Fermi National Accelerator Laboratory

FERMILAB-Conf-99/263-E
CDF

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October 1999

Published Proceedings of the *International Europhysics Conference on High-Energy Physics (EOS-HEP 99)*, Tampere, Finland, July 15-21, 1999

Operated by Universities Research Association Inc. under Contract No. DE-AC02-76CH03000 with the United States Department of Energy

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Higgs Searches at the Tevatron in Run I

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Abstract

This paper summarizes recent Higgs searches in $p\bar{p}$ collisions at $\sqrt{s} = 1.8$ TeV from the Tevatron using Run I data. Emphasis is given to a new result from the CDF collaboration in searching for neutral minimal SUSY Higgs bosons through the four jet reaction $p\bar{p} \to b\bar{b}\varphi \to b\bar{b}b\bar{b}$. Both the CDF and D$\emptyset$ experiments have also searched for standard model as well as other non-standard Higgs signatures in the mass region below ~ 140 GeV/c^2 with no evidence of new physics.

1. Introduction

One of the most important goals of present and future high energy colliders is to reveal the mechanism responsible for electroweak symmetry breaking. In the standard model (SM) the Higgs mechanism introduces spontaneous symmetry breaking by the introduction of a scalar field doublet. This leaves a single observable scalar particle, the Higgs boson, with unknown mass but fixed couplings to other particles. In the minimal supersymmetric extension of the standard model (MSSM) electroweak symmetry breaking of the Higgs sector requires a spectrum of five elementary Higgs particles: three neutral scalars (h, H, and A) and two charged Higgs bosons ($H^{\pm}$). The MSSM predictions for the Higgs boson masses have important phenomenological consequences. The lightest CP-even Higgs boson mass M_h is constrained to $M_h \lesssim 130$ GeV/c^2 while the masses of the other Higgs bosons are expected to be larger and, in some cases, degenerate.

In this paper a summary of Tevatron results on neutral Higgs searches using the Run I data sample is presented. The searches cover both the SM as well as non-standard Higgs bosons like the MSSM and other non-minimal Higgs sectors.

2. CDF MSSM Neutral Higgs Search

CDF has searched for the process $p\bar{p} \to b\bar{b}X \to b\bar{b}b\bar{b}$ with 91 pb^{-1} of Run I data. This reaction is particularly important in the MSSM where the Yukawa couplings between the Higgs scalars and the b quarks are enhanced for large $\tan\beta$ values with respect to the SM. Four-jet events with at least three of them b-tagged are required to select the event sample. In addition, a mass dependent E_T cut on the three highest-E_T reconstructed jets in the event is also imposed. Dominant background is QCD heavy flavor production with other contributions from fake triple tags, $t\bar{t}$ and W/Z+jets. Fig. 1 shows the data distributions compared with the expected SM backgrounds after the initial selection. The distributions shown correspond to the invariant mass $M_{b\bar{b}}$, the $\Delta R_{b\bar{b}} = \sqrt{\Delta\eta_{b\bar{b}} + \Delta\varphi_{b\bar{b}}}$, and the invariant masses for the two highest-E_T jets, M_{12}, and the second and third highest-E_T jets in the event, M_{23}. A cut on the b-tagged dijet angular distribution further increases the significance of the signal by eliminating the

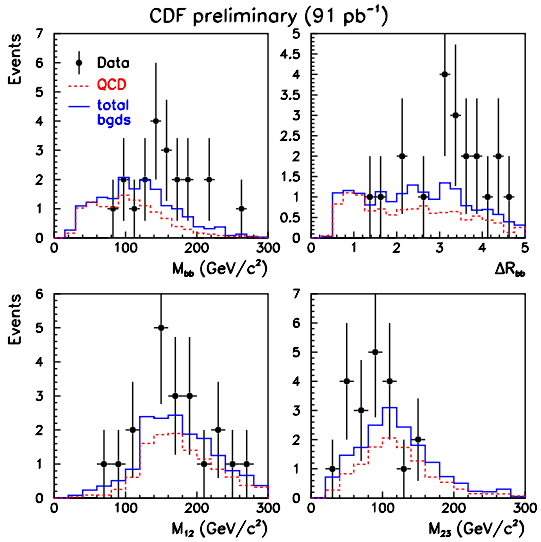

Figure 1. $M_{b\bar{b}}$, $\Delta R_{b\bar{b}}$, M_{12} and M_{23} distributions for data compared to the expected SM backgrounds.

Table 1. CDF observed (N^{obs}) and expected (N^{back}) events as a function of mass and after final requirements.

Mass (GeV/c^2)	N^{obs}	N^{back}
80	3	4.5 ± 1.4
120	2	3.5 ± 1.1
200	0	1.2 ± 0.7

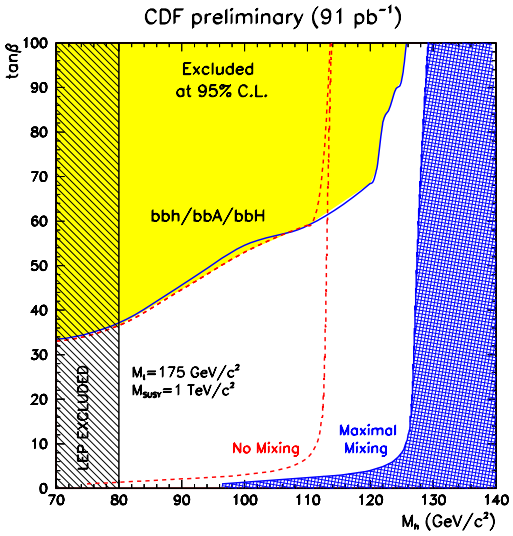

Figure 2. CDF 95% CL exclusion region in the $\tan\beta$ vs M_h plane. Shown also are the present LEP exclusion region (left) and theoretically forbidden regions (right).

gluon splitting QCD component of the sample. The observed number of data events is in agreement with the expected SM contributions. This is shown in Table 1 for three mass points. Figs 2 and 3 show the 95% CL excluded regions in the $\tan\beta$ vs M_h and M_A plane respectively. Results are shown for two stop mixing scenarios, no mixing and maximal mixing, and for a SUSY mass scale of 1 TeV.

3. SM Neutral Higgs Search

Both CDF and D$\emptyset$ have searched for the SM Higgs boson through associated production with a vector boson. The searches are restricted to the mass region below $\sim$ 140 GeV/c^2 where the $H \to b\bar{b}$ dominates. The decay mode of the vector boson dictates the final signature. CDF has published results for the signatures $WH \to l\nu b\bar{b}$ ($l = e, \mu$) and $VH \to q\bar{q}b\bar{b}$ ($V = W, Z$) [1]. More recently the channels $ZH \to \nu\bar{\nu}b\bar{b}$ and $ZH \to l^+l^-b\bar{b}$ ($l = e, \mu$) have also been investigated.

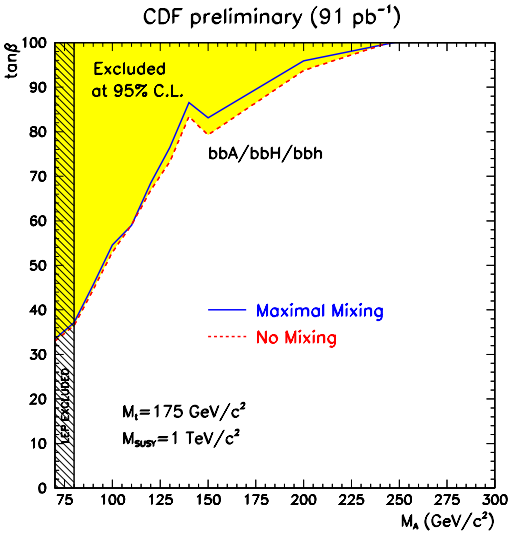

Figure 3. CDF 95% CL exclusion region in the $\tan\beta$ vs M_A plane.

The CDF search for $\nu\bar{\nu}b\bar{b}$ events requires a $\not\!\!E_T \geq 40$ GeV cut, a lepton veto and 2 or 3 jets in the event. In addition either one or two of these jets are required to be b-tagged. The main backgrounds are QCD events with $\not\!\!E_T$ from jet energy mismeasurements, W/Z + jets, $t\bar{t}$, diboson production and single top events. A total of 40 (4) events is observed with 39 ± 4 (3.9 ± 0.6) expected from the single (double) tagged sample.

For $l^+l^-b\bar{b}$ events, a high p_T lepton sample is utilized. A second isolated lepton is also required with a dilepton invariant mass consistent with the Z mass. This is a rather clean channel although the acceptance is compromised by the low Z branching ratio to l^+l^-. 5 events are observed with a total background of 3.2 ± 0.7 from diboson production, $t\bar{t}$ and Z + heavy flavors. Individual and combined 95% CL upper limits on the production cross sections for VH ($V = W, Z$) are shown in Fig. 4.

D$\emptyset$ has also searched for $WH \to l\nu b\bar{b}$ and $ZH \to \nu\bar{\nu}b\bar{b}$ events. The results have already been shown in past conferences [2] and will not be covered in this paper.

4. Higgs Di-photon Search

Both CDF and D$\emptyset$ have used the complete Run I data sample seeking for non-standard Higgs bosons, whose coupling to fermions relative to $\gamma\gamma$ is suppresed. In these "fermiophobic" models the Higgs decay to $\gamma\gamma$ is the dominant decay mode for low Higgs masses. The production of such a Higgs together with a W or Z results in a signature of two

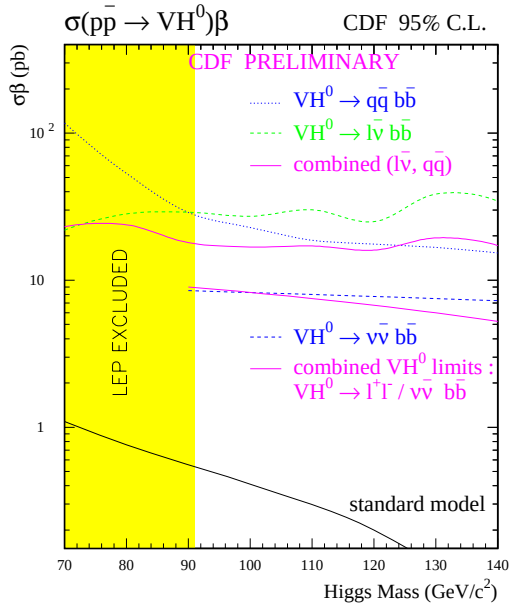

Figure 4. CDF Run I individual and combined 95% CL upper limits on $\sigma(VH)\beta(H \to b\bar{b})$ as a function of signal mass.

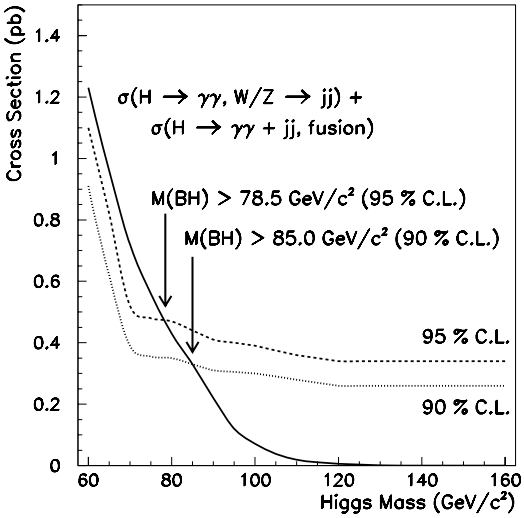

Figure 5. DØ 90% and 95% CL cross section exclusion contours as a function of the di-photon mass.

photons + leptons, $\not\!\!E_T$, or jets. The CDF diphoton sample consists of events with two isolated central ($|\eta| < 1.0$) photon candidates with $E_T > 25$ GeV. DØ uses a similar sample with slightly different thresholds. These high p_T photon samples suffer from significant backgrounds from jets misidentified as photons. These backgrounds are calculated from independent fake control samples with modified isolation requirements. CDF requires further the presence of a high p_T lepton (e, μ), or $\not\!\!E_T$, or two jets, covering all possible decay channels of the vector bosons. 6 events are left with an expected background of 6.2 ± 2.1. DØ requires only the presence of two additional jets. They find 4 candidates with an expected background of 6.0 ± 2.1 events. Fig. 5 shows the DØ 95% CL exclusion contour as a function of the diphoton mass. This corresponds to a lower limit for a bosonic Higgs mass of 78.5 GeV/c^2. CDF excludes a bosonic Higgs mass below 82 GeV/c^2 at the 95% CL.

5. Conclusions

Results from past and ongoing analyses on Higgs searches at the Tevatron have been shown. All analyses are based on the complete Run I data sample of $\sim$ 100 pb^{-1}/experiment. All searches for the SM Higgs boson are constrained to the low mass region ($\lesssim$ 140 GeV/c^2) where the $H \to b\bar{b}$ decay dominates. The present sensitivity is limited by statistics to cross sections of $\sim$ 7 pb. Assuming no signal, a simple extrapolation to Run II (2 fb^{-1}) indicates a sensitivity reach of $\sim 0.8(0.5)$ pb for a two(three)-fold increase in acceptance due to the new detectors and triggers. This would result in a mass exclusion limit at the 95% CL of up to $\sim$120 GeV/c^2. These results are in agreement with the Run II SUSY/Higgs Workshop prospects [3] also presented at this conference [4].

CDF has also for the first time shown Run I sensitivity to the neutral MSSM Higgs sector using the reaction $p\bar{p} \to b\bar{b}\varphi \to b\bar{b}b\bar{b}$. With basic parameter choices for the SUSY scale and the stop mixing, 95% CL lower mass limits are derived for the neutral Higgs bosons of the MSSM for $\tan\beta$ values in excess of 30.

References

[1] F. Abe *et al.*, Phys. Rev Lett. **79**, 3819 (1997). F. Abe *et al.*, Phys. Rev Lett. **81**, 5748 (1998). J. Valls, *MSSM and Higgs Search at the Tevatron*, Procs. of ICHEP 98, Vancouver, Canada, July 1998.

[2] *Search for Di-jet Resonances Produced in Association with W Bosons at DØ* , Procs. of ICHEP 96, Warsaw, Poland, July 1996. *Search for $ZX \to \nu\bar{\nu}b\bar{b}$ Events in the DØ Detector*, Procs. of XVIII Int. Symp. on Lep. Phot. Int., Hamburg, Germany, July 1997.

[3] Procs. of the Physics at Run II SUSY/Higgs Workshop, FNAL, in preparation.

[4] M. Roco, these proceedings.