DØ RESULTS ON HIGGS SEARCHES

Y. ENARI*

Brown University
Fermilab/D-zero, Kirk and Pine street,
Batavia, IL 60510, USA
E-mail: enari@fnal.gov

The Tevatron is currently the only accelerator which allows to explore the Higgs boson directly. In this presentation, we report on recent results of Higgs search from the DØ collaboration. We emphasize the latest result of SM Higgs search in the low mass region and the MSSM Higgs search in τ and photon channels which are based on an integrated luminosity of 1 fb^{-1}, along with summarizing previous Higgs results from the DØ collaboration.

1. Introduction

Higgs boson is expected to exist as one of the fundamental particles in the Standard Model (SM) but has not been found yet. The SM cannot describe our world without the Higgs boson. The mass of the fundamental particles are given by the Higgs mechanism. Experimentally, there are 95% C.L. limit on the SM Higgs mass, M_H, one result is $M_H > 114.4$ GeV from LEP2 [2], another is $M_H < 166(199)$ GeV [a] from global EW fits [3]. In this talk, we present results of SM Higgs boson direct searches from DØ at the Tevatron. Also results of MSSM Higgs and fermiophobic Higgs are reported.

1.1. *Experimental Improvements*

DØ [1] is moving forward in hardware and analysis tools. One good example is the installation of a new inner layer of the Silicon tracker detector which has been successfully installed during the shutdown from March 2006 to

*on behalf of DØ collaboration
[a] The value in the bracket is result including LEP2 direct search. This number was obtained in Feb 2007. It has been updated as $M_H < 144(182)$ GeV due to the new top and W mass results from both CDF and DØ.

June 2006. This leads to a better impact parameter resolution that results in more effective b-tagging. It is a key issue of SM Higgs search at low mass, as described in next section. An example of improvement on algorithm is b-jet tagging. By implementing a Neural Net(NN) into the b-jet tagging algorithm, we obtain a 33% higher efficiency with same fake rate of 0.5% compared to past impact parameter based b-jet tagging algorithm.

2. SM Higgs Search at Tevatron

Higgs production cross section and branching ratio depend on Higgs boson Mass (M_H), we need to analyze many modes in the mass range from 115 GeV to 185 GeV. At high mass region, $M_H > 135$ GeV, the dominant decay mode is $H \to WW$, so that we use $WW \to \ell\ell + missingE_T$ final state via gluon fusion production which has the highest production cross section. In the low mass region, $M_H < 135$ GeV, where the Higgs predominantly decay to $b\bar{b}$ we use vector boson associated Higgs production ($WH \to \ell\nu b\bar{b}$, $ZH \to \ell\ell b\bar{b}$ and $ZH \to \nu\nu b\bar{b}$ final state) due to QCD background. In this talk, new results on the $ZH \to \ell\ell b\bar{b}$ channels are presented.

2.1. *High Mass Region: $H \to WW$*

To reconstruct WW, two isolated high p_T lepton and missing E_T are required. Here all combinations of two leptons except τ, $e^\pm e^\mp$, $\mu^\pm\mu^\mp$ and $e^\pm\mu^\mp$ are searched with $\sim$940 pb^{-1} of data. We use their angular correlation to extract the Higgs signal from the BG which origins from scalar particle decays into WW, and both of them decaying leptonically. In this case the charged leptons from W tend to have the same direction. Therefore, we use the opening angle in r-ϕ plane ($\Delta\phi$) between $\ell^+\ell^-$. After applying cuts on invariant mass of two lepton $M_{\ell\ell}$, sum of p_T, scalar sum of p_T, and transverse mass of lepton and missing E_T, we find data of 10, 8, 18 events with BG expectations of 10.3 ± 1.5, 9.8 ± 1.5 and 24.4 ± 3.7 events for $e^\pm e^\mp$, $\mu^\pm\mu^\mp$ and $e^\pm\mu^\mp$ channel, respectively.

2.2. *Low Mass Region: $ZH \to \ell\ell b\bar{b}$*

Di-electrons or di-muons with $p_T^\ell > 15$ GeV are used to reconstruct invariant mass of $\ell\ell$ to select Z bosons. Two b jets tagged by the NN b-tagging algorithm are required that are used for reconstruction of the di-jet mass. The di-jet invariant mass is shown in Fig. 1 after selecting Z peak with proper mass window cut. We observe 7 and 11 events with BG expectations of 10.7 ± 3.7 and 9.6 ± 3.4 events for e^+e^- and $\mu^+\mu^-$ channels, respectively. Because no excess is obtained, we set upper limits by using modified frequentist approach (CLs)[4] from the di-jet mass distributions with both 1 b-jet events 2 b-jet events which is shown in Fig. 1.

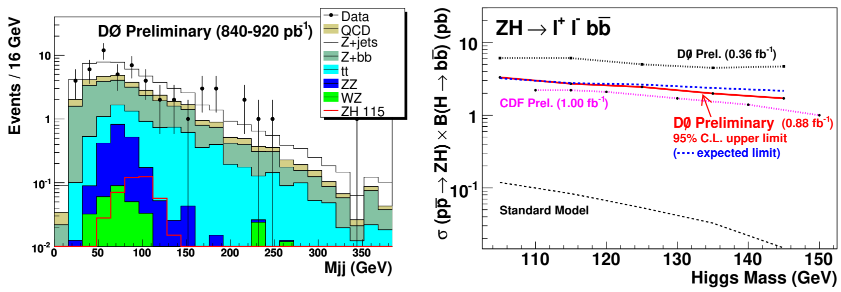

Figure 1. Left: The di-jet invariant mass distribution in the events with 2 or more b-tagged jets. Right: The 95% CL upper limit on ZH cross sections. The limits are derived from combination of $Z \to e^+e^-$ and $Z \to \mu^+\mu^-$ + 2 b-jets samples. The CDF 1 fb^{-1} result uses a Neural Net event selection.

2.3. *Combination*

Figure 2 shows the combined 95% C.L. upper limit on cross section divided by SM expectation as function of the Higgs mass. In this figure the latest results on $ZH \to \ell\ell b\bar{b}$ are not included, but the following modes are included: low mass mode with data of $260 - 390 pb^{-1}$ ($WH \to \ell\nu b\bar{b}$, $ZH \to \ell\ell b\bar{b}$, $ZH \to \nu\nu b\bar{b}$) high mass mode with data of $940 pb^{-1}$ ($H \to WW$). At $M_H = 160$ GeV, the upper limit is only a factor 4 above from the SM prediction and a factor 10 at $M_H = 115$ GeV.

3. MSSM Higgs

At the Tevatron, the cross sections of MSSM Higgs production is proportional to $\tan\beta^2$[b]. In this talk, the result of a search for MSSM neutral Higgs ϕ decaying to $\tau\tau$ with 1 fb^{-1} data is reported. To search for $\phi \to \tau^+\tau^-$, we require one τ decaying into lepton, the other τ decaying hadronically. In this analysis, only the muon channel is considered.

Hadronic tau ID is critical for this analysis. We are using NN identification for Hadronic τ with eight variables related to jet shape. In order to

[b] $\tan\beta$ is the ratio between up and down type of vacuum expectation value

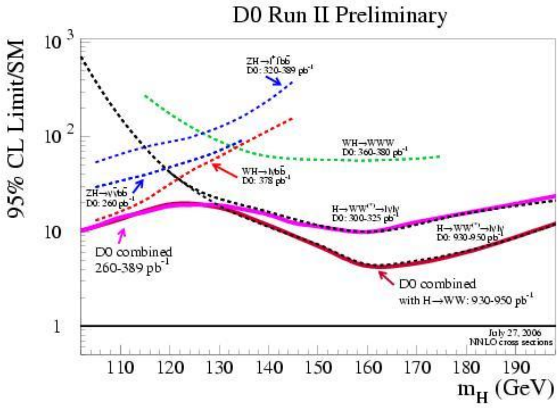

Figure 2. The combined 95% CL upper limit on SM Higgs production. Here $ZH \to \ell\ell b\bar{b}$, $ZH \to \nu\nu b\bar{b}$, $WH \to \ell\nu b\bar{b}$ with data of $260 \sim 390 fb^{-1}$ for low mass region, and $H \to \ell\nu\ell\nu$ with data of 950 fb^{-1} are combined. New result of $ZH \to \ell\ell b\bar{b}$ is not included.

obtain best S/N separation, NN are trained for each topology separately[c]. We observe 1141 events with expected BG of 1287 $\pm$ 130 events after applying $NN_\tau > 0.9$, $\Delta R_{\mu\tau} > 0.5$ and $M_W < 20$ GeV. Figure 3 shows visible mass M_{vis} which is calculated from p_T of μ and τ and missing p_T.

Recently CDF claimed 2σ excess around 160 GeV in M_{vis}, but there is no excess in our result. To maximize the sensitivity, NN analysis is applied in the limit calculation. The new limit on Higgs mass M_A-tan β plane is shown in Fig. 3.

4. Fermiophobic Higgs search

In this analysis we look for four photon+X final state which is enhanced through Vector-H-h_f coupling in a two Higgs double model (2HDM) which is a minimal extension of the Standard Model[d]. Experimentally, in order to search for $p\bar{p} \to H^\pm h_h \to h_f h_f W^\pm \to \gamma\gamma\gamma(\gamma)X$, we require three photons which have p_T greater than 30 GeV, 20 GeV and 15 GeV for leading, 2nd and 3rd leading photons, respectively. After applying a cut on the vectorial

[c](i) 1 track ($\tau \to h\nu$ like), (ii) 1 track with π^0 ($\tau \to h\pi^0\nu$ like) and (iii) 3 track ($\tau \to 3h\nu$ like). By applying NN τID, high efficiencies of 60%, 60%, 40% with low fake rate of 2%, 4%, 3% can be obtained for tau type (i), (ii), (iii), respectively

[d]Related searches have been done at LEP and Tevatron RunI, which were focused on Standard Model Vector-Vector-Higgs coupling by searching a Vector boson and two photon Higgs final state

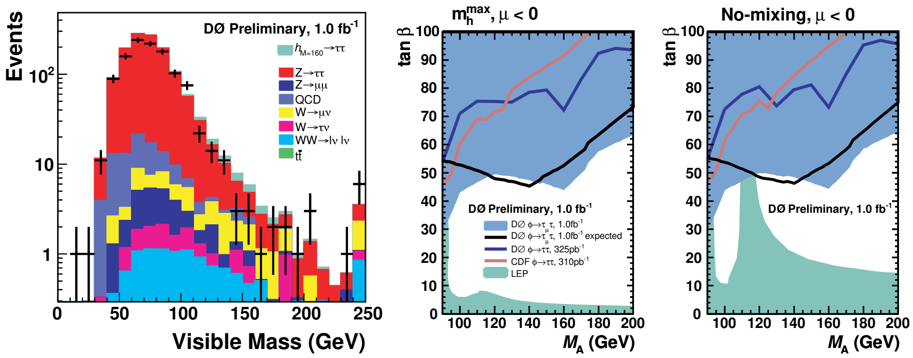

Figure 3. left: Visible mass distribution with data (cross points), sum of expected BG (histogram) and signal of M_ϕ=160 GeV (top histogram). Exclude region in the $\tan\beta$-m_A plane for $\mu < 0$ in the m_h^{max} scenario (middle) and the no-mixing scenario (right).

sum of the p_T of the 3 photons > 25 GeV no event is observed, with BG expectation of 1.1 ± 0.2 event and a signal acceptance of 0.16 ± 0.03 event. We set an upper limit on the production cross section of VHh_F of 25.3 fb at 95% C.L.

5. Summary

In this talk, we presented new results on searches for the SM Higgs in the $ZH \to \ell\ell b\bar{b}$ channel, MSSM Higgs in the $\phi \to \tau\tau$ channel, and fermiophobic Higgs in the $H^{\pm}h_h \to 3\gamma + X$ channel using 1 fb^{-1} of DØ data. There is no excess in either analysis, so we set 95 % C.L. upper limits on the Higgs production cross section in all modes. We have now 2.3 fb^{-1} of data on tape, and will have 6 to 8 fb^{-1} by the end of 2009. Also we are improving all the analyses, i.e., applying multivariable analysis, adding new mode, increasing acceptance, reducing systematic uncertainty. Our sensitivity will reach SM Higgs expectation after combining with CDF results in the near future.

References

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