Model independent determination of the top quark Yukawa coupling from LHC and ILC data

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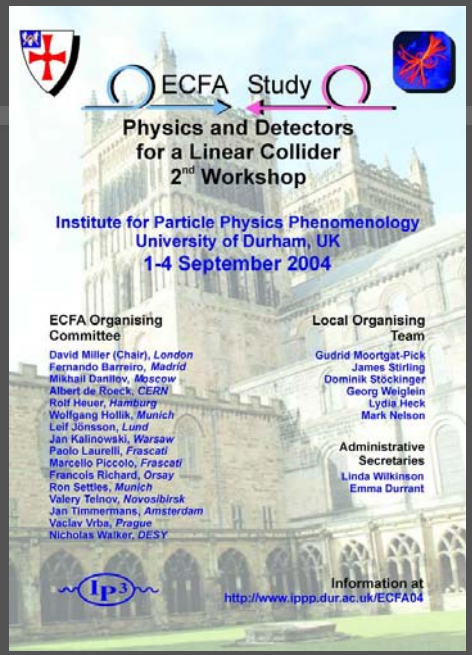


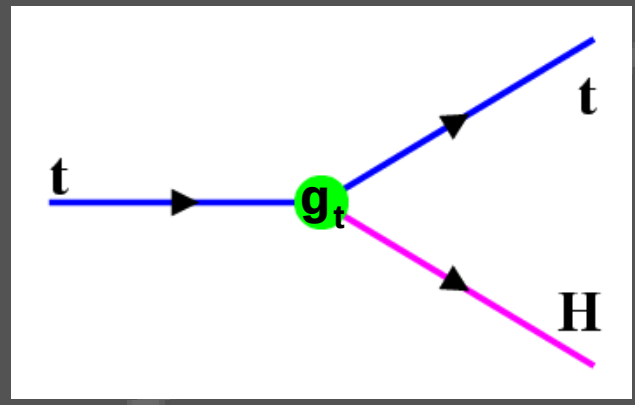
- Motivation and Idea
- LHC rate measurement
- ILC branching ratio measurement
- Determination of g_t

Motivation

- test whether: $m_f \sim g_f$
- top Yukawa coupling largest:

  $g_t \sim O(1)$ ($g_b \sim O(10^{-4})$)
- theoretical prejudice:

  maybe surprises for top quark ?

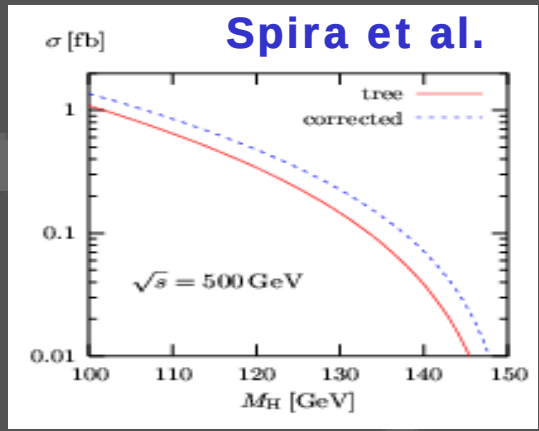


- light Higgs: g_t from ttH associated production
- framework: data from LHC (L= 30 and 300 fb^{-1})

  data from ILC at E_{CM} = 500 GeV , L=500 fb^{-1}

- ILC: small cross section ~ 1.5 to 0.01 fb

  for M_H= 100 to 145 GeV @ E_{CM}=500GeV

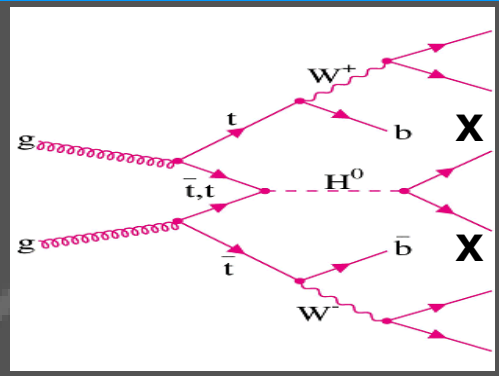


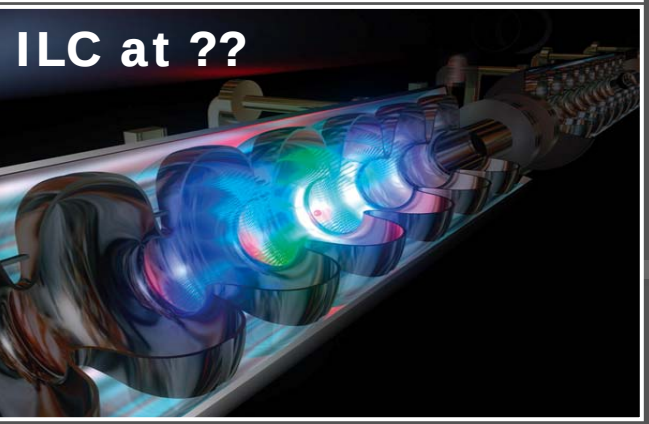
- LHC: only rate pp→ttH, H→xx model independent measurable

Idea

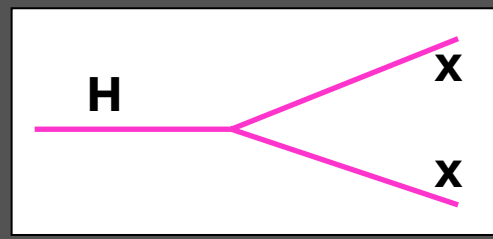
LHC: measurement of rate
σ_{tth} x BR(H→bb)
σ_{tth} x BR(H→WW)

→ g_t^2 x BR(H→xx)



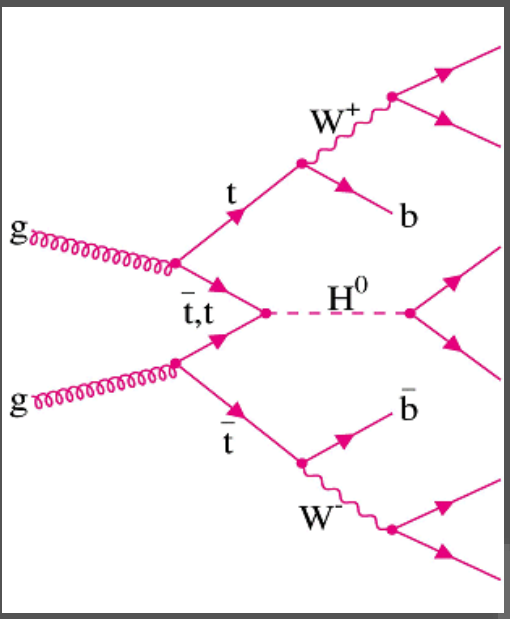


ILC: measurement of branching ratio
BR(H→bb)
BR(H→WW)



Combination of both measurements
→model independent determination
of top quark Yukawa coupling

LHC rate measurements



H→bb:

t→bqq t→blν H→bb

σ ~ 110 fb @ M_H = 120 GeV

H→WW:

a) 2 likesign leptons: t→bl⁺ν t→qq H→l⁺ ν qq

b) 3 leptons: t → blν t → blν H → WW → qq l ν

t → blν t → bqq H → WW → l ν l ν

σ ~ 2 x 18 fb @ M_H = 160 GeV

Backgrounds considered :

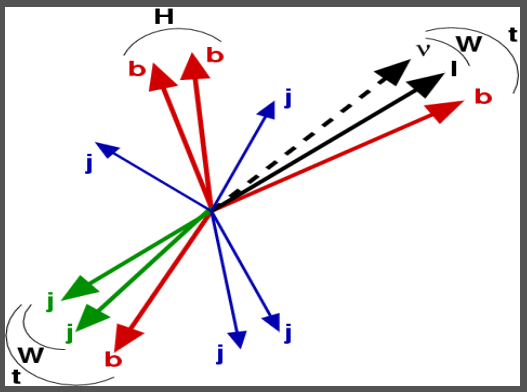
tt + W, Z, Wj, tt, WW, bb, jj WW, WZ, Wbb, Z+j, W+j, W+t

Cross sections: 492 pb to 5×10^{-3} pb

Results from published ATLAS fast MC studies:

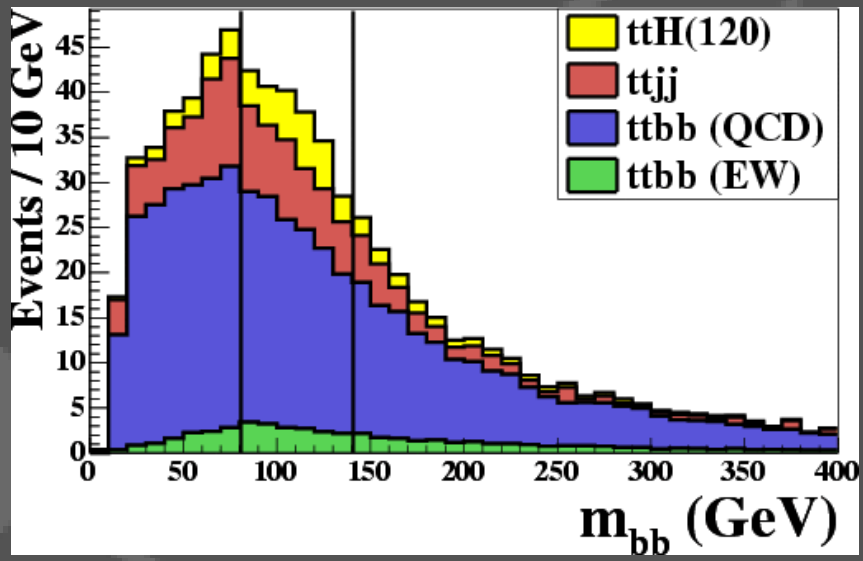
b-tagging, mass rsolutions, lepton isolation from full simulation

ttH with H→bb (ATL-PHYS-2003-024, J. Cammin, MS)



1 lepton, missing energy, 6 jets, 4 b-tagged

consistent with ttH,H→bb production, $m_{bb} \sim m_H$

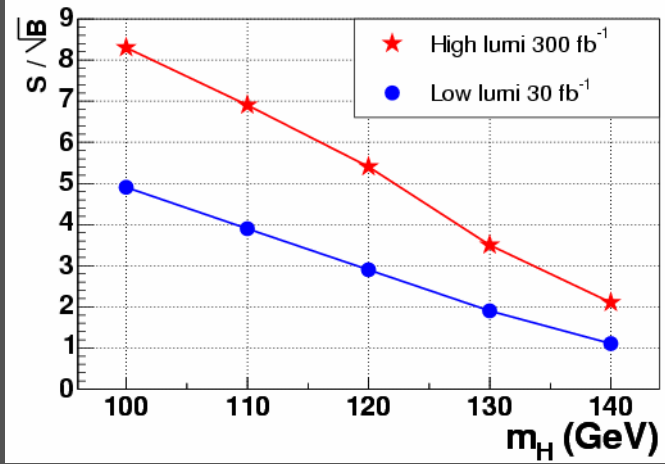


background estimate from data foreseen

expected signal and background events

m_H (GeV)	30fb^{-1}		300fb^{-1}	
	$t\bar{t}H^0$ $H^0 \to bb$	background	$t\bar{t}H^0$ $H^0 \to bb$	background
100	83.4	303.4	279.0	1101.3
110	63.0	275.7	232.5	1140.6
120	43.0	234.1	173.1	1054.2
130	26.5	200.1	112.5	1015.8
140	13.9	178.2	62.4	947.1

Eff.= 1.5 % 0.5 %



ttH with H→WW (ATL-PHYS-2002-019, J. Leveque et al.)

2 lepton topology:

$t \to b l^+ \nu$ $t \to bqq$ $H \to l^+ \nu qq$

2 likesign leptons,

6 jets, 2 b-tagged

b-lepton veto

„mass“ reconstruction

3 lepton topology:

$t \to bl\nu$ $t \to bl\nu$ $H \to qql\nu$

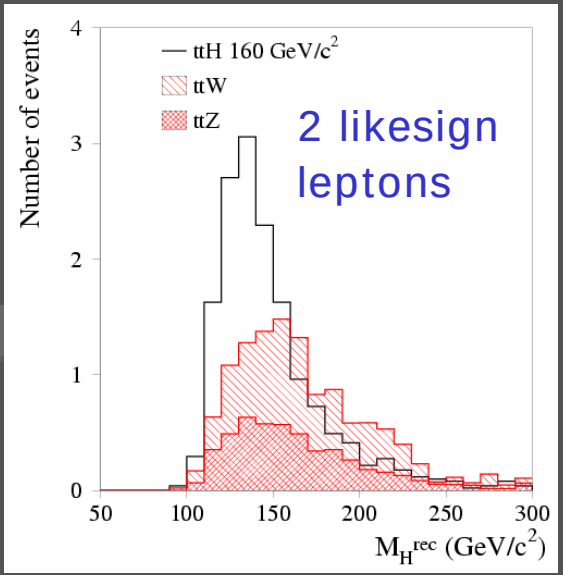
$t \to bl\nu$ $t \to bqq$ $H \to l\nu l\nu$

three leptons

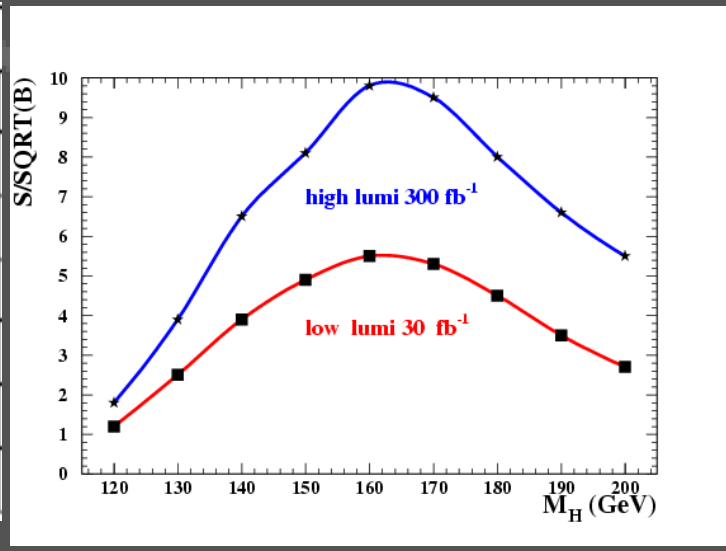
4 jets, 2 b-tagged

b-lepton veto

Z veto



m_H (GeV)	30 fb^{-1}				300 fb^{-1}			
	$t\bar{t}H^0 H^0 \to WW(2\ell)$		$t\bar{t}H^0 H^0 \to WW(3\ell)$		$t\bar{t}H^0 H^0 \to WW(2\ell)$		$t\bar{t}H^0 H^0 \to WW(3\ell)$	
	signal	bckgr	signal	bckgr	signal	bckgr	signal	bckgr
120	4.4	19.6	2.7	21.2	12.7	80.6	10.5	97.6
140	15.0	19.6	8.7	21.2	50.0	80.6	33.7	97.6
160	21.1	19.6	13.0	21.2	72.3	80.6	55.3	97.6
180	17.3	19.6	10.3	21.2	60.9	80.6	41.7	97.6
200	10.5	19.6	5.7	21.2	43.2	80.6	26.4	97.6



Rate measurement σ x BR

$$\left(\frac{\Delta(\sigma\times BR)}{\sigma\times BR}\right)^2 = \frac{S+B}{S^2} + \left(\frac{\Delta B_{sys}}{S}\right)^2 + \left(\frac{\Delta\mathcal{L}}{\mathcal{L}}\right)^2 + \left(\frac{\Delta\epsilon}{\epsilon}\right)^2$$

ΔB_{sys}: from sidebands +control samples
10 % for H → bb at low luminosity
5 % otherwise

$\Delta\,\varepsilon$: efficiency uncertainty from (depends on nr. of leptons and bs):
lepton isolation + reconstruction : 3 % +2 %
b-tagging: 3 % overall reconstruction: 2 %

ΔL: luminosity uncertainty 5 %

Expected accuracy on
σ x BR including
systematic uncertainties

m_H (GeV)	30 fb^{-1}		300 fb^{-1}	
	$H^0\to b\bar{b}$	$H^0\to WW$	$H^0\to b\bar{b}$	$H^0\to WW$
100	0.398(0.236)		0.249(0.133)	
110	0.476(0.292)		0.287(0.159)	
120	0.598(0.387)	1.023(0.974)	0.345(0.202)	0.732(0.611)
130	0.840(0.568)	0.524(0.492)	0.488(0.299)	0.362(0.295)
140	1.444(0.997)	0.370(0.339)	0.804(0.509)	0.252(0.193)
160		0.287(0.254)		0.196(0.137)
180		0.331(0.300)		0.221(0.163)
200		0.486(0.454)		0.282(0.222)

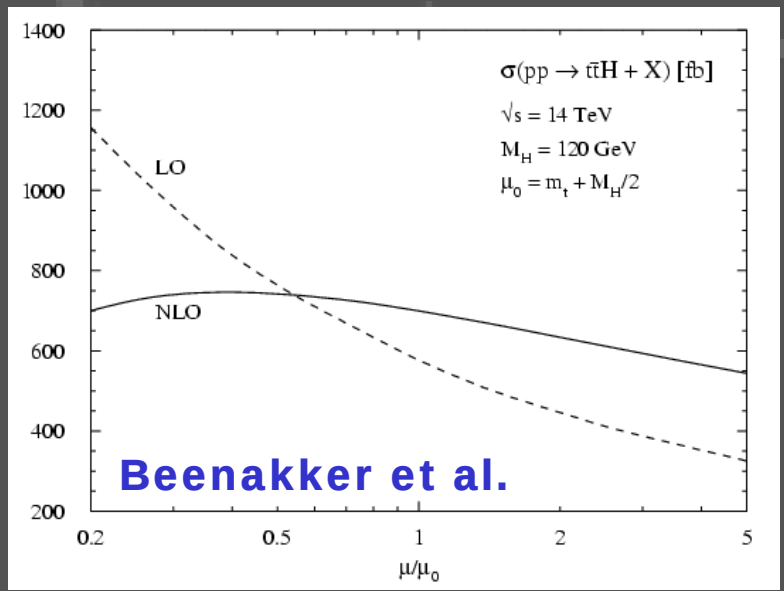
From σ x BR to g_t^2 x BR

Comparing observed rate with theoretical prediction:

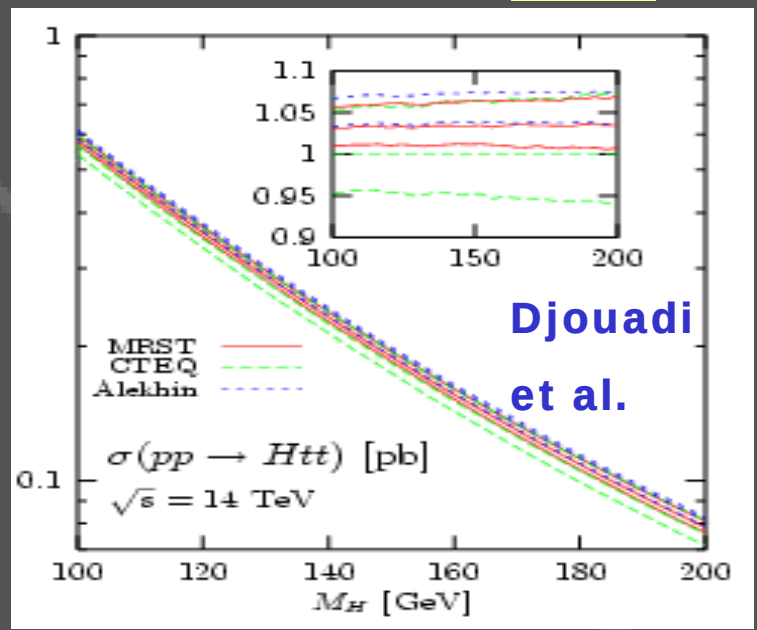
σ x BR $\qquad\qquad$ g_t^2 x BR

$$\left(\frac{\Delta(g^2_{ttH}\times BR)}{g^2_{ttH}\times BR}\right)^2 = \left(\frac{\Delta(\sigma\times BR)}{\sigma\times BR}\right)^2_{exp} + \left(\frac{\Delta\sigma}{\sigma}\right)^2_{theo}$$

Estimate of higher order uncertainty in cross section: 15 %

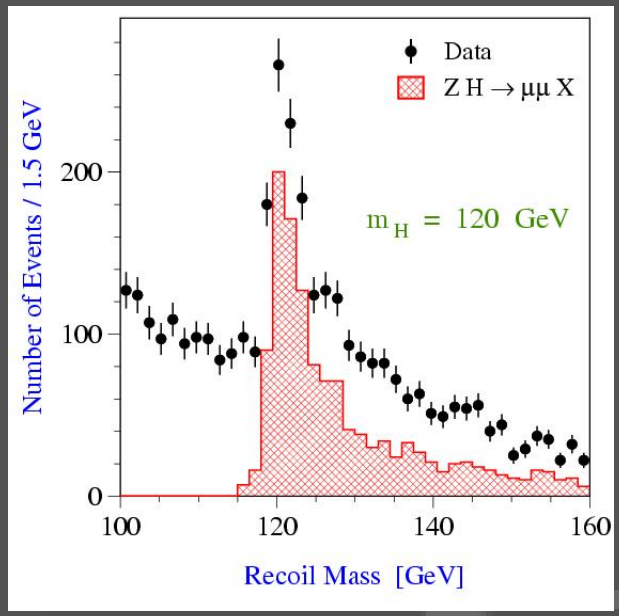


PDF uncertainty: 5 %

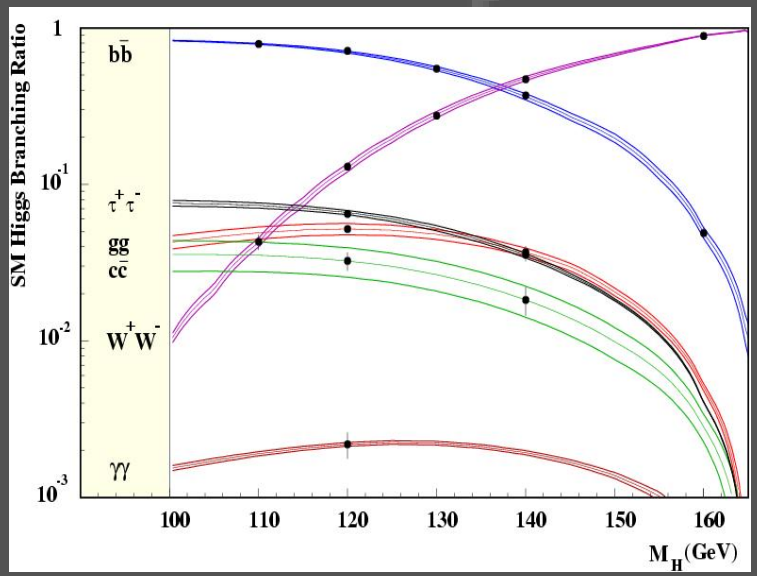


Both contributions added quadratically

Measurement of branching ratios at ILC



- model independent determination of σ_{ZH} from recoil mass in $e^+e^- \rightarrow ZH \rightarrow ll\ X$
- measurment of rate σ_{ZH} x BR (H→xx)
  - i) $e^+e^- \rightarrow ZH \rightarrow ll\ bb$
  - ii) $e^+e^- \rightarrow ZH \rightarrow ll\ WW$
- determination of BR(H→bb) and BR(H→WW)



accuracy on BR determination

m_H (GeV)	ΔBR(*bb*)/BR(*bb*)	ΔBR(WW)/BR(WW)
100	0.024	
120	0.024	0.051
140	0.026	0.025
160	0.065	0.021
200		0.021

(TESLA TDR, 500 fb^{-1})

Determination of g_t

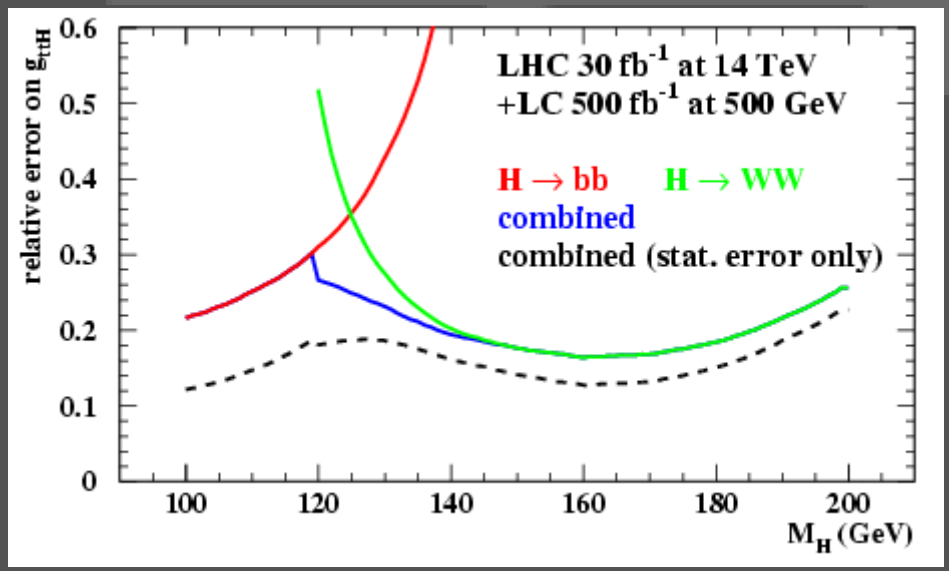
Assume Born level relation: $\sigma \sim g_t^2$

Combination of LHC and ILC

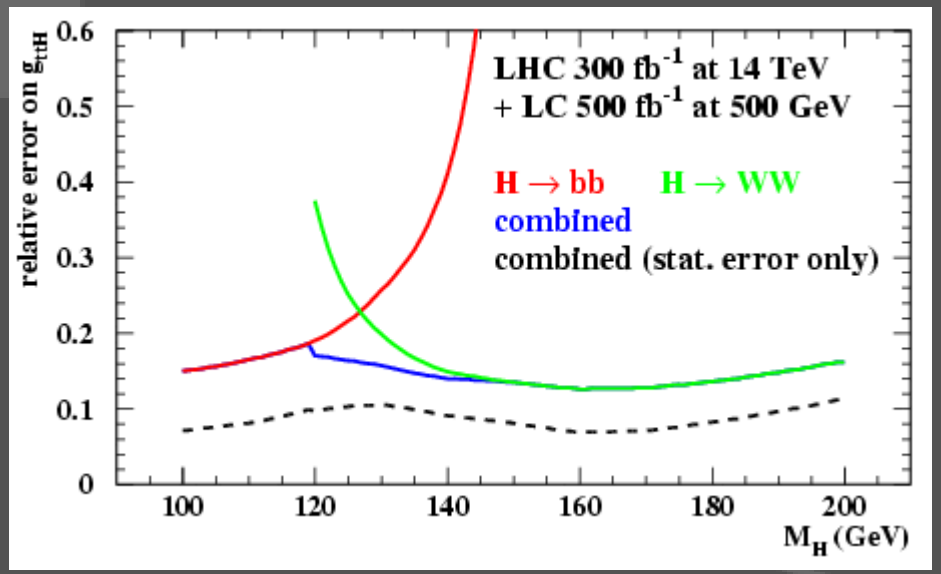
$$\frac{\Delta g_t}{g_t} = \frac{1}{2}\sqrt{\left(\frac{\Delta(g_{ttH}^2 \times BR)}{g_{ttH}^2 \times BR}\right)^2_{LHC} + \left(\frac{\Delta BR}{BR}\right)^2_{ILC}}$$

Combination of H→bb and H→WW

$$\left(\frac{\Delta g_{ttH}}{g_{ttH}}\right)^{-2}_{comb.} = \left(\frac{\Delta g_{ttH}}{g_{ttH}}\right)^{-2}_{WW} + \left(\frac{\Delta g_{ttH}}{g_{ttH}}\right)^{-2}_{b\bar{b}}$$



$\Delta g_t \sim$ 16 to 27 % (12 to 23 %)



$\Delta g_t \sim$ 13 to 17 % (7 to 11 %)

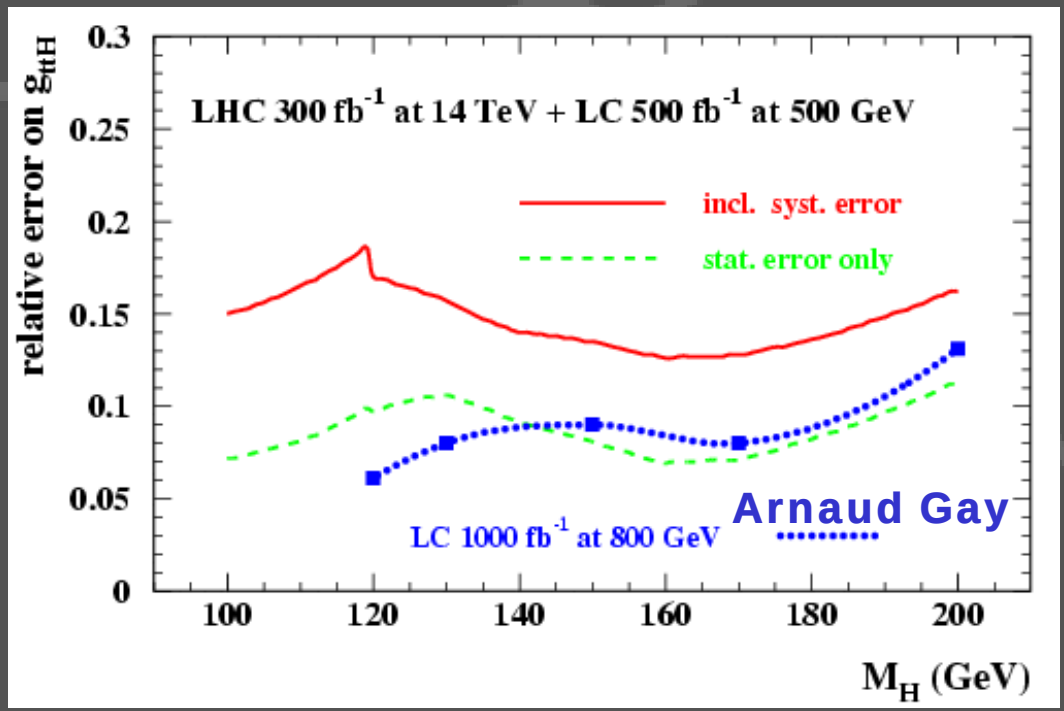
Conclusions

- synergy of LHC and ILC allows model independent determination of top quark Yukawa coupling from combination of data

- expected error on g_t:

  $\Delta g_t / g_t$ = 13 to 17 %

  dominated by systematic uncertainties



More info: hep-ph 0407159

Accuracy in determination of g_t

m_H	30 fb^{-1}			300 fb^{-1}		
(GeV)	bb	WW	bb+WW	bb	WW	bb + WW
100	0.22(0.12)			0.15(0.07)		
110	0.25(0.15)			0.17(0.08)		
120	0.31(0.19)	0.52(0.49)	0.27(0.18)	0.19(0.10)	0.38(0.31)	0.17(0.10)
130	0.43(0.28)	0.28(0.25)	0.23(0.19)	0.26(0.15)	0.20(0.15)	0.16(0.11)
140	0.72(0.50)	0.20(0.17)	0.19(0.16))	0.41(0.26)	0.15(0.10)	0.14(0.09)
150		0.18(0.14)		1.88(1.21)	0.14(0.08)	0.14(0.08)
160		0.16(0.13)			0.13(0.07)	
170		0.17(0.13)			0.13(0.07)	
180		0.18(0.15)			0.14(0.08)	
190		0.22(0.19)			0.15(0.10)	
200		0.26(0.23)			0.16(0.11)	