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HIGGS SEARCHES AT TEVATRON

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We report on the most recent higgs searches by CDF and DØ collaboration in RunII Tevatron $p\bar{p}$ collisions at $\sqrt{s}$=1.96TeV. This searches used around 200 pb^{-1} and no Higgs signal has been observed. Limits on Standard Model Higgs and on Higgs beyond the Standard Model has been established.

1 Introduction

The Higgs boson has a central place in the SM and its discovery would allow further insights in the electroweak symmetry breaking mechanism. The hints seen at LEP [1] and the electroweak fit predictions favor a relatively light SM Higgs and the upper limit set by LEP underlines the importance of Higgs search at the Tevatron as part of the RunII physics program of the CDF and DØ experiments [2]. For Higgs bosons with masses below 140 GeV, the main production channel is WH, with $H \to b\bar{b}$ with $Wb\bar{b}$ being the main background. The second most important production channel of a light SM Higgs is ZH, where $H \to b\bar{b}$. Inclusive $Z + b$ production accounts for the most important background to Standard Model Higgs and to Supersymmetric Higgs production ($gb \to hb$). Moreover, it probes the parton distribution function (PDF) of the b quark, because the initial state involves a b coming from the sea. For Higgs masses higher than 140 GeV, the Higgs is produced directly, with $H \to WW^*$. The main background of this channel is the direct production of WW.

Beyond the SM, in two-Higgs doublet models of Electro-Weak Symmetry Breaking, as for example in the Minimal Supersymmetric extension of the SM (MSSM), there are five physical Higgs states: two neutral CP-even scalars, h and H (with $m_H \geq m_h$), a neutral CP-odd scalar, A, and two charged states H$^{\pm}$. The neutral Higgs bosons are expected to decay about 90% of the time to a pair of bottom quarks [3].

In the SM, Higgs boson decays mostly to b quark, W or Z boson pairs depending on the mass range, while its $\gamma\gamma$ decay branching ratio is too small (10^{-3}– 10^{-4}) to be visible at the Tevatron. However many extensions of the SM allow an enhanced $\gamma\gamma$ decay rate of the Higgs largely due to suppressed couplings to fermions [4]. The two scenarios studied involved Fermiophobic Higgs and Topcolor Higgs.

Doubly-charged Higgs bosons appear in theories beyond the Standard Model, in particular, in left-right symmetric models, in Higgs triplet models and in Little-Higgs models [5]. The models predict dominant decay modes to like sign lepton pairs, $H^{\pm\pm} \to l^{\pm}l^{\pm}$. Pairs of doubly-charged Higgs bosons can be produced through the Drell-Yan process $q\bar{q} \to \gamma^*/Z \to H^{++}H^{--}$.

The crucial point for the searches of $H \to b\bar{b}$ is the identification of jets coming from a b quark. CDF and DØ have developped differents algorithms to tag b-jet. They used secondary vertices or impact parameter and their performance are similar between the two experiments: 50% of efficiency of b tagging for central jets with about 0.6% of mistagging.

2 $WH \to Wb\bar{b}$

DØ has studied $Wb\bar{b}$ production which is the main background to WH production. This study has been performed in the electron channel on a sample with an integrated luminosity of 174 pb^{-1}. The final state of $Wb\bar{b} \to e\nu b\bar{b}$ is requiring an electron, large amount of missing energy and two b-tagged jets. The event selection is based on a central isolated electron with $E_T > 20$ GeV, at least 25 GeV of missing transverse energy and at least two jets with $E_T > 20$ GeV. b-jets are identified using an algorithm based on the tracks having large impact parameter. In order to reduce the background from multijets and $t\bar{t}$ dileptons events, events with a W transverse mass lower than 25 GeV or greater than 125 GeV are rejected. 5 events are observed to be compared to 6.9 ± 1.8 events expected from the sum of simulated processes: $W/Z + jets$ with mistagged b-jets, multijets events with one of the jet misidentified as an electron, top pair production, $Wb\bar{b}$ production and single top production. No excess is observed, an upper limit on the $Wb\bar{b}$ production cross-section is set at 20.3 pb with a 95% confidence level. In the case of WH production, the main remaining background is top pair production. This background is reduced when requiring for exactly two jets in the event. Two events are observed to be compared to 2.5 ± 0.5 events expected. The dijet invariant mass spectra of these candidates is shown on figure 1a). Also shown is the contribution expected for a SM Higgs of 115 GeV. In a mass window of 85-135 GeV, no data event is observed, 0.54 ± 0.14 background events and 0.03 ± 0.01 WH events are expected. An upper limit on production $\sigma(WH) \times BR(H \to b\bar{b})$ of 12.4 pb is established for an Higgs mass of 115 GeV at a 95% confidence level.

CDF has performed the search of Higgs boson in the channel $WH \to Wb\bar{b}$ where W is decaying in the electron or muon channel. For this analysis a data sample with an integrated luminosity of 162 pb^{-1} has been used. The selection is based on one central, isolated electron or muon with $E_T > 20$ GeV, at least 20 GeV of missing transverse energy and exactly two jets with $E_T > 15$ GeV. Events with two or more leptons are rejected. In order to enrich the content of events with a b-jet, at least one jet must be tagged by a secondary vertices algorithm. 62 events are observed to be compared to 61 ± 5 events expected from the simulation: $W + jets$ with a mistagged b-jet, multijets events with lepton's misidentification, $Wc\bar{c}$ production, top production and diboson production. With this selection, 0.3 events for WH production are expected. For mass points between 110 GeV and 130 GeV, upper limits on production $\sigma(WH) \times BR(H \to b\bar{b})$ of approximately 5 pb are set and are shown on figure 1b). This result is improving the published Run I CDF result: for mass points between 70 GeV and 120 GeV, uppers limits on cross-section production $\sigma(WH) \times BR(H \to b\bar{b})$ are between 14 and 19 pb [6].

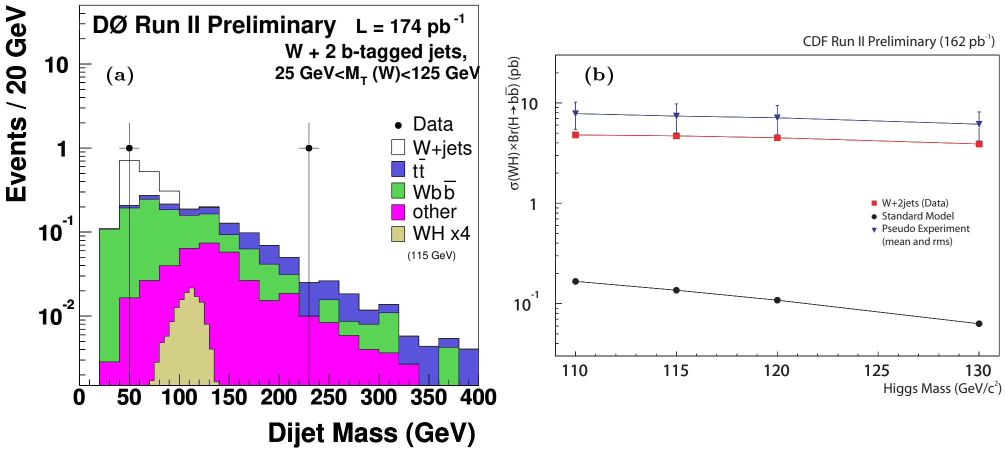

Figure 1. a) Dijet invariant mass in WH analysis, the two jets are b-tagged jets. Also shown is the contribution expected for a SM Higgs of 115 GeV; b) Upper limits on $\sigma(H) \times BR(H \to b\bar{b})$ as a function of SM Higgs mass have been established at the 95% confidence level.

3 Zb Production

For a SM light Higgs, the channel $ZH \to Zb\bar{b}$ is the second most sensitive channel. The understanding of the PDF of b quark is essential. In this context, a study of $Z + b$ production has been made by DØ. The aim is to measure the ratio $\frac{\sigma(Z+b)}{\sigma(Z+j)}$. The event selection is using the leptonical decay of the Z boson in electrons or muons. A data sample with an integrated luminosity of 184pb^{-1} is used in the electron channel and 152pb^{-1} for the muon channel. The selection requires two isolated leptons (two electrons or two muons) with $E_T > 15(20)$ GeV for electrons (muons), at least one jet with $E_T > 20$ GeV and at least one jet tagged as a b-jet. This selection gives a measure of the ratio $\frac{\sigma(Z+b)}{\sigma(Z+j)}$ of 0.024 ± 0.005 (statistics) $^{+0.005}_{-0.004}$ (systematics). The theoretical calculation predicts a ratio of 0.02 [7] which is compatible with the measurement.

4 $H \to WW^*$

In case of a SM Higgs mass greater than 140 GeV, the dominant production channel is $gg \to H \to WW^*$. The direct search of Higgs production is made using the leptonical decay of the W boson, $WW^* \to l\nu l\nu$ where l is an electron or a muon. This analysis uses a data sample with an integrated luminosity of 150pb^{-1} in the $\mu\mu$ final state, 160pb^{-1} in the $e\mu$ final state and 180pb^{-1} in the ee final state recorded by DØ. The event selection depends on the channel studied and require two isolated leptons with opposite charge: for the ee channel, the electrons must have $E_T > 12$

GeV and $E_T > 8$ GeV. For the $e\mu$ channel, the electron is required to have $E_T > 12$ GeV and the muon to have $E_T > 8$ GeV. For the $\mu\mu$ channel, the muon must have $E_T > 20$ GeV and $E_T > 10$ GeV. The selection requires 20(30) GeV of missing transverse energy for $ee, e\mu$ ($\mu\mu$) channels to account for the neutrinos. The events are rejected if the invariant mass of the two leptons is around the Z peak and if energetic jets are present in the event.

The major background is WW direct production. This background is reduced using spin correlation: the Higgs boson has a spin 0 therefore the two leptons coming from the Higgs decay tend to be collinear. $\Delta\phi_{ll}$ between the two leptons is required to be less than 1.5 radians for the ee channel and 2.0 radians for the $e\mu$ and the $\mu\mu$ channel.

With this selection no excess in the number of events is observed. Upper limits on $\sigma(H) \times BR(H \rightarrow WW^*)$ have been established at the 95% confidence level for mass points between 100 GeV up to 200 GeV as shown on figure 2. For masses between 140 GeV and 180 GeV, the upper limits set are between 6.7pb and 8.2pb.

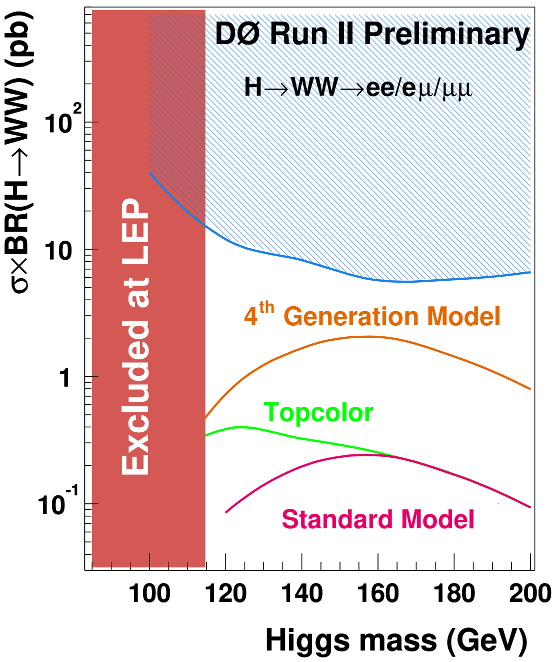

Figure 2. Upper limits on $\sigma(H) \times BR(H \rightarrow WW^*)$ as a function of SM Higgs mass have been established at the 95% confidence level.

5 Neutral Higgs boson at high tanβ

A search for the production of neutral Higgs bosons in the context of the MSSM at high tanβ has been made using around 130pb^{-1} of DØ Run II data. The analysis searches a Higgs produced in association with $b\bar{b}$ pairs and decaying into $b\bar{b}$. The final state is made of 4 b-jets. The event selection is based on events containing at least 3 jets with $E_T > 20$ GeV for the leading jet and $E_T > 15$ GeV for the two remaining jets. In these events at least 3 jets must be b-tagged. The signal is searched using the invariant mass of the two leading b-tagged jets. No excess has be observed and upper limits at 95% confidence level have been set in the tan$\beta \times m_A$ plane. For m_A= 100 GeV, tan$\beta > 97$ and for m_A= 150 GeV, tan$\beta > 140$ are excluded.

6 Non Standard Model $H \to \gamma\gamma$

The search of SM Higgs decaying in $\gamma\gamma$ channel is not possible at the Tevatron due to the very small branching ratio in this channel. However in some extensions of SM (Fermiophobic higgs or Topcolor Higgs), Higgs boson has very large branching ratio $BR(H \to \gamma\gamma)$. The data analysed correspond to an integrated luminosity of 190pb^{-1} recorded by the DØ detector. The selection is based on the presence of two isolated photons with $E_T > 25$ GeV. Moreover, the transverse momentum of the system of the two photons must be greater than 35 GeV. No excess is observed and by performing a counting experiment on optimized sliding mass window, limits on $BR(H \to \gamma\gamma)$ as a function of Higgs mass are established as shown in figure 3a).

7 $H^{\pm\pm}$ Searches

A doubled charged Higgs boson exists in some triplet Higgs model such as the Left-Right symmetric model. Such Higgs bosons will be searched with a signature of two same sign leptons. The data analyzed correspond to an integrated luminosity of 240 pb^{-1} recorded by the CDF detector. The event selection is based on same sign leptons (electrons or/and muons) with an invariant mass around 10% of the predicted Higgs mass. This channel has a low SM background and is providing a clean environnement for SUSY searches. Different Higgs mass points have been studied and no excess has been found. Exclusion of mass values at 95% confidence level has been established depending on decay channel as shown is figure 3b). In case of double charged Higgs Left handed, masses below 135 GeV are excluded in the channel ee and $\mu\mu$ and masses below 115 GeV are excluded in $e\mu$ channel.

8 Conclusion

CDF and DØ have shown their first results from Run II on Higgs searches. In case of the SM Higgs, the main channels have been studied, no excess is found and limits are set. For Higgs beyond SM, SUSY, Fermiophobic and triplet Higgs models have been considered. The limits established from the Run II data aready improve the Run I results.

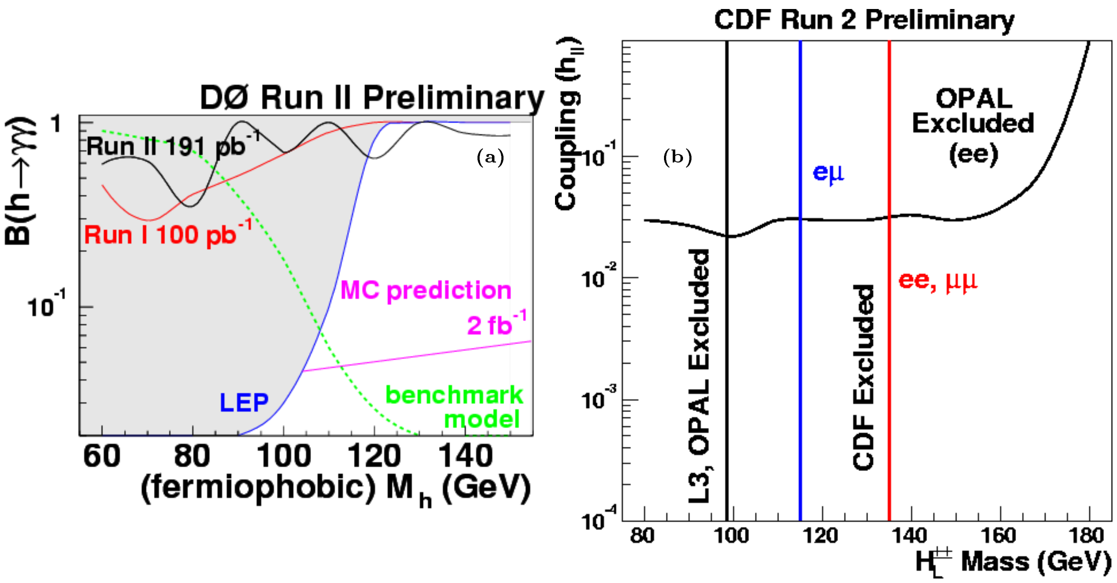

Figure 3. a) Limits at the 95% confidence level on $BR(H \rightarrow \gamma\gamma)$ as a function of Higgs mass are established in the Fermiophobic model. b) Exclusion of double charged Higgs mass values at 95% confidence level has been established.

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