Renormalizable Wess-Zumino Model on Bosonic-Fermionic Noncommutative Superspace

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Content

Bosonic Noncommutative Superspace

- Obtain bosonic noncommutative superspace from string theory, [N. Seiberg et al, hep-th/9908142].
- Construct Wess-Zumino and super Yang-Mills model on bosonic noncommutative superspace. [S. Ferrara et al, hep-th/0002084, hep-th/0307039].
- Bosonic noncommutative Wess-Zumino model is renormalizable to all orders, [H. O. Girotti et al, hep-th/0005272, A. A. Bichl et al, hep-th/0007050, I. L. Buchbinder et al, hep-th/0107022].

NAC Superspace

- Obtain NAC superspace from string theory, [H. Ooguri et al, hep-th/0303063, N. Berkovits et al, hep-th/0306226].
- Construct Wess-Zumino and super Yang-Mills model on NAC superspace, [N. Seiberg, hep-th/0305248].
- New renormalization theorem for NAC Wess-Zumino model, [R. Britto et al, hep-th/0306215].
- Calculate the 1PI effective action for NAC Wess-Zumino model, [M. T. Grisaru et al, hep-th/0307099].
- Analyze renormalization of NAC Wess-Zumino model by using two global $U(1)$ symmetry, [R. Britto et al, hep-th/0307165, A. Romagnoni, hep-th/0307209].

BFNC Superspace

- Obtain BFNC superspace from string theory, [J. de Boer et al, hep-th/0302078].
- Investigate BFNC Wess-Zumino model, [Y. Kobayashi et al, hep-th/0505011].
- One-loop renormalizable BFNC Wess-Zumino model, [Y. G. Miao et al, arXiv: 1403.4705]
- BFNC Wess-Zumino model renormalizable to all orders, [Y. G. Miao et al, arXiv: 1403.5046]

- One-Loop Renormalizable BFNC Wess-Zumino Model

Chiral Superfield

- Q and D are defined by,

$$\begin{aligned} Q_\alpha &\equiv \frac{\partial}{\partial\theta^\alpha}, \quad \bar{Q}_{\dot\alpha} \equiv -\frac{\partial}{\partial\bar\theta^{\dot\alpha}} + 2i\theta^\beta \sigma^k{}_{\beta\dot\alpha}\frac{\partial}{\partial y^k}, \\ D_\alpha &\equiv \frac{\partial}{\partial\theta^\alpha} + 2i\sigma^k{}_{\alpha\dot\beta}\bar\theta^{\dot\beta}\frac{\partial}{\partial y^k}, \quad \bar{D}_{\dot\alpha} \equiv -\frac{\partial}{\partial\bar\theta^{\dot\alpha}}. \end{aligned}$$

- The chiral superfield Φ and the antichiral superfields Φ^+ satisfy the following conditions, respectively,

$$\bar{D}_{\dot\alpha}\Phi = 0, \quad D_\alpha\Phi^+ = 0.$$

- They can be expressed by component fields as follows,

$$\begin{aligned} \Phi(y,\theta) &= A(y) + \sqrt{2}\theta^\alpha\psi_\alpha(y) + \theta^\alpha\theta_\alpha F(y), \\ \Phi^+(y,\theta,\bar\theta) &= A^*(y) + \sqrt{2}\bar\theta_{\dot\alpha}\bar\psi^{\dot\alpha}(y) + \bar\theta_{\dot\alpha}\bar\theta^{\dot\alpha}F^*(y) - 2i\sigma^k{}_{\alpha\dot\beta}\theta^\alpha\bar\theta^{\dot\beta}\partial_k A^*(y) \\ &\quad + i\sqrt{2}\sigma^k{}_{\alpha\dot\beta}\theta^\alpha\bar\theta_{\dot\zeta}\bar\theta^{\dot\zeta}\partial_k\bar\psi^{\dot\beta}(y) + \eta^{kl}\theta^\alpha\theta_\alpha\bar\theta_{\dot\beta}\bar\theta^{\dot\beta}\partial_k\partial_l A^*(y), \end{aligned}$$

Wess-Zumino Model

- The action of the Wess-Zumino model is

$$\begin{aligned} \mathcal{S}_{\rm WZ} &= \int d^4x \Big\{ \Phi^+\Phi|_{\theta^2\bar{\theta}^2} + \frac{m}{2}\Phi\Phi|_{\theta^2} + \frac{m}{2}\Phi^+\Phi^+|_{\bar{\theta}^2} \\ &\quad + \frac{g}{3}\Phi\Phi\Phi|_{\theta^2} + \frac{g}{3}\Phi^+\Phi^+\Phi^+|_{\bar{\theta}^2} \Big\}, \end{aligned}$$

  where $\Phi^+\Phi|_{\theta^2\bar{\theta}^2}$ denotes the $\theta^2\bar{\theta}^2$ component of $\Phi^+\Phi$, and the other terms have the similar meaning.
- The Wess-Zumino action can be transformed to a total superspace integral,

$$\begin{aligned} \mathcal{S}_{\rm WZ} &= \int d^8z \Big\{ \Phi^+\Phi - \frac{m}{8}\Phi\left(\frac{D^2}{\Box}\Phi\right) - \frac{m}{8}\Phi^+\left(\frac{\bar{D}^2}{\Box}\Phi^+\right) \\ &\quad - \frac{g}{12}\Phi\Phi\left(\frac{D^2}{\Box}\Phi\right) - \frac{g}{12}\Phi^+\Phi^+\left(\frac{\bar{D}^2}{\Box}\Phi^+\right) \Big\}. \end{aligned}$$

BFNC Star Product

- The BFNC $\star$-product can be expressed in terms of the tensor algebraic notation which is frequently used in quantum group theory,

$$\mathbf{F}\star\mathbf{G}\equiv\mu\left\{\exp\left[\frac{i}{2}\Lambda^{k\alpha}\left(\frac{\partial}{\partial y^k}\otimes\frac{\partial}{\partial\theta^\alpha}-\frac{\partial}{\partial\theta^\alpha}\otimes\frac{\partial}{\partial y^k}\right)\right]\triangleright(\mathbf{F}\otimes\mathbf{G})\right\},$$

- The Taylor expansion takes the form,

$$\begin{aligned}\mathbf{F}\star\mathbf{G} \;=\;& \mathbf{F}\mathbf{G}-\frac{i}{2}\Lambda^{k\alpha}\left(\partial_\alpha\mathbf{F}\right)\left(\partial_k\mathbf{G}\right)+(-1)^{|\mathbf{F}|}\frac{i}{2}\Lambda^{k\alpha}\left(\partial_k\mathbf{F}\right)\left(\partial_\alpha\mathbf{G}\right)\\ &+\frac{1}{8}\Lambda^{k\alpha}\Lambda^{l\beta}\left(\partial_k\partial_l\mathbf{F}\right)\left(\partial_\alpha\partial_\beta\mathbf{G}\right)+\frac{1}{8}\Lambda^{k\alpha}\Lambda^{l\beta}\left(\partial_\alpha\partial_\beta\mathbf{F}\right)\left(\partial_k\partial_l\mathbf{G}\right)\\ &+(-1)^{|\mathbf{F}|}\frac{1}{4}\Lambda^{k\alpha}\Lambda^{l\beta}\left(\partial_\beta\partial_k\mathbf{F}\right)\left(\partial_\alpha\partial_l\mathbf{G}\right)\\ &-\frac{i}{16}\Lambda^{k\alpha}\Lambda^{l\beta}\Lambda^{m\zeta}\left(\partial_\alpha\partial_l\partial_m\mathbf{F}\right)\left(\partial_\beta\partial_\zeta\partial_k\mathbf{G}\right)\\ &+(-1)^{|\mathbf{F}|}\frac{i}{16}\Lambda^{k\alpha}\Lambda^{l\beta}\Lambda^{m\zeta}\left(\partial_\alpha\partial_\beta\partial_m\mathbf{F}\right)\left(\partial_\zeta\partial_k\partial_l\mathbf{G}\right)\\ &-\frac{1}{64}\Lambda^{k\alpha}\Lambda^{l\beta}\Lambda^{m\zeta}\Lambda^{n\iota}\left(\partial_\alpha\partial_\zeta\partial_l\partial_n\mathbf{F}\right)\left(\partial_\beta\partial_\iota\partial_k\partial_m\mathbf{G}\right),\end{aligned}$$

where $\partial_k\equiv\frac{\partial}{\partial y^k}$, and $\partial_\alpha\equiv\frac{\partial}{\partial\theta^\alpha}$.

BFNC $\star$-Algebraic Relations of Coordinates

- As a simple application of the $\star$-product, we calculate some $\star$-algebraic relations of coordinates,

$$
\begin{aligned}
\left\{y^k, \theta^\alpha\right\}_\star &= i\Lambda^{k\alpha}, \qquad \left[x^k, y^l\right]_\star = -\sigma^k{}_{\alpha\dot\beta}\Lambda^{l\alpha}\bar\theta^{\dot\beta}, \qquad \left[x^k, \theta^\alpha\right]_\star = i\Lambda^{k\alpha}, \\
\left[x^k, x^l\right]_\star &= \sigma^l{}_{\alpha\dot\beta}\Lambda^{k\alpha}\bar\theta^{\dot\beta} - \sigma^k{}_{\alpha\dot\beta}\Lambda^{l\alpha}\bar\theta^{\dot\beta},
\end{aligned}
$$

BFNC Wess-Zumino Model

- To analyze the effect of the BFNC superspace on the Wess-Zumino model, we replace the ordinary product by the $\star$-product and give the deformed action,

$$\mathcal{S}_{\rm NC} \equiv \int d^4x \left\{ \Phi^+ \star \Phi|_{\theta^2\bar\theta^2} + \frac{m}{2}\Phi \star \Phi|_{\theta^2} + \frac{m}{2}\Phi^+ \star \Phi^+|_{\bar\theta^2} + \frac{g}{3}\Phi \star \Phi \star \Phi|_{\theta^2} + \frac{g}{3}\Phi^+ \star \Phi^+ \star \Phi^+|_{\bar\theta^2} \right\},$$

- We make the transformation for the deformed action from its component form to the desired superfield form. This performance is necessary for us to compute effective actions.

$$\begin{aligned}
\mathcal{S}_{\rm NC} = \int d^8z \Bigg\{ & \Phi^+\Phi - \frac{m}{8}\Phi\left(\frac{D^2}{\Box}\Phi\right) - \frac{m}{8}\Phi^+\left(\frac{\bar D^2}{\Box}\Phi^+\right) - \frac{g}{12}\Phi\Phi\left(\frac{D^2}{\Box}\Phi\right) - \frac{g}{12}\Phi^+\Phi^+\left(\frac{\bar D^2}{\Box}\Phi^+\right) \\
& + \frac{1}{32}(-g)\Lambda^{kl}\theta^4\Phi\left(D^2\Phi\right)\partial_l\partial_k\left(D^2\Phi\right) + \frac{1}{32}(-g)\Lambda^{kl}\theta^4\Phi\partial_k\left(D^2\Phi\right)\partial_l\left(D^2\Phi\right) \\
& + \frac{1}{6}(-g)\Lambda^{kl}\theta^4\Phi^+\Box\Phi^+\partial_k\partial_l\Phi^+ + \frac{1}{3}(-g)\left(\sigma\Lambda\Lambda^{kl}\right)^{no}\theta^4\Phi^+\partial_k\partial_n\Phi^+\partial_l\partial_o\Phi^+ \\
& + \frac{1}{6}g\eta^{kl}\Lambda^{no}\theta^4\Phi^+\partial_k\partial_n\Phi^+\partial_l\partial_o\Phi^+ + \frac{1}{16}(-g)\epsilon^{\alpha\beta}\Lambda^{kl}\theta^4\partial_k\left(D_\alpha\Phi\right)\partial_l\left(D_\beta\Phi\right)\left(D^2\Phi\right) \\
& + \frac{1}{16}(-g)\epsilon^{\alpha\beta}\epsilon^{\zeta\iota}\Lambda^k{}_\beta\Lambda^l{}_\iota\theta^4\partial_k\left(D_\alpha\Phi\right)\partial_l\left(D_\zeta\Phi\right)\left(D^2\Phi\right) \\
& + \frac{1}{3072}(-g)\Lambda^{kl}\Lambda^{no}\theta^4\left(D^2\Phi\right)\partial_l\partial_k\left(D^2\Phi\right)\partial_o\partial_n\left(D^2\Phi\right) \Bigg\},
\end{aligned}$$

Background Field Method

1. Split superfields,
$$\Phi \to \Phi + \Phi_q, \quad \Phi^+ \to \Phi^+ + \Phi_q^+,$$
2. Represent them by the general superfields,
$$\Phi_q = -\frac{1}{4}\bar{D}^2\Sigma, \quad \Phi_q^+ = -\frac{1}{4}D^2\Sigma^+,$$
3. New gauge symmetry,
$$\Sigma \to \Sigma + \bar{D}_{\dot\alpha}\bar{\Lambda}^{\dot\alpha}, \quad \Sigma^+ \to \Sigma^+ + D^\alpha\Lambda_\alpha,$$
4. Gauge fixing action $\mathcal{S}_{\rm GF}$,
$$\mathcal{S}_{\rm GF} = \int d^8z \left\{-\frac{3}{16}\xi\epsilon^{\dot\alpha\dot\beta}\left(\bar{D}_{\dot\alpha}\Sigma^+\right)\left(\bar{D}_{\dot\beta}D^2\Sigma\right) - \frac{1}{4}\xi\epsilon^{\alpha\beta}\epsilon^{\dot\zeta i}\left(\bar{D}_{\dot\zeta}\Sigma^+\right)\left(D_\beta\bar{D}_i D_\alpha\Sigma\right)\right\},$$
5. Quadratic part,
$$\mathcal{S}^{(2)} = \frac{1}{2}\int d^8z \begin{pmatrix} \Sigma & \Sigma^+ \end{pmatrix}(M+V)\begin{pmatrix} \Sigma \\ \Sigma^+ \end{pmatrix},$$
6. One-loop n-point,
$$\Gamma = \frac{i}{2}\mathrm{STr}\ln\left(1+M^{-1}V\right) = \frac{i}{2}\sum_{n=1}^{\infty}\mathrm{STr}\left[\frac{(-1)^{n+1}}{n}\left(M^{-1}V\right)^n\right] \equiv \sum_{n=1}^{\infty}\Gamma^{(n)},$$

Calculate Supertrace

1. N points,

$$\mathrm{STr}\left\{\underbrace{\left(\mathcal{D}_{A_1}\partial_{C_1}\frac{1}{\square-m^2}\left(\square^{-1}\right)^{s_1}\theta^4\mathcal{F}_{B_1}\partial_{C_1'}\mathcal{D}_{A_1'}\right)\cdots\left(\mathcal{D}_{A_n}\partial_{C_n}\frac{1}{\square-m^2}\left(\square^{-1}\right)^{s_n}\theta^4\mathcal{F}_{B_n}\partial_{C_n'}\mathcal{D}_{A_n'}\right)}_{\text{n terms}}\right\},$$

2. Take $n = 2$ as a sample,

$$(-1)^{|\mathcal{X}\|\mathcal{Y}|}\mathrm{STr}\left\{\partial_{C_2'}\mathcal{D}_{A_2'}\left(\mathcal{D}_{A_1}\partial_{C_1}\frac{1}{\square-m^2}\left(\square^{-1}\right)^{s_1}\theta^4\mathcal{F}_{B_1}\partial_{C_1'}\mathcal{D}_{A_1'}\right)\mathcal{D}_{A_2}\partial_{C_2}\frac{1}{\square-m^2}\left(\square^{-1}\right)^{s_2}\theta^4\mathcal{F}_{B_2}\right\},$$

3. Move D operators,

$$\mathrm{STr}\left\{\partial_{C_2'}\partial_{C_1}\frac{1}{\square-m^2}\left(\square^{-1}\right)^{s_1}\left(\mathcal{D}_{A_1''}\theta^4\right)\mathcal{F}_{B_1'}\partial_{C_1'}\partial_{C_2}\frac{1}{\square-m^2}\left(\square^{-1}\right)^{s_2}\mathcal{D}_{A_2''}\theta^4\mathcal{F}_{B_2}\right\},$$

4. Only when $\mathcal{D}_{A_1''} = D^2\bar{D}^2$,

$$\mathrm{STr}\left\{\partial_{C_2'}\partial_{C_1}\frac{1}{\square-m^2}\left(\square^{-1}\right)^{s_1}\mathcal{F}_{B_1'}\partial_{C_1'}\partial_{C_2}\frac{1}{\square-m^2}\left(\square^{-1}\right)^{s_2}\mathcal{D}_{A_2''}\theta^4\mathcal{F}_{B_2}\right\},$$

5. Only when $\mathcal{D}_{A_2''} = D^2\bar{D}^2$,

$$\mathrm{Tr}\left\{\partial_{C_2'}\partial_{C_1}\frac{1}{\square-m^2}\left(\square^{-1}\right)^{s_1}\mathcal{F}_{B_1'}\partial_{C_1'}\partial_{C_2}\frac{1}{\square-m^2}\left(\square^{-1}\right)^{s_2}\theta^4\mathcal{F}_{B_2}\right\},$$

The Actual Calculation

- Design Mathematica program to manage the algebra.
- Simplify the result as much as possible.
- Verify the result by using 1/2 supersymmetry invariance.
- Find new algebra relations.
- Optimize program.
- Represent the result.

$$\text{simplification} \quad \Leftrightarrow \quad \text{verification}$$

New Notations for Presenting Effective Actions

- We define the new symbols for presenting actions in a concise form,

$$\Lambda^{kl} \equiv \epsilon^{\alpha\beta}\Lambda^{k}{}_{\beta}\Lambda^{l}{}_{\alpha}, \qquad \Lambda^2 \equiv \eta_{kl}\Lambda^{kl},$$

$$\sigma\Lambda\Lambda \equiv \eta_{kn}\eta_{lo}\left(\sigma^{kl}\right)^{\alpha\beta}\Lambda^{n}{}_{\alpha}\Lambda^{o}{}_{\beta}, \qquad \left(\sigma\Lambda^{kl}\right)^{n\alpha} \equiv \left(\sigma^{kl}\right)^{\beta\alpha}\Lambda^{n}{}_{\beta},$$

$$\left(\eta\sigma\Lambda^{k}\right)^{\alpha} \equiv \eta_{ln}\left(\sigma^{nk}\right)^{\beta\alpha}\Lambda^{l}{}_{\beta}, \qquad \left(\eta\sigma\Lambda\Lambda^{k}\right)^{l} \equiv \eta_{no}\left(\sigma^{ok}\right)^{\alpha\beta}\Lambda^{n}{}_{\alpha}\Lambda^{l}{}_{\beta},$$

$$\left(\sigma\Lambda\Lambda^{kl}\right)^{no} \equiv \left(\sigma^{kl}\right)^{\alpha\beta}\Lambda^{n}{}_{\alpha}\Lambda^{o}{}_{\beta}.$$

- In addition, we hide the superscripts and/or subscripts of Bosonic derivatives, but only show the number of their product, for example, $\partial_k\partial_l$ is written as $\partial\partial$, and also hide the subscripts of Fermionic derivatives, such as D and $\bar{D}$ denoting D_α and $\bar{D}_{\dot{\beta}}$, respectively.
- In particular, for all terms in effective actions we pick out different BFNC parameter factors as one class and different operator factors as the other class, which gives an explicit outline of effective actions.

Structure of $\mathcal{S}_{\rm NC}$

$$
\begin{aligned}
\mathcal{S}_{\rm NC} \quad = \quad & \int d^8 z \left\{ \Phi^+\Phi - \frac{m}{8}\Phi\left(\frac{D^2}{\Box}\Phi\right) - \frac{m}{8}\Phi^+\left(\frac{\bar{D}^2}{\Box}\Phi^+\right) - \frac{g}{12}\Phi\Phi\left(\frac{D^2}{\Box}\Phi\right) - \frac{g}{12}\Phi^+\Phi^+\left(\frac{\bar{D}^2}{\Box}\Phi^+\right) \right. \\
& + \frac{1}{32}(-g)\Lambda^{kl}\theta^4\Phi\left(D^2\Phi\right)\partial_l\partial_k\left(D^2\Phi\right) + \frac{1}{32}(-g)\Lambda^{kl}\theta^4\Phi\partial_k\left(D^2\Phi\right)\partial_l\left(D^2\Phi\right) \\
& + \frac{1}{6}(-g)\Lambda^{kl}\theta^4\Phi^+\Box\Phi^+\partial_k\partial_l\Phi^+ + \frac{1}{3}(-g)\left(\sigma\Lambda\Lambda^{kl}\right)^{no}\theta^4\Phi^+\partial_k\partial_n\Phi^+\partial_l\partial_o\Phi^+ \\
& + \frac{1}{6}g\eta^{kl}\Lambda^{no}\theta^4\Phi^+\partial_k\partial_n\Phi^+\partial_l\partial_o\Phi^+ + \frac{1}{16}(-g)\epsilon^{\alpha\beta}\Lambda^{kl}\theta^4\partial_k\left(D_\alpha\Phi\right)\partial_l\left(D_\beta\Phi\right)\left(D^2\Phi\right) \\
& + \frac{1}{16}(-g)\epsilon^{\alpha\beta}\epsilon^{\zeta\iota}\Lambda^k{}_\beta\Lambda^l{}_\iota\theta^4\partial_k\left(D_\alpha\Phi\right)\partial_l\left(D_\zeta\Phi\right)\left(D^2\Phi\right) \\
& \left. + \frac{1}{3072}(-g)\Lambda^{kl}\Lambda^{no}\theta^4\left(D^2\Phi\right)\partial_l\partial_k\left(D^2\Phi\right)\partial_o\partial_n\left(D^2\Phi\right) \right\},
\end{aligned}
$$

- Structure of $\mathcal{S}_{\rm NC}$, BFNC parameter factors and operators,

$$
\begin{aligned}
& \Lambda^{kl}, \quad \left(\sigma\Lambda\Lambda^{kl}\right)^{no}, \quad \eta^{kl}\Lambda^{no}, \quad \epsilon^{\alpha\beta}\Lambda^{kl}, \quad \epsilon^{\alpha\beta}\epsilon^{\zeta\iota}\Lambda^k{}_\beta\Lambda^l{}_\iota, \quad \Lambda^{kl}\Lambda^{no}, \\
& \partial\partial\Phi\left(D^2\Phi\right)\left(D^2\Phi\right), \quad \partial\partial(D\Phi)(D\Phi)\left(D^2\Phi\right), \quad \partial\partial\partial\partial\Phi^+\Phi^+\Phi^+, \\
& \partial\partial\partial\partial\left(D^2\Phi\right)\left(D^2\Phi\right)\left(D^2\Phi\right).
\end{aligned}
$$

Structure of Γ_{1st} in order Λ^2

As the first step of searching the renormalizable Wess-Zumino model on the BFNC superspace, we calculate the effective action of $\mathcal{S}_{\mathrm{NC}}$ by using the background field method and denote it as Γ_{1st}. The structure of Γ_{1st} in order Λ^2 is as follows,

- 14 BFNC parameter factors,

$$\left(\eta\sigma\Lambda\Lambda^k\right)^l, \quad \Lambda^2, \quad \Lambda^{kl}, \quad \epsilon^{\alpha\beta}\left(\eta\sigma\Lambda\Lambda^k\right)^l, \quad \epsilon^{\alpha\beta}\Lambda^{kl}, \quad \Lambda^2\eta^{kl}, \quad \Lambda^2\epsilon^{\alpha\beta}, \quad \Lambda^2\epsilon^{\dot{\alpha}\dot{\beta}},$$

$$\Lambda^2\left(\bar{\sigma}^k\right)^{\dot{\alpha}\beta}, \quad \Lambda^2\eta^{kl}\epsilon^{\alpha\beta}, \quad \Lambda^{kl}\eta_{ln}\left(\bar{\sigma}^n\right)^{\dot{\alpha}\beta}, \quad \eta_{kl}\left(\bar{\sigma}^l\right)^{\dot{\alpha}\beta}\left(\eta\sigma\Lambda\Lambda^k\right)^n, \quad \epsilon^{\alpha\beta}\epsilon^{\zeta\iota}\Lambda^k{}_\beta\Lambda^l{}_\iota,$$

$$\epsilon^{\alpha\beta}\eta_{kl}\left(\sigma\Lambda^{ln}\right)^{o\zeta}\Lambda^k{}_\beta.$$

- 4 operators for 2 points,

$$\partial\partial\Phi\left(D^2\Phi\right), \quad \partial\partial(D\Phi)(D\Phi), \quad \partial\partial\left(D^2\Phi\right)\Phi^+, \quad \partial\partial\partial\partial\left(D^2\Phi\right)\Phi^+;$$

- 5 operators for 3 points,

$$\left(D^2\Phi\right)\left(D^2\Phi\right)\left(\bar{D}^2\Phi^+\right), \quad \partial(D\Phi)\left(D^2\Phi\right)\left(\bar{D}\Phi^+\right), \quad \partial\partial\Phi\left(D^2\Phi\right)\Phi^+,$$

$$\partial\partial(D\Phi)(D\Phi)\Phi^+, \quad \partial\partial\left(D^2\Phi\right)\Phi^+\Phi^+;$$

- 5 operators for 4 points,

$$\left(D^2\Phi\right)\left(D^2\Phi\right)\left(\bar{D}\Phi^+\right)\left(\bar{D}\Phi^+\right), \quad \left(D^2\Phi\right)\left(D^2\Phi\right)\Phi^+\left(\bar{D}^2\Phi^+\right),$$

$$\partial(D\Phi)\left(D^2\Phi\right)\Phi^+\left(\bar{D}\Phi^+\right), \quad \partial\partial\Phi\left(D^2\Phi\right)\Phi^+\Phi^+, \quad \partial\partial(D\Phi)(D\Phi)\Phi^+\Phi^+.$$

Comments

- We verify that $\Gamma_{\rm 1st}$ is invariant under the 1/2 supersymmetry transformation.
- We see explicitly that $\Gamma_{\rm 1st}$ cannot be absorbed by $\mathcal{S}_{\rm NC}$ because $\Gamma_{\rm 1st}$ contains many extra terms that do not exist in $\mathcal{S}_{\rm NC}$.

Compare With NAC

- NAC, [M. T. Grisaru et al, hep-th/0307099].

$$\frac{-1}{\epsilon} g^2 \int d^8z \ (m^*)^2 \, U \left(D^2\Phi\right)^2, \quad U = \theta^2 \bar{\theta}^2 C^2,$$

The renormalizable action can be obtained by adding the effective action to the deformed Wess-Zumino model on the NAC superspace.

- BFNC: In our case the number of correction terms that should be added to $\mathcal{S}_{\rm NC}$ is very large, for instance, $\Gamma_{\rm 1st}$ contains 68 terms only at the order of Λ^2. So, it is a tremendously exciting challenge to find out the successive effective actions needed.

Define $\mathcal{S}_{(1)}$, Calculate Its Effective Action $\Gamma_{\rm 2nd}$

- $\Gamma_{\rm 2nd}$: effective action of $\mathcal{S}_{\rm NC} + \Gamma_{\rm 1st}$.

$$\begin{aligned} \mathcal{S}_{(1)} &\equiv \mathcal{S}_{\rm WZ} + \mathcal{S}_{\Lambda}\left(\Lambda^2\right) + \Gamma_{\rm 1st}\left(\Lambda^2\right), \\ \mathcal{S}_{\rm WZ} &= \mathcal{S}_0 + \mathcal{S}_{\rm int}. \end{aligned}$$

- Gauge fixing term: $\mathcal{S}_{\rm GF}$. $\mathcal{S}_0 + \mathcal{S}_{\rm GF} \to M$. $\mathcal{S}_{\rm int} + \Gamma_{\rm 1st}\left(\Lambda^2\right) \to V_{(1)}$.
- Result: 13 BFNC parameter factors, 6 groups of different operator factors.
- $\Gamma_{\rm 2nd}\left(\Lambda^2\right)$ cannot be absorbed by $\mathcal{S}_{(1)}$.

Structure of Γ_{2nd} in order Λ^2

13 BFNC parameter factors, 6 groups of different operator factors.

$$\sigma\Lambda\Lambda,\quad \Lambda^2\left(\sigma^{kl}\right)^{\alpha\beta},\quad \sigma\Lambda\Lambda\eta^{kl},\quad \sigma\Lambda\Lambda\epsilon^{\alpha\beta},\quad \sigma\Lambda\Lambda\epsilon^{\dot\alpha\dot\beta},\quad \sigma\Lambda\Lambda\left(\bar\sigma^{k}\right)^{\dot\alpha\beta},\quad \epsilon^{\alpha\beta}\left(\eta\sigma\Lambda^{k}\right)^{\zeta}\Lambda^{l}{}_{\beta},\quad \Lambda^2\eta^{kl}\eta^{no},$$
$$\Lambda^{kl}\eta_{ln}\left(\sigma^{no}\right)^{\alpha\beta},\quad \sigma\Lambda\Lambda\eta^{kl}\epsilon^{\alpha\beta},\quad \eta_{kl}\left(\bar\sigma^{l}\right)^{\dot\alpha\beta}\left(\eta\sigma\Lambda\Lambda^{n}\right)^{k},\quad \epsilon^{\alpha\beta}\eta_{kl}\left(\eta\sigma\Lambda^{l}\right)^{\zeta}\Lambda^{k}{}_{\beta},\quad \epsilon^{\alpha\beta}\epsilon^{\zeta\iota}\epsilon^{klno}\eta_{np}\eta_{oq}\Lambda^{p}{}_{\beta}\Lambda^{q}{}_{\iota}.$$

$D^2\Phi$; (1)

$\Phi\left(D^2\Phi\right)$, $(D\Phi)(D\Phi)$, $\left(D^2\Phi\right)\left(D^2\Phi\right)$, $\left(D^2\Phi\right)\left(\bar D^2\Phi^+\right)$, $\left(D^2\Phi\right)\Phi^+$, $\partial(D\Phi)\left(\bar D\Phi^+\right)$, $\partial\partial\Phi\Phi^+$,
$\partial\partial\left(D^2\Phi\right)\left(D^2\Phi\right)$, $\partial\partial\Phi^+\Phi^+$, $\partial\partial\partial\partial\Phi^+\Phi^+$; (10)

$\Phi\Phi\left(D^2\Phi\right)$, $\Phi(D\Phi)(D\Phi)$, $\Phi\left(D^2\Phi\right)\left(D^2\Phi\right)$, $\Phi\left(D^2\Phi\right)\Phi^+$, $(D\Phi)(D\Phi)\left(D^2\Phi\right)$, $(D\Phi)(D\Phi)\Phi^+$, $\left(D^2\Phi\right)\left(D^2\Phi\right)\Phi^+$,
$\left(D^2\Phi\right)\left(\bar D\Phi^+\right)\left(\bar D\Phi^+\right)$, $\left(D^2\Phi\right)\Phi^+\left(\bar D^2\Phi^+\right)$, $\left(D^2\Phi\right)\Phi^+\Phi^+$, $\partial(D\Phi)\Phi^+\left(\bar D\Phi^+\right)$, $\partial\partial\Phi\Phi^+\Phi^+$, $\partial\partial\Phi^+\Phi^+\Phi^+$; (13)

$\Phi\Phi\left(D^2\Phi\right)\left(D^2\Phi\right)$, $\Phi\Phi\left(D^2\Phi\right)\Phi^+$, $\Phi(D\Phi)(D\Phi)\left(D^2\Phi\right)$, $\Phi(D\Phi)(D\Phi)\Phi^+$, $\Phi\left(D^2\Phi\right)\left(D^2\Phi\right)\Phi^+$, $\Phi\left(D^2\Phi\right)\Phi^+\Phi^+$,
$(D\Phi)(D\Phi)\left(D^2\Phi\right)\Phi^+$, $(D\Phi)(D\Phi)\Phi^+\Phi^+$, $\left(D^2\Phi\right)\Phi^+\left(\bar D\Phi^+\right)\left(\bar D\Phi^+\right)$, $\left(D^2\Phi\right)\Phi^+\Phi^+\left(\bar D^2\Phi^+\right)$, $\left(D^2\Phi\right)\Phi^+\Phi^+\Phi^+$,
$\partial(D\Phi)\Phi^+\Phi^+\left(\bar D\Phi^+\right)$, $\partial\partial\Phi\Phi^+\Phi^+\Phi^+$, $\partial\partial\Phi^+\Phi^+\Phi^+\Phi^+$; (14)

$\Phi\Phi\left(D^2\Phi\right)\left(D^2\Phi\right)\Phi^+$, $\Phi\Phi\left(D^2\Phi\right)\Phi^+\Phi^+$, $\Phi(D\Phi)(D\Phi)\left(D^2\Phi\right)\Phi^+$, $\Phi(D\Phi)(D\Phi)\Phi^+\Phi^+$, $\Phi\left(D^2\Phi\right)\Phi^+\Phi^+\Phi^+$,
$(D\Phi)(D\Phi)\Phi^+\Phi^+\Phi^+$, $\left(D^2\Phi\right)\Phi^+\Phi^+\left(\bar D\Phi^+\right)\left(\bar D\Phi^+\right)$, $\left(D^2\Phi\right)\Phi^+\Phi^+\Phi^+\left(\bar D^2\Phi^+\right)$, $\partial(D\Phi)\Phi^+\Phi^+\Phi^+\left(\bar D\Phi^+\right)$,
$\partial\partial\Phi\Phi^+\Phi^+\Phi^+\Phi^+$; (10)

$\Phi\Phi\left(D^2\Phi\right)\Phi^+\Phi^+\Phi^+$, $\Phi(D\Phi)(D\Phi)\Phi^+\Phi^+\Phi^+$. (2)

Comments

- Because of the existence of the above new forms, $\Gamma_{\rm 2nd}\left(\Lambda^2\right)$ cannot be absorbed by $\mathcal{S}_{(1)}$, which means $\mathcal{S}_{(1)}$ is still not renormalizable.
- Different from NAC case, we have to compute the third successive effective action $\Gamma_{\rm 3rd}$.

Define $\mathcal{S}_{(2)}$, Calculate Its Effective Action $\Gamma_{\rm 3rd}$

- Define

$$\mathcal{S}_{(2)} \equiv \mathcal{S}_{(1)} + \Gamma_{\rm 2nd}\left(\Lambda^2\right),$$

- New BFNC parameter factors that do not appear in $\mathcal{S}_{(2)}$,

$$\eta^{kl}\left(\eta\sigma\Lambda\Lambda^n\right)^o, \quad \sigma\Lambda\Lambda\left(\sigma^{kl}\right)^{\alpha\beta}.$$

- The operator factors in $\Gamma_{\rm 3rd}\left(\Lambda^2\right)$ are exactly same as that in $\mathcal{S}_{(2)}$.

Comments

- Therefore, there are still some terms in $\Gamma_{\rm 3rd}\left(\Lambda^2\right)$ that cannot be absorbed by $\mathcal{S}_{(2)}$. The reason is obvious because these terms are the products of the new BFNC parameter factors and the operator factors.
- This implies that we have to continue the iterative procedure in order to find the renormalizable Wess-Zumino model that possesses the 1/2 supersymmetry invariance on the BFNC superspace.
- At this stage, we notice that many terms in $\Gamma_{\rm 1st}\left(\Lambda^2\right)$, $\Gamma_{\rm 2nd}\left(\Lambda^2\right)$, and $\Gamma_{\rm 3rd}\left(\Lambda^2\right)$ are same, which brings us to compare the three effective actions and to analyze their structures.

1/2 Supersymmetry Invariant Subset

We explain our proposal as follows by using $\Gamma_{\rm 1st}\left(\Lambda^2\right)$ as an example.

$$\Gamma_{\rm 1st}\left(\Lambda^2\right) = \sum_{i=1}^{n} L_i \quad \longrightarrow \quad A = \sum_{i=1}^{n} X_i L_i \quad \longrightarrow \quad \delta_\xi A = \sum_{j=1}^{n'} Y_j L'_j$$

$$Y_j = \sum_{i=1}^{n} c_{ji} X_i \quad \longrightarrow \quad U_j = \{X_{i_1}, X_{i_2}, \cdots\} \quad \longrightarrow \quad W = \{U_1, U_2, \cdots, U_{n'}\}$$

$$U_j \cap U_{j'} \neq \emptyset \quad \longrightarrow \quad U_{jj'} \equiv U_j \cup U_{j'}, \quad (j \neq j')$$

$$W \quad \longrightarrow \quad W' = \{I_1, I_2, \cdots, I_m, \cdots\}, \quad (I_m \cap I_{m'} = \emptyset \ when\ m \neq m')$$

$$I_m = \{X_{m_1}, X_{m_2}, \cdots\} \quad \longrightarrow \quad f_m = \sum_{i=\{m_1, m_2, \cdots\}} L_i$$

- The numbers of 1/2 supersymmetry invariant subsets of $\mathcal{S}_\Lambda\left(\Lambda^2\right)$, $\Gamma_{\rm 1st}\left(\Lambda^2\right)$, $\Gamma_{\rm 2nd}\left(\Lambda^2\right)$ and $\Gamma_{\rm 3rd}\left(\Lambda^2\right)$ are 4, 17, 64 and 73.

Analysis of Effective Actions by Invariant Subsets

- Construct a new action,

$$\Gamma\left(\Lambda^2\right) = a_0\,\mathcal{S}_\Lambda\left(\Lambda^2\right) + a_1\,\Gamma_{1\mathrm{st}}\left(\Lambda^2\right) + a_2\,\Gamma_{2\mathrm{nd}}\left(\Lambda^2\right) + a_3\,\Gamma_{3\mathrm{rd}}\left(\Lambda^2\right),$$

- f_i represent all 74 invariant subsets of $\Gamma\left(\Lambda^2\right)$,

$$\Gamma\left(\Lambda^2\right) = \sum_{i=1}^{74} f_i,$$

We list the 74 subsets f_i's below, each of them is invariant under the 1/2 supersymmetry transformation.

$$
\begin{aligned}
f_1 &= \frac{1}{512} g^4 m^4 \left(3\Lambda^2 + 2\sigma\Lambda\Lambda\right)\left(10a_2 - 71g^2a_3\right)\epsilon^{\alpha\beta}\theta^4 \left(D_\alpha\Phi\right)\left(D_\beta\Phi\right) \\
&\quad + \frac{1}{512} g^4 m^4 \left(3\Lambda^2 + 2\sigma\Lambda\Lambda\right)\left(-10a_2 + 71g^2a_3\right)\theta^4\Phi\left(D^2\Phi\right), \\
f_2 &= \frac{1}{256} g^5 m^3 \left(3\Lambda^2 + 2\sigma\Lambda\Lambda\right)\left(10a_2 - 71g^2a_3\right)\epsilon^{\alpha\beta}\theta^4\Phi\left(D_\alpha\Phi\right)\left(D_\beta\Phi\right) \\
&\quad + \frac{1}{512} g^5 m^3 \left(3\Lambda^2 + 2\sigma\Lambda\Lambda\right)\left(-10a_2 + 71g^2a_3\right)\theta^4\Phi\Phi\left(D^2\Phi\right), \\
f_3 &= \frac{3}{256} g^5 m^3 \left(3\Lambda^2 + 2\sigma\Lambda\Lambda\right)\left(10a_2 - 71g^2a_3\right)\epsilon^{\alpha\beta}\theta^4 \left(D_\alpha\Phi\right)\left(D_\beta\Phi\right)\Phi^+ \\
&\quad + \frac{3}{256} g^5 m^3 \left(3\Lambda^2 + 2\sigma\Lambda\Lambda\right)\left(-10a_2 + 71g^2a_3\right)\theta^4\Phi\left(D^2\Phi\right)\Phi^+, \\
f_4 &= \frac{3}{128} g^6 m^2 \left(3\Lambda^2 + 2\sigma\Lambda\Lambda\right)\left(10a_2 - 71g^2a_3\right)\epsilon^{\alpha\beta}\theta^4\Phi\left(D_\alpha\Phi\right)\left(D_\beta\Phi\right)\Phi^+ \\
&\quad + \frac{3}{256} g^6 m^2 \left(3\Lambda^2 + 2\sigma\Lambda\Lambda\right)\left(-10a_2 + 71g^2a_3\right)\theta^4\Phi\Phi\left(D^2\Phi\right)\Phi^+, \\
f_5 &= \frac{3}{128} g^6 m^2 \left(3\Lambda^2 + 2\sigma\Lambda\Lambda\right)\left(10a_2 - 71g^2a_3\right)\epsilon^{\alpha\beta}\theta^4 \left(D_\alpha\Phi\right)\left(D_\beta\Phi\right)\Phi^+\Phi^+ \\
&\quad + \frac{3}{128} g^6 m^2 \left(3\Lambda^2 + 2\sigma\Lambda\Lambda\right)\left(-10a_2 + 71g^2a_3\right)\theta^4\Phi\left(D^2\Phi\right)\Phi^+\Phi^+,
\end{aligned}
$$

$$\begin{aligned}
f_6 &= \frac{3}{64}g^7 m\left(3\Lambda^2+2\sigma\Lambda\Lambda\right)\left(10a_2-71g^2a_3\right)\epsilon^{\alpha\beta}\theta^4\Phi\left(D_\alpha\Phi\right)\left(D_\beta\Phi\right)\Phi^+\Phi^+ \\
&+\frac{3}{128}g^7 m\left(3\Lambda^2+2\sigma\Lambda\Lambda\right)\left(-10a_2+71g^2a_3\right)\theta^4\Phi\Phi\left(D^2\Phi\right)\Phi^+\Phi^+, \\
f_7 &= \frac{1}{64}g^7 m\left(3\Lambda^2+2\sigma\Lambda\Lambda\right)\left(10a_2-71g^2a_3\right)\epsilon^{\alpha\beta}\theta^4\left(D_\alpha\Phi\right)\left(D_\beta\Phi\right)\Phi^+\Phi^+\Phi^+ \\
&+\frac{1}{64}g^7 m\left(3\Lambda^2+2\sigma\Lambda\Lambda\right)\left(-10a_2+71g^2a_3\right)\theta^4\Phi\left(D^2\Phi\right)\Phi^+\Phi^+\Phi^+, \\
f_8 &= \frac{1}{32}g^8\left(3\Lambda^2+2\sigma\Lambda\Lambda\right)\left(10a_2-71g^2a_3\right)\epsilon^{\alpha\beta}\theta^4\Phi\left(D_\alpha\Phi\right)\left(D_\beta\Phi\right)\Phi^+\Phi^+\Phi^+ \\
&+\frac{1}{64}g^8\left(3\Lambda^2+2\sigma\Lambda\Lambda\right)\left(-10a_2+71g^2a_3\right)\theta^4\Phi\Phi\left(D^2\Phi\right)\Phi^+\Phi^+\Phi^+, \\
f_9 &= \frac{1}{512}g^5 m^2\left(3\Lambda^2+2\sigma\Lambda\Lambda\right)\left(2a_2-15g^2a_3\right)\epsilon^{\alpha\beta}\theta^4\left(D_\alpha\Phi\right)\left(D_\beta\Phi\right)\left(D^2\Phi\right) \\
&+\frac{1}{512}g^5 m^2\left(3\Lambda^2+2\sigma\Lambda\Lambda\right)\left(-2a_2+15g^2a_3\right)\theta^4\Phi\left(D^2\Phi\right)\left(D^2\Phi\right), \\
f_{10} &= \frac{1}{256}g^6 m\left(3\Lambda^2+2\sigma\Lambda\Lambda\right)\left(2a_2-15g^2a_3\right)\epsilon^{\alpha\beta}\theta^4\Phi\left(D_\alpha\Phi\right)\left(D_\beta\Phi\right)\left(D^2\Phi\right) \\
&+\frac{1}{512}g^6 m\left(3\Lambda^2+2\sigma\Lambda\Lambda\right)\left(-2a_2+15g^2a_3\right)\theta^4\Phi\Phi\left(D^2\Phi\right)\left(D^2\Phi\right), \\
f_{11} &= \frac{1}{256}g^6 m\left(3\Lambda^2+2\sigma\Lambda\Lambda\right)\left(2a_2-15g^2a_3\right)\epsilon^{\alpha\beta}\theta^4\left(D_\alpha\Phi\right)\left(D_\beta\Phi\right)\left(D^2\Phi\right)\Phi^+ \\
&+\frac{1}{256}g^6 m\left(3\Lambda^2+2\sigma\Lambda\Lambda\right)\left(-2a_2+15g^2a_3\right)\theta^4\Phi\left(D^2\Phi\right)\left(D^2\Phi\right)\Phi^+,
\end{aligned}$$

$$
\begin{aligned}
f_{12} &= \frac{1}{128}g^7\left(3\Lambda^2+2\sigma\Lambda\Lambda\right)\left(2a_2-15g^2a_3\right)\epsilon^{\alpha\beta}\theta^4\Phi\left(D_\alpha\Phi\right)\left(D_\beta\Phi\right)\left(D^2\Phi\right)\Phi^+ \\
&\quad+\frac{1}{256}g^7\left(3\Lambda^2+2\sigma\Lambda\Lambda\right)\left(-2a_2+15g^2a_3\right)\theta^4\Phi\Phi\left(D^2\Phi\right)\left(D^2\Phi\right)\Phi^+, \\
f_{13} &= \frac{1}{64}ig^5m^2\left(3\Lambda^2-2\sigma\Lambda\Lambda\right)\left(a_2-4g^2a_3\right)\left(\bar\sigma^k\right)^{\dot\alpha\beta}\theta^4\left(D_\beta\Phi\right)\partial_k\Phi^+\left(\bar D_{\dot\alpha}\Phi^+\right) \\
&\quad+\frac{1}{32}g^5m^2\left(3\Lambda^2-2\sigma\Lambda\Lambda\right)\left(-a_2+4g^2a_3\right)\eta^{kl}\theta^4\Phi\partial_k\Phi^+\partial_l\Phi^+ \\
&\quad+\frac{1}{512}g^5m^2\left(3\Lambda^2-2\sigma\Lambda\Lambda\right)\left(-a_2+4g^2a_3\right)\epsilon^{\dot\alpha\dot\beta}\theta^4\left(D^2\Phi\right)\left(\bar D_{\dot\alpha}\Phi^+\right)\left(\bar D_{\dot\beta}\Phi^+\right), \\
f_{14} &= \frac{1}{16}ig^6m\left(3\Lambda^2-2\sigma\Lambda\Lambda\right)\left(a_2-4g^2a_3\right)\left(\bar\sigma^k\right)^{\dot\alpha\beta}\theta^4\left(D_\beta\Phi\right)\Phi^+\partial_k\Phi^+\left(\bar D_{\dot\alpha}\Phi^+\right) \\
&\quad+\frac{1}{8}g^6m\left(3\Lambda^2-2\sigma\Lambda\Lambda\right)\left(-a_2+4g^2a_3\right)\eta^{kl}\theta^4\Phi\Phi^+\partial_k\Phi^+\partial_l\Phi^+ \\
&\quad+\frac{1}{128}g^6m\left(3\Lambda^2-2\sigma\Lambda\Lambda\right)\left(-a_2+4g^2a_3\right)\epsilon^{\dot\alpha\dot\beta}\theta^4\left(D^2\Phi\right)\Phi^+\left(\bar D_{\dot\alpha}\Phi^+\right)\left(\bar D_{\dot\beta}\Phi^+\right), \\
f_{15} &= \frac{1}{16}ig^7\left(3\Lambda^2-2\sigma\Lambda\Lambda\right)\left(a_2-4g^2a_3\right)\left(\bar\sigma^k\right)^{\dot\alpha\beta}\theta^4\left(D_\beta\Phi\right)\Phi^+\Phi^+\partial_k\Phi^+\left(\bar D_{\dot\alpha}\Phi^+\right) \\
&\quad+\frac{1}{8}g^7\left(3\Lambda^2-2\sigma\Lambda\Lambda\right)\left(-a_2+4g^2a_3\right)\eta^{kl}\theta^4\Phi\Phi^+\Phi^+\partial_k\Phi^+\partial_l\Phi^+ \\
&\quad+\frac{1}{128}g^7\left(3\Lambda^2-2\sigma\Lambda\Lambda\right)\left(-a_2+4g^2a_3\right)\epsilon^{\dot\alpha\dot\beta}\theta^4\left(D^2\Phi\right)\Phi^+\Phi^+\left(\bar D_{\dot\alpha}\Phi^+\right)\left(\bar D_{\dot\beta}\Phi^+\right), \\
f_{16} &= \frac{1}{2304}g^4m^2\left(-4a_2+23g^2a_3\right)\left(\eta\sigma\Lambda\Lambda^k\right)^l\theta^4\Phi\partial_k\partial_l\left(D^2\Phi\right)
\end{aligned}
$$

$$
\begin{aligned}
& +\frac{1}{2304} g^4 m^2 \left(-4a_2 + 23g^2 a_3\right) \epsilon^{\alpha\beta} \left(\eta\sigma\Lambda\Lambda^k\right)^l \theta^4 \left(D_\beta\Phi\right) \partial_k \partial_l \left(D_\alpha\Phi\right), \\
f_{17} \quad = \quad & \frac{1}{288} g^5 m a_2 \epsilon^{\alpha\beta} \left(\eta\sigma\Lambda^k\right)^\zeta \Lambda^l{}_\beta \theta^4 \left(D_\alpha\Phi\right) \partial_k \partial_l \left(D_\zeta\Phi\right) \Phi^+ \\
& -\frac{1}{36} g^5 m a_2 \epsilon^{\alpha\beta} \left(\eta\sigma\Lambda^k\right)^\zeta \Lambda^l{}_\beta \theta^4 \partial_k \left(D_\alpha\Phi\right) \partial_l \left(D_\zeta\Phi\right) \Phi^+ \\
& +\frac{1}{9216} i g^5 m \left(-4a_2 + 23g^2 a_3\right) \eta_{kl} \left(\bar\sigma^l\right)^{\dot\alpha\beta} \left(\eta\sigma\Lambda\Lambda^n\right)^k \theta^4 \left(D_\beta\Phi\right) \partial_n \left(D^2\Phi\right) \left(\bar D_{\dot\alpha}\Phi^+\right) \\
& -\frac{1}{9216} i g^5 m \left(-4a_2 + 23g^2 a_3\right) \eta_{kl} \left(\bar\sigma^l\right)^{\dot\alpha\beta} \left(\eta\sigma\Lambda\Lambda^n\right)^k \theta^4 \partial_n \left(D_\beta\Phi\right) \left(D^2\Phi\right) \left(\bar D_{\dot\alpha}\Phi^+\right) \\
& -\frac{1}{4608} i g^5 m \left(-4a_2 + 23g^2 a_3\right) \epsilon^{\alpha\beta} \epsilon^{\zeta\iota} \epsilon^{klno} \eta_{np} \eta_{oq} \Lambda^p{}_\beta \Lambda^q{}_\iota \theta^4 \partial_k \left(D_\alpha\Phi\right) \partial_l \left(D_\zeta\Phi\right) \Phi^+ \\
& +\frac{1}{1152} g^5 m \left(28a_2 + 23g^2 a_3\right) \Lambda^{kl} \eta_{ln} \left(\sigma^{no}\right)^{\alpha\beta} \theta^4 \partial_k \left(D_\alpha\Phi\right) \partial_o \left(D_\beta\Phi\right) \Phi^+ \\
& +\frac{1}{4608} g^5 m \left(-124a_2 + 129g^2 a_3\right) \epsilon^{\alpha\beta} \Lambda^{kl} \theta^4 \partial_k \left(D_\alpha\Phi\right) \partial_l \left(D_\beta\Phi\right) \Phi^+ \\
& +\frac{1}{288} g^3 m \left(9a_1 - 6g^2 a_2 + 17g^4 a_3\right) \Lambda^{kl} \theta^4 \partial_l \Phi \partial_k \left(D^2\Phi\right) \Phi^+ \\
& +\frac{1}{288} g^3 m \left(27a_1 - 37g^2 a_2 + 69g^4 a_3\right) \Lambda^{kl} \theta^4 \partial_k \partial_l \Phi \left(D^2\Phi\right) \Phi^+ \\
& -\frac{1}{4608} i g^3 m \left(36a_1 - 52g^2 a_2 + 83g^4 a_3\right) \Lambda^{kl} \eta_{ln} \left(\bar\sigma^n\right)^{\dot\alpha\beta} \theta^4 \left(D_\beta\Phi\right) \partial_k \left(D^2\Phi\right) \left(\bar D_{\dot\alpha}\Phi^+\right) \\
& +\frac{1}{4608} i g^3 m \left(36a_1 - 52g^2 a_2 + 83g^4 a_3\right) \Lambda^{kl} \eta_{ln} \left(\bar\sigma^n\right)^{\dot\alpha\beta} \theta^4 \partial_k \left(D_\beta\Phi\right) \left(D^2\Phi\right) \left(\bar D_{\dot\alpha}\Phi^+\right)
\end{aligned}
$$

$$+\frac{1}{576}g^3m\left(36a_1-40g^2a_2+87g^4a_3\right)\left(\eta\sigma\Lambda\Lambda^k\right)^l\theta^4\partial_k\partial_l\Phi\left(D^2\Phi\right)\Phi^+$$
$$-\frac{1}{288}g^3m\left(36a_1-57g^2a_2+106g^4a_3\right)\epsilon^{\alpha\beta}\eta_{kl}\left(\sigma\Lambda^{ln}\right)^{o\zeta}\Lambda^k{}_\beta\theta^4\left(D_\alpha\Phi\right)\partial_n\partial_o\left(D_\zeta\Phi\right)\Phi^+$$
$$-\frac{1}{576}g^3m\left(72a_1-92g^2a_2+189g^4a_3\right)\epsilon^{\alpha\beta}\eta_{kl}\left(\sigma\Lambda^{ln}\right)^{o\zeta}\Lambda^k{}_\beta\theta^4\partial_n\left(D_\alpha\Phi\right)\partial_o\left(D_\zeta\Phi\right)\Phi^+$$
$$+\frac{1}{576}g^3m\left(72a_1-96g^2a_2+193g^4a_3\right)\left(\eta\sigma\Lambda\Lambda^k\right)^l\theta^4\Phi\partial_k\partial_l\left(D^2\Phi\right)\Phi^+$$
$$+\frac{1}{1152}g^3m\left(72a_1-96g^2a_2+193g^4a_3\right)\Lambda^{kl}\theta^4\Phi\partial_l\partial_k\left(D^2\Phi\right)\Phi^+$$
$$+\frac{1}{288}g^3m\left(72a_1-96g^2a_2+193g^4a_3\right)\epsilon^{\alpha\beta}\left(\eta\sigma\Lambda\Lambda^k\right)^l\theta^4\left(D_\beta\Phi\right)\partial_k\partial_l\left(D_\alpha\Phi\right)\Phi^+$$
$$+\frac{1}{2304}g^3m\left(144a_1-156g^2a_2+325g^4a_3\right)\left(\eta\sigma\Lambda\Lambda^k\right)^l\theta^4\partial_l\Phi\partial_k\left(D^2\Phi\right)\Phi^+$$
$$+\frac{1}{9216}ig^3m\left(144a_1-220g^2a_2+401g^4a_3\right)$$
$$\eta_{kl}\left(\bar\sigma^l\right)^{\dot\alpha\beta}\left(\eta\sigma\Lambda\Lambda^k\right)^n\theta^4\left(D_\beta\Phi\right)\partial_n\left(D^2\Phi\right)\left(\bar D_{\dot\alpha}\Phi^+\right)$$
$$-\frac{1}{9216}ig^3m\left(144a_1-220g^2a_2+401g^4a_3\right)$$
$$\eta_{kl}\left(\bar\sigma^l\right)^{\dot\alpha\beta}\left(\eta\sigma\Lambda\Lambda^k\right)^n\theta^4\partial_n\left(D_\beta\Phi\right)\left(D^2\Phi\right)\left(\bar D_{\dot\alpha}\Phi^+\right)$$
$$+\frac{1}{2304}g^3m\left(144a_1-220g^2a_2+401g^4a_3\right)\epsilon^{\alpha\beta}\epsilon^{\zeta\iota}\Lambda^k{}_\beta\Lambda^l{}_\iota\theta^4\partial_k\left(D_\alpha\Phi\right)\partial_l\left(D_\zeta\Phi\right)\Phi^+$$

$$+\frac{1}{1152}g^3m\left(180a_1-244g^2a_2+469g^4a_3\right)\epsilon^{\alpha\beta}\Lambda^{kl}\theta^4\left(D_\beta\Phi\right)\partial_l\partial_k\left(D_\alpha\Phi\right)\Phi^+$$
$$+\frac{1}{2304}g^3m\left(288a_1-372g^2a_2+703g^4a_3\right)\left(\eta\sigma\Lambda\Lambda^k\right)^l\theta^4\partial_k\Phi\partial_l\left(D^2\Phi\right)\Phi^+$$
$$+\frac{1}{1152}g^3m\left(288a_1-372g^2a_2+703g^4a_3\right)\epsilon^{\alpha\beta}\left(\eta\sigma\Lambda\Lambda^k\right)^l\theta^4\partial_k\left(D_\beta\Phi\right)\partial_l\left(D_\alpha\Phi\right)\Phi^+$$
$$+\frac{1}{2304}\left(4g^5ma_2-23g^7ma_3\right)\epsilon^{\alpha\beta}\eta_{kl}\left(\eta\sigma\Lambda^l\right)^\zeta\Lambda^k{}_\beta\theta^4\left(D_\alpha\Phi\right)\Box\left(D_\zeta\Phi\right)\Phi^+$$
$$+\frac{1}{576}\left(6g^5ma_2-23g^7ma_3\right)\Lambda^{kl}\eta_{ln}\left(\sigma^{no}\right)^{\alpha\beta}\theta^4\left(D_\alpha\Phi\right)\partial_k\partial_o\left(D_\beta\Phi\right)\Phi^+$$
$$+\frac{1}{9216}g^3m\left(288\Lambda^2a_1-16g^2\left(22\Lambda^2-7\sigma\Lambda\Lambda\right)a_2+3g^4\left(407\Lambda^2-122\sigma\Lambda\Lambda\right)a_3\right)$$
$$\theta^4\Box\Phi\left(D^2\Phi\right)\Phi^+$$
$$+\frac{1}{49152}g^3m\left(48\Lambda^2a_1-8g^2\left(15\Lambda^2+2\sigma\Lambda\Lambda\right)a_2+3g^4\left(127\Lambda^2+18\sigma\Lambda\Lambda\right)a_3\right)$$
$$\theta^4\left(D^2\Phi\right)\left(D^2\Phi\right)\left(\bar{D}^2\Phi^+\right)$$
$$+\frac{1}{4608}g^5m\left(148\Lambda^2a_2+g^2\left(-689\Lambda^2+252\sigma\Lambda\Lambda\right)a_3\right)$$
$$\left(\sigma^{kl}\right)^{\alpha\beta}\theta^4\partial_k\left(D_\alpha\Phi\right)\partial_l\left(D_\beta\Phi\right)\Phi^+$$
$$+\frac{1}{2304}g^3m\left(72\Lambda^2a_1+g^2\left(\left(-51\Lambda^2+30\sigma\Lambda\Lambda\right)a_2+g^2\left(133\Lambda^2-40\sigma\Lambda\Lambda\right)a_3\right)\right)$$

$$
\begin{aligned}
& \theta^4 \Phi \Box \left(D^2\Phi\right) \Phi^+ \\
& + \frac{1}{9216} g^3 m \left(576\Lambda^2 a_1 + g^2 \left(\left(-636\Lambda^2 + 72\sigma\Lambda\Lambda\right) a_2 + g^2 \left(1565\Lambda^2 + 106\sigma\Lambda\Lambda\right) a_3\right)\right) \\
& \eta^{kl} \theta^4 \partial_l \Phi \partial_k \left(D^2\Phi\right) \Phi^+ \\
& + \frac{1}{36864} i g^3 m \left(288\Lambda^2 a_1 + g^2 \left(-4\left(217\Lambda^2 + 26\sigma\Lambda\Lambda\right) a_2 + g^2 \left(2975\Lambda^2 + 118\sigma\Lambda\Lambda\right) a_3\right)\right) \\
& \left(\bar{\sigma}^k\right)^{\dot{\alpha}\beta} \theta^4 \partial_k \left(D_\beta \Phi\right) \left(D^2\Phi\right) \left(\bar{D}_{\dot{\alpha}} \Phi^+\right) \\
& + \frac{1}{9216} g^3 m \left(-288\Lambda^2 a_1 + g^2 \left(-84\left(\Lambda^2 + 2\sigma\Lambda\Lambda\right) a_2 + g^2 \left(721\Lambda^2 + 218\sigma\Lambda\Lambda\right) a_3\right)\right) \\
& \eta^{kl} \epsilon^{\alpha\beta} \theta^4 \partial_k \left(D_\alpha \Phi\right) \partial_l \left(D_\beta \Phi\right) \Phi^+ \\
& + \frac{1}{36864} i g^3 m \left(288\Lambda^2 a_1 + g^2 \left(-44\left(13\Lambda^2 + 2\sigma\Lambda\Lambda\right) a_2 + g^2 \left(1597\Lambda^2 + 530\sigma\Lambda\Lambda\right) a_3\right)\right) \\
& \left(\bar{\sigma}^k\right)^{\dot{\alpha}\beta} \theta^4 \left(D_\beta \Phi\right) \partial_k \left(D^2\Phi\right) \left(\bar{D}_{\dot{\alpha}} \Phi^+\right) \\
& + \frac{1}{9216} g^3 m \left(288\Lambda^2 a_1 + g^2 \left(4\left(41\Lambda^2 + 84\sigma\Lambda\Lambda\right) a_2 - g^2 \left(533\Lambda^2 + 896\sigma\Lambda\Lambda\right) a_3\right)\right) \\
& \epsilon^{\alpha\beta} \theta^4 \left(D_\beta \Phi\right) \Box \left(D_\alpha \Phi\right) \Phi^+,
\end{aligned}
$$

$$
\begin{aligned}
f_{18} = & \frac{1}{4608} g^2 m^2 \left(144 a_1 - 220 g^2 a_2 + 401 g^4 a_3\right) \Lambda^{kl} \theta^4 \Phi \partial_l \partial_k \left(D^2\Phi\right) \\
& + \frac{1}{4608} g^2 m^2 \left(144 a_1 - 220 g^2 a_2 + 401 g^4 a_3\right) \epsilon^{\alpha\beta} \Lambda^{kl} \theta^4 \left(D_\beta \Phi\right) \partial_l \partial_k \left(D_\alpha \Phi\right),
\end{aligned}
$$

$$
\begin{aligned}
f_{19} &= \frac{1}{576}\left(-72g^4 a_1 + 116g^6 a_2 - 235g^8 a_3\right)\epsilon^{\alpha\beta}\left(\eta\sigma\Lambda\Lambda^k\right)^l \theta^4 \left(D_\alpha\Phi\right)\left(D_\beta\Phi\right)\Phi^+\partial_k\partial_l\Phi^+ \\
&+\frac{1}{576}\left(72g^4 a_1 - 116g^6 a_2 + 235g^8 a_3\right)\left(\eta\sigma\Lambda\Lambda^k\right)^l \theta^4\Phi\left(D^2\Phi\right)\Phi^+\partial_k\partial_l\Phi^+, \\
f_{20} &= \frac{1}{1152}\left(-72g^4 a_1 + 116g^6 a_2 - 235g^8 a_3\right)\epsilon^{\alpha\beta}\Lambda^{kl}\theta^4\left(D_\alpha\Phi\right)\left(D_\beta\Phi\right)\Phi^+\partial_k\partial_l\Phi^+ \\
&+\frac{1}{1152}\left(72g^4 a_1 - 116g^6 a_2 + 235g^8 a_3\right)\Lambda^{kl}\theta^4\Phi\left(D^2\Phi\right)\Phi^+\partial_k\partial_l\Phi^+, \\
f_{21} &= \frac{g^6 a_2}{288}\epsilon^{\alpha\beta}\left(\eta\sigma\Lambda^k\right)^\zeta \Lambda^l{}_\beta\theta^4\left(D_\alpha\Phi\right)\partial_k\partial_l\left(D_\zeta\Phi\right)\Phi^+\Phi^+ \\
&-\frac{1}{36}g^6 a_2\epsilon^{\alpha\beta}\left(\eta\sigma\Lambda^k\right)^\zeta \Lambda^l{}_\beta\theta^4\partial_k\left(D_\alpha\Phi\right)\partial_l\left(D_\zeta\Phi\right)\Phi^+\Phi^+ \\
&-\frac{1}{768}ig^6\left(3\Lambda^2 + 2\sigma\Lambda\Lambda\right)\left(-5a_2 + 18g^2 a_3\right) \\
&\qquad\left(\bar{\sigma}^k\right)^{\dot{\alpha}\beta}\theta^4\left(D_\beta\Phi\right)\left(D^2\Phi\right)\Phi^+\partial_k\left(\bar{D}_{\dot{\alpha}}\Phi^+\right) \\
&+\frac{1}{576}\left(-72g^4 a_1 + 92g^6 a_2 - 189g^8 a_3\right) \\
&\qquad\epsilon^{\alpha\beta}\eta_{kl}\left(\sigma\Lambda^{ln}\right)^{o\zeta}\Lambda^k{}_\beta\theta^4\partial_n\left(D_\alpha\Phi\right)\partial_o\left(D_\zeta\Phi\right)\Phi^+\Phi^+ \\
&+\frac{1}{1152}\left(-36g^4 a_1 + 92g^6 a_2 - 167g^8 a_3\right)\Lambda^{kl}\theta^4\partial_l\Phi\partial_k\left(D^2\Phi\right)\Phi^+\Phi^+ \\
&+\frac{1}{2304}\left(76g^6 a_2 - 145g^8 a_3\right)\left(\eta\sigma\Lambda\Lambda^k\right)^l\theta^4\partial_l\Phi\partial_k\left(D^2\Phi\right)\Phi^+\Phi^+
\end{aligned}
$$

$$+\frac{1}{288}\left(-36g^4 a_1 + 57g^6 a_2 - 106g^8 a_3\right)$$
$$\epsilon^{\alpha\beta}\eta_{kl}\left(\sigma\Lambda^{ln}\right)^{o\zeta}\Lambda^k{}_\beta\theta^4\left(D_\alpha\Phi\right)\partial_n\partial_o\left(D_\zeta\Phi\right)\Phi^+\Phi^+$$
$$+\frac{1}{1152}\left(36g^6 a_2 - 61g^8 a_3\right)\left(\eta\sigma\Lambda\Lambda^k\right)^l\theta^4\partial_k\partial_l\Phi\left(D^2\Phi\right)\Phi^+\Phi^+$$
$$+\frac{1}{2304}\left(4g^6 a_2 - 23g^8 a_3\right)\epsilon^{\alpha\beta}\eta_{kl}\left(\eta\sigma\Lambda^l\right)^\zeta\Lambda^k{}_\beta\theta^4\left(D_\alpha\Phi\right)\Box\left(D_\zeta\Phi\right)\Phi^+\Phi^+$$
$$+\frac{1}{576}\left(6g^6 a_2 - 23g^8 a_3\right)\Lambda^{kl}\eta_{ln}\left(\sigma^{no}\right)^{\alpha\beta}\theta^4\left(D_\alpha\Phi\right)\partial_k\partial_o\left(D_\beta\Phi\right)\Phi^+\Phi^+$$
$$+\left(\frac{3g^4 a_1}{32} - \frac{g^6 a_2}{9} + \frac{13g^8 a_3}{64}\right)\epsilon^{\alpha\beta}\Lambda^{kl}\theta^4\left(D_\beta\Phi\right)\partial_l\partial_k\left(D_\alpha\Phi\right)\Phi^+\Phi^+$$
$$+\frac{1}{4608}i\left(-4g^6 a_2 + 23g^8 a_3\right)\eta_{kl}\left(\bar\sigma^l\right)^{\dot\alpha\beta}\left(\eta\sigma\Lambda\Lambda^n\right)^k\theta^4\left(D_\beta\Phi\right)\partial_n\left(D^2\Phi\right)\Phi^+\left(\bar D_{\dot\alpha}\Phi^+\right)$$
$$-\frac{1}{4608}i\left(-4g^6 a_2 + 23g^8 a_3\right)\eta_{kl}\left(\bar\sigma^l\right)^{\dot\alpha\beta}\left(\eta\sigma\Lambda\Lambda^n\right)^k\theta^4\partial_n\left(D_\beta\Phi\right)\left(D^2\Phi\right)\Phi^+\left(\bar D_{\dot\alpha}\Phi^+\right)$$
$$-\frac{1}{4608}i\left(-4g^6 a_2 + 23g^8 a_3\right)\epsilon^{\alpha\beta}\epsilon^{\zeta\iota}\epsilon^{klno}\eta_{np}\eta_{oq}\Lambda^p{}_\beta\Lambda^q{}_\iota\theta^4\partial_k\left(D_\alpha\Phi\right)\partial_l\left(D_\zeta\Phi\right)\Phi^+\Phi^+$$
$$+\frac{1}{1152}\left(28g^6 a_2 + 23g^8 a_3\right)\Lambda^{kl}\eta_{ln}\left(\sigma^{no}\right)^{\alpha\beta}\theta^4\partial_k\left(D_\alpha\Phi\right)\partial_o\left(D_\beta\Phi\right)\Phi^+\Phi^+$$
$$-\frac{1}{2304}i\left(36g^4 a_1 - 52g^6 a_2 + 83g^8 a_3\right)\Lambda^{kl}\eta_{ln}\left(\bar\sigma^n\right)^{\dot\alpha\beta}\theta^4\left(D_\beta\Phi\right)\partial_k\left(D^2\Phi\right)\Phi^+\left(\bar D_{\dot\alpha}\Phi^+\right)$$

$$+\frac{1}{2304}i\left(36g^4a_1-52g^6a_2+83g^8a_3\right)\Lambda^{kl}\eta_{ln}\left(\bar{\sigma}^n\right)^{\dot{\alpha}\beta}\theta^4\partial_k\left(D_\beta\Phi\right)\left(D^2\Phi\right)\Phi^+\left(\bar{D}_{\dot{\alpha}}\Phi^+\right)$$

$$+\frac{1}{1152}\left(72g^4a_1-76g^6a_2+151g^8a_3\right)\left(\eta\sigma\Lambda\Lambda^k\right)^l\theta^4\Phi\partial_k\partial_l\left(D^2\Phi\right)\Phi^+\Phi^+$$

$$+\frac{1}{2304}\left(72g^4a_1-76g^6a_2+151g^8a_3\right)\Lambda^{kl}\theta^4\Phi\partial_l\partial_k\left(D^2\Phi\right)\Phi^+\Phi^+$$

$$+\frac{1}{576}\left(72g^4a_1-76g^6a_2+151g^8a_3\right)\epsilon^{\alpha\beta}\left(\eta\sigma\Lambda\Lambda^k\right)^l\theta^4\left(D_\beta\Phi\right)\partial_k\partial_l\left(D_\alpha\Phi\right)\Phi^+\Phi^+$$

$$+\frac{1}{2304}\left(144g^4a_1-140g^6a_2+233g^8a_3\right)\left(\eta\sigma\Lambda\Lambda^k\right)^l\theta^4\partial_k\Phi\partial_l\left(D^2\Phi\right)\Phi^+\Phi^+$$

$$+\frac{1}{1152}\left(144g^4a_1-140g^6a_2+233g^8a_3\right)\epsilon^{\alpha\beta}\left(\eta\sigma\Lambda\Lambda^k\right)^l\theta^4\partial_k\left(D_\beta\Phi\right)\partial_l\left(D_\alpha\Phi\right)\Phi^+\Phi^+$$

$$+\frac{1}{2304}\left(144g^4a_1-180g^6a_2+317g^8a_3\right)\Lambda^{kl}\theta^4\partial_k\partial_l\Phi\left(D^2\Phi\right)\Phi^+\Phi^+$$

$$+\frac{1}{4608}i\left(144g^4a_1-220g^6a_2+401g^8a_3\right)$$

$$\eta_{kl}\left(\bar{\sigma}^l\right)^{\dot{\alpha}\beta}\left(\eta\sigma\Lambda\Lambda^k\right)^n\theta^4\left(D_\beta\Phi\right)\partial_n\left(D^2\Phi\right)\Phi^+\left(\bar{D}_{\dot{\alpha}}\Phi^+\right)$$

$$-\frac{1}{4608}i\left(144g^4a_1-220g^6a_2+401g^8a_3\right)$$

$$\eta_{kl}\left(\bar{\sigma}^l\right)^{\dot{\alpha}\beta}\left(\eta\sigma\Lambda\Lambda^k\right)^n\theta^4\partial_n\left(D_\beta\Phi\right)\left(D^2\Phi\right)\Phi^+\left(\bar{D}_{\dot{\alpha}}\Phi^+\right)$$

$$+\frac{1}{2304}\left(144g^4a_1-220g^6a_2+401g^8a_3\right)$$

$$\epsilon^{\alpha\beta}\epsilon^{\zeta\iota}\Lambda^{k}{}_{\beta}\Lambda^{l}{}_{\iota}\theta^4\partial_k\left(D_\alpha\Phi\right)\partial_l\left(D_\zeta\Phi\right)\Phi^+\Phi^+$$

$$+\frac{1}{4608}\left(288g^4 a_1 - 588g^6 a_2 + 1069g^8 a_3\right)$$

$$\epsilon^{\alpha\beta}\Lambda^{kl}\theta^4\partial_k\left(D_\alpha\Phi\right)\partial_l\left(D_\beta\Phi\right)\Phi^+\Phi^+$$

$$+\frac{1}{9216}g^6\left(\left(-68\Lambda^2+152\sigma\Lambda\Lambda\right)a_2+g^2\left(521\Lambda^2-542\sigma\Lambda\Lambda\right)a_3\right)$$

$$\eta^{kl}\epsilon^{\alpha\beta}\theta^4\partial_k\left(D_\alpha\Phi\right)\partial_l\left(D_\beta\Phi\right)\Phi^+\Phi^+$$

$$+\frac{1}{9216}g^4\left(144\Lambda^2 a_1-36g^2\left(5\Lambda^2-2\sigma\Lambda\Lambda\right)a_2+g^4\left(673\Lambda^2-418\sigma\Lambda\Lambda\right)a_3\right)$$

$$\theta^4\Box\Phi\left(D^2\Phi\right)\Phi^+\Phi^+$$

$$+\frac{1}{8192}g^4\left(16\Lambda^2 a_1-4g^2\left(5\Lambda^2-2\sigma\Lambda\Lambda\right)a_2+5g^4\left(11\Lambda^2-6\sigma\Lambda\Lambda\right)a_3\right)$$

$$\epsilon^{\dot\alpha\dot\beta}\theta^4\left(D^2\Phi\right)\left(D^2\Phi\right)\left(\bar D_{\dot\alpha}\Phi^+\right)\left(\bar D_{\dot\beta}\Phi^+\right)$$

$$+\frac{1}{24576}g^4\left(48\Lambda^2 a_1-8g^2\left(15\Lambda^2+2\sigma\Lambda\Lambda\right)a_2+3g^4\left(127\Lambda^2+18\sigma\Lambda\Lambda\right)a_3\right)$$

$$\theta^4\left(D^2\Phi\right)\left(D^2\Phi\right)\Phi^+\left(\bar D^2\Phi^+\right)$$

$$+\frac{1}{1152}g^4\left(-36\Lambda^2 a_1-2g^2\left(\Lambda^2+20\sigma\Lambda\Lambda\right)a_2+5g^4\left(5\Lambda^2+19\sigma\Lambda\Lambda\right)a_3\right)$$

$$\epsilon^{\alpha\beta}\theta^4\left(D_\alpha\Phi\right)\left(D_\beta\Phi\right)\Phi^+\Box\Phi^+$$

$$+\frac{1}{9216}g^6\left(4\left(37\Lambda^2+4\sigma\Lambda\Lambda\right)a_2-g^2\left(333\Lambda^2+136\sigma\Lambda\Lambda\right)a_3\right)$$

$$\epsilon^{\alpha\beta}\theta^4\left(D_\beta\Phi\right)\Box\left(D_\alpha\Phi\right)\Phi^+\Phi^+$$

$$+\frac{1}{4608}\left(148g^6\Lambda^2 a_2+g^8\left(-689\Lambda^2+252\sigma\Lambda\Lambda\right)a_3\right)$$

$$\left(\sigma^{kl}\right)^{\alpha\beta}\theta^4\partial_k\left(D_\alpha\Phi\right)\partial_l\left(D_\beta\Phi\right)\Phi^+\Phi^+$$

$$+\frac{1}{18432}i\left(288g^4\Lambda^2 a_1+g^6\left(\left(-508\Lambda^2+136\sigma\Lambda\Lambda\right)a_2+g^2\left(1679\Lambda^2-746\sigma\Lambda\Lambda\right)a_3\right)\right)$$

$$\left(\bar{\sigma}^k\right)^{\dot{\alpha}\beta}\theta^4\partial_k\left(D_\beta\Phi\right)\left(D^2\Phi\right)\Phi^+\left(\bar{D}_{\dot{\alpha}}\Phi^+\right)$$

$$+\frac{1}{18432}i\left(288g^4\Lambda^2 a_1+g^6\left(-4\left(53\Lambda^2-38\sigma\Lambda\Lambda\right)a_2+g^2\left(301\Lambda^2-334\sigma\Lambda\Lambda\right)a_3\right)\right)$$

$$\left(\bar{\sigma}^k\right)^{\dot{\alpha}\beta}\theta^4\left(D_\beta\Phi\right)\partial_k\left(D^2\Phi\right)\Phi^+\left(\bar{D}_{\dot{\alpha}}\Phi^+\right)$$

$$+\frac{1}{9216}\left(288g^4\Lambda^2 a_1+g^6\left(-4\left(73\Lambda^2+2\sigma\Lambda\Lambda\right)a_2+g^2\left(469\Lambda^2+2\sigma\Lambda\Lambda\right)a_3\right)\right)$$

$$\eta^{kl}\theta^4\partial_l\Phi\partial_k\left(D^2\Phi\right)\Phi^+\Phi^+$$

$$+\frac{1}{1152}\left(36g^4\Lambda^2 a_1+g^6\left(\left(-43\Lambda^2+10\sigma\Lambda\Lambda\right)a_2+g^2\left(137\Lambda^2+13\sigma\Lambda\Lambda\right)a_3\right)\right)$$

$$\theta^4\Phi\left(D^2\Phi\right)\Phi^+\Box\Phi^+$$

$$+\frac{1}{2304}\left(36g^4\Lambda^2 a_1-g^6\left(4\left(2\Lambda^2-5\sigma\Lambda\Lambda\right)a_2+g^2\left(4\Lambda^2+53\sigma\Lambda\Lambda\right)a_3\right)\right)$$

$$\theta^4\Phi\Box\left(D^2\Phi\right)\Phi^+\Phi^+,$$

$$
\begin{aligned}
f_{22} &= \frac{1}{9216} g^4 m^2 \left(20\left(\Lambda^2+2\sigma\Lambda\Lambda\right) a_2 + g^2\left(47\Lambda^2-158\sigma\Lambda\Lambda\right) a_3\right)\theta^4 \Phi\Box\left(D^2\Phi\right) \\
&+\frac{1}{9216} g^4 m^2 \left(20\left(\Lambda^2+2\sigma\Lambda\Lambda\right) a_2 + g^2\left(47\Lambda^2-158\sigma\Lambda\Lambda\right) a_3\right)\epsilon^{\alpha\beta}\theta^4\left(D_\beta\Phi\right)\Box\left(D_\alpha\Phi\right), \\
f_{23} &= \frac{1}{768} i g^4 m^3 \left(12\Lambda^2 a_2 - g^2\left(69\Lambda^2+14\sigma\Lambda\Lambda\right) a_3\right)\left(\bar\sigma^k\right)^{\dot\alpha\beta}\theta^4\left(D_\beta\Phi\right)\partial_k\left(\bar D_{\dot\alpha}\Phi^+\right) \\
&+\frac{1}{384} g^4 m^3 \left(-12\Lambda^2 a_2 + g^2\left(69\Lambda^2+14\sigma\Lambda\Lambda\right) a_3\right)\theta^4\Phi\Box\Phi^+ \\
&+\frac{1}{6144} g^4 m^3 \left(-12\Lambda^2 a_2 + g^2\left(69\Lambda^2+14\sigma\Lambda\Lambda\right) a_3\right)\theta^4\left(D^2\Phi\right)\left(\bar D^2\Phi^+\right), \\
f_{24} &= \frac{1}{128} i g^5 m^2 \left(12\Lambda^2 a_2 - g^2\left(69\Lambda^2+14\sigma\Lambda\Lambda\right) a_3\right)\left(\bar\sigma^k\right)^{\dot\alpha\beta}\theta^4\left(D_\beta\Phi\right)\Phi^+\partial_k\left(\bar D_{\dot\alpha}\Phi^+\right) \\
&+\frac{1}{64} g^5 m^2 \left(-12\Lambda^2 a_2 + g^2\left(69\Lambda^2+14\sigma\Lambda\Lambda\right) a_3\right)\theta^4\Phi\Phi^+\Box\Phi^+ \\
&+\frac{1}{1024} g^5 m^2 \left(-12\Lambda^2 a_2 + g^2\left(69\Lambda^2+14\sigma\Lambda\Lambda\right) a_3\right)\theta^4\left(D^2\Phi\right)\Phi^+\left(\bar D^2\Phi^+\right), \\
f_{25} &= \frac{1}{64} i g^6 m \left(12\Lambda^2 a_2 - g^2\left(69\Lambda^2+14\sigma\Lambda\Lambda\right) a_3\right)\left(\bar\sigma^k\right)^{\dot\alpha\beta}\theta^4\left(D_\beta\Phi\right)\Phi^+\Phi^+\partial_k\left(\bar D_{\dot\alpha}\Phi^+\right) \\
&+\frac{1}{32} g^6 m \left(-12\Lambda^2 a_2 + g^2\left(69\Lambda^2+14\sigma\Lambda\Lambda\right) a_3\right)\theta^4\Phi\Phi^+\Phi^+\Box\Phi^+ \\
&+\frac{1}{512} g^6 m \left(-12\Lambda^2 a_2 + g^2\left(69\Lambda^2+14\sigma\Lambda\Lambda\right) a_3\right)\theta^4\left(D^2\Phi\right)\Phi^+\Phi^+\left(\bar D^2\Phi^+\right), \\
f_{26} &= \frac{1}{96} i g^7 \left(12\Lambda^2 a_2 - g^2\left(69\Lambda^2+14\sigma\Lambda\Lambda\right) a_3\right)\left(\bar\sigma^k\right)^{\dot\alpha\beta}\theta^4\left(D_\beta\Phi\right)\Phi^+\Phi^+\Phi^+\partial_k\left(\bar D_{\dot\alpha}\Phi^+\right)
\end{aligned}
$$

$$
\begin{aligned}
&+\frac{1}{768}g^7\left(-12\Lambda^2 a_2+g^2\left(69\Lambda^2+14\sigma\Lambda\Lambda\right)a_3\right)\theta^4\left(D^2\Phi\right)\Phi^+\Phi^+\Phi^+\left(\bar{D}^2\Phi^+\right)\\
&+\left(-\frac{1}{4}g^7\Lambda^2 a_2+\frac{1}{48}g^9\left(69\Lambda^2+14\sigma\Lambda\Lambda\right)a_3\right)\theta^4\Phi\Phi^+\Phi^+\Phi^+\Box\Phi^+,\\
f_{27} =\ & \frac{1}{110592}g^5\left(-72\left(4\Lambda^2-\sigma\Lambda\Lambda\right)a_2+g^2\left(287\Lambda^2-398\sigma\Lambda\Lambda\right)a_3\right)\\
&\qquad\theta^4\Phi\left(D^2\Phi\right)\Box\left(D^2\Phi\right)\\
&+\frac{1}{36864}g^5\left(-72\Lambda^2 a_2+g^2\left(107\Lambda^2-74\sigma\Lambda\Lambda\right)a_3\right)\\
&\qquad\eta^{kl}\theta^4\Phi\partial_k\left(D^2\Phi\right)\partial_l\left(D^2\Phi\right)\\
&-\frac{1}{27648}g^5\left(36\left(\Lambda^2-\sigma\Lambda\Lambda\right)a_2+g^2\left(17\Lambda^2+88\sigma\Lambda\Lambda\right)a_3\right)\\
&\qquad\epsilon^{\alpha\beta}\theta^4\left(D_\beta\Phi\right)\Box\left(D_\alpha\Phi\right)\left(D^2\Phi\right)\\
&+\frac{1}{110592}g^5\left(-72\left(\Lambda^2+2\sigma\Lambda\Lambda\right)a_2+g^2\left(389\Lambda^2+130\sigma\Lambda\Lambda\right)a_3\right)\\
&\qquad\eta^{kl}\epsilon^{\alpha\beta}\theta^4\partial_k\left(D_\alpha\Phi\right)\partial_l\left(D_\beta\Phi\right)\left(D^2\Phi\right),\\
f_{28} =\ & \frac{1}{2304}\left(9g^5 a_2-13g^7 a_3\right)\left(\eta\sigma\Lambda\Lambda^k\right)^l\theta^4\Phi\partial_k\left(D^2\Phi\right)\partial_l\left(D^2\Phi\right)\\
&-\frac{3}{256}\left(-2g^5 a_2+3g^7 a_3\right)\epsilon^{\alpha\beta}\eta_{kl}\left(\sigma\Lambda^{ln}\right)^{o\zeta}\Lambda^k{}_\beta\theta^4\partial_n\left(D_\alpha\Phi\right)\partial_o\left(D_\zeta\Phi\right)\left(D^2\Phi\right)\\
&+\frac{1}{6912}5\left(-18g^5 a_2+23g^7 a_3\right)\epsilon^{\alpha\beta}\left(\eta\sigma\Lambda\Lambda^k\right)^l\theta^4\left(D_\beta\Phi\right)\partial_k\partial_l\left(D_\alpha\Phi\right)\left(D^2\Phi\right)
\end{aligned}
$$

$$
\begin{aligned}
& +\frac{1}{13824}(-36g^5 a_2 + 37g^7 a_3)\left(\eta\sigma\Lambda\Lambda^k\right)^l \theta^4\Phi\left(D^2\Phi\right)\partial_k\partial_l\left(D^2\Phi\right) \\
& +\frac{1}{13824}(-396g^5 a_2 + 551g^7 a_3)\epsilon^{\alpha\beta}\left(\eta\sigma\Lambda\Lambda^k\right)^l \theta^4\partial_k\left(D_\beta\Phi\right)\partial_l\left(D_\alpha\Phi\right)\left(D^2\Phi\right), \\
f_{29} \quad = \quad & \frac{1}{13824}5\,(-18g^5 a_2 + 23g^7 a_3)\epsilon^{\alpha\beta}\Lambda^{kl}\theta^4\left(D_\beta\Phi\right)\partial_l\partial_k\left(D_\alpha\Phi\right)\left(D^2\Phi\right) \\
& +\frac{1}{3072}(-192g a_0 - 36g^5 a_2 + 55g^7 a_3)\epsilon^{\alpha\beta}\epsilon^{\zeta\iota}\Lambda^k{}_\beta\Lambda^l{}_\iota\theta^4\partial_k\left(D_\alpha\Phi\right)\partial_l\left(D_\zeta\Phi\right)\left(D^2\Phi\right) \\
& +\frac{1}{4608}(-144g a_0 - 45g^5 a_2 + 68g^7 a_3)\Lambda^{kl}\theta^4\Phi\partial_k\left(D^2\Phi\right)\partial_l\left(D^2\Phi\right) \\
& +\frac{1}{27648}(-864g a_0 - 360g^5 a_2 + 523g^7 a_3)\Lambda^{kl}\theta^4\Phi\left(D^2\Phi\right)\partial_l\partial_k\left(D^2\Phi\right) \\
& +\frac{1}{55296}(-3456g a_0 - 504g^5 a_2 + 851g^7 a_3)\epsilon^{\alpha\beta}\Lambda^{kl}\theta^4\partial_k\left(D_\alpha\Phi\right)\partial_l\left(D_\beta\Phi\right)\left(D^2\Phi\right), \\
f_{30} \quad = \quad & \frac{1}{2048}g^3 m^5\left(3\Lambda^2 + 2\sigma\Lambda\Lambda\right)\left(-10a_2 + 71g^2 a_3\right)\theta^4\left(D^2\Phi\right), \\
f_{31} \quad = \quad & -\frac{g\,a_0}{3}\left(\sigma\Lambda\Lambda^{kl}\right)^{no}\theta^4\Phi^+\partial_k\partial_n\Phi^+\partial_l\partial_o\Phi^+, \\
f_{32} \quad = \quad & -\frac{37g^7\Lambda^2 a_3}{6144}\left(\sigma^{kl}\right)^{\alpha\beta}\theta^4\partial_k\left(D_\alpha\Phi\right)\partial_l\left(D_\beta\Phi\right)\left(D^2\Phi\right), \\
f_{33} \quad = \quad & \frac{7g^7 a_3}{54}\eta^{kl}\left(\eta\sigma\Lambda\Lambda^n\right)^o\theta^4\Phi^+\partial_l\partial_n\Phi^+\partial_k\partial_o\Phi^+, \\
f_{34} \quad = \quad & \frac{1}{192}g^8 m a_3\left(\eta\sigma\Lambda\Lambda^k\right)^l\theta^4\Phi^+\Phi^+\partial_k\Phi^+\partial_l\Phi^+,
\end{aligned}
$$

$$
\begin{aligned}
f_{35} &= \frac{1}{576} g^8 m a_3 \left(\eta\sigma\Lambda\Lambda^k\right)^l \theta^4 \Phi^+ \Phi^+ \Phi^+ \partial_k \partial_l \Phi^+, \\
f_{36} &= \frac{g^7 a_3}{1536} \Lambda^{kl} \eta_{ln} \left(\sigma^{no}\right)^{\alpha\beta} \theta^4 \partial_k \left(D_\alpha \Phi\right) \partial_o \left(D_\beta \Phi\right) \left(D^2 \Phi\right), \\
f_{37} &= -\frac{i g^7 a_3}{6144} \epsilon^{\alpha\beta} \epsilon^{\zeta\iota} \epsilon^{klno} \eta_{np} \eta_{oq} \Lambda^p{}_\beta \Lambda^q{}_\iota \theta^4 \partial_k \left(D_\alpha \Phi\right) \partial_l \left(D_\zeta \Phi\right) \left(D^2 \Phi\right), \\
f_{38} &= \frac{1}{2048} g^4 m^3 \left(3\Lambda^2 + 2\sigma\Lambda\Lambda\right) \left(-2 a_2 + 15 g^2 a_3\right) \theta^4 \left(D^2 \Phi\right) \left(D^2 \Phi\right), \\
f_{39} &= \frac{1}{128} g^4 m^3 \left(3\Lambda^2 + 2\sigma\Lambda\Lambda\right) \left(-2 a_2 + 15 g^2 a_3\right) \theta^4 \Phi^+ \Box \Phi^+, \\
f_{40} &= \frac{1}{1024} g^5 m^2 \left(3\Lambda^2 + 2\sigma\Lambda\Lambda\right) \left(-2 a_2 + 15 g^2 a_3\right) \theta^4 \left(D^2 \Phi\right) \left(D^2 \Phi\right) \Phi^+, \\
f_{41} &= \frac{1}{64} g^5 m^2 \left(3\Lambda^2 + 2\sigma\Lambda\Lambda\right) \left(-2 a_2 + 15 g^2 a_3\right) \theta^4 \Phi^+ \Phi^+ \Box \Phi^+, \\
f_{42} &= \frac{1}{27648} 5 g^4 m \left(-18 a_2 + 23 g^2 a_3\right) \left(\eta\sigma\Lambda\Lambda^k\right)^l \theta^4 \left(D^2 \Phi\right) \partial_k \partial_l \left(D^2 \Phi\right), \\
f_{43} &= \frac{1}{1728} 5 g^4 m \left(-18 a_2 + 23 g^2 a_3\right) \left(\eta\sigma\Lambda\Lambda^k\right)^l \theta^4 \Phi^+ \Box \partial_k \partial_l \Phi^+, \\
f_{44} &= \frac{1}{55296} 5 g^4 m \left(-18 a_2 + 23 g^2 a_3\right) \Lambda^{kl} \theta^4 \left(D^2 \Phi\right) \partial_l \partial_k \left(D^2 \Phi\right), \\
f_{45} &= \frac{1}{3456} 5 g^4 m \left(-18 a_2 + 23 g^2 a_3\right) \Lambda^{kl} \theta^4 \Phi^+ \Box \partial_k \partial_l \Phi^+,
\end{aligned}
$$

$$f_{46} = \frac{1}{1728} g^5 \Lambda^2 \left(9a_2 + 32g^2 a_3\right) \eta^{kl} \eta^{no} \theta^4 \Phi^+ \partial_k \partial_n \Phi^+ \partial_l \partial_o \Phi^+,$$

$$f_{47} = \frac{1}{96} g^6 m \left(-21a_2 + 47g^2 a_3\right) \Lambda^{kl} \theta^4 \Phi^+ \Phi^+ \partial_k \Phi^+ \partial_l \Phi^+,$$

$$f_{48} = \frac{1}{288} g^6 m \left(-21a_2 + 47g^2 a_3\right) \Lambda^{kl} \theta^4 \Phi^+ \Phi^+ \Phi^+ \partial_k \partial_l \Phi^+,$$

$$f_{49} = \frac{1}{1024} 3g^4 m^4 \left(3\Lambda^2 + 2\sigma\Lambda\Lambda\right) \left(-10a_2 + 71g^2 a_3\right) \theta^4 \left(D^2\Phi\right) \Phi^+,$$

$$f_{50} = \frac{3}{512} g^5 m^3 \left(3\Lambda^2 + 2\sigma\Lambda\Lambda\right) \left(-10a_2 + 71g^2 a_3\right) \theta^4 \left(D^2\Phi\right) \Phi^+ \Phi^+,$$

$$f_{51} = \frac{1}{256} g^6 m^2 \left(3\Lambda^2 + 2\sigma\Lambda\Lambda\right) \left(-10a_2 + 71g^2 a_3\right) \theta^4 \left(D^2\Phi\right) \Phi^+ \Phi^+ \Phi^+,$$

$$f_{52} = \frac{1}{864} g^5 \left(-54a_2 + 143g^2 a_3\right) \left(\eta\sigma\Lambda\Lambda^k\right)^l \theta^4 \Phi^+ \Box\Phi^+ \partial_k \partial_l \Phi^+,$$

$$f_{53} = \frac{1}{1152} g^3 m \left(72a_1 - 76g^2 a_2 + 151g^4 a_3\right) \left(\eta\sigma\Lambda\Lambda^k\right)^l \theta^4 \left(D^2\Phi\right) \partial_k \Phi^+ \partial_l \Phi^+,$$

$$f_{54} = \frac{1}{2304} g^3 m \left(72a_1 - 76g^2 a_2 + 151g^4 a_3\right) \Lambda^{kl} \theta^4 \left(D^2\Phi\right) \partial_k \Phi^+ \partial_l \Phi^+,$$

$$f_{55} = \frac{1}{1152} g^2 m^2 \left(72a_1 - 96g^2 a_2 + 193g^4 a_3\right) \left(\eta\sigma\Lambda\Lambda^k\right)^l \theta^4 \left(D^2\Phi\right) \partial_k \partial_l \Phi^+,$$

$$f_{56} = \frac{1}{2304} g^2 m^2 \left(72a_1 - 96g^2 a_2 + 193g^4 a_3\right) \Lambda^{kl} \theta^4 \left(D^2\Phi\right) \partial_k \partial_l \Phi^+,$$

$$f_{57} = \frac{1}{576} g^3 m \left(72a_1 - 96g^2 a_2 + 193g^4 a_3\right) \left(\eta\sigma\Lambda\Lambda^k\right)^l \theta^4 \left(D^2\Phi\right) \Phi^+ \partial_k \partial_l \Phi^+,$$

$$f_{58} = \frac{1}{1152} g^3 m \left(72 a_1 - 96 g^2 a_2 + 193 g^4 a_3\right) \Lambda^{kl} \theta^4 \left(D^2\Phi\right) \Phi^+ \partial_k \partial_l \Phi^+,$$

$$f_{59} = \frac{1}{192} \left(-2g^2 a_1 + g^6 a_3\right) \left(\eta\sigma\Lambda\Lambda^k\right)^l \theta^4 \left(D^2\Phi\right) \Box \partial_k \partial_l \Phi^+,$$

$$f_{60} = \frac{1}{384} \left(-2g^2 a_1 + g^6 a_3\right) \Lambda^{kl} \theta^4 \left(D^2\Phi\right) \Box \partial_k \partial_l \Phi^+,$$

$$f_{61} = \frac{1}{432} \left(-9g^5 a_2 - 35 g^7 a_3\right) \left(\eta\sigma\Lambda\Lambda^k\right)^l \theta^4 \Phi^+ \Phi^+ \Box \partial_k \partial_l \Phi^+,$$

$$f_{62} = \left(\frac{g a_0}{6} + \frac{g^5 a_2}{96} - \frac{2 g^7 a_3}{27}\right) \eta^{kl} \Lambda^{no} \theta^4 \Phi^+ \partial_k \partial_n \Phi^+ \partial_l \partial_o \Phi^+,$$

$$f_{63} = \left(-\frac{7}{384} g^5 a_2 + \frac{55 g^7 a_3}{864}\right) \Lambda^{kl} \theta^4 \Phi^+ \Phi^+ \Box \partial_k \partial_l \Phi^+,$$

$$f_{64} = \frac{1}{1728} \left(-288 g a_0 - 45 g^5 a_2 + 23 g^7 a_3\right) \Lambda^{kl} \theta^4 \Phi^+ \Box \Phi^+ \partial_k \partial_l \Phi^+,$$

$$f_{65} = \frac{1}{3456} g^5 \left(-45\Lambda^2 a_2 + g^2 \left(29\Lambda^2 - 60\sigma\Lambda\Lambda\right) a_3\right) \theta^4 \Phi^+ \Box \Phi^+ \Box \Phi^+,$$

$$f_{66} = \frac{1}{384} g^6 m \left(2\left(53\Lambda^2 - 12\sigma\Lambda\Lambda\right) a_2 + g^2 \left(68\Lambda^2 - 37\sigma\Lambda\Lambda\right) a_3\right) \eta^{kl} \theta^4 \Phi^+ \Phi^+ \partial_k \Phi^+ \partial_l \Phi^+,$$

$$f_{67} = -\frac{1}{1536} g^2 \left(4\Lambda^2 a_1 + g^4 \left(\Lambda^2 + 2\sigma\Lambda\Lambda\right) a_3\right) \theta^4 \left(D^2\Phi\right) \Box\Box \Phi^+,$$

$$f_{68} = -\frac{1}{6912} g^5 \left(9\left(\Lambda^2 - 4\sigma\Lambda\Lambda\right) a_2 + 2g^2 \left(55\Lambda^2 + 14\sigma\Lambda\Lambda\right) a_3\right) \theta^4 \Phi^+ \Phi^+ \Box\Box \Phi^+,$$

$$
\begin{aligned}
f_{69} &= \frac{1}{1152} g^6 m \left(\left(34\Lambda^2 - 72\sigma\Lambda\Lambda\right) a_2 + 19 g^2 \left(32\Lambda^2 + 17\sigma\Lambda\Lambda\right) a_3\right) \theta^4 \Phi^+ \Phi^+ \Phi^+ \Box \Phi^+, \\
f_{70} &= \frac{1}{2304} g^3 m \left(4\left(9\Lambda^2 a_1 + g^2\left(-2\Lambda^2 + 5\sigma\Lambda\Lambda\right) a_2\right) - g^4\left(4\Lambda^2 + 53\sigma\Lambda\Lambda\right) a_3\right) \\
&\qquad \eta^{kl} \theta^4 \left(D^2\Phi\right) \partial_k \Phi^+ \partial_l \Phi^+, \\
f_{71} &= -\frac{1}{110592} g^4 m \left(36\left(\Lambda^2 - \sigma\Lambda\Lambda\right) a_2 + g^2\left(17\Lambda^2 + 88\sigma\Lambda\Lambda\right) a_3\right) \theta^4 \left(D^2\Phi\right) \Box \left(D^2\Phi\right), \\
f_{72} &= -\frac{1}{6912} g^4 m \left(36\left(\Lambda^2 - \sigma\Lambda\Lambda\right) a_2 + g^2\left(17\Lambda^2 + 88\sigma\Lambda\Lambda\right) a_3\right) \theta^4 \Phi^+ \Box\Box \Phi^+, \\
f_{73} &= \frac{1}{4608} g^2 m^2 \left(72\Lambda^2 a_1 + g^2\left(\left(-51\Lambda^2 + 30\sigma\Lambda\Lambda\right) a_2 + g^2\left(133\Lambda^2 - 40\sigma\Lambda\Lambda\right) a_3\right)\right) \\
&\qquad \theta^4 \left(D^2\Phi\right) \Box \Phi^+, \\
f_{74} &= \frac{1}{2304} g^3 m \left(72\Lambda^2 a_1 + g^2\left(\left(-51\Lambda^2 + 30\sigma\Lambda\Lambda\right) a_2 + g^2\left(133\Lambda^2 - 40\sigma\Lambda\Lambda\right) a_3\right)\right) \\
&\qquad \theta^4 \left(D^2\Phi\right) \Phi^+ \Box \Phi^+.
\end{aligned}
$$

Basis of Supersymmetry Invariant Subset

Based on the analysis made to the 74 supersymmetry invariant subsets, we try to construct more general 1/2 supersymmetry invariant subsets in order to deduce the one-loop renormalizable Wess-Zumino action on the BFNC superspace.

$$f_i = \sum_{j=1}^{n_i} C_{ij} L_j \quad \longrightarrow \quad A_i \equiv \sum_{j=1}^{n_i} \left(x_{i,j} + y_{i,j}\Lambda^2 + z_{i,j}\sigma\Lambda\Lambda \right) L_j \quad \longrightarrow \quad A'_i, \quad (i = 1, 2, \cdots, 74)$$

$$\delta A'_i = \sum_{k=1}^{n'_i} G_{i,k}(x, y, z) L'_k, \quad \left(G_{i,k}(x, y, z) \sim x_{i,j}, y_{i,j}, z_{i,j} \right)$$

$$\delta A'_i = 0 \quad \longrightarrow \quad G_{i,k}(x, y, z) = 0, \quad (L'_k \text{ independent to each other})$$

$$A'_i \quad \longrightarrow \quad B_i, \quad (\text{eliminate the dependent parameters})$$

We list the 74 bases B_i's below, each of them is invariant under the 1/2 supersymmetry transformation.

$$
\begin{aligned}
B_1 &= \left(-\Lambda^2 y_{1,2} - \sigma\Lambda\Lambda z_{1,2}\right) \epsilon^{\alpha\beta}\theta^4 \left(D_\alpha\Phi\right)\left(D_\beta\Phi\right) \\
&\quad + \left(\Lambda^2 y_{1,2} + \sigma\Lambda\Lambda z_{1,2}\right) \theta^4\Phi\left(D^2\Phi\right), \\
B_2 &= \left(-2\Lambda^2 y_{2,2} - 2\sigma\Lambda\Lambda z_{2,2}\right) \epsilon^{\alpha\beta}\theta^4\Phi\left(D_\alpha\Phi\right)\left(D_\beta\Phi\right) \\
&\quad + \left(\Lambda^2 y_{2,2} + \sigma\Lambda\Lambda z_{2,2}\right) \theta^4\Phi\Phi\left(D^2\Phi\right), \\
B_3 &= \left(-\Lambda^2 y_{3,2} - \sigma\Lambda\Lambda z_{3,2}\right) \epsilon^{\alpha\beta}\theta^4 \left(D_\alpha\Phi\right)\left(D_\beta\Phi\right)\Phi^+ \\
&\quad + \left(\Lambda^2 y_{3,2} + \sigma\Lambda\Lambda z_{3,2}\right) \theta^4\Phi\left(D^2\Phi\right)\Phi^+, \\
B_4 &= \left(-2\Lambda^2 y_{4,2} - 2\sigma\Lambda\Lambda z_{4,2}\right) \epsilon^{\alpha\beta}\theta^4\Phi\left(D_\alpha\Phi\right)\left(D_\beta\Phi\right)\Phi^+ \\
&\quad + \left(\Lambda^2 y_{4,2} + \sigma\Lambda\Lambda z_{4,2}\right) \theta^4\Phi\Phi\left(D^2\Phi\right)\Phi^+, \\
B_5 &= \left(-\Lambda^2 y_{5,2} - \sigma\Lambda\Lambda z_{5,2}\right) \epsilon^{\alpha\beta}\theta^4 \left(D_\alpha\Phi\right)\left(D_\beta\Phi\right)\Phi^+\Phi^+ \\
&\quad + \left(\Lambda^2 y_{5,2} + \sigma\Lambda\Lambda z_{5,2}\right) \theta^4\Phi\left(D^2\Phi\right)\Phi^+\Phi^+, \\
B_6 &= \left(-2\Lambda^2 y_{6,2} - 2\sigma\Lambda\Lambda z_{6,2}\right) \epsilon^{\alpha\beta}\theta^4\Phi\left(D_\alpha\Phi\right)\left(D_\beta\Phi\right)\Phi^+\Phi^+ \\
&\quad + \left(\Lambda^2 y_{6,2} + \sigma\Lambda\Lambda z_{6,2}\right) \theta^4\Phi\Phi\left(D^2\Phi\right)\Phi^+\Phi^+, \\
B_7 &= \left(-\Lambda^2 y_{7,2} - \sigma\Lambda\Lambda z_{7,2}\right) \epsilon^{\alpha\beta}\theta^4 \left(D_\alpha\Phi\right)\left(D_\beta\Phi\right)\Phi^+\Phi^+\Phi^+ \\
&\quad + \left(\Lambda^2 y_{7,2} + \sigma\Lambda\Lambda z_{7,2}\right) \theta^4\Phi\left(D^2\Phi\right)\Phi^+\Phi^+\Phi^+, \\
B_8 &= \left(-2\Lambda^2 y_{8,2} - 2\sigma\Lambda\Lambda z_{8,2}\right) \epsilon^{\alpha\beta}\theta^4\Phi\left(D_\alpha\Phi\right)\left(D_\beta\Phi\right)\Phi^+\Phi^+\Phi^+
\end{aligned}
$$

$$
\begin{aligned}
& + \left(\Lambda^2 y_{8,2} + \sigma\Lambda\Lambda z_{8,2}\right) \theta^4 \Phi\Phi \left(D^2\Phi\right) \Phi^+\Phi^+\Phi^+, \\
B_9 \quad = \quad & \left(-\Lambda^2 y_{9,2} - \sigma\Lambda\Lambda z_{9,2}\right) \epsilon^{\alpha\beta}\theta^4 \left(D_\alpha\Phi\right) \left(D_\beta\Phi\right) \left(D^2\Phi\right) \\
& + \left(\Lambda^2 y_{9,2} + \sigma\Lambda\Lambda z_{9,2}\right) \theta^4 \Phi \left(D^2\Phi\right) \left(D^2\Phi\right), \\
B_{10} \quad = \quad & \left(-2\Lambda^2 y_{10,2} - 2\sigma\Lambda\Lambda z_{10,2}\right) \epsilon^{\alpha\beta}\theta^4 \Phi \left(D_\alpha\Phi\right) \left(D_\beta\Phi\right) \left(D^2\Phi\right) \\
& + \left(\Lambda^2 y_{10,2} + \sigma\Lambda\Lambda z_{10,2}\right) \theta^4 \Phi\Phi \left(D^2\Phi\right) \left(D^2\Phi\right), \\
B_{11} \quad = \quad & \left(-\Lambda^2 y_{11,2} - \sigma\Lambda\Lambda z_{11,2}\right) \epsilon^{\alpha\beta}\theta^4 \left(D_\alpha\Phi\right) \left(D_\beta\Phi\right) \left(D^2\Phi\right) \Phi^+ \\
& + \left(\Lambda^2 y_{11,2} + \sigma\Lambda\Lambda z_{11,2}\right) \theta^4 \Phi \left(D^2\Phi\right) \left(D^2\Phi\right) \Phi^+, \\
B_{12} \quad = \quad & \left(-2\Lambda^2 y_{12,2} - 2\sigma\Lambda\Lambda z_{12,2}\right) \epsilon^{\alpha\beta}\theta^4 \Phi \left(D_\alpha\Phi\right) \left(D_\beta\Phi\right) \left(D^2\Phi\right) \Phi^+ \\
& + \left(\Lambda^2 y_{12,2} + \sigma\Lambda\Lambda z_{12,2}\right) \theta^4 \Phi\Phi \left(D^2\Phi\right) \left(D^2\Phi\right) \Phi^+, \\
B_{13} \quad = \quad & \left(-8i\Lambda^2 y_{13,3} - 8i\sigma\Lambda\Lambda z_{13,3}\right) \left(\bar{\sigma}^k\right)^{\dot{\alpha}\beta} \theta^4 \left(D_\beta\Phi\right) \partial_k\Phi^+ \left(\bar{D}_{\dot{\alpha}}\Phi^+\right) \\
& + \left(16\Lambda^2 y_{13,3} + 16\sigma\Lambda\Lambda z_{13,3}\right) \eta^{kl}\theta^4 \Phi\partial_k\Phi^+\partial_l\Phi^+ \\
& + \left(\Lambda^2 y_{13,3} + \sigma\Lambda\Lambda z_{13,3}\right) \epsilon^{\dot{\alpha}\dot{\beta}}\theta^4 \left(D^2\Phi\right) \left(\bar{D}_{\dot{\alpha}}\Phi^+\right) \left(\bar{D}_{\dot{\beta}}\Phi^+\right), \\
B_{14} \quad = \quad & \left(-8i\Lambda^2 y_{14,3} - 8i\sigma\Lambda\Lambda z_{14,3}\right) \left(\bar{\sigma}^k\right)^{\dot{\alpha}\beta} \theta^4 \left(D_\beta\Phi\right) \Phi^+\partial_k\Phi^+ \left(\bar{D}_{\dot{\alpha}}\Phi^+\right) \\
& + \left(16\Lambda^2 y_{14,3} + 16\sigma\Lambda\Lambda z_{14,3}\right) \eta^{kl}\theta^4 \Phi\Phi^+\partial_k\Phi^+\partial_l\Phi^+ \\
& + \left(\Lambda^2 y_{14,3} + \sigma\Lambda\Lambda z_{14,3}\right) \epsilon^{\dot{\alpha}\dot{\beta}}\theta^4 \left(D^2\Phi\right) \Phi^+ \left(\bar{D}_{\dot{\alpha}}\Phi^+\right) \left(\bar{D}_{\dot{\beta}}\Phi^+\right),
\end{aligned}
$$

$$
\begin{aligned}
B_{15} &= \left(-8i\Lambda^2 y_{15,3} - 8i\sigma\Lambda\Lambda z_{15,3}\right)\left(\bar{\sigma}^k\right)^{\dot{\alpha}\beta}\theta^4\left(D_\beta\Phi\right)\Phi^+\Phi^+\partial_k\Phi^+\left(\bar{D}_{\dot{\alpha}}\Phi^+\right) \\
&\quad + \left(16\Lambda^2 y_{15,3} + 16\sigma\Lambda\Lambda z_{15,3}\right)\eta^{kl}\theta^4\Phi\Phi^+\Phi^+\partial_k\Phi^+\partial_l\Phi^+ \\
&\quad + \left(\Lambda^2 y_{15,3} + \sigma\Lambda\Lambda z_{15,3}\right)\epsilon^{\dot{\alpha}\dot{\beta}}\theta^4\left(D^2\Phi\right)\Phi^+\Phi^+\left(\bar{D}_{\dot{\alpha}}\Phi^+\right)\left(\bar{D}_{\dot{\beta}}\Phi^+\right), \\
B_{16} &= x_{16,2}\left(\eta\sigma\Lambda\Lambda^k\right)^l\theta^4\Phi\partial_k\partial_l\left(D^2\Phi\right) \\
&\quad + x_{16,2}\epsilon^{\alpha\beta}\left(\eta\sigma\Lambda\Lambda^k\right)^l\theta^4\left(D_\beta\Phi\right)\partial_k\partial_l\left(D_\alpha\Phi\right), \\
B_{17} &= \left(4x_{17,16} + x_{17,21} - 2x_{17,22} + x_{17,26} + 4z_{17,30} + 8iz_{17,34} - 2z_{17,35}\right) \\
&\qquad \epsilon^{\alpha\beta}\left(\eta\sigma\Lambda^k\right)^\zeta\Lambda^l{}_\beta\theta^4\left(D_\alpha\Phi\right)\partial_k\partial_l\left(D_\zeta\Phi\right)\Phi^+ \\
&\quad + \left(x_{17,14} + 2x_{17,21} - 8z_{17,30} - 16iz_{17,34} + 4z_{17,35}\right) \\
&\qquad \epsilon^{\alpha\beta}\left(\eta\sigma\Lambda^k\right)^\zeta\Lambda^l{}_\beta\theta^4\partial_k\left(D_\alpha\Phi\right)\partial_l\left(D_\zeta\Phi\right)\Phi^+ \\
&\quad + \left(iz_{17,30} - 2z_{17,34} - \frac{1}{2}iz_{17,35}\right) \\
&\qquad \eta_{kl}\left(\bar{\sigma}^l\right)^{\dot{\alpha}\beta}\left(\eta\sigma\Lambda\Lambda^n\right)^k\theta^4\left(D_\beta\Phi\right)\partial_n\left(D^2\Phi\right)\left(\bar{D}_{\dot{\alpha}}\Phi^+\right) \\
&\quad + \left(-iz_{17,30} + 2z_{17,34} + \frac{1}{2}iz_{17,35}\right) \\
&\qquad \eta_{kl}\left(\bar{\sigma}^l\right)^{\dot{\alpha}\beta}\left(\eta\sigma\Lambda\Lambda^n\right)^k\theta^4\partial_n\left(D_\beta\Phi\right)\left(D^2\Phi\right)\left(\bar{D}_{\dot{\alpha}}\Phi^+\right)
\end{aligned}
$$

$$+\left(-2iz_{17,30}+4z_{17,34}+iz_{17,35}\right)$$
$$\epsilon^{\alpha\beta}\epsilon^{\zeta\iota}\epsilon^{klno}\eta_{np}\eta_{oq}\Lambda^{p}{}_{\beta}\Lambda^{q}{}_{\iota}\theta^4\partial_k\left(D_\alpha\Phi\right)\partial_l\left(D_\zeta\Phi\right)\Phi^+$$
$$+\left(-x_{17,14}+4x_{17,16}-x_{17,21}-2x_{17,22}+4z_{17,30}+8iz_{17,34}-2z_{17,35}\right)$$
$$\Lambda^{kl}\eta_{ln}\left(\sigma^{no}\right)^{\alpha\beta}\theta^4\partial_k\left(D_\alpha\Phi\right)\partial_o\left(D_\beta\Phi\right)\Phi^+$$
$$+\left(-x_{17,8}+\frac{x_{17,21}}{2}\right)\epsilon^{\alpha\beta}\Lambda^{kl}\theta^4\partial_k\left(D_\alpha\Phi\right)\partial_l\left(D_\beta\Phi\right)\Phi^+$$
$$+x_{17,8}\Lambda^{kl}\theta^4\partial_l\Phi\partial_k\left(D^2\Phi\right)\Phi^+$$
$$+\left(-x_{17,16}+x_{17,22}\right)\Lambda^{kl}\theta^4\partial_k\partial_l\Phi\left(D^2\Phi\right)\Phi^+$$
$$+\left(\frac{1}{2}ix_{17,16}-\frac{1}{4}ix_{17,22}\right)\Lambda^{kl}\eta_{ln}\left(\bar\sigma^{n}\right)^{\dot\alpha\beta}\theta^4\left(D_\beta\Phi\right)\partial_k\left(D^2\Phi\right)\left(\bar D_{\dot\alpha}\Phi^+\right)$$
$$+\left(-\frac{1}{2}ix_{17,16}+\frac{1}{4}ix_{17,22}\right)\Lambda^{kl}\eta_{ln}\left(\bar\sigma^{n}\right)^{\dot\alpha\beta}\theta^4\partial_k\left(D_\beta\Phi\right)\left(D^2\Phi\right)\left(\bar D_{\dot\alpha}\Phi^+\right)$$
$$+\left(\frac{x_{17,17}}{2}-x_{17,21}-4z_{17,30}-8iz_{17,34}+2z_{17,35}\right)$$
$$\left(\eta\sigma\Lambda\Lambda^k\right)^l\theta^4\partial_k\partial_l\Phi\left(D^2\Phi\right)\Phi^+$$
$$+\left(4x_{17,16}-x_{17,21}-2x_{17,22}+x_{17,26}-4z_{17,30}-8iz_{17,34}+2z_{17,35}\right)$$
$$\epsilon^{\alpha\beta}\eta_{kl}\left(\sigma\Lambda^{ln}\right)^{o\zeta}\Lambda^{k}{}_{\beta}\theta^4\left(D_\alpha\Phi\right)\partial_n\partial_o\left(D_\zeta\Phi\right)\Phi^+$$
$$+x_{17,14}\epsilon^{\alpha\beta}\eta_{kl}\left(\sigma\Lambda^{ln}\right)^{o\zeta}\Lambda^{k}{}_{\beta}\theta^4\partial_n\left(D_\alpha\Phi\right)\partial_o\left(D_\zeta\Phi\right)\Phi^+$$

$$+\frac{1}{2}x_{17,17}\left(\eta\sigma\Lambda\Lambda^{k}\right)^{l}\theta^{4}\Phi\partial_{k}\partial_{l}\left(D^{2}\Phi\right)\Phi^{+}$$

$$+x_{17,16}\Lambda^{kl}\theta^{4}\Phi\partial_{l}\partial_{k}\left(D^{2}\Phi\right)\Phi^{+}$$

$$+x_{17,17}\epsilon^{\alpha\beta}\left(\eta\sigma\Lambda\Lambda^{k}\right)^{l}\theta^{4}\left(D_{\beta}\Phi\right)\partial_{k}\partial_{l}\left(D_{\alpha}\Phi\right)\Phi^{+}$$

$$+\left(-x_{17,21}+\frac{x_{17,24}}{2}+4z_{17,30}+8iz_{17,34}-2z_{17,35}\right)\left(\eta\sigma\Lambda\Lambda^{k}\right)^{l}\theta^{4}\partial_{l}\Phi\partial_{k}\left(D^{2}\Phi\right)\Phi^{+}$$

$$+\frac{1}{4}\left(ix_{17,21}\right)\eta_{kl}\left(\bar{\sigma}^{l}\right)^{\dot{\alpha}\beta}\left(\eta\sigma\Lambda\Lambda^{k}\right)^{n}\theta^{4}\left(D_{\beta}\Phi\right)\partial_{n}\left(D^{2}\Phi\right)\left(\bar{D}_{\dot{\alpha}}\Phi^{+}\right)$$

$$+\frac{1}{4}\left(-ix_{17,21}\right)\eta_{kl}\left(\bar{\sigma}^{l}\right)^{\dot{\alpha}\beta}\left(\eta\sigma\Lambda\Lambda^{k}\right)^{n}\theta^{4}\partial_{n}\left(D_{\beta}\Phi\right)\left(D^{2}\Phi\right)\left(\bar{D}_{\dot{\alpha}}\Phi^{+}\right)$$

$$+x_{17,21}\epsilon^{\alpha\beta}\epsilon^{\zeta\iota}\Lambda^{k}{}_{\beta}\Lambda^{l}{}_{\iota}\theta^{4}\partial_{k}\left(D_{\alpha}\Phi\right)\partial_{l}\left(D_{\zeta}\Phi\right)\Phi^{+}$$

$$+x_{17,22}\epsilon^{\alpha\beta}\Lambda^{kl}\theta^{4}\left(D_{\beta}\Phi\right)\partial_{l}\partial_{k}\left(D_{\alpha}\Phi\right)\Phi^{+}$$

$$+\frac{1}{2}x_{17,24}\left(\eta\sigma\Lambda\Lambda^{k}\right)^{l}\theta^{4}\partial_{k}\Phi\partial_{l}\left(D^{2}\Phi\right)\Phi^{+}$$

$$+x_{17,24}\epsilon^{\alpha\beta}\left(\eta\sigma\Lambda\Lambda^{k}\right)^{l}\theta^{4}\partial_{k}\left(D_{\beta}\Phi\right)\partial_{l}\left(D_{\alpha}\Phi\right)\Phi^{+}$$

$$+\left(-4z_{17,30}-8iz_{17,34}+2z_{17,35}\right)\epsilon^{\alpha\beta}\eta_{kl}\left(\eta\sigma\Lambda^{l}\right)^{\zeta}\Lambda^{k}{}_{\beta}\theta^{4}\left(D_{\alpha}\Phi\right)\Box\left(D_{\zeta}\Phi\right)\Phi^{+}$$

$$+x_{17,26}\Lambda^{kl}\eta_{ln}\left(\sigma^{no}\right)^{\alpha\beta}\theta^{4}\left(D_{\alpha}\Phi\right)\partial_{k}\partial_{o}\left(D_{\beta}\Phi\right)\Phi^{+}$$

$$+\left(\Lambda^{2}\left(-2iy_{17,32}+\frac{y_{17,35}}{2}\right)+\sigma\Lambda\Lambda\left(z_{17,30}-2iz_{17,32}+2iz_{17,34}\right)\right)$$

$$
\begin{aligned}
& \theta^4 \Box\Phi \left(D^2\Phi\right) \Phi^+ \\
& + \left(\Lambda^2 \left(-\frac{1}{16} i y_{17,32} - \frac{1}{16} i y_{17,34}\right) + \sigma\Lambda\Lambda \left(-\frac{1}{16} i z_{17,32} - \frac{1}{16} i z_{17,34}\right)\right) \\
& \qquad \theta^4 \left(D^2\Phi\right) \left(D^2\Phi\right) \left(\bar{D}^2\Phi^+\right) \\
& + \left(\Lambda^2 \left(4 i y_{17,32} - 4 i y_{17,34}\right) + \sigma\Lambda\Lambda \left(4 z_{17,30} + 4 i z_{17,32} + 4 i z_{17,34} - 2 z_{17,35}\right)\right) \\
& \qquad \left(\sigma^{kl}\right)^{\alpha\beta} \theta^4 \partial_k \left(D_\alpha\Phi\right) \partial_l \left(D_\beta\Phi\right) \Phi^+ \\
& + \left(\Lambda^2 \left(-2 i y_{17,34} + \frac{y_{17,35}}{2}\right) + \sigma\Lambda\Lambda z_{17,30}\right) \theta^4 \Phi \Box \left(D^2\Phi\right) \Phi^+ \\
& + \left(\Lambda^2 \left(-2 i y_{17,32} - y_{17,33} - 2 i y_{17,34}\right) + \sigma\Lambda\Lambda \left(-2 i z_{17,32} - z_{17,33} - 2 i z_{17,34}\right)\right) \\
& \qquad \eta^{kl} \theta^4 \partial_l \Phi \partial_k \left(D^2\Phi\right) \Phi^+ \\
& + \left(\Lambda^2 y_{17,32} + \sigma\Lambda\Lambda z_{17,32}\right) \left(\bar{\sigma}^k\right)^{\dot{\alpha}\beta} \theta^4 \partial_k \left(D_\beta\Phi\right) \left(D^2\Phi\right) \left(\bar{D}_{\dot{\alpha}}\Phi^+\right) \\
& + \left(\Lambda^2 y_{17,33} + \sigma\Lambda\Lambda z_{17,33}\right) \eta^{kl} \epsilon^{\alpha\beta} \theta^4 \partial_k \left(D_\alpha\Phi\right) \partial_l \left(D_\beta\Phi\right) \Phi^+ \\
& + \left(\Lambda^2 y_{17,34} + \sigma\Lambda\Lambda z_{17,34}\right) \left(\bar{\sigma}^k\right)^{\dot{\alpha}\beta} \theta^4 \left(D_\beta\Phi\right) \partial_k \left(D^2\Phi\right) \left(\bar{D}_{\dot{\alpha}}\Phi^+\right) \\
& + \left(\Lambda^2 y_{17,35} + \sigma\Lambda\Lambda z_{17,35}\right) \epsilon^{\alpha\beta} \theta^4 \left(D_\beta\Phi\right) \Box \left(D_\alpha\Phi\right) \Phi^+,
\end{aligned}
$$

$$
\begin{aligned}
B_{18} \quad = \quad & x_{18,2} \Lambda^{kl} \theta^4 \Phi \partial_l \partial_k \left(D^2\Phi\right) \\
& + x_{18,2} \epsilon^{\alpha\beta} \Lambda^{kl} \theta^4 \left(D_\beta\Phi\right) \partial_l \partial_k \left(D_\alpha\Phi\right),
\end{aligned}
$$

$$
\begin{aligned}
B_{19} &= -x_{19,2}\epsilon^{\alpha\beta}\left(\eta\sigma\Lambda\Lambda^k\right)^l\theta^4\left(D_\alpha\Phi\right)\left(D_\beta\Phi\right)\Phi^+\partial_k\partial_l\Phi^+ \\
&\quad +x_{19,2}\left(\eta\sigma\Lambda\Lambda^k\right)^l\theta^4\Phi\left(D^2\Phi\right)\Phi^+\partial_k\partial_l\Phi^+, \\
B_{20} &= -x_{20,2}\epsilon^{\alpha\beta}\Lambda^{kl}\theta^4\left(D_\alpha\Phi\right)\left(D_\beta\Phi\right)\Phi^+\partial_k\partial_l\Phi^+ \\
&\quad +x_{20,2}\Lambda^{kl}\theta^4\Phi\left(D^2\Phi\right)\Phi^+\partial_k\partial_l\Phi^+, \\
B_{21} &= \left(x_{21,10}+2x_{21,19}-2x_{21,23}+x_{21,26}+z_{21,34}-2iz_{21,35}+2iz_{21,36}\right) \\
&\qquad \epsilon^{\alpha\beta}\left(\eta\sigma\Lambda^k\right)^\zeta\Lambda^l{}_\beta\theta^4\left(D_\alpha\Phi\right)\partial_k\partial_l\left(D_\zeta\Phi\right)\Phi^+\Phi^+ \\
&\quad +\left(-x_{21,15}+2x_{21,19}-2x_{21,23}+x_{21,26}-z_{21,34}+2iz_{21,35}-2iz_{21,36}\right) \\
&\qquad \epsilon^{\alpha\beta}\left(\eta\sigma\Lambda^k\right)^\zeta\Lambda^l{}_\beta\theta^4\partial_k\left(D_\alpha\Phi\right)\partial_l\left(D_\zeta\Phi\right)\Phi^+\Phi^+ \\
&\quad +\left(\Lambda^2\left(-\frac{1}{2}iy_{21,32}-\frac{1}{2}iy_{21,38}\right)+\sigma\Lambda\Lambda\left(-\frac{1}{2}iz_{21,32}-\frac{1}{2}iz_{21,38}\right)\right) \\
&\qquad \left(\bar\sigma^k\right)^{\dot\alpha\beta}\theta^4\left(D_\beta\Phi\right)\left(D^2\Phi\right)\Phi^+\partial_k\left(\bar D_{\dot\alpha}\Phi^+\right) \\
&\quad +\left(-x_{21,15}+2x_{21,19}-2x_{21,23}-x_{21,26}+z_{21,34}-2iz_{21,35}+2iz_{21,36}\right) \\
&\qquad \epsilon^{\alpha\beta}\eta_{kl}\left(\sigma\Lambda^{ln}\right)^{o\zeta}\Lambda^k{}_\beta\theta^4\partial_n\left(D_\alpha\Phi\right)\partial_o\left(D_\zeta\Phi\right)\Phi^+\Phi^+ \\
&\quad +\left(\frac{x_{21,26}}{2}-x_{21,27}\right)\Lambda^{kl}\theta^4\partial_l\Phi\partial_k\left(D^2\Phi\right)\Phi^+\Phi^+ \\
&\quad +\left(\frac{x_{21,22}}{2}-x_{21,26}+z_{21,34}-2iz_{21,35}+2iz_{21,36}\right)
\end{aligned}
$$

$$\left(\eta\sigma\Lambda\Lambda^{k}\right)^{l}\theta^{4}\partial_{l}\Phi\partial_{k}\left(D^{2}\Phi\right)\Phi^{+}\Phi^{+}$$

$$+\left(x_{21,10}+2x_{21,19}-2x_{21,23}-x_{21,26}-z_{21,34}+2iz_{21,35}-2iz_{21,36}\right)$$

$$\epsilon^{\alpha\beta}\eta_{kl}\left(\sigma\Lambda^{ln}\right)^{o\zeta}\Lambda^{k}{}_{\beta}\theta^{4}\left(D_{\alpha}\Phi\right)\partial_{n}\partial_{o}\left(D_{\zeta}\Phi\right)\Phi^{+}\Phi^{+}$$

$$+\left(\frac{x_{21,20}}{2}-x_{21,26}-z_{21,34}+2iz_{21,35}-2iz_{21,36}\right)$$

$$\left(\eta\sigma\Lambda\Lambda^{k}\right)^{l}\theta^{4}\partial_{k}\partial_{l}\Phi\left(D^{2}\Phi\right)\Phi^{+}\Phi^{+}$$

$$+\left(-z_{21,34}+2iz_{21,35}-2iz_{21,36}\right)\epsilon^{\alpha\beta}\eta_{kl}\left(\eta\sigma\Lambda^{l}\right)^{\zeta}\Lambda^{k}{}_{\beta}\theta^{4}\left(D_{\alpha}\Phi\right)\Box\left(D_{\zeta}\Phi\right)\Phi^{+}\Phi^{+}$$

$$+x_{21,10}\Lambda^{kl}\eta_{ln}\left(\sigma^{no}\right)^{\alpha\beta}\theta^{4}\left(D_{\alpha}\Phi\right)\partial_{k}\partial_{o}\left(D_{\beta}\Phi\right)\Phi^{+}\Phi^{+}$$

$$+\left(x_{21,19}+x_{21,23}\right)\epsilon^{\alpha\beta}\Lambda^{kl}\theta^{4}\left(D_{\beta}\Phi\right)\partial_{l}\partial_{k}\left(D_{\alpha}\Phi\right)\Phi^{+}\Phi^{+}$$

$$+\left(\frac{1}{2}iz_{21,34}+z_{21,35}-z_{21,36}\right)$$

$$\eta_{kl}\left(\bar{\sigma}^{l}\right)^{\dot{\alpha}\beta}\left(\eta\sigma\Lambda\Lambda^{n}\right)^{k}\theta^{4}\left(D_{\beta}\Phi\right)\partial_{n}\left(D^{2}\Phi\right)\Phi^{+}\left(\bar{D}_{\dot{\alpha}}\Phi^{+}\right)$$

$$+\left(-\frac{1}{2}iz_{21,34}-z_{21,35}+z_{21,36}\right)$$

$$\eta_{kl}\left(\bar{\sigma}^{l}\right)^{\dot{\alpha}\beta}\left(\eta\sigma\Lambda\Lambda^{n}\right)^{k}\theta^{4}\partial_{n}\left(D_{\beta}\Phi\right)\left(D^{2}\Phi\right)\Phi^{+}\left(\bar{D}_{\dot{\alpha}}\Phi^{+}\right)$$

$$+\left(-\frac{1}{2}iz_{21,34}-z_{21,35}+z_{21,36}\right)$$

$$\epsilon^{\alpha\beta}\epsilon^{\zeta\iota}\epsilon^{klno}\eta_{np}\eta_{oq}\Lambda^p{}_\beta\Lambda^q{}_\iota\theta^4\partial_k\left(D_\alpha\Phi\right)\partial_l\left(D_\zeta\Phi\right)\Phi^+\Phi^+$$
$$+x_{21,15}\Lambda^{kl}\eta_{ln}\left(\sigma^{no}\right)^{\alpha\beta}\theta^4\partial_k\left(D_\alpha\Phi\right)\partial_o\left(D_\beta\Phi\right)\Phi^+\Phi^+$$
$$+\left(\frac{1}{2}ix_{21,19}-\frac{1}{2}ix_{21,23}\right)\Lambda^{kl}\eta_{ln}\left(\bar\sigma^n\right)^{\dot\alpha\beta}\theta^4\left(D_\beta\Phi\right)\partial_k\left(D^2\Phi\right)\Phi^+\left(\bar D_{\dot\alpha}\Phi^+\right)$$
$$+\left(-\frac{1}{2}ix_{21,19}+\frac{1}{2}ix_{21,23}\right)\Lambda^{kl}\eta_{ln}\left(\bar\sigma^n\right)^{\dot\alpha\beta}\theta^4\partial_k\left(D_\beta\Phi\right)\left(D^2\Phi\right)\Phi^+\left(\bar D_{\dot\alpha}\Phi^+\right)$$
$$+\frac{1}{2}x_{21,20}\left(\eta\sigma\Lambda\Lambda^k\right)^l\theta^4\Phi\partial_k\partial_l\left(D^2\Phi\right)\Phi^+\Phi^+$$
$$+x_{21,19}\Lambda^{kl}\theta^4\Phi\partial_l\partial_k\left(D^2\Phi\right)\Phi^+\Phi^+$$
$$+x_{21,20}\epsilon^{\alpha\beta}\left(\eta\sigma\Lambda\Lambda^k\right)^l\theta^4\left(D_\beta\Phi\right)\partial_k\partial_l\left(D_\alpha\Phi\right)\Phi^+\Phi^+$$
$$+\frac{1}{2}x_{21,22}\left(\eta\sigma\Lambda\Lambda^k\right)^l\theta^4\partial_k\Phi\partial_l\left(D^2\Phi\right)\Phi^+\Phi^+$$
$$+x_{21,22}\epsilon^{\alpha\beta}\left(\eta\sigma\Lambda\Lambda^k\right)^l\theta^4\partial_k\left(D_\beta\Phi\right)\partial_l\left(D_\alpha\Phi\right)\Phi^+\Phi^+$$
$$+x_{21,23}\Lambda^{kl}\theta^4\partial_k\partial_l\Phi\left(D^2\Phi\right)\Phi^+\Phi^+$$
$$+\frac{1}{2}\left(ix_{21,26}\right)\eta_{kl}\left(\bar\sigma^l\right)^{\dot\alpha\beta}\left(\eta\sigma\Lambda\Lambda^k\right)^n\theta^4\left(D_\beta\Phi\right)\partial_n\left(D^2\Phi\right)\Phi^+\left(\bar D_{\dot\alpha}\Phi^+\right)$$
$$+\frac{1}{2}\left(-ix_{21,26}\right)\eta_{kl}\left(\bar\sigma^l\right)^{\dot\alpha\beta}\left(\eta\sigma\Lambda\Lambda^k\right)^n\theta^4\partial_n\left(D_\beta\Phi\right)\left(D^2\Phi\right)\Phi^+\left(\bar D_{\dot\alpha}\Phi^+\right)$$
$$+x_{21,26}\epsilon^{\alpha\beta}\epsilon^{\zeta\iota}\Lambda^k{}_\beta\Lambda^l{}_\iota\theta^4\partial_k\left(D_\alpha\Phi\right)\partial_l\left(D_\zeta\Phi\right)\Phi^+\Phi^+$$

$$+x_{21,27}\epsilon^{\alpha\beta}\Lambda^{kl}\theta^4\partial_k\left(D_\alpha\Phi\right)\partial_l\left(D_\beta\Phi\right)\Phi^+\Phi^+$$

$$+\left(\Lambda^2\left(-iy_{21,35}-iy_{21,36}-y_{21,37}\right)+\sigma\Lambda\Lambda\left(-iz_{21,35}-iz_{21,36}-z_{21,37}\right)\right)$$
$$\eta^{kl}\epsilon^{\alpha\beta}\theta^4\partial_k\left(D_\alpha\Phi\right)\partial_l\left(D_\beta\Phi\right)\Phi^+\Phi^+$$

$$+\left(\Lambda^2\left(-iy_{21,35}+iy_{21,36}+y_{21,39}\right)+\sigma\Lambda\Lambda\left(-iz_{21,35}+iz_{21,36}+z_{21,39}\right)\right)$$
$$\theta^4\Box\Phi\left(D^2\Phi\right)\Phi^+\Phi^+$$

$$+\left(\Lambda^2\left(-\frac{1}{16}iy_{21,35}-\frac{1}{16}iy_{21,36}\right)+\sigma\Lambda\Lambda\left(-\frac{1}{16}iz_{21,35}-\frac{1}{16}iz_{21,36}\right)\right)$$
$$\epsilon^{\dot\alpha\dot\beta}\theta^4\left(D^2\Phi\right)\left(D^2\Phi\right)\left(\bar D_{\dot\alpha}\Phi^+\right)\left(\bar D_{\dot\beta}\Phi^+\right)$$

$$+\left(\Lambda^2\left(\frac{y_{21,32}}{16}-\frac{1}{16}iy_{21,35}-\frac{1}{16}iy_{21,36}+\frac{y_{21,38}}{16}\right)\right.$$
$$\left.+\sigma\Lambda\Lambda\left(\frac{z_{21,32}}{16}-\frac{1}{16}iz_{21,35}-\frac{1}{16}iz_{21,36}+\frac{z_{21,38}}{16}\right)\right)$$
$$\theta^4\left(D^2\Phi\right)\left(D^2\Phi\right)\Phi^+\left(\bar D^2\Phi^+\right)$$

$$+\left(\Lambda^2y_{21,32}+\sigma\Lambda\Lambda z_{21,32}\right)\epsilon^{\alpha\beta}\theta^4\left(D_\alpha\Phi\right)\left(D_\beta\Phi\right)\Phi^+\Box\Phi^+$$

$$+\left(\Lambda^2\left(2iy_{21,36}+2y_{21,39}\right)+\sigma\Lambda\Lambda\left(-\frac{z_{21,34}}{2}+iz_{21,35}+iz_{21,36}+2z_{21,39}\right)\right)$$
$$\epsilon^{\alpha\beta}\theta^4\left(D_\beta\Phi\right)\Box\left(D_\alpha\Phi\right)\Phi^+\Phi^+$$

$$+\left(\Lambda^2\left(2iy_{21,35}-2iy_{21,36}\right)+\sigma\Lambda\Lambda z_{21,34}\right)\left(\sigma^{kl}\right)^{\alpha\beta}\theta^4\partial_k\left(D_\alpha\Phi\right)\partial_l\left(D_\beta\Phi\right)\Phi^+\Phi^+$$

$$
\begin{aligned}
& + \left(\Lambda^2 y_{21,35} + \sigma\Lambda\Lambda z_{21,35}\right) \left(\bar{\sigma}^k\right)^{\dot{\alpha}\beta} \theta^4 \partial_k \left(D_\beta \Phi\right) \left(D^2\Phi\right) \Phi^+ \left(\bar{D}_{\dot{\alpha}}\Phi^+\right) \\
& + \left(\Lambda^2 y_{21,36} + \sigma\Lambda\Lambda z_{21,36}\right) \left(\bar{\sigma}^k\right)^{\dot{\alpha}\beta} \theta^4 \left(D_\beta \Phi\right) \partial_k \left(D^2\Phi\right) \Phi^+ \left(\bar{D}_{\dot{\alpha}}\Phi^+\right) \\
& + \left(\Lambda^2 y_{21,37} + \sigma\Lambda\Lambda z_{21,37}\right) \eta^{kl} \theta^4 \partial_l \Phi \partial_k \left(D^2\Phi\right) \Phi^+ \Phi^+ \\
& + \left(\Lambda^2 y_{21,38} + \sigma\Lambda\Lambda z_{21,38}\right) \theta^4 \Phi \left(D^2\Phi\right) \Phi^+ \Box \Phi^+ \\
& + \left(\Lambda^2 y_{21,39} + \sigma\Lambda\Lambda z_{21,39}\right) \theta^4 \Phi \Box \left(D^2\Phi\right) \Phi^+ \Phi^+ , \\
B_{22} \quad = \quad & \left(\Lambda^2 y_{22,2} + \sigma\Lambda\Lambda z_{22,2}\right) \theta^4 \Phi \Box \left(D^2\Phi\right) \\
& + \left(\Lambda^2 y_{22,2} + \sigma\Lambda\Lambda z_{22,2}\right) \epsilon^{\alpha\beta} \theta^4 \left(D_\beta \Phi\right) \Box \left(D_\alpha \Phi\right) , \\
B_{23} \quad = \quad & \left(-8i\Lambda^2 y_{23,3} - 8i\sigma\Lambda\Lambda z_{23,3}\right) \left(\bar{\sigma}^k\right)^{\dot{\alpha}\beta} \theta^4 \left(D_\beta \Phi\right) \partial_k \left(\bar{D}_{\dot{\alpha}}\Phi^+\right) \\
& + \left(16\Lambda^2 y_{23,3} + 16\sigma\Lambda\Lambda z_{23,3}\right) \theta^4 \Phi \Box \Phi^+ \\
& + \left(\Lambda^2 y_{23,3} + \sigma\Lambda\Lambda z_{23,3}\right) \theta^4 \left(D^2\Phi\right) \left(\bar{D}^2\Phi^+\right) , \\
B_{24} \quad = \quad & \left(-8i\Lambda^2 y_{24,3} - 8i\sigma\Lambda\Lambda z_{24,3}\right) \left(\bar{\sigma}^k\right)^{\dot{\alpha}\beta} \theta^4 \left(D_\beta \Phi\right) \Phi^+ \partial_k \left(\bar{D}_{\dot{\alpha}}\Phi^+\right) \\
& + \left(16\Lambda^2 y_{24,3} + 16\sigma\Lambda\Lambda z_{24,3}\right) \theta^4 \Phi \Phi^+ \Box \Phi^+ \\
& + \left(\Lambda^2 y_{24,3} + \sigma\Lambda\Lambda z_{24,3}\right) \theta^4 \left(D^2\Phi\right) \Phi^+ \left(\bar{D}^2\Phi^+\right) , \\
B_{25} \quad = \quad & \left(-8i\Lambda^2 y_{25,3} - 8i\sigma\Lambda\Lambda z_{25,3}\right) \left(\bar{\sigma}^k\right)^{\dot{\alpha}\beta} \theta^4 \left(D_\beta \Phi\right) \Phi^+ \Phi^+ \partial_k \left(\bar{D}_{\dot{\alpha}}\Phi^+\right) \\
& + \left(16\Lambda^2 y_{25,3} + 16\sigma\Lambda\Lambda z_{25,3}\right) \theta^4 \Phi \Phi^+ \Phi^+ \Box \Phi^+
\end{aligned}
$$

$$
\begin{aligned}
& + \left(\Lambda^2 y_{25,3} + \sigma\Lambda\Lambda z_{25,3}\right) \theta^4 \left(D^2\Phi\right) \Phi^+\Phi^+ \left(\bar{D}^2\Phi^+\right), \\
B_{26} \;=\; & \left(-\frac{1}{2} i\Lambda^2 y_{26,3} - \frac{1}{2} i\sigma\Lambda\Lambda z_{26,3}\right) \left(\bar{\sigma}^k\right)^{\dot{\alpha}\beta} \theta^4 \left(D_\beta\Phi\right) \Phi^+\Phi^+\Phi^+ \partial_k \left(\bar{D}_{\dot{\alpha}}\Phi^+\right) \\
& + \left(\frac{1}{16}\Lambda^2 y_{26,3} + \frac{1}{16}\sigma\Lambda\Lambda z_{26,3}\right) \theta^4 \left(D^2\Phi\right) \Phi^+\Phi^+\Phi^+ \left(\bar{D}^2\Phi^+\right) \\
& + \left(\Lambda^2 y_{26,3} + \sigma\Lambda\Lambda z_{26,3}\right) \theta^4 \Phi\Phi^+\Phi^+\Phi^+ \Box\Phi^+, \\
B_{27} \;=\; & \left(\Lambda^2 \left(\frac{3y_{27,3}}{2} + y_{27,4}\right) + \sigma\Lambda\Lambda \left(\frac{3z_{27,3}}{2} + z_{27,4}\right)\right) \theta^4 \Phi \left(D^2\Phi\right) \Box \left(D^2\Phi\right) \\
& + \left(\Lambda^2 \left(y_{27,3} + y_{27,4}\right) + \sigma\Lambda\Lambda \left(z_{27,3} + z_{27,4}\right)\right) \eta^{kl} \theta^4 \Phi \partial_k \left(D^2\Phi\right) \partial_l \left(D^2\Phi\right) \\
& + \left(\Lambda^2 y_{27,3} + \sigma\Lambda\Lambda z_{27,3}\right) \epsilon^{\alpha\beta} \theta^4 \left(D_\beta\Phi\right) \Box \left(D_\alpha\Phi\right) \left(D^2\Phi\right) \\
& + \left(\Lambda^2 y_{27,4} + \sigma\Lambda\Lambda z_{27,4}\right) \eta^{kl} \epsilon^{\alpha\beta} \theta^4 \partial_k \left(D_\alpha\Phi\right) \partial_l \left(D_\beta\Phi\right) \left(D^2\Phi\right), \\
B_{28} \;=\; & \left(-\frac{x_{28,3}}{2} + x_{28,4}\right) \left(\eta\sigma\Lambda\Lambda^k\right)^l \theta^4 \Phi \partial_k \left(D^2\Phi\right) \partial_l \left(D^2\Phi\right) \\
& + \left(3x_{28,3} - 2x_{28,4} - 2x_{28,5}\right) \epsilon^{\alpha\beta} \eta_{kl} \left(\sigma\Lambda^{ln}\right)^{o\zeta} \Lambda^k{}_\beta \theta^4 \partial_n \left(D_\alpha\Phi\right) \partial_o \left(D_\zeta\Phi\right) \left(D^2\Phi\right) \\
& + x_{28,3} \epsilon^{\alpha\beta} \left(\eta\sigma\Lambda\Lambda^k\right)^l \theta^4 \left(D_\beta\Phi\right) \partial_k\partial_l \left(D_\alpha\Phi\right) \left(D^2\Phi\right) \\
& + x_{28,4} \left(\eta\sigma\Lambda\Lambda^k\right)^l \theta^4 \Phi \left(D^2\Phi\right) \partial_k\partial_l \left(D^2\Phi\right) \\
& + x_{28,5} \epsilon^{\alpha\beta} \left(\eta\sigma\Lambda\Lambda^k\right)^l \theta^4 \partial_k \left(D_\beta\Phi\right) \partial_l \left(D_\alpha\Phi\right) \left(D^2\Phi\right),
\end{aligned}
$$

$$
\begin{aligned}
B_{29} &= \left(-2x_{29,3}+2x_{29,4}\right)\epsilon^{\alpha\beta}\Lambda^{kl}\theta^4\left(D_\beta\Phi\right)\partial_l\partial_k\left(D_\alpha\Phi\right)\left(D^2\Phi\right)\\
&\quad+\left(-6x_{29,3}+4x_{29,4}+2x_{29,5}\right)\epsilon^{\alpha\beta}\epsilon^{\zeta\iota}\Lambda^k{}_\beta\Lambda^l{}_\iota\theta^4\partial_k\left(D_\alpha\Phi\right)\partial_l\left(D_\zeta\Phi\right)\left(D^2\Phi\right)\\
&\quad+x_{29,3}\Lambda^{kl}\theta^4\Phi\partial_k\left(D^2\Phi\right)\partial_l\left(D^2\Phi\right)\\
&\quad+x_{29,4}\Lambda^{kl}\theta^4\Phi\left(D^2\Phi\right)\partial_l\partial_k\left(D^2\Phi\right)\\
&\quad+x_{29,5}\epsilon^{\alpha\beta}\Lambda^{kl}\theta^4\partial_k\left(D_\alpha\Phi\right)\partial_l\left(D_\beta\Phi\right)\left(D^2\Phi\right),\\
B_{30} &= \left(\Lambda^2 y_{30,1}+\sigma\Lambda\Lambda z_{30,1}\right)\theta^4\left(D^2\Phi\right),\\
B_{31} &= x_{31,1}\left(\sigma\Lambda\Lambda^{kl}\right)^{no}\theta^4\Phi^+\partial_k\partial_n\Phi^+\partial_l\partial_o\Phi^+,\\
B_{32} &= \left(\Lambda^2 y_{32,1}+\sigma\Lambda\Lambda z_{32,1}\right)\left(\sigma^{kl}\right)^{\alpha\beta}\theta^4\partial_k\left(D_\alpha\Phi\right)\partial_l\left(D_\beta\Phi\right)\left(D^2\Phi\right),\\
B_{33} &= x_{33,1}\eta^{kl}\left(\eta\sigma\Lambda\Lambda^n\right)^o\theta^4\Phi^+\partial_l\partial_n\Phi^+\partial_k\partial_o\Phi^+,\\
B_{34} &= x_{34,1}\left(\eta\sigma\Lambda\Lambda^k\right)^l\theta^4\Phi^+\Phi^+\partial_k\Phi^+\partial_l\Phi^+,\\
B_{35} &= x_{35,1}\left(\eta\sigma\Lambda\Lambda^k\right)^l\theta^4\Phi^+\Phi^+\Phi^+\partial_k\partial_l\Phi^+,\\
B_{36} &= x_{36,1}\Lambda^{kl}\eta_{ln}\left(\sigma^{no}\right)^{\alpha\beta}\theta^4\partial_k\left(D_\alpha\Phi\right)\partial_o\left(D_\beta\Phi\right)\left(D^2\Phi\right),\\
B_{37} &= x_{37,1}\epsilon^{\alpha\beta}\epsilon^{\zeta\iota}\epsilon^{klno}\eta_{np}\eta_{oq}\Lambda^p{}_\beta\Lambda^q{}_\iota\theta^4\partial_k\left(D_\alpha\Phi\right)\partial_l\left(D_\zeta\Phi\right)\left(D^2\Phi\right),\\
B_{38} &= \left(\Lambda^2 y_{38,1}+\sigma\Lambda\Lambda z_{38,1}\right)\theta^4\left(D^2\Phi\right)\left(D^2\Phi\right),\\
B_{39} &= \left(\Lambda^2 y_{39,1}+\sigma\Lambda\Lambda z_{39,1}\right)\theta^4\Phi^+\Box\Phi^+,
\end{aligned}
$$

$$
\begin{aligned}
B_{40} &= \left(\Lambda^2 y_{40,1} + \sigma\Lambda\Lambda z_{40,1}\right)\theta^4\left(D^2\Phi\right)\left(D^2\Phi\right)\Phi^+, \\
B_{41} &= \left(\Lambda^2 y_{41,1} + \sigma\Lambda\Lambda z_{41,1}\right)\theta^4\Phi^+\Phi^+\Box\Phi^+, \\
B_{42} &= x_{42,1}\left(\eta\sigma\Lambda\Lambda^k\right)^l\theta^4\left(D^2\Phi\right)\partial_k\partial_l\left(D^2\Phi\right), \\
B_{43} &= x_{43,1}\left(\eta\sigma\Lambda\Lambda^k\right)^l\theta^4\Phi^+\Box\partial_k\partial_l\Phi^+, \\
B_{44} &= x_{44,1}\Lambda^{kl}\theta^4\left(D^2\Phi\right)\partial_l\partial_k\left(D^2\Phi\right), \\
B_{45} &= x_{45,1}\Lambda^{kl}\theta^4\Phi^+\Box\partial_k\partial_l\Phi^+, \\
B_{46} &= \left(\Lambda^2 y_{46,1} + \sigma\Lambda\Lambda z_{46,1}\right)\eta^{kl}\eta^{no}\theta^4\Phi^+\partial_k\partial_n\Phi^+\partial_l\partial_o\Phi^+, \\
B_{47} &= x_{47,1}\Lambda^{kl}\theta^4\Phi^+\Phi^+\partial_k\Phi^+\partial_l\Phi^+, \\
B_{48} &= x_{48,1}\Lambda^{kl}\theta^4\Phi^+\Phi^+\Phi^+\partial_k\partial_l\Phi^+, \\
B_{49} &= \left(\Lambda^2 y_{49,1} + \sigma\Lambda\Lambda z_{49,1}\right)\theta^4\left(D^2\Phi\right)\Phi^+, \\
B_{50} &= \left(\Lambda^2 y_{50,1} + \sigma\Lambda\Lambda z_{50,1}\right)\theta^4\left(D^2\Phi\right)\Phi^+\Phi^+, \\
B_{51} &= \left(\Lambda^2 y_{51,1} + \sigma\Lambda\Lambda z_{51,1}\right)\theta^4\left(D^2\Phi\right)\Phi^+\Phi^+\Phi^+, \\
B_{52} &= x_{52,1}\left(\eta\sigma\Lambda\Lambda^k\right)^l\theta^4\Phi^+\Box\Phi^+\partial_k\partial_l\Phi^+, \\
B_{53} &= x_{53,1}\left(\eta\sigma\Lambda\Lambda^k\right)^l\theta^4\left(D^2\Phi\right)\partial_k\Phi^+\partial_l\Phi^+, \\
B_{54} &= x_{54,1}\Lambda^{kl}\theta^4\left(D^2\Phi\right)\partial_k\Phi^+\partial_l\Phi^+,
\end{aligned}
$$

$$
\begin{aligned}
B_{55} &= x_{55,1}\left(\eta\sigma\Lambda\Lambda^{k}\right)^{l}\theta^{4}\left(D^{2}\Phi\right)\partial_{k}\partial_{l}\Phi^{+},\\
B_{56} &= x_{56,1}\Lambda^{kl}\theta^{4}\left(D^{2}\Phi\right)\partial_{k}\partial_{l}\Phi^{+},\\
B_{57} &= x_{57,1}\left(\eta\sigma\Lambda\Lambda^{k}\right)^{l}\theta^{4}\left(D^{2}\Phi\right)\Phi^{+}\partial_{k}\partial_{l}\Phi^{+},\\
B_{58} &= x_{58,1}\Lambda^{kl}\theta^{4}\left(D^{2}\Phi\right)\Phi^{+}\partial_{k}\partial_{l}\Phi^{+},\\
B_{59} &= x_{59,1}\left(\eta\sigma\Lambda\Lambda^{k}\right)^{l}\theta^{4}\left(D^{2}\Phi\right)\Box\partial_{k}\partial_{l}\Phi^{+},\\
B_{60} &= x_{60,1}\Lambda^{kl}\theta^{4}\left(D^{2}\Phi\right)\Box\partial_{k}\partial_{l}\Phi^{+},\\
B_{61} &= x_{61,1}\left(\eta\sigma\Lambda\Lambda^{k}\right)^{l}\theta^{4}\Phi^{+}\Phi^{+}\Box\partial_{k}\partial_{l}\Phi^{+},\\
B_{62} &= x_{62,1}\eta^{kl}\Lambda^{no}\theta^{4}\Phi^{+}\partial_{k}\partial_{n}\Phi^{+}\partial_{l}\partial_{o}\Phi^{+},\\
B_{63} &= x_{63,1}\Lambda^{kl}\theta^{4}\Phi^{+}\Phi^{+}\Box\partial_{k}\partial_{l}\Phi^{+},\\
B_{64} &= x_{64,1}\Lambda^{kl}\theta^{4}\Phi^{+}\Box\Phi^{+}\partial_{k}\partial_{l}\Phi^{+},\\
B_{65} &= \left(\Lambda^{2}y_{65,1}+\sigma\Lambda\Lambda z_{65,1}\right)\theta^{4}\Phi^{+}\Box\Phi^{+}\Box\Phi^{+},\\
B_{66} &= \left(\Lambda^{2}y_{66,1}+\sigma\Lambda\Lambda z_{66,1}\right)\eta^{kl}\theta^{4}\Phi^{+}\Phi^{+}\partial_{k}\Phi^{+}\partial_{l}\Phi^{+},\\
B_{67} &= \left(\Lambda^{2}y_{67,1}+\sigma\Lambda\Lambda z_{67,1}\right)\theta^{4}\left(D^{2}\Phi\right)\Box\Box\Phi^{+},\\
B_{68} &= \left(\Lambda^{2}y_{68,1}+\sigma\Lambda\Lambda z_{68,1}\right)\theta^{4}\Phi^{+}\Phi^{+}\Box\Box\Phi^{+},\\
B_{69} &= \left(\Lambda^{2}y_{69,1}+\sigma\Lambda\Lambda z_{69,1}\right)\theta^{4}\Phi^{+}\Phi^{+}\Phi^{+}\Box\Phi^{+},
\end{aligned}
$$

$$
\begin{aligned}
B_{70} &= \left(\Lambda^2 y_{70,1} + \sigma\Lambda\Lambda z_{70,1}\right) \eta^{kl}\theta^4 \left(D^2\Phi\right) \partial_k\Phi^+\partial_l\Phi^+, \\
B_{71} &= \left(\Lambda^2 y_{71,1} + \sigma\Lambda\Lambda z_{71,1}\right) \theta^4 \left(D^2\Phi\right) \Box \left(D^2\Phi\right), \\
B_{72} &= \left(\Lambda^2 y_{72,1} + \sigma\Lambda\Lambda z_{72,1}\right) \theta^4 \Phi^+\Box\Box\Phi^+, \\
B_{73} &= \left(\Lambda^2 y_{73,1} + \sigma\Lambda\Lambda z_{73,1}\right) \theta^4 \left(D^2\Phi\right) \Box\Phi^+, \\
B_{74} &= \left(\Lambda^2 y_{74,1} + \sigma\Lambda\Lambda z_{74,1}\right) \theta^4 \left(D^2\Phi\right) \Phi^+\Box\Phi^+.
\end{aligned}
$$

Invariant subset No. 29.

$$
\begin{aligned}
f_{29} \quad = \quad & \frac{5\left(-18g^5 a_2+23g^7 a_3\right)}{13824}\epsilon^{\alpha\beta}\Lambda^{kl}\theta^4\left(D_\beta\Phi\right)\partial_l\partial_k\left(D_\alpha\Phi\right)\left(D^2\Phi\right) \\
&+\frac{-192g a_0-36g^5 a_2+55g^7 a_3}{3072}\epsilon^{\alpha\beta}\epsilon^{\zeta\iota}\Lambda^k{}_\beta\Lambda^l{}_\iota\theta^4\partial_k\left(D_\alpha\Phi\right)\partial_l\left(D_\zeta\Phi\right)\left(D^2\Phi\right) \\
&+\frac{-144g a_0-45g^5 a_2+68g^7 a_3}{4608}\Lambda^{kl}\theta^4\Phi\partial_k\left(D^2\Phi\right)\partial_l\left(D^2\Phi\right) \\
&+\frac{-864g a_0-360g^5 a_2+523g^7 a_3}{27648}\Lambda^{kl}\theta^4\Phi\left(D^2\Phi\right)\partial_l\partial_k\left(D^2\Phi\right) \\
&+\frac{-3456g a_0-504g^5 a_2+851g^7 a_3}{55296}\epsilon^{\alpha\beta}\Lambda^{kl}\theta^4\partial_k\left(D_\alpha\Phi\right)\partial_l\left(D_\beta\Phi\right)\left(D^2\Phi\right). \\
B_{29} \quad = \quad & \left(-2x_{29,3}+2x_{29,4}\right)\epsilon^{\alpha\beta}\Lambda^{kl}\theta^4\left(D_\beta\Phi\right)\partial_l\partial_k\left(D_\alpha\Phi\right)\left(D^2\Phi\right) \\
&+\left(-6x_{29,3}+4x_{29,4}+2x_{29,5}\right)\epsilon^{\alpha\beta}\epsilon^{\zeta\iota}\Lambda^k{}_\beta\Lambda^l{}_\iota\theta^4\partial_k\left(D_\alpha\Phi\right)\partial_l\left(D_\zeta\Phi\right)\left(D^2\Phi\right) \\
&+x_{29,3}\Lambda^{kl}\theta^4\Phi\partial_k\left(D^2\Phi\right)\partial_l\left(D^2\Phi\right) \\
&+x_{29,4}\Lambda^{kl}\theta^4\Phi\left(D^2\Phi\right)\partial_l\partial_k\left(D^2\Phi\right) \\
&+x_{29,5}\epsilon^{\alpha\beta}\Lambda^{kl}\theta^4\partial_k\left(D_\alpha\Phi\right)\partial_l\left(D_\beta\Phi\right)\left(D^2\Phi\right), \\
& x_{29,3}\to-\frac{1}{32},\quad x_{29,4}\to-\frac{1}{32},\quad x_{29,5}\to-\frac{1}{16};\quad\left(\mathcal{S}_\Lambda\left(\Lambda^2\right)\right) \\
& x_{29,3}\to-\frac{5}{512},\quad x_{29,4}\to-\frac{5}{384},\quad x_{29,5}\to-\frac{7}{768};\quad\left(\Gamma_{\text{2nd}}\left(\Lambda^2\right)\right) \\
& x_{29,3}\to\frac{17}{1152},\quad x_{29,4}\to\frac{523}{27648},\quad x_{29,5}\to\frac{851}{55296}.\quad\left(\Gamma_{\text{3rd}}\left(\Lambda^2\right)\right)
\end{aligned}
$$

Renormalizable Action

$$\mathcal{S}_{(3)} = \mathcal{S}_{\rm WZ} + \int d^8 z \left(\sum_{i=1}^{74} B_i \right), \quad \text{(Its effective action is defined as } \Gamma_{4\text{th}}\left(\Lambda^2\right)\text{)}$$

$$\begin{aligned}
B'_{29} = & \left(-2x'_{29,3} + 2x'_{29,4}\right) \epsilon^{\alpha\beta} \Lambda^{kl} \theta^4 \left(D_\beta \Phi\right) \partial_l \partial_k \left(D_\alpha \Phi\right) \left(D^2 \Phi\right) \\
& + \left(-6x'_{29,3} + 4x'_{29,4} + 2x'_{29,5}\right) \epsilon^{\alpha\beta} \epsilon^{\zeta\iota} \Lambda^k{}_\beta \Lambda^l{}_\iota \theta^4 \partial_k \left(D_\alpha \Phi\right) \partial_l \left(D_\zeta \Phi\right) \left(D^2 \Phi\right) \\
& + x'_{29,3} \Lambda^{kl} \theta^4 \Phi \partial_k \left(D^2 \Phi\right) \partial_l \left(D^2 \Phi\right) + x'_{29,4} \Lambda^{kl} \theta^4 \Phi \left(D^2 \Phi\right) \partial_l \partial_k \left(D^2 \Phi\right) \\
& + x'_{29,5} \epsilon^{\alpha\beta} \Lambda^{kl} \theta^4 \partial_k \left(D_\alpha \Phi\right) \partial_l \left(D_\beta \Phi\right) \left(D^2 \Phi\right),
\end{aligned}$$

$$x'_{29,3} = \frac{-g}{32\pi^2 \epsilon} \left(4x_{21,23} - x_{21,26} + 2x_{21,27}\right),$$

$$x'_{29,4} = \frac{-g}{96\pi^2 \epsilon} \left(2x_{20,2} + 6x_{21,19} + 12x_{21,23} - 3x_{21,26} + 6x_{21,27}\right),$$

$$x'_{29,5} = \frac{g}{48\pi^2 \epsilon} \left(2x_{20,2} + 6x_{21,19} - 6x_{21,23} - 3x_{21,26} - 3x_{21,27}\right),$$

$$(x_0)_{29,3} = x_{29,3} \left(1 - \frac{x'_{29,3}}{x_{29,3}}\right) \left(\frac{1}{\sqrt{Z}}\right)^3.$$

Renormalization of all the parameters m, g, $x_{i,j}$, $y_{i,j}$, and $z_{i,j}$ is compatible.

Comments

- Through analyzing the Wess-Zumino model on the BFNC superspace, we know that the action obtained by replacing the ordinary product by the star product is not renormalizable in general.
- To make it renormalizable one should add to it correction terms. For the NAC superspace, which is a simpler case, one just needs to add the terms from the primary one-loop effective action, and then provides the renormalizable action to all orders in perturbation theory.
- However, for the BFNC superspace the situation is much more complicated. The iterative process should go up to the third time.
- Moreover, the complexity also includes that the obtained renormalizable action has so many terms that can be classified on the one hand into 74 subsets each of which has the $1/2$ supersymmetry invariance, and on the other hand into 74 bases that correspond to the 74 subsets.
- In particular, in light of the invariant bases we construct the one-loop renormalizable action up to the second order of the BFNC parameters $\Lambda^{k\alpha}$'s.

- BFNC Wess-Zumino Model Renormalizable to All Orders

Description of Idea and Treatment

- The method we take is similar to the one used to construct NAC Wess-Zumino action. [R. Britto et al, hep-th/0307165, A. Romagnoni, hep-th/0307209]
- The one loop renormalizable BFNC Wess-Zumino action $\mathcal{S}_{(3)}$ has only 1/2 supersymmetry but not global $U(1)$ symmetries, because the mass and interaction parameters are real numbers.
- If we want to use the symmetry analysis method that is very powerful for the construction of renormalizable NAC Wess-Zumino action, we have to introduce two global $U(1)$ symmetries, such as $U(1)_{\mathrm{R}}$ R-symmetry and $U(1)_{\Phi}$ flavor symmetry for $\mathcal{S}_{(3)}$.
- At first, we generalize the mass and interaction parameters to complex numbers, and define the $U(1)_{\mathrm{R}}$ R-symmetry and $U(1)_{\Phi}$ flavor symmetry charges for operators as well as mass and interaction parameters, exactly following the NAC case.
- Then, we define the global $U(1)$ symmetry charges for BFNC parameter $\Lambda^{k}{}_{\alpha}$.

Modify $\mathcal{S}_{(3)}$

- The undeformed part of $\mathcal{S}_{(3)}$,

$$\mathcal{S}'_{\mathrm{WZ}} = \int d^8z \left\{ \Phi^+\Phi - \frac{m}{8}\Phi\left(\frac{D^2}{\Box}\Phi\right) - \frac{m^*}{8}\Phi^+\left(\frac{\bar{D}^2}{\Box}\Phi^+\right) - \frac{g}{12}\Phi\Phi\left(\frac{D^2}{\Box}\Phi\right) - \frac{g^*}{12}\Phi^+\Phi^+\left(\frac{\bar{D}^2}{\Box}\Phi^+\right) \right\}.$$

- The deformed part of $\mathcal{S}_{(3)}$,

$$\int d^8z\, m^{a_1}(m^*)^{a_2} g^{a_3}(g^*)^{a_4}\, X$$

Its mass dimension, $U(1)_{\mathrm{R}}$ charge, $U(1)_{\Phi}$ charge should be zero.

- We deduce from $\mathcal{S}_{(3)}$ the modified action,

$$\mathcal{S}'_{(3)} = \mathcal{S}'_{\mathrm{WZ}} + \int d^8z \left(\sum_{i=1}^{74} c_i B_i\right).$$

The Coefficients c_i's I

The coefficients c_i's, where $i = 1, \cdots, 89$, are listed below.

$$
\begin{aligned}
c_1 &= g^2 m (m^*)^3, & c_2 &= g^3 (m^*)^3, & c_3 &= gm (m^*)^2, & c_4 &= g^2 (m^*)^2, \\
c_5 &= mm^*, & c_6 &= gm^*, & c_7 &= mg^*, & c_8 &= 1, \\
c_9 &= gmm^*, & c_{10} &= g^2 m^*, & c_{11} &= m, & c_{12} &= g, \\
c_{13} &= g (m^*)^2, & c_{14} &= m^*, & c_{15} &= g^*, & c_{16} &= g^4 (m^*)^5, \\
c_{17} &= gm^*, & c_{18} &= g^2 (m^*)^2, & c_{19} &= g^2 (m^*)^3, & c_{20} &= 1, \\
c_{21} &= 1, & c_{22} &= g^2 (m^*)^2, & c_{23} &= g^2 (m^*)^3, & c_{24} &= g (m^*)^2, \\
c_{25} &= m^*, & c_{26} &= g^*, & c_{27} &= g, & c_{28} &= g^3 (m^*)^3, \\
c_{29} &= g, & c_{30} &= gm^2 (m^*)^3, & c_{31} &= g (m^*)^3, & c_{32} &= g, \\
c_{33} &= g (m^*)^3, & c_{34} &= m (m^*)^3, & c_{35} &= m (m^*)^3, & c_{36} &= g, \\
c_{37} &= g, & c_{38} &= m^2 m^*, & c_{39} &= m (m^*)^2, & c_{40} &= m^2 g^*, \\
c_{41} &= mg^* m^*, & c_{42} &= g^2 m (m^*)^3, & c_{43} &= g^2 (m^*)^4, & c_{44} &= m, \\
c_{45} &= m^*, & c_{46} &= g^*, & c_{47} &= m (g^*)^2, & c_{48} &= m (g^*)^2, \\
c_{49} &= m^2 (m^*)^2, & c_{50} &= m^2 g^* m^*, & c_{51} &= m^2 (g^*)^2, & c_{52} &= g (m^*)^3, \\
c_{53} &= gm (m^*)^3, & c_{54} &= mg^*, & c_{55} &= g^2 m (m^*)^4, & c_{56} &= mm^*,
\end{aligned}
$$

The Coefficients c_i's II

$$
\begin{aligned}
&c_{57} = gm\left(m^*\right)^3, && c_{58} = mg^*, && c_{59} = g^2\left(m^*\right)^3, && c_{60} = 1, \\
&c_{61} = g\left(m^*\right)^3, && c_{62} = g^*, && c_{63} = g^*, && c_{64} = g^*, \\
&c_{65} = g^*, && c_{66} = m\left(g^*\right)^2, && c_{67} = 1, && c_{68} = g^*, \\
&c_{69} = m\left(g^*\right)^2, && c_{70} = mg^*, && c_{71} = m, && c_{72} = m^*, \\
&c_{73} = mm^*, && c_{74} = mg^*, && c_{75} = gm^2\left(m^*\right)^4, && c_{76} = m^2\left(m^*\right)^3, \\
&c_{77} = m^2 g^*\left(m^*\right)^2, && c_{78} = m^2\left(g^*\right)^2 m^*, && c_{79} = m^2\left(g^*\right)^3, && c_{80} = g^3\left(m^*\right)^5, \\
&c_{81} = g^2\left(m^*\right)^4, && c_{82} = g\left(m^*\right)^3, && c_{83} = \left(m^*\right)^2, && c_{84} = g^* m^*, \\
&c_{85} = \left(g^*\right)^2, && c_{86} = m\left(m^*\right)^2, && c_{87} = g^2 m\left(m^*\right)^5, && c_{88} = mg^* m^*, \\
&c_{89} = gm\left(m^*\right)^4.
\end{aligned}
$$

Symmetry Charges

	dim	$U(1)_R$	$U(1)_\Phi$		dim	$U(1)_R$	$U(1)_\Phi$
m	1	0	-2	m^*	1	0	2
g	0	-1	-3	g^*	0	1	3
$(\Lambda^k{}_\alpha)^2$	-3	2	0	V	-5	2	0
$d^4\theta$	2	0	0	θ^4	-2	0	0
Φ	1	1	1	Φ^+	1	-1	-1
D_α	$\frac{1}{2}$	-1	0	$\bar{D}_{\dot{\alpha}}$	$\frac{1}{2}$	1	0
D^2	1	-2	0	$\bar{D}^2$	1	2	0
∂_k	1	0	0	d^4x	-4	0	0

Table : Mass dimensions and symmetry charges of parameters and operators.

Constraints on Divergent Operators from Symmetries

$$
\begin{aligned}
\Gamma &= \int d^4x\, \lambda\, \mathcal{O}, \quad \lambda \sim \Lambda_{UV}^{d} g^{x-R} g^{*x} \left(\frac{m}{\Lambda_{UV}}\right)^{y} \left(\frac{m^*}{\Lambda_{UV}}\right)^{y+\frac{S-3R}{2}}, \\
\mathcal{O} &= d^4\theta (D^2)^{\gamma} (\bar{D}^2)^{\delta} (\partial D \bar{D})^{\eta} (\partial\partial)^{\zeta} V^{\rho} \Phi^{\alpha} (\Phi^{+})^{\beta}, \quad V \equiv (\Lambda^{k}{}_{\alpha})^2\, \theta^4, \\
d &= 2-\alpha-\beta-\gamma-\delta-2\zeta-2\eta+5\rho, \quad R = -\alpha+\beta+2\gamma-2\delta-2\rho, \quad S = -\alpha+\beta, \\
P &= d+\frac{3R}{2}-\frac{S}{2}-2y = 2-2y-2\alpha+2\gamma-4\delta-2\zeta-2\eta+2\rho \geq 0, \\
\gamma &\leq \alpha-\eta, \quad \delta \leq \beta-\eta, \\
\gamma &\geq 0, \quad \delta \geq 0, \quad \alpha \geq 0, \quad \eta \geq 0, \quad \rho \geq 0, \quad \zeta \geq 0, \quad \beta \geq 0, \\
\rho &= 1, \\
y &\geq 0, \quad x \geq 0, \quad x+\alpha-\beta-2\gamma+2\delta+2\rho \geq 0, \quad y+\alpha-\beta-3\gamma+3\delta+3\rho \geq 0.
\end{aligned}
$$

They are just linear equations and can be solved easily.

Divergent Operators

$\Phi,\quad \Phi\Phi,\quad \Phi\Phi^+,\quad \Phi\Phi^+\Phi^+,\quad \Phi\Phi^+\Phi^+\Phi^+,\quad \Phi\Phi^+\Phi^+\Phi^+\Phi^+,\quad \Phi\Phi^+\Phi^+\Phi^+\Phi^+\Phi^+,$
$\Phi\Phi\Phi^+,\quad \Phi\Phi\Phi^+\Phi^+,\quad \Phi\Phi\Phi^+\Phi^+\Phi^+,\quad \Phi\Phi\Phi^+\Phi^+\Phi^+\Phi^+,\quad \Phi\Phi\Phi^+\Phi^+\Phi^+\Phi^+\Phi^+;$ (1)
$\partial\partial\Phi,\quad \partial\partial\Phi^+,\quad \partial\partial\partial\partial\Phi^+,\quad D^2\partial\partial\Phi,\quad D^2\partial\partial\partial\partial\Phi;$ (2)
$\Phi^+,\quad \Phi^+\Phi^+,\quad \Phi^+\Phi^+\Phi^+,\quad \Phi^+\Phi^+\Phi^+\Phi^+,\quad \Phi^+\Phi^+\Phi^+\Phi^+\Phi^+,\quad \bar{D}^2\Phi^+,\quad \bar{D}^2\Phi^+\Phi^+,$
$\bar{D}^2\Phi^+\Phi^+\Phi^+,\quad \bar{D}^2\Phi^+\Phi^+\Phi^+\Phi^+,\quad \bar{D}^2\Phi^+\Phi^+\Phi^+\Phi^+\Phi^+,\quad \bar{D}^2\Phi^+\Phi^+\Phi^+\Phi^+\Phi^+\Phi^+.$ (3)
$D^2\Phi;$ (4.1) $D^2\Phi\Phi,\quad D^2D^2\Phi\Phi,\quad \partial\partial\Phi^+\Phi^+,\quad \partial\partial\partial\partial\Phi^+\Phi^+,\quad D^2\partial\partial\Phi\Phi,\quad D^2\Phi\Phi^+,$
$D^2D^2\partial\partial\Phi\Phi,\quad \partial\partial\Phi\Phi^+,\quad \partial D\bar{D}\Phi\Phi^+,\quad D^2\partial\partial\Phi\Phi^+,\quad D^2\partial\partial\partial\partial\Phi\Phi^+,\quad D^2\overline{D}^2\Phi\Phi^+;$ (4.2)
$D^2\Phi\Phi\Phi,\quad D^2D^2\Phi\Phi\Phi,\quad \partial\partial\Phi^+\Phi^+\Phi^+,\quad \partial\partial\partial\partial\Phi^+\Phi^+\Phi^+,\quad D^2\Phi\Phi^+\Phi^+,\quad D^2\Phi\Phi\Phi^+,$
$D^2D^2\partial\partial\Phi\Phi\Phi,\quad D^2D^2\Phi\Phi\Phi^+,\quad \partial\partial\Phi\Phi^+\Phi^+,\quad \partial D\bar{D}\Phi\Phi^+\Phi^+,\quad D^2\partial\partial\Phi\Phi^+\Phi^+,$
$D^2\partial\partial\Phi\Phi\Phi^+,\quad D^2\partial D\bar{D}\Phi\Phi\Phi^+,\quad D^2\overline{D}^2\Phi\Phi^+\Phi^+,\quad D^2D^2\overline{D}^2\Phi\Phi\Phi^+;$ (4.3)
$D^2D^2\Phi\Phi\Phi\Phi,\quad \partial\partial\Phi^+\Phi^+\Phi^+\Phi^+,\quad D^2\Phi\Phi^+\Phi^+\Phi^+,\quad D^2\Phi\Phi\Phi^+\Phi^+,\quad D^2\Phi\Phi\Phi\Phi^+,$
$D^2D^2\Phi\Phi\Phi\Phi^+,\quad \partial\partial\Phi\Phi^+\Phi^+\Phi^+,\quad \partial D\bar{D}\Phi\Phi^+\Phi^+\Phi^+,\quad D^2\partial\partial\Phi\Phi\Phi^+\Phi^+,$
$D^2\partial D\bar{D}\Phi\Phi\Phi^+\Phi^+,\quad D^2\overline{D}^2\Phi\Phi^+\Phi^+\Phi^+,\quad D^2D^2\overline{D}^2\Phi\Phi\Phi^+\Phi^+;$ (4.4)
$D^2\Phi\Phi\Phi^+\Phi^+\Phi^+,\quad D^2\Phi\Phi\Phi\Phi^+\Phi^+,\quad D^2D^2\Phi\Phi\Phi\Phi\Phi^+,\quad \partial\partial\Phi\Phi^+\Phi^+\Phi^+\Phi^+,$
$\partial D\bar{D}\Phi\Phi^+\Phi^+\Phi^+\Phi^+,\quad D^2\overline{D}^2\Phi\Phi^+\Phi^+\Phi^+\Phi^+;$ (4.5) $D^2\Phi\Phi\Phi\Phi^+\Phi^+\Phi^+$ (4.6).

BFNC Parameters

By using the following symbols,

$$\epsilon_{\alpha\beta}, \quad \epsilon^{\alpha\beta}, \quad \epsilon_{\dot\alpha\dot\beta}, \quad \epsilon^{\dot\alpha\dot\beta}, \quad \eta_{kl}, \quad \eta^{kl}, \quad \epsilon^{klmn}, \quad (\sigma^{kl})^{\alpha\beta}, \quad (\bar\sigma^{k})^{\dot\alpha\beta}, \quad \Lambda^{k}{}_{\alpha}.$$

we can construct various possible forms of BFNC parameters,

$$\Lambda^2, \quad \sigma\Lambda\Lambda; \quad (\eta\sigma\Lambda\Lambda^k)^l, \quad \Lambda^{kl}, \quad \Lambda^2\eta^{kl}, \quad \sigma\Lambda\Lambda\eta^{kl};$$
$$\Lambda^2\epsilon^{\alpha\beta}, \quad \sigma\Lambda\Lambda\epsilon^{\alpha\beta}; \quad \Lambda^2\epsilon^{\dot\alpha\dot\beta}, \quad \sigma\Lambda\Lambda\epsilon^{\dot\alpha\dot\beta};$$
$$\Lambda^2(\bar\sigma^k)^{\dot\alpha\beta}, \quad \sigma\Lambda\Lambda(\bar\sigma^k)^{\dot\alpha\beta}, \quad \Lambda^{kl}\eta_{ln}(\bar\sigma^n)^{\dot\alpha\beta}, \quad \eta_{nl}(\bar\sigma^l)^{\dot\alpha\beta}(\eta\sigma\Lambda\Lambda^n)^k, \quad \eta_{nl}(\bar\sigma^l)^{\dot\alpha\beta}(\eta\sigma\Lambda\Lambda^k)^n;$$
$$\Lambda^2\eta^{kl}\eta^{no}, \quad \sigma\Lambda\Lambda\eta^{kl}\eta^{no}, \quad \eta^{kl}\Lambda^{no}, \quad (\sigma\Lambda\Lambda^{kl})^{no}, \quad \eta^{kl}(\eta\sigma\Lambda\Lambda^n)^o;$$
$$\epsilon^{\alpha\beta}(\eta\sigma\Lambda\Lambda^k)^l, \quad \epsilon^{\alpha\beta}\Lambda^{kl}, \quad \Lambda^2\eta^{kl}\epsilon^{\alpha\beta}, \quad \sigma\Lambda\Lambda\eta^{kl}\epsilon^{\alpha\beta}, \quad \Lambda^2(\sigma^{kl})^{\alpha\beta}, \quad \sigma\Lambda\Lambda(\sigma^{kl})^{\alpha\beta},$$
$$\Lambda^{ko}\eta_{on}(\sigma^{nl})^{\alpha\beta}, \quad \epsilon^{\alpha\zeta}\epsilon^{\beta\iota}\epsilon^{klno}\eta_{np}\eta_{oq}\Lambda^p{}_\zeta\Lambda^q{}_\iota, \quad \epsilon^{\alpha\zeta}\eta_{no}(\sigma\Lambda^{ok})^{l\beta}\Lambda^n{}_\zeta, \quad \epsilon^{\alpha\zeta}(\eta\sigma\Lambda^k)^\beta\Lambda^l{}_\zeta,$$
$$\epsilon^{\alpha\zeta}\epsilon^{\beta\iota}\Lambda^k{}_\zeta\Lambda^l{}_\iota, \quad \eta^{kl}\epsilon^{\alpha\zeta}\eta_{no}(\eta\sigma\Lambda^n)^\beta\Lambda^o{}_\zeta.$$

Construction of the Effective Action of $\mathcal{S}'_{(3)}$

$$
\begin{aligned}
B_{75} &= \left(\Lambda^2 y_{75,1} + \sigma\Lambda\Lambda z_{75,1}\right)\theta^4\Phi^+, \quad B_{76} = \left(\Lambda^2 y_{76,1} + \sigma\Lambda\Lambda z_{76,1}\right)\theta^4\Phi^+\Phi^+, \\
B_{77} &= \left(\Lambda^2 y_{77,1} + \sigma\Lambda\Lambda z_{77,1}\right)\theta^4\Phi^+\Phi^+\Phi^+, \quad B_{78} = \left(\Lambda^2 y_{78,1} + \sigma\Lambda\Lambda z_{78,1}\right)\theta^4\Phi^+\Phi^+\Phi^+\Phi^+, \\
B_{79} &= \left(\Lambda^2 y_{79,1} + \sigma\Lambda\Lambda z_{79,1}\right)\theta^4\Phi^+\Phi^+\Phi^+\Phi^+\Phi^+; \\
B_{80} &= \left(\Lambda^2 y_{80,1} + \sigma\Lambda\Lambda z_{80,1}\right)\theta^4\left(\bar{D}^2\Phi^+\right), \\
B_{81} &= \left(\Lambda^2 y_{81,2} + \sigma\Lambda\Lambda z_{81,2}\right)\theta^4\left(\bar{D}^2\Phi^+\right)\Phi^+ + \left(\Lambda^2 y_{81,2} + \sigma\Lambda\Lambda z_{81,2}\right)\epsilon^{\dot\alpha\dot\beta}\theta^4\left(\bar{D}_{\dot\alpha}\Phi^+\right)\left(\bar{D}_{\dot\beta}\Phi^+\right), \\
B_{82} &= \left(\frac{1}{2}\Lambda^2 y_{82,2} + \frac{1}{2}\sigma\Lambda\Lambda z_{82,2}\right)\theta^4\left(\bar{D}^2\Phi^+\right)\Phi^+\Phi^+ + \left(\Lambda^2 y_{82,2} + \sigma\Lambda\Lambda z_{82,2}\right)\epsilon^{\dot\alpha\dot\beta}\theta^4\left(\bar{D}_{\dot\alpha}\Phi^+\right)\left(\bar{D}_{\dot\beta}\Phi^+\right)\Phi^+, \\
B_{83} &= \left(\frac{1}{3}\Lambda^2 y_{83,2} + \frac{1}{3}\sigma\Lambda\Lambda z_{83,2}\right)\theta^4\left(\bar{D}^2\Phi^+\right)\Phi^+\Phi^+\Phi^+ + \left(\Lambda^2 y_{83,2} + \sigma\Lambda\Lambda z_{83,2}\right)\epsilon^{\dot\alpha\dot\beta}\theta^4\left(\bar{D}_{\dot\alpha}\Phi^+\right)\left(\bar{D}_{\dot\beta}\Phi^+\right)\Phi^+\Phi^+, \\
B_{84} &= \left(\frac{1}{4}\Lambda^2 y_{84,2} + \frac{1}{4}\sigma\Lambda\Lambda z_{84,2}\right)\theta^4\left(\bar{D}^2\Phi^+\right)\Phi^+\Phi^+\Phi^+\Phi^+ \\
&\quad + \left(\Lambda^2 y_{84,2} + \sigma\Lambda\Lambda z_{84,2}\right)\epsilon^{\dot\alpha\dot\beta}\theta^4\left(\bar{D}_{\dot\alpha}\Phi^+\right)\left(\bar{D}_{\dot\beta}\Phi^+\right)\Phi^+\Phi^+\Phi^+, \\
B_{85} &= \left(\frac{1}{5}\Lambda^2 y_{85,2} + \frac{1}{5}\sigma\Lambda\Lambda z_{85,2}\right)\theta^4\left(\bar{D}^2\Phi^+\right)\Phi^+\Phi^+\Phi^+\Phi^+\Phi^+ \\
&\quad + \left(\Lambda^2 y_{85,2} + \sigma\Lambda\Lambda z_{85,2}\right)\epsilon^{\dot\alpha\dot\beta}\theta^4\left(\bar{D}_{\dot\alpha}\Phi^+\right)\left(\bar{D}_{\dot\beta}\Phi^+\right)\Phi^+\Phi^+\Phi^+\Phi^+; \\
B_{86} &= x_{86,1}\Lambda^{kl}\theta^4\Phi^+\partial_k\partial_l\Phi^+, \quad B_{87} = x_{87,1}\left(\eta\sigma\Lambda\Lambda^k\right)^l\theta^4\Phi^+\partial_k\partial_l\Phi^+, \\
B_{88} &= x_{88,1}\Lambda^{kl}\theta^4\Phi^+\Phi^+\partial_k\partial_l\Phi^+, \quad B_{89} = x_{89,1}\left(\eta\sigma\Lambda\Lambda^k\right)^l\theta^4\Phi^+\Phi^+\partial_k\partial_l\Phi^+.
\end{aligned}
$$

Construct Action Renormalizable to All Orders

We now deduce that $\mathcal{S}'_{(3)}$ plus these terms is renormalizable to all orders in perturbation theory,

$$\mathcal{S}'_{(3)} + \int d^8z \left(\sum_{i=75}^{89} c_i B_i \right).$$

Conclusion and Outlook

- One-loop renormalizable BFNC Wess-Zumino model.
- BFNC Wess-Zumino model Renormalizable to all orders.
- BFNC Wess-Zumino renormalizable at a higher order of BFNC parameters.
- NAC Yang-Mills model is renormalizable in Wess-Zumino gauge based on dimensional analysis, [O. Lunin et al, hep-th/0307275, D. Berenstein, hep-th/0308049].
- Check the dimensional analysis result for NAC Yang-Mills model in terms of components form in the WZ gauge. [M. Alishahiha et al, hep-th/0309037, I. Jack et al, hep-th/0412009, hep-th/0505248, hep-th/0509089, hep-th/0701096, arXiv:0808.0400, arXiv:0901.2876, arXiv:0909.1929, arXiv:1012.2000].
- Do perturbation analysis for NAC Yang-Mills model directly in superspace without expanding in components in a particular gauge, [S. Penati, hep-th/0412041, arXiv:0901.3094, M. T. Grisaru, hep-th/0510175, M. S. Bianchi et al, arXiv:0904.3260].