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The electroweak sector of the NMSSM at the one-loop level

Florian Staub[1,a], **Werner Porod**[1,2,b], **Björn Herrmann**[3,1,c]

[1] *Institut für Theoretische Physik und Astrophysik, Universität Würzburg, D-97074 Würzburg, Germany*

[2] *AHEP Group, Institut de Física Corpuscular - C.S.I.C., Universitat de València, E-46071 València, Spain*

[3] *Deutsches Elektronen-Synchrotron (DESY), Theory group, Notkestraße 85, D-22603 Hamburg, Germany*

[a] *Email:* florian.staub@physik.uni-wuerzburg.de

[b] *Email:* porod@physik.uni-wuerzburg.de

[c] *Email:* bjoern.herrmann@desy.de

Abstract: We present the electroweak spectrum for the Next-to-Minimal Supersymmetric Standard Model at the one-loop level, e.g. the masses of Higgs bosons, sleptons, charginos and neutralinos. For the numerical evaluation we present a mSUGRA variant with non-universal Higgs mass parameters squared and we compare our results with existing ones in the literature. Moreover, we briefly discuss the implications of our results for the calculation of the relic density.

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1. Introduction

Supersymmetric extensions of the standard model (SM) are promising candidates for new physics at the TeV scale [1, 2, 3] as the solve several short-comings of the Standard Model (SM). The Minimal Supersymmetric Standard Model (MSSM) solves the hierarchy problem of the SM [4], leads to a unification of the gauge couplings [5] and introduces several candidates for dark matter depending on how SUSY is broken [6, 7]. On the other hand, a new problem arises in the MSSM: the superpotential contains a parameter with mass dimension, namely the so called μ parameter which gives mass to the Higgs bosons and higgsinos. From a purely theoretical point of view, the value of this parameter is expected to be either of the order of the GUT/Planck scale or exactly zero, if it is protected by a symmetry. For phenomenological aspects, however, it is necessary that it is of the order of the scale of electroweak symmetry breaking (EWSB) and it has to be non-zero to be consistent with experimental data. This discrepancy is the so called μ-problem of the MSSM [8].

The Next-to-Minimal Supersymmetric Standard Model (NMSSM) [9] provides an elegant solution to this problem. The particle content of the MSSM is extended by an additional gauge singlet, which receives a vacuum expectation value when supersymmetry is broken. The corresponding term in the superpotential gives then rise to an effective μ-term which is naturally of the order of the EWSB scale. Also in this model several regions exist in parameter space where one obtains the correct relic density to explained the observed dark matter [10, 11]. It turns out that in high scale models like mSUGRA several regions exist which are rather sensitive to mass differences of the various supersymmetric particles, in particular the masses of the Higgs bosons, the neutralinos and the staus, the supersymmetric partners of the tau-lepton, and require precise calculations of these masses. The corresponding regions are the so-called Higgs funnel(s) and the co-annihilation regions. Motivated by this observation we calculate the Higgs masses, the neutralino masses and the staus at the one-loop level.

This paper is organized as follows. We first detail our calculation of the mass spectrum in sec. 2. In sec. 3 we present the constrained NMSSM, which serves as our reference scenario and perform a numerical analysis of our implementation. sec. 4 is devoted to a comparison of our results with the public program package `NMSSM-Tools` [12]. Finally, we give a few examples for the calculation of the dark matter relic density in sec. 5 and draw our conclusions in sec. 6. We collect the couplings and one-loop self-energies in the appendix where we include for completeness also those for the Z-boson and neutral Higgs bosons which have already been given in ref. [13].

2. Calculation of the One-Loop Mass Spectrum

In this section we fix our notation and discuss briefly the $\overline{\rm DR}$ renormalization of the

relevant masses, where we follow closely ref. [14].

2.1 Superpotential and soft SUSY breaking terms of the NMSSM

As already stated above, the solution to the μ-problem of the MSSM is the replacement of the bilinear μ-term by a coupling between the Higgs superfields and an additional gauge singlet $\hat{S}$ leading to the superpotential

$$W_{\rm NMSSM} = -\hat{H}_u \hat{Q} Y_u \hat{U}^c + \hat{H}_d \hat{Q} Y_d \hat{D}^c + \hat{H}_d \hat{L} Y_e \hat{E}^c + \lambda \hat{H}_u \hat{H}_d \hat{S} + \frac{1}{3}\kappa \hat{S}\hat{S}\hat{S}. \tag{2.1}$$

where the last term is introduced to forbid a Peccei-Quinn symmetry which would lead to an axion in contradiction to experimental results, see e.g. ref. [15] and refs. therein. Moreover, we have only taken into account dimensionless couplings to avoid the μ-problem of the MSSM.

The scalar component S of $\hat{S}$ receives after SUSY breaking a vacuum expectation value (VEV), denoted v_s, which leads to

$$\mu_{\rm eff} = \frac{1}{\sqrt{2}} \lambda v_s, \tag{2.2}$$

where we have used the decomposition

$$S = \frac{1}{\sqrt{2}} \left(\phi_s + i\sigma_s + v_s \right). \tag{2.3}$$

Since v_s and thus also $\mu_{\rm eff}$ are a consequence of SUSY breaking one finds that $\mu_{\rm eff}$ is naturally of the order of the SUSY breaking scale.

All interactions are fixed by the gauge structure and the above superpotential. We have used the Mathemtica package `SARAH` [16] to calculate all vertices, mass matrices including the one-loop corrections and renormalization group equations of the model.

In the following, we use the standard conventions, where for a matter superfield $\hat{X}$, $\tilde{X}$ denotes its scalar component and X denotes its fermionic component. In case of the Higgs fields and the gauge singlet, $H_{u,d}/S$ are the scalar components, while $\tilde{H}_{u,d}/\tilde{S}$ are the fermionic higgsinos and the singlino.

At tree level the scalar potential receives contributions from several sources: from the the superpotential in eq. (2.1) the so-called F-terms given by

$$\mathcal{V}_{\rm F} = \sum_i \left| \frac{\partial W(\phi_j)}{\partial \phi_i} \right|. \tag{2.4}$$

The sum runs over all chiral superfields $\hat{\phi}_i$, which are then replaced by their scalar component ϕ_j. The D-terms are

$$\mathcal{V}_{\rm D} = \frac{1}{2} \sum_g \sum_a \left| \sum_{i,j} \phi_i^* T_g^a \phi_j \right|^2, \tag{2.5}$$

and finally the soft breaking terms

$$\begin{aligned}\mathcal{V}_{\rm SB,2} = {} & m_{H_u}^2|H_u|^2 + m_{H_d}^2|H_d|^2 + m_S^2|S|^2 + \tilde{Q}^\dagger m_{\tilde{Q}}^2 \tilde{Q} + \\ & + \tilde{L}^\dagger m_{\tilde{L}}^2 \tilde{L} + \tilde{D}^\dagger m_{\tilde{D}}^2 \tilde{D} + \tilde{U}^\dagger m_{\tilde{U}}^2 \tilde{U} + \\ & + \frac{1}{2}\left(M_1\, \tilde{B}\tilde{B} + M_2\, \tilde{W}_a \tilde{W}^a + M_3\, \tilde{g}_\alpha \tilde{g}^\alpha + h.c. \right) \end{aligned} \tag{2.6}$$

$$\mathcal{V}_{\rm SB,3} = -H_u \tilde{Q} T_u \tilde{U}^\dagger + H_d \tilde{Q} T_d \tilde{D}^\dagger + H_d \tilde{L} T_e \tilde{E}^\dagger + T_\lambda H_u H_d S + \frac{1}{3} T_\kappa S S S \tag{2.7}$$

The sum in eq. (2.5) runs over all gauge groups g and over the corresponding generators a, i.e. $\frac{1}{2}\lambda^a$ in the case of $SU(3)$, $\frac{1}{2}\sigma^a$ in the case of $SU(2)$, and $\frac{3}{5}Y^2$ for the $U(1)$. Here, λ^a are the Gell-Mann matrices, σ^a the Pauli-matrices, and Y is the hypercharge.

2.2 Minimum Conditions of the Vacuum

Once electroweak symmetry gets broken, both Higgs doublets receive a VEV and we decompose the scalars similar to eq. (2.3)

$$H_{u,d} = \frac{1}{\sqrt{2}} \left(\phi_{u,d} + i\sigma_{u,d} + v_{u,d} \right). \tag{2.8}$$

At tree level, the minimum conditions for the vacuum are the so-called tadpole equations

$$T_i = \frac{\partial V}{\partial v_i}\Big|_{\phi_i=0,\sigma_i=0} = 0 \tag{2.9}$$

with

$$\begin{aligned} T_d = \frac{\partial V}{\partial v_d} = {} & m_{H_d}^2 v_d + \frac{1}{8} v_d \big(v_d^2 - v_u^2\big)\big(g_1^2 + g_2^2\big) + \frac{1}{2} v_d \big(v_u^2 + v_s^2\big)|\lambda|^2 \\ & - \frac{1}{2} v_s^2 v_u \mathrm{Re}\big\{\kappa\lambda\big\} - \frac{1}{\sqrt{2}} v_s v_u \mathrm{Re}\big\{T_\lambda\big\}, \end{aligned} \tag{2.10}$$

$$\begin{aligned} T_u = \frac{\partial V}{\partial v_u} = {} & m_{H_u}^2 v_d + \frac{1}{8} v_u \big(v_u^2 - v_d^2\big)\big(g_1^2 + g_2^2\big) + \frac{1}{2} v_u \big(v_d^2 + v_s^2\big)|\lambda|^2 \\ & - \frac{1}{2} v_s^2 v_d \mathrm{Re}\big\{\kappa\lambda\big\} - \frac{1}{\sqrt{2}} v_s v_d \mathrm{Re}\big\{T_\lambda\big\}, \end{aligned} \tag{2.11}$$

$$\begin{aligned} T_s = \frac{\partial V}{\partial v_s} = {} & m_S^2 v_s + v_s^3 |\kappa|^2 - v_d v_s v_u \mathrm{Re}\big\{\kappa\lambda\big\} + \frac{1}{2}\big(v_d^2 + v_u^2\big) v_s |\lambda|^2 \\ & + \frac{1}{\sqrt{2}} v_s^2 \mathrm{Re}\big\{T_\kappa\big\} - \frac{1}{\sqrt{2}} v_d v_u \mathrm{Re}\big\{T_\lambda\big\}. \end{aligned} \tag{2.12}$$

Here we have chosen a phase convention where all VEVs are real. For the later calculation of the one-loop corrections to the Higgs boson masses one needs the evaluation of the tadpole equations at the one-loop level, leading to corrections $\delta t_i^{(1)}$. As renormalization condition we demand

$$T_i + \delta t_i^{(1)} = 0 \qquad \text{for} \quad i = d, u, s. \tag{2.13}$$

All calculations are performed in 't Hooft gauge using the diagrammatic approach. The explicit formulas for $\delta t_i^{(1)}$ are given in app. D. In our subsequent analysis we will solve eqs. (2.13) for the soft SUSY breaking masses squared: $m_{H_d}^2, m_{H_u}^2$, and m_S^2.

All parameters in eqs. (2.10)-(2.12) are understood as running parameters at a given renormalization scale Q. Note that the VEVs v_d and v_u are obtained from the running mass $m_Z(Q)$ of the Z-boson, which is related to the pole mass m_Z through

$$m_Z^2(Q) = \frac{g_1^2 + g_2^2}{4}(v_u^2 + v_d^2) = m_Z^2 + \mathrm{Re}\big\{\Pi_{ZZ}^T(m_Z^2)\big\}. \tag{2.14}$$

The transverse self-energy Π_{ZZ}^T is given in app. E.1. Details on the calculation of the running gauge couplings at $Q = m_Z$ can be found in ref. [14]. The ratio of these VEVs is denoted as in the MSSM by $\tan\beta = v_u/v_d$.

2.3 Masses of the Higgs bosons

The tree-level mass matrices for the neutral scalar Higgs bosons and pseudo scalar Higgs bosons can be calculated from the scalar potential according to

$$m_{T,ij}^{2,h} = \left.\frac{\partial^2 V}{\partial\phi_i\partial\phi_j}\right|_{\phi_k=0,\sigma_k=0}, \qquad m_{T,ij}^{2,A^0} = \left.\frac{\partial^2 V}{\partial\sigma_i\partial\sigma_j}\right|_{\phi_k=0,\sigma_k=0}, \tag{2.15}$$

respectively, with $i,j = 1,2,3 = u,d,s$. The matrices are symmetric and the entries in case of the scalar Higgs bosons are

$$m_{T,11}^{2,h} = m_{H_d}^2 + \frac{1}{2}\big(v_u^2 + v_s^2\big)|\lambda|^2 + \frac{1}{8}\big(g_1^2 + g_2^2\big)\big(3v_d^2 - v_u^2\big), \tag{2.16}$$

$$m_{T,12}^{2,h} = -\frac{1}{\sqrt{2}}v_s\mathrm{Re}\big\{T_\lambda\big\} - \frac{1}{2}v_s^2\mathrm{Re}\big\{\kappa\lambda\big\} - \frac{1}{4}\big(g_1^2 + g_2^2 - 4|\lambda|^2\big)v_d v_u, \tag{2.17}$$

$$m_{T,13}^{2,h} = -\frac{1}{\sqrt{2}}v_u\mathrm{Re}\big\{T_\lambda\big\} + v_s v_d|\lambda|^2 - v_s v_u\mathrm{Re}\big\{\kappa\big\}, \tag{2.18}$$

$$m_{T,22}^{2,h} = m_{H_u}^2 + \frac{1}{2}\big(v_d^2 + v_s^2\big)|\lambda|^2 + \frac{1}{8}\big(g_1^2 + g_2^2\big)\big(3v_u^2 - v_d^2\big), \tag{2.19}$$

$$m_{T,23}^{2,h} = -\frac{1}{\sqrt{2}}v_d\mathrm{Re}\big\{T_\lambda\big\} + v_s v_u|\lambda|^2 - v_s v_d\mathrm{Re}\big\{\lambda\kappa\big\}, \tag{2.20}$$

$$m_{T,33}^{2,h} = m_S^2 + 3v_s^2|\kappa|^2 + \frac{1}{2}\big(v_d^2 + v_u^2\big)|\lambda|^2 + \sqrt{2}v_s\mathrm{Re}\big\{T_\kappa\big\} - v_d v_u\mathrm{Re}\big\{\kappa\lambda\big\}, \tag{2.21}$$

while those of the pseudo-scalar ones are

$$m^{2,A^0}_{T,11} = m^2_{H_d} + \frac{1}{2}\big(v_u^2 + v_s^2\big)|\lambda|^2 + \frac{1}{8}\big(g_1^2 + g_2^2\big)\big(v_d^2 - v_u^2\big), \tag{2.22}$$

$$m^{2,A^0}_{T,12} = \frac{1}{\sqrt{2}} v_s \mathrm{Re}\big\{T_\lambda\big\} + \frac{1}{2} v_s^2 \mathrm{Re}\big\{\kappa\lambda\big\}, \tag{2.23}$$

$$m^{2,A^0}_{T,13} = \frac{1}{\sqrt{2}} v_u \mathrm{Re}\big\{T_\lambda\big\} - v_s v_u \mathrm{Re}\big\{\kappa\lambda\big\}, \tag{2.24}$$

$$m^{2,A^0}_{T,22} = m^2_{H_u} + \frac{1}{2}\big(v_d^2 + v_s^2\big)|\lambda|^2 + \frac{1}{8}\big(g_1^2 + g_2^2\big)\big(v_u^2 - v_d^2\big), \tag{2.25}$$

$$m^{2,A^0}_{T,23} = \frac{1}{\sqrt{2}} v_d \mathrm{Re}\big\{T_\lambda\big\} - v_d v_s \mathrm{Re}\big\{\kappa\lambda\big\}, \tag{2.26}$$

$$m^{2,A^0}_{T,33} = m^2_S + v_s^2\kappa^2 + \frac{1}{2}\big(v_d^2 + v_u^2\big)|\lambda|^2 - \sqrt{2} v_s \mathrm{Re}\big\{T_\kappa\big\} + v_d v_u \mathrm{Re}\big\{\kappa\lambda\big\}, \tag{2.27}$$

where $m^2_{H_d}$, $m^2_{H_u}$ and m^2_S satisfy the tadpole equations.

The diagonalization of the mass matrices $m^{2,h}_T$ and m^{2,A^0}_T leads in total to five physical mass eigenstates and one neutral Goldstone boson which becomes the longitudinal component of the Z-boson. The five physical degrees of freedom are: three CP-even Higgs bosons denoted $h_{1,2,3}$ and two CP-odd bosons denoted $A^0_{1,2}$. The corresponding rotation matrices Z^h und Z^{A^0} are defined through

$$Z^x m^{2,x} Z^{x,T} = m^{2,x}_{\mathrm{diag}}, \qquad x = h, A^0\,. \tag{2.28}$$

Moreover, we note that we order all masses such, that $m_i \leq m_j$ if $i < j$.

The one-loop scalar Higgs masses are then calculated by taking the real part of the poles of the corresponding propagator matrices

$$\mathrm{Det}\left[p_i^2 \mathbf{1} - m^{2,h}_{1L}(p^2)\right] = 0, \tag{2.29}$$

where

$$m^{2,h}_{1L}(p^2) = \tilde{m}^{2,h}_T - \Pi_{hh}(p^2). \tag{2.30}$$

Here, $\tilde{m}_h$ is the tree-level mass matrix from eq. (2.15). Equation (2.29) has to be solved for each eigenvalue $p^2 = m_i^2$. The same procedure is also applied for the pseudo scalar Higgs bosons. The complete 1-loop expressions for the self energy of the CP-odd and even Higgs bosons are given in apps. E.2 and E.3.

The charged Higgs sector consists of H_d^- and H_u^+. The mass matrix in the basis $\big(H_d^-, H_u^{+,*}\big)$ is diagonalized by a unitary matrix Z^+

$$Z^+ m^{2,H^+} Z^{+,\dagger} = m^{2,H^+}_{\mathrm{diag}}\,. \tag{2.31}$$

The eigenstates yield as in the MSSM the longitudinal component of the W-boson and a charged Higgs boson H^+ with mass

$$m^{2,H^+}_T = \frac{(v_d^2 + v_u^2)(2 v_s \mathrm{Re}\big\{\kappa\lambda\big\} + v_d v_u (g_2^2 - 2|\lambda|^2) + 2\sqrt{2} v_s \mathrm{Re}\big\{T_\lambda\big\})}{4 v_d v_u} \tag{2.32}$$

and the one-loop mass

$$m_{1L}^{2,H^+} = m_T^{2,H^+} - \mathrm{Re}\{\Pi_{H^+H^+}(m_{1L}^{2,H^+})\} \tag{2.33}$$

where the self-energy can be found in app. E.4

2.4 Chargino and neutralino masses

As for the Higgs bosons discussed in the previous section, one has to find the real parts of the poles of the propagator matrix to obtain the masses of charginos and neutralinos. At the tree-level the chargino mass matrix in the basis $\tilde{\psi}^- = (\tilde{W}^-, \tilde{H}_d^-)^T$, $\tilde{\psi}^+ = (\tilde{W}^+, \tilde{H}_u^+)$ is given by

$$\mathcal{L}_{\tilde{\psi}^+} = -\tilde{\psi}^{-T} M_T^{\tilde{\chi}^+} \tilde{\psi}^+ + \text{h.c.} \tag{2.34}$$

with

$$M_T^{\tilde{\chi}^+} = \begin{pmatrix} M_2 & \frac{1}{\sqrt{2}} g_2 v_u \\ \frac{1}{\sqrt{2}} g_2 v_d & \frac{1}{\sqrt{2}} v_s \lambda \end{pmatrix}. \tag{2.35}$$

This mass matrix is diagonalized by a biunitary transformation such that $U^* M_T^{\tilde{\chi}^+} V^\dagger$ is diagonal. The matrices U and V are obtained by diagonalizing $M_T^{\tilde{\chi}^+}(M_T^{\tilde{\chi}^+})^\dagger$ and $(M_T^{\tilde{\chi}^+})^*(M_T^{\tilde{\chi}^+})^T$, respectively. At the one-loop level, one has to add the self-energies

$$M_{1L}^{\tilde{\chi}^+}(p_i^2) = M_T^{\tilde{\chi}^+} - \Sigma_S^+(p_i^2) - \Sigma_R^+(p_i^2) M_T^{\tilde{\chi}^+} - M_T^{\tilde{\chi}^+} \Sigma_L^+(p_i^2). \tag{2.36}$$

In case of the neutralinos one has a complex symmetric 5×5 mass matrix which in the basis $\tilde{\psi}^0 = (\tilde{B}, \tilde{W}^0, \tilde{H}_d^0, \tilde{H}_u^0, \tilde{S})^T$ is at the tree-level given by

$$M_T^{\tilde{\chi}^0} = \begin{pmatrix} M_1 & 0 & -\frac{1}{2} g_1 v_d & \frac{1}{2} g_1 v_u & 0 \\ 0 & M_2 & \frac{1}{2} g_2 v_d & -\frac{1}{2} g_2 v_u & 0 \\ -\frac{1}{2} g_1 v_d & \frac{1}{2} g_2 v_d & 0 & -\frac{1}{\sqrt{2}} v_s \lambda & -\frac{1}{\sqrt{2}} v_u \lambda \\ \frac{1}{2} g_1 v_u & -\frac{1}{2} g_2 v_u & -\frac{1}{\sqrt{2}} v_s \lambda & 0 & -\frac{1}{\sqrt{2}} v_d \lambda \\ 0 & 0 & -\frac{1}{\sqrt{2}} v_u \lambda & -\frac{1}{\sqrt{2}} v_d \lambda & \sqrt{2} v_s \kappa \end{pmatrix}. \tag{2.37}$$

One can show that for real parameters the matrix $M_T^{\tilde{\chi}^0}$ can be diagonalized directly by a 5×5 mixing matrix N such that $N^* M_T^{\tilde{\chi}^0} N^\dagger$ is diagonal. In the complex case, one has to diagonalize $M_T^{\tilde{\chi}^0}(M_T^{\tilde{\chi}^0})^\dagger$. At the one-loop level we obtain

$$\begin{aligned} M_{1L}^{\tilde{\chi}^0}(p_i^2) = M_T^{\tilde{\chi}^0} - \frac{1}{2}\Big[& \Sigma_S^0(p_i^2) + \Sigma_S^{0,T}(p_i^2) + \left(\Sigma_L^{0,T}(p_i^2) + \Sigma_R^0(p_i^2)\right) M_T^{\tilde{\chi}^0} \\ & + M_T^{\tilde{\chi}^0} \left(\Sigma_R^{0,T}(p_i^2) + \Sigma_L^0(p_i^2)\right) \Big]. \end{aligned} \tag{2.38}$$

The complete self-energies for neutralinos and charginos are given in apps. E.5 and E.6, respectively.

2.5 Masses of sleptons

In the basis $(\tilde{e}_L, \tilde{\mu}_L, \tilde{\tau}_L, \tilde{e}_R, \tilde{\mu}_R, \tilde{\tau}_R)$, the mass matrix of the charged sleptons at the tree-level is given by

$$m_T^{2,\tilde{l}} = \begin{pmatrix} m_{LL}^2 & -\frac{1}{2}v_s v_u \lambda^* Y_e^T + \frac{1}{\sqrt{2}} v_d T_e^T \\ -\frac{1}{2}v_s v_u \lambda Y_e^* + \frac{1}{\sqrt{2}} v_d T_e^* & m_{RR}^2 \end{pmatrix} \tag{2.39}$$

with the diagonal entries

$$m_{LL}^2 = m_{\tilde{L}}^2 + \frac{v_d^2}{2}(Y_e)^*(Y_e)^T + \frac{1}{8}\Big(g_1^2 - g_2^2\Big)\Big(v_d^2 - v_u^2\Big)\mathbf{1}_3, \tag{2.40}$$

$$m_{RR}^2 = m_{\tilde{E}}^2 + \frac{v_d^2}{2}(Y_e)^T(Y_e)^* + \frac{g_1^2}{4}\Big(v_u^2 - v_d^2\Big)\mathbf{1}_3. \tag{2.41}$$

Where $\mathbf{1}_3$ is the 3×3 unit matrix. This matrix is diagonalized by a unitary mixing matrix Z^E:

$$Z^E m_T^{2,\tilde{l}} Z^{E\dagger} = m_{\text{diag}}^{2,\tilde{l}}\,. \tag{2.42}$$

The corresponding mass matrix at the one-loop level is again obtained by taking into account the self-energy according to

$$m_{1L}^{2,\tilde{l}}(p_i^2) = m_T^{2,\tilde{l}} - \Pi_{\tilde{l}\tilde{l}}(p_i^2), \tag{2.43}$$

and the one-loop masses are obtained by calculating the real parts of the poles of the propagator matrix. The expression for $\Pi_{\tilde{l}\tilde{l}}(p_i^2)$ can be found in app. E.7.

Finally, in the basis $(\tilde{\nu}_e, \tilde{\nu}_\mu, \tilde{\nu}_\tau)$ the tree-level sneutrino mass matrix is given by

$$m_T^{2,\tilde{\nu}} = m_{\tilde{L}}^2 + \frac{1}{8}\Big(g_1^2 + g_2^2\Big)\Big(v_d^2 - v_u^2\Big)\mathbf{1}_3. \tag{2.44}$$

This matrix is diagonalized by a unitary mixing matrix Z^E:

$$Z^\nu m_T^{2,\tilde{\nu}} Z^{\nu\dagger} = m_{\text{diag}}^{2,\tilde{\nu}}\,. \tag{2.45}$$

Similarly as above the one loop mass matrix is given by

$$m_{1L}^{2,\tilde{\nu}}(p_i^2) = m_T^{2,\tilde{\nu}} - \Pi_{\tilde{\nu}\tilde{\nu}}(p_i^2). \tag{2.46}$$

The one-loop masses are obtained by calculating the real parts of the poles of the propagator matrix. The expression for $\Pi_{\tilde{\nu}\tilde{\nu}}(p_i^2)$ can be found in app. E.8.

3. The constrained NMSSM

3.1 The model and its free parameters

In the subsequent numerical analysis, we are mainly interested in precision calculation of the SUSY masses and potential effects in the calculation of the relic density. To

reduce the number of free parameters we therefore focus on a scenario motivated by minimal supergravity (mSUGRA) [17]. More precisely, we study a variant of the constrained NMSSM [18, 19] where we allow for non-universal Higgs mass parameters squared at the GUT scale. In our setup, these parameters are determined with the help of the tadpole equations (2.13) at the electroweak scale. As a side remark, we note that also other recently used mSUGRA versions of the NMSSM contained non-minimal features either for the scalar mass parameter and/or for the trilinear couplings.

We apply the following boundary conditions for the gaugino masses M_1, M_2, M_3 and the soft breaking masses of the squarks and sleptons m_i^2 at the GUT scale, which is defined as the scale where the $U_Y(1)$ and $SU(2)_L$ couplings fulfill $\sqrt{\frac{5}{3}} g_1 = g_2$:

$$M_1 = M_2 = M_3 \equiv M_{1/2}, \tag{3.1}$$

$$m_{\tilde{D}}^2 = m_{\tilde{U}}^2 = m_{\tilde{Q}}^2 = m_{\tilde{E}}^2 = m_{\tilde{L}}^2 \equiv m_0^2 \, \mathbf{1}_3. \tag{3.2}$$

The trilinear scalar couplings T_i are given by

$$T_u = A_0 Y_u, \quad T_d = A_0 Y_d, \quad T_e = A_0 Y_e, \quad T_\lambda = A_\lambda \lambda, \quad \text{and} \quad T_\kappa = A_\kappa \kappa. \tag{3.3}$$

Here, A_0 is defined at the GUT scale, while λ, κ, A_λ and A_κ can be defined either at the GUT or at the SUSY scale. Together with the values for $\tan\beta = \frac{v_u}{v_d}$ and v_s the spectrum is fixed. To summarize, we have nine input parameters,

$$M_{1/2}, \quad m_0, \quad A_0, \quad \lambda, \quad \kappa, \quad A_\lambda, \quad A_\kappa, \quad v_s, \quad \text{and} \quad \tan\beta. \tag{3.4}$$

Note, that we allow for non-universalities in the trilinear parameters for an easier comparison with the existing literature but in principal we could take all A-parameters equal at the GUT scale. We choose in the following $v_s > 0$ and $\lambda, \kappa \in [-1, 1]$.

3.2 Procedure to evaluate the SUSY parameters at the electroweak scale

In order to connect the parameters at various scales, we use the renormalization group equations (RGEs), which are calculated at the two-loop level in the most general form using the generic formulas given in ref. [20]. We have compared the obtained expressions for the RGEs with those given in ref. [15] in the limit where only the third generation Yukawa couplings contributes. There has been a slight difference in the two-loop β-function of $A_\lambda = T_\lambda/\lambda$, but it was confirmed by the authors of ref. [15] that our result is correct. The RGEs themselves can easily be calculated by the `CalcRGEs` command of `SARAH` and a print-out can be found at [21].

In the calculation of the gauge and Yukawa couplings we follow closely the procedure described in ref. [22]: the values for the Yukawa couplings giving mass to the SM fermions and the gauge couplings are determined at the scale M_Z based on the measured values for the quark, lepton and vector boson masses as well as for the gauge

couplings. Here, we have included the one-loop corrections to the mass of W- and Z-boson as well as the SUSY contributions to δ_{VB} for calculating the gauge couplings. Similarly, we have included the complete one-loop corrections to the self-energies of SM fermions extending the formulas of [14] to include the additional neutralino and Higgs bosons. Moreover, we have resummed the $\tan\beta$ enhanced terms for the calculation of the Yukawa couplings of the b-quark and the τ-lepton as in [22]. The vacuum expectation values v_d and v_u are calculated with respect to the given value of $\tan\beta$ at M_Z. Furthermore, we solve the tadpole equations to get initial values for $m^2_{H_d}$, $m^2_{H_u}$ and m^2_S. Afterwards the RGEs are used to obtain the values at the GUT scale and all boundary conditions including λ and κ are set as described above. Then, an RGE running to the SUSY scale is performed and the SUSY masses are calculated at the one-loop level and for the neutral and pseudo scalar Higgs bosons we include beside the one-loop contributions presented here also the known two-loop contributions [13]. For this purpose also the numerical the values for the VEVs at $M_{\rm SUSY}$ are needed. These are derived using the two-loop RGEs

$$\beta_{v_i} = -v_i \left(\gamma_i^{(1)} + \gamma_i^{(2)}\right) \tag{3.5}$$

with $i = u, d$. Here, $\gamma_i^{(1)}$ and $\gamma_i^{(2)}$ are the anomalous dimensions for the two Higgs-doublets at the one- and two-loop level, respectively. The corresponding expressions are given in app. B. Let us recall that the input value for v_s is already given at $M_{\rm SUSY}$. These steps are iterated until the masses converge with a relative precision of 10^{-5}. The complete procedure has been implemented in `SPheno` [22][1].

3.3 An example spectrum

In Table 1 we give as an example the masses of the Higgs bosons, chargino, neutralinos and third generation sfermions at tree-level as well as at the one- and two- loop level for the parameter set

$$m_0 = 180 \text{ GeV}, m_{1/2} = 500 \text{ GeV},\ A_0 = A_\lambda^{\rm GUT} = -1500 \text{ GeV},\ A_\kappa^{\rm GUT} = -36 \text{ GeV},$$
$$\tan\beta = 10,\ \kappa^{\rm GUT} = 0.11,\ \lambda^{\rm GUT} = 0.1,\ v_s = 13689 \text{ GeV}\ .$$

which is close to the benchmark scenario 1 of ref. [18]. As can be seen in Table 1, the corrections are sizable ranging from 0.1 % to 23.6 % in case of the lightest Higgs boson. This large correction is well known and the main reason for including the two-loop corrections. The corresponding two-loop Higgs masses as well as the relative correction with respect to the one-loop results are also displayed in Table 1. Again the largest correction with 5.2 % is in case of the lightest Higgs boson mass.

As an estimate of the remaining theoretical uncertainty we have varied the renormalization scale in `SPheno`. We show in fig. 1 the scale dependence for masses of

[1] This special version can be obtained from the authors and will become public in the near future.

Particle	m_T [GeV]	m_{1L} [GeV]	Δ [%]	m_{2L} [GeV]	Δ [%]
h_1	86.7	113.3	23.5	119.6	5.2
h_2	863.1	934.2	7.6	937.3	0.3
h_3	2073.9	2073.9	< 0.1	2073.9	< 0.1
A_1^0	76.4	69.3	10.2	69.5	0.3
A_2^0	865.2	937.2	7.7	940.4	0.3
$\tilde{\chi}_1^0$	211.6	207.6	1.9	-	-
$\tilde{\chi}_2^0$	388.2	398.4	2.6	-	-
$\tilde{\chi}_3^0$	987.9	980.5	0.7	-	-
$\tilde{\chi}_4^0$	993.0	985.1	0.8	-	-
$\tilde{\chi}_5^0$	2074.8	2074.9	< 0.1	-	-
$\tilde{\chi}_1^+$	388.2	398.6	2.6	-	-
$\tilde{\chi}_2^+$	993.3	985.9	0.7	-	-
$\tilde{\tau}_1$	191.1	193.3	1.2	-	-
$\tilde{\tau}_2$	388.1	393.1	1.1	-	-
$\tilde{t}_1$	506.9	541.8	6.4	-	-
$\tilde{t}_2$	914.4	949.3	3.7	-	-
$\tilde{b}_1$	845.3	880.4	3.9	-	-
$\tilde{b}_2$	961.9	1008.5	4.6	-	-
$\tilde{g}$	1107.2	1154.2	4.1	-	-

Table 1: Comparison of the tree-level m_T and loop masses at 1-loop (m_{1L}) and 2-loop (m_{2L}). Δ is the relative difference $|1 - \frac{m_T}{m_{1L}}|$ respectively $|1 - \frac{m_{1L}}{m_{2L}}|$.

neutral scalar Higgs boson at the one- and two-loop masses normalized to their values at $Q = 1$ TeV and vary the renormalization scale Q between 200 GeV and 2.2 TeV. As can be seen, the large variation of 8% at one-loop for the lightest Higgs, which is mainly the lighter $SU(2)$ doublet Higgs in this case, is reduced at two-loop to less than 2%. In case of the heavier Higgs bosons the scale dependence is significantly smaller showing a significant improvement when going from the one-loop level to the two-loop level. However, we remark that the values of λ and κ are small in this scenario and we expect a stronger dependence in case of larger couplings.

The picture changes slightly in the case of the pseudo scalar bosons as can be seen in fig. 2. While the heavier pseudo scalar behaves exactly as the second scalar field since both originate to 99.5% from H_d, the scale dependence for the lighter pseudo scalar is smaller compared to the lightest scalar field, but hardly improves at the two-loop level. This is because in the two-loop part contain 'only' the strong contributions of the third generation squarks whereas this state is mainly a singlet state and, thus, the contributions due to the Yukawa couplings would be needed for a further improvement.

Figure 1: Dependence of CP even Higgs masses on the renormalization scale Q at 1-loop (red) and 2-loop level (dashed blue) normalized to the value at $Q = 1$ TeV. From left to right: m_{h_1}, m_{h_2} and m_{h_3}.

Figure 2: Dependence of CP odd Higgs masses on the renormalization scale Q at 1-loop (red) and 2-loop level (dashed blue) normalized to the value at $Q = 1$ TeV. Left: $m_{A_1^0}$. Right: $m_{A_2^0}$.

In Figure 3 the scale dependence for different neutralinos is shown. As can be seen, in case of the three lighter states the scale dependence is reduced from the level of about 1.5% to 3-5 per-mill. In case of the singlet state $\tilde{\chi}_5$ the scale dependence is already small due to the small values of λ and κ. We note that the scale dependence of $\tilde{\chi}_1^+$ ($\tilde{\chi}_2^+$ and $\tilde{\chi}_4^0$) is nearly the same as that of $\tilde{\chi}_2^0$ ($\tilde{\chi}_3^0$) as these state have their main origin in the same electroweak multiplet.

Finally we show in fig. 4 the scale dependence of the staus. The scale dependence at tree level amounts to about 2-2.5% and is reduced at one-loop level to about 1% and less where the $\tilde{\tau}_1$ shows still the larger dependence. The sleptons of the first two generations show a somewhat smaller scale dependence as in their cases the Yukawa couplings do not play any role.

4. Comparison with the literature

To date, the program package `NMSSM-Tools` [12] has been the only complete spectrum calculator for the NMSSM. `NMSSM-Tools` uses for the constrained NMSSM the parameters m_0, $M_{1/2}$, A_0 and A_κ at the GUT scale whereas $\tan\beta$ and λ are given at

Figure 3: Dependence of the masses of the light neutralinos on the renormalization scale Q at tree (red) and 1-loop level (dashed blue) normalized to the value at $Q = 1$ TeV: From left to right and from above to below: $m_{\tilde{\chi}_1^0}$, $m_{\tilde{\chi}_2^0}$, $m_{\tilde{\chi}_3^0}$ and $m_{\tilde{\chi}_5^0}$.

Figure 4: Dependence of the stau masses of the sleptons on the renormalization scale Q at tree (red) and 1-loop level (dashed blue) normalized to the value at $Q = 1$ TeV.

the electroweak scale. Moreover, in `NMSSM-Tools` the tadpole equations are solved with respect to $|v_s|$, κ, and m_S^2. We have performed a detailed numerical comparison of our implementation with the version 2.3.1 and present here a few typical examples.

4.1 Differences between the programs

Since both programs use different methods to calculate the spectrum, we have also done a comparison where we modified the codes such that both codes use equivalent

methods except for small details. First, the implementation of NMSSM-Tools involves two different scales, namely the SUSY scale defined as

$$Q^2_{\rm SUSY} = M^2_{\rm SUSY} = \frac{1}{4}\left(2m^2_{\tilde{q}_{11}} + m^2_{\tilde{u}_{11}} + m^2_{\tilde{d}_{11}}\right), \tag{4.1}$$

and the scale at which the masses are calculated,

$$Q^2_{\rm STSB} = m_{\tilde{q}_3} m_{\tilde{u}_3}. \tag{4.2}$$

In SPheno, all masses are evaluated at the SUSY scale, so that we had to set $Q_{\rm STSB} = Q_{\rm SUSY}$ in the relevant routines of NMSSM-Tools. Second, as already stated in sec. 3.2, the two-loop β function of A_λ has been corrected in the public version of NMSSM-Tools. However, in general the numerical effect on the spectrum is rather small.

In the Higgs sector the loop contributions are taken into account differently in both codes. While SPheno takes the complete one-loop correction including the dependence of the external momenta, NMSSM-Tools uses the effective potential approach, e.g. setting the external momenta to zero. NMSSM-Tools calculates afterwards the momentum dependent contributions from top and bottom quarks. Also the included contributions differ: in SPheno the complete one-loop corrections to both, scalar and pseudo scalar Higgs bosons, and the two-loop contributions as given in ref. [13] are included. In NMSSM-Tools beside the dominant contributions due to third generation sfermions also electroweak corrections and some leading two-loop corrections for the scalars are calculated, while for the pseudo-scalars only the dominant one-loop corrections due to tops, stops, bottoms, and sbottoms are included. In addition, some corrections due to charginos and neutralinos are absorbed in a redefined A_λ. To account for these differences we have switched off the two-loop parts in both codes. Furthermore, we have set the external momenta of the loop-diagrams of scalars in SPheno to zero. Finally, we have kept only those corrections to the pseudo-scalar masses in SPheno which are also included in NMSSM-Tools, but neglected the additional corrections absorbed in A_λ. In the following, we refer to these modified versions by SPheno mod and NMSSM-Tools mod, respectively.

Also in the chargino and neutralino sector the implementations are different: in SPheno the complete one-loop corrections are implemented whereas in NMSSM-Tools the corrections to the parameters M_1, M_2, and $\mu_{\rm eff}$ are taken into account. In the slepton sector the differences are largest: SPheno contains the complete one-loop corrections whereas in NMSSM-Tools the calculation is done at tree-level. Last but not least we note that the data transfer has been done using the SLHA2 conventions [23].

4.2 Results of the comparison

As a first reference scenario, we take the benchmark point 1 proposed in ref. [18].

The corresponding input parameters for NMSSM-Tools are

$$m_0 = 180\,\text{GeV},\ m_{1/2} = 500\,\text{GeV},\ \text{A}_0 = -1500\,\text{GeV},\ \tan\beta = 10,$$
$$\lambda^{\text{SUSY}} = 0.1,\ A_\kappa^{\text{GUT}} = -33.45,\ \mu_{\text{eff}} > 0. \tag{4.3}$$

In the following we will vary m_0 and the keep the other parameters to the values shown here.

In the left graph of fig. 5, we show the mass of the lightest scalar h_1 as a function of m_0. The largest discrepancies arise for the lighter scalar and pseudo scalar boson, where the relative differences between the complete calculation of both programs amount up to 2.5 and 35%, respectively. In case of h_1^0 this is a combination of the p^2 terms in the loop-functions and the additional two-loop contributions. The differences in case of A_1^0 can easily be understood by noting that in NMSSM-Tools only the contribution of third-generation sfermions are taken into account whereas we include the complete one-loop corrections plus the known two-loop contributions. In case of the modified program codes these differences reduce to at most 2% which is meanly due to two differences: (i) the way the top Yukawa coupling is calculated and (ii) the way the tadpole equations are solved which leads to somewhat different values between the two programs. There is no visible difference between NMSSM-Tools and NMSSM-Tools mod for the pseudo scalar and the heavy scalars. The reason is that in the case of the pseudo scalar no two-loop corrections are calculated in NMSSM-Tools and in case of the heavy scalars they are very small.

Finally, we have also cross-checked our results in the Higgs sector with ref. [13] and we have found agreement better than one per-mill when using the set of soft SUSY parameters at the scale Q_{STSB}. This small difference is an effect of the Yukawa and scalar-trilinear couplings of the first two generations which we take also into account. If we restrict ourself to third generation couplings there is an exact agreement between both calculations.

Concerning the chargino and neutralino masses, the agreement between the two spectrum calculators is rather good as can be seen in fig. 6. The relative differences are at most 1% and in general slightly below 0.5%. In case of the sleptons the differences are more pronounced as can be seen in fig. 7 which is due to the differences between tree-level and one-loop calculation and amounts in up to 3% and 0.6% for the light and heavy stau, respectively. Note, that although for LHC physics one expects similar experimental uncertainties, this precision necessary for a future linear collider or dark matter calculation require the inclusion of the radiative corrections to the slepton masses.

5. Effects on the relic density of dark matter

It is well known that the prediction of the dark matter relic density $\Omega_{\text{CDM}}h^2$ is very sensitive to the exact mass configuration of the scenario under consideration [24]. For

Figure 5: Comparison of the masses in GeV of the lightest scalar (upper left) , the lightest pseudo scalar (upper right), heavier scalar masses (lower left) and heavier pseudo scalar mass (lower right) as a function of m_0 (in GeV). All other parameters are fixed as in eq. (4.3). The lines correspond to: are for unmodified version of `SPheno` (full red), `NMSSM-Tools` (dotted blue), `SPheno mod` (dashed red) and `NMSSM-Tools mod` (dot-dashed blue).

a neutralino LSP, this is, e.g., the case for the annihilation through Higgs-resonances, but also in the case of neutralino-sfermion co-annihilation. For the latter, the mass difference between the two particles plays a key role in the calculation of the resulting relic density. Therefore, it is necessary to calculate the complete spectrum as precisely as possible to get viable results of allowed regions of parameter space with respect to the constraints imposed by the presence of dark matter. Let us recall that recent measurements by the WMAP satellite in combination with further cosmological data lead to the favored interval

$$0.1018 < \Omega_{\rm CDM} h^2 < 0.1228 \tag{5.1}$$

at 3σ confidence level [25].

We compute the relic density of the lightest neutralino using the public program package `micrOMEGAs 2.4.0` [26]. To this end, we have implemented the NMSSM particle content and corresponding interactions into a model file for `CalcHEP` [27], which is used by `micrOMEGAs` to evaluate the (co)annihilation cross-section. The relevant interactions have again been calculated and written into the model files by

Figure 6: Comparison of chargino and neutralino masses (in GeV) as a function of m_0 (in GeV). All other parameters are fixed as in eq. (4.3). The lines correspond to the unmodified versions of `SPheno` (full red) and `NMSSM-Tools` (dashed blue). Up left: light neutralinos $\tilde{\chi}_1^0$. Up right: neutralino $\tilde{\chi}_2$ and chargino $\tilde{\chi}_1^+$ (`SPheno`: black dotdashed, `NMSSM-Tools`: black dotted). Down left: neutralinos $\tilde{\chi}_3$ (thin lines), $\tilde{\chi}_4$ (thick lines) and chargino $\tilde{\chi}_2^+$ (`SPheno`: black dotdashed, `NMSSM-Tools`: green dotted). Down right: $\tilde{\chi}_5$.

the program package `SARAH`. Let us note, that we take into account important QCD effects, such as the running strong coupling constant and the running quark masses [28, 29, 30].

As an example, we illustrate the effect of the one-loop correction to the slepton masses on the dark matter relic density in a region of dominant neutralino-stau coannihilations. In fig. 8, we show the isolines corresponding to the upper and lower limit of eq. (5.1) in the m_0–$m_{1/2}$ plane. All remaining parameters of eq. (3.4) are fixed to

$$\begin{aligned} \tan\beta = 15,\ \kappa^{\rm SUSY} = -0.05,\ \lambda^{\rm SUSY} = -0.1, \\ A_\kappa^{\rm GUT} = 30\,{\rm GeV},\ A_0 = A_\lambda^{\rm GUT} = 1000\,{\rm GeV}, v_s = 2\cdot 10^4\,{\rm GeV}. \end{aligned} \tag{5.2}$$

One clearly sees that the allowed parameter range gets shifted depending on the precision with which the spectrum is calculated. More, the two regions shown do not overlap as can also be clearly be seen in the figure to the right.

Figure 7: Comparison of selectron and stau masses (in GeV) as a function of m_0. All other parameters are fixed as in eq. (4.3). The lines correspond to the unmodified versions of `SPheno` (full red) and `NMSSM-Tools` (dashed blue).

Figure 8: The isolines corresponding to $\Omega_{\rm CDM}h^2 = 0.1018$ and $\Omega_{\rm CDM}h^2 = 0.1228$ in the m_0–$m_{1/2}$ plane for dominant neutralino-stau coannihilations. All other parameters are fixed as in eq. (5.2). The red solid lines have been obtained for the complete mass spectrum at the one-loop level, while for the black dashed line the loop corrections to the slepton masses have been disabled. The right graph corresponds to a zoom into the left one.

For a point with $\Omega_{\rm CDM}h^2 = 0.112$ at $m_{1/2} \simeq 451.2$ GeV, the resulting one-loop corrected masses of the lightest neutralino and the lighter stau are $m_{\tilde{\chi}_1^0} = 186.0$ GeV and $m_{\tilde{\tau}_1} = 196.8$ GeV, respectively. In consequence, coannihilations account for about 60% of the total annihilation cross-section, where the most important final states are τh_1 (27%) and τZ^0 (15%). A sizable contribution of about 14% (5%) comes also from stau-antistau (stau-stau) annihilation. The remaining contributions are mainly from neutralino pair annihilation. For lower values of $m_{1/2} \lesssim 200$ GeV, the coannihilations become less important within the WMAP-favored region, the dominant mechanism is then neutralino pair annihilation into $\tau^+\tau^-$ pairs through stau-exchange.

6. Conclusion

The NMSSM is an attractive extension of the MSSM, in particular as it solves the μ-problem of the MSSM and as it leads to new phenomenology at present and future collider experiments. It can also explain the observed amount of dark matter in the universe. However, in particular for comparison of the WMAP data improved theoretical predictions are necessary. We therefore have presented in this paper the complete one-loop calculation of the electroweak sector: Higgs bosons, charginos, neutralinos and sleptons. While in case of the Higgs bosons we have reproduced known results, the corrections to the other particles have not yet been discussed in the literature. We have shown that the corrections amount to the order of a few percent. While the corrections are most likely below the precision of the coming LHC data, they are clearly important for comparison with WMAP data and also with a future international linear collider, and thus crucial for precision investigations of the NMSSM parameter space.

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A. Squark mass matrices

For completeness, we display here the mass matrices of the squarks, since they also enter the one-loop corrections and are particularly important in the case of the Higgs-bosons. In the basis $\left(\tilde{d}_L, \tilde{s}_L, \tilde{b}_L, \tilde{d}_R, \tilde{s}_R, \tilde{b}_R\right)$, the mass matrix for the down-type squarks is given by

$$m_T^{2,\tilde{d}} = \begin{pmatrix} m_{LL}^{2,d} & \frac{1}{2}\left(\sqrt{2} v_d T_d^T - v_s v_u \lambda^* Y_d^T\right) \\ \frac{1}{2}\left(\sqrt{2} v_d T_d^* - v_s v_u \lambda Y_d^*\right) & m_{RR}^{2,d} \end{pmatrix}, \tag{A.1}$$

where the diagonal entries read

$$\begin{aligned} m_{LL}^{2,d} &= m_{\tilde{Q}}^2 + \frac{v_d^2}{2} Y_d^* Y_d^T - \frac{3g_2^2 + g_1^2}{24}\left(v_d^2 - v_u^2\right)\mathbf{1}_3, \\ m_{RR}^{2,d} &= m_{\tilde{D}}^2 + \frac{v_d^2}{2} Y_d^T Y_d^* + \frac{g_1^2}{12}\left(v_u^2 - v_d^2\right)\mathbf{1}_3. \end{aligned} \tag{A.2}$$

The corresponding expressions for the up-type squarks in the basis $\left(\tilde{u}_L, \tilde{c}_L, \tilde{t}_L, \tilde{u}_R, \tilde{c}_R, \tilde{t}_R\right)$ are

$$m_T^{2,\tilde{u}} = \begin{pmatrix} m_{LL}^{2,u} & \frac{1}{2}\left(\sqrt{2} v_u T_u^T - v_d v_s \lambda^* Y_u^T\right) \\ \frac{1}{2}\left(\sqrt{2} v_u T_u^* - v_d v_s \lambda Y_u^*\right) & m_{RR}^{2,u} \end{pmatrix} \tag{A.3}$$

with

$$\begin{aligned} m_{LL}^{2,u} &= m_{\tilde{Q}}^2 + \frac{v_u^2}{2} Y_u^* Y_u^T + \frac{3g_2^2 - g_1^2}{24}\left(v_d^2 - v_u^2\right)\mathbf{1}_3, \\ m_{RR}^{2,u} &= m_{\tilde{U}}^2 + \frac{v_u^2}{2} Y_u^T Y_u^* + \frac{g_1^2}{6}\Big(v_d^2 - v_u^2\Big)\mathbf{1}_3 \end{aligned} \tag{A.4}$$

These matrix are diagonalized by unitary mixing matrices Z^Q:

$$Z^Q m_T^{2,\tilde{q}} Z^{Q\dagger} = m_{\text{diag}}^{2,\tilde{q}}\ ,\ q = d, u\,. \tag{A.5}$$

B. Anomalous Dimensions

In this app., we give the detailed expressions of the anomalous dimension of the Higgs-fields, which are needed for the RGE evaluation of the VEVs.

$$\gamma_{\hat{H}_d}^{(1)} = 3\text{Tr}\Big(Y_d Y_d^\dagger\Big) - \frac{3}{10}g_1^2 - \frac{3}{2}g_2^2 + |\lambda|^2 + \text{Tr}\Big(Y_e Y_e^\dagger\Big) \tag{B.1}$$

$$\begin{aligned} \gamma_{\hat{H}_d}^{(2)} = {} & \frac{207}{100}g_1^4 + \frac{9}{10}g_1^2 g_2^2 + \frac{15}{4}g_2^4 - 2|\lambda|^2|\kappa|^2 - 3|\lambda|^4 - \frac{2}{5}g_1^2\text{Tr}\Big(Y_d Y_d^\dagger\Big) \\ & + 16{g_3}^2\text{Tr}\Big(Y_d Y_d^\dagger\Big) + \frac{6}{5}g_1^2\text{Tr}\Big(Y_e Y_e^\dagger\Big) - 3|\lambda|^2\text{Tr}\Big(Y_u Y_u^\dagger\Big) - 9\text{Tr}\Big(Y_d Y_d^\dagger Y_d Y_d^\dagger\Big) \\ & - 3\text{Tr}\Big(Y_d Y_d^\dagger Y_u Y_u^\dagger\Big) - 3\text{Tr}\Big(Y_e Y_e^\dagger Y_e Y_e^\dagger\Big) \end{aligned} \tag{B.2}$$

$$\gamma_{\hat{H}_u}^{(1)} = 3\text{Tr}\Big(Y_u Y_u^\dagger\Big) - \frac{3}{10}g_1^2 - \frac{3}{2}g_2^2 + |\lambda|^2 \tag{B.3}$$

$$\begin{aligned} \gamma_{\hat{H}_u}^{(2)} = {} & \frac{207}{100}g_1^4 + \frac{9}{10}g_1^2 g_2^2 + \frac{15}{4}g_2^4 - 2|\lambda|^2|\kappa|^2 - 3|\lambda|^4 - 3|\lambda|^2\text{Tr}\Big(Y_d Y_d^\dagger\Big) \\ & - |\lambda|^2\text{Tr}\Big(Y_e Y_e^\dagger\Big) + \frac{4}{5}g_1^2\text{Tr}\Big(Y_u Y_u^\dagger\Big) + 16{g_3}^2\text{Tr}\Big(Y_u Y_u^\dagger\Big) - 3\text{Tr}\Big(Y_d Y_d^\dagger Y_u Y_u^\dagger\Big) \\ & - 9\text{Tr}\Big(Y_u Y_u^\dagger Y_u Y_u^\dagger\Big) \end{aligned} \tag{B.4}$$

$$\gamma_{\hat{s}}^{(1)} = 2|\kappa|^2 + 2|\lambda|^2 \tag{B.5}$$

$$\begin{aligned} \gamma_{\hat{s}}^{(2)} = {} & \frac{6}{5}g_1^2|\lambda|^2 + 6g_2^2|\lambda|^2 - 8|\kappa|^4 - 8|\lambda|^2|\kappa|^2 - 4|\lambda|^4 - 6|\lambda|^2\text{Tr}\Big(Y_d Y_d^\dagger\Big) \\ & - 2|\lambda|^2\text{Tr}\Big(Y_e Y_e^\dagger\Big) - 6|\lambda|^2\text{Tr}\Big(Y_u Y_u^\dagger\Big) \end{aligned} \tag{B.6}$$

C. Couplings

We list in the following all couplings of the NMSSM which contribute to the electroweak self-energies or influence the annihilation or coannihilation of the neutralino.

These and all other couplings of the NMSSM can be derived with the command `MakeVertexList[EWSB]` of `SARAH`. A pdf version is also available at [21].

We define the following abbreviations:

$$\tilde{\lambda} \equiv +g_1^2 + g_2^2 - 4\lambda^2 \tag{C.1}$$
$$\bar{\lambda} \equiv g_2^2 - 2\lambda^2 \tag{C.2}$$
$$g_-^2 \equiv g_2^2 - g_1^2 \tag{C.3}$$
$$g_+^2 \equiv g_1^2 + g_2^2 \tag{C.4}$$
$$\Lambda_1 \equiv 2v_s\kappa\lambda^* + 2v_s\lambda\kappa^* + \sqrt{2}\,2\,\mathrm{Re}\{T_\lambda\} \tag{C.5}$$
$$\Lambda_2 \equiv -2v_u\lambda + v_d\kappa \tag{C.6}$$
$$\Lambda_3 \equiv -2v_d\lambda + v_u\kappa \tag{C.7}$$

Furthermore, c_Θ is $\cos(\Theta_W)$ and s_Θ is $\sin(\Theta_W)$.

C.1 Two fermion - One Scalar

$$\begin{aligned}\Gamma^L_{\tilde{\chi}^0_{t_1}\tilde{\chi}^0_{t_2}h_{t_3}} =& \frac{i}{2}\Big(- g_2 N^*_{t_1 2} N^*_{t_2 3} Z^H_{t_3 1} + \sqrt{2}\lambda N^*_{t_1 5} N^*_{t_2 4} Z^H_{t_3 1} + \sqrt{2}\lambda N^*_{t_1 4} N^*_{t_2 5} Z^H_{t_3 1} \\ & - g_1 N^*_{t_1 4} N^*_{t_2 1} Z^H_{t_3 2} + g_2 N^*_{t_1 4} N^*_{t_2 2} Z^H_{t_3 2} + \sqrt{2}\lambda N^*_{t_1 5} N^*_{t_2 3} Z^H_{t_3 2} + g_2 N^*_{t_1 2} N^*_{t_2 4} Z^H_{t_3 2} \\ & + g_1 N^*_{t_1 1}\Big(N^*_{t_2 3} Z^H_{t_3 1} - N^*_{t_2 4} Z^H_{t_3 2}\Big) + \sqrt{2}\lambda N^*_{t_1 4} N^*_{t_2 3} Z^H_{t_3 3} - 2\sqrt{2}\kappa N^*_{t_1 5} N^*_{t_2 5} Z^H_{t_3 3} \\ & + N^*_{t_1 3}\Big(g_1 N^*_{t_2 1} Z^H_{t_3 1} - g_2 N^*_{t_2 2} Z^H_{t_3 1} + \sqrt{2}\lambda\Big(N^*_{t_2 4} Z^H_{t_3 3} + N^*_{t_2 5} Z^H_{t_3 2}\Big)\Big)\Big)\end{aligned} \tag{C.8}$$

$$\begin{aligned}\Gamma^R_{\tilde{\chi}^0_{t_1}\tilde{\chi}^0_{t_2}h_{t_3}} =& \frac{i}{2}\Big(Z^H_{t_3 1}\Big(N_{t_1 3}\Big(g_1 N_{t_2 1} - g_2 N_{t_2 2}\Big) + g_1 N_{t_1 1} N_{t_2 3} - g_2 N_{t_1 2} N_{t_2 3} + \sqrt{2}\lambda^* N_{t_1 5} N_{t_2 4} \\ & + \sqrt{2}\lambda^* N_{t_1 4} N_{t_2 5}\Big) + \sqrt{2} Z^H_{t_3 3}\Big(- 2\kappa^* N_{t_1 5} N_{t_2 5} + \lambda^*\Big(N_{t_1 3} N_{t_2 4} + N_{t_1 4} N_{t_2 3}\Big)\Big) \\ & + Z^H_{t_3 2}\Big(N_{t_1 4}\Big(- g_1 N_{t_2 1} + g_2 N_{t_2 2}\Big) + \Big(- g_1 N_{t_1 1} + g_2 N_{t_1 2}\Big) N_{t_2 4} \\ & + \sqrt{2}\lambda^*\Big(N_{t_1 3} N_{t_2 5} + N_{t_1 5} N_{t_2 3}\Big)\Big)\Big)\end{aligned} \tag{C.9}$$

$$\begin{aligned}\Gamma^L_{\tilde{\chi}^0_{t_1}\tilde{\chi}^0_{t_2}A^0_{t_3}} =& \frac{1}{2}\Big(- g_2 N^*_{t_1 2} N^*_{t_2 3} Z^A_{t_3 1} - \sqrt{2}\lambda N^*_{t_1 5} N^*_{t_2 4} Z^A_{t_3 1} - \sqrt{2}\lambda N^*_{t_1 4} N^*_{t_2 5} Z^A_{t_3 1} \\ & - g_1 N^*_{t_1 4} N^*_{t_2 1} Z^A_{t_3 2} + g_2 N^*_{t_1 4} N^*_{t_2 2} Z^A_{t_3 2} - \sqrt{2}\lambda N^*_{t_1 5} N^*_{t_2 3} Z^A_{t_3 2} + g_2 N^*_{t_1 2} N^*_{t_2 4} Z^A_{t_3 2} \\ & - N^*_{t_1 1}\Big(- g_1 N^*_{t_2 3} Z^A_{t_3 1} + g_1 N^*_{t_2 4} Z^A_{t_3 2}\Big) - \sqrt{2}\lambda N^*_{t_1 4} N^*_{t_2 3} Z^A_{t_3 3} \\ & + 2\sqrt{2}\kappa N^*_{t_1 5} N^*_{t_2 5} Z^A_{t_3 3} - N^*_{t_1 3}\Big(- g_1 N^*_{t_2 1} Z^A_{t_3 1} + g_2 N^*_{t_2 2} Z^A_{t_3 1} \\ & + \sqrt{2}\lambda\Big(N^*_{t_2 4} Z^A_{t_3 3} + N^*_{t_2 5} Z^A_{t_3 2}\Big)\Big)\Big)\end{aligned} \tag{C.10}$$

$$\begin{aligned}\Gamma^R_{\tilde{\chi}^0_{t_1}\tilde{\chi}^0_{t_2}A^0_{t_3}} =& \frac{1}{2}\Big(- Z^A_{t_3 1}\Big(N_{t_1 3}\Big(g_1 N_{t_2 1} - g_2 N_{t_2 2}\Big) + g_1 N_{t_1 1} N_{t_2 3} - g_2 N_{t_1 2} N_{t_2 3} \\ & - \sqrt{2}\lambda^* N_{t_1 5} N_{t_2 4} - \sqrt{2}\lambda^* N_{t_1 4} N_{t_2 5}\Big) + \sqrt{2} Z^A_{t_3 3}\Big(- 2\kappa^* N_{t_1 5} N_{t_2 5}\end{aligned}$$

$$+\lambda^*\Big(N_{t_13}N_{t_24}+N_{t_14}N_{t_23}\Big)\Big)+Z^A_{t_32}\Big(N_{t_14}\Big(g_1N_{t_21}-g_2N_{t_22}\Big)$$
$$+\Big(g_1N_{t_11}-g_2N_{t_12}\Big)N_{t_24}+\sqrt{2}\lambda^*\Big(N_{t_13}N_{t_25}+N_{t_15}N_{t_23}\Big)\Big)\Big) \tag{C.11}$$

$$\Gamma^L_{\tilde\chi^0_{t_1}\tilde\chi^-_{t_2}H^+_{t_3}}=i\Big(-g_2V^*_{t_21}N^*_{t_13}Z^+_{t_31}+V^*_{t_22}\Big(\frac{1}{\sqrt2}g_1N^*_{t_11}Z^+_{t_31}+\frac{1}{\sqrt2}g_2N^*_{t_12}Z^+_{t_31}-\lambda N^*_{t_15}Z^+_{t_32}\Big)\Big) \tag{C.12}$$

$$\Gamma^R_{\chi_{t_1}\tilde\chi^-_{t_2}H^+_{t_3}}=i\Big(-\frac{1}{2}\Big(2g_2U_{t_21}N_{t_14}+\sqrt2U_{t_22}\Big(g_1N_{t_11}+g_2N_{t_12}\Big)\Big)Z^+_{t_32}-\lambda^*U_{t_22}N_{t_15}Z^+_{t_31}\Big) \tag{C.13}$$

$$\Gamma^L_{\tilde\chi^-_{t_1}\tilde\chi^+_{t_2}h_{t_3}}=-i\frac{1}{\sqrt2}\Big(g_2V^*_{t_21}U^*_{t_12}Z^H_{t_32}+V^*_{t_22}\Big(g_2U^*_{t_11}Z^H_{t_31}+\lambda U^*_{t_12}Z^H_{t_33}\Big)\Big) \tag{C.14}$$

$$\Gamma^R_{\tilde\chi^-_{t_1}\tilde\chi^+_{t_2}h_{t_3}}=-i\frac{1}{\sqrt2}\Big(g_2V_{t_11}U_{t_22}Z^H_{t_32}+V_{t_12}\Big(g_2U_{t_21}Z^H_{t_31}+\lambda^*U_{t_22}Z^H_{t_33}\Big)\Big) \tag{C.15}$$

$$\Gamma^L_{\tilde\chi^-_{t_1}\tilde\chi^+_{t_2}A^0_{t_3}}=-\frac{1}{\sqrt2}\Big(g_2V^*_{t_21}U^*_{t_12}Z^A_{t_32}+V^*_{t_22}\Big(g_2U^*_{t_11}Z^A_{t_31}-\lambda U^*_{t_12}Z^A_{t_33}\Big)\Big) \tag{C.16}$$

$$\Gamma^R_{\tilde\chi^-_{t_1}\tilde\chi^+_{t_2}A^0_{t_3}}=\frac{1}{\sqrt2}\Big(g_2V_{t_11}U_{t_22}Z^A_{t_32}+V_{t_12}\Big(g_2U_{t_21}Z^A_{t_31}-\lambda^*U_{t_22}Z^A_{t_33}\Big)\Big) \tag{C.17}$$

$$\Gamma^R_{\bar\nu_{t_1}\tilde\chi^0_{t_2}\tilde\nu_{t_3}}=i\frac{1}{\sqrt2}Z^{\nu,*}_{t_3t_1}\Big(g_1N_{t_21}-g_2N_{t_22}\Big) \tag{C.18}$$

$$\Gamma^R_{\bar\nu_{t_1}\tilde\chi^+_{t_2}\tilde e_{t_3}}=i\Big(-g_2Z^{E,*}_{t_3t_1}V_{t_21}+\sum_{j_1=1}^{3}Y^*_{e,t_1j_1}Z^{E,*}_{t_33+j_1}V_{t_22}\Big) \tag{C.19}$$

$$\Gamma^R_{\bar\nu_{t_1}e_{t_2}H^+_{t_3}}=i\sum_{j_1=1}^{3}Y^*_{e,t_1j_1}U^e_{R,t_2j_1}Z^+_{t_31} \tag{C.20}$$

$$\Gamma^L_{\tilde\chi^0_{t_1}e_{t_2}\tilde e^*_{t_3}}=i\Big(\frac{1}{\sqrt2}g_1N^*_{t_11}\sum_{j_1=1}^{3}U^{e,*}_{L,t_2j_1}Z^E_{t_3j_1}+\frac{1}{\sqrt2}g_2N^*_{t_12}\sum_{j_1=1}^{3}U^{e,*}_{L,t_2j_1}Z^E_{t_3j_1}$$
$$-N^*_{t_13}\sum_{j_2=1}^{3}\sum_{j_1=1}^{3}U^{e,*}_{L,t_2j_1}Y_{e,j_1j_2}Z^E_{t_33+j_2}\Big) \tag{C.21}$$

$$\Gamma^R_{\tilde\chi^0_{t_1}e_{t_2}\tilde e^*_{t_3}}=i\Big(-\sqrt2g_1\sum_{j_1=1}^{3}Z^E_{t_33+j_1}U^e_{R,t_2j_1}N_{t_11}-\sum_{j_2=1}^{3}\sum_{j_1=1}^{3}Y^*_{e,j_1j_2}Z^E_{t_3j_1}U^e_{R,t_2j_2}N_{t_13}\Big) \tag{C.22}$$

$$\Gamma^L_{\tilde\chi^0_{t_1}d_{t_2\alpha_2}\tilde d^*_{t_3\alpha_3}}=-\frac{i}{6}\delta_{\alpha_2,\alpha_3}\Big(\sqrt2g_1N^*_{t_11}\sum_{j_1=1}^{3}U^{d,*}_{L,t_2j_1}Z^D_{t_3j_1}-3\sqrt2g_2N^*_{t_12}\sum_{j_1=1}^{3}U^{d,*}_{L,t_2j_1}Z^D_{t_3j_1}$$
$$+6N^*_{t_13}\sum_{j_2=1}^{3}\sum_{j_1=1}^{3}U^{d,*}_{L,t_2j_1}Y_{d,j_1j_2}Z^D_{t_33+j_2}\Big) \tag{C.23}$$

$$\Gamma^R_{\tilde{\chi}^0_{t_1} d_{t_2\alpha_2} \tilde{d}^*_{t_3\alpha_3}} = -\frac{i}{3}\delta_{\alpha_2,\alpha_3}\Big(\sqrt{2}g_1 \sum_{j_1=1}^{3} Z^D_{t_3 3+j_1} U^d_{R,t_2 j_1} N_{t_1 1} + 3\sum_{j_2=1}^{3}\sum_{j_1=1}^{3} Y^*_{d,j_1 j_2} Z^D_{t_3 j_1} U^d_{R,t_2 j_2} N_{t_1 3}\Big) \tag{C.24}$$

$$\begin{aligned}\Gamma^L_{\tilde{\chi}^0_{t_1} u_{t_2\alpha_2} \tilde{u}^*_{t_3\alpha_3}} = &-\frac{i}{6}\delta_{\alpha_2,\alpha_3}\Big(\sqrt{2}g_1 N^*_{t_1 1}\sum_{j_1=1}^{3} U^{u,*}_{L,t_2 j_1} Z^U_{t_3 j_1} + 3\sqrt{2}g_2 N^*_{t_1 2}\sum_{j_1=1}^{3} U^{u,*}_{L,t_2 j_1} Z^U_{t_3 j_1} \\ &+ 6N^*_{t_1 4}\sum_{j_2=1}^{3}\sum_{j_1=1}^{3} U^{u,*}_{L,t_2 j_1} Y_{u,j_1 j_2} Z^U_{t_3 3+j_2}\Big)\end{aligned} \tag{C.25}$$

$$\Gamma^R_{\tilde{\chi}^0_{t_1} u_{t_2\alpha_2} \tilde{u}^*_{t_3\alpha_3}} = \frac{i}{3}\delta_{\alpha_2,\alpha_3}\Big(2\sqrt{2}g_1 \sum_{j_1=1}^{3} Z^U_{t_3 3+j_1} U^u_{R,t_2 j_1} N_{t_1 1} - 3\sum_{j_2=1}^{3}\sum_{j_1=1}^{3} Y^*_{u,j_1 j_2} Z^U_{t_3 j_1} U^u_{R,t_2 j_2} N_{t_1 4}\Big) \tag{C.26}$$

$$\Gamma^L_{\tilde{\chi}^+_{t_1} e_{t_2} \tilde{\nu}^*_{t_3}} = -ig_2 U^*_{t_1 1}\sum_{j_1=1}^{3} U^{e,*}_{L,t_2 j_1} Z^\nu_{t_3 j_1} \tag{C.27}$$

$$\Gamma^R_{\tilde{\chi}^+_{t_1} e_{t_2} \tilde{\nu}^*_{t_3}} = i\sum_{j_2=1}^{3}\sum_{j_1=1}^{3} Y^*_{e,j_1 j_2} Z^\nu_{t_3 j_1} U^e_{R,t_2 j_2} V_{t_1 2} \tag{C.28}$$

$$\Gamma^L_{\tilde{\chi}^+_{t_1} d_{t_2\alpha_2} \tilde{u}^*_{t_3\alpha_3}} = i\delta_{\alpha_2,\alpha_3}\Big(-g_2 U^*_{t_1 1}\sum_{j_1=1}^{3} U^{d,*}_{L,t_2 j_1} Z^U_{t_3 j_1} + U^*_{t_1 2}\sum_{j_2=1}^{3}\sum_{j_1=1}^{3} U^{d,*}_{L,t_2 j_1} Y_{u,j_1 j_2} Z^U_{t_3 3+j_2}\Big) \tag{C.29}$$

$$\Gamma^R_{\tilde{\chi}^+_{t_1} d_{t_2\alpha_2} \tilde{u}^*_{t_3\alpha_3}} = i\delta_{\alpha_2,\alpha_3}\sum_{j_2=1}^{3}\sum_{j_1=1}^{3} Y^*_{d,j_1 j_2} Z^U_{t_3 j_1} U^d_{R,t_2 j_2} V_{t_1 2} \tag{C.30}$$

$$\Gamma^L_{\bar{e}_{t_1} e_{t_2} h_{t_3}} = -i\frac{1}{\sqrt{2}}\sum_{j_2=1}^{3} U^{e,*}_{R,t_1 j_2}\sum_{j_1=1}^{3} U^{e,*}_{L,t_2 j_1} Y_{e,j_1 j_2} Z^H_{t_3 1} \tag{C.31}$$

$$\Gamma^R_{\bar{e}_{t_1} e_{t_2} h_{t_3}} = -i\frac{1}{\sqrt{2}}\sum_{j_2=1}^{3}\sum_{j_1=1}^{3} Y^*_{e,j_1 j_2} U^e_{L,t_1 j_1} U^e_{R,t_2 j_2} Z^H_{t_3 1} \tag{C.32}$$

$$\Gamma^L_{\bar{e}_{t_1} e_{t_2} A^0_{t_3}} = \frac{1}{\sqrt{2}}\sum_{j_2=1}^{3} U^{e,*}_{R,t_1 j_2}\sum_{j_1=1}^{3} U^{e,*}_{L,t_2 j_1} Y_{e,j_1 j_2} Z^A_{t_3 1} \tag{C.33}$$

$$\Gamma^R_{\bar{e}_{t_1} e_{t_2} A^0_{t_3}} = -\frac{1}{\sqrt{2}}\sum_{j_2=1}^{3}\sum_{j_1=1}^{3} Y^*_{e,j_1 j_2} U^e_{L,t_1 j_1} U^e_{R,t_2 j_2} Z^A_{t_3 1} \tag{C.34}$$

$$\Gamma^L_{\bar{d}_{t_1\alpha_1} d_{t_2\alpha_2} h_{t_3}} = -i\frac{1}{\sqrt{2}}\delta_{\alpha_1,\alpha_2}\sum_{j_2=1}^{3} U^{d,*}_{R,t_1 j_2}\sum_{j_1=1}^{3} U^{d,*}_{L,t_2 j_1} Y_{d,j_1 j_2} Z^H_{t_3 1} \tag{C.35}$$

$$\Gamma^R_{\bar{d}_{t_1\alpha_1} d_{t_2\alpha_2} h_{t_3}} = -i\frac{1}{\sqrt{2}}\delta_{\alpha_1,\alpha_2}\sum_{j_2=1}^{3}\sum_{j_1=1}^{3} Y^*_{d,j_1 j_2} U^d_{L,t_1 j_1} U^d_{R,t_2 j_2} Z^H_{t_3 1} \tag{C.36}$$

$$\Gamma^{L}_{\bar{d}_{t_1\alpha_1}d_{t_2\alpha_2}A^0_{t_3}} = \frac{1}{\sqrt{2}}\delta_{\alpha_1,\alpha_2}\sum_{j_2=1}^{3}U^{d,*}_{R,t_1j_2}\sum_{j_1=1}^{3}U^{d,*}_{L,t_2j_1}Y_{d,j_1j_2}Z^{A}_{t_31} \tag{C.37}$$

$$\Gamma^{R}_{\bar{d}_{t_1\alpha_1}d_{t_2\alpha_2}A^0_{t_3}} = -\frac{1}{\sqrt{2}}\delta_{\alpha_1,\alpha_2}\sum_{j_2=1}^{3}\sum_{j_1=1}^{3}Y^{*}_{d,j_1j_2}U^{d}_{L,t_1j_1}U^{d}_{R,t_2j_2}Z^{A}_{t_31} \tag{C.38}$$

$$\Gamma^{L}_{\bar{d}_{t_1\alpha_1}u_{t_2\alpha_2}H^-_{t_3}} = iZ^{+,*}_{t_31}\delta_{\alpha_1,\alpha_2}\sum_{j_2=1}^{3}U^{d,*}_{R,t_1j_2}\sum_{j_1=1}^{3}U^{u,*}_{L,t_2j_1}Y_{d,j_1j_2} \tag{C.39}$$

$$\Gamma^{R}_{\bar{d}_{t_1\alpha_1}u_{t_2\alpha_2}H^-_{t_3}} = iZ^{+,*}_{t_32}\delta_{\alpha_1,\alpha_2}\sum_{j_2=1}^{3}\sum_{j_1=1}^{3}Y^{*}_{u,j_1j_2}U^{d}_{L,t_1j_1}U^{u}_{R,t_2j_2} \tag{C.40}$$

$$\Gamma^{L}_{\bar{u}_{t_1\alpha_1}u_{t_2\alpha_2}h_{t_3}} = -i\frac{1}{\sqrt{2}}\delta_{\alpha_1,\alpha_2}\sum_{j_2=1}^{3}U^{u,*}_{R,t_1j_2}\sum_{j_1=1}^{3}U^{u,*}_{L,t_2j_1}Y_{u,j_1j_2}Z^{H}_{t_32} \tag{C.41}$$

$$\Gamma^{R}_{\bar{u}_{t_1\alpha_1}u_{t_2\alpha_2}h_{t_3}} = -i\frac{1}{\sqrt{2}}\delta_{\alpha_1,\alpha_2}\sum_{j_2=1}^{3}\sum_{j_1=1}^{3}Y^{*}_{u,j_1j_2}U^{u}_{L,t_1j_1}U^{u}_{R,t_2j_2}Z^{H}_{t_32} \tag{C.42}$$

$$\Gamma^{L}_{\bar{u}_{t_1\alpha_1}u_{t_2\alpha_2}A^0_{t_3}} = \frac{1}{\sqrt{2}}\delta_{\alpha_1,\alpha_2}\sum_{j_2=1}^{3}U^{u,*}_{R,t_1j_2}\sum_{j_1=1}^{3}U^{u,*}_{L,t_2j_1}Y_{u,j_1j_2}Z^{A}_{t_32} \tag{C.43}$$

$$\Gamma^{R}_{\bar{u}_{t_1\alpha_1}u_{t_2\alpha_2}A^0_{t_3}} = -\frac{1}{\sqrt{2}}\delta_{\alpha_1,\alpha_2}\sum_{j_2=1}^{3}\sum_{j_1=1}^{3}Y^{*}_{u,j_1j_2}U^{u}_{L,t_1j_1}U^{u}_{R,t_2j_2}Z^{A}_{t_32} \tag{C.44}$$

C.2 Two Fermion - one vector boson interaction

$$\Gamma^{L}_{\bar{\nu}_{t_1}\nu_{t_2}Z_\mu} = -\frac{i}{2}\delta_{t_1,t_2}\Big(g_1s_\Theta + g_2c_\Theta\Big) \tag{C.45}$$

$$\Gamma^{L}_{\bar{\nu}_{t_1}e_{t_2}W^+_\mu} = -i\frac{1}{\sqrt{2}}g_2U^{e,*}_{L,t_2t_1} \tag{C.46}$$

$$\Gamma^{L}_{\tilde{\chi}^0_{t_1}\tilde{\chi}^0_{t_2}\gamma_\mu} = \frac{i}{2}\Big(g_1c_\Theta - g_2s_\Theta\Big)\Big(N^{*}_{t_23}N_{t_13} - N^{*}_{t_24}N_{t_14}\Big) \tag{C.47}$$

$$\Gamma^{R}_{\tilde{\chi}^0_{t_1}\tilde{\chi}^0_{t_2}\gamma_\mu} = -\frac{i}{2}\Big(g_1c_\Theta - g_2s_\Theta\Big)\Big(N^{*}_{t_13}N_{t_23} - N^{*}_{t_14}N_{t_24}\Big) \tag{C.48}$$

$$\Gamma^{L}_{\tilde{\chi}^0_{t_1}\tilde{\chi}^0_{t_2}Z_\mu} = -\frac{i}{2}\Big(g_1s_\Theta + g_2c_\Theta\Big)\Big(N^{*}_{t_23}N_{t_13} - N^{*}_{t_24}N_{t_14}\Big) \tag{C.49}$$

$$\Gamma^{R}_{\tilde{\chi}^0_{t_1}\tilde{\chi}^0_{t_2}Z_\mu} = \frac{i}{2}\Big(g_1s_\Theta + g_2c_\Theta\Big)\Big(N^{*}_{t_13}N_{t_23} - N^{*}_{t_14}N_{t_24}\Big) \tag{C.50}$$

$$\Gamma^{L}_{\tilde{\chi}^0_{t_1}\tilde{\chi}^-_{t_2}W^+_\mu} = -\frac{i}{2}g_2\Big(2V^{*}_{t_21}N_{t_12} + \sqrt{2}V^{*}_{t_22}N_{t_13}\Big) \tag{C.51}$$

$$\Gamma^{R}_{\tilde{\chi}^0_{t_1}\tilde{\chi}^-_{t_2}W^+_\mu} = -\frac{i}{2}g_2\Big(2N^{*}_{t_12}U_{t_21} - \sqrt{2}N^{*}_{t_14}U_{t_22}\Big) \tag{C.52}$$

$$\Gamma^{L}_{\tilde{\chi}^+_{t_1}\tilde{\chi}^-_{t_2}\gamma_\mu} = \frac{i}{2}\Big(2g_2V^{*}_{t_21}s_\Theta V_{t_11} + V^{*}_{t_22}\Big(g_1c_\Theta + g_2s_\Theta\Big)V_{t_12}\Big) \tag{C.53}$$

$$\Gamma^{R}_{\tilde{\chi}^+_{t_1}\tilde{\chi}^-_{t_2}\gamma_\mu} = \frac{i}{2}\Big(2g_2U^{*}_{t_11}s_\Theta U_{t_21} + U^{*}_{t_12}\Big(g_1c_\Theta + g_2s_\Theta\Big)U_{t_22}\Big) \tag{C.54}$$

$$\Gamma^L_{\tilde{\chi}^+_{t_1}\tilde{\chi}^-_{t_2}Z_\mu} = \frac{i}{2}\Big(2g_2V^*_{t_21}c_\Theta V_{t_11} + V^*_{t_22}\Big(-g_1s_\Theta + g_2c_\Theta\Big)V_{t_12}\Big) \tag{C.55}$$

$$\Gamma^R_{\tilde{\chi}^+_{t_1}\tilde{\chi}^-_{t_2}Z_\mu} = \frac{i}{2}\Big(2g_2U^*_{t_11}c_\Theta U_{t_21} + U^*_{t_12}\Big(-g_1s_\Theta + g_2c_\Theta\Big)U_{t_22}\Big) \tag{C.56}$$

$$\Gamma^L_{\bar{e}_{t_1}e_{t_2}\gamma_\mu} = \frac{i}{2}\delta_{t_1,t_2}\Big(g_1c_\Theta + g_2s_\Theta\Big) \tag{C.57}$$

$$\Gamma^R_{\bar{e}_{t_1}e_{t_2}\gamma_\mu} = ig_1c_\Theta\delta_{t_1,t_2} \tag{C.58}$$

$$\Gamma^L_{\bar{e}_{t_1}e_{t_2}Z_\mu} = \frac{i}{2}\delta_{t_1,t_2}\Big(-g_1s_\Theta + g_2c_\Theta\Big) \tag{C.59}$$

$$\Gamma^R_{\bar{e}_{t_1}e_{t_2}Z_\mu} = -ig_1\delta_{t_1,t_2}s_\Theta \tag{C.60}$$

$$\Gamma^L_{\bar{d}_{t_1\alpha_1}d_{t_2\alpha_2}\gamma_\mu} = -\frac{i}{6}\delta_{\alpha_1,\alpha_2}\delta_{t_1,t_2}\Big(-3g_2s_\Theta + g_1c_\Theta\Big) \tag{C.61}$$

$$\Gamma^R_{\bar{d}_{t_1\alpha_1}d_{t_2\alpha_2}\gamma_\mu} = \frac{i}{3}g_1c_\Theta\delta_{\alpha_1,\alpha_2}\delta_{t_1,t_2} \tag{C.62}$$

$$\Gamma^L_{\bar{d}_{t_1\alpha_1}d_{t_2\alpha_2}Z_\mu} = \frac{i}{6}\delta_{\alpha_1,\alpha_2}\delta_{t_1,t_2}\Big(3g_2c_\Theta + g_1s_\Theta\Big) \tag{C.63}$$

$$\Gamma^R_{\bar{d}_{t_1\alpha_1}d_{t_2\alpha_2}Z_\mu} = -\frac{i}{3}g_1\delta_{\alpha_1,\alpha_2}\delta_{t_1,t_2}s_\Theta \tag{C.64}$$

$$\Gamma^L_{\bar{d}_{t_1\alpha_1}u_{t_2\alpha_2}W^-_\mu} = -i\frac{1}{\sqrt{2}}g_2\delta_{\alpha_1,\alpha_2}\sum_{j_1=1}^{3}U^{u,*}_{L,t_2j_1}U^d_{L,t_1j_1} \tag{C.65}$$

$$\Gamma^L_{\bar{u}_{t_1\alpha_1}u_{t_2\alpha_2}\gamma_\mu} = -\frac{i}{6}\delta_{\alpha_1,\alpha_2}\delta_{t_1,t_2}\Big(3g_2s_\Theta + g_1c_\Theta\Big) \tag{C.66}$$

$$\Gamma^R_{\bar{u}_{t_1\alpha_1}u_{t_2\alpha_2}\gamma_\mu} = -\frac{2i}{3}g_1c_\Theta\delta_{\alpha_1,\alpha_2}\delta_{t_1,t_2} \tag{C.67}$$

$$\Gamma^L_{\bar{u}_{t_1\alpha_1}u_{t_2\alpha_2}Z_\mu} = -\frac{i}{6}\delta_{\alpha_1,\alpha_2}\delta_{t_1,t_2}\Big(3g_2c_\Theta - g_1s_\Theta\Big) \tag{C.68}$$

$$\Gamma^R_{\bar{u}_{t_1\alpha_1}u_{t_2\alpha_2}Z_\mu} = \frac{2i}{3}g_1\delta_{\alpha_1,\alpha_2}\delta_{t_1,t_2}s_\Theta \tag{C.69}$$

C.3 Two Scalar - one vector boson interaction

$$\Gamma_{\tilde{d}_{t_1\alpha_1}\tilde{d}^*_{t_2\alpha_2}\gamma_\mu} = -\frac{i}{6}\delta_{\alpha_1,\alpha_2}\Big(\Big(-3g_2s_\Theta + g_1c_\Theta\Big)\sum_{j_1=1}^{3}Z^{D,*}_{t_1j_1}Z^D_{t_2j_1} - 2g_1c_\Theta\sum_{j_1=1}^{3}Z^{D,*}_{t_13+j_1}Z^D_{t_23+j_1}\Big) \tag{C.70}$$

$$\Gamma_{\tilde{d}_{t_1\alpha_1}\tilde{d}^*_{t_2\alpha_2}Z_\mu} = \frac{i}{6}\delta_{\alpha_1,\alpha_2}\Big(\Big(3g_2c_\Theta + g_1s_\Theta\Big)\sum_{j_1=1}^{3}Z^{D,*}_{t_1j_1}Z^D_{t_2j_1} - 2g_1s_\Theta\sum_{j_1=1}^{3}Z^{D,*}_{t_13+j_1}Z^D_{t_23+j_1}\Big) \tag{C.71}$$

$$\Gamma_{\tilde{\nu}_{t_1}\tilde{e}^*_{t_2}W^-_\mu} = -i\frac{1}{\sqrt{2}}g_2\sum_{j_1=1}^{3}Z^{\nu,*}_{t_1j_1}Z^E_{t_2j_1} \tag{C.72}$$

$$\Gamma_{\tilde{\nu}_{t_1}\tilde{\nu}^*_{t_2}Z_\mu} = -\frac{i}{2}\sum_{j_1=1}^{3}Z^{\nu,*}_{t_1j_1}Z^\nu_{t_2j_1}\Big(g_1s_\Theta + g_2c_\Theta\Big) \tag{C.73}$$

$$\Gamma_{\tilde{u}_{t_1\alpha_1}\tilde{d}^*_{t_2\alpha_2}W^-_\mu} = -i\frac{1}{\sqrt{2}}g_2\delta_{\alpha_1,\alpha_2}\sum_{j_1=1}^{3} Z^{U,*}_{t_1j_1}Z^D_{t_2j_1} \tag{C.74}$$

$$\Gamma_{\tilde{u}_{t_1\alpha_1}\tilde{u}^*_{t_2\alpha_2}\gamma_\mu} = -\frac{i}{6}\delta_{\alpha_1,\alpha_2}\Big(\Big(3g_2s_\Theta + g_1c_\Theta\Big)\sum_{j_1=1}^{3} Z^{U,*}_{t_1j_1}Z^U_{t_2j_1} + 4g_1c_\Theta\sum_{j_1=1}^{3} Z^{U,*}_{t_13+j_1}Z^U_{t_23+j_1}\Big) \tag{C.75}$$

$$\Gamma_{\tilde{u}_{t_1\alpha_1}\tilde{u}^*_{t_2\alpha_2}Z_\mu} = -\frac{i}{6}\delta_{\alpha_1,\alpha_2}\Big(\Big(3g_2c_\Theta - g_1s_\Theta\Big)\sum_{j_1=1}^{3} Z^{U,*}_{t_1j_1}Z^U_{t_2j_1} - 4g_1s_\Theta\sum_{j_1=1}^{3} Z^{U,*}_{t_13+j_1}Z^U_{t_23+j_1}\Big) \tag{C.76}$$

$$\Gamma_{\tilde{e}_{t_1}\tilde{e}^*_{t_2}\gamma_\mu} = \frac{i}{2}\Big(\Big(g_1c_\Theta + g_2s_\Theta\Big)\sum_{j_1=1}^{3} Z^{E,*}_{t_1j_1}Z^E_{t_2j_1} + 2g_1c_\Theta\sum_{j_1=1}^{3} Z^{E,*}_{t_13+j_1}Z^E_{t_23+j_1}\Big) \tag{C.77}$$

$$\Gamma_{\tilde{e}_{t_1}\tilde{e}^*_{t_2}Z_\mu} = \frac{i}{2}\Big(\Big(-g_1s_\Theta + g_2c_\Theta\Big)\sum_{j_1=1}^{3} Z^{E,*}_{t_1j_1}Z^E_{t_2j_1} - 2g_1s_\Theta\sum_{j_1=1}^{3} Z^{E,*}_{t_13+j_1}Z^E_{t_23+j_1}\Big) \tag{C.78}$$

$$\Gamma_{h_{t_1}H^+_{t_2}W^-_\mu} = -\frac{i}{2}g_2\Big(Z^H_{t_11}Z^+_{t_21} - Z^H_{t_12}Z^+_{t_22}\Big) \tag{C.79}$$

$$\Gamma_{h_{t_1}A^0_{t_2}Z_\mu} = \frac{1}{2}\Big(-g_1s_\Theta - g_2c_\Theta\Big)\Big(Z^A_{t_21}Z^H_{t_11} - Z^A_{t_22}Z^H_{t_12}\Big) \tag{C.80}$$

$$\Gamma_{A^0_{t_1}H^+_{t_2}W^-_\mu} = \frac{1}{2}g_2\Big(Z^A_{t_11}Z^+_{t_21} + Z^A_{t_12}Z^+_{t_22}\Big) \tag{C.81}$$

$$\Gamma_{H^-_{t_1}H^+_{t_2}\gamma_\mu} = \frac{i}{2}\Big(g_1c_\Theta + g_2s_\Theta\Big)\Big(Z^{+,*}_{t_11}Z^+_{t_21} + Z^{+,*}_{t_12}Z^+_{t_22}\Big) \tag{C.82}$$

$$\Gamma_{H^-_{t_1}H^+_{t_2}Z_\mu} = \frac{i}{2}\Big(-g_1s_\Theta + g_2c_\Theta\Big)\Big(Z^{+,*}_{t_11}Z^+_{t_21} + Z^{+,*}_{t_12}Z^+_{t_22}\Big) \tag{C.83}$$

C.4 One Scalar - two vector boson - interaction

$$\Gamma_{h_{t_1}W^+_\sigma W^-_\mu} = \frac{i}{2}g_2^2\Big(v_dZ^H_{t_11} + v_uZ^H_{t_12}\Big) \tag{C.84}$$

$$\Gamma_{h_{t_1}Z_\sigma Z_\mu} = \frac{i}{2}\left(g_1s_\Theta + g_2c_\Theta\right)^2\Big(v_dZ^H_{t_11} + v_uZ^H_{t_12}\Big) \tag{C.85}$$

$$\Gamma_{H^-_{t_1}W^+_\sigma\gamma_\mu} = -\frac{i}{2}g_1g_2\Big(v_dZ^{+,*}_{t_11} - v_uZ^{+,*}_{t_12}\Big)c_\Theta \tag{C.86}$$

$$\Gamma_{H^-_{t_1}W^+_\sigma Z_\mu} = \frac{i}{2}g_1g_2\Big(v_dZ^{+,*}_{t_11} - v_uZ^{+,*}_{t_12}\Big)s_\Theta \tag{C.87}$$

C.5 Two Scalar - two vector boson interaction

$$\Gamma_{\tilde{\nu}_{t_1}W^-_\sigma\tilde{\nu}^*_{t_3}W^+_\nu} = \frac{i}{2}g_2^2\delta_{t_1,t_3} \tag{C.88}$$

$$\Gamma_{\tilde{\nu}_{t_1}Z_\sigma\tilde{\nu}^*_{t_3}Z_\nu} = \frac{i}{2}\delta_{t_1,t_3}\left(g_1s_\Theta + g_2c_\Theta\right)^2 \tag{C.89}$$

$$\Gamma_{\tilde{e}_{t_1} W_\sigma^- \tilde{e}_{t_3}^* W_\nu^+} = \frac{i}{2} g_2^2 \sum_{j_2=1}^{3} Z_{t_1 j_2}^{E,*} Z_{t_3 j_2}^{E} \tag{C.90}$$

$$\Gamma_{\tilde{e}_{t_1} Z_\sigma \tilde{e}_{t_3}^* Z_\nu} = -i\Big(-\frac{1}{2} \left(-g_1 s_\Theta + g_2 c_\Theta\right)^2 \sum_{j_2=1}^{3} Z_{t_1 j_2}^{E,*} Z_{t_3 j_2}^{E} - 2 g_1^2 {s_\Theta}^2 \sum_{j_2=1}^{3} Z_{t_1 3+j_2}^{E,*} Z_{t_3 3+j_2}^{E} \Big) \tag{C.91}$$

$$\Gamma_{h_{t_1} W_\sigma^- h_{t_3} W_\nu^+} = \frac{i}{2} g_2^2 \Big(Z_{t_1 1}^{H} Z_{t_3 1}^{H} + Z_{t_1 2}^{H} Z_{t_3 2}^{H} \Big) \tag{C.92}$$

$$\Gamma_{h_{t_1} Z_\sigma h_{t_3} Z_\nu} = \frac{i}{2} \left(g_1 s_\Theta + g_2 c_\Theta\right)^2 \Big(Z_{t_1 1}^{H} Z_{t_3 1}^{H} + Z_{t_1 2}^{H} Z_{t_3 2}^{H} \Big) \tag{C.93}$$

$$\Gamma_{A_{t_1}^0 W_\sigma^- A_{t_3}^0 W_\nu^+} = \frac{i}{2} g_2^2 \Big(Z_{t_1 1}^{A} Z_{t_3 1}^{A} + Z_{t_1 2}^{A} Z_{t_3 2}^{A} \Big) \tag{C.94}$$

$$\Gamma_{A_{t_1}^0 Z_\sigma A_{t_3}^0 Z_\nu} = \frac{i}{2} \left(g_1 s_\Theta + g_2 c_\Theta\right)^2 \Big(Z_{t_1 1}^{A} Z_{t_3 1}^{A} + Z_{t_1 2}^{A} Z_{t_3 2}^{A} \Big) \tag{C.95}$$

$$\Gamma_{H_{t_1}^- W_\sigma^- H_{t_3}^+ W_\nu^+} = \frac{i}{2} g_2^2 \Big(Z_{t_1 1}^{+,*} Z_{t_3 1}^{+} + Z_{t_1 2}^{+,*} Z_{t_3 2}^{+} \Big) \tag{C.96}$$

$$\Gamma_{H_{t_1}^- Z_\sigma H_{t_3}^+ Z_\nu} = \frac{i}{2} \left(-g_1 s_\Theta + g_2 c_\Theta\right)^2 \Big(Z_{t_1 1}^{+,*} Z_{t_3 1}^{+} + Z_{t_1 2}^{+,*} Z_{t_3 2}^{+} \Big) \tag{C.97}$$

C.6 Four Scalar

We define

$$A_1 = \frac{i}{12} \Big(\Big(C_L^1 g_1^2 + 3 C_L^2 g_2^2 \Big) \sum_{j_1=1}^{3} Z_{t_3 j_1}^{F,*} Z_{t_1 j_1}^{F} + 2 C_R^1 g_1^2 \sum_{j_1=1}^{3} Z_{t_3 3+j_1}^{F,*} Z_{t_1 3+j_1}^{F} \Big) \tag{C.98}$$

$$A_2 = -i\Big(\sum_{j_3=1}^{3} Z_{t_3 3+j_3}^{F,*} \sum_{j_2=1}^{3} \sum_{j_1=1}^{3} Y_{f,j_1 j_3}^{*} Y_{f,j_1 j_2} Z_{t_1 3+j_2}^{F} + \sum_{j_3=1}^{3} \sum_{j_2=1}^{3} Z_{t_3 j_2}^{F,*} \sum_{j_1=1}^{3} Y_{f,j_3 j_1}^{*} Y_{f,j_2 j_1} Z_{t_1 j_3}^{F} \Big) \tag{C.99}$$

$$A_3 = \frac{i}{2} \Big(\lambda \sum_{j_2=1}^{3} Z_{t_3 3+j_2}^{F,*} \sum_{j_1=1}^{3} Y_{f,j_1 j_2}^{*} Z_{t_1 j_1}^{F} + \lambda^* \sum_{j_2=1}^{3} \sum_{j_1=1}^{3} Z_{t_3 j_1}^{F,*} Y_{f,j_1 j_2} Z_{t_1 3+j_2}^{F} \Big) \tag{C.100}$$

$$A_4 = -\frac{i}{\sqrt{2}} \Big(\sum_{j_2=1}^{3} Z_{t_1 3+j_2}^{F,*} \sum_{j_1=1}^{3} T_{f,j_1 j_2}^{*} Z_{t_2 j_1}^{F} + \sum_{j_2=1}^{3} \sum_{j_1=1}^{3} Z_{t_1 j_1}^{F,*} T_{f,j_1 j_2} Z_{t_2 3+j_2}^{F} \Big) \tag{C.101}$$

$$A_5 = \frac{i}{12} \Big(\Big(C_R^1 g_1^2 + 3 C_L^1 g_2^2 \Big) \sum_{j_1=1}^{3} Z_{t_1 j_1}^{F,*} Z_{t_2 j_1}^{F} + 2 g_1^2 \sum_{j_1=1}^{3} Z_{t_1 3+j_1}^{F,*} Z_{t_2 3+j_1}^{F} \Big) \tag{C.102}$$

$$A_6 = \frac{i}{2} \Big(\lambda \sum_{j_2=1}^{3} Z_{t_1 3+j_2}^{F,*} \sum_{j_1=1}^{3} Y_{f,j_1 j_2}^{*} Z_{t_2 j_1}^{F} + \lambda^* \sum_{j_2=1}^{3} \sum_{j_1=1}^{3} Z_{t_1 j_1}^{F,*} Y_{f,j_1 j_2} Z_{t_2 3+j_2}^{F} \Big) \tag{C.103}$$

$$A_7 = -i\Big(\sum_{j_3=1}^{3} Z_{t_1 3+j_3}^{F,*} \sum_{j_2=1}^{3} \sum_{j_1=1}^{3} Y_{f,j_1 j_3}^{*} Y_{f,j_1 j_2} Z_{t_2 3+j_2}^{F}$$

$$+\sum_{j_3=1}^{3}\sum_{j_2=1}^{3} Z^{F,*}_{t_1 j_2}\sum_{j_1=1}^{3} Y^*_{f,j_3 j_1} Y_{f,j_2 j_1} Z^F_{t_2\ j_3}\Big) \tag{C.104}$$

$$A_8 = \frac{1}{\sqrt{2}}\Big(-\sum_{j_2=1}^{3} Z^{F,*}_{t_1 3+j_2}\sum_{j_1=1}^{3} T^*_{f,j_1 j_2} Z^F_{t_2 j_1} + \sum_{j_2=1}^{3}\sum_{j_1=1}^{3} Z^{F,*}_{t_1 j_1} T_{f,j_1 j_2}\ Z^F_{t_2 3+j_2}\Big) \tag{C.105}$$

$$A_9 = \frac{1}{2}\Big(-\lambda\sum_{j_2=1}^{3} Z^{F,*}_{t_1 3+j_2}\sum_{j_1=1}^{3} Y^*_{f,j_1 j_2} Z^F_{t_2 j_1} + \lambda^*\sum_{j_2=1}^{3}\sum_{j_1=1}^{3} Z^{F,*}_{t_1 j_1} Y_{f,j_1 j_2} Z^F_{t_2 3+j_2}\Big) \tag{C.106}$$

With this definitions often appearing terms in the vertices involving squarks and sleptons are given by

$$D_i = A_i \text{ with } Y_f \to Y_d, T_f \to T_d, Z^F \to Z^D, C^1_L \to 1, C^1_R \to 1, C^2_L \to 1 \tag{C.107}$$

$$U_i = A_i \text{ with } Y_f \to Y_u, T_f \to T_u, Z^F \to Z^U, C^1_L \to 1, C^1_R \to -2, C^2_L \to -1 \tag{C.108}$$

$$E_i = A_i \text{ with } Y_f \to Y_e, T_f \to T_e, Z^F \to Z^E, C^1_L \to 3, C^1_R \to -3, C^2_L \to -1 \tag{C.109}$$

$$\begin{aligned}\Gamma_{\tilde{d}_{t_1\alpha_1} h_{t_2} \tilde{d}^*_{t_3\alpha_3} h_{t_4}} =& \delta_{\alpha_1,\alpha_2}\Big(D_1\Big(Z^H_{t_2 1} Z^H_{t_4 1} - Z^H_{t_2 2} Z^H_{t_4 2}\Big) + D_2 Z^H_{t_2 1} Z^H_{t_4 1} \\ &+ D_3\Big(Z^H_{t_2 2} Z^H_{t_4 3} + Z^H_{t_2 3} Z^H_{t_4 2}\Big)\Big)\end{aligned} \tag{C.110}$$

$$\begin{aligned}\Gamma_{\tilde{d}_{t_1\alpha_1} A^0_{t_2} \tilde{d}^*_{t_3\alpha_3} A^0_{t_4}} =& \delta_{\alpha_1,\alpha_2}\Big(D_1\Big(Z^A_{t_2 1} Z^A_{t_4 1} - Z^A_{t_2 2} Z^A_{t_4 2}\Big) + D_2 Z^A_{t_2 1} Z^A_{t_4 1} \\ &+ D_3\Big(-Z^A_{t_2 2} Z^A_{t_4 3} - Z^A_{t_2 3} Z^A_{t_4 2}\Big)\Big)\end{aligned} \tag{C.111}$$

$$\begin{aligned}\Gamma_{\tilde{u}_{t_1\alpha_1} h_{t_2} \tilde{u}^*_{t_3\alpha_3} h_{t_4}} =& \delta_{\alpha_1,\alpha_2}\Big(U_1\Big(Z^H_{t_2 1} Z^H_{t_4 1} - Z^H_{t_2 2} Z^H_{t_4 2}\Big) + U_2 Z^H_{t_2 2} Z^H_{t_4 2} \\ &+ U_3\Big(Z^H_{t_2 1} Z^H_{t_4 3} + Z^H_{t_2 3} Z^H_{t_4 1}\Big)\Big)\end{aligned} \tag{C.112}$$

$$\begin{aligned}\Gamma_{\tilde{u}_{t_1\alpha_1} A^0_{t_2} \tilde{u}^*_{t_3\alpha_3} A^0_{t_4}} =& \delta_{\alpha_1,\alpha_2}\Big(U_1\Big(Z^A_{t_2 1} Z^A_{t_4 1} - Z^A_{t_2 2} Z^A_{t_4 2}\Big) + U_2 Z^A_{t_2 2} Z^A_{t_4 2} \\ &+ U_3\Big(-Z^A_{t_2 1} Z^A_{t_4 3} - Z^A_{t_2 3} Z^A_{t_4 1}\Big)\Big)\end{aligned} \tag{C.113}$$

$$\Gamma_{\tilde{e}_{t_1} h_{t_2} \tilde{e}^*_{t_3} h_{t_4}} = E_1\Big(-Z^H_{t_2 1} Z^H_{t_4 1} + Z^H_{t_2 2} Z^H_{t_4 2}\Big) + E_2 Z^H_{t_2 1} Z^H_{t_4 1} + E_3\Big(Z^H_{t_2 2} Z^H_{t_4 3} + Z^H_{t_2 3} Z^H_{t_4 2}\Big) \tag{C.114}$$

$$\Gamma_{\tilde{e}_{t_1} A_{h,t_2} \tilde{e}^*_{t_3} A_{h,t_4}} = E_1\Big(-Z^A_{t_2 1} Z^A_{t_4 1} + Z^A_{t_2 2} Z^A_{t_4 2}\Big) + E_2 Z^A_{t_2 1} Z^A_{t_4 1} + E_3\Big(-Z^A_{t_2 2} Z^A_{t_4 3} - Z^A_{t_2 3} Z^A_{t_4 2}\Big) \tag{C.115}$$

$$\begin{aligned}\Gamma_{h_{t_1} h_{t_2} h_{t_3} h_{t_4}} =& \frac{i}{4}\Big(Z^H_{t_1 1}\Big(Z^H_{t_2 1}\Big(-3g^2_+ Z^H_{t_3 1} Z^H_{t_4 1} + \tilde{\lambda} Z^H_{t_3 2} Z^H_{t_4 2} - 4|\lambda|^2 Z^H_{t_3 3} Z^H_{t_4 3}\Big) \\ &+ Z^H_{t_2 2}\Big(\tilde{\lambda} Z^H_{t_3 2} Z^H_{t_4 1} + \tilde{\lambda} Z^H_{t_3 1} Z^H_{t_4 2} + 4\mathrm{Re}\big\{\kappa\lambda\big\} Z^H_{t_3 3} Z^H_{t_4 3}\Big) \\ &+ 2 Z^H_{t_2 3}\Big(\lambda\kappa^*\Big(Z^H_{t_3 2} Z^H_{t_4 3} + Z^H_{t_3 3} Z^H_{t_4 2}\Big) \\ &+ \lambda^*\Big(\Big(\kappa Z^H_{t_3 2} - 2\lambda Z^H_{t_3 1}\Big) Z^H_{t_4 3} + Z^H_{t_3 3}\Big(\kappa Z^H_{t_4 2} - 2\lambda Z^H_{t_4 1}\Big)\Big)\Big)\Big)\end{aligned} \tag{C.116}$$

$$
\begin{aligned}
&+ Z^H_{t_12}\Big(Z^H_{t_22}\Big(- 3g_+^2 Z^H_{t_32}Z^H_{t_42} + \tilde{\lambda} Z^H_{t_31}Z^H_{t_41} - 4|\lambda|^2 Z^H_{t_33}Z^H_{t_43}\Big)\\
&+ Z^H_{t_21}\Big(\tilde{\lambda} Z^H_{t_32}Z^H_{t_41} + \tilde{\lambda} Z^H_{t_31}Z^H_{t_42} + 4\mathrm{Re}\big\{\kappa\lambda\big\} Z^H_{t_33}Z^H_{t_43}\Big)\\
&+ 2Z^H_{t_23}\Big(\lambda\kappa^*\Big(Z^H_{t_31}Z^H_{t_43} + Z^H_{t_33}Z^H_{t_41}\Big)\\
&+ \lambda^*\Big(\Big(\kappa Z^H_{t_31} - 2\lambda Z^H_{t_32}\Big)Z^H_{t_43} + Z^H_{t_33}\Big(\kappa Z^H_{t_41} - 2\lambda Z^H_{t_42}\Big)\Big)\Big)\Big)\\
&+ 2Z^H_{t_13}\Big(\lambda^*\Big(Z^H_{t_23}\Big(Z^H_{t_31}\Big(\kappa Z^H_{t_42} - 2\lambda Z^H_{t_41}\Big) + Z^H_{t_32}\Big(\kappa Z^H_{t_41} - 2\lambda Z^H_{t_42}\Big)\Big)\\
&+ Z^H_{t_21}\Big(\Big(\kappa Z^H_{t_32} - 2\lambda Z^H_{t_31}\Big)Z^H_{t_43} + Z^H_{t_33}\Big(\kappa Z^H_{t_42} - 2\lambda Z^H_{t_41}\Big)\Big)\\
&+ Z^H_{t_22}\Big(\Big(\kappa Z^H_{t_31} - 2\lambda Z^H_{t_32}\Big)Z^H_{t_43} + Z^H_{t_33}\Big(\kappa Z^H_{t_41} - 2\lambda Z^H_{t_42}\Big)\Big)\Big)\\
&+ \kappa^*\Big(Z^H_{t_23}\Big(- 12\kappa Z^H_{t_33}Z^H_{t_43} + \lambda Z^H_{t_31}Z^H_{t_42} + \lambda Z^H_{t_32}Z^H_{t_41}\Big)\\
&+ \lambda\Big(Z^H_{t_21}\Big(Z^H_{t_32}Z^H_{t_43} + Z^H_{t_33}Z^H_{t_42}\Big) + Z^H_{t_22}\Big(Z^H_{t_31}Z^H_{t_43} + Z^H_{t_33}Z^H_{t_41}\Big)\Big)\Big)\Big)\Big)
\end{aligned}
\tag{C.116}
$$

$$
\begin{aligned}
\Gamma_{h_{t_1}h_{t_2}A^0_{t_3}A^0_{t_4}} = \frac{i}{4}\Big(&Z^A_{t_32}\Big(Z^A_{t_42}\Big(\tilde{\lambda} Z^H_{t_11}Z^H_{t_21} - 4|\lambda|^2 Z^H_{t_13}Z^H_{t_23} - g_+^2 Z^H_{t_12}Z^H_{t_22}\Big)\\
&+ 2\Big(\kappa\lambda^* + \lambda\kappa^*\Big)\Big(- Z^A_{t_41}Z^H_{t_13}Z^H_{t_23} + Z^A_{t_43}\Big(Z^H_{t_11}Z^H_{t_23} + Z^H_{t_13}Z^H_{t_21}\Big)\Big)\Big)\\
&+ Z^A_{t_31}\Big(- Z^A_{t_41}\Big(- \tilde{\lambda} Z^H_{t_12}Z^H_{t_22} + 4|\lambda|^2 Z^H_{t_13}Z^H_{t_23} + g_+^2 Z^H_{t_11}Z^H_{t_21}\Big)\\
&+ 2\Big(\kappa\lambda^* + \lambda\kappa^*\Big)\Big(- Z^A_{t_42}Z^H_{t_13}Z^H_{t_23} + Z^A_{t_43}\Big(Z^H_{t_12}Z^H_{t_23} + Z^H_{t_13}Z^H_{t_22}\Big)\Big)\Big)\\
&+ 2Z^A_{t_33}\Big(\lambda^*\Big(- Z^A_{t_43}\Big(Z^H_{t_11}\Big(2\lambda Z^H_{t_21} + \kappa Z^H_{t_22}\Big) + Z^H_{t_12}\Big(2\lambda Z^H_{t_22} + \kappa Z^H_{t_21}\Big)\Big)\\
&+ \kappa\Big(Z^A_{t_41}\Big(Z^H_{t_12}Z^H_{t_23} + Z^H_{t_13}Z^H_{t_22}\Big) + Z^A_{t_42}\Big(Z^H_{t_11}Z^H_{t_23} + Z^H_{t_13}Z^H_{t_21}\Big)\Big)\Big)\\
&+ \kappa^*\Big(- Z^A_{t_43}\Big(4\kappa Z^H_{t_13}Z^H_{t_23} + \lambda Z^H_{t_11}Z^H_{t_22} + \lambda Z^H_{t_12}Z^H_{t_21}\Big)\\
&+ \lambda\Big(Z^A_{t_41}\Big(Z^H_{t_12}Z^H_{t_23} + Z^H_{t_13}Z^H_{t_22}\Big) + Z^A_{t_42}\Big(Z^H_{t_11}Z^H_{t_23} + Z^H_{t_13}Z^H_{t_21}\Big)\Big)\Big)\Big)\Big)
\end{aligned}
\tag{C.117}
$$

$$
\begin{aligned}
\Gamma_{h_{t_1}H^+_{t_2}h_{t_3}H^+_{t_4}} = \frac{i}{4}\Big(&- Z^{+,*}_{t_22}\Big(4\lambda^* Z^H_{t_13}Z^H_{t_33}\Big(\kappa Z^+_{t_41} + \lambda Z^+_{t_42}\Big) + Z^H_{t_11}\Big(\bar{\lambda} Z^H_{t_32}Z^+_{t_41} + g_-^2 Z^H_{t_31}Z^+_{t_42}\Big)\\
&+ Z^H_{t_12}\Big(\bar{\lambda} Z^H_{t_31}Z^+_{t_41} + g_+^2 Z^H_{t_32}Z^+_{t_42}\Big)\Big) - Z^{+,*}_{t_21}\Big(4\lambda Z^H_{t_13}Z^H_{t_33}\Big(\kappa^* Z^+_{t_42} + \lambda^* Z^+_{t_41}\Big)\\
&+ Z^H_{t_12}\Big(\bar{\lambda} Z^H_{t_31}Z^+_{t_42} + g_-^2 Z^H_{t_32}Z^+_{t_41}\Big) + Z^H_{t_11}\Big(\bar{\lambda} Z^H_{t_32}Z^+_{t_42} + g_+^2 Z^H_{t_31}Z^+_{t_41}\Big)\Big)\Big)
\end{aligned}
\tag{C.118}
$$

$$
\begin{aligned}
\Gamma_{A^0_{t_1}A^0_{t_2}A^0_{t_3}A^0_{t_4}} = \frac{i}{4}\Big(&Z^A_{t_11}\Big(Z^A_{t_21}\Big(- 3g_+^2 Z^A_{t_31}Z^A_{t_41} + \tilde{\lambda} Z^A_{t_32}Z^A_{t_42} - 4|\lambda|^2 Z^A_{t_33}Z^A_{t_43}\Big)\\
&+ Z^A_{t_22}\Big(\tilde{\lambda} Z^A_{t_32}Z^A_{t_41} + \tilde{\lambda} Z^A_{t_31}Z^A_{t_42} + 4\mathrm{Re}\big\{\kappa\lambda\big\} Z^A_{t_33}Z^A_{t_43}\Big)\\
&+ 2Z^A_{t_23}\Big(\lambda\kappa^*\Big(Z^A_{t_32}Z^A_{t_43} + Z^A_{t_33}Z^A_{t_42}\Big) + \lambda^*\Big(\Big(- 2\lambda Z^A_{t_31} + \kappa Z^A_{t_32}\Big)Z^A_{t_43}
\end{aligned}
$$

$$
\begin{aligned}
&+ Z^A_{t_3 3}\Big(- 2\lambda Z^A_{t_4 1} + \kappa Z^A_{t_4 2}\Big)\Big)\Big)\Big) \\
&+ Z^A_{t_1 2}\Big(Z^A_{t_2 2}\Big(- 3g_+^2 Z^A_{t_3 2} Z^A_{t_4 2} + \tilde{\lambda} Z^A_{t_3 1} Z^A_{t_4 1} - 4|\lambda|^2 Z^A_{t_3 3} Z^A_{t_4 3}\Big) \\
&+ Z^A_{t_2 1}\Big(\tilde{\lambda} Z^A_{t_3 2} Z^A_{t_4 1} + \tilde{\lambda} Z^A_{t_3 1} Z^A_{t_4 2} + 4\mathrm{Re}\big\{\kappa\lambda\big\} Z^A_{t_3 3} Z^A_{t_4 3}\Big) \\
&+ 2 Z^A_{t_2 3}\Big(\lambda\kappa^*\Big(Z^A_{t_3 1} Z^A_{t_4 3} + Z^A_{t_3 3} Z^A_{t_4 1}\Big) \\
&+ \lambda^*\Big(\Big(- 2\lambda Z^A_{t_3 2} + \kappa Z^A_{t_3 1}\Big) Z^A_{t_4 3} + Z^A_{t_3 3}\Big(\kappa Z^A_{t_4 1} - 2\lambda Z^A_{t_4 2}\Big)\Big)\Big)\Big) \\
&+ 2 Z^A_{t_1 3}\Big(\lambda^*\Big(Z^A_{t_2 3}\Big(Z^A_{t_3 1}\Big(- 2\lambda Z^A_{t_4 1} + \kappa Z^A_{t_4 2}\Big) + Z^A_{t_3 2}\Big(\kappa Z^A_{t_4 1} - 2\lambda Z^A_{t_4 2}\Big)\Big) \\
&+ Z^A_{t_2 1}\Big(\Big(- 2\lambda Z^A_{t_3 1} + \kappa Z^A_{t_3 2}\Big) Z^A_{t_4 3} + Z^A_{t_3 3}\Big(- 2\lambda Z^A_{t_4 1} + \kappa Z^A_{t_4 2}\Big)\Big) \\
&+ Z^A_{t_2 2}\Big(\Big(- 2\lambda Z^A_{t_3 2} + \kappa Z^A_{t_3 1}\Big) Z^A_{t_4 3} + Z^A_{t_3 3}\Big(- 2\lambda Z^A_{t_4 2} + \kappa Z^A_{t_4 1}\Big)\Big)\Big) \\
&+ \kappa^*\Big(Z^A_{t_2 3}\Big(- 12\kappa Z^A_{t_3 3} Z^A_{t_4 3} + \lambda Z^A_{t_3 1} Z^A_{t_4 2} + \lambda Z^A_{t_3 2} Z^A_{t_4 1}\Big) \\
&+ \lambda\Big(Z^A_{t_2 1}\Big(Z^A_{t_3 2} Z^A_{t_4 3} + Z^A_{t_3 3} Z^A_{t_4 2}\Big) + Z^A_{t_2 2}\Big(Z^A_{t_3 1} Z^A_{t_4 3} + Z^A_{t_3 3} Z^A_{t_4 1}\Big)\Big)\Big)\Big)\Big)
\end{aligned}
\tag{C.119}
$$

$$
\begin{aligned}
\Gamma_{A^0_{t_1} H^-_{t_2} A^0_{t_3} H^+_{t_4}} = \frac{i}{4}\Big(&- Z^{+,*}_{t_2 2}\Big(4\lambda^* Z^A_{t_1 3} Z^A_{t_3 3}\Big(\lambda Z^+_{t_4 2} - \kappa Z^+_{t_4 1}\Big) + Z^A_{t_1 1}\Big(g_-^2 Z^A_{t_3 1} Z^+_{t_4 2} - \bar{\lambda} Z^A_{t_3 2} Z^+_{t_4 1}\Big) \\
&+ Z^A_{t_1 2}\Big(g_+^2 Z^A_{t_3 2} Z^+_{t_4 2} - \bar{\lambda} Z^A_{t_3 1} Z^+_{t_4 1}\Big)\Big) - Z^{+,*}_{t_2 1}\Big(4\lambda Z^A_{t_1 3} Z^A_{t_3 3}\Big(\lambda^* Z^+_{t_4 1} - \kappa^* Z^+_{t_4 2}\Big) \\
&+ Z^A_{t_1 2}\Big(g_-^2 Z^A_{t_3 2} Z^+_{t_4 1} - \bar{\lambda} Z^A_{t_3 1} Z^+_{t_4 2}\Big) + Z^A_{t_1 1}\Big(g_+^2 Z^A_{t_3 1} Z^+_{t_4 1} - \bar{\lambda} Z^A_{t_3 2} Z^+_{t_4 2}\Big)\Big)\Big)
\end{aligned}
\tag{C.120}
$$

$$
\begin{aligned}
\Gamma_{H^-_{t_1} H^-_{t_2} H^+_{t_3} H^+_{t_4}} = \frac{i}{4}\Big(&Z^{+,*}_{t_1 2}\Big(- 2g_+^2 Z^{+,*}_{t_2 2} Z^+_{t_3 2} Z^+_{t_4 2} + \tilde{\lambda} Z^{+,*}_{t_2 1}\Big(Z^+_{t_3 1} Z^+_{t_4 2} + Z^+_{t_3 2} Z^+_{t_4 1}\Big)\Big) \\
&+ Z^{+,*}_{t_1 1}\Big(- 2g_+^2 Z^{+,*}_{t_2 1} Z^+_{t_3 1} Z^+_{t_4 1} + \tilde{\lambda} Z^{+,*}_{t_2 2}\Big(Z^+_{t_3 1} Z^+_{t_4 2} + Z^+_{t_3 2} Z^+_{t_4 1}\Big)\Big)\Big)
\end{aligned}
\tag{C.121}
$$

$$
\begin{aligned}
\Gamma_{\tilde{d}_{t_1\alpha_1}\tilde{\nu}_{t_2}\tilde{d}^*_{t_3\alpha_3}\tilde{\nu}^*_{t_4}} = \frac{i}{24}\delta_{\alpha_1,\alpha_3}\Big(&\delta_{t_2,t_4}\Big(2g_1^2 \sum_{j_1=1}^{3} Z^{D,*}_{t_1 3+j_1} Z^D_{t_3 3+j_1} + \Big(3g_2^2 + g_1^2\Big) \sum_{j_1=1}^{3} Z^{D,*}_{t_1 j_1} Z^D_{t_3 j_1}\Big) \\
&+ \delta_{t_2,t_4}\Big(2g_1^2 \sum_{j_2=1}^{3} Z^{D,*}_{t_1 3+j_2} Z^D_{t_3 3+j_2} + \Big(3g_2^2 + g_1^2\Big) \sum_{j_2=1}^{3} Z^{D,*}_{t_1 j_2} Z^D_{t_3 j_2}\Big)\Big)
\end{aligned}
\tag{C.122}
$$

$$
\begin{aligned}
\Gamma_{\tilde{d}_{t_1\alpha_1}\tilde{e}_{t_2}\tilde{d}^*_{t_3\alpha_3}\tilde{e}^*_{t_4}} = &- \frac{i}{24}\delta_{\alpha_1,\alpha_3}\Big(2g_1^2 \sum_{j_1=1}^{3} Z^{E,*}_{t_2 3+j_1} Z^E_{t_4 3+j_1}\Big(2\sum_{j_2=1}^{3} Z^{D,*}_{t_1 3+j_2} Z^D_{t_3 3+j_2} + \sum_{j_2=1}^{3} Z^{D,*}_{t_1 j_2} Z^D_{t_3 j_2}\Big) \\
&- \sum_{j_1=1}^{3} Z^{E,*}_{t_2 j_1} Z^E_{t_4 j_1}\Big(2g_1^2 \sum_{j_2=1}^{3} Z^{D,*}_{t_1 3+j_2} Z^D_{t_3 3+j_2} + \Big(g_1^2 - 3g_2^2\Big) \sum_{j_2=1}^{3} Z^{D,*}_{t_1 j_2} Z^D_{t_3 j_2}\Big)
\end{aligned}
$$

$$
\begin{aligned}
&- \Big(2g_1^2 \sum_{j_1=1}^{3} Z^{D,*}_{t_1 3+j_1} Z^{D}_{t_3 3+j_1} + \Big(g_1^2 - 3g_2^2\Big) \sum_{j_1=1}^{3} Z^{D,*}_{t_1 j_1} Z^{D}_{t_3 j_1}\Big) \sum_{j_2=1}^{3} Z^{E,*}_{t_2 j_2} Z^{E}_{t_4 j_2} \\
&+ 2g_1^2 \Big(2 \sum_{j_1=1}^{3} Z^{D,*}_{t_1 3+j_1} Z^{D}_{t_3 3+j_1} + \sum_{j_1=1}^{3} Z^{D,*}_{t_1 j_1} Z^{D}_{t_3 j_1}\Big) \sum_{j_2=1}^{3} Z^{E,*}_{t_2 3+j_2} Z^{E}_{t_4 3+j_2} \\
&+ 24 \Big(\sum_{j_2=1}^{3} \sum_{j_1=1}^{3} Z^{E,*}_{t_2 j_1} Y_{e,j_1 j_2} Z^{E}_{t_4 3+j_2} \sum_{j_4=1}^{3} Z^{D,*}_{t_1 3+j_4} \sum_{j_3=1}^{3} Y^{*}_{d,j_3 j_4} Z^{D}_{t_3 j_3} \\
&+ \sum_{j_2=1}^{3} \sum_{j_1=1}^{3} Z^{D,*}_{t_1 j_1} Y_{d,j_1 j_2} Z^{D}_{t_3 3+j_2} \sum_{j_4=1}^{3} Z^{E,*}_{t_2 3+j_4} \sum_{j_3=1}^{3} Y^{*}_{e,j_3 j_4} Z^{E}_{t_4 j_3} \Big)\Big)
\end{aligned}
\tag{C.123}
$$

$$
\begin{aligned}
\Gamma_{\tilde{d}_{t_1\alpha_1} H^{-}_{t_2} \tilde{d}^{*}_{t_3\alpha_3} H^{+}_{t_4}} = \frac{i}{12} \delta_{\alpha_1,\alpha_3} \Big(& Z^{+,*}_{t_2 1} \Big(\Big(g_1^2 - 3g_2^2\Big) \sum_{j_1=1}^{3} Z^{D,*}_{t_1 j_1} Z^{D}_{t_3 j_1} + 2g_1^2 \sum_{j_1=1}^{3} Z^{D,*}_{t_1 3+j_1} Z^{D}_{t_3 3+j_1} \\
&- 12 \sum_{j_3=1}^{3} Z^{D,*}_{t_1 3+j_3} \sum_{j_2=1}^{3} \sum_{j_1=1}^{3} Y^{*}_{d,j_1 j_3} Y_{d,j_1 j_2} Z^{D}_{t_3 3+j_2} \Big) Z^{+}_{t_4 1} \\
&- Z^{+,*}_{t_2 2} \Big(\Big(g_1^2 - 3g_2^2\Big) \sum_{j_1=1}^{3} Z^{D,*}_{t_1 j_1} Z^{D}_{t_3 j_1} + 2g_1^2 \sum_{j_1=1}^{3} Z^{D,*}_{t_1 3+j_1} Z^{D}_{t_3 3+j_1} \\
&+ 12 \sum_{j_3=1}^{3} \sum_{j_2=1}^{3} Z^{D,*}_{t_1 j_2} \sum_{j_1=1}^{3} Y^{*}_{u,j_3 j_1} Y_{u,j_2 j_1} Z^{D}_{t_3 j_3} \Big) Z^{+}_{t_4 2} \Big)
\end{aligned}
\tag{C.124}
$$

$$
\Gamma_{\tilde{\nu}_{t_1} \tilde{\nu}_{t_2} \tilde{\nu}^{*}_{t_3} \tilde{\nu}^{*}_{t_4}} = - \frac{i}{8} \Big(g_1^2 + g_2^2\Big) \Big(2\delta_{t_1,t_3}\delta_{t_2,t_4} + 2\delta_{t_1,t_4}\delta_{t_2,t_3}\Big) \tag{C.125}
$$

$$
\begin{aligned}
\Gamma_{\tilde{\nu}_{t_1} \tilde{u}_{t_2\alpha_2} \tilde{\nu}^{*}_{t_3} \tilde{u}^{*}_{t_4\alpha_4}} = \frac{i}{24} \delta_{\alpha_2,\alpha_4} \Big(& \delta_{t_1,t_3} \Big(\Big(-3g_2^2 + g_1^2\Big) \sum_{j_1=1}^{3} Z^{U,*}_{t_2 j_1} Z^{U}_{t_4 j_1} - 4g_1^2 \sum_{j_1=1}^{3} Z^{U,*}_{t_2 3+j_1} Z^{U}_{t_4 3+j_1} \Big) \\
&+ \delta_{t_1,t_3} \Big(\Big(-3g_2^2 + g_1^2\Big) \sum_{j_2=1}^{3} Z^{U,*}_{t_2 j_2} Z^{U}_{t_4 j_2} - 4g_1^2 \sum_{j_2=1}^{3} Z^{U,*}_{t_2 3+j_2} Z^{U}_{t_4 3+j_2} \Big)\Big)
\end{aligned}
\tag{C.126}
$$

$$
\begin{aligned}
\Gamma_{\tilde{\nu}_{t_1} \tilde{e}_{t_2} \tilde{\nu}^{*}_{t_3} \tilde{e}^{*}_{t_4}} = - \frac{i}{4} \Big(& \delta_{t_1,t_3} \Big(\Big(g_1^2 - g_2^2\Big) \sum_{j_1=1}^{3} Z^{E,*}_{t_2 j_1} Z^{E}_{t_4 j_1} - 2g_1^2 \sum_{j_1=1}^{3} Z^{E,*}_{t_2 3+j_1} Z^{E}_{t_4 3+j_1} \Big) \\
&+ g_2^2 \Big(\sum_{j_1=1}^{3} Z^{E,*}_{t_2 j_1} Z^{\nu}_{t_3 j_1} \sum_{j_2=1}^{3} Z^{\nu,*}_{t_1 j_2} Z^{E}_{t_4 j_2} + \sum_{j_1=1}^{3} Z^{\nu,*}_{t_1 j_1} Z^{E}_{t_4 j_1} \sum_{j_2=1}^{3} Z^{E,*}_{t_2 j_2} Z^{\nu}_{t_3 j_2} \Big) \\
&+ 4 \sum_{j_2=1}^{3} \sum_{j_1=1}^{3} Z^{\nu,*}_{t_1 j_1} Y_{e,j_1 j_2} Z^{E}_{t_4 3+j_2} \sum_{j_4=1}^{3} Z^{E,*}_{t_2 3+j_4} \sum_{j_3=1}^{3} Y^{*}_{e,j_3 j_4} Z^{\nu}_{t_3 j_3} \Big)
\end{aligned}
\tag{C.127}
$$

$$
\Gamma_{\tilde{\nu}_{t_1} h_{t_2} \tilde{\nu}^{*}_{t_3} h_{t_4}} = - \frac{i}{4} \Big(g_1^2 + g_2^2\Big) \delta_{t_1,t_3} \Big(Z^{H}_{t_2 1} Z^{H}_{t_4 1} - Z^{H}_{t_2 2} Z^{H}_{t_4 2} \Big) \tag{C.128}
$$

$$\Gamma_{\tilde{\nu}_{t_1}A^0_{t_2}\tilde{\nu}^*_{t_3}A^0_{t_4}} = -\frac{i}{4}\Big(g_1^2+g_2^2\Big)\delta_{t_1,t_3}\Big(Z^A_{t_21}Z^A_{t_41}-Z^A_{t_22}Z^A_{t_42}\Big) \tag{C.129}$$

$$\begin{aligned}\Gamma_{\tilde{\nu}_{t_1}H^-_{t_2}\tilde{\nu}^*_{t_3}H^+_{t_4}} =& \frac{i}{4}\Big(Z^{+,*}_{t_21}\Big(\Big(g_2^2-g_1^2\Big)\delta_{t_1,t_3}-4\sum_{j_3=1}^{3}\sum_{j_2=1}^{3}Z^{\nu,*}_{t_1j_2}\sum_{j_1=1}^{3}Y^*_{e,j_3j_1}Y_{e,j_2j_1}Z^{\nu}_{t_3j_3}\Big)Z^+_{t_41}\\ &+\Big(g_1^2-g_2^2\Big)Z^{+,*}_{t_22}\delta_{t_1,t_3}Z^+_{t_42}\Big)\end{aligned} \tag{C.130}$$

$$\begin{aligned}\Gamma_{\tilde{u}_{t_1\alpha_1}\tilde{e}_{t_2}\tilde{u}^*_{t_3\alpha_3}\tilde{e}^*_{t_4}} =& \frac{i}{24}\delta_{\alpha_1,\alpha_3}\Big(-4g_1^2\sum_{j_1=1}^{3}Z^{U,*}_{t_13+j_1}Z^U_{t_33+j_1}\Big(\sum_{j_2=1}^{3}Z^{E,*}_{t_2j_2}Z^E_{t_4j_2}-2\sum_{j_2=1}^{3}Z^{E,*}_{t_23+j_2}Z^E_{t_43+j_2}\Big)\\ &+\sum_{j_1=1}^{3}Z^{U,*}_{t_1j_1}Z^U_{t_3j_1}\Big(\Big(3g_2^2+g_1^2\Big)\sum_{j_2=1}^{3}Z^{E,*}_{t_2j_2}Z^E_{t_4j_2}-2g_1^2\sum_{j_2=1}^{3}Z^{E,*}_{t_23+j_2}Z^E_{t_43+j_2}\Big)\\ &+\Big(\Big(3g_2^2+g_1^2\Big)\sum_{j_1=1}^{3}Z^{E,*}_{t_2j_1}Z^E_{t_4j_1}-2g_1^2\sum_{j_1=1}^{3}Z^{E,*}_{t_23+j_1}Z^E_{t_43+j_1}\Big)\sum_{j_2=1}^{3}Z^{U,*}_{t_1j_2}Z^U_{t_3j_2}\\ &-4g_1^2\Big(\sum_{j_1=1}^{3}Z^{E,*}_{t_2j_1}Z^E_{t_4j_1}-2\sum_{j_1=1}^{3}Z^{E,*}_{t_23+j_1}Z^E_{t_43+j_1}\Big)\sum_{j_2=1}^{3}Z^{U,*}_{t_13+j_2}Z^U_{t_33+j_2}\Big)\end{aligned} \tag{C.131}$$

$$\begin{aligned}\Gamma_{\tilde{u}_{t_1\alpha_1}H^-_{t_2}\tilde{u}^*_{t_3\alpha_3}H^+_{t_4}} =& \frac{i}{12}\delta_{\alpha_1,\alpha_3}\Big(Z^{+,*}_{t_21}\Big(\Big(3g_2^2+g_1^2\Big)\sum_{j_1=1}^{3}Z^{U,*}_{t_1j_1}Z^U_{t_3j_1}-4\Big(g_1^2\sum_{j_1=1}^{3}Z^{U,*}_{t_13+j_1}Z^U_{t_33+j_1}\\ &+3\sum_{j_3=1}^{3}\sum_{j_2=1}^{3}Z^{U,*}_{t_1j_2}\sum_{j_1=1}^{3}Y^*_{d,j_3j_1}Y_{d,j_2j_1}Z^U_{t_3j_3}\Big)\Big)Z^+_{t_41}\\ &-Z^{+,*}_{t_22}\Big(\Big(3g_2^2+g_1^2\Big)\sum_{j_1=1}^{3}Z^{U,*}_{t_1j_1}Z^U_{t_3j_1}-4g_1^2\sum_{j_1=1}^{3}Z^{U,*}_{t_13+j_1}Z^U_{t_33+j_1}\\ &+12\sum_{j_3=1}^{3}Z^{U,*}_{t_13+j_3}\sum_{j_2=1}^{3}\sum_{j_1=1}^{3}Y^*_{u,j_1j_3}Y_{u,j_1j_2}Z^U_{t_33+j_2}\Big)Z^+_{t_42}\Big)\end{aligned} \tag{C.132}$$

$$\begin{aligned}\Gamma_{\tilde{e}_{t_1}\tilde{e}_{t_2}\tilde{e}^*_{t_3}\tilde{e}^*_{t_4}} =& -\frac{i}{8}\Big(g_1^2\sum_{j_1=1}^{3}Z^{E,*}_{t_1j_1}Z^E_{t_4j_1}\sum_{j_2=1}^{3}Z^{E,*}_{t_2j_2}Z^E_{t_3j_2}+g_2^2\sum_{j_1=1}^{3}Z^{E,*}_{t_1j_1}Z^E_{t_4j_1}\sum_{j_2=1}^{3}Z^{E,*}_{t_2j_2}Z^E_{t_3j_2}\\ &-2g_1^2\sum_{j_1=1}^{3}Z^{E,*}_{t_13+j_1}Z^E_{t_43+j_1}\sum_{j_2=1}^{3}Z^{E,*}_{t_2j_2}Z^E_{t_3j_2}\\ &-2g_1^2\sum_{j_1=1}^{3}Z^{E,*}_{t_23+j_1}Z^E_{t_43+j_1}\Big(\sum_{j_2=1}^{3}Z^{E,*}_{t_1j_2}Z^E_{t_3j_2}-2\sum_{j_2=1}^{3}Z^{E,*}_{t_13+j_2}Z^E_{t_33+j_2}\Big)\\ &+\sum_{j_1=1}^{3}Z^{E,*}_{t_2j_1}Z^E_{t_4j_1}\Big(\Big(g_1^2+g_2^2\Big)\sum_{j_2=1}^{3}Z^{E,*}_{t_1j_2}Z^E_{t_3j_2}-2g_1^2\sum_{j_2=1}^{3}Z^{E,*}_{t_13+j_2}Z^E_{t_33+j_2}\Big)\end{aligned}$$

$$
\begin{aligned}
&- 2g_1^2\Big(\sum_{j_1=1}^{3} Z^{E,*}_{t_1 j_1} Z^{E}_{t_4 j_1} \sum_{j_2=1}^{3} Z^{E,*}_{t_2 3+j_2} Z^{E}_{t_3 3+j_2} + \sum_{j_1=1}^{3} Z^{E,*}_{t_2 j_1} Z^{E}_{t_3 j_1} \sum_{j_2=1}^{3} Z^{E,*}_{t_1 3+j_2} Z^{E}_{t_4 3+j_2}\Big) \\
&+ 4g_1^2\Big(\sum_{j_1=1}^{3} Z^{E,*}_{t_1 3+j_1} Z^{E}_{t_4 3+j_1} \sum_{j_2=1}^{3} Z^{E,*}_{t_2 3+j_2} Z^{E}_{t_3 3+j_2} \\
&\qquad\qquad + \sum_{j_1=1}^{3} Z^{E,*}_{t_2 3+j_1} Z^{E}_{t_3 3+j_1} \sum_{j_2=1}^{3} Z^{E,*}_{t_1 3+j_2} Z^{E}_{t_4 3+j_2}\Big) \\
&+ g_1^2 \sum_{j_1=1}^{3} Z^{E,*}_{t_2 j_1} Z^{E}_{t_3 j_1} \sum_{j_2=1}^{3} Z^{E,*}_{t_1 j_2} Z^{E}_{t_4 j_2} + g_2^2 \sum_{j_1=1}^{3} Z^{E,*}_{t_2 j_1} Z^{E}_{t_3 j_1} \sum_{j_2=1}^{3} Z^{E,*}_{t_1 j_2} Z^{E}_{t_4 j_2} \\
&- 2g_1^2 \sum_{j_1=1}^{3} Z^{E,*}_{t_2 3+j_1} Z^{E}_{t_3 3+j_1} \sum_{j_2=1}^{3} Z^{E,*}_{t_1 j_2} Z^{E}_{t_4 j_2} + g_1^2 \sum_{j_1=1}^{3} Z^{E,*}_{t_1 j_1} Z^{E}_{t_3 j_1} \sum_{j_2=1}^{3} Z^{E,*}_{t_2 j_2} Z^{E}_{t_4 j_2} \\
&+ g_2^2 \sum_{j_1=1}^{3} Z^{E,*}_{t_1 j_1} Z^{E}_{t_3 j_1} \sum_{j_2=1}^{3} Z^{E,*}_{t_2 j_2} Z^{E}_{t_4 j_2} - 2g_1^2 \sum_{j_1=1}^{3} Z^{E,*}_{t_1 3+j_1} Z^{E}_{t_3 3+j_1} \sum_{j_2=1}^{3} Z^{E,*}_{t_2 j_2} Z^{E}_{t_4 j_2} \\
&2g_1^2\Big(\sum_{j_1=1}^{3} Z^{E,*}_{t_1 j_1} Z^{E}_{t_3 j_1} - 2\sum_{j_1=1}^{3} Z^{E,*}_{t_1 3+j_1} Z^{E}_{t_3 3+j_1}\Big) \sum_{j_2=1}^{3} Z^{E,*}_{t_2 3+j_2} Z^{E}_{t_4 3+j_2} \\
&+ 8\Big(\sum_{j_2=1}^{3}\sum_{j_1=1}^{3} Z^{E,*}_{t_2 j_1} Y_{e,j_1 j_2} Z^{E}_{t_4 3+j_2} \sum_{j_4=1}^{3} Z^{E,*}_{t_1 3+j_4} \sum_{j_3=1}^{3} Y^{*}_{e,j_3 j_4} Z^{E}_{t_3 j_3} \\
&+ \sum_{j_2=1}^{3}\sum_{j_1=1}^{3} Z^{E,*}_{t_1 j_1} Y_{e,j_1 j_2} Z^{E}_{t_4 3+j_2} \sum_{j_4=1}^{3} Z^{E,*}_{t_2 3+j_4} \sum_{j_3=1}^{3} Y^{*}_{e,j_3 j_4} Z^{E}_{t_3 j_3} \\
&+ \sum_{j_2=1}^{3}\sum_{j_1=1}^{3} Z^{E,*}_{t_2 j_1} Y_{e,j_1 j_2} Z^{E}_{t_3 3+j_2} \sum_{j_4=1}^{3} Z^{E,*}_{t_1 3+j_4} \sum_{j_3=1}^{3} Y^{*}_{e,j_3 j_4} Z^{E}_{t_4 j_3} \\
&+ \sum_{j_2=1}^{3}\sum_{j_1=1}^{3} Z^{E,*}_{t_1 j_1} Y_{e,j_1 j_2} Z^{E}_{t_3 3+j_2} \sum_{j_4=1}^{3} Z^{E,*}_{t_2 3+j_4} \sum_{j_3=1}^{3} Y^{*}_{e,j_3 j_4} Z^{E}_{t_4 j_3}\Big)\Big)
\end{aligned}
\tag{C.133}
$$

$$
\begin{aligned}
\Gamma_{\tilde{e}_{t_1} H^-_{t_2} \tilde{e}^*_{t_3} H^+_{t_4}} = \frac{i}{4}\Big(&- Z^{+,*}_{t_2 1}\Big(\Big(g_1^2+g_2^2\Big)\sum_{j_1=1}^{3} Z^{E,*}_{t_1 j_1} Z^{E}_{t_3 j_1} - 2g_1^2 \sum_{j_1=1}^{3} Z^{E,*}_{t_1 3+j_1} Z^{E}_{t_3 3+j_1} \\
&+ 4\sum_{j_3=1}^{3} Z^{E,*}_{t_1 3+j_3} \sum_{j_2=1}^{3}\sum_{j_1=1}^{3} Y^{*}_{e,j_1 j_3} Y_{e,j_1 j_2} Z^{E}_{t_3 3+j_2}\Big) Z^{+}_{t_4 1} \\
&+ Z^{+,*}_{t_2 2}\Big(-2g_1^2 \sum_{j_1=1}^{3} Z^{E,*}_{t_1 3+j_1} Z^{E}_{t_3 3+j_1} + \Big(g_1^2+g_2^2\Big)\sum_{j_1=1}^{3} Z^{E,*}_{t_1 j_1} Z^{E}_{t_3 j_1}\Big) Z^{+}_{t_4 2}\Big)
\end{aligned}
\tag{C.134}
$$

C.7 Three Scalar

$$\Gamma_{\tilde{d}_{t_1\alpha_1}\tilde{d}^*_{t_2\alpha_2}h_{t_3}} = \delta_{\alpha_1,\alpha_2}\Big(D_4 Z^H_{t_3 1} + D_7 v_d Z^H_{t_3 1} + D_5\Big(v_d Z^H_{t_3 1} - v_u Z^H_{t_3 2}\Big) + D_6\Big(v_s Z^H_{t_3 2} + v_u Z^H_{t_3 3}\Big)\Big) \tag{C.135}$$

$$\Gamma_{\tilde{d}_{t_1\alpha_1}\tilde{d}^*_{t_2\alpha_2}A_{h^*,t_3}} = \delta_{\alpha_1,\alpha_2}\Big(D_8 Z^A_{t_3 1} + D_9\Big(v_s Z^A_{t_3 2} + v_u Z^A_{t_3 3}\Big)\Big) \tag{C.136}$$

$$\Gamma_{\tilde{u}_{t_1\alpha_1}\tilde{u}^*_{t_2\alpha_2}h_{t_3}} = \delta_{\alpha_1,\alpha_2}\Big(U_4 Z^H_{t_3 2} + U_7 v_u Z^H_{t_3 2} + U_5\Big(v_d Z^H_{t_3 1} - v_u Z^H_{t_3 2}\Big) + U_6\Big(v_d Z^H_{t_3 3} + v_s Z^H_{t_3 1}\Big)\Big) \tag{C.137}$$

$$\Gamma_{\tilde{u}_{t_1\alpha_1}\tilde{u}^*_{t_2\alpha_2}A^0_{t_3}} = \delta_{\alpha_1,\alpha_2}\Big(U_8 Z^A_{t_3 2} + U_9\Big(v_d Z^A_{t_3 3} + v_s Z^A_{t_3 1}\Big)\Big) \tag{C.138}$$

$$\Gamma_{\tilde{e}_{t_1}\tilde{e}^*_{t_2}h_{t_3}} = E_4 Z^H_{t_3 1} + E_7 v_d Z^H_{t_3 1} + E_5\Big(-v_d Z^H_{t_3 1} + v_u Z^H_{t_3 2}\Big) + E_6\Big(v_s Z^H_{t_3 2} + v_u Z^H_{t_3 3}\Big) \tag{C.139}$$

$$\Gamma_{\tilde{e}_{t_1}\tilde{e}^*_{t_2}A^0_{t_3}} = E_8 Z^A_{t_3 1} + E_9\Big(v_s Z^A_{t_3 2} + v_u Z^A_{t_3 3}\Big) \tag{C.140}$$

$$\begin{aligned}
\Gamma_{\tilde{u}_{t_1\alpha_1}\tilde{d}^*_{t_2\alpha_2}H^-_{t_3}} = & -\frac{i}{4}\delta_{\alpha_1,\alpha_2}\Big(Z^{+,*}_{t_3 1}\Big(\sqrt{2}g_2^2 v_d \sum_{j_1=1}^{3} Z^{U,*}_{t_1 j_1} Z^D_{t_2 j_1} \\
& - 2\Big(\sqrt{2}v_s\lambda \sum_{j_2=1}^{3} Z^{U,*}_{t_1 3+j_2} \sum_{j_1=1}^{3} Y^*_{u,j_1 j_2} Z^D_{t_2 j_1} + 2\sum_{j_2=1}^{3}\sum_{j_1=1}^{3} Z^{U,*}_{t_1 j_1} T_{d,j_1 j_2} Z^D_{t_2 3+j_2} \\
& + \sqrt{2}\Big(v_u \sum_{j_3=1}^{3} Z^{U,*}_{t_1 3+j_3} \sum_{j_2=1}^{3}\sum_{j_1=1}^{3} Y^*_{u,j_1 j_3} Y_{d,j_1 j_2} Z^D_{t_2 3+j_2} \\
& + v_d \sum_{j_3=1}^{3}\sum_{j_2=1}^{3} Z^{U,*}_{t_1 j_2} \sum_{j_1=1}^{3} Y^*_{d,j_3 j_1} Y_{d,j_2 j_1} Z^D_{t_2 j_3}\Big)\Big)\Big) + Z^{+,*}_{t_3 2}\Big(\sqrt{2}g_2^2 v_u \sum_{j_1=1}^{3} Z^{U,*}_{t_1 j_1} Z^D_{t_2 j_1} \\
& - 2\Big(2\sum_{j_2=1}^{3} Z^{U,*}_{t_1 3+j_2} \sum_{j_1=1}^{3} T^*_{u,j_1 j_2} Z^D_{t_2 j_1} + \sqrt{2}\Big(v_s\lambda^* \sum_{j_2=1}^{3}\sum_{j_1=1}^{3} Z^{U,*}_{t_1 j_1} Y_{d,j_1 j_2} Z^D_{t_2 3+j_2} \\
& + v_d \sum_{j_3=1}^{3} Z^{U,*}_{t_1 3+j_3} \sum_{j_2=1}^{3}\sum_{j_1=1}^{3} Y^*_{u,j_1 j_3} Y_{d,j_1 j_2} Z^D_{t_2 3+j_2} \\
& + v_u \sum_{j_3=1}^{3}\sum_{j_2=1}^{3} Z^{U,*}_{t_1 j_2} \sum_{j_1=1}^{3} Y^*_{u,j_3 j_1} Y_{u,j_2 j_1} Z^D_{t_2 j_3}\Big)\Big)\Big)\Big)
\end{aligned} \tag{C.141}$$

$$\Gamma_{\tilde{\nu}_{t_1}\tilde{\nu}^*_{t_2}h_{t_3}} = -\frac{i}{4}\Big(g_1^2 + g_2^2\Big)\delta_{t_1,t_2}\Big(v_d Z^H_{t_3 1} - v_u Z^H_{t_3 2}\Big) \tag{C.142}$$

$$\begin{aligned}
\Gamma_{\tilde{\nu}_{t_1}\tilde{e}^*_{t_2}H^-_{t_3}} = & \frac{i}{4}\Big(\sqrt{2}Z^{+,*}_{t_3 2}\Big(-g_2^2 v_u \sum_{j_1=1}^{3} Z^{\nu,*}_{t_1 j_1} Z^E_{t_2 j_1} + 2v_s\lambda^* \sum_{j_2=1}^{3}\sum_{j_1=1}^{3} Z^{\nu,*}_{t_1 j_1} Y_{e,j_1 j_2} Z^E_{t_2 3+j_2}\Big) \\
& + Z^{+,*}_{t_3 1}\Big(-\sqrt{2}g_2^2 v_d \sum_{j_1=1}^{3} Z^{\nu,*}_{t_1 j_1} Z^E_{t_2 j_1} + 4\sum_{j_2=1}^{3}\sum_{j_1=1}^{3} Z^{\nu,*}_{t_1 j_1} T_{e,j_1 j_2} Z^E_{t_2 3+j_2}
\end{aligned}$$

$$+ 2\sqrt{2}v_d \sum_{j_3=1}^{3}\sum_{j_2=1}^{3} Z^{\nu,*}_{t_1 j_2} \sum_{j_1=1}^{3} Y^*_{e,j_3 j_1} Y_{e,j_2 j_1} Z^E_{t_2 j_3}\Big)\Big) \tag{C.143}$$

$$\begin{aligned}
\Gamma_{h_{t_1}h_{t_2}h_{t_3}} = \frac{i}{4}\Big(& Z^H_{t_1 1}\Big(Z^H_{t_2 1}\Big(-3g_+^2 v_d Z^H_{t_3 1} - 4v_s|\lambda|^2 Z^H_{t_3 3} + v_u\tilde{\lambda} Z^H_{t_3 2}\Big)\\
&+ Z^H_{t_2 2}\Big(v_u\tilde{\lambda} Z^H_{t_3 1} + v_d\tilde{\lambda} Z^H_{t_3 2} + \Lambda_1 Z^H_{t_3 3}\Big)\\
&+ Z^H_{t_2 3}\Big(\sqrt{2}\,2\,\mathrm{Re}\big\{T_\lambda\big\} Z^H_{t_3 2} + 2\lambda\kappa^*\Big(v_s Z^H_{t_3 2} + v_u Z^H_{t_3 3}\Big)\\
&+ 2\lambda^*\Big(\Lambda_3 Z^H_{t_3 3} - 2v_s\lambda Z^H_{t_3 1} + v_s\kappa Z^H_{t_3 2}\Big)\Big)\Big)\\
&+ Z^H_{t_1 2}\Big(Z^H_{t_2 2}\Big(-3g_+^2 v_u Z^H_{t_3 2} - 4v_s|\lambda|^2 Z^H_{t_3 3} + v_d\tilde{\lambda} Z^H_{t_3 1}\Big)\\
&+ Z^H_{t_2 1}\Big(v_u\tilde{\lambda} Z^H_{t_3 1} + v_d\tilde{\lambda} Z^H_{t_3 2} + \Lambda_1 Z^H_{t_3 3}\Big)\\
&+ Z^H_{t_2 3}\Big(\sqrt{2}\mathrm{Re}\big\{T_\lambda\big\} Z^H_{t_3 1} + 2\lambda\kappa^*\Big(v_d Z^H_{t_3 3} + v_s Z^H_{t_3 1}\Big)\\
&+ 2\lambda^*\Big(-2v_s\lambda Z^H_{t_3 2} + \Lambda_2 Z^H_{t_3 3} + v_s\kappa Z^H_{t_3 1}\Big)\Big)\Big)\\
&+ Z^H_{t_1 3}\Big(\sqrt{2}\Big(-4\mathrm{Re}\big\{T_\kappa\big\} Z^H_{t_2 3} Z^H_{t_3 3} + T^*_\lambda\Big(Z^H_{t_2 1} Z^H_{t_3 2} + Z^H_{t_2 2} Z^H_{t_3 1}\Big)\\
&+ T_\lambda\Big(Z^H_{t_2 1} Z^H_{t_3 2} + Z^H_{t_2 2} Z^H_{t_3 1}\Big)\Big) + 2\kappa^*\Big(\lambda Z^H_{t_2 2}\Big(v_d Z^H_{t_3 3} + v_s Z^H_{t_3 1}\Big)\\
&+ \lambda Z^H_{t_2 1}\Big(v_s Z^H_{t_3 2} + v_u Z^H_{t_3 3}\Big) + Z^H_{t_2 3}\Big(-12v_s\kappa Z^H_{t_3 3} + v_d\lambda Z^H_{t_3 2} + v_u\lambda Z^H_{t_3 1}\Big)\Big)\\
&+ 2\lambda^*\Big(Z^H_{t_2 3}\Big(\Lambda_3 Z^H_{t_3 1} + \Lambda_2 Z^H_{t_3 2}\Big) + Z^H_{t_2 1}\Big(\Lambda_3 Z^H_{t_3 3} - 2v_s\lambda Z^H_{t_3 1} + v_s\kappa Z^H_{t_3 2}\Big)\\
&+ Z^H_{t_2 2}\Big(-2v_s\lambda Z^H_{t_3 2} + \Lambda_2 Z^H_{t_3 3} + v_s\kappa Z^H_{t_3 1}\Big)\Big)\Big)\Big)
\end{aligned} \tag{C.144}$$

$$\begin{aligned}
\Gamma_{h_{t_1}A^0_{t_2}A^0_{t_3}} = \frac{i}{4}\Big(& -Z^A_{t_2 1}\Big(-4v_s\mathrm{Re}\big\{\lambda\kappa\big\} Z^A_{t_3 3} Z^H_{t_1 2} + \sqrt{2}\,2\,\mathrm{Re}\big\{T_\lambda\big\} Z^A_{t_3 3} Z^H_{t_1 2}\\
&+ 4v_s\mathrm{Re}\big\{\lambda\kappa\big\} Z^A_{t_3 2} Z^H_{t_1 3} + \sqrt{2}\,2\,\mathrm{Re}\big\{T_\lambda\big\} Z^A_{t_3 2} Z^H_{t_1 3} - 4v_u\mathrm{Re}\big\{\lambda\kappa\big\} Z^A_{t_3 3} Z^H_{t_1 3}\\
&+ Z^A_{t_3 1}\Big(4v_s|\lambda|^2 Z^H_{t_1 3} + g_+^2 v_d Z^H_{t_1 1} - v_u\tilde{\lambda} Z^H_{t_1 2}\Big)\Big)\\
&+ Z^A_{t_2 2}\Big(2v_s\kappa\lambda^* Z^A_{t_3 3} Z^H_{t_1 1} - \sqrt{2}T^*_\lambda Z^A_{t_3 3} Z^H_{t_1 1} - \sqrt{2}T_\lambda Z^A_{t_3 3} Z^H_{t_1 1} - 2v_s\kappa\lambda^* Z^A_{t_3 1} Z^H_{t_1 3}\\
&- \sqrt{2}T^*_\lambda Z^A_{t_3 1} Z^H_{t_1 3} - \sqrt{2}T_\lambda Z^A_{t_3 1} Z^H_{t_1 3} + 2v_d\kappa\lambda^* Z^A_{t_3 3} Z^H_{t_1 3}\\
&+ Z^A_{t_3 2}\Big(-4v_s|\lambda|^2 Z^H_{t_1 3} - g_+^2 v_u Z^H_{t_1 2} + v_d\tilde{\lambda} Z^H_{t_1 1}\Big)\\
&+ 2\lambda\kappa^*\Big(-v_s Z^A_{t_3 1} Z^H_{t_1 3} + Z^A_{t_3 3}\Big(v_d Z^H_{t_1 3} + v_s Z^H_{t_1 1}\Big)\Big)\Big)\\
&+ Z^A_{t_2 3}\Big(-\sqrt{2}\Big(-2\mathrm{Re}\big\{T_\kappa\big\} Z^A_{t_3 3} Z^H_{t_1 3} + T^*_\lambda\Big(Z^A_{t_3 1} Z^H_{t_1 2} + Z^A_{t_3 2} Z^H_{t_1 1}\Big)\\
&+ T_\lambda\Big(Z^A_{t_3 1} Z^H_{t_1 2} + Z^A_{t_3 2} Z^H_{t_1 1}\Big)\Big) + 2\lambda^*\Big(-Z^A_{t_3 3}\Big(\Big(2v_d\lambda + v_u\kappa\Big) Z^H_{t_1 1}\\
&+ \Big(2v_u\lambda + v_d\kappa\Big) Z^H_{t_1 2}\Big) + \kappa Z^A_{t_3 2}\Big(v_d Z^H_{t_1 3} + v_s Z^H_{t_1 1}\Big) + \kappa Z^A_{t_3 1}\Big(v_s Z^H_{t_1 2} + v_u Z^H_{t_1 3}\Big)\Big)\\
&+ 2\kappa^*\Big(\lambda Z^A_{t_3 2}\Big(v_d Z^H_{t_1 3} + v_s Z^H_{t_1 1}\Big) + \lambda Z^A_{t_3 1}\Big(v_s Z^H_{t_1 2} + v_u Z^H_{t_1 3}\Big)
\end{aligned}$$

$$- Z^A_{t_3 3}\Big(4v_s\kappa Z^H_{t_1 3} + v_d\lambda Z^H_{t_1 2} + v_u\lambda Z^H_{t_1 1}\Big)\Big)\Big)\Big) \tag{C.145}$$

$$\begin{aligned}\Gamma_{h_{t_1}H^+_{t_2}H^-_{t_3}} =& \frac{i}{4}\Big(- Z^{+,*}_{t_3 1}\Big(Z^H_{t_1 2}\Big(g^2_- v_u Z^+_{t_2 1} + v_d\bar\lambda Z^+_{t_2 2}\Big) + Z^H_{t_1 1}\Big(g^2_+ v_d Z^+_{t_2 1} + v_u\bar\lambda Z^+_{t_2 2}\Big)\\ &+ 2Z^H_{t_1 3}\Big(2v_s|\lambda|^2 Z^+_{t_2 1} + \Big(2v_s\lambda\kappa^* + \sqrt{2}T_\lambda\Big)Z^+_{t_2 2}\Big)\Big)\\ &- Z^{+,*}_{t_3 2}\Big(Z^H_{t_1 1}\Big(g^2_- v_d Z^+_{t_2 2} + v_u\bar\lambda Z^+_{t_2 1}\Big) + Z^H_{t_1 2}\Big(g^2_+ v_u Z^+_{t_2 2} + v_d\bar\lambda Z^+_{t_2 1}\Big)\\ &+ 2Z^H_{t_1 3}\Big(2v_s\lambda^*\Big(\kappa Z^+_{t_2 1} + \lambda Z^+_{t_2 2}\Big) + \sqrt{2}T^*_\lambda Z^+_{t_2 1}\Big)\Big)\Big)\end{aligned} \tag{C.146}$$

$$\begin{aligned}\Gamma_{A^0_{t_1}H^+_{t_2}H^-_{t_3}} =& \frac{1}{4}\Big(Z^{+,*}_{t_3 2}\Big(2\Big(2v_s\kappa\lambda^* - \sqrt{2}T^*_\lambda\Big)Z^A_{t_1 3} + v_d\bar\lambda Z^A_{t_1 2} + v_u\bar\lambda Z^A_{t_1 1}\Big)Z^+_{t_2 1}\\ &- Z^{+,*}_{t_3 1}\Big(2\Big(2v_s\lambda\kappa^* - \sqrt{2}T_\lambda\Big)Z^A_{t_1 3} + v_d\bar\lambda Z^A_{t_1 2} + v_u\bar\lambda Z^A_{t_1 1}\Big)Z^+_{t_2 2}\Big)\end{aligned} \tag{C.147}$$

D. One-loop tadpoles

In this and the subsequent Apps., particles that are denoted with a hat, e.g. $\hat{h}_i$, are the unrotated external states. In the corresponding vertices the associated mixing matrix has to be replaced by the identity matrix. Moreover, we have summed her and in the subsequent section in all the vertices implicitly over the colour indices of quarks and squarks.

At the one-loop level, the expressions for the tadpoles of eq. (2.13) are given by

$$\begin{aligned}\delta t_i =& \frac{3}{2}A_0\big(m^2_Z\big)\Gamma_{\hat{h}_i,Z,Z} + 3A_0\big(m^2_W\big)\Gamma_{\hat{h}_i,W^+,W^-} - \sum_{s_1=1}^{2}A_0\big(m^2_{H^+_{s_1}}\big)\Gamma_{\hat{h}_i,H^+_{s_1},H^-_{s_1}}\\ &+ 4\sum_{s_1=1}^{2}A_0\big(m^2_{\tilde\chi^+_{s_1}}\big)\Gamma_{\hat{h}_i,\tilde\chi^+_{s_1},\tilde\chi^-_{s_1}}m^2_{\tilde\chi^+_{s_1}} - \frac{1}{2}\sum_{s_1=1}^{3}A_0\big(m^2_{A^0_{s_1}}\big)\Gamma_{\hat{h}_i,A^0_{s_1},A^0_{s_1}}\\ &- \frac{1}{2}\sum_{s_1=1}^{3}A_0\big(m^2_{h_{s_1}}\big)\Gamma_{\hat{h}_i,h_{s_1},h_{s_1}} + 12\sum_{s_1=1}^{3}A_0\big(m^2_{d_{s_1}}\big)\Gamma_{\hat{h}_i,\bar{d}_{s_1},d_{s_1}}m^2_{d_{s_1}}\\ &+ 4\sum_{s_1=1}^{3}A_0\big(m^2_{e_{s_1}}\big)\Gamma_{\hat{h}_i,\bar{e}_{s_1},e_{s_1}}m^2_{e_{s_1}} + 12\sum_{s_1=1}^{3}A_0\big(m^2_{u_{s_1}}\big)\Gamma_{\hat{h}_i,\bar{u}_{s_1},u_{s_1}}m^2_{u_{s_1}}\\ &+ 2\sum_{s_1=1}^{5}A_0\big(m^2_{\tilde\chi^0_{s_1}}\big)\Gamma_{\hat{h}_i,\tilde\chi^0_{s_1},\tilde\chi^0_{s_1}}m^2_{\tilde\chi^0_{s_1}} - 3\sum_{s_1=1}^{6}A_0\big(m^2_{\tilde d_{s_1}}\big)\Gamma_{\hat{h}_i,\tilde d^*_{s_1},\tilde d_{s_1}}\\ &- 3\sum_{s_1=1}^{6}A_0\big(m^2_{\tilde u_{s_1}}\big)\Gamma_{\hat{h}_i,\tilde u^*_{s_1},\tilde u_{s_1}} - \sum_{s_1=1}^{3}A_0\big(m^2_{\tilde\nu_{s_1}}\big)\Gamma_{\hat{h}_i,\tilde\nu^*_{s_1},\tilde\nu_{s_1}}\\ &- \sum_{s_1=1}^{6}A_0\big(m^2_{\tilde e_{s_1}}\big)\Gamma_{\hat{h}_i,\tilde e^*_{s_1},\tilde e_{s_1}}\end{aligned} \tag{D.1}$$

E. One-loop self-energies

The definitions of the scalar one-loop functions and their explicit analytic expressions can be found in ref. [14].

E.1 Self energy of Z-boson

In agreement with ref. [13] we obtain for the transverse self-energy of the Z-boson

$$
\begin{aligned}
\Pi^T_{ZZ}(p^2) =& \frac{1}{2} g_2^2 c_\Theta^2 \Big(-8 B_{22}\Big(p^2, m_W^2, m_W^2\Big) - B_0\Big(p^2, m_W^2, m_W^2\Big)\Big(2m_W^2 + 4p^2\Big)\Big) \\
& - 4 \sum_{s_1=1}^{2}\sum_{s_2=1}^{2} |\Gamma_{Z,H^+_{s_1},H^-_{s_2}}|^2 B_{22}\Big(p^2, m^2_{H^+_{s_1}}, m^2_{H^+_{s_2}}\Big) \\
& + \frac{1}{2} \sum_{s_1=1}^{2}\sum_{s_2=1}^{2} \Big[\Big(|\Gamma^L_{Z,\tilde{\chi}^+_{s_1},\tilde{\chi}^-_{s_2}}|^2 + |\Gamma^R_{Z,\tilde{\chi}^+_{s_1},\tilde{\chi}^-_{s_2}}|^2 \Big) H_0\Big(p^2, m^2_{\tilde{\chi}^+_{s_1}}, m^2_{\tilde{\chi}^+_{s_2}}\Big) \\
& + 4 B_0\Big(p^2, m^2_{\tilde{\chi}^+_{s_1}}, m^2_{\tilde{\chi}^+_{s_2}}\Big) m_{\tilde{\chi}^+_{s_1}} m_{\tilde{\chi}^-_{s_2}} \mathrm{Re}\Big\{ \Gamma^{L*}_{Z,\tilde{\chi}^+_{s_1},\tilde{\chi}^-_{s_2}} \Gamma^R_{Z,\tilde{\chi}^+_{s_1},\tilde{\chi}^-_{s_2}} \Big\} \Big] \\
& - 4 \sum_{s_1=1}^{3}\sum_{s_2=1}^{3} |\Gamma_{Z,A^0_{s_1},h_{s_2}}|^2 B_{22}\Big(p^2, m^2_{h_{s_1}}, m^2_{A^0_{s_2}}\Big) \\
& - 4 \sum_{s_1=1}^{3}\sum_{s_2=1}^{3} |\Gamma_{Z,\tilde{\nu}^*_{s_1},\tilde{\nu}_{s_2}}|^2 B_{22}\Big(p^2, m^2_{\tilde{\nu}_{s_1}}, m^2_{\tilde{\nu}_{s_2}}\Big) \\
& + \frac{3}{2} \sum_{s_1=1}^{3}\sum_{s_2=1}^{3} \Big[\Big(|\Gamma^L_{Z,\bar{d}_{s_1},d_{s_2}}|^2 + |\Gamma^R_{Z,\bar{d}_{s_1},d_{s_2}}|^2 \Big) H_0\Big(p^2, m^2_{d_{s_1}}, m^2_{d_{s_2}}\Big) \\
& + 4 B_0\Big(p^2, m^2_{d_{s_1}}, m^2_{d_{s_2}}\Big) m_{\bar{d}_{s_1}} m_{d_{s_2}} \mathrm{Re}\Big\{ \Gamma^{L*}_{Z,\bar{d}_{s_1},d_{s_2}} \Gamma^R_{Z,\bar{d}_{s_1},d_{s_2}} \Big\} \Big] \\
& + \frac{1}{2} \sum_{s_1=1}^{3}\sum_{s_2=1}^{3} \Big[\Big(|\Gamma^L_{Z,\bar{e}_{s_1},e_{s_2}}|^2 + |\Gamma^R_{Z,\bar{e}_{s_1},e_{s_2}}|^2 \Big) H_0\Big(p^2, m^2_{e_{s_1}}, m^2_{e_{s_2}}\Big) \\
& + 4 B_0\Big(p^2, m^2_{e_{s_1}}, m^2_{e_{s_2}}\Big) m_{\bar{e}_{s_1}} m_{e_{s_2}} \mathrm{Re}\Big\{ \Gamma^{L*}_{Z,\bar{e}_{s_1},e_{s_2}} \Gamma^R_{Z,\bar{e}_{s_1},e_{s_2}} \Big\} \Big] \\
& + \frac{3}{2} \sum_{s_1=1}^{3}\sum_{s_2=1}^{3} \Big[\Big(|\Gamma^L_{Z,\bar{u}_{s_1},u_{s_2}}|^2 + |\Gamma^R_{Z,\bar{u}_{s_1},u_{s_2}}|^2 \Big) H_0\Big(p^2, m^2_{u_{s_1}}, m^2_{u_{s_2}}\Big) \\
& + 4 B_0\Big(p^2, m^2_{u_{s_1}}, m^2_{u_{s_2}}\Big) m_{\bar{u}_{s_1}} m_{u_{s_2}} \mathrm{Re}\Big\{ \Gamma^{L*}_{Z,\bar{u}_{s_1},u_{s_2}} \Gamma^R_{Z,\bar{u}_{s_1},u_{s_2}} \Big\} \Big] \\
& + \frac{1}{2} \sum_{s_1=1}^{3}\sum_{s_2=1}^{3} \Big[\Big(|\Gamma^L_{Z,\bar{\nu}_{s_1},\nu_{s_2}}|^2 + |\Gamma^R_{Z,\bar{\nu}_{s_1},\nu_{s_2}}|^2 \Big) H_0\Big(p^2, 0, 0\Big) \\
& + \frac{1}{4} \sum_{s_1=1}^{5}\sum_{s_2=1}^{5} \Big[\Big(|\Gamma^L_{Z,\tilde{\chi}^0_{s_1},\tilde{\chi}^0_{s_2}}|^2 + |\Gamma^R_{Z,\tilde{\chi}^0_{s_1},\tilde{\chi}^0_{s_2}}|^2 \Big) H_0\Big(p^2, m^2_{\tilde{\chi}^0_{s_1}}, m^2_{\tilde{\chi}^0_{s_2}}\Big) \\
& + 4 B_0\Big(p^2, m^2_{\tilde{\chi}^0_{s_1}}, m^2_{\tilde{\chi}^0_{s_2}}\Big) m_{\tilde{\chi}^0_{s_1}} m_{\tilde{\chi}^0_{s_2}} \mathrm{Re}\Big\{ \Gamma^{L*}_{Z,\tilde{\chi}^0_{s_1},\tilde{\chi}^0_{s_2}} \Gamma^R_{Z,\tilde{\chi}^0_{s_1},\tilde{\chi}^0_{s_2}} \Big\} \Big]
\end{aligned}
$$

$$
\begin{aligned}
&- 12 \sum_{s_1=1}^{6} \sum_{s_2=1}^{6} |\Gamma_{Z,\tilde{d}^*_{s_1},\tilde{d}_{s_2}}|^2 B_{22}\Big(p^2, m^2_{\tilde{d}_{s_1}}, m^2_{\tilde{d}_{s_2}}\Big) \\
&- 4 \sum_{s_1=1}^{6} \sum_{s_2=1}^{6} |\Gamma_{Z,\tilde{e}^*_{s_1},\tilde{e}_{s_2}}|^2 B_{22}\Big(p^2, m^2_{\tilde{e}_{s_1}}, m^2_{\tilde{e}_{s_2}}\Big) \\
&- 12 \sum_{s_1=1}^{6} \sum_{s_2=1}^{6} |\Gamma_{Z,\tilde{u}^*_{s_1},\tilde{u}_{s_2}}|^2 B_{22}\Big(p^2, m^2_{\tilde{u}_{s_1}}, m^2_{\tilde{u}_{s_2}}\Big) \\
&+ \frac{1}{2} \sum_{s_2=1}^{3} |\Gamma_{Z,Z,h_{s_2}}|^2 B_0\Big(p^2, m^2_Z, m^2_{h_{s_2}}\Big)
\end{aligned} \tag{E.1}
$$

E.2 Self-energy of CP-even Higgs-bosons

$$
\begin{aligned}
\Pi_{h_i,h_j}(p^2) = &\frac{7}{4} B_0\Big(p^2, m^2_Z, m^2_Z\Big) \Gamma^*_{\hat{h}_j,Z,Z} \Gamma_{\hat{h}_i,Z,Z} \\
&+ \frac{7}{2} B_0\Big(p^2, m^2_W, m^2_W\Big) \Gamma^*_{\hat{h}_j,W^+,W^-} \Gamma_{\hat{h}_i,W^+,W^-} + 2A_0\Big(m^2_Z\Big) \Gamma_{\hat{h}_i,\hat{h}_j,Z,Z} \\
&+ 4A_0\Big(m^2_W\Big) \Gamma_{\hat{h}_i,\hat{h}_j,W^+,W^-} - \sum_{s_1=1}^{2} A_0\Big(m^2_{H^+_{s_1}}\Big) \Gamma_{\hat{h}_i,\hat{h}_j,H^+_{s_1},H^-_{s_1}} \\
&+ \sum_{s_1=1}^{2} \sum_{s_2=1}^{2} B_0\Big(p^2, m^2_{H^+_{s_1}}, m^2_{H^+_{s_2}}\Big) \Gamma^*_{\hat{h}_j,H^+_{s_1},H^-_{s_2}} \Gamma_{\hat{h}_i,H^+_{s_1},H^-_{s_2}} \\
&- 2 \sum_{s_1=1}^{2} m_{\tilde{\chi}^+_{s_1}} \sum_{s_2=1}^{2} \Big[B_0\Big(p^2, m^2_{\tilde{\chi}^+_{s_1}}, m^2_{\tilde{\chi}^+_{s_2}}\Big) m_{\tilde{\chi}^-_{s_2}} \Big(\Gamma^{L*}_{\hat{h}_j,\tilde{\chi}^+_{s_1},\tilde{\chi}^-_{s_2}} \Gamma^{R}_{\hat{h}_i,\tilde{\chi}^+_{s_1},\tilde{\chi}^-_{s_2}} \\
&\qquad + \Gamma^{R*}_{\hat{h}_j,\tilde{\chi}^+_{s_1},\tilde{\chi}^-_{s_2}} \Gamma^{L}_{\hat{h}_i,\tilde{\chi}^+_{s_1},\tilde{\chi}^-_{s_2}} \Big) \Big] \\
&+ \sum_{s_1=1}^{2} \sum_{s_2=1}^{2} \Big[G_0\Big(p^2, m^2_{\tilde{\chi}^+_{s_1}}, m^2_{\tilde{\chi}^+_{s_2}}\Big) \Big(\Gamma^{L*}_{\hat{h}_j,\tilde{\chi}^+_{s_1},\tilde{\chi}^-_{s_2}} \Gamma^{L}_{\hat{h}_i,\tilde{\chi}^+_{s_1},\tilde{\chi}^-_{s_2}} \\
&\qquad + \Gamma^{R*}_{\hat{h}_j,\tilde{\chi}^+_{s_1},\tilde{\chi}^-_{s_2}} \Gamma^{R}_{\hat{h}_i,\tilde{\chi}^+_{s_1},\tilde{\chi}^-_{s_2}} \Big) \Big] \\
&- \frac{1}{2} \sum_{s_1=1}^{3} A_0\Big(m^2_{A^0_{s_1}}\Big) \Gamma_{\hat{h}_i,\hat{h}_j,A^0_{s_1},A^0_{s_1}} - \sum_{s_1=1}^{3} A_0\Big(m^2_{\tilde{\nu}_{s_1}}\Big) \Gamma_{\hat{h}_i,\hat{h}_j,\tilde{\nu}^*_{s_1},\tilde{\nu}_{s_1}} \\
&- \frac{1}{2} \sum_{s_1=1}^{3} A_0\Big(m^2_{h_{s_1}}\Big) \Gamma_{\hat{h}_i,\hat{h}_j,h_{s_1},h_{s_1}} \\
&+ \frac{1}{2} \sum_{s_1=1}^{3} \sum_{s_2=1}^{3} B_0\Big(p^2, m^2_{A^0_{s_1}}, m^2_{A^0_{s_2}}\Big) \Gamma^*_{\hat{h}_j,A^0_{s_1},A^0_{s_2}} \Gamma_{\hat{h}_i,A^0_{s_1},A^0_{s_2}} \\
&+ \sum_{s_1=1}^{3} \sum_{s_2=1}^{3} B_0\Big(p^2, m^2_{A^0_{s_1}}, m^2_{h_{s_2}}\Big) \Gamma^*_{\hat{h}_j,A^0_{s_1},h_{s_2}} \Gamma_{\hat{h}_i,A^0_{s_1},h_{s_2}}
\end{aligned}
$$

$$
\begin{aligned}
&+ \sum_{s_1=1}^{3}\sum_{s_2=1}^{3} B_0\Big(p^2, m^2_{\tilde{\nu}_{s_1}}, m^2_{\tilde{\nu}_{s_2}}\Big)\Gamma^*_{\hat{h}_j,\tilde{\nu}^*_{s_1},\tilde{\nu}_{s_2}}\Gamma_{\hat{h}_i,\tilde{\nu}^*_{s_1},\tilde{\nu}_{s_2}} \\
&+ \frac{1}{2}\sum_{s_1=1}^{3}\sum_{s_2=1}^{3} B_0\Big(p^2, m^2_{h_{s_1}}, m^2_{h_{s_2}}\Big)\Gamma^*_{\hat{h}_j,h_{s_1},h_{s_2}}\Gamma_{\hat{h}_i,h_{s_1},h_{s_2}} \\
&- 6\sum_{s_1=1}^{3} m_{\bar{d}_{s_1}}\sum_{s_2=1}^{3}\Big[B_0\Big(p^2, m^2_{d_{s_1}}, m^2_{d_{s_2}}\Big)m_{d_{s_2}}\Big(\Gamma^{L*}_{\hat{h}_j,\bar{d}_{s_1},d_{s_2}}\Gamma^{R}_{\hat{h}_i,\bar{d}_{s_1},d_{s_2}} \\
&\qquad\qquad + \Gamma^{R*}_{\hat{h}_j,\bar{d}_{s_1},d_{s_2}}\Gamma^{L}_{\hat{h}_i,\bar{d}_{s_1},d_{s_2}}\Big)\Big] \\
&+ 3\sum_{s_1=1}^{3}\sum_{s_2=1}^{3}\Big[G_0\Big(p^2, m^2_{d_{s_1}}, m^2_{d_{s_2}}\Big)\Big(\Gamma^{L*}_{\hat{h}_j,\bar{d}_{s_1},d_{s_2}}\Gamma^{L}_{\hat{h}_i,\bar{d}_{s_1},d_{s_2}} \\
&\qquad\qquad + \Gamma^{R*}_{\hat{h}_j,\bar{d}_{s_1},d_{s_2}}\Gamma^{R}_{\hat{h}_i,\bar{d}_{s_1},d_{s_2}}\Big)\Big] \\
&- 2\sum_{s_1=1}^{3} m_{\bar{e}_{s_1}}\sum_{s_2=1}^{3}\Big[B_0\Big(p^2, m^2_{e_{s_1}}, m^2_{e_{s_2}}\Big)m_{e_{s_2}}\Big(\Gamma^{L*}_{\hat{h}_j,\bar{e}_{s_1},e_{s_2}}\Gamma^{R}_{\hat{h}_i,\bar{e}_{s_1},e_{s_2}} \\
&\qquad\qquad + \Gamma^{R*}_{\hat{h}_j,\bar{e}_{s_1},e_{s_2}}\Gamma^{L}_{\hat{h}_i,\bar{e}_{s_1},e_{s_2}}\Big)\Big] \\
&+ \sum_{s_1=1}^{3}\sum_{s_2=1}^{3}\Big[G_0\Big(p^2, m^2_{e_{s_1}}, m^2_{e_{s_2}}\Big)\Big(\Gamma^{L*}_{\hat{h}_j,\bar{e}_{s_1},e_{s_2}}\Gamma^{L}_{\hat{h}_i,\bar{e}_{s_1},e_{s_2}} \\
&\qquad\qquad + \Gamma^{R*}_{\hat{h}_j,\bar{e}_{s_1},e_{s_2}}\Gamma^{R}_{\hat{h}_i,\bar{e}_{s_1},e_{s_2}}\Big)\Big] \\
&- 6\sum_{s_1=1}^{3} m_{\bar{u}_{s_1}}\sum_{s_2=1}^{3}\Big[B_0\Big(p^2, m^2_{u_{s_1}}, m^2_{u_{s_2}}\Big)m_{u_{s_2}}\Big(\Gamma^{L*}_{\hat{h}_j,\bar{u}_{s_1},u_{s_2}}\Gamma^{R}_{\hat{h}_i,\bar{u}_{s_1},u_{s_2}} \\
&\qquad\qquad + \Gamma^{R*}_{\hat{h}_j,\bar{u}_{s_1},u_{s_2}}\Gamma^{L}_{\hat{h}_i,\bar{u}_{s_1},u_{s_2}}\Big)\Big] \\
&+ 3\sum_{s_1=1}^{3}\sum_{s_2=1}^{3}\Big[G_0\Big(p^2, m^2_{u_{s_1}}, m^2_{u_{s_2}}\Big)\Big(\Gamma^{L*}_{\hat{h}_j,\bar{u}_{s_1},u_{s_2}}\Gamma^{L}_{\hat{h}_i,\bar{u}_{s_1},u_{s_2}} \\
&\qquad\qquad + \Gamma^{R*}_{\hat{h}_j,\bar{u}_{s_1},u_{s_2}}\Gamma^{R}_{\hat{h}_i,\bar{u}_{s_1},u_{s_2}}\Big)\Big] \\
&- \sum_{s_1=1}^{5} m_{\tilde{\chi}^0_{s_1}}\sum_{s_2=1}^{5}\Big[B_0\Big(p^2, m^2_{\tilde{\chi}^0_{s_1}}, m^2_{\tilde{\chi}^0_{s_2}}\Big)m_{\tilde{\chi}^0_{s_2}}\Big(\Gamma^{L*}_{\hat{h}_j,\tilde{\chi}^0_{s_1},\tilde{\chi}^0_{s_2}}\Gamma^{R}_{\hat{h}_i,\tilde{\chi}^0_{s_1},\tilde{\chi}^0_{s_2}} \\
&\qquad\qquad + \Gamma^{R*}_{\hat{h}_j,\tilde{\chi}^0_{s_1},\tilde{\chi}^0_{s_2}}\Gamma^{L}_{\hat{h}_i,\tilde{\chi}^0_{s_1},\tilde{\chi}^0_{s_2}}\Big)\Big] \\
&+ \frac{1}{2}\sum_{s_1=1}^{5}\sum_{s_2=1}^{5}\Big[G_0\Big(p^2, m^2_{\tilde{\chi}^0_{s_1}}, m^2_{\tilde{\chi}^0_{s_2}}\Big)\Big(\Gamma^{L*}_{\hat{h}_j,\tilde{\chi}^0_{s_1},\tilde{\chi}^0_{s_2}}\Gamma^{L}_{\hat{h}_i,\tilde{\chi}^0_{s_1},\tilde{\chi}^0_{s_2}} \\
&\qquad\qquad + \Gamma^{R*}_{\hat{h}_j,\tilde{\chi}^0_{s_1},\tilde{\chi}^0_{s_2}}\Gamma^{R}_{\hat{h}_i,\tilde{\chi}^0_{s_1},\tilde{\chi}^0_{s_2}}\Big)\Big]
\end{aligned}
$$

$$
\begin{aligned}
&- 3\sum_{s_1=1}^{6} A_0\Big(m^2_{\tilde{d}_{s_1}}\Big)\Gamma_{\hat{h}_i,\hat{h}_j,\tilde{d}^*_{s_1},\tilde{d}_{s_1}} - \sum_{s_1=1}^{6} A_0\Big(m^2_{\tilde{e}_{s_1}}\Big)\Gamma_{\hat{h}_i,\hat{h}_j,\tilde{e}^*_{s_1},\tilde{e}_{s_1}} \\
&- 3\sum_{s_1=1}^{6} A_0\Big(m^2_{\tilde{u}_{s_1}}\Big)\Gamma_{\hat{h}_i,\hat{h}_j,\tilde{u}^*_{s_1},\tilde{u}_{s_1}} \\
&+ 3\sum_{s_1=1}^{6}\sum_{s_2=1}^{6} B_0\Big(p^2, m^2_{\tilde{d}_{s_1}}, m^2_{\tilde{d}_{s_2}}\Big)\Gamma^*_{\hat{h}_j,\tilde{d}^*_{s_1},\tilde{d}_{s_2}}\Gamma_{\hat{h}_i,\tilde{d}^*_{s_1},\tilde{d}_{s_2}} \\
&+ \sum_{s_1=1}^{6}\sum_{s_2=1}^{6} B_0\Big(p^2, m^2_{\tilde{e}_{s_1}}, m^2_{\tilde{e}_{s_2}}\Big)\Gamma^*_{\hat{h}_j,\tilde{e}^*_{s_1},\tilde{e}_{s_2}}\Gamma_{\hat{h}_i,\tilde{e}^*_{s_1},\tilde{e}_{s_2}} \\
&+ 3\sum_{s_1=1}^{6}\sum_{s_2=1}^{6} B_0\Big(p^2, m^2_{\tilde{u}_{s_1}}, m^2_{\tilde{u}_{s_2}}\Big)\Gamma^*_{\hat{h}_j,\tilde{u}^*_{s_1},\tilde{u}_{s_2}}\Gamma_{\hat{h}_i,\tilde{u}^*_{s_1},\tilde{u}_{s_2}} \\
&+ 2\sum_{s_2=1}^{2} \Gamma^*_{\hat{h}_j,W^+,H^-_{s_2}}\Gamma_{\hat{h}_i,W^+,H^-_{s_2}} F_0\Big(p^2, m^2_{H^+_{s_2}}, m^2_W\Big) \\
&+ \sum_{s_2=1}^{3} \Gamma^*_{\hat{h}_j,Z,A^0_{s_2}}\Gamma_{\hat{h}_i,Z,A^0_{s_2}} F_0\Big(p^2, m^2_{A^0_{s_2}}, m^2_Z\Big)
\end{aligned} \tag{E.2}
$$

E.3 Self-energy of CP-odd Higgs-bosons

$$
\begin{aligned}
\Pi_{A^0_i,A^0_j}(p^2) =\, & 2A_0\Big(m^2_Z\Big)\Gamma_{\hat{A}_{h,i},\hat{A}_{h,j},Z,Z} + 4A_0\Big(m^2_W\Big)\Gamma_{\hat{A}_{h,i},\hat{A}_{h,j},W^+,W^-} \\
&- \sum_{s_1=1}^{2} A_0\Big(m^2_{H^+_{s_1}}\Big)\Gamma_{\hat{A}_{h,i},\hat{A}_{h,j},H^+_{s_1},H^-_{s_1}} \\
&+ \sum_{s_1=1}^{2}\sum_{s_2=1}^{2} B_0\Big(p^2, m^2_{H^+_{s_1}}, m^2_{H^+_{s_2}}\Big)\Gamma^*_{\hat{A}_{h,j},H^+_{s_1},H^-_{s_2}}\Gamma_{\hat{A}_{h,i},H^+_{s_1},H^-_{s_2}} \\
&- 2\sum_{s_1=1}^{2} m_{\tilde{\chi}^+_{s_1}} \sum_{s_2=1}^{2}\Big[B_0\Big(p^2, m^2_{\tilde{\chi}^+_{s_1}}, m^2_{\tilde{\chi}^+_{s_2}}\Big) m_{\tilde{\chi}^-_{s_2}}\Big(\Gamma^{L*}_{\hat{A}_{h,j},\tilde{\chi}^+_{s_1},\tilde{\chi}^-_{s_2}}\Gamma^{R}_{\hat{A}_{h,i},\tilde{\chi}^+_{s_1},\tilde{\chi}^-_{s_2}} \\
&\qquad + \Gamma^{R*}_{\hat{A}_{h,j},\tilde{\chi}^+_{s_1},\tilde{\chi}^-_{s_2}}\Gamma^{L}_{\hat{A}_{h,i},\tilde{\chi}^+_{s_1},\tilde{\chi}^-_{s_2}}\Big)\Big] \\
&+ \sum_{s_1=1}^{2}\sum_{s_2=1}^{2}\Big[G_0\Big(p^2, m^2_{\tilde{\chi}^+_{s_1}}, m^2_{\tilde{\chi}^+_{s_2}}\Big)\Big(\Gamma^{L*}_{\hat{A}_{h,j},\tilde{\chi}^+_{s_1},\tilde{\chi}^-_{s_2}}\Gamma^{L}_{\hat{A}_{h,i},\tilde{\chi}^+_{s_1},\tilde{\chi}^-_{s_2}} \\
&\qquad + \Gamma^{R*}_{\hat{A}_{h,j},\tilde{\chi}^+_{s_1},\tilde{\chi}^-_{s_2}}\Gamma^{R}_{\hat{A}_{h,i},\tilde{\chi}^+_{s_1},\tilde{\chi}^-_{s_2}}\Big)\Big] \\
&- \frac{1}{2}\sum_{s_1=1}^{3} A_0\Big(m^2_{A^0_{s_1}}\Big)\Gamma_{\hat{A}_{h,i},\hat{A}_{h,j},A^0_{s_1},A^0_{s_1}} - \sum_{s_1=1}^{3} A_0\Big(m^2_{\tilde{\nu}_{s_1}}\Big)\Gamma_{\hat{A}_{h,i},\hat{A}_{h,j},\tilde{\nu}^*_{s_1},\tilde{\nu}_{s_1}} \\
&- \frac{1}{2}\sum_{s_1=1}^{3} A_0\Big(m^2_{h_{s_1}}\Big)\Gamma_{\hat{A}_{h,i},\hat{A}_{h,j},h_{s_1},h_{s_1}}
\end{aligned}
$$

$$
\begin{aligned}
&+\frac{1}{2}\sum_{s_1=1}^{3}\sum_{s_2=1}^{3}B_0\Big(p^2,m^2_{A^0_{s_1}},m^2_{A^0_{s_2}}\Big)\Gamma^*_{\hat{A}_{h,j},A^0_{s_1},A^0_{s_2}}\Gamma_{\hat{A}_{h,i},A^0_{s_1},A^0_{s_2}}\\
&+\sum_{s_1=1}^{3}\sum_{s_2=1}^{3}B_0\Big(p^2,m^2_{A^0_{s_1}},m^2_{h_{s_2}}\Big)\Gamma^*_{\hat{A}_{h,j},A^0_{s_1},h_{s_2}}\Gamma_{\hat{A}_{h,i},A^0_{s_1},h_{s_2}}\\
&+\frac{1}{2}\sum_{s_1=1}^{3}\sum_{s_2=1}^{3}B_0\Big(p^2,m^2_{h_{s_1}},m^2_{h_{s_2}}\Big)\Gamma^*_{\hat{A}_{h,j},h_{s_1},h_{s_2}}\Gamma_{\hat{A}_{h,i},h_{s_1},h_{s_2}}\\
&-6\sum_{s_1=1}^{3}m_{\bar{d}_{s_1}}\sum_{s_2=1}^{3}\Big[B_0\Big(p^2,m^2_{d_{s_1}},m^2_{d_{s_2}}\Big)m_{d_{s_2}}\Big(\Gamma^{L*}_{\hat{A}_{h,j},\bar{d}_{s_1},d_{s_2}}\Gamma^{R}_{\hat{A}_{h,i},\bar{d}_{s_1},d_{s_2}}\\
&\qquad\qquad+\Gamma^{R*}_{\hat{A}_{h,j},\bar{d}_{s_1},d_{s_2}}\Gamma^{L}_{\hat{A}_{h,i},\bar{d}_{s_1},d_{s_2}}\Big)\Big]\\
&+3\sum_{s_1=1}^{3}\sum_{s_2=1}^{3}\Big[G_0\Big(p^2,m^2_{d_{s_1}},m^2_{d_{s_2}}\Big)\Big(\Gamma^{L*}_{\hat{A}_{h,j},\bar{d}_{s_1},d_{s_2}}\Gamma^{L}_{\hat{A}_{h,i},\bar{d}_{s_1},d_{s_2}}\\
&\qquad\qquad+\Gamma^{R*}_{\hat{A}_{h,j},\bar{d}_{s_1},d_{s_2}}\Gamma^{R}_{\hat{A}_{h,i},\bar{d}_{s_1},d_{s_2}}\Big)\Big]\\
&-2\sum_{s_1=1}^{3}m_{\bar{e}_{s_1}}\sum_{s_2=1}^{3}\Big[B_0\Big(p^2,m^2_{e_{s_1}},m^2_{e_{s_2}}\Big)m_{e_{s_2}}\Big(\Gamma^{L*}_{\hat{A}_{h,j},\bar{e}_{s_1},e_{s_2}}\Gamma^{R}_{\hat{A}_{h,i},\bar{e}_{s_1},e_{s_2}}\\
&\qquad\qquad+\Gamma^{R*}_{\hat{A}_{h,j},\bar{e}_{s_1},e_{s_2}}\Gamma^{L}_{\hat{A}_{h,i},\bar{e}_{s_1},e_{s_2}}\Big)\Big]\\
&+\sum_{s_1=1}^{3}\sum_{s_2=1}^{3}\Big[G_0\Big(p^2,m^2_{e_{s_1}},m^2_{e_{s_2}}\Big)\Big(\Gamma^{L*}_{\hat{A}_{h,j},\bar{e}_{s_1},e_{s_2}}\Gamma^{L}_{\hat{A}_{h,i},\bar{e}_{s_1},e_{s_2}}\\
&\qquad\qquad+\Gamma^{R*}_{\hat{A}_{h,j},\bar{e}_{s_1},e_{s_2}}\Gamma^{R}_{\hat{A}_{h,i},\bar{e}_{s_1},e_{s_2}}\Big)\Big]\\
&-6\sum_{s_1=1}^{3}m_{\bar{u}_{s_1}}\sum_{s_2=1}^{3}\Big[B_0\Big(p^2,m^2_{u_{s_1}},m^2_{u_{s_2}}\Big)m_{u_{s_2}}\Big(\Gamma^{L*}_{\hat{A}_{h,j},\bar{u}_{s_1},u_{s_2}}\Gamma^{R}_{\hat{A}_{h,i},\bar{u}_{s_1},u_{s_2}}\\
&\qquad\qquad+\Gamma^{R*}_{\hat{A}_{h,j},\bar{u}_{s_1},u_{s_2}}\Gamma^{L}_{\hat{A}_{h,i},\bar{u}_{s_1},u_{s_2}}\Big)\Big]\\
&+3\sum_{s_1=1}^{3}\sum_{s_2=1}^{3}\Big[G_0\Big(p^2,m^2_{u_{s_1}},m^2_{u_{s_2}}\Big)\Big(\Gamma^{L*}_{\hat{A}_{h,j},\bar{u}_{s_1},u_{s_2}}\Gamma^{L}_{\hat{A}_{h,i},\bar{u}_{s_1},u_{s_2}}\\
&\qquad\qquad+\Gamma^{R*}_{\hat{A}_{h,j},\bar{u}_{s_1},u_{s_2}}\Gamma^{R}_{\hat{A}_{h,i},\bar{u}_{s_1},u_{s_2}}\Big)\Big]\\
&-\sum_{s_1=1}^{5}m_{\tilde{\chi}^0_{s_1}}\sum_{s_2=1}^{5}\Big[B_0\Big(p^2,m^2_{\tilde{\chi}^0_{s_1}},m^2_{\tilde{\chi}^0_{s_2}}\Big)m_{\tilde{\chi}^0_{s_2}}\Big(\Gamma^{L*}_{\hat{A}_{h,j},\tilde{\chi}^0_{s_1},\tilde{\chi}^0_{s_2}}\Gamma^{R}_{\hat{A}_{h,i},\tilde{\chi}^0_{s_1},\tilde{\chi}^0_{s_2}}\\
&\qquad\qquad+\Gamma^{R*}_{\hat{A}_{h,j},\tilde{\chi}^0_{s_1},\tilde{\chi}^0_{s_2}}\Gamma^{L}_{\hat{A}_{h,i},\tilde{\chi}^0_{s_1},\tilde{\chi}^0_{s_2}}\Big)\Big]\\
&+\frac{1}{2}\sum_{s_1=1}^{5}\sum_{s_2=1}^{5}\Big[G_0\Big(p^2,m^2_{\tilde{\chi}^0_{s_1}},m^2_{\tilde{\chi}^0_{s_2}}\Big)\Big(\Gamma^{L*}_{\hat{A}_{h,j},\tilde{\chi}^0_{s_1},\tilde{\chi}^0_{s_2}}\Gamma^{L}_{\hat{A}_{h,i},\tilde{\chi}^0_{s_1},\tilde{\chi}^0_{s_2}}
\end{aligned}
$$

$$+ \Gamma^{R*}_{\hat{A}_{h,j},\tilde{\chi}^0_{s_1},\tilde{\chi}^0_{s_2}} \Gamma^{R}_{\hat{A}_{h,i},\tilde{\chi}^0_{s_1},\tilde{\chi}^0_{s_2}} \Big) \Big]$$

$$- 3 \sum_{s_1=1}^{6} A_0\Big(m^2_{\tilde{d}_{s_1}}\Big) \Gamma_{\hat{A}_{h,i},\hat{A}_{h,j},\tilde{d}^*_{s_1},\tilde{d}_{s_1}} - \sum_{s_1=1}^{6} A_0\Big(m^2_{\tilde{e}_{s_1}}\Big) \Gamma_{\hat{A}_{h,i},\hat{A}_{h,j},\tilde{e}^*_{s_1},\tilde{e}_{s_1}}$$

$$- 3 \sum_{s_1=1}^{6} A_0\Big(m^2_{\tilde{u}_{s_1}}\Big) \Gamma_{\hat{A}_{h,i},\hat{A}_{h,j},\tilde{u}^*_{s_1},\tilde{u}_{s_1}}$$

$$+ 3 \sum_{s_1=1}^{6} \sum_{s_2=1}^{6} B_0\Big(p^2, m^2_{\tilde{d}_{s_1}}, m^2_{\tilde{d}_{s_2}}\Big) \Gamma^*_{\hat{A}_{h,j},\tilde{d}^*_{s_1},\tilde{d}_{s_2}} \Gamma_{\hat{A}_{h,i},\tilde{d}^*_{s_1},\tilde{d}_{s_2}}$$

$$+ \sum_{s_1=1}^{6} \sum_{s_2=1}^{6} B_0\Big(p^2, m^2_{\tilde{e}_{s_1}}, m^2_{\tilde{e}_{s_2}}\Big) \Gamma^*_{\hat{A}_{h,j},\tilde{e}^*_{s_1},\tilde{e}_{s_2}} \Gamma_{\hat{A}_{h,i},\tilde{e}^*_{s_1},\tilde{e}_{s_2}}$$

$$+ 3 \sum_{s_1=1}^{6} \sum_{s_2=1}^{6} B_0\Big(p^2, m^2_{\tilde{u}_{s_1}}, m^2_{\tilde{u}_{s_2}}\Big) \Gamma^*_{\hat{A}_{h,j},\tilde{u}^*_{s_1},\tilde{u}_{s_2}} \Gamma_{\hat{A}_{h,i},\tilde{u}^*_{s_1},\tilde{u}_{s_2}}$$

$$+ 2 \sum_{s_2=1}^{2} \Gamma^*_{\hat{A}_{h,j},W^+,H^-_{s_2}} \Gamma_{\hat{A}_{h,i},W^+,H^-_{s_2}} F_0\Big(p^2, m^2_{H^+_{s_2}}, m^2_W\Big)$$

$$+ \sum_{s_2=1}^{3} \Gamma^*_{\hat{A}_{h,j},Z,h_{s_2}} \Gamma_{\hat{A}_{h,i},Z,h_{s_2}} F_0\Big(p^2, m^2_{h_{s_2}}, m^2_Z\Big) \tag{E.3}$$

E.4 Self-energy of the charged Higgs-boson

$$\Pi_{H^-_i,H^-_j}(p^2) = \frac{7}{2} B_0\Big(p^2, m^2_Z, m^2_W\Big) \Gamma^*_{\hat{H}^+_j,W^-,Z} \Gamma_{\hat{H}^+_i,W^-,Z} + 2A_0\Big(m^2_Z\Big) \Gamma_{\hat{H}^+_i,\hat{H}^-_j,Z,Z}$$

$$+ 4A_0\Big(m^2_W\Big) \Gamma_{\hat{H}^+_i,\hat{H}^-_j,W^+,W^-} - \sum_{s_1=1}^{2} A_0\Big(m^2_{H^+_{s_1}}\Big) \Gamma_{\hat{H}^+_i,\hat{H}^-_j,H^+_{s_1},H^-_{s_1}}$$

$$- 2 \sum_{s_1=1}^{2} m_{\tilde{\chi}^-_{s_1}} \sum_{s_2=1}^{5} \Big[B_0\Big(p^2, m^2_{\tilde{\chi}^+_{s_1}}, m^2_{\tilde{\chi}^0_{s_2}}\Big) m_{\tilde{\chi}^0_{s_2}} \Big(\Gamma^{L*}_{\hat{H}^+_j,\tilde{\chi}^-_{s_1},\tilde{\chi}^0_{s_2}} \Gamma^{R}_{\hat{H}^+_i,\tilde{\chi}^-_{s_1},\tilde{\chi}^0_{s_2}}$$

$$+ \Gamma^{R*}_{\hat{H}^+_j,\tilde{\chi}^-_{s_1},\tilde{\chi}^0_{s_2}} \Gamma^{L}_{\hat{H}^+_i,\tilde{\chi}^-_{s_1},\tilde{\chi}^0_{s_2}} \Big) \Big]$$

$$+ \sum_{s_1=1}^{2} \sum_{s_2=1}^{5} \Big[G_0\Big(p^2, m^2_{\tilde{\chi}^+_{s_1}}, m^2_{\tilde{\chi}^0_{s_2}}\Big) \Big(\Gamma^{L*}_{\hat{H}^+_j,\tilde{\chi}^-_{s_1},\tilde{\chi}^0_{s_2}} \Gamma^{L}_{\hat{H}^+_i,\tilde{\chi}^-_{s_1},\tilde{\chi}^0_{s_2}}$$

$$+ \Gamma^{R*}_{\hat{H}^+_j,\tilde{\chi}^-_{s_1},\tilde{\chi}^0_{s_2}} \Gamma^{R}_{\hat{H}^+_i,\tilde{\chi}^-_{s_1},\tilde{\chi}^0_{s_2}} \Big) \Big]$$

$$- \frac{1}{2} \sum_{s_1=1}^{3} A_0\Big(m^2_{A^0_{s_1}}\Big) \Gamma_{\hat{H}^+_i,\hat{H}^-_j,A^0_{s_1},A^0_{s_1}} - \sum_{s_1=1}^{3} A_0\Big(m^2_{\tilde{\nu}_{s_1}}\Big) \Gamma_{\hat{H}^+_i,\hat{H}^-_j,\tilde{\nu}^*_{s_1},\tilde{\nu}_{s_1}}$$

$$- \frac{1}{2} \sum_{s_1=1}^{3} A_0\Big(m^2_{h_{s_1}}\Big) \Gamma_{\hat{H}^+_i,\hat{H}^-_j,h_{s_1},h_{s_1}}$$

$$
\begin{aligned}
&+ \sum_{s_1=1}^{3} \sum_{s_2=1}^{2} B_0\Big(p^2, m^2_{A^0_{s_1}}, m^2_{H^+_{s_2}}\Big) \Gamma^*_{\hat{H}^+_j, A^0_{s_1}, H^-_{s_2}} \Gamma_{\hat{H}^+_i, A^0_{s_1}, H^-_{s_2}} \\
&+ \sum_{s_1=1}^{3} \sum_{s_2=1}^{2} B_0\Big(p^2, m^2_{h_{s_1}}, m^2_{H^+_{s_2}}\Big) \Gamma^*_{\hat{H}^+_j, h_{s_1}, H^-_{s_2}} \Gamma_{\hat{H}^+_i, h_{s_1}, H^-_{s_2}} \\
&- 6 \sum_{s_1=1}^{3} m_{d_{s_1}} \sum_{s_2=1}^{3} \Big[B_0\Big(p^2, m^2_{d_{s_1}}, m^2_{u_{s_2}}\Big) m_{\bar{u}_{s_2}} \Big(\Gamma^{L*}_{\hat{H}^+_j, d_{s_1}, \bar{u}_{s_2}} \Gamma^{R}_{\hat{H}^+_i, d_{s_1}, \bar{u}_{s_2}} \\
&\qquad\qquad + \Gamma^{R*}_{\hat{H}^+_j, d_{s_1}, \bar{u}_{s_2}} \Gamma^{L}_{\hat{H}^+_i, d_{s_1}, \bar{u}_{s_2}} \Big) \Big] \\
&+ 3 \sum_{s_1=1}^{3} \sum_{s_2=1}^{3} \Big[G_0\Big(p^2, m^2_{d_{s_1}}, m^2_{u_{s_2}}\Big) \Big(\Gamma^{L*}_{\hat{H}^+_j, d_{s_1}, \bar{u}_{s_2}} \Gamma^{L}_{\hat{H}^+_i, d_{s_1}, \bar{u}_{s_2}} \\
&\qquad\qquad + \Gamma^{R*}_{\hat{H}^+_j, d_{s_1}, \bar{u}_{s_2}} \Gamma^{R}_{\hat{H}^+_i, d_{s_1}, \bar{u}_{s_2}} \Big) \Big] \\
&- 2 \sum_{s_1=1}^{3} m_{e_{s_1}} \sum_{s_2=1}^{3} \Big[B_0\Big(p^2, m^2_{e_{s_1}}, m^2_{\nu_{s_2}}\Big) m_{\bar{\nu}_{s_2}} \Big(\Gamma^{L*}_{\hat{H}^+_j, e_{s_1}, \bar{\nu}_{s_2}} \Gamma^{R}_{\hat{H}^+_i, e_{s_1}, \bar{\nu}_{s_2}} \\
&\qquad\qquad + \Gamma^{R*}_{\hat{H}^+_j, e_{s_1}, \bar{\nu}_{s_2}} \Gamma^{L}_{\hat{H}^+_i, e_{s_1}, \bar{\nu}_{s_2}} \Big) \Big] \\
&+ \sum_{s_1=1}^{3} \sum_{s_2=1}^{3} \Big[G_0\Big(p^2, m^2_{e_{s_1}}, m^2_{\nu_{s_2}}\Big) \Big(\Gamma^{L*}_{\hat{H}^+_j, e_{s_1}, \bar{\nu}_{s_2}} \Gamma^{L}_{\hat{H}^+_i, e_{s_1}, \bar{\nu}_{s_2}} \\
&\qquad\qquad + \Gamma^{R*}_{\hat{H}^+_j, e_{s_1}, \bar{\nu}_{s_2}} \Gamma^{R}_{\hat{H}^+_i, e_{s_1}, \bar{\nu}_{s_2}} \Big) \Big] \\
&- 3 \sum_{s_1=1}^{6} A_0\Big(m^2_{\tilde{d}_{s_1}}\Big) \Gamma_{\hat{H}^+_i, \hat{H}^-_j, \tilde{d}^*_{s_1}, \tilde{d}_{s_1}} - \sum_{s_1=1}^{6} A_0\Big(m^2_{\tilde{e}_{s_1}}\Big) \Gamma_{\hat{H}^+_i, \hat{H}^-_j, \tilde{e}^*_{s_1}, \tilde{e}_{s_1}} \\
&- 3 \sum_{s_1=1}^{6} A_0\Big(m^2_{\tilde{u}_{s_1}}\Big) \Gamma_{\hat{H}^+_i, \hat{H}^-_j, \tilde{u}^*_{s_1}, \tilde{u}_{s_1}} \\
&+ \sum_{s_1=1}^{6} \sum_{s_2=1}^{3} B_0\Big(p^2, m^2_{\tilde{e}_{s_1}}, m^2_{\tilde{\nu}_{s_2}}\Big) \Gamma^*_{\hat{H}^+_j, \tilde{e}_{s_1}, \tilde{\nu}^*_{s_2}} \Gamma_{\hat{H}^+_i, \tilde{e}_{s_1}, \tilde{\nu}^*_{s_2}} \\
&+ 3 \sum_{s_1=1}^{6} \sum_{s_2=1}^{6} B_0\Big(p^2, m^2_{\tilde{d}_{s_1}}, m^2_{\tilde{u}_{s_2}}\Big) \Gamma^*_{\hat{H}^+_j, \tilde{d}_{s_1}, \tilde{u}^*_{s_2}} \Gamma_{\hat{H}^+_i, \tilde{d}_{s_1}, \tilde{u}^*_{s_2}} \\
&+ \sum_{s_2=1}^{2} \Gamma^*_{\hat{H}^+_j, \gamma, H^-_{s_2}} \Gamma_{\hat{H}^+_i, \gamma, H^-_{s_2}} F_0\Big(p^2, m^2_{H^+_{s_2}}, 0\Big) \\
&+ \sum_{s_2=1}^{2} \Gamma^*_{\hat{H}^+_j, Z, H^-_{s_2}} \Gamma_{\hat{H}^+_i, Z, H^-_{s_2}} F_0\Big(p^2, m^2_{H^+_{s_2}}, m^2_Z\Big) \\
&+ \sum_{s_2=1}^{3} \Gamma^*_{\hat{H}^+_j, W^-, A^0_{s_2}} \Gamma_{\hat{H}^+_i, W^-, A^0_{s_2}} F_0\Big(p^2, m^2_{A^0_{s_2}}, m^2_W\Big)
\end{aligned}
$$

$$+\sum_{s_2=1}^{3}\Gamma^{*}_{\hat{H}_j^+,W^-,h_{s_2}}\Gamma_{\hat{H}_i^+,W^-,h_{s_2}}F_0\Big(p^2,m^2_{h_{s_2}},m^2_W\Big) \tag{E.4}$$

E.5 Self-energy of neutralinos

$$\begin{aligned}
\Sigma^S_{\tilde{\chi}^0_i,\tilde{\chi}^0_j}(p^2) = &\sum_{s_1=1}^{2}\sum_{s_2=1}^{2}B_0\Big(p^2,m^2_{\tilde{\chi}^+_{s_2}},m^2_{H^+_{s_1}}\Big)\Gamma^{L*}_{\hat{\chi}^0_j,H^+_{s_1},\tilde{\chi}^-_{s_2}}m_{\tilde{\chi}^-_{s_2}}\Gamma^{R}_{\hat{\chi}^0_i,H^+_{s_1},\tilde{\chi}^-_{s_2}}\\
&+\sum_{s_1=1}^{3}\sum_{s_2=1}^{3}B_0\Big(p^2,0,0\Big)\Gamma^{L*}_{\hat{\chi}^0_j,\tilde{\nu}^*_{s_1},\nu_{s_2}}m_{\nu_{s_2}}\Gamma^{R}_{\hat{\chi}^0_i,\tilde{\nu}^*_{s_1},\nu_{s_2}}\\
&+\frac{1}{2}\sum_{s_1=1}^{3}\sum_{s_2=1}^{5}B_0\Big(p^2,m^2_{\tilde{\chi}^0_{s_2}},m^2_{A^0_{s_1}}\Big)\Gamma^{L*}_{\hat{\chi}^0_j,A^0_{s_1},\tilde{\chi}^0_{s_2}}m_{\tilde{\chi}^0_{s_2}}\Gamma^{R}_{\hat{\chi}^0_i,A^0_{s_1},\tilde{\chi}^0_{s_2}}\\
&+\frac{1}{2}\sum_{s_1=1}^{3}\sum_{s_2=1}^{5}B_0\Big(p^2,m^2_{\tilde{\chi}^0_{s_2}},m^2_{h_{s_1}}\Big)\Gamma^{L*}_{\hat{\chi}^0_j,h_{s_1},\tilde{\chi}^0_{s_2}}m_{\tilde{\chi}^0_{s_2}}\Gamma^{R}_{\hat{\chi}^0_i,h_{s_1},\tilde{\chi}^0_{s_2}}\\
&+3\sum_{s_1=1}^{6}\sum_{s_2=1}^{3}B_0\Big(p^2,m^2_{d_{s_2}},m^2_{\tilde{d}_{s_1}}\Big)\Gamma^{L*}_{\hat{\chi}^0_j,\tilde{d}^*_{s_1},d_{s_2}}m_{d_{s_2}}\Gamma^{R}_{\hat{\chi}^0_i,\tilde{d}^*_{s_1},d_{s_2}}\\
&+\sum_{s_1=1}^{6}\sum_{s_2=1}^{3}B_0\Big(p^2,m^2_{e_{s_2}},m^2_{\tilde{e}_{s_1}}\Big)\Gamma^{L*}_{\hat{\chi}^0_j,\tilde{e}^*_{s_1},e_{s_2}}m_{e_{s_2}}\Gamma^{R}_{\hat{\chi}^0_i,\tilde{e}^*_{s_1},e_{s_2}}\\
&+3\sum_{s_1=1}^{6}\sum_{s_2=1}^{3}B_0\Big(p^2,m^2_{u_{s_2}},m^2_{\tilde{u}_{s_1}}\Big)\Gamma^{L*}_{\hat{\chi}^0_j,\tilde{u}^*_{s_1},u_{s_2}}m_{u_{s_2}}\Gamma^{R}_{\hat{\chi}^0_i,\tilde{u}^*_{s_1},u_{s_2}}\\
&-4\sum_{s_2=1}^{2}B_0\Big(p^2,m^2_{\tilde{\chi}^+_{s_2}},m^2_W\Big)\Gamma^{R*}_{\hat{\chi}^0_j,W^+,\tilde{\chi}^-_{s_2}}m_{\tilde{\chi}^-_{s_2}}\Gamma^{L}_{\hat{\chi}^0_i,W^+,\tilde{\chi}^-_{s_2}}\\
&-2\sum_{s_2=1}^{5}B_0\Big(p^2,m^2_{\tilde{\chi}^0_{s_2}},m^2_Z\Big)\Gamma^{R*}_{\hat{\chi}^0_j,Z,\tilde{\chi}^0_{s_2}}m_{\tilde{\chi}^0_{s_2}}\Gamma^{L}_{\hat{\chi}^0_i,Z,\tilde{\chi}^0_{s_2}}
\end{aligned} \tag{E.5}$$

$$\begin{aligned}
\Sigma^R_{\tilde{\chi}^0_i,\tilde{\chi}^0_j}(p^2) = &\sum_{s_1=1}^{2}\sum_{s_2=1}^{2}B_0\Big(p^2,m^2_{\tilde{\chi}^+_{s_2}},m^2_{H^+_{s_1}}\Big)\Gamma^{L*}_{\hat{\chi}^0_j,H^+_{s_1},\tilde{\chi}^-_{s_2}}m_{\tilde{\chi}^-_{s_2}}\Gamma^{R}_{\hat{\chi}^0_i,H^+_{s_1},\tilde{\chi}^-_{s_2}}\\
&+\sum_{s_1=1}^{3}\sum_{s_2=1}^{3}B_0\Big(p^2,0,0\Big)\Gamma^{L*}_{\hat{\chi}^0_j,\tilde{\nu}^*_{s_1},\nu_{s_2}}m_{\nu_{s_2}}\Gamma^{R}_{\hat{\chi}^0_i,\tilde{\nu}^*_{s_1},\nu_{s_2}}\\
&+\frac{1}{2}\sum_{s_1=1}^{3}\sum_{s_2=1}^{5}B_0\Big(p^2,m^2_{\tilde{\chi}^0_{s_2}},m^2_{A^0_{s_1}}\Big)\Gamma^{L*}_{\hat{\chi}^0_j,A^0_{s_1},\tilde{\chi}^0_{s_2}}m_{\tilde{\chi}^0_{s_2}}\Gamma^{R}_{\hat{\chi}^0_i,A^0_{s_1},\tilde{\chi}^0_{s_2}}\\
&+\frac{1}{2}\sum_{s_1=1}^{3}\sum_{s_2=1}^{5}B_0\Big(p^2,m^2_{\tilde{\chi}^0_{s_2}},m^2_{h_{s_1}}\Big)\Gamma^{L*}_{\hat{\chi}^0_j,h_{s_1},\tilde{\chi}^0_{s_2}}m_{\tilde{\chi}^0_{s_2}}\Gamma^{R}_{\hat{\chi}^0_i,h_{s_1},\tilde{\chi}^0_{s_2}}\\
&+3\sum_{s_1=1}^{6}\sum_{s_2=1}^{3}B_0\Big(p^2,m^2_{d_{s_2}},m^2_{\tilde{d}_{s_1}}\Big)\Gamma^{L*}_{\hat{\chi}^0_j,\tilde{d}^*_{s_1},d_{s_2}}m_{d_{s_2}}\Gamma^{R}_{\hat{\chi}^0_i,\tilde{d}^*_{s_1},d_{s_2}}
\end{aligned}$$

$$
\begin{aligned}
&+ \sum_{s_1=1}^{6}\sum_{s_2=1}^{3} B_0\Big(p^2, m^2_{e_{s_2}}, m^2_{\tilde{e}_{s_1}}\Big)\Gamma^{L*}_{\hat{\tilde{\chi}}^0_j,\tilde{e}^*_{s_1},e_{s_2}} m_{e_{s_2}} \Gamma^{R}_{\hat{\tilde{\chi}}^0_i,\tilde{e}^*_{s_1},e_{s_2}} \\
&+ 3\sum_{s_1=1}^{6}\sum_{s_2=1}^{3} B_0\Big(p^2, m^2_{u_{s_2}}, m^2_{\tilde{u}_{s_1}}\Big)\Gamma^{L*}_{\hat{\tilde{\chi}}^0_j,\tilde{u}^*_{s_1},u_{s_2}} m_{u_{s_2}} \Gamma^{R}_{\hat{\tilde{\chi}}^0_i,\tilde{u}^*_{s_1},u_{s_2}} \\
&- 4\sum_{s_2=1}^{2} B_0\Big(p^2, m^2_{\tilde{\chi}^+_{s_2}}, m^2_W\Big)\Gamma^{R*}_{\hat{\tilde{\chi}}^0_j,W^+,\tilde{\chi}^-_{s_2}} m_{\tilde{\chi}^-_{s_2}} \Gamma^{L}_{\hat{\tilde{\chi}}^0_i,W^+,\tilde{\chi}^-_{s_2}} \\
&- 2\sum_{s_2=1}^{5} B_0\Big(p^2, m^2_{\tilde{\chi}^0_{s_2}}, m^2_Z\Big)\Gamma^{R*}_{\hat{\tilde{\chi}}^0_j,Z,\tilde{\chi}^0_{s_2}} m_{\tilde{\chi}^0_{s_2}} \Gamma^{L}_{\hat{\tilde{\chi}}^0_i,Z,\tilde{\chi}^0_{s_2}} \qquad \text{(E.6)}
\end{aligned}
$$

$$
\begin{aligned}
\Sigma^L_{\tilde{\chi}^0_i,\tilde{\chi}^0_j}(p^2) = &\sum_{s_1=1}^{2}\sum_{s_2=1}^{2} B_0\Big(p^2, m^2_{\tilde{\chi}^+_{s_2}}, m^2_{H^+_{s_1}}\Big)\Gamma^{L*}_{\hat{\tilde{\chi}}^0_j,H^+_{s_1},\tilde{\chi}^-_{s_2}} m_{\tilde{\chi}^-_{s_2}} \Gamma^{R}_{\hat{\tilde{\chi}}^0_i,H^+_{s_1},\tilde{\chi}^-_{s_2}} \\
&+ \sum_{s_1=1}^{3}\sum_{s_2=1}^{3} B_0\Big(p^2, 0, 0\Big)\Gamma^{L*}_{\hat{\tilde{\chi}}^0_j,\tilde{\nu}^*_{s_1},\nu_{s_2}} m_{\nu_{s_2}} \Gamma^{R}_{\hat{\tilde{\chi}}^0_i,\tilde{\nu}^*_{s_1},\nu_{s_2}} \\
&+ \frac{1}{2}\sum_{s_1=1}^{3}\sum_{s_2=1}^{5} B_0\Big(p^2, m^2_{\tilde{\chi}^0_{s_2}}, m^2_{A^0_{s_1}}\Big)\Gamma^{L*}_{\hat{\tilde{\chi}}^0_j,A^0_{s_1},\tilde{\chi}^0_{s_2}} m_{\tilde{\chi}^0_{s_2}} \Gamma^{R}_{\hat{\tilde{\chi}}^0_i,A^0_{s_1},\tilde{\chi}^0_{s_2}} \\
&+ \frac{1}{2}\sum_{s_1=1}^{3}\sum_{s_2=1}^{5} B_0\Big(p^2, m^2_{\tilde{\chi}^0_{s_2}}, m^2_{h_{s_1}}\Big)\Gamma^{L*}_{\hat{\tilde{\chi}}^0_j,h_{s_1},\tilde{\chi}^0_{s_2}} m_{\tilde{\chi}^0_{s_2}} \Gamma^{R}_{\hat{\tilde{\chi}}^0_i,h_{s_1},\tilde{\chi}^0_{s_2}} \\
&+ 3\sum_{s_1=1}^{6}\sum_{s_2=1}^{3} B_0\Big(p^2, m^2_{d_{s_2}}, m^2_{\tilde{d}_{s_1}}\Big)\Gamma^{L*}_{\hat{\tilde{\chi}}^0_j,\tilde{d}^*_{s_1},d_{s_2}} m_{d_{s_2}} \Gamma^{R}_{\hat{\tilde{\chi}}^0_i,\tilde{d}^*_{s_1},d_{s_2}} \\
&+ \sum_{s_1=1}^{6}\sum_{s_2=1}^{3} B_0\Big(p^2, m^2_{e_{s_2}}, m^2_{\tilde{e}_{s_1}}\Big)\Gamma^{L*}_{\hat{\tilde{\chi}}^0_j,\tilde{e}^*_{s_1},e_{s_2}} m_{e_{s_2}} \Gamma^{R}_{\hat{\tilde{\chi}}^0_i,\tilde{e}^*_{s_1},e_{s_2}} \\
&+ 3\sum_{s_1=1}^{6}\sum_{s_2=1}^{3} B_0\Big(p^2, m^2_{u_{s_2}}, m^2_{\tilde{u}_{s_1}}\Big)\Gamma^{L*}_{\hat{\tilde{\chi}}^0_j,\tilde{u}^*_{s_1},u_{s_2}} m_{u_{s_2}} \Gamma^{R}_{\hat{\tilde{\chi}}^0_i,\tilde{u}^*_{s_1},u_{s_2}} \\
&- 4\sum_{s_2=1}^{2} B_0\Big(p^2, m^2_{\tilde{\chi}^+_{s_2}}, m^2_W\Big)\Gamma^{R*}_{\hat{\tilde{\chi}}^0_j,W^+,\tilde{\chi}^-_{s_2}} m_{\tilde{\chi}^-_{s_2}} \Gamma^{L}_{\hat{\tilde{\chi}}^0_i,W^+,\tilde{\chi}^-_{s_2}} \\
&- 2\sum_{s_2=1}^{5} B_0\Big(p^2, m^2_{\tilde{\chi}^0_{s_2}}, m^2_Z\Big)\Gamma^{R*}_{\hat{\tilde{\chi}}^0_j,Z,\tilde{\chi}^0_{s_2}} m_{\tilde{\chi}^0_{s_2}} \Gamma^{L}_{\hat{\tilde{\chi}}^0_i,Z,\tilde{\chi}^0_{s_2}} \qquad \text{(E.7)}
\end{aligned}
$$

E.6 Self-energy of charginos

$$
\begin{aligned}
\Sigma^S_{\tilde{\chi}^+_i,\tilde{\chi}^+_j}(p^2) = &\sum_{s_1=1}^{2}\sum_{s_2=1}^{5} B_0\Big(p^2, m^2_{\tilde{\chi}^0_{s_2}}, m^2_{H^+_{s_1}}\Big)\Gamma^{L*}_{\hat{\tilde{\chi}}^+_j,H^-_{s_1},\tilde{\chi}^0_{s_2}} m_{\tilde{\chi}^0_{s_2}} \Gamma^{R}_{\hat{\tilde{\chi}}^+_i,H^-_{s_1},\tilde{\chi}^0_{s_2}} \\
&+ \sum_{s_1=1}^{3}\sum_{s_2=1}^{2} B_0\Big(p^2, m^2_{\tilde{\chi}^+_{s_2}}, m^2_{A^0_{s_1}}\Big)\Gamma^{L*}_{\hat{\tilde{\chi}}^+_j,A^0_{s_1},\tilde{\chi}^-_{s_2}} m_{\tilde{\chi}^-_{s_2}} \Gamma^{R}_{\hat{\tilde{\chi}}^+_i,A^0_{s_1},\tilde{\chi}^-_{s_2}}
\end{aligned}
$$

$$
\begin{aligned}
&+\sum_{s_1=1}^{3}\sum_{s_2=1}^{2} B_0\Big(p^2, m^2_{\tilde{\chi}^+_{s_2}}, m^2_{h_{s_1}}\Big)\Gamma^{L*}_{\hat{\tilde{\chi}}^+_j,h_{s_1},\tilde{\chi}^-_{s_2}} m_{\tilde{\chi}^-_{s_2}} \Gamma^{R}_{\hat{\tilde{\chi}}^+_i,h_{s_1},\tilde{\chi}^-_{s_2}}\\
&+\sum_{s_1=1}^{3}\sum_{s_2=1}^{3} B_0\Big(p^2, m^2_{e_{s_2}}, m^2_{\tilde{\nu}_{s_1}}\Big)\Gamma^{L*}_{\hat{\tilde{\chi}}^+_j,\tilde{\nu}^*_{s_1},e_{s_2}} m_{e_{s_2}} \Gamma^{R}_{\hat{\tilde{\chi}}^+_i,\tilde{\nu}^*_{s_1},e_{s_2}}\\
&+3\sum_{s_1=1}^{6}\sum_{s_2=1}^{3} B_0\Big(p^2, m^2_{d_{s_2}}, m^2_{\tilde{u}_{s_1}}\Big)\Gamma^{L*}_{\hat{\tilde{\chi}}^+_j,\tilde{u}^*_{s_1},d_{s_2}} m_{d_{s_2}} \Gamma^{R}_{\hat{\tilde{\chi}}^+_i,\tilde{u}^*_{s_1},d_{s_2}}\\
&+3\sum_{s_1=1}^{6}\sum_{s_2=1}^{3} B_0\Big(p^2, m^2_{u_{s_2}}, m^2_{\tilde{d}_{s_1}}\Big)\Gamma^{L*}_{\hat{\tilde{\chi}}^+_j,\tilde{d}_{s_1},\bar{u}_{s_2}} m_{\bar{u}_{s_2}} \Gamma^{R}_{\hat{\tilde{\chi}}^+_i,\tilde{d}_{s_1},\bar{u}_{s_2}}\\
&+\sum_{s_1=1}^{6}\sum_{s_2=1}^{3} B_0\Big(p^2, m^2_{\nu_{s_2}}, m^2_{\tilde{e}_{s_1}}\Big)\Gamma^{L*}_{\hat{\tilde{\chi}}^+_j,\tilde{e}_{s_1},\bar{\nu}_{s_2}} m_{\bar{\nu}_{s_2}} \Gamma^{R}_{\hat{\tilde{\chi}}^+_i,\tilde{e}_{s_1},\bar{\nu}_{s_2}}\\
&-4\sum_{s_2=1}^{2} B_0\Big(p^2, m^2_{\tilde{\chi}^+_{s_2}}, 0\Big)\Gamma^{R*}_{\hat{\tilde{\chi}}^+_j,\gamma,\tilde{\chi}^-_{s_2}} m_{\tilde{\chi}^-_{s_2}} \Gamma^{L}_{\hat{\tilde{\chi}}^+_i,\gamma,\tilde{\chi}^-_{s_2}}\\
&-4\sum_{s_2=1}^{2} B_0\Big(p^2, m^2_{\tilde{\chi}^+_{s_2}}, m^2_{Z}\Big)\Gamma^{R*}_{\hat{\tilde{\chi}}^+_j,Z,\tilde{\chi}^-_{s_2}} m_{\tilde{\chi}^-_{s_2}} \Gamma^{L}_{\hat{\tilde{\chi}}^+_i,Z,\tilde{\chi}^-_{s_2}}\\
&-4\sum_{s_2=1}^{5} B_0\Big(p^2, m^2_{\tilde{\chi}^0_{s_2}}, m^2_{W}\Big)\Gamma^{R*}_{\hat{\tilde{\chi}}^+_j,W^-,\tilde{\chi}^0_{s_2}} m_{\tilde{\chi}^0_{s_2}} \Gamma^{L}_{\hat{\tilde{\chi}}^+_i,W^-,\tilde{\chi}^0_{s_2}} \qquad \text{(E.8)}
\end{aligned}
$$

$$
\begin{aligned}
\Sigma^{R}_{\tilde{\chi}^+_i,\tilde{\chi}^+_j}(p^2) = &\sum_{s_1=1}^{2}\sum_{s_2=1}^{5} B_0\Big(p^2, m^2_{\tilde{\chi}^0_{s_2}}, m^2_{H^+_{s_1}}\Big)\Gamma^{L*}_{\hat{\tilde{\chi}}^+_j,H^-_{s_1},\tilde{\chi}^0_{s_2}} m_{\tilde{\chi}^0_{s_2}} \Gamma^{R}_{\hat{\tilde{\chi}}^+_i,H^-_{s_1},\tilde{\chi}^0_{s_2}}\\
&+\sum_{s_1=1}^{3}\sum_{s_2=1}^{2} B_0\Big(p^2, m^2_{\tilde{\chi}^+_{s_2}}, m^2_{A^0_{s_1}}\Big)\Gamma^{L*}_{\hat{\tilde{\chi}}^+_j,A^0_{s_1},\tilde{\chi}^-_{s_2}} m_{\tilde{\chi}^-_{s_2}} \Gamma^{R}_{\hat{\tilde{\chi}}^+_i,A^0_{s_1},\tilde{\chi}^-_{s_2}}\\
&+\sum_{s_1=1}^{3}\sum_{s_2=1}^{2} B_0\Big(p^2, m^2_{\tilde{\chi}^+_{s_2}}, m^2_{h_{s_1}}\Big)\Gamma^{L*}_{\hat{\tilde{\chi}}^+_j,h_{s_1},\tilde{\chi}^-_{s_2}} m_{\tilde{\chi}^-_{s_2}} \Gamma^{R}_{\hat{\tilde{\chi}}^+_i,h_{s_1},\tilde{\chi}^-_{s_2}}\\
&+\sum_{s_1=1}^{3}\sum_{s_2=1}^{3} B_0\Big(p^2, m^2_{e_{s_2}}, m^2_{\tilde{\nu}_{s_1}}\Big)\Gamma^{L*}_{\hat{\tilde{\chi}}^+_j,\tilde{\nu}^*_{s_1},e_{s_2}} m_{e_{s_2}} \Gamma^{R}_{\hat{\tilde{\chi}}^+_i,\tilde{\nu}^*_{s_1},e_{s_2}}\\
&+3\sum_{s_1=1}^{6}\sum_{s_2=1}^{3} B_0\Big(p^2, m^2_{d_{s_2}}, m^2_{\tilde{u}_{s_1}}\Big)\Gamma^{L*}_{\hat{\tilde{\chi}}^+_j,\tilde{u}^*_{s_1},d_{s_2}} m_{d_{s_2}} \Gamma^{R}_{\hat{\tilde{\chi}}^+_i,\tilde{u}^*_{s_1},d_{s_2}}\\
&+3\sum_{s_1=1}^{6}\sum_{s_2=1}^{3} B_0\Big(p^2, m^2_{u_{s_2}}, m^2_{\tilde{d}_{s_1}}\Big)\Gamma^{L*}_{\hat{\tilde{\chi}}^+_j,\tilde{d}_{s_1},\bar{u}_{s_2}} m_{\bar{u}_{s_2}} \Gamma^{R}_{\hat{\tilde{\chi}}^+_i,\tilde{d}_{s_1},\bar{u}_{s_2}}\\
&+\sum_{s_1=1}^{6}\sum_{s_2=1}^{3} B_0\Big(p^2, m^2_{\nu_{s_2}}, m^2_{\tilde{e}_{s_1}}\Big)\Gamma^{L*}_{\hat{\tilde{\chi}}^+_j,\tilde{e}_{s_1},\bar{\nu}_{s_2}} m_{\bar{\nu}_{s_2}} \Gamma^{R}_{\hat{\tilde{\chi}}^+_i,\tilde{e}_{s_1},\bar{\nu}_{s_2}}
\end{aligned}
$$

$$
\begin{aligned}
&- 4\sum_{s_2=1}^{2} B_0\Big(p^2, m^2_{\tilde{\chi}^+_{s_2}}, 0\Big)\Gamma^{R*}_{\hat{\chi}^+_j,\gamma,\tilde{\chi}^-_{s_2}} m_{\tilde{\chi}^-_{s_2}} \Gamma^{L}_{\hat{\chi}^+_i,\gamma,\tilde{\chi}^-_{s_2}} \\
&- 4\sum_{s_2=1}^{2} B_0\Big(p^2, m^2_{\tilde{\chi}^+_{s_2}}, m^2_Z\Big)\Gamma^{R*}_{\hat{\chi}^+_j,Z,\tilde{\chi}^-_{s_2}} m_{\tilde{\chi}^-_{s_2}} \Gamma^{L}_{\hat{\chi}^+_i,Z,\tilde{\chi}^-_{s_2}} \\
&- 4\sum_{s_2=1}^{5} B_0\Big(p^2, m^2_{\tilde{\chi}^0_{s_2}}, m^2_W\Big)\Gamma^{R*}_{\hat{\chi}^+_j,W^-,\tilde{\chi}^0_{s_2}} m_{\tilde{\chi}^0_{s_2}} \Gamma^{L}_{\hat{\chi}^+_i,W^-,\tilde{\chi}^0_{s_2}} \qquad \text{(E.9)}
\end{aligned}
$$

$$
\begin{aligned}
\Sigma^L_{\tilde{\chi}^+_i,\tilde{\chi}^+_j}(p^2) = &\sum_{s_1=1}^{2}\sum_{s_2=1}^{5} B_0\Big(p^2, m^2_{\tilde{\chi}^0_{s_2}}, m^2_{H^+_{s_1}}\Big)\Gamma^{L*}_{\hat{\chi}^+_j,H^-_{s_1},\tilde{\chi}^0_{s_2}} m_{\tilde{\chi}^0_{s_2}} \Gamma^{R}_{\hat{\chi}^+_i,H^-_{s_1},\tilde{\chi}^0_{s_2}} \\
&+ \sum_{s_1=1}^{3}\sum_{s_2=1}^{2} B_0\Big(p^2, m^2_{\tilde{\chi}^+_{s_2}}, m^2_{A^0_{s_1}}\Big)\Gamma^{L*}_{\hat{\chi}^+_j,A^0_{s_1},\tilde{\chi}^-_{s_2}} m_{\tilde{\chi}^-_{s_2}} \Gamma^{R}_{\hat{\chi}^+_i,A^0_{s_1},\tilde{\chi}^-_{s_2}} \\
&+ \sum_{s_1=1}^{3}\sum_{s_2=1}^{2} B_0\Big(p^2, m^2_{\tilde{\chi}^+_{s_2}}, m^2_{h_{s_1}}\Big)\Gamma^{L*}_{\hat{\chi}^+_j,h_{s_1},\tilde{\chi}^-_{s_2}} m_{\tilde{\chi}^-_{s_2}} \Gamma^{R}_{\hat{\chi}^+_i,h_{s_1},\tilde{\chi}^-_{s_2}} \\
&+ \sum_{s_1=1}^{3}\sum_{s_2=1}^{3} B_0\Big(p^2, m^2_{e_{s_2}}, m^2_{\tilde{\nu}_{s_1}}\Big)\Gamma^{L*}_{\hat{\chi}^+_j,\tilde{\nu}^*_{s_1},e_{s_2}} m_{e_{s_2}} \Gamma^{R}_{\hat{\chi}^+_i,\tilde{\nu}^*_{s_1},e_{s_2}} \\
&+ 3\sum_{s_1=1}^{6}\sum_{s_2=1}^{3} B_0\Big(p^2, m^2_{d_{s_2}}, m^2_{\tilde{u}_{s_1}}\Big)\Gamma^{L*}_{\hat{\chi}^+_j,\tilde{u}^*_{s_1},d_{s_2}} m_{d_{s_2}} \Gamma^{R}_{\hat{\chi}^+_i,\tilde{u}^*_{s_1},d_{s_2}} \\
&+ 3\sum_{s_1=1}^{6}\sum_{s_2=1}^{3} B_0\Big(p^2, m^2_{u_{s_2}}, m^2_{\tilde{d}_{s_1}}\Big)\Gamma^{L*}_{\hat{\chi}^+_j,\tilde{d}_{s_1},\bar{u}_{s_2}} m_{\bar{u}_{s_2}} \Gamma^{R}_{\hat{\chi}^+_i,\tilde{d}_{s_1},\bar{u}_{s_2}} \\
&+ \sum_{s_1=1}^{6}\sum_{s_2=1}^{3} B_0\Big(p^2, m^2_{\nu_{s_2}}, m^2_{\tilde{e}_{s_1}}\Big)\Gamma^{L*}_{\hat{\chi}^+_j,\tilde{e}_{s_1},\bar{\nu}_{s_2}} m_{\bar{\nu}_{s_2}} \Gamma^{R}_{\hat{\chi}^+_i,\tilde{e}_{s_1},\bar{\nu}_{s_2}} \\
&- 4\sum_{s_2=1}^{2} B_0\Big(p^2, m^2_{\tilde{\chi}^+_{s_2}}, 0\Big)\Gamma^{R*}_{\hat{\chi}^+_j,\gamma,\tilde{\chi}^-_{s_2}} m_{\tilde{\chi}^-_{s_2}} \Gamma^{L}_{\hat{\chi}^+_i,\gamma,\tilde{\chi}^-_{s_2}} \\
&- 4\sum_{s_2=1}^{2} B_0\Big(p^2, m^2_{\tilde{\chi}^+_{s_2}}, m^2_Z\Big)\Gamma^{R*}_{\hat{\chi}^+_j,Z,\tilde{\chi}^-_{s_2}} m_{\tilde{\chi}^-_{s_2}} \Gamma^{L}_{\hat{\chi}^+_i,Z,\tilde{\chi}^-_{s_2}} \\
&- 4\sum_{s_2=1}^{5} B_0\Big(p^2, m^2_{\tilde{\chi}^0_{s_2}}, m^2_W\Big)\Gamma^{R*}_{\hat{\chi}^+_j,W^-,\tilde{\chi}^0_{s_2}} m_{\tilde{\chi}^0_{s_2}} \Gamma^{L}_{\hat{\chi}^+_i,W^-,\tilde{\chi}^0_{s_2}} \qquad \text{(E.10)}
\end{aligned}
$$

E.7 Self-energy of sleptons

$$
\begin{aligned}
\Pi_{\tilde{e}_i,\tilde{e}_j}(p^2) = &\, 2A_0\Big(m^2_Z\Big)\Gamma_{\hat{\tilde{e}}^*_i,\hat{\tilde{e}}_j,Z,Z} + 4A_0\Big(m^2_W\Big)\Gamma_{\hat{\tilde{e}}^*_i,\hat{\tilde{e}}_j,W^+,W^-} \\
&- \sum_{s_1=1}^{2} A_0\Big(m^2_{H^+_{s_1}}\Big)\Gamma_{\hat{\tilde{e}}^*_i,\hat{\tilde{e}}_j,H^+_{s_1},H^-_{s_1}}
\end{aligned}
$$

$$
\begin{aligned}
&+\sum_{s_1=1}^{2}\sum_{s_2=1}^{3} B_0\Big(p^2, m^2_{H^+_{s_1}}, m^2_{\tilde{\nu}_{s_2}}\Big)\Gamma^*_{\hat{\bar{e}}^*_j,H^-_{s_1},\tilde{\nu}_{s_2}}\Gamma_{\hat{\bar{e}}^*_i,H^-_{s_1},\tilde{\nu}_{s_2}}\\
&-2\sum_{s_1=1}^{2} m_{\tilde{\chi}^-_{s_1}}\sum_{s_2=1}^{3}\Big[B_0\Big(p^2, m^2_{\tilde{\chi}^+_{s_1}}, 0\Big)m_{\nu_{s_2}}\Big(\Gamma^{L*}_{\hat{\bar{e}}^*_j,\tilde{\chi}^-_{s_1},\nu_{s_2}}\Gamma^{R}_{\hat{\bar{e}}^*_i,\tilde{\chi}^-_{s_1},\nu_{s_2}}\\
&\qquad\qquad +\Gamma^{R*}_{\hat{\bar{e}}^*_j,\tilde{\chi}^-_{s_1},\nu_{s_2}}\Gamma^{L}_{\hat{\bar{e}}^*_i,\tilde{\chi}^-_{s_1},\nu_{s_2}}\Big)\Big]\\
&+\sum_{s_1=1}^{2}\sum_{s_2=1}^{3}\Big[G_0\Big(p^2, m^2_{\tilde{\chi}^+_{s_1}}, 0\Big)\Big(\Gamma^{L*}_{\hat{\bar{e}}^*_j,\tilde{\chi}^-_{s_1},\nu_{s_2}}\Gamma^{L}_{\hat{\bar{e}}^*_i,\tilde{\chi}^-_{s_1},\nu_{s_2}}\\
&\qquad\qquad +\Gamma^{R*}_{\hat{\bar{e}}^*_j,\tilde{\chi}^-_{s_1},\nu_{s_2}}\Gamma^{R}_{\hat{\bar{e}}^*_i,\tilde{\chi}^-_{s_1},\nu_{s_2}}\Big)\Big]\\
&-\frac{1}{2}\sum_{s_1=1}^{3} A_0\Big(m^2_{A^0_{s_1}}\Big)\Gamma_{\hat{\bar{e}}^*_i,\hat{\bar{e}}_j,A^0_{s_1},A^0_{s_1}}-\sum_{s_1=1}^{3} A_0\Big(m^2_{\tilde{\nu}_{s_1}}\Big)\Gamma_{\hat{\bar{e}}^*_i,\hat{\bar{e}}_j,\tilde{\nu}^*_{s_1},\tilde{\nu}_{s_1}}\\
&-\frac{1}{2}\sum_{s_1=1}^{3} A_0\Big(m^2_{h_{s_1}}\Big)\Gamma_{\hat{\bar{e}}^*_i,\hat{\bar{e}}_j,h_{s_1},h_{s_1}}\\
&+\sum_{s_1=1}^{3}\sum_{s_2=1}^{6} B_0\Big(p^2, m^2_{A^0_{s_1}}, m^2_{\tilde{e}_{s_2}}\Big)\Gamma^*_{\hat{\bar{e}}^*_j,A^0_{s_1},\tilde{e}_{s_2}}\Gamma_{\hat{\bar{e}}^*_i,A^0_{s_1},\tilde{e}_{s_2}}\\
&+\sum_{s_1=1}^{3}\sum_{s_2=1}^{6} B_0\Big(p^2, m^2_{h_{s_1}}, m^2_{\tilde{e}_{s_2}}\Big)\Gamma^*_{\hat{\bar{e}}^*_j,h_{s_1},\tilde{e}_{s_2}}\Gamma_{\hat{\bar{e}}^*_i,h_{s_1},\tilde{e}_{s_2}}\\
&-2\sum_{s_1=1}^{5} m_{\tilde{\chi}^0_{s_1}}\sum_{s_2=1}^{3}\Big[B_0\Big(p^2, m^2_{\tilde{\chi}^0_{s_1}}, m^2_{e_{s_2}}\Big)m_{e_{s_2}}\Big(\Gamma^{L*}_{\hat{\bar{e}}^*_j,\tilde{\chi}^0_{s_1},e_{s_2}}\Gamma^{R}_{\hat{\bar{e}}^*_i,\tilde{\chi}^0_{s_1},e_{s_2}}\\
&\qquad\qquad +\Gamma^{R*}_{\hat{\bar{e}}^*_j,\tilde{\chi}^0_{s_1},e_{s_2}}\Gamma^{L}_{\hat{\bar{e}}^*_i,\tilde{\chi}^0_{s_1},e_{s_2}}\Big)\Big]\\
&+\sum_{s_1=1}^{5}\sum_{s_2=1}^{3}\Big[G_0\Big(p^2, m^2_{\tilde{\chi}^0_{s_1}}, m^2_{e_{s_2}}\Big)\Big(\Gamma^{L*}_{\hat{\bar{e}}^*_j,\tilde{\chi}^0_{s_1},e_{s_2}}\Gamma^{L}_{\hat{\bar{e}}^*_i,\tilde{\chi}^0_{s_1},e_{s_2}}\\
&\qquad\qquad +\Gamma^{R*}_{\hat{\bar{e}}^*_j,\tilde{\chi}^0_{s_1},e_{s_2}}\Gamma^{R}_{\hat{\bar{e}}^*_i,\tilde{\chi}^0_{s_1},e_{s_2}}\Big)\Big]\\
&-3\sum_{s_1=1}^{6} A_0\Big(m^2_{\tilde{d}_{s_1}}\Big)\Gamma_{\hat{\bar{e}}^*_i,\hat{\bar{e}}_j,\tilde{d}^*_{s_1},\tilde{d}_{s_1}}-\sum_{s_1=1}^{6} A_0\Big(m^2_{\tilde{e}_{s_1}}\Big)\Gamma_{\hat{\bar{e}}^*_i,\hat{\bar{e}}_j,\tilde{e}^*_{s_1},\tilde{e}_{s_1}}\\
&-3\sum_{s_1=1}^{6} A_0\Big(m^2_{\tilde{u}_{s_1}}\Big)\Gamma_{\hat{\bar{e}}^*_i,\hat{\bar{e}}_j,\tilde{u}^*_{s_1},\tilde{u}_{s_1}}+\sum_{s_2=1}^{3}\Gamma^*_{\hat{\bar{e}}^*_j,W^-,\tilde{\nu}_{s_2}}\Gamma_{\hat{\bar{e}}^*_i,W^-,\tilde{\nu}_{s_2}}F_0\Big(p^2, m^2_{\tilde{\nu}_{s_2}}, m^2_W\Big)\\
&+\sum_{s_2=1}^{6}\Gamma^*_{\hat{\bar{e}}^*_j,\gamma,\tilde{e}_{s_2}}\Gamma_{\hat{\bar{e}}^*_i,\gamma,\tilde{e}_{s_2}}F_0\Big(p^2, m^2_{\tilde{e}_{s_2}}, 0\Big)\\
&+\sum_{s_2=1}^{6}\Gamma^*_{\hat{\bar{e}}^*_j,Z,\tilde{e}_{s_2}}\Gamma_{\hat{\bar{e}}^*_i,Z,\tilde{e}_{s_2}}F_0\Big(p^2, m^2_{\tilde{e}_{s_2}}, m^2_Z\Big) \qquad \text{(E.11)}
\end{aligned}
$$

E.8 Self-energy of sneutrinos

$$
\begin{aligned}
\Pi_{\tilde{\nu}_i,\tilde{\nu}_j}(p^2) =& 2A_0\Big(m_Z^2\Big)\Gamma_{\hat{\tilde{\nu}}_i^*,\hat{\tilde{\nu}}_j,Z,Z} + 4A_0\Big(m_W^2\Big)\Gamma_{\hat{\tilde{\nu}}_i^*,\hat{\tilde{\nu}}_j,W^+,W^-} \\
&- 2\sum_{s_1=1}^{2} m_{\tilde{\chi}_{s_1}^+}\sum_{s_2=1}^{3}\Big[B_0\Big(p^2, m_{\tilde{\chi}_{s_1}^+}^2, m_{e_{s_2}}^2\Big) m_{e_{s_2}}\Big(\Gamma^{L*}_{\hat{\tilde{\nu}}_j^*,\tilde{\chi}_{s_1}^+,e_{s_2}}\Gamma^{R}_{\hat{\tilde{\nu}}_i^*,\tilde{\chi}_{s_1}^+,e_{s_2}} \\
&\qquad + \Gamma^{R*}_{\hat{\tilde{\nu}}_j^*,\tilde{\chi}_{s_1}^+,e_{s_2}}\Gamma^{L}_{\hat{\tilde{\nu}}_i^*,\tilde{\chi}_{s_1}^+,e_{s_2}}\Big)\Big] \\
&+ \sum_{s_1=1}^{2}\sum_{s_2=1}^{3}\Big[G_0\Big(p^2, m_{\tilde{\chi}_{s_1}^+}^2, m_{e_{s_2}}^2\Big)\Big(\Gamma^{L*}_{\hat{\tilde{\nu}}_j^*,\tilde{\chi}_{s_1}^+,e_{s_2}}\Gamma^{L}_{\hat{\tilde{\nu}}_i^*,\tilde{\chi}_{s_1}^+,e_{s_2}} \\
&\qquad + \Gamma^{R*}_{\hat{\tilde{\nu}}_j^*,\tilde{\chi}_{s_1}^+,e_{s_2}}\Gamma^{R}_{\hat{\tilde{\nu}}_i^*,\tilde{\chi}_{s_1}^+,e_{s_2}}\Big)\Big] \\
&+ \sum_{s_1=1}^{2}\sum_{s_2=1}^{6} B_0\Big(p^2, m_{H_{s_1}^+}^2, m_{\tilde{e}_{s_2}}^2\Big)\Gamma^{*}_{\hat{\tilde{\nu}}_j^*,H_{s_1}^+,\tilde{e}_{s_2}}\Gamma_{\hat{\tilde{\nu}}_i^*,H_{s_1}^+,\tilde{e}_{s_2}} \\
&- \frac{1}{2}\sum_{s_1=1}^{3} A_0\Big(m_{A_{s_1}^0}^2\Big)\Gamma_{\hat{\tilde{\nu}}_i^*,\hat{\tilde{\nu}}_j,A_{s_1}^0,A_{s_1}^0} - \sum_{s_1=1}^{3} A_0\Big(m_{\tilde{\nu}_{s_1}}^2\Big)\Gamma_{\hat{\tilde{\nu}}_i^*,\hat{\tilde{\nu}}_j,\tilde{\nu}_{s_1}^*,\tilde{\nu}_{s_1}} \\
&- \frac{1}{2}\sum_{s_1=1}^{3} A_0\Big(m_{h_{s_1}}^2\Big)\Gamma_{\hat{\tilde{\nu}}_i^*,\hat{\tilde{\nu}}_j,h_{s_1},h_{s_1}} - \sum_{s_1=1}^{2} A_0\Big(m_{H_{s_1}^+}^2\Big)\Gamma_{\hat{\tilde{\nu}}_i^*,\hat{\tilde{\nu}}_j,H_{s_1}^+,H_{s_1}^-} \\
&+ \sum_{s_1=1}^{3}\sum_{s_2=1}^{3} B_0\Big(p^2, m_{h_{s_1}}^2, m_{\tilde{\nu}_{s_2}}^2\Big)\Gamma^{*}_{\hat{\tilde{\nu}}_j^*,h_{s_1},\tilde{\nu}_{s_2}}\Gamma_{\hat{\tilde{\nu}}_i^*,h_{s_1},\tilde{\nu}_{s_2}} \\
&- 2\sum_{s_1=1}^{5} m_{\tilde{\chi}_{s_1}^0}\sum_{s_2=1}^{3}\Big[B_0\Big(p^2, m_{\tilde{\chi}_{s_1}^0}^2, 0\Big) m_{\nu_{s_2}}\Big(\Gamma^{L*}_{\hat{\tilde{\nu}}_j^*,\tilde{\chi}_{s_1}^0,\nu_{s_2}}\Gamma^{R}_{\hat{\tilde{\nu}}_i^*,\tilde{\chi}_{s_1}^0,\nu_{s_2}} \\
&\qquad + \Gamma^{R*}_{\hat{\tilde{\nu}}_j^*,\tilde{\chi}_{s_1}^0,\nu_{s_2}}\Gamma^{L}_{\hat{\tilde{\nu}}_i^*,\tilde{\chi}_{s_1}^0,\nu_{s_2}}\Big)\Big] \\
&+ \sum_{s_1=1}^{5}\sum_{s_2=1}^{3}\Big[G_0\Big(p^2, m_{\tilde{\chi}_{s_1}^0}^2, 0\Big)\Big(\Gamma^{L*}_{\hat{\tilde{\nu}}_j^*,\tilde{\chi}_{s_1}^0,\nu_{s_2}}\Gamma^{L}_{\hat{\tilde{\nu}}_i^*,\tilde{\chi}_{s_1}^0,\nu_{s_2}} \\
&\qquad + \Gamma^{R*}_{\hat{\tilde{\nu}}_j^*,\tilde{\chi}_{s_1}^0,\nu_{s_2}}\Gamma^{R}_{\hat{\tilde{\nu}}_i^*,\tilde{\chi}_{s_1}^0,\nu_{s_2}}\Big)\Big] \\
&- 3\sum_{s_1=1}^{6} A_0\Big(m_{\tilde{d}_{s_1}}^2\Big)\Gamma_{\hat{\tilde{\nu}}_i^*,\hat{\tilde{\nu}}_j,\tilde{d}_{s_1}^*,\tilde{d}_{s_1}} - \sum_{s_1=1}^{6} A_0\Big(m_{\tilde{e}_{s_1}}^2\Big)\Gamma_{\hat{\tilde{\nu}}_i^*,\hat{\tilde{\nu}}_j,\tilde{e}_{s_1}^*,\tilde{e}_{s_1}} \\
&- 3\sum_{s_1=1}^{6} A_0\Big(m_{\tilde{u}_{s_1}}^2\Big)\Gamma_{\hat{\tilde{\nu}}_i^*,\hat{\tilde{\nu}}_j,\tilde{u}_{s_1}^*,\tilde{u}_{s_1}} + \sum_{s_2=1}^{3}\Gamma^{*}_{\hat{\tilde{\nu}}_j^*,Z,\tilde{\nu}_{s_2}}\Gamma_{\hat{\tilde{\nu}}_i^*,Z,\tilde{\nu}_{s_2}} F_0\Big(p^2, m_{\tilde{\nu}_{s_2}}^2, m_Z^2\Big) \\
&+ \sum_{s_2=1}^{6}\Gamma^{*}_{\hat{\tilde{\nu}}_j^*,W^+,\tilde{e}_{s_2}}\Gamma_{\hat{\tilde{\nu}}_i^*,W^+,\tilde{e}_{s_2}} F_0\Big(p^2, m_{\tilde{e}_{s_2}}^2, m_W^2\Big) \qquad \text{(E.12)}
\end{aligned}
$$

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