Search for the Higgs Boson in $H \to WW^{(*)}$ Decays in $p\bar{p}$ Collisions at $\sqrt{s} = 1.96$ TeV

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At the $p\bar{p}$ collider TeVatron the Standard Model Higgs boson is mainly produced via gluon-gluon fusion with a production cross section in the range of 0.1 to 2 pb. For masses $m_H > 135$ GeV the Higgs boson decays dominantly into W boson pairs. The leptonic decay channels of the W bosons provide a clear signature to discriminate against background processes [1].

The process $H \to WW^{(*)} \to \mu^+\nu_\mu\mu^-\bar{\nu}_\mu$ is studied in data taken with the DØ experiment [2] between April 2002 and June 2004. The integrated luminosity of the sample corresponds to $\mathcal{L} = 299 \pm 19\,\text{pb}^{-1}$. The signature of the process is characterised by two isolated muons with high transverse momentum p_T and a significant missing transverse energy in the event originating from the undetected neutrinos. Processes with the similar event topology are Drell-Yan $Z/\gamma^* \to \mu\mu, \tau\tau$ production, WW, $t\bar{t}$, $b\bar{b}$, QCD and W+jets production. All processes were studied using the PYTHIA Monte Carlo generator with full detector simulation and parton distribution function CTEQ 5L and are compared to data. To be independent of the MC modelling the contributions from QCD and W+jets production are studied in data and MC combination.

The components of the DØ Run II detector important to this analysis are described elsewhere [2,3]. To exploit the full kinematic range that changes with increasing Higgs mass m_H various cuts are used dependent on the Higgs mass. Two muons originating from the same vertex are required to be of opposite charge, isolated and must have $p_T > 15$ GeV for the leading muon and $p_T > 10$ GeV for the trailing one.

The background is largely dominated by Z/γ^* production which is suppressed by requiring the $\not\!\!E_T$ to be greater than 20 GeV. Events are also removed if the $\not\!\!E_T$ has a large contribution from the mismeasurement of jet energy, using a cut on the scaled $\not\!\!E_T$ to be greater than 15. Additional cuts are applied to further reduce the Z/γ^* background and other backgrounds. Depending on the Higgs mass m_H the invariant mass $m_{\mu\mu}$ is required to be $m_{\mu\mu} < m_H/2\,\text{GeV}$. A lower cut boundary with $m_{\mu\mu} > 20$ GeV is required to remove events from J/ψ and Υ production. The sum of the muon transverse momentum p_T and the missing transverse momentum $\not\!\!E_T$ is required to be in the range $m_H/2 + 10\,\text{GeV} < p_T^{\mu_1} + p_T^{\mu_2} + \not\!\!E_T < m_H$. The transverse mass $m_T = \sqrt{2p_T^{\mu\mu}\not\!\!E_T(1 - \cos\Delta\phi(\mu\mu, \not\!\!E_T))}$ computed from the di-muon momentum and the missing transverse momentum should be in the range $m_H/2 < m_T < m_H - 10\,\text{GeV}$. The latter two cuts further reduce backgrounds from Z/γ^* production. Finally, to suppress the background from $t\bar{t}$ production, the scalar sum of the transverse energies of all jets with $E_T^{\text{jet}} > 20$ GeV and $|\eta| < 2.5$, H_T, is required to be less than 100 GeV. For Higgs masses $m_H = 140$ and 160 GeV a slightly modified selection is chosen to improve the signal to background ratio.

The efficiency for $H \to WW^{(*)}$ production at the beginning of the $\mu\mu$ channel selection is (31.5±0.2)%. Applying all selection criteria reduces the efficiency to (4.0±0.4)% to (15.2±0.6)% depending on the Higgs mass assumed in the selection. The expectations from all the backgrounds after all cuts is between 6.1 ± 0.6 (stat) ± 0.5 (syst) and 12.9 ± 1.1 (stat) ± 2.3 (syst) events whereas 4 to 8 events are observed in the $\mu\mu$ data depending on the selection. The $Z/\gamma^* \to \mu\mu$ decays always contribute more than half to the background expectation.

Sources of systematic uncertainties that affect the number of background events and signal efficiency such as the trigger efficiency, and muon identification (ID) efficiencies, jet energy scale (JES), electron and muon momentum resolution, cross section calculation of Z/γ^* WW and $t\bar{t}$ events, and the determination of W+jet/γ background contributions have been studied.

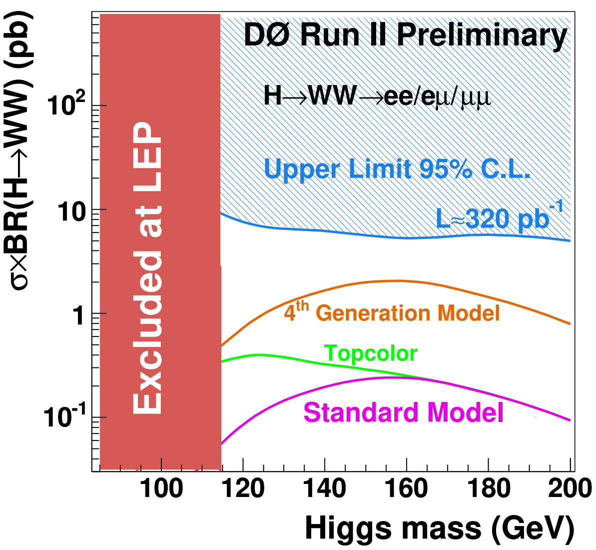

Fig. 1: Excluded cross section times branching ratio $\sigma \times BR(H \to WW^{(*)})$ at 95% CL together with expectations from standard model Higgs boson production and alternative models.

No excess was found in data and upper limits on the cross section of $H \to WW^{(*)} \to \mu^+\nu_\mu\mu^-\bar{\nu}_\mu$ decays have been calculated at 95% CL in a combination of the ee, $e\mu$ and $\mu\mu$ final states. Figure 1 shows the calculated cross section limits on $\sigma \times BR(H \to WW)$ for the different Higgs masses compared with the Standard Model prediction and alternative models. Should the Higgs resemble the Standard model prediction, however, a discovery can only be made by a combination of all these decay channels with the full Run II dataset.

References

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