Higgs Searches at CDF

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1 Introduction

The standard model of particles physics incorporates a Higgs field in order to provide a mechanism for spontaneous symmetry breaking in the electroweak sector[1]. One of the consequences of this field is the presence of a massive, scalar boson, the Higgs boson. Current electroweak precision fits prefer a Higgs mass of less than 152 GeV/c^2 [2] at 95% confidence level. Direct searches at the LEP-II[3] and LHC experiments[4, 5]provide a 95% confidence exclusion limits on the Higgs mass for the regions below 117 GeV/c^2, between 119 GeV/c^2 and 122 GeV/c^2, and above 127 GeV/c^2. These proceedings report on direct searches for a standard model Higgs boson at the Tevatron with the CDF II detector[6].

At the Tevatron, the dominant production mechanism for a SM Higgs is through gluon fusion. But for a low mass Higgs ($m_H < 135$ GeV/c^2) where the $H \rightarrow WW$ decay is no longer dominant, the production of a Higgs boson in association with a vector boson and subsequent decay to a $b\bar{b}$ pair is the most sensitive search channel for a light SM Higgs. In these proceedings, emphasis is placed on improvements in analysis techniques in searches for Higgs production in association with W/Z bosons in the mass range $100 < m_H < 150$ GeV/c^2 and final states containing $b\bar{b}$ candidates. The results of searches utilizing up to $10 fb^{-1}$ of integrated luminosity are presented when combining all search channels at CDF. As well, the details of the numerous search channels can be found in several publications[7].

2 Improved CDF b-tagging

Several different b-quark identification algorithms have been developed by the CDF Collaboration, but previous techniques had not been optimized specifically for direct Higgs searches with $H \rightarrow bb$ final states. The Higgs Optimized B Identification Tagger (HOBIT) was developed to utilize information information from previous algorithms, combine this information within a Neural Network discriminant, and then tune the performance of selection thresholds for maximum Higgs sensitivity. Using the

TMVA[8] framework, the HOBIT Neural Network was trained with 25 input variables that help distinguish b-quark jets from non-b jets and is fully described in [9]. The HOBIT response to b-quark and light-quark jets in simulated data was calibrated in a top enriched sample and in a sample of dijets event containing an electron from the semi-leptonic decay of a b-quark. For the tight (loose) HOBIT threshold, the measured b-quark jet identification efficiency is 42% (70%) with a misidentification rate of light-quark jets of 0.89% (8.9%). The increase in sensitivity for the $WH \to \ell\nu b\bar{b}$[10] analysis with the HOBIT tagger is compared with the previous tagging strategy[11] in Table 1.

3 Improved Multivariate Discriminants

New multivariate techniques were developed for the $WH \to \ell\nu b\bar{b}$ and $ZH \to \ell\ell b\bar{b}$ analyses using several MVA discriminants trained specifically for a single background. The analysis ordered the backgrounds to reject the most efficiently rejected backgrounds first, and then subsequent discriminants trained on the remaining samples. Within the $ZH \to \ell\ell b\bar{b}$ analysis at CDF[12], the discriminants were developed to reject backgrounds in the order: top-quark production, then $Z + q\bar{q}$ to includes charm, then diboson production, and the final discriminant enhancing the ZH signal over all remaining backgrounds and is shown in Figure 1. The new MVA techniques improved sensitivity by 10% over previous single discriminants.

4 Full Combination of CDF Higgs Searches

A combined search for standard model Higgs production is performed using up to 10 fb^{-1} of data. The channels considered are $WH \to \ell\nu b\bar{b}$, $VH \to \nu\nu b\bar{b}$, $ZH \to \ell\ell b\bar{b}$, $H \to \gamma\gamma$, $VH \to jjb\bar{b}$, $H \to WW$, $H \to \tau\tau + 2jets$, $H \to ZZ \to \ell\ell\ell\ell$, two

Old Taggers		HOBIT	
Tag Category	S/$\sqrt{B}$	Tag Category	S/$\sqrt{B}$
SecVtx+SecVtx	0.228	Tight-Tight	0.266
SecVtx+JetProb	0.160	Tight-Loose	0.200
SecVtx+Roma	0.103	Single Tight	0.143
Single SecVtx	0.146	Loose-Loose	0.053
Sum	0.331	Sum	0.369

Table 1: The signal divided by the square-root of background in several tagging categories in the $WH \to \ell\nu b\bar{b}$ analysis along with the sum in quadrature of the several categories for the previous analysis and with the HOBIT tagger.

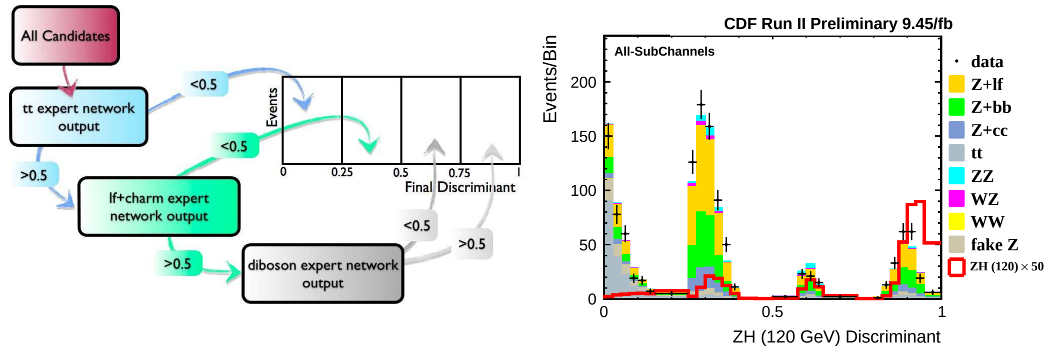

Figure 1: The final discriminant for the $ZH \to \ell\ell b\bar{b}$ analysis at CDF with the left figure showing the event selection flow, and the right figure showing the data distribution compared with simulation.

searches for ttH production, and a search for associated production of WH or ZH utilizing tau selection. The 95% C.L. upper limits on Higgs boson production are 2.17, 2.67 and 0.41 times the SM cross section for Higgs boson masses of mH=115, 125, and 165 GeV/c2, respectively and are shown in Figure 2. CDF excludes, at the 95% C.L., the region $148.8 < m_H < 175.2 GeV/c^2$ and $m_H < 96.9 GeV/c^2$, with an expected exclusion region of $m_H < 94.2 GeV/c^2$, $96.1 < m_H < 106 GeV/c^2$ and $153.8 < m_H < 176.1 GeV/c^2$. The largest excess at $m_H = 120 GeV/c^2$ has a local p-value corresponding to a local significance of 2.6σ. The global significance for such an excess anywhere in the full mass range is approximately 2.1σ. We perform an exclusive combination of searches for $H \to b\bar{b}$ and find that the global probability of the background to fluctuate to produce the 2.9σ excess observed in the data at any mass in the $H \to b\bar{b}$ search region is estimated to be 2.7σ.

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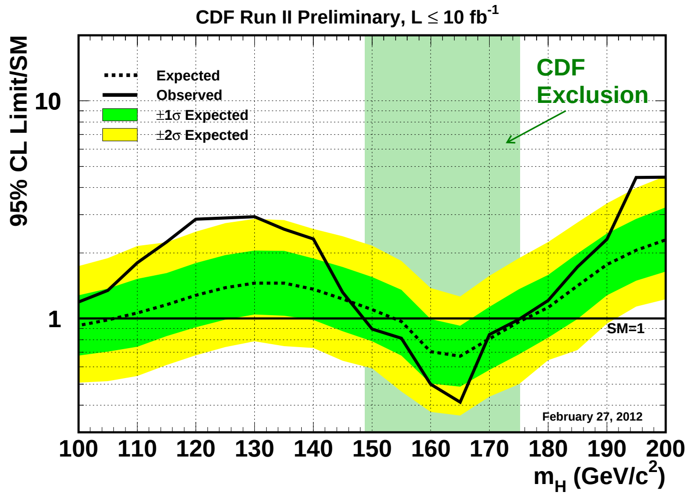

Figure 2: The ratio of the 95% confidence level Higgs cross-section limit from combining all search channels at CDF divided by the SM Higgs cross-section for potential Higgs masses between 100 and 200 GeV/c^2. The solid line shows the observed imit with the dotted line showing the expected limit. The green and yellow bands show the 1σ and 2σ variation respectively on the 95% CL expected limit.

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