Prospects for Higgs boson measurements at the LHC in the $H \rightarrow \tau\tau$ decay mode

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The associated Higgs boson production modes *WH*, *ZH*, and *t̄tH*, where the Higgs boson subsequently decays to a pair of tau leptons, can be used to measure the relative branching ratios of a low-mass Higgs boson at the Large Hadron Collider and hence measure the ratio of Yukawa couplings as predicted by the Standard Model. We find that these modes can enhance coupling-ratio sensitivity with 50 fb^{-1} of *pp* collision data at a center of mass energy equal to 14 TeV, for a Higgs boson mass between 115 and 135 GeV/c^2.

1. Introduction

The early collisions at the Large Hadron Collider (LHC) [1] are an important step on the path to discovery of the last unobserved particle of the Standard Model (SM), the Higgs boson. While the prospects for Higgs boson discovery and measurement have been studied extensively [2], low-rate processes observable with the full LHC design luminosity have not been completely explored. We investigate the sensitivity of 50 fb^{-1} of LHC data to the Higgs boson production processes WH, ZH, and $t\bar{t}H$, followed by $H \to \tau\tau$ and at least one $W \to l\nu$ or $Z \to ll$ decay.

Combining these channels with the recently enhanced prospects for $W/Z/t\bar{t} + H \to bb$ observation [3] improves the expected LHC sensitivity to several quantities, most notably the Yukawa coupling ratio $g_{Hbb}/g_{H\tau\tau}$, determined at tree level by the bottom-quark and tau-lepton masses, and sensitive to differences in the source of mass for quarks and leptons.

2. Detector Simulation and Selection Criteria

Associated Higgs boson production signal and background processes (including di-boson, vector boson + jet(s), $t\bar{t}$ and $t\bar{t}$ + jet(s) production) were generated using the Sherpa [5] and Herwig++ [6] Monte Carlo generators. Detector effects and acceptances were simulated using the Delphes framework [7], a fast simulation program that can be parameterised to approximate a detector with properties similar to the ATLAS and CMS detectors. Lepton and hadronically decaying tau (τ_{jet}) identification and misidentifiaction rates [8] are summarised in Table 1. An example of the reconstructed object selection criteria is shown in Table 2 below for WH events, with two leptons and one τ_{jet} (all momenta are in GeV/c and masses are in GeV/c^2).

Object	ID efficiency (%)	Jet mis-identification rate (%)	Trigger efficiency (%)
e	64.2	0.0108	65
μ	94.2	0.169	90
τ_{jet}	40	2.3	lepton triggers used

Table 1: Simulated detector indentification and triggering efficiencies.

$P_T^{l_1}$	$P_T^{l_2}$	$P_T^{\tau_{jet}}$	$\not{E}_T$	$m_{l^+l^-}$	$|\Sigma_{charges}|$	$\Sigma \overrightarrow{P_T}$
25	15	25	$20 < \not{E}_T < 100$	< 76 or > 106	1	< 60

Table 2: WH search channel selection criteria

3. Monte Carlo Pseudo-experiment Results.

Since momentum is carried away by at least two neutrinos in these events, conventional mass reconstruction is not possible. The invariant mass of the visible tau decay products is used to create templates in the $t\bar{t}H$ and WH analyses while the collinear mass approximation [8] is used in the ZH analysis to reconstruct the $\tau\tau$ mass.

Pseudo-experiments are generated from signal and background MC distributions according to a Poisson distribution, $P(k;\lambda) = \frac{\lambda^k \exp^{-\lambda}}{k!}$, for k observed events and λ expected events. The

number of signal events is extracted by minimising the log-likelihood as a function of the signal yield. Using this signal yield, the expected statistical significance and corresponding uncertainty on $\sigma_{(WH,ZH,t\bar{t}H)} \times BR_{H\to\tau\tau}$ are calculated for a range of input Higgs masses for a given integrated luminosity per experiment, assuming a 10% systematic uncertainty on the background yield (shown in Figure 1).
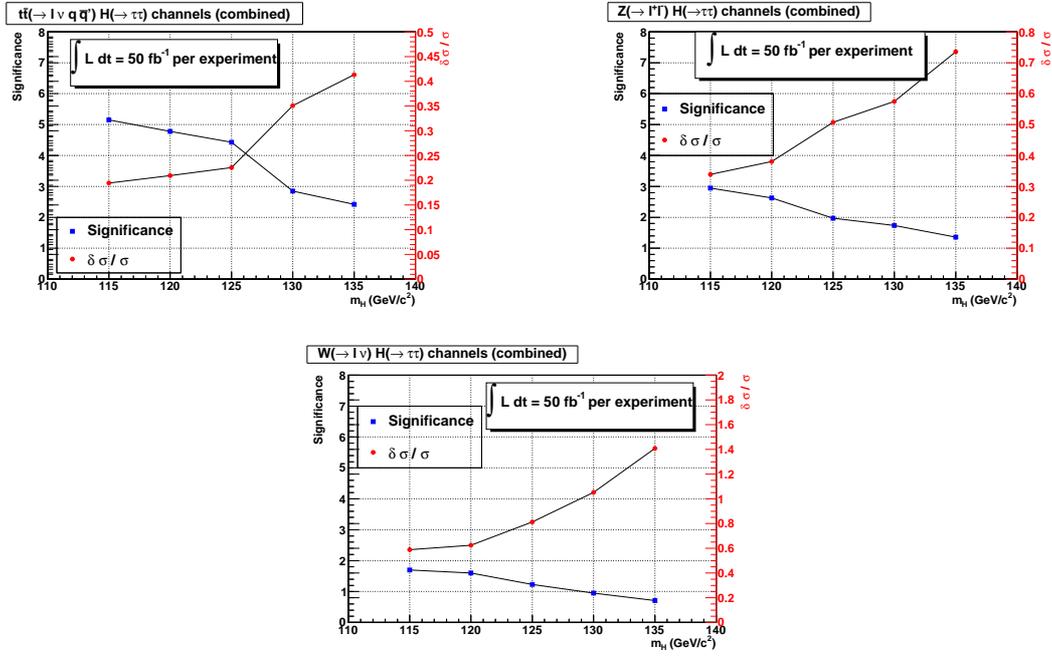

Figure 1: Expected signal significances.

4. Conclusion

The prospects for measuring the Higgs boson couplings at the LHC are good in several previously unexplored Higgs production and decay channels. We plan to further refine the selection criteria to improve the expected significance.

References

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