COMBINATION OF STANDARD MODEL HIGGS SEARCHES AT THE TEVATRON

BODHITHA JAYATILAKA
(on behalf of the CDF and DØ Collaborations)
Duke University, Department of Physics,
Durham, NC 27708, USA

We present a new combination of searches for a standard model Higgs Boson by the CDF and D0 experiments at the Fermilab Tevatron. This combination, covering possible Higgs boson masses between 130 GeV/c^2 and 200 GeV/c^2 and emphasizing the $H \rightarrow W^+W^-$ decay channel, utilizes up to 7.1 fb^{-1} of data collected at CDF and up to 8.2^{-1} of data collected at D0. We present 95% CL upper limits on standard model Higgs boson production in this mass range, including exclusion of the range $158 < m_H < 173$ GeV/c^2.

1 Introduction

In the standard model (SM) of particle physics, the observed spontaneous breaking of the electroweak symmetry can be explained via the Higgs mechanism. In addition to providing mass to fundamental particles, the Higgs mechanism would also manifest a physical particle, the Higgs boson. Finding experimental evidence of the Higgs boson or excluding its existence has been a high priority for the field of high-energy physics. A global fit of SM observables indicates a most likely Higgs boson mass $m_H = 89^{+35}_{-26}$ GeV/c^2 with 95% confidence level (CL) upper limit of 158 GeV/c^2, while direct searches at LEP have excluded $m_H < 114.4$ GeV/c^2 at 95% CL. The remaining likely region is within kinematic reach of the Fermilab Tevatron, a $\sqrt{s} = 1.96$ TeV $p\bar{p}$ collider. Thus, in the last few years, the CDF and D0 experiments have made substantial improvements in direct searches for the SM Higgs boson. Here, we present the most recent combination of direct search results from CDF and D0 in the range $130 < m_H < 200$ GeV/c^2.

2 Tevatron Higgs Search Channnels

Higgs boson production at the Tevatron is dominated by the process $gg \rightarrow H$ while its decay is dominated by $H \rightarrow b\bar{b}$ for $m_H < 130$ GeV/c^2, categorized as "low mass", and $H \rightarrow W^+W^-$ for $m_H > 130$ GeV/c^2, categorized as "high mass." The sensitivity of the high mass regime is dominated by searches for $gg \rightarrow H \rightarrow W^+W^-$. However, smaller channels are considered as well. Additionally, multivariate techniques such as artificial neural networks, boosted decision trees and matrix element calculations are utilized to enhance sensitivity to the small Higgs signal expected. A total of 12 mutually exclusive final states are considered by CDF (Table 1) and 35 by D0 (Table 2).

More details on the individual analyses can be found elsewhere[1]. For all processes considered, we normalize our Higgs boson signal prediction to the most recent highest-order calculations

Table 1: Luminosity, explored mass range and references for the different processes and final states ($\ell = e, \mu$) for the CDF analyses. A total of 12 mutually exclusive final states are considered.

Channel	Luminosity (fb^{-1})	m_H (GeV/c^2)
$H \to W^+W^-$ 2×(0,1 jets)+(≥2 jets)+(low-$m_{\ell\ell}$)+(e/μ-τ_{had})	7.1	130-200
$WH \to WW^+W^-$ (same-sign leptons ≥1 jets)+(tri-leptons)	7.1	130-200
$ZH \to ZW^+W^-$ (tri-lepton 1 jet)+(tri-lepton ≥2 jets)	7.1	130-200

Table 2: Luminosity, explored mass range and references for the different processes and final states ($\ell = e, \mu$) for the D0 analyses. A total of 35 mutually exclusive final states are considered.

Channel	Luminosity (fb^{-1})	m_H (GeV/c^2)
$H \to W^+W^- \to \ell^\pm\nu\ell^\mp\nu$ (0,1,2+ jets)	8.1	130-200
$H \to W^+W^- \to \mu\nu\tau_{had}\nu$	7.3	130-200
$H \to W^+W^- \to \ell\bar{\nu}jj$	5.4	130-200
$VH \to \ell^+\ell^- + X$	5.3	130-200
$H + X \to \ell^\pm\tau^\mp_{had}jj$	4.3	130-200
$H \to \gamma\gamma$	8.2	130-150

available.

3 Combination Procedure

In order to ensure that the combined result does not depend on the statistical method employed, the combination is performed using two methods: a Bayesian and Modified Frequentist method. At each m_H hypothesis considered, the result from the two methods is required to agree within 5% while the average over all masses agrees within 2%. Both methods utilize the distribution of final discriminants from each input analysis and utilize Poisson statistics.

3.1 Systematic Uncertainties

Systematic uncertainties are treated as nuisance parameters and both methods utilize the data to constrain these nuisance parameters. Two categories of systematic uncertainties are considered: rate systematics (such as tag uncertainty), which affect the overall normalization, and shape systematics (such as jet energy scale), which also affect the overall distributions.

Systematic uncertainties due to integrated luminosity and theoretical prediction of signal and background cross-sections are treated as correlated between CDF and D0 while other systematic uncertainties are treated as uncorrelated between experiments but correlated between analyses of a given experiment. Sources of these uncertainties include b-quark tagging efficiency, lepton selection, QCD radiation, jet energy scale, and other detector effects.

3.2 Validation with Data

In order to check the agreement between data and expectation, we can aggregate signal and background expectations in all analyses, bin them by signal-to-background ratio, s/b, and overlay the data binned in the same way, as shown in Figure 1 for $m_H = 165$ GeV/c^2. Additionally, we can subtract the expected background from the data distribution and compare to the expected Higgs signal. This comparison, again sorted by s/b, is shown in Figure 2 for $m_H = 165$ GeV/c^2. No significant excess is seen in high s/b bins.

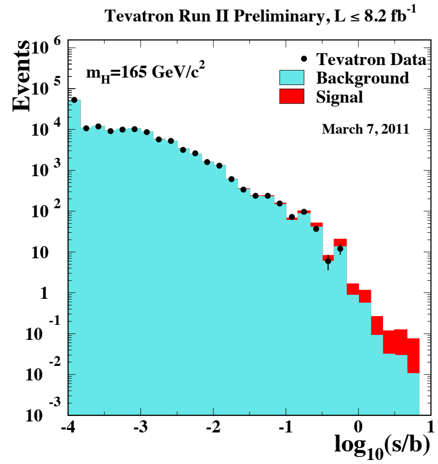

Figure 1: Distribution of $\log_{10}(s/b)$ from all contributing channels from CDF and D0 for $m_H = 165$ GeV$/c^2$.

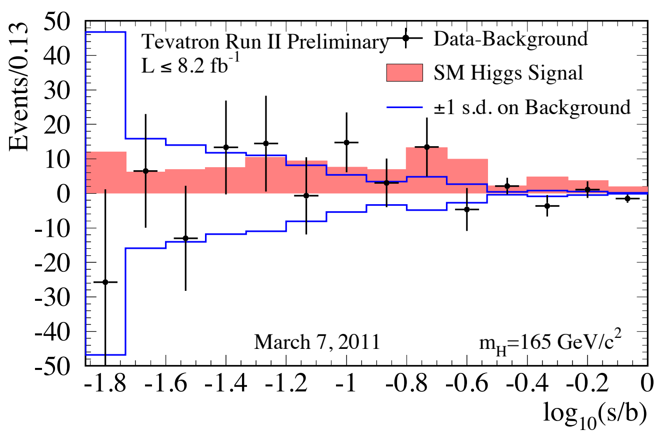

Figure 2: Background subtracted data distribution for discriminant histograms from all contributing channels from CDF and D0, for $m_H = 165$ GeV$/c^2$. Expected SM Higgs contribution is overlaid.

4 Results

Using the techniques outlined in Section 3, we combine SM Higgs boson searches from CDF and D0 in the mass range of $130 < m_H < 200$ GeV$/c^2$. We have decided, *a priori*, to quote results obtained from the Bayesian approach. Complete limits from both techniques can be found elsewhere [2]. Figure 3 shows the ratio of 95% CL expected and observed limits to the SM cross-section times branching ratio expected at the Tevatron after combining CDF and D0 results. We exclude at the 95% CL, the region $158 < m_H < 173$ GeV$/c^2$ with the expected exclusion being $153 < m_H < 179$ GeV$/c^2$. Observed exclusion at other confidence levels are shown in Figure 4, showing the Tevatron excluding SM Higgs production at 99.5% CL around $m_H = 165$ GeV$/c^2$.

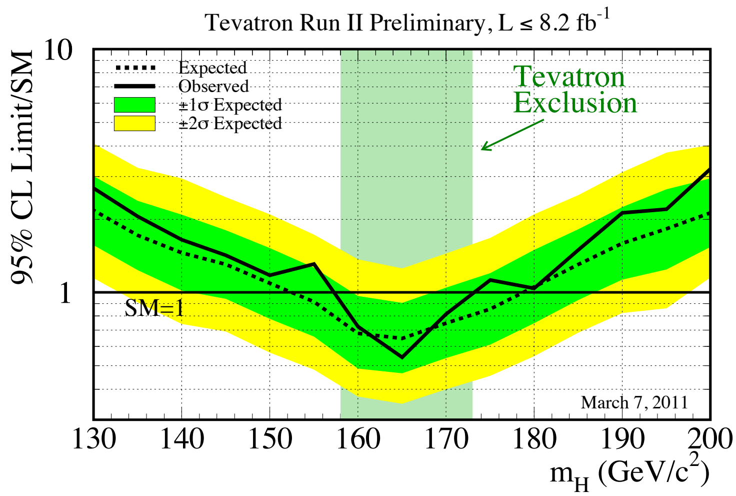

Figure 3: Observed and expected 95% CL upper limits on the ratios to the SM cross section, as a function of m_H. The 68% and 95% probability regions where the limit can fluctuate, in the absence of signal, are indicated by the green and yellow bands, respectively. The region excluded by Tevatron data is shown.

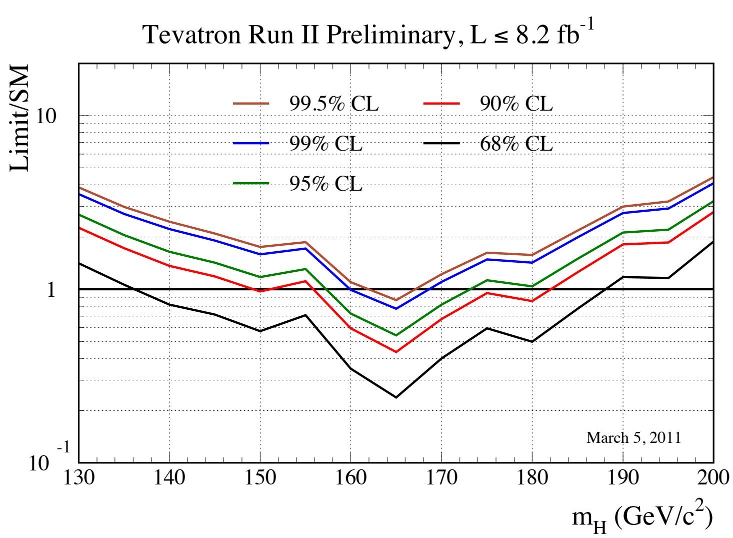

Figure 4: Observed limits on the ratio to the SM Higgs boson cross section at 68%, 90%, 95%, 99% and 99.5% CL.

5 Conclusions

We present the most recent combination of SM Higgs searches from the CDF and D0 experiments in the region $130 < m_H < 200$ GeV/c^2. In up to 8.2 fb^{-1} of data, the Tevatron has excluded the SM Higgs in the region $158 < m_H < 173$ GeV/c^2 at 95% CL. Additionally, the combined Tevatron SM Higgs searches in the mass range including $100 < m_H < 130$ GeV/c^2, presented elsewhere[3], exclude the region $100 < m_H < 109$ GeV/c^2 at 95% CL. With over 10 fb^{-1} of data expected by the end of the Tevatron run in September 2011 and further analysis improvements in progress, the region excluded is expected to grow.

Acknowledgments

The author would like to thank the organizers of XLVI Recontres de Moriond for the invitation to speak at a scientifically rewarding and well-organized conference. The author would also like to thank the dedicated teams at the CDF and D0 collaborations for the results presented, as well as the many funding agencies worldwide that make the Tevatron research program possible.

References

1. Totaro, P. "Search for Low Mass Higgs Boson at the Tevatron," this proceeding.
   Petridis, K. "High mass SM Higgs," this proceeding.
2. The CDF and D0 Collaborations and the TEVNPHWG Working Group, arXiv:1103.3233 [hep-ex] (2011)
3. The CDF and D0 Collaborations and the TEVNPHWG Working Group, arXiv:1007.4587 [hep-ex] (2010)