Prospects for Higgs Physics at CDF

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Paris, 05/2007

1. The SM Higgs boson
2. A SM-like MSSM Higgs boson
3. The light heavy MSSM Higgs bosons
4. A short theorist's wishlist

1. The SM Higgs boson

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:

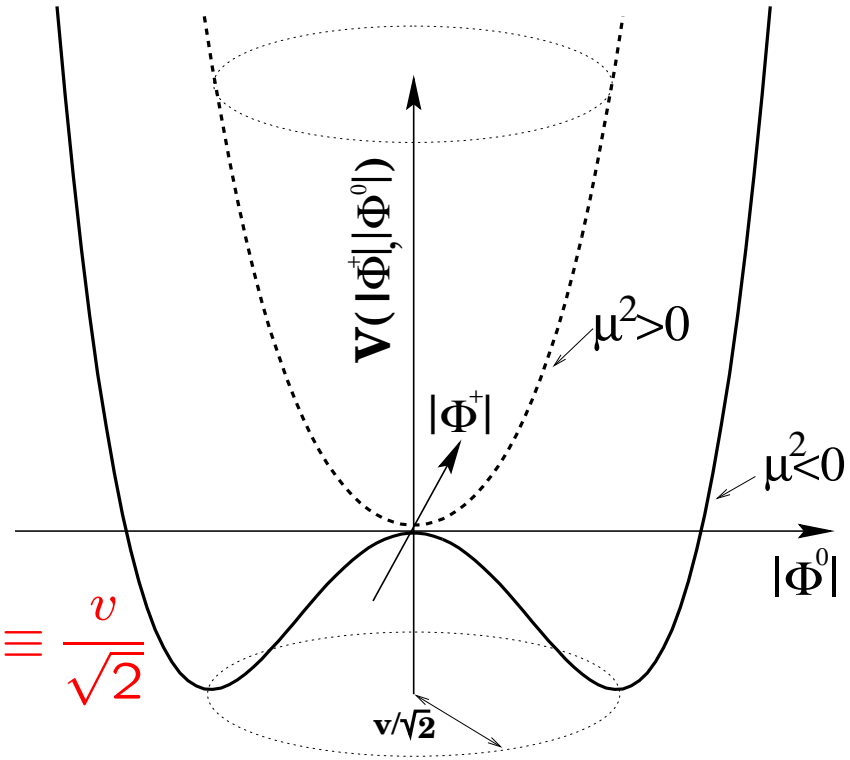
Scalar SU(2) doublet: $\Phi = \begin{pmatrix} \phi^+ \\ \phi^0 \end{pmatrix}$

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 $|\langle \Phi_0 \rangle| = \sqrt{\frac{-\mu^2}{2\lambda}} \equiv \frac{v}{\sqrt{2}}$



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

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

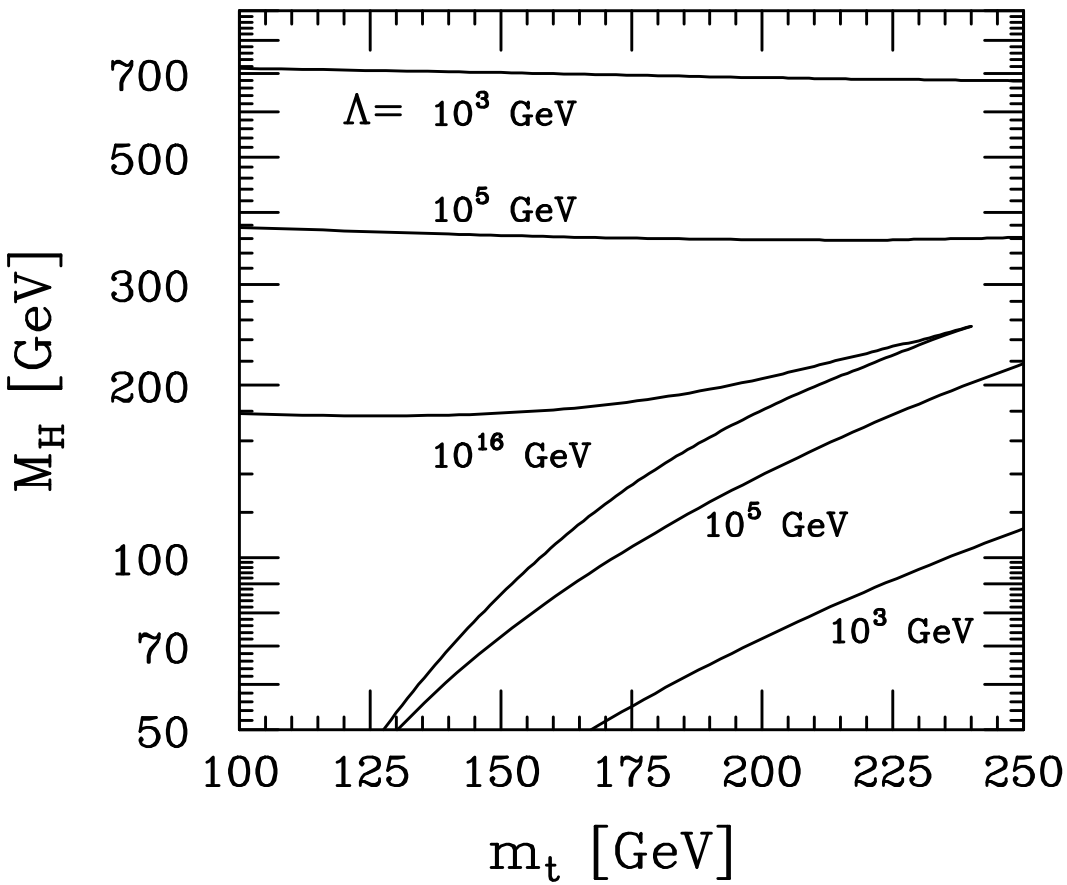
$$\begin{aligned} iD_\mu &= i\partial - g_2 \vec{I}\vec{W} - g_1 Y B \\ \Phi_c &= i\sigma_2 \Phi^\dagger \qquad\qquad Q_L \sim \begin{pmatrix} u_L \\ d_L \end{pmatrix}, \; \Phi \sim \begin{pmatrix} 0 \\ v \end{pmatrix}, \; \Phi_c \sim \begin{pmatrix} v \\ 0 \end{pmatrix} \end{aligned}$$

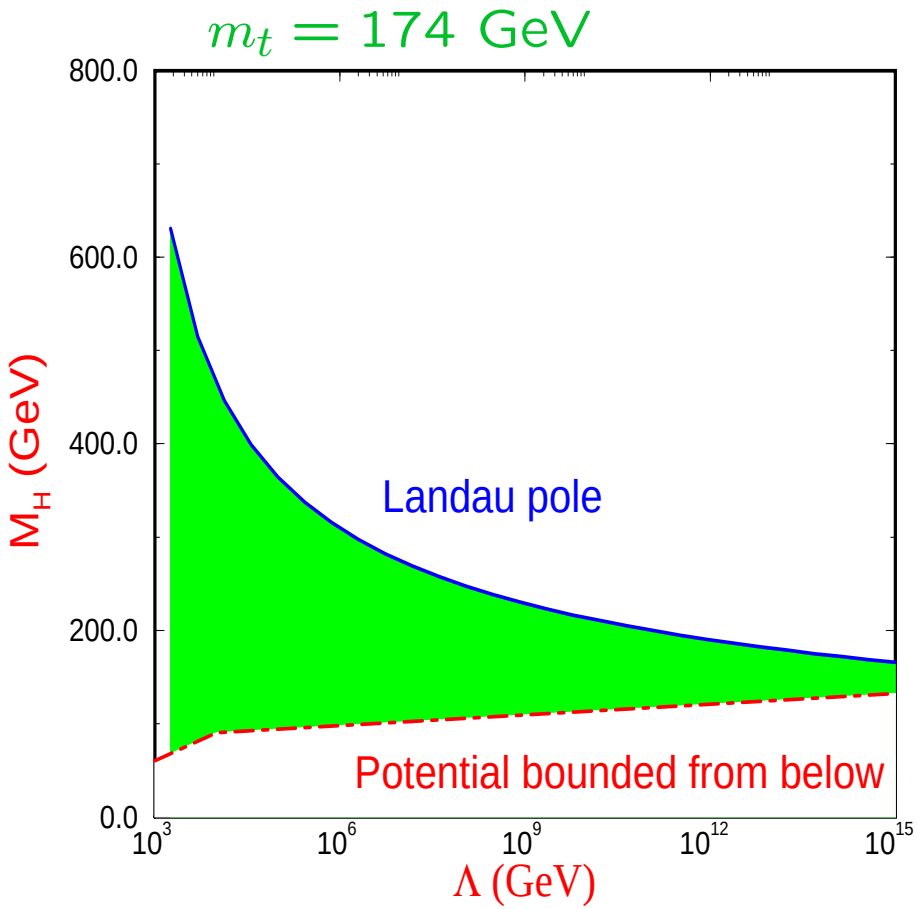
Gauge invariant coupling to gauge fields

$\Rightarrow$ mass terms for gauge bosons and fermions

Theory bounds on M_H:

Perturbativity of Higgs self-coupling & Stability of Potential:





Λ: scale up to which the SM is valid

$\Lambda = M_{\text{GUT}} \Rightarrow 130 \text{ GeV} \lesssim M_H \lesssim 180 \text{ GeV}$

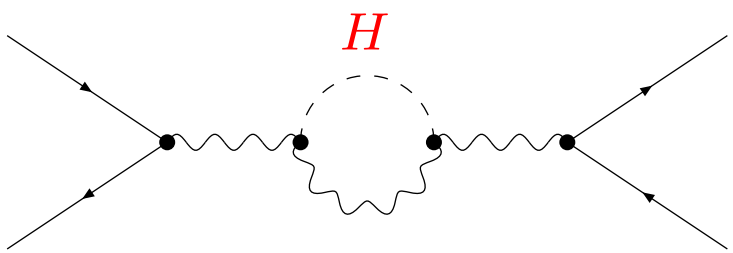
Indirect bounds on M_H: Electroweak Precision Observables (EWPO):

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*]

$$\Delta r_{1-\text{loop}} = \Delta\alpha - \frac{c_W^2}{s_W^2}\Delta\rho + \Delta r_{\text{rem}}(M_H)$$

$$\sim \log\frac{M_Z}{m_f} \qquad \sim m_t^2 \qquad \sim \log(M_H/M_W)$$

$$\sim 6\% \qquad \sim 3.3\% \qquad \sim 1\%$$

Comparison of SM prediction of M_W with direct measurements:

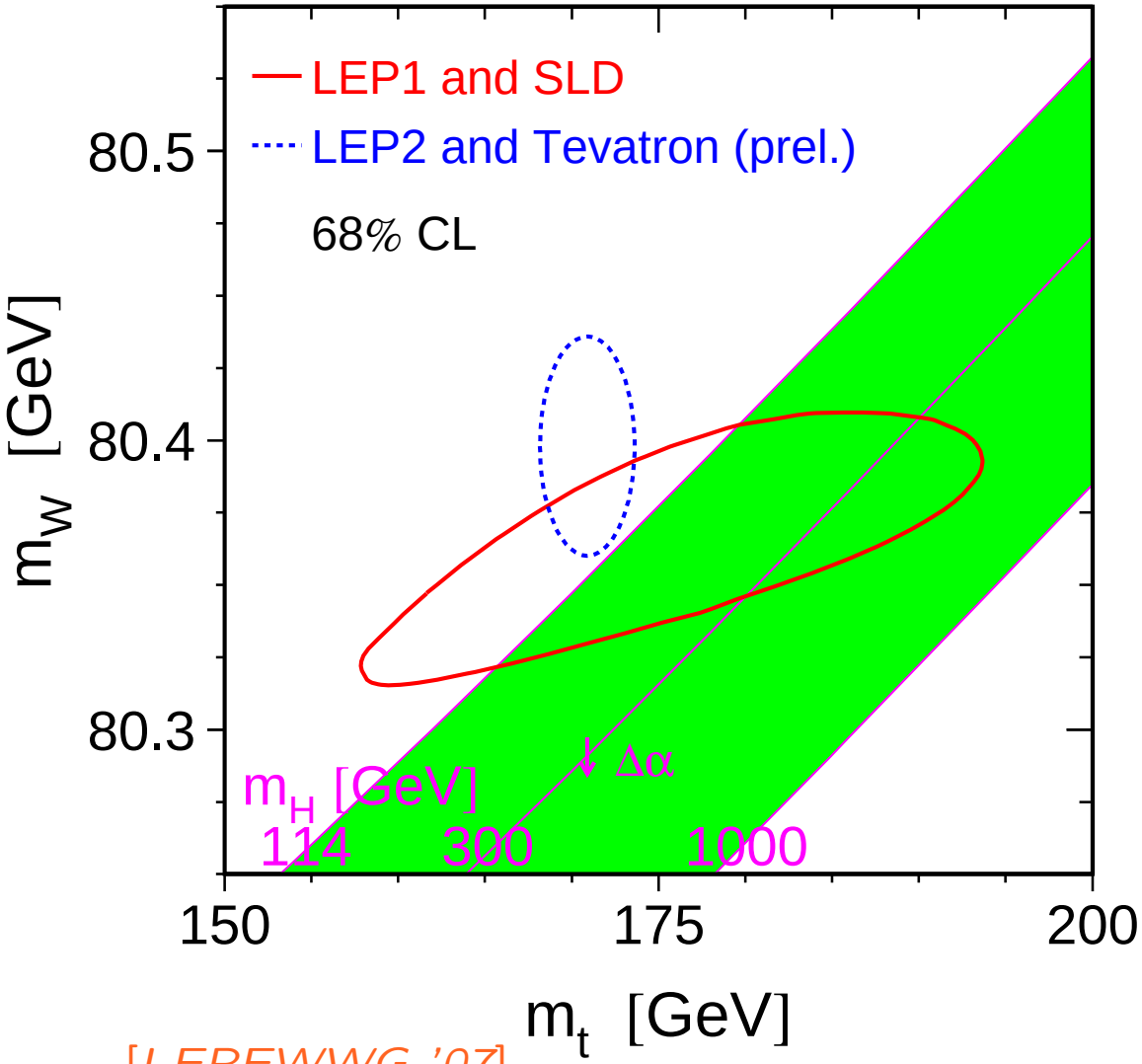
$$\Delta r = -\frac{11 g_2^2}{96\,\pi^2}\frac{s_W^2}{c_W^2}\log\left(\frac{M_H}{M_W}\right)$$

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



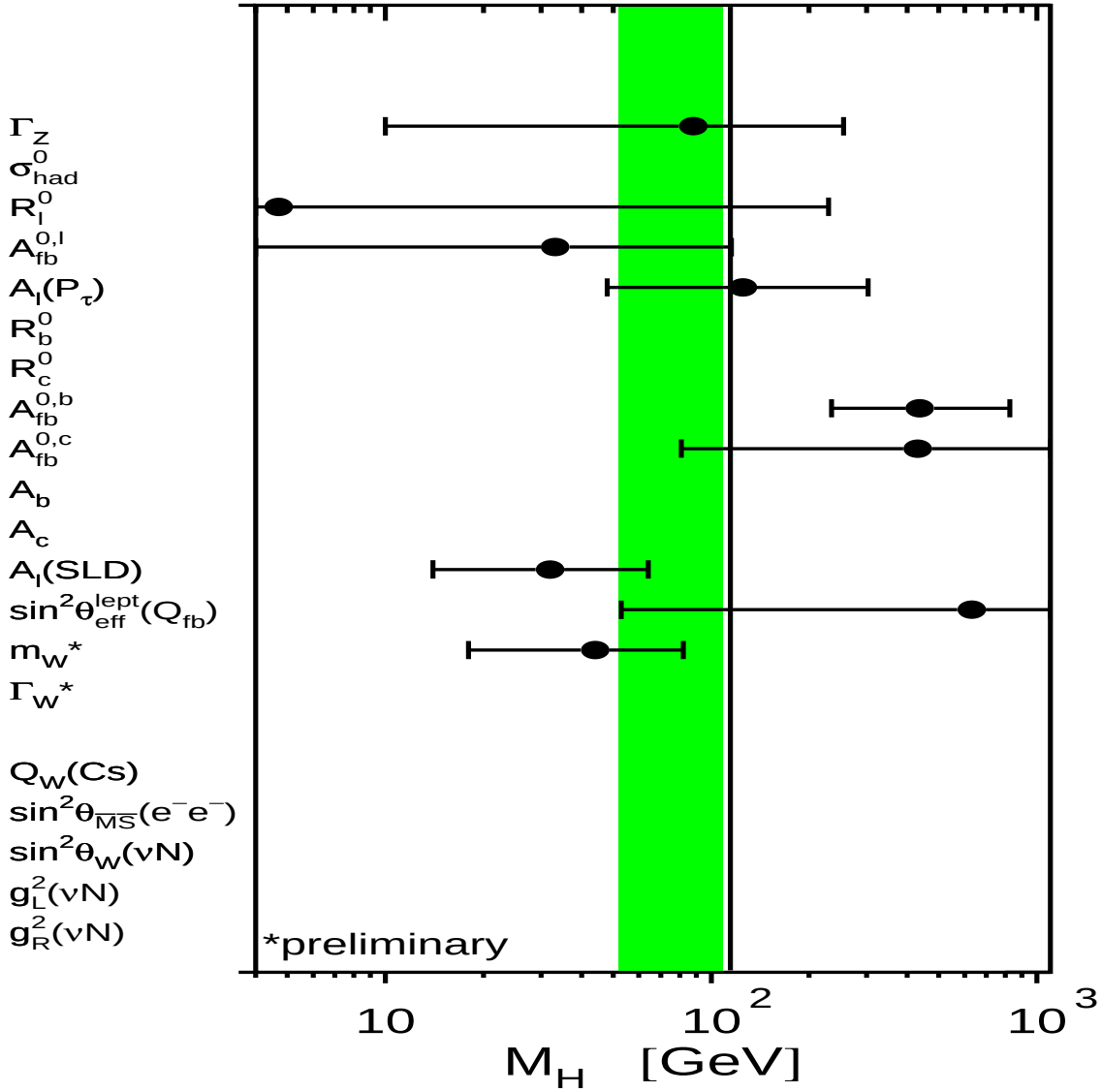
[*LEPEWWG '07*]

⇒ light Higgs boson preferred

Results for M_H from other EWPO:

light Higgs preferred by:
M_W, A_l^{LR} (SLD)

heavier Higgs preferred by:
A_b^{FB} (LEP)
$\Rightarrow$ keeps SM alive



[*LEPEWWG '07*]

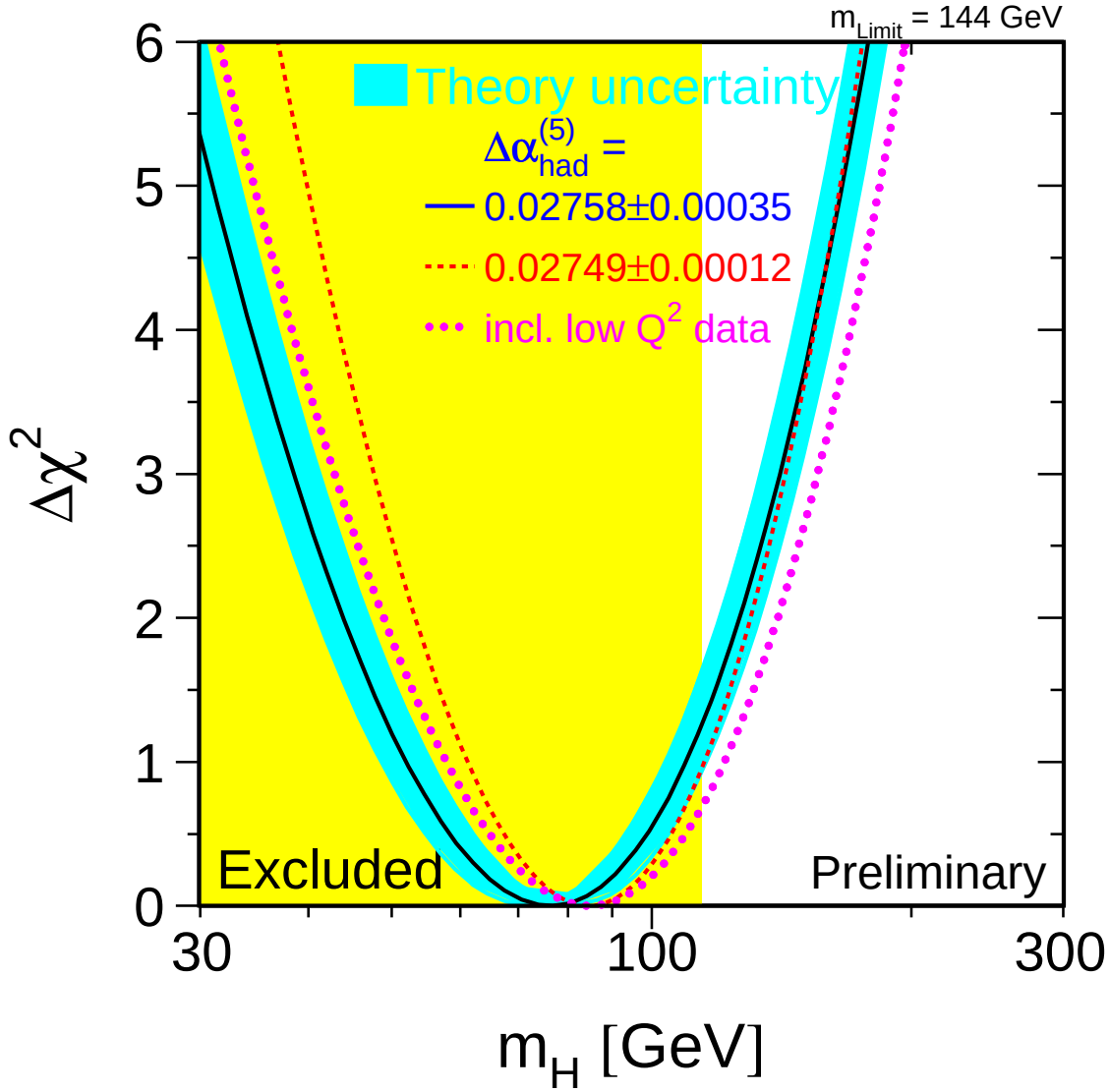
$\Rightarrow$ light Higgs boson preferred

Global fit to all SM data:

[*LEPEWWG '07*]

$\Rightarrow M_H = 76^{+33}_{-24}$ GeV

$M_H < 144$ GeV, 95% C.L.



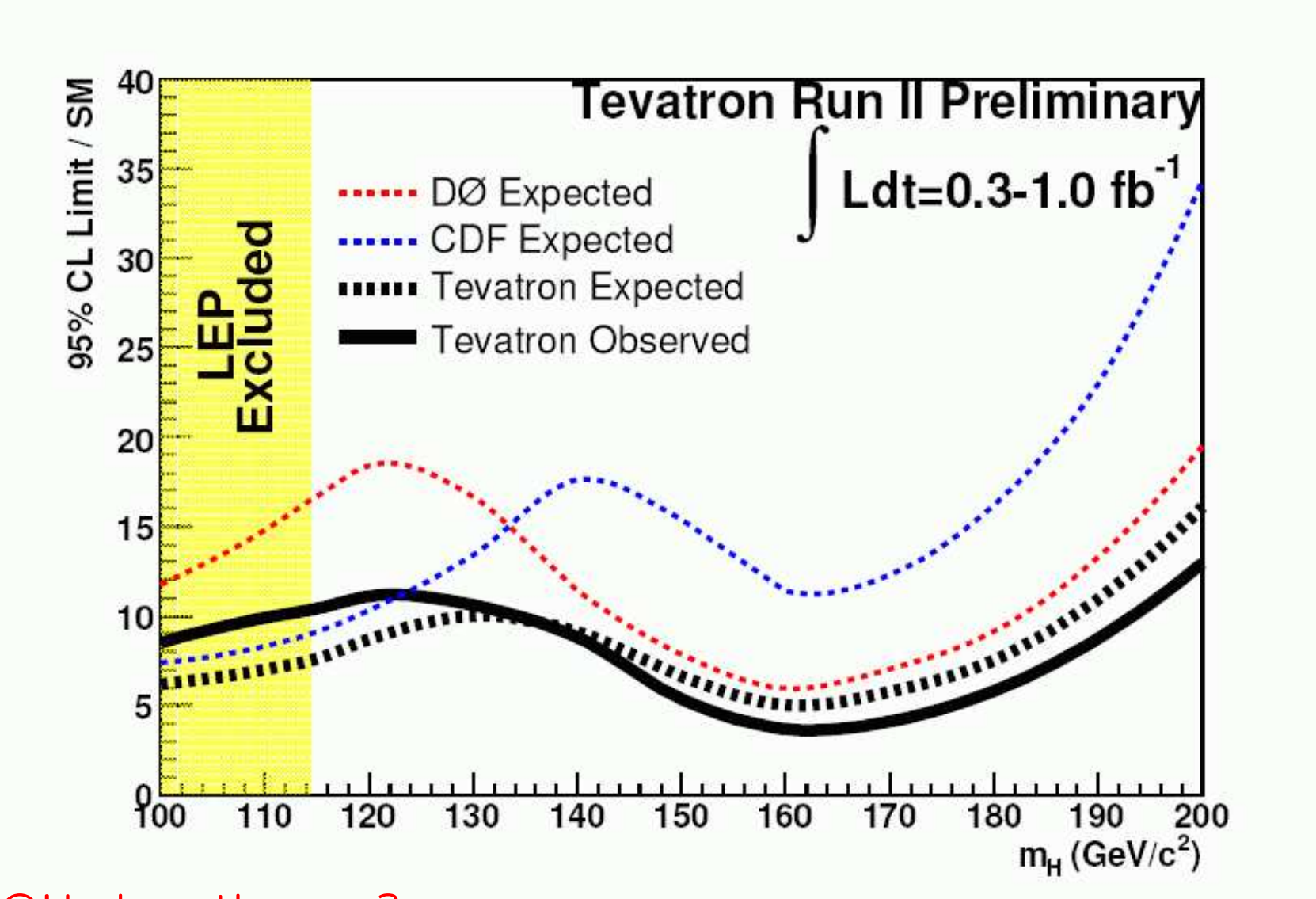
Assumption for the fit:
SM incl. Higgs boson

$\Rightarrow$ no confirmation of Higgs mechanism

$\Rightarrow$ Higgs boson seems to be light, $M_H \lesssim 150$ GeV

Current status (latest results) of SM Higgs search:

[*CDF, D0 '06*]



Can YOU close the gap?

Remember your promise:

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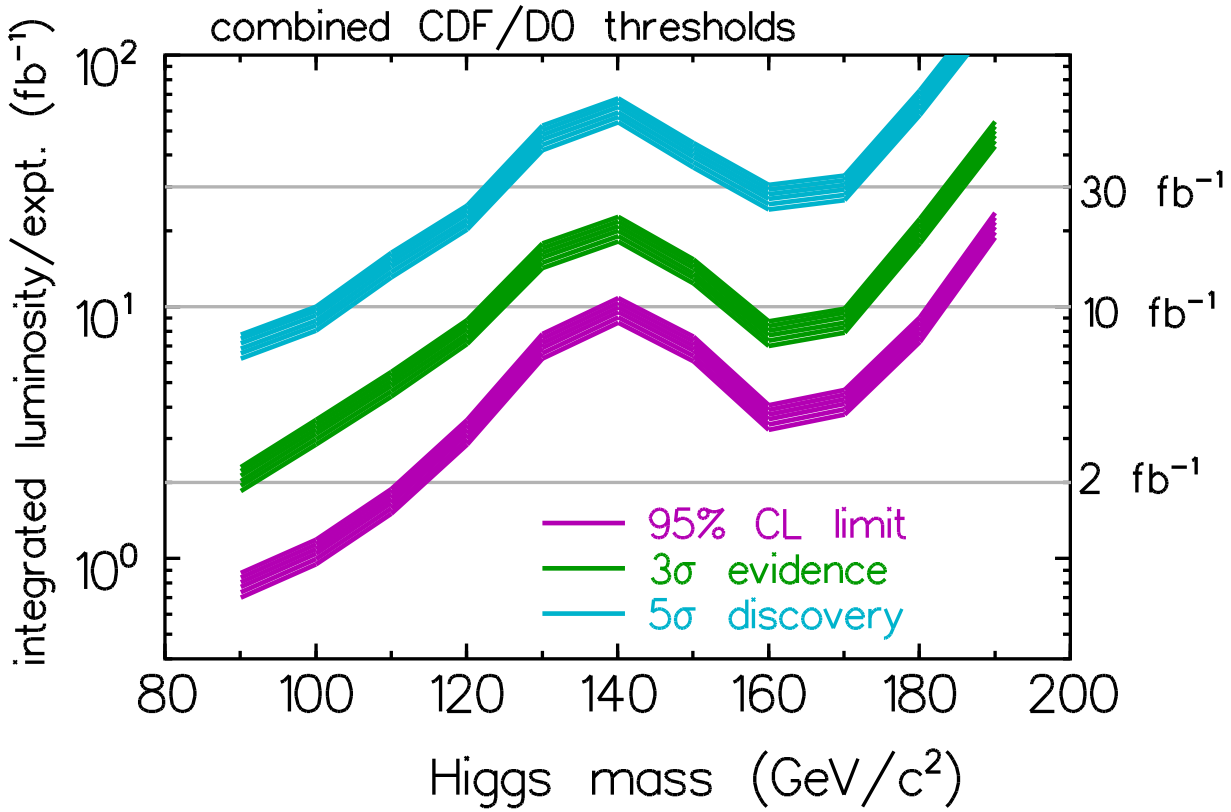

Unfortunately: luminosity problems in the start of RunII
$\Rightarrow$ progress slower than anticipated

For SM Higgs boson with $M_H \sim 120$ GeV:

$\approx$ 2008/09: sensitivity for 95% C.L. exclusion

$\approx$ 2009: sensitivity for 3σ evidence
or exclude SM Higgs with $M_H \lesssim 130$ GeV

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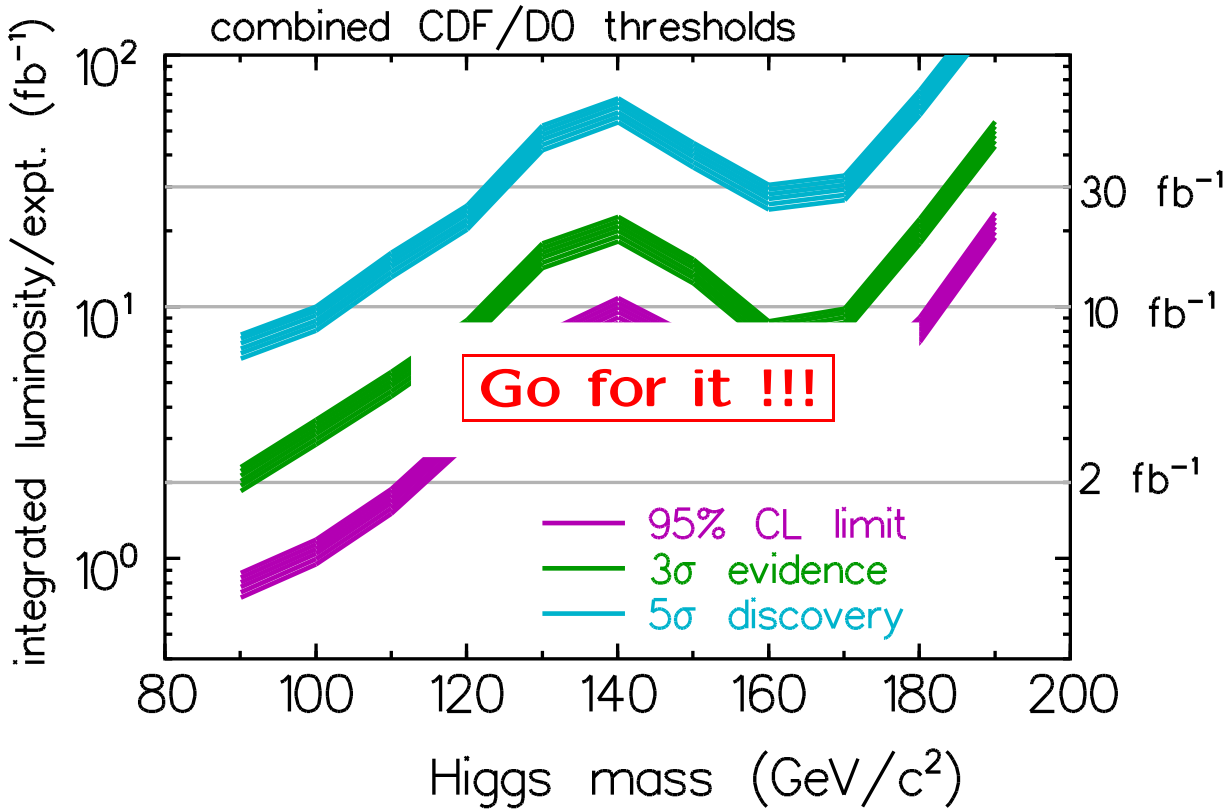

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2. A SM-like MSSM Higgs boson

Supersymmetry (SUSY) : 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:

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

$\Rightarrow$ each SM multiplet is enlarged to its double size

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

Reality: $m_e \neq m_{\tilde{e}} \Rightarrow$ 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.

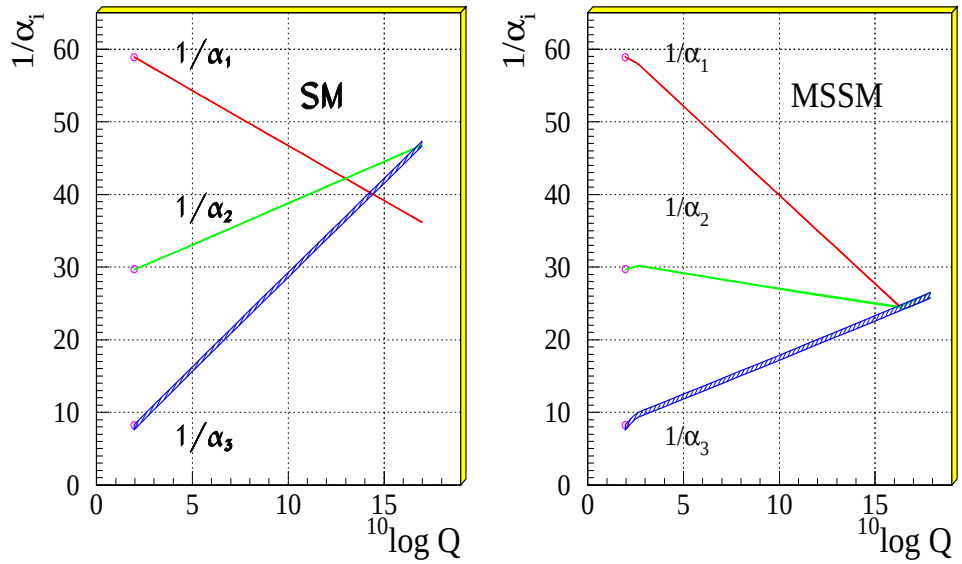
2.) Unification of gauge couplings: Not possible in the SM, but in the MSSM (although it was not designed for it.)

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

4.) SUSY provides CDM candidate

5.) . . .

Unification of the Coupling Constants in the SM and the minimal MSSM



[*Amaldi, de Boer, Fürstenau '92*]

The Minimal Supersymmetric Standard Model (MSSM)

Superpartners for Standard Model particles

$$\left[u,d,c,s,t,b\right]_{L,R} \quad \left[e,\mu,\tau\right]_{L,R} \quad \left[\nu_{e,\mu,\tau}\right]_{L} \qquad \text{Spin } \tfrac{1}{2}$$

$$\left[\tilde{u},\tilde{d},\tilde{c},\tilde{s},\tilde{t},\tilde{b}\right]_{L,R} \quad \left[\tilde{e},\tilde{\mu},\tilde{\tau}\right]_{L,R} \quad \left[\tilde{\nu}_{e,\mu,\tau}\right]_{L} \qquad \text{Spin } 0$$

$$g \quad \underbrace{W^{\pm}, H^{\pm}} \quad \underbrace{\gamma, Z, H_1^0, H_2^0} \qquad \text{Spin } 1 \text{ / Spin } 0$$

$$\tilde{g} \quad \tilde{\chi}^{\pm}_{1,2} \quad \tilde{\chi}^{0}_{1,2,3,4} \qquad \text{Spin } \frac{1}{2}$$

Enlarged Higgs sector: Two Higgs doublets

Simplified versions of the MSSM: unification at (some) GUT scale

- CMSSM/mSUGRA
- GMSB $\Rightarrow$ most pheno analyses build on these models
- AMSB

$\tilde{t}/\tilde{b}$ sector of the MSSM: (scalar partner of the top/bottom quark)

Stop, sbottom mass matrices ($X_t = A_t - \mu^*/\tan\beta$, $X_b = A_b - \mu^* \tan\beta$):

$$\mathcal{M}^2_{\tilde{t}} = \begin{pmatrix} M^2_{\tilde{t}_L} + m_t^2 + DT_{t_1} & m_t X_t^* \\ m_t X_t & M^2_{\tilde{t}_R} + m_t^2 + DT_{t_2} \end{pmatrix} \xrightarrow{\theta_{\tilde{t}}} \begin{pmatrix} m^2_{\tilde{t}_1} & 0 \\ 0 & m^2_{\tilde{t}_2} \end{pmatrix}$$

$$\mathcal{M}^2_{\tilde{b}} = \begin{pmatrix} M^2_{\tilde{b}_L} + m_b^2 + DT_{b_1} & m_b X_b^* \\ m_b X_b & M^2_{\tilde{b}_R} + m_b^2 + DT_{b_2} \end{pmatrix} \xrightarrow{\theta_{\tilde{b}}} \begin{pmatrix} m^2_{\tilde{b}_1} & 0 \\ 0 & m^2_{\tilde{b}_2} \end{pmatrix}$$

mixing important in stop sector (also in sbottom sector for large $\tan\beta$)

soft SUSY-breaking parameters A_t, A_b also appear in ϕ-$\tilde{t}/\tilde{b}$ couplings

$$SU(2) \text{ relation} \Rightarrow M_{\tilde{t}_L} = M_{\tilde{b}_L}$$

$\Rightarrow$ relation between $m_{\tilde{t}_1}, m_{\tilde{t}_2}, \theta_{\tilde{t}}, m_{\tilde{b}_1}, m_{\tilde{b}_2}, \theta_{\tilde{b}}$

Enlarged Higgs sector: Two Higgs doublets

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

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

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

$$+ \underbrace{\frac{{g_1}^2 + g_2^2}{8}}_{\text{gauge couplings, in contrast to SM}} (H_1 \bar{H}_1 - H_2 \bar{H}_2)^2 + \underbrace{\frac{g_2^2}{2}}_{} |H_1 \bar{H}_2|^2$$

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

Goldstone bosons: $G^0, G^\pm$

Input parameters: (to be determined experimentally)

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

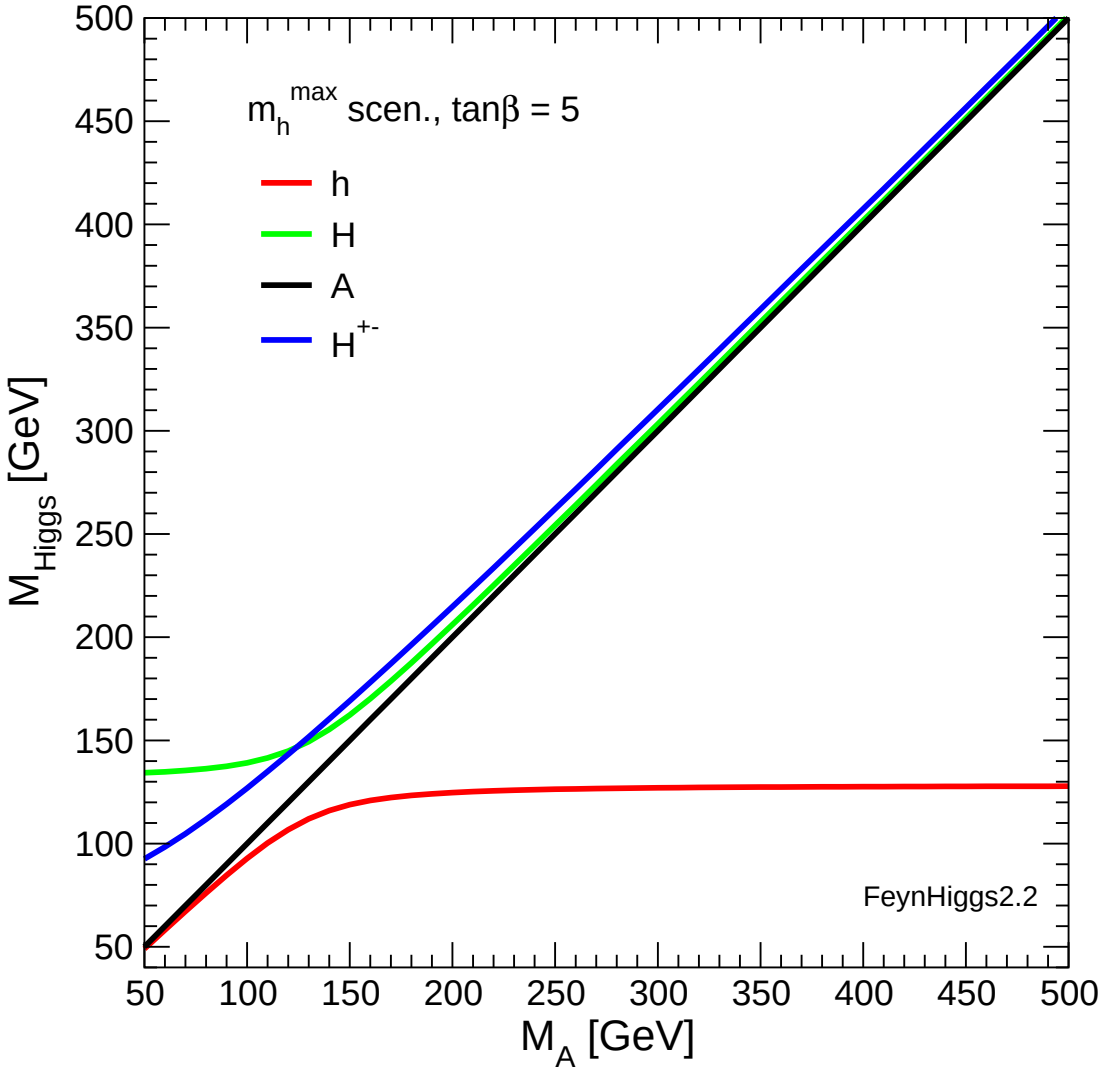
A SM like MSSM Higgs boson: The decoupling limit:

For $M_A \gtrsim 150$ GeV:

The lightest MSSM Higgs is SM-like

The heavy MSSM Higgses: $M_A \approx M_H \approx M_{H^\pm}$

of course there are exceptions . . .



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

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

for $m_t = 170.9 \pm 1.8$ GeV

(including theoretical uncertainties from unknown higher orders)

$\Rightarrow$ observable/exclusion at the Tevatron?

Obtained with:

FeynHiggs

[*S.H., W. Hollik, G. Weiglein '98, '00, '02*]

[*T. Hahn, S.H., W. Hollik, G. Weiglein '03 – '07*]

`www.feynhiggs.de`

$\rightarrow$ all Higgs masses, couplings, XSs, BRs (easy to link, easy to use :-)

2A) SM-like MSSM Higgs: exclusion potential

Three facts and one conclusion:

Fact # 1: your promise:

$\approx$ 2009:

exclude SM Higgs with $M_H \lesssim 130$ GeV

Fact # 2: our calculation:

"Unconstrained MSSM":

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

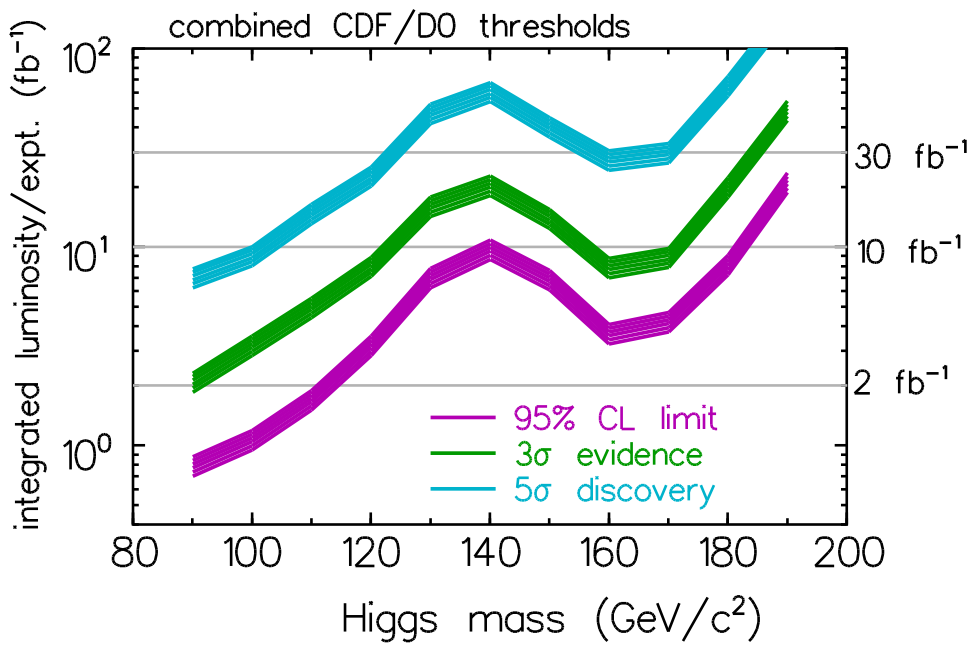
Fact # 3: simplified versions:

unification at (some) GUT scale

- CMSSM/mSUGRA
- GMSB
- AMSB

$\Rightarrow$ most analyses build on these models

$\Rightarrow$ Conclusion?



Conclusion: Search for a "SM-like" light Higgs:

Prediction in "simplified" versions of the MSSM:
($m_t^{\rm exp} = 170.9$ GeV, $\delta m_t^{\rm exp} = 1.8$ GeV, $M_{\rm SUSY} \lesssim$ few TeV)
[*A. Dedes, S.H., S. Su, G. Weiglein '03*] [*S.H., W. Hollik, G. Weiglein '04,'05*]

	max. M_h [GeV]	$\delta M_h/\delta m_t$	for $m_t^{\rm exp} + 2\delta m_t$
mSUGRA/CMSSM	124.5	0.65	126.9
mGMSB	118.8	0.70	121.3
mAMSB	120.5	0.58	122.6

Exclusion potential of the Tevatron: $M_H^{\rm SM} \lesssim 130$ GeV

mSUGRA/CMSSM, mGMSB, mAMSB: no suppression of hVV coupling
$\Rightarrow$ SM bound applies

$\Rightarrow$ Tevatron can exclude mSUGRA/CMSSM, mGMSB, mAMSB, ...

$\Rightarrow$ potentially huge impact on search strategies at LHC

2B) SM-like MSSM Higgs: discovery potential

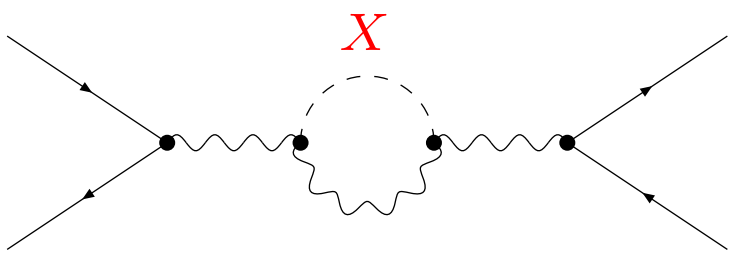
Precision Observables (POs):

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



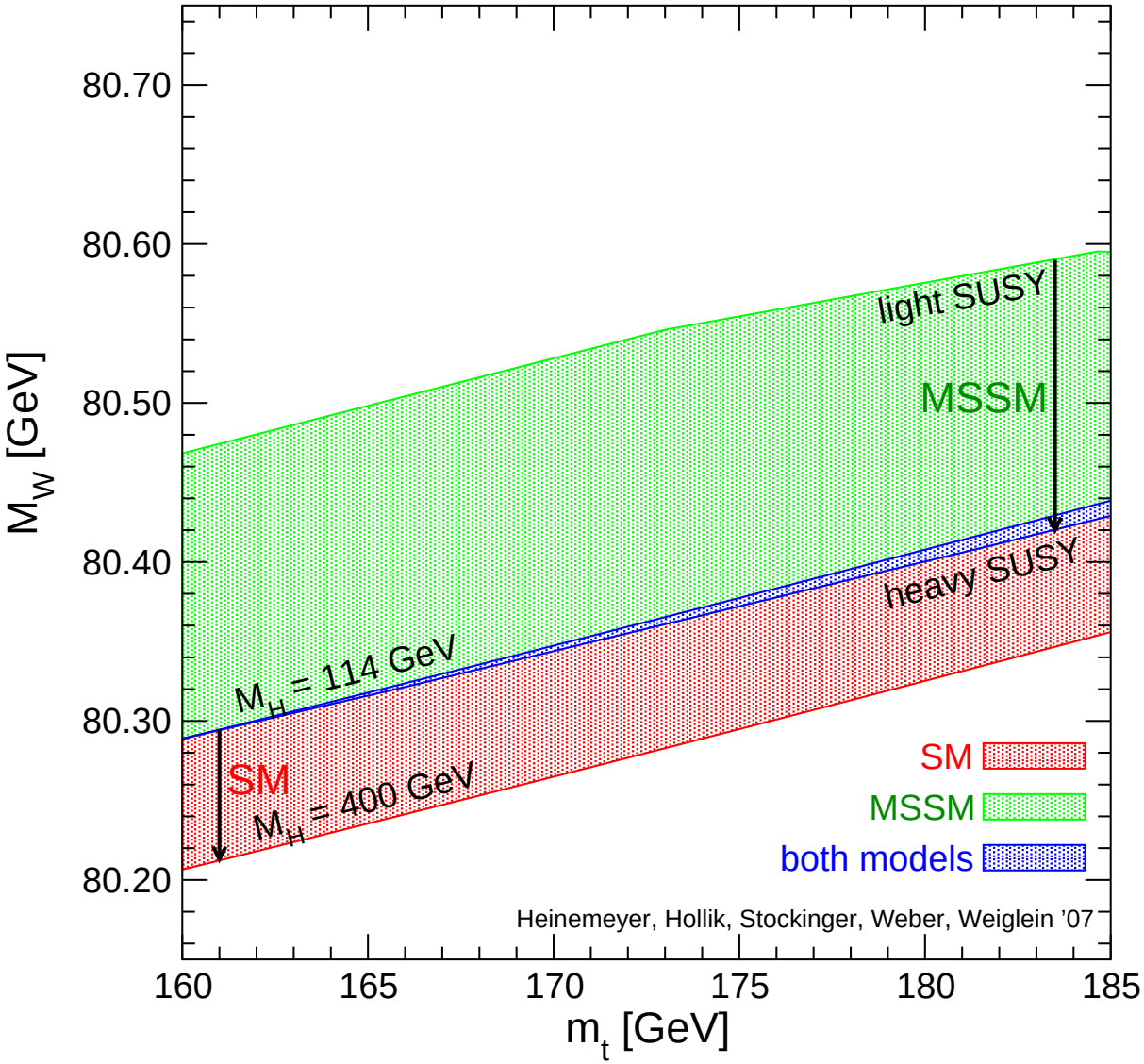
$\Downarrow$

MSSM: limits on new model parameters

Very high accuracy of measurements and theoretical predictions needed

Example: Prediction for M_W in the SM and the MSSM :

[*S.H., W. Hollik, D. Stockinger, A.M. Weber, G. Weiglein '07*]



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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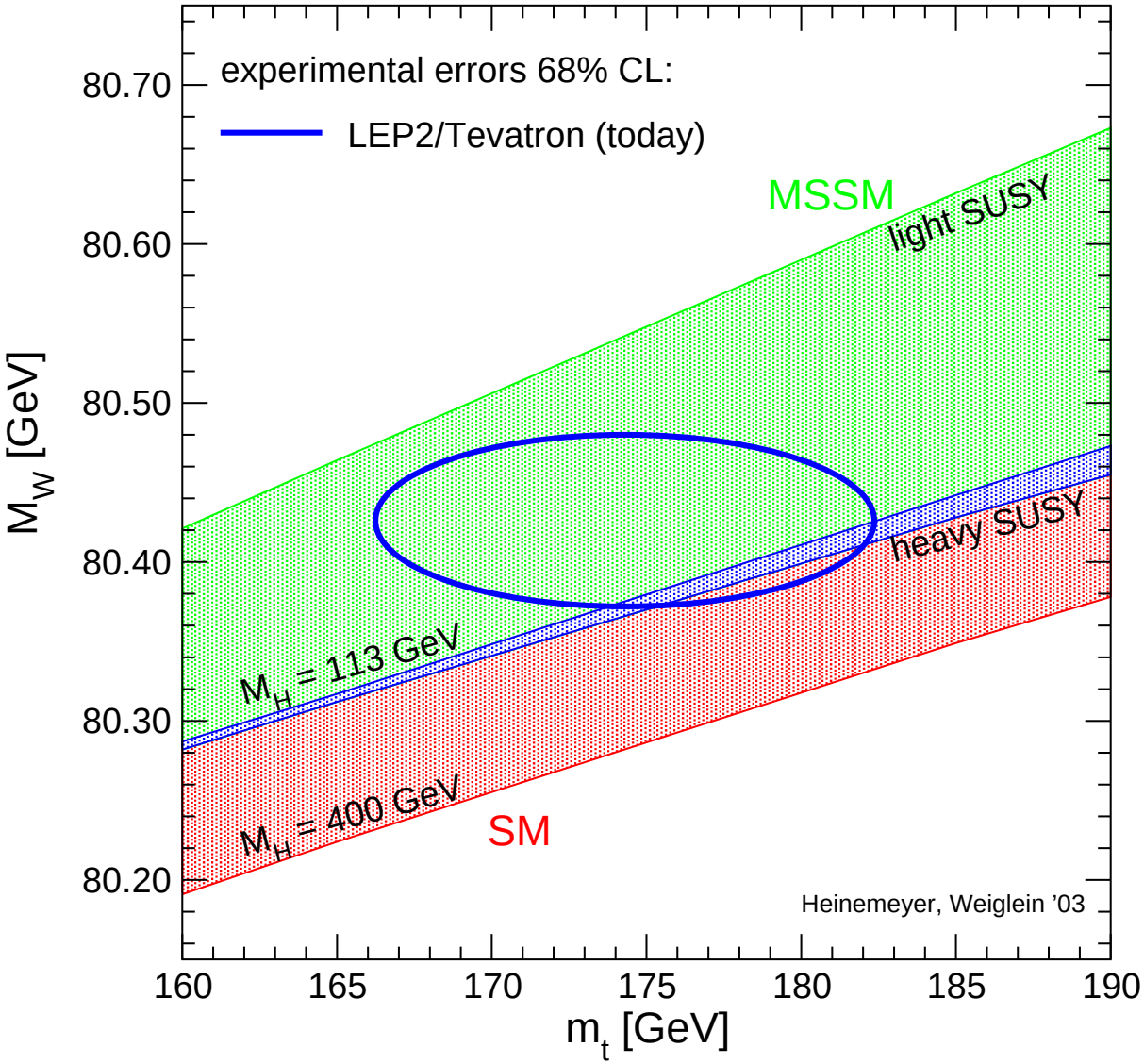

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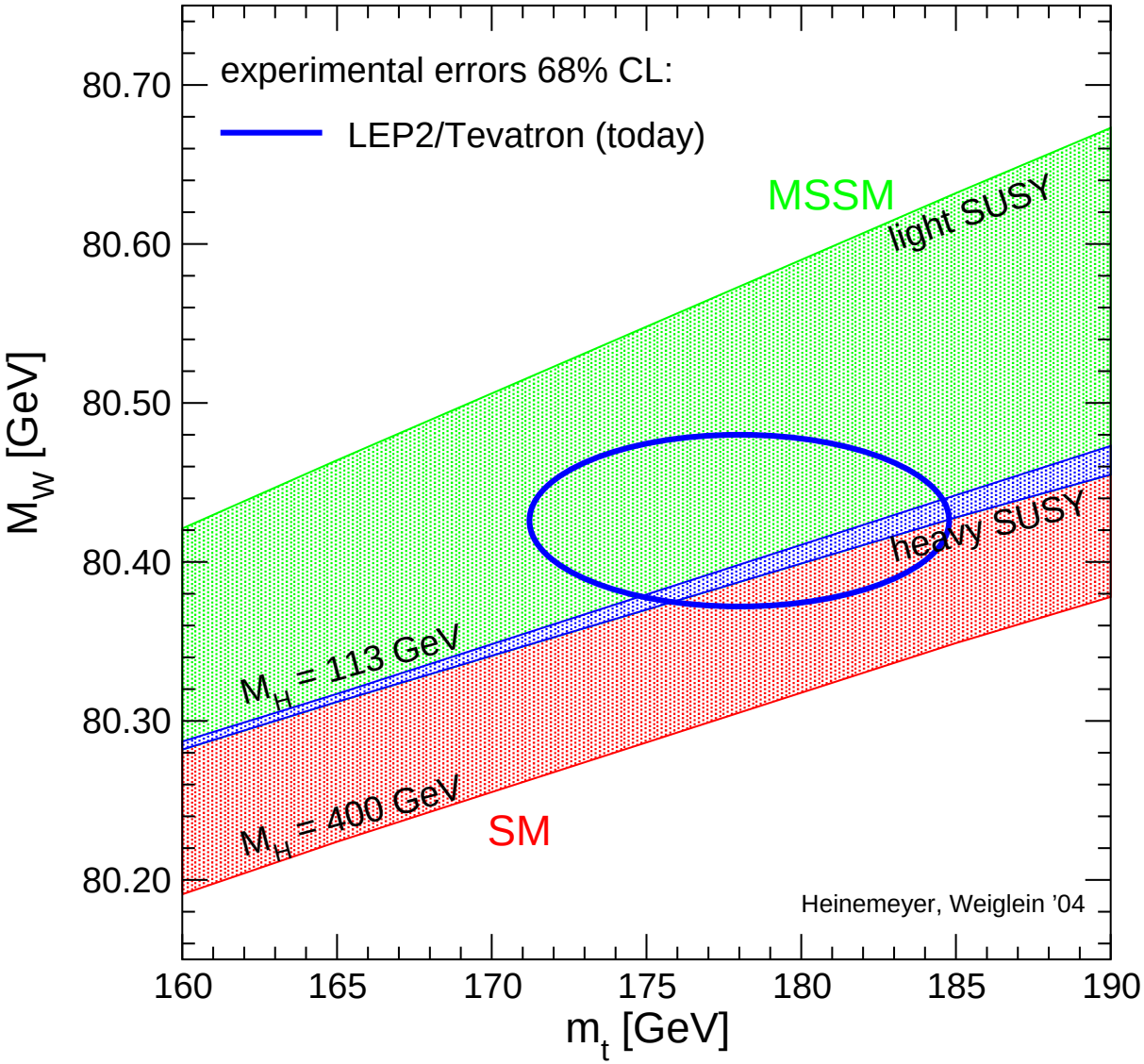

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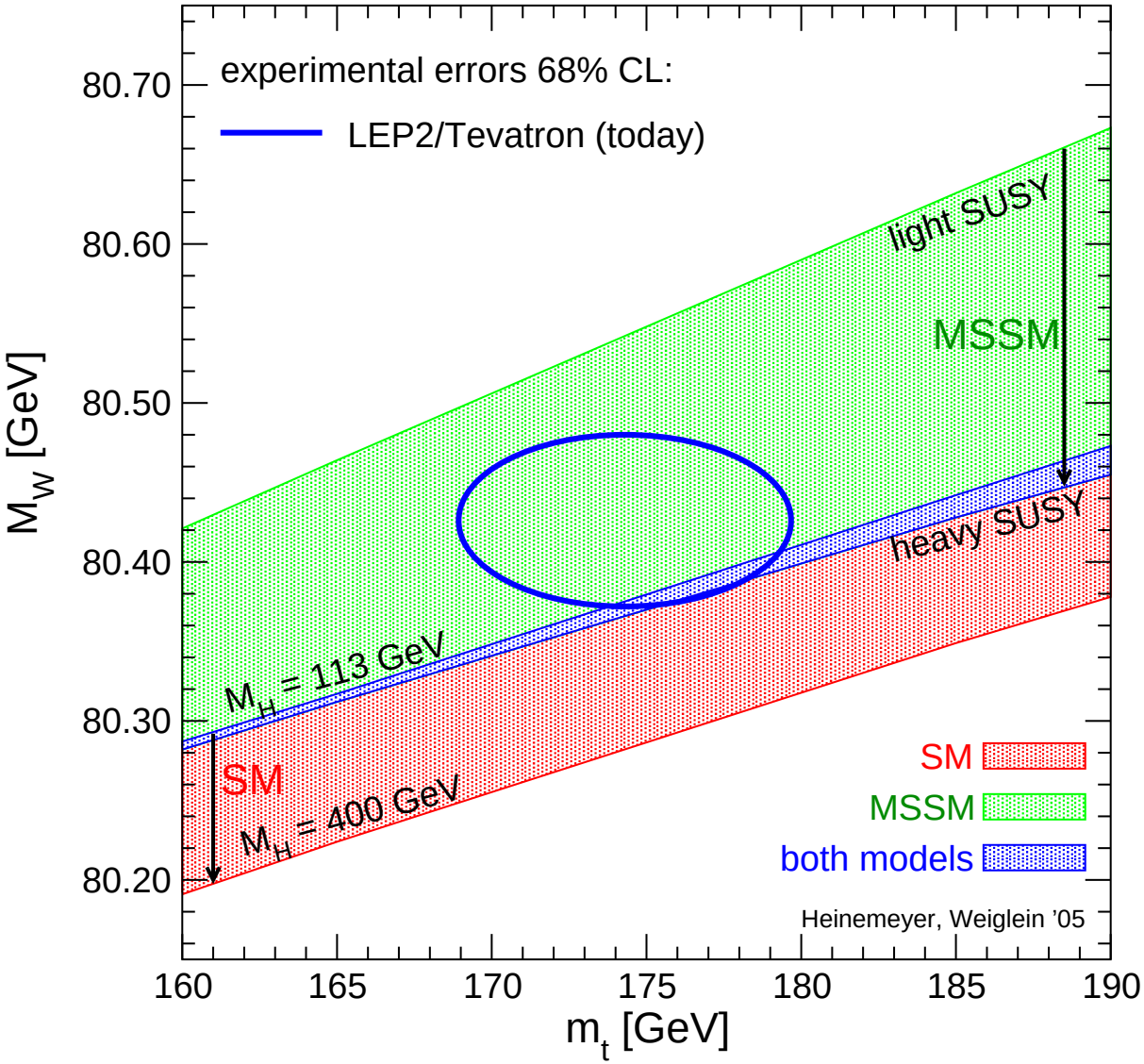

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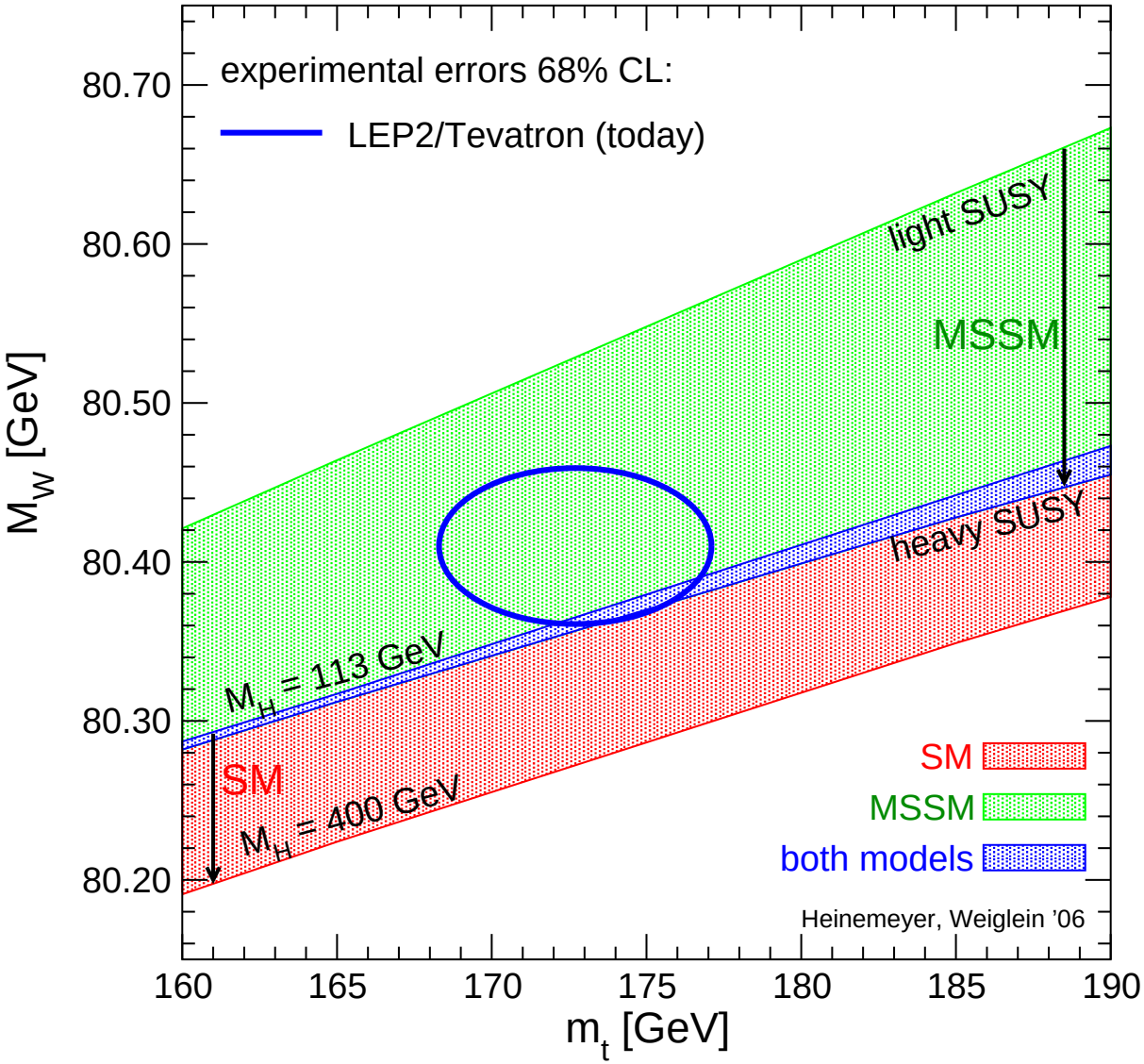

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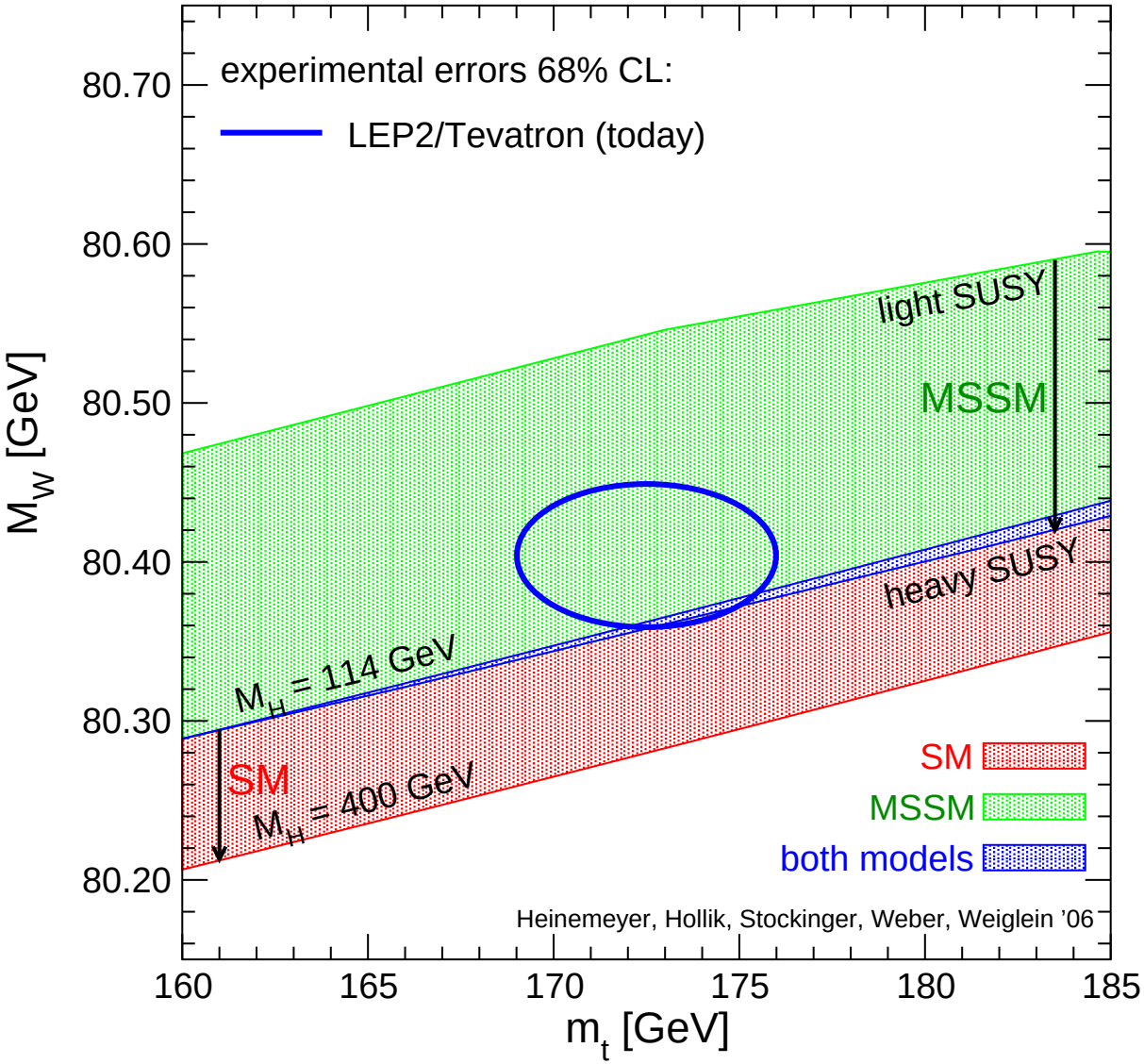

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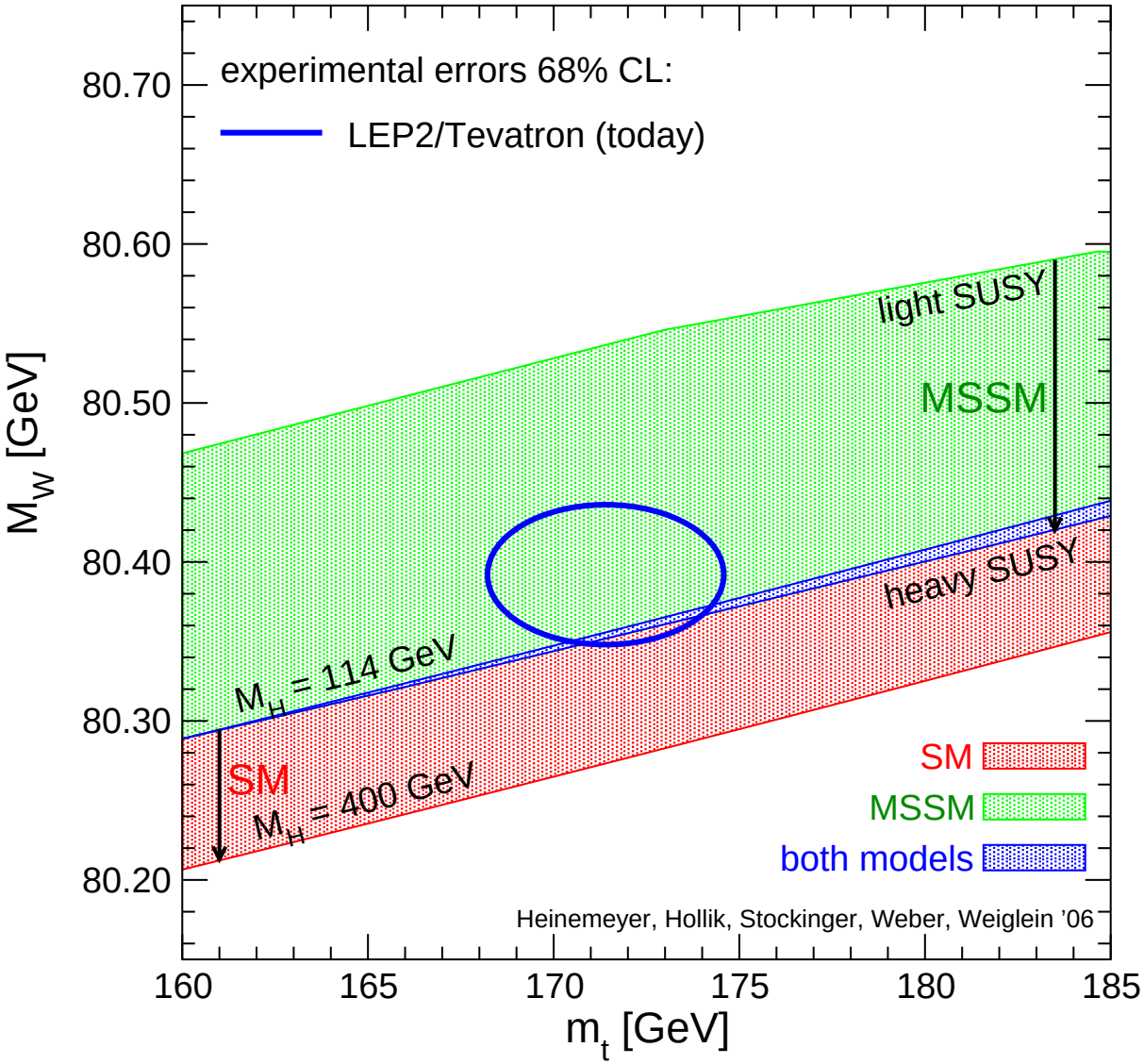

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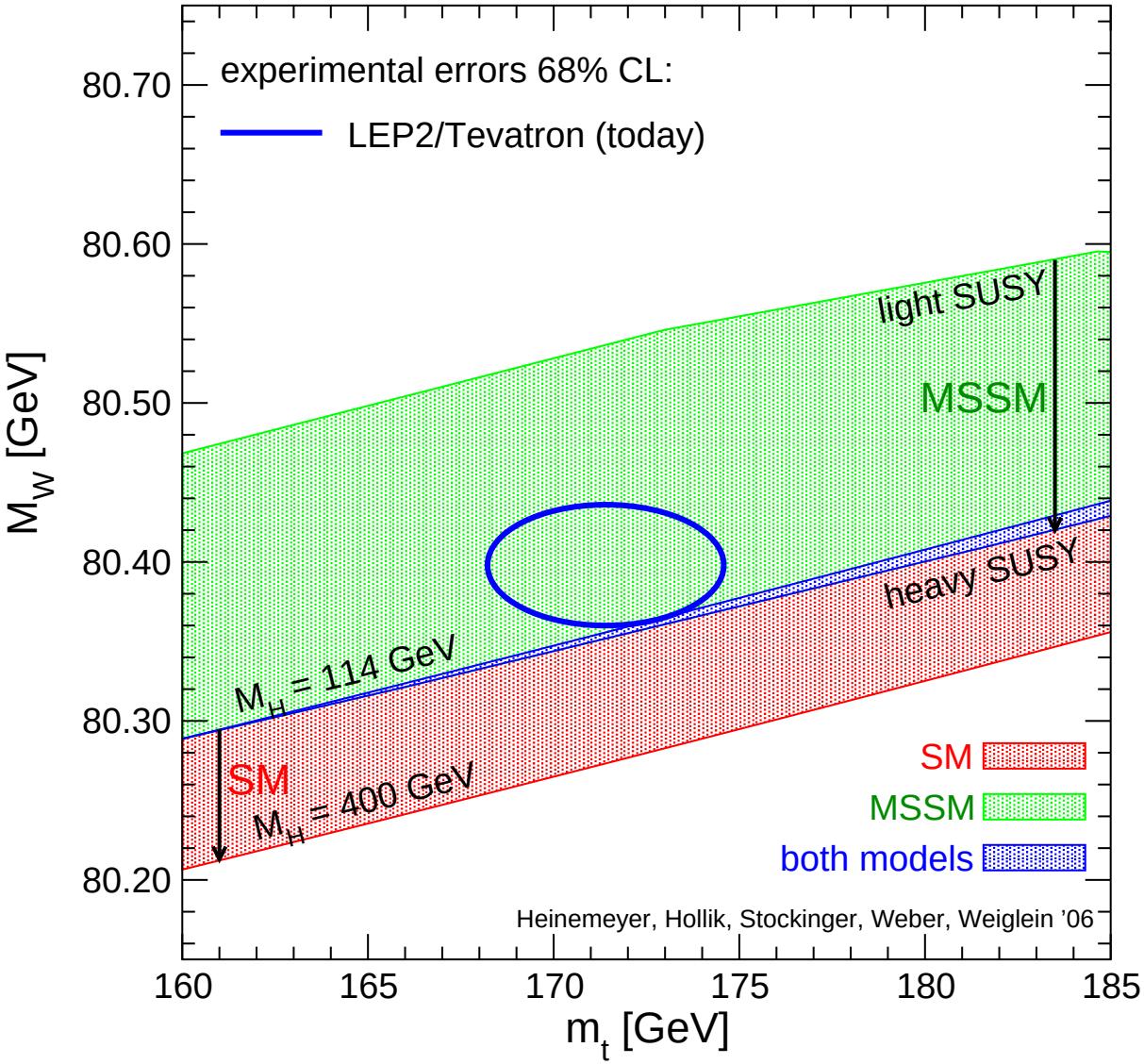

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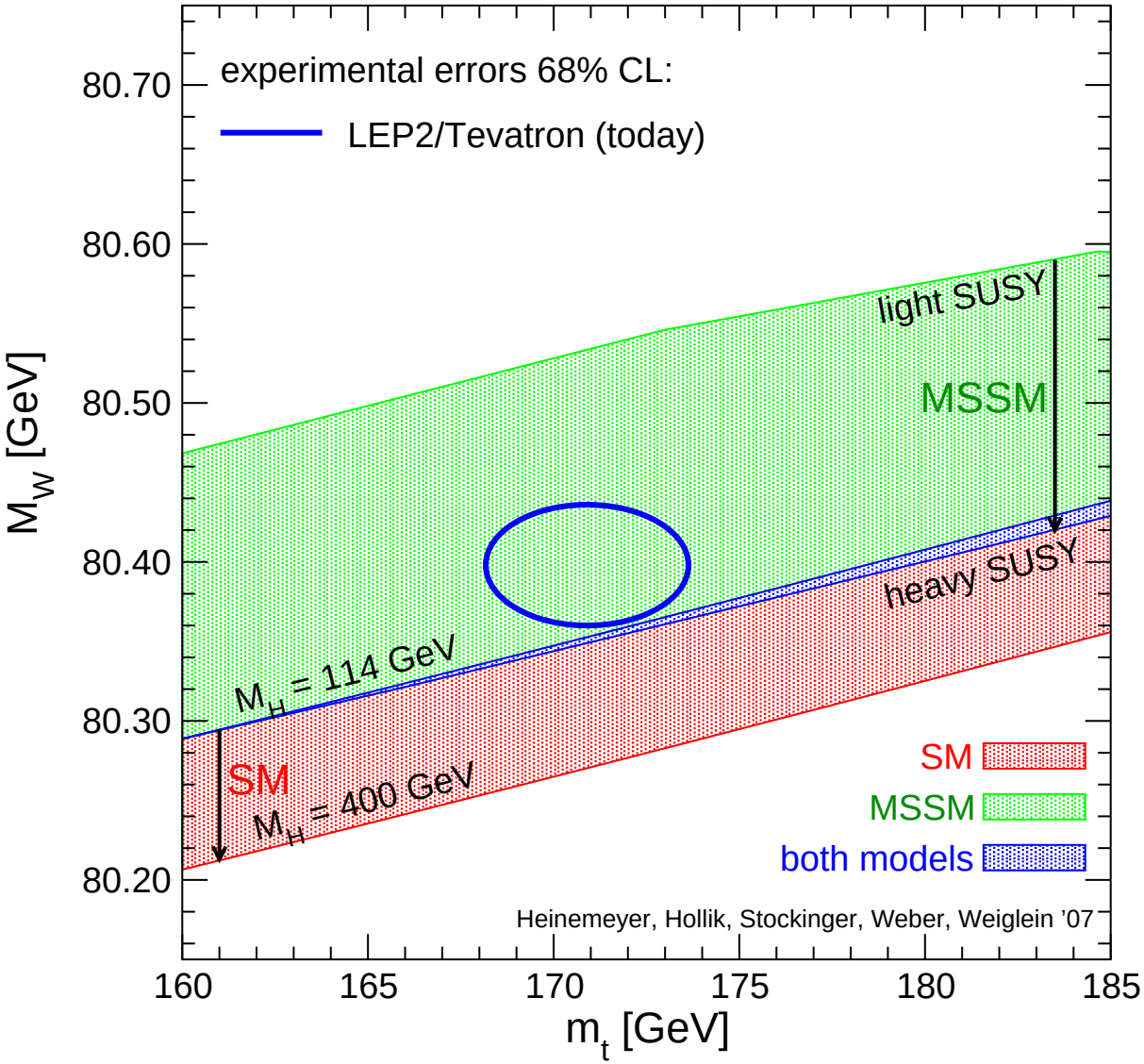

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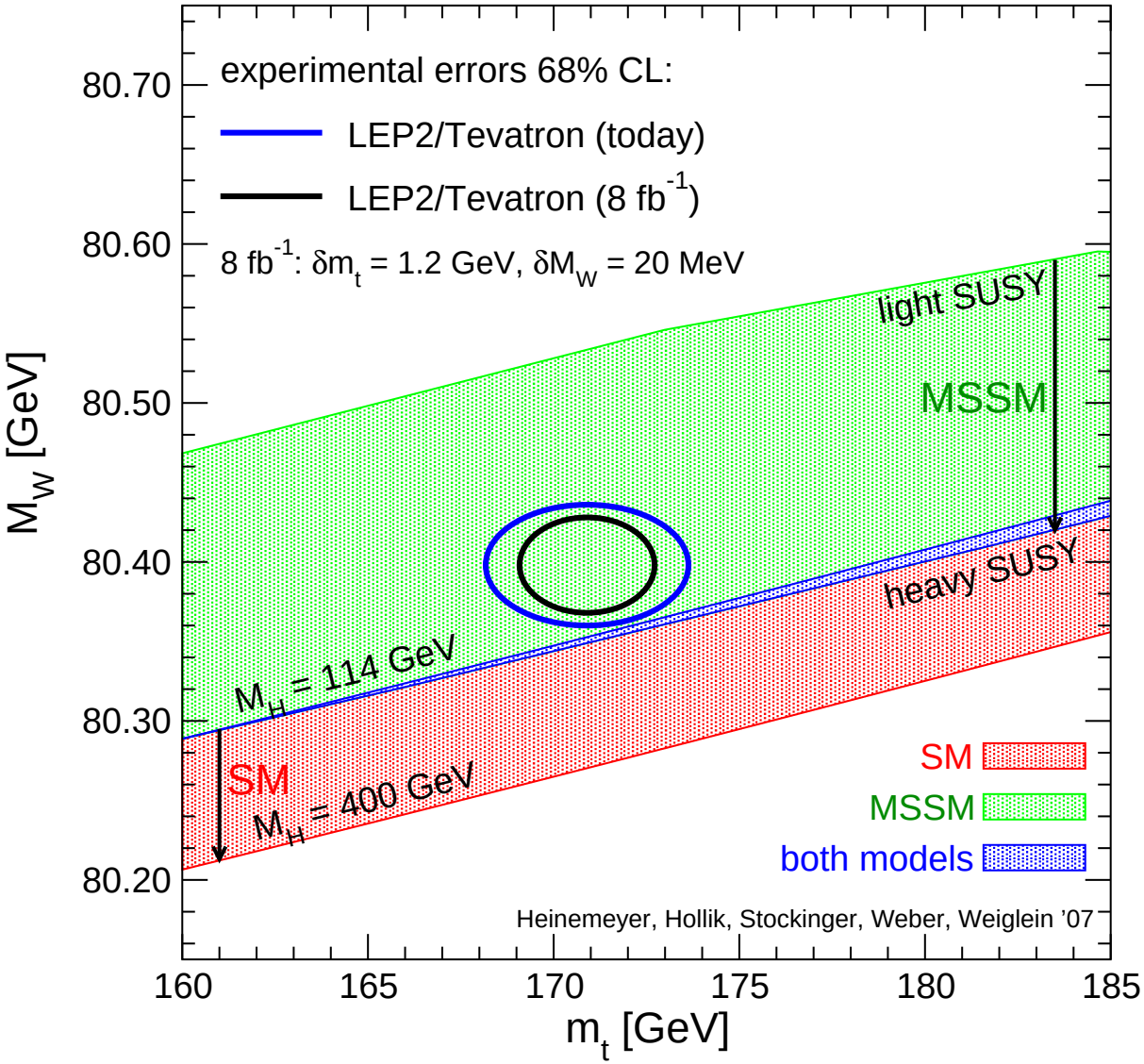

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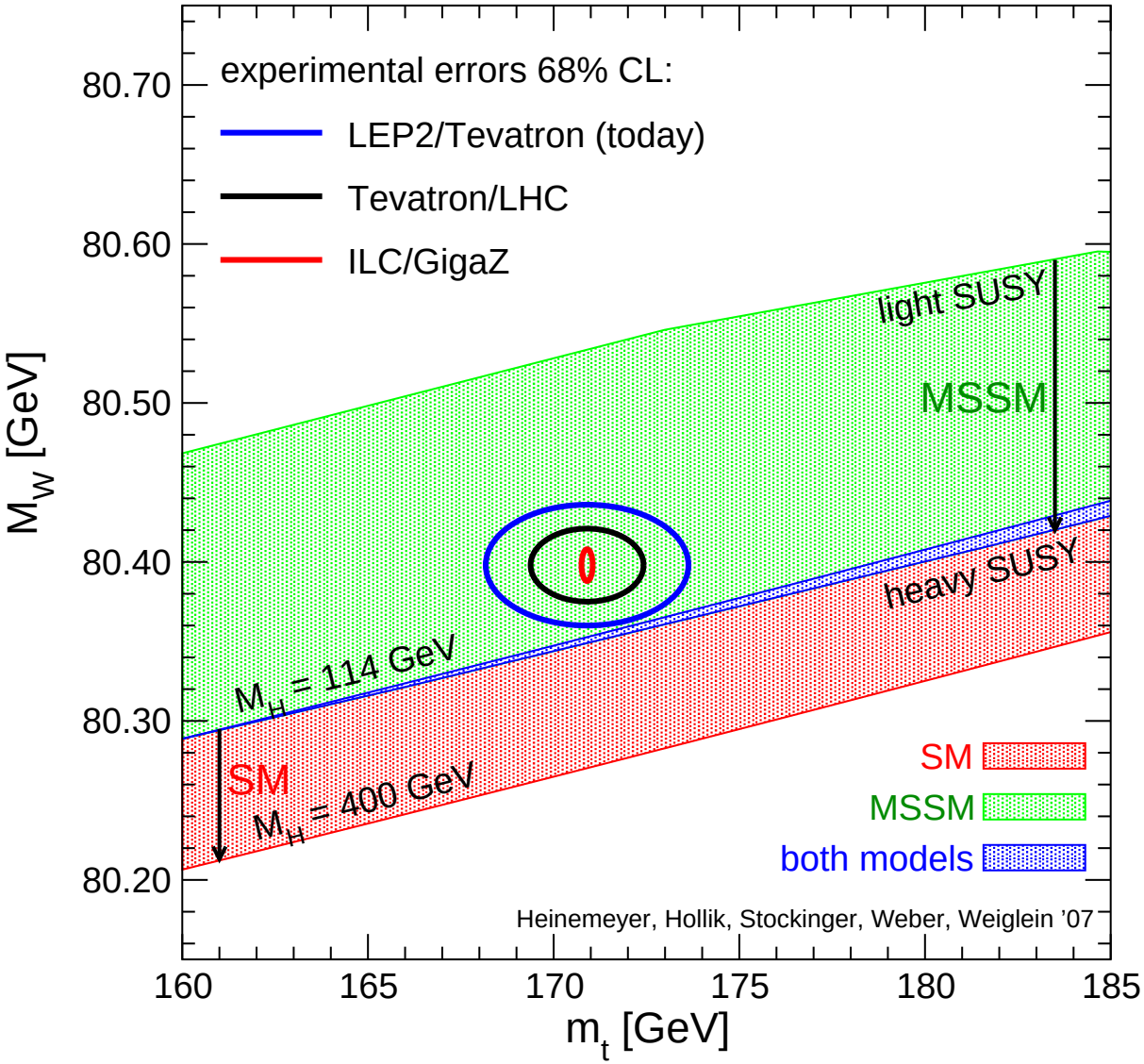
SM band:
variation of M_H^{SM}

Example: Prediction for M_W in the SM and the MSSM :

[*S.H., W. Hollik, D. Stockinger, A.M. Weber, G. Weiglein '07*]



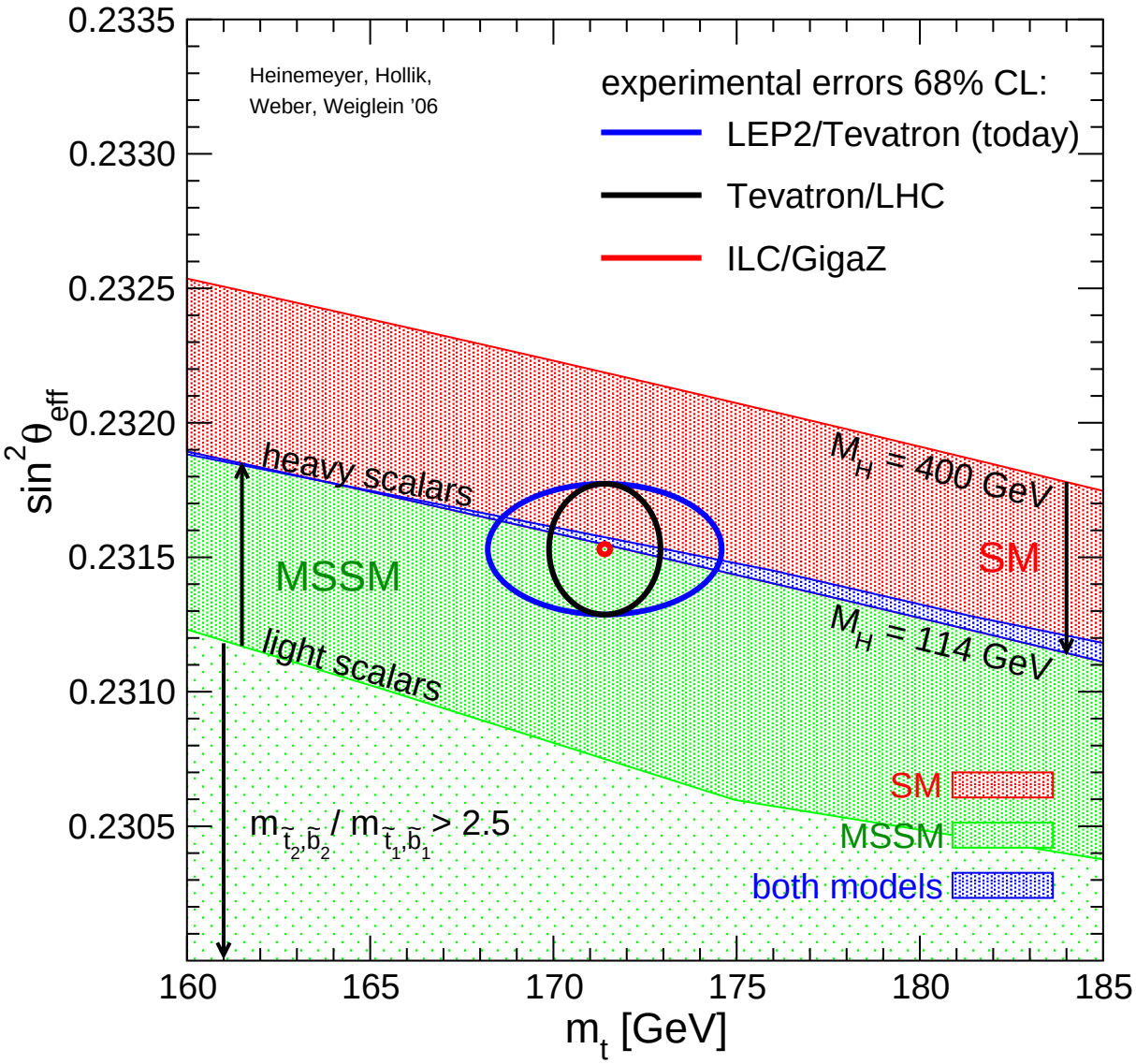
MSSM band:
scan over
SUSY masses

overlap:
SM is MSSM-like
MSSM is SM-like

SM band:
variation of M_H^{SM}

Prediction for $\sin^2\theta_{\rm eff}$ in the SM and the MSSM :

[*S.H., W. Hollik, A.M. Weber, G. Weiglein '07*]



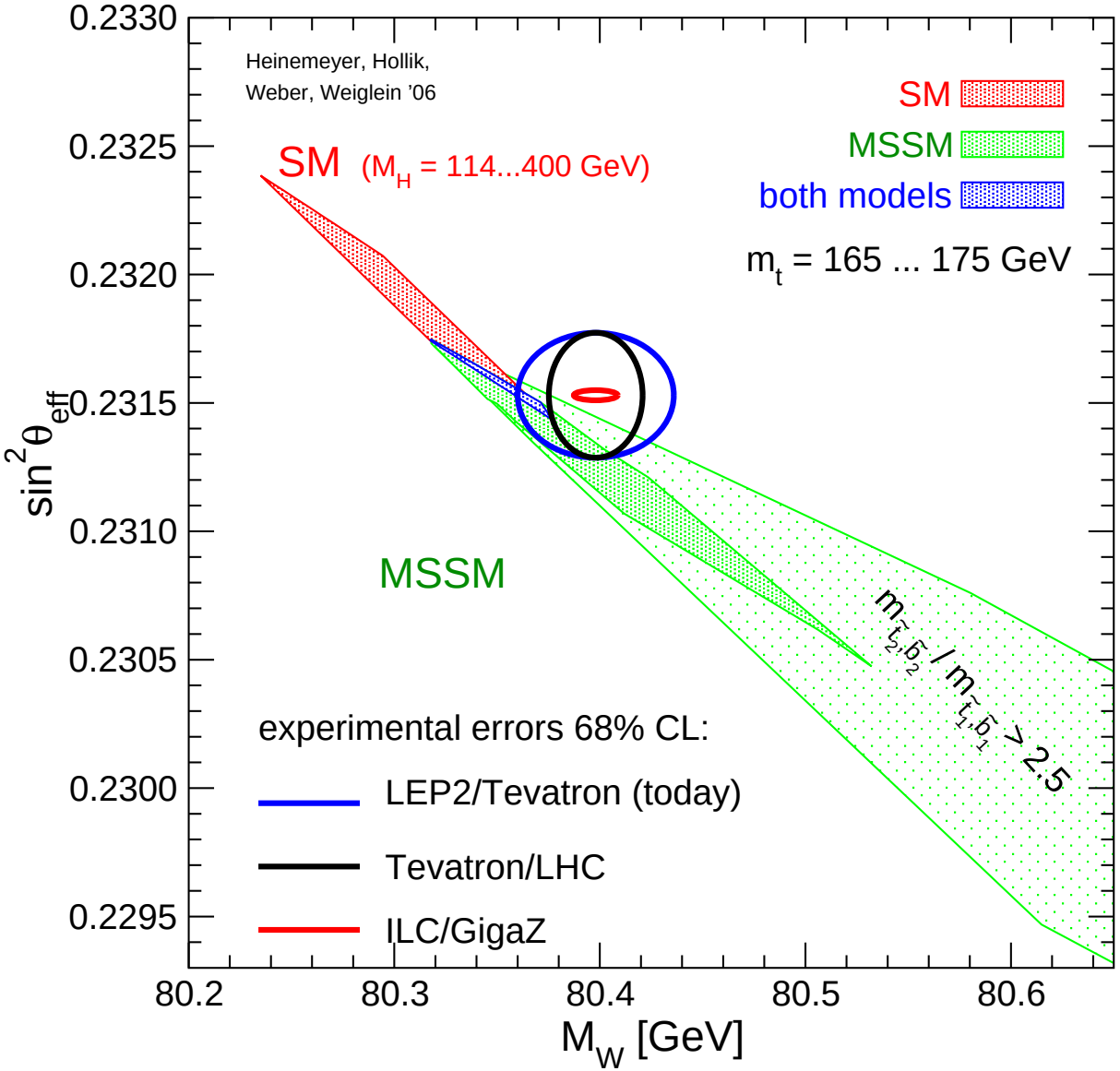
MSSM band:
scan over
SUSY masses

overlap:
SM is MSSM-like
MSSM is SM-like

SM band:
variation of $M_H^{\rm SM}$

Prediction for M_W and $\sin^2\theta_{\text{eff}}$ in the SM and the MSSM :

[*S.H., W. Hollik, A.M. Weber, G. Weiglein '07*]



MSSM band:
scan over
SUSY masses

overlap:
SM is MSSM-like
MSSM is SM-like

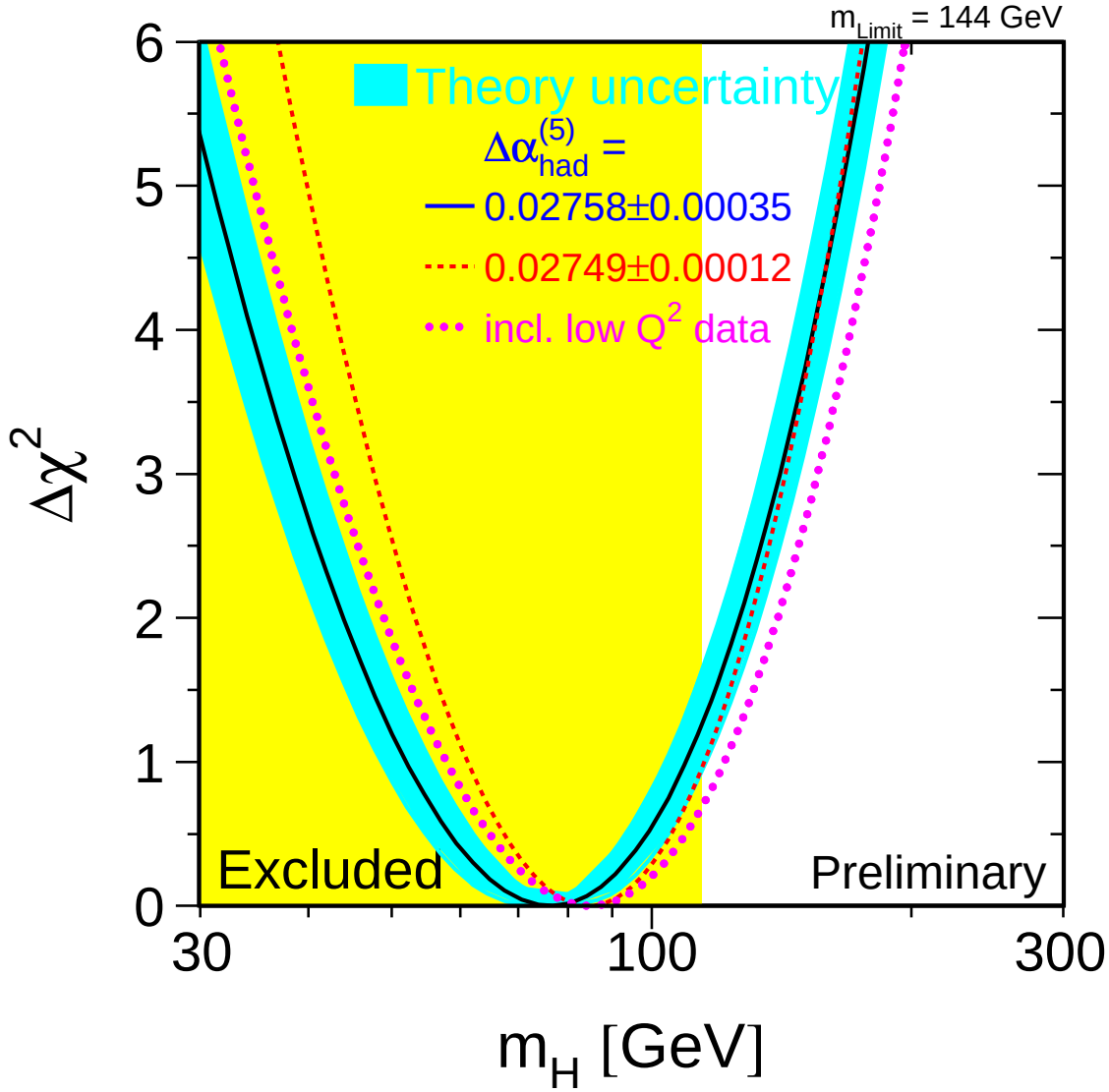
SM band:
variation of M_H^{SM}

Global fit to all SM data:

[*LEPEWWG '07*]

$\Rightarrow M_H = 76^{+33}_{-24}$ GeV

$M_H < 144$ GeV, 95% C.L.



Assumption for the fit:
SM incl. Higgs boson

$\Rightarrow$ no confirmation of Higgs mechanism

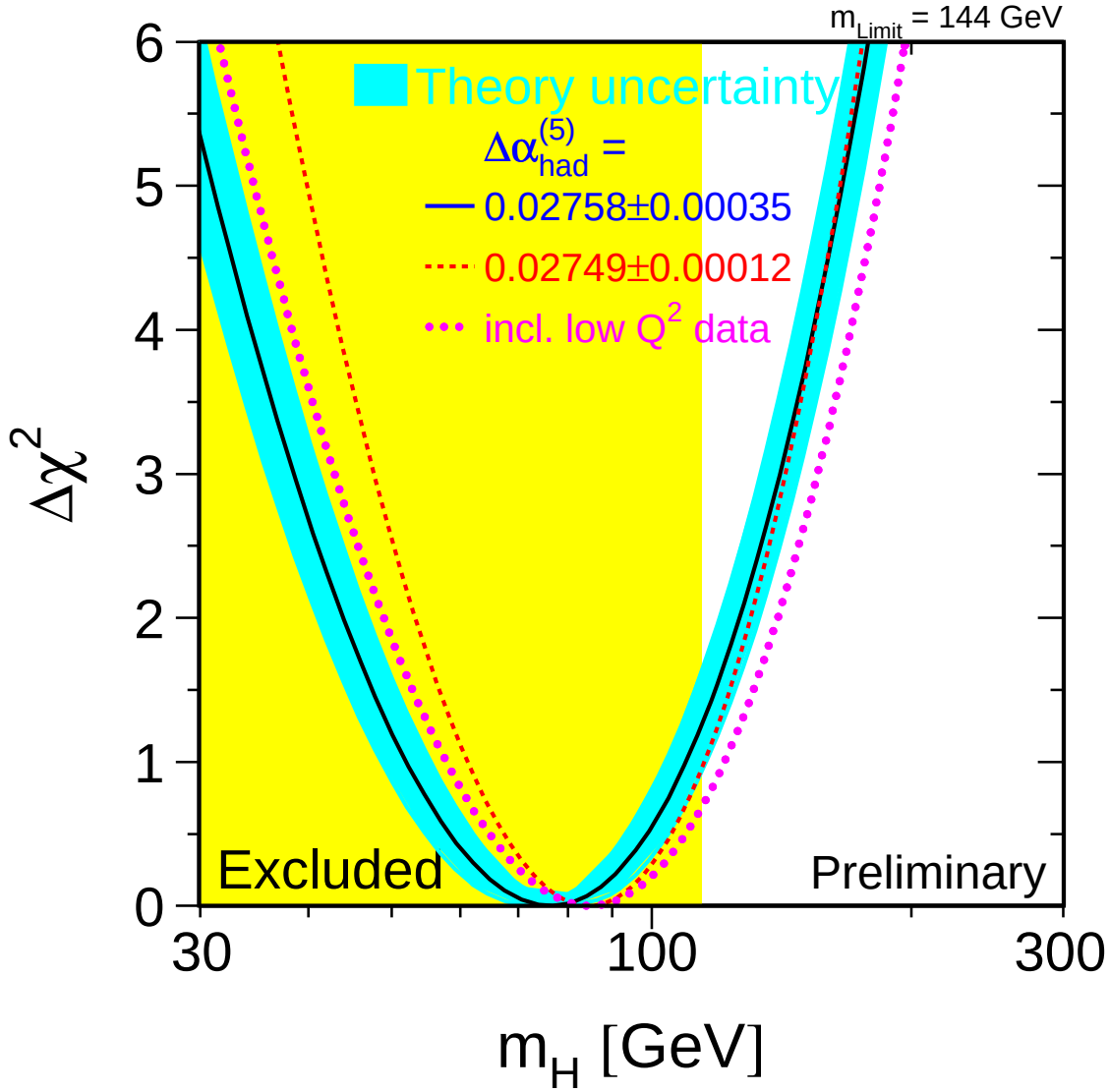
$\Rightarrow$ Higgs boson seems to be light, $M_H \lesssim 150$ GeV

Global fit to all SM data:

[*LEPEWWG '07*]

$\Rightarrow M_H = 76^{+33}_{-24}$ GeV

$M_H < 144$ GeV, 95% C.L.



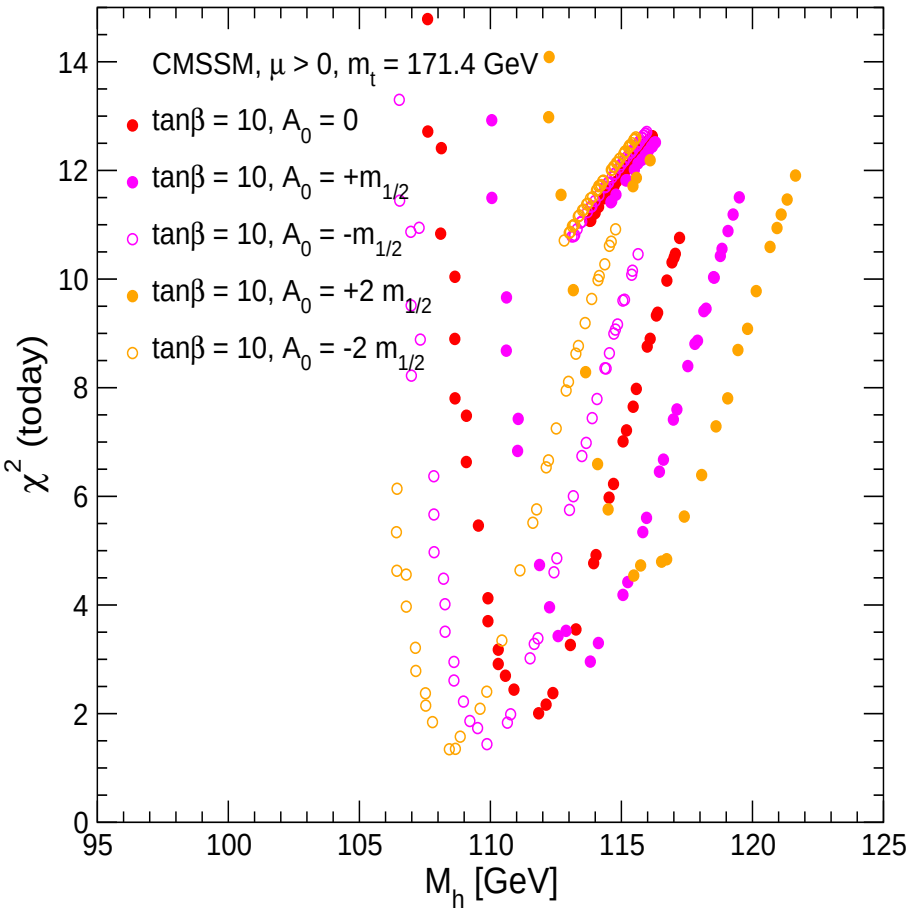
Assumption for the fit:
SM incl. Higgs boson

$\Rightarrow$ no confirmation of Higgs mechanism

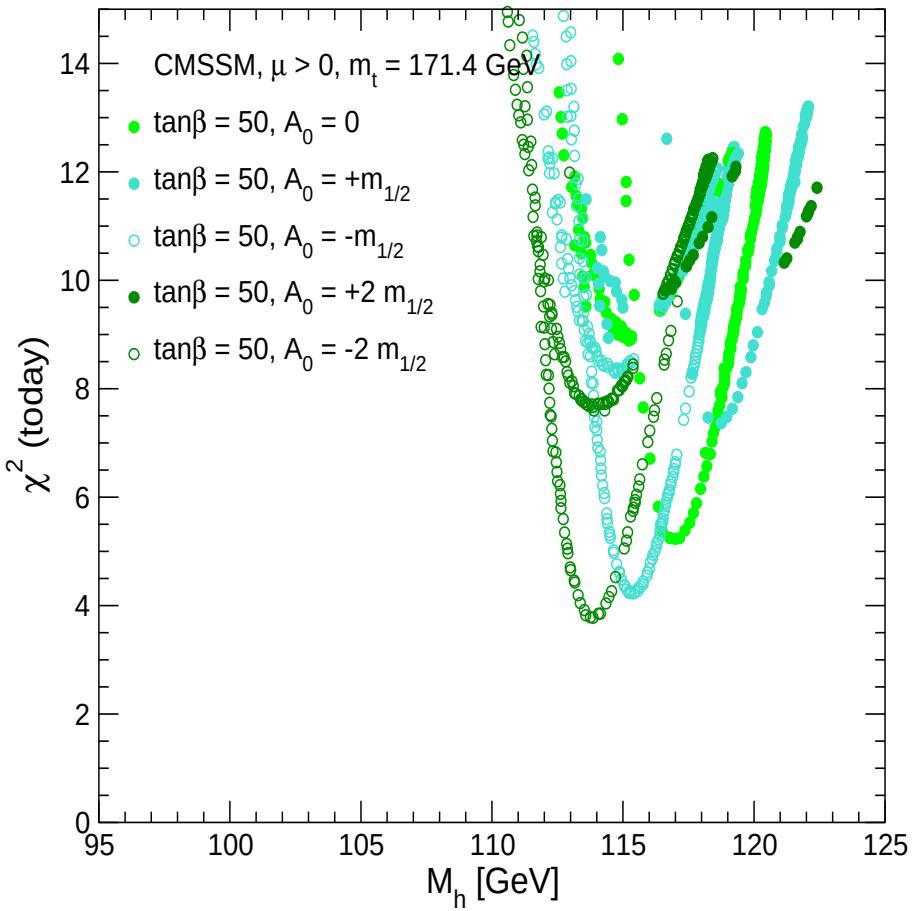
$\Rightarrow$ Higgs boson seems to be light – too light?

Results: CMSSM: "blue band" for M_h

$\tan\beta = 10$

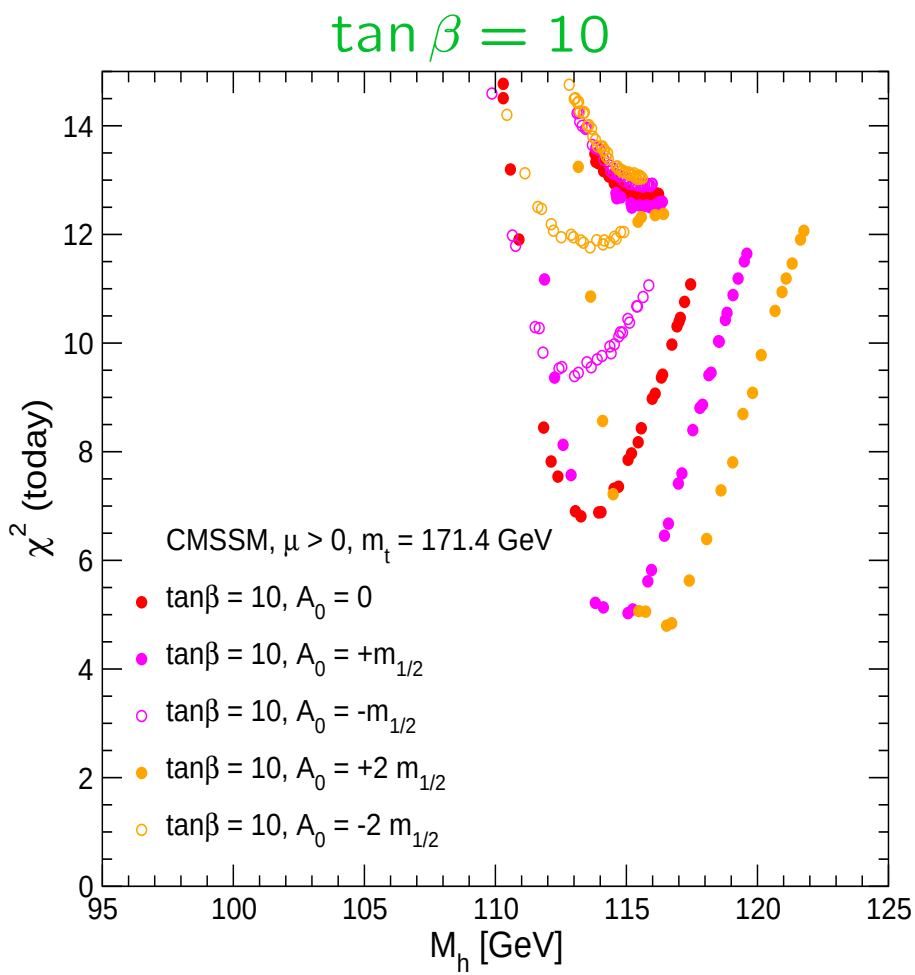


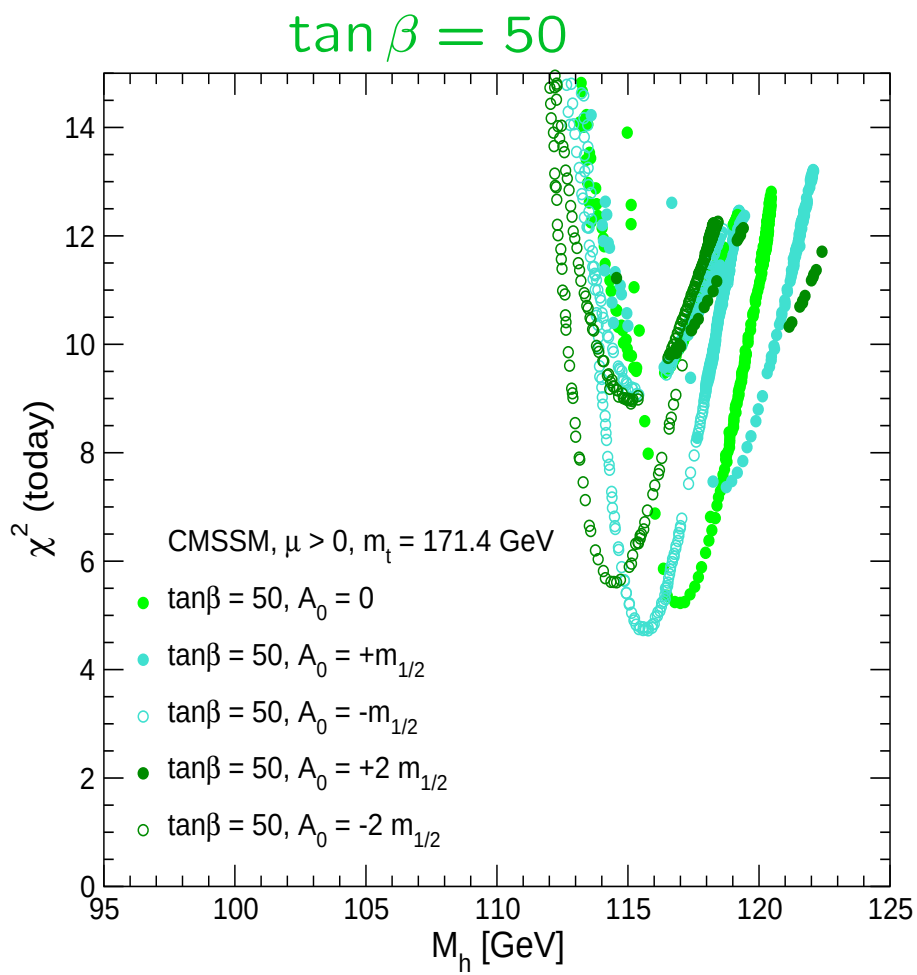
$\tan\beta = 50$



$\Rightarrow$ much "better" than in the SM

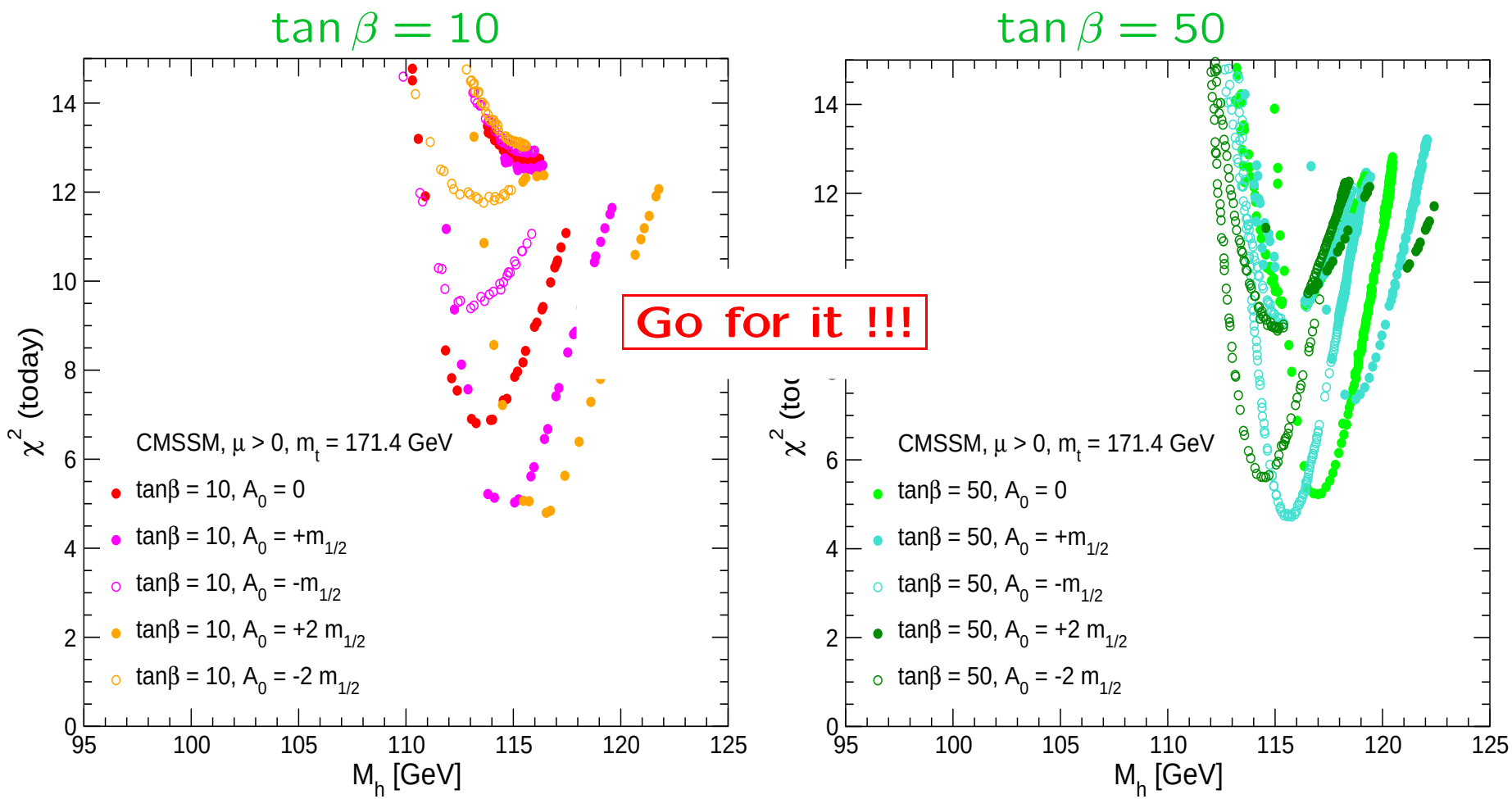
Results: CMSSM (including LEP bounds): prediction for M_h





$\Rightarrow$ preference for $M_h \sim 115$ GeV (LEP . . .)

Results: CMSSM (including LEP bounds): prediction for M_h



$\Rightarrow$ preference for $M_h \sim 115$ GeV (LEP . . .)

3. The light heavy MSSM Higgs bosons

Search modes:

$$b\,\bar{b} \to \phi\, b\,\bar{b}\ , \quad \phi = h, H, A$$
$$p\,\bar{p} \to \phi \to \tau^+\,\tau^-\ , \quad \phi = h, H, A$$

Strong enhancement compared to the SM:

$$\sigma(b\bar{b}A) \times \mathrm{BR}(A \to b\bar{b}) \simeq \sigma(b\bar{b}A)_{\mathrm{SM}} \frac{\tan^2\beta}{(1+\Delta_b)^2} \times \frac{9}{(1+\Delta_b)^2+9}$$

$$\sigma(gg, b\bar{b} \to A) \times \mathrm{BR}(A \to \tau^+\tau^-) \simeq \sigma(gg, b\bar{b} \to A)_{\mathrm{SM}} \frac{\tan^2\beta}{(1+\Delta_b)^2+9}$$

$$\Delta_b = \frac{2\alpha_s}{3\pi} m_{\tilde{g}}\,\mu\,\tan\beta \times I(m_{\tilde{b}_1}, m_{\tilde{b}_2}, m_{\tilde{g}}) + \frac{\alpha_t}{4\pi} A_t\,\mu\,\tan\beta \times I(m_{\tilde{t}_1}, m_{\tilde{t}_2}, \mu)$$

Either $H \approx A$ or $h \approx A \Rightarrow$ another factor of 2

Search for the MSSM Higgs bosons at LEP/Tevatron/...:

→ investigate benchmark scenarios:

→ Vary only M_A and $\tan\beta$
→ Keep all other SUSY parameters fixed

1. m_h^{max} scenario:
   → obtain conservative $\tan\beta$ exclusion bounds ($X_t = 2\,M_{\text{SUSY}}$)

2. no-mixing scenario
   → no mixing in the scalar top sector ($X_t = 0$)

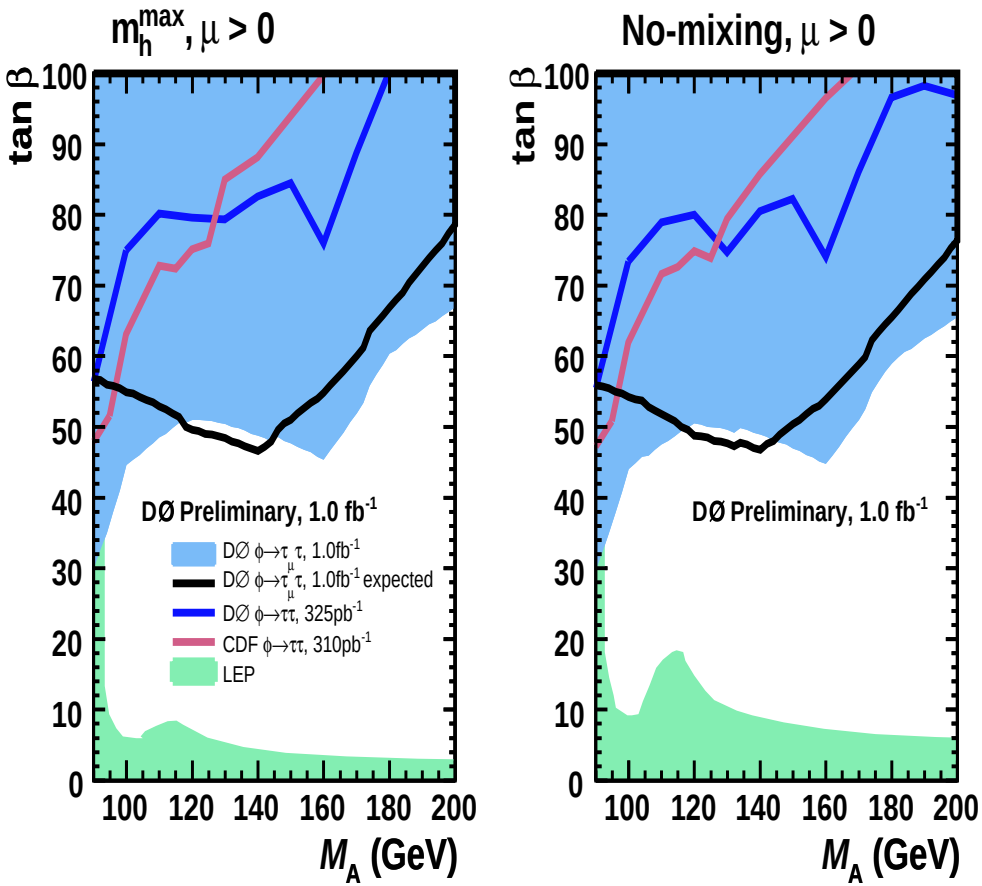
3. small α_{eff} scenario
   → $hb\bar{b}$ coupling $\sim \sin\alpha_{\text{eff}}/\cos\beta$ can be zero: $\alpha_{\text{eff}} \to 0$:
   main decay mode vanishes, important search channel vanishes

4. gluophobic Higgs scenario
   → hgg coupling is small: main LHC production mode vanishes

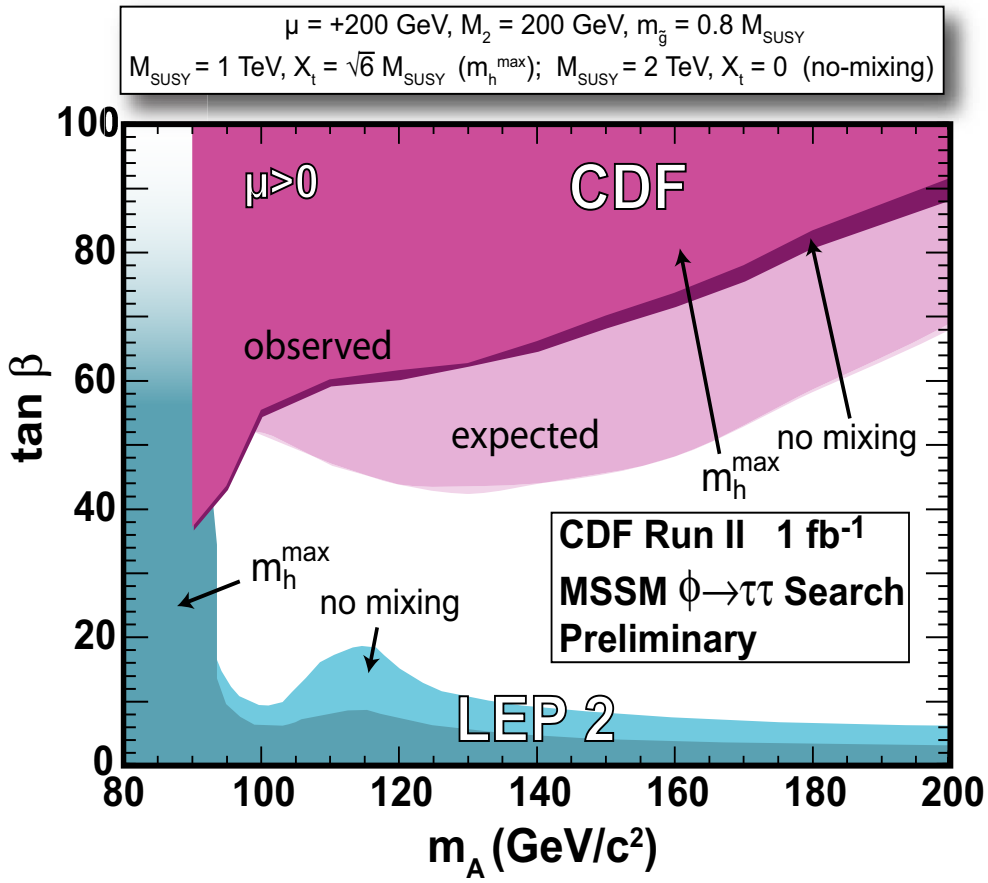
[*M. Carena, S.H., C. Wagner, G. Weiglein '02*]

→ μ fixed (small impact on search for the lightest MSSM Higgs)
→ CDM ignored (for certain (good) reasons)

Existing Tevatron analyses: $h/H/A \to \tau\tau$ (1 fb^{-1}):



[D0 '07]



[CDF '07]

⇒ Bounds on the MSSM parameter space for low M_A, high $\tan\beta$:
$\tan\beta \approx 50$ excluded for $M_A \approx 100$ GeV

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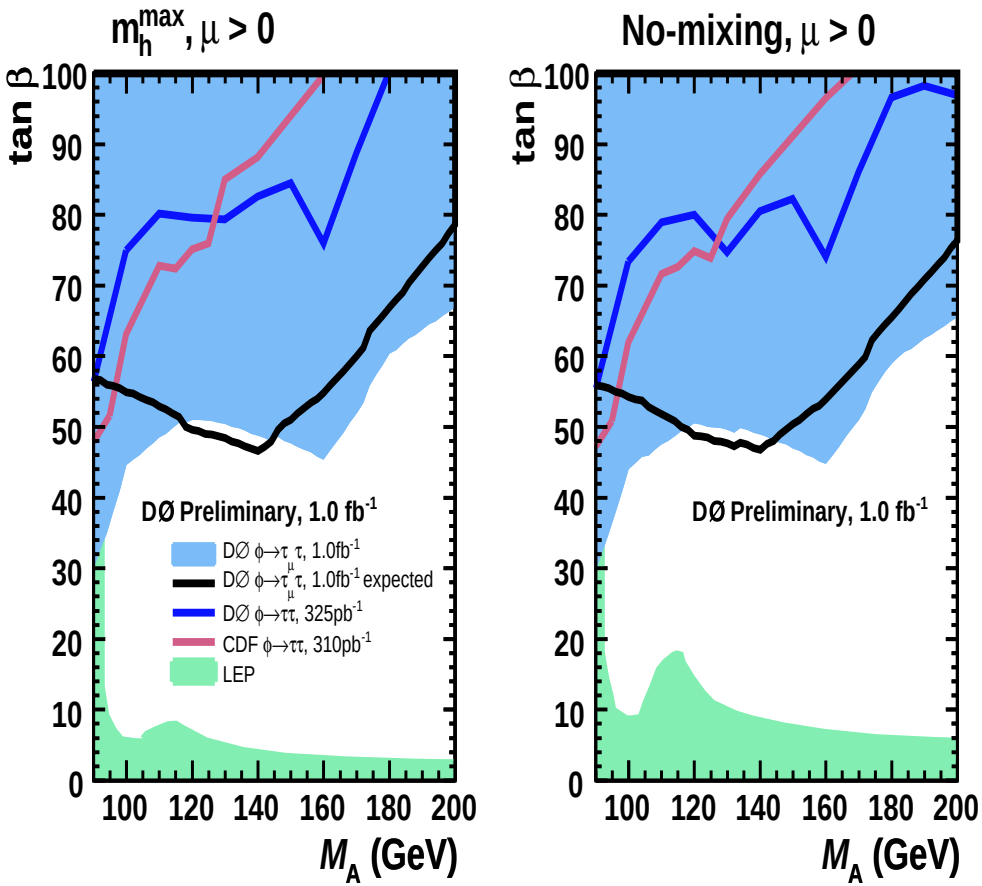

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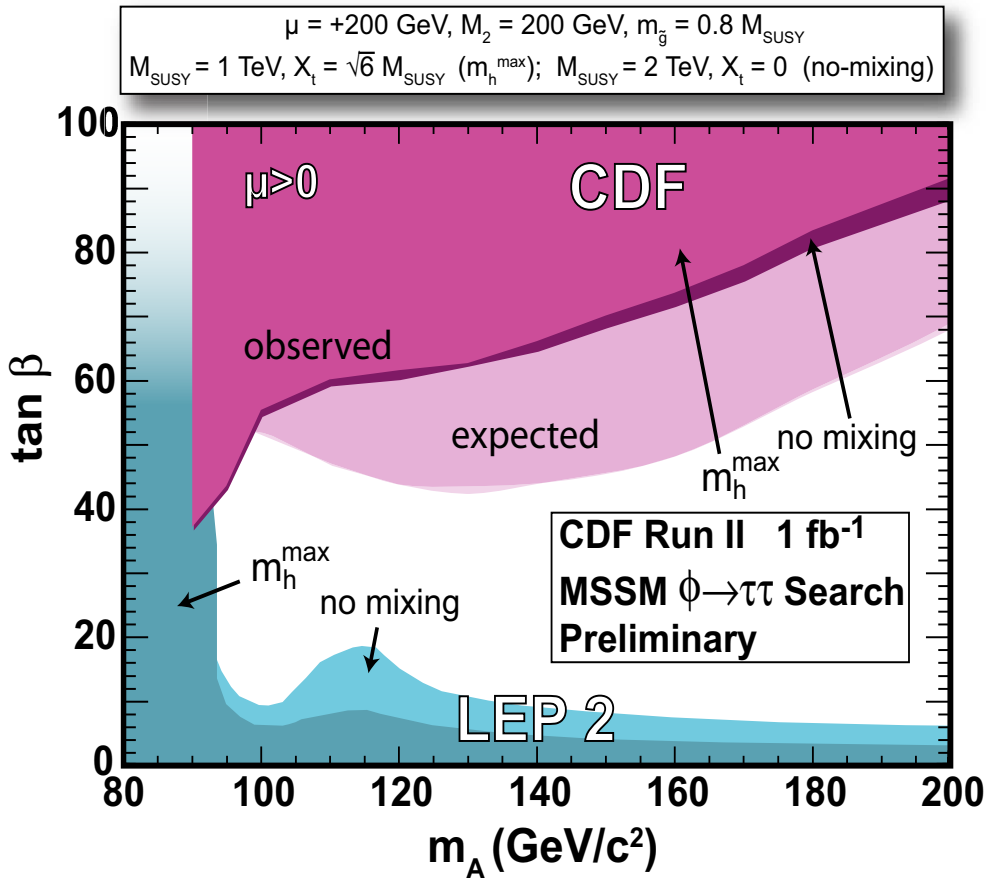
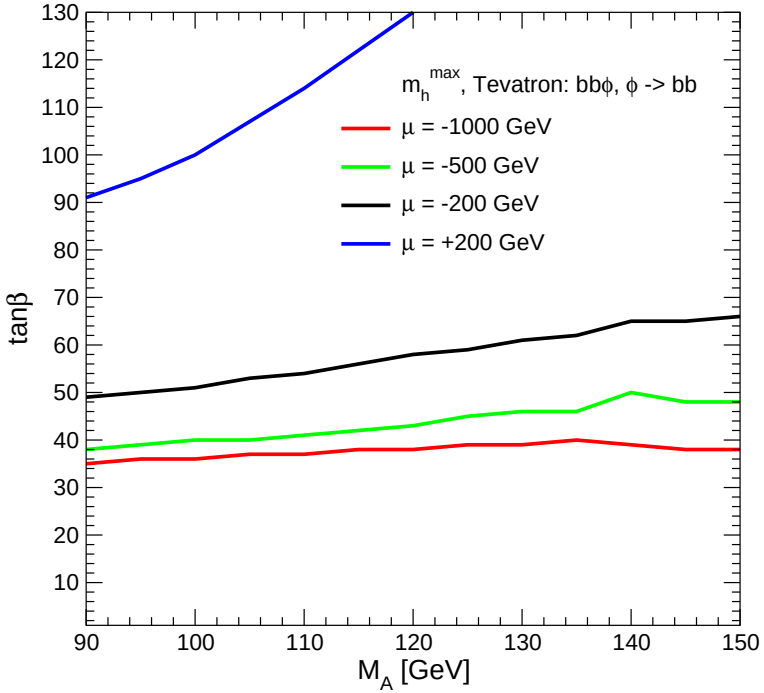


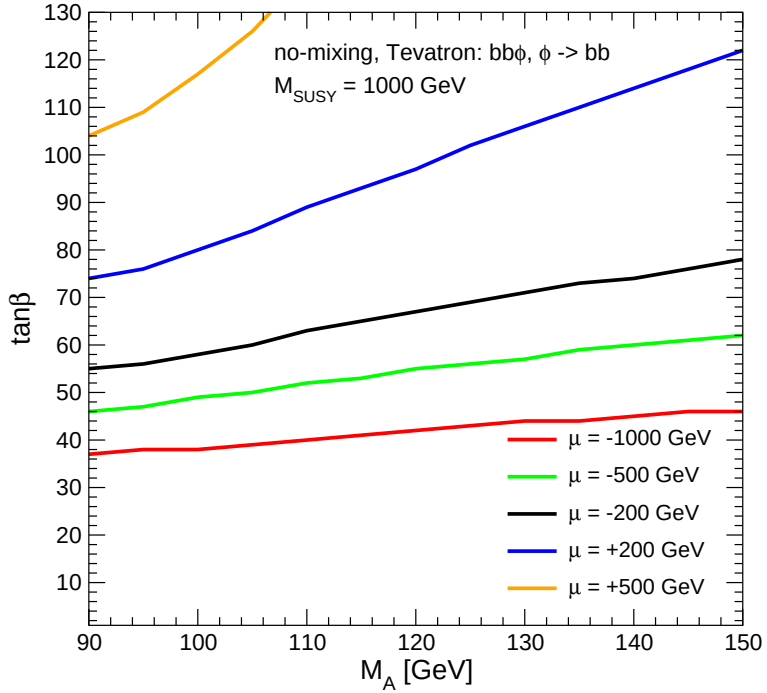
[CDF '07]

⇒ Bounds on the MSSM parameter space for low M_A, high $\tan\beta$:
$\tan\beta \approx 50$ excluded for $M_A \approx 100$ GeV
in certain benchmark scenarios!

Dependence of Tevatron bounds from $b\bar{b}\phi, \phi \to b\bar{b}$ on μ:

[*M. Carena, S.H., C. Wagner, G. Weiglein '05*]





$\Rightarrow$ strong variation with the sign and absolute value of μ

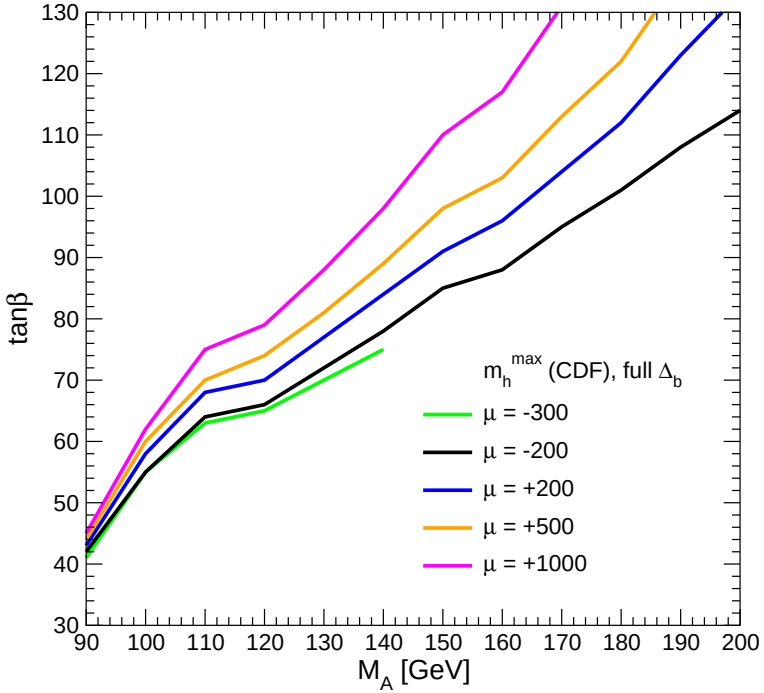
$\Rightarrow$ much stronger or weaker bounds possible

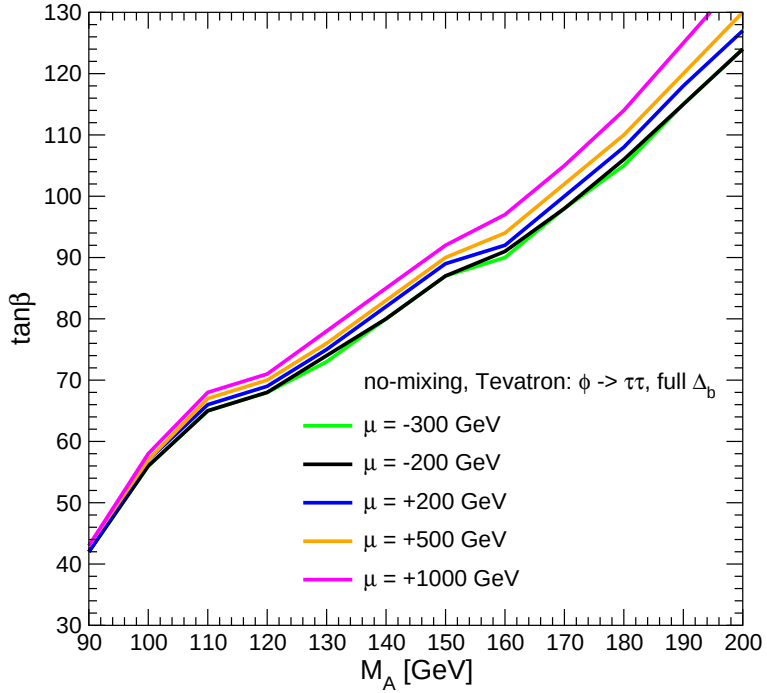
no bounds for $\mu \gtrsim 200$ GeV

(positive μ preferred by $(g-2)_\mu$)

Dependence of Tevatron bounds from $p\bar{p} \to \phi, \phi \to \tau^+\tau^-$ on μ:

[*M. Carena, S.H., C. Wagner, G. Weiglein '05*]





⇒ less strong variation with the sign and absolute value of μ

(→ numerical compensations in production and decay)

⇒ still much stronger or weaker bounds possible

strong dependence on benchmark scenario

Cold Dark Matter exists:

$\Rightarrow$ It all fits together

$$\Omega_{\text{tot}} \approx 1$$

$$\Omega_M h^2 = 0.135^{+0.008}_{-0.009}$$

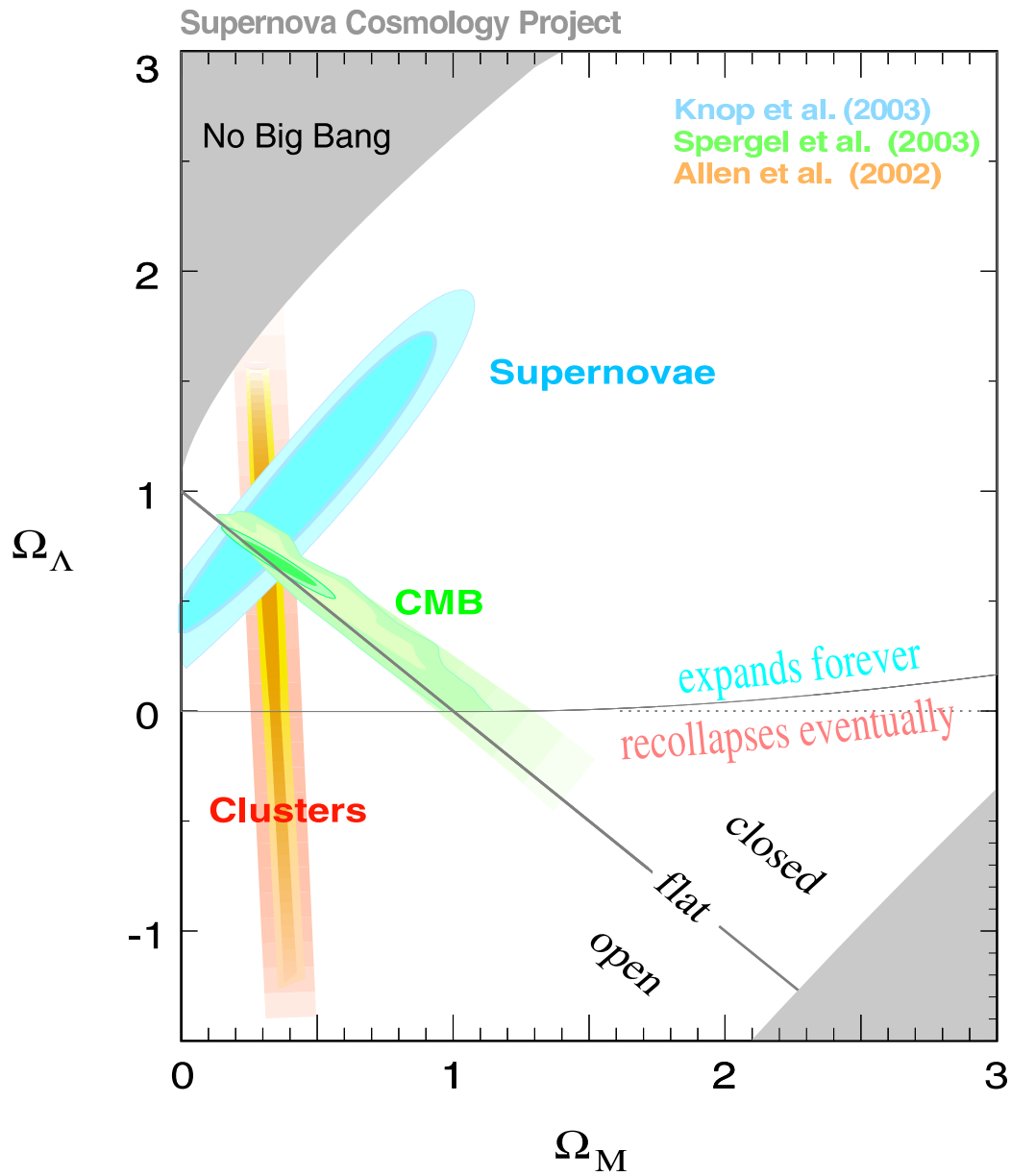
$$\Omega_B h^2 = 0.0224 \pm 0.0009$$

$$\Omega_\chi h^2 = 0.112 \pm 0.018$$

$$\Omega_\Lambda \approx 0.73$$

$\Omega_\chi \Rightarrow$ dark matter

$\Omega_\Lambda \Rightarrow$ dark energy . . .



How to define reasonable benchmark scenarios in agreement with CDM?

$\Rightarrow$ choose a GUT model!

CMSSM (or mSUGRA):

$\Rightarrow$ Scenario characterized by

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

m_0 : universal scalar mass parameter

$m_{1/2}$: universal gaugino mass parameter

A_0 : universal trilinear coupling

} at the GUT scale

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

sign(μ) : sign of supersymmetric Higgs parameter

$\Rightarrow$ no M_A–$\tan\beta$ planes in agreement with CDM possible

How to define reasonable benchmark scenarios in agreement with CDM?

$\Rightarrow$ choose a GUT model!

CMSSM (or mSUGRA):

$\Rightarrow$ Scenario characterized by

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

NUHM: (Non-universal Higgs mass model)

Assumption:

no unification of scalar fermion and scalar Higgs parameters at the GUT scale

$\Rightarrow$ effectively M_A and μ free parameters at the EW scale

$\Rightarrow$ besides the CMSSM parameters

$$M_A \text{ and } \mu$$

$\Rightarrow$ M_A–$\tan\beta$ planes in agreement with CDM possible!

$\Rightarrow$ M_A–tan β planes in agreement with CDM possible!

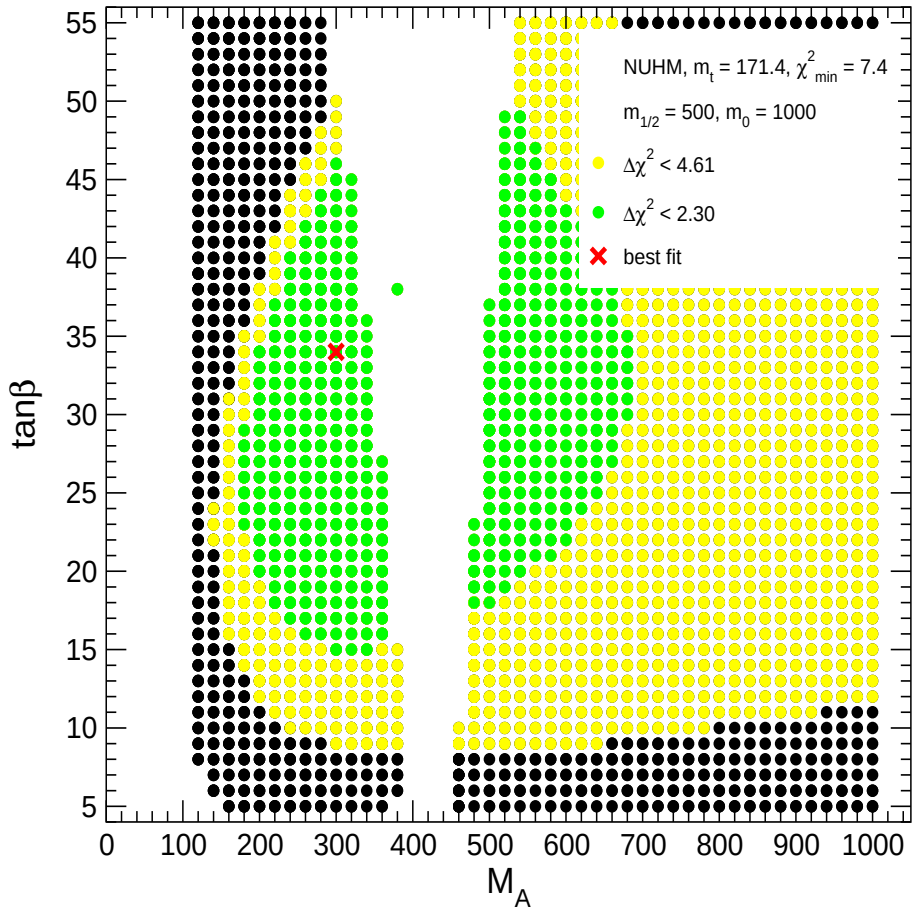
But what about other constraints from
electroweak precision observables and B physics observables?

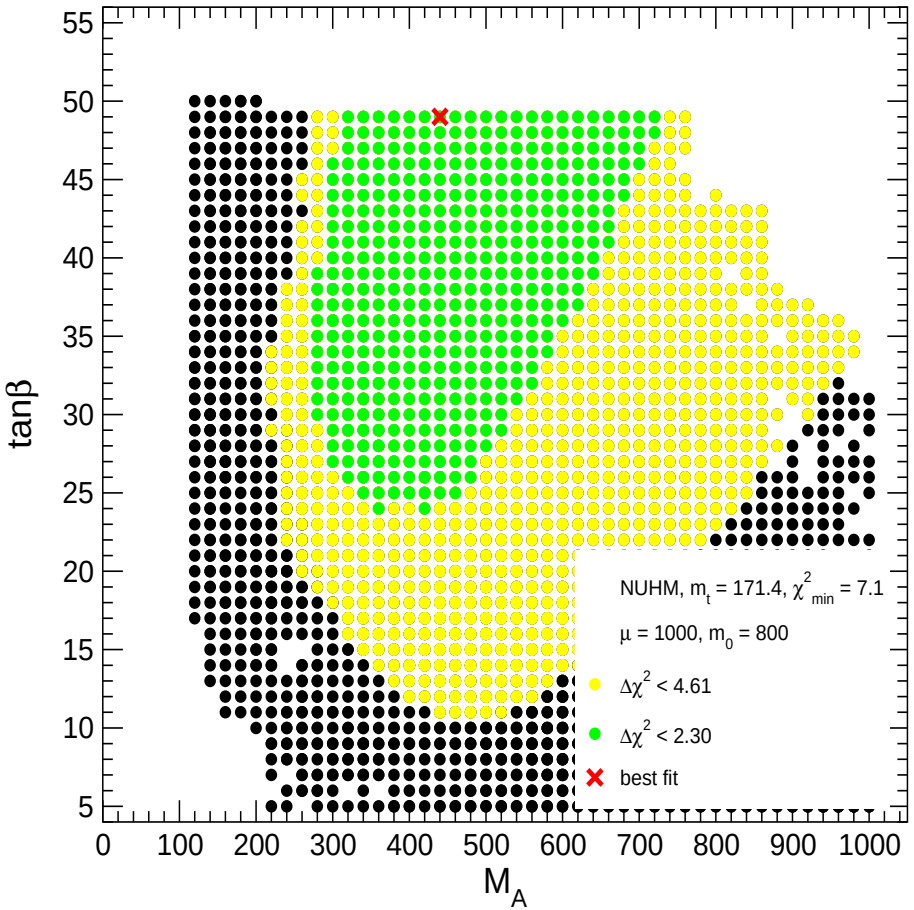
$\Rightarrow$ χ^2 test with:

1. W boson mass M_W
2. effective leptonic weak mixing angle $\sin^2\theta_{\text{eff}}$
3. total Z boson width Γ_Z
4. lightest Higgs boson mass M_h
5. anomalous magnetic moment of the muon $(g-2)_\mu$
6. b decay BR$(b \to s\gamma)$
7. b decay BR$(B_s \to \mu^+\mu^-)$
8. b decay BR$(B_u \to \tau\nu_\tau)$
9. B_s mixing ΔM_{B_s}

Results: NUHM: planes 2,3

[J. Ellis, S.H., K. Olive, A.M. Weber, G. Weiglein '07]

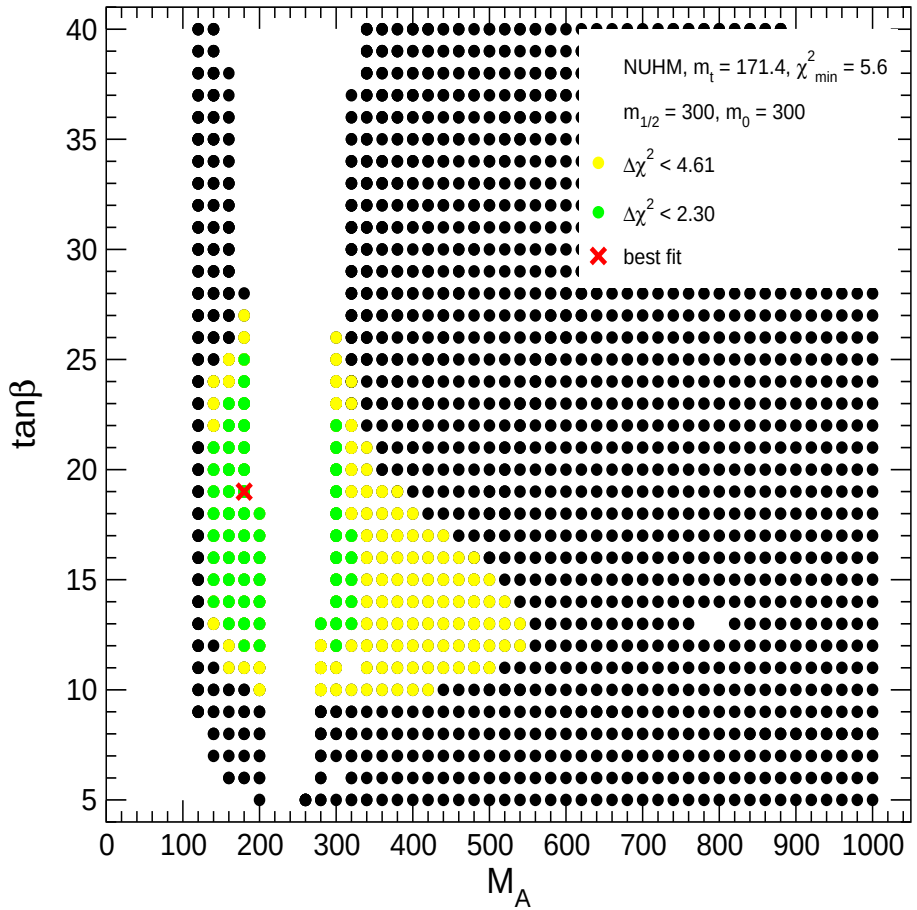


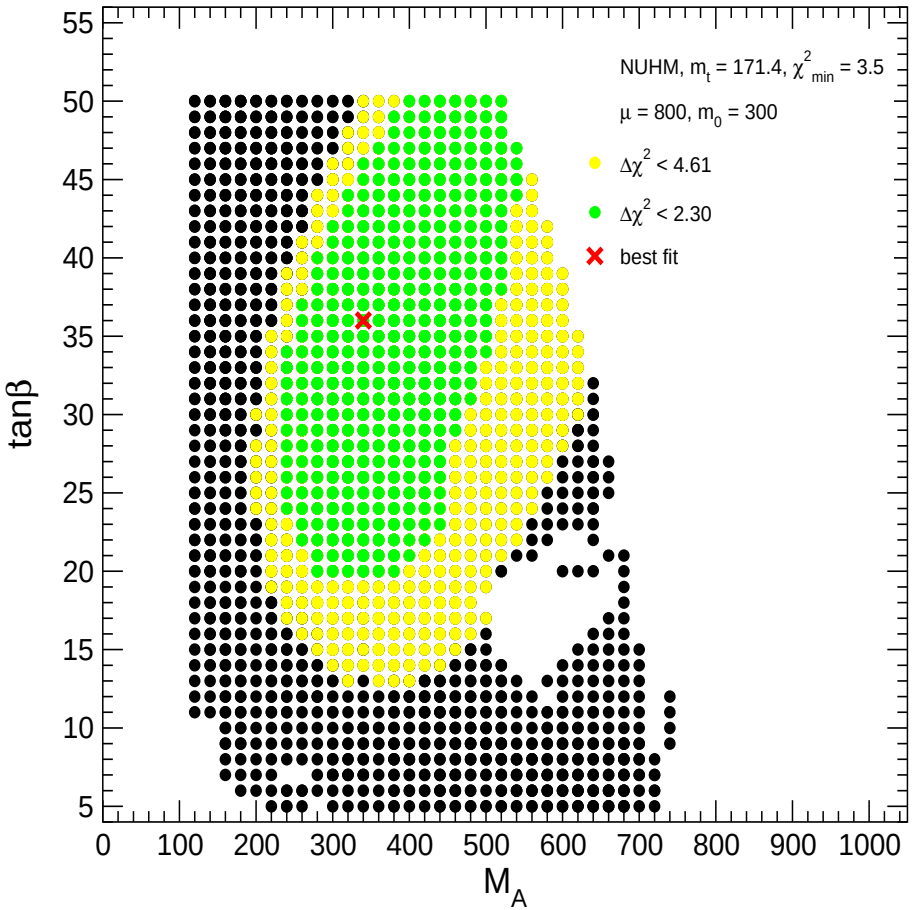


⇒ good χ^2, larger regions o.k.

Results: NUHM: planes 4,5

[J. Ellis, S.H., K. Olive, A.M. Weber, G. Weiglein '07]

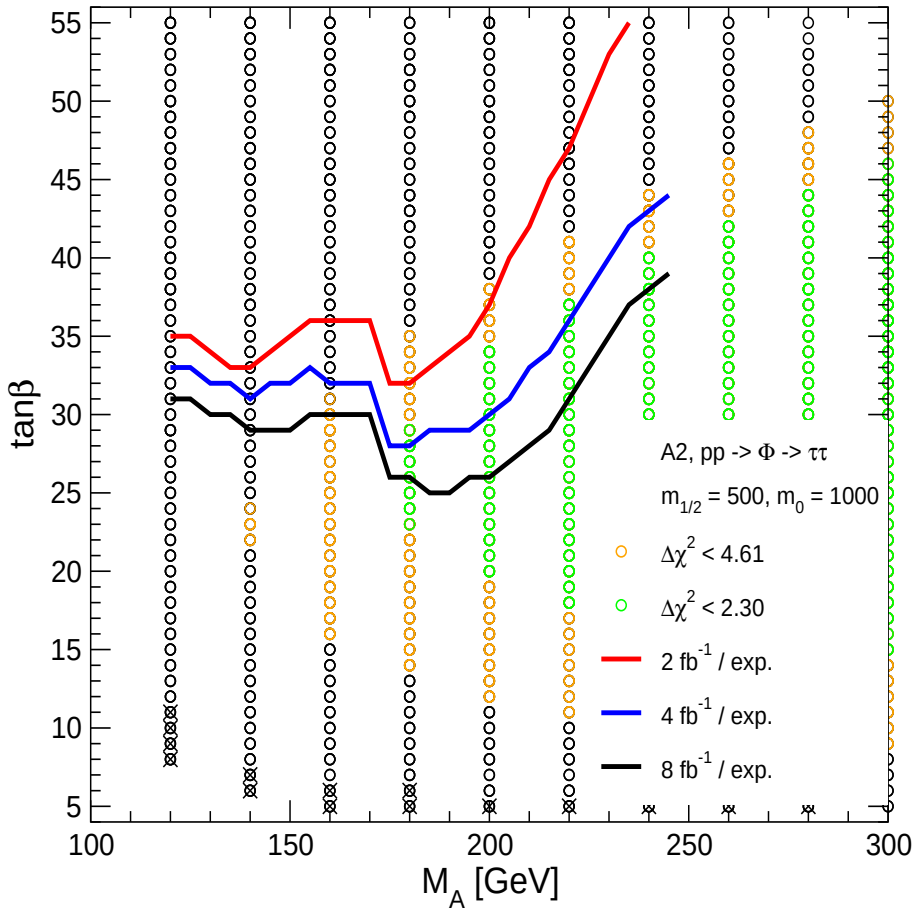


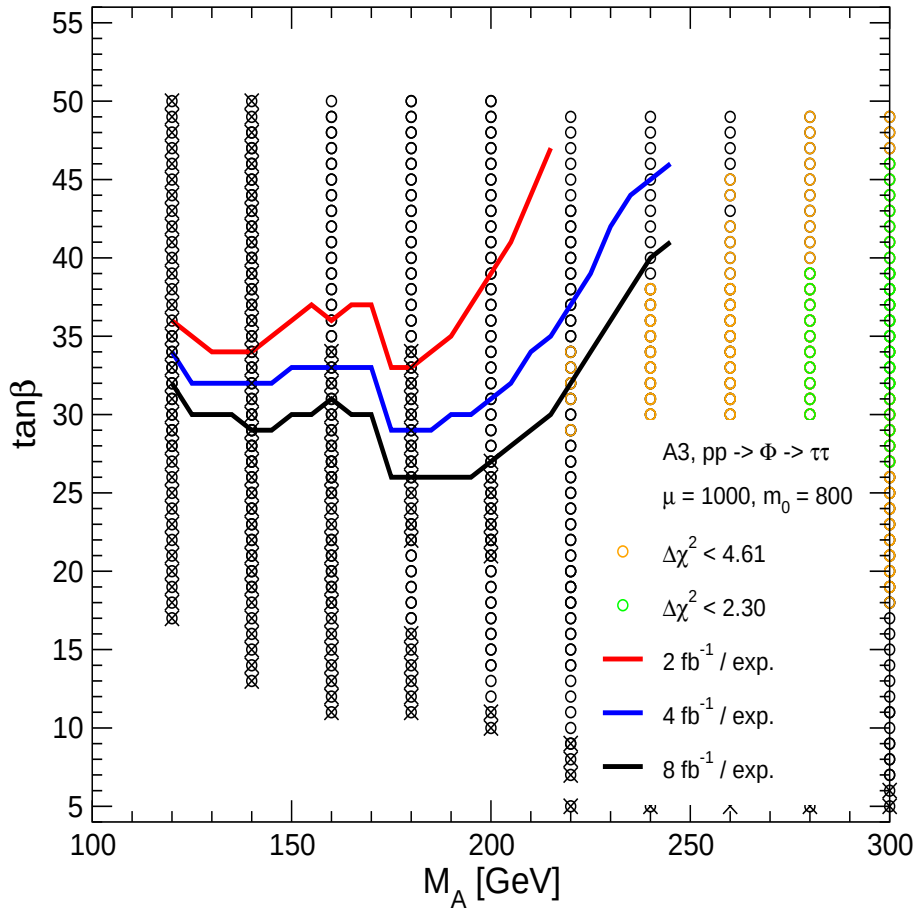


⇒ good χ^2, larger regions o.k.

Tevatron reach in $H/A \to \tau^+\tau^-$: planes 2,3

[*J. Ellis, T. Hahn, S.H., K. Olive, G. Weiglein '07*]

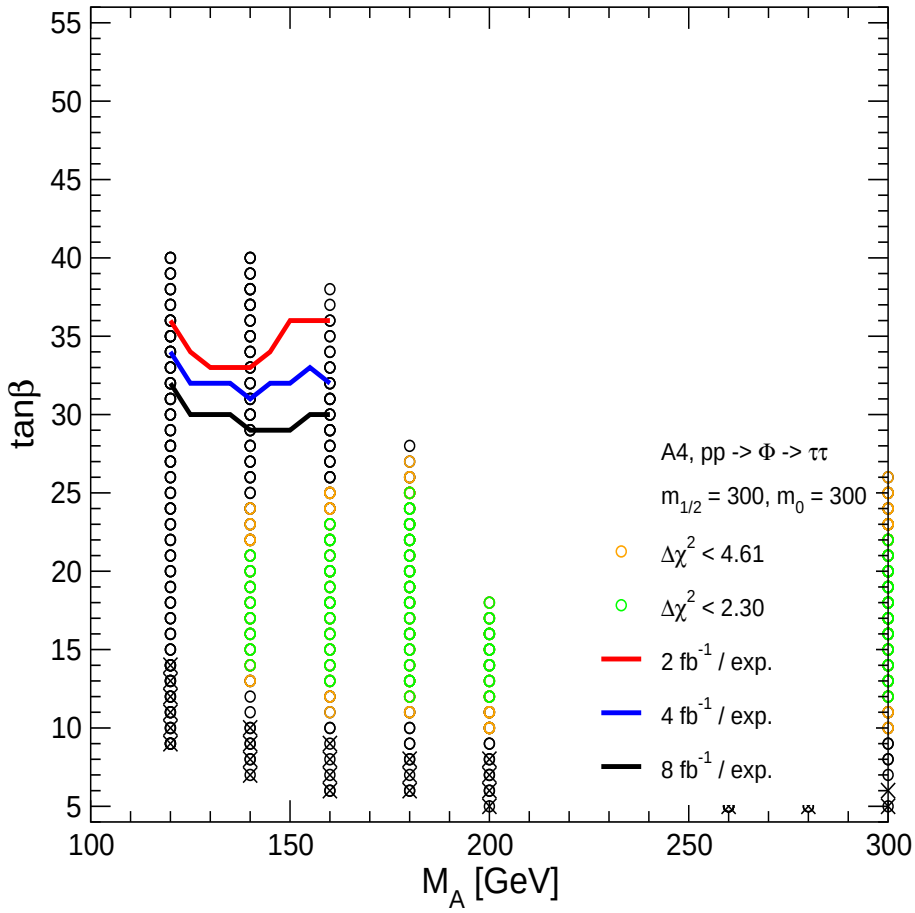


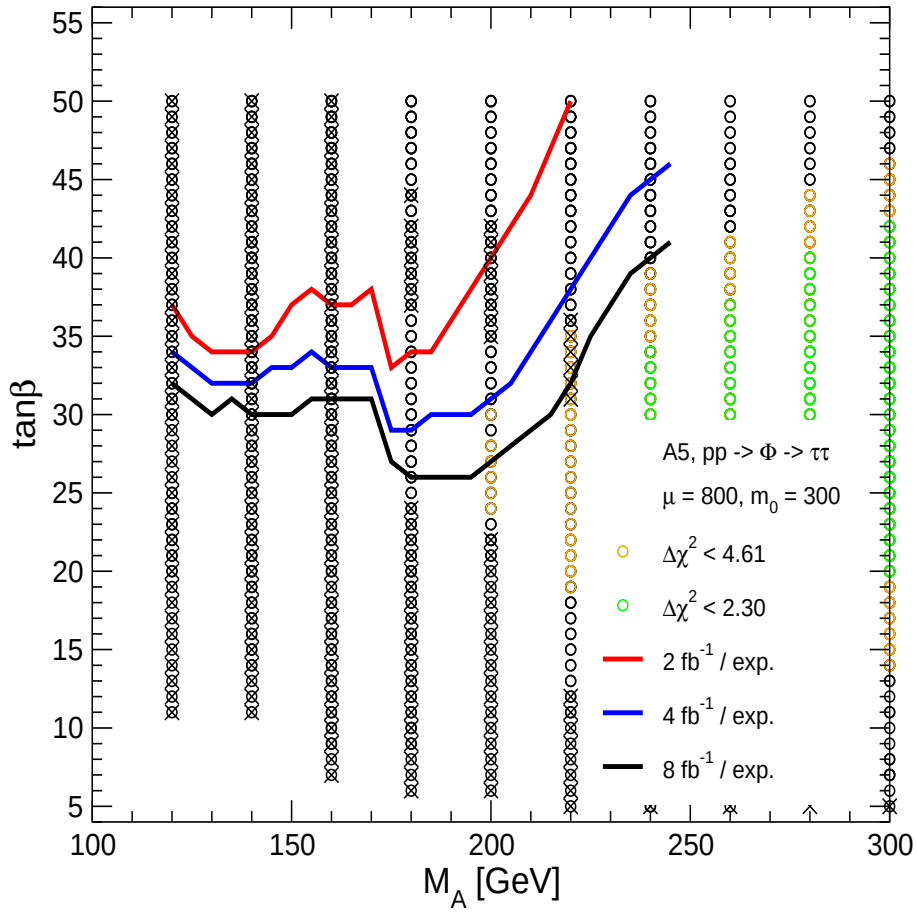


$\Rightarrow$ start to cut in the interesting regions

Tevatron reach in $H/A \to \tau^+\tau^-$: planes 4,5

[*J. Ellis, T. Hahn, S.H., K. Olive, G. Weiglein '07*]





$\Rightarrow$ hardly cuts in the interesting regions

Q: Can YOU do phenomenology with these new benchmarks?

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A: YES!

Q: Can YOU do phenomenology with these new benchmarks?

A: YES!

They are included in FeynHiggs 2.6

(to be released in June 2007 (i.e. tomorrow?))

available at `www.feynhiggs.de`

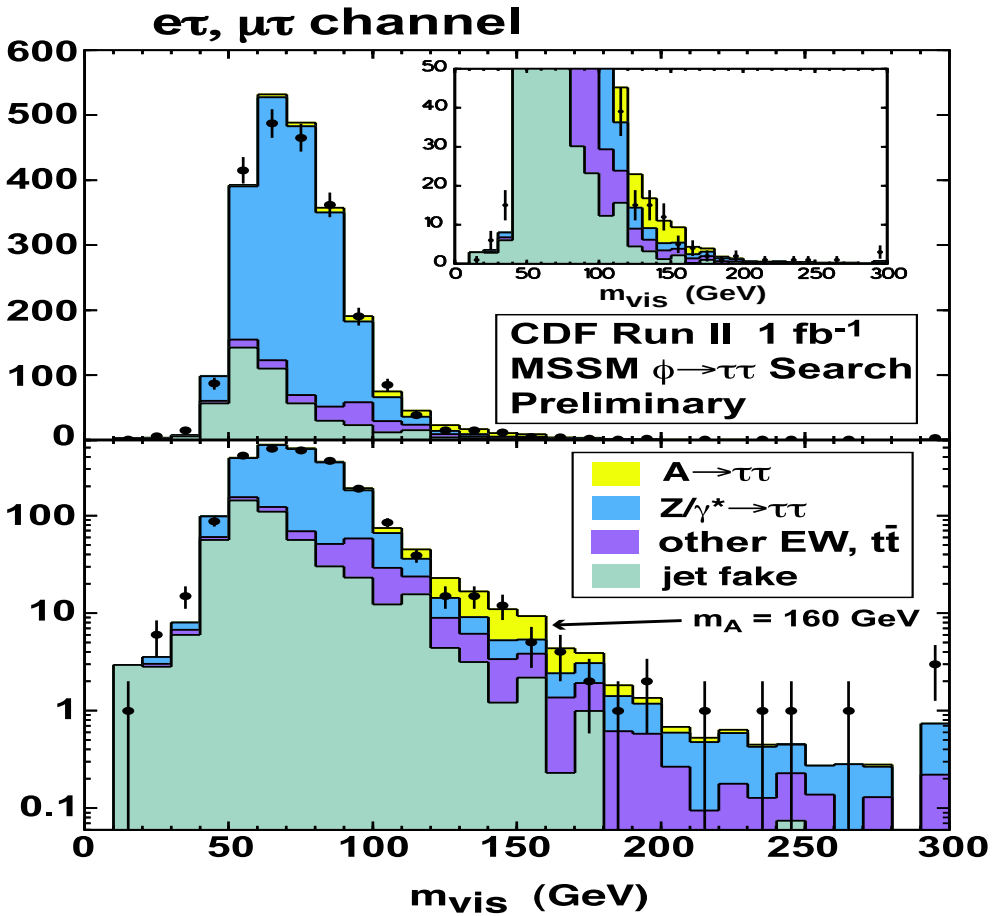
You specify:

- number of the plane
- M_A and $\tan\beta$

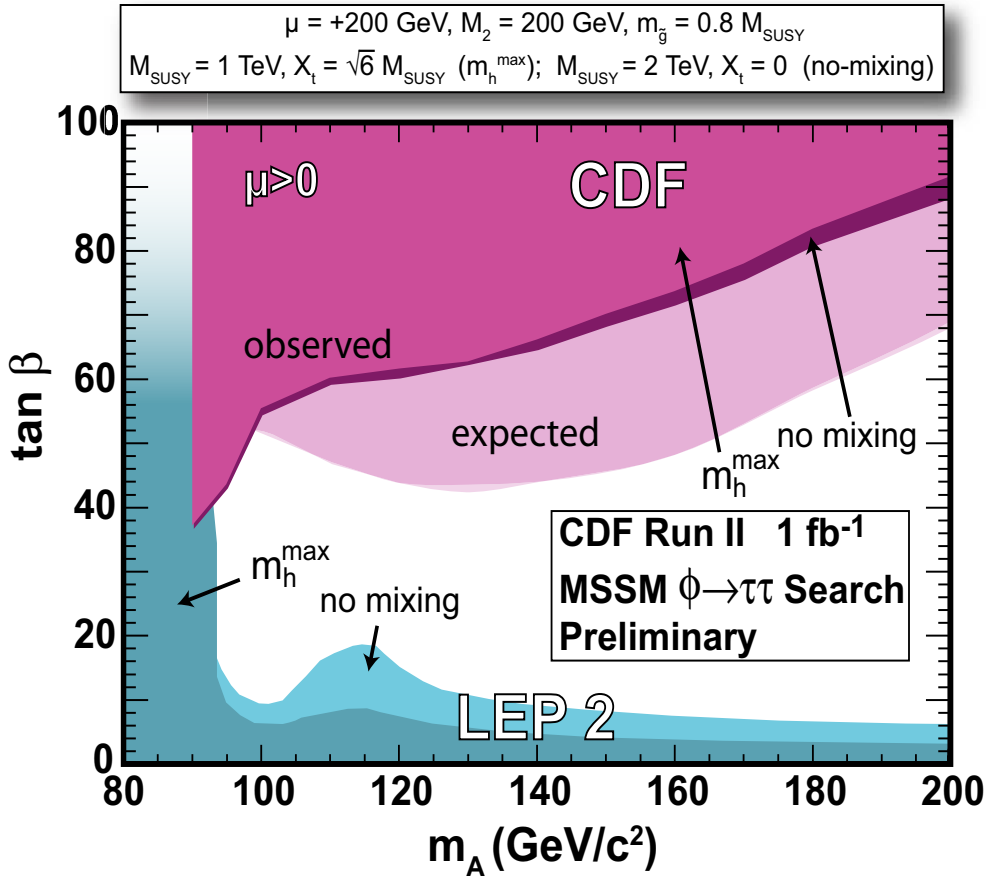
You get:

- all low energy parameters
- Higgs masses and mixings
- all Higgs branching ratios
- all Higgs production cross sections
- further precision observables

NUHM compatible with $M_A \approx 160$ GeV, $\tan\beta \gtrsim 45$?



[CDF '07]



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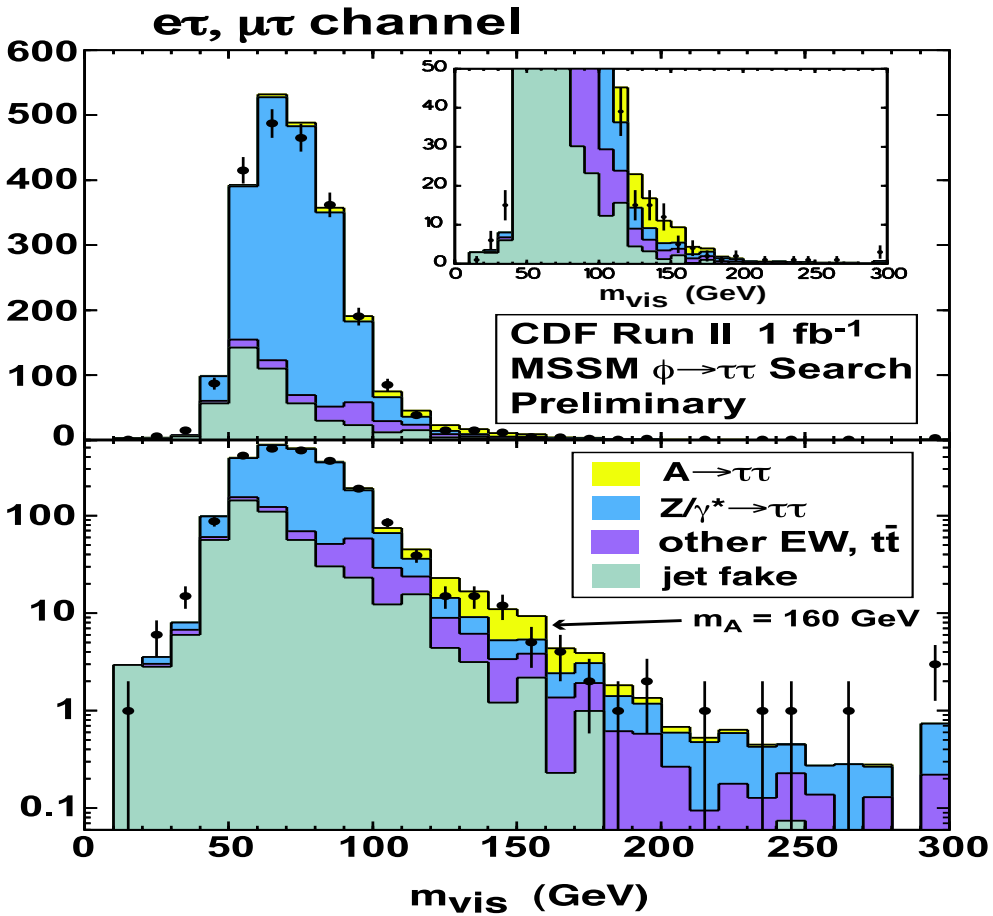

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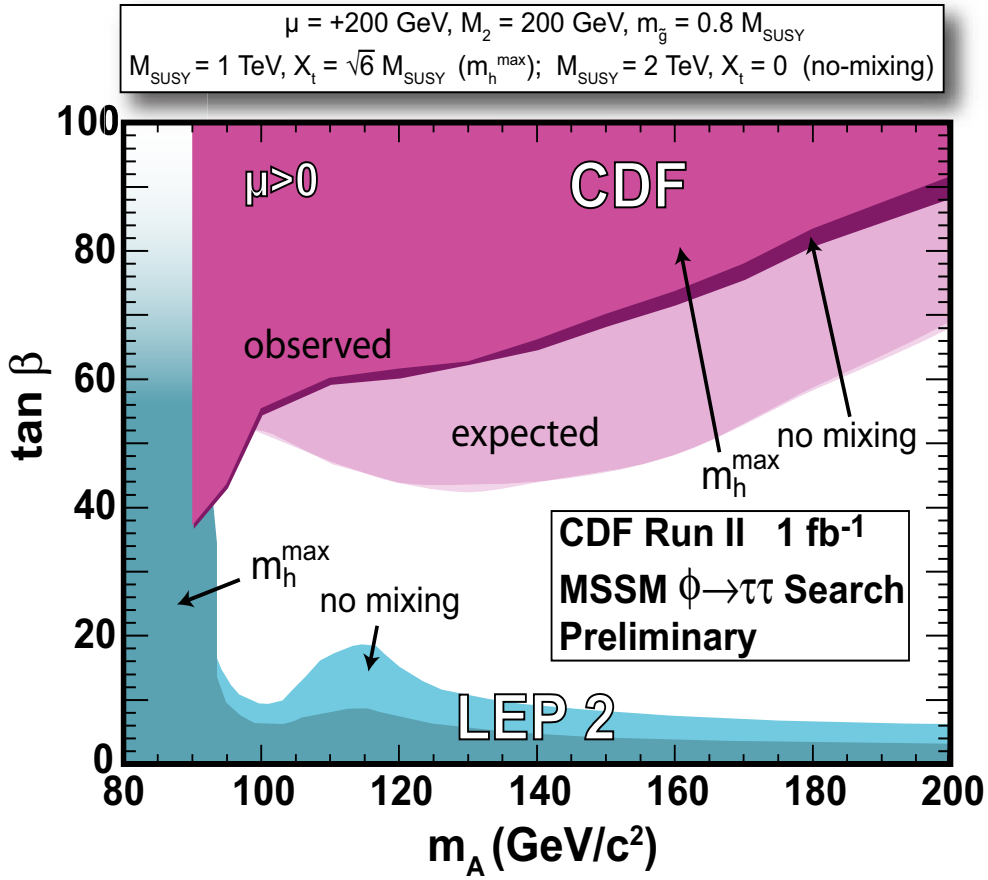


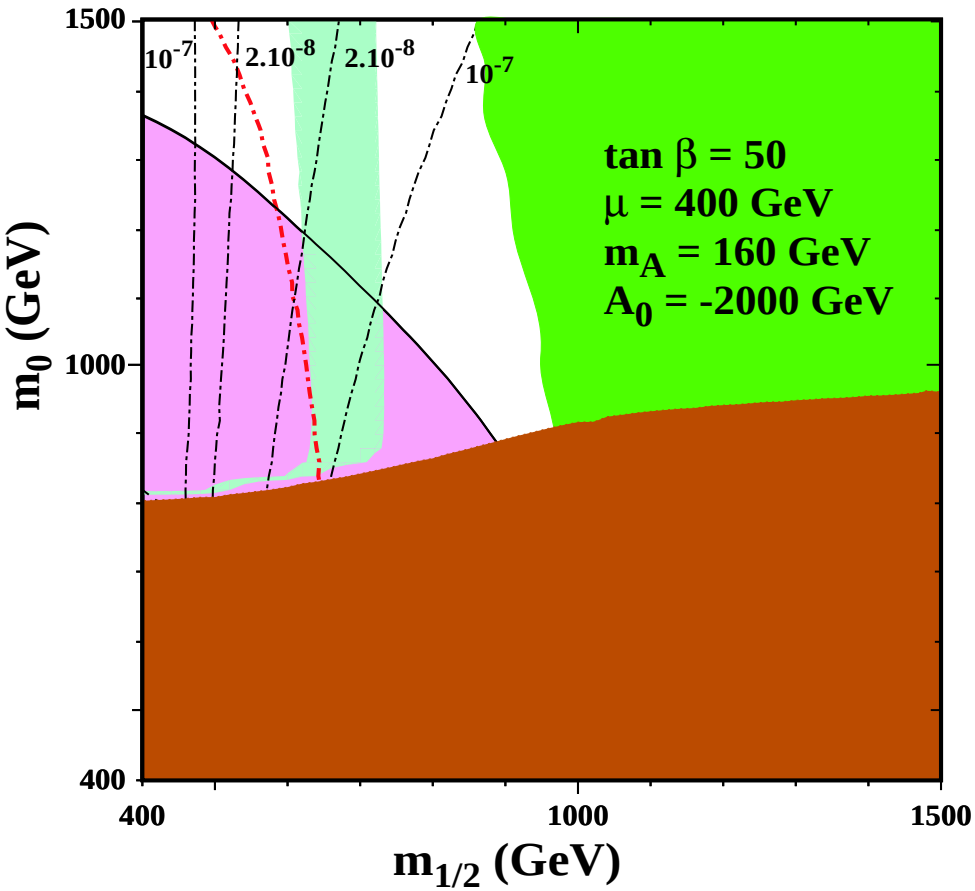
[CDF '07]

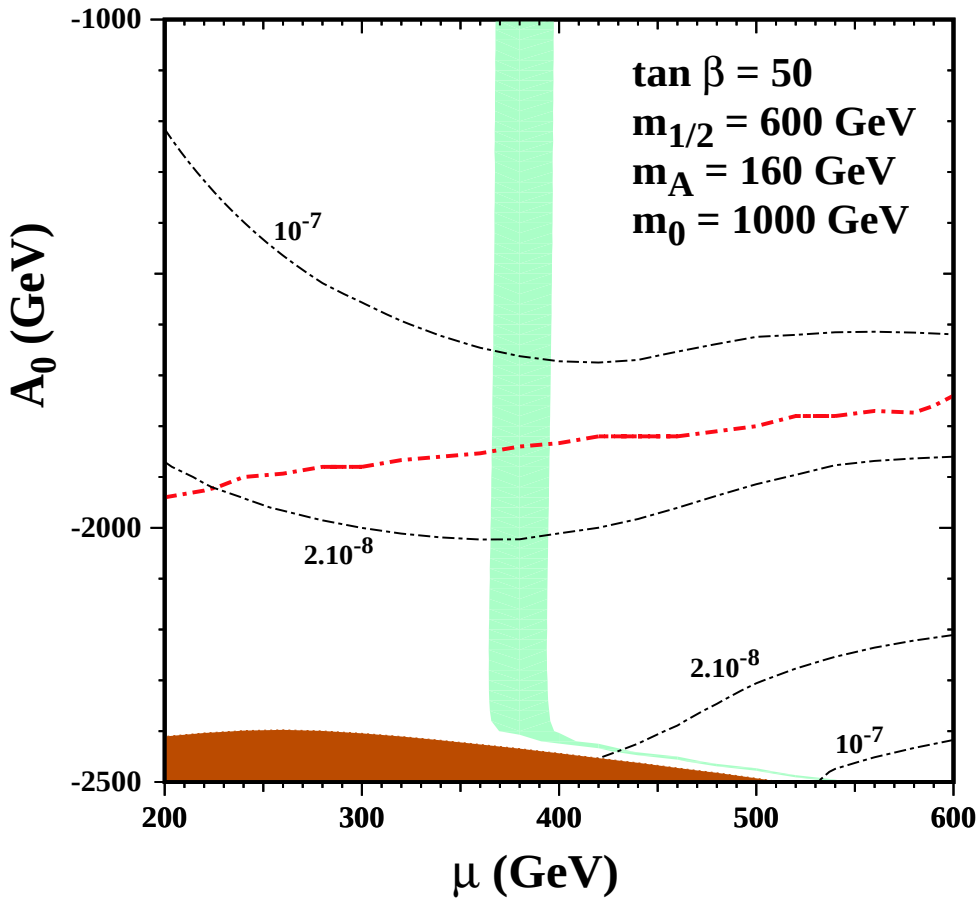
YES! With important consequences!

NUHM parameters:

$M_A = 160$ GeV, $\tan\beta = 45$–55

$m_{1/2} \sim 600$ GeV, $m_0 \sim 1000$ GeV, $A_0 \sim -1800$ GeV, $\mu \sim 400$ GeV





[*J. Ellis, S.H., K. Olive, G. Weiglein '07*]

NUHM compatible with $M_A \approx 160$ GeV, $\tan\beta \gtrsim 45$?

YES! With important consequences!

1. lightest Higgs mass: $M_H \lesssim 115$ GeV
2. anomalous magnetic moment of the muon: $\Delta(\text{MSSM} - \text{SM}) \sim 1 - 2\,\sigma$
3. b decay $\text{BR}(b \to s\gamma) = 3.5 - 4.5 \times 10^{-4}$
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5. b decay $\text{BR}(B_u \to \tau\nu_\tau)$: MSSM/SM ≈ 0.33
6. direct detection of dark matter: CDMS or Xe10 should see a signal very soon

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4. A short theorist's wishlist

- Search for the SM Higgs boson

  ⇒ it is most probably right around the corner!

  → framework to combine channels/CDF and D0

  → cross section bounds

- Search for SUSY Higgses: SM-like

  ⇒ it must be right around the corner!

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- Search for SUSY Higgses: the "heavy" Higgses

  ⇒ You have a great search potential!

  → same as above

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  $\Rightarrow$ investigate new CDM benchmarks

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  $\Rightarrow$ investigate new CDM benchmarks

- $\Rightarrow$ Please try as hard as you can, it is definitely worth the effort!