Search for WH Production with the DØ Experiment

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Without the Higgs mechanism to generate mass for the W and Z bosons, and the fermions, the standard model is meaningless. An important prediction of the Higgs mechanism is the existence of a spin-0 boson, which is known as the Higgs boson. So far, the Higgs boson has not been observed experimentally.

The standard model does not directly predict what the Higgs boson mass is. However, through radiative corrections, parameters and properties of other constituents of the standard model are dependent on the Higgs boson mass. Assuming the standard model with the Higgs mechanism is correct, precision measurements of parameters of the standard model can be used to predict the mass of the Higgs boson. At the end of 2008, this fit of the data to the standard model, states that $m_{\text{Higgs}} = 84^{+34}_{-26}$ GeV [1]. If this is combined with the direct search limit from LEP [2], then it follows that at 95% Confidence Level (CL), $114 < m_{\text{Higgs}} < 185$ GeV.

The Tevatron $p\bar{p}$ collider at Fermilab is currently the only running accelerator facility where the Higgs boson can be searched for. In the expected Higgs boson mass range, the Tevatron experiments DØ and CDF have excellent sensitivity. The most sensitive search channel at low mass ($m_{\text{Higgs}} \lesssim 140$ GeV) is the production of a Higgs boson in association with a W boson, where the Higgs boson decays to a $b\bar{b}$-pair and the W boson decays to a lepton and a neutrino.

The basic event selection for a WH signal is straightforward (one lepton, missing transverse energy and at least two jets). To reduce the overwhelming background from production of a W with two or more jets, where the jets do not originate from a Higgs boson decay, it is required that one or two of the jets in the event have a signature of a long-living b-hadron (from the fragmentation of a b-quark).

In principle, a Higgs boson signal would be visible as a peak in the invariant mass distribution of two jets with a b-signature. However, the sensitivity of the analysis can be improved significantly by using advanced multivariate techniques. This can be done by combining kinematic variables in a neural network. To gain even more sensitivity, an additional input to the neural network can be a matrix-element discriminant, which gives the probability that a given event corresponds to a signal or background event based on the theoretical matrix element.

The result of the WH search using 2.7 fb^{-1} of integrated luminosity collected by the DØ experiment is shown in Fig. 1. The left diagram shows the invariant mass of two jets in the sub-channel where three jets are selected, one of which has the signature of a b-quark. The right distribution shows the neural network output distribution for events with exactly two identified b-jets. The neural network used here includes a matrix-element discriminant as an input. In both cases, the data agree with the expected contributions from background processes (dominantly $Wb\bar{b}$ and $t\bar{t}$ production).

In the absence of signal, cross section limits are set on WH production, as a function of Higgs boson mass. The results are shown in Fig. 2. At a Higgs boson mass of 115 GeV, this analysis sets a limit at 95% CL of 6.7 (6.4 expected) times the standard model cross section.

At the end of 2008, the combined DØ and CDF search results [3] excluded a Higgs boson mass of 170 GeV. With the expected integrated luminosity of the Tevatron, and expected improvements in the analysis techniques, the two experiments will obtain sensitivity to a Higgs boson over the full allowed Higgs boson mass range, in the very near future.

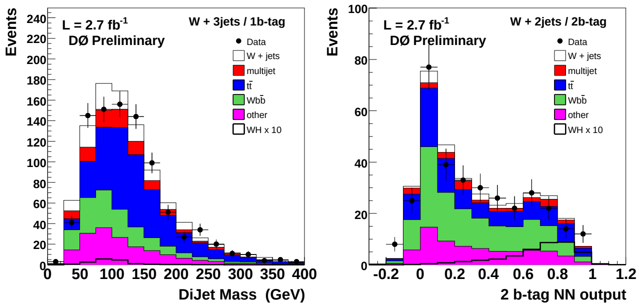

Fig. 1: Distribution of the di-jet invariant mass in events with three jets with one identified b-jet (left), and the neural network output for events with exactly two identified b-jets (right). The data are represented by the black dots, the different background contributions are represented by the histograms, the expected WH signal (multiplied by a factor ten) for a Higgs boson mass of 115 GeV is shown as the black histogram.

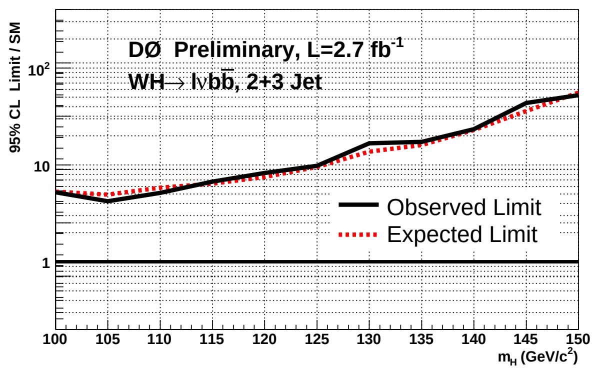

Fig. 2: Ratio of the cross section limit at 95% CL and the expected standard model cross section, as a function of the Higgs boson mass, for the DØ WH search.

References

[1] The ALEPH, CDF, D0, DELPHI, L3, OPAL, SLD Collaborations, the LEP Electroweak Working Group, the Tevatron Electroweak Working Group, and the SLD electroweak and heavy flavour groups, "Precision Electroweak Measurements and Constraints on the Standard Model", arXiv:0811.4682 [hep-ex].

[2] ALEPH, DELPHI, L3 and OPAL Collaborations, LEP working group for Higgs boson searches, "Search for the standard model Higgs boson at LEP", Phys. Lett. **B 565** (61) 2003

[3] The Tevatron New-Phenomena and Higgs Working Group, for the CDF and DØ Collaborations, "Combined CDF and DØ Upper Limits on Standard Model Higgs Boson Production at High Mass (155-200 GeV/c^2) with 3 fb^{-1} of data", arXiv:0808.0534 [hep-ex]