Appendix C

Higgs boson decay Widths

Here, we list the partial widths of all possible tree-level two-body decays of the various Higgs bosons of the MSSM.

C.1 Decays to SM fermions

The partial widths for the decays of MSSM Higgs bosons to SM fermions are given by:

$$\Gamma(h \to u\bar{u}) = \frac{g^2}{32\pi} N_c \frac{\cos^2\alpha}{\sin^2\beta} \left(\frac{m_u}{M_W}\right)^2 m_h \left(1 - \frac{4m_u^2}{m_h^2}\right)^{\frac{3}{2}}, \tag{C.1a}$$

$$\Gamma(h \to d\bar{d}) = \frac{g^2}{32\pi} N_c \frac{\sin^2\alpha}{\cos^2\beta} \left(\frac{m_d}{M_W}\right)^2 m_h \left(1 - \frac{4m_d^2}{m_h^2}\right)^{\frac{3}{2}}, \tag{C.1b}$$

$$\Gamma(h \to \ell^+\ell^-) = \frac{g^2}{32\pi} \frac{\sin^2\alpha}{\cos^2\beta} \left(\frac{m_\ell}{M_W}\right)^2 m_h \left(1 - \frac{4m_\ell^2}{m_h^2}\right)^{\frac{3}{2}}, \tag{C.1c}$$

$$\Gamma(H \to u\bar{u}) = \frac{g^2}{32\pi} N_c \frac{\sin^2\alpha}{\sin^2\beta} \left(\frac{m_u}{M_W}\right)^2 m_H \left(1 - \frac{4m_u^2}{m_H^2}\right)^{\frac{3}{2}}, \tag{C.2a}$$

$$\Gamma(H \to d\bar{d}) = \frac{g^2}{32\pi} N_c \frac{\cos^2\alpha}{\cos^2\beta} \left(\frac{m_d}{M_W}\right)^2 m_H \left(1 - \frac{4m_d^2}{m_H^2}\right)^{\frac{3}{2}}, \tag{C.2b}$$

$$\Gamma(H \to \ell^+\ell^-) = \frac{g^2}{32\pi} \frac{\cos^2\alpha}{\cos^2\beta} \left(\frac{m_\ell}{M_W}\right)^2 m_H \left(1 - \frac{4m_\ell^2}{m_H^2}\right)^{\frac{3}{2}}, \tag{C.2c}$$

and

$$\Gamma(A \to u\bar{u}) = \frac{g^2}{32\pi} N_c \cot^2\beta \left(\frac{m_u}{M_W}\right)^2 m_A \left(1 - \frac{4m_u^2}{m_A^2}\right)^{\frac{1}{2}}, \tag{C.3a}$$

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$$\Gamma(A \to d\bar{d}) = \frac{g^2}{32\pi} N_c \tan^2\beta \left(\frac{m_d}{M_W}\right)^2 m_A \left(1 - \frac{4m_d^2}{m_A^2}\right)^{\frac{1}{2}}, \tag{C.3b}$$

$$\Gamma(A \to \ell^+\ell^-) = \frac{g^2}{32\pi} \tan^2\beta \left(\frac{m_\ell}{M_W}\right)^2 m_A \left(1 - \frac{4m_\ell^2}{m_A^2}\right)^{\frac{1}{2}}, \tag{C.3c}$$

where the color factor $N_c = 3$ for decays to quarks.

For charged Higgs boson decays, we find

$$\Gamma(H^+ \to u\bar{d}) = \Gamma(H^- \to d\bar{u}) = \frac{g^2}{32\pi M_W^2 m_{H^+}} N_c \lambda^{\frac{1}{2}}\left(1, \frac{m_u^2}{m_{H^+}^2}, \frac{m_d^2}{m_{H^+}^2}\right)$$
$$\times \left[(m_d^2 \tan^2\beta + m_u^2 \cot^2\beta)(m_{H^+}^2 - m_u^2 - m_d^2) - 4m_u^2 m_d^2\right]. \tag{C.4}$$

To get $\Gamma(H^+ \to \nu_\ell \bar{\ell})$ simply replace $m_d \to m_\ell$, $m_u \to 0$, and $N_c = 1$ in (C.4).

The dominant radiative corrections can be included by replacing the fermion masses that enter the prefactors of these formulae via the corresponding Yukawa couplings by running masses evaluated at the scale $Q = m_{h,H,A}$.

C.2 Decays to gauge bosons

The heavy scalar H may decay to ZZ or WW with partial widths given by

$$\Gamma(H \to Z^0Z^0) = \frac{g^2 \cos^2(\alpha+\beta) M_W^2}{32\pi \cos^4\theta_W m_H}\left[3 - \frac{m_H^2}{M_Z^2} + \frac{m_H^4}{4M_Z^4}\right]\lambda^{\frac{1}{2}}\left(1, \frac{M_Z^2}{m_H^2}, \frac{M_Z^2}{m_H^2}\right) \tag{C.5a}$$

and

$$\Gamma(H \to W^+W^-)$$
$$= \frac{g^2 \cos^2(\alpha+\beta) M_W^2}{16\pi m_H}\left[3 - \frac{m_H^2}{M_W^2} + \frac{m_H^4}{4M_W^4}\right]\lambda^{\frac{1}{2}}\left(1, \frac{M_W^2}{m_H^2}, \frac{M_W^2}{m_H^2}\right). \tag{C.5b}$$

The A has no tree-level couplings to vector boson pairs, but a coupling can be induced at the one-loop level. The h is too light to decay to electroweak vector boson pairs. Note, however, that the branching fractions for the three-body decays of h or H to WW^* or ZZ^* may be large, since these have only to compete with two-body decays mediated by bottom Yukawa couplings; formulae for these partial widths in the SM are given by Keung and Marciano.[1] It is simple to modify these by inserting the appropriate factor that arises in the hVV or HVV ($V = W, Z$) coupling in the MSSM.

[1] W. Y. Keung and W. Marciano, *Phys. Rev.* **D30**, 248 (1984).

In the MSSM, charged Higgs bosons cannot decay via $H^{\pm} \to W^{\pm} Z^0$ at the tree level.

C.3 Decays to sfermions

The partial widths for *scalar* neutral Higgs boson decays to a pair of squarks or sleptons are given by,

$$\Gamma(h,\ H \to \tilde{f}_i \bar{\tilde{f}}_j) = \frac{|\mathcal{A}^{h,H}_{\tilde{f}_i \bar{\tilde{f}}_j}|^2}{16\pi m_{h,H}} N_c(f) \lambda^{\frac{1}{2}} \left(1, \frac{m^2_{\tilde{f}_1}}{m^2_{h,H}}, \frac{m^2_{\tilde{f}_2}}{m^2_{h,H}}\right) \tag{C.6}$$

where $i, j = 1, 2$ and $N_c(f) = 3$ (1) for squarks (sleptons). The relevant couplings are given by

$$\mathcal{A}^{h,H}_{\tilde{f}_1 \bar{\tilde{f}}_1} = \mathcal{A}_{\tilde{f}_L \bar{\tilde{f}}_L} \cos^2\theta_f + \mathcal{A}_{\tilde{f}_R \bar{\tilde{f}}_R} \sin^2\theta_f - 2\mathcal{A}_{\tilde{f}_L \bar{\tilde{f}}_R} \cos\theta_f \sin\theta_f, \tag{C.7a}$$

$$\mathcal{A}^{h,H}_{\tilde{f}_2 \bar{\tilde{f}}_2} = \mathcal{A}_{\tilde{f}_L \bar{\tilde{f}}_L} \sin^2\theta_f + \mathcal{A}_{\tilde{f}_R \bar{\tilde{f}}_R} \cos^2\theta_f + 2\mathcal{A}_{\tilde{f}_L \bar{\tilde{f}}_R} \cos\theta_f \sin\theta_f, \tag{C.7b}$$

$$\mathcal{A}^{h,H}_{\tilde{f}_1 \bar{\tilde{f}}_2} = \mathcal{A}_{\tilde{f}_L \bar{\tilde{f}}_L} \cos\theta_f \sin\theta_f - \mathcal{A}_{\tilde{f}_R \bar{\tilde{f}}_R} \cos\theta_f \sin\theta_f + \mathcal{A}_{\tilde{f}_L \bar{\tilde{f}}_R} \cos 2\theta_f, \tag{C.7c}$$

and $\mathcal{A}^{h,H}_{\tilde{f}_2 \bar{\tilde{f}}_1} = \mathcal{A}^{h,H}_{\tilde{f}_1 \bar{\tilde{f}}_2}$.

The couplings $\mathcal{A}^{h,H}_{\tilde{q}_L \tilde{q}_L}$, $\mathcal{A}^{h,H}_{\tilde{q}_R \tilde{q}_R}$ and $\mathcal{A}^{h,H}_{\tilde{q}_L \tilde{q}_R}$ are given by,

$$\mathcal{A}^h_{\tilde{u}_L \bar{\tilde{u}}_L} = g\left[M_W(\frac{1}{2} - \frac{1}{6}\tan^2\theta_W)\sin(\beta-\alpha) - \frac{m_u^2 \cos\alpha}{M_W \sin\beta}\right], \tag{C.8a}$$

$$\mathcal{A}^h_{\tilde{d}_L \bar{\tilde{d}}_L} = g\left[M_W(-\frac{1}{2} - \frac{1}{6}\tan^2\theta_W)\sin(\beta-\alpha) - \frac{m_d^2 \sin\alpha}{M_W \cos\beta}\right], \tag{C.8b}$$

$$\mathcal{A}^h_{\tilde{u}_R \bar{\tilde{u}}_R} = g\left[\frac{2}{3} M_W \tan^2\theta_W \sin(\beta-\alpha) - \frac{m_u^2 \cos\alpha}{M_W \sin\beta}\right], \tag{C.8c}$$

$$\mathcal{A}^h_{\tilde{d}_R \bar{\tilde{d}}_R} = g\left[-\frac{1}{3} M_W \tan^2\theta_W \sin(\beta-\alpha) - \frac{m_d^2 \sin\alpha}{M_W \cos\beta}\right], \tag{C.8d}$$

and

$$\mathcal{A}^H_{\tilde{u}_L \bar{\tilde{u}}_L} = g\left[-M_W(\frac{1}{2} - \frac{1}{6}\tan^2\theta_W)\cos(\beta-\alpha) + \frac{m_u^2 \sin\alpha}{M_W \sin\beta}\right], \tag{C.9a}$$

$$\mathcal{A}^H_{\tilde{d}_L \bar{\tilde{d}}_L} = g\left[M_W(\frac{1}{2} + \frac{1}{6}\tan^2\theta_W)\cos(\beta-\alpha) - \frac{m_d^2 \cos\alpha}{M_W \cos\beta}\right], \tag{C.9b}$$

$$\mathcal{A}^H_{\tilde{u}_R \bar{\tilde{u}}_R} = g\left[-\frac{2}{3} M_W \tan^2\theta_W \cos(\beta-\alpha) + \frac{m_u^2 \sin\alpha}{M_W \sin\beta}\right], \tag{C.9c}$$

$$\mathcal{A}^H_{\tilde{d}_R \bar{\tilde{d}}_R} = g\left[\frac{1}{3} M_W \tan^2\theta_W \cos(\beta-\alpha) - \frac{m_d^2 \cos\alpha}{M_W \cos\beta}\right]. \tag{C.9d}$$

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Furthermore,

$$\mathcal{A}^h_{\tilde{u}_L\bar{\tilde{u}}_R} = \frac{g m_u}{2M_W \sin\beta}(-\mu\sin\alpha + A_u\cos\alpha), \tag{C.10a}$$

$$\mathcal{A}^h_{\tilde{d}_L\bar{\tilde{d}}_R} = \frac{g m_d}{2M_W \cos\beta}(-\mu\cos\alpha + A_d\sin\alpha), \tag{C.10b}$$

and

$$\mathcal{A}^H_{\tilde{u}_L\bar{\tilde{u}}_R} = \frac{g m_u}{2M_W \cos\beta}(-\mu\cos\alpha - A_u\sin\alpha), \tag{C.11a}$$

$$\mathcal{A}^H_{\tilde{d}_L\bar{\tilde{d}}_R} = \frac{g m_d}{2M_W \cos\beta}(\mu\sin\alpha + A_d\cos\alpha). \tag{C.11b}$$

The pseudoscalar A cannot decay into $\tilde{f}_i\bar{\tilde{f}}_i$ pairs because of CP conservation. It may, however, decay into unlike sfermion–antisfermion pairs with a width,

$$\Gamma(A\to\tilde{f}_1\bar{\tilde{f}}_2) = \Gamma(A\to\tilde{f}_2\bar{\tilde{f}}_1) = \frac{|\mathcal{A}^A_{\tilde{f}_L\bar{\tilde{f}}_R}|^2}{16\pi m_A}N_c(f)\lambda^{\frac{1}{2}}\left(1, \frac{m^2_{\tilde{f}_1}}{m_A^2}, \frac{m^2_{\tilde{f}_2}}{m_A^2}\right), \tag{C.12}$$

where the relevant couplings for decays to squarks are given by,

$$\mathcal{A}^A_{\tilde{u}_L\bar{\tilde{u}}_R} = \frac{g m_u}{2M_W}(\mu + A_u\cot\beta), \tag{C.13a}$$

$$\mathcal{A}^A_{\tilde{d}_L\bar{\tilde{d}}_R} = \frac{g m_d}{2M_W}(\mu + A_d\tan\beta). \tag{C.13b}$$

Notice that this decay rate does not depend on the sfermion mixing angle.

The couplings for decays of h, H or A decays to sleptons can be obtained from those for their decays to squarks via the substitutions listed below Eq. (8.125d).

The partial width for the decay of the charged Higgs boson to squarks is given by,

$$\Gamma(H^+\to\tilde{q}_i\bar{\tilde{q}}'_j) = \Gamma(H^-\to\tilde{q}'_j\bar{\tilde{q}}_i) = \frac{\mathcal{C}^2_{\tilde{q}_i\bar{\tilde{q}}'_j}}{16\pi m_{H^+}}N_c\lambda^{\frac{1}{2}}\left(1, \frac{m^2_{\tilde{q}_i}}{m^2_{H^+}}, \frac{m^2_{\tilde{q}'_j}}{m^2_{H^+}}\right), \tag{C.14}$$

where

$$\begin{aligned}\mathcal{C}_{\tilde{u}_1\bar{\tilde{d}}_1} &= \mathcal{C}_{\tilde{u}_L\bar{\tilde{d}}_L}\cos\theta_u\cos\theta_d + \mathcal{C}_{\tilde{u}_R\bar{\tilde{d}}_R}\sin\theta_u\sin\theta_d \\ &\quad - \mathcal{C}_{\tilde{u}_L\bar{\tilde{d}}_R}\cos\theta_u\sin\theta_d - \mathcal{C}_{\tilde{u}_R\bar{\tilde{d}}_L}\sin\theta_u\cos\theta_d,\end{aligned} \tag{C.15a}$$

$$\begin{aligned}\mathcal{C}_{\tilde{u}_2\bar{\tilde{d}}_2} &= \mathcal{C}_{\tilde{u}_L\bar{\tilde{d}}_L}\sin\theta_u\sin\theta_d + \mathcal{C}_{\tilde{u}_R\bar{\tilde{d}}_R}\cos\theta_u\cos\theta_d \\ &\quad + \mathcal{C}_{\tilde{u}_L\bar{\tilde{d}}_R}\sin\theta_u\cos\theta_d + \mathcal{C}_{\tilde{u}_R\bar{\tilde{d}}_L}\cos\theta_u\sin\theta_d,\end{aligned} \tag{C.15b}$$

$$\begin{aligned}\mathcal{C}_{\tilde{u}_1\bar{\tilde{d}}_2} &= \mathcal{C}_{\tilde{u}_L\bar{\tilde{d}}_L}\cos\theta_u\sin\theta_d - \mathcal{C}_{\tilde{u}_R\bar{\tilde{d}}_R}\sin\theta_u\cos\theta_d \\ &\quad + \mathcal{C}_{\tilde{u}_L\bar{\tilde{d}}_R}\cos\theta_u\cos\theta_d - \mathcal{C}_{\tilde{u}_R\bar{\tilde{d}}_L}\sin\theta_u\sin\theta_d,\end{aligned} \tag{C.15c}$$

$$\mathcal{C}_{\tilde{u}_2\bar{\tilde{d}}_1} = \mathcal{C}_{\tilde{u}_L\bar{\tilde{d}}_L} \sin\theta_u \cos\theta_d - \mathcal{C}_{\tilde{u}_R\bar{\tilde{d}}_R} \cos\theta_u \sin\theta_d - \mathcal{C}_{\tilde{u}_L\bar{\tilde{d}}_R} \sin\theta_u \sin\theta_d + \mathcal{C}_{\tilde{u}_R\bar{\tilde{d}}_L} \cos\theta_u \cos\theta_d, \tag{C.15d}$$

with

$$\mathcal{C}_{\tilde{u}_L\bar{\tilde{d}}_L} = \frac{g}{\sqrt{2}}\left[-M_W \sin 2\beta + \frac{m_d^2 \tan\beta + m_u^2 \cot\beta}{M_W}\right], \tag{C.16a}$$

$$\mathcal{C}_{\tilde{u}_R\bar{\tilde{d}}_R} = \left[\frac{g m_u m_d(\cot\beta + \tan\beta)}{\sqrt{2}M_W}\right], \tag{C.16b}$$

$$\mathcal{C}_{\tilde{u}_L\bar{\tilde{d}}_R} = \left[\frac{-g m_d}{\sqrt{2}M_W}(A_d \tan\beta + \mu)\right], \tag{C.16c}$$

$$\mathcal{C}_{\tilde{u}_R\bar{\tilde{d}}_L} = \left[\frac{-g m_u}{\sqrt{2}M_W}(A_u \cot\beta + \mu)\right]. \tag{C.16d}$$

For $H^+ \to \tilde{\nu}_L \bar{\tilde{\ell}}_{1,2}$ decay, replace $\mathcal{C}_{\tilde{q}_i\bar{\tilde{q}}'_j} \to \mathcal{C}_{\tilde{\nu}_L\bar{\tilde{\ell}}_{1,2}}$, $m_{\tilde{q}_i} \to m_{\tilde{\nu}_L}$, $m_{\tilde{q}_j} \to m_{\tilde{\ell}_{1,2}}$, $N_c = 1$ and use

$$\mathcal{C}_{\tilde{\nu}_L\bar{\tilde{\ell}}_1} = \mathcal{C}_{\tilde{\nu}_L\bar{\tilde{\ell}}_L} \cos\theta_\ell - \mathcal{C}_{\tilde{\nu}_L\bar{\tilde{\ell}}_R} \sin\theta_\ell, \tag{C.17a}$$

$$\mathcal{C}_{\tilde{\nu}_L\bar{\tilde{\ell}}_2} = \mathcal{C}_{\tilde{\nu}_L\bar{\tilde{\ell}}_L} \sin\theta_\ell + \mathcal{C}_{\tilde{\nu}_L\bar{\tilde{\ell}}_R} \cos\theta_\ell, \tag{C.17b}$$

with

$$\mathcal{C}_{\tilde{\nu}_L\bar{\tilde{\ell}}_L} = \frac{g}{\sqrt{2}}\left[-M_W \sin 2\beta + \frac{m_\ell^2 \tan\beta}{M_W}\right], \quad \text{and} \tag{C.18a}$$

$$\mathcal{C}_{\tilde{\nu}_L\bar{\tilde{\ell}}_R} = \left[\frac{-g m_\ell}{\sqrt{2}M_W}(A_\ell \tan\beta + \mu)\right]. \tag{C.18b}$$

C.4 Decays to charginos and neutralinos

The partial width for the decays of neutral Higgs bosons, $\phi = h,\ H$ or A, to chargino pairs is given by,

$$\Gamma(\phi \to \widetilde{W}_i^+ \widetilde{W}_i^-) = \frac{g^2}{4\pi}|S_i^\phi|^2 m_\phi \left(1 - 4\frac{{m_{\widetilde{W}_i}}^2}{{m_\phi}^2}\right)^{\delta_\phi}, \tag{C.19}$$

where $\delta_{h,H} = 3/2$ and $\delta_A = 1/2$, and

$$\Gamma(\phi \to \widetilde{W}_1^+ \widetilde{W}_2^-) = \lambda^{\frac{1}{2}}\left(1, \frac{m_{\widetilde{W}_1}^2}{m_\phi^2}, \frac{m_{\widetilde{W}_2}^2}{m_\phi^2}\right)\frac{g^2}{16\pi m_\phi}\left\{|S^\phi|^2\left[m_\phi^2 - (m_{\widetilde{W}_2} + m_{\widetilde{W}_1})^2\right] + |P^\phi|^2\left[m_\phi^2 - (m_{\widetilde{W}_2} - m_{\widetilde{W}_1})^2\right]\right\}, \tag{C.20}$$

with $\Gamma(h,\ H,\ A \to \widetilde{W}_1^+ \widetilde{W}_2^-) = \Gamma(h,\ H,\ A \to \widetilde{W}_2^+ \widetilde{W}_1^-)$ by CP invariance. The various couplings S_i^ϕ, P_i^ϕ, S^ϕ, and P^ϕ have been listed in Eq. (8.116a)–(8.116c) and in the accompanying discussion for $\phi = h, H$, and in (8.119a)–(8.119c) for $\phi = A$.

The neutral Higgs bosons can also decay into neutralino pairs with partial widths given by,

$$\Gamma(\phi \to \widetilde{Z}_i \widetilde{Z}_j) = \frac{\Delta_{ij}}{8\pi m_\phi} \left(X^\phi_{ij} + X^\phi_{ji} \right)^2 \left[m_\phi^2 - (m_{\widetilde{Z}_i} + (-1)^{\theta_i + \theta_j + \theta_\phi} m_{\widetilde{Z}_j})^2 \right] \times \lambda^{\frac{1}{2}} \left(1, \frac{m^2_{\widetilde{Z}_i}}{m^2_\phi}, \frac{m^2_{\widetilde{Z}_j}}{m^2_\phi} \right), \tag{C.21}$$

where $\theta_\phi = 0$ if $\phi = h, H$ and $\theta_\phi = 1$ if $\phi = A$, $\Delta_{ij} = \frac{1}{2}$ (1) for $i = j$ ($i \neq j$), and where $X^{h,H,A}_{ij}$ are given in Eq. (8.117) and (8.120).

Finally, the partial width for a charged Higgs boson to decay into a chargino and a neutralino is given by

$$\Gamma(H^+ \to \widetilde{W}_i^+ \widetilde{Z}_j) = \Gamma(H^- \to \widetilde{W}_i^- \widetilde{Z}_j) = \frac{1}{8\pi m_{H^+}} \lambda^{\frac{1}{2}} \left(1, \frac{m^2_{\widetilde{W}_i}}{m^2_{H^+}}, \frac{m^2_{\widetilde{Z}_j}}{m^2_{H^+}} \right) \times \left[(R^2_{ij} + S^2_{ij})(m^2_{H^+} - m^2_{\widetilde{W}_i} - m^2_{\widetilde{Z}_j}) - 2(R^2_{ij} - S^2_{ij}) m_{\widetilde{W}_i} m_{\widetilde{Z}_j} \right], \tag{C.22}$$

where

$$R_{1j} = \frac{1}{2} \left[(-1)^{\theta_{\widetilde{W}_1}} A^j_2 \cos\beta - (-1)^{\theta_j} A^j_4 \sin\beta \right], \tag{C.23a}$$

$$R_{2j} = \frac{1}{2} \left[(-1)^{\theta_{\widetilde{W}_2}} \theta_y A^j_1 \cos\beta - (-1)^{\theta_j} \theta_x A^j_3 \sin\beta \right], \tag{C.23b}$$

and

$$S_{1j} = \frac{1}{2} \left[(-1)^{\theta_{\widetilde{W}_1}} A^j_2 \cos\beta + (-1)^{\theta_j} A^j_4 \sin\beta \right], \tag{C.24a}$$

$$S_{2j} = \frac{1}{2} \left[(-1)^{\theta_{\widetilde{W}_2}} \theta_y A^j_1 \cos\beta + (-1)^{\theta_j} \theta_x A^j_3 \sin\beta \right], \tag{C.24b}$$

with A^j_1–A^j_4 as given in (8.122a)–(8.122d).

C.5 Decays to Higgs bosons

Finally, we list Higgs boson decay widths to other Higgs bosons, including decays to Higgs boson–gauge boson final states:

$$\Gamma(H \to hh) = \frac{\xi^2_{Hhh}}{8\pi m_H} \left(1 - \frac{4m_h^2}{m_H^2} \right)^{\frac{1}{2}}, \tag{C.25a}$$

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where

$$\xi_{Hhh} = \frac{gM_Z}{4\cos\theta_W}\left[\cos 2\alpha \cos(\beta-\alpha) + 2\sin 2\alpha \sin(\beta-\alpha)\right]; \tag{C.25b}$$

$$\Gamma(H \to AA) = \frac{\xi^2_{HAA}}{8\pi m_H}\left(1 - \frac{4m_A^2}{m_H^2}\right)^{\frac{1}{2}}, \tag{C.26a}$$

where

$$\xi_{HAA} = -\frac{gM_Z}{4\cos\theta_W}\cos(\beta-\alpha)\cos 2\beta; \tag{C.26b}$$

$$\Gamma(H \to H^+H^-) = \frac{\xi^2_{H+-}}{16\pi m_H}\left(1 - \frac{4m^2_{H^+}}{m_H^2}\right)^{\frac{1}{2}}, \tag{C.27a}$$

where

$$\xi_{H+-} = gM_W\left[\cos(\beta+\alpha) - \frac{\cos(\beta-\alpha)\cos 2\beta}{2\cos^2\theta_W}\right]; \tag{C.27b}$$

$$\Gamma(h \to AA) = \frac{\xi^2_{hAA}}{8\pi m_h}\left(1 - \frac{4m_A^2}{m_h^2}\right)^{\frac{1}{2}}, \tag{C.28a}$$

where

$$\xi_{hAA} = \left(\frac{gM_Z}{4\cos\theta_W}\right)\sin(\beta-\alpha)\cos 2\beta. \tag{C.28b}$$

Higgs bosons may also decay into gauge bosons and a lighter Higgs boson. The partial widths for these decays are given by,

$$\Gamma(H \to Z^0A) = \frac{(g\cos\theta_W + g'\sin\theta_W)^2\sin^2(\alpha+\beta)m_H^3}{64\pi m_Z^2}\lambda^{\frac{3}{2}}\left(1, \frac{m_A^2}{m_H^2}, \frac{M_Z^2}{m_H^2}\right), \tag{C.29a}$$

$$\Gamma(A \to Z^0h) = \frac{(g\cos\theta_W + g'\sin\theta_W)^2\cos^2(\alpha+\beta)m_A^3}{64\pi m_Z^2}\lambda^{\frac{3}{2}}\left(1, \frac{m_h^2}{m_A^2}, \frac{M_Z^2}{m_A^2}\right), \tag{C.29b}$$

and

$$\Gamma(H^\pm \to W^\pm h) = \frac{g^2\cos^2(\alpha+\beta)m^3_{H^+}}{64\pi M_W^2}\lambda^{\frac{3}{2}}\left(1, \frac{M_W^2}{m^2_{H^+}}, \frac{m_h^2}{m^2_{H^+}}\right). \tag{C.29c}$$

The decays $H^\pm \to W^\pm A$ and $W^\pm H$ are kinematically forbidden in the MSSM, assuming tree-level formulae for their masses.