Higgs and alternatives – theory

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Outline

A Higgs for perturbative unitarity

Precision electroweak data and a light Higgs

Mass generation and Higgs couplings in the SM
$\rightarrow$ LHC predictions

Beyond the SM Higgs: the hierarchy problem

Modified Higgs couplings beyond the SM

Conclusions

The Standard Model is extremely successful so far.

Q: Can't we get by with just the degrees of freedom that we've observed?

- 3 generations of quarks; CKM matrix for flavor physics
- 3 generations of charged leptons
- Neutrinos with mass (might need something new there)
- gluons from SU(3) strong interaction
- photon plus massive $W^{\pm}$ and Z from SU(2) $\times$ U(1)

(Electroweak symmetry is broken, but do we really have to worry about how?)

- (Dark matter?)
- (Quantum gravity?)

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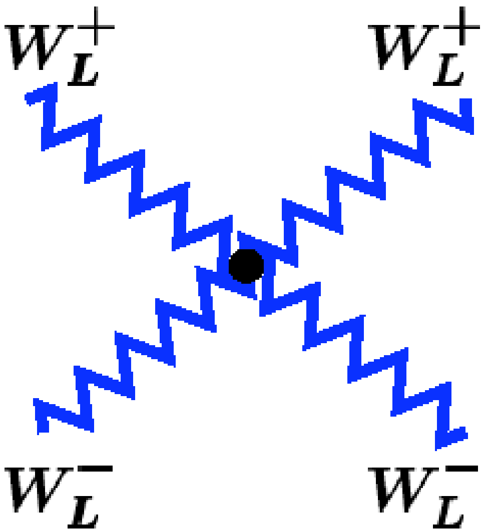
A: No! The SM without a Higgs is intrinsically incomplete.

Most straightforward way to see this:
Scattering of longitudinally-polarized W or Z bosons.



Longitudinal polarization state only exists for a massive gauge boson.

Polarization vector: $\epsilon^\mu(k) = \frac{1}{M_V}(|\vec{k}|, 0, 0, E)$

$k^\mu = (E, 0, 0, |\vec{k}|)$

4-point diagram: $\mathcal{M} \sim E^4/M_V^4$ when $E \gg M_V$

Why this is a problem:

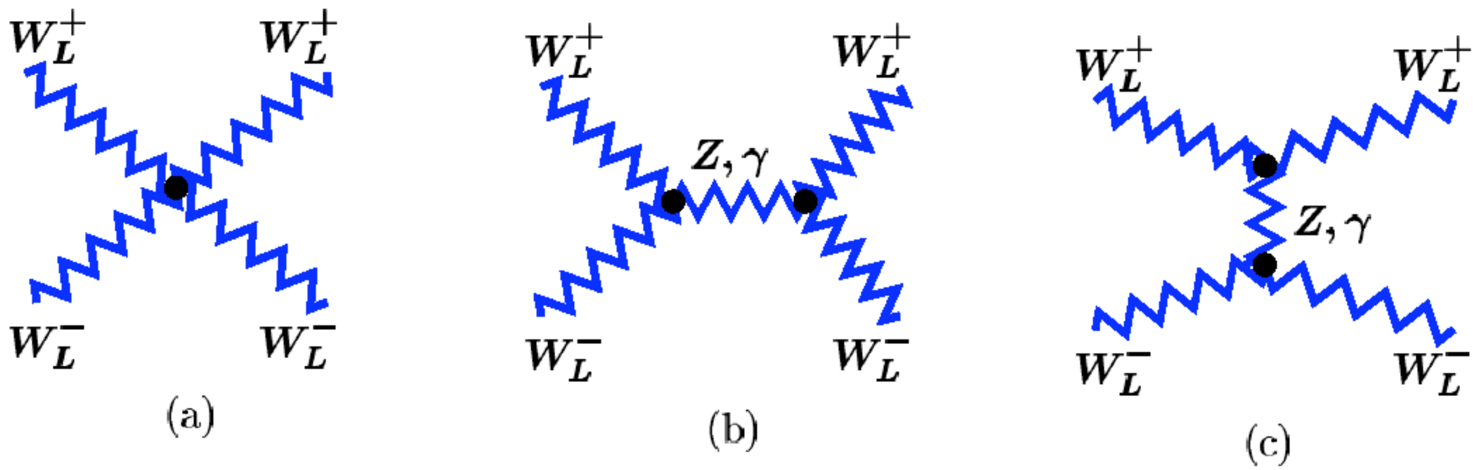
- Write matrix element in terms of partial waves:

$$\mathcal{M} = 16\pi \sum_J (2J+1) a_J P_J(\cos\theta)$$

- Unitarity of the scattering matrix requires $|a_0| \leq 1$.
- Violation implies that higher-order diagrams are equally important: breakdown of perturbation theory.

Scattering of longitudinally-polarized Ws exposes need for a Higgs*

SU(2) x U(1) @ E^4



Graphs	$g^2 \frac{E^4}{m_w^4}$
(a)	$-3 + 6\cos\theta + \cos^2\theta$
(b)	$-4\cos\theta$
(c)	$+3 - 2\cos\theta - \cos^2\theta$
Sum	0

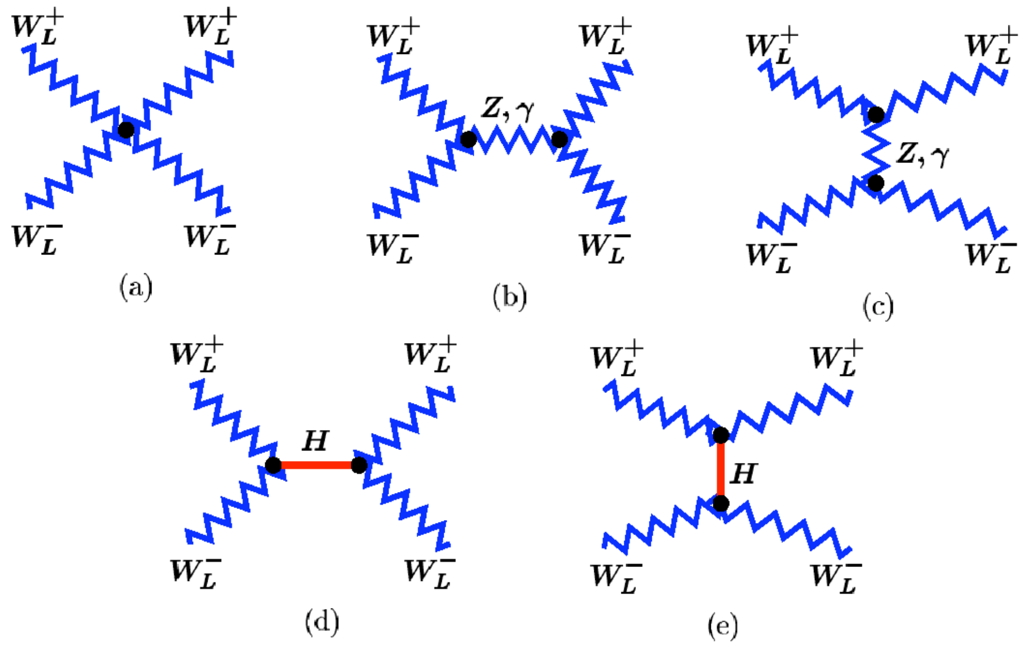
$$\epsilon_L^\mu(k) = \frac{k^\mu}{m_w} + \mathcal{O}\left(\frac{m_w}{E}\right)$$

Graphics from R.S. Chivukula, LHC4ILC 2007

*or something to play its role

Scattering of longitudinally-polarized Ws exposes need for a Higgs*

SU(2) x U(1) @ E^2



Graphs	$g^2 \frac{E^2}{m_w^2}$
(a)	$+2 - 6\cos\theta$
(b)	$-\cos\theta$
(c)	$-\frac{3}{2} + \frac{15}{2}\cos\theta$
(d + e)	$-\frac{1}{2} - \frac{1}{2}\cos\theta$
Sum including (d+e)	**0**

- $\mathcal{O}(E^0) \Rightarrow$ 4d m_H bound: $m_H < \sqrt{16\pi/3}\,v \simeq 1.0$ TeV
- If no Higgs $\Rightarrow \mathcal{O}(E^2) \Rightarrow E < \sqrt{8\pi}v \simeq 1.2\,\text{TeV}$

Graphics from R.S. Chivukula, LHC4ILC 2007

*or something to play its role

Electroweak precision data and a light Higgs

SM processes have some sensitivity to the Higgs mass through radiative corrections involving the Higgs.

Tree level:

- Measure underlying electroweak parameters g, g', v:

$$\alpha = \frac{e^2}{4\pi} = \frac{g^2 g'^2}{4\pi(g^2+g'^2)}, \quad M_Z = \frac{\sqrt{g^2+g'^2}\, v}{2}, \quad G_F = \frac{1}{\sqrt{2} v^2}$$

- Predict $M_W = \frac{gv}{2}$ using $M_W^2 (1 - \frac{M_W^2}{M_Z^2}) = \frac{\pi\alpha}{\sqrt{2} G_F}$

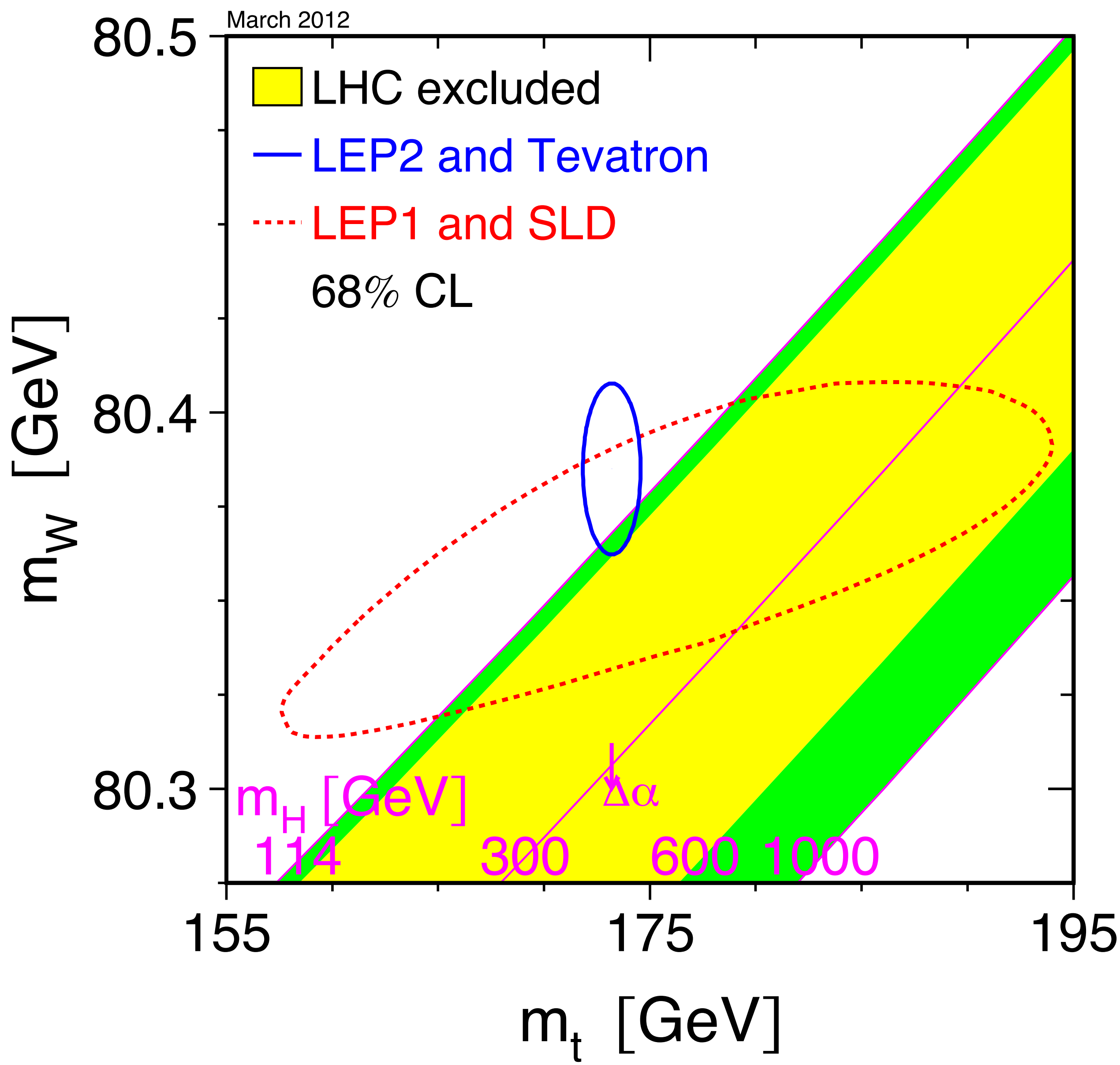
1-loop level:

- Relation among α, M_Z, G_F, M_W shifted by radiative corrections
- Most important: top loop $\sim (m_t/M_W)^2$; Higgs loop $\sim \ln(M_H/M_W)$
- Get some extra sensitivity by including $\sin^2\theta_W$ observables

$\rightarrow$ Measure m_t and M_W, fit EW observables for Higgs mass

Key assumption: no new physics, only the SM Higgs.

Electroweak precision data and a light Higgs



Light Higgs strongly favoured in the SM.

LEP EWWG 2012

including latest M_W, m_t

Options:

- Light SM-like Higgs, 114 GeV $\lesssim M_H \lesssim$ 130 GeV ★ EW data

  constrained by LEP and LHC exclusions

- Heavy SM-like Higgs, $M_H \gtrsim$ 500 GeV

  lineshape and interference with continuum WW, ZZ backgrounds

Need new physics to cancel heavy Higgs contribution to precision electroweak observables.

- No Higgs below the TeV scale

Need new physics for $W_L W_L$ scattering unitarity, mass generation for SM particles; must be consistent with precision electroweak measurements

- Non-SM-like Higgs ★ EW data?

  evade direct searches through suppressed production/decays

Standard Model Higgs mechanism

Electroweak symmetry broken by an SU(2)-doublet scalar field:

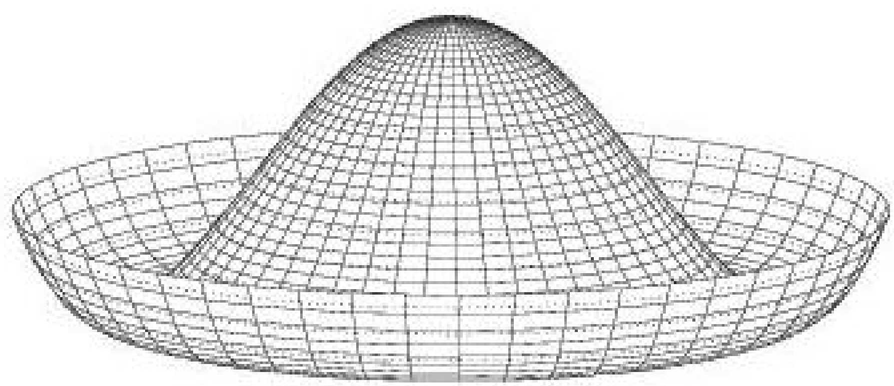
$$H = \begin{pmatrix} G^+ \\ (h+v)/\sqrt{2} + iG^0/\sqrt{2} \end{pmatrix}$$

- G^+ and G^0 are the Goldstone bosons (eaten by W^+ and Z).
- v is the SM Higgs vacuum expectation value (vev), $v = 2M_W/g \simeq 246$ GeV.
- h is the SM Higgs field, a physical particle.

Electroweak symmetry breaking comes from the Higgs potential:

$$V = \mu^2 H^\dagger H + \lambda (H^\dagger H)^2$$

where $\lambda \sim \mathcal{O}(1)$ 0.129
and $\mu^2 \sim -\mathcal{O}(M_{\rm EW}^2)$ $-(88.4\ \text{GeV})^2$
$\Rightarrow v^2 = -\mu^2/\lambda = (246\ \text{GeV})^2$
$\Rightarrow M_h^2 = 2\lambda v^2 = -2\mu^2$ 125 GeV



Higgs couplings in the Standard Model

SM Higgs couplings to SM particles are fixed by the mass-generation mechanism.

W and Z: $g_Z \equiv \sqrt{g^2 + g'^2}$, $v = 246$ GeV

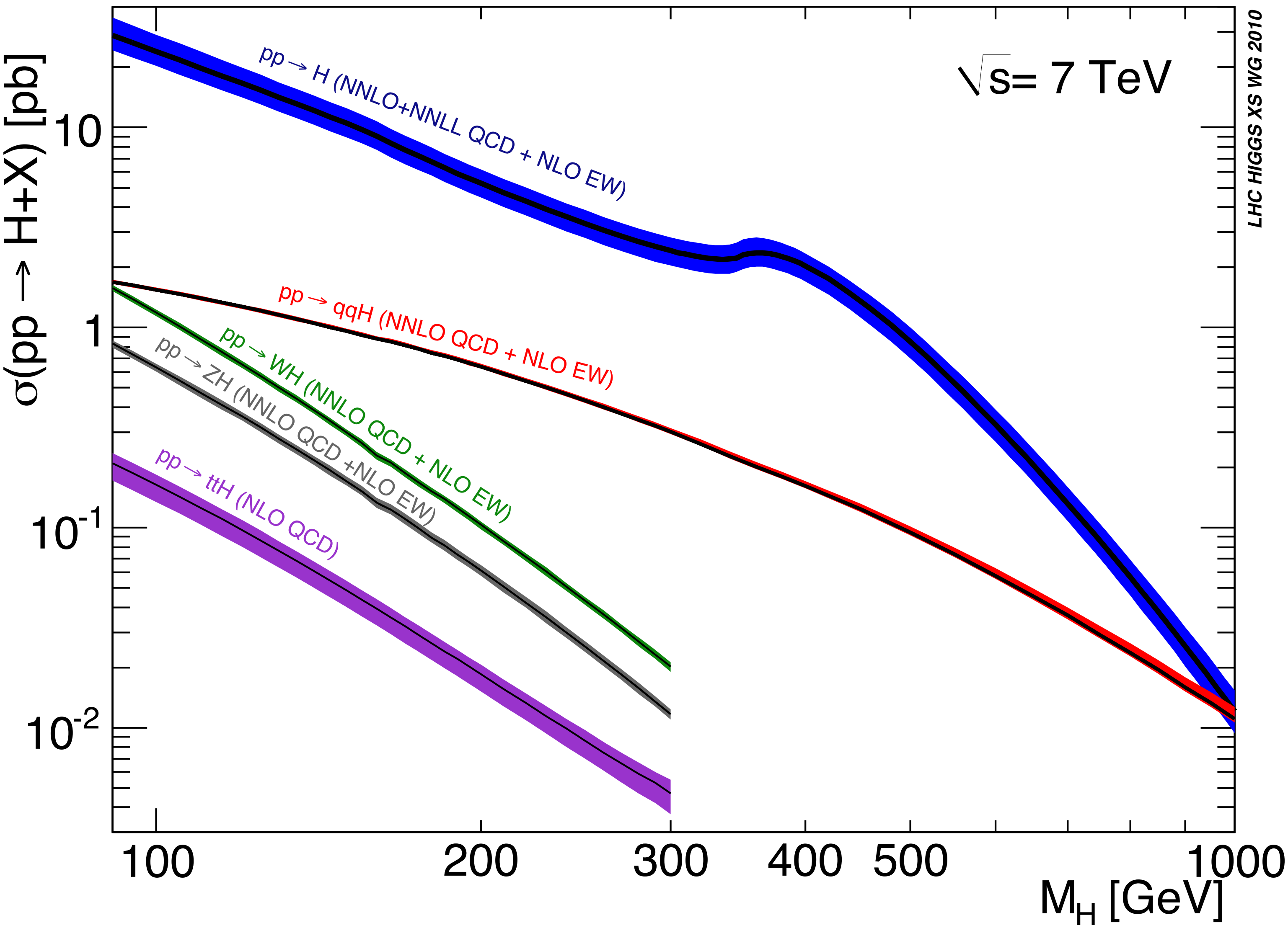
$$\mathcal{L} = |\mathcal{D}_\mu H|^2 \;\rightarrow\; (g^2/4)(h+v)^2 W^+ W^- + (g_Z^2/8)(h+v)^2 ZZ$$
$$M_W^2 = g^2 v^2/4 \qquad hWW:\; i(g^2 v/2) g^{\mu\nu}$$
$$M_Z^2 = g_Z^2 v^2/4 \qquad hZZ:\; i(g_Z^2 v/2) g^{\mu\nu}$$

Fermions:

$$\mathcal{L} = -y_f \bar{f}_R H^\dagger Q_L + \cdots \;\rightarrow\; -(y_f/\sqrt{2})(h+v)\bar{f}_R f_L + \text{h.c.}$$
$$m_f = y_f v/\sqrt{2} \qquad h\bar{f}f:\; i m_f/v$$

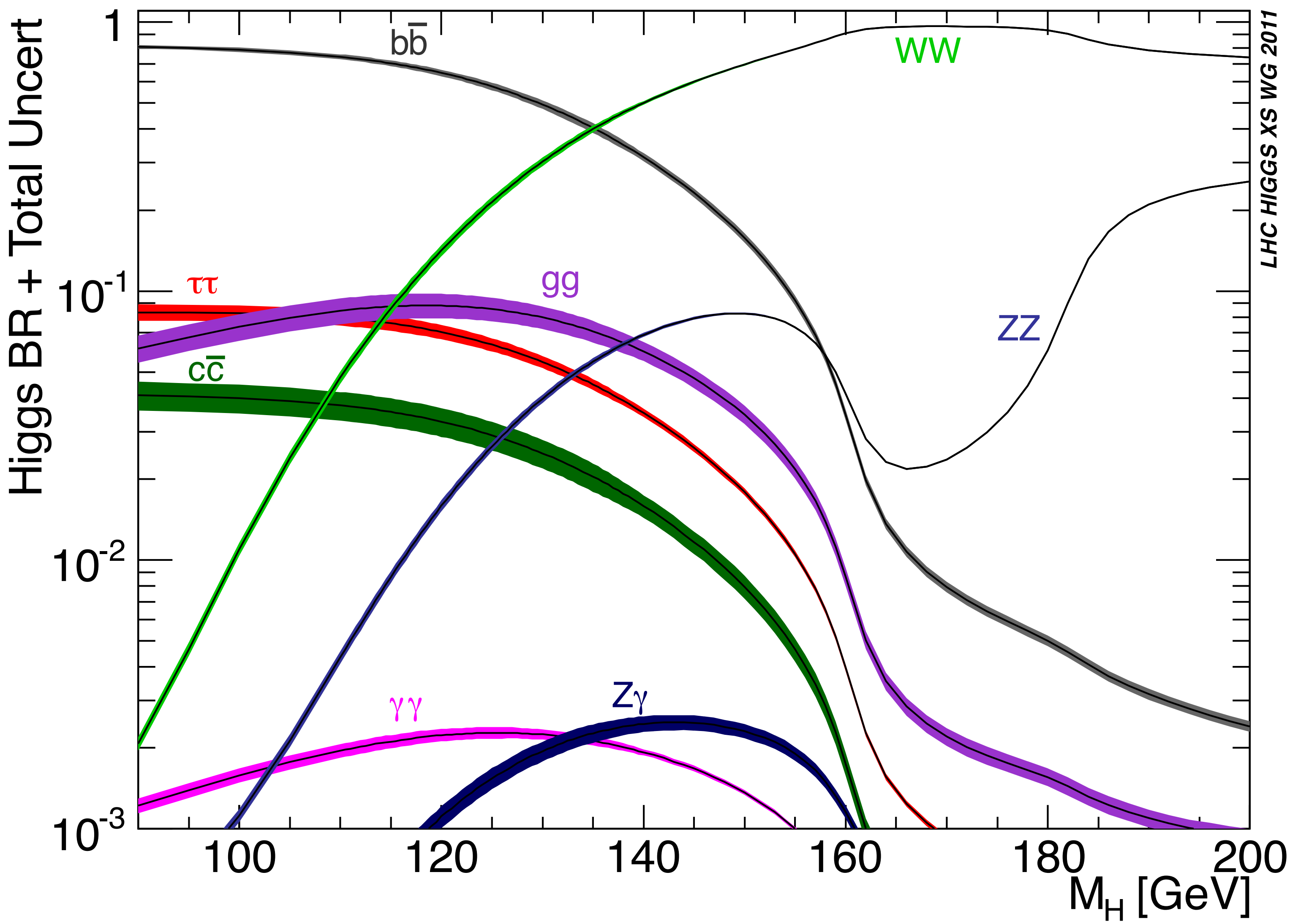
Gluon pairs and photon pairs:
induced at 1-loop by fermions (mostly t), W-boson.

Predict SM Higgs production cross sections



Predict SM Higgs decay branching ratios

Variation with M_h due purely to kinematics



SM Higgs signatures are fully predicted as a function of M_h.

- Vast amount of work on radiative corrections
- Vast amount of work on PDFs
- Vast amount of work on detailed understanding of SM backgrounds

One can exclude the SM Higgs hypothesis.

But one cannot discover the SM Higgs, only an object consistent with the SM Higgs: a "SM-like Higgs".

$\Rightarrow$ Measure Higgs couplings to characterize the new particle.

- Is our Higgs fully responsible for the masses of W, Z, and fermions?
- Is our Higgs fully responsible for unitarizing $W_L W_L$ scattering?
- Is there other physics needed to complete any of these?
  (and if so, what is the upper bound on its energy scale?)

Deviation from the SM prediction $\Rightarrow$ additional new physics.

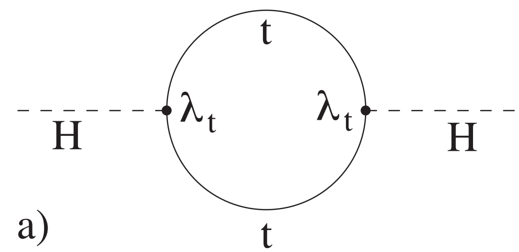
Why expect more than the SM Higgs: the Hierarchy Problem

The Higgs mass-squared parameter μ^2 gets quantum corrections that depend quadratically on the high-scale cutoff of the theory.

Calculate radiative corrections from, e.g., a top quark loop.

$$\mu^2 = \mu_0^2 + \Delta\mu^2$$

$$V = \mu^2 H^\dagger H + \lambda (H^\dagger H)^2$$



For internal momentum p, large compared to m_t and external h momentum:

$$\begin{aligned} \text{Diagram} &= \int \frac{d^4p}{(2\pi)^4} (-) N_c \mathrm{Tr}\left[i\lambda_t \frac{i}{\not p} i\lambda_t \frac{i}{\not p} \right] \\ &= -N_c \lambda_t^2 \int \frac{d^4p}{(2\pi)^4} \mathrm{Tr}\left[\frac{1}{p^2}\right] \qquad \mathrm{Tr}[1] = 4 \\ &= -\frac{4 N_c \lambda_t^2}{(2\pi)^4} \int \frac{d^4p}{p^2} \end{aligned}$$

Momentum cutoff Λ: Integral diverges like Λ^2.

Full 1-loop calculation gives

$$\Delta\mu^2 = \frac{N_c \lambda_t^2}{16\pi^2}\left[-2\Lambda^2 + 6 m_t^2 \ln(\Lambda/m_t) + \cdots\right]$$

We measure $\mu^2 \sim -\mathcal{O}(M_{\rm EW}^2) \sim -(100\ \text{GeV})^2 = -10^4\ \text{GeV}^2$.
Nature sets the bare parameter μ_0^2 at the cutoff scale Λ.
If $\Lambda = M_{\rm Pl} = \frac{1}{\sqrt{8\pi G_N}} \sim 10^{18}$ GeV, then $\Delta\mu^2 \sim -10^{35}\ \text{GeV}^2$!

- Not an inconsistency in the theory.

Renormalizable: absorb the divergence into the bare parameter μ_0^2.

- But it is an implausibly huge top-down coincidence that μ_0^2 and $\Delta\mu^2$ cancel to 31 decimal places! Looks horribly fine-tuned.

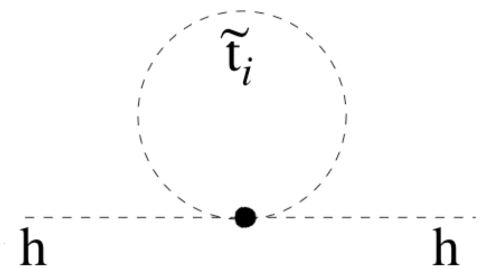
and not just at one loop: must cancel two-, three-, four-, ... loop contributions

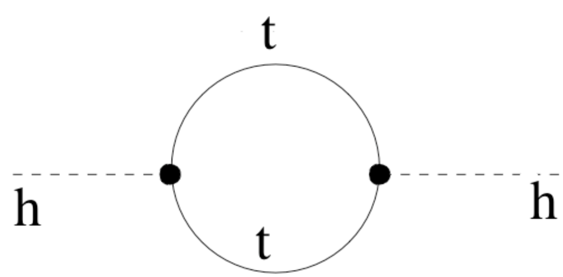
Want $|\Delta\mu^2| \sim (100\ \text{GeV})^2 \ \Rightarrow\ \Lambda \sim 1$ TeV.
Expect New Physics that solves hierarchy problem at TeV scale!

Two main classes of solutions to the hierarchy problem:

1) Supersymmetry

SUSY relates μ^2 to a fermion mass, which only runs logarithmically. Guarantees cancellation between SM loop diagrams and SUSY loop diagrams.





2) Composite Higgs

Higgs is some kind of bound state ("meson") of fundamental fermions, held together by a new force that gets strong at the TeV scale. Above a TeV there are no fundamental scalars, so no hierarchy problem.

(Includes extra-dimension/RS models by AdS/CFT duality; also Little Higgs)

Two ways to model deviations from SM Higgs couplings:

- Explicit models of extended Higgs sectors

  perturbative unitarity restored by extra Higgs states

- Multi-Higgs models; supersymmetric models

- Chiral Lagrangian (effective field theory) approach

  additional new physics required to restore perturbative unitarity

- Used for composite Higgs, Little Higgs models

Higgs couplings beyond the SM: extended Higgs sector

W and Z:

- EWSB can come from more than one Higgs doublet, which then mix to give h mass eigenstate. $v \equiv \sqrt{v_1^2 + v_2^2}$, $\phi_v = \frac{v_1}{v} h_1 + \frac{v_2}{v} h_2$

$$\mathcal{L} = |\mathcal{D}_\mu H_1|^2 + |\mathcal{D}_\mu H_2|^2$$
$$M_W^2 = g^2 v^2/4 \qquad hWW: \; i\langle h|\phi_v\rangle (g^2 v/2) g^{\mu\nu} \equiv i\bar{g}_W (g^2 v/2) g^{\mu\nu}$$
$$M_Z^2 = g_Z^2 v^2/4 \qquad hZZ: \; i\langle h|\phi_v\rangle (g_Z^2 v/2) g^{\mu\nu} \equiv i\bar{g}_Z (g^2 v/2) g^{\mu\nu}$$

Note $\bar{g}_W = \bar{g}_Z$. Also, $\bar{g}_{W,Z} = 1$ when $h = \phi_v$: "decoupling limit".

- Part of EWSB from larger representation of SU(2). $Q = T^3 + Y/2$

$$\mathcal{L} \supset |\mathcal{D}_\mu \Phi|^2 \rightarrow \quad (g^2/4)[2T(T+1) - Y^2/2](\phi + v)^2 W^+ W^- + (g_Z^2/8) Y^2 (\phi + v)^2 ZZ$$

Can get $\bar{g}_W \neq \bar{g}_Z$ and/or $\bar{g}_{W,Z} > 1$ after mixing to form h.

Tightly constrained by ρ parameter, $\rho \equiv M_W^2 / M_Z^2 \cos^2\theta_W = 1$ in SM.

Higgs couplings beyond the SM: extended Higgs sector

Fermions:

Masses of different fermions can come from different Higgs doublets, which then mix to give h mass eigenstate:

$$\mathcal{L} = -y_f \bar{f}_R \Phi_f^\dagger F_L + \text{(other fermions)} + \text{h.c.}$$

$$m_f = y_f v_f/\sqrt{2} \qquad h\bar{f}f: \; i\langle h|\phi_f\rangle(v/v_f) m_f/v \equiv i\bar{g}_f m_f/v$$

In general $\bar{g}_t \neq \bar{g}_b \neq \bar{g}_\tau$; e.g. MSSM with large $\tan\beta$ (Δ_b).

Note $\langle h|\phi_f\rangle(v/v_f) = \langle h|\phi_f\rangle/\langle\phi_v|\phi_f\rangle$

$\Rightarrow$ $\bar{g}_f = 1$ when $h = \phi_v$: "decoupling limit".

Higgs couplings beyond the SM: extended Higgs sector

Gluon pairs and photon pairs:

- $\bar{g}_t$ and $\bar{g}_W$ change the normalization of top quark and W loops.

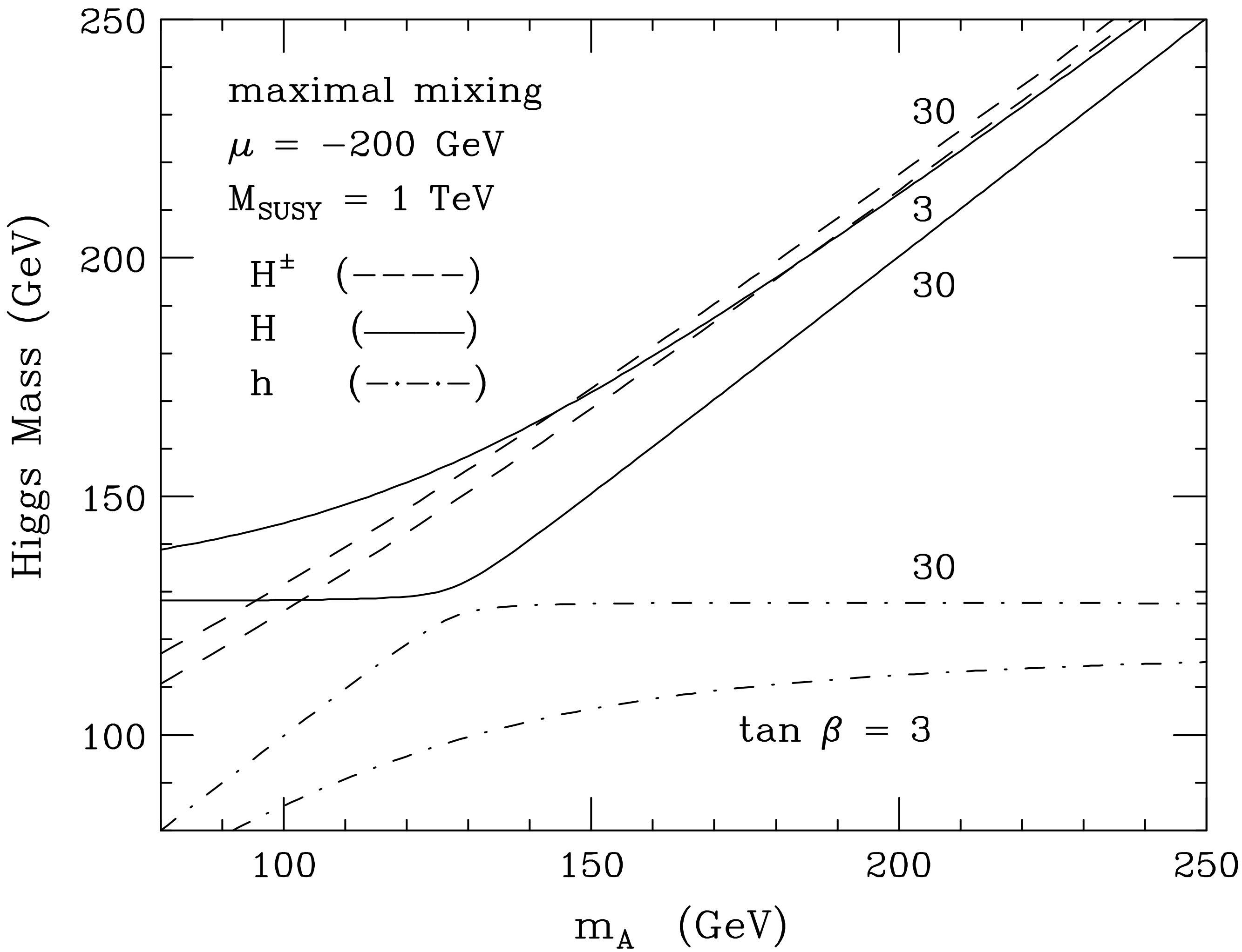
- New coloured or charged particles give new loop contributions.
  e.g. top squark, charginos, charged Higgs in MSSM

New particles in the loop can affect $h \leftrightarrow gg$ and $h \to \gamma\gamma$ even if h is otherwise SM-like.

$\Rightarrow$ Treat $\bar{g}_g$ and $\bar{g}_\gamma$ as additional independent coupling parameters.
Loop-induced effective couplings: momentum-dependence issues at NLO!
(more on this later)

Higgs couplings beyond the SM: MSSM example

MSSM contains a light, SM-like Higgs h^0 plus extra states H^0, A^0, $H^\pm$



Carena & Haber, hep-ph/0208209

Decoupling limit: $H^0, A^0, H^\pm$ heavy $\Rightarrow$ h^0 couplings SM-like

$$\langle h|\phi_v\rangle = \sin(\beta-\alpha), \text{ where } \cos(\beta-\alpha) \simeq \frac{M_Z^2 \sin 4\beta}{2M_A^2}$$

$\sin 4\beta \simeq -4\cot\beta$ at large $\tan\beta$

h^0WW and h^0ZZ couplings:

$$\frac{\text{coupling}}{\text{SM}} = \sin(\beta-\alpha) = 1 + \mathcal{O}(M_Z^4 \cot^2\beta / M_A^4)$$

$h^0t\bar{t}$ coupling:

$$\frac{\text{coupling}}{\text{SM}} = \frac{\cos\alpha}{\sin\beta} = \sin(\beta-\alpha)+\cot\beta\cos(\beta-\alpha) = 1+\mathcal{O}(M_Z^2\cot^2\beta/M_A^2)$$

$h^0b\bar{b}$ and $h^0\tau\tau$ couplings:

$$\frac{\text{coupling}}{\text{SM}} = -\frac{\sin\alpha}{\cos\beta} = \sin(\beta-\alpha) - \tan\beta\cos(\beta-\alpha) = 1 + \mathcal{O}(M_Z^2/M_A^2)$$

Sensitivity to new physics is not the same for all couplings.

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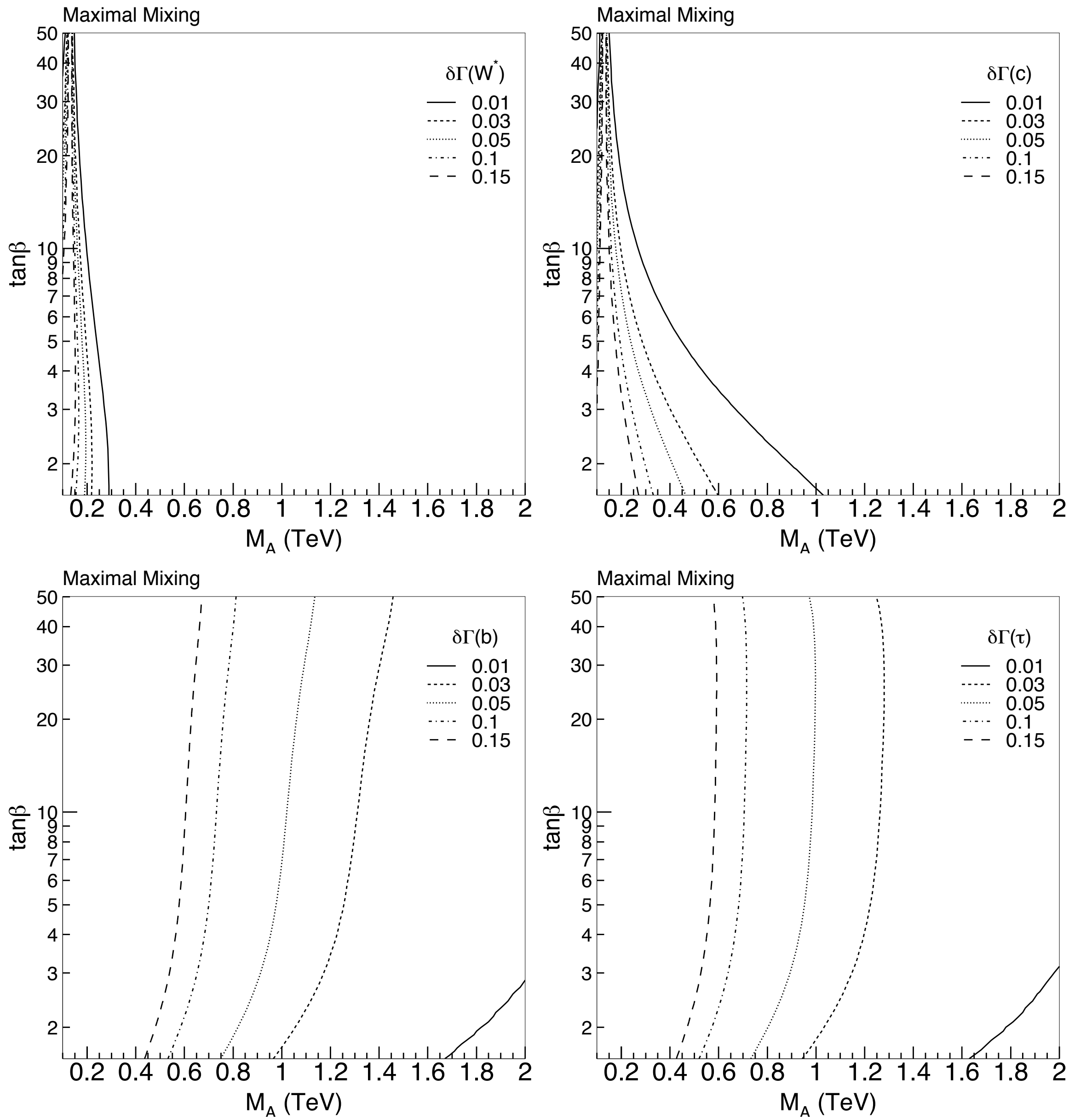


Carena, Haber, HEL, Mrenna, PRD65, 055005 (2002)

Higgs couplings beyond the SM: chiral Lagrangian approach

Without a Higgs, the SM Lagrangian looks like this:

$$\mathcal{L} \;=\; -\frac{1}{4}B_{\mu\nu}B^{\mu\nu} - \frac{1}{4}W^a_{\mu\nu}W^{a\mu\nu} - \frac{1}{4}G^a_{\mu\nu}G^{a\mu\nu} + \bar{\psi}_i \mathcal{D}_\mu \gamma^\mu \psi_i$$

- Describes gauge and fermion fields and their interactions.
- Everything must be massless!

In order to put in masses consistent with gauge invariance, fermions and gauge bosons need to couple to a weak-charged vacuum condensate:

$$\langle \Sigma \rangle = \begin{pmatrix} 0 \\ v/\sqrt{2} \end{pmatrix}$$

Here $v \equiv 246$ GeV is a constant (we know its value from the W mass and coupling).

($v \equiv$ vacuum expectation value; the $\sqrt{2}$ is a conventional normalization)

Higgs couplings beyond the SM: chiral Lagrangian approach

Gauge transformations require the existence of 3 dynamical d.o.f.:
Recall in electromagnetism: $A^\mu \to A^\mu - \partial^\mu \lambda(x)$, $\psi \to e^{-i\lambda(x)}\psi$.

$$\begin{pmatrix} 0 \\ v/\sqrt{2} \end{pmatrix} \to \Sigma \equiv e^{-i\xi^a(x)\sigma^a/v} \begin{pmatrix} 0 \\ v/\sqrt{2} \end{pmatrix} = \begin{pmatrix} \left[-\xi^2(x) - i\xi^1(x)\right]/\sqrt{2} \\ \left[v + i\xi^3(x)\right]/\sqrt{2} \end{pmatrix} + \cdots$$

σ^a are the three Pauli spin matrices.

Put in a gauge-kinetic term for Σ and interactions with fermions:

$$\begin{aligned} \mathcal{L} &= -\frac{1}{4}B_{\mu\nu}B^{\mu\nu} - \frac{1}{4}W^a_{\mu\nu}W^{a\mu\nu} - \frac{1}{4}G^a_{\mu\nu}G^{a\mu\nu} + \bar{\psi}_i \mathcal{D}_\mu \gamma^\mu \psi_i \\ &\quad + \left(\mathcal{D}_\mu \Sigma\right)^\dagger \left(\mathcal{D}^\mu \Sigma\right) - y_{ij}\bar{\psi}_i \Sigma \psi_j \end{aligned}$$

- These generate the W, Z, and fermion masses $\propto v$.
- The ξ^a degrees of freedom correspond to the third polarization states of the massive W and Z (Goldstone bosons).
- This "nonlinear sigma model" is non-renormalizable and breaks down at a scale around $4\pi\langle\Sigma\rangle \sim 1.5$ TeV.

Higgs couplings beyond the SM: chiral Lagrangian approach

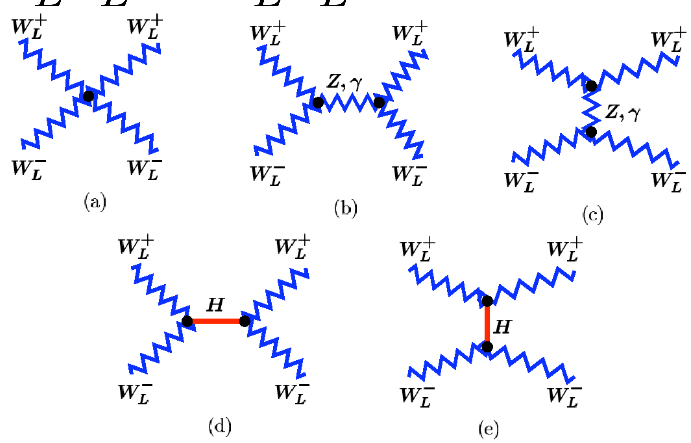
Σ is formally dimensionless (in terms of fields).

Free to add powers of an extra scalar field h up to dimension 4:

$$\mathcal{L} = -\frac{1}{4}B_{\mu\nu}B^{\mu\nu} - \frac{1}{4}W^a_{\mu\nu}W^{a\mu\nu} - \frac{1}{4}G^a_{\mu\nu}G^{a\mu\nu} + \bar{\psi}_i \mathcal{D}_\mu \gamma^\mu \psi_i$$
$$+ (\mathcal{D}_\mu \Sigma)^\dagger (\mathcal{D}^\mu \Sigma) \left(1 + a\frac{2h}{v} + b\frac{h^2}{v^2}\right) - y_{ij}\bar{\psi}_i \Sigma \psi_j \left(1 + c\frac{h}{v}\right)$$

Tree-level unitarity:

$V_L V_L \to V_L V_L$ is unitarized by h if $a^2 = 1$



diagrams from R.S. Chivukula

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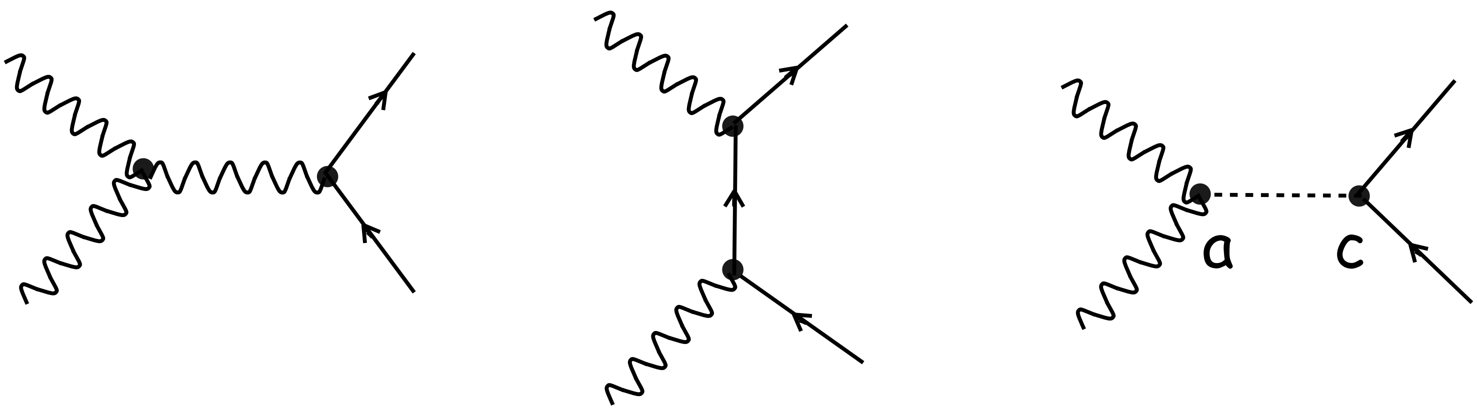
Tree-level unitarity:
$V_LV_L \to V_LV_L$ is unitarized by h if $a^2 = 1$
$V_LV_L \to f\bar{f}$ is unitarized by h if $ac = 1$



diagrams from C. Grojean

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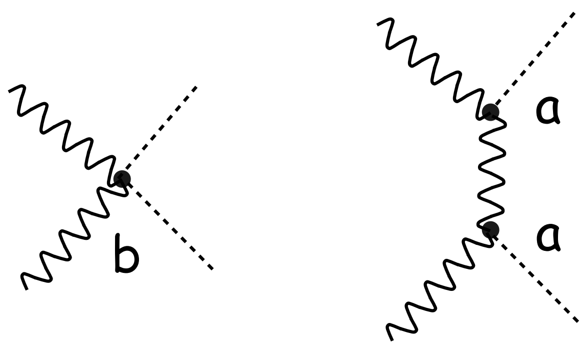
Tree-level unitarity:
$V_LV_L \to V_LV_L$ is unitarized by h if $a^2 = 1$
$V_LV_L \to f\bar{f}$ is unitarized by h if $ac = 1$
$V_LV_L \to hh$ is also unitary if $b = a^2$



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Tree-level unitarity:
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$V_L V_L \to f\bar{f}$ is unitarized by h if $ac = 1$
$V_L V_L \to hh$ is also unitary if $b = a^2$

With $a = b = c = 1$, can absorb h into the Σ field to make a "linear sigma model", i.e., the Standard Model Higgs field:

$$\overline{\Sigma} = e^{-i\xi^a(x)\sigma^a/v} \begin{pmatrix} 0 \\ (v+h)/\sqrt{2} \end{pmatrix}$$

Higgs couplings beyond the SM: chiral Lagrangian approach

Σ is formally dimensionless (in terms of fields).

Free to add powers of an extra scalar field h up to dimension 4:

$$\mathcal{L} = -\frac{1}{4}B_{\mu\nu}B^{\mu\nu} - \frac{1}{4}W^a_{\mu\nu}W^{a\mu\nu} - \frac{1}{4}G^a_{\mu\nu}G^{a\mu\nu} + \bar{\psi}_i \mathcal{D}_\mu \gamma^\mu \psi_i$$
$$+ (\mathcal{D}_\mu \Sigma)^\dagger (\mathcal{D}^\mu \Sigma) \left(1 + a\frac{2h}{v} + b\frac{h^2}{v^2}\right) - y_{ij}\bar{\psi}_i \Sigma \psi_j \left(1 + c\frac{h}{v}\right)$$

Chiral Lagrangian commonly used to model a composite Higgs:
- Deviations in couplings $a, b, c \neq 1$ ultimately come from higher-dimensional operators: $\sim 1 + \mathcal{O}(v^2/f^2)$

  $f =$ scale of strong interactions; typically $f \gg v$.

  Note the "decoupling limit": $h \to$ SM-like

Examples:
- Little Higgs models (these use a nonlinear sigma model)
- 5-dimensional Composite Higgs models
- Extended Higgs sectors (after integrating out extra states)

Conclusions

Without a Higgs, the SM weak interactions become strongly coupled around the TeV scale.

Fit to precision electroweak data in the SM favours a light Higgs $\lesssim$ 200 GeV.

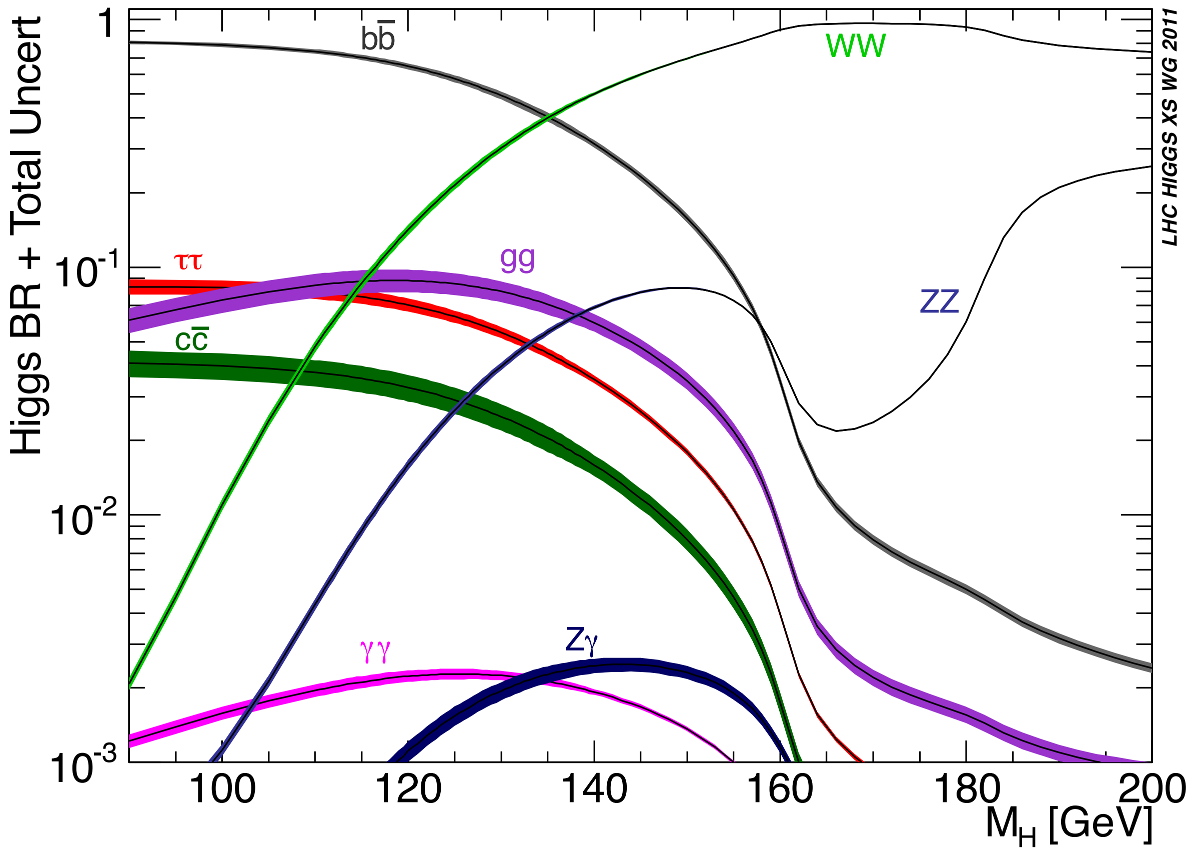
SM Higgs couplings are fixed with no free parameters: concrete predictions for LHC.

To fully understand the dynamics of electroweak symmetry breaking, need to measure Higgs couplings.

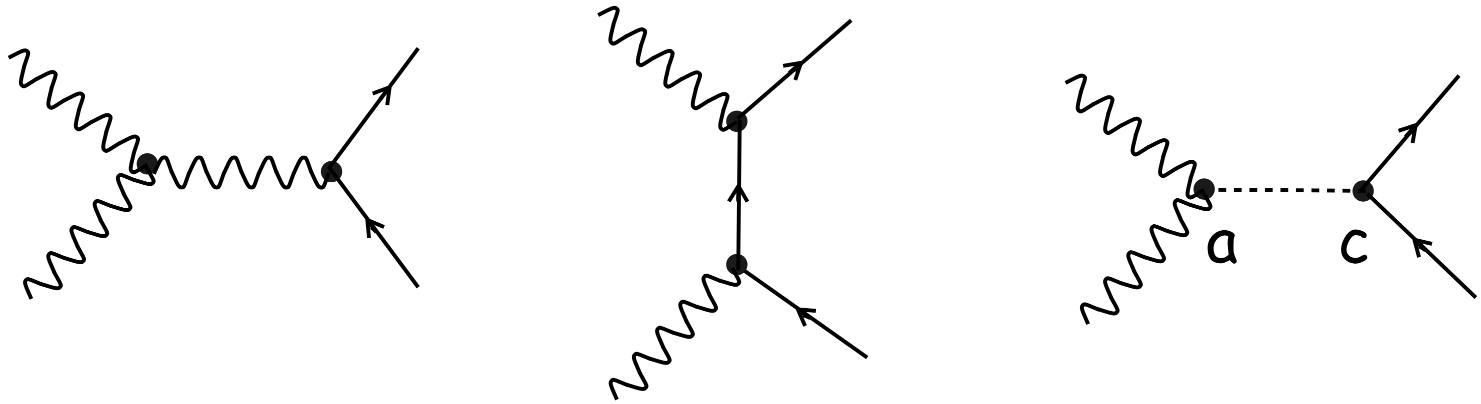
BACKUP SLIDES

An aside on Higgs mass dependence:

SM Higgs couplings to all SM particles are fixed by the mass-generation mechanism $\rightarrow$ variation with M_h is due to kinematics.



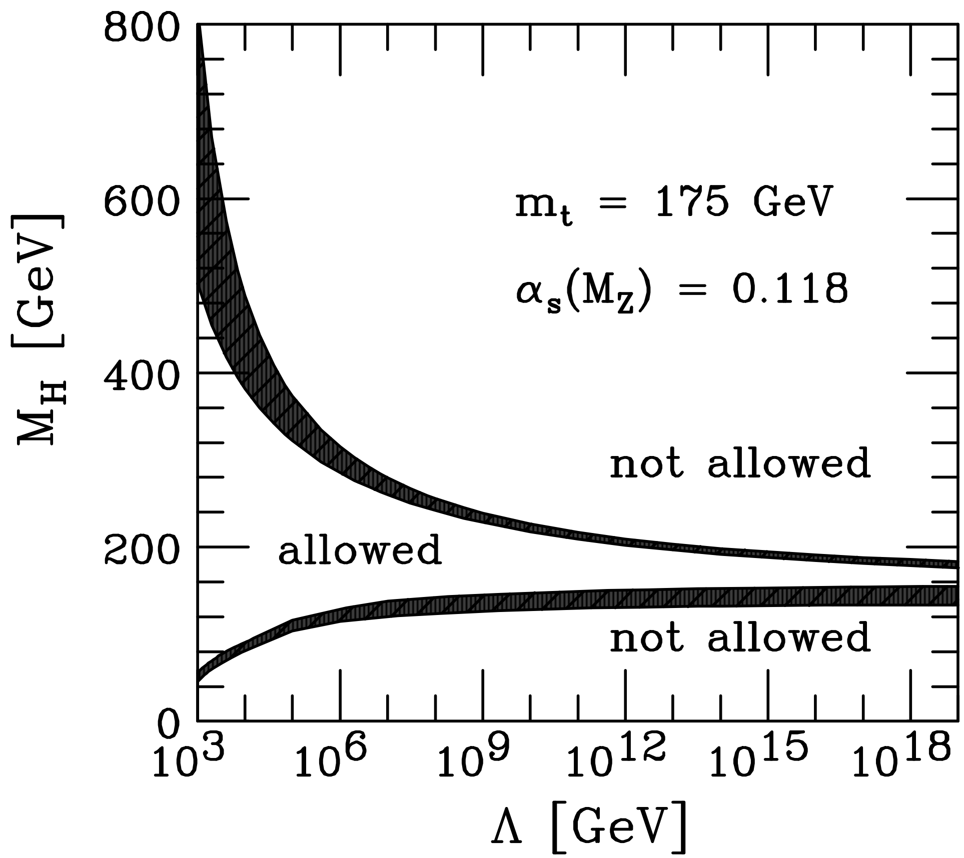
1 GeV uncertainty in $M_h \Rightarrow$ 5% uncertainty in $\bar{g}_b/\bar{g}_W$.
100 MeV uncertainty in $M_h \Rightarrow$ 0.5% uncertainty in $\bar{g}_b/\bar{g}_W$.



diagrams from C. Grojean, talk at Chicago Higgs WS 2012

Appelquist-Chanowitz (1987) for fermions: top quark implies NP related to top quark mass generation below 18 TeV if no Higgs.

Can the SM be valid all the way to the Planck scale?



Landau Pole:

Higgs self-coupling too large; blows up at scale Λ.

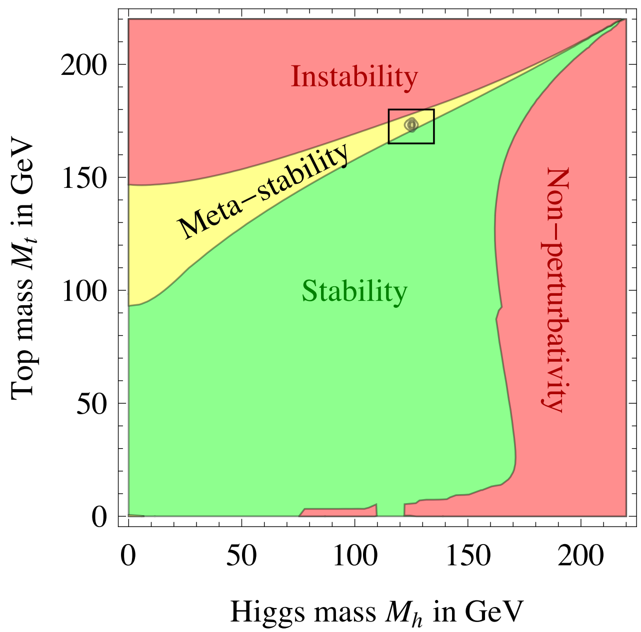
Vacuum Instability:

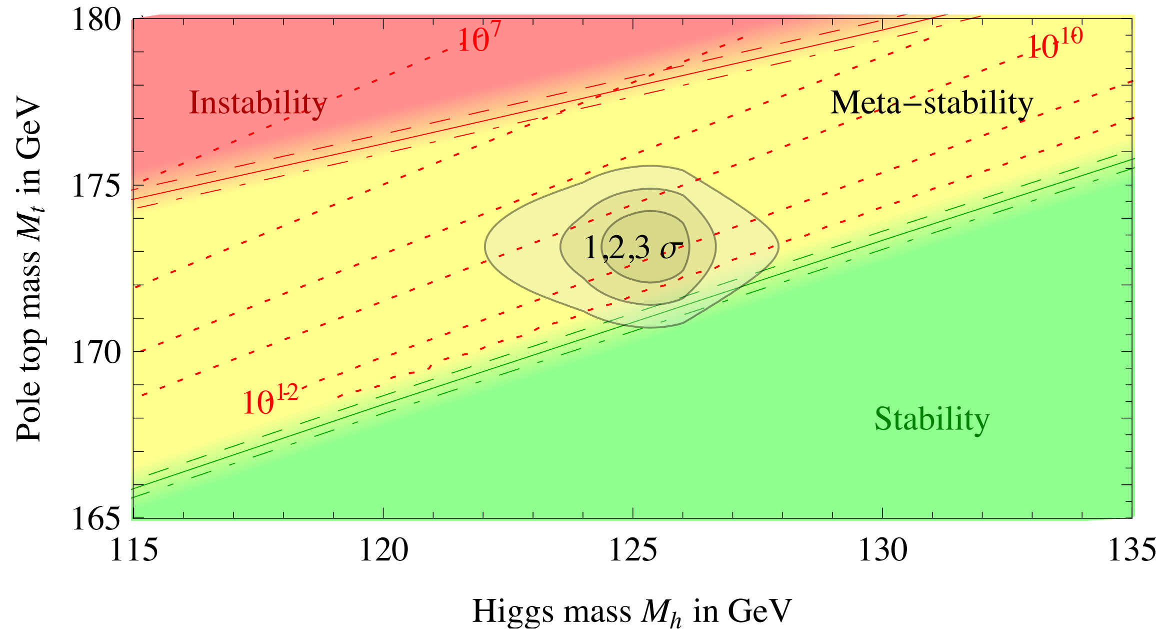
Higgs self-coupling too small compared to top Yukawa; runs negative at scale Λ.

Hambye & Riesselmann, hep-ph/9708416

SM Higgs sector is perturbative and stable (but terribly fine-tuned) all the way to the Planck scale for M_h in the "chimney".

New NNLO analysis [Degrassi et al, arXiv:1205.6497]:

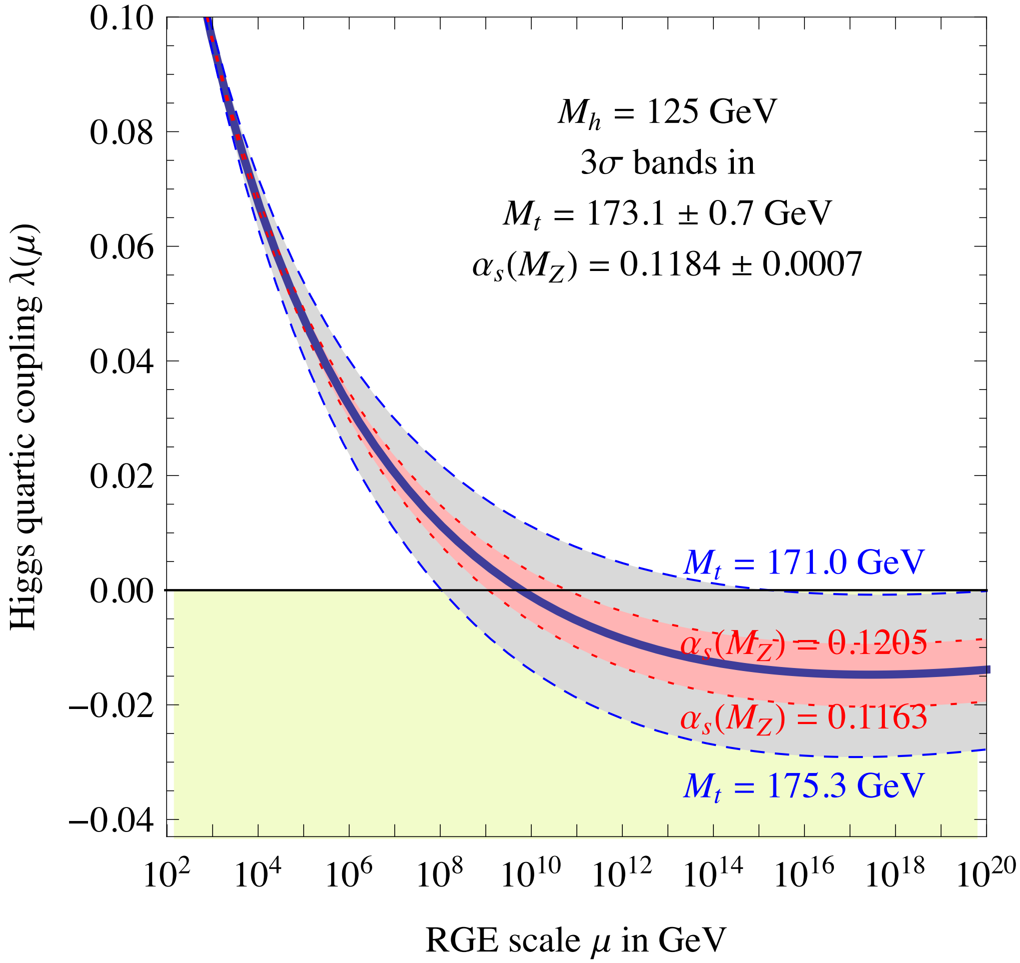




Running of quartic coupling mostly from top Yukawa + QCD as well as Higgs self-interactions.

Meta-stability: false vacuum's tunnelling lifetime is large compared to age of universe.

New NNLO analysis [Degrassi et al, arXiv:1205.6497]



$M_h = 125$ GeV:

Higgs potential becomes unstable at intermediate scale $\sim 10^{10}$ GeV.

Motivates high-precision measurement of Higgs couplings, especially to WW, ZZ, $t\bar{t}$:

Do we need new physics to cure perturbative unitarity below $\sim 10^{10}$ GeV?