Model Dependent Higgs Couplings

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Model Independent Coupling Determination

Fit for 9 couplings and the Higgs total width

$(g_{Z}, g_{W}, g_{b}, g_{c}, g_{g}, g_{\tau}, g_{\mu}, g_{t}, g_{\gamma}, \Gamma_0)$

by minimizing χ^2 :

$$\chi^2 = \sum_{i=1}^{33} \left(\frac{Y_i - Y_i'}{\Delta Y_i} \right)^2 \qquad Y_i = \begin{cases} \sigma \times BR \text{ , i=1,..,32} \\ \sigma_{ZH} \text{ , } i = 33 \end{cases}$$

$$Y_i' = F_i \bullet \frac{g_Z^2 g_X^2}{\Gamma_0} \quad , \quad F_i \bullet \frac{g_W^2 g_X^2}{\Gamma_0} \quad \text{or} \quad F_i \bullet \frac{g_t^2 g_X^2}{\Gamma_0}$$

We neglect theory errors on F_i

Model Independent Coupling Summary

$$\Delta g_{Hxx} \,/\, g_{Hxx}$$

	Mode	ILC(250)	ILC500	ILC(1000)	ILC(LumUp)
	WW	4.8 %	1.4 %	1.4 %	0.65 %
	ZZ	1.3 %	1.3 %	1.3 %	0.61 %
	$t\bar{t}$	–	18 %	4.0 %	2.5 %
	$b\bar{b}$	5.3 %	1.8 %	1.5 %	0.75 %
	$\tau^+\tau^-$	5.7 %	2.5 %	2.0 %	1.0 %
	$\gamma\gamma$	18 %	8.4 %	4.1 %	2.4 %
	gg	6.4 %	2.5 %	1.8 %	0.94 %
	$c\bar{c}$	6.8 %	3.0 %	2.0 %	1.1 %
	$\mu^+\mu^-$	–	–	16 %	10 %
	$\Gamma_T(h)$	11 %	6.0 %	5.6 %	2.7 %
	self	–	88%	25 %	16 %
*	BR(invis.)	< 0.69 %	< 0.69 %	< 0.69 %	< 0.32 %

* 95% C.L. limit

Model Dependent Coupling Fits

Alternatively, ILC can fit for the κ_i coupling scaling factors of arXiv : 1029.0040.

SFitter

ILC (250)

coupling	250 GeV
κ_W	5.6 %
κ_Z	1.1 %
κ_t	9.8 %
κ_b	6.0 %
κ_τ	7.2 %
κ_γ	18.0 %
κ_g	8.6 %

Model Independent Coupling Fits

Mode	ILC(250)	ILC500	ILC(1000)	ILC(LumUp)
WW	4.8 %	1.4 %	1.4 %	0.65 %
ZZ	1.3 %	1.3 %	1.3 %	0.61 %
$t\bar{t}$	–	18 %	4.0 %	2.5 %
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$\tau^+\tau^-$	5.7 %	2.5 %	2.0 %	1.0 %
$\gamma\gamma$	18 %	8.4 %	4.1 %	2.4 %
gg	6.4 %	2.5 %	1.8 %	0.94 %

SFitter

ILC (LumUp)

coupling	high-lumi
κ_W	0.57 %
κ_Z	0.47 %
κ_t	1.7 %
κ_b	1.2 %
κ_τ	1.7 %
κ_γ	3.4 %
κ_g	1.7 %

This isn't right. The model dependent values should ALWAYS be better than the model indepedent values because we are adding constraints to the model independent fits when we do model dependent fits.

Model Dependent Coupling Determination Proposal

This example uses the constraints from the 7 parameter fit
$(\kappa_{Z,}\kappa_{W,}\kappa_{b,}\kappa_{g,}\kappa_{\tau,}\kappa_{t,}\kappa_{\gamma})$ by ATLAS and CMS

The constraints are $\kappa_c = \kappa_t$ & $\kappa_H^2 \bullet \Gamma_0 = \sum_i \kappa_i^2 \bullet \Gamma_i$

For ILC we still fit for 9 couplings and the Higgs total width
$(g_{Z,} g_{W,} g_{b,} g_{c,} g_{g,} g_{\tau,} g_{\mu,} g_{t,} g_{\gamma,} \Gamma_0)$
but now by minimizing this χ^2 :

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

where

$$\xi_{ct} = \frac{g_c}{g_c^{SM}(M_c,...)} - \frac{g_t}{g_t^{SM}(M_t,...)} \qquad \xi_{\Gamma} = \Gamma_0 - \sum_{i=1}^{9} \Gamma_i \quad , \quad \Gamma_i = G_i(M_H,...) \bullet g_i^2$$

$\Delta\xi_{ct}$ = theory error on ξ_{ct} obtained by propagating theory errors on $g_c^{SM}(M_c,...)$ and $g_t^{SM}(M_t,...)$
$\Delta\xi_{\Gamma}$ = theory error on ξ_{Γ} obtained by propagating (correlated) theory errors on $G_i(M_H,...)$

5

Model Dependent Coupling Fits

Alternatively, ILC can fit for the κ_i coupling scaling factors of arXiv:1029.0040.

SFitter
with Theory Error
ILC (LumUp)

coupling	high-lumi
κ_W	0.57 %
κ_Z	0.47 %
κ_t	1.7 %
κ_b	1.2 %
κ_τ	1.7 %
κ_γ	3.4 %
κ_g	1.7 %

Model Independent Coupling Fits

Mode	ILC(LumUp)
WW	0.65 %
ZZ	0.61 %
$t\bar{t}$	2.5 %
$b\bar{b}$	0.75 %
$\tau^+\tau^-$	1.0 %
$\gamma\gamma$	2.4 %
gg	0.94 %

SFitter
no Theory Error
ILC (LumUp)

coupling	high-lumi
κ_W	0.20%
κ_Z	0.28%
κ_t	0.91%
κ_b	0.37%
κ_τ	0.82%
κ_γ	2.52%
κ_g	0.73%

Theory Error Comments

We have to distinguish between theory errors that affect the coupling determination, and those that affect the interpretation of the experimental results. I believe the only theory errors that we should be concerned with are those that affect the coupling determination. Let's first look at the theory errors in the model independent coupling determination.

Theory Errors in Model Independent Coupling Determination

The measurements $Y_i = \begin{cases} \sigma \times BR \text{ , i=1,..,32} \\ \sigma_{ZH} \text{ , } i = 33 \end{cases}$ have theory sys errors associated with them due to missing higher order corrections in the MC simulation of signal and background data samples used to determine the detection efficiencies. I believe we are completely justified (based e.g. on our LEP experience) in claiming that these are currently negligible or will be negligible compared to the stat errors on $\sigma \times BR$ and σ_{ZH} even in our high luminosity scenario.

The factors F_i in our functions

$$Y_i' = F_i \bullet \frac{g_Z^2 g_X^2}{\Gamma_0} \quad , \quad F_i \bullet \frac{g_W^2 g_X^2}{\Gamma_0} \quad \text{or} \quad F_i \bullet \frac{g_t^2 g_X^2}{\Gamma_0}$$

do have theory errors due to uncertainties in the Higgs mass, α_S, and missing higher order QCD and EW rad corrections. However they DO NOT contain theory errors associated with the calculation of $\frac{g_Z^2 g_X^2}{\Gamma_0}$, etc. For example, there is no quark mass uncertainty associated with g_b^2 & Γ_0