Another Higgs production at ILC250

大阪大学
「ワニ博士」

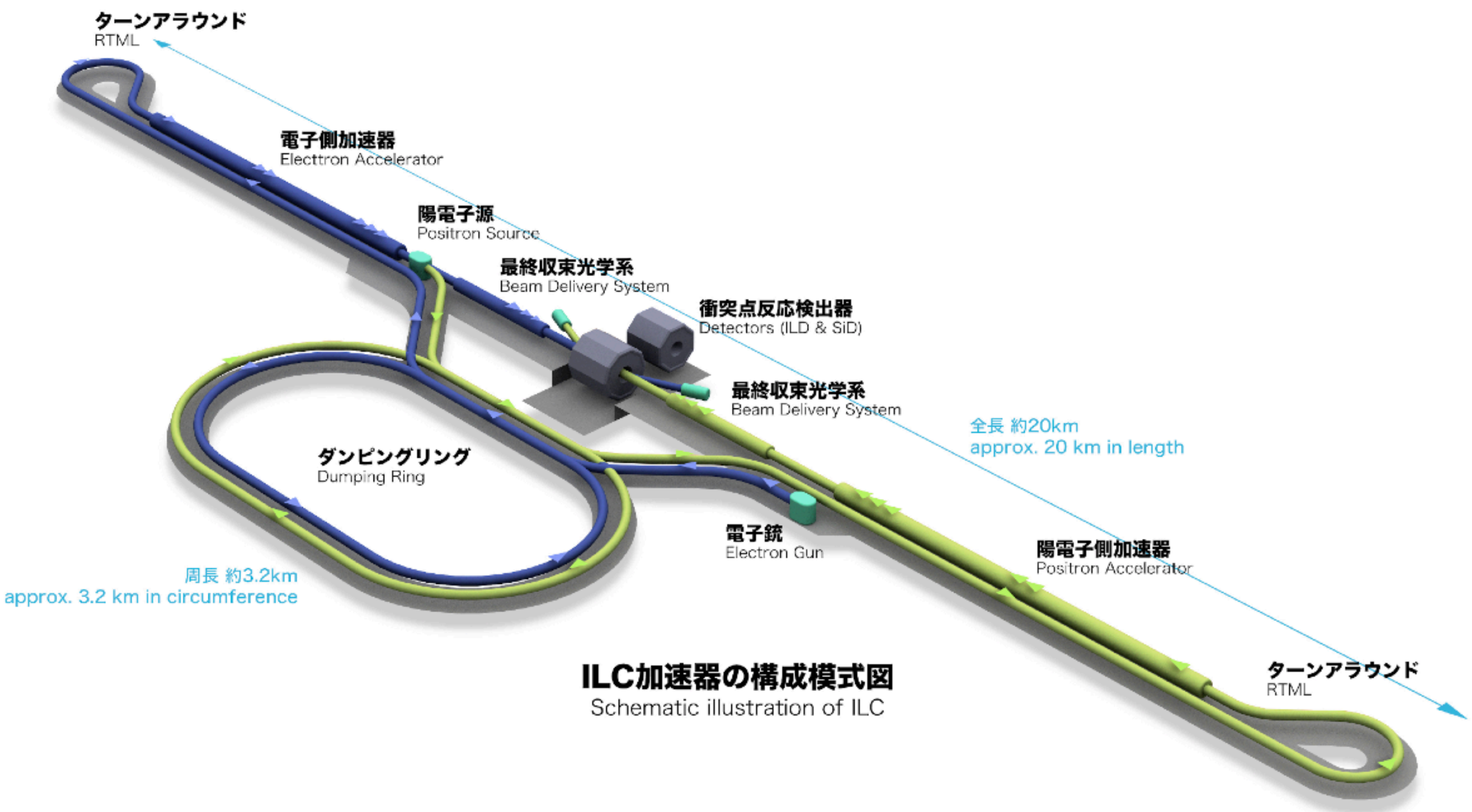
International Linear Collider @ 250GeV

大阪大学
OSAKA UNIVERSITY

馬渡 健太郎

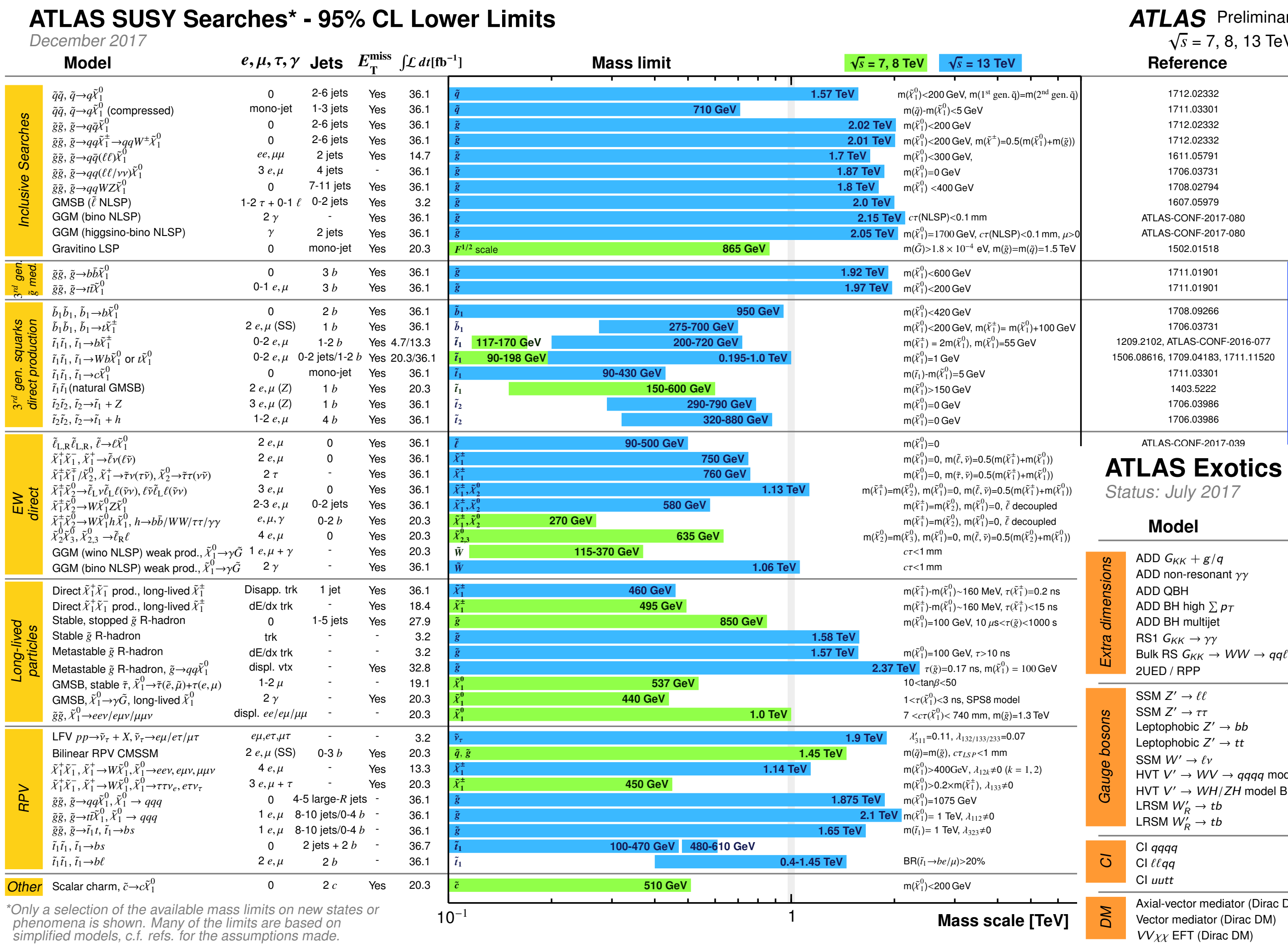
arXiv: 1808.xxxxx

共同研究者:
兼村 晋哉 (大阪大)
桜井 亘大 (富山大/大阪大)



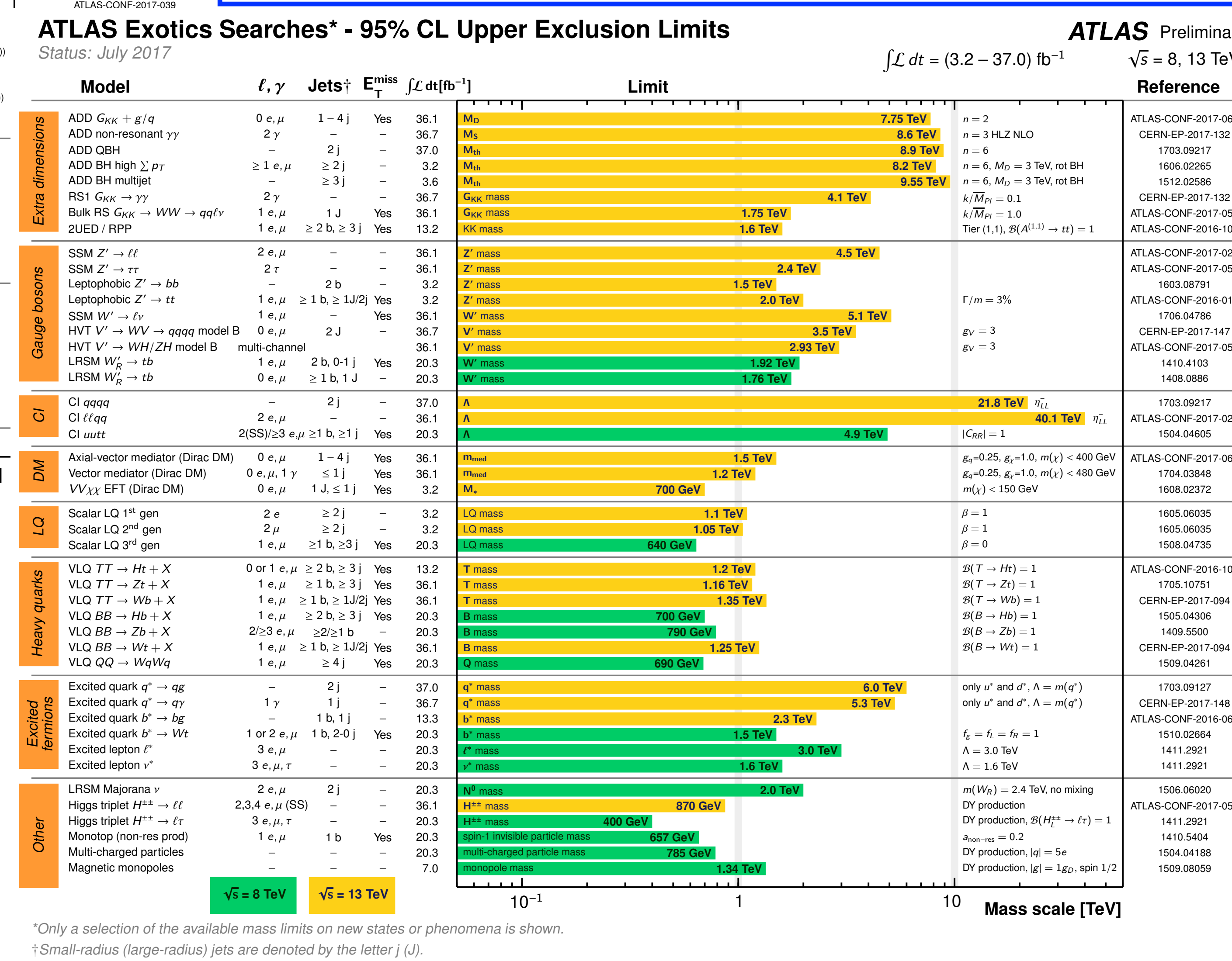
そもそも、なぜILCが必要か？

新物理(New Physics)の兆候が未だに現れない…

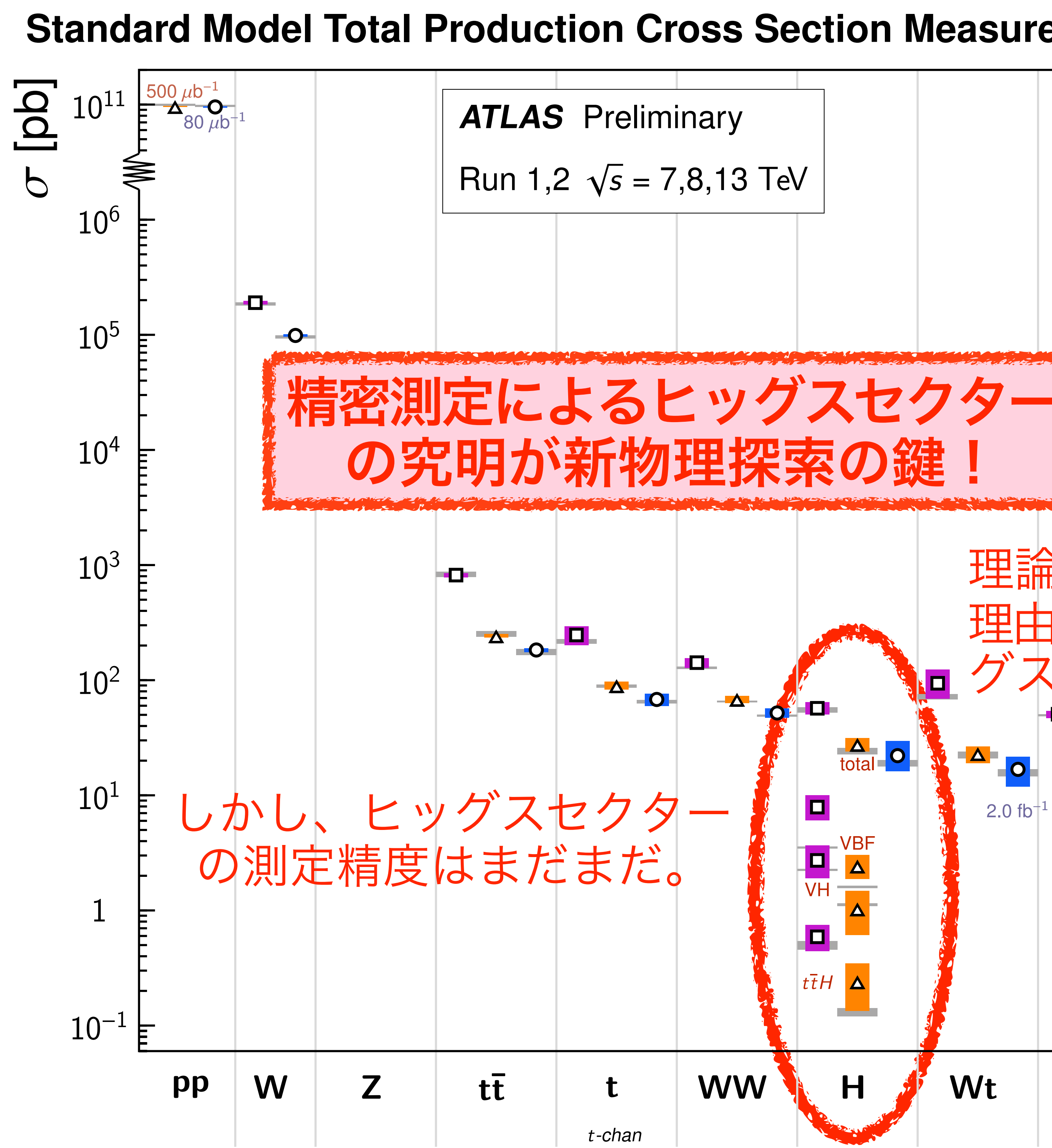


SUSY(超対称性)粒子の質量への制限

Non-SUSY粒子(e.g. 余剰次元模型のKaluza-Klein粒子)の質量への制限



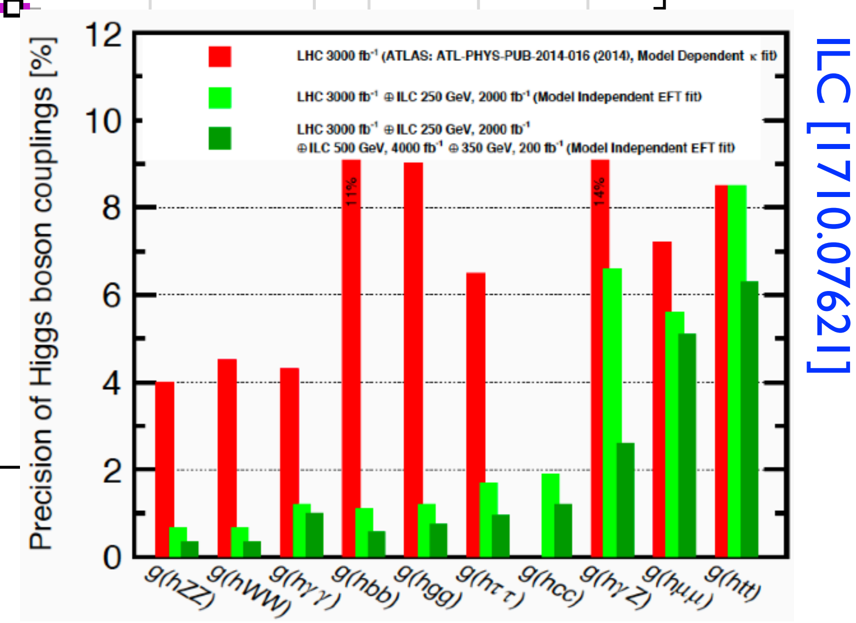
LHCデータ≈標準模型(SM)の予言



精密測定によるヒッグスセクターの究明が新物理探索の鍵！

理論的にヒッグス2重項が1つである理由はなく、新物理模型の多くはヒッグスセクターの拡張を要請。

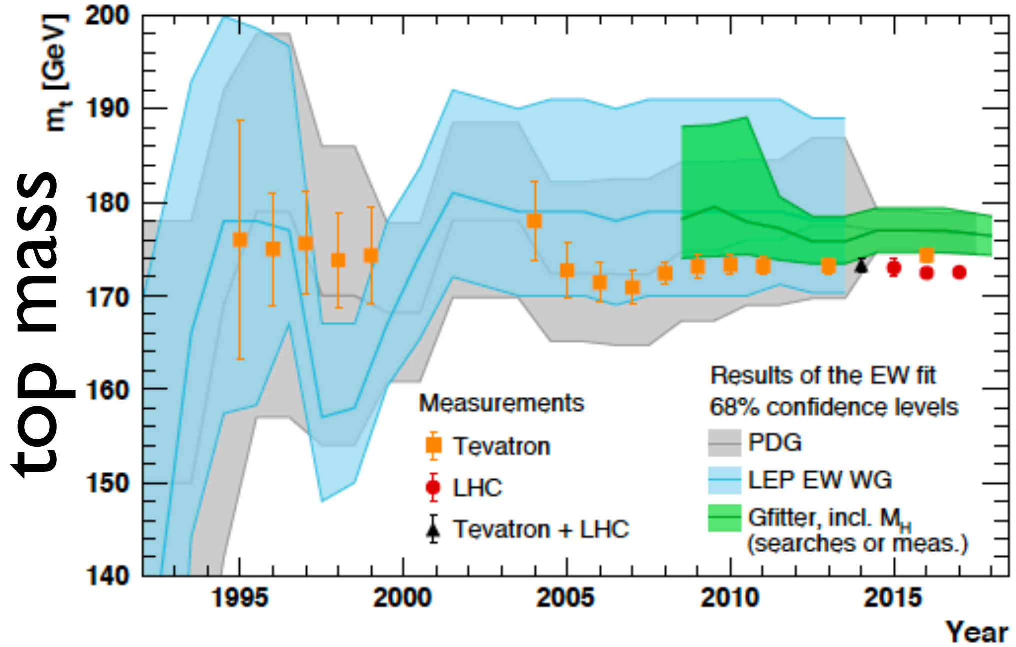
しかし、ヒッグスセクターの測定精度はまだまだ。

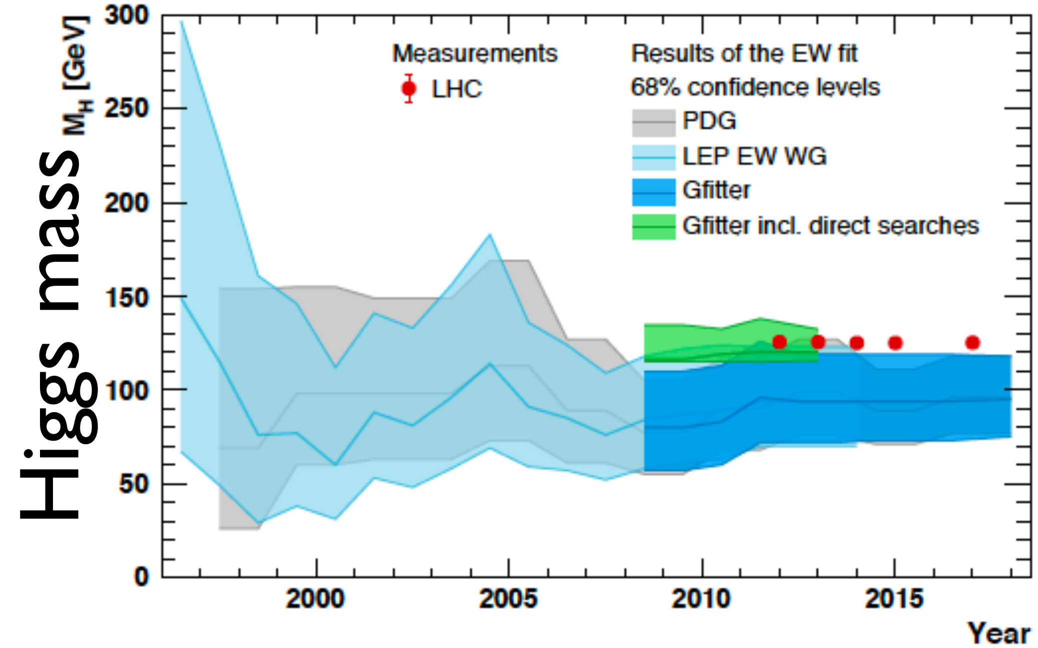


ILC [1710.07621]

精密測定 ➡ 間接的に未発見粒子の質量/性質を予言

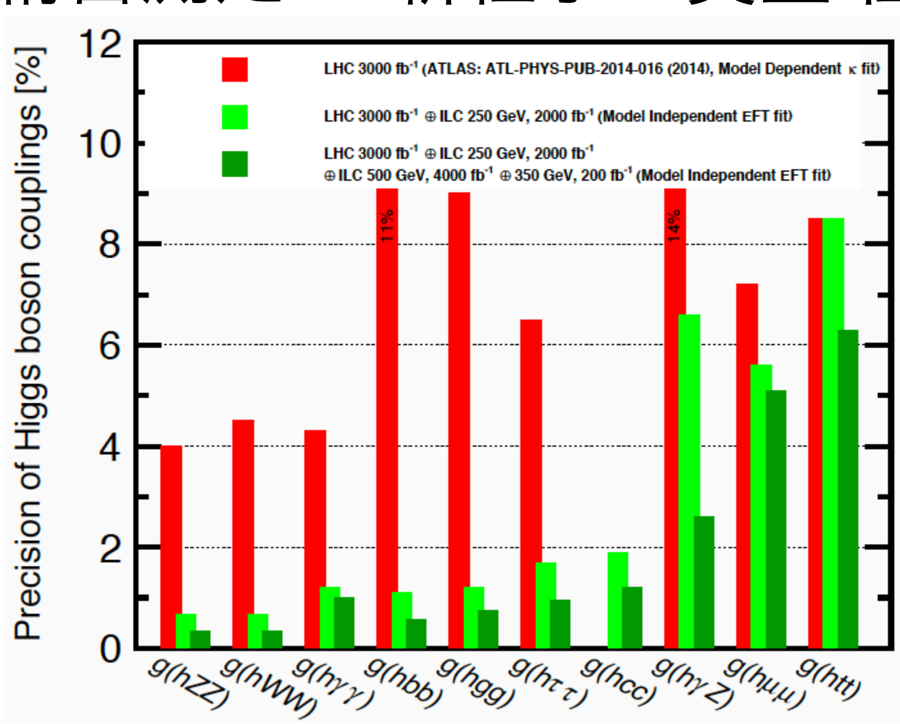
- LEP: W, Z精密測定 ➡ top/Higgs の質量を予言 ➡ Tevatron/LHCで発見



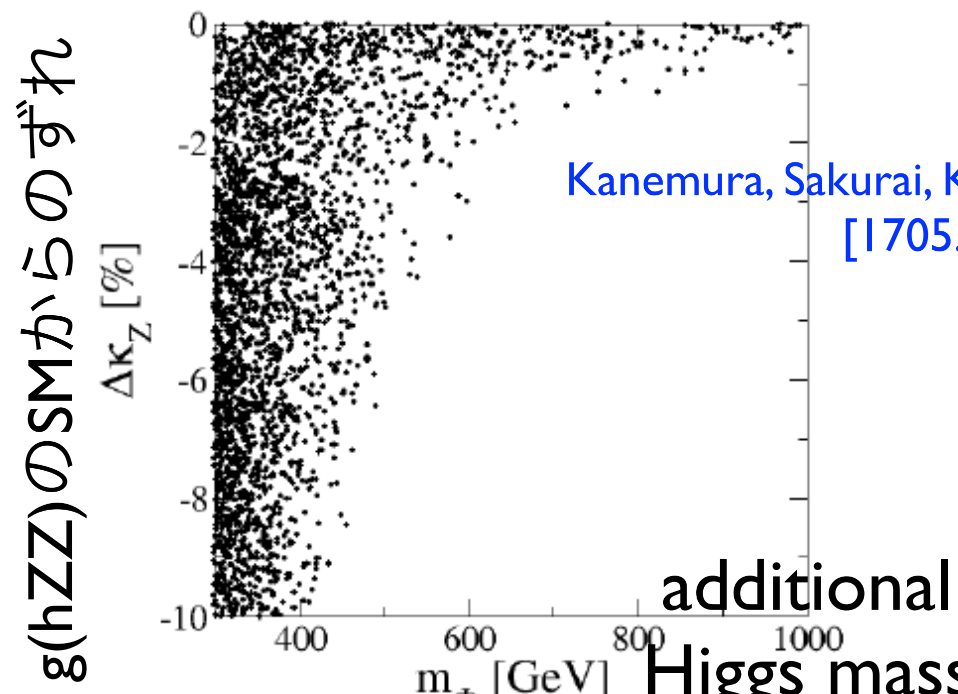


Gfitter [1803.01853]

- ILC: Higgs精密測定 ➡ 新粒子の質量/性質を予言 ➡ 100TeVコライダーで発見？



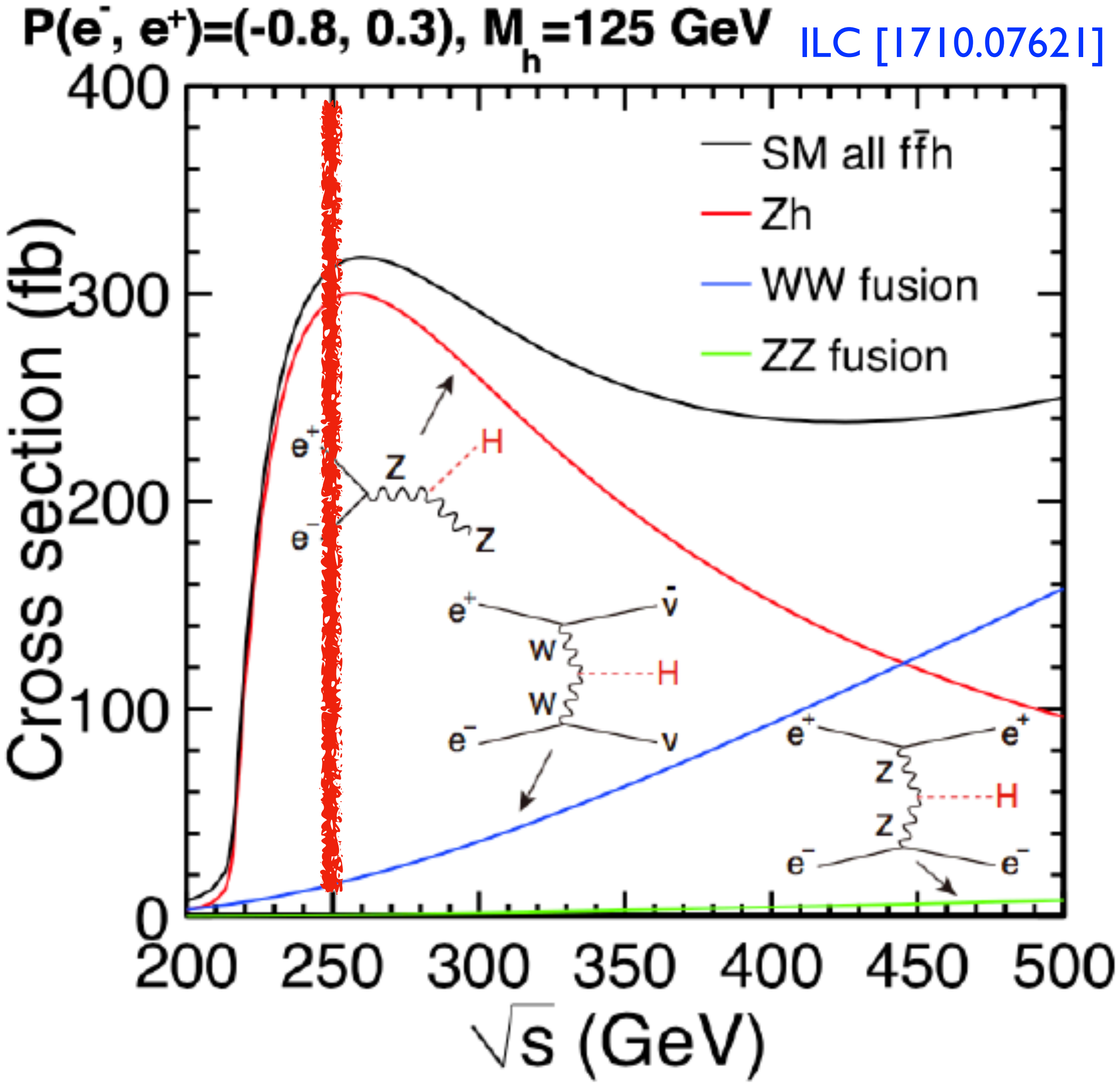
ILC [1710.07621]

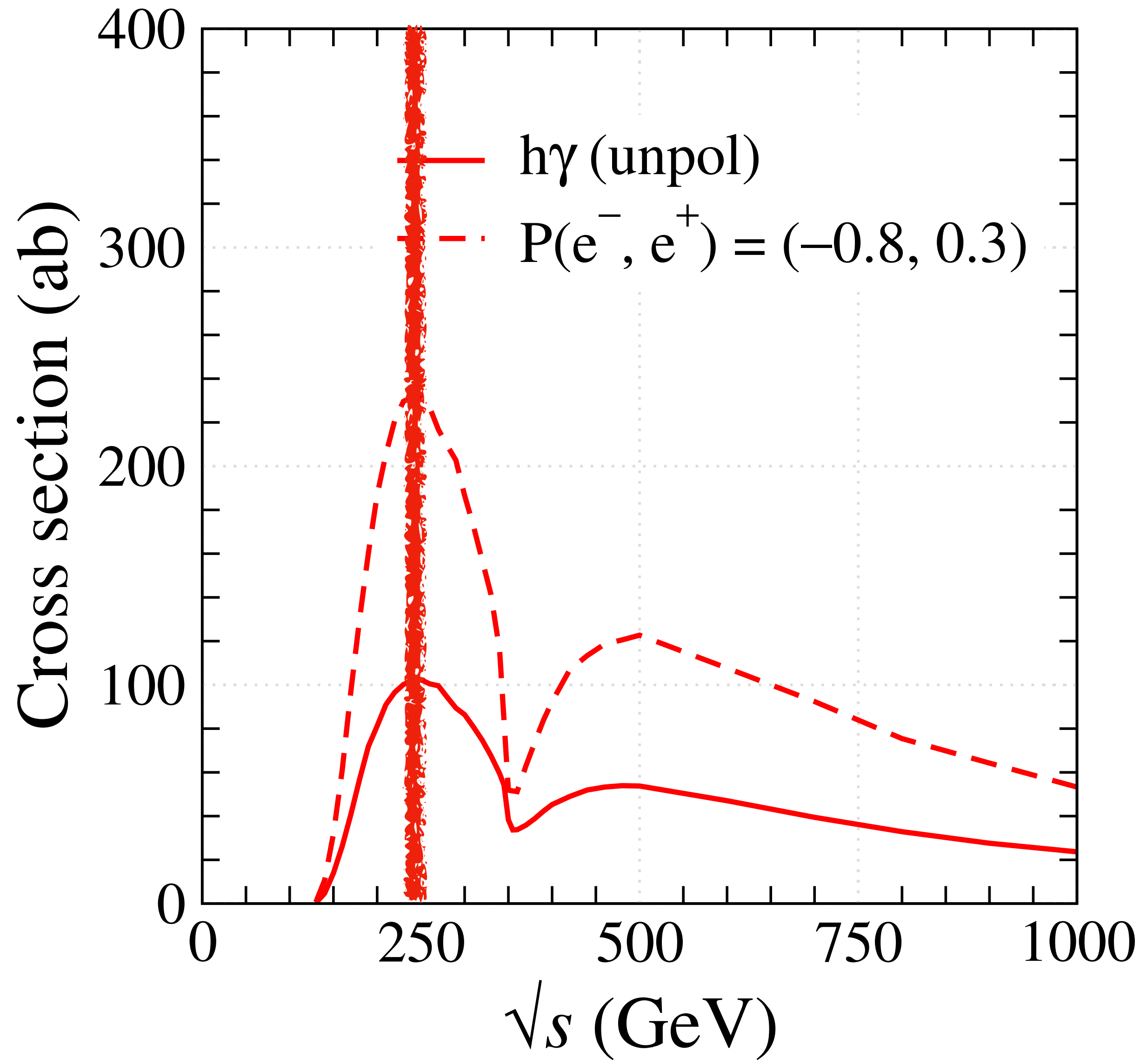


Kanemura, Sakurai, Kikuchi, Yagyu
[1705.05399, PRD]

なぜ200, 300, 500GeVではなく250GeV？

Higgs productions at ILC250





This is not the only Higgs production which has a peak at 250GeV at e+e- colliders.

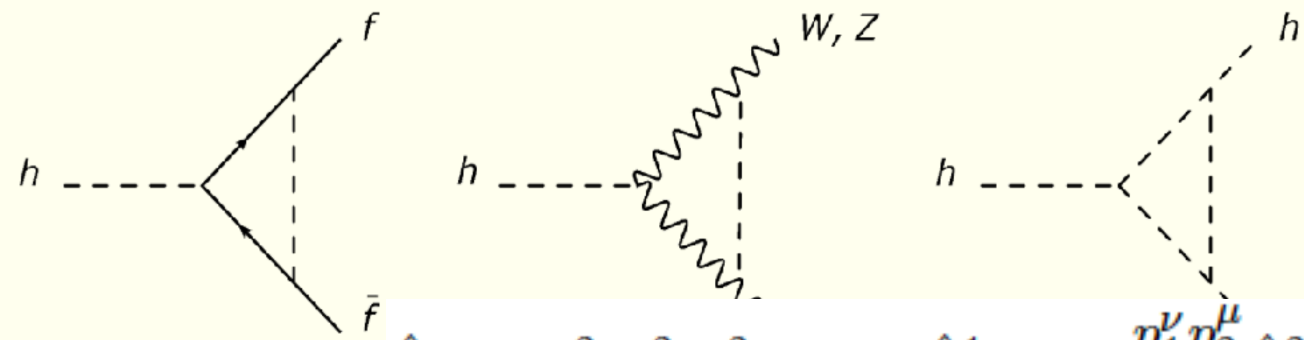
- σ(hγ) ~ σ (hZ)x10-3 due to loop-induced.
- Beam polarization helps.
- A monochromatic photon.
- sensitive to New Physics!

$$E_\gamma = \frac{\sqrt{s}}{2}\left(1 - \frac{m_h^2}{s}\right)$$
$$\sim 93.8\text{GeV} \ @\sqrt{s} = 250\text{GeV}$$

なぜこのプロセスに興味を持ったのか？

www-het.phys.sci.osaka-u.ac.jp

H-COUP



$$\hat{\Gamma}^{\mu\nu}_{hVV}(p_1^2, p_2^2, q^2) = g^{\mu\nu}\hat{\Gamma}^1_{hVV} + \frac{p_1^\nu p_2^\mu}{m_V^2}\hat{\Gamma}^2_{hVV} + i\epsilon^{\mu\nu\rho\sigma}\frac{p_{1\rho}p_{2\sigma}}{m_V^2}\hat{\Gamma}^3_{hVV}$$

H-COUP is a calculation tool composed of a set of Fortran codes to compute the renormalized Higgs boson couplings with radiative corrections in various non-minimal Higgs models, such as the Higgs singlet model, four types of two Higgs doublet models and the inert doublet model. The impolved on-shell renormalization scheme is adopted, where the gauge depdence is eliminated.

Authors: Shinya Kanemura, Mariko Kikuchi, Kodai Sakurai and Kei Yagyu +K. Mawatari

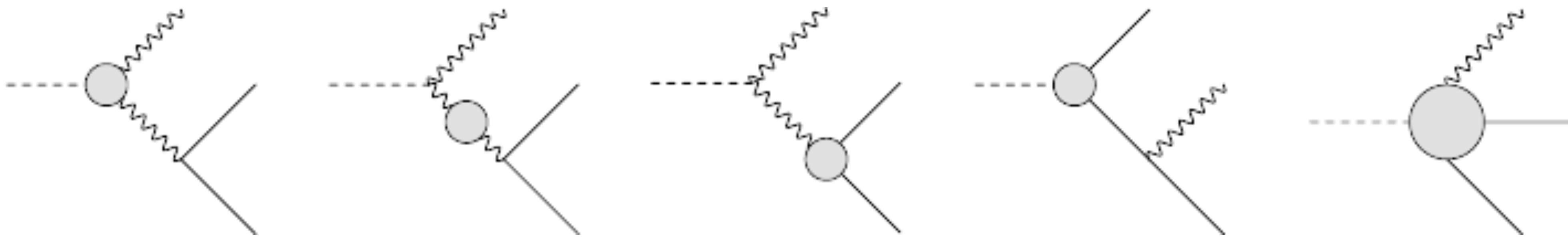
The manual for H-COUP version 1.0 can be taken on arXiv:1710.04603 [hep-ph].

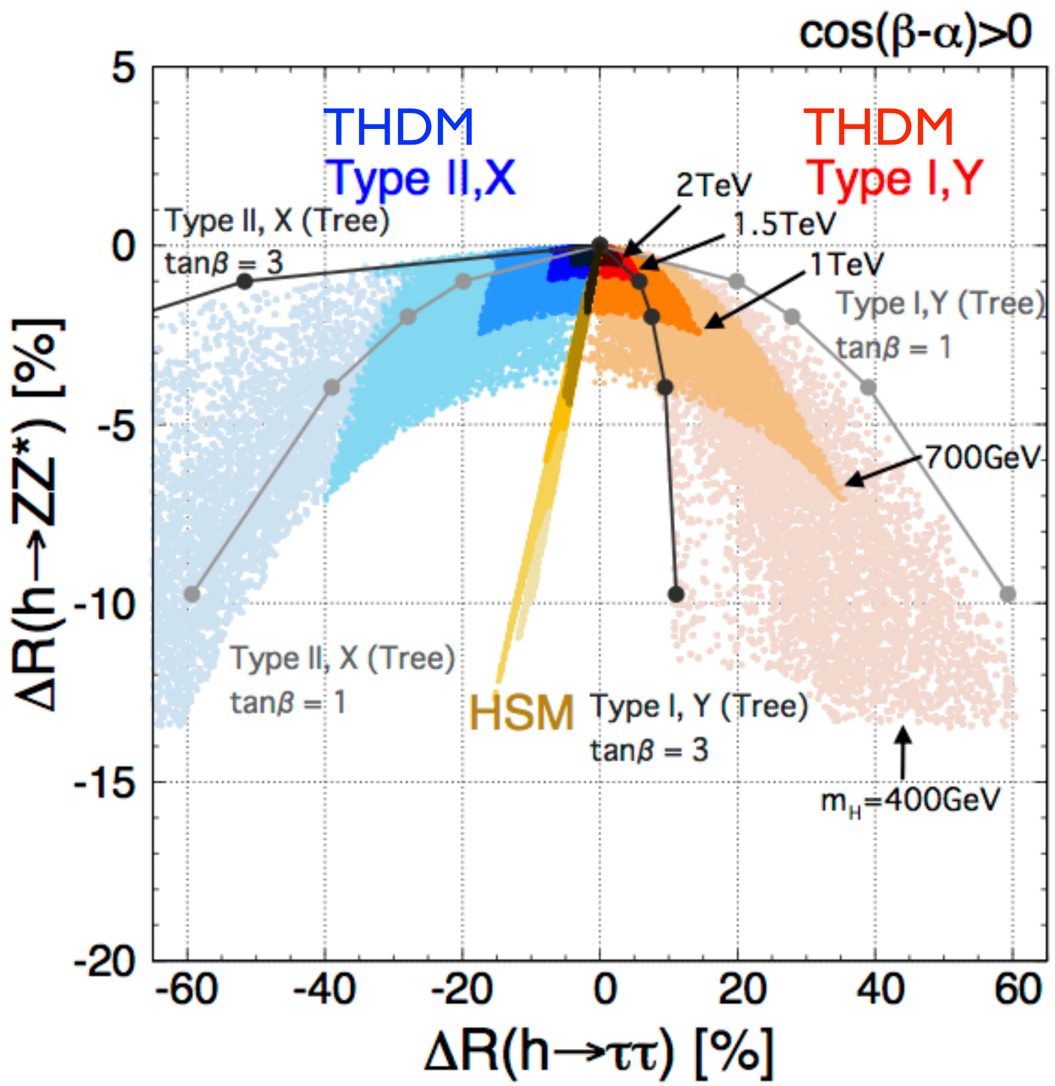
Loop effects on the Higgs decay widths
in extended Higgs models [1803.01456, PLB]

Downloads

- H-COUP version 1.0 : [HCOUP-1.0.zip] [The manual is here]

Higgs decay: h → Z Z* → Z f f~





Kanemura, Kikuchi, KM, Sakurai, Yagyu [1803.01456, PLB]

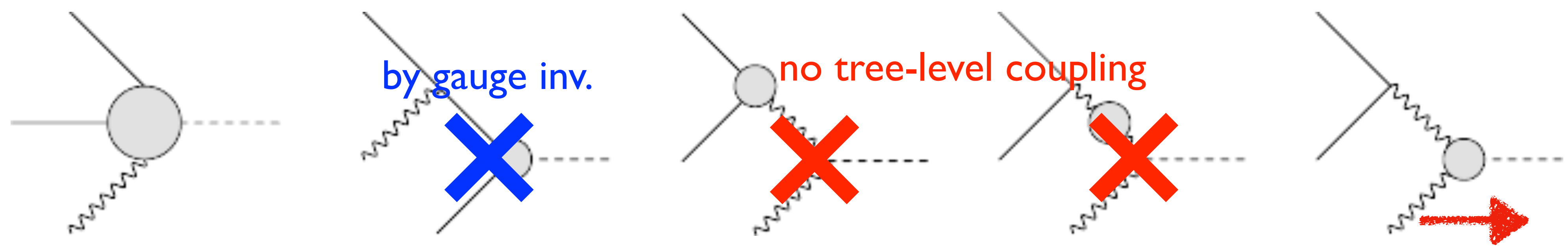
＊See Kodai Sakurai's poster today

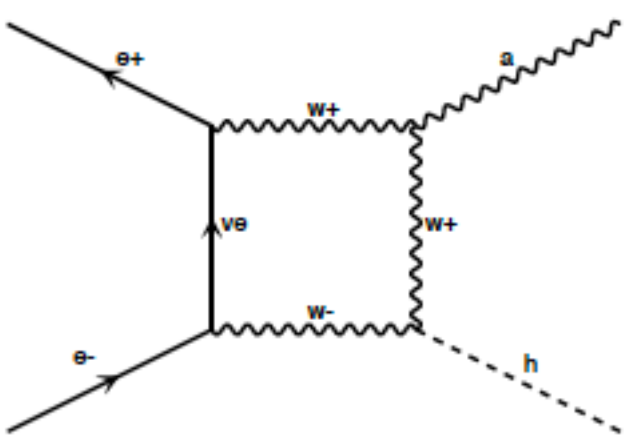
THDM
= Two Higgs Double Model

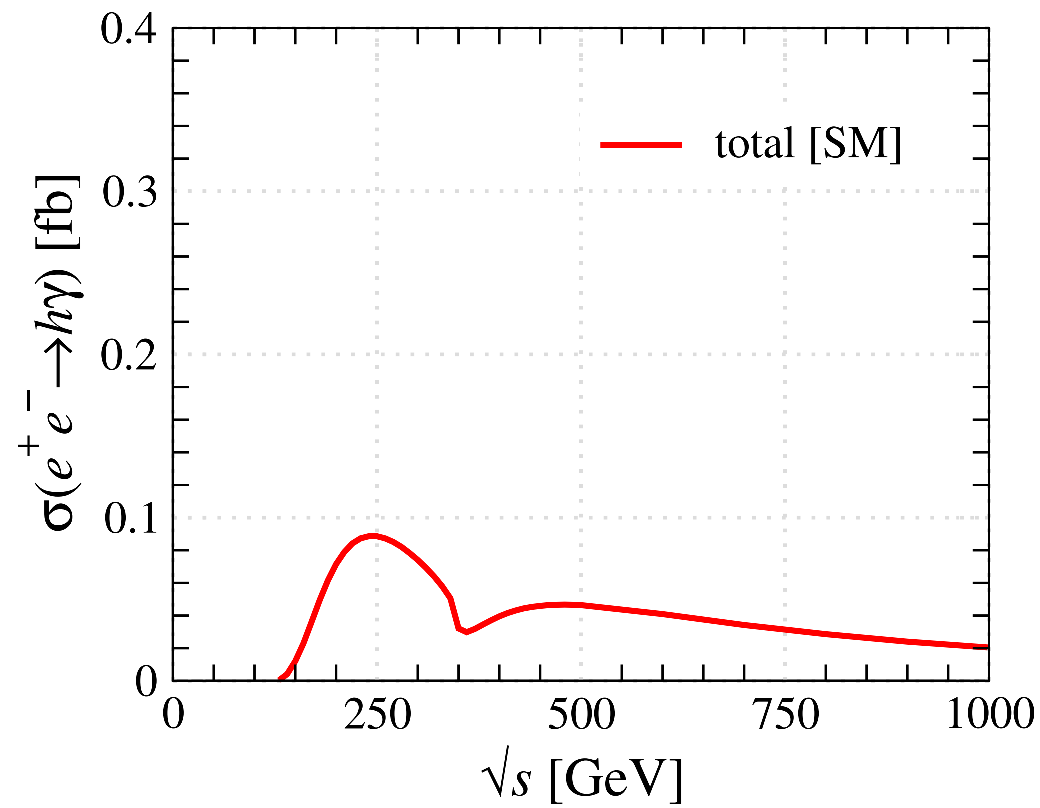
HSM
= Higgs Singlet Model

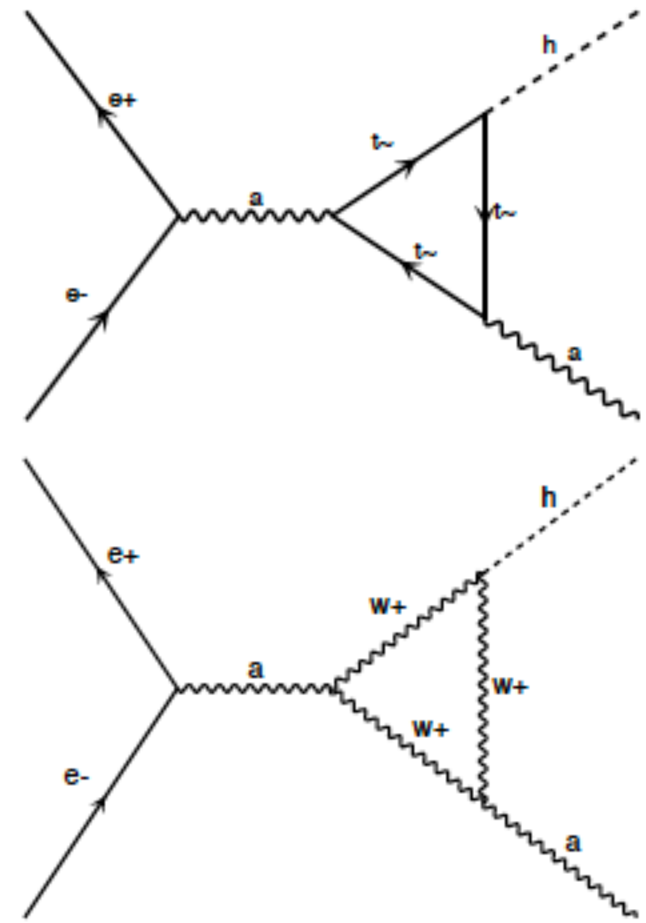
$$\Delta R(h \to XX) = \frac{\Gamma_{\rm NP}(h \to XX)}{\Gamma_{\rm SM}(h \to XX)} - 1$$

Higgs production: e+ e- → h γ

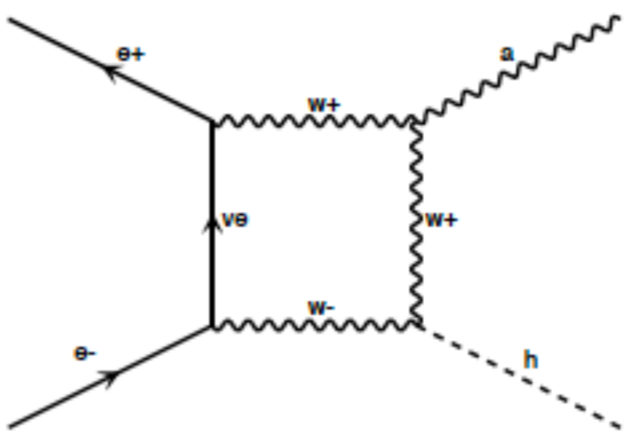


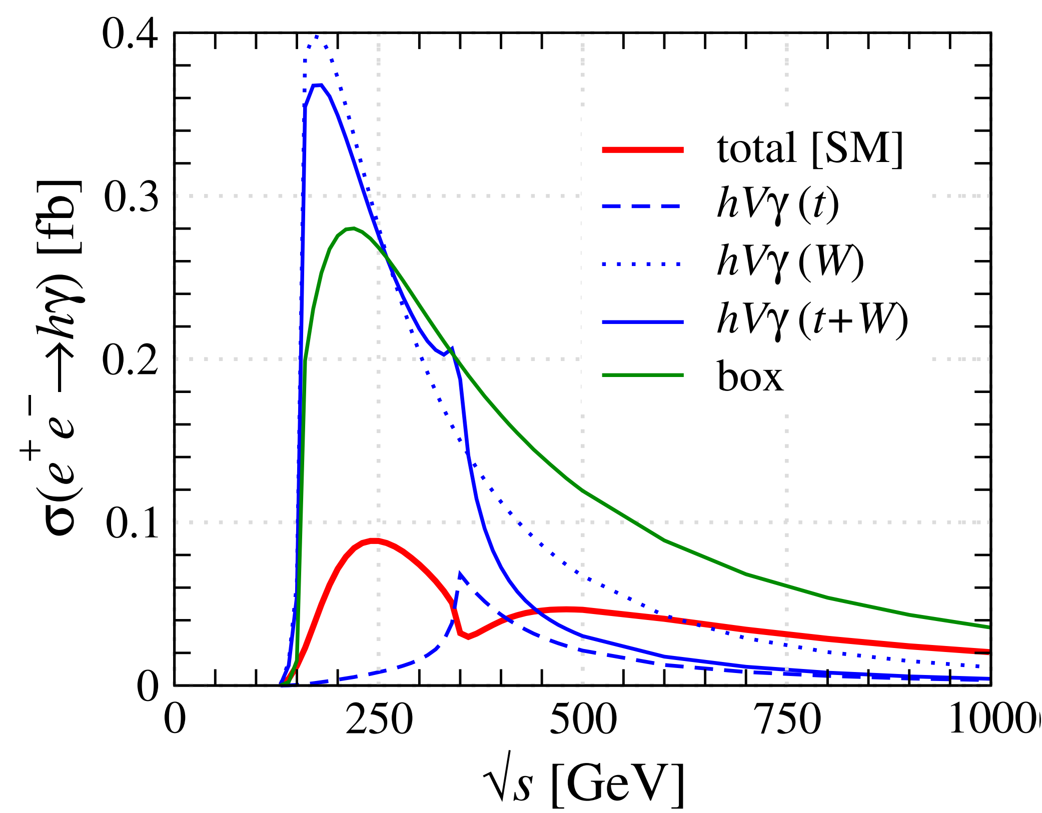


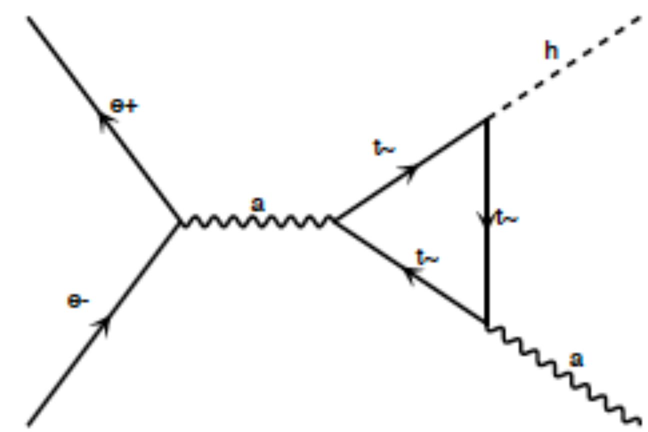


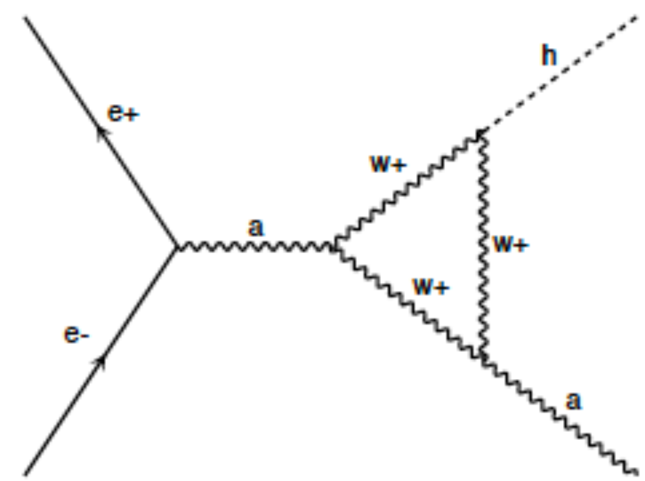


e+ e- → h γ in the SM



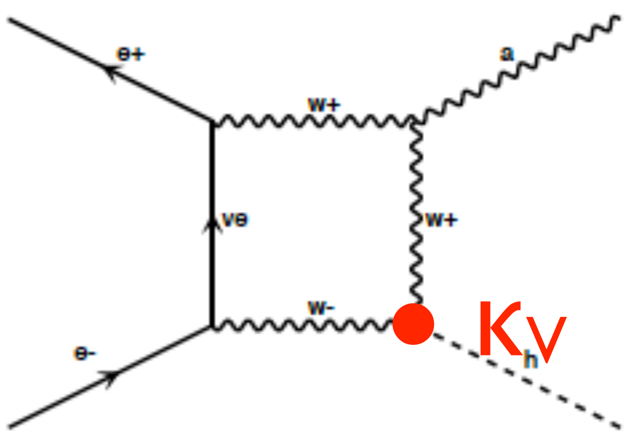


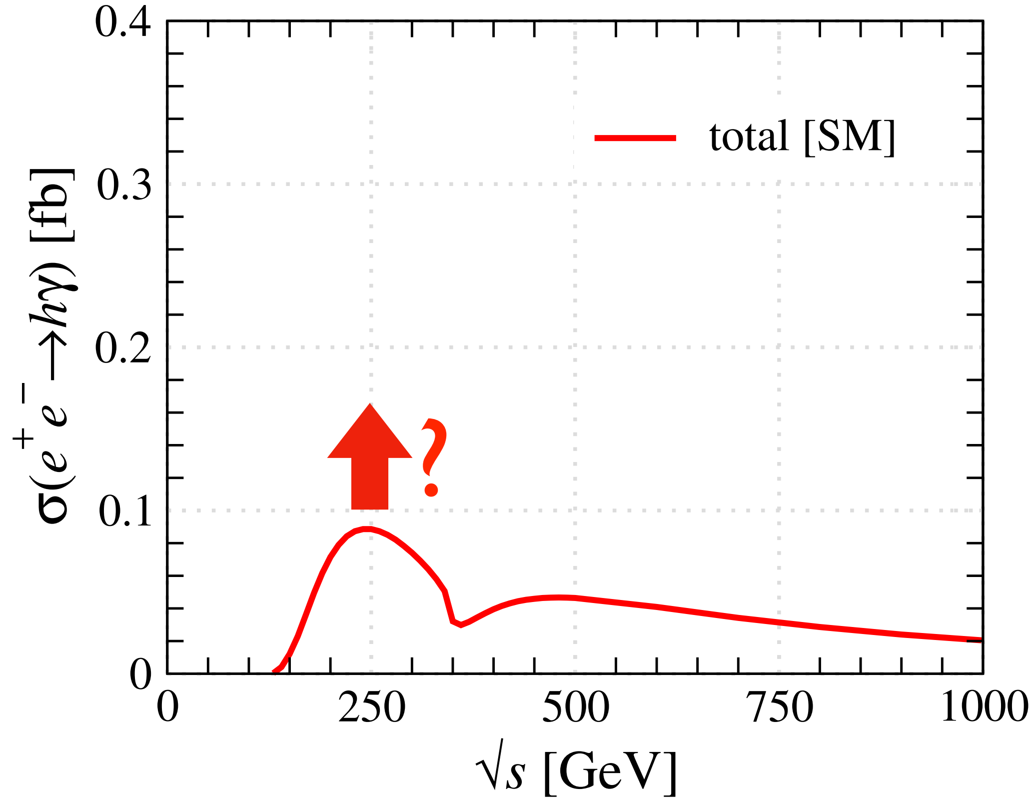


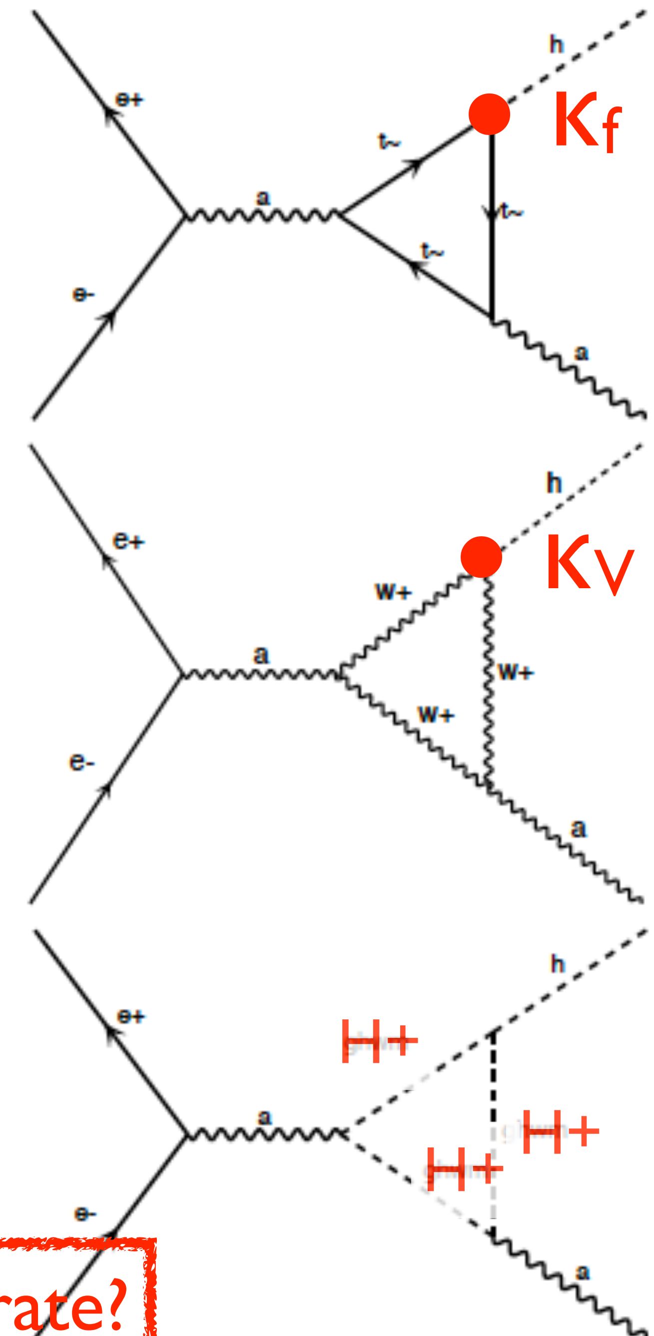


Unfortunate destructive interference among the different contributions…

e+ e- → h γ in new physics models



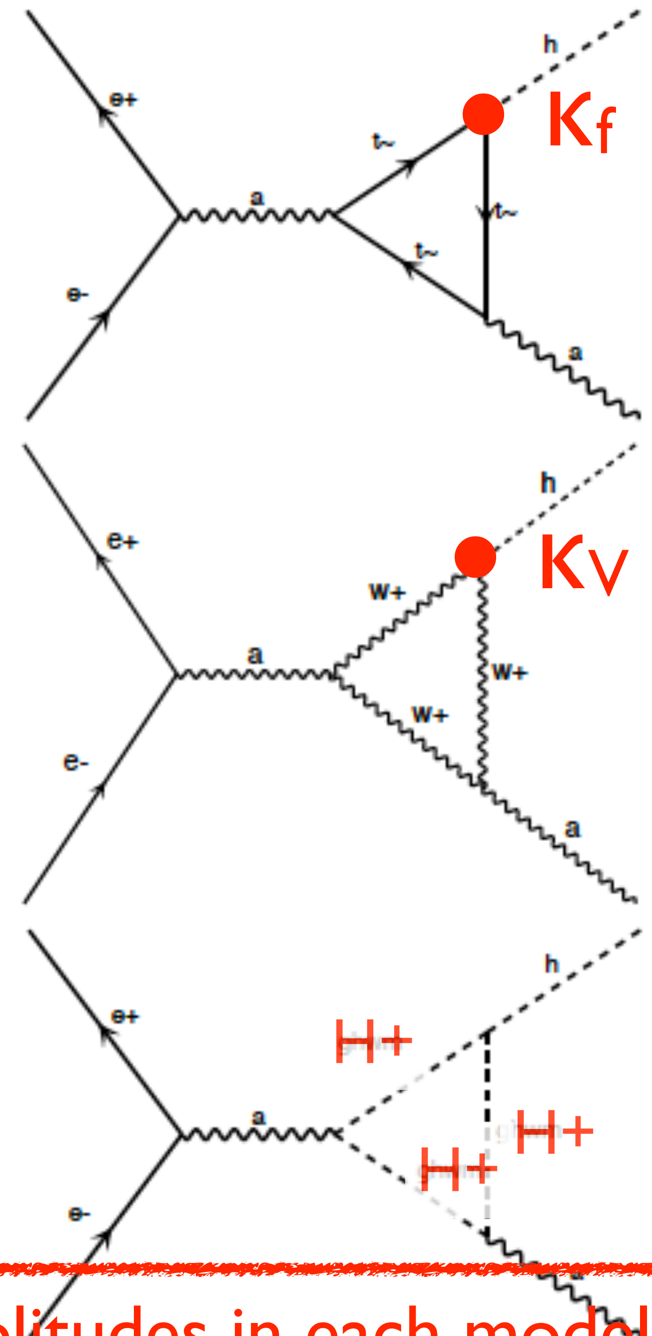




Can new physics enhance the production rate?

3 extended Higgs models

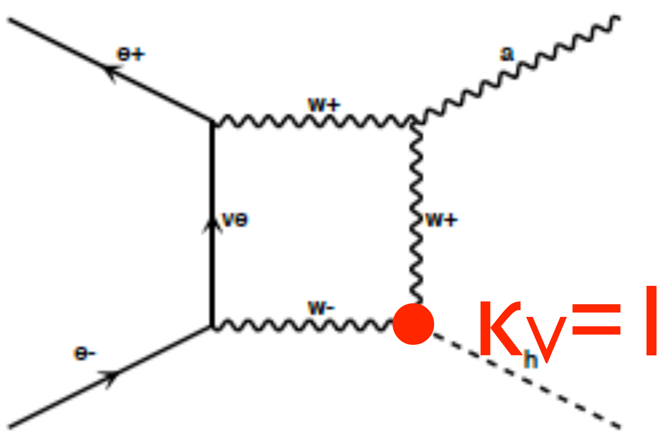
	κ_f (=t)	κ_V	H+	H++
IDM (Inert doublet model)	1	1	○	×
	Arhrib, Benbrik, Yuan [1401.6698, EPJC]			
ITM (Inert triplet model)	1	1	○	○
THDM (Two Higgs doublet model)	$s_{\beta-\alpha}$ $-c_{\beta-\alpha}/t_\beta$	$s_{\beta-\alpha}$	○	×



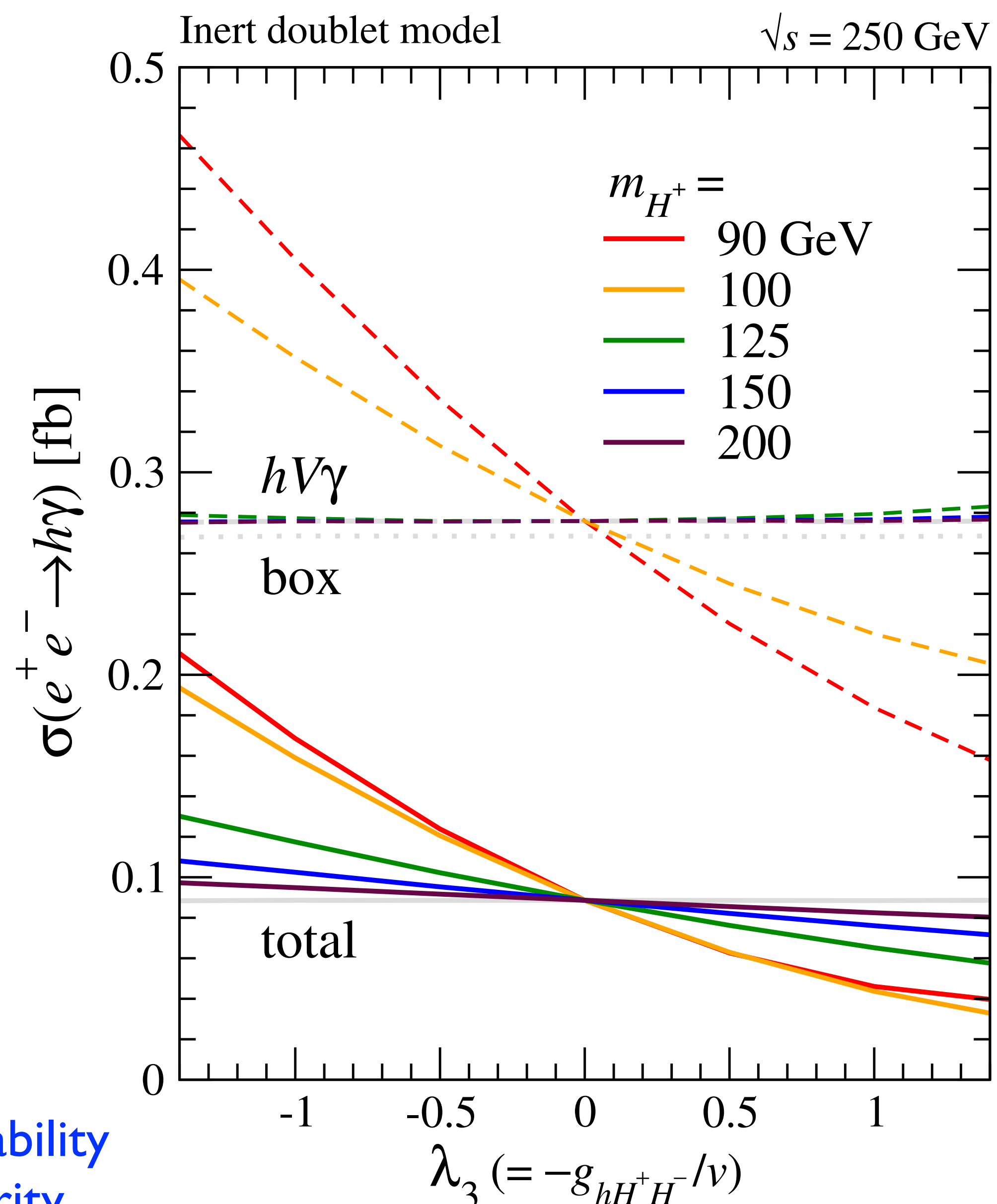
We employ the H-COUP program to compute the loop amplitudes in each model.

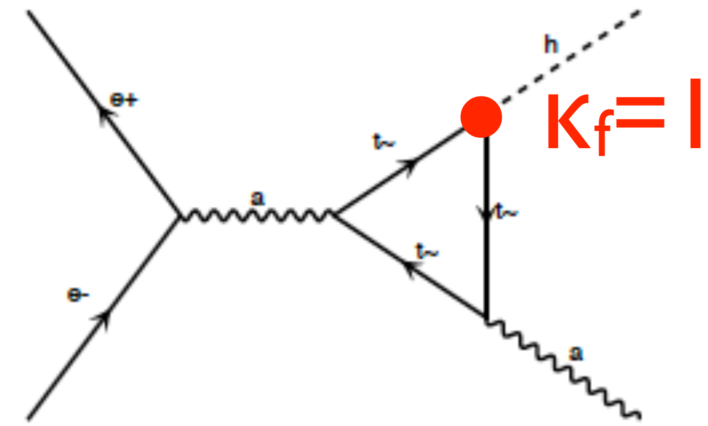
∗ An additional Higgs doublet with an exact Z_2 symmetry

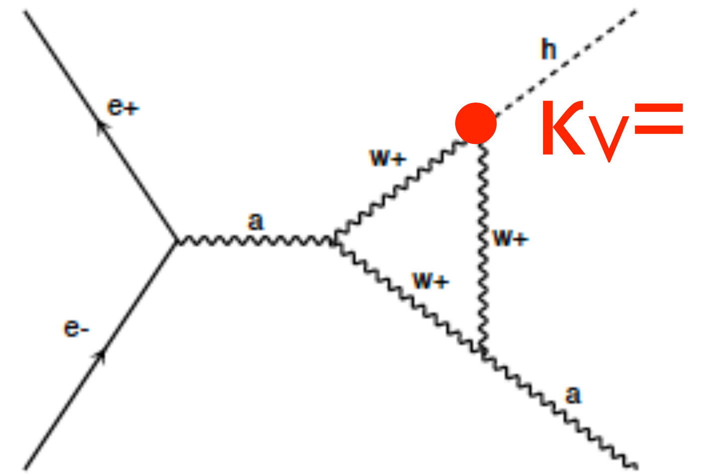
e+ e- → h γ in the IDM

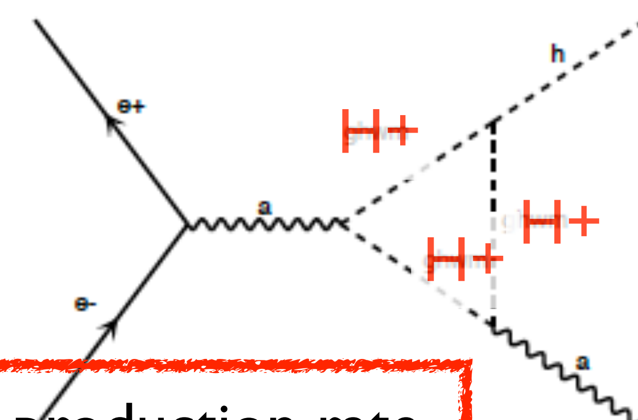


$$
\begin{aligned}
V &= \mu_1^2|\Phi_1|^2 + \mu_2^2|\Phi_2|^2 \\
&+ \frac{1}{2}\lambda_1|\Phi_1|^4 + \frac{1}{2}\lambda_2|\Phi_2|^4 \\
&+ \lambda_3|\Phi_1|^2|\Phi_2|^2 + \lambda_4|\Phi_1^\dagger\Phi_2|^2 \\
&+ \frac{1}{2}\lambda_5\{(\Phi_1^\dagger\Phi_2)^2 + \text{h.c.}\}
\end{aligned}
$$







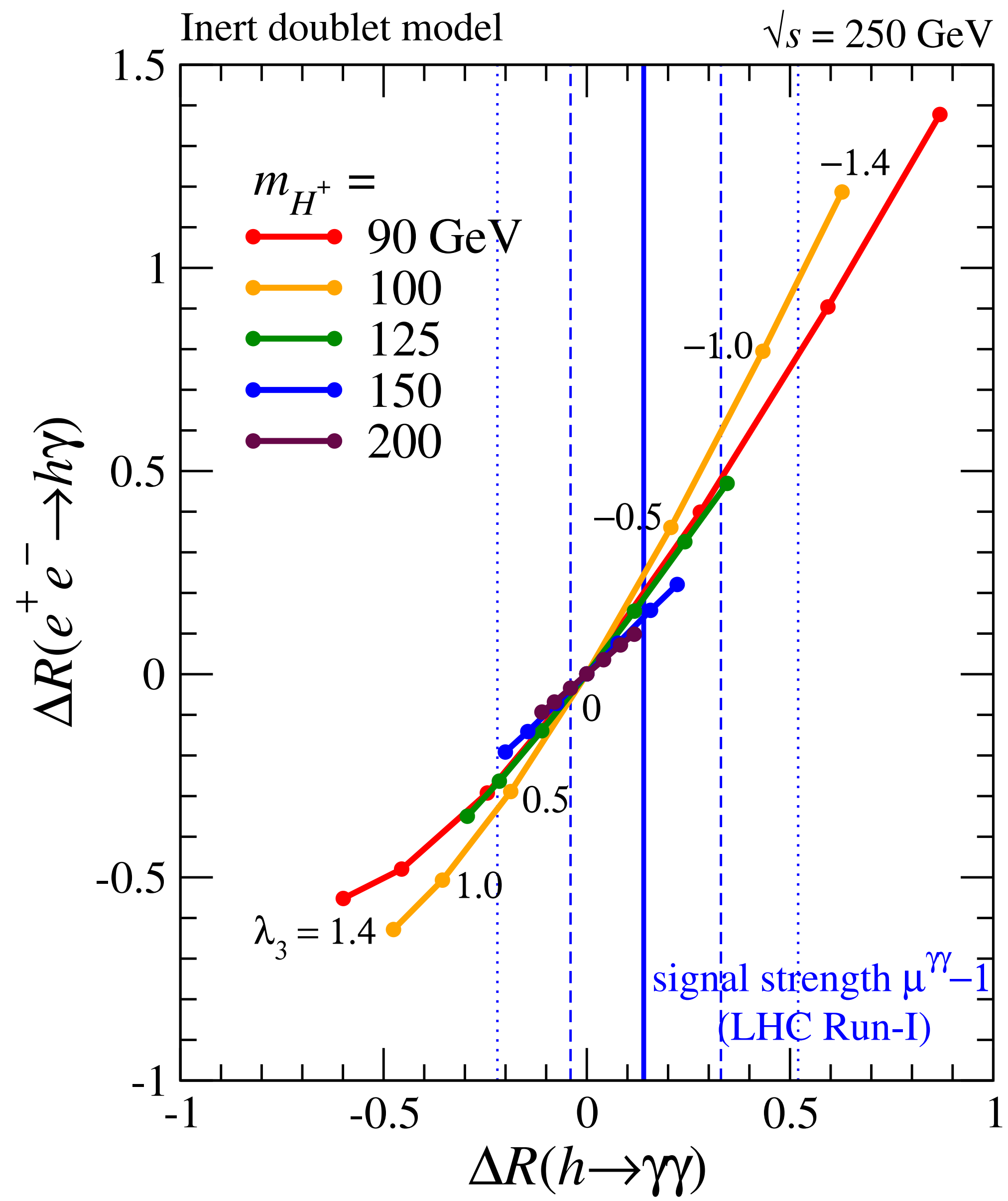


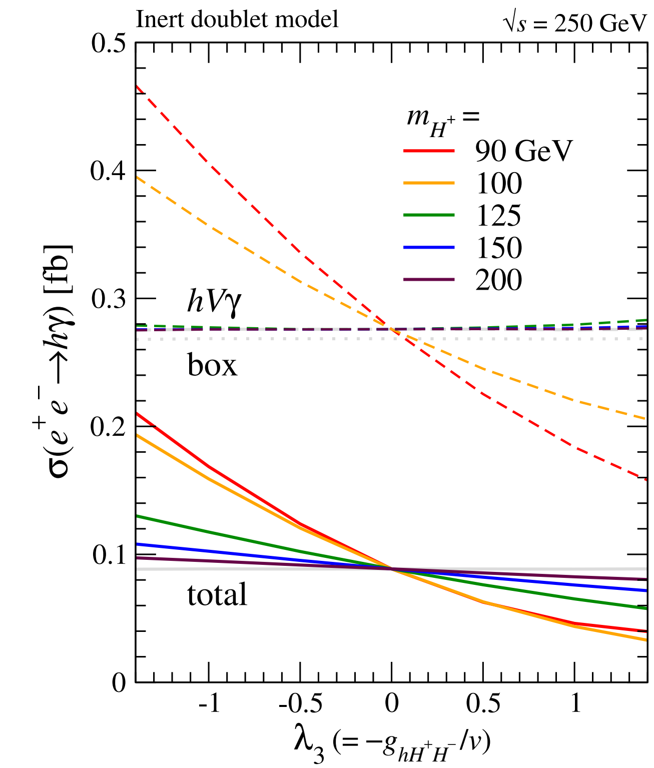
∗ $\lambda_3 > -1.4$ by vacuum stability and perturbative unitarity.

Lighter charged scalars with a negative λ_3 can enhance the production rate.

$$\Delta R(e^+e^- \to h\gamma) = \frac{\sigma_{\rm NP}(e^+e^- \to h\gamma)}{\sigma_{\rm SM}(e^+e^- \to h\gamma)} - 1, \quad \Delta R(h \to \gamma\gamma) = \frac{\Gamma_{\rm NP}(h \to \gamma\gamma)}{\Gamma_{\rm SM}(h \to \gamma\gamma)} - 1$$

(e+e-→hγ) vs. (h→γγ) in the IDM

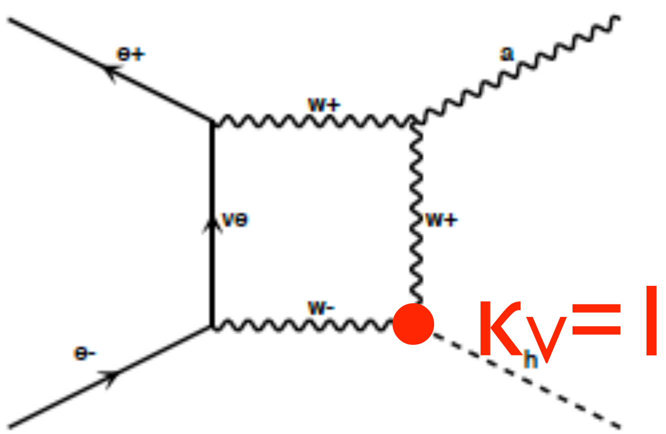




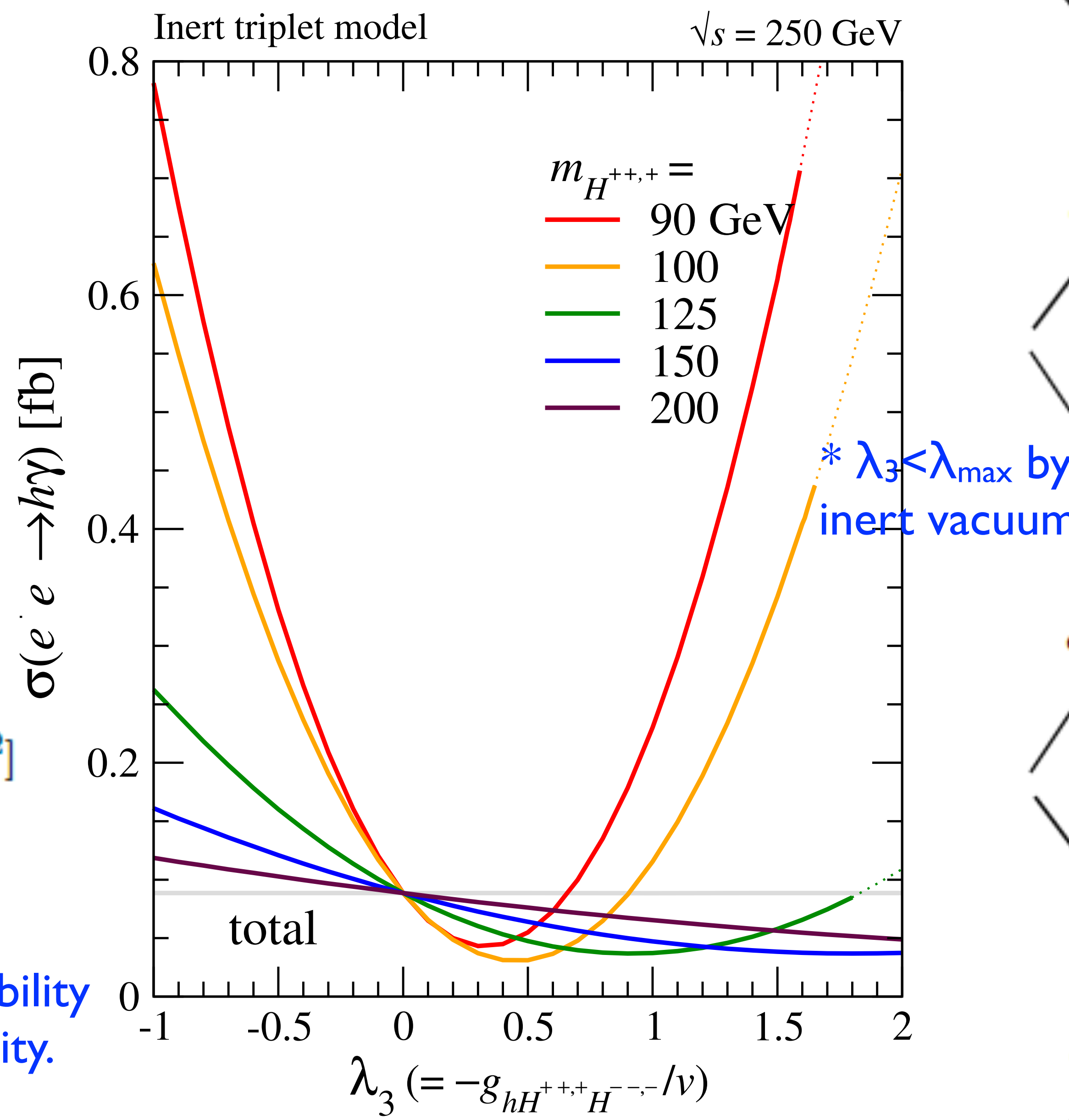
- Strong positive correlation.
- Stronger constraints for light H+ by the Higgs measurement.

* An additional Higgs triplet with an exact Z_2 symmetry

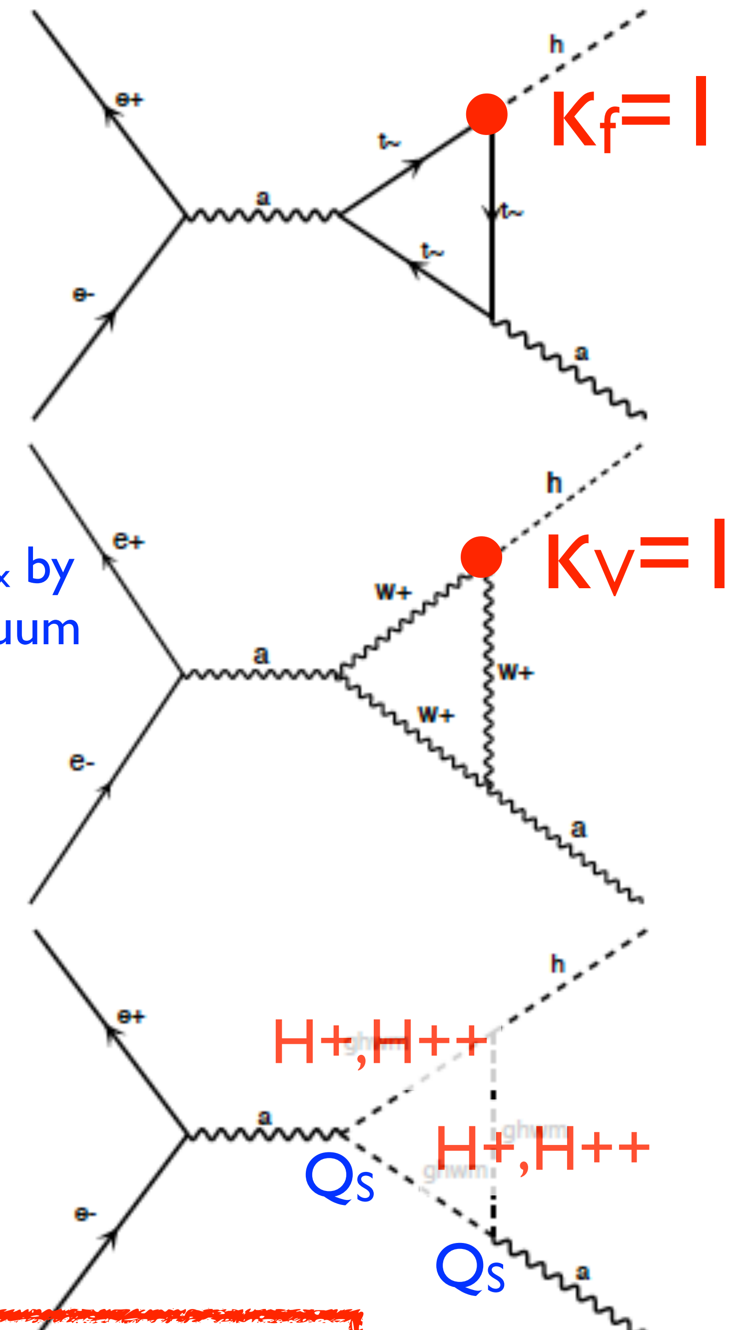
e+ e- → h γ in the ITM



$$V = \mu_1^2|\Phi|^2 + \mu_2^2 \mathrm{Tr}[\Delta^\dagger\Delta] + \frac{1}{2}\lambda_1|\Phi|^4 + \frac{1}{2}\lambda_2(\mathrm{Tr}[\Delta^\dagger\Delta])^2 + \lambda_3|\Phi|^2\mathrm{Tr}[\Delta^\dagger\Delta] + \frac{1}{2}\lambda_4\mathrm{Tr}[(\Delta^\dagger\Delta)^2] + \lambda_5\Phi^\dagger\Delta\Delta^\dagger\Phi$$



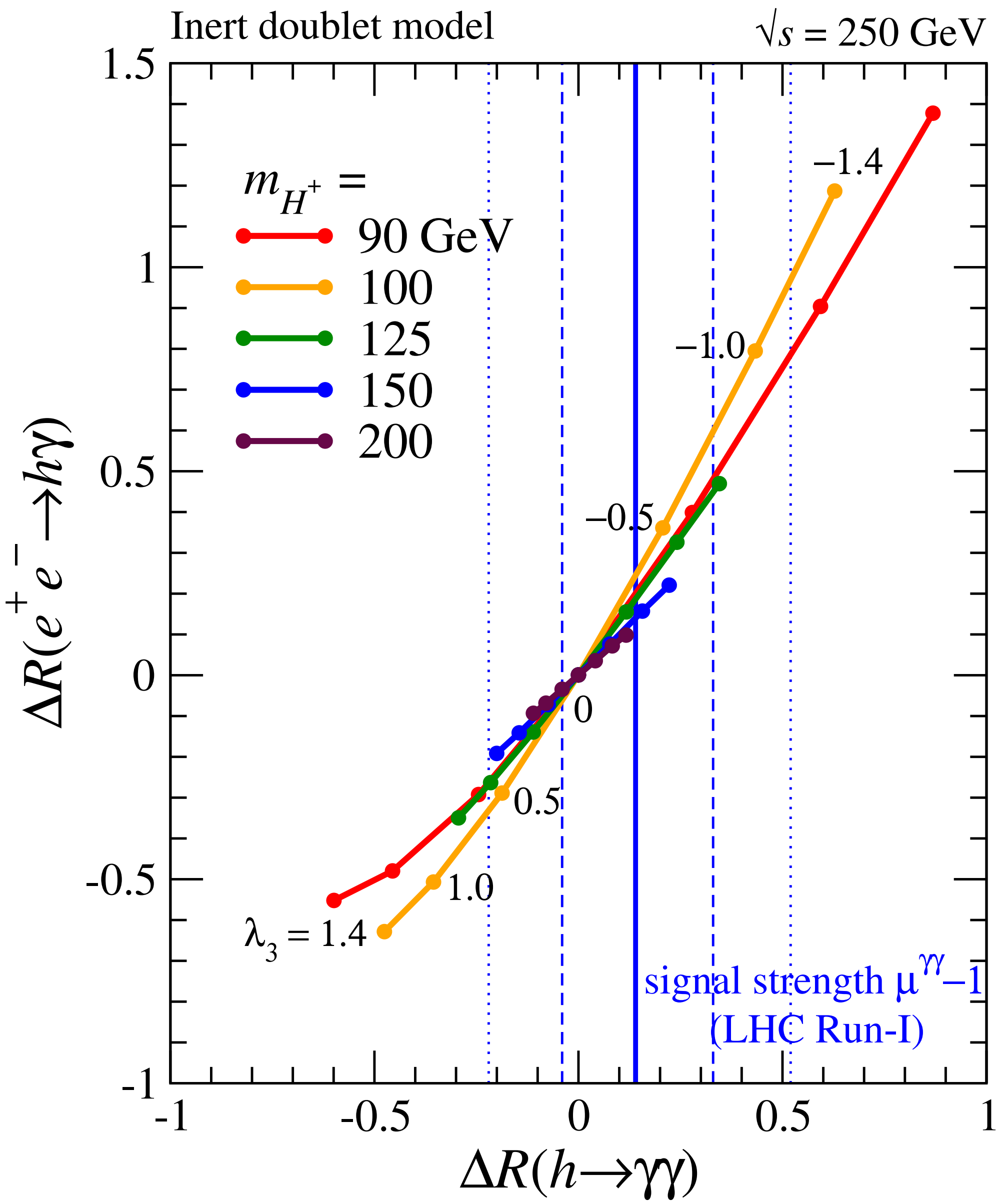
* $\lambda_3 > -1.4$ by vacuum stability and perturbative unitarity.

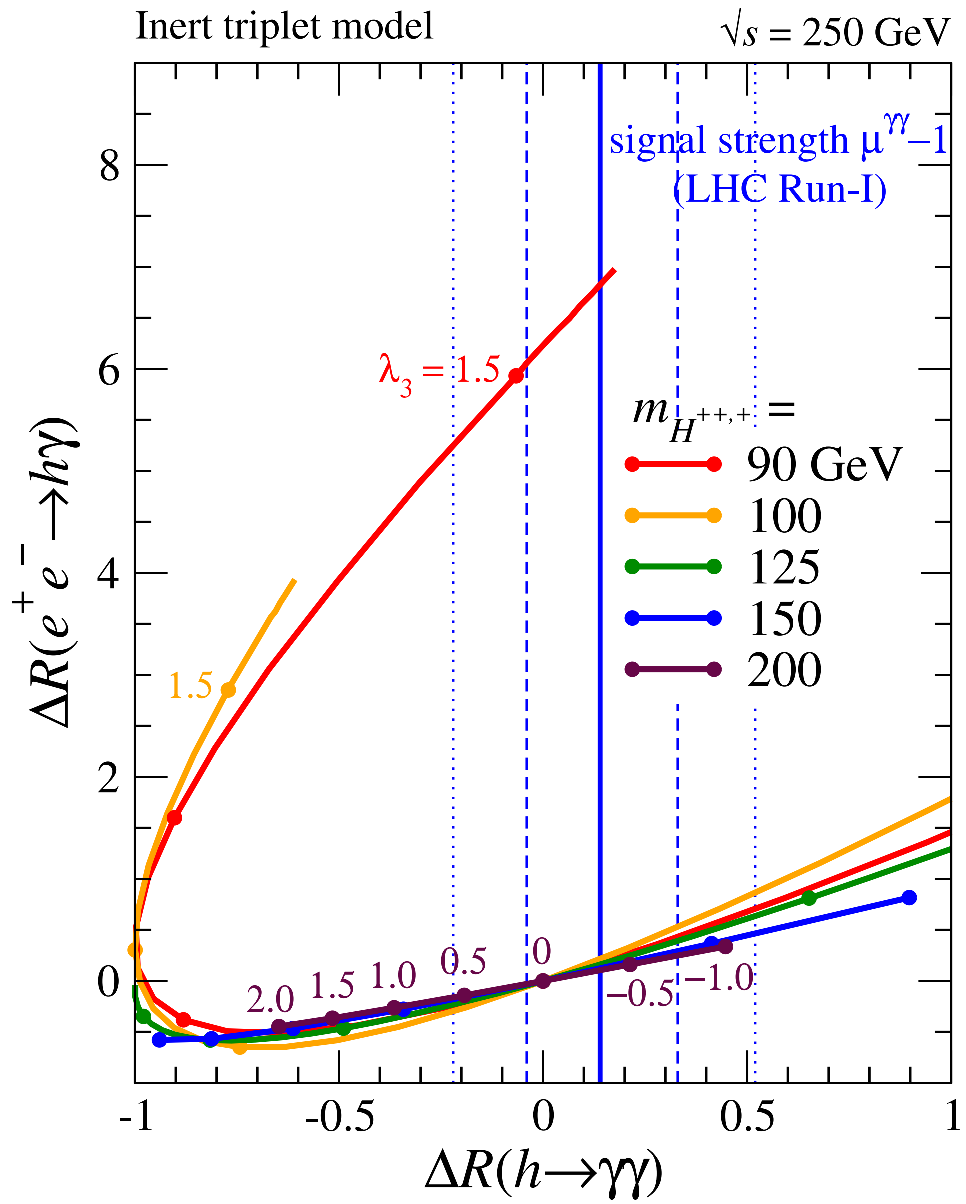


If $m_H^{++,+} \sim$ 100GeV, a positive λ_3 can also enhance the production rate.

$$\Delta R(e^+e^- \to h\gamma) = \frac{\sigma_{\rm NP}(e^+e^- \to h\gamma)}{\sigma_{\rm SM}(e^+e^- \to h\gamma)} - 1, \quad \Delta R(h \to \gamma\gamma) = \frac{\Gamma_{\rm NP}(h \to \gamma\gamma)}{\Gamma_{\rm SM}(h \to \gamma\gamma)} - 1$$

(e+e-→hγ) vs. (h→γγ) in the IDM/ITM

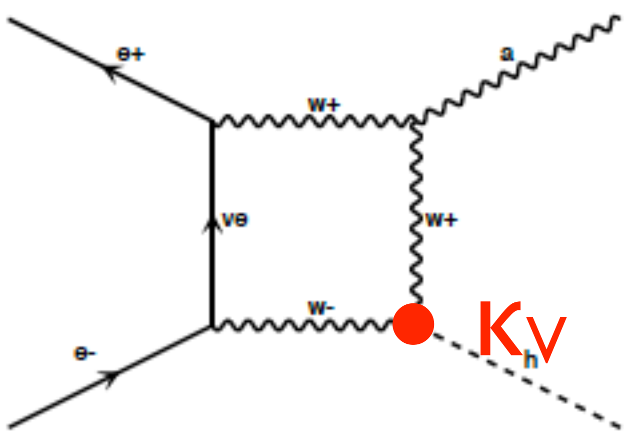




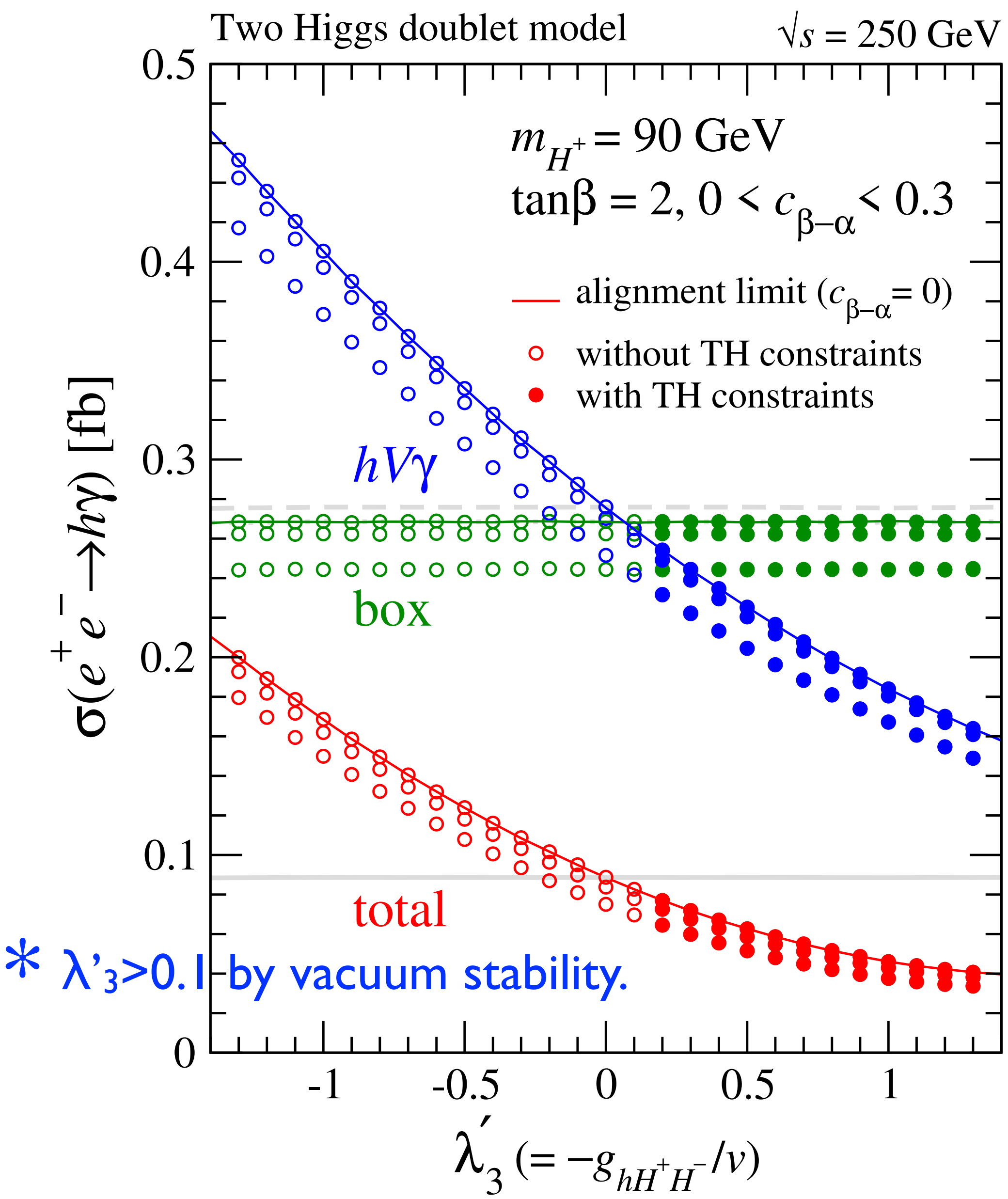
In the ITM, We can find a particular parameter region where the hγ production significantly increases, but still remaining the h→γγ decay as in the SM.

* An additional Higgs doublet with a softly broken Z_2 symmetry

e+ e- → h γ in the THDM

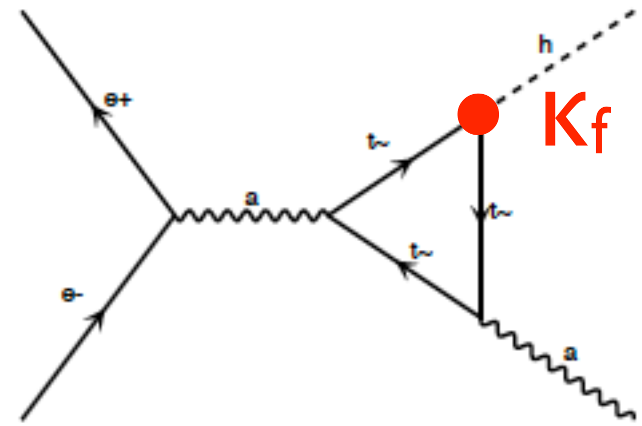


$$
\begin{aligned}
V = {} & m_1^2|\Phi_1|^2 + m_2^2|\Phi_2|^2 \\
& - m_3^2(\Phi_1^\dagger\Phi_2 + \text{h.c.}) \\
& + \frac{1}{2}\lambda_1|\Phi_1|^4 + \frac{1}{2}\lambda_2|\Phi_2|^4 \\
& + \lambda_3|\Phi_1|^2|\Phi_2|^2 + \lambda_4|\Phi_1^\dagger\Phi_2|^2 \\
& + \frac{1}{2}\lambda_5\{(\Phi_1^\dagger\Phi_2)^2 + \text{h.c.}\}
\end{aligned}
$$

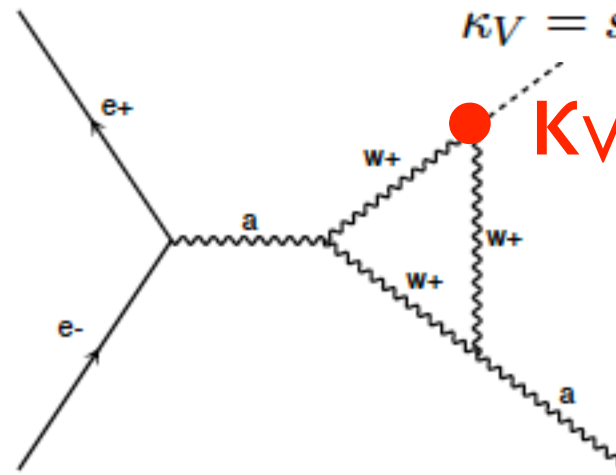


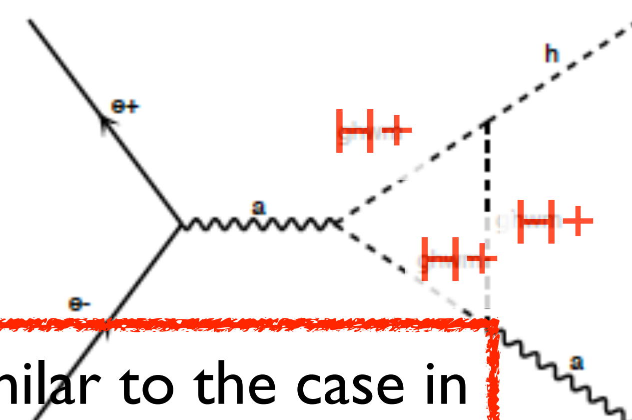
* $\lambda'_3 > 0.1$ by vacuum stability.

$\kappa_f = s_{\beta-\alpha} + \zeta_f c_{\beta-\alpha}$



$\kappa_V = s_{\beta-\alpha}$

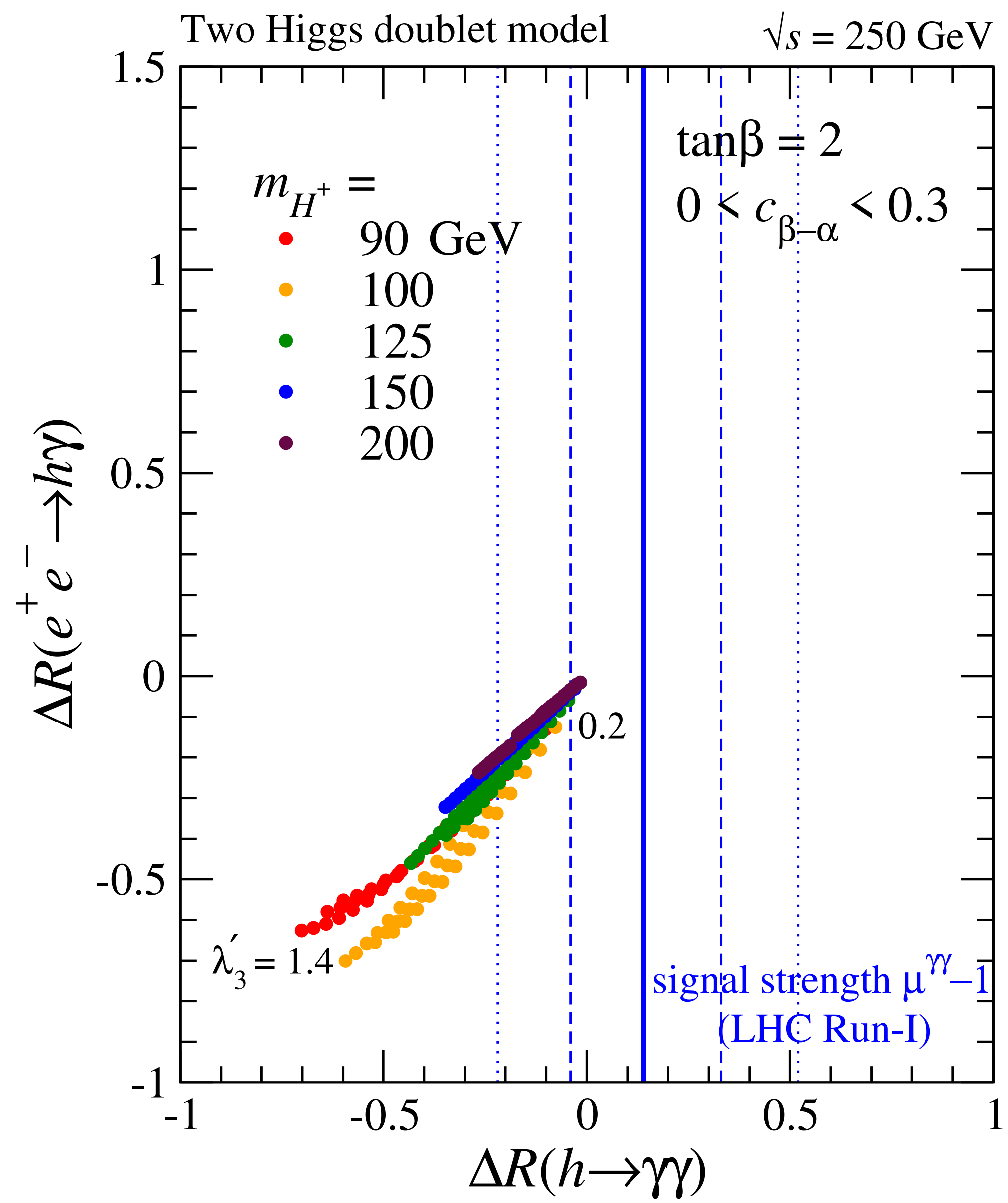


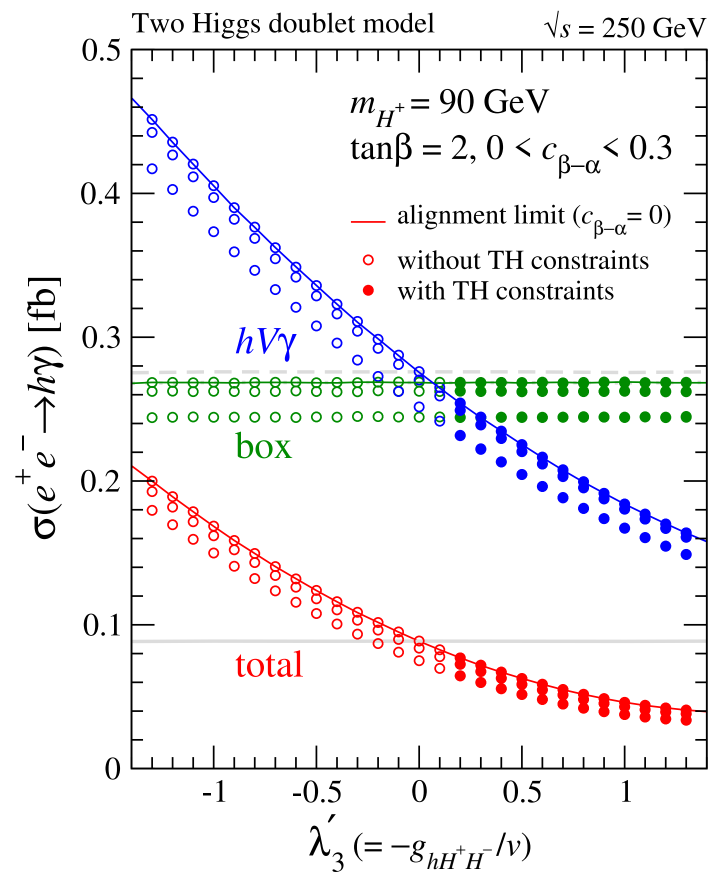


Except the small mixing effects, the qualitative behaviors are similar to the case in the IDM, but the enhanced parameter region is excluded by the TH constraints…

$$\Delta R(e^+e^- \to h\gamma) = \frac{\sigma_{\rm NP}(e^+e^- \to h\gamma)}{\sigma_{\rm SM}(e^+e^- \to h\gamma)} - 1, \quad \Delta R(h \to \gamma\gamma) = \frac{\Gamma_{\rm NP}(h \to \gamma\gamma)}{\Gamma_{\rm SM}(h \to \gamma\gamma)} - 1$$

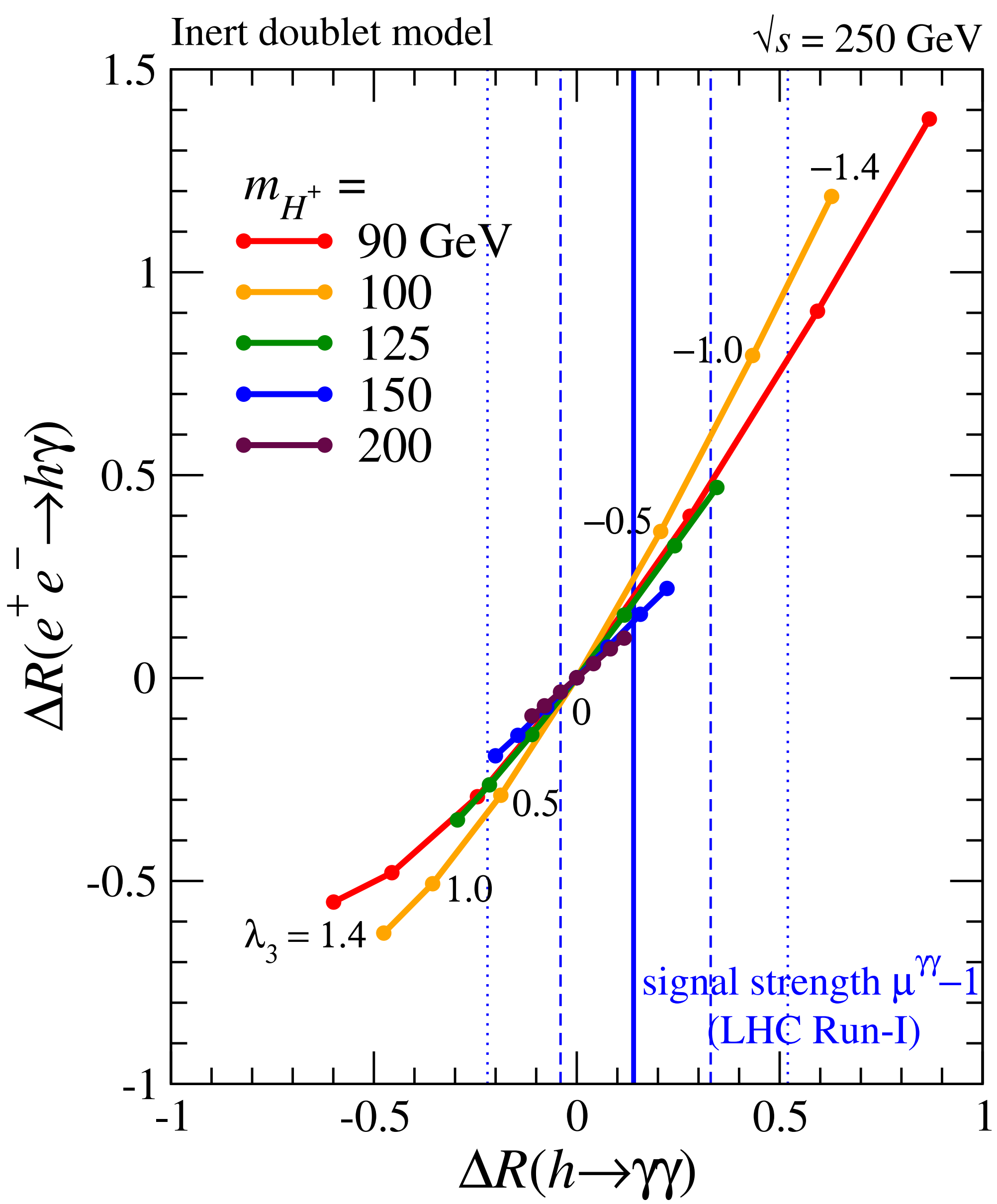
(e+e-→hγ) vs. (h→γγ) in the THDM

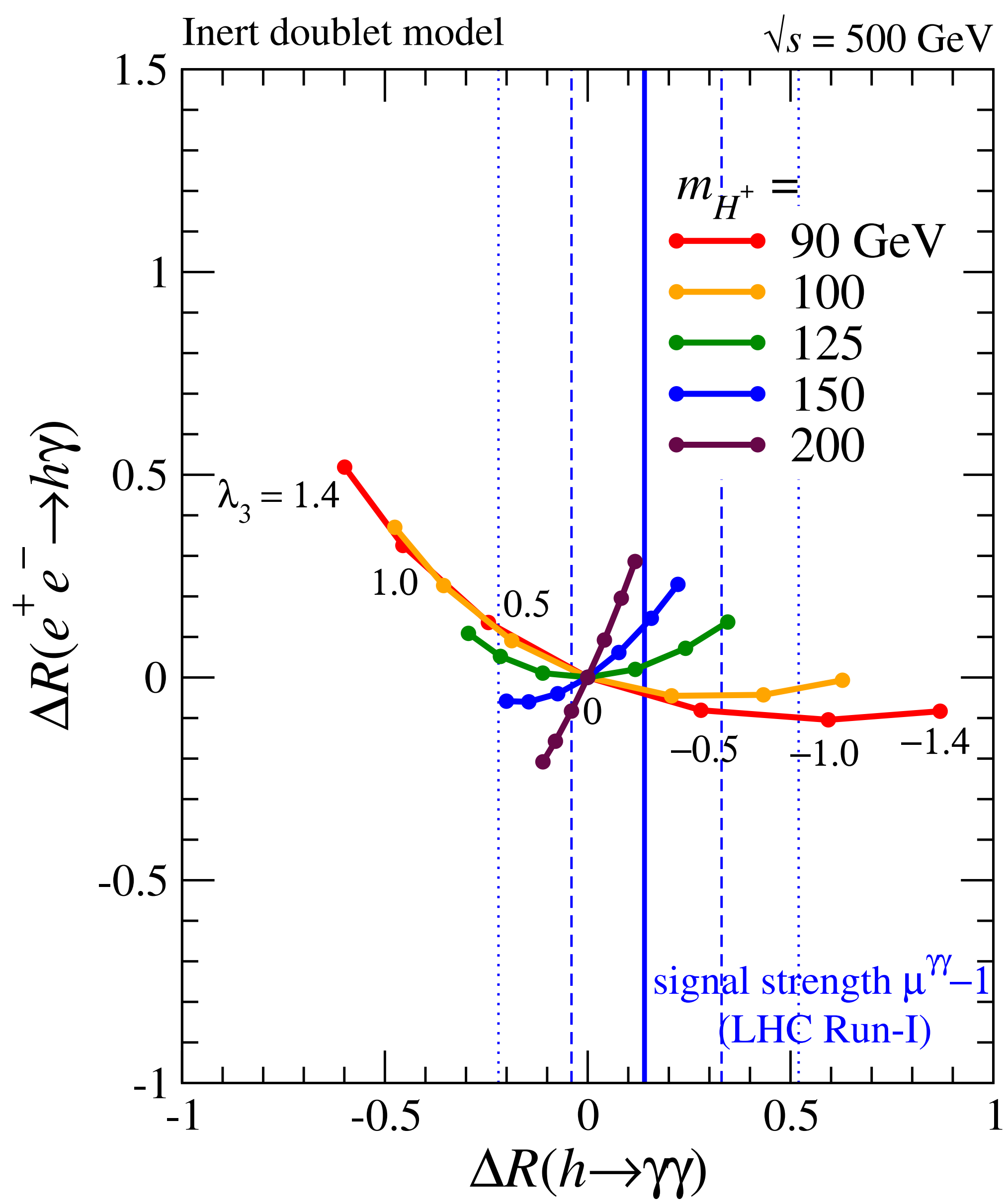




Possible deviations from the SM prediction are minor in the viable parameter space.

250 GeV vs. 500 GeV (IDM)

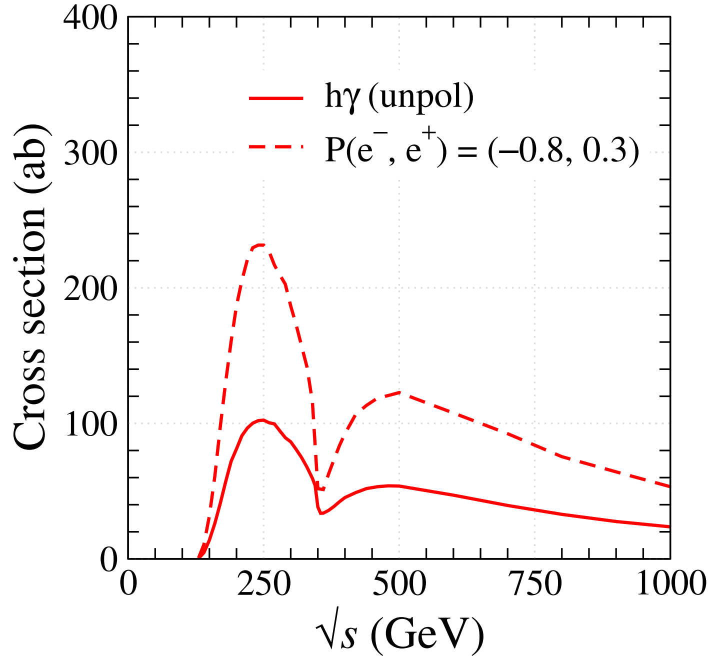




The correlations are different. ➡ A possibility to access more information on the Higgs sector!

Summary

- h+γ production at ILC250 is an interesting channel, although the cross section is rather small, σ〜O(0.1fb).
  - The cross section is peaked at E=250GeV.
  - Beam polarization can enhance the cross section.
  - The signal is clean and very sensitive to New Physics.



- By using the H-COUP program, we have been studying the process in various extended Higgs models, such as IDM/ITM/THDM, systematically.
  - Light charged scalars (m_{H^+}〜100GeV) can enhance the event rates by a factor of 2 at most under the theoretical and experimental constraints.
  - In the ITM, we can also find a particular parameter region where the hγ production significantly increases, but still remaining the h→γγ decay as in the SM.