1. Kinematics

Decay rate and cross section (Note: $\mathcal{M}$ has a mass dimension of $4 - N_\mathrm{i} - N_\mathrm{f}$.)

$$\text{decay rate (rest frame; } \sqrt{s} = M_0) : \quad \mathrm{d}\Gamma = \frac{\overline{\mathrm{d}\Pi^{N_\mathrm{f}}}}{2M_0} \left| \mathcal{M}(M_0 \to \{p_1, p_2, \cdots, p_{N_\mathrm{f}}\}) \right|^2, \tag{1.1}$$

$$\text{cross section (Lorentz invariant)} : \quad \mathrm{d}\sigma = \frac{\overline{\mathrm{d}\Pi^{N_\mathrm{f}}}}{2E_A 2E_B\, v_{\text{Møl}}} \left| \mathcal{M}(p_A, p_B \to \{p_1, p_2, \cdots, p_{N_\mathrm{f}}\}) \right|^2, \tag{1.2}$$

where $\overline{\mathrm{d}\Pi^n}$ is n-particle Lorentz-invariant phase space with momentum conservation

$$\overline{\mathrm{d}\Pi^n} := \mathrm{d}\Pi_1\, \mathrm{d}\Pi_2 \cdots \mathrm{d}\Pi_n\, (2\pi)^4\, \delta^{(4)} \left(P_0 - \sum p_n \right); \quad \mathrm{d}\Pi := \frac{\mathrm{d}^3 \boldsymbol{p}}{(2\pi)^3} \frac{1}{2E_{\boldsymbol{p}}}. \tag{1.3}$$

At the CM frame, two-body phase-space are characterized by the final momentum $\|\boldsymbol{p}\|$ and given by

$$\overline{\mathrm{d}\Pi^2} = \frac{\|\boldsymbol{p}\|}{4\pi\sqrt{s}} \frac{\mathrm{d}\Omega}{4\pi} = \frac{\|\boldsymbol{p}\|}{8\pi\sqrt{s}}\, \mathrm{d}\cos\theta = \frac{1}{16\pi} \sqrt{1 - \frac{2(m_1^2 + m_2^2)}{s} + \frac{(m_1^2 - m_2^2)^2}{s^2}}\, \mathrm{d}\cos\theta \tag{1.4}$$

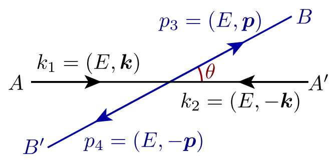
with $\sqrt{s} = M_0$ or E_{CM}, θ is the angle between initial and final motion, and

$$\|\boldsymbol{p}\| = \frac{\sqrt{s}}{2}\, \lambda^{1/2} \left(1; \frac{m_1^2}{s}, \frac{m_2^2}{s} \right), \quad E_1 = \frac{s + m_1^2 - m_2^2}{2\sqrt{s}}, \quad E_2 = \frac{s - m_1^2 + m_2^2}{2\sqrt{s}}, \quad p_1 \cdot p_2 = \frac{s - (m_1^2 + m_2^2)}{2}.$$

Mandelstam variables For $(k_1, k_2) \to (p_3, p_4)$ collision,

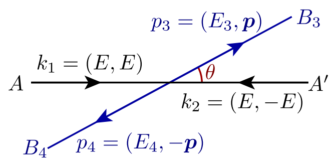
$$s = (k_1 + k_2)^2 = (p_3 + p_4)^2, \qquad t = (p_3 - k_1)^2 = (p_4 - k_2)^2, \qquad u = (p_3 - k_2)^2 = (p_4 - k_1)^2;$$
$$s + t + u = m_1^2 + m_2^2 + m_3^2 + m_4^2.$$

If the collision is with the "same mass" $(m_A, m_A) \to (m_B, m_B)$,



$$t = m_A^2 + m_B^2 - s/2 + 2kp\cos\theta, \qquad (k_1 - k_2)^2 = 4m_A^2 - s,$$
$$u = m_A^2 + m_B^2 - s/2 - 2kp\cos\theta, \qquad (p_3 - p_4)^2 = 4m_B^2 - s,$$
$$k = \frac{\sqrt{s - 4m_A^2}}{2}, \qquad k_1 \cdot k_2 = \frac{s}{2} - m_A^2, \qquad k_1 \cdot p_3 = k_2 \cdot p_4 = \frac{m_A^2 + m_B^2 - t}{2},$$
$$p = \frac{\sqrt{s - 4m_B^2}}{2}, \qquad p_3 \cdot p_4 = \frac{s}{2} - m_B^2, \qquad k_1 \cdot p_4 = k_2 \cdot p_3 = \frac{m_A^2 + m_B^2 - u}{2}.$$

Instead, if the collision is "initially massless" $(0, 0) \to (m_3, m_4)$,



$$t = (m_3^2 + m_4^2 - s)/2 + p\sqrt{s}\cos\theta,$$
$$u = (m_3^2 + m_4^2 - s)/2 - p\sqrt{s}\cos\theta,$$
$$p = (\sqrt{s}/2)\, \lambda^{1/2} \left(1; m_3^2/s, m_4^2/s \right).$$

1.1. Fundamentals

Lorentz-invariant phase space:

$$\int \mathrm{d}\Pi = \int \frac{\mathrm{d}^3\boldsymbol{p}}{(2\pi)^3}\frac{1}{2E_{\boldsymbol{p}}} = \int \frac{\mathrm{d}^3\boldsymbol{p}}{(2\pi)^3}\frac{1}{2\sqrt{m^2+\|\boldsymbol{p}\|^2}} = \int \frac{\mathrm{d}p_0\,\mathrm{d}^3\boldsymbol{p}}{(2\pi)^4}(2\pi)\,\delta\left(p_0^2-\|\boldsymbol{p}\|^2-m^2\right)\Theta(p_0)$$

Källén function:

$$\lambda(x,y,z) = x^2+y^2+z^2-2xy-2yz-2zx = (x-y-z)^2-4yz;$$

$$\lambda(1;\alpha_1^2,\alpha_2^2) = (1-(\alpha_1+\alpha_2)^2)(1-(\alpha_1-\alpha_2)^2) = (1+\alpha_1+\alpha_2)(1-\alpha_1-\alpha_2)(1+\alpha_1-\alpha_2)(1-\alpha_1+\alpha_2).$$

$$\lambda^{1/2}\left(s;m_1^2,m_2^2\right) = s\,\lambda^{1/2}\left(1;\frac{m_1^2}{s},\frac{m_2^2}{s}\right); \qquad \lambda^{1/2}\left(1;\frac{m^2}{s},\frac{m^2}{s}\right) = \sqrt{1-\frac{4m^2}{s}},$$

$$\lambda^{1/2}\left(1;\frac{m_1^2}{s},\frac{m_2^2}{s}\right) = \sqrt{1-\frac{2(m_1^2+m_2^2)}{s}+\frac{(m_1^2-m_2^2)^2}{s^2}}, \qquad \lambda^{1/2}\left(1;\frac{m_1^2}{s},0\right) = \frac{s-m_1^2}{s}.$$

Two-body phase space If $f(p_1^\mu,p_2^\mu)$ is Lorentz invariant, $f\equiv f(p_1^2,p_2^2,p_1^\mu p_{2\mu})\equiv f(p_1,p_2,\cos\theta_{12})$. Meanwhile,

$$\int \mathrm{d}\Pi_1\,\mathrm{d}\Pi_2 = \int \frac{\mathrm{d}^3\boldsymbol{p}_1}{(2\pi)^3}\frac{\mathrm{d}^3\boldsymbol{p}_2}{(2\pi)^3}\frac{1}{2E_1 2E_2} = \int \frac{(4\pi)\,\mathrm{d}p_1\,p_1^2}{(2\pi)^3}\frac{(2\pi)\,\mathrm{d}p_2\,p_2^2\,\mathrm{d}\cos\theta_{12}}{(2\pi)^3}\frac{1}{2E_1 2E_2} = \int \frac{\mathrm{d}E_+\,\mathrm{d}E_-\,\mathrm{d}s}{128\pi^4}, \tag{1.5}$$

with the replacement of the variables

$$E_\pm = E_1 \pm E_2, \qquad s=(p_1+p_2)^2 = m_1^2+m_2^2+2E_1E_2-2\|\boldsymbol{p}_1\|\|\boldsymbol{p}_2\|\cos\theta_{12};$$

$$\left|\frac{\mathrm{d}(E_+,E_-,s)}{\mathrm{d}(p_1,p_2,\cos\theta_{12})}\right| = \frac{4p_1^2p_2^2}{E_1E_2}, \qquad \left|\frac{\mathrm{d}(E_1,E_2,s)}{\mathrm{d}(p_1,p_2,\cos\theta_{12})}\right| = \frac{2p_1^2p_2^2}{E_1E_2}.$$

Therefore,

$$\int \mathrm{d}\Pi_1\,\mathrm{d}\Pi_2 = \frac{1}{128\pi^4}\int_{(m_1+m_2)^2}^{\infty}\mathrm{d}s\int_{\sqrt{s}}^{\infty}\mathrm{d}E_+\int_{\min}^{\max}\mathrm{d}E_-, \tag{1.6}$$

where the boundary of E_- is given by

$$\cos\theta_{12} = \frac{E_+^2-E_-^2+2\left(m_1^2+m_2^2-s\right)}{\sqrt{(E_++E_-)^2-4m_1^2}\sqrt{(E_+-E_-)^2-4m_2^2}} \in [-1,1]$$

$$\therefore \quad \left|E_- - \frac{m_1^2-m_2^2}{s}E_+\right| \le \sqrt{E_+^2-s}\cdot\lambda^{1/2}\left(1;\frac{m_1^2}{s},\frac{m_2^2}{s}\right) = 2p\sqrt{\frac{E_+^2-s}{s}}.$$

Two-body phase space with momentum conservation As a general representation in any frame,

$$\overline{\mathrm{d}\Pi^2} = \frac{\mathrm{d}p_1\,\mathrm{d}\Omega\,p_1^2}{16\pi^2}\frac{\delta(E_0-\sqrt{m_1^2+p_1^2}-\sqrt{m_2^2+\|\boldsymbol{P}_0-\boldsymbol{p}_1\|^2})}{E_1E_2} = \frac{1}{8\pi}\,\mathrm{d}\cos\theta_1\frac{p_1^2}{E_0p_1-P_0E_1\cos\theta_1}, \tag{1.7}$$

where the momentum p_1 is given by

$$p_1 = \frac{(E_0^2+m_1^2-m_2^2-P_0^2)P_0\cos\theta_1+E_0\sqrt{\lambda(E_0^2,m_1^2,m_2^2)+P_0^4-2P_0^2(E_0^2+m_1^2-2m_1^2\cos^2\theta_1-m_2^2)}}{2(E_0^2-P_0^2\cos^2\theta_1)}. \tag{1.8}$$

CM frame result is recovered by setting $E_0=\sqrt{s}$ and $P_0=0$.

1.2. Decay rate and Cross section

As $\langle\text{out}|\text{in}\rangle = (2\pi)^4\,\delta^{(4)}(p_\text{i}-p_\text{f})\text{i}\mathcal{M}$ (for in $\neq$ out) and $\langle\boldsymbol{p}|\boldsymbol{p}\rangle = 2E_{\boldsymbol{p}}(2\pi)^3\,\delta^{(3)}(\boldsymbol{0}) = 2E_{\boldsymbol{p}}V$ for one-particle state,

$$\frac{N_\text{ev}}{\prod_\text{in}N_\text{particle}} = \int \mathrm{d}\Pi^\text{out}\frac{|\langle\text{out}|\text{in}\rangle|^2}{\langle\text{in}|\text{in}\rangle} = \int \mathrm{d}\Pi^\text{out}\frac{(2\pi)^8|\mathcal{M}|^2}{\prod_\text{in}(2E)V}\frac{VT}{(2\pi^4)}\delta^{(4)}(p_\text{i}-p_\text{f}) = VT\int\overline{\mathrm{d}\Pi^{N_\text{f}}}\frac{|\mathcal{M}|^2}{\prod_\text{in}(2E)V}. \tag{1.9}$$

Therefore, decay rate (at the rest frame) is given by

$$\mathrm{d}\Gamma := \frac{1}{T}\frac{\mathrm{d}N_\text{ev}}{N_\text{particle}} = \frac{1}{T}VT\overline{\mathrm{d}\Pi^{N_\text{f}}}\frac{|\mathcal{M}|^2}{(2E)V} = \frac{1}{2M_0}\overline{\mathrm{d}\Pi^{N_\text{f}}}|\mathcal{M}|^2. \tag{1.10}$$

We also define Lorentz-invariant cross section σ by $N_\text{ev} =: (\rho_A v_\text{Møl}T\sigma)N_B = (\rho_A v_\text{Møl}T\sigma)(\rho_B V)$, or

$$\mathrm{d}\sigma := \frac{\mathrm{d}N_\text{ev}}{\rho_A v_\text{Møl}TN_B} = \frac{V}{v_\text{Møl}T}VT\overline{\mathrm{d}\Pi^{N_\text{f}}}\frac{|\mathcal{M}|^2}{2E_A2E_BV^2} = \frac{1}{2E_A2E_B\,v_\text{Møl}}\overline{\mathrm{d}\Pi^{N_\text{f}}}|\mathcal{M}|^2. \tag{1.11}$$

where the Møller parameter $v_\text{Møl}$ is equal to $v_\text{rel}^\text{NR} = \|\boldsymbol{v}_A-\boldsymbol{v}_B\|$ if $\boldsymbol{v}_A \mathbin{/\!/} \boldsymbol{v}_B$ (cf. Ref. [**?**]). Generally,

$$v_\text{Møl} := \frac{\sqrt{(p_A\cdot p_B)^2-m_A^2m_B^2}}{E_AE_B} = \frac{p_A\cdot p_B}{E_AE_B}v_\text{rel} = (1-\boldsymbol{v}_A\cdot\boldsymbol{v}_B)v_\text{rel}, \tag{1.12}$$

where v_rel is the actual relative velocity

$$v_\text{rel} = \sqrt{1-\frac{(1-v_A^2)(1-v_B^2)}{1-(\boldsymbol{v}_A\cdot\boldsymbol{v}_B)^2}} = \frac{\sqrt{\|\boldsymbol{v}_A-\boldsymbol{v}_B\|^2-\|\boldsymbol{v}_A\times\boldsymbol{v}_B\|^2}}{1-\boldsymbol{v}_A\cdot\boldsymbol{v}_B} = \frac{\lambda^{1/2}(s,m_A^2,m_B^2)}{s-(m_A^2+m_B^2)} \neq v_\text{rel}^\text{NR}. \tag{1.13}$$

(Note that $p_A\cdot p_B/E_AE_B = 1$ if $\boldsymbol{p}_A=0$ or $\boldsymbol{p}_B=0$. Also, Each of v_rel, VT, and $E_AE_Bv_\text{Møl}$ is Lorentz invariant.)

2. Gauge theory

SU(2) Fundamental representation $\mathbf{2} = (T^a)_{ij}$, adjoint representation adj. $= (\epsilon^a)^{bc}$.[*1]

$$T_a = \frac{1}{2}\sigma_a, \qquad \mathrm{Tr}(T_a T_b) = \frac{1}{2}\delta_{ab}, \qquad [T_a, T_b] = \mathrm{i}\epsilon^{abc}T^c, \qquad \epsilon^{abc}\epsilon^{ade} = \delta_{bd}\delta_{ce} - \delta_{be}\delta_{cd}$$

Since $\overline{\mathbf{2}} = -(T^a)^*_{ij}$ has identities $-\epsilon T^a \epsilon = -T^{a*}$ and $-\epsilon(-T^{a*})\epsilon = T^a$, we see that $\epsilon^{ab}\mathbf{2}^b$ transforms as $\overline{\mathbf{2}}^a$:

$$\epsilon^{ab}\mathbf{2}^b \to \epsilon^{ab}[\exp(\mathrm{i}g\theta^\alpha T^\alpha)]^{bc}\mathbf{2}^c = \epsilon^{ab}[\exp(\mathrm{i}g\theta^\alpha T^\alpha)]^{bc}(\epsilon^{-1})^{cd}(\epsilon^{de}\mathbf{2}^e) = [\exp(-\mathrm{i}g\theta^\alpha T^{\alpha*})]^{ab}(\epsilon^{bc}\mathbf{2}^c). \tag{2.1}$$

SU(3) Fundamental representation $\mathbf{3} = (\tau^a)_{ij}$, $\overline{\mathbf{3}} = -(\tau^a)^*_{ij}$; adjoint representation adj. $= \mathbf{8} = (f^a)^{bc}$.
Gell-Mann matrices:

$$\lambda_{1\text{–}8} = \begin{pmatrix} 0&1&0\\ 1&0&0\\ 0&0&0 \end{pmatrix}, \begin{pmatrix} 0&-\mathrm{i}&0\\ \mathrm{i}&0&0\\ 0&0&0 \end{pmatrix}, \begin{pmatrix} 1&0&0\\ 0&-1&0\\ 0&0&0 \end{pmatrix}, \begin{pmatrix} 0&0&1\\ 0&0&0\\ 1&0&0 \end{pmatrix}, \begin{pmatrix} 0&0&-\mathrm{i}\\ 0&0&0\\ \mathrm{i}&0&0 \end{pmatrix}, \begin{pmatrix} 0&0&0\\ 0&0&1\\ 0&1&0 \end{pmatrix}, \begin{pmatrix} 0&0&0\\ 0&0&-\mathrm{i}\\ 0&\mathrm{i}&0 \end{pmatrix}, \frac{1}{\sqrt{3}}\begin{pmatrix} 1&0&0\\ 0&1&0\\ 0&0&-2 \end{pmatrix}. \tag{2.2}$$

$$\tau_a = \frac{1}{2}\lambda_a, \qquad \mathrm{Tr}(\tau_a\tau_b) = \frac{1}{2}\delta_{ab}, \qquad [\tau_a, \tau_b] = \mathrm{i}f^{abc}\tau^c, \qquad f^{ade}f^{bcd} + f^{bde}f^{cad} + f^{cde}f^{abd} = 0.$$

$$\begin{aligned} \mathbf{3}:\quad & \phi_a \to [\exp(\mathrm{i}g\theta^\alpha\tau^\alpha)]_{ab}\phi_b \simeq \phi_a + \mathrm{i}g\theta^\alpha\tau^\alpha_{ab}\phi_b \\ & \phi^*_a \to [\exp(-\mathrm{i}g\theta^\alpha\tau^{\alpha*})]_{ab}\phi^*_b \simeq \phi^*_a - \mathrm{i}g\theta^\alpha\tau^{\alpha*}_{ab}\phi^*_b \\ & \qquad = \phi^*_b[\exp(-\mathrm{i}g\theta^\alpha\tau^\alpha)]_{ba} \simeq \phi^*_a - \mathrm{i}g\theta^\alpha\phi^*_b\tau^\alpha_{ba} \end{aligned}$$

$$\begin{aligned} \overline{\mathbf{3}}:\quad & \phi_a \to [\exp(-\mathrm{i}g\theta^\alpha\tau^{\alpha*})]_{ab}\phi_b \simeq \phi_a - \mathrm{i}g\theta^\alpha\tau^{\alpha*}_{ab}\phi_b \\ & \phi^*_a \to [\exp(\mathrm{i}g\theta^\alpha\tau^\alpha)]_{ab}\phi^*_b \simeq \phi^*_a + \mathrm{i}g\theta^\alpha\tau^\alpha_{ab}\phi^*_b \end{aligned}$$

[*1] We do not distinguish sub- and superscripts for gauge indices.

3. Spinors

$$(\overline{\psi_1}\psi_2)^* = (\psi_2)^\dagger(\overline{\psi}_1)^\dagger = \overline{\psi_2}\psi_1. \tag{3.1}$$

4. Minimal Supersymmetric Standard Model

Gauge symmetry: $\mathrm{SU}(3)_{\mathrm{color}} \times \mathrm{SU}(2)_{\mathrm{weak}} \times \mathrm{U}(1)_Y$

Particle content:

(a) Chiral superfields

	SU(3)	SU(2)	U(1)	B	L	scalar/spinor
Q_i	$\mathbf{3}$	$\mathbf{2}$	$1/6$	$1/3$		$\tilde{q}_{\mathrm{L}}, q_{\mathrm{L}}$ $[\to (u_{\mathrm{L}}, d_{\mathrm{L}})]$
L_i		$\mathbf{2}$	$-1/2$		1	$\tilde{l}_{\mathrm{L}}, l_{\mathrm{L}}$ $[\to (\nu_{\mathrm{L}}, l_{\mathrm{L}})]$
U_i^{c}	$\overline{\mathbf{3}}$		$-2/3$	$-1/3$		$\tilde{u}_{\mathrm{R}}^{\mathrm{c}}, u_{\mathrm{R}}^{\mathrm{c}}$
D_i^{c}	$\overline{\mathbf{3}}$		$1/3$	$-1/3$		$\tilde{d}_{\mathrm{R}}^{\mathrm{c}}, d_{\mathrm{R}}^{\mathrm{c}}$
E_i^{c}			1		-1	$\tilde{e}_{\mathrm{R}}^{\mathrm{c}}, e_{\mathrm{R}}^{\mathrm{c}}$
H_{u}		$\mathbf{2}$	$1/2$			$h_{\mathrm{u}}, \tilde{h}_{\mathrm{u}}$ $[\to (h_{\mathrm{u}}^+, h_{\mathrm{u}}^0)]$
H_{d}		$\mathbf{2}$	$-1/2$			$h_{\mathrm{d}}, \tilde{h}_{\mathrm{d}}$ $[\to (h_{\mathrm{d}}^0, h_{\mathrm{d}}^-)]$

(b) Vector superfields

	SU(3)	SU(2)	U(1)	ino/boson
g	adj.			$\tilde{g}, g_\mu$
W		adj.		$\tilde{w}, W_\mu$
B				$\tilde{b}, B_\mu$

Here, each of the column groups shows (from left to right) superfield name, charges for the gauge symmetries, other quantum numbers if relevant, and notation for corresponding fields (and SU(2) decomposition).

"c"-notation For scalars, $\tilde{\phi}_{\mathrm{R}}^{\mathrm{c}} := \phi_{\mathrm{R}}^* = \mathsf{C}\phi_{\mathrm{R}}\mathsf{C}$ (because the intrinsic phase for C is $+1$ for quarks and leptons.)

For matter spinors, $\psi_{\mathrm{R}}^{\mathrm{c}} := \bar{\psi}_{\mathrm{R}}$ (and $\psi_{\mathrm{R}} = \bar{\psi}_{\mathrm{R}}^{\mathrm{c}}$); Dirac spinors are thus

$$\psi_{\mathrm{L}} = \begin{pmatrix} \psi_{\mathrm{L}} \\ 0 \end{pmatrix}, \quad \overline{\psi_{\mathrm{L}}} = \begin{pmatrix} 0 & \bar{\psi}_{\mathrm{L}} \end{pmatrix}, \quad \psi_{\mathrm{R}}^{\mathrm{c}} := \begin{pmatrix} \psi_{\mathrm{R}}^{\mathrm{c}} \\ 0 \end{pmatrix} = C \begin{pmatrix} 0 \\ \psi_{\mathrm{R}} \end{pmatrix} = C\psi_{\mathrm{R}}, \quad \overline{\psi_{\mathrm{R}}^{\mathrm{c}}} = \begin{pmatrix} 0 & \psi_{\mathrm{R}} \end{pmatrix} = \begin{pmatrix} \bar{\psi}_{\mathrm{R}} & 0 \end{pmatrix} C = \overline{\psi_{\mathrm{R}}} C.$$

Superpotential and ~~SUSY~~-terms

$$W_{\mathrm{RPC}} = \mu H_{\mathrm{u}} H_{\mathrm{d}} - y_{\mathrm{u}ij} U_i^{\mathrm{c}} H_{\mathrm{u}} Q_j + y_{\mathrm{d}ij} D_i^{\mathrm{c}} H_{\mathrm{d}} Q_j + y_{\mathrm{e}ij} E_i^{\mathrm{c}} H_{\mathrm{d}} L_j, \tag{4.1}$$

$$W_{\mathrm{RPV}} = -\kappa_i L_i H_{\mathrm{u}} + \frac{1}{2}\lambda_{ijk} L_i L_j E_k^{\mathrm{c}} + \lambda'_{ijk} L_i Q_j D_k^{\mathrm{c}} + \frac{1}{2}\lambda''_{ijk} U_i^{\mathrm{c}} D_j^{\mathrm{c}} D_k^{\mathrm{c}}, \tag{4.2}$$

$$\mathcal{L}_{\cancel{\mathrm{SUSY}}} = -\frac{1}{2}\left(M_3 \tilde{g}\tilde{g} + M_2 \tilde{w}\tilde{w} + M_1 \tilde{b}\tilde{b} + \text{H.c.}\right) - V_{\cancel{\mathrm{SUSY}}}; \tag{4.3}$$

$$\begin{aligned} V_{\cancel{\mathrm{SUSY}}}^{\mathrm{RPC}} = {} & \left(\tilde{q}_{\mathrm{L}}^* m_Q^2 \tilde{q}_{\mathrm{L}} + \tilde{l}_{\mathrm{L}}^* m_L^2 \tilde{l}_{\mathrm{L}} + \tilde{u}_{\mathrm{R}}^* m_{U^{\mathrm{c}}}^2 \tilde{u}_{\mathrm{R}} + \tilde{d}_{\mathrm{R}}^* m_{D^{\mathrm{c}}}^2 \tilde{d}_{\mathrm{R}} + \tilde{e}_{\mathrm{R}}^* m_{E^{\mathrm{c}}}^2 \tilde{e}_{\mathrm{R}} + m_{H_{\mathrm{u}}}^2 |h_{\mathrm{u}}|^2 + m_{H_{\mathrm{d}}}^2 |h_{\mathrm{d}}|^2\right) \\ & + \left(-\tilde{u}_{\mathrm{R}}^* h_{\mathrm{u}} a_{\mathrm{u}} \tilde{q}_{\mathrm{L}} + \tilde{d}_{\mathrm{R}}^* h_{\mathrm{d}} a_{\mathrm{d}} \tilde{q}_{\mathrm{L}} + \tilde{e}_{\mathrm{R}}^* h_{\mathrm{d}} a_{\mathrm{e}} \tilde{l}_{\mathrm{L}} + b H_{\mathrm{u}} H_{\mathrm{d}} + \text{H.c.}\right) \\ & + \left(-\tilde{u}_{\mathrm{R}}^* h_{\mathrm{d}}^* c_{\mathrm{u}} \tilde{q}_{\mathrm{L}} + \tilde{d}_{\mathrm{R}}^* h_{\mathrm{u}}^* c_{\mathrm{d}} \tilde{q}_{\mathrm{L}} + \tilde{e}_{\mathrm{R}}^* h_{\mathrm{u}}^* c_{\mathrm{e}} \tilde{l}_{\mathrm{L}} + \text{H.c.}\right), \end{aligned} \tag{4.4}$$

$$\begin{aligned} V_{\cancel{\mathrm{SUSY}}}^{\mathrm{RPV}} = {} & \left(-b_i \tilde{l}_{\mathrm{L}i} H_{\mathrm{u}} + \frac{1}{2} T_{ijk} \tilde{l}_{\mathrm{L}i} \tilde{l}_{\mathrm{L}j} \tilde{e}_{\mathrm{R}k}^* + T'_{ijk} \tilde{l}_{\mathrm{L}i} \tilde{q}_{\mathrm{L}j} \tilde{d}_{\mathrm{R}k}^* + \frac{1}{2} T''_{ijk} \tilde{u}_{\mathrm{R}i}^* \tilde{d}_{\mathrm{R}j}^* \tilde{d}_{\mathrm{R}k}^* + \tilde{l}_{\mathrm{L}i}^* M_{Li}^2 H_{\mathrm{d}} + \text{H.c.}\right) \\ & + \left(C_{ijk}^1 \tilde{l}_{\mathrm{L}i}^* \tilde{q}_{\mathrm{L}j} \tilde{u}_{\mathrm{R}k}^* + C_i^2 h_{\mathrm{u}}^* h_{\mathrm{d}} \tilde{e}_{\mathrm{R}i}^* + C_{ijk}^3 \tilde{d}_{\mathrm{R}i} \tilde{u}_{\mathrm{R}j}^* \tilde{e}_{\mathrm{R}k}^* + \frac{1}{2} C_{ijk}^4 \tilde{d}_{\mathrm{R}i} \tilde{q}_{\mathrm{L}j} \tilde{q}_{\mathrm{L}k} + \text{H.c.}\right), \end{aligned} \tag{4.5}$$

($\lambda_{ijk} = -\lambda_{jik}$, $\lambda''_{ijk} = -\lambda''_{ikj}$, and $C_{ijk}^4 = C_{ikj}^4$.)

We follow the notation of DHM [?, PhysRept] and Martin [?, v7] (but note that Martin uses $(-,+,+,+)$-metric) for RPC part and SLHA2 convention for RPV part.

4.1. Lagrangian construction

As in Ref. [?],

$$\mathcal{L} = \frac{1}{2}\int \mathrm{d}^4\theta \left[K(\mathrm{e}^{2gV}\Phi, \Phi^\dagger) + K(\Phi, \Phi^\dagger\,\mathrm{e}^{2gV})\right] + \left[\int \mathrm{d}^2\theta \left(W(\Phi) + \sum_{\text{gauges}} \frac{f_{ab}(\Phi)}{4}\mathcal{W}^{\alpha a}\mathcal{W}^b_\alpha\right) + \text{H.c.}\right] \tag{4.6}$$

4.2. Scalar potential

The MSSM scalar potential has contributions from F-terms and D-terms:

$$V_{\text{SUSY}} = F_i^* F_i + \frac{1}{2}D^a D^a; \qquad F_i = -W_i^* = -\frac{\delta W^*}{\delta \phi_i^*}, \qquad D^a = -g(\phi^* T^a \phi), \tag{4.7}$$

where T_a corresponds to the gauge-symmetry generator relevant for each ϕ. They are given by

$$-F^*_{h_{\mathrm{u}}^a} = \epsilon^{ab}\left(-\tilde{u}_{\mathrm{R}}^{x*} y_{\mathrm{u}} \tilde{q}_{\mathrm{L}}^{bx} + \mu h_{\mathrm{d}}^b + \mu_i' \tilde{l}_{\mathrm{L}i}^b\right), \tag{4.8}$$

$$-F^*_{h_{\mathrm{d}}^a} = \epsilon^{ab}\left(\tilde{e}_{\mathrm{R}}^* y_{\mathrm{e}} \tilde{l}_{\mathrm{L}}^b + \tilde{d}_{\mathrm{R}}^{x*} y_{\mathrm{d}} \tilde{q}_{\mathrm{L}}^{bx} - \mu h_{\mathrm{u}}^b\right), \tag{4.9}$$

$$-F^*_{\tilde{q}_{\mathrm{L}i}^{ax}} = \epsilon^{ab}\left(-y_{\mathrm{d}ji} h_{\mathrm{d}}^b \tilde{d}_{\mathrm{R}j}^{x*} + y_{\mathrm{u}ji} h_{\mathrm{u}}^b \tilde{u}_{\mathrm{R}j}^{x*} - \lambda'_{kij} \tilde{d}_{\mathrm{R}j}^{x*} \tilde{l}_{\mathrm{L}k}^b\right), \tag{4.10}$$

$$-F^*_{\tilde{u}_{\mathrm{R}i}^{x*}} = -y_{\mathrm{u}ij} h_{\mathrm{u}} \tilde{q}_{\mathrm{L}j}^x + \frac{1}{2}\epsilon^{xyz}\lambda''_{ijk} \tilde{d}_{\mathrm{R}j}^{y*} \tilde{d}_{\mathrm{R}k}^{z*}, \tag{4.11}$$

$$-F^*_{\tilde{d}_{\mathrm{R}i}^{x*}} = y_{\mathrm{d}ij} h_{\mathrm{d}} \tilde{q}_{\mathrm{L}j}^x + \lambda'_{jki} \tilde{l}_{\mathrm{L}j} \tilde{q}_{\mathrm{L}k}^x - \lambda''_{jik}\epsilon^{xyz} \tilde{u}_{\mathrm{R}j}^{y*} \tilde{d}_{\mathrm{R}k}^{z*}, \tag{4.12}$$

$$-F^*_{\tilde{l}_{\mathrm{L}i}^a} = \epsilon^{ab}\left(-y_{\mathrm{e}ji} \tilde{e}_{\mathrm{R}j}^* h_{\mathrm{d}}^b - \mu_i' h_{\mathrm{u}}^b + \lambda_{ijk} \tilde{l}_{\mathrm{L}j}^b \tilde{e}_{\mathrm{R}k}^* + \lambda'_{ijk} \tilde{q}_{\mathrm{L}j}^{bx} \tilde{d}_{\mathrm{R}k}^{x*}\right), \tag{4.13}$$

$$-F^*_{\tilde{e}_{\mathrm{R}i}^*} = y_{\mathrm{e}ij} h_{\mathrm{d}} \tilde{l}_{\mathrm{L}j} + \frac{1}{2}\lambda_{jki} \tilde{l}_{\mathrm{L}j} \tilde{l}_{\mathrm{L}k}. \tag{4.14}$$

$$D^\alpha_{\mathrm{SU}(3)} = -g_3 \sum_{i=1}^{3}\left(\sum_{a=1,2} \tilde{q}_{\mathrm{L}i}^{a*}\tau^\alpha \tilde{q}_{\mathrm{L}i}^a - \tilde{u}_{\mathrm{R}i}^*\tau^\alpha \tilde{u}_{\mathrm{R}i} - \tilde{d}_{\mathrm{R}i}^*\tau^\alpha \tilde{d}_{\mathrm{R}i}\right), \tag{4.15}$$

$$D^\alpha_{\mathrm{SU}(2)} = -g_2 \left[\sum_{i=1}^{3}\left(\sum_{x=1}^{3} \tilde{q}_{\mathrm{L}i}^{x*} T^\alpha \tilde{q}_{\mathrm{L}i}^x + \tilde{l}_{\mathrm{L}i}^* T^\alpha \tilde{l}_{\mathrm{L}i}\right) + h_{\mathrm{u}}^* T^\alpha h_{\mathrm{u}} + h_{\mathrm{d}}^* T^\alpha h_{\mathrm{d}}\right], \tag{4.16}$$

$$D_{\mathrm{U}(1)} = -g_1\left(\frac{1}{6}|\tilde{q}_{\mathrm{L}}|^2 - \frac{1}{2}|\tilde{l}_{\mathrm{L}}|^2 - \frac{2}{3}|\tilde{u}_{\mathrm{R}}|^2 + \frac{1}{3}|\tilde{d}_{\mathrm{R}}|^2 + |\tilde{e}_{\mathrm{R}}|^2 + \frac{1}{2}|h_{\mathrm{u}}|^2 - \frac{1}{2}|h_{\mathrm{d}}|^2\right). \tag{4.17}$$

Combining these, the full SUSY scalar potential is given by

$$V = V_{\text{SUSY}} + V_{\cancel{\text{SUSY}}}; \tag{4.18}$$

$$\begin{aligned}
V_{\text{SUSY}} &= |h_{\text{u}}|^2\left(|\mu|^2+|\mu'|^2\right)+|\mu|^2|h_{\text{d}}|^2+\left(\mu_i'^*\mu\tilde{l}_{\text{L}i}^*h_{\text{d}}+\text{H.c.}\right)+\mu_i'^*\mu_j'\tilde{l}_{\text{L}i}^*\tilde{l}_{\text{L}j}\\
&\quad+\Big[-y_{\text{u}ij}\mu^*h_{\text{d}}^*\tilde{u}_{\text{R}i}^*\tilde{q}_{\text{L}j}-y_{\text{u}ij}\mu_k'^*\tilde{u}_{\text{R}i}^*\tilde{q}_{\text{L}j}\tilde{l}_{\text{L}k}^*-\left(y_{\text{d}ij}\mu^*+\lambda'_{kji}\mu_k'^*\right)h_{\text{u}}^*\tilde{d}_{\text{R}i}^*\tilde{q}_{\text{L}j}\\
&\qquad+y_{\text{e}ij}\mu_j'^*\tilde{e}_{\text{R}i}^*h_{\text{u}}^*h_{\text{d}}+\left(\lambda_{jki}\mu_k'^*-y_{\text{e}ij}\mu^*\right)h_{\text{u}}^*\tilde{e}_{\text{R}i}^*\tilde{l}_{\text{L}j}+\text{H.c.}\Big]\\
&\quad+\frac{1}{8}\left(g_2^2+g_Y^2\right)|h_{\text{d}}|^4+\frac{1}{8}\left(g_2^2+g_Y^2\right)|h_{\text{u}}|^4+\left(-\frac{g_2^2}{4}|h_{\text{d}}|^2|h_{\text{u}}|^2-\frac{g_Y^2}{4}|h_{\text{d}}|^2|h_{\text{u}}|^2+\frac{g_2^2}{2}|h_{\text{d}}^*h_{\text{u}}|^2\right)\\
&\quad+\left(-\frac{g_2^2}{4}|h_{\text{u}}|^2|\tilde{q}_{\text{L}}|^2+\frac{g_Y^2}{12}|h_{\text{u}}|^2|\tilde{q}_{\text{L}}|^2+\frac{g_2^2}{2}|h_{\text{u}}^b\tilde{q}_{\text{L}i}|^2+\epsilon^{ac}\epsilon^{bd}(y_{\text{u}}^\dagger y_{\text{u}})_{ji}h_{\text{u}}^ah_{\text{u}}^{b*}\tilde{q}_{\text{L}i}^c\tilde{q}_{\text{L}j}^{d*}\right)\\
&\quad+\left(-\frac{g_2^2}{4}|h_{\text{d}}|^2|\tilde{q}_{\text{L}}|^2-\frac{g_Y^2}{12}|h_{\text{d}}|^2|\tilde{q}_{\text{L}}|^2+\frac{g_2^2}{2}|h_{\text{d}}^*\tilde{q}_{\text{L}i}|^2+\epsilon^{ac}\epsilon^{bd}(y_{\text{d}}^\dagger y_{\text{d}})_{ji}h_{\text{d}}^ah_{\text{d}}^{b*}\tilde{q}_{\text{L}i}^c\tilde{q}_{\text{L}j}^{d*}\right)\\
&\quad+\left(-\frac{g_2^2}{4}|h_{\text{u}}|^2|\tilde{l}_{\text{L}}|^2-\frac{g_Y^2}{4}|h_{\text{u}}|^2|\tilde{l}_{\text{L}}|^2+\frac{g_2^2}{2}|h_{\text{u}}^*\tilde{l}_{\text{L}i}|^2\right)\\
&\quad+\left(-\frac{g_2^2}{4}|h_{\text{d}}|^2|\tilde{l}_{\text{L}}|^2+\frac{g_Y^2}{4}|h_{\text{d}}|^2|\tilde{l}_{\text{L}}|^2+\frac{g_2^2}{2}|h_{\text{d}}^*\tilde{l}_{\text{L}i}|^2+\epsilon^{ac}\epsilon^{bd}(y_{\text{e}}^\dagger y_{\text{e}})_{ji}h_{\text{d}}^ah_{\text{d}}^{b*}\tilde{l}_{\text{L}i}^c\tilde{l}_{\text{L}j}^{d*}\right)\\
&\quad+|h_{\text{u}}|^2\left(-\frac{g_Y^2}{3}|\tilde{u}_{\text{R}}|^2+(y_{\text{u}}y_{\text{u}}^\dagger)_{ij}\tilde{u}_{\text{R}i}^*\tilde{u}_{\text{R}j}\right)+\frac{g_Y^2}{3}|h_{\text{d}}|^2|\tilde{u}_{\text{R}}|^2\\
&\quad+\frac{g_Y^2}{6}|h_{\text{u}}|^2|\tilde{d}_{\text{R}}|^2+|h_{\text{d}}|^2\left(-\frac{g_Y^2}{6}|\tilde{d}_{\text{R}}|^2+(y_{\text{d}}y_{\text{d}}^\dagger)_{ij}\tilde{d}_{\text{R}i}^*\tilde{d}_{\text{R}j}\right)-\left[(y_{\text{u}}y_{\text{d}}^\dagger)_{ij}\tilde{u}_{\text{R}i}^*\tilde{d}_{\text{R}j}(h_{\text{d}}^*h_{\text{u}})+\text{H.c.}\right]\\
&\quad+\frac{g_Y^2}{2}|h_{\text{u}}|^2|\tilde{e}_{\text{R}}|^2+|h_{\text{d}}|^2\left(-\frac{g_Y^2}{2}|\tilde{e}_{\text{R}}|^2+(y_{\text{e}}y_{\text{e}}^\dagger)_{ij}\tilde{e}_{\text{R}i}^*\tilde{e}_{\text{R}j}\right)\\
&\quad+\Big[-\frac{1}{2}\epsilon^{ab}\epsilon^{xyz}y_{\text{u}lk}\lambda''^*_{lij}h_{\text{u}}^a\tilde{d}_{\text{R}i}^x\tilde{d}_{\text{R}j}^y\tilde{q}_{\text{L}k}^{bz}+\epsilon^{ab}\epsilon^{xyz}y_{\text{d}lk}\lambda''^*_{ijl}h_{\text{d}}^a\tilde{u}_{\text{R}i}^x\tilde{d}_{\text{R}j}^y\tilde{q}_{\text{L}k}^{bz}-y_{\text{u}il}\lambda'^*_{klj}h_{\text{u}}^a\tilde{u}_{\text{R}i}^*\tilde{d}_{\text{R}j}\tilde{l}_{\text{L}k}^{a*}\\
&\qquad+y_{\text{d}il}\lambda'^*_{klj}h_{\text{d}}^a\tilde{d}_{\text{R}i}^*\tilde{d}_{\text{R}j}\tilde{l}_{\text{L}k}^{a*}-\epsilon^{ab}\epsilon^{cd}y_{\text{d}li}\lambda'^*_{kjl}h_{\text{d}}^a\tilde{q}_{\text{L}i}^b\tilde{q}_{\text{L}j}^{c*}\tilde{l}_{\text{L}k}^{d*}+y_{\text{e}il}\lambda^*_{klj}h_{\text{d}}^a\tilde{e}_{\text{R}i}^*\tilde{e}_{\text{R}j}\tilde{l}_{\text{L}k}^{a*}\\
&\qquad-y_{\text{e}jl}\lambda'^*_{lki}h_{\text{d}}^a\tilde{e}_{\text{R}j}^*\tilde{d}_{\text{R}i}\tilde{q}_{\text{L}k}^{a*}+\frac{1}{2}\epsilon^{ab}\epsilon^{cd}y_{\text{e}li}\lambda^*_{jkl}h_{\text{d}}^a\tilde{l}_{\text{L}i}^b\tilde{l}_{\text{L}j}^{c*}\tilde{l}_{\text{L}k}^{d*}+\text{H.c.}\Big]\\
&\quad+\left[\left(-\frac{g_3^2}{12}+\frac{g_Y^2}{72}-\frac{g_2^2}{8}\right)|\tilde{q}_{\text{L}}|^4+\frac{g_2^2}{4}\tilde{q}_{\text{L}i}^{ax}\tilde{q}_{\text{L}j}^{by}\tilde{q}_{\text{L}i}^{bx*}\tilde{q}_{\text{L}j}^{ay*}+\frac{g_3^2}{4}\tilde{q}_{\text{L}i}^{ax}\tilde{q}_{\text{L}j}^{by}\tilde{q}_{\text{L}i}^{ay*}\tilde{q}_{\text{L}j}^{bx*}\right]\\
&\quad+\left[\left(-\frac{g_3^2}{12}+\frac{2g_Y^2}{9}\right)|\tilde{u}_{\text{R}}|^4+\frac{g_3^2}{4}\tilde{u}_{\text{R}i}^{x*}\tilde{u}_{\text{R}j}^{y*}\tilde{u}_{\text{R}i}^y\tilde{u}_{\text{R}j}^x\right]\\
&\quad+\left[\left(-\frac{g_3^2}{12}+\frac{g_Y^2}{18}\right)|\tilde{d}_{\text{R}}|^4+\frac{g_3^2}{4}\tilde{d}_{\text{R}i}^{x*}\tilde{d}_{\text{R}j}^{y*}\tilde{d}_{\text{R}i}^y\tilde{d}_{\text{R}j}^x+\frac{1}{2}\lambda''_{mij}\lambda''^*_{mkl}\tilde{d}_{\text{R}i}^{x*}\tilde{d}_{\text{R}j}^{y*}\tilde{d}_{\text{R}k}^x\tilde{d}_{\text{R}l}^y\right]\\
&\quad+\left[\left(\frac{g_3^2}{6}-\frac{g_Y^2}{9}\right)|\tilde{u}_{\text{R}}|^2|\tilde{q}_{\text{L}}|^2-\frac{g_3^2}{2}\tilde{u}_{\text{R}i}^{x*}\tilde{q}_{\text{L}j}^{ax}\tilde{u}_{\text{R}i}^y\tilde{q}_{\text{L}j}^{ay*}+y_{\text{u}ik}y_{\text{u}jl}^*\tilde{u}_{\text{R}i}^{x*}\tilde{u}_{\text{R}j}^y\tilde{q}_{\text{L}k}^{ax}\tilde{q}_{\text{L}l}^{ay*}\right]\\
&\quad+\left[\left(\frac{g_3^2}{6}+\frac{g_Y^2}{18}\right)|\tilde{d}_{\text{R}}|^2|\tilde{q}_{\text{L}}|^2-\frac{g_3^2}{2}\tilde{d}_{\text{R}i}^{x*}\tilde{q}_{\text{L}j}^{ax}\tilde{d}_{\text{R}i}^y\tilde{q}_{\text{L}j}^{ay*}+\left(y_{\text{d}ik}y_{\text{d}jl}^*+\lambda'_{mki}\lambda'^*_{mlj}\right)\tilde{d}_{\text{R}i}^{x*}\tilde{q}_{\text{L}k}^{ax}\tilde{d}_{\text{R}j}^y\tilde{q}_{\text{L}l}^{ay*}\right]\\
&\quad+\left[-\left(\frac{g_3^2}{6}+\frac{2g_Y^2}{9}\right)|\tilde{d}_{\text{R}}|^2|\tilde{u}_{\text{R}}|^2+\left(\frac{g_3^2}{2}-\lambda''_{ikm}\lambda''^*_{ljm}\right)\tilde{u}_{\text{R}i}^{x*}\tilde{d}_{\text{R}j}^x\tilde{d}_{\text{R}j}^{y*}\tilde{u}_{\text{R}i}^y+\lambda''_{ikm}\lambda''^*_{jlm}\tilde{u}_{\text{R}i}^{x*}\tilde{u}_{\text{R}j}^x\tilde{d}_{\text{R}k}^{y*}\tilde{d}_{\text{R}l}^y\right]\\
&\quad+\left[-\left(\frac{g_2^2}{4}+\frac{g_Y^2}{12}\right)|\tilde{l}_{\text{L}}|^2|\tilde{q}_{\text{L}}|^2+\frac{g_2^2}{2}\tilde{q}_{\text{L}i}^{ax}\tilde{q}_{\text{L}i}^{bx*}\tilde{l}_{\text{L}j}^b\tilde{l}_{\text{L}j}^{a*}+\epsilon^{ac}\epsilon^{bd}\lambda'_{kim}\lambda'^*_{ljm}\tilde{q}_{\text{L}i}^{ax}\tilde{q}_{\text{L}j}^{bx*}\tilde{l}_{\text{L}k}^c\tilde{l}_{\text{L}l}^{d*}\right]+\frac{g_Y^2}{6}|\tilde{e}_{\text{R}}|^2|\tilde{q}_{\text{L}}|^2\\
&\quad+\left(-\frac{g_Y^2}{6}|\tilde{d}_{\text{R}}|^2|\tilde{l}_{\text{L}}|^2+\lambda'_{lmi}\lambda'^*_{kmj}\tilde{d}_{\text{R}i}^*\tilde{d}_{\text{R}j}\tilde{l}_{\text{L}k}^*\tilde{l}_{\text{L}l}\right)+\frac{g_Y^2}{3}|\tilde{u}_{\text{R}}|^2|\tilde{l}_{\text{L}}|^2-\frac{2g_Y^2}{3}|\tilde{u}_{\text{R}}|^2|\tilde{e}_{\text{R}}|^2+\frac{g_Y^2}{3}|\tilde{d}_{\text{R}}|^2|\tilde{e}_{\text{R}}|^2\\
&\quad+\left[\left(-\frac{g_2^2}{8}+\frac{g_Y^2}{8}\right)|\tilde{l}_{\text{L}}|^4+\frac{g_2^2}{4}\tilde{l}_{\text{L}i}^a\tilde{l}_{\text{L}j}^b\tilde{l}_{\text{L}i}^{b*}\tilde{l}_{\text{L}j}^{a*}+\frac{1}{4}\epsilon^{ab}\epsilon^{cd}\lambda_{ijm}\lambda^*_{klm}\tilde{l}_{\text{L}i}^a\tilde{l}_{\text{L}j}^b\tilde{l}_{\text{L}k}^{c*}\tilde{l}_{\text{L}l}^{d*}\right]\\
&\quad+\frac{g_Y^2}{2}|\tilde{e}_{\text{R}}|^4+\left[-\frac{g_Y^2}{2}|\tilde{e}_{\text{R}}|^2|\tilde{l}_{\text{L}}|^2+\left(y_{\text{e}ik}y_{\text{e}jl}^*+\lambda_{kmi}\lambda^*_{lmj}\right)\tilde{e}_{\text{R}i}^*\tilde{e}_{\text{R}j}\tilde{l}_{\text{L}k}\tilde{l}_{\text{L}l}^*\right]\\
&\quad+\left[\left(y_{\text{d}ik}y_{\text{e}jl}^*-\lambda'_{mki}\lambda^*_{lmj}\right)\tilde{d}_{\text{R}i}^{x*}\tilde{q}_{\text{L}k}^{ax}\tilde{e}_{\text{R}j}\tilde{l}_{\text{L}l}^{a*}-\epsilon^{ab}\epsilon^{xyz}\lambda'_{lkm}\lambda''^*_{ijm}\tilde{l}_{\text{L}l}^b\tilde{q}_{\text{L}k}^{az}\tilde{d}_{\text{R}j}^y\tilde{u}_{\text{R}i}^x+\text{H.c.}\right].
\end{aligned} \tag{4.19}$$

4.3. SLHA convention

SLHA	our notation	Martin/DHM
(H_1, H_2)	$= (H_\mathrm{d}, H_\mathrm{u})$	
$Y_{\mathrm{u,d,e}}$	$= (y_{\mathrm{u,d,e}})^\mathrm{T}$	
$T_{\mathrm{u,d,e}}$	$= (a_{\mathrm{u,d,e}})^\mathrm{T}$	
$A_{\mathrm{u,d,e}}$	$= (A_{\mathrm{u,d,e}})^\mathrm{T}$	
$m^2_{U^\mathrm{c},D^\mathrm{c},E\mathrm{c}}$	$= (m^2_{U^\mathrm{c},D^\mathrm{c},E^\mathrm{c}})^\dagger$	
$M_{1,2,3}$	$= -M_{1,2,3}$	
m_3^2	$= b$	
m_A^2	$= m^2_{A_0}$ (tree)	
	κ_i	$= -\mu'_i$ (rarely used)
D_i	$= b_i$	
$m^2_{\tilde{L}_i H_1}$	$= M^2_{Li}$	

The SLHA convention [**?**] is different from our notation; the reinterpretation rules for the MSSM parameters are given in the right table, while

$\mu, b, m^2_{Q,L,H_\mathrm{u},H_\mathrm{d}}$, RPV-trilinears ($\lambda$s and Ts)

are in common.

A. Mathematics

A.1. Matrix exponential

Excerpted from §2 and §5 of Hall 2015 [**?**]:

$$\mathrm{e}^X := \sum_{m=0}^{\infty} \frac{X^m}{m!} \quad \text{(converges for any } X\text{)}, \quad \log X := \sum_{m=1}^{\infty} (-1)^{m+1} \frac{(A-1)^m}{m} \quad \text{(conv. if } \|A - I\| < 1\text{)}. \tag{A.1}$$

$$\mathrm{e}^{\log A} = A \quad \text{(if } \|A - I\| < 1\text{)}, \quad \log \mathrm{e}^X = X \text{ and } \|\mathrm{e}^X - 1\| < 1 \quad \text{(if } \|X\| < \log 2\text{)}. \tag{A.2}$$

$$\text{Hilbert-Schmidt norm}: \ \|X\|^2 := \sum_{i,j} |X_{ij}|^2 = \operatorname{Tr} X^\dagger X. \tag{A.3}$$

Properties:

$$\mathrm{e}^{(X^{\mathrm{T}})} = (\mathrm{e}^X)^{\mathrm{T}}, \qquad \mathrm{e}^{(X^*)} = (\mathrm{e}^X)^*, \qquad (\mathrm{e}^X)^{-1} = \mathrm{e}^{-X}, \qquad \mathrm{e}^{YXY^{-1}} = Y\,\mathrm{e}^X Y^{-1},$$

$$\det \exp X = \exp \operatorname{Tr} X, \qquad \frac{\mathrm{d}}{\mathrm{d}t}\mathrm{e}^{tX} = X\,\mathrm{e}^{tX} = \mathrm{e}^{tX} X \qquad \mathrm{e}^{(\alpha+\beta)X} = \mathrm{e}^{\alpha X}\,\mathrm{e}^{\beta X} \text{ for } \alpha, \beta \in \mathbb{C};$$

Baker-Campbell-Hausdorff:

$$\mathrm{e}^X Y\,\mathrm{e}^{-X} = Y + [X, Y] + \frac{1}{2!}[X, [X, Y]] + \frac{1}{3!}[X, [X, [X, Y]]] + \cdots; \tag{A.4}$$

$$\log(\mathrm{e}^X\,\mathrm{e}^Y) = X + \int_0^1 \mathrm{d}t\, g(\mathrm{e}^{[X,\cdot}\,\mathrm{e}^{t[Y,\cdot})Y \qquad \left[g(z) = \frac{\log z}{1 - z^{-1}} = 1 + \sum_{n=1}^{\infty} \frac{(-1)^{n+1}(z-1)^n}{n(n+1)}\right] \tag{A.5}$$

$$= X + Y + \frac{1}{2}[X, Y] + \frac{1}{12}[X, [X, Y]] - \frac{1}{12}[Y, [X, Y]] + \cdots \quad \text{(Baker-Campbell-Hausdorff)}. \tag{A.6}$$