_T vs dilepton system p_T), while DØ is using a likelihood. The event selection requires two like-sign isolated high p_T leptons with good track quality to reduce the probability of charge flips. This selection largely reduces SM backgrounds. Instrumental backgrounds due to charge flips, and muons from pion and kaon decays, are estimated from data. Figures 9 and 10 show the dilepton invariant mass distribution in the muon channel before and after applying track quality cuts.

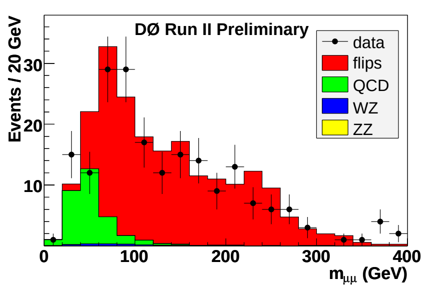

Figure 9: Di-muon invariant mass before applying track quality cuts.

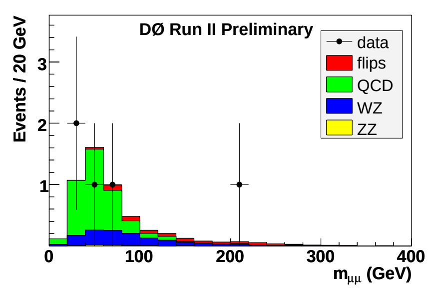

Figure 10: Di-muon invariant mass after applying track quality cuts.

4. Tevatron Higgs Combination

In the absence of a Higgs signal an exclusion limit is set combining CDF and DØ results ([7]). Cross checks are performed to verify the independence of the statistical formulation, using Bayesian and Modified Frequentist approaches. The results from this study agree within 10%.

Figure 11 shows the sensitivity of the combined analysis vs m_H by studying log likelihood ratios (LLR) for different hypotheses.

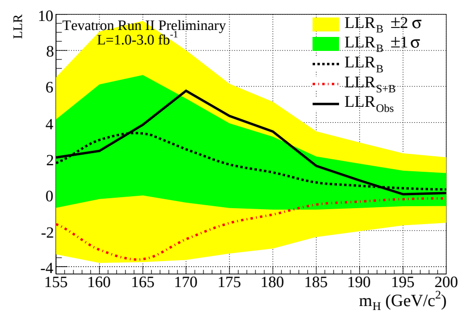

Figure 11: Distributions of LLR as a function of the Higgs boson mass (in steps of 5 GeV/c^2) for the combination of CDF and DØ analyses.

Figure 12 shows the result for the ratios of 95% CL observed and expected limits to the SM cross section. We exclude at the 95% CL the production of a SM Higgs boson with a mass of 170 GeV/c^2.

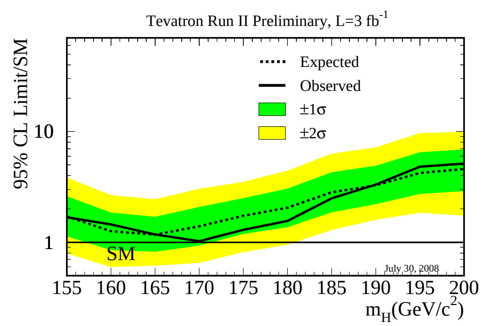

Figure 12: Observed and expected 95% CL upper limits on the ratios to the SM cross section, as functions of the Higgs boson mass for the combined CDF and DØ analyses. The bands indicate the 68% and 95% probability regions where the limits can fluctuate, in the absence of signal.

This is the first exclusion of a SM Higgs boson beyond the LEP limit at a hadron collider.

References

[1] The CDFII Detector Technical Design Report, Fermilab-PUB-96/390-E

[2] DØ Collaboration, V. Abazov et al., Nucl. Instrum. Methods Phys. Res. A. 565, 463 (2006)

[3] CDF Collaboration, CDF Note 9500

[4] DØ Collaboration, DØ Note 5757-CONF

[5] CDF/ANAL/EXOTIC/PUBLIC/7307

[6] DØ Collaboration, DØ Note 5485-CONF

[7] FERMILAB-PUB-08-270-E

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