The ILC Higgs White Paper

Tim Barklow (SLAC)

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ILC Higgs White Paper

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General ILC Intro

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circa Summer 2013

Luminosity based on ILC TDR

Many New Post-DBD Studies

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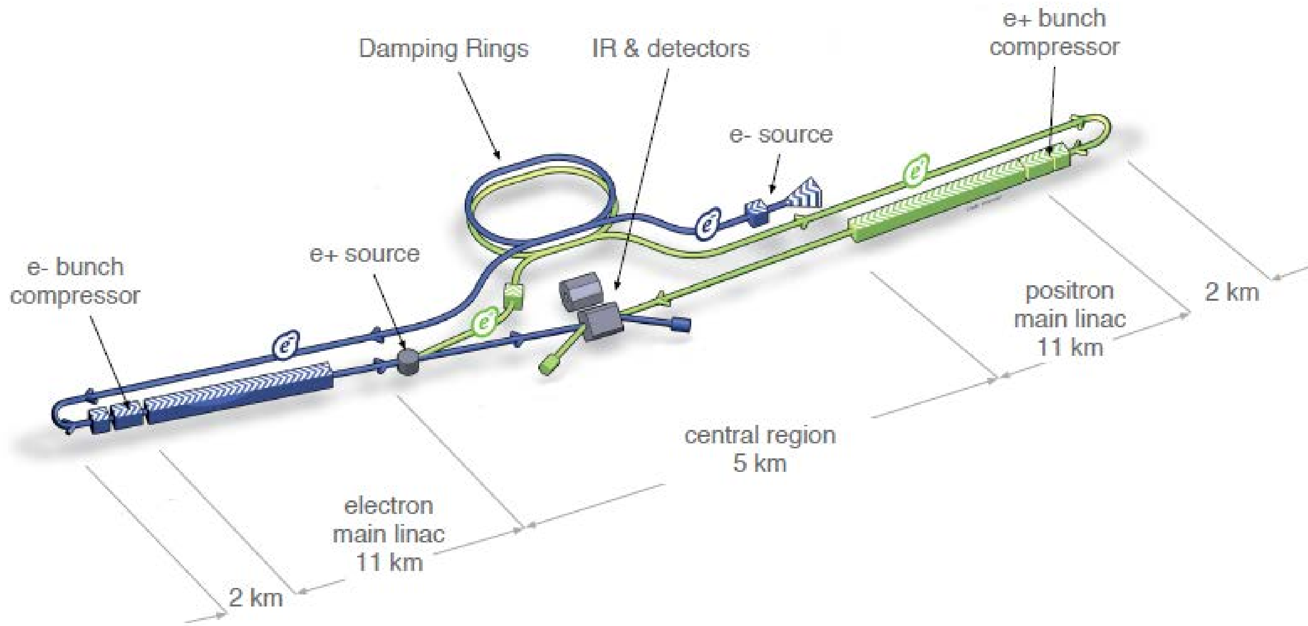
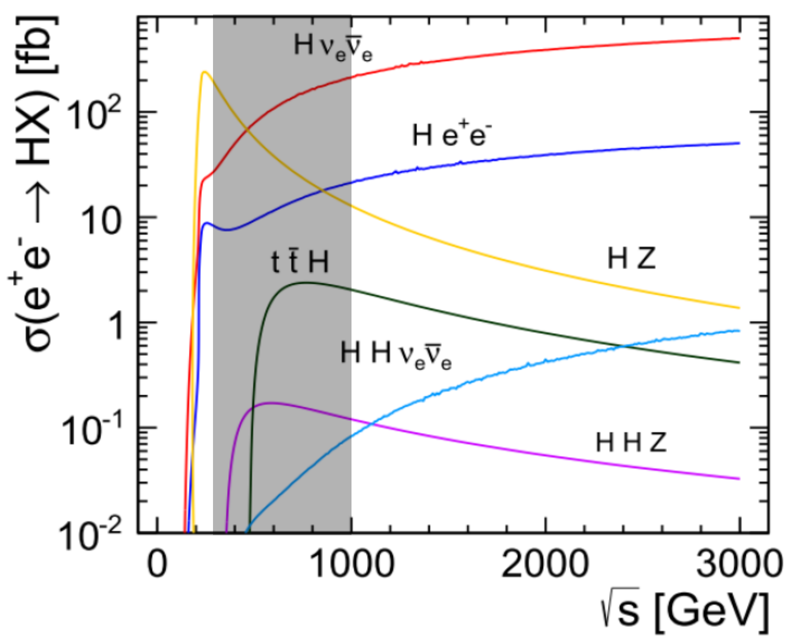
ILC : e^+e^- Linear Collider at 250 GeV < $\sqrt{s}$ < 1000 GeV





Energy/Lumi Scenarios for White Paper

- Each scenario corresponds to accumulated luminosity at a certain point in time.
- Assumption: run for $3X10^7$ s at baseline lumi at each of Ecm=250,500,1000 GeV, in that order. Then go back and run for $3X10^7$ s at upgrade lumi at each of Ecm=250,500,1000 GeV.

Nickname	Ecm(1) (GeV)	Lumi(1) (fb^{-1})	+	Ecm(2) (GeV)	Lumi(2) (fb^{-1})	+	Ecm(3) (GeV)	Lumi(3) (fb^{-1})	Runtime (yr)	Wallplug E (MW-yr)
ILC(250)	250	250							1.1	130
ILC(500)	250	250		500	500				2.0	270
ILC(1000)	250	250		500	500		1000	1000	2.9	540
ILC(LumUp)	250	1150		500	1600		1000	2500	5.8	1220

b-tag efficiency study

for White Paper,

T. Suehara ,Tohoku Univ. &

T. Tanabe, Univ Tokyo

Table 2.6. Expected b-tagging uncertainties at various selection efficiencies.

Efficiency	Uncertainty
80%	0.46%
70%	0.53%
60%	0.57%
50%	0.58%

Table 2.7. Summary of selection for the fake rate measurement. Here the b tag selection is such that one of the two jets will pass the b tag requirement at the specified efficiency.

Process	Before selection	After selection	b tag ($\epsilon_b = 80\%$)	b tag ($\epsilon_b = 50\%$)
$WW \to \ell\nu cs$	1.3×10^6	1.3×10^5 (10%)	11310 (8.7%)	234 (0.18%)
$WW \to \ell\nu ud$	1.3×10^6	1.3×10^5 (10%)	2080 (1.6%)	130 (0.1%)
$ZZ \to \tau\tau b\bar{b}$	8500	85 (1%)	82 (96%)	64 (75%)

Table 2.8. Systematic errors assumed throughout the paper.

	Baseline	LumUp
luminosity	0.1%	0.05%
polarization	0.1%	0.05%
b-tag efficiency	0.3%	0.15%

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ILC model independent global coupling fit using 32 $\sigma \bullet BR$ measurements Y_i and σ_{ZH} measurement Y_{33}

$$\chi^2 = \sum_{i=1}^{i=33} \left(\frac{Y_i - Y_i'}{\Delta Y_i}\right)^2 ,$$

$$Y_i' = F_i \cdot \frac{g^2_{HZZ} g^2_{Hb\bar{b}}}{\Gamma_0}, \text{ or } Y_i' = F_i \cdot \frac{g^2_{HWW} g^2_{Hb\bar{b}}}{\Gamma_0}, \text{ or } Y_i' = F_i \cdot \frac{g^2_{Htt} g^2_{Hb\bar{b}}}{\Gamma_0}$$

$$F_i = S_i G_i \quad \text{where } S_i = \left(\frac{\sigma_{ZH}}{g^2_Z}\right), \ \left(\frac{\sigma_{\nu\bar{\nu}H}}{g^2_W}\right), \text{ or } \left(\frac{\sigma_{t\bar{t}H}}{g^2_t}\right), \text{ and } G_i = \left(\frac{\Gamma_i}{g^2_i}\right).$$

The cross section calculations S_i do not involve QCD ISR.

The partial width calculations G_i do not require quark masses as input.

We are confident that the total theory errors for S_i and G_i will be at the 0.1% level at the time of ILC running.

$\sigma(e^+e^- \to ZH)$ at ILC

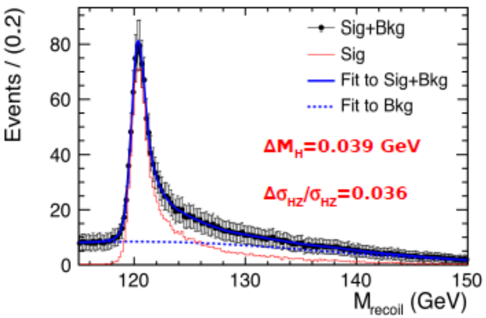
- Almost all ILC Higgs measurements are measurements of $\sigma \bullet BR$.
- One crucial measurement is different: the Higgs recoil measurement of $\sigma(e^+e^- \to ZH)$.
- σ_{ZH} is the key that unlocks the door to model independent measurements of the Higgs BR's and Γ_{tot} at the ILC.

$$\sqrt{s} = 250 \text{ GeV}$$

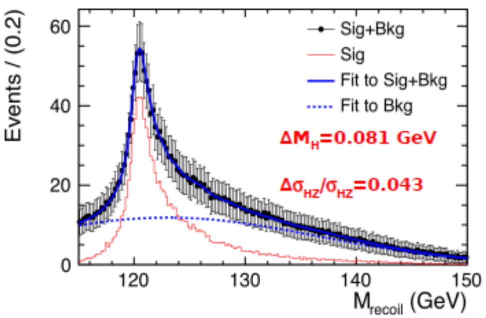
ILD & SiD LOI

& new M_H=125 GeV study by

S. Watanuki, Tohoku Univ.

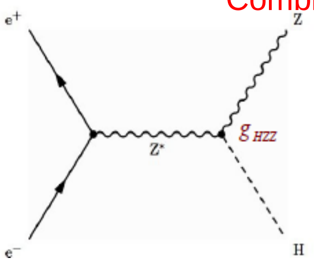


Very Precise Measurement
S/B = 8 in Peak Region



Less Precise
Bremsstrahlung in detector material

Combined: $\Delta M_H = .032$ GeV, $\Delta\sigma_{HZ} / \sigma_{HZ}$=2.6% for L= 250 fb^{-1}



$\sigma_{HZ} \sim g_{HZZ}^2$

$\Rightarrow \Delta g_{HZZ} / g_{HZZ} = 1.3\%$ for L=250 fb^{-1}

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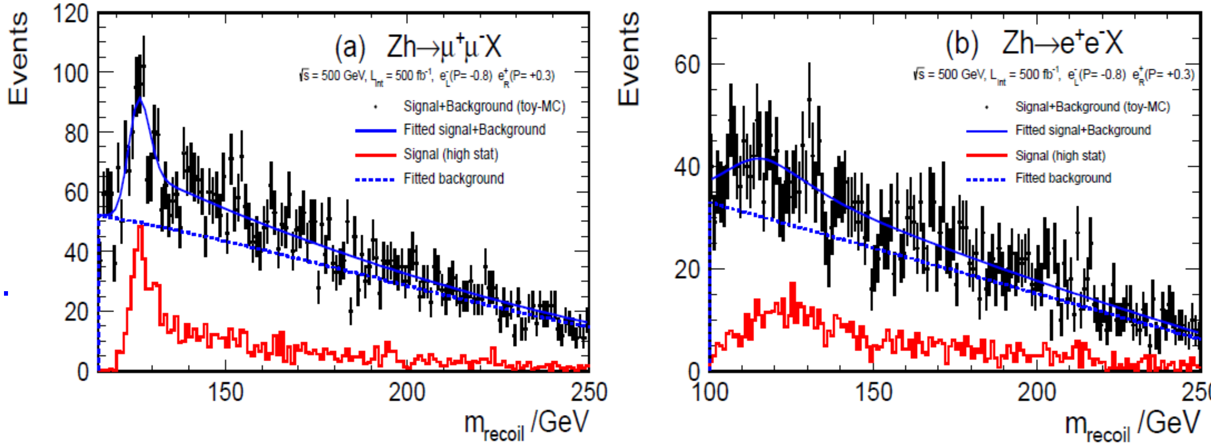
$\sigma(e^+e^- \to ZH)$: New Analyses at $\sqrt{s} = 500$ GeV

$ZH \to l^+l^-X$

$\Delta\sigma/\sigma = 4.8\%$

for 500 fb^{-1}

T. Suehara, Tohoku Univ.

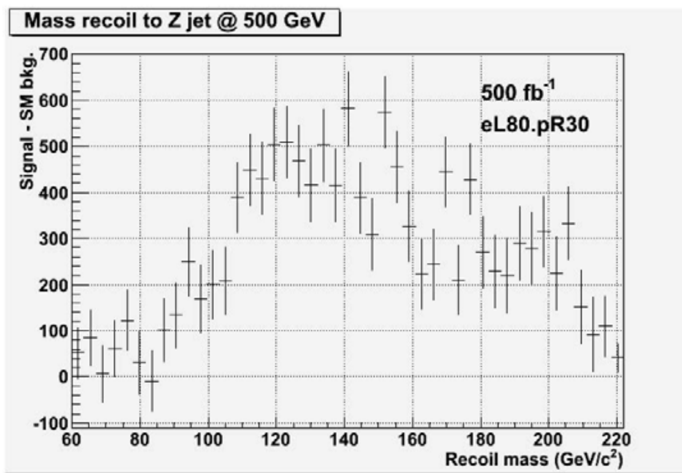


$ZH \to q\bar{q}X$

$\Delta\sigma/\sigma = 3.9\%$

for 500 fb^{-1}

A. Miyamoto, KEK

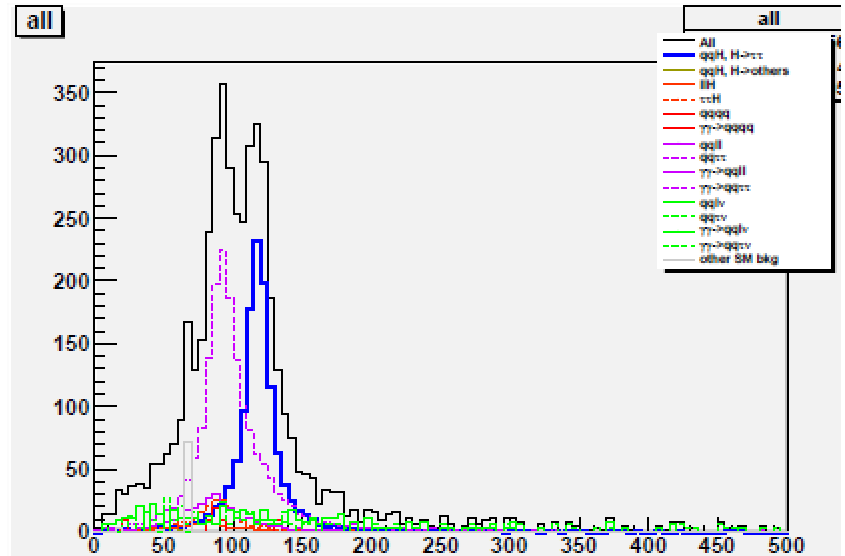


Combining all channels for 500 fb^{-1} at $\sqrt{s} = 500$ GeV: $\Delta\sigma(e^+e^- \to ZH)/\sigma(e^+e^- \to ZH) = 3.0\%$

Combining 250 fb^{-1} at $\sqrt{s} = 250$ GeV & 500 fb^{-1} at $\sqrt{s} = 500$ GeV: $\Delta\sigma(e^+e^- \to ZH)/\sigma(e^+e^- \to ZH) = 2.0\%$

$\sigma \bullet BR(H \to \tau^+\tau^-)$: New Analysis at $\sqrt{s} = 250$ GeV

$ZH \to q\bar{q}\tau^+\tau^-$



$M_{\tau^+\tau^-}(collinear\ \ approx)$ (GeV)

$H \to \tau^+\tau^-$

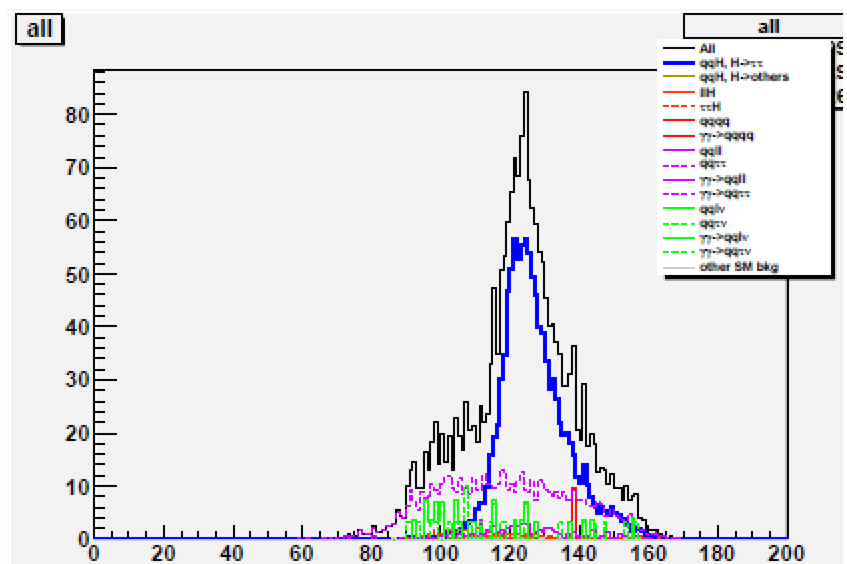
$\Delta\sigma \bullet B / \sigma \bullet B = 4.2\%$

for 250 fb^{-1} @ $\sqrt{s} = 250$ GeV

S. Kawada & T. Takahashi (Hiroshima Univ)

K. Fujii (KEK)

T. Suehara & T. Tanabe (Univ Tokyo)



$M(recoil)$ (GeV)

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$\sigma \bullet BR(H \to b\bar{b})$: New Analysis at $\sqrt{s} = 500$ GeV

$H \to b\bar{b}$

$\Delta\sigma \bullet B / \sigma \bullet B = 0.7\%$

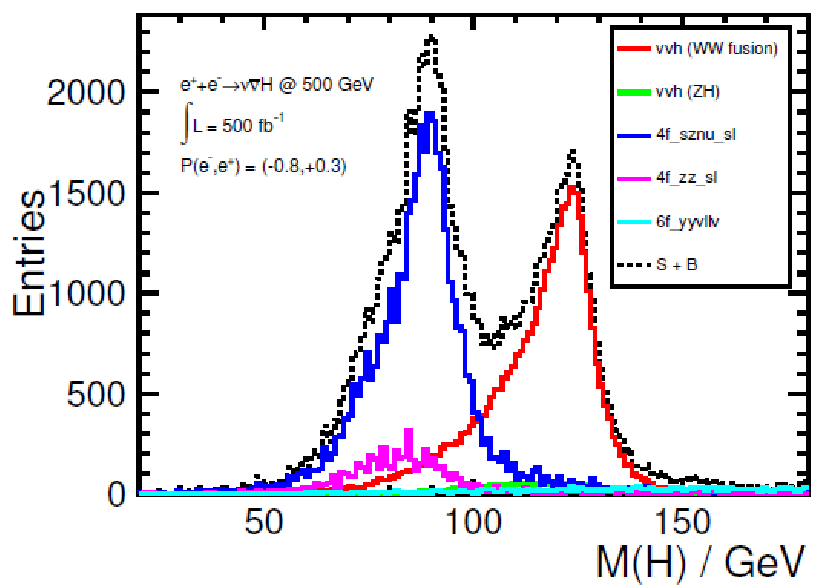
for 500 fb^{-1} @ $\sqrt{s} = 500$ GeV

J.Tian & K. Fujii (KEK)

C. Dürig & J. List (DESY)

TABLE II: The reduction table for signal and backgrounds in the analysis of $\nu\bar{\nu}H \to \nu\bar{\nu}b\bar{b}$ at 500 GeV. The cut names are explained in text. $\nu\bar{\nu}H$ has two types, one of signal WW-fusion process, the other from ZH process. The number of signal events after Cut5 in the parenthesis is for $H \to b\bar{b}$.

Process	expected	pre-selection	Cut1	Cut2	Cut3	Cut4	Cut5
$\nu\bar{\nu}H$(fusion)	7.47×10^4	59698	54529	54048	35598	34278	299199 (28598)
$\nu\bar{\nu}H(ZH)$	1.02×10^4	7839	7301	7224	4863	1951	1512
4f_sznu_sl	2.79×10^5	234259	203489	202977	44943	39125	3957
4f_sw_sl	2.43×10^6	228436	135164	121791	1495	911	132
4f_zz_sl	1.83×10^5	102172	60684	59865	13036	5736	461
4f_ww_sl	2.78×10^6	653997	287428	250944	3851	1145	176
4f_sze_sl	9.41×10^5	65011	1311	1259	91.1	40.7	5.51
6f_yyveev	6.05×10^3	931	306	104	96.6	87.4	20.4
6f_yyvelv	2.37×10^4	5450	2425	1116	997	907	237
6f_yyvllv	2.36×10^4	8009	4272	2813	2556	2383	674
BG	6.68×10^6	1.31×10^6	702379	648094	71929	52285	7176
significance	16.6	35.0	43.3	44.6	106	114	150



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$\sigma \bullet BR(H \to WW^*)$:   New Analysis at $\sqrt{s} = 500$ GeV

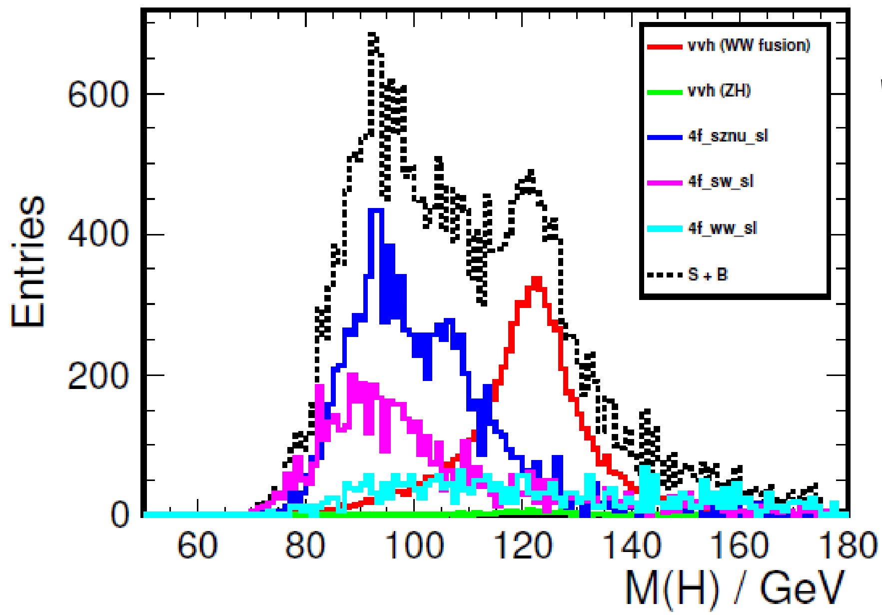
$H \to WW^*$

$\Delta\sigma \bullet B / \sigma \bullet B = 2.4\%$

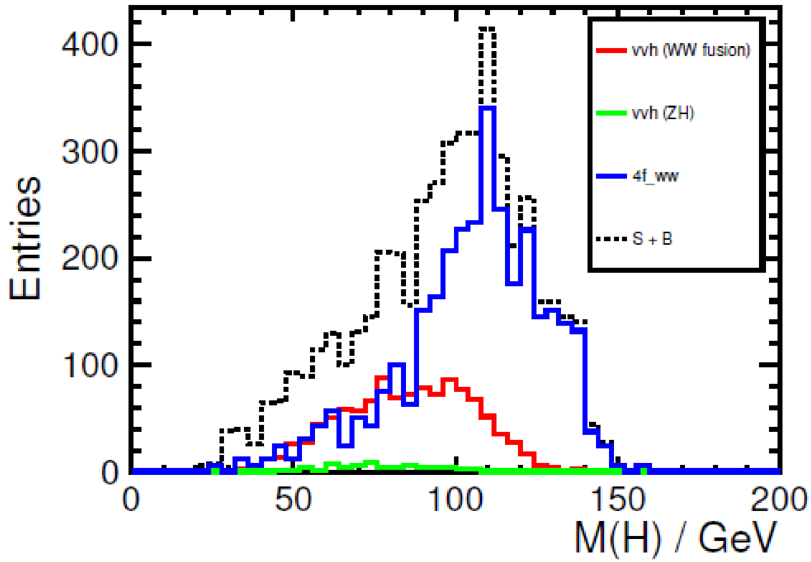
for 500 fb^{-1} @ $\sqrt{s} = 500$ GeV

J.Tian & K. Fujii (KEK)

C. Dürig & J. List (DESY)



$WW^* \to q\bar{q}q\bar{q}$



$WW^* \to l\nu q\bar{q}$

$\sigma \bullet BR(H \to \gamma\gamma)$: New Analysis at $\sqrt{s} = 250$ & 500 GeV

$H \to \gamma\gamma$

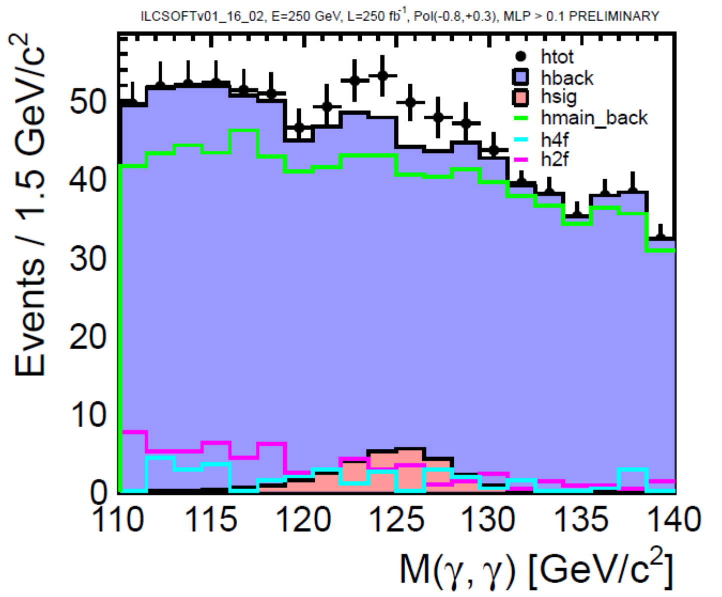
$\Delta\sigma{\bullet}B / \sigma{\bullet}B = 34\%$

for 250 fb^{-1} @ $\sqrt{s} = 250$ GeV

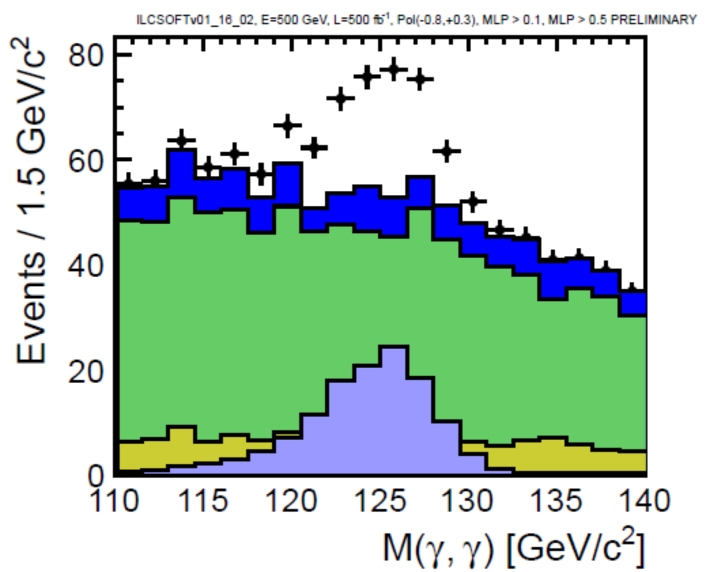
$\Delta\sigma{\bullet}B / \sigma{\bullet}B = 23\%$

for 500 fb^{-1} @ $\sqrt{s} = 500$ GeV

C. Calancha (KEK)



$\sqrt{s} = 250$ GeV



$\sqrt{s} = 500$ GeV

$\sigma \bullet BR(H \to ZZ^*)$: New Analysis at $\sqrt{s} = 250$ GeV

Table 5.3. Composition of the events passing all analysis selections for the polarizations $P(e^-) = +80\%$, $P(e^+) = -30\%$ and an integrated luminosity of 250 fb^{-1} collected by SiD at a center of mass energy of 250 GeV.

	$h \to ZZ^*$ (%)
$e^+e^- \to 2$ fermions	50
$e^+e^- \to 4$ fermions	462
$e^+e^- \to 6$ fermions	0
$\gamma\gamma \to X$	0
$\gamma e^+ \to X$	0
$e^-\gamma \to X$	0
$qqh \to ZZ^*$	68
$eeh, \mu\mu h \to ZZ^*$	24
$\tau\tau h \to ZZ^*$	3
$\nu\nu h \to ZZ^*$	49

$H \to ZZ^*$

$\Delta\sigma \bullet B / \sigma \bullet B = 18\%$

for 250 fb^{-1} @ $\sqrt{s} = 250$ GeV

H. Neal, SLAC

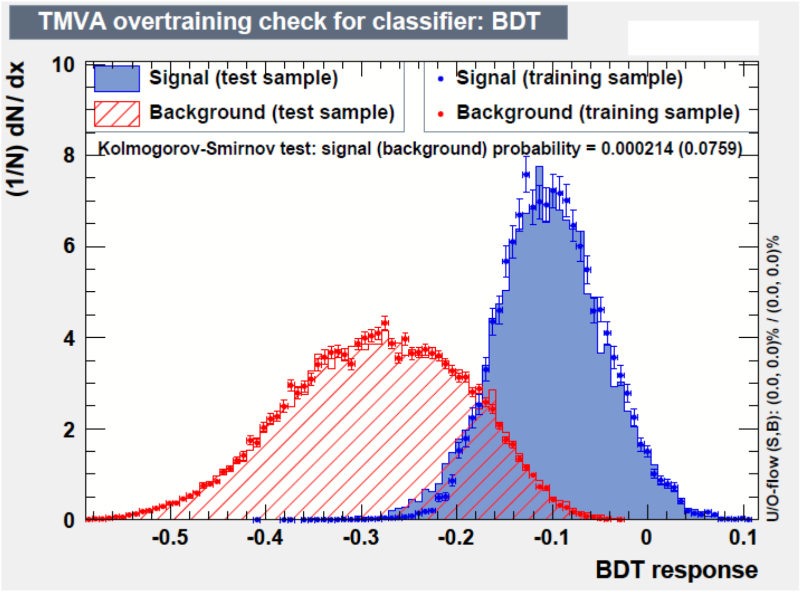


Figure 5.2. The multi-variate BDT output for the signal ($h \to ZZ^*$) and background for the training samples and test samples (points).

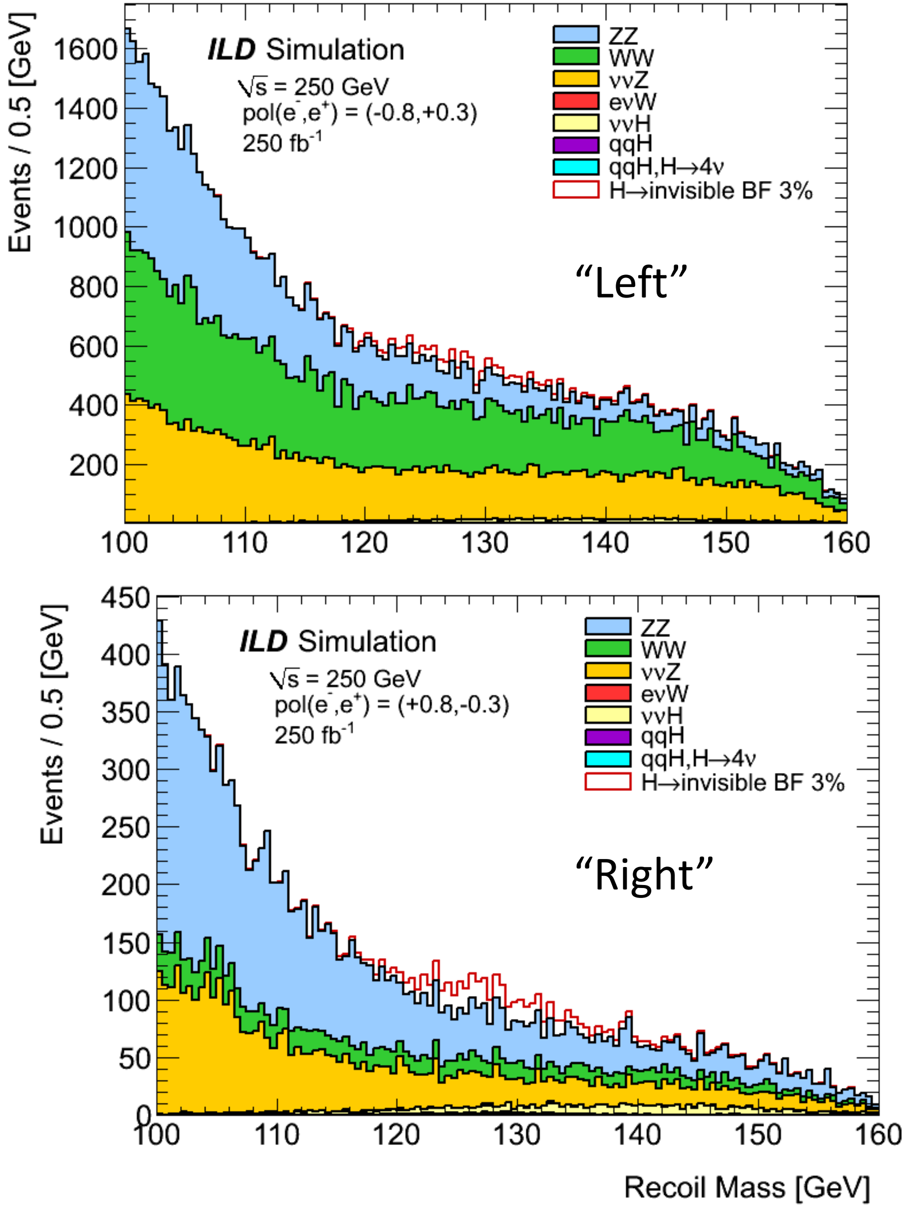
$\sigma \bullet BR(H \to invisible)$: New Analysis at $\sqrt{s} = 250$ GeV

$H \to invisible$

BR(*invisible*) $< 0.9\%$ at 95% CL

for 250 fb^{-1} @ $\sqrt{s} = 250$ GeV

A. Ishikawa (Tohoku Univ)



$e^+e^- \to ZHH,\ \nu\bar{\nu}$HH, $HH \to b\bar{b}WW^*$: New Topology for Higgs Self Coupling at $\sqrt{s} = 500$ & 1000 GeV

$e^+e^- \to ZHH$

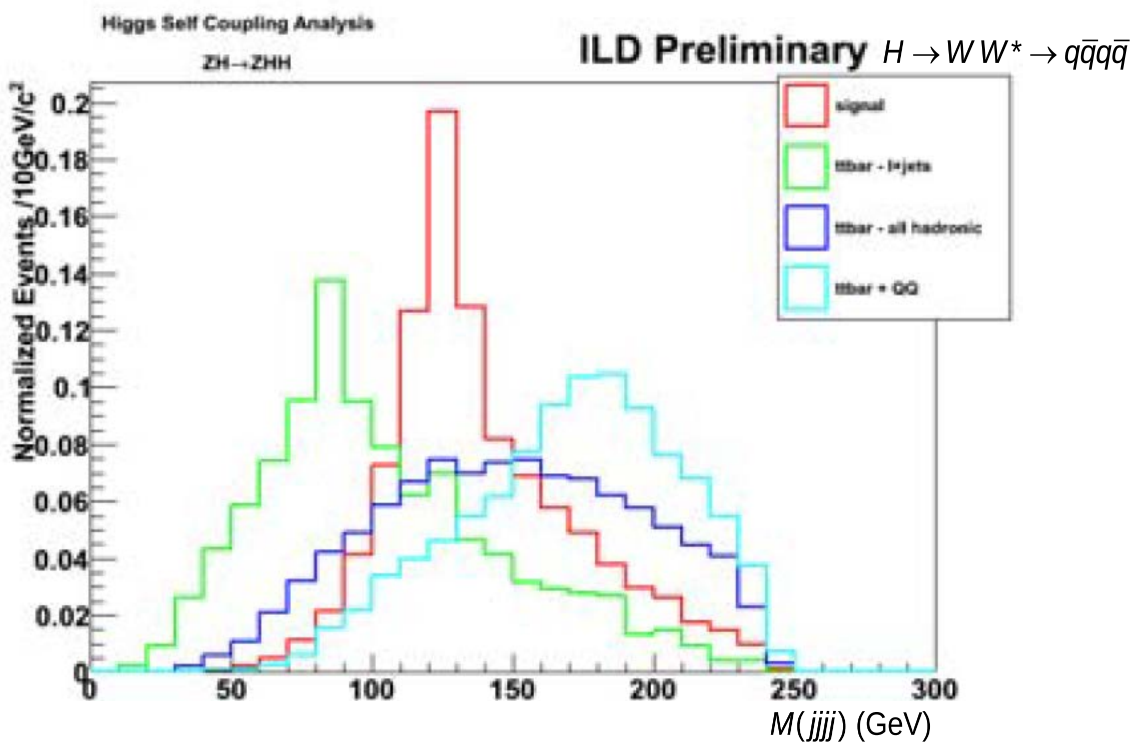
Combing HH $\to$ $b\bar{b}b\bar{b}$ & $b\bar{b}$W W*

$\Delta\sigma / \sigma = 42.7\%$ for 500 fb^{-1} at $\sqrt{s} = 500$ GeV

M. Kurata, T. Tanbe (Univ Tokyo)

J. TIan, K. Fujii (KEK)

T. Suehara (Tohoku Univ)



Energy(GeV)	Modes	Z decay	Signal	Background	Significance
500	All hadronic	$Z\to b\bar{b}$ 4-btag	15.20	87.52	1.50σ
		$Z\to b\bar{b}$ 3-btag	19.43	3099.49	0.35σ
		$Z\to c\bar{c}$	11.29	366.13	0.58σ
500	Lepton + jets	$Z\to b\bar{b}$	1.65	17.62	0.38σ
500		$Z\to c\bar{c}$	0.88	146.09	0.04σ
500	Dilepton	$Z\to l\bar{l}$	2.24	8.44	0.69σ
500	Trilepton	$Z\to l\bar{l}$	1.05	2.60	0.55σ
combined					1.91σ

ILC Measurement Summary

Table 5.1. Expected accuracies for cross section and cross section times branching ratio measurements for the 125 GeV h boson assuming you run 3×10^7 s at the baseline differential luminosity for each center of mass energy. For invisible decays of the Higgs, the number quoted is the 95% confidence upper limit on the branching ratio.

$\sqrt{s}$ and $\mathcal{L}$ (P_{e^-}, P_{e^+})	250 fb^{-1} at 250 GeV (-0.8,+0.3)		500 fb^{-1} at 500 GeV (-0.8,+0.3)				1 ab^{-1} at 1 TeV (-0.8,+0.2)		
	Zh	$\nu\bar{\nu}h$	Zh	$\nu\bar{\nu}h$	$t\bar{t}h$	Zhh	$\nu\bar{\nu}h$	$t\bar{t}h$	$\nu\bar{\nu}hh$
$\Delta\sigma/\sigma$	2.6%	-	3.0	-		42.7%			26.3%
BR(invis.)	$<$ 0.9 %	-	-	-	-				
mode	$\Delta(\sigma \cdot BR)/(\sigma \cdot BR)$								
$h \to b\bar{b}$	1.2%	10.5%	1.8%	0.7%	28%		0.5%	6.0%	
$h \to c\bar{c}$	8.3%	-	13%	6.2%			3.1%		
$h \to gg$	7.0%	-	11%	4.1%			2.3%		
$h \to WW^*$	6.4%	-	9.2%	2.4%			1.6%		
$h \to \tau^+\tau^-$	4.2%	-	5.4%	9.0%			3.1%		
$h \to ZZ^*$	19%	-	25%	8.2%			4.1%		
$h \to \gamma\gamma$	34%	-	34%	23%			8.5%		
$h \to \mu^+\mu^-$	100%	-	-	-			31%		

Table 5.2. Expected accuracies for cross section and cross section times branching ratio measurements for the 125 GeV h boson assuming you run 3×10^7 s at the sum of the baseline and upgrade differential luminosities for each center of mass energy. For invisible decays of the Higgs, the number quoted is the 95% confidence upper limit on the branching ratio.

$\sqrt{s}$ and $\mathcal{L}$ (P_{e^-}, P_{e^+})	1150 fb^{-1} at 250 GeV (-0.8,+0.3)		1600 fb^{-1} at 500 GeV (-0.8,+0.3)				2.5 ab^{-1} at 1 TeV (-0.8,+0.2)		
	Zh	$\nu\bar{\nu}h$	Zh	$\nu\bar{\nu}h$	$t\bar{t}h$	Zhh	$\nu\bar{\nu}h$	$t\bar{t}h$	$\nu\bar{\nu}hh$
$\Delta\sigma/\sigma$	1.2%	-	1.7	-		23.7%			16.7%
BR(invis.)	$<$ 0.4 %	-	-	-			-		
mode	$\Delta(\sigma \cdot BR)/(\sigma \cdot BR)$								
$h \to b\bar{b}$	0.6%	4.9%	1.0%	0.4%	16%		0.3%	3.8%	
$h \to c\bar{c}$	3.9%	-	7.2%	3.5%			2.0%		
$h \to gg$	3.3%	-	6.0%	2.3%			1.4%		
$h \to WW^*$	3.0%	-	5.1%	1.3%			1.0%		
$h \to \tau^+\tau^-$	2.0%	-	3.0%	5.0%			2.0%		
$h \to ZZ^*$	8.8%	-	14%	4.6%			2.6%		
$h \to \gamma\gamma$	16%	-	19%	13%			5.4%		
$h \to \mu^+\mu^-$	46.6%	-	-	-			20%		

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Model Independent Fit of Cross Sections and BR's

Table 6.3. Summary of expected accuracies for the three cross sections and eight branching ratios obtained from an eleven parameter global fit of all available data.

	ILC(250)	ILC500	ILC(1000)	ILC(LumUp)
process	$\Delta\sigma/\sigma$			
$e^+e^- \to ZH$	2.6 %	2.0 %	2.0 %	1.0 %
$e^+e^- \to \nu\bar{\nu}H$	11 %	2.3 %	2.2 %	1.1 %
$e^+e^- \to t\bar{t}H$	-	28 %	6.3 %	3.8 %
mode	$\Delta\mathrm{Br}/\mathrm{Br}$			
$H \to ZZ$	19 %	7.5 %	4.2 %	2.4 %
$H \to WW$	6.9 %	3.1 %	2.5 %	1.3 %
$H \to b\bar{b}$	2.9 %	2.2 %	2.2 %	1.1 %
$H \to c\bar{c}$	8.7 %	5.1 %	3.4 %	1.9 %
$H \to gg$	7.5 %	4.0 %	2.9 %	1.6 %
$H \to \tau^+\tau^-$	4.9 %	3.7 %	3.0 %	1.6 %
$H \to \gamma\gamma$	34 %	17 %	7.9 %	4.7 %
$H \to \mu^+\mu^-$	100 %	100 %	31 %	20 %

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Model Independent Fit of Higgs Couplings

Table 9.1. Summary of expected accuracies $\Delta g_i/g_i$ for model independent determinations of the Higgs boson couplings. The theory errors are $\Delta F_i/F_i = 0.1\%$. For the invisible branching ratio, the numbers quoted are 95% confidence upper limits.

	ILC(250)	ILC(500)	ILC(1000)	ILC(LumUp)
$\sqrt{s}$ (GeV)	250	250+500	250+500+1000	250+500+1000
L (fb^{-1})	250	250+500	250+500+1000	1150+1600+2500
$\gamma\gamma$	18 %	8.4 %	4.0 %	2.4 %
gg	6.4 %	2.3 %	1.6 %	0.9 %
WW	4.8 %	1.1 %	1.1 %	0.6 %
ZZ	1.3 %	1.0 %	1.0 %	0.5 %
$t\bar{t}$	–	14 %	3.1 %	1.9 %
$b\bar{b}$	5.3 %	1.6 %	1.3 %	0.7 %
$\tau^+\tau^-$	5.7 %	2.3 %	1.6 %	0.9 %
$c\bar{c}$	6.8 %	2.8 %	1.8 %	1.0 %
$\mu^+\mu^-$	91%	91%	16 %	10 %
$\Gamma_T(h)$	12 %	4.9 %	4.5 %	2.3 %
hhh	–	83 %	21 %	13 %
BR(invis.)	$<$ 0.9 %	$<$ 0.9 %	$<$ 0.9 %	$<$ 0.4 %

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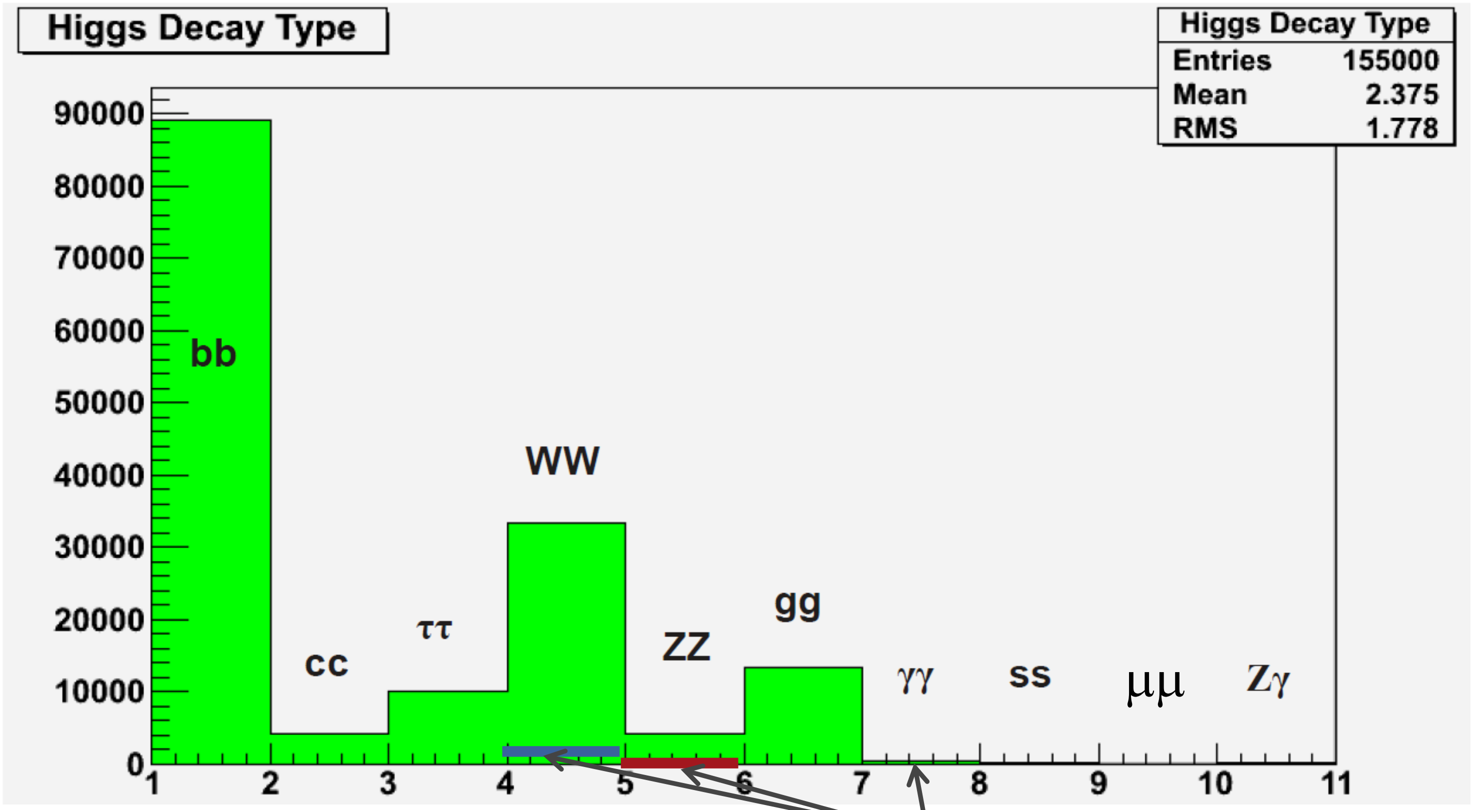
ILC vs LHC: General Considerations

- All beam crossings are triggered at the ILC
- All background is electroweak.
- Roughly, the detection efficiency is independent of decay mode $\Rightarrow \Delta(\sigma \bullet BR) / \sigma \bullet BR \propto 1/\sqrt{BR}$

- LHC Higgs detection efficiency is uneven across decay modes.
- Higgs was discovered in decays modes with γ, e, μ, which have relatively small BR's
- Qualitatively, there is complementarity between the ILC and LHC with respect to decay modes.



$WW \rightarrow l\nu l\nu \quad l = e, \mu$

$ZZ \rightarrow l^+ l^- l^+ l^- \quad l = e, \mu$

7 Parameter HXSWG Benchmark *

Mode	LHC 300 fb^{-1}	LHC 3000 fb^{-1}	ILC(1000)	ILC(LumUp)	
			250+500+1000	250+500+1000	$\sqrt{s}$ (GeV)
			250+500+1000	1150+1600+2500	L (fb^{-1})
$\gamma\gamma$	$(5-7)\%$	$(2-5)\%$	3.8 %	2.3 %	
gg	$(6-8)\%$	$(3-5)\%$	1.1 %	0.7 %	
WW	$(4-5)\%$	$(2-3)\%$	0.3 %	0.2 %	
ZZ	$(4-5)\%$	$(2-3)\%$	0.5 %	0.3 %	
$t\bar{t}$	$(14-15)\%$	$(7-10)\%$	1.3 %	0.9 %	
$b\bar{b}$	$(10-13)\%$	$(4-7)\%$	0.6 %	0.4 %	
$\tau^+\tau^-$	$(6-8)\%$	$(2-5)\%$	1.3 %	0.7 %	

* Assume $\kappa_c = \kappa_t$ & $\Gamma_{tot} = \sum_{\text{SM decays } i} \Gamma_i^{SM} \kappa_i^2$

Other Higgs Couplings

Mode	LHC 300 fb^{-1}	LHC 3000 fb^{-1}	ILC(1000)	ILC(LumUp)	
			250+500+1000	250+500+1000	$\sqrt{s}$ (GeV)
			250+500+1000	1150+1600+2500	L (fb^{-1})
$c\bar{c}$	-	-	1.8 %	1.0 %	
$\mu^+\mu^-$	30%	10%	16 %	10 %	
$\Gamma_T(h)$	-	-	4.5 %	2.3 %*	
hhh	-	50%	21 %	13 %*	
BR(invis.)	< (17 – 28)%	< (6-17)%	< 0.9 %	< 0.4 %	

* Does not include results from searches for non-SM decays, including invisible decays. The error on the total width will improve significantly once these results are incorporated into the fit.

* Current full simulation result using $H \to b\bar{b}$, WW^* only. Results will improve as more Higgs decay modes are added, and as jet combinatoric problems are solved.

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Alternate Luminosity Scenario

Nickname	Ecm(1) (GeV)	Lumi(1) (fb^{-1})	+	Ecm(2) (GeV)	Lumi(2) (fb^{-1})	Runtime (yr)	Wallplug E (MW-yr)
ILC(250)	250	250				1.1	130
ILC(500)	250	250		500	500	2.0	270
ILC500(LumUp)	250	1150		500	1600	3.9	660

7 Parameter HXSWG Benchmark *

	ILC500(LumUp)	ILC(LumUp)
$\sqrt{s}$ (GeV)	250+500	250+500+1000
L (fb^{-1})	1150+1600	1150+1600+2500
$\gamma\gamma$	4.4 %	2.3 %
gg	1.1 %	0.7 %
WW	0.3 %	0.2 %
ZZ	0.3 %	0.3 %
$t\bar{t}$	1.4 %	0.9 %
$b\bar{b}$	0.6 %	0.4 %
$\tau^+\tau^-$	1.0 %	0.7 %

* Assume $\kappa_c = \kappa_t$ & $\Gamma_{tot} = \sum_{\text{SM decays i}} \Gamma_i^{SM} \kappa_i^2$

Alternate Luminosity Scenario

Nickname	Ecm(1) (GeV)	Lumi(1) (fb^{-1})	+	Ecm(2) (GeV)	Lumi(2) (fb^{-1})	Runtime (yr)	Wallplug E (MW-yr)
ILC(250)	250	250				1.1	130
ILC(500)	250	250		500	500	2.0	270
ILC500(LumUp)	250	1150		500	1600	3.9	660

Other Higgs Couplings

	ILC500(LumUp)	ILC(LumUp)
$\sqrt{s}$ (GeV)	250+500	250+500+1000
L (fb^{-1})	1150+1600	1150+1600+2500
$c\bar{c}$	1.5 %	1.0 %
$\mu^+\mu^-$	42 %	10 %
$\Gamma_T(h)$	2.5 %	2.3 %
hhh	46 %	13 %
BR(invis.)	$<$ 0.4 %	$<$ 0.4 %

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Combining LHC Results with Results from Various Future e^+e^- Colliders

(from D. Zerwas and the SFITTER Group)

Range corresponds to 2 different sys error assumptions for HL-LHC

coupling	LHC +ILC	LHC +ILC Lumi-up	HL-LHC +ILC Lumi-up	HL-LHC +CLIC	HL-LHC +ILC Lumi-up +CLIC	HL-LHC +TLEP +CLIC
Γ_H	2.0 – 2.0%	1.1 – 1.1%	1.1 – 1.1%	4.4 – 7.3%	0.9 – 1.0%	1.1 – 1.2%
$\mathrm{BR}_{\mathrm{inv}}$	0.8 – 0.8%	0.4 – 0.4%	0.4 – 0.4%	2.2 – 3.9%	0.4 – 0.4%	0.5 – 0.5%
κ_γ	2.4 – 2.7%	2.0 – 2.2%	1.3 – 2.0%	1.8 – 3.4%	1.2 – 2.0%	1.2 – 1.6%
κ_g	1.3 – 1.3%	0.8 – 0.8%	0.8 – 0.8%	1.3 – 2.0%	0.6 – 0.6%	0.6 – 0.6%
κ_W	0.5 – 0.5%	0.3 – 0.3%	0.3 – 0.3%	1.1 – 1.9%	0.3 – 0.3%	0.3 – 0.3%
κ_Z	0.6 – 0.6%	0.3 – 0.3%	0.3 – 0.3%	1.1 – 1.9%	0.3 – 0.3%	0.3 – 0.3%
κ_μ	13.8 – 14.2%	9.9 – 9.9%	7.0 – 7.8%	5.2 – 6.0%	4.6 – 4.7%	4.0 – 4.1%
κ_τ	1.5 – 1.6%	0.9 – 0.9%	0.7 – 0.9%	1.3 – 2.3%	0.7 – 0.8%	0.5 – 0.6%
κ_c	1.6 – 1.6%	0.9 – 0.9%	0.9 – 0.9%	1.4 – 2.1%	0.7 – 0.7%	0.7 – 0.7%
κ_b	0.8 – 0.8%	0.5 – 0.5%	0.5 – 0.5%	1.1 – 1.9%	0.3 – 0.3%	0.4 – 0.4%
κ_t	2.8 – 2.9%	1.9 – 1.9%	1.7 – 1.8%	3.5 – 4.5%	1.7 – 1.8%	3.2 – 3.8%
Δ_γ	2.5 – 2.8%	2.0 – 2.2%	1.5 – 2.1%	2.8 – 4.6%	1.4 – 2.0%	1.7 – 2.0%
Δ_g	3.8 – 3.8%	2.5 – 2.5%	2.3 – 2.4%	4.1 – 4.8%	2.1 – 2.3%	4.0 – 4.7%

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What do these precision values mean?

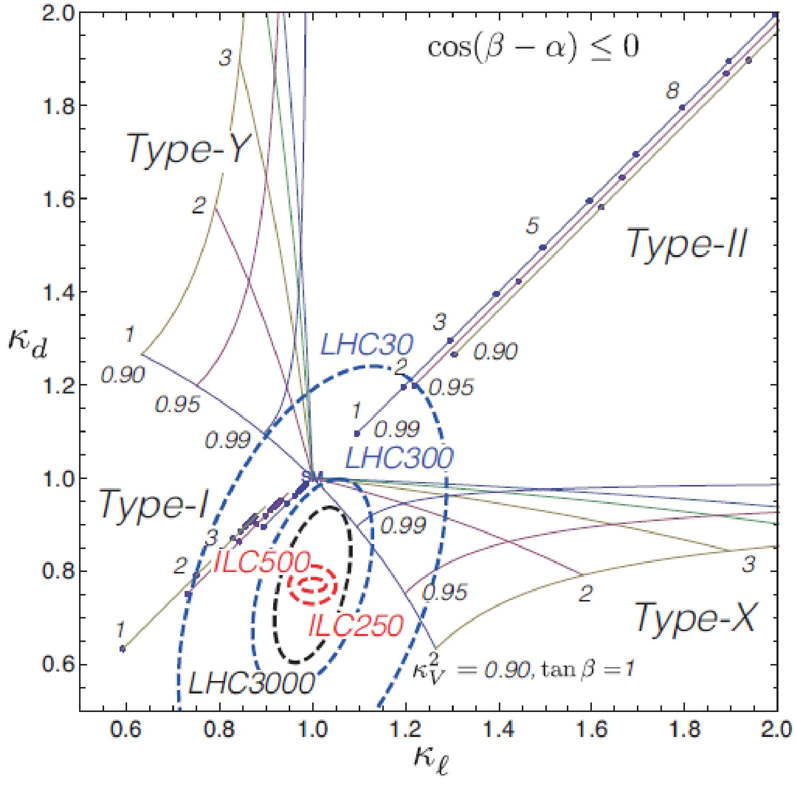
For Higgs couplings, better precision means greater discovery potential.

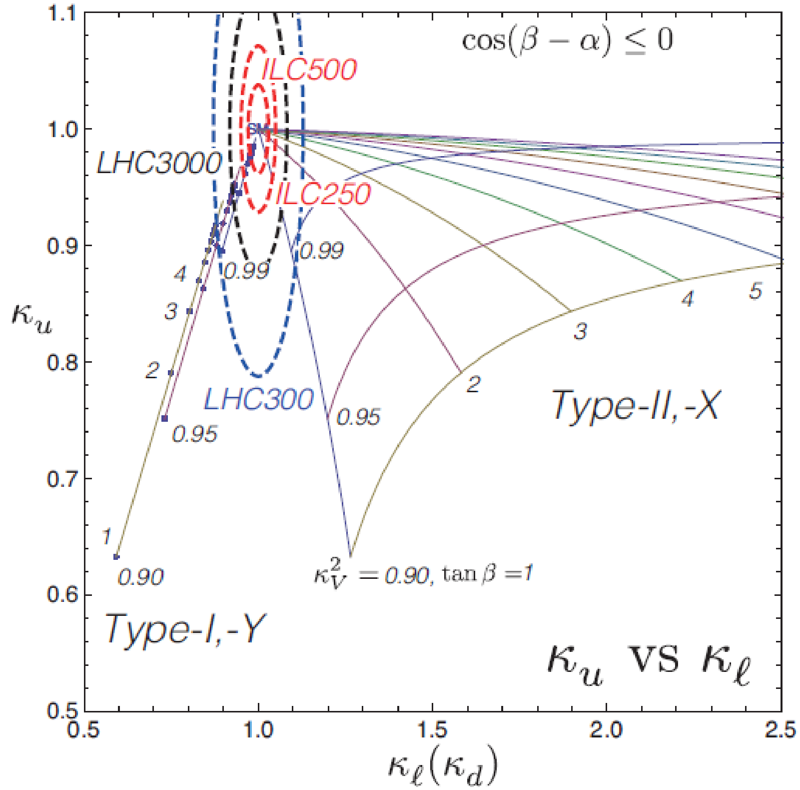
Typical coupling variations for several BSM Higgs models:

	κ_V	κ_b	κ_γ
Singlet Mixing	$\sim 6\%$	$\sim 6\%$	$\sim 6\%$
2HDM	$\sim 1\%$	$\sim 10\%$	$\sim 1\%$
Decoupling MSSM	$\sim -0.0013\%$	$\sim 1.6\%$	$< 1.5\%$
Composite	$\sim -3\%$	$\sim -(3-9)\%$	$\sim -9\%$
Top Partner	$\sim -2\%$	$\sim -2\%$	$\sim -3\%$

Plots from Theory Section of ILC Higgs White Paper

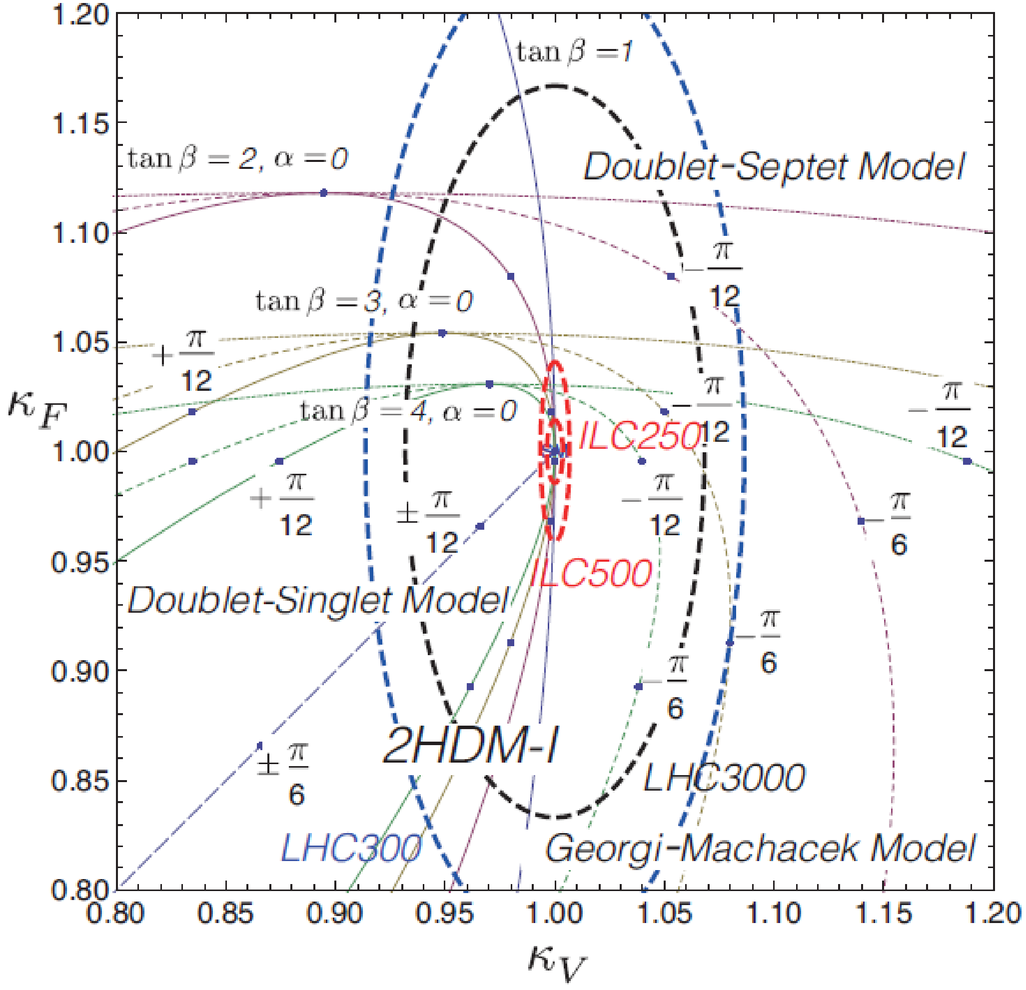
2HDM:





Plots from Theory Section of ILC Higgs White Paper

Models with Universal Yukawa and Gauge Couplings



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Other Studies Included in ILC Higgs White Paper

- Higgs CP using $e^+e^- \rightarrow t\bar{t}h$
- Lorentz Structure of hW W coupling
- Higgs physics with an ILC $\gamma\gamma$ collider