Higgs Couplings from H→ττ Decays

Chris Boddy, Sinead Farrington, Chris Hays

UNIVERSITY OF OXFORD

THE UNIVERSITY OF WARWICK

Introduction

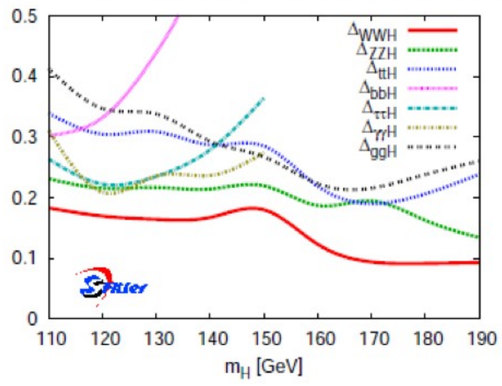
Latest search results

- A resonance has been observed with a mass of ~125 GeV. In the observed final states the resonance is consistent with the predicted Higgs boson of the SM. Measurements of additional channels are needed to determine if it is indeed the Higgs boson.

Previous coupling studies

- A Higgs boson with a mass of 125 GeV can be measured in many production and decay channels. This has been studied extensively.

production	decay
$gg \to H$	ZZ
qqH	ZZ
$gg \to H$	WW
qqH	WW
$t\bar{t}H$	$WW(3\ell)$
$t\bar{t}H$	$WW(2\ell)$
inclusive	$\gamma\gamma$
qqH	$\gamma\gamma$
$t\bar{t}H$	$\gamma\gamma$
WH	$\gamma\gamma$
ZH	$\gamma\gamma$
qqH	$\tau\tau(2\ell)$
qqH	$\tau\tau(1\ell)$
$t\bar{t}H$	$b\bar{b}$
WH/ZH	$b\bar{b}$ (subjet)

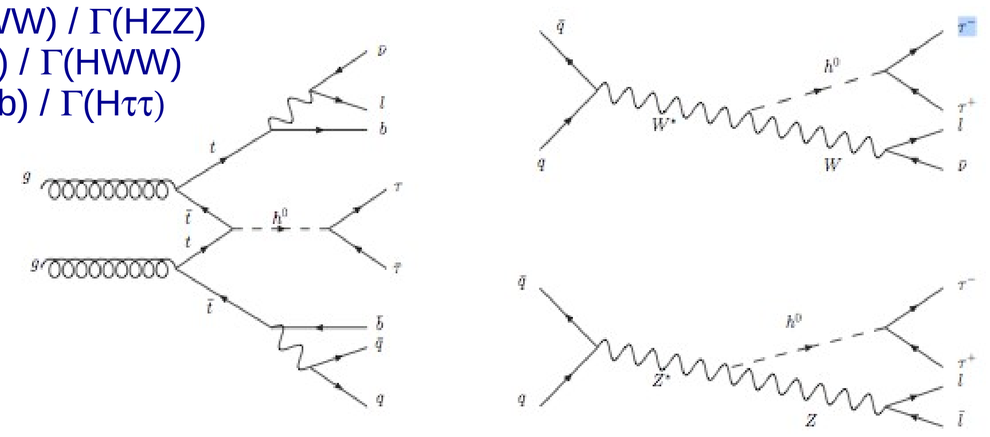


Lafaye et al. JHEP0908, 009 (2009)

Extracting couplings from X H→ X ττ

- Prospects for Higgs couplings to tau leptons have been studied for vector-boson fusion production. At higher luminosity the associated production processes (WH, ZH, $t\bar{t}H$) probe additional couplings.

- We have performed a study of these processes assuming 100 fb^{-1} of 14 TeV pp collision data and show that the following ratios can be measured with improved precision:
  - Γ(HWW) / Γ(HZZ)
  - Γ(Htt) / Γ(HWW)
  - Γ(Hbb) / Γ(Hττ)



Sensitivity to X H→ X ττ Production and Partial Widths

Signal and background processes

- Background processes are normalized to NLO cross sections for all processes except tt+2 jets and W+6 jets, for which we use LO cross sections from ALPGEN.

- Signal cross sections are normalized to NLO calculations with branching ratios determined by HDECAY.

- Events are generated with Sherpa and detector response modelled with DELPHES. Tau identification is modelled assuming the performance achieved with 7 TeV data.

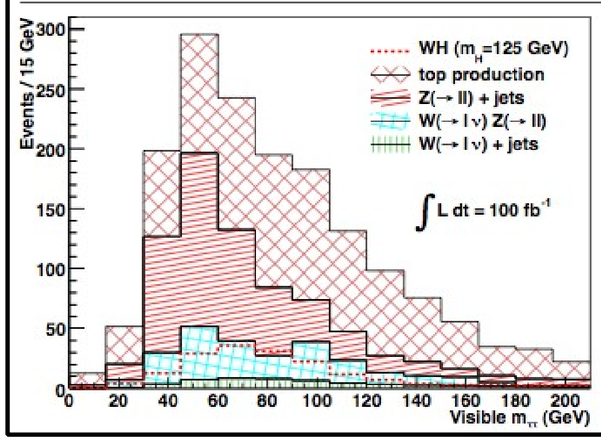
Object	Efficiency (%)		Misidentification rate (%)
	Trigger	Identification	
e/μ	87	79	0.085
τ_h	-	40	1.0

Production process	Cross section × BR
$W(\to l\nu)Z/\gamma^*(\to ll)$	52.4 pb × 3.27% = 1.56 pb
$Z/\gamma^*(\to ll)Z/\gamma^*(\to \tau\tau)$	17.7 pb × 0.340% = 60.2 fb
$W(\to l\nu) + 2$ jets	26772 pb × 32.4% = 8674 pb
$Z/\gamma^*(\to ll) + 1$ jet	24466 pb × 10.1% = 2471 pb
$Z/\gamma^*(\to ll) + 2$ jets	9018 pb × 10.1% = 911 pb
$W(\to l\nu) + 6$ jets	23.5 pb × 32.4% = 7.61 pb
$t\bar{t}(\to l\nu l\nu b\bar{b})$	933 pb × 10.5% = 97.9 pb
$t\bar{t}(\to l\nu q\bar{q}b\bar{b}) + 2$ jets	255 pb × 43.8% = 112 pb
$t\bar{t}(\to l\nu l\nu b\bar{b}) + 2$ jets	255 pb × 10.5% = 26.8 pb
$tW(\to l\nu bl\nu)$	61.8 pb × 10.5% = 6.49 pb
$t\bar{t}(\to l\nu q\bar{q}b\bar{b})Z/\gamma^*(\to ll)$	973 fb × 4.34% = 42.2 fb

m_H (GeV)	$\sigma(pp \to WH)$	$\sigma(pp \to ZH)$	$\sigma(pp \to t\bar{t}H)$	BR$(H \to \tau\tau)$
115	1.98 pb	1.05 pb	0.785 pb	0.0739
120	1.74 pb	0.922 pb	0.694 pb	0.0689
125	1.53 pb	0.813 pb	0.623 pb	0.0620
130	1.35 pb	0.718 pb	0.559 pb	0.0537
135	1.19 pb	0.638 pb	0.501 pb	0.0444

WH production

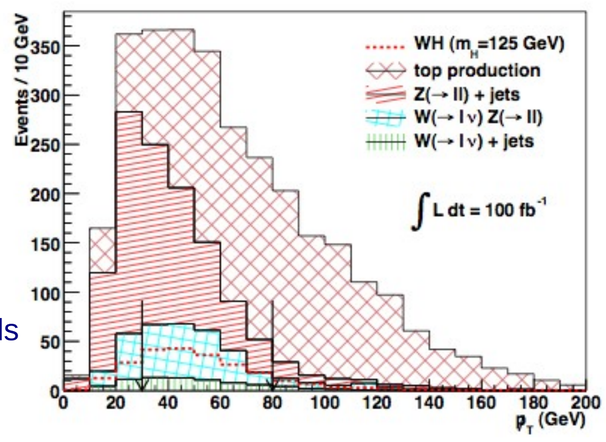
Selection	N_s^{WH}	N_b^{WH}	$N_s^{WH}/\sqrt{N_b^{WH}}$
$p_T^{l_W} > 25$ GeV, $p_T^{\tau_l,\tau_h} > 15$ GeV, $\sum q_l = \pm 1$ and no jet	422	184260	1.0
$30 < \not{p}_T < 80$ GeV	245	21079	1.7
$m_T > 50$ GeV	190	2165	4.1
No opposite-sign same-flavour $l_W\tau_l$	171	1629	4.2



- The top-quark and WZ backgrounds are lowest in the final state with one hadronically decaying tau (τ_h) and one leptonically decaying tau (τ_l).

- Kinematic selection reduces the dominant top-quark and Z+jet backgrounds.

- The signal yield is extracted from a fit to the visible mass distribution.

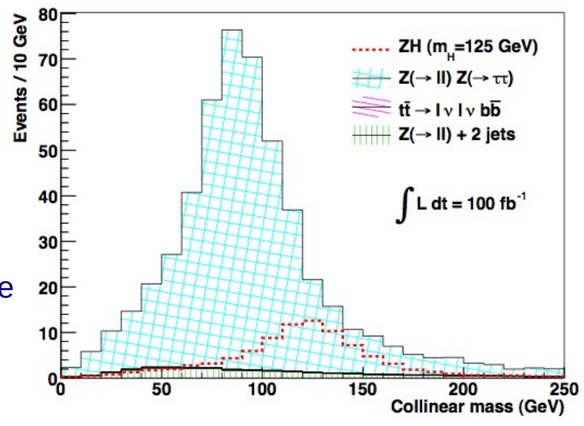


Process	Number of events
$t\bar{t}(\to l\nu l\nu b\bar{b})$	723
$Z/\gamma^*(\to ll) + 1$ jet	516
$W(\to l\nu)Z/\gamma^*(\to \tau\tau)$	161
$tW(\to l\nu bl\nu)$	129
$W(\to l\nu) + 2$ jets	52
$W(\to l\nu)Z/\gamma^*(\to ee/\mu\mu)$	48
Total	1629

ZH production

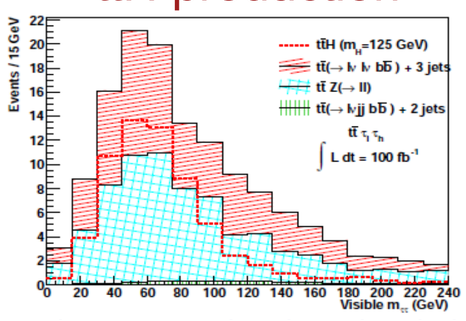
- ZH production is one of the most promising channels at high luminosity. The final state of two electrons or muons and two tau leptons has high purity and can be separated from ZZ production using the ditau mass.

- The signal is extracted by fitting the collinear mass distribution. The calculation assumes the tau decay products are collinear, a good approximation given the large boost of the tau leptons.



Selection	N_s^{ZH}	N_b^{ZH}	$N_s^{ZH}/\sqrt{N_b^{ZH}}$
Opposite-charge $\tau_h\tau_h$ and l_Zl_Z;			
highest (lowest) $p_T^{l_Z} > 25$ (15) GeV; $p_T^{\tau_h} > 25$ GeV	49	341	2.7
Collinear mass solution	41	246	2.6
Opposite-charge $\tau_h\tau_l$ and l_Zl_Z;			
highest (lowest) $p_T^{l_Z} > 25$ (15) GeV; $p_T^{\tau_h(\tau_l)} > 25$ (15) GeV	58	352	3.1
Collinear mass solution	47	263	2.9

ttH production

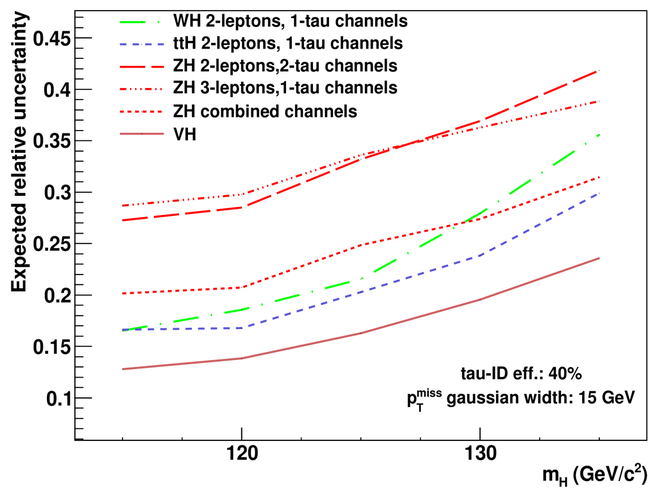


- We select top-quark pairs using their semileptonic decays. The background to the τ_h τ_l channel is dominated by tt+jets and tt+Z.

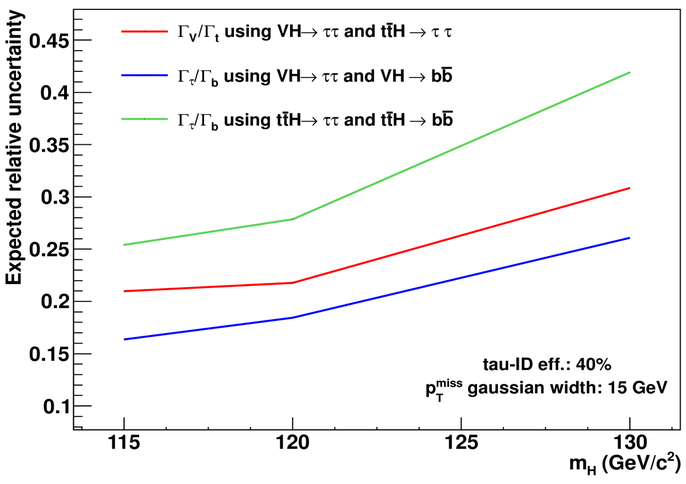
Process	Number of events
$t\bar{t}(\to l\nu l\nu b\bar{b}) + 3$ jets	62
$t\bar{t}(\to l\nu q\bar{q}b\bar{b}) + Z/\gamma^*(\to ee/\mu\mu)$	47
$t\bar{t}(\to l\nu q\bar{q}b\bar{b}) + Z/\gamma^*(\to \tau\tau)$	22
$t\bar{t}(\to l\nu q\bar{q}b\bar{b}) + 2$ jets	3
Total	134

Expected uncertainties

- From the likelihood fits to the mass distributions, including an assumed 10% background normalization uncertainty, we obtain the following relative uncertainties on cross section times branching ratios



- The uncertainty on the partial-width ratio Γ_V/Γ_t is extracted using only these channels. Combining with equivalent channels with decays to b-quarks provides access to the partial width ratio Γ_t/Γ_b.



- We have also investigated the sensitivity for the case where tau identification is 28% efficient for the same jet rejection rate: