SEARCHES FOR THE STANDARD MODEL HIGGS AT THE TEVATRON

P.M. JONSSON
(For the CDF and DØ Collaborations)

Imperial College London, Prince Consort Road,
London SW7 2BW, United Kingdom

Abstract. Recent preliminary results obtained by the CDF and DØ collaborations on searches for the Standard Model (SM) Higgs boson in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV at the Fermilab Tevatron are discussed. The data, corresponding to integrated luminosities between $260 - 950$ pb^{-1}, show no excess of a signal above the expected background in any of the decay channels examined. Instead, upper limits at 95% Confidence Level (C.L.) on the cross section are established. For the first time, a combined SM cross section limit based on 14 orthogonal analysis channels from DØ is presented.

1 Introduction

The search for the SM Higgs boson is one of the main challenges for particle physics and as such a high priority for the upgraded CDF and DØ detectors at Run II of the Tevatron. The Higgs boson, which is needed to explain the mechanism of electroweak symmetry breaking, is the only particle predicted in the SM which has not been discovered. Indirect constraints on the mass (m_H), which is a free parameter, from fits to the global set of electroweak data, favor a light SM Higgs boson of 89 GeV with an upper limit of 175 GeV at 95% C.L[1]. The direct searches at LEP have already excluded a SM Higgs mass below 114.4 GeV [2]. A discovery of the Higgs may be within reach by the end of Run II, thanks to the excellent accelerator and detector performance. The expected combined sensitivity to exclude a SM Higgs at 114 GeV at the Tevatron starts around 2 fb^{-1} [3] and both CDF and DØ have now each recorded an integrated luminosity of over 1 fb^{-1}.

2 Low Mass Searches, $m_H < 135$ GeV

Higgs boson production cross sections in the SM are small at Tevatron energies, of the order of 1-0.1 pb depending on the production mechanism. Gluon fusion, $gg \to H$, is the dominant production mechanism. However, for masses below 135 GeV, where $H \to b\bar{b}$ decays dominate, the QCD background is overwhelming. The smaller but cleaner channels of associated ZH and WH production, with the vector bosons decaying into leptons can instead be used for direct searches. These analyses rely on efficient b-tagging and lepton identification as well as precise Monte Carlo (MC) modeling of the backgrounds. Progress is being made on understanding the W/Z + jets background. A recent study from DØ for example, shows good detector level agreement up to $n_{jet} = 4$ between SHERPA 1.0.6, a matrix element + parton shower MC generator, and 950 pb^{-1} of selected $Z(\to e^+e^-) + n_{jet}$ data [4].

2.1 $ZH \to \nu\bar{\nu}b\bar{b}$

This channel has a good sensitivity because of the large $Z \to \nu\bar{\nu}$ and $H \to b\bar{b}$ branching ratios. Since the two b-jets are boosted, the final state contains a signature of acoplanar jets in contrast to typical QCD dijets. The main backgrounds are W/Z+jets, WZ, ZZ and $t\bar{t}$ where the lepton or jets escape. Multijets, with mis-measured jets dominate the difficult instrumental backgrounds. CDF has performed a search with 289 pb^{-1} of data [5] and DØ has analyzed 261pb^{-1} of data [6a]. The event selections include 1 or 2 b-tagged jets and large missing transverse energy ($\not\!\!E_T$). Since no significant excess is observed over the expected backgrounds, upper limits at 95% C.L. are calculated for $\sigma_{ZH} \times BR(H \to b\bar{b})$. The resulting limits are shown, together with the other Tevatron limits, in Fig. 2.

2.2 $WH \to l\nu b\bar{b}$

Associated WH production, with the W decaying to a charged lepton and a neutrino, provides perhaps the most promising channel. CDF has performed a search with 319 pb^{-1} of data [7] and DØ reports new preliminary results for both the electron and muon channel based on 378 pb^{-1} of data [8]. The analysis selects candidate events by identifying the W through its decay to an electron or muon and a neutrino. The events are required to have a central, isolated electron or muon with $p_T > 20$ GeV, $\not\!\!E_T > 20$ GeV (DØ : $\not\!\!E_T > 25$ GeV) and two jets with $E_T > 15$ GeV in a pseudo rapidity region of $|\eta| < 2.0$ (DØ : $E_T > 20$ GeV within $|\eta| < 2.5$). In addition, one or two b-tagged jets are required. Fig. 1 shows the invariant dijet mass distribution of the final event samples from CDF and DØ . No significant excess is observed and therefore upper limits at 95% C.L. are calculated. The limits are illustrated in Fig. 2.

3 High Mass Searches, $m_H > 135$ GeV

At higher Higgs masses, where they are kinematically possible, $H \to WW^{(*)}$ decays with subsequent electronic and/or muonic decays of the Ws, provide promising search channels with manageable backgrounds.

3.1 $WH \to WWW^{(*)}$

Because of the like-signed leptons in the final state, much of the SM backgrounds from diboson and $t\bar{t}$ production can be reduced in this channel.

[a] In addition, this analysis is also used at DØ in the search for $WH \to l\nu b\bar{b}$ with a missed lepton to improve the WH sensitivity.

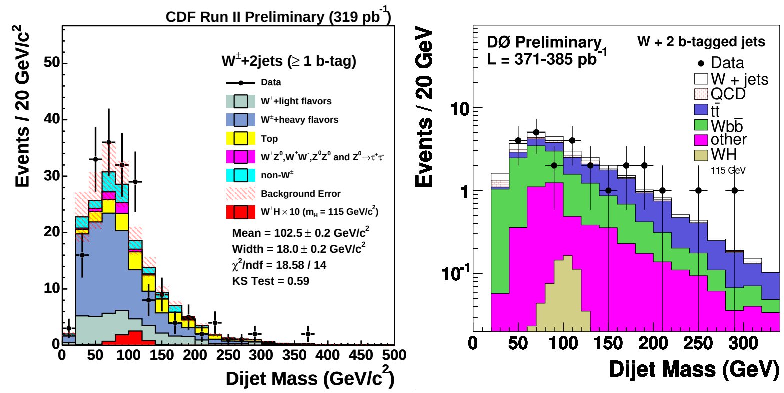

Figure 1: The dijet mass distribution in data from the WH search along with the background expectations. Left: CDF. Right: The final double b-tagged events from DØ in logarithmic scale.

DØ has performed a recent search with $363 - 384$ pb^{-1} of data [9] (CDF has a previous result based on the analysis of 194 pb^{-1} of data [10]). The analysis selects two isolated like signed leptons ($ee, e\mu$ or $\mu\mu$) with $p_T > 15$ GeV and $\not\!\!E_T > 20$ GeV. After final event selection 6 events remain in data, which is in agreement with the predicted SM background. The resulting upper limit on the cross section is illustrated in Fig. 2.

3.2 $H \to WW^{(*)}$

The signature of this signal consists of two isolated, oppositely charged leptons together with large $\not\!\!E_T$. Direct reconstruction of the Higgs mass is not possible, due to the two neutrinos in the final state. Instead, the spin-correlations between the decay products of the Higgs boson can be used to suppress the background. The charged leptons from the signal events tend to be collinear. CDF has analyzed 360 pb^{-1} of data [11] and DØ has presented a new result based on 950 pb^{-1} for the $e\mu$ and ee channels [12]. After final event selection, which also includes a veto around the Z mass, good agreement with the SM background predictions is observed. The resulting CDF cross section limit, obtained from fits to the $\Delta\phi_{ll}$ distribution, is illustrated together with the DØ result in Fig. 2.

4 Combined Limits

DØ has, for the first time, calculated a combined upper SM Higgs cross section limit at 95% C.L. based on fourteen orthogonal search channels[b] [13]. The resulting combined limit is shown together with the other SM Higgs limits from the Tevatron in Fig. 2. The SM cross section is still a factor 15(7) away from the new upper limit at $m_H = 115(160)$ GeV.

5 Conclusions

The new preliminary results presented at this conference together with the recent performance of the Tevatron and the experiments, are very encouraging for the Higgs searches at Run II. The combined preliminary limit on the SM cross section from DØ demonstrates a large improvement in sensitivity over previous results. With upcoming improvements to the analyses and combination of more channels from both experiments, the Tevatron sensitivity can be expected to approach the SM level for a 115 GeV Higgs with 2 fb^{-1} of data.

[b] The single and double b-tagged events from the ZH and WH searches are treated as separate channels.

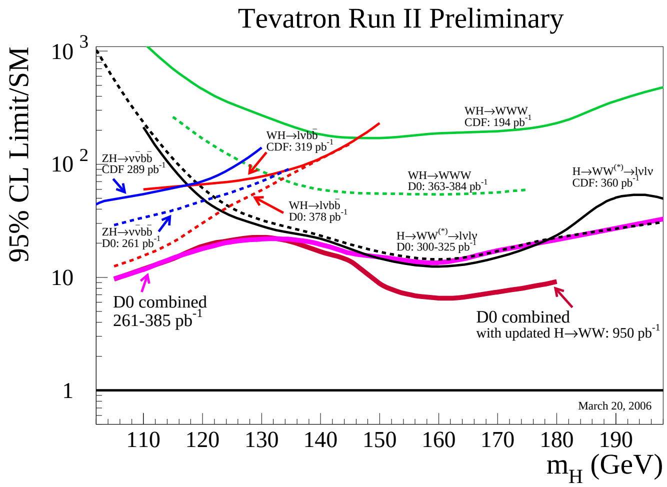

Figure 2: The ratio of the excluded cross section (at 95% C.L.) to the SM cross section as a function of the Higgs mass for the various Higgs searches at the Tevatron. The effect of including the new $H \to WW^{(*)}$ analysis in the combined DØ limit is clear. At $m_H = 160$ GeV the new limit from DØ is only a factor 7 from the SM.

Acknowledgments

I would like to thank my colleagues from the CDF and DØ collaborations for providing material for this talk and the organizers of Rencontres de Moriond for a most stimulating conference.

References

1. S. Roth, "W mass measurement at LEP and Standard model fits" in *XLIst Rencontres de Moriond - March 18-25 2006, QCD and Hadronic interactions at high energy.*
2. ALEPH, DELPHI, L3 and OPAL Collaborations, The LEP Working Group for Higgs Boson Searches, *Phys. Lett.* B **565**, 61 (2003).
3. CDF and DØ Collaborations, "Results of the Tevatron Higgs Sensitivity Study", FERMILAB-PUB-03/320-E.
4. DØ Collab., "Z + jet production in the DØ experiment: A comparison between data and the PYTHIA and SHERPA Monte Carlos" , DØ note 5066-CONF.
5. CDF Collab.,"Search for the Standard Model Higgs boson in the ZH→ $\nu\bar{\nu}b\bar{b}$ Channel in $p\bar{p}$ Collisions at $\sqrt{s} = 1.96 TeV$, CDF/ANAL/EXOTIC/PUBLIC/7983.
6. DØ Collab., "A search for the Standard Model Higgs boson using the $ZH \to \nu\bar{\nu}b\bar{b}$ channel in $p\bar{p}$ Collisions at $\sqrt{s} = 1.96$ TeV", DØ note 5060-CONF.
7. CDF Collab.,"Search for New Particles $H \to b\bar{b}$ Produced in Association with $W^{\pm}$ Bosons in $p\bar{p}$ Collisions at $\sqrt{s} = 1.96$ TeV", CDF/PUB/EXOTIC/PUBLIC/7740.
8. DØ Collab., "A search for WH Production at $\sqrt{s} = 1.96$ TeV", DØ note 5054-CONF.
9. DØ Collab., "A search for the Associated Higgs Boson Production $p\bar{p} \to WH \to WWW^* \to l^{\pm}\nu l'^{\pm}\nu q\bar{q}$ at $\sqrt{s} = 1.96$ TeV", DØ note 4861-CONF.
10. CDF Collab.,"Search for the WH Production Using High-p_T Isolated Like-Sign Dilepton Events in Run II", CDF/PUB/EXOTIC/PUBLIC/7307.
11. CDF Collab.,"Search for the Standard Model Higgs Production of $H \to WW^{(*)} \to l^-\nu l^+\bar{\nu}$ in $p\bar{p}$ Collisions at $\sqrt{s} = 1.96$ TeV", CDF note 7893.
12. DØ Collab.,"Search for the Higgs boson in $H \to WW^* \to ll'(l, l' = e, \mu)$ decays with 950 pb^{-1} at DØ in Run II", DØ note 5063-CONF.
13. DØ Collab.,"Limits on Standard Model Higgs Boson Production", DØ note 5056-CONF.