Published for SISSA by Springer

Received: October 12, 2023
Revised: April 14, 2024
Accepted: May 3, 2024
Published: May 20, 2024

Complete UV resonances of the dimension-8 SMEFT operators

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Abstract: The effective field theory approach parameterizes the low energy behaviors of all possible ultraviolet (UV) theories in a systematic way. One of the most important tasks is thus to find the connection between the effective operators and their UV origins. The redundancy relations among operators make the connection very subtle, hence we proposed the J-basis prescription to illuminate the correspondence between operators and their UV resonances in the bottom-up way. In this work, we work out the dimension-8 J-basis operators in the standard model effective field theory (SMEFT), and find all the 146 (82) tree-level UV resonances along with their couplings up to mass dimension 5 (4). Furthermore, we point out a few subtleties on operator generation via field redefinition and on the UV Lagrangian for generic spin resonances. We also provide a data base storing our results and a `Mathematica` notebook for extracting those results for the reader's conveinence.

Keywords: Effective Field Theories, Other Weak Scale BSM Models, SMEFT

ArXiv ePrint: 2309.15933

https://doi.org/10.1007/JHEP05(2024)238

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Contents

1 Introduction

The standard model effective field theory (SMEFT) provides the most general parametrization on all possible Lorentz-invariant new physics, encoded in the Wilson coefficients of the effective operators, see refs. [1, 2] for recent review. These effective operators are written based on the standard model field building blocks, following the Lorentz and gauge symmetry. They are organized order by order via the canonical mass dimension and they form the complete and independent basis at each order, and the operator basis has been enumerated up to dimension 9 and higher [3–12], for generic procedure to all order, see ref. [13]. After obtaining the complete basis of effective operators, the next question would be what kinds of new physics should be identified for each type of effective operators. Current experimental data show null results on new physics searches, which indicates experimental constraints on the Wilson coefficients of the SMEFT operators, e.g. ref. [14] for a global analysis. Once future data exhibit significant deviation from the SM prediction, the corresponding effective operator should be specified and their Wilson coefficients can thus be determined.

There are usually two ways to find the connection between the effective operators and their possible UV origins: the top-down approach and the bottom-up approach. In the top-down approach, a well-motivated UV model is specified with field contents and symmetry, and there are scale separation between new particles and SM particles. Then one performs the matching procedure by integrating out the heavy degrees of freedom in this model, and obtains the non-vanishing Wilson coefficients for some effective operators, which is a subset of the complete and independent operators. In this approach, it is easy to systematically identify all possible effective operators corresponding to single UV model. However, it is quite difficult to find all the possible UV origins of effective operator without performing an exhaustive search of various possible UV models, which is very time-consuming and error-prone due to the large variety of UV models. The work along this direction includes the classification of the tree-level and loop-level generated operators [15–22], the complete tree-level and one-loop dictionary for the dimension-6 operators [23, 24], and the dimension-7 operators [25], etc.

In the bottom-up approach, the aim is to find all the possible UV origins of an effective operator without writing down explicit UV Lagrangian, and it can be realized by examining the Lorentz and gauge quantum numbers for the contact on-shell amplitudes generated by the J-basis operators, proposed in ref. [26]. This approach is made possible by introducing the J-basis of the effective operators [26–28], together with the whole mechanism of Young tensor method [8, 10, 13, 29–31] including the operator reduction procedure. It is well-known that a lot of equivalence relations exist among the effective operators, and thus we have a large variety of different operator bases to choose from. One way to choose the basis, which results in the J-basis, is to find the eigenstates of all the symmetry groups, including the Poincaré group and the internal symmetry groups, when their algebra act on a "partition" of the external particles. The J in the name J-basis comes from the frame-independent angular momenta of an operator with respect to a partition defined by the Casimir W^2 of the Poincaré group. From the perspective of looking for UV origins of effective operators, the J-basis has the privilege that the quantum numbers of the possible UV resonances in a particular tree partition are fixed by the corresponding quantum numbers of the amplitude and the associated operator. Therefore, it becomes straightforward to deduce the possible resonances in the UV origin of an operator.

In this paper, we for the first time clarify the conventions for the couplings involving massive particles of spin $J \geq 1$. First, for these higher-spin massive fields in the Lagrangian, there are different choices of gauge for their couplings to the other fields that lead to different conclusions regarding whether they are responsible for certain low-energy effective operators. In particular, the source they couple to can also be decomposed into different irreducible tensors with certain spins, while the components with mismatched spins can always be converted to operators without these fields via a field redefinition. For example, the current coupling to a vector field can be decomposed into a conserved current and a total derivative, the latter being a spin-0 component and can be removed. This prescription is related to the on-shell amplitude/operator correspondence [8, 32, 33], as the couplings with non-conserved current does not produce on-shell spin-1 particle. It also leads to the justification of our J-basis algorithm, since the spin-0 coupling generates $J = 0$ amplitude and the corresponding $J = 0$ effective operator at low energy, not a $J = 1$ operator indicated by the resonance as it cannot be generated on-shell. Second, we enumerate the tree-level couplings involving massive particles of spin $J \geq 1$ in the UV theory in terms of the external particle species. We adopt the canonically normalized fields for all the particles, so that the bosons are all dimension-1 and the fermions are all dimension-3/2. Based on these tree-level couplings, we could classify the effective operators into tree-level generated and loop-induced, which is an important piece of information in phenomenology. Thirdly, we resolve the subtleties related to the generation of the operator by field redefinitions. We build a diagrammatic correspondence between the operator generation via field redefinition and the substitution of the heavy resonance with SM particles of the same quantum numbers in the tree diagram. In this way, from a seed UV theory obtained by our ordinary J-basis analysis, one can recursively remove relevant heavy resonances in the diagram to obtain a series of UV theories that can generate the operator under analysis via field redefinition after the top-down matching.

For the convenience of our readers, we have created a database in the form of a `Mathematica` package that stores all possible tree-level UV theories for each dimension-8 operator in the arXiv webpage. Each UV theory is defined by a list of new fields and new interactions, with interactions colored in red if their possible minimal dimension is greater than 4 according to our convention. Using this database, we have identified a total of 146 (82) UV resonances that can participate in the generation of dimension-8 operators at the tree level when the maximum allowed interaction dimension is set to 5 (4). Among these resonances, 88 (35) are new and not previously involved in the tree-level generation of dimension-6 and dimension-7 operators [23, 26]. However, for those restricted to a maximum dimension-4 UV interactions, all 35 of the new resonances alone are incapable of generating dimension-8 operators. They must accompany at least one other resonance that also contributes to dimension-6 or dimension-7 operators.

This paper is organized as follows. In section 2, we review the basic knowledge of our Young Tensor method, with emphasis on the method of construction of j-basis operator. In section 3, we explain the meaning of renormalizable operators and tree-level interactions in an on-shell convention, and list all the amplitude form for renormalizable 3-pt and 4-pt interactions involving different number of massive particles. In section 3 we also explain how to include those UV theories that generate a given operator via field redefinition. In section 4, we summarize the procedure for obtaining a complete set of UV theories for a given operator type using the updated J-basis analysis and introduce a database with auxiliary functions to extract all the UV theories related to a given operator in the form of a `Mathematica` package. In the meantime, we list the operator types that must be generate with at least one new UV resonance, the list of UV theoreies that does not generate dimension 6 operators, and finally the detailed information for the J-basis for each operator type. We conclude in section 5.

2 Brief review on J-basis and UV correspondence

In our previous work [26], we introduced a systematic method to obtain UV resonances by construction of j-basis of SMEFT. In this section, we briefly review basic knowledge of operator basis construction, especially the j-basis. The operator j-basis gives quantum numbers of partial wave expansion of an operator type, including partial wave of its kinematic and gauge structure. The quantum numbers stand for possible UV resonances of a scattering channel, which is the j-basis/UV correspondence.

2.1 Operator-amplitude correspondence and operator bases

The SMEFT operators are classified by dimension, class and type. An operator class shows helicities of each field and the number of derivatives, while a type also includes gauge quantum numbers of each field. A systematic method of constructing a non-redundant operator basis was introduced in [8, 10]. The method involves the operator-amplitude correspondence and a generalized Young diagram method. The operator-amplitude correspondence is based on the Fourier transformation of a field. For example, a derivative ∂ becomes a momentum

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p after the Fourier transformation. This feature allows us to construct an amplitude basis instead of directly constructing an operator basis, so that we can apply all the properties of an on-shell amplitude. The generalized Young diagram method is originated from tensor representation of the Poincaré and gauge groups.

2.1.1 Operator-amplitude correspondence

There is a one-to-one map between contact amplitudes and irrelevant EFT operators, also shown in [8, 10, 26, 32]. A following problem comes from the covariant derivative D, causing a condition that one operator probably contributes to several vertices. Therefore we only pay attention to the leading vertex with minimal fields, treating D as ∂, and $F_{\mu\nu}$ as $\partial_\mu A_\nu - \partial_\nu A_\mu$. The two other redundancies of operators, integration by part (IBP) and equation of motion (EoM), can be erased automatically by on-shell amplitude basis construction. To be more specific, the on-shell operator-amplitude correspondence is an isomorphism between the linear spaces of irrelevant operators and independent contact amplitudes. Thus the key idea is (i) to find the map between the building blocks of operators and amplitudes, (ii) to construct an independent amplitude basis, so that we obtain an independent operator basis.

We start with the building blocks of operators and amplitudes, which are the representations of the Lorentz group $\mathrm{SO}(3,1) \sim \mathrm{SL}(2,\mathbb{C}) = \mathrm{SU}(2)_l \times \mathrm{SU}(2)_r$ and the gauge group $\mathrm{SU}(3)_C \otimes \mathrm{SU}(2)_W \otimes \mathrm{U}(1)_Y$. The operator building blocks of the Lorentz symmetry are

Irrep	$(0,0)$	$(\frac{1}{2},0)$	$(0,\frac{1}{2})$	$(1,0)$	$(0,1)$	$(\frac{1}{2},\frac{1}{2})$
Operator block	ϕ	ψ	$\psi^\dagger$	$F_L = \frac{1}{2}(F + i\tilde{F})$	$F_R = \frac{1}{2}(F - i\tilde{F})$	D

(2.1)

Meanwhile the amplitudes are expressed in the spinor-helicity formalism, where a massless particle i of helicity h_i gives $\lambda_i^{r_i-h_i}\tilde{\lambda}_i^{r_i+h_i}$. A Lorentz singlet can be determined by a proper set of $\{h_i, r_i\}$. Also, since $p_i = \lambda_i\tilde{\lambda}_i \sim (\frac{1}{2},\frac{1}{2}) \sim D$, the following translation can be inferred

Amplitude Block	$\lambda_i^{r_i}\tilde{\lambda}_i^{r_i}$	$\lambda_i^{r_i+1/2}\tilde{\lambda}_i^{r_i-1/2}$	$\lambda_i^{r_i-1/2}\tilde{\lambda}_i^{r_i+1/2}$	$\lambda_i^{r_i+1}\tilde{\lambda}_i^{r_i-1}$	$\lambda_i^{r_i-1}\tilde{\lambda}_i^{r_i+1}$
Operator Block	$D^{r_i}\phi_i$	$D^{r_i-1/2}\psi_i$	$D^{r_i-1/2}\psi_i^\dagger$	$D^{r_i-1}F_L$	$D^{r_i-1}F_R$

(2.2)

The translation implies that the covariant derivative commutator (CDC) is treated as a Lorentz redundancy and eliminated, which satisfies the choice of leading vertex. The amplitude blocks show that helicity indices of the derivatives on a field are symmetric and without contraction, or there will be $[D,D] = F$ or EoM.

2.1.2 Operator basis construction

In [8, 10], a complete and independent operator basis is given by the semi-standard Young tableau (SSYT) and the generalized Littlewood-Richardson (LR) rule for Lorentz and gauge group respectively.

The Young diagram of $\mathrm{SL}(2,\mathbb{C}) \times \mathrm{U}(N)$ is

$$[\mathcal{M}]_{N,\tilde{n},n} = N-2\left\{\begin{array}{l} \underbrace{\boxed{}\cdots\boxed{}}_{\tilde{n}}\overbrace{\boxed{}\cdots\boxed{}}^{n} \\ \boxed{}\cdots\boxed{}\boxed{}\cdots\boxed{} \\ \vdots \qquad \vdots \\ \boxed{}\cdots\boxed{} \\ \underbrace{\boxed{}\cdots\boxed{}}_{\tilde{n}} \end{array}\right. , \tag{2.3}$$

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where N is the number of particles. The number of columns for $\mathrm{SL}(2,\mathbb{C}) \times \mathrm{U}(N)$ irrep n and conjugate irrep $\tilde{n}$ are determined by

$$n = \frac{k}{2} + \sum_{h_i<0} h_i, \tilde{n} = \frac{k}{2} + \sum_{h_i>0} h_i, \#i = \tilde{n} - 2h_i, \tag{2.4}$$

where k is the number of derivative, h_i is the helicity of particle i, and $\#i$ is the number of label i appearing in the SSYTs. The SSYTs are translated into amplitudes as

$$\langle ij\rangle \sim \begin{array}{|c|}\hline i \\ \hline j \\ \hline\end{array}, \quad [ij] \sim \mathcal{E}^{k_1\dots k_{N-2}ij}\tilde{\lambda}_i\tilde{\lambda}_j \sim \left.\rotatebox{90}{$N-2$}\right\{ \begin{array}{|c|}\hline k_1 \\ \hline k_2 \\ \hline \vdots \\ \hline k_{N-2} \\ \hline\end{array}\,, \tag{2.5}$$

and a complete amplitude is the product of all columns. Once the parameters are determined, the SSYTs give a complete and independent amplitude basis, free from IBP, EoM and Schouten identity redundancies.

For example, the helicity category of type $De_{\mathbb{C}}{}^{\dagger}HQ^3$ is $\{-\frac{1}{2}, -\frac{1}{2}, -\frac{1}{2}, 0, +\frac{1}{2}\}$, and there is one momentum given by the derivative D. Following eq. (2.3), (2.4), one can obtain type $De_{\mathbb{C}}{}^{\dagger}HQ^3$'s Lorentz y-basis

$$\mathcal{B}^y = \begin{pmatrix} \langle 12\rangle\langle 34\rangle[45] \\ -\langle 13\rangle\langle 23\rangle[35] \\ \langle 13\rangle\langle 24\rangle[45] \end{pmatrix}. \tag{2.6}$$

The gauge y-basis construction is based on the tensor representation of $\mathrm{SU}(N)$ gauge group. A field $\mathcal{F}$ with anti-fundamental or adjoint indices are converted into $N-1$ or N fundamental indices respectively,

$$\mathcal{F}^A \to \mathcal{F}_{a_1\dots a_{N-1}i} \equiv \mathcal{F}^A(T^A)_i^{a_N}\epsilon_{a_1\dots a_N} \sim \begin{array}{|c|c|}\hline a_1 & i \\ \hline \vdots & \multicolumn{1}{c}{} \\ \cline{1-1} a_{M-1} & \multicolumn{1}{c}{} \\ \cline{1-1}\end{array} \; ; \tag{2.7}$$

$$\mathcal{F}^a \to \mathcal{F}_{a_1\dots a_{N-1}} \equiv \mathcal{F}^a\epsilon_{a_1\dots a_{N-1}a} \sim \begin{array}{|c|}\hline a_1 \\ \hline \vdots \\ \hline a_{N-1} \\ \hline\end{array}\,. \tag{2.8}$$

Then we apply the generalized L-R rule to Young tableaux to construct a series of $\mathrm{SU}(N)$ singlets, where each column represents an ϵ tensor, and each expression within a y-basis is the product of the ϵ tensors derived from its Young tableau.

The type $De_{\mathbb{C}}{}^{\dagger}HQ^3$ contains four $\mathrm{SU}(2)_W$-doublets

$$Q_{i_1}, Q_{i_2}, Q_{i_3}, H_{i_4}. \tag{2.9}$$

According to the generalized L-R rule, the $\mathrm{SU}(2)_W$ y-basis is constructed as

$$\boxed{i_1} \xrightarrow{\boxed{i_2}} \begin{array}{|c|c|}\hline i_1 & i_2 \\ \hline\end{array} \xrightarrow{\boxed{i_3}} \begin{array}{|c|c|}\hline i_1 & i_2 \\ \hline i_3 \\ \cline{1-1}\end{array} \xrightarrow{\boxed{i_4}} \begin{array}{|c|c|}\hline i_1 & i_2 \\ \hline i_3 & i_4 \\ \hline\end{array} \sim \mathcal{T}^y_2 = \epsilon^{i_1 i_3}\epsilon^{i_2 i_4}, \tag{2.10}$$

$$\mathcal{T}^y_1 = \epsilon^{i_1 i_2}\epsilon^{i_3 i_4}. \tag{2.11}$$

The y-basis is not necessarily composed of monomials after simplification, because of eq. (2.7), (2.8), but we can always choose a group of independent and complete monomials from the y-basis, namely the monomial basis (m-basis) [8, 10, 13]. In the former example $De_{\mathbb{C}}{}^{\dagger}HQ^3$, we are lucky to find out that its $\mathrm{SU}(2)_W$ y-basis is composed of monomials. Along with the $\mathrm{SU}(3)_C$ structure, the m-basis of type $De_{\mathbb{C}}{}^{\dagger}HQ^3$ is

$$\mathcal{O}^m = \begin{pmatrix} \mathcal{O}^m_1 \\ \mathcal{O}^m_2 \\ \mathcal{O}^m_3 \\ \mathcal{O}^m_4 \\ \mathcal{O}^m_5 \\ \mathcal{O}^m_6 \end{pmatrix} = \begin{pmatrix} i\epsilon^{abc}\epsilon^{ik}\epsilon^{jl}(D_\mu H_l)(Q_{sck}\sigma^\mu e_{\mathbb{C}}{}^{\dagger}_t)(Q_{pai}Q_{rbj}) \\ i\epsilon^{abc}\epsilon^{ik}\epsilon^{jl}H_l(Q_{pai}\sigma^\mu e_{\mathbb{C}}{}^{\dagger}_t)(Q_{rbj}(D_\mu Q_{sck})) \\ i\epsilon^{abc}\epsilon^{ik}\epsilon^{jl}(D_\mu H_l)(Q_{rbj}\sigma^\mu e_{\mathbb{C}}{}^{\dagger}_t)(Q_{pai}Q_{sck}) \\ i\epsilon^{abc}\epsilon^{ij}\epsilon^{kl}(D_\mu H_l)(Q_{sck}\sigma^\mu e_{\mathbb{C}}{}^{\dagger}_t)(Q_{pai}Q_{rbj}) \\ i\epsilon^{abc}\epsilon^{ij}\epsilon^{kl}H_l(Q_{pai}\sigma^\mu e_{\mathbb{C}}{}^{\dagger}_t)(Q_{rbj}(D_\mu Q_{sck})) \\ i\epsilon^{abc}\epsilon^{ij}\epsilon^{kl}(D_\mu H_l)(Q_{rbj}\sigma^\mu e_{\mathbb{C}}{}^{\dagger}_t)(Q_{pai}Q_{sck}) \end{pmatrix}, \tag{2.12}$$

where $\{a,b,c\}$ are $\mathrm{SU}(3)_C$ fundamental indices, $\{i,j,k,l\}$ SU(2) fundamental, and $\{p,r,s,t\}$ flavor.

In some cases it is inevitable to deal with repeated fields. If we want to have a flavor specified independent basis (discussed in [13]), we need to rearrange the operators into irreducible representations (irreps) of the $\mathrm{SU}(n_f)$ flavor group. The process from m-basis to flavor-specified basis (f-basis) requires two steps. First we construct irreps of permutation group S_m and obtain the permutation basis (p-basis), where m is the number of repeated fields. According to the Schur-Weyl duality, any irrep of S_m is also an irrep of $\mathrm{SU}(n_f)$. Then we select the operators that span different $\mathrm{SU}(n_f)$ tensor spaces of each irrep, and obtain the f-basis.

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For example, type $De_{\mathbb{C}}{}^{\dagger}HQ^3$ has three repeated Q's. The irreps of $\mathrm{SU}(n_f)$ (S_3) by $\{Q_r, Q_s, Q_t\}$ are $\{\ytableaushort{rst}, \ytableaushort{rs,t}, \ytableaushort{r,s,t}\}$, and the p-basis is

$$\mathcal{O}^p_{\ydiagram{3}} = \mathcal{Y}[\ytableaushort{rst}]\mathcal{O}^m_1, \tag{2.13}$$

$$\mathcal{O}^p_{\ydiagram{2,1}} = \begin{pmatrix} \mathcal{Y}[\ytableaushort{rs,t}]\mathcal{O}^m_1 \\ (s\ t)\mathcal{Y}[\ytableaushort{rs,t}]\mathcal{O}^m_1 \\ \mathcal{Y}[\ytableaushort{rs,t}]\mathcal{O}^m_2 \\ (s\ t)\mathcal{Y}[\ytableaushort{rs,t}]\mathcal{O}^m_2 \end{pmatrix}, \tag{2.14}$$

$$\mathcal{O}^p_{\ydiagram{1,1,1}} = \mathcal{Y}[\ytableaushort{r,s,t}]\mathcal{O}^m_1. \tag{2.15}$$

Notice that $\mathcal{Y}[\ytableaushort{rs,t}]$ and $(s\ t)\mathcal{Y}[\ytableaushort{rs,t}]$ span the same linear space of an irrep of $\mathrm{SU}(n_f)$, so the f-basis is

$$\mathcal{O}^f_{\ydiagram{3}} = \mathcal{Y}[\ytableaushort{rst}]\mathcal{O}^m_1, \tag{2.16}$$

$$\mathcal{O}^f_{\ydiagram{2,1}} = \begin{pmatrix} \mathcal{Y}[\ytableaushort{rs,t}]\mathcal{O}^m_1 \\ \mathcal{Y}[\ytableaushort{rs,t}]\mathcal{O}^m_2 \end{pmatrix}, \tag{2.17}$$

$$\mathcal{O}^f_{\ydiagram{1,1,1}} = \mathcal{Y}[\ytableaushort{r,s,t}]\mathcal{O}^m_1. \tag{2.18}$$

So far the bases we have introduced do not directly predict the possible UV origins. From the group theory point of view, the UV particles generating the effective operators are the possible irreps of the Poincaré group and the gauge group. This recognition leads to the partial wave expansion of amplitudes of a certain scattering process that gives the angular momentum J and gauge quantum number $\mathbf{R}$ of the multi-particle state at the scattering channel. The traditional partial wave expansion mainly focuses on $2 \to N$ scattering, but we can always generalize the concept to $M \to N$ scattering and multi-partite scattering, as is shown in [26], in order to obtain complete tree-level UV origins. Along with the operator-amplitude correspondence, we can apply the partial wave expansion on a complete and independent operator basis under any possible topology, and gain the information of the resonances. The result is named j-basis. J-basis is an eigenbasis of the partial Casimir operators under the given topology. We shall discuss the details of j-basis construction after introducing the Casimir operators of Poincaré group and $\mathrm{SU}(N)$ and the definition of partial Casimir operators in the next subsection. The key idea is to transfer the partial wave problem into a linear algebra problem about solving the eigenfunctions of partial Casimir operators. Figure 1, proposed in [26], gives the relations among all the bases mentioned above.

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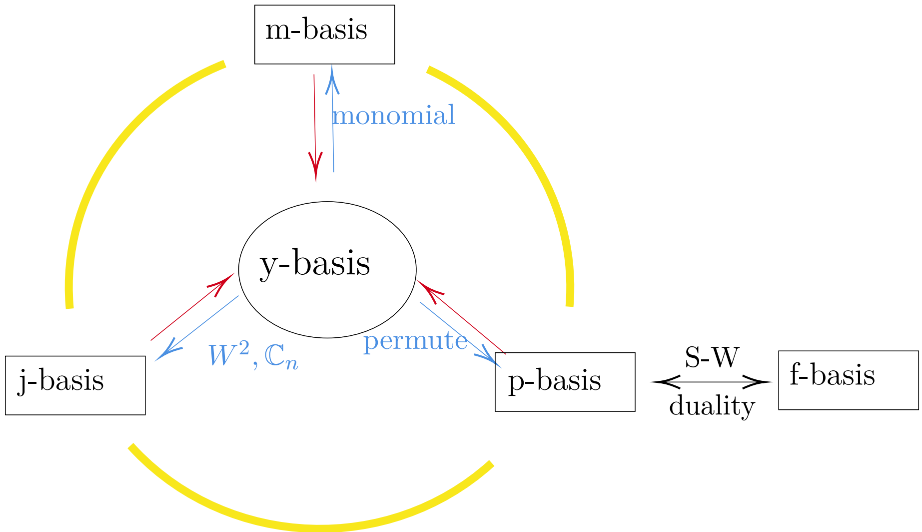

Figure 1. Relations among the different bases [13]. The red arrow means that the basis can always be expressed as linear combination of the y-basis through a reduce procedure. The yellow circle indicates that the m-basis, the p-basis and the j-basis are related by linear transformations. The operators in the p-basis are tensors of the symmetric group S_m, and those in the f-basis are tensors of $\mathrm{SU}(n_f)$ group, where m is the number of repeated fields and n_f is the flavor number of each repeated field. These two basis are connected by the Schur-Weyl duality.

2.2 Pauli-Lubanski and gauge Casimir projection

First we need to determine all the scattering channels to do the partial wave expansion, which requires the concept of partition. Let us start with the traditional $2 \to N$ scattering. This process involves $N+2$ particles totally, with the incoming channel $\mathcal{I}_1 = \{12\}$ and the outgoing one $\mathcal{I}_2 = \{3 \ldots (N+2)\}$, so its partition is $\{12|3 \ldots (N+2)\}$. Notice that the partition satisfies two conditions that (i) $\mathcal{I}_1 \cup \mathcal{I}_2 = \{1, 2, 3, \ldots, (N+2)\}$; and (ii) the two channels do not overlap $\mathcal{I}_1 \cap \mathcal{I}_2 = \varnothing$. This specific example also satisfies $\mathcal{I}_1 = \bar{\mathcal{I}}_2$, where $\bar{\mathcal{I}}_i \equiv \{1, \ldots, N, N+1, N+2\} - \mathcal{I}_i$, which is the feature of a 2-partite partition.

Then we generalize 2-partite partitions to multi-partite partitions. For simplicity, we treat all particles as incoming ones, and suppose there are totally N external particles. Intuitively, we can obtain a multi-partite partition by dividing the N external particles into several channels, satisfying the generalized conditions of (i) and (ii) mentioned in the last paragraph. An m-partite partition of N external particles is denoted as $N|m \equiv \mathcal{I}_{1,\ldots,m} \subset \{1, \ldots, N\}$, with requirement (i) and the generalized one of (ii), denoted as (ii$'$)

$$\mathcal{I}_i \cap \mathcal{I}_j = \varnothing \text{ or } \mathcal{I}_i \cap \bar{\mathcal{I}}_j = \varnothing \tag{2.19}$$

that any two channels are either non-overlapping or contain one another. All the possible partitions of particles $\{1, \ldots, N\}$ form a space $\mathbb{P}_N$ with S_N symmetry. If we apply the quotient set $\mathbb{P}_N / S_N$, the result is a set of all possible topologies, usually labeled by diagrams. For example, when $N = 6$, one of all the possible partitions is $\{12|123|456|56\}$. Channel $\{12\} \subset \{123\}$ and $\{12\} \cap \{456\} = \varnothing$ satisfies the requirement (ii$'$). In this case, both $\{12|123|456|56\}$ and $\{12|124|356|56\}$ belong to topology .

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The multi-partite partitions provide favorable conditions of defining partial Casimir operators. Casimir operators label the irreps of their group/algebra, which can be very useful to partial wave expansion. A partial Casimir operator thus labels the irreps of a specific channel, so that the resonance information of all scattering channels can be obtained if we consider all the partial Casimir operators.

2.2.1 Lorentz j-basis

There are two Casimir operators in the Poincaré algebra, momentum $\mathbf{P}^2$ and the Pauli-Lubanski operator $\mathbf{W}^2$, which label irreps of the Poincaré group

$$\mathbf{W}^2|P,J,\sigma\rangle = -P^2 J(J+1)|P,J,\sigma\rangle, \tag{2.20}$$

$$\mathbf{P}^2|P,J,\sigma\rangle = P^2|P,J,\sigma\rangle. \tag{2.21}$$

The partial wave expansion of an N-pt scattering amplitude $\mathcal{M}(\{\Psi\}_{N|m})$ in partition $N|m$ is in the form

$$\mathcal{M}(\{\Psi\}_{N|m}) = \sum_{J_1,\dots,J_m}\sum_a \mathcal{M}_a^{J_1,\dots,J_m}(\{s\}_{N|m})\overline{\mathcal{B}}_a^{J_1,\dots,J_m}(\{\Psi\}_{N|m}), \tag{2.22}$$

where $\{\Psi\}_{N|m}$ denotes the states of N particles divided into partition $N|m$, J_i denotes the total angular momentum of channel $\mathcal{I}_i$, $\mathcal{M}_a^{J_1,\dots,J_m}(\{s\}_{N|m})$ contains the physical information of the scattering process and is irrelevant to the partial wave, a is the possible degeneracy, and $\overline{\mathcal{B}}_a^{J_1,\dots,J_m}(\{\Psi\}_{N|m})$ is the partial wave basis

$$\overline{\mathcal{B}}_a^{J_1,\dots,J_m}(\{\Psi\}_{N|m}) = (\prod_{i=1}^m \langle P_i,J_i,\sigma_i|\{\Psi\}_{N_i}\rangle) b_a^{J_1,\dots,J_m}. \tag{2.23}$$

If we only pay attention to channel $\mathcal{I}_i$, we can always act $\mathbf{W}^2$ on state $|P_i,J_i,\sigma_i\rangle$

$$\langle P_i,J_i,\sigma_i|\mathbf{W}^2|\{\Psi\}_{N_i}\rangle \equiv W^2_{\mathcal{I}_i}\langle P_i,J_i,\sigma_i|\{\Psi\}_{N_i}\rangle = -P_i^2 J_i(J_i+1)\langle P_i,J_i,\sigma_i|\{\Psi\}_{N_i}\rangle, \tag{2.24}$$

where $W^2_{\mathcal{I}_i}$ is defined as the partial Casimir operator of $\mathbf{W}^2$ only concerning channel $\mathcal{I}_i$. The definition is essential, because an amplitude is always a Lorentz singlet, but part of the external particles in a specific channel may form a non-trivial irrep that can be detected by the partial Casimir operator of this channel. Since $W^2_{\mathcal{I}_i}$ is defined in the subspace $|\{\Psi\}_{N_i}\rangle$ in $|\{\Psi\}_N\rangle$, it must satisfy

$$W^2_{\mathcal{I}_i}\langle P_j,J_j,\sigma_j|\{\Psi\}_{N_j}\rangle = 0 \ (\forall i\neq j). \tag{2.25}$$

Therefore

$$W^2_{\mathcal{I}_i}\overline{\mathcal{B}}_a^{J_1,\dots,J_m}(\{\Psi\}_{N|m}) = -s_{\mathcal{I}_i}J_i(J_i+1)\overline{\mathcal{B}}_a^{J_1,\dots,J_m}(\{\Psi\}_{N|m}), \tag{2.26}$$

where $s_{\mathcal{I}_i} = P_i^2$ is the Mandelstam variable of channel $\mathcal{I}_i$. We apply the spinor-helicity formalism, and the form of W^2 given in [27] is thus

$$W^2 = \frac{1}{8}P^2(\mathrm{Tr}[M^2]+\mathrm{Tr}[\widetilde{M}^2]) - \frac{1}{4}\mathrm{Tr}[P^\intercal M P\widetilde{M}], \tag{2.27}$$

where $P = P_\mu \sigma^\mu_{\alpha\dot\alpha}$, $P^\intercal = P_\mu \bar\sigma^{\mu\dot\alpha\alpha}$, and M, $\widetilde{M}$ are the chiral components of the Lorentz generator $M_{\mu\nu}\sigma^\mu_{\alpha\dot\alpha}\sigma^\nu_{\beta\dot\beta} = \epsilon_{\alpha\beta}\widetilde{M}_{\dot\alpha\dot\beta} + \tilde\epsilon_{\dot\alpha\dot\beta}M_{\alpha\beta}$.

Eq. (2.26) is an eigenfunction of $W^2_{\mathcal{I}_i}$, so a natural question emerges whether there is a basis to solve the eigenfunction, so that the partial wave expansion becomes a linear algebra problem. Luckily, we have already introduced how to construct a complete and independent basis classified by dimension and external particles. To sum up, the process of partial wave expansion consists of five steps:

1. Find out the linear space spanned by a complete and independent basis (usually the y-basis) at dimension d, $V^d \equiv [\mathcal{B}^{y,d}]$;

2. Determine the partition $N|m$ and its corresponding partial Casimir operators $\{W^2_{\mathcal{I}_i}\}$;

3. Act each partial Casimir operator on the basis $\{W^2_{\mathcal{I}_i}\mathcal{B}^{y,d}\}$ and obtain a series of equations;

4. Solve the eigenfunction of each $W^2_{\mathcal{I}_i}$ and obtain the corresponding irreps;

5. Find out the linear intersections of the irreps' spaces of each $W^2_{\mathcal{I}_i}$ and obtain a series of eigenbasis of $\{W^2_{\mathcal{I}_i}\}$, which is named as the Lorentz j-basis.

We still study type $De_{\mathbb{C}}{}^\dagger HQ^3$ as an example and construct its Lorentz j-basis of partition

$\{12|5|34\}$, .

Eq. (2.6) gives its Lorentz y-basis. Since partition $\{12|5|34\}$ contains two resonances, we only need to focus on channel $\{12\}$ and $\{34\}$. Act $W^2_{\{12\}}$ on $\mathcal{B}^y$ and

$$W^2_{\{12\}}\mathcal{B}^y = -s_{12}\mathcal{W}_{\{12\}}\mathcal{B}^y,\ \mathcal{W}_{\{12\}} = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 2 & 0 \\ -1 & 0 & 2 \end{pmatrix}. \tag{2.28}$$

Diagonalize the matrix $\mathcal{W}_{\{12\}}$

$$\mathcal{K}^{jy}_{\{12\}} = \begin{pmatrix} -1 & 0 & 2 \\ 0 & 1 & 0 \\ 1 & 0 & 0 \end{pmatrix}, \quad \mathcal{K}^{jy}_{\{12\}}\mathcal{W}_{\{12\}}(\mathcal{K}^{jy}_{\{12\}})^{-1} = \mathrm{diag}(2,2,0) \\ \Rightarrow J_{\{12\}} = (1,1,0), \tag{2.29}$$

where $\mathcal{B}^j_{\mathcal{I}} = \mathcal{K}^{jy}_{\mathcal{I}}\mathcal{B}^y$. The amplitude space $[\mathcal{B}^y]$ is decomposed into two subspaces of irreps $J_{\{12\}} = 1$ and $J_{\{12\}} = 0$ respectively. Similarly for channel $\{34\}$, the transformation matrix $\mathcal{K}^{jy}_{\{34\}}$ and the corresponding spins $J_{\{34\}}$ are

$$\mathcal{K}^{jy}_{\{34\}} = \begin{pmatrix} -1 & 1 & 2 \\ 0 & -1 & 1 \\ 1 & 0 & 0 \end{pmatrix}, \quad J_{\{34\}} = \left(\frac{3}{2}, \frac{1}{2}, \frac{1}{2}\right). \tag{2.30}$$

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So far there are two kinds of decomposition of space $[\mathcal{B}^y]$, $[J_{\{12\}}=1]\oplus[J_{\{12\}}=0]$ and $[J_{\{34\}}=\frac{3}{2}]\oplus[J_{\{34\}}=\frac{1}{2}]$, derived from $W^2_{\{12\}}\mathcal{B}^y$ and $W^2_{\{34\}}\mathcal{B}^y$ respectively. Then we find out the linear intersections of the subspaces

$$[J_{\{12\}}=1]\bigcap\left[J_{\{34\}}=\frac{3}{2}\right]=\mathrm{Span}[\begin{pmatrix}1 & -1 & -2\end{pmatrix}\mathcal{B}^y], \tag{2.31}$$

$$[J_{\{12\}}=1]\bigcap\left[J_{\{34\}}=\frac{1}{2}\right]=\mathrm{Span}[\begin{pmatrix}-1 & -2 & 2\end{pmatrix}\mathcal{B}^y], \tag{2.32}$$

$$[J_{\{12\}}=0]\bigcap\left[J_{\{34\}}=\frac{1}{2}\right]=\mathrm{Span}[\begin{pmatrix}-1 & 0 & 0\end{pmatrix}\mathcal{B}^y], \tag{2.33}$$

where the row vectors on the r.h.s. are left eigenvectors of $W^2_{\{12\}}$ and $W^2_{\{34\}}$. Therefore the Lorentz j-basis of partition $\{12|125|34\}$ is

$$\mathcal{B}^j_{\{12|125|34\}}=\mathcal{K}^{jy}_{\{12|125|34\}}\mathcal{B}^y=\begin{pmatrix}1 & -1 & -2\\ -1 & -2 & 2\\ -1 & 0 & 0\end{pmatrix}\mathcal{B}^y,\ (J_{\{12\}},J_{\{34\}})=\begin{pmatrix}(1,\frac{3}{2})\\ (1,\frac{1}{2})\\ (0,\frac{1}{2})\end{pmatrix}. \tag{2.34}$$

2.2.2 Gauge j-basis

The partial wave expansion for gauge group shares a similar principle to the Poincaré group, that the Casimir operator labels the irreps of its group

$$\underset{\mathbb{S}}{\mathbb{C}_n}\circ\mathcal{T}(\mathbf{R};\mathbb{S})_{I_1\ldots I_N}=\underset{\mathbb{S}}{C_n}(\mathbf{R})\mathcal{T}(\mathbf{R};\mathbb{S})_{I_1\ldots I_N} \tag{2.35}$$

where $\mathbb{C}_n$ is a Casimir operator, $\mathbb{S}\subset\{1,\ldots,N\}$ labels a channel of particles with direct product of irreps $\otimes\{\mathbf{r}_i|i\in\mathbb{S}\}$, $\mathcal{T}(\mathbf{R};\mathbb{S})_{I_1\ldots I_N}$ is a tensor in a partial wave basis of the irrep $\mathbf{R}$ and $\otimes\{\mathbf{r}_i|i\in\mathbb{S}\}$, and $C_n(\mathbf{R})$ is the eigenvalue of $\mathbf{R}$.

Since we mainly focus on the Standard Model gauge group, we only give the Casimir operators of SU(2) and SU(3)

$$\mathbb{C}_2=\mathbb{T}^a\mathbb{T}^a,\ \text{for both SU(2) and SU(3)}, \tag{2.36}$$

$$\mathbb{C}_3=d^{abc}\mathbb{T}^a\mathbb{T}^b\mathbb{T}^c,\ \text{for SU(3) only}, \tag{2.37}$$

where $\mathbb{T}$'s are generators of their corresponding groups. The generator of direct product of irreps derived from the exponential map of SU(N) is in the form

$$\mathbb{T}^A_{\otimes\{\mathbf{r}_i\}}=\sum_{i=1}^{N}T^A_{\mathbf{r}_i}\prod_{j\neq i}E_{\mathbf{r}_j}, \tag{2.38}$$

where $E_{\mathbf{r}_j}$ is the identity matrix of irrep $\mathbf{r}_j$, and $T^A_{\mathbf{r}_i}$ is the generator of irrep $\mathbf{r}_i$. Such a generator acting on a tensor in the space of $\otimes\{\mathbf{r}_i\}$ gives

$$\mathbb{T}^A_{\otimes\{\mathrm{r}_i\}}\circ\Theta_{I_1\ldots I_i\ldots I_N}=\sum_{i=1}^{N}(T^A_{\mathbf{r}_i})^J_{I_i}\Theta_{I_1\ldots J\ldots I_N}. \tag{2.39}$$

To realize the partial Casimir operator $\underset{\mathbb{S}}{\mathbb{C}_n}$, we define the partial generator of $i\in\mathbb{S}$

$$\underset{\mathbb{S}}{\mathbb{T}}^A\circ\Theta_{I_1\ldots I_N}=\sum_{i\in\mathbb{S}}(T^A_{\mathbf{r}_i})^J_{I_i}\Theta_{I_1\ldots J\ldots I_N}. \tag{2.40}$$

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We still focus on type $De_{\mathbb{C}}{}^{\dagger}HQ^3$, and construct its $\mathrm{SU}(2)_W$ j-basis of partition $\{12|5|34\}$, following the same pattern as the construction of its Lorentz j-basis. First we act the partial Casimir operator on the gauge y-basis (also its gauge m-basis) in eq. (2.10)

$$\begin{aligned}\underset{\{12\}}{\mathbb{C}_2}\circ\mathcal{T}^y_1 &= \underset{\{12\}}{\mathbb{T}}{}^I\circ\underset{\{12\}}{\mathbb{T}}{}^I\circ\mathcal{T}^y_1 = \underset{\{12\}}{\mathbb{T}}{}^I\circ(\tau^{I}{}^{i_1}_{j}\epsilon^{ji_3}\epsilon^{i_2i_4}+\tau^{I}{}^{i_2}_{j}\epsilon^{i_1i_3}\epsilon^{ji_4})\\ &= \epsilon^{i_1i_3}\epsilon^{i_2i_4}+\epsilon^{i_1i_4}\epsilon^{i_2i_3} = 2\mathcal{T}^y_1-\mathcal{T}^y_2,\end{aligned} \tag{2.41}$$

$$\underset{\{12\}}{\mathbb{C}_2}\circ\mathcal{T}^y = (\underset{\{12\}}{C_2})^{\mathrm{T}}\mathcal{T}^y = \begin{pmatrix}2 & -1\\ 0 & 0\end{pmatrix}\begin{pmatrix}\mathcal{T}^y_1\\ \mathcal{T}^y_2\end{pmatrix} \tag{2.42}$$

and obtain the matrix $(\underset{\{12\}}{C_2})^{\mathrm{T}}$. Then we diagonalize $(\underset{\{12\}}{C_2})^{\mathrm{T}}$ and gain the transformation matrix $\mathcal{K}^{jy}_{\{12\}}$ from y(m)-basis to j-basis of channel $\{12\}$

$$\mathcal{K}^{jy}_{\{12\}}(\underset{\{12\}}{C_2})^{\mathrm{T}}(\mathcal{K}^{jy}_{\{12\}})^{-1} = \mathrm{diag}\{2,0\},\ \text{with } \mathcal{K}^{jy}_{\{12\}} = \begin{pmatrix}-2 & 1\\ 0 & 1\end{pmatrix}. \tag{2.43}$$

The process for channel $\{34\}$ is the same. Finally we find out the linear intersections of irreps in each channel, and the result is

$$\mathcal{T}^j_{\{12|5|34\}} = \mathcal{K}^{jy}_{\{12|5|34\}}\mathcal{T}^y = \begin{pmatrix}2 & -1\\ 0 & -1\end{pmatrix}\begin{pmatrix}\mathcal{T}^y_1\\ \mathcal{T}^y_2\end{pmatrix}\ \text{with } (\mathbf{R}_{\{12\}},\mathbf{R}_{\{34\}}) = \begin{pmatrix}(\mathbf{3},\mathbf{3})\\ (\mathbf{1},\mathbf{1})\end{pmatrix}. \tag{2.44}$$

3 UV resonance and effective operators

3.1 Higher spin resonances the on-shell way

In the Young tensor method, the building blocks for particles with spin $J \geq 1$ are the field strength, such as $F_{\mu\nu}$ for spin-1 particles and the Weyl tensor $C_{\mu\nu\rho\lambda}$ for spin-2 particles. However, when we construct the UV theory with such higher spin massive particles, the basic building blocks are usually taken to be V_μ and $h_{\mu\nu}$ for spin-1 and spin-2 particles, which involves longitudinal polarizations that are not allowed in the massless theories due to the gauge symmetries. These building blocks allow for larger freedom of constructing operators, but more redundancy relations are also introduced by the EOM. For example, the EOM of the vector field V_μ is

$$\partial^\nu F_{\mu\nu} + M^2 V_\mu + J_\mu = 0\,, \tag{3.1}$$

where J_μ is the source of V^μ. Applying ∂^μ we get another EOM

$$\partial^\mu V_\mu = -\frac{1}{M^2}\partial^\mu J_\mu\ . \tag{3.2}$$

The fact that there is no V_μ field on the right-hand side reflects the physical constraint on the polarization vector $k^\mu\epsilon_\mu = 0$, which indicates that the left-hand side does not create on-shell vector particle. It proves that we can always replace the $\partial^\mu V_\mu$ part in the operator by V-independent pieces. More specifically, suppose the source can be decomposed as

$$J_\mu = \partial_\mu\Phi + \mathcal{J}_\mu\,, \tag{3.3}$$

where Φ is a scalar operator. We can perform a field redefinition $V_\mu \to V_\mu - \frac{1}{M^2}\partial_\mu \Phi$, such that

$$\begin{aligned} &\mathcal{L}_{\rm UV} = -\frac{1}{4}F_{\mu\nu}F^{\mu\nu} + \frac{1}{2}M^2 V_\mu V^\mu + V_\mu J^\mu \\ \to \quad &\tilde{\mathcal{L}}_{\rm UV} = -\frac{1}{4}F_{\mu\nu}F^{\mu\nu} + \frac{1}{2}M^2 V_\mu V^\mu - \frac{1}{2M^2}\partial_\mu\Phi\partial^\mu\Phi + V^\mu \mathcal{J}_\mu - \frac{1}{M^2}\partial^\mu\Phi\mathcal{J}_\mu \ . \end{aligned} \tag{3.4}$$

In the new Lagrangian, there is no longer a coupling between V and the scalar source Φ. Letting $\mathcal{J}_\mu$ be a conserved current, the last term will also drop out after IBP.

From the on-shell perspective, the motivation of the above practice is twofold: first it makes sure that the amplitude-operator correspondence still holds, thus operators involving vector fields V_μ always correspond to scattering amplitudes involving the vector particle; second, the j-basis/UV resonance correspondence is kept valid. The latter can be understood by integrating out the heavy vector and examine the effective operators after matching. Without the replacement in eq. (3.4), the term $-\frac{1}{2M^2}\partial_\mu\Phi\partial^\mu\Phi$ is obtained through matching, and one may attribute it to the spin-1 resonance while it's a $J=0$ operator in the j-basis. On the contrary, if we start from $\tilde{\mathcal{L}}_{\rm UV}$, the term $-\frac{1}{2M^2}\partial_\mu\Phi\partial^\mu\Phi$ would be present in the UV which is irrelevant of the heavy vector, while the matching only produces the contact interaction of the conserved current $\mathcal{J}^\mu\mathcal{J}_\mu$, which is indeed $J=1$ operator in the j-basis.

The requirement can be extended to arbitrary spins. The key point is to decompose the tensor field into components with various spins, while only the component with correct spin could create the on-shell particle. For the spin-2 particle, the rank-2 tensor source can be decomposed as

$$T_{\mu\nu} = \Phi g_{\mu\nu} + (\partial_\mu J_\nu + \partial_\nu J_\mu) + \mathcal{T}_{\mu\nu} \ . \tag{3.5}$$

Like for the vector, the couplings to the scalar trace component Φ and the vectorial longitudinal component J_μ can be removed by field redefinition. In our on-shell prescription, we always choose the gauge that the spin-2 particle couples to the transverse-traceless source. This principle can be applied to arbitrary higher spins.

After choosing such a gauge, the correspondence between the UV resonance and the resulting low-energy operators is well defined without ambiguity. As explained previously, we can use the correspondence to find the UV origin of an effective operator. One remaining subtlety of the UV origin issue is when the 3-point UV couplings involved in the tree decomposition of the amplitude are considered "loop-induced". The typical example is the coupling between a vector resonance and two same-helicity fermions $\mathcal{B}(V_1,\psi_2,\psi_3) = \langle \mathbf{12}\rangle\langle \mathbf{13}\rangle$, which corresponds to the contribution of a dimension-5 operator $\mathcal{O} = \partial_\mu V_{1\nu}\bar{\psi}_2\sigma^{\mu\nu}\psi_3$. Therefore it is sometimes convenient to pick out those tree decompositions involving such couplings.

The tree level UV couplings are mostly 3-point, with a few exceptions at 4-point. For clarity, we start with 3-point couplings with one spin-S heavy particle, while the other two are treated as massless with helicities (h_1,h_2). The on-shell amplitudes for such couplings have a general form [34]

$$\mathcal{M}(h_1,h_2,S) \sim \langle 12\rangle^{S-h_1-h_2}[1\mathbf{3}]^{S+h_1-h_2}[2\mathbf{3}]^{S-h_1+h_2} \tag{3.6}$$

where the little group indices on the spinors $|\mathbf{3}]$ are implicitly totally symmetric. The power $S-h_1-h_2$ can be negative, which means it should be replaced by $[12]^{-S+h_1+h_2}$, while the other two powers should be non-negative, implying the requirement $S \geq |h_1 - h_2|$. This general form is written in the so-called *chiral basis*, where only the square brackets of the massive particles are used, but the mass dimension of the corresponding operator $d_{\mathcal{O}}$ becomes illusive. For example, $\mathcal{M}(+1/2, -1/2, 1) \sim \langle 12\rangle [1\mathbf{3}]^2$ would directly correspond to the dimension-6 operator $(\partial_\mu \psi_1^\dagger)\bar{\sigma}_\nu \psi_2 F_3^{\mu\nu}$, which is actually equivalent to a dimension-4 operator as $\psi_1^\dagger \bar{\sigma}_\mu \psi_2 V_3^\mu$ by the EOM and IBP. It turns out that to obtain an equivalent form of the operator with lowest mass dimension, a more convenient basis would be the *symmetric basis*, where the number of square brackets and angle brackets for the massive particles are equal for bosons, and differ by 1 for fermions. They correspond to the amplitudes in terms of polarization vectors $\epsilon_i^\mu \equiv \frac{\langle \mathbf{i}|\sigma^\mu|\mathbf{i}]}{\sqrt{2}M}$ and $u = (|\mathbf{i}\rangle, |\mathbf{i}])^T$ as the solution of the Dirac equation, such as $\chi^\mu \simeq \epsilon^\mu u =$ for the spin-3/2 Rarita-Schwinger field and $h^{\mu\nu} \simeq \epsilon^\mu \epsilon^\nu$ for the spin-2 Fierz-Pauli field. Assuming that the fields are all canonically normalized, their mass dimensions would be precisely 1 more than their wave functions. In general we have[1]

$$d_{\mathcal{O}} = N + d_{\mathcal{M}} \tag{3.7}$$

Therefore, to have $d_{\mathcal{O}} \leq 4$ for the tree-level couplings, the corresponding $N = 3$-point amplitudes should satisfy $d_{\mathcal{M}} \leq 1$ when the factors of $1/(\sqrt{2}M)$ are included. We use the convention for arbitrarily high spin fields such that the wave functions of the massive fields are

$$\begin{aligned}
&\text{spin-}S\text{ bosons:} \quad && \epsilon_i^{(\mu_1}\epsilon_i^{\mu_2}\ldots\epsilon_i^{\mu_S)} = \frac{1}{(\sqrt{2}M)^{2S}}\langle \mathbf{i}|\sigma^{\mu_1}|\mathbf{i}]\langle \mathbf{i}|\sigma^{\mu_2}|\mathbf{i}]\ldots\langle \mathbf{i}|\sigma^{\mu_S}|\mathbf{i}] \\
&\text{spin-}S\text{ fermions:} \quad && \epsilon_i^{(\mu_1}\ldots\epsilon_i^{\mu_{S-1/2})}u_i \sim \frac{1}{(\sqrt{2}M)^{2S-1}}\langle \mathbf{i}|\sigma^{\mu_1}|\mathbf{i}]\ldots\langle \mathbf{i}|\sigma^{\mu_{S-1/2}}|\mathbf{i}]\begin{pmatrix}|\mathbf{i}\rangle \\ |\mathbf{i}]\end{pmatrix}
\end{aligned} \tag{3.8}$$

all of which are in the symmetric basis. For comparison, the amplitudes in the chiral basis correspond to fields with derivatives, for instance

$$i\sigma_{\mu\nu}\partial^\mu \chi^\nu \simeq |\mathbf{i}\rangle\langle \mathbf{i}|\langle \mathbf{i}|\,, \quad (\partial_\mu h_{\nu\rho})\sigma^{\mu\nu} \simeq \frac{1}{\sqrt{2}M}|\mathbf{i}\rangle[\mathbf{i}|\sigma_\rho|\mathbf{i}\rangle\langle \mathbf{i}|. \tag{3.9}$$

For the previous example, the lowest dimensional amplitude we can get is $\mathcal{M}(+1/2, -1/2, 1) \sim \frac{1}{\sqrt{2}M}[1\mathbf{3}]\langle 2\mathbf{3}\rangle$, which has mass dimension $d_{\mathcal{M}} = 1$. We list below all the two-light-one-heavy couplings with $d_{\mathcal{M}} \leq 1$

light particles	heavy particles	amplitude	operator
φ, φ	ϕ	1	$\varphi_1\varphi_2\phi$
ψ, ψ	ϕ	$\langle 12\rangle$	$(\psi_1\psi_2)\phi$
φ, ψ	χ	$\langle 2\mathbf{3}\rangle$	$\varphi(\psi\chi)$
φ, φ	V	$\frac{1}{\sqrt{2}M}\langle 2\mathbf{3}\rangle[2\mathbf{3}]$	$\varphi_1\partial_\mu\varphi_2 V^\mu$
$\psi, \psi^\dagger$	V	$\frac{1}{\sqrt{2}M}[1\mathbf{3}]\langle 2\mathbf{3}\rangle$	$\psi_1\sigma_\mu\psi_2^\dagger V^\mu$

(3.10)

[1] This formula only holds for canonically normalized kinetic terms for the massive fields, which means that the bosonic fields have mass dimension 1 while the fermionic fields have mass dimension 3/2. It is not the convention for gravitons, for instance, whose kinetic term has a factor of M_{pl}^2 and the field is dimensionless. However, for massive fields, it is natural to stick to this convention.

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Note that there are no heavy particles beyond $J=1$, as they are all considered loop-induced in this convention. For example, the coupling of a light fermion and scalar with a heavy spin-3/2 particle has the amplitude

$$\mathcal{M}(\varphi,\psi,\chi^{(3/2)}) = \frac{1}{\sqrt{2}M}\langle\mathbf{13}\rangle\langle\mathbf{23}\rangle[\mathbf{13}] \simeq (\partial_\mu\varphi)(\psi\chi^\mu)\,, \tag{3.11}$$

which corresponds to a dimension-5 operator in terms of the Rarita-Schwinger field. We can also write down couplings with a heavy spin-2 particle such as

$$\mathcal{M}(\psi,\psi^\dagger,h^{(2)}) = \frac{1}{(\sqrt{2}M)^2}\langle\mathbf{13}\rangle\langle\mathbf{23}\rangle[\mathbf{23}]^2 \simeq (\psi\sigma_\mu\partial_\nu\psi^\dagger)h^{\mu\nu}\,, \tag{3.12}$$

also corresponding to a dimension-5 operator.

To proceed, we look at the case with one light (massless) particle and two heavy particles. In the generic case, the massless particle can only be a scalar or a spin-1/2 fermion, while the spins of the two massive particles can differ by 0, 1 or 1/2. The amplitudes of the couplings are

$$\mathcal{M}(\varphi,\Psi^{(S)},\Psi^{(S)}) = \begin{cases} \frac{1}{(\sqrt{2}M)^{2S}}\langle\mathbf{23}\rangle^S[\mathbf{23}]^S & S\in\mathbb{Z} \\ \frac{1}{(\sqrt{2}M)^{2S-1}}\langle\mathbf{23}\rangle^{S+1/2}[\mathbf{23}]^{S-1/2} & S\in\mathbb{Z}+\frac{1}{2} \end{cases} \tag{3.13}$$

$$\mathcal{M}(\varphi,\Psi^{(S)},\Psi^{(S+1)}) = \frac{1}{(\sqrt{2}M)^{2S+1}}\langle\mathbf{13}\rangle[\mathbf{13}]\langle\mathbf{23}\rangle^S[\mathbf{23}]^S\,, \qquad S\in\mathbb{Z} \tag{3.14}$$

$$\mathcal{M}(\psi,\Psi^{(S)},\Psi^{(S+1/2)}) = \begin{cases} \frac{1}{(\sqrt{2}M)^{2S}}\langle\mathbf{13}\rangle\langle\mathbf{23}\rangle^S[\mathbf{23}]^S & S\in\mathbb{Z} \\ \frac{1}{(\sqrt{2}M)^{2S}}\langle\mathbf{13}\rangle\langle\mathbf{23}\rangle^{S-1/2}[\mathbf{23}]^{S+1/2} & S\in\mathbb{Z}+\frac{1}{2} \end{cases} \tag{3.15}$$

A subtlety rises when the two heavy particles have the same mass, so that the x factor can be introduced which is massless and carries -1 helicity of the massless particle. It is defined as

$$x|1] \equiv \frac{p_2|1\rangle}{M} \tag{3.16}$$

where the proportionality is guaranteed by the kinematics $[1|p_2|1\rangle = 2p_1\cdot p_2 = m_3^2 - m_2^2 = 0$. It typically appears in the gauge interaction where the massless particle is the gauge boson. Consider a $|h|\geq 1$ massless boson A coupled to equal mass particles, the only couplings satisfying $d_{\mathcal{M}}\leq 1$ are[2]

$$\mathcal{M}(A^{(h)},\Psi^{(S)},\Psi^{(S)}) = x^h\times\begin{cases} \frac{1}{(\sqrt{2}M)^{2S}}\langle\mathbf{23}\rangle^S[\mathbf{23}]^S & S\in\mathbb{Z} \\ \frac{1}{(\sqrt{2}M)^{2S-1}}\langle\mathbf{23}\rangle^{S+1/2}[\mathbf{23}]^{S-1/2} & S\in\mathbb{Z}+\frac{1}{2} \end{cases} \tag{3.17}$$

The last case is the couplings among three heavy particles. Suppose the three spins are ordered $S_1\leq S_2\leq S_3$, we can write down the general formula

$$\begin{aligned}\mathcal{M}(\Psi^{(S_1)},\Psi^{(S_2)},\Psi^{(S_3)}) &= \frac{1}{(\sqrt{2}M)^{S_1+S_2+S_3}} \\ &\times\begin{cases} \left(\langle\mathbf{12}\rangle^{\frac{S_1+S_2-S_3}{2}}\langle\mathbf{23}\rangle^{\frac{-S_1+S_2+S_3}{2}}\langle\mathbf{31}\rangle^{\frac{S_1-S_2+S_3}{2}}\times c.c.\right), & S_1+S_2+S_3\in 2\mathbb{Z} \\ \left(\langle\mathbf{12}\rangle^{\frac{S_1+S_2-S_3+1}{2}}\langle\mathbf{23}\rangle^{\frac{-S_1+S_2+S_3-1}{2}}\langle\mathbf{31}\rangle^{\frac{S_1-S_2+S_3-1}{2}}\times c.c.\right)\times\langle\mathbf{3}|p_1|\mathbf{3}], & S_1+S_2+S_3\in 2\mathbb{Z}+1 \end{cases}\end{aligned} \tag{3.18}$$

[2] When the variable x is chosen, only one of $|1\rangle$ and $|1]$ can be used as an independent variable due to the relation eq. (3.16), thus the counterpart of eq. (3.14) is not present for the gauge interaction.

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while we see that the positivity of the powers require $S_3 \leq S_1 + S_2 + 1$. The above are all the 3-point tree-level couplings we should count in the tree decomposition of the effective operators. Those not listed above should be considered as loop-induced, which may be more suppressed at low energy.

Sometimes we also need 4-point couplings, and there are not many of them at tree level. First, only bosonic fields can be involved, because the wave functions of fermionic fields are always dimensionful. Second, gauge bosons are not allowed, because the gauge invariant field strength must involve derivatives, while the special kinematics required by the gauge couplings are also absent at 4-point. Therefore, the only massless particles that can be involved are scalars, thus we have

$$\mathcal{M}(\varphi,\varphi,\varphi,\varphi) = 1 \tag{3.19}$$

$$\mathcal{M}(\varphi,\varphi,\Psi^{(S)},\Psi^{(S)}) = \langle\mathbf{34}\rangle^S\,[\mathbf{34}]^S \tag{3.20}$$

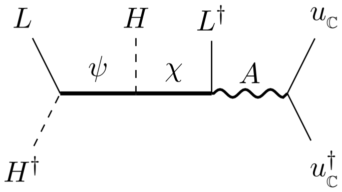
$$\mathcal{M}(\varphi,\Psi^{(S_1)},\Psi^{(S_2)},\Psi^{(S_3)}) = \frac{1}{(\sqrt{2}M)^{S_1+S_2+S_3}} \times \left(\langle\mathbf{12}\rangle^{\frac{S_1+S_2-S_3}{2}}\,\langle\mathbf{23}\rangle^{\frac{-S_1+S_2+S_3}{2}}\,\langle\mathbf{31}\rangle^{\frac{S_1-S_2+S_3}{2}} \times c.c.\right). \tag{3.21}$$

When all the 4 particles are massive with spins $S_1 \leq S_2 \leq S_3 \leq S_4$, there would be generically no unique couplings, but the criteria for the existence of tree-level couplings are $S_1 + S_2 + S_3 + S_4 \in 2\mathbb{Z}$ and $S_4 \leq S_1 + S_2 + S_3$.

When all the UV couplings involved in the tree decomposition of an effective operator are tree-level, i.e. $d_{\mathcal{O}} \leq 4$, the matching will always give the j-basis operator with the correct quantum numbers. Nevertheless, when higher-dimensional couplings are involved, the resulting operator would have a minimal mass dimension, so that certain j-basis operators at lower dimensions are not accessible through matching. For example, the four fermion operator $(\psi_1\sigma^{\mu\nu}\psi_2)(\psi_3\sigma_{\mu\nu}\psi_4)$ is a $J=1$ operator in the $\{1,2\} \to \{3,4\}$ channel, but a heavy vector resonance in this channel requires dimension-5 couplings with the fermions $\mathcal{M}(\psi,\psi,V) = \langle\mathbf{13}\rangle\,\langle\mathbf{23}\rangle \simeq \frac{1}{\Lambda}\psi\sigma_{\mu\nu}\psi\partial^\mu V^\nu$ on both sides, resulting in at least dimension-8 effective operators at low energy $\mathcal{O} \sim 1/(\Lambda^2 M^2)$. Hence the dimension-6 operator cannot be generated in the matching. We take this into account by analysing the mass dimensions of all the UV couplings and setting the minimal dimension for the generated j-basis operators, and the process is named *Dim selection* [26].

3.2 Subtleties on field redefinitions conversion

The analysis presented in section 2.2 offers a diagrammatic perspective that allows us to directly discern the potential UV origins responsible for the specific operator. This analysis encompasses crucial information, such as the quantum numbers of new resonances and their interactions with Standard Model (SM) particles. For instance, when examining the operator type $u_{\mathbb{C}}u_{\mathbb{C}}^\dagger LL^\dagger HH^\dagger$, conducting a j-basis analysis on the partition $\{\{L,H^\dagger\},\{u_{\mathbb{C}},u_{\mathbb{C}}^\dagger\},\{H,L^\dagger\}\}$ results in a UV theory involving three heavy resonances: $\psi(\mathbf{1},\mathbf{1},-1,1/2)$, $\chi(\mathbf{1},\mathbf{2},-1/2,1/2)$, and $A^\mu(\mathbf{1},\mathbf{1},0,1)$, where numbers in the parenthesis indicate the $(\mathrm{SU}(3)_C$, $\mathrm{SU}(2)_L$, $\mathrm{U}(1)_Y$, Spin$)$ quantum numbers of the corresponding fields. Diagrammatically, the process of generating operators of the type $u_{\mathbb{C}}u_{\mathbb{C}}^\dagger LL^\dagger HH^\dagger$ in matching such a UV theory is illustrated as follows:

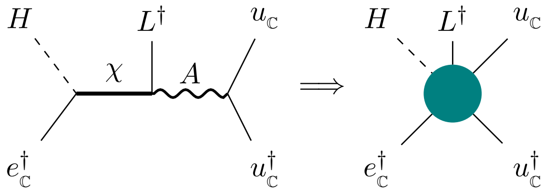


$$
\begin{aligned}
&= \bar{u}_R\gamma^\nu u_R\langle A^\mu A^\nu\rangle \bar{l}_L\gamma^\mu\langle\chi\bar{\chi}\rangle H\langle\psi\bar{\psi}\rangle H^\dagger l_L \\
&\sim \bar{u}_R\gamma^\nu u_R\frac{g_{\mu\nu}}{M_A}\bar{l}_L\gamma^\mu\frac{1}{M_\chi}H\frac{1}{M_\psi}H^\dagger l_L \\
&= \frac{1}{M_\psi M_\chi M_A^2}\bar{u}_R\gamma_\mu u_R\bar{l}_L\gamma^\mu HH^\dagger l_L, \qquad (3.22)
\end{aligned}
$$

where the angle brackets above represent the contraction of the heavy fields in the corresponding amplitude, and we have used the four-component notation for spinor field. The interactions needed in the UV theory are also easy to read out from the above diagram:

$$
\mathcal{L}_{\text{int}}^{\text{UV}} \supset (\bar{l}_L H\psi + \bar{\chi}H\psi + \bar{l}_L \not{A}\chi + h.c.) + \overline{u_R}\not{A}u_R. \qquad (3.23)
$$

In light of the diagrammatic interpretation, it appears that the current approach may not fully encompass UV theories capable of generating the specific type of operator by converting other operators produced during the matching procedure via field redefinition. For example, if we take away the heavy field ψ from the aforementioned UV theory and take into account the possible interaction $\bar{\chi}He_R + h.c.$, then integrating out χ and A^μ in a similar diagram with the amputation of the part that connects to the ψ leads to the operator of the type $u_{\mathbb{C}}u_{\mathbb{C}}^\dagger L^\dagger He_{\mathbb{C}}^\dagger D$ as follows:



(3.24)

$$
\begin{aligned}
&= \bar{u}_R\gamma^\nu u_R\langle A^\mu A^\nu\rangle \bar{l}_L\gamma^\mu\langle\chi\bar{\chi}\rangle He_R \\
&\sim \bar{u}_R\gamma_\mu u_R\frac{1}{M_A^2}\bar{l}_L\gamma^\mu\frac{\not{p}_H+\not{p}_{e_R}}{M_\chi^2}He_R \Longleftrightarrow \frac{1}{M_A^2M_\chi^2}\bar{u}_R\gamma_\mu u_R\bar{l}_L\gamma^\mu\not{D}(He_R). \qquad (3.25)
\end{aligned}
$$

If $\bar{u}_R\gamma_\mu u_R\bar{l}_L\gamma^\mu\not{D}(He_R)$ is considered to be a basis operator of the type $u_{\mathbb{C}}u_{\mathbb{C}}^\dagger L^\dagger He_{\mathbb{C}}^\dagger D$ in a complete and independent operator basis, then we would conclude that such a UV theory do not generate the operator $\bar{u}_R\gamma_\mu u_R\bar{l}_L\gamma^\mu HH^\dagger l_L$. However, if one prefer an operator basis where $\bar{u}_R\gamma_\mu u_R\bar{l}_L\gamma^\mu\not{D}(He_R)$ is not a part of basis operators like ours in ref. [8], then during the intermediate step of operator conversion, one has to convert the operator $\bar{u}_R\gamma_\mu u_R\bar{l}_L\gamma^\mu H(\not{D}e_R)$ with equation of motion $\not{D}e_R = y_e\bar{L}H$, which leads to the generation of the operator $\bar{u}_R\gamma_\mu u_R\bar{l}_L\gamma^\mu HH^\dagger l_L$. Therefore, if one is working in the second basis, then such a UV is indeed responsible for the operator $\bar{u}_R\gamma_\mu u_R\bar{l}_L\gamma^\mu HH^\dagger l_L$. In this sense, if we only perform the j-basis analysis for the type $u_{\mathbb{C}}u_{\mathbb{C}}^\dagger LL^\dagger HH^\dagger$ with diagrams containing only heavy propagator, we would miss the relevant UV theory containing heavy field χ and A^μ but not ψ.

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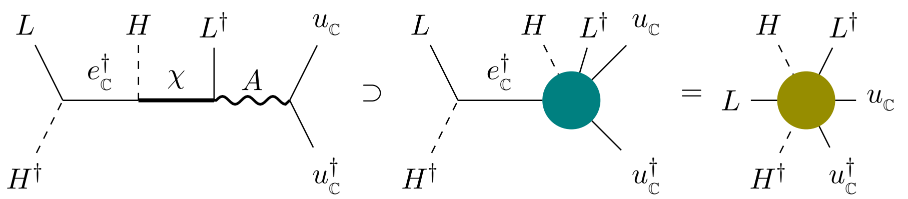
To avoid such an issue of missing potential UV contributions, we propose that with a small modification to the ordinary j-basis analysis one can take into account all kinds of UV theories responsible for an operator type. The modification is to include an additional step to verifying whether the quantum numbers of the resonances align with those of SM particles. If there exists a resonance in the candidate UV theory with quantum numbers matching those of a SM particle, we claim that a UV theory without that resonance is still capable of generating the target operator. This corresponds to a UV theory generating the target operators via field redefinition in removing those *off-shell basis operators*.[3] At the dim-6 level, the field redefinition used to remove those off-shell basis operators is equivalent to replacing the kinetic part in the operators with EOMs of the corresponding fields. Diagrammatically it corresponds to the equivalence between the local on-shell amplitude generated by the seemingly non-local diagram with the massless pole being canceled by the insertion of off-shell basis operators and the same amplitude generated by the contact diagram with the converted operators. Therefore, replacing a UV resonance propagator with the SM one in the diagram in the j-basis analysis exactly corresponds to the procedure of producing the target operator by converting the operators of other types via EOMs. We illustrate this point with the above $u_{\mathbb{C}}u_{\mathbb{C}}^{\dagger}LL^{\dagger}HH^{\dagger}$ example, the quantum numbers of the three resonance ψ, χ and A^{μ} are the same as those for SM fields $e_{\mathbb{C}}^{\dagger}$, L and B^{μ} respectively. Therefore following the earlier argument, we can replace the field ψ in the diagram with $e_{\mathbb{C}}^{\dagger}(e_R)$, and the new UV theory containing only heavy fields χ and A^{μ} are expected to also generate the operator of type $u_{\mathbb{C}}u_{\mathbb{C}}^{\dagger}LL^{\dagger}HH^{\dagger}$ by converting operator of type $u_{\mathbb{C}}u_{\mathbb{C}}^{\dagger}L^{\dagger}He_{\mathbb{C}}^{\dagger}D$ with EOM of $e_{\mathbb{C}}^{\dagger}$ as we discussed in the text below eq. (3.25). At the amplitude level, we can illustrate this procedure diagrammatically as follows:



(3.26)

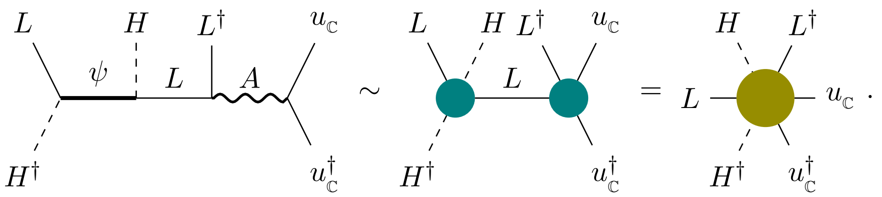
$$
\begin{aligned}
&= \bar{u}_R\gamma^{\nu}u_R\langle A^{\mu}A^{\nu}\rangle\bar{l}_L\gamma^{\mu}\langle\chi\bar{\chi}\rangle H\langle e_R\bar{e}_R\rangle H^{\dagger}l_L \\
&\supset \bar{u}_R\gamma^{\nu}u_R\frac{1}{M_A^2}\bar{l}_L\gamma^{\mu}\frac{\not{p}_{e_R}}{M_\chi^2}H\frac{1}{\not{p}_{e_R}}H^{\dagger}l_L \Longleftrightarrow \frac{1}{M_\chi^2 M_A^2}\bar{u}_R\gamma^{\nu}u_R\bar{l}_L\gamma^{\mu}H\not{D}\langle e_R\bar{e}_R\rangle l_L H^{\dagger} \\
&= \frac{1}{M_\chi^2 M_A^2}\bar{u}_R\gamma^{\nu}u_R\bar{l}_L\gamma^{\mu}HH^{\dagger}l_L,
\end{aligned}
\tag{3.27}
$$

where in the second line, we only include the part of the amplitude that is local due to the cancellation of the momentum coming from the propagator of χ in the numerator and the massless propagator of e_R in the denominator colored in blue, and the expression on the right-handed side with teal color corresponds to the insertion of the dim-8 operator $O_1 = \bar{u}_R\gamma^{\nu}u_R\bar{l}_L\gamma^{\mu}H\not{D}e_R$ generated by integrating out χ and A as we discussed in the previous paragraph. This O_1 operator contributes a momentum $\not{p}$ that cancels with the massless pole of e_R and the resulting amplitude is equal to the one generated by insertion of the operator $\bar{u}_R\gamma^{\nu}u_R\bar{l}_L\gamma^{\mu}HH^{\dagger}l_L$ obtained by the replacement of EOM of e_R in O_1. The conversions

[3] The off-shell basis operators are those does not contribute to the local tree-level on-shell amplitude for the scattering states involving external particles that are one-to-one correspondent to the fields in the operator.

between dim-8 operators with EOMs can always be expressed in such a diagrammatic way, which in turn can be captured by our j-basis analysis, because the external particles in the process fix the possible quantum numbers of the internal lines in the tree diagram, thus by traversing all possible partitions we recursively include all the possible way for generating the operator via conversion with EOMs.

At the dim-8 level, the relation between the field redefinition and the conversion of EOMs is more subtle [20, 35]. Apart from the conversion within the dim-8 operators with EOMs of renormalizable Lagrangian, one also needs to consider the dim-8 operators generated by the conversion of dim-6 operators with EOMs of dim-6 Lagrangian and a remaining part that captures the difference between the EOMs replacement and field redefinition. We shall show that these two additional effects can also be linked to the diagrammatic origin and thus can be included in the j-basis analysis. The case of generation of dim-8 operators via the conversion of dim-6 operators with EOMs of dim-6 Lagrangian can be illustrated by replacing the heavy propagator of χ with the SM lepton doublet field L in the diagram in eq. (3.22):



In the middle diagram, the left and right blobs in teal color represent the dim-6 operators generated by integrating out ψ and A respectively: $(\not{D}\bar{l}_L)HH^\dagger l_L$ and $(\bar{l}_L\gamma^\mu l_L)(\bar{u}_R\gamma_\mu u_R)$. The latter contributes to the dim-6 EOM $-\not{D}\bar{l}_L \supset (\bar{u}_R\gamma_\mu u_R)\bar{l}_L\gamma^\mu$, and the equivalence between the amplitudes generated by the middle and the right diagram exactly corresponds to the substitution of the $\not{D}\bar{l}_L$ in the operator $(\not{D}\bar{l}_L)HH^\dagger l_L$ with EOM of $\bar{l}_L$ at dim-6 resulting in the dim-8 operator $\bar{u}_R\gamma^\mu u_R\bar{l}_L\gamma^\mu HH^\dagger l_L$.

Lastly, the remaining origin for dim-8 operators that comes from the field redefinition and cannot be captured by substitutions of EOMs are those from the second order variation of the renormalizable part of EFT Lagrangian: $1/2f^\alpha\delta^2\mathcal{L}_4/(\delta\Phi_\alpha\delta\Phi_\beta)f_\beta$, where Φ_α is the corresponding SM fields, which to be shifted by $\Phi_\alpha \to \Phi_\alpha + f_\alpha$ to eliminate the dim-6 off-shell basis operators, and the repeated indices α and β traversing all the SM fields undergoing redefinition are summed implicitly. For the dim-8 operator generated in this way to be tree-level, the corresponding relevant dim-6 operators that were to be removed by the field redefinition must also be generated at the tree level. This requirement reduces dim-6 operators into two classes of operator: $\psi^\dagger\psi H^\dagger HD$ and $H^2H^{\dagger 2}D^2$. Removing redundant Green basis operators $|H|^2H^\dagger D^2H$ and $\bar{\psi}_2 i\overleftrightarrow{\not{D}}\psi_1 HH^\dagger$ in these two class generated during the matching amounts to make field redefinition $\psi_1 \to \psi_1 - \xi\psi_2 HH^\dagger$, $\psi_2 \to \psi_2 - \xi\psi_1 HH^\dagger$, and $H \to H + \xi' H|H|^2$, where ξ and ξ' are equal to the Wilson coefficient of the corresponding operators generated during matching, and we have omitted gauge contractions in the expressions. Diagrammatically, these second-order variation contributions can be further classified into

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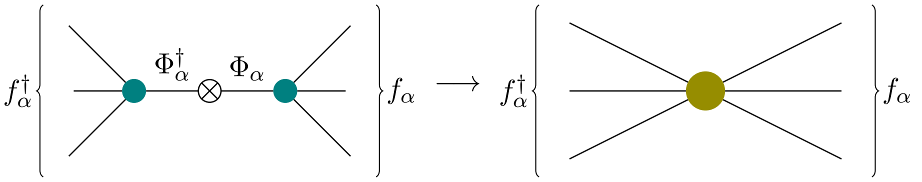
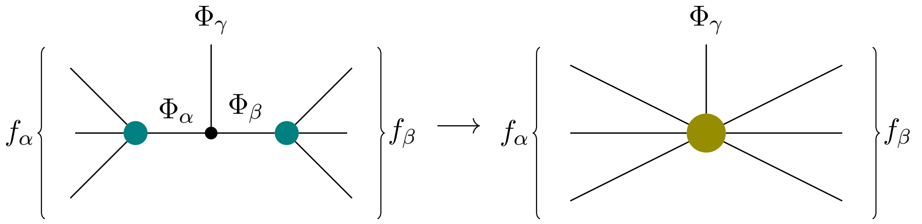
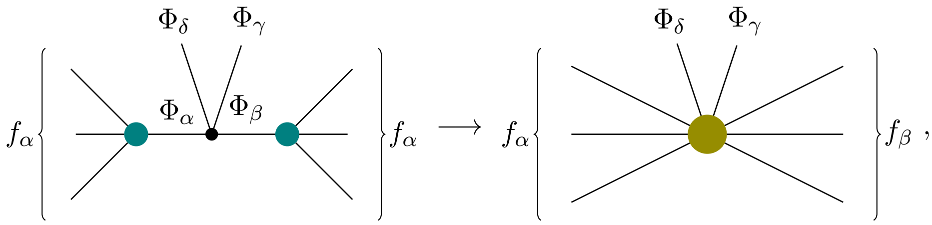
the following three categories:

Kinetic term: 

(3.28)

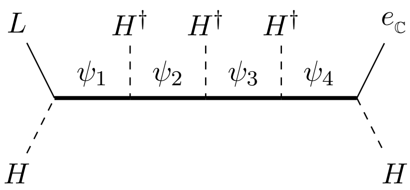
Yukawa term: 

(3.29)

Quartic term: 

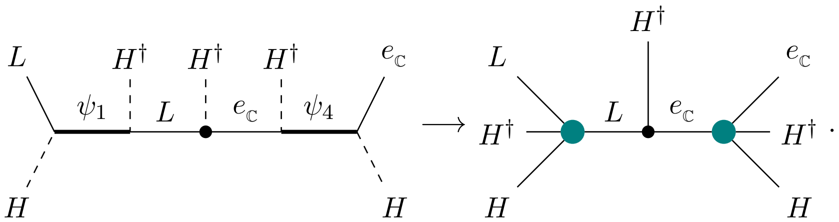
(3.30)

where Φ's are either SM fermions or Higgs fields, f's are determined by which source particle it stems from. The blobs in teal color in the above diagrams correspond to either dim-6 operators $|H|^2 H^\dagger D^2 H$ or $\bar{\psi}_2 i \overleftrightarrow{\not{D}} \psi_1 H H^\dagger$, and opening further these blobs with finer partition helps to obtain the corresponding UV theories responsible for generating the dim-8 operators in olive blobs on by second-order variation in field redefinition. Again this must be included in our j-basis analysis plus identifying the intermediate resonances with the same quantum numbers of SM particles. To be more concrete, we illustrate this scenario with an example of the j-basis analysis of operator type $H^2 H^{\dagger 3} L e_{\mathbb{C}}$ with patition $\{\{L,H\},\{L,H,H^\dagger\},\{e_{\mathbb{C}},H\},\{e_{\mathbb{C}},H,H^\dagger\}\}$ in the following diagram:



$$\begin{pmatrix} \psi_1(\mathbf{1},\mathbf{3},1,1/2) \\ \psi_2(\mathbf{1},\mathbf{2},-1/2,1/2) \\ \psi_3(\mathbf{1},\mathbf{1},1,1/2) \\ \psi_4(\mathbf{1},\mathbf{2},3/2,1/2) \end{pmatrix}, \ \psi_i(\mathrm{SU}(3)_C,\mathrm{SU}(2)_L,\mathrm{U}(1)_Y,\mathrm{Spin})$$

$\Downarrow$



(3.31)

We find that one of the UV contains four fermion fields ψ_1 to ψ_4 from our ordinary j-basis analysis, and according to the aforementioned discussion, we identify that ψ_2 and ψ_3 have the same quantum numbers with the SM fields L and $e_{\mathbb{C}}$ respectively. Therefore we conclude that the UV theories with only ψ_1 and ψ_4 can also generate dim-8 operator $H^2 H^{\dagger 3} L e_{\mathbb{C}}$ by field redefinition of in removing dim-6 off-shell basis operators $\bar{L} i \overleftrightarrow{\not{D}} L H H^\dagger$ and $\bar{e}_R i \overleftrightarrow{\not{D}} e_R H H^\dagger$ when integrating out ψ_1 and ψ_4, which can actually be easily verified by readers.

To summarize the above discussion:

- We have established a diagrammatic correspondence between the UV theory and dim-8 operators, which include two distinct processes for generating a dim-8 operator type: direct integration of heavy resonances and operator conversion through field redefinitions.
- Through the j-basis analysis, we can effectively capture all these diagrammatic scenarios by systematically traversing the partitions for a given operator type. With an additional step to identify and drop the resonances in the UV theories that share the same quantum numbers as the Standard Model (SM) particles, we effectively include the UV origins for the other operator types that can be converted to the given operator type with field redefinition.
- As a result of this careful analysis, the UV theories that contribute to a specific type of operator, as discovered through our j-basis analysis, are considered complete. We have successfully accounted for all the relevant mechanisms, leading to a comprehensive understanding of the operator's origins.

Finally, we comment that people in the phenomenology community like to speak of the UV resonance of certain EFT operators is not meaningful without fixing whole the operator basis at a certain dimension. Because the concept of "UV origin" of an operator is ambiguous due to the freedom to convert an operator to a different one with field redefinition. Due to this ambiguity and the fact that the operators are just intermediate tools to compute the predictions of physical observables, we think that the "UV origin" of an operator type which fixed the field contents and the number of derivatives is a more reasonable question to investigate.

4 Complete sets of the UV resonances for the dim-8 operators

Based on the discussions in previous sections, we summarize here the steps for obtaining the UV origins for a type of operator:

1. Obtain the independent partitions for the type of operators.
2. For each partition, find out all possible insertion quantum numbers of the resonance using our j-basis analysis. Each set of resonance and associated interactions read out from the corresponding diagram is a candidate UV theory.
3. For each candidate UV theory, we determine whether each interaction is "renormalizable" as discussed in section 3.1. Only retain those UV theories with all interactions that are renormalizable.

```
In[11]:= DIM8UV["D"^2 "dc" "dc†" "ec" "ec†"]

Out[11]= <|basis → <|1 → (dc_p^a ec_r) ((D_μ dc†_sa) (D^μ ec†_t)), 2 → i (dc_p^a σ_μν ec_r) ((D^μ dc†_sa) (D^ν ec†_t))|>,
   UVs → <|1 → {<|New Fields → {{-4/3, {1, 0}, {0}, 0}}, Vertices List → {{{dc†, ec†, {4/3, {0, 1}, {0}, 0}}}}|>,
      <|New Fields → {{0, {0, 0}, {0}, 2}}, Vertices List → {{{dc, dc†, {0, {0, 0}, {0}, 2}}, {ec, ec†, {0, {0, 0}, {0}, 2}}}}|>,
      <|New Fields → {{0, {0, 0}, {0}, 1}}, Vertices List → {{{dc, dc†, {0, {0, 0}, {0}, 1}}, {ec, ec†, {0, {0, 0}, {0}, 1}}}}|>,
      <|New Fields → {{2/3, {1, 0}, {0}, 2}}, Vertices List → {{{dc, ec†, {2/3, {1, 0}, {0}, 2}}}}|>,
      <|New Fields → {{2/3, {1, 0}, {0}, 1}}, Vertices List → {{{dc, ec†, {2/3, {1, 0}, {0}, 1}}}}|>},
    2 → {<|New Fields → {{-4/3, {1, 0}, {0}, 1}}, Vertices List → {{{dc†, ec†, {4/3, {0, 1}, {0}, 1}}}}|>,
      <|New Fields → {{0, {0, 0}, {0}, 2}}, Vertices List → {{{dc, dc†, {0, {0, 0}, {0}, 2}}, {ec, ec†, {0, {0, 0}, {0}, 2}}}}|>,
      <|New Fields → {{0, {0, 0}, {0}, 1}}, Vertices List → {{{dc, dc†, {0, {0, 0}, {0}, 1}}, {ec, ec†, {0, {0, 0}, {0}, 1}}}}|>,
      <|New Fields → {{2/3, {1, 0}, {0}, 2}}, Vertices List → {{{dc, ec†, {2/3, {1, 0}, {0}, 2}}}}|>,
      <|New Fields → {{2/3, {1, 0}, {0}, 1}}, Vertices List → {{{dc, ec†, {2/3, {1, 0}, {0}, 1}}}}|>}|>|>
```

Figure 2. Extract the relevant UV theories of a given operator type.

4. For each remaining UV theory, find out whether there exist special resonances in the theory that coincide with the quantum numbers of SM particles. Remove those special resonances in all kinds of ways and keep at least one new resonance in the UV theory. Each way of removing special resonances corresponds to a new UV theory responsible for the operator type under investigation.

The UV resonances for operators involving 4 particles are listed in appendix A. The UV resonances for operators involving 5 and more particles are not listed, but a supplementary material is provided. In the following we summarize the results we obtained from our analysis and introduce a `Mathematica` package for readers to extract those UV information. We have put those resonances that have the same quantum number of the SM particles in blue color. They are $S4[H]$, $F2[e_{\mathbb{C}}]$, $F3[L^\dagger]$, $F10[d_{\mathbb{C}}^\dagger]$, $F11[u_{\mathbb{C}}^\dagger]$, $F13[Q]$, $V1[B]$, $V6[W]$ and $V28[G]$. We find 40 scalar resonances, 25 fermion resonances, 30 vector resonances, 20 spin-3/2 resonances, and 15 spin-2 resonances that are relevant for the generation of operators, and we give their names in table 1. Keep in mind that in deriving these results, we retain the models with interactions of dimension up to 5, which means some couplings are be "loop-induced".

Compared with the heavy fields responsible for the dim-6 and dim-7 operators, we have 20 new scalar resonances, 15 new fermion resonances, 10 new vector resonances, 21 new spin-3/2 resonances, and 18 spin-2 resonances, which are tabulated in table 2.

For reader convenience, we provide a `Mathematica` package "`DIM8UV.m`" to extract the information of UV theories for a given operator. To use the package one only needs to get the content by the command:

```
In[1]:= Get["/path/to/DIM8UV.m"];
```

This is a standalone package that does not have any extra dependency. To extract the UV information for a given type, just use the function **DIM8UV**. The structure of the output is illustrated in the following example in figure 2. The output is an association with two "keys" — "basis" and "UVs", The value of "basis" gives a map between the indices that label the f-basis operators and the forms of the f-basis operators. The value of the "UVs" gives an association, where keys are the indices of the f-basis operator, and the values are all possible

Scalar	$S1\ (\mathbf{1},\mathbf{1},0)$, $S2\ (\mathbf{1},\mathbf{1},1)$, $S3\ (\mathbf{1},\mathbf{1},2)$, $S4\ (\mathbf{1},\mathbf{2},\frac{1}{2})$, $S5\ (\mathbf{1},\mathbf{2},\frac{3}{2})$
	$S6\ (\mathbf{1},\mathbf{2},\frac{5}{2})$, $S7\ (\mathbf{1},\mathbf{3},0)$, $S8\ (\mathbf{1},\mathbf{3},1)$, $S9\ (\mathbf{1},\mathbf{4},\frac{1}{2})$, $S10\ (\mathbf{1},\mathbf{4},\frac{3}{2})$
	$S11\ (\mathbf{1},\mathbf{5},0)$, $S12\ (\mathbf{1},\mathbf{5},1)$, $S13\ (\mathbf{1},\mathbf{5},2)$, $S14\ (\mathbf{3},\mathbf{1},-\frac{4}{3})$, $S15\ (\mathbf{3},\mathbf{1},-\frac{1}{3})$
	$S16\ (\mathbf{3},\mathbf{1},\frac{2}{3})$, $S17\ (\mathbf{3},\mathbf{1},\frac{5}{3})$, $S18\ (\mathbf{3},\mathbf{2},-\frac{11}{6})$, $S19\ (\mathbf{3},\mathbf{2},-\frac{5}{6})$, $S20\ (\mathbf{3},\mathbf{2},\frac{1}{6})$
	$S21\ (\mathbf{3},\mathbf{2},\frac{7}{6})$, $S22\ (\mathbf{3},\mathbf{3},-\frac{1}{3})$, $S23\ (\mathbf{3},\mathbf{3},\frac{2}{3})$, $S24\ (\mathbf{3},\mathbf{3},\frac{5}{3})$, $S25\ (\mathbf{3},\mathbf{4},-\frac{5}{6})$
	$S26\ (\mathbf{3},\mathbf{4},\frac{1}{6})$, $S27\ (\mathbf{6},\mathbf{1},-\frac{2}{3})$, $S28\ (\mathbf{6},\mathbf{1},\frac{1}{3})$, $S29\ (\mathbf{6},\mathbf{1},\frac{4}{3})$, $S30\ (\mathbf{6},\mathbf{2},-\frac{7}{6})$
	$S31\ (\mathbf{6},\mathbf{2},-\frac{1}{6})$, $S32\ (\mathbf{6},\mathbf{2},\frac{5}{6})$, $S33\ (\mathbf{6},\mathbf{2},\frac{11}{6})$, $S34\ (\mathbf{6},\mathbf{3},\frac{1}{3})$, $S35\ (\mathbf{6},\mathbf{4},-\frac{1}{6})$
	$S36\ (\mathbf{6},\mathbf{4},\frac{5}{6})$, $S37\ (\mathbf{8},\mathbf{1},0)$, $S38\ (\mathbf{8},\mathbf{1},1)$, $S39\ (\mathbf{8},\mathbf{2},\frac{1}{2})$, $S40\ (\mathbf{8},\mathbf{3},0)$
Fermion	$F1\ (\mathbf{1},\mathbf{1},0)$, $F2\ (\mathbf{1},\mathbf{1},1)$, $F3\ (\mathbf{1},\mathbf{2},\frac{1}{2})$, $F4\ (\mathbf{1},\mathbf{2},\frac{3}{2})$, $F5\ (\mathbf{1},\mathbf{3},0)$
	$F6\ (\mathbf{1},\mathbf{3},1)$, $F7\ (\mathbf{1},\mathbf{3},2)$, $F8\ (\mathbf{1},\mathbf{4},\frac{1}{2})$, $F9\ (\mathbf{1},\mathbf{4},\frac{3}{2})$, $F10\ (\mathbf{3},\mathbf{1},-\frac{1}{3})$
	$F11\ (\mathbf{3},\mathbf{1},\frac{2}{3})$, $F12\ (\mathbf{3},\mathbf{2},-\frac{5}{6})$, $F13\ (\mathbf{3},\mathbf{2},\frac{1}{6})$, $F14\ (\mathbf{3},\mathbf{2},\frac{7}{6})$, $F15\ (\mathbf{3},\mathbf{3},-\frac{4}{3})$
	$F16\ (\mathbf{3},\mathbf{3},-\frac{1}{3})$, $F17\ (\mathbf{3},\mathbf{3},\frac{2}{3})$, $F18\ (\mathbf{3},\mathbf{3},\frac{5}{3})$, $F19\ (\mathbf{3},\mathbf{4},-\frac{5}{6})$, $F20\ (\mathbf{3},\mathbf{4},\frac{1}{6})$
	$F21\ (\mathbf{3},\mathbf{4},\frac{7}{6})$, $F22\ (\mathbf{6},\mathbf{1},-\frac{2}{3})$, $F23\ (\mathbf{6},\mathbf{1},\frac{1}{3})$, $F24\ (\mathbf{6},\mathbf{2},-\frac{1}{6})$, $F25\ (\mathbf{8},\mathbf{1},1)$
Vector	$V1\ (\mathbf{1},\mathbf{1},0)$, $V2\ (\mathbf{1},\mathbf{1},1)$, $V3\ (\mathbf{1},\mathbf{1},2)$, $V4\ (\mathbf{1},\mathbf{2},\frac{1}{2})$, $V5\ (\mathbf{1},\mathbf{2},\frac{3}{2})$
	$V6\ (\mathbf{1},\mathbf{3},0)$, $V7\ (\mathbf{1},\mathbf{3},1)$, $V8\ (\mathbf{1},\mathbf{4},\frac{1}{2})$, $V9\ (\mathbf{1},\mathbf{5},0)$, $V10\ (\mathbf{1},\mathbf{5},1)$
	$V11\ (\mathbf{3},\mathbf{1},-\frac{4}{3})$, $V12\ (\mathbf{3},\mathbf{1},-\frac{1}{3})$, $V13\ (\mathbf{3},\mathbf{1},\frac{2}{3})$, $V14\ (\mathbf{3},\mathbf{1},\frac{5}{3})$, $V15\ (\mathbf{3},\mathbf{2},-\frac{11}{6})$
	$V16\ (\mathbf{3},\mathbf{2},-\frac{5}{6})$, $V17\ (\mathbf{3},\mathbf{2},\frac{1}{6})$, $V18\ (\mathbf{3},\mathbf{2},\frac{7}{6})$, $V19\ (\mathbf{3},\mathbf{3},-\frac{1}{3})$, $V20\ (\mathbf{3},\mathbf{3},\frac{2}{3})$
	$V21\ (\mathbf{3},\mathbf{3},\frac{5}{3})$, $V22\ (\mathbf{3},\mathbf{4},-\frac{5}{6})$, $V23\ (\mathbf{3},\mathbf{4},\frac{1}{6})$, $V24\ (\mathbf{6},\mathbf{1},-\frac{2}{3})$, $V25\ (\mathbf{6},\mathbf{1},\frac{1}{3})$
	$V26\ (\mathbf{6},\mathbf{1},\frac{4}{3})$, $V27\ (\mathbf{6},\mathbf{2},-\frac{1}{6})$, $V28\ (\mathbf{6},\mathbf{2},\frac{5}{6})$, $V29\ (\mathbf{6},\mathbf{3},\frac{1}{3})$, $V30\ (\mathbf{8},\mathbf{1},0)$
Spin-3/2	$R1\ (\mathbf{1},\mathbf{1},0)$, $R2\ (\mathbf{1},\mathbf{1},1)$, $R3\ (\mathbf{1},\mathbf{2},\frac{1}{2})$, $R4\ (\mathbf{1},\mathbf{2},\frac{3}{2})$, $R5\ (\mathbf{1},\mathbf{3},0)$
	$R6\ (\mathbf{1},\mathbf{3},1)$, $R7\ (\mathbf{1},\mathbf{4},\frac{1}{2})$, $R8\ (\mathbf{3},\mathbf{1},-\frac{1}{3})$, $R9\ (\mathbf{3},\mathbf{1},\frac{2}{3})$, $R10\ (\mathbf{3},\mathbf{2},-\frac{5}{6})$
	$R11\ (\mathbf{3},\mathbf{2},\frac{1}{6})$, $R12\ (\mathbf{3},\mathbf{2},\frac{7}{6})$, $R13\ (\mathbf{3},\mathbf{3},-\frac{1}{3})$, $R14\ (\mathbf{3},\mathbf{3},\frac{2}{3})$, $R15\ (\mathbf{3},\mathbf{4},\frac{1}{6})$
	$R16\ (\mathbf{6},\mathbf{1},-\frac{2}{3})$, $R17\ (\mathbf{6},\mathbf{1},\frac{1}{3})$, $R18\ (\mathbf{6},\mathbf{2},-\frac{1}{6})$, $R19\ (\mathbf{8},\mathbf{1},1)$, $R20\ (\mathbf{8},\mathbf{2},\frac{1}{2})$
Spin-2	$T1\ (\mathbf{1},\mathbf{1},0)$, $T2\ (\mathbf{1},\mathbf{1},1)$, $T3\ (\mathbf{1},\mathbf{2},\frac{3}{2})$, $T4\ (\mathbf{1},\mathbf{3},0)$, $T5\ (\mathbf{1},\mathbf{3},1)$
	$T6\ (\mathbf{1},\mathbf{5},0)$, $T7\ (\mathbf{3},\mathbf{1},\frac{2}{3})$, $T8\ (\mathbf{3},\mathbf{1},\frac{5}{3})$, $T9\ (\mathbf{3},\mathbf{2},-\frac{5}{6})$, $T10\ (\mathbf{3},\mathbf{2},\frac{1}{6})$
	$T11\ (\mathbf{3},\mathbf{3},\frac{2}{3})$, $T12\ (\mathbf{6},\mathbf{2},-\frac{1}{6})$, $T13\ (\mathbf{6},\mathbf{2},\frac{5}{6})$, $T14\ (\mathbf{8},\mathbf{1},0)$, $T15\ (\mathbf{8},\mathbf{1},1)$

Table 1. Heavy resonances that are relevant for dim-8 operators, the sequential numbers in the parenthesis in order are dimension of the $\mathrm{SU}(3)_C$ and $\mathrm{SU}(2)_L$ groups and the hypercharge of $\mathrm{U}(1)_Y$.

UV theories that can generate the operator. Each class of UV theories that share the same set of new fields is also represented by an association, with key "New Fields" storing the list of quantum numbers of new fields in the theory in the order of ($U1_Y$,$\mathrm{SU}(3)_C$,$\mathrm{SU}(2)_L$, Spin), and the key "Vertices List" consisting of a list of vertex list in the UV theories. Each vertex list combined with the list of new fields, which fixed interactions in the Lagrangian ubiquitously determine a UV theory. For example, in figure 2, the first class of UV theory that responsible for the first f-basis operator has one new scalar field with ($\mathrm{U}(1)_Y$,$\mathrm{SU}(3)_C$,$\mathrm{SU}(2)_L$) quantum numbers equal to ($-4/3$, $\mathbf{3}$,$\mathbf{1}$), which is $S14$ in our notation. It turns out that for this class, one only has one concrete UV theory with interactions between the new scalar and $e_{\mathbb{C}}^\dagger$ and $d_{\mathbb{C}}^\dagger$ where we have omit the conjugate part. The vertices in red color in the list are those with dimensions larger than 4, which according to our discussion in section 3, can be regarded as "loop-induced". One can also remove those UV theories containing "loop-induced" couplings by passing a second argument "Tree Couplings" to the function as shown in figure 3. To help

Scalar	$S5\ (\mathbf{1},\mathbf{2},\frac{3}{2}),\ S6\ (\mathbf{1},\mathbf{2},\frac{5}{2}),\ S11\ (\mathbf{1},\mathbf{5},0),\ S12\ (\mathbf{1},\mathbf{5},1),\ S13\ (\mathbf{1},\mathbf{5},2)$ $S17\ (\mathbf{3},\mathbf{1},\frac{5}{3}),\ S18\ (\mathbf{3},\mathbf{2},-\frac{11}{6}),\ S19\ (\mathbf{3},\mathbf{2},-\frac{5}{6}),\ S23\ (\mathbf{3},\mathbf{3},\frac{2}{3}),\ S24\ (\mathbf{3},\mathbf{3},\frac{5}{3})$ $S25\ (\mathbf{3},\mathbf{4},-\frac{5}{6}),\ S26\ (\mathbf{3},\mathbf{4},\frac{1}{6}),\ S30\ (\mathbf{6},\mathbf{2},-\frac{7}{6}),\ S31\ (\mathbf{6},\mathbf{2},-\frac{1}{6}),\ S32\ (\mathbf{6},\mathbf{2},\frac{5}{6})$ $S33\ (\mathbf{6},\mathbf{2},\frac{11}{6}),\ S35\ (\mathbf{6},\mathbf{4},-\frac{1}{6}),\ S36\ (\mathbf{6},\mathbf{4},\frac{5}{6}),\ S37\ (\mathbf{8},\mathbf{1},0),\ S38\ (\mathbf{8},\mathbf{1},1)$
Fermion	$F7\ (\mathbf{1},\mathbf{3},2),\ F9\ (\mathbf{1},\mathbf{4},\frac{3}{2}),\ F15\ (\mathbf{3},\mathbf{3},-\frac{4}{3}),\ F18\ (\mathbf{3},\mathbf{3},\frac{5}{3}),\ F19\ (\mathbf{3},\mathbf{4},-\frac{5}{6})$ $F20\ (\mathbf{3},\mathbf{4},\frac{1}{6}),\ F21\ (\mathbf{3},\mathbf{4},\frac{7}{6}),\ F22\ (\mathbf{6},\mathbf{1},-\frac{2}{3}),\ F23\ (\mathbf{6},\mathbf{1},\frac{1}{3}),\ F24\ (\mathbf{6},\mathbf{2},-\frac{1}{6})$ $F25\ (\mathbf{8},\mathbf{1},1),\ F26\ (\mathbf{8},\mathbf{2},\frac{1}{2}),\ F27\ (\mathbf{15},\mathbf{1},-\frac{1}{3}),\ F28\ (\mathbf{15},\mathbf{1},\frac{2}{3}),\ F29\ (\mathbf{15},\mathbf{2},\frac{1}{6})$
Vector	$V3\ (\mathbf{1},\mathbf{1},2),\ V9\ (\mathbf{1},\mathbf{5},0),\ V10\ (\mathbf{1},\mathbf{5},1),\ V15\ (\mathbf{3},\mathbf{2},-\frac{11}{6}),\ V21\ (\mathbf{3},\mathbf{3},\frac{5}{3})$ $V22\ (\mathbf{3},\mathbf{4},-\frac{5}{6}),\ V23\ (\mathbf{3},\mathbf{4},\frac{1}{6}),\ V24\ (\mathbf{6},\mathbf{1},-\frac{2}{3}),\ V26\ (\mathbf{6},\mathbf{1},\frac{4}{3}),\ V29\ (\mathbf{6},\mathbf{3},\frac{1}{3})$
Spin-3/2	$R2\ (\mathbf{1},\mathbf{1},1),\ R3\ (\mathbf{1},\mathbf{2},\frac{1}{2}),\ R4\ (\mathbf{1},\mathbf{2},\frac{3}{2}),\ R6\ (\mathbf{1},\mathbf{3},1),\ R7\ (\mathbf{1},\mathbf{4},\frac{1}{2})$ $R8\ (\mathbf{3},\mathbf{1},-\frac{1}{3}),\ R9\ (\mathbf{3},\mathbf{1},\frac{2}{3}),\ R10\ (\mathbf{3},\mathbf{2},-\frac{5}{6}),\ R11\ (\mathbf{3},\mathbf{2},\frac{1}{6}),\ R12\ (\mathbf{3},\mathbf{2},\frac{7}{6})$ $R13\ (\mathbf{3},\mathbf{3},-\frac{1}{3}),\ R14\ (\mathbf{3},\mathbf{3},\frac{2}{3}),\ R15\ (\mathbf{3},\mathbf{4},\frac{1}{6}),\ R16\ (\mathbf{6},\mathbf{1},-\frac{2}{3}),\ R17\ (\mathbf{6},\mathbf{1},\frac{1}{3})$ $R18\ (\mathbf{6},\mathbf{2},-\frac{1}{6}),\ R19\ (\mathbf{8},\mathbf{1},1),\ R20\ (\mathbf{8},\mathbf{2},\frac{1}{2}),\ R21\ (\mathbf{15},\mathbf{1},-\frac{1}{3}),\ R22\ (\mathbf{15},\mathbf{1},\frac{2}{3})$
Spin-2	$T1\ (\mathbf{1},\mathbf{1},0),\ T2\ (\mathbf{1},\mathbf{1},1),\ T3\ (\mathbf{1},\mathbf{2},\frac{3}{2}),\ T4\ (\mathbf{1},\mathbf{3},0),\ T5\ (\mathbf{1},\mathbf{3},1)$ $T6\ (\mathbf{1},\mathbf{5},0),\ T7\ (\mathbf{3},\mathbf{1},\frac{2}{3}),\ T8\ (\mathbf{3},\mathbf{1},\frac{5}{3}),\ T9\ (\mathbf{3},\mathbf{2},-\frac{5}{6}),\ T10\ (\mathbf{3},\mathbf{2},\frac{1}{6})$ $T11\ (\mathbf{3},\mathbf{3},\frac{2}{3}),\ T12\ (\mathbf{6},\mathbf{2},-\frac{1}{6}),\ T13\ (\mathbf{6},\mathbf{2},\frac{5}{6}),\ T14\ (\mathbf{8},\mathbf{1},0),\ T15\ (\mathbf{8},\mathbf{1},1)$

Table 2. New resonance appeared at dim-8, the sequential numbers in the parenthesis in order are dimension of the $\mathrm{SU}(3)_C$ and $\mathrm{SU}(2)_L$ groups and the hypercharge of $\mathrm{U}(1)_Y$.

```
In[12]:= DIM8UV["D"^2 "dc" "dc†" "ec" "ec†", "Tree Couplings"]

Out[12]= ⟨|basis → ⟨|1 → (dc_p^a ec_r) ((D_μ dc†_sa) (D^μ ec†_t)), 2 → i (dc_p^a σ_μν ec_r) ((D^μ dc†_sa) (D^ν ec†_t))|⟩,
   UVs → ⟨|1 → {⟨|New Fields → {{-4/3, {1, 0}, {0}, 0}}, Vertices List → {{{dc†, ec†, {4/3, {0, 1}, {0}, 0}}}}|⟩,
      ⟨|New Fields → {{0, {0, 0}, {0}, 1}}, Vertices List → {{{dc, dc†, {0, {0, 0}, {0}, 1}}, {ec, ec†, {0, {0, 0}, {0}, 1}}}}|⟩,
      ⟨|New Fields → {{2/3, {1, 0}, {0}, 1}}, Vertices List → {{{dc, ec†, {2/3, {1, 0}, {0}, 1}}}}|⟩},
    2 → {⟨|New Fields → {{0, {0, 0}, {0}, 1}}, Vertices List → {{{dc, dc†, {0, {0, 0}, {0}, 1}}, {ec, ec†, {0, {0, 0}, {0}, 1}}}}|⟩,
      ⟨|New Fields → {{2/3, {1, 0}, {0}, 1}}, Vertices List → {{{dc, ec†, {2/3, {1, 0}, {0}, 1}}}}|⟩}|⟩|⟩
```

Figure 3. Extract the relevant UV theories of a given operator type that do not contain any "loop-induced" couplings.

reader to identity those models with the naming scheme in table 1, we provided a function called **TabulateUVs**, which takes in two arguments — the operator type and the index of the f-basis as in figure 4. It will first print the form of the operator, and in case of the presence of repeated fields, the corresponding flavor symmetry of each group of repeated fields will be shown in the form of the shape of the Young diagram. Here in the example, we have the flavor indices of the two $u_{\mathbb{C}}$ anti-symmetrized. The table has two columns and the left one records the "New Fields" — the list of new fields present in the UV theory with their quantum numbers, and the right column lists the different UVs that differ by the interactions. Certainly, one can also select to only output those models with renormalizable UV couplings by specifying the option "TreeCouplings" to true as in figure 5.

For user convenience, we also store the results in the package, using the function **ResList2Type**, reader can find the possible contribution to certain operator types for a class of UV theories identified by a list of new fields as in figure 6. The reader can also restrict to the scenario where only renormalizable UV couplings are allowed as in figure 7.

TabulateUVs["BL" "dc" "ec" "uc"^{2}, 3]

$3 \to \{\{uc \to \{1, 1\}\}, i\,\epsilon_{abc} BL^{\mu\nu} (dc_p{}^a \sigma_{\mu\nu} ec_r)(uc_s{}^b uc_t{}^c)\}$

F10(**3**,**1**,-1/3), V12(**3**,**1**,-1/3)	(BL,dc,F10) (ec,uc,V12) (uc,F10†,V12†)
V12(**3**,**1**,-1/3)	(ec,uc,V12) (uc,F10†,V12†) (dc,uc,V12†) (uc,V12,F2) (BL,V12,V12†) (dc,uc,V12†) (ec,uc,V12)
S15(**3**,**1**,-1/3), F10(**3**,**1**,-1/3)	(BL,dc,F10) (ec,uc,S15) (uc,S15†,F10†)
S15(**3**,**1**,-1/3)	(ec,uc,S15) (uc,S15†,F10†) (dc,uc,S15†) (uc,S15,F2)
S14(**3**,**1**,-4/3), F10(**3**,**1**,-1/3)	(BL,dc,F10) (ec,S14,F10†) (uc,uc,S14†)
S14(**3**,**1**,-4/3)	(ec,S14,F10†) (uc,uc,S14†) (dc,S14,F2) (uc,uc,S14†)
V12(**3**,**1**,-1/3), F2(**1**,**1**,1)	(BL,ec,F2†) (dc,uc,V12†) (uc,V12,F2)
S15(**3**,**1**,-1/3), F2(**1**,**1**,1)	(BL,ec,F2†) (dc,uc,S15†) (uc,S15,F2)
S14(**3**,**1**,-4/3), F2(**1**,**1**,1)	(BL,ec,F2†) (dc,S14,F2) (uc,uc,S14†)
V11(**3**,**1**,-4/3), F11(**3**,**1**,2/3)	(BL,uc,F11) (dc,ec,V11) (uc,F11†,V11†)
V12(**3**,**1**,-1/3), F11(**3**,**1**,2/3)	(BL,uc,F11) (dc,uc,V12†) (ec,F11†,V12) (BL,uc,F11) (dc,F11†,V12†) (ec,uc,V12)
S15(**3**,**1**,-1/3), F11(**3**,**1**,2/3)	(BL,uc,F11) (dc,uc,S15†) (ec,F11†,S15) (BL,uc,F11) (dc,F11†,S15†) (ec,uc,S15)
S14(**3**,**1**,-4/3), V11(**3**,**1**,-4/3)	(BL,S14,V11†) (dc,ec,V11) (uc,uc,S14†)
S15(**3**,**1**,-1/3), V12(**3**,**1**,-1/3)	(BL,V12,S15†) (dc,uc,V12†) (ec,uc,S15) (BL,S15,V12†) (dc,uc,S15†) (ec,uc,V12)

Figure 4. To put the relevant UV theories in a nicer form.

TabulateUVs["BL" "dc" "ec" "uc"^{2}, 3, TreeCouplings → True]

$3 \to \{\{uc \to \{1, 1\}\}, i\,\epsilon_{abc} BL^{\mu\nu} (dc_p{}^a \sigma_{\mu\nu} ec_r)(uc_s{}^b uc_t{}^c)\}$

S15(**3**,**1**,-1/3)	(ec,uc,S15) (uc,S15†,F10†) (dc,uc,S15†) (uc,S15,F2)
S14(**3**,**1**,-4/3)	(ec,S14,F10†) (uc,uc,S14†) (dc,S14,F2) (uc,uc,S14†)

Figure 5. Select to tabulate those UV theories with only renormalizable couplings.

In[8]:= ResList2Type[{"V2"}]

Out[8]= $\{D^2 L^2 L^{\dagger 2}, D^2\, dc\, dc^\dagger\, uc\, uc^\dagger, D^3\, dc\, H^{\dagger 2}\, uc^\dagger, D^4 H^2 H^{\dagger 2}, BL\, dc\, dc^\dagger\, uc\, uc^\dagger, dc\, dc^\dagger\, GL\, uc\, uc^\dagger, D\, dc^\dagger\, ec\, H\, L\, uc, D\, dc\, H^\dagger\, Q\, uc\, uc^\dagger, D\, dc\, dc^\dagger\, H\, Q\, uc,$
$BL\, D\, dc\, H^{\dagger 2}\, uc^\dagger, BL\, D\, dc^\dagger\, H^2\, uc, D\, dc\, GL\, H^{\dagger 2}\, uc^\dagger, D^2\, ec\, H\, H^{\dagger 2}\, L, D^2\, dc\, H\, H^{\dagger 2}\, Q, D^2 H^2 H^\dagger\, Q\, uc, BL\, D^2 H^2 H^{\dagger 2}, dc\, dc^\dagger\, H\, H^\dagger\, uc\, uc^\dagger, D\, dc\, H\, H^{\dagger 3}\, uc^\dagger, D^2 H^3 H^{\dagger 3}\}$

In[11]:= ResList2Type[{"V2", "S1"}]

Out[11]= $\{dc\, dc^\dagger\, H\, H^\dagger\, uc\, uc^\dagger, D\, dc\, H\, H^{\dagger 3}\, uc^\dagger, D^2 H^3 H^{\dagger 3}\}$

Figure 6. Get the relevant operator types for a set of new fields.

In[12]:= ResList2Type[{"V2"}, "Tree Couplings"]

Out[12]= $\{D^2\, dc\, dc^\dagger\, uc\, uc^\dagger, D^3\, dc\, H^{\dagger 2}\, uc^\dagger, D^4 H^2 H^{\dagger 2}, BL\, dc\, dc^\dagger\, uc\, uc^\dagger, dc\, dc^\dagger\, GL\, uc\, uc^\dagger, D\, dc^\dagger\, ec\, H\, L\, uc, D\, dc\, H^\dagger\, Q\, uc\, uc^\dagger, D\, dc\, dc^\dagger\, H\, Q\, uc, BL\, D\, dc\, H^{\dagger 2}\, uc^\dagger,$
$BL\, D\, dc^\dagger\, H^2\, uc, D\, dc\, GL\, H^{\dagger 2}\, uc^\dagger, D^2\, ec\, H\, H^{\dagger 2}\, L, D^2\, dc\, H\, H^{\dagger 2}\, Q, D^2 H^2 H^\dagger\, Q\, uc, BL\, D^2 H^2 H^{\dagger 2}, dc\, dc^\dagger\, H\, H^\dagger\, uc\, uc^\dagger, D\, dc\, H\, H^{\dagger 3}\, uc^\dagger, D^2 H^3 H^{\dagger 3}\}$

Figure 7. Get the relevant operator types for a set of new fields.

From the bottom-up point of view, it is of interest to find out what dim-8 operators can be generated at tree-level when UV must contain a new resonance in table 2, and we list such operator types in table 3. In the right column, we list the set of resonances in square brackets that are responsible for the generation of the dim-8 operators in the left column. From the top-down point of view, it is also interesting to find out those resonances that only generate dim-8 operators but not dim-6 operators at tree-level. We list this kind of UV theories in

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List of operators			
$B_L G_L{}^3$	$[S37\ (\mathbf{8},\mathbf{1},0)]$		
$B_L B_R G_L G_R$	$[S37\ (\mathbf{8},\mathbf{1},0)]$	$[T1\ (\mathbf{1},\mathbf{1},0)]$	$[T14\ (\mathbf{8},\mathbf{1},0)]$
$B_L G_L G_R{}^2$	$[S37\ (\mathbf{8},\mathbf{1},0)]$	$[T14\ (\mathbf{8},\mathbf{1},0)]$	
$G_L G_R W_L W_R$	$[S40\ (\mathbf{8},\mathbf{3},0)]$	$[T1\ (\mathbf{1},\mathbf{1},0)]$	$[T16\ (\mathbf{8},\mathbf{3},0)]$
$De_{\mathbb{C}}e_{\mathbb{C}}^{\dagger}G_L G_R$	$[T1\ (\mathbf{1},\mathbf{1},0)]$	$[F25\ (\mathbf{8},\mathbf{1},1)]$	$[R19\ (\mathbf{8},\mathbf{1},1)]$
$DG_L G_R LL^{\dagger}$	$[T1\ (\mathbf{1},\mathbf{1},0)]$	$\left[F26\ (\mathbf{8},\mathbf{2},\frac{1}{2})\right]$	$\left[R20\ (\mathbf{8},\mathbf{2},\frac{1}{2})\right]$

Table 3. The dim-8 operator types that must need at least a new resonance to be generated.The grayed resonance are the one also contribute to the dim-6 operators.

table 4 and 5 and the associated operator types they may generate, and we find that all these UV theories must contain at least one "loop-induced" couplings.

UV (SU(3)$_C$, SU(2)$_L$, U(1)$_Y$)	dim-8 operators
$S11\ (\mathbf{1},\mathbf{5},0)$	$W_L{}^4\quad W_L{}^2W_R{}^2$
$S37\ (\mathbf{8},\mathbf{1},0)$	$B_L{}^2G_L{}^2\quad B_LG_L{}^3\quad G_L{}^4\quad B_LB_RG_LG_R$ $B_LG_LG_R{}^2\quad G_L{}^2G_R{}^2\quad B_Ld_{\mathbb{C}}G_LH^{\dagger}Q\quad B_LG_LHQu_{\mathbb{C}}$ $d_{\mathbb{C}}G_L{}^2H^{\dagger}Q\quad G_L{}^2HQu_{\mathbb{C}}\quad B_LG_LH^{\dagger}Q^{\dagger}u_{\mathbb{C}}^{\dagger}\quad B_Ld_{\mathbb{C}}^{\dagger}G_LHQ^{\dagger}$ $G_L{}^2H^{\dagger}Q^{\dagger}u_{\mathbb{C}}^{\dagger}\quad d_{\mathbb{C}}^{\dagger}G_L{}^2HQ^{\dagger}$
$S40\ (\mathbf{8},\mathbf{3},0)$	$G_L{}^2W_L{}^2\quad G_LG_RW_LW_R\quad d_{\mathbb{C}}G_LH^{\dagger}QW_L\quad G_LHQu_{\mathbb{C}}W_L$ $G_LH^{\dagger}Q^{\dagger}u_{\mathbb{C}}^{\dagger}W_L\quad d_{\mathbb{C}}^{\dagger}G_LHQ^{\dagger}W_L$
$S42\ (\mathbf{27},\mathbf{1},0)$	$G_L{}^4\quad G_L{}^2G_R{}^2$
$T1\ (\mathbf{1},\mathbf{1},0)$	$B_L{}^2B_R{}^2\quad B_LB_RW_LW_R\quad B_LB_RG_LG_R\quad W_L{}^2W_R{}^2$ $G_LG_RW_LW_R\quad G_L{}^2G_R{}^2\quad B_LB_RDe_{\mathbb{C}}e_{\mathbb{C}}^{\dagger}\quad B_LB_RDLL^{\dagger}$ $B_LB_RDd_{\mathbb{C}}d_{\mathbb{C}}^{\dagger}\quad B_LB_RDu_{\mathbb{C}}u_{\mathbb{C}}^{\dagger}\quad B_LB_RDQQ^{\dagger}\quad De_{\mathbb{C}}e_{\mathbb{C}}^{\dagger}W_LW_R$ $DLL^{\dagger}W_LW_R\quad Dd_{\mathbb{C}}d_{\mathbb{C}}^{\dagger}W_LW_R\quad Du_{\mathbb{C}}u_{\mathbb{C}}^{\dagger}W_LW_R\quad DQQ^{\dagger}W_LW_R$ $De_{\mathbb{C}}e_{\mathbb{C}}^{\dagger}G_LG_R\quad DG_LG_RLL^{\dagger}\quad Dd_{\mathbb{C}}d_{\mathbb{C}}^{\dagger}G_LG_R\quad DG_LG_Ru_{\mathbb{C}}u_{\mathbb{C}}^{\dagger}$ $DG_LG_RQQ^{\dagger}\quad D^2e_{\mathbb{C}}{}^2e_{\mathbb{C}}^{\dagger\,2}\quad D^2e_{\mathbb{C}}e_{\mathbb{C}}^{\dagger}LL^{\dagger}\quad D^2d_{\mathbb{C}}d_{\mathbb{C}}^{\dagger}LL^{\dagger}$ $D^2LL^{\dagger}u_{\mathbb{C}}u_{\mathbb{C}}^{\dagger}\quad D^2e_{\mathbb{C}}e_{\mathbb{C}}^{\dagger}QQ^{\dagger}\quad D^2L^2L^{\dagger 2}\quad D^2d_{\mathbb{C}}d_{\mathbb{C}}^{\dagger}e_{\mathbb{C}}e_{\mathbb{C}}^{\dagger}$ $D^2e_{\mathbb{C}}e_{\mathbb{C}}^{\dagger}u_{\mathbb{C}}u_{\mathbb{C}}^{\dagger}\quad D^2d_{\mathbb{C}}{}^2d_{\mathbb{C}}^{\dagger\,2}\quad D^2d_{\mathbb{C}}d_{\mathbb{C}}^{\dagger}u_{\mathbb{C}}u_{\mathbb{C}}^{\dagger}\quad D^2u_{\mathbb{C}}{}^2u_{\mathbb{C}}^{\dagger\,2}$ $D^2LL^{\dagger}QQ^{\dagger}\quad D^2d_{\mathbb{C}}d_{\mathbb{C}}^{\dagger}QQ^{\dagger}\quad D^2QQ^{\dagger}u_{\mathbb{C}}u_{\mathbb{C}}^{\dagger}\quad D^2Q^2Q^{\dagger 2}$ $B_LB_RD^2HH^{\dagger}\quad D^2HH^{\dagger}W_LW_R\quad D^2G_LG_RHH^{\dagger}\quad D^3e_{\mathbb{C}}e_{\mathbb{C}}^{\dagger}HH^{\dagger}$ $D^3HH^{\dagger}LL^{\dagger}\quad D^3d_{\mathbb{C}}d_{\mathbb{C}}^{\dagger}HH^{\dagger}\quad D^3HH^{\dagger}u_{\mathbb{C}}u_{\mathbb{C}}^{\dagger}\quad D^3HH^{\dagger}QQ^{\dagger}$
$T4\ (\mathbf{1},\mathbf{3},0)$	$B_L{}^2W_R{}^2\quad B_LB_RW_LW_R\quad W_L{}^2W_R{}^2\quad B_LDLL^{\dagger}W_R$ $B_LDQQ^{\dagger}W_R\quad DLL^{\dagger}W_LW_R\quad DQQ^{\dagger}W_LW_R\quad D^2L^2L^{\dagger 2}$ $D^2LL^{\dagger}QQ^{\dagger}\quad D^2Q^2Q^{\dagger 2}\quad B_LD^2HH^{\dagger}W_R\quad D^2HH^{\dagger}W_LW_R$ $D^3HH^{\dagger}LL^{\dagger}\quad D^3HH^{\dagger}QQ^{\dagger}\quad D^4H^2H^{\dagger 2}$
$T14\ (\mathbf{8},\mathbf{1},0)$	$B_L{}^2G_R{}^2\quad B_LB_RG_LG_R\quad B_LG_LG_R{}^2\quad G_L{}^2G_R{}^2$ $B_LDd_{\mathbb{C}}d_{\mathbb{C}}^{\dagger}G_R\quad B_LDG_Ru_{\mathbb{C}}u_{\mathbb{C}}^{\dagger}\quad B_LDG_RQQ^{\dagger}\quad Dd_{\mathbb{C}}d_{\mathbb{C}}^{\dagger}G_LG_R$ $DG_LG_Ru_{\mathbb{C}}u_{\mathbb{C}}^{\dagger}\quad DG_LG_RQQ^{\dagger}\quad D^2d_{\mathbb{C}}{}^2d_{\mathbb{C}}^{\dagger\,2}\quad D^2d_{\mathbb{C}}d_{\mathbb{C}}^{\dagger}u_{\mathbb{C}}u_{\mathbb{C}}^{\dagger}$ $D^2u_{\mathbb{C}}{}^2u_{\mathbb{C}}^{\dagger\,2}\quad D^2d_{\mathbb{C}}d_{\mathbb{C}}^{\dagger}QQ^{\dagger}\quad D^2QQ^{\dagger}u_{\mathbb{C}}u_{\mathbb{C}}^{\dagger}\quad D^2Q^2Q^{\dagger 2}$
$T6\ (\mathbf{1},\mathbf{5},0)$	$W_L{}^2W_R{}^2$
$T16\ (\mathbf{8},\mathbf{3},0)$	$G_R{}^2W_L{}^2\quad G_LG_RW_LW_R\quad DG_RQQ^{\dagger}W_L\quad D^2Q^2Q^{\dagger 2}$
$T18\ (\mathbf{27},\mathbf{1},0)$	$G_L{}^2G_R{}^2$
$T17\ (\mathbf{10},\mathbf{1},0)$	$G_L{}^2G_R{}^2$

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$R2$ $(\mathbf{1},\mathbf{1},1)$	$B_L B_R D e_{\mathbb{C}} e_{\mathbb{C}}^{\dagger} \quad B_R D^2 e_{\mathbb{C}} H^{\dagger} L \quad D^3 H H^{\dagger} L L^{\dagger} \quad B_L e_{\mathbb{C}}{}^2 e_{\mathbb{C}}^{\dagger 2}$ $B_L e_{\mathbb{C}} e_{\mathbb{C}}^{\dagger} L L^{\dagger} \quad B_L e_{\mathbb{C}} e_{\mathbb{C}}^{\dagger} Q Q^{\dagger} \quad B_L d_{\mathbb{C}} d_{\mathbb{C}}^{\dagger} e_{\mathbb{C}} e_{\mathbb{C}}^{\dagger} \quad B_L e_{\mathbb{C}} e_{\mathbb{C}}^{\dagger} u_{\mathbb{C}} u_{\mathbb{C}}^{\dagger}$ $B_L{}^2 e_{\mathbb{C}}^{\dagger} H L^{\dagger} \quad D e_{\mathbb{C}}{}^2 e_{\mathbb{C}}^{\dagger} H^{\dagger} L \quad D e_{\mathbb{C}} H^{\dagger} L^2 L^{\dagger} \quad D d_{\mathbb{C}} d_{\mathbb{C}}^{\dagger} e_{\mathbb{C}} H^{\dagger} L$ $D e_{\mathbb{C}} H^{\dagger} L u_{\mathbb{C}} u_{\mathbb{C}}^{\dagger} \quad D e_{\mathbb{C}} H^{\dagger} L Q Q^{\dagger} \quad B_L D e_{\mathbb{C}} e_{\mathbb{C}}^{\dagger} H H^{\dagger} \quad B_L D H H^{\dagger} L L^{\dagger}$
$R3$ $(\mathbf{1},\mathbf{2},\frac{1}{2})$	$B_L B_R D L L^{\dagger} \quad B_L D L L^{\dagger} W_R \quad D L L^{\dagger} W_L W_R \quad B_R D^2 e_{\mathbb{C}} H^{\dagger} L$ $D^2 e_{\mathbb{C}} H^{\dagger} L W_R \quad D^3 e_{\mathbb{C}} e_{\mathbb{C}}^{\dagger} H H^{\dagger} \quad B_L e_{\mathbb{C}} e_{\mathbb{C}}^{\dagger} L L^{\dagger} \quad B_L d_{\mathbb{C}} d_{\mathbb{C}}^{\dagger} L L^{\dagger}$ $B_L L L^{\dagger} u_{\mathbb{C}} u_{\mathbb{C}}^{\dagger} \quad B_L L^2 L^{\dagger 2} \quad B_L L L^{\dagger} Q Q^{\dagger} \quad e_{\mathbb{C}} e_{\mathbb{C}}^{\dagger} L L^{\dagger} W_L$ $d_{\mathbb{C}} d_{\mathbb{C}}^{\dagger} L L^{\dagger} W_L \quad L L^{\dagger} u_{\mathbb{C}} u_{\mathbb{C}}^{\dagger} W_L \quad L^2 L^{\dagger 2} W_L \quad L L^{\dagger} Q Q^{\dagger} W_L$ $D e_{\mathbb{C}}{}^2 e_{\mathbb{C}}^{\dagger} H^{\dagger} L \quad D e_{\mathbb{C}} H^{\dagger} L^2 L^{\dagger} \quad D d_{\mathbb{C}} d_{\mathbb{C}}^{\dagger} e_{\mathbb{C}} H^{\dagger} L \quad D e_{\mathbb{C}} H^{\dagger} L u_{\mathbb{C}} u_{\mathbb{C}}^{\dagger}$ $D e_{\mathbb{C}} H^{\dagger} L Q Q^{\dagger} \quad B_L D H H^{\dagger} L L^{\dagger} \quad D H H^{\dagger} L L^{\dagger} W_L \quad D^2 e_{\mathbb{C}} H H^{\dagger 2} L$
$R8$ $(\mathbf{3},\mathbf{1},-\frac{1}{3})$	$B_L B_R D d_{\mathbb{C}} d_{\mathbb{C}}^{\dagger} \quad B_L D d_{\mathbb{C}} d_{\mathbb{C}}^{\dagger} G_R \quad D d_{\mathbb{C}} d_{\mathbb{C}}^{\dagger} G_L G_R \quad B_R D^2 d_{\mathbb{C}} H^{\dagger} Q$ $D^2 d_{\mathbb{C}} G_R H^{\dagger} Q \quad D^3 H H^{\dagger} Q Q^{\dagger} \quad B_L d_{\mathbb{C}} d_{\mathbb{C}}^{\dagger} L L^{\dagger} \quad B_L d_{\mathbb{C}} d_{\mathbb{C}}^{\dagger} e_{\mathbb{C}} e_{\mathbb{C}}^{\dagger}$ $B_L d_{\mathbb{C}}{}^2 d_{\mathbb{C}}^{\dagger 2} \quad B_L d_{\mathbb{C}} d_{\mathbb{C}}^{\dagger} u_{\mathbb{C}} u_{\mathbb{C}}^{\dagger} \quad B_L d_{\mathbb{C}} d_{\mathbb{C}}^{\dagger} Q Q^{\dagger} \quad d_{\mathbb{C}} d_{\mathbb{C}}^{\dagger} G_L L L^{\dagger}$ $d_{\mathbb{C}} d_{\mathbb{C}}^{\dagger} e_{\mathbb{C}} e_{\mathbb{C}}^{\dagger} G_L \quad d_{\mathbb{C}}{}^2 d_{\mathbb{C}}^{\dagger 2} G_L \quad d_{\mathbb{C}} d_{\mathbb{C}}^{\dagger} G_L u_{\mathbb{C}} u_{\mathbb{C}}^{\dagger} \quad d_{\mathbb{C}} d_{\mathbb{C}}^{\dagger} G_L Q Q^{\dagger}$ $B_L{}^2 d_{\mathbb{C}}^{\dagger} H Q^{\dagger} \quad B_L d_{\mathbb{C}}^{\dagger} G_L H Q^{\dagger} \quad d_{\mathbb{C}}^{\dagger} G_L{}^2 H Q^{\dagger} \quad D d_{\mathbb{C}} e_{\mathbb{C}} e_{\mathbb{C}}^{\dagger} H^{\dagger} Q$ $D d_{\mathbb{C}} H^{\dagger} L L^{\dagger} Q \quad D d_{\mathbb{C}}{}^2 d_{\mathbb{C}}^{\dagger} H^{\dagger} Q \quad D d_{\mathbb{C}} H^{\dagger} Q u_{\mathbb{C}} u_{\mathbb{C}}^{\dagger} \quad D d_{\mathbb{C}} H^{\dagger} Q^2 Q^{\dagger}$ $B_L D d_{\mathbb{C}} d_{\mathbb{C}}^{\dagger} H H^{\dagger} \quad B_L D d_{\mathbb{C}}^{\dagger} H^2 u_{\mathbb{C}} \quad B_L D H H^{\dagger} Q Q^{\dagger} \quad D d_{\mathbb{C}} d_{\mathbb{C}}^{\dagger} G_L H H^{\dagger}$ $D d_{\mathbb{C}}^{\dagger} G_L H^2 u_{\mathbb{C}} \quad D G_L H H^{\dagger} Q Q^{\dagger} \quad D^2 d_{\mathbb{C}} H H^{\dagger 2} Q \quad D^2 H^2 H^{\dagger} Q u_{\mathbb{C}}$
$R9$ $(\mathbf{3},\mathbf{1},\frac{2}{3})$	$B_L B_R D u_{\mathbb{C}} u_{\mathbb{C}}^{\dagger} \quad B_L D G_R u_{\mathbb{C}} u_{\mathbb{C}}^{\dagger} \quad D G_L G_R u_{\mathbb{C}} u_{\mathbb{C}}^{\dagger} \quad B_R D^2 H Q u_{\mathbb{C}}$ $D^2 G_R H Q u_{\mathbb{C}} \quad D^3 H H^{\dagger} Q Q^{\dagger} \quad B_L L L^{\dagger} u_{\mathbb{C}} u_{\mathbb{C}}^{\dagger} \quad B_L e_{\mathbb{C}} e_{\mathbb{C}}^{\dagger} u_{\mathbb{C}} u_{\mathbb{C}}^{\dagger}$ $B_L d_{\mathbb{C}} d_{\mathbb{C}}^{\dagger} u_{\mathbb{C}} u_{\mathbb{C}}^{\dagger} \quad B_L u_{\mathbb{C}}{}^2 u_{\mathbb{C}}^{\dagger 2} \quad B_L Q Q^{\dagger} u_{\mathbb{C}} u_{\mathbb{C}}^{\dagger} \quad G_L L L^{\dagger} u_{\mathbb{C}} u_{\mathbb{C}}^{\dagger}$ $e_{\mathbb{C}} e_{\mathbb{C}}^{\dagger} G_L u_{\mathbb{C}} u_{\mathbb{C}}^{\dagger} \quad d_{\mathbb{C}} d_{\mathbb{C}}^{\dagger} G_L u_{\mathbb{C}} u_{\mathbb{C}}^{\dagger} \quad G_L u_{\mathbb{C}}{}^2 u_{\mathbb{C}}^{\dagger 2} \quad G_L Q Q^{\dagger} u_{\mathbb{C}} u_{\mathbb{C}}^{\dagger}$ $D e_{\mathbb{C}} e_{\mathbb{C}}^{\dagger} H Q u_{\mathbb{C}} \quad D H L L^{\dagger} Q u_{\mathbb{C}} \quad D d_{\mathbb{C}} d_{\mathbb{C}}^{\dagger} H Q u_{\mathbb{C}} \quad D H Q u_{\mathbb{C}}{}^2 u_{\mathbb{C}}^{\dagger}$ $D H Q^2 Q^{\dagger} u_{\mathbb{C}} \quad B_L D d_{\mathbb{C}} H^{\dagger 2} u_{\mathbb{C}}^{\dagger} \quad B_L D H H^{\dagger} u_{\mathbb{C}} u_{\mathbb{C}}^{\dagger} \quad D d_{\mathbb{C}} G_L H^{\dagger 2} u_{\mathbb{C}}^{\dagger}$ $D G_L H H^{\dagger} u_{\mathbb{C}} u_{\mathbb{C}}^{\dagger} \quad D^2 d_{\mathbb{C}} H H^{\dagger 2} Q \quad D^2 H^2 H^{\dagger} Q u_{\mathbb{C}}$
$R11$ $(\mathbf{3},\mathbf{2},\frac{1}{6})$	$B_L B_R D Q Q^{\dagger} \quad B_L D Q Q^{\dagger} W_R \quad B_L D G_R Q Q^{\dagger} \quad D Q Q^{\dagger} W_L W_R$ $D G_R Q Q^{\dagger} W_L \quad D G_L G_R Q Q^{\dagger} \quad B_R D^2 d_{\mathbb{C}} H^{\dagger} Q \quad D^2 d_{\mathbb{C}} H^{\dagger} Q W_R$ $D^2 d_{\mathbb{C}} G_R H^{\dagger} Q \quad B_R D^2 H Q u_{\mathbb{C}} \quad D^2 H Q u_{\mathbb{C}} W_R \quad D^2 G_R H Q u_{\mathbb{C}}$ $D^3 d_{\mathbb{C}} H^{\dagger 2} u_{\mathbb{C}}^{\dagger} \quad D^3 d_{\mathbb{C}} d_{\mathbb{C}}^{\dagger} H H^{\dagger} \quad D^3 H H^{\dagger} u_{\mathbb{C}} u_{\mathbb{C}}^{\dagger} \quad B_L e_{\mathbb{C}} e_{\mathbb{C}}^{\dagger} Q Q^{\dagger}$ $B_L L L^{\dagger} Q Q^{\dagger} \quad B_L d_{\mathbb{C}} d_{\mathbb{C}}^{\dagger} Q Q^{\dagger} \quad B_L Q Q^{\dagger} u_{\mathbb{C}} u_{\mathbb{C}}^{\dagger} \quad B_L Q^2 Q^{\dagger 2}$ $e_{\mathbb{C}} e_{\mathbb{C}}^{\dagger} Q Q^{\dagger} W_L \quad L L^{\dagger} Q Q^{\dagger} W_L \quad d_{\mathbb{C}} d_{\mathbb{C}}^{\dagger} Q Q^{\dagger} W_L \quad Q Q^{\dagger} u_{\mathbb{C}} u_{\mathbb{C}}^{\dagger} W_L$ $Q^2 Q^{\dagger 2} W_L \quad e_{\mathbb{C}} e_{\mathbb{C}}^{\dagger} G_L Q Q^{\dagger} \quad G_L L L^{\dagger} Q Q^{\dagger} \quad d_{\mathbb{C}} d_{\mathbb{C}}^{\dagger} G_L Q Q^{\dagger}$ $G_L Q Q^{\dagger} u_{\mathbb{C}} u_{\mathbb{C}}^{\dagger} \quad G_L Q^2 Q^{\dagger 2} \quad B_L{}^2 H^{\dagger} Q^{\dagger} u_{\mathbb{C}}^{\dagger} \quad B_L{}^2 d_{\mathbb{C}}^{\dagger} H Q^{\dagger}$ $B_L H^{\dagger} Q^{\dagger} u_{\mathbb{C}}^{\dagger} W_L \quad B_L d_{\mathbb{C}}^{\dagger} H Q^{\dagger} W_L \quad H^{\dagger} Q^{\dagger} u_{\mathbb{C}}^{\dagger} W_L{}^2 \quad d_{\mathbb{C}}^{\dagger} H Q^{\dagger} W_L{}^2$ $B_L G_L H^{\dagger} Q^{\dagger} u_{\mathbb{C}}^{\dagger} \quad B_L d_{\mathbb{C}}^{\dagger} G_L H Q^{\dagger} \quad G_L H^{\dagger} Q^{\dagger} u_{\mathbb{C}}^{\dagger} W_L \quad d_{\mathbb{C}}^{\dagger} G_L H Q^{\dagger} W_L$ $G_L{}^2 H^{\dagger} Q^{\dagger} u_{\mathbb{C}}^{\dagger} \quad d_{\mathbb{C}}^{\dagger} G_L{}^2 H Q^{\dagger} \quad D d_{\mathbb{C}} e_{\mathbb{C}} e_{\mathbb{C}}^{\dagger} H^{\dagger} Q \quad D e_{\mathbb{C}} e_{\mathbb{C}}^{\dagger} H Q u_{\mathbb{C}}$ $D d_{\mathbb{C}} H^{\dagger} L L^{\dagger} Q \quad D d_{\mathbb{C}}{}^2 d_{\mathbb{C}}^{\dagger} H^{\dagger} Q \quad D d_{\mathbb{C}} H^{\dagger} Q u_{\mathbb{C}} u_{\mathbb{C}}^{\dagger} \quad D H L L^{\dagger} Q u_{\mathbb{C}}$ $D d_{\mathbb{C}} d_{\mathbb{C}}^{\dagger} H Q u_{\mathbb{C}} \quad D H Q u_{\mathbb{C}}{}^2 u_{\mathbb{C}}^{\dagger} \quad D d_{\mathbb{C}} H^{\dagger} Q^2 Q^{\dagger} \quad D H Q^2 Q^{\dagger} u_{\mathbb{C}}$ $B_L D d_{\mathbb{C}} H^{\dagger 2} u_{\mathbb{C}}^{\dagger} \quad B_L D d_{\mathbb{C}} d_{\mathbb{C}}^{\dagger} H H^{\dagger} \quad B_L D H H^{\dagger} u_{\mathbb{C}} u_{\mathbb{C}}^{\dagger} \quad B_L D d_{\mathbb{C}}^{\dagger} H^2 u_{\mathbb{C}}$ $B_L D H H^{\dagger} Q Q^{\dagger} \quad D d_{\mathbb{C}} H^{\dagger 2} u_{\mathbb{C}}^{\dagger} W_L \quad D d_{\mathbb{C}} d_{\mathbb{C}}^{\dagger} H H^{\dagger} W_L \quad D H H^{\dagger} u_{\mathbb{C}} u_{\mathbb{C}}^{\dagger} W_L$ $D d_{\mathbb{C}}^{\dagger} H^2 u_{\mathbb{C}} W_L \quad D H H^{\dagger} Q Q^{\dagger} W_L \quad D d_{\mathbb{C}} G_L H^{\dagger 2} u_{\mathbb{C}}^{\dagger} \quad D d_{\mathbb{C}} d_{\mathbb{C}}^{\dagger} G_L H H^{\dagger}$ $D G_L H H^{\dagger} u_{\mathbb{C}} u_{\mathbb{C}}^{\dagger} \quad D d_{\mathbb{C}}^{\dagger} G_L H^2 u_{\mathbb{C}} \quad D G_L H H^{\dagger} Q Q^{\dagger} \quad D^2 d_{\mathbb{C}} H H^{\dagger 2} Q$
$R6$ $(\mathbf{1},\mathbf{3},1)$	$D e_{\mathbb{C}} e_{\mathbb{C}}^{\dagger} W_L W_R \quad D^2 e_{\mathbb{C}} H^{\dagger} L W_R \quad D^3 H H^{\dagger} L L^{\dagger} \quad e_{\mathbb{C}} e_{\mathbb{C}}^{\dagger} L L^{\dagger} W_L$ $e_{\mathbb{C}} e_{\mathbb{C}}^{\dagger} Q Q^{\dagger} W_L \quad e_{\mathbb{C}}^{\dagger} H L^{\dagger} W_L{}^2 \quad D e_{\mathbb{C}} H^{\dagger} L^2 L^{\dagger} \quad D e_{\mathbb{C}} H^{\dagger} L Q Q^{\dagger}$ $D e_{\mathbb{C}} e_{\mathbb{C}}^{\dagger} H H^{\dagger} W_L \quad D H H^{\dagger} L L^{\dagger} W_L \quad D^2 e_{\mathbb{C}} H H^{\dagger 2} L$
$R7$ $(\mathbf{1},\mathbf{4},\frac{1}{2})$	$D L L^{\dagger} W_L W_R \quad L^2 L^{\dagger 2} W_L \quad L L^{\dagger} Q Q^{\dagger} W_L \quad D H H^{\dagger} L L^{\dagger} W_L$
$R13$ $(\mathbf{3},\mathbf{3},-\frac{1}{3})$	$D d_{\mathbb{C}} d_{\mathbb{C}}^{\dagger} W_L W_R \quad D^2 d_{\mathbb{C}} H^{\dagger} Q W_R \quad D^3 H H^{\dagger} Q Q^{\dagger} \quad d_{\mathbb{C}} d_{\mathbb{C}}^{\dagger} L L^{\dagger} W_L$ $d_{\mathbb{C}} d_{\mathbb{C}}^{\dagger} Q Q^{\dagger} W_L \quad d_{\mathbb{C}}^{\dagger} H Q^{\dagger} W_L{}^2 \quad D d_{\mathbb{C}} H^{\dagger} L L^{\dagger} Q \quad D d_{\mathbb{C}} H^{\dagger} Q^2 Q^{\dagger}$ $D d_{\mathbb{C}} d_{\mathbb{C}}^{\dagger} H H^{\dagger} W_L \quad D d_{\mathbb{C}}^{\dagger} H^2 u_{\mathbb{C}} W_L \quad D H H^{\dagger} Q Q^{\dagger} W_L \quad D^2 d_{\mathbb{C}} H H^{\dagger 2} Q$
$R14$ $(\mathbf{3},\mathbf{3},\frac{2}{3})$	$D u_{\mathbb{C}} u_{\mathbb{C}}^{\dagger} W_L W_R \quad D^2 H Q u_{\mathbb{C}} W_R \quad D^3 H H^{\dagger} Q Q^{\dagger} \quad L L^{\dagger} u_{\mathbb{C}} u_{\mathbb{C}}^{\dagger} W_L$ $Q Q^{\dagger} u_{\mathbb{C}} u_{\mathbb{C}}^{\dagger} W_L \quad D H L L^{\dagger} Q u_{\mathbb{C}} \quad D H Q^2 Q^{\dagger} u_{\mathbb{C}} \quad D d_{\mathbb{C}} H^{\dagger 2} u_{\mathbb{C}}^{\dagger} W_L$ $D H H^{\dagger} u_{\mathbb{C}} u_{\mathbb{C}}^{\dagger} W_L \quad D^2 d_{\mathbb{C}} H H^{\dagger 2} Q \quad D^2 H^2 H^{\dagger} Q u_{\mathbb{C}}$

$F20\ (\mathbf{3},\mathbf{4},\frac{1}{6})$	$DQQ^\dagger W_L W_R \quad d_{\mathbb{C}}H^\dagger Q{W_L}^2 \quad HQu_{\mathbb{C}}{W_L}^2 \quad LL^\dagger QQ^\dagger W_L \quad Q^2Q^{\dagger 2}W_L \quad DHH^\dagger QQ^\dagger W_L \quad d_{\mathbb{C}}HH^{\dagger 2}QW_L \quad H^2H^\dagger Qu_{\mathbb{C}}W_L$
$R15\ (\mathbf{3},\mathbf{4},\frac{1}{6})$	$DQQ^\dagger W_L W_R \quad LL^\dagger QQ^\dagger W_L \quad Q^2Q^{\dagger 2}W_L \quad H^\dagger Q^\dagger u_{\mathbb{C}}^\dagger {W_L}^2 \quad d_{\mathbb{C}}^\dagger HQ^\dagger {W_L}^2 \quad DHH^\dagger QQ^\dagger W_L$
$F25\ (\mathbf{8},\mathbf{1},1)$	$De_{\mathbb{C}}e_{\mathbb{C}}^\dagger G_LG_R \quad e_{\mathbb{C}}{G_L}^2H^\dagger L \quad e_{\mathbb{C}}e_{\mathbb{C}}^\dagger G_LQQ^\dagger \quad d_{\mathbb{C}}d_{\mathbb{C}}^\dagger e_{\mathbb{C}}e_{\mathbb{C}}^\dagger G_L$
$R19\ (\mathbf{8},\mathbf{1},1)$	$De_{\mathbb{C}}e_{\mathbb{C}}^\dagger G_LG_R \quad e_{\mathbb{C}}e_{\mathbb{C}}^\dagger G_LQQ^\dagger \quad d_{\mathbb{C}}d_{\mathbb{C}}^\dagger e_{\mathbb{C}}e_{\mathbb{C}}^\dagger G_L \quad e_{\mathbb{C}}e_{\mathbb{C}}^\dagger G_Lu_{\mathbb{C}}u_{\mathbb{C}}^\dagger$
$F26\ (\mathbf{8},\mathbf{2},\frac{1}{2})$	$DG_LG_RLL^\dagger \quad d_{\mathbb{C}}d_{\mathbb{C}}^\dagger G_LLL^\dagger \quad G_LLL^\dagger u_{\mathbb{C}}u_{\mathbb{C}}^\dagger \quad G_LLL^\dagger QQ^\dagger$
$R20\ (\mathbf{8},\mathbf{2},\frac{1}{2})$	$DG_LG_RLL^\dagger \quad d_{\mathbb{C}}d_{\mathbb{C}}^\dagger G_LLL^\dagger \quad G_LLL^\dagger u_{\mathbb{C}}u_{\mathbb{C}}^\dagger \quad G_LLL^\dagger QQ^\dagger$
$F27\ (\mathbf{15},\mathbf{1},-\frac{1}{3})$	$Dd_{\mathbb{C}}d_{\mathbb{C}}^\dagger G_LG_R \quad d_{\mathbb{C}}{G_L}^2H^\dagger Q \quad {d_{\mathbb{C}}}^2d_{\mathbb{C}}^{\dagger 2}G_L \quad d_{\mathbb{C}}d_{\mathbb{C}}^\dagger G_Lu_{\mathbb{C}}u_{\mathbb{C}}^\dagger$
$F23\ (\mathbf{6},\mathbf{1},\frac{1}{3})$	$Dd_{\mathbb{C}}d_{\mathbb{C}}^\dagger G_LG_R \quad d_{\mathbb{C}}{G_L}^2H^\dagger Q \quad {d_{\mathbb{C}}}^2d_{\mathbb{C}}^{\dagger 2}G_L \quad d_{\mathbb{C}}d_{\mathbb{C}}^\dagger G_Lu_{\mathbb{C}}u_{\mathbb{C}}^\dagger$
$R21\ (\mathbf{15},\mathbf{1},-\frac{1}{3})$	$Dd_{\mathbb{C}}d_{\mathbb{C}}^\dagger G_LG_R \quad {d_{\mathbb{C}}}^2d_{\mathbb{C}}^{\dagger 2}G_L \quad d_{\mathbb{C}}d_{\mathbb{C}}^\dagger G_Lu_{\mathbb{C}}u_{\mathbb{C}}^\dagger \quad d_{\mathbb{C}}d_{\mathbb{C}}^\dagger G_LQQ^\dagger$
$R17\ (\mathbf{6},\mathbf{1},\frac{1}{3})$	$Dd_{\mathbb{C}}d_{\mathbb{C}}^\dagger G_LG_R \quad {d_{\mathbb{C}}}^2d_{\mathbb{C}}^{\dagger 2}G_L \quad d_{\mathbb{C}}d_{\mathbb{C}}^\dagger G_Lu_{\mathbb{C}}u_{\mathbb{C}}^\dagger \quad d_{\mathbb{C}}d_{\mathbb{C}}^\dagger G_LQQ^\dagger$
$F28\ (\mathbf{15},\mathbf{1},\frac{2}{3})$	$DG_LG_Ru_{\mathbb{C}}u_{\mathbb{C}}^\dagger \quad d_{\mathbb{C}}d_{\mathbb{C}}^\dagger G_Lu_{\mathbb{C}}u_{\mathbb{C}}^\dagger \quad G_L{u_{\mathbb{C}}}^2u_{\mathbb{C}}^{\dagger 2} \quad G_LQQ^\dagger u_{\mathbb{C}}u_{\mathbb{C}}^\dagger$
$F22\ (\mathbf{6},\mathbf{1},-\frac{2}{3})$	$DG_LG_Ru_{\mathbb{C}}u_{\mathbb{C}}^\dagger \quad d_{\mathbb{C}}d_{\mathbb{C}}^\dagger G_Lu_{\mathbb{C}}u_{\mathbb{C}}^\dagger \quad G_L{u_{\mathbb{C}}}^2u_{\mathbb{C}}^{\dagger 2} \quad G_LQQ^\dagger u_{\mathbb{C}}u_{\mathbb{C}}^\dagger$
$R22\ (\mathbf{15},\mathbf{1},\frac{2}{3})$	$DG_LG_Ru_{\mathbb{C}}u_{\mathbb{C}}^\dagger \quad d_{\mathbb{C}}d_{\mathbb{C}}^\dagger G_Lu_{\mathbb{C}}u_{\mathbb{C}}^\dagger \quad G_L{u_{\mathbb{C}}}^2u_{\mathbb{C}}^{\dagger 2} \quad G_LQQ^\dagger u_{\mathbb{C}}u_{\mathbb{C}}^\dagger$
$R16\ (\mathbf{6},\mathbf{1},-\frac{2}{3})$	$DG_LG_Ru_{\mathbb{C}}u_{\mathbb{C}}^\dagger \quad d_{\mathbb{C}}d_{\mathbb{C}}^\dagger G_Lu_{\mathbb{C}}u_{\mathbb{C}}^\dagger \quad G_L{u_{\mathbb{C}}}^2u_{\mathbb{C}}^{\dagger 2} \quad G_LQQ^\dagger u_{\mathbb{C}}u_{\mathbb{C}}^\dagger$
$F29\ (\mathbf{15},\mathbf{2},\frac{1}{6})$	$DG_LG_RQQ^\dagger \quad d_{\mathbb{C}}{G_L}^2H^\dagger Q \quad {G_L}^2HQu_{\mathbb{C}} \quad d_{\mathbb{C}}d_{\mathbb{C}}^\dagger G_LQQ^\dagger \quad G_LQQ^\dagger u_{\mathbb{C}}u_{\mathbb{C}}^\dagger \quad G_LQ^2Q^{\dagger 2}$
$F24\ (\mathbf{6},\mathbf{2},-\frac{1}{6})$	$DG_LG_RQQ^\dagger \quad d_{\mathbb{C}}{G_L}^2H^\dagger Q \quad {G_L}^2HQu_{\mathbb{C}} \quad d_{\mathbb{C}}d_{\mathbb{C}}^\dagger G_LQQ^\dagger \quad G_LQQ^\dagger u_{\mathbb{C}}u_{\mathbb{C}}^\dagger \quad G_LQ^2Q^{\dagger 2}$
$R23\ (\mathbf{15},\mathbf{2},\frac{1}{6})$	$DG_LG_RQQ^\dagger \quad d_{\mathbb{C}}d_{\mathbb{C}}^\dagger G_LQQ^\dagger \quad G_LQQ^\dagger u_{\mathbb{C}}u_{\mathbb{C}}^\dagger \quad G_LQ^2Q^{\dagger 2} \quad {G_L}^2H^\dagger Q^\dagger u_{\mathbb{C}}^\dagger \quad d_{\mathbb{C}}^\dagger {G_L}^2HQ^\dagger$
$R18\ (\mathbf{6},\mathbf{2},-\frac{1}{6})$	$DG_LG_RQQ^\dagger \quad d_{\mathbb{C}}d_{\mathbb{C}}^\dagger G_LQQ^\dagger \quad G_LQQ^\dagger u_{\mathbb{C}}u_{\mathbb{C}}^\dagger \quad G_LQ^2Q^{\dagger 2} \quad {G_L}^2H^\dagger Q^\dagger u_{\mathbb{C}}^\dagger \quad d_{\mathbb{C}}^\dagger {G_L}^2HQ^\dagger$
$V3\ (\mathbf{1},\mathbf{1},2)$	$D^2{e_{\mathbb{C}}}^2e_{\mathbb{C}}^{\dagger 2} \quad D{e_{\mathbb{C}}}^2e_{\mathbb{C}}^\dagger H^\dagger L \quad {e_{\mathbb{C}}}^2H^{\dagger 2}L^2$
$T3\ (\mathbf{1},\mathbf{2},\frac{3}{2})$	$D^2e_{\mathbb{C}}e_{\mathbb{C}}^\dagger LL^\dagger$
$T7\ (\mathbf{3},\mathbf{1},\frac{2}{3})$	$D^2d_{\mathbb{C}}^\dagger e_{\mathbb{C}}LQ^\dagger \quad D^2d_{\mathbb{C}}d_{\mathbb{C}}^\dagger e_{\mathbb{C}}e_{\mathbb{C}}^\dagger \quad D^2LL^\dagger QQ^\dagger$
$T9\ (\mathbf{3},\mathbf{2},-\frac{5}{6})$	$D^2d_{\mathbb{C}}^\dagger e_{\mathbb{C}}LQ^\dagger \quad D^2d_{\mathbb{C}}d_{\mathbb{C}}^\dagger LL^\dagger \quad D^2e_{\mathbb{C}}e_{\mathbb{C}}^\dagger QQ^\dagger \quad D^2e_{\mathbb{C}}Q^{\dagger 2}u_{\mathbb{C}} \quad D^2d_{\mathbb{C}}L^\dagger Q^\dagger u_{\mathbb{C}} \quad D^2QQ^\dagger u_{\mathbb{C}}u_{\mathbb{C}}^\dagger$
$T10\ (\mathbf{3},\mathbf{2},\frac{1}{6})$	$D^2LL^\dagger u_{\mathbb{C}}u_{\mathbb{C}}^\dagger \quad D^2d_{\mathbb{C}}L^\dagger Q^\dagger u_{\mathbb{C}} \quad D^2d_{\mathbb{C}}d_{\mathbb{C}}^\dagger QQ^\dagger$
$T8\ (\mathbf{3},\mathbf{1},\frac{5}{3})$	$D^2e_{\mathbb{C}}e_{\mathbb{C}}^\dagger u_{\mathbb{C}}u_{\mathbb{C}}^\dagger$
$V24\ (\mathbf{6},\mathbf{1},-\frac{2}{3})$	$D^2{d_{\mathbb{C}}}^2d_{\mathbb{C}}^{\dagger 2} \quad D{d_{\mathbb{C}}}^2d_{\mathbb{C}}^\dagger H^\dagger Q \quad {d_{\mathbb{C}}}^2H^{\dagger 2}Q^2$
$T15\ (\mathbf{8},\mathbf{1},1)$	$D^2d_{\mathbb{C}}d_{\mathbb{C}}^\dagger u_{\mathbb{C}}u_{\mathbb{C}}^\dagger$
$T2\ (\mathbf{1},\mathbf{1},1)$	$D^2d_{\mathbb{C}}d_{\mathbb{C}}^\dagger u_{\mathbb{C}}u_{\mathbb{C}}^\dagger$
$V26\ (\mathbf{6},\mathbf{1},\frac{4}{3})$	$D^2{u_{\mathbb{C}}}^2u_{\mathbb{C}}^{\dagger 2}$
$T11\ (\mathbf{3},\mathbf{3},\frac{2}{3})$	$D^2LL^\dagger QQ^\dagger$
$T12\ (\mathbf{6},\mathbf{2},-\frac{1}{6})$	$D^2d_{\mathbb{C}}d_{\mathbb{C}}^\dagger QQ^\dagger$
$T13\ (\mathbf{6},\mathbf{2},\frac{5}{6})$	$D^2QQ^\dagger u_{\mathbb{C}}u_{\mathbb{C}}^\dagger$
$V29\ (\mathbf{6},\mathbf{3},\frac{1}{3})$	$D^2Q^2Q^{\dagger 2} \quad Dd_{\mathbb{C}}H^\dagger Q^2Q^\dagger \quad DHQ^2Q^\dagger u_{\mathbb{C}} \quad {d_{\mathbb{C}}}^2H^{\dagger 2}Q^2 \quad d_{\mathbb{C}}HH^\dagger Q^2u_{\mathbb{C}} \quad H^2Q^2{u_{\mathbb{C}}}^2$
$R4\ (\mathbf{1},\mathbf{2},\frac{3}{2})$	$D^3e_{\mathbb{C}}e_{\mathbb{C}}^\dagger HH^\dagger \quad D^2e_{\mathbb{C}}HH^{\dagger 2}L$
$R10\ (\mathbf{3},\mathbf{2},-\frac{5}{6})$	$D^3d_{\mathbb{C}}d_{\mathbb{C}}^\dagger HH^\dagger \quad D^2d_{\mathbb{C}}HH^{\dagger 2}Q$
$R12\ (\mathbf{3},\mathbf{2},\frac{7}{6})$	$D^3HH^\dagger u_{\mathbb{C}}u_{\mathbb{C}}^\dagger$
$T5\ (\mathbf{1},\mathbf{3},1)$	$D^4H^2H^{\dagger 2}$

Table 4. UV theories that contain a single new particle and do not generate dim-6 operators at tree level.

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UV	dim-8 types
$F23\ (\mathbf{6},\mathbf{1},\frac{1}{3}), V26\ (\mathbf{6},\mathbf{1},\frac{4}{3})$	$d_{\mathbb{C}}e_{\mathbb{C}}G_L{u_{\mathbb{C}}}^2$
$F25\ (\mathbf{8},\mathbf{1},1), V26\ (\mathbf{6},\mathbf{1},\frac{4}{3})$	$d_{\mathbb{C}}e_{\mathbb{C}}G_L{u_{\mathbb{C}}}^2$
$V29\ (\mathbf{6},\mathbf{3},\frac{1}{3}), F26\ (\mathbf{8},\mathbf{2},\frac{1}{2})$	G_LLQ^3
$F24\ (\mathbf{6},\mathbf{2},-\frac{1}{6}), V29\ (\mathbf{6},\mathbf{3},\frac{1}{3})$	G_LLQ^3
$F26\ (\mathbf{8},\mathbf{2},\frac{1}{2}), F25\ (\mathbf{8},\mathbf{1},1)$	$e_{\mathbb{C}}{G_L}^2H^\dagger L$
$F27\ (\mathbf{15},\mathbf{1},-\frac{1}{3}), F29\ (\mathbf{15},\mathbf{2},\frac{1}{6})$	$d_{\mathbb{C}}{G_L}^2H^\dagger Q$
$F24\ (\mathbf{6},\mathbf{2},-\frac{1}{6}), F23\ (\mathbf{6},\mathbf{1},\frac{1}{3})$	$d_{\mathbb{C}}{G_L}^2H^\dagger Q$
$F29\ (\mathbf{15},\mathbf{2},\frac{1}{6}), F28\ (\mathbf{15},\mathbf{1},\frac{2}{3})$	${G_L}^2HQu_{\mathbb{C}}$
$F22\ (\mathbf{6},\mathbf{1},-\frac{2}{3}), F24\ (\mathbf{6},\mathbf{2},-\frac{1}{6})$	${G_L}^2HQu_{\mathbb{C}}$
$R2\ (\mathbf{1},\mathbf{1},1), V3\ (\mathbf{1},\mathbf{1},2)$	$B_L{e_{\mathbb{C}}}^2{e_{\mathbb{C}}^\dagger}^2 \quad D{e_{\mathbb{C}}}^2e_{\mathbb{C}}^\dagger H^\dagger L$
$V24\ (\mathbf{6},\mathbf{1},-\frac{2}{3}), R8\ (\mathbf{3},\mathbf{1},-\frac{1}{3})$	$B_L{d_{\mathbb{C}}}^2{d_{\mathbb{C}}^\dagger}^2 \quad {d_{\mathbb{C}}}^2{d_{\mathbb{C}}^\dagger}^2G_L \quad D{d_{\mathbb{C}}}^2d_{\mathbb{C}}^\dagger H^\dagger Q$
$R9\ (\mathbf{3},\mathbf{1},\frac{2}{3}), V26\ (\mathbf{6},\mathbf{1},\frac{4}{3})$	$B_L{u_{\mathbb{C}}}^2{u_{\mathbb{C}}^\dagger}^2 \quad G_L{u_{\mathbb{C}}}^2{u_{\mathbb{C}}^\dagger}^2 \quad DHQ{u_{\mathbb{C}}}^2u_{\mathbb{C}}^\dagger$
$R11\ (\mathbf{3},\mathbf{2},\frac{1}{6}), V29\ (\mathbf{6},\mathbf{3},\frac{1}{3})$	$B_LQ^2Q^{\dagger2} \quad Q^2Q^{\dagger2}W_L \quad G_LQ^2Q^{\dagger2} \quad Dd_{\mathbb{C}}H^\dagger Q^2Q^\dagger$
$R15\ (\mathbf{3},\mathbf{4},\frac{1}{6}), V29\ (\mathbf{6},\mathbf{3},\frac{1}{3})$	$Q^2Q^{\dagger2}W_L$
$V24\ (\mathbf{6},\mathbf{1},-\frac{2}{3}), R21\ (\mathbf{15},\mathbf{1},-\frac{1}{3})$	${d_{\mathbb{C}}}^2{d_{\mathbb{C}}^\dagger}^2G_L$
$R22\ (\mathbf{15},\mathbf{1},\frac{2}{3}), V26\ (\mathbf{6},\mathbf{1},\frac{4}{3})$	$G_L{u_{\mathbb{C}}}^2{u_{\mathbb{C}}^\dagger}^2$
$R23\ (\mathbf{15},\mathbf{2},\frac{1}{6}), V29\ (\mathbf{6},\mathbf{3},\frac{1}{3})$	$G_LQ^2Q^{\dagger2}$
$R11\ (\mathbf{3},\mathbf{2},\frac{1}{6}), R9\ (\mathbf{3},\mathbf{1},\frac{2}{3})$	${B_L}^2H^\dagger Q^\dagger u_{\mathbb{C}}^\dagger \quad B_LH^\dagger Q^\dagger u_{\mathbb{C}}^\dagger W_L \quad B_LG_LH^\dagger Q^\dagger u_{\mathbb{C}}^\dagger \quad G_LH^\dagger Q^\dagger u_{\mathbb{C}}^\dagger W_L$ ${G_L}^2H^\dagger Q^\dagger u_{\mathbb{C}}^\dagger \quad B_LDd_{\mathbb{C}}H^{\dagger2}u_{\mathbb{C}}^\dagger \quad B_LDHH^\dagger u_{\mathbb{C}}u_{\mathbb{C}}^\dagger \quad B_LDHH^\dagger QQ^\dagger$ $DHH^\dagger QQ^\dagger W_L \quad Dd_{\mathbb{C}}G_LH^{\dagger2}u_{\mathbb{C}}^\dagger \quad DG_LHH^\dagger u_{\mathbb{C}}u_{\mathbb{C}}^\dagger \quad DG_LHH^\dagger QQ^\dagger$ $D^2d_{\mathbb{C}}HH^{\dagger2}Q \quad D^2H^2H^\dagger Qu_{\mathbb{C}}$
$R3\ (\mathbf{1},\mathbf{2},\frac{1}{2}), R2\ (\mathbf{1},\mathbf{1},1)$	${B_L}^2e_{\mathbb{C}}^\dagger HL^\dagger \quad B_Le_{\mathbb{C}}^\dagger HL^\dagger W_L \quad B_LDe_{\mathbb{C}}e_{\mathbb{C}}^\dagger HH^\dagger \quad B_LDHH^\dagger LL^\dagger$ $DHH^\dagger LL^\dagger W_L \quad D^2e_{\mathbb{C}}HH^{\dagger2}L$
$R8\ (\mathbf{3},\mathbf{1},-\frac{1}{3}), R11\ (\mathbf{3},\mathbf{2},\frac{1}{6})$	${B_L}^2d_{\mathbb{C}}^\dagger HQ^\dagger \quad B_Ld_{\mathbb{C}}^\dagger HQ^\dagger W_L \quad B_Ld_{\mathbb{C}}^\dagger G_LHQ^\dagger \quad d_{\mathbb{C}}^\dagger G_LHQ^\dagger W_L$ $d_{\mathbb{C}}^\dagger {G_L}^2HQ^\dagger \quad B_LDd_{\mathbb{C}}d_{\mathbb{C}}^\dagger HH^\dagger \quad B_LDd_{\mathbb{C}}^\dagger H^2u_{\mathbb{C}} \quad B_LDHH^\dagger QQ^\dagger$ $DHH^\dagger QQ^\dagger W_L \quad Dd_{\mathbb{C}}d_{\mathbb{C}}^\dagger G_LHH^\dagger \quad Dd_{\mathbb{C}}^\dagger G_LH^2u_{\mathbb{C}} \quad DG_LHH^\dagger QQ^\dagger$ $D^2d_{\mathbb{C}}HH^{\dagger2}Q \quad D^2H^2H^\dagger Qu_{\mathbb{C}}$
$R11\ (\mathbf{3},\mathbf{2},\frac{1}{6}), R14\ (\mathbf{3},\mathbf{3},\frac{2}{3})$	$B_LH^\dagger Q^\dagger u_{\mathbb{C}}^\dagger W_L \quad H^\dagger Q^\dagger u_{\mathbb{C}}^\dagger {W_L}^2 \quad G_LH^\dagger Q^\dagger u_{\mathbb{C}}^\dagger W_L \quad B_LDHH^\dagger QQ^\dagger$ $Dd_{\mathbb{C}}H^{\dagger2}u_{\mathbb{C}}^\dagger W_L \quad DHH^\dagger u_{\mathbb{C}}u_{\mathbb{C}}^\dagger W_L \quad DHH^\dagger QQ^\dagger W_L \quad DG_LHH^\dagger QQ^\dagger$ $D^2d_{\mathbb{C}}HH^{\dagger2}Q \quad D^2H^2H^\dagger Qu_{\mathbb{C}}$
$R3\ (\mathbf{1},\mathbf{2},\frac{1}{2}), R6\ (\mathbf{1},\mathbf{3},1)$	$B_Le_{\mathbb{C}}^\dagger HL^\dagger W_L \quad e_{\mathbb{C}}^\dagger HL^\dagger {W_L}^2 \quad B_LDHH^\dagger LL^\dagger \quad De_{\mathbb{C}}e_{\mathbb{C}}^\dagger HH^\dagger W_L$ $DHH^\dagger LL^\dagger W_L \quad D^2e_{\mathbb{C}}HH^{\dagger2}L$
$R13\ (\mathbf{3},\mathbf{3},-\frac{1}{3}), R11\ (\mathbf{3},\mathbf{2},\frac{1}{6})$	$B_Ld_{\mathbb{C}}^\dagger HQ^\dagger W_L \quad d_{\mathbb{C}}^\dagger HQ^\dagger {W_L}^2 \quad d_{\mathbb{C}}^\dagger G_LHQ^\dagger W_L \quad B_LDHH^\dagger QQ^\dagger$ $Dd_{\mathbb{C}}d_{\mathbb{C}}^\dagger HH^\dagger W_L \quad Dd_{\mathbb{C}}^\dagger H^2u_{\mathbb{C}}W_L \quad DHH^\dagger QQ^\dagger W_L \quad DG_LHH^\dagger QQ^\dagger$ $D^2d_{\mathbb{C}}HH^{\dagger2}Q \quad D^2H^2H^\dagger Qu_{\mathbb{C}}$
$R15\ (\mathbf{3},\mathbf{4},\frac{1}{6}), R14\ (\mathbf{3},\mathbf{3},\frac{2}{3})$	$H^\dagger Q^\dagger u_{\mathbb{C}}^\dagger {W_L}^2 \quad DHH^\dagger QQ^\dagger W_L$
$R7\ (\mathbf{1},\mathbf{4},\frac{1}{2}), R6\ (\mathbf{1},\mathbf{3},1)$	$e_{\mathbb{C}}^\dagger HL^\dagger {W_L}^2 \quad DHH^\dagger LL^\dagger W_L$
$R13\ (\mathbf{3},\mathbf{3},-\frac{1}{3}), R15\ (\mathbf{3},\mathbf{4},\frac{1}{6})$	$d_{\mathbb{C}}^\dagger HQ^\dagger {W_L}^2 \quad DHH^\dagger QQ^\dagger W_L$
$R23\ (\mathbf{15},\mathbf{2},\frac{1}{6}), R22\ (\mathbf{15},\mathbf{1},\frac{2}{3})$	${G_L}^2H^\dagger Q^\dagger u_{\mathbb{C}}^\dagger$
$R16\ (\mathbf{6},\mathbf{1},-\frac{2}{3}), R18\ (\mathbf{6},\mathbf{2},-\frac{1}{6})$	${G_L}^2H^\dagger Q^\dagger u_{\mathbb{C}}^\dagger$
$R20\ (\mathbf{8},\mathbf{2},\frac{1}{2}), R19\ (\mathbf{8},\mathbf{1},1)$	$e_{\mathbb{C}}^\dagger {G_L}^2HL^\dagger$
$R21\ (\mathbf{15},\mathbf{1},-\frac{1}{3}), R23\ (\mathbf{15},\mathbf{2},\frac{1}{6})$	$d_{\mathbb{C}}^\dagger {G_L}^2HQ^\dagger$
$R18\ (\mathbf{6},\mathbf{2},-\frac{1}{6}), R17\ (\mathbf{6},\mathbf{1},\frac{1}{3})$	$d_{\mathbb{C}}^\dagger {G_L}^2HQ^\dagger$
$R2\ (\mathbf{1},\mathbf{1},1), R4\ (\mathbf{1},\mathbf{2},\frac{3}{2})$	$B_LDe_{\mathbb{C}}e_{\mathbb{C}}^\dagger HH^\dagger \quad D^2e_{\mathbb{C}}HH^{\dagger2}L$

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$R10\ (\mathbf{3},\mathbf{2},-\frac{5}{6}), R8\ (\mathbf{3},\mathbf{1},-\frac{1}{3})$	$B_L D d_{\mathbb{C}} d_{\mathbb{C}}^\dagger H H^\dagger \quad D d_{\mathbb{C}} d_{\mathbb{C}}^\dagger G_L H H^\dagger \quad D^2 d_{\mathbb{C}} H H^{\dagger 2} Q$
$R9\ (\mathbf{3},\mathbf{1},\frac{2}{3}), R12\ (\mathbf{3},\mathbf{2},\frac{7}{6})$	$B_L D H H^\dagger u_{\mathbb{C}} u_{\mathbb{C}}^\dagger \quad D G_L H H^\dagger u_{\mathbb{C}} u_{\mathbb{C}}^\dagger \quad D^2 H^2 H^\dagger Q u_{\mathbb{C}}$
$R6\ (\mathbf{1},\mathbf{3},1), R4\ (\mathbf{1},\mathbf{2},\frac{3}{2})$	$D e_{\mathbb{C}} e_{\mathbb{C}}^\dagger H H^\dagger W_L \quad D^2 e_{\mathbb{C}} H H^{\dagger 2} L$
$R10\ (\mathbf{3},\mathbf{2},-\frac{5}{6}), R13\ (\mathbf{3},\mathbf{3},-\frac{1}{3})$	$D d_{\mathbb{C}} d_{\mathbb{C}}^\dagger H H^\dagger W_L \quad D^2 d_{\mathbb{C}} H H^{\dagger 2} Q$
$R14\ (\mathbf{3},\mathbf{3},\frac{2}{3}), R12\ (\mathbf{3},\mathbf{2},\frac{7}{6})$	$D H H^\dagger u_{\mathbb{C}} u_{\mathbb{C}}^\dagger W_L \quad D^2 H^2 H^\dagger Q u_{\mathbb{C}}$
$V24\ (\mathbf{6},\mathbf{1},-\frac{2}{3}), V29\ (\mathbf{6},\mathbf{3},\frac{1}{3})$	${d_{\mathbb{C}}}^2 H^{\dagger 2} Q^2$
$V29\ (\mathbf{6},\mathbf{3},\frac{1}{3}), V26\ (\mathbf{6},\mathbf{1},\frac{4}{3})$	$H^2 Q^2 {u_{\mathbb{C}}}^2$

Table 5. UV theories that contain more than one new particles and do not generate dim-6 operators at tree level.

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5 Conclusion

In this work we investigate the connection between effective operators and their UV resonances in the bottom-up way. We utilize the J-basis technique to investigate all possible tree-level UV origins for the dimension-8 SMEFT operators in the Young Tensor basis. We list a complete set of 146 (82) possible UV resonances which could generate the dimension-8 SMEFT operators at the tree-level, and we write down all possible UV couplings up to mass dimension 5 (4). Except presenting the above results, two important theoretical issures are also addressed.

First, we clarify the ambiguity in the J-basis/UV resonance correspondence for the UV theories with heavy particles with spin $J \geq 1$, and illustrate that the couplings between the spin-J massive particles and the current of a different angular momentum $J' \neq J$ can be replaced by higher dimensional operators via field redefinition. In this way, we can classify the couplings in the UV theories into the "loop-induced" ones and the authentic tree-level ones. Following the line, we enumerate all the 3-pt and 4-pt "tree-level" couplings in the form of on-shell amplitudes involving massive particles of arbitrary spin-J. The convention also resolves to some extent the issue of whether a non-renormalizable operator can be generated at tree-level in a UV theory.

Second, we tackle the subtlety about the UV theories responsible for the generation of operators via field redefinition. In this work, we build a diagrammatic illustration, showing that these UV theories can be included by adding another step after the ordinary J-basis analysis — recursively identifying and replacing the heavy resonance in the diagram with the SM particles with the same quantum numbers. In doing so, we can proliferate the UV theories obtained from an ordinary j-basis analysis and thus take into account all the UV theories responsible for the operators in certain operator basis.

Finally, for the readers' convenience, we provide a UV database for dimension 8 operators in the form of `Mathematica` package, with which one can easily extract the relevant UV theories for generating a specific F-basis operator, including the information of new fields and interactions. Given these information, it provides new strategy on searching for new resonances at the large hadron collider (LHC). Current LHC searches focus on resonances signatures on various new physics models, and various simplified models, which can not be exhaustively searched. In this bottom-up EFT approach, the new resonances are organized by the mass dimension of the effective operators. Truncated to certain mass dimension,

Type: ${B_L}^4$	
$\mathcal{O}^f_1 = \frac{1}{24}\mathcal{Y}[\boxed{}\boxed{}\boxed{}\boxed{}_{B_L}]{B_L}^{\lambda\mu}{B_L}^{\lambda\rho}{B_L}^{\mu\nu}{B_L}^{\nu\rho}$.	
group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$ $\{B_{L1}, B_{L2}\}$ $\{B_{L3}, B_{L4}\}$	$\mathcal{O}^j$
* $(2,1,1,0)$	$-64\mathcal{O}^f_1$
* $(0,1,1,0)$	$16\mathcal{O}^f_1$

Table 6. UV resonance of type ${B_L}^4$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

such as dimension 8, only limited new resonances contribute to physical processes at the LHC. Thus only searching for such new resonances would be enough. In summary, we believe our results on listing UV resonances would benefit the phenomenology community in the future LHC searches.

Acknowledgments

J.H.Y. is supported by the National Science Foundation of China under Grants No. 12347105, No. 12375099 and No. 12047503, and the National Key Research and Development Program of China Grant No. 2020YFC2201501, No. 2021YFA0718304. M.-L.X. is supported in part by the Jay Jones Fund in the Department of Physics and Astronomy at Northwestern University, and by the Junior Foundation of Sun Yat-Sen University. H.-L.L. is supported by the 4.4517.08 IISN-F.N.R.S convention.

A UV list for operators involving 4 particles

In the following, we present the comprehensive results of the j-basis operators of dimension-8 SMEFT for each type of operators, and for each partition. The j-basis operators are expressed in terms of the f-basis operators modulo any pieces that can be converted by the field redefinition and covariant derivative commutator. For those operators with fermion fields, the flavor indices of fermion are labeled in alphabetic order starting with "p, r, s, t,..." depending on their order in the appearance in the operator type.

Type: ${B_L}^2{W_L}^2$		
$\mathcal{O}_1^f = \frac{1}{4}\mathcal{Y}[\Box\Box_{B_L}]\mathcal{Y}[\Box\Box_{W_L}]{B_L}^{\lambda\rho}{B_L}^{\mu\nu}{W_L}^{I\lambda\mu}{W_L}^{I\nu\rho}$,		
$\mathcal{O}_2^f = \frac{1}{4}\mathcal{Y}[\Box\Box_{B_L}]\mathcal{Y}[\Box\Box_{W_L}]{B_L}^{\mu\nu}{B_L}^{\mu\nu}{W_L}^{I\lambda\rho}{W_L}^{I\lambda\rho}$.		
group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$		$\mathcal{O}^j$
	$\{B_{L1}, B_{L2}\}$ $\{W_{L3}, W_{L4}\}$	
*	$(2,1,1,0)$	$48\mathcal{O}_1^f - 4\mathcal{O}_2^f$
*	$(0,1,1,0)$	$4\mathcal{O}_2^f$
	$\{B_{L1}, W_{L3}\}$ $\{B_{L2}, W_{L4}\}$	$\mathcal{O}^j$
*	$(2,1,3,0)$	$8\mathcal{O}_1^f - 14\mathcal{O}_2^f$
*	$(1,1,3,0)$	$8\mathcal{O}_1^f + 2\mathcal{O}_2^f$
*	$(0,1,3,0)$	$-8\mathcal{O}_1^f + 2\mathcal{O}_2^f$

Table 7. UV resonance of type ${B_L}^2{W_L}^2$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: ${W_L}^4$		
$\mathcal{O}_1^f = \frac{1}{24}\mathcal{Y}[\Box\Box\Box\Box_{W_L}]{W_L}^{I\mu\nu}{W_L}^{I\nu\rho}{W_L}^{J\lambda\mu}{W_L}^{J\lambda\rho}$,		
$\mathcal{O}_2^f = \frac{1}{24}\mathcal{Y}[\Box\Box\Box\Box_{W_L}]{W_L}^{I\lambda\rho}{W_L}^{I\mu\nu}{W_L}^{J\lambda\rho}{W_L}^{J\mu\nu}$.		
group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$		$\mathcal{O}^j$
	$\{W_{L1}, W_{L2}\}$ $\{W_{L3}, W_{L4}\}$	
*	$(2,1,5,0)$	$352\mathcal{O}_1^f + 24\mathcal{O}_2^f$
*	$(0,1,5,0)$	$32\mathcal{O}_1^f + 24\mathcal{O}_2^f$
*	$(2,1,1,0)$	$-32\mathcal{O}_1^f - 24\mathcal{O}_2^f$
*	$(0,1,1,0)$	$-16\mathcal{O}_1^f$
*	$(1,1,3,0)$	$32\mathcal{O}_1^f + 8\mathcal{O}_2^f$

Table 8. UV resonance of type ${W_L}^4$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

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Type: ${B_L}^2{G_L}^2$		
$\mathcal{O}^f_1 = \frac{1}{4}\mathcal{Y}[\square\square_{B_L}]\mathcal{Y}[\square\square_{G_L}]{B_L}^{\lambda\rho}{B_L}^{\mu\nu}{G_L}^{A\lambda\mu}{G_L}^{A\nu\rho}$,		
$\mathcal{O}^f_2 = \frac{1}{4}\mathcal{Y}[\square\square_{B_L}]\mathcal{Y}[\square\square_{G_L}]{B_L}^{\mu\nu}{B_L}^{\mu\nu}{G_L}^{A\lambda\rho}{G_L}^{A\lambda\rho}$.		
group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$		$\mathcal{O}^j$
	$\{B_{L1}, B_{L2}\}$ $\{G_{L3}, G_{L4}\}$	
*	$(2,1,1,0)$	$-48\mathcal{O}^f_1 + 4\mathcal{O}^f_2$
*	$(0,1,1,0)$	$-4\mathcal{O}^f_2$
	$\{B_{L1}, G_{L3}\}$ $\{B_{L2}, G_{L4}\}$	$\mathcal{O}^j$
*	$(2,8,1,0)$	$-8\mathcal{O}^f_1 + 14\mathcal{O}^f_2$
*	$(1,8,1,0)$	$-8\mathcal{O}^f_1 - 2\mathcal{O}^f_2$
*	$(0,8,1,0)$	$8\mathcal{O}^f_1 - 2\mathcal{O}^f_2$

Table 9. UV resonance of type ${B_L}^2{G_L}^2$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: ${G_L}^2{W_L}^2$		
$\mathcal{O}^f_1 = \frac{1}{4}\mathcal{Y}[\square\square_{G_L}]\mathcal{Y}[\square\square_{W_L}]{G_L}^{A\lambda\rho}{G_L}^{A\mu\nu}{W_L}^{I\lambda\mu}{W_L}^{I\nu\rho}$,		
$\mathcal{O}^f_2 = \frac{1}{4}\mathcal{Y}[\square\square_{G_L}]\mathcal{Y}[\square\square_{W_L}]{G_L}^{A\mu\nu}{G_L}^{A\mu\nu}{W_L}^{I\lambda\rho}{W_L}^{I\lambda\rho}$.		
group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$		$\mathcal{O}^j$
	$\{G_{L1}, G_{L2}\}$ $\{W_{L3}, W_{L4}\}$	
*	$(2,1,1,0)$	$48\mathcal{O}^f_1 - 4\mathcal{O}^f_2$
*	$(0,1,1,0)$	$4\mathcal{O}^f_2$
	$\{G_{L1}, W_{L3}\}$ $\{G_{L2}, W_{L4}\}$	$\mathcal{O}^j$
*	$(2,8,3,0)$	$8\mathcal{O}^f_1 - 14\mathcal{O}^f_2$
*	$(1,8,3,0)$	$8\mathcal{O}^f_1 + 2\mathcal{O}^f_2$
*	$(0,8,3,0)$	$-8\mathcal{O}^f_1 + 2\mathcal{O}^f_2$

Table 10. UV resonance of type ${G_L}^2{W_L}^2$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

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Type: $B_L G_L{}^3$		
$\mathcal{O}^f_1 = \frac{1}{6}\mathcal{Y}[\boxed{}\boxed{}\boxed{}_{G_L}] B_L{}^{\mu\nu} d^{ABC} G_L{}^{A\lambda\rho} G_L{}^{B\nu\rho} G_L{}^{C\lambda\mu}$.		
	group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$ $\{B_{L1}, G_{L2}\}$ $\{G_{L3}, G_{L4}\}$	$\mathcal{O}^j$
*	$(2, 8, 1, 0)$	$-64\mathcal{O}^f_1$
*	$(0, 8, 1, 0)$	$16\mathcal{O}^f_1$

Table 11. UV resonance of type $B_L G_L{}^3$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: $G_L{}^4$		
$\mathcal{O}^f_1 = \frac{1}{24}\mathcal{Y}[\boxed{}\boxed{}\boxed{}\boxed{}_{G_L}] d^{ABE} d^{CDE} G_L{}^{A\mu\nu} G_L{}^{B\lambda\rho} G_L{}^{C\nu\rho} G_L{}^{D\lambda\mu}$, $\mathcal{O}^f_2 = \frac{1}{24}\mathcal{Y}[\boxed{}\boxed{}\boxed{}\boxed{}_{G_L}] d^{ABE} d^{CDE} G_L{}^{A\mu\nu} G_L{}^{B\mu\nu} G_L{}^{C\lambda\rho} G_L{}^{D\lambda\rho}$, $\mathcal{O}^f_3 = \frac{1}{24}\mathcal{Y}[\boxed{}\boxed{}\boxed{}\boxed{}_{G_L}] f^{ABE} f^{CDE} G_L{}^{A\mu\nu} G_L{}^{B\lambda\rho} G_L{}^{C\mu\nu} G_L{}^{D\lambda\rho}$.		
	group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$ $\{G_{L1}, G_{L2}\}$ $\{G_{L3}, G_{L4}\}$	$\mathcal{O}^j$
*	$(2, 27, 1, 0)$	$522\mathcal{O}^f_1 - \frac{387}{2}\mathcal{O}^f_2 - 125\mathcal{O}^f_3$
*	$(0, 27, 1, 0)$	$-90\mathcal{O}^f_1 + \frac{117}{2}\mathcal{O}^f_2 - 25\mathcal{O}^f_3$
*	$(1, 10, 1, 0)$	$-12i\mathcal{O}^f_1 - 3i\mathcal{O}^f_2 + \frac{10i}{3}\mathcal{O}^f_3$
*	$(1, \overline{10}, 1, 0)$	$12i\mathcal{O}^f_1 + 3i\mathcal{O}^f_2 - \frac{10i}{3}\mathcal{O}^f_3$
*	$(2, 1, 1, 0)$	$-24\mathcal{O}^f_1 + 42\mathcal{O}^f_2 - 20\mathcal{O}^f_3$
*	$(0, 1, 1, 0)$	$24\mathcal{O}^f_1 - 6\mathcal{O}^f_2 - 4\mathcal{O}^f_3$
*	$(2, 8, 1, 0)$	$-48\mathcal{O}^f_1 + 4\mathcal{O}^f_2$
*	$(1, 8, 1, 0)$	$-8\mathcal{O}^f_3$
*	$(0, 8, 1, 0)$	$-4\mathcal{O}^f_2$

Table 12. UV resonance of type $G_L{}^4$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

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Type: $B_L D L L^\dagger W_L$		
$\mathcal{O}^f_1 = i((D_\nu L_{p_i})\sigma_\mu {L^\dagger}_r{}^j)\tau^I{}^i_j {B_L}^{\lambda\nu} {W_L}^{I\lambda\mu}.$		
group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$		$\mathcal{O}^j$
	$\{B_{L1}, W_{L2}\}$ $\{L_3, {L^\dagger}_4\}$	
*	$(1, 1, 3, 0)$	$-4\mathcal{O}^f_1$
	$\{B_{L1}, L_3\}$ $\{W_{L2}, {L^\dagger}_4\}$	$\mathcal{O}^j$
*	$(\frac{3}{2}, 1, 2, -\frac{1}{2})$	$-4\mathcal{O}^f_1$
	$\{B_{L1}, {L^\dagger}_4\}$ $\{W_{L2}, L_3\}$	$\mathcal{O}^j$
*	$(\frac{3}{2}, 1, 2, \frac{1}{2})$	$-4\mathcal{O}^f_1$

Table 13. UV resonance of type $B_L D L L^\dagger W_L$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: $B_L D Q Q^\dagger W_L$		
$\mathcal{O}^f_1 = i((D_\nu {Q_p}^{ai})\sigma_\mu {Q^\dagger}_r{}^{aj})\tau^I{}^i_j {B_L}^{\lambda\nu} {W_L}^{I\lambda\mu}.$		
group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$		$\mathcal{O}^j$
	$\{B_{L1}, W_{L2}\}$ $\{Q_3, {Q^\dagger}_4\}$	
*	$(1, 1, 3, 0)$	$-4\mathcal{O}^f_1$
	$\{B_{L1}, Q_3\}$ $\{W_{L2}, {Q^\dagger}_4\}$	$\mathcal{O}^j$
*	$(\frac{3}{2}, 3, 2, \frac{1}{6})$	$-4\mathcal{O}^f_1$
	$\{B_{L1}, {Q^\dagger}_4\}$ $\{W_{L2}, Q_3\}$	$\mathcal{O}^j$
*	$(\frac{3}{2}, \overline{3}, 2, -\frac{1}{6})$	$-4\mathcal{O}^f_1$

Table 14. UV resonance of type $B_L D Q Q^\dagger W_L$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: $DLL^{\dagger}{W_L}^2$

$\mathcal{O}^f_1 = \frac{1}{2}\mathcal{Y}[\square\square_{W_L}]\epsilon^{IJK}i{\tau^K}^i_j {W_L}^{I\lambda\nu}{W_L}^{J\lambda\mu}((D_\nu L_{p_i})\sigma_\mu {L^\dagger_r}^j)$.

	group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$	$\mathcal{O}^j$
	$\{W_{L1}, W_{L2}\}$ $\{L_3, {L^\dagger}_4\}$	
*	$(1, 1, 3, 0)$	$-4\mathcal{O}^f_1$
	$\{W_{L1}, L_3\}$ $\{W_{L2}, {L^\dagger}_4\}$	$\mathcal{O}^j$
*	$(\frac{3}{2}, 1, 4, -\frac{1}{2})$	$-4\mathcal{O}^f_1$
*	$(\frac{3}{2}, 1, 2, -\frac{1}{2})$	$-4\mathcal{O}^f_1$

Table 15. UV resonance of type $DLL^{\dagger}{W_L}^2$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: $DQQ^{\dagger}{W_L}^2$

$\mathcal{O}^f_1 = \frac{1}{2}\mathcal{Y}[\square\square_{W_L}]\epsilon^{IJK}i{\tau^K}^i_j {W_L}^{I\lambda\nu}{W_L}^{J\lambda\mu}((D_\nu {Q_p}^{ai})\sigma_\mu {Q^\dagger_r}^{aj})$.

	group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$	$\mathcal{O}^j$
	$\{W_{L1}, W_{L2}\}$ $\{Q_3, {Q^\dagger}_4\}$	
*	$(1, 1, 3, 0)$	$-4\mathcal{O}^f_1$
	$\{W_{L1}, Q_3\}$ $\{W_{L2}, {Q^\dagger}_4\}$	$\mathcal{O}^j$
*	$(\frac{3}{2}, 3, 4, \frac{1}{6})$	$-4\mathcal{O}^f_1$
*	$(\frac{3}{2}, 3, 2, \frac{1}{6})$	$-4\mathcal{O}^f_1$

Table 16. UV resonance of type $DQQ^{\dagger}{W_L}^2$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

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Type: $B_L D d_{\mathbb{C}} {d_{\mathbb{C}}}^\dagger G_L$		
$\mathcal{O}^f_1 = i((D_\nu {d_{\mathbb{C}}}_p{}^a)\sigma_\mu {d_{\mathbb{C}}^\dagger}_{rb})\lambda^{A}{}^b_a {B_L}^{\lambda\nu} {G_L}^{A\lambda\mu}$.		
group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$		$\mathcal{O}^j$
	$\{B_{L1}, G_{L2}\}$ $\{d_{\mathbb{C}3}, {d_{\mathbb{C}}^\dagger}_4\}$	
*	$(1, 8, 1, 0)$	$4\mathcal{O}^f_1$
	$\{B_{L1}, d_{\mathbb{C}3}\}$ $\{G_{L2}, {d_{\mathbb{C}}^\dagger}_4\}$	$\mathcal{O}^j$
*	$(\frac{3}{2}, \overline{3}, 1, \frac{1}{3})$	$4\mathcal{O}^f_1$
	$\{B_{L1}, {d_{\mathbb{C}}^\dagger}_4\}$ $\{G_{L2}, d_{\mathbb{C}3}\}$	$\mathcal{O}^j$
*	$(\frac{3}{2}, 3, 1, -\frac{1}{3})$	$4\mathcal{O}^f_1$

Table 17. UV resonance of type $B_L D d_{\mathbb{C}} {d_{\mathbb{C}}}^\dagger G_L$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: $B_L D G_L u_{\mathbb{C}} {u_{\mathbb{C}}}^\dagger$		
$\mathcal{O}^f_1 = i((D_\nu {u_{\mathbb{C}}}_p{}^a)\sigma_\mu {u_{\mathbb{C}}^\dagger}_{rb})\lambda^{A}{}^b_a {B_L}^{\lambda\nu} {G_L}^{A\lambda\mu}$.		
group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$		$\mathcal{O}^j$
	$\{B_{L1}, G_{L2}\}$ $\{u_{\mathbb{C}3}, {u_{\mathbb{C}}^\dagger}_4\}$	
*	$(1, 8, 1, 0)$	$4\mathcal{O}^f_1$
	$\{B_{L1}, u_{\mathbb{C}3}\}$ $\{G_{L2}, {u_{\mathbb{C}}^\dagger}_4\}$	$\mathcal{O}^j$
*	$(\frac{3}{2}, \overline{3}, 1, -\frac{2}{3})$	$4\mathcal{O}^f_1$
	$\{B_{L1}, {u_{\mathbb{C}}^\dagger}_4\}$ $\{G_{L2}, u_{\mathbb{C}3}\}$	$\mathcal{O}^j$
*	$(\frac{3}{2}, 3, 1, \frac{2}{3})$	$4\mathcal{O}^f_1$

Table 18. UV resonance of type $B_L D G_L u_{\mathbb{C}} {u_{\mathbb{C}}}^\dagger$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

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Type: $B_L D G_L Q Q^\dagger$	
$\mathcal{O}^f_1 = i((D_\nu {Q_p}^{ai})\sigma_\mu {Q^\dagger_r}^{bi})\lambda^{Aa}_{\ b} {B_L}^{\lambda\nu} {G_L}^{A\lambda\mu}.$	
group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$ $\{B_{L1}, G_{L2}\}$ $\{Q_3, {Q^\dagger}_4\}$	$\mathcal{O}^j$
* $(1, 8, 1, 0)$	$-4\mathcal{O}^f_1$
$\{B_{L1}, Q_3\}$ $\{G_{L2}, {Q^\dagger}_4\}$	$\mathcal{O}^j$
* $(\frac{3}{2}, 3, 2, \frac{1}{6})$	$-4\mathcal{O}^f_1$
$\{B_{L1}, {Q^\dagger}_4\}$ $\{G_{L2}, Q_3\}$	$\mathcal{O}^j$
* $(\frac{3}{2}, \overline{3}, 2, -\frac{1}{6})$	$-4\mathcal{O}^f_1$

Table 19. UV resonance of type $B_L D G_L Q Q^\dagger$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: $D G_L Q Q^\dagger W_L$	
$\mathcal{O}^f_1 = i((D_\nu {Q_p}^{ai})\sigma_\mu {Q^\dagger_r}^{bj})\lambda^{Aa}_{\ b} \tau^{Ii}_{\ j} {G_L}^{A\lambda\nu} {W_L}^{I\lambda\mu}.$	
group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$ $\{G_{L1}, W_{L2}\}$ $\{Q_3, {Q^\dagger}_4\}$	$\mathcal{O}^j$
* $(1, 8, 3, 0)$	$-4\mathcal{O}^f_1$
$\{G_{L1}, Q_3\}$ $\{W_{L2}, {Q^\dagger}_4\}$	$\mathcal{O}^j$
* $(\frac{3}{2}, 3, 2, \frac{1}{6})$	$-4\mathcal{O}^f_1$
$\{G_{L1}, {Q^\dagger}_4\}$ $\{W_{L2}, Q_3\}$	$\mathcal{O}^j$
* $(\frac{3}{2}, \overline{3}, 2, -\frac{1}{6})$	$-4\mathcal{O}^f_1$

Table 20. UV resonance of type $D G_L Q Q^\dagger W_L$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

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Type: $Dd_{\mathbb{C}}d_{\mathbb{C}}^{\dagger}G_L{}^2$		
$\mathcal{O}_1^f = \frac{1}{2}\mathcal{Y}[\square\square_{G_L}]f^{ABC}G_L{}^{A\lambda\nu}G_L{}^{B\lambda\mu}i\lambda^{Cb}_{\ a}((D_\nu d_{\mathbb{C}p}{}^a)\sigma_\mu d_{\mathbb{C}}{}^{\dagger}{}_{rb})$.		
group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$		$\mathcal{O}^j$
	$\{G_{L1}, G_{L2}\}$ $\{d_{\mathbb{C}3}, d_{\mathbb{C}}{}^{\dagger}{}_4\}$	
*	$(1, 8, 1, 0)$	$4\mathcal{O}_1^f$
	$\{G_{L1}, d_{\mathbb{C}3}\}$ $\{G_{L2}, d_{\mathbb{C}}{}^{\dagger}{}_4\}$	$\mathcal{O}^j$
*	$(\frac{3}{2}, \overline{15}, 1, \frac{1}{3})$	$4\mathcal{O}_1^f$
*	$(\frac{3}{2}, \overline{6}, 1, \frac{1}{3})$	$4\mathcal{O}_1^f$
*	$(\frac{3}{2}, \overline{3}, 1, \frac{1}{3})$	$4\mathcal{O}_1^f$

Table 21. UV resonance of type $Dd_{\mathbb{C}}d_{\mathbb{C}}^{\dagger}G_L{}^2$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: $DG_L{}^2u_{\mathbb{C}}u_{\mathbb{C}}^{\dagger}$		
$\mathcal{O}_1^f = \frac{1}{2}\mathcal{Y}[\square\square_{G_L}]f^{ABC}G_L{}^{A\lambda\nu}G_L{}^{B\lambda\mu}i\lambda^{Cb}_{\ a}((D_\nu u_{\mathbb{C}p}{}^a)\sigma_\mu u_{\mathbb{C}}{}^{\dagger}{}_{rb})$.		
group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$		$\mathcal{O}^j$
	$\{G_{L1}, G_{L2}\}$ $\{u_{\mathbb{C}3}, u_{\mathbb{C}}{}^{\dagger}{}_4\}$	
*	$(1, 8, 1, 0)$	$4\mathcal{O}_1^f$
	$\{G_{L1}, u_{\mathbb{C}3}\}$ $\{G_{L2}, u_{\mathbb{C}}{}^{\dagger}{}_4\}$	$\mathcal{O}^j$
*	$(\frac{3}{2}, \overline{15}, 1, -\frac{2}{3})$	$4\mathcal{O}_1^f$
*	$(\frac{3}{2}, \overline{6}, 1, -\frac{2}{3})$	$4\mathcal{O}_1^f$
*	$(\frac{3}{2}, \overline{3}, 1, -\frac{2}{3})$	$4\mathcal{O}_1^f$

Table 22. UV resonance of type $DG_L{}^2u_{\mathbb{C}}u_{\mathbb{C}}^{\dagger}$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

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Type: $DG_L{}^2QQ^\dagger$		
$\mathcal{O}^f_1 = \frac{1}{2}\mathcal{Y}[\boxed{}\boxed{}_{G_L}] f^{ABC} G_L{}^{A\lambda\nu} G_L{}^{B\lambda\mu} i\lambda^{Ca}{}_b((D_\nu Q_p{}^{ai})\sigma_\mu Q^\dagger{}_r{}^{bi}).$		
group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$		$\mathcal{O}^j$
	$\{G_{L1}, G_{L2}\}\quad\{Q_3, Q^\dagger{}_4\}$	
*	$(1, 8, 1, 0)$	$-4\mathcal{O}^f_1$
	$\{G_{L1}, Q_3\}\quad\{G_{L2}, Q^\dagger{}_4\}$	$\mathcal{O}^j$
*	$(\frac{3}{2}, 15, 2, \frac{1}{6})$	$-4\mathcal{O}^f_1$
*	$(\frac{3}{2}, 6, 2, \frac{1}{6})$	$-4\mathcal{O}^f_1$
*	$(\frac{3}{2}, 3, 2, \frac{1}{6})$	$-4\mathcal{O}^f_1$

Table 23. UV resonance of type $DG_L{}^2QQ^\dagger$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: $D^2 d_{\mathbb{C}} e_{\mathbb{C}} u_{\mathbb{C}}{}^2$		
$\mathcal{O}^f_1 = \frac{1}{2}\mathcal{Y}[\boxed{s}\boxed{t}](\epsilon_{abc}((D_\mu e_{\mathbb{C}r})(D^\mu u_{\mathbb{C}t}{}^c))(d_{\mathbb{C}p}{}^a u_{\mathbb{C}s}{}^b)),$ $\mathcal{O}^f_2 = \frac{1}{2}\mathcal{Y}[\begin{smallmatrix}\boxed{s}\\\boxed{t}\end{smallmatrix}](\epsilon_{abc}((D_\mu u_{\mathbb{C}s}{}^b)(D^\mu u_{\mathbb{C}t}{}^c))(d_{\mathbb{C}p}{}^a e_{\mathbb{C}r})),$ $\mathcal{O}^f_3 = \frac{1}{2}\mathcal{Y}[\begin{smallmatrix}\boxed{s}\\\boxed{t}\end{smallmatrix}](\epsilon_{abc}((D_\mu e_{\mathbb{C}r})(D^\mu u_{\mathbb{C}t}{}^c))(d_{\mathbb{C}p}{}^a u_{\mathbb{C}s}{}^b)).$		
group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$		$\mathcal{O}^j$
	$\{d_{\mathbb{C}1}, e_{\mathbb{C}2}\}\quad\{u_{\mathbb{C}3}, u_{\mathbb{C}4}\}$	
*	$(2, \overline{3}, 1, \frac{4}{3})$	$-4\mathcal{O}^f_2 + 12\mathcal{O}^f_3$
*	$(1, \overline{3}, 1, \frac{4}{3})$	$-4\mathcal{O}^f_1$
	$(0, \overline{3}, 1, \frac{4}{3})$	$-2\mathcal{O}^f_2$
	$\{d_{\mathbb{C}1}, u_{\mathbb{C}3}\}\quad\{e_{\mathbb{C}2}, u_{\mathbb{C}4}\}$	$\mathcal{O}^j$
*	$(2, 3, 1, -\frac{1}{3})$	$-10\mathcal{O}^f_1 + 6\mathcal{O}^f_2 + 2\mathcal{O}^f_3$
*	$(1, 3, 1, -\frac{1}{3})$	$-2\mathcal{O}^f_1 - 2\mathcal{O}^f_2 + 2\mathcal{O}^f_3$
	$(0, 3, 1, -\frac{1}{3})$	$-2\mathcal{O}^f_1 - 2\mathcal{O}^f_3$

Table 24. UV resonance of type $D^2 d_{\mathbb{C}} e_{\mathbb{C}} u_{\mathbb{C}}{}^2$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

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Type: $D^2 e_{\mathbb{C}} L Q u_{\mathbb{C}}$

$$
\begin{aligned}
\mathcal{O}_1^f &= \epsilon^{ij}((D_\mu Q_s{}^{aj})(D^\mu u_{\mathbb{C}t}{}^a))(e_{\mathbb{C}p} L_{ri}),\\
\mathcal{O}_2^f &= \epsilon^{ij}((D_\mu L_{ri})(D^\mu u_{\mathbb{C}t}{}^a))(e_{\mathbb{C}p} Q_s{}^{aj}),\\
\mathcal{O}_3^f &= i\epsilon^{ij}((D^\mu Q_s{}^{aj})(D^\nu u_{\mathbb{C}t}{}^a))(e_{\mathbb{C}p} \sigma_{\mu\nu} L_{ri}).
\end{aligned}
$$

group:	$(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$	$\mathcal{O}^j$
	$\{e_{\mathbb{C}1}, L_2\}$ $\{Q_3, u_{\mathbb{C}4}\}$	
*	$(2, 1, 2, \frac{1}{2})$	$4\mathcal{O}_1^f - 12\mathcal{O}_2^f - 6\mathcal{O}_3^f$
*	$(1, 1, 2, \frac{1}{2})$	$-2\mathcal{O}_3^f$
	$(0, 1, 2, \frac{1}{2})$	$2\mathcal{O}_1^f$
	$\{e_{\mathbb{C}1}, Q_3\}$ $\{L_2, u_{\mathbb{C}4}\}$	$\mathcal{O}^j$
*	$(2, 3, 2, \frac{7}{6})$	$-6\mathcal{O}_1^f - 2\mathcal{O}_2^f - 6\mathcal{O}_3^f$
*	$(1, 3, 2, \frac{7}{6})$	$2\mathcal{O}_1^f - 2\mathcal{O}_2^f - 2\mathcal{O}_3^f$
	$(0, 3, 2, \frac{7}{6})$	$2\mathcal{O}_2^f$
	$\{e_{\mathbb{C}1}, u_{\mathbb{C}4}\}$ $\{L_2, Q_3\}$	$\mathcal{O}^j$
*	$(2, \overline{3}, 1, \frac{1}{3})$	$6\mathcal{O}_1^f + 2\mathcal{O}_2^f - 4\mathcal{O}_3^f$
*	$(1, \overline{3}, 1, \frac{1}{3})$	$-2\mathcal{O}_1^f + 2\mathcal{O}_2^f$
	$(0, \overline{3}, 1, \frac{1}{3})$	$-2\mathcal{O}_2^f - 2\mathcal{O}_3^f$

Table 25. UV resonance of type $D^2 e_{\mathbb{C}} L Q u_{\mathbb{C}}$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

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Type: $D^2 d_{\mathbb{C}} Q^2 u_{\mathbb{C}}$

$$\begin{aligned}
\mathcal{O}^f_1 &= \tfrac{1}{2}\mathcal{Y}[\boxed{r\,|\,s}](\epsilon^{ij}((D_\mu Q_s{}^{aj})(D^\mu u_{\mathbb{C}t}{}^b))(d_{\mathbb{C}p}{}^a Q_r{}^{bi})),\\
\mathcal{O}^f_2 &= \tfrac{1}{2}\mathcal{Y}[\boxed{r\,|\,s}](\epsilon^{ij}((D_\mu Q_r{}^{bi})(D^\mu u_{\mathbb{C}t}{}^b))(d_{\mathbb{C}p}{}^a Q_s{}^{aj})),\\
\mathcal{O}^f_3 &= \tfrac{1}{2}\mathcal{Y}[\boxed{r\,|\,s}]\epsilon^{ij} i((D^\mu Q_s{}^{aj})(D^\nu u_{\mathbb{C}t}{}^b))(d_{\mathbb{C}p}{}^a \sigma_{\mu\nu} Q_r{}^{bi}),\\
\mathcal{O}^f_4 &= \tfrac{1}{2}\mathcal{Y}[\boxed{\begin{smallmatrix} r \\ s \end{smallmatrix}}](\epsilon^{ij}((D_\mu Q_s{}^{aj})(D^\mu u_{\mathbb{C}t}{}^b))(d_{\mathbb{C}p}{}^a Q_r{}^{bi})),\\
\mathcal{O}^f_5 &= \tfrac{1}{2}\mathcal{Y}[\boxed{\begin{smallmatrix} r \\ s \end{smallmatrix}}](\epsilon^{ij}((D_\mu Q_r{}^{bi})(D^\mu u_{\mathbb{C}t}{}^b))(d_{\mathbb{C}p}{}^a Q_s{}^{aj})),\\
\mathcal{O}^f_6 &= \tfrac{1}{2}\mathcal{Y}[\boxed{\begin{smallmatrix} r \\ s \end{smallmatrix}}]\epsilon^{ij} i((D^\mu Q_s{}^{aj})(D^\nu u_{\mathbb{C}t}{}^b))(d_{\mathbb{C}p}{}^a \sigma_{\mu\nu} Q_r{}^{bi}).
\end{aligned}$$

group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$		$\mathcal{O}^j$
	$\{d_{\mathbb{C}1}, Q_2\}$ $\{Q_3, u_{\mathbb{C}4}\}$	
*	$(2, 8, 2, \frac{1}{2})$	$6\mathcal{O}^f_1 - 38\mathcal{O}^f_2 - 24\mathcal{O}^f_3 + 18\mathcal{O}^f_4 - 34\mathcal{O}^f_5 - 12\mathcal{O}^f_6$
*	$(1, 8, 2, \frac{1}{2})$	$2\mathcal{O}^f_1 - 2\mathcal{O}^f_2 - 8\mathcal{O}^f_3 - 2\mathcal{O}^f_4 + 2\mathcal{O}^f_5 - 4\mathcal{O}^f_6$
	$(0, 8, 2, \frac{1}{2})$	$6\mathcal{O}^f_1 + 2\mathcal{O}^f_2 + 6\mathcal{O}^f_4 - 2\mathcal{O}^f_5$
*	$(2, 1, 2, \frac{1}{2})$	$6\mathcal{O}^f_1 + 2\mathcal{O}^f_2 + 6\mathcal{O}^f_3 - 6\mathcal{O}^f_4 - 2\mathcal{O}^f_5 - 6\mathcal{O}^f_6$
*	$(1, 1, 2, \frac{1}{2})$	$-2\mathcal{O}^f_1 + 2\mathcal{O}^f_2 + 2\mathcal{O}^f_3 + 2\mathcal{O}^f_4 - 2\mathcal{O}^f_5 - 2\mathcal{O}^f_6$
	$(0, 1, 2, \frac{1}{2})$	$-2\mathcal{O}^f_2 + 2\mathcal{O}^f_5$
	$\{d_{\mathbb{C}1}, u_{\mathbb{C}4}\}$ $\{Q_2, Q_3\}$	$\mathcal{O}^j$
*	$(2, 6, 1, -\frac{1}{3})$	$12\mathcal{O}^f_4 + 4\mathcal{O}^f_5 - 8\mathcal{O}^f_6$
*	$(1, 6, 1, -\frac{1}{3})$	$-4\mathcal{O}^f_1 + 4\mathcal{O}^f_2$
	$(0, 6, 1, -\frac{1}{3})$	$-4\mathcal{O}^f_5 - 4\mathcal{O}^f_6$
*	$(2, 3, 1, -\frac{1}{3})$	$-12\mathcal{O}^f_1 - 4\mathcal{O}^f_2 + 8\mathcal{O}^f_3$
*	$(1, 3, 1, -\frac{1}{3})$	$4\mathcal{O}^f_4 - 4\mathcal{O}^f_5$
	$(0, 3, 1, -\frac{1}{3})$	$4\mathcal{O}^f_2 + 4\mathcal{O}^f_3$

Table 26. UV resonance of type $D^2 d_{\mathbb{C}} Q^2 u_{\mathbb{C}}$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

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Type: D^2LQ^3	
$\mathcal{O}^f_1 = \frac{1}{6}\mathcal{Y}[\boxed{r\ s\ t}]\epsilon^{abc}\epsilon^{ik}\epsilon^{jl}((D_\mu Q_s{}^{bk})(D^\mu Q_t{}^{cl}))(L_{p_i}Q_r{}^{aj})$,	
$\mathcal{O}^f_2 = \frac{1}{3}\mathcal{Y}[\begin{smallmatrix} r & s \\ t & \end{smallmatrix}]\epsilon^{abc}\epsilon^{ik}\epsilon^{jl}((D_\mu Q_s{}^{bk})(D^\mu Q_t{}^{cl}))(L_{p_i}Q_r{}^{aj})$,	
$\mathcal{O}^f_3 = \frac{1}{3}\mathcal{Y}[\begin{smallmatrix} r & s \\ t & \end{smallmatrix}]\epsilon^{abc}\epsilon^{ij}\epsilon^{kl}((D_\mu Q_s{}^{bk})(D^\mu Q_t{}^{cl}))(L_{p_i}Q_r{}^{aj})$,	
$\mathcal{O}^f_4 = \frac{1}{6}\mathcal{Y}[\begin{smallmatrix} r \\ s \\ t \end{smallmatrix}]\epsilon^{abc}\epsilon^{ik}\epsilon^{jl}((D_\mu Q_s{}^{bk})(D^\mu Q_t{}^{cl}))(L_{p_i}Q_r{}^{aj})$.	
group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$ $\{L_1, Q_2\}$ $\{Q_3, Q_4\}$	$\mathcal{O}^j$
* $(2, 3, 3, -\frac{1}{3})$	$-20\mathcal{O}^f_4 + \mathcal{O}^f_2(-2 + 2(st)) + \mathcal{O}^f_3(-8 + 8(st))$
* $(1, 3, 3, -\frac{1}{3})$	$12\mathcal{O}^f_1 + \mathcal{O}^f_2(-6 - 6(st))$
$(0, 3, 3, -\frac{1}{3})$	$-4\mathcal{O}^f_4 + \mathcal{O}^f_3(2 - 2(st)) + \mathcal{O}^f_2(-4 + 4(st))$
* $(2, 3, 1, -\frac{1}{3})$	$20\mathcal{O}^f_1 + \mathcal{O}^f_2(18 + 18(st)) + \mathcal{O}^f_3(-8 - 8(st))$
* $(1, 3, 1, -\frac{1}{3})$	$4\mathcal{O}^f_4 + \mathcal{O}^f_2(-2 + 2(st))$
$(0, 3, 1, -\frac{1}{3})$	$4\mathcal{O}^f_1 + \mathcal{O}^f_3(2 + 2(st))$

Table 27. UV resonance of type D^2LQ^3. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: $B_L D^2 e_{\mathbb{C}} H^\dagger L$	
$\mathcal{O}^f_1 = i(e_{\mathbb{C}p}\sigma_{\mu\nu}(D_\lambda L_{ri}))(D^\nu H^{\dagger i})B_L{}^{\lambda\mu}$,	
$\mathcal{O}^f_2 = (e_{\mathbb{C}p}(D_\mu L_{ri}))(D_\nu H^{\dagger i})B_L{}^{\mu\nu}$.	
group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$ $\{B_{L1}, e_{\mathbb{C}2}\}$ $\{L_3, H^\dagger{}_4\}$	$\mathcal{O}^j$
* $(\frac{3}{2}, 1, 1, 1)$	$2\mathcal{O}^f_1 + 10\mathcal{O}^f_2$
* $(\frac{1}{2}, 1, 1, 1)$	$2\mathcal{O}^f_1 - 2\mathcal{O}^f_2$
$\{B_{L1}, L_3\}$ $\{e_{\mathbb{C}2}, H^\dagger{}_4\}$	$\mathcal{O}^j$
* $(\frac{3}{2}, 1, 2, -\frac{1}{2})$	$-2\mathcal{O}^f_1 + 10\mathcal{O}^f_2$
* $(\frac{1}{2}, 1, 2, -\frac{1}{2})$	$2\mathcal{O}^f_1 + 2\mathcal{O}^f_2$
$\{B_{L1}, H^\dagger{}_4\}$ $\{e_{\mathbb{C}2}, L_3\}$	$\mathcal{O}^j$
* $(2, 1, 2, -\frac{1}{2})$	$4\mathcal{O}^f_1$
* $(1, 1, 2, -\frac{1}{2})$	$4\mathcal{O}^f_2$

Table 28. UV resonance of type $B_L D^2 e_{\mathbb{C}} H^\dagger L$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

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Type: $B_L D^2 d_{\mathbb{C}} H^\dagger Q$		
$\mathcal{O}^f_1 = i(d_{\mathbb{C}p}{}^a \sigma_{\mu\nu}(D_\lambda Q_r{}^{ai}))(D^\nu H^{\dagger i})B_L{}^{\lambda\mu}$, $\mathcal{O}^f_2 = (d_{\mathbb{C}p}{}^a (D_\mu Q_r{}^{ai}))(D_\nu H^{\dagger i})B_L{}^{\mu\nu}$.		
group: (Spin, $\mathrm{SU}(3)_c$, $\mathrm{SU}(2)_w$, $\mathrm{U}(1)_y$)		$\mathcal{O}^j$
	$\{B_{L1}, d_{\mathbb{C}2}\}$ $\{Q_3, H^\dagger{}_4\}$	
*	$(\frac{3}{2}, \overline{3}, 1, \frac{1}{3})$	$2\mathcal{O}^f_1 + 10\mathcal{O}^f_2$
*	$(\frac{1}{2}, \overline{3}, 1, \frac{1}{3})$	$2\mathcal{O}^f_1 - 2\mathcal{O}^f_2$
	$\{B_{L1}, Q_3\}$ $\{d_{\mathbb{C}2}, H^\dagger{}_4\}$	$\mathcal{O}^j$
*	$(\frac{3}{2}, 3, 2, \frac{1}{6})$	$-2\mathcal{O}^f_1 + 10\mathcal{O}^f_2$
*	$(\frac{1}{2}, 3, 2, \frac{1}{6})$	$2\mathcal{O}^f_1 + 2\mathcal{O}^f_2$
	$\{B_{L1}, H^\dagger{}_4\}$ $\{d_{\mathbb{C}2}, Q_3\}$	$\mathcal{O}^j$
*	$(2, 1, 2, -\frac{1}{2})$	$4\mathcal{O}^f_1$
*	$(1, 1, 2, -\frac{1}{2})$	$4\mathcal{O}^f_2$

Table 29. UV resonance of type $B_L D^2 d_{\mathbb{C}} H^\dagger Q$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: $B_L D^2 H Q u_{\mathbb{C}}$		
$\mathcal{O}^f_1 = i\epsilon^{ij}(Q_p{}^{ai}\sigma_{\mu\nu}(D_\lambda u_{\mathbb{C}r}{}^a))(D^\nu H_j)B_L{}^{\lambda\mu}$, $\mathcal{O}^f_2 = \epsilon^{ij}(Q_p{}^{ai}(D_\mu u_{\mathbb{C}r}{}^a))(D_\nu H_j)B_L{}^{\mu\nu}$.		
group: (Spin, $\mathrm{SU}(3)_c$, $\mathrm{SU}(2)_w$, $\mathrm{U}(1)_y$)		$\mathcal{O}^j$
	$\{B_{L1}, Q_2\}$ $\{u_{\mathbb{C}3}, H_4\}$	
*	$(\frac{3}{2}, 3, 2, \frac{1}{6})$	$2\mathcal{O}^f_1 + 10\mathcal{O}^f_2$
*	$(\frac{1}{2}, 3, 2, \frac{1}{6})$	$2\mathcal{O}^f_1 - 2\mathcal{O}^f_2$
	$\{B_{L1}, u_{\mathbb{C}3}\}$ $\{Q_2, H_4\}$	$\mathcal{O}^j$
*	$(\frac{3}{2}, \overline{3}, 1, -\frac{2}{3})$	$-2\mathcal{O}^f_1 + 10\mathcal{O}^f_2$
*	$(\frac{1}{2}, \overline{3}, 1, -\frac{2}{3})$	$2\mathcal{O}^f_1 + 2\mathcal{O}^f_2$
	$\{B_{L1}, H_4\}$ $\{Q_2, u_{\mathbb{C}3}\}$	$\mathcal{O}^j$
*	$(2, 1, 2, \frac{1}{2})$	$4\mathcal{O}^f_1$
*	$(1, 1, 2, \frac{1}{2})$	$4\mathcal{O}^f_2$

Table 30. UV resonance of type $B_L D^2 H Q u_{\mathbb{C}}$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: $D^2 e_{\mathbb{C}} H^\dagger L W_L$	
$\mathcal{O}^f_1 = i(e_{\mathbb{C}p}\sigma_{\mu\nu}(D_\lambda L_{ri}))(D^\nu H^{\dagger j})\tau^{I}{}^{i}_{j} W_L{}^{I\lambda\mu}$, $\mathcal{O}^f_2 = (e_{\mathbb{C}p}(D_\mu L_{ri}))(D_\nu H^{\dagger j})\tau^{I}{}^{i}_{j} W_L{}^{I\mu\nu}$.	
group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$ $\{W_{L1}, e_{\mathbb{C}2}\}$ $\{L_3, H^\dagger{}_4\}$	$\mathcal{O}^j$
* $(\frac{3}{2}, 1, 3, -1)$	$2\mathcal{O}^f_1 + 10\mathcal{O}^f_2$
* $(\frac{1}{2}, 1, 3, -1)$	$2\mathcal{O}^f_1 - 2\mathcal{O}^f_2$
$\{W_{L1}, L_3\}$ $\{e_{\mathbb{C}2}, H^\dagger{}_4\}$	$\mathcal{O}^j$
* $(\frac{3}{2}, 1, 2, \frac{1}{2})$	$-2\mathcal{O}^f_1 + 10\mathcal{O}^f_2$
* $(\frac{1}{2}, 1, 2, \frac{1}{2})$	$2\mathcal{O}^f_1 + 2\mathcal{O}^f_2$
$\{W_{L1}, H^\dagger{}_4\}$ $\{e_{\mathbb{C}2}, L_3\}$	$\mathcal{O}^j$
* $(2, 1, 2, \frac{1}{2})$	$4\mathcal{O}^f_1$
* $(1, 1, 2, \frac{1}{2})$	$4\mathcal{O}^f_2$

Table 31. UV resonance of type $D^2 e_{\mathbb{C}} H^\dagger L W_L$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: $D^2 d_{\mathbb{C}} H^\dagger Q W_L$	
$\mathcal{O}^f_1 = i(d_{\mathbb{C}p}{}^a\sigma_{\mu\nu}(D_\lambda Q_r{}^{ai}))(D^\nu H^{\dagger j})\tau^{I}{}^{i}_{j} W_L{}^{I\lambda\mu}$, $\mathcal{O}^f_2 = (d_{\mathbb{C}p}{}^a(D_\mu Q_r{}^{ai}))(D_\nu H^{\dagger j})\tau^{I}{}^{i}_{j} W_L{}^{I\mu\nu}$.	
group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$ $\{W_{L1}, d_{\mathbb{C}2}\}$ $\{Q_3, H^\dagger{}_4\}$	$\mathcal{O}^j$
* $(\frac{3}{2}, 3, 3, -\frac{1}{3})$	$2\mathcal{O}^f_1 + 10\mathcal{O}^f_2$
* $(\frac{1}{2}, 3, 3, -\frac{1}{3})$	$2\mathcal{O}^f_1 - 2\mathcal{O}^f_2$
$\{W_{L1}, Q_3\}$ $\{d_{\mathbb{C}2}, H^\dagger{}_4\}$	$\mathcal{O}^j$
* $(\frac{3}{2}, \overline{3}, 2, -\frac{1}{6})$	$-2\mathcal{O}^f_1 + 10\mathcal{O}^f_2$
* $(\frac{1}{2}, \overline{3}, 2, -\frac{1}{6})$	$2\mathcal{O}^f_1 + 2\mathcal{O}^f_2$
$\{W_{L1}, H^\dagger{}_4\}$ $\{d_{\mathbb{C}2}, Q_3\}$	$\mathcal{O}^j$
* $(2, 1, 2, \frac{1}{2})$	$4\mathcal{O}^f_1$
* $(1, 1, 2, \frac{1}{2})$	$4\mathcal{O}^f_2$

Table 32. UV resonance of type $D^2 d_{\mathbb{C}} H^\dagger Q W_L$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: $D^2HQu_{\mathbb{C}}W_L$	
$\mathcal{O}^f_1 = i\epsilon^{jk}(Q_p{}^{ai}\sigma_{\mu\nu}(D_\lambda u_{\mathbb{C}r}{}^a))(D^\nu H_j)\tau^{I}{}^i_k W_L{}^{I\lambda\mu}$, $\mathcal{O}^f_2 = \epsilon^{jk}(Q_p{}^{ai}(D_\mu u_{\mathbb{C}r}{}^a))(D_\nu H_j)\tau^{I}{}^i_k W_L{}^{I\mu\nu}$.	
group: (Spin, SU(3)$_c$, SU(2)$_w$, U(1)$_y$) $\{W_{L1}, Q_2\}$ $\{u_{\mathbb{C}3}, H_4\}$	$\mathcal{O}^j$
* $(\frac{3}{2}, \overline{3}, 2, -\frac{1}{6})$	$2\mathcal{O}^f_1 + 10\mathcal{O}^f_2$
* $(\frac{1}{2}, \overline{3}, 2, -\frac{1}{6})$	$2\mathcal{O}^f_1 - 2\mathcal{O}^f_2$
$\{W_{L1}, u_{\mathbb{C}3}\}$ $\{Q_2, H_4\}$	$\mathcal{O}^j$
* $(\frac{3}{2}, 3, 3, \frac{2}{3})$	$-2\mathcal{O}^f_1 + 10\mathcal{O}^f_2$
* $(\frac{1}{2}, 3, 3, \frac{2}{3})$	$2\mathcal{O}^f_1 + 2\mathcal{O}^f_2$
$\{W_{L1}, H_4\}$ $\{Q_2, u_{\mathbb{C}3}\}$	$\mathcal{O}^j$
* $(2, 1, 2, -\frac{1}{2})$	$4\mathcal{O}^f_1$
* $(1, 1, 2, -\frac{1}{2})$	$4\mathcal{O}^f_2$

Table 33. UV resonance of type $D^2HQu_{\mathbb{C}}W_L$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: $D^2d_{\mathbb{C}}G_LH^\dagger Q$	
$\mathcal{O}^f_1 = i(d_{\mathbb{C}p}{}^a\sigma_{\mu\nu}(D_\lambda Q_r{}^{bi}))(D^\nu H^{\dagger i})\lambda^{A}{}^b_a G_L{}^{A\lambda\mu}$, $\mathcal{O}^f_2 = (d_{\mathbb{C}p}{}^a(D_\mu Q_r{}^{bi}))(D_\nu H^{\dagger i})\lambda^{A}{}^b_a G_L{}^{A\mu\nu}$.	
group: (Spin, SU(3)$_c$, SU(2)$_w$, U(1)$_y$) $\{G_{L1}, d_{\mathbb{C}2}\}$ $\{Q_3, H^\dagger{}_4\}$	$\mathcal{O}^j$
* $(\frac{3}{2}, \overline{3}, 1, \frac{1}{3})$	$2\mathcal{O}^f_1 + 10\mathcal{O}^f_2$
* $(\frac{1}{2}, \overline{3}, 1, \frac{1}{3})$	$2\mathcal{O}^f_1 - 2\mathcal{O}^f_2$
$\{G_{L1}, Q_3\}$ $\{d_{\mathbb{C}2}, H^\dagger{}_4\}$	$\mathcal{O}^j$
* $(\frac{3}{2}, \overline{3}, 2, -\frac{1}{6})$	$-2\mathcal{O}^f_1 + 10\mathcal{O}^f_2$
* $(\frac{1}{2}, \overline{3}, 2, -\frac{1}{6})$	$2\mathcal{O}^f_1 + 2\mathcal{O}^f_2$
$\{G_{L1}, H^\dagger{}_4\}$ $\{d_{\mathbb{C}2}, Q_3\}$	$\mathcal{O}^j$
* $(2, 8, 2, \frac{1}{2})$	$4\mathcal{O}^f_1$
* $(1, 8, 2, \frac{1}{2})$	$4\mathcal{O}^f_2$

Table 34. UV resonance of type $D^2d_{\mathbb{C}}G_LH^\dagger Q$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

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Type: $D^2G_LHQu_{\mathbb{C}}$		
$\mathcal{O}^f_1 = i\epsilon^{ij}({Q_p}^{ai}\sigma_{\mu\nu}(D_\lambda {u_{\mathbb{C}r}}^b))(D^\nu H_j)\lambda^{Aa}_{b}{G_L}^{A\lambda\mu},$ $\mathcal{O}^f_2 = \epsilon^{ij}({Q_p}^{ai}(D_\mu {u_{\mathbb{C}r}}^b))(D_\nu H_j)\lambda^{Aa}_{b}{G_L}^{A\mu\nu}.$		
group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$		$\mathcal{O}^j$
	$\{G_{L1}, Q_2\}$ $\{u_{\mathbb{C}3}, H_4\}$	
*	$(\frac{3}{2}, 3, 2, \frac{1}{6})$	$2\mathcal{O}^f_1 + 10\mathcal{O}^f_2$
*	$(\frac{1}{2}, 3, 2, \frac{1}{6})$	$2\mathcal{O}^f_1 - 2\mathcal{O}^f_2$
	$\{G_{L1}, u_{\mathbb{C}3}\}$ $\{Q_2, H_4\}$	$\mathcal{O}^j$
*	$(\frac{3}{2}, \overline{3}, 1, -\frac{2}{3})$	$-2\mathcal{O}^f_1 + 10\mathcal{O}^f_2$
*	$(\frac{1}{2}, \overline{3}, 1, -\frac{2}{3})$	$2\mathcal{O}^f_1 + 2\mathcal{O}^f_2$
	$\{G_{L1}, H_4\}$ $\{Q_2, u_{\mathbb{C}3}\}$	$\mathcal{O}^j$
*	$(2, 8, 2, \frac{1}{2})$	$4\mathcal{O}^f_1$
*	$(1, 8, 2, \frac{1}{2})$	$4\mathcal{O}^f_2$

Table 35. UV resonance of type $D^2G_LHQu_{\mathbb{C}}$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: ${B_L}^2D^2HH^\dagger$		
$\mathcal{O}^f_1 = \frac{1}{2}\mathcal{Y}[\square\square_{B_L}]{B_L}^{\lambda\nu}{B_L}^{\nu\lambda}(D_\mu H_i)(D^\mu {H^\dagger}^i).$		
group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$		$\mathcal{O}^j$
	$\{B_{L1}, B_{L2}\}$ $\{H_3, {H^\dagger}_4\}$	
*	$(0, 1, 1, 0)$	$-4\mathcal{O}^f_1$
	$\{B_{L1}, H_3\}$ $\{B_{L2}, {H^\dagger}_4\}$	$\mathcal{O}^j$
*	$(2, 1, 2, \frac{1}{2})$	$10\mathcal{O}^f_1$
*	$(1, 1, 2, \frac{1}{2})$	$-2\mathcal{O}^f_1$

Table 36. UV resonance of type ${B_L}^2D^2HH^\dagger$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: $B_L D^2 H H^\dagger W_L$	
$\mathcal{O}^f_1 = (D_\mu H_i)(D^\mu H^{\dagger j})\tau^{I}{}^i_j B_L{}^{\nu\lambda} W_L{}^{I\lambda\nu}$, $\mathcal{O}^f_2 = (D_\mu H_i)(D_\nu H^{\dagger j})\tau^{I}{}^i_j B_L{}^{\lambda\nu} W_L{}^{I\lambda\mu}$.	
group: (Spin, $\mathrm{SU}(3)_c$, $\mathrm{SU}(2)_w$, $\mathrm{U}(1)_y$) $\{B_{L1}, W_{L2}\}$ $\{H_3, H^\dagger{}_4\}$	$\mathcal{O}^j$
* $(1, 1, 3, 0)$	$-4\mathcal{O}^f_1 - 16\mathcal{O}^f_2$
* $(0, 1, 3, 0)$	$-4\mathcal{O}^f_1$
$\{B_{L1}, H_3\}$ $\{W_{L2}, H^\dagger{}_4\}$	$\mathcal{O}^j$
* $(2, 1, 2, \frac{1}{2})$	$4\mathcal{O}^f_1 - 24\mathcal{O}^f_2$
* $(1, 1, 2, \frac{1}{2})$	$-4\mathcal{O}^f_1 - 8\mathcal{O}^f_2$
$\{B_{L1}, H^\dagger{}_4\}$ $\{W_{L2}, H_3\}$	$\mathcal{O}^j$
* $(2, 1, 2, -\frac{1}{2})$	$-16\mathcal{O}^f_1 - 24\mathcal{O}^f_2$
* $(1, 1, 2, -\frac{1}{2})$	$-8\mathcal{O}^f_2$

Table 37. UV resonance of type $B_L D^2 H H^\dagger W_L$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: $D^2 H H^\dagger W_L{}^2$	
$\mathcal{O}^f_1 = \frac{1}{2}\mathcal{Y}[\boxed{}\boxed{}_{W_L}] W_L{}^{I\lambda\nu} W_L{}^{I\nu\lambda}(D_\mu H_i)(D^\mu H^{\dagger i})$, $\mathcal{O}^f_2 = \frac{1}{2}\mathcal{Y}[\boxed{}\boxed{}_{W_L}] \epsilon^{IJK}\tau^{K}{}^i_j W_L{}^{I\lambda\nu} W_L{}^{J\lambda\mu}(D_\mu H_i)(D_\nu H^{\dagger j})$.	
group: (Spin, $\mathrm{SU}(3)_c$, $\mathrm{SU}(2)_w$, $\mathrm{U}(1)_y$) $\{W_{L1}, W_{L2}\}$ $\{H_3, H^\dagger{}_4\}$	$\mathcal{O}^j$
* $(1, 1, 3, 0)$	$-16\mathcal{O}^f_2$
* $(0, 1, 1, 0)$	$-4\mathcal{O}^f_1$
$\{W_{L1}, H_3\}$ $\{W_{L2}, H^\dagger{}_4\}$	$\mathcal{O}^j$
* $(2, 1, 4, \frac{1}{2})$	$-20i\mathcal{O}^f_1 - 24\mathcal{O}^f_2$
* $(1, 1, 4, \frac{1}{2})$	$4i\mathcal{O}^f_1 - 8\mathcal{O}^f_2$
* $(2, 1, 2, \frac{1}{2})$	$10i\mathcal{O}^f_1 - 24\mathcal{O}^f_2$
* $(1, 1, 2, \frac{1}{2})$	$-2i\mathcal{O}^f_1 - 8\mathcal{O}^f_2$

Table 38. UV resonance of type $D^2 H H^\dagger W_L{}^2$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

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Type: $D^2{G_L}^2HH^\dagger$		
$\mathcal{O}^f_1 = \frac{1}{2}\mathcal{Y}[\square\square_{G_L}]{G_L}^{A\lambda\nu}{G_L}^{A\nu\lambda}(D_\mu H_i)(D^\mu {H^\dagger}^i)$.		
	group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$ $\{G_{L1}, G_{L2}\}$ $\{H_3, {H^\dagger}_4\}$	$\mathcal{O}^j$
*	$(0, 1, 1, 0)$	$-4\mathcal{O}^f_1$
	$\{G_{L1}, H_3\}$ $\{G_{L2}, {H^\dagger}_4\}$	$\mathcal{O}^j$
*	$(2, 8, 2, \frac{1}{2})$	$10\mathcal{O}^f_1$
*	$(1, 8, 2, \frac{1}{2})$	$-2\mathcal{O}^f_1$

Table 39. UV resonance of type $D^2{G_L}^2HH^\dagger$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: ${B_L}^2{B_R}^2$		
$\mathcal{O}^f_1 = {B_L}^{\lambda\rho}{B_L}^{\mu\nu}{B_R}^{\lambda}_{\mu}{B_R}^{\nu}_{\rho}$.		
	group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$ $\{B_{L1}, B_{L2}\}$ $\{B_{R3}, B_{R4}\}$	$\mathcal{O}^j$
*	$(0, 1, 1, 0)$	$16\mathcal{O}^f_1$
	$\{B_{L1}, B_{R3}\}$ $\{B_{L2}, B_{R4}\}$	$\mathcal{O}^j$
*	$(2, 1, 1, 0)$	$16\mathcal{O}^f_1$

Table 40. UV resonance of type ${B_L}^2{B_R}^2$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: ${B_L}^2{W_R}^2$		
$\mathcal{O}^f_1 = {B_L}^{\lambda\rho}{B_L}^{\mu\nu}{W_R}^{I\lambda}_{\mu}{W_R}^{I\nu}_{\rho}$.		
	group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$ $\{B_{L1}, B_{L2}\}$ $\{W_{R3}, W_{R4}\}$	$\mathcal{O}^j$
*	$(0, 1, 1, 0)$	$-16\mathcal{O}^f_1$
	$\{B_{L1}, W_{R3}\}$ $\{B_{L2}, W_{R4}\}$	$\mathcal{O}^j$
*	$(2, 1, 3, 0)$	$-16\mathcal{O}^f_1$

Table 41. UV resonance of type ${B_L}^2{W_R}^2$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

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Type: $B_L B_R W_L W_R$		
$\mathcal{O}_1^f = B_L{}^{\mu\nu} B_{R\rho}^{\nu} W_L{}^{I\lambda\rho} W_{R\mu}^{I\lambda}$.		
group: (Spin, $\mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y$) $\{B_{L1}, W_{L2}\}$ $\{B_{R3}, W_{R4}\}$		$\mathcal{O}^j$
*	$(0,1,3,0)$	$-16\mathcal{O}_1^f$
	$\{B_{L1}, B_{R3}\}$ $\{W_{L2}, W_{R4}\}$	$\mathcal{O}^j$
*	$(2,1,1,0)$	$-16\mathcal{O}_1^f$
	$\{B_{L1}, W_{R4}\}$ $\{W_{L2}, B_{R3}\}$	$\mathcal{O}^j$
*	$(2,1,3,0)$	$-16\mathcal{O}_1^f$

Table 42. UV resonance of type $B_L B_R W_L W_R$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: ${B_L}^2 {G_R}^2$		
$\mathcal{O}_1^f = B_L{}^{\lambda\rho} B_L{}^{\mu\nu} G_{R\mu}^{A\lambda} G_{R\rho}^{A\nu}$.		
group: (Spin, $\mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y$) $\{B_{L1}, B_{L2}\}$ $\{G_{R3}, G_{R4}\}$		$\mathcal{O}^j$
*	$(0,1,1,0)$	$16\mathcal{O}_1^f$
	$\{B_{L1}, G_{R3}\}$ $\{B_{L2}, G_{R4}\}$	$\mathcal{O}^j$
*	$(2,8,1,0)$	$16\mathcal{O}_1^f$

Table 43. UV resonance of type ${B_L}^2 {G_R}^2$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: $B_L B_R G_L G_R$		
$\mathcal{O}^f_1 = B_L{}^{\mu\nu} B_R{}^{\nu}_{\rho} G_L{}^{A\lambda\rho} G_R{}^{A\lambda}_{\mu}$.		
group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$	$\{B_{L1}, G_{L2}\}$ $\{B_{R3}, G_{R4}\}$	$\mathcal{O}^j$
*	$(0, 8, 1, 0)$	$16\mathcal{O}^f_1$
	$\{B_{L1}, B_{R3}\}$ $\{G_{L2}, G_{R4}\}$	$\mathcal{O}^j$
*	$(2, 1, 1, 0)$	$16\mathcal{O}^f_1$
	$\{B_{L1}, G_{R4}\}$ $\{G_{L2}, B_{R3}\}$	$\mathcal{O}^j$
*	$(2, 8, 1, 0)$	$16\mathcal{O}^f_1$

Table 44. UV resonance of type $B_L B_R G_L G_R$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: $W_L{}^2 W_R{}^2$		
$\mathcal{O}^f_1 = \frac{1}{4}\mathcal{Y}[\square\square_{W_L}]\mathcal{Y}[\square\square_{W_R}] W_L{}^{I\mu\nu} W_L{}^{J\lambda\rho} W_R{}^{I\nu}_{\rho} W_R{}^{J\lambda}_{\mu}$, $\mathcal{O}^f_2 = \frac{1}{4}\mathcal{Y}[\square\square_{W_L}]\mathcal{Y}[\square\square_{W_R}] W_L{}^{I\lambda\rho} W_L{}^{I\mu\nu} W_R{}^{K\lambda}_{\mu} W_R{}^{K\nu}_{\rho}$.		
group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$	$\{W_{L1}, W_{L2}\}$ $\{W_{R3}, W_{R4}\}$	$\mathcal{O}^j$
*	$(0, 1, 5, 0)$	$-96\mathcal{O}^f_1 + 32\mathcal{O}^f_2$
*	$(0, 1, 1, 0)$	$-16\mathcal{O}^f_2$
	$\{W_{L1}, W_{R3}\}$ $\{W_{L2}, W_{R4}\}$	$\mathcal{O}^j$
*	$(2, 1, 5, 0)$	$-16\mathcal{O}^f_1 - 48\mathcal{O}^f_2$
*	$(2, 1, 1, 0)$	$-16\mathcal{O}^f_1$
*	$(2, 1, 3, 0)$	$-16\mathcal{O}^f_1 + 16\mathcal{O}^f_2$

Table 45. UV resonance of type $W_L{}^2 W_R{}^2$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

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Type: ${G_R}^2{W_L}^2$		
$\mathcal{O}^f_1 = {G_R}_\mu^{A\lambda}{G_R}_\rho^{A\nu}{W_L}^{I\lambda\rho}{W_L}^{I\mu\nu}$.		
group: $(\mathrm{Spin},\mathrm{SU}(3)_c,\mathrm{SU}(2)_w,\mathrm{U}(1)_y)$		$\mathcal{O}^j$
	$\{W_{L1},W_{L2}\}\quad\{G_{R3},G_{R4}\}$	
*	$(0,1,1,0)$	$-16\mathcal{O}^f_1$
	$\{W_{L1},G_{R3}\}\quad\{W_{L2},G_{R4}\}$	$\mathcal{O}^j$
*	$(2,8,3,0)$	$-16\mathcal{O}^f_1$

Table 46. UV resonance of type ${G_R}^2{W_L}^2$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: $G_LG_RW_LW_R$		
$\mathcal{O}^f_1 = {G_L}^{A\mu\nu}{G_R}_\rho^{A\nu}{W_L}^{I\lambda\rho}{W_R}_\mu^{I\lambda}$.		
group: $(\mathrm{Spin},\mathrm{SU}(3)_c,\mathrm{SU}(2)_w,\mathrm{U}(1)_y)$		$\mathcal{O}^j$
	$\{G_{L1},W_{L2}\}\quad\{G_{R3},W_{R4}\}$	
*	$(0,8,3,0)$	$-16\mathcal{O}^f_1$
	$\{G_{L1},G_{R3}\}\quad\{W_{L2},W_{R4}\}$	$\mathcal{O}^j$
*	$(2,1,1,0)$	$-16\mathcal{O}^f_1$
	$\{G_{L1},W_{R4}\}\quad\{W_{L2},G_{R3}\}$	$\mathcal{O}^j$
*	$(2,8,3,0)$	$-16\mathcal{O}^f_1$

Table 47. UV resonance of type $G_LG_RW_LW_R$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: $B_LG_L{G_R}^2$		
$\mathcal{O}^f_1 = \frac{1}{2}\mathcal{Y}[\square\square_{G_R}]{B_L}^{\mu\nu}d^{ABC}{G_L}^{A\lambda\rho}{G_R}_\rho^{B\nu}{G_R}_\mu^{C\lambda}$.		
group: $(\mathrm{Spin},\mathrm{SU}(3)_c,\mathrm{SU}(2)_w,\mathrm{U}(1)_y)$		$\mathcal{O}^j$
	$\{B_{L1},G_{L2}\}\quad\{G_{R3},G_{R4}\}$	
*	$(0,8,1,0)$	$16\mathcal{O}^f_1$
	$\{B_{L1},G_{R3}\}\quad\{G_{L2},G_{R4}\}$	$\mathcal{O}^j$
*	$(2,8,1,0)$	$16\mathcal{O}^f_1$

Table 48. UV resonance of type $B_LG_L{G_R}^2$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

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Type: ${G_L}^2{G_R}^2$		
$\mathcal{O}^f_1 = \frac{1}{4}\mathcal{Y}[\square\square_{G_L}]\mathcal{Y}[\square\square_{G_R}]d^{ABE}d^{CDE}{G_L}^{A\mu\nu}{G_L}^{B\lambda\rho}{G_R}_\rho^{C\nu}{G_R}_\mu^{D\lambda}$, $\mathcal{O}^f_2 = \frac{1}{4}\mathcal{Y}[\square\square_{G_L}]\mathcal{Y}[\square\square_{G_R}]{G_L}^{A\lambda\rho}{G_L}^{A\mu\nu}{G_R}_\mu^{C\lambda}{G_R}_\rho^{C\nu}$, $\mathcal{O}^f_3 = \frac{1}{4}\mathcal{Y}[\square\square_{G_L}]\mathcal{Y}[\square\square_{G_R}]{G_L}^{A\mu\nu}{G_L}^{B\lambda\rho}{G_R}_\rho^{A\nu}{G_R}_\mu^{B\lambda}$.		
group: (Spin, $\mathrm{SU}(3)_c$, $\mathrm{SU}(2)_w$, $\mathrm{U}(1)_y$) $\{G_{L1}, G_{L2}\}$ $\{G_{R3}, G_{R4}\}$		$\mathcal{O}^j$
*	$(0, 27, 1, 0)$	$96\mathcal{O}^f_1 + 20\mathcal{O}^f_2 - 160\mathcal{O}^f_3$
*	$(0, 1, 1, 0)$	$16\mathcal{O}^f_2$
*	$(0, 8, 1, 0)$	$16\mathcal{O}^f_1$
	$\{G_{L1}, G_{R3}\}$ $\{G_{L2}, G_{R4}\}$	$\mathcal{O}^j$
*	$(2, 27, 1, 0)$	$-\frac{48}{5}\mathcal{O}^f_1 - \frac{64}{5}\mathcal{O}^f_2 - \frac{28}{5}\mathcal{O}^f_3$
*	$(2, 10, 1, 0)$	$12\mathcal{O}^f_1 - 8\mathcal{O}^f_2 + 4\mathcal{O}^f_3$
*	$(2, \overline{10}, 1, 0)$	$12\mathcal{O}^f_1 - 8\mathcal{O}^f_2 + 4\mathcal{O}^f_3$
*	$(2, 1, 1, 0)$	$16\mathcal{O}^f_3$
*	$(2, 8, 1, 0)$	$-8\mathcal{O}^f_1 + \frac{8}{3}\mathcal{O}^f_2 + \frac{16}{3}\mathcal{O}^f_3$ $16\mathcal{O}^f_1 + \frac{32}{3}\mathcal{O}^f_2 - \frac{32}{3}\mathcal{O}^f_3$

Table 49. UV resonance of type ${G_L}^2{G_R}^2$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: $B_L B_R D e_{\mathbb{C}} {e_{\mathbb{C}}}^\dagger$		
$\mathcal{O}^f_1 = i(e_{\mathbb{C}p}\sigma_\mu(D_\nu {e_{\mathbb{C}}}^\dagger{}_r)){B_L}^{\lambda\nu}{B_R}_\mu^\lambda$.		
group: (Spin, $\mathrm{SU}(3)_c$, $\mathrm{SU}(2)_w$, $\mathrm{U}(1)_y$) $\{B_{L1}, e_{\mathbb{C}2}\}$ $\{{e_{\mathbb{C}}}^\dagger{}_3, B_{R4}\}$		$\mathcal{O}^j$
*	$(\frac{1}{2}, 1, 1, 1)$	$4\mathcal{O}^f_1$
	$\{B_{L1}, {e_{\mathbb{C}}}^\dagger{}_3\}$ $\{e_{\mathbb{C}2}, B_{R4}\}$	$\mathcal{O}^j$
*	$(\frac{3}{2}, 1, 1, -1)$	$4\mathcal{O}^f_1$
	$\{B_{L1}, B_{R4}\}$ $\{e_{\mathbb{C}2}, {e_{\mathbb{C}}}^\dagger{}_3\}$	$\mathcal{O}^j$
*	$(2, 1, 1, 0)$	$4\mathcal{O}^f_1$

Table 50. UV resonance of type $B_L B_R D e_{\mathbb{C}} {e_{\mathbb{C}}}^\dagger$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

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Type: $B_L B_R D L L^\dagger$	
$\mathcal{O}^f_1 = i(L_{p_i}\sigma_\mu(D_\nu {L^\dagger}_r{}^i)){B_L}^{\lambda\nu}{B_R}^\lambda_\mu$.	
group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$ $\{B_{L1}, L_2\}$ $\{L^\dagger{}_3, B_{R4}\}$	$\mathcal{O}^j$
* $(\frac{1}{2}, 1, 2, -\frac{1}{2})$	$-4\mathcal{O}^f_1$
$\{B_{L1}, L^\dagger{}_3\}$ $\{L_2, B_{R4}\}$	$\mathcal{O}^j$
* $(\frac{3}{2}, 1, 2, \frac{1}{2})$	$-4\mathcal{O}^f_1$
$\{B_{L1}, B_{R4}\}$ $\{L_2, L^\dagger{}_3\}$	$\mathcal{O}^j$
* $(2, 1, 1, 0)$	$-4\mathcal{O}^f_1$

Table 51. UV resonance of type $B_L B_R D L L^\dagger$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: $B_L D L L^\dagger W_R$	
$\mathcal{O}^f_1 = i(L_{p_i}\sigma_\mu(D_\nu {L^\dagger}_r{}^j))\tau^{I\,i}_{\ j}{B_L}^{\lambda\nu}{W_R}^{I\lambda}_\mu$.	
group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$ $\{B_{L1}, L_2\}$ $\{L^\dagger{}_3, W_{R4}\}$	$\mathcal{O}^j$
* $(\frac{1}{2}, 1, 2, -\frac{1}{2})$	$-4\mathcal{O}^f_1$
$\{B_{L1}, L^\dagger{}_3\}$ $\{L_2, W_{R4}\}$	$\mathcal{O}^j$
* $(\frac{3}{2}, 1, 2, \frac{1}{2})$	$-4\mathcal{O}^f_1$
$\{B_{L1}, W_{R4}\}$ $\{L_2, L^\dagger{}_3\}$	$\mathcal{O}^j$
* $(2, 1, 3, 0)$	$-4\mathcal{O}^f_1$

Table 52. UV resonance of type $B_L D L L^\dagger W_R$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

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Type: $B_L B_R D d_{\mathbb{C}} d_{\mathbb{C}}^\dagger$		
$\mathcal{O}_1^f = i({d_{\mathbb{C}}}_p{}^a \sigma_\mu (D_\nu {d_{\mathbb{C}}^\dagger}_{ra})) {B_L}^{\lambda\nu} {B_R}_\mu^\lambda$.		
group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$	$\{B_{L1}, d_{\mathbb{C}2}\}$ $\{{d_{\mathbb{C}}^\dagger}_3, B_{R4}\}$	$\mathcal{O}^j$
*	$(\frac{1}{2}, \overline{3}, 1, \frac{1}{3})$	$4\mathcal{O}_1^f$
	$\{B_{L1}, {d_{\mathbb{C}}^\dagger}_3\}$ $\{d_{\mathbb{C}2}, B_{R4}\}$	$\mathcal{O}^j$
*	$(\frac{3}{2}, 3, 1, -\frac{1}{3})$	$4\mathcal{O}_1^f$
	$\{B_{L1}, B_{R4}\}$ $\{d_{\mathbb{C}2}, {d_{\mathbb{C}}^\dagger}_3\}$	$\mathcal{O}^j$
*	$(2, 1, 1, 0)$	$4\mathcal{O}_1^f$

Table 53. UV resonance of type $B_L B_R D d_{\mathbb{C}} d_{\mathbb{C}}^\dagger$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: $B_L B_R D u_{\mathbb{C}} u_{\mathbb{C}}^\dagger$		
$\mathcal{O}_1^f = i({u_{\mathbb{C}}}_p{}^a \sigma_\mu (D_\nu {u_{\mathbb{C}}^\dagger}_{ra})) {B_L}^{\lambda\nu} {B_R}_\mu^\lambda$.		
group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$	$\{B_{L1}, u_{\mathbb{C}2}\}$ $\{{u_{\mathbb{C}}^\dagger}_3, B_{R4}\}$	$\mathcal{O}^j$
*	$(\frac{1}{2}, \overline{3}, 1, -\frac{2}{3})$	$4\mathcal{O}_1^f$
	$\{B_{L1}, {u_{\mathbb{C}}^\dagger}_3\}$ $\{u_{\mathbb{C}2}, B_{R4}\}$	$\mathcal{O}^j$
*	$(\frac{3}{2}, 3, 1, \frac{2}{3})$	$4\mathcal{O}_1^f$
	$\{B_{L1}, B_{R4}\}$ $\{u_{\mathbb{C}2}, {u_{\mathbb{C}}^\dagger}_3\}$	$\mathcal{O}^j$
*	$(2, 1, 1, 0)$	$4\mathcal{O}_1^f$

Table 54. UV resonance of type $B_L B_R D u_{\mathbb{C}} u_{\mathbb{C}}^\dagger$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: $B_L D d_{\mathbb{C}} {d_{\mathbb{C}}}^\dagger G_R$		
$\mathcal{O}^f_1 = i({d_{\mathbb{C}}}_p{}^a \sigma_\mu (D_\nu {d_{\mathbb{C}}}^\dagger{}_{rb}))\lambda^{A}{}^b_a {B_L}^{\lambda\nu} {G_R}^{A\lambda}_\mu.$		
	group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$	$\mathcal{O}^j$
	$\{B_{L1}, d_{\mathbb{C}2}\}$ $\{{d_{\mathbb{C}}}^\dagger{}_3, G_{R4}\}$	
*	$(\frac{1}{2}, \overline{3}, 1, \frac{1}{3})$	$4\mathcal{O}^f_1$
	$\{B_{L1}, {d_{\mathbb{C}}}^\dagger{}_3\}$ $\{d_{\mathbb{C}2}, G_{R4}\}$	$\mathcal{O}^j$
*	$(\frac{3}{2}, 3, 1, -\frac{1}{3})$	$4\mathcal{O}^f_1$
	$\{B_{L1}, G_{R4}\}$ $\{d_{\mathbb{C}2}, {d_{\mathbb{C}}}^\dagger{}_3\}$	$\mathcal{O}^j$
*	$(2, 8, 1, 0)$	$4\mathcal{O}^f_1$

Table 55. UV resonance of type $B_L D d_{\mathbb{C}} {d_{\mathbb{C}}}^\dagger G_R$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: $B_L D G_R u_{\mathbb{C}} {u_{\mathbb{C}}}^\dagger$		
$\mathcal{O}^f_1 = i({u_{\mathbb{C}}}_p{}^a \sigma_\mu (D_\nu {u_{\mathbb{C}}}^\dagger{}_{rb}))\lambda^{A}{}^b_a {B_L}^{\lambda\nu} {G_R}^{A\lambda}_\mu.$		
	group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$	$\mathcal{O}^j$
	$\{B_{L1}, u_{\mathbb{C}2}\}$ $\{{u_{\mathbb{C}}}^\dagger{}_3, G_{R4}\}$	
*	$(\frac{1}{2}, \overline{3}, 1, -\frac{2}{3})$	$4\mathcal{O}^f_1$
	$\{B_{L1}, {u_{\mathbb{C}}}^\dagger{}_3\}$ $\{u_{\mathbb{C}2}, G_{R4}\}$	$\mathcal{O}^j$
*	$(\frac{3}{2}, 3, 1, \frac{2}{3})$	$4\mathcal{O}^f_1$
	$\{B_{L1}, G_{R4}\}$ $\{u_{\mathbb{C}2}, {u_{\mathbb{C}}}^\dagger{}_3\}$	$\mathcal{O}^j$
*	$(2, 8, 1, 0)$	$4\mathcal{O}^f_1$

Table 56. UV resonance of type $B_L D G_R u_{\mathbb{C}} {u_{\mathbb{C}}}^\dagger$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: $B_L B_R D Q Q^\dagger$		
$\mathcal{O}^f_1 = i({Q_p}^{ai}\sigma_\mu(D_\nu {Q^\dagger}_r{}^{ai})){B_L}^{\lambda\nu}{B_R}^\lambda_\mu.$		
group:	$(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$ $\{B_{L1}, Q_2\}$ $\{{Q^\dagger}_3, B_{R4}\}$	$\mathcal{O}^j$
*	$(\frac{1}{2}, 3, 2, \frac{1}{6})$	$-4\mathcal{O}^f_1$
	$\{B_{L1}, {Q^\dagger}_3\}$ $\{Q_2, B_{R4}\}$	$\mathcal{O}^j$
*	$(\frac{3}{2}, \overline{3}, 2, -\frac{1}{6})$	$-4\mathcal{O}^f_1$
	$\{B_{L1}, B_{R4}\}$ $\{Q_2, {Q^\dagger}_3\}$	$\mathcal{O}^j$
*	$(2, 1, 1, 0)$	$-4\mathcal{O}^f_1$

Table 57. UV resonance of type $B_L B_R D Q Q^\dagger$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: $B_L D Q Q^\dagger W_R$		
$\mathcal{O}^f_1 = i({Q_p}^{ai}\sigma_\mu(D_\nu {Q^\dagger}_r{}^{aj}))\tau^{I}{}^i_j{B_L}^{\lambda\nu}{W_R}^{I\lambda}_\mu.$		
group:	$(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$ $\{B_{L1}, Q_2\}$ $\{{Q^\dagger}_3, W_{R4}\}$	$\mathcal{O}^j$
*	$(\frac{1}{2}, 3, 2, \frac{1}{6})$	$-4\mathcal{O}^f_1$
	$\{B_{L1}, {Q^\dagger}_3\}$ $\{Q_2, W_{R4}\}$	$\mathcal{O}^j$
*	$(\frac{3}{2}, \overline{3}, 2, -\frac{1}{6})$	$-4\mathcal{O}^f_1$
	$\{B_{L1}, W_{R4}\}$ $\{Q_2, {Q^\dagger}_3\}$	$\mathcal{O}^j$
*	$(2, 1, 3, 0)$	$-4\mathcal{O}^f_1$

Table 58. UV resonance of type $B_L D Q Q^\dagger W_R$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

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Type: $B_L D G_R Q Q^\dagger$	
$\mathcal{O}^f_1 = i({Q_p}^{ai}\sigma_\mu(D_\nu {Q^\dagger}_r^{bi}))\lambda^{A}{}^a_b {B_L}^{\lambda\nu} {G_R}^{A\lambda}_\mu.$	
group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$ $\{B_{L1}, Q_2\}$ $\{{Q^\dagger}_3, G_{R4}\}$	$\mathcal{O}^j$
$*$ $(\frac{1}{2}, 3, 2, \frac{1}{6})$	$-4\mathcal{O}^f_1$
$\{B_{L1}, {Q^\dagger}_3\}$ $\{Q_2, G_{R4}\}$	$\mathcal{O}^j$
$*$ $(\frac{3}{2}, \overline{3}, 2, -\frac{1}{6})$	$-4\mathcal{O}^f_1$
$\{B_{L1}, G_{R4}\}$ $\{Q_2, {Q^\dagger}_3\}$	$\mathcal{O}^j$
$*$ $(2, 8, 1, 0)$	$-4\mathcal{O}^f_1$

Table 59. UV resonance of type $B_L D G_R Q Q^\dagger$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: $D e_{\mathbb{C}} {e_{\mathbb{C}}}^\dagger W_L W_R$	
$\mathcal{O}^f_1 = i(e_{\mathbb{C}p}\sigma_\mu(D_\nu {e_{\mathbb{C}}^\dagger}_r)){W_L}^{I\lambda\nu} {W_R}^{I\lambda}_\mu.$	
group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$ $\{W_{L1}, e_{\mathbb{C}2}\}$ $\{{e_{\mathbb{C}}^\dagger}_3, W_{R4}\}$	$\mathcal{O}^j$
$*$ $(\frac{1}{2}, 1, 3, -1)$	$-4\mathcal{O}^f_1$
$\{W_{L1}, {e_{\mathbb{C}}^\dagger}_3\}$ $\{e_{\mathbb{C}2}, W_{R4}\}$	$\mathcal{O}^j$
$*$ $(\frac{3}{2}, 1, 3, 1)$	$-4\mathcal{O}^f_1$
$\{W_{L1}, W_{R4}\}$ $\{e_{\mathbb{C}2}, {e_{\mathbb{C}}^\dagger}_3\}$	$\mathcal{O}^j$
$*$ $(2, 1, 1, 0)$	$-4\mathcal{O}^f_1$

Table 60. UV resonance of type $D e_{\mathbb{C}} {e_{\mathbb{C}}}^\dagger W_L W_R$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: $DLL^\dagger W_L W_R$	
$\mathcal{O}^f_1 = i\epsilon^{IJK}(L_{p_i}\sigma_\mu(D_\nu L^\dagger{}_r{}^j))\tau^{K}{}^i_j W_L{}^{I\lambda\nu}W_{R\mu}^{J\lambda}$, $\mathcal{O}^f_2 = i(L_{p_i}\sigma_\mu(D_\nu L^\dagger{}_r{}^i))W_L{}^{I\lambda\nu}W_{R\mu}^{I\lambda}$.	
group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$ $\{W_{L1}, L_2\}$ $\{L^\dagger{}_3, W_{R4}\}$	$\mathcal{O}^j$
* $(\frac{1}{2}, 1, 4, \frac{1}{2})$	$-4i\mathcal{O}^f_1 - 8\mathcal{O}^f_2$
* $(\frac{1}{2}, 1, 2, \frac{1}{2})$	$4i\mathcal{O}^f_1 - 4\mathcal{O}^f_2$
$\{W_{L1}, L^\dagger{}_3\}$ $\{L_2, W_{R4}\}$	$\mathcal{O}^j$
* $(\frac{3}{2}, 1, 4, -\frac{1}{2})$	$4i\mathcal{O}^f_1 - 8\mathcal{O}^f_2$
* $(\frac{3}{2}, 1, 2, -\frac{1}{2})$	$-4i\mathcal{O}^f_1 - 4\mathcal{O}^f_2$
$\{W_{L1}, W_{R4}\}$ $\{L_2, L^\dagger{}_3\}$	$\mathcal{O}^j$
* $(2, 1, 3, 0)$	$-4\mathcal{O}^f_1$
* $(2, 1, 1, 0)$	$-4\mathcal{O}^f_2$

Table 61. UV resonance of type $DLL^\dagger W_L W_R$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: $Dd_{\mathbb{C}}d_{\mathbb{C}}{}^\dagger W_L W_R$	
$\mathcal{O}^f_1 = i(d_{\mathbb{C}p}{}^a\sigma_\mu(D_\nu d_{\mathbb{C}}{}^\dagger{}_{ra}))W_L{}^{I\lambda\nu}W_{R\mu}^{I\lambda}$.	
group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$ $\{W_{L1}, d_{\mathbb{C}2}\}$ $\{d_{\mathbb{C}}{}^\dagger{}_3, W_{R4}\}$	$\mathcal{O}^j$
* $(\frac{1}{2}, 3, 3, -\frac{1}{3})$	$-4\mathcal{O}^f_1$
$\{W_{L1}, d_{\mathbb{C}}{}^\dagger{}_3\}$ $\{d_{\mathbb{C}2}, W_{R4}\}$	$\mathcal{O}^j$
* $(\frac{3}{2}, \overline{3}, 3, \frac{1}{3})$	$-4\mathcal{O}^f_1$
$\{W_{L1}, W_{R4}\}$ $\{d_{\mathbb{C}2}, d_{\mathbb{C}}{}^\dagger{}_3\}$	$\mathcal{O}^j$
* $(2, 1, 1, 0)$	$-4\mathcal{O}^f_1$

Table 62. UV resonance of type $Dd_{\mathbb{C}}d_{\mathbb{C}}{}^\dagger W_L W_R$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

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Type: $Du_{\mathbb{C}}u_{\mathbb{C}}{}^{\dagger}W_LW_R$		
$\mathcal{O}^f_1 = i(u_{\mathbb{C}p}{}^a\sigma_\mu(D_\nu u_{\mathbb{C}}{}^{\dagger}{}_{ra}))W_L{}^{I\lambda\nu}W_{R\mu}^{I\lambda}.$		
group: $(\mathrm{Spin},\mathrm{SU}(3)_c,\mathrm{SU}(2)_w,\mathrm{U}(1)_y)$ $\{W_{L1},u_{\mathbb{C}2}\}$ $\{u_{\mathbb{C}}{}^{\dagger}{}_3,W_{R4}\}$		$\mathcal{O}^j$
*	$(\frac{1}{2},3,3,\frac{2}{3})$	$-4\mathcal{O}^f_1$
	$\{W_{L1},u_{\mathbb{C}}{}^{\dagger}{}_3\}$ $\{u_{\mathbb{C}2},W_{R4}\}$	$\mathcal{O}^j$
*	$(\frac{3}{2},\overline{3},3,-\frac{2}{3})$	$-4\mathcal{O}^f_1$
	$\{W_{L1},W_{R4}\}$ $\{u_{\mathbb{C}2},u_{\mathbb{C}}{}^{\dagger}{}_3\}$	$\mathcal{O}^j$
*	$(2,1,1,0)$	$-4\mathcal{O}^f_1$

Table 63. UV resonance of type $Du_{\mathbb{C}}u_{\mathbb{C}}{}^{\dagger}W_LW_R$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: $DQQ^{\dagger}W_LW_R$		
$\mathcal{O}^f_1 = i\epsilon^{IJK}(Q_p{}^{ai}\sigma_\mu(D_\nu Q^{\dagger}{}_r{}^{aj}))\tau^K{}^i_j W_L{}^{I\lambda\nu}W_{R\mu}^{J\lambda},$ $\mathcal{O}^f_2 = i(Q_p{}^{ai}\sigma_\mu(D_\nu Q^{\dagger}{}_r{}^{ai}))W_L{}^{I\lambda\nu}W_{R\mu}^{I\lambda}.$		
group: $(\mathrm{Spin},\mathrm{SU}(3)_c,\mathrm{SU}(2)_w,\mathrm{U}(1)_y)$ $\{W_{L1},Q_2\}$ $\{Q^{\dagger}{}_3,W_{R4}\}$		$\mathcal{O}^j$
*	$(\frac{1}{2},\overline{3},4,-\frac{1}{6})$	$-4i\mathcal{O}^f_1-8\mathcal{O}^f_2$
*	$(\frac{1}{2},\overline{3},2,-\frac{1}{6})$	$4i\mathcal{O}^f_1-4\mathcal{O}^f_2$
	$\{W_{L1},Q^{\dagger}{}_3\}$ $\{Q_2,W_{R4}\}$	$\mathcal{O}^j$
*	$(\frac{3}{2},3,4,\frac{1}{6})$	$4i\mathcal{O}^f_1-8\mathcal{O}^f_2$
*	$(\frac{3}{2},3,2,\frac{1}{6})$	$-4i\mathcal{O}^f_1-4\mathcal{O}^f_2$
	$\{W_{L1},W_{R4}\}$ $\{Q_2,Q^{\dagger}{}_3\}$	$\mathcal{O}^j$
*	$(2,1,3,0)$	$-4\mathcal{O}^f_1$
*	$(2,1,1,0)$	$-4\mathcal{O}^f_2$

Table 64. UV resonance of type $DQQ^{\dagger}W_LW_R$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

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Type: $DG_RQQ^\dagger W_L$	
$\mathcal{O}^f_1 = i({Q_p}^{ai}\sigma_\mu(D_\nu {Q^\dagger}_r{}^{bj}))\lambda^{A}{}^a_b\tau^I{}^i_j G_R{}^{A\lambda}_\mu {W_L}^{I\lambda\nu}.$	
group: (Spin, SU(3)$_c$, SU(2)$_w$, U(1)$_y$) $\{W_{L1}, Q_2\}$ $\{Q^\dagger{}_3, G_{R4}\}$	$\mathcal{O}^j$
* $(\frac{1}{2}, \overline{3}, 2, -\frac{1}{6})$	$-4\mathcal{O}^f_1$
$\{W_{L1}, Q^\dagger{}_3\}$ $\{Q_2, G_{R4}\}$	$\mathcal{O}^j$
* $(\frac{3}{2}, 3, 2, \frac{1}{6})$	$-4\mathcal{O}^f_1$
$\{W_{L1}, G_{R4}\}$ $\{Q_2, Q^\dagger{}_3\}$	$\mathcal{O}^j$
* $(2, 8, 3, 0)$	$-4\mathcal{O}^f_1$

Table 65. UV resonance of type $DG_RQQ^\dagger W_L$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: $De_{\mathbb{C}}e_{\mathbb{C}}{}^\dagger G_LG_R$	
$\mathcal{O}^f_1 = i(e_{\mathbb{C}p}\sigma_\mu(D_\nu e_{\mathbb{C}}{}^\dagger{}_r))G_L{}^{A\lambda\nu}G_R{}^{A\lambda}_\mu.$	
group: (Spin, SU(3)$_c$, SU(2)$_w$, U(1)$_y$) $\{G_{L1}, e_{\mathbb{C}2}\}$ $\{e_{\mathbb{C}}{}^\dagger{}_3, G_{R4}\}$	$\mathcal{O}^j$
* $(\frac{1}{2}, 8, 1, -1)$	$4\mathcal{O}^f_1$
$\{G_{L1}, e_{\mathbb{C}}{}^\dagger{}_3\}$ $\{e_{\mathbb{C}2}, G_{R4}\}$	$\mathcal{O}^j$
* $(\frac{3}{2}, 8, 1, 1)$	$4\mathcal{O}^f_1$
$\{G_{L1}, G_{R4}\}$ $\{e_{\mathbb{C}2}, e_{\mathbb{C}}{}^\dagger{}_3\}$	$\mathcal{O}^j$
* $(2, 1, 1, 0)$	$4\mathcal{O}^f_1$

Table 66. UV resonance of type $De_{\mathbb{C}}e_{\mathbb{C}}{}^\dagger G_LG_R$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: $DG_LG_RLL^\dagger$		
$\mathcal{O}^f_1 = i(L_{p_i}\sigma_\mu(D_\nu {L^\dagger}_r^{\ i}))G_L{}^{A\lambda\nu}G_{R\mu}^{A\lambda}$.		
group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$	$\{G_{L1}, L_2\}$ $\{L^\dagger{}_3, G_{R4}\}$	$\mathcal{O}^j$
*	$(\frac{1}{2}, 8, 2, -\frac{1}{2})$	$-4\mathcal{O}^f_1$
	$\{G_{L1}, L^\dagger{}_3\}$ $\{L_2, G_{R4}\}$	$\mathcal{O}^j$
*	$(\frac{3}{2}, 8, 2, \frac{1}{2})$	$-4\mathcal{O}^f_1$
	$\{G_{L1}, G_{R4}\}$ $\{L_2, L^\dagger{}_3\}$	$\mathcal{O}^j$
*	$(2, 1, 1, 0)$	$-4\mathcal{O}^f_1$

Table 67. UV resonance of type $DG_LG_RLL^\dagger$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: $Dd_{\mathbb{C}}d_{\mathbb{C}}{}^\dagger G_LG_R$		
$\mathcal{O}^f_1 = id^{ABC}({d_{\mathbb{C}p}}^a\sigma_\mu(D_\nu {d_{\mathbb{C}}{}^\dagger}_{rb}))\lambda^{Cb}_{\ a}G_L{}^{A\lambda\nu}G_{R\mu}^{B\lambda}$, $\mathcal{O}^f_2 = if^{ABC}({d_{\mathbb{C}p}}^a\sigma_\mu(D_\nu {d_{\mathbb{C}}{}^\dagger}_{rb}))\lambda^{Cb}_{\ a}G_L{}^{A\lambda\nu}G_{R\mu}^{B\lambda}$, $\mathcal{O}^f_3 = i({d_{\mathbb{C}p}}^a\sigma_\mu(D_\nu {d_{\mathbb{C}}{}^\dagger}_{ra}))G_L{}^{A\lambda\nu}G_{R\mu}^{A\lambda}$.		
group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$	$\{G_{L1}, d_{\mathbb{C}2}\}$ $\{d_{\mathbb{C}}{}^\dagger{}_3, G_{R4}\}$	$\mathcal{O}^j$
*	$(\frac{1}{2}, 15, 1, -\frac{1}{3})$	$\frac{6}{5}\mathcal{O}^f_1 - 2i\mathcal{O}^f_2 + 4\mathcal{O}^f_3$
*	$(\frac{1}{2}, 6, 1, -\frac{1}{3})$	$-6\mathcal{O}^f_1 + 2i\mathcal{O}^f_2 + 4\mathcal{O}^f_3$
*	$(\frac{1}{2}, 3, 1, -\frac{1}{3})$	$6\mathcal{O}^f_1 + 6i\mathcal{O}^f_2 + 4\mathcal{O}^f_3$
	$\{G_{L1}, d_{\mathbb{C}}{}^\dagger{}_3\}$ $\{d_{\mathbb{C}2}, G_{R4}\}$	$\mathcal{O}^j$
*	$(\frac{3}{2}, \overline{15}, 1, \frac{1}{3})$	$\frac{6}{5}\mathcal{O}^f_1 + 2i\mathcal{O}^f_2 + 4\mathcal{O}^f_3$
*	$(\frac{3}{2}, \overline{6}, 1, \frac{1}{3})$	$-6\mathcal{O}^f_1 - 2i\mathcal{O}^f_2 + 4\mathcal{O}^f_3$
*	$(\frac{3}{2}, \overline{3}, 1, \frac{1}{3})$	$6\mathcal{O}^f_1 - 6i\mathcal{O}^f_2 + 4\mathcal{O}^f_3$
	$\{G_{L1}, G_{R4}\}$ $\{d_{\mathbb{C}2}, d_{\mathbb{C}}{}^\dagger{}_3\}$	$\mathcal{O}^j$
*	$(2, 8, 1, 0)$	$4\mathcal{O}^f_2$ $4\mathcal{O}^f_1$
*	$(2, 1, 1, 0)$	$4\mathcal{O}^f_3$

Table 68. UV resonance of type $Dd_{\mathbb{C}}d_{\mathbb{C}}{}^\dagger G_LG_R$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: $DG_LG_Ru_{\mathbb{C}}u_{\mathbb{C}}{}^{\dagger}$

$$\begin{aligned}
\mathcal{O}^f_1 &= id^{ABC}(u_{\mathbb{C}p}{}^{a}\sigma_\mu(D_\nu u_{\mathbb{C}}{}^{\dagger}{}_{rb}))\lambda^{C}{}^{b}_{a}G_L{}^{A\lambda\nu}G_{R\mu}^{B\lambda},\\
\mathcal{O}^f_2 &= if^{ABC}(u_{\mathbb{C}p}{}^{a}\sigma_\mu(D_\nu u_{\mathbb{C}}{}^{\dagger}{}_{rb}))\lambda^{C}{}^{b}_{a}G_L{}^{A\lambda\nu}G_{R\mu}^{B\lambda},\\
\mathcal{O}^f_3 &= i(u_{\mathbb{C}p}{}^{a}\sigma_\mu(D_\nu u_{\mathbb{C}}{}^{\dagger}{}_{ra}))G_L{}^{A\lambda\nu}G_{R\mu}^{A\lambda}.
\end{aligned}$$

group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$		$\mathcal{O}^j$
	$\{G_{L1}, u_{\mathbb{C}2}\}$ $\{u_{\mathbb{C}}{}^{\dagger}{}_3, G_{R4}\}$	
*	$(\frac{1}{2}, \overline{15}, 1, -\frac{2}{3})$	$\frac{6}{5}\mathcal{O}^f_1 - 2i\mathcal{O}^f_2 + 4\mathcal{O}^f_3$
*	$(\frac{1}{2}, \overline{6}, 1, -\frac{2}{3})$	$-6\mathcal{O}^f_1 + 2i\mathcal{O}^f_2 + 4\mathcal{O}^f_3$
*	$(\frac{1}{2}, \overline{3}, 1, -\frac{2}{3})$	$6\mathcal{O}^f_1 + 6i\mathcal{O}^f_2 + 4\mathcal{O}^f_3$
	$\{G_{L1}, u_{\mathbb{C}}{}^{\dagger}{}_3\}$ $\{u_{\mathbb{C}2}, G_{R4}\}$	$\mathcal{O}^j$
*	$(\frac{3}{2}, 15, 1, \frac{2}{3})$	$\frac{6}{5}\mathcal{O}^f_1 + 2i\mathcal{O}^f_2 + 4\mathcal{O}^f_3$
*	$(\frac{3}{2}, 6, 1, \frac{2}{3})$	$-6\mathcal{O}^f_1 - 2i\mathcal{O}^f_2 + 4\mathcal{O}^f_3$
*	$(\frac{3}{2}, 3, 1, \frac{2}{3})$	$6\mathcal{O}^f_1 - 6i\mathcal{O}^f_2 + 4\mathcal{O}^f_3$
	$\{G_{L1}, G_{R4}\}$ $\{u_{\mathbb{C}2}, u_{\mathbb{C}}{}^{\dagger}{}_3\}$	$\mathcal{O}^j$
*	$(2, 8, 1, 0)$	$4\mathcal{O}^f_2$
		$4\mathcal{O}^f_1$
*	$(2, 1, 1, 0)$	$4\mathcal{O}^f_3$

Table 69. UV resonance of type $DG_LG_Ru_{\mathbb{C}}u_{\mathbb{C}}{}^{\dagger}$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: $DG_LG_RQQ^\dagger$	
$\mathcal{O}_1^f = id^{ABC}(Q_p{}^{ai}\sigma_\mu(D_\nu Q^\dagger{}_r{}^{bi}))\lambda^{Ca}_b G_L{}^{A\lambda\nu}G_{R\mu}^{B\lambda}$, $\mathcal{O}_2^f = if^{ABC}(Q_p{}^{ai}\sigma_\mu(D_\nu Q^\dagger{}_r{}^{bi}))\lambda^{Ca}_b G_L{}^{A\lambda\nu}G_{R\mu}^{B\lambda}$, $\mathcal{O}_3^f = i(Q_p{}^{ai}\sigma_\mu(D_\nu Q^\dagger{}_r{}^{ai}))G_L{}^{A\lambda\nu}G_{R\mu}^{A\lambda}$.	
group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$ $\{G_{L1}, Q_2\}$ $\{Q^\dagger{}_3, G_{R4}\}$	$\mathcal{O}^j$
* $(\frac{1}{2}, 15, 2, \frac{1}{6})$	$-\frac{6}{5}\mathcal{O}_1^f - 2i\mathcal{O}_2^f - 4\mathcal{O}_3^f$
* $(\frac{1}{2}, 6, 2, \frac{1}{6})$	$6\mathcal{O}_1^f + 2i\mathcal{O}_2^f - 4\mathcal{O}_3^f$
* $(\frac{1}{2}, 3, 2, \frac{1}{6})$	$-6\mathcal{O}_1^f + 6i\mathcal{O}_2^f - 4\mathcal{O}_3^f$
$\{G_{L1}, Q^\dagger{}_3\}$ $\{Q_2, G_{R4}\}$	$\mathcal{O}^j$
* $(\frac{3}{2}, \overline{15}, 2, -\frac{1}{6})$	$-\frac{6}{5}\mathcal{O}_1^f + 2i\mathcal{O}_2^f - 4\mathcal{O}_3^f$
* $(\frac{3}{2}, \overline{6}, 2, -\frac{1}{6})$	$6\mathcal{O}_1^f - 2i\mathcal{O}_2^f - 4\mathcal{O}_3^f$
* $(\frac{3}{2}, \overline{3}, 2, -\frac{1}{6})$	$-6\mathcal{O}_1^f - 6i\mathcal{O}_2^f - 4\mathcal{O}_3^f$
$\{G_{L1}, G_{R4}\}$ $\{Q_2, Q^\dagger{}_3\}$	$\mathcal{O}^j$
* $(2, 8, 1, 0)$	$-4\mathcal{O}_2^f$ $-4\mathcal{O}_1^f$
* $(2, 1, 1, 0)$	$-4\mathcal{O}_3^f$

Table 70. UV resonance of type $DG_LG_RQQ^\dagger$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: $B_RD^2e_{\mathbb{C}}H^\dagger L$	
$\mathcal{O}_1^f = i(D_\lambda D^\nu H^{\dagger i})(e_{\mathbb{C}p}\sigma_{\mu\nu}L_{ri})B_{R\mu}^{\lambda}$.	
group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$ $\{e_{\mathbb{C}1}, L_2\}$ $\{H^\dagger{}_3, B_{R4}\}$	$\mathcal{O}^j$
* $(1, 1, 2, \frac{1}{2})$	$2\mathcal{O}_1^f$
$\{e_{\mathbb{C}1}, H^\dagger{}_3\}$ $\{L_2, B_{R4}\}$	$\mathcal{O}^j$
* $(\frac{3}{2}, 1, 2, \frac{1}{2})$	$2\mathcal{O}_1^f$
$\{e_{\mathbb{C}1}, B_{R4}\}$ $\{L_2, H^\dagger{}_3\}$	$\mathcal{O}^j$
* $(\frac{3}{2}, 1, 1, 1)$	$2\mathcal{O}_1^f$

Table 71. UV resonance of type $B_RD^2e_{\mathbb{C}}H^\dagger L$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

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Type: $D^2 e_{\mathbb{C}} H^\dagger L W_R$	
$\mathcal{O}^f_1 \ = i(D_\lambda D^\nu H^{\dagger j})(e_{\mathbb{C}p}\sigma_{\mu\nu}L_{ri})\tau^{I}{}^i_j W_R{}^{I\lambda}_\mu.$	
group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$ $\{e_{\mathbb{C}1}, L_2\} \quad \{H^\dagger{}_3, W_{R4}\}$	$\mathcal{O}^j$
* $(1, 1, 2, \frac{1}{2})$	$2\mathcal{O}^f_1$
$\{e_{\mathbb{C}1}, H^\dagger{}_3\} \quad \{L_2, W_{R4}\}$	$\mathcal{O}^j$
* $(\frac{3}{2}, 1, 2, \frac{1}{2})$	$2\mathcal{O}^f_1$
$\{e_{\mathbb{C}1}, W_{R4}\} \quad \{L_2, H^\dagger{}_3\}$	$\mathcal{O}^j$
* $(\frac{3}{2}, 1, 3, 1)$	$2\mathcal{O}^f_1$

Table 72. UV resonance of type $D^2 e_{\mathbb{C}} H^\dagger L W_R$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: $B_R D^2 d_{\mathbb{C}} H^\dagger Q$	
$\mathcal{O}^f_1 \ = i(D_\lambda D^\nu H^{\dagger i})(d_{\mathbb{C}p}{}^a \sigma_{\mu\nu} Q_r{}^{ai}) B_R{}^\lambda_\mu.$	
group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$ $\{d_{\mathbb{C}1}, Q_2\} \quad \{H^\dagger{}_3, B_{R4}\}$	$\mathcal{O}^j$
* $(1, 1, 2, \frac{1}{2})$	$2\mathcal{O}^f_1$
$\{d_{\mathbb{C}1}, H^\dagger{}_3\} \quad \{Q_2, B_{R4}\}$	$\mathcal{O}^j$
* $(\frac{3}{2}, \overline{3}, 2, -\frac{1}{6})$	$2\mathcal{O}^f_1$
$\{d_{\mathbb{C}1}, B_{R4}\} \quad \{Q_2, H^\dagger{}_3\}$	$\mathcal{O}^j$
* $(\frac{3}{2}, \overline{3}, 1, \frac{1}{3})$	$2\mathcal{O}^f_1$

Table 73. UV resonance of type $B_R D^2 d_{\mathbb{C}} H^\dagger Q$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

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Type: $D^2 d_{\mathbb{C}} H^\dagger Q W_R$		
$\mathcal{O}_1^f = i(D_\lambda D^\nu H^{\dagger j})(d_{\mathbb{C}p}{}^a \sigma_{\mu\nu} Q_r{}^{ai}) \tau^{I}{}^i_j W_{R\mu}^{I\lambda}$.		
group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$		$\mathcal{O}^j$
	$\{d_{\mathbb{C}1}, Q_2\}$ $\{H^\dagger{}_3, W_{R4}\}$	
*	$(1, 1, 2, \frac{1}{2})$	$2\mathcal{O}_1^f$
	$\{d_{\mathbb{C}1}, H^\dagger{}_3\}$ $\{Q_2, W_{R4}\}$	$\mathcal{O}^j$
*	$(\frac{3}{2}, \overline{3}, 2, -\frac{1}{6})$	$2\mathcal{O}_1^f$
	$\{d_{\mathbb{C}1}, W_{R4}\}$ $\{Q_2, H^\dagger{}_3\}$	$\mathcal{O}^j$
*	$(\frac{3}{2}, \overline{3}, 3, \frac{1}{3})$	$2\mathcal{O}_1^f$

Table 74. UV resonance of type $D^2 d_{\mathbb{C}} H^\dagger Q W_R$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: $D^2 d_{\mathbb{C}} G_R H^\dagger Q$		
$\mathcal{O}_1^f = i(D_\lambda D^\nu H^{\dagger i})(d_{\mathbb{C}p}{}^a \sigma_{\mu\nu} Q_r{}^{bi}) \lambda^{A}{}^b_a G_{R\mu}^{A\lambda}$.		
group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$		$\mathcal{O}^j$
	$\{d_{\mathbb{C}1}, Q_2\}$ $\{H^\dagger{}_3, G_{R4}\}$	
*	$(1, 8, 2, \frac{1}{2})$	$2\mathcal{O}_1^f$
	$\{d_{\mathbb{C}1}, H^\dagger{}_3\}$ $\{Q_2, G_{R4}\}$	$\mathcal{O}^j$
*	$(\frac{3}{2}, \overline{3}, 2, -\frac{1}{6})$	$2\mathcal{O}_1^f$
	$\{d_{\mathbb{C}1}, G_{R4}\}$ $\{Q_2, H^\dagger{}_3\}$	$\mathcal{O}^j$
*	$(\frac{3}{2}, \overline{3}, 1, \frac{1}{3})$	$2\mathcal{O}_1^f$

Table 75. UV resonance of type $D^2 d_{\mathbb{C}} G_R H^\dagger Q$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

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Type: $B_R D^2 H Q u_{\mathbb{C}}$	
$\mathcal{O}^f_1 = i\epsilon^{ij}(D_\lambda D^\nu H_j)(Q_p{}^{ai}\sigma_{\mu\nu}u_{\mathbb{C}r}{}^a)B_{R\mu}^{\lambda}$.	
group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$ $\{Q_1, u_{\mathbb{C}2}\}$ $\{H_3, B_{R4}\}$	$\mathcal{O}^j$
* $(1, 1, 2, \frac{1}{2})$	$2\mathcal{O}^f_1$
$\{Q_1, H_3\}$ $\{u_{\mathbb{C}2}, B_{R4}\}$	$\mathcal{O}^j$
* $(\frac{3}{2}, 3, 1, \frac{2}{3})$	$2\mathcal{O}^f_1$
$\{Q_1, B_{R4}\}$ $\{u_{\mathbb{C}2}, H_3\}$	$\mathcal{O}^j$
* $(\frac{3}{2}, 3, 2, \frac{1}{6})$	$2\mathcal{O}^f_1$

Table 76. UV resonance of type $B_R D^2 H Q u_{\mathbb{C}}$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: $D^2 H Q u_{\mathbb{C}} W_R$	
$\mathcal{O}^f_1 = i\epsilon^{jk}(D_\lambda D^\nu H_j)(Q_p{}^{ai}\sigma_{\mu\nu}u_{\mathbb{C}r}{}^a)\tau^{I}{}^i_k W_{R\mu}^{I\lambda}$.	
group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$ $\{Q_1, u_{\mathbb{C}2}\}$ $\{H_3, W_{R4}\}$	$\mathcal{O}^j$
* $(1, 1, 2, \frac{1}{2})$	$2\mathcal{O}^f_1$
$\{Q_1, H_3\}$ $\{u_{\mathbb{C}2}, W_{R4}\}$	$\mathcal{O}^j$
* $(\frac{3}{2}, 3, 3, \frac{2}{3})$	$2\mathcal{O}^f_1$
$\{Q_1, W_{R4}\}$ $\{u_{\mathbb{C}2}, H_3\}$	$\mathcal{O}^j$
* $(\frac{3}{2}, 3, 2, \frac{1}{6})$	$2\mathcal{O}^f_1$

Table 77. UV resonance of type $D^2 H Q u_{\mathbb{C}} W_R$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: $D^2G_RHQu_{\mathbb{C}}$		
$\mathcal{O}_1^f = i\epsilon^{ij}(D_\lambda D^\nu H_j)(Q_p{}^{ai}\sigma_{\mu\nu}u_{\mathbb{C}r}{}^b)\lambda^{Aa}_{\ b}G_R{}^{A\lambda}_\mu.$		
group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$		$\mathcal{O}^j$
	$\{Q_1, u_{\mathbb{C}2}\}$ $\{H_3, G_{R4}\}$	
*	$(1, 8, 2, \frac{1}{2})$	$2\mathcal{O}_1^f$
	$\{Q_1, H_3\}$ $\{u_{\mathbb{C}2}, G_{R4}\}$	$\mathcal{O}^j$
*	$(\frac{3}{2}, 3, 1, \frac{2}{3})$	$2\mathcal{O}_1^f$
	$\{Q_1, G_{R4}\}$ $\{u_{\mathbb{C}2}, H_3\}$	$\mathcal{O}^j$
*	$(\frac{3}{2}, 3, 2, \frac{1}{6})$	$2\mathcal{O}_1^f$

Table 78. UV resonance of type $D^2G_RHQu_{\mathbb{C}}$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: $D^2e_{\mathbb{C}}{}^2e_{\mathbb{C}}{}^{\dagger 2}$		
$\mathcal{O}_1^f = \frac{1}{4}\mathcal{Y}[\boxed{p}\boxed{r}]\mathcal{Y}[\boxed{s}\boxed{t}](((D_\mu e_{\mathbb{C}}{}^\dagger{}_s)(D^\mu e_{\mathbb{C}}{}^\dagger{}_t))(e_{\mathbb{C}p}e_{\mathbb{C}r})),$ $\mathcal{O}_2^f = \frac{1}{4}\mathcal{Y}[\begin{array}{\|c\|}\hline p \\ \hline r \\ \hline\end{array}]\mathcal{Y}[\begin{array}{\|c\|}\hline s \\ \hline t \\ \hline\end{array}](i((D^\mu e_{\mathbb{C}}{}^\dagger{}_s)(D^\nu e_{\mathbb{C}}{}^\dagger{}_t))(e_{\mathbb{C}p}\sigma_{\mu\nu}e_{\mathbb{C}r})).$		
group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$		$\mathcal{O}^j$
	$\{e_{\mathbb{C}1}, e_{\mathbb{C}2}\}$ $\{e_{\mathbb{C}}{}^\dagger{}_3, e_{\mathbb{C}}{}^\dagger{}_4\}$	
*	$(1, 1, 1, 2)$	$2\mathcal{O}_2^f$
	$(0, 1, 1, 2)$	$-2\mathcal{O}_1^f$
	$\{e_{\mathbb{C}1}, e_{\mathbb{C}}{}^\dagger{}_3\}$ $\{e_{\mathbb{C}2}, e_{\mathbb{C}}{}^\dagger{}_4\}$	$\mathcal{O}^j$
*	$(2, 1, 1, 0)$	$5\mathcal{O}_1^f + 3\mathcal{O}_2^f$
	$(1, 1, 1, 0)$	$-\mathcal{O}_1^f + \mathcal{O}_2^f$

Table 79. UV resonance of type $D^2e_{\mathbb{C}}{}^2e_{\mathbb{C}}{}^{\dagger 2}$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: $D^2 e_{\mathbb{C}} e_{\mathbb{C}}^{\dagger} L L^{\dagger}$	
$\mathcal{O}^f_1 = ((D_\mu e_{\mathbb{C}}{}^{\dagger}{}_s)(D^\mu L^{\dagger}{}_t{}^i))(e_{\mathbb{C}p} L_{ri})$, $\mathcal{O}^f_2 = i((D^\mu e_{\mathbb{C}}{}^{\dagger}{}_s)(D^\nu L^{\dagger}{}_t{}^i))(e_{\mathbb{C}p}\sigma_{\mu\nu} L_{ri})$.	
group: (Spin, SU(3)$_c$, SU(2)$_w$, U(1)$_y$) $\{e_{\mathbb{C}1}, L_2\}$ $\{e_{\mathbb{C}}{}^{\dagger}{}_3, L^{\dagger}{}_4\}$	$\mathcal{O}^j$
* $(1, 1, 2, \frac{1}{2})$	$-2\mathcal{O}^f_2$
$(0, 1, 2, \frac{1}{2})$	$2\mathcal{O}^f_1$
$\{e_{\mathbb{C}1}, e_{\mathbb{C}}{}^{\dagger}{}_3\}$ $\{L_2, L^{\dagger}{}_4\}$	$\mathcal{O}^j$
* $(2, 1, 1, 0)$	$-5\mathcal{O}^f_1 - 3\mathcal{O}^f_2$
$(1, 1, 1, 0)$	$\mathcal{O}^f_1 - \mathcal{O}^f_2$
$\{e_{\mathbb{C}1}, L^{\dagger}{}_4\}$ $\{L_2, e_{\mathbb{C}}{}^{\dagger}{}_3\}$	$\mathcal{O}^j$
* $(2, 1, 2, \frac{3}{2})$	$5\mathcal{O}^f_1 - 3\mathcal{O}^f_2$
$(1, 1, 2, \frac{3}{2})$	$-\mathcal{O}^f_1 - \mathcal{O}^f_2$

Table 80. UV resonance of type $D^2 e_{\mathbb{C}} e_{\mathbb{C}}^{\dagger} L L^{\dagger}$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: $D^2 d_{\mathbb{C}}^{\dagger} e_{\mathbb{C}} L Q^{\dagger}$	
$\mathcal{O}^f_1 = ((D_\mu d_{\mathbb{C}}{}^{\dagger}{}_{sa})(D^\mu Q^{\dagger}{}_t{}^{ai}))(e_{\mathbb{C}p} L_{ri})$, $\mathcal{O}^f_2 = i((D^\mu d_{\mathbb{C}}{}^{\dagger}{}_{sa})(D^\nu Q^{\dagger}{}_t{}^{ai}))(e_{\mathbb{C}p}\sigma_{\mu\nu} L_{ri})$.	
group: (Spin, SU(3)$_c$, SU(2)$_w$, U(1)$_y$) $\{e_{\mathbb{C}1}, L_2\}$ $\{d_{\mathbb{C}}{}^{\dagger}{}_3, Q^{\dagger}{}_4\}$	$\mathcal{O}^j$
* $(1, 1, 2, -\frac{1}{2})$	$-2\mathcal{O}^f_2$
$(0, 1, 2, -\frac{1}{2})$	$2\mathcal{O}^f_1$
$\{e_{\mathbb{C}1}, d_{\mathbb{C}}{}^{\dagger}{}_3\}$ $\{L_2, Q^{\dagger}{}_4\}$	$\mathcal{O}^j$
* $(2, 3, 1, \frac{2}{3})$	$-5\mathcal{O}^f_1 - 3\mathcal{O}^f_2$
$(1, 3, 1, \frac{2}{3})$	$\mathcal{O}^f_1 - \mathcal{O}^f_2$
$\{e_{\mathbb{C}1}, Q^{\dagger}{}_4\}$ $\{L_2, d_{\mathbb{C}}{}^{\dagger}{}_3\}$	$\mathcal{O}^j$
* $(2, \overline{3}, 2, \frac{5}{6})$	$5\mathcal{O}^f_1 - 3\mathcal{O}^f_2$
$(1, \overline{3}, 2, \frac{5}{6})$	$-\mathcal{O}^f_1 - \mathcal{O}^f_2$

Table 81. UV resonance of type $D^2 d_{\mathbb{C}}^{\dagger} e_{\mathbb{C}} L Q^{\dagger}$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: $D^2 d_{\mathbb{C}} {d_{\mathbb{C}}}^\dagger L L^\dagger$	
$\mathcal{O}^f_1 = ((D_\mu {d_{\mathbb{C}}^\dagger}_{sa})(D^\mu {L^\dagger_t}^i))({d_{\mathbb{C}p}}^a L_{ri})$, $\mathcal{O}^f_2 = i((D^\mu {d_{\mathbb{C}}^\dagger}_{sa})(D^\nu {L^\dagger_t}^i))({d_{\mathbb{C}p}}^a \sigma_{\mu\nu} L_{ri})$.	
group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$ $\{d_{\mathbb{C}1}, L_2\}$ $\{{d_{\mathbb{C}}^\dagger}_3, {L^\dagger}_4\}$	$\mathcal{O}^j$
* $(1, \overline{3}, 2, -\frac{1}{6})$	$-2\mathcal{O}^f_2$
$(0, \overline{3}, 2, -\frac{1}{6})$	$2\mathcal{O}^f_1$
$\{d_{\mathbb{C}1}, {d_{\mathbb{C}}^\dagger}_3\}$ $\{L_2, {L^\dagger}_4\}$	$\mathcal{O}^j$
* $(2, 1, 1, 0)$	$-5\mathcal{O}^f_1 - 3\mathcal{O}^f_2$
$(1, 1, 1, 0)$	$\mathcal{O}^f_1 - \mathcal{O}^f_2$
$\{d_{\mathbb{C}1}, {L^\dagger}_4\}$ $\{L_2, {d_{\mathbb{C}}^\dagger}_3\}$	$\mathcal{O}^j$
* $(2, \overline{3}, 2, \frac{5}{6})$	$5\mathcal{O}^f_1 - 3\mathcal{O}^f_2$
$(1, \overline{3}, 2, \frac{5}{6})$	$-\mathcal{O}^f_1 - \mathcal{O}^f_2$

Table 82. UV resonance of type $D^2 d_{\mathbb{C}} {d_{\mathbb{C}}}^\dagger L L^\dagger$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: $D^2 L L^\dagger u_{\mathbb{C}} {u_{\mathbb{C}}}^\dagger$	
$\mathcal{O}^f_1 = ((D_\mu {L^\dagger_s}^i)(D^\mu {u_{\mathbb{C}}^\dagger}_{ta}))(L_{p_i} {u_{\mathbb{C}r}}^a)$, $\mathcal{O}^f_2 = i((D^\mu {L^\dagger_s}^i)(D^\nu {u_{\mathbb{C}}^\dagger}_{ta}))(L_{p_i} \sigma_{\mu\nu} {u_{\mathbb{C}r}}^a)$.	
group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$ $\{L_1, u_{\mathbb{C}2}\}$ $\{{L^\dagger}_3, {u_{\mathbb{C}}^\dagger}_4\}$	$\mathcal{O}^j$
* $(1, \overline{3}, 2, -\frac{7}{6})$	$-2\mathcal{O}^f_2$
$(0, \overline{3}, 2, -\frac{7}{6})$	$2\mathcal{O}^f_1$
$\{L_1, {L^\dagger}_3\}$ $\{u_{\mathbb{C}2}, {u_{\mathbb{C}}^\dagger}_4\}$	$\mathcal{O}^j$
* $(2, 1, 1, 0)$	$-5\mathcal{O}^f_1 - 3\mathcal{O}^f_2$
$(1, 1, 1, 0)$	$\mathcal{O}^f_1 - \mathcal{O}^f_2$
$\{L_1, {u_{\mathbb{C}}^\dagger}_4\}$ $\{u_{\mathbb{C}2}, {L^\dagger}_3\}$	$\mathcal{O}^j$
* $(2, 3, 2, \frac{1}{6})$	$5\mathcal{O}^f_1 - 3\mathcal{O}^f_2$
$(1, 3, 2, \frac{1}{6})$	$-\mathcal{O}^f_1 - \mathcal{O}^f_2$

Table 83. UV resonance of type $D^2 L L^\dagger u_{\mathbb{C}} {u_{\mathbb{C}}}^\dagger$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

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Type: $D^2 e_{\mathbb{C}} {e_{\mathbb{C}}}^\dagger Q Q^\dagger$	
$\mathcal{O}^f_1 = ((D_\mu {e_{\mathbb{C}}^\dagger}_s)(D^\mu {Q^\dagger}_t{}^{ai}))(e_{\mathbb{C}p} Q_r{}^{ai}),$ $\mathcal{O}^f_2 = i((D^\mu {e_{\mathbb{C}}^\dagger}_s)(D^\nu {Q^\dagger}_t{}^{ai}))(e_{\mathbb{C}p} \sigma_{\mu\nu} Q_r{}^{ai}).$	
group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$ $\{e_{\mathbb{C}1}, Q_2\}$ $\{{e_{\mathbb{C}}^\dagger}_3, {Q^\dagger}_4\}$	$\mathcal{O}^j$
* $(1, 3, 2, \frac{7}{6})$	$-2\mathcal{O}^f_2$
$(0, 3, 2, \frac{7}{6})$	$2\mathcal{O}^f_1$
$\{e_{\mathbb{C}1}, {e_{\mathbb{C}}^\dagger}_3\}$ $\{Q_2, {Q^\dagger}_4\}$	$\mathcal{O}^j$
* $(2, 1, 1, 0)$	$-5\mathcal{O}^f_1 - 3\mathcal{O}^f_2$
$(1, 1, 1, 0)$	$\mathcal{O}^f_1 - \mathcal{O}^f_2$
$\{e_{\mathbb{C}1}, {Q^\dagger}_4\}$ $\{Q_2, {e_{\mathbb{C}}^\dagger}_3\}$	$\mathcal{O}^j$
* $(2, \overline{3}, 2, \frac{5}{6})$	$5\mathcal{O}^f_1 - 3\mathcal{O}^f_2$
$(1, \overline{3}, 2, \frac{5}{6})$	$-\mathcal{O}^f_1 - \mathcal{O}^f_2$

Table 84. UV resonance of type $D^2 e_{\mathbb{C}} {e_{\mathbb{C}}}^\dagger Q Q^\dagger$. “*” in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

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Type: $D^2L^2{L^\dagger}^2$

$$\mathcal{O}_1^f = \frac{1}{4}\mathcal{Y}[\,\boxed{p\,|\,r}\,]\mathcal{Y}[\,\boxed{s\,|\,t}\,](((D_\mu {L^\dagger}_s{}^i)(D^\mu {L^\dagger}_t{}^j))(L_{p_i}L_{rj})),$$
$$\mathcal{O}_2^f = \frac{1}{4}\mathcal{Y}[\,\boxed{p\,|\,r}\,]\mathcal{Y}[\,\boxed{s\,|\,t}\,](i((D^\mu {L^\dagger}_s{}^i)(D^\nu {L^\dagger}_t{}^j))(L_{p_i}\sigma_{\mu\nu}L_{rj})),$$
$$\mathcal{O}_3^f = \frac{1}{4}\mathcal{Y}\left[\begin{array}{|c|}\hline p\\\hline r\\\hline\end{array}\right]\mathcal{Y}\left[\begin{array}{|c|}\hline s\\\hline t\\\hline\end{array}\right](((D_\mu {L^\dagger}_s{}^i)(D^\mu {L^\dagger}_t{}^j))(L_{p_i}L_{rj})),$$
$$\mathcal{O}_4^f = \frac{1}{4}\mathcal{Y}\left[\begin{array}{|c|}\hline p\\\hline r\\\hline\end{array}\right]\mathcal{Y}\left[\begin{array}{|c|}\hline s\\\hline t\\\hline\end{array}\right](i((D^\mu {L^\dagger}_s{}^i)(D^\nu {L^\dagger}_t{}^j))(L_{p_i}\sigma_{\mu\nu}L_{rj})).$$

group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$		$\mathcal{O}^j$
	$\{L_1, L_2\}\quad\{{L^\dagger}_3, {L^\dagger}_4\}$	
*	$(1, 1, 3, -1)$	$-4\mathcal{O}_4^f$
	$(0, 1, 3, -1)$	$4\mathcal{O}_1^f$
*	$(1, 1, 1, -1)$	$4\mathcal{O}_2^f$
	$(0, 1, 1, -1)$	$-4\mathcal{O}_3^f$
	$\{L_1, {L^\dagger}_3\}\quad\{L_2, {L^\dagger}_4\}$	$\mathcal{O}^j$
*	$(2, 1, 3, 0)$	$-5\mathcal{O}_1^f + 9\mathcal{O}_2^f + 15\mathcal{O}_3^f - 3\mathcal{O}_4^f$
	$(1, 1, 3, 0)$	$\mathcal{O}_1^f + 3\mathcal{O}_2^f - 3\mathcal{O}_3^f - \mathcal{O}_4^f$
*	$(2, 1, 1, 0)$	$-5\mathcal{O}_1^f - 3\mathcal{O}_2^f - 5\mathcal{O}_3^f - 3\mathcal{O}_4^f$
	$(1, 1, 1, 0)$	$\mathcal{O}_1^f - \mathcal{O}_2^f + \mathcal{O}_3^f - \mathcal{O}_4^f$

Table 85. UV resonance of type $D^2L^2{L^\dagger}^2$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: $D^2 d_{\mathbb{C}} {d_{\mathbb{C}}}^{\dagger} e_{\mathbb{C}} {e_{\mathbb{C}}}^{\dagger}$

$$\mathcal{O}_1^f = ((D_\mu {d_{\mathbb{C}}}^{\dagger}{}_{sa})(D^\mu {e_{\mathbb{C}}}^{\dagger}{}_{t}))({d_{\mathbb{C}}}_p{}^a {e_{\mathbb{C}}}_r),$$
$$\mathcal{O}_2^f = i((D^\mu {d_{\mathbb{C}}}^{\dagger}{}_{sa})(D^\nu {e_{\mathbb{C}}}^{\dagger}{}_{t}))({d_{\mathbb{C}}}_p{}^a \sigma_{\mu\nu} {e_{\mathbb{C}}}_r).$$

	group: (Spin, $\mathrm{SU}(3)_c$, $\mathrm{SU}(2)_w$, $\mathrm{U}(1)_y$)	$\mathcal{O}^j$
	$\{d_{\mathbb{C}1}, e_{\mathbb{C}2}\}$ $\{{d_{\mathbb{C}}}^{\dagger}{}_3, {e_{\mathbb{C}}}^{\dagger}{}_4\}$	
*	$(1, \overline{3}, 1, \frac{4}{3})$	$2\mathcal{O}_2^f$
	$(0, \overline{3}, 1, \frac{4}{3})$	$-2\mathcal{O}_1^f$
	$\{d_{\mathbb{C}1}, {d_{\mathbb{C}}}^{\dagger}{}_3\}$ $\{e_{\mathbb{C}2}, {e_{\mathbb{C}}}^{\dagger}{}_4\}$	$\mathcal{O}^j$
*	$(2, 1, 1, 0)$	$5\mathcal{O}_1^f + 3\mathcal{O}_2^f$
	$(1, 1, 1, 0)$	$-\mathcal{O}_1^f + \mathcal{O}_2^f$
	$\{d_{\mathbb{C}1}, {e_{\mathbb{C}}}^{\dagger}{}_4\}$ $\{e_{\mathbb{C}2}, {d_{\mathbb{C}}}^{\dagger}{}_3\}$	$\mathcal{O}^j$
*	$(2, \overline{3}, 1, -\frac{2}{3})$	$-5\mathcal{O}_1^f + 3\mathcal{O}_2^f$
	$(1, \overline{3}, 1, -\frac{2}{3})$	$\mathcal{O}_1^f + \mathcal{O}_2^f$

Table 86. UV resonance of type $D^2 d_{\mathbb{C}} {d_{\mathbb{C}}}^{\dagger} e_{\mathbb{C}} {e_{\mathbb{C}}}^{\dagger}$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: $D^2 e_{\mathbb{C}} {e_{\mathbb{C}}}^{\dagger} u_{\mathbb{C}} {u_{\mathbb{C}}}^{\dagger}$

$$\mathcal{O}_1^f = ((D_\mu {e_{\mathbb{C}}}^{\dagger}{}_{s})(D^\mu {u_{\mathbb{C}}}^{\dagger}{}_{ta}))({e_{\mathbb{C}}}_p {u_{\mathbb{C}}}_r{}^a),$$
$$\mathcal{O}_2^f = i((D^\mu {e_{\mathbb{C}}}^{\dagger}{}_{s})(D^\nu {u_{\mathbb{C}}}^{\dagger}{}_{ta}))({e_{\mathbb{C}}}_p \sigma_{\mu\nu} {u_{\mathbb{C}}}_r{}^a).$$

	group: (Spin, $\mathrm{SU}(3)_c$, $\mathrm{SU}(2)_w$, $\mathrm{U}(1)_y$)	$\mathcal{O}^j$
	$\{e_{\mathbb{C}1}, u_{\mathbb{C}2}\}$ $\{{e_{\mathbb{C}}}^{\dagger}{}_3, {u_{\mathbb{C}}}^{\dagger}{}_4\}$	
*	$(1, \overline{3}, 1, \frac{1}{3})$	$2\mathcal{O}_2^f$
	$(0, \overline{3}, 1, \frac{1}{3})$	$-2\mathcal{O}_1^f$
	$\{e_{\mathbb{C}1}, {e_{\mathbb{C}}}^{\dagger}{}_3\}$ $\{u_{\mathbb{C}2}, {u_{\mathbb{C}}}^{\dagger}{}_4\}$	$\mathcal{O}^j$
*	$(2, 1, 1, 0)$	$5\mathcal{O}_1^f + 3\mathcal{O}_2^f$
	$(1, 1, 1, 0)$	$-\mathcal{O}_1^f + \mathcal{O}_2^f$
	$\{e_{\mathbb{C}1}, {u_{\mathbb{C}}}^{\dagger}{}_4\}$ $\{u_{\mathbb{C}2}, {e_{\mathbb{C}}}^{\dagger}{}_3\}$	$\mathcal{O}^j$
*	$(2, 3, 1, \frac{5}{3})$	$-5\mathcal{O}_1^f + 3\mathcal{O}_2^f$
	$(1, 3, 1, \frac{5}{3})$	$\mathcal{O}_1^f + \mathcal{O}_2^f$

Table 87. UV resonance of type $D^2 e_{\mathbb{C}} {e_{\mathbb{C}}}^{\dagger} u_{\mathbb{C}} {u_{\mathbb{C}}}^{\dagger}$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

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Type: $D^2{d_{\mathbb{C}}}^2{d_{\mathbb{C}}^{\dagger}}^2$	
$\mathcal{O}^f_1 = \frac{1}{4}\mathcal{Y}[\boxed{p\ r}]\mathcal{Y}[\boxed{s\ t}](((D_\mu {d_{\mathbb{C}}^{\dagger}}_{sa})(D^\mu {d_{\mathbb{C}}^{\dagger}}_{tb}))({d_{\mathbb{C}}}_p{}^a {d_{\mathbb{C}}}_r{}^b)),$ $\mathcal{O}^f_2 = \frac{1}{4}\mathcal{Y}[\boxed{p\ r}]\mathcal{Y}[\boxed{s\ t}](i((D^\mu {d_{\mathbb{C}}^{\dagger}}_{sa})(D^\nu {d_{\mathbb{C}}^{\dagger}}_{tb}))({d_{\mathbb{C}}}_p{}^a \sigma_{\mu\nu} {d_{\mathbb{C}}}_r{}^b)),$ $\mathcal{O}^f_3 = \frac{1}{4}\mathcal{Y}[\boxed{\begin{array}{c}p\\r\end{array}}]\mathcal{Y}[\boxed{\begin{array}{c}s\\t\end{array}}](((D_\mu {d_{\mathbb{C}}^{\dagger}}_{sa})(D^\mu {d_{\mathbb{C}}^{\dagger}}_{tb}))({d_{\mathbb{C}}}_p{}^a {d_{\mathbb{C}}}_r{}^b)),$ $\mathcal{O}^f_4 = \frac{1}{4}\mathcal{Y}[\boxed{\begin{array}{c}p\\r\end{array}}]\mathcal{Y}[\boxed{\begin{array}{c}s\\t\end{array}}](i((D^\mu {d_{\mathbb{C}}^{\dagger}}_{sa})(D^\nu {d_{\mathbb{C}}^{\dagger}}_{tb}))({d_{\mathbb{C}}}_p{}^a \sigma_{\mu\nu} {d_{\mathbb{C}}}_r{}^b)).$	
group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$ $\{d_{\mathbb{C}1}, d_{\mathbb{C}2}\}$ $\{{d_{\mathbb{C}}^{\dagger}}_3, {d_{\mathbb{C}}^{\dagger}}_4\}$	$\mathcal{O}^j$
* $(1, 6, 1, \frac{2}{3})$	$4\mathcal{O}^f_4$
$(0, 6, 1, \frac{2}{3})$	$-4\mathcal{O}^f_1$
* $(1, 3, 1, \frac{2}{3})$	$-4\mathcal{O}^f_2$
$(0, 3, 1, \frac{2}{3})$	$4\mathcal{O}^f_3$
$\{d_{\mathbb{C}1}, {d_{\mathbb{C}}^{\dagger}}_3\}$ $\{d_{\mathbb{C}2}, {d_{\mathbb{C}}^{\dagger}}_4\}$	$\mathcal{O}^j$
* $(2, 8, 1, 0)$	$-10\mathcal{O}^f_1 + 12\mathcal{O}^f_2 + 20\mathcal{O}^f_3 - 6\mathcal{O}^f_4$
$(1, 8, 1, 0)$	$2\mathcal{O}^f_1 + 4\mathcal{O}^f_2 - 4\mathcal{O}^f_3 - 2\mathcal{O}^f_4$
* $(2, 1, 1, 0)$	$5\mathcal{O}^f_1 + 3\mathcal{O}^f_2 + 5\mathcal{O}^f_3 + 3\mathcal{O}^f_4$
$(1, 1, 1, 0)$	$-\mathcal{O}^f_1 + \mathcal{O}^f_2 - \mathcal{O}^f_3 + \mathcal{O}^f_4$

Table 88. UV resonance of type $D^2{d_{\mathbb{C}}}^2{d_{\mathbb{C}}^{\dagger}}^2$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: $D^2 d_{\mathbb{C}} {d_{\mathbb{C}}}^\dagger u_{\mathbb{C}} {u_{\mathbb{C}}}^\dagger$

$$
\begin{aligned}
\mathcal{O}^f_1 &= ((D_\mu {d_{\mathbb{C}}}^\dagger{}_{sa})(D^\mu {u_{\mathbb{C}}}^\dagger{}_{tb}))({d_{\mathbb{C}p}}^a {u_{\mathbb{C}r}}^b),\\
\mathcal{O}^f_2 &= i((D^\mu {d_{\mathbb{C}}}^\dagger{}_{sa})(D^\nu {u_{\mathbb{C}}}^\dagger{}_{tb}))({d_{\mathbb{C}p}}^a \sigma_{\mu\nu} {u_{\mathbb{C}r}}^b),\\
\mathcal{O}^f_3 &= ((D_\mu {d_{\mathbb{C}}}^\dagger{}_{sb})(D^\mu {u_{\mathbb{C}}}^\dagger{}_{ta}))({d_{\mathbb{C}p}}^a {u_{\mathbb{C}r}}^b),\\
\mathcal{O}^f_4 &= i((D^\mu {d_{\mathbb{C}}}^\dagger{}_{sb})(D^\nu {u_{\mathbb{C}}}^\dagger{}_{ta}))({d_{\mathbb{C}p}}^a \sigma_{\mu\nu} {u_{\mathbb{C}r}}^b).
\end{aligned}
$$

	group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$	$\mathcal{O}^j$
	$\{d_{\mathbb{C}1}, u_{\mathbb{C}2}\}$ $\{{d_{\mathbb{C}}}^\dagger{}_3, {u_{\mathbb{C}}}^\dagger{}_4\}$	
*	$(1, 6, 1, -\frac{1}{3})$	$2\mathcal{O}^f_2 + 2\mathcal{O}^f_4$
	$(0, 6, 1, -\frac{1}{3})$	$-2\mathcal{O}^f_1 - 2\mathcal{O}^f_3$
*	$(1, 3, 1, -\frac{1}{3})$	$-2\mathcal{O}^f_2 + 2\mathcal{O}^f_4$
	$(0, 3, 1, -\frac{1}{3})$	$2\mathcal{O}^f_1 - 2\mathcal{O}^f_3$
	$\{d_{\mathbb{C}1}, {d_{\mathbb{C}}}^\dagger{}_3\}$ $\{u_{\mathbb{C}2}, {u_{\mathbb{C}}}^\dagger{}_4\}$	$\mathcal{O}^j$
*	$(2, 8, 1, 0)$	$5\mathcal{O}^f_1 + 3\mathcal{O}^f_2 - 15\mathcal{O}^f_3 - 9\mathcal{O}^f_4$
	$(1, 8, 1, 0)$	$-\mathcal{O}^f_1 + \mathcal{O}^f_2 + 3\mathcal{O}^f_3 - 3\mathcal{O}^f_4$
*	$(2, 1, 1, 0)$	$5\mathcal{O}^f_1 + 3\mathcal{O}^f_2$
	$(1, 1, 1, 0)$	$-\mathcal{O}^f_1 + \mathcal{O}^f_2$
	$\{d_{\mathbb{C}1}, {u_{\mathbb{C}}}^\dagger{}_4\}$ $\{u_{\mathbb{C}2}, {d_{\mathbb{C}}}^\dagger{}_3\}$	$\mathcal{O}^j$
*	$(2, 8, 1, 1)$	$-15\mathcal{O}^f_1 + 9\mathcal{O}^f_2 + 5\mathcal{O}^f_3 - 3\mathcal{O}^f_4$
	$(1, 8, 1, 1)$	$3\mathcal{O}^f_1 + 3\mathcal{O}^f_2 - \mathcal{O}^f_3 - \mathcal{O}^f_4$
*	$(2, 1, 1, 1)$	$-5\mathcal{O}^f_3 + 3\mathcal{O}^f_4$
	$(1, 1, 1, 1)$	$\mathcal{O}^f_3 + \mathcal{O}^f_4$

Table 89. UV resonance of type $D^2 d_{\mathbb{C}} {d_{\mathbb{C}}}^\dagger u_{\mathbb{C}} {u_{\mathbb{C}}}^\dagger$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

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Type: $D^2{u_{\mathbb{C}}}^2{u_{\mathbb{C}}^{\dagger}}^2$

$$\begin{aligned}
\mathcal{O}^f_1 &= \tfrac{1}{4}\mathcal{Y}[\begin{array}{|c|c|}\hline p & r \\ \hline\end{array}]\mathcal{Y}[\begin{array}{|c|c|}\hline s & t \\ \hline\end{array}]\left(\left(\left(D_\mu {u_{\mathbb{C}}^{\dagger}}_{sa}\right)\left(D^\mu {u_{\mathbb{C}}^{\dagger}}_{tb}\right)\right)\left({u_{\mathbb{C}}}_p{}^a {u_{\mathbb{C}}}_r{}^b\right)\right),\\
\mathcal{O}^f_2 &= \tfrac{1}{4}\mathcal{Y}[\begin{array}{|c|c|}\hline p & r \\ \hline\end{array}]\mathcal{Y}[\begin{array}{|c|c|}\hline s & t \\ \hline\end{array}]\left(i\left(\left(D^\mu {u_{\mathbb{C}}^{\dagger}}_{sa}\right)\left(D^\nu {u_{\mathbb{C}}^{\dagger}}_{tb}\right)\right)\left({u_{\mathbb{C}}}_p{}^a \sigma_{\mu\nu} {u_{\mathbb{C}}}_r{}^b\right)\right),\\
\mathcal{O}^f_3 &= \tfrac{1}{4}\mathcal{Y}[\begin{array}{|c|}\hline p \\ \hline r \\ \hline\end{array}]\mathcal{Y}[\begin{array}{|c|}\hline s \\ \hline t \\ \hline\end{array}]\left(\left(\left(D_\mu {u_{\mathbb{C}}^{\dagger}}_{sa}\right)\left(D^\mu {u_{\mathbb{C}}^{\dagger}}_{tb}\right)\right)\left({u_{\mathbb{C}}}_p{}^a {u_{\mathbb{C}}}_r{}^b\right)\right),\\
\mathcal{O}^f_4 &= \tfrac{1}{4}\mathcal{Y}[\begin{array}{|c|}\hline p \\ \hline r \\ \hline\end{array}]\mathcal{Y}[\begin{array}{|c|}\hline s \\ \hline t \\ \hline\end{array}]\left(i\left(\left(D^\mu {u_{\mathbb{C}}^{\dagger}}_{sa}\right)\left(D^\nu {u_{\mathbb{C}}^{\dagger}}_{tb}\right)\right)\left({u_{\mathbb{C}}}_p{}^a \sigma_{\mu\nu} {u_{\mathbb{C}}}_r{}^b\right)\right).
\end{aligned}$$

	group: (Spin, $SU(3)_c$, $SU(2)_w$, $U(1)_y$) $\{u_{\mathbb{C}1}, u_{\mathbb{C}2}\}$ $\{{u_{\mathbb{C}}^\dagger}_3, {u_{\mathbb{C}}^\dagger}_4\}$	$\mathcal{O}^j$
*	$(1, 6, 1, -\frac{4}{3})$	$4\mathcal{O}^f_4$
	$(0, 6, 1, -\frac{4}{3})$	$-4\mathcal{O}^f_1$
*	$(1, 3, 1, -\frac{4}{3})$	$-4\mathcal{O}^f_2$
	$(0, 3, 1, -\frac{4}{3})$	$4\mathcal{O}^f_3$
	$\{u_{\mathbb{C}1}, {u_{\mathbb{C}}^\dagger}_3\}$ $\{u_{\mathbb{C}2}, {u_{\mathbb{C}}^\dagger}_4\}$	$\mathcal{O}^j$
*	$(2, 8, 1, 0)$	$-10\mathcal{O}^f_1 + 12\mathcal{O}^f_2 + 20\mathcal{O}^f_3 - 6\mathcal{O}^f_4$
	$(1, 8, 1, 0)$	$2\mathcal{O}^f_1 + 4\mathcal{O}^f_2 - 4\mathcal{O}^f_3 - 2\mathcal{O}^f_4$
*	$(2, 1, 1, 0)$	$5\mathcal{O}^f_1 + 3\mathcal{O}^f_2 + 5\mathcal{O}^f_3 + 3\mathcal{O}^f_4$
	$(1, 1, 1, 0)$	$-\mathcal{O}^f_1 + \mathcal{O}^f_2 - \mathcal{O}^f_3 + \mathcal{O}^f_4$

Table 90. UV resonance of type $D^2{u_{\mathbb{C}}}^2{u_{\mathbb{C}}^{\dagger}}^2$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: $D^2 e_{\mathbb{C}} {Q^\dagger}^2 u_{\mathbb{C}}$

$$\begin{aligned}
\mathcal{O}^f_1 &= \tfrac{1}{2}\mathcal{Y}[\begin{array}{|c|c|}\hline s & t \\ \hline\end{array}]\epsilon_{abc}\epsilon_{ij}\left(\left(D_\mu {Q^\dagger}_s{}^{bi}\right)\left(D^\mu {Q^\dagger}_t{}^{cj}\right)\right)\left({e_{\mathbb{C}}}_p {u_{\mathbb{C}}}_r{}^a\right),\\
\mathcal{O}^f_2 &= \tfrac{1}{2}\mathcal{Y}[\begin{array}{|c|}\hline s \\ \hline t \\ \hline\end{array}]\epsilon_{abc}\epsilon_{ij} i\left(\left(D^\mu {Q^\dagger}_s{}^{bi}\right)\left(D^\nu {Q^\dagger}_t{}^{cj}\right)\right)\left({e_{\mathbb{C}}}_p \sigma_{\mu\nu} {u_{\mathbb{C}}}_r{}^a\right).
\end{aligned}$$

	group: (Spin, $SU(3)_c$, $SU(2)_w$, $U(1)_y$) $\{e_{\mathbb{C}1}, u_{\mathbb{C}2}\}$ $\{{Q^\dagger}_3, {Q^\dagger}_4\}$	$\mathcal{O}^j$
*	$(1, \overline{3}, 1, \frac{1}{3})$	$-2\mathcal{O}^f_2$
	$(0, \overline{3}, 1, \frac{1}{3})$	$2\mathcal{O}^f_1$
	$\{e_{\mathbb{C}1}, {Q^\dagger}_3\}$ $\{u_{\mathbb{C}2}, {Q^\dagger}_4\}$	$\mathcal{O}^j$
*	$(2, \overline{3}, 2, \frac{5}{6})$	$-5\mathcal{O}^f_1 - 3\mathcal{O}^f_2$
	$(1, \overline{3}, 2, \frac{5}{6})$	$\mathcal{O}^f_1 - \mathcal{O}^f_2$

Table 91. UV resonance of type $D^2 e_{\mathbb{C}} {Q^\dagger}^2 u_{\mathbb{C}}$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: $D^2 d_{\mathbb{C}} L^{\dagger} Q^{\dagger} u_{\mathbb{C}}$		
$\mathcal{O}^f_1 = \epsilon_{ij}\epsilon_{abc}((D_\mu {L^\dagger}_s{}^i)(D^\mu {Q^\dagger}_t{}^{cj}))({d_{\mathbb{C}}}_p{}^a {u_{\mathbb{C}}}_r{}^b)$, $\mathcal{O}^f_2 = i\epsilon_{ij}\epsilon_{abc}((D^\mu {L^\dagger}_s{}^i)(D^\nu {Q^\dagger}_t{}^{cj}))({d_{\mathbb{C}}}_p{}^a \sigma_{\mu\nu} {u_{\mathbb{C}}}_r{}^b)$.		
group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$		$\mathcal{O}^j$
	$\{d_{\mathbb{C}1}, u_{\mathbb{C}2}\}$ $\{{L^\dagger}_3, {Q^\dagger}_4\}$	
*	$(1, 3, 1, -\frac{1}{3})$	$-2\mathcal{O}^f_2$
	$(0, 3, 1, -\frac{1}{3})$	$2\mathcal{O}^f_1$
	$\{d_{\mathbb{C}1}, {L^\dagger}_3\}$ $\{u_{\mathbb{C}2}, {Q^\dagger}_4\}$	$\mathcal{O}^j$
*	$(2, \overline{3}, 2, \frac{5}{6})$	$-5\mathcal{O}^f_1 - 3\mathcal{O}^f_2$
	$(1, \overline{3}, 2, \frac{5}{6})$	$\mathcal{O}^f_1 - \mathcal{O}^f_2$
	$\{d_{\mathbb{C}1}, {Q^\dagger}_4\}$ $\{u_{\mathbb{C}2}, {L^\dagger}_3\}$	$\mathcal{O}^j$
*	$(2, 3, 2, \frac{1}{6})$	$5\mathcal{O}^f_1 - 3\mathcal{O}^f_2$
	$(1, 3, 2, \frac{1}{6})$	$-\mathcal{O}^f_1 - \mathcal{O}^f_2$

Table 92. UV resonance of type $D^2 d_{\mathbb{C}} L^{\dagger} Q^{\dagger} u_{\mathbb{C}}$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

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Type: $D^2LL^\dagger QQ^\dagger$

$$
\begin{aligned}
\mathcal{O}^f_1 &= ((D_\mu L^\dagger{}_s{}^i)(D^\mu Q^\dagger{}_t{}^{aj}))(L_{p_i} Q_r{}^{aj}),\\
\mathcal{O}^f_2 &= i((D^\mu L^\dagger{}_s{}^i)(D^\nu Q^\dagger{}_t{}^{aj}))(L_{p_i}\sigma_{\mu\nu} Q_r{}^{aj}),\\
\mathcal{O}^f_3 &= ((D_\mu L^\dagger{}_s{}^j)(D^\mu Q^\dagger{}_t{}^{ai}))(L_{p_i} Q_r{}^{aj}),\\
\mathcal{O}^f_4 &= i((D^\mu L^\dagger{}_s{}^j)(D^\nu Q^\dagger{}_t{}^{ai}))(L_{p_i}\sigma_{\mu\nu} Q_r{}^{aj}).
\end{aligned}
$$

	group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$	$\mathcal{O}^j$
	$\{L_1, Q_2\}\quad\{L^\dagger{}_3, Q^\dagger{}_4\}$	
*	$(1, 3, 3, -\frac{1}{3})$	$-2\mathcal{O}^f_2 - 2\mathcal{O}^f_4$
	$(0, 3, 3, -\frac{1}{3})$	$2\mathcal{O}^f_1 + 2\mathcal{O}^f_3$
*	$(1, 3, 1, -\frac{1}{3})$	$2\mathcal{O}^f_2 - 2\mathcal{O}^f_4$
	$(0, 3, 1, -\frac{1}{3})$	$-2\mathcal{O}^f_1 + 2\mathcal{O}^f_3$
	$\{L_1, L^\dagger{}_3\}\quad\{Q_2, Q^\dagger{}_4\}$	$\mathcal{O}^j$
*	$(2, 1, 3, 0)$	$5\mathcal{O}^f_1 + 3\mathcal{O}^f_2 - 10\mathcal{O}^f_3 - 6\mathcal{O}^f_4$
	$(1, 1, 3, 0)$	$-\mathcal{O}^f_1 + \mathcal{O}^f_2 + 2\mathcal{O}^f_3 - 2\mathcal{O}^f_4$
*	$(2, 1, 1, 0)$	$-5\mathcal{O}^f_1 - 3\mathcal{O}^f_2$
	$(1, 1, 1, 0)$	$\mathcal{O}^f_1 - \mathcal{O}^f_2$
	$\{L_1, Q^\dagger{}_4\}\quad\{Q_2, L^\dagger{}_3\}$	$\mathcal{O}^j$
*	$(2, \overline{3}, 3, -\frac{2}{3})$	$-10\mathcal{O}^f_1 + 6\mathcal{O}^f_2 + 5\mathcal{O}^f_3 - 3\mathcal{O}^f_4$
	$(1, \overline{3}, 3, -\frac{2}{3})$	$2\mathcal{O}^f_1 + 2\mathcal{O}^f_2 - \mathcal{O}^f_3 - \mathcal{O}^f_4$
*	$(2, \overline{3}, 1, -\frac{2}{3})$	$5\mathcal{O}^f_3 - 3\mathcal{O}^f_4$
	$(1, \overline{3}, 1, -\frac{2}{3})$	$-\mathcal{O}^f_3 - \mathcal{O}^f_4$

Table 93. UV resonance of type $D^2LL^\dagger QQ^\dagger$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

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Type: $D^2 d_{\mathbb{C}} d_{\mathbb{C}}{}^{\dagger} Q Q^{\dagger}$		
$\mathcal{O}^f_1 = ((D_\mu d_{\mathbb{C}}{}^{\dagger}{}_{sa})(D^\mu Q^{\dagger}{}_t{}^{bi}))(d_{\mathbb{C}p}{}^a Q_r{}^{bi}),$ $\mathcal{O}^f_2 = i((D^\mu d_{\mathbb{C}}{}^{\dagger}{}_{sa})(D^\nu Q^{\dagger}{}_t{}^{bi}))(d_{\mathbb{C}p}{}^a \sigma_{\mu\nu} Q_r{}^{bi}),$ $\mathcal{O}^f_3 = ((D_\mu d_{\mathbb{C}}{}^{\dagger}{}_{sc})(D^\mu Q^{\dagger}{}_t{}^{ci}))(d_{\mathbb{C}p}{}^a Q_r{}^{ai}),$ $\mathcal{O}^f_4 = i((D^\mu d_{\mathbb{C}}{}^{\dagger}{}_{sc})(D^\nu Q^{\dagger}{}_t{}^{ci}))(d_{\mathbb{C}p}{}^a \sigma_{\mu\nu} Q_r{}^{ai}).$		
group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$		$\mathcal{O}^j$
	$\{d_{\mathbb{C}1}, Q_2\} \quad \{d_{\mathbb{C}}{}^{\dagger}{}_3, Q^{\dagger}{}_4\}$	
*	$(1, 8, 2, \frac{1}{2})$	$-6\mathcal{O}^f_2 + 2\mathcal{O}^f_4$
	$(0, 8, 2, \frac{1}{2})$	$6\mathcal{O}^f_1 - 2\mathcal{O}^f_3$
*	$(1, 1, 2, \frac{1}{2})$	$-2\mathcal{O}^f_4$
	$(0, 1, 2, \frac{1}{2})$	$2\mathcal{O}^f_3$
	$\{d_{\mathbb{C}1}, d_{\mathbb{C}}{}^{\dagger}{}_3\} \quad \{Q_2, Q^{\dagger}{}_4\}$	$\mathcal{O}^j$
*	$(2, 8, 1, 0)$	$-5\mathcal{O}^f_1 - 3\mathcal{O}^f_2 + 15\mathcal{O}^f_3 + 9\mathcal{O}^f_4$
	$(1, 8, 1, 0)$	$\mathcal{O}^f_1 - \mathcal{O}^f_2 - 3\mathcal{O}^f_3 + 3\mathcal{O}^f_4$
*	$(2, 1, 1, 0)$	$-5\mathcal{O}^f_1 - 3\mathcal{O}^f_2$
	$(1, 1, 1, 0)$	$\mathcal{O}^f_1 - \mathcal{O}^f_2$
	$\{d_{\mathbb{C}1}, Q^{\dagger}{}_4\} \quad \{Q_2, d_{\mathbb{C}}{}^{\dagger}{}_3\}$	$\mathcal{O}^j$
*	$(2, 6, 2, \frac{1}{6})$	$5\mathcal{O}^f_1 - 3\mathcal{O}^f_2 + 5\mathcal{O}^f_3 - 3\mathcal{O}^f_4$
	$(1, 6, 2, \frac{1}{6})$	$-\mathcal{O}^f_1 - \mathcal{O}^f_2 - \mathcal{O}^f_3 - \mathcal{O}^f_4$
*	$(2, 3, 2, \frac{1}{6})$	$-5\mathcal{O}^f_1 + 3\mathcal{O}^f_2 + 5\mathcal{O}^f_3 - 3\mathcal{O}^f_4$
	$(1, 3, 2, \frac{1}{6})$	$\mathcal{O}^f_1 + \mathcal{O}^f_2 - \mathcal{O}^f_3 - \mathcal{O}^f_4$

Table 94. UV resonance of type $D^2 d_{\mathbb{C}} d_{\mathbb{C}}{}^{\dagger} Q Q^{\dagger}$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

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Type: $D^2QQ^\dagger u_\mathbb{C} u_\mathbb{C}{}^\dagger$	
$\mathcal{O}^f_1 = ((D_\mu Q^\dagger{}_s{}^{ci})(D^\mu u_\mathbb{C}{}^\dagger{}_{tc}))(Q_p{}^{ai} u_{\mathbb{C}r}{}^a)$, $\mathcal{O}^f_2 = i((D^\mu Q^\dagger{}_s{}^{ci})(D^\nu u_\mathbb{C}{}^\dagger{}_{tc}))(Q_p{}^{ai}\sigma_{\mu\nu} u_{\mathbb{C}r}{}^a)$, $\mathcal{O}^f_3 = ((D_\mu Q^\dagger{}_s{}^{ai})(D^\mu u_\mathbb{C}{}^\dagger{}_{tb}))(Q_p{}^{ai} u_{\mathbb{C}r}{}^b)$, $\mathcal{O}^f_4 = i((D^\mu Q^\dagger{}_s{}^{ai})(D^\nu u_\mathbb{C}{}^\dagger{}_{tb}))(Q_p{}^{ai}\sigma_{\mu\nu} u_{\mathbb{C}r}{}^b)$.	
group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$ $\{Q_1, u_{\mathbb{C}2}\}$ $\{Q^\dagger{}_3, u_\mathbb{C}{}^\dagger{}_4\}$	$\mathcal{O}^j$
* $(1, 8, 2, -\frac{1}{2})$	$-2\mathcal{O}^f_2 + 6\mathcal{O}^f_4$
$(0, 8, 2, -\frac{1}{2})$	$2\mathcal{O}^f_1 - 6\mathcal{O}^f_3$
* $(1, 1, 2, -\frac{1}{2})$	$-2\mathcal{O}^f_2$
$(0, 1, 2, -\frac{1}{2})$	$2\mathcal{O}^f_1$
$\{Q_1, Q^\dagger{}_3\}$ $\{u_{\mathbb{C}2}, u_\mathbb{C}{}^\dagger{}_4\}$	$\mathcal{O}^j$
* $(2, 8, 1, 0)$	$-15\mathcal{O}^f_1 - 9\mathcal{O}^f_2 + 5\mathcal{O}^f_3 + 3\mathcal{O}^f_4$
$(1, 8, 1, 0)$	$3\mathcal{O}^f_1 - 3\mathcal{O}^f_2 - \mathcal{O}^f_3 + \mathcal{O}^f_4$
* $(2, 1, 1, 0)$	$-5\mathcal{O}^f_3 - 3\mathcal{O}^f_4$
$(1, 1, 1, 0)$	$\mathcal{O}^f_3 - \mathcal{O}^f_4$
$\{Q_1, u_\mathbb{C}{}^\dagger{}_4\}$ $\{u_{\mathbb{C}2}, Q^\dagger{}_3\}$	$\mathcal{O}^j$
* $(2, \overline{6}, 2, \frac{5}{6})$	$5\mathcal{O}^f_1 - 3\mathcal{O}^f_2 + 5\mathcal{O}^f_3 - 3\mathcal{O}^f_4$
$(1, \overline{6}, 2, \frac{5}{6})$	$-\mathcal{O}^f_1 - \mathcal{O}^f_2 - \mathcal{O}^f_3 - \mathcal{O}^f_4$
* $(2, \overline{3}, 2, \frac{5}{6})$	$-5\mathcal{O}^f_1 + 3\mathcal{O}^f_2 + 5\mathcal{O}^f_3 - 3\mathcal{O}^f_4$
$(1, \overline{3}, 2, \frac{5}{6})$	$\mathcal{O}^f_1 + \mathcal{O}^f_2 - \mathcal{O}^f_3 - \mathcal{O}^f_4$

Table 95. UV resonance of type $D^2QQ^\dagger u_\mathbb{C} u_\mathbb{C}{}^\dagger$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: $D^2Q^2{Q^\dagger}^2$		
	$$\begin{array}{rcl} \mathcal{O}^f_1 &=& \frac{1}{4}\mathcal{Y}[\begin{array}{|c|c|}\hline p & r\\\hline\end{array}]\mathcal{Y}[\begin{array}{|c|c|}\hline s & t\\\hline\end{array}](((D_\mu {Q^\dagger}_s{}^{ai})(D^\mu {Q^\dagger}_t{}^{bj}))(Q_p{}^{ai}Q_r{}^{bj})),\\ \mathcal{O}^f_2 &=& \frac{1}{4}\mathcal{Y}[\begin{array}{|c|c|}\hline p & r\\\hline\end{array}]\mathcal{Y}[\begin{array}{|c|c|}\hline s & t\\\hline\end{array}](i((D^\mu {Q^\dagger}_s{}^{ai})(D^\nu {Q^\dagger}_t{}^{bj}))(Q_p{}^{ai}\sigma_{\mu\nu}Q_r{}^{bj})),\\ \mathcal{O}^f_3 &=& \frac{1}{4}\mathcal{Y}[\begin{array}{|c|c|}\hline p & r\\\hline\end{array}]\mathcal{Y}[\begin{array}{|c|c|}\hline s & t\\\hline\end{array}](((D_\mu {Q^\dagger}_s{}^{aj})(D^\mu {Q^\dagger}_t{}^{bi}))(Q_p{}^{ai}Q_r{}^{bj})),\\ \mathcal{O}^f_4 &=& \frac{1}{4}\mathcal{Y}[\begin{array}{|c|c|}\hline p & r\\\hline\end{array}]\mathcal{Y}[\begin{array}{|c|c|}\hline s & t\\\hline\end{array}](i((D^\mu {Q^\dagger}_s{}^{aj})(D^\nu {Q^\dagger}_t{}^{bi}))(Q_p{}^{ai}\sigma_{\mu\nu}Q_r{}^{bj})),\\ \mathcal{O}^f_5 &=& \frac{1}{4}\mathcal{Y}[\begin{array}{|c|}\hline p\\\hline r\\\hline\end{array}]\mathcal{Y}[\begin{array}{|c|}\hline s\\\hline t\\\hline\end{array}](((D_\mu {Q^\dagger}_s{}^{ai})(D^\mu {Q^\dagger}_t{}^{bj}))(Q_p{}^{ai}Q_r{}^{bj})),\\ \mathcal{O}^f_6 &=& \frac{1}{4}\mathcal{Y}[\begin{array}{|c|}\hline p\\\hline r\\\hline\end{array}]\mathcal{Y}[\begin{array}{|c|}\hline s\\\hline t\\\hline\end{array}](i((D^\mu {Q^\dagger}_s{}^{ai})(D^\nu {Q^\dagger}_t{}^{bj}))(Q_p{}^{ai}\sigma_{\mu\nu}Q_r{}^{bj})),\\ \mathcal{O}^f_7 &=& \frac{1}{4}\mathcal{Y}[\begin{array}{|c|}\hline p\\\hline r\\\hline\end{array}]\mathcal{Y}[\begin{array}{|c|}\hline s\\\hline t\\\hline\end{array}](((D_\mu {Q^\dagger}_s{}^{aj})(D^\mu {Q^\dagger}_t{}^{bi}))(Q_p{}^{ai}Q_r{}^{bj})),\\ \mathcal{O}^f_8 &=& \frac{1}{4}\mathcal{Y}[\begin{array}{|c|}\hline p\\\hline r\\\hline\end{array}]\mathcal{Y}[\begin{array}{|c|}\hline s\\\hline t\\\hline\end{array}](i((D^\mu {Q^\dagger}_s{}^{aj})(D^\nu {Q^\dagger}_t{}^{bi}))(Q_p{}^{ai}\sigma_{\mu\nu}Q_r{}^{bj})). \end{array}$$	
group: $(\mathrm{Spin},\mathrm{SU}(3)_c,\mathrm{SU}(2)_w,\mathrm{U}(1)_y)$		$\mathcal{O}^j$
	$\{Q_1,Q_2\}$ $\{{Q^\dagger}_3,{Q^\dagger}_4\}$	
*	$(1,\overline{6},3,\frac{1}{3})$	$-4\mathcal{O}^f_6-4\mathcal{O}^f_8$
	$(0,\overline{6},3,\frac{1}{3})$	$4\mathcal{O}^f_1+4\mathcal{O}^f_3$
*	$(1,\overline{6},1,\frac{1}{3})$	$4\mathcal{O}^f_2-4\mathcal{O}^f_4$
	$(0,\overline{6},1,\frac{1}{3})$	$-4\mathcal{O}^f_5+4\mathcal{O}^f_7$
*	$(1,\overline{3},3,\frac{1}{3})$	$4\mathcal{O}^f_2+4\mathcal{O}^f_4$
	$(0,\overline{3},3,\frac{1}{3})$	$-4\mathcal{O}^f_5-4\mathcal{O}^f_7$
*	$(1,\overline{3},1,\frac{1}{3})$	$-4\mathcal{O}^f_6+4\mathcal{O}^f_8$
	$(0,\overline{3},1,\frac{1}{3})$	$4\mathcal{O}^f_1-4\mathcal{O}^f_3$
	$\{Q_1,{Q^\dagger}_3\}$ $\{Q_2,{Q^\dagger}_4\}$	$\mathcal{O}^j$
*	$(2,8,3,0)$	$35\mathcal{O}^f_1-15\mathcal{O}^f_2-25\mathcal{O}^f_3+3\mathcal{O}^f_4-25\mathcal{O}^f_5+2\mathcal{O}^f_6+5\mathcal{O}^f_7-15\mathcal{O}^f_8$
	$(1,8,3,0)$	$-7\mathcal{O}^f_1-5\mathcal{O}^f_2+5\mathcal{O}^f_3+\mathcal{O}^f_4+5\mathcal{O}^f_5+7\mathcal{O}^f_6-\mathcal{O}^f_7-5\mathcal{O}^f_8$
*	$(2,8,1,0)$	$-5\mathcal{O}^f_1-3\mathcal{O}^f_2+15\mathcal{O}^f_3-9\mathcal{O}^f_4-5\mathcal{O}^f_5-3\mathcal{O}^f_6-15\mathcal{O}^f_7+9\mathcal{O}^f_8$
	$(1,8,1,0)$	$\mathcal{O}^f_1-\mathcal{O}^f_2-3\mathcal{O}^f_3-3\mathcal{O}^f_4+\mathcal{O}^f_5-\mathcal{O}^f_6+3\mathcal{O}^f_7+3\mathcal{O}^f_8$
*	$(2,1,3,0)$	$5\mathcal{O}^f_1+3\mathcal{O}^f_2-10\mathcal{O}^f_3-6\mathcal{O}^f_4+5\mathcal{O}^f_5+3\mathcal{O}^f_6-10\mathcal{O}^f_7-6\mathcal{O}^f_8$
	$(1,1,3,0)$	$-\mathcal{O}^f_1+\mathcal{O}^f_2+2\mathcal{O}^f_3-2\mathcal{O}^f_4-\mathcal{O}^f_5+\mathcal{O}^f_6+2\mathcal{O}^f_7-2\mathcal{O}^f_8$
*	$(2,1,1,0)$	$-5\mathcal{O}^f_1-3\mathcal{O}^f_2-5\mathcal{O}^f_5-3\mathcal{O}^f_6$
	$(1,1,1,0)$	$\mathcal{O}^f_1-\mathcal{O}^f_2+\mathcal{O}^f_5-\mathcal{O}^f_6$

Table 96. UV resonance of type $D^2Q^2{Q^\dagger}^2$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

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Type: $B_L B_R D^2 H H^\dagger$	
$\mathcal{O}^f_1 = (D_\mu D_\nu H^{\dagger i}) H_i B_L{}^{\lambda\nu} B_R{}^\lambda_\mu.$	
group: (Spin, SU(3)$_c$, SU(2)$_w$, U(1)$_y$) $\{B_{L1}, H_2\}$ $\{H^\dagger{}_3, B_{R4}\}$	$\mathcal{O}^j$
* $(1,1,2,\frac{1}{2})$	$8\mathcal{O}^f_1$
$\{B_{L1}, H^\dagger{}_3\}$ $\{H_2, B_{R4}\}$	$\mathcal{O}^j$
* $(1,1,2,-\frac{1}{2})$	$8\mathcal{O}^f_1$
$\{B_{L1}, B_{R4}\}$ $\{H_2, H^\dagger{}_3\}$	$\mathcal{O}^j$
* $(2,1,1,0)$	$8\mathcal{O}^f_1$

Table 97. UV resonance of type $B_L B_R D^2 H H^\dagger$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: $B_L D^2 H H^\dagger W_R$	
$\mathcal{O}^f_1 = (D_\mu D_\nu H^{\dagger j}) \tau^{I}{}^i_j H_i B_L{}^{\lambda\nu} W_R{}^{I\lambda}_\mu.$	
group: (Spin, SU(3)$_c$, SU(2)$_w$, U(1)$_y$) $\{B_{L1}, H_2\}$ $\{H^\dagger{}_3, W_{R4}\}$	$\mathcal{O}^j$
* $(1,1,2,\frac{1}{2})$	$8\mathcal{O}^f_1$
$\{B_{L1}, H^\dagger{}_3\}$ $\{H_2, W_{R4}\}$	$\mathcal{O}^j$
* $(1,1,2,-\frac{1}{2})$	$8\mathcal{O}^f_1$
$\{B_{L1}, W_{R4}\}$ $\{H_2, H^\dagger{}_3\}$	$\mathcal{O}^j$
* $(2,1,3,0)$	$8\mathcal{O}^f_1$

Table 98. UV resonance of type $B_L D^2 H H^\dagger W_R$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

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Type: $D^2HH^\dagger W_LW_R$	
$\mathcal{O}_1^f = \epsilon^{IJK}(D_\mu D_\nu H^{\dagger j})\tau^{K i}_{\ j}H_i W_L{}^{I\lambda\nu}W_{R\mu}^{J\lambda}$, $\mathcal{O}_2^f = (D_\mu D_\nu H^{\dagger i})H_i W_L{}^{I\lambda\nu}W_{R\mu}^{I\lambda}$.	
group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$ $\{W_{L1}, H_2\}$ $\{H^\dagger{}_3, W_{R4}\}$	$\mathcal{O}^j$
* $(1,1,4,-\frac{1}{2})$	$8i\mathcal{O}_1^f + 16\mathcal{O}_2^f$
* $(1,1,2,-\frac{1}{2})$	$-8i\mathcal{O}_1^f + 8\mathcal{O}_2^f$
$\{W_{L1}, H^\dagger{}_3\}$ $\{H_2, W_{R4}\}$	$\mathcal{O}^j$
* $(1,1,4,\frac{1}{2})$	$-8i\mathcal{O}_1^f + 16\mathcal{O}_2^f$
* $(1,1,2,\frac{1}{2})$	$8i\mathcal{O}_1^f + 8\mathcal{O}_2^f$
$\{W_{L1}, W_{R4}\}$ $\{H_2, H^\dagger{}_3\}$	$\mathcal{O}^j$
* $(2,1,3,0)$	$8\mathcal{O}_1^f$
* $(2,1,1,0)$	$8\mathcal{O}_2^f$

Table 99. UV resonance of type $D^2HH^\dagger W_LW_R$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

Type: $D^2G_LG_RHH^\dagger$	
$\mathcal{O}_1^f = (D_\mu D_\nu H^{\dagger i})H_i G_L{}^{A\lambda\nu}G_{R\mu}^{A\lambda}$.	
group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$ $\{G_{L1}, H_2\}$ $\{H^\dagger{}_3, G_{R4}\}$	$\mathcal{O}^j$
* $(1,8,2,\frac{1}{2})$	$8\mathcal{O}_1^f$
$\{G_{L1}, H^\dagger{}_3\}$ $\{H_2, G_{R4}\}$	$\mathcal{O}^j$
* $(1,8,2,-\frac{1}{2})$	$8\mathcal{O}_1^f$
$\{G_{L1}, G_{R4}\}$ $\{H_2, H^\dagger{}_3\}$	$\mathcal{O}^j$
* $(2,1,1,0)$	$8\mathcal{O}_1^f$

Table 100. UV resonance of type $D^2G_LG_RHH^\dagger$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

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Type: $D^3 e_{\mathbb{C}} {e_{\mathbb{C}}}^\dagger H H^\dagger$		
$\mathcal{O}^f_1 = i(e_{\mathbb{C}p}\sigma_\mu(D^\nu {e_{\mathbb{C}}^\dagger}_r))(D_\nu D^\mu {H^\dagger}^i)H_i,$ $\mathcal{O}^f_2 = i(e_{\mathbb{C}p}\sigma_\mu(D^\nu {e_{\mathbb{C}}^\dagger}_r))(D_\nu H_i)(D^\mu {H^\dagger}^i).$		
	group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$ $\{e_{\mathbb{C}1}, H_2\}$ $\{{H^\dagger}_3, {e_{\mathbb{C}}^\dagger}_4\}$	$\mathcal{O}^j$
*	$(\frac{3}{2}, 1, 2, \frac{3}{2})$	$-4\mathcal{O}^f_1 - 6\mathcal{O}^f_2$
	$(\frac{1}{2}, 1, 2, \frac{3}{2})$	$2\mathcal{O}^f_1$
	$\{e_{\mathbb{C}1}, {H^\dagger}_3\}$ $\{H_2, {e_{\mathbb{C}}^\dagger}_4\}$	$\mathcal{O}^j$
*	$(\frac{3}{2}, 1, 2, \frac{1}{2})$	$-6\mathcal{O}^f_1 - 4\mathcal{O}^f_2$
	$(\frac{1}{2}, 1, 2, \frac{1}{2})$	$-2\mathcal{O}^f_2$
	$\{e_{\mathbb{C}1}, {e_{\mathbb{C}}^\dagger}_4\}$ $\{H_2, {H^\dagger}_3\}$	$\mathcal{O}^j$
*	$(2, 1, 1, 0)$	$2\mathcal{O}^f_1 - 2\mathcal{O}^f_2$
	$(1, 1, 1, 0)$	$-2\mathcal{O}^f_1 - 2\mathcal{O}^f_2$

Table 101. UV resonance of type $D^3 e_{\mathbb{C}} {e_{\mathbb{C}}}^\dagger H H^\dagger$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

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Type: $D^3HH^\dagger LL^\dagger$	
$\mathcal{O}^f_1 = i(L_{p_i}\sigma_\mu(D^\nu L^\dagger{}_r{}^j))(D_\nu D^\mu H^{\dagger i})H_j,$ $\mathcal{O}^f_2 = i(L_{p_i}\sigma_\mu(D^\nu L^\dagger{}_r{}^j))(D_\nu H_j)(D^\mu H^{\dagger i}),$ $\mathcal{O}^f_3 = i(L_{p_i}\sigma_\mu(D^\nu L^\dagger{}_r{}^i))(D_\nu D^\mu H^{\dagger j})H_j,$ $\mathcal{O}^f_4 = i(L_{p_i}\sigma_\mu(D^\nu L^\dagger{}_r{}^i))(D_\nu H_j)(D^\mu H^{\dagger j}).$	
group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$ $\{L_1, H_2\}$ $\{H^\dagger{}_3, L^\dagger{}_4\}$	$\mathcal{O}^j$
* $(\frac{3}{2}, 1, 3, 0)$	$-4\mathcal{O}^f_1 - 6\mathcal{O}^f_2 - 4\mathcal{O}^f_3 - 6\mathcal{O}^f_4$
$(\frac{1}{2}, 1, 3, 0)$	$2\mathcal{O}^f_1 + 2\mathcal{O}^f_3$
* $(\frac{3}{2}, 1, 1, 0)$	$4\mathcal{O}^f_1 + 6\mathcal{O}^f_2 - 4\mathcal{O}^f_3 - 6\mathcal{O}^f_4$
$(\frac{1}{2}, 1, 1, 0)$	$-2\mathcal{O}^f_1 + 2\mathcal{O}^f_3$
$\{L_1, H^\dagger{}_3\}$ $\{H_2, L^\dagger{}_4\}$	$\mathcal{O}^j$
* $(\frac{3}{2}, 1, 3, 1)$	$6\mathcal{O}^f_1 + 4\mathcal{O}^f_2 - 12\mathcal{O}^f_3 - 8\mathcal{O}^f_4$
$(\frac{1}{2}, 1, 3, 1)$	$2\mathcal{O}^f_2 - 4\mathcal{O}^f_4$
* $(\frac{3}{2}, 1, 1, 1)$	$-6\mathcal{O}^f_1 - 4\mathcal{O}^f_2$
$(\frac{1}{2}, 1, 1, 1)$	$-2\mathcal{O}^f_2$
$\{L_1, L^\dagger{}_4\}$ $\{H_2, H^\dagger{}_3\}$	$\mathcal{O}^j$
* $(2, 1, 3, 0)$	$-4\mathcal{O}^f_1 + 4\mathcal{O}^f_2 + 2\mathcal{O}^f_3 - 2\mathcal{O}^f_4$
$(1, 1, 3, 0)$	$4\mathcal{O}^f_1 + 4\mathcal{O}^f_2 - 2\mathcal{O}^f_3 - 2\mathcal{O}^f_4$
* $(2, 1, 1, 0)$	$2\mathcal{O}^f_3 - 2\mathcal{O}^f_4$
$(1, 1, 1, 0)$	$-2\mathcal{O}^f_3 - 2\mathcal{O}^f_4$

Table 102. UV resonance of type $D^3HH^\dagger LL^\dagger$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

	Type: $D^3 d_{\mathbb{C}} {H^\dagger}^2 {u_{\mathbb{C}}}^\dagger$	
	$\mathcal{O}^f_1 = \frac{1}{2}\mathcal{Y}[\square\square_{H^\dagger}]\epsilon_{ij} {H^\dagger}^i i({d_{\mathbb{C}}}_p{}^a \sigma_\mu (D^\nu {{u_{\mathbb{C}}}^\dagger}_{ra}))(D_\nu D^\mu {H^\dagger}^j)$.	
	group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$ $\{d_{\mathbb{C}1}, {H^\dagger}_2\}$ $\{{H^\dagger}_3, {u_{\mathbb{C}}^\dagger}_4\}$	$\mathcal{O}^j$
*	$(\frac{3}{2}, \overline{3}, 2, -\frac{1}{6})$	$-10\mathcal{O}^f_1$
	$(\frac{1}{2}, \overline{3}, 2, -\frac{1}{6})$	$2\mathcal{O}^f_1$
	$\{d_{\mathbb{C}1}, {u_{\mathbb{C}}^\dagger}_4\}$ $\{{H^\dagger}_2, {H^\dagger}_3\}$	$\mathcal{O}^j$
	$(1, 1, 1, 1)$	$-4\mathcal{O}^f_1$

Table 103. UV resonance of type $D^3 d_{\mathbb{C}} {H^\dagger}^2 {u_{\mathbb{C}}}^\dagger$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

	Type: $D^3 d_{\mathbb{C}} {d_{\mathbb{C}}}^\dagger H H^\dagger$	
	$\mathcal{O}^f_1 = i({d_{\mathbb{C}}}_p{}^a \sigma_\mu (D^\nu {{d_{\mathbb{C}}}^\dagger}_{ra}))(D_\nu D^\mu {H^\dagger}^i) H_i$, $\mathcal{O}^f_2 = i({d_{\mathbb{C}}}_p{}^a \sigma_\mu (D^\nu {{d_{\mathbb{C}}}^\dagger}_{ra}))(D_\nu H_i)(D^\mu {H^\dagger}^i)$.	
	group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$ $\{d_{\mathbb{C}1}, H_2\}$ $\{{H^\dagger}_3, {d_{\mathbb{C}}^\dagger}_4\}$	$\mathcal{O}^j$
*	$(\frac{3}{2}, \overline{3}, 2, \frac{5}{6})$	$-4\mathcal{O}^f_1 - 6\mathcal{O}^f_2$
	$(\frac{1}{2}, \overline{3}, 2, \frac{5}{6})$	$2\mathcal{O}^f_1$
	$\{d_{\mathbb{C}1}, {H^\dagger}_3\}$ $\{H_2, {d_{\mathbb{C}}^\dagger}_4\}$	$\mathcal{O}^j$
*	$(\frac{3}{2}, \overline{3}, 2, -\frac{1}{6})$	$-6\mathcal{O}^f_1 - 4\mathcal{O}^f_2$
	$(\frac{1}{2}, \overline{3}, 2, -\frac{1}{6})$	$-2\mathcal{O}^f_2$
	$\{d_{\mathbb{C}1}, {d_{\mathbb{C}}^\dagger}_4\}$ $\{H_2, {H^\dagger}_3\}$	$\mathcal{O}^j$
*	$(2, 1, 1, 0)$	$2\mathcal{O}^f_1 - 2\mathcal{O}^f_2$
	$(1, 1, 1, 0)$	$-2\mathcal{O}^f_1 - 2\mathcal{O}^f_2$

Table 104. UV resonance of type $D^3 d_{\mathbb{C}} {d_{\mathbb{C}}}^\dagger H H^\dagger$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

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Type: $D^3HH^\dagger u_{\mathbb{C}}u_{\mathbb{C}}{}^\dagger$		
$\mathcal{O}^f_1 = i(u_{\mathbb{C}p}{}^a\sigma_\mu(D^\nu u_{\mathbb{C}}{}^\dagger{}_{ra}))(D_\nu D^\mu H^{\dagger i})H_i,$ $\mathcal{O}^f_2 = i(u_{\mathbb{C}p}{}^a\sigma_\mu(D^\nu u_{\mathbb{C}}{}^\dagger{}_{ra}))(D_\nu H_i)(D^\mu H^{\dagger i}).$		
group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$		$\mathcal{O}^j$
	$\{u_{\mathbb{C}1}, H_2\} \quad \{H^\dagger{}_3, u_{\mathbb{C}}{}^\dagger{}_4\}$	
*	$(\frac{3}{2}, 3, 2, \frac{1}{6})$	$-4\mathcal{O}^f_1 - 6\mathcal{O}^f_2$
	$(\frac{1}{2}, 3, 2, \frac{1}{6})$	$2\mathcal{O}^f_1$
	$\{u_{\mathbb{C}1}, H^\dagger{}_3\} \quad \{H_2, u_{\mathbb{C}}{}^\dagger{}_4\}$	$\mathcal{O}^j$
*	$(\frac{3}{2}, 3, 2, \frac{7}{6})$	$-6\mathcal{O}^f_1 - 4\mathcal{O}^f_2$
	$(\frac{1}{2}, 3, 2, \frac{7}{6})$	$-2\mathcal{O}^f_2$
	$\{u_{\mathbb{C}1}, u_{\mathbb{C}}{}^\dagger{}_4\} \quad \{H_2, H^\dagger{}_3\}$	$\mathcal{O}^j$
*	$(2, 1, 1, 0)$	$2\mathcal{O}^f_1 - 2\mathcal{O}^f_2$
	$(1, 1, 1, 0)$	$-2\mathcal{O}^f_1 - 2\mathcal{O}^f_2$

Table 105. UV resonance of type $D^3HH^\dagger u_{\mathbb{C}}u_{\mathbb{C}}{}^\dagger$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

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Type: $D^3HH^\dagger QQ^\dagger$

$$\begin{aligned}
\mathcal{O}_1^f &= i(Q_p{}^{ai}\sigma_\mu(D^\nu Q^\dagger{}_r{}^{aj}))(D_\nu D^\mu H^{\dagger i})H_j,\\
\mathcal{O}_2^f &= i(Q_p{}^{ai}\sigma_\mu(D^\nu Q^\dagger{}_r{}^{aj}))(D_\nu H_j)(D^\mu H^{\dagger i}),\\
\mathcal{O}_3^f &= i(Q_p{}^{ai}\sigma_\mu(D^\nu Q^\dagger{}_r{}^{ai}))(D_\nu D^\mu H^{\dagger j})H_j,\\
\mathcal{O}_4^f &= i(Q_p{}^{ai}\sigma_\mu(D^\nu Q^\dagger{}_r{}^{ai}))(D_\nu H_j)(D^\mu H^{\dagger j}).
\end{aligned}$$

group: $(\mathrm{Spin}, \mathrm{SU}(3)_c, \mathrm{SU}(2)_w, \mathrm{U}(1)_y)$		$\mathcal{O}^j$
	$\{Q_1, H_2\}$ $\{H^\dagger{}_3, Q^\dagger{}_4\}$	
*	$(\frac{3}{2}, \overline{3}, 3, -\frac{2}{3})$	$-4\mathcal{O}_1^f - 6\mathcal{O}_2^f - 4\mathcal{O}_3^f - 6\mathcal{O}_4^f$
	$(\frac{1}{2}, \overline{3}, 3, -\frac{2}{3})$	$2\mathcal{O}_1^f + 2\mathcal{O}_3^f$
*	$(\frac{3}{2}, \overline{3}, 1, -\frac{2}{3})$	$4\mathcal{O}_1^f + 6\mathcal{O}_2^f - 4\mathcal{O}_3^f - 6\mathcal{O}_4^f$
	$(\frac{1}{2}, \overline{3}, 1, -\frac{2}{3})$	$-2\mathcal{O}_1^f + 2\mathcal{O}_3^f$
	$\{Q_1, H^\dagger{}_3\}$ $\{H_2, Q^\dagger{}_4\}$	$\mathcal{O}^j$
*	$(\frac{3}{2}, \overline{3}, 3, \frac{1}{3})$	$6\mathcal{O}_1^f + 4\mathcal{O}_2^f - 12\mathcal{O}_3^f - 8\mathcal{O}_4^f$
	$(\frac{1}{2}, \overline{3}, 3, \frac{1}{3})$	$2\mathcal{O}_2^f - 4\mathcal{O}_4^f$
*	$(\frac{3}{2}, \overline{3}, 1, \frac{1}{3})$	$-6\mathcal{O}_1^f - 4\mathcal{O}_2^f$
	$(\frac{1}{2}, \overline{3}, 1, \frac{1}{3})$	$-2\mathcal{O}_2^f$
	$\{Q_1, Q^\dagger{}_4\}$ $\{H_2, H^\dagger{}_3\}$	$\mathcal{O}^j$
*	$(2, 1, 3, 0)$	$-4\mathcal{O}_1^f + 4\mathcal{O}_2^f + 2\mathcal{O}_3^f - 2\mathcal{O}_4^f$
	$(1, 1, 3, 0)$	$4\mathcal{O}_1^f + 4\mathcal{O}_2^f - 2\mathcal{O}_3^f - 2\mathcal{O}_4^f$
*	$(2, 1, 1, 0)$	$2\mathcal{O}_3^f - 2\mathcal{O}_4^f$
	$(1, 1, 1, 0)$	$-2\mathcal{O}_3^f - 2\mathcal{O}_4^f$

Table 106. UV resonance of type $D^3HH^\dagger QQ^\dagger$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

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Type: $D^4H^2{H^\dagger}^2$	
$\mathcal{O}^f_1 = \frac{1}{4}\mathcal{Y}[\square\square_H]\mathcal{Y}[\square\square_{H^\dagger}]H_iH_j(D_\mu D_\nu {H^\dagger}^i)(D^\mu D^\nu {H^\dagger}^j),$ $\mathcal{O}^f_2 = \frac{1}{4}\mathcal{Y}[\square\square_H]\mathcal{Y}[\square\square_{H^\dagger}]{H^\dagger}^i H_i(D_\mu D_\nu H_j)(D^\mu D^\nu {H^\dagger}^j),$ $\mathcal{O}^f_3 = \frac{1}{4}\mathcal{Y}[\square\square_H]\mathcal{Y}[\square\square_{H^\dagger}]H_i(D_\mu H_j)(D_\nu {H^\dagger}^i)(D^\mu D^\nu {H^\dagger}^j).$	
group: (Spin, SU(3)$_c$, SU(2)$_w$, U(1)$_y$) $\{H_1, H_2\}$ $\{{H^\dagger}_3, {H^\dagger}_4\}$	$\mathcal{O}^j$
* $(2, 1, 3, 1)$	$-8\mathcal{O}^f_1 - 48\mathcal{O}^f_2 - 48\mathcal{O}^f_3$
$(0, 1, 3, 1)$	$8\mathcal{O}^f_1$
$(1, 1, 1, 1)$	$8\mathcal{O}^f_1 + 16\mathcal{O}^f_3$
$\{H_1, {H^\dagger}_3\}$ $\{H_2, {H^\dagger}_4\}$	$\mathcal{O}^j$
* $(2, 1, 3, 0)$	$16\mathcal{O}^f_1 - 4\mathcal{O}^f_2 + 56\mathcal{O}^f_3$
$(1, 1, 3, 0)$	$8\mathcal{O}^f_1 - 4\mathcal{O}^f_2 + 8\mathcal{O}^f_3$
$(0, 1, 3, 0)$	$8\mathcal{O}^f_1 + 4\mathcal{O}^f_2 + 16\mathcal{O}^f_3$
* $(2, 1, 1, 0)$	$-24\mathcal{O}^f_1 - 4\mathcal{O}^f_2 - 24\mathcal{O}^f_3$
$(1, 1, 1, 0)$	$-4\mathcal{O}^f_2 - 8\mathcal{O}^f_3$
$(0, 1, 1, 0)$	$4\mathcal{O}^f_2$

Table 107. UV resonance of type $D^4H^2{H^\dagger}^2$. "*" in front of each row indicates topologies with nonrenormalizable vertices. The UV resonances colored in gray are eliminated by UV selection.

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