SUPERSYMMETRIC HIGGS YUKAWA COUPLINGS TO BOTTOM QUARKS AT NNLO

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I Introduction

II $\phi^0 b\bar{b}$ Couplings

III Conclusions

in collaboration with D. Noth

I *INTRODUCTION*

MSSM

- 2 Higgs doublets $\stackrel{\text{ESB}}{\longrightarrow}$ 5 Higgs bosons: $h, H, A, H^\pm$

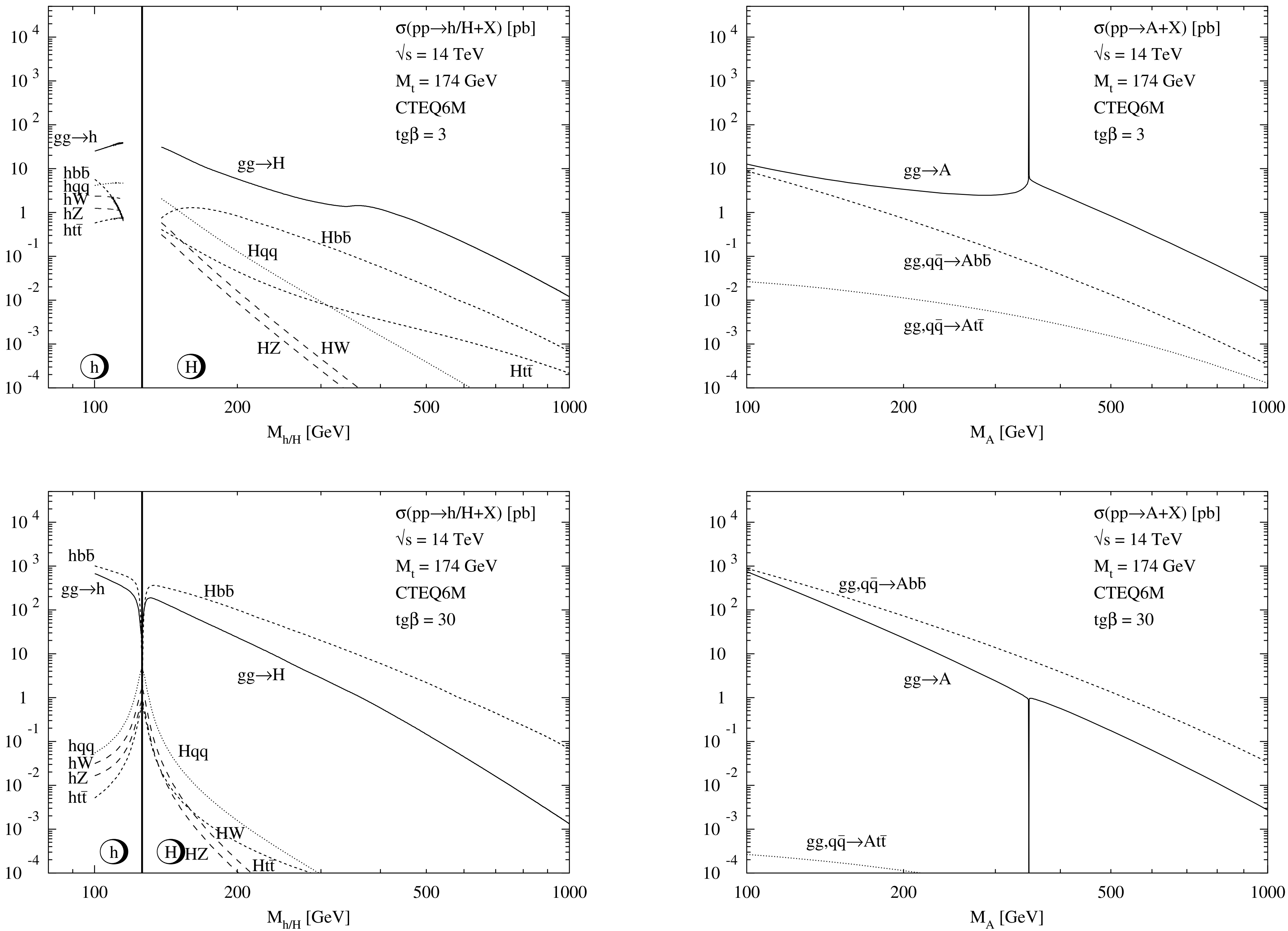
- LO: 2 input parameters: $M_A, \text{tg}\beta = \frac{v_2}{v_1}$

- radiative corrections $\propto m_t^4 \log \frac{m_{\tilde{t}_1} m_{\tilde{t}_2}}{m_t^2} \quad \rightarrow \boxed{M_h \lesssim 135 \text{ GeV}}$

Haber, Hempfling
Carena,...
Heinemeyer,...
Zhang
Slavich,...
Martin
Harlander,...
...

- Yukawa couplings: $\text{tg}\beta\uparrow \quad \Rightarrow \quad g_u^\phi\downarrow \quad g_d^\phi\uparrow \quad g_V^\phi\downarrow$

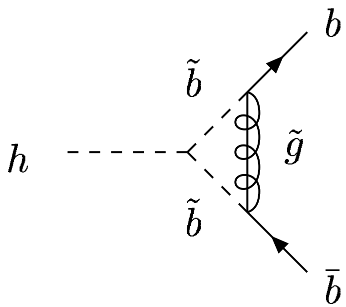
- LHC: $gg \rightarrow \phi$ dominant for $\text{tg}\beta \lesssim 10$
  $gg \rightarrow \phi b\bar{b}$ dominant for $\text{tg}\beta \gtrsim 10$


σ(pp→h/H+X) [pb]
√s = 14 TeV
M_t = 174 GeV
CTEQ6M
tgβ = 3
gg→h
hbb̄
hqq
hW
hZ
htt̄
gg→H
Hbb̄
Hqq
HZ
HW
Htt̄
h
H
M_h/H [GeV]
σ(pp→A+X) [pb]
√s = 14 TeV
M_t = 174 GeV
CTEQ6M
tgβ = 3
gg→A
gg,qq̄→Abb̄
gg,qq̄→Att̄
M_A [GeV]
σ(pp→h/H+X) [pb]
√s = 14 TeV
M_t = 174 GeV
CTEQ6M
tgβ = 30
σ(pp→A+X) [pb]
√s = 14 TeV
M_t = 174 GeV
CTEQ6M
tgβ = 30

II $\phi^0 b\bar{b}$ COUPLINGS

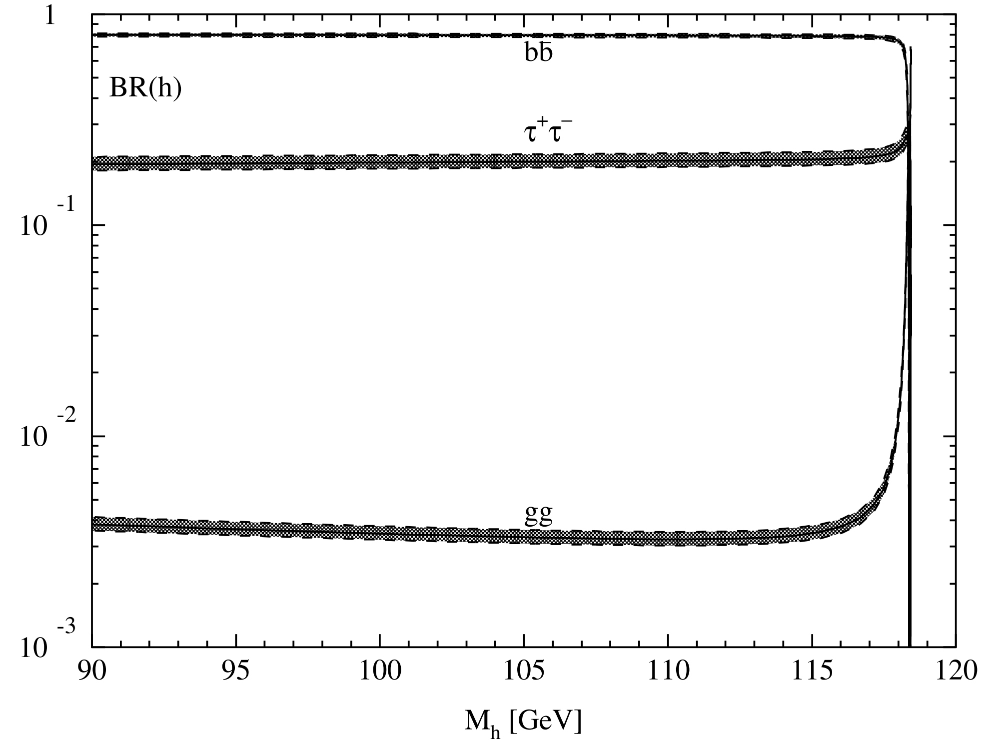
Braaten, Leveille
Drees, Hikasa
Kataev,. . .
Chetyrkin,. . .
etc.

- QCD corrections to $\phi^0 \to b\bar{b}$ known to NNLO
- large SUSY–QCD corrections to $\phi^0 \to b\bar{b}$ $\qquad (\Delta\Gamma/\Gamma \sim 10\%)$



$$+ \cdots \qquad \propto \frac{\alpha_s}{\pi} \frac{M_{\tilde{g}} \mu \, \mathrm{tg}\beta}{M_{SUSY}^2}$$

Hall,. . .
Carena,. . .
Nierste,. . .
Guasch,. . .
etc.



dominated by scale dependence of α_s

Guasch, Häfliger, S.

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SUSY-QCD Corrections to $b\bar{b}\phi^0$ $\qquad [\Delta \lesssim 1\%]$

$$\mathcal{L}_{eff} = -\lambda_b \overline{b_R}\left[\phi_1^0 + \frac{\Delta_b}{\mathrm{tg}\beta}\phi_2^{0*}\right] b_L + h.c. \quad \text{valid to all orders in } \Delta_b$$

$$= -m_b \bar{b}\left[1 + i\gamma_5 \frac{G^0}{v}\right] b - \frac{m_b/v}{1+\Delta_b}\bar{b}\left[g_b^h\left(1 - \frac{\Delta_b}{\mathrm{tg}\alpha\ \mathrm{tg}\beta}\right) h + g_b^H\left(1 + \Delta_b \frac{\mathrm{tg}\alpha}{\mathrm{tg}\beta}\right) H - g_b^A\left(1 - \frac{\Delta_b}{\mathrm{tg}^2\beta}\right) i\gamma_5 A\right] b$$

$$\Delta_b = \Delta_b^{QCD(1)} + \Delta_b^{elw(1)}$$

$$\Delta_b^{QCD(1)} = \frac{2}{3}\frac{\alpha_s(\mu_R)}{\pi} M_{\tilde{g}}\ \mu\ \mathrm{tg}\beta\ I(m_{\tilde{b}_1}^2, m_{\tilde{b}_2}^2, M_{\tilde{g}}^2)$$

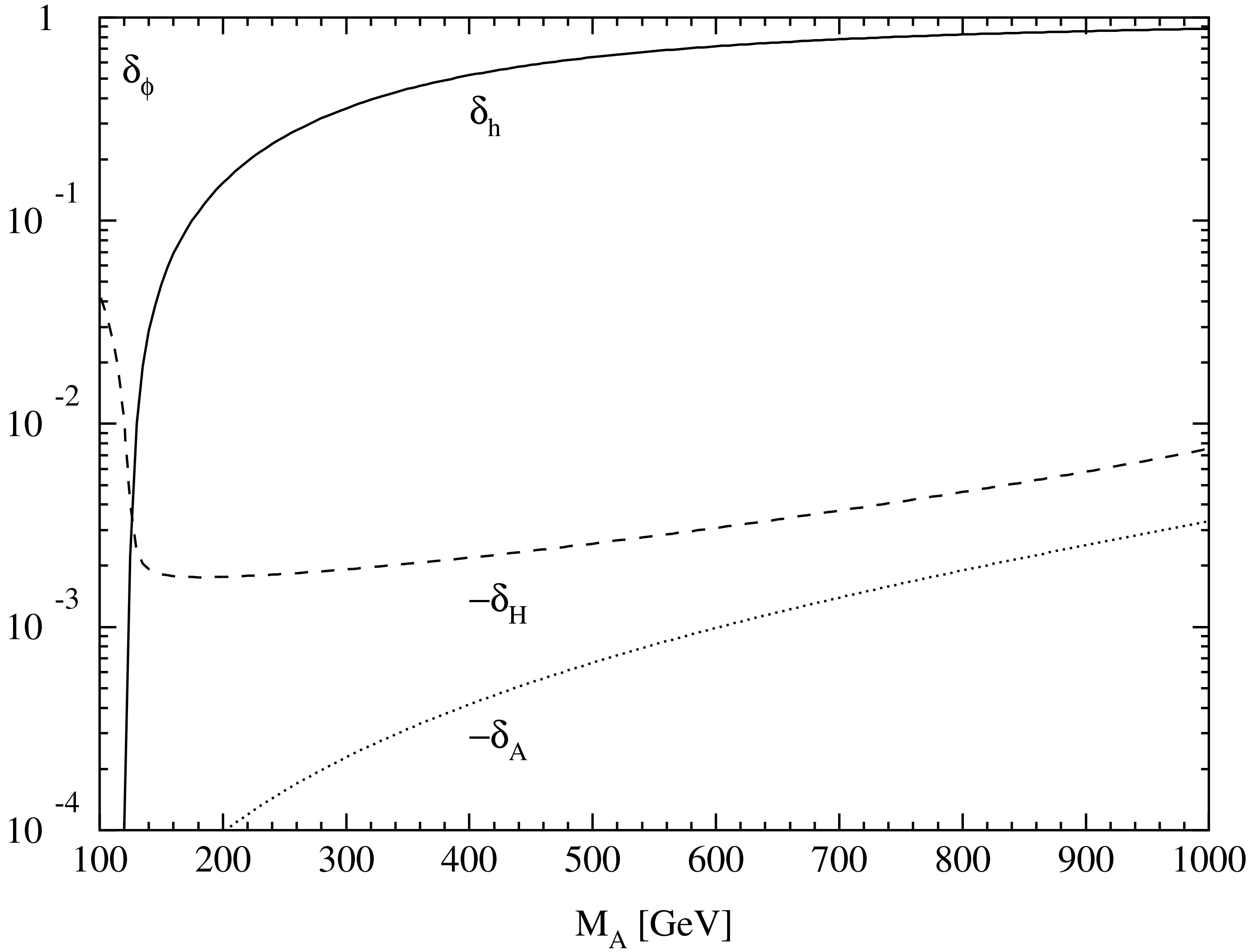
$$\Delta_b^{elw(1)} = \frac{\lambda_t^2(\mu_R)}{(4\pi)^2}\ \mu\ A_t\ \mathrm{tg}\beta\ I(m_{\tilde{t}_1}^2, m_{\tilde{t}_2}^2, \mu^2)$$

$$I(a,b,c) = \frac{ab\log\frac{a}{b} + bc\log\frac{b}{c} + ca\log\frac{c}{a}}{(a-b)(b-c)(a-c)}$$

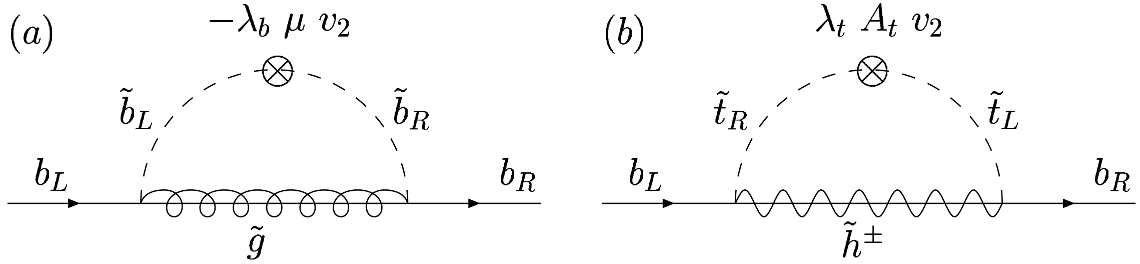
$\Rightarrow$ resummed Yukawa couplings

Carena, Garcia, Nierste, Wagner
Guasch, Häfliger, S.

$$\Gamma(\phi \to b\bar{b}) : \qquad \delta_\phi = \frac{\delta_{SUSY} - \delta_{SUSY}^{LE}}{\delta_{SUSY}} \to 2\frac{A_b + \mu/\mathrm{tg}\beta}{\mu \mathrm{tg}\beta} \qquad (M_\phi^2 \gg M_{SUSY}^2)$$

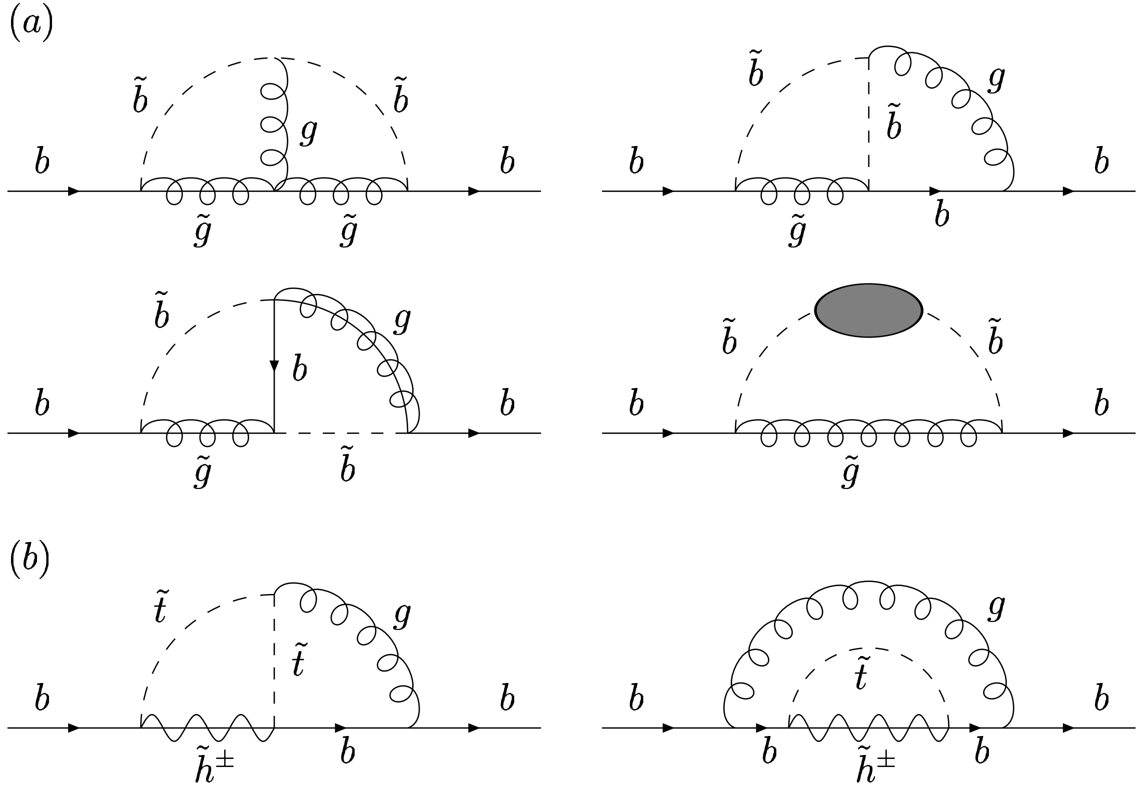


$$h : \qquad \frac{1}{1+\Delta_b}\left(1 - \frac{\Delta_b}{\mathrm{tg}\alpha\ \mathrm{tg}\beta}\right) \to 1 \qquad \text{in decoupling limit}$$



- LET: $v_2 \to \sqrt{2}\phi_2^{0*}$

Ellis,. . .
Shifman,. . .



Bednyakov,. . .
Martin
Bauer,. . .

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- 2-loop self-energies @ vanishing momentum

- dimensional regularization in $n = 4 - 2\epsilon$ dimensions

- integration by parts: reduction to 1-point functions

$$A_0(m) = \int \frac{d^n k}{(2\pi)^n} \frac{1}{k^2 - m^2}$$

and 2-loop master integrals

$$T_{134}(m_1, m_3, m_4) = \int \frac{d^n k}{(2\pi)^n} \frac{d^n q}{(2\pi)^n} \frac{1}{(k^2 - m_1^2)[(k-q)^2 - m_3^2](q^2 - m_4^2)}$$

- α_s, λ_t: $\overline{\text{MS}}$ scheme [5 flavours]
  masses, A_t: on-shell

- dim. reg. violates SUSY: anomalous counter terms

$$\begin{aligned}
\hat{g}_s &= g_s \left[1 + \left(\frac{C_A}{6} - \frac{C_F}{8}\right)\frac{\alpha_s}{\pi}\right] \\
\lambda_{Hbb} &= \lambda_{H\tilde{b}\tilde{b}} \left[1 + \frac{C_F}{4}\frac{\alpha_s}{\pi}\right] = \lambda_{\tilde{H}\tilde{b}b} \left[1 + \frac{3}{8} C_F \frac{\alpha_s}{\pi}\right]
\end{aligned}$$

Martin, Vaughn

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Limits $[N_F = 5]$

- $m_t^2 \ll m_{\tilde{g}}^2 = m_{\tilde{b}_i}^2 = \mu^2 = m_{\tilde{t}_i}^2 \equiv M^2$:

$$\Delta_b^{QCD\,(1)} = \frac{C_F}{4}\frac{\alpha_s(\mu_R)}{\pi}\mathrm{tg}\beta$$

$$\Delta_b^{QCD\,(2)} = \frac{\alpha_s}{\pi}\left\{\frac{C_A}{3} + C_F + \frac{N_F+1}{4} + \underbrace{\frac{1}{6}\log\frac{M^2}{m_t^2}}_{\to\ \alpha_s^{(6)}} + \beta_0^L \log\frac{\mu_R^2}{M^2}\right\}\Delta_b^{QCD\,(1)}$$

$$\Delta_b^{elw\,(1)} = \frac{1}{2}\frac{\lambda_t^2(\mu_R)}{(4\pi)^2}\frac{A_t\mathrm{tg}\beta}{M}$$

$$\Delta_b^{elw\,(2)} = C_F\frac{\alpha_s}{\pi}\left\{\frac{7}{4} + \underbrace{\frac{3}{2}\log\frac{\mu_R^2}{m_t M}}_{\lambda_t(\mu_R)\ \to\ \lambda_{t,MO}^{\tilde{h}^\pm}(m_t)}\right\}\Delta_b^{elw\,(1)}$$

Noth, S.

$$\lambda_t(\mu_R) = \lambda_{t,MO}^{\tilde{h}^\pm}(\mu_R)\left\{1 - C_F\frac{\alpha_s}{\pi}\left[\frac{3}{8}\log\frac{\mu_R^2}{M^2} - \frac{1}{8}\right]\right\} \qquad [\mu_R \ll M]$$

$$\beta_0^L = \frac{11C_A - 2N_F}{12}$$

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- $m_t^2, m_{\tilde{b}_i}^2, \mu^2, m_{\tilde{t}_i}^2 \ll m_{\tilde{g}}^2$:

$$\Delta_b^{QCD\,(1)} = \frac{C_F}{2}\frac{\alpha_s(\mu_R)}{\pi}\frac{\mu \mathrm{tg}\beta}{m_{\tilde{g}}} \left\{ -\log\frac{m_{\tilde{g}}^2}{m_{\tilde{b}_2}^2} + \frac{m_{\tilde{b}_1}^2}{m_{\tilde{b}_2}^2 - m_{\tilde{b}_1}^2}\log\frac{m_{\tilde{b}_2}^2}{m_{\tilde{b}_1}^2} \right\}$$

$$\Delta_b^{QCD\,(2)} = \frac{\alpha_s}{\pi}\left\{\frac{4}{3}C_A + C_F\left[\log\frac{m_{\tilde{g}}^2}{m_{\tilde{b}_2}^2} - \frac{m_{\tilde{b}_1}^2}{m_{\tilde{b}_2}^2 - m_{\tilde{b}_1}^2}\log\frac{m_{\tilde{b}_2}^2}{m_{\tilde{b}_1}^2} + \frac{5}{2}\right] - \frac{N_F+1}{2}\right.$$
$$\left. + \underbrace{\frac{1}{6}\log\frac{m_{\tilde{g}}^2}{m_t^2} + \frac{1}{24}\sum_{\tilde{q}}\log\frac{m_{\tilde{g}}^2}{m_{\tilde{q}}^2}}_{\to\ \alpha_s^{(SUSY)}} + \beta_0^L\log\frac{\mu_R^2}{m_{\tilde{g}}^2}\right\}\Delta_b^{QCD\,(1)}$$

$$\Delta_b^{elw\,(2)} = C_F\frac{\alpha_s}{\pi}\left\{\frac{23}{8} + \underbrace{\frac{3}{2}\log\frac{\mu_R^2}{m_t m_{\tilde{g}}}}_{\lambda_t(\mu_R)\ \to\ \lambda_{t,MO}^{\tilde{h}^\pm}(m_t)}\right\}\Delta_b^{elw\,(1)}$$

Noth, S.

$$\lambda_t(\mu_R) = \lambda_{t,MO}^{\tilde{h}^\pm}(\mu_R)\left\{1 - C_F\frac{\alpha_s}{\pi}\left[\frac{3}{8}\log\frac{\mu_R^2}{m_{\tilde{g}}^2} + \frac{9}{16}\right]\right\} \qquad [\mu_R \ll m_{\tilde{g}}]$$

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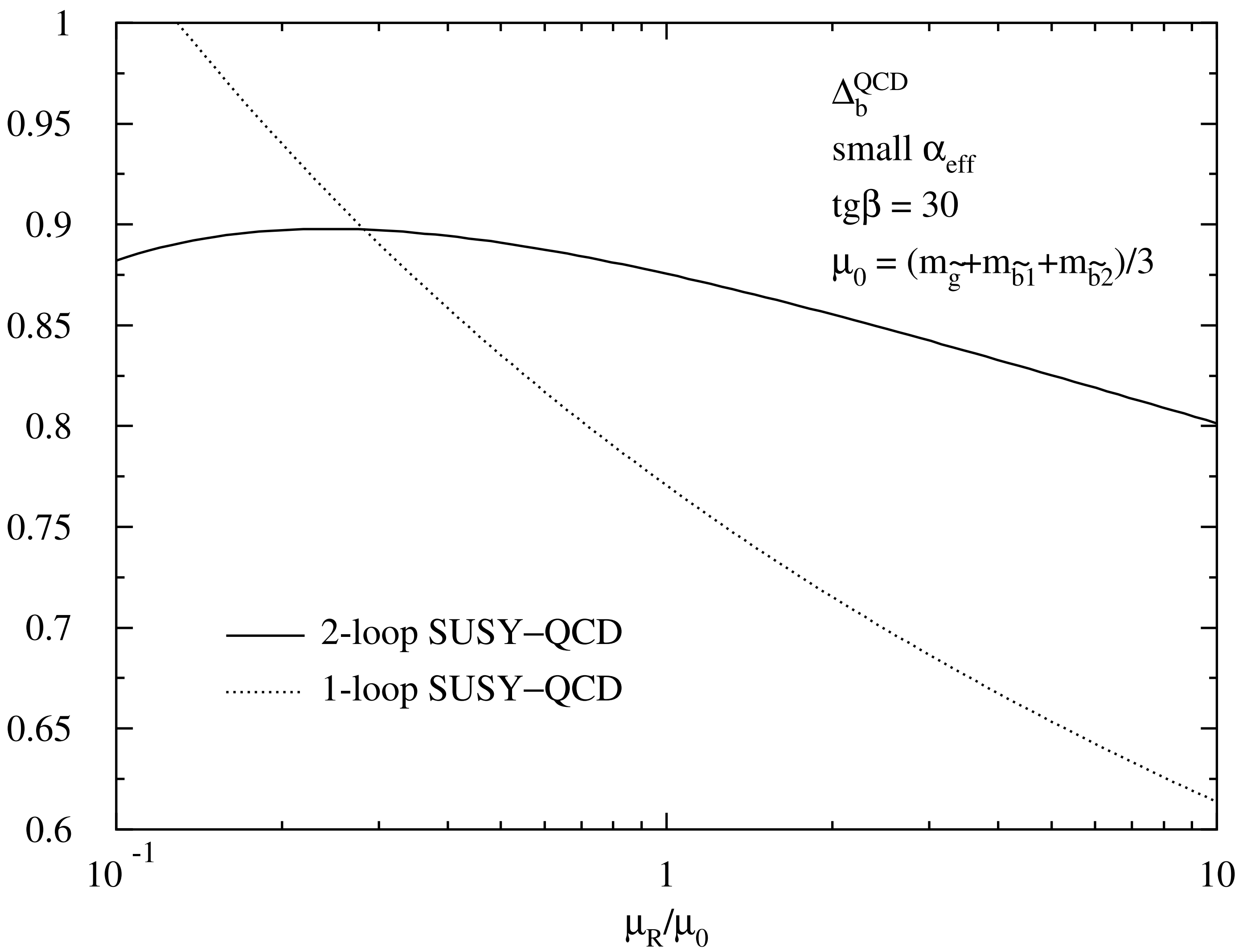
small α_{eff} scenario [modified]

Carena, Heinemeyer, Wagner, Weiglein

$$
\begin{aligned}
\mathrm{tg}\beta &= 30 \\
M_{\tilde{Q}} &= 800\ \mathrm{GeV} \\
M_{\tilde{g}} &= 1000\ \mathrm{GeV} \qquad \longleftarrow \\
M_2 &= 500\ \mathrm{GeV} \\
A_b = A_t &= -1.133\ \mathrm{TeV} \\
\mu &= 2\ \mathrm{TeV}
\end{aligned}
$$

$$
\begin{aligned}
m_{\tilde{t}_1} &= 679\ \mathrm{GeV} \qquad & m_{\tilde{t}_2} &= 935\ \mathrm{GeV} \\
m_{\tilde{b}_1} &= 601\ \mathrm{GeV} \qquad & m_{\tilde{b}_2} &= 961\ \mathrm{GeV}
\end{aligned}
$$



Δ_b^{QCD}
small α_{eff}
tgβ = 30
$\mu_0 = (m_{\tilde{g}}+m_{\tilde{b}1}+m_{\tilde{b}2})/3$
2-loop SUSY−QCD
1-loop SUSY−QCD
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
10^{-1}
1
10
μ_R/μ_0

Noth, S.

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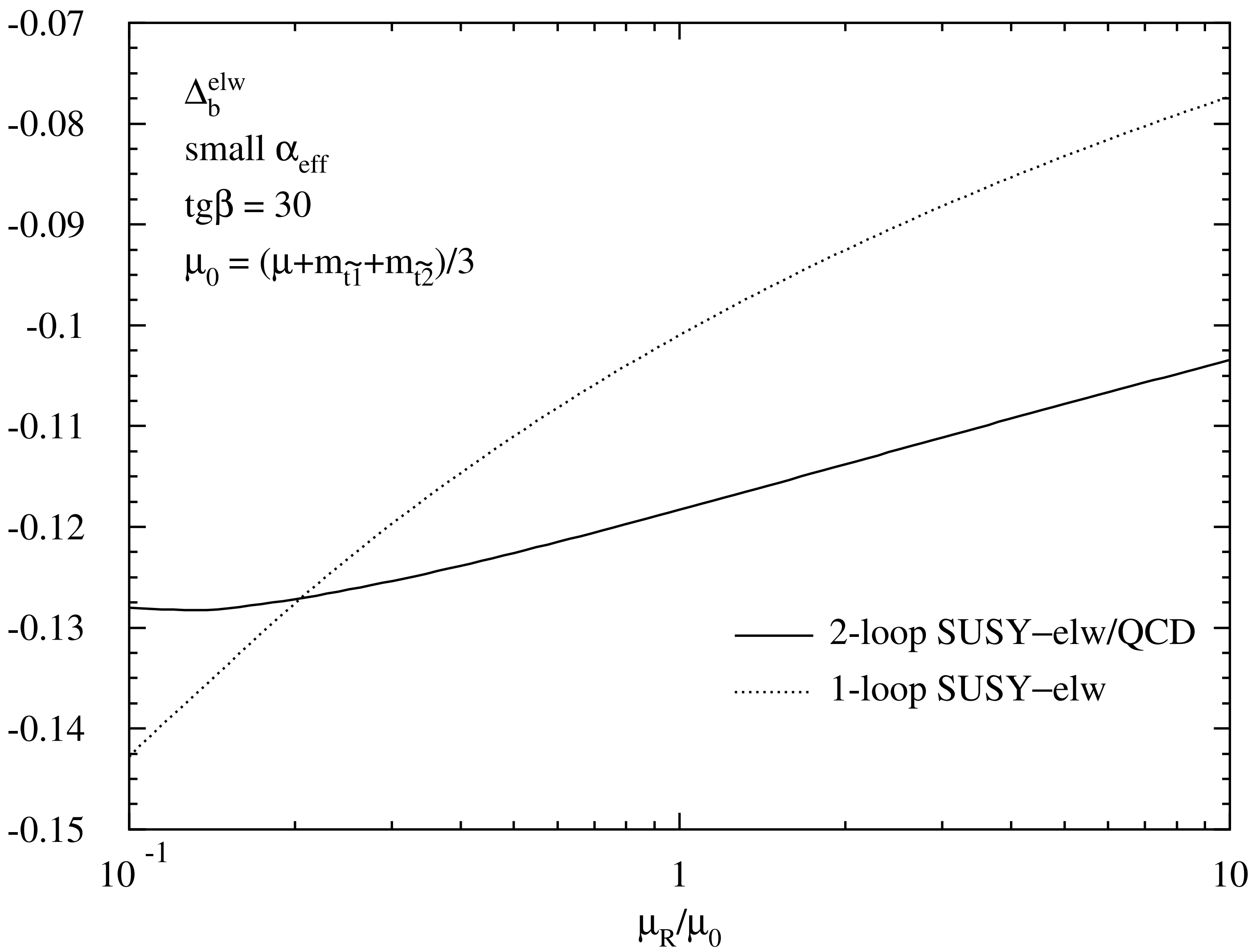
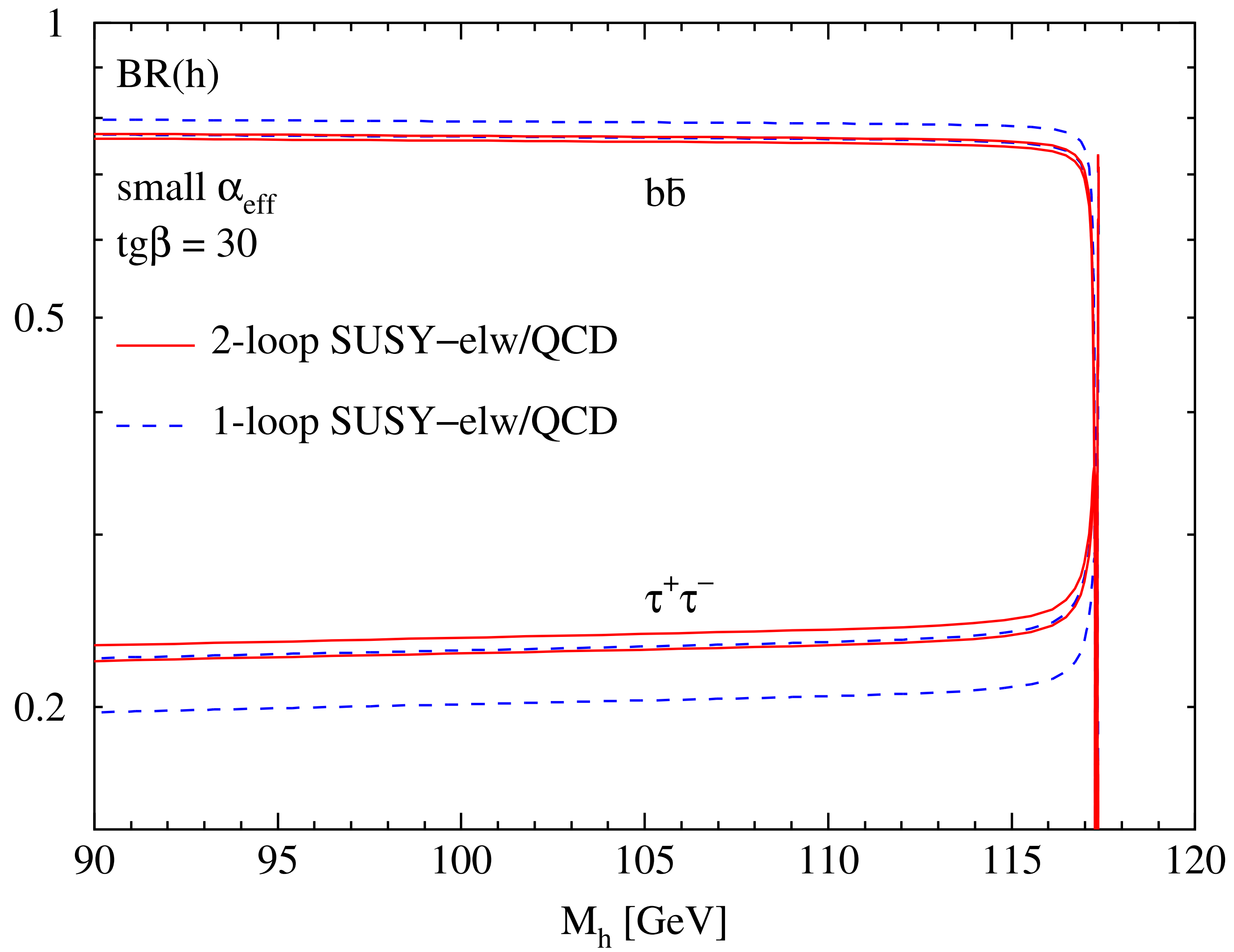
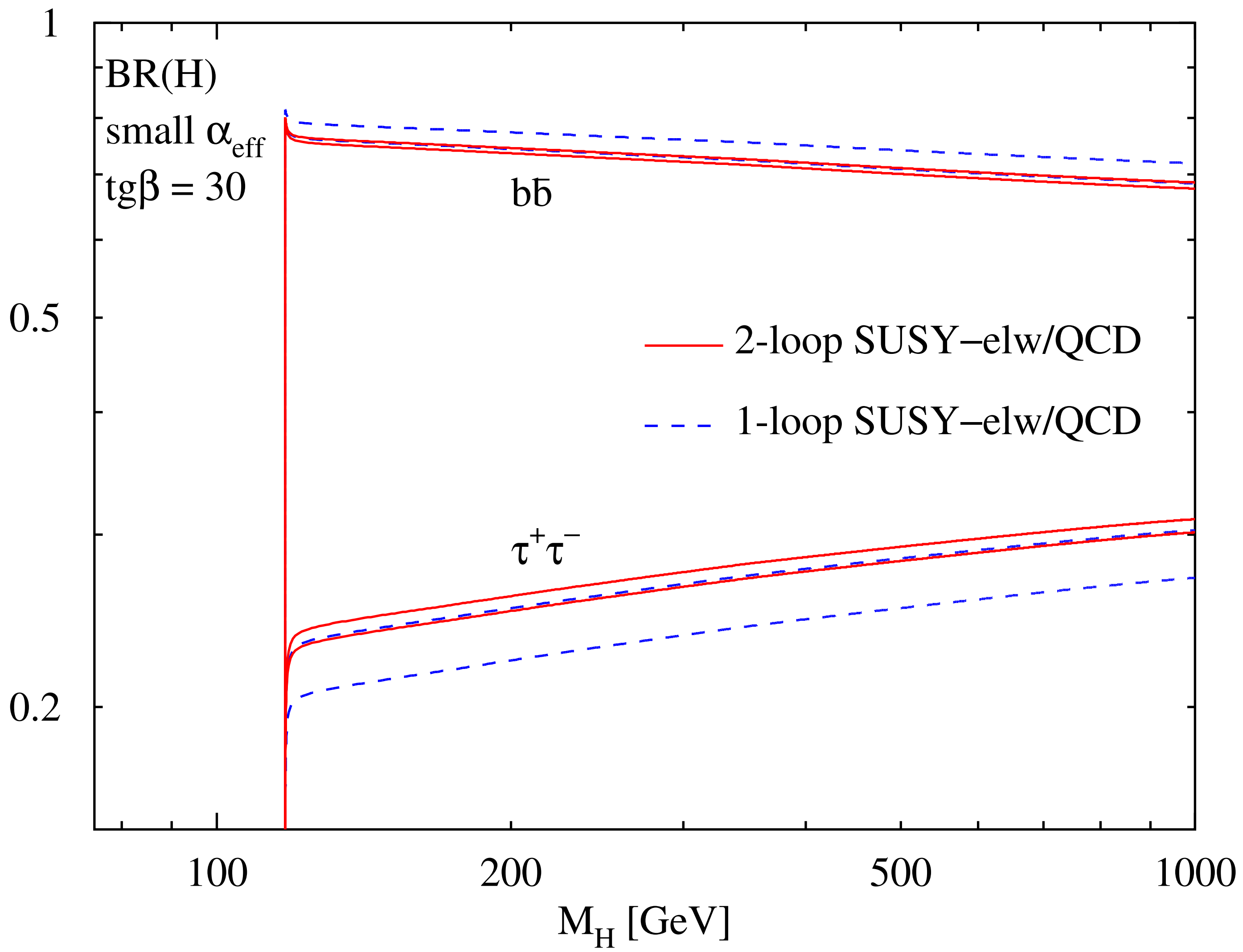


Noth, S.



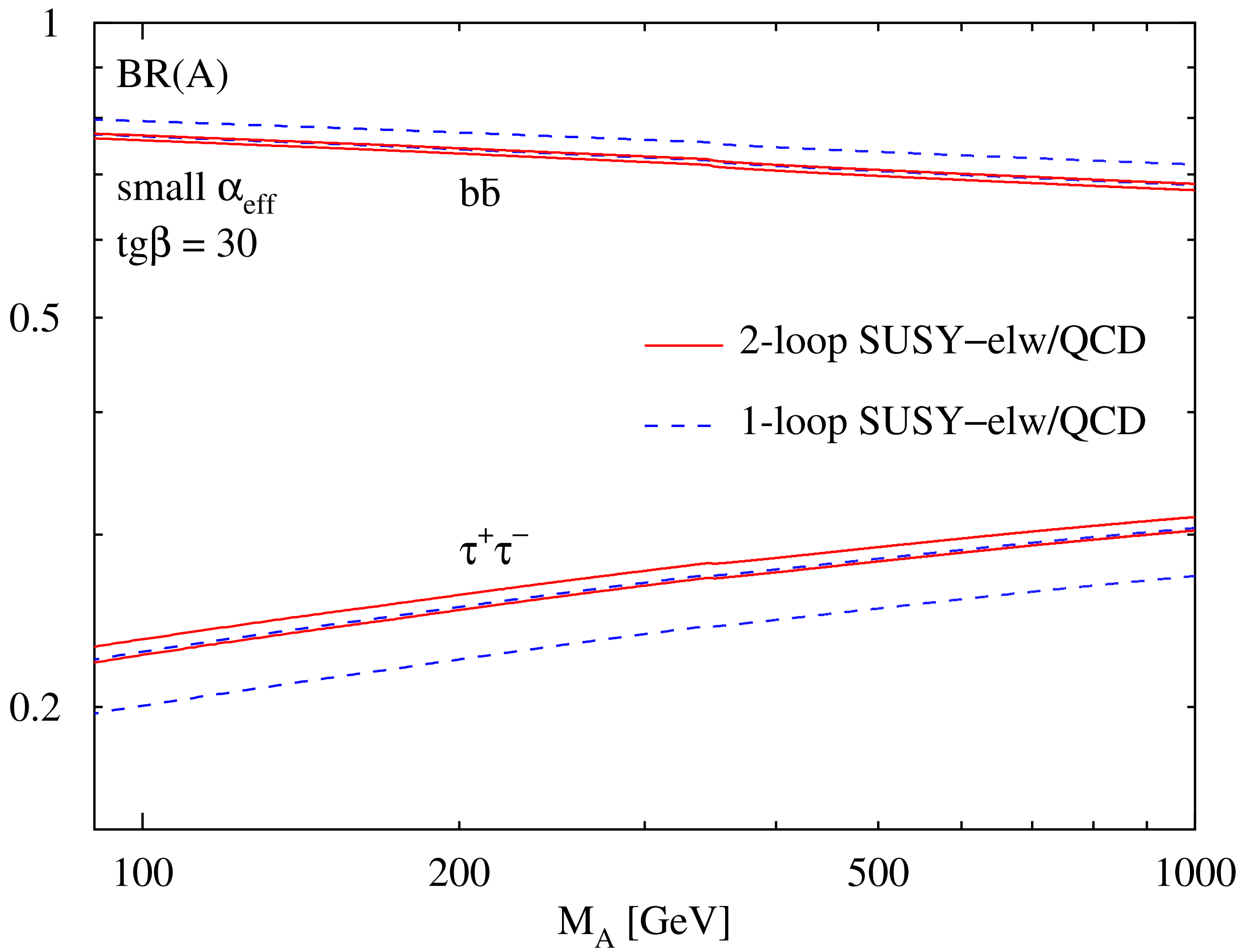
1
0.5
0.2
BR(h)
small α_{eff}
$tg\beta = 30$
$b\bar{b}$
2-loop SUSY−elw/QCD
1-loop SUSY−elw/QCD
$\tau^+\tau^-$
90
95
100
105
110
115
120
M_h [GeV]

Noth, S.



1
0.5
0.2
BR(H)
small α_{eff}
tgβ = 30
$b\bar{b}$
2-loop SUSY–elw/QCD
1-loop SUSY–elw/QCD
$\tau^+\tau^-$
100
200
500
1000
M_H [GeV]

Noth, S.


1
BR(A)
small α_{eff}
$tg\beta = 30$
$b\bar{b}$
0.5
2-loop SUSY−elw/QCD
1-loop SUSY−elw/QCD
$\tau^+\tau^-$
0.2
100
200
500
1000
M_A [GeV]

Noth, S.

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V *SUMMARY*

- Higgs boson searches @ Tevatron, LHC, ILC major endeavours

- MSSM: bottom Yukawa couplings dominate Higgs boson production & decay processes for large tgβ

- large NLO SUSY corrections to bottom Yukawa couplings [$\leftarrow \Delta_b$]

- NNLO corrections to Δ_b: $\mathcal{O}(10\%)$, $\Delta_{scale} \sim \mathcal{O}(10\%) \to \mathcal{O}(1\%)$
  [mutual agreement with Mihaila, Reisser]

  $\to$ HDECAY

Djouadi, Kalinowski, Mühlleitner, S.

- applicable for $e^+e^- \to b\bar{b}\phi^0, t\bar{b}H^-$ and $pp \to b\bar{b}\phi^0, t\bar{b}H^-$

BACKUP SLIDES

Comparison with A. Bauer *et al.*, JHEP **0902** (2009) 037

- MSSM decoupling relations: $\overline{m}_b^{(5)}(\mu_R) = \zeta_{m_b} m_b^{(SQCD)}(\mu_R)$ (bottom mass)

(i) Equal masses: $m_t^2 \ll m_{\tilde{g}}^2 = m_{\tilde{b}_i}^2 = \mu^2 = m_{\tilde{t}_i}^2 \equiv M^2$

- decoupling heavy particles from α_s and A_b: ($L_i = \log \frac{\mu_R^2}{m_i^2}$)

$$\begin{aligned}
\alpha_s^{SUSY}(\mu_R) &= \alpha_s^{\overline{MS}}(\mu_R)\left\{1 + \frac{\alpha_s}{\pi}\left[C_A\frac{1+2L_M}{12} + \frac{L_t}{6} + \frac{N_F+1}{12}L_M\right]\right\} \\
A_b^{SUSY}(\mu_R) &= A_b^{\overline{MS}}(\mu_R)\left\{1 - \frac{3}{4}C_F\frac{\alpha_s}{\pi}\,\frac{A_b - \mu\mathrm{tg}\beta}{A_b}L_M\right\}
\end{aligned}$$

$$\begin{aligned}
\bar{\zeta}_{m_b}^{(2)} &= C_F\left(\frac{\alpha_s}{\pi}\right)^2\frac{\mu\mathrm{tg}\beta}{M}\left\{C_A\frac{1+3L_M}{16} + C_F\frac{4-3L_M}{16} + \frac{N_F+1}{12}\,\frac{3-3L_M}{4}\right\} + \Delta_{\alpha_s} + \Delta_{A_b} \\
&= \Delta_{QCD}^{(1)}\frac{\alpha_s}{\pi}\left\{C_A\frac{1+3L_M}{4} + C_F\frac{4-3L_M}{4} + \frac{N_F+1}{12}(3-3L_M)\right\} + \Delta_{\alpha_s} + \Delta_{A_b} \\
\Delta_{\alpha_s} &= \Delta_{QCD}^{(1)}\frac{\alpha_s}{\pi}\left\{C_A\frac{1+2L_M}{12} + \frac{L_t}{6} + \frac{N_F+1}{12}L_M\right\} \\
\Delta_{A_b} &= \Delta_{QCD}^{(1)}\frac{\alpha_s}{\pi}\frac{3}{4}C_F\frac{\alpha_s}{\pi}L_M
\end{aligned}$$

$$\beta_0^L = \frac{11C_A - 2N_F}{12}$$

$$\boxed{\bar{\zeta}_{m_b}^{(2)} = \Delta_{QCD}^{(1)}\frac{\alpha_s}{\pi}\left\{\frac{C_A}{3} + C_F + \frac{N_F+1}{4} + \frac{1}{6}\log\frac{M^2}{m_t^2} + \beta_0^L\log\frac{\mu_R^2}{M^2}\right\}}$$

(ii) Large gluino mass: $m_t^2, m_{\tilde{b}_i}^2, \mu^2, m_{\tilde{t}_i}^2 \ll m_{\tilde{g}}^2$ $\qquad [m_{\tilde{b}}^2 = m_{\tilde{b}_1}^2 = m_{\tilde{b}_2}^2]$

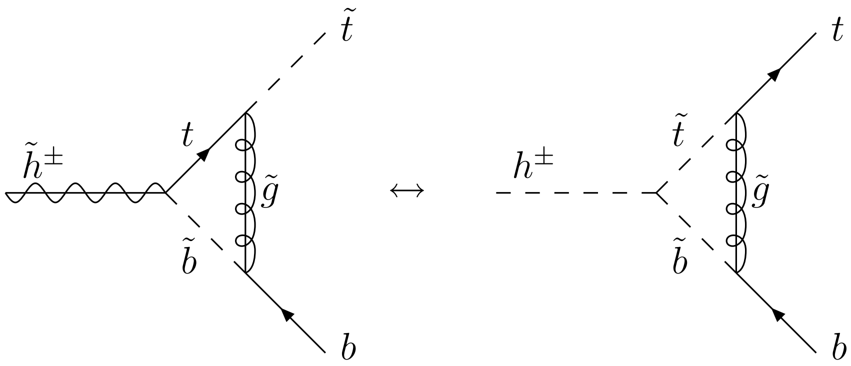
- decoupling heavy particles from α_s and A_b: $(L_i = \log \frac{\mu_R^2}{m_i^2})$

$$\begin{aligned}
\alpha_s^{SUSY}(\mu_R) &= \alpha_s^{\overline{MS}}(\mu_R)\left\{1 + \frac{\alpha_s}{\pi}\left[C_A\frac{1+2L_{\tilde{g}}}{12} + \frac{L_t}{6} + \frac{1}{24}\sum_{\tilde{q}} L_{\tilde{q}}\right]\right\} \\
A_b^{SUSY}(\mu_R) &= A_b^{\overline{MS}}(\mu_R)\left\{1 - C_F\frac{\alpha_s}{\pi}\;\frac{A_b - \mu \mathrm{tg}\beta}{A_b}\left[\log\frac{m_{\tilde{g}}^2}{m_{\tilde{b}}^2} + \frac{9}{8} + \frac{3}{4}L_{\tilde{g}}\right]\right\}
\end{aligned}$$

$$\begin{aligned}
\bar{\zeta}_{m_b}^{(2)} &= \Delta_{QCD}^{(1)}\frac{\alpha_s}{\pi}\left\{C_A\left[\frac{5}{4} + \frac{3}{4}L_{\tilde{g}}\right] + C_F\left[\frac{3}{8} - \frac{3}{4}L_{\tilde{g}}\right] - \frac{N_F+1}{4}(2 + L_{\tilde{g}})\right\} + \Delta_{\alpha_s} + \Delta_{A_b} \\
\Delta_{\alpha_s} &= \Delta_{QCD}^{(1)}\frac{\alpha_s}{\pi}\left\{C_A\frac{1+2L_{\tilde{g}}}{12} + \frac{L_t}{6} + \frac{1}{24}\sum_{\tilde{q}} L_{\tilde{q}}\right\} \\
\Delta_{A_b} &= \Delta_{QCD}^{(1)}C_F\frac{\alpha_s}{\pi}\left\{\log\frac{m_{\tilde{g}}^2}{m_{\tilde{b}}^2} + \frac{9}{8} + \frac{3}{4}L_{\tilde{g}}\right\} \qquad \beta_0^L = \frac{11C_A - 2N_F}{12}
\end{aligned}$$

$$\boxed{\bar{\zeta}_{m_b}^{(2)} = \Delta_{QCD}^{(1)}\frac{\alpha_s}{\pi}\left\{\frac{4}{3}C_A + C_F\left[\log\frac{m_{\tilde{g}}^2}{m_{\tilde{b}}^2} + \frac{3}{2}\right] - \frac{N_F+1}{2} + \frac{1}{6}\log\frac{m_{\tilde{g}}^2}{m_t^2} + \frac{1}{24}\sum_{\tilde{q}}\log\frac{m_{\tilde{g}}^2}{m_{\tilde{q}}^2} + \beta_0^L\log\frac{\mu_R^2}{m_{\tilde{g}}^2}\right\}}$$

Decoupling of heavy particles



(i) Equal masses: $m_t^2 \ll m_{\tilde{g}}^2 = m_{\tilde{b}_i}^2 = \mu^2 = m_{\tilde{t}_i}^2 \equiv M^2$

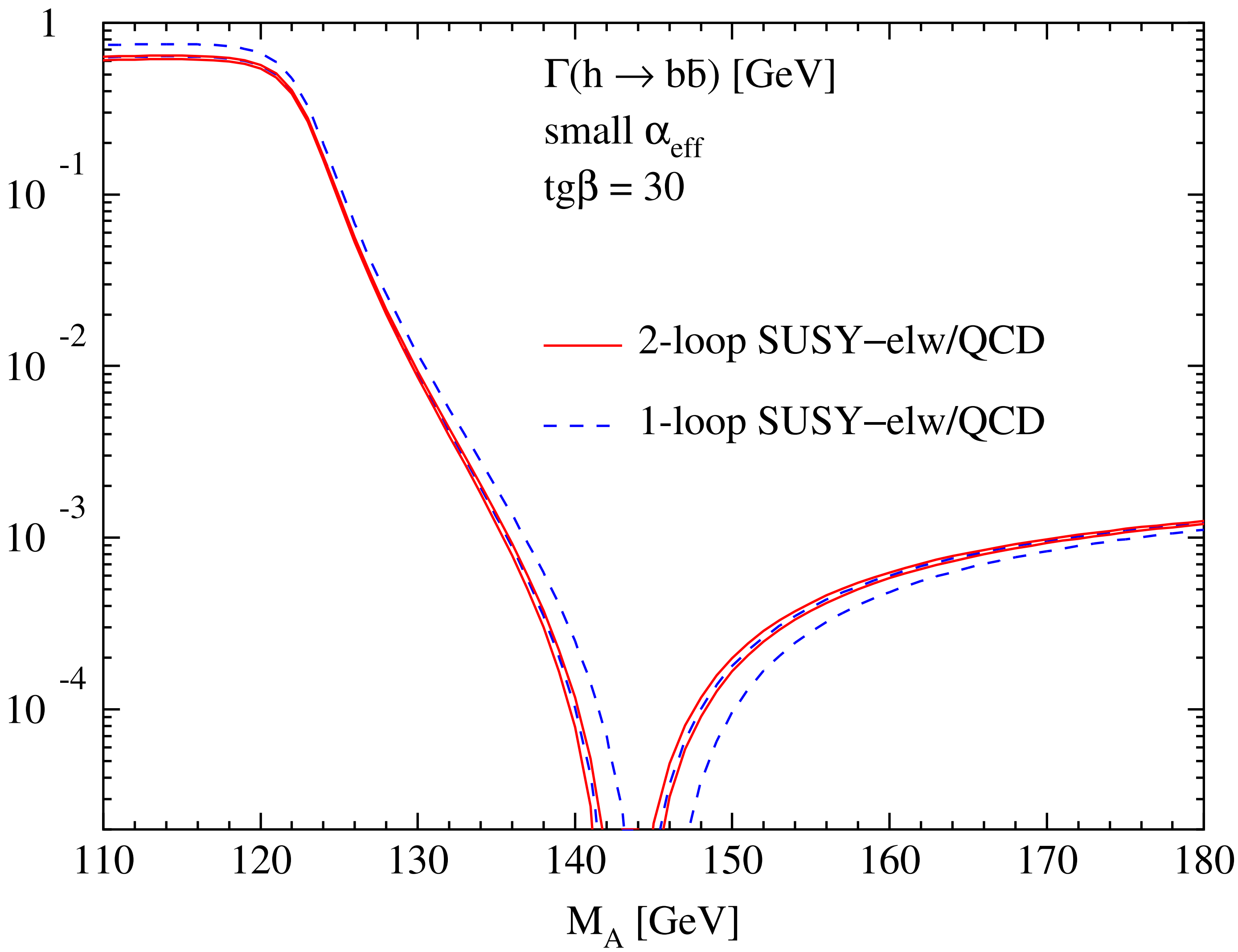
$$\lambda_{t,MO}(\mu_R) = \lambda_{t,MO}^{\tilde{h}}(\mu_R)\left\{1 - C_F\frac{\alpha_s}{\pi}\left[\frac{3}{8}\log\frac{\mu_R^2}{M^2} - \frac{1}{8}\right]\right\}$$

(ii) Large gluino mass: $m_t^2, m_{\tilde{b}_i}^2, \mu^2, m_{\tilde{t}_i}^2 \ll m_{\tilde{g}}^2$

$$\lambda_{t,MO}(\mu_R) = \lambda_{t,MO}^{\tilde{h}}(\mu_R)\left\{1 - C_F\frac{\alpha_s}{\pi}\left[\frac{3}{8}\log\frac{\mu_R^2}{m_{\tilde{g}}^2} + \frac{9}{16}\right]\right\}$$

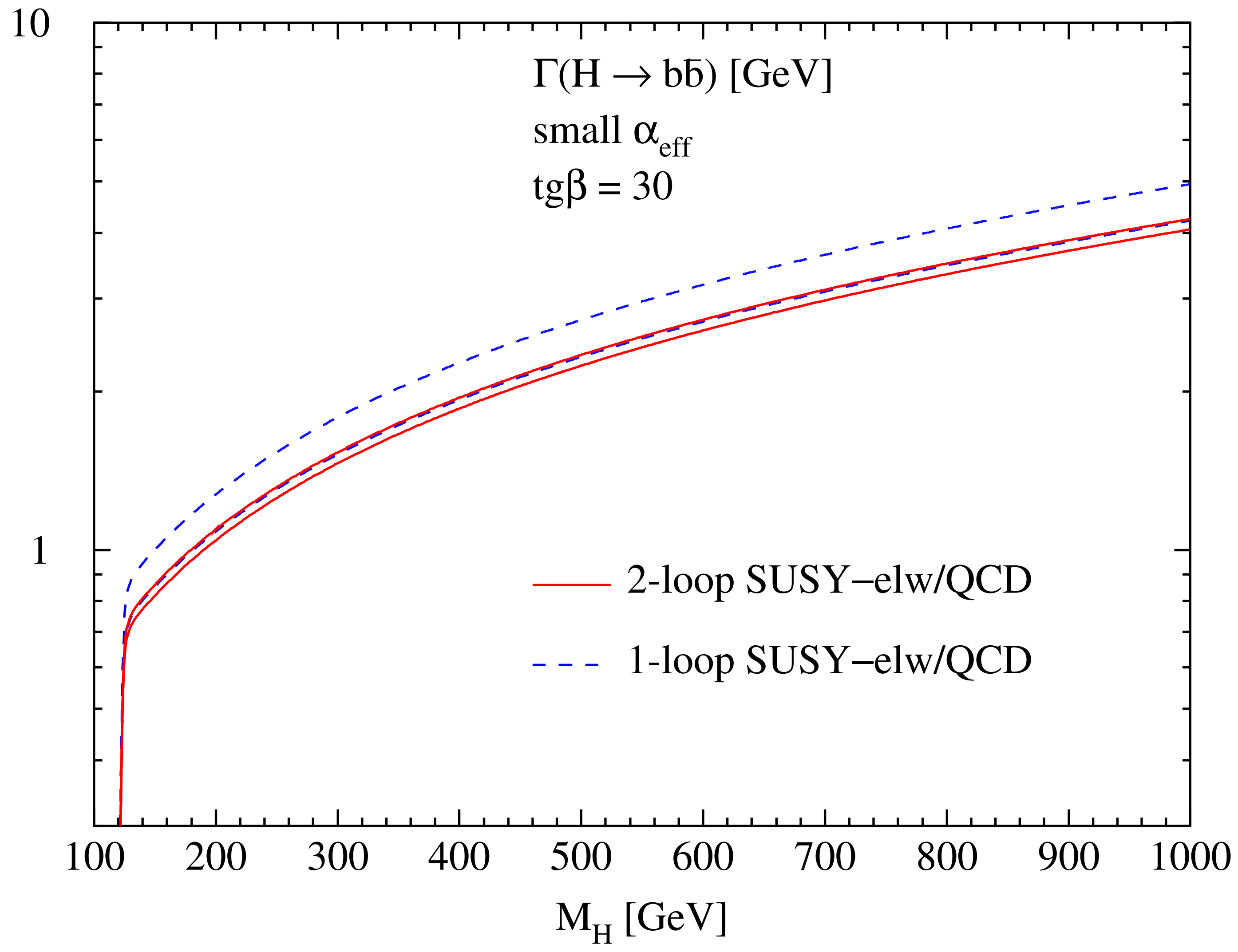
$$
\begin{aligned}
m^{0\,2}_{\tilde{q}_i} &= m^2_{\tilde{q}_i} + \delta m^2_{\tilde{q}_i} & m^0_{\tilde{g}} &= m_{\tilde{g}} + \delta m_{\tilde{g}} & \beta_0 &= \frac{3C_A - N_F - 1}{4} \\
\lambda^0_t &= \lambda_t(\mu_R) + \delta\lambda_t & \alpha^0_s &= \alpha_s(\mu_R) + \delta\alpha_s & A^0_t &= A_t + \delta A_t
\end{aligned}
$$

$$
\begin{aligned}
\delta m^2_{\tilde{t}_i} &= -iC_F g_s^2 \left\{2A_0(m_{\tilde{t}_i}) - 2A_0(m_{\tilde{g}}) - 2A_0(m_t) - 4m^2_{\tilde{t}_i} B_0(m^2_{\tilde{t}_i}; 0, m_{\tilde{t}_i}) \right. \\
&\qquad \left. +2(m^2_{\tilde{t}_i} - m^2_{\tilde{g}} - m^2_t) B_0(m^2_{\tilde{t}_i}; m_{\tilde{g}}, m_t)\right\} \\
\delta m^2_{\tilde{b}_i} &= -iC_F g_s^2 \left\{2A_0(m_{\tilde{b}_i}) - 2A_0(m_{\tilde{g}}) - 4m^2_{\tilde{b}_i} B_0(m^2_{\tilde{b}_i}; 0, m_{\tilde{b}_i}) + 2(m^2_{\tilde{b}_i} - m^2_{\tilde{g}}) B_0(m^2_{\tilde{b}_i}; m_{\tilde{g}}, 0)\right\} \\
\frac{\delta m_{\tilde{g}}}{m_{\tilde{g}}} &= -ig_s^2 \left\{ C_A \left[2B_0(m^2_{\tilde{g}}; 0, m_{\tilde{g}}) - 2B_1(m^2_{\tilde{g}}; 0, m_{\tilde{g}}) - \frac{i}{(4\pi)^2}\right] \right. \\
&\qquad \left. - \sum_q \left[B_0(m^2_{\tilde{g}}; m_{\tilde{q}_1}, m_q) - B_0(m^2_{\tilde{g}}; m_{\tilde{q}_2}, m_q) - B_1(m^2_{\tilde{g}}; m_{\tilde{q}_1}, m_q) - B_1(m^2_{\tilde{g}}; m_{\tilde{q}_2}, m_q)\right] \right\} \\
\frac{\delta\lambda_t}{\lambda_t} &= C_F \frac{\alpha_s}{\pi} \Gamma(1+\epsilon)(4\pi)^\epsilon \frac{3}{4} \left\{-\frac{1}{\epsilon} + \log\frac{\mu_R^2}{\bar{\mu}^2}\right\} + iC_F g_s^2 \left\{B_1(m_t^2; m_{\tilde{g}}, m_{\tilde{t}_1}) + B_1(m_t^2; m_{\tilde{g}}, m_{\tilde{t}_2})\right\} \\
\frac{\delta\alpha_s}{\alpha_s} &= \frac{\alpha_s}{\pi} \Gamma(1+\epsilon)(4\pi)^\epsilon \left\{ \left(-\frac{1}{\epsilon} + \log\frac{\mu_R^2}{\bar{\mu}^2}\right)\beta_0 + \frac{C_A}{6}\log\frac{\mu_R^2}{m^2_{\tilde{g}}} + \frac{1}{6}\log\frac{\mu_R^2}{m_t^2} + \sum_{\tilde{q}_i} \frac{1}{24}\log\frac{\mu_R^2}{m^2_{\tilde{q}_i}} \right\} \\
\frac{\delta A_t}{A_t} &= -iC_F g_s^2 \left\{ \frac{A_0(m_t)}{m_t^2} + 2B_0(m_t^2; 0, m_t) + B_1(m_t^2; m_{\tilde{g}}, m_{\tilde{t}_1}) + B_1(m_t^2; m_{\tilde{g}}, m_{\tilde{t}_2}) \right. \\
&\qquad -4\frac{m^2_{\tilde{t}_1} B_0(m^2_{\tilde{t}_1}; 0, m_{\tilde{t}_1}) - m^2_{\tilde{t}_2} B_0(m^2_{\tilde{t}_2}; 0, m_{\tilde{t}_2})}{m^2_{\tilde{t}_1} - m^2_{\tilde{t}_2}} \\
&\qquad \left. +2\frac{(m^2_{\tilde{t}_1} - m^2_{\tilde{g}} - m^2_t) B_0(m^2_{\tilde{t}_1}; m_{\tilde{g}}, m_t) - (m^2_{\tilde{t}_2} - m^2_{\tilde{g}} - m^2_t) B_0(m^2_{\tilde{t}_2}; m_{\tilde{g}}, m_t)}{m^2_{\tilde{t}_1} - m^2_{\tilde{t}_2}} \right\}
\end{aligned}
$$



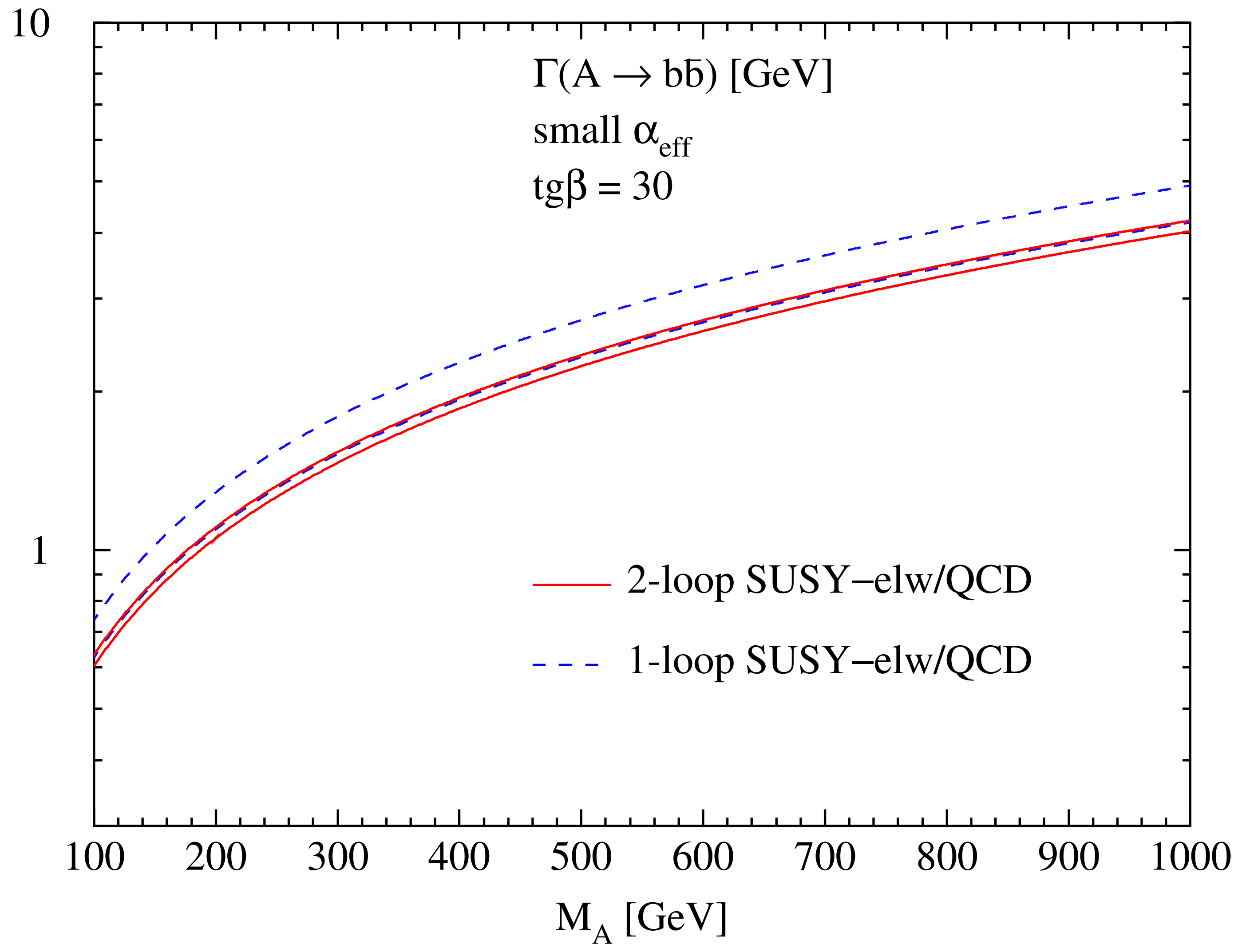
$\Gamma(h \to b\bar{b})$ [GeV]
small α_{eff}
tgβ = 30
2-loop SUSY–elw/QCD
1-loop SUSY–elw/QCD
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
110
120
130
140
150
160
170
180
M_A [GeV]

Noth, S.



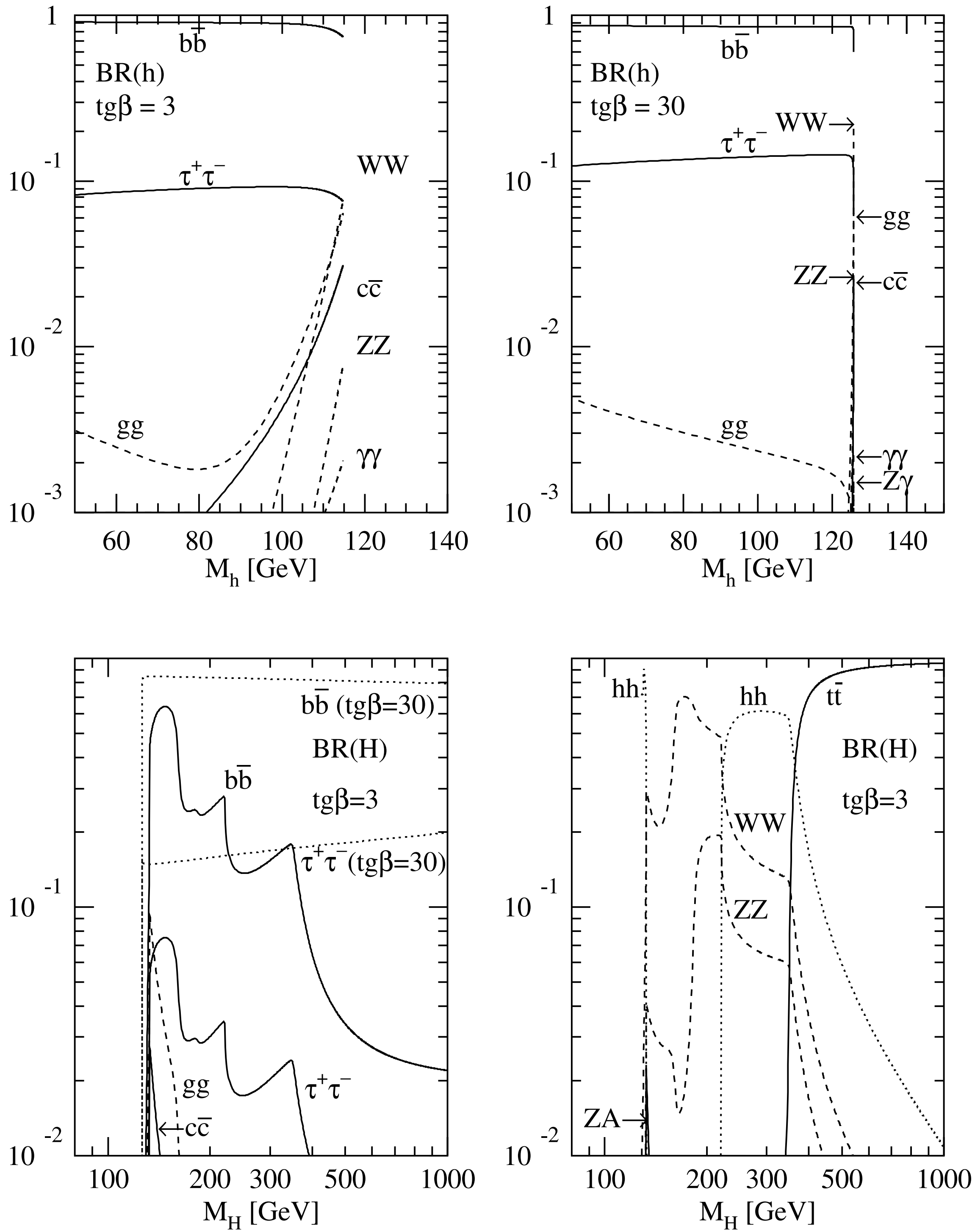
10
1
Γ(H → bb̄) [GeV]
small α_eff
tgβ = 30
2-loop SUSY−elw/QCD
1-loop SUSY−elw/QCD
100
200
300
400
500
600
700
800
900
1000
M_H [GeV]

Noth, S.



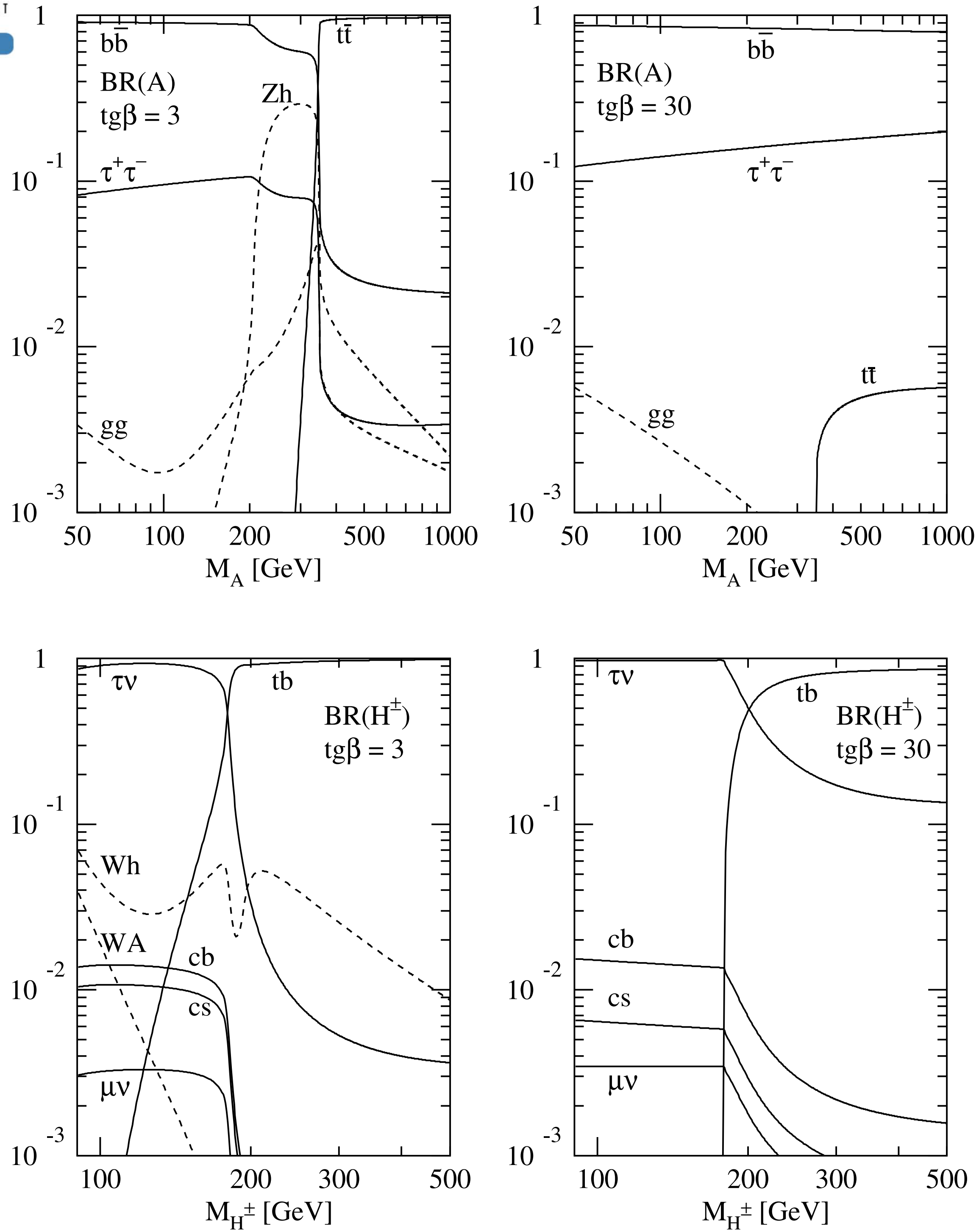
10
1
$\Gamma(A \rightarrow b\bar{b})$ [GeV]
small α_{eff}
$tg\beta = 30$
2-loop SUSY−elw/QCD
1-loop SUSY−elw/QCD
100
200
300
400
500
600
700
800
900
1000
M_A [GeV]

Noth, S.



BR(h)
tgβ = 3
$b\bar{b}$
$\tau^+\tau^-$
WW
$c\bar{c}$
ZZ
gg
γγ
M_h [GeV]
BR(h)
tgβ = 30
$b\bar{b}$
$\tau^+\tau^-$
WW→
←gg
ZZ→
←$c\bar{c}$
gg
←γγ
←Zγ
M_h [GeV]
$b\bar{b}$ (tgβ=30)
BR(H)
tgβ=3
$b\bar{b}$
$\tau^+\tau^-$(tgβ=30)
gg
←$c\bar{c}$
$\tau^+\tau^-$
M_H [GeV]
hh
hh
$t\bar{t}$
BR(H)
tgβ=3
WW
ZZ
ZA→
M_H [GeV]

HDECAY


BR(A)
tgβ = 3
bb̄
tt̄
Zh
τ+τ−
gg
BR(A)
tgβ = 30
M_A [GeV]
BR(H±)
tgβ = 3
τν
tb
Wh
WA
cb
cs
μν
BR(H±)
tgβ = 30
M_H± [GeV]

HDECAY