Chiral Lagrangians for mesons with a single heavy quark

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We construct the relativistic chiral Lagrangians for heavy-light mesons ($Q\bar{q}$) to the $\mathcal{O}(p^4)$ order. From $\mathcal{O}(p^2)$ to $\mathcal{O}(p^4)$, there are 17, 67, and 404 independent terms in the flavor $SU(2)$ case and 20, 84, and 655 independent terms in the flavor $SU(3)$ case. The Lagrangians in the heavy quark limit are also obtained. From $\mathcal{O}(p^2)$ to $\mathcal{O}(p^4)$, there are 7, 25, and 136 independent terms in the flavor $SU(2)$ case and 8, 33, and 212 independent terms in the flavor $SU(3)$ case. The relations between low-energy constants based on the heavy quark symmetry are also given up to the $\mathcal{O}(p^3)$ order.

I. INTRODUCTION

The spontaneous breaking of the global chiral symmetry of QCD is an important feature in the low-energy non-perturbative region of strong interactions. It has been widely accepted that the low-lying pseudoscalar mesons are those Goldstone bosons generated from the symmetry breaking. The effective theory based on this symmetry and its breaking is the chiral perturbation theory (ChPT) [1–3], which originally describes only low-energy dynamics of such mesons. Later, the theory was extended to cases involving octet baryons [4], decuplet baryons [5,6], and heavy quark hadrons [7,8]. The matter fields involved in the present study are those heavy-light mesons whose quark content is $Q\bar{q}$ ($Q = c, b; q = u, d, s$).

Because of the light quark, the low-energy interactions for the heavy-light mesons are governed by the chiral symmetry. In addition, the interactions also obey the spin-flavor heavy quark (HQ) symmetry in the limit $M_Q \to \infty$ [8–11]. The heavy quark flavor symmetry means that different heavy flavors have the same dynamics while the heavy quark spin symmetry results in degenerate hadron doublets containing states with different spins. In ChPT, increasing number of low-energy constants (LECs) need to be determined when high order chiral corrections are considered. For the case involving the heavy-light mesons, the heavy quark symmetry may provide relations

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between LECs [12]. Before we can determine their values with other approaches, these constraints just from symmetry are certainly instructive. Of course, the corrections to such relations due to finite quark mass may also be needed for more detailed investigations.

With the chiral Lagrangians involving heavy-light mesons, a wide range of problems can be studied [13–25], such as properties of heavy-light mesons, mass difference between heavy-light mesons in the same doublet, interactions between the Goldstone bosons and the heavy-light mesons, interactions between heavy-light mesons, properties of new open-flavor particles [26], and so on. Up to now, the chiral Lagrangian in the sector of light pseudoscalar mesons has been constructed up to the $\mathcal{O}(p^8)$ order [27–35]. Recently, there have also been developments in the sector of light baryons [36–42]. However, the existing heavy-light meson chiral Lagrangian is still at low orders. The leading order result was obtained long time ago [7,8,12]. For higher order results, only parts of them were constructed for special problems, which can be found in Refs. [13–25]. Some similar works are about the $SU(2)$ pion-kaon chiral Lagrangian. This chiral Lagrangian has the same structures as that for the heavy-light pseudoscalar mesons. It has been constructed to the $\mathcal{O}(p^4)$ order [43–45]. In the present work, we systematically construct the relativistic chiral Lagrangians in the sector of heavy-light mesons up to the fourth chiral order. To find some relations of LECs by using the heavy quark symmetry, we also construct directly chiral Lagrangians with the super-field H containing the $J^P = 0^-$ and 1^- $Q\bar{q}$ mesons. By comparing the relativistic Lagrangians with those in the HQ limit, one obtains relations between LECs.

This paper is organized as follows. In Sec. II, we review briefly the building blocks for the construction of chiral Lagrangians. In Sec. III, from the structures of Lagrangians

to linear relations between various ingredients, we introduce the procedure to construct the heavy-light meson chiral Lagrangians step by step. In Sec. IV, the way to find relations between LECs with the heavy quark symmetry is introduced. In Sec. V, we list our results. The last Sec. VI is a short summary.

II. DEFINITIONS AND BUILDING BLOCKS

In this section, we give the building blocks necessary for the construction of Lagrangians. Some simple properties are also shown. These building blocks involve both relativistic and HQ forms. One may find details about them in Refs. [3,7,8,12,27,29,30,32,34,35,46–49].

A. Goldstone bosons and external sources

The QCD Lagrangian $\mathcal{L}_{QCD}^0$ with N_f-flavor massless quarks is

$$\mathcal{L} = \mathcal{L}_{QCD}^0 + \bar{q}(\slashed{v} + \slashed{a}\gamma_5 - s + ip\gamma_5)q, \qquad (1)$$

where q denotes the light quark field. s, p, v^μ, and a^μ are scalar, pseudoscalar, vector, and axial-vector external sources, respectively. The tensor source and the θ term are ignored in this paper. As usual, both a^μ and v^μ are considered traceless in the flavor $SU(3)$ case, but only a^μ is traceless in the flavor $SU(2)$ case to study the electroweak interactions.

In ChPT, the low-lying pseudoscalar mesons are considered to be Goldstone bosons coming from the spontaneous breaking of the global symmetry $SU(N_f)_L \times SU(N_f)_R$ into $SU(N_f)_V$. The meson field u in matrix form transforms as

$$u \to g_R u h^\dagger = h u g_L^\dagger \qquad (2)$$

under the chiral rotation, where g_L and g_R are group elements of $SU(N_f)_L$ and $SU(N_f)_R$, respectively, and h is a compensator field which is a function of the pion fields.

Usually, the meson fields and external sources are combined to building blocks whose forms are as follows,

$$u^\mu = i\{u^\dagger(\partial^\mu - ir^\mu)u - u(\partial^\mu - il^\mu)u^\dagger\},$$
$$\chi_\pm = u^\dagger\chi u^\dagger \pm u\chi^\dagger u,$$
$$h^{\mu\nu} = \nabla^\mu u^\nu + \nabla^\nu u^\mu,$$
$$f_+^{\mu\nu} = uF_L^{\mu\nu}u^\dagger + u^\dagger F_R^{\mu\nu}u,$$
$$f_-^{\mu\nu} = uF_L^{\mu\nu}u^\dagger - u^\dagger F_R^{\mu\nu}u = -\nabla^\mu u^\nu + \nabla^\nu u^\mu, \qquad (3)$$

where $r^\mu = v^\mu + a^\mu$, $l^\mu = v^\mu - a^\mu$, $\chi = 2B_0(s + ip)$, $F_R^{\mu\nu} = \partial^\mu r^\nu - \partial^\nu r^\mu - i[r^\mu, r^\nu]$, $F_L^{\mu\nu} = \partial^\mu l^\nu - \partial^\nu l^\mu - i[l^\mu, l^\nu]$, and B_0 is a constant related to the quark condensate. The covariant derivative for any building block X is defined through

$$\nabla^\mu X = \partial^\mu X + [\Gamma^\mu, X], \qquad (4)$$

$$\Gamma^\mu = \frac{1}{2}\{u^\dagger(\partial^\mu - ir^\mu)u + u(\partial^\mu - il^\mu)u^\dagger\}. \qquad (5)$$

The advantage of using these building blocks is that all of them transform under the chiral rotation (R) in the same way,

$$X \xrightarrow{R} X' = hXh^\dagger. \qquad (6)$$

B. Heavy-light mesons

A heavy-light meson contains one heavy quark Q (c or b) and one light antiquark $\bar{q}$ ($\bar{u}$, $\bar{d}$, or $\bar{s}$). The lowest lying heavy-light mesons are the pseudoscalar P with $J^P = 0^-$ and vector P^* with $J^P = 1^-$. In the flavor $SU(3)$ case (Q as a flavor singlet), they are represented as row vectors,

$$P = \begin{cases} (D^0, D^+, D_s^+), \\ (B^-, \bar{B}^0, \bar{B}_s^0), \end{cases} \quad P^* = \begin{cases} (D^{*0}, D^{*+}, D_s^{*+}), \\ (B^{*-}, \bar{B}^{*0}, \bar{B}_s^{*0}). \end{cases} \qquad (7)$$

In the flavor $SU(2)$ case, the third $Q\bar{s}$ mesons need to be removed. The Lagrangians in these two cases have different independent chiral-invariant terms and we consider results in both cases. The covariant derivative for $\tilde{P}$ (P or $P^{*\mu}$) is

$$D^\mu\tilde{P}^\dagger = (\partial^\mu + \Gamma^\mu)\tilde{P}^\dagger, \qquad (8)$$

$$D^\mu\tilde{P} = \tilde{P}(\overleftarrow{\partial}^\mu + \Gamma^{\mu\dagger}), \qquad (9)$$

$$D^{\mu\nu\cdots\rho} \equiv \frac{1}{n!}\underbrace{(D^\mu D^\nu \cdots D^\rho}_{n} + \text{full permutation of } D\text{'s}). \quad (10)$$

Equation (10) defines a totally symmetrical covariant derivative like the πN case [36]. The reason for this definition is that permutations of derivatives acting on a building block do not change the chiral dimension (as Eq. (23) below). The defined symmetrical derivative will simplify some calculations (see Sec. IV). The chiral transformations for heavy-light meson fields read

$$\tilde{P} \xrightarrow{R} \tilde{P}' = \tilde{P}h^\dagger, \qquad \tilde{P}^\dagger \xrightarrow{R} \tilde{P}'^\dagger = h\tilde{P}^\dagger. \qquad (11)$$

To adopt the heavy quark symmetry, one collects the heavy-light mesons in a superfield as usual [50],

$$H = \sqrt{M}\frac{1+\slashed{v}}{2}(P_{Q,\mu}^*\gamma^\mu + \delta P_Q\gamma_5), \quad \bar{H} \equiv \gamma^0 H^\dagger\gamma^0, \qquad (12)$$

where $M \equiv M_P = M_{P^*}$ is the heavy-light meson masses in the HQ limit and v^μ with $v^2 = 1$ is the velocity of heavy-light mesons, $P_{Q,\mu}^*$ and P_Q only contain the annihilation operator. Now, H contains only annihilation operators for

$Q\bar{q}$ mesons and its mass dimension is $3/2$. We here use δ to denote the arbitrary relative phase between the mesons P_Q and P_Q^*. Different conventions exist in the literature, e.g., $\delta = 1$ in [7], $\delta = -1$ in [47], and $\delta = i$ in [51]. This phase does not have physical effects and its choice does not impact on the form of Lagrangians, either. Scaling the superfield by $e^{-iMv\cdot x}$ will modify the energy measure from M_Q to M and the covariant derivative on matter fields becomes $D^\mu H(x) = -iMv^\mu H(x)$. Obviously, the chiral transformations for H and $\bar{H}$ are the same as those for $\tilde{P}$ and $\tilde{P}^\dagger$, respectively.

III. LAGRANGIAN CONSTRUCTION

This section shows the basic steps to construct the Lagrangian for heavy-light mesons. First, one analyzes the structures of chiral Lagrangians because they have effects on some properties of building blocks. Second, one establishes the P-parity, C-parity, and Hermitian properties of all the building blocks. Third, one finds out available linear relations in order to reduce linearly dependent terms. Finally, one constructs all possible structures of the chiral Lagrangian and gets independent terms by using the linear relations.

A. Structures of chiral Lagrangians

The relativistic heavy-light meson chiral Lagrangian can be written as

$$\mathcal{L} = \mathcal{L}_{PP} + \mathcal{L}_{P^*P^*} + \mathcal{L}_{PP^*} \tag{13}$$

$$= \sum_n C_n P \cdots P^\dagger + \sum_m C_m P^* \cdots P^{*\dagger}$$
$$+ \sum_p C_p (P \cdots P^{*\dagger} + P^* \cdots P^\dagger), \tag{14}$$

where $\mathcal{L}_{PP}$, $\mathcal{L}_{P^*P^*}$, and $\mathcal{L}_{PP^*}$ represent the interaction terms involving only heavy pseudoscalar mesons, only heavy vector mesons, and both heavy pseudoscalar and heavy vector mesons, respectively. The symbol "$\cdots$" includes allowed combinations of building blocks given in Sec. II A and appropriate coefficients (± 1 or $\pm i$) to keep the symmetry of $\mathcal{L}$. For convenience, the LECs (C_n, C_m, and C_p) are all assumed to be real constants and we use the convention that all the possible covariant derivatives in "$\cdots$" act on the right side heavy-light meson fields.

To find out relations between LECs in the HQ limit, we also construct chiral Lagrangians involving the superfield H directly. The Lagrangian in this formalism looks like

$$\mathcal{L} = \sum_n D_n \langle H \cdots \Gamma \bar{H} \rangle, \tag{15}$$

where D_n's represent LECs in this case, Γ is an element of the Clifford algebra, and $\langle \cdots \rangle$ means trace in the spin

TABLE I. Chiral dimension (Dim), parity (P), charge conjugation (C), and Hermiticity (H.c.) of the building blocks, the matter fields, and the Levi-Civita tensor.

	Dim	P	C	H.c.
u^μ	1	$-u_\mu$	$(u^\mu)^T$	u^μ
$h^{\mu\nu}$	2	$-h_{\mu\nu}$	$(h^{\mu\nu})^T$	$h^{\mu\nu}$
$\chi_\pm$	2	$\pm\chi_\pm$	$(\chi_\pm)^T$	$\pm\chi_\pm$
$f_\pm^{\mu\nu}$	2	$\pm f_{\pm\mu\nu}$	$\mp (f_\pm^{\mu\nu})^T$	$f_\pm^{\mu\nu}$
P	0	$-P$	$(P^\dagger)^T$	$P^\dagger$
$P^{*\mu}$	0	P_μ^*	$(P^{*\mu\dagger})^T$	$P^{*\mu\dagger}$
$D^\mu P$	0	$-D_\mu P$	$(D^\mu P^\dagger)^T$	$(D^\mu P)^\dagger$
$D^\mu P^{*\nu}$	0	$D_\mu P_\nu^*$	$(D^\mu P^{*\nu\dagger})^T$	$(D^\mu P^{*\nu})^\dagger$
$\varepsilon^{\mu\nu\lambda\rho}$	0	$-\varepsilon_{\mu\nu\lambda\rho}$	$\varepsilon^{\mu\nu\lambda\rho}$	$\varepsilon^{\mu\nu\lambda\rho}$

space. If flavor traces for building blocks are needed in "$\cdots$", we also use this symbol $\langle \cdots \rangle$. The heavy quark symmetry requires that the position of Γ should be after H but before $\bar{H}$.

B. Properties of building blocks

The properties of the building blocks have been discussed in a lot of references. Here we only collect relevant results. One may find details about them in Refs. [2,3,7,27,29–31,34–36,47,51].

Table I lists the chiral dimensions, parity transformations (P), charge conjugation transformations (C), and Hermitian transformations (H.c.) of the building blocks, the matter fields, and the Levi-Civita tensor. Since the heavy-light mesons are not purely neutral states, the phases for the charge conjugation transformation of them are uncertain. Choosing "+" for P is natural since $J^{PC} = 0^{--}$ are exotic quantum numbers. For P^*, we use the convention "+" and will discuss another one.

Table II lists the corresponding properties of the Clifford algebra and the velocity of heavy-light mesons, which are considered between H and $\bar{H}$ as (15). H, $\bar{H}$, and v^μ are chiral dimensionless and their properties are considered together with Clifford algebra, like the πN case in Ref. [36]. Table II only displays the extra signs. We do not show anything about γ_5 because $\langle H\gamma_5\bar{H} \rangle = 0$ gives no contributions. H only contains the $Q\bar{q}$ fields, but not $\bar{Q}q$ fields. Hence the Lagrangian in heavy quark symmetry does not

TABLE II. Chiral dimension (Dim), parity (P), charge conjugation (C), and Hermiticity (H.c.) of the Clifford algebra elements and the velocity of heavy-light mesons.

	Dim	P	C	H.c.
1	0	+	+	+
γ^μ	0	+	−	+
$\gamma_5\gamma^\mu$	0	−	+	+
$\sigma^{\mu\nu}$	0	+	−	+
v^μ	0	+	−	+

have to be C-invariant. The meaning of the charge conjugation in Table II will be discussed in Sec. IV.

C. Linear relations

Linear relations exist which are essential in reducing the chiral-invariant terms to a minimal set. For details about them, one may consult Refs. [27,29,30,34,35].

(i) Partial integration.

Ignoring higher order terms, one has

$$0 \doteq \tilde{P} \overleftarrow{D}^\mu X \tilde{P}^\dagger + \tilde{P} X D^\mu \tilde{P}^\dagger, \qquad (16)$$

where X is any building block or their products and "$\doteq$" means that both sides are approximately equal with their difference appearing at the order $\mathcal{O}(p^1)$. With this relation, we can move the covariant derivatives to the right position so that they act only on the field $\tilde{P}^\dagger$.

(ii) Schouten identity.

This is a relation about the Levi-Civita tensor,

$$\epsilon^{\mu\nu\lambda\rho} A^\sigma - \epsilon^{\sigma\nu\lambda\rho} A^\mu - \epsilon^{\mu\sigma\lambda\rho} A^\nu - \epsilon^{\mu\nu\sigma\rho} A^\lambda$$
$$- \epsilon^{\mu\nu\lambda\sigma} A^\rho = 0, \qquad (17)$$

where A is anything having Lorentz index (indices). The five indices in the left-hand side are totally antisymmetric.

(iii) Equations of motions (EOMs).

The EOMs and subsidiary condition for light pseudoscalar and heavy-light mesons are

$$\nabla_\mu u^\mu \doteq \frac{i}{2} \left(\chi_- - \frac{1}{N_f} \langle \chi_- \rangle \right), \qquad (18)$$

$$(D^2 + M_P^2) P^\dagger \doteq 0, \qquad (19)$$

$$(D^2 + M_{P^*}^2) P_\mu^{*\dagger} \doteq 0, \qquad (20)$$

$$D^\mu P_\mu^{*\dagger} \doteq 0, \qquad (21)$$

$$v^\mu P_{Q,\mu}^{*\dagger} = 0, \qquad (22)$$

where N_f is the number of light quark flavors and the conjugations of these equations are omitted. Equation (22) only works in the heavy quark limit. The right-hand sides of Eqs. (19)–(21) are at least at the order $\mathcal{O}(p^1)$. At the $\mathcal{O}(p^1)$ order, they contain one u^μ. Hence, $D^2 \tilde{P}$ can be changed to $-M_{\tilde{P}}^2 \tilde{P}$ and does not happen in the Lagrangian. $D^\mu P_\mu^*$ is at the order $\mathcal{O}(p^1)$. It removes the redundant degree of freedom of P_μ^* field, and $D^\mu P_\mu^*$ does not appear in the Lagrangian, either.

(iv) Covariant derivatives and Bianchi identity.

The commutative relation for the covariant derivatives acting on any building block X is

$$[\nabla^\mu, \nabla^\nu] X = [\Gamma^{\mu\nu}, X], \qquad (23)$$

$$\Gamma^{\mu\nu} = \frac{1}{4} [u^\mu, u^\nu] - \frac{i}{2} f_+^{\mu\nu}. \qquad (24)$$

Rewriting it explicitly, one has

$$\nabla^\mu \nabla^\nu X - \nabla^\nu \nabla^\mu X - \frac{1}{4} u^\mu u^\nu X + \frac{1}{4} u^\nu u^\mu X + \frac{i}{2} f_+^{\mu\nu} X$$
$$+ \frac{1}{4} X u^\mu u^\nu - \frac{1}{4} X u^\nu u^\mu - \frac{i}{2} X f_+^{\mu\nu} = 0. \qquad (25)$$

Another relation about covariant derivatives is Bianchi identity

$$\nabla^\mu \Gamma^{\nu\lambda} + \nabla^\nu \Gamma^{\lambda\mu} + \nabla^\lambda \Gamma^{\mu\nu} = 0. \qquad (26)$$

Its explicit form is

$$\nabla^\mu f_+^{\nu\lambda} + \nabla^\nu f_+^{\lambda\mu} + \nabla^\lambda f_+^{\mu\nu} + \frac{i}{2} [u^\mu, f_-^{\nu\lambda}]$$
$$+ \frac{i}{2} [u^\nu, f_-^{\lambda\mu}] + \frac{i}{2} [u^\lambda, f_-^{\mu\nu}] = 0. \qquad (27)$$

These two explicit relations are for determining the strict relations of LECs which will be discussed in Sec. IV.

(v) Cayley-Hamilton relations.

Any 2×2 matrices A and B have the relation

$$AB + BA - A\langle B \rangle - B\langle A \rangle - \langle AB \rangle + \langle A \rangle \langle B \rangle = 0. \qquad (28)$$

Any 3×3 matrices A, B, and C have the relation

$$0 = ABC + ACB + BAC + BCA + CAB + CBA$$
$$- AB\langle C \rangle - AC\langle B \rangle - BA\langle C \rangle - BC\langle A \rangle - CA\langle B \rangle$$
$$- CB\langle A \rangle - A\langle BC \rangle - B\langle AC \rangle - C\langle AB \rangle - \langle ABC \rangle$$
$$- \langle ACB \rangle + A\langle B \rangle \langle C \rangle + B\langle A \rangle \langle C \rangle + C\langle A \rangle \langle B \rangle$$
$$+ \langle A \rangle \langle BC \rangle + \langle B \rangle \langle AC \rangle + \langle C \rangle \langle AB \rangle - \langle A \rangle \langle B \rangle \langle C \rangle. \qquad (29)$$

(vi) Contact terms.

The contact terms need to be picked up independently. Such terms appear only at the $\mathcal{O}(p^4)$ order. To show their irrelevance with pion fields, we change the building blocks from u^μ, $h^{\mu\nu}$, $f_\pm^{\mu\nu}$, and $\chi_\pm$ to $F_{R,L}^{\mu\nu}$, χ, and $\chi^\dagger$. The relevant relations are

TABLE III. Chiral rotations (R), parity (P), charge conjugation (C), and Hermiticity (H.c.) of the LR-basis.

	R	P	C	H.c.
χ	$g_R\chi g_L^\dagger$	$\chi^\dagger$	χ^T	$\chi^\dagger$
$\chi^\dagger$	$g_L\chi^\dagger g_R^\dagger$	χ	$\chi^{\dagger T}$	χ
$F_L^{\mu\nu}$	$g_L F_L^{\mu\nu} g_L^\dagger$	$F_R^{\mu\nu}$	$-(F_R^{\mu\nu})^T$	$F_L^{\mu\nu}$
$F_R^{\mu\nu}$	$g_R F_R^{\mu\nu} g_R^\dagger$	$F_L^{\mu\nu}$	$-(F_L^{\mu\nu})^T$	$F_R^{\mu\nu}$

$$F_L^{\mu\nu} = \frac{1}{2}u^\dagger(f_+^{\mu\nu} + f_-^{\mu\nu})u, \qquad (30)$$

$$F_R^{\mu\nu} = \frac{1}{2}u(f_+^{\mu\nu} - f_-^{\mu\nu})u^\dagger, \qquad (31)$$

$$\chi = \frac{1}{2}u(\chi_+ + \chi_-)u, \qquad (32)$$

$$\chi^\dagger = \frac{1}{2}u^\dagger(\chi_+ - \chi_-)u^\dagger. \qquad (33)$$

We show the properties of these building blocks (LR-basis) [27,34] in Table III. The number of resultant contact terms is found small. They are listed at the end of each part for $\mathcal{L}_{PP}$, $\mathcal{L}_{P^*P^*}$, and $\mathcal{L}_{PP^*}$ in Table IX and such terms in the HQ limit are given at the end of Table X.

The process to pick up independent terms is very boring and is done by computer. The details about the operation have been presented in Refs. [34,39,40].

IV. LEC RELATIONS IN THE HEAVY QUARK LIMIT

According to the heavy quark symmetry, relations exist among LECs for $PP^\dagger$ terms, those for $P^*P^{*\dagger}$ terms, and those for $PP^{*\dagger}$ terms. In order to find them, we firstly redefine the independent terms and their corresponding LECs in Eq. (14) to be

$$\tilde{O}_n = O_n/M^r, \qquad \tilde{C}_n = C_n M^r, \qquad (34)$$

where r is the number of covariant derivative acting on the heavy-light meson fields. Now, all $\tilde{C}_n$'s at a given order have the same mass dimension.

At least two methods can be used to get the LEC relations. The first one is to change the relativistic Lagrangians to the HQ form. With Eq. (12), one obtains

$$\sqrt{M}P_Q = \frac{1}{2}\delta^*\langle H\gamma_5\rangle, \qquad \sqrt{M}P_{Q,\mu}^* = \frac{1}{2}\langle H\gamma_\mu\rangle,$$

$$\sqrt{M}P_Q^\dagger = -\frac{1}{2}\delta\langle\bar{H}\gamma_5\rangle, \qquad \sqrt{M}P_{Q,\mu}^{*\dagger} = \frac{1}{2}\langle\bar{H}\gamma_\mu\rangle. \qquad (35)$$

These fields contain only operators to annihilate or generate $Q\bar{q}$ mesons, but no operators for $\bar{Q}q$ mesons. If we assume

that the fields in Eq. (14) also describe only $Q\bar{q}$ mesons, the Lagrangian there can be changed to that in Eq. (15) by using the Fierz identity. Retaining only terms satisfying the heavy quark symmetry and comparing independent terms, one can obtain relations between C_n's and D_n's.

The second method is opposite by changing the form of Eq. (15) to that of Eq. (14),

$$\langle H\bar{H}\rangle \rightarrow M(-2P_Q P_Q^\dagger + 2P_Q^{*\mu} P_{Q,\mu}^{*\dagger}), \qquad (36)$$

$$\langle H\gamma_5\bar{H}\rangle \rightarrow 0, \qquad (37)$$

$$\langle H\gamma^\mu\bar{H}\rangle \rightarrow M(-\langle Hv^\mu\bar{H}\rangle) = \sqrt{M}(-2iP_Q D^\mu P_Q^\dagger/M \\ + 2iP_Q^{*\nu} D^\mu P_{Q,\nu}^{*\dagger}/M), \qquad (38)$$

$$\langle H\gamma_5\gamma^\mu\bar{H}\rangle \rightarrow M(-2\varepsilon^{\mu\nu\lambda\rho}P_{Q,\lambda}^* D_\nu P_{Q,\rho}^{*\dagger}/M + 2\delta P_Q P_Q^{*\dagger\mu} \\ + 2\delta^* P_Q^{*\mu} P_Q^\dagger), \qquad (39)$$

$$\langle H\sigma^{\mu\nu}\bar{H}\rangle \rightarrow M(2iP_Q^{*\mu} P_Q^{*\dagger\nu} - 2iP_Q^{*\nu} P_Q^{*\dagger\mu} \\ + 2i\varepsilon^{\mu\nu\lambda\rho}\delta P_Q D_\lambda P_{Q,\rho}^{*\dagger}/M \\ + 2i\varepsilon^{\mu\nu\lambda\rho}\delta^* P_{Q,\rho}^* D_\lambda P_Q^\dagger/M), \qquad (40)$$

where we have used the definition $\langle\gamma^\mu\gamma^\nu\gamma^\lambda\gamma^\rho\gamma_5\rangle = -4i\varepsilon^{\mu\nu\lambda\rho}$. The factor M comes from the definition in Eq. (12). From the above equations, one finds that only structures $\langle H\bar{H}\rangle$, $\langle H\gamma_5\gamma^\mu\bar{H}\rangle$, and $\langle H\sigma^{\mu\nu}\bar{H}\rangle$ exist in the final results, a feature consistent with the pion-nucleon case [36]. In order to obtain the relativistic Lagrangian, the right-hand sides of the above equations also need C invariant. If one substitutes $\tilde{P}_Q \rightarrow \tilde{P}$ and chooses the "C-parity" of the Clifford algebra and the velocity as those in Table II, these terms automatically contain the C-invariant.

To get the exact relations between $\tilde{C}_k$ and D_l, the strict linear relations are needed. In Sec. III C, we have found them in the relativistic case. Hence, we choose the second method to do the calculation. This method also avoids complex calculation from the Fierz identity. The relations are

$$\tilde{C}_k = M\sum_l D_l A_{lk}, \qquad (41)$$

where M is a usual normalization factor coming from Eq. (12). All elements in matrix A_{lk} are dimensionless. Since the number of D_l is much less than the number of $\tilde{C}_k$ (see the results in Sec. V), D_l may be obtained more easily in other ways. If all D_l are known, Eq. (41) gives a rough estimation of $\tilde{C}_k$. It also gives some constraint conditions of $\tilde{C}_k$ in the heavy quark limit.

To calculate Eq. (41), we avoid the approximate relations (marked by "$\dot{=}$") in Sec. III C as far as possible. Higher order contribution of the EOM for pseudoscalar mesons

[Eq. (18)] does not work to the $\mathcal{O}(p^2)$ order, and higher order contribution of the EOMs for heavy-light mesons does not work to the $\mathcal{O}(p^3)$ order. Hence, all relations in Sec. III C are strict ones to the $\mathcal{O}(p^3)$ order.

V. RESULTS

Following the above steps, we get the final results expressed as

$$\mathcal{L}^{(m)} = \sum_n C_n^{(m)} O_n^{(m)} = \sum_n \tilde{C}_n^{(m)} \tilde{O}_n^{(m)}, \qquad N_f = 3 \quad (42)$$

$$\mathcal{L}^{(m)} = \sum_n c_n^{(m)} o_n^{(m)} = \sum_n \tilde{c}_n^{(m)} \tilde{o}_n^{(m)}, \qquad N_f = 2 \quad (43)$$

$$\mathcal{L}_{HQ}^{(m)} = \sum_n D_n^{(m)} P_n^{(m)}, \qquad N_f = 3 \quad (44)$$

$$\mathcal{L}_{HQ}^{(m)} = \sum_n d_n^{(m)} p_n^{(m)}, \qquad N_f = 2. \quad (45)$$

where m is the chiral dimension.

A. Results at the $\mathcal{O}(p^1)$ and $\mathcal{O}(p^2)$ orders

The obtained relativistic result at the leading order,

$$\mathcal{L}^{(1)} = D_\mu P D^\mu P^\dagger - M_P^2 P P^\dagger$$
$$- \frac{1}{2}(D^\mu P^{*\nu} - D^\nu P^{*\mu})(D_\mu P_\nu^{*\dagger} - D_\nu P_\mu^{*\dagger}) + M_{P^*}^2 P^{*\mu} P_\mu^{*\dagger}$$
$$+ \frac{1}{2}f_Q(Pu^\mu P_\mu^{*\dagger} + \text{H.c.})$$
$$+ \frac{1}{4}g_Q \epsilon^{\mu\nu\lambda\rho}(P_\rho^* u_\lambda(D_\mu P_\nu^{*\dagger} - D_\nu P_\mu^{*\dagger}) + \text{H.c.}), \quad (46)$$

is the same as that in Ref. [7]. The form obeying the heavy quark symmetry is [8]

$$\mathcal{L}_{HQ}^{(1)} = \langle H i v^\mu D_\mu \bar{H}\rangle - \frac{1}{2}g\langle H u_\lambda \gamma_5 \gamma^\lambda \bar{H}\rangle. \quad (47)$$

The relations between f_Q, g_Q, and g are found to be

$$f_Q = 2g_Q M = -2gM. \quad (48)$$

TABLE IV. The $\mathcal{O}(p^2)$ order relativistic results. The columns 2, 3, and 4 (5, 6, and 7) are for the flavor $SU(2)$ [$SU(3)$] case. When a term O_n is not given a label in the 2nd (5th) column, it is not independent and can be expressed with terms having a label in the 2nd (5th) column. "I" means that the structures of those terms are chosen as independent ones in the HQ limit.

O_n	$SU(2)$	$\tilde{c}_n^{(2)}$	$\tilde{c}_n^{(2)}$	$SU(3)$	$\tilde{C}_n^{(2)}$	$\tilde{C}_n^{(2)}$
$Pu^\mu u_\mu P^\dagger$	1	$-2d_1^{(2)}$	I	1	$-2D_1^{(2)}$	I
$Pu^\mu u^\nu D_{\mu\nu} P^\dagger$	2	$2d_2^{(2)}$	I	2	$2D_2^{(2)}$	I
$P\langle u^\mu u_\mu\rangle P^\dagger$				3	$-2D_4^{(2)}$	I
$P\langle u^\mu u^\nu\rangle D_{\mu\nu} P^\dagger$				4	$2D_5^{(2)}$	I
$P\chi_+ P^\dagger$	3	$-2d_6^{(2)}$	I	5	$-2D_7^{(2)}$	I
$P\langle \chi_+\rangle P^\dagger$	4	$-2d_7^{(2)}$	I	6	$-2D_8^{(2)}$	I
$P^{*\mu} u_\mu u^\nu P_\nu^{*\dagger}$	5	$-2d_3^{(2)}$	I	7	$-2D_3^{(2)}$	I
$P^{*\mu} u^\nu u_\mu P_\nu^{*\dagger}$	6	$2d_3^{(2)}$	$-\tilde{c}_5^{(2)}$	8	$2D_3^{(2)}$	$-\tilde{C}_7^{(2)}$
$P^{*\mu} u^\nu u_\nu P_\mu^{*\dagger}$	7	$2d_1^{(2)}$	$-\tilde{c}_1^{(2)}$	9	$2D_1^{(2)}$	$-\tilde{C}_1^{(2)}$
$P^{*\mu} u^\nu u^\lambda D_{\nu\lambda} P_\mu^{*\dagger}$	8	$-2d_2^{(2)}$	$-\tilde{c}_2^{(2)}$	10	$-2D_2^{(2)}$	$-\tilde{C}_2^{(2)}$
$P^{*\mu}\langle u_\mu u^\nu\rangle P_\nu^{*\dagger}$				11	0	0
$P^{*\mu}\langle u^\nu u_\nu\rangle P_\mu^{*\dagger}$				12	$2D_4^{(2)}$	$-\tilde{C}_3^{(2)}$
$P^{*\mu}\langle u^\nu u^\lambda\rangle D_{\nu\lambda} P_\mu^{*\dagger}$				13	$-2D_5^{(2)}$	$-\tilde{C}_4^{(2)}$
$iP^{*\mu} f_{+\mu}{}^\nu P_\nu^{*\dagger}$	9	$4d_4^{(2)}$	I	14	$4D_6^{(2)}$	I
$iP^{*\mu}\langle f_{+\mu}{}^\nu\rangle P_\nu^{*\dagger}$	10	$4d_5^{(2)}$	I			
$P^{*\mu}\chi_+ P_\mu^{*\dagger}$	11	$2d_6^{(2)}$	$-\tilde{c}_3^{(2)}$	15	$2D_7^{(2)}$	$-\tilde{C}_5^{(2)}$
$P^{*\mu}\langle\chi_+\rangle P_\mu^{*\dagger}$	12	$2d_7^{(2)}$	$-\tilde{c}_4^{(2)}$	16	$2D_8^{(2)}$	$-\tilde{C}_6^{(2)}$
$\epsilon^{\mu\nu\lambda\rho} Pu_\mu u_\nu D_\lambda P_\rho^{*\dagger} + \text{H.c.}$	13	$-2d_3^{(2)}$	$\tilde{c}_5^{(2)}$	17	$-2D_3^{(2)}$	$\tilde{C}_7^{(2)}$
$Pf_-^{\mu\nu} D_\mu P_\nu^{*\dagger} + \text{H.c.}$	14	0	0	18	0	0
$Ph^{\mu\nu} D_\mu P_\nu^{*\dagger} + \text{H.c.}$	15	0	0	19	0	0
$i\epsilon^{\mu\nu\lambda\rho} Pf_{+\mu\nu} D_\lambda P_\rho^{*\dagger} + \text{H.c.}$	16	$2d_4^{(2)}$	$\frac{1}{2}\tilde{c}_9^{(2)}$	20	$2D_6^{(2)}$	$\frac{1}{2}\tilde{C}_{14}^{(2)}$
$i\epsilon^{\mu\nu\lambda\rho} P\langle f_{+\mu\nu}\rangle D_\lambda P_\rho^{*\dagger} + \text{H.c.}$	17	$2d_5^{(2)}$	$\frac{1}{2}\tilde{c}_{10}^{(2)}$			

TABLE V. The $\mathcal{O}(p^2)$ order results in the HQ limit. When a term P_n is not given a label in the 2nd (3rd) column, it is not independent and can be expressed with terms having a label in the 2nd (3rd) column.

P_n	$SU(2)$	$SU(3)$
$\langle Hu^\mu u_\mu \bar{H}\rangle$	1	1
$\langle Hu^\mu u^\nu v_\mu v_\nu \bar{H}\rangle$	2	2
$i\langle Hu^\mu u^\nu \sigma_{\mu\nu}\bar{H}\rangle$	3	3
$\langle H\langle u^\mu u_\mu\rangle \bar{H}\rangle$		4
$\langle H\langle u^\mu u^\nu\rangle v_\mu v_\nu \bar{H}\rangle$		5
$\langle Hf_+{}^{\mu\nu}\sigma_{\mu\nu}\bar{H}\rangle$	4	6
$\langle H\langle f_+{}^{\mu\nu}\rangle\sigma_{\mu\nu}\bar{H}\rangle$	5	
$\langle H\chi_+\bar{H}\rangle$	6	7
$\langle H\langle \chi_+\rangle\bar{H}\rangle$	7	8

The results at this order are applicable for both two- and three- flavor cases.

We show the $\mathcal{O}(p^2)$ Lagrangian in the relativistic form and HQ form in Tables IV and V, respectively. The 2nd and 5th columns of Table IV (2nd and 3rd columns of Table V) give the labels for each term in the flavor $SU(2)$ case and $SU(3)$ case, respectively. The 3rd and 6th columns of Table IV list the corresponding LECs in the HQ limit. The 4th and 7th columns of Table IV display the LEC relations between the relativistic terms according to the heavy quark symmetry, where "I" means that corresponding terms can be treated as the independent ones. Some monomials only happen in the either $SU(2)$ or $SU(3)$ case because of the Cayley-Hamilton relations and the convention of the trace of the vector source v^μ. Hence, the other column is not labeled. Only a few analogous results in the references are found. The $\mathcal{O}(p^2)$ order $\mathcal{L}_{PP}$ is the same as that in Ref. [20].

B. Results at the $\mathcal{O}(p^3)$ and $\mathcal{O}(p^4)$ orders

The $\mathcal{O}(p^3)$ and $\mathcal{O}(p^4)$ order results are too long and we give them in Appendix A. The relativistic results are collected in Tables VII and IX while those in the HQ limit are listed in Tables VIII and X. The 3rd and 6th columns of Table VII show the corresponding LECs in the HQ limit while the 4th and 7th columns of the same table display the LEC relations between the relativistic terms obtained from the heavy quark symmetry. "I" in Tables VII and IX again means that the relevant terms are considered independent in

the HQ limit. Some long expressions marked with "*" in Table VII are given explicitly below the table.

At present, we are not able to give the strict LEC relations for terms at the $\mathcal{O}(p^4)$ order. The $\mathcal{O}(p^1)$ order EOMs will appear because of the Schouten identity. Schouten identity can change the positions of some indexes and will give the factors as $D^\mu P^{*\dagger}{}_\mu$ or $D^2\tilde{P}$. Hence the LECs at the $\mathcal{O}(p^1)$ order will appear in these relations. The exact relations need the determination of the inverse of a large symbolic matrix. Hence, we only mark the independent terms in the HQ limit in Table IX. In the table, the 52–57, 241–253, and 402–404 terms in the two-flavor case (97–99, 413–418, and 655 terms in the three-flavor case) are contact terms. In Table X, the 128–136 terms in the two-flavor case (209–212 terms in the three-flavor case) are contact terms.

C. Discussions

We have chosen the convention $\delta = 1$ in presenting our final results. If one wants to use another convention, all the results need not be changed. For the C-parity transformation of P^*, we also use the "+" convention. Another convention only has an impact on $\mathcal{L}_{PP^*}$. Let us consider any C-, P- and H.c.-invariant $\mathcal{L}_{PP^*}$ term

$$(PO_\mu P^{*\dagger\mu} + \delta_C P^{*\mu}O_{C,\mu}P^\dagger), \qquad (49)$$

where O_μ is any possible structure, $O_{C,\mu}$ is an appropriate structure keeping the symmetry, and δ_C is the C-parity transformation factor of P^*. If one chooses an opposite sign of δ_C, an extra i factor is needed to keep Hermiticity.

VI. SUMMARY

In the present paper, we extend our previous studies and construct the relativistic chiral Lagrangians for mesons with a heavy quark to one loop, both for the flavor $SU(3)$ case and for the flavor $SU(2)$ case. The chiral Lagrangians in the heavy quark limit are also obtained. The number of independent terms in the heavy quark limit is much less than that in the relativistic case, which is illustrated in Table VI. By comparing independent terms in the relativistic form and those in the HQ limit, one finds LEC relations at each order which result from the heavy quark symmetry. These relations would get corrections once the breaking of heavy quark symmetry is considered.

TABLE VI. Number of independent terms at each chiral order.

	Relativistic				HQ limit			
Chiral order	$\mathcal{O}(p^1)$	$\mathcal{O}(p^2)$	$\mathcal{O}(p^3)$	$\mathcal{O}(p^4)$	$\mathcal{O}(p^1)$	$\mathcal{O}(p^2)$	$\mathcal{O}(p^3)$	$\mathcal{O}(p^4)$
$SU(2)$	1	17	67	404	1	7	25	136
$SU(3)$	1	20	84	655	1	8	33	212

APPENDIX: $\mathcal{O}(p^3)$ AND $\mathcal{O}(p^4)$ ORDER RESULTS

The long relations in the fourth column of Table VII are

$$\tilde{c}_{44}^{(3)} = (\tilde{c}_{10}^{(3)} + 2\tilde{c}_{11}^{(3)} - \tilde{c}_{26}^{(3)}) - 2\tilde{c}_{14}^{(3)},$$

$$\tilde{c}_{45}^{(3)} = -(\tilde{c}_{10}^{(3)} + 2\tilde{c}_{11}^{(3)} - \tilde{c}_{26}^{(3)}),$$

$$\tilde{c}_{53}^{(3)} = \tilde{c}_{24}^{(3)} + \tilde{c}_{25}^{(3)} - \tilde{c}_{26}^{(3)}. \tag{A1}$$

TABLE VII. The $\mathcal{O}(p^3)$ order relativistic results. The columns 2, 3, and 4 (5, 6, and 7) are for the flavor $SU(2)$ [SU(3)] case. When a term O_n is not given a label in the 2nd (5th) column, it is not independent and can be expressed with terms having a label in the 2nd (5th) column. "I" means that the structures of those terms are chosen as independent ones in the HQ limit. Relations marked with "*" are given below this table.

O_n	$SU(2)$	$\tilde{c}_n^{(3)}$	$\tilde{c}_n^{(3)}$	$SU(3)$	$\tilde{C}_n^{(3)}$	$\tilde{C}_n^{(3)}$
$\varepsilon^{\mu\nu\lambda\rho}P u_\mu u_\nu u_\lambda D_\rho P^\dagger$	1	$-2d_5^{(3)}$	I	1	$-2D_9^{(3)}$	I
$\varepsilon^{\mu\nu\lambda\rho}P\langle u_\mu u_\nu u_\lambda\rangle D_\rho P^\dagger$				2	$-2D_{10}^{(3)}$	I
$P u^\mu f_{-\mu}{}^\nu D_\nu P^\dagger + \text{H.c.}$	2	$-2d_{17}^{(3)}$	I	3	$-2D_{24}^{(3)}$	I
$P u^\mu h_\mu{}^\nu D_\nu P^\dagger + \text{H.c.}$	3	$-2d_{20}^{(3)}$	I	4	$-2D_{27}^{(3)}$	I
$P u^\mu h^{\nu\lambda} D_{\mu\nu\lambda} P^\dagger + \text{H.c.}$	4	$2d_{21}^{(3)}$	I	5	$2D_{28}^{(3)}$	I
$i\varepsilon^{\mu\nu\lambda\rho}P f_{+\mu\nu} u_\lambda D_\rho P^\dagger + \text{H.c.}$	5	$2d_{12}^{(3)}$	I	6	$2D_{18}^{(3)}$	I
$i\varepsilon^{\mu\nu\lambda\rho}P\langle f_{+\mu\nu}\rangle u_\lambda D_\rho P^\dagger$	6	$2d_{13}^{(3)}$	I			
$i\varepsilon^{\mu\nu\lambda\rho}P\langle f_{+\mu\nu} u_\lambda\rangle D_\rho P^\dagger$				7	$2D_{19}^{(3)}$	I
$iP\nabla^\mu f_{+\mu}{}^\nu D_\nu P^\dagger$	7	$2d_{23}^{(3)}$	I	8	$2D_{33}^{(3)}$	I
$iP\langle\nabla^\mu f_{+\mu}{}^\nu\rangle D_\nu P^\dagger$	8	$2d_{24}^{(3)}$	I			
$iP u^\mu \chi_- D_\mu P^\dagger + \text{H.c.}$	9	$2d_{16}^{(3)}$	I	9	$2D_{23}^{(3)}$	I
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu u_\nu u_\lambda u^\sigma D_\rho P^{*\dagger}{}_\sigma + \text{H.c.}$	10	$-2d_2^{(3)}$	I	10	$*$	I
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu u_\nu u_\lambda u^\sigma D_\sigma P^{*\dagger}{}_\rho + \text{H.c.}$	11	$d_2^{(3)} + d_4^{(3)}$	I	11	$*$	I
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu u_\nu u^\sigma u_\lambda D_\rho P^{*\dagger}{}_\sigma + \text{H.c.}$	12	$-2d_2^{(3)} - 3d_5^{(3)}$	$\frac{3}{2}\tilde{c}_1^{(3)} + \tilde{c}_{10}^{(3)}$	12	$-D_9^{(3)}$	$\frac{1}{2}\tilde{C}_1^{(3)}$
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu u_\nu u^\sigma u_\sigma D_\lambda P^{*\dagger}{}_\rho + \text{H.c.}$	13	$-2d_1^{(3)} - d_2^{(3)}$	I	13	$*$	I
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu u^\sigma u_\nu u_\lambda D_\rho P^{*\dagger}{}_\sigma + \text{H.c.}$				14	$*$	$-\tilde{C}_1^{(3)} - \tilde{C}_{10}^{(3)}$
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu u_\nu u^\sigma u^\delta D_{\lambda\sigma\delta} P^{*\dagger}{}_\rho + \text{H.c.}$	14	$2d_3^{(3)} + d_4^{(3)}$	I	15	$*$	I
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu\langle u_\nu u_\lambda u^\sigma\rangle D_\rho P^{*\dagger}{}_\sigma + \text{H.c.}$				16	$3D_{10}^{(3)}$	$-\frac{3}{2}\tilde{C}_2^{(3)}$
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu\langle u_\nu u^\sigma\rangle u_\lambda D_\rho P^{*\dagger}{}_\sigma + \text{H.c.}$				17	$-2D_5^{(3)} + D_6^{(3)}$	I
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu\langle u_\nu u^\sigma\rangle u_\lambda D_\sigma P^{*\dagger}{}_\rho$				18	$*$	I
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu\langle u_\nu u^\sigma\rangle u_\sigma D_\lambda P^{*\dagger}{}_\rho$				19	$-2D_5^{(3)} + 3D_6^{(3)}$	I
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu\langle u_\nu u^\sigma\rangle u^\delta D_{\lambda\sigma\delta} P^{*\dagger}{}_\rho$				20	$2D_7^{(3)} - 3D_8^{(3)}$	I
$P^{*\mu} u_\mu f_-{}^{\nu\lambda} D_\nu P^{*\dagger}{}_\lambda + \text{H.c.}$	15	$-2d_{18}^{(3)}$	I	21	$-2D_{25}^{(3)}$	I
$P^{*\mu} u^\nu f_{-\mu}{}^\lambda D_\nu P^{*\dagger}{}_\lambda + \text{H.c.}$	16	$4d_{19}^{(3)}$	I	22	$4D_{26}^{(3)}$	I
$P^{*\mu} u^\nu f_{-\mu}{}^\lambda D_\lambda P^{*\dagger}{}_\nu + \text{H.c.}$	17	$-2d_{18}^{(3)}$	$\tilde{c}_{15}^{(3)}$	23	$-2D_{25}^{(3)}$	$\tilde{C}_{21}^{(3)}$
$P^{*\mu} u^\nu f_{-\nu}{}^\lambda D_\lambda P^{*\dagger}{}_\mu + \text{H.c.}$	18	$2d_{17}^{(3)}$	$-\tilde{c}_2^{(3)}$	24	$2D_{24}^{(3)}$	$-\tilde{C}_3^{(3)}$
$P^{*\mu} u_\mu h^{\nu\lambda} D_\nu P^{*\dagger}{}_\lambda + \text{H.c.}$	19	$2d_{22}^{(3)}$	I	25	$2D_{29}^{(3)}$	I
$P^{*\mu} u^\nu h_\mu{}^\lambda D_\nu P^{*\dagger}{}_\lambda + \text{H.c.}$	20	0	0	26	0	0
$P^{*\mu} u^\nu h_\mu{}^\lambda D_\lambda P^{*\dagger}{}_\nu + \text{H.c.}$	21	$-2d_{22}^{(3)}$	$-\tilde{c}_{19}^{(3)}$	27	$-2D_{29}^{(3)}$	$-\tilde{C}_{25}^{(3)}$
$P^{*\mu} u^\nu h_\nu{}^\lambda D_\lambda P^{*\dagger}{}_\mu + \text{H.c.}$	22	$2d_{20}^{(3)}$	$-\tilde{c}_3^{(3)}$	28	$2D_{27}^{(3)}$	$-\tilde{C}_4^{(3)}$

(Table continued)

TABLE VII. *(Continued)*

O_n	$SU(2)$	$\tilde{c}_n^{(3)}$	$\tilde{c}_n^{(3)}$	$SU(3)$	$\tilde{C}_n^{(3)}$	$\tilde{C}_n^{(3)}$
$P^{*\mu} u^\nu h^{\lambda\rho} D_{\nu\lambda\rho} P^{*\dagger}{}_\mu + \text{H.c.}$	23	$-2d_{21}^{(3)}$	$-\tilde{c}_4^{(3)}$	29	$-2D_{28}^{(3)}$	$-\tilde{C}_5^{(3)}$
$P^{*\mu}\langle u_\mu f_-{}^{\nu\lambda}\rangle D_\nu P^{*\dagger}{}_\lambda + \text{H.c.}$				30	$-2D_{30}^{(3)}$	I
$P^{*\mu}\langle u^\nu f_{-\mu}{}^\lambda\rangle D_\nu P^{*\dagger}{}_\lambda$				31	$4D_{31}^{(3)}$	I
$P^{*\mu}\langle u_\mu h^{\nu\lambda}\rangle D_\nu P^{*\dagger}{}_\lambda + \text{H.c.}$				32	$2D_{32}^{(3)}$	I
$\varepsilon^{\mu\nu\lambda\rho} P^*{}_\mu \nabla_\nu f_{-\lambda}{}^\sigma D_\rho P^{*\dagger}{}_\sigma + \text{H.c.}$	24	$2d_9^{(3)}$	I	33	$2D_{15}^{(3)}$	I
$\varepsilon^{\mu\nu\lambda\rho} P^*{}_\mu \nabla_\nu f_{-\lambda}{}^\sigma D_\sigma P^{*\dagger}{}_\rho$	25	$-2d_9^{(3)} + 2d_{10}^{(3)}$	I	34	$-2D_{15}^{(3)} + 2D_{16}^{(3)}$	I
$\varepsilon^{\mu\nu\lambda\rho} P^*{}_\mu \nabla_\nu h^{\sigma\delta} D_{\lambda\sigma\delta} P^{*\dagger}{}_\rho$	26	$2d_{11}^{(3)}$	I	35	$2D_{17}^{(3)}$	I
$i\varepsilon^{\mu\nu\lambda\rho} P^*{}_\mu f_{+\nu\lambda} u^\sigma D_\rho P^{*\dagger}{}_\sigma + \text{H.c.}$	27	$-2d_{12}^{(3)}$	$-\tilde{c}_5^{(3)}$	36	$-2D_{18}^{(3)}$	$-\tilde{C}_6^{(3)}$
$i\varepsilon^{\mu\nu\lambda\rho} P^*{}_\mu f_{+\nu\lambda} u^\sigma D_\sigma P^{*\dagger}{}_\rho + \text{H.c.}$	28	$-d_7^{(3)}$	I	37	$-D_{12}^{(3)}$	I
$i\varepsilon^{\mu\nu\lambda\rho} P^*{}_\mu f_{+\nu}{}^\sigma u_\lambda D_\rho P^{*\dagger}{}_\sigma + \text{H.c.}$	29	$4d_{12}^{(3)}$	$2\tilde{c}_5^{(3)}$	38	$4D_{18}^{(3)}$	$2\tilde{C}_6^{(3)}$
$i\varepsilon^{\mu\nu\lambda\rho} P^*{}_\mu f_{+\nu}{}^\sigma u_\sigma D_\lambda P^{*\dagger}{}_\rho + \text{H.c.}$	30	$2d_6^{(3)}$	I	39	$2D_{11}^{(3)}$	I
$i\varepsilon^{\mu\nu\lambda\rho} P^*{}_\mu \langle f_{+\nu\lambda}\rangle u^\sigma D_\rho P^{*\dagger}{}_\sigma + \text{H.c.}$	31	$-d_{13}^{(3)}$	$-\frac{1}{2}\tilde{c}_6^{(3)}$			
$i\varepsilon^{\mu\nu\lambda\rho} P^*{}_\mu \langle f_{+\nu}{}^\sigma\rangle u_\lambda D_\rho P^{*\dagger}{}_\sigma + \text{H.c.}$	32	$2d_{13}^{(3)}$	$\tilde{c}_6^{(3)}$			
$i\varepsilon^{\mu\nu\lambda\rho} P^*{}_\mu \langle f_{+\nu\lambda} u^\sigma\rangle D_\rho P^{*\dagger}{}_\sigma + \text{H.c.}$				40	$-D_{19}^{(3)}$	$-\frac{1}{2}\tilde{C}_7^{(3)}$
$i\varepsilon^{\mu\nu\lambda\rho} P^*{}_\mu \langle f_{+\nu}{}^\sigma u_\lambda\rangle D_\rho P^{*\dagger}{}_\sigma + \text{H.c.}$				41	$2D_{19}^{(3)}$	$\tilde{C}_7^{(3)}$
$iP^{*\mu}\nabla_\mu f_+{}^{\nu\lambda} D_\nu P^{*\dagger}{}_\lambda + \text{H.c.}$	33	0	0	42	0	0
$iP^{*\mu}\nabla^\nu f_{+\nu}{}^\lambda D_\lambda P^{*\dagger}{}_\mu$	34	$-2d_{23}^{(3)}$	$-\tilde{c}_7^{(3)}$	43	$-2D_{33}^{(3)}$	$-\tilde{C}_8^{(3)}$
$iP^{*\mu}\langle \nabla_\mu f_+{}^{\nu\lambda}\rangle D_\nu P^{*\dagger}{}_\lambda + \text{H.c.}$	35	0	0			
$iP^{*\mu}\langle \nabla^\nu f_{+\nu}{}^\lambda\rangle D_\lambda P^{*\dagger}{}_\mu$	36	$-2d_{24}^{(3)}$	$-\tilde{c}_8^{(3)}$			
$\varepsilon^{\mu\nu\lambda\rho} P^*{}_\mu u_\nu \chi_+ D_\lambda P^{*\dagger}{}_\rho + \text{H.c.}$	37	$-2d_{14}^{(3)}$	I	44	$-2D_{20}^{(3)}$	I
$\varepsilon^{\mu\nu\lambda\rho} P^*{}_\mu \langle u_\nu \chi_+\rangle D_\lambda P^{*\dagger}{}_\rho$	38	$-2d_{15}^{(3)}$	I	45	$-2D_{21}^{(3)}$	I
$\varepsilon^{\mu\nu\lambda\rho} P^*{}_\mu \langle \chi_+\rangle u_\nu D_\lambda P^{*\dagger}{}_\rho$				46	$-2D_{22}^{(3)}$	I
$iP^{*\mu} u^\nu \chi_- D_\nu P^{*\dagger}{}_\mu + \text{H.c.}$	39	$-2d_{16}^{(3)}$	$-\tilde{c}_9^{(3)}$	47	$-2D_{23}^{(3)}$	$-\tilde{C}_9^{(3)}$
$i\varepsilon^{\mu\nu\lambda\rho} P^*{}_\mu \nabla_\nu \chi_- D_\lambda P^{*\dagger}{}_\rho$	40	$-2d_{25}^{(3)}$	I	48	$-2D_{13}^{(3)}$	I
$i\varepsilon^{\mu\nu\lambda\rho} P^*{}_\mu \langle \nabla_\nu \chi_-\rangle D_\lambda P^{*\dagger}{}_\rho$	41	$-2d_8^{(3)}$	I	49	$-2D_{14}^{(3)}$	I
$P u^\mu u_\mu u^\nu P^{*\dagger}{}_\nu + \text{H.c.}$	42	$4d_1^{(3)}$	$\tilde{c}_{10}^{(3)} - 2\tilde{c}_{13}^{(3)}$	50	$2D_1^{(3)}$	*
$P u^\mu u^\nu u_\mu P^{*\dagger}{}_\nu + \text{H.c.}$	43	$2d_2^{(3)}$	$-\tilde{c}_{10}^{(3)}$	51	$2D_2^{(3)}$	*
$P u^\mu u^\nu u_\nu P^{*\dagger}{}_\mu + \text{H.c.}$				52	$2D_1^{(3)}$	*
$P u^\mu u^\nu u^\lambda D_{\mu\nu} P^{*\dagger}{}_\lambda + \text{H.c.}$	44	$-4d_3^{(3)} - 2d_{11}^{(3)}$	*	53	*	*
$P u^\mu u^\nu u^\lambda D_{\mu\lambda} P^{*\dagger}{}_\nu + \text{H.c.}$	45	$-2d_4^{(3)} + 2d_{11}^{(3)}$	*	54	*	*
$P u^\mu u^\nu u^\lambda D_{\nu\lambda} P^{*\dagger}{}_\mu + \text{H.c.}$				55	*	*
$P\langle u^\mu u_\mu\rangle u^\nu P^{*\dagger}{}_\nu + \text{H.c.}$				56	$2D_5^{(3)}$	$-\frac{3}{2}\tilde{C}_{17}^{(3)} + \frac{1}{2}\tilde{C}_{19}^{(3)}$
$P\langle u^\mu u_\mu u^\nu\rangle P^{*\dagger}{}_\nu + \text{H.c.}$				57	$2D_6^{(3)}$	$-\tilde{C}_{17}^{(3)} + \tilde{C}_{19}^{(3)}$
$P\langle u^\mu u^\nu\rangle u^\lambda D_{\mu\nu} P^{*\dagger}{}_\lambda + \text{H.c.}$				58	$D_7^{(3)}$	*
$P\langle u^\mu u^\nu u^\lambda\rangle D_{\mu\nu} P^{*\dagger}{}_\lambda + \text{H.c.}$				59	$2D_7^{(3)} - 2D_8^{(3)}$	*
$\varepsilon^{\mu\nu\lambda\rho} P u_\mu f_{-\nu\lambda} P^{*\dagger}{}_\rho + \text{H.c.}$	46	$-2d_{19}^{(3)}$	$-\frac{1}{2}\tilde{c}_{16}^{(3)}$	60	$-2D_{26}^{(3)}$	$-\frac{1}{2}\tilde{C}_{22}^{(3)}$
$\varepsilon^{\mu\nu\lambda\rho} P f_{-\mu\nu} u_\lambda P^{*\dagger}{}_\rho + \text{H.c.}$	47	$-d_{18}^{(3)}$	$\frac{1}{2}\tilde{c}_{15}^{(3)}$	61	$-D_{25}^{(3)}$	$\frac{1}{2}\tilde{C}_{21}^{(3)}$
$\varepsilon^{\mu\nu\lambda\rho} P u_\mu f_{-\nu}{}^\sigma D_{\lambda\sigma} P^{*\dagger}{}_\rho + \text{H.c.}$	48	$2d_{18}^{(3)} - 4d_{19}^{(3)}$	$-\tilde{c}_{15}^{(3)} - \tilde{c}_{16}^{(3)}$	62	$2D_{25}^{(3)} - 4D_{26}^{(3)}$	$-\tilde{C}_{21}^{(3)} - \tilde{C}_{22}^{(3)}$
$\varepsilon^{\mu\nu\lambda\rho} P f_{-\mu\nu} u^\sigma D_{\lambda\sigma} P^{*\dagger}{}_\rho + \text{H.c.}$	49	$-d_{18}^{(3)} + 2d_{19}^{(3)}$	$\frac{1}{2}\tilde{c}_{15}^{(3)} + \frac{1}{2}\tilde{c}_{16}^{(3)}$	63	$-D_{25}^{(3)} + 2D_{26}^{(3)}$	$\frac{1}{2}\tilde{C}_{21}^{(3)} + \frac{1}{2}\tilde{C}_{22}^{(3)}$
$\varepsilon^{\mu\nu\lambda\rho} P u_\mu h_\nu{}^\sigma D_{\lambda\sigma} P^{*\dagger}{}_\rho + \text{H.c.}$	50	$2d_{22}^{(3)}$	$\tilde{c}_{19}^{(3)}$	64	$2D_{29}^{(3)}$	$\tilde{C}_{25}^{(3)}$
$\varepsilon^{\mu\nu\lambda\rho} P h_\mu{}^\sigma u_\nu D_{\lambda\sigma} P^{*\dagger}{}_\rho + \text{H.c.}$	51	$-2d_{22}^{(3)}$	$-\tilde{c}_{19}^{(3)}$	65	$-2D_{29}^{(3)}$	$-\tilde{C}_{25}^{(3)}$
$\varepsilon^{\mu\nu\lambda\rho} P\langle u_\mu f_{-\nu\lambda}\rangle P^{*\dagger}{}_\rho + \text{H.c.}$				66	$-2D_{31}^{(3)}$	$-\frac{1}{2}\tilde{C}_{31}^{(3)}$
$\varepsilon^{\mu\nu\lambda\rho} P\langle u_\mu f_{-\nu}{}^\sigma\rangle D_{\lambda\sigma} P^{*\dagger}{}_\rho + \text{H.c.}$				67	$2D_{30}^{(3)} - 4D_{31}^{(3)}$	$-\tilde{C}_{30}^{(3)} - \tilde{C}_{31}^{(3)}$

(Table continued)

TABLE VII. (*Continued*)

O_n	$SU(2)$	$\tilde{c}_n^{(3)}$	$\tilde{c}_n^{(3)}$	$SU(3)$	$\tilde{C}_n^{(3)}$	$\tilde{C}_n^{(3)}$
$\varepsilon^{\mu\nu\lambda\rho}P\langle u_\mu h_\nu{}^\sigma\rangle D_{\lambda\sigma}P^{*\dagger}{}_\rho$ + H.c.				68	$2D_{32}^{(3)}$	$\tilde{C}_{32}^{(3)}$
$P\nabla^\mu f_{-\mu}{}^\nu P^{*\dagger}{}_\nu$ + H.c.	52	$2d_9^{(3)}$	$\tilde{c}_{24}^{(3)}$	69	$2D_{15}^{(3)}$	$\tilde{C}_{33}^{(3)}$
$P\nabla^\mu f_-{}^{\nu\lambda}D_{\mu\nu}P^{*\dagger}{}_\lambda$ + H.c.	53	$2d_{10}^{(3)} - 2d_{11}^{(3)}$	*	70	$2D_{16}^{(3)} - 2D_{17}^{(3)}$	*
$P\nabla^\mu h^{\nu\lambda}D_{\mu\nu}P^{*\dagger}{}_\lambda$ + H.c.	54	$-2d_{11}^{(3)}$	$-\tilde{c}_{26}^{(3)}$	71	$-2D_{17}^{(3)}$	$-\tilde{C}_{35}^{(3)}$
$iPf_+{}^{\mu\nu}u_\mu P^{*\dagger}{}_\nu$ + H.c.	55	$2d_6^{(3)}$	$\tilde{c}_{30}^{(3)}$	72	$2D_{11}^{(3)}$	$\tilde{C}_{39}^{(3)}$
$iPu^\mu f_{+\mu}{}^\nu P^{*\dagger}{}_\nu$ + H.c.	56	$-2d_6^{(3)}$	$-\tilde{c}_{30}^{(3)}$	73	$-2D_{11}^{(3)}$	$-\tilde{C}_{39}^{(3)}$
$iPf_+{}^{\mu\nu}u^\lambda D_{\mu\lambda}P^{*\dagger}{}_\nu$ + H.c.	57	$2d_7^{(3)} - 2d_{11}^{(3)}$	$-\tilde{c}_{26}^{(3)} - 2\tilde{c}_{28}^{(3)}$	74	$2D_{12}^{(3)} - 2D_{17}^{(3)}$	$-\tilde{C}_{35}^{(3)} - 2\tilde{C}_{37}^{(3)}$
$iPu^\mu f_+{}^{\nu\lambda}D_{\mu\nu}P^{*\dagger}{}_\lambda$ + H.c.	58	$-2d_7^{(3)} + 2d_{11}^{(3)}$	$\tilde{c}_{26}^{(3)} + 2\tilde{c}_{28}^{(3)}$	75	$-2D_{12}^{(3)} + 2D_{17}^{(3)}$	$\tilde{C}_{35}^{(3)} + 2\tilde{C}_{37}^{(3)}$
$iP\langle f_+{}^{\mu\nu}\rangle u_\mu P^{*\dagger}{}_\nu$ + H.c.	59	0	0			
$iP\langle f_+{}^{\mu\nu}\rangle u^\lambda D_{\mu\lambda}P^{*\dagger}{}_\nu$ + H.c.	60	0	0			
$iP\langle f_+{}^{\mu\nu}u_\mu\rangle P^{*\dagger}{}_\nu$ + H.c.				76	0	0
$iP\langle f_+{}^{\mu\nu}u^\lambda\rangle D_{\mu\lambda}P^{*\dagger}{}_\nu$ + H.c.				77	0	0
$i\varepsilon^{\mu\nu\lambda\rho}P\nabla_\mu f_{+\nu}{}^\sigma D_{\lambda\sigma}P^{*\dagger}{}_\rho$ + H.c.	61	0	0	78	0	0
$i\varepsilon^{\mu\nu\lambda\rho}P\langle\nabla_\mu f_{+\nu}{}^\sigma\rangle D_{\lambda\sigma}P^{*\dagger}{}_\rho$ + H.c.	62	0	0			
$Pu^\mu\chi_+P^{*\dagger}{}_\mu$ + H.c.	63	$2d_{14}^{(3)}$	$-\tilde{c}_{37}^{(3)}$	79	$2D_{20}^{(3)}$	$-\tilde{C}_{44}^{(3)}$
$P\chi_+u^\mu P^{*\dagger}{}_\mu$ + H.c.	64	$2d_{14}^{(3)}$	$-\tilde{c}_{37}^{(3)}$	80	$2D_{20}^{(3)}$	$-\tilde{C}_{44}^{(3)}$
$P\langle u^\mu\chi_+\rangle P^{*\dagger}{}_\mu$ + H.c.	65	$2d_{15}^{(3)}$	$-\tilde{c}_{38}^{(3)}$	81	$2D_{21}^{(3)}$	$-\tilde{C}_{45}^{(3)}$
$P\langle\chi_+\rangle u^\mu P^{*\dagger}{}_\mu$ + H.c.				82	$2D_{22}^{(3)}$	$-\tilde{C}_{46}^{(3)}$
$iP\nabla^\mu\chi_-P^{*\dagger}{}_\mu$ + H.c.	66	$2d_{25}^{(3)}$	$-\tilde{c}_{40}^{(3)}$	83	$2D_{13}^{(3)}$	$-\tilde{C}_{48}^{(3)}$
$iP\langle\nabla^\mu\chi_-\rangle P^{*\dagger}{}_\mu$ + H.c.	67	$2d_8^{(3)}$	$-\tilde{c}_{41}^{(3)}$	84	$2D_{14}^{(3)}$	$-\tilde{C}_{49}^{(3)}$

TABLE VIII. The $\mathcal{O}(p^3)$ order results in the HQ limit. When a term P_n is not given a label in the 2nd or 5th (3rd or 6th) column, it is not independent and can be expressed with terms having a label in the 2nd and 5th (3rd and 6th) columns.

P_n	$SU(2)$	$SU(3)$	P_n	$SU(2)$	$SU(3)$
$\langle Hu^\mu u_\mu u^\nu\gamma_5\gamma_\nu\bar{H}\rangle$ + H.c.	1	1	$\varepsilon^{\mu\nu\lambda\rho}\langle H\langle f_{+\mu\nu}\rangle u_\lambda v_\rho\bar{H}\rangle$	13	
$\langle Hu^\mu u^\nu u_\mu\gamma_5\gamma_\nu\bar{H}\rangle$	2	2	$\varepsilon^{\mu\nu\lambda\rho}\langle H\langle f_{+\mu\nu}u_\lambda\rangle v_\rho\bar{H}\rangle$		19
$\langle Hu^\mu u^\nu u^\lambda\gamma_5\gamma_\mu v_\nu v_\lambda\bar{H}\rangle$ + H.c.	3	3	$\langle Hu^\mu\chi_+\gamma_5\gamma_\mu\bar{H}\rangle$ + H.c.	14	20
$\langle Hu^\mu u^\nu u^\lambda\gamma_5\gamma_\nu v_\mu v_\lambda\bar{H}\rangle$	4	4	$\langle H\langle u^\mu\chi_+\rangle\gamma_5\gamma_\mu\bar{H}\rangle$	15	21
$\langle H\langle u^\mu u_\mu\rangle u^\nu\gamma_5\gamma_\nu\bar{H}\rangle$		5	$\langle H\langle\chi_+\rangle u^\mu\gamma_5\gamma_\mu\bar{H}\rangle$		22
$\langle H\langle u^\mu u_\mu u^\nu\rangle\gamma_5\gamma_\nu\bar{H}\rangle$		6	$\langle Hu^\mu\chi_- v_\mu\bar{H}\rangle$ + H.c.	16	23
$\langle H\langle u^\mu u^\nu\rangle u^\lambda\gamma_5\gamma_\mu v_\nu v_\lambda\bar{H}\rangle$		7	$i\langle Hu^\mu f_{-\mu}{}^\nu v_\nu\bar{H}\rangle$ + H.c.	17	24
$\langle H\langle u^\mu u^\nu u^\lambda\rangle\gamma_5\gamma_\mu v_\nu v_\lambda\bar{H}\rangle$		8	$\langle Hu^\mu f_-{}^{\nu\lambda}\sigma_{\mu\nu}v_\lambda\bar{H}\rangle$ + H.c.	18	25
$i\varepsilon^{\mu\nu\lambda\rho}\langle Hu_\mu u_\nu u_\lambda v_\rho\bar{H}\rangle$	5	9	$\langle Hu^\mu f_-{}^{\nu\lambda}\sigma_{\nu\lambda}v_\mu\bar{H}\rangle$ + H.c.	19	26
$i\varepsilon^{\mu\nu\lambda\rho}\langle H\langle u_\mu u_\nu u_\lambda\rangle v_\rho\bar{H}\rangle$		10	$i\langle Hu^\mu h_\mu{}^\nu v_\nu\bar{H}\rangle$ + H.c.	20	27
$i\langle Hf_+{}^{\mu\nu}u_\mu\gamma_5\gamma_\nu\bar{H}\rangle$ + H.c.	6	11	$i\langle Hu^\mu h^{\nu\lambda}v_\mu v_\nu v_\lambda\bar{H}\rangle$ + H.c.	21	28
$i\langle Hf_+{}^{\mu\nu}u^\lambda\gamma_5\gamma_\mu v_\nu v_\lambda\bar{H}\rangle$ + H.c.	7	12	$\langle Hu^\mu h^{\nu\lambda}\sigma_{\mu\nu}v_\lambda\bar{H}\rangle$ + H.c.	22	29
$i\langle H\nabla^\mu\chi_-\gamma_5\gamma_\mu\bar{H}\rangle$		13	$\langle H\langle u^\mu f_-{}^{\nu\lambda}\rangle\sigma_{\mu\nu}v_\lambda\bar{H}\rangle$		30
$i\langle H\langle\nabla^\mu\chi_-\rangle\gamma_5\gamma_\mu\bar{H}\rangle$	8	14	$\langle H\langle u^\mu f_-{}^{\nu\lambda}\rangle\sigma_{\nu\lambda}v_\mu\bar{H}\rangle$		31
$\langle H\nabla^\mu f_{-\mu}{}^\nu\gamma_5\gamma_\nu\bar{H}\rangle$	9	15	$\langle H\langle u^\mu h^{\nu\lambda}\rangle\sigma_{\mu\nu}v_\lambda\bar{H}\rangle$		32
$\langle H\nabla^\mu f_-{}^{\nu\lambda}\gamma_5\gamma_\nu v_\mu v_\lambda\bar{H}\rangle$	10	16	$\langle H\nabla^\mu f_{+\mu}{}^\nu v_\nu\bar{H}\rangle$	23	33
$\langle H\nabla^\mu h^{\nu\lambda}\gamma_5\gamma_\mu v_\nu v_\lambda\bar{H}\rangle$	11	17	$\langle H\langle\nabla^\mu f_{+\mu}{}^\nu\rangle v_\nu\bar{H}\rangle$	24	
$\varepsilon^{\mu\nu\lambda\rho}\langle Hf_{+\mu\nu}u_\lambda v_\rho\bar{H}\rangle$ + H.c.	12	18	$i\langle H\nabla^\mu\chi_-\gamma_5\gamma_\mu\bar{H}\rangle$	25	

TABLE IX. The $\mathcal{O}(p^4)$ order relativistic results. The columns 2, 3, 7, and 8 (4, 5, 9, and 10) are for the flavor $SU(2)$ [$SU(3)$] case. When a term O_n is not given a label in the 2nd or 7th (4th or 8th) column, it is not independent and can be expressed with terms having a label in the $SU(2)$ ($SU(3)$) case. "I" means that the structures of those terms are chosen as independent ones in the HQ limit. "P." stands for parity-transformed part.

O_n	$SU(2)$	$\tilde{c}_n^{(4)}$	$SU(3)$	$\tilde{C}_n^{(4)}$	O_n	$SU(2)$	$\tilde{c}_n^{(4)}$	$SU(3)$	$\tilde{C}_n^{(4)}$
$P\langle u^\mu u_\mu\rangle u^\nu u_\nu P^\dagger$	1	I	1	I	$iP^{*\mu}\nabla_\mu\nabla^\nu f_+{}^{\lambda\rho}D_{\nu\lambda}P^{*\dagger}{}_\rho +$H.c.	182	I	334	I
$P\langle u^\mu u^\nu\rangle u_\mu u_\nu P^\dagger$	2	I	2	I	$iP^{*\mu}\nabla^\nu\nabla^\lambda f_{+\mu}{}^\rho D_{\nu\lambda}P^{*\dagger}{}_\rho$	183	I	335	I
$P\langle u^\mu u_\mu\rangle u^\nu u^\lambda D_{\nu\lambda}P^\dagger$	3	I	3	I	$P^{*\mu}f_{+\mu}{}^\nu f_{+\nu}{}^\lambda P^{*\dagger}{}_\lambda$	184	I	336	I
$P\langle u^\mu u^\nu\rangle u_\mu u^\lambda D_{\nu\lambda}P^\dagger +$H.c.	4	I	4	I	$P^{*\mu}f_+{}^{\nu\lambda}f_{+\mu\nu}P^{*\dagger}{}_\lambda$	185		337	
$P\langle u^\mu u^\nu\rangle u^\lambda u_\lambda D_{\mu\nu}P^\dagger$			5	I	$P^{*\mu}f_+{}^{\nu\lambda}f_{+\nu\lambda}P^{*\dagger}{}_\mu$	186		338	
$P\langle u^\mu u^\nu\rangle u^\lambda u^\rho D_{\mu\nu\lambda\rho}P^\dagger$	5	I	6	I	$P^{*\mu}f_{+\mu}{}^\nu f_+{}^{\lambda\rho}D_{\nu\lambda}P^{*\dagger}{}_\rho$	187	I	339	I
$P\langle u^\mu u_\mu u^\nu\rangle u_\nu P^\dagger$			7	I	$P^{*\mu}f_+{}^{\nu\lambda}f_{+\mu}{}^\rho D_{\nu\rho}P^{*\dagger}{}_\lambda$	188		340	
$P\langle u^\mu u_\mu u^\nu\rangle u^\lambda D_{\nu\lambda}P^\dagger$			8	I	$P^{*\mu}f_+{}^{\nu\lambda}f_{+\nu}{}^\rho D_{\lambda\rho}P^{*\dagger}{}_\mu$	189		341	
$P\langle u^\mu u^\nu u^\lambda\rangle u_\mu D_{\nu\lambda}P^\dagger$			9	I	$P^{*\mu}\langle f_{+\mu}{}^\nu\rangle f_{+\nu}{}^\lambda P^{*\dagger}{}_\lambda +$H.c.	190			
$P\langle u^\mu u^\nu u^\lambda\rangle u^\rho D_{\mu\nu\lambda\rho}P^\dagger$			10	I	$P^{*\mu}\langle f_+{}^{\nu\lambda}\rangle f_{+\nu\lambda}P^{*\dagger}{}_\mu$	191			
$P\langle u^\mu u_\mu u^\nu u_\nu\rangle P^\dagger$			11	I	$P^{*\mu}\langle f_{+\mu}{}^\nu\rangle f_+{}^{\lambda\rho}D_{\nu\lambda}P^{*\dagger}{}_\rho +$H.c.	192			
$P\langle u^\mu u^\nu u_\mu u_\nu\rangle P^\dagger$			12	I	$P^{*\mu}\langle f_+{}^{\nu\lambda}\rangle f_{+\nu}{}^\rho D_{\lambda\rho}P^{*\dagger}{}_\mu$	193			
$P\langle u^\mu u_\mu u^\nu u^\lambda\rangle D_{\nu\lambda}P^\dagger$			13	I	$P^{*\mu}\langle f_{+\mu}{}^\nu f_{+\nu}{}^\lambda\rangle P^{*\dagger}{}_\lambda$			342	I
$P\langle u^\mu u^\nu u_\mu u^\lambda\rangle D_{\nu\lambda}P^\dagger$			14	I	$P^{*\mu}\langle f_+{}^{\nu\lambda}f_{+\nu\lambda}\rangle P^{*\dagger}{}_\mu$			343	
$P\langle u^\mu u^\nu u^\lambda u^\rho\rangle D_{\mu\nu\lambda\rho}P^\dagger$			15	I	$P^{*\mu}\langle f_{+\mu}{}^\nu f_+{}^{\lambda\rho}\rangle D_{\nu\lambda}P^{*\dagger}{}_\rho$			344	I
$Pu^\mu u_\mu u^\nu u_\nu P^\dagger$			16	I	$P^{*\mu}\langle f_+{}^{\nu\lambda}f_{+\nu}{}^\rho\rangle D_{\lambda\rho}P^{*\dagger}{}_\mu$			345	
$Pu^\mu u^\nu u_\mu u_\nu P^\dagger$			17	I	$P^{*\mu}u_\mu u^\nu\chi_+ P^{*\dagger}{}_\nu +$H.c.	194	I	346	I
$Pu^\mu u_\mu u^\nu u^\lambda D_{\nu\lambda}P^\dagger +$H.c.			18	I	$P^{*\mu}u^\nu u_\mu\chi_+ P^{*\dagger}{}_\nu +$H.c.	195		347	
$Pu^\mu u^\nu u_\mu u^\lambda D_{\nu\lambda}P^\dagger +$H.c.			19	I	$P^{*\mu}u^\nu u_\nu\chi_+ P^{*\dagger}{}_\mu +$H.c.	196		348	
$\varepsilon^{\mu\nu\lambda\rho}Pu_\mu u_\nu f_{-\lambda\rho}P^\dagger +$H.c.	6	I	20	I	$P^{*\mu}u_\mu\chi_+ u^\nu P^{*\dagger}{}_\nu$	197	I	349	I
$\varepsilon^{\mu\nu\lambda\rho}Pu_\mu u_\nu f_{-\lambda}{}^\sigma D_{\rho\sigma}P^\dagger +$H.c.	7	I	21	I	$P^{*\mu}u^\nu\chi_+ u_\mu P^{*\dagger}{}_\nu$	198		350	
$\varepsilon^{\mu\nu\lambda\rho}Pu_\mu u^\sigma f_{-\nu\lambda}D_{\rho\sigma}P^\dagger +$H.c.	8	I	22	I	$P^{*\mu}u^\nu\chi_+ u_\nu P^{*\dagger}{}_\mu$	199		351	
$\varepsilon^{\mu\nu\lambda\rho}Pu_\mu f_{-\nu\lambda}u^\sigma D_{\rho\sigma}P^\dagger +$H.c.	9	I	23	I	$P^{*\mu}u^\nu u^\lambda\chi_+ D_{\nu\lambda}P^{*\dagger}{}_\mu +$H.c.	200		352	
$\varepsilon^{\mu\nu\lambda\rho}Pu_\mu u_\nu h_\lambda{}^\sigma D_{\rho\sigma}P^\dagger +$H.c.	10	I	24	I	$P^{*\mu}u^\nu\chi_+ u^\lambda D_{\nu\lambda}P^{*\dagger}{}_\mu$	201		353	
$\varepsilon^{\mu\nu\lambda\rho}P\langle u_\mu f_{-\nu\lambda}\rangle u_\rho P^\dagger$			25	I	$P^{*\mu}\langle u_\mu u^\nu\rangle\chi_+ P^{*\dagger}{}_\nu$			354	I
$\varepsilon^{\mu\nu\lambda\rho}P\langle u_\mu f_{-\nu}{}^\sigma\rangle u_\lambda D_{\rho\sigma}P^\dagger$			26	I	$P^{*\mu}\langle u_\mu u^\nu\chi_+\rangle P^{*\dagger}{}_\nu$	202	I	355	I
$\varepsilon^{\mu\nu\lambda\rho}P\langle u_\mu u^\sigma\rangle f_{-\nu\lambda}D_{\rho\sigma}P^\dagger$			27	I	$P^{*\mu}\langle u^\nu\chi_+\rangle u_\mu P^{*\dagger}{}_\nu +$H.c.			356	I
$\varepsilon^{\mu\nu\lambda\rho}P\langle u_\mu u^\sigma f_{-\nu\lambda}\rangle D_{\rho\sigma}P^\dagger +$H.c.			28	I	$P^{*\mu}\langle\chi_+\rangle u_\mu u^\nu P^{*\dagger}{}_\nu$			357	I
$\varepsilon^{\mu\nu\lambda\rho}P\langle u_\mu h_\nu{}^\sigma\rangle u_\lambda D_{\rho\sigma}P^\dagger$			29	I	$P^{*\mu}\langle u^\nu u_\mu\chi_+\rangle P^{*\dagger}{}_\nu$			358	
$Pf_-{}^{\mu\nu}f_{-\mu\nu}P^\dagger$			30	I	$P^{*\mu}\langle\chi_+\rangle u^\nu u_\mu P^{*\dagger}{}_\nu$			359	
$Pf_-{}^{\mu\nu}f_{-\mu}{}^\lambda D_{\nu\lambda}P^\dagger$			31	I	$P^{*\mu}\langle u^\nu u_\nu\rangle\chi_+ P^{*\dagger}{}_\mu$			360	
$Pf_-{}^{\mu\nu}h_\mu{}^\lambda D_{\nu\lambda}P^\dagger +$H.c.	11	I	32	I	$P^{*\mu}\langle u^\nu u_\nu\chi_+\rangle P^{*\dagger}{}_\mu$	203		361	
$Ph^{\mu\nu}h_{\mu\nu}P^\dagger$	12	I	33	I	$P^{*\mu}\langle u^\nu\chi_+\rangle u_\nu P^{*\dagger}{}_\mu$			362	
$Ph^{\mu\nu}h_\mu{}^\lambda D_{\nu\lambda}P^\dagger$	13	I	34	I	$P^{*\mu}\langle\chi_+\rangle u^\nu u_\nu P^{*\dagger}{}_\mu$			363	
$Ph^{\mu\nu}h^{\lambda\rho}D_{\mu\nu\lambda\rho}P^\dagger$	14	I	35	I	$P^{*\mu}\langle u^\nu u^\lambda\rangle\chi_+ D_{\nu\lambda}P^{*\dagger}{}_\mu$			364	
$Pu^\mu\nabla^\nu f_{-\mu\nu}P^\dagger +$H.c.	15	I	36	I	$P^{*\mu}\langle u^\nu u^\lambda\chi_+\rangle D_{\nu\lambda}P^{*\dagger}{}_\mu$	204		365	
$Pu^\mu\nabla^\nu f_{-\mu}{}^\lambda D_{\nu\lambda}P^\dagger +$H.c.	16	I	37	I	$P^{*\mu}\langle u^\nu\chi_+\rangle u^\lambda D_{\nu\lambda}P^{*\dagger}{}_\mu$			366	
$Pu^\mu\nabla^\nu f_{-\nu}{}^\lambda D_{\mu\lambda}P^\dagger +$H.c.	17	I	38	I	$P^{*\mu}\langle\chi_+\rangle u^\nu u^\lambda D_{\nu\lambda}P^{*\dagger}{}_\mu$			367	
$Pu^\mu\nabla_\mu h^{\nu\lambda}D_{\nu\lambda}P^\dagger +$H.c.	18	I	39	I	$\varepsilon^{\mu\nu\lambda\rho}P^*{}_\mu f_{-\nu\lambda}\chi_+ P^{*\dagger}{}_\rho +$H.c.	205	I	368	I
$Pu^\mu\nabla^\nu h^{\lambda\rho}D_{\mu\nu\lambda\rho}P^\dagger +$H.c.	19	I	40	I	$\varepsilon^{\mu\nu\lambda\rho}P^*{}_\mu h_\nu{}^\sigma\chi_+ D_{\lambda\sigma}P^{*\dagger}{}_\rho +$H.c.	206	I	369	I
$P\langle f_-{}^{\mu\nu}h_\mu{}^\lambda\rangle D_{\nu\lambda}P^\dagger$			41	I	$\varepsilon^{\mu\nu\lambda\rho}P^*{}_\mu u_\nu\nabla_\lambda\chi_+ P^{*\dagger}{}_\rho +$H.c.	207	I	370	I
$P\langle h^{\mu\nu}h_{\mu\nu}\rangle P^\dagger$			42	I	$\varepsilon^{\mu\nu\lambda\rho}P^*{}_\mu u_\nu\nabla^\sigma\chi_+ D_{\lambda\sigma}P^{*\dagger}{}_\rho +$H.c.	208	I	371	I
$P\langle h^{\mu\nu}h_\mu{}^\lambda\rangle D_{\nu\lambda}P^\dagger$			43	I	$P^{*\mu}\nabla_\mu\nabla^\nu\chi_+ P^{*\dagger}{}_\nu$	209	I	372	I
$P\langle h^{\mu\nu}h^{\lambda\rho}\rangle D_{\mu\nu\lambda\rho}P^\dagger$			44	I	$P^{*\mu}\nabla^\nu\nabla_\nu\chi_+ P^{*\dagger}{}_\mu$	210		373	
$P\langle u^\mu\nabla^\nu f_{-\mu\nu}\rangle P^\dagger$			45	I	$P^{*\mu}\nabla^\nu\nabla^\lambda\chi_+ D_{\nu\lambda}P^{*\dagger}{}_\mu$	211		374	
$P\langle u^\mu\nabla^\nu f_{-\mu}{}^\lambda\rangle D_{\nu\lambda}P^\dagger$			46	I	$P^{*\mu}\langle\nabla_\mu\nabla^\nu\chi_+\rangle P^{*\dagger}{}_\nu$	212	I	375	I

(Table continued)

TABLE IX. (Continued)

O_n	$SU(2)$	$\tilde{c}_n^{(4)}$	$SU(3)$	$\tilde{C}_n^{(4)}$	O_n	$SU(2)$	$\tilde{c}_n^{(4)}$	$SU(3)$	$\tilde{C}_n^{(4)}$
$P\langle u^\mu\nabla^\nu f_{-\nu}{}^\lambda\rangle D_{\mu\lambda}P^\dagger$			47	I	$P^{*\mu}\langle\nabla^\nu\nabla_\nu\chi_+\rangle P^{*\dagger}{}_\mu$	213		376	
$P\langle u^\mu\nabla_\mu h^{\nu\lambda}\rangle D_{\nu\lambda}P^\dagger$			48	I	$P^{*\mu}\langle\nabla^\nu\nabla^\lambda\chi_+\rangle D_{\nu\lambda}P^{*\dagger}{}_\mu$	214		377	
$P\langle u^\mu\nabla^\nu h^{\lambda\rho}\rangle D_{\mu\nu\lambda\rho}P^\dagger$			49	I	$iP^{*\mu}f_{+\mu}{}^\nu\chi_+ P^{*\dagger}{}_\nu$ + H.c.	215	I	378	I
$iP f_+^{\mu\nu}u_\mu u_\nu P^\dagger$ + H.c.	20	I	50	I	$iP^{*\mu}\langle f_{+\mu}{}^\nu\rangle\chi_+ P^{*\dagger}{}_\nu$	216	I		
$iP u^\mu f_{+\mu}{}^\nu u_\nu P^\dagger$	21	I	51	I	$iP^{*\mu}\langle f_{+\mu}{}^\nu\chi_+\rangle P^{*\dagger}{}_\nu$	217	I	379	I
$iP f_+^{\mu\nu}u_\mu u^\lambda D_{\nu\lambda}P^\dagger$ + H.c.	22	I	52	I	$iP^{*\mu}\langle\chi_+\rangle f_{+\mu}{}^\nu P^{*\dagger}{}_\nu$	218	I	380	I
$iP f_+^{\mu\nu}u^\lambda u_\mu D_{\nu\lambda}P^\dagger$ + H.c.			53	I	$P^{*\mu}\chi_+^2 P^{*\dagger}{}_\mu$	219		381	
$iP u^\mu f_{+\mu}{}^\nu u^\lambda D_{\nu\lambda}P^\dagger$ + H.c.	23	I	54	I	$P^{*\mu}\langle\chi_+\rangle\chi_+ P^{*\dagger}{}_\mu$			382	
$iP\langle f_+^{\mu\nu}u_\mu u_\nu\rangle P^\dagger$			55	I	$P^{*\mu}\langle\chi_+^2\rangle P^{*\dagger}{}_\mu$	220		383	
$iP\langle f_+^{\mu\nu}u_\mu u^\lambda\rangle D_{\nu\lambda}P^\dagger$ + H.c.			56	I	$P^{*\mu}\langle\chi_+\rangle\langle\chi_+\rangle P^{*\dagger}{}_\mu$			384	
$i\epsilon^{\mu\nu\lambda\rho}P f_{+\mu\nu}f_{-\lambda\rho}P^\dagger$ + H.c.	24	I	57	I	$i\epsilon^{\mu\nu\lambda\rho}P^*{}_\mu u_\nu u_\lambda\chi_- P^{*\dagger}{}_\rho$ + H.c.	221	I	385	I
$i\epsilon^{\mu\nu\lambda\rho}P f_{+\mu\nu}f_{-\lambda}{}^\sigma D_{\rho\sigma}P^\dagger$ + H.c.	25	I	58	I	$i\epsilon^{\mu\nu\lambda\rho}P^*{}_\mu u_\nu\chi_- u_\lambda P^{*\dagger}{}_\rho$	222	I	386	I
$i\epsilon^{\mu\nu\lambda\rho}P f_{+\mu\nu}h_\lambda{}^\sigma D_{\rho\sigma}P^\dagger$ + H.c.	26	I	59	I	$i\epsilon^{\mu\nu\lambda\rho}P^*{}_\mu u_\nu u^\sigma\chi_- D_{\lambda\sigma}P^{*\dagger}{}_\rho$ + H.c.			387	I
$i\epsilon^{\mu\nu\lambda\rho}P\nabla_\mu f_{+\nu}{}^\sigma u_\lambda D_{\rho\sigma}P^\dagger$ + H.c.	27	I	60	I	$i\epsilon^{\mu\nu\lambda\rho}P^*{}_\mu\langle u_\nu u_\lambda\chi_-\rangle P^{*\dagger}{}_\rho$			388	I
$P f_+^{\mu\nu}f_{+\mu\nu}P^\dagger$	28	I	61	I	$i\epsilon^{\mu\nu\lambda\rho}P^*{}_\mu\langle\chi_-\rangle u_\nu u_\lambda P^{*\dagger}{}_\rho$			389	I
$P f_+^{\mu\nu}f_{+\mu}{}^\lambda D_{\nu\lambda}P^\dagger$	29	I	62	I	$iP^{*\mu}f_{-\mu}{}^\nu\chi_- P^{*\dagger}{}_\nu$ + H.c.	223	I	390	I
$P\langle f_+^{\mu\nu}\rangle f_{+\mu\nu}P^\dagger$	30	I			$iP^{*\mu}h_\mu{}^\nu\chi_- P^{*\dagger}{}_\nu$ + H.c.	224	I	391	I
$P\langle f_+^{\mu\nu}\rangle f_{+\mu}{}^\lambda D_{\nu\lambda}P^\dagger$	31	I			$iP^{*\mu}h^{\nu\lambda}\chi_- D_{\nu\lambda}P^{*\dagger}{}_\mu$ + H.c.	225		392	
$P\langle f_+^{\mu\nu}f_{+\mu\nu}\rangle P^\dagger$			63	I	$iP^{*\mu}u_\mu\nabla^\nu\chi_- P^{*\dagger}{}_\nu$ + H.c.	226	I	393	I
$P\langle f_+^{\mu\nu}f_{+\mu}{}^\lambda\rangle D_{\nu\lambda}P^\dagger$			64	I	$iP^{*\mu}u^\nu\nabla_\mu\chi_- P^{*\dagger}{}_\nu$ + H.c.	227		394	
$P u^\mu u_\mu\chi_+ P^\dagger$ + H.c.	32	I	65	I	$iP^{*\mu}u^\nu\nabla_\nu\chi_- P^{*\dagger}{}_\mu$ + H.c.	228		395	
$P u^\mu\chi_+ u_\mu P^\dagger$	33	I	66	I	$iP^{*\mu}u^\nu\nabla^\lambda\chi_- D_{\nu\lambda}P^{*\dagger}{}_\mu$ + H.c.	229		396	
$P u^\mu u^\nu\chi_+ D_{\mu\nu}P^\dagger$ + H.c.	34	I	67	I	$iP^{*\mu}\langle h_\mu{}^\nu\chi_-\rangle P^{*\dagger}{}_\nu$	230	I	397	I
$P u^\mu\chi_+ u^\nu D_{\mu\nu}P^\dagger$	35	I	68	I	$iP^{*\mu}\langle\chi_-\rangle h_\mu{}^\nu P^{*\dagger}{}_\nu$			398	I
$P\langle u^\mu u_\mu\rangle\chi_+ P^\dagger$			69	I	$iP^{*\mu}\langle h^{\nu\lambda}\chi_-\rangle D_{\nu\lambda}P^{*\dagger}{}_\mu$	231		399	
$P\langle u^\mu u_\mu\chi_+\rangle P^\dagger$	36	I	70	I	$iP^{*\mu}\langle\chi_-\rangle h^{\nu\lambda}D_{\nu\lambda}P^{*\dagger}{}_\mu$			400	
$P\langle u^\mu\chi_+\rangle u_\mu P^\dagger$			71	I	$iP^{*\mu}\langle u_\mu\nabla^\nu\chi_-\rangle P^{*\dagger}{}_\nu$ + H.c.	232	I	401	I
$P\langle\chi_+\rangle u^\mu u_\mu P^\dagger$			72	I	$iP^{*\mu}\langle\nabla^\nu\chi_-\rangle u_\mu P^{*\dagger}{}_\nu$ + H.c.			402	I
$P\langle u^\mu u^\nu\rangle\chi_+ D_{\mu\nu}P^\dagger$			73	I	$iP^{*\mu}\langle u^\nu\nabla_\nu\chi_-\rangle P^{*\dagger}{}_\mu$	233		403	
$P\langle u^\mu u^\nu\chi_+\rangle D_{\mu\nu}P^\dagger$	37	I	74	I	$iP^{*\mu}\langle\nabla^\nu\chi_-\rangle u_\nu P^{*\dagger}{}_\mu$			404	
$P\langle u^\mu\chi_+\rangle u^\nu D_{\mu\nu}P^\dagger$			75	I	$iP^{*\mu}\langle u^\nu\nabla^\lambda\chi_-\rangle D_{\nu\lambda}P^{*\dagger}{}_\mu$	234		405	
$P\langle\chi_+\rangle u^\mu u^\nu D_{\mu\nu}P^\dagger$			76	I	$iP^{*\mu}\langle\nabla^\nu\chi_-\rangle u^\lambda D_{\nu\lambda}P^{*\dagger}{}_\mu$			406	
$P\nabla^\mu\nabla_\mu\chi_+ P^\dagger$	38	I	77	I	$\epsilon^{\mu\nu\lambda\rho}P^*{}_\mu f_{+\nu\lambda}\chi_- P^{*\dagger}{}_\rho$ + H.c.	235	I	407	I
$P\nabla^\mu\nabla^\nu\chi_+ D_{\mu\nu}P^\dagger$	39	I	78	I	$\epsilon^{\mu\nu\lambda\rho}P^*{}_\mu\langle f_{+\nu\lambda}\rangle\chi_- P^{*\dagger}{}_\rho$	236	I		
$P\langle\nabla^\mu\nabla_\mu\chi_+\rangle P^\dagger$	40	I	79	I	$\epsilon^{\mu\nu\lambda\rho}P^*{}_\mu\langle f_{+\nu\lambda}\chi_-\rangle P^{*\dagger}{}_\rho$	237	I	408	I
$P\langle\nabla^\mu\nabla^\nu\chi_+\rangle D_{\mu\nu}P^\dagger$	41	I	80	I	$\epsilon^{\mu\nu\lambda\rho}P^*{}_\mu\langle\chi_-\rangle f_{+\nu\lambda}P^{*\dagger}{}_\rho$	238	I	409	I
$P\chi_+^2 P^\dagger$	42	I	81	I	$P^{*\mu}\chi_-^2 P^{*\dagger}{}_\mu$	239		410	
$P\langle\chi_+\rangle\chi_+ P^\dagger$			82	I	$P^{*\mu}\langle\chi_-\rangle\chi_- P^{*\dagger}{}_\mu$	240		411	
$P\langle\chi_+^2\rangle P^\dagger$	43	I	83	I	$P^{*\mu}\langle\chi_-\rangle\langle\chi_-\rangle P^{*\dagger}{}_\mu$			412	
$P\langle\chi_+\rangle\langle\chi_+\rangle P^\dagger$			84	I	$iP^{*\mu}\langle D_\mu D^\nu F_{L\nu}{}^\lambda\rangle P^{*\dagger}{}_\lambda$ + P. + H.c.	241	I		
$iP h^{\mu\nu}\chi_- D_{\mu\nu}P^\dagger$ + H.c.	44	I	85	I	$iP^{*\mu}\langle D_\mu D^\nu F_L{}^{\lambda\rho}\rangle D_{\nu\lambda}P^{*\dagger}{}_\rho$ + P. + H.c.	242	I		
$iP u^\mu\nabla_\mu\chi_- P^\dagger$ + H.c.	45	I	86	I	$P^{*\mu}\langle F_{L\mu}{}^\nu F_{L\nu}{}^\lambda\rangle P^{*\dagger}{}_\lambda$ + H.c.	243		413	I
$iP u^\mu\nabla^\nu\chi_- D_{\mu\nu}P^\dagger$ + H.c.	46	I	87	I	$P^{*\mu}\langle F_L^{\nu\lambda}F_{L\nu\lambda}\rangle P^{*\dagger}{}_\mu$ + H.c.	244		414	
$iP\langle h^{\mu\nu}\chi_-\rangle D_{\mu\nu}P^\dagger$	47	I	88	I	$P^{*\mu}\langle F_{L\mu}{}^\nu F_L{}^{\lambda\rho}\rangle D_{\nu\lambda}P^{*\dagger}{}_\rho$ + H.c.	245		415	I
$iP\langle\chi_-\rangle h^{\mu\nu}D_{\mu\nu}P^\dagger$			89	I	$P^{*\mu}\langle F_L^{\nu\lambda}F_{L\nu}{}^\rho\rangle D_{\lambda\rho}P^{*\dagger}{}_\mu$ + H.c.	246		416	
$iP\langle u^\mu\nabla_\mu\chi_-\rangle P^\dagger$	48	I	90	I	$P^{*\mu}\langle F_{L\mu}{}^\nu\rangle\langle F_{L\nu}{}^\lambda\rangle P^{*\dagger}{}_\lambda$ + H.c.	247			
$iP\langle\nabla^\mu\chi_-\rangle u_\mu P^\dagger$			91	I	$P^{*\mu}\langle F_L^{\nu\lambda}\rangle\langle F_{L\nu\lambda}\rangle P^{*\dagger}{}_\mu$ + H.c.	248			
$iP\langle u^\mu\nabla^\nu\chi_-\rangle D_{\mu\nu}P^\dagger$	49	I	92	I	$P^{*\mu}\langle F_{L\mu}{}^\nu\rangle\langle F_L{}^{\lambda\rho}\rangle D_{\nu\lambda}P^{*\dagger}{}_\rho$ + H.c.	249			

(Table continued)

TABLE IX. *(Continued)*

O_n	$SU(2)$	$\tilde{c}_n^{(4)}$	$SU(3)$	$\tilde{C}_n^{(4)}$	O_n	$SU(2)$	$\tilde{c}_n^{(4)}$	$SU(3)$	$\tilde{C}_n^{(4)}$
$iP\langle\nabla^\mu\chi_-\rangle u^\nu D_{\mu\nu}P^\dagger$			93	I	$P^{*\mu}\langle F_L{}^{\nu\lambda}\rangle\langle F_{L\nu}{}^\rho\rangle D_{\lambda\rho}P^{*\dagger}{}_\mu$ + H.c.	250			
$P\chi_-^2 P^\dagger$	50	I	94	I	$i\varepsilon^{\mu\nu\lambda\rho}P^*{}_\mu\langle F_{L\nu\lambda}F_L{}^{\sigma\delta}\rangle D_{\rho\sigma}P^{*\dagger}{}_\delta$ + P. + H.c.	251	I	417	I
$P\langle\chi_-\rangle\chi_- P^\dagger$	51	I	95	I	$P^{*\mu}\langle\chi\chi^\dagger\rangle P^{*\dagger}{}_\mu$	252		418	
$P\langle\chi_-\rangle\langle\chi_-\rangle P^\dagger$			96	I	$P^{*\mu}\det\chi P^{*\dagger}{}_\mu$ + H.c.	253			
$P\langle F_L{}^{\mu\nu}F_{L\mu\nu}\rangle P^\dagger$ + H.c.	52	I	97	I	$\varepsilon^{\mu\nu\lambda\rho}Pu_\mu u_\nu u_\lambda u^\sigma D_\rho P^{*\dagger}{}_\sigma$ + H.c.	254		419	
$P\langle F_L{}^{\mu\nu}F_{L\mu}{}^\lambda\rangle D_{\nu\lambda}P^\dagger$ + H.c.	53	I	98	I	$\varepsilon^{\mu\nu\lambda\rho}Pu_\mu u_\nu u_\lambda u^\sigma D_\sigma P^{*\dagger}{}_\rho$ + H.c.	255		420	
$P\langle F_L{}^{\mu\nu}\rangle\langle F_{L\mu\nu}\rangle P^\dagger$ + H.c.	54	I			$\varepsilon^{\mu\nu\lambda\rho}Pu_\mu u_\nu u^\sigma u_\lambda D_\rho P^{*\dagger}{}_\sigma$ + H.c.			421	
$P\langle F_L{}^{\mu\nu}\rangle\langle F_{L\mu}{}^\lambda\rangle D_{\nu\lambda}P^\dagger$ + H.c.	55	I			$\varepsilon^{\mu\nu\lambda\rho}Pu_\mu u_\nu u^\sigma u_\lambda D_\sigma P^{*\dagger}{}_\rho$ + H.c.			422	
$P\langle\chi\chi^\dagger\rangle P^\dagger$	56	I	99	I	$\varepsilon^{\mu\nu\lambda\rho}Pu_\mu u_\nu u^\sigma u_\sigma D_\lambda P^{*\dagger}{}_\rho$ + H.c.	256		423	
$P\det\chi P^\dagger$ + H.c.	57	I			$\varepsilon^{\mu\nu\lambda\rho}Pu_\mu u^\sigma u_\nu u_\lambda D_\rho P^{*\dagger}{}_\sigma$ + H.c.			424	
$P^{*\mu}\langle u_\mu u^\nu\rangle u^\lambda P^{*\dagger}{}_\lambda$ + H.c.	58	I	100	I	$\varepsilon^{\mu\nu\lambda\rho}Pu_\mu u^\sigma u_\nu u_\lambda D_\sigma P^{*\dagger}{}_\rho$ + H.c.			425	
$P^{*\mu}\langle u_\mu u^\nu\rangle u^\lambda u_\nu P^{*\dagger}{}_\lambda$ + H.c.	59	I	101	I	$\varepsilon^{\mu\nu\lambda\rho}Pu_\mu u^\sigma u_\nu u_\sigma D_\lambda P^{*\dagger}{}_\rho$ + H.c.			426	
$P^{*\mu}\langle u_\mu u^\nu\rangle u^\lambda u_\lambda P^{*\dagger}{}_\nu$	60	I	102	I	$\varepsilon^{\mu\nu\lambda\rho}Pu_\mu u^\sigma u_\sigma u_\nu D_\lambda P^{*\dagger}{}_\rho$ + H.c.			427	
$P^{*\mu}\langle u^\nu u_\nu\rangle u_\mu u^\lambda P^{*\dagger}{}_\lambda$	61		103	I	$\varepsilon^{\mu\nu\lambda\rho}Pu_\mu u_\nu u^\sigma u^\delta D_{\lambda\sigma\delta}P^{*\dagger}{}_\rho$ + H.c.	257		428	
$P^{*\mu}\langle u^\nu u_\nu\rangle u^\lambda u_\mu P^{*\dagger}{}_\lambda$			104		$\varepsilon^{\mu\nu\lambda\rho}Pu_\mu u^\sigma u_\nu u^\delta D_{\lambda\sigma\delta}P^{*\dagger}{}_\rho$ + H.c.			429	
$P^{*\mu}\langle u^\nu u_\nu\rangle u^\lambda u_\lambda P^{*\dagger}{}_\mu$	62		105		$\varepsilon^{\mu\nu\lambda\rho}Pu_\mu u^\sigma u^\delta u_\nu D_{\lambda\sigma\delta}P^{*\dagger}{}_\rho$ + H.c.			430	
$P^{*\mu}\langle u^\nu u^\lambda\rangle u_\nu u_\lambda P^{*\dagger}{}_\mu$	63		106		$\varepsilon^{\mu\nu\lambda\rho}P\langle u_\mu u^\sigma\rangle u_\nu u_\lambda D_\rho P^{*\dagger}{}_\sigma$ + H.c.			431	
$P^{*\mu}\langle u_\mu u^\nu\rangle u^\lambda u^\rho D_{\nu\lambda}P^{*\dagger}{}_\rho$ + H.c.	64	I	107	I	$\varepsilon^{\mu\nu\lambda\rho}P\langle u_\mu u^\sigma\rangle u_\nu u_\lambda D_\sigma P^{*\dagger}{}_\rho$ + H.c.			432	
$P^{*\mu}\langle u_\mu u^\nu\rangle u^\lambda u^\rho D_{\nu\rho}P^{*\dagger}{}_\lambda$ + H.c.	65	I	108	I	$\varepsilon^{\mu\nu\lambda\rho}P\langle u_\mu u^\sigma\rangle u_\nu u_\sigma D_\lambda P^{*\dagger}{}_\rho$ + H.c.			433	I
$P^{*\mu}\langle u_\mu u^\nu\rangle u^\lambda u^\rho D_{\lambda\rho}P^{*\dagger}{}_\nu$	66	I	109	I	$\varepsilon^{\mu\nu\lambda\rho}P\langle u_\mu u^\sigma\rangle u_\nu u^\delta D_{\lambda\sigma\delta}P^{*\dagger}{}_\rho$ + H.c.			434	I
$P^{*\mu}\langle u^\nu u_\nu\rangle u^\lambda u^\rho D_{\lambda\rho}P^{*\dagger}{}_\mu$	67		110		$\varepsilon^{\mu\nu\lambda\rho}P\langle u_\mu u_\nu u_\lambda\rangle u^\sigma D_\rho P^{*\dagger}{}_\sigma$ + H.c.			435	
$P^{*\mu}\langle u^\nu u^\lambda\rangle u_\mu u^\rho D_{\nu\lambda}P^{*\dagger}{}_\rho$	68		111	I	$\varepsilon^{\mu\nu\lambda\rho}P\langle u_\mu u_\nu u_\lambda\rangle u^\sigma D_\sigma P^{*\dagger}{}_\rho$ + H.c.			436	
$P^{*\mu}\langle u^\nu u^\lambda\rangle u_\nu u^\rho D_{\lambda\rho}P^{*\dagger}{}_\mu$ + H.c.	69		112		$P\langle u^\mu u_\mu\rangle f_-{}^{\nu\lambda}D_\nu P^{*\dagger}{}_\lambda$ + H.c.	258	I	437	
$P^{*\mu}\langle u^\nu u^\lambda\rangle u^\rho u_\mu D_{\nu\lambda}P^{*\dagger}{}_\rho$			113		$P\langle u^\mu u^\nu\rangle f_{-\mu}{}^\lambda D_\nu P^{*\dagger}{}_\lambda$ + H.c.	259	I	438	
$P^{*\mu}\langle u^\nu u^\lambda\rangle u^\rho u_\rho D_{\nu\lambda}P^{*\dagger}{}_\mu$			114		$P\langle u^\mu u^\nu\rangle f_{-\mu}{}^\lambda D_\lambda P^{*\dagger}{}_\nu$ + H.c.	260	I	439	
$P^{*\mu}\langle u^\nu u^\lambda\rangle u^\rho u^\sigma D_{\nu\lambda\rho\sigma}P^{*\dagger}{}_\mu$	70		115		$P\langle u^\mu u^\nu\rangle f_-{}^{\lambda\rho}D_{\mu\nu\lambda}P^{*\dagger}{}_\rho$ + H.c.	261	I	440	
$P^{*\mu}\langle u_\mu u^\nu u_\nu\rangle u^\lambda P^{*\dagger}{}_\lambda$ + H.c.			116		$P\langle u^\mu u_\mu\rangle h^{\nu\lambda}D_\nu P^{*\dagger}{}_\lambda$ + H.c.	262	I	441	
$P^{*\mu}\langle u_\mu u^\nu u^\lambda\rangle u_\nu P^{*\dagger}{}_\lambda$			117	I	$P\langle u^\mu u^\nu\rangle h_\mu{}^\lambda D_\nu P^{*\dagger}{}_\lambda$ + H.c.	263	I	442	
$P^{*\mu}\langle u_\mu u^\nu u^\lambda\rangle u_\lambda P^{*\dagger}{}_\nu$			118		$P\langle u^\mu u^\nu\rangle h_\mu{}^\lambda D_\lambda P^{*\dagger}{}_\nu$ + H.c.	264	I	443	
$P^{*\mu}\langle u^\nu u_\nu u^\lambda\rangle u_\lambda P^{*\dagger}{}_\mu$			119		$P\langle u^\mu u^\nu\rangle h^{\lambda\rho}D_{\mu\nu\lambda}P^{*\dagger}{}_\rho$ + H.c.	265	I	444	
$P^{*\mu}\langle u_\mu u^\nu u^\lambda\rangle u^\rho D_{\nu\lambda}P^{*\dagger}{}_\rho$ + H.c.			120		$P\langle u^\mu u^\nu\rangle h^{\lambda\rho}D_{\mu\lambda\rho}P^{*\dagger}{}_\nu$ + H.c.	266	I	445	
$P^{*\mu}\langle u_\mu u^\nu u^\lambda\rangle u^\rho D_{\nu\rho}P^{*\dagger}{}_\lambda$			121	I	$P\langle u^\mu f_{-\mu}{}^\nu\rangle u^\lambda D_\lambda P^{*\dagger}{}_\nu$ + H.c.	267	I	446	
$P^{*\mu}\langle u_\mu u^\nu u^\lambda\rangle u^\rho D_{\lambda\rho}P^{*\dagger}{}_\nu$			122		$P\langle u^\mu f_{-\mu}{}^\nu\rangle u^\lambda D_\nu P^{*\dagger}{}_\lambda$ + H.c.	268	I	447	
$P^{*\mu}\langle u^\nu u_\nu u^\lambda\rangle u^\rho D_{\lambda\rho}P^{*\dagger}{}_\mu$			123		$P\langle u^\mu f_-{}^{\nu\lambda}\rangle u_\mu D_\nu P^{*\dagger}{}_\lambda$ + H.c.	269	I	448	
$P^{*\mu}\langle u^\nu u^\lambda u^\rho\rangle u_\nu D_{\lambda\rho}P^{*\dagger}{}_\mu$			124		$P\langle u^\mu f_-{}^{\nu\lambda}\rangle u_\nu D_\mu P^{*\dagger}{}_\lambda$ + H.c.	270	I	449	
$P^{*\mu}\langle u^\nu u^\lambda u^\rho\rangle u^\sigma D_{\nu\lambda\rho\sigma}P^{*\dagger}{}_\mu$			125		$P\langle u^\mu f_-{}^{\nu\lambda}\rangle u_\nu D_\lambda P^{*\dagger}{}_\mu$ + H.c.	271	I	450	
$P^{*\mu}\langle u_\mu u^\nu u_\nu u^\lambda\rangle P^{*\dagger}{}_\lambda$			126	I	$P\langle u^\mu f_-{}^{\nu\lambda}\rangle u^\rho D_{\mu\nu\rho}P^{*\dagger}{}_\lambda$ + H.c.	272	I	451	
$P^{*\mu}\langle u_\mu u^\nu u^\lambda u_\nu\rangle P^{*\dagger}{}_\lambda$			127	I	$P\langle u^\mu h_\mu{}^\nu\rangle u^\lambda D_\lambda P^{*\dagger}{}_\nu$ + H.c.	273	I	452	
$P^{*\mu}\langle u_\mu u^\nu u^\lambda u_\lambda\rangle P^{*\dagger}{}_\nu$			128		$P\langle u^\mu h_\mu{}^\nu\rangle u^\lambda D_\nu P^{*\dagger}{}_\lambda$ + H.c.	274	I	453	
$P^{*\mu}\langle u^\nu u_\nu u^\lambda u_\lambda\rangle P^{*\dagger}{}_\mu$			129		$P\langle u^\mu h^{\nu\lambda}\rangle u_\mu D_\nu P^{*\dagger}{}_\lambda$ + H.c.	275	I	454	
$P^{*\mu}\langle u^\nu u^\lambda u_\nu u_\lambda\rangle P^{*\dagger}{}_\mu$			130		$P\langle u^\mu h^{\nu\lambda}\rangle u_\nu D_\mu P^{*\dagger}{}_\lambda$ + H.c.	276	I	455	
$P^{*\mu}\langle u_\mu u^\nu u^\lambda u^\rho\rangle D_{\nu\lambda}P^{*\dagger}{}_\rho$			131	I	$P\langle u^\mu h^{\nu\lambda}\rangle u_\nu D_\lambda P^{*\dagger}{}_\mu$ + H.c.	277	I	456	
$P^{*\mu}\langle u_\mu u^\nu u^\lambda u^\rho\rangle D_{\nu\rho}P^{*\dagger}{}_\lambda$			132	I	$P\langle u^\mu h^{\nu\lambda}\rangle u^\rho D_{\mu\nu\rho}P^{*\dagger}{}_\lambda$ + H.c.	278	I	457	
$P^{*\mu}\langle u_\mu u^\nu u^\lambda u^\rho\rangle D_{\lambda\rho}P^{*\dagger}{}_\nu$			133		$P\langle u^\mu h^{\nu\lambda}\rangle u^\rho D_{\mu\nu\lambda}P^{*\dagger}{}_\rho$ + H.c.	279	I	458	
$P^{*\mu}\langle u^\nu u_\nu u^\lambda u^\rho\rangle D_{\lambda\rho}P^{*\dagger}{}_\mu$			134		$P\langle u^\mu h^{\nu\lambda}\rangle u^\rho D_{\nu\lambda\rho}P^{*\dagger}{}_\mu$ + H.c.	280	I	459	
$P^{*\mu}\langle u^\nu u^\lambda u_\nu u^\rho\rangle D_{\lambda\rho}P^{*\dagger}{}_\mu$			135		$P\langle u^\mu u_\mu f_-{}^{\nu\lambda}\rangle D_\nu P^{*\dagger}{}_\lambda$ + H.c.			460	
$P^{*\mu}\langle u^\nu u^\lambda u^\rho u^\sigma\rangle D_{\nu\lambda\rho\sigma}P^{*\dagger}{}_\mu$			136		$P\langle u^\mu u^\nu f_{-\mu}{}^\lambda\rangle D_\nu P^{*\dagger}{}_\lambda$ + H.c.	281		461	
$P^{*\mu}u_\mu u^\nu u_\nu u^\lambda P^{*\dagger}{}_\lambda$			137		$P\langle u^\mu u^\nu f_{-\mu}{}^\lambda\rangle D_\lambda P^{*\dagger}{}_\nu$ + H.c.	282		462	

(Table continued)

TABLE IX. *(Continued)*

O_n	$SU(2)$	$\tilde c_n^{(4)}$	$SU(3)$	$\tilde C_n^{(4)}$	O_n	$SU(2)$	$\tilde c_n^{(4)}$	$SU(3)$	$\tilde C_n^{(4)}$
$P^{*\mu}u_\mu u^\nu u^\lambda u_\nu P^{*\dagger}_\lambda$ + H.c.			138		$P\langle u^\mu u^\nu f_{-\nu}{}^\lambda\rangle D_\mu P^{*\dagger}_\lambda$ + H.c.			463	
$P^{*\mu}u^\nu u_\mu u^\lambda u_\nu P^{*\dagger}_\lambda$			139		$P\langle u^\mu u^\nu f_{-\nu}{}^\lambda\rangle D_\lambda P^{*\dagger}_\mu$ + H.c.			464	
$P^{*\mu}u^\nu u_\mu u^\lambda u_\lambda P^{*\dagger}_\nu$ + H.c.			140		$P\langle u^\mu u^\nu f_-{}^{\lambda\rho}\rangle D_{\mu\nu\lambda}P^{*\dagger}_\rho$ + H.c.			465	
$P^{*\mu}u^\nu u_\nu u^\lambda u_\lambda P^{*\dagger}_\mu$			141		$P\langle u^\mu u_\mu h^{\nu\lambda}\rangle D_\nu P^{*\dagger}_\lambda$ + H.c.			466	
$P^{*\mu}u^\nu u^\lambda u_\nu u_\lambda P^{*\dagger}_\mu$			142		$P\langle u^\mu u^\nu h_\mu{}^\lambda\rangle D_\nu P^{*\dagger}_\lambda$ + H.c.	283		467	
$P^{*\mu}u_\mu u^\nu u^\lambda u^\rho D_{\nu\lambda}P^{*\dagger}_\rho$			143	I	$P\langle u^\mu u^\nu h_\mu{}^\lambda\rangle D_\lambda P^{*\dagger}_\nu$ + H.c.	284		468	
$P^{*\mu}u_\mu u^\nu u^\lambda u^\rho D_{\nu\rho}P^{*\dagger}_\lambda$ + H.c.			144		$P\langle u^\mu u^\nu h_\nu{}^\lambda\rangle D_\mu P^{*\dagger}_\lambda$ + H.c.			469	
$P^{*\mu}u^\nu u_\mu u^\lambda u^\rho D_{\nu\rho}P^{*\dagger}_\lambda$			145		$P\langle u^\mu u^\nu h_\nu{}^\lambda\rangle D_\lambda P^{*\dagger}_\mu$ + H.c.			470	
$P^{*\mu}u^\nu u_\mu u^\lambda u^\rho D_{\lambda\rho}P^{*\dagger}_\nu$ + H.c.			146		$P\langle u^\mu u^\nu h^{\lambda\rho}\rangle D_{\mu\nu\lambda}P^{*\dagger}_\rho$ + H.c.			471	
$P^{*\mu}u^\nu u_\nu u^\lambda u^\rho D_{\lambda\rho}P^{*\dagger}_\mu$ + H.c.			147		$P\langle u^\mu u^\nu h^{\lambda\rho}\rangle D_{\mu\lambda\rho}P^{*\dagger}_\nu$ + H.c.	285		472	
$P^{*\mu}u^\nu u^\lambda u_\nu u^\rho D_{\lambda\rho}P^{*\dagger}_\mu$ + H.c.			148		$P\langle u^\mu u^\nu h^{\lambda\rho}\rangle D_{\nu\lambda\rho}P^{*\dagger}_\mu$ + H.c.			473	
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu u_\nu u_\lambda f_{-\rho}{}^\sigma P^{*\dagger}_\sigma$ + H.c.	71		149		$Pu^\mu u_\mu f_-{}^{\nu\lambda}D_\nu P^{*\dagger}_\lambda$ + H.c.			474	
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu u_\nu u^\sigma f_{-\lambda\rho}P^{*\dagger}_\sigma$ + H.c.	72		150		$Pu^\mu u^\nu f_{-\mu}{}^\lambda D_\nu P^{*\dagger}_\lambda$ + H.c.			475	
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu u_\nu u^\sigma f_{-\lambda\sigma}P^{*\dagger}_\rho$ + H.c.	73	I	151	I	$Pu^\mu u^\nu f_{-\mu}{}^\lambda D_\lambda P^{*\dagger}_\nu$ + H.c.			476	I
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu u^\sigma u_\nu f_{-\lambda\rho}P^{*\dagger}_\sigma$ + H.c.	74		152		$Pu^\mu u^\nu f_{-\nu}{}^\lambda D_\mu P^{*\dagger}_\lambda$ + H.c.			477	
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu u^\sigma u_\nu f_{-\lambda\sigma}P^{*\dagger}_\rho$ + H.c.			153	I	$Pu^\mu u^\nu f_{-\nu}{}^\lambda D_\lambda P^{*\dagger}_\mu$ + H.c.			478	I
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu u^\sigma u_\sigma f_{-\nu\lambda}P^{*\dagger}_\rho$ + H.c.			154	I	$Pu^\mu u^\nu f_-{}^{\lambda\rho}D_{\mu\nu\lambda}P^{*\dagger}_\rho$ + H.c.			479	I
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu u_\nu u_\lambda f_-{}^{\sigma\delta}D_{\rho\sigma}P^{*\dagger}_\delta$ + H.c.	75		155		$Pu^\mu u_\mu h^{\nu\lambda}D_\nu P^{*\dagger}_\lambda$ + H.c.			480	
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu u_\nu u^\sigma f_{-\lambda}{}^\delta D_{\rho\sigma}P^{*\dagger}_\delta$ + H.c.	76		156		$Pu^\mu u^\nu h_\mu{}^\lambda D_\nu P^{*\dagger}_\lambda$ + H.c.			481	
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu u_\nu u^\sigma f_{-\lambda}{}^\delta D_{\rho\delta}P^{*\dagger}_\sigma$ + H.c.	77		157		$Pu^\mu u^\nu h_\mu{}^\lambda D_\lambda P^{*\dagger}_\nu$ + H.c.			482	
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu u_\nu u^\sigma f_{-\lambda}{}^\delta D_{\sigma\delta}P^{*\dagger}_\rho$ + H.c.			158	I	$Pu^\mu u^\nu h_\nu{}^\lambda D_\mu P^{*\dagger}_\lambda$ + H.c.			483	
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu u_\nu u^\sigma f_{-\sigma}{}^\delta D_{\lambda\delta}P^{*\dagger}_\rho$ + H.c.	78	I	159	I	$Pu^\mu u^\nu h_\nu{}^\lambda D_\lambda P^{*\dagger}_\mu$ + H.c.			484	
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu u^\sigma u_\nu f_{-\lambda}{}^\delta D_{\rho\delta}P^{*\dagger}_\sigma$ + H.c.	79		160		$Pu^\mu u^\nu h^{\lambda\rho}D_{\mu\nu\lambda}P^{*\dagger}_\rho$ + H.c.			485	
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu u^\sigma u_\nu f_{-\sigma}{}^\delta D_{\lambda\delta}P^{*\dagger}_\rho$ + H.c.			161	I	$Pu^\mu u^\nu h^{\lambda\rho}D_{\mu\lambda\rho}P^{*\dagger}_\nu$ + H.c.			486	I
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu u_\nu u_\lambda h_\rho{}^\sigma P^{*\dagger}_\sigma$ + H.c.	80	I	162	I	$Pu^\mu u^\nu h^{\lambda\rho}D_{\nu\lambda\rho}P^{*\dagger}_\mu$ + H.c.			487	
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu u_\nu u^\sigma h_{\lambda\sigma}P^{*\dagger}_\rho$ + H.c.	81	I	163	I	$Pu^\mu f_{-\mu}{}^\nu u^\lambda D_\nu P^{*\dagger}_\lambda$ + H.c.			488	
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu u^\sigma u_\nu h_{\lambda\sigma}P^{*\dagger}_\rho$ + H.c.			164	I	$Pu^\mu f_{-\mu}{}^\nu u^\lambda D_\lambda P^{*\dagger}_\nu$ + H.c.			489	
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu u_\nu u_\lambda h^{\sigma\delta}D_{\rho\sigma}P^{*\dagger}_\delta$ + H.c.	82		165		$Pu^\mu f_-{}^{\nu\lambda}u_\mu D_\nu P^{*\dagger}_\lambda$ + H.c.			490	
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu u_\nu u_\lambda h^{\sigma\delta}D_{\sigma\delta}P^{*\dagger}_\rho$ + H.c.	83	I	166	I	$Pu^\mu f_-{}^{\nu\lambda}u_\nu D_\mu P^{*\dagger}_\lambda$ + H.c.			491	
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu u_\nu u^\sigma h_\lambda{}^\delta D_{\rho\sigma}P^{*\dagger}_\delta$ + H.c.	84	I	167	I	$Pu^\mu f_-{}^{\nu\lambda}u_\nu D_\lambda P^{*\dagger}_\mu$ + H.c.			492	
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu u_\nu u^\sigma h_\lambda{}^\delta D_{\rho\delta}P^{*\dagger}_\sigma$ + H.c.	85		168		$Pu^\mu f_-{}^{\nu\lambda}u^\rho D_{\mu\nu\rho}P^{*\dagger}_\lambda$ + H.c.			493	
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu u_\nu u^\sigma h_\lambda{}^\delta D_{\sigma\delta}P^{*\dagger}_\rho$ + H.c.			169	I	$Pu^\mu h_\mu{}^\nu u^\lambda D_\nu P^{*\dagger}_\lambda$ + H.c.			494	
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu u_\nu u^\sigma h_\sigma{}^\delta D_{\lambda\delta}P^{*\dagger}_\rho$ + H.c.	86	I	170	I	$Pu^\mu h_\mu{}^\nu u^\lambda D_\lambda P^{*\dagger}_\nu$ + H.c.			495	
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu u^\sigma u_\nu h_\lambda{}^\delta D_{\rho\delta}P^{*\dagger}_\sigma$ + H.c.	87		171		$Pu^\mu h^{\nu\lambda}u_\mu D_\nu P^{*\dagger}_\lambda$ + H.c.			496	
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu u^\sigma u_\nu h_\sigma{}^\delta D_{\lambda\delta}P^{*\dagger}_\rho$ + H.c.			172	I	$Pu^\mu h^{\nu\lambda}u_\nu D_\mu P^{*\dagger}_\lambda$ + H.c.			497	
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu u^\sigma u_\sigma h_\nu{}^\delta D_{\lambda\delta}P^{*\dagger}_\rho$ + H.c.			173	I	$Pu^\mu h^{\nu\lambda}u_\nu D_\lambda P^{*\dagger}_\mu$ + H.c.			498	
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu u_\nu u^\sigma h^{\delta\alpha}D_{\lambda\sigma\delta\alpha}P^{*\dagger}_\rho$ + H.c.			174	I	$Pu^\mu h^{\nu\lambda}u^\rho D_{\mu\nu\lambda}P^{*\dagger}_\rho$ + H.c.			499	
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu u_\nu f_{-\lambda\rho}u^\sigma P^{*\dagger}_\sigma$ + H.c.	88		175		$Pu^\mu h^{\nu\lambda}u^\rho D_{\mu\nu\rho}P^{*\dagger}_\lambda$ + H.c.			500	
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu u_\nu f_{-\lambda}{}^\sigma u_\rho P^{*\dagger}_\sigma$ + H.c.			176	I	$Pu^\mu h^{\nu\lambda}u^\rho D_{\nu\lambda\rho}P^{*\dagger}_\mu$ + H.c.			501	
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu u_\nu f_{-\lambda}{}^\sigma u^\delta D_{\rho\sigma}P^{*\dagger}_\delta$ + H.c.	89		177		$Pf_-{}^{\mu\nu}u_\mu u^\lambda D_\nu P^{*\dagger}_\lambda$ + H.c.			502	
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu u_\nu f_{-\lambda}{}^\sigma u^\delta D_{\rho\delta}P^{*\dagger}_\sigma$ + H.c.	90		178		$Pf_-{}^{\mu\nu}u_\mu u^\lambda D_\lambda P^{*\dagger}_\nu$ + H.c.			503	
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu u_\nu f_-{}^{\sigma\delta}u_\lambda D_{\rho\sigma}P^{*\dagger}_\delta$ + H.c.			179	I	$Ph^{\mu\nu}u_\mu u^\lambda D_\nu P^{*\dagger}_\lambda$ + H.c.			504	
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu u_\nu h_\lambda{}^\sigma u_\rho P^{*\dagger}_\sigma$ + H.c.			180	I	$Ph^{\mu\nu}u_\mu u^\lambda D_\lambda P^{*\dagger}_\nu$ + H.c.			505	
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu u_\nu h_\lambda{}^\sigma u^\delta D_{\rho\sigma}P^{*\dagger}_\delta$ + H.c.	91	I	181	I	$Ph^{\mu\nu}u^\lambda u^\rho D_{\mu\nu\lambda}P^{*\dagger}_\rho$ + H.c.			506	
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu u_\nu h_\lambda{}^\sigma u^\delta D_{\rho\delta}P^{*\dagger}_\sigma$ + H.c.	92	I	182	I	$\varepsilon^{\mu\nu\lambda\rho}Pu_\mu\nabla_\nu f_{-\lambda}{}^\sigma D_\rho P^{*\dagger}_\sigma$ + H.c.	286		507	
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu u_\nu h_\lambda{}^\sigma u^\delta D_{\sigma\delta}P^{*\dagger}_\rho$ + H.c.			183	I	$\varepsilon^{\mu\nu\lambda\rho}Pu_\mu\nabla_\nu f_{-\lambda}{}^\sigma D_\sigma P^{*\dagger}_\rho$ + H.c.	287		508	
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu u_\nu h^{\sigma\delta}u_\lambda D_{\rho\sigma}P^{*\dagger}_\delta$ + H.c.			184	I	$\varepsilon^{\mu\nu\lambda\rho}Pu_\mu\nabla^\sigma f_{-\nu\sigma}D_\lambda P^{*\dagger}_\rho$ + H.c.	288		509	
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu \langle u_\nu u^\sigma\rangle f_{-\lambda\rho}P^{*\dagger}_\sigma$ + H.c.			185		$\varepsilon^{\mu\nu\lambda\rho}Pu_\mu\nabla^\sigma f_{-\nu}{}^\delta D_{\lambda\sigma\delta}P^{*\dagger}_\rho$ + H.c.	289		510	

(Table continued)

TABLE IX. *(Continued)*

O_n	$SU(2)$	$\tilde{c}_n^{(4)}$	$SU(3)$	$\tilde{C}_n^{(4)}$	O_n	$SU(2)$	$\tilde{c}_n^{(4)}$	$SU(3)$	$\tilde{C}_n^{(4)}$
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu\langle u_\nu u^\sigma\rangle f_{-\lambda}{}^\delta D_{\rho\sigma}P^{*\dagger}_\delta$ + H.c.			186		$\varepsilon^{\mu\nu\lambda\rho}Pu_\mu\nabla_\nu h^{\sigma\delta}D_{\lambda\sigma\delta}P^{*\dagger}_\rho$ + H.c.	290		511	
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu\langle u_\nu u^\sigma\rangle f_{-\lambda}{}^\delta D_{\rho\delta}P^{*\dagger}_\sigma$ + H.c.			187		$\varepsilon^{\mu\nu\lambda\rho}P\nabla_\mu f_{-\nu}{}^\sigma u_\lambda D_\rho P^{*\dagger}_\sigma$ + H.c.	291		512	
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu\langle u_\nu u^\sigma\rangle h_\lambda{}^\delta D_{\rho\sigma}P^{*\dagger}_\delta$ + H.c.			188	I	$\varepsilon^{\mu\nu\lambda\rho}P\nabla_\mu f_{-\nu}{}^\sigma u_\lambda D_\sigma P^{*\dagger}_\rho$ + H.c.	292		513	
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu\langle u_\nu u^\sigma\rangle h_\lambda{}^\delta D_{\rho\delta}P^{*\dagger}_\sigma$ + H.c.			189	I	$\varepsilon^{\mu\nu\lambda\rho}P\nabla_\mu f_{-\nu}{}^\sigma u_\sigma D_\lambda P^{*\dagger}_\rho$ + H.c.	293		514	
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu\langle u_\nu f_{-\lambda\rho}\rangle u^\sigma P^{*\dagger}_\sigma$ + H.c.			190		$\varepsilon^{\mu\nu\lambda\rho}P\nabla_\mu f_{-\nu}{}^\sigma u^\delta D_{\lambda\sigma\delta}P^{*\dagger}_\rho$ + H.c.	294		515	
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu\langle u_\nu f_{-\lambda}{}^\sigma\rangle u_\rho P^{*\dagger}_\sigma$ + H.c.			191		$\varepsilon^{\mu\nu\lambda\rho}Pf_{-\mu\nu}f_{-\lambda}{}^\sigma D_\rho P^{*\dagger}_\sigma$ + H.c.	295		516	
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu\langle u^\sigma f_{-\nu\lambda}\rangle u_\rho P^{*\dagger}_\sigma$ + H.c.			192		$\varepsilon^{\mu\nu\lambda\rho}Pf_{-\mu\nu}f_{-\lambda}{}^\sigma D_\sigma P^{*\dagger}_\rho$ + H.c.	296		517	
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu\langle u_\nu f_{-\lambda}{}^\sigma\rangle u^\delta D_{\rho\delta}P^{*\dagger}_\sigma$ + H.c.			193		$\varepsilon^{\mu\nu\lambda\rho}Pf_{-\mu\nu}h_\lambda{}^\sigma D_\rho P^{*\dagger}_\sigma$ + H.c.	297		518	
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu\langle u_\nu f_{-\lambda}{}^\sigma\rangle u^\delta D_{\rho\sigma}P^{*\dagger}_\delta$ + H.c.			194		$\varepsilon^{\mu\nu\lambda\rho}Pf_{-\mu\nu}h_\lambda{}^\sigma D_\sigma P^{*\dagger}_\rho$ + H.c.	298		519	
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu\langle u_\nu f_-{}^{\sigma\delta}\rangle u_\lambda D_{\rho\sigma}P^{*\dagger}_\delta$ + H.c.			195		$\varepsilon^{\mu\nu\lambda\rho}Pf_{-\mu\nu}h^{\sigma\delta}D_{\lambda\sigma\delta}P^{*\dagger}_\rho$ + H.c.	299		520	
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu\langle u^\sigma f_{-\nu\lambda}\rangle u^\delta D_{\rho\delta}P^{*\dagger}_\sigma$ + H.c.			196		$\varepsilon^{\mu\nu\lambda\rho}P\nabla_\mu h^{\sigma\delta}u_\nu D_{\lambda\sigma\delta}P^{*\dagger}_\rho$ + H.c.	300		521	
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu\langle u_\nu h_\lambda{}^\sigma\rangle u_\rho P^{*\dagger}_\sigma$ + H.c.			197	I	$\varepsilon^{\mu\nu\lambda\rho}Ph_\mu{}^\sigma f_{-\nu\lambda}D_\rho P^{*\dagger}_\sigma$ + H.c.	301		522	
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu\langle u_\nu h_\lambda{}^\sigma\rangle u^\delta D_{\rho\sigma}P^{*\dagger}_\sigma$ + H.c.			198	I	$\varepsilon^{\mu\nu\lambda\rho}Ph_\mu{}^\sigma f_{-\nu\lambda}D_\sigma P^{*\dagger}_\rho$ + H.c.	302		523	
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu\langle u_\nu h_\lambda{}^\sigma\rangle u^\delta D_{\rho\sigma}P^{*\dagger}_\delta$ + H.c.			199		$\varepsilon^{\mu\nu\lambda\rho}Ph_\mu{}^\sigma f_{-\nu}{}^\delta D_{\lambda\sigma\delta}P^{*\dagger}_\rho$ + H.c.	303		524	
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu\langle u_\nu h^{\sigma\delta}\rangle u_\lambda D_{\rho\sigma}P^{*\dagger}_\delta$ + H.c.			200		$\varepsilon^{\mu\nu\lambda\rho}Ph_\mu{}^\sigma h_{\nu\sigma}D_\lambda P^{*\dagger}_\rho$ + H.c.	304		525	
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu\langle u^\sigma h_\nu{}^\delta\rangle u_\lambda D_{\rho\sigma}P^{*\dagger}_\delta$ + H.c.			201		$\varepsilon^{\mu\nu\lambda\rho}Ph_\mu{}^\sigma h_\nu{}^\delta D_{\lambda\sigma\delta}P^{*\dagger}_\rho$ + H.c.	305		526	
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu\langle u_\nu u_\lambda f_{-\rho}{}^\sigma\rangle P^{*\dagger}_\sigma$ + H.c.			202	I	$\varepsilon^{\mu\nu\lambda\rho}P\langle u_\mu\nabla_\nu f_{-\lambda}{}^\sigma\rangle D_\rho P^{*\dagger}_\sigma$ + H.c.			527	I
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu\langle u_\nu u_\lambda f_-{}^{\sigma\delta}\rangle D_{\rho\sigma}P^{*\dagger}_\delta$ + H.c.			203	I	$\varepsilon^{\mu\nu\lambda\rho}P\langle u_\mu\nabla_\nu f_{-\lambda}{}^\sigma\rangle D_\sigma P^{*\dagger}_\rho$ + H.c.			528	I
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu\langle u_\nu u_\lambda h_\rho{}^\sigma\rangle P^{*\dagger}_\sigma$ + H.c.			204	I	$\varepsilon^{\mu\nu\lambda\rho}P\langle u_\mu\nabla^\sigma f_{-\nu\sigma}\rangle D_\lambda P^{*\dagger}_\rho$ + H.c.			529	I
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu\langle u_\nu u_\lambda h^{\sigma\delta}\rangle D_{\rho\sigma}P^{*\dagger}_\delta$ + H.c.			205	I	$\varepsilon^{\mu\nu\lambda\rho}P\langle u_\mu\nabla^\sigma f_{-\nu}{}^\delta\rangle D_{\lambda\sigma\delta}P^{*\dagger}_\rho$ + H.c.			530	I
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu\langle u_\nu u_\lambda h^{\sigma\delta}\rangle D_{\sigma\delta}P^{*\dagger}_\rho$			206	I	$\varepsilon^{\mu\nu\lambda\rho}P\langle u_\mu\nabla_\nu h^{\sigma\delta}\rangle D_{\lambda\sigma\delta}P^{*\dagger}_\rho$ + H.c.			531	I
$P^{*\mu}\langle u_\mu\nabla^\nu f_{-\nu}{}^\lambda\rangle P^{*\dagger}_\lambda$ + H.c.	93	I	207	I	$\varepsilon^{\mu\nu\lambda\rho}P\langle f_{-\mu\nu}h_\lambda{}^\sigma\rangle D_\rho P^{*\dagger}_\sigma$ + H.c.			532	I
$P^{*\mu}\langle u^\nu\nabla_\mu f_{-\nu}{}^\lambda\rangle P^{*\dagger}_\lambda$ + H.c.	94	I	208	I	$\varepsilon^{\mu\nu\lambda\rho}P\langle f_{-\mu\nu}h_\lambda{}^\sigma\rangle D_\sigma P^{*\dagger}_\rho$ + H.c.			533	I
$P^{*\mu}\langle u^\nu\nabla^\lambda f_{-\nu\lambda}\rangle P^{*\dagger}_\mu$	95		209		$\varepsilon^{\mu\nu\lambda\rho}P\langle f_{-\mu\nu}h^{\sigma\delta}\rangle D_{\lambda\sigma\delta}P^{*\dagger}_\rho$ + H.c.			534	I
$P^{*\mu}\langle u_\mu\nabla^\nu f_-{}^{\lambda\rho}\rangle D_{\nu\lambda}P^{*\dagger}_\rho$ + H.c.	96	I	210	I	$P\nabla^\mu\nabla_\mu f_-{}^{\nu\lambda}D_\nu P^{*\dagger}_\lambda$ + H.c.	306	I	535	I
$P^{*\mu}\langle u^\nu\nabla_\mu f_-{}^{\lambda\rho}\rangle D_{\nu\lambda}P^{*\dagger}_\rho$ + H.c.	97	I	211	I	$P\nabla^\mu\nabla^\nu f_{-\mu}{}^\lambda D_\nu P^{*\dagger}_\lambda$ + H.c.	307	I	536	I
$P^{*\mu}\langle u^\nu\nabla^\lambda f_{-\nu}{}^\rho\rangle D_{\lambda\rho}P^{*\dagger}_\mu$	98		212		$P\nabla^\mu\nabla^\nu f_-{}^{\lambda\rho}D_{\mu\nu\lambda}P^{*\dagger}_\rho$ + H.c.	308	I	537	I
$P^{*\mu}\langle u^\nu\nabla^\lambda f_{-\lambda}{}^\rho\rangle D_{\nu\rho}P^{*\dagger}_\mu$	99		213		$P\nabla^\mu\nabla^\nu h^{\lambda\rho}D_{\mu\nu\lambda}P^{*\dagger}_\rho$ + H.c.	309	I	538	I
$P^{*\mu}\langle u^\nu\nabla_\nu h_\nu{}^\lambda\rangle P^{*\dagger}_\lambda$ + H.c.	100	I	214	I	$i\varepsilon^{\mu\nu\lambda\rho}Pf_{+\mu\nu}u_\lambda u^\sigma D_\rho P^{*\dagger}_\sigma$ + H.c.	310		539	
$P^{*\mu}\langle u_\mu\nabla^\nu h^{\lambda\rho}\rangle D_{\nu\lambda}P^{*\dagger}_\rho$ + H.c.	101	I	215	I	$i\varepsilon^{\mu\nu\lambda\rho}Pf_{+\mu\nu}u_\lambda u^\sigma D_\sigma P^{*\dagger}_\rho$ + H.c.	311		540	
$P^{*\mu}\langle u^\nu\nabla_\mu h^{\lambda\rho}\rangle D_{\nu\lambda}P^{*\dagger}_\rho$ + H.c.	102	I	216	I	$i\varepsilon^{\mu\nu\lambda\rho}Pf_{+\mu\nu}u^\sigma u_\lambda D_\rho P^{*\dagger}_\sigma$ + H.c.	312		541	
$P^{*\mu}\langle u^\nu\nabla_\nu h^{\lambda\rho}\rangle D_{\lambda\rho}P^{*\dagger}_\mu$	103		217		$i\varepsilon^{\mu\nu\lambda\rho}Pf_{+\mu\nu}u^\sigma u_\lambda D_\sigma P^{*\dagger}_\rho$ + H.c.	313		542	
$P^{*\mu}\langle u^\nu\nabla^\lambda h^{\rho\sigma}\rangle D_{\nu\lambda\rho\sigma}P^{*\dagger}_\mu$	104		218		$i\varepsilon^{\mu\nu\lambda\rho}Pf_{+\mu\nu}u^\sigma u_\sigma D_\lambda P^{*\dagger}_\rho$ + H.c.	314		543	
$P^{*\mu}\langle f_{-\mu}{}^\nu h_\nu{}^\lambda\rangle P^{*\dagger}_\lambda$ + H.c.	105	I	219	I	$i\varepsilon^{\mu\nu\lambda\rho}Pf_{+\mu\nu}u^\sigma u^\delta D_{\lambda\sigma\delta}P^{*\dagger}_\rho$ + H.c.	315		544	
$P^{*\mu}\langle f_{-\mu}{}^\nu h^{\lambda\rho}\rangle D_{\nu\lambda}P^{*\dagger}_\rho$ + H.c.	106	I	220	I	$i\varepsilon^{\mu\nu\lambda\rho}Pu_\mu f_{+\nu\lambda}u^\sigma D_\rho P^{*\dagger}_\sigma$ + H.c.	316		545	
$P^{*\mu}\langle f_-{}^{\nu\lambda}h_\nu{}^\rho\rangle D_{\lambda\rho}P^{*\dagger}_\mu$	107		221		$i\varepsilon^{\mu\nu\lambda\rho}Pu_\mu f_{+\nu\lambda}u^\sigma D_\sigma P^{*\dagger}_\rho$ + H.c.	317		546	
$P^{*\mu}\langle h_\mu{}^\nu h_\nu{}^\lambda\rangle P^{*\dagger}_\lambda$	108	I	222	I	$i\varepsilon^{\mu\nu\lambda\rho}Pu_\mu f_{+\nu}{}^\sigma u_\lambda D_\rho P^{*\dagger}_\sigma$ + H.c.	318		547	
$P^{*\mu}\langle h^{\nu\lambda}h_{\nu\lambda}\rangle P^{*\dagger}_\mu$	109		223		$i\varepsilon^{\mu\nu\lambda\rho}Pu_\mu f_{+\nu}{}^\sigma u_\lambda D_\sigma P^{*\dagger}_\rho$ + H.c.	319		548	
$P^{*\mu}\langle h_\mu{}^\nu h^{\lambda\rho}\rangle D_{\nu\lambda}P^{*\dagger}_\rho$	110	I	224	I	$i\varepsilon^{\mu\nu\lambda\rho}Pu_\mu f_{+\nu}{}^\sigma u_\sigma D_\lambda P^{*\dagger}_\rho$ + H.c.	320		549	
$P^{*\mu}\langle h_\mu{}^\nu h^{\lambda\rho}\rangle D_{\lambda\rho}P^{*\dagger}_\nu$	111	I	225	I	$i\varepsilon^{\mu\nu\lambda\rho}Pu_\mu f_{+\nu}{}^\sigma u^\delta D_{\lambda\sigma\delta}P^{*\dagger}_\rho$ + H.c.	321		550	
$P^{*\mu}\langle h^{\nu\lambda}h_\nu{}^\rho\rangle D_{\lambda\rho}P^{*\dagger}_\mu$	112		226		$i\varepsilon^{\mu\nu\lambda\rho}Pu_\mu u_\nu f_{+\lambda}{}^\sigma D_\rho P^{*\dagger}_\sigma$ + H.c.	322		551	
$P^{*\mu}\langle h^{\nu\lambda}h^{\rho\sigma}\rangle D_{\nu\lambda\rho\sigma}P^{*\dagger}_\mu$	113		227		$i\varepsilon^{\mu\nu\lambda\rho}Pu_\mu u_\nu f_{+\lambda}{}^\sigma D_\sigma P^{*\dagger}_\rho$ + H.c.	323		552	
$P^{*\mu}u_\mu\nabla^\nu f_{-\nu}{}^\lambda P^{*\dagger}_\lambda$ + H.c.	114		228	I	$i\varepsilon^{\mu\nu\lambda\rho}P\langle f_{+\mu\nu}\rangle u_\lambda u^\sigma D_\rho P^{*\dagger}_\sigma$ + H.c.	324			
$P^{*\mu}u^\nu\nabla_\mu f_{-\nu}{}^\lambda P^{*\dagger}_\lambda$ + H.c.	115		229	I	$i\varepsilon^{\mu\nu\lambda\rho}P\langle f_{+\mu\nu}\rangle u_\lambda u^\sigma D_\sigma P^{*\dagger}_\rho$ + H.c.	325			
$P^{*\mu}u^\nu\nabla_\nu f_{-\mu}{}^\lambda P^{*\dagger}_\lambda$ + H.c.			230	I	$i\varepsilon^{\mu\nu\lambda\rho}P\langle f_{+\mu\nu}\rangle u^\sigma u_\sigma D_\lambda P^{*\dagger}_\rho$ + H.c.	326			
$P^{*\mu}u^\nu\nabla^\lambda f_{-\mu\lambda}P^{*\dagger}_\nu$ + H.c.			231		$i\varepsilon^{\mu\nu\lambda\rho}P\langle f_{+\mu\nu}\rangle u^\sigma u^\delta D_{\lambda\sigma\delta}P^{*\dagger}_\rho$ + H.c.	327			
$P^{*\mu}u^\nu\nabla^\lambda f_{-\nu\lambda}P^{*\dagger}_\mu$ + H.c.			232		$i\varepsilon^{\mu\nu\lambda\rho}Pu_\mu u^\sigma f_{+\nu\lambda}D_\rho P^{*\dagger}_\sigma$ + H.c.			553	
$P^{*\mu}u_\mu\nabla^\nu f_-{}^{\lambda\rho}D_{\nu\lambda}P^{*\dagger}_\rho$ + H.c.	116		233	I	$i\varepsilon^{\mu\nu\lambda\rho}Pu_\mu u^\sigma f_{+\nu\lambda}D_\sigma P^{*\dagger}_\rho$ + H.c.			554	

(Table continued)

TABLE IX. *(Continued)*

O_n	SU(2)	$\tilde{c}_n^{(4)}$	SU(3)	$\tilde{C}_n^{(4)}$	O_n	SU(2)	$\tilde{c}_n^{(4)}$	SU(3)	$\tilde{C}_n^{(4)}$
$P^{*\mu}u^\nu\nabla_\mu f_-^{\lambda\rho}D_{\nu\lambda}P^{*\dagger}_\rho$ + H.c.	117		234	I	$i\varepsilon^{\mu\nu\lambda\rho}Pu_\mu u^\sigma f_{+\nu\sigma}D_\lambda P^{*\dagger}_\rho$ + H.c.			555	
$P^{*\mu}u^\nu\nabla^\lambda f_{-\mu}{}^\rho D_{\nu\lambda}P^{*\dagger}_\rho$ + H.c.			235	I	$i\varepsilon^{\mu\nu\lambda\rho}Pu_\mu u^\sigma f_{+\nu}{}^\delta D_{\lambda\sigma\delta}P^{*\dagger}_\rho$ + H.c.			556	
$P^{*\mu}u^\nu\nabla^\lambda f_{-\mu}{}^\rho D_{\lambda\rho}P^{*\dagger}_\nu$ + H.c.			236		$i\varepsilon^{\mu\nu\lambda\rho}P\langle f_{+\mu\nu}u_\lambda\rangle u^\sigma D_\rho P^{*\dagger}_\sigma$ + H.c.			557	
$P^{*\mu}u^\nu\nabla^\lambda f_{-\nu}{}^\rho D_{\lambda\rho}P^{*\dagger}_\mu$ + H.c.			237		$i\varepsilon^{\mu\nu\lambda\rho}P\langle f_{+\mu\nu}u_\lambda\rangle u^\sigma D_\sigma P^{*\dagger}_\rho$ + H.c.			558	
$P^{*\mu}u^\nu\nabla^\lambda f_{-\lambda}{}^\rho D_{\nu\rho}P^{*\dagger}_\mu$ + H.c.			238		$i\varepsilon^{\mu\nu\lambda\rho}P\langle f_{+\mu\nu}u^\sigma\rangle u_\lambda D_\rho P^{*\dagger}_\sigma$ + H.c.			559	
$P^{*\mu}u^\nu\nabla_\mu h_\nu{}^\lambda P^{*\dagger}_\lambda$ + H.c.			239	I	$i\varepsilon^{\mu\nu\lambda\rho}P\langle f_{+\mu\nu}u^\sigma\rangle u_\lambda D_\sigma P^{*\dagger}_\rho$ + H.c.			560	
$P^{*\mu}u_\mu\nabla^\nu h^{\lambda\rho}D_{\nu\lambda}P^{*\dagger}_\rho$ + H.c.	118		240		$i\varepsilon^{\mu\nu\lambda\rho}P\langle f_{+\mu\nu}u^\sigma\rangle u_\sigma D_\lambda P^{*\dagger}_\rho$ + H.c.			561	
$P^{*\mu}u^\nu\nabla_\mu h^{\lambda\rho}D_{\nu\lambda}P^{*\dagger}_\rho$ + H.c.			241	I	$i\varepsilon^{\mu\nu\lambda\rho}P\langle f_{+\mu\nu}u^\sigma\rangle u^\delta D_{\lambda\sigma\delta}P^{*\dagger}_\rho$ + H.c.			562	
$P^{*\mu}u^\nu\nabla_\mu h^{\lambda\rho}D_{\lambda\rho}P^{*\dagger}_\nu$ + H.c.			242		$i\varepsilon^{\mu\nu\lambda\rho}P\langle f_{+\mu\nu}u_\lambda u^\sigma\rangle D_\rho P^{*\dagger}_\sigma$ + H.c.			563	
$P^{*\mu}u^\nu\nabla_\nu h^{\lambda\rho}D_{\lambda\rho}P^{*\dagger}_\mu$ + H.c.			243		$i\varepsilon^{\mu\nu\lambda\rho}P\langle f_{+\mu\nu}u_\lambda u^\sigma\rangle D_\sigma P^{*\dagger}_\rho$ + H.c.			564	
$P^{*\mu}u^\nu\nabla^\lambda h^{\rho\sigma}D_{\nu\lambda\rho\sigma}P^{*\dagger}_\mu$ + H.c.			244		$i\varepsilon^{\mu\nu\lambda\rho}P\langle f_{+\mu\nu}u^\sigma u_\lambda\rangle D_\rho P^{*\dagger}_\sigma$ + H.c.			565	
$P^{*\mu}f_{-\mu}{}^\nu f_{-\nu}{}^\lambda P^{*\dagger}_\lambda$	119	I	245	I	$i\varepsilon^{\mu\nu\lambda\rho}P\langle f_{+\mu\nu}u^\sigma u_\lambda\rangle D_\sigma P^{*\dagger}_\rho$ + H.c.			566	
$P^{*\mu}f_-^{\nu\lambda}f_{-\mu\nu}P^{*\dagger}_\lambda$			246		$i\varepsilon^{\mu\nu\lambda\rho}P\langle f_{+\mu\nu}u^\sigma u_\sigma\rangle D_\lambda P^{*\dagger}_\rho$ + H.c.			567	
$P^{*\mu}f_-^{\nu\lambda}f_{-\nu\lambda}P^{*\dagger}_\mu$			247		$i\varepsilon^{\mu\nu\lambda\rho}P\langle f_{+\mu\nu}u^\sigma u^\delta\rangle D_{\lambda\sigma\delta}P^{*\dagger}_\rho$ + H.c.			568	
$P^{*\mu}f_{-\mu}{}^\nu f_-^{\lambda\rho}D_{\nu\lambda}P^{*\dagger}_\rho$	120	I	248	I	$iPf_+{}^{\mu\nu}f_{-\mu}{}^\lambda D_\nu P^{*\dagger}_\lambda$ + H.c.	328		569	
$P^{*\mu}f_-^{\nu\lambda}f_{-\mu}{}^\rho D_{\nu\rho}P^{*\dagger}_\lambda$			249		$iPf_+{}^{\mu\nu}f_{-\mu}{}^\lambda D_\lambda P^{*\dagger}_\nu$ + H.c.	329		570	
$P^{*\mu}f_-^{\nu\lambda}f_{-\nu}{}^\rho D_{\lambda\rho}P^{*\dagger}_\mu$			250		$iPf_-{}^{\mu\nu}f_{+\mu}{}^\lambda D_\nu P^{*\dagger}_\lambda$ + H.c.	330		571	
$P^{*\mu}f_{-\mu}{}^\nu h_\nu{}^\lambda P^{*\dagger}_\lambda$ + H.c.	121		251	I	$iPf_-{}^{\mu\nu}f_{+\mu}{}^\lambda D_\lambda P^{*\dagger}_\nu$ + H.c.	331		572	
$P^{*\mu}f_-^{\nu\lambda}h_{\mu\nu}P^{*\dagger}_\lambda$ + H.c.			252		$iPf_+{}^{\mu\nu}h_\mu{}^\lambda D_\nu P^{*\dagger}_\lambda$ + H.c.	332		573	
$P^{*\mu}f_{-\mu}{}^\nu h^{\lambda\rho}D_{\nu\lambda}P^{*\dagger}_\rho$ + H.c.	122		253	I	$iPf_+{}^{\mu\nu}h_\mu{}^\lambda D_\lambda P^{*\dagger}_\nu$ + H.c.	333		574	
$P^{*\mu}f_{-\mu}{}^\nu h^{\lambda\rho}D_{\lambda\rho}P^{*\dagger}_\nu$ + H.c.	123	I	254	I	$iPh^{\mu\nu}f_{+\mu}{}^\lambda D_\nu P^{*\dagger}_\lambda$ + H.c.	334		575	
$P^{*\mu}f_-^{\nu\lambda}h_\mu{}^\rho D_{\nu\rho}P^{*\dagger}_\lambda$ + H.c.			255		$iPh^{\mu\nu}f_{+\mu}{}^\lambda D_\lambda P^{*\dagger}_\nu$ + H.c.	335		576	
$P^{*\mu}f_-^{\nu\lambda}h_\nu{}^\rho D_{\lambda\rho}P^{*\dagger}_\mu$ + H.c.			256		$iPf_+{}^{\mu\nu}h^{\lambda\rho}D_{\mu\lambda\rho}P^{*\dagger}_\nu$ + H.c.	336		577	
$P^{*\mu}h_\mu{}^\nu h_\nu{}^\lambda P^{*\dagger}_\lambda$	124		257	I	$iPh^{\mu\nu}f_+{}^{\lambda\rho}D_{\mu\nu\lambda}P^{*\dagger}_\rho$ + H.c.	337		578	
$P^{*\mu}h^{\nu\lambda}h_{\mu\nu}P^{*\dagger}_\lambda$			258		$iP\nabla^\mu f_{+\mu}{}^\nu u^\lambda D_\nu P^{*\dagger}_\lambda$ + H.c.	338		579	
$P^{*\mu}h^{\nu\lambda}h_{\nu\lambda}P^{*\dagger}_\mu$			259		$iP\nabla^\mu f_{+\mu}{}^\nu u^\lambda D_\lambda P^{*\dagger}_\nu$ + H.c.	339		580	
$P^{*\mu}h_\mu{}^\nu h^{\lambda\rho}D_{\nu\lambda}P^{*\dagger}_\rho$	125		260	I	$iP\nabla^\mu f_+{}^{\nu\lambda}u_\mu D_\nu P^{*\dagger}_\lambda$ + H.c.	340		581	
$P^{*\mu}h_\mu{}^\nu h^{\lambda\rho}D_{\lambda\rho}P^{*\dagger}_\nu$ + H.c.			261	I	$iP\nabla^\mu f_+{}^{\nu\lambda}u_\nu D_\mu P^{*\dagger}_\lambda$ + H.c.	341		582	
$P^{*\mu}h^{\nu\lambda}h_\mu{}^\rho D_{\nu\rho}P^{*\dagger}_\lambda$			262		$iPu^\mu\nabla_\mu f_+{}^{\nu\lambda}D_\nu P^{*\dagger}_\lambda$ + H.c.	342		583	
$P^{*\mu}h^{\nu\lambda}h_\nu{}^\rho D_{\lambda\rho}P^{*\dagger}_\mu$			263		$iPu^\mu\nabla^\nu f_{+\mu}{}^\lambda D_\nu P^{*\dagger}_\lambda$ + H.c.	343		584	
$P^{*\mu}h^{\nu\lambda}h^{\rho\sigma}D_{\nu\lambda\rho\sigma}P^{*\dagger}_\mu$			264		$iPu^\mu\nabla^\nu f_{+\nu}{}^\lambda D_\mu P^{*\dagger}_\lambda$ + H.c.	344		585	
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu\nabla_\nu\nabla^\sigma f_{-\lambda}{}^\delta D_{\rho\sigma}P^{*\dagger}_\delta$ + H.c.	126	I	265	I	$iPu^\mu\nabla^\nu f_{+\nu}{}^\lambda D_\lambda P^{*\dagger}_\mu$ + H.c.	345		586	
$\varepsilon^{\mu\nu\lambda\rho}P^*_\mu\nabla^\sigma\nabla^\delta f_{-\nu\lambda}D_{\rho\sigma}P^{*\dagger}_\delta$ + H.c.	127	I	266	I	$iP\nabla^\mu f_+{}^{\nu\lambda}u^\rho D_{\mu\nu\rho}P^{*\dagger}_\lambda$ + H.c.	346		587	
$iP^{*\mu}\langle f_{+\mu}{}^\nu\rangle u_\nu u^\lambda P^{*\dagger}_\lambda$ + H.c.	128	I			$iPu^\mu\nabla^\nu f_+{}^{\lambda\rho}D_{\mu\nu\lambda}P^{*\dagger}_\rho$ + H.c.	347		588	
$iP^{*\mu}\langle f_{+\mu}{}^\nu\rangle u^\lambda u_\nu P^{*\dagger}_\lambda$ + H.c.	129				$iP\langle f_+{}^{\mu\nu}\rangle f_{-\mu}{}^\lambda D_\nu P^{*\dagger}_\lambda$ + H.c.	348			
$iP^{*\mu}\langle f_{+\mu}{}^\nu\rangle u^\lambda u_\lambda P^{*\dagger}_\nu$	130	I			$iP\langle f_+{}^{\mu\nu}\rangle h_\mu{}^\lambda D_\nu P^{*\dagger}_\lambda$ + H.c.	349			
$iP^{*\mu}\langle f_+{}^{\nu\lambda}\rangle u_\nu u_\lambda P^{*\dagger}_\mu$	131				$iP\langle f_+{}^{\mu\nu}\rangle h_\mu{}^\lambda D_\lambda P^{*\dagger}_\nu$ + H.c.	350			
$iP^{*\mu}\langle f_{+\mu}{}^\nu\rangle u^\lambda u^\rho D_{\nu\lambda}P^{*\dagger}_\rho$ + H.c.	132	I			$iP\langle f_+{}^{\mu\nu}\rangle h^{\lambda\rho}D_{\mu\lambda\rho}P^{*\dagger}_\nu$ + H.c.	351			
$iP^{*\mu}\langle f_{+\mu}{}^\nu\rangle u^\lambda u^\rho D_{\nu\rho}P^{*\dagger}_\lambda$ + H.c.	133				$iP\langle\nabla^\mu f_{+\mu}{}^\nu\rangle u^\lambda D_\nu P^{*\dagger}_\lambda$ + H.c.	352			
$iP^{*\mu}\langle f_{+\mu}{}^\nu\rangle u^\lambda u^\rho D_{\lambda\rho}P^{*\dagger}_\nu$	134	I			$iP\langle\nabla^\mu f_{+\mu}{}^\nu\rangle u^\lambda D_\lambda P^{*\dagger}_\nu$ + H.c.	353			
$iP^{*\mu}\langle f_+{}^{\nu\lambda}\rangle u_\nu u^\rho D_{\lambda\rho}P^{*\dagger}_\mu$ + H.c.	135				$iP\langle\nabla^\mu f_+{}^{\nu\lambda}\rangle u_\mu D_\nu P^{*\dagger}_\lambda$ + H.c.	354			
$iP^{*\mu}\langle f_{+\mu}{}^\nu u_\nu\rangle u^\lambda P^{*\dagger}_\lambda$ + H.c.	136	I	267	I	$iP\langle\nabla^\mu f_+{}^{\nu\lambda}\rangle u_\nu D_\mu P^{*\dagger}_\lambda$ + H.c.	355			
$iP^{*\mu}\langle f_{+\mu}{}^\nu u^\lambda\rangle u_\nu P^{*\dagger}_\lambda$ + H.c.	137	I	268	I	$iP\langle\nabla^\mu f_+{}^{\nu\lambda}\rangle u^\rho D_{\mu\nu\rho}P^{*\dagger}_\lambda$ + H.c.	356			
$iP^{*\mu}\langle f_{+\mu}{}^\nu u^\lambda\rangle u_\lambda P^{*\dagger}_\nu$	138	I	269	I	$iP\langle f_+{}^{\mu\nu}f_{-\mu}{}^\lambda\rangle D_\nu P^{*\dagger}_\lambda$ + H.c.			589	
$iP^{*\mu}\langle f_{+\mu}{}^\nu u^\lambda\rangle u^\rho D_{\nu\lambda}P^{*\dagger}_\rho$ + H.c.	139	I	270	I	$iP\langle f_+{}^{\mu\nu}h_\mu{}^\lambda\rangle D_\nu P^{*\dagger}_\lambda$ + H.c.			590	
$iP^{*\mu}\langle f_{+\mu}{}^\nu u^\lambda\rangle u^\rho D_{\nu\rho}P^{*\dagger}_\lambda$ + H.c.	140	I	271	I	$iP\langle f_+{}^{\mu\nu}h_\mu{}^\lambda\rangle D_\lambda P^{*\dagger}_\nu$ + H.c.			591	
$iP^{*\mu}\langle f_{+\mu}{}^\nu u^\lambda\rangle u^\rho D_{\lambda\rho}P^{*\dagger}_\nu$	141	I	272	I	$iP\langle f_+{}^{\mu\nu}h^{\lambda\rho}\rangle D_{\mu\lambda\rho}P^{*\dagger}_\nu$ + H.c.			592	
$iP^{*\mu}\langle f_{+\mu}{}^\nu u_\nu u^\lambda\rangle P^{*\dagger}_\lambda$ + H.c.	142	I	273	I	$iP\langle\nabla^\mu f_{+\mu}{}^\nu u^\lambda\rangle D_\nu P^{*\dagger}_\lambda$ + H.c.			593	

(Table continued)

TABLE IX. *(Continued)*

O_n	$SU(2)$	$\tilde{c}_n^{(4)}$	$SU(3)$	$\tilde{C}_n^{(4)}$	O_n	$SU(2)$	$\tilde{c}_n^{(4)}$	$SU(3)$	$\tilde{C}_n^{(4)}$
$iP^{*\mu}\langle f_{+\mu}{}^\nu u^\lambda u_\nu\rangle P^{*\dagger}{}_\lambda$ + H.c.			274		$iP\langle\nabla^\mu f_{+\mu}{}^\nu u^\lambda\rangle D_\lambda P^{*\dagger}{}_\nu$ + H.c.			594	
$iP^{*\mu}\langle f_{+\mu}{}^\nu u^\lambda u_\lambda\rangle P^{*\dagger}{}_\nu$			275	I	$iP\langle\nabla^\mu f_+{}^{\nu\lambda}u_\mu\rangle D_\nu P^{*\dagger}{}_\lambda$ + H.c.			595	
$iP^{*\mu}\langle f_+{}^{\nu\lambda}u_\nu u_\lambda\rangle P^{*\dagger}{}_\mu$	143		276		$iP\langle\nabla^\mu f_+{}^{\nu\lambda}u_\nu\rangle D_\mu P^{*\dagger}{}_\lambda$ + H.c.			596	
$iP^{*\mu}\langle f_+{}^\nu u^\lambda u^\rho\rangle D_{\nu\lambda}P^{*\dagger}{}_\rho$ + H.c.	144	I	277	I	$iP\langle\nabla^\mu f_+{}^{\nu\lambda}u^\rho\rangle D_{\mu\nu}P^{*\dagger}{}_\lambda$ + H.c.			597	
$iP^{*\mu}\langle f_+{}^\nu u^\lambda u^\rho\rangle D_{\nu\rho}P^{*\dagger}{}_\lambda$ + H.c.			278		$i\varepsilon^{\mu\nu\lambda\rho}P\nabla_\mu\nabla^\sigma f_{+\nu\sigma}D_\lambda P^{*\dagger}{}_\rho$ + H.c.	357		598	
$iP^{*\mu}\langle f_+{}^\nu u^\lambda u^\rho\rangle D_{\lambda\rho}P^{*\dagger}{}_\nu$			279	I	$i\varepsilon^{\mu\nu\lambda\rho}P\nabla_\mu\nabla^\sigma f_{+\nu}{}^\delta D_{\lambda\sigma\delta}P^{*\dagger}{}_\rho$ + H.c.	358		599	
$iP^{*\mu}\langle f_+{}^{\nu\lambda}u_\nu u^\rho\rangle D_{\lambda\rho}P^{*\dagger}{}_\mu$ + H.c.	145		280		$\varepsilon^{\mu\nu\lambda\rho}Pf_{+\mu\nu}f_{+\lambda}{}^\sigma D_\rho P^{*\dagger}{}_\sigma$ + H.c.	359		600	
$iP^{*\mu}\langle u_\mu u^\nu\rangle f_{+\nu}{}^\lambda P^{*\dagger}{}_\lambda$ + H.c.	146	I	281	I	$\varepsilon^{\mu\nu\lambda\rho}Pf_{+\mu\nu}f_{+\lambda}{}^\sigma D_\sigma P^{*\dagger}{}_\rho$ + H.c.	360		601	
$iP^{*\mu}\langle u^\nu u_\nu\rangle f_{+\mu}{}^\lambda P^{*\dagger}{}_\lambda$	147	I	282	I	$\varepsilon^{\mu\nu\lambda\rho}P\langle f_{+\mu\nu}\rangle f_{+\lambda}{}^\sigma D_\rho P^{*\dagger}{}_\sigma$ + H.c.	361	I		
$iP^{*\mu}\langle u_\mu u^\nu\rangle f_+{}^{\lambda}D_{\nu\lambda}P^{*\dagger}{}_\rho$ + H.c.	148	I	283	I	$\varepsilon^{\mu\nu\lambda\rho}P\langle f_{+\mu\nu}\rangle f_{+\lambda}{}^\sigma D_\sigma P^{*\dagger}{}_\rho$ + H.c.	362	I		
$iP^{*\mu}\langle u^\nu u^\lambda\rangle f_{+\mu}{}^\rho D_{\nu\lambda}P^{*\dagger}{}_\rho$	149	I	284	I	$\varepsilon^{\mu\nu\lambda\rho}Pu_\mu u_\nu\chi_+ D_\lambda P^{*\dagger}{}_\rho$ + H.c.	363		602	
$iP^{*\mu}f_{+\mu}{}^\nu u_\nu u^\lambda P^{*\dagger}{}_\lambda$ + H.c.			285	I	$\varepsilon^{\mu\nu\lambda\rho}Pu_\mu\chi_+ u_\nu D_\lambda P^{*\dagger}{}_\rho$ + H.c.	364		603	
$iP^{*\mu}f_{+\mu}{}^\nu u^\lambda u_\nu P^{*\dagger}{}_\lambda$ + H.c.			286	I	$\varepsilon^{\mu\nu\lambda\rho}P\chi_+ u_\mu u_\nu D_\lambda P^{*\dagger}{}_\rho$ + H.c.	365		604	
$iP^{*\mu}f_{+\mu}{}^\nu u^\lambda u_\lambda P^{*\dagger}{}_\nu$ + H.c.			287	I	$\varepsilon^{\mu\nu\lambda\rho}P\langle u_\mu u_\nu\chi_+\rangle D_\lambda P^{*\dagger}{}_\rho$ + H.c.			605	
$iP^{*\mu}f_+{}^{\nu\lambda}u_\mu u_\nu P^{*\dagger}{}_\lambda$ + H.c.			288		$\varepsilon^{\mu\nu\lambda\rho}P\langle u_\mu\chi_+\rangle u_\nu D_\lambda P^{*\dagger}{}_\rho$ + H.c.			606	I
$iP^{*\mu}f_+{}^{\nu\lambda}u_\nu u_\mu P^{*\dagger}{}_\lambda$ + H.c.			289		$\varepsilon^{\mu\nu\lambda\rho}P\langle\chi_+\rangle u_\mu u_\nu D_\lambda P^{*\dagger}{}_\rho$ + H.c.			607	
$iP^{*\mu}f_+{}^{\nu\lambda}u_\nu u_\lambda P^{*\dagger}{}_\mu$ + H.c.			290		$Pf_-{}^{\mu\nu}\chi_+ D_\mu P^{*\dagger}{}_\nu$ + H.c.	366		608	
$iP^{*\mu}f_{+\mu}{}^\nu u^\lambda u^\rho D_{\nu\lambda}P^{*\dagger}{}_\rho$ + H.c.			291	I	$P\chi_+ f_-{}^{\mu\nu}D_\mu P^{*\dagger}{}_\nu$ + H.c.	367		609	
$iP^{*\mu}f_{+\mu}{}^\nu u^\lambda u^\rho D_{\nu\rho}P^{*\dagger}{}_\lambda$ + H.c.			292	I	$Ph^{\mu\nu}\chi_+ D_\mu P^{*\dagger}{}_\nu$ + H.c.	368		610	
$iP^{*\mu}f_{+\mu}{}^\nu u^\lambda u^\rho D_{\lambda\rho}P^{*\dagger}{}_\nu$ + H.c.			293	I	$P\chi_+ h^{\mu\nu}D_\mu P^{*\dagger}{}_\nu$ + H.c.	369		611	
$iP^{*\mu}f_+{}^{\nu\lambda}u_\mu u^\rho D_{\nu\rho}P^{*\dagger}{}_\lambda$ + H.c.			294		$Pu^\mu\nabla^\nu\chi_+ D_\mu P^{*\dagger}{}_\nu$ + H.c.	370		612	
$iP^{*\mu}f_+{}^{\nu\lambda}u_\nu u^\rho D_{\lambda\rho}P^{*\dagger}{}_\mu$ + H.c.			295		$Pu^\mu\nabla^\nu\chi_+ D_\nu P^{*\dagger}{}_\mu$ + H.c.	371		613	
$iP^{*\mu}f_+{}^{\nu\lambda}u^\rho u_\mu D_{\nu\rho}P^{*\dagger}{}_\lambda$ + H.c.			296		$P\nabla^\nu\chi_+ u^\mu D_\mu P^{*\dagger}{}_\nu$ + H.c.	372		614	
$iP^{*\mu}f_+{}^{\nu\lambda}u^\rho u_\nu D_{\lambda\rho}P^{*\dagger}{}_\mu$ + H.c.			297		$P\nabla^\mu\chi_+ u^\nu D_\nu P^{*\dagger}{}_\mu$ + H.c.	373		615	
$iP^{*\mu}u_\mu f_+{}^{\nu\lambda}u_\nu P^{*\dagger}{}_\lambda$ + H.c.			298	I	$P\langle f_-{}^{\mu\nu}\chi_+\rangle D_\mu P^{*\dagger}{}_\nu$ + H.c.	374	I	616	I
$iP^{*\mu}u^\nu f_{+\nu}{}^\lambda u_\lambda P^{*\dagger}{}_\mu$			299		$P\langle\chi_+\rangle f_-{}^{\mu\nu}D_\mu P^{*\dagger}{}_\nu$ + H.c.			617	I
$iP^{*\mu}u_\mu f_+{}^{\nu\lambda}u^\rho D_{\nu\rho}P^{*\dagger}{}_\lambda$ + H.c.			300		$P\langle h^{\mu\nu}\chi_+\rangle D_\mu P^{*\dagger}{}_\nu$ + H.c.	375	I	618	I
$iP^{*\mu}u^\nu f_{+\nu}{}^\lambda u^\rho D_{\lambda\rho}P^{*\dagger}{}_\mu$ + H.c.			301		$P\langle\chi_+\rangle h^{\mu\nu}D_\mu P^{*\dagger}{}_\nu$ + H.c.			619	I
$i\varepsilon^{\mu\nu\lambda\rho}P^*{}_\mu\nabla_\nu f_{+\lambda}{}^\sigma u_\rho P^{*\dagger}{}_\sigma$ + H.c.	150		302		$P\langle u^\mu\nabla^\nu\chi_+\rangle D_\mu P^{*\dagger}{}_\nu$ + H.c.	376	I	620	I
$i\varepsilon^{\mu\nu\lambda\rho}P^*{}_\mu\nabla_\nu f_{+\lambda}{}^\sigma u_\sigma P^{*\dagger}{}_\rho$ + H.c.	151	I	303	I	$P\langle\nabla^\mu\chi_+\rangle u^\nu D_\nu P^{*\dagger}{}_\mu$ + H.c.			621	I
$i\varepsilon^{\mu\nu\lambda\rho}P^*{}_\mu\nabla^\sigma f_{+\nu\sigma}u_\lambda P^{*\dagger}{}_\rho$ + H.c.	152		304	I	$P\langle u^\mu\nabla^\nu\chi_+\rangle D_\nu P^{*\dagger}{}_\mu$ + H.c.	377	I	622	I
$i\varepsilon^{\mu\nu\lambda\rho}P^*{}_\mu\nabla_\nu f_{+\lambda}{}^\sigma u^\delta D_{\rho\sigma}P^{*\dagger}{}_\delta$ + H.c.	153		305		$P\langle\nabla^\mu\chi_+\rangle u^\nu D_\mu P^{*\dagger}{}_\nu$ + H.c.			623	I
$i\varepsilon^{\mu\nu\lambda\rho}P^*{}_\mu\nabla_\nu f_{+\lambda}{}^\sigma u^\delta D_{\rho\delta}P^{*\dagger}{}_\sigma$ + H.c.	154		306		$i\varepsilon^{\mu\nu\lambda\rho}Pf_{+\mu\nu}\chi_+ D_\lambda P^{*\dagger}{}_\rho$ + H.c.	378		624	
$i\varepsilon^{\mu\nu\lambda\rho}P^*{}_\mu\nabla_\nu f_{+\lambda}{}^\sigma u^\delta D_{\sigma\delta}P^{*\dagger}{}_\rho$ + H.c.	155	I	307	I	$i\varepsilon^{\mu\nu\lambda\rho}P\chi_+ f_{+\mu\nu}D_\lambda P^{*\dagger}{}_\rho$ + H.c.	379		625	
$i\varepsilon^{\mu\nu\lambda\rho}P^*{}_\mu\nabla_\nu f_+{}^{\sigma\delta}u_\lambda D_{\rho\sigma}P^{*\dagger}{}_\delta$ + H.c.	156		308		$i\varepsilon^{\mu\nu\lambda\rho}P\langle f_{+\mu\nu}\rangle\chi_+ D_\lambda P^{*\dagger}{}_\rho$ + H.c.	380			
$i\varepsilon^{\mu\nu\lambda\rho}P^*{}_\mu\nabla_\nu f_+{}^{\sigma\delta}u_\sigma D_{\lambda\delta}P^{*\dagger}{}_\rho$ + H.c.	157	I	309	I	$i\varepsilon^{\mu\nu\lambda\rho}P\langle f_{+\mu\nu}\chi_+\rangle D_\lambda P^{*\dagger}{}_\rho$ + H.c.	381		626	
$i\varepsilon^{\mu\nu\lambda\rho}P^*{}_\mu\nabla^\sigma f_{+\nu\sigma}u^\delta D_{\lambda\delta}P^{*\dagger}{}_\rho$ + H.c.	158	I	310	I	$i\varepsilon^{\mu\nu\lambda\rho}P\langle\chi_+\rangle f_{+\mu\nu}D_\lambda P^{*\dagger}{}_\rho$ + H.c.	382		627	
$i\varepsilon^{\mu\nu\lambda\rho}P^*{}_\mu f_{+\nu\lambda}f_{-\rho}{}^\sigma P^{*\dagger}{}_\sigma$ + H.c.	159		311		$iPu^\mu u^\nu\chi_- D_\mu P^{*\dagger}{}_\nu$ + H.c.	383	I	628	
$i\varepsilon^{\mu\nu\lambda\rho}P^*{}_\mu f_{+\nu}{}^\sigma f_{-\lambda\rho}P^{*\dagger}{}_\sigma$ + H.c.	160		312		$iPu^\mu u^\nu\chi_- D_\nu P^{*\dagger}{}_\mu$ + H.c.	384		629	
$i\varepsilon^{\mu\nu\lambda\rho}P^*{}_\mu f_{+\nu}{}^\sigma f_{-\lambda\sigma}P^{*\dagger}{}_\rho$ + H.c.	161	I	313	I	$iPu^\mu\chi_- u^\nu D_\mu P^{*\dagger}{}_\nu$ + H.c.	385		630	
$i\varepsilon^{\mu\nu\lambda\rho}P^*{}_\mu f_{+\nu\lambda}f_-{}^{\sigma\delta}D_{\rho\sigma}P^{*\dagger}{}_\delta$ + H.c.	162		314		$iPu^\mu\chi_- u^\nu D_\nu P^{*\dagger}{}_\mu$ + H.c.	386		631	
$i\varepsilon^{\mu\nu\lambda\rho}P^*{}_\mu f_{+\nu}{}^\sigma f_{-\lambda}{}^\delta D_{\rho\delta}P^{*\dagger}{}_\sigma$ + H.c.	163		315		$iP\chi_- u^\mu u^\nu D_\mu P^{*\dagger}{}_\nu$ + H.c.	387		632	
$i\varepsilon^{\mu\nu\lambda\rho}P^*{}_\mu f_{+\nu}{}^\sigma f_{-\sigma}{}^\delta D_{\lambda\delta}P^{*\dagger}{}_\rho$ + H.c.	164		316	I	$iP\chi_- u^\mu u^\nu D_\nu P^{*\dagger}{}_\mu$ + H.c.			633	
$i\varepsilon^{\mu\nu\lambda\rho}P^*{}_\mu f_{+\nu\lambda}h_\rho{}^\sigma P^{*\dagger}{}_\sigma$ + H.c.	165	I	317	I	$iP\langle u^\mu u^\nu\rangle\chi_- D_\mu P^{*\dagger}{}_\nu$ + H.c.			634	I
$i\varepsilon^{\mu\nu\lambda\rho}P^*{}_\mu f_{+\nu}{}^\sigma h_{\lambda\sigma}P^{*\dagger}{}_\rho$ + H.c.	166	I	318	I	$iP\langle u^\mu u^\nu\chi_-\rangle D_\mu P^{*\dagger}{}_\nu$ + H.c.	388	I	635	
$i\varepsilon^{\mu\nu\lambda\rho}P^*{}_\mu f_{+\nu\lambda}h^{\sigma\delta}D_{\rho\sigma}P^{*\dagger}{}_\delta$ + H.c.	167		319		$iP\langle u^\mu\chi_-\rangle u^\nu D_\nu P^{*\dagger}{}_\mu$ + H.c.			636	I
$i\varepsilon^{\mu\nu\lambda\rho}P^*{}_\mu f_{+\nu\lambda}h^{\sigma\delta}D_{\sigma\delta}P^{*\dagger}{}_\rho$ + H.c.	168		320	I	$iP\langle\chi_-\rangle u^\mu u^\nu D_\mu P^{*\dagger}{}_\nu$ + H.c.			637	
$i\varepsilon^{\mu\nu\lambda\rho}P^*{}_\mu f_{+\nu}{}^\sigma h_\lambda{}^\delta D_{\rho\delta}P^{*\dagger}{}_\sigma$ + H.c.	169		321		$iP\langle u^\mu u^\nu\chi_-\rangle D_\nu P^{*\dagger}{}_\mu$ + H.c.			638	

(Table continued)

TABLE IX. *(Continued)*

O_n	$SU(2)$	$\tilde{c}_n^{(4)}$	$SU(3)$	$\tilde{C}_n^{(4)}$	O_n	$SU(2)$	$\tilde{c}_n^{(4)}$	$SU(3)$	$\tilde{C}_n^{(4)}$
$i\epsilon^{\mu\nu\lambda\rho}P^*_\mu f_{+\nu}{}^\sigma h_\sigma{}^\delta D_{\lambda\delta}P^{*\dagger}_\rho$ + H.c.	170	I	322	I	$iP\langle u^\mu\chi_-\rangle u^\nu D_\mu P^{*\dagger}_\nu$ + H.c.			639	I
$i\epsilon^{\mu\nu\lambda\rho}P^*_\mu\langle\nabla_\nu f_{+\lambda}{}^\sigma\rangle u_\rho P^{*\dagger}_\sigma$ + H.c.	171	I			$iP\langle\chi_-\rangle u^\mu u^\nu D_\nu P^{*\dagger}_\mu$ + H.c.			640	
$i\epsilon^{\mu\nu\lambda\rho}P^*_\mu\langle\nabla_\nu f_{+\lambda}{}^\sigma\rangle u_\sigma P^{*\dagger}_\rho$	172	I			$i\epsilon^{\mu\nu\lambda\rho}Pf_{-\mu\nu}\chi_- D_\lambda P^{*\dagger}_\rho$ + H.c.	389		641	
$i\epsilon^{\mu\nu\lambda\rho}P^*_\mu\langle\nabla_\nu f_{+\lambda}{}^\sigma\rangle u^\delta D_{\rho\sigma}P^{*\dagger}_\delta$ + H.c.	173	I			$i\epsilon^{\mu\nu\lambda\rho}P\chi_- f_{-\mu\nu}D_\lambda P^{*\dagger}_\rho$ + H.c.	390		642	
$i\epsilon^{\mu\nu\lambda\rho}P^*_\mu\langle\nabla_\nu f_{+\lambda}{}^\sigma\rangle u^\delta D_{\rho\delta}P^{*\dagger}_\sigma$ + H.c.	174	I			$i\epsilon^{\mu\nu\lambda\rho}Pu_\mu\nabla_\nu\chi_- D_\lambda P^{*\dagger}_\rho$ + H.c.	391		643	
$i\epsilon^{\mu\nu\lambda\rho}P^*_\mu\langle\nabla_\nu f_{+\lambda}{}^\sigma\rangle u^\delta D_{\sigma\delta}P^{*\dagger}_\rho$	175	I			$i\epsilon^{\mu\nu\lambda\rho}P\nabla_\mu\chi_- u_\nu D_\lambda P^{*\dagger}_\rho$ + H.c.	392		644	
$i\epsilon^{\mu\nu\lambda\rho}P^*_\mu\langle f_{+\nu\lambda}\rangle f_{-\rho}{}^\sigma P^{*\dagger}_\sigma$ + H.c.	176	I			$i\epsilon^{\mu\nu\lambda\rho}P\langle f_{-\mu\nu}\chi_-\rangle D_\lambda P^{*\dagger}_\rho$ + H.c.	393	I	645	I
$i\epsilon^{\mu\nu\lambda\rho}P^*_\mu\langle f_{+\nu\lambda}\rangle h_\rho{}^\sigma P^{*\dagger}_\sigma$ + H.c.	177	I			$i\epsilon^{\mu\nu\lambda\rho}P\langle\chi_-\rangle f_{-\mu\nu}D_\lambda P^{*\dagger}_\rho$ + H.c.			646	I
$i\epsilon^{\mu\nu\lambda\rho}P^*_\mu\langle f_{+\nu\lambda}\rangle h^{\sigma\delta}D_{\rho\sigma}P^{*\dagger}_\delta$ + H.c.	178	I			$i\epsilon^{\mu\nu\lambda\rho}P\langle u_\mu\nabla_\nu\chi_-\rangle D_\lambda P^{*\dagger}_\rho$ + H.c.	394	I	647	I
$i\epsilon^{\mu\nu\lambda\rho}P^*_\mu\langle f_{+\nu\lambda}\rangle h^{\sigma\delta}D_{\sigma\delta}P^{*\dagger}_\rho$	179	I			$i\epsilon^{\mu\nu\lambda\rho}P\langle\nabla_\mu\chi_-\rangle u_\nu D_\lambda P^{*\dagger}_\rho$ + H.c.			648	I
$i\epsilon^{\mu\nu\lambda\rho}P^*_\mu\langle\nabla_\nu f_{+\lambda}{}^\sigma u_\rho\rangle P^{*\dagger}_\sigma$ + H.c.			323	I	$iP\nabla^\mu\nabla^\nu\chi_- D_\mu P^{*\dagger}_\nu$ + H.c.	395	I	649	I
$i\epsilon^{\mu\nu\lambda\rho}P^*_\mu\langle\nabla_\nu f_{+\lambda}{}^\sigma u_\sigma\rangle P^{*\dagger}_\rho$			324	I	$iP\langle\nabla^\mu\nabla^\nu\chi_-\rangle D_\mu P^{*\dagger}_\nu$ + H.c.	396	I	650	I
$i\epsilon^{\mu\nu\lambda\rho}P^*_\mu\langle\nabla_\nu f_{+\lambda}{}^\sigma u^\delta\rangle D_{\rho\sigma}P^{*\dagger}_\delta$ + H.c.			325	I	$Pf_+{}^{\mu\nu}\chi_- D_\mu P^{*\dagger}_\nu$ + H.c.	397		651	
$i\epsilon^{\mu\nu\lambda\rho}P^*_\mu\langle\nabla_\nu f_{+\lambda}{}^\sigma u^\delta\rangle D_{\rho\delta}P^{*\dagger}_\sigma$ + H.c.			326	I	$P\chi_- f_+{}^{\mu\nu}D_\mu P^{*\dagger}_\nu$ + H.c.	398		652	
$i\epsilon^{\mu\nu\lambda\rho}P^*_\mu\langle\nabla_\nu f_{+\lambda}{}^\sigma u^\delta\rangle D_{\sigma\delta}P^{*\dagger}_\rho$			327	I	$P\langle f_+{}^{\mu\nu}\rangle\chi_- D_\mu P^{*\dagger}_\nu$ + H.c.	399			
$i\epsilon^{\mu\nu\lambda\rho}P^*_\mu\langle f_{+\nu\lambda}f_{-\rho}{}^\sigma\rangle P^{*\dagger}_\sigma$ + H.c.			328	I	$P\langle f_+{}^{\mu\nu}\chi_-\rangle D_\mu P^{*\dagger}_\nu$ + H.c.	400		653	
$i\epsilon^{\mu\nu\lambda\rho}P^*_\mu\langle f_{+\nu\lambda}h_\rho{}^\sigma\rangle P^{*\dagger}_\sigma$ + H.c.			329	I	$P\langle\chi_-\rangle f_+{}^{\mu\nu}D_\mu P^{*\dagger}_\nu$ + H.c.	401		654	
$i\epsilon^{\mu\nu\lambda\rho}P^*_\mu\langle f_{+\nu\lambda}h^{\sigma\delta}\rangle D_{\rho\sigma}P^{*\dagger}_\delta$ + H.c.			330	I	$i\epsilon^{\mu\nu\lambda\rho}P\langle D_\mu D^\sigma F_{L\nu\sigma}\rangle D_\lambda P^{*\dagger}_\rho$ + P. + +H.c.	402			
$i\epsilon^{\mu\nu\lambda\rho}P^*_\mu\langle f_{+\nu\lambda}h^{\sigma\delta}\rangle D_{\sigma\delta}P^{*\dagger}_\rho$			331	I	$i\epsilon^{\mu\nu\lambda\rho}P\langle D_\mu D^\sigma F_{L\nu}{}^\delta\rangle D_{\lambda\sigma\delta}P^{*\dagger}_\rho$ + P. + +H.c.	403			
$iP^{*\mu}\nabla_\mu\nabla^\nu f_{+\nu}{}^\lambda P^{*\dagger}_\lambda$ + H.c.	180	I	332	I	$iP\langle F_L{}^{\mu\nu}F_{L\mu}{}^\lambda\rangle D_\nu P^{*\dagger}_\lambda$ + P. + H.c.	404		655	
$iP^{*\mu}\nabla^\nu\nabla_\nu f_{+\mu}{}^\lambda P^{*\dagger}_\lambda$	181	I	333	I					

The long relations in the sixth column of Table VII are

$$\tilde{C}_{10}^{(3)} = -D_2^{(3)} - D_6^{(3)} + D_9^{(3)}, \qquad \tilde{C}_{11}^{(3)} = D_2^{(3)} + D_4^{(3)} + D_6^{(3)} + D_8^{(3)}, \qquad \tilde{C}_{13}^{(3)} = -2D_1^{(3)} - D_2^{(3)} - 3D_6^{(3)},$$

$$\tilde{C}_{14}^{(3)} = D_2^{(3)} + D_6^{(3)} + D_9^{(3)}, \qquad \tilde{C}_{15}^{(3)} = 2D_3^{(3)} + D_4^{(3)} + 3D_8^{(3)}, \qquad \tilde{C}_{18}^{(3)} = 2D_5^{(3)} - D_6^{(3)} - D_8^{(3)},$$

$$\tilde{C}_{53}^{(3)} = \tilde{C}_{55}^{(3)} = -2D_3^{(3)} - 2D_7^{(3)} - D_{17}^{(3)}, \qquad \tilde{C}_{54}^{(3)} = -2D_4^{(3)} - 2D_7^{(3)} + 2D_{17}^{(3)}. \tag{A2}$$

TABLE X. The $\mathcal{O}(p^4)$ order results in the HQ limit. When a term P_n is not given a label in the 2nd or 5th (3rd or 6th) column, it is not independent and can be expressed with terms having a label in the 2nd and 5th (3rd and 6th) columns.

P_n	$SU(2)$	$SU(3)$	P_n	$SU(2)$	$SU(3)$
$\langle H\langle u^\mu u_\mu\rangle u^\nu u_\nu\bar H\rangle$	1	1	$\langle H\langle f_+{}^{\mu\nu}u^\lambda\rangle u^\rho\sigma_{\mu\rho}v_\nu v_\lambda\bar H\rangle$	72	
$\langle H\langle u^\mu u^\nu\rangle u_\mu u_\nu\bar H\rangle$	2	2	$\langle H\nabla^\mu\nabla_\mu\chi_+\bar H\rangle$		111
$\langle H\langle u^\mu u_\mu\rangle u^\nu u^\lambda v_\nu v_\lambda\bar H\rangle$	3	3	$\langle H\nabla^\mu\nabla^\nu\chi_+ v_\mu v_\nu\bar H\rangle$		112
$\langle H\langle u^\mu u^\nu\rangle u_\mu u^\lambda v_\nu v_\lambda\bar H\rangle$ + H.c.	4	4	$\langle H\langle\nabla^\mu\nabla_\mu\chi_+\rangle\bar H\rangle$		113
$\langle H\langle u^\mu u^\nu\rangle u^\lambda u_\lambda v_\mu v_\nu\bar H\rangle$		5	$\langle H\langle\nabla^\mu\nabla^\nu\chi_+\rangle v_\mu v_\nu\bar H\rangle$		114
$\langle H\langle u^\mu u^\nu\rangle u^\lambda u^\rho v_\mu v_\nu v_\lambda v_\rho\bar H\rangle$	5	6	$\langle H\langle f_+{}^{\mu\nu}u_\mu u^\lambda\rangle\sigma_{\nu\lambda}\bar H\rangle$ + H.c.		115
$\langle H\langle u^\mu u_\mu u^\nu\rangle u_\nu\bar H\rangle$		7	$\langle H\langle f_+{}^{\mu\nu}u^\lambda u_\lambda\rangle\sigma_{\mu\nu}\bar H\rangle$		116
$\langle H\langle u^\mu u_\mu u^\nu\rangle u^\lambda v_\nu v_\lambda\bar H\rangle$		8	$\langle H\langle f_+{}^{\mu\nu}u^\lambda u^\rho\rangle\sigma_{\mu\nu}v_\lambda v_\rho\bar H\rangle$		117
$\langle H\langle u^\mu u^\nu u^\lambda\rangle u_\mu v_\nu v_\lambda\bar H\rangle$		9	$\langle H\langle f_+{}^{\mu\nu}u^\lambda u^\rho\rangle\sigma_{\mu\lambda}v_\nu v_\rho\bar H\rangle$ + H.c.		118
$\langle H\langle u^\mu u^\nu u^\lambda\rangle u^\rho v_\mu v_\nu v_\lambda v_\rho\bar H\rangle$		10	$i\langle Hu^\mu f_{+\mu}{}^\nu u_\nu\bar H\rangle$		119
$\langle H\langle u^\mu u_\mu u^\nu u_\nu\rangle\bar H\rangle$		11	$i\langle Hu^\mu f_{+\mu}{}^\nu u^\lambda v_\nu v_\lambda\bar H\rangle$ + H.c.		120
$\langle H\langle u^\mu u^\nu u_\mu u_\nu\rangle\bar H\rangle$		12	$\langle H\langle u^\mu u_\mu\rangle f_+{}^{\nu\lambda}\sigma_{\nu\lambda}\bar H\rangle$	73	121

(Table continued)

TABLE X. *(Continued)*

P_n	$SU(2)$	$SU(3)$	P_n	$SU(2)$	$SU(3)$
$\langle H\langle u^\mu u_\mu u^\nu u^\lambda\rangle v_\nu v_\lambda \bar H\rangle$		13	$\langle H\langle u^\mu u^\nu\rangle f_{+\mu}{}^\lambda \sigma_{\nu\lambda}\bar H\rangle$	74	122
$\langle H\langle u^\mu u^\nu u_\mu u^\lambda\rangle v_\nu v_\lambda \bar H\rangle$		14	$\langle H\langle u^\mu u^\nu\rangle f_+^{\lambda\rho}\sigma_{\mu\lambda}v_\nu v_\rho\bar H\rangle$	75	123
$\langle H\langle u^\mu u^\nu u^\lambda u^\rho\rangle v_\mu v_\nu v_\lambda v_\rho \bar H\rangle$		15	$\langle H\langle u^\mu u^\nu\rangle f_+^{\lambda\rho}\sigma_{\lambda\rho}v_\mu v_\nu\bar H\rangle$	76	124
$i\langle H\langle u^\mu u_\mu\rangle u^\nu u^\lambda \sigma_{\nu\lambda}\bar H\rangle$	6	16	$\langle Hf_+^{\mu\nu}u_\mu u^\lambda\sigma_{\nu\lambda}\bar H\rangle + \text{H.c.}$		125
$i\langle H\langle u^\mu u^\nu\rangle u_\mu u^\lambda \sigma_{\nu\lambda}\bar H\rangle + \text{H.c.}$	7	17	$\langle Hf_+^{\mu\nu}u^\lambda u_\mu\sigma_{\nu\lambda}\bar H\rangle + \text{H.c.}$		126
$i\langle H\langle u^\mu u^\nu\rangle u^\lambda u^\rho \sigma_{\mu\lambda}v_\nu v_\rho\bar H\rangle + \text{H.c.}$	8	18	$\langle Hf_+^{\mu\nu}u^\lambda u_\lambda\sigma_{\mu\nu}\bar H\rangle + \text{H.c.}$		127
$i\langle H\langle u^\mu u^\nu\rangle u^\lambda u^\rho \sigma_{\lambda\rho}v_\mu v_\nu\bar H\rangle$	9	19	$\langle Hf_+^{\mu\nu}u^\lambda u^\rho\sigma_{\mu\nu}v_\lambda v_\rho\bar H\rangle + \text{H.c.}$		128
$i\langle H\langle f_+^{\mu\nu}\rangle u_\mu u_\nu\bar H\rangle$	10		$\langle Hf_+^{\mu\nu}u^\lambda u^\rho\sigma_{\mu\lambda}v_\nu v_\rho\bar H\rangle + \text{H.c.}$		129
$i\langle H\langle f_+^{\mu\nu}\rangle u_\mu u^\lambda v_\nu v_\lambda\bar H\rangle + \text{H.c.}$	11		$\langle Hf_+^{\mu\nu}u^\lambda u^\rho\sigma_{\mu\rho}v_\nu v_\lambda\bar H\rangle + \text{H.c.}$		130
$i\langle H\langle u^\mu u^\nu u^\lambda\rangle u_\mu\sigma_{\nu\lambda}\bar H\rangle$		20	$\langle Hf_+^{\mu\nu}f_{+\mu\nu}\bar H\rangle$	77	131
$i\langle H\langle u^\mu u^\nu u^\lambda\rangle u^\rho\sigma_{\mu\nu}v_\lambda v_\rho\bar H\rangle$		21	$\langle Hf_+^{\mu\nu}f_{+\mu}{}^\lambda v_\nu v_\lambda\bar H\rangle$	78	132
$i\langle H\langle u^\mu u_\mu u^\nu u^\lambda\rangle\sigma_{\nu\lambda}\bar H\rangle$		22	$i\langle Hf_+^{\mu\nu}f_{+\mu}{}^\lambda\sigma_{\nu\lambda}\bar H\rangle$	79	133
$i\langle H\langle u^\mu u^\nu u^\lambda u^\rho\rangle\sigma_{\mu\nu}v_\lambda v_\rho\bar H\rangle$		23	$i\langle Hf_+^{\mu\nu}f_+^{\lambda\rho}\sigma_{\mu\lambda}v_\nu v_\rho\bar H\rangle$	80	134
$\langle Hu^\mu u_\mu u^\nu u_\nu\bar H\rangle$		24	$\langle H\langle f_+^{\mu\nu}\rangle f_{+\mu\nu}\bar H\rangle$	81	
$\langle Hu^\mu u^\nu u_\mu u_\nu\bar H\rangle$		25	$\langle H\langle f_+^{\mu\nu}\rangle f_{+\mu}{}^\lambda v_\nu v_\lambda\bar H\rangle$	82	
$\langle Hu^\mu u_\mu u^\nu u^\lambda v_\nu v_\lambda\bar H\rangle + \text{H.c.}$		26	$\langle H\langle f_+^{\mu\nu}f_{+\mu\nu}\rangle\bar H\rangle$		135
$\langle Hu^\mu u^\nu u_\mu u^\lambda v_\nu v_\lambda\bar H\rangle + \text{H.c.}$		27	$\langle H\langle f_+^{\mu\nu}f_{+\mu}{}^\lambda\rangle v_\nu v_\lambda\bar H\rangle$		136
$i\langle Hu^\mu u_\mu u^\nu u^\lambda\sigma_{\nu\lambda}\bar H\rangle + \text{H.c.}$		28	$\langle Hu^\mu u_\mu\chi_+\bar H\rangle + \text{H.c.}$	83	137
$i\langle Hu^\mu u^\nu u_\mu u^\lambda\sigma_{\nu\lambda}\bar H\rangle + \text{H.c.}$		29	$\langle Hu^\mu\chi_+ u_\mu\bar H\rangle$	84	138
$i\langle Hu^\mu u^\nu u^\lambda u^\rho\sigma_{\mu\nu}v_\lambda v_\rho\bar H\rangle + \text{H.c.}$		30	$\langle Hu^\mu u^\nu\chi_+ v_\mu v_\nu\bar H\rangle + \text{H.c.}$	85	139
$i\langle Hu^\mu u^\nu u^\lambda u^\rho\sigma_{\mu\lambda}v_\nu v_\rho\bar H\rangle + \text{H.c.}$		31	$\langle Hu^\mu\chi_+ u^\nu v_\mu v_\nu\bar H\rangle$	86	140
$i\langle H\langle f_+^{\mu\nu}u_\mu u_\nu\rangle\bar H\rangle$	12	32	$i\langle Hu^\mu u^\nu\chi_+\sigma_{\mu\nu}\bar H\rangle + \text{H.c.}$	87	141
$i\langle H\langle f_+^{\mu\nu}u_\mu u^\lambda\rangle v_\nu v_\lambda\bar H\rangle + \text{H.c.}$	13	33	$i\langle Hu^\mu\chi_+ u^\nu\sigma_{\mu\nu}\bar H\rangle$	88	142
$\langle H\langle f_+^{\mu\nu}\rangle u_\mu u^\lambda\sigma_{\nu\lambda}\bar H\rangle + \text{H.c.}$	14		$\langle H\langle u^\mu u_\mu\rangle\chi_+\bar H\rangle$		143
$\langle H\langle f_+^{\mu\nu}\rangle u^\lambda u_\lambda\sigma_{\mu\nu}\bar H\rangle$	15		$\langle H\langle u^\mu u_\mu\chi_+\rangle\bar H\rangle$	89	144
$\langle H\langle f_+^{\mu\nu}\rangle u^\lambda u^\rho\sigma_{\mu\nu}v_\lambda v_\rho\bar H\rangle$	16		$\langle H\langle u^\mu\chi_+\rangle u_\mu\bar H\rangle$		145
$\langle H\langle f_+^{\mu\nu}\rangle u^\lambda u^\rho\sigma_{\mu\lambda}v_\nu v_\rho\bar H\rangle + \text{H.c.}$	17		$\langle H\langle\chi_+\rangle u^\mu u_\mu\bar H\rangle$		146
$\langle H\langle f_+^{\mu\nu}\rangle h^{\lambda\rho}\gamma_5\gamma_\mu v_\nu v_\lambda v_\rho\bar H\rangle$	18		$\langle H\langle u^\mu u^\nu\rangle\chi_+ v_\mu v_\nu\bar H\rangle$		147
$i\langle Hf_+^{\mu\nu}u_\mu u_\nu\bar H\rangle + \text{H.c.}$		34	$\langle H\langle u^\mu u^\nu\chi_+\rangle v_\mu v_\nu\bar H\rangle$	90	148
$i\langle Hf_+^{\mu\nu}u_\mu u^\lambda v_\nu v_\lambda\bar H\rangle + \text{H.c.}$		35	$\langle H\langle u^\mu\chi_+\rangle u^\nu v_\mu v_\nu\bar H\rangle$		149
$i\langle Hf_+^{\mu\nu}u^\lambda u_\mu v_\nu v_\lambda\bar H\rangle + \text{H.c.}$		36	$\langle H\langle\chi_+\rangle u^\mu u^\nu v_\mu v_\nu\bar H\rangle$		150
$\langle H\langle f_+^{\mu\nu}u_\mu\rangle u^\lambda\sigma_{\nu\lambda}\bar H\rangle$		37	$i\langle H\langle u^\mu u^\nu\chi_+\rangle\sigma_{\mu\nu}\bar H\rangle$		151
$\langle H\langle f_+^{\mu\nu}u^\lambda\rangle u_\mu\sigma_{\nu\lambda}\bar H\rangle$		38	$i\langle H\langle\chi_+\rangle u^\mu u^\nu\sigma_{\mu\nu}\bar H\rangle$		152
$\langle H\langle f_+^{\mu\nu}u^\lambda\rangle u_\lambda\sigma_{\mu\nu}\bar H\rangle$		39	$\langle Hf_+^{\mu\nu}\chi_+\sigma_{\mu\nu}\bar H\rangle + \text{H.c.}$	91	153
$\langle H\langle f_+^{\mu\nu}u^\lambda\rangle u^\rho\sigma_{\mu\nu}v_\lambda v_\rho\bar H\rangle$		40	$\langle H\langle f_+^{\mu\nu}\rangle\chi_+\sigma_{\mu\nu}\bar H\rangle$	92	
$\langle H\langle f_+^{\mu\nu}u^\lambda\rangle u^\rho\sigma_{\mu\lambda}v_\nu v_\rho\bar H\rangle$		41	$\langle H\langle f_+^{\mu\nu}\chi_+\rangle\sigma_{\mu\nu}\bar H\rangle$	93	154
$\langle H\langle f_+^{\mu\nu}u^\lambda\rangle u^\rho\sigma_{\mu\rho}v_\nu v_\lambda\bar H\rangle$		42	$\langle H\langle\chi_+\rangle f_+^{\mu\nu}\sigma_{\mu\nu}\bar H\rangle$	94	155
$\langle Hf_+^{\mu\nu}h^{\lambda\rho}\gamma_5\gamma_\mu v_\nu v_\lambda v_\rho\bar H\rangle + \text{H.c.}$		43	$\langle H\chi_+^2\bar H\rangle$	95	156
$\langle H\nabla^\mu f_{+\mu}{}^\nu u^\lambda\gamma_5\gamma_\nu v_\lambda\bar H\rangle + \text{H.c.}$		44	$\langle H\nabla^\mu\nabla_\mu\chi_+\bar H\rangle$	96	
$\langle H\nabla^\mu f_{+\mu}{}^\nu u^\lambda\gamma_5\gamma_\lambda v_\nu\bar H\rangle + \text{H.c.}$		45	$\langle H\nabla^\mu\nabla^\nu\chi_+ v_\mu v_\nu\bar H\rangle$	97	
$\langle H\nabla^\mu f_+^{\nu\lambda}u_\mu\gamma_5\gamma_\nu v_\lambda\bar H\rangle + \text{H.c.}$		46	$\langle H\langle\nabla^\mu\nabla_\mu\chi_+\rangle\bar H\rangle$	98	
$\langle H\nabla^\mu f_+^{\nu\lambda}u_\nu\gamma_5\gamma_\mu v_\lambda\bar H\rangle + \text{H.c.}$		47	$\langle H\langle\nabla^\mu\nabla^\nu\chi_+\rangle v_\mu v_\nu\bar H\rangle$	99	
$\langle H\nabla^\mu f_+^{\nu\lambda}u^\rho\gamma_5\gamma_\nu v_\mu v_\lambda v_\rho\bar H\rangle + \text{H.c.}$		48	$\langle H\langle\chi_+\rangle\chi_+\bar H\rangle$		157
$\langle H\langle f_+^{\mu\nu}f_{-\mu}{}^\lambda\rangle\gamma_5\gamma_\nu v_\lambda\bar H\rangle$		49	$\langle H\langle\chi_+^2\rangle\bar H\rangle$	100	158
$\langle H\langle f_+^{\mu\nu}h_\mu{}^\lambda\rangle\gamma_5\gamma_\nu v_\lambda\bar H\rangle$		50	$\langle H\langle\chi_+\rangle\langle\chi_+\rangle\bar H\rangle$		159
$\langle H\langle f_+^{\mu\nu}h_\mu{}^\lambda\rangle\gamma_5\gamma_\lambda v_\nu\bar H\rangle$		51	$\langle Hu^\mu u^\nu\chi_-\gamma_5\gamma_\mu v_\nu\bar H\rangle + \text{H.c.}$	101	160
$\langle H\langle f_+^{\mu\nu}h^{\lambda\rho}\rangle\gamma_5\gamma_\mu v_\nu v_\lambda v_\rho\bar H\rangle$		52	$\langle Hu^\mu u^\nu\chi_-\gamma_5\gamma_\nu v_\mu\bar H\rangle + \text{H.c.}$		161
$\langle H\langle\nabla^\mu f_{+\mu}{}^\nu u^\lambda\rangle\gamma_5\gamma_\nu v_\lambda\bar H\rangle$	19	53	$\langle Hu^\mu\chi_- u^\nu\gamma_5\gamma_\mu v_\nu\bar H\rangle + \text{H.c.}$	102	162
$\langle H\langle\nabla^\mu f_{+\mu}{}^\nu u^\lambda\rangle\gamma_5\gamma_\lambda v_\nu\bar H\rangle$	20	54	$\langle H\langle u^\mu u^\nu\chi_-\rangle\gamma_5\gamma_\mu v_\nu\bar H\rangle + \text{H.c.}$		163

(Table continued)

TABLE X. *(Continued)*

P_n	$SU(2)$	$SU(3)$	P_n	$SU(2)$	$SU(3)$
$\langle H\langle\nabla^\mu f_{+}{}^{\nu\lambda}u_\mu\rangle\gamma_5\gamma_\nu v_\lambda\bar H\rangle$	21	55	$\langle H\langle\chi_-\rangle u^\mu u^\nu\gamma_5\gamma_\mu v_\nu\bar H\rangle$ + H.c.		164
$\langle H\langle\nabla^\mu f_{+}{}^{\nu\lambda}u_\nu\rangle\gamma_5\gamma_\mu v_\lambda\bar H\rangle$	22	56	$i\langle Hf_{-}{}^{\mu\nu}\chi_-\gamma_5\gamma_\mu v_\nu\bar H\rangle$ + H.c.	103	165
$\langle H\langle\nabla^\mu f_{+}{}^{\nu\lambda}u^\rho\rangle\gamma_5\gamma_\nu v_\mu v_\lambda v_\rho\bar H\rangle$	23	57	$i\langle H\langle f_{-}{}^{\mu\nu}\rangle\chi_-\gamma_5\gamma_\mu v_\nu\bar H\rangle$	104	
$\langle H\langle f_{+}{}^{\mu\nu}f_{-\mu}{}^\lambda\rangle\gamma_5\gamma_\nu v_\lambda\bar H\rangle$	24		$i\langle H\langle f_{+}{}^{\mu\nu}\chi_-\rangle\gamma_5\gamma_\mu v_\nu\bar H\rangle$	105	166
$\langle H\langle f_{+}{}^{\mu\nu}h_\mu{}^\lambda\rangle\gamma_5\gamma_\nu v_\lambda\bar H\rangle$	25		$i\langle H\langle\chi_-\rangle f_{+}{}^{\mu\nu}\gamma_5\gamma_\mu v_\nu\bar H\rangle$	106	167
$\langle H\langle f_{+}{}^{\mu\nu}h_\mu{}^\lambda\rangle\gamma_5\gamma_\lambda v_\nu\bar H\rangle$	26		$\langle H\chi_-^2\bar H\rangle$	107	168
$\langle H\langle f_{+}{}^{\mu\nu}h^{\lambda\rho}\rangle\gamma_5\gamma_\mu v_\nu v_\lambda v_\rho\bar H\rangle$	27		$\langle H\langle\chi_-\rangle\chi_-\bar H\rangle$	108	169
$i\varepsilon^{\mu\nu\lambda\rho}\langle Hf_{+\mu\nu}f_{-\lambda\rho}\bar H\rangle$ + H.c.	28	58	$\langle H\langle\chi_-\rangle\langle\chi_-\rangle\bar H\rangle$		170
$i\varepsilon^{\mu\nu\lambda\rho}\langle Hf_{+\mu\nu}f_{-\lambda}{}^\sigma v_\rho v_\sigma\bar H\rangle$ + H.c.	29	59	$i\langle H\langle u^\mu u^\nu f_{-\mu}{}^\lambda\rangle\gamma_5\gamma_\nu v_\lambda\bar H\rangle$ + H.c.	109	171
$i\varepsilon^{\mu\nu\lambda\rho}\langle Hf_{+\mu\nu}h_\lambda{}^\sigma v_\rho v_\sigma\bar H\rangle$ + H.c.	30	60	$i\langle H\langle u^\mu u^\nu f_{-\mu}{}^\lambda\rangle\gamma_5\gamma_\lambda v_\nu\bar H\rangle$ + H.c.	110	172
$i\varepsilon^{\mu\nu\lambda\rho}\langle H\nabla_\mu f_{+\nu}{}^\sigma u_\lambda v_\rho v_\sigma\bar H\rangle$ + H.c.	31	61	$i\langle H\langle u^\mu u^\nu h_\mu{}^\lambda\rangle\gamma_5\gamma_\nu v_\lambda\bar H\rangle$ + H.c.	111	173
$i\langle Hf_{-}{}^{\mu\nu}\chi_+\gamma_5\gamma_\mu v_\nu\bar H\rangle$ + H.c.	32	62	$i\langle H\langle u^\mu u^\nu h_\mu{}^\lambda\rangle\gamma_5\gamma_\lambda v_\nu\bar H\rangle$ + H.c.	112	174
$i\langle Hh^{\mu\nu}\chi_+\gamma_5\gamma_\mu v_\nu\bar H\rangle$ + H.c.	33	63	$i\langle H\langle u^\mu u^\nu h^{\lambda\rho}\rangle\gamma_5\gamma_\nu v_\nu v_\lambda v_\rho\bar H\rangle$ + H.c.	113	175
$i\langle Hu^\mu\nabla^\nu\chi_+\gamma_5\gamma_\mu v_\nu\bar H\rangle$ + H.c.	34	64	$i\langle Hu^\mu u_\mu f_{-}{}^{\nu\lambda}\gamma_5\gamma_\nu v_\lambda\bar H\rangle$ + H.c.		176
$i\langle Hu^\mu\nabla^\nu\chi_+\gamma_5\gamma_\nu v_\mu\bar H\rangle$ + H.c.	35	65	$i\langle Hu^\mu u^\nu f_{-\mu}{}^\lambda\gamma_5\gamma_\nu v_\lambda\bar H\rangle$ + H.c.		177
$\langle Hf_{-}{}^{\mu\nu}\chi_-\sigma_{\mu\nu}\bar H\rangle$ + H.c.	36	66	$i\langle Hu^\mu u^\nu f_{-\mu}{}^\lambda\gamma_5\gamma_\lambda v_\nu\bar H\rangle$ + H.c.		178
$i\langle Hh^{\mu\nu}\chi_- v_\mu v_\nu\bar H\rangle$ + H.c.	37	67	$i\langle Hu^\mu u^\nu f_{-\nu}{}^\lambda\gamma_5\gamma_\mu v_\lambda\bar H\rangle$ + H.c.		179
$i\langle Hu^\mu\nabla_\mu\chi_-\bar H\rangle$ + H.c.	38	68	$i\langle Hu^\mu u^\nu f_{-\nu}{}^\lambda\gamma_5\gamma_\lambda v_\mu\bar H\rangle$ + H.c.		180
$i\langle Hu^\mu\nabla^\nu\chi_- v_\mu v_\nu\bar H\rangle$ + H.c.	39	69	$i\langle Hu^\mu u^\nu f_{-}{}^{\lambda\rho}\gamma_5\gamma_\lambda v_\mu v_\nu v_\rho\bar H\rangle$ + H.c.		181
$\langle Hu^\mu\nabla^\nu\chi_-\sigma_{\mu\nu}\bar H\rangle$ + H.c.	40	70	$i\langle Hu^\mu u_\mu h^{\nu\lambda}\gamma_5\gamma_\nu v_\lambda\bar H\rangle$ + H.c.		182
$i\langle H\langle h^{\mu\nu}\chi_-\rangle v_\mu v_\nu\bar H\rangle$	41	71	$i\langle Hu^\mu u^\nu h_\mu{}^\lambda\gamma_5\gamma_\nu v_\lambda\bar H\rangle$ + H.c.		183
$i\langle H\langle\chi_-\rangle h^{\mu\nu}v_\mu v_\nu\bar H\rangle$		72	$i\langle Hu^\mu u^\nu h_\mu{}^\lambda\gamma_5\gamma_\lambda v_\nu\bar H\rangle$ + H.c.		184
$i\langle H\langle u^\mu\nabla_\mu\chi_-\rangle\bar H\rangle$	42	73	$i\langle Hu^\mu u^\nu h_\nu{}^\lambda\gamma_5\gamma_\mu v_\lambda\bar H\rangle$ + H.c.		185
$i\langle H\langle\nabla^\mu\chi_-\rangle u_\mu\bar H\rangle$		74	$i\langle Hu^\mu u^\nu h_\nu{}^\lambda\gamma_5\gamma_\lambda v_\mu\bar H\rangle$ + H.c.		186
$i\langle H\langle u^\mu\nabla^\nu\chi_-\rangle v_\mu v_\nu\bar H\rangle$	43	75	$i\langle Hu^\mu u^\nu h^{\lambda\rho}\gamma_5\gamma_\mu v_\nu v_\lambda v_\rho\bar H\rangle$ + H.c.		187
$i\langle H\langle\nabla^\mu\chi_-\rangle u^\nu v_\mu v_\nu\bar H\rangle$		76	$i\langle Hu^\mu u^\nu h^{\lambda\rho}\gamma_5\gamma_\nu v_\mu v_\lambda v_\rho\bar H\rangle$ + H.c.		188
$\langle H\langle u^\mu\nabla^\nu f_{-\mu\nu}\rangle\bar H\rangle$	44	77	$i\langle Hu^\mu u^\nu h^{\lambda\rho}\gamma_5\gamma_\lambda v_\mu v_\nu v_\rho\bar H\rangle$ + H.c.		189
$\langle H\langle u^\mu\nabla^\nu f_{-\mu}{}^\lambda\rangle v_\nu v_\lambda\bar H\rangle$	45	78	$i\langle Hu^\mu f_{-\mu}{}^\nu u^\lambda\gamma_5\gamma_\nu v_\lambda\bar H\rangle$ + H.c.		190
$\langle H\langle u^\mu\nabla^\nu f_{-\nu}{}^\lambda\rangle v_\mu v_\lambda\bar H\rangle$	46	79	$i\langle Hu^\mu f_{-\mu}{}^\nu u^\lambda\gamma_5\gamma_\lambda v_\nu\bar H\rangle$ + H.c.		191
$\langle H\langle u^\mu\nabla_\mu h^{\nu\lambda}\rangle v_\nu v_\lambda\bar H\rangle$	47	80	$i\langle Hu^\mu h_\mu{}^\nu u^\lambda\gamma_5\gamma_\nu v_\lambda\bar H\rangle$ + H.c.		192
$\langle H\langle u^\mu\nabla^\nu h^{\lambda\rho}\rangle v_\mu v_\nu v_\lambda v_\rho\bar H\rangle$	48	81	$i\langle Hu^\mu h_\mu{}^\nu u^\lambda\gamma_5\gamma_\lambda v_\nu\bar H\rangle$ + H.c.		193
$\langle H\langle f_{-}{}^{\mu\nu}h_\mu{}^\lambda\rangle v_\nu v_\lambda\bar H\rangle$	49	82	$i\langle Hu^\mu h^{\nu\lambda}u^\rho\gamma_5\gamma_\mu v_\nu v_\lambda v_\rho\bar H\rangle$ + H.c.		194
$\langle H\langle h^{\mu\nu}h_{\mu\nu}\rangle\bar H\rangle$	50	83	$\varepsilon^{\mu\nu\lambda\rho}\langle Hu_\mu u_\nu f_{-\lambda\rho}\bar H\rangle$ + H.c.	114	195
$\langle H\langle h^{\mu\nu}h_\mu{}^\lambda\rangle v_\nu v_\lambda\bar H\rangle$	51	84	$\varepsilon^{\mu\nu\lambda\rho}\langle Hu_\mu u_\nu f_{-\lambda}{}^\sigma v_\rho v_\sigma\bar H\rangle$ + H.c.	115	196
$\langle H\langle h^{\mu\nu}h^{\lambda\rho}\rangle v_\mu v_\nu v_\lambda v_\rho\bar H\rangle$	52	85	$\varepsilon^{\mu\nu\lambda\rho}\langle Hu_\mu u^\sigma f_{-\nu\lambda}v_\rho v_\sigma\bar H\rangle$ + H.c.	116	197
$\langle Hu^\mu\nabla^\nu f_{-\mu\nu}\bar H\rangle$ + H.c.		86	$\varepsilon^{\mu\nu\lambda\rho}\langle Hu_\mu f_{-\nu\lambda}u^\sigma v_\rho v_\sigma\bar H\rangle$ + H.c.	117	198
$\langle Hu^\mu\nabla^\nu f_{-\mu}{}^\lambda v_\nu v_\lambda\bar H\rangle$ + H.c.		87	$\varepsilon^{\mu\nu\lambda\rho}\langle Hu_\mu u_\nu h_\lambda{}^\sigma v_\rho v_\sigma\bar H\rangle$ + H.c.	118	199
$\langle Hu^\mu\nabla_\nu f_{-\nu}{}^\lambda v_\mu v_\lambda\bar H\rangle$ + H.c.		88	$\langle H\langle\nabla^\mu f_{+\mu}{}^\nu\rangle u^\lambda\gamma_5\gamma_\nu v_\lambda\bar H\rangle$	119	
$\langle Hu^\mu\nabla_\mu h^{\nu\lambda}v_\nu v_\lambda\bar H\rangle$ + H.c.		89	$\langle H\langle\nabla^\mu f_{+\mu}{}^\nu\rangle u^\lambda\gamma_5\gamma_\lambda v_\nu\bar H\rangle$	120	
$\langle Hu^\mu\nabla^\nu h^{\lambda\rho}v_\mu v_\nu v_\lambda v_\rho\bar H\rangle$ + H.c.		90	$\langle H\langle\nabla^\mu f_{+}{}^{\nu\lambda}\rangle u_\mu\gamma_5\gamma_\nu v_\lambda\bar H\rangle$	121	
$\langle Hf_{-}{}^{\mu\nu}f_{-\mu\nu}\bar H\rangle$		91	$\langle H\langle\nabla^\mu f_{+}{}^{\nu\lambda}\rangle u_\nu\gamma_5\gamma_\mu v_\lambda\bar H\rangle$	122	
$\langle Hf_{-}{}^{\mu\nu}f_{-\mu}{}^\lambda v_\nu v_\lambda\bar H\rangle$		92	$\langle H\langle\nabla^\mu f_{+}{}^{\nu\lambda}\rangle u^\rho\gamma_5\gamma_\nu v_\mu v_\lambda v_\rho\bar H\rangle$	123	
$\langle Hf_{-}{}^{\mu\nu}h_\mu{}^\lambda v_\nu v_\lambda\bar H\rangle$ + H.c.		93	$\langle H\langle f_{+}{}^{\mu\nu}\rangle f_{-\mu}{}^\lambda\gamma_5\gamma_\nu v_\lambda\bar H\rangle$	124	
$\langle Hh^{\mu\nu}h_{\mu\nu}\bar H\rangle$		94	$\langle H\langle f_{+}{}^{\mu\nu}\rangle f_{-\mu}{}^\lambda\gamma_5\gamma_\lambda v_\nu\bar H\rangle$	125	
$\langle Hh^{\mu\nu}h_\mu{}^\lambda v_\nu v_\lambda\bar H\rangle$		95	$\langle H\langle f_{+}{}^{\mu\nu}\rangle h_\mu{}^\lambda\gamma_5\gamma_\nu v_\lambda\bar H\rangle$	126	
$\langle Hh^{\mu\nu}h^{\lambda\rho}v_\mu v_\nu v_\lambda v_\rho\bar H\rangle$		96	$\langle H\langle f_{+}{}^{\mu\nu}\rangle h_\mu{}^\lambda\gamma_5\gamma_\lambda v_\nu\bar H\rangle$	127	
$i\langle Hu^\mu\nabla_\mu f_{-}{}^{\nu\lambda}\sigma_{\nu\lambda}\bar H\rangle$ + H.c.	53	97	$\varepsilon^{\mu\nu\lambda\rho}\langle H\langle u_\mu f_{-\nu\lambda}\rangle u_\rho\bar H\rangle$		200
$i\langle Hu^\mu\nabla^\nu f_{-\nu}{}^\lambda\sigma_{\mu\lambda}\bar H\rangle$ + H.c.	54	98	$\varepsilon^{\mu\nu\lambda\rho}\langle H\langle u_\mu f_{-\nu}{}^\sigma\rangle u_\lambda v_\rho v_\sigma\bar H\rangle$		201
$i\langle Hu^\mu\nabla^\nu f_{-}{}^{\lambda\rho}\sigma_{\mu\lambda}v_\nu v_\rho\bar H\rangle$ + H.c.	55	99	$\varepsilon^{\mu\nu\lambda\rho}\langle H\langle u_\mu u^\sigma\rangle f_{-\nu\lambda}v_\rho v_\sigma\bar H\rangle$		202

(Table continued)

TABLE X. *(Continued)*

P_n	$SU(2)$	$SU(3)$	P_n	$SU(2)$	$SU(3)$
$i\langle Hu^\mu\nabla^\nu f_-^{\lambda\rho}\sigma_{\nu\lambda}v_\mu v_\rho\bar H\rangle +$ H.c.	56	100	$\varepsilon^{\mu\nu\lambda\rho}\langle H\langle u_\mu u^\sigma f_{-\nu\lambda}\rangle v_\rho v_\sigma\bar H\rangle +$ H.c.		203
$i\langle Hu^\mu\nabla^\nu h^{\lambda\rho}\sigma_{\mu\nu}v_\lambda v_\rho\bar H\rangle +$ H.c.	57	101	$\varepsilon^{\mu\nu\lambda\rho}\langle H\langle u_\mu h_\nu^{\ \sigma}\rangle u_\lambda v_\rho v_\sigma\bar H\rangle$		204
$i\langle Hf_-^{\mu\nu}f_{-\mu}^{\ \lambda}\sigma_{\nu\lambda}\bar H\rangle$	58	102	$\langle Hf_+^{\mu\nu}f_{-\mu}^{\ \lambda}\gamma_5\gamma_\nu v_\lambda\bar H\rangle +$ H.c.		205
$i\langle Hf_-^{\mu\nu}f_-^{\lambda\rho}\sigma_{\mu\lambda}v_\nu v_\rho\bar H\rangle$	59	103	$\langle Hf_+^{\mu\nu}f_{-\mu}^{\ \lambda}\gamma_5\gamma_\lambda v_\nu\bar H\rangle +$ H.c.		206
$i\langle Hf_-^{\mu\nu}h_\mu^{\ \lambda}\sigma_{\nu\lambda}\bar H\rangle +$ H.c.	60	104	$\langle Hf_+^{\mu\nu}h_\mu^{\ \lambda}\gamma_5\gamma_\nu v_\lambda\bar H\rangle +$ H.c.		207
$i\langle Hf_-^{\mu\nu}h^{\lambda\rho}\sigma_{\mu\nu}v_\lambda v_\rho\bar H\rangle +$ H.c.	61	105	$\langle Hf_+^{\mu\nu}h_\mu^{\ \lambda}\gamma_5\gamma_\lambda v_\nu\bar H\rangle +$ H.c.		208
$i\langle Hf_-^{\mu\nu}h^{\lambda\rho}\sigma_{\mu\lambda}v_\nu v_\rho\bar H\rangle +$ H.c.	62	106	$\langle H\langle D^\mu D_\mu F_L^{\ \nu\lambda}\rangle\sigma_{\nu\lambda}\bar H\rangle +$ H.c.	128	
$i\langle Hh^{\mu\nu}h_\mu^{\ \lambda}\sigma_{\nu\lambda}\bar H\rangle$	63	107	$\langle H\langle D^\mu D^\nu F_L^{\ \lambda\rho}\rangle\sigma_{\mu\lambda}v_\nu v_\rho\bar H\rangle +$ H.c.	129	
$i\langle Hh^{\mu\nu}h^{\lambda\rho}\sigma_{\mu\lambda}v_\nu v_\rho\bar H\rangle$	64	108	$\langle H\langle F_L^{\mu\nu}F_{L\mu\nu}\rangle\bar H\rangle +$ H.c.	130	209
$\langle H\nabla^\mu\nabla_\mu f_+^{\ \nu\lambda}\sigma_{\nu\lambda}\bar H\rangle$	65	109	$\langle H\langle F_L^{\mu\nu}F_{L\mu}^{\ \lambda}\rangle v_\nu v_\lambda\bar H\rangle +$ H.c.	131	210
$\langle H\nabla^\mu\nabla^\nu f_+^{\ \lambda\rho}\sigma_{\mu\lambda}v_\nu v_\rho\bar H\rangle$	66	110	$\langle H\langle F_L^{\mu\nu}F_{L\mu}^{\ \lambda}\rangle\gamma_5\gamma_\nu v_\lambda\bar H\rangle +$ H.c.	132	211
$\langle H\langle f_+^{\mu\nu}u_\mu\rangle u^\lambda\sigma_{\nu\lambda}\bar H\rangle$	67		$\langle H\langle F_L^{\mu\nu}\rangle\langle F_{L\mu\nu}\rangle\bar H\rangle +$ H.c.	133	
$\langle H\langle f_+^{\mu\nu}u^\lambda\rangle u_\mu\sigma_{\nu\lambda}\bar H\rangle$	68		$\langle H\langle F_L^{\mu\nu}\rangle\langle F_{L\mu}^{\ \lambda}\rangle v_\nu v_\lambda\bar H\rangle +$ H.c.	134	
$\langle H\langle f_+^{\mu\nu}u^\lambda\rangle u_\lambda\sigma_{\mu\nu}\bar H\rangle$	69		$\langle H\langle\chi\chi^\dagger\rangle\bar H\rangle$	135	212
$\langle H\langle f_+^{\mu\nu}u^\lambda\rangle u^\rho\sigma_{\mu\nu}v_\lambda v_\rho\bar H\rangle$	70		$\langle H\det\chi\bar H\rangle +$ H.c.	136	
$\langle H\langle f_+^{\mu\nu}u^\lambda\rangle u^\rho\sigma_{\mu\lambda}v_\nu v_\rho\bar H\rangle$	71				

The long relations in the seventh column in Table VII are

$$\tilde{C}_{50}^{(3)} = \tilde{C}_{52}^{(3)} = \frac{1}{2}\tilde{C}_1^{(3)} + \tilde{C}_{10}^{(3)} - \tilde{C}_{13}^{(3)} + \tilde{C}_{17}^{(3)} - \tilde{C}_{19}^{(3)}, \qquad \tilde{C}_{51}^{(3)} = -\tilde{C}_1^{(3)} - 2\tilde{C}_{10}^{(3)} + \tilde{C}_{17}^{(3)} - \tilde{C}_{19}^{(3)},$$

$$\tilde{C}_{53}^{(3)} = \tilde{C}_{55}^{(3)} = \frac{1}{2}\tilde{C}_1^{(3)} + \tilde{C}_{10}^{(3)} + \tilde{C}_{11}^{(3)} - \tilde{C}_{15}^{(3)} + \tilde{C}_{17}^{(3)} + \tilde{C}_{18}^{(3)} - \tilde{C}_{20}^{(3)} - \frac{1}{2}\tilde{C}_{35}^{(3)},$$

$$\tilde{C}_{54}^{(3)} = -\tilde{C}_1^{(3)} - 2\tilde{C}_{10}^{(3)} - 2\tilde{C}_{11}^{(3)} + \tilde{C}_{17}^{(3)} + \tilde{C}_{18}^{(3)} - \tilde{C}_{20}^{(3)} + \tilde{C}_{35}^{(3)}, \qquad \tilde{C}_{58}^{(3)} = -\frac{3}{2}\tilde{C}_{17}^{(3)} - \frac{3}{2}\tilde{C}_{18}^{(3)} + \frac{1}{2}\tilde{C}_{20}^{(3)},$$

$$\tilde{C}_{59}^{(3)} = -\tilde{C}_{17}^{(3)} - \tilde{C}_{18}^{(3)} + \tilde{C}_{20}^{(3)}, \qquad \tilde{C}_{70}^{(3)} = \tilde{C}_{33}^{(3)} + \tilde{C}_{34}^{(3)} - \tilde{C}_{35}^{(3)}. \tag{A3}$$

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