W/Z+HEAVY FLAVOR PRODUCTION AND THE STANDARD MODEL HIGGS SEARCHES AT THE TEVATRON

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Searches for the Standard Model Higgs in WH and $H \to WW$ channels by CDF and DØ collaborations are presented. The preliminary results are based on $< 180\text{pb}^{-1}$ of data analyzed by each experiment. Important backgrounds to Higgs searches, such as heavy flavor production in association with massive vector bosons (W and Z) are studied in the process.

1 Introduction

Many years of experimental results have shown remarkable consistency with the Standard Model (SM). According to the SM, electromagnetic interaction and weak interaction are manifestations of a hidden symmetry ($SU(2)_L \times U(1)_Y$) which is broken. The electroweak symmetry breaking is achieved through the Higgs mechanism, where the Higgs boson allows for the massive gauge bosons which are responsible for mediating the weak interaction. It can also explain the masses of charged leptons and quarks through Yukawa coupling. Higgs boson plays an essential role in the SM.

Current mass limit on the Higgs from direct searches is $m_H > 114$ GeV at 95% confidence level (C.L.) [1]. Global fit to precision electroweak observables places an upper limit of $m_H < 260$ GeV at 95% C.L. Until LHC begins collisions, Fermilab Tevatron is the only accelerator capable of probing that mass range.

1.1 SM Higgs Production at the Tevatron

At the Fermilab Tevatron, there are a few accessible production modes of the SM Higgs[2] (Fig. 1). Gluon fusion mode ($gg \to H$) via a top quark loop is accessible for $m_H > 135$ GeV, where it is expected to decay dominantly into WW and background is manageable. For $m_H < 135$ GeV, associated vector boson production modes (WH and ZH) are useful because charged lepton from vector boson decay together with $H \to b\bar{b}$ provide a handle against backgrounds.

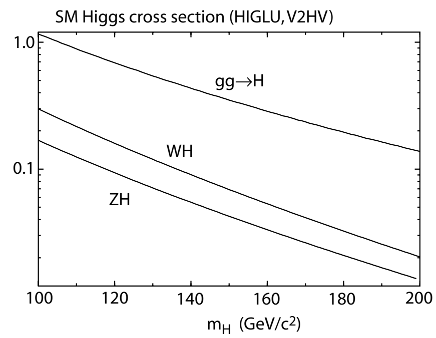

Figure 1. Higgs production cross sections at the Tevatron.

2 W + heavy flavor production and search for the SM Higgs in WH channel

2.1 $W + b\bar{b}$ and WH searches at DØ

$W + b\bar{b}$ is an important background to the Higgs production in WH channel, therefore it is interesting to search for it and study it in detail. DØ searched for $W + b\bar{b}$ in 175pb^{-1} of data collected by requiring a high transverse momentum (p_T) electron at the trigger level. $W \to e\nu$ sample is selected by requiring an isolated electron $p_T > 20$ GeV in pseudo-rapidity of $|\eta| < 1.1$ and missing transverse energy $\not{E}_T > 25$ GeV. Events with any additional leptons are rejected to reduce the Z background. After requiring W and two hadronic jets with $p_T > 20$ GeV and in $|\eta| < 2.5$, 2567 events remain in the data. 2670 ± 838 events are expected from $W(\rightarrow e\nu) + jj$, $Z \rightarrow ee$, $Z \rightarrow \tau\tau$, inclusive $W \rightarrow \tau\nu$, $t\bar{t}$. $W + jj$ is simulated using ALPGEN leading-order (LO) event generator, where partons are passed through PYTHIA showering with full detector simulation. Next-to-leading (NLO) production cross sections are used for background processes. Instrumental background due to fake electrons is estimated from the data.

A b-tagging algorithm is used to identify the jets originating from b-quarks. Jet lifetime impact-parameter (JLIP) tagging algorithm which makes use of the distribution of impact parameters of the charged tracks associated to a jet in order to calculate the probability of the jet to be consistent with a jet without significantly displaced tracks. After requiring that there be two jets tagged with the JLIP algorithm, 5 events remain. This is in good agreement with 6.9 ± 1.8 total events expected, out of which 3.8 events are expected to come from $t\bar{t}$ and single top productions. In order to reject $t\bar{t}$ backgrounds, exactly 2 jets are required to be present in the event. Two events remain after this requirement whereas 2.5 ± 0.5 events are expected. 1.4 events are expected to be from $W + b\bar{b}$. Since no significant excess is observed above the other backgrounds, $W + b\bar{b}$ production cross section upper limit is set at 20.3 pb at 95% C.L.

The result above can be translated into an upper limit on $\sigma(WH) \times BR(H \rightarrow b\bar{b})$. A simple counting experiment is performed. For a Higgs boson of $m_H = 115$ GeV, we measure approximately 14% relative mass resolution from Monte Carlo simulation. The mass window in which counting experiment is done is 1.5 times the mass resolution on either side. 0 event is observed in the window and the preliminary upper limit is $\sigma(WH) \times BR(H \rightarrow b\bar{b}) < 12.4$ pb at 95% C.L.

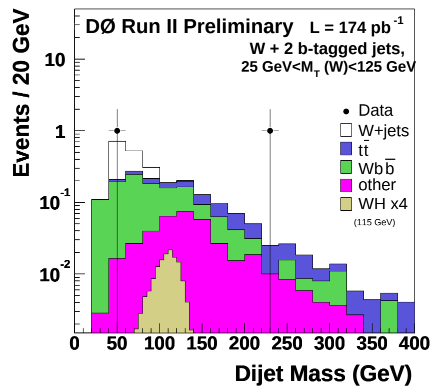

Figure 2. Dijet mass spectrum of b-tagged jets from DØ.

2.2 *Higgs Search in WH at CDF*

CDF searched for the Higgs in 162 pb^{-1} of data combining both the electron and muon decay channels of the W. To select $W+2$ jets events, either an electron or muon of $p_T > 20$ GeV in the central rapidity region, $\not{E}_T > 20$ GeV, and two jets of $E_T > 15$ GeV are required. Events with additional high p_T tracks are removed to reduce the Z background. In order to reduce the backgrounds from $t\bar{t}$, sophisticated cuts are applied to the third and the fourth leading E_T jets.

A secondary vertex b-tagging algorithm is applied to the exclusive $W + 2$ jets events, requiring at least a single b-tag. 62 events are observed and 67 ± 9 events are expected. Approximately 32.4 events are expected from $W + b\bar{b}$, $W + c\bar{c}$, and $W + c$. $W + j$ mis-tags contribute 14.1 events. $t\bar{t}$ and single top backgrounds are small (8.9 events) due to optimized cuts on the jets.

The performance of the b-tagging used in the analysis has lower efficiency but a much smaller mis-tag rate compared to DØ b-tagging algorithm. Good signal significance is obtained by requiring that at least one jet be tagged. It is a good complementary method to the double tagged analysis by DØ.

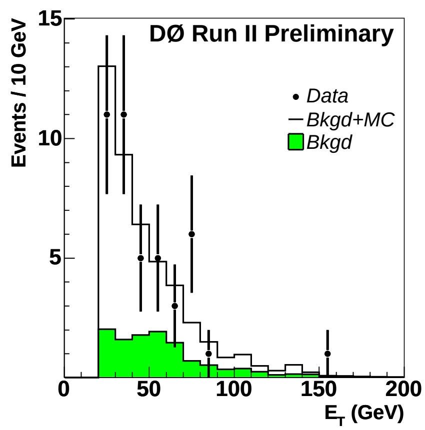

Figure 3. Jet E_T distribution of b-tagged jets in $Z+b-jet$ events. The background shown in green is from mis-tagged light-jets and instrumental backgrounds.

The signal acceptance is moderately flat between $110 < m_H < 150$ GeV at $1.5 \sim 1.7\%$ in this analysis. In lack of any excess of events, a preliminary limit on $\sigma(WH) \times BR(H \to b\bar{b})$ is set as a function of the m_H (Fig. 5).

3 $Z+b$ inclusive production

Inclusive production of $Z+b$-jet is a background to the Higgs search in ZH mode where $H \to b\bar{b}$. It is also a probe of b-quark parton distribution function in the five-flavor scheme[3].

DØ looked for an evidence of heavy flavor production in association with the Z boson. In particular, a ratio inclusive production cross-sections $\sigma(Z+b\text{–jet})/\sigma(Z+\text{jet})$ is measured using 180pb^{-1} of data. Samples triggered with single lepton and dilepton triggers are used. In the ratio measurement, trigger efficiencies and luminosity uncertainties cancel identically. To first order, it is not sensitive to experimental effects such as jet energy scale, jet energy resolution, and jet reconstruction efficiency. However, it is sensitive to any differences between light-jet and b-jet responses in the detector.

3458 events remain after $Z+jet$ events are selected by requiring the presence of two high $p_T > 15$ GeV electrons or muons, dilepton invariant mass consistent with that of Z, and at least one hadronic jet of $p_T > 20$ GeV and $|\eta| < 2.5$.

42 events remain after applying secondary vertex tag with 8.3 events expected to come from instrumental background which is estimated from the data. Events left after background subtraction is a combination of $Z+b$ (N_b) and mis-tagged events from $Z+c$ (N_c) and Z+light-jets (N_L). The efficiencies for tagging b-jets(ϵ_b) and light-jets (ϵ_L) are measured from the data. Tagging efficiency of c-jets (ϵ_c) is measured in simulated events and scaled by $(\epsilon_b)_{Data}/(\epsilon_b)_{MC}$. Two equations relating the number of events before b-tagging and after b-tagging with N_b, N_c, and N_L together with the ϵ's can be written. To solve the system of equations, we assume from theory the ratio of $N_c/N_b = 1.69$.

The preliminary result is $\sigma(Z+b\text{–jet})/\sigma(Z+\text{jet}) = N_b/(N_b + N_c + N_L) = 0.024 \pm 0.005(stat) \pm 0.005(syst)$, where the dominant sources of systematic uncertainties are b-tagging efficiency and background estimation. The measurement is in agreement with the NLO theory prediction of 0.018 ± 0.004.

4 Search for $H \to WW$

Both CDF and DØ presented the measurements of WW production cross section at this conference, which are in good agreement with the Standard Model prediction. The Standard Model WW production is one of the major irreducible backgrounds in the search for Higgs in the $H \to WW$ channel. Some separation between the WW SM production of WW and $H \to WW$ can be attained by the fact that H is a spin 0 object, hence, the W's will have spins relatively oppositely-aligned. The charged leptons from the $W \to \ell\nu$ in $H \to WW$ will have a smaller azimuthal opening angle ($\Delta\Phi_{\ell\ell}$) compared to the WW

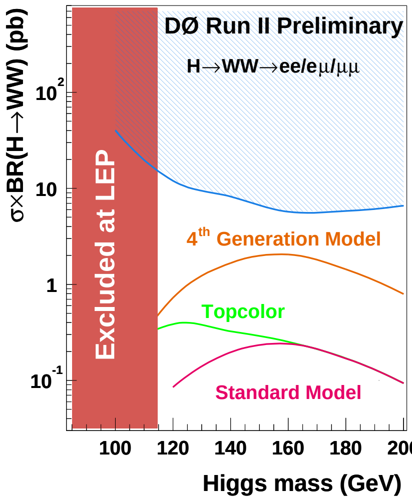

Figure 4. DØ results on $\sigma \times Br(H \to WW)$.

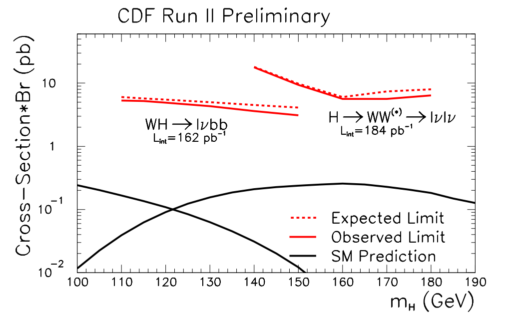

Figure 5. Summary plot of CDF results on the SM Higgs searches.

production.

4.1 DØ

DØ analyzed $147 \sim 177\text{pb}^{-1}$ of data by requiring 2 oppositely charged leptons (e or μ), large $\not{E}_T$ for the presence of a neutrino in the event, cut on dilepton mass or minimal transverse mass, scalar sum of lepton p_T and missing E_T. Finally, events with jets are rejected. The selection is designed to optimize on signal significance (for each m_H) by rejecting background from Z, $W + jets$, and $t\bar{t}$. Finally, counting experiment is performed in the region of small $\Delta\Phi_{\ell\ell}$. No significance excess above the background is observed and the upper limit on $\sigma \times Br(H \to WW)$ as a function of the m_H is set (Fig. 4).

4.2 CDF

Event selection of the CDF analysis is similar to that of DØ. The cut on dilepton mass is $M_{\ell\ell} < m_H/2$. Limit on $\sigma \times Br(H \to WW)$ as a function of m_H is extracted by performing likelihood fits to the observed $\Delta\Phi_{\ell\ell}$ distribution, and it is shown in Fig. 5.

5 Summary and Outlook

Both CDF and DØ experiments have started to search for the SM Higgs boson. Studies of rare but irreducible SM backgrounds are also underway. The results presented does not make use of any advanced analysis techniques. Use of multivariate methods is expected to improve the sensitivity. With approximately 2fb^{-1} of luminosity, Fermilab Tevatron is expected to probe the range of m_H excluded by the LEP 2 experiments. With the projected integrated luminosities of $4 \sim 8\text{fb}^{-1}$ to be delivered to each experiment by 2009, exciting period lies ahead of us in the quest for the Higgs.

References

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