SUSY Higgs phenomenology

DESY Theory Workshop 2012

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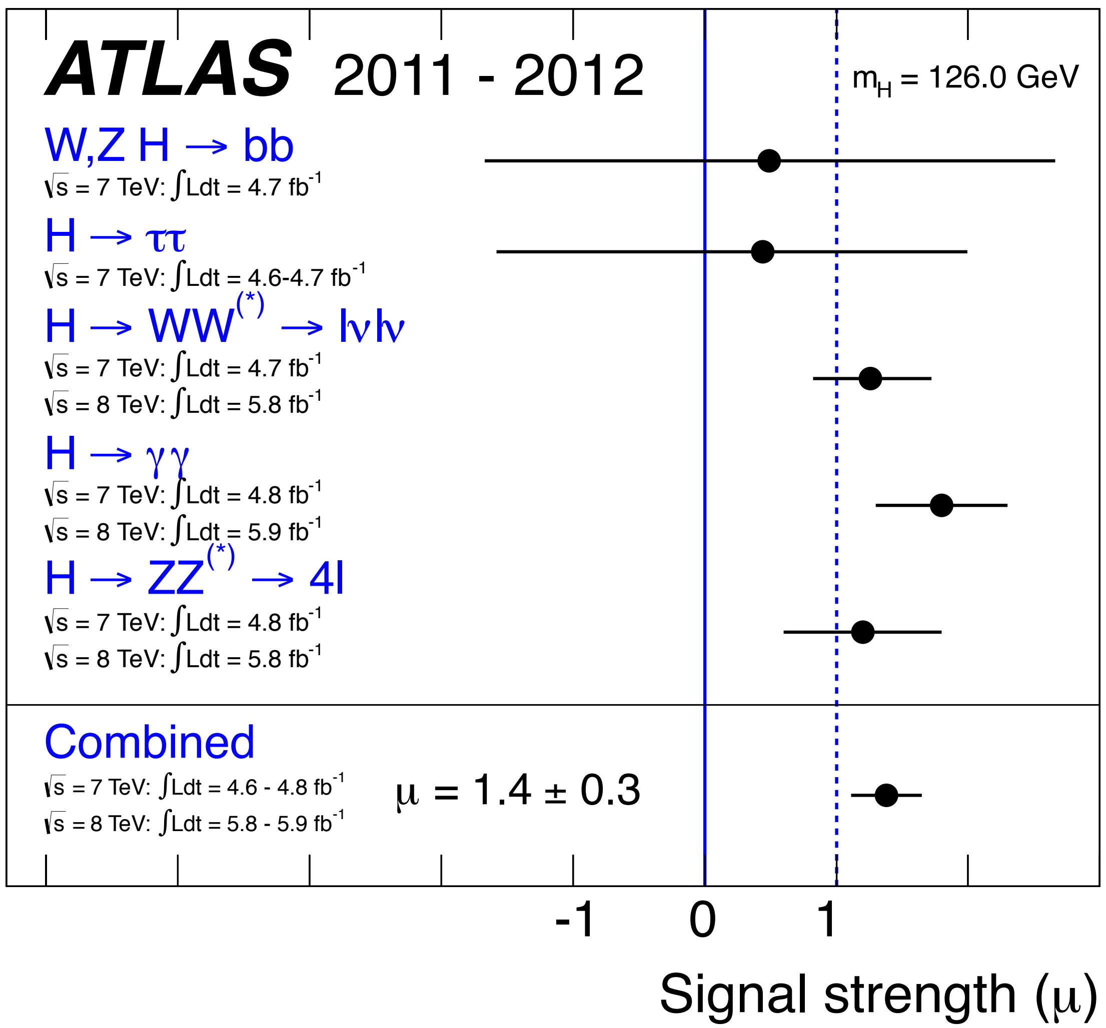
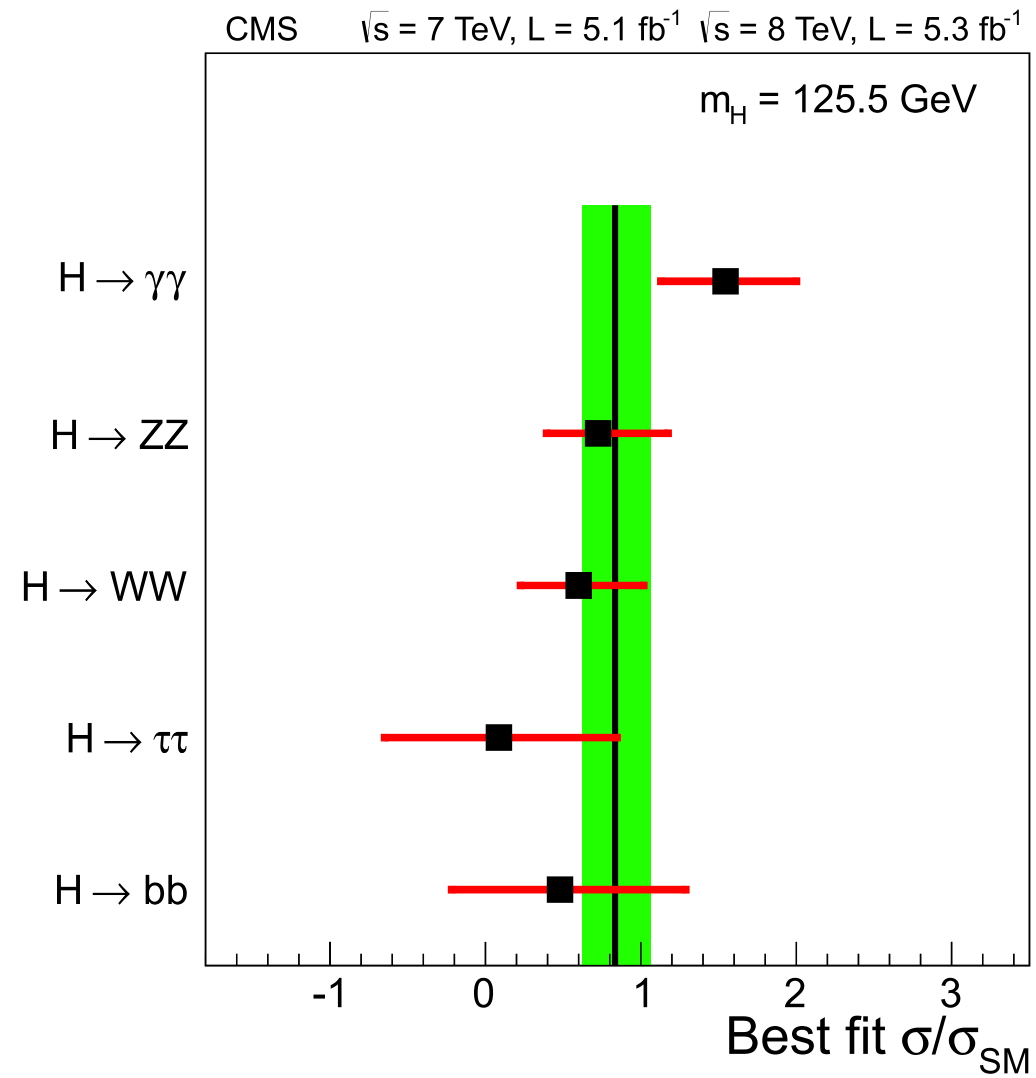
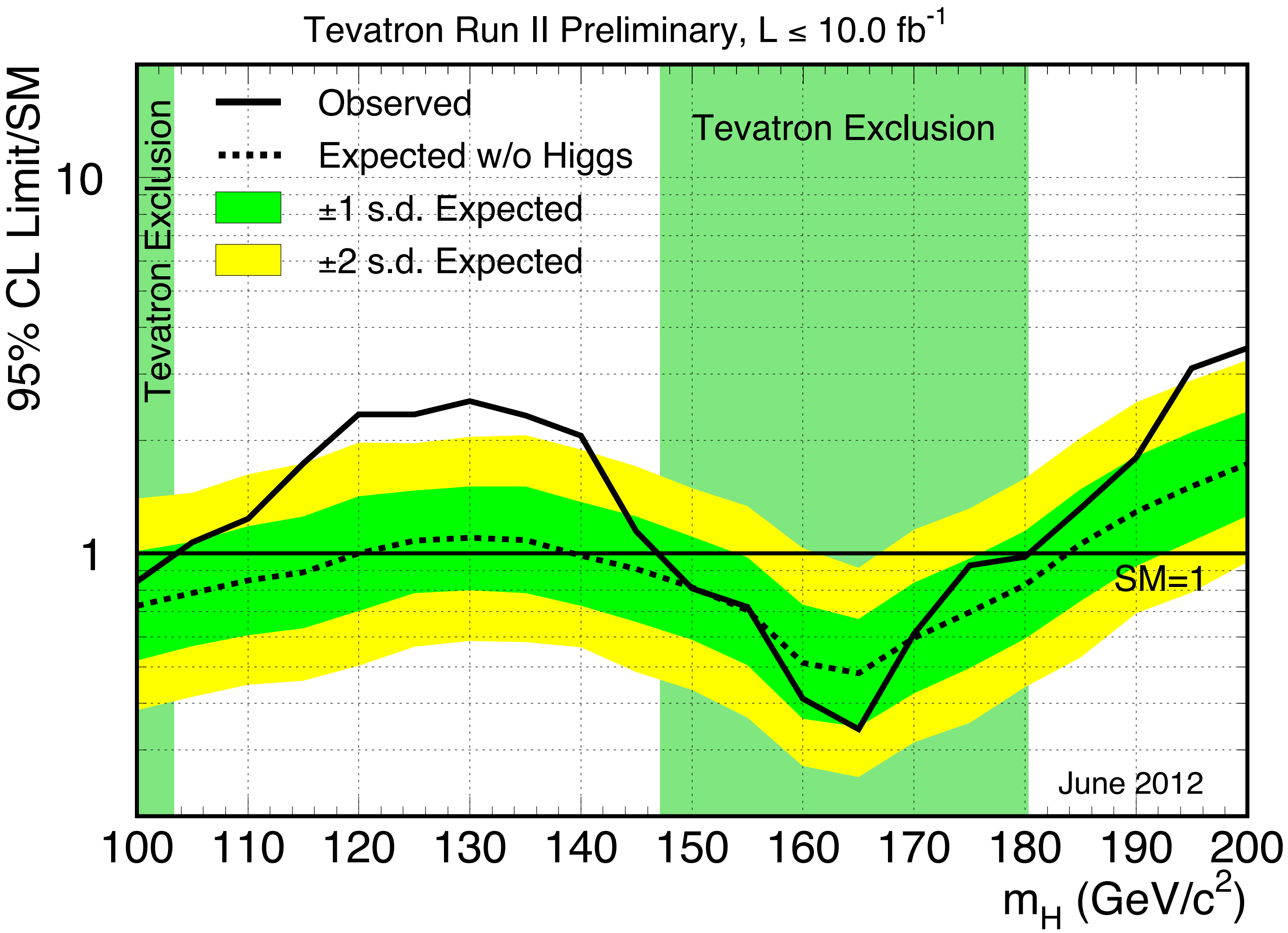
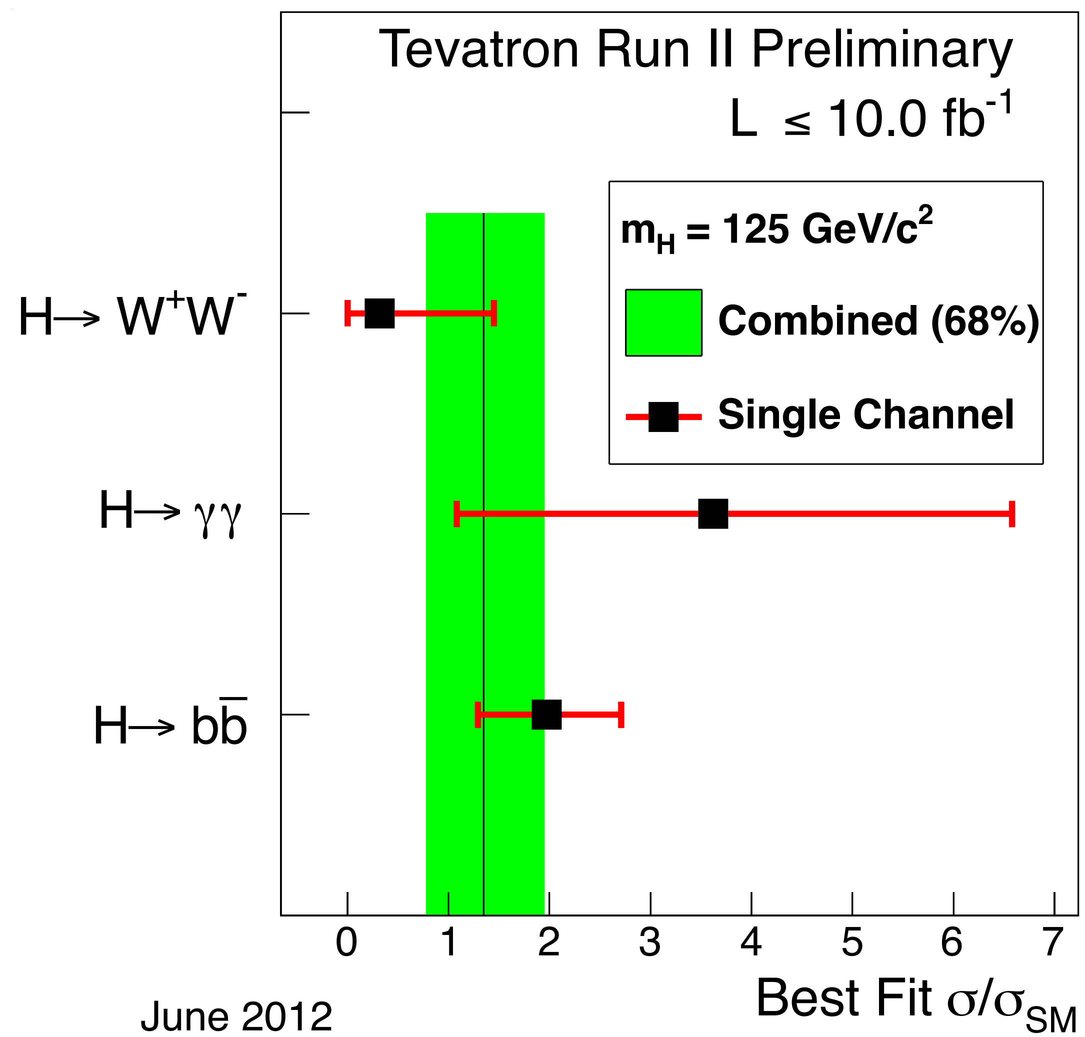
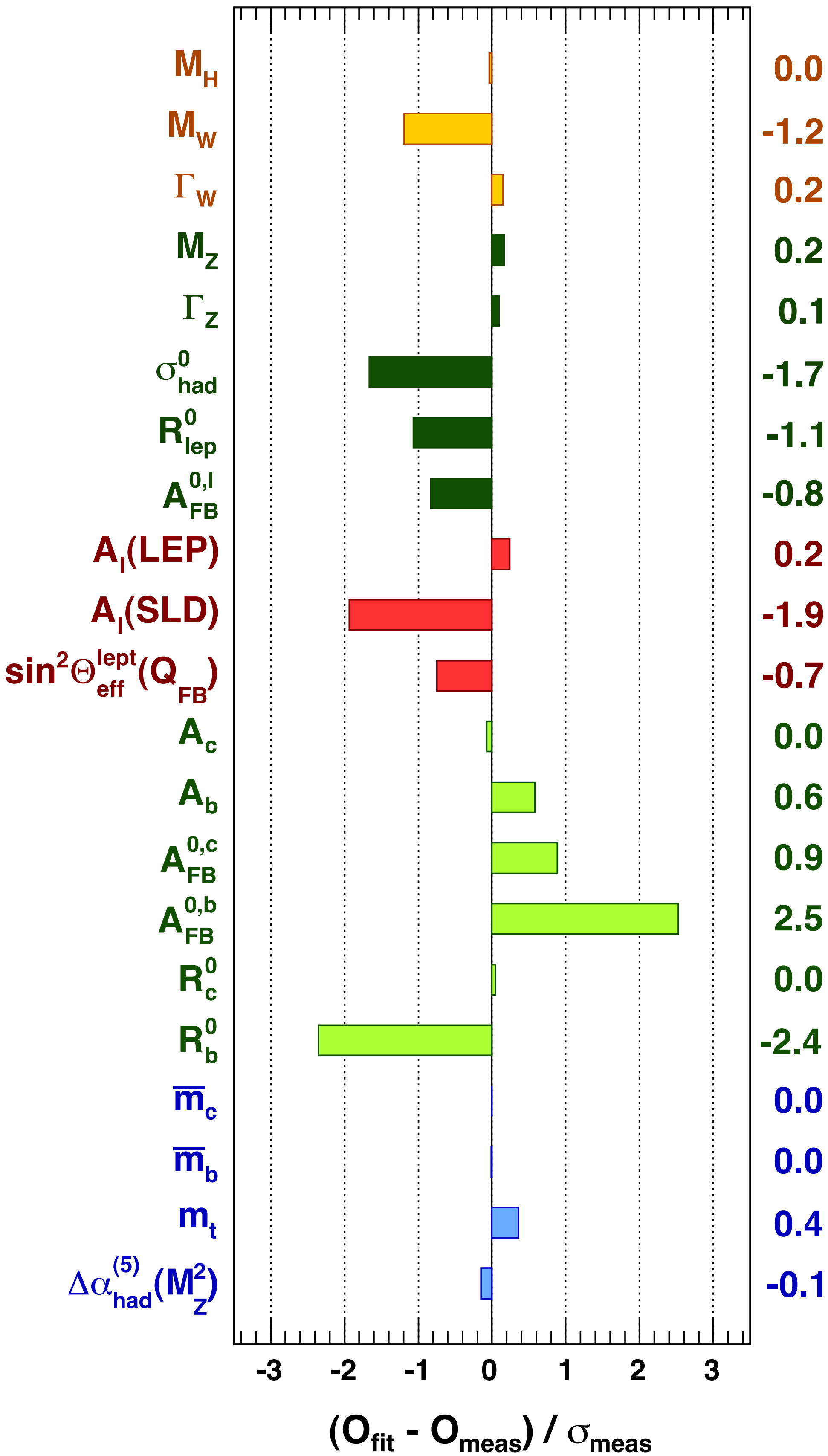
PHYSICS AT THE TERA SCALE Helmholtz Alliance


ATLAS 2011 - 2012
m_H = 126.0 GeV
W,Z H → bb
$\sqrt{s}$ = 7 TeV: $\int Ldt$ = 4.7 fb^{-1}
H → ττ
$\sqrt{s}$ = 7 TeV: $\int Ldt$ = 4.6-4.7 fb^{-1}
H → $WW^{(*)}$ → lνlν
$\sqrt{s}$ = 7 TeV: $\int Ldt$ = 4.7 fb^{-1}
$\sqrt{s}$ = 8 TeV: $\int Ldt$ = 5.8 fb^{-1}
H → γγ
$\sqrt{s}$ = 7 TeV: $\int Ldt$ = 4.8 fb^{-1}
$\sqrt{s}$ = 8 TeV: $\int Ldt$ = 5.9 fb^{-1}
H → $ZZ^{(*)}$ → 4l
$\sqrt{s}$ = 7 TeV: $\int Ldt$ = 4.8 fb^{-1}
$\sqrt{s}$ = 8 TeV: $\int Ldt$ = 5.8 fb^{-1}
Combined
$\sqrt{s}$ = 7 TeV: $\int Ldt$ = 4.6 - 4.8 fb^{-1}
$\sqrt{s}$ = 8 TeV: $\int Ldt$ = 5.8 - 5.9 fb^{-1}
μ = 1.4 ± 0.3
-1
0
1
Signal strength (μ)

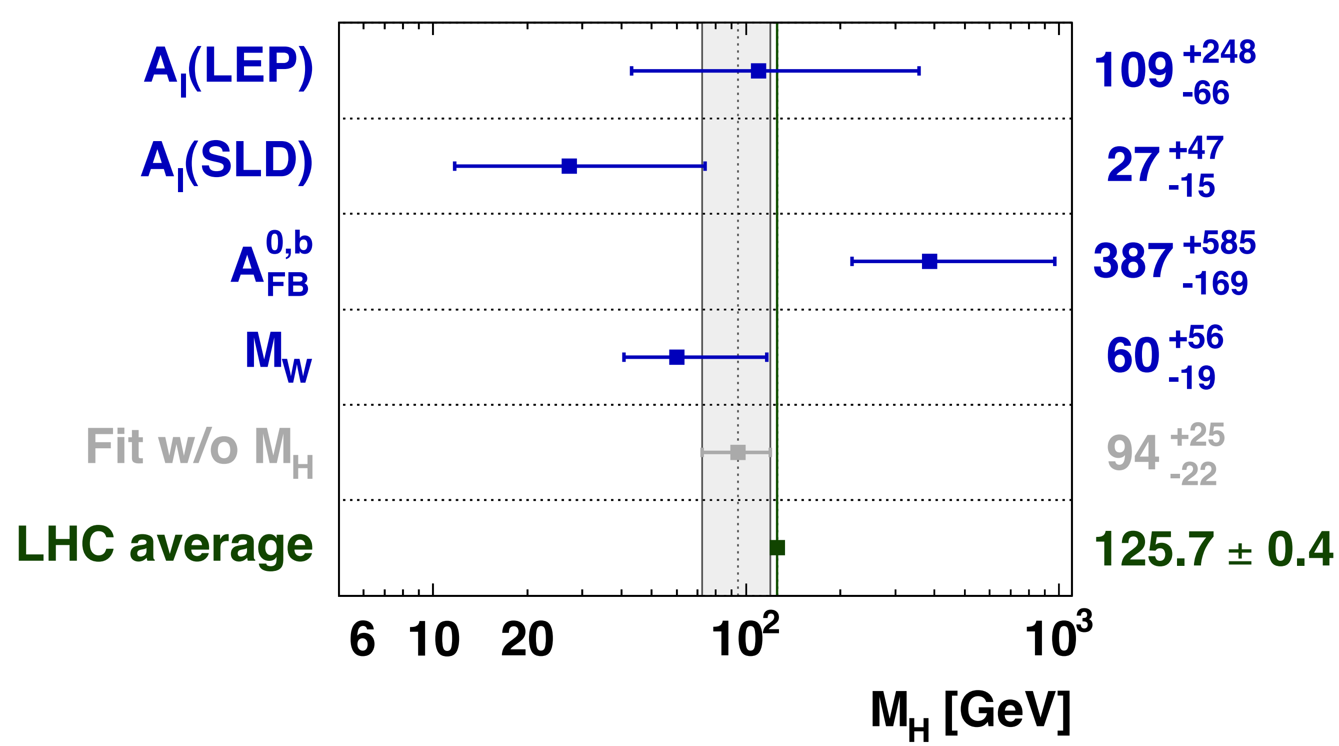

CMS $\sqrt{s}$ = 7 TeV, L = 5.1 fb^{-1} $\sqrt{s}$ = 8 TeV, L = 5.3 fb^{-1}
m_H = 125.5 GeV
H → γγ
H → ZZ
H → WW
H → ττ
H → bb
-1
0
1
2
3
Best fit σ/σ_{SM}


Tevatron Run II Preliminary, L ≤ 10.0 fb-1
95% CL Limit/SM
Tevatron Exclusion
Observed
Expected w/o Higgs
±1 s.d. Expected
±2 s.d. Expected
Tevatron Exclusion
SM=1
June 2012
10
1
100
110
120
130
140
150
160
170
180
190
200
mH (GeV/c2)


Tevatron Run II Preliminary
L ≤ 10.0 fb-1
mH = 125 GeV/c2
Combined (68%)
Single Channel
H→ W+W-
H→ γγ
H→ bb̄
0
1
2
3
4
5
6
7
Best Fit σ/σSM
June 2012


M_H 0.0
M_W -1.2
Γ_W 0.2
M_Z 0.2
Γ_Z 0.1
σ⁰_had -1.7
R⁰_lep -1.1
A^{0,l}_FB -0.8
A_l(LEP) 0.2
A_l(SLD) -1.9
sin²Θ^lept_eff(Q_FB) -0.7
A_c 0.0
A_b 0.6
A^{0,c}_FB 0.9
A^{0,b}_FB 2.5
R⁰_c 0.0
R⁰_b -2.4
m̄_c 0.0
m̄_b 0.0
m_t 0.4
Δα^{(5)}_had(M²_Z) -0.1
-3 -2 -1 0 1 2 3
(O_fit - O_meas) / σ_meas

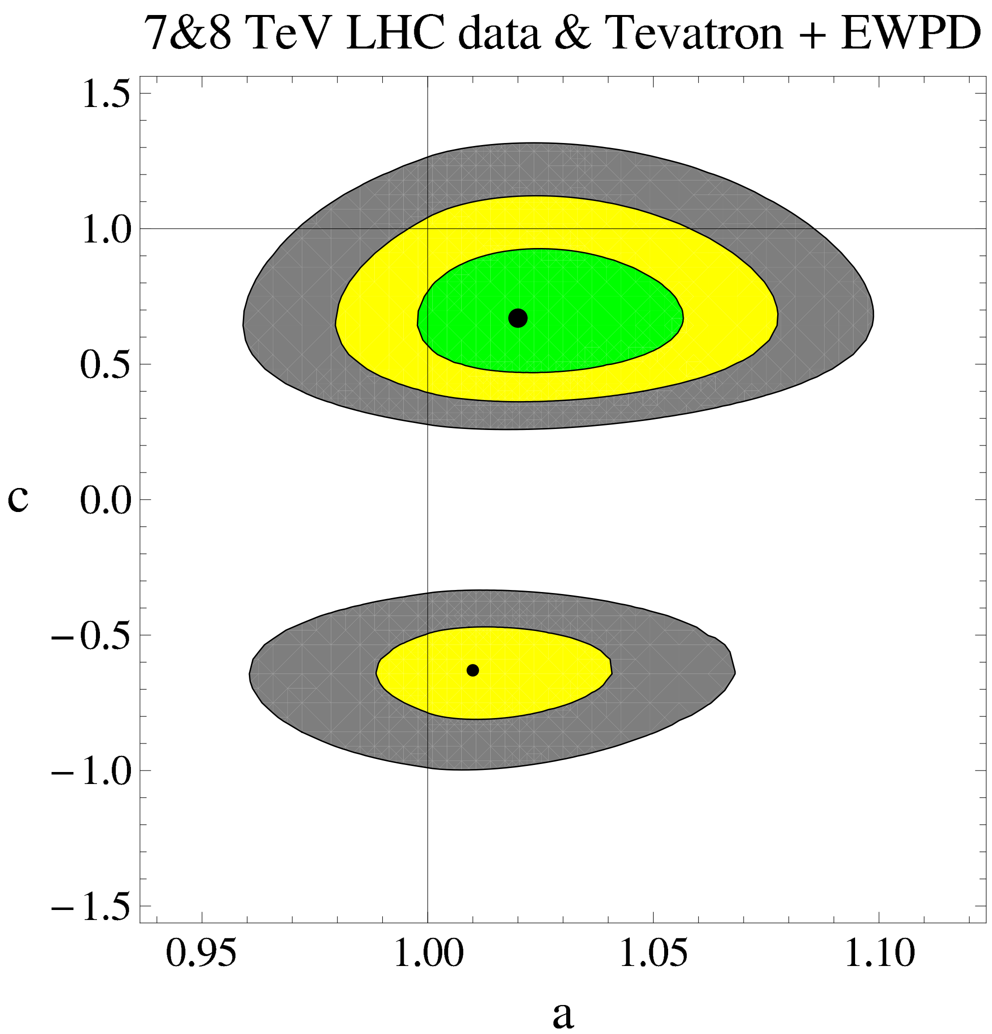
GFitter '12


A_l(LEP) 109 +248 -66
A_l(SLD) 27 +47 -15
A^{0,b}_FB 387 +585 -169
M_W 60 +56 -19
Fit w/o M_H 94 +25 -22
LHC average 125.7 ± 0.4
6 10 20 10² 10³
M_H [GeV]

$$\mathcal{L} = \mathcal{L}_h - (M_W^2 W_\mu^+ W^{\mu -} + \frac{1}{2} M_Z^2 Z_\mu Z^\mu)[1 + 2a\frac{h}{v} + \mathcal{O}(h^2)]$$
$$- m_{\psi_i} \bar{\psi}_i \psi_i [1 + c\frac{h}{v} + \mathcal{O}(h^2)] + \ldots$$

Contino et al '10,'12

SM: $(a, c) = (1, 1)$



Espinosa, Grojean, Mühlleitner, Trott '12

So, why SUSY?

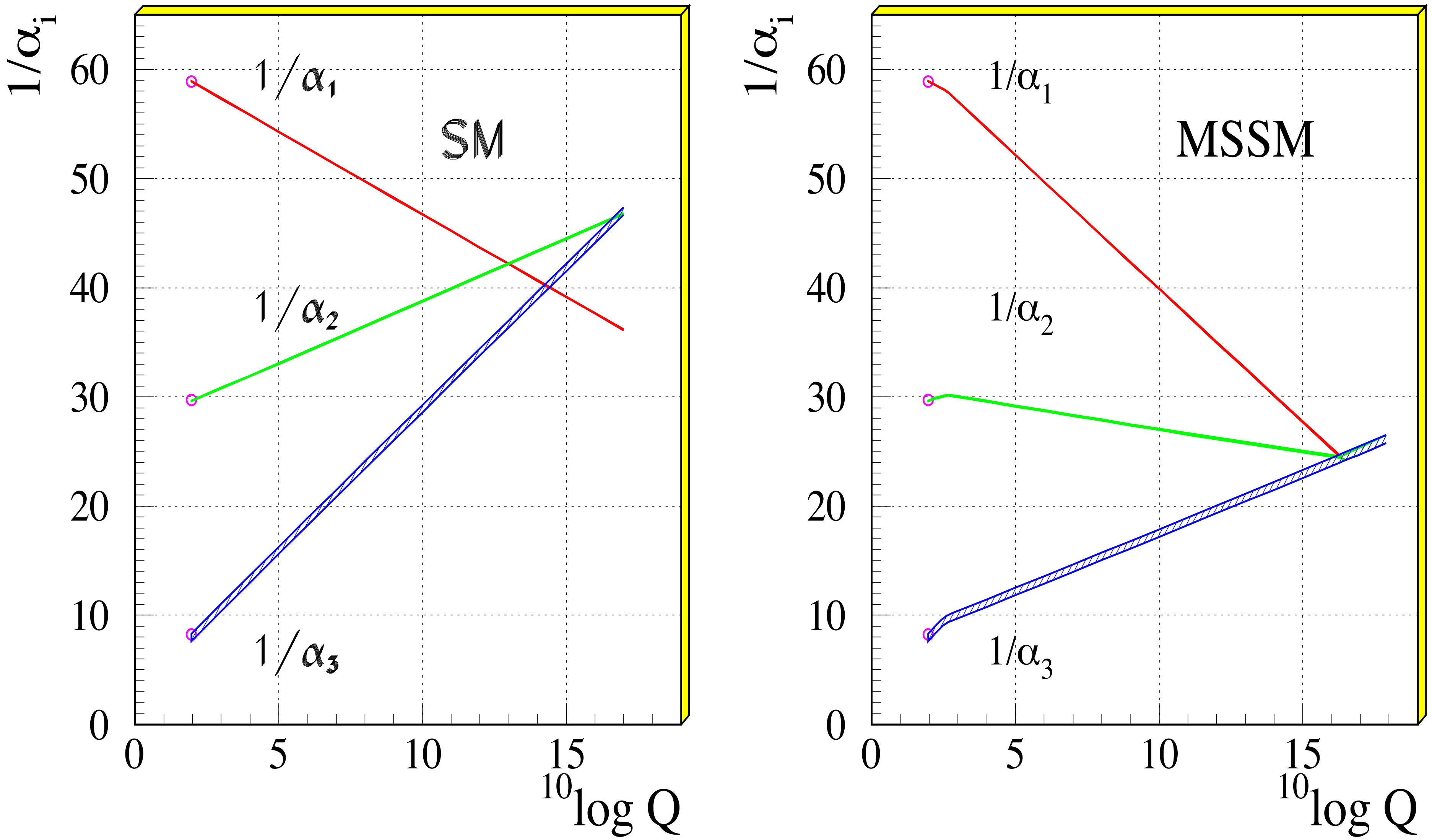
Theory:

$$
\begin{aligned}
[P_\mu, P_\nu] &= 0 \\
[P_\rho, M_{\mu\nu}] &= i\big(\eta_{\mu\rho}P_\nu - \eta_{\nu\rho}P_\mu\big) \equiv i\eta_{\mu\rho}P_\nu + \text{symm.}\ , \\
[M_{\mu\nu}, M_{\rho\sigma}] &= -i\big(\eta_{\mu\rho}M_{\nu\sigma} + \text{symm.}\big)\ .
\end{aligned}
$$

Theory:

$$
\begin{aligned}
[P_\mu, P_\nu] &= 0 \\
[P_\rho, M_{\mu\nu}] &= i\big(\eta_{\mu\rho} P_\nu - \eta_{\nu\rho} P_\mu\big) \equiv i\eta_{\mu\rho} P_\nu + \text{symm.}\ , \\
[M_{\mu\nu}, M_{\rho\sigma}] &= -i\big(\eta_{\mu\rho} M_{\nu\sigma} + \text{symm.}\big)\ . \\
[P_\mu, Q^i_\alpha] &= [P_\mu, \bar{Q}_{i\dot{\alpha}}] = 0\ , \\
\big[M_{\mu\nu}, Q^i_\alpha\big] &= i(\sigma_{\mu\nu})_\alpha{}^\beta\, Q^i_\beta\ , \\
\big[M_{\mu\nu}, \bar{Q}^{\dot{\alpha}}_i\big] &= i(\bar{\sigma}_{\mu\nu})^{\dot{\alpha}}{}_{\dot{\beta}}\, \bar{Q}^{\dot{\beta}}_i\ , \\
\{Q^i_\alpha, Q^j_\beta\} &= \{\bar{Q}_{i\dot{\alpha}}, \bar{Q}_{j\dot{\beta}}\} = 0\ , \\
\{Q^i_\alpha, \bar{Q}_{j\dot{\alpha}}\} &= 2\,\delta^i_j\,\sigma^\mu_{\alpha\dot{\alpha}} P_\mu\ ,
\end{aligned}
$$

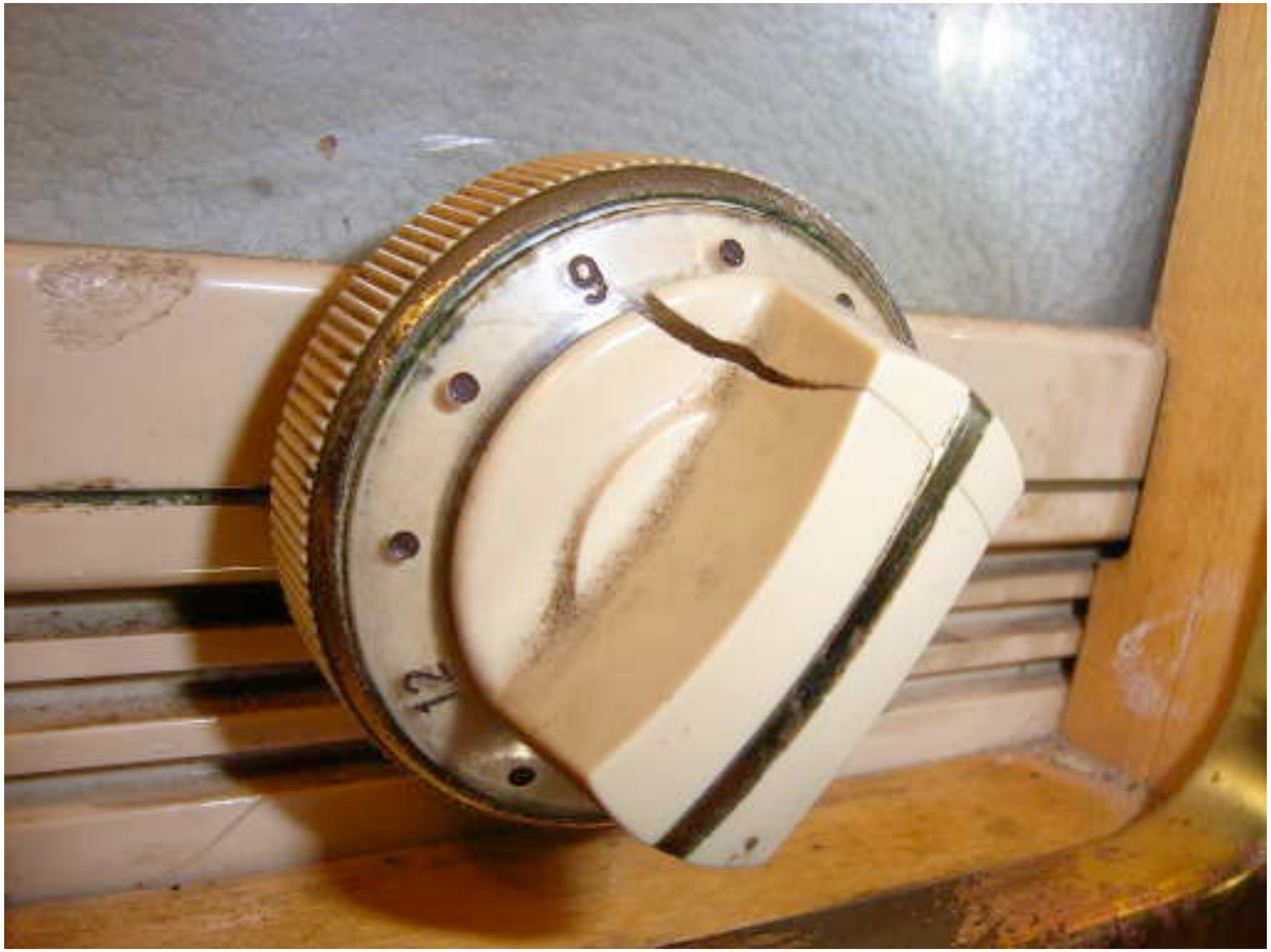
Unification of the Coupling Constants in the SM and the minimal MSSM

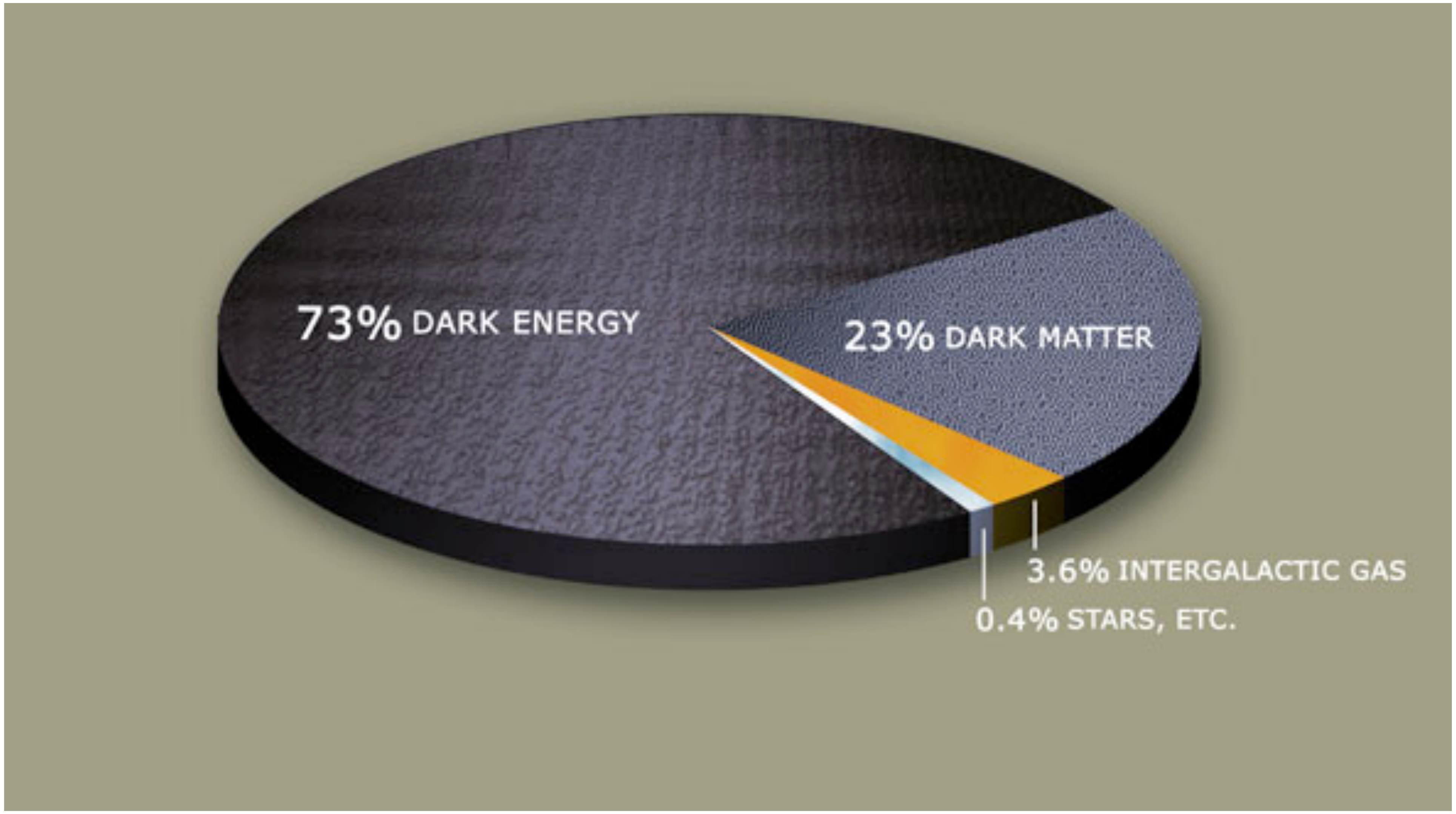


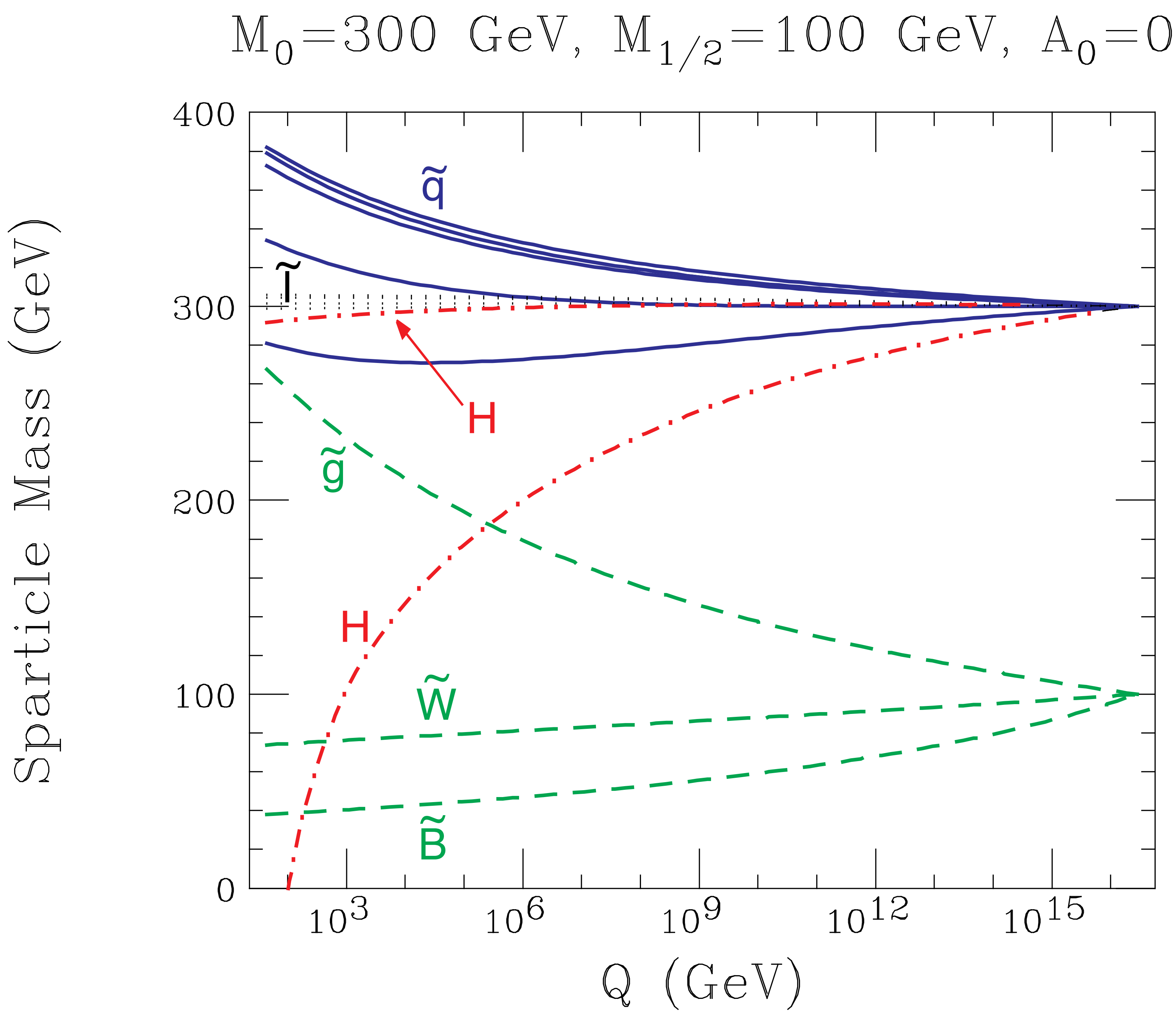
3-loop:
Jack, Jones ’97
RH, Mihaila, Steinhauser ’05, ’07, ’09

Amaldi, de Boer, Fürstenau ’91
Langacker, Luo ’91
Ellis, Kelley, Nanopoulos ’90

Fine Tuning

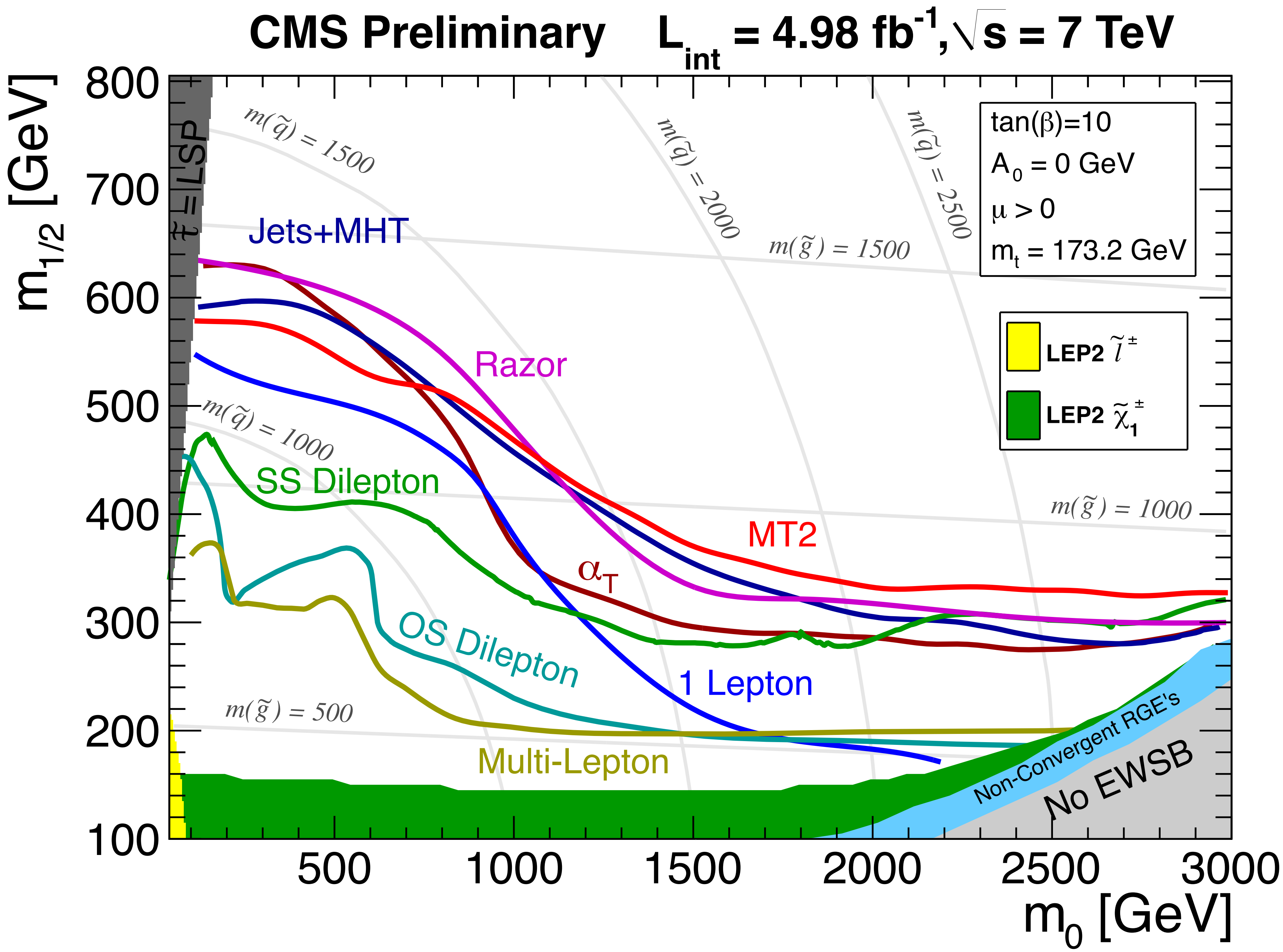



73% DARK ENERGY
23% DARK MATTER
3.6% INTERGALACTIC GAS
0.4% STARS, ETC.

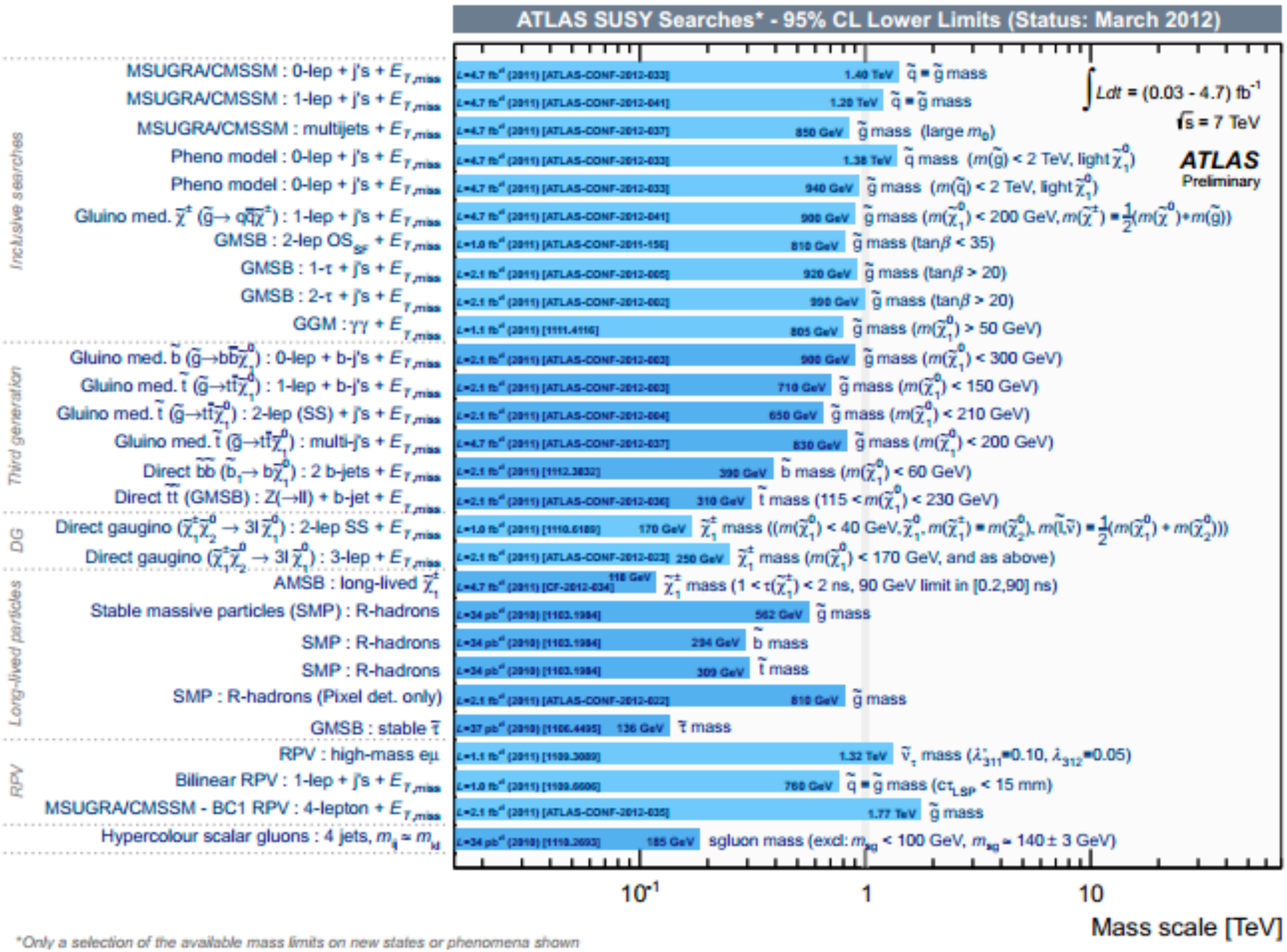


M0=300 GeV, M1/2=100 GeV, A0=0
Sparticle Mass (GeV)
Q (GeV)
q̃
l̃
H
g̃
H
W̃
B̃
400
300
200
100
0
10^3
10^6
10^9
10^12
10^15

I am not a SUSY fan.



CMS Preliminary L_{int} = 4.98 fb^{-1}, $\sqrt{s}$ = 7 TeV
$m_{1/2}$ [GeV]
m_0 [GeV]
800
700
600
500
400
300
200
100
500
1000
1500
2000
2500
3000
$\tilde{\tau}$ = LSP
$m(\tilde{q})$ = 1500
$m(\tilde{q})$ = 2000
$m(\tilde{q})$ = 2500
$m(\tilde{q})$ = 1000
$m(\tilde{g})$ = 1500
$m(\tilde{g})$ = 1000
$m(\tilde{g})$ = 500
tan(β)=10
A_0 = 0 GeV
μ > 0
m_t = 173.2 GeV
LEP2 $\tilde{l}^{\pm}$
LEP2 $\tilde{\chi}_1^{\pm}$
Jets+MHT
Razor
SS Dilepton
MT2
α_T
OS Dilepton
1 Lepton
Multi-Lepton
Non-Convergent RGE's
No EWSB


ATLAS SUSY Searches* - 95% CL Lower Limits (Status: March 2012)
ATLAS
Preliminary
Inclusive searches
Third generation
DG
Long-lived particles
RPV
MSUGRA/CMSSM : 0-lep + j's + E_T,miss
MSUGRA/CMSSM : 1-lep + j's + E_T,miss
MSUGRA/CMSSM : multijets + E_T,miss
Pheno model : 0-lep + j's + E_T,miss
Pheno model : 0-lep + j's + E_T,miss
GMSB : 2-lep OS_SF + E_T,miss
GMSB : 1-τ + j's + E_T,miss
GMSB : 2-τ + j's + E_T,miss
GGM : γγ + E_T,miss
AMSB : long-lived
Stable massive particles (SMP) : R-hadrons
SMP : R-hadrons
SMP : R-hadrons
SMP : R-hadrons (Pixel det. only)
RPV : high-mass eμ
Bilinear RPV : 1-lep + j's + E_T,miss
MSUGRA/CMSSM - BC1 RPV : 4-lepton + E_T,miss
Hypercolour scalar gluons : 4 jets
1.40 TeV
1.20 TeV
850 GeV
1.38 TeV
940 GeV
900 GeV
810 GeV
920 GeV
990 GeV
805 GeV
900 GeV
710 GeV
650 GeV
830 GeV
390 GeV
310 GeV
170 GeV
250 GeV
118 GeV
562 GeV
294 GeV
309 GeV
810 GeV
136 GeV
1.32 TeV
760 GeV
1.77 TeV
185 GeV
sgluon mass
Mass scale [TeV]
*Only a selection of the available mass limits on new states or phenomena shown

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

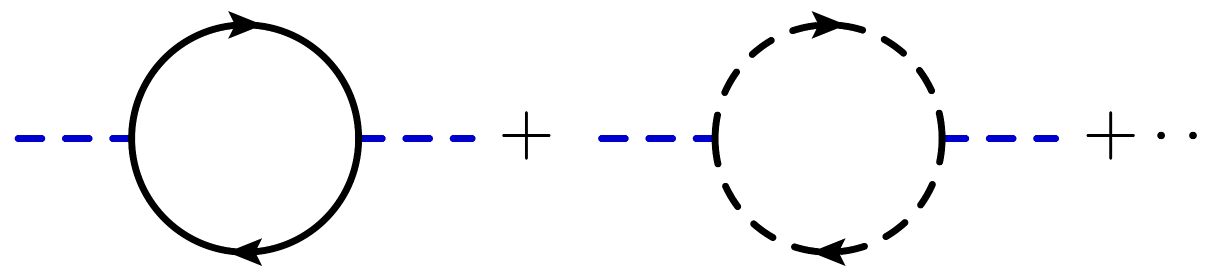
physical states: $h^0, H^0, A^0, H^\pm$

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

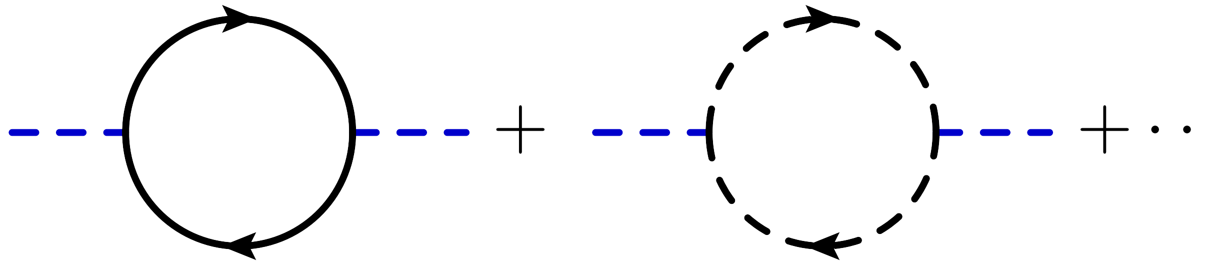
Input parameters: (to be determined experimentally)

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

$$\mathcal{M}_H^2 \;=\; \mathcal{M}_{H,\text{tree}}^2 - \begin{pmatrix} \hat{\Sigma}_{\phi_1} & \hat{\Sigma}_{\phi_1\phi_2} \\ \hat{\Sigma}_{\phi_1\phi_2} & \hat{\Sigma}_{\phi_2} \end{pmatrix}$$



$$\mathcal{M}_H^2 = \mathcal{M}_{H,\mathrm{tree}}^2 - \begin{pmatrix} \hat{\Sigma}_{\phi_1} & \hat{\Sigma}_{\phi_1\phi_2} \\ \hat{\Sigma}_{\phi_1\phi_2} & \hat{\Sigma}_{\phi_2} \end{pmatrix}$$

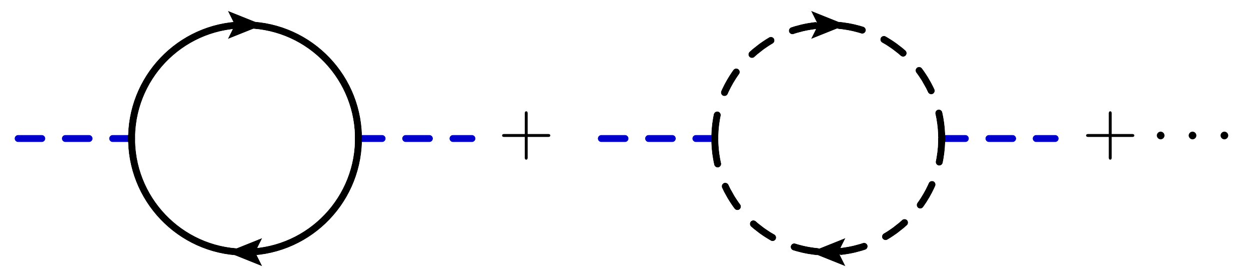


For moderate to large values of tan beta and large non-standard Higgs masses

$$m_h^2 \cong M_Z^2 \cos^2 2\beta + \frac{3}{4\pi^2}\frac{m_t^4}{v^2}\left[\frac{1}{2}\tilde{X}_t + t + \frac{1}{16\pi^2}\left(\frac{3}{2}\frac{m_t^2}{v^2} - 32\pi\alpha_3\right)\left(\tilde{X}_t t + t^2\right)\right]$$

$t = \log(M_{SUSY}^2 / m_t^2)$ $\quad \tilde{X}_t = \frac{2X_t^2}{M_{SUSY}^2}\left(1 - \frac{X_t^2}{12 M_{SUSY}^2}\right)$ $\quad X_t = A_t - \mu/\tan\beta \rightarrow$ LR stop mixing

$$\mathcal{M}_H^2 = \mathcal{M}_{H,\text{tree}}^2 - \begin{pmatrix} \hat{\Sigma}_{\phi_1} & \hat{\Sigma}_{\phi_1\phi_2} \\ \hat{\Sigma}_{\phi_1\phi_2} & \hat{\Sigma}_{\phi_2} \end{pmatrix}$$

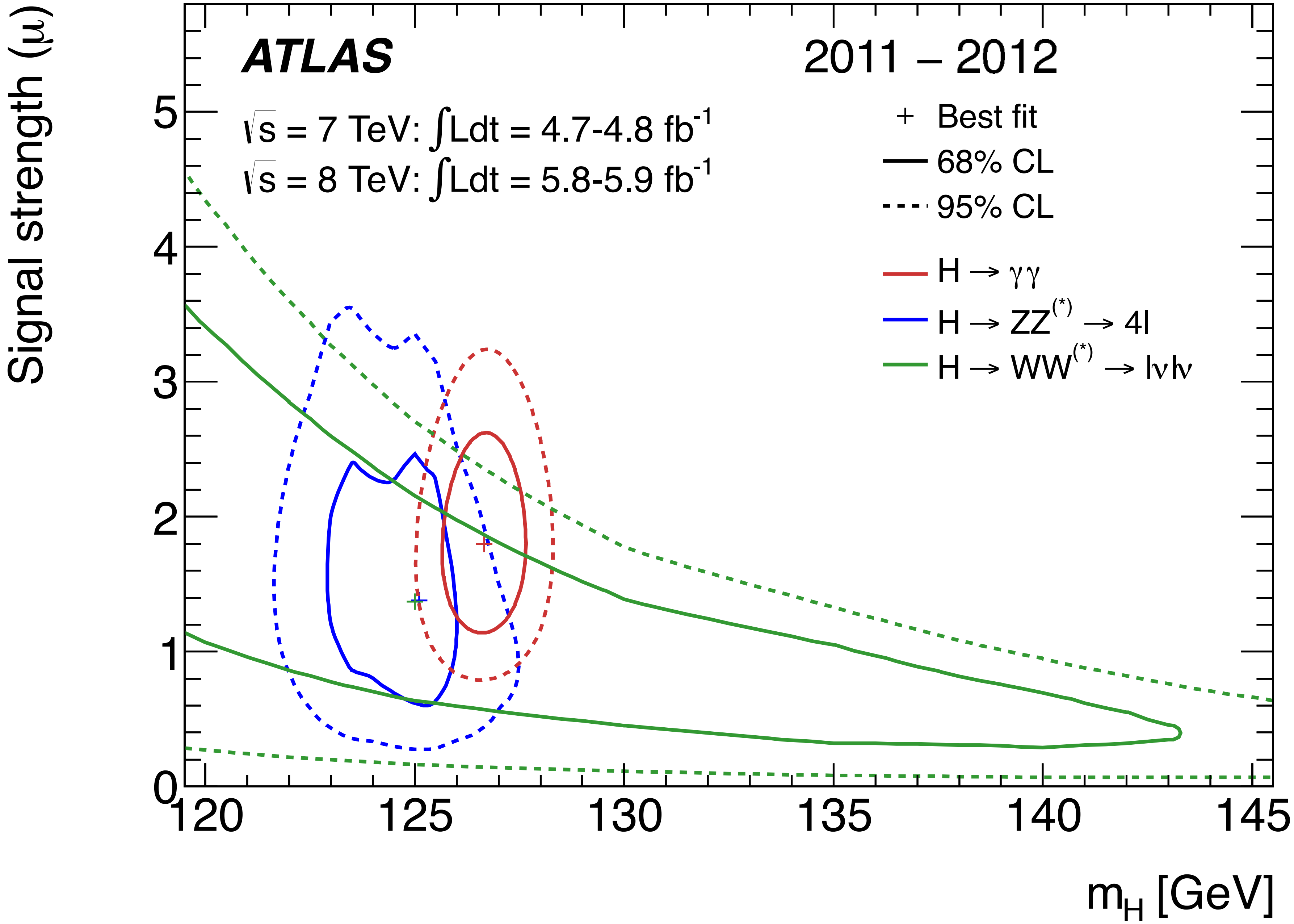


For moderate to large values of tan beta and large non-standard Higgs masses

$$m_h^2 \cong M_Z^2 \cos^2 2\beta + \frac{3}{4\pi^2}\frac{m_t^4}{v^2}\left[\frac{1}{2}\tilde{X}_t + t + \frac{1}{16\pi^2}\left(\frac{3}{2}\frac{m_t^2}{v^2} - 32\pi\alpha_3\right)\left(\tilde{X}_t t + t^2\right)\right]$$

$t = \log(M_{SUSY}^2/m_t^2)$ $\quad \tilde{X}_t = \frac{2X_t^2}{M_{SUSY}^2}\left(1 - \frac{X_t^2}{12 M_{SUSY}^2}\right)$ $\quad X_t = A_t - \mu/\tan\beta \rightarrow$ LR stop mixing

M_H precision observable for SUSY



M=126.0 ± 0.4(stat) ± 0.4(sys) GeV

1-loop

[J. Ellis, Ridolfi, Zwirner ’91], [Okada, Yamaguchi, Yanagida ’91], [Haber, Hempfling ’91] [Chankowski, Pokorski, Rosiek ’92], [Brignole ’92], [Dabelstein ’95], [Pierce, Bagger, Matchev, Zhang ’97]

2-loop

[Carena, Espinosa, Quiros, Wagner ’95], [Haber, Hempfling, Hoang ’97], [Espinosa, Navarro ’02]

[Hempfling, Hoang ’94], [Heinemeyer, Hollik, Weiglein ’98 + Rzehak ’05], [Zhang ’98], [Espinosa, Zhang ’00], [Degrassi, Slavich, Zwirner ’01], [Brignole, Degrassi, Slavich, Zwirner ’02], [Dedes, Degrassi, Slavich ’03], . . .

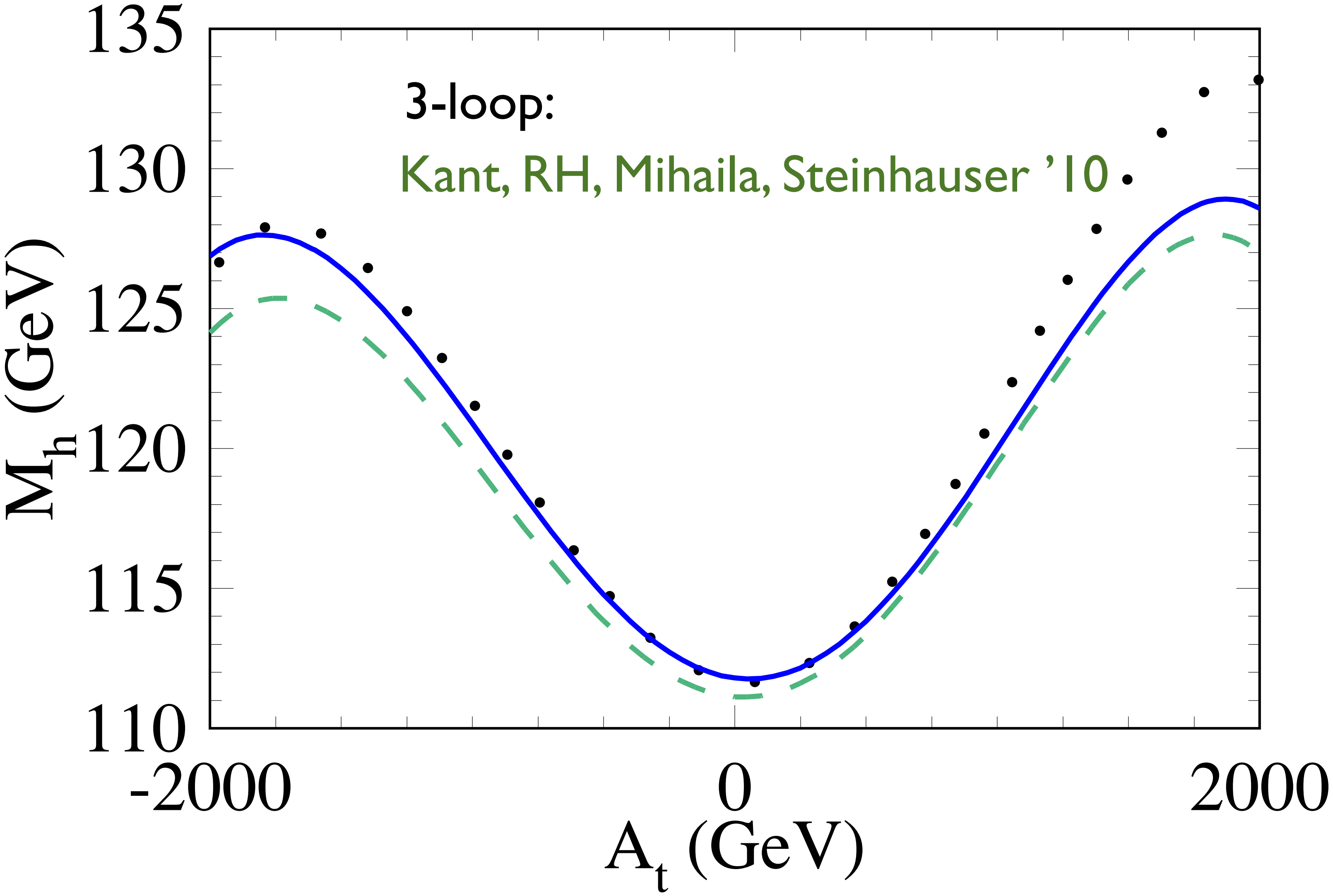
$\rightarrow$ `FeynHiggs` [Heinemeyer, Hollik, Weiglein + Hahn, Frank, Rzehak + Degrassi, Slavich]

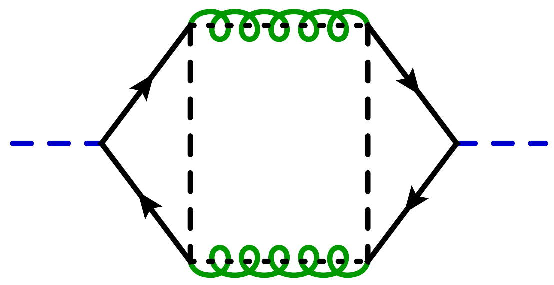
`CPSuperH` [Lee, Pilaftsis, Carena, Choi, Drees, Ellis, Wagner]

3-loop

[Martin ’07]

[Kant, RH, Mihaila, Steinhauser ’10]

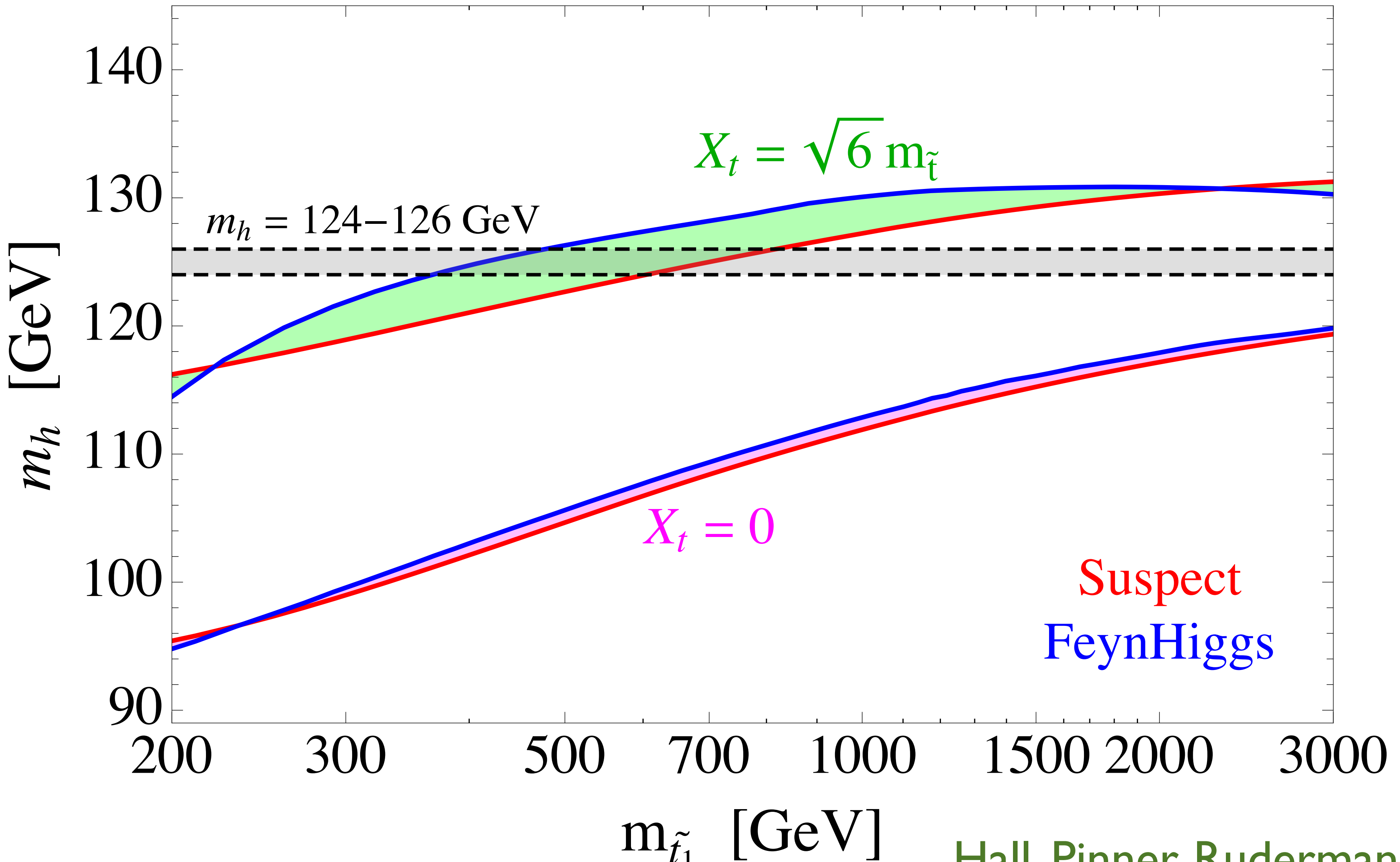




≈30,000 diagrams

$$m_{\tilde{t}_1} = 500\ \text{GeV}\,,$$
$$m_{\tilde{t}_2} = 1000\ \text{GeV}\,,$$
$$m_{\tilde{g}} = 500\ \text{GeV}\,,$$
$$m_{\tilde{q}} = 2000\ \text{GeV}\,,$$
$$\mu_{\text{SUSY}} = 800\ \text{GeV}\,,$$
$$\tan\beta = 10\,,$$
$$M_A = 1500\ \text{GeV}\,.$$

MSSM Higgs Mass



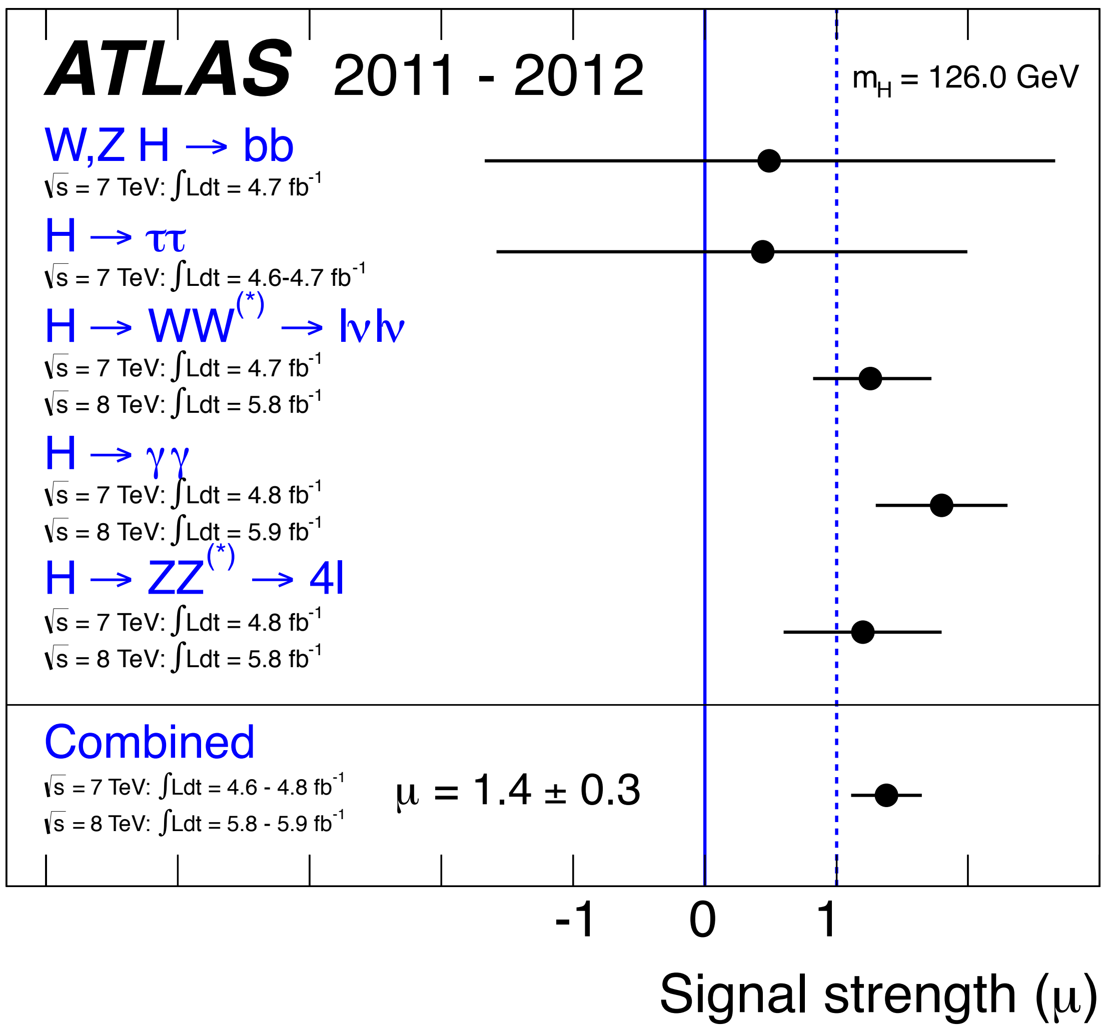
Hall, Pinner, Ruderman '12

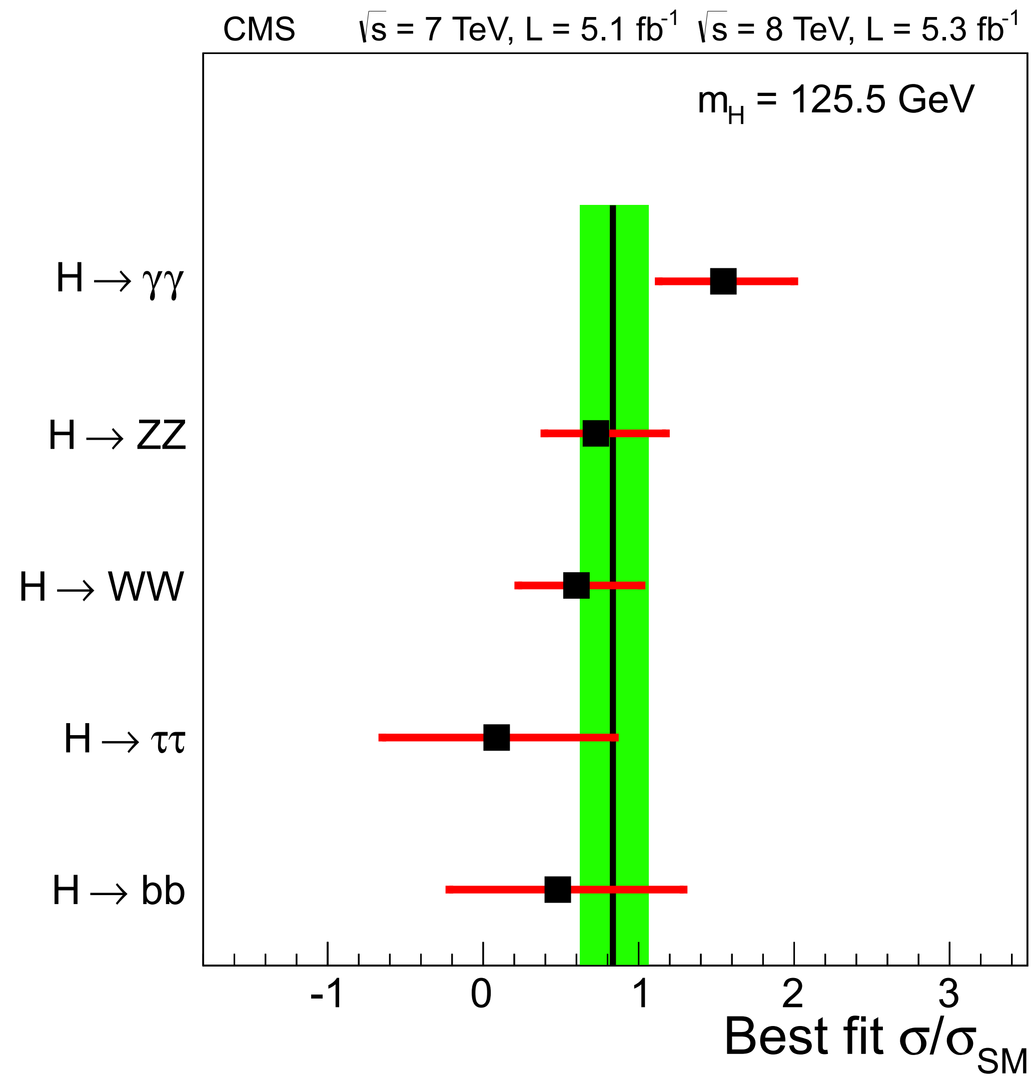
see also:

Heinemeyer, Stål, Weiglein '12

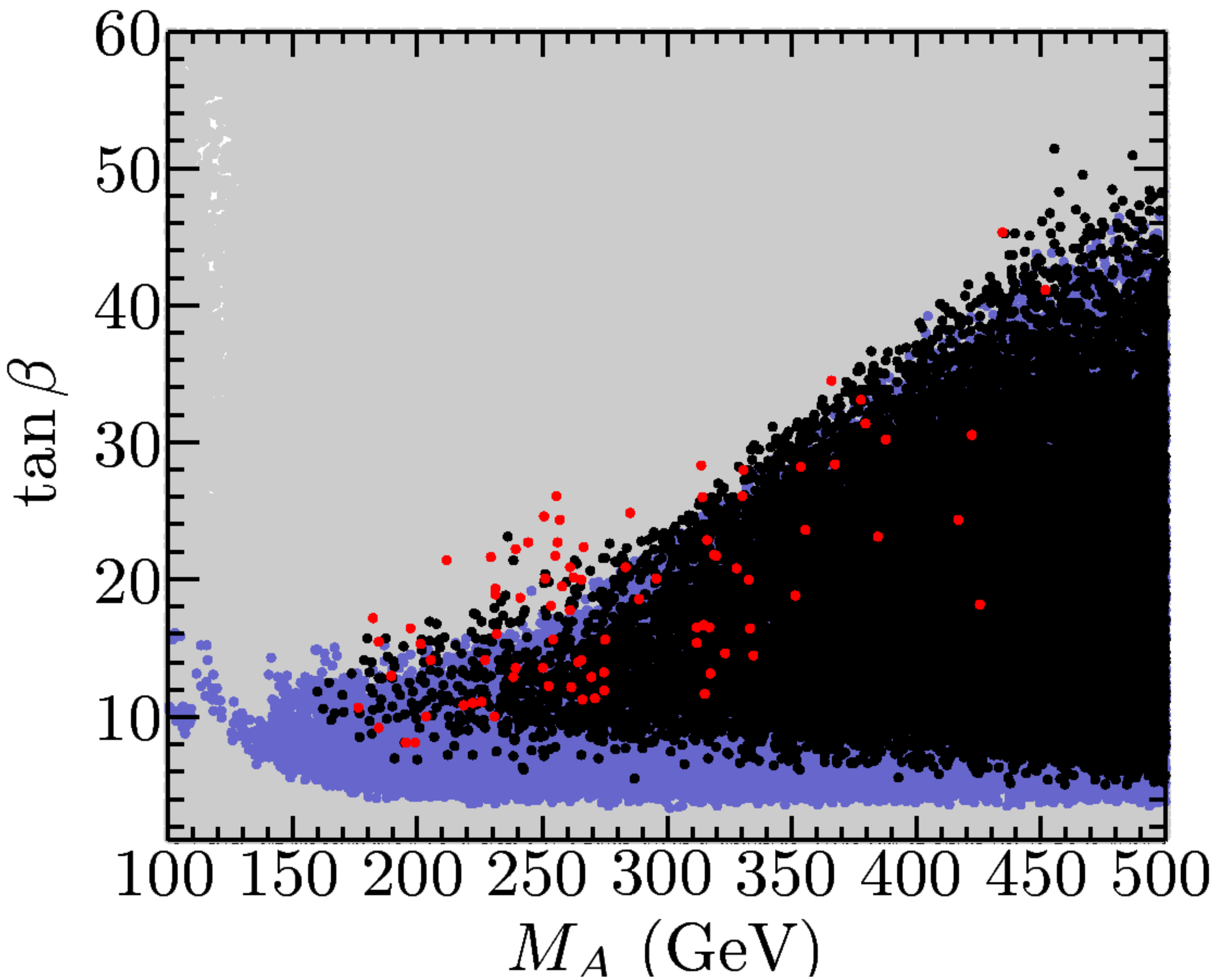
Arbey, Battaglia, Djouadi, Mahmoudi, Quevillon '12

...





$$BR(h^{125\,\text{GeV}} \to \gamma\gamma) = \frac{\Gamma(h^{125\,\text{GeV}} \to \gamma\gamma)}{(\Gamma_{b\bar{b}} + \Gamma_{WW} + \Gamma_{ZZ} + \ldots)[h^{125\,\text{GeV}}]}$$



Grey: excluded

Black: $R_{\gamma\gamma} > 1$

Red: $R_{\gamma\gamma} > 2$

Benbrik, Gomez Bock, Heinemeyer, Stål, Weiglein, Zeune '12

Parameter	Minimum	Maximum
$M_{\rm SUSY}$	750	1500
$M_2 \simeq 2M_1$	200	500
$A_t = A_b = A_\tau$	-2400	2400
μ	200	3000
M_A	100	600
$\tan\beta$	1	60

$$R_X^{h_i} = \frac{\sigma(pp \to h_i) \times {\rm BR}(h_i \to X)}{\sigma(pp \to H_{\rm SM}) \times {\rm BR}(H_{\rm SM} \to X)} \, .$$

$X = \gamma\gamma$

NMSSM:

7 Higgs bosons: $H_1, H_2, H_3, A_1, A_2, H^+, H^-$

MSSM: $m_h^2 \approx M_Z^2 \cos^2 2\beta + \Delta m_h^2$

NMSSM: $m_h^2 \approx M_Z^2 \cos^2 2\beta + \lambda^2 v^2 \sin^2 2\beta + \Delta m_h^2$

Radiative corrections:

Ellwanger '93; Elliot, King, White '93; Pandita '93; Ellwanger, Hugonie '05; Degrassi, Slavich '10; Staub, Porod, Hermann '10

`NMSSMTools` Ellwanger, Gunion, Hugonie '05

Hall, Pinner, Ruderman '12

King, Mühlleitner, Nevzorov '12

Benbrik, Gomez Bock, Heinemeyer, Stål, Weiglein, Zeune '12

Signal could be the heavy Higgs, also in the MSSM!

Belanger, Ellwanger, Gunion, Jiang, Kraml '12

Have we seen two Higgses?

Is it a Higgs?

Is it a Higgs?
Is it *the* Higgs?

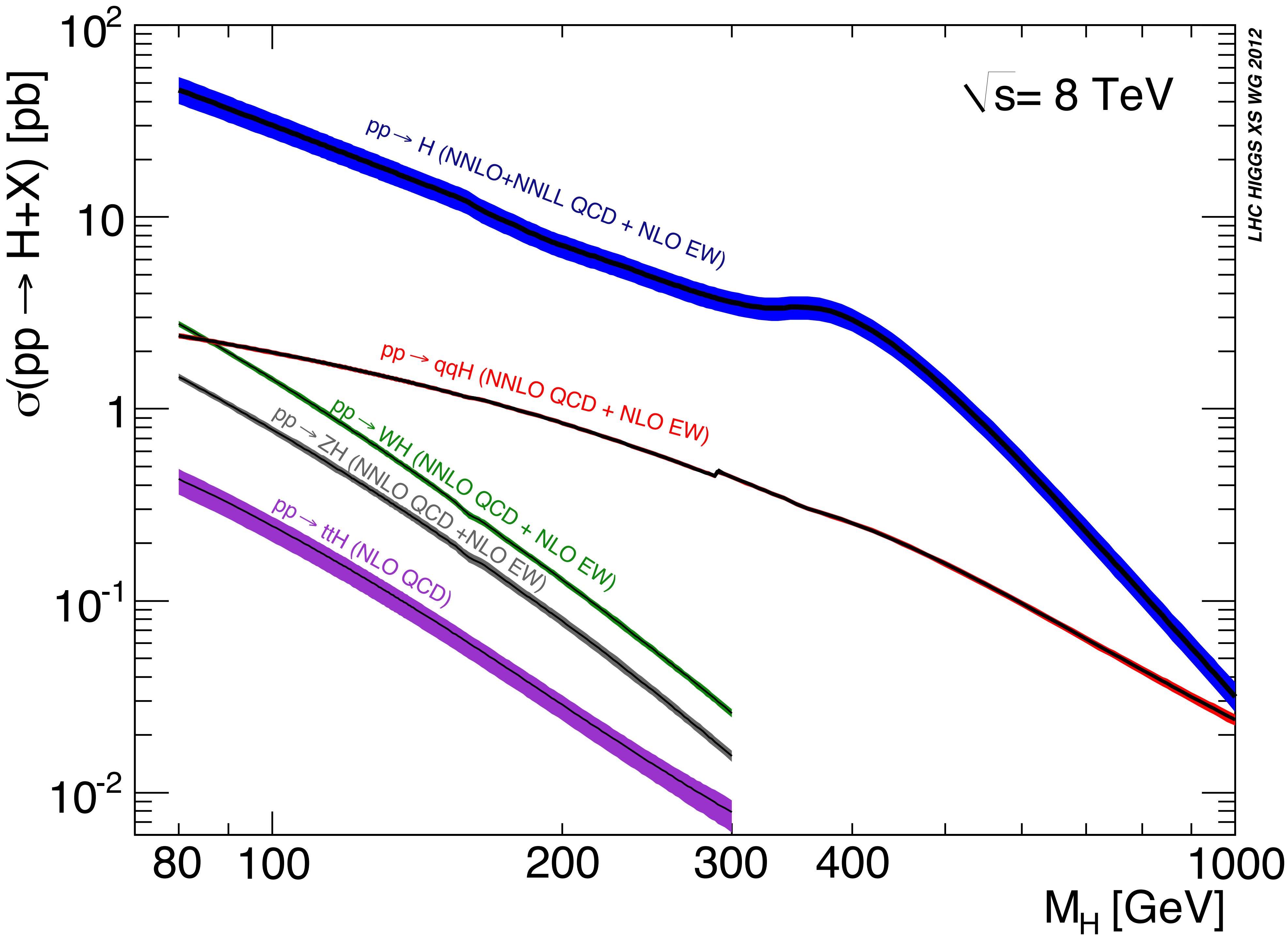
Is it a Higgs?
Is it *the* Higgs?
Is it a *SUSY* Higgs?

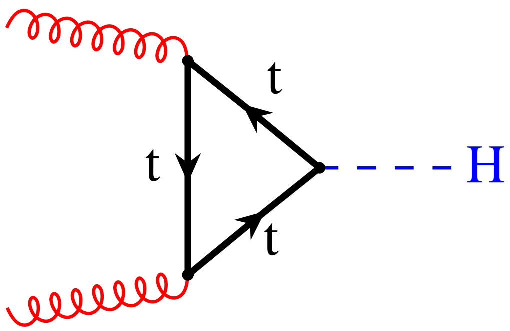
Is it a Higgs?
Is it *the* Higgs?
Is it a *SUSY* Higgs?
Which one? Which SUSY??

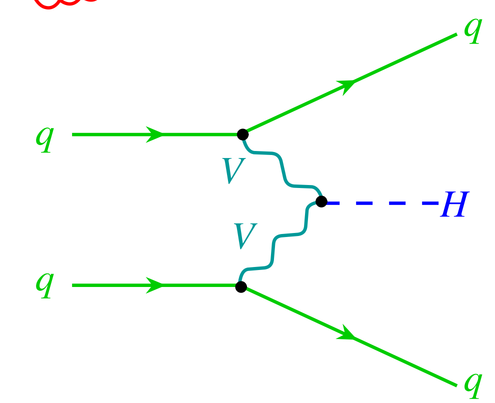
Is it a Higgs?
Is it *the* Higgs?
Is it a *SUSY* Higgs?
Which one? Which SUSY??

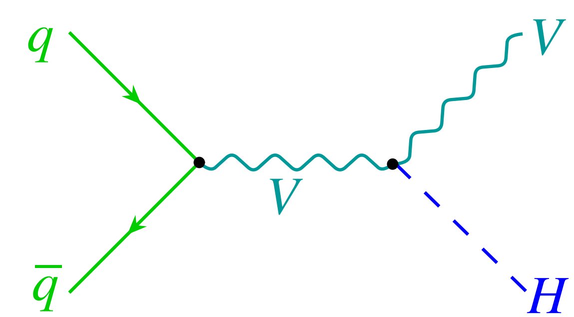
Experiment ⊗ Theory

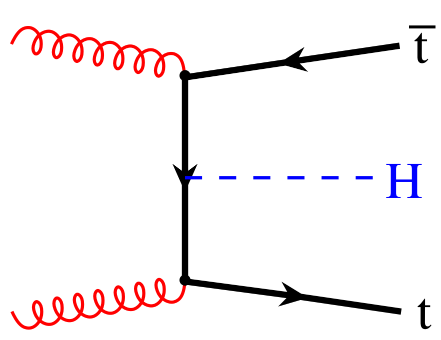
Higgs production in the Standard Model

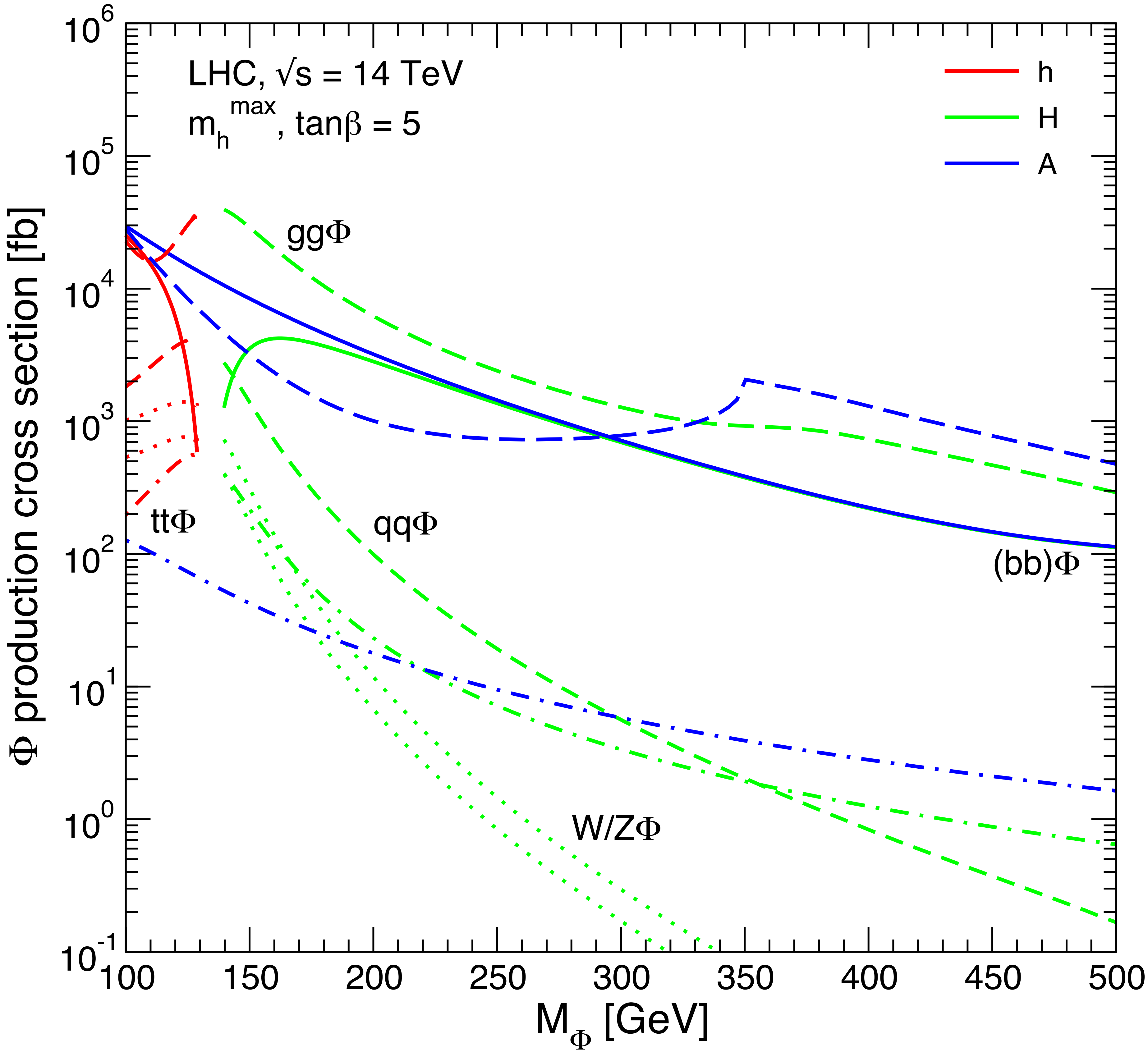




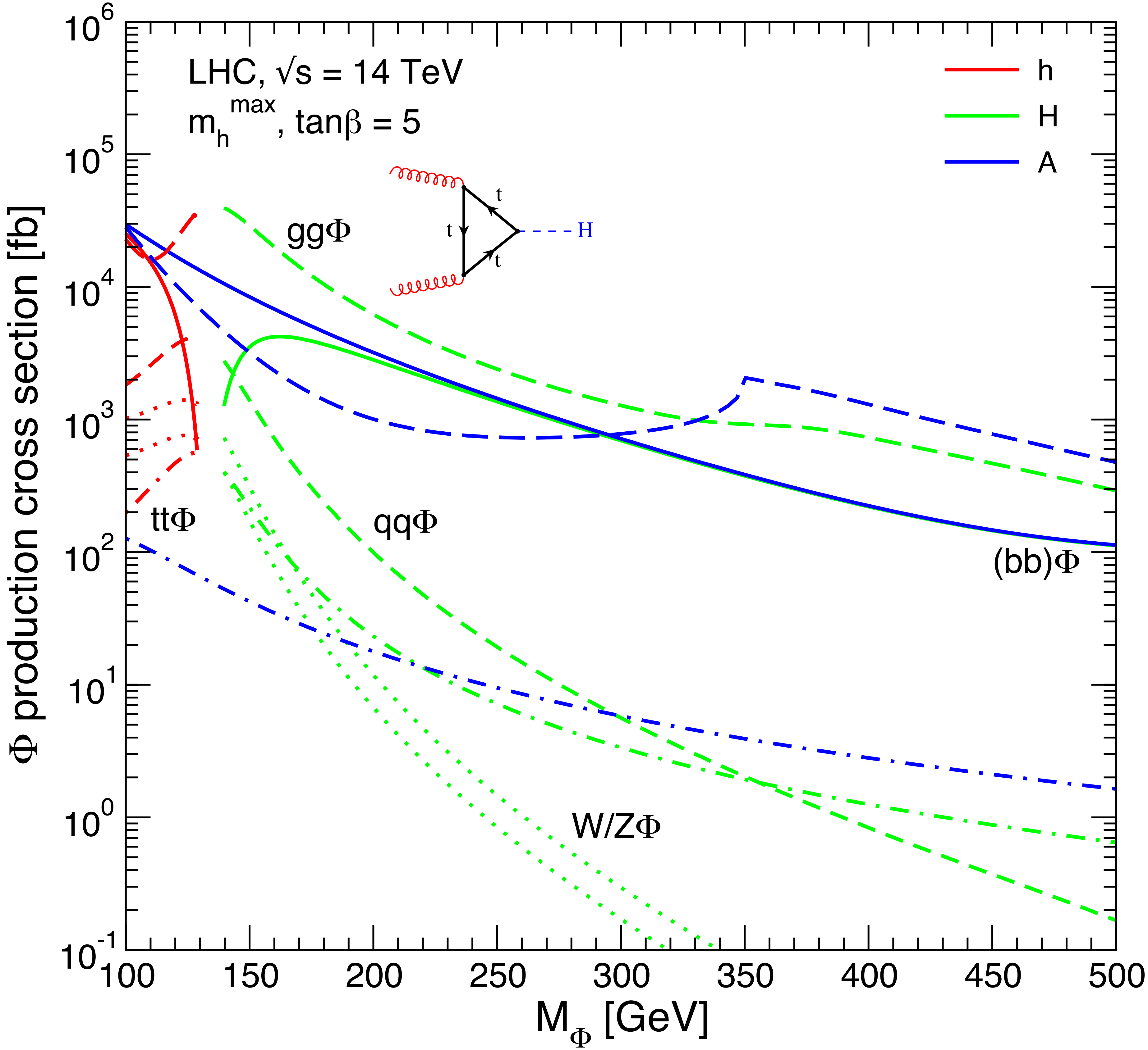




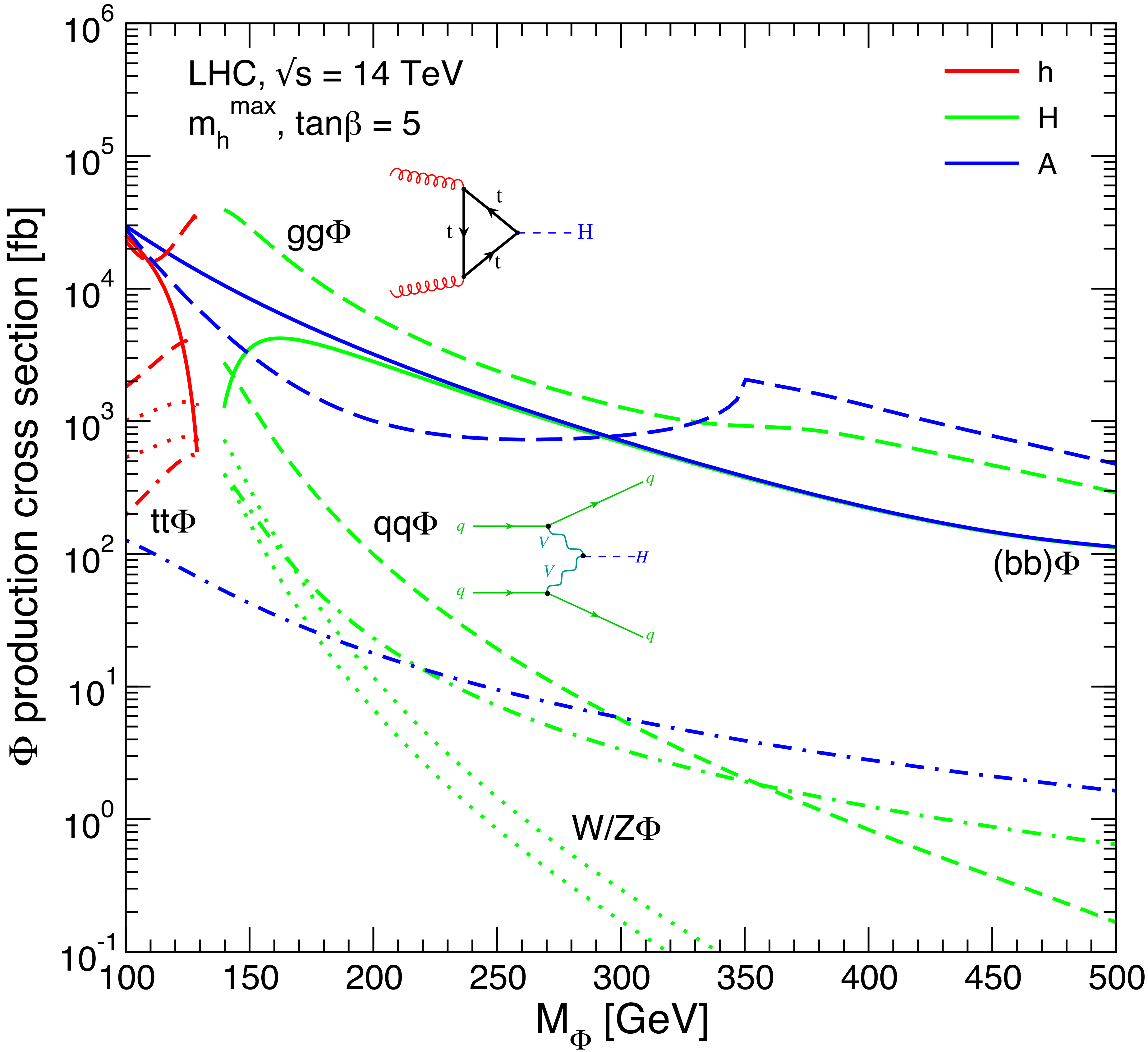


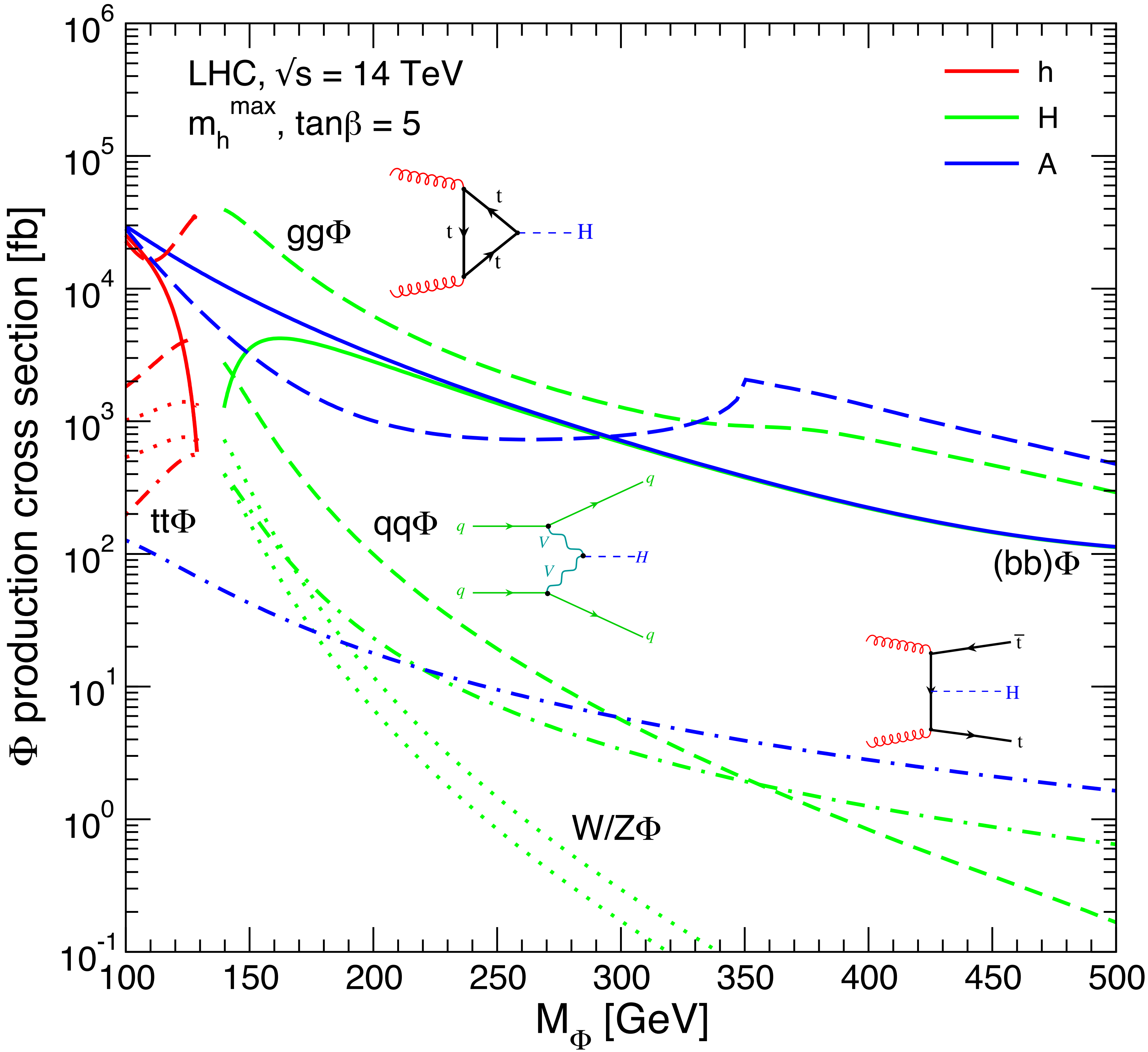


LHC, √s = 14 TeV
m_h^{max}, tanβ = 5
h
H
A
ggΦ
ttΦ
qqΦ
(bb)Φ
W/ZΦ
10^6
10^5
10^4
10^3
10^2
10^1
10^0
10^{-1}
100
150
200
250
300
350
400
450
500
Φ production cross section [fb]
M_Φ [GeV]

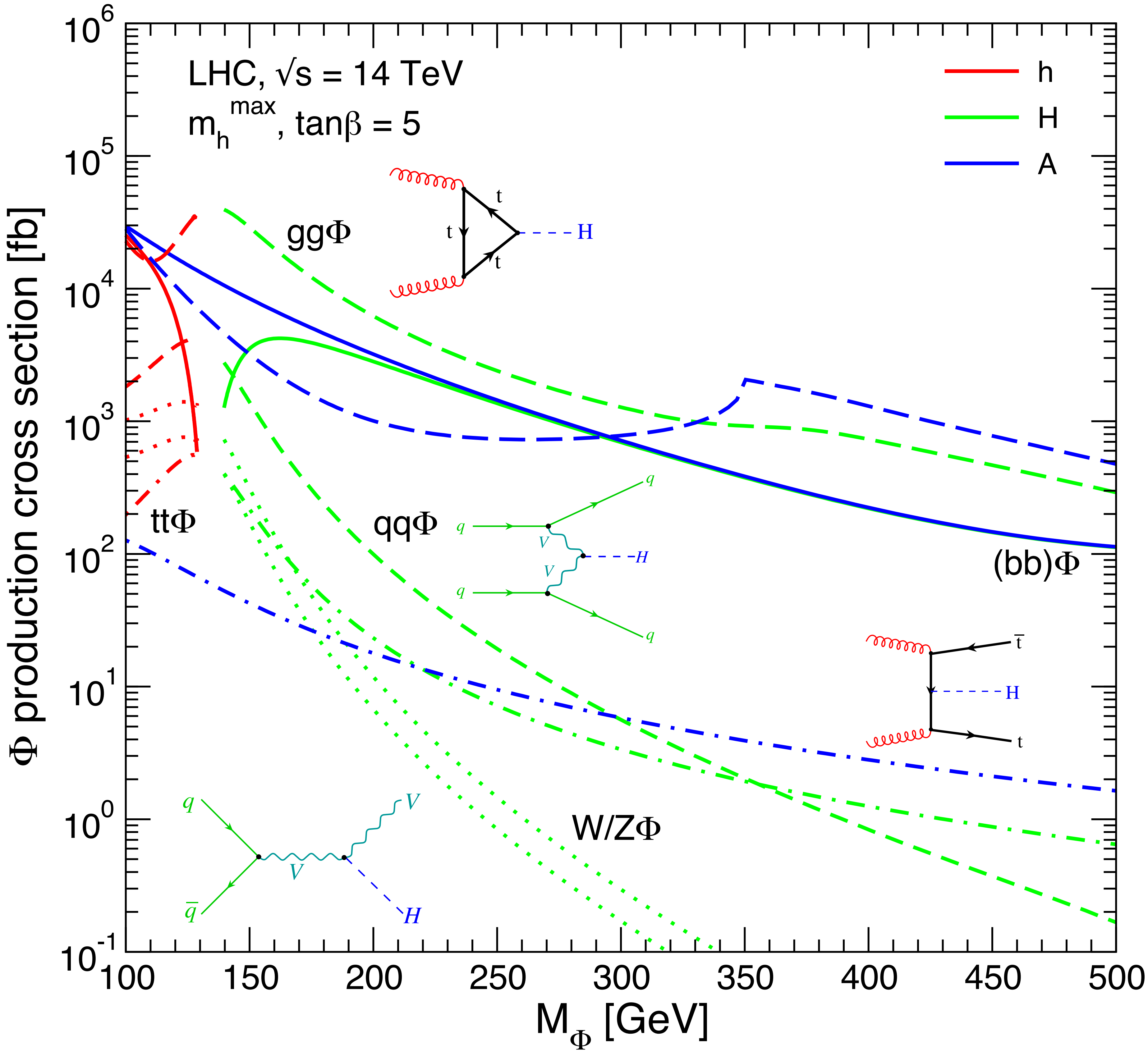


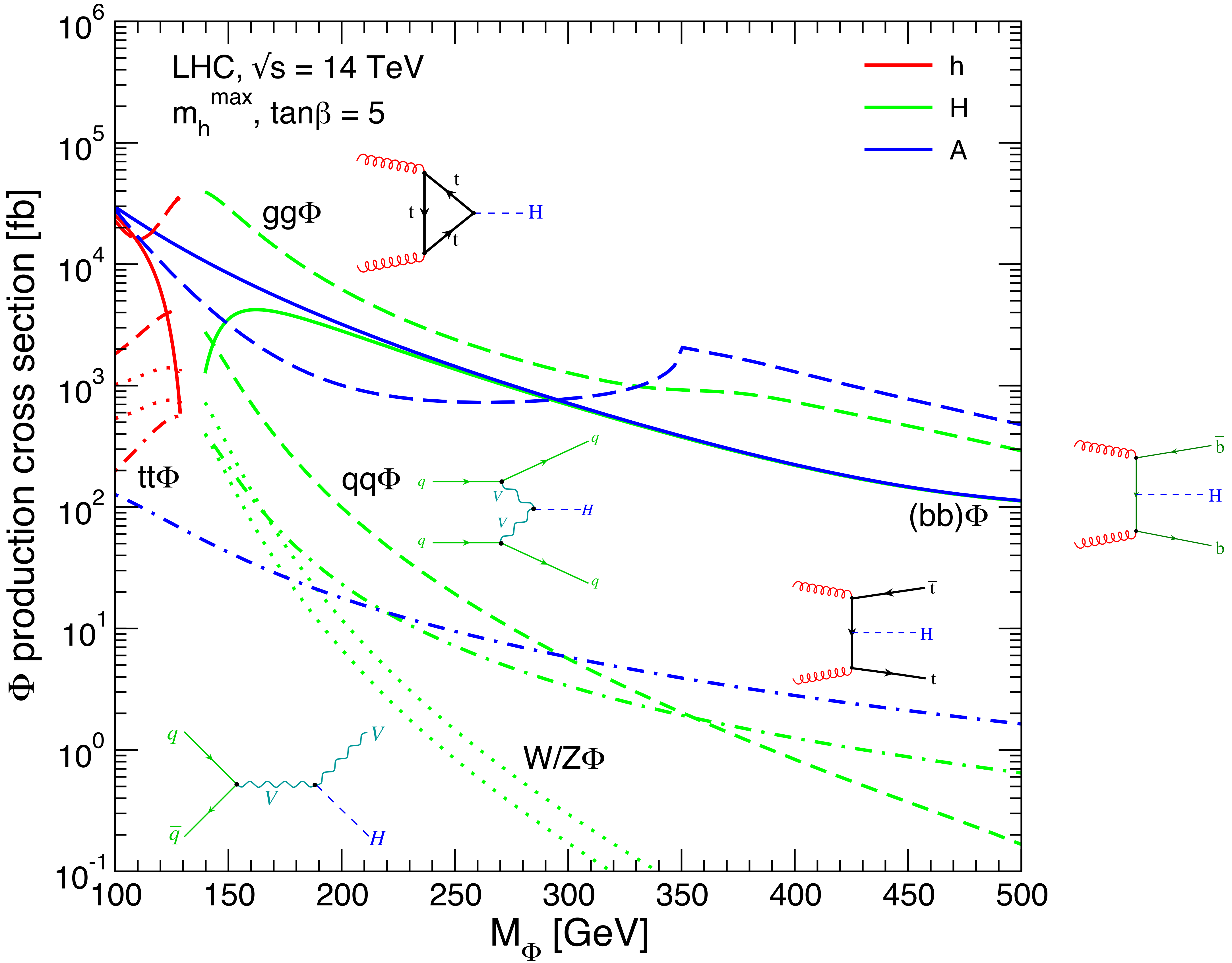
LHC, √s = 14 TeV
m_h^{max}, tanβ = 5
h
H
A
ggΦ
t
t
t
H
ttΦ
qqΦ
(bb)Φ
W/ZΦ
Φ production cross section [fb]
M_Φ [GeV]


LHC, √s = 14 TeV
m_h^{max}, tanβ = 5
h
H
A
ggΦ
t
t
t
H
ttΦ
qqΦ
q
q
V
V
H
q
q
(bb)Φ
W/ZΦ
Φ production cross section [fb]
M_Φ [GeV]
10^{-1}
10^0
10^1
10^2
10^3
10^4
10^5
10^6
100
150
200
250
300
350
400
450
500

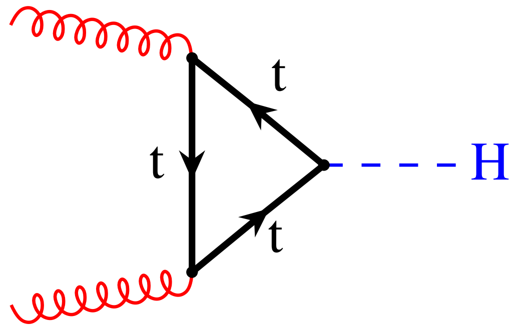


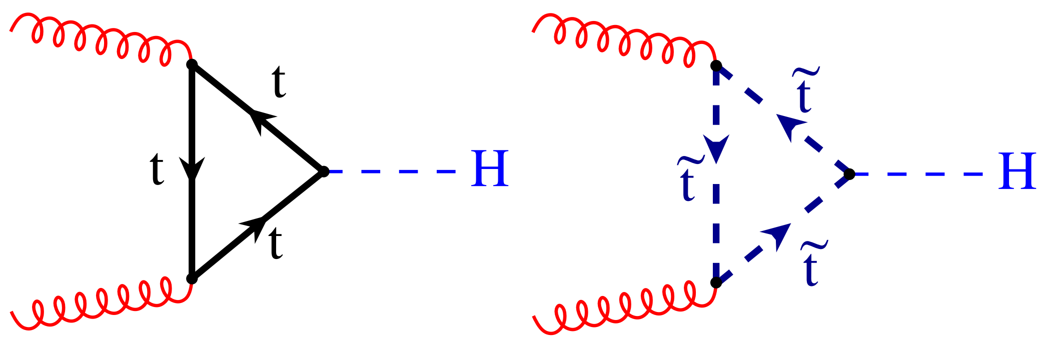
Tuesday, September 25, 2012

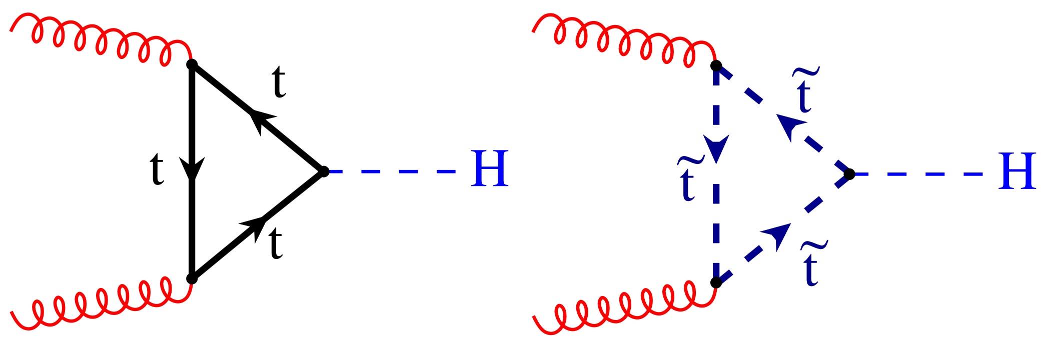

LHC, √s = 14 TeV
m_h^{max}, tanβ = 5
h
H
A
ggΦ
ttΦ
qqΦ
(bb)Φ
W/ZΦ
Φ production cross section [fb]
M_Φ [GeV]



LHC, √s = 14 TeV
m_h^{max}, tanβ = 5
h
H
A
ggΦ
ttΦ
qqΦ
(bb)Φ
W/ZΦ
Φ production cross section [fb]
M_Φ [GeV]

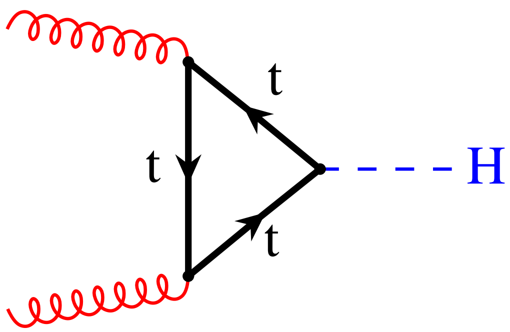

t
t
H
t

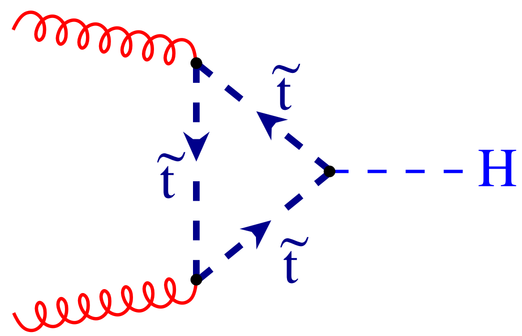

t
t
t
H
t̃
t̃
t̃
H

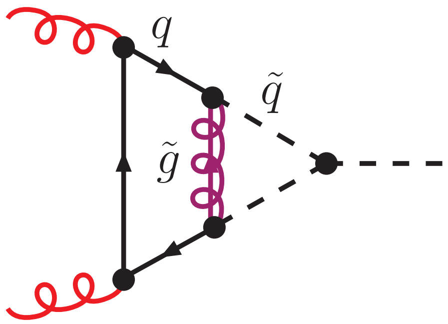


LHC Higgs XS WG:

$$\sigma^{\rm MSSM}({\rm gg}\to\phi) \;=\; \left(\frac{g_{\rm t}^{\rm MSSM}}{g_{\rm t}^{\rm SM}}\right)^2 \sigma_{\rm tt}({\rm gg}\to\phi) + \left(\frac{g_{\rm b}^{\rm MSSM}}{g_{\rm b}^{\rm SM}}\right)^2 \sigma_{\rm bb}({\rm gg}\to\phi) + \frac{g_{\rm t}^{\rm MSSM}}{g_{\rm t}^{\rm SM}}\,\frac{g_{\rm b}^{\rm MSSM}}{g_{\rm b}^{\rm SM}} \sigma_{\rm tb}({\rm gg}\to\phi),$$

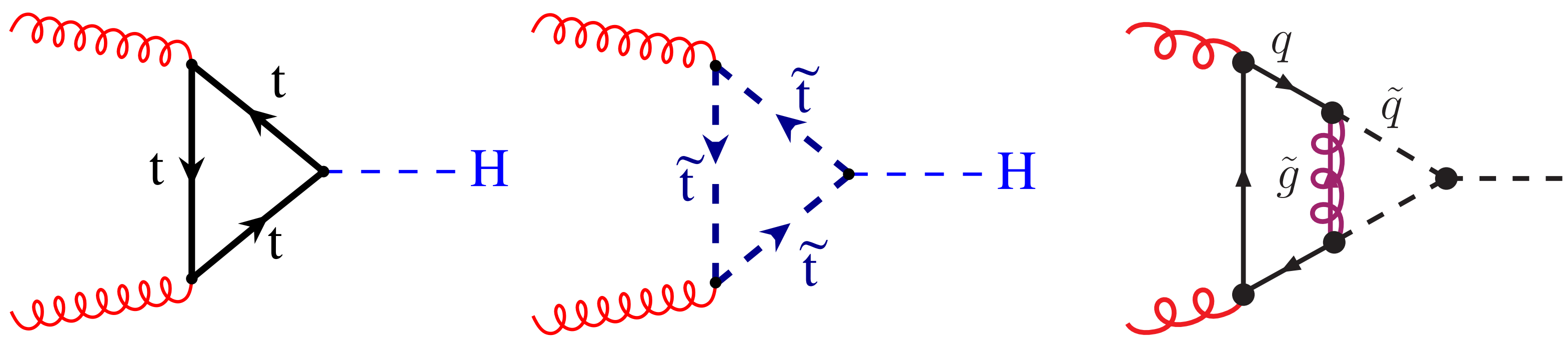






LHC Higgs XS WG:

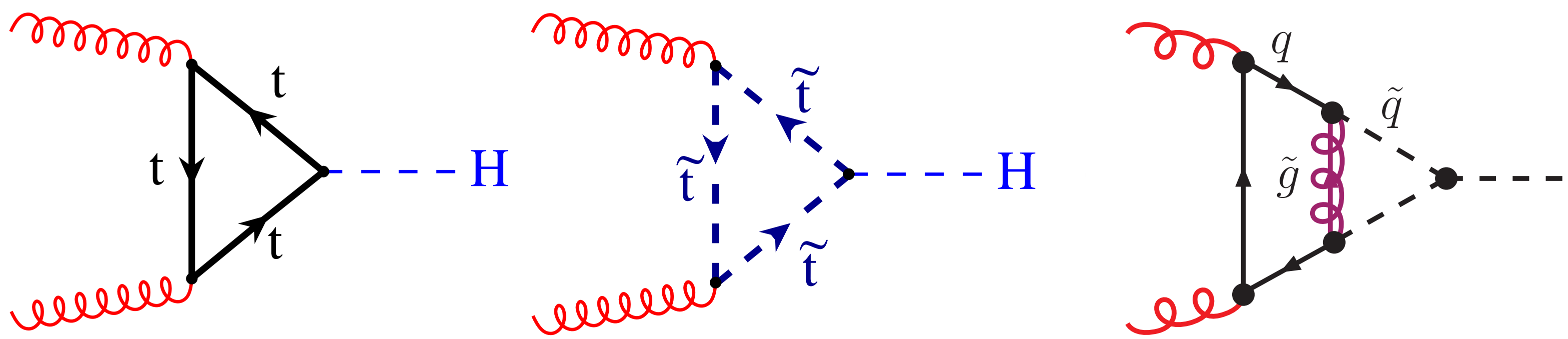
$$\sigma^{\mathrm{MSSM}}(\mathrm{gg}\to\phi) \quad = \quad \left(\frac{g_{\mathrm{t}}^{\mathrm{MSSM}}}{g_{\mathrm{t}}^{\mathrm{SM}}}\right)^2 \sigma_{\mathrm{tt}}(\mathrm{gg}\to\phi) + \left(\frac{g_{\mathrm{b}}^{\mathrm{MSSM}}}{g_{\mathrm{b}}^{\mathrm{SM}}}\right)^2 \sigma_{\mathrm{bb}}(\mathrm{gg}\to\phi) + \frac{g_{\mathrm{t}}^{\mathrm{MSSM}}}{g_{\mathrm{t}}^{\mathrm{SM}}}\,\frac{g_{\mathrm{b}}^{\mathrm{MSSM}}}{g_{\mathrm{b}}^{\mathrm{SM}}}\sigma_{\mathrm{tb}}(\mathrm{gg}\to\phi),$$



LHC Higgs XS WG:

$$\sigma^{\mathrm{MSSM}}(gg \to \phi) \quad = \quad \left(\frac{g_{\mathrm{t}}^{\mathrm{MSSM}}}{g_{\mathrm{t}}^{\mathrm{SM}}}\right)^2 \sigma_{\mathrm{tt}}(gg \to \phi) + \left(\frac{g_{\mathrm{b}}^{\mathrm{MSSM}}}{g_{\mathrm{b}}^{\mathrm{SM}}}\right)^2 \sigma_{\mathrm{bb}}(gg \to \phi) + \frac{g_{\mathrm{t}}^{\mathrm{MSSM}}}{g_{\mathrm{t}}^{\mathrm{SM}}} \frac{g_{\mathrm{b}}^{\mathrm{MSSM}}}{g_{\mathrm{b}}^{\mathrm{SM}}} \sigma_{\mathrm{tb}}(gg \to \phi),$$

All contributions for NLO MSSM Higgs known:

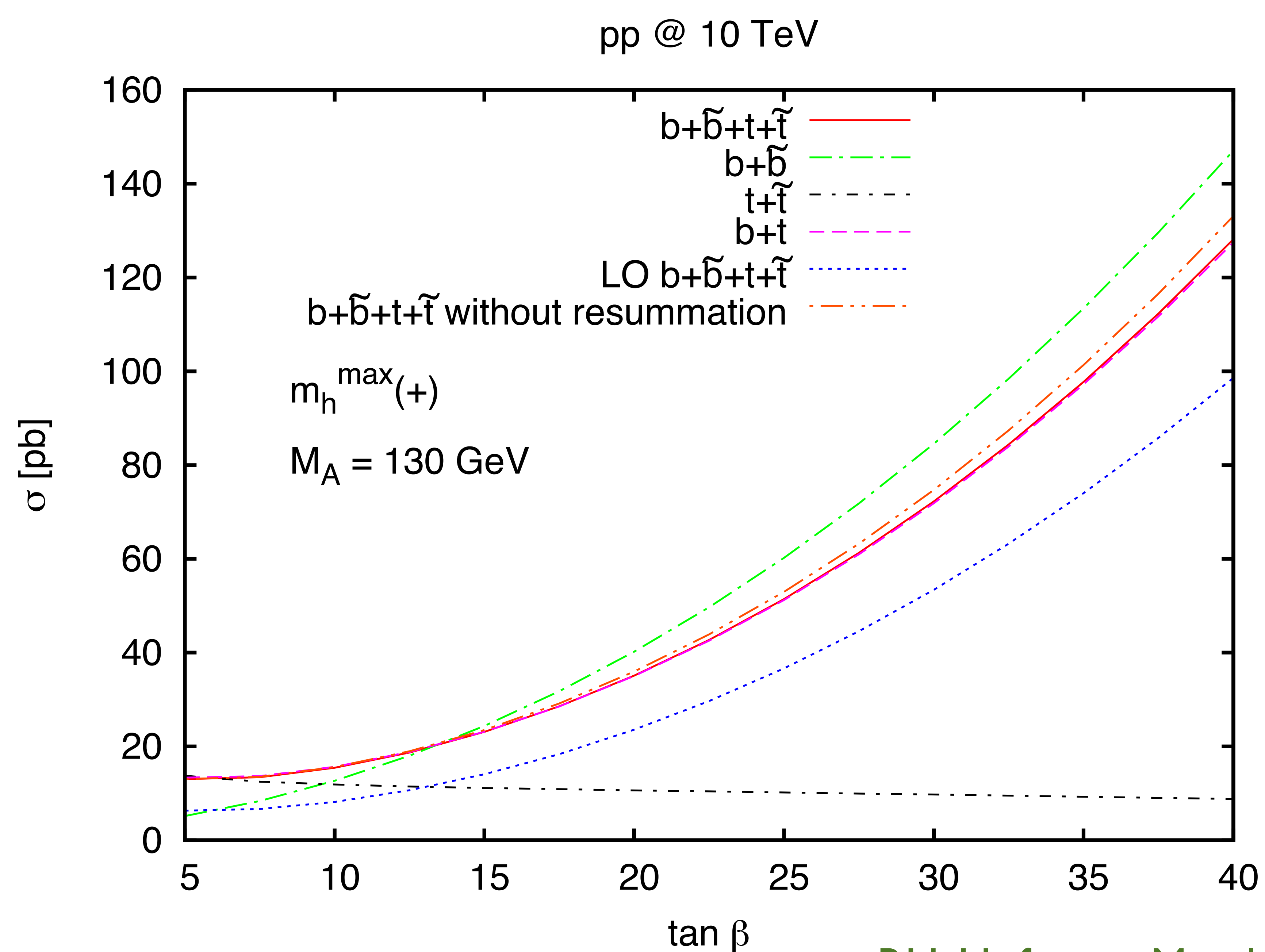


LHC Higgs XS WG:

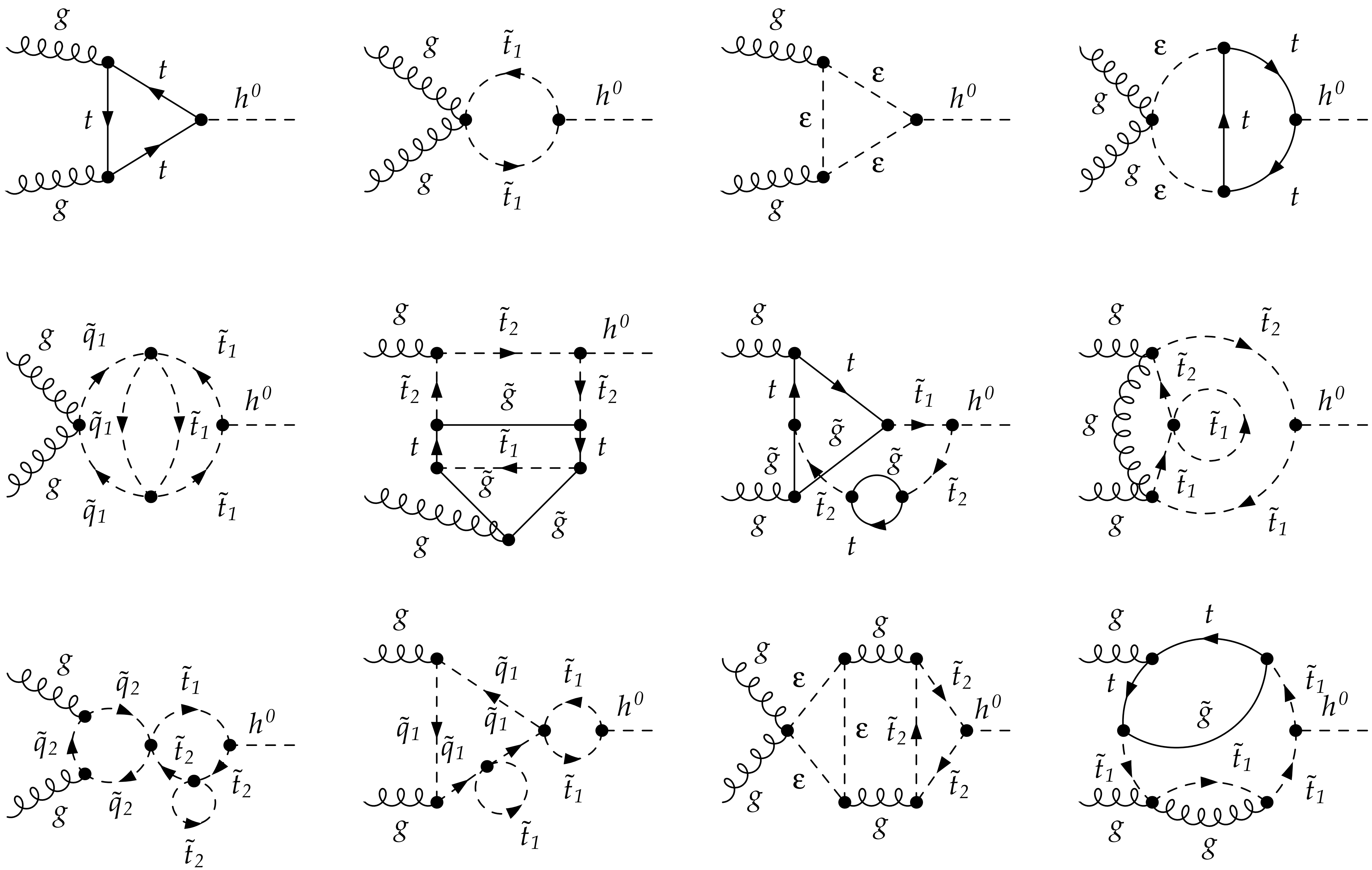
$$\sigma^{\mathrm{MSSM}}(\mathrm{gg}\to\phi) = \left(\frac{g_{\mathrm{t}}^{\mathrm{MSSM}}}{g_{\mathrm{t}}^{\mathrm{SM}}}\right)^2 \sigma_{\mathrm{tt}}(\mathrm{gg}\to\phi) + \left(\frac{g_{\mathrm{b}}^{\mathrm{MSSM}}}{g_{\mathrm{b}}^{\mathrm{SM}}}\right)^2 \sigma_{\mathrm{bb}}(\mathrm{gg}\to\phi) + \frac{g_{\mathrm{t}}^{\mathrm{MSSM}}}{g_{\mathrm{t}}^{\mathrm{SM}}}\,\frac{g_{\mathrm{b}}^{\mathrm{MSSM}}}{g_{\mathrm{b}}^{\mathrm{SM}}}\sigma_{\mathrm{tb}}(\mathrm{gg}\to\phi),$$

All contributions for NLO MSSM Higgs known:

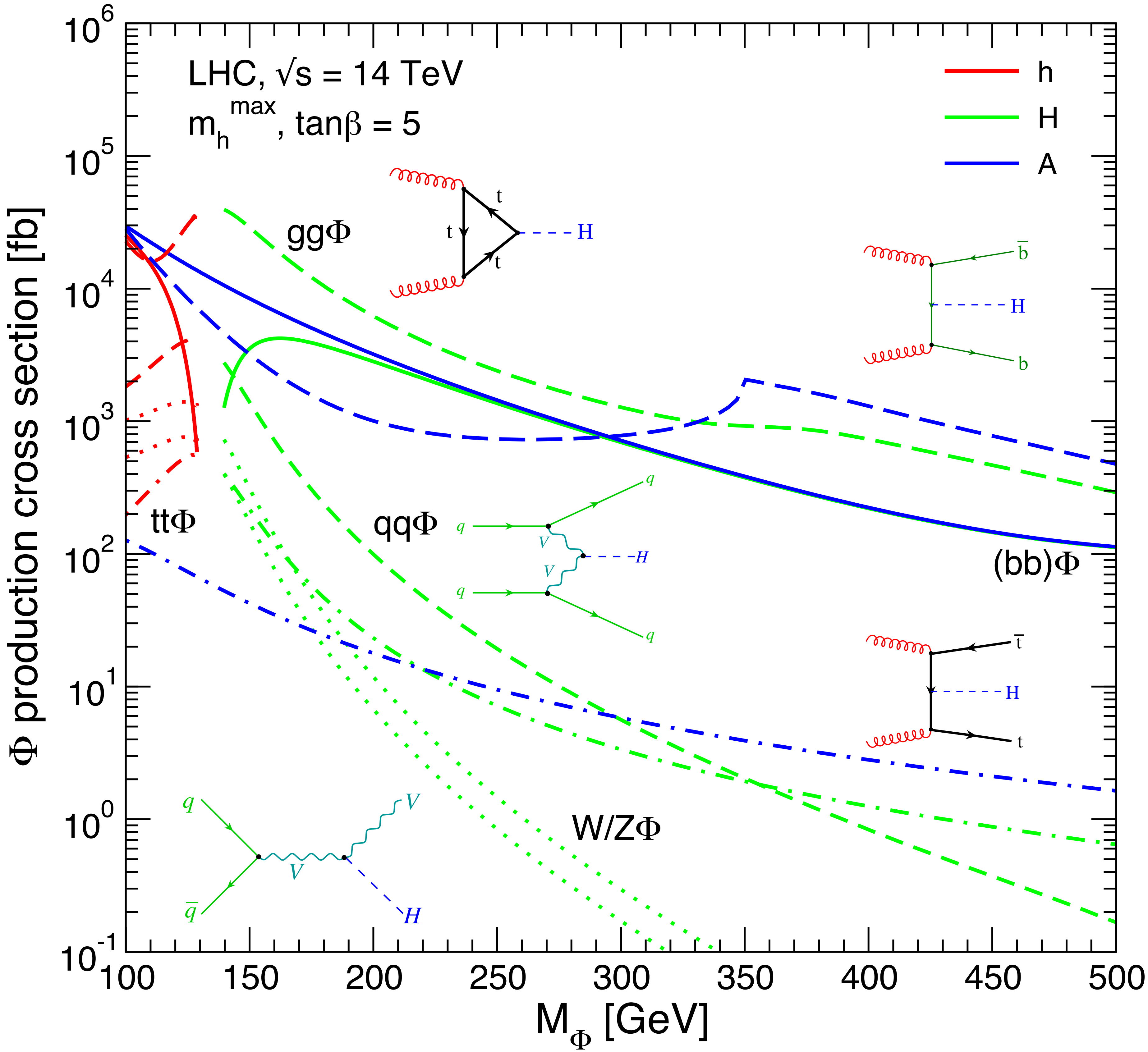
NLO: RH, Steinhauser ’04; Anastasiou, Beerli, Daleo ’08; + Bucherer, Kunszt ’06; Mühlleitner, Rzehak, Spira ’07/’08; Aglietti, Bonciani, Degrassi, Vicini ’06; RH, Hofmann, Mantler ’11; Degrassi, Slavich ’08/’10/’12; + Bagnasci, Vicini ’11/’12



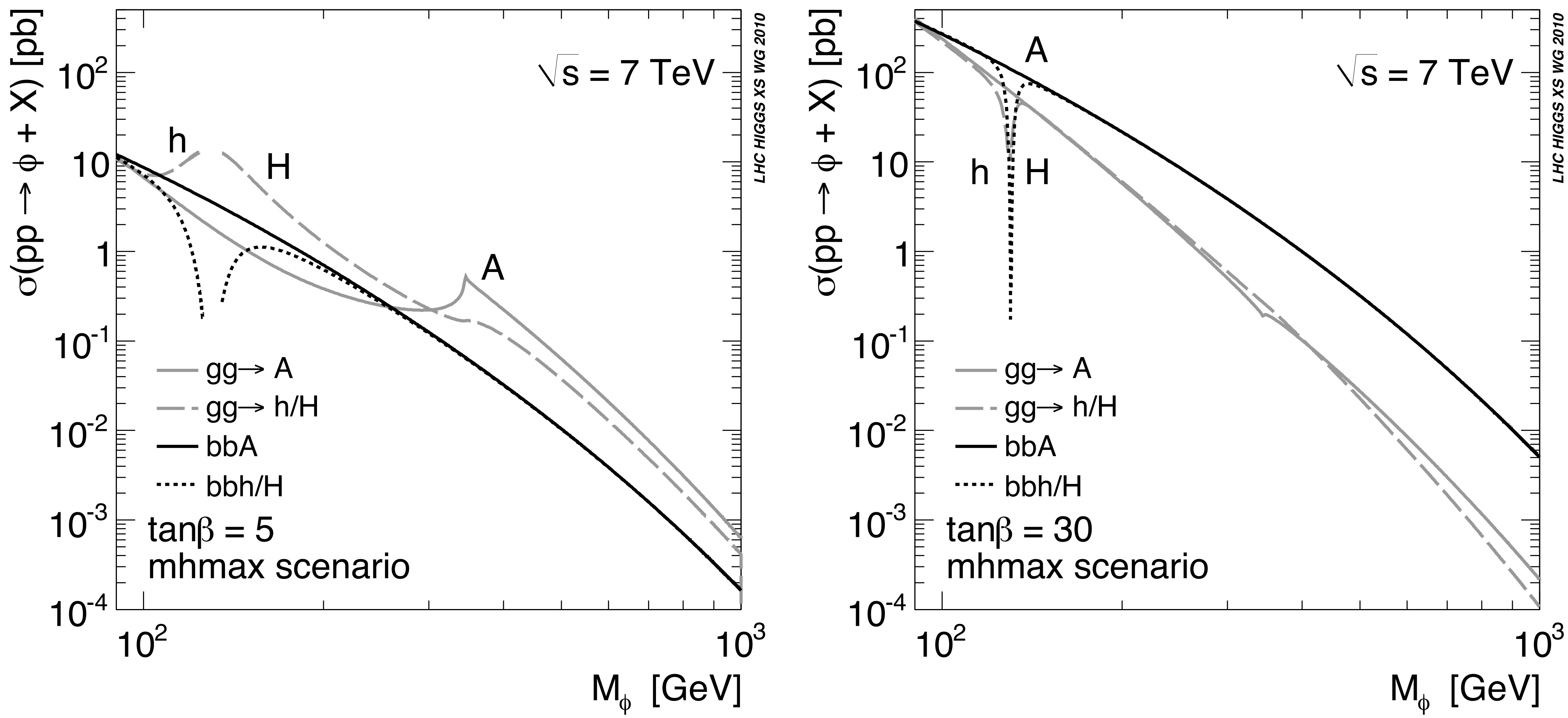
RH, Hofmann, Mantler '11



Pak, Steinhauser, Zerf '11/'12

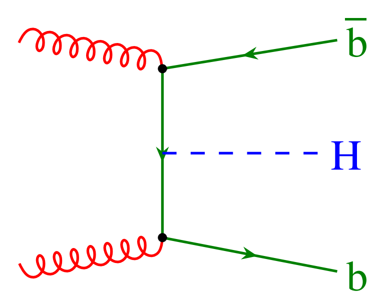


Tuesday, September 25, 2012

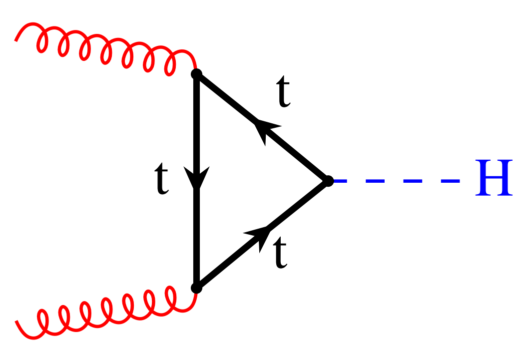


σ(pp → φ + X) [pb]
√s = 7 TeV
LHC HIGGS XS WG 2010
h
H
A
gg→ A
gg→ h/H
bbA
bbh/H
tanβ = 5
mhmax scenario
tanβ = 30
mhmax scenario
M_φ [GeV]

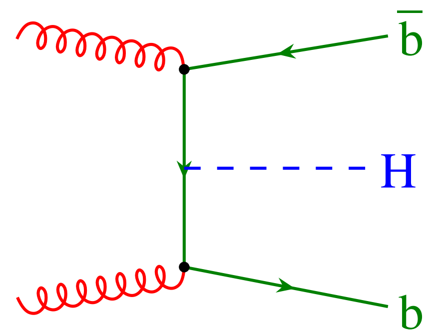
(a) (b)



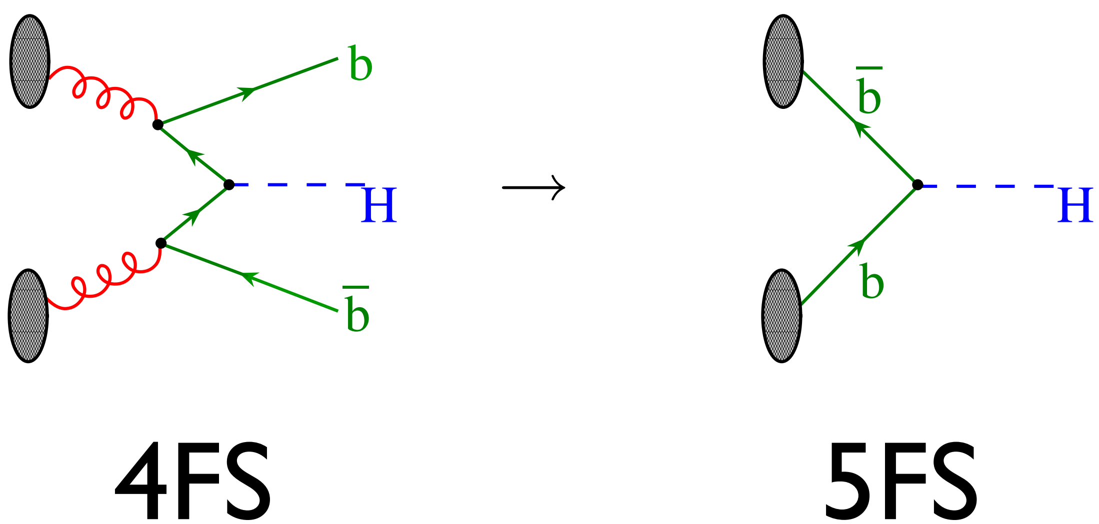
b̄
H
b

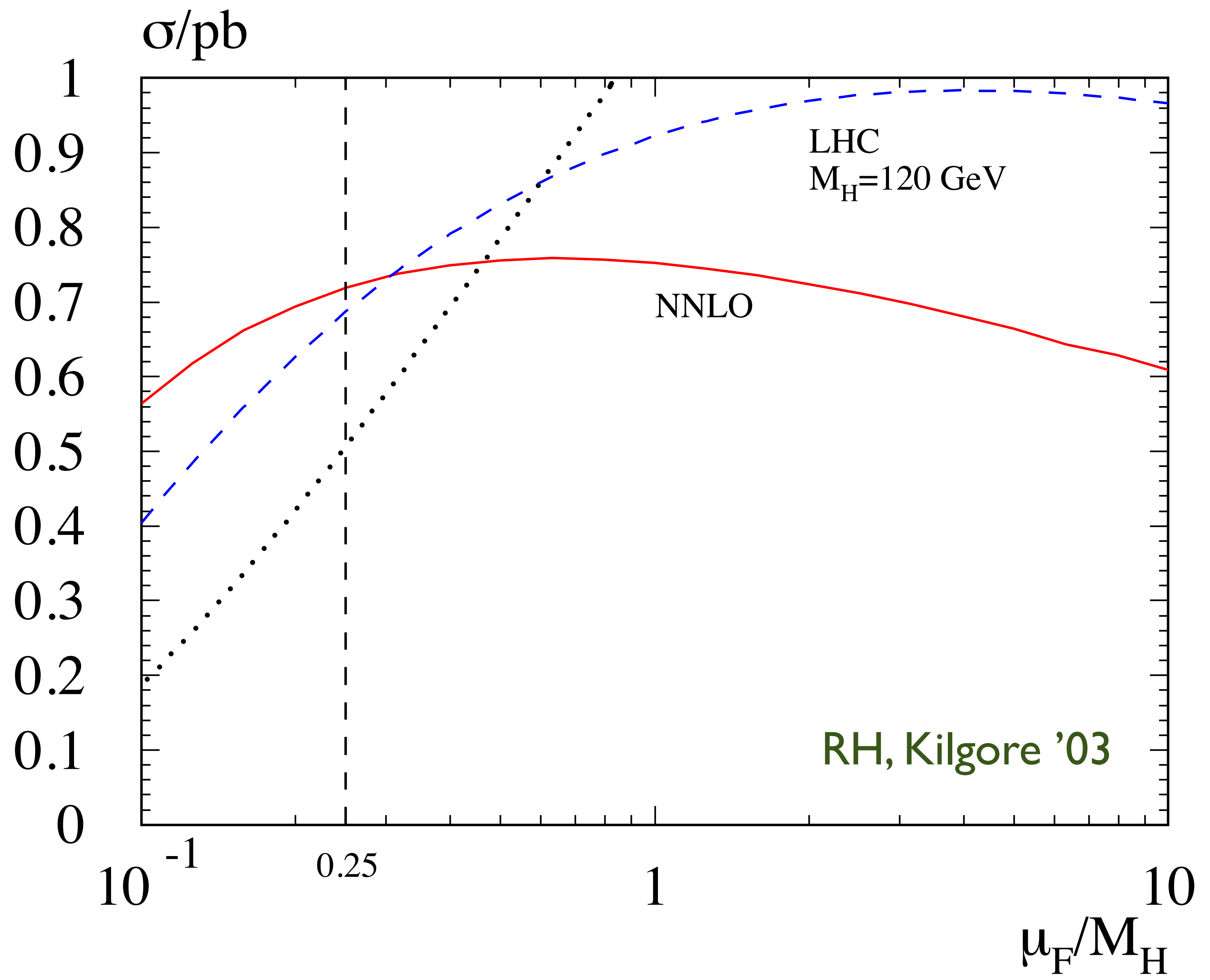


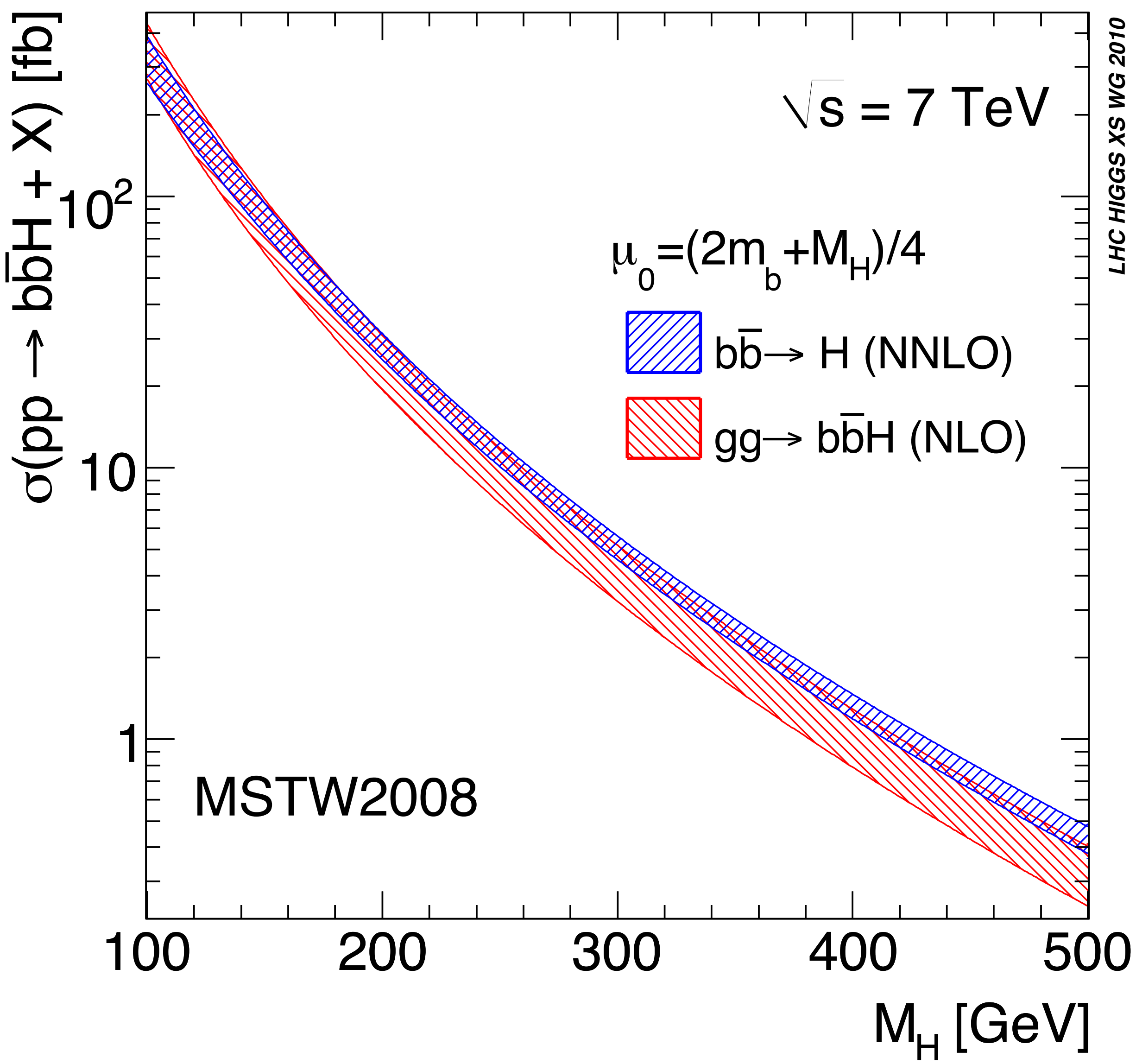
t
t
t
H



- collinear logarithms: $\sim \alpha_s \ln(m_b/M_H) \sim \alpha_s \ln(5/200)$
- resummation: bottom quarks as partons




σ/pb
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
LHC
M_H=120 GeV
NNLO
RH, Kilgore '03
10^-1
0.25
1
10
μ_F/M_H



Santander matching:

$$\sigma = \frac{\sigma^{4FS} + w\sigma^{5FS}}{1+w}$$

$$w = \log\frac{M_H}{m_b} - 1$$

RH, Krämer, Schumacher '11

see also
Maltoni, Ridolfi, Ubiali '12

SUSY Higgs Xsecs

SUSY Higgs Xsecs

- SUSY theory predictions lag behind SM

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- only partially transferable

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- SUSY theory predictions lag behind SM
- only partially transferable
- calculational and conceptional issues

SUSY Higgs Xsecs

- SUSY theory predictions lag behind SM
- only partially transferable
- calculational and conceptional issues
- QCD uncertainties need to be fixed

What now?

What now?

- find another particle

What now?

- find another particle
  superpartner, charged Higgs, exotic Higgs decays,...

What now?

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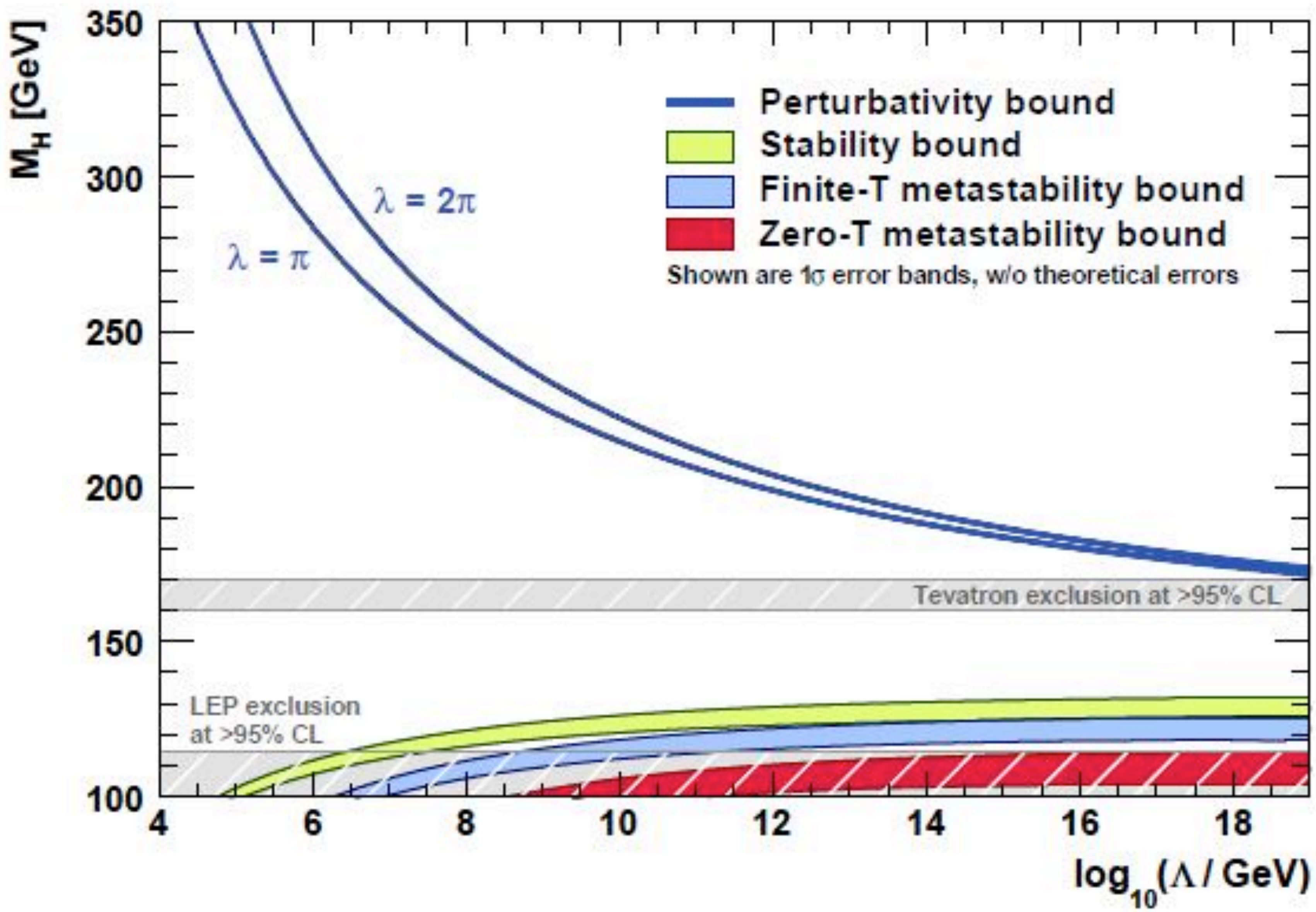
- if not: precision physics

What now?

- find another particle
  superpartner, charged Higgs, exotic Higgs decays,...
- if not: precision physics
- if not: understand naturalness, ...



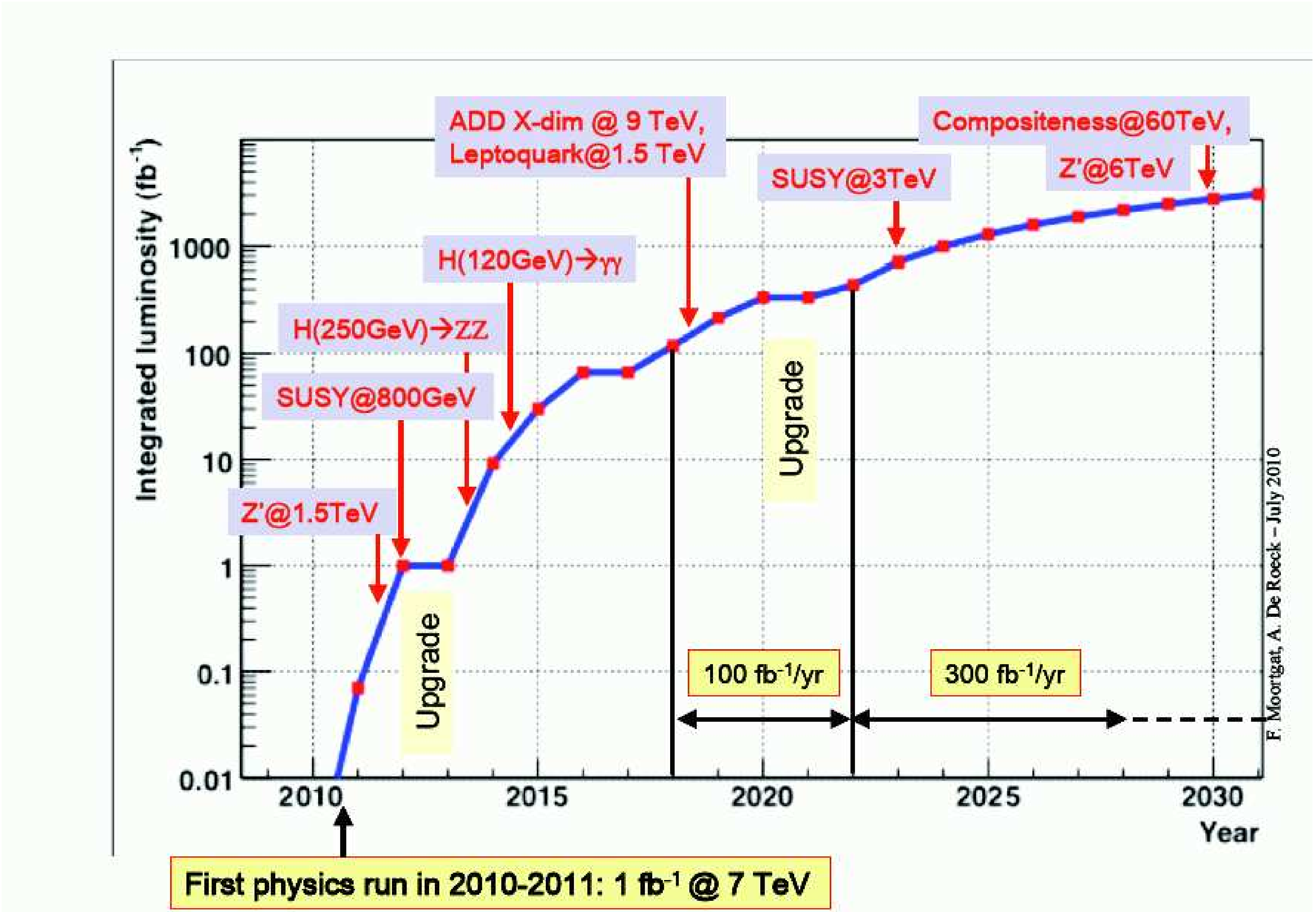
M_H [GeV]
350
300
250
200
150
100
4
6
8
10
12
14
16
18
$\log_{10}(\Lambda / \text{GeV})$
Perturbativity bound
Stability bound
Finite-T metastability bound
Zero-T metastability bound
Shown are 1σ error bands, w/o theoretical errors
$\lambda = 2\pi$
$\lambda = \pi$
Tevatron exclusion at >95% CL
LEP exclusion
at >95% CL

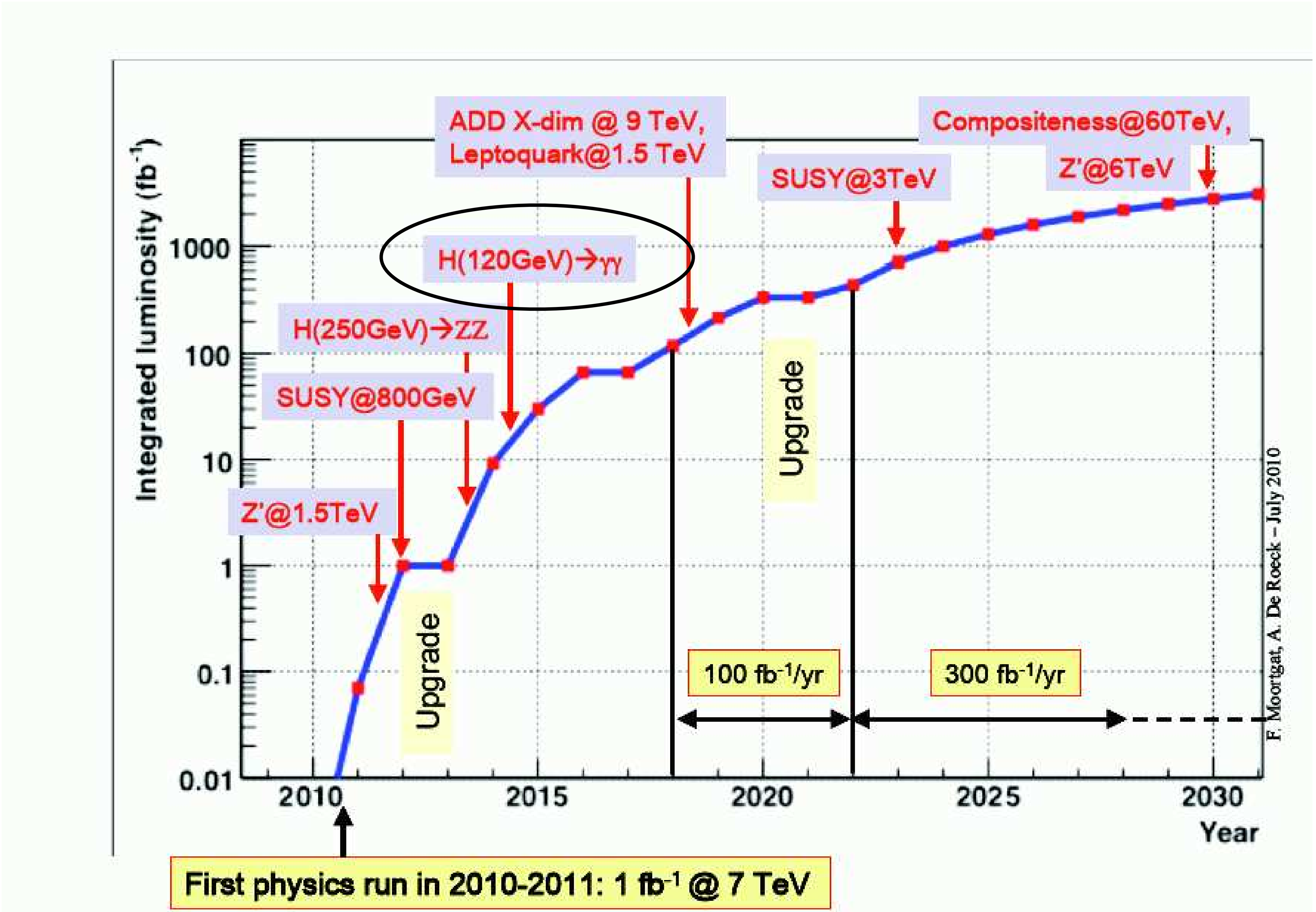
$$V = -m^2|H|^2 + \lambda|H|^4$$

Degrassi et al. '12

Conclusions

- Theory seems intact
- SM still unchallenged
- SUSY gets cornered
- be prepared for precision physics!


ADD X-dim @ 9 TeV,
Leptoquark@1.5 TeV
Compositeness@60TeV,
Z'@6TeV
SUSY@3TeV
H(120GeV)→γγ
H(250GeV)→ZZ
SUSY@800GeV
Z'@1.5TeV
Upgrade
Upgrade
100 fb-1/yr
300 fb-1/yr
Integrated luminosity (fb-1)
1000
100
10
1
0.1
0.01
2010
2015
2020
2025
2030
Year
F. Moortgat, A. De Roeck – July 2010
First physics run in 2010-2011: 1 fb-1 @ 7 TeV



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H(250GeV)→ZZ
SUSY@800GeV
Z'@1.5TeV
Upgrade
Upgrade
100 fb-1/yr
300 fb-1/yr
Integrated luminosity (fb-1)
1000
100
10
1
0.1
0.01
2010
2015
2020
2025
2030
Year
F. Moortgat, A. De Roeck – July 2010
First physics run in 2010-2011: 1 fb-1 @ 7 TeV

"Borrowed" from material by:

Sven Heinemeyer, Maggie Mühlleitner, Carlos Wagner, ...