Higgs: where are we now?

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Outline

1. Theoretical framework for electroweak symmetry breaking (EWSB)
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   - Extended Higgs sectors—2HDM, MSSM Higgs and beyond
   - The decoupling limit
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Framework for Electroweak Symmetry Breaking (EWSB)

The observed phenomena of the fundamental particles and their interactions can be explained by an SU(3)×SU(2)×U(1) gauge theory, in which the $W^\pm$, Z, quark and charged lepton masses arise from the interactions with (massless) Goldstone bosons $G^\pm$ and G^0, e.g.

The Goldstone bosons are a consequence of (presently unknown) EWSB dynamics, which could be . . .

- weakly-interacting scalar dynamics, in which the scalar potential acquires a non-zero vacuum expectation value (vev) $v = 2m_W/g = (246~\text{GeV})^2$ [resulting in elementary Higgs bosons]

- strong-interaction dynamics (involving new matter and gauge fields) [technicolor, dynamical EWSB, Higgsless models, composite Higgs bosons, extra-dimensional symmetry breaking, . . .]

The Principle of Naturalness

JULY 1, 1939 PHYSICAL REVIEW VOLUME 56

On the Self-Energy and the Electromagnetic Field of the Electron

V. F. Weisskopf
University of Rochester, Rochester, New York
(Received April 12, 1939)

In 1939, Weisskopf announces in the abstract to this paper that "the self-energy of charged particles obeying Bose statistics is found to be quadratically divergent"….

…. and concludes that in theories of elementary bosons, new phenomena must enter at an energy scale of order m/e (e is the relevant coupling)—the first application of naturalness.

which is about 10^{-58} times smaller than the classical electron radius. The "critical length" of the positron theory is thus infinitely smaller than usually assumed.

The situation is, however, entirely different for a particle with Bose statistics. Even the Coulombian part of the self-energy diverges to a first approximation as $W_{st} \sim e^2h/(mca^2)$ and requires a much larger critical length that is $a=(hc/e^2)^{-\frac{1}{2}}\cdot h/(mc)$, to keep it of the order of magnitude of mc^2. This may indicate that a theory of particles obeying Bose statistics must involve new features at this critical length, or at energies corresponding to this length; whereas a theory of particles obeying the exclusion principle is probably consistent down to much smaller lengths or up to much higher energies.

Principle of naturalness in modern times

How can we understand the magnitude of the EWSB scale? In the absence of new physics beyond the Standard Model, its natural value would be the Planck scale (or perhaps the GUT scale or seesaw scale that controls neutrino masses). The alternatives are:

- Naturalness is restored by a symmetry principle—supersymmetry—which ties the bosons to the more well-behaved fermions.

- The Higgs boson is an approximate Goldstone boson—the only other known mechanism for keeping an elementary scalar light.

- The Higgs boson is a composite scalar, with an inverse length of order the TeV-scale.

- The naturalness principle does not hold in this case. Unnatural choices for the EWSB parameters arise from other considerations (landscape?).

Higgs physics as a window to physics beyond the Standard Model (BSM)

Conventional wisdom from 2001–2010 was that if new physics did not appear in Run 2 of the Tevatron, then it would certainly show up in the first few fb^{-1} of LHC running. The Higgs search was likely to be a challenge, and any definitive discovery was relegated to a later date.

Today, the attitudes are reversed. The Higgs search is front and center, whereas the lack of any clear BSM signal is discouraging (cf. the Lykken quote to the BBC [google "BBC supersymmetry"]).

Indeed, clarification of the mechanism of EWSB will likely be an essential step in the pursuit of BSM physics. The discovery the Higgs boson and its properties, and/or the exclusion of the Standard Model (SM) Higgs boson will have a profound impact on how we think about BSM physics.

The Higgs bosons can also couple to hidden sectors (which are singlets with respect to the SM) via the *Higgs portal*, $\mathscr{L}_{\rm int} = H^\dagger H f(\phi_{\rm hidden})$.

Higgs boson couplings in the Standard Model

At tree level (where $V = W^\pm$ or Z),

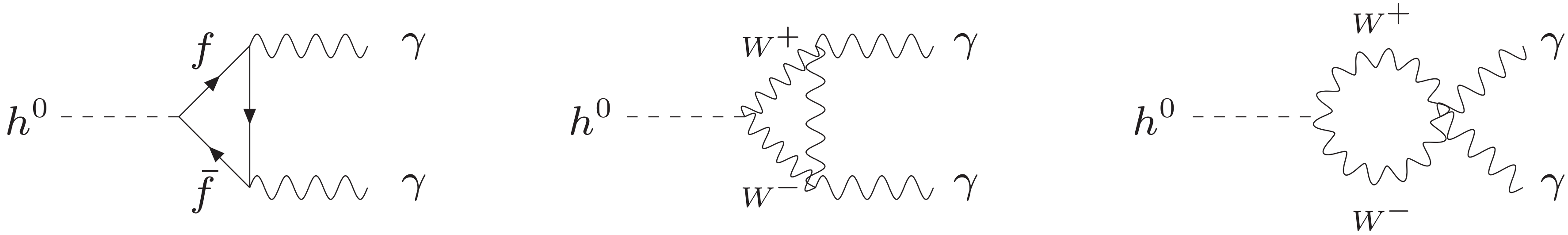
Vertex	Coupling
hVV	$2m_V^2/v$
$hhVV$	$2m_V^2/v^2$
hhh	$3m_h^2/v$
$hhhh$	$3m_h^2/v^2$
$hf\bar{f}$	m_f/v

At one-loop, the Higgs boson can couple to gluons and photons. Only particles in the loop with mass $\gtrsim \mathcal{O}(m_h)$ contribute appreciably.

One-loop Vertex	identity of particles in the loop
hgg	quarks
$h\gamma\gamma$	$W^\pm$, quarks and charged leptons
$hZ\gamma$	$W^\pm$, quarks and charged leptons

Higgs boson coupling to photons

At one-loop, the Higgs boson couples to photons via a loop of charged particles:



If charged scalars exist, they would contribute as well.

Importance of the loop-induced Higgs couplings for the LHC Higgs program

1. Dominant LHC Higgs production mechanism: gluon-gluon fusion. At leading order,

$$\frac{d\sigma}{dy}(pp \to h^0 + X) = \frac{\pi^2 \Gamma(h^0 \to gg)}{8m_h^3} g(x_+, m_h^2) g(x_-, m_h^2) \,,$$

where $g(x, Q^2)$ is the gluon distribution function at the scale Q^2 and $x_\pm \equiv m_h e^{\pm y}/\sqrt{s}$, $y = \frac{1}{2}\ln\left(\frac{E+p_L}{E-p_L}\right)$.

2. For $m_h \simeq 120$ GeV, the discovery channel for the Higgs boson at the LHC is via the rare decay $h^0 \to \gamma\gamma$.

Extended Higgs sectors: 2HDM, MSSM and beyond

For an arbitrary Higgs sector, the tree-level ρ-parameter is given by

$$\rho_0 \equiv \frac{m_W^2}{m_Z^2 \cos^2\theta_W} = 1 \qquad \Longleftrightarrow \qquad (2T+1)^2 - 3Y^2 = 1\,,$$

independently of the Higgs vevs, where T and Y specify the weak-isospin and the hypercharge of the Higgs representation to which it belongs. Y is normalized such that the electric charge of the scalar field is $Q = T_3 + Y/2$. The simplest solutions are Higgs singlets $(T, Y) = (0, 0)$ and hypercharge-one complex Higgs doublets $(T, Y) = (\frac{1}{2}, 1)$.

Thus, we shall consider non-minimal Higgs sectors consisting of multiple Higgs doublets (and perhaps Higgs singlets), but no higher Higgs representations, to avoid the fine-tuning of Higgs vevs.

Higgs boson phenomena beyond the SM

The two-Higgs-doublet model (2HDM) consists of two hypercharge-one scalar doublets. Of the eight initial degrees of freedom, three correspond to the Goldstone bosons and five are physical: a charged Higgs pair, $H^\pm$ and three neutral scalars.

In contrast to the SM, whereas the Higgs-sector is CP-conserving, the 2HDM allows for Higgs-mediated CP-violation. If CP is conserved, the Higgs spectrum contains two CP-even scalars, h^0 and H^0 and a CP-odd scalar A^0. Thus, new features of the extended Higgs sector include:

- Charged Higgs bosons
- A CP-odd Higgs boson (if CP is conserved in the Higgs sector)
- Higgs-mediated CP-violation (and neutral Higgs states of indefinite CP)

More exotic Higgs sectors allow for doubly-charged Higgs bosons, etc.

Higgs-fermion Yukawa couplings in the 2HDM

The 2HDM Higgs-fermion Yukawa Lagrangian is:

$$-\mathscr{L}_{\rm Y} = \overline{U}_L \Phi_a^{0\,*} h_a^U U_R - \overline{D}_L K^\dagger \Phi_a^- h_a^U U_R + \overline{U}_L K \Phi_a^+ h_a^{D\,\dagger} D_R + \overline{D}_L \Phi_a^0 h_a^{D\,\dagger} D_R + {\rm h.c.}\,,$$

where K is the CKM mixing matrix, and there is an implicit sum over $a = 1, 2$. The $h^{U,D}$ are 3×3 Yukawa coupling matrices and

$$\langle \Phi_a^0 \rangle \equiv \frac{v_a}{\sqrt{2}}\,, \qquad v^2 \equiv v_1^2 + v_2^2 = (246~{\rm GeV})^2\,.$$

If all terms are present, then tree-level Higgs-mediated flavor-changing neutral currents (FCNCs) and CP-violating neutral Higgs-fermion couplings are both present. Both can be avoided by imposing a discrete symmetry to restrict the structure of the Higgs-fermion Yukawa Lagrangian. Different choices for the discrete symmetry yield:

- Type-I Yukawa couplings: $h_2^U = h_2^D = 0$,
- Type-II Yukawa couplings: $h_1^U = h_2^D = 0$,

The parameter $\tan\beta = \langle \Phi_2^0 \rangle / \langle \Phi_1^0 \rangle$ governs the structure of the Higgs-fermion couplings. The parameter α emerges after diagonalizing the CP-even Higgs squared-mass matrix.

Tree-level Higgs couplings in the 2HDM

Tree-level couplings of Higgs bosons with gauge bosons are often suppressed by an angle factor, either $\cos(\beta-\alpha)$ or $\sin(\beta-\alpha)$.

$\cos(\beta-\alpha)$	$\sin(\beta-\alpha)$	angle-independent
$H^0W^+W^-$	$h^0W^+W^-$	—
H^0ZZ	h^0ZZ	—
ZA^0h^0	ZA^0H^0	ZH^+H^-, γH^+H^-
$W^\pm H^\mp h^0$	$W^\pm H^\mp H^0$	$W^\pm H^\mp A^0$

Tree-level Higgs-fermion couplings may be either suppressed or enhanced with respect to the SM value, $gm_f/2m_W$. For Model-II Higgs-fermion Yukawa couplings, the couplings of H^0 and A^0 to $b\bar{b}$ and $\tau^+\tau^-$ are enhanced by a factor of $\tan\beta$ (in parameter regimes where the h^0 couplings approximate those of the SM).

The Higgs sector of the MSSM

The Higgs sector of the MSSM is a Type-II 2HDM, whose Yukawa couplings and Higgs potential are constrained by supersymmetry (SUSY). Minimizing the Higgs potential, the neutral components of the Higgs fields acquire vevs:

$$\langle H_d \rangle = \frac{1}{\sqrt{2}} \begin{pmatrix} v_d \\ 0 \end{pmatrix}, \qquad \langle H_u \rangle = \frac{1}{\sqrt{2}} \begin{pmatrix} 0 \\ v_u \end{pmatrix},$$

where $v^2 \equiv v_d^2 + v_u^2 = 4m_W^2/g^2 = (246 \text{ GeV})^2$. The ratio of the two vevs is an important parameter of the model:

$$\boxed{\tan\beta \equiv \frac{v_u}{v_d}}$$

The five physical Higgs particles consist of a charged Higgs pair $H^\pm$, one CP-odd scalar A^0, and two CP-even scalars h^0, H^0, obtained by diagonalizing All Higgs masses and couplings can be expressed in terms of two parameters usually chosen to be m_A and $\tan\beta$.

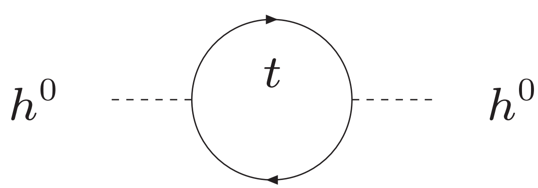
At tree level,

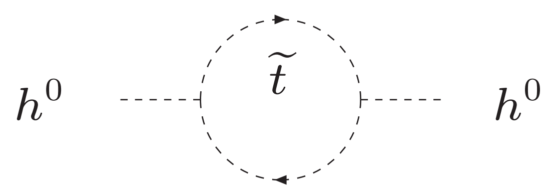
$$m_{H^\pm}^2 = m_A^2 + m_W^2 \,,$$
$$m_{H,h}^2 = \tfrac{1}{2}\left(m_A^2 + m_Z^2 \pm \sqrt{(m_A^2+m_Z^2)^2 - 4m_Z^2 m_A^2\cos^2 2\beta}\;\right) \,,$$

where α is the angle that diagonalizes the CP-even Higgs squared-mass matrix. Hence,

$$\boxed{m_h \le m_Z|\cos 2\beta| \le m_Z \,,}$$

which is ruled out by LEP data. But, this inequality receives quantum corrections. The Higgs mass can be shifted due to loops of particles and their superpartners (an incomplete cancellation, which would have been exact if supersymmetry were unbroken):

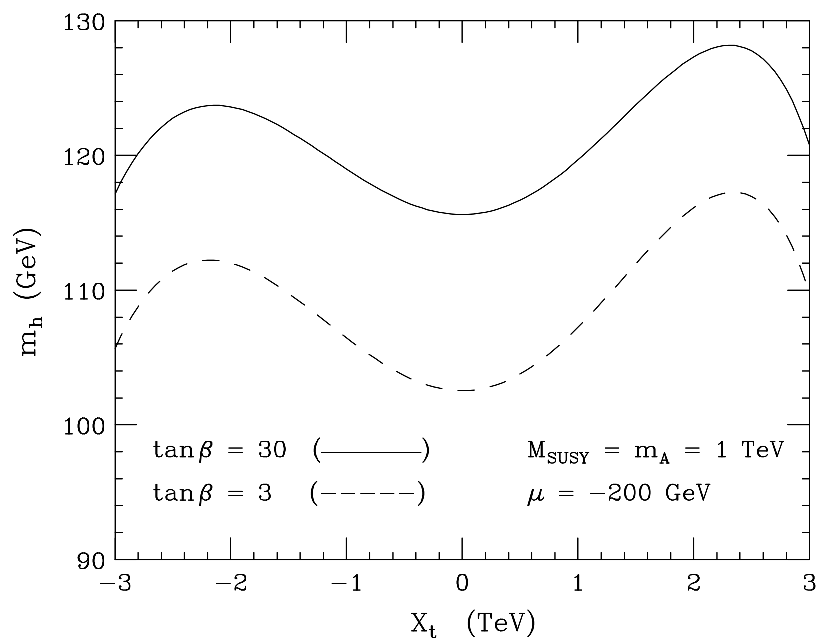


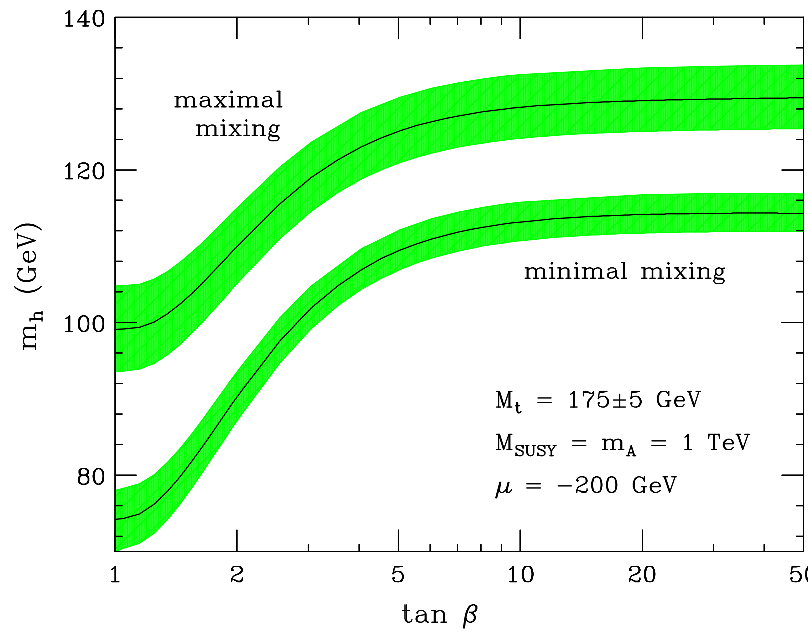


$$m_h^2 \lesssim m_Z^2 + \frac{3g^2 m_t^4}{8\pi^2 m_W^2}\left[\ln\left(\frac{M_S^2}{m_t^2}\right) + \frac{X_t^2}{M_S^2}\left(1 - \frac{X_t^2}{12M_S^2}\right)\right] \,,$$

where $X_t \equiv A_t - \mu\cot\beta$ governs stop mixing and M_S^2 is the average top-squark squared-mass.

The state-of-the-art computation includes the full one-loop result, all the significant two-loop contributions, some of the leading three-loop terms, and renormalization-group improvements. The final conclusion is that $m_h \lesssim 130$ GeV [assuming that the top-squark mass is no heavier than about 2 TeV].





Maximal mixing corresponds to choosing the MSSM Higgs parameters in such a way that m_h is maximized (for a fixed $\tan\beta$). This occurs for $X_t/M_S \sim 2$. As $\tan\beta$ varies, m_h reaches is maximal value, $(m_h)_{\rm max} \simeq 130$ GeV, for $\tan\beta \gg 1$ and $m_A \gg m_Z$.

Higgs bosons in models beyond the MSSM

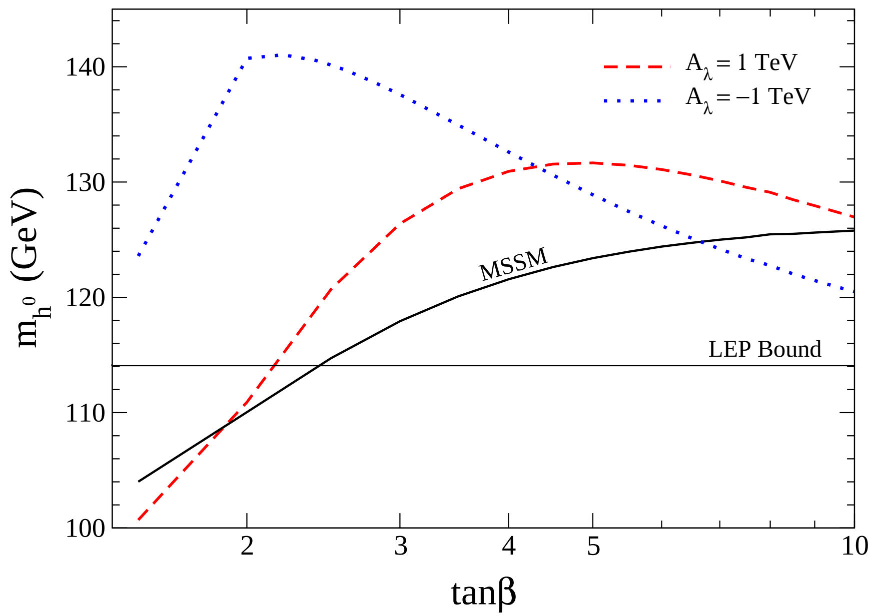
Why go beyond the MSSM? The LEP Higgs mass bounds have already made adherents of the MSSM uncomfortable, as the mass of h^0 must be somewhat close to its maximally allowed value, which requires rather heavy stop masses and significant stop mixing. The absence of observed SUSY particles just emphasizes this apparent *little hierarchy problem* that seems to require at least 1% fine-tuning of MSSM parameters to explain the magnitude of the EWSB scale.

In the NMSSM, a Higgs singlet superfield $\hat{S}$ is added to the MSSM. The corresponding superpotential terms,

$$(\mu + \lambda\hat{S})\hat{H}_u\hat{H}_d + \tfrac{1}{2}\mu_S\hat{S}^2 + \tfrac{1}{3}\kappa\hat{S}^3\,,$$

and soft-SUSY-breaking terms $B_sS^2 + \lambda A_\lambda SH_uH_d$ add additional parameters to the model, which can modify the bounds on the lightest Higgs mass.

For example, in a recent paper by Delgado, Kolda, Olson and de la Puente,



Other authors (e.g. Dermisek and Gunion) have advocated NMSSM models as a way to partially alleviate the little hierarchy problem. More generally, there is a large literature (beginning with Haber and Sher in 1987) suggesting the possibility of relaxing the Higgs mass upper bound in extensions of the MSSM.

In 1993, Espinosa and Quiros showed that it was relatively easy to construct extended models with the lightest Higgs boson mass as large as 155 GeV. Other authors found ways to push this bound higher (although these are perhaps less interesting in light of present experimental Higgs searches).

The Decoupling Limit

The Higgs boson serves as a window to BSM physics only if one can experimentally establish deviations of Higgs couplings from their SM values, or discover new scalar degrees of freedom beyond the SM-like Higgs boson.

The prospects to achieve this are challenging in general due to the decoupling limit. In extended Higgs models, most of the parameter space typically yields a neutral CP Higgs boson with SM-like tree-level couplings and additional scalar states that are somewhat heavier in mass (of order Λ), with small mass splittings of order m_Z^2/Λ. Below the scale Λ, the effective Higgs theory coincides with that of the SM.

This behavior is exhibited by the MSSM Higgs sector. In the limit of $m_A \gg m_Z$, the expressions for the Higgs masses and mixing angle simplify:

$$m_h^2 \simeq m_Z^2 \cos^2 2\beta\,, \qquad\qquad m_H^2 \simeq m_A^2 + m_Z^2 \sin^2 2\beta\,,$$

$$m_{H^\pm}^2 = m_A^2 + m_W^2\,, \qquad\qquad \cos^2(\beta-\alpha) \simeq \frac{m_Z^4 \sin^2 4\beta}{4m_A^4}\,.$$

Two consequences are immediately apparent. First, $m_A \simeq m_H \simeq m_{H^\pm}$, up to corrections of $\mathcal{O}(m_Z^2/m_A)$. Second, $\cos(\beta-\alpha)=0$ up to corrections of $\mathcal{O}(m_Z^2/m_A^2)$. In general, in the limit of $\cos(\beta-\alpha)\to 0$, all the h^0 couplings to SM particles approach their SM limits. In particular, if λ_V is a Higgs coupling to vector bosons and λ_f is a Higgs couplings to fermions, then

$$\frac{\lambda_V}{[\lambda_V]_{\rm SM}} = 1+\mathcal{O}\left(\frac{m_Z^4}{m_A^4}\right)\,,$$
$$\frac{\lambda_f}{[\lambda_f]_{\rm SM}} = 1+\mathcal{O}\left(\frac{m_Z^2}{m_A^2}\right)\,.$$

The behavior of the $h^0 ff$ coupling is seen from:

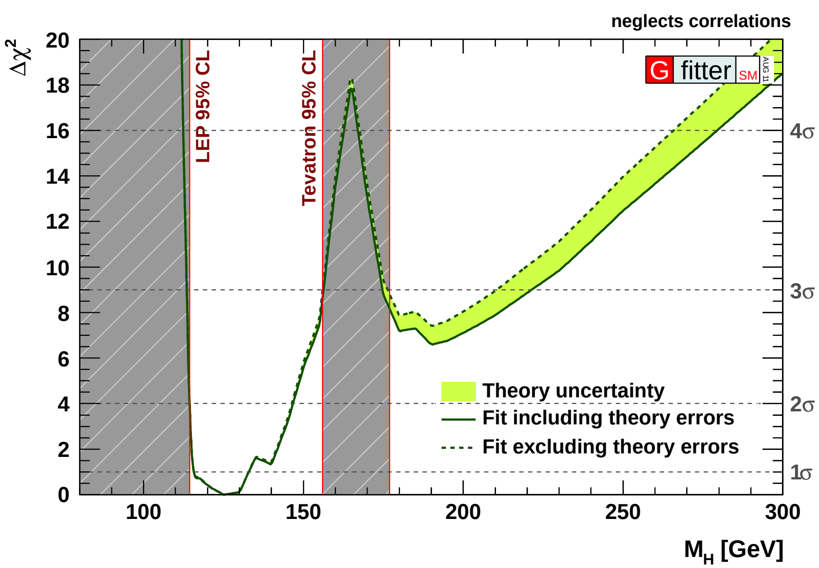
$$h^0 b\bar{b} \quad ({\rm or}\ h^0\tau^+\tau^-): \qquad -\frac{\sin\alpha}{\cos\beta} = \sin(\beta-\alpha) - \tan\beta\cos(\beta-\alpha)\,,$$
$$h^0 t\bar{t}: \qquad \frac{\cos\alpha}{\sin\beta} = \sin(\beta-\alpha) + \cot\beta\cos(\beta-\alpha)\,,$$

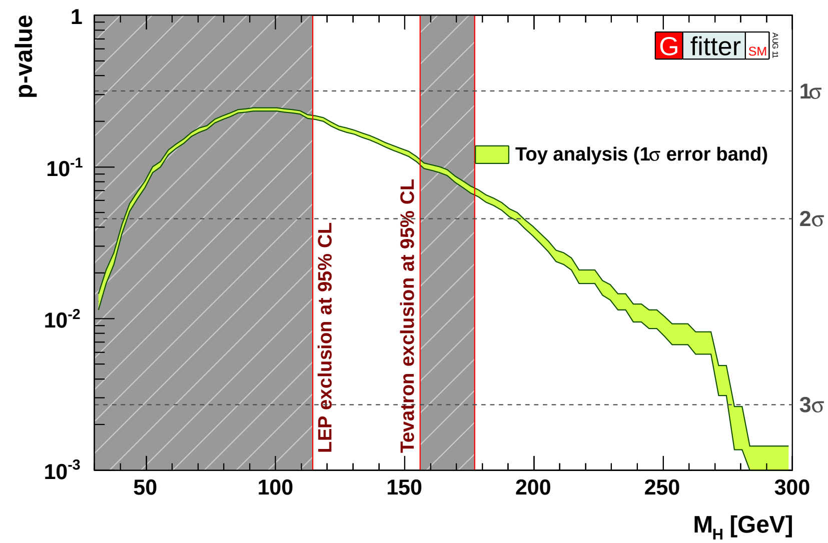
Note the extra $\tan\beta$ enhancement in the deviation of λ_{h^0bb}.

Present Status of the Higgs boson

1. Consequences of precision electroweak data.

In the SM, virtual Higgs exchange contributes to precision electroweak observables, primarily through small shifts in the W and Z self-energies.





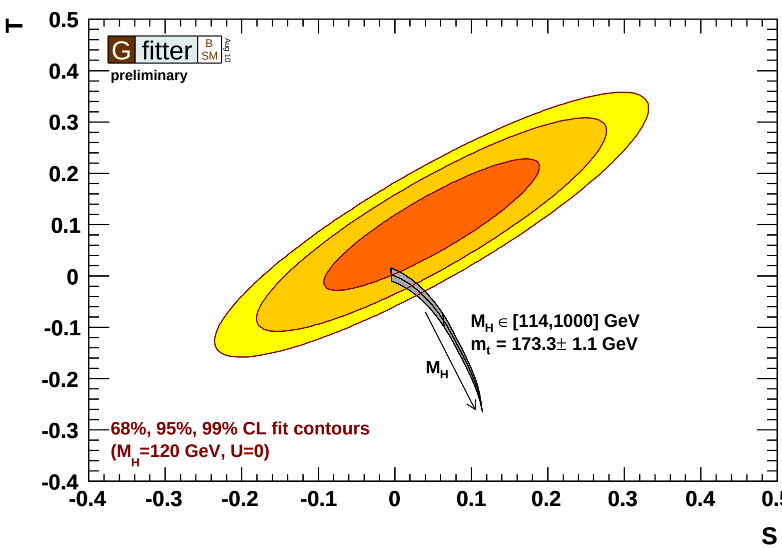
This suggests that we should expect a SM-like Higgs boson in a mass region between 114 GeV and 150 GeV. Of course, there are still ways to circumvent this conclusion.

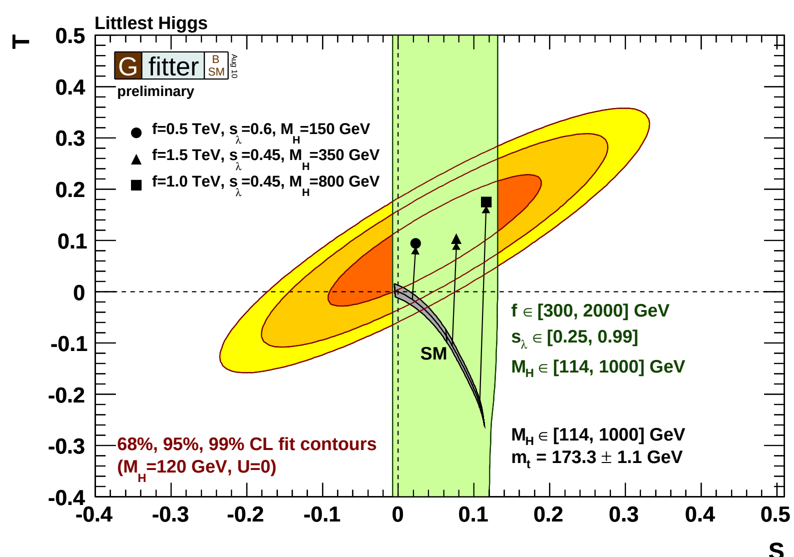
If BSM physics exists, then additional corrections to precision electroweak observables arise that can compensate the effects of a heavier Higgs boson (or no Higgs boson at all!). In many cases, these effects can be parameterized in terms of two quantities, S and T

$$\overline{\alpha}\, T \equiv \frac{\Pi^{\rm new}_{WW}(0)}{m_W^2} - \frac{\Pi^{\rm new}_{ZZ}(0)}{m_Z^2}\,,$$

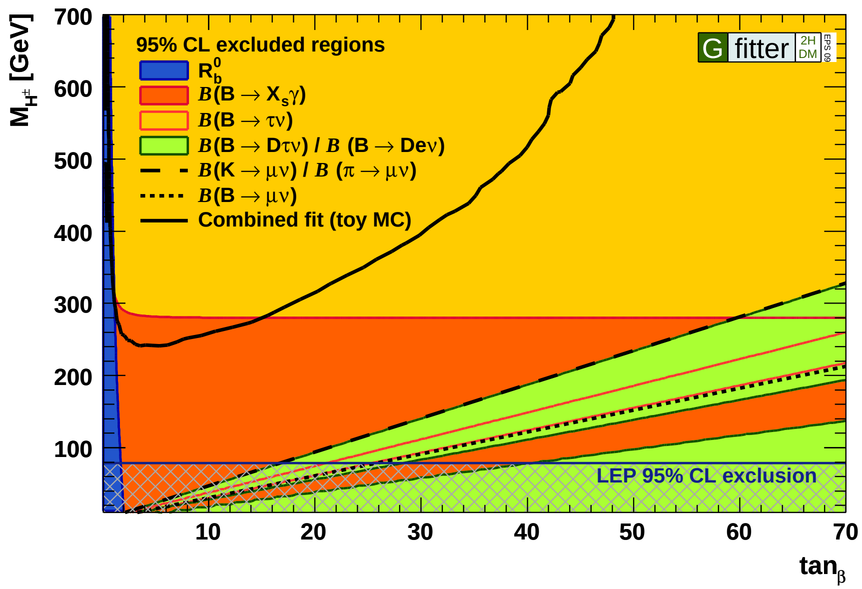
$$\frac{\overline{\alpha}}{4\overline{s}_Z^2\overline{c}_Z^2}\, S \equiv \frac{\Pi^{\rm new}_{ZZ}(m_Z^2) - \Pi^{\rm new}_{ZZ}(0)}{m_Z^2} - \left(\frac{\overline{c}_Z^2 - \overline{s}_Z^2}{\overline{c}_Z\overline{s}_Z}\right)\frac{\Pi^{\rm new}_{Z\gamma}(m_Z^2)}{m_Z^2} - \frac{\Pi^{\rm new}_{\gamma\gamma}(m_Z^2)}{m_Z^2}\,,$$

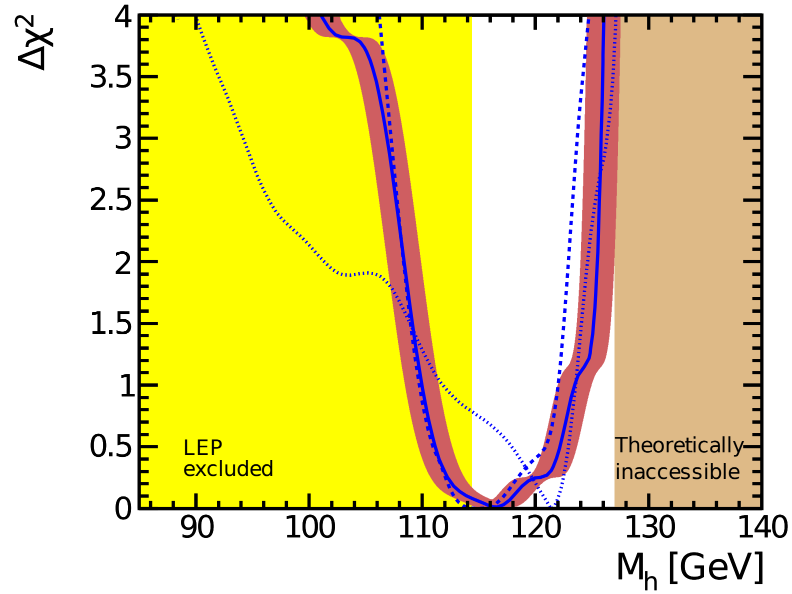
where $s \equiv \sin\theta_W$, $c \equiv \cos\theta_W$, and barred quantities are defined in the $\overline{\rm MS}$ scheme evaluated at m_Z. The $\Pi^{\rm new}_{V_aV_b}$ are the new physics contributions to the one-loop V_a—V_b vacuum polarization functions [Peskin and Takeuchi].





Precision electroweak constraints can also be applied to the 2HDM and the MSSM.





The left-hand plot provides constraints on the Type-II 2HDM.

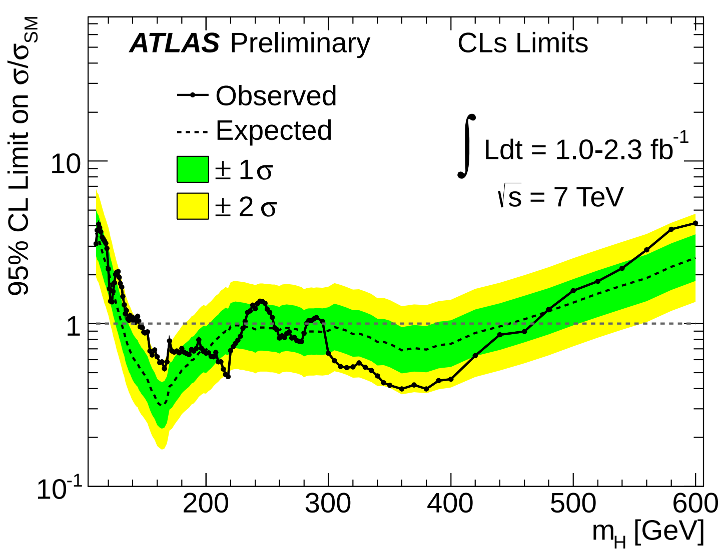
The right-hand plot [taken from O. Buchmüller et al., Eur. Phys. J. **C71**, 1634 (2011)] shows Higgs mass constraints in the NUHM1 extension of the CMSSM (with non-universal Higgs mass parameters).

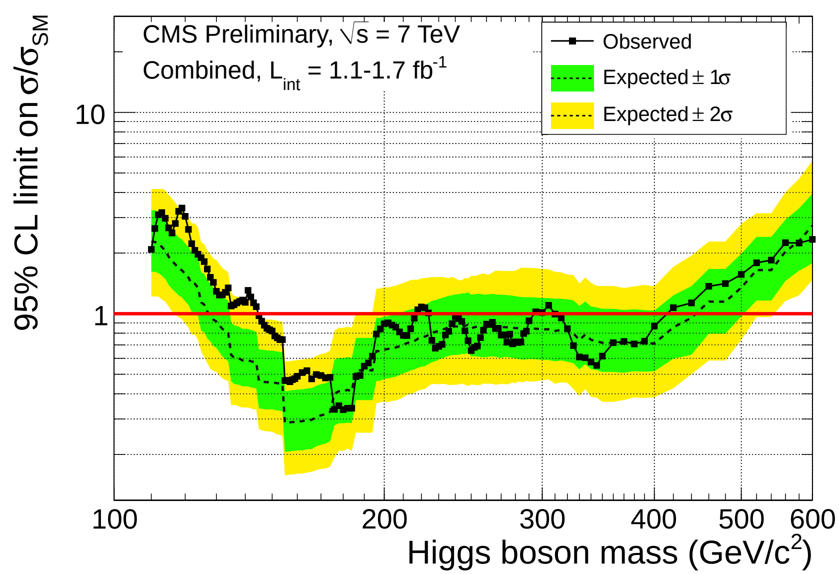
2. Higgs mass bounds from collider searches.

From 1989–2000, experiments at LEP searched for $e^+e^- \to Z \to h^0 Z$ (where one of the Z-bosons is on-shell and one is off-shell). No significant evidence was found leading to a lower bound on the SM Higgs mass

$$\boxed{m_h > 114.4 \text{ GeV} \quad \text{at} \quad 95\% \text{ CL.}}$$

Searches at the Tevatron and LHC extend the 95% excluded region of Higgs masses.

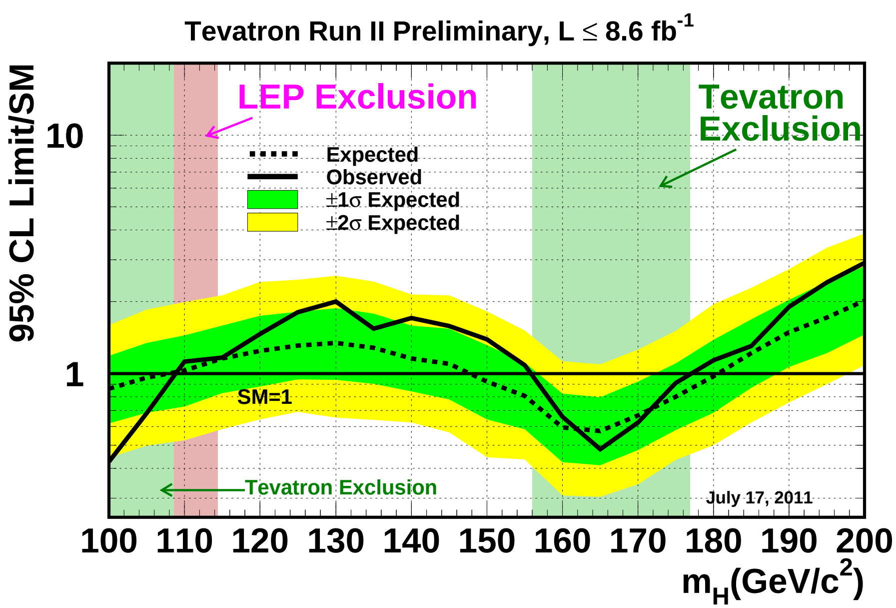




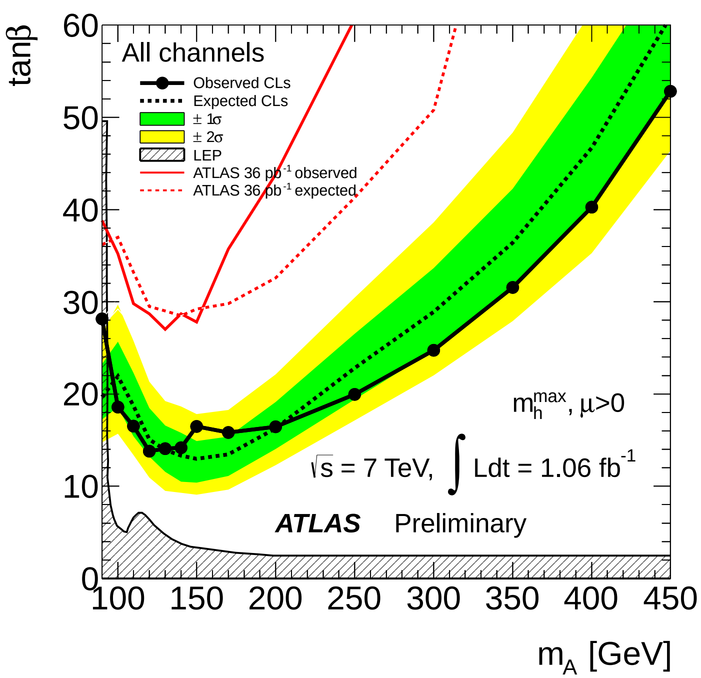
The excluded mass region above the LEP Higgs mass bound obtained by the CMS collaboration is:

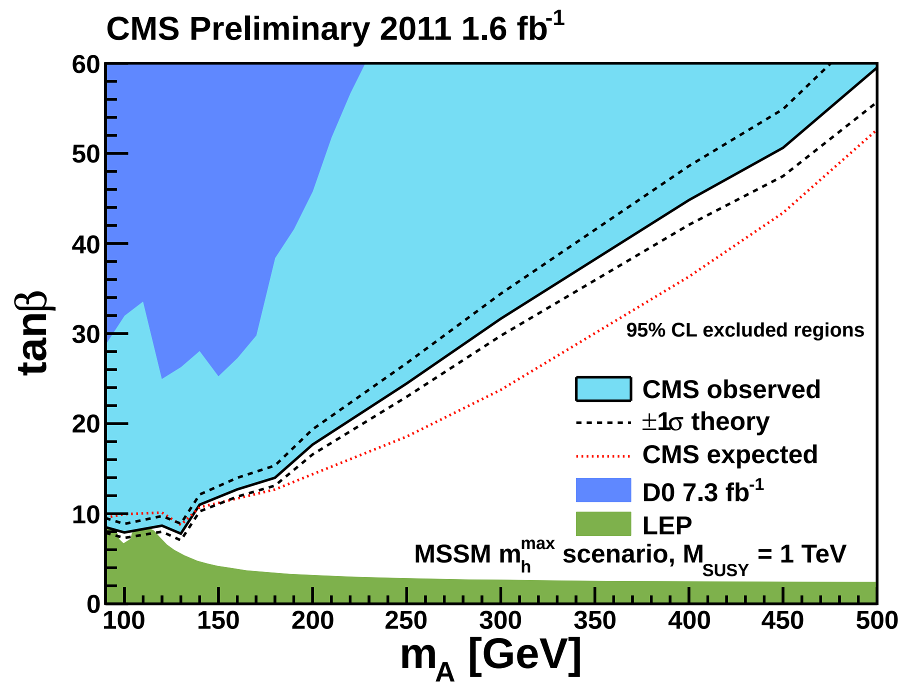
$$\boxed{144 \text{ GeV} < m_h < 440 \text{ GeV} \quad \text{at} \;\; 90\% \text{ CL.}}$$

CMS and ATLAS also obtain 95% CL exclusion regions that are roughly similar with a few small intervals in the above mass range that cannot quite be excluded with present data. The current Tevatron excluded mass region of $158 \text{ GeV} < m_h < 175 \text{ GeV}$ at 95% CL adds statistical significance to the results.



The LHC search for MSSM Higgs bosons also has produced interesting limits in the non-decoupling regime, where $m_A \lesssim 150$ GeV.

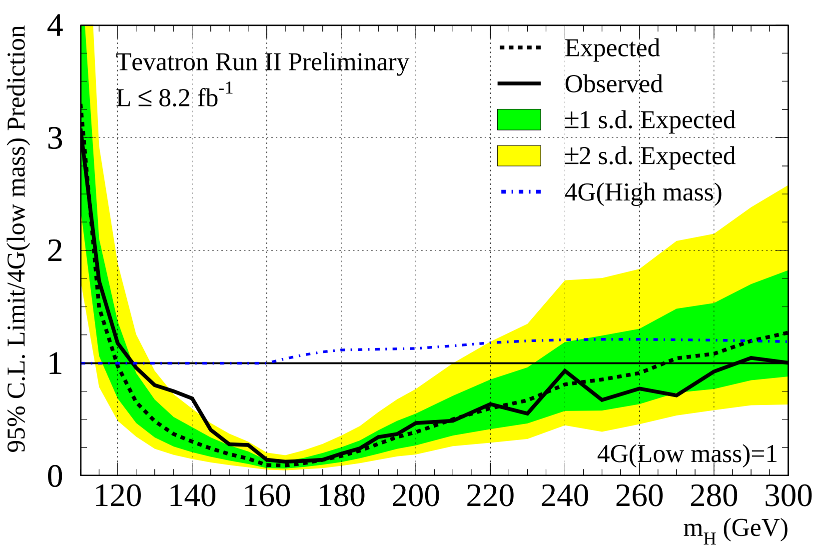


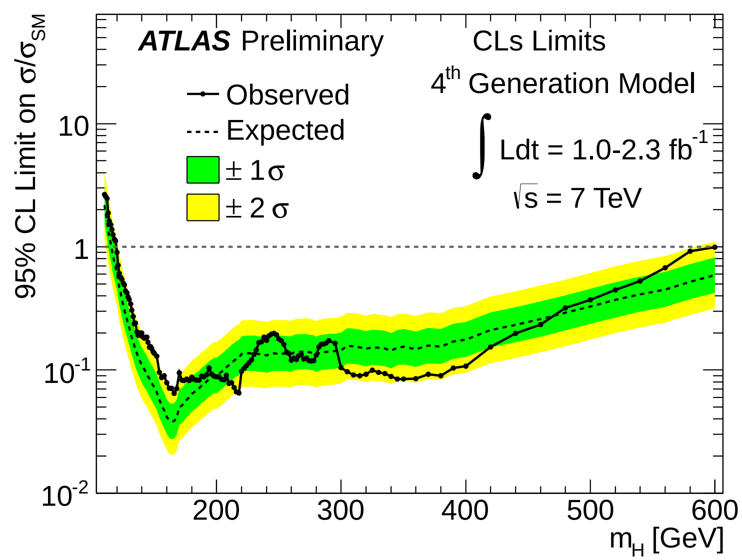


With more data, LHC data can be used to rule out more of the $\tan\beta$–m_A plane. However, in the region of large m_A and moderate $\tan\beta$, it will be difficult to detect H^0, A^0 and $H^\pm$ even with a significant increase of luminosity. This is the infamous *LHC wedge region*, where only the SM-like h^0 of the MSSM can be observed.

Other scenarios of new physics are constrained by the collider Higgs search. The radiatively induced hgg and $h\gamma\gamma$ couplings can deviate from their SM values due to non-decoupling effects of BSM heavy particles in the loops, *even if the tree-level Higgs couplings take on their SM values*.

For example, models with four quark and lepton generations yield stronger constraints on the possible values of the SM Higgs mass.





Where do we stand? Where are we headed?

No evidence for the Higgs boson has yet been observed. But, this is precisely what is expected, given the the SM global fits based on precision electroweak data. The LHC now begins to zero in on the Higgs mass range, $114~\text{GeV} < m_h < 145~\text{GeV}$, the region where the SM Higgs boson (if it exists) is likely to reside. With $5~\text{fb}^{-1}$ of data recorded by the end of this year, and another $15~\text{fb}^{-1}$ of data anticipated by next summer, there is some chance for evidence of the Higgs boson by the end of this year and an announcement of a discovery at ICHEP next summer.

If a candidate Higgs boson is discovered, one must then address the following questions:

- Is it a Higgs boson?
- Is it *the* SM Higgs boson?

The measurement of Higgs boson properties will be critical in order to answer these questions:

- mass, width, CP-quantum numbers (CP-violation?)
- Higgs cross sections
- branching ratios and Higgs couplings
- reconstructing the Higgs potential

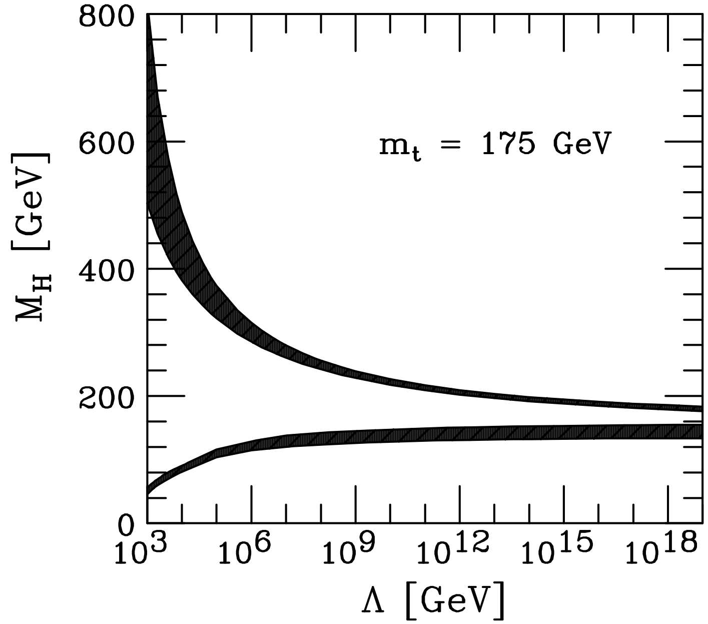
Scenarios and exit strategies

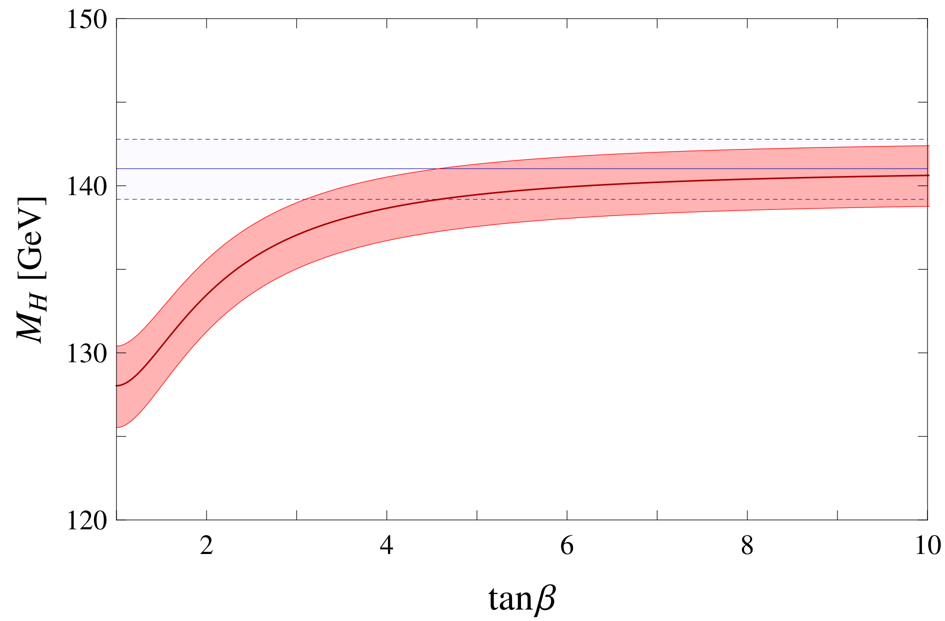
Possible scenarios include:

1. A SM-like Higgs boson is discovered. No evidence for BSM physics is evident.
2. A SM-like Higgs boson is discovered. Separate evidence for BSM physics emerges.
3. A light Higgs-like scalar is discovered, with properties that deviate from the SM.
4. A very heavy scalar state is discovered.
5. No Higgs boson candidate is discovered, and the entire mass range for a SM-like Higgs boson below 1 TeV is excluded.

In the last three cases, theoretical consistency implies that BSM physics must exist at the TeV energy scale that is observable at the LHC (with sufficient luminosity). Cases 4 and 5 would likely be incompatible with TeV-scale supersymmetry, whereas cases 2 and 3 would strongly encourage supersymmetric enthusiasts.

Case 1 would strongly cast doubts on the principle of naturalness. Nevertheless, is it still possible to learn about physics at higher mass scales?





Left-hand plot: The present-day theoretical uncertainties on the lower [Altarelli and Isidori; Casas, Espinosa and Quirós] and upper [Hambye and Riesselmann] Higgs mass bounds as a function of energy scale Λ at which the Standard Model breaks down, assuming $m_t = 175$ GeV and $\alpha_s(m_Z) = 0.118$. The shaded areas above reflect the theoretical uncertainties in the calculations of the Higgs mass bounds.

Right-hand plot: The SM Higgs mass prediction for theories where the boundary condition for the quartic coupling at 10^{14} GeV is fixed by the MSSM, and $\alpha_s(m_Z) = 0.1176$ and $m_t = 173.1 \pm 1.3$ GeV. The horizontal blue lines show the asymptotes of the prediction for large $tan\beta$. Taken from L.J. Hall, Y. Nomura, JHEP **1003**, 076 (2010).

Conclusions

• The SM is not yet complete. The nature of the dynamics responsible for EWSB (and generating the Goldstone bosons that provide the longitudinal components of the massive $W^\pm$ and Z bosons) is not yet known.

• There are strong hints that a weakly-coupled elementary Higgs boson exists in nature (although loopholes still exist).

• If TeV-scale supersymmetry is responsible for EWSB, then the Higgs sector will be richer than in the SM. However, in the decoupling regime, it may be difficult to to detect deviations from SM Higgs properties at the LHC or evidence for new scalar states beyond the SM-like Higgs boson.

• Ultimately, one must discover the TeV-scale dynamics associated with EWSB, e.g. low-energy supersymmetry and/or new particles and phenomena responsible for creating the Goldstone bosons. So far, no evidence for physics BSM has been forthcoming.

• If there is only a Higgs boson and no evidence for new physics beyond the SM, then . . .?