

Search for associated Higgs boson production at DØ

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Abstract.

Using 1 fb^{-1} of data the DØ collaboration has searched for the production of a Higgs boson in association with a W or a Z boson. The W or Z boson is required to decay leptonically and whereas the Higgs boson decays into a $b\bar{b}$ pair. Searches in these final states are the most sensitive for a Higgs boson with a mass less than about $130 \text{ GeV}/c^2$. No evidence for Higgs boson production has been observed and 95% C.L. upper limits on the Higgs boson production cross section are derived.

1. Introduction

The most sensitive search channel at the Tevatron for a Higgs boson with a mass below approximately $130 \text{ GeV}/c^2$ is for a Higgs boson produced in association with a W or a Z boson. For $m_H < 130 \text{ GeV}/c^2$ the dominant Higgs decay mode is $H \rightarrow b\bar{b}$. This note reports on a searches for a Higgs boson in the following final states: $e\nu b\bar{b}$, $\mu\nu b\bar{b}$, $e\bar{e}b\bar{b}$, $\mu\bar{\mu}b\bar{b}$, $\nu\bar{\nu}b\bar{b}$.

2. The DØ detector

The DØ Run II detector [1, 2] consists of the following main components: a central tracking system, a liquid-argon/uranium calorimeter, and a muon spectrometer.

The central tracking system includes a silicon microstrip tracker (SMT) and a central fiber tracker (CFT), both located in a 2 T superconducting solenoid magnet.

The calorimeter is divided into a central section (CC) providing coverage out to $|\eta| \approx 1$, and two end calorimeters (EC) extending coverage to $|\eta| \approx 4$.

The muon system, covering pseudorapidities of $|\eta| < 2$, resides beyond the calorimetry, and consists of three layers of tracking detectors and scintillating trigger counters.

3. Identification of b -quark jets

Given the large branching fraction for the decay $H \rightarrow b\bar{b}$ for Higgs masses between $115 - 130 \text{ GeV}/c^2$, there is a large probability to have two b jets in the final state of a WH or ZH event. All analyses presented in this note therefore requires that one or both of the jets are identified by a neural network (NN) b -tagging algorithm. The variables used to identify jets originating from long-lived b hadrons rely on the presence and characteristics of a secondary vertex and tracks inside the jets which are displaced with respect to the primary interaction.

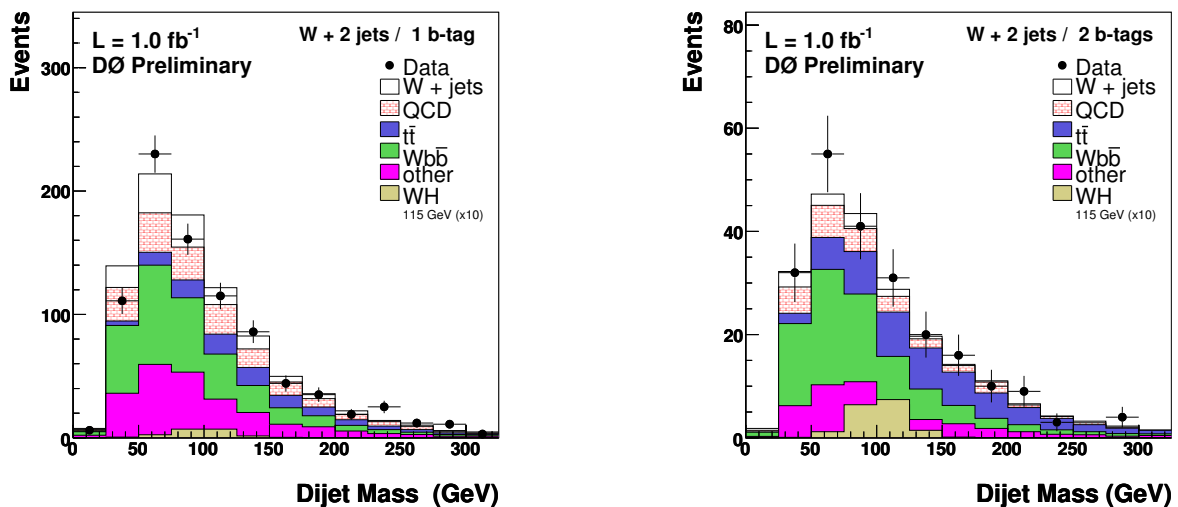
¹ For the DØ collaboration.

4. Analyses

This section provides a brief description of the analyses together with the observed upper limit (95% C.L.) on the Higgs boson production cross section.

4.1. $WH \rightarrow e(\mu)\nu b\bar{b}$

The WH production mode with $W e(\mu)\nu$ and $H \rightarrow b\bar{b}$ is the single most sensitive search channel for a Higgs with a mass below $130 \text{ GeV}/c^2$ at the Tevatron. Events are selected requiring exactly one electron (muon) with $p_T > 20 \text{ GeV}/c$ and detector $|\eta| < 1.1$ ($|\eta| < 2.0$), missing transverse energy $\cancel{E}_T > 20 \text{ GeV}$, and two jets with $p_T > 20 \text{ GeV}/c$ and $|\eta| < 2.5$ [3]. The events are also required to have a reconstructed primary vertex within $\pm 60 \text{ cm}$ of the nominal interaction point with at least three attached tracks. At least one of the jets is required to be identified as coming from a b -quark [3]. The events are classified as double tagged if both jets pass a loose selection on the NN b -tagger output (efficiency for this loose selection is 70% for b -jets and 4.5% for light quark or gluon jets). If the event is not double tagged, it can be classified as single tagged if one of the jets passes a tighter cut on the NN b -tagger output (efficiency for b -jets 48%, efficiency for light quark or gluon jets 0.5%). The distribution of the invariant mass of the two jets for the observed single tagged (figure 1(a)) and double tagged (figure 1(b)) events, together with the estimated number of events from the various standard model (SM) backgrounds, are shown in figure 1. No excess of events over the expected background is observed and therefore an upper limit (at 95% C.L.) is set on the Higgs boson production cross section, see figure 2 (red curve).



(a) Single tagged events.

(b) Double tagged events

Figure 1. Invariant mass of the two jets in the $WH \rightarrow e(\mu)\nu b\bar{b}$ analysis.

4.1.1. *Using a matrix element discriminant* An alternative analysis was performed in the same channels using a discriminant based on leading order matrix elements to separate between signal and background [4]. The event selection and dataset was slightly different from the one described in section 4.1. No excess of events was observed over the expected background and an upper limit on the Higgs boson production cross section was derived, see figure 2 (green curve).

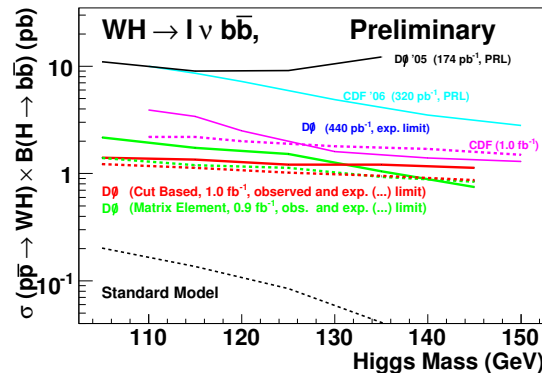
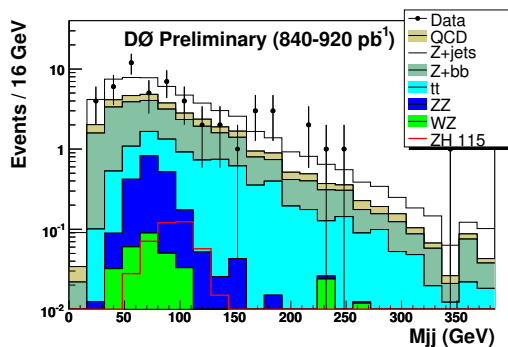


Figure 2. Upper limits on the Higgs boson production cross section in the $WH \rightarrow e(\mu)\nu b\bar{b}$ analyses using a cut-based method (red curves) and a matrix element discriminant (green curves). The solid red and green curves correspond to the observed limits, whereas the dashed red and green curves correspond to the expected limits.

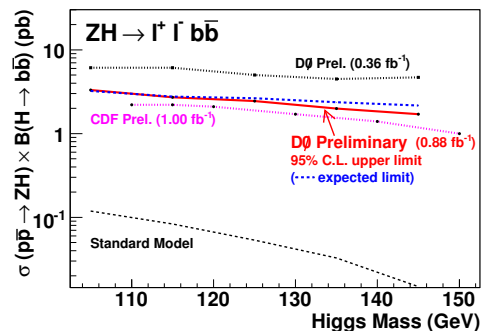
4.2. $ZH \rightarrow e\bar{e}(\mu\bar{\mu})b\bar{b}$

Events are required to have two electrons (muons) with $p_T > 15$ GeV/ c and an invariant mass consistent with coming from a Z boson ($65 < M_{ee} < 115$ GeV/ c^2 or $70 < M_{\mu\mu} < 110$ GeV/ c^2), at least two jets with $p_T > 15$ GeV/ c and $|\eta| < 2.5$ and a reconstructed primary vertex within ± 60 cm of the nominal interaction point with at least three attached tracks [5]. Two jets are required to be tagged as coming from b -quarks using the NN-based b -tagging algorithm 3. The selection chosen for the NN b -tagger output gives an efficiency for b -jets of 72% and 6% for jets from light quarks or gluons.

The distribution of invariant mass of the two b -tagged jets is shown in figure 3(a). No excess is observed over the expected number of events from background processes. Therefore an upper limit (at 95% C.L.) on the Higgs boson production cross section is derived (figure 3(b)).



(a) Invariant mass of the two b -tagged jets.



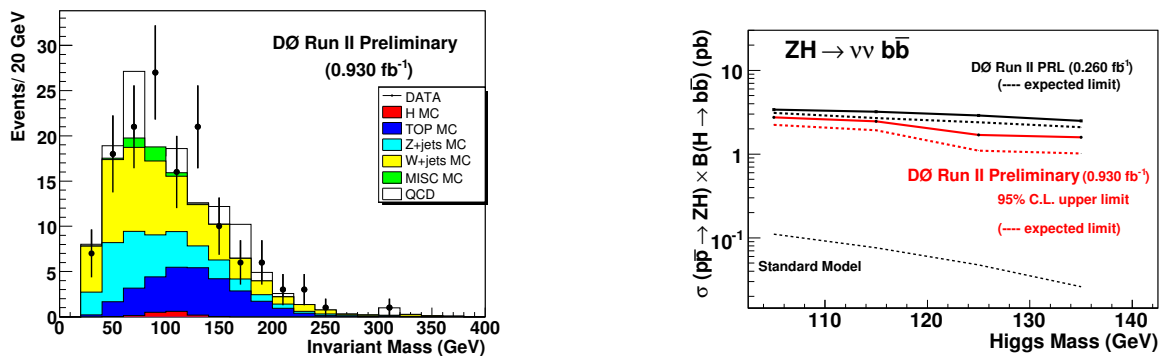
(b) Upper limit on the Higgs boson production cross section 95% C.L.).

Figure 3. Result in the $ZH \rightarrow e\bar{e}(\mu\bar{\mu})b\bar{b}$ analyses.

4.3. $ZH \rightarrow \nu\bar{\nu}b\bar{b}$

The $ZH \rightarrow \nu\bar{\nu}b\bar{b}$ analysis benefits from the larger branching ratio for $Z \rightarrow \nu\bar{\nu}$ compared to $Z \rightarrow e\bar{e}(\mu\bar{\mu})$. Since there are no charged leptons in the final state it is more difficult to trigger on and it suffers more from the multijet background compared to $ZH \rightarrow e\bar{e}(\mu\bar{\mu})b\bar{b}$. Events are selected requiring at least two jets with $p_T > 20$ GeV/ c and $|\eta| < 1.1$ or $1.4 < |\eta| < 2.5$, opening angle $\Delta\phi$ between the jets $\Delta\phi < 165^\circ$, $\cancel{E}_T > 50$ GeV, the scalar sum of transverse momentum in the event $H_T < 240$ GeV/ c , and that there are no isolated charged leptons in the event [6]. One of the jets is required to pass a tight selection on the NN b -tagger output (43% efficiency for b -jets and 0.3% for light quark or gluon jets) and another jet is required to pass a looser selection on the NN b -tagger output (72% efficiency for b -jets and 6% for light quark or gluon jets).

The distribution of the invariant mass of the two b -tagged jets is shown in figure 4(a). No excess is observed over the expected number of events from background processes. Therefore an upper limit (at 95% C.L.) on the Higgs boson production cross section is derived (figure 4(b)).



(a) Invariant mass of the two b -tagged jets.

(b) Upper limit on the Higgs boson production cross section 95% C.L.).

Figure 4. Result in the $ZH \rightarrow \nu\bar{\nu}b\bar{b}$ analyses.

5. Conclusions

Using 1 fb^{-1} of data, the DØ collaboration has performed several searches for Higgs boson production in association with a W or a Z boson. No excess of events over the expected background has been observed in any analysis, and each result has been converted into and upper limit on the production cross section for the Higgs boson.

References

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- [6] DØ Collaboration, “A Search for the Standard Model Higgs Boson in the Channel $ZH \rightarrow \nu\bar{\nu}b\bar{b}$ at $\sqrt{s} = 1.96$ TeV”, DØ Note 5353-CONF (2007).