Search for the Higgs Boson in $\mathrm{H} \to \mathrm{WW}^{(*)} \to \mu^+\nu_\mu\mu^-\bar{\nu}_\mu$ Decays 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 $\mathrm{m_H} > 135\,\mathrm{GeV}$ 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 $\mathrm{H} \to \mathrm{WW}^{(*)} \to \mu^+\nu_\mu\mu^-\bar{\nu}_\mu$ is studied in data taken with the DØ experiment [2] between August 2002 and September 2003. The integrated luminosity of the sample corresponds to $\mathcal{L} \approx 146.9\,\mathrm{pb}^{-1}$. The signature of the process is characterised 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 $Z/\gamma^* \to \mu\mu, \tau\tau$ 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 modelling the contributions from QCD and W+jets production are studied in data and MC combination.

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 and corrected for the muon momentum. Figure 1 shows the distribution of the missing transverse energy $\not{E}_\mathrm{T}$ for isolated muons with transverse momentum $\mathrm{p_T} > 10\,\mathrm{GeV}$. The sample is dominated by Drell-Yan Z/γ^* production.

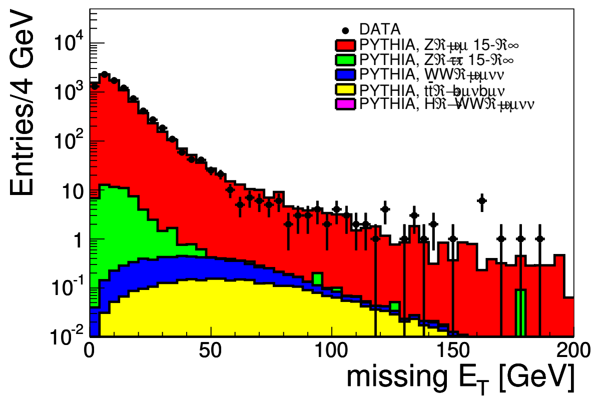

Fig. 1: Distribution of missing transverse energy in the event.

Successive cuts are used for further background reduction. The di-muon invariant mass $\mathrm{m}_{\mu\mu}$ should be greater than $m_{\mu\mu} > 20\,\mathrm{GeV}$ and outside the Z peak window of $|m_{\mu\mu} - m_\mathrm{Z}| > 15\,\mathrm{GeV}$. The first cut rejects events from Υ decays whereas the second 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 $\not{E}_T > 30\,\mathrm{GeV}$ and $\not{E}_T > 0.75 \cdot p_\mathrm{T}^{\mu1} + 10\,\mathrm{GeV}$. The latter cut reduces the contribution by mis-measured muon tracks with high transverse momentum. These tracks produce an unphysical high missing transverse energy in the event. Multi-jet events namely events from $t\bar{t}$ production are rejected by a cut on the jet transverse momentum. Jets with the highest and second highest value of $p_\mathrm{T}^\mathrm{Jet}$ should fulfil: $p_\mathrm{T}^\mathrm{Jet1} < 60\,\mathrm{GeV}$ and $p_\mathrm{T}^\mathrm{Jet2} < 30\,\mathrm{GeV}$.

The opening angle $\Delta\phi_{\mu\mu}$ between the two muons in the plane transverse to the beam axis is required to be smaller than 2. Muons from $\mathrm{H} \to \mathrm{WW}^{(*)} \to \mathrm{l}\nu\mathrm{l}\nu$ 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.

After applying all cuts 5 event remain in data whereas $5.3 \pm 0.6(stat.)$ events are expected from background Monte Carlo and $0.085 \pm 0.001(stat.)$ events are expected from a Standard Model $\mathrm{H} \to \mathrm{WW}^{(*)} \to \mu^+\nu_\mu\mu^-\bar{\nu}_\mu$ decay with a Higgs mass of $m_\mathrm{H} = 160\,\mathrm{GeV}$.

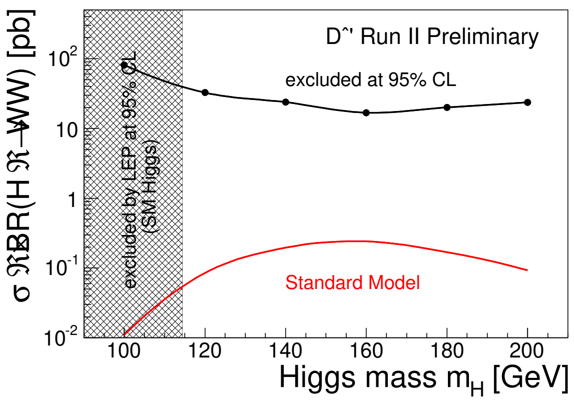

Fig. 2: Cross section limit curve $\sigma \times BR(H \to WW)$ for the process $\mathrm{H} \to \mathrm{WW}^{(*)} \to \mu^+\nu_\mu\mu^-\bar{\nu}_\mu$ and the Standard Model prediction.

Upper limits on cross section of $\mathrm{H} \to \mathrm{WW}^{(*)} \to \mu^+\nu_\mu\mu^-\bar{\nu}_\mu$ decays have been calculated at 95% CL. Figure 2 shows the calculated cross section limits on $\sigma \times BR(H \to WW)$ for the different Higgs masses compared with the Standard Model prediction. A combination with other decay channels with ee and $e\mu$ final states has been performed and improves the upper limits on the cross section by a factor of 2-3. Should the Higgs resemble the Standard model prediction, however, a discovery can only be made by a combination of all these decay channels with the full Run II dataset.

References

[1] J. Elmsheuser, Search for the Higgs boson in $\mathrm{H} \to \mathrm{WW}^{(*)} \to \mu^+\nu_\mu\mu^-\bar{\nu}_\mu$ decays at DØ in Run II, DØ note 4223.

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