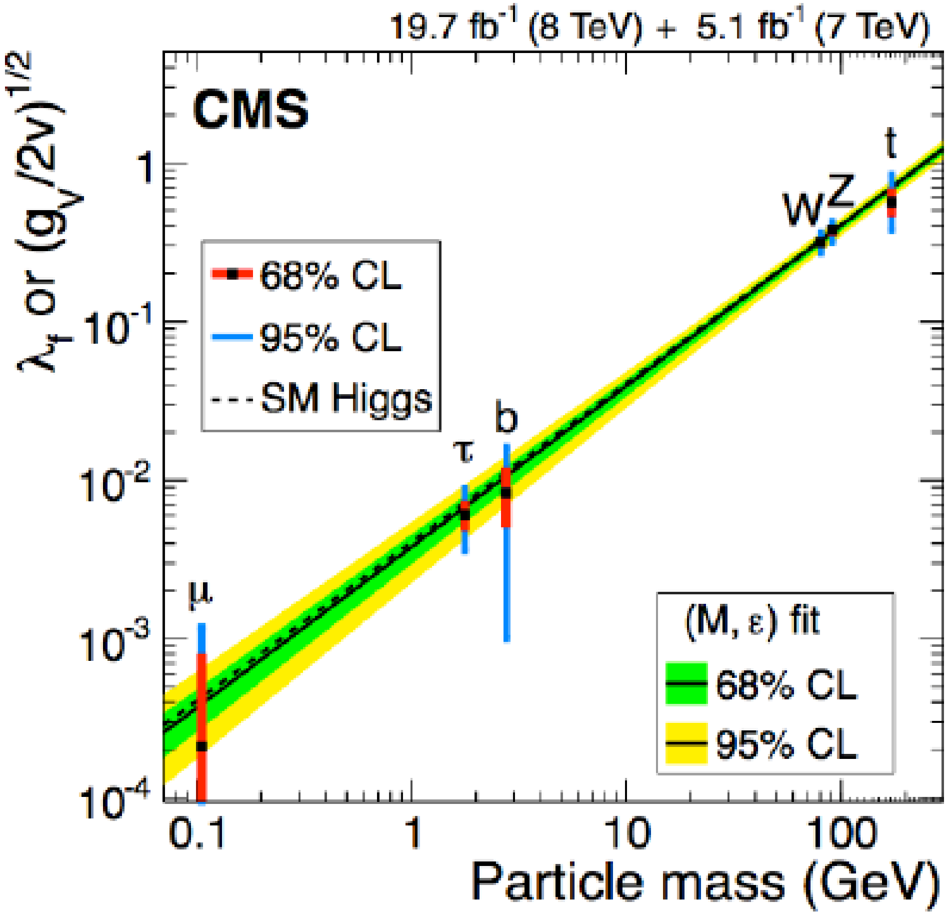
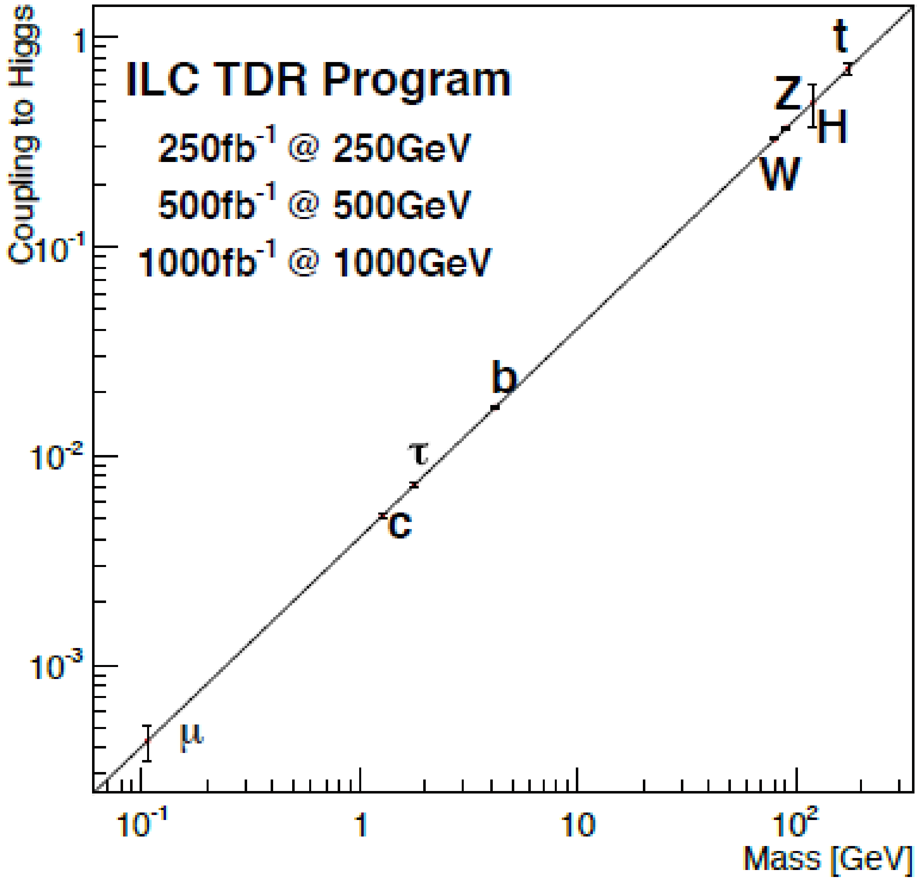
Topic around the Higgs couplings

Special Topic　09/07/2018

Couplings and the Particle Mass





What is Higgs coupling

Interaction related with the Higgs term

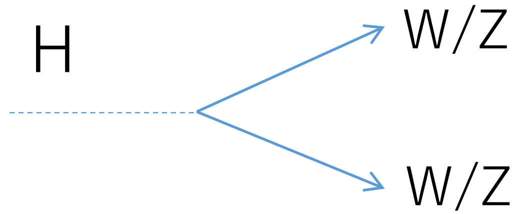
- **W/Z boson - Higgs**

$$\mathscr{L}_1^{\mathrm{HB}} = \frac{1}{2} v g^2 W_\alpha^\dagger W^\alpha \sigma + \frac{1}{4} g^2 W_\alpha^\dagger W^\alpha \sigma^2 + \frac{v g^2}{4\cos^2\theta_W} Z_\alpha Z^\alpha \sigma + \frac{g^2}{8\cos^2\theta_W} Z_\alpha Z^\alpha \sigma^2.$$

$$\frac{1}{2\nu} m_W^2$$

$$m_W = \frac{1}{2} v g, \quad m_Z = m_W / \cos\theta_W, \quad m_H = \sqrt{(-2\mu^2)},$$

Coupling (x ν) $\propto m_W^2$



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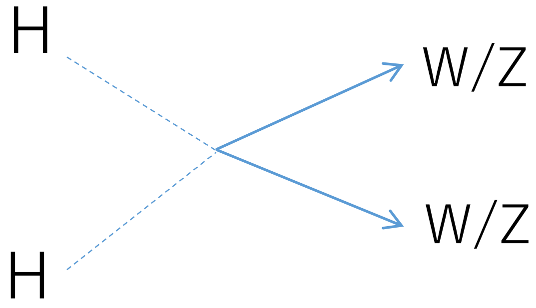
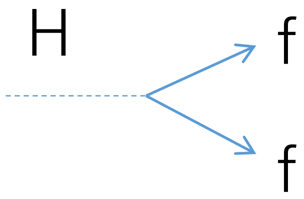


- **Fermion - Higgs**

$$\mathscr{L}_1^{\mathrm{HL}} = -\frac{1}{v} m_l \bar{\psi}_l \psi_l \sigma - \frac{1}{v} m_{\nu_l} \bar{\psi}_{\nu_l} \psi_{\nu_l} \sigma.$$

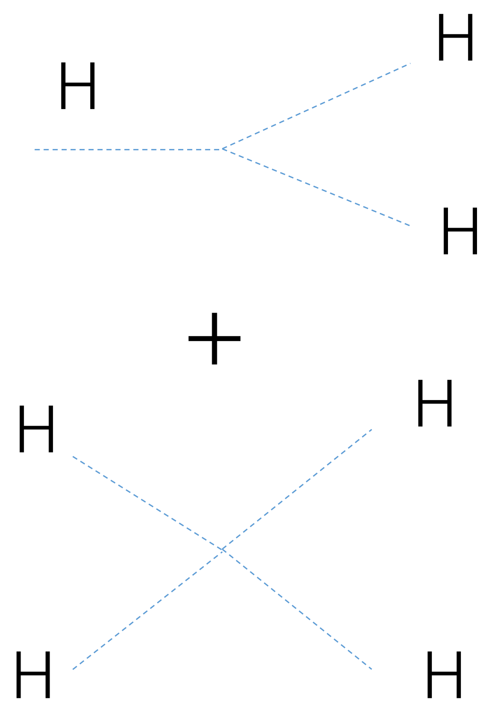
Coupling (x ν) $\propto m_f$



Interaction related with the Higgs term

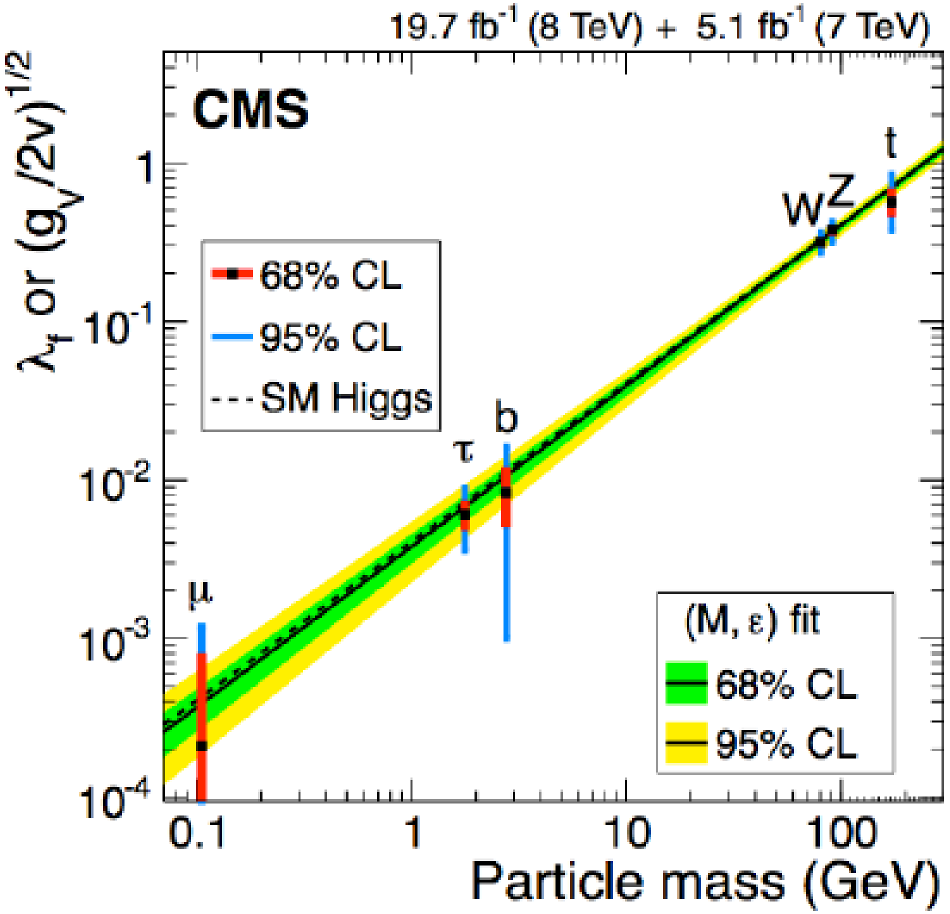
- **Higgs - Higgs**

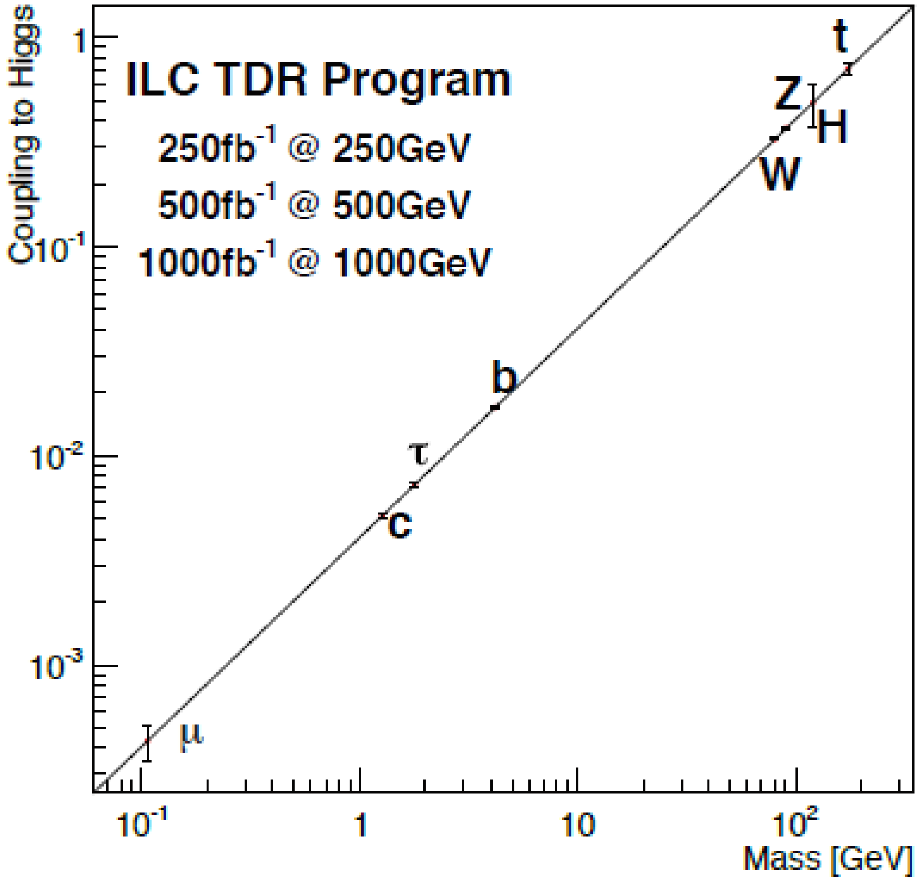
$$\mathscr{L}_1^{\mathrm{HH}} = -\frac{1}{4}\lambda\sigma^4 - \lambda v\sigma^3$$



-- need higher energy than 250 GeV (CEPC) to explore this coupling.

Couplings and the Particle Mass





Which precision on the measurement of the couplings , we want/need to achieve

Comparison of precision of the Higgs coupling

κ : ratio of the coupling constant (with the SM prediction)

$$\kappa_V = \frac{g(hVV)}{g(hVV;\mathrm{SM})}$$

$$\kappa_f = \frac{g(hff)}{g(hff;\mathrm{SM})},$$

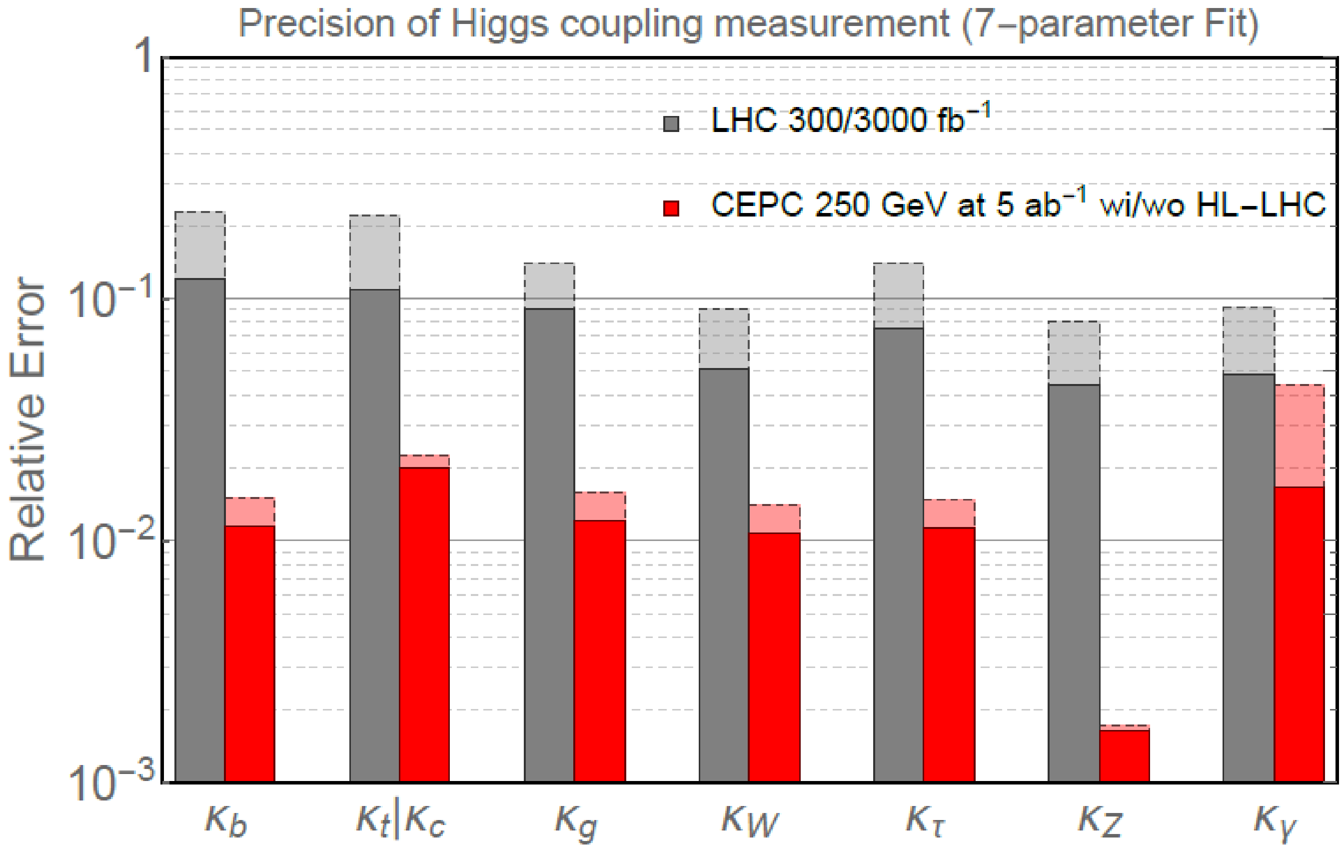


Figure 15. The 7 parameter fit result, and comparison with the HL-LHC [45]. The projections for the CEPC at 250 GeV with 5 ab^{-1} integrated luminosity are shown. The CEPC results without combination with the HL-LHC input are shown with dashed edges. The LHC projections for an integrated luminosity of 300 fb^{-1} are shown in dashed edges.

Example of Higgs coupling deviation

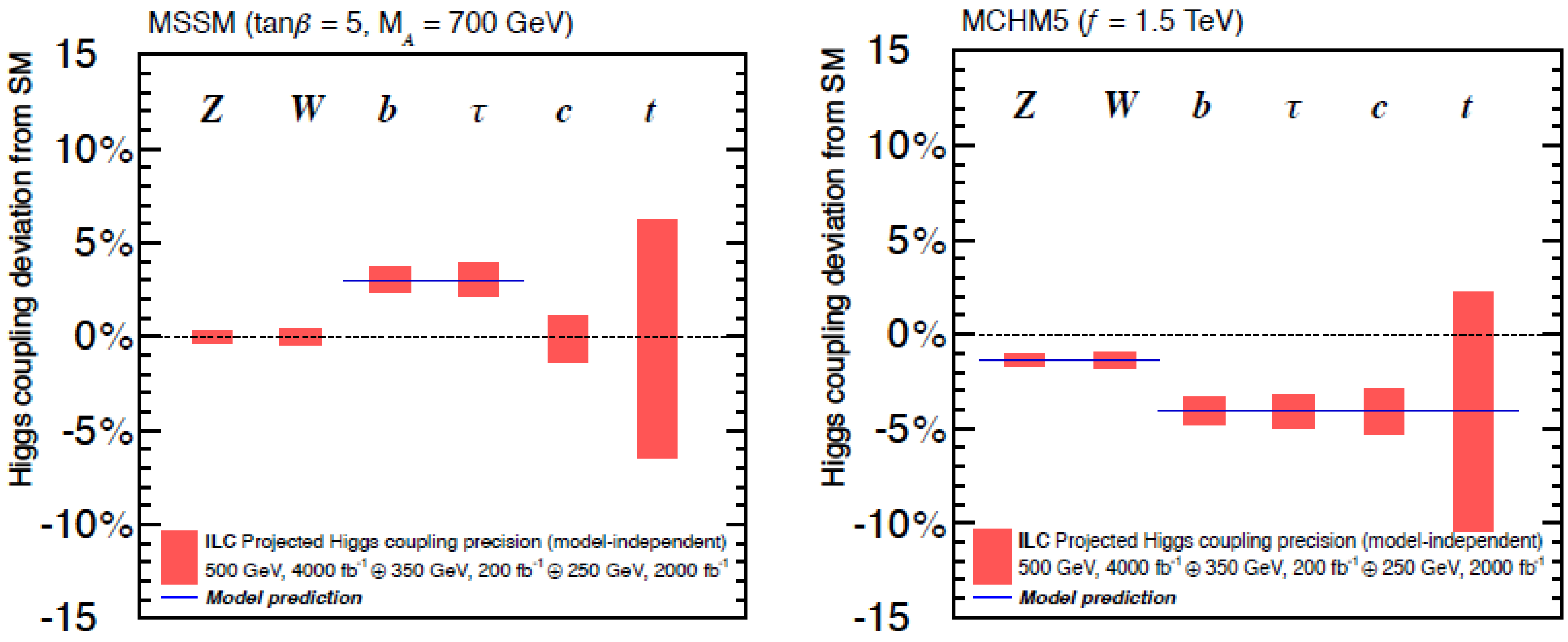
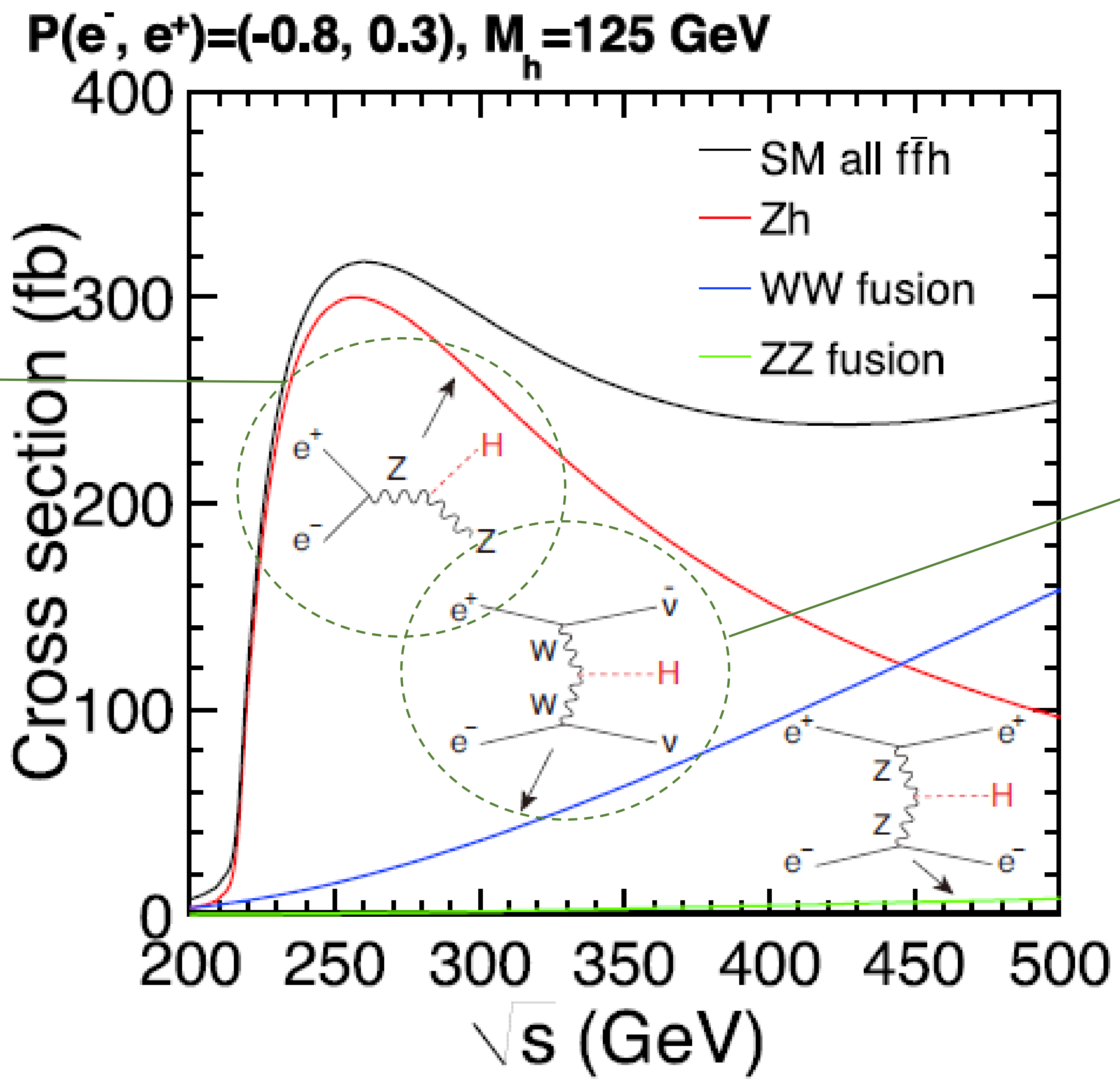


Figure 6: Two examples of models of new physics and their predicted effects on the pattern of Higgs boson couplings. Left: a supersymmetric model. Right: a model with Higgs boson compositeness. The error bars indicate the 1σ uncertainties expected from the model-independent fit to the full ILC data set.

This is quite model dependent !!

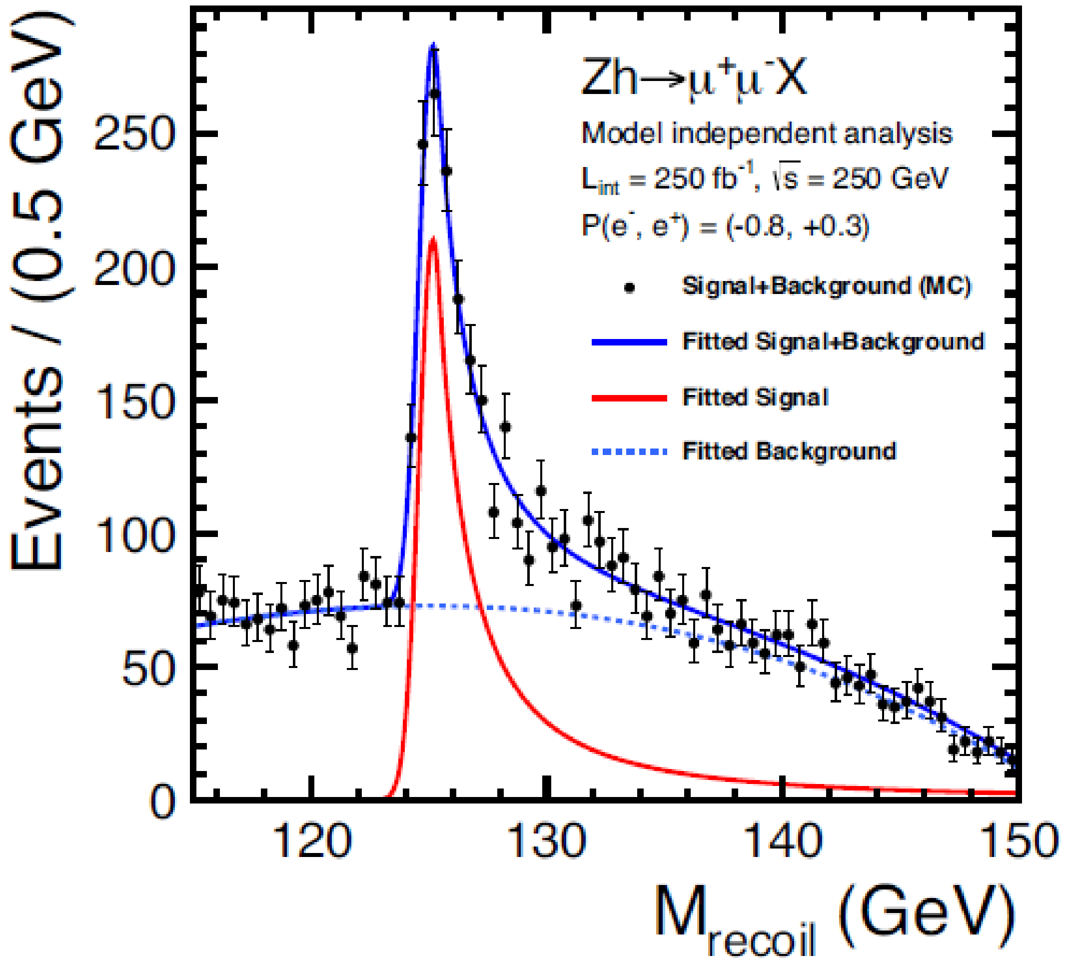
How to measure/determine the couplings

Determine precisely the coupling of H->ZZ



Determine precisely the coupling of H->WW

Higgs Cross section (Z*->ZH <=> H->ZZ) can be obtained by using the inclusive Higgs decay



Note :   the Higgs total width is expected as ~ 4MeV, which can not measure directly, even with this inclusive analysis.

How to obtain the couplings

1. $$\Gamma_h = \frac{\Gamma_{ZZ}}{BR_{ZZ}} = \frac{\Gamma_{WW}}{BR_{WW}}$$

→ By measuring the BRs, total width of Higgs boson is obtained .

2. $$BR(h \to A\overline{A}) = \Gamma(h \to A\overline{A})/\Gamma_h$$

→ By measuring the BRs for each particle, combined with the total width of Higgs, the partial width -> coupling constant can be obtained.

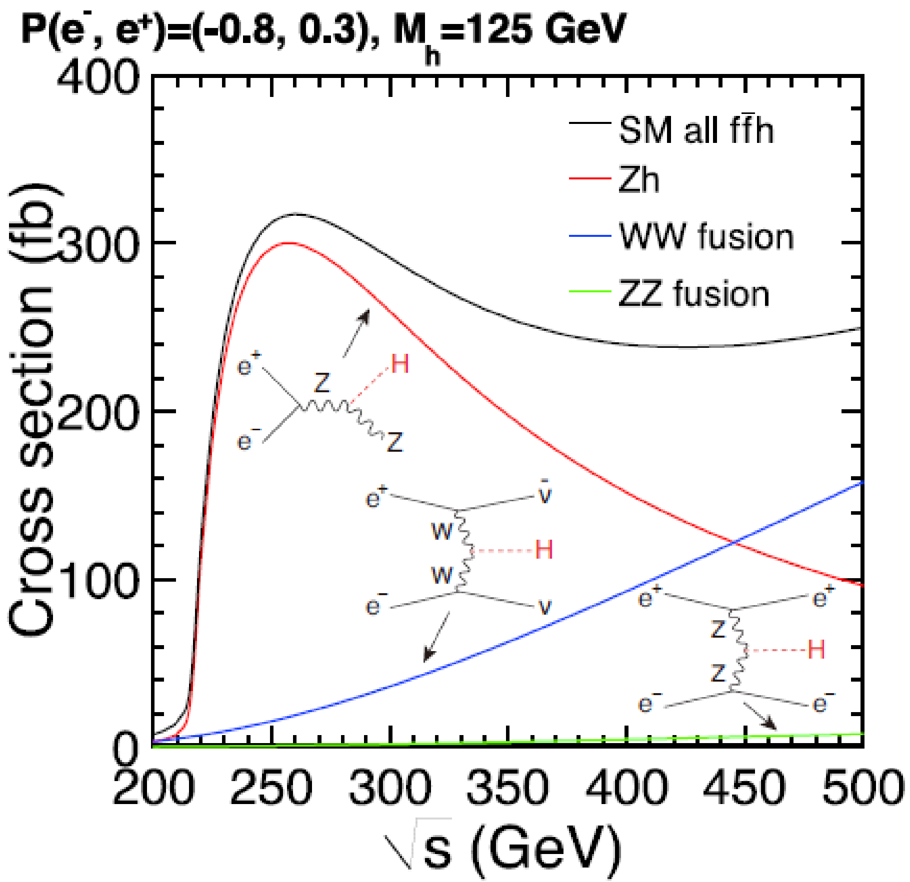
How to obtain the couplings

[Key Point]

$$\Gamma_h = \frac{\Gamma_{ZZ}}{BR_{ZZ}} = \frac{\Gamma_{WW}}{BR_{WW}}$$

-- Γ_{zz}/Γ_{ww} can be determined relatively precise (less than 1%).

-- Precision of the Br(ZZ) is limited by the statistics ! (next page)



➡ Seems to be , , , Γ_h will be decided from WW side.

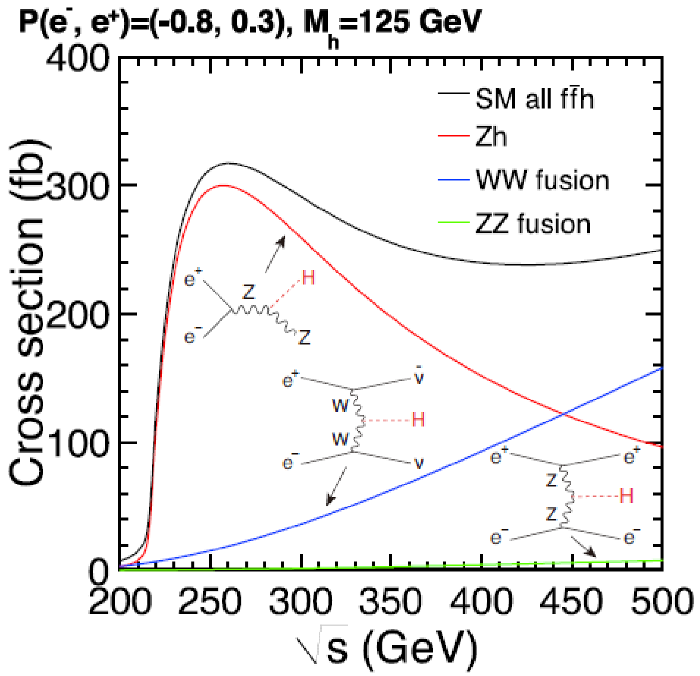
Table 9. Estimated precision of Higgs boson property measurements at the CEPC. All precision are relative except for m_H and $\mathrm{BR}(H \to \mathrm{inv})$ for which Δm_H and 95% CL upper limit are quoted respectively.

Δm_H	Γ_H	$\sigma(ZH)$	$\sigma(\nu\bar{\nu}H) \times \mathrm{BR}(H \to b\bar{b})$
5.9 MeV	3.3%	0.50%	3.1%

Decay mode	$\sigma(ZH) \times \mathrm{BR}$	BR
$H \to b\bar{b}$	0.28%	0.57%
$H \to c\bar{c}$	3.3%	3.4%
$H \to gg$	1.3%	1.4%
$H \to \tau^+\tau^-$	0.8%	0.9%
$H \to WW^*$	1.1%	1.2%
$H \to ZZ^*$	5.1%	5.1%
$H \to \gamma\gamma$	8.2%	8.3%
$H \to \mu^+\mu^-$	16%	16%
$(H \to \mathrm{inv})_{\mathrm{BSM}}$	–	$< 0.32\%$

Comments

It is also mentioned that there is a significant contamination of ZH “background” , Z->νν, H->bb , for the WW fusion , for 250 GeV… and it is not clear for me (but at present) this effect .



reference from the ILC

and less significant beamstrahlung effect. On the other hand, the lowered energy is expected to have a significant impact on the measurement of the WW fusion process ($e^+e^- \to \nu\bar{\nu}h$), the cross section of which becomes almost a factor of 10 smaller. Moreover, due to the limited available phase space at 250 GeV, the missing mass spectrum in the $\nu\bar{\nu}h$ process is significantly overlapping with that in the $Zh, Z \to \nu\bar{\nu}$

reference from the CEPC

The precision from the method of 5.3 is 5.4%, dominated by the statistics of $e^+e^- \to ZH$ events with $H \to ZZ^*$, after ignoring the measurements correlation with other channels. Keeping only the correlations between the measured sub channels appearing in the expression of 5.4, the precision on Higgs width is is 3.7%, dominated by the statistics of $e^+e^- \to \nu\bar{\nu}H$ events with $H \to b\bar{b}$. This method uses the large $Br(H \to b\bar{b})$ value to compensate the smaller cross section of the W fusion process $\sigma_{\nu\nu H}$. The combined precision of the two measurements is 3.3%.