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Combined $WH \rightarrow lvbb$ search at CDF with Neural Network and Matrix Element techniques

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We present a Standard Model (SM) Higgs search at CDF for $WH \rightarrow l\nu b\bar{b}$ produced by $p\bar{p}$ collisions at a center-of-mass energy of $\sqrt{s} = 1.96$ TeV using an integrated luminosity of 4.3 fb^{-1}. This new analysis uses several improvements to increase sensitivity for Higgs searches including a Neural Network (NN) b-tagger, a b-jet energy correction which improves Higgs dijet mass resolution, isolated track selection to increase lepton acceptance, a NN-flavor separator to reduce mistags, and a three-jet category to complement the standard two-jet procedure.
We perform two independent analyses with distinct multivariate discriminant techniques, NN-analysis and Matrix Element Technique (ME).
The NN analysis sets limits across a range of Higgs masses from 100 GeV/c^2 to 150 GeV/c^2, with observed limits ranging from $\sigma(p\bar{p} \rightarrow W^{\pm}H) \times \mathrm{BR}(H \rightarrow b\bar{b}) < 4.0$ to 37.6 times the SM prediction and 5.3 $\times$ SM observed (4.0 expected) at M(H) = 115 GeV/c^2.
The ME analysis sets limits with observed limits ranging from $\sigma(p\bar{p} \rightarrow W^{\pm}H) \times \mathrm{BR}(H \rightarrow b\bar{b}) <$ 4.5 to 48.8 times the SM prediction and 6.6 $\times$ SM observed (4.1 expected) at M(H) = 115 GeV/c^2.
For the CDF combination we use two-jet events from NN analysis and three-jet events from ME analysis together with other CDF searches. We observe no excess in data and we calculate combined upper limits on the ratio of the Higgs boson cross section times the branching ratio to its SM prediction for Higgs boson masses between 100 and 200 GeV/c^2. The results are in good agreement with the expectations obtained from background-only pseudo-experiments. The observed (expected) 95% CL upper limit is 3.1 (2.4) higher than the SM production cross section for Higgs boson mass of 115 GeV/c^2.

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The success of the Standard Model (SM) in explaining and predicting experimental data provides strong motivation for the existence of a neutral Higgs boson. Current electroweak fits combined with direct searches from LEP2 and Tevatron indicate the mass of the Higgs boson is less than 153 GeV/c^2 at 95% confidence level [1, 2], assuming the existence of a SM-like Higgs boson.

In proton-antiproton collisions of $\sqrt{s} = 1.96$ TeV at the Tevatron, the Standard Model Higgs boson may be produced in association with a W boson [3]. For low Higgs masses (below 135 GeV/c^2), the dominant decay mode is $H \to b\bar{b}$. The final state from the WH production is therefore $\ell\nu b\bar{b}$. We use complimentary high-p_T lepton and missing transverse energy $\not\!\!E_T$ triggers to maximize our signal acceptance.

We use lepton, $\not\!\!E_T$ + jets, and $\not\!\!E_T$ triggered data collected through March 2009, corresponding to an integrated luminosity of 4.3 fb^{-1}. The events are collected by the CDF II detector and classified according to their trigger type.

We require central leptons triggered by high-p_T electron or muon triggers which have an 18 GeV threshold [4] to be isolated with E_T (or p_T) > 20 GeV.

Since W+jets signature has a large missing transverse energy, we require $\not\!\!E_T > 20$ GeV. We select forward (plug) electron events with a trigger intended for W candidate events. The plug electron trigger requires both a plug electron candidate and missing transverse energy. Plug electrons events are futher required offline to have $E_T > 20$ GeV and $\not\!\!E_T > 25$ GeV. We increase the purity of the sample by applying cuts intended to remove events from QCD processes with falsely-identified leptons and $\not\!\!E_T$. Our QCD veto consists of the following cuts, linear cut on the $\not\!\!E_T$ and the azimuthal angle (ϕ) between the $\not\!\!E_T$ and the each of the jets ($\not\!\!E_T > 45 - (30 \cdot |\Delta\phi|)$), large transverse mass of the reconstructed W ($M_T(W) > 20$), large $\not\!\!E_T$ significance $\not\!\!E_T^{sig}$, where $\not\!\!E_T^{sig}$ is defined as ratio of $\not\!\!E_T$ to a weighted sum of factors correlated with mismeasurement, such as angles between the $\not\!\!E_T$ and the jet and amount of jet energy corrections. We select $\not\!\!E_T$+ jet and $\not\!\!E_T$ triggered events that have an identified loose (non-triggered) lepton. For trigger pre-selection, we require two jets with $E_T > 25$ GeV, $\Delta R > 1.0$, and at least one central jet with $\eta < 0.9$ for $\not\!\!E_T$+ jet triggered event. The trigger requires 35 GeV of uncorrected missing transverse energy. If the trigger requirement is not satisfied, we use $\not\!\!E_T$ triggered events. This trigger requires 45 GeV of uncorrected missing transverse energy. We parameterize the trigger cut as a sigmoid turn-on in uncorrected $\not\!\!E_T$. We identify a single category of loose leptons called isolated tracks. We require isolated tracks to have $p_T > 20$ GeV and be isolated from other track activity in the event. As in the central leptons, events with the W+jets signature are confirmed with $\not\!\!E_T > 20$ GeV. The events from all trigger types are classified according to the number of jets having $E_T > 20$ GeV and $|\eta| < 2.0$. Because the Higgs boson decays to $b\bar{b}$ pairs, we employ b-tagging algorithms which rely on the long lifetime and large mass of the b quark. We require at least one of the jets in the event to be b-tagged. For events with one SecVtx tagged jet and one other jet which is not tagged by any algorithm, we reduce the contamination from events with a fake W's by applying cuts on the transverse mass and angular variables. To greatly reduce the backgrounds to this Higgs search, we require that at least one jet in the event be identified as originating from a b quark by the secondary vertex tagging algorithm. The secondary vertex tagging algorithm identifies b quarks by fitting tracks displaced from the primary vertex. This method has been used in other Higgs searches and top quark analyses [5, 6]. In addition, we use the jet probability tagging algorithm that identifies b quarks by requiring a low probability that all tracks contained in a jet originated from the primary vertex, based on the track impact parameters. We also use Neural Network (NN) based tagging algorithm that identifies b quarks by combining the informations of displaced vertex, displaced tracks and soft muon. We use four exclusive tagging categories: two secondary vertex tags (ST+ST), one secondary vertex tag and one jet probability tag (ST+JP), one secondary vertex tag and one NN tag (ST+NN) and exactly one secvtx tag (1-ST).

We improve dijet mass resolution with NN b-jet energy correction that combines vertexing, tracking and secvtx information into standard calorimeter jets.

We perform two independent analyses with distinct multivariate discriminant techniques, one using Neural Networks [7] as final discriminats to separate signal candidate events from background and other one using Matrix Element (ME) method [7] that compares reconstructed events to theoretical matrix element calculations of signal and background processes(Fig. 1). For the CDF combination [7] we include two-jet events from the NN-analysis and three-jet events from the ME-analysis together with other CDF Higgs searches. NN analysis results into observed sensitivity of 5.3 $\times$ the SM prediction (4.0 expected), ME analysis 6.6 $\times$ SM observed (4.1 expected) and CDF combination 3.1 $\times$ SM observed (2.4 expected) at M(H) = 115 GeV/c^2.

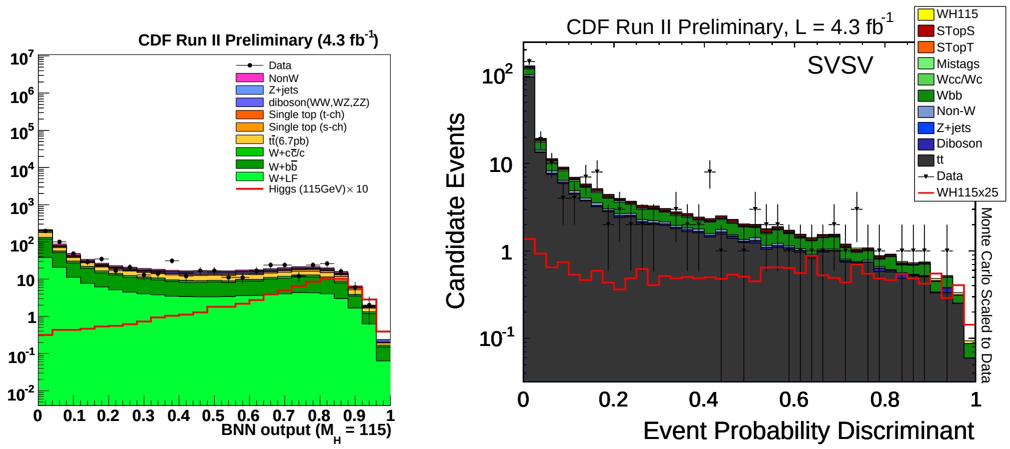

Figure 1: Right plot shows final discriminant in NN analysis for 115 GeV/c^2 Higgs search with all *b*-tagging and lepton categories combined. Right plot shows ME output in three-jet bin for double-tagged events with all lepton categories combined.

References

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