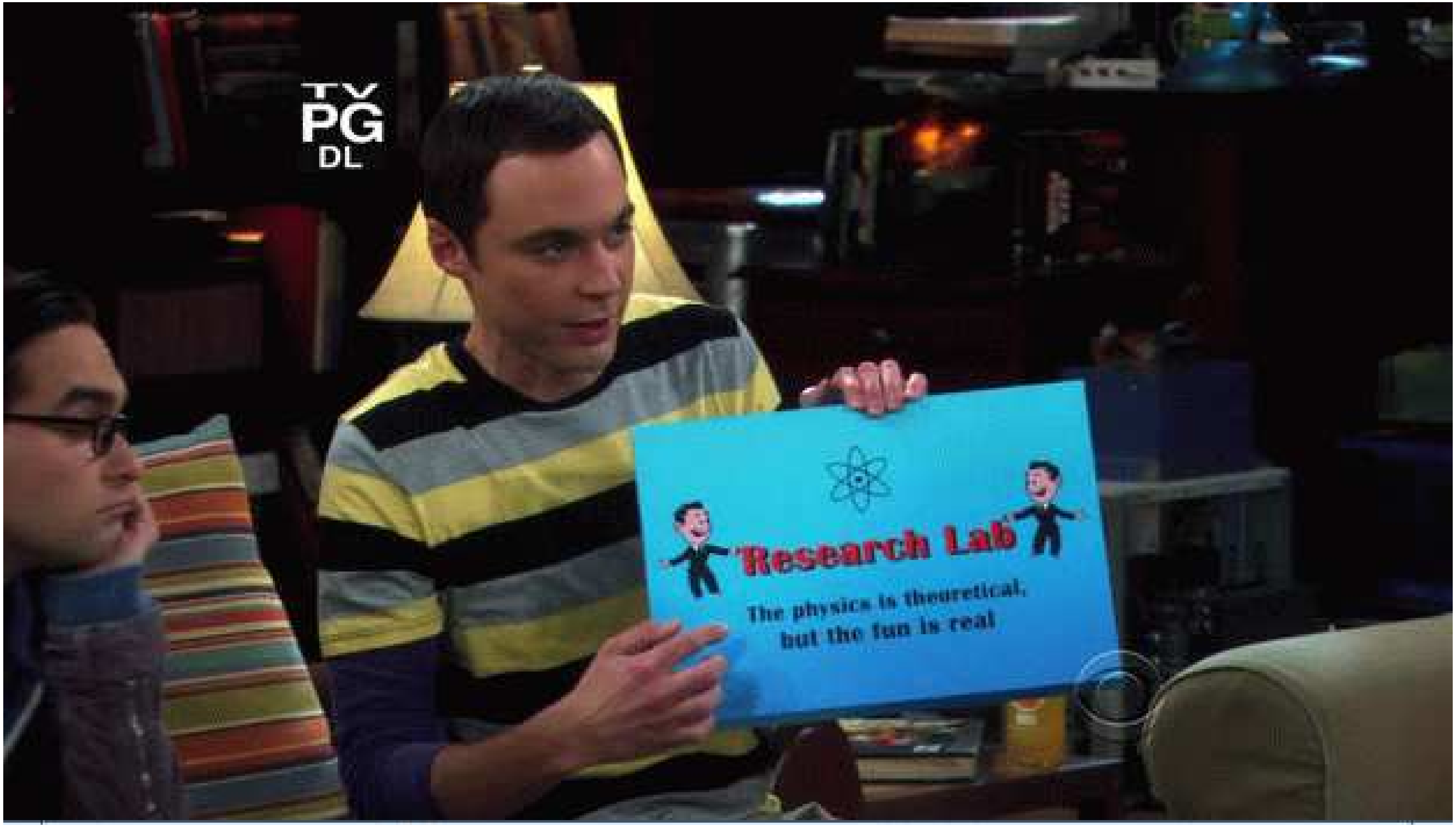

SAY GOD PARTICLE
ONE MORE
GODDAMN TIME



Sheldon: “Research Lab” is more than a game:
The physics is theoretical, but the fun is real!

Electroweak Symmetry Breaking
in the SM and MSSM

Sven Heinemeyer, IFCA (CSIC,Santander)

Bad Honnef, 12/2012

1. Introduction and motivation

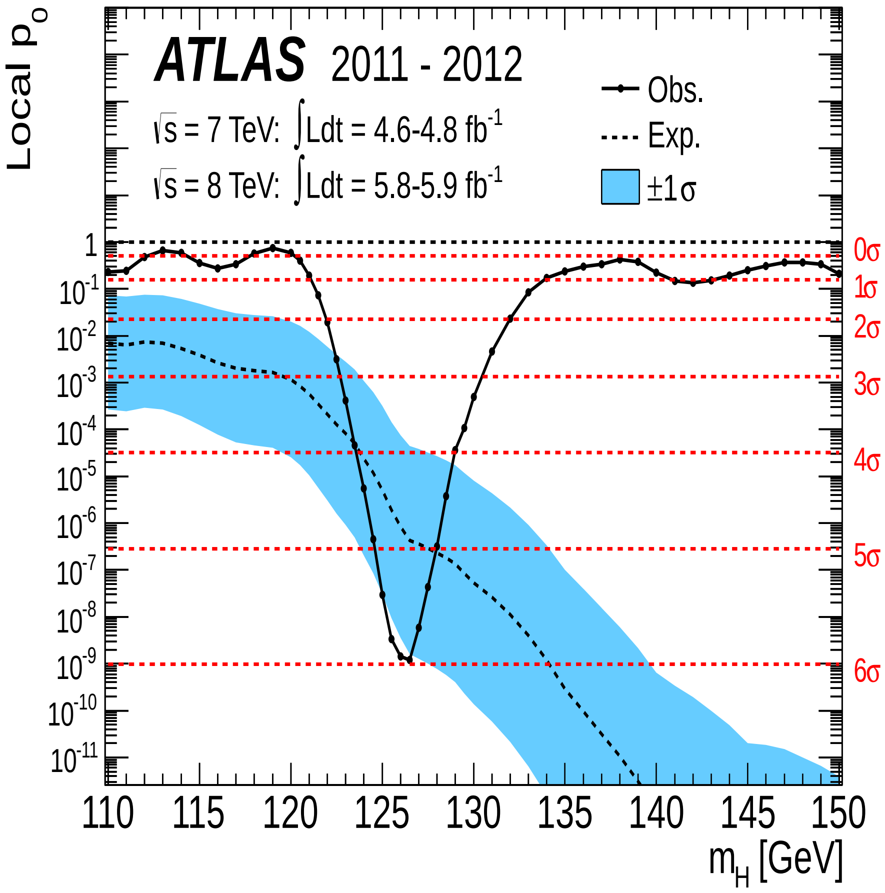
2. The Standard Model and the Higgs boson

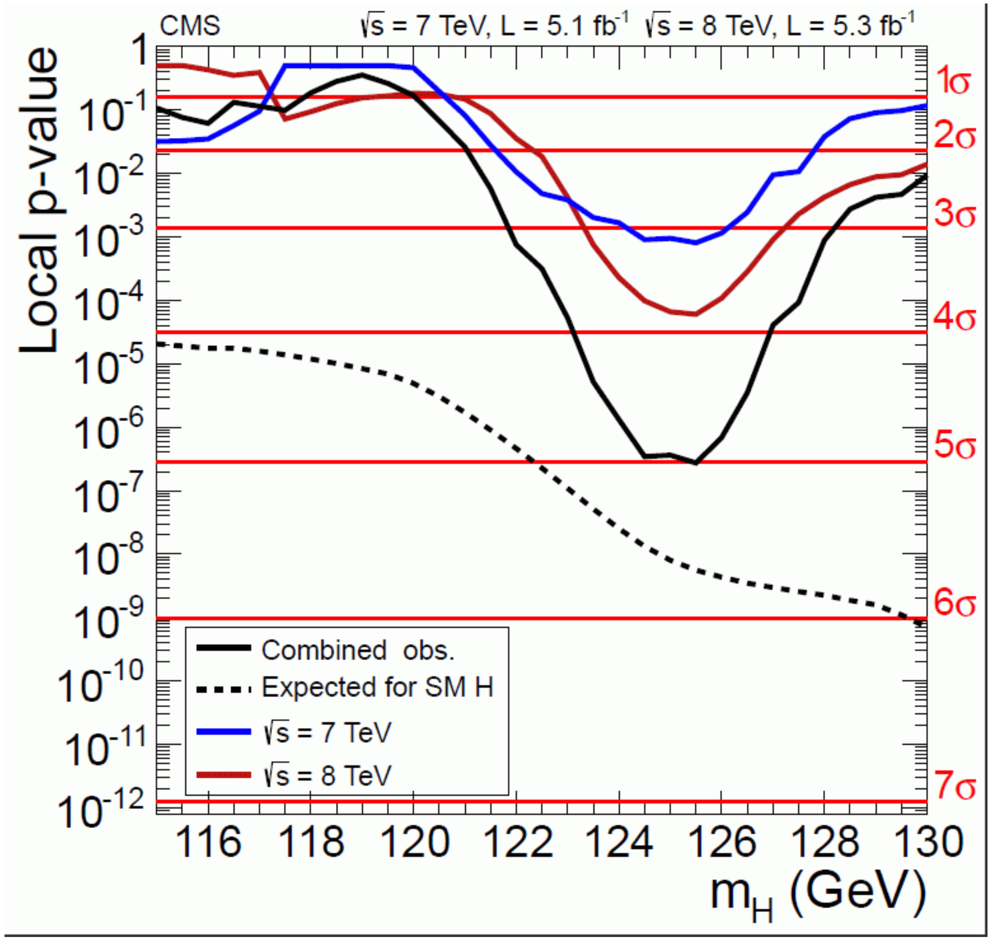
3. The Minimal Supersymmetric Standard Model and the Higgs boson(s)

4. Conclusions

1. Introduction and motivation

We have a discovery!





We have a discovery!

But what is it?

Q: Is it a Higgs boson?

Q: Is it the Higgs boson (i.e. of the SM)?

Q: Is it an MSSM Higgs boson?

Q: Is it a Higgs boson of a different model?

Q: Is it an impostor?

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A: Compare to the predictions of the various models

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A: Compare to the predictions of the various models

⇒ Overview about electroweak symmetry breaking in the SM and MSSM!

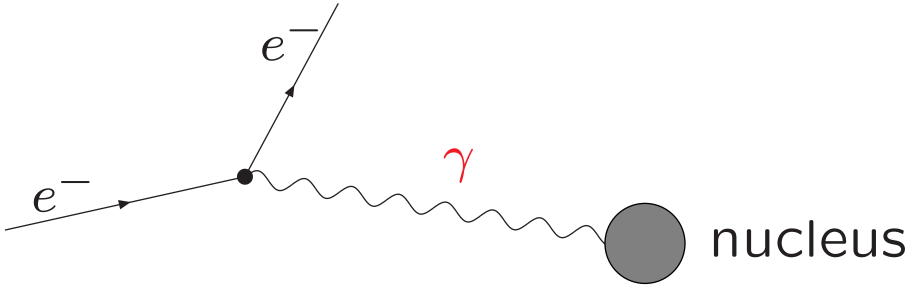
2. The Standard Model and the Higgs boson

SM: Quantum field theory $\Rightarrow$ interaction: exchange of field quanta

Construction principle of the SM: gauge invariance

Example: Quantum electro-dynamics (QED)

field quanta: photon A_μ



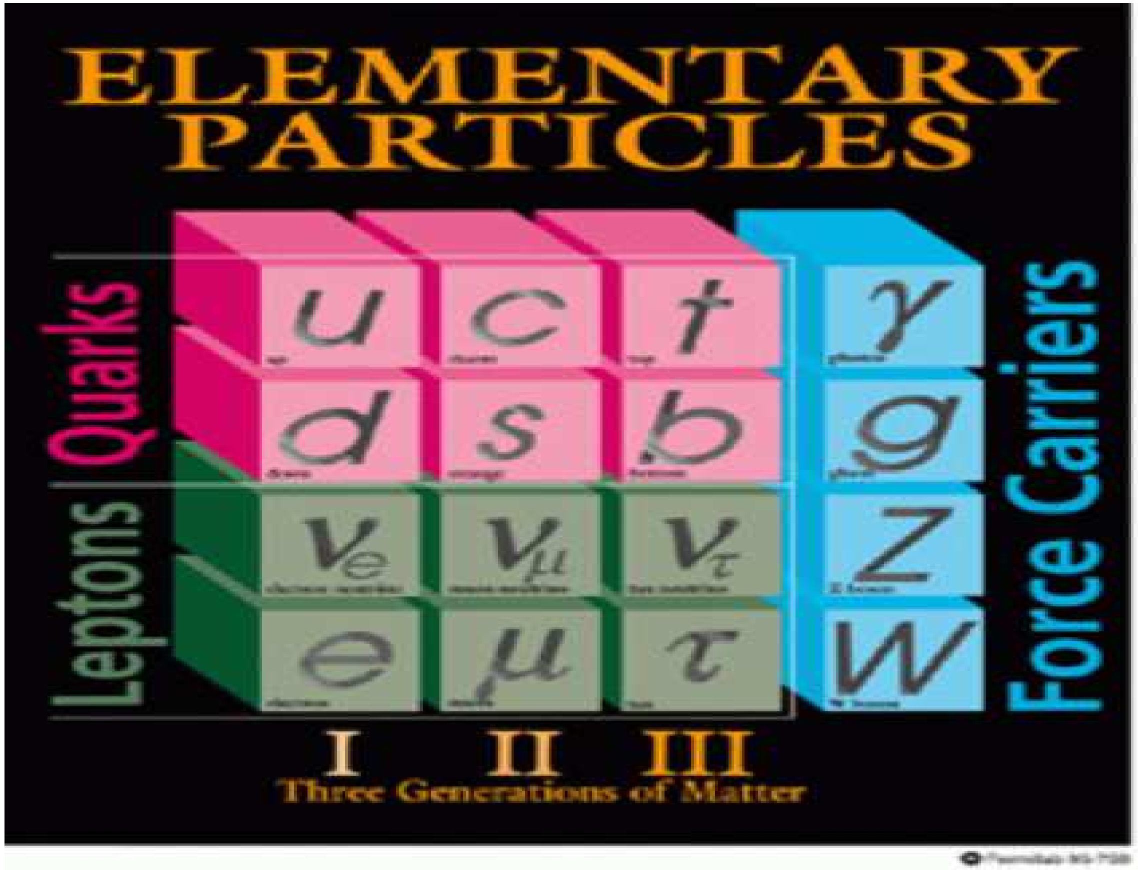
$\mathcal{L}_{\text{QED}}$ invariant under gauge transformation:

$\Psi \to e^{i\,e\,\lambda(x)}\Psi$, $A_\mu \to A_\mu + \partial_\mu\lambda(x)$

mass term for photon: $m^2 A^\mu A_\mu$ not gauge invariant

$\Rightarrow$ A_μ is massless gauge field

Current status of knowledge: the Standard Model (SM)



⇒ all particles experimentally seen

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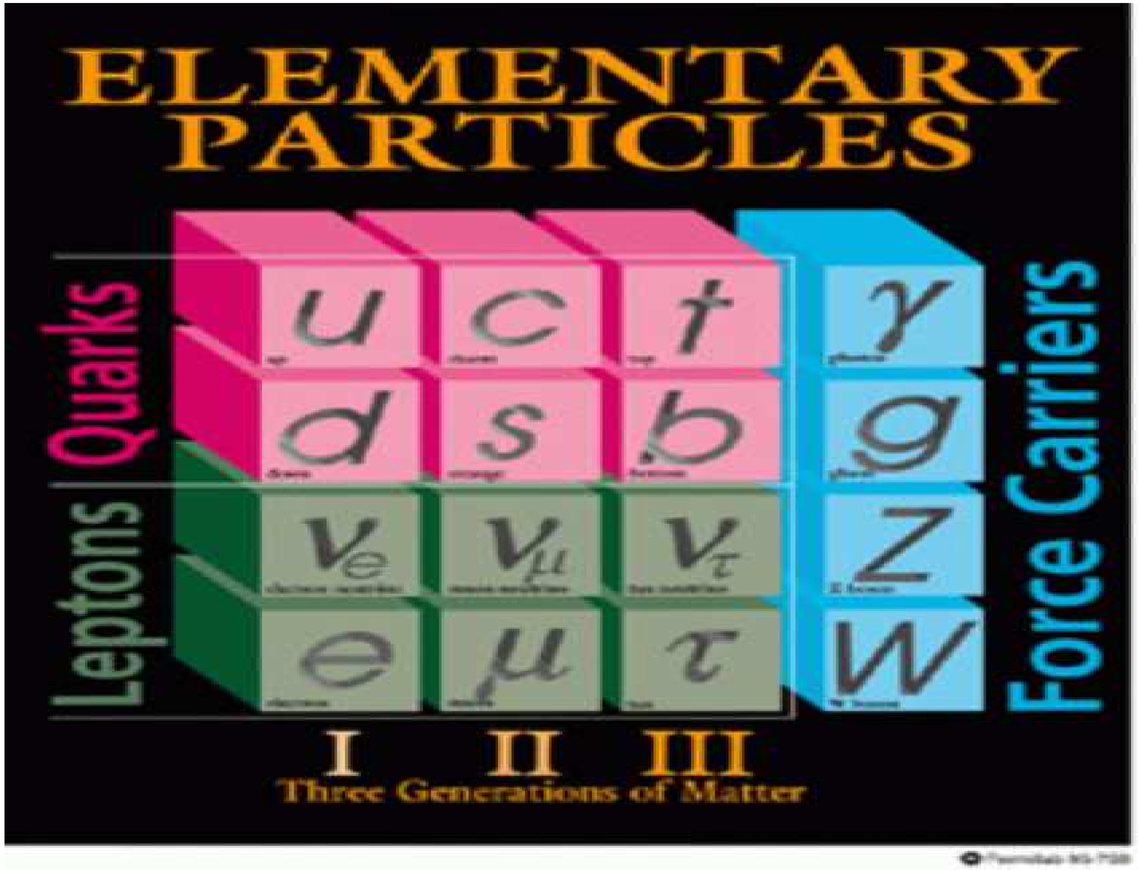


⇒ all particles experimentally seen

⇒ but it predicts massless gauge bosons . . .

Problem:

Gauge fields Z, W^+, W^- are massive

explicite mass terms in the Lagrangian $\Leftrightarrow$ breaking of gauge invariance

Solution: Higgs mechanism

scalar field postulated, mass terms from coupling to Higgs field

Higgs sector in the Standard Model:

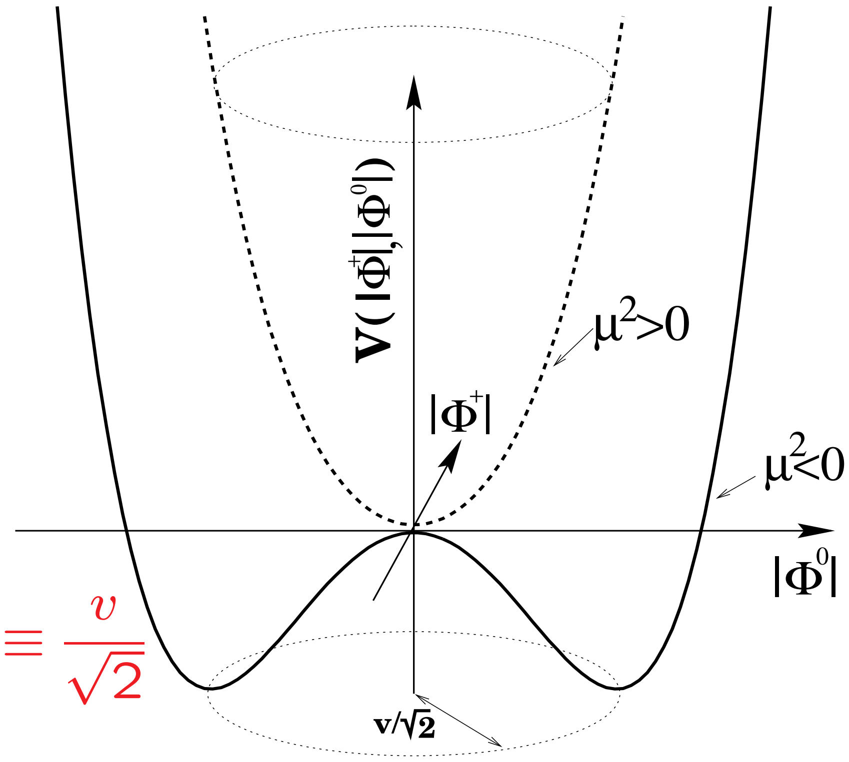
Scalar SU(2) doublet: $\Phi = \begin{pmatrix} \phi^+ \\ \phi^0 \end{pmatrix}$

Higgs potential:

$$V(\phi) = \mu^2 \left|\Phi^\dagger \Phi\right| + \lambda \left|\Phi^\dagger \Phi\right|^2, \quad \lambda > 0$$

$\mu^2 < 0$: Spontaneous symmetry breaking

minimum of potential at $|\langle\Phi_0\rangle| = \sqrt{\frac{-\mu^2}{2\,\lambda}} \equiv \frac{v}{\sqrt{2}}$



$$\Phi = \frac{1}{\sqrt{2}} \begin{pmatrix} 0 \\ v + H \end{pmatrix} \qquad \text{(unitary gauge)}$$

H: elementary scalar field, Higgs boson

Lagrange density:

$$\begin{aligned} \mathcal{L}_{\text{Higgs}} = \quad & (D_\mu \Phi)^\dagger (D^\mu \Phi) \\ & - g_d \bar{Q}_L \Phi d_R \; - \; g_u \bar{Q}_L \Phi_c u_R \\ & - V(\Phi) \end{aligned}$$

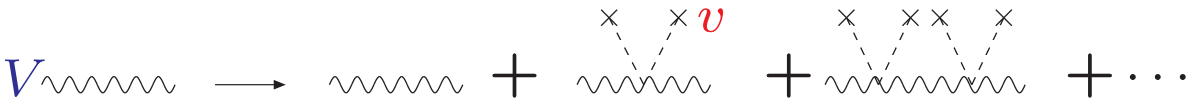
with

$$\begin{aligned} iD_\mu &= i\partial_\mu - g_2 \vec{I}\vec{W}_\mu - g_1 Y B_\mu \\ \Phi_c &= i\sigma_2 \Phi^* \qquad\qquad Q_L \sim \begin{pmatrix} u_L \\ d_L \end{pmatrix}, \; \Phi \sim \begin{pmatrix} 0 \\ v \end{pmatrix}, \; \Phi_c \sim \begin{pmatrix} v \\ 0 \end{pmatrix} \end{aligned}$$

Gauge invariant coupling to gauge fields

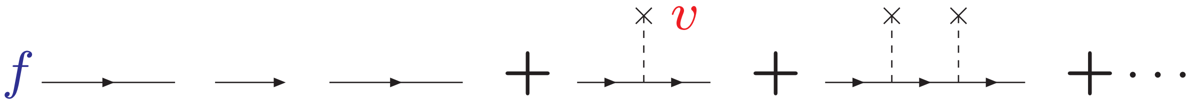
⇒ mass terms for gauge bosons and fermions

1.) $VV\Phi\Phi$ coupling:



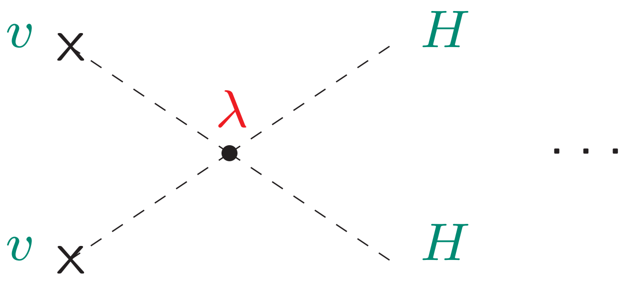
$$\frac{1}{q^2} \to \frac{1}{q^2} + \sum_j \frac{1}{q^2}\left[\left(\frac{gv}{\sqrt{2}}\right)^2 \frac{1}{q^2}\right]^j = \frac{1}{q^2 - M^2} \ : \ M^2 = g^2\frac{v^2}{2} \qquad \Rightarrow M \propto g$$

2.) fermion mass terms: Yukawa couplings:



$$\frac{1}{\not{q}} \to \frac{1}{\not{q}} + \sum_j \frac{1}{\not{q}}\left[\frac{g_f v}{\sqrt{2}}\frac{1}{\not{q}}\right]^j = \frac{1}{\not{q} - m_f} \ : \ m_f = g_f\frac{v}{\sqrt{2}} \qquad \Rightarrow m_f \propto g_f$$

3.) mass of the Higgs boson: self coupling



$$\lambda = M_H^2/v$$

$M_H = v\sqrt{\lambda}$ free parameter

→ last unknown(??) parameter of the SM

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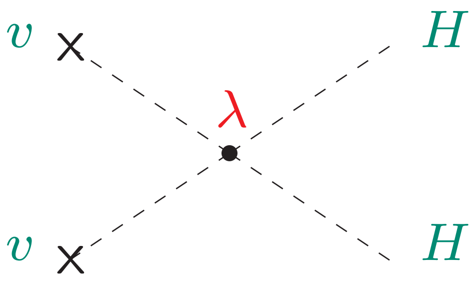


. . .

$$\lambda = M_H^2/v$$

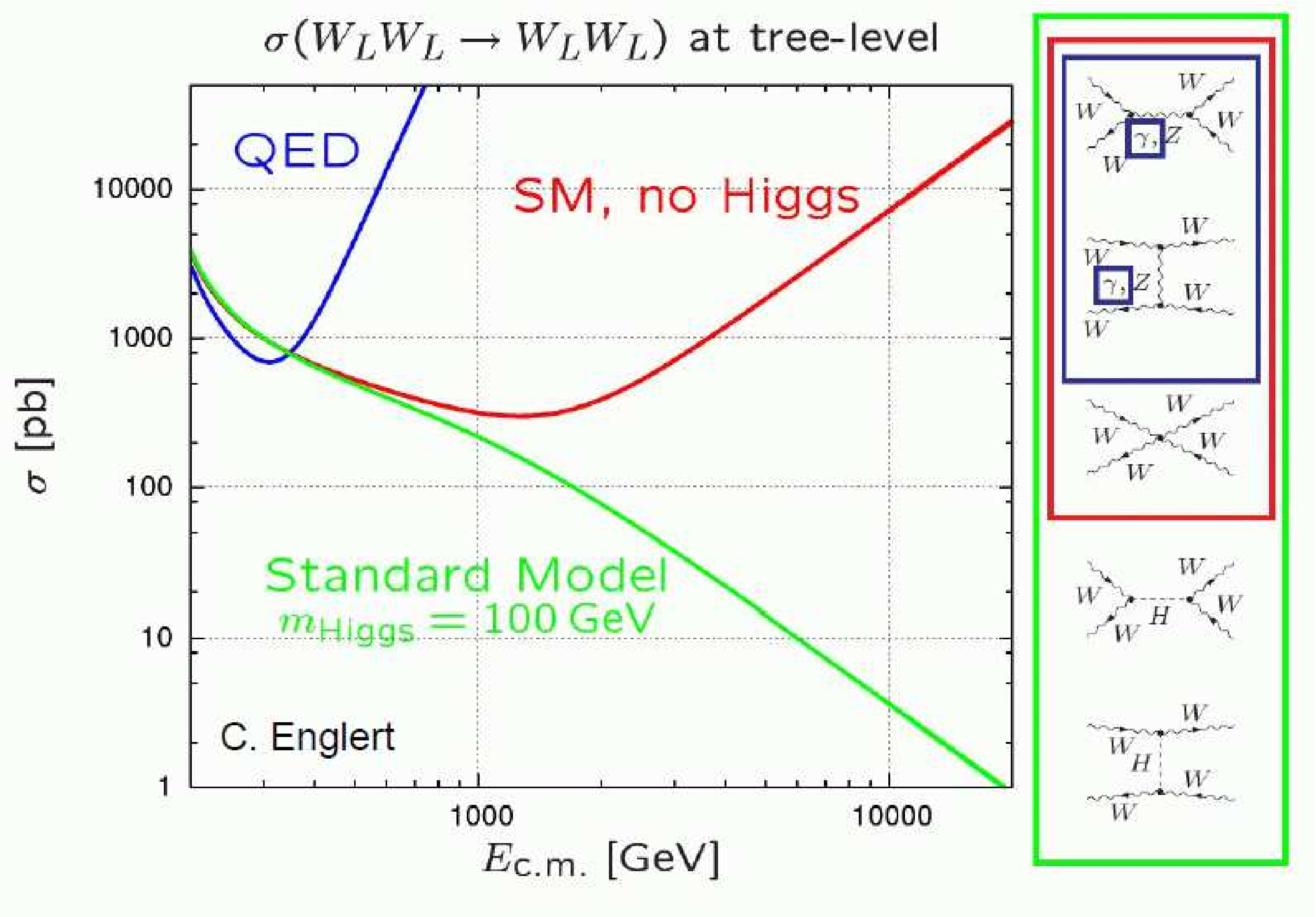
$M_H = v\sqrt{\lambda}$ free parameter

→ last unknown(??) parameter of the SM

$\Rightarrow$ establish Higgs mechanism $\equiv$ find the Higgs $\oplus$ measure its couplings

$W_L W_L \to W_L W_L$ cross section with/without the Higgs:

[taken from M. Schumacher '12 / C. Englert]



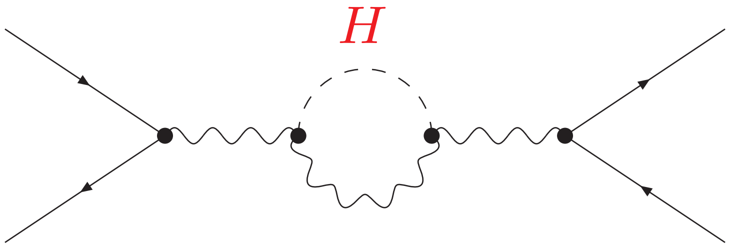
Electroweak Precision Observables (EWPO):

Comparison of electro-weak precision observables with theory:

EW Precision data:		Theory:
$M_W, \sin^2\theta_{\text{eff}}, a_\mu$	$\leftrightarrow$	SM, MSSM , . . .

$\Downarrow$

Test of theory at quantum level: Sensitivity to loop corrections, e.g. H



$\Downarrow$

SM: limits on M_H

Very high accuracy of measurements and theoretical predictions needed

Example: prediction of M_W

Theoretical prediction for M_W in terms of $M_Z, \alpha, G_\mu, \Delta r$:

$$M_W^2 \left(1 - \frac{M_W^2}{M_Z^2}\right) = \frac{\pi\,\alpha}{\sqrt{2}\,G_\mu}(1 + \Delta r)$$

$\Updownarrow$

loop corrections

Evaluate Δr from μ decay $\Rightarrow M_W$

One-loop result for M_W in the SM:

[*A. Sirlin '80*] , [*W. Marciano, A. Sirlin '80*]

$$\begin{array}{lcccc} \Delta r_{1-\mathrm{loop}} = & \Delta\alpha & - & \frac{c_W^2}{s_W^2}\Delta\rho & + \quad \Delta r_{\mathrm{rem}}(M_H) \\ & \sim \log\frac{M_Z}{m_f} & & \sim m_t^2 & \log(M_H/M_W) \\ & \sim 6\% & & \sim 3.3\% & \sim 1\% \end{array}$$

Comparison of SM prediction of M_W with direct measurements:

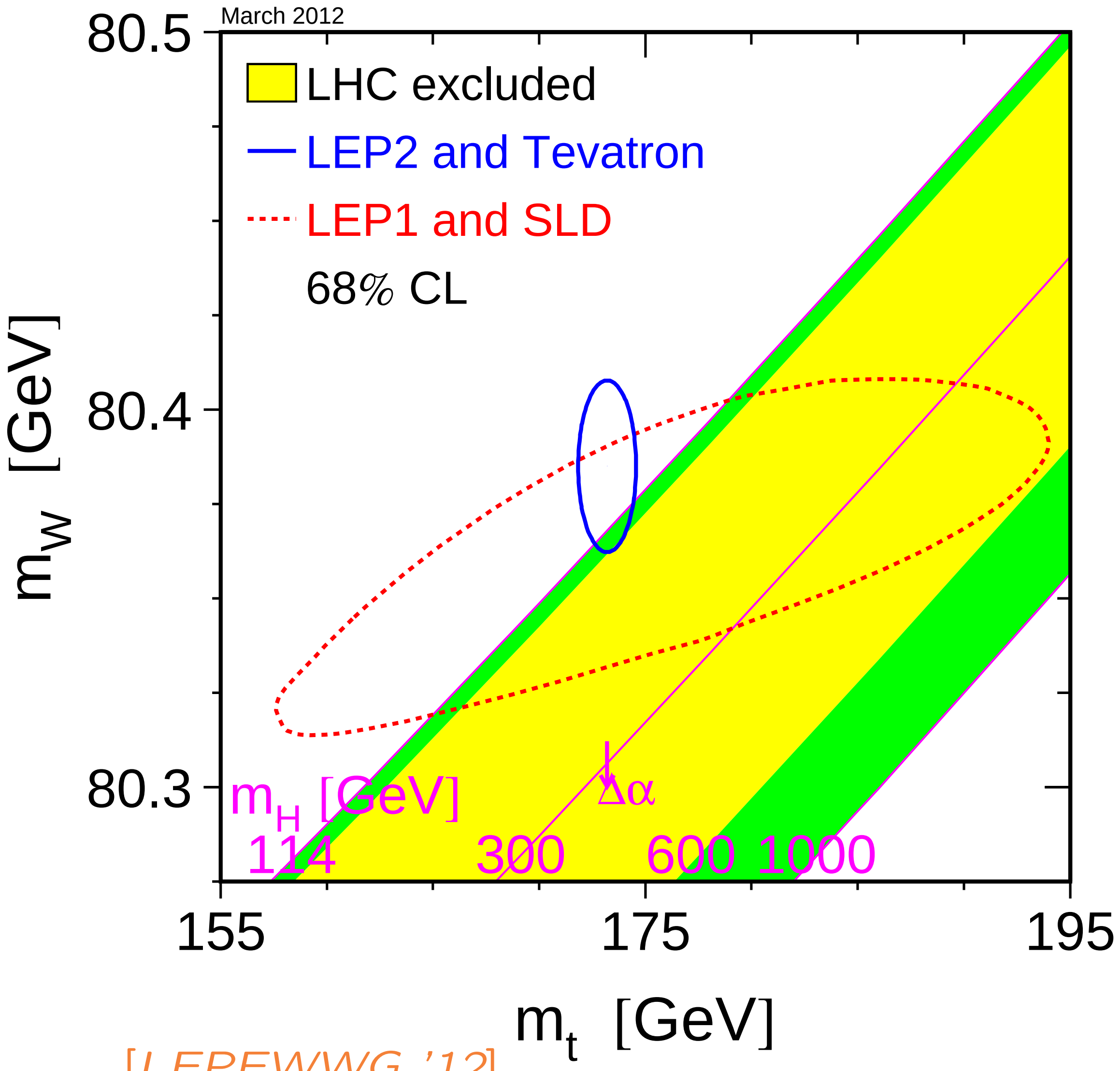
$$\Delta r = -\frac{11 g_2^2}{96\,\pi^2}\frac{s_W^2}{c_W^2}\log\left(\frac{M_H}{M_W}\right)$$

general for EWPO:

$$\Delta \sim g_2^2\left[\log\left(\frac{M_H}{M_W}\right) + g_2^2\frac{M_H^2}{M_W^2}\right]$$

leading term: $\log(M_H)$

first term $\sim M_H^2$ with g_2^4

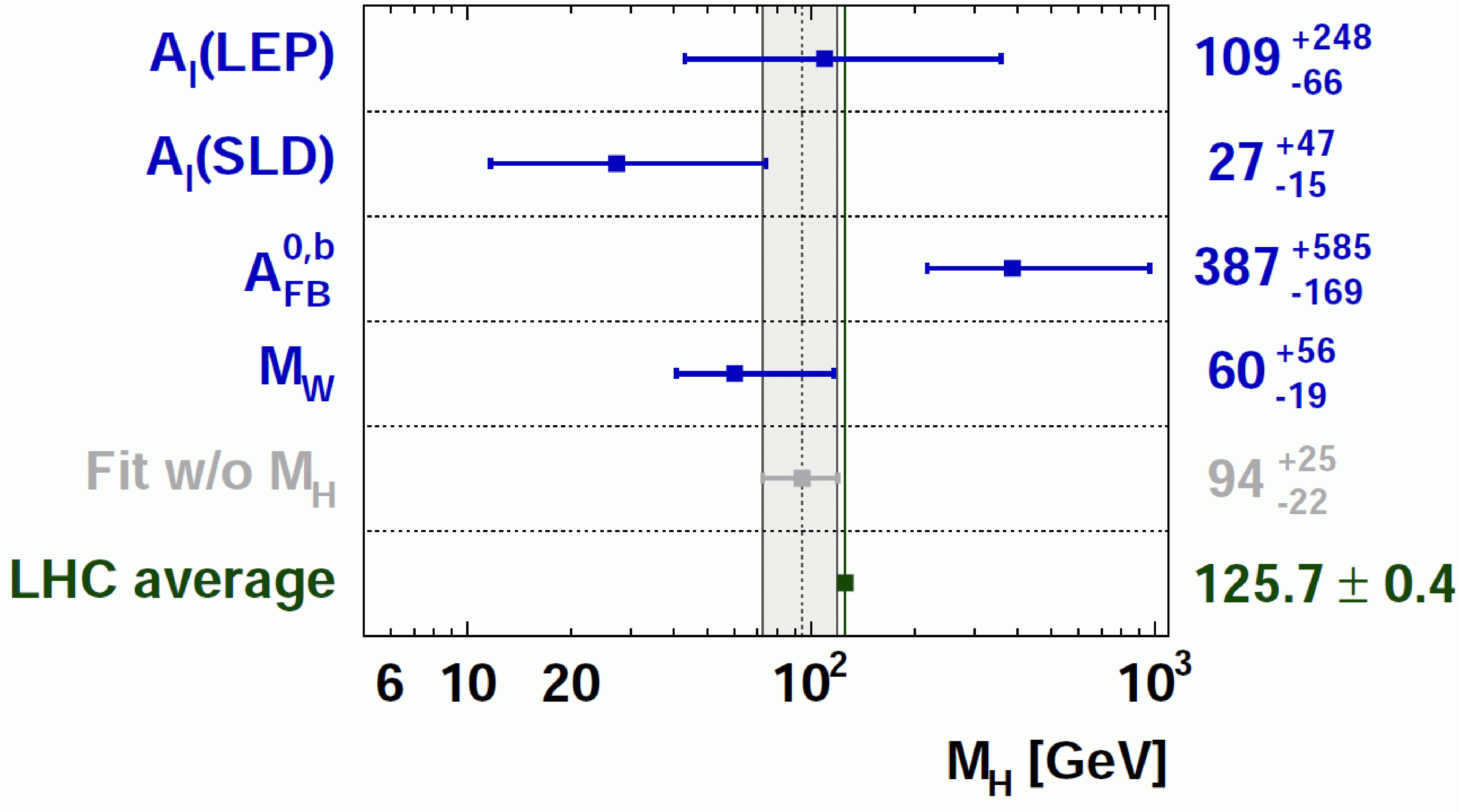


[LEPEWWG '12]

⇒ light Higgs boson preferred

Comparison for single observables:

[*GFitter '12*]

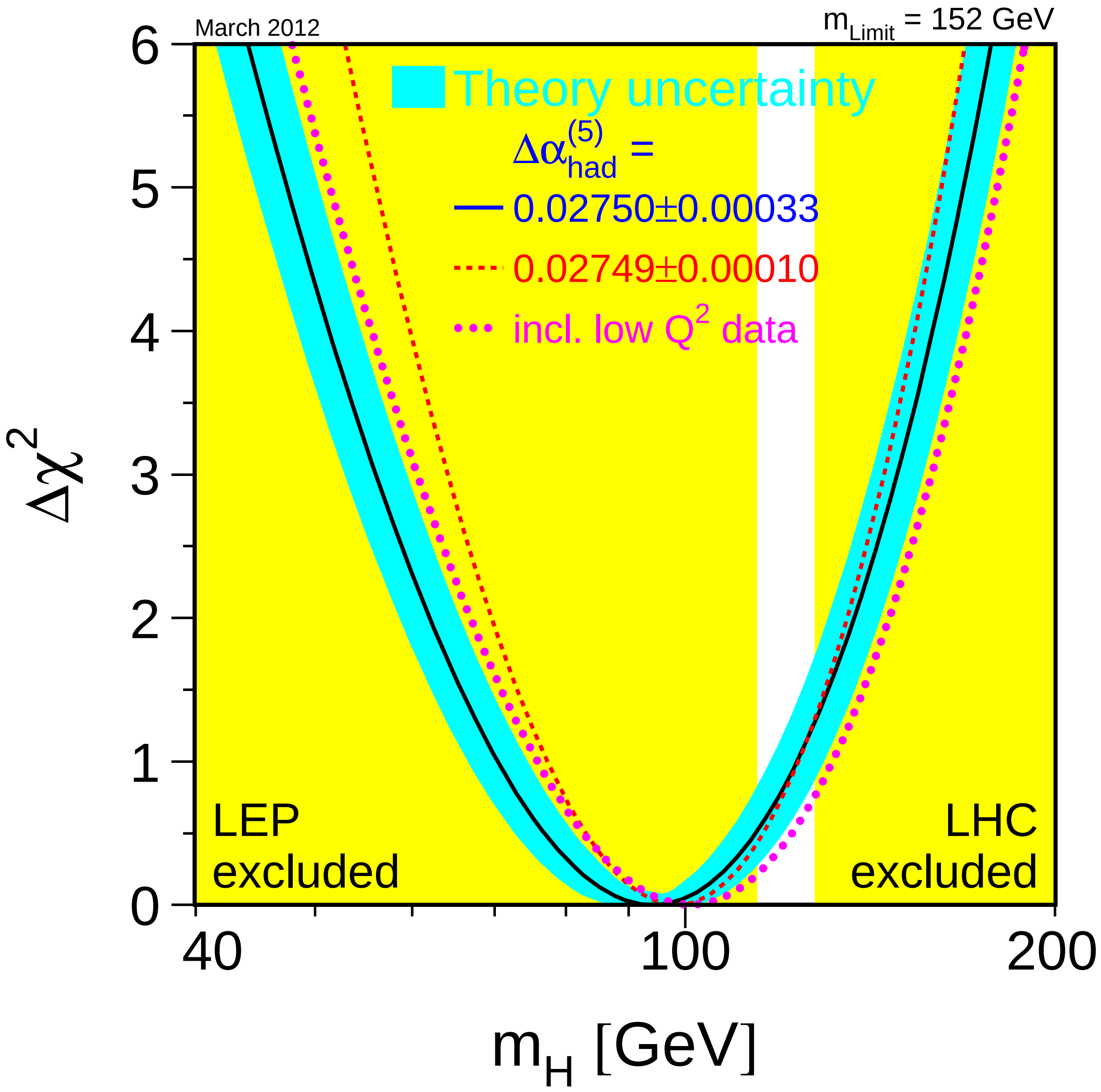


Global fit to all SM data:

[*LEPEWWG '12*]

$\Rightarrow M_H = 94^{+29}_{-24}$ GeV

$M_H < 152$ GeV, 95% C.L.



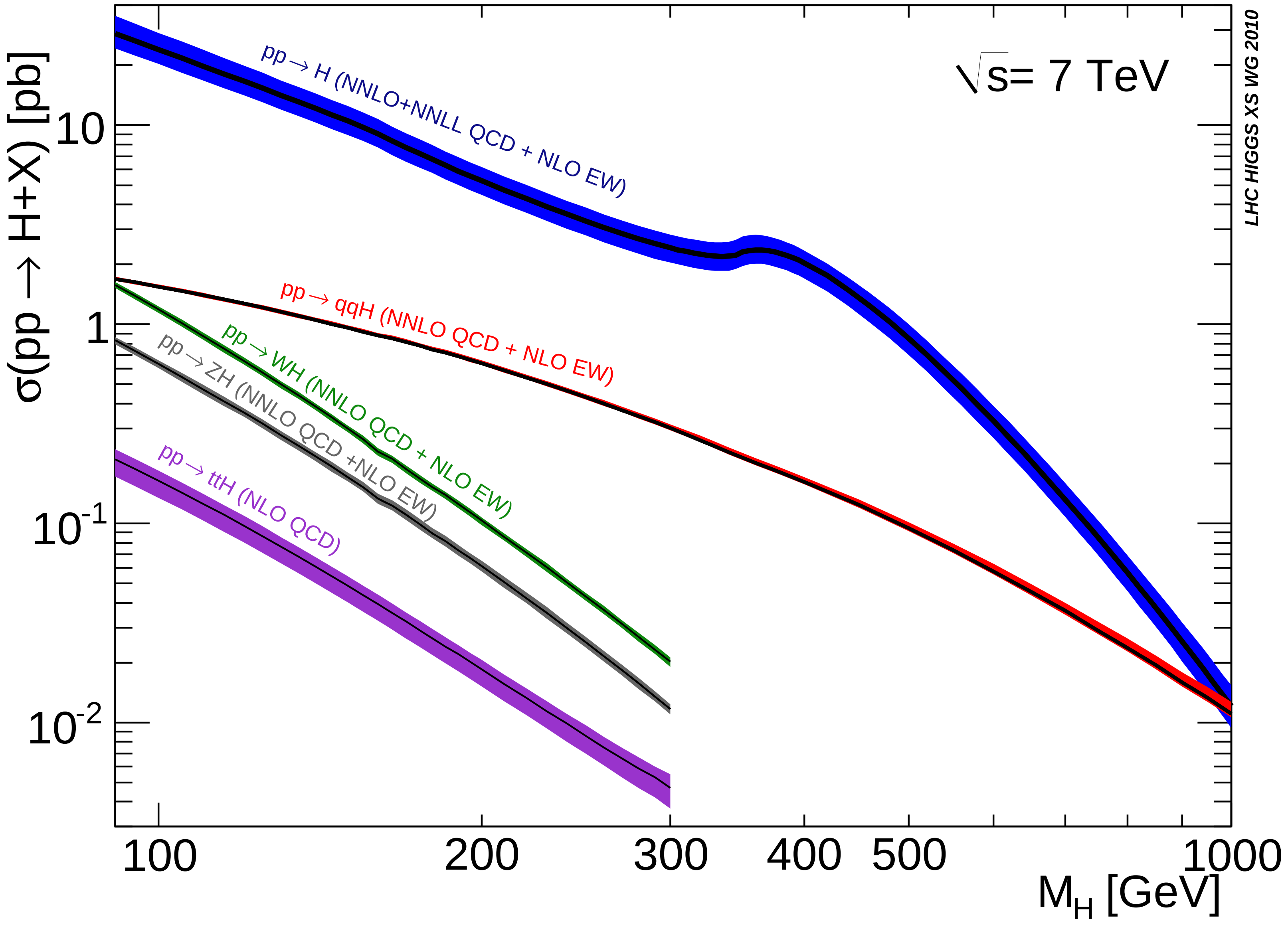
Assumption for the fit:
SM incl. Higgs boson

$\Rightarrow$ no confirmation of
Higgs mechanism

$\Rightarrow$ Fit is in agreement with a Higgs boson at 126 GeV!

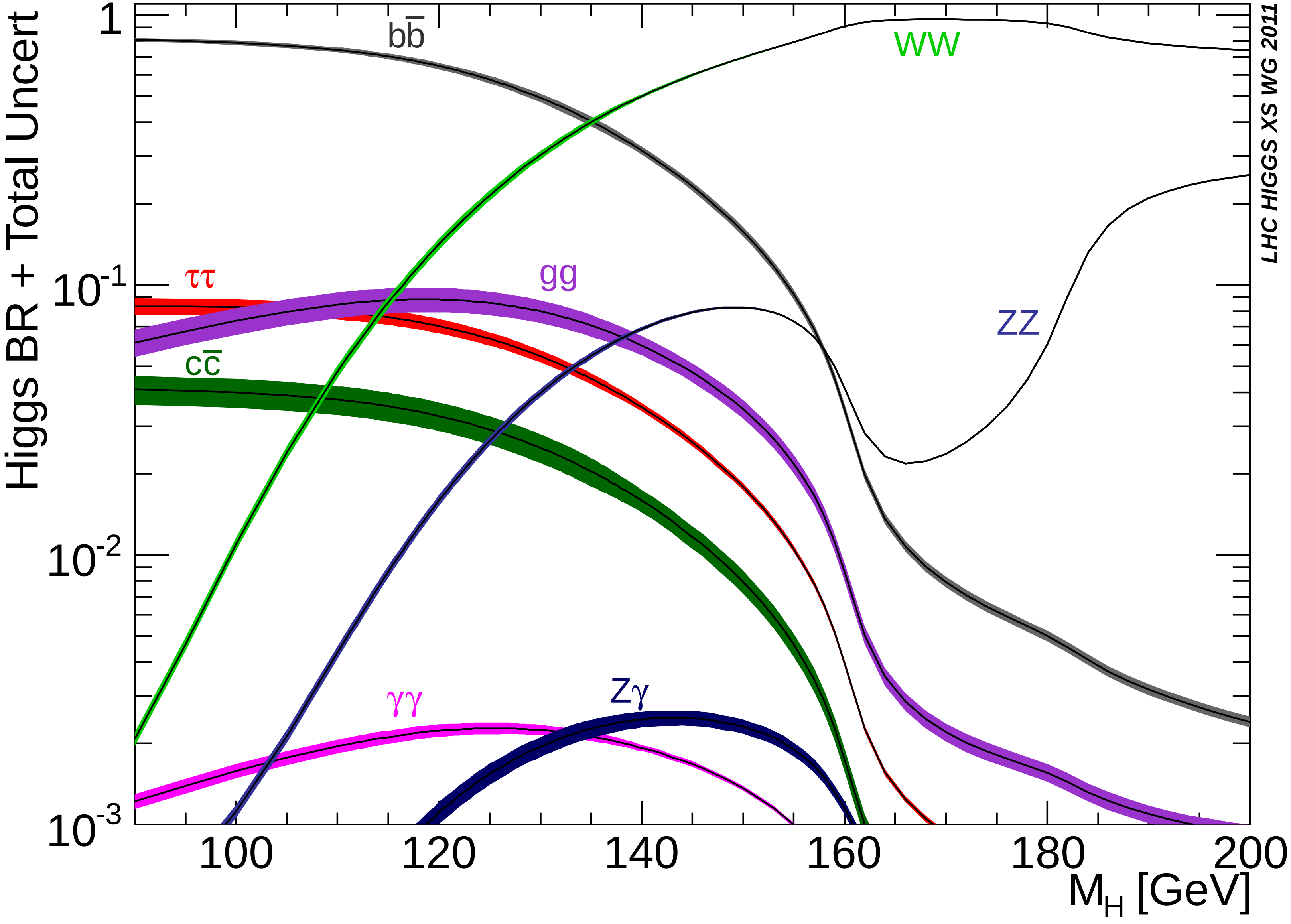
Latest theory predictions for the SM Higgs: LHC production XS

[*LHC Higgs XS WG '10 – '12*]



Latest theory predictions for the SM Higgs: branching ratios

[*LHC Higgs XS WG '10 – '12*]



Identifying the Higgs boson

What has to be done?

1. Find the new particle

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2. measure its mass ($\Rightarrow$ ok?)

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2. measure its mass (⇒ ok?)
3. measure coupling to gauge bosons
4. measure couplings to fermions
5. measure self-couplings

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6. measure spin, $\mathcal{CP}$, . . .

Identifying the Higgs boson

What has to be done?

1. Find the new particle	L
2. measure its mass ($\Rightarrow$ ok?)	L
3. measure coupling to gauge bosons	
4. measure couplings to fermions	
5. measure self-couplings	
6. measure spin, $\mathcal{CP}$, ...	

L = possible at the LHC

Identifying the Higgs boson

What has to be done?

1. Find the new particle L
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L = possible at the LHC
L = partially possible at the LHC

Identifying the Higgs boson

What has to be done?

1. Find the new particle L
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3. measure coupling to gauge bosons L
4. measure couplings to fermions L
5. measure self-couplings L
6. measure spin, $\mathcal{CP}$, . . . L

L = possible at the LHC
L = partially possible at the LHC
L = LHC perspective unclear

Identifying the Higgs boson

What has to be done?

1. Find the new particle	L	I
2. measure its mass (⇒ ok?)	L	I
3. measure coupling to gauge bosons	L	I
4. measure couplings to fermions	L	I
5. measure self-couplings	L	I
6. measure spin, $\mathcal{CP}$, . . .	L	I

L = possible at the LHC
L = partially possible at the LHC
L = LHC perspective unclear

I = easy at the ILC

Has the SM Higgs particle been discovered?

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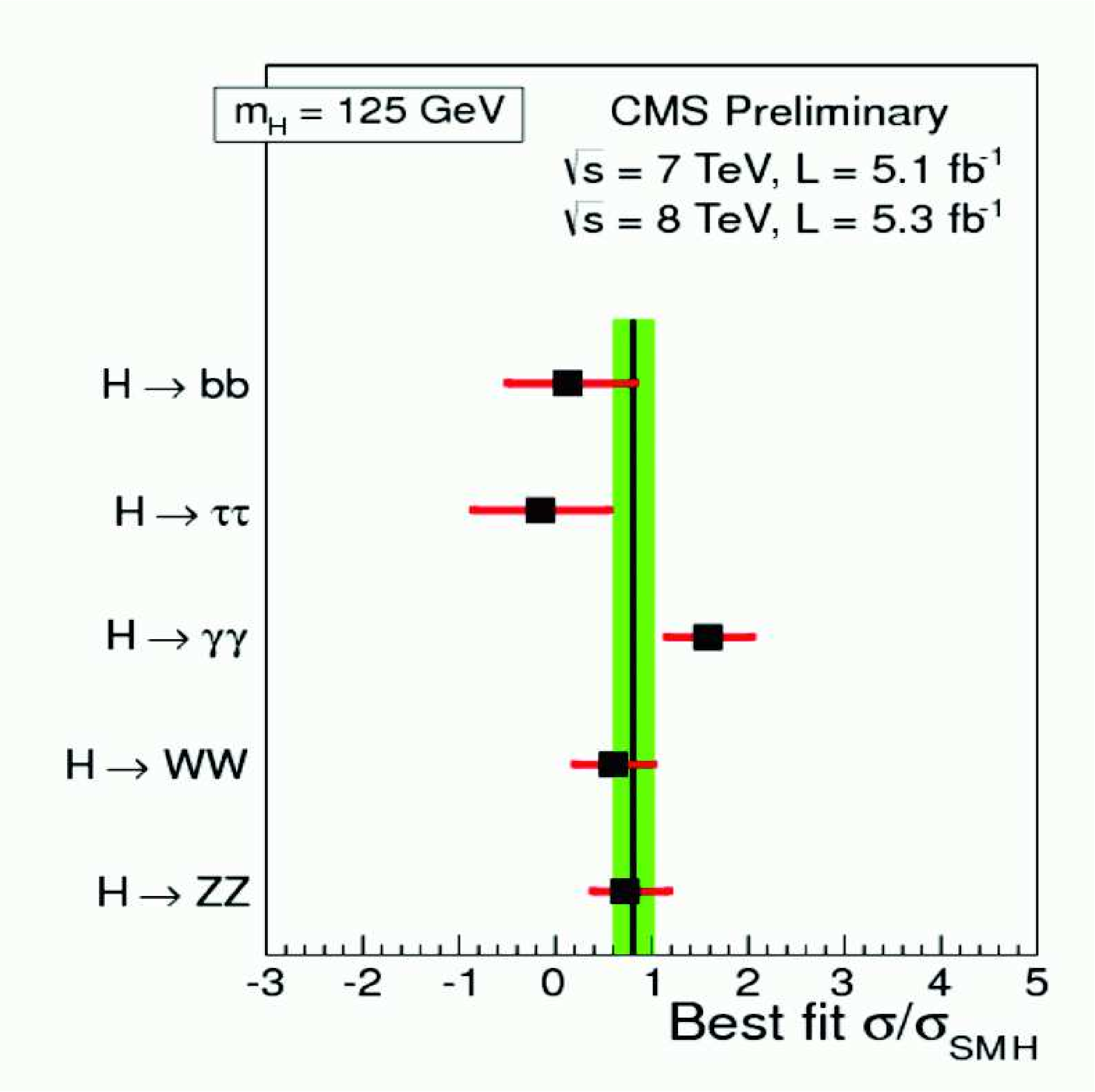
We have
discovered a new particle ,
which is compatible with the
predictions of the SM Higgs boson

How can we be sure about SM?
⇒ we have to measure
all its characteristics
– mass
– couplings to SM particles
– CP, quantum numbers, . . .

⇒ exploit the LHC!

⇒ finish up at the ILC!



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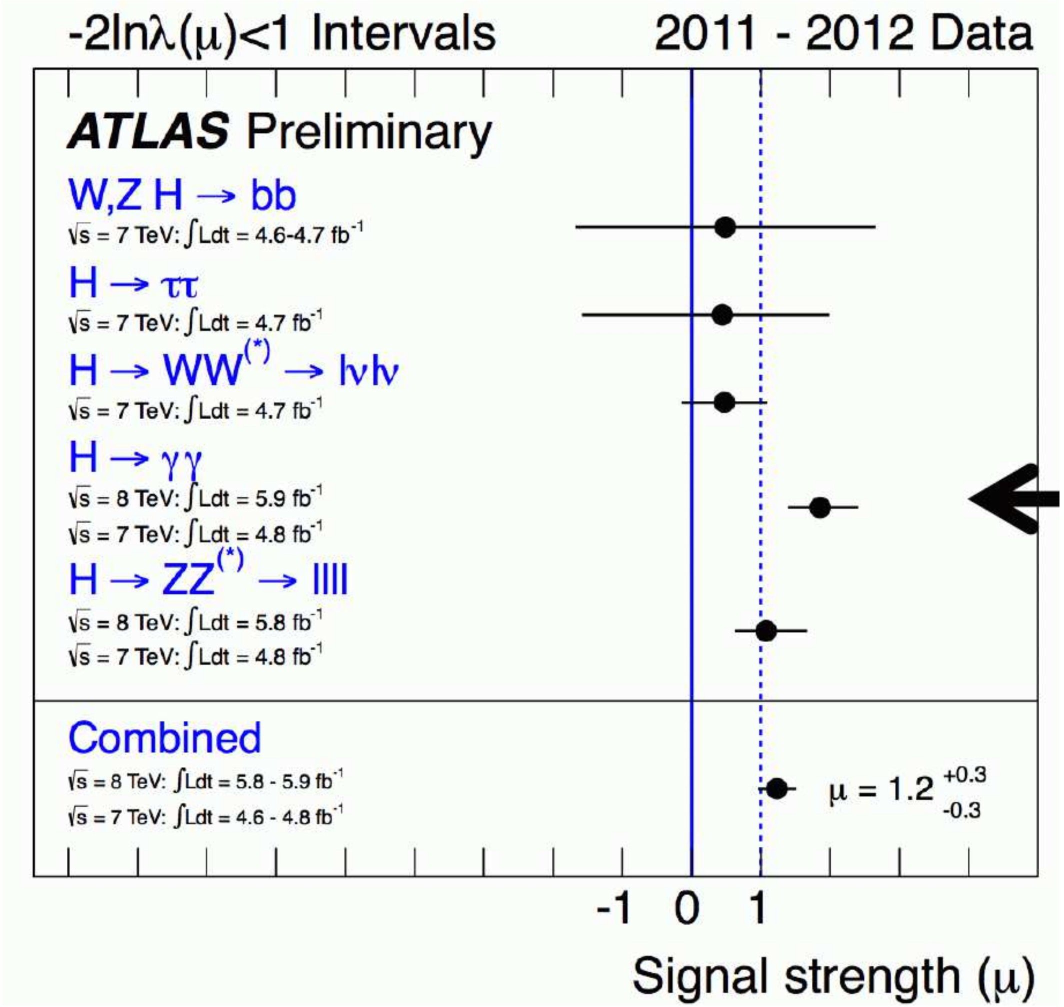
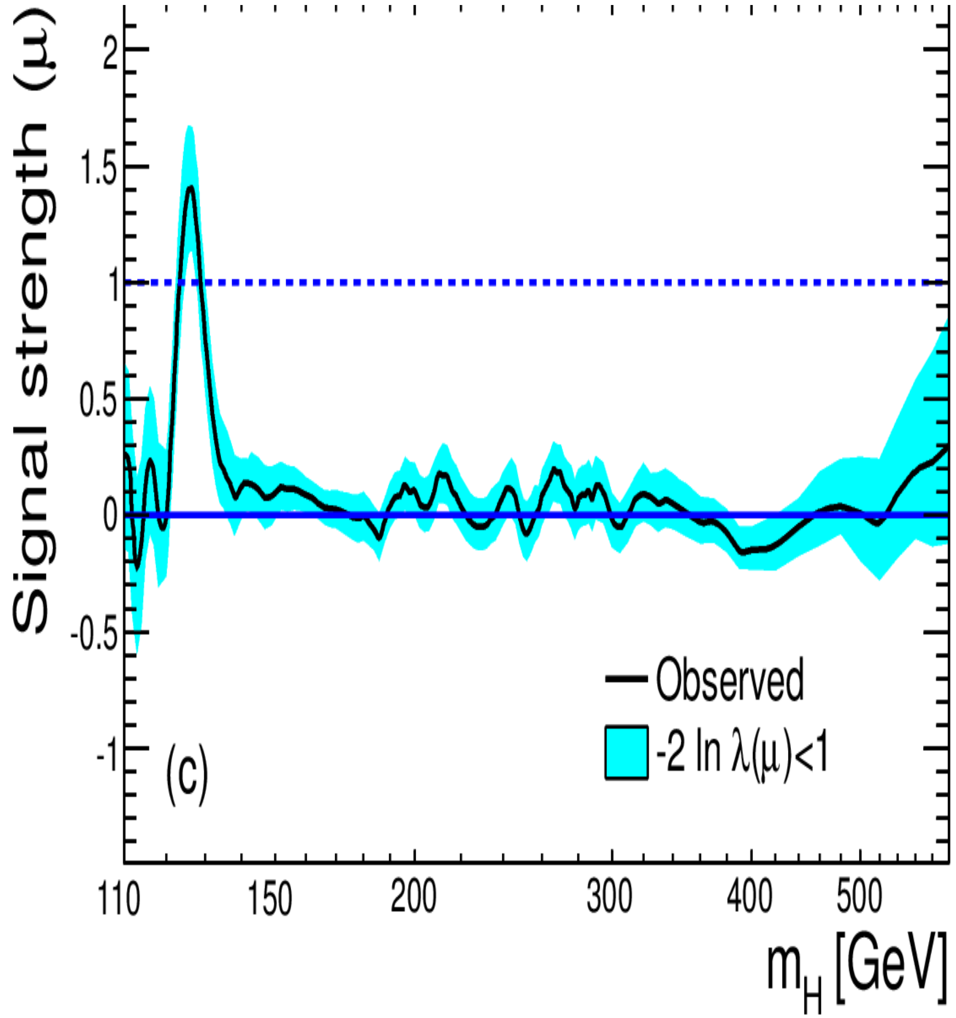
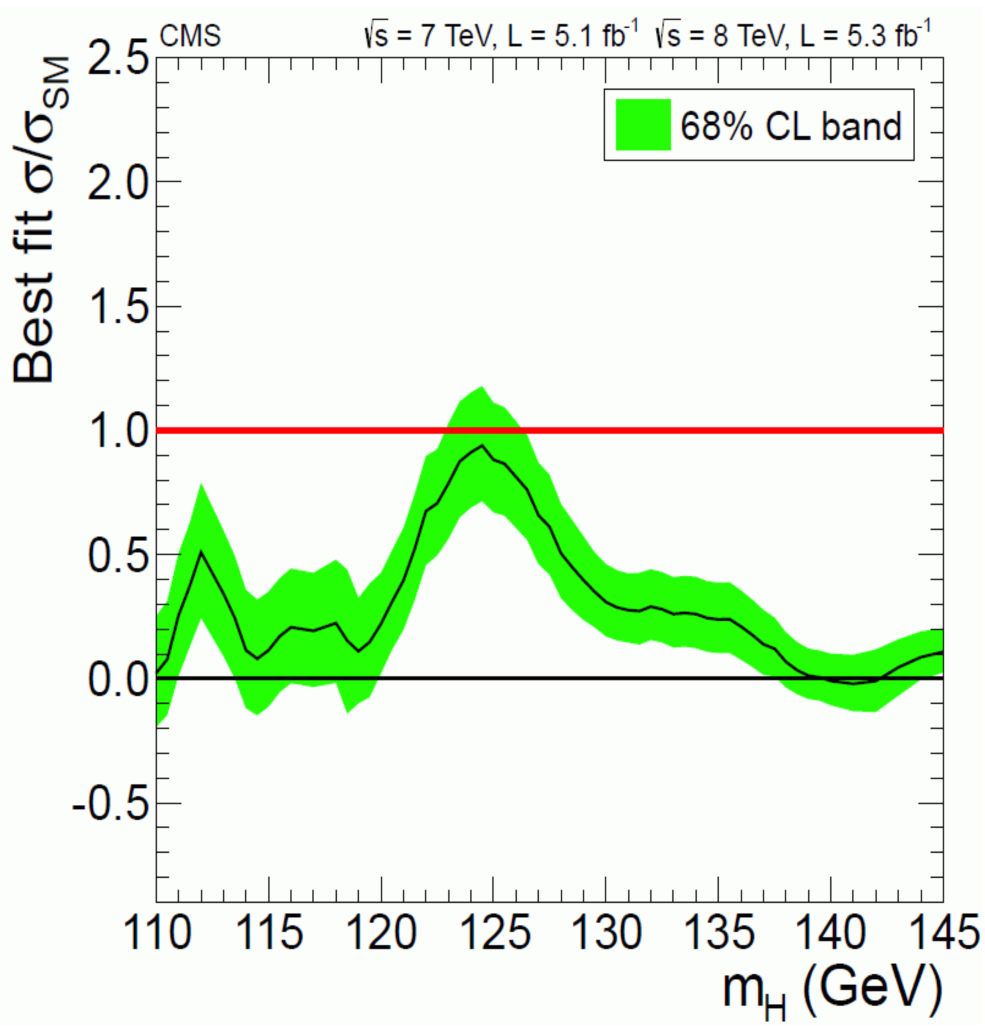


Towards a coupling determination

Signal strength:





⇒ looks well compatible with the SM Higgs!

LHC Higgs Cross Section Working Group: Low Mass (LM) subgroup:

Assumptions (for 2012 data):

1. Signal corresponds to only one state, no overlapping signal etc.
2. Zero-width approximation
3. Only modification of coupling strength (absolute values of couplings) but not of tensore structure wrt. to SM

Recommendations (for 2012 data):

1. Use state-of-the-art predictions in the SM and rescale the predictions with "leading order inspired" scale factors κ_i ($\kappa_i = 1$ corresponds to the SM case)
2. Most general case: κ_W, κ_Z, κ_t, κ_b, κ_τ, $\ldots$ $\oplus$ extra loop contributions to $\sigma(gg \to H)$, $\Gamma(H \to gg)$, $\Gamma(H \to \gamma\gamma)$, $\Gamma_{H,\text{tot}}$
3. benchmarks:
   - one parameter: overall signal strength $\kappa \equiv \mu$
   - two parameters: $\kappa_V := \kappa_W = \kappa_Z$, $\kappa_F := \kappa_t = \kappa_b = \kappa_\tau = \ldots$
   - ...

Recommendations continued:

Total width $\Gamma_{H,\text{tot}}$ cannot be measured without further theory assumptions.
(This is not a recommendation, but a fact!)

For each benchmark (except overall coupling strength) two versions are proposed:
with and without taking into account the possibility of additional contributions to the total width

– additional contributions to $\Gamma_{H,\text{tot}}$ are allowed:

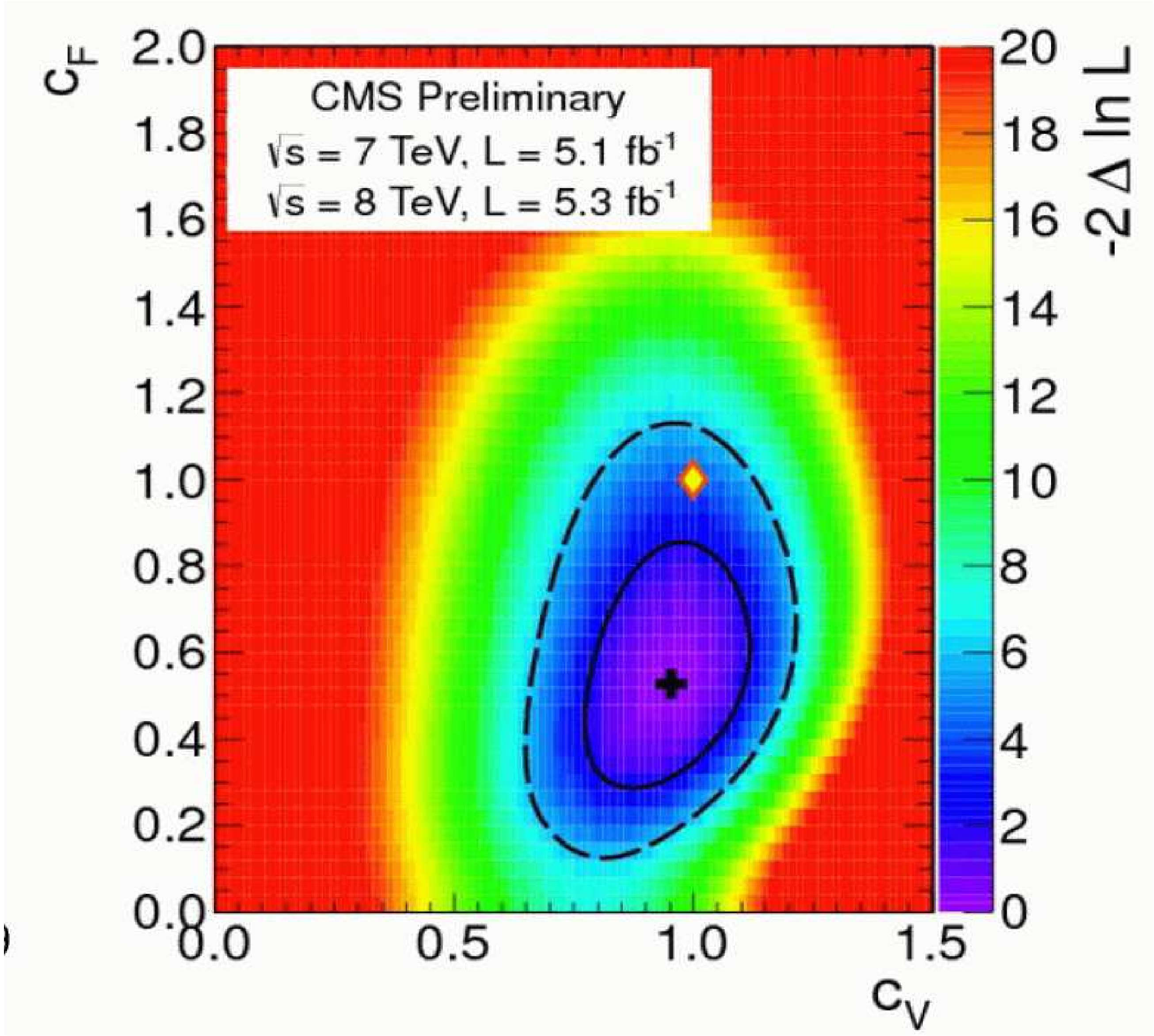
$\Rightarrow$ Determination of ratios of scaling factors, e.g. $\kappa_i \kappa_j / \kappa_H$

– no additional contributions to $\Gamma_{H,\text{tot}}$ are allowed:

$\Rightarrow$ Determination of κ_i (evaluated to NLO QCD accuracy)

Example of application (I):

[*CMS '12*]



Note: χ^2/d.o.f. excellent already in SM!

Example of application (II):

[SFitter '12]

$$g_x = g_x^{\mathsf{SM}}\,(1 + \Delta_x)$$

Fit 1:

One coupling modifier for everything: Δ_H

Fit 2:

One for gauge bosons, Δ_V, one for fermions, Δ_f

Fit 3:

Fit individual couplings: Δ_W, Δ_Z, Δ_t, Δ_b, Δ_τ

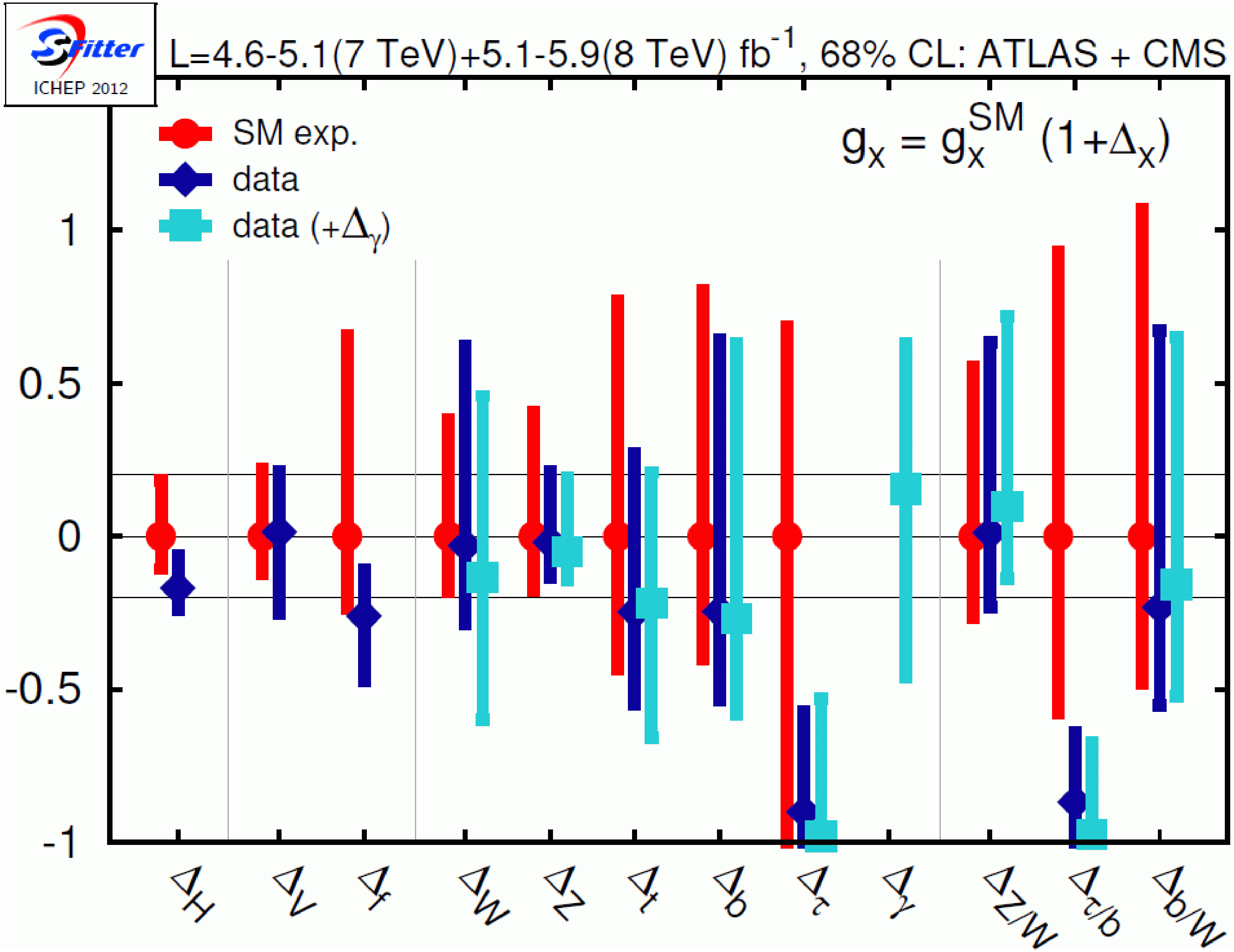
⇒ theory assumptions on total width necessary!

Fit 4:

Allow additionally loop contributions in $H \to \gamma\gamma$: Δ_γ

Coupling fits from SFitter:

[SFitter '12]



⇒ no deviation from the SM observed (within the uncertainties)

3. The MSSM and the Higgs boson(s):

Supersymmetry: Symmetry between

$$\text{Bosons} \leftrightarrow \text{Fermions}$$

$$Q\ |\text{Fermion}\rangle \rightarrow |\text{Boson}\rangle$$
$$Q\ |\text{Boson}\rangle \rightarrow |\text{Fermion}\rangle$$

Simplified examples:

$$Q\ |\text{top},\ t\rangle \rightarrow |\text{scalar top},\ \tilde{t}\rangle$$
$$Q\ |\text{gluon},\ g\rangle \rightarrow |\text{gluino},\ \tilde{g}\rangle$$

⇒ each SM multiplet is enlarged to its double size

Unbroken SUSY: All particles in a multiplet have the same mass

Reality: $m_e \neq m_{\tilde{e}}$ ⇒ SUSY is broken . . .

. . . via soft SUSY-breaking terms in the Lagrangian (added by hand)

SUSY particles are made heavy: $\boxed{M_{\text{SUSY}} = \mathcal{O}(1\ \text{TeV})}$

Supersymmetry: Motivation

The SM is in a pretty good shape.

Why MSSM? (Is it worth to double the particle spectrum?)

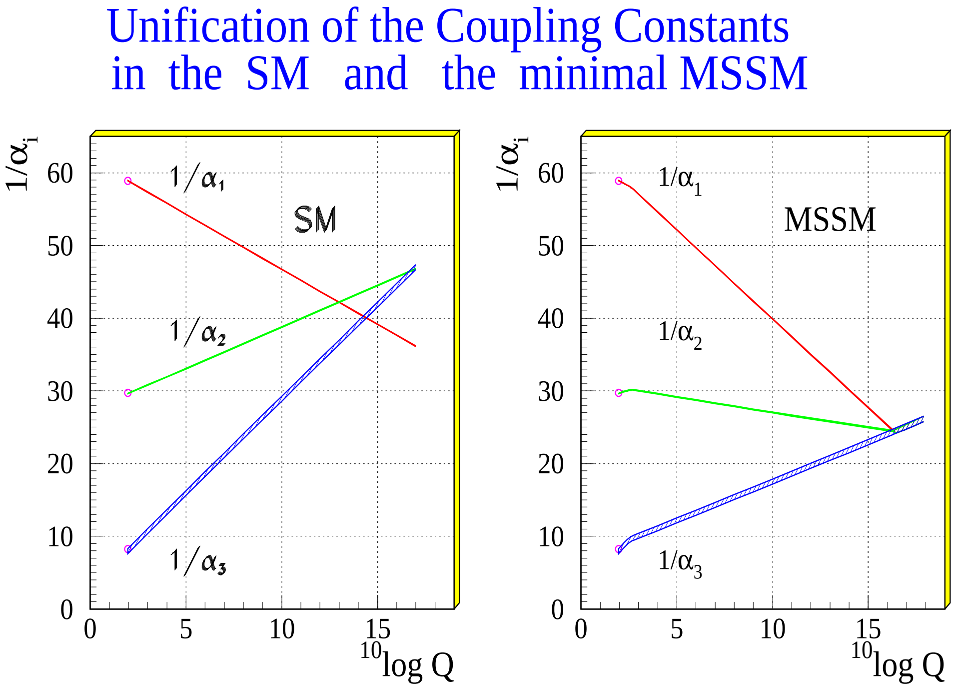
1.) Stability of the Higgs mass against higher-order corr.

2.) Unification of gauge couplings: Not possible in the SM, but in the MSSM (although it was not designed for it.)

3.) Spontaneous symmetry breaking via Higgs mechanism is automatic in SUSY GUTs

4.) SUSY provides CDM candidate

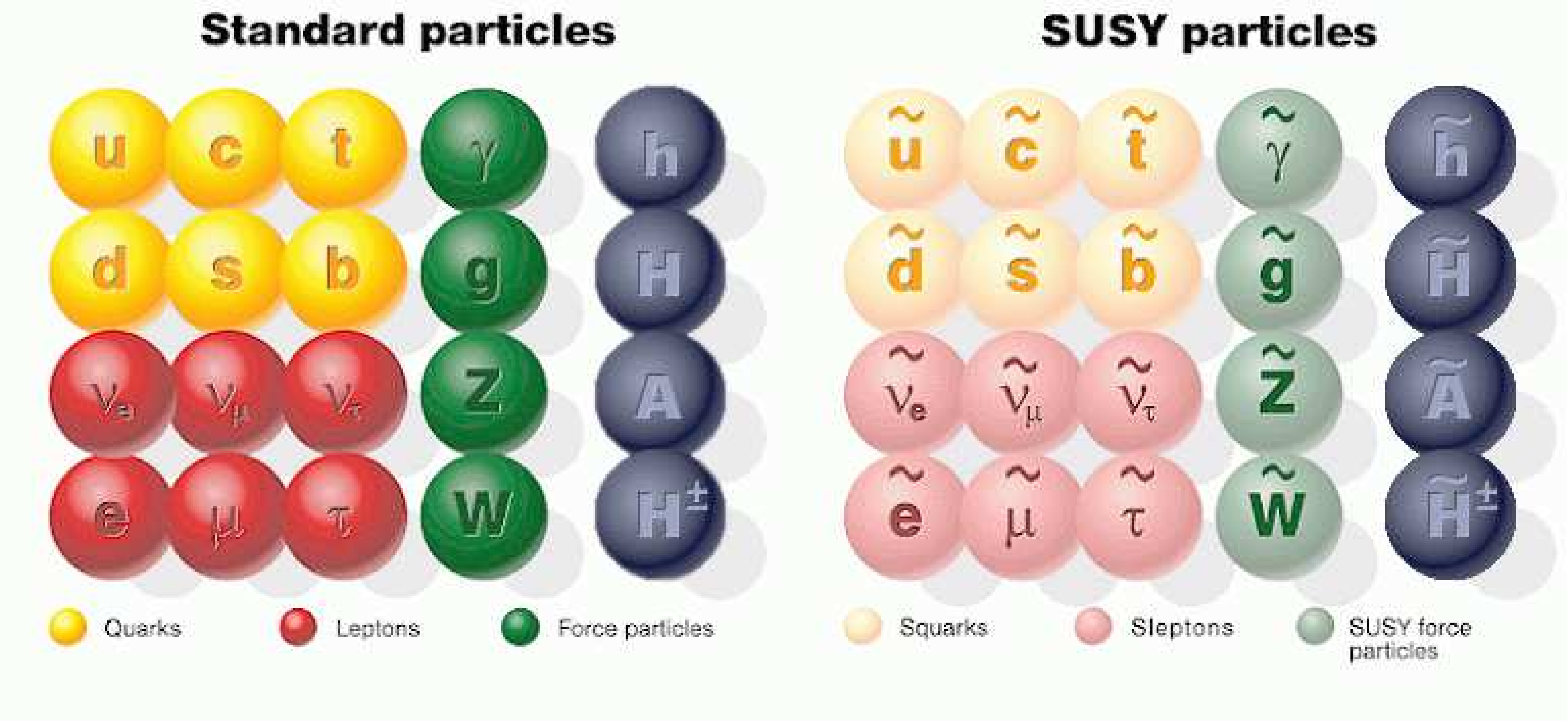
5.) . . .



[Amaldi, de Boer, Fürstenau '92]

The Minimal Supersymmetric Standard Model (MSSM)

Superpartners for Standard Model particles



Example for GUT based models: CMSSM

⇒ Scenario characterized by

$$m_0,\ m_{1/2},\ A_0,\ \tan\beta,\ \text{sign}\,\mu$$

$$\left.\begin{array}{l} m_0 : \text{universal scalar mass parameter} \\[1em] m_{1/2} : \text{universal gaugino mass parameter} \\[1em] A_0 : \text{universal trilinear coupling} \end{array}\right\}\ \text{at the GUT scale}$$

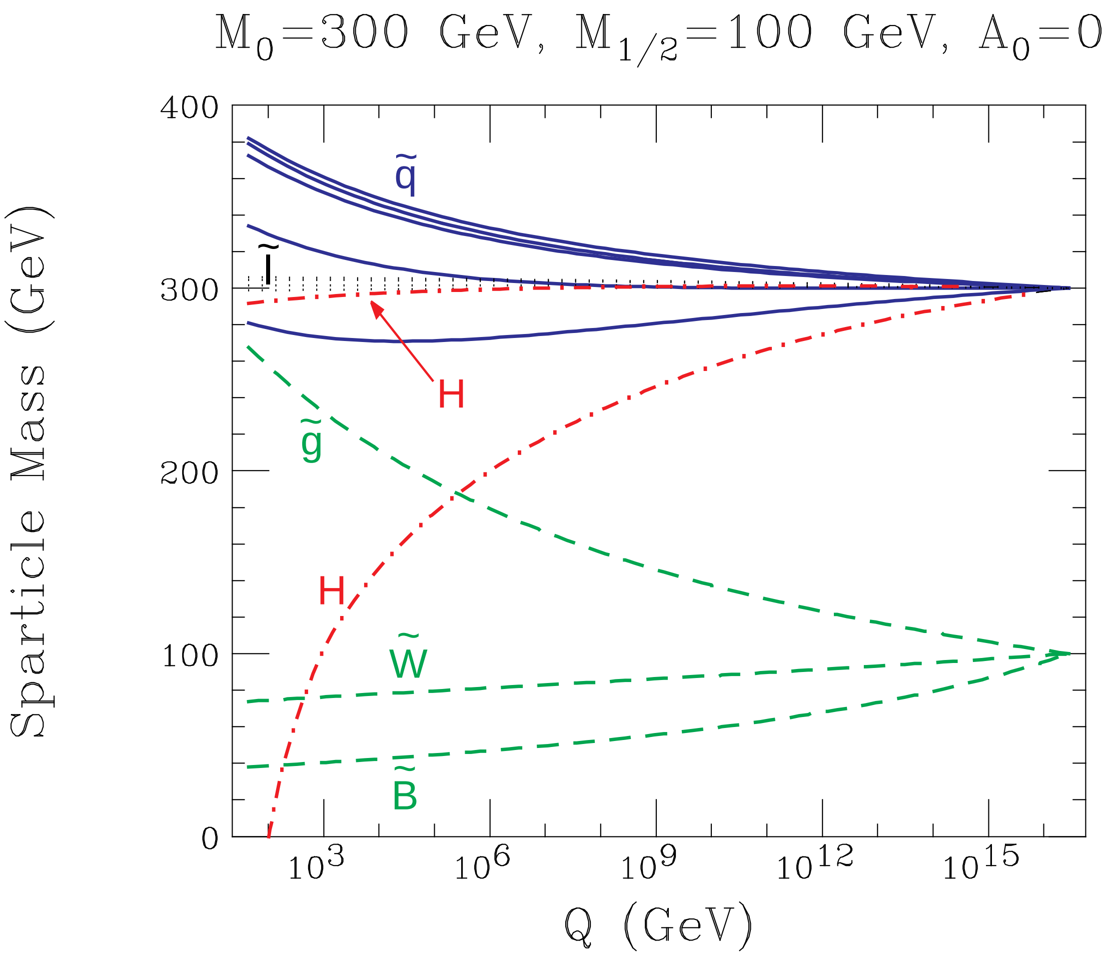
$\tan\beta$: ratio of Higgs vacuum expectation values

sign(μ) : sign of supersymmetric Higgs parameter

⇒ particle spectra from renormalization group running to weak scale

⇒ Lightest SUSY particle (LSP) is the lightest neutralino

⇒ particle spectra from renormalization group running to weak scale



⇒ one parameter turns negative ⇒ Higgs mechanism for free

Comparison of the MSSM Higgs sector with SM case:

$$\mathcal{L}_{\mathrm{SM}} = \underbrace{m_d \bar{Q}_L \Phi d_R}_{\text{d-quark mass}} + \underbrace{m_u \bar{Q}_L \Phi_c u_R}_{\text{u-quark mass}}$$

$$Q_L = \begin{pmatrix} u \\ d \end{pmatrix}_L , \quad \Phi_c = i\sigma_2 \Phi^*, \quad \Phi \to \begin{pmatrix} 0 \\ v \end{pmatrix}, \quad \Phi_c \to \begin{pmatrix} v \\ 0 \end{pmatrix}$$

In SUSY: term $\bar{Q}_L \Phi^*$ not allowed

Superpotential is holomorphic function of chiral superfields, i.e. depends only on φ_i, not on φ_i^*

No soft SUSY-breaking terms allowed for chiral fermions

$\Rightarrow$ $H_d (\equiv H_1)$ and $H_u (\equiv H_2)$ needed to give masses to down- and up-type fermions

Furthermore: two doublets also needed for cancellation of anomalies, quadratic divergences

Enlarged Higgs sector: Two Higgs doublets

$$H_1 = \begin{pmatrix} H_1^1 \\ H_1^2 \end{pmatrix} = \begin{pmatrix} v_1 + (\phi_1 + i\chi_1)/\sqrt{2} \\ \phi_1^- \end{pmatrix}$$

$$H_2 = \begin{pmatrix} H_2^1 \\ H_2^2 \end{pmatrix} = \begin{pmatrix} \phi_2^+ \\ v_2 + (\phi_2 + i\chi_2)/\sqrt{2} \end{pmatrix}$$

$$V = m_1^2 H_1 \bar{H}_1 + m_2^2 H_2 \bar{H}_2 - m_{12}^2 (\epsilon_{ab} H_1^a H_2^b + \text{h.c.})$$

$$+ \underbrace{\frac{g'^2 + g^2}{8}} (H_1 \bar{H}_1 - H_2 \bar{H}_2)^2 + \underbrace{\frac{g^2}{2}} |H_1 \bar{H}_2|^2$$

gauge couplings, in contrast to SM $\Rightarrow m_h \leq M_Z$

physical states: $h^0, H^0, A^0, H^\pm$ Goldstone bosons: $G^0, G^\pm$

Input parameters: (to be determined experimentally)

$$\tan\beta = \frac{v_2}{v_1}, \qquad M_A^2 = -m_{12}^2 (\tan\beta + \cot\beta)$$

The lightest MSSM Higgs boson

MSSM predicts upper bound on M_h:

tree-level bound: $m_h < M_Z$, excluded by LEP Higgs searches!

Large radiative corrections:

Yukawa couplings: $\frac{\mathrm{e}\, m_t}{2 M_W s_\mathrm{W}}, \frac{\mathrm{e}\, m_t^2}{M_W s_\mathrm{W}}, \ldots$

⇒ Dominant one-loop corrections: $\Delta M_h^2 \sim G_\mu m_t^4 \log\left(\frac{m_{\tilde{t}_1} m_{\tilde{t}_2}}{m_t^2}\right)$

The MSSM Higgs sector is connected to all other sector via loop corrections (especially to the scalar top sector)

Present status of M_h prediction in the MSSM:

Complete one-loop, "almost complete" two-loop,
very leading three-loop results available

Upper bound on M_h in the MSSM:

"Unconstrained MSSM":

M_A, $\tan\beta$, 5 parameters in $\tilde{t}$–$\tilde{b}$ sector, μ, $m_{\tilde{g}}$, M_2

$$\boxed{M_h \lesssim 135 \text{ GeV}}$$

for $m_t = 173.2 \pm 0.9\,\text{GeV}$

(including theoretical uncertainties from unknown higher orders)

Obtained with:

FeynHiggs

`www.feynhiggs.de`

[*T. Hahn, S.H., W. Hollik, H. Rzehak, G. Weiglein (K. Williams) '98 – '12*]

→ all Higgs masses, couplings, BRs, XSs (easy to link, easy to use :-)

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The decoupling limit:

For $M_A \gtrsim 150$ GeV:

The lightest MSSM Higgs
is SM-like

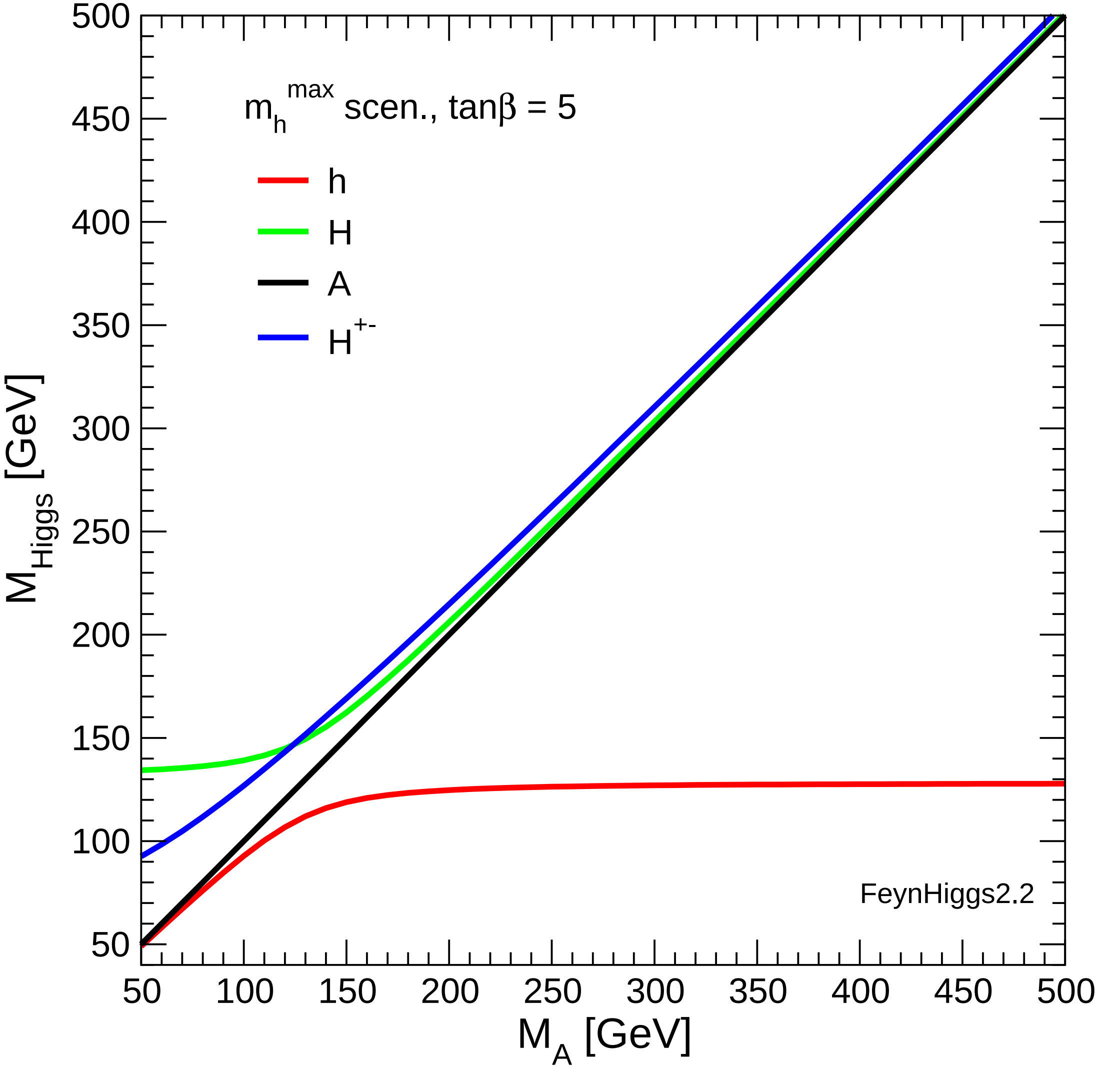
$\Rightarrow$ SM analysis applies!

The heavy MSSM Higgses:

$M_A \approx M_H \approx M_{H^\pm}$

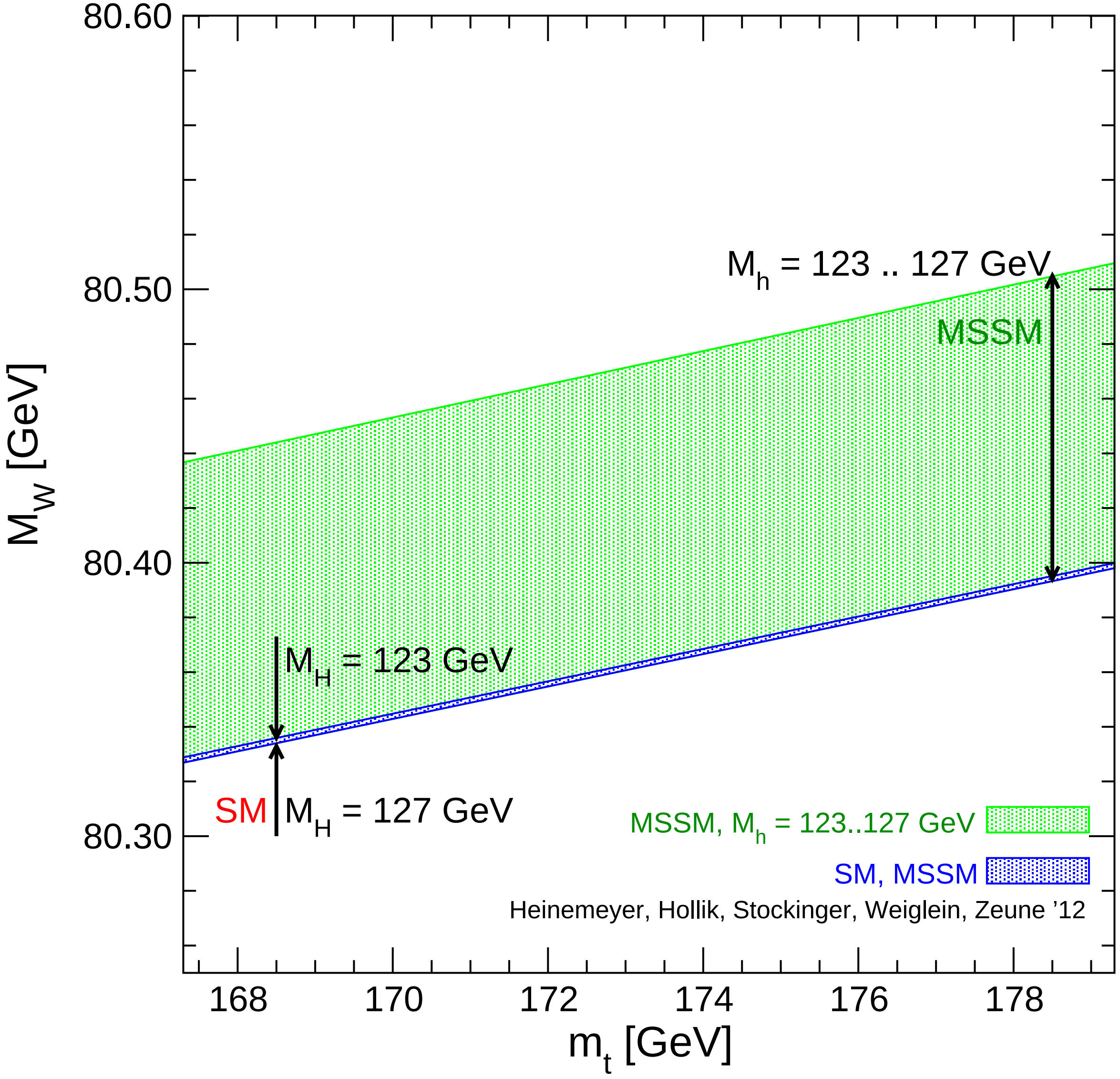
$\rightarrow$ coupling to gauge bosons ~ 0

$\Rightarrow$ no decay $H \to WW^{(*)}$, . . .



Prediction for M_W in the SM and the MSSM :

[*S.H., W. Hollik, D. Stockinger, G. Weiglein, L. Zeune '12*]



MSSM band:

scan over

SUSY masses

overlap:

SM is MSSM-like

MSSM is SM-like

SM band:

variation of M_H^{SM}

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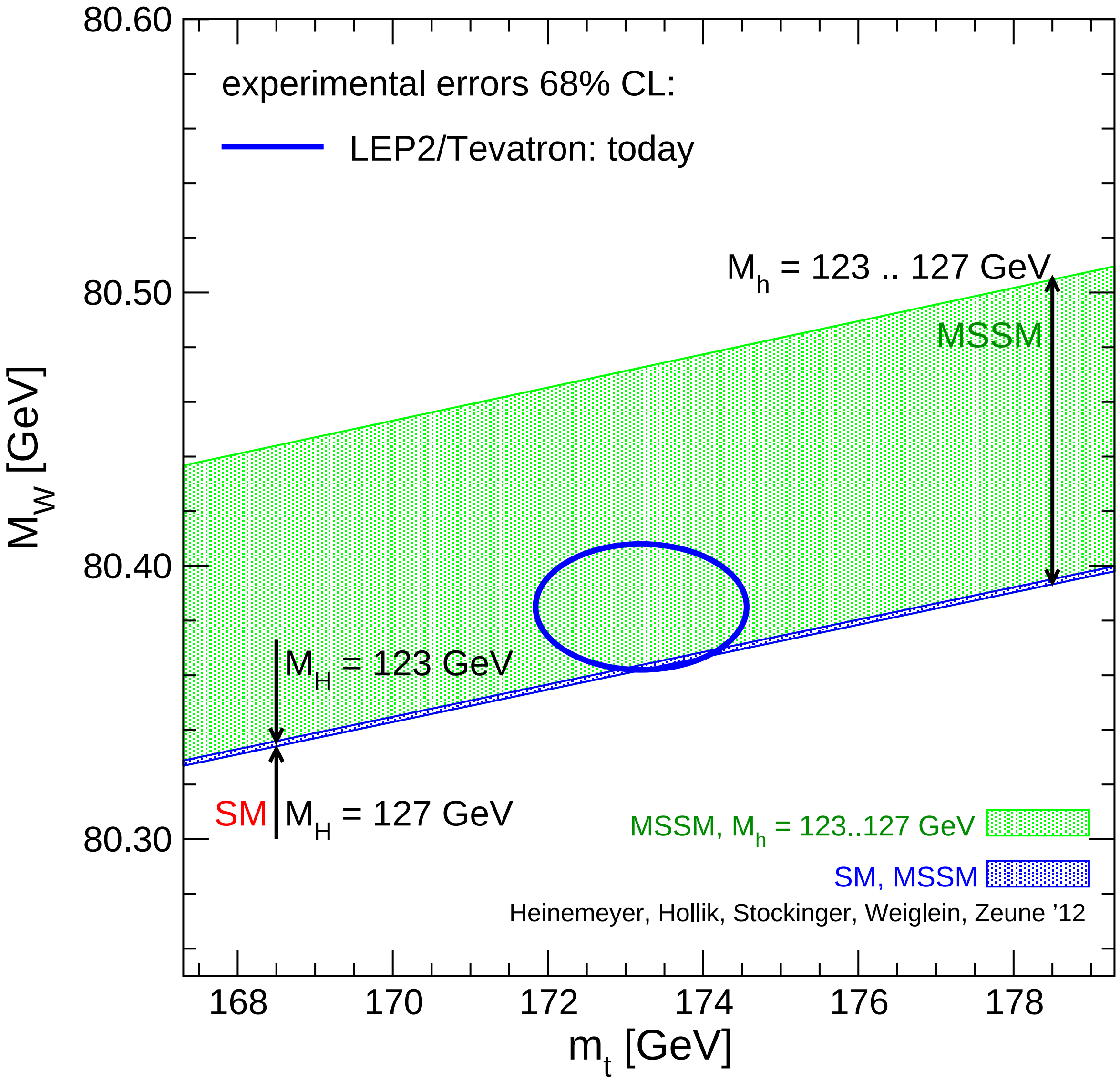

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Indirect constraints on M_h from existing data?

- Electroweak precision observables (EWPO) ?
- B physics observables (BPO) ?
- Cold dark matter (CDM) ?
- SUSY/Higgs data ?

  $\Rightarrow$ combination of EWPO, BPO, CDM, SUSY/Higgs ?

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SUSY limits: information on $m_{\tilde{q}_{1,2}}$, $m_{\tilde{g}}$

Higgs results: informatin on $m_{\tilde{t}}, m_{\tilde{b}}, \ldots$

EWPO $(g-2)_\mu$: information on $\tan\beta$ and/or $m_{\tilde{\chi}^0}$, $m_{\tilde{\chi}^\pm}$ and/or $m_{\tilde{\mu}}$, $m_{\tilde{\nu}_\mu}$

BPO BR$(b \to s\gamma)$: information on $\tan\beta$ and/or $M_{H^\pm}$ and/or $m_{\tilde{t}}$, $m_{\tilde{\chi}^\pm}$

CDM (LSP gives CDM) : information on $m_{\tilde{\chi}_1^0}$ and $m_{\tilde{\tau}}$ or M_A or . . .

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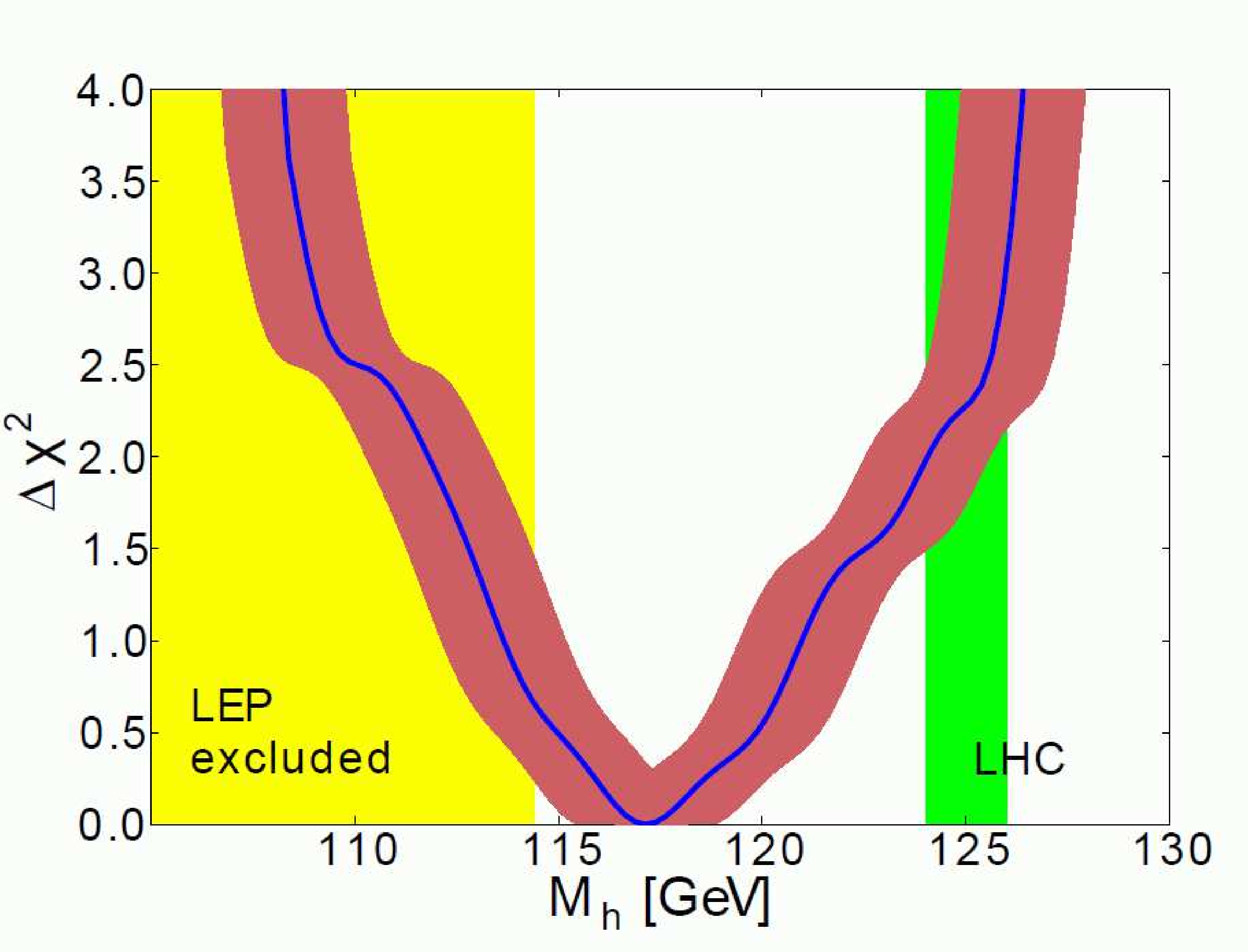
$\Rightarrow$ combination (so far) makes only sense if all parameters are connected!
$\Rightarrow$ GUT based models, ... $\Rightarrow$ M_h in the CMSSM!

CMSSM: post-LHC (5+5 fb^{-1}) red band plot:

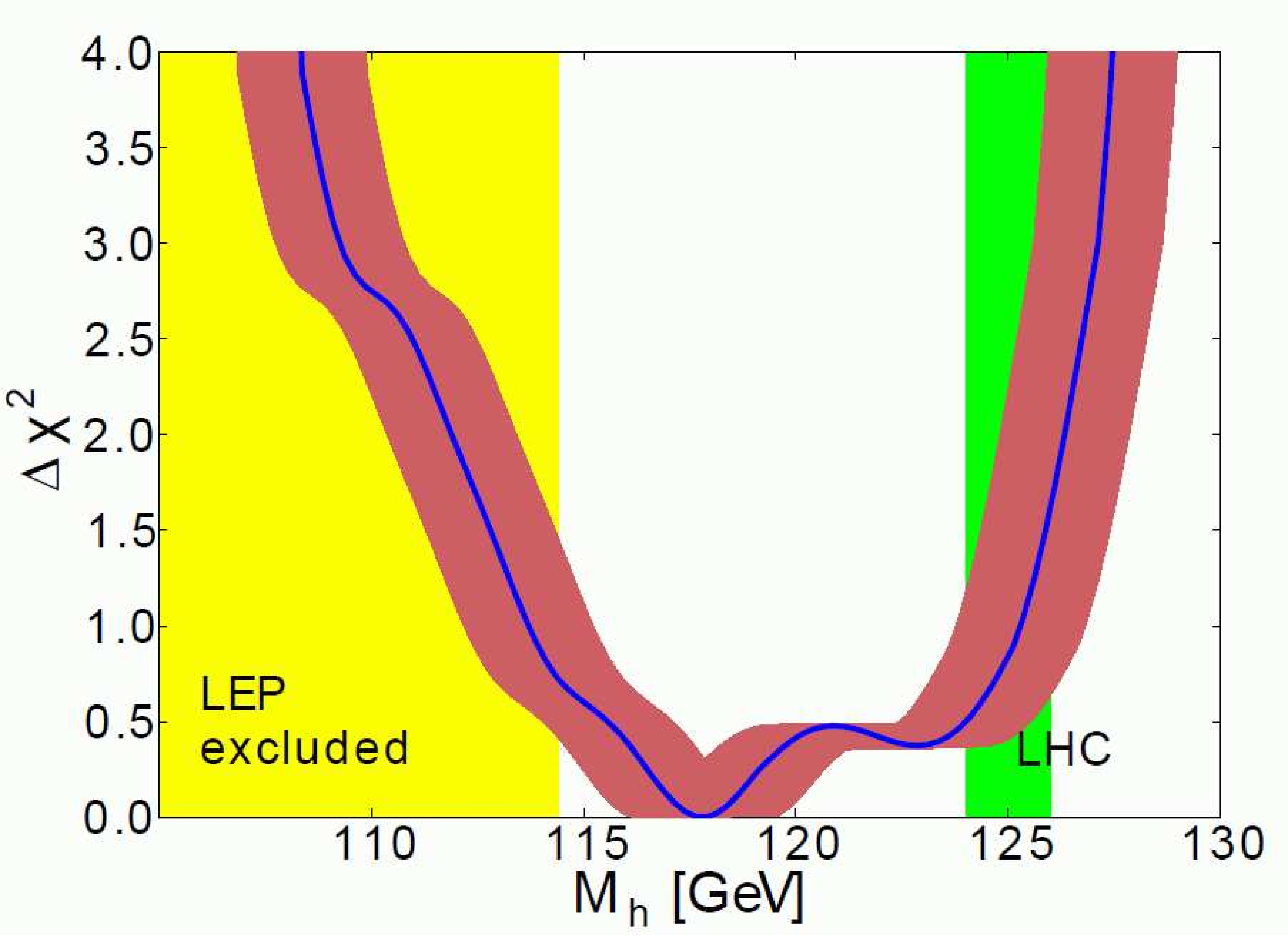
[2012]



$M_h = 117 \pm 4\,(\text{exp}) \pm 1.5(\text{theo})$ GeV $\quad \Delta\chi^2(M_h = 125 \text{ GeV}) \lesssim 2$

NUHM1: post-LHC (5+5 fb^{-1}) red band plot:

[2012]



$M_h \approx 118^{+7}_{-4}$ (exp) $\pm\, 1.5$(theo) GeV $\quad \Delta\chi^2(M_h = 125$ GeV$) \approx 0.5$

pMSSM7 analysis for the various enhancements/suppressions:

[*P. Bechtle, S.H. O. Stål, T. Stefaniak, G. Weiglein, L. Zeune '12*]

Some details on the pMSSM7 scan:

	Min	Max
M_A	90 GeV	1000 GeV
$\tan\beta$	1	60
M_{Q_3}	200 GeV	1500 GeV
A_t	$-3M_{Q_3}$	$+3M_{Q_3}$
μ	200 GeV	3000 GeV
M_{L_3}	200 GeV	1500 GeV
M_2	200 GeV	500 GeV

$M_{Q_{1,2}} = M_{U_{1,2}} = M_{D_{1,2}} = 1$ TeV

$M_{D_3} = M_{U_3} = M_{Q_3}$

$M_{L_{1,2}} = M_{E_{1,2}} = 300$ GeV

$A_b = A_\tau = A_t$

$M_3 = 1$ TeV

M_1 fixed by GUT relation

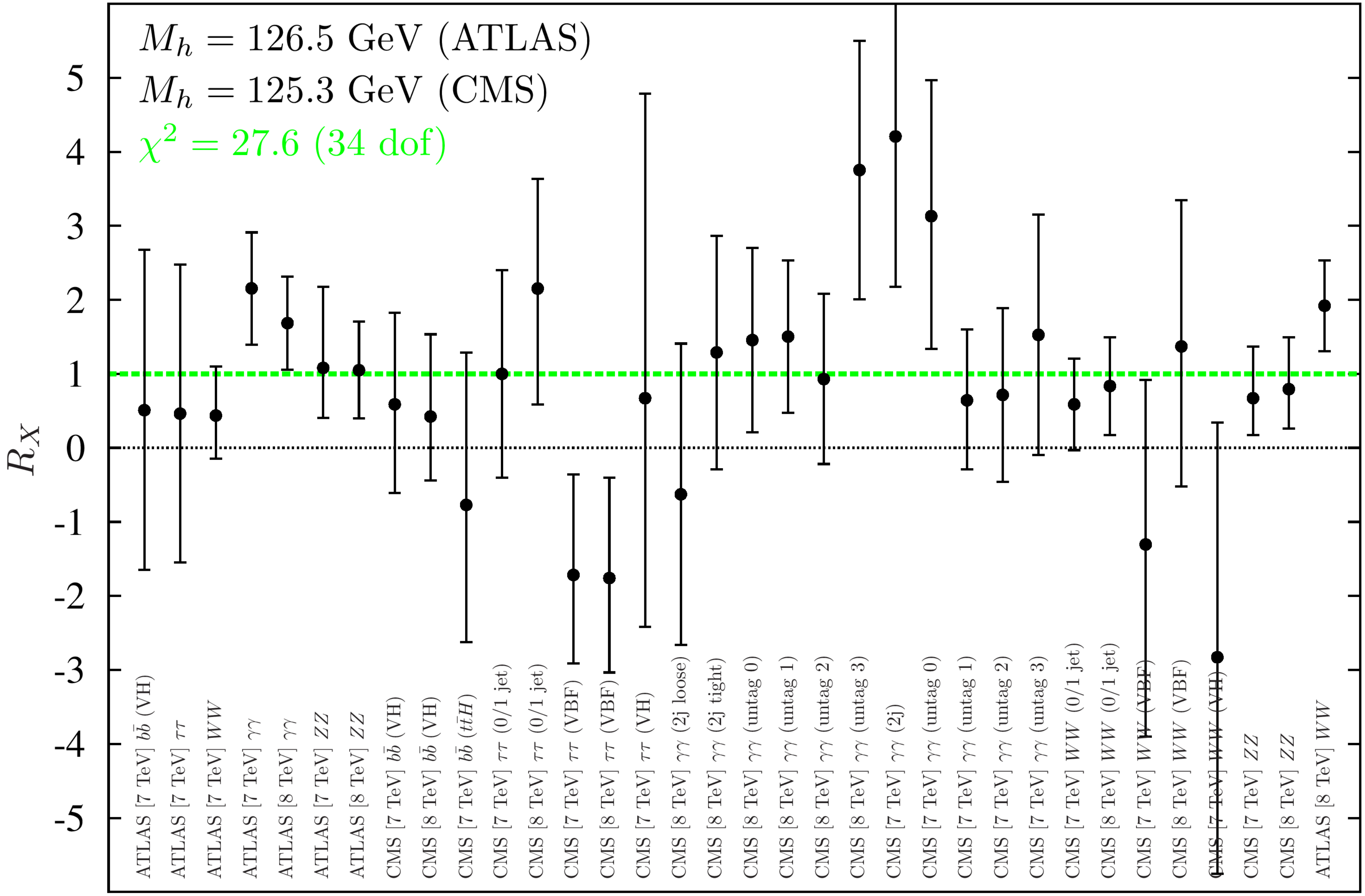
10^7 random points

MSSM predictions from FeynHiggs

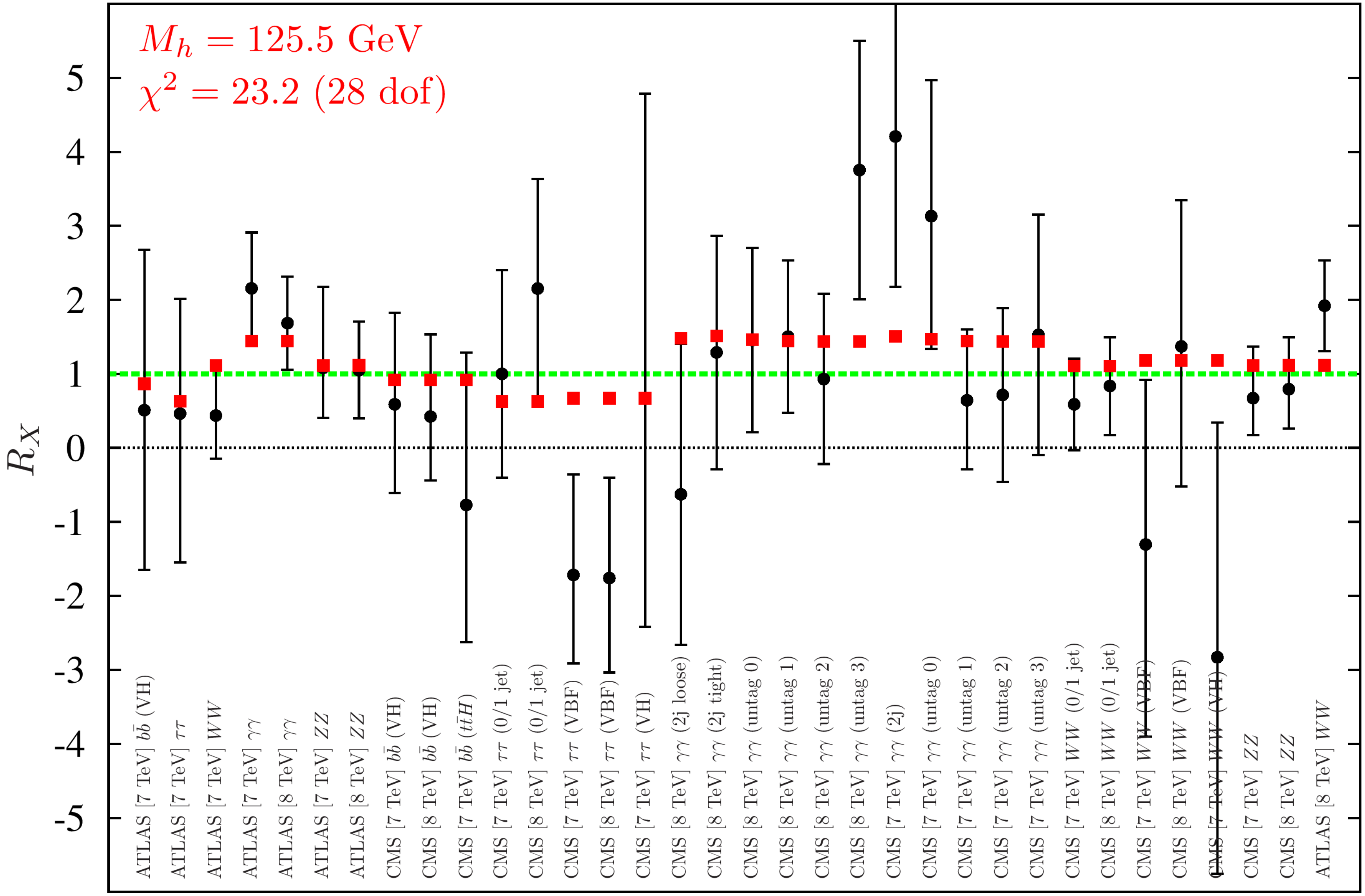
Higgs constraints from HiggsBounds

⇒ "naive" χ^2 evaluation

LHC data set (pre HCP):



Best fit for light Higgs:



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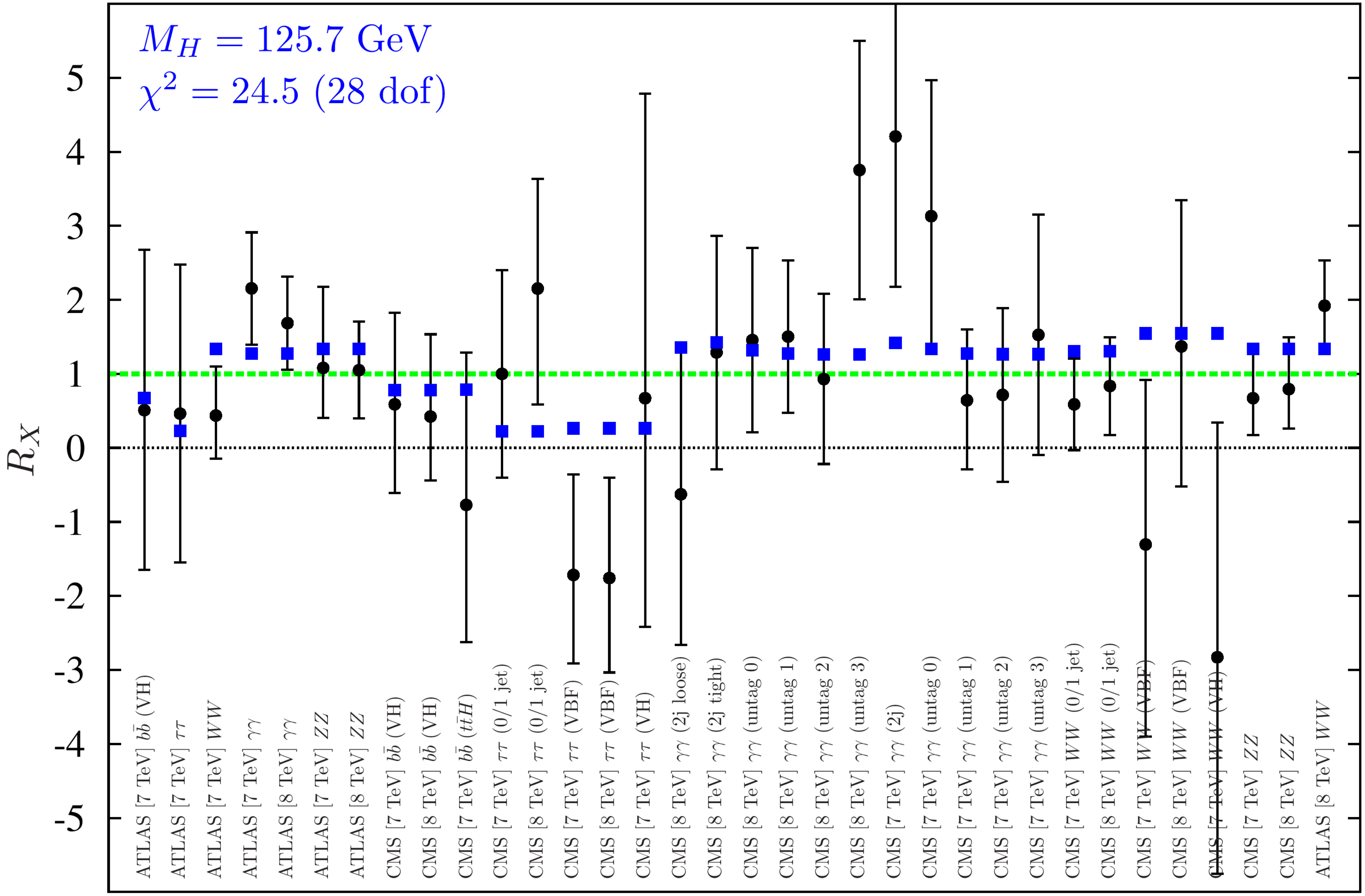
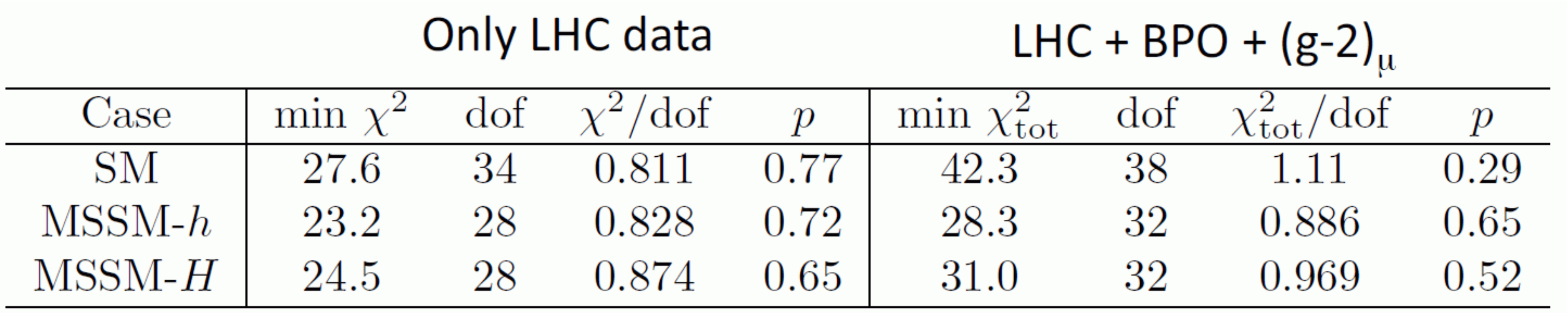


Final χ^2 overview:



	Only LHC data				LHC + BPO + $(g\text{-}2)_\mu$			
Case	min χ^2	dof	χ^2/dof	p	min χ^2_{tot}	dof	$\chi^2_{\text{tot}}/\text{dof}$	p
SM	27.6	34	0.811	0.77	42.3	38	1.11	0.29
MSSM-h	23.2	28	0.828	0.72	28.3	32	0.886	0.65
MSSM-H	24.5	28	0.874	0.65	31.0	32	0.969	0.52

BPO: BR($b \to s\gamma$), BR($B_s \to \mu^+\mu^-$), BR($B_u \to \tau\nu_\tau$)

Observations:

– SM fits well (too good?)

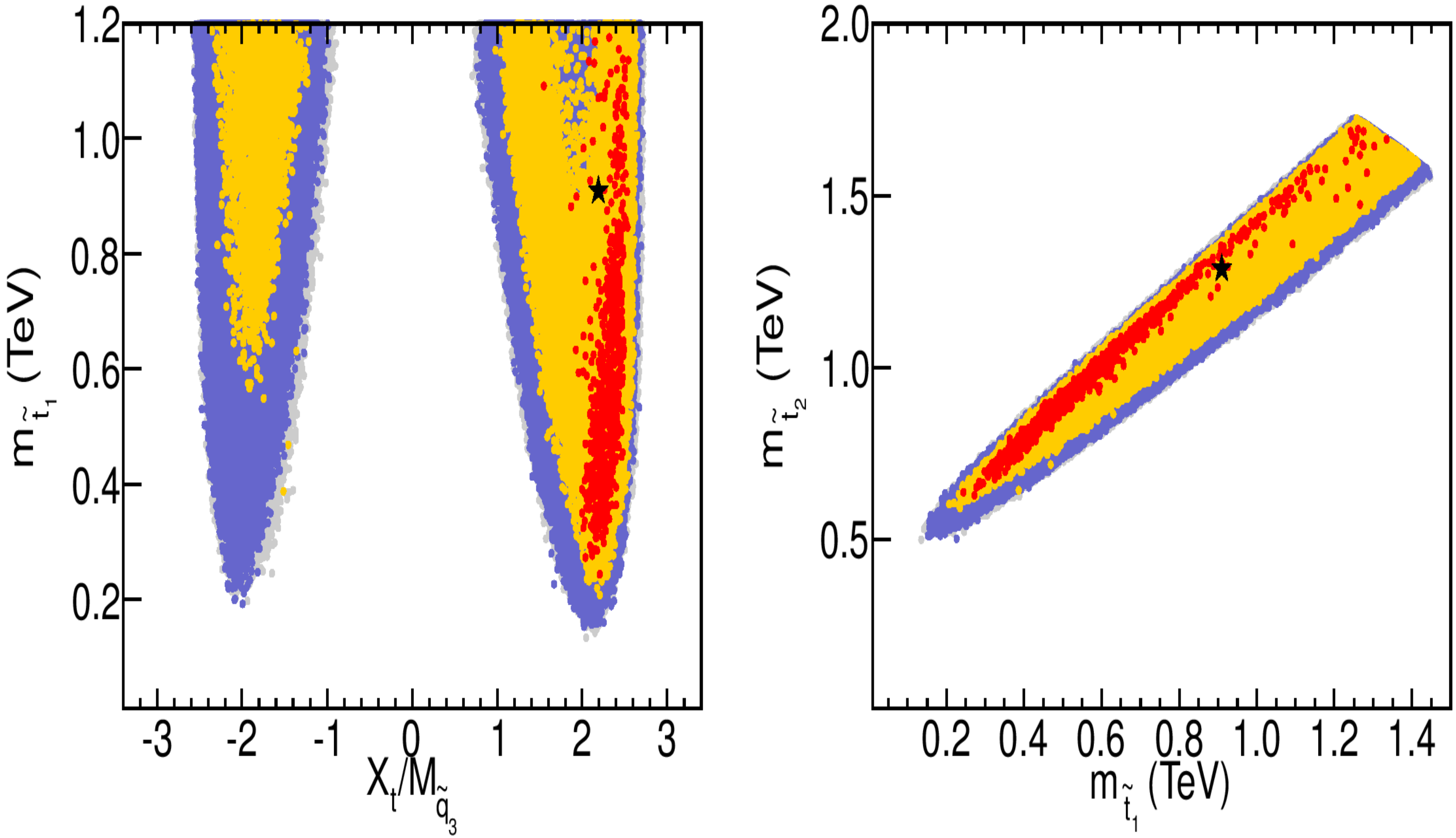
– MSSM-h fits at least equally well

– MSSM-H fits also quite well

– SM takes hit from $(g-2)_\mu$

$\Rightarrow$ more data needed to clarify the situation!

Stop masses for the "light Higgs case":



⇒ light stops compatible with $M_h \simeq 126$ GeV

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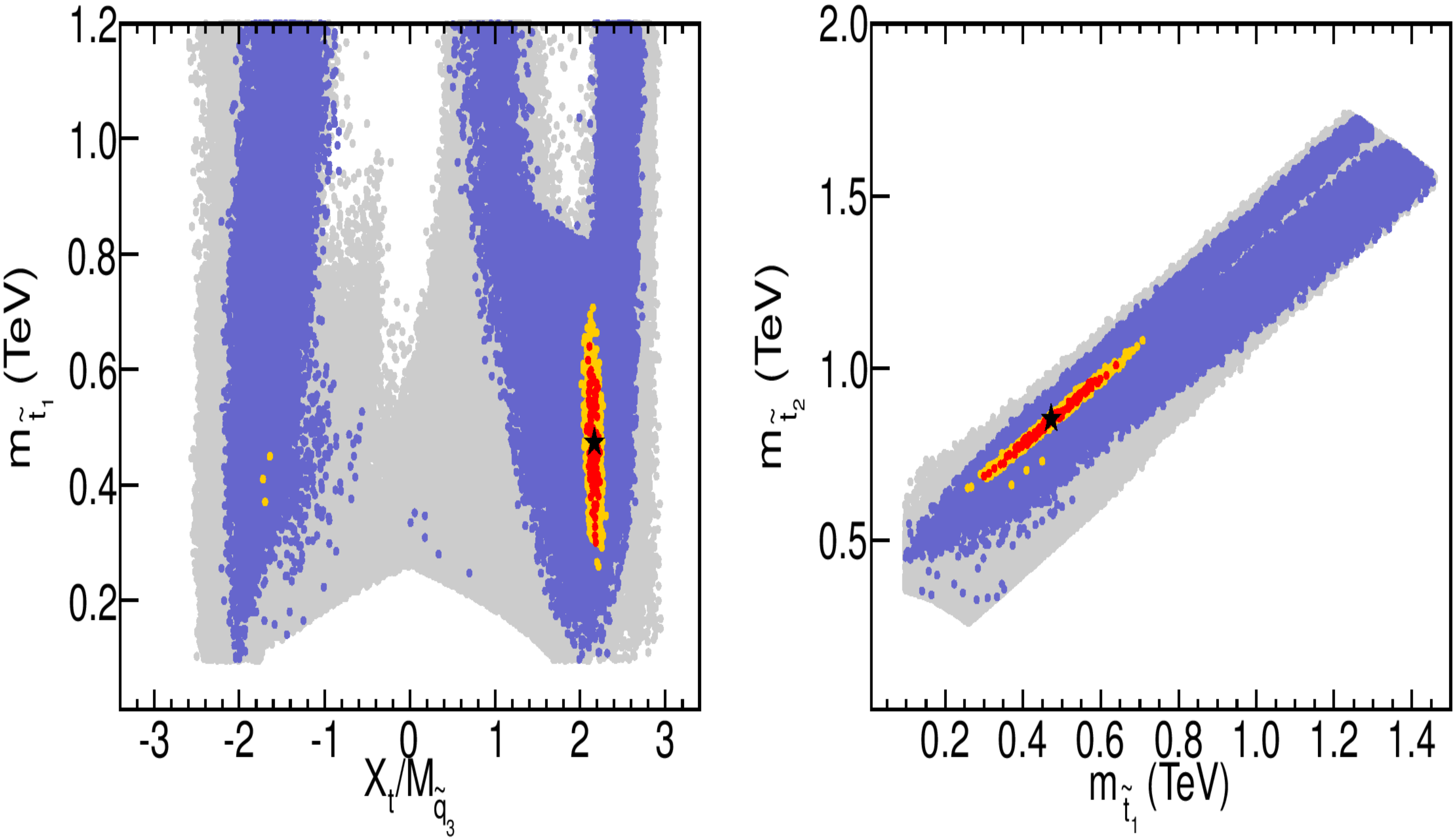
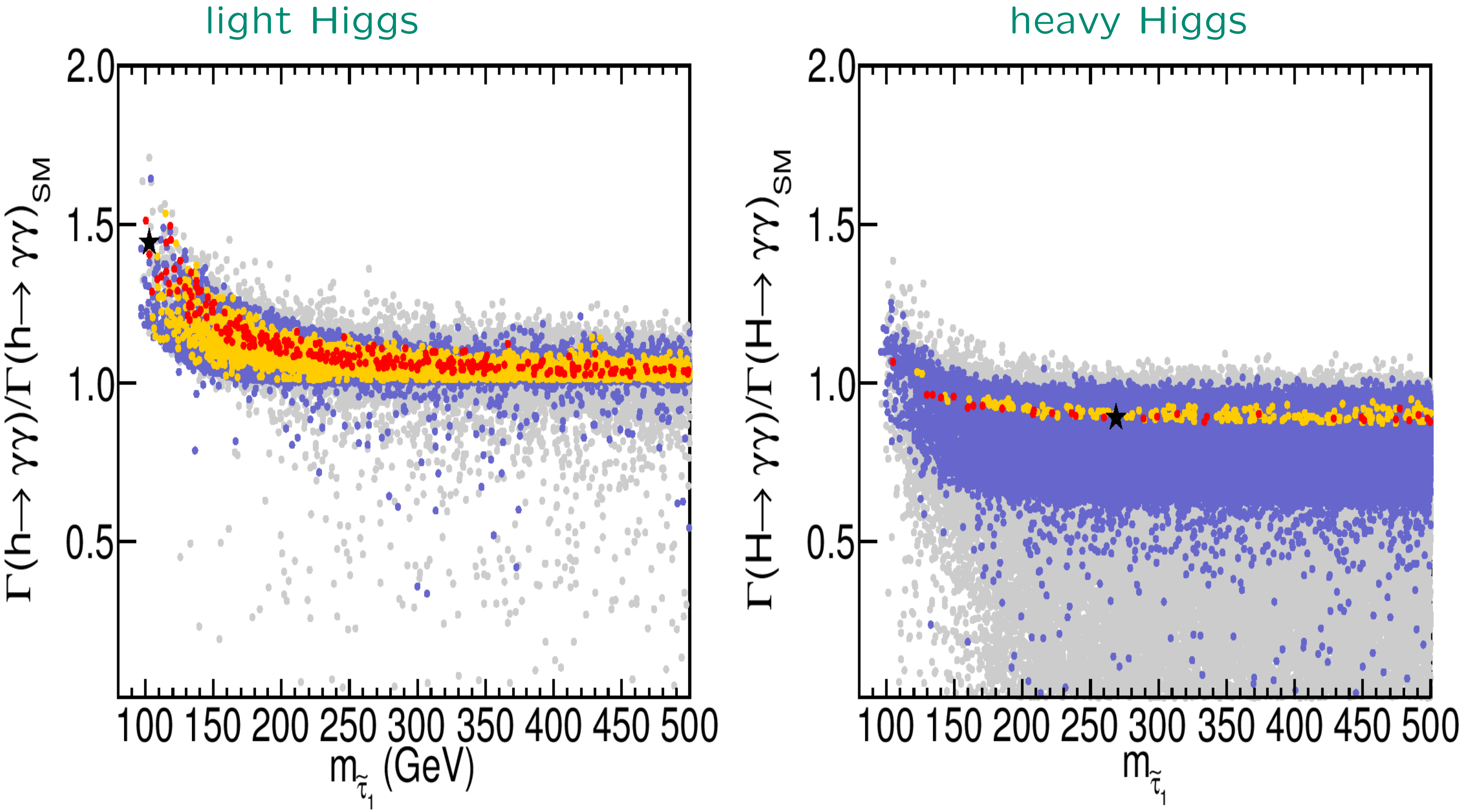


⇒ light stops compatible with $M_H \simeq 126$ GeV

Enhancement of $\Gamma(h, H \to \gamma\gamma)$ from light staus?



⇒ light staus can enhance $\Gamma(h \to \gamma\gamma)$!

4. Conclusinos

- LHC Higgs searches: we have a **DISCOVERY !!! :-)**

  ⇒ compatible with $M_H \simeq 126$ GeV

- SM: predicts one Higgs boson with free mass
  Mass prediction via EWPO: fits well with $M_H^{\text{SM}} \simeq 126$ GeV

- MSSM: predicts five Higgs bosons, $M_h \lesssim 135$ GeV
  ⇒ Higgs mass was predicted correctly!
  GUT based models: fits well with $M_h \simeq 126$ GeV
  two possibilities: light or heavy $\mathcal{CP}$-even Higgs around $\simeq 126$ GeV

- ⇒ slowly approaching coupling determination

- Fit to rates in the pMSSM7:
  SM: fits well (but takes $(g-2)_\mu$ hit)
  MSSM-h: fits equally well (including $(g-2)_\mu$!)
  MSSM-H: fits nearly as well
  ⇒ fits too good?