PROCEEDINGS OF SCIENCE

Combined Upper Limits on Standard Model Higgs Boson Production from the DØ Experiment in up to 8.6 fb^{-1} of Data

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Searches for standard model Higgs boson production in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV are carried out for Higgs boson masses (m_H) in the range $100 < m_H < 200$ GeV/c^2. The contributing production processes include gluon-gluon fusion ($gg \to H$), associated production ($qqH \to W/ZH$) and vector boson fusion ($q\bar{q} \to q\bar{q}H$). Analyses are conducted in 40 distinct channels with integrated luminosities ranging from 4.3 to 8.6 fb^{-1}. As no significant excess is observed, we set limits on standard model Higgs boson production. The observed 95% C.L. upper limits are found to be a factor of 1.83 (0.71) times the predicted standard model cross section at $m_H = 115$ (165) GeV/c^2, while the expected limit is found to be a factor of 1.90 (0.87) times the standard model prediction for the same mass. We exclude at the 95% C.L. the region $161 < m_H < 170$ GeV/c^2 with an a priori expected exclusion of $159 < m_H < 170$ GeV/c^2.

The 2011 Europhysics Conference on High Energy Physics-HEP 2011,
July 21-27, 2011
Grenoble, Rhône-Alpes France

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1. Introduction

In the Standard Model (SM) the Higgs mechanism which involves the introduction of a complex doublet of scalar fields that generate the masses of elementary particles via their mutual interactions is a simple mechanism to explain electroweak symmetry breaking. It leads to the prediction of the existence of a relatively light massive scalar boson. Direct searches in $e^+e^- \rightarrow Z^* \rightarrow ZH$ at the Large Electron Positron (LEP) collider yielded a lower mass limit at m$_H$ > 114.4 GeV/c^2 [1] while precision electroweak data yield the indirect constraint m$_H$ < 158 GeV/c^2 [2], with both limits set at 95% confidence level (C.L.). By also considering the direct limit, the indirect constraint predicts m$_H$ < 185 GeV/c^2, indicating that the range 100 <m$_H$< 200 GeV/c^2 is the most important search region for a SM Higgs boson. The search for a SM Higgs boson is one of the main goals of the DØ Tevatron physics program.

In this update, we present a new combination of searches performed using data collected with the DØ detector using a larger data set and improved analysis techniques when compared with the last DØ SM combined Higgs boson search [3, 4]. The following channels have been updated the $WH \rightarrow l\nu b\bar{b}$, $ZH \rightarrow \nu\nu b\bar{b}$, $ZH \rightarrow llb\bar{b}$, $H \rightarrow W^+W^- \rightarrow l^\pm\nu l^\mp\nu$, 0/1/2+ jet, $H \rightarrow W^+W^- \rightarrow l\nu qq$, $H \rightarrow \gamma\gamma$. The $H + X \rightarrow \mu^\pm\tau^\mp_{had} + \leq 1$ jet channel is included for the first time in this full mass combination. The searches have been separated into 40 mutually exclusive final states over the mass range 100 < m_H < 200 GeV/c^2. They are summarized in Table 1.

Channel	Luminosity (fb^{-1})	# Sub-Channels	Reference
$WH \rightarrow l\nu b\bar{b}$, ST/DT, 2/3 jet	8.5	8	[3]
$ZH \rightarrow \nu\nu b\bar{b}$, ST/	8.4	2	[4]
$ZH \rightarrow llb\bar{b}$, ST/DT	8.6	10	[5]
$H \rightarrow W^+W^- \rightarrow l^\pm\nu l^\mp\nu$, 0/1/2+ jet	8.1	9	[6]
$H \rightarrow W^+W^- \rightarrow l\nu qq$	5.4	2	[7]
$H + X \rightarrow \mu^\pm\tau^\mp_{had} + \leq 1$ jet	7.3	3	[8]
$VH \rightarrow l^\pm l^\pm + X$	5.3	3	[9]
$H + X \rightarrow l^\pm\tau^\mp_{had} jj$	4.3	2	[10]
$H \rightarrow \gamma\gamma$	8.2	1	[11]

Table 1: List of analysis channels, corresponding integrated luminosities and subchannels ($l = e, \mu$).

2. Combination and limits calculations

The individual channels are combined using the CL_s method with a negative log-likelihood ratio (LLR) test statistic [14]. The value of CL_s is defined as $CL_s = CL_{s+b}/CL_b$ where CL_{s+b} and CL_b are, respectively the confidence levels for the signal-plus-background hypothesis and the background-only hypothesis. In this method binned final-variable distributions rather than a single-bin (fully integrated) value for each contributing analysis are used. Fig. 1 shows the Decision Tree output of 2 of the most sensitive channels in the low and high Higgs mass search regions. The exclusion criteria are determined by increasing the signal cross section until CL_s = 1-α, which defines a signal cross section excluded at 95% confidence level for α = 0.95. Systematics are treated

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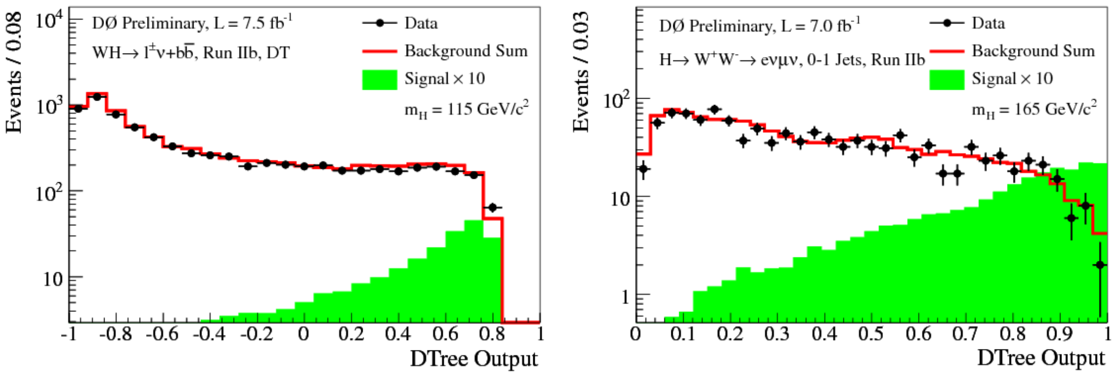

Figure 1: Examples of the final variable distributions for the $WH \rightarrow b\bar{b}$ (left) with 2 b-tags (DT) and $H \rightarrow W^+W^- \rightarrow l^{\pm}\nu l^{\mp}\nu + 0,1$ jet (right) analyses used to extract the upper limits on the SM Higgs production cross section.

as Gaussian uncertainties which values are sampled for each MC trial (pseudo-experiment) using Poisson distributions for the number of signal and background events. To minimize the degrading effects of systematics on the search sensitivity, the individual background contributions are fitted to the data observation by maximizing a likelihood function for each hypothesis [15].

3. Results

Results are presented in terms of the ratio of 95% C.L. upper cross section limits to the SM predicted cross section as a function of Higgs boson mass. The SM prediction for Higgs boson production would therefore be considered excluded at 95% C.L. when this limit ratio falls below unity. All analyses are performed on a Higgs boson mass grid with steps of 5 GeV/c^2. The most important sources of systematic uncertainties are summarized in the following. The uncertainty in the integrated luminosity is 6.1% [16] while for jet measurement and acceptances it is ≈7%. The b-tagging rate uncertainties varies in the range of 1-10% and the lepton measurement and acceptances ones range typically from 1-9% depending on the final state. The biggest contribution to the total uncertainty for all analyses comes from the different background cross sections which errors range at 4-30% depending on the analysis channel. The uncertainty on the expected multijet background is usually dominated by the statistics of the data sample from which it is measured. Fig. 2 shows the expected and observed 95% C.L. cross section limits as a ratio to the SM cross section as well as the exclusion probability for the probed mass region ($100 < m_H < 200$ GeV/c^2), with all analyses combined together.

4. Conclusion

Upper limits on SM Higgs boson production derived from the combination of 40 Higgs search analyses including data corresponding to 4.3-8.6 fb^{-1} have been presented. As no significant excess is observed, 95% C.L. limits on standard model Higgs boson production They are found to be a

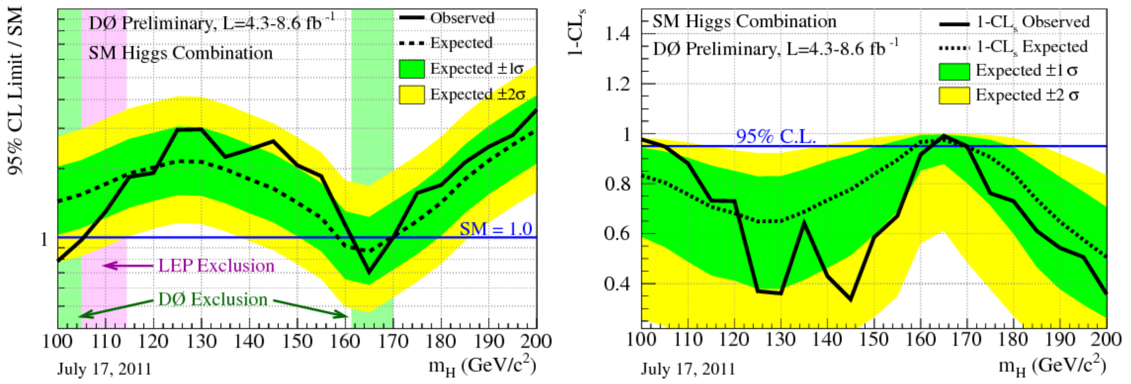

Figure 2: The expected and observed 95% C.L. cross section limits as a ratio to the SM cross section (left) and the 1-CL_S (exclusion probability) distribution for the combined $WH/ZH/H, H \rightarrow b\bar{b}, W^+W^-, \gamma\gamma, \tau^+\tau^-$ analyses over the $100 < m_H < 200$ GeV/c^2 mass range. The green and yellow bands correspond to the regions enclosing 1-σ and 2-σ fluctuations of the background, respectively

factor of 1.83 (0.71) times the predicted SM cross section at m_H = 115(165) GeV/c^2, while the expected limit is found to be a factor of 1.90 (0.87) times the SM prediction for the same mass. We exclude at the 95% C.L. the region $161 < m_H < 170$ GeV/c^2 with an a priori expected exclusion of $159 < m_H < 170$ GeV/c^2. We are also becoming sensitive to the low mass region where we exclude with 95% C.L. the region $100 < m_H < 105$ GeV/c^2, in agreement with the LEP exclusion.

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