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Search for a SM Higgs boson in dilepton plus missing transverse energy final state with the DØ detector at $\sqrt{s} = 1.96$ TeV

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Abstract. A search is presented for the Standard Model (SM) Higgs boson optimized in the decay channel $H \rightarrow W^+W^-$, where both W bosons decay leptonically. The final state considered contains dileptons and missing transverse energy from the neutrinos. A multivariate analysis is used to suppress the background. No significant excess above the SM background has been observed and limits set on the Higgs boson production cross-section $*$ the branching ratio for $m_{\mathrm{H}} = 115$–200 GeV are computed. Results using 8.1 fb^{-1} of data are presented.

Keywords. DØ; decision tree; log-likelihood ratio; confidence level.

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1. Introduction

In this search channel, final states containing two leptons ($e^{\pm}\mu^{\mp}$, e^+e^- or $\mu^+\mu^-$) and missing transverse energy are considered. The production of Higgs boson by gluon fusion, vector boson fusion and production in association with a vector boson (W/ZH) are considered. The analysis relies on the efficient reconstruction of objects using all subdetectors of Run II DØ detector [1]. The data sample used in this analysis was collected between April 2002 and December 2010 by the DØ detector at the Fermilab Tevatron collider at $\sqrt{s} = 1.96$ TeV, and corresponds to an integrated luminosity of 8.1 fb^{-1} after imposing data quality requirements.

2. Preselection

All events are required to have two oppositely charged leptons originating from the same position (within 2 cm) along the beamline. In the e^+e^- channel, the leading electron is required to have $p_{\mathrm{T}} > 15$ GeV and the second electron is required to have $p_{\mathrm{T}} > 10$ GeV. In the $e^{\pm}\mu^{\mp}$ channel, the muon must have $p_{\mathrm{T}} > 10$ GeV, while the electron is required to have $p_{\mathrm{T}} > 15$ GeV. In the $\mu^+\mu^-$ channel, the leading muon is required to have $p_{\mathrm{T}} > 15$ GeV, and the second muon must have $p_{\mathrm{T}} > 10$ GeV. The dielectron and dimuon channels also applied a cut on the $M_{\rm ll} > 15$ GeV. This stage of the analysis is referred to as ‘preselection’. To improve the sensitivity of the analysis, the preselection sample is further subdivided by the number of jets present in the event. Jets are required to have $p_{\rm T} > 20$ GeV, $|\eta| < 2.4$, pass quality requirements, and to have charged tracks associated with the primary $p\bar{p}$ vertex.

3. Final selection

The dielectron and dimuon channels use a decision tree (DT) discriminant against the dominant Z/γ^* background. The DT was trained for each Higgs mass point considered in each jet bin separately for dielectron and dimuon channels. To reject most of the Z/γ^* background, a cut is applied on this discriminant. The choice of the cut varies for each Higgs mass point in each jet bin. The electron–muon final state does not utilize a DT discriminant, rather it requires the minimum transverse mass to be larger than 20 GeV and rejects majority of these events.

4. Final discriminants

After preselection, the signal is separated from the remaining background using an additional random forest DT. Different discriminating variables are employed to distinguish

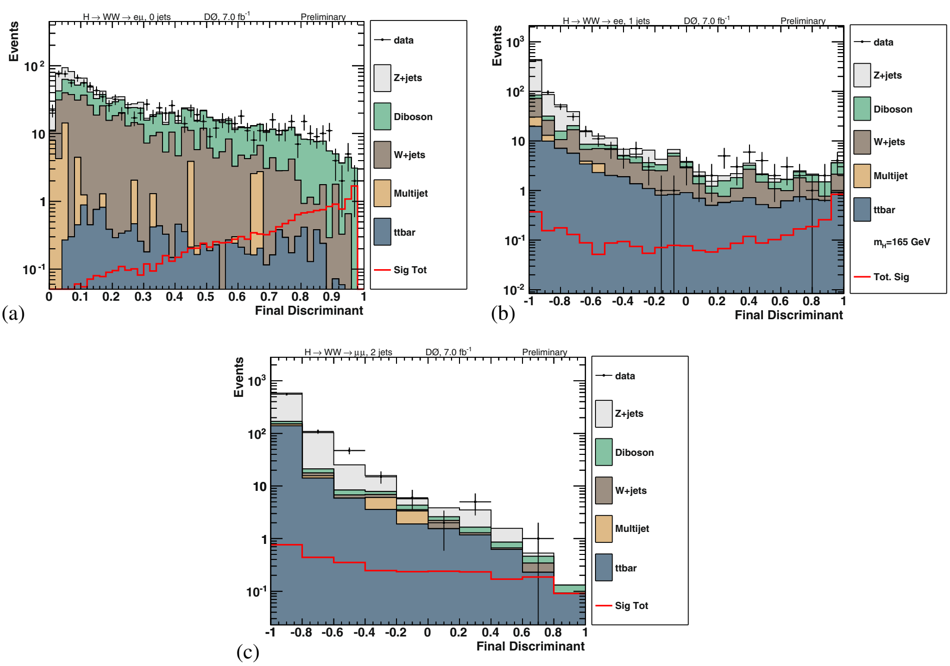

Figure 1. Final DT discriminant for the (**a**) 0-jet bin in $e\mu$ channel, (**b**) 1-jet bin in the ee channel, (**c**) ≥2-jet bin in the $\mu\mu$ channel. The discriminant shown is trained for a Higgs mass of 165 GeV.

signal from background in various jet bins. The DT discriminant for separate channels for a Higgs boson mass of 165 GeV can be found in figure 1.

5. Results and conclusions

Since no significant excess is observed in data, limits are set on the Higgs boson inclusive production cross-section $\sigma(p\bar{p} \rightarrow H + X)$ (figure 2), assuming Standard Model

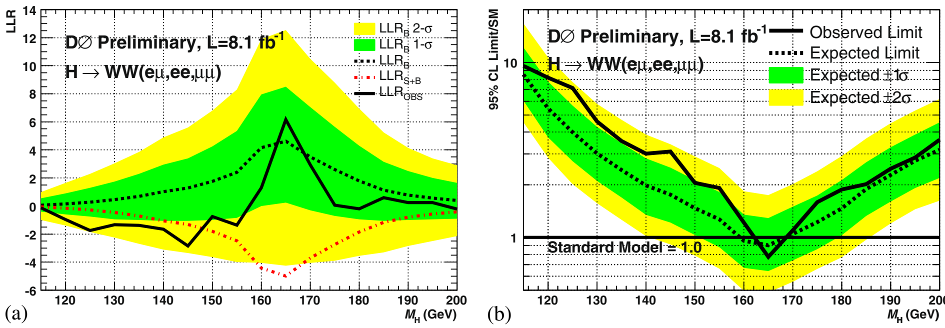

Figure 2. Excluded cross-section ($\sigma(p\bar{p} \rightarrow H + X)$) at 95% CL in units of the SM cross-section and the corresponding LLR are shown as a function of Higgs boson mass ($M_{\rm H}$).

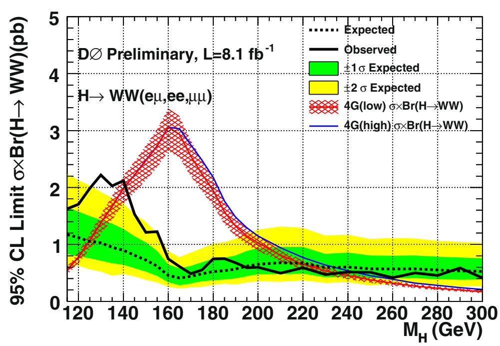

Figure 3. $\sigma_{\rm ggH} \times {\rm BR}(H \rightarrow WW)$ limit for the dilepton final state. The theoretical line corresponds to the fourth-generation model with $m_{\nu_4} = 80$ GeV, $m_{l_4} = 100$ GeV and $m_{d_4} = 400$ GeV.

Table 1. Expected and observed upper limits at 95% CL for $\sigma(p\bar{p} \rightarrow H+X)$ relative to the SM prediction for the dielpton combination.

$M_{\rm H} =$	115	120	125	130	135	140	145	150	155	160	165	170	175	180	185	190	195	200
Expected	8.55	5.83	4.39	3.38	2.66	2.23	1.94	1.71	1.44	1.05	0.97	1.15	1.30	1.57	1.93	2.25	2.75	3.20
Observed	9.95	9.12	8.06	4.97	4.25	3.45	3.83	2.85	2.73	1.61	0.91	1.55	1.65	1.91	2.56	2.93	3.55	4.15

(SM) values for the branching ratios. Limits are calculated using a modified frequentist method (CLs), with a log-likelihood ratio (LLR) test statistic [2]. To minimize the degrading effects of systematics, the individual background contributions are fitted to the data observation by maximizing a profile likelihood function for each hypothesis [3] (figure 3). The expected and observed limits are shown in table 1.

The cross-section limit of the $gg \rightarrow H \rightarrow VV$ ($V = Z, W$) process is interpreted under the assumption of a fourth-generation of fermions. A heavy fourth SM family of quarks leads to a significant enhancement of the $gg \rightarrow H$ production cross-section arising from contributions to the quark loop [4].

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