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Prospects for Higgs search at DØ

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Abstract. The status of the Higgs search at the upgraded DØ detector is discussed.

1. Introduction

A major goal of experimental high-energy physics in the next decade is to characterize the Higgs sector of the standard model. The minimal version of the standard model requires a single scalar particle, though many extensions predict additional particles. Fits to the global set of electroweak data provide an indirect upper limit on the mass of a scalar Higgs boson of $m_H < 195$ GeV/c^2, with a preference for low masses, with the minimum at $m_H = 81$ GeV/c^2 [1,2]. Direct searches at LEP have ruled out a scalar Higgs boson $m_H < 114.4$ GeV/c^2. These results provide a strong motivation to search for Higgs bosons at the Tevatron. This article summarizes the state of the Higgs searches at DØ as of summer 2002.

2. The Run II DØ detector

Both the Tevatron collider and the collider experiments have been significantly upgraded since the last run. The Tevatron was augmented with a new injector, the collision energy was raised from 1.8 to 1.96 TeV, and the bunch spacing decreased from 3.6 μs to 396 ns. The goal for the current collider run is to accumulate 10–15 fb^{-1} per experiment. By the end of 2002, the peak collider luminosity was over 3×10^{31} cm^{-2} s^{-1}, beating the record from Run I. As of that date, DØ had recorded about 50 pb^{-1} of data, at a peak rate of about 1 pb^{-1} per day. These rates are expected to increase with further collider improvements.

Since Run I, the central tracker of the DØ experiment has been completely replaced. It now consists of a silicon vertex detector with four superlayers surrounded by a 16-layer scintillating fiber tracker, using 835 μm diameter fibers, the whole immersed in a 2T solenoidal magnetic field. Pre-shower detectors have also been added in front of the calorimeters. The calorimeters themselves are the same as Run I, except that some of the electronics has been replaced to handle the reduced bunch spacing. The muon system has also been significantly upgraded to improve coverage and to allow better triggering in high luminosity environments. The trigger and data acquisition systems were also replaced. As of the end of 2002, all detector components were operating well, except some trigger systems which remain to be commissioned.

3. Higgs production at the Tevatron

A comprehensive study of the potential for discovering Higgs at the Tevatron was carried out by the Higgs Working Group (HWG) [3] based on a parameterized detector simulation that assumed averaged properties of the two detectors. Unlike at the LHC, here there is no single channel in which a significant result can be expected. Rather, we must combine results from all decay modes, and also combine the data from the two experiments. A 5σ discovery for $m_H = 120$ GeV/c^2 would then be expected to require about $15\,\mathrm{fb}^{-1}$ of data.

The $gg \to H$ mode has the largest cross-section (about 1 pb for $m_H = 120$ GeV/c^2). However, for a light Higgs $m_H < 140$ GeV/c^2, the dominant decay mode is $H \to b\bar{b}$, rendering this mode hopeless against the large backgrounds of $b\bar{b}$ production from other sources. In this mass range, one must look for Higgs bosons produced in association with a W or Z boson, the latter then decaying leptonically (reducing the available cross-section by about a factor of 30). For higher mass Higgs bosons, the process $gg \to H \to WW$ may be feasible. Modes involving Higgs bosons produced with a heavy quark pair ($b\bar{b}$ or $t\bar{t}$) have spectacular final states, but very small cross-sections (<10 fb). However, some extensions to the standard model predict enhancements to the $Hb\bar{b}$ and $H \to \gamma\gamma$ modes.

4. DØ status

The DØ experiment has repeated the analyses of the HWG, using the full DØ detector simulation. The conclusions are roughly the same. Work is in progress on applying more sophisticated analysis techniques, such as neural networks, to the problem.

For the $H \to b\bar{b}$ channels, identifying b jets is crucial, both by using displaced vertices and by looking for soft leptons from b-quark decay. Monte Carlo (MC) simulations show that displaced vertex tagging can have efficiencies as high as 60% for high-transverse energy (E_{T}) jets, with a fake rate from light quarks on the order of a few per cent. The tagging performance depends on the track impact parameter resolution, which has been measured in current data to be $20\,\mu$m, already close to MC expectations. The work of determining the alignment of the tracking components is still in progress, so this will improve.

For the $W(\to e\nu/\mu\nu)H(\to b\bar{b})$ channels, one looks for a final state containing exactly one high-p_{T} lepton, large missing E_{T} ($\not{E}_{\mathrm{T}}$), and two b jets. The major physics background to these channels is $Wb\bar{b}$; other significant backgrounds include $t\bar{t}$ and WZ. An example of the results for the channel is shown in figure 1. Here, we require $E_{\mathrm{T}}(e) > 20\,\mathrm{GeV}$, $\not{E}_{\mathrm{T}} > 20\,\mathrm{GeV}$, two tagged b-jets with $E_{\mathrm{T}} > 15\,\mathrm{GeV}$, and for the third jet (if any), $E_{\mathrm{T}}(j_3) < 25\,\mathrm{GeV}$. This last requirement rejects $t\bar{t}$ background. The resulting $S/\sqrt{B}$ of 0.20 for the electron channel is comparable to

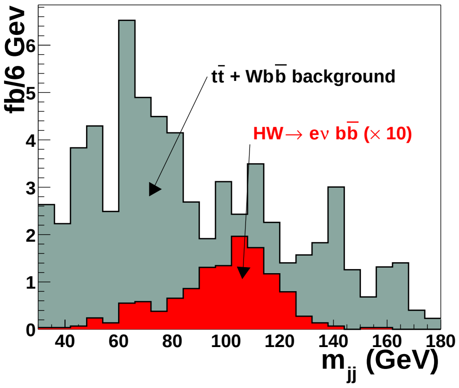

Figure 1. $m_{b\bar{b}}$ distribution from the $WH \to e\nu b\bar{b}$ MC analysis, using full detector simulation. Plotted are the contributions from the principal backgrounds ($Wb\bar{b}$ and $t\bar{t}$) and the signal expectation for $m_H = 120$ GeV/c^2 (scaled up by a factor of 10).

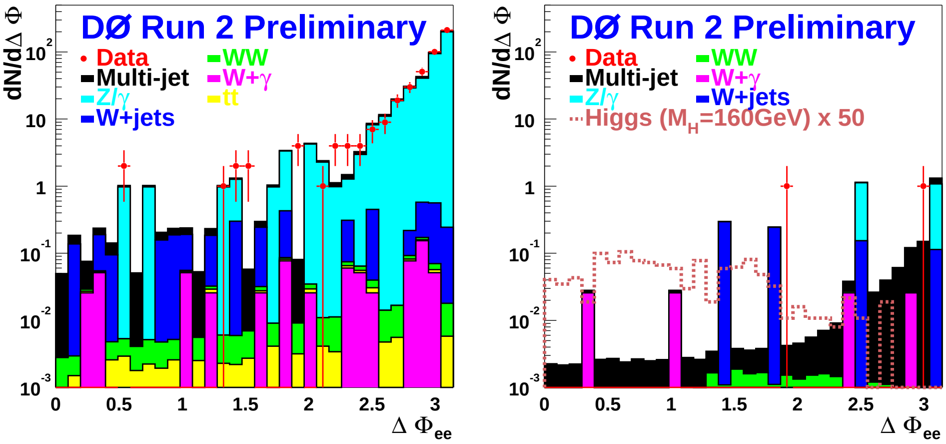

Figure 2. Results from the $H \to WW^* \to ee\nu\nu$ analysis, plotting the $\Delta\phi(ee)$ distribution for the data and the principal backgrounds. The left plot is after the electron E_{T} cuts only, the right plot is after all section cuts. The right plot also shows the signal expected for $m_H = 160$ GeV/c^2 (scaled up by a factor of 50 to make it more visible).

the expectations from the HWG, but should be improved significantly with the use of more sophisticated, multivariate analysis methods.

For $Z(\to ee/\mu\mu)H(\to b\bar{b})$, one requires two oppositely charged isolated leptons with a mass consistent with a Z boson and two b jets. A significance comparable to the WH channels is achievable though the overall event rate is lower. The $\nu\bar{\nu}b\bar{b}$ channel is also powerful since the branching fraction of a Z boson to neutrinos is three times larger than that for any single lepton flavor. For this channel, one requires the b jets plus large $\not{E}_{\mathrm{T}}$.

The $H \to WW^* \to \ell\ell\nu\nu$ channels are important for higher mass Higgses, $m_H >$ 130 GeV/c^2, where the decay $H \to WW$ is significant. Important backgrounds include WW, $t\bar{t}$, W/Z+jets, and QCD. In our preliminary analysis, we require two electrons with $E_{\mathrm{T}} > 20\,\mathrm{GeV}$, $m(ee) < 78$ GeV/c^2, $\not{E}_{\mathrm{T}} > 20\,\mathrm{GeV}$, and no jets with $E_{\mathrm{T}} > 20\,\mathrm{GeV}$. In addition, since the W boson pair comes from the decay of a spin-0 particle, spin correlation variables are useful, like the azimuthal angle between the leptons ($\Delta\phi(\ell\ell)$) (see figure 2).

5. Summary

The DØ experiment is recording physics quality data. Both the detector and the accelerator performance are continuously improving. We are studying issues such as the $b\bar{b}$ mass resolution, b-jet tagging efficiency, missing E_{T} resolution, and backgrounds to Higgs processes. We look forward to seeing exciting results!

References

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