News from the Higgs at the Linear Collider

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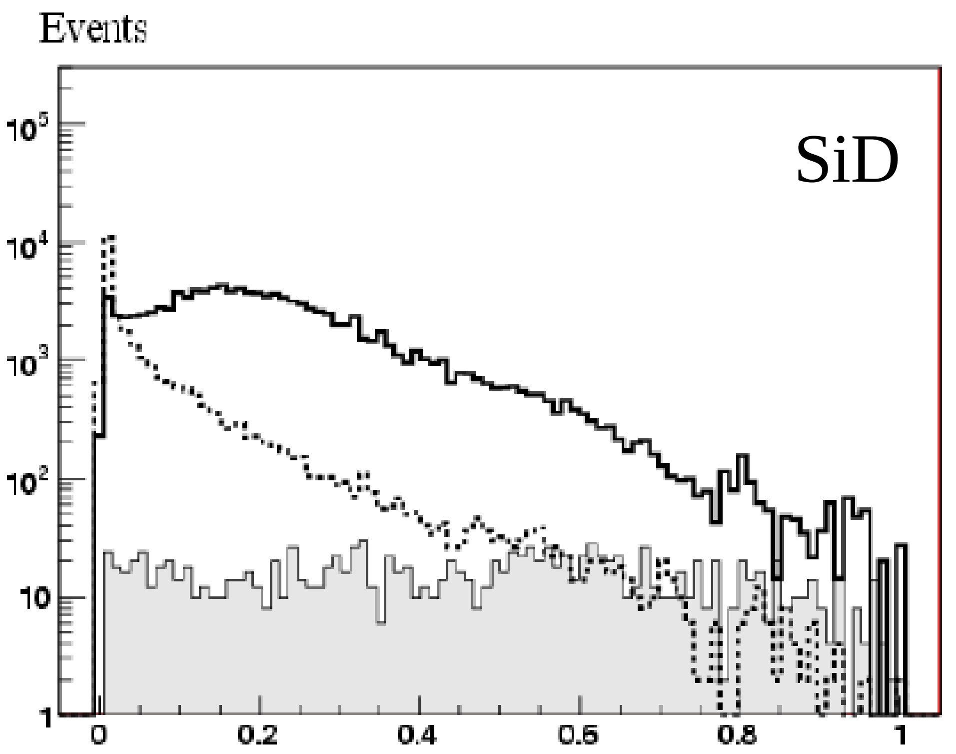
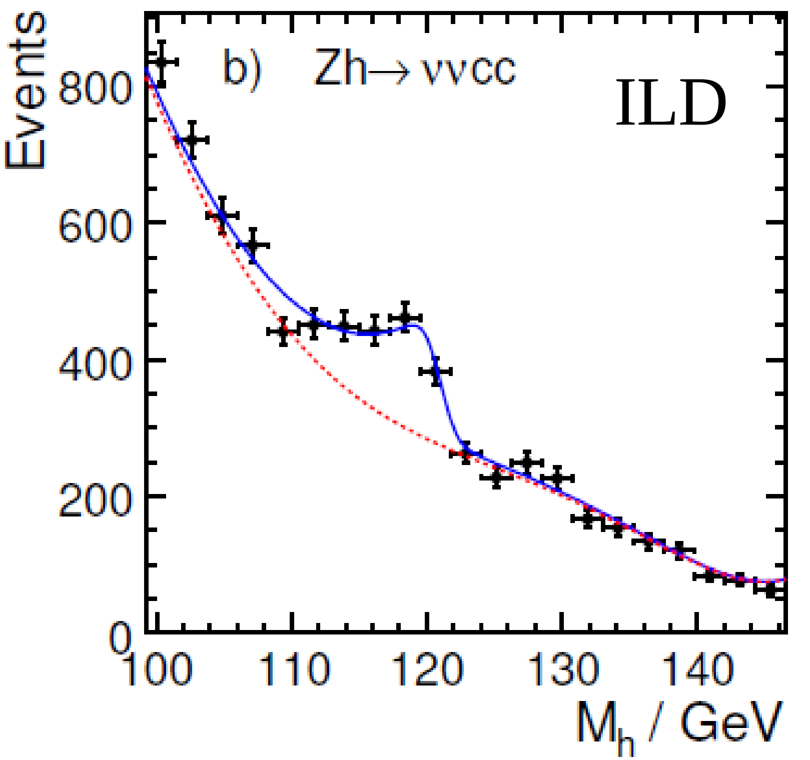
Geneva, 18-22 October 2010

Higgs Couplings





Detailed studies based on full simulation and reconstruction for the detector concept LoI have confirmed accuracies on determination of Higgs Brs broadly in agreement with those from parametrised simulation studies for TESLA TDR.

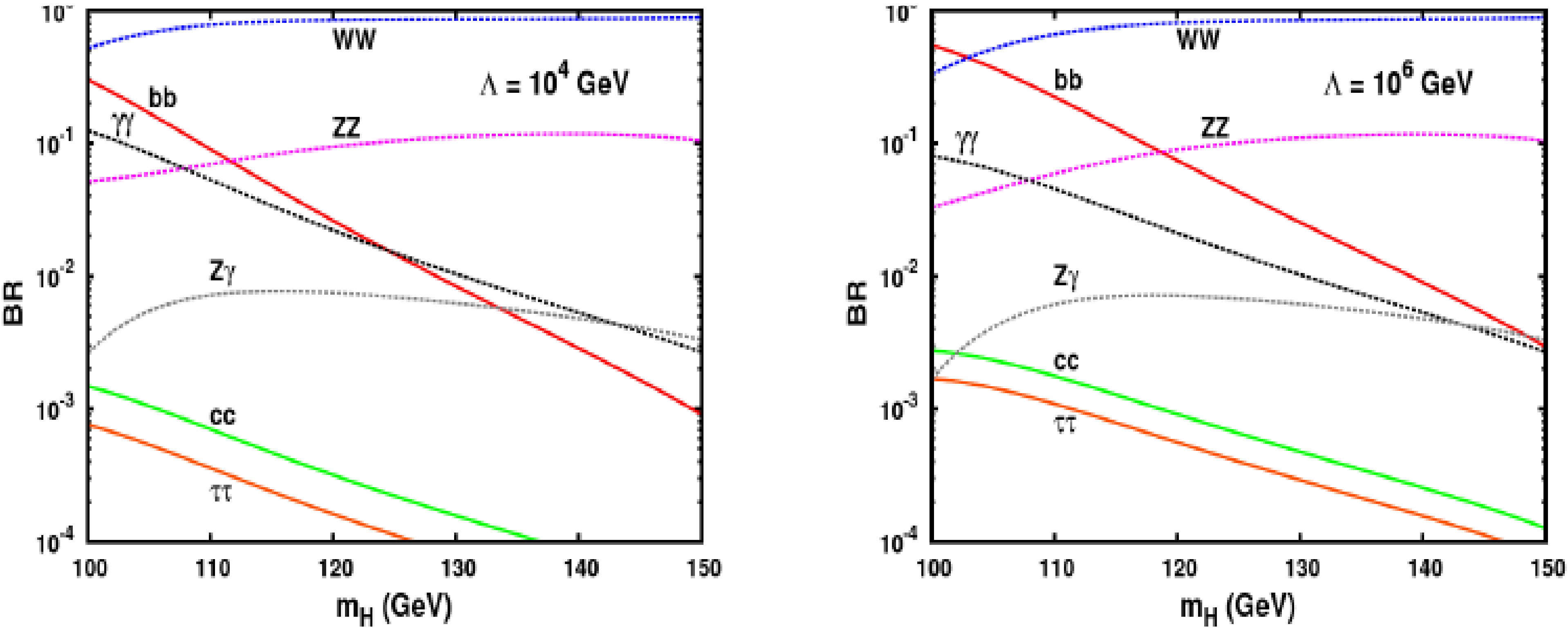
Higgs Couplings

gHtt	~0.10
gHbb	0.015
gHcc	0.042
gHμμ	0.04-0.06
gHHH	???

These accuracies promote new questions on sensitivity to new physics through correction to Higgs coupling to fermions
Extracting Higgs CP phases in ττ channel (Videau, IWLC2010)

Some channels have been left aside since long (γγ, Zγ), almost all work has concentrated on a 120 GeV Higgs, what if the Higgs mass is somehow heavier ? what if it is ~ 185 GeV ? Can we still study its couplings to fermions through H → bb as a rare process in WW fusion production at 1-3 TeV ?

Higgs Couplings



Fermion masses generated by new, non-Higgs mechanism at high L scale (Gabrielli, IWLC2010)

Higgs Couplings

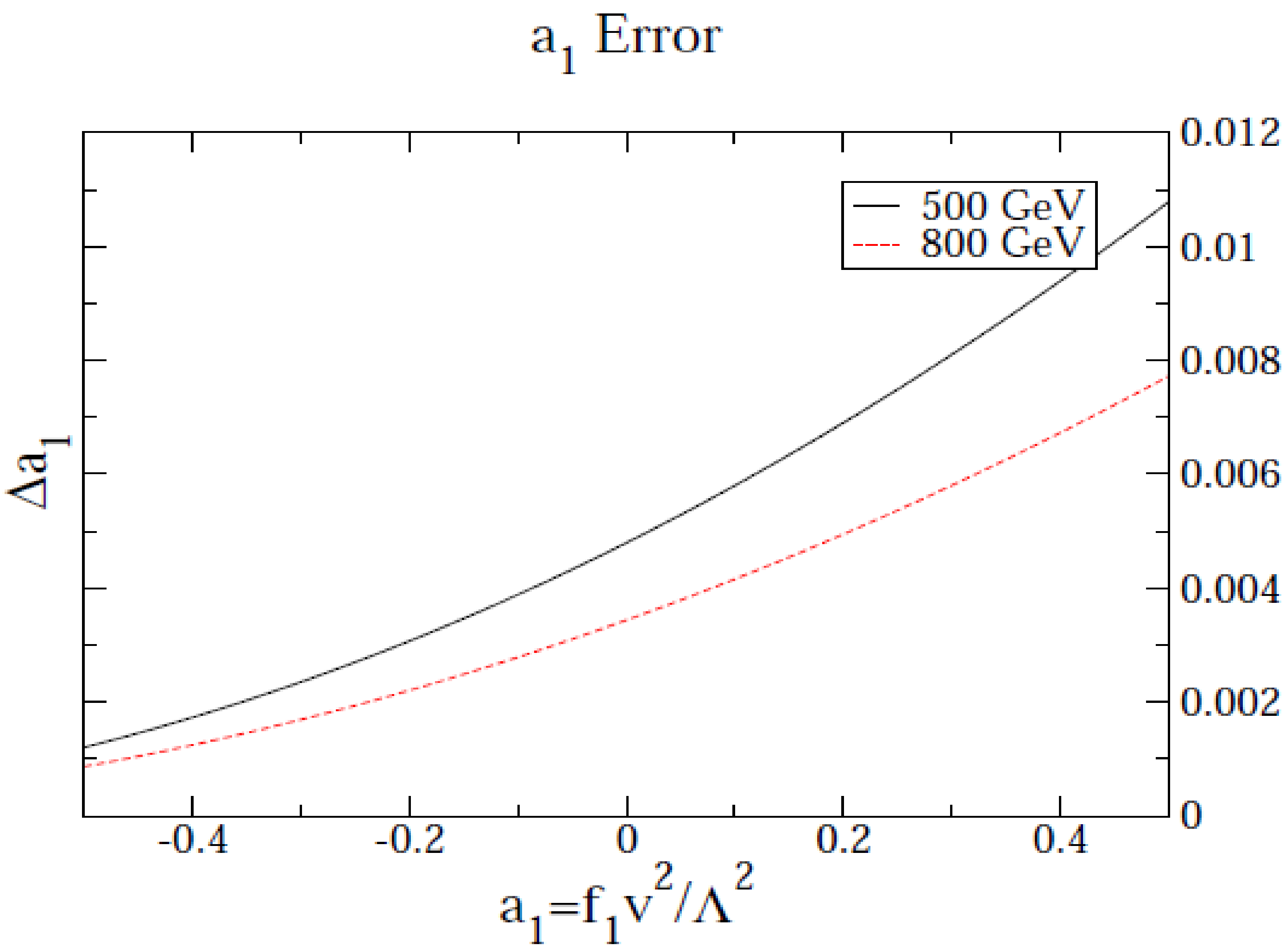
$$\Gamma(h \to f\bar{f}) = \Gamma(h \to f\bar{f})_{SM}[1 - \xi(c_H + 2c_y)],$$
$$\Gamma(h \to gg) = \Gamma(h \to gg)_{SM}\left[1 - \xi\,\mathrm{Re}\left(c_H + 2c_y + \frac{4y_t^2 c_g}{g_\rho^2 I_g}\right)\right]$$

Study effect of dim-6 operators in SILH scenario on Higgs BRs to explore nature of the Higgs boson. LC can improve sensitivity to v^2/f^2 down to 0.01 corresponding to scale of 30 TeV virtually saturating the phase space for a light composite Higgs

Effective Lagrangian for composite Higgs (Giudice et al.)

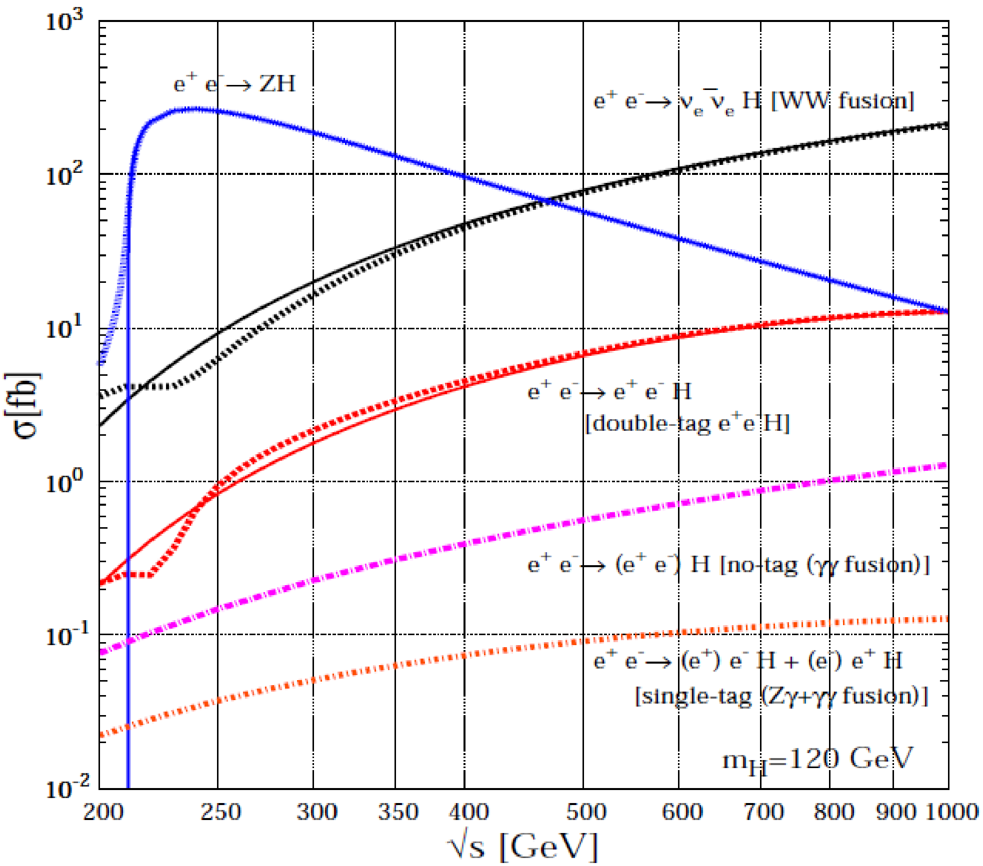
"CLIC will fully test the relevance of compositeness to electro-weak symmetry breaking" (Rattazzi, IWLC2010)

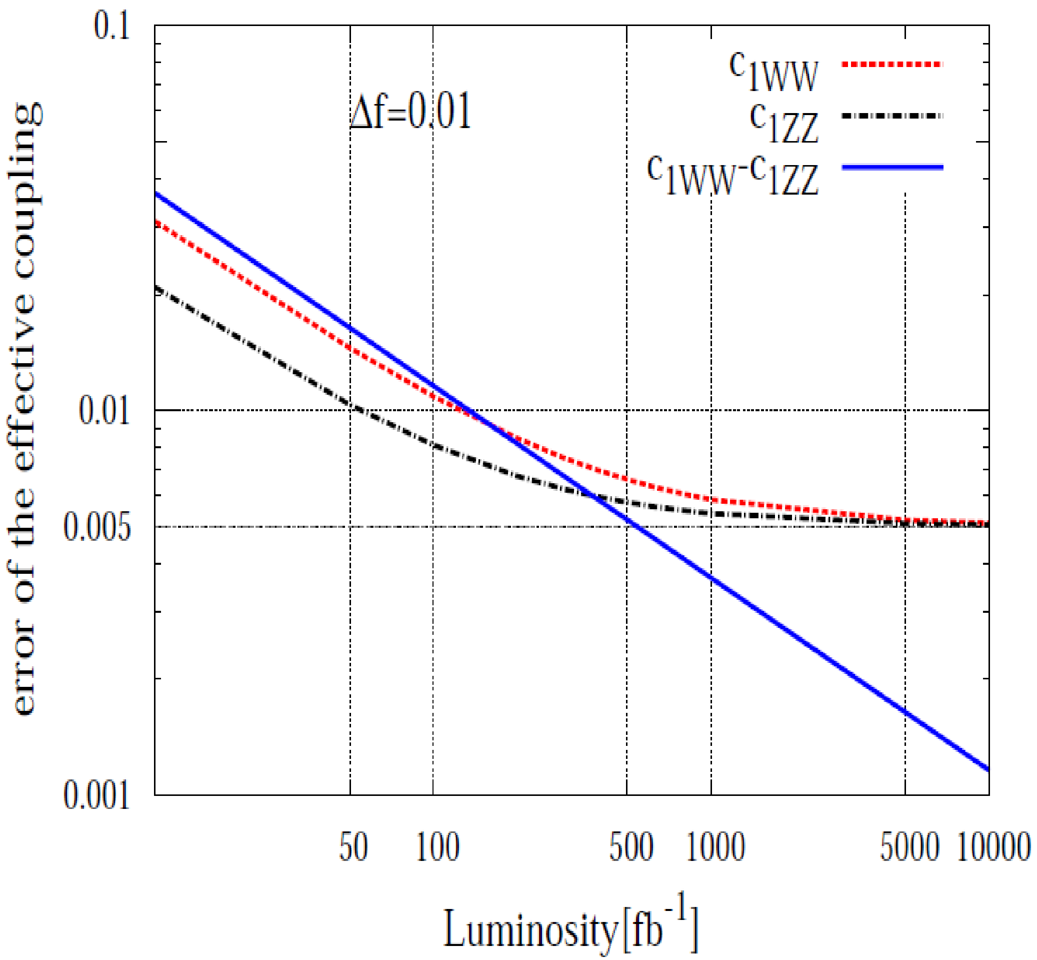
Higgs Anomalous Couplings
0.5 TeV ILC 1 ab^{-1}



Barger et al
PRD67 (2003)]

Higgs Anomalous Couplings

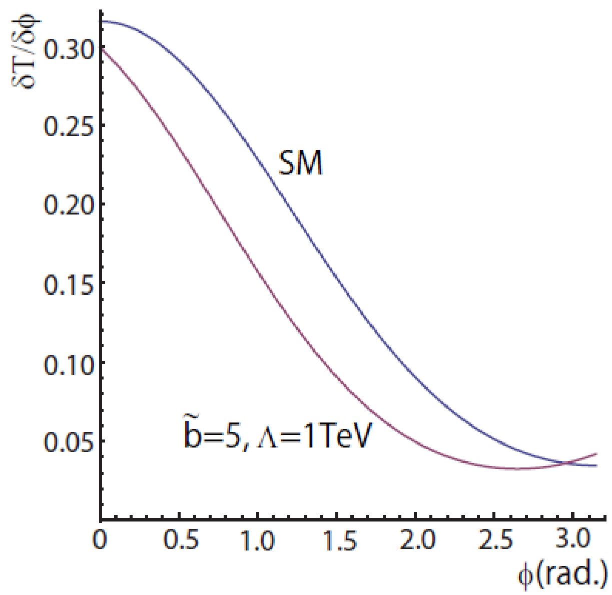


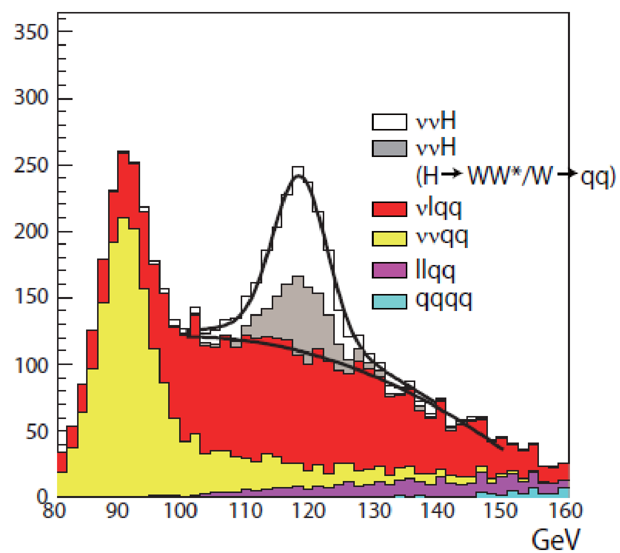


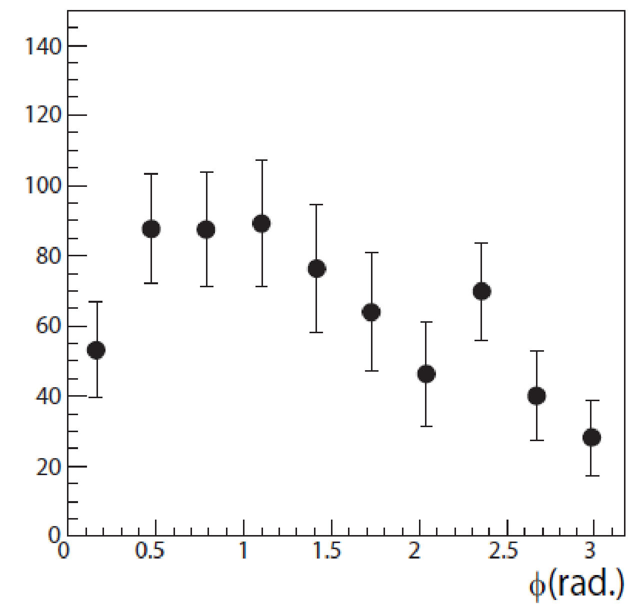
Analysis of CP-evenHVV coupling term affected by dim-6 operators using optimal observables method for the kinematic distribution in ννH (HWW), ZH (HZZ, HZγ), eeH (HZZ, Hzγ, Hγγ) with beam polarisation from 250 GeV up to 1 TeV

Dutta et al.
PRD 78 (2008)

Higgs Anomalous Couplings



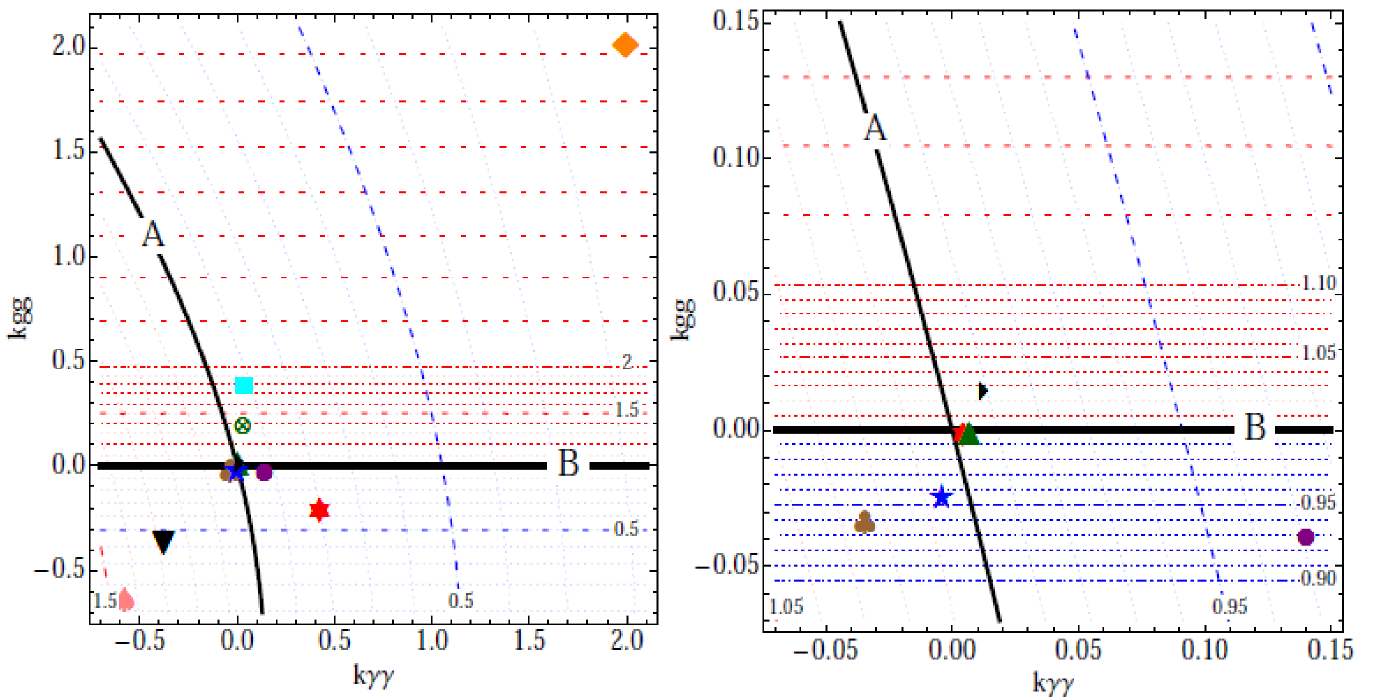




Search for anomalous couplings in double-tagged $ZH \to \nu\nu WW^* \to \nu\nu cscs$

Takubo et al.
arXiv:1006.3427 [hep-ex]

Higgs → γγ and gg



Combined analysis of γγ and gg gives access to shifts arising from a variety of new physics processes whose contributions can be parametrised as:

$$\overline{BR}(H \to \gamma\gamma) = \frac{\Gamma^{NP}_{\gamma\gamma}}{\Gamma^{SM}_{\gamma\gamma}} \frac{\Gamma^{SM}_{\text{tot}}}{\Gamma^{NP}_{gg} + \Gamma^{NP}_{\gamma\gamma} + \Gamma^{SM}_{\text{others}}}$$

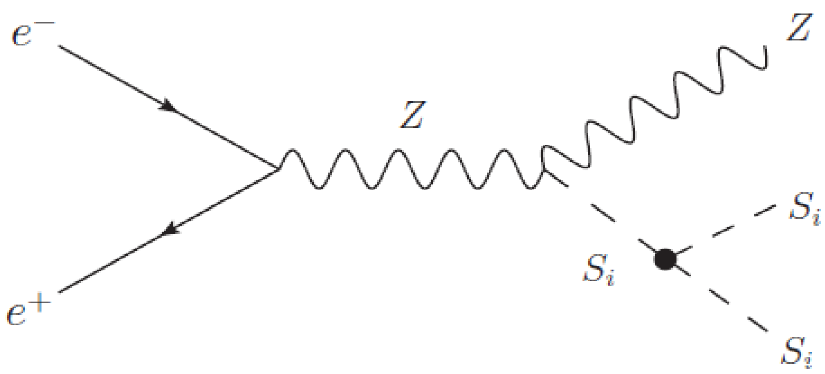
$$\simeq \left(1 + \frac{\kappa_{\gamma\gamma}}{\frac{9}{16}A_W(\tau_W) + 1}\right)^2 \frac{\Gamma^{SM}_{\text{tot}}}{(1+\kappa_{gg})^2\Gamma^{SM}_{gg} + (\Gamma^{SM}_{\text{tot}} - \Gamma^{SM}_{gg})} .$$

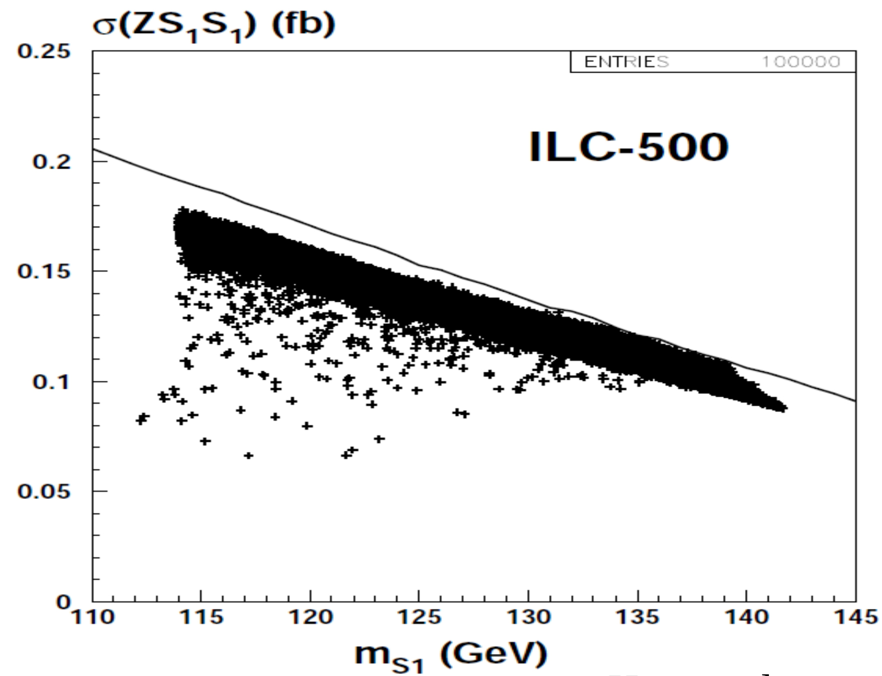
Cacciapaglia et al.
JHEP0902 049

Higgs Self Coupling

Determination of gHHH and study of Higgs potential possibly last missing channel to be validated by detailed simulation at the level of accuracy estimated with fast simulations;
Task appears more challenging than anticipated despite increased sofistication of event reconstruction software (PFA, b tagging, kin fits, ...), current studies at Multi-TeV may represent an opportunity to assess LC potential in triple Higgs production.

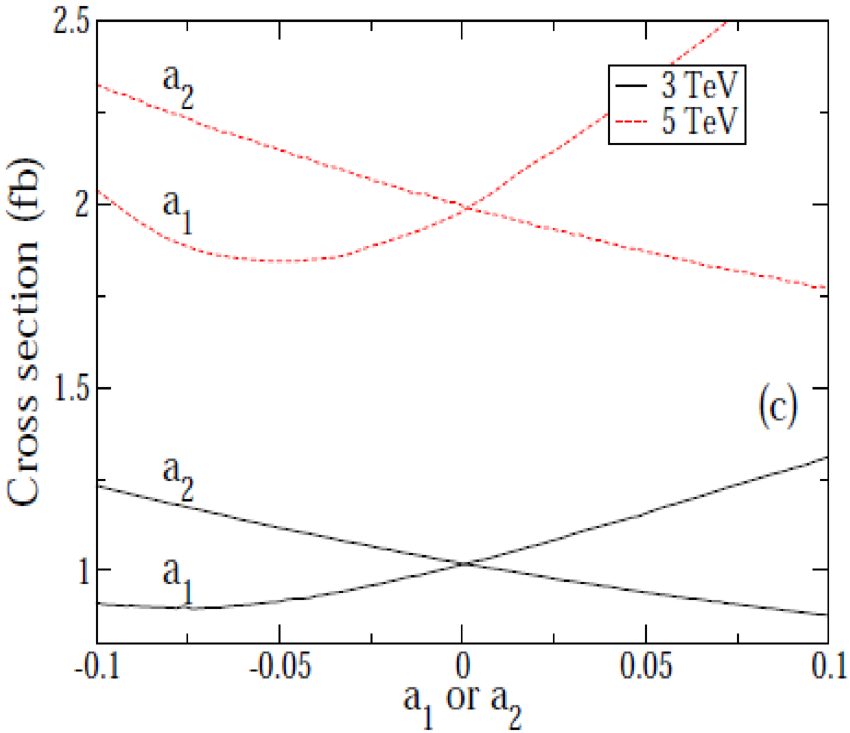
Models with non-minimal Higgs sector modify the Higgs self-coupling as already studied in the case of the MSSM. In string-motivated E6 SUSY two Higgs doublets and two singlets give four neutral bosons. Contribution of heavy scalars are small and double Higgs production with Z is SM-like.

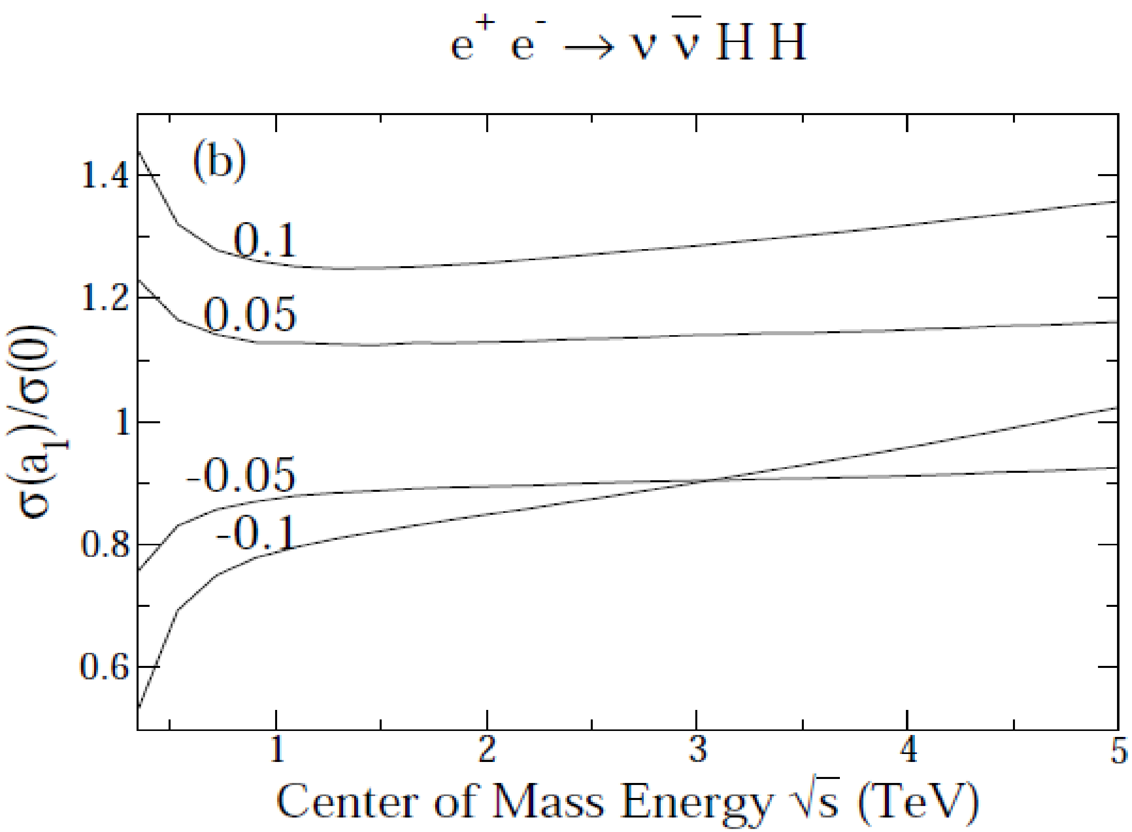




Ham et al.
arXiv:0911.5551 [hep-ph]

Higgs Self Coupling





Double Higgs production in WW fusion appears most sensitive to anomalous Couplings in WWHH, HHH.

Barger et al
PRD67 (2003)]

Higgs Self Coupling

ZHH study based on fast simulation at 0.5 TeV for M_H=120 GeV with 2 ab^{-1}

tt bkg too large in qq bb WW channel, some excess of signal events can be observed in the ll bb bb channel. But observing ZHH events is not equivalent to assess that $g_{HHH} > 0$.

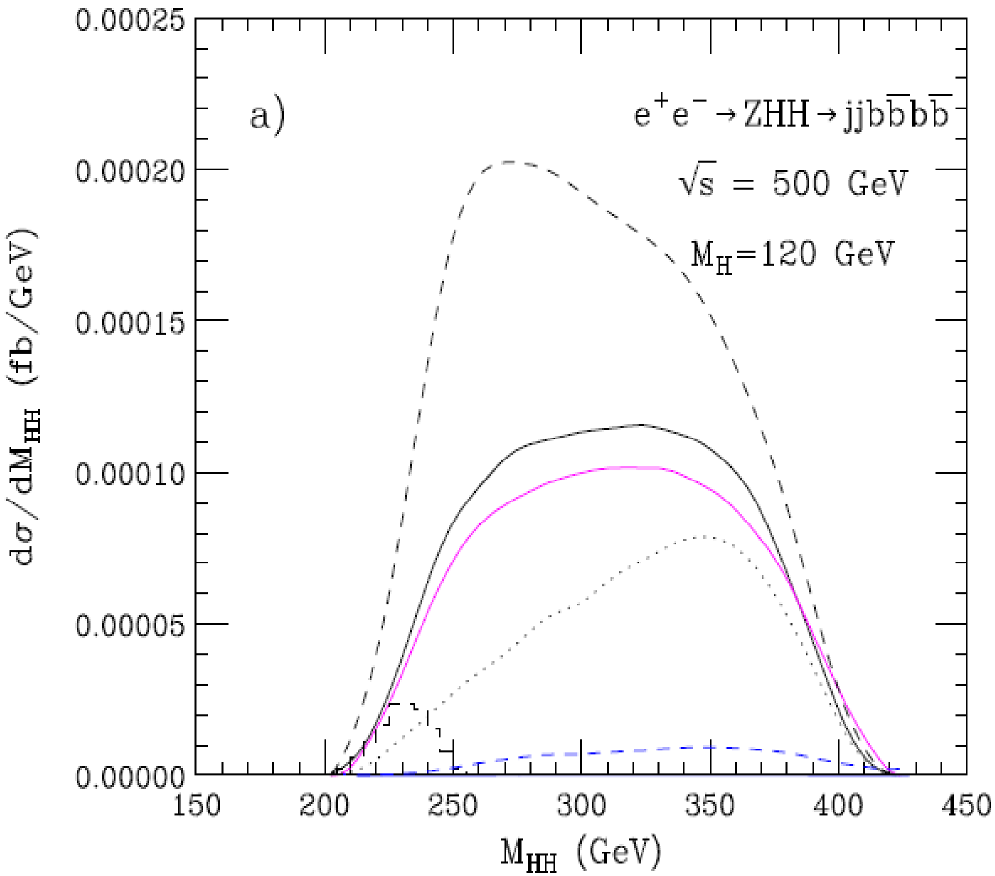
TABLE IV: Cut statistics of $e^+ + e^- \to ZHH \to (l\bar{l})(b\bar{b})(b\bar{b})$

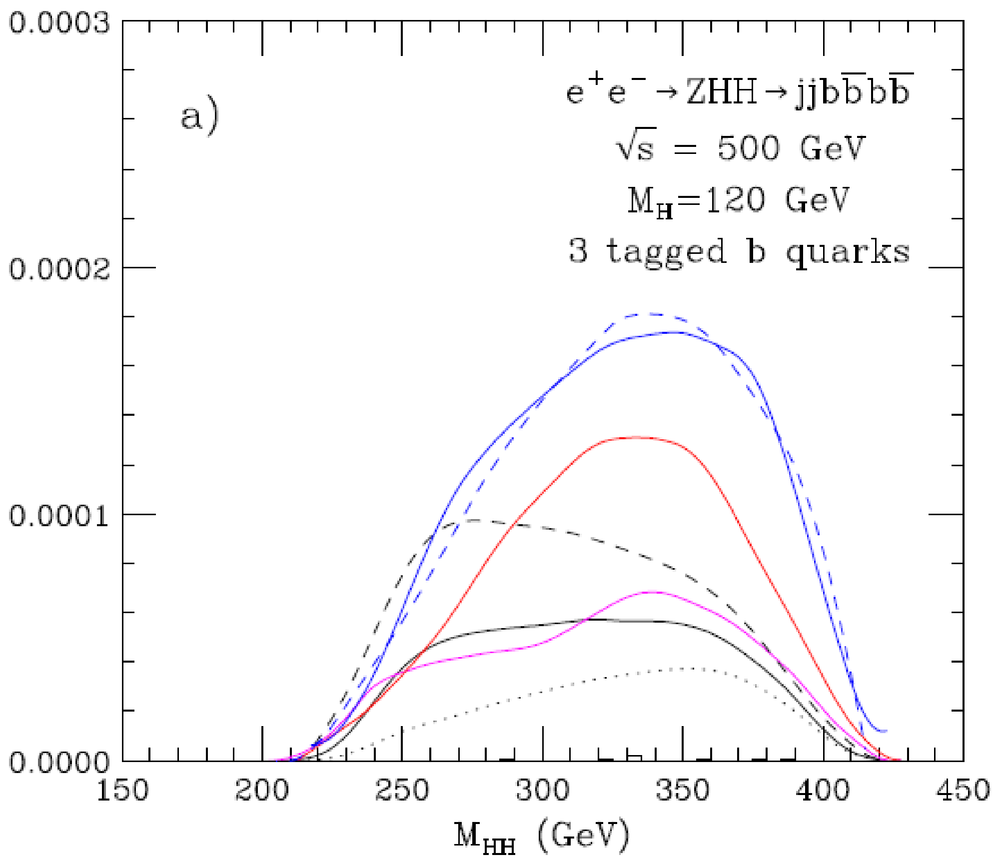
Process	ZHH	$t\bar{t}$	ZZZ	WWZ	ZZ	ZH
generated	1M	4.5M	500K	750K	1.25M	250K
theoretical	304	1062000	1600	72300	1030000	140000
pre-selection	15.4	9023	125	1943	3560	1618
$mva\_tt > 0.98$ $mva\_wwz > 1.0$ $mva\_zz > 0.97$ $mva\_zh > 0.97$ $mva\_zzz > 0$	11.7	312	12.9	12.7	16.5	5.6
$70GeV < M_Z < 110GeV$	9.7	106	11.7	7.5	16.5	0.56
$Y_{cut} > 0.015$	9.1	91.3	10.6	6.9	6.6	0
$2b(H_1)(N_{off} > 0)$	6.3	28	5.5	1.8	0	0
$2b(H_2)(N_{off} > 1)$	3.5	0.71	2.3	0	0	0
$mva\_zzz > 0.86$	3.0	0	0.82	0	0	0

Tian et al.
arXiv:1008.0921 [hep-ex]

Higgs Self Coupling

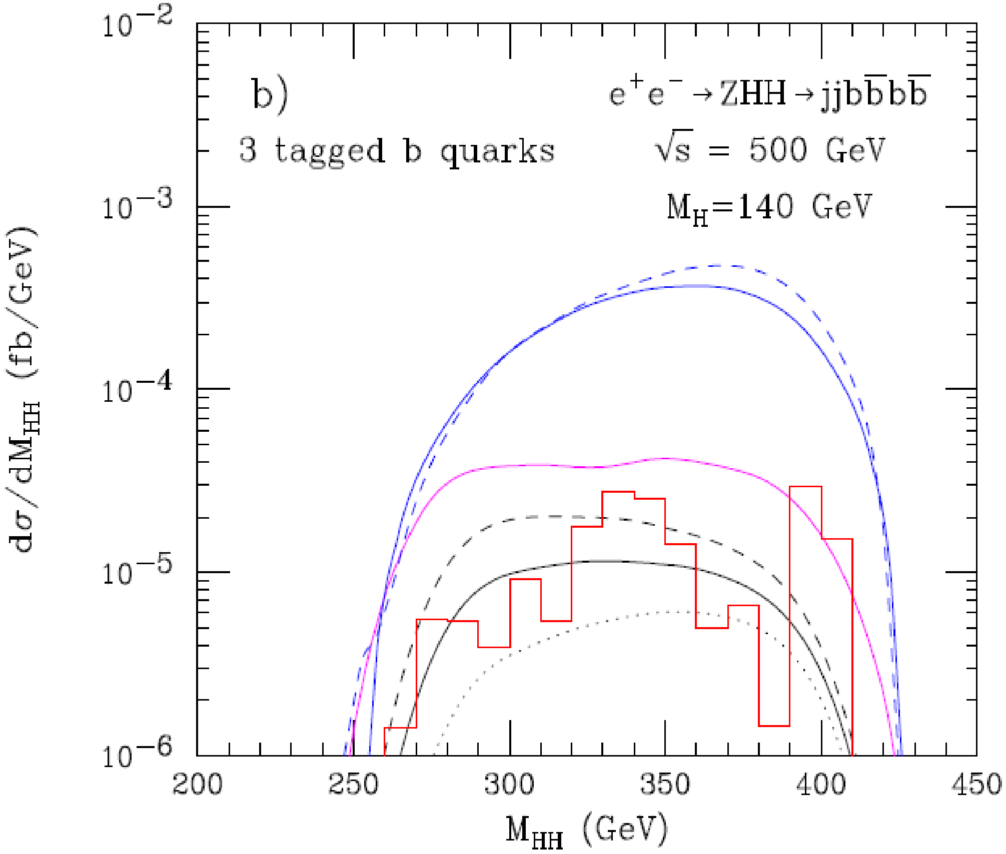
g_{HHH} determination will be an experimental “tour de force” and precise interplay of process (ZHH, HHνν, ttHH, ...), energy, luminosity and detector performance still needs to be fully clarified.

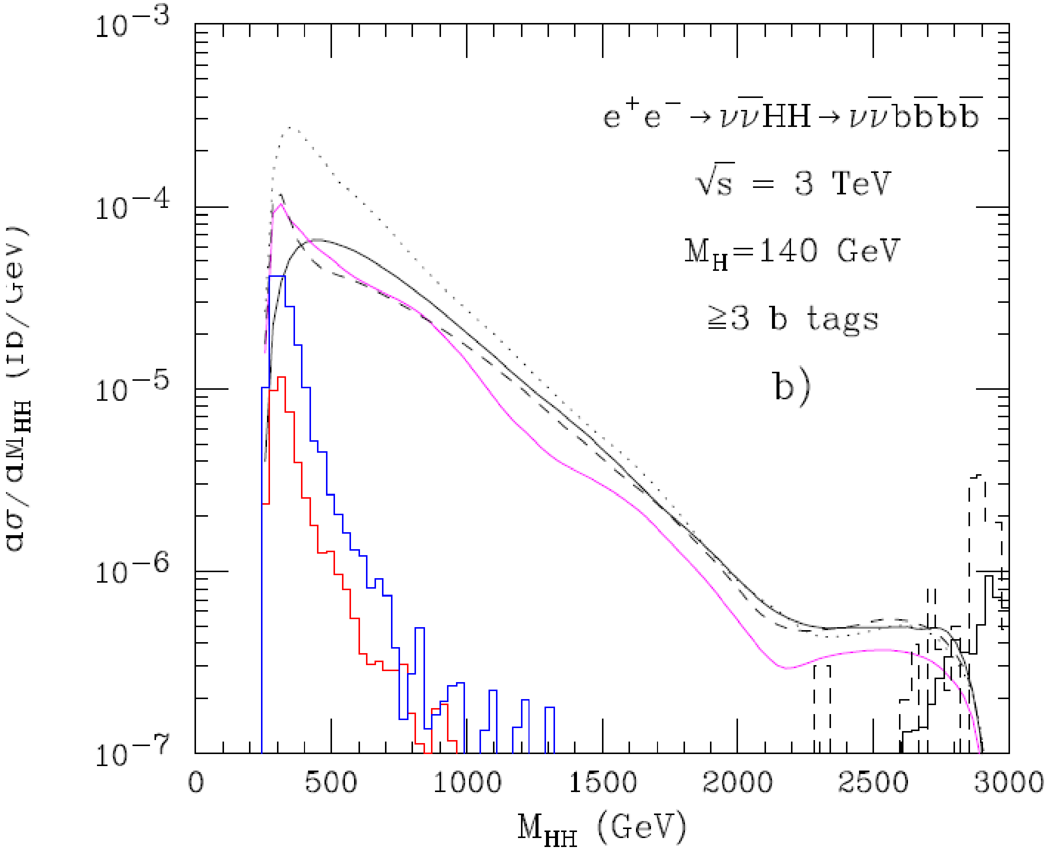




Baur.
PRD 80 (2009)

Higgs Self Coupling





Baur.
PRD 80 (2009)

Higgs Self Coupling

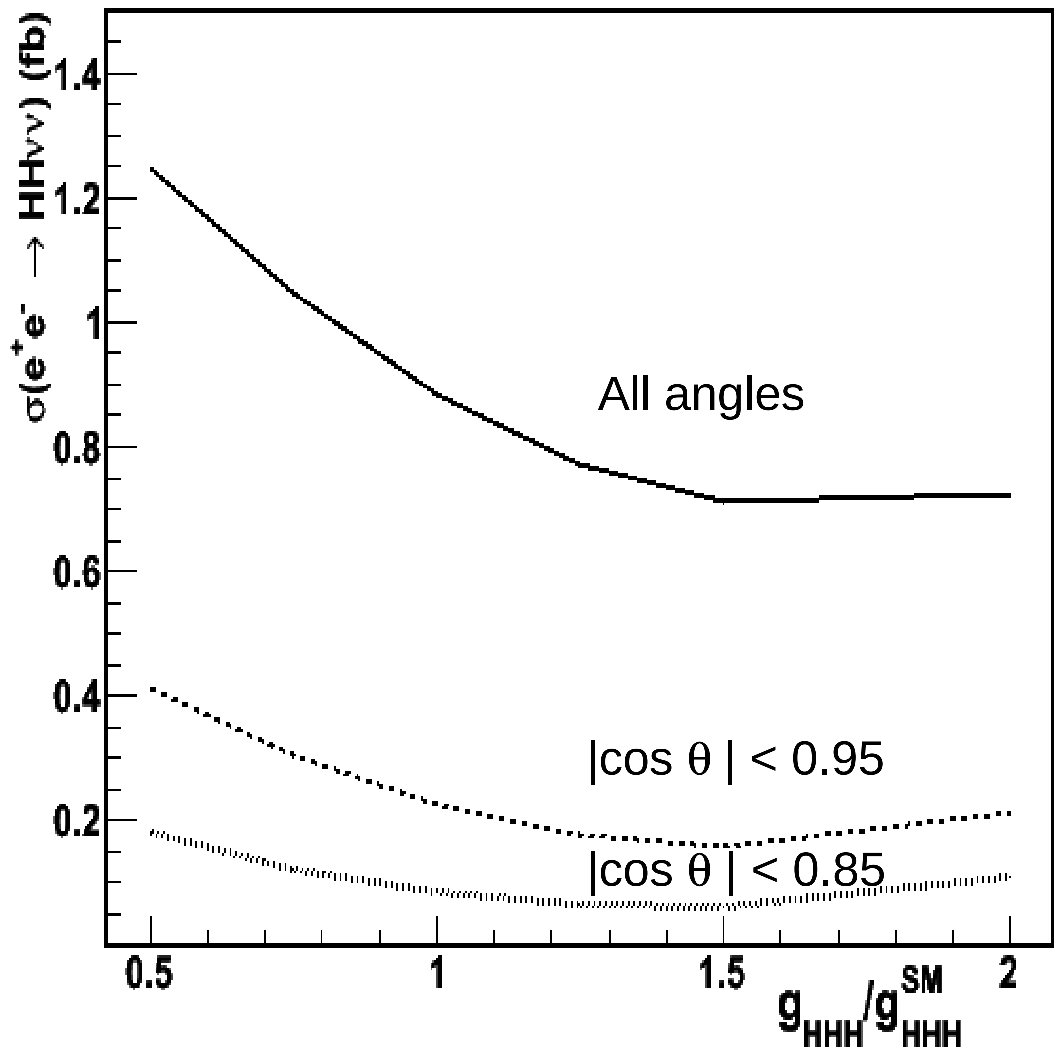
$\sqrt{s} = 1$ TeV			
	0.5 ab^{-1}	1 ab^{-1}	2 ab^{-1}
$m_H = 120$ GeV	$+0.58$ -0.27	$+0.30$ -0.21	$+0.20$ -0.17
$m_H = 140$ GeV	$+0.99$ -0.41	$+0.94$ -0.38	$+0.78$ -0.25
$m_H = 180$ GeV	$+0.56$ -0.32	$+0.55$ -0.29	$+0.59$ -0.28
$\sqrt{s} = 3$ TeV			
	1 ab^{-1}	2 ab^{-1}	3 ab^{-1}
$m_H = 120$ GeV	$+0.14$ -0.12	$+0.11$ -0.10	$+0.10$ -0.09
$m_H = 140$ GeV	$+0.15$ -0.19	$+0.15$ -0.15	$+0.11$ -0.14
$m_H = 180$ GeV	$+0.16$ -0.20	$+0.15$ -0.13	$+0.12$ -0.12

Baur.
PRD 80 (2009)

Higgs Self Coupling

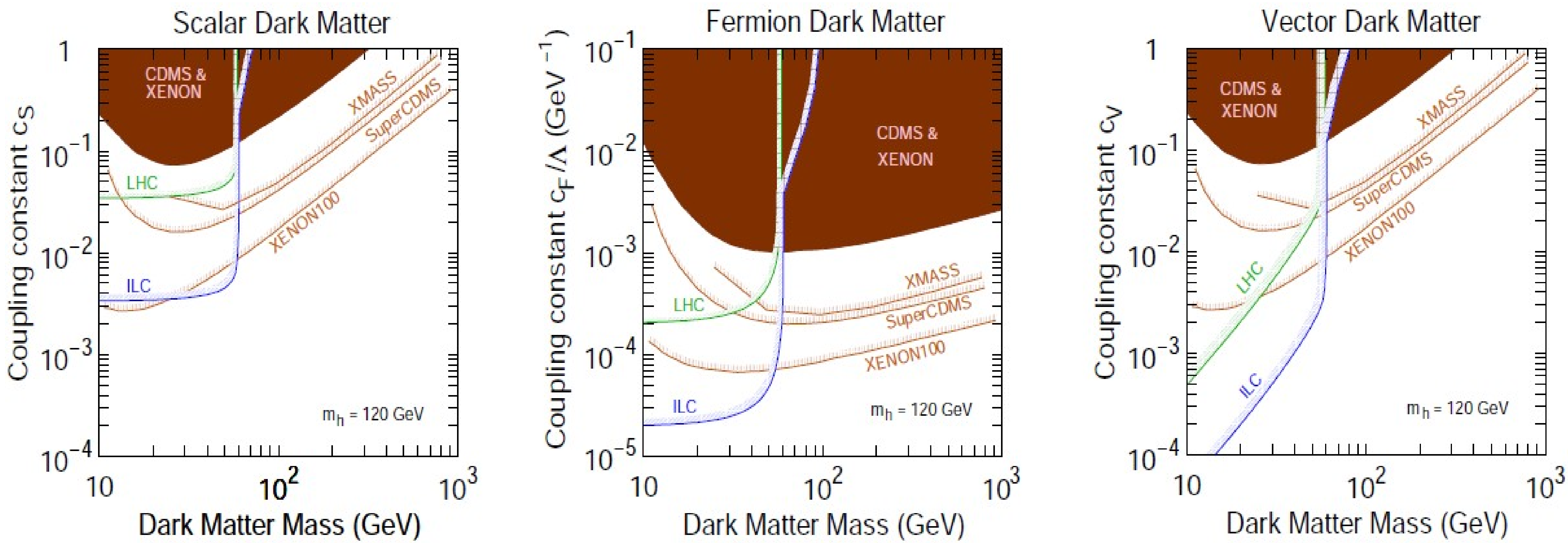
Exploiting the potentially large sensitivity in nnHH at 1 TeV and above requires very stringent constraints on jet reconstruction and tagging down to very small angles to preserve sensitivity to g_{HHH}

Detailed study is required based on realistic simulation and reconstruction and accounting for SM and accelerator-induced bkg.



MB, CLIC09

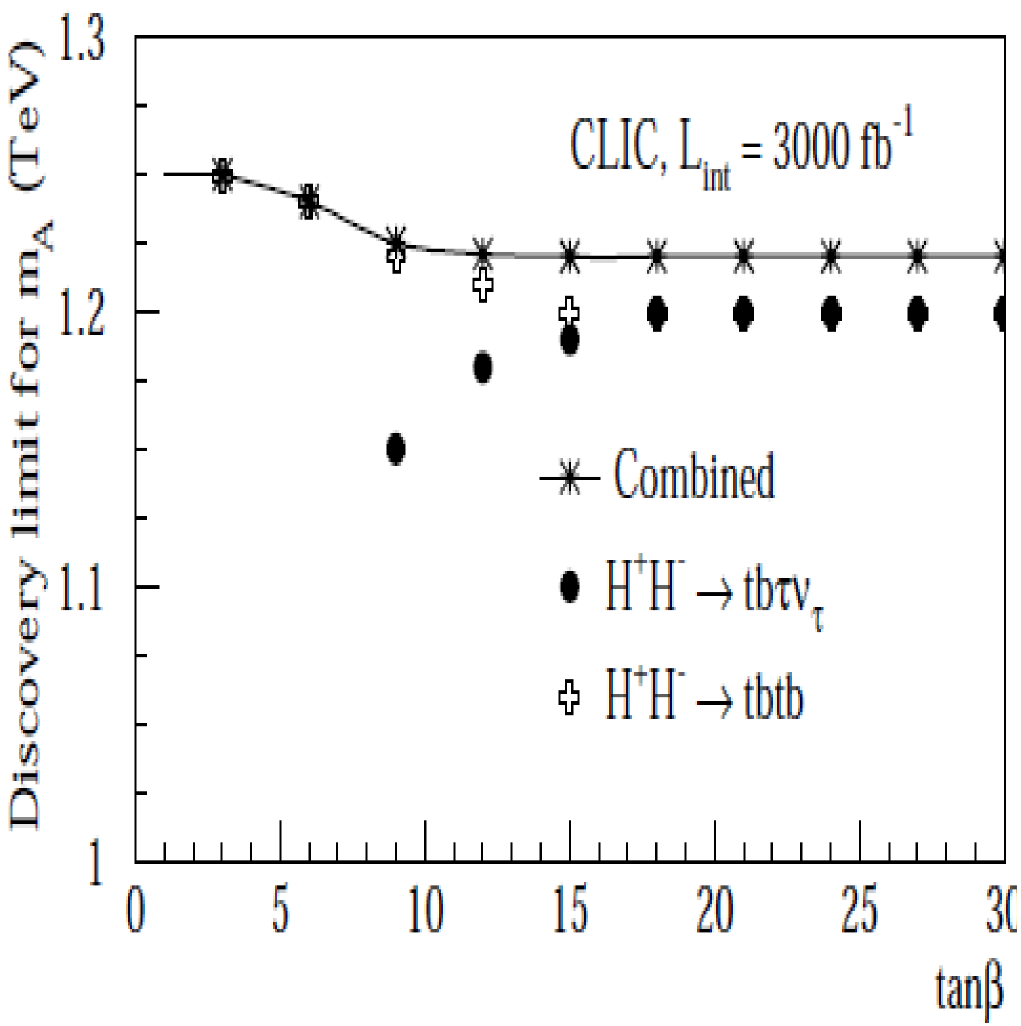
Higgs → invisible decays

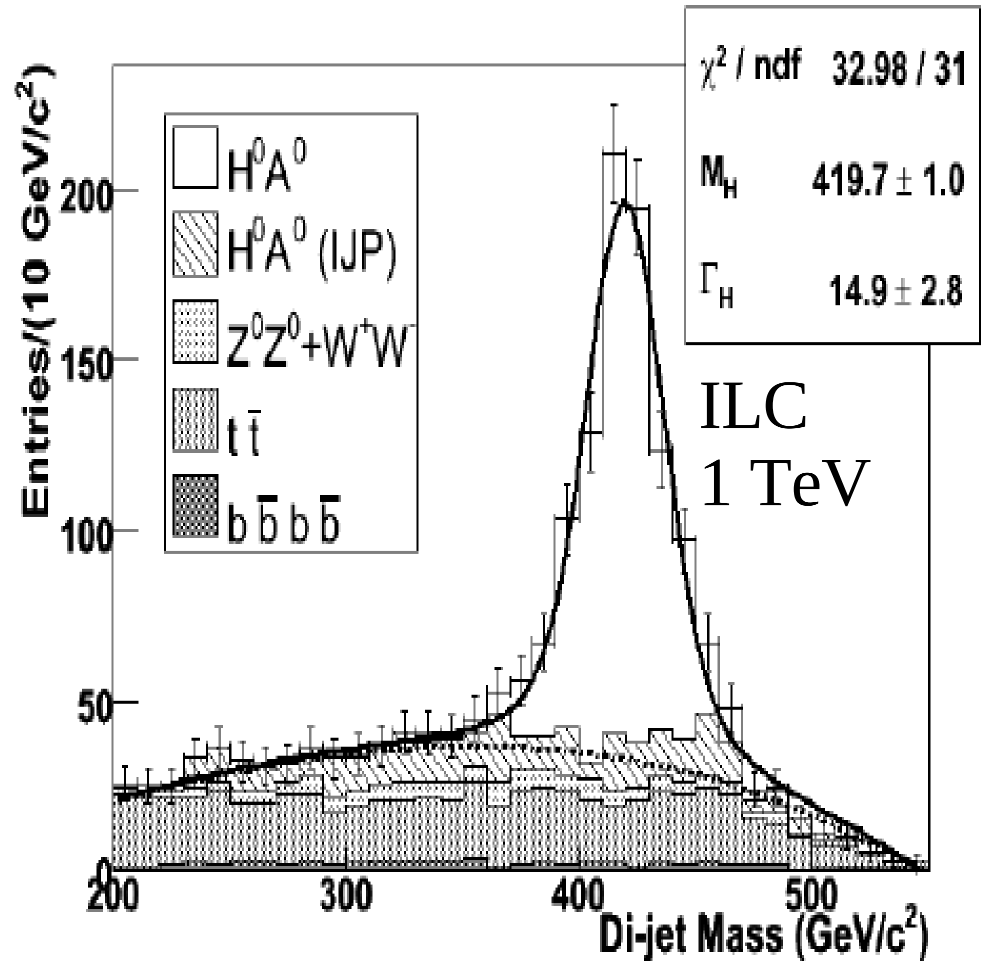


Coupling of DM to Higgs boson studied through invisible Higgs decays in Higgsstrahlung production.

Matsumoto et al.
arXiv:1006.5268 [hep-ph]

Heavy Higgs Bosons





Coniavitis, Ferrari
PRD 75 (2007)

MB et al.
PRD 78 (2008)

H^+ Mass Determination

Mass (GeV)	Ecm (TeV)	L (ab^{-1})	Selection Efficiency	$\delta M/M$
145	0.5	0.5	-	0.006
200	0.8	0.5	0.02	0.002
300	0.8	0.5	0.04	0.004
702	3.0	3.0	0.02	0.007
1136	3.0	3.0	0.05	0.005

A^0 Mass Determination

Mass (GeV)	Ecm (TeV)	L (ab^{-1})	Selection Efficiency	$\delta M/M$
260	0.8	0.2		0.002
420	1.0	2.0	0.17	0.002
1140	3.0	3.0	0.15	0.005

Conclusions

LoI studies have confirmed level of accuracy in the reconstruction of a light Higgs profile with the increased realism of a full simulation and reconstruction at 250-500 GeV. Several new (and more generic) scenarios are being tested against accuracy on Higgs couplings;

Beyond main channels studied in LoIs, several additional channels exist for which studies should be repeated with more realistic simulation and full backgrounds;

ILC and CLIC studies at 1 – 3 TeV shift attention towards Higgs processes which are too rare for detailed study at lower energies (double Higgs production, $H \rightarrow \mu\mu$, $H \rightarrow bb$ for intermediate mass Higgs boson, …) and heavy Higgses in extended models. Potential in double Higgs production and triple Higgs coupling needs reassessment with detailed and realistic simulation.

Sensitivity to heavy Higgs bosons up to ~ pair production kinematic limit is confirmed by several study, mass resolution to few permil level over full accessible mass spectrum, width, decay BRs, CP violation in charged Higgs decays (+...) still to be studied in details.