Current and Proposed Improvements to the Search For Standard Model Higgs Bosons using $H \rightarrow WW^*$

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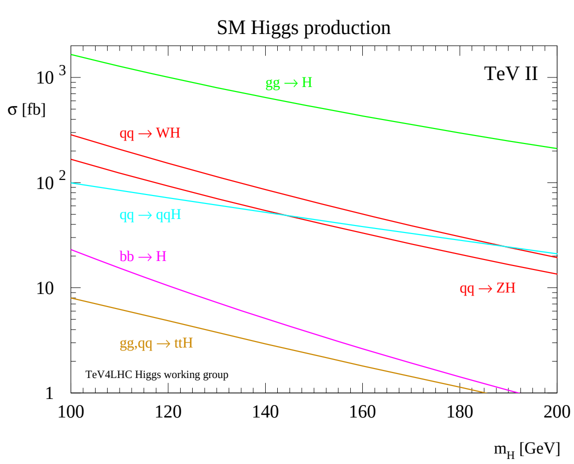
Abstract

We propose to improve the sensitivity of the search for a standard model Higgs boson by fully utilizing the associated production mode. A recent search has been completed that includes same-sign lepton events from associated production. In combination with opposite sign lepton Higgs production and decay topologies, this search achieved a limit on the production cross section of 1.33 times the predicted σ_H for $m_H = 165$ GeV. Another proposed improvement further utilizing the associated production mode is the study of trilepton events in associated Higgs production:

$$q\bar{q} \rightarrow WH \rightarrow WWW \rightarrow l\nu l\nu l\nu$$

where l can be e, μ, or even τ provided it then decays leptonically. This channel has the potential to improve the sensitivity by ~10%. We will also explore an expansion of acceptance to events with small opening angle as well as to events with hadronic tau decays. With improvements such as these, the search for a Higgs boson decaying to two W bosons will achieve standard model sensitivity at the CDF experiment.

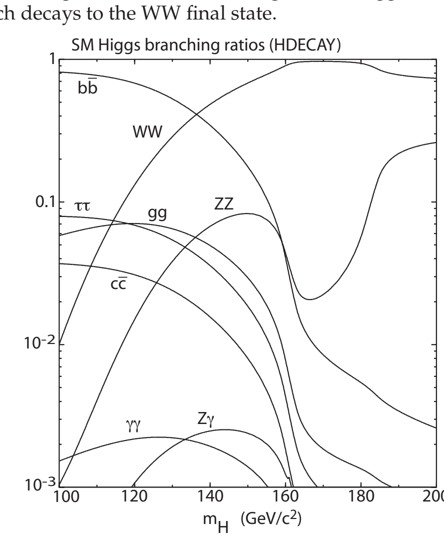
Introduction to $H \rightarrow WW$



The Higgs mechanism is used in the standard model (SM) to break the electroweak $SU(2)_L \times U(1)_Y$ symmetry, giving rise to the masses of the W and Z bosons, and the fermions. The existence of the Higgs boson is a consequence of electroweak symmetry breaking in the SM, but experimental verification of the Higgs' existence is necessary to confirm the validity of this mechanism.

There are several possible modes to produce a Higgs boson. As illustrated above, $gg \rightarrow H$ is the most common and when the Higgs boson decays to two W bosons the $gg \rightarrow H$ mode contributes substantially to the production of two opposite-sign leptons. Associated production with a W or Z boson are the next most common and the focus of the improvements presented here.

As shown in the figure below, for $m_H > 135$ GeV/c^2 the SM Higgs boson decays primarily to the WW final state. This analysis is designed to search for a high mass Higgs boson, one which decays to the WW final state.



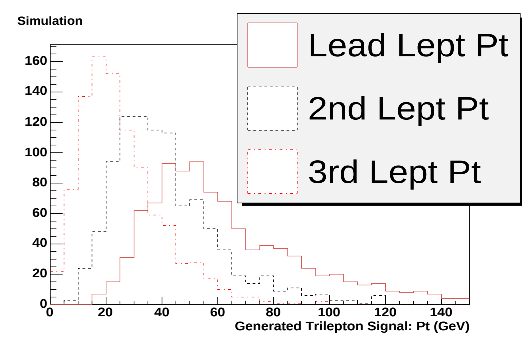
New Study: Trilepton Analysis

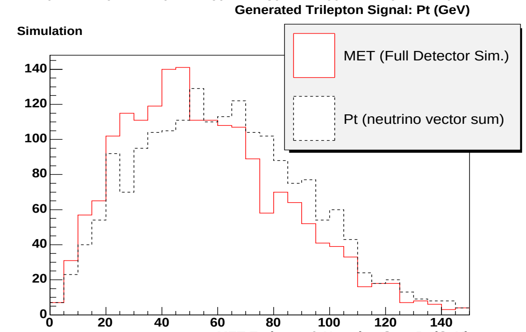
We propose to improve the sensitivity of the search for a SM Higgs boson in decays to two W bosons by the inclusion of trilepton events as an additional final state in associated Higgs production channels:

$$q\bar{q} \rightarrow WH \rightarrow WWW \rightarrow l\nu l\nu l\nu$$

$$q\bar{q} \rightarrow ZH \rightarrow ZWW \rightarrow lll\nu l\nu$$

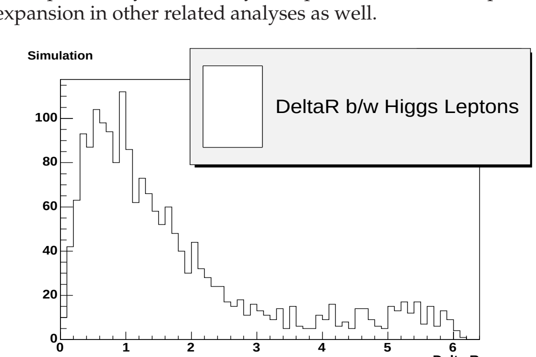
where, in the case of $ZH \rightarrow ZWW$, one lepton is not reconstructed. Including the trilepton final state has the potential to improve the sensitivity by $\sim$ 10%. The signal includes three leptons and missing energy searched primarily in events with zero reconstructed jets, with a likely addition of events with 1 reconstructed jet. Since all three W bosons decay leptonically in this study, backgrounds are expected to be heavily suppressed.





Small Opening-Angle Leptons

We will explore an expansion in acceptance to events with small opening angles between leptons. Monte Carlo modeling indicates that 14% of generated trilepton events with acceptable p_T and pseudorapidity values will have two of the three leptons within $\Delta R < 0.4$ and 78% of these close lepton pairs come directly from the decay of the Higgs boson. Hence, the study of expanding acceptance into these areas is important to a trilepton analysis, but may also provide similar acceptance expansion in other related analyses as well.



Hadronic Taus

We will explore an expansion in acceptance to events with hadronic tau decays. In trilepton events, there is a 70% chance that at least one lepton is a tau and then a 39% chance that such an event has a hadronic decay. Such an expansion in acceptance is a priority for the $H \rightarrow WW$ group since it would also be applicable to the dilepton studies.

Same Sign Dilepton Analysis

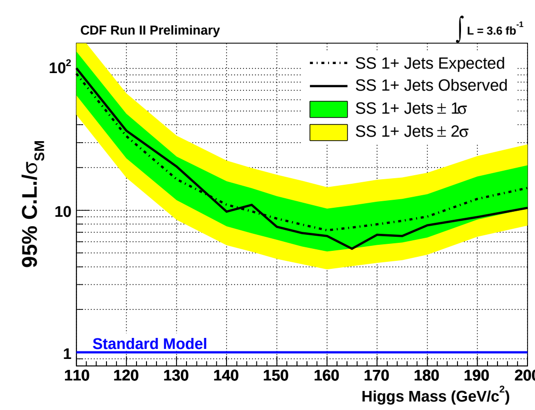
The $H \rightarrow WW$ result has recently received a boost in sensitivity from a same-sign dilepton analysis. This signal occurs naturally in the associated production channels $WH \rightarrow WWW$ and $ZH \rightarrow ZWW$, but is not expected in $gg \rightarrow H$ or vector boson fusion unless a lepton charge is misidentified. The study is conducted in the 1+ jets channel so W+jets is the primary background, with diboson and Drell Yan production contributing. The expected background and signal summary, along with observation, is:

CDF Run II Preliminary	$\int \mathcal{L} = 3.6$ fb^{-1}		
$M_H = 160$ GeV/c^2			
$t\bar{t}$	0.11	±	0.03
DY	11.99	±	3.65
WW	0.020	±	0.005
WZ	6.82	±	0.93
ZZ	1.44	±	0.20
W+jets	22.45	±	6.73
$W\gamma$	3.23	±	1.00
Total Background	**46.07**	±	**8.02**
WH	1.19	±	0.16
ZH	0.19	±	0.02
Total Signal	**1.38**	±	**0.18**
Data	**41**		

SS 1+ Jets

Same Sign Dilepton Results

These are the expected and observed limits versus Higgs Mass for same-sign 1+ Jets Channel. The observed limit alone is within 7 times the SM production for a Higgs mass of 165 GeV.



Combined Dilepton Results

These are the expected and observed limits versus Higgs mass for the combined opposite-sign and same-sign studies in the $H \rightarrow WW$ group. With the $H \rightarrow WW$ group achieving SM sensitivity alone, the combined CDF $H \rightarrow WW$ group and D0 results approach discovering or ruling out the Higgs boson's existence.