Studies for the Search of the Higgs Boson in the Channel $\mathrm{H} \rightarrow \mathrm{WW}^{(*)} \rightarrow \mu^+\nu_\mu\mu^-\bar{\nu}_\mu$ at DØ in Run II

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At the $p\bar{p}$ collider TeVatron the Standard model Higgs boson is mainly produced via gluon-gluon fusion with a production cross section in the range of 0.1 to 2 pb. For masses $m_H > 135$ GeV the Higgs boson decays dominantly into W boson pairs. The leptonic decay channels of the W bosons provide a clear signature to discriminate against background processes [1].

The process $\mathrm{H} \rightarrow \mathrm{WW}^{(*)} \rightarrow \mu^+\nu_\mu\mu^-\bar{\nu}_\mu$ is studied in data taken with the DØ experiment [2] between August 2002 and February 2003. The integrated luminosity of the sample corresponds to $\mathcal{L} \approx 48.4\,\mathrm{pb}^{-1}$. The signature of the process is characterized by two isolated muons with high transverse momentum p_T and a significant missing transverse energy in the event originating from the undetected neutrinos. Processes with the similar event topology are Drell-Yan $Z/\gamma^* \rightarrow \mu\mu, \tau\tau$ production, WW, $t\bar{t}$, $b\bar{b}$, QCD and W+jets production. All processes were studied using the PYTHIA Monte Carlo generator with full detector simulation and parton distribution function CTEQ 4L and are compared to data. To be independent of the MC modeling the contributions from QCD and W+jets production are studied in data only.

Muon tracks are reconstructed with the three layer DØ muon system and matched to tracks from the central tracking system. The missing transverse energy is calculated from the energy deposits in the liquid-argon calorimeter. Figure 1 shows the distribution of the missing transverse energy $\not{E}_T$ for isolated muons with transverse momentum $p_T > 15$ GeV. The sample is dominated by Drell-Yan Z/γ^* production.

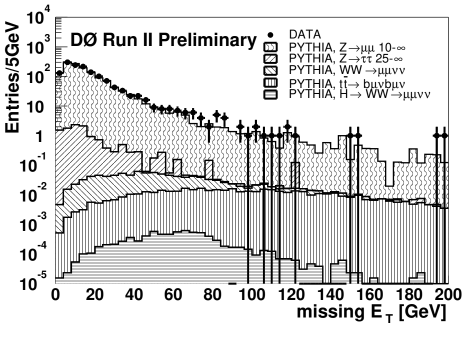
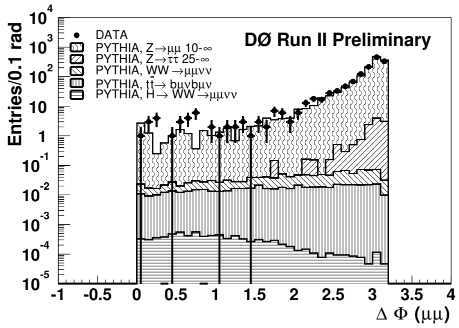


Fig. 1: Distribution of missing transverse energy in the event.

Successive cuts are used for further background reduction. The di-muon invariant mass $m_{\mu\mu}$ should be in a range of $20\,\mathrm{GeV} < m_{\mu\mu} < 75\,\mathrm{GeV}$. The lower cut rejects events from Υ decays whereas the higher cut significantly reduces the contribution of events from Z decays. To account for the neutrinos in the event the missing transverse energy is required to have a value of $\not{E}_T > 20$ GeV. The transverse mass m_T calculated from the di-muon momentum and the missing transverse energy has to be in the range of $50 < m_T < 200$ GeV.

Figure 2 shows the opening angle $\Delta\phi_{\mu\mu}$ between the two muons in the plane transverse to the beam axis. Muons from $\mathrm{H} \rightarrow \mathrm{WW}^{(*)} \rightarrow l\nu l\nu$ decays tend to have smaller opening angles than muons from background sources. The scalar Higgs boson decays into two W bosons with spin anti-correlation. Since the W^+ and W^- boson have opposite spin projections the two muons tend to be emitted close to each other. The upper plot in figure 2 shows the data and Monte Carlo comparison for events with two isolated muons with a transverse momentum $p_T > 15$ GeV. The lower plot shows data and Monte Carlo after application of the successive cuts described in the previous paragraph. To reduce further background contributions a cut on the opening angle $\Delta\phi_{\mu\mu} < 2$ is applied.



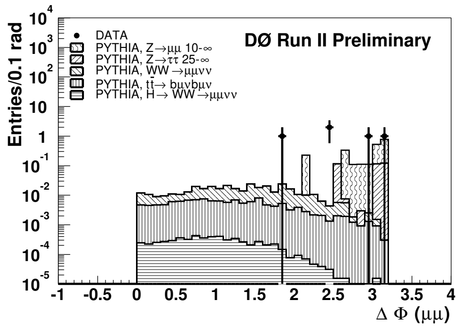


Fig. 2: Azimuthal opening angle $\Delta\Phi_{\mu\mu}$ between the two muon tracks after two different cuts: Z selection (top) and before the last cut (bottom).

After all cuts 1 event remains in data with $0.32 \pm 0.01(stat.)$ events expected from Monte Carlo simulation. In the future more integrated luminosity will help to understand the effects of the different contributing channels. Should the Higgs resemble the Standard model prediction, however, a discovery can only be made by a combination of all decay channels with the full Run II dataset.

References

[1] J. Elmsheuser, Background studies for the search of the Higgs boson in the channel $\mathrm{H} \rightarrow \mathrm{WW}^{(*)} \rightarrow \mu^+\nu_\mu\mu^-\bar{\nu}_\mu$ at DØ in Run II, DØ note 4121.

[2] T. Christansen *et al.*, The DØ experiment, Annual report 2001, p. 43