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

J. Elmsheuser, O. Biebel, M. Binder, P. Calfayan, F. Fiedler, D. Görisch, A. Grohsjean, P. Haefner, T. Nunnemann, D. Schaile, P. Schieferdecker, R. Ströhmer, and B. Tiller

In the standard model (SM), the hypothetical Higgs boson is crucial to the understanding of electroweak symmetry breaking (EWSB) and the mass generation of electroweak gauge bosons and fermions. Spontaneous EWSB predicts the existence of this neutral scalar particle with mass M_H, a free parameter in the SM. Direct searches at the CERN e^+e^- collider (LEP) yield a lower limit for the Higgs boson mass of $M_H > 114.4$ GeV at the 95% confidence level (CL). Indirect measurements via fits to the electroweak precision data give an upper bound of $M_H < 186$ GeV at the 95% CL.

We present a search for the Higgs boson in $H \to WW^{(*)} \to \ell\nu\,\ell'\nu'$ $(\ell, \ell' = e, \mu, \tau)$ decays with e^+e^-, $e^\pm\mu^\mp$, or $\mu^+\mu^-$ final states [1]. Tau decays are detected in their leptonic decay modes to electrons or muons. We use data collected by the DØ detector [2] between April 2002 and June 2004 in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV of the Fermilab Tevatron Collider. The integrated luminosities are $299 - 325$ pb^{-1} depending on the final state, where the relative uncertainty is 6.5%. Next-to-leading order (NLO) calculations predict the product of the SM Higgs boson production cross section and the branching ratio $\sigma(p\bar{p} \to H) \times BR(H \to WW^{(*)})$ of 11–250 fb for the Higgs masses between 100 and 200 GeV. Extensions of the SM including a fourth fermion family predict an enhanced Higgs boson production cross section (Fig 1).

The decay of the two W bosons into electrons or muons results in three different final states $e^+e^- + X$ (ee channel), $e^\pm\mu^\mp + X$ ($e\mu$ channel) and $\mu^+\mu^- + X$ ($\mu\mu$ channel), each of which consists of two oppositely charged isolated leptons with high transverse momentum and large missing transverse energy, $\not\!\!E_T$, due to the undetected neutrinos. The selection criteria for each channel were chosen to minimize the cross section upper limit on Higgs production expected in the absence of signal. To take into account the signal kinematic characteristics that change with the Higgs boson mass, M_H, some selection cuts are M_H dependent. Six Higgs boson masses from 100 GeV to 200 GeV have been studied. All selection cuts are described in detail in Ref. [1]

The efficiency for $H \to WW^{(*)} \to \ell\nu\,\ell'\nu'$ signal events to pass the acceptance and selection criteria is determined using the PYTHIA 6.2 event generator followed by a detailed GEANT-based simulation of the DØ detector. All trigger, reconstruction and identification efficiencies are derived from the data. The kinematic acceptance efficiency is derived from Monte Carlo simulations (MC). The overall detection efficiencies range from $(0.44 \pm 0.03)\%$ to $(3.9 \pm 0.2)\%$ depending on the decay channel and M_H. Using the NLO cross sections, the expected number of events for $H \to WW^{(*)}$ decays from all three channels is $0.68 \pm 0.03\,(\text{syst}) \pm 0.04\,(\text{lum})$ events for a Higgs boson mass $M_H = 160$ GeV.

Background contributions from Z/γ^*, W+jet/γ, $t\bar{t}$, WW, WZ and ZZ events are estimated using the PYTHIA event generator with total cross-sections normalized to their NLO cross sections. All events are processed through the full detector simulation. The background due to multijet production, when a jet is misidentified as an electron, is determined from the data using a sample of like-sign dilepton events with inverted lepton quality cuts. There is good agreement between the number of events observed in the data and the various backgrounds in all three channels. The $e\mu$ channel has both the highest signal efficiency and best signal-to-background ratio.

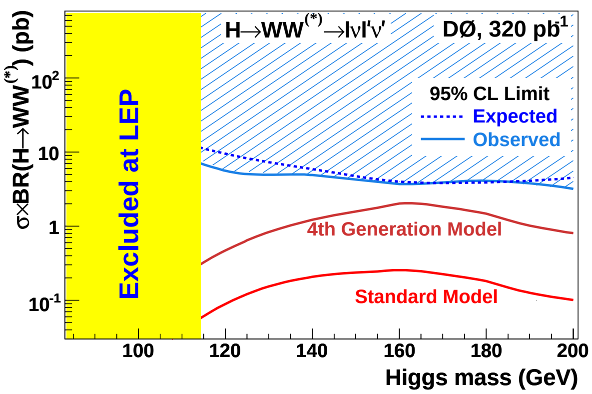

Fig. 1: Expected and observed upper limits on the cross section times branching ratio $\sigma \times BR(H \to WW^{(*)})$ at the 95% CL together with expectations from standard model Higgs boson production and an alternative model.

Various sources of systematic uncertainties that affect the background estimation and signal efficiencies have been studied. The trigger efficiency, electron and muon identification efficiencies, jet energy scale, electron and muon momentum resolution, parton distribution function (PDF) uncertainty and cross section calculation of Z/γ^*, WW and $t\bar{t}$ events contribute to the systematic uncertainties.

Since the remaining candidate events after the selection are consistent with the background expectation, limits on the production cross section times branching ratio $\sigma \times BR(H \to WW^{(*)})$ are derived using a modified frequentist method. The best limits are achieved for large Higgs masses since background expectations decrease while signal efficiencies increase. Figure 1 shows the expected and observed cross section limits for $\sigma \times BR(H \to WW^{(*)})$ for the different Higgs boson masses compared with predictions from the SM and from an extension including a fourth fermion family. With the current dataset, no region of the SM prediction can be excluded. With the full Tevatron Run II statistics, the SM predictions are within reach.

References

[1] DØ Collaboration, V. M. Abazov *et al.*, Phys. Rev. Lett. **96** (2006) 011801 [arXiv:hep-ex/0508054].

[2] DØ Collaboration, V. M. Abazov *et al.*, submitted to Nucl. Instrum. Methods A [arXiv:physics/0507191].