$\mathrm{O}(\alpha_s)$ RADIATIVE CORRECTIONS TO POLARIZED TOP QUARK DECAY INTO A CHARGED HIGGS

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Outline

Introduction

Charged Higgs occur

- in the 2-Higgs doublet SM,
- in the MSSM (naturally).

- Mass of the charged Higgs is not known.
  Particle Data Group: $m_{H\pm} > 79.3$ GeV. (CL 95%)

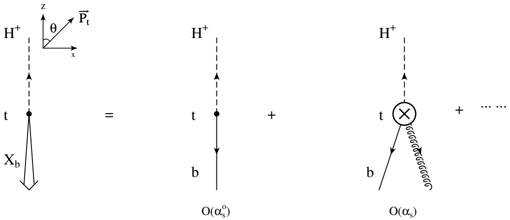
- Possible decay processes:

$$t \longrightarrow H^+ + b \quad \text{if} \quad m_H < m_t - m_b$$

$$H^- \rightarrow \bar{t} + b \ \text{ or } \ H^+ \rightarrow t + \bar{b} \quad \text{if} \quad m_H > m_t + m_b$$

THE GENERAL ANGULAR DECAY DISTRIBUTION

The decay $t(\uparrow) \to b + H^+$:



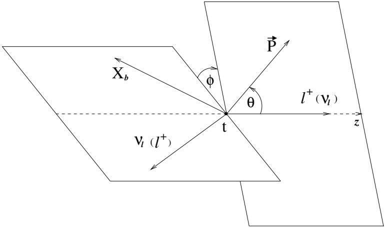
$$\frac{d\Gamma}{d\cos\theta} = \frac{1}{2}(\Gamma + P_t\,\Gamma^P \cos\theta)$$

$$\text{asymmetry parameter } \alpha_H := \frac{\Gamma^P}{\Gamma}$$

Another example of angular decay distributions

The angular decay distribution in the decay $t(\uparrow) \to b + W^+(\ell^+\nu)$:

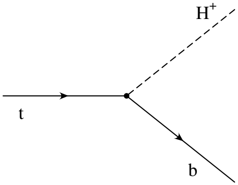
$$\frac{d\Gamma}{dx_{\ell,\nu}\, d\cos\theta\, d\phi} = \frac{1}{4\pi}\Big[\frac{d\Gamma_A}{dx_{\ell,\nu}} + P\big(\frac{d\Gamma_B}{dx_{\ell,\nu}}\cos\theta + \frac{d\Gamma_C}{dx_{\ell,\nu}}\sin\theta\cos\phi\big)\Big]$$



$$\vec{P} = (\sin\theta\cos\phi,\ \sin\theta\sin\phi,\ \cos\theta)$$

$$x_{\ell,\nu} = \frac{2E_{\ell,\nu}}{m_t}$$

Born term results



Structure of tbH-vertex: $(a + b\gamma_5)$: $(\tan\beta = \frac{v_1}{v_2})$

model 1:

$$a = \frac{g_w}{2\sqrt{2}m_W} V_{tb}(m_t - m_b)\cot\beta,$$

$$b = \frac{g_w}{2\sqrt{2}m_W} V_{tb}(m_t + m_b)\cot\beta,$$

model 2:

$$a = \frac{g_w}{2\sqrt{2}m_W} V_{tb}(m_t\cot\beta + m_b\tan\beta),$$

$$b = \frac{g_w}{2\sqrt{2}m_W} V_{tb}(m_t\cot\beta - m_b\tan\beta).$$

In the leading-order calculation we define following scaled masses

$$y := \frac{m_{H^+}}{m_t}, \qquad \epsilon := \frac{m_b}{m_t}$$

and scaled kinetic variables

$$p_0 := \frac{1}{2}(1 + \epsilon^2 - y^2)$$
$$p_3 := \frac{1}{2}\sqrt{\lambda(1, \epsilon^2, y^2)}$$

where $\lambda(a, b, c) := a^2 + b^2 + c^2 - 2(a\,b + b\,c + c\,a)$ (Källén function).

The Born amplitude is: $\mathcal{M}_0 = \bar{u}_b(a\mathbb{1} + b\gamma_5)u_t$

Total rates

$$\Gamma_{Born} = \frac{p_3}{16\pi m_t^3}\left\{2p_0(a^2 + b^2) + 2\,\epsilon\,(a^2 - b^2)\right\}$$

$$\Gamma^P_{Born} = \frac{p_3}{16\pi m_t^3}\left\{4ab\,p_3\right\}.$$

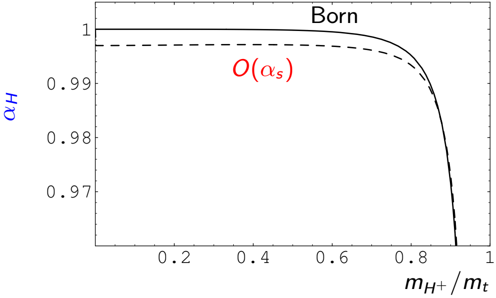


Figure 1

Asymmetry parameter α_H for model 1:
$m_b = 4.8$ GeV, $m_t = 175$ GeV,
Born term: full line,
$O(\alpha_s)$: dashed line.
($\tan\beta = 10$)

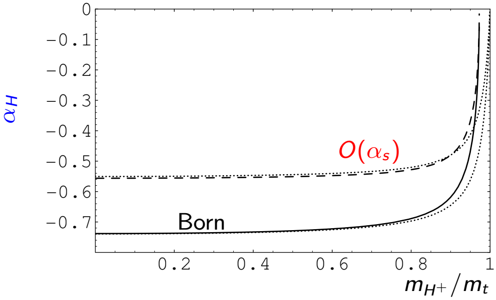


Figure 2

Asymmetry parameter α_H for model 2:
$m_b = 4.8$ GeV, $m_t = 175$ GeV,
Born term: full line,
$O(\alpha_s)$: dashed line.
($\tan\beta = 10$)

Next–to–leading order corrections

- The virtual corrections
- The real corrections

Variables in the NLO calculations

Scaled masses:

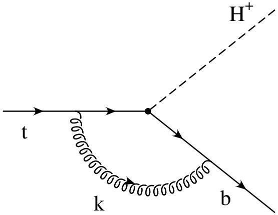
$$y := \frac{m_{H^+}}{m_t}, \qquad \epsilon := \frac{m_b}{m_t} \qquad \Lambda := \frac{m_g}{m_t}$$

Scaled kinetic variables

$$\begin{array}{ll|l} p_0 := \frac{1}{2}(1+\epsilon^2-y^2), & & w_0 := \frac{1}{2}(1-\epsilon^2+y^2), \\ p_3 := \frac{1}{2}\sqrt{\lambda(1,\epsilon^2,y^2)}, & & w_3 := p_3, \\ p_\pm := p_0 \pm p_3, & & w_\pm := w_0 \pm w_3, \\ Y_p := \frac{1}{2}\ln\frac{p_+}{p_-}\ . & & Y_w := \frac{1}{2}\ln\frac{w_+}{w_-}. \end{array}$$

where $\lambda(a,b,c) := a^2+b^2+c^2-2(a\,b+b\,c+c\,a)$ (Källén function)

Virtual corrections



$$\bar{u}_b \int \frac{d^D k}{(2\pi)^4} \Big(\frac{-ig_s\lambda^a}{2}\gamma_\mu\Big) \frac{i}{(\not{p}_b - \not{k}) - m_b}(a + b\gamma_5)\frac{i}{(\not{p}_t - \not{k}) - m_t}\Big(\gamma_\nu \frac{-ig_s\lambda^b}{2}\Big) u_t \Big(-i\delta_{ab}\frac{g^{\mu\nu}}{k^2 - m_g^2}\Big)$$

$$= -ig_s^2 C_F \bar{u}_b \int \frac{d^D k}{(2\pi)^4} \frac{\gamma_\mu(\not{p}_b - \not{k} + m_b)(a + b\gamma_5)(\not{p}_b - \not{k} + m_t)\gamma^\mu}{[(p_b - k)^2 - m_b^2][(p_t - k)^2 - m_t^2][k^2 - m_g^2]} u_t$$

numerator : $4(p_t \cdot p_b) - 2\not{p}_t\not{k} + 2\not{p}_b\not{k} - Dk^2$ *with* $D = 4 - 2\omega$

denominator : $[(p_b - k)^2 - m_b^2][(p_t - k)^2 - m_t^2][k^2 - m_g^2] := D_b \cdot D_t \cdot D_g$

Types of integrals in the loop

$$\int \frac{d^D k}{(2\pi)^4} \frac{1}{D_b \cdot D_t \cdot D_g} := \underbrace{C_0}_{IR-div.}$$

$$\int \frac{d^D k}{(2\pi)^4} \frac{k^\mu}{D_b \cdot D_t \cdot D_g} := I_3^\mu = C_1 p_t^\mu + C_2 p_b^\mu$$

$$\int \frac{d^D k}{(2\pi)^4} \frac{k^2}{D_b \cdot D_t \cdot D_g} = \int \frac{d^D k}{(2\pi)^4} \frac{k^2 - m_g^2 + m_g^2}{D_b \cdot D_t \cdot D_g}$$

$$= \int \frac{d^D k}{(2\pi)^4} \frac{1}{D_b \cdot D_t} + m_g^2 \int \frac{d^D k}{(2\pi)^4} \frac{1}{D_b \cdot D_t \cdot D_g}$$

$$:= \underbrace{B_0}_{UV-div.} + m_g^2 C_0$$

$$C_0 \rightarrow \text{scalar three-point one-loop integral}$$

$$B_0 \rightarrow \text{scalar two-point one-loop integral}$$

$$I_3^\mu = C_1 p_t^\mu + C_2 p_b^\mu \rightarrow \text{tensor three-point one-loop integral,}$$

$$\text{calculated using Passarino-Veltman method}$$

$$
\begin{aligned}
& I_3(m_H^2, m_t^2, m_b^2, m_g^2) \\
= \quad & -\frac{i}{16\pi^2}\,\frac{1}{2\sqrt{\lambda(m_H^2, m_t^2, m_b^2)}}\Bigg[\ln\left(\frac{m_t^2+m_b^2-m_H^2+\sqrt{\lambda(m_H^2, m_t^2, m_b^2)}}{m_t^2+m_b^2-m_H^2-\sqrt{\lambda(m_H^2, m_t^2, m_b^2)}}\right)\ln\left(\frac{m_t m_b}{m_g^2}\right) \\
& \quad + \ln\left(\frac{m_t^2+m_b^2-m_H^2+\sqrt{\lambda(m_H^2, m_t^2, m_b^2)}}{2m_t^2}\right)\ln\left(\frac{\left(m_t^2-m_b^2+\sqrt{\lambda(m_H^2, m_t^2, m_b^2)}\right)^2-\left(m_H^2\right)^2}{\left(m_t^2-m_b^2-\sqrt{\lambda(m_H^2, m_t^2, m_b^2)}\right)^2-\left(m_H^2\right)^2}\right) \\
& \left(\quad -2\mathrm{Li}_2\left(\frac{2\sqrt{\lambda(m_H^2, m_t^2, m_b^2)}}{m_t^2-m_b^2+m_H^2+\sqrt{\lambda(m_H^2, m_t^2, m_b^2)}}\right)+2\mathrm{Li}_2\left(\frac{2\sqrt{\lambda(m_H^2, m_t^2, m_b^2)}}{m_t^2-m_b^2-m_H^2+\sqrt{\lambda(m_H^2, m_t^2, m_b^2)}}\right)\right.\Bigg]
\end{aligned}
$$

Loop integrals

$$
\begin{aligned}
C_1 &= -\frac{1}{m_t^2 y^2}\left\{\ln\epsilon + \frac{1}{2p_3}(1-\epsilon^2-y^2)\right\},\\
C_2 &= \frac{1}{m_t^2 y^2}\left\{\ln\epsilon + \frac{1}{2p_3}(1-\epsilon^2+y^2)\right\},\\
B_0 &= \frac{1}{\omega} + \gamma_E + \ln(\frac{4\pi\mu^2}{m_t^2}) + 2 + \frac{2p_3}{y^2}Y_p + \frac{1-\epsilon^2+y^2}{y^2}\ln\epsilon,\\
C_0 &= -\frac{1}{4m_t^2 p_3}\Big\{(\ln\epsilon - 2\ln\Lambda)Y_p + 2(Y_p+\ln\epsilon)(Y_w+Y_p)\\
&\quad -2\mathrm{Li}_2(1-\frac{w_-}{w_+}) + 2\mathrm{Li}_2(1-\frac{w_-}{w_+}\frac{p_-}{p_+})\Big\}.
\end{aligned}
$$

Renormalized amplitude of the virtual corrections

$$\mathcal{M}_{loop} = \bar{u}_b \Big\{ \Big(a\mathbb{1} + b\gamma_5 \Big) \Lambda_1 + a\Lambda_2 + \delta\Lambda \Big\} u_t$$

$$\Lambda_1 = \frac{\alpha_s C_F m_t^2}{2\pi} \Big\{ 2p_0\, C_0 + (2p_0 + (1+\epsilon))\, C_1 + (2p_0 + (1+\epsilon))\, C_2 + 2B_0 - 1) \Big\},$$
$$\Lambda_2 = \frac{\alpha_s C_F}{\pi} \Big\{ -\epsilon(C_1 + C_2) \Big\},$$

Renormalization gives:

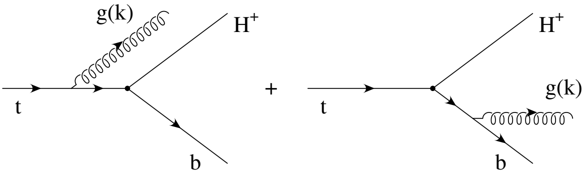
$$\delta\Lambda = (a+b)\frac{\mathbb{1}+\gamma_5}{2}\left(\frac{1}{2}(Z_2^t - 1) + \frac{1}{2}(Z_2^b - 1) - \frac{\delta m_t}{m_t}\right) +$$

$$+(a-b)\frac{\mathbb{1}-\gamma_5}{2}\left(\frac{1}{2}(Z_2^t - 1) + \frac{1}{2}(Z_2^b - 1) - \frac{\delta m_b}{m_b}\right).$$

THE VIRTUAL ONE-LOOP CORRECTIONS

$$\begin{aligned}
\Gamma_{loop} &= \Gamma_{Born}\left(Z_2^t - 1 + Z_2^b - 1 - \frac{\delta m_t}{m_t} - \frac{\delta m_b}{m_b} + 2\Lambda_1\right) + \\
&+ \frac{4 m_t p_3}{16\pi}\left(2\,a^2\,\Lambda_2(p_0+\epsilon) - 2ab\,p_0\left(\frac{\delta m_t}{m_t} - \frac{\delta m_b}{m_b}\right)\right), \\
\Gamma^P_{loop} &= \Gamma^P_{Born}\left(Z_2^t - 1 + Z_2^b - 1 - \frac{\delta m_t}{m_t} - \frac{\delta m_b}{m_b} + 2\Lambda_1\right) + \\
&+ \frac{4 m_t p_3^2}{16\pi}\left(2ab\,\Lambda_2 - (a^2+b^2)\left(\frac{\delta m_t}{m_t} - \frac{\delta m_b}{m_b}\right)\right).
\end{aligned}$$

Real emissions



$$\mathcal{M}_{tree} = g_s \frac{\lambda^a}{2} \bar{u}_b \left\{ \frac{2p_t^\sigma - \not{k}\gamma^\sigma}{2k\cdot p_t} - \frac{2p_b^\sigma + \gamma^\sigma \not{k}}{2k\cdot p_b} \right\} (a\mathbb{1} + b\gamma_5) u_t \varepsilon_\sigma^*(k)$$

$$= g_s \frac{\lambda^a}{2} \bar{u}_b \left\{ \left(\frac{2p_t^\sigma}{2k\cdot p_t} - \frac{2p_b^\sigma}{2k\cdot p_b} \right) + \left(\frac{-\not{k}\gamma^\sigma}{2k\cdot p_t} - \frac{\gamma^\sigma \not{k}}{2k\cdot p_b} \right) \right\} (a\mathbb{1} + b\gamma_5) u_t \varepsilon_\sigma^*(k)$$

Convergent and divergent part of the tree

$$|\mathcal{M}_{tree}|^2 = |\mathcal{M}_{tree}^{con}|^2 + |\widetilde{\mathcal{M}}_0|^2 |\mathcal{M}|^2_{SGF}$$

where the universal soft–gluon factor $|\mathcal{M}|^2_{SGF}$ is given by

$$|\mathcal{M}|^2_{SGF} = -\frac{\alpha_s}{4\pi} C_F \left\{ \frac{m_t^2}{(k\cdot p_t)^2} + \frac{m_b^2}{(k\cdot p_b)^2} - 2\frac{p_b\cdot p_t}{(k\cdot p_b)(k\cdot p_t)} \right\}$$

Difficulty!

Divergent integration $|\widetilde{\mathcal{M}}_0|^2 |\mathcal{M}|^2_{SGF}$ is very difficult because of $m_g \neq 0$.

Solution

Integration $(|\widetilde{\mathcal{M}}_0|^2 - |\mathcal{M}_0|^2)|\mathcal{M}|^2_{SGF}$ is convergent and simpler.

- $|\widetilde{\mathcal{M}}_0|^2$: Born term structure with **three body** kinematics, $p_t = p_b + p_H + k$,
- $|\mathcal{M}_0|^2$: Born term structure with **two body** kinematics, $p_t = p_b + p_H$.

$$|\mathcal{M}_{tree}|^2 = \left\{ |\mathcal{M}_{tree}^{con}|^2 + \left(|\widetilde{\mathcal{M}}_0|^2 - |\mathcal{M}_0|^2\right)|\mathcal{M}|^2_{SGF} \right\} + |\mathcal{M}_0|^2 |\mathcal{M}|^2_{SGF}$$

Phase space integration without factorization

$$\Gamma = \frac{1}{2m_t}\frac{1}{(2\pi)^5}\int dR_3(p_t; p_H, p_b, k)|M_{tree}|^2$$
$$= \frac{1}{2m_t}\frac{1}{(2\pi)^5}\int \frac{d^3\vec{p}_H}{2E_H}\frac{d^3\vec{p}_b}{2E_b}\frac{d^3\vec{k}}{2E_g}\delta^4(p_t - p_b - p_H - k)|M_{tree}|^2$$
$$= \frac{1}{8m_t}\frac{1}{(2\pi)^3}\int_{E_H^{min}}^{E_H^{max}} dE_H \int_{k_0^{min}}^{k_0^{max}} dk_0 |M_{tree}|^2$$

with the integration limits

$$k_0^{max} = \frac{(m_t - E_H)(m_t^2 - m_b^2 + m_H^2 + m_g^2 - 2m_tE_H)}{2(m_t^2 + m_H^2 - 2m_tE_H)} + \frac{\sqrt{(E_H^2 - m_H^2)(m_t^2 + m_H^2 - 2m_tE_H - (m_b + m_g)^2)(m_t^2 + m_H^2 - 2m_tE_H - (m_b - m_g)^2)}}{2(m_t^2 + m_H^2 - 2m_tE_H)}$$

$$k_0^{min} = \frac{(m_t - E_H)(m_t^2 - m_b^2 + m_H^2 + m_g^2 - 2m_tE_H)}{2(m_t^2 + m_H^2 - 2m_tE_H)}$$

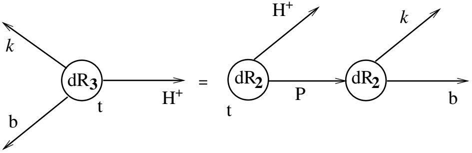
$$E_H^{max} = \frac{m_t^2 + m_H^2 - (m_b + m_g)^2}{2m_t}$$
$$E_H^{min} = m_H$$

In the $m_g \to 0$ the integration limits simplifies to

$$k_0^{max} = \frac{(m_t - E_H + \sqrt{E_H^2 - m_H^2})(m_t^2 - m_b^2 + m_H^2 + 2m_t E_H)}{2(m_t^2 + m_H^2 - 2m_t E_H)}$$
$$k_0^{max} = \frac{(m_t - E_H - \sqrt{E_H^2 - m_H^2})(m_t^2 - m_b^2 + m_H^2 + 2m_t E_H)}{2(m_t^2 + m_H^2 - 2m_t E_H)}$$

$$E_H^{max} = \frac{m_t^2 + m_H^2 - m_b^2}{2m_t}$$
$$E_H^{min} = m_H$$

Advantages of factorizing the phase space

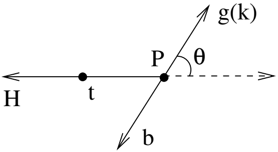


$$dR_3\left(p_t; p_H, p_b, k\right) = \int \frac{d^3\vec{p}_H}{2E_H}\frac{d^3\vec{p}_b}{2E_b}\frac{d^3\vec{k}}{2E_g}\delta^4(p_t - p_b - p_H - k)$$
$$= dP^2 dR_2\left(p_t; p_H, P\right) dR_2\left(P; p_b, k\right)$$
$$= m_t^2 {\color{red}dz}\, \underbrace{dR_2\left(p_t; p_H, P\right)}_{(1)} \underbrace{dR_2\left(P; p_b, k\right)}_{(2)}$$

with $z = \frac{P^2}{m_t^2} = \frac{(p_b+k)^2}{m_t^2}$.

Integration ① is trivial: $\int dR_2\,(p_t; p_H, P) = \frac{\sqrt{\lambda(1,y^2,z)}}{8} 4\pi$

Integration ② is done in P-rest frame:



$\int dR_2\,(P; p_b, k)$	$\lvert M_{tree}\rvert^2$
$= \int \frac{d^3 p_b}{2E_b} d^4 k \delta(k^2 - m_g^2)\delta^4(P - p_b - k)$	$(p_t\cdot P, P\cdot k, p_t\cdot k)$
$= \int \frac{\pi p_g^*}{2\sqrt{z}}\, d\cos\theta$	$\left\{\frac{1+z-y^2}{2}, \frac{z+\Lambda^2-\epsilon^2}{2}, \frac{(PG)(QP)}{2P^2} + \frac{(PG)\sqrt{\lambda(z,y^2,\Lambda^2)}}{2P^2}\cos\theta)\right\}$

with $p_g^* = \frac{\sqrt{\lambda(z,y^2,\Lambda^2)}}{2\sqrt{z}}$ is the modulus of gluon momentum in P-rest frame.

The conlusion is

$$\int dR_2\,(P; p_b, k)\,\lvert M_{tree}\rvert^2 \to \int d\cos\theta\,(p_t\cdot k)^n$$

$\int dz$ INTEGRATION

$$R(n) := \int_{\epsilon^2}^{(1-y)^2} \frac{dz}{(z-\epsilon^2)\sqrt{\lambda'^n}},$$

$$R(m,n) := \int_{\epsilon^2}^{(1-y)^2} \frac{z^m\, dz}{\sqrt{\lambda'^n}},$$

$$S(n) := \int_{\epsilon^2}^{(1-y)^2} \frac{1}{(z-\epsilon^2)\sqrt{\lambda'^n}} \ln\left(\frac{1-y^2+z+\sqrt{\lambda'}}{1-y^2+z-\sqrt{\lambda'}}\right) dz,$$

$$S(m,n) := \int_{\epsilon^2}^{(1-y)^2} \frac{z^m}{\sqrt{\lambda'^n}} \ln\left(\frac{1-y^2+z+\sqrt{\lambda'}}{1-y^2+z-\sqrt{\lambda'}}\right) dz.$$

with $\lambda' := \lambda(1, z, y^2)$.

Soft gluon integration

$$
\begin{aligned}
\Delta_{SGF} &= \int dz \int d\cos\theta |M|^2_{SGF} \\
&= 4(1-\frac{p_0 Y_p}{p_3})(\ln[(1-y)^2-\epsilon^2]-\ln\Lambda-\ln\epsilon \\
&\quad \frac{2p_0}{p_3}\Big\{2\mathrm{Li}_2(1-\frac{1-y}{p_+})-2\mathrm{Li}_2(1-\frac{1-y}{p_-}) \\
&\quad -\mathrm{Li}_2(1-\frac{p_-}{p_+})\Big\}-2+Y_p(Y_p+1)
\end{aligned}
$$

TREE RESULTS

$$\Gamma_{tree} = -\frac{1}{4\pi m_t}\left[\frac{\alpha_s}{4\pi} C_F\, m_t^2(a^2+b^2)\left\{\frac{3}{4}R(0,-1) + \frac{\epsilon^2(1-y^2)}{4}R(-2,-2) - \frac{1-y^2+3\epsilon^2}{4} + \frac{1}{2}\epsilon^2 S(0,0) - \frac{1}{2}S(1,0)\right\} + \mathrm{PS}_2^{-1}\,\Gamma_{Born}\,\Delta_{SGF}\right],$$

$$\begin{aligned}\Gamma^P_{tree} \;=\; & -\frac{1}{4\pi m_t}\left[\frac{\alpha_s}{4\pi} C_F\, m_t^2\, 2ab\left\{ -4p_3\, R(-1) + 4{p_3}^2\, R(0) + \frac{1}{4}(1-y^2)^2\epsilon^2 R(-2,0)\right.\right. \\ & -\frac{1}{4}((1-y^2)^2 + 2\,(3-y^2)\,\epsilon^2)\, R(-1,0) + \frac{1}{4}(2+10\,y^2-\epsilon^2)\, R(0,0) + \frac{7}{4}R(1,0) \\ & -+(1-y^2+\epsilon^2)\, 2p_3\, S(0) - (1-y^2+\epsilon^2)\, 2{p_3}^2\, S(1) + 2p_3 S(0,0) \\ & +\frac{1}{2}\left(4\,y^2\,\left(1-y^2\right) + \left(7+5\,y^2\right)\,\epsilon^2 - 2\,\epsilon^4\right)\, S(0,1) - \frac{1}{2}\left(3-3\,y^2+\epsilon^2\right)\, S(1,1) \\ & \left.\left. -\frac{1}{2}S(2,1) + \mathrm{PS}_2^{-1}\,\Gamma^P_{Born}\,\Delta_{SGF}\right.\right],\end{aligned}$$

where $\mathrm{PS}_2 = \frac{p_3}{16\pi m_t}$ is the two- body phase space.

Total QCD NLO result

$$\begin{aligned}\text{Total result} &= \text{Loop} + \text{Tree} \\ &= \text{Loop} + (\text{ Tree div.} + \text{Tree conv. }) \\ &= \underbrace{(Loop + Treediv.)}_{cancellation\ \ of\ \ \ln m_g\ \ div.} + \text{Tree conv.}\end{aligned}$$

$$\Gamma^P = \frac{\alpha_s C_F}{8\pi^2} m_t \Big\{ -3(a^2+b^2)p_3^2 \ln(\epsilon)$$
$$+ab(\frac{1}{4}(-11+28y) - 16y^2 - 8y^3 + 7y^4 + \epsilon^2(4+8y-14y^2) + 7\epsilon^4$$
$$+(2-9y^2+y^4-\epsilon^2(4+3y^2)+2\epsilon^4)\frac{p_3}{y^2}Y_p + \frac{8p_3^2 w_0}{y^2}\ln(\epsilon)$$
$$+8p_3^2\ln(\frac{1-y}{(1-y)^2-\epsilon^2}) + (3-3y^2+2\epsilon^2(4+y^2)-2\epsilon^4)\ln(\frac{1-y}{\epsilon})$$
$$+4p_0p_3(2\mathrm{Li}_2(1-\frac{1-y}{p_-}) - 2\mathrm{Li}_2(1-\frac{1-y}{p_+}) - \mathrm{Li}_2(w_-) + \mathrm{Li}_2(w_-) + 2\ln(\frac{(1-y^2)-\epsilon^2}{\epsilon^2})Y_p)$$
$$-(2+y^2-\epsilon^2(3+2y^2)+\epsilon^4)(2\mathrm{Li}_2(y) - \mathrm{Li}_2(w_-) - \mathrm{Li}_2(w_-))\Big\}$$

- Our unpolarized results agree with A.Czarnecki and S.Davidson (1993).

Summary of the NLO calculation techniques

Important points:

- Three-point one-loop integration C_0
- Soft gluon factor integration

Time consuming calculations:

- Phase space integration of the real emission
- Collecting virtual and real corrections and simplifying

Cancellation of divergencies:

- UV-divergencies are regulated by dimensional regularization. They cancel in the loop.
- IR-divergencies are regulated by a gluon mass. Both loop and tree have IR-divergencies but they cancel in the sum.
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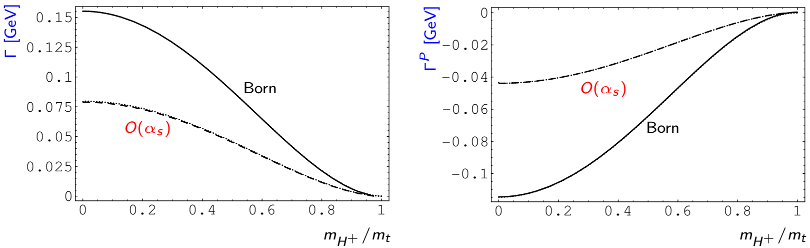

Figure 3

Unpolarized (on the left) and polarized (on the right) decay rate for model 2:
$m_b = 4.8$ GeV, $m_t = 175$ GeV,
Born term: full line,
$O(\alpha_s)$: dashed line.
The barely visible dotted lines show the corresponding $m_b \longrightarrow 0$ curves.

($\tan\beta = 10$)

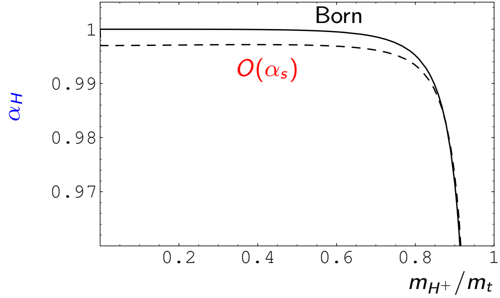

Figure 1

Asymmetry parameter α_H for model 1:
$m_b = 4.8$ GeV, $m_t = 175$ GeV,
Born term: full line,
$O(\alpha_s)$: dashed line.
($\tan\beta = 10$)

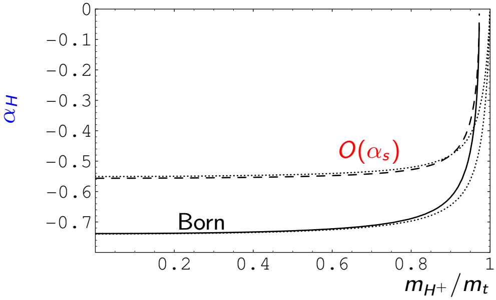

Figure 2

Asymmetry parameter α_H for model 2:
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Conclusions

- Radiative corrections to the unpolarized, polarized rates and the asymmetry parameter can become quite large (depending on the model and the value of $\tan\beta$).
- We present a compact expression for the unpolarized and polarized rates which can be employed to scan the predictions of the 2HDM parameter space.

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