Searches for non Standard Model Higgs bosons at the Tevatron

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Abstract. Recent preliminary results obtained by the CDF and DØ Collaborations on searches for Higgs bosons beyond the Standard Model at Run II of the Tevatron are discussed. The data, corresponding to integrated luminosities of up to 1 fb^{-1}, are compared to theoretical expectations. No significant excess of signal above the expected background is observed in any of the various final states examined, and so limits at 95% Confidence Level (C.L.) are presented.

1. Introduction

The search for Higgs bosons 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.

Higgs boson production cross sections in the Standard Model (SM) are small at the Tevatron. However some models beyond the SM predict larger Higgs cross sections and cleaner search channels, some within reach with the present data set. The Minimal Supersymmetric extension of the SM (MSSM)[1] contains five physical Higgs bosons. Two of them are CP-even scalars, h and H, of which h is the lighter and SM like. The other three consist of a charged Higgs pair, $H^{\pm}$, and a CP-odd scalar, A, the mass of which is one of two free parameters of the model at tree level. The production cross section of the Higgs in the MSSM is proportional to the square of the second free parameter of the model, tanβ, the ratio of the vacuum expectation values of the Higgs doublets, ν_u and ν_d. A large value of tanβ could hence result in significantly increased Higgs cross sections compared to the SM. Moreover, at the large tan β limit one of the CP-even scalars and the CP-odd scalar are degenerate in mass, leading to a further enhanced cross section compared to the SM. Searches for $h/H/A$ in final states with τ leptons or two b-quarks are therefore well motivated by this model, even at present luminosities.

Other possible extensions to the SM such as Top-color[2] or Fermiophobic[3] Higgs models, could lead to enhanced decays of Higgs $\rightarrow \gamma\gamma$, which is negligible in the SM. There are consequently a number of Higgs searches already being actively pursued with the first fb^{-1} of data collected during Run II.

2. Limits on neutral SUSY Higgs at high tanβ

The main production mechanism for neutral Higgs bosons in the MSSM would be through diagrams like $gg, b\bar{b} \rightarrow \phi$ and $gg, q\bar{q} \rightarrow \phi + b\bar{b}$, where $\phi = h, H, A$. The branching ratio of $\phi \rightarrow b\bar{b}$ is around 90% and $\phi \rightarrow \tau^+\tau^-$ is around 10%. The overall experimental sensitivity is however similar for the two channels, due to lower background in the τ channel.

2.1. Higgs $\to \tau^+\tau^-$

The main background sources in this channel are $Z \to \tau^+\tau^-$ (irreducible), $W+$ jets, $Z \to \mu^+\mu^-/e^+e^-$ with multi-jet and di-boson events also contributing. DØ has performed a search in the channel where one of the τ leptons decays to a μ. The event selection requires only one isolated muon, separated from the hadronic τ with opposite sign. The τ identification is performed with a neural network. A 25 GeV cut on M_W, the reconstructed W boson mass, removes most of the remaining W background. The final separation of signal from background is achieved with a set of neural networks, optimized for different Higgs masses and trained on the visible mass, m_{vis}, and τ and μ kinematics. The data are found to be in good agreement with the background only expectation. Figure 1 shows the resulting 95 % C.L. exclusion in the MSSM parameter space.

CDF has performed a similar search, including channels where one τ lepton decays to an electron. The event selection includes an isolated electron/muon, τ identification with a variable cone-size algorithm and jet background suppression with a cut on $|p_T^l| + |p_T^{had} + |E_T^{miss}| > 55$ GeV. Most of the W background is removed by cuts on the relative directions of the visible τ decay products and the missing E_T. Limits on cross section times branching ratio and exclusion regions in the MSSM parameter space are derived from the m_{vis} distribution. Figure 2 shows the exclusion in the $\tan\beta - m_A$ plane. Due to a small excess in the region of 130 GeV $< m_{vis} <$ 160 GeV, the limits are weaker than expected. However, when all channels and windows are considered the significance of the observed excess is found to be less than two standard deviations.

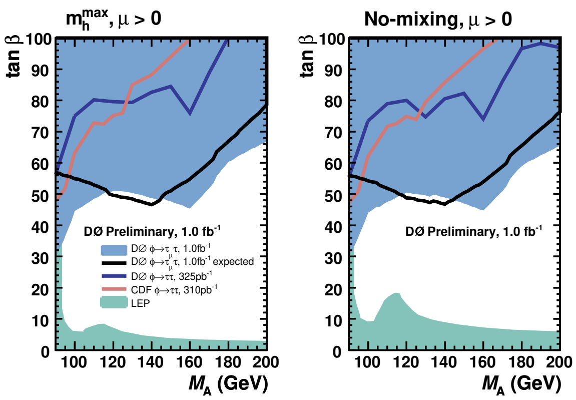

Figure 1. Excluded region in the $\tan\beta - m_A$ plane from DØ for a positive mass parameter μ in a) the m_h^{max} scenario and b) the no-mixing scenario. These two scenarios are defined by the MSSM parameters at the top of figure 2. Also shown is the LEP limit[4] and the previous CDF[5] and DØ [6] results for $\phi \to \tau\tau$.

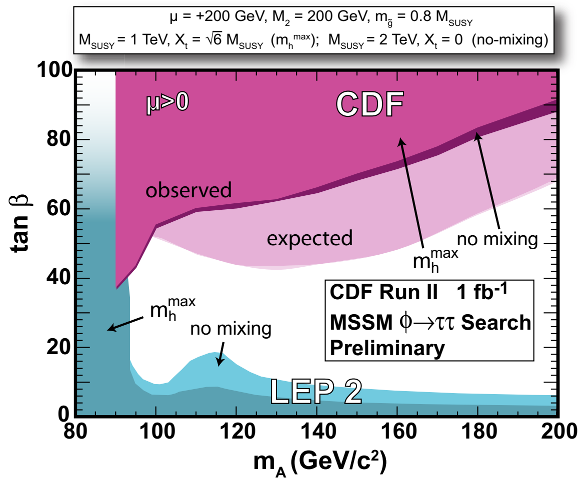

Figure 2. Excluded region in the $\tan\beta - m_A$ plane from CDF in the m_h^{max} and no-mixing scenarios for $\mu > 0$.

2.2. Higgs $+b \to b\bar{b}b$

A multi-jet event sample collected by DØ corresponding to an integrated luminosity of 0.9 fb^{-1} is used in this search. Candidate events are required to contain at least three jets with $p_T > 15$ GeV, the leading jet must further be above 40 GeV and the second jet above 25 GeV. It is further required that at least three jets are identified as b-jets by a neural network b-tagging algorithm. A signal is then looked for in the invariant mass spectrum of the two leading b-tagged jets. The simulation of signal and background is performed with PYTHIA[7] or ALPGEN[8] interfaced with PYTHIA and passed through the detailed detector simulation program. The dominant background is multi-jet production and is estimated from the data outside the signal search region. The signal acceptance is found to be 1.7-2.6% depending on the Higgs mass. No indication of a signal was detected and instead preliminary exclusion limits at 95% C.L. were calculated. Cross sections down to 20 pb are excluded for Higgs masses upto 170 GeV.

3. Limits on non-SM Higgs $\rightarrow \gamma\gamma$

The decay of Higgs to photons is negligible in the SM, but some extensions predict a large $h \rightarrow \gamma\gamma$ branching ratio. A fermiophobic Higgs does not couple to fermions at all and a Top-color Higgs has zero coupling to all fermions except the top quark. Such models would hence result in an enhanced rate of Higgs bosons decaying to photons.

DØ has searched for Higgs bosons in $3\gamma + X$ final states in data corresponding to an integrated luminosity of 0.83 fb^{-1}. The event selection includes three isolated photons with $E_T > 15$ GeV within $|\eta| < 1.1$ (Central Calorimeter). The combined transverse momentum of the three photons is further required to be larger than 25 GeV. 0 events are selected with a total expected background of 1.1 ± 0.2 events. The background is dominated by direct triple photon production with a small contribution of QCD and $Z/W + X$. There is no evidence of an excess in this search and hence excluded fermiophobic Higgs masses at 95 % C.L. are calculated with Bayesian statistics. This search excludes a fermiophobic Higgs below 80 GeV for a charged Higgs mass below 100 GeV and tan$\beta = 30$.

4. Conclusions

The preliminary results presented at this conference by the CDF and DØ collaborations, together with the recent performance of the experiments and the Tevatron, are very encouraging for the Higgs searches at Run II. The 1 fb^{-1} searches for Higgs bosons beyond the SM, in the MSSM scenario and other extensions, show very promising sensitivity and have already produced new powerful limits on $h/H/A \rightarrow \tau\tau/b\bar{b}$ and $h \rightarrow \gamma\gamma$.

Having successfully accomplished the analysis of the first fb^{-1} of Run II data, we are confidently looking forward to exploring the almost 3 fb^{-1} of data per experiment which has already been written to tape. New MSSM results can be expected shortly from both experiments and the focus is also on combining the results from the different channels of both experiments to gain maximum sensitivity.

Acknowledgments

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