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A SEARCH FOR HIGGS DECAYS TO WW^* AT DØ

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A search for the Higgs boson in the channels $H \to WW^* \to l^+ l^{'-} \nu\bar{\nu}$ ($l = e, \mu$) at DØ is described. The data, corresponding to an integrated luminosity of up to 177 pb^{-1}, are compared to theoretical predictions. No excess of events above the expected background is observed in any of the leptonic final states. Limits on the production cross-section times branching ratio, σ x $BR(H \to WW^*)$, are therefore set at the 95% Confidence Level.

Keywords: Higgs to WW.

1. Introduction

The search for the Higgs boson is a crucial part of the DØ physics program. The Tevatron has significant discovery potential,[1, 2] with renewed enthusiasm due to the improved accelerator performance. If the Standard Model (SM) Higgs is light (with mass below 135 GeV/c^2), it decays predominantly to b-quark pairs. The light-Higgs search uses associated WH or ZH production, with the vector bosons decaying leptonically. For a heavier Higgs, however, where $M_H > 135\, GeV/c^2$, the $H \to WW^*$ decay mode becomes kinematically possible and gluon-gluon fusion is exploited as the production mechanism. In this regime, the leptonic decays of WW^* pairs provide a promising search channel with manageable backgrounds.

The discovery of a SM Higgs decaying to WW^* will only be possible with the full Run II dataset. However, much can be done with the existing data. More exotic models lead to a significantly enhanced production cross-section through the existence of extra quark generations.[3] The enhancement factor depends upon the Higgs and quark masses; for example, for a 4th generation with $m_4 = 320$ GeV/c^2, an enhancement factor of 8.5 is expected. Such scenarios offer the exciting possibility of discovery with less data.

2. Experimental Signature

The final states of the $H \to WW^*$ process are characterized by two isolated leptons (e or μ) with high transverse momentum p_T, accompanied by a significant missing transverse energy E_T originating from the undetected neutrinos. Reconstruction of the Higgs mass is not possible due to the presence of the two neutrinos in the final state. However, spin correlations between the decay products of the Higgs can be used to suppress the background. The charged leptons from signal events tend to be collinear, hence the azimuthal opening angle between them is particularly useful in rejecting background. The major background processes include Z/γ^* ($\rightarrow l^+l^-$) + jets, WW, WZ, W + jets, $t\bar{t} \rightarrow bl^+\nu\bar{b}l^-\bar{\nu}$ and QCD production.

3. Data and Monte Carlo Samples

The search described here employs data collected by the DØ detector[4] between April 2002 and September 2003. DØ has analyzed 177 pb^{-1}, 158 pb^{-1} and 147 pb^{-1} of data in the ee, $e\mu$ and $\mu\mu$ final states respectively.[5] Runs with hardware failures or incomplete luminosity information were removed from the dataset.

Monte Carlo events were generated using PYTHIA[6] or ALPGEN[7] and passed through the detailed detector response, except for the QCD contribution which was evaluated from the data. Events were overlaid with an average of 0.8 minimum bias events. All rates have been normalized to the NLO cross-section values.[8]

4. Event Selection

Event cuts were optimized to suppress background while maximising signal efficiency for each final state. Selected events must have two isolated leptons with $p_T > 12$ and 8 GeV/c ($ee/e\mu$ channels) or $p_T > 20$ and 10 GeV/c ($\mu\mu$ channel). In addition, events must have a missing $E_T > 20$ GeV/c ($ee/e\mu$ channels) or > 30 GeV/c ($\mu\mu$ channel). Z candidates and energetic jets are rejected. The azimuthal opening angle between the two final state leptons is constrained to $\Delta\phi(l^+l^{'-}) < 1.5$ (ee final state) and $\Delta\phi(l^+l^{'-}) < 2.0$ ($e\mu$ and $\mu\mu$ final states).

Figures 1 and 2 show some of the handles used in the event selection. Good agreement between data and Monte Carlo is observed at each step of the event selection. The distribution of the azimuthal opening angle between the electron and muon is illustrated in Figure 1 after event preselection, i.e. applying p_T and isolation criteria, (left panel) and after all cuts have been applied (right plot). In Figure 2 we plot distributions from the dimuon final states after basic event selection: the dimuon invariant mass (left) and missing energy spectrum (right). Events observed in data (black dots) are overlaid onto events predicted from Monte Carlo. The dark blue histograms in Figure 1 and the left-hand plot of Figure 2 correspond to a Higgs signal for $M_H = 160$ GeV/c^2.

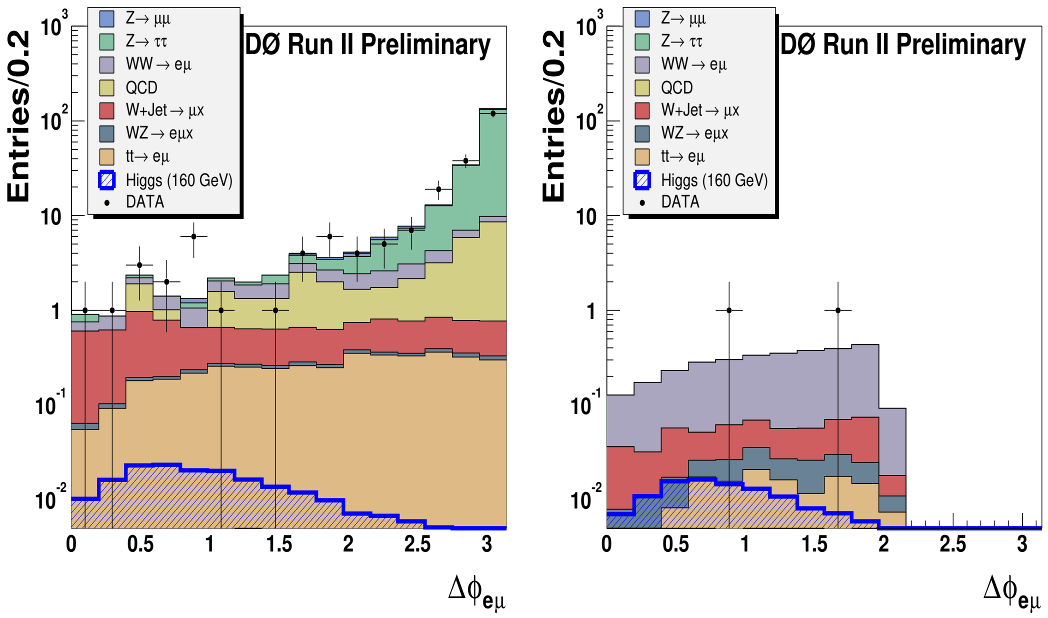

Fig. 1. Distribution of the azimuthal opening angle between the electron and muon after event preselection (left) and after all cuts have been applied (right).

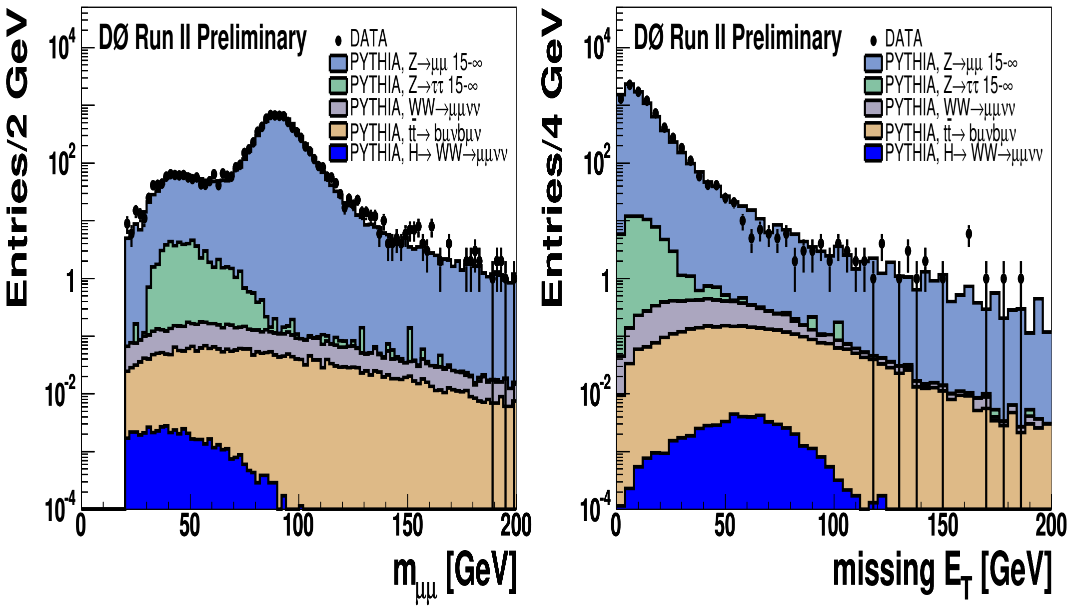

Fig. 2. Distibutions for the $\mu\mu$ channel of the dimuon invariant mass (left) and missing transverse energy (right), both after event preselection.

5. Final Event Counts

After all event selection has been performed, the final data samples of ee, $e\mu$ and $\mu\mu$ final states contain 2, 2 and 5 events respectively, while 2.7 ± 0.4, 3.1 ± 0.3 and 5.3 ± 0.6 events are expected from Monte Carlo. The signal acceptance ranges from approximately 0.02 to 0.2 depending on the Higgs mass and/or final state. Event counts are listed for all background sources in Table 1.

Table 1. Comparison of event counts in data with signal and background expectations from Monte Carlo.

Source	$ll' = ee$ $L = 177pb^{-1}$	$ll' = e\mu$ $L = 177pb^{-1}$	$ll' = \mu\mu$ $L = 177pb^{-1}$
$t\bar{t} \to bl\nu bl'\bar{\nu}$	0.06 ± 0.01	0.13 ± 0.01	0.03 ± 0.003
$WZ \to ll' + X$	0.04 ± 0.01	0.11 ± 0.01	
$\Upsilon \to e^+e^-$	0.00 ± 0.01		
$WW \to l\nu l'\bar{\nu}$	1.17 ± 0.02	2.51 ± 0.05	1.28 ± 0.03
$W + jets$	1.24 ± 0.07	0.34 ± 0.02	
$QCD/W + jets$			0.02 ± 0.02
QCD	0.00 ± 0.50	0.00 ± 0.20	
$Z/\gamma^* \to e^+e^-$	0.10 ± 0.10		
$Z/\gamma^* \to \mu^+\mu^-$		0.00 ± 0.05	3.90 ± 0.60
$Z/\gamma^* \to \tau^+\tau^-$	0.00 ± 0.10	0.00 ± 0.10	0.00 ± 0.00
Total Background Sum	**2.70 ± 0.40**	**3.10 ± 0.30**	**5.30 ± 0.60**
Expected Signal for SM Higgs ($M_H = 160GeV/c^2$)	**0.073 ± 0.002**	**0.111 ± 0.004**	**0.085 ± 0.001**
Data	**2**	**2**	**5**

6. Exclusion Limits

In the absence of an observed excess of signal, upper limits are set on the Higgs boson production cross-section times branching ratio into W bosons, at the 95% C.L., as illustrated in Figure 3. Limits are calculated for each leptonic decay mode separately and likelihood functions from each channel are then combined to obtain an overall result.[9] The combined result for σ x $BR(H \to WW^*)$ ranges from 6.6 to 40 pb, depending on the Higgs mass.

7. Prospects

Upper limits have been set on the $H \to WW^*$ production process in the Standard Model. Having successfully accomplished this first search for $H \to WW^*$ in Run II at DØ, the future looks very promising. We look forward to improving this measurement by exploring the full 0.5 fb^{-1} of data that has already been written to tape.

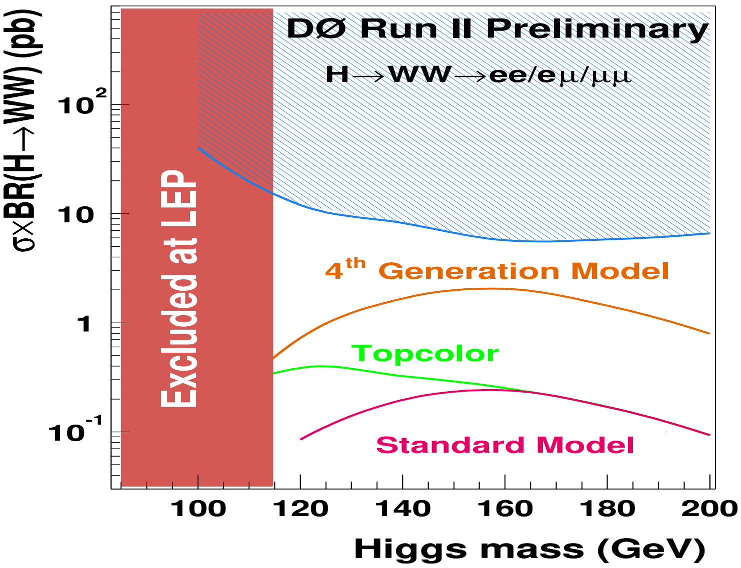

Fig. 3. Excluded cross-section times branching ratio at 95% C.L., together with expectations from SM Higgs boson production and alternative models. The LEP limit on the SM Higgs production is taken from Ref. 10, the 4th Generation model is presented in Ref. 3 and the TopColor scenario is described in Ref. 1.

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