Search for $H \to W^+W^- \to l^+l^-$ at DØ

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We present a search for the Standard Model Higgs boson produced via $H \to W^+W^- \to l^+l^-(ee, e\mu, \mu\mu, \tau \to e/\mu)$ process at $\sqrt{s} = 1.96$ TeV with the DØ detector at the Fermilab Tevatron collider. A Higgs particle with mass greater than 140 GeV decays primarily to a pair of W bosons and the leptonic decay modes provide a clean signature. This channel provides the greatest senstivity to the Higgs at Tevatron. Sophisticated multivariate techniques are used. No excess above the Standard Model is observed, hence upper limits on the Higgs production cross-section for m_H=115-200 GeV are set.

1 Introduction

A search for Higgs boson decyaing to WW* with the DØ detector [1] is presented. At Tevatron, the dominant production mechanism for a high mass ($m_H > 135$ GeV/c^2) Higgs is gluon fusion with the dominant decay mode of the Higgs to two W bosons. In order to enhance signal to background significance, W's decaying to electrons and muons are used. Contributions from both vector boson fusion(VBF) and associated production (WH/ZH) have also been used.

2 Event Selection

Each event is characterized by two oppositely charged leptons and missing transverse energy $\not\!\!E_T$. Events are selected by using a three level trigger system with either a single or dilepton requirements. In the offline analysis, electrons are identified using calorimeter and tracking information, whereas muons are reconstructed from hits in the muon system along with a track match in the central tracker.

The leptons in each final state are required to be isolated, oppositely charged with a p_T greater than 15 GeV. Additionaly the invariant mass of each event is required to be greater than 15 GeV. This is referred to as the pre-selection. At this stage, the dominant backgrounds are the Drell-Yann production and the multijet/qcd background which are subsequently removed by applying requirements on the $\not\!\!E_T$ and the scaled $\not\!\!E_T$, defined as :

$$\not\!\!E_T{}^{scaled} = \frac{\not\!\!E_T}{\sqrt{\sum_{jets}(\Delta E^{jets} \cdot \sin\theta^{jet} \cdot \cos\Delta\phi(jet, \not\!\!E_T))^2}} \qquad (1)$$

This quantity removes events where the $\not\!\!E_T$ could be a result of mis-measurement of jet energies.

A further requirement on the minimal transverse mass M_T between either of the leptons and $\not{E}_T$ reduces further variuos backgrounds.

$$M_T(\ell, \not{E}_T) = \sqrt{2p_T^\ell \not{E}_T (1 - \cos \Delta\phi(\ell, \not{E}_T))} \tag{2}$$

Lastly, a large fraction of remaining back to back Z $\rightarrow ll$ events are removed by rejecting events with large opening angle between the leptons ($\Delta\phi(l1, l2)$).

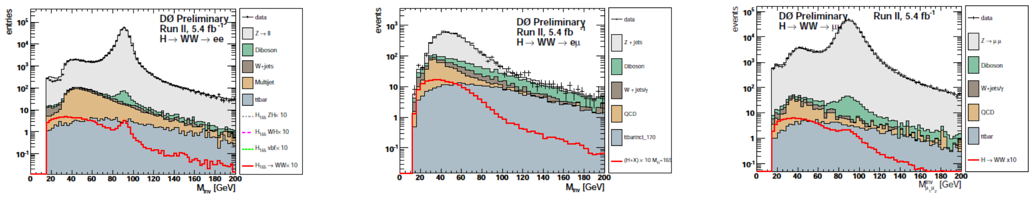

Figure 1: Invariant Mass for the each final state at the preselection stage.

	ee pre-selection	ee final	$e\mu$ pre-selection	$e\mu$ final	$\mu\mu$ pre-selection
$Z \rightarrow ee$	274746 ± 266	163.2 ± 2.3	306.4 ± 2.2	0.0 ± 0.0	–
$Z \rightarrow \mu\mu$	–	–	312.3 ± 1.0	6.5 ± 0.1	370375 ± 273
$Z \rightarrow \tau\tau$	1459 ± 15	0.7 ± 0.2	3858 ± 2	7.5 ± 0.1	2292 ± 3
$t\bar{t}$	158.1 ± 0.7	46.8 ± 0.4	321.3 ± 0.2	97.1 ± 0.1	158.3 ± 0.6
W+jets	302.8 ± 5.9	120.6 ± 4.0	274.2 ± 4.6	115.2 ± 3.3	150.9 ± 2.2
WW	202.6 ± 0.5	73.6 ± 0.3	495.5 ± 0.1	179.1 ± 0.1	235.6 ± 0.4
WZ	135.4 ± 0.1	11.5 ± 0.0	24.1 ± 0.0	7.7 ± 0.0	154.9 ± 0.1
ZZ	114.4 ± 0.1	73.6 ± 0.3	6.3 ± 0.0	0.8 ± 0.0	140.0 ± 0.1
Multijet	1370 ± 41	1.0 ± 1.1	461.7 ± 21.5	5.6 ± 2.4	332 ± 26
Signal ($M_H = 165$ GeV)	10.81 ± 0.01	7.30 ± 0.01	20.3 ± 0.0	14.7 ± 0.0	11.9 ± 0.0
Total Background	278489 ± 269	426.5 ± 4.8	6060 ± 22	419.6 ± 4.1	373838 ± 275
Data	277986	421	6123	403	376973

Figure 2: The event yield's for each final state at pre-selection and final cut stage. The errors shown are purely stastical only.

3 Neural Network

As a final discriminant, neural networks(NN) are used. The NNs are trained for each Higgs boson mass as well as for each final state against all Standard Model backgrounds. Gluon fusion as well as the vector boson fusion are fed as the signal to the NNs. The discriminating inputs used in the network are well described kinematic and topological variables that exploait the difference between the signal and the background, the network is trained and applied on all events passing the final selection requirements as descibed above.

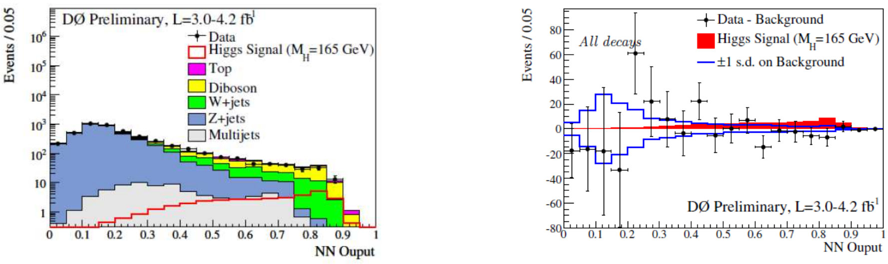

Figure 3: The NN output for all the channels combined(left) and the background subtracted(right).

4 Results and Conclusion

Limits on the cross sections for $\sigma \times BR(H \rightarrow W^+W^- \rightarrow l^+l^-)$ final states are derived at the 95% confidence level (C.L). The estimates for the expected number of background and signal events depend on numerous factors, and each of them introduce a systematic uncertainty.
Two kinds of systematics are considered in this analysis: flat systematics and shape systematics which modify the shape of the NN distribution. The total uncertainty on the background is approximately 13% and 10% for the Higgs signal. No evidence of Higgs boson is seen ans thus limts on the cross-section times the branching ratios are set. Limits for the combination of all the three channels are calculated using a modified frequentist method, the CL$_s$ method with a log-likeihood ratio (LLR) test statistic.

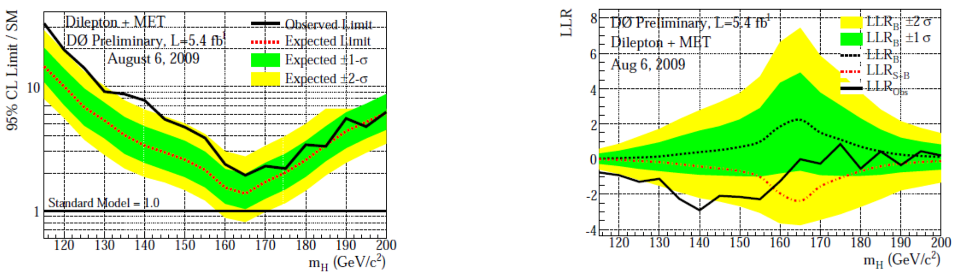

Figure 4: The NN output and the background subtracted nn output.

References

[1] DØ Collaboration, V. Abazov *et al.*, "The Upgraded DØ Detector," Nucl. Instrum. Methods Phys. Res. A **565**, 463 (2006).