# Top Higgs Yukawa Coupling Analysis – Status Report

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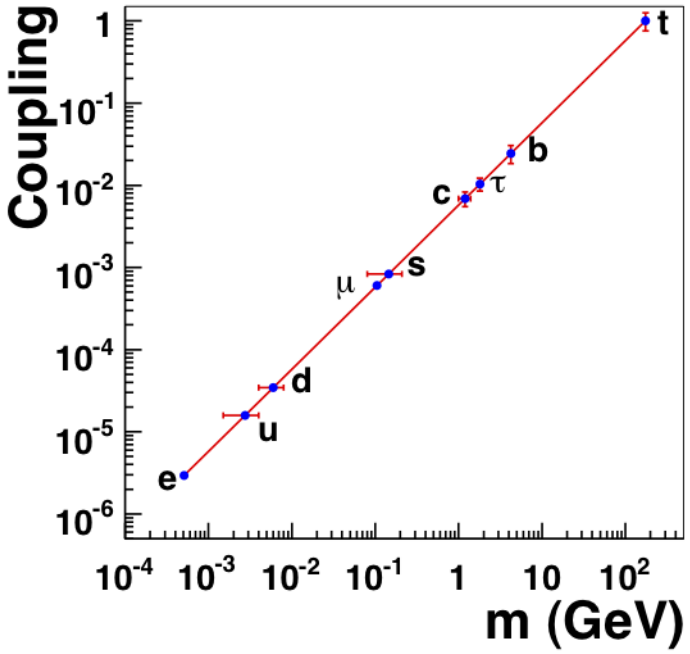
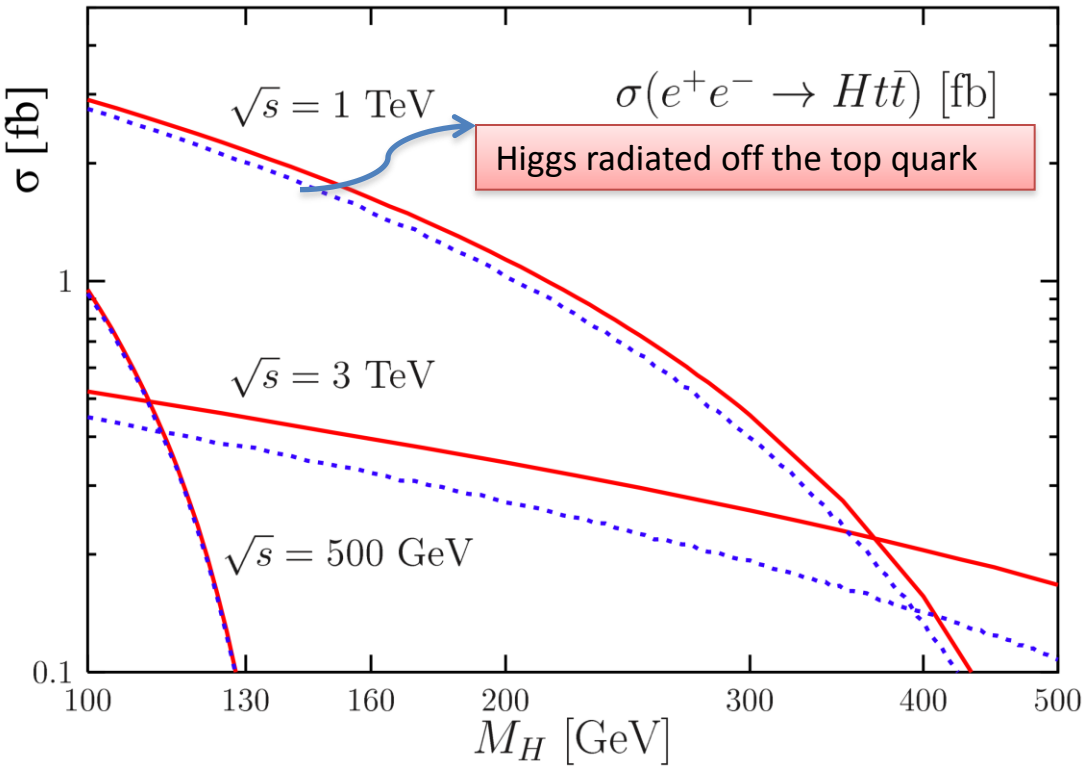
# Motivation

- Discovery of Higgs at LHC
- Investigation of Higgs boson profile starts at LHC and continue with higher precision at ILC
  - Mass
  - Spin, charge and parity
  - BRs, total width, coupling
  - Self coupling
- Coupling can be done with precision at ILC.
  - precision test of the Higgs sector of the SM
  - Will show largest deviations to new physics (SUSY, ED, Little H, TC)



# Top Yukawa coupling at ILC

- The production cross section for associated Higgs boson with $t\bar{t}$ pair at √s = 0.5, 1 and 3 TeV.
- 500 GeV is the threshold energy so interesting to study.
- 1 TeV is the energy with higher cross section



# Signal and Background Processes

- $e^+ e^- \rightarrow \bar{t}\, tH \rightarrow \bar{b}W^- bW^+ \bar{b}\, b$
- Three channels corresponding to the W decay.
  - Leptonic ~ 4%
  - Semi-leptonic ~ 28%
  - Hadronic ~ 49%
- Higgs Strahlung has small contribution so negligible
- $\bar{t}$ tZ: very close to the signal in cross section
- $\bar{t}$ t: very large cross section and often mimic signal

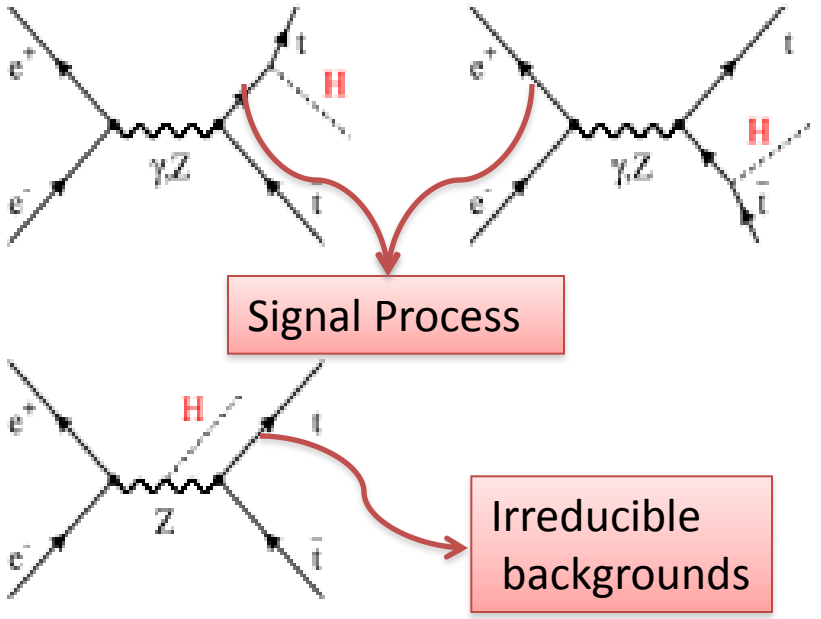


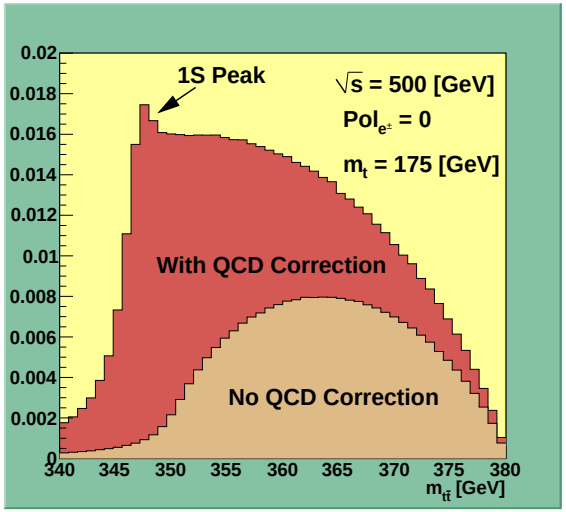

Fig. 1. Lowest order Feynman diagrams of the process $e^+e^- \rightarrow ttH$

# Past Work for ILC

# Fast simulation Results

[PRD 84, 014033 (2011)]

differential cross section of tth with respect to ttbar invariant mass




- Given:
  - $\sqrt{s}$ = 500 GeV
  - L = 1000 fb$^{-1}$
- The fast simulation study showed that $g_t$ can be measured to approx. 10% (stat.).

| Polarization (e-,e+) | 6 Jet + Lepton $S/\sqrt{(S+B)}$ | 8 Jet $S/\sqrt{(S+B)}$ | Combined Significance | Combined $\Delta g_t / g_t$ |
|---|---|---|---|---|
| (±0.0, ±0.0) | 3.50 | 2.59 | 4.35 | 11.5 |
| (-0.8, +0.3) | 4.55 | 3.35 | 5.65 | 8.8 |

(stat. error only)

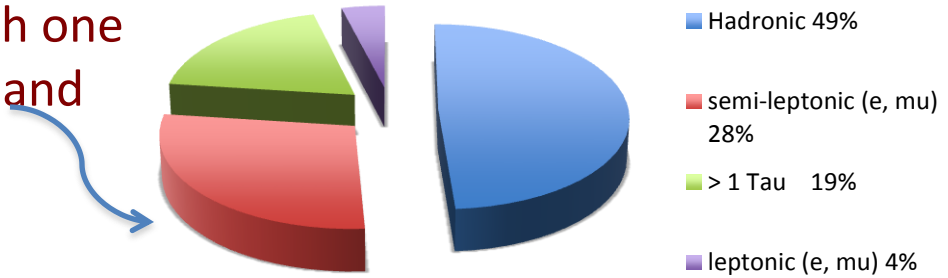
R. Yonamine (Sokendai), T. Tanabe (Tokyo), K. Ikematsu, K. Fujii, Y. Kiyo (KEK), Y. Sumino (Tohoku), S. U ozumi (KNU), H. Yokoya (CERN)

# Top Higgs Yukawa Coupling Measurements for $L = 1000\ fb^{-1}$, $\sqrt{s} = 500\ GeV$

**H. Tabassam, V. Martin**

$e^+ e^- \rightarrow \bar{t}\, tH \rightarrow \bar{b} W^- b W^+ \bar{b}\, b$

Focus on semi-leptonic final state with one W decaying into lepton and neutrino and other W decaying into light jets

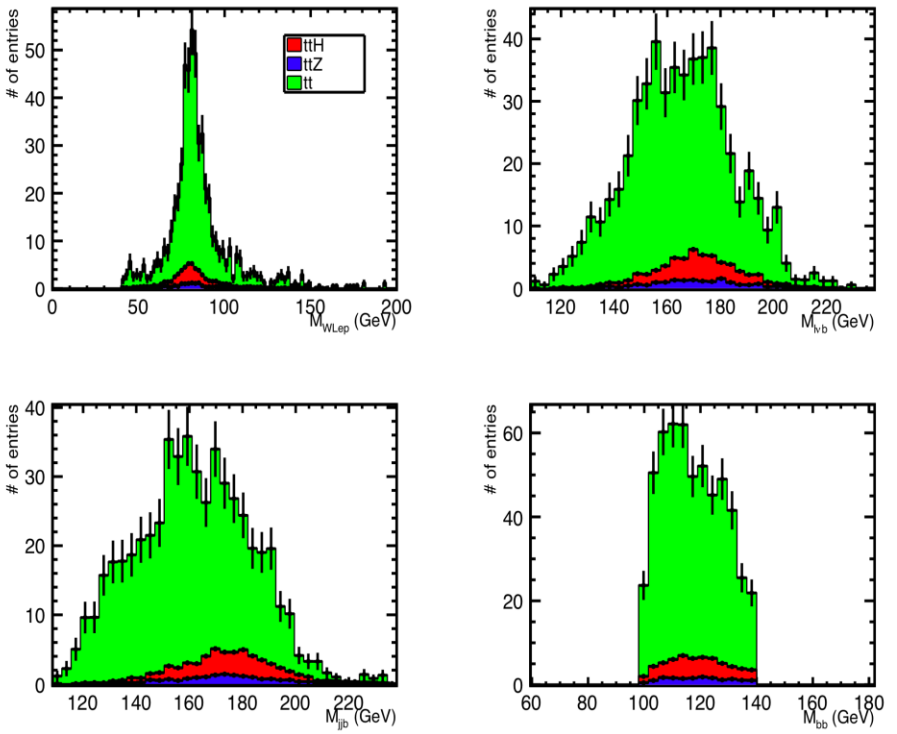



- Identified leptons are removed from the sample
- remaining particles are forced into 6 Jets using JetFinder algorithm
- Jets pass LCFIVertex reconstruction [arXiv:0908.3019v1]
- LCFI flavour tagging is used to separate light and b-jets
- Jets are sorted in descending order of b-tag value
- top four jets with highest b-tag value are selected as b-jets
- Light jets are used to reconstruct hadronic W
- Some selection variables used for background separation are:
  - Energy and momentum of reconstructed lepton, jets and missing energy
  - B-tag of 3rd and 4th jets, chisq

# Top Higgs Yukawa Coupling Measurements for $L = 1000\ fb^{-1}$, $\sqrt{s} = 500$ GeV

**H. Tabassam, V. Martin**

Final scaled distributions for Higgs and top masses after applying cuts on all selection variables




The efficiency and effective cross section for signal ($\bar{t}\,tH$) and background ($\bar{t}\,tZ$, $\bar{t}\,t$)

| Final State | $\epsilon_{sel}$ (%) | $\sigma_{eff}$ (fb$^{-1}$) |
|---|---|---|
| $t\bar{t}H$ | $7.57 \pm 0.19$ | 0.04 |
| $t\bar{t}$ | $0.11 \pm 0.00$ | 0.29 |
| $t\bar{t}Z$ | $2.76 \pm 0.12$ | 0.02 |

RESULTS:

For $L = 1000\ fb^{-1}$, $\sqrt{s}$=500 GeV,the measured uncertainty in the top-Higgs-Yukawa coupling is 27.9%

| Parameter | value (%) |
|---|---|
| $\frac{\Delta\sigma_{eff}^{BG}}{\sigma_{eff}^{BG}}$ | 5 |
| $\epsilon_{sel}$ | $7.6 \pm 0.2$ |
| $\rho_{sample}^{sel}$ | $12.5 \pm 0.3$ |
| $\left(\frac{\Delta g_{t\bar{t}H}}{g_{t\bar{t}H}}\right)_{stat}$ | 21.6 |
| $\left(\frac{\Delta g_{t\bar{t}H}}{g_{t\bar{t}H}}\right)_{syst}$ | 17.6 |
| $\frac{\Delta g_{t\bar{t}H}}{g_{t\bar{t}H}}$ | 27.9 |

# Current Work

# Strategy

- Looking at tth events with $m_H$ = 120 GeV/c2, √s = 500 GeV and 1 TeV.
- $e^+ e^- \rightarrow \bar{t}\, tH \rightarrow \bar{b}W^- bW^+ \bar{b}\, b$
- Currently samples are generated with
  - iLCSOft v01-13-05,, and
  - geant4.9.5
  - ILDConfig v00-02
- Mass production sample will be used as soon as available
- Different parts of the analysis are being studied at different places, with the aim of combining them for DBD. Some of our results are presented here.

# Update for Semi-leptonic channel at

## √s = 1 TeV [Tony price, Victoria Martin]

- Simulated and reconstructed 10k events of the signal and
- $e^+ e^- \rightarrow \bar{t}\, tH \rightarrow \bar{b}W^- bW^+ \bar{b}\, b$
- Focus on semi-leptonic final state with one W decaying into lepton and neutrino and other W decaying into light jets
- Final state is 1 lepton, missing energy, 6 Jets with 4 b-jets
- Isolating leptons from the sample.
- Remove the leptons and force remaining particles into 6-jets (JetFinder Algorithm)
- High momentum Lepton and large missing momentum signature
- In the process of optimising cuts to reduce background.

# Update for Hadronic channel at

## √s = 1 TeV [H. Tabassam, Victoria Martin]

- $e^+ e^- \rightarrow \bar{t}\, tH \rightarrow \bar{b}W^- bW^+ \bar{b}\, b \rightarrow \bar{b}2j\, b2j\, \bar{b}\, b$
- This channel has 4 light and 4 b-jets in final state with 8 jets in total
- Final state is more crowded
- We will have more combinations
- Four b-jets are used to reconstruct two tops and Higgs particle
- To reduce combinatorial backgrounds, minimisation of $\chi^2$ technique will be used

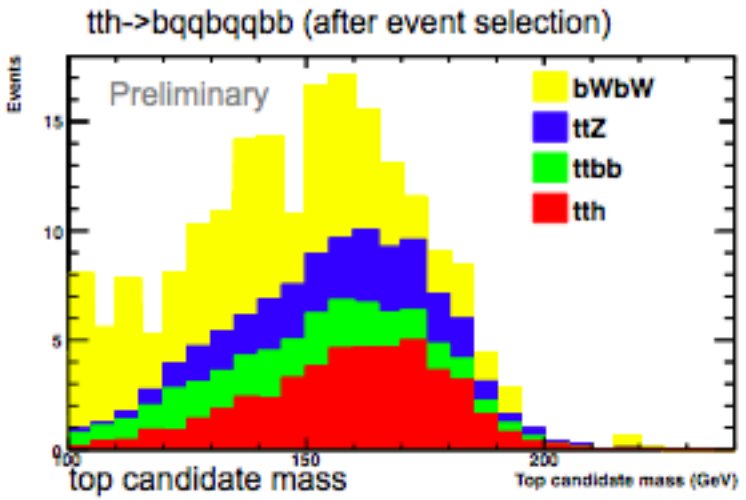
$$\chi^2 = \frac{(m_{2j} - M_H)^2}{\sigma_H^2} + \frac{(m_{2j} - M_{W_1})^2}{\sigma_{W_1}^2} + \frac{(m_{3j} - M_{t_1})^2}{\sigma_{t_1}^2} + \left\{ \frac{(m_{2j} - M_{W_2})^2}{\sigma_{W_2}^2} + \frac{(m_{3j} - M_{t_2})^2}{\sigma_{t_2}^2} \right\}_{8j}$$

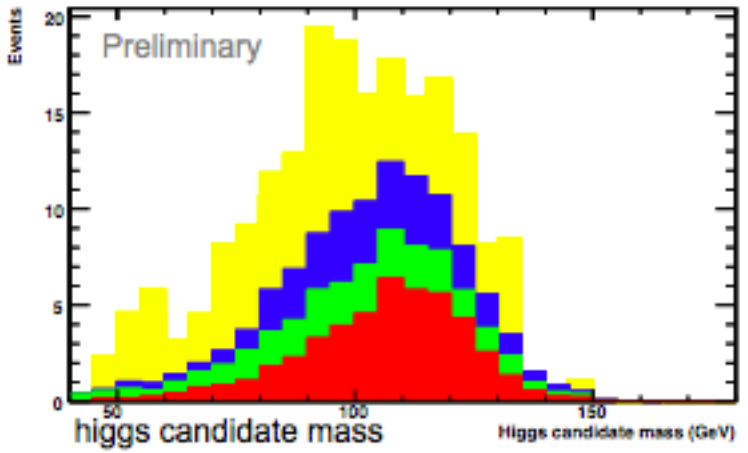
- A number of selection variables will be used to separate the signal and background e.g energy and momentum of the reconstructed particles, b-tags information, mass cuts.

# Current Top Yukawa coupling study at √s = 500 GeV

**[R. Yonamine, T. Tanabe, K. Fujii]**

- Full simulation study has been started.
- Some differences:
  - Event generators (tth & ttZ) include the non-relativistic QCD effects on an event-by-event basis.
  - Include tth->bqqbqqbb final state.
  - Include background of ttbar with a hard gluon from the top (ttbb)
- Event reconstruction based on
  - Isolated lepton finding/veto, event shape, jet clustering, b-tagging, mass reconstruction through jet combination.
- tth->bqqbqqbb after event selection (lumi = $1ab^{-1}$, polarized beams)
  - Signal yield: 29
  - Background: 33(ttbar), 24(ttZ), 24(ttbb)
  - Significance ~2.9 (stat.)



# Summary/Future Plans

- We are starting to develop a strategy for our analysis.
- We intend to keep working on this analysis, and we are collaborating to get reasonable results for DBD.
- √s = 500 GeV and 1 TeV are currently being studied
- Once the centrally reconstructed samples are ready, will employ them for the study.