LOW MASS STANDARD MODEL HIGGS SEARCH AT THE TEVATRON

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On Behalf of the CDF and D0 Collaborations

Results from the low mass Standard Model Higgs search at the Fermilab Tevatron $p\bar{p}$ collider are presented based on large luminosity data samples collected by the CDF and D0 Collaborations. Combined upper limits at 95% Confidence Level on the ratio of the production cross section $\times$ branching ratio to the Standard Model expectation are also presented.

1 Introduction

Searches for the Standard Model Higgs boson in the low Higgs mass (m_H) regime focus primarily on the region $100 < m_H < 150$ GeV. In this range the predominant Higgs production and Higgs decay processes at the Tevatron are expected to be gluon-gluon fusion ($gg \to H$) and the Higgs decay into a pair of b-quarks ($H \to b\bar{b}$). Direct searches for the process $e^+e^- \to ZH$ at the LEP collider are used to constrain the minimum Standard Model Higgs mass to $m_H > 114.4$ GeV, whereas a fit to precision electroweak measurements of the top-quark and W boson masses infer an upper limit of $m_H < 157$ GeV at 95% Confidence Level (CL).[1,2]

Searches using the gluon-gluon fusion search channel at the Tevatron are particularly challenging due to the large multijet background contribution within the preselected data samples. The associated production mechanism, in which a W or Z boson are reconstructed in addition to jets the final state, typically display improved sensitivities with the additional vector boson requirement serving to reduce backgrounds. At the Tevatron, searches also include the Vector Boson Fusion (VBF) production process and make use of other subdominant Higgs decay modes such as $H \to \tau\tau$ and $H \to \gamma\gamma$.

2 Associated VH Production Searches

Associated VH production samples are preselected by requiring isolated leptons (l) and/or significant transverse energy imbalance ($\not\!\!E_T$) in the detectors. To search for $H \to b\bar{b}$ decays the preselected W and Z boson samples are also required to contain two reconstructed jets. Separate V+3jet event samples are also constructed to allow for e.g additional initial or final state radiation in the event.

To further suppress backgrounds at least one jet is then required to be tagged as a heavy flavor jet. This is done using either a Neural Network approach, applying secondary vertex information and/or by requiring that the probability for a jet to have originated directly from the primary vertex be small. A series of double and single b-tagged samples of varying sensitivities

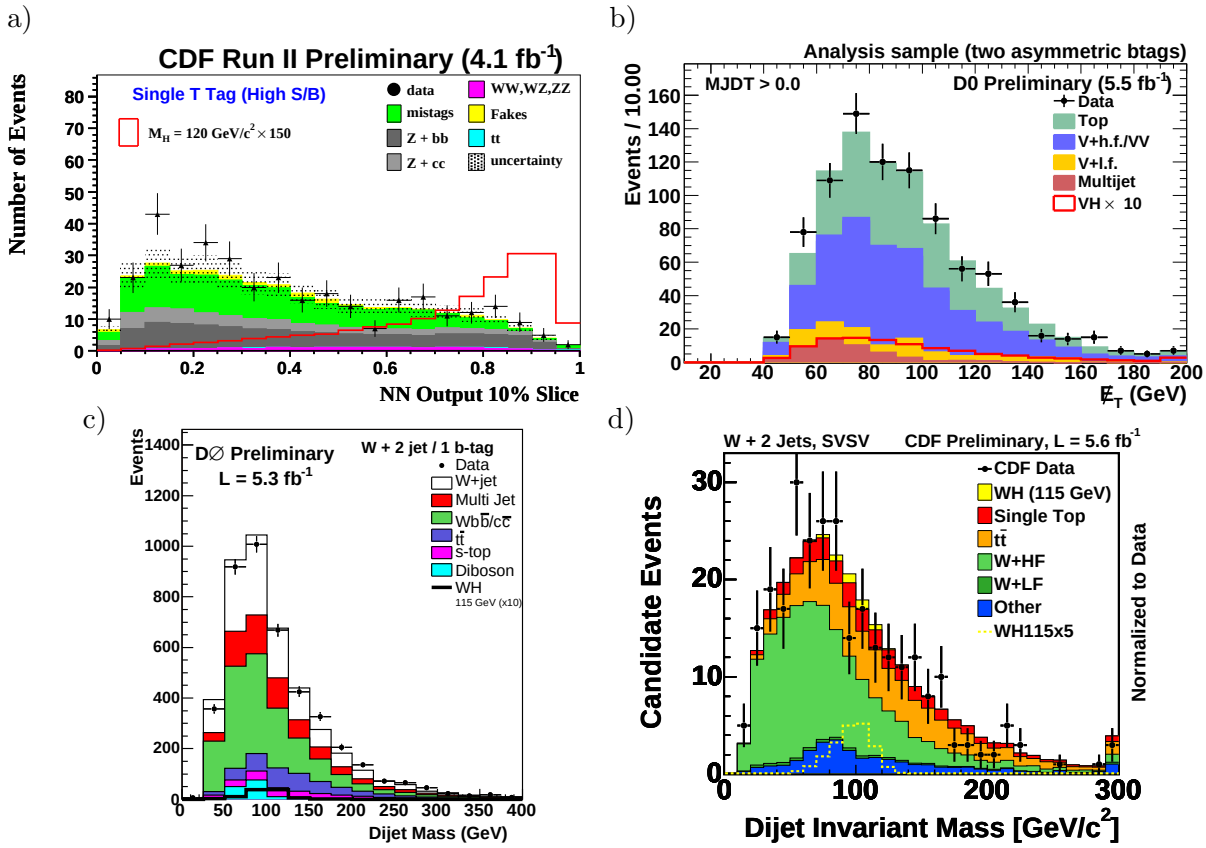

Figure 1: Results from the Tevatron associated VH production searches: a) Search for $ZH \rightarrow llb\bar{b}$, b) Search for $VH \rightarrow \not\!\!E_T\, b\bar{b}$ and c-d) Searches for associated $WH \rightarrow l\nu b\bar{b}$ production.

are then obtained with each candidate event appearing in a single sample only (orthogonality). In each search the expected background contributions are normalized to their theoretically expected cross sections and/or modelled and verified using separate kinematically defined control samples. Each of the associated VH production searches then apply discriminant techniques to further suppress remaining backgrounds.

Searches for the associated $ZH \rightarrow llb\bar{b}$ production mechanism, at both the CDF and D0 collaborations, subdivide the preselected samples with two additional orthogonal Z boson selections.[3,4]. Figure 1a) shows the output of the second stage two-dimensional Neural Net (NN) discriminant in the high sensitivity Z, single b-tag selected region of the 4.1 fb^{-1} search of the CDF collaboration. The search includes sensitivity improvements applied to the dijet mass resolution. Both the CDF and D0 searches utilize both the $Z \rightarrow e^+e^-$ and $Z \rightarrow \mu^+\mu^-$ decay modes. The sensitivity of the D0 result has been been extended with the addition of 3.1 fb^{-1} of data.

Searches for associated $VH \rightarrow \not\!\!E_T\, b\bar{b}$ production are not only sensitive to $Z \rightarrow \nu\nu$ decays but also to $W \rightarrow l\nu$ associated production events in which the decay lepton of the W fails lepton identification requirements and is reconstructed within the $VH \rightarrow \not\!\!E_T\, b\bar{b}$ sample. The searches utilize the correlation between the event $\not\!\!E_T$ measured using calorimeter information, and the event missing track-based $\not\!\!p_T$ to suppress the multijet background and improve sensitivity.[5,6] Figure 1b) shows the $\not\!\!E_T$ distribution in a 5.5 fb^{-1} sample of double b-tagged candidate events taken from the associated $VH \rightarrow \not\!\!E_T\, b\bar{b}$ search of the D0 experiment. The expected cross section $\times$ branching ratio in these channels is similar to that of the $WH \rightarrow l\nu b\bar{b}$ searches.

Figures 1c) and d) show dijet invariant mass distributions after b-tagging from the CDF and D0 associated $WH \rightarrow l\nu b\bar{b}$ searches.[7,8]. The W Boson is selected via the $W \rightarrow e\nu$ and $W \rightarrow \mu\nu$

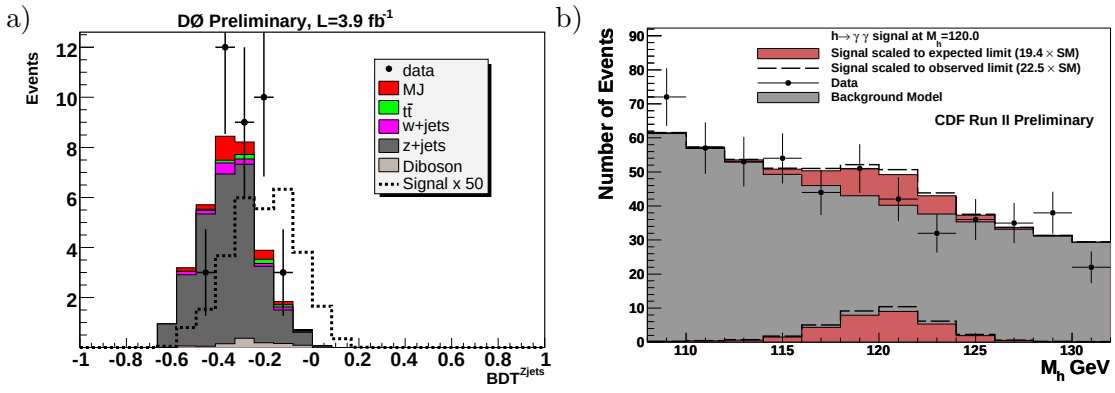

Figure 2: Tevatron search results in the a) $\tau\tau q\bar{q}$ and b) $H \to \gamma\gamma$ final states.

decays at both experiments. The expected signal contributions to the sample are also shown scaled for presentation purposes.

3 Searches in the $\tau\tau q\bar{q}$ Final State

Searches in the $\tau\tau q\bar{q}$ final state search for both the decay $H \to \tau\tau$ as well as selecting events containing $Z \to \tau\tau$ decays. Since no explicit b-tagging requirement is applied these searches are sensitive to both the gluon-gluon fusion and VBF mechanisms with $H \to \tau\tau$ as well as the associated production processes $ZH \to q\bar{q}\tau\tau$, $ZH \to \tau\tau b\bar{b}$ and $WH \to q\bar{q}\tau\tau$. The events are selected via $\not\!\!E_T$ requirements with $\tau \to \mu\nu_\tau\bar{\nu}_\mu$ as well as hadronic τ decay modes.[9,10]

Figure 2a) shows the result of the D0 search which utilizes a total of 32 orthogonal samples fed though a Boosted Decision Tree (BDT) discriminant. The distribution shows the combined BDT output samples for the $m_H = 100, 105, 115$ GeV mass hypotheses.

4 $H \to \gamma\gamma$ Searches

Although the branching ratio of the Standard Model Higgs decay into a pair of photons is small, searches in the diphoton decay channel are appealing due to the improved energy resolution for reconstructing photons with respect to reconstructing jets. [11,12] The branching ratio is also often enhanced in beyond-the-Standard Model Higgs scenarios. Figure 2b) shows a result from the CDF search in which two central photons are selected in the pseudorapidity interval ($\eta_\gamma < 1.05$). The diphoton invariant mass ($M_{\gamma\gamma}$) spectrum is scanned for the presence of resonances. For each hypothetical Higgs mass the background is fitted after the expected signal region (according to the measured mass resolution) has been excluded. Figure 2b) shows the $m_H = 120$ GeV mass hypothesis result with the expected signal scaled to the expected and observed limits.

5 Tevatron Combined Limits

With the orthogonality preserved between individual search channels, the results are combined to yield full Tevatron expected and observed limits. Figure 3 shows the combined expected and observed limits obtained from a total of 36 analyzes from the CDF collaboration and 54 analyzes from the D0 collaboration.[13] The Bayesian and Modified Frequentist approaches have been shown to agree to with 10% of each other. The bands show the $\pm 1\sigma$ and $\pm 2\sigma$ uncertainty regions around the expected limit and include the effects of both the systematic as well as Poisson statistical uncertainties. The observed limit is currently within two to three times the Standard Model expectation (at 95% CL) in the low mass region.

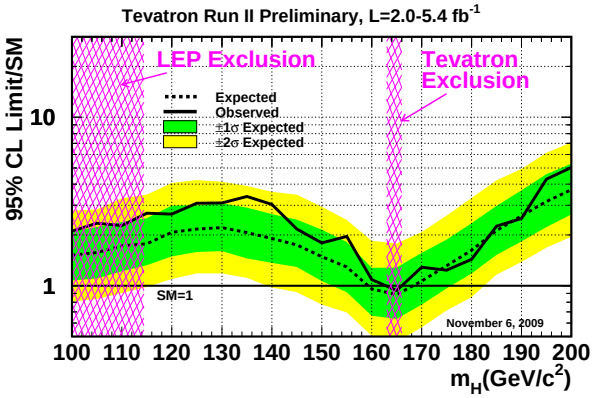

Figure 3: Tevatron expected and observed limits obtained from a combination of 90 analyzes from the CDF and D0 Collaborations. The bands include the effects of systematic as well as Poisson statistical uncertainties.

6 Summary

Standard Model Higgs boson search results in the low mass region, based on large luminosity data samples collected by the CDF and D0 collaborations, lead to a Tevatron combined observed limit currently within two to three times the Standard Model expectation (at 95% CL). The ongoing increase in delivered and collected luminosities at the Tevatron, combined with analysis level improvements, are expected to lead to continued sensitivity gains.

References

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