HIGGS BR CALCULATIONS

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I Introduction

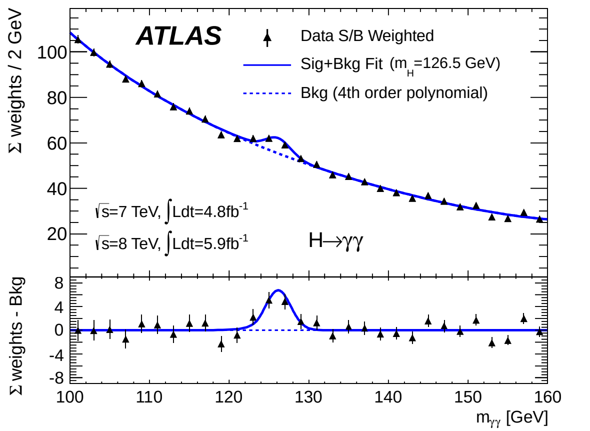
II Higgs Boson Decays

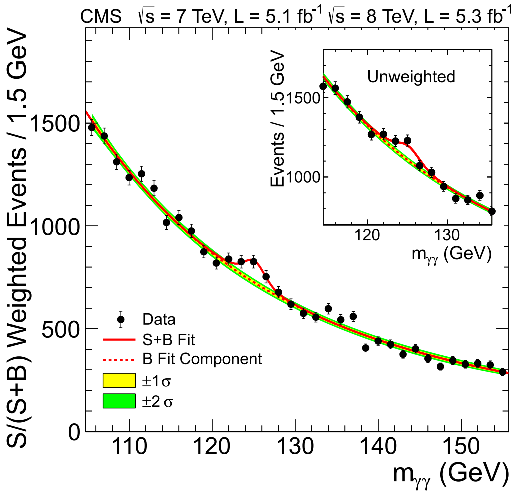
III HEFT

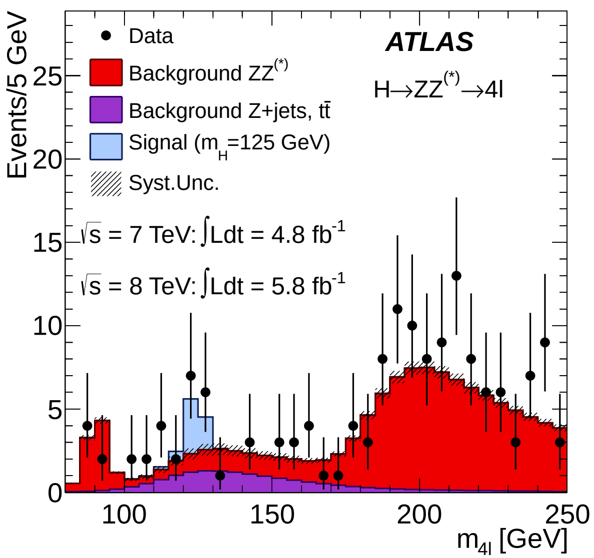
IV Conclusions

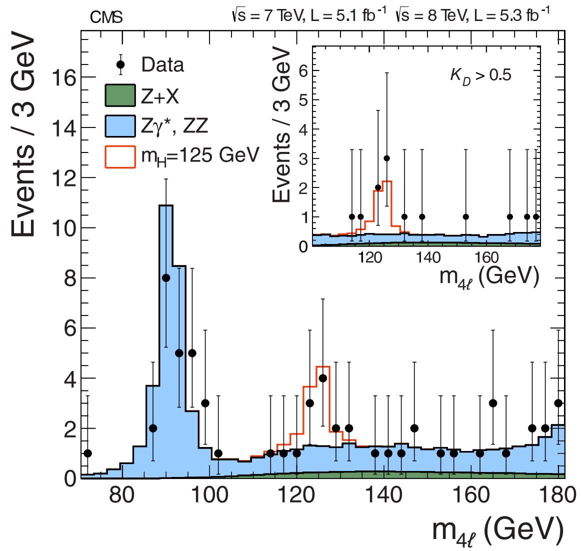
I INTRODUCTION

- we have found the Higgs: $M_H \sim 125$ GeV
- $gg \to H$ dominant









- Discovery: LHC [Tevatron]

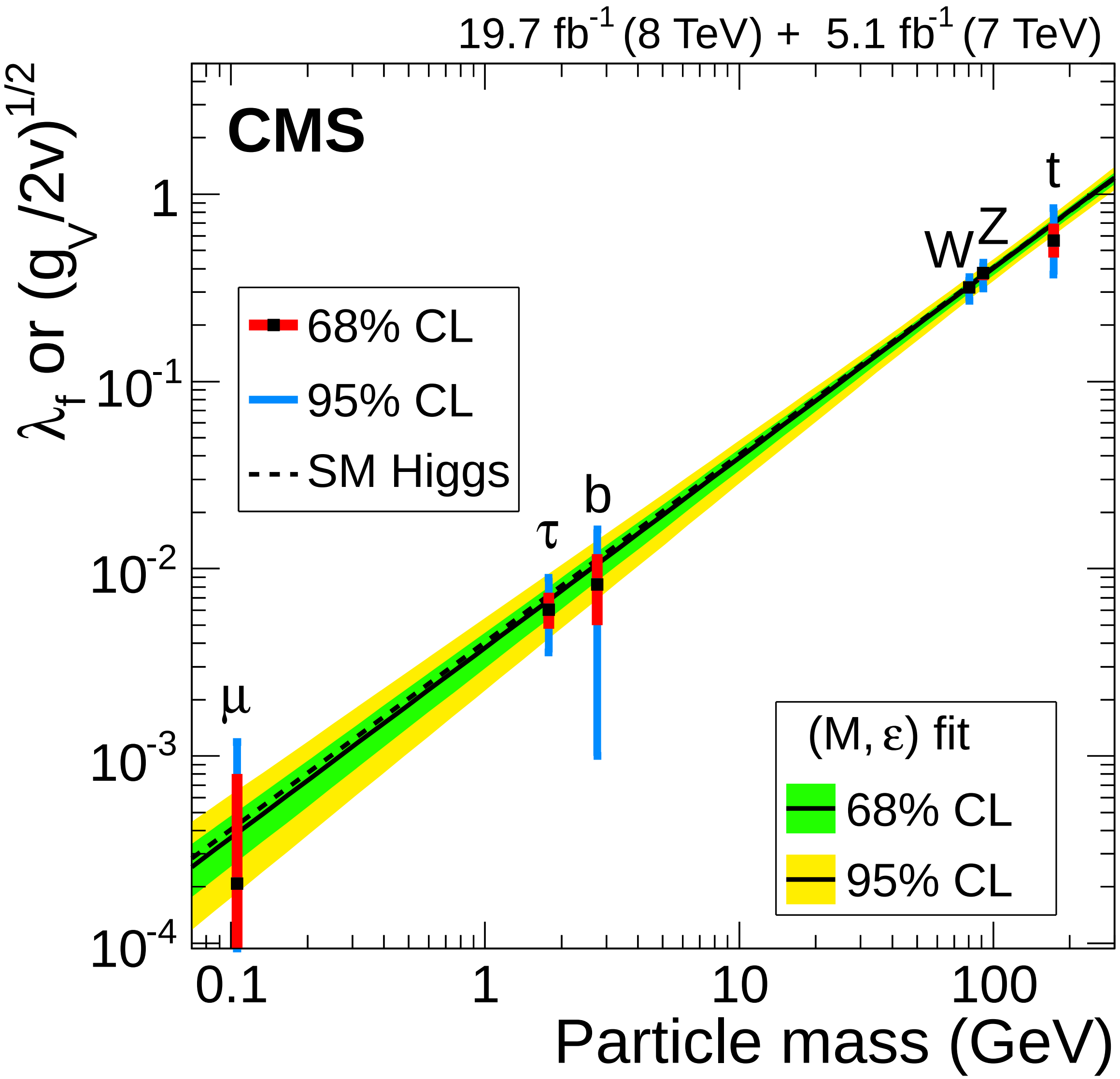
  → Higgs mass

  couplings

  spin

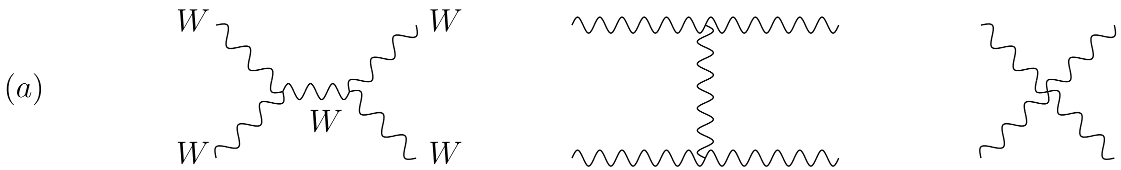
  $\mathcal{CP}$

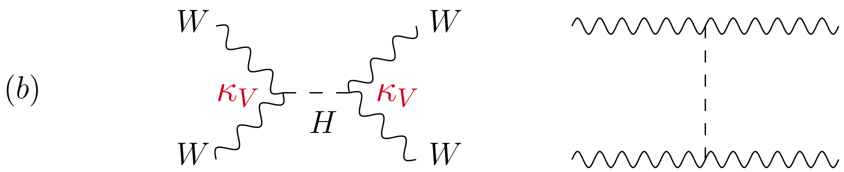
  λ ?



CMS

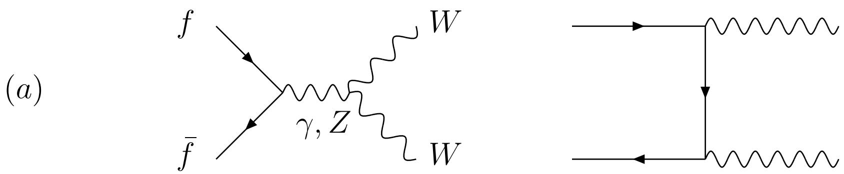
- $WW \to WW$ @ high energies

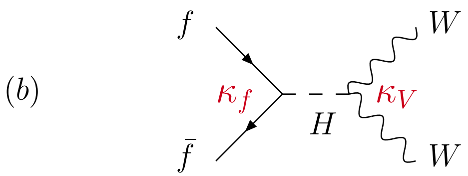




$$\mathcal{A} = \frac{s}{v^2}\left\{1 - \frac{\kappa_V^2 s}{s - M_H^2}\right\} \quad \Rightarrow \quad \kappa_V = 1$$

- $f\bar{f} \to WW$ @ high energies





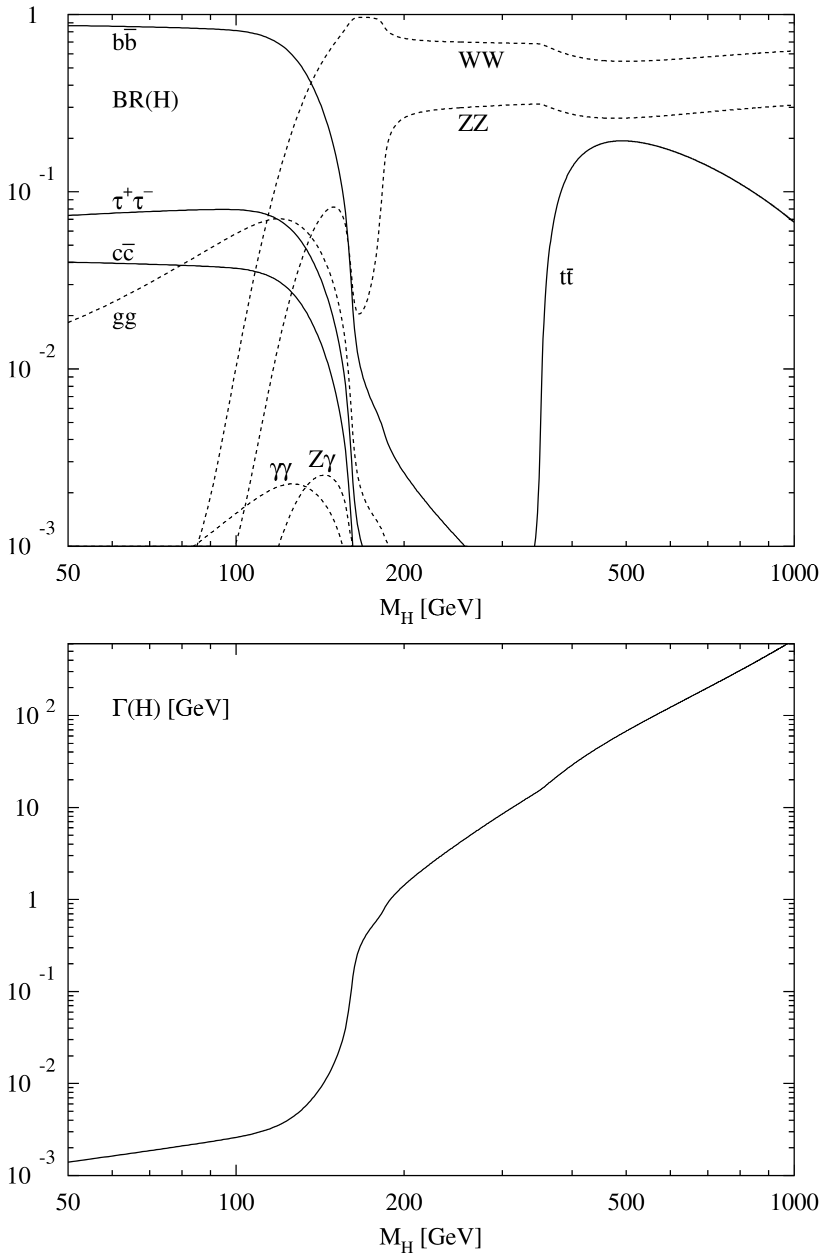
$$\mathcal{A} = \frac{m_f\sqrt{s}}{v^2}\left\{1 - \frac{\kappa_f \kappa_V s}{s - M_H^2}\right\} \quad \Rightarrow \quad \kappa_f = \kappa_V = 1$$

- analogously for κ_H

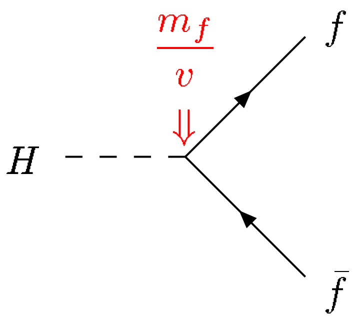
- modifications: (i) higher-dim. operators $\to$ eff. Lagrangians
  (ii) extended Higgs sectors (mixing, loop effects)

II *HIGGS BOSON DECAYS*

Standard Model



HDECAY

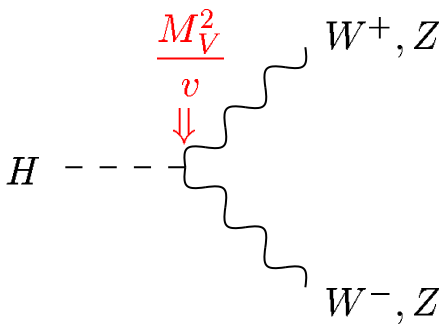


- QCD corrections large: $\sim -50\% \to m_Q(M_H)$
  known to N^{4}LO

Braaten, Leveille
Drees, Hikasa
Baikov, Chetyrkin
etc.

- elw. corrections $\mathcal{O}(5\%)$

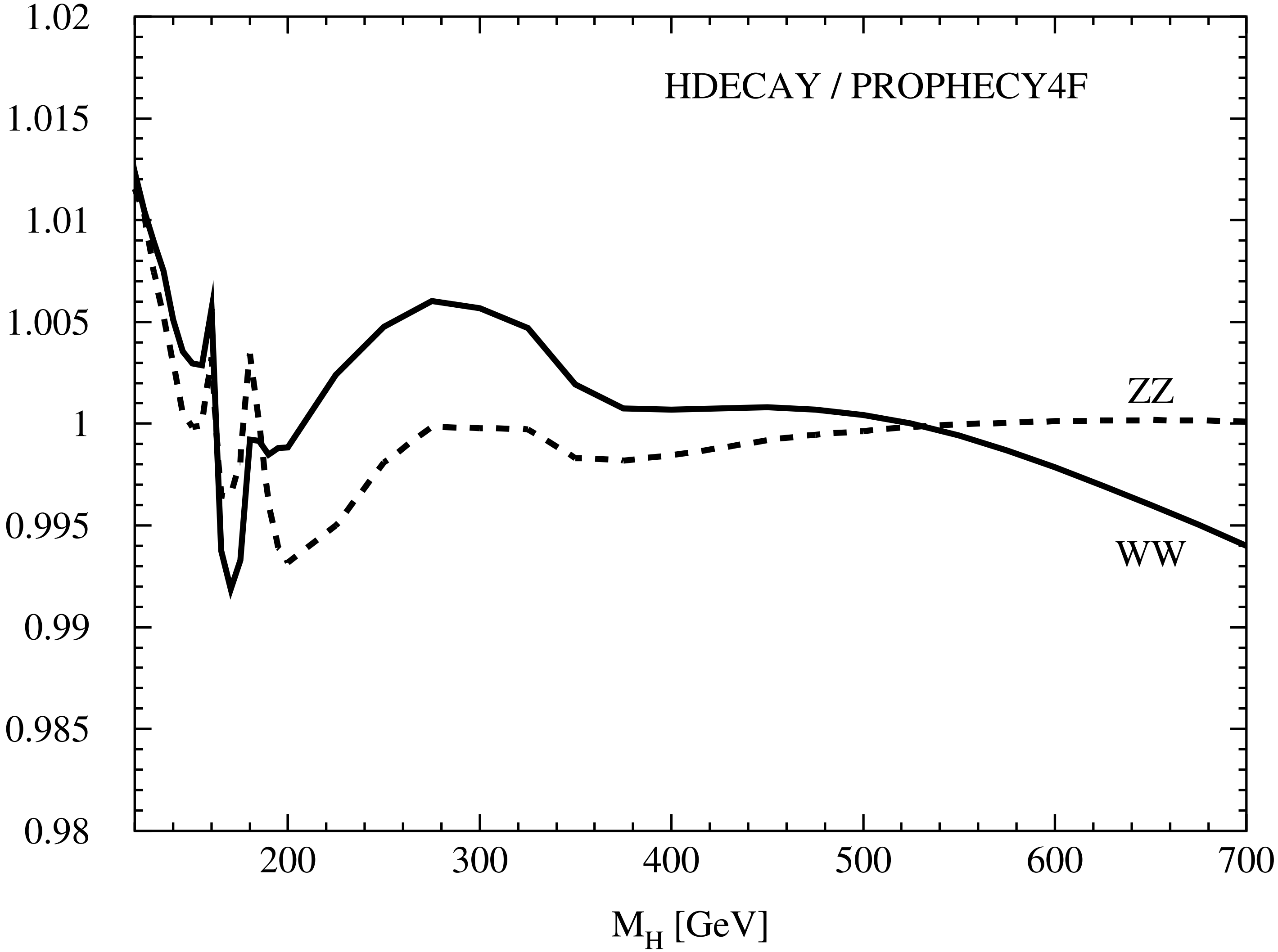
Fleischer, Jegerlehner
Bardin, Vilensky, Khristova
Dabelstein, Hollik

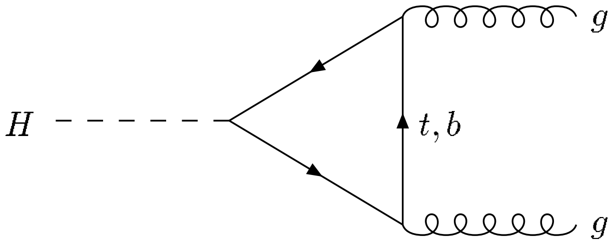


- elw. corrections: $\sim 10\%$ @ NLO
  $\to$ Prophecy4f

Fleischer, Jegerlehner
Kniehl
Bardin,. . .
Bredenstein,. . .

$H \rightarrow ZZ/WW \rightarrow 4f$



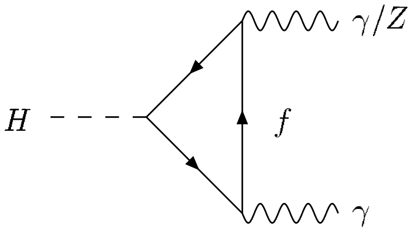


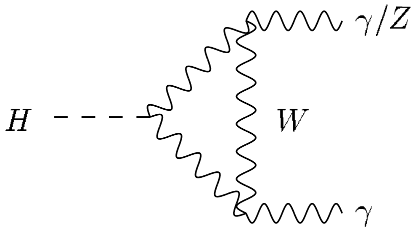
- QCD corrections large: $\sim +70\%$
  known to N^{3}LO

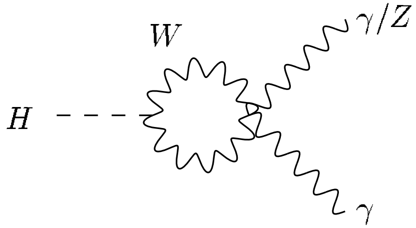
Inami, Kubota, Okada
S., Djouadi, Graudenz, Zerwas
Baikov, Chetyrkin
etc.

- elw. corrections $\mathcal{O}(5\%)$

Djouadi, Gambino
Aglietti, . . .
Actis, Passarino, Sturm, Uccirati







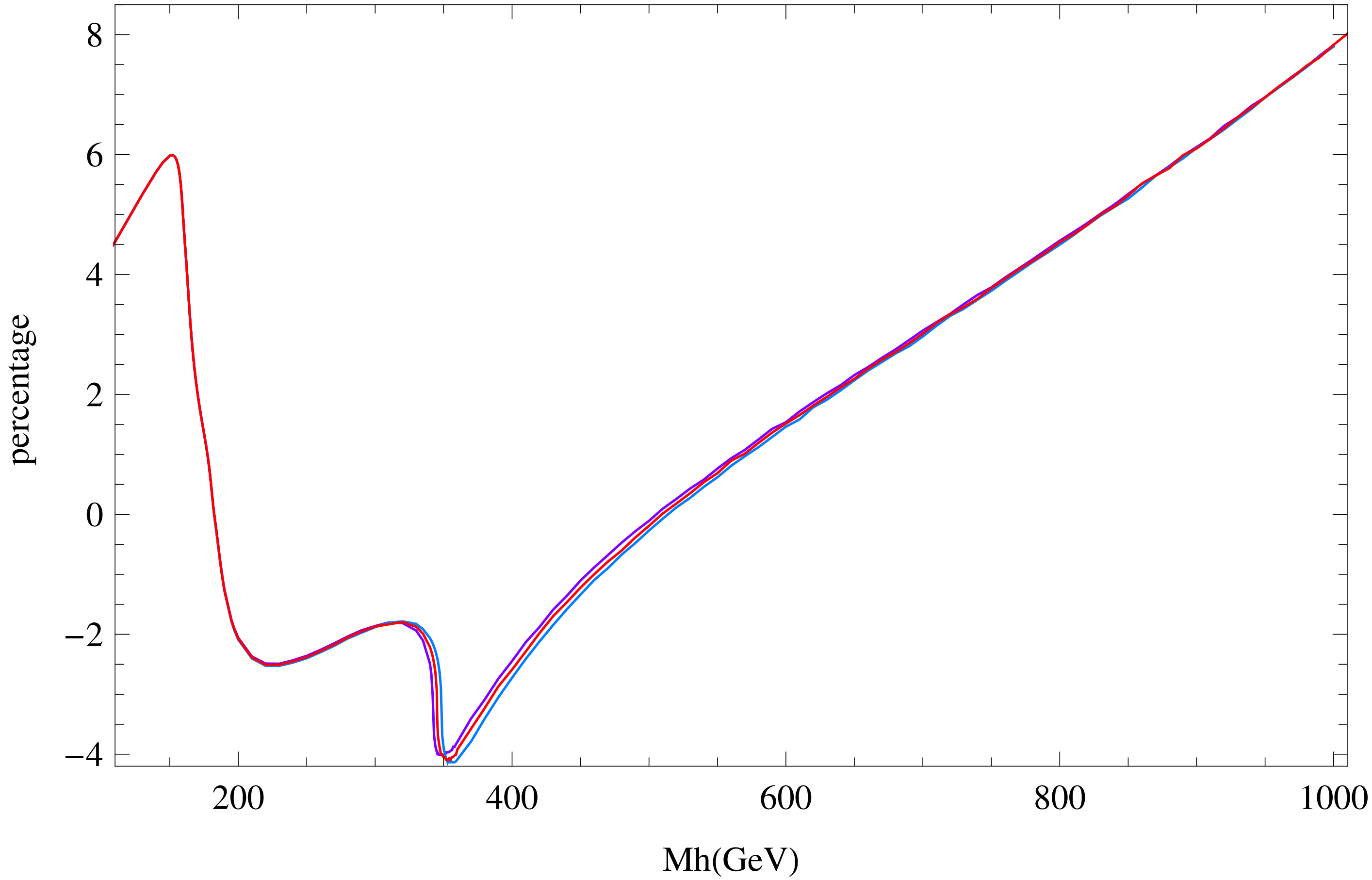
- QCD corrections $\sim 2 - 3\%$

S., Djouadi, Zerwas
Melnikov, Yakovlev
Inoue, Najima, Oka, Saito
Steinhauser
Maierhöfer, Marquard

- elw. corrections: $\mathcal{O}(5\%)$

Passarino, Sturm, Uccirati
etc.

$H \to gg$

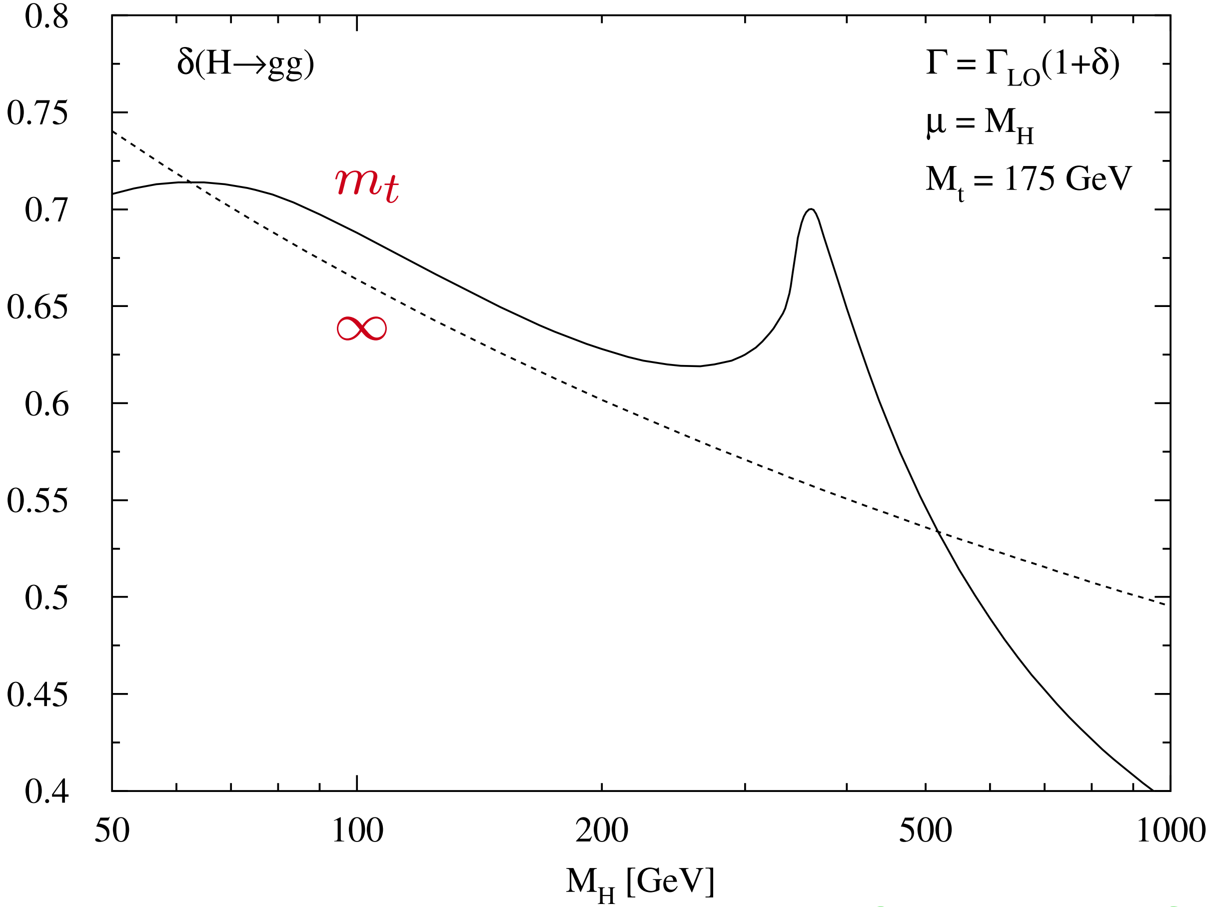


Actis, Passarino, Sturm, Uccirati

NLO elw.: full mass dependence $\to$ HDECAY

NNNLO QCD corrections ($m_t^2 \gg M_H^2$) $\to$ HDECAY Baikov, Chetyrkin

$$\Gamma(H \to gg) = \kappa_t^2 \Gamma_{tt} + \kappa_t \kappa_b \Gamma_{tb} + \kappa_b^2 \Gamma_{bb} \ [+\Gamma_{rem}]$$

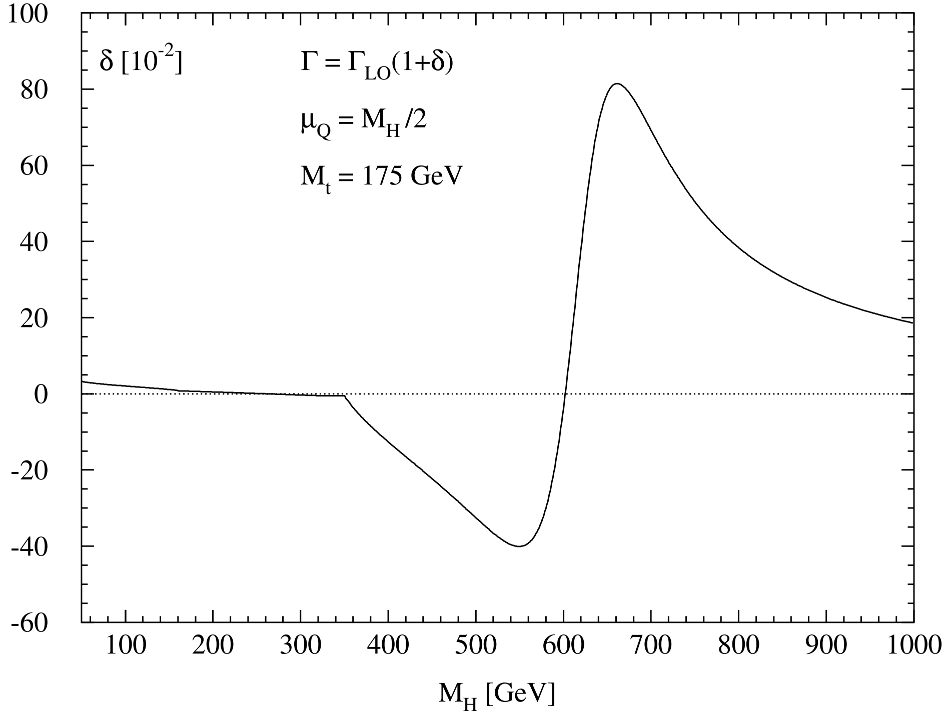


S., Djouadi, Graudenz, Zerwas

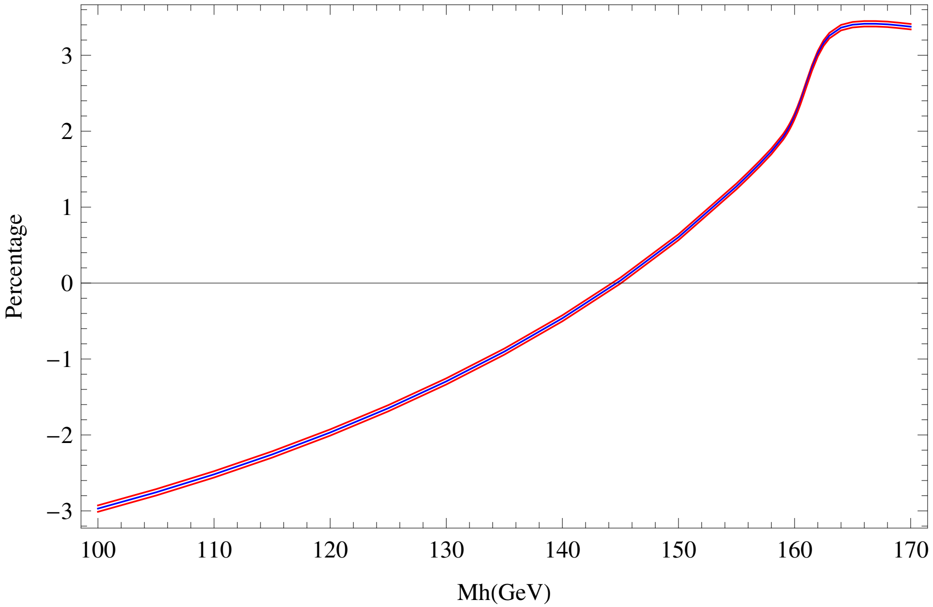
NLO QCD: full mass dependence → HDECAY

charm loops: $\sim 2\%$ → HDECAY

$\underline{H \to \gamma\gamma}$



S., Djouadi, Zerwas



Actis, Passarino, Sturm, Uccirati

NLO QCD + elw.: full mass dependence $\to$ HDECAY

Partial Width	QCD	Electroweak	Total	on-shell Higgs
$H \to b\bar{b}/c\bar{c}$	$\sim 0.1\%$	$\sim$ 1–2% for $M_H \lesssim 135$GeV	$\sim 2\%$	NNNNLO / NLO
$H \to \tau^+\tau^-/\mu^+\mu^-$		$\sim$ 1–2% for $M_H \lesssim 135$GeV	$\sim 2\%$	NLO
$H \to t\bar{t}$	$\lesssim 5\%$	$\lesssim$ 2–5% for $M_H < 500$GeV	$\sim 5\%$	(NNN)NLO / LO
		$\sim 0.1(\frac{M_H}{1\text{TeV}})^4$ for $M_H > 500$GeV	$\sim$ 5–10%	
$H \to gg$	$\sim 3\%$	$\sim 1\%$	$\sim 3\%$	NNNLO approx. / NLO
$H \to \gamma\gamma$	$< 1\%$	$< 1\%$	$\sim 1\%$	NLO / NLO
$H \to Z\gamma$	$< 1\%$	$\sim 5\%$	$\sim 5\%$	(N)LO / LO
$H \to WW/ZZ \to 4f$	$< 0.5\%$	$\sim 0.5\%$ for $M_H < 500$GeV	$\sim 0.5\%$	(N)NLO
		$\sim 0.17(\frac{M_H}{1\text{TeV}})^4$ for $M_H > 500$GeV	$\sim$ 0.5–15%	

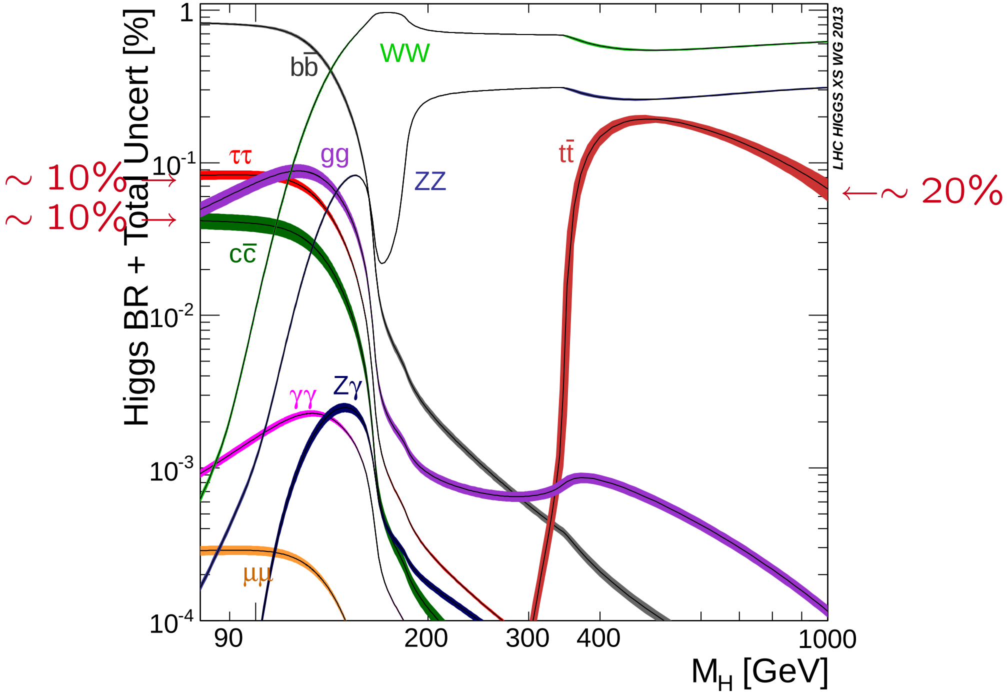
- QCD: variation of Higgs widths for scale by factor 2 and 1/2
  elw: missing HO estimated from known structure at NLO
  $M_H \gtrsim 500$ GeV: Higgs self-interactions dominate error
  different uncertainties added linearly for each channel

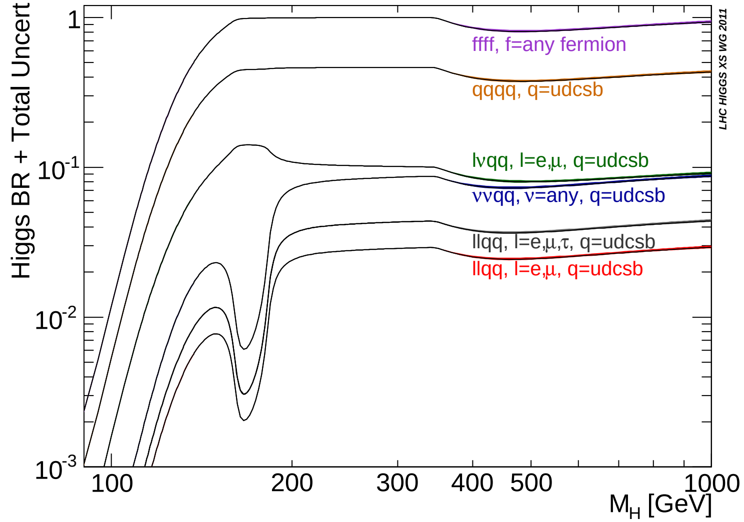
- parametric uncertainties:
  $m_t = 172.5 \pm 2.5$ GeV $\qquad \alpha_s(M_Z) = 0.119 \pm 0.002$
  $m_b(m_b) = 4.16 \pm 0.06$ GeV $\qquad m_c(m_c) = 1.28 \pm 0.03$ GeV
  different uncertainties added quadratically for each channel

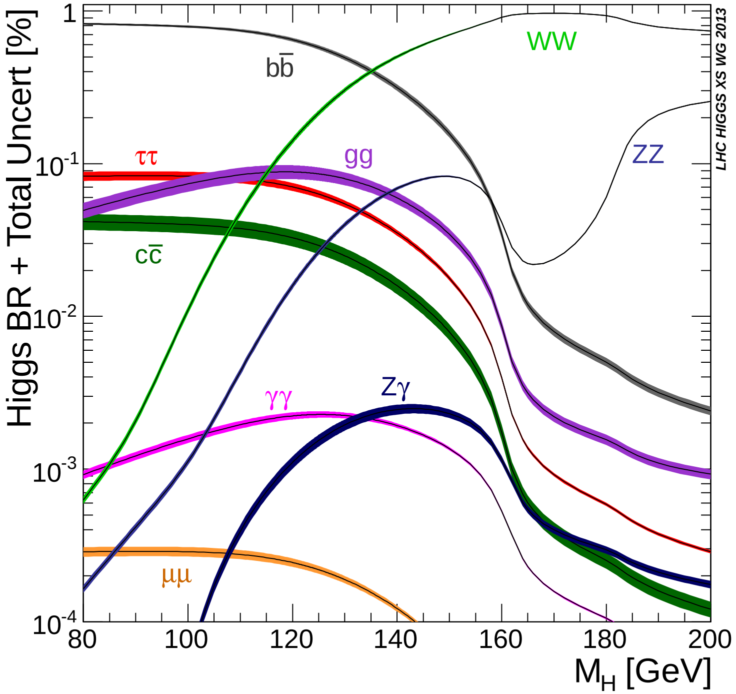
Partial Width	QCD	Electroweak	Total	on-shell Higgs
$H \to b\bar{b}/c\bar{c}$	$\sim 0.3\%$	$\sim 0.5\%$ for $M_H \lesssim 500$GeV	$\sim 0.5\%$	NNNNLO / NLO
		$\sim 0.1(\frac{M_H}{1\text{TeV}})^4$ for $M_H > 500$GeV	~ 0.5–10%	
$H \to \tau^+\tau^-/\mu^+\mu^-$		$\sim 0.5\%$ for $M_H \lesssim 500$GeV	$\sim 0.5\%$	NLO
		$\sim 0.1(\frac{M_H}{1\text{TeV}})^4$ for $M_H > 500$GeV	~ 0.5–10%	
$H \to t\bar{t}$	$\lesssim 5\%$	$\lesssim 0.5\%$ for $M_H < 500$GeV	$\sim 5\%$	(NNN)NLO / LO
		$\sim 0.1(\frac{M_H}{1\text{TeV}})^4$ for $M_H > 500$GeV	~ 5–10%	
$H \to gg$	$\sim 3\%$	$\sim 1\%$	$\sim 3\%$	NNNLO approx. / NLO
$H \to \gamma\gamma$	$< 1\%$	$< 1\%$	$\sim 1\%$	NLO / NLO
$H \to Z\gamma$	$< 1\%$	$\sim 5\%$	$\sim 5\%$	(N)LO / LO
$H \to WW/ZZ \to 4f$	$< 0.5\%$	$\sim 0.5\%$ for $M_H < 500$GeV	$\sim 0.5\%$	(N)NLO
		$\sim 0.17(\frac{M_H}{1\text{TeV}})^4$ for $M_H > 500$GeV	~ 0.5–15%	

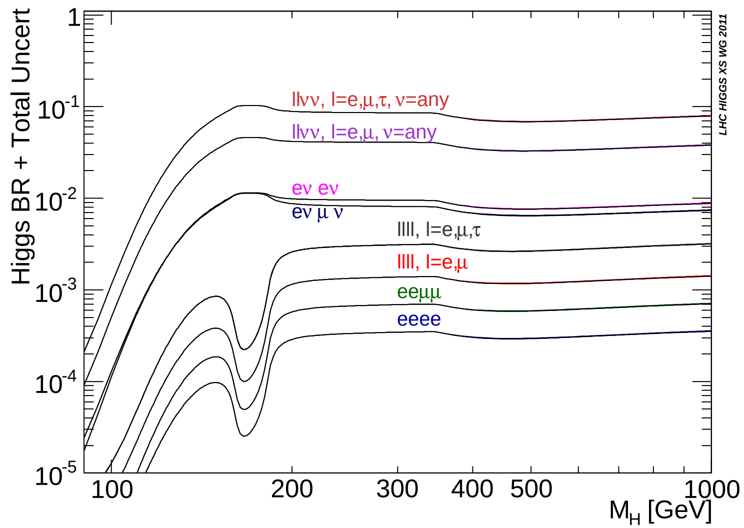
- QCD: variation of Higgs widths for scale by factor 2 and 1/2
  elw: missing HO estimated from known structure at NLO
  $M_H \gtrsim 500$ GeV: Higgs self-interactions dominate error
  different uncertainties added linearly for each channel
- parametric uncertainties: [$\to$ discussions SM input parameters]
  $m_t = 173.2 \pm 0.9$ GeV $\alpha_s(M_Z) = 0.118 \pm 0.001$
  $m_b(m_b) = 4.18 \pm 0.03$ GeV $m_c(3\text{GeV}) = 0.986 \pm 0.025$ GeV
  different uncertainties added quadratically for each channel
- total uncertainties: parametric & theor. uncertainties added linearly

HDECAY & Prophecy4f



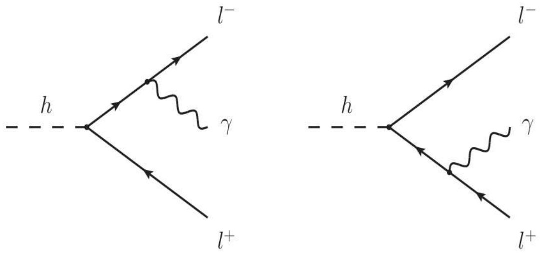




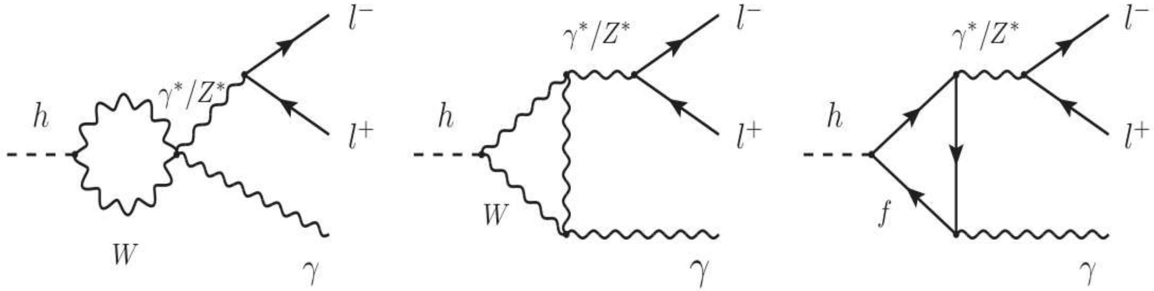


Denner, Heinemeyer, Puljak, Rebuzzi, S.

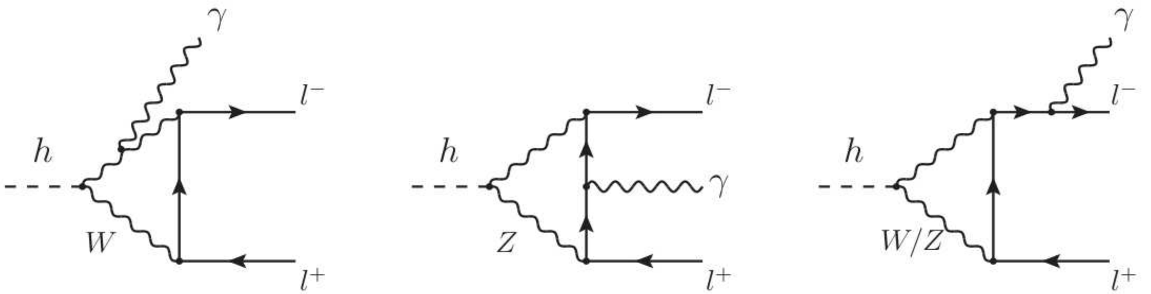
HIGGS DALITZ DECAYS



tree



off-shell



boxes

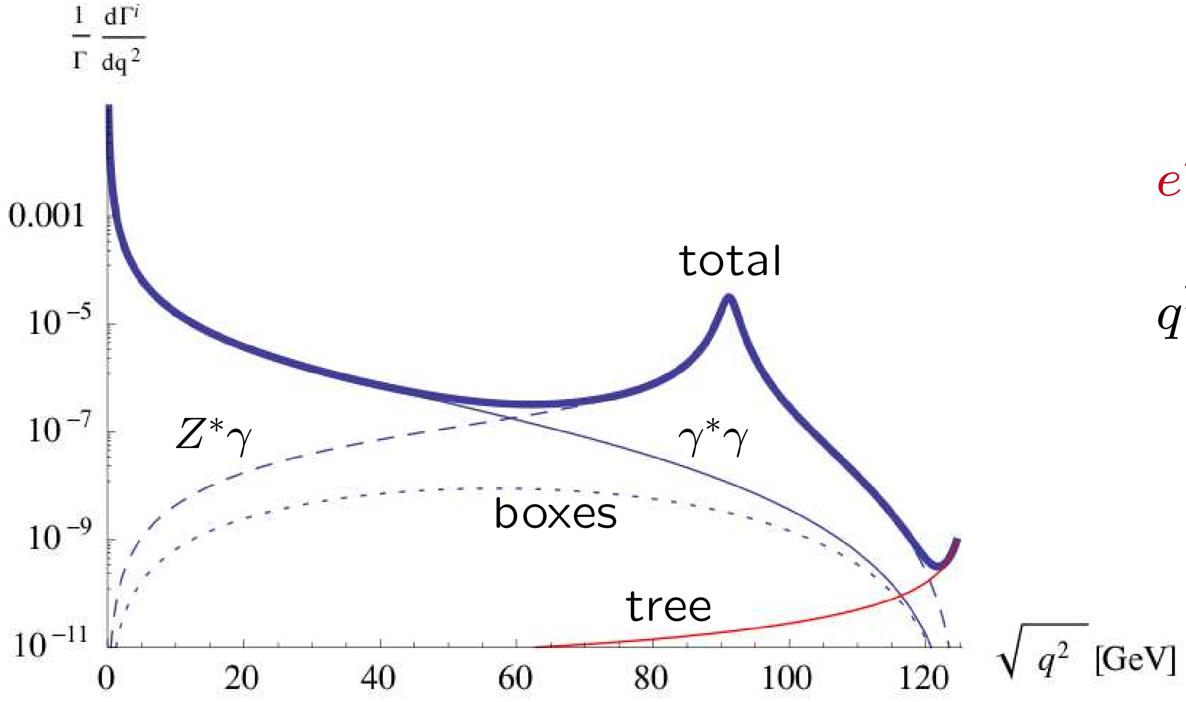
Abbasabadi, Bowser–Chao, Dicus, Repko
Sun, Chang, Gao
Passarino

$$\frac{\Gamma(h \to \gamma e^+ e^-)}{\Gamma(h \to \gamma\gamma)} = 5.7\%$$

$$\frac{\Gamma(h \to \gamma \mu^+ \mu^-)}{\Gamma(h \to \gamma\gamma)} = 5.8\%$$

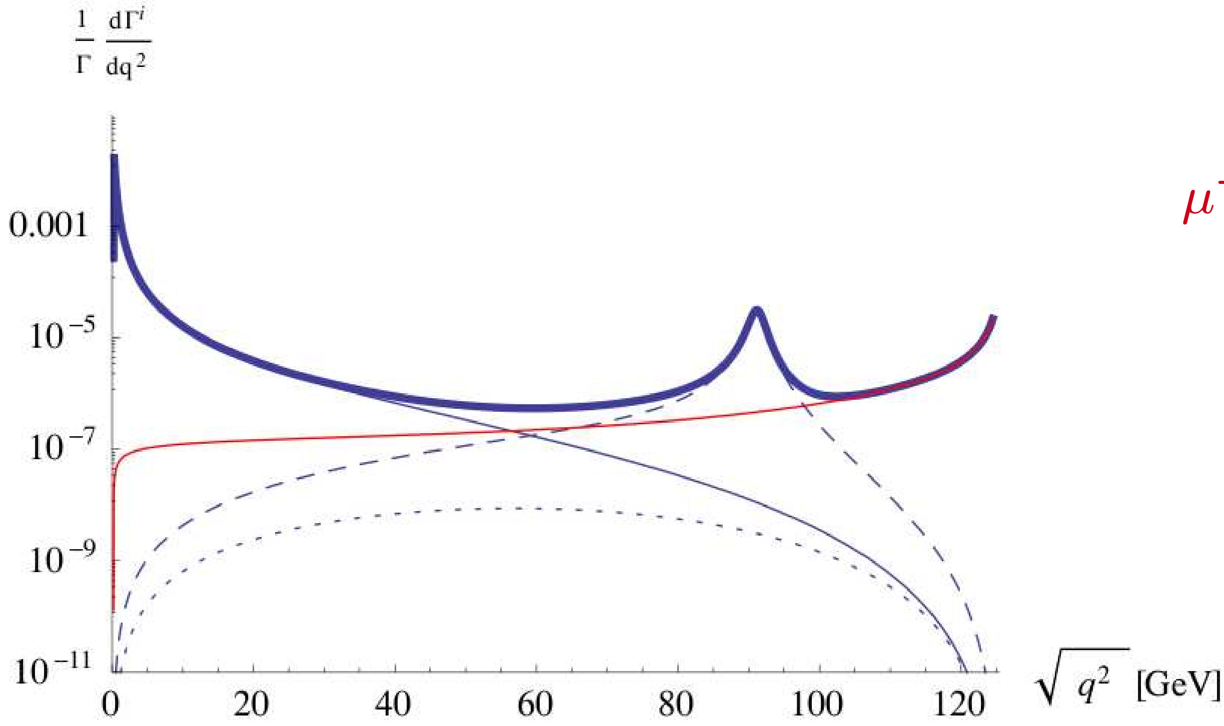
($E_\gamma > 1$ GeV)

$$\frac{\Gamma(h \to \gamma \tau^+ \tau^-)}{\Gamma(h \to \gamma\gamma)} = 3.04$$



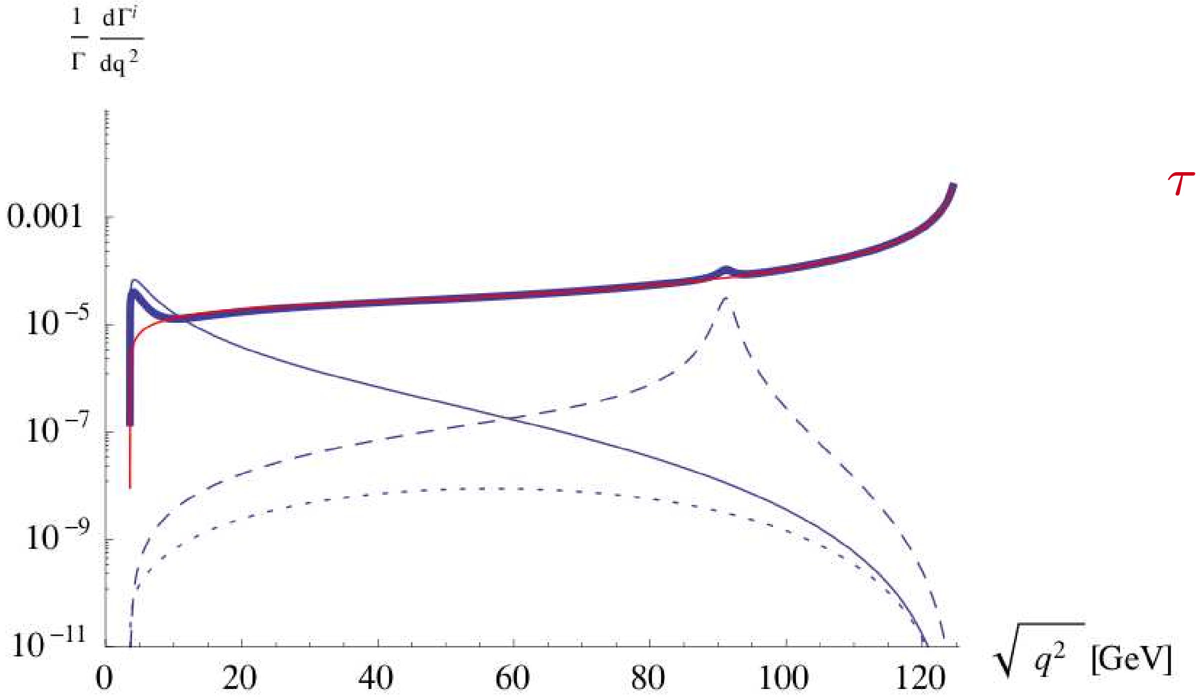
$e^+e^-\gamma$

$q^2 = M^2_{\ell^+\ell^-}$



Sun, Chang, Gao

$\mu^+\mu^-\gamma$



$\tau^+\tau^-\gamma$

Sun, Chang, Gao

II $\mathcal{HEFT}$

(i) weakly interacting theories

- effective higher dimension operators up to dim 6

Buchmüller, Wyler
Grzadkowski, Iskrzynski, Misiak, Rosiek
Giudice, Grojean, Pomarol, Rattazzi

$$\begin{aligned} \mathcal{L} &= \mathcal{L}_{SM} + \frac{1}{\Lambda^2}\sum_i \alpha_i O_i \\ &\equiv \mathcal{L}_{SM} + \sum_i \bar{c}_i O_i \\ &\equiv \mathcal{L}_{SM} + \Delta\mathcal{L}_{SILH} + \Delta\mathcal{L}_{F_1} + \Delta\mathcal{L}_{F_2} + \Delta\mathcal{L}_{bos} + \Delta\mathcal{L}_{4f} + \Delta\mathcal{L}_{\mathcal{CP}} \end{aligned}$$

[assume Λ large]

- assume Higgs $SU(2)$-doublet

$$H = \begin{pmatrix} \phi^+ \\ \phi^0 \end{pmatrix}$$

$$
\begin{aligned}
\Delta\mathcal{L}_{SILH} \;=\;& \frac{\bar{c}_H}{2v^2}\,\partial^\mu\Big(H^\dagger H\Big)\,\partial_\mu\Big(H^\dagger H\Big) + \frac{\bar{c}_T}{2v^2}\left(H^\dagger \overleftrightarrow{D^\mu} H\right)\Big(H^\dagger \overleftrightarrow{D}_\mu H\Big) - \frac{\bar{c}_6\,\lambda}{v^2}\Big(H^\dagger H\Big)^3 \\
& + \left(\frac{\bar{c}_u}{v^2}\,y_u\,H^\dagger H\,\bar{q}_L H^c u_R + \frac{\bar{c}_d}{v^2}\,y_d\,H^\dagger H\,\bar{q}_L H d_R + \frac{\bar{c}_l}{v^2}\,y_l\,H^\dagger H\,\bar{L}_L H l_R + h.c.\right) \\
& + \frac{i\bar{c}_W\,g}{2m_W^2}\left(H^\dagger\sigma^i \overleftrightarrow{D^\mu} H\right)(D^\nu W_{\mu\nu})^i + \frac{i\bar{c}_B\,g'}{2m_W^2}\left(H^\dagger \overleftrightarrow{D^\mu} H\right)(\partial^\nu B_{\mu\nu}) \\
& + \frac{i\bar{c}_{HW}\,g}{m_W^2}\,(D^\mu H)^\dagger\sigma^i(D^\nu H)W^i_{\mu\nu} + \frac{i\bar{c}_{HB}\,g'}{m_W^2}\,(D^\mu H)^\dagger(D^\nu H)B_{\mu\nu} \\
& + \frac{\bar{c}_\gamma\,{g'}^2}{m_W^2}\,H^\dagger H B_{\mu\nu}B^{\mu\nu} + \frac{\bar{c}_g\,g_S^2}{m_W^2}\,H^\dagger H G^a_{\mu\nu}G^{a\mu\nu} \\
\Delta\mathcal{L}_{F_1} \;=\;& \frac{i\bar{c}_{Hq}}{v^2}\,(\bar{q}_L\gamma^\mu q_L)\Big(H^\dagger \overleftrightarrow{D}_\mu H\Big) + \frac{i\bar{c}'_{Hq}}{v^2}\Big(\bar{q}_L\gamma^\mu\sigma^i q_L\Big)\Big(H^\dagger\sigma^i \overleftrightarrow{D}_\mu H\Big) \\
& + \frac{i\bar{c}_{Hu}}{v^2}\,(\bar{u}_R\gamma^\mu u_R)\Big(H^\dagger \overleftrightarrow{D}_\mu H\Big) + \frac{i\bar{c}_{Hd}}{v^2}\Big(\bar{d}_R\gamma^\mu d_R\Big)\Big(H^\dagger \overleftrightarrow{D}_\mu H\Big) \\
& + \left(\frac{i\bar{c}_{Hud}}{v^2}\,(\bar{u}_R\gamma^\mu d_R)\Big(H^{c\,\dagger} \overleftrightarrow{D}_\mu H\Big) + h.c.\right) \\
& + \frac{i\bar{c}_{HL}}{v^2}\Big(\bar{L}_L\gamma^\mu L_L\Big)\Big(H^\dagger \overleftrightarrow{D}_\mu H\Big) + \frac{i\bar{c}'_{HL}}{v^2}\Big(\bar{L}_L\gamma^\mu\sigma^i L_L\Big)\Big(H^\dagger\sigma^i \overleftrightarrow{D}_\mu H\Big) \\
& + \frac{i\bar{c}_{Hl}}{v^2}\Big(\bar{l}_R\gamma^\mu l_R\Big)\Big(H^\dagger \overleftrightarrow{D}_\mu H\Big) \\
\Delta\mathcal{L}_{F_2} \;=\;& \frac{\bar{c}_{uB}\,g'}{m_W^2}\,y_u\,\bar{q}_L H^c\sigma^{\mu\nu}u_R\,B_{\mu\nu} + \frac{\bar{c}_{uW}\,g}{m_W^2}\,y_u\,\bar{q}_L\sigma^i H^c\sigma^{\mu\nu}u_R\,W^i_{\mu\nu} + \frac{\bar{c}_{uG}\,g_S}{m_W^2}\,y_u\,\bar{q}_L H^c\sigma^{\mu\nu}\lambda^a u_R\,G^a_{\mu\nu} \\
& + \frac{\bar{c}_{dB}\,g'}{m_W^2}\,y_d\,\bar{q}_L H\sigma^{\mu\nu}d_R\,B_{\mu\nu} + \frac{\bar{c}_{dW}\,g}{m_W^2}\,y_d\,\bar{q}_L\sigma^i H\sigma^{\mu\nu}d_R\,W^i_{\mu\nu} + \frac{\bar{c}_{dG}\,g_S}{m_W^2}\,y_d\,\bar{q}_L H\sigma^{\mu\nu}\lambda^a d_R\,G^a_{\mu\nu} \\
& + \frac{\bar{c}_{lB}\,g'}{m_W^2}\,y_l\,\bar{L}_L H\sigma^{\mu\nu}l_R\,B_{\mu\nu} + \frac{\bar{c}_{lW}\,g}{m_W^2}\,y_l\,\bar{L}_L\sigma^i H\sigma^{\mu\nu}l_R\,W^i_{\mu\nu} + h.c.
\end{aligned}
$$

$$
\begin{aligned}
\Delta\mathcal{L}_{bos} &= \frac{\bar{c}_{3W}\, g^3}{m_W^2}\, \epsilon^{ijk} W_\mu^{i\,\nu} W_\nu^{j\,\rho} W_\rho^{k\,\mu} + \frac{\bar{c}_{3G}\, g_S^3}{m_W^2}\, f^{abc} G_\mu^{a\,\nu} G_\nu^{b\,\rho} G_\rho^{c\,\mu} \\
&+ \frac{\bar{c}_{2W}}{m_W^2} \left(D^\mu W_{\mu\nu}\right)^i \left(D_\rho W^{\rho\nu}\right)^i + \frac{\bar{c}_{2B}}{m_W^2} \left(\partial^\mu B_{\mu\nu}\right) \left(\partial_\rho B^{\rho\nu}\right) + \frac{\bar{c}_{2G}}{m_W^2} \left(D^\mu G_{\mu\nu}\right)^a \left(D_\rho G^{\rho\nu}\right)^a \\
\Delta\mathcal{L}_{4f} &= \sum_{\psi,L/R,T^a} \bar{\psi}_i \gamma^\mu T^a \psi_j \bar{\psi}_k \gamma_\mu T^a \psi_l + \bar{\psi}_i T^a \psi_j \bar{\psi}_k T^a \psi_l \\
\Delta\mathcal{L}_{\mathcal{CP}} &= \frac{i\tilde{c}_{HW}\, g}{m_W^2} (D^\mu H)^\dagger \sigma^i (D^\nu H) \tilde{W}_{\mu\nu}^i + \frac{i\tilde{c}_{HB}\, g'}{m_W^2} (D^\mu H)^\dagger (D^\nu H) \tilde{B}_{\mu\nu} \\
&\quad + \frac{\tilde{c}_\gamma\, g'^2}{m_W^2} H^\dagger H B_{\mu\nu} \tilde{B}^{\mu\nu} + \frac{\tilde{c}_g\, g_S^2}{m_W^2} H^\dagger H G_{\mu\nu}^a \tilde{G}^{a\mu\nu} \\
&\quad + \frac{\tilde{c}_{3W}\, g^3}{m_W^2}\, \epsilon^{ijk} W_\mu^{i\,\nu} W_\nu^{j\,\rho} \tilde{W}_\rho^{k\,\mu} + \frac{\tilde{c}_{3G}\, g_S^3}{m_W^2}\, f^{abc} G_\mu^{a\,\nu} G_\nu^{b\,\rho} \tilde{G}_\rho^{c\,\mu}
\end{aligned}
$$

$$
\tilde{V}_{\mu\nu} = \frac{1}{2} \epsilon_{\mu\nu\alpha\beta} V^{\alpha\beta}
$$

- after using EOM: 53 (59) independent dim6 operators

- canonical normalization

$$\mathcal{L} = \frac{1}{2}\partial_\mu h\ \partial^\mu h - \frac{1}{2}m_h^2 h^2 - c_3 \frac{1}{6}\left(\frac{3m_h^2}{v}\right) h^3 - \sum_{\psi=u,d,l} m_{\psi^{(i)}}\, \bar{\psi}^{(i)}\psi^{(i)} \left(1 + c_\psi \frac{h}{v} + \dots\right)$$
$$+ m_W^2\, W_\mu W^\mu \left(1 + 2c_W \frac{h}{v} + \dots\right) + \frac{1}{2}m_Z^2\, Z_\mu Z^\mu \left(1 + 2c_Z \frac{h}{v} + \dots\right) + \dots$$
$$+ \left(c_{WW}\, W^+_{\mu\nu} W^{-\mu\nu} + \frac{c_{ZZ}}{2}\, Z_{\mu\nu}Z^{\mu\nu} + c_{Z\gamma}\, Z_{\mu\nu}\gamma^{\mu\nu} + \frac{c_{\gamma\gamma}}{2}\,\gamma_{\mu\nu}\gamma^{\mu\nu} + \frac{c_{gg}}{2}\, G^a_{\mu\nu}G^{a\mu\nu}\right)\frac{h}{v}$$
$$+ \left(c_{W\partial W}\left(W^-_\nu D_\mu W^{+\mu\nu} + h.c.\right) + c_{Z\partial Z}\, Z_\nu \partial_\mu Z^{\mu\nu} + c_{Z\partial\gamma}\, Z_\nu \partial_\mu \gamma^{\mu\nu}\right)\frac{h}{v} + \dots$$

Higgs couplings	$\Delta\mathcal{L}_{SILH}$	MCHM4	MCHM5
c_W	$1 - \bar{c}_H/2$	$\sqrt{1-\xi}$	$\sqrt{1-\xi}$
c_Z	$1 - \bar{c}_H/2 - \bar{c}_T$	$\sqrt{1-\xi}$	$\sqrt{1-\xi}$
$c_\psi\ \ (\psi = u,d,l)$	$1 - (\bar{c}_H/2 + \bar{c}_\psi)$	$\sqrt{1-\xi}$	$\frac{1-2\xi}{\sqrt{1-\xi}}$
c_3	$1 + \bar{c}_6 - 3\bar{c}_H/2$	$\sqrt{1-\xi}$	$\frac{1-2\xi}{\sqrt{1-\xi}}$
c_{gg}	$8\,(\alpha_s/\alpha_2)\,\bar{c}_g$	0	0
$c_{\gamma\gamma}$	$8\sin^2\theta_W\,\bar{c}_\gamma$	0	0
$c_{Z\gamma}$	$\left(\bar{c}_{HB} - \bar{c}_{HW} - 8\,\bar{c}_\gamma \sin^2\theta_W\right)\tan\theta_W$	0	0
c_{WW}	$-2\,\bar{c}_{HW}$	0	0
c_{ZZ}	$-2\left(\bar{c}_{HW} + \bar{c}_{HB}\tan^2\theta_W - 4\bar{c}_\gamma \tan^2\theta_W \sin^2\theta_W\right)$	0	0
$c_{W\partial W}$	$-2(\bar{c}_W + \bar{c}_{HW})$	0	0
$c_{Z\partial Z}$	$-2(\bar{c}_W + \bar{c}_{HW}) - 2\,(\bar{c}_B + \bar{c}_{HB})\tan^2\theta_W$	0	0
$c_{Z\partial\gamma}$	$2\,(\bar{c}_B + \bar{c}_{HB} - \bar{c}_W - \bar{c}_{HW})\tan\theta_W$	0	0

small deviations from SM couplings

Contino, Ghezzi, Grojean, Mühlleitner, S.

$$
\begin{aligned}
\mathcal{L} = \;& \tfrac{1}{2}\partial_\mu h\ \partial^\mu h - \tfrac{1}{2}m_h^2 h^2 - c_3 \tfrac{1}{6}\left(\tfrac{3m_h^2}{v}\right) h^3 - \textstyle\sum_{\psi=u,d,l} m_{\psi^{(i)}}\, \bar{\psi}^{(i)}\psi^{(i)} \left(1 + c_\psi \tfrac{h}{v} + \ldots\right) \\
& + m_W^2\, W_\mu W^\mu \left(1 + 2c_W\, \tfrac{h}{v} + \ldots\right) + \tfrac{1}{2}m_Z^2\, Z_\mu Z^\mu \left(1 + 2c_Z\, \tfrac{h}{v} + \ldots\right) + \ldots \\
& + \left(c_{WW}\, W_{\mu\nu}^+ W^{-\mu\nu} + \tfrac{c_{ZZ}}{2}\, Z_{\mu\nu}Z^{\mu\nu} + c_{Z\gamma}\, Z_{\mu\nu}\gamma^{\mu\nu} + \tfrac{c_{\gamma\gamma}}{2}\, \gamma_{\mu\nu}\gamma^{\mu\nu} + \tfrac{c_{gg}}{2}\, G^a_{\mu\nu}G^{a\mu\nu}\right) \tfrac{h}{v} \\
& + \Big(c_{W\partial W}\left(W_\nu^- D_\mu W^{+\mu\nu} + h.c.\right) + c_{Z\partial Z}\, Z_\nu \partial_\mu Z^{\mu\nu} + c_{Z\partial\gamma}\, Z_\nu \partial_\mu \gamma^{\mu\nu}\Big) \tfrac{h}{v} + \ldots
\end{aligned}
$$

- also valid in case of a non-linear Lagrangian for a light Higgs-like scalar [h generic $\mathcal{CP}$-even scalar]

$\Rightarrow$ expansion in E/M (derivatives) only, large deviations from SM couplings allowed

SILH: expansion in $v^2/f^2, E^2/M^2, \alpha_s/\pi, \alpha/\pi$

non-lin.: expansion in $E^2/M^2, \alpha_s/\pi$

III $e\mathcal{HDECAY}$

http://www.itp.kit.edu/~maggie/eHDECAY/

- $h \to f\bar{f}$:

$$\Gamma(\bar{\psi}\psi)\big|_{SILH} = \Gamma_0^{SM}(\bar{\psi}\psi)\left[1 - \bar{c}_H - 2\bar{c}_\psi + \frac{2}{|A_0^{SM}|^2}\mathrm{Re}\left(A_0^{*SM} A_{1,ew}^{SM}\right)\right]\left[1 + \delta_\psi\,\kappa^{QCD}\right]$$

$$\Gamma(\bar{\psi}\psi)\big|_{NL} = c_\psi^2\,\Gamma_0^{SM}(\bar{\psi}\psi)\left[1 + \delta_\psi\,\kappa^{QCD}\right]$$

A_0^{SM}: SM tree-level amplitude
$A_{1,ew}^{SM}$: SM elw. amplitude [real corrections treated analogously]

- factorization of QCD $\leftrightarrow$ elw. [limit small m_h]

- NL: no elw. corrections!

- other decay modes analogous

- approximate formulae [w/o elw. corrections]: $\alpha_2 = \sqrt{2} G_F m_W^2/\pi$

$$\frac{\Gamma(\bar\psi\psi)}{\Gamma(\bar\psi\psi)_{SM}} \simeq 1 - \bar c_H - 2\,\bar c_\psi \qquad \text{(small } \bar c_t \text{ contamination for } s\bar s, c\bar c, b\bar b\text{)}$$

$$\frac{\Gamma(h\to W^{(*)}W^*)}{\Gamma(h\to W^{(*)}W^*)_{SM}} \simeq 1 - \bar c_H + 2.2\,\bar c_W + 3.7\,\bar c_{HW}$$

$$\frac{\Gamma(h\to Z^{(*)}Z^*)}{\Gamma(h\to Z^{(*)}Z^*)_{SM}} \simeq 1 - \bar c_H - 2\bar c_T + 2.0\left(\bar c_W + \tan^2\theta_W\,\bar c_B\right) + 3.0\left(\bar c_{HW} + \tan^2\theta_W\,\bar c_{HB}\right) - 0.26\,\bar c_\gamma$$

$$\frac{\Gamma(h\to Z\gamma)}{\Gamma(h\to Z\gamma)_{SM}} \simeq 1 - \bar c_H + 0.12\,\bar c_t - 5\cdot 10^{-4}\,\bar c_c - 0.003\,\bar c_b - 9\cdot 10^{-5}\,\bar c_\tau + 4.2\,\bar c_W + 0.19\left(\bar c_{HW} - \bar c_{HB} + 8\,\bar c_\gamma \sin^2\theta_W\right)\frac{4\pi}{\sqrt{\alpha_2\alpha_{em}}}$$

$$\frac{\Gamma(h\to\gamma\gamma)}{\Gamma(h\to\gamma\gamma)_{SM}} \simeq 1 - \bar c_H + 0.54\,\bar c_t - 0.003\,\bar c_c - 0.007\,\bar c_b - 0.007\,\bar c_\tau + 5.04\,\bar c_W - 0.54\,\bar c_\gamma\frac{4\pi}{\alpha_{em}}$$

$$\frac{\Gamma(h\to gg)}{\Gamma(h\to gg)_{SM}} \simeq 1 - \bar c_H - 2.12\,\bar c_t + 0.024\,\bar c_c + 0.1\,\bar c_b + 22.2\,\bar c_g\frac{4\pi}{\alpha_2}$$

III *CONCLUSIONS*

- SM Higgs decay widths quite accurately known

- global analysis of THUs and PUs $\to$ PUs dominant
  errors on $\alpha_s, m_b(m_c)$ crucial

- coupling variation: extension to HEFT $\to$ eHDECAY

BACKUP SLIDES