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High mass Standard Model Higgs boson searches at CDF

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We present a search for Standard Model (SM) Higgs to WW production in dilepton plus missing transverse energy final states using 4.8 fb^{-1} of integrated luminosity. In order to maximize sensitivity, the multivariate discriminants used to separate signal from background in the opposite-sign dilepton event sample have been independently optimized for final states with either zero, one, or two or more identified jets. All significant Higgs boson production modes (gluon fusion, associated production with either a W or Z boson, and vector boson fusion) are considered in determining potential signal contributions. We also incorporate a separate analysis of the same-sign dilepton event sample which can potentially contain additional signal events originating from the associated Higgs boson production mechanisms. Cross section limits relative to the combined SM prediction are presented for a range of different Higgs mass hypothesis between 110 and 200 GeV/c^2.

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One of the cornerstones of how we understand electroweak symmetry breaking in the standard model (SM) rests on the existence of the Higgs boson, which in the SM provides the mechanism by which particles acquire mass. This striking feature of the SM has neither been observed nor completely ruled out. It is the only fundamental particle predicted by the SM which has yet to be observed.

In the SM the couplings of this Higgs boson to other particles are specified and are a function of the mass of the Higgs boson (m_H), which itself is unspecified. Direct searches at LEP give a lower limit on m_H of 114.4 GeV/c^2 [1]. Indirect constraints from precision electroweak measurements indicate that the Higgs mass is likely less than 160 GeV/c^2 [2]. When the two are combined the upper limit increases to 191 GeV/c^2.

For $m_H > 135$ GeV/c^2 the Higgs boson predominantly decays to W-boson pairs. CDF searches for the decay $H \to W^+W^-$ in the range $110 < m_H < 200$ GeV/c^2 where the final state consists of 2 charged leptons $+X$ [3]. All relevant production mechanisms ($gg \to H$, WH, ZH, $qq \to qqH$) are used in the analysis described here.

The CDF detector is described in detail elsewhere [4]. The analysis described here generally makes use of charged particle tracking spectrometers, calorimetry, muon detectors in the outermost portions of the detector, and high-p_T lepton (e, μ) triggers from the online triggering system. The analysis shown here makes use of 4.8 fb^{-1} of $p\bar{p}$ collision luminosity provided by Fermilab's Tevatron at a center of mass energy of $\sqrt{s} = 1.96$ TeV.

The final state of interest in these analyses involve two high-p_T charged leptons and and a net energy imbalance due to the undetected neutrinos from leptonic decays of W bosons. The largest background tends to be from Drell-Yan production where the large production rates combined with imperfect measurements of lepton momenta and hadronic portion of the event results in a non-trivial amount of such events passing a requirement on the missing transverse energy, though it is largely suppressed by this requirement and typically classified as non-Higgs-like by a neural network. Other backgrounds involving high-p_T leptons include diboson production (WW, WZ, ZZ) and top pair production ($t\bar{t}$). Both W+jets and multi-jet production will will enter into the final sample due to the misidentification of hadronic jets as charged leptons. $W\gamma$ will also enter the sample when the photon is misidentified as a charged lepton (typically an electron from conversion).

This analysis investigates events containing 2 high-p_T leptons (e or μ) which have significant missing transverse energy as is expected in the decay $H \to WW$. There are three channels for opposite-charge dilepton candidates which are constructed using the number of reconstructed jets in an event ($N_{jet} = 0$, $N_{jet} = 1$, and $N_{jet} \geq 2$). Only the gluon fusion process is considered in the 0-jet analysis. The other production processes (WH, ZH, and $qq \to qqH$) are included for events containing at least 1 jet where these processes contribute significantly. The fourth channel consists of like-charge dileptons where the signal considered is from both WH and ZH where one would expect to find real like-charge dilepton pairs. A fifth channel is added for events in which the dilepton invariant mass is below 16 GeV/c^2.

Cross checks in orthogonal event selection regions are done and compared to the data showing good agreement. Additionally, using the same lepton selection and similar event selection CDF measures the W-boson pair production cross section showing excellent agreement with theory [5]. Many rate and shape systematics are investigated (too many to list here) [3].

The final discriminant is a neural network output. A neural network is trained separately for

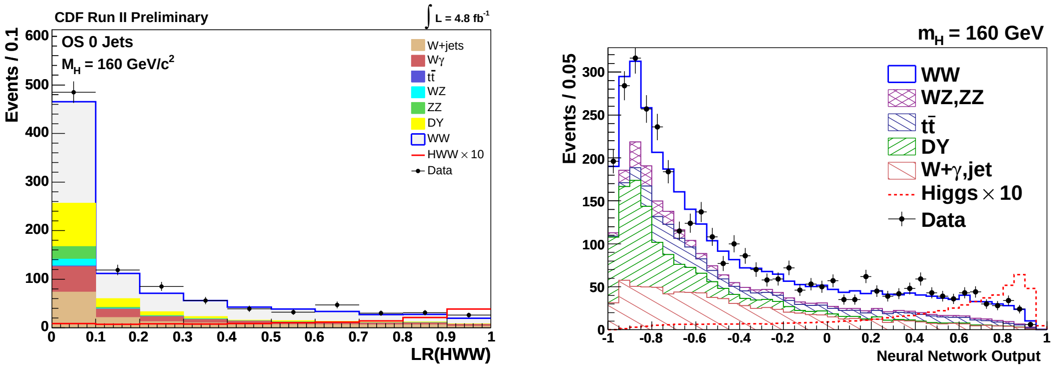

Figure 1: Matrix element based likelihood ratio used in the CDF 0-jet analysis (*left*) and a combined neural network output from all channels for $M_H = 160$ GeV/c^2 (*right*).

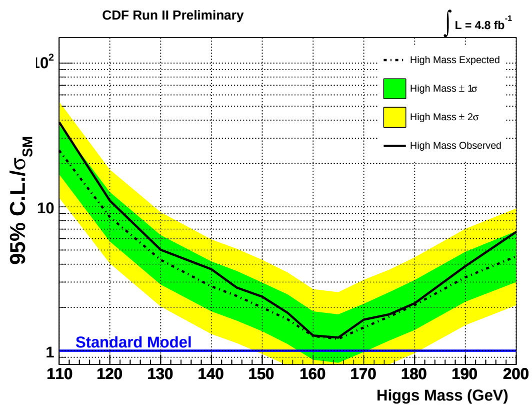

Figure 2: Upper limits on SM Higgs production as a function of the Higgs mass. Limits are quoted at 95% C.L. and are shown as a ratio to the expected SM production. The solid line is the observed limit. The dashed line and colored bands represent the expected limit and the $\pm\,1\sigma$ and 2σ variations.

each channel at each mass using several variables which have been optimized for each individual channel. An example of one of these variables is a matrix element based likelihood ratio shown in figure 1. Once the networks have been trained templates are created for each signal and background which are used to place upper limits on SM Higgs production.

CDF sets upper limits on SM Higgs production in the mass range of $110 \leq m_H \leq 200$ GeV/c^2. These limits are shown as a function of the Higgs mass in figure 2.

References

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