tth at
500 GeV and
1 TeV

T. Price

Motivation

Signals and
Background

500 GeV
Studies

1 TeV Studies

Towards the
DBD

Conclusions

Precision measurements of the Top Higgs Yukawa Coupling at 500 GeV and 1 TeV at the ILC

T. Price, N. Watson, V. Martin, H. Tabassam, T. Tanabe, R. Yonamine, K. Fujii

International Large Detector

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October 23, 2012

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Overview

Motivation

- Need to understand the origin of EWSB and mass generation
- The ILC will allow precise measurements of the 126 GeV Higgs couplings to the gauge bosons and fermions
- Coupling to fermions

$$g_{ffH} = \frac{m_f}{\nu}$$

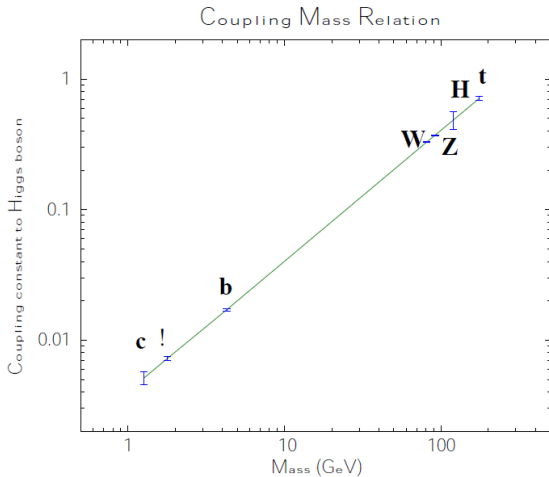- Top quark heaviest fermion so coupling will be greatest
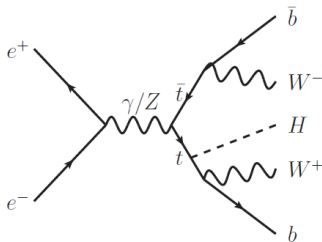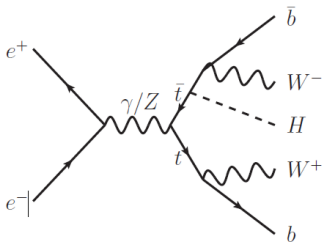
Motivation

Coupling constant of Higgs with mass

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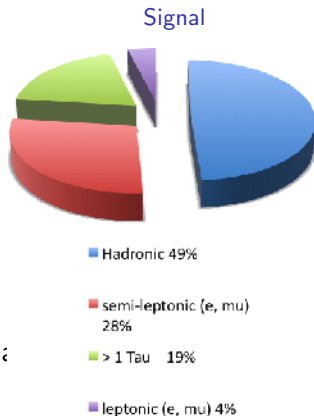Conclusions

Motivation

- $\sqrt{s}$ at the ILC will increase in stages
- Important to evaluate the physics potential at multiple $\sqrt{s}$
- $m_t + m_t + m_{higgs} \approx 470$ GeV
- g_{ffH} measurement is benchmark study for ILD DBD at 1 TeV
- Measurement also possible at 500 GeV due to QCD effects leading to enhancements near production threshold

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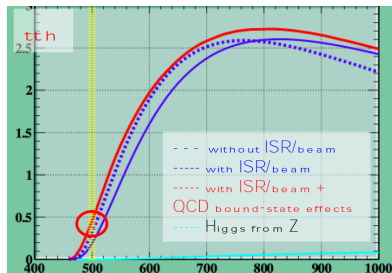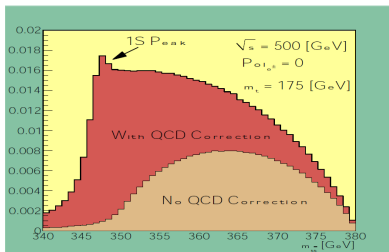
Signal and Backgrounds

Signal

- Study process $e^+e^- \rightarrow ttH$
- Multiple final states
- Assume 100 % t→bW
- $W \rightarrow q\bar{q}, l\nu$
- $H \rightarrow b\bar{b}, WW, \gamma\gamma, ZZ$
- $M_H \approx 126 \; GeV \quad H \rightarrow b\bar{b}$ domin[a]
- Leads to 3 possible states
  - $e^+e^- \rightarrow bq\bar{q} \; \bar{b}q\bar{q} \; b\bar{b}$ (hadronic)
  - $e^+e^- \rightarrow bl\nu \; \bar{b}q\bar{q} \; b\bar{b}$ (semi lep)
  - $e^+e^- \rightarrow bl\nu \; \bar{b}l\nu \; b\bar{b}$ (leptonic)

- Hadronic 49%
- semi-leptonic (e, mu) 28%
- > 1 Tau 19%
- leptonic (e, mu) 4%

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Signal and Backgrounds
Signal

Hadronic

- 8 Jet final state
- 4 b-jets
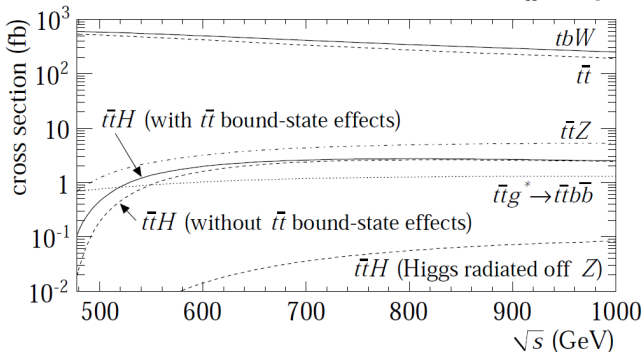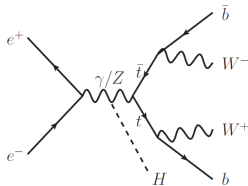- Reconstructed masses $M_{jj}=M_W\times2$, $M_{jjj}=M_t\times2$, $M_{jj}=M_H$

Semi Leptonic

- 6 Jet final state
- 4 b-jets
- Isolated lepton
- Missing energy and momentum (neutrino)
- Reconstructed masses $M_{l\nu}=M_W=M_{jj}$, $M_{l\nu j}=M_t=M_{jjj}$, $M_{jj}=M_H$

Signal and Backgrounds

Backgrounds

- Main backgrounds to this channel are
  - $e^+e^- \rightarrow t\bar{t}b\bar{b}$
  - $e^+e^- \rightarrow t\bar{t}Z$
  - $e^+e^- \rightarrow t\bar{t}$
- Smaller backgrounds from
  - $H \nrightarrow b\bar{b}$
  - H radiated from Z

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Signal and Backgrounds
Event Selection

Reduce background by selecting events on the following criteria

- No. Isolated Leptons
- No. reconstructed PFOs
- Thrust of event
- Durham jet resolution parameters Y_{ij}
- Btag values of b-jets 3 and 4
- Reconstructed Masses

The tools to do this available within iLCSoft
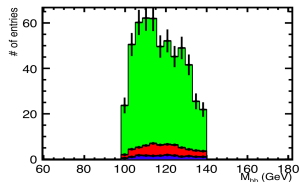
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Top Yukawa Coupling @ 500 GeV

- ILD full simulation studies based on LOI tools
  - ILD_00 Geometry
  - Flavour tagging $\rightarrow$ LCFIVertex

  Work has been completed by two subgroups

H. Tabassam, V. Martin

- Semi Leptonic

- Unpolarised beam

- $L = 1000$ fb^{-1}

- Cut based method

R. Yonamine, T. Tanabe, K. Fujii

- Semi Leptonic + Hadronic

- e^+ +0.3, e^- -0.8

- $L = 1000$ fb^{-1}

- Cut based method + Likelihood

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Top Yukawa Coupling @ 500 GeV
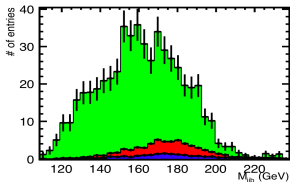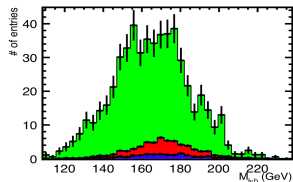
H. Tabassam, V.Martin

Final scaled distributions of top masses and Higgs
mass after all cuts have been applied
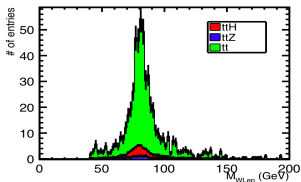
Top Yukawa Coupling @ 500 GeV

H. Tabassam, V.Martin

Final State	ϵ_{sel} %	σ_{eff} (fb)
ttH	7.57 ± 0.19	0.04
tt	0.11 ± 0.00	0.29
ttZ	2.76 ± 0.12	0.02

Efficiency and effective cross-sections for signal and background

Parameter	value (%)
$\frac{\Delta\sigma_{eff}^{BG}}{\sigma_{eff}^{BG}}$	5
ϵ_{sel}	7.6 ± 0.2
ρ_{sample}^{sel}	12.5 ± 0.3
$\left(\frac{\Delta g_{ttH}}{g_{ttH}}\right)_{stat}$	21.6
$\left(\frac{\Delta g_{ttH}}{g_{ttH}}\right)_{syst}$	17.6
$\left(\frac{\Delta g_{ttH}}{g_{ttH}}\right)$	27.9

For semi leptonic mode with unpolarised beams can measure g_{ttH} to 27.9 %

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Top Yukawa Coupling @ 500 GeV

R. Yonamine, T. Tanabe, K. Fujii

Cut based
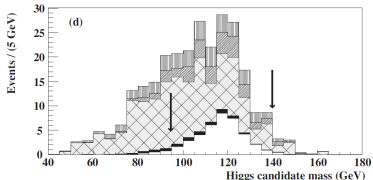
Likelihood

M_H for the 6 jet + lepton
after selection cuts
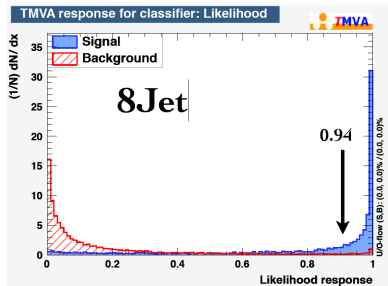
TMVA response for signal
selection for 8 jet

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Top Yukawa Coupling @ 500 GeV

R. Yonamine, T. Tanabe, K. Fujii

6 jet + lep	tth (6J+L)	bb4f	ttZ	ttbb	Sig
No Selection	246	9.09×10^5	1910	1060	
Cut-based	32	39	21	15	3.1
Likelihood	39	58	29	22	3.2

Semi Leptonic [E_{CM}=500 GeV, L=1 ab^{-1}, Pol=(-0.8,+0.3)]

8 jet	tth (8J)	bb4f	ttZ	ttbb	Sig
No Selection	235	9.09×10^5	1910	1060	
Cut-based	38	41	25	16	3.5
Likelihood	78	241	63	46	3.8

Hadronic [E_{CM}=500 GeV, L=1 ab^{-1}, Pol=(-0.8,+0.3)]

| 6 jet & 8 jet modes	Combined Sig	$\left(\frac{\Delta g_{ttH}}{g_{ttH}} \right)_{stat}$
Cut-based	4.7	11 %
Likelihood	5.0	10 %

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Top Yukawa Coupling @ 1 TeV

T. Price, N. Watson, V. Martin

- Benchmark for ILD DBD
- Updated tools to represent this
  - PandoraPFA→PandoraPFANew
  - LCFIVertex→LCFIPlus
  - Tracking re-written
  - Updated Simulation and Reconstruction tools

Samples

Samples created using official stdhep files whilst waiting for Central Samples. Results shown are using my samples.

- iLCSoft v01-13-05
- MOKKA v07-07-07
- Reconstructed with v01-15-03-p00
- Polarisation $e^+ = $ -1.0, $e^- = +1.0$
- No $\gamma\gamma \to$hadrons background

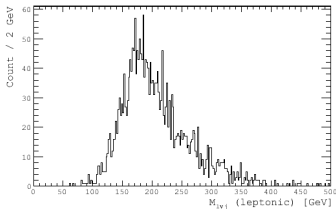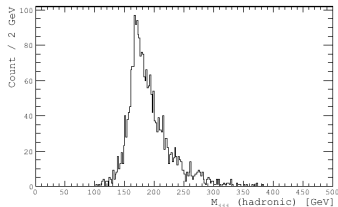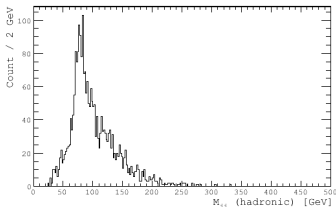# Top Yukawa Coupling @ 1 TeV

T. Price, N. Watson, V. Martin
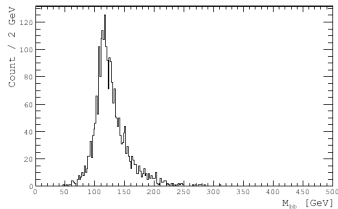
$$\chi^2 = \frac{(M_{bb} - M_H)^2}{\sigma_{bb}^2} + \frac{(M_{bjj} - M_t)^2}{\sigma_{bjj}^2} + \frac{(M_{bl\nu} - M_t)^2}{\sigma_{bl\nu}^2}$$
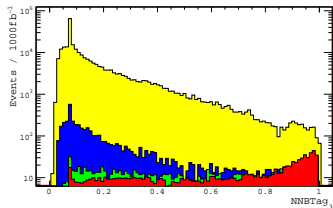
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Top Yukawa Coupling @ 1 TeV

T. Price, N. Watson, V. Martin
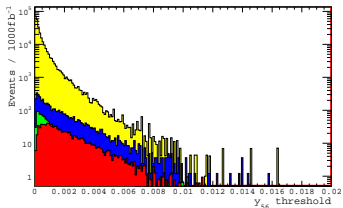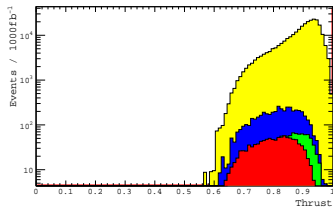
Selected cut variables before any cuts have been applied
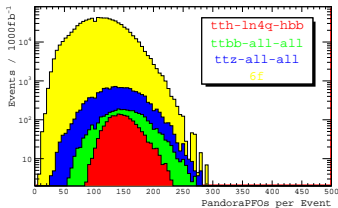
Top Yukawa Coupling @ 1 TeV

T. Price, N. Watson, V. Martin

| Cut	tth	ttz	ttbb	6f	ϵ_{sel}	Sig
Total Events	1734	14021	3429	808312	1	1.9
IsoLep=1	1066	4660	1178	274486	0.62	2.0
nPFOs	832	2399	707	46679	0.48	3.7
Thrust	686	1909	462	20594	0.40	4.5
Y_{56}	636	1769	407	16761	0.37	4.5
BTag	391	293	204	793	0.23	9.5
χ^2	390	291	202	791	0.23	9.5
M_H	371	253	183	672	0.21	9.6

$$\left(\frac{\Delta g_{ttH}}{g_{ttH}}\right)_{stat} = 5.2\ \% \qquad\qquad \left(\frac{\Delta g_{ttH}}{g_{ttH}}\right)_{syst} = 7.6\ \%$$

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Towards the DBD
Simulation and Reconstruction

- Simulations use iLCSoft v01-14-01
- Reconstruction uses v01-16-p03
- Reconstruction of all samples running now
- Run analysis at $e^+ = +0.2$, $e^- = -0.8$
- $\gamma\gamma \rightarrow$ hadrons now included
- Add H$\nrightarrow$bb and 8J backgrounds
- Complete 8J background to combine results
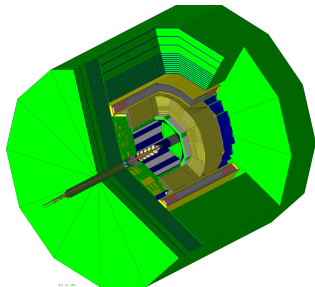
ILD_o1_v05

All the tools setup, Reconstruction running now

Conclusions

500 GeV

- $\left(\frac{\Delta g_{ttH}}{g_{ttH}}\right)_{stat} = 21.6$ % for semi leptonic mode and unpolarised beams

- $\left(\frac{\Delta g_{ttH}}{g_{ttH}}\right)_{stat} = 10.0$ % combined for e^+ +0.3, e^- -0.8 with likelihood

1 TeV

- Tools there which allow good reconstruction of semi leptonic mode

- $\left(\frac{\Delta g_{ttH}}{g_{ttH}}\right)_{stat} = 5.2$ % for semi leptonic mode and fully polarised beams

- Simulations for DBD complete

- Reconstruction for DBD almost complete

- DBD benchmark to be completed within a few weeks