PROCEEDINGS OF SCIENCE

Search for the Standard Model Higgs Boson in $ZH \rightarrow \nu\bar{\nu}b\bar{b}$ channel at D0.

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We present a search for a low mass Standard Model Higgs boson produced in association with a Z boson decaying invisibly into a pair of neutrinos at a center-of-mass energy of $\sqrt{s}$ =1.96 TeV with the D0 detector at the Fermilab Tevatron collider. The final state is characterised by the presence of two b-tagged jets from the Higgs boson decay and a large imbalance in the transverse energy of the event. This channel is very powerful because of the large $Z \rightarrow \nu\bar{\nu}$ branching ratio, but also has many experimental challenges due to the large multijet background and the absence of visible carged leptons in the final state. We present the result with 5.2 fb^{-1} of data and discuss the recent improvements in the sensitivity.

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1. INTRODUCTION

The associated ZH production in $p\overline{p}$ collisions, with $H \to b\overline{b}$ and $Z \to \nu\overline{\nu}$, is one of the most sensitive channels for the low mass Higgs production at the Fermilab Tevatron [1]. A lower limit of 114 GeV on Higgs boson mass was set by the LEP experiments [2], while an upper limit of 144 GeV can be inferred from precision electroweak data [3]. Here and in the following, all limits quoted are at the 95% confidence level.

The final state considered in this analysis is a pair of acoplanar b jets from the Higgs decay, with missing transverse energy ($\not\!\!E_T$) due to the neutrinos from the Z decay. The search is therefore also sensitive to the HW channel ($W \to \ell\nu$) when the charged lepton is not detected. The main backgrounds arise from $(W/Z)b\overline{b}$, from (W/Z)+(non-b jets) due to flavor misidentification (mistagging), from top quark production e.g., $t\overline{t} \to \ell\nu bq\overline{q}'\overline{b}$ and $t(q)\overline{b} \to \ell\nu b(q)\overline{b}$, from diboson production such as $(W \to q\overline{q}')(Z \to \nu\overline{\nu})$ or $(Z \to b\overline{b})(Z \to \nu\overline{\nu})$, and from multijet events produced via the strong interaction, with real-b or mistagged light parton jets and $\not\!\!E_T$resulting from fluctuations in measurement of jet energies.

A kinematic selection is first applied to reject the bulk of multijet events. The two jets expected from the Higgs boson decay are next required to be tagged as b jets, using a neural network b-tagging algorithm. Finally, discrimination between the signal and the remaining backgrounds is achieved by means of a boosted decision tree (BDT) technique.

2. DATA AND SIMULATED SAMPLES

The analysis presented here is based on a integrated luminosity of (5.16 ± 0.32) fb^{-1}collected with the DØ detector [4] using triggers designed to select events with jets and $\not\!\!E_T$. The physics objects used are charged particle tracks, the primary interaction vertex, calorimeter jets reconstructed in a cone of radius R=0.5 by the iterative midpoint cone algorithm [5] and with $p_T > 15$ GeV. Electrons or muons are identified by the association of charged particles with electromagnetic calorimeter clusters or with hits in the muon detector, respectively. The $\not\!\!E_T$ is reconstructed as the opposite of the vectorial sum of the transverse energies deposited in the calorimeter and is corrected for reconstructed muons. Jet energies are calibrated by requiring transverse energy balance in photon+jet events, and these calibrations are propagated to the $\not\!\!E_T$.

The multijet background is estimated from the data, all other standard model (SM) background processes are determined by Monte Carlo simulation. The (W/Z)+jets processes are generated with ALPGEN [6] interfaced with PYTHIA [7]. For $t\overline{t}$ and for electroweak single top production, the ALPGEN and COMPHEP [8] generators are used, respectively, while vector-boson pair production processes is generated with PYTHIA. The signal processes (HZ and HW) are generated with PYTHIA for all Higgs masses.

3. EVENTS SELECTION

Events with two or three jets with transverse momentum $p_T > 20$ GeV and $|\eta_{jet}| < 2.5$ are selected, one of which must be the leading (highest p_T) jet. The two leading jets must not be back-to-back in the plane transverse to the beam direction ($\Delta\phi(\mathrm{jet}_1, \mathrm{jet}_2) < 165°$), and must be accompanied by charged particle tracks so that the b-tagging algorithm can operate efficiently. We require to have $\not\!\!E_T > 40$ GeV. To suppress multijet background we apply a cut on "$\not\!\!E_T$ significance" S, which takes into account the resolution of jet energies to separate real $\not\!\!E_T$ from expected fluctuations in measured jet energies. $S > 5$ ensures the observed $\not\!\!E_T$ is not due to such fluctuations. In signal events, the vectorial sum p_T^{trk} of the charged particle transverse momenta is expected to point in a direction opposite to that of the $\not\!\!E_T$, while this is not expected in multijet events where a jet energy has been mismeasured. Advantage is taken of this feature by requiring $D = \Delta\phi(\not\!\!E_T, \not\!p_T^{\mathrm{trk}}) < \pi/2$. To reject backgrounds from W+jets, top, and diboson production, events containing an isolated electron or muon are rejected. To define a sample dominated by the multijet background we require $D > \pi/2$ and there we substract contributions from all simulated SM processes.

Monte Carlo simulation of the SM backgrounds is verified in a control sample mainly composed of W+jets events, by requiring the presence of a muon instead of vetoing it. Multijet modelling is verified in a seperate control sample by lowering the cut on $\not\!\!E_T$ without a cut on S.

Large branching fraction for $H \to b\bar{b}$ is utilised by b-tagging of one or both of the two leading jets. The double tag sample is selected with asymmetric requirements on the output of a neural network b tagging algorithm [9], such that one jet is tagged with an efficiency of 70% ("loose tag") and other with an efficiency of 50% ("tight tag"). This asymmetric tagging procedure provides the best sensivity to a Higgs boson signal. To enhance search sensitivity an independent single tag sample is defined by requiring one of the jets to be tight tagged and other failes to be loose tag.

A BDT technique [10] is used for the final discrimination which takes advantage of the different kinematics of signal and background processes. For each Higgs mass value (m_H) a decision tree is trained to discriminate signal against multijet background, using 23 kinematic variables, and is optimized to remove most of the multijet background while retaining most of the signal. Additional training is done to discriminate the signal from other SM backgrounds.

Systematic uncertainities are assigned and their impact is assessed in overall normalization and shape of final discriminants. Agreement between data and expectation from SM and multijet background is observed both for number of selected events and for distributions of final discriminants. A modified frequentist approach [11] is used to set limits on cross section for the SM Higgs production. The test statistic is a joint log-likelihood ratio (LLR) of the background only and of signal+background hypothesis, obtained by summing LLR values over the bins of final discriminant. The impact of systematic uncertainities on the sensitivity of analysis is reduced by maximizing a profile likelihood function [12] in which these uncertainities are given Gaussian constraints associated with their priors.

4. RESULTS

Fig. 1 and Table 1 shows the observed and expected limit [13], in terms of the ratio of the excluded cross section to the SM expected production cross section multiplied by branching fraction of $H \to b\bar{b}$. The LLRs are also shown in Fig. 1. For a Higgs boson of mass 115 GeV, the observed and expected limits on the combined cross section of ZH and WH production multiplied by the branching fraction of $H \to b\bar{b}$ are factors of 3.7 and 4.6 times the SM value, respectively.

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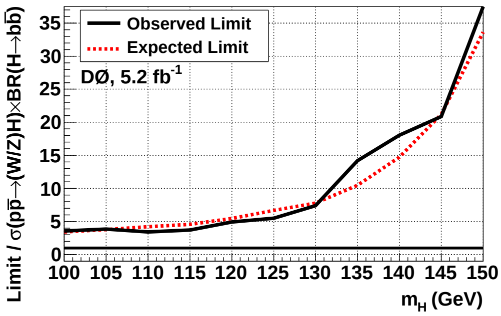

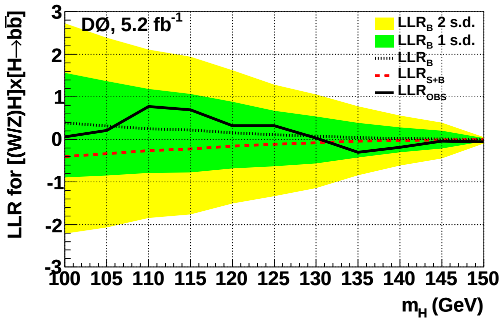

Figure 1: Expected and observed limits on the cross section ratios and log-likelihood ratios for combined ZH and WH production using the boosted decision trees.

Table 1: Observed and expected ratios of excluded to SM production cross section multiplied by the branching fraction for $H \rightarrow b\bar{b}$, as a function of m_H.

m_H (GeV)	100	105	110	115	120	125	130	135	140	145	150
Observed	3.7	4.0	3.2	3.7	4.6	5.6	8.2	14.5	15.3	24.4	43.6
Expected	3.5	3.7	4.2	4.6	5.4	6.3	7.6	10.5	14.0	20.5	32.3

References

[1] M. Carena *et al.*, *"Report of the Tevatron Higgs Working Group"*, `arXiv:hep-ph/0010338`; CDF and DØ Collaborations, *"Results of the Tevatron Higgs Sensitivity Study"*, FERMILAB-PUB-03/320-E (2003).

[2] R. Barate *et al.* [LEP Working Group for Higgs boson searches], Phys. Lett. B **565**, 61 (2003).

[3] The LEP Electroweak Working Group, *"Status of August 2009"*, `http://lepewwg.web.cern.ch/LEPEWWG/`.

[4] V.M. Abazov *et al.* (D0 Collaboration), Nucl. Instrum. Methods in Phys. Res. A **565**, 463, (2006).

[5] G.C. Blazey *et al.*, `arXiv:hep-ex/0005012 (2000);`

[6] M.L. Mangano *et al.*, JHEP **0307**, 001 (2003); version 2.11 is used.

[7] T. Sjöstrand, S. Mrenna and P. Skands, JHEP **0605**, 026 (2006); version 6.409 is used.

[8] E. Boos *et al.* (CompHEP Collaboration), Nucl. Instrum. Methods in Phys. Res. A **534**, 250 (2004).

[9] T. Scanlon, FERMILAB-THESIS-2006-43

[10] L. Breiman *et al.*, *"Classification and Regression Trees,"* Wadsworth (1984).

[11] T. Junk, Nucl. Instrum. Methods in Phys. Res. A **534**, 250 (2004).

[12] W. Fisher, *"Systematics and limit calculations"*, FERMILAB-TM-2386-E (2006).

[13] V.M. Abazov *et al.* `arXiv:hep-ex/0912.5285 (2009);`