Run II Standard Model Higgs Searches at DØ

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ABSTRACT

Preliminary results from Standard Model Higgs searches carried out by the DØ Collaboration at Run II of the Tevatron are detailed. The data, corresponding to integrated luminosities of up to 191 pb^{-1}, are compared to theoretical expectations. As no excess of events above the expected background is observed in any of the final states examined, limits at 95 % Confidence Level are set.

1. Introduction

The search for the Higgs is a high priority for the DØ experiment. Both the indirect constraints and the direct searches indicate that the Higgs is light. The Tevatron has significant discovery potential [1,2], with renewed enthusiasm due to the improved accelerator performance. For a light mass Higgs (below 135 GeV) $H \rightarrow b\bar{b}$ decays dominate and so the most powerful channels are associated ZH and WH production, with the vector bosons decaying to leptons. $H \rightarrow WW^*$ decays, with subsequent leptonic decays of the Ws, provide a promising search channel at higher Higgs masses, allowing the gluon fusion production mechanism to be exploited. The data analysed so far are essential for optimising detector performance and studying background processes, both critical issues for a future discovery, once we have larger data samples. Furthermore, some scenarios beyond the Standard Model (SM) require less data for discovery, see [3].

2. WH associated production

Associated WH production, with the W decaying to a charged lepton and a neutrino, is one of the most promising channels. Preliminary results for the electron channel are reported [4]. The events are required to have a central, isolated electron with $p_T > 20$GeV, missing transverse energy > 25GeV and at least two jets with $E_T > 20$GeV and within $|\eta| < 2.5$. Nearly 2,600 such candidate events are selected in 174 pb^{-1} of data. Good agreement between data and MC is observed. The reconstructed transverse W mass distribution is shown in figure 1(left). The W + 2 jets processes are generated with the ALPGEN [5] parton generator, interfaced with PYTHIA [6], and then passed through the detailed detector simulation. The cross sections are normalised to MCFM Next to Leading Order calculations [7]. The QCD background is evaluated from the data, while remaining SM processes are generated with PYTHIA. After requiring at least two b-tagged jets, 8 events remain in data, while 8.3 ± 2.2 are expected from the SM simulations. For consistency, different b-tag algorithms, both impact parameter and secondary vertex based, were tested and found to give similar results. To further suppress the dominant $t\bar{t}$ background, only events with exactly two jets, both of them tagged as b-jets, are retained. Figure 1(right) shows the di-jet invariant mass distribution of the final sample. 2 events are observed in data while 2.5 ± 0.5 events are expected from SM simulations.

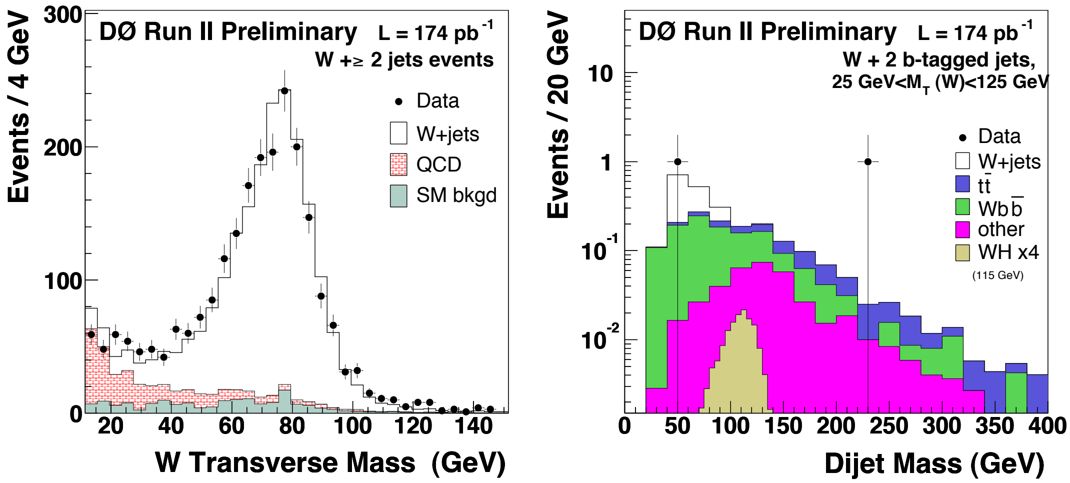

Figure 1: Left) The W transverse mass. Right) The di-jet mass spectrum when both jets are tagged as b-jets. Neither of the two observed final candidates is in the expected Higgs mass window.

The background is dominated by $Wb\bar{b}$ production (1.4 $\pm$ 0.4) with a non-negligible contribution from $Wc\bar{c}/j\bar{j}$ (0.4 $\pm$ 0.1), $t\bar{t}$ and single top processes (0.6 $\pm$ 0.2). Upper limits at 95% C. L. are set on the $Wb\bar{b}$ production cross section of < 20.3 pb, and, in the absence of an observed excess, on the $WH(H \to b\bar{b})$ process, of < 12.4 pb for a Higgs mass of 115 GeV. Systematic errors (26%) on the $Wb\bar{b}$ cross section include uncertainties from MC simulations (15%), the jet energy scale (14%), b-tagging (11%), jet identification (7%), trigger and electron identification (5%) and the electromagnetic energy scale (5%).

3. Measurement of the $\sigma(Z+b)/\sigma(Z+j)$ cross section ratio

Z boson production in association with one or more b-jets is an important process to study. It probes the b-quark content of the proton parton distribution functions, is a major background in ZH Higgs searches and is an important benchmark process for non-SM Higgs searches in b(b)h/A/H associated production.

A first preliminary measurement of the cross section ratio, $\sigma(Z+b)/\sigma(Z+j)$, using both electron and muon channels, with integrated luminosities of 184 and 152 pb^{-1} respectively, is reported [8]. Many systematics affecting the total cross sections cancel in the ratio. The event selection requires two isolated leptons with p_T > 15 GeV within $|\eta|$ < 2.5 (electron channel) or p_T > 20 GeV within $|\eta|$ < 2 (muon channel). The Z mass peak is used to select signal events, while the side bands are used for the background evaluation. Events are further required to have a jet with E_T > 20 GeV within $|\eta|$ < 2.5. Simulations are done with PYTHIA or ALPGEN interfaced with PYTHIA and then passed through the detailed detector response. The QCD and mis-tag background is estimated from the data. The total rate in the Z + jet sample, including light quarks and gluon jets, is normalised to data while the relative content of b- and c-jets is taken from the NLO calculations [9], since the b-tag algorithm cannot distinguish between b- and c-jets. The fraction of events with one b-tagged jet is then measured in data. Figure 2 shows the E_T

spectrum of the b-tagged jets in the selected Z+j sample. The measured ratio of 0.024 $\pm$ 0.005(stat.) $^{+0.005}_{-0.004}$ (syst.) agrees well with the predicted value of $\sim$0.02 [9]. The systematic errors include uncertainties due to the jet tagging efficiency (16%), the jet energy scale (11%), background estimations (6%) and assumptions on the relative fraction of b- and c-jets (3%).

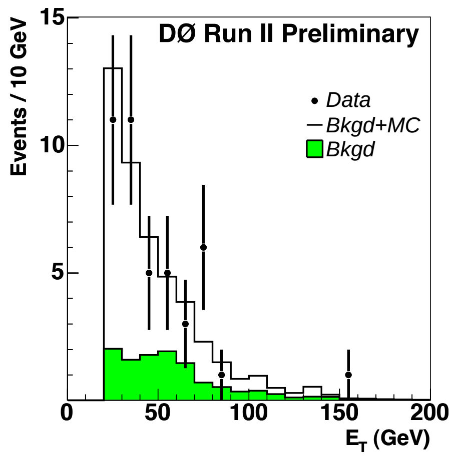

Figure 2: E_T spectrum of the b-tagged jets in the Z+j sample (statistical errors shown)

4. Higgs searches in $H \to WW^* \to l^+\nu l^-\bar{\nu}$

At Higgs boson masses above 135 GeV, where the $H \to WW^*$ decay mode is kinematically possible, leptonic decays of W pairs provide a promising search channel. DØ has analysed $\sim$ 180, 160 and 150 pb^{-1} of data in the ee, eμ and $\mu\mu$ final states respectively [10]. Selected events must have two isolated leptons with p_T > 12 and 8 GeV (ee/eμ) channels) or p_T > 20 and 10 GeV ($\mu\mu$ channel), missing E_T > 20 GeV (ee/eμ channels) or missing E_T > 30 GeV ($\mu\mu$ channel). Z candidates and energetic jets are rejected from the analysis. Simulations are done with PYTHIA and passed through the detailed detector response, except for the QCD contribution which is evaluated from the data. The rates are normalised to the NLO cross section values. Good agreement between data and MC is observed at each step of the event selection. The two neutrinos prevent a direct reconstruction of the Higgs mass, thus spin-correlations are used. The charged leptons from the Higgs decay tend to be collinear and hence the azimuthal opening angle between them is particularly useful in rejecting background. Figure 3(left) shows the distribution of the azimuthal opening angle between the electron and muon after all cuts have been applied. The final data samples of ee, eμ and $\mu\mu$ final states contain 2, 2 and 5 events, respectively, while 2.7 $\pm$ 0.4, 3.1 $\pm$ 0.3 and 5.3 $\pm$ 0.6 events are expected from MC. The background in the eμ sample consists of WW production (2.51 $\pm$ 0.05), W + jets (0.34 $\pm$ 0.02), WZ (0.11 $\pm$ 0.01) and $t\bar{t}$ (0.13 $\pm$ 0.01). The signal acceptance is between 0.02 and 0.2 depending on the Higgs mass and final state. In the absence of an observed excess, limits are set at 95% C.L. on the Higgs boson production cross section times branching ratio into W bosons as illustrated in figure 3(right).

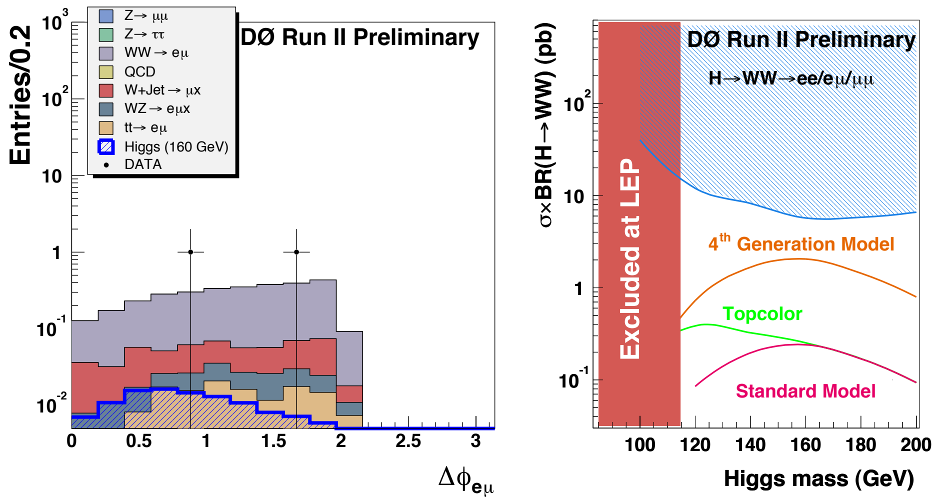

Figure 3: Left) Azimuthal opening angle between electron and muon. Right) Excluded cross section times branching ratio to W-pairs, $\sigma \times BR(H \to WW^{*})$, along with the expectations from SM Higgs boson production and the 4^{th} generation [11] and TopColour models [1].

5. Conclusions

These preliminary results, using less than half the total data on tape ($\sim$0.5fb^{-1}), together with the recent performance of the Tevatron, are very encouraging for the Higgs searches at Run II. The results are either unmatched by, or superior to, Run I results.

6. Acknowledgements

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7. References

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