Published for SISSA by Springer

Received: *May 18, 2015*
Revised: *June 17, 2015*
Accepted: *June 19, 2015*
Published: *July 31, 2015*

NLO Higgs effective field theory and κ-framework[1]

Margherita Ghezzi, Raquel Gomez-Ambrosio, Giampiero Passarino and Sandro Uccirati

Dipartimento di Fisica Teorica, Università di Torino, Torino, Italy
INFN, Sezione di Torino, Torino, Italy

E-mail: margherita.ghezzi@to.infn.it, raquel.gomez@to.infn.it, giampiero@to.infn.it, uccirati@to.infn.it

Abstract: A consistent framework for studying Standard Model deviations is developed. It assumes that New Physics becomes relevant at some scale beyond the present experimental reach and uses the Effective Field Theory approach by adding higher-dimensional operators to the Standard Model Lagrangian and by computing relevant processes at the next-to-leading order, extending the original κ-framework. The generalized κ-framework provides a useful technical tool to decompose amplitudes at NLO accuracy into a sum of well defined gauge-invariant sub components.

Keywords: Higgs Physics, Beyond Standard Model, Effective field theories

ArXiv ePrint: 1505.03706

[1]Work supported by MIUR under contract 2001023713_006, by UniTo — Compagnia di San Paolo under contract ORTO11TPXK and by the Executive Research Agency (REA) of the European Union under the Grant Agreement PITN-GA-2012-316704 (HiggsTools).

doi:10.1007/JHEP07(2015)175

Contents

JHEP07(2015)175

---

1 Introduction

During Run$-$1 LHC has discovered a resonance which is a candidate for the Higgs boson of the Standard Model (SM) [1, 2]. The spin-0 nature of the resonance is well established [3] but there is no direct evidence for New Physics; furthermore, the available studies on the couplings of the resonance show compatibility with the Higgs boson of the SM. One possible scenario, in preparation for the results of Run$-$2, requires a consistent theory of SM deviations. Ongoing and near future experiments can achieve an estimated per mille sensitivity on precision Higgs and electroweak

(EW) observables. This level of precision provides a window to indirectly explore the theory space of Beyond-the-SM (BSM) physics and place constraints on specific UV models. For this purpose, a consistent procedure of constructing SM deviations is clearly desirable.

The first attempt to build a framework for SM-deviations is represented by the so-called κ-framework, introduced in refs. [4, 5]. There is no need to repeat here the main argument, splitting and shifting different loop contributions in the amplitudes for Higgs-mediated processes. The κ-framework is an intuitive language which misses internal consistency when one moves beyond leading order (LO). As originally formulated, it violates gauge-invariance and unitarity. In a Quantum Field Theory (QFT) approach to a spontaneously broken theory, fermion masses and Yukawa couplings are deeply related and one cannot shift couplings while keeping masses fixed.

To be more specific the original framework has the following limitations: kinematics is not affected by κ-parameters, therefore the framework works at the level of total cross-sections, not for differential distributions; it is LO, partially accomodating factorizable QCD but not EW corrections; it is not QFT-compatible (ad-hoc variation of the SM parameters, violates gauge symmetry and unitarity).

However, the original κ-framework has one main virtue, to represent the first attempt towards a fully consistent QFT of SM deviations. The question is: can we make it fully consistent? The answer is evidently yes, although the construction of a consistent theory of SM deviations (beyond LO) is far from trivial, especially from the technical point of view.

Recent years have witnessed an increasing interest in Higgs/SM EFT, see in particular refs. [6–8], refs. [9–15], refs. [16, 17], ref. [18], ref. [19], ref. [20], refs. [21, 22], ref. [23], refs. [24–26] and refs. [27–32].

In this work we will reestablish that Effective Field Theory (EFT) can provide an adequate answer beyond LO. Furthermore, EFT represents the optimal approach towards Model Independence. Of course, there is no formulation that is completely model independent and EFT, as any other approach, is based on a given set of (well defined) assumptions. Working within this set we will show how to use EFT for building a framework for SM deviations, generalizing the work of ref. [33]. A short version of our results, containing simple examples, was given in ref. [34] and presented in [35, 36].

In full generality we can distinguish a top-down approach (model dependent) and a bottom-up approach. The top-down approach is based on several steps. First one has to classify BSM models, possibly respecting custodial symmetry and decoupling, then the corresponding EFT can be constructed, e.g. via a covariant derivative expansion [37]. Once the EFT is derived one can construct (model by model) the corresponding SM deviations.

The bottom-up approach starts with the inclusion of a basis of $\dim = 6$ operators and proceeds directly to the classification of SM deviations, possibly respecting the analytic structure of the SM amplitudes.

The Higgs EFT described and constructed in this work is based on several assumptions. We consider one Higgs doublet with a linear representation; this is flexible. We assume that there are no new "light" d.o.f. and decoupling of heavy d.o.f.; these are rigid assumptions. Absence of mass mixing of new heavy scalars with the SM Higgs doublet is also required.

We only work with $\dim = 6$ operators. Therefore the scale Λ that characterizes the EFT cannot be too small, otherwise neglecting $\dim = 8$ operators is not allowed. Furthermore, Λ cannot be too large, otherwise dim $= 4$ higher-order loops are more important than dim $= 6$ interference effects. It is worth noting that these statements do not imply an inconsistency of EFT. It only means that higher dimensional operators and/or higher order EW effects (e.g. ref. [38]) must be included as well.

To summarize the strategy that will be described in this work we identify the following steps: start with EFT at a given order (here dim $= 6$ and NLO) and write any amplitude as a sum of κ-deformed SM sub-amplitudes (e.g. t, b and bosonic loops in $\mathrm{H} \to \gamma\gamma$). Another sum of κ-deformed non-SM amplitudes is needed to complete the answer; at this point we can show that the κ-parameters are linear combinations of Wilson coefficients.

The rationale for this course of action is better understood in terms of a comparison between LEP and LHC. Physics is symmetry plus dynamics and symmetry is quintessential (gauge invariance etc.); however, symmetry without dynamics does not bring us this far. At LEP dynamics was the SM, unknowns were $M_{\mathrm{H}}\,(\alpha_{\mathrm{s}}(M_{\mathrm{Z}}),\dots)$; at LHC (post the discovery) unknowns are SM-deviations, dynamics? Specific BSM models are a choice but one would like to try also a model-independent approach. Instead of inventing unknown form factors we propose a decomposition where dynamics is controlled by dim $= 4$ amplitudes (with known analytical properties) and deviations (with a direct link to UV completion) are (constant) combinations of Wilson coefficients.

Our extended κ-framework is a novel technical tool for studying SM deviations; what should be extracted from the data is another story. There are many alternatives, starting from direct extraction of Wilson coefficents or combinations of Wilson coefficients. We do not claim any particular advantage in selecting generalized κ-parameters as LHC observables. Only the comparison with experimental data will allow us to judge the goodness of a proposal. Our belief is based on the fact that SM deviations need a SM basis.

On-shell studies at LHC will tell us a lot, off-shell ones will tell us (hopefully) much more [39–43]. If we run away from the H peak with a SM-deformed theory, up to some reasonable value $s \ll \Lambda^2$, we need to reproduce (deformed) SM low-energy effects, e.g. VV and tt thresholds. The BSM loops will remain unresolved (as SM loops are unresolved in the Fermi theory). That is why we need to expand the SM-deformations into a SM basis with the correct (low energy) behavior. If we stay in the neighbourhood of the peak any function will work, if we run away we have to know more of the analytical properties.

The outline of the paper is as follows: in section 2 we introduce the EFT Lagrangian. In section 3 we describe the various aspects of the calculation; in section 4 we present details of the renormalization procedure, decays of the Higgs boson are described in section 5, EW precision data in section 6. Technical details, as well as the complete list of counterterms and amplitudes are given in several appendices.

2 The Lagrangian

In this section we collect all definitions that are needed to write the Lagrangian defined by

$$\mathscr{L}_{\mathrm{EFT}} = \mathscr{L}_4 + \sum_{n>4} \sum_{i=1}^{N_n} \frac{a_i^n}{\Lambda^{n-4}}\, \mathscr{O}_i^{(d=n)}\,, \tag{2.1}$$

where $\mathscr{L}_4$ is the SM Lagrangian [44] and a_i^n are arbitrary Wilson coefficients. Our EFT is defined by eq. (2.1) and it is based on a number of assumptions: there is only one Higgs doublet (flexible), a linear realization is used (flexible), there are no new "light" d.o.f. and decoupling is assumed (rigid), the UV completion is weakly-coupled and renormalizable (flexible). Furthermore, neglecting dim $= 8$ operators and NNLO EW corrections implies the following range of applicability: 3 TeV $< \Lambda <$ 5 TeV.

We can anticipate the strategy by saying that we are at the border of two HEP phases. A "predictive" phase: in any (strictly) renormalizable theory with n parameters one needs to match n data points, the $(n+1)$th calculation is a prediction, e.g. as doable in the SM. A "fitting" (approximate predictive) phase: there are (N_6+N_8+ $\cdots = \infty$) renormalized Wilson coefficients that have to be fitted, e.g. measuring SM deformations due to a single $\mathscr{O}^{(6)}$ insertion (N_6 is enough for per mille accuracy).

2.1 Conventions

We begin by considering the field-content of the Lagrangian. The scalar field Φ (with hypercharge $1/2$) is defined by

$$\Phi = \frac{1}{\sqrt{2}} \begin{pmatrix} \mathrm{H} + 2\,\frac{M}{g} + i\,\phi^0 \\ \sqrt{2}\,i\,\phi^- \end{pmatrix} \tag{2.2}$$

H is the custodial singlet in $(2_{\mathrm{L}} \otimes 2_{\mathrm{R}}) = 1 \oplus 3$. Charge conjugation gives $\Phi^c_i = \varepsilon_{ij}\,\Phi^*_j$, or

$$\Phi^c = -\frac{1}{\sqrt{2}} \begin{pmatrix} \sqrt{2}\,i\,\phi^+ \\ \mathrm{H} + 2\,\frac{M}{g} - i\,\phi^0 \end{pmatrix} \tag{2.3}$$

The covariant derivative D_μ is

$$D_\mu\,\Phi = \left(\partial_\mu - \frac{i}{2}\,g_{_0}\,B^a_\mu\,\tau_a - \frac{i}{2}\,g\,g_{_1}\,B^0_\mu\right)\Phi\,, \tag{2.4}$$

with $g_{_1} = -\mathrm{s}_\theta/\mathrm{c}_\theta$ and where τ^a are Pauli matrices while $\mathrm{s}_\theta(\mathrm{c}_\theta)$ is the sine(cosine) of the weak-mixing angle. Furthermore

$$\mathrm{W}^{\pm}_\mu = \frac{1}{\sqrt{2}}\left(B^1_\mu \mp i\,B^2_\mu\right), \qquad \mathrm{Z}_\mu = \mathrm{c}_\theta\,B^3_\mu - \mathrm{s}_\theta\,B^0_\mu\,, \qquad \mathrm{A}_\mu = \mathrm{s}_\theta\,B^3_\mu + \mathrm{c}_\theta\,B^0_\mu\,, \tag{2.5}$$

$$F^a_{\mu\nu} = \partial_\mu\,B^a_\nu - \partial_\nu\,B^a_\mu + g_{_0}\,\varepsilon^{abc}\,B^b_\mu\,B^c_\nu\,, \qquad F^0_{\mu\nu} = \partial_\mu\,B^0_\nu - \partial_\nu\,B^0_\mu\,. \tag{2.6}$$

Here $a, b, \dots = 1, \dots, 3$. Furthermore, for the QCD part we introduce

$$\mathrm{G}^a_{\mu\nu} = \partial_\mu\,\mathrm{g}^a_\nu - \partial_\nu\,\mathrm{g}^a_\mu + g_{\mathrm{S}}\,f^{abc}\,\mathrm{g}^b_\mu\,\mathrm{g}^c_\nu\,. \tag{2.7}$$

Here $a, b, \dots = 1, \dots, 8$ and the f are the SU(3) structure constants. Finally, we introduce fermions,

$$\psi_{\mathrm{L}} = \begin{pmatrix} \mathrm{u} \\ \mathrm{d} \end{pmatrix}_{\mathrm{L}} \qquad \mathrm{f}_{\mathrm{L,R}} = \frac{1}{2}\left(1 \pm \gamma^5\right)\mathrm{f} \tag{2.8}$$

and their covariant derivatives

$$D_\mu\,\psi_{\mathrm{L}} = \left(\partial_\mu + g\,B^i_\mu\,T_i\right)\psi_{\mathrm{L}}, i \qquad\qquad = 0, \dots, 3$$

$$T^a = -\frac{i}{2}\tau^a\,, \qquad\qquad T^0 = -\frac{i}{2}\,g_{_2}\,I\,, \tag{2.9}$$

$$D_\mu\,\psi_R = \left(\partial_\mu + g\,B^i_\mu\,t_i\right)\,\psi_R\,, \qquad\qquad t^a = 0\;\;(a \neq 0)\,, \tag{2.10}$$

$$t^0 = -\frac{i}{2}\begin{pmatrix} g_{_3} & 0 \\ 0 & g_{_4} \end{pmatrix} \tag{2.11}$$

with $g_i = -\mathrm{s}_{\theta}/\mathrm{c}_{\theta}\,\lambda_i$ and

$$\lambda_2 = 1 - 2\,Q_{\mathrm{u}}\,, \quad \lambda_3 = -2\,Q_{\mathrm{u}}\,, \quad \lambda_4 = -2\,Q_{\mathrm{d}}\,. \tag{2.12}$$

The Standard Model Lagrangian is the sum of several terms:

$$\mathscr{L}_{\mathrm{SM}} = \mathscr{L}_{\mathrm{YM}} + \mathscr{L}_{\Phi} + \mathscr{L}_{\mathrm{gf}} + \mathscr{L}_{\mathrm{FP}} + \mathscr{L}_{\mathrm{f}} \tag{2.13}$$

i.e., Yang-Mills, scalar, gauge-fixing, Faddeev-Popov ghosts and fermions. Furthermore, for a proper treatment of the neutral sector of the SM, we express $g_{_0}$ in terms of the coupling constant g,

$$g_{_0} = g\,\left(1 + g^2\,\Gamma\right)\,, \tag{2.14}$$

where Γ is fixed by the request that the $\mathrm{Z} - \mathrm{A}$ transition is zero at $p^2 = 0$, see ref. [45]. The scalar Lagrangian is given by

$$\mathscr{L}_{\Phi} = -\,\left(D_\mu\,\Phi\right)^\dagger\,D_\mu\,\Phi - \mu^2\,\Phi^\dagger\,\Phi - \frac{1}{2}\,\lambda\,\left(\Phi^\dagger\,\Phi\right)^2\,. \tag{2.15}$$

We will work in the β_{h}-scheme of ref. [45], where parameters are transformed according to the following equations:

$$\mu^2 = \beta_{\mathrm{h}} - 2\,\frac{\lambda}{g^2}\,M^2\,, \qquad \lambda = \frac{1}{4}\,g^2\,\frac{M^2_{\mathrm{H}}}{M^2}\,. \tag{2.16}$$

Furthermore, we introduce the Higgs VEV, $v = \sqrt{2}M/g$, and fix β_{h} order-by-order in perturbation theory by requiring $\langle 0\,|\,\mathrm{H}\,|\,0\rangle = 0$. Here we follow the approach described in refs. [45, 46].

2.2 $\mathrm{dim} = 6$ operators

Our list of $d = 6$ operators is based on the work of refs. [47–50] and of refs. [51–54] (see also refs. [55, 56], ref. [57], refs. [58–62], refs. [63–65] and ref. [66]) and is given in table 1. We are not reporting the full set of $\mathrm{dim} = 6$ operators introduced in ref. [48] but only those that are relevant for our calculations, e.g. CP-odd operators have not been considered in this work. It is worth noting that we do not assume flavor universality.

We need matching of UV models onto EFT, order-by-order in a loop expansion. If $L = \{\mathscr{O}^{(d)}_1, \dots \mathscr{O}^{(d)}_n\}$ is a list of operators in $V^{(d)}$ (the space of d-dimensional, gauge invariant operators), then these operators form a basis for $V^{(d)}$ iff every $\mathscr{O}^{(d)} \in V^{(d)}$ can be uniquely written as a linear combination of the elements in L.

While overcomplete sets (e.g. those derived without using equations of motion) are useful for cross-checking, a set that is not a basis (discarding a priori subsets of operators) is questionable,

JHEP07(2015)175

$\mathcal{O}_1 = g^3\, \mathcal{O}_{\phi} = g^3\, \left(\Phi^\dagger \Phi\right)^3$	$\mathcal{O}_2 = g^2\, \mathcal{O}_{\phi\Box} = g^2\, \left(\Phi^\dagger \Phi\right) \Box \left(\Phi^\dagger \Phi\right)$
$\mathcal{O}_3 = g^2\, \mathcal{O}_{\phi \mathrm{D}} = g^2\, \left(\Phi^\dagger \mathrm{D}_\mu \Phi\right) \left[\left(\mathrm{D}_\mu \Phi\right)^\dagger \Phi\right]$	$\mathcal{O}_4 = g^2\, \mathcal{O}_{\mathrm{l}\phi} = g^2\, \left(\Phi^\dagger \Phi\right) \bar{\mathrm{L}}_{\mathrm{L}}\, \Phi^c\, \mathrm{l}_{\mathrm{R}}$
$\mathcal{O}_5 = g^2\, \mathcal{O}_{\mathrm{u}\phi} = g^2\, \left(\Phi^\dagger \Phi\right) \bar{\mathrm{q}}_{\mathrm{L}}\, \Phi\, \mathrm{u}_{\mathrm{R}}$	$\mathcal{O}_6 = g^2\, \mathcal{O}_{\mathrm{d}\phi} = g^2\, \left(\Phi^\dagger \Phi\right) \bar{\mathrm{q}}_{\mathrm{L}}\, \Phi^c\, \mathrm{d}_{\mathrm{R}}$
$\mathcal{O}_7 = g^2\, \mathcal{O}^{(1)}_{\phi \mathrm{l}} = g^2\, \Phi^\dagger \mathrm{D}^{(\leftrightarrow)}_\mu \Phi \bar{\mathrm{L}}_{\mathrm{L}} \gamma^\mu \mathrm{L}_{\mathrm{L}}$	$\mathcal{O}_8 = g^2\, \mathcal{O}^{(1)}_{\phi \mathrm{q}} = g^2\, \Phi^\dagger \mathrm{D}^{(\leftrightarrow)}_\mu\, \Phi \bar{\mathrm{q}}_{\mathrm{L}} \gamma^\mu \mathrm{q}_{\mathrm{L}}$
$\mathcal{O}_9 = g^2\, \mathcal{O}_{\phi \mathrm{l}} = g^2\, \Phi^\dagger\, \mathrm{D}^{(\leftrightarrow)}_\mu\, \Phi \bar{\mathrm{l}}_{\mathrm{R}} \gamma^\mu \mathrm{l}_{\mathrm{R}}$	$\mathcal{O}_{10} = g^2\, \mathcal{O}_{\phi \mathrm{u}} = g^2\, \Phi^\dagger \mathrm{D}^{(\leftrightarrow)}_\mu\, \Phi \bar{\mathrm{u}}_{\mathrm{R}} \gamma^\mu \mathrm{u}_{\mathrm{R}}$
$\mathcal{O}_{11} = g^2\, \mathcal{O}_{\phi \mathrm{d}} = g^2\, \Phi^\dagger \mathrm{D}^{(\leftrightarrow)}_\mu\, \Phi \bar{\mathrm{d}}_{\mathrm{R}} \gamma^\mu \mathrm{d}_{\mathrm{R}}$	$\mathcal{O}_{12} = g^2\, \mathcal{O}_{\phi \mathrm{ud}} = i\, g^2\, \left(\Phi^\dagger D_\mu \Phi\right) \bar{\mathrm{u}}_{\mathrm{R}}\, \gamma^\mu\, \mathrm{d}_{\mathrm{R}}$
$\mathcal{O}_{13} = g^2\, \mathcal{O}^{(3)}_{\phi \mathrm{l}} = g^2\, \Phi^\dagger\, \tau^a\, \mathrm{D}^{(\leftrightarrow)}_\mu\, \Phi \bar{\mathrm{L}}_{\mathrm{L}}\, \tau_a\, \gamma^\mu\, \mathrm{L}_{\mathrm{L}}$	$\mathcal{O}_{14} = g^2\, \mathcal{O}^{(3)}_{\phi \mathrm{q}} = g^2\, \Phi^\dagger\, \tau^a\, \mathrm{D}^{(\leftrightarrow)}_\mu\, \Phi \bar{\mathrm{q}}_{\mathrm{L}}\, \tau_a\, \gamma^\mu\, \mathrm{q}_{\mathrm{L}}$
$\mathcal{O}_{15} = g\, \mathcal{O}_{\phi \mathrm{G}} = g\, \left(\Phi^\dagger \Phi\right) \mathrm{G}^{a\mu\nu}\, \mathrm{G}^a_{\mu\nu}$	$\mathcal{O}_{16} = g\, \mathcal{O}_{\phi \mathrm{W}} = g\, \left(\Phi^\dagger \Phi\right) \mathrm{F}^{a\mu\nu}\, \mathrm{F}^a_{\mu\nu}$
$\mathcal{O}_{17} = g\, \mathcal{O}_{\phi \mathrm{B}} = g\, \left(\Phi^\dagger \Phi\right) \mathrm{F}^{0\mu\nu}\, \mathrm{F}^0_{\mu\nu}$	$\mathcal{O}_{18} = g\, \mathcal{O}_{\phi \mathrm{WB}} = g\, \Phi^\dagger\, \tau^a\, \Phi\, \mathrm{F}^{\mu\nu}_a\, \mathrm{F}^0_{\mu\nu}$
$\mathcal{O}_{19} = g\, \mathcal{O}_{\mathrm{lW}} = g\, \bar{\mathrm{L}}_{\mathrm{L}}\, \sigma^{\mu\nu}\, \mathrm{l}_{\mathrm{R}}\, \tau_a\, \Phi^c\, \mathrm{F}^a_{\mu\nu}$	$\mathcal{O}_{20} = g\, \mathcal{O}_{\mathrm{uW}} = g\, \bar{\mathrm{q}}_{\mathrm{L}}\, \sigma^{\mu\nu}\, \mathrm{u}_{\mathrm{R}}\, \tau_a\, \Phi\, \mathrm{F}^a_{\mu\nu}$
$\mathcal{O}_{21} = g\, \mathcal{O}_{\mathrm{dW}} = g\, \bar{\mathrm{q}}_{\mathrm{L}}\, \sigma^{\mu\nu}\, \mathrm{d}_{\mathrm{R}}\, \tau_a\, \Phi^c\, \mathrm{F}^a_{\mu\nu}$	$\mathcal{O}_{22} = g\, \mathcal{O}_{\mathrm{lB}} = g\, \bar{\mathrm{L}}_{\mathrm{L}}\, \sigma^{\mu\nu}\, \mathrm{l}_{\mathrm{R}}\, \Phi^c\, \mathrm{F}^0_{\mu\nu}$
$\mathcal{O}_{23} = g\, \mathcal{O}_{\mathrm{uB}} = g\, \bar{\mathrm{q}}_{\mathrm{L}}\, \sigma^{\mu\nu}\, \mathrm{u}_{\mathrm{R}}\, \Phi\, \mathrm{F}^0_{\mu\nu}$	$\mathcal{O}_{24} = g\, \mathcal{O}_{\mathrm{dB}} = g\, \bar{\mathrm{q}}_{\mathrm{L}}\, \sigma^{\mu\nu}\, \mathrm{d}_{\mathrm{R}}\, \Phi^c\, \mathrm{F}^0_{\mu\nu}$
$\mathcal{O}_{25} = g\, \mathcal{O}_{\mathrm{uG}} = g\, \bar{\mathrm{q}}_{\mathrm{L}}\, \sigma^{\mu\nu}\, \mathrm{u}_{\mathrm{R}}\, \lambda_a\, \Phi\, \mathrm{G}^a_{\mu\nu}$	$\mathcal{O}_{26} = g\, \mathcal{O}_{\mathrm{dG}} = g\, \bar{\mathrm{q}}_{\mathrm{L}}\, \sigma^{\mu\nu}\, \mathrm{d}_{\mathrm{R}}\, \lambda_a\, \Phi^c\, \mathrm{G}^a_{\mu\nu}$

Table 1. List of dim = 6 operators, see ref. [48], entering the renormalization procedure and the phenomenological applications described in this paper.

e.g. it is not closed under complete renormalization and may lead to violation of Ward-Slavnov-Taylor (WST) identities [67–69]. Finally, a basis is optimal insofar as it allows to write Feynman rules in arbitrary gauges. Our choice is given by

$$\mathcal{L}_{\mathrm{EFT}_6} = \mathcal{L}_{\mathrm{SM}} + \sum_i \frac{a_i}{\Lambda^2}\, \mathcal{O}^{(6)}_i\,. \tag{2.17}$$

In table 1 we drop the superscript (6) and write the explicit correspondence with the operators of the so-called Warsaw basis, see ref. [48]. We also introduce

$$\mathrm{q}_{\mathrm{L}} = \begin{pmatrix} \mathrm{u} \\ \mathrm{d} \end{pmatrix}_{\mathrm{L}}\,, \qquad \mathrm{L}_{\mathrm{L}} = \begin{pmatrix} \nu_{\mathrm{l}} \\ \mathrm{l} \end{pmatrix}_{\mathrm{L}} \tag{2.18}$$

where u stands for a generic up-quark ($\{\mathrm{u}\,,\,\mathrm{c}\,,\,\dots\}$), d stands for a generic down-quark ($\{\mathrm{d}\,,\,\mathrm{s}\,,\,\dots\}$) and l for $\{\mathrm{e}\,,\,\mu\,,\,\dots\}$. As usual, $\mathrm{f}_{\mathrm{L}\,,\,\mathrm{R}} = \frac{1}{2}\,\left(1 \pm \gamma^5\right)\,\mathrm{f}$. Furthermore,

$$\Phi^\dagger\, \mathrm{D}^{(\leftrightarrow)}_\mu\, \Phi = \Phi^\dagger D_\mu \Phi - \left(D_\mu \Phi\right)^\dagger \Phi\,. \tag{2.19}$$

We also transform Wilson coefficients according to table 2. As was pointed out in table C.1 of ref. [70] the operators can be classified as potentially-tree-generated (PTG) and loop-generated (LG). If we assume that the high-energy theory is weakly-coupled and renormalizable it follows that the PTG/LG classification of ref. [70] (used here) is correct. If we do not assume the above but work always in some EFT context (i.e. also the next high-energy theory is EFT, possibly involving some strongly interacting theory) then classification changes, see eqs. (A1-A2) of ref. [15].

$g\,a_1 = a_{\phi}$	$g^2\,a_2 = -a_{\phi\Box}$	$g^2\,a_3 = -a_{\phi D}$	$g\sqrt{2}a_4 = -\frac{M_l}{M}\,a_{L\phi}$
$g\sqrt{2}a_5 = -\frac{M_u}{M}\,a_{u\phi}$	$g\sqrt{2}a_6 = -\frac{M_d}{M}\,a_{d\phi}$	$g^2\,a_7 = -a^{(1)}_{\phi l}$	$g^2\,a_8 = -a^{(1)}_{\phi q}$
$g^2\,a_9 = -a_{\phi l}$	$g^2\,a_{10} = -a_{\phi u}$	$g^2\,a_{11} = -a_{\phi d}$	$g^2\,a_{12} = -a_{\phi ud}$
$g^2\,a_{13} = -a^{(3)}_{\phi l}$	$g^2\,a_{14} = -a^{(3)}_{\phi q}$	$g^2\,a_{15} = g_S\,a_{\phi G}$	$g\,a_{16} = a_{\phi W}$
$g\,a_{17} = a_{\phi B}$	$g\,a_{18} = a_{\phi WB}$	$g\sqrt{2}a_{19} = \frac{M_l}{M}\,a_{lW}$	$g\sqrt{2}a_{20} = \frac{M_u}{M}\,a_{uW}$
$g\sqrt{2}a_{21} = \frac{M_d}{M}\,a_{dW}$	$g\sqrt{2}a_{22} = \frac{M_l}{M}\,a_{lB}$	$g\sqrt{2}a_{23} = \frac{M_u}{M}\,a_{uB}$	$g\sqrt{2}a_{24} = \frac{M_d}{M}\,a_{dB}$
$g^2\,a_{25} = g_S\,a_{uG}$	$g^2\,a_{26} = g_S\,a_{dG}$		

Table 2. Redefinition of Wilson coefficients.

2.3 Four-fermion operators

For processes that involve external fermions and for the fermion self-energies we also need dim $= 6$ four-fermion operators (see table 3 of ref. [48]). We show here one explicit example

$$
\begin{aligned}
V_{uudd} &= \frac{1}{4}\,\frac{g^2 g_6}{M^2}\,a^{(1)}_{qq}\,\gamma^{\mu}\,\gamma_+ \otimes \gamma_{\mu}\,\gamma_+ + \frac{1}{8}\,\frac{g^2 g_6}{M^2}\,a^{(1)}_{qd}\,\gamma^{\mu}\,\gamma_+ \otimes \gamma_{\mu}\,\gamma_- \\
&+ \frac{1}{8}\,\frac{g^2 g_6}{M^2}\,a^{(1)}_{qu}\,\gamma^{\mu}\,\gamma_- \otimes \gamma_{\mu}\,\gamma_+ + \frac{1}{8}\,\frac{g^2 g_6}{M^2}\,a^{(1)}_{ud}\,\gamma^{\mu}\,\gamma_- \otimes \gamma_{\mu}\,\gamma_- \\
&+ \frac{1}{16}\,\frac{g^2 g_6}{M^2}\,a^{(1)}_{quqd}\,\gamma_+ \otimes \gamma_+ + \frac{1}{16}\,\frac{g^2 g_6}{M^2}\,a^{(1)}_{quqd}\,\gamma_- \otimes \gamma_-\,,
\end{aligned}
\tag{2.20}
$$

giving the uudd four-fermion vertex. Here $\gamma_{\pm} = 1/2\,(1 \pm \gamma^5)$ and g_6 is defined in eq. (2.28).

2.4 From the Lagrangian to the S-matrix

There are several technical points that deserve a careful treatment when constructing S-matrix elements from the Lagrangian of eq. (2.17). We perform field and parameter redefinitions so that all kinetic and mass terms in the Lagrangian of eq. (2.17) have the canonical normalization. First we define

$$
\beta_h = 12\,\frac{M^4\,a_{\phi}}{g^2\,\Lambda^2} + \beta'_h\,, \qquad \beta'_h = \left(1 + dR_{\beta_h}\,\frac{M^2}{\Lambda^2}\right)\,\overline{\beta}_h
\tag{2.21}
$$

and $\overline{\beta}_h$ is fixed, order-by-order, to have zero vacuum expectation value for the (properly normalized) Higgs field.

Particular care should be devoted in selecting the starting gauge-fixing Lagrangian. In order to reproduce the free SM Lagrangian (after redefinitions) we fix an arbitrary gauge, described by four ξ parameters,

$$
\mathscr{L}_{gf} = -\mathscr{C}^+\,\mathscr{C}^- - \frac{1}{2}\,\mathscr{C}^2_Z - \frac{1}{2}\,\mathscr{C}^2_A\,,
\tag{2.22}
$$

$$
\mathscr{C}^{\pm} = -\xi_W\,\partial_{\mu}\,W^{\pm}_{\mu} + \xi_{\pm}\,M\,\phi^{\pm}\,, \qquad \mathscr{C}_Z = -\xi_Z\,\partial_{\mu}\,Z_{\mu} + \xi_0\,\frac{M}{c_{\theta}}\,\phi^0\,, \qquad \mathscr{C}_A = \xi_A\,\partial_{\mu}\,A_{\mu}\,.
\tag{2.23}
$$

$\Delta R_{\rm W} = a_{\phi \rm W}$	$\Delta R_{\rm ZZ} = a_{\rm ZZ}$	$\Delta R_{\rm AA} = a_{\rm AA}$
$\Delta R_{\rm H} = -\frac{1}{4}\, a_{\phi \rm D} + a_{\phi \Box}$	$\Delta R_{\phi^\pm} = 0$	$\Delta R_{\phi^0} = -\frac{1}{4}\, a_{\phi \rm D}$
$\Delta R_{\rm X^\pm} = \frac{1}{2}\, a_{\phi \rm W}$	$\Delta R_{\rm Y_Z} = \frac{1}{2}\, a_{\rm ZZ}$	$\Delta R_{\rm Y_A} = \frac{1}{2}\, a_{\rm AA}$
$\Delta R_{\rm u} = -\frac{1}{2}\, a_{\rm u \phi}$	$\Delta R_{\rm d} = \frac{1}{2}\, a_{\rm d \phi}$	$\Delta R_{\beta_{\rm h}} = a_{\phi \rm W} + \frac{1}{4}\, a_{\phi \rm D} - a_{\phi \Box}$
$\Delta R_{\xi_{\rm W}} = -a_{\phi \rm W}$	$\Delta R_{\xi_{\rm Z}} = -a_{\rm ZZ}$	$\Delta R_{\xi_{\rm A}} = -a_{\rm AA}$
$\Delta R_{\xi_\pm} = a_{\phi \rm W}$	$\Delta R_{\xi_0} = \frac{1}{2}\, a_{\phi \rm D} + a_{\rm ZZ}$	$\Delta R_{M_{\rm H}} = \frac{1}{2}\, a_{\phi \rm D} - 2\, a_{\phi \Box} + 12\, \frac{\overline{\rm M}^2}{\overline{\rm M}^2_{\rm H}}\, a_\phi$
$\Delta R_M = -2\, a_{\phi \rm W}$	$\Delta R_{\rm c_\theta} = -\frac{1}{4}\, a_{\phi \rm D} + \bar{\rm s}^2_\theta\, (a_{\rm AA} - a_{\rm ZZ}) + \bar{\rm s}_\theta\, \bar{\rm c}_\theta\, a_{\rm AZ}$	

Table 3. Normalization conditions.

The full list of redefinitions is given in the following equations, where we have introduced $\mathrm{R}_\Lambda = M^2/\Lambda^2$. First the Lagrangian parameters,

$$M^2_{\rm H} = \overline{\rm M}^2_{\rm H} \left(1 + {\rm dR}_{\rm M_H}\, {\rm R}_\Lambda\right), \quad M^2 = \overline{\rm M}^2 \left(1 + {\rm dR}_{\rm M}\, {\rm R}_\Lambda\right), \quad M_{\rm f} = \overline{\rm M}^{\rm f} \left(1 + {\rm dR}_{\rm M_f}\, {\rm R}_\Lambda\right), \tag{2.24}$$

$$\mathrm{c}_\theta = \left(1 + {\rm dR}_{\rm c_\theta}\, {\rm R}_\Lambda\right) \bar{\rm c}_\theta, \qquad \mathrm{s}_\theta = \left(1 + {\rm dR}_{\rm s_\theta}\, {\rm R}_\Lambda\right) \bar{\rm s}_\theta, \tag{2.25}$$

secondly, the fields:

$$\begin{array}{lll} {\rm H} = \left(1 + {\rm dR_H}\, {\rm R}_\Lambda\right) \overline{\rm H} & \phi^0 = \left(1 + {\rm dR}_{\phi^0}\, {\rm R}_\Lambda\right) \bar\phi^0 & \phi^\pm = \left(1 + {\rm dR}_{\phi^\pm}\, {\rm R}_\Lambda\right) \bar\phi^\pm \\ {\rm Z}_\mu = \left(1 + {\rm dR_{ZZ}}\, {\rm R}_\Lambda\right) \overline{\rm Z}_\mu & {\rm A}_\mu = \left(1 + {\rm dR_{AA}}\, {\rm R}_\Lambda\right) \overline{\rm A}_\mu & {\rm W}^\pm_\mu = \left(1 + {\rm dR}_{\rm W^\pm}\, {\rm R}_\Lambda\right) \overline{\rm W}^\pm_\mu \\ {\rm X}^\pm = \left(1 + {\rm dR}_{\rm X^\pm}\, {\rm R}_\Lambda\right) \overline{\rm X}^\pm & {\rm Y_Z} = \left(1 + {\rm dR}_{\rm Y_Z}\, {\rm R}_\Lambda\right) \overline{\rm Y}_{\rm Z} & {\rm Y_A} = \left(1 + {\rm dR}_{\rm Y_A}\, {\rm R}_\Lambda\right) \overline{\rm Y}_{\rm A} \end{array} \tag{2.26}$$

where $\mathrm{X}^\pm, \mathrm{Y_Z}$ and $\mathrm{Y_A}$ are FP ghosts. Finally, the gauge parameters, normalized to one:

$$\xi_i = 1 + {\rm dR}_{\xi_i}\, {\rm R}_\Lambda \qquad i = {\rm A, Z, W}, \pm, 0. \tag{2.27}$$

We introduce a new coupling constant

$$g_6 = \frac{1}{\sqrt{2}\, G_{\rm F}\, \Lambda^2} = 0.0606 \left(\frac{\rm TeV}{\Lambda}\right)^2, \tag{2.28}$$

where $G_{\rm F}$ is the Fermi coupling constant and derive the following solutions:

$${\rm dR}_i\, {\rm R}_\Lambda = g_6\, \Delta R_i, \tag{2.29}$$

where the ΔR_i are given in table 3. One could also write a more general relation

$${\rm Z}_\mu = {\rm R_{ZZ}}\, \overline{\rm Z}^\mu + {\rm R_{ZA}}\, \overline{\rm A}^\mu, \qquad {\rm A}_\mu = {\rm R_{AZ}}\, \overline{\rm Z}^\mu + {\rm R_{AA}}\, \overline{\rm A}^\mu, \tag{2.30}$$

where non diagonal terms start at $\mathscr{O}(g^2)$. In this way we could also require cancellation of the Z$-$A transition at $\mathscr{O}(g_6)$ but, in our experience, there is little to gain with this option. We have introduced the following combinations of Wilson coefficients:

$$
\begin{aligned}
a_{\mathrm{ZZ}} &= \bar{\mathrm{s}}_\theta^2\, a_{\phi\mathrm{B}} + \bar{\mathrm{c}}_\theta^2\, a_{\phi\mathrm{W}} - \bar{\mathrm{s}}_\theta\, \bar{\mathrm{c}}_\theta\, a_{\phi\mathrm{WB}}\,, \\
a_{\mathrm{AA}} &= \bar{\mathrm{c}}_\theta^2\, a_{\phi\mathrm{B}} + \bar{\mathrm{s}}_\theta^2\, a_{\phi\mathrm{W}} + \bar{\mathrm{s}}_\theta\, \bar{\mathrm{c}}_\theta\, a_{\phi\mathrm{WB}}\,, \\
a_{\mathrm{AZ}} &= 2\,\bar{\mathrm{c}}_\theta\, \bar{\mathrm{s}}_\theta\, \left(a_{\phi\mathrm{W}} - a_{\phi\mathrm{B}}\right) + \left(2\,\bar{\mathrm{c}}_\theta^2 - 1\right)\, a_{\phi\mathrm{WB}}\,.
\end{aligned}
\tag{2.31}
$$

With our choice of reparametrization the final result can be written as follows:

$$
\mathscr{L}\left(\{\Phi\}\,,\{p\}\right) = \mathscr{L}_4\left(\{\overline{\Phi}\}\,,\{\overline{p}\}\right) + g_6\, a_{\mathrm{AZ}}\,\left(\partial_\mu \overline{Z}_\nu\, \partial^\mu \overline{A}^\nu - \partial_\mu \overline{Z}_\nu\, \partial^\nu \overline{A}^\mu\right) + \mathscr{L}_6^{\mathrm{int}}\left(\{\overline{\Phi}\}\,,\{\overline{p}\}\right)\,,
\tag{2.32}
$$

where $\{\Phi\}$ denotes the collection of fields and $\{p\}$ the collection of parameters. In the following we will abandon the $\overline{\Phi}$, $\overline{p}$ notation since no confusion can arise.

3 Overview of the calculation

NLO EFT (dim $= 6$) is constructed according to the following scheme: each amplitude, e.g. $\mathrm{H} \to \mid \mathrm{f}\rangle$, contains one-loop SM diagrams up to the relevant order in g, (tree) contact terms with one dim $= 6$ operator and one-loop diagrams with one dim $= 6$ operator insertion. Note that the latter contain also diagrams that do not have a counterpart in the SM (e.g. bubbles with 3 external lines). In full generality each amplitude is written as follows:

$$
\mathscr{A} = \sum_{n=\mathrm{N}}^{\infty} g^n\, \mathscr{A}_n^{(4)} + \sum_{n=\mathrm{N}_6}^{\infty} \sum_{l=0}^{n} \sum_{k=1}^{\infty} g^n\, g_{4+2k}^l\, \mathscr{A}_{nlk}^{(4+2k)}\,,
\tag{3.1}
$$

where g is the SU(2) coupling constant and $g_{4+2k} = 1/(\sqrt{2}\,G_{\mathrm{F}}\,\Lambda^2)^k$. For each process the dim $= 4$ LO defines the value of N (e.g. $N = 1$ for $\mathrm{H} \to \mathrm{VV}$, $N = 3$ for $\mathrm{H} \to \gamma\gamma$ etc.). Furthermore, $N_6 = N$ for tree initiated processes and $N-2$ for loop initiated ones. The full amplitude is obtained by inserting wave-function factors and finite renormalization counterterms. Renormalization makes UV finite all relevant, on-shell, S-matrix elements. It is made in two steps: first we introduce counterterms

$$
\Phi = \mathrm{Z}_\Phi\, \Phi_{\mathrm{ren}}\,, \qquad p = \mathrm{Z}_p\, p_{\mathrm{ren}}\,,
\tag{3.2}
$$

for fields and parameters. Counterterms are defined by

$$
\mathrm{Z}_i = 1 + \frac{g^2}{16\,\pi^2}\,\left(\mathrm{dZ}_i^{(4)} + g_6\,\mathrm{dZ}_i^{(6)}\right)\,.
\tag{3.3}
$$

We construct self-energies, Dyson resum them and require that all propagators are UV finite. In a second step we construct 3-point (or higher) functions, check their $\mathscr{O}^{(4)}$-finiteness and remove the remaining $\mathscr{O}^{(6)}$ UV divergences by mixing the Wilson coefficients W_i:

$$
\mathrm{W}_i = \sum_j Z_{ij}^{\mathrm{W}}\, \mathrm{W}_j^{\mathrm{ren}}\,.
\tag{3.4}
$$

Renormalized Wilson coefficients are scale dependent and the logarithm of the scale can be resummed in terms of the LO coefficients of the anomalous dimension matrix [11].

Our aim is to discuss Higgs couplings and their SM deviations which requires precise definitions [71–73]:

JHEP07(2015)175

Definition *The Higgs couplings can be extracted from Green's functions in well-defined kinematic limits, e.g. residue of the poles after extracting the parts which are* $1P$ *reducible. These are well-defined QFT objects, that we can probe both in production and in decays; from this perspective,* VH *production or vector-boson-fusion are on equal footing with* gg *fusion and Higgs decays. Therefore, the first step requires computing these residues which is the main result of this paper.*

Every approach designed for studying SM deviations at LHC and beyond has to face a critical question: generally speaking, at LHC the EW core is embedded into a QCD environment, subject to large perturbative corrections and we expect considerable progress in the "evolution" of these corrections; the same considerations apply to PDFs. Therefore, does it make sense to 'fit" the EW core? Note that this is a general question which is not confined to our NLO approach.

In practice, our procedure is to write the answer in terms of SM deviations, i.e. the dynamical parts are dim $= 4$ and certain combinations of the deviation parameters will define the pseudo-observables (PO) to be fitted. Optimally, part of the factorizing QCD corrections could enter the PO definition. The suggested procedure requires the parametrization to be as general as possible, i.e. no a priori dropping of terms in the basis of operators. This will allow us to "reweight" the results when new (differential) K-factors become available; new input will touch only the dim $= 4$ components. PDFs changing is the most serious problem: at LEP the e^+e^- structure functions were known to very high accuracy (the effect was tested by using different QED radiators, differing by higher orders treatment); a change of PDFs at LHC will change the convolution and make the reweighting less simple, but still possible. For recent progress on the impact of QCD corrections within the EFT approach we quote ref. [23].

4 Renormalization

There are several steps in the renormalization procedure. The orthodox approach to renormalization uses the language of "counterterms". It is worth noting that this is not a mandatory step, since one could write directly renormalization equations that connect the bare parameters of the Lagrangian to a set of data, skipping the introduction of intermediate renormalized quantities and avoiding any unnecessary reference to a given renormalization scheme.

In this approach, carried on at one loop in [74], no special attention is paid to individual Green functions, and one is mainly concerned with UV finiteness of S-matrix elements after the proper treatment of external legs in amputated Green functions, which greatly reduces the complexity of the calculation.

However, renormalization equations are usually organized through different building blocks, where gauge-boson self-energies embed process-independent (universal) higher-order corrections and play a privileged role. Therefore, their structure has to be carefully analyzed, and the language of counterterms allows to disentangle UV overlapping divergences which show up at two loops.

In a renormalizable gauge theory, in fact, the UV poles of any Green function can be removed order-by-order in perturbation theory. In addition, the imaginary part of a Green function at a given order is fixed, through unitarity constraints, by the previous orders. Therefore, UV-subtraction terms have to be at most polynomials in the external momenta (in the following, "local" subtraction terms). Therefore, we will express our results using the language of counterterms: we promote bare quantities (parameters and fields) to renormalized ones and fix the counterterms at one loop in order to remove the UV poles.

Obviously, the absorption of UV divergences into local counterterms does not exhaust the renormalization procedure, because we have still to connect renormalized quantities to experimental data points, thus making the theory predictive. In the remainder of this section we discuss renormalization constants for all parameters and fields. We introduce the following quantities

$$\Delta_{\rm UV} = \frac{2}{\varepsilon} - \gamma_{\rm E} - \ln\pi - \ln\frac{\mu_{\rm R}^2}{\mu^2}\,, \qquad \Delta_{\rm UV}(x) = \frac{2}{\varepsilon} - \gamma_{\rm E} - \ln\pi - \ln\frac{x}{\mu^2}\,, \tag{4.1}$$

where $\varepsilon = 4 - {\rm d}$, d is the space-time dimension, $\gamma_{\rm E} = 0.5772$ is the Euler - Mascheroni constant and $\mu_{\rm R}$ is the renormalization scale. In eq. (4.1) we have introduced an auxiliary mass μ which cancels in any UV-renormalized quantity; $\mu_{\rm R}$ cancels only after finite renormalization. Furthermore, x is positive definite. Only few functions are needed for renormalization purposes,

$$A_0\,(m) = \frac{\mu^\varepsilon}{i\,\pi^2}\int d^dq\,\frac{1}{q^2+m^2} = -\,m^2\,\Big[\Delta_{\rm UV}\left(M_{\rm W}^2\right) + a_0^{\rm fin}\,(m)\Big]\,, \quad a_0^{\rm fin}\,(m) = 1 - \ln\frac{m^2}{M_{\rm W}^2}\,, \tag{4.2}$$

$$B_0\,(-s\,;m_1\,,m_2) = \frac{\mu^\varepsilon}{i\,\pi^2}\int d^dq\,\frac{1}{(q^2+m_1^2)\,((q+p)^2+m_2^2)} = \Delta_{\rm UV}\left(M_{\rm W}^2\right) + {\rm B}_0^{\rm fin}\,(-s\,;m_1\,,m_2)\,, \tag{4.3}$$

where the finite part is

$${\rm B}_0^{\rm fin}\,(-s\,;m_1\,,m_2) = 2 - \ln\frac{m_1m_2}{M_{\rm W}^2} - {\rm R} - \frac{1}{2}\,\frac{m_1^2-m_2^2}{s}\,\ln\frac{m_1^2}{m_2^2}\,, \quad {\rm R} = \frac{\Lambda}{s}\,\ln\frac{m_1^2+m_2^2-s-\Lambda-i0}{2\,m_2\,m_2}\,, \tag{4.4}$$

where $p^2 = -s$ and $\Lambda^2 = \lambda\left(s\,,m_1^2\,,m_2^2\right)$ is the Källen lambda function. Furthermore we introduce

$${\rm L}_{\rm R} = \ln\frac{\mu_{\rm R}^2}{M_{\rm W}^2}\,, \tag{4.5}$$

with the choice of the EW scale, $x = M_{\rm W}^2$, in eq. (4.1).

Technically speaking the renormalization program is complete only when UV poles are removed from all, off-shell, Green functions, something that is beyond the scope of this paper. Furthermore, we introduce UV decompositions also for Green functions: given a one-loop Green function with N external lines carrying Lorentz indices μ_j, $j = 1,\dots,N$, we introduce form factors,

$$S_{\mu_1\,\dots\,\mu_{\rm N}} = \sum_{a=1}^{\rm A} S_a\,K^a_{\mu_1\,\dots\,\mu_{\rm N}}\,. \tag{4.6}$$

Here the set K^a, with $a = 1,\dots,A$, contains independent tensor structures made up of external momenta, Kronecker-delta functions, elements of the Clifford algebra and Levi-Civita tensors. A large fraction of the form factors drops from the final answer when we make approximations, e.g. vector bosons couple only to conserved currents etc. Requiring that all (off-shell) form factors (including external unphysical lines) are made UV finite by means of local counterterms implies working in the $R_{\xi\xi}$ -gauge, as shown (up to two loops in the SM) in ref. [75].

A full generality is beyond the scope of this paper, we will limit ourselves to the usual 't Hooft-Feynman gauge and to those Green functions that are relevant for the phenomenological applications considered in this paper.

4.1 Tadpoles and transitions

We begin by considering the treatment of tadpoles: we fix $\overline{\beta}_{\rm h}$, eq. (2.21), such that $\langle 0\,|\overline{\rm H}|\,0\,\rangle = 0$ [45]. The solution is

$$\overline{\beta}_{\rm h} = i\,g^2\,M_{\rm W}^2\,\left(\overline{\beta}_{\rm h}^{(4)} + g_6\,\overline{\beta}_{\rm h}^{(6)}\right)\,, \tag{4.7}$$

where we split according to the following equation (see eq. (4.1))

$$\overline{\beta}_{\rm h}^{(n)} = \beta_{-1}^{(n)}\,\Delta_{\rm UV}\left(M_{\rm W}^2\right) + \beta_0^{(n)} + \beta_{\rm fin}^{(n)}\,. \tag{4.8}$$

The full result for the coefficients $\beta^{(n)}$ is given in appendix A. The parameter Γ, defined in eq. (2.14), is fixed by the request that the $\rm Z-A$ transition is zero at $p^2 = 0$; the corresponding expression is also reported in appendix A.

4.2 H self-energy

The one-loop H self-energy is given by

$$S_{\rm HH} = \frac{g^2}{16\,\pi^2}\,\Sigma_{\rm HH} = \frac{g^2}{16\,\pi^2}\,\left(\Sigma_{\rm HH}^{(4)} + g_6\,\Sigma_{\rm HH}^{(6)}\right)\,. \tag{4.9}$$

The bare H self-energy is decomposed as follows:

$$\Sigma_{\rm HH}^{(n)} = \Sigma_{\rm HH\,;\,UV}^{(n)}\,\Delta_{\rm UV}\left(M_{\rm W}^2\right) + \Sigma_{\rm HH\,;\,fin}^{(n)}\,. \tag{4.10}$$

Furthermore we introduce

$$\Sigma_{\rm HH\,;\,fin}^{(n)}(s) = \Delta_{\rm HH\,;\,fin}^{(n)}(s)\,M_{\rm W}^2 + \Pi_{\rm HH\,;\,fin}^{(n)}(s)\,s\,. \tag{4.11}$$

The full result for the H self-energy is given in appendix B.

4.3 A self-energy

The one-loop A self-energy is given by

$$S_{\rm AA}^{\mu\nu} = \frac{g^2}{16\,\pi^2}\,\Sigma_{\rm AA}^{\mu\nu}\,, \qquad \Sigma_{\rm AA}^{\mu\nu} = \Pi_{\rm AA}\,{\rm T}^{\mu\nu}\,, \tag{4.12}$$

where the Lorentz structure is specified by the tensor

$$T^{\mu\nu} = -s\,\delta^{\mu\nu} - p^\mu\,p^\nu\,, \tag{4.13}$$

and $p^2 = -s$. Furthermore the bare $\Pi_{\rm AA}$ is decomposed as follows:

$$\Pi_{\rm AA} = \Pi_{\rm AA}^{(4)} + g_6\,\Pi_{\rm AA}^{(6)}\,, \quad \Pi_{\rm AA}^{(n)} = \Pi_{\rm AA\,;UV}^{(n)}\,\Delta_{\rm UV}\left(M_{\rm W}^2\right) + \Pi_{\rm AA\,;\,fin}^{(n)}\,. \tag{4.14}$$

It is worth noting that the A−A transition satisfies a doubly-contracted Ward identity

$$p_\mu\,S_{\rm AA}^{\mu\nu}\,p_\nu = 0\,. \tag{4.15}$$

The full result for the A self-energy is given in appendix B.

4.4 W,Z self-energies

The one-loop W,Z self-energies are given by

$$S^{\mu\nu}_{\mathrm{VV}} = \frac{g^2}{16\,\pi^2}\,\Sigma^{\mu\nu}_{\mathrm{VV}}\,, \qquad \Sigma^{\mu\nu}_{\mathrm{VV}} = \mathrm{D}_{\mathrm{VV}}\,\delta^{\mu\nu} + \mathrm{P}_{\mathrm{VV}}\,p^{\mu}\,p^{\nu}\,, \tag{4.16}$$

where the form factors are decomposed according to

$$\mathrm{D}_{\mathrm{VV}} = \mathrm{D}^{(4)}_{\mathrm{VV}} + g_{_6}\,\mathrm{D}^{(6)}_{\mathrm{VV}}\,, \qquad \mathrm{P}_{\mathrm{VV}} = \mathrm{P}^{(4)}_{\mathrm{VV}} + g_{_6}\,\mathrm{P}^{(6)}_{\mathrm{VV}}\,. \tag{4.17}$$

We also introduce the residue of the UV pole and the finite part:

$$\mathrm{D}^{(n)}_{\mathrm{VV}} = \mathrm{D}^{(n)}_{\mathrm{VV}\,;\,\mathrm{UV}}\,\Delta_{\mathrm{UV}}\left(M^2_{\mathrm{W}}\right) + \mathrm{D}^{(n)}_{\mathrm{VV}\,;\,\mathrm{fin}}\,, \tag{4.18}$$

etc. The full result for these self-energies is given in appendix B. We also introduce

$$\mathrm{D}^{(n)}_{\mathrm{VV}\,;\,\mathrm{fin}}(s) = \Delta^{(n)}_{\mathrm{VV}\,;\,\mathrm{fin}}(s)\,M^2_{\mathrm{W}} + \Pi^{(n)}_{\mathrm{VV}\,;\,\mathrm{fin}}(s)\,s = \Delta^{(n)}_{\mathrm{VV}\,;\,\mathrm{fin}}(0)\,M^2_{\mathrm{W}} + \left[\Omega^{(n)}_{\mathrm{VV}\,;\,\mathrm{fin}}(0) + \mathrm{L}^{\mathrm{VV}\,;\,\mathrm{fin}}_{s}\right]s + \mathscr{O}(s^2)\,.$$

$$\mathrm{L}^{\mathrm{ZZ}\,;\,\mathrm{fin}}_{s} = -\frac{1}{6}\,\ln\left(-\frac{s}{M^2}\right)\,\frac{1}{\mathrm{c}^2_{\theta}}\,\mathrm{N}_{\mathrm{gen}}\,, \qquad L^{\mathrm{WW}}_{s} = 0\,. \tag{4.19}$$

4.5 $\mathrm{Z}-\mathrm{A}$ transition

The $\mathrm{Z}-\mathrm{A}$ transition (up to one loop) is given by

$$S^{\mu\nu}_{\mathrm{ZA}} = \frac{g^2}{16\,\pi^2}\,\Sigma^{\mu\nu}_{\mathrm{ZA}} + g_{_6}\,\mathrm{T}^{\mu\nu}\,a_{_{\mathrm{AZ}}}\,, \qquad \Sigma^{\mu\nu}_{\mathrm{ZA}} = \Pi_{\mathrm{ZA}}\,\mathrm{T}^{\mu\nu} + \mathrm{P}_{\mathrm{ZA}}\,p^{\mu}\,p^{\nu}\,, \tag{4.20}$$

$$\Pi_{\mathrm{ZA}} = \Pi^{(4)}_{\mathrm{ZA}} + g_{_6}\,\Pi^{(6)}_{\mathrm{ZA}}\,, \qquad \mathrm{P}_{\mathrm{ZA}} = \mathrm{P}^{(4)}_{\mathrm{ZA}} + g_{_6}\,\mathrm{P}^{(6)}_{\mathrm{ZA}}\,, \tag{4.21}$$

where we have included the term in the bare Lagrangian starting at $\mathscr{O}(g_{_6})$. The full result for the $\mathrm{Z}-\mathrm{A}$ transition is given in appendix B.

4.6 The fermion self-energy

The fermion self-energy is given by

$$\mathrm{S}_{\mathrm{f}} = \frac{g^2}{16\,\pi^2}\,\left[\Delta_{\mathrm{f}} + \left(\mathrm{V}_{\mathrm{f}} - \mathrm{A}_{\mathrm{f}}\,\gamma^5\right)\,i\not{p}\right]\,, \tag{4.22}$$

with a decomposition

$$\Delta_{\mathrm{f}} = \Delta^{(4)}_{\mathrm{f}} + g_{_6}\,\Delta^{(6)}_{\mathrm{f}}\,, \tag{4.23}$$

etc. The full result for the fermion self-energies ($\mathrm{f} = \nu, \mathrm{l}, \mathrm{u}, \mathrm{d}$) is given in appendix B.

4.7 Ward-Slavnon-Taylor identities

Let us consider doubly-contracted two-point WST identity [67–69], obtained by connecting two sources through vertices and propagators. Here we get, at every order in perturbation theory, the identities of figure 1. WST identities [67–69] require additional self-energies and transitions, i.e. scalar-scalar and vector-scalar components

$$S_{\mathrm{SS}} = \frac{g^2}{16\,\pi^2}\,\left[\Sigma^{(4)}_{\mathrm{SS}} + g_{_6}\,\Sigma^{(6)}_{\mathrm{SS}}\right]\,, \qquad S^{\mu}_{\mathrm{VS}} = i\,\frac{g^2}{16\,\pi^2}\,\left[\Sigma^{(4)}_{\mathrm{VS}} + g_{_6}\,\Sigma^{(6)}_{\mathrm{VS}}\right]\,p^{\mu}\,. \tag{4.24}$$

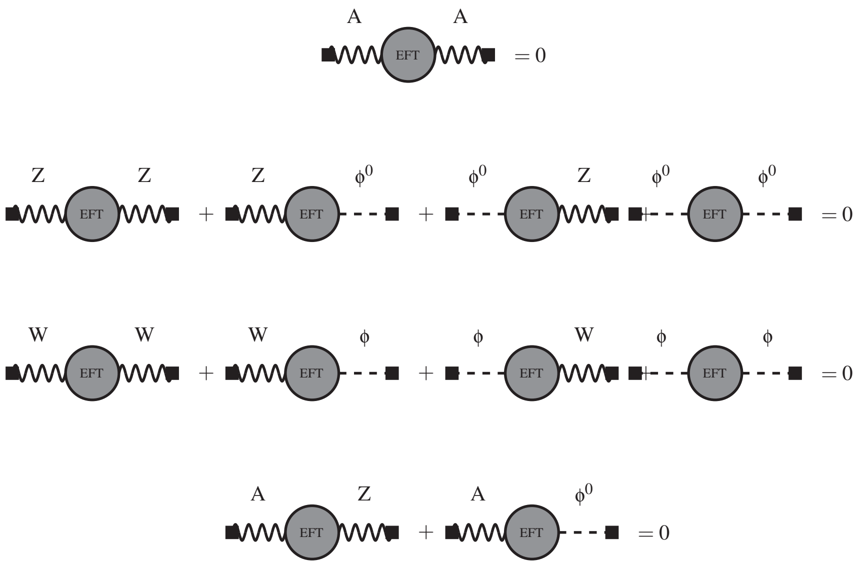

Figure 1. Doubly-contracted WST identities with two external gauge bosons. Gray circles denote the sum of the needed Feynman diagrams at any given order in EFT.

4.8 Dyson resummed propagators

We will now present the Dyson resummed propagators for the electroweak gauge bosons. The function $\Pi^{\rm I}_{ij}$ represents the sum of all 1PI diagrams with two external boson fields, i and j, to all orders in perturbation theory (as usual, the external Born propagators are not to be included in the expression for $\Pi^{\rm I}_{ij}$). We write explicitly its Lorentz structure,

$$\Pi^{\rm I}_{\mu\nu,\rm VV} = {\rm D}^{\rm I}_{\rm VV}\,\delta_{\mu\nu} + {\rm P}^{\rm I}_{\rm VV}\,p_\mu\,p_\nu\,, \tag{4.25}$$

where V indicates SM vector fields, and p_μ is the incoming momentum of the vector boson. The full propagator for a field i which mixes with a field j via the function $\Pi^{\rm I}_{ij}$ is given by the perturbative series

$$\begin{aligned}\bar{\Delta}_{ii} &= \Delta_{ii} + \Delta_{ii}\sum_{n=0}^{\infty}\prod_{l=1}^{n+1}\sum_{k_l}\Pi^{\rm I}_{k_{l-1}k_l}\Delta_{k_lk_l}\,, \\ &= \Delta_{ii} + \Delta_{ii}\,\Pi^{\rm I}_{ii}\,\Delta_{ii} + \Delta_{ii}\sum_{k_1=i,j}\Pi^{\rm I}_{ik_1}\Delta_{k_1k_1}\Pi^{\rm I}_{k_1i}\Delta_{ii} + \dots\end{aligned} \tag{4.26}$$

where $k_0 = k_{n+1} = i$, while for $l \neq n+1$, k_l can be i or j. Δ_{ii} is the Born propagator of the field i. We write

$$\bar{\Delta}_{ii} = \Delta_{ii}\,\left[1-(\Pi\,\Delta)_{ii}\right]^{-1}\,, \tag{4.27}$$

and refer to $\bar{\Delta}_{ii}$ as the resummed propagator. The quantity $(\Pi\,\Delta)_{ii}$ is the sum of all the possible products of Born propagators and self-energies, starting with a 1PI self-energy $\Pi^{\rm I}_{ii}$, or transition $\Pi^{\rm I}_{ij}$, and ending with a propagator Δ_{ii}, such that each element of the sum cannot be obtained as a product of other elements in the sum.

In practice it is useful to define, as an auxiliary quantity, the "partially resummed" propagator for the field i, $\hat{\Delta}_{ii}$, in which we resum only the proper 1PI self-energy insertions $\Pi^{\rm I}_{ii}$, namely,

$$\hat{\Delta}_{ii} = \Delta_{ii}\left[1-\Pi^{\rm I}_{ii}\Delta_{ii}\right]^{-1}. \tag{4.28}$$

If the particle i were not mixing with j through loops or two-leg vertex insertions, $\hat{\Delta}_{ii}$ would coincide with the resummed propagator $\bar{\Delta}_{ii}$. Partially resummed propagators allow for a compact expression for $(\Pi\Delta)_{ii}$,

$$(\Pi\Delta)_{ii} = \Pi^{\rm I}_{ii}\Delta_{ii} + \Pi^{\rm I}_{ij}\hat{\Delta}_{jj}\Pi^{\rm I}_{ji}\Delta_{ii}\,, \tag{4.29}$$

so that the resummed propagator of the field i can be cast in the form

$$\bar{\Delta}_{ii} = \Delta_{ii}\left[1-\left(\Pi^{\rm I}_{ii}+\Pi^{\rm I}_{ij}\hat{\Delta}_{jj}\Pi^{\rm I}_{ji}\right)\Delta_{ii}\right]^{-1} \tag{4.30}$$

We can also define a resummed propagator for the i-j transition. In this case there is no corresponding Born propagator, and the resummed one is given by the sum of all possible products of 1PI i and j self-energies, transitions, and Born propagators starting with Δ_{ii} and ending with Δ_{jj}. This sum can be simply expressed in the following compact form,

$$\bar{\Delta}_{ij} = \bar{\Delta}_{ii}\Pi^{\rm I}_{ij}\hat{\Delta}_{jj}\,. \tag{4.31}$$

4.9 Renormalization of two-point functions

Dyson resummed propagators are crucial for discussing several issues, from renormalization to Ward-Slavnov-Taylor (WST) identities [67–69]. Consider the W or Z self-energy; in general we have

$$\Sigma^{\rm VV}_{\mu\nu}(s) = \frac{g^2}{16\pi^2}\left[{\rm D}^{\rm VV}(s)\,\delta_{\mu\nu} + {\rm P}^{\rm VV}(s)\,p_\mu p_\nu\right]. \tag{4.32}$$

The corresponding partially resummed propagator is

$$\hat{\Delta}^{\rm VV}_{\mu\nu} = -\frac{\delta_{\mu\nu}}{s-M^2_{\rm V}+\frac{g^2}{16\pi^2}{\rm D}^{\rm VV}} + \frac{g^2}{16\pi^2}\,\frac{{\rm P}^{\rm VV}\,p_\mu p_\nu}{\left(s-M^2_{\rm V}+\frac{g^2}{16\pi^2}{\rm D}^{\rm VV}\right)\left(s-M^2_{\rm V}+\frac{g^2}{16\pi^2}{\rm D}^{\rm VV}-\frac{g^2}{16\pi^2}{\rm P}^{\rm VV}\,s\right)}\,. \tag{4.33}$$

We only consider the case where V couples to a conserved current; furthermore, we start by including one-particle irreducible (1PI) self-energies. Therefore the inverse propagators are defined as follows:

- H partially resummed propagator is given by

$$g^{-2}\,\hat{\Delta}^{-1}_{\rm HH}(s) = -g^{-2}\,{\rm Z_H}\left(s-M^2_{\rm H}\right) - \frac{1}{16\pi^2}\,\Sigma_{\rm HH}\,. \tag{4.34}$$

- A partially resummed propagator is given by

$$g^{-2}\,\hat{\Delta}^{-1}_{\rm AA}(s) = -g^{-2}\,s\left({\rm Z_A} - \frac{1}{16\pi^2}\,\Pi_{\rm AA}\right). \tag{4.35}$$

- W partially resummed propagator is given by

$$g^{-2}\,\hat{\Delta}^{-1}_{\rm WW}(s) = -g^{-2}\,{\rm Z_W}\left(s-M^2\right) - \frac{1}{16\pi^2}\,{\rm D_{WW}}\,. \tag{4.36}$$

- Z partially resummed propagator is given by

$$g^{-2}\,\hat{\Delta}^{-1}_{\rm ZZ}(s) = -g^{-2}\,{\rm Z_Z}\,\left(s - M_0^2\right) - \frac{1}{16\,\pi^2}\,{\rm D_{ZZ}}\,. \tag{4.37}$$

- Z−A transition is given by

$$S^{\rm ZA}_{\mu\nu} + S^{\rm ZA\,ct}_{\mu\nu} \qquad S^{\rm ZA\,ct}_{\mu\nu} = \frac{g^2}{16\,\pi^2}\,\Sigma^{\rm ZA\,ct}_{\mu\nu}\,\Delta_{\rm UV}\,, \tag{4.38}$$

where $S^{\rm ZA}_{\mu\nu}$ is given in eq. (4.20) and

$$\Sigma^{\rm ZA\,ct}_{\mu\nu} = s\,{\rm dZ}^{(4)}_{\rm AZ}\,\delta_{\mu\nu} + g_6\,\left[s\,{\rm dZ}^{(6)}_{\rm AZ}\,\delta_{\mu\nu} - a_{\rm AZ}\,\left({\rm dZ}^{(4)}_{\rm Z} + {\rm dZ}^{(4)}_{\rm A}\right)\,p_\mu\,p_\nu\right]\,. \tag{4.39}$$

- f resummed propagator is given by

$${\rm G}^{-1}_{\rm f}(p) = \overline{\rm Z}_{\rm f}\,\left(i\,\not{p} + m_{\rm f}\right){\rm Z}_{\rm f} - {\rm S}_{\rm f}\,, \tag{4.40}$$

where the counterterms are

$${\rm Z}_{\rm f} = {\rm Z}_{\rm R\,f}\,\gamma^- + {\rm Z}_{\rm L\,f}\,\gamma^+\,, \qquad \overline{\rm Z}_{\rm f} = {\rm Z}_{\rm L\,f}\,\gamma^+ + {\rm Z}_{\rm R\,f}\,\gamma^- \qquad \gamma^\pm = \frac{1}{2}\,\left(1 \pm \gamma^5\right)\,, \tag{4.41}$$

$${\rm Z}_{\rm If} = 1 - \frac{1}{2}\,\frac{g^2}{16\,\pi^2}\,\left[{\rm dZ}^{(4)}_{\rm If} + g_6\,{\rm dZ}^{(6)}_{\rm If}\,\Delta_{\rm UV}\right]\,, \quad m_{\rm f} = M_{\rm f}\,\left(1 + \frac{g^2}{16\,\pi^2}\,{\rm dZ}_{m_{\rm f}}\,\Delta_{\rm UV}\right)\,, \tag{4.42}$$

where $M_{\rm f}$ denotes the renormalized fermion mass and ${\rm I} = {\rm L},{\rm R}$. We have introduced counterterms for fields

$$\Phi = {\rm Z}_\Phi\,\Phi_{\rm ren}\,, \quad {\rm Z}_\Phi = 1 + \frac{g^2}{16\,\pi^2}\,\left({\rm dZ}^{(4)}_\Phi + g_6\,{\rm dZ}^{(6)}_\Phi\right)\,\Delta_{\rm UV}\,. \tag{4.43}$$

The bare photon field represents an exception, and here we use

$${\rm A}_\mu = {\rm Z_A}\,{\rm A}^{\rm ren}_\mu + {\rm Z_{AZ}}\,{\rm Z}^{\rm ren}_\mu\,, \qquad {\rm Z_{AZ}} = \frac{g^2}{16\,\pi^2}\,\left({\rm dZ}^{(4)}_{\rm AZ} + g_6\,{\rm dZ}^{(6)}_{\rm AZ}\right)\,\Delta_{\rm UV}\,. \tag{4.44}$$

In addition, bare fermion fields ψ are written by means of bare left-handed and right-handed chiral fields, $\psi_{\rm L}$ and $\psi_{\rm R}$. The latter are traded for renormalized fields.

For masses we introduce

$${\rm M}^2 = {\rm Z_M}\,{\rm M}^2_{\rm ren} \quad {\rm Z_M} = 1 + \frac{g^2}{16\,\pi^2}\,\left({\rm dZ}^{(4)}_{\rm M} + g_6\,{\rm dZ}^{(6)}_{\rm M}\right)\,\Delta_{\rm UV} \tag{4.45}$$

and for parameters

$${\rm p} = {\rm Z_p}\,{\rm p_{ren}} \quad {\rm Z_p} = 1 + \frac{g^2}{16\,\pi^2}\,\left({\rm dZ}^{(4)}_{\rm p} + g_6\,{\rm dZ}^{(6)}_{\rm p}\right)\,\Delta_{\rm UV}\,. \tag{4.46}$$

The full list of counterterms is given in appendix C. It is worth noting that the insertion of dim $= 6$ operators in the fermion self-energy introduces UV divergences in $\Delta^{(6)}_{\rm f}$, eq. (4.23), that are proportional to s and cannot be absorbed by counterterms. They enter wave-function renormalization factors and will be cancelled at the level of mixing among Wilson coefficients.

4.10 One-particle reducible transitions

Our procedure is such that there is a Z−A vertex of $\mathscr{O}(g_6)$

$$\mathrm{V}^{\mathrm{ZA}}_{\mu\nu} = g_6\, \mathrm{T}_{\mu\nu}\, a_{\mathrm{AZ}}\,, \qquad \mathrm{T}_{\mu\nu} = -s\,\delta_{\mu\nu} - p_\mu\, p_\nu\,, \tag{4.47}$$

inducing one-particle reducible (1PR) contributions to the self-energies. Since $p^\mu\,\mathrm{T}_{\mu\nu} = 0$ we obtain

$$\begin{aligned}
\Pi^{\mathrm{AA}}\Big|_{\mathrm{1PR}} &= \frac{g^2 g_6}{16\,\pi^2}\,\frac{\mathrm{s}_\theta}{\mathrm{c}_\theta}\,\frac{s}{s-M_0^2}\,a_{\mathrm{AZ}}\,\Pi^{(4)}_{\mathrm{ZA}}\,,\\
\Pi^{\mathrm{ZZ}}\Big|_{\mathrm{1PR}} &= \frac{g^2 g_6}{16\,\pi^2}\,\frac{\mathrm{s}_\theta}{\mathrm{c}_\theta}\,a_{\mathrm{AZ}}\,\Pi^{(4)}_{\mathrm{ZA}}\,,\\
\Pi^{\mathrm{ZA}}\Big|_{\mathrm{1PR}} &= \frac{g^2 g_6}{16\,\pi^2}\,\mathrm{s}^2_\theta\,a_{\mathrm{AZ}}\,\Pi^{(4)}_{\mathrm{AA}}\,.
\end{aligned} \tag{4.48}$$

4.11 A − A, Z − A, Z − Z and W − W transitions at $s = 0$

The value $s = 0$ is particularly important since S, T and U parameters [76] require self-energies and transitions at $s = 0$. We introduce the following functions:

$$\mathrm{B}^{\mathrm{fin}}_0(-s\,; m_1\,, m_2) = \mathrm{B}^{\mathrm{fin}}_0(0\,; m_1\,, m_2) - s\,\mathrm{B}^{\mathrm{fin}}_{0\mathrm{p}}(0\,; m_1\,, m_2) + \frac{1}{2}\,s^2\,\mathrm{B}^{\mathrm{fin}}_{0\mathrm{s}}(0\,; m_1\,, m_2) + \mathscr{O}(s^3)\,, \tag{4.49}$$

where, with two different masses, we obtain

$$\begin{aligned}
\mathrm{B}^{\mathrm{fin}}_0(0\,; m_1\,, m_2) &= \frac{m_2^2\,a^{\mathrm{fin}}_0(m_2) - m_1^2\,a^{\mathrm{fin}}_0(m_1)}{m_1^2 - m_2^2}\,,\\
\mathrm{B}^{\mathrm{fin}}_{0\mathrm{p}}(0\,; m_1\,, m_2) &= -\frac{1}{\left(m_1^2-m_2^2\right)^3}\left[\frac{1}{2}\left(m_1^4 - m_2^4\right) + m_2^4\,a^{\mathrm{fin}}_0(m_2) - m_1^4\,a^{\mathrm{fin}}_0(m_1)\right]\\
&\quad - \frac{1}{\left(m_1^2-m_2^2\right)^2}\left[m_1^2\,a^{\mathrm{fin}}_0(m_1) + m_2^2\,a^{\mathrm{fin}}_0(m_2)\right],\\
\mathrm{B}^{\mathrm{fin}}_{0\mathrm{s}}(0\,; m_1\,, m_2) &= \frac{1}{\left(m_1^2-m_2^2\right)^5}\left[\frac{10}{3}\left(m_1^6 - m_2^6\right) + 4\,m_2^6\,a^{\mathrm{fin}}_0(m_2) - 4\,m_1^6\,a^{\mathrm{fin}}_0(m_1)\right]\\
&\quad + \frac{3}{\left(m_1^2-m_2^2\right)^4}\left[2\,m_1^4\,a^{\mathrm{fin}}_0(m_1) + 2\,m_2^4\,a^{\mathrm{fin}}_0(m_2) - m_1^4 - m_2^4\right]\\
&\quad + \frac{2}{\left(m_1^2-m_2^2\right)^3}\left[m_2^2\,a^{\mathrm{fin}}_0(m_2) - m_1^2\,a^{\mathrm{fin}}_0(m_1)\right].
\end{aligned} \tag{4.50}$$

For equal masses we derive

$$\mathrm{B}^{\mathrm{fin}}_0(0\,; m\,, m) = 1 - a^{\mathrm{fin}}_0(m)\,, \quad \mathrm{B}^{\mathrm{fin}}_{0\mathrm{p}}(0\,; m\,, m) = -\frac{1}{6\,m^2}\,, \quad \mathrm{B}^{\mathrm{fin}}_{0\mathrm{s}}(0\,; m\,, m) = \frac{1}{30\,m^4}\,. \tag{4.51}$$

After renormalization we obtain the results of appendix D, with Π defined in eq. (4.12) and Δ, Ω defined in eq. (4.19). Furthermore $\mathrm{N}_{\mathrm{gen}}$ is the number of fermion generations and L_{R} is defined in eq. (4.5). All functions defined in eq. (4.51) are successively scaled with M_{W}. In appendix D we have used $s = \mathrm{s}_\theta$, $c = \mathrm{c}_\theta$ and x_i are ratios of renormalized masses, i.e. $x_{\mathrm{H}} = M_{\mathrm{H}}/M$, etc.

The expressions corresponding to dim = 6 are rather long and we found convenient to introduce linear combinations of Wilson coefficients, given in eq. (4.52).

$$
\begin{aligned}
&a_{\phi\mathrm{W}} = \mathrm{s}_\theta^2\, a_{\mathrm{AA}} + \mathrm{c}_\theta \mathrm{s}_\theta\, a_{\mathrm{AZ}} + \mathrm{c}_\theta^2\, a_{\mathrm{ZZ}} && a_{\phi\mathrm{B}} = \mathrm{c}_\theta^2\, a_{\mathrm{AA}} - \mathrm{c}_\theta \mathrm{s}_\theta\, a_{\mathrm{AZ}} + \mathrm{s}_\theta^2\, a_{\mathrm{ZZ}} \\
&a_{\phi\mathrm{WB}} = 2\,\mathrm{c}_\theta \mathrm{s}_\theta\,(a_{\mathrm{AA}} - a_{\mathrm{ZZ}}) + (1 - 2\,\mathrm{s}_\theta^2)\, a_{\mathrm{AZ}} && a_{\phi\mathrm{l}} = \tfrac{1}{2}\left(a_{\phi\mathrm{l\,A}} - a_{\phi\mathrm{l\,V}}\right) \\
&a_{\phi\mathrm{u}} = \tfrac{1}{2}\left(a_{\phi\mathrm{u\,V}} - a_{\phi\mathrm{u\,A}}\right) && a_{\phi\mathrm{d}} = \tfrac{1}{2}\left(a_{\phi\mathrm{d\,A}} - a_{\phi\mathrm{d\,V}}\right) \\
&a^{(1)}_{\phi\mathrm{l}} = a^{(3)}_{\phi\mathrm{l}} - \tfrac{1}{2}\left(a_{\phi\mathrm{l\,V}} + a_{\phi\mathrm{l\,A}}\right) && a^{(3)}_{\phi\mathrm{l}} = \tfrac{1}{4}\left(a_{\phi\mathrm{l\,V}} + a_{\phi\mathrm{l\,A}} + a_{\phi\mathrm{v}}\right) \\
&a^{(1)}_{\phi\mathrm{q}} = \tfrac{1}{4}\left(a_{\phi\mathrm{u\,V}} + a_{\phi\mathrm{u\,A}} - a_{\phi\mathrm{d\,V}} - a_{\phi\mathrm{d\,A}}\right) && a^{(3)}_{\phi\mathrm{q}} = \tfrac{1}{4}\left(a_{\phi\mathrm{d\,V}} + a_{\phi\mathrm{d\,A}} + a_{\phi\mathrm{u\,V}} + a_{\phi\mathrm{u\,A}}\right) \\
&a_{\mathrm{l\,W}} = \mathrm{s}_\theta\, a_{\mathrm{l\,WB}} + \mathrm{c}_\theta\, a_{\mathrm{l\,BW}} && a_{\mathrm{l\,B}} = \mathrm{s}_\theta\, a_{\mathrm{l\,BW}} - \mathrm{c}_\theta\, a_{\mathrm{l\,WB}}
\end{aligned}
$$

$$
\begin{aligned}
&a_{\mathrm{d\,W}} = \mathrm{s}_\theta\, a_{\mathrm{d\,WB}} + \mathrm{c}_\theta\, a_{\mathrm{d\,BW}} && a_{\mathrm{d\,B}} = \mathrm{s}_\theta\, a_{\mathrm{d\,BW}} - \mathrm{c}_\theta\, a_{\mathrm{d\,WB}} \\
&a_{\mathrm{u\,W}} = \mathrm{s}_\theta\, a_{\mathrm{u\,WB}} + \mathrm{c}_\theta\, a_{\mathrm{u\,BW}} && a_{\mathrm{u\,B}} = -\mathrm{s}_\theta\, a_{\mathrm{u\,BW}} + \mathrm{c}_\theta\, a_{\mathrm{u\,WB}} \\
&a_{\phi\mathrm{WB}} = \mathrm{c}_\theta\, a_{\phi\mathrm{WA}} - \mathrm{s}_\theta\, a_{\phi\mathrm{WZ}} && a_{\phi\mathrm{W}} = \mathrm{s}_\theta\, a_{\phi\mathrm{WA}} + \mathrm{c}_\theta\, a_{\phi\mathrm{WZ}} \\
&a_{\phi\mathrm{D}} = a_{\phi\mathrm{DB}} - 8\,\mathrm{s}_\theta^2\, a_{\phi\mathrm{B}} && a^{(+)}_{\phi\mathrm{WD}} = 4\,a_{\phi\mathrm{W}} + a_{\phi\mathrm{D}} \\
&a^{(-)}_{\phi\mathrm{WD}} = 4\,a_{\phi\mathrm{W}} - a_{\phi\mathrm{D}} && a^{(3)}_{\phi\mathrm{l\,W}} = 4\,a^{(3)}_{\phi\mathrm{l}} + 2\,a_{\phi\mathrm{W}} \\
&a^{(3)}_{\phi\mathrm{q\,W}} = 4\,a^{(3)}_{\phi\mathrm{q}} + 2\,a_{\phi\mathrm{W}} && a^{(-)}_{\phi\mathrm{WDB}} = a^{(+)}_{\phi\mathrm{WD}} - 4\,a_{\phi\Box} \\
&a^{(+)}_{\phi\mathrm{WDB}} = a^{(+)}_{\phi\mathrm{WD}} + 4\,a_{\phi\Box} && a^{(a)}_{\phi\mathrm{WB}} = a_{\phi\mathrm{B}} - a_{\phi\mathrm{W}}
\end{aligned}
\tag{4.52}
$$

The results for dim = 6 simplify considerably if we neglect loop generated operators, for instance one obtains full factorization for $\Pi_{\mathrm{AA}}(0)$,

$$
\Pi^{(6)}_{\mathrm{AA}}(0) = -8\,\frac{\mathrm{c}_\theta^2}{\mathrm{s}_\theta^2}\, a_{\phi\mathrm{D}}\, \Pi^{(4)}_{\mathrm{AA}}(0) \tag{4.53}
$$

and partial factorization for the rest, e.g.

$$
\begin{aligned}
\Pi^{(6)}_{\mathrm{ZA}}(0) = {} & -4\,\frac{\mathrm{c}_\theta^2}{\mathrm{s}_\theta^2}\, a_{\phi\mathrm{D}}\, \Pi^{(4)}_{\mathrm{ZA}}(0) + \frac{\mathrm{s}_\theta}{\mathrm{c}_\theta}\, a_{\phi\mathrm{D}}\, \Pi^{(6)\,\mathrm{nfc}}_{\mathrm{ZA}}(0) \\
& - \frac{2}{3}\,(1 - \mathrm{L_R})\, \frac{\mathrm{s}_\theta}{\mathrm{c}_\theta} \sum_{\mathrm{gen}} \left(a_{\phi\mathrm{l\,V}} + 2\,a_{\phi\mathrm{u\,V}} + a_{\phi\mathrm{d\,V}}\right) \\
& - \frac{2}{3}\,\frac{\mathrm{s}_\theta}{\mathrm{c}_\theta} \sum_{\mathrm{gen}} \left[2\,a_0^{\mathrm{fin}}(M_{\mathrm{u}})\, a_{\phi\mathrm{u\,V}} + a_0^{\mathrm{fin}}(M_{\mathrm{d}})\, a_{\phi\mathrm{d\,V}} + a_0^{\mathrm{fin}}(M_{\mathrm{l}})\, a_{\phi\mathrm{l\,V}}\right]
\end{aligned}
\tag{4.54}
$$

$$
\begin{aligned}
\Pi^{(6)\,\mathrm{nfc}}_{\mathrm{ZA}}(0) = {} & -\frac{1}{24}\,(1 - 14\,\mathrm{c}_\theta^2) - \frac{1}{24}\,(1 + 18\,\mathrm{c}_\theta^2)\,\mathrm{L_R} - \frac{1}{9}\,(5 + 8\,\mathrm{c}_\theta^2)\,(1 - \mathrm{L_R})\,\mathrm{N_{gen}} \\
& - \frac{1}{12}\,(3 + 4\,\mathrm{c}_\theta^2) \sum_{\mathrm{gen}} a_0^{\mathrm{fin}}(M_{\mathrm{l}}) - \frac{1}{18}\,(5 + 8\,\mathrm{c}_\theta^2) \sum_{\mathrm{gen}} a_0^{\mathrm{fin}}(M_{\mathrm{u}}) - \frac{1}{36}\,(1 + 4\,\mathrm{c}_\theta^2) \sum_{\mathrm{gen}} a_0^{\mathrm{fin}}(M_{\mathrm{d}}) \\
& + \frac{1}{24}\,(1 + 18\,\mathrm{c}_\theta^2)\, a_0^{\mathrm{fin}}(M)
\end{aligned}
\tag{4.55}
$$

The rather long expressions with PTG and LG operator insertions are reported in appendix D. Results in this section and in appendix D refer to the expansion of the 1PI self-energies; inclusion of 1PR components amounts to the following replacements

$$
\Sigma^{(\mathrm{1PI+1PR})}_{\mathrm{AA}}(s) = -\Pi^{(\mathrm{1PI})}_{\mathrm{AA}}(0)\, s - \frac{\left[\Pi^{(\mathrm{1PR})}_{\mathrm{ZA}}(0)\, s\right]^2}{s - M_0^2} + \mathscr{O}(s^2) = -\Pi^{(\mathrm{1PI})}_{\mathrm{AA}}(0)\, s + \mathscr{O}(s^2),
$$

JHEP07(2015)175

$$D^{(1\text{PI}+1\text{PR})}_{\text{ZZ}}(s) = \Delta^{(1\text{PI})}_{\text{ZZ}}(0) + \left\{\Omega^{(1\text{PI})}_{\text{ZZ}}(0) - \left[\Pi^{(1\text{PR})}_{\text{ZA}}(0)\right]^2\right\} s + \mathscr{O}(s^2)\,. \tag{4.56}$$

4.12 Finite renormalization

The last step in one-loop renormalization is the connection between renormalized quantities and POs. Since all quantities at this stage are UV-free, we term it "finite renormalization". Note that the absorption of UV divergences into local counterterms is, to some extent, a trivial step; finite renormalization, instead, requires more attention. For example, beyond one loop one cannot use on-shell masses but only complex poles for all unstable particles [71, 77]. Let us show some examples where the concept of an on-shell mass can be employed. Suppose that we renormalize a physical (pseudo-)observable F,

$$F = F_{\text{B}} + \frac{g^2}{16\,\pi^2}\left[F^{(4)}_{1\text{L}}(m^2) + g_6\,F^{(6)}_{1\text{L}}(m^2)\right] + \mathscr{O}(g^4)\,, \tag{4.57}$$

where m is some renormalized mass. Consider two cases: a) two-loop corrections are not included and b) m appears at one and two loops in $F_{1\text{L}}$ and $F_{2\text{L}}$ but does not show up in the Born term F_{B}. In these cases we can use the concept of an on-shell mass performing a finite mass renormalization at one loop. If m_0 is the bare mass for the field V we write

$$m_0^2 = M^2_{\text{OS}}\left\{1 + \frac{g^2}{16\,\pi^2}\,\text{Re}\,\Sigma_{\text{VV}\,;\,\text{fin}}\Big|_{s=M^2_{\text{OS}}}\right\} = M^2_{\text{OS}} + g^2\,\Delta M^2\,, \tag{4.58}$$

where M_{OS} is the on-shell mass and Σ is extracted from the required one-particle irreducible Green function; eq. (4.58) is still meaningful (no dependence on gauge parameters) and will be used inside the result.

In the Complex Pole scheme we replace the conventional on-shell mass renormalization equation with the associated expression for the complex pole

$$m_0^2 = M^2_{\text{OS}}\left[1 + \frac{g^2}{16\,\pi^2}\,\text{Re}\,\Sigma_{\text{VV}\,;\,\text{fin}}\left(M^2_{\text{OS}}\right)\right] \Longrightarrow m_0^2 = s_{\text{V}}\left[1 + \frac{g^2}{16\,\pi^2}\,\Sigma_{\text{VV}\,;\,\text{fin}}\left(M^2_{\text{OS}}\right)\right]\,, \tag{4.59}$$

where s_{V} is the complex pole associated to V. In this section we will discuss on-shell finite renormalization; after removal of UV poles we have replaced $m_0 \to m_{\text{ren}}$ etc. and we introduce

$$M_{\text{V ren}} = M_{\text{V}\,;\,\text{OS}} + \frac{g^2_{\text{ren}}}{16\,\pi^2}\left(\text{d}\mathscr{Z}^{(4)}_{M_{\text{V}}} + g_6\,\text{d}\mathscr{Z}^{(6)}_{M_{\text{V}}}\right) \tag{4.60}$$

and require that $s = M_{\text{V}\,;\,\text{OS}}$ is a zero of the real part of the inverse V propagator, up to $\mathscr{O}(g^2 g_6)$. Therefore we introduce

$$\begin{aligned}
M^2_{\text{ren}} &= M^2_{\text{W}\,;\,\text{OS}}\left[1 + \frac{g^2_{\text{ren}}}{16\,\pi^2}\left(\text{d}\mathscr{Z}^{(4)}_{M_{\text{W}}} + g_6\,\text{d}\mathscr{Z}^{(6)}_{M_{\text{W}}}\right)\right]\,,\\
M^2_{\text{H ren}} &= M^2_{\text{H}\,;\,\text{OS}}\left[1 + \frac{g^2_{\text{ren}}}{16\,\pi^2}\left(\text{d}\mathscr{Z}^{(4)}_{M_{\text{H}}} + g_6\,\text{d}\mathscr{Z}^{(6)}_{M_{\text{H}}}\right)\right]\,,\\
\text{c}^{\text{ren}}_{\theta} &= \text{c}_{\text{W}}\left[1 + \frac{g^2_{\text{ren}}}{16\,\pi^2}\left(\text{d}\mathscr{Z}^{(4)}_{\text{c}_\theta} + g_6\,\text{d}\mathscr{Z}^{(6)}_{\text{c}_\theta}\right)\right]\,,
\end{aligned} \tag{4.61}$$

where $\text{c}^2_{\text{W}} = M^2_{\text{W}\,;\,\text{OS}}/M^2_{\text{Z}\,;\,\text{OS}}$ and $s = M^2_{\text{Z}\,;\,\text{OS}}$ will be a zero of the real part of the inverse Z propagator.

Finite renormalization in the fermion sector requires the following steps: if $M_{\mathrm{f;OS}}$ denotes the on-shell fermion mass, using eq. (4.41), we write

$$M_{\mathrm{f}}\left[\mathrm{d}\mathscr{Z}^{(4)}_{M_{\mathrm{f}}}+g_6\,\mathrm{d}\mathscr{Z}^{(6)}_{M_{\mathrm{f}}}\right]=\Delta_{\mathrm{f}}\left(M^2_{\mathrm{f;OS}}\right)+M_{\mathrm{f;OS}}\,V_{\mathrm{f}}\left(M^2_{\mathrm{f;OS}}\right) \tag{4.62}$$

and determine the finite counterterms which are given in appendix E.

4.12.1 G_{F} renormalization scheme

In the G_{F}-scheme we write the following equation for the g finite renormalization

$$g_{\mathrm{ren}}=g_{\mathrm{exp}}+\frac{g^2_{\mathrm{exp}}}{16\,\pi^2}\left(\mathrm{d}\mathscr{Z}^{(4)}_{g}+g_6\,\mathrm{d}\mathscr{Z}^{(6)}_{g}\right), \tag{4.63}$$

where g_{exp} will be expressed in terms of the Fermi coupling constant G_{F}. The μ-lifetime can be written in the form

$$\frac{1}{\tau_\mu}=\frac{M^5_\mu}{192\,\pi^3}\,\frac{g^4}{32\,M^4}\,\left(1+\delta_\mu\right). \tag{4.64}$$

The radiative corrections are $\delta_\mu=\delta^{\mathrm{W}}_\mu+\delta_{\mathrm{G}}$ where δ_{G} is the sum of vertices, boxes etc and δ^{W}_μ is due to the W self-energy. The renormalization equation becomes

$$\frac{G_{\mathrm{F}}}{\sqrt{2}}=\frac{g^2}{8\,M^2}\left\{1+\frac{g^2}{16\,\pi^2}\left[\delta_{\mathrm{G}}+\frac{1}{M^2}\,\Sigma_{\mathrm{WW}}(0)\right]\right\}, \tag{4.65}$$

where we expand the solution for g

$$g^2_{\mathrm{ren}}=4\,\sqrt{2}\,G_{\mathrm{F}}\,M^2_{\mathrm{W;OS}}\left\{1+\frac{G_{\mathrm{F}}M^2_{\mathrm{W;OS}}}{2\,\sqrt{2}\,\pi^2}\left[\delta_{\mathrm{G}}+\frac{1}{M^2}\,\Sigma_{\mathrm{WW;fin}}(0)\right]\right\} \tag{4.66}$$

Note that the non universal part of the corrections is given by

$$\delta_{\mathrm{G}}=\delta^{(4)}_{\mathrm{G}}+g_6\,\delta^{(6)}_{\mathrm{G}},\qquad \delta^{(4)}_{\mathrm{G}}=6+\frac{7-4\,\mathrm{s}^2_\theta}{2\,\mathrm{s}^2_\theta}\,\ln\mathrm{c}^2_\theta, \tag{4.67}$$

but the contribution of dim $=6$ operators to muon decay is not available yet and will not be included in the calculation. It is worth noting that eqs. (4.61)–(4.65) define finite renormalization in the $\{G_{\mathrm{F}}\,, M_{\mathrm{W}}\,, M_{\mathrm{Z}}\}$ input parameter set.

We show few explicit examples of finite renormalization, i.e. how to fix finite counterterms. From the H propagator and the definition of on-shell H mass one obtains

$$\mathrm{d}\mathscr{Z}^{(n)}_{M_{\mathrm{H}}}=\frac{M^2_{\mathrm{W;OS}}}{M^2_{\mathrm{H;OS}}}\,\mathrm{Re}\,\Delta^{(n)}_{\mathrm{HH;fin}}\left(M^2_{\mathrm{H;OS}}\right)+\mathrm{Re}\,\Pi^{(n)}_{\mathrm{HH;fin}}\left(M^2_{\mathrm{H;OS}}\right), \tag{4.68}$$

where M_{H} is the renormalized H mass and $M_{\mathrm{H;OS}}$ is the on-shell H mass. ¿From the W propagator we have

$$\mathrm{d}\mathscr{Z}^{(n)}_{M_{\mathrm{W}}}=\mathrm{Re}\,\Delta^{(n)}_{\mathrm{WW;fin}}\left(M^2_{\mathrm{W;OS}}\right)+\mathrm{Re}\,\Pi^{(n)}_{\mathrm{WW;fin}}\left(M^2_{\mathrm{W;OS}}\right). \tag{4.69}$$

¿From the Z propagator and the definition of on-shell Z mass we have

$$\mathrm{d}\mathscr{Z}^{(n)}_{\mathrm{c}_\theta}=\frac{1}{2}\,\mathrm{Re}\left[\mathrm{d}\mathscr{Z}^{(n)}_{M_{\mathrm{W}}}-\mathrm{c}^2_{\mathrm{W}}\,\Delta^{(n)}_{\mathrm{ZZ;fin}}\left(M^2_{\mathrm{Z;OS}}\right)-\Pi^{(n)}_{\mathrm{ZZ;fin}}\left(M^2_{\mathrm{Z;OS}}\right)\right], \tag{4.70}$$

with $\mathrm{c}^2_{\mathrm{W}}=M^2_{\mathrm{W;OS}}/M^2_{\mathrm{Z;OS}}$. All quantities in eqs. (4.68)–(4.70) are the renormalized ones.

4.12.2 α renormalization scheme

This scheme uses the fine structure constant α. The new renormalization equation is

$$g^2\,s_\theta^2 = 4\,\pi\alpha\left[1 - \frac{\alpha}{4\,\pi}\,\frac{\Pi_{AA}(0)}{s_\theta^2}\right], \tag{4.71}$$

where $\alpha = \alpha_{QED}(0)$. Therefore, in this scheme, the finite counterterms are

$$g_{ren}^2 = g_A^2\left[1 + \frac{\alpha}{4\,\pi}\,d\mathscr{Z}_g\right], \quad c_\theta^{ren} = \hat{c}_\theta\left[1 + \frac{\alpha}{4\,\pi}\,d\mathscr{Z}_{c_\theta}\right], \quad M_{ren} = M_{Z\,;OS}\,\hat{c}_\theta^2\left[1 + \frac{\alpha}{8\,\pi}\,d\mathscr{Z}_{M_W}\right], \tag{4.72}$$

where the parameters $\hat{c}_\theta$ and g_A are defined by

$$g_A^2 = \frac{4\,\pi\,\alpha}{\hat{s}_\theta^2} \qquad \hat{s}_\theta^2 = \frac{1}{2}\left[1 - \sqrt{1 - 4\,\frac{\pi\,\alpha}{\sqrt{2}\,G_F\,M_{Z\,;OS}^2}}\right]. \tag{4.73}$$

The reason for introducing this scheme is that the S, T and U parameters (see ref. [76]) have been originally given in the $\{\alpha\,,G_F\,,M_Z\}$ scheme while, for the rest of the calculations we have adopted the more convenient $\{G_F\,,M_W\,,M_Z\}$ scheme. In this scheme, after requiring that $M_{Z\,;OS}^2$ is a zero of the real part of the inverse Z propagator, we are left with one finite counterterm, $d\mathscr{Z}_g$. The latter is fixed by using G_F and requiring that

$$\frac{1}{\sqrt{2}}\,G_F = \frac{g^2}{8\,M^2}\left\{1 + \frac{g^2}{16\,\pi^2}\left[\delta_G + \frac{1}{M^2}\,\Delta_{WW}(0) - \left(dZ_W + dZ_{M_W}\right)\,\Delta_{UV}\right]\right\}, \tag{4.74}$$

where we use

$$g = g_{ren}\,\left(1 + \frac{g_{ren}^2}{16\,\pi^2}\,dZ_g\,\Delta_{UV}\right), \qquad g_{ren} = g_A\,\left(1 + \frac{\alpha}{8\,\pi}\,d\mathscr{Z}_g\right), \tag{4.75}$$

for UV and finite renormalization.

4.13 Wave function renormalization

Let us summarize the various steps in renormalization. Consider the V propagator, assuming that V couples to conserved currents (in the following we will drop the label V). We have

$$\overline{\Delta}_{\mu\nu} = -\,\frac{\delta_{\mu\nu}}{s - M^2 + \frac{g^2}{16\,\pi^2}\,D} = -\,\delta_{\mu\nu}\,\Delta^{-1}(s)\,, \tag{4.76}$$

where M is the V bare mass. The procedure is as follows: we introduce UV counterterms for the field and its mass,

$$\Delta(s)\Big|_{ren} = Z_V\,\left(s - Z_M\,M_{ren}^2\right) + \frac{g^2}{16\,\pi^2}\,D(s) = s - M_{ren}^2 + \frac{g^2}{16\,\pi^2}\,D(s)\Big|_{ren} \tag{4.77}$$

and write the (finite) renormalization equation

$$M_{ren}^2 = M_{OS}^2 + \frac{g^2}{16\,\pi^2}\,\mathrm{Re}\,D\left(M_{OS}^2\right)\Big|_{ren}, \tag{4.78}$$

where $M_{\rm OS}$ is the (on-shell) physical mass. After UV and finite renormalization we can write the following Taylor expansion:

$$\Delta(s)\Big|_{\rm ren} = \left(s - M^2_{\rm OS}\right)\left(1 + \frac{g^2_{\rm exp}}{16\,\pi^2}\,{\rm W}\right) + \mathscr{O}\left((s - M^2_{\rm OS})^2\right)\,, \tag{4.79}$$

where $g_{\rm exp}$ is defined in eq. (4.63). The wave-function renormalization factor for the field Φ will be denoted by

$${\rm Z}^{-1/2}_{{\rm WF};\Phi} = \left(1 + \frac{g^2_{\rm exp}}{16\,\pi^2}\,{\rm W}_\Phi\right)^{-1/2}\,. \tag{4.80}$$

For fermion fields we use eq. (4.41) and introduce

$$V'_{\rm f}(s) = -\frac{d}{ds}\,V_{\rm f}(s)\,. \tag{4.81}$$

Next we multiply spinors by the appropriate factors, i.e.

$$u_{\rm f}(p) \to \left(1 + {\rm W}_{\rm fV} + {\rm W}_{\rm fA}\,\gamma^5\right)\,u_{\rm f}(p) \quad \overline{u}_{\rm f}(p) \to \overline{u}_{\rm f}(p)\,\left(1 + {\rm W}_{\rm fV} - {\rm W}_{\rm fA}\,\gamma^5\right)\,, \tag{4.82}$$

where the wave-function renormalization factors are obtained from eq. (4.22)

$${\rm W}_{\rm fV} = \frac{1}{2}\,\left[V_{\rm f} + 2\,M_{\rm f}\,\Delta'_{\rm f} - 2\,M^2_{\rm f}\,V'_{\rm f}\right]\Big|_{s=M^2_{\rm f}}\,, \qquad {\rm W}_{\rm fA} = -\frac{1}{2}\,A_{\rm f}\Big|_{s=M^2_{\rm f}}\,. \tag{4.83}$$

For illustration we present the H wave-function factor

$$\begin{aligned}
{\rm W}_{\rm H} &= {\rm Re}\,\left({\rm W}^{(4)}_{\rm H} + g_6\,{\rm W}^{(6)}_{\rm H}\right)\,,\\
{\rm W}^{(n)}_{\rm H} &= d\Pi^{(n)}_{\rm HH}\left(M^2_{\rm H;OS}\right)\,M^2_{\rm H;OS} + d\Delta^{(n)}_{\rm HH}\left(M^2_{\rm H;OS}\right)\,M^2_{\rm W;OS} + \Pi^{(n)}_{\rm HH}\left(M^2_{\rm H;OS}\right) - 2\,{\rm d}\mathscr{Z}^{(n)}_g
\end{aligned} \tag{4.84}$$

and we expand any function of s as follows:

$$f(s) = f\left(M^2_{\rm OS}\right) + \left(s - M^2_{\rm OS}\right)\,df\left(M^2_{\rm OS}\right) + \mathscr{O}\left((s - M^2_{\rm OS})^2\right)\,, \tag{4.85}$$

with $f = \Pi^{(n)}, \Delta^{(n)}$. For the $\rm W, Z$ wave-function factor we obtain

$$\begin{aligned}
{\rm W}^{(n)}_{\rm W} &= d\Pi^{(n)}_{\rm WW}\left(M^2_{\rm W;OS}\right)\,M^2_{\rm W;OS} + d\Delta^{(n)}_{\rm WW}\left(M^2_{\rm W;OS}\right)\,M^2_{\rm W;OS} + \Pi^{(n)}_{\rm WW}\left(M^2_{\rm W;OS}\right) - 2\,{\rm d}\mathscr{Z}^{(n)}_g\,,\\
{\rm W}^{(n)}_{\rm Z} &= d\Pi^{(n)}_{\rm ZZ}\left(M^2_{\rm Z;OS}\right)\,M^2_{\rm Z;OS} + d\Delta^{(n)}_{\rm ZZ}\left(M^2_{\rm Z;OS}\right)\,M^2_{\rm W;OS} + \Pi^{(n)}_{\rm ZZ}\left(M^2_{\rm Z;OS}\right) - 2\,{\rm d}\mathscr{Z}^{(n)}_g\,.
\end{aligned} \tag{4.86}$$

Explicit expressions for the wave-function factors are given in appendix F.

4.14 Life and death of renormalization scale

Consider the A bare propagator

$$\overline{\Delta}^{-1}_{\rm AA} = s + \frac{g^2}{16\,\pi^2}\,\Sigma_{\rm AA}(s) \quad \Sigma_{\rm AA}(s) = \left({\rm R}^{(4)} + g_6\,{\rm R}^{(6)}\right)\,\frac{1}{\varepsilon} + \sum_{x\in\mathscr{X}}\left({\rm L}^{(4)}_x + g_6\,{\rm L}^{(6)}_x\right)\,\ln\frac{x}{\mu^2_{\rm R}} + \Sigma^{\rm rest}_{\rm AA}\,, \tag{4.87}$$

where $\mathrm{R}^{(n)}$ are the residues of the UV poles and $\mathrm{L}^{(n)}$ are arbitrary coefficients of the scale-dependent logarithms. Furthermore,

$$\{\mathscr{X}\} = \{s\,, m^2\,, m_0^2\,, m_{\mathrm{H}}^2\,, m_{\mathrm{t}}^2\,, m_{\mathrm{b}}^2\}\,. \tag{4.88}$$

The renormalized propagator is

$$\overline{\Delta}_{\mathrm{AA}}^{-1}\Big|_{\mathrm{ren}} = \mathrm{Z_A}\, s + \frac{g^2}{16\,\pi^2}\,\Sigma_{\mathrm{AA}}(s) = s + \frac{g^2}{16\,\pi^2}\,\Sigma_{\mathrm{AA}}^{\mathrm{ren}}(s)\,. \tag{4.89}$$

Furthermore, we can write

$$\Sigma_{\mathrm{AA}}^{\mathrm{ren}}(s) = \sum_{x\in\mathscr{X}} \left(\mathrm{L}_x^{(4)} + g_6\,\mathrm{L}_x^{(6)}\right)\,\ln\frac{x}{\mu_{\mathrm{R}}^2} + \Sigma_{\mathrm{AA}}^{\mathrm{rest}}\,. \tag{4.90}$$

Finite renormalization amounts to write $\Sigma_{\mathrm{AA}}^{\mathrm{ren}}(s) = \Pi_{\mathrm{AA}}^{\mathrm{ren}}(s)\,s$ and to use $s=0$ as subtraction point. Therefore, one can easily prove that

$$\frac{\partial}{\partial\mu_{\mathrm{R}}}\left[\Pi_{\mathrm{AA}}^{\mathrm{ren}}(s) - \Pi_{\mathrm{AA}}^{\mathrm{ren}}(0)\right] = 0\,, \tag{4.91}$$

including $\mathscr{O}^{(6)}$ contribution. Therefore we may conclude that there is no μ_{R} problem when a subtraction point is available. After discussing decays of the Higgs boson in section 5 we will see that an additional step is needed in the renormalization procedure, i.e. mixing of the Wilson coefficients. At this point the scale dependence problem will surface again and renormalized Wilson coefficients become scale dependent.

5 Decays of the Higgs boson

In this section we will present results for two-body decays of the Higgs boson while four-body decays will be included in a forthcoming publication. Our approach is based on the fact that renormalizing a theory must be a fully general procedure; only when this step is completed one may consider making approximations, e.g. neglecting the lepton masses, keeping only PTG terms etc. In particular, neglecting LG Wilson coefficients sensibly reduces the number of terms in any amplitude.

It is useful to introduce a more compact notation for Wilson coefficients, given in table 4 and to use the following definition:

Definition The PTG scenario: any amplitude computed at $\mathscr{O}(g^n\,g_6)$ has a SM component of $\mathscr{O}(g^n)$ and two dim $=6$ components: at $\mathscr{O}(g^{n-2}\,g_6)$ we allow both PTG and LG operator while at $\mathscr{O}(g^n\,g_6)$ only PTG operators are included.

5.1 Loop-induced processes: $\mathrm{H}\to\gamma\gamma$

The amplitude for the process $\mathrm{H}(P)\to \mathrm{A}_\mu(p_1)\mathrm{A}_\nu(p_2)$ can be written as

$$\mathrm{A}_{\mathrm{HAA}}^{\mu\nu} = \mathscr{T}_{\mathrm{HAA}}\,T^{\mu\nu}\,,\quad M_{\mathrm{H}}^2\,T^{\mu\nu} = p_2^\mu\,p_1^\nu - p_1\cdot p_2\,\delta^{\mu\nu}\,. \tag{5.1}$$

The S-matrix element follows from eq. (5.1) when we multiply the amplitude by the photon polarizations $e_\mu(p_1)\,e_\nu(p_2)$; in writing eq. (5.1) we have used $p\cdot e(p)=0$.

$a_{AA} = W_1$	$a_{ZZ} = W_2$	$a_{AZ} = W_3$
$a_{\phi D} = W_4$	$a_{\phi \square} = W_5$	$a_{\phi} = W_6$
$a_{l\,WB} = W_7$	$a_{l\,BW} = W_8$	$a_{d\,WB} = W_9$
$a_{d\,BW} = W_{10}$	$a_{u\,WB} = W_{11}$	$a_{u\,BW} = W_{12}$
$a_{l\,\phi} = W_{13}$	$a_{d\,\phi} = W_{14}$	$a_{u\,\phi} = W_{15}$
$a_{\phi\,l\,A} = W_{16}$	$a_{\phi\,l\,V} = W_{17}$	$a_{\phi\,v} = W_{18}$
$a_{\phi\,d\,A} = W_{19}$	$a_{\phi\,d\,V} = W_{20}$	$a_{\phi\,u\,A} = W_{21}$
$a_{\phi\,u\,V} = W_{22}$	$a_{\phi LldQ} = W_{23}$	$a^{(1)}_{QuQd} = W_{24}$

Table 4. Vector-like notation for Wilson coefficients.

Next we introduce dim $= 4$, LO, sub-amplitudes for t, b loops and for the bosonic loops,

$$
\begin{aligned}
\frac{3}{8}\,\frac{M_W}{M_t^2}\,\mathscr{T}^{\,t}_{HAA\,;LO} &= 2 + \left(M_H^2 - 4M_t^2\right)\,C_0\left(-M_H^2\,,0\,,0;M_t\,,M_t\,,M_t\right)\,,\\
\frac{9}{2}\,\frac{M_W}{M_b^2}\,\mathscr{T}^{\,b}_{HAA\,;LO} &= 2 + \left(M_H^2 - 4M_b^2\right)\,C_0\left(-M_H^2\,,0\,,0;M_b\,,M_b\,,M_b\right)\,,\\
\frac{1}{M_W}\,\mathscr{T}^{\,W}_{HAA\,;LO} &= -6 - 6\,\left(M_H^2 - 2M_W^2\right)\,C_0\left(-M_H^2\,,0\,,0;M_W\,,M_W\,,M_W\right)\,,
\end{aligned}
\tag{5.2}
$$

where C_0 is the scalar three-point function. The following result is obtained:

$$
\mathscr{T}_{HAA} = i\,\frac{g^3}{16\,\pi^2}\,\left(\mathscr{T}^{(4)}_{HAA} + g_6\,\mathscr{T}^{(6),b}_{HAA}\right) + i\,g\,g_6\,\mathscr{T}^{(6),a}_{HAA}\,,
\tag{5.3}
$$

where the dim $= 4$ part of the amplitude

$$
\mathscr{T}^{(4)}_{HAA} = 2\,s_\theta^2\,\left(\sum_{gen}\sum_{f}\mathscr{T}^{\,f}_{HAA\,;LO} + \mathscr{T}^{\,W}_{HAA\,;LO}\right)
\tag{5.4}
$$

is UV finite, as well as $\mathscr{T}^{(6),a}$ which is given by

$$
\mathscr{T}^{(6),a}_{HAA} = 2\,\frac{M_H^2}{M}\,\left(s_\theta^2\,a_{\phi W} + c_\theta^2\,a_{\phi B} + s_\theta\,c_\theta\,a_{\phi WB}\right)\,.
\tag{5.5}
$$

The $\mathscr{T}^{(6),b}$ component contains an UV-divergent part. UV renormalization requires

$$
\mathscr{T}^{ren}_{HAA} = \mathscr{T}_{HAA}\left[1 + \frac{g^2}{16\,\pi^2}\left(dZ_A + \frac{1}{2}\,dZ_H + 3\,dZ_g\right)\Delta_{UV}\right],
\tag{5.6}
$$

$$
c_\theta = c_\theta^{ren}\left(1 + \frac{g^2}{16\,\pi^2}\,dZ_{c_\theta}\,\Delta_{UV}\right)\,,\qquad g = g_{ren}\left(1 + \frac{g_{ren}^2}{16\,\pi^2}\,dZ_g\,\Delta_{UV}\right)
\tag{5.7}
$$

and we obtain the renormalized version of the amplitude

$$
\begin{aligned}
\mathcal{T}^{\rm ren}_{\rm HAA} &= i\,\frac{g^3_{\rm ren}}{16\,\pi^2}\,\Big(\mathcal{T}^{(4)}_{\rm HAA} + g_6\,\mathcal{T}^{(6),b}_{\rm HAA\,;\,fin}\Big) + i\,g_{\rm ren}\,g_6\,\mathcal{T}^{(6),a}_{\rm HAA\,;\,ren} + i\,\frac{g^3_{\rm ren}}{16\,\pi^2}\,g_6\,\mathcal{T}^{(6)}_{{\rm HAA}\,;\,div}\,,\\
\mathcal{T}^{(6)}_{{\rm HAA}\,;\,div} &= \mathcal{T}^{(6),b}_{\rm HAA\,;\,div}\,\Delta_{\rm UV}\Big(M^2_{\rm W}\Big) + \frac{M^2_{\rm H\,ren}}{M_{\rm ren}}\Big\{\Big[{\rm dZ}^{(4)}_{\rm H} - {\rm dZ}^{(4)}_{M_{\rm W}} + 2\,{\rm dZ}^{(4)}_{\rm A} - 2\,{\rm dZ}^{(4)}_{g}\Big]\,a_{\rm AA} - 2\,\frac{{\rm c}^{\rm ren}_{\theta}}{s^{\rm ren}_{\theta}}\,{\rm dZ}^{(4)}_{{\rm c}_\theta}\,a_{\rm AZ}\Big\}\,\Delta_{\rm UV}\,,\\
\mathcal{T}^{(6),a}_{\rm HAA\,;\,ren} &= 2\,\frac{M^2_{\rm H\,ren}}{M_{\rm ren}}\,a_{\rm AA}\,, \qquad (5.8)
\end{aligned}
$$

where $a_{\rm AA} = {\rm s}_\theta {\rm c}_\theta\, a_{\phi\,\rm WB} + {\rm c}^2_\theta\, a_{\phi\,\rm B} + {\rm s}^2_\theta\, a_{\phi\,\rm W}$ and ${\rm c}_\theta = {\rm c}^{\rm ren}_\theta$ etc. The last step in the UV-renormalization procedure requires a mixing among Wilson coefficients which cancels the remaining (dim $=6$) parts. To this purpose we define

$$
{\rm W}_i = \sum_j Z^{\rm W}_{ij}\,{\rm W}^{\rm ren}_j\,, \qquad Z^{\rm W}_{ij} = \delta_{ij} + \frac{g^2}{16\,\pi^2}\,{\rm dZ}^{\rm W}_{ij}\,\Delta_{\rm UV}\,. \qquad (5.9)
$$

The matrix ${\rm dZ}^{\rm W}$ is fixed by requiring cancellation of the residual UV poles and we obtain

$$
\mathcal{T}^{(6)}_{\rm HAA\,;\,div} \to \mathcal{T}^{(6),\rm R}_{\rm HAA}\,\ln\frac{\mu^2_{\rm R}}{M^2}\,. \qquad (5.10)
$$

Elements of the mixing matrix derived from $\rm H \to AA$ are given in appendix G. The result of eq. (5.8) becomes

$$
\mathcal{T}^{\rm ren}_{\rm HAA} = i\,\frac{g^3_{\rm ren}}{16\,\pi^2}\left(\mathcal{T}^{(4)}_{\rm HAA} + g_6\,\mathcal{T}^{(6),b}_{\rm HAA\,;\,fin} + g_6\,\mathcal{T}^{(6),\rm R}_{\rm HAA}\,\ln\frac{\mu^2_{\rm R}}{M^2}\right) + i\,g_{\rm ren}\,g_6\,\mathcal{T}^{(6),a}_{\rm HAA}\,. \qquad (5.11)
$$

Inclusion of wave-function renormalization factors and of external leg factors (due to field redefinition described in section 2.4) gives

$$
\mathcal{T}^{\rm ren}_{\rm HAA}\left[1 - \frac{g^2_{\rm ren}}{16\,\pi^2}\left({\rm W}_{\rm A} + \frac{1}{2}\,{\rm W}_{\rm H}\right)\right]\left[1 + g_6\left(2\,a_{\rm AA} + a_{\phi\,\Box} - \frac{1}{4}\,a_{\phi\,\rm D}\right)\right]. \qquad (5.12)
$$

Finite renormalization requires writing

$$
\begin{aligned}
M^2_{\rm ren} &= M^2_{\rm W}\left(1 + \frac{g^2_{\rm ren}}{16\,\pi^2}\,{\rm d}\mathcal{Z}_{M_{\rm W}}\right),\\
{\rm c}^{\rm ren}_\theta &= {\rm c}_{\rm W}\left(1 + \frac{g^2_{\rm ren}}{16\,\pi^2}\,{\rm d}\mathcal{Z}_{{\rm c}_\theta}\right),\\
g_{\rm ren} &= g_{\rm F}\left(1 + \frac{g^2_{\rm F}}{16\,\pi^2}\,{\rm d}\mathcal{Z}_{g}\right), \qquad (5.13)
\end{aligned}
$$

where $g^2_{\rm F} = 4\,\sqrt{2}\,G_{\rm F}\,M^2_{\rm W}$ and ${\rm c}_{\rm W} = M_{\rm W}/M_{\rm Z}$. Another convenient way for writing the answer is the following: after renormalization we neglect all fermion masses but $\rm t, b$ and write

$$
\begin{aligned}
\mathcal{T}_{\rm HAA} &= i\,\frac{g^3_{\rm F}\,{\rm s}^2_{\rm W}}{8\,\pi^2}\sum_{\rm I=W,t,b}\kappa^{\rm HAA}_{\rm I}\,\mathcal{T}^{\rm I}_{\rm HAA\,;\,LO} + i\,g_{\rm F}\,g_6\,\frac{M^2_{\rm H}}{M_{\rm W}}\,{\rm W}^{\rm ren}_1\\
&\quad + i\,\frac{g^3_{\rm F}\,g_6}{\pi^2}\left[\sum_{i=1,3}\mathcal{A}^{\rm nfc}_{{\rm W},i}\,{\rm W}^{\rm ren}_i + \mathcal{T}^{\rm nfc}_{\rm HAA\,;\,b}\,{\rm W}^{\rm ren}_9 + \sum_{i=1,2}\mathcal{T}^{\rm nfc}_{{\rm HAA}\,;\,{\rm t},i}\,{\rm W}^{\rm ren}_{10+i}\right], \qquad (5.14)
\end{aligned}
$$

where Wilson coefficients are those in table 4. The κ-factors are given by

$$\kappa_{\mathrm{I}}^{\mathrm{proc}} = 1 + g_6\, \Delta\kappa_{\mathrm{I}}^{\mathrm{proc}} \tag{5.15}$$

and there are additional, non-factorizable, contributions. The κ factors are

$$\begin{aligned}
\Delta\kappa_{\mathrm{t}}^{\mathrm{HAA}} &= \frac{3}{16}\,\frac{M_{\mathrm{H}}^2}{\mathrm{s_W}\, M_{\mathrm{W}}^2}\, a_{\mathrm{t\,WB}} + (2-\mathrm{s_W^2})\,\frac{\mathrm{c_W}}{\mathrm{s_W}}\, a_{\mathrm{AZ}} + (6-\mathrm{s_W^2})\, a_{\mathrm{AA}} \\
&\quad - \frac{1}{2}\left[a_{\phi\mathrm{D}} + 2\,\mathrm{s_W^2}\,(\mathrm{c_W^2}\, a_{\mathrm{ZZ}} - a_{\mathrm{t}\phi} - 2\, a_{\phi\Box})\right]\frac{1}{\mathrm{s_W^2}}\,, \\
\Delta\kappa_{\mathrm{b}}^{\mathrm{HAA}} &= -\frac{3}{8}\,\frac{M_{\mathrm{H}}^2}{\mathrm{s_W}\, M_{\mathrm{W}}^2}\, a_{\mathrm{b\,WB}} + (2-\mathrm{s_W^2})\,\frac{\mathrm{c_W}}{\mathrm{s_W}}\, a_{\mathrm{AZ}} + (6-\mathrm{s_W^2})\, a_{\mathrm{AA}} \\
&\quad - \frac{1}{2}\left[a_{\phi\mathrm{D}} + 2\,\mathrm{s_W^2}\,(\mathrm{c_W^2}\, a_{\mathrm{ZZ}} + a_{\mathrm{b}\phi} - 2\, a_{\phi\Box})\right]\frac{1}{\mathrm{s_W^2}}\,, \\
\Delta\kappa_{\mathrm{W}}^{\mathrm{HAA}} &= (2+\mathrm{s_W^2})\,\frac{\mathrm{c_W}}{\mathrm{s_W}}\, a_{\mathrm{AZ}} + (6+\mathrm{s_W^2})\, a_{\mathrm{AA}} \\
&\quad - \frac{1}{2}\left[a_{\phi\mathrm{D}} - 2\,\mathrm{s_W^2}\,(2\, a_{\phi\Box} + \mathrm{c_W^2}\, a_{\mathrm{ZZ}})\right]\frac{1}{\mathrm{s_W^2}}\,,
\end{aligned} \tag{5.16}$$

where Wilson coefficients are the renormalized ones. In the PTG scenario we only keep $a_{\mathrm{t}\phi}, a_{\mathrm{b}\phi}, a_{\phi\mathrm{D}}$ and $a_{\phi\Box}$ in eq. (5.16).

The advantage of eq. (5.14) is to establish a link between EFT and κ-language of ref. [4], which has a validity restricted to LO. As a matter of fact eq. (5.14) tells you that κ-factors can be introduced also at NLO level; they are combinations of Wilson coefficients but we have to extend the scheme with the inclusion of process dependent, non-factorizable, contributions.

Returning to the original convention for Wilson coefficients we derive the following result for the non-factorizable part of the amplitude:

$$\mathscr{T}_{\mathrm{HAA}}^{\mathrm{nfc}} = M_{\mathrm{W}} \sum_{a\in\{A\}} \mathscr{T}_{\mathrm{HAA}}^{\mathrm{nfc}}(a)\, a\,, \tag{5.17}$$

where $\{A\} = \{a_{\mathrm{t\,WB}}, a_{\mathrm{b\,WB}}, a_{\mathrm{AA}}, a_{\mathrm{AZ}}, a_{\mathrm{ZZ}}\}$. Finite counterterms, $\mathrm{d}\mathscr{Z}_{M_{\mathrm{H}}}, \mathrm{d}\mathscr{Z}_g$ and $\mathrm{d}\mathscr{Z}_{M_{\mathrm{W}}}$ are defined in eq. (4.61) and in eq. (4.63). The results are reported on appendix H. In the PTG scenario all non-factorizable amplitudes for $\mathrm{H}\to\mathrm{AA}$ vanish.

5.2 $\mathrm{H}\to\mathrm{Z}\gamma$

The amplitude for $\mathrm{H}(P)\to\mathrm{A}_\mu(p_1)\mathrm{Z}_\nu(p_2)$ can be written as

$$\mathrm{A}_{\mathrm{HAZ}}^{\mu\nu} = M_{\mathrm{H}}^2\, \mathscr{D}_{\mathrm{HAZ}}\, \delta^{\mu\nu} + \mathscr{P}_{\mathrm{HAZ}}^{11}\, p_1^\mu\, p_1^\nu + \mathscr{P}_{\mathrm{HAZ}}^{12}\, p_1^\mu\, p_2^\nu + \mathscr{P}_{\mathrm{HAZ}}^{21}\, p_2^\mu\, p_1^\nu + \mathscr{P}_{\mathrm{HAZ}}^{22}\, p_2^\mu\, p_2^\nu\,. \tag{5.18}$$

The result of eq. (5.18) is fully general and can be used to prove WST identities. As far as the partial decay width is concerned only $\mathscr{P}_{\mathrm{HAZ}}^{21}$ will be relevant, due to $p\cdot e(p) = 0$ where e is the polarization vector. We start by considering the 1PI component of the amplitude and obtain

$$\mathrm{A}_{\mathrm{HAZ}}^{\mu\nu}\Big|_{\mathrm{1PI}} = M_{\mathrm{H}}^2\, \mathscr{D}_{\mathrm{HAZ}}^{(\mathrm{1PI})}\, \delta^{\mu\nu} + \mathscr{T}_{\mathrm{HAZ}}^{(\mathrm{1PI})}\, T^{\mu\nu}\,, \tag{5.19}$$

where T is given by

$$M_H^2\, T^{\mu\nu} = p_2^\mu\, p_1^\nu - p_1 \cdot p_2\, \delta^{\mu\nu}\,. \tag{5.20}$$

Furthermore we can write the following decomposition:

$$\mathscr{T}^{(1\text{PI})}_{\text{HAZ}} = i\,\frac{g^3}{16\,\pi^2}\,\Bigl(\mathscr{T}^{(4)}_{\text{HAZ}} + g_6\,\mathscr{T}^{(6),b}_{\text{HAZ}}\Bigr) + i\,g\,g_6\,\mathscr{T}^{(6),a}_{\text{HAZ}}\,, \qquad \mathscr{D}^{(1\text{PI})}_{\text{HAZ}} = i\,\frac{g^3 g_6}{16\,\pi^2}\,\mathscr{D}^{(6)}_{\text{HAZ}}\,, \tag{5.21}$$

$$\mathscr{D}^{(6)}_{\text{HAZ}} = 3\,c_\theta\, s_\theta^2\,\frac{M_0^3}{M_H^2}\,C_0\Bigl(-M_H^2\,,0\,,-M_0^2\,;M\,,M\,,M\Bigr)\,a_{AZ}\,,$$

$$\mathscr{T}^{(6),a}_{\text{HAZ}} = \frac{M_H^2}{M}\Bigl[2\,s_\theta c_\theta\,(a_{\phi W} - a_{\phi B}) + \bigl(2\,c_\theta^2 - 1\bigr)\,a_{\phi WB}\Bigr]. \tag{5.22}$$

Explicit expressions for $\mathscr{T}^{(4)}_{\text{HAZ}}, \mathscr{T}^{(6),b}_{\text{HAZ}}$ will not be reported here. The 1PR component of the amplitude is given by

$$A^{\mu\nu}_{\text{HAZ}}\Big|_{1\text{PR}} = -\frac{1}{M_0^2}\,A^{\mu\alpha\,\text{off}}_{\text{HAA}}(p_1\,,p_2)\,S^{\alpha\nu}_{AZ}(p_2) = M_H^2\,\mathscr{D}^{(1\text{PR})}_{\text{HAZ}}\,\delta^{\mu\nu} + \mathscr{T}^{(1\text{PR})}_{\text{HAZ}}\,T^{\mu\nu}\,, \tag{5.23}$$

where $A^{\mu\alpha\,\text{off}}_{\text{HAA}}$ denotes the off-shell $H \to AA$ amplitude. It is straightforward to derive

$$\mathscr{D}_{\text{HAZ}} = \mathscr{D}^{(1\text{PI})}_{\text{HAZ}} + \mathscr{D}^{(1\text{PR})}_{\text{HAZ}} = 0 \tag{5.24}$$

i.e. the complete amplitude for $H \to AZ$ is proportional to $T^{\mu\nu}$ and, therefore, is transverse. UV renormalization requires the introduction of counterterms,

$$\mathscr{T}^{\text{ren}}_{\text{HAZ}} = \mathscr{T}_{\text{HAZ}}\left[1 + \frac{1}{2}\,\frac{g^2}{16\,\pi^2}\,\bigl(dZ_H + dZ_A + dZ_Z - 6\,dZ_g\bigr)\,\Delta_{UV}\right], \tag{5.25}$$

$$c_\theta = c_\theta^{\text{ren}}\left(1 + \frac{g^2_{\text{ren}}}{16\,\pi^2}\,dZ_{c_\theta}\,\Delta_{UV}\right), \qquad g = g_{\text{ren}}\left(1 + \frac{g^2_{\text{ren}}}{16\,\pi^2}\,dZ_g\,\Delta_{UV}\right) \tag{5.26}$$

and we obtain the following result for the renormalized amplitude:

$$\begin{aligned}
\mathscr{T}^{\text{ren}}_{\text{HAZ}} &= i\,\frac{g^3_{\text{ren}}}{16\,\pi^2}\,\Bigl(\mathscr{T}^{(4)}_{\text{HAZ}} + g_6\,\mathscr{T}^{(6),b}_{\text{HAZ}\,;\,\text{fin}}\Bigr) + i\,g_{\text{ren}}\,g_6\,\mathscr{T}^{(6),a}_{\text{HAZ}\,;\,\text{ren}} + i\,\frac{g^3_{\text{ren}}}{16\,\pi^2}\,g_6\,\mathscr{T}^{(6)}_{\text{HAZ}\,;\,div}\,,\\
\mathscr{T}^{(6)}_{\text{HAZ}\,;\,div} &= \mathscr{T}^{(6),b}_{\text{HAZ}\,;\,\text{div}}\,\Delta_{UV}\Bigl(M_W^2\Bigr) + \frac{M^2_{H\,\text{ren}}}{M_{\text{ren}}}\left\{\left[\frac{1}{2}\,dZ^{(4)}_H + dZ^{(4)}_A - \frac{1}{2}\,dZ^{(4)}_{M_W} - 2\,dZ^{(4)}_g\right]a_{AZ}\right.\\
&\quad \left. +2\,\frac{c_\theta^{\text{ren}}}{s_\theta^{\text{ren}}}\,dZ^{(4)}_{c_\theta}\,(a_{AA} - a_{ZZ})\right\}\Delta_{UV}\,,\\
\mathscr{T}^{(6),a}_{\text{HAZ}\,;\,\text{ren}} &= \frac{M^2_{H\,\text{ren}}}{M_{\text{ren}}}\,a_{AZ}\,,
\end{aligned} \tag{5.27}$$

where $a_{AA} = s_\theta c_\theta\, a_{\phi WB} + c_\theta^2\, a_{\phi B} + s_\theta^2\, a_{\phi W}$ and $c_\theta = c_\theta^{\text{ren}}$ etc. Once again, the last step in the UV-renormalization procedure requires a mixing among Wilson coefficients, performed according to eq. (5.9). We obtain

$$\mathscr{T}^{(6)}_{\text{HAZ}\,;\,\text{div}} \to \mathscr{T}^{(6),R}_{\text{HAZ}}\,\ln\frac{\mu_R^2}{M^2}\,. \tag{5.28}$$

Elements of the mixing matrix derived from the process $\mathrm{H} \to \mathrm{AZ}$ are given in appendix G. After mixing the result of eq. (5.27) becomes

$$\mathscr{T}^{\mathrm{ren}}_{\mathrm{HAZ}} = i\,\frac{g^3_{\mathrm{ren}}}{16\,\pi^2}\,\left(\mathscr{T}^{(4)}_{\mathrm{HAZ}} + g_6\,\mathscr{T}^{(6),b}_{\mathrm{HAZ\,;\,fin}} + g_6\,\mathscr{T}^{(6),\mathrm{R}}_{\mathrm{HAZ}}\,\ln\frac{\mu^2_{\mathrm{R}}}{M^2}\right) + i\,g_{\mathrm{ren}}\,g_6\,\mathscr{T}^{(6),a}_{\mathrm{HAZ}}\,. \tag{5.29}$$

Inclusion of wave-function renormalization factors and of external leg factors (due to field redefinition, defined in section 2.4) gives

$$\mathscr{T}^{\mathrm{ren}}_{\mathrm{HAZ}}\left[1 - \frac{1}{2}\,\frac{g^2_{\mathrm{ren}}}{16\,\pi^2}\,\left(\mathrm{W_H} + \mathrm{W_A} + \mathrm{W_Z}\right)\right]\left[1 + g_6\,\left(a_{\mathrm{AA}} + a_{\mathrm{ZZ}} + a_{\phi\Box} - \frac{1}{4}\,a_{\phi\mathrm{D}}\right)\right]. \tag{5.30}$$

Finite renormalization is performed by using eq. (5.13). To write the final answer it is convenient to define dim $= 4$ sub-amplitudes $\mathscr{T}^{\mathrm{I}}_{\mathrm{HAZ\,;\,LO}}$ ($I = \mathrm{W,t,b}$): they are given in appendix I. Another convenient way for writing $\mathscr{T}^{\mathrm{ren}}_{\mathrm{HAZ}}$ is the following:

$$\begin{aligned}
\mathscr{T}^{\mathrm{ren}}_{\mathrm{HAZ}} = i\,\frac{g^3_{\mathrm{F}}}{\pi^2 M_{\mathrm{Z}}}\sum_{\mathrm{I=W,t,b}}\kappa^{\mathrm{HAZ}}_{\mathrm{I}}\,\mathscr{T}^{\mathrm{I}}_{\mathrm{HAZ\,;\,LO}} + i\,g_{\mathrm{F}}\,g_6\,\frac{M^2_{\mathrm{H}}}{M}\,\mathrm{W}^{\mathrm{ren}}_3 \\
+ i\,\frac{g^3_{\mathrm{F}}\,g_6}{\pi^2}\left[\sum_{i=1,4}\mathscr{T}^{\mathrm{nfc}}_{\mathrm{HAZ\,;\,W},i}\,\mathrm{W}^{\mathrm{ren}}_i + \sum_{i=11,12,22}\mathscr{T}^{\mathrm{nfc}}_{\mathrm{HAZ\,;\,t},i}\,\mathrm{W}^{\mathrm{ren}}_i + \sum_{i=9,10,20}\mathscr{T}^{\mathrm{nfc}}_{\mathrm{HAZ\,;\,b},i}\,\mathrm{W}^{\mathrm{ren}}_i\right].
\end{aligned} \tag{5.31}$$

The factorizable part is defined in terms of κ-factors, see eq. (5.15)

$$\begin{aligned}
\Delta\kappa^{\mathrm{HAZ}}_{\mathrm{t}} &= \frac{1}{2}\,\left(2\,a_{\mathrm{t}\phi} + 4\,a_{\phi\Box} - a_{\phi\mathrm{D}} + 6\,a_{\mathrm{AA}} + 2\,a_{\mathrm{ZZ}}\right), \\
\Delta\kappa^{\mathrm{HAZ}}_{\mathrm{b}} &= -\frac{1}{2}\,\left(2\,a_{\mathrm{b}\phi} - 4\,a_{\phi\Box} + a_{\phi\mathrm{D}} - 6\,a_{\mathrm{AA}} - 2\,a_{\mathrm{ZZ}}\right), \\
\Delta\kappa^{\mathrm{HAZ}}_{\mathrm{W}} &= \frac{1 + 6\,\mathrm{c}^2_{\mathrm{W}}}{\mathrm{c}^2_{\mathrm{W}}}\,a_{\phi\Box} - \frac{1}{4}\,\frac{1 + 4\,\mathrm{c}^2_{\mathrm{W}}}{\mathrm{c}^2_{\mathrm{W}}}\,a_{\phi\mathrm{D}} - \frac{1}{2}\,\frac{1 + \mathrm{c}^2_{\mathrm{W}} - 24\,\mathrm{c}^4_{\mathrm{W}}}{\mathrm{c}^2_{\mathrm{W}}}\,a_{\mathrm{AA}}\,, \\
&\quad + \frac{1}{4}\,\left(1 + 12\,\mathrm{c}^2_{\mathrm{W}} - 48\,\mathrm{c}^4_{\mathrm{W}}\right)\,\frac{\mathrm{s_W}}{\mathrm{c}^3_{\mathrm{W}}}\,a_{\mathrm{AZ}} + \frac{1}{2}\,\frac{1 + 15\,\mathrm{c}^2_{\mathrm{W}} - 24\,\mathrm{c}^4_{\mathrm{W}}}{\mathrm{c}^2_{\mathrm{W}}}\,a_{\mathrm{ZZ}}\,.
\end{aligned} \tag{5.32}$$

In the PTG scenario we only keep $a_{\mathrm{t}\phi}, a_{\mathrm{b}\phi}, a_{\phi\mathrm{D}}$ and $a_{\phi\Box}$ in eq. (5.32).

Returning to the original convention for Wilson coefficients we derive the following result for the non-factorizable part of the amplitude:

$$\mathscr{T}^{\mathrm{nfc}}_{\mathrm{HAZ}} = \sum_{a\in\{A\}}\mathscr{T}^{\mathrm{nfc}}_{\mathrm{HAZ}}(a)\,a\,, \tag{5.33}$$

where $\{A\} = \{a_{\phi\mathrm{tV}}, a_{\mathrm{tBW}}, a_{\mathrm{tWB}}, a_{\phi\mathrm{bV}}, a_{\mathrm{bWB}}, a_{\mathrm{bBW}}, a_{\phi\mathrm{D}}, a_{\mathrm{AZ}}, a_{\mathrm{AA}}, a_{\mathrm{ZZ}}\}$. In the PTG scenario there are only 3 non-factorizable amplitudes for $\mathrm{H} \to \mathrm{AZ}$, those proportional to $a_{\phi\mathrm{tV}}, a_{\phi\mathrm{bV}}$ and $a_{\phi\mathrm{D}}$. The full results are reported on appendix H where

$$\lambda_{\mathrm{AZ}} = \frac{M^2_{\mathrm{H}}}{M^2_{\mathrm{W}}} - \frac{M^2_{\mathrm{Z}}}{M^2_{\mathrm{W}}}\,. \tag{5.34}$$

5.3 $\mathrm{H} \to \mathrm{ZZ}$

The amplitude for $\mathrm{H}(P) \to \mathrm{Z}_\mu(p_1)\mathrm{Z}_\nu(p_2)$ can be written as

$$\mathrm{A}^{\mu\nu}_{\mathrm{HZZ}} = \mathscr{D}_{\mathrm{HZZ}}\,\delta^{\mu\nu} + \mathscr{P}^{11}_{\mathrm{HZZ}}\,p_1^\mu\,p_1^\nu + \mathscr{P}^{12}_{\mathrm{HZZ}}\,p_1^\mu\,p_2^\nu + \mathscr{P}^{21}_{\mathrm{HZZ}}\,p_2^\mu\,p_1^\nu + \mathscr{P}^{22}_{\mathrm{HZZ}}\,p_2^\mu\,p_2^\nu\,. \tag{5.35}$$

The result in eq. (5.35) is fully general and can be used to prove WST identities. As far as the partial decay width is concerned only $\mathscr{P}^{21}_{\mathrm{HZZ}} \equiv \mathscr{P}_{\mathrm{HZZ}}$ will be relevant, due to $p \cdot e(p) = 0$ where e is the polarization vector. Note that computing WST identities requires additional amplitudes, i.e. $\mathrm{H} \to \phi^0\gamma$ and $\mathrm{H} \to \phi^0\phi^0$.

We discuss first the 1PI component of the process: as done before the form factors in eq. (5.35) are decomposed as follows:

$$\begin{aligned}
\mathscr{D}^{\mathrm{1PI}}_{\mathrm{HZZ}} &= -i\,g\,\frac{M}{\mathrm{c}_\theta^2} + i\,\frac{g^3}{16\,\pi^2}\,\left(\mathscr{D}^{(4)\,\mathrm{1PI}}_{\mathrm{HZZ}} + g_6\,\mathscr{D}^{(6)\,\mathrm{1PI},b}_{\mathrm{HZZ}}\right) + i\,g\,g_6\,\mathscr{D}^{(6)\,\mathrm{1PI},a}_{\mathrm{HZZ}}\,,\\
\mathscr{P}^{\mathrm{1PI}}_{\mathrm{HZZ}} &= i\,\frac{g^3}{16\,\pi^2}\,\left(\mathscr{P}^{(4)\,\mathrm{1PI}}_{\mathrm{HZZ}} + g_6\,\mathscr{P}^{(6)\,\mathrm{1PI},b}_{\mathrm{HZZ}}\right) + i\,g\,g_6\,\mathscr{P}^{(6)\,\mathrm{1PI},a}_{\mathrm{HZZ}}\,.
\end{aligned} \tag{5.36}$$

It is easily seen that only $\mathscr{D}$ contains $\dim = 4$ UV divergences. The 1PR component of the process involves the A$-$Z transition and it is given by

$$\mathrm{A}^{\mu\nu}_{\mathrm{HZZ}}\Big|_{\mathrm{1PR}} = \frac{i}{M_0^2}\,\left[\mathscr{T}^{\alpha\nu}_{\mathrm{HAA}}(p_1\,,\,p_2)\,\Sigma^{\alpha\mu}_{\mathrm{AZ}}(p_1) + \mathscr{T}^{\mu\alpha}_{\mathrm{HAA}}(p_1\,,\,p_2)\,\Sigma^{\alpha\nu}_{\mathrm{AZ}}(p_2)\right], \tag{5.37}$$

where the $\mathrm{H} \to \mathrm{AZ}$ component is computed with off-shell A. The r.h.s. of eq. (5.37) is expanded up to $\mathscr{O}(g^3\,g_6)$ and we will use

$$\mathscr{D}_{\mathrm{HZZ}} = \mathscr{D}^{\mathrm{1PI}}_{\mathrm{HZZ}} + \mathscr{D}^{\mathrm{1PR}}_{\mathrm{HZZ}}\,, \qquad \mathscr{P}_{\mathrm{HZZ}} = \mathscr{P}^{\mathrm{1PI}}_{\mathrm{HZZ}} + \mathscr{P}^{\mathrm{1PR}}_{\mathrm{HZZ}}\,. \tag{5.38}$$

Complete, bare, amplitudes are constructed

$$\begin{aligned}
\mathscr{D}_{\mathrm{HZZ}} &= -i\,g\,\frac{M}{\mathrm{c}_\theta^2} + i\,\frac{g^3}{16\,\pi^2}\,\left(\mathscr{D}^{(4)}_{\mathrm{HZZ}} + g_6\,\mathscr{D}^{(6),b}_{\mathrm{HZZ}}\right) + i\,g\,g_6\,\mathscr{D}^{(6),a}_{\mathrm{HZZ}}\,,\\
\mathscr{P}_{\mathrm{HZZ}} &= i\,\frac{g^3}{16\,\pi^2}\,\left(\mathscr{P}^{(4)}_{\mathrm{HZZ}} + g_6\,\mathscr{P}^{(6),b}_{\mathrm{HZZ}}\right) + i\,g\,g_6\,\mathscr{P}^{(6),a}_{\mathrm{HZZ}}\,,
\end{aligned} \tag{5.39}$$

where the $\mathscr{O}(g g_6)$ components are:

$$\begin{aligned}
\mathscr{D}^{(6),a}_{\mathrm{HZZ}} &= -\frac{M}{\mathrm{c}_\theta^2}\,\left(a_{\phi\Box} + \frac{1}{4}\,a_{\phi\mathrm{D}}\right) + \left(\frac{M_{\mathrm{H}}^2 - 2\,M_{\mathrm{Z}}^2}{M} - M\right)\,a_{\mathrm{ZZ}} - M\,\frac{\mathrm{s}_\theta^2}{\mathrm{c}_\theta^2}\,a_{\mathrm{AA}} - M\,\frac{\mathrm{s}_\theta}{\mathrm{c}_\theta}\,a_{\mathrm{AZ}}\,,\\
\mathscr{P}^{(6),a}_{\mathrm{HZZ}} &= 2\,\frac{1}{M}\,a_{\mathrm{ZZ}}\,.
\end{aligned} \tag{5.40}$$

UV renormalization requires introduction of counterterms,

$$\mathscr{F}^{\mathrm{ren}}_{\mathrm{HZZ}} = \mathscr{D}_{\mathrm{HZZ}}\left[1 + \frac{g^2}{16\,\pi^2}\,\left(\mathrm{dZ}_{\mathrm{Z}} + \frac{1}{2}\,\mathrm{dZ}_{\mathrm{H}} - 3\,\mathrm{dZ}_g\right)\right], \tag{5.41}$$

where $\mathscr{F} = \mathscr{D}, \mathscr{P}$ and $\mathrm{dZ}_i = \mathrm{dZ}_i^{(4)} + g_6\,\mathrm{dZ}_i^{(6)}$. We obtain

$$\mathscr{D}_{\mathrm{HZZ}} = -i\,g_{\mathrm{ren}}\,\frac{M_{\mathrm{ren}}}{(\mathrm{c}_\theta^{\mathrm{ren}})^2} + i\,\frac{g^3_{\mathrm{ren}}}{16\,\pi^2}\,\left(\mathscr{D}^{(4)}_{\mathrm{HZZ}} + g_6\,\mathscr{D}^{(6)}_{\mathrm{HZZ}\,;\,\mathrm{fin}}\right)$$

JHEP07(2015)175

$$+i\, g_{\rm ren}\, g_6\, \mathscr{D}^{(6),{\rm ren},a}_{\rm HZZ} + i\, \frac{g^3_{\rm ren}}{16\,\pi^2}\, g_6\, \mathscr{D}^{(6)}_{\rm HZZ\,;\,div}\,,$$

$$\mathscr{P}_{\rm HZZ} = i\, \frac{g^3_{\rm ren}}{16\,\pi^2}\, \left(\mathscr{P}^{(4)}_{\rm HZZ} + g_6\, \mathscr{P}^{(6)}_{\rm HZZ\,;\,fin} \right)$$
$$+i\, g_{\rm ren}\, g_6\, \mathscr{P}^{(6),{\rm ren},a}_{\rm HZZ} + i\, \frac{g^3_{\rm ren}}{16\,\pi^2}\, g_6\, \mathscr{P}^{(6)}_{\rm HZZ\,;\,div}\,. \tag{5.42}$$

The explicit expressions for $\mathscr{F}^{(6)}_{\rm HZZ\,;\,div}$ will not be reported here. The last step in UV-renormalization requires a mixing among Wilson coefficients, performed according to eq. (5.9). After the removal of the remaining (dim $= 6$) UV parts we obtain

$$\mathscr{F}^{(6)}_{\rm HZZ\,;\,div} \to \mathscr{F}^{(6),{\rm R}}_{\rm HZZ}\, \ln \frac{\mu^2_{\rm R}}{M^2}\,. \tag{5.43}$$

Elements of the mixing matrix derived from $\mathrm{H} \to \mathrm{ZZ}$ are given in appendix G. Inclusion of wave-function renormalization factors and of external leg factors (due to field redefinition, introduced in section 2.4) gives

$$\mathscr{F}^{\rm ren}_{\rm HZZ} \left[1 - \frac{1}{2}\, \frac{g^2_{\rm ren}}{16\,\pi^2}\, \left(\mathrm{W_H} + 2\,\mathrm{W_Z} \right) \right] \left[1 + g_6\, \left(2\, a_{\rm ZZ} + a_{\phi\,\square} - \frac{1}{4}\, a_{\phi\,\rm D} \right) \right]. \tag{5.44}$$

Finite renormalization is performed by using eq. (5.13). The process $\mathrm{H} \to \mathrm{ZZ}$ starts at $\mathscr{O}(g)$, therefore, the full set of counterterms must be included, not only the dim $= 4$ part, as we have done for the loop induced processes.

It is convenient to define NLO sub-amplitudes; however, to respect a factorization into t, b and bosonic components, we have to introduce the following quantities:

$$\begin{aligned}
&\mathrm{W_H} = \mathrm{W_{H\;w}} + \mathrm{W_{H\;t}} + \mathrm{W_{H\;b}} && \mathrm{W_Z} = \mathrm{W_{Z\;w}} + \mathrm{W_{Z\;t}} + \mathrm{W_{Z\;b}} + \overline{\sum}_{\rm gen}\, \mathrm{W_{Z\,;\,f}} \\
&\mathrm{d}\mathscr{Z}_g = \mathrm{d}\mathscr{Z}_{g\,;\,\rm w} + \sum_{\rm gen} \mathrm{d}\mathscr{Z}_{g\,;\,\rm f} && \mathrm{d}\mathscr{Z}_{c_\theta} = \mathrm{d}\mathscr{Z}_{c_\theta\,;\,\rm w} + \mathrm{d}\mathscr{Z}_{c_\theta\,;\,\rm t} + \mathrm{d}\mathscr{Z}_{c_\theta\,;\,\rm b} + \overline{\sum}_{\rm gen}\, \mathrm{d}\mathscr{Z}_{c_\theta\,;\,\rm f} \\
&\mathrm{d}\mathscr{Z}_{M_{\rm W}} = \mathrm{d}\mathscr{Z}_{M_{\rm W}\,;\,\rm w} + \sum_{\rm gen} \mathrm{d}\mathscr{Z}_{M_{\rm W}\,;\,\rm f} &&
\end{aligned} \tag{5.45}$$

where $\mathrm{W}_{\Phi\,;\,\phi}$ denotes the ϕ component of the Φ wave-function factor etc. Furthermore, $\sum_{\rm gen}$ implies summing over all fermions and all generations, while $\overline{\sum}_{\rm gen}$ excludes t and b from the sum. We can now define κ-factors for the process, see eq. (5.15):

$$\Delta\kappa^{\rm HZZ}_{\rm D\,;\,LO} = \mathrm{s}^2_{\rm W}\, a_{\rm AA} + \left[4 + \mathrm{c}^2_{\rm W}\, \left(1 - \frac{M^2_{\rm H}}{M^2_{\rm W}} \right) \right] a_{\rm ZZ} + \mathrm{c_W}\, \mathrm{s_W}\, a_{\rm AZ} + 2\, a_{\phi\,\square}\,, \tag{5.46}$$

$$\Delta\kappa^{\rm HZZ}_{\rm t\,;\,D\,;\,NLO} = a_{\rm t\,\phi} + 2\, a_{\phi\,\square} - \frac{1}{2}\, a_{\phi\,\rm D} + 2\, a_{\rm ZZ} + \mathrm{s}^2_{\rm W}\, a_{\rm AA}\,,$$

$$\Delta\kappa^{\rm HZZ}_{\rm b\,;\,D\,;\,NLO} = -a_{\rm b\,\phi} + 2\, a_{\phi\,\square} - \frac{1}{2}\, a_{\phi\,\rm D} + 2\, a_{\rm ZZ} + \mathrm{s}^2_{\rm W}\, a_{\rm AA}\,,$$

$$\Delta\kappa^{\rm HZZ}_{\rm W\,;\,D\,;\,NLO} = \frac{1}{12}\, \left(4 + \frac{1}{\mathrm{c}^2_{\rm W}} \right)\, a_{\phi\,\rm D} + 2\, a_{\phi\,\square} + \mathrm{s}^2_{\rm W}\, a_{\rm AA}$$
$$+\mathrm{s}^2_{\rm W}\, \left(3\, \mathrm{c_W} + \frac{5}{3}\, \frac{1}{\mathrm{c_W}} \right)\, a_{\rm AZ} + \left(4 + \mathrm{c}^2_{\rm W} \right)\, a_{\rm ZZ}\,,$$

$$\Delta\kappa^{\rm HZZ}_{\rm t\,;P\,;NLO} = a_{\rm t\,\phi} + 2\,a_{\phi\,\Box} - \frac{1}{2}\,a_{\phi\,\rm D} + 2\,a_{\rm ZZ} + s^2_{\rm W}\,a_{\rm AA}\,,$$
$$\Delta\kappa^{\rm HZZ}_{\rm b\,;P\,;NLO} = -a_{\rm b\,\phi} + 2\,a_{\phi\,\Box} - \frac{1}{2}\,a_{\phi\,\rm D} + 2\,a_{\rm ZZ} + s^2_{\rm W}\,a_{\rm AA}\,,$$
$$\Delta\kappa^{\rm HZZ}_{\rm W\,;P\,;NLO} = 4\,a_{\phi\,\Box} + \frac{5}{2}\,a_{\phi\,\rm D} + 12\,a_{\rm ZZ} + 3\,s^2_{\rm W}\,a_{\rm AA} \tag{5.47}$$

and obtain the final result for the amplitudes

$$\mathscr{D}_{\rm HZZ} = -i\,g_{\rm F}\,\frac{M_{\rm W}}{c^2_{\rm W}}\,\kappa^{\rm HZZ}_{\rm D\,;LO} + i\,\frac{g^3_{\rm F}}{\pi^2}\sum_{\rm I=t,b,W}\kappa^{\rm HZZ}_{\rm I\,;D\,;NLO}\,\mathscr{D}^{\rm I}_{\rm HZZ\,;NLO}$$
$$+ i\,\frac{g^3_{\rm F}}{\pi^2}\,\mathscr{D}^{(4)\,;\rm nfc}_{\rm HZZ} + i\,\frac{g^3_{\rm F}}{\pi^2}\,g_6\sum_{\{a\}}\mathscr{D}^{(6)\,;\rm nfc}_{\rm HZZ}(a)\,,$$
$$\mathscr{P}_{\rm HZZ} = 2\,i\,g_{\rm F}\,g_6\,\frac{a_{\rm ZZ}}{M_{\rm W}} + i\,\frac{g^3_{\rm F}}{\pi^2}\sum_{\rm I=t,b,W}\kappa^{\rm HZZ}_{\rm I\,;P\,;NLO}\,\mathscr{P}^{\rm I}_{\rm HZZ\,;NLO}$$
$$+ i\,\frac{g^3_{\rm F}}{\pi^2}\,g_6\sum_{\{a\}}\mathscr{P}^{(6)\,;\rm nfc}_{\rm HZZ}(a)\,. \tag{5.48}$$

Here we have introduced

$$\mathscr{D}^{(4)\,;\rm nfc}_{\rm HZZ} = \frac{1}{32}\,\frac{M_{\rm W}}{c^2_{\rm W}}\left(2\,\overline{\sum}_{\rm gen}{\rm W}_{\rm Z\,;f} - \sum_{\rm gen}{\rm dZ}_{M_{\rm W}\,;f} + 4\,\overline{\sum}_{\rm gen}{\rm dZ}_{c_\theta\,;f} - 2\sum_{\rm gen}{\rm dZ}_{g\,;f}\right)\,. \tag{5.49}$$

Dimension 4 sub-amplitudes $\mathscr{D}^{\rm I}_{\rm HZZ\,;NLO}$, $\mathscr{P}^{\rm I}_{\rm HZZ\,;NLO}$ ($I = {\rm W, t, b}$) are defined by using

$$\lambda_{\rm Z} = M^2_{\rm H} - 4\,M^2_{\rm Z}\,, \qquad \lambda_{\rm ZZ} = \frac{M^2_{\rm H}}{M^2_{\rm W}} - 4\,\frac{M^2_{\rm Z}}{M^2_{\rm W}}\,, \tag{5.50}$$

and are given in appendix I. Non-factorizable dim $= 6$ amplitudes are reported in appendix H, using again eq. (5.50).

5.4 $\rm H \to WW$

The derivation of the amplitude for $\rm H \to WW$ follows closely the one for $\rm H \to ZZ$. There are two main differences, there are only 1PI contributions for $\rm H \to WW$ and the the process shows an infrared (IR) component.

The IR part originates from two different sources. Vertex diagrams generate an IR C_0 function:

$$\mathrm{C}_0\left(-M^2_{\rm H}\,, M^2_{\rm W}\,, M^2_{\rm W}\,; M_{\rm W}\,, 0\,, M_{\rm W}\right) = \frac{1}{\beta_{\rm W}\,M^2_{\rm H}}\,\ln\frac{\beta_{\rm W}-1}{\beta_{\rm W}+1}\,\Delta_{\rm IR} + \mathrm{C}^{\rm fin}_0\left(-M^2_{\rm H}\,, M^2_{\rm W}\,, M^2_{\rm W}\,; M_{\rm W}\,, 0\,, M_{\rm W}\right)\,, \tag{5.51}$$

where we have introduced

$$\beta^2_{\rm W} = 1 - 4\,\frac{M^2_{\rm W}}{M^2_{\rm H}}\,, \qquad \Delta_{\rm IR} = \frac{1}{\hat{\varepsilon}} + \ln\frac{M^2_{\rm W}}{\mu^2}\,. \tag{5.52}$$

The second source of IR behavior is found in the W wave-function factor:

$$\mathrm{W}_{\rm W} = -2\,s^2_\theta\,\Delta_{\rm IR} + \mathrm{W}_{\rm W}\Big|_{\rm fin}\,. \tag{5.53}$$

The lowest-order part of the amplitude is

$$\mathscr{D}^{\mathrm{LO}}_{\mathrm{HWW}} = -g\,M\,. \tag{5.54}$$

The $\mathscr{O}(gg_6)$ components of $\mathrm{H}\to\mathrm{WW}$ are:

$$\begin{aligned}
\mathscr{D}^{(6),a}_{\mathrm{HWW}} &= \left(\frac{M^2_{\mathrm{H}} - 2M^2_{\mathrm{W}}}{M} + M\right) a_{\phi\,\mathrm{W}} - M\,a_{\phi\,\Box} + \frac{1}{4}M\,a_{\phi\,\mathrm{D}} - M\,\frac{\mathrm{s}^2_{\theta}}{\mathrm{c}^2_{\theta}}\,a_{\mathrm{AA}} - M\,\frac{\mathrm{s}_{\theta}}{\mathrm{c}_{\theta}}\,a_{\mathrm{AZ}}\,,\\
\mathscr{P}^{(6),a}_{\mathrm{HWW}} &= 2\,\frac{1}{M}\,a_{\phi\,\mathrm{W}}\,.
\end{aligned} \tag{5.55}$$

With their help we can isolate the IR part of the $\mathrm{H}\to\mathrm{WW}$ amplitude

$$\mathscr{D}_{\mathrm{HWW}}\Big|_{1\mathrm{IR}} = \mathrm{I}^{1\mathrm{IR}}_{\mathrm{HWW}}\,\frac{1}{\beta_{\mathrm{W}}\,M^2_{\mathrm{H}}}\,\ln\frac{\beta_{\mathrm{W}}-1}{\beta_{\mathrm{W}}+1}\,\Delta_{\mathrm{IR}}\,, \tag{5.56}$$

$$\begin{aligned}
\mathrm{I}^{1\mathrm{IR}}_{\mathrm{HWW}} &= \frac{1}{8}\,i\,\frac{g^2_{\mathrm{F}}}{\pi^2}\,\mathrm{s}^2_{\mathrm{W}}\,M^2_{\mathrm{H}}\left(\mathscr{D}^{\mathrm{LO}}_{\mathrm{HWW}} + g_6\,\mathscr{D}^{(6),a}_{\mathrm{HWW}}\right)\\
&\quad + \frac{1}{16}\,i\,\frac{g^2_{\mathrm{F}}}{\pi^2}\,g_6\,\mathscr{D}^{\mathrm{LO}}_{\mathrm{HWW}}\left[2\left(M^2_{\mathrm{H}} + M^2_{\mathrm{W}}\right)\frac{M^2_{\mathrm{H}}}{M^2_{\mathrm{W}}}\,\mathrm{s}^2_{\theta}\,a_{\phi\,\mathrm{W}} - 4\,\mathrm{s}^2_{\theta}\,M^2_{\mathrm{H}}\,a_{\phi\,\mathrm{W}} - 2\,\mathrm{s}^2_{\theta}\,M^2_{\mathrm{H}}\right].
\end{aligned} \tag{5.57}$$

Having isolated the IR part of the amplitude we can repeat, step by step, the procedure developed in the previous sections. There is a non trivial aspect in the mixing of Wilson coefficients: the $\dim = 6$ parts of $\mathrm{H}\to\mathrm{AA},\mathrm{AZ}$ and $\mathscr{P}^{(6)}_{\mathrm{HZZ,HWW}}$ contain UV divercences proportional to $W_{1,2,3}$; once renormalization is completed for $\mathrm{H}\to\mathrm{AA},\mathrm{AZ}$ and ZZ there is no freedom left and UV finiteness of $\mathrm{H}\to\mathrm{WW}$ must follow, proving closure of the $\dim = 6$ basis with respect to renormalization.

We can now define κ-factors for $\mathrm{H}\to\mathrm{WW}$, see eq. (5.15). They are as follows:

$$\Delta\kappa^{\mathrm{HWW}}_{\mathrm{D;LO}} = \mathrm{s}^2_{\mathrm{W}}\left(\frac{M^2_{\mathrm{H}}}{M_{\mathrm{W}}} - 5M_{\mathrm{W}}\right)(a_{\mathrm{AA}} + a_{\mathrm{AZ}} + a_{\mathrm{ZZ}}) + \frac{1}{2}M_{\mathrm{W}}\,a_{\phi\,\mathrm{D}} - 2M_{\mathrm{W}}\,a_{\phi\,\Box}\,, \tag{5.58}$$

$$\begin{aligned}
\Delta\kappa^{\mathrm{HWW}}_{\mathrm{q;D;NLO}} &= a_{\phi\,\mathrm{t\,V}} + a_{\phi\,\mathrm{t\,A}} + a_{\phi\,\mathrm{b\,V}} + a_{\phi\,\mathrm{b\,A}} - a_{\mathrm{d}\,\phi} + 2\,a_{\phi\,\Box} - \frac{1}{2}\,a_{\phi\,\mathrm{D}}\\
&\quad + \mathrm{s}_{\mathrm{W}}\,a_{\mathrm{b\,WB}} + \mathrm{c}_{\mathrm{W}}\,a_{\mathrm{b\,BW}} + 5\,\mathrm{s}^2_{\mathrm{W}}\,a_{\mathrm{AA}} + 5\,\mathrm{c}_{\mathrm{W}}\,\mathrm{s}_{\mathrm{W}}\,a_{\mathrm{AZ}} + 5\,\mathrm{c}^2_{\mathrm{W}}\,a_{\mathrm{ZZ}}\,,\\
\Delta\kappa^{\mathrm{HWW}}_{\mathrm{W;D;NLO}} &= \frac{1}{96}\,\frac{\mathrm{s}^2_{\mathrm{W}}}{\mathrm{c}^2_{\mathrm{W}}}\,a_{\phi\,\mathrm{D}} + \frac{23}{12}\,a_{\phi\,\Box} - \frac{35}{96}\,a_{\phi\,\mathrm{D}}\\
&\quad + 4\,\mathrm{s}^2_{\mathrm{W}}\,a_{\mathrm{AA}} + \frac{1}{12}\,\mathrm{s}_{\theta}\left(3\,\frac{1}{\mathrm{c}_{\mathrm{W}}} + 49\,\mathrm{c}_{\mathrm{W}}\right)a_{\mathrm{AZ}} + \frac{1}{2}\left(9\,\mathrm{c}^2_{\mathrm{W}} + \mathrm{s}^2_{\mathrm{W}}\right)a_{\mathrm{ZZ}}\,,\\
\Delta\kappa^{\mathrm{HWW}}_{\mathrm{Q;P;NLO}} &= a_{\phi\,\mathrm{t\,V}} + a_{\phi\,\mathrm{t\,A}} + a_{\phi\,\mathrm{b\,V}} + a_{\phi\,\mathrm{b\,A}} - a_{\mathrm{d}\,\phi} + 2\,a_{\phi\,\Box} - \frac{1}{2}\,a_{\phi\,\mathrm{D}}\\
&\quad + \mathrm{s}_{\mathrm{W}}\,a_{\mathrm{d\,WB}} + \mathrm{c}_{\mathrm{W}}\,a_{\mathrm{d\,BW}} + 5\,\mathrm{s}^2_{\mathrm{W}}\,a_{\mathrm{AA}} + 5\,\mathrm{c}_{\mathrm{W}}\,\mathrm{s}_{\mathrm{W}}\,a_{\mathrm{AZ}} + 5\,\mathrm{c}^2_{\mathrm{W}}\,a_{\mathrm{ZZ}}\,,\\
\Delta\kappa^{\mathrm{HWW}}_{\mathrm{W;P;NLO}} &= 7\,a_{\phi\,\Box} - 2\,a_{\phi\,\mathrm{D}} + 5\,\mathrm{s}^2_{\mathrm{W}}\,a_{\mathrm{AA}} + 5\,\mathrm{c}_{\mathrm{W}}\,\mathrm{s}_{\mathrm{W}}\,a_{\mathrm{AZ}} + 5\,\mathrm{c}^2_{\mathrm{W}}\,a_{\mathrm{ZZ}}\,.
\end{aligned} \tag{5.59}$$

Next we obtain the final result for the amplitudes

$$\mathscr{D}_{\mathrm{HWW}} = -i\,g_{\mathrm{F}}\,M_{\mathrm{W}}\,\kappa^{\mathrm{HWW}}_{\mathrm{D;LO}} + i\,\frac{g^3_{\mathrm{F}}}{\pi^2}\sum_{\mathrm{I=q,W}}\kappa^{\mathrm{HWW}}_{\mathrm{I;D;NLO}}\,\mathscr{D}^{\mathrm{I}}_{\mathrm{HWW;NLO}}$$

JHEP07(2015)175

$$+i\,\frac{g_F^3}{\pi^2}\,\mathscr{D}^{(4)\,;\,\mathrm{nfc}}_{\mathrm{HWW}} + i\,\frac{g_F^3}{\pi^2}\,g_6\,\sum_{\{a\}}\mathscr{D}^{(6)\,;\,\mathrm{nfc}}_{\mathrm{HWW}}(a)\,,$$

$$\mathscr{P}_{\mathrm{HWW}} = 2\,i\,g_F\,g_6\,\frac{1}{M_W}\,\left(s_W^2\,a_{AA} + c_W^2\,a_{ZZ} + c_W\,s_W\,a_{AZ}\right) + i\,\frac{g_F^3}{\pi^2}\,\sum_{I=q}\kappa^{\mathrm{HWW}}_{I\,;\,P\,;\,\mathrm{NLO}}\,\mathscr{P}^{I}_{\mathrm{HWW}\,;\,\mathrm{NLO}}$$

$$+i\,\frac{g_F^3}{\pi^2}\,g_6\,\sum_{\{a\}}\mathscr{P}^{(6)\,;\,\mathrm{nfc}}_{\mathrm{HWW}}(a)\,, \tag{5.60}$$

where we have introduced

$$\mathscr{D}^{(4)\,;\,\mathrm{nfc}}_{\mathrm{HWW}} = \frac{1}{32}\,M_W\,\overline{\sum}_{\mathrm{gen}}\,\left(2\,W_{W\,;\,f} - d\mathscr{Z}_{M_W\,;\,f} - 2\,d\mathscr{Z}_{g\,;\,f}\right)\,. \tag{5.61}$$

Dimension 4 sub-amplitudes $\mathscr{D}^{I}_{\mathrm{HWW}\,;\,\mathrm{NLO}}$, $\mathscr{P}^{I}_{\mathrm{HWW}\,;\,\mathrm{NLO}}$ ($I = W, t, b$) are defined by introducing

$$\lambda_W = M_H^2 - 4\,M_W^2\,, \qquad \lambda_{WW} = \frac{M_H^2}{M_W^2} - 4\,, \tag{5.62}$$

and are given in appendix I. Non-factorizable dim $= 6$ amplitudes are reported in appendix H, using again eq. (5.62).

5.5 $H \to \overline{b}b(\tau^+\tau^-)$ and $H \to 4l$

These processes share the same level of complexity of $H \to ZZ(WW)$, including the presence of IR singularities. They will be discussed in details in a forthcoming publication.

6 ElectroWeak precision data

EFT is not confined to describe Higgs couplings and their SM deviations. It can be used to reformulate the constraints coming from electroweak precision data (EWPD), starting from the S, T and U parameters of ref. [76] and including the full list of LEP pseudo-observables (PO).

There are several ways for incorporating EWPD: the preferred option, so far, is reducing (a priori) the number of dim $= 6$ operators. More generally, one could proceed by imposing penalty functions ω on the global LHC fit, that is functions defining an ω-penalized LS estimator for a set of global penalty parameters (perhaps using *merit functions* and the *homotopy method*). One could also consider using a Bayesian approach [78], with a flat prior for the parameters. Open questions are: one κ at the time? Fit first to the EWPD and then to H observables? Combination of both?

In the following we give a brief description of our procedure: from eq. (4.12) and eq. (4.48) we obtain

$$\Sigma^{1PI+1PR}_{AA}(s) = -\left[\Pi^{1PI}_{AA}(0) + g_6\,\frac{s_\theta}{c_\theta}\,\frac{1}{M_0^2}\,a_{AZ}\,\Pi^{1PI}_{ZA}(0)\right]s + \mathscr{O}(s^2) = \Pi^{c}_{AA}\,s + \mathscr{O}(s^2)\,. \tag{6.1}$$

¿From eq. (4.20) and eq. (4.48) we obtain

$$\Sigma^{1PI+1PR}_{ZA}(s) = -\left[\Pi^{1PI}_{ZA}(0) + g_6\,s_\theta^2\,a_{AZ}\,\Pi^{1PI}_{AA}(0)\right]s + \mathscr{O}(s^2) = \Pi^{c}_{ZA}\,s + \mathscr{O}(s^2)\,. \tag{6.2}$$

From eq. (4.16) and eq. (4.48) we derive

$$\mathrm{D}^{\mathrm{1PI+1PR}}_{\mathrm{ZZ}}(s) = \Delta_{\mathrm{ZZ}}(0) + \left[\Omega_{\mathrm{ZZ}}(0) - g_6\,\frac{\mathrm{s}_\theta}{\mathrm{c}_\theta}\,a_{\mathrm{AZ}}\,\Pi^{\mathrm{1PI}}_{\mathrm{ZA}}(0)\right] s + \mathscr{O}(s^2) = \Delta_{\mathrm{ZZ}}(0) + \Omega^{c}_{\mathrm{ZZ}}(0)\,s + \mathscr{O}(s^2)\,. \tag{6.3}$$

Similarly, we obtain

$$\mathrm{D}^{\mathrm{1PI}}_{\mathrm{WW}}(s) = \Delta_{\mathrm{WW}}(0) + \Omega_{\mathrm{WW}}(0)\,s + \mathscr{O}(s^2)\,. \tag{6.4}$$

The S, T and U parameters are defined in terms of (complete) self-energies at $s = 0$ and of their (first) derivatives. However, one has to be careful because the corresponding definition (see ref. [76]) is given in the $\{\alpha\,, G_{\mathrm{F}}\,, M_{\mathrm{Z}}\}$ scheme, while we have adopted the more convenient $\{G_{\mathrm{F}}\,, M_{\mathrm{W}}\,, M_{\mathrm{Z}}\}$ scheme. Working in the α-scheme has one advantage, the possibility of predicting the W (on-shell) mass. After UV renormalization and finite renormalization in the α-scheme we define $M^2_{\mathrm{W;OS}}$ as the zero of the real part of the inverse W propagator and derive the effect of dim $= 6$ operators.

6.1 W mass

Working in the α-scheme we can predict M_{W}. The solution is

$$\begin{aligned}\frac{M^2_{\mathrm{W}}}{M^2_{\mathrm{Z}}} = \hat{\mathrm{c}}^2_\theta + \frac{\alpha}{\pi}\,\mathrm{Re}\Bigg\{&\left(1 - \frac{1}{2}\,g_6\,a_{\phi\mathrm{D}}\right)\Delta^{(4)}_{\mathrm{B}}\,M_{\mathrm{W}} + \sum_{\mathrm{gen}}\left[\left(1 + 4\,g_6\,a^{(3)}_{\phi\mathrm{l}}\right)\Delta^{(4)}_{\mathrm{l}}\,M_{\mathrm{W}} + \left(1 + 4\,g_6\,a^{(3)}_{\phi\mathrm{q}}\right)\Delta^{(4)}_{\mathrm{q}}\,M_{\mathrm{W}}\right] \\ &+ g_6\left[\Delta^{(6)}_{\mathrm{B}}\,M_{\mathrm{W}} + \sum_{\mathrm{gen}}\left(\Delta^{(6)}_{\mathrm{l}}\,M_{\mathrm{W}} + \Delta^{(6)}_{\mathrm{q}}\,M_{\mathrm{W}}\right)\right]\Bigg\}\,. \end{aligned} \tag{6.5}$$

where $\hat{\mathrm{c}}^2_\theta$ is defined in eq. (4.73) and we drop the subscript OS (on-shell). Corrections are given in appendix J. The expansion in eq. (6.5) can be improved when working within the SM (dim $= 4$), see ref. [44]: for instance, the expansion parameter is set to $\alpha(M_{\mathrm{Z}})$ instead of $\alpha(0)$, etc. Any equation that gives dim $= 6$ corrections to the SM result will always be understood as

$$\mathscr{O} = \mathscr{O}^{\mathrm{SM}}\Big|_{\mathrm{imp}} + \frac{\alpha}{\pi}\,g_6\,\mathscr{O}^{(6)} \tag{6.6}$$

in order to match the TOPAZ0/Zfitter SM results when $g_6 \to 0$, see refs. [79–81] and refs. [82, 83].

6.2 S, T and U parameters

The S, U and T (the original ρ-parameter of Veltman [84]) are defined as follows:

$$\begin{aligned}\alpha\,\mathrm{T} &= \frac{1}{M^2_{\mathrm{W}}}\,\mathrm{D}_{\mathrm{WW}}(0) - \frac{1}{M^2_{\mathrm{Z}}}\,\mathrm{D}_{\mathrm{ZZ}}(0)\,, \\ \frac{\alpha}{4\,\hat{\mathrm{s}}^2_\theta\hat{\mathrm{c}}^2_\theta}\,\mathrm{S} &= \Omega_{\mathrm{ZZ}}(0) - \frac{\hat{\mathrm{c}}^2_\theta - \hat{\mathrm{s}}^2_\theta}{\hat{\mathrm{s}}_\theta\,\hat{\mathrm{c}}_\theta}\,\Pi_{\mathrm{ZA}}(0) - \Pi_{\mathrm{AA}}(0)\,, \\ \frac{\alpha}{4\,\hat{\mathrm{s}}^2_\theta}\,\mathrm{U} &= \Omega_{\mathrm{WW}}(0) - \hat{\mathrm{c}}^2_\theta\,\Omega_{\mathrm{ZZ}}\,\Pi_{\mathrm{ZA}}(0) - \hat{\mathrm{s}}^2_\theta\,\Pi_{\mathrm{AA}}(0)\,, \end{aligned} \tag{6.7}$$

where all the self-energies are renormalized and $\hat{\mathrm{s}}_\theta$ is defined in eq. (4.73). One of the interesting properties of these parameters is that, within the SM, they are UV finite, i.e. all UV divergences cancel in eq. (6.7) if they are written in terms of bare parameters and bare self-energies. When dim $= 6$ operators are inserted we obtain the following results:

$$
\begin{aligned}
\alpha\,\mathrm{T} &= \alpha\,\mathscr{T}^{(4)} + \alpha\,g_6\,\mathscr{T}^{(6)}\,,\\
\alpha\,\mathrm{S} &= \alpha\,\mathscr{S}^{(4)} - 4\,g_6\,\frac{1-2\,\hat{s}^2_{\theta}}{\hat{s}_{\theta}\,\hat{c}_{\theta}}\,a_{\mathrm{AZ}} + \alpha\,g_6\,\mathscr{S}^{(6)}\,,\\
\alpha\,\mathrm{U} &= \alpha\,\mathscr{U}^{(4)} - 4\,g_6\,\frac{1-2\,\hat{s}^2_{\theta}}{\hat{s}_{\theta}\,\hat{c}^3_{\theta}}\,a_{\mathrm{AZ}} + \alpha\,g_6\,\mathscr{U}^{(6)}
\end{aligned}
\tag{6.8}
$$

and the introduction of counterterms is crucial to obtain an UV finite results. Explicit results for the T parameter are given in appendix K where, for simplicity, we only include PTG operators in loops.

7 Conclusions

In this paper we have developed a theory for Standard Model deviations based on the Effective Field Theory approach. In particular, we have considered the introduction of dim $= 6$ operators and extended their application at the NLO level (for a very recent development see ref. [85]).

The main result is represented by a consistent generalization of the LO κ-framework, currently used by ATLAS and CMS. We believe that the generalized κ-framework provides a useful technical tool to decompose amplitudes at NLO accuracy into a sum of well defined gauge-invariant sub components.

This step forward is better understood when comparing the present situation with the one at LEP; there the dynamics was fully described within the SM, with $M_{\mathrm{H}}\,\alpha_{\mathrm{s}}(M_{\mathrm{Z}}),\dots$ as unknowns. Today, post the LHC discovery of a H-candidate, unknowns are SM-deviations. This fact poses precise questions on the next level of dynamics. A specific BSM model is certainly a choice but one would like to try a more model independent approach.

The aim of this paper is to propose a decomposition where dynamics is controlled by dim $= 4$ amplitudes (with known analytical properties) and deviations (with a direct link to UV completions) are (constant) combinations of Wilson coefficients for dim $= 6$ operators.

Generalized κ-parameters form hyperplanes in the space of Wilson coefficients; each κ-plane describes (tangent) flat directions while normal directions are blind. Finally, κ-planes intersect, providing correlations among different processes.

There are many alternatives for extracting informations on Higgs couplings from the data, all of them allowing a theoretically robust matching between theory and experiments; one can start from direct extraction of Wilson coefficents or use combinations of Wilson coefficients. We do not claim any particular advantage in selecting generalized κ-parameters as LHC observables. Our NLO expressions have a general validity and can be used to construct any set of independent combinations of Wilson coefficients at NLO accuracy.

JHEP07(2015)175

8 Note added in proof

In order to compare our results with those in ref. [85] we have to take into account the different schemes adopted, in particular the different treatment for the Z−A transition. Therefore, we define

$$\mathscr{L}_{\mathrm{EFT}}^{\mathrm{WB}} = \mathscr{L}_4 + \left(\frac{g_0}{g}\right)^2 a_{\phi\mathrm{W}}\mathscr{O}_{\phi\mathrm{W}} + a_{\phi\mathrm{B}}\mathscr{O}_{\phi\mathrm{B}} + \frac{g_0}{g}\, a_{\phi\mathrm{WB}}\mathscr{O}_{\phi\mathrm{WB}}\,, \tag{8.1}$$

where g_0 is given in eq. (2.14). Furthermore, we define

$$a_{\phi\mathrm{B}} = \frac{\mathrm{s}_\theta^2}{\mathrm{c}_\theta^2}\,\mathrm{C_{HB}}\,, \quad a_{\phi\mathrm{W}} = \mathrm{C_{HW}}\,, \quad a_{\phi\mathrm{WB}} = -\frac{\mathrm{s}_\theta}{\mathrm{c}_\theta}\,\mathrm{C_{HWB}}\,. \tag{8.2}$$

When our results are translated in terms of the C-coefficients of ref. [85] we find perfect agreement for the universal part of the running (the $\mathrm{L_R}$-terms in our language), i.e. for those logarithms that do not depend on the renormalization scheme (G_{F}-scheme in our case). We would like to thank Christine Hartmann and Michael Trott for their help in clarifying the issue.

Acknowledgments

We gratefully acknowledge several important discussions with A. David, M. Duehrssen and the participants in the “Pseudo-observables: from LEP to LHC” and “ATLAS Higgs (N)NLO MC and Tools Workshop for LHC RUN-2” events at Cern.

This work is supported by MIUR under contract 2001023713_006, by UniTo-Compagnia di San Paolo under contract ORTO11TPXK and by FP7-PEOPLE-2012-ITN HiggsTools PITN-GA-2012−316704.

A $\overline{\beta}_{\mathrm{h}}$ and Γ

In this appendix we present the full result for $\overline{\beta}_{\mathrm{h}}$, defined in eq. (4.7). We have introduced ratios of masses

$$x_{\mathrm{H}} = \frac{M_{\mathrm{H}}}{M_{\mathrm{W}}}, \quad x_{\mathrm{f}} = \frac{M_{\mathrm{f}}}{M_{\mathrm{W}}} \tag{A.1}$$

etc. The various components are given by

$$\begin{aligned}
\beta_{-1}^{(4)} &= -\sum_{\mathrm{gen}}(x_{\mathrm{l}}^2 + 3x_{\mathrm{d}}^2 + 3x_{\mathrm{u}}^2) + \frac{1}{8}(12 + 2x_{\mathrm{H}} + 3x_{\mathrm{H}}^2) + \frac{1}{8}\frac{6 + \mathrm{c}_\theta^2 x_{\mathrm{H}}}{\mathrm{c}_\theta^4} \\
\beta_{0}^{(4)} &= -\frac{1}{2}\frac{1 + 2\mathrm{c}_\theta^4}{\mathrm{c}_\theta^4} \\
\beta_{\mathrm{fin}}^{(4)} &= -\frac{1}{4}a_0^{\mathrm{fin}}(M_{\mathrm{W}})\,(6 + x_{\mathrm{H}}) - \frac{3}{8}a_0^{\mathrm{fin}}(M_{\mathrm{H}})\,x_{\mathrm{H}}^2 - \frac{1}{8}\frac{6 + \mathrm{c}_\theta^2 x_{\mathrm{H}}}{\mathrm{c}_\theta^4}\,a_0^{\mathrm{fin}}(M_{\mathrm{Z}}) \\
&\quad + \sum_{\mathrm{gen}}\Big[3\,a_0^{\mathrm{fin}}(M_{\mathrm{u}})\,x_{\mathrm{u}}^2 + 3\,a_0^{\mathrm{fin}}(M_{\mathrm{d}})\,x_{\mathrm{d}}^2 + a_0^{\mathrm{fin}}(M_{\mathrm{l}})\,x_{\mathrm{l}}^2\Big]
\end{aligned} \tag{A.2}$$

$$\beta_{-1}^{(6)} = \frac{1}{8}\frac{12 + x_{\mathrm{H}}}{\mathrm{c}_\theta^2}\,a_{\phi\mathrm{W}} + \frac{1}{8}(36 + 2x_{\mathrm{H}} + 3x_{\mathrm{H}}^2)\,a_{\phi\mathrm{W}} - \frac{1}{4}\sum_{\mathrm{gen}}\Big[3\,(4a_{\mathrm{u}\phi} + 4a_{\phi\Box} + 4a_{\phi\mathrm{W}} - a_{\phi\mathrm{D}})\,x_{\mathrm{u}}^2$$

JHEP07(2015)175

$$
\begin{aligned}
&-3\,(4\,a_{\mathrm{d}\,\phi}-4\,a_{\phi\Box}-4\,a_{\phi\mathrm{W}}+a_{\phi\mathrm{D}})\,x_{\mathrm{d}}^2+(4\,a_{\phi\Box}+4\,a_{\phi\mathrm{W}}-a_{\phi\mathrm{D}}-4\,a_{\mathrm{L}\,\phi})\,x_{\mathrm{l}}^2\Big]\\
&+\frac{3}{16}\,(4\,a_{\phi\Box}+4\,a_{\phi\mathrm{W}}+a_{\phi\mathrm{D}}+8\,\mathrm{s}_\theta^2\,a_{\phi\mathrm{B}}-8\,\mathrm{c}_\theta\,\mathrm{s}_\theta\,a_{\phi\mathrm{WB}})\,\frac{1}{\mathrm{c}_\theta^4}+\frac{1}{32}\,(4\,a_{\phi\Box}-a_{\phi\mathrm{D}})\,(12-2\,x_{\mathrm{H}}+7\,x_{\mathrm{H}}^2)\\
&-\frac{1}{32}\,(4\,a_{\phi\Box}+a_{\phi\mathrm{D}}+96\,\mathrm{c}_\theta^2\,a_\phi)\,\frac{x_{\mathrm{H}}}{\mathrm{c}_\theta^2}
\end{aligned}
$$

$$
\beta_0^{(6)}=-\frac{1}{8}\Big[8\,\mathrm{s}_\theta^2\,a_{\phi\mathrm{B}}+4\,(1+2\,\mathrm{c}_\theta^4)\,a_{\phi\Box}+4\,(1+2\,\mathrm{c}_\theta^2+6\,\mathrm{c}_\theta^4)\,a_{\phi\mathrm{W}}+(1-2\,\mathrm{c}_\theta^4)\,a_{\phi\mathrm{D}}-8\,\mathrm{c}_\theta\,\mathrm{s}_\theta\,a_{\phi\mathrm{WB}}\Big]\,\frac{1}{\mathrm{c}_\theta^4}
$$

$$
\begin{aligned}
\beta_{\mathrm{fin}}^{(6)}&=3\,a_0^{\mathrm{fin}}\,(M_{\mathrm{H}})\,a_\phi\,x_{\mathrm{H}}-\frac{1}{4}\,a_0^{\mathrm{fin}}\,(M_{\mathrm{W}})\,(18+x_{\mathrm{H}})\,a_{\phi\mathrm{W}}-\frac{1}{8}\,a_0^{\mathrm{fin}}\,(M_{\mathrm{Z}})\,\frac{12+x_{\mathrm{H}}}{\mathrm{c}_\theta^2}\,a_{\phi\mathrm{W}}\\
&+\frac{1}{4}\sum_{\mathrm{gen}}\Big[3\,(4\,a_{\mathrm{u}\,\phi}+4\,a_{\phi\Box}+4\,a_{\phi\mathrm{W}}-a_{\phi\mathrm{D}})\,a_0^{\mathrm{fin}}\,(M_{\mathrm{u}})\,x_{\mathrm{u}}^2-3\,(4\,a_{\mathrm{d}\,\phi}-4\,a_{\phi\Box}-4\,a_{\phi\mathrm{W}}+a_{\phi\mathrm{D}})\,a_0^{\mathrm{fin}}\,(M_{\mathrm{d}})\,x_{\mathrm{d}}^2\\
&+(4\,a_{\phi\Box}+4\,a_{\phi\mathrm{W}}-a_{\phi\mathrm{D}}-4\,a_{\mathrm{L}\,\phi})\,a_0^{\mathrm{fin}}\,(M_{\mathrm{l}})\,x_{\mathrm{l}}^2\Big]\\
&-\frac{3}{16}\,(4\,a_{\phi\Box}+4\,a_{\phi\mathrm{W}}+a_{\phi\mathrm{D}}+8\,\mathrm{s}_\theta^2\,a_{\phi\mathrm{B}}-8\,\mathrm{c}_\theta\,\mathrm{s}_\theta\,a_{\phi\mathrm{WB}})\,\frac{1}{\mathrm{c}_\theta^4}\,a_0^{\mathrm{fin}}\,(M_{\mathrm{Z}})-\frac{1}{16}\,(4\,a_{\phi\Box}-a_{\phi\mathrm{D}})\,a_0^{\mathrm{fin}}\,(M_{\mathrm{W}})\,(6-x_{\mathrm{H}})\\
&+\frac{1}{32}\,(4\,a_{\phi\Box}+a_{\phi\mathrm{D}})\,a_0^{\mathrm{fin}}\,(M_{\mathrm{Z}})\,\frac{x_{\mathrm{H}}}{\mathrm{c}_\theta^2}-\frac{1}{32}\,(28\,a_{\phi\Box}+12\,a_{\phi\mathrm{W}}-7\,a_{\phi\mathrm{D}})\,a_0^{\mathrm{fin}}\,(M_{\mathrm{H}})\,x_{\mathrm{H}}^2 \qquad \text{(A.3)}
\end{aligned}
$$

We also present the full result for Γ, defined in eq. (2.14). We have

$$
\Gamma_{-1}^{(4)}=-\frac{1}{8}\quad \Gamma_0^{(4)}=\frac{1}{8}\quad \Gamma_{\mathrm{fin}}^{(4)}=\frac{1}{8}\,a_0^{\mathrm{fin}}\,(M) \qquad \text{(A.4)}
$$

$$
\Gamma_{-1}^{(6)}=-\frac{1}{4}\,a_{\phi\mathrm{W}}\quad \Gamma_0^{(6)}=\frac{1}{4}\,a_{\phi\mathrm{W}}\quad \Gamma_{\mathrm{fin}}^{(6)}=\frac{1}{4}\,a_0^{\mathrm{fin}}\,(M)\,a_{\phi\mathrm{W}} \qquad \text{(A.5)}
$$

i.e. $\Gamma=\Gamma^{(4)}\,(1+2\,g_6\,a_{\phi\mathrm{W}})$.

B Renormalized self-energies

In this appendix we present the full set of renormalized self-energies. To keep the notation as compact as possible a number of auxiliary quantities has been introduced.

B.1 Notations

First we define the following set of polynomials:

F where $s=\mathrm{s}_\theta$ and $c=\mathrm{c}_\theta$

$$
\begin{aligned}
&\mathrm{F}_0^a=1-6\,c \quad \mathrm{F}_1^a=4-9\,c \quad \mathrm{F}_2^a=1-c\\
&\mathrm{F}_3^a=2-15\,c \quad \mathrm{F}_4^a=2+3\,c \quad \mathrm{F}_5^a=11-3\,s\\
&\mathrm{F}_6^a=8-3\,s
\end{aligned}
$$

$F^b_0 = 1+2c$	$F^b_1 = 1+3c$	$F^b_2 = 1+18c$
$F^b_3 = 1+c$	$F^b_4 = 1+4c$	$F^b_5 = 1-2s$
$F^b_6 = 1+24s^2c$	$F^b_7 = 1+F^a_0 c$	$F^b_8 = 1+4F^a_1 c$
$F^b_9 = 3+4c$	$F^b_{10} = 5+8c$	$F^b_{11} = 1-40c+36sc$
$F^b_{12} = 1+20c-12sc$	$F^b_{13} = 5-20c+12sc$	$F^b_{14} = 5-3s$
$F^b_{15} = 1-12F^a_2 c$	$F^b_{16} = 3+8sc$	$F^b_{17} = 13+4F^a_3 c$
$F^b_{18} = 19-18s$	$F^b_{19} = 1-12c^2$	$F^b_{20} = 1-24c^3$
$F^b_{21} = 1+4F^a_4 c$	$F^b_{22} = 1+8F^a_4 c^2$	$F^b_{23} = 4-3s$
$F^b_{24} = 5+12c^2$	$F^b_{25} = 5-4F^a_4 c$	$F^b_{26} = 13-F^a_5 s$
$F^b_{27} = 21-4F^a_6 s$	$F^b_{28} = 39-40s$	$F^b_{29} = 1-4sc$
$F^b_{30} = 3-10c$	$F^b_{31} = 3-2s$	$F^b_{32} = c+2s$
$F^b_{33} = 4-7c$	$F^b_{34} = 2+c$	

G where we have introduced

$$v_f = 1 - 2\,\frac{Q_f}{I^3_f}\,s^2_\theta$$

where $Q_l = -1$, $Q_u = \frac{2}{3}$ and $Q_d = -\frac{1}{3}$; I^3_f is the third component of isospin. Furthermore

$$v^{(1)}_{gen} = v^2_l + 3\left(v^2_u + v_d\right) \qquad v^{(2)}_{gen} = v^2_l + 2\,v^2_u + v_d$$

$G_0 = 1-3v_d$	$G_1 = 3-v_l$	$G_2 = 5-3v_u$
$G_3 = 20-3v^{(2)}_{gen}$	$G_4 = 1+v^2_u$	$G_5 = 1+v^2_d$
$G_6 = 1+v^2_l$	$G_7 = 9+v^{(1)}_{gen}$	$G_8 = 2-v^2_u$
$G_9 = 2-v^2_d$	$G_{10} = 2-v^2_l$	$G_{11} = 1-v_l$
$G_{12} = 1-v_u$	$G_{13} = 1+v_u$	$G_{14} = 1-v_d$
$G_{15} = 1+v_d$	$G_{16} = 1-3v_l$	$G_{17} = 1+v_l$
$G_{18} = 2+v_u+v_d$	$G_{19} = 3-5v_u$	$G_{20} = 3-v_d$
$G_{21} = 3+v_l$	$G_{22} = 9-5v_u-v_d-3v_l$	$G_{23} = v_u-v_d$
$G_{24} = 2-v_u$	$G_{25} = 2+v_u$	$G_{26} = 2-v_d$
$G_{27} = 2+v_d$	$G_{28} = 2-v_l$	$G_{29} = 2+v_l$
$G_{30} = 2+3v_l$	$G_{31} = 6+5v_u$	$G_{32} = 6+v_d$
$G_{33} = 1-v^2_l$	$G_{34} = 1-2v_l$	$G_{35} = 1+2v_l$
$G_{36} = 1+7v_l$	$G_{37} = 3-4v_l$	$G_{38} = 3+4v_l$
$G_{39} = 8+3v_l$	$G_{40} = 1-7v_l$	$G_{41} = 7-v_l$
$G_{42} = 1-v^2_u$	$G_{43} = 1-2v_u$	$G_{44} = 1+2v_u$
$G_{45} = 3-4v_u$	$G_{46} = 3+4v_u$	$G_{47} = 3+13v_u$
$G_{48} = 4+3v_u$	$G_{49} = 16+9v_u$	$G_{50} = 3-13v_u$
$G_{51} = 13-3v_u$	$G_{52} = 1-v^2_d$	$G_{53} = 1-2v_d$
$G_{54} = 1+2v_d$	$G_{55} = 2+3v_d$	$G_{56} = 3-4v_d$
$G_{57} = 3+4v_d$	$G_{58} = 3+5v_d$	$G_{59} = 8+9v_d$
$G_{60} = 3-5v_d$	$G_{61} = 5-3v_d$	

JHEP07(2015)175

H where we have introduced

$$x_{\rm f} = \frac{M_{\rm f}}{M} \qquad \text{etc.}$$

$H_0 = 3x_u^2 + 3x_d^2 + x_l^2$	$H_1 = 3x_u^4 + 3x_d^4 + x_l^4$	$H_2 = 4x_u^2 + x_d^2 + 3x_l^2$
$H_3 = -2x_u^2 + x_d^2$	$H_4 = 2x_u^2 + x_d^2$	$H_5 = 10x_u^2 + x_d^2 + 9x_l^2$
$H_6 = -x_u^2 + x_d^2$	$H_7 = x_u^2 + x_d^2$	$H_8 = x_u^4 - 2x_d^2 x_u^2 + x_d^4$
$H_9 = 1 + x_d^2$	$H_{10} = 1 - x_d^2$	$H_{11} = 2 - x_d^2 - x_d^4$
$H_{12} = 2 + x_d^2$	$H_{13} = 2 - x_d^2$	$H_{14} = 1 + x_u^2$
$H_{15} = 1 - x_u^2$	$H_{16} = 2 - x_u^2 - x_u^4$	$H_{17} = 2 + x_u^2$
$H_{18} = 2 - x_u^2$		

I where we have introduced

$$x_{\rm F} = \frac{M_{\rm F}}{M} \qquad \text{etc.}$$

$I_0 = 2 + x_L^2$	$I_1 = 2 - x_L^2$	$I_2 = 1 + 2x_L^2$
$I_3 = 2 + 3x_L^2$	$I_4 = 4 - x_L^2$	$I_5 = 4 + x_L^2$
$I_6 = 1 + 2x_U^2$	$I_7 = 1 + x_U^2$	$I_8 = 2 + 3x_U^2$
$I_9 = 1 + 2x_D^2$	$I_{10} = 1 + x_D^2$	$I_{11} = 2 + 3x_D^2$

J where we have introduced

$$x_{\rm H} = \frac{M_{\rm H}}{M} \qquad x_{\rm S} = \frac{s}{M^2}$$

$J_0 = 2 + x_H^4$	$J_1 = 12 + x_H^4$	$J_2 = 2 - x_H^2$
$J_3 = 4 - 7x_H^2$	$J_4 = 4 - 5x_H^2$	$J_5 = 12 - x_H^4$
$J_6 = 2 + 11x_H^2$	$J_7 = 3 + 4x_H^4$	$J_8 = 4 + 5x_H^4$
$J_9 = 10 + x_H^4$	$J_{10} = 36 + x_H^4$	$J_{11} = 4 + 3x_S$
$J_{12} = 2 + x_H^2$	$J_{13} = 3 + x_H^2$	$J_{14} = 4 + x_S$
$J_{15} = 6 - x_H^2$	$J_{16} = 8 - x_S$	$J_{17} = 8 + x_S$
$J_{18} = 10 - x_H^2$	$J_{19} = 12 + x_S$	$J_{20} = 2 - 3x_H^2$
$J_{21} = 12 - x_S$	$J_{22} = 12 + 5x_S$	$J_{23} = 12 - x_H^2$
$J_{24} = 32 - 3x_S$	$J_{25} = 32 + x_S$	$J_{26} = 48 + x_S$
$J_{27} = 2x_S - x_H^2$	$J_{28} = 2x_S + x_H^2$	$J_{29} = 5x_S - x_H^2$
$J_{30} = 19 - 3x_H^2$	$J_{31} = 58 - 3x_H^2$	$J_{32} = 70 - 3x_H^2$
$J_{33} = 106 - 3x_H^2$	$J_{34} = x_S - x_H^2$	$J_{35} = 1 + x_H^2$
$J_{36} = 8 + 3x_H^2$	$J_{37} = 11x_S - x_H^2$	$J_{38} = 12x_S - 2x_H^2 x_S + x_H^4$

$\mathrm{J}_{39} = 1 - 2x_{\rm S}$	$\mathrm{J}_{40} = 1 + 2x_{\rm S}$	$\mathrm{J}_{41} = 1 + 2x_{\rm S} - x_{\rm H}^2$
$\mathrm{J}_{42} = 1 + 10x_{\rm S}$	$\mathrm{J}_{43} = 1 + 10x_{\rm S} - 2x_{\rm H}^2 - 2x_{\rm H}^2 x_{\rm S} + x_{\rm H}^4$	$\mathrm{J}_{44} = 1 + 18x_{\rm S}$
$\mathrm{J}_{45} = 2 - 68x_{\rm S} - x_{\rm H}^2$	$\mathrm{J}_{46} = 3 + 5x_{\rm S}$	$\mathrm{J}_{47} = 42 + x_{\rm H}^2$
$\mathrm{J}_{48} = 9 - 5x_{\rm S}$	$\mathrm{J}_{49} = 1 + 5x_{\rm S}$	$\mathrm{J}_{50} = 3 + x_{\rm S}$
$\mathrm{J}_{51} = 7 - 5x_{\rm S}$	$\mathrm{J}_{52} = 8 - 5x_{\rm S}$	$\mathrm{J}_{53} = 13 + 5x_{\rm S}$
$\mathrm{J}_{54} = 20 - 3x_{\rm H}^2$	$\mathrm{J}_{55} = 23 - 15x_{\rm S}$	$\mathrm{J}_{56} = 1 + 3x_{\rm S}$
$\mathrm{J}_{57} = 1 - 7x_{\rm S}$	$\mathrm{J}_{58} = 1 - 9x_{\rm S}$	$\mathrm{J}_{59} = 1 - 5x_{\rm S}$
$\mathrm{J}_{60} = 1 - 3x_{\rm S}$	$\mathrm{J}_{61} = 1 - x_{\rm S}$	$\mathrm{J}_{62} = 1 + x_{\rm S} - x_{\rm H}^2$
$\mathrm{J}_{63} = 1 + 4x_{\rm S}$	$\mathrm{J}_{64} = 1 + 9x_{\rm S}$	$\mathrm{J}_{65} = 1 + 12x_{\rm S}$
$\mathrm{J}_{66} = 1 + 14x_{\rm S}$	$\mathrm{J}_{67} = 1 + 14x_{\rm S} - x_{\rm H}^2$	$\mathrm{J}_{68} = 1 + 22x_{\rm S} - 2x_{\rm H}^2 - 14x_{\rm H}^2 x_{\rm S} + x_{\rm H}^4$
$\mathrm{J}_{69} = 2 - 56x_{\rm S} - x_{\rm H}^2$	$\mathrm{J}_{70} = 2 - x_{\rm S}$	$\mathrm{J}_{71} = 2 + 3x_{\rm S}$
$\mathrm{J}_{72} = 2 + 5x_{\rm S}$	$\mathrm{J}_{73} = 3 + 14x_{\rm S}$	$\mathrm{J}_{74} = 8 + 24x_{\rm S} - x_{\rm H}^2$
$\mathrm{J}_{75} = 20 - x_{\rm H}^2$	$\mathrm{J}_{76} = 1 + x_{\rm S}$	

K

$\mathrm{K}_0 = x_{\rm S} + 2x_{\rm u}^2$	$\mathrm{K}_1 = x_{\rm S} + 2x_{\rm d}^2$	$\mathrm{K}_2 = x_{\rm S} + 2x_{\rm l}^2$
$\mathrm{K}_3 = x_{\rm S} - 6x_{\rm l}^2$	$\mathrm{K}_4 = x_{\rm S} + x_{\rm l}^2$	$\mathrm{K}_5 = 2x_{\rm S} - x_{\rm l}^2$
$\mathrm{K}_6 = 2 - x_{\rm S}$	$\mathrm{K}_7 = 2 + x_{\rm S}$	

L

$\mathrm{L}_0 = -x_{\rm L}^2 + x_{\rm S}$	$\mathrm{L}_1 = -2x_{\rm L}^2 + x_{\rm S}$	$\mathrm{L}_2 = x_{\rm L}^2 + x_{\rm S}$
$\mathrm{L}_3 = -x_{\rm L}^2 + 2x_{\rm S}$	$\mathrm{L}_4 = x_{\rm L}^2 + 2x_{\rm S}$	$\mathrm{L}_5 = xL^4 - 2x_{\rm S}\, x_{\rm L}^2 + x_{\rm S}^2$
$\mathrm{L}_6 = -x_{\rm U}^2 + x_{\rm S}$	$\mathrm{L}_7 = -2x_{\rm U}^2 + x_{\rm S}$	$\mathrm{L}_8 = x_{\rm U}^2 + x_{\rm S}$
$\mathrm{L}_9 = -x_{\rm U}^2 + 2x_{\rm S}$	$\mathrm{L}_{10} = x_{\rm U}^4 - 2x_{\rm S}\, x_{\rm U}^2 + x_{\rm S}^2$	$\mathrm{L}_{11} = -x_{\rm D}^2 + x_{\rm S}$
$\mathrm{L}_{12} = -2x_{\rm D}^2 + x_{\rm S}$	$\mathrm{L}_{13} = x_{\rm D}^2 + x_{\rm S}$	$\mathrm{L}_{14} = -x_{\rm D}^2 + 2x_{\rm S}$
$\mathrm{L}_{15} = x_{\rm D}^4 - 2x_{\rm S}\, x_{\rm D}^2 + x_{\rm S}^2$		

B.2 Renormalized self-energies

The (renormalized) bosonic self-energies are decomposed according to

$$D_{ij}(s) = \frac{g^2}{16\pi^2}\left[\Delta_{ij}^{(4)}(s)\, M_{\rm W}^2 + \Pi_{ij}^{(4)}(s)\, s + g_6\left(\Delta_{ij}^{(6)}(s)\, M_{\rm W}^2 + \Pi_{ij}^{(6)}(s)\, s\right)\right] \tag{B.1}$$

while the (renormalized) fermionic self-energies are decomposed as

$$S_{\rm f} = \frac{g^2}{16\pi^2}\left[V_{\rm ff}^{(4)}\, i\not{p} + A_{\rm ff}^{(4)}\, i\not{p}\,\gamma^5 + \Sigma_{\rm ff}^{(4)}\, M_{\rm W} + g_6\left(V_{\rm ff}^{(6)}\, i\not{p} + A_{\rm ff}^{(6)}\, i\not{p}\,\gamma^5 + \Sigma_{\rm ff}^{(6)}\, M_{\rm W}\right)\right] \tag{B.2}$$

In the following list we introduce a shorthand notation:

$$\mathrm{B}_0^{\rm fin}(m_1, m_2) = \mathrm{B}_0^{\rm fin}(-s; m_1, m_2) \tag{B.3}$$

and several linear combinations of Wilson coefficients

$$
\begin{array}{ll}
a_{\phi \mathrm{W}} = \mathrm{c}_\theta^2\, a_{\mathrm{ZZ}} + \mathrm{s}_\theta^2\, a_{\mathrm{AA}} + \mathrm{c}_\theta \mathrm{s}_\theta\, a_{\mathrm{AZ}} & a_{\phi \mathrm{B}} = \mathrm{c}_\theta^2\, a_{\mathrm{AA}} + \hat{\mathrm{s}}_\theta^2\, a_{\mathrm{ZZ}} - \mathrm{c}_\theta \mathrm{s}_\theta\, a_{\mathrm{AZ}} \\
a_{\phi \mathrm{WB}} = \left(1 - 2\,\mathrm{s}_\theta^2\right) a_{\mathrm{AZ}} + 2\,\mathrm{c}_\theta \mathrm{s}_\theta\, \left(a_{\mathrm{AA}} - a_{\mathrm{ZZ}}\right) & a_{\phi \mathrm{WB}} = \mathrm{c}_\theta\, a_{\phi \mathrm{WA}} - \mathrm{s}_\theta\, a_{\phi \mathrm{WZ}} \\
a_{\phi \mathrm{W}} = \mathrm{s}_\theta\, a_{\phi \mathrm{WA}} + \mathrm{c}_\theta\, a_{\phi \mathrm{WZ}} & a^{(a)}_{\phi \mathrm{WB}} = a_{\phi \mathrm{B}} - a_{\phi \mathrm{W}} \\
a_{\phi \mathrm{d}} = \frac{1}{2}\, \left(a_{\phi \mathrm{d\,A}} - a_{\phi \mathrm{d\,V}}\right) & a_{\phi \mathrm{u}} = \frac{1}{2}\, \left(a_{\phi \mathrm{u\,V}} - a_{\phi \mathrm{u\,A}}\right) \\
a^{(1)}_{\phi \mathrm{q}} = \frac{1}{4}\, \left(a_{\phi \mathrm{u\,V}} + a_{\phi \mathrm{u\,A}} - a_{\phi \mathrm{d\,V}} - a_{\phi \mathrm{d\,A}}\right) & a^{(3)}_{\phi \mathrm{q}} = \frac{1}{4}\, \left(a_{\phi \mathrm{d\,V}} + a_{\phi \mathrm{d\,A}} + a_{\phi \mathrm{u\,V}} + a_{\phi \mathrm{u\,A}}\right) \\
a_{\phi \mathrm{u\,VA}} = 2\, \left(a^{(3)}_{\phi \mathrm{q}} + a^{(1)}_{\phi \mathrm{q}}\right) & a_{\phi \mathrm{d\,VA}} = 2\, \left(a^{(3)}_{\phi \mathrm{q}} - a^{(1)}_{\phi \mathrm{q}}\right)
\end{array}
$$

$$
\begin{array}{ll}
a_{\phi \mathrm{l}} = \frac{1}{2}\, \left(a_{\phi \mathrm{l\,A}} - a_{\phi \mathrm{l\,V}}\right) & a^{(1)}_{\phi \mathrm{l}} = a^{(3)}_{\phi \mathrm{l}} - \frac{1}{2}\, \left(a_{\phi \mathrm{l\,V}} + a_{\phi \mathrm{l\,A}}\right) \\
a^{(3)}_{\phi \mathrm{l}} = \frac{1}{4}\, \left(a_{\phi \mathrm{l\,V}} + a_{\phi \mathrm{l\,A}} + a_{\phi \nu}\right) & a_{\phi \mathrm{l\,VA}} = 2\, \left(a^{(3)}_{\phi \mathrm{l}} - a^{(1)}_{\phi \mathrm{l}}\right) \\
a_{\mathrm{l\,W}} = \mathrm{s}_\theta\, a_{\mathrm{l\,WB}} + \mathrm{c}_\theta\, a_{\mathrm{l\,BW}} & a_{\mathrm{l\,B}} = -\mathrm{c}_\theta\, a_{\mathrm{l\,WB}} + \mathrm{s}_\theta\, a_{\mathrm{l\,BW}} \\
a_{\mathrm{u\,W}} = \mathrm{s}_\theta\, a_{\mathrm{u\,WB}} + \mathrm{c}_\theta\, a_{\mathrm{u\,BW}} & a_{\mathrm{u\,B}} = \mathrm{c}_\theta\, a_{\mathrm{u\,WB}} - \mathrm{s}_\theta\, a_{\mathrm{u\,BW}} \\
a_{\mathrm{d\,W}} = \mathrm{s}_\theta\, a_{\mathrm{d\,WB}} + \mathrm{c}_\theta\, a_{\mathrm{d\,BW}} & a_{\mathrm{d\,B}} = -\mathrm{c}_\theta\, a_{\mathrm{d\,WB}} + \mathrm{s}_\theta\, a_{\mathrm{d\,BW}} \\
a^{(3)}_{\phi \mathrm{l\,W}} = 4\, a^{(3)}_{\phi \mathrm{l}} + 2\, a_{\phi \mathrm{W}} & a^{(3)}_{\phi \mathrm{q\,W}} = 4\, a^{(3)}_{\phi \mathrm{q}} + 2\, a_{\phi \mathrm{W}} \\
a^{(+)}_{\phi \mathrm{WD}} + a^{(-)}_{\phi \mathrm{WD}} = 8\, a_{\phi \mathrm{W}} & a^{(+)}_{\phi \mathrm{WD}} - a^{(-)}_{\phi \mathrm{WD}} = 2\, a_{\phi \mathrm{D}} \\
a_{\phi \mathrm{WAB}} = a_{\phi \mathrm{WA}} - 2\,\mathrm{s}_\theta\, a_{\phi \mathrm{B}} & a_{\phi \mathrm{WAD}} = 4\,\mathrm{s}_\theta\, a_{\phi \mathrm{WA}} - \mathrm{c}_\theta^2\, a_{\phi \mathrm{D}} \\
a_{\mathrm{l}\,\phi \Box} = a_{\mathrm{l}\,\phi} - a_{\phi \Box} & a_{\mathrm{u}\,\phi \Box} = a_{\mathrm{u}\,\phi} + a_{\phi \Box} \\
a_{\mathrm{d}\,\phi \Box} = a_{\mathrm{d}\,\phi} - a_{\phi \Box} &
\end{array}
\tag{B.4}
$$

All functions in the following list are decomposed according to

$$
F = \sum_{n=0}^{2} F_n \tag{B.5}
$$

where F_0 is the constant part (containing a dependence on μ_{R}), F_1 contains (finite) one-point functions and F_2 the (finite) two-point functions. Capital letters (U etc.) denote a specific fermion, small letters (u etc.) are used when summing over fermions.

- H self-energy

$$
\Pi^{(4)}_{\mathrm{HH}\,;0} = \frac{1}{2}\,\mathrm{F}_0^b\,\frac{\mathrm{L_R}}{c^2} - \frac{1}{2}\sum_{\mathrm{gen}} \mathrm{H}_0\,\mathrm{L_R}
$$

$$
\Pi^{(4)}_{\mathrm{HH}\,;1} = 0
$$

$$
\begin{aligned}
\Pi^{(4)}_{\mathrm{HH}\,;2} = {} & \frac{1}{2}\,\frac{1}{c^2}\,\mathrm{B}_0^{\mathrm{fin}}\left(M_0\,,M_0\right) + \mathrm{B}_0^{\mathrm{fin}}\left(M\,,M\right) - \frac{1}{2}\sum_{\mathrm{gen}} x_{\mathrm{l}}^2\,\mathrm{B}_0^{\mathrm{fin}}\left(M_{\mathrm{l}}\,,M_{\mathrm{l}}\right) \\
& - \frac{3}{2}\sum_{\mathrm{gen}} x_{\mathrm{u}}^2\,\mathrm{B}_0^{\mathrm{fin}}\left(M_{\mathrm{u}}\,,M_{\mathrm{u}}\right) - \frac{3}{2}\sum_{\mathrm{gen}} x_{\mathrm{d}}^2\,\mathrm{B}_0^{\mathrm{fin}}\left(M_{\mathrm{d}}\,,M_{\mathrm{d}}\right)
\end{aligned}
$$

$$
\Delta^{(4)}_{\mathrm{HH}\,;0} = 2 + \frac{1}{2}\,\frac{1}{c^4}\,\left(2 - 3\,\mathrm{L_R}\right) - \frac{3}{2}\,\mathrm{J}_0\,\mathrm{L_R} + 2\sum_{\mathrm{gen}} \mathrm{H}_1\,\mathrm{L_R}
$$

$$\Delta^{(4)}_{\mathrm{HH}\,;\,1} = 0$$

$$\Delta^{(4)}_{\mathrm{HH}\,;\,2} = -\frac{1}{4}\,\mathrm{J}_1\,\mathrm{B}^{\mathrm{fin}}_0\,(M\,,M) - \frac{9}{8}\,x^4_{\mathrm{H}}\,\mathrm{B}^{\mathrm{fin}}_0\left(M_{\mathrm{H}}\,,M_{\mathrm{H}}\right) + 2\sum_{\mathrm{gen}} x^4_{\mathrm{l}}\,\mathrm{B}^{\mathrm{fin}}_0\left(M_{\mathrm{l}}\,,M_{\mathrm{l}}\right)$$
$$+6\sum_{\mathrm{gen}} x^4_{\mathrm{u}}\,\mathrm{B}^{\mathrm{fin}}_0\left(M_{\mathrm{u}}\,,M_{\mathrm{u}}\right) + 6\sum_{\mathrm{gen}} x^4_{\mathrm{d}}\,\mathrm{B}^{\mathrm{fin}}_0\left(M_{\mathrm{d}}\,,M_{\mathrm{d}}\right) - \frac{1}{8}\,(12 + c^4\,x^4_{\mathrm{H}})\,\frac{1}{c^4}\,\mathrm{B}^{\mathrm{fin}}_0\,(M_0\,,M_0)$$

$$\Pi^{(6)}_{\mathrm{HH}\,;\,0} = -4\,a_{\phi\,\mathrm{W}}\,(1 - 2\,\mathrm{L_R}) - \frac{1}{c^2}\,a_{\mathrm{ZZ}}\,(2 - 3\,\mathrm{L_R})$$
$$+\frac{1}{8}\left[(8\,a_{\phi\,\mathrm{W}} + a_{\phi\,\mathrm{D}} + 8\,a_{\phi\,\square}) + (4\,\mathrm{J}_3\,a_{\phi\,\square} - \mathrm{J}_4\,a_{\phi\,\mathrm{D}})\,c^2\right]\frac{\mathrm{L_R}}{c^2}$$
$$-\frac{1}{4}\sum_{\mathrm{gen}}\left[(a^{(-)}_{\phi\,\mathrm{WD}} + 4\,a_{\phi\,\square})\,\mathrm{H}_0 + 4\,(-3\,x^2_{\mathrm{d}}\,a_{\mathrm{d}\,\phi} + 3\,x^2_{\mathrm{u}}\,a_{\mathrm{u}\,\phi} - x^2_{\mathrm{l}}\,a_{\mathrm{l}\,\phi})\right]\mathrm{L_R}$$

$$\Pi^{(6)}_{\mathrm{HH}\,;\,1} = -\frac{1}{8}\,\frac{1}{c^2}\,a_{\phi\,\mathrm{D}}\,a^{\mathrm{fin}}_0\,(M_0) - \frac{1}{8}\,(a_{\phi\,\mathrm{D}} - 4\,a_{\phi\,\square})\,x^2_{\mathrm{H}}\,a^{\mathrm{fin}}_0\left(M_{\mathrm{H}}\right)$$

$$\Pi^{(6)}_{\mathrm{HH}\,;\,2} = \frac{1}{4}\left[32\,a_{\phi\,\mathrm{W}} - (a_{\phi\,\mathrm{D}} - 4\,a_{\phi\,\square})\,\mathrm{J}_2\right]\mathrm{B}^{\mathrm{fin}}_0\,(M\,,M)$$
$$-\frac{1}{8}\left[-8\,(3\,a_{\mathrm{ZZ}} + a_{\phi\,\mathrm{W}} + a_{\phi\,\square}) + (a_{\phi\,\mathrm{D}} + 4\,a_{\phi\,\square})\,c^2\,x^2_{\mathrm{H}}\right]\frac{1}{c^2}\,\mathrm{B}^{\mathrm{fin}}_0\,(M_0\,,M_0)$$
$$+\frac{3}{8}\,(a_{\phi\,\mathrm{D}} - 4\,a_{\phi\,\square})\,x^2_{\mathrm{H}}\,\mathrm{B}^{\mathrm{fin}}_0\left(M_{\mathrm{H}}\,,M_{\mathrm{H}}\right)$$
$$-\frac{1}{4}\sum_{\mathrm{gen}}(a^{(-)}_{\phi\,\mathrm{WD}} - 4\,a_{\mathrm{l}\,\phi\,\square})\,x^2_{\mathrm{l}}\,\mathrm{B}^{\mathrm{fin}}_0\left(M_{\mathrm{l}}\,,M_{\mathrm{l}}\right) - \frac{3}{4}\sum_{\mathrm{gen}}(a^{(-)}_{\phi\,\mathrm{WD}} - 4\,a_{\mathrm{d}\,\phi\,\square})\,x^2_{\mathrm{d}}\,\mathrm{B}^{\mathrm{fin}}_0\left(M_{\mathrm{d}}\,,M_{\mathrm{d}}\right)$$
$$-\frac{3}{4}\sum_{\mathrm{gen}}(a^{(-)}_{\phi\,\mathrm{WD}} + 4\,a_{\mathrm{u}\,\phi\,\square})\,x^2_{\mathrm{u}}\,\mathrm{B}^{\mathrm{fin}}_0\left(M_{\mathrm{u}}\,,M_{\mathrm{u}}\right)$$

$$\Delta^{(6)}_{\mathrm{HH}\,;\,0} = \frac{1}{2}\left[(6\,a_{\phi} + a_{\phi\,\mathrm{D}}\,x^2_{\mathrm{H}}) + (6\,\mathrm{J}_6\,a_{\phi} + \mathrm{J}_7\,a_{\phi\,\mathrm{D}} - 3\,\mathrm{J}_8\,a_{\phi\,\square} - 6\,\mathrm{J}_9\,a_{\phi\,\mathrm{W}})\,c^2\right]\frac{\mathrm{L_R}}{c^2}$$
$$+\frac{1}{4}\,(16\,a_{\mathrm{ZZ}} + 4\,a_{\phi\,\mathrm{W}} + 3\,a_{\phi\,\mathrm{D}} + 4\,a_{\phi\,\square})\,\frac{1}{c^4}\,(2 - 3\,\mathrm{L_R}) + (20\,a_{\phi\,\mathrm{W}} - a_{\phi\,\mathrm{D}} + 4\,a_{\phi\,\square})$$
$$+\sum_{\mathrm{gen}}\left[(a^{(-)}_{\phi\,\mathrm{WD}} + 4\,a_{\phi\,\square})\,\mathrm{H}_1 + 8\,(-3\,x^4_{\mathrm{d}}\,a_{\mathrm{d}\,\phi} + 3\,x^4_{\mathrm{u}}\,a_{\mathrm{u}\,\phi} - x^4_{\mathrm{l}}\,a_{\mathrm{l}\,\phi})\right]\mathrm{L_R}$$

$$\Delta^{(6)}_{\mathrm{HH}\,;\,1} = 4\sum_{\mathrm{gen}} x^4_{\mathrm{l}}\,a_{\mathrm{l}\,\phi}\,a^{\mathrm{fin}}_0\left(M_{\mathrm{l}}\right) - 12\sum_{\mathrm{gen}} x^4_{\mathrm{u}}\,a_{\mathrm{u}\,\phi}\,a^{\mathrm{fin}}_0\left(M_{\mathrm{u}}\right) + 12\sum_{\mathrm{gen}} x^4_{\mathrm{d}}\,a_{\mathrm{d}\,\phi}\,a^{\mathrm{fin}}_0\left(M_{\mathrm{d}}\right)$$
$$-\frac{3}{4}\left[20\,a_{\phi} + (a_{\phi\,\mathrm{D}} - 4\,a_{\phi\,\square})\,x^2_{\mathrm{H}}\right]x^2_{\mathrm{H}}\,a^{\mathrm{fin}}_0\left(M_{\mathrm{H}}\right)$$
$$-\frac{1}{4}\left[c^2\,a_{\phi\,\mathrm{D}}\,x^2_{\mathrm{H}} - 6\,(4\,a_{\mathrm{ZZ}} + a_{\phi\,\mathrm{D}} - 2\,c^2\,a_{\phi})\right]\frac{1}{c^4}\,a^{\mathrm{fin}}_0\,(M_0)$$
$$-6\,(a_{\phi} - 2\,a_{\phi\,\mathrm{W}})\,a^{\mathrm{fin}}_0\,(M)$$

$$\Delta^{(6)}_{\mathrm{HH}\,;\,2} = \frac{3}{16}\left[96\,a_{\phi} + (-12\,a_{\phi\,\mathrm{W}} + 7\,a_{\phi\,\mathrm{D}} - 28\,a_{\phi\,\square})\,x^2_{\mathrm{H}}\right]x^2_{\mathrm{H}}\,\mathrm{B}^{\mathrm{fin}}_0\left(M_{\mathrm{H}}\,,M_{\mathrm{H}}\right)$$
$$+\frac{1}{16}\left[4\,c^2\,a_{\phi\,\mathrm{D}}\,x^2_{\mathrm{H}} - 12\,(a^{(+)}_{\phi\,\mathrm{WD}} + 8\,a_{\mathrm{ZZ}} + 4\,a_{\phi\,\square}) - (a^{(-)}_{\phi\,\mathrm{WD}} - 4\,a_{\phi\,\square})\,c^4\,x^4_{\mathrm{H}}\right]\frac{1}{c^4}\,\mathrm{B}^{\mathrm{fin}}_0\,(M_0\,,M_0)$$
$$-\frac{1}{8}\left[4\,\mathrm{J}_{10}\,a_{\phi\,\mathrm{W}} - (a_{\phi\,\mathrm{D}} - 4\,a_{\phi\,\square})\,\mathrm{J}_5\right]\mathrm{B}^{\mathrm{fin}}_0\,(M\,,M)$$
$$+\sum_{\mathrm{gen}}(a^{(-)}_{\phi\,\mathrm{WD}} - 4\,a_{\mathrm{l}\,\phi\,\square})\,x^4_{\mathrm{l}}\,\mathrm{B}^{\mathrm{fin}}_0\left(M_{\mathrm{l}}\,,M_{\mathrm{l}}\right)$$
$$+3\sum_{\mathrm{gen}}(a^{(-)}_{\phi\,\mathrm{WD}} - 4\,a_{\mathrm{d}\,\phi\,\square})\,x^4_{\mathrm{d}}\,\mathrm{B}^{\mathrm{fin}}_0\left(M_{\mathrm{d}}\,,M_{\mathrm{d}}\right)$$

$$+3\sum_{\rm gen}(a^{(-)}_{\phi\rm WD}+4\,a_{\rm u\,\phi\,\Box})\,x_{\rm u}^4\,{\rm B}_0^{\rm fin}\left(M_{\rm u}\,,M_{\rm u}\right)$$

- A self-energy

$$\Pi^{(4)}_{\rm AA\,;0}=3\,s^2\,{\rm L_R}+\frac{32}{27}\,s^2\,{\rm N_{gen}}\,(1-3\,{\rm L_R})+4\,\frac{s^2}{x_{\rm s}}-\frac{8}{9}\sum_{\rm gen}\frac{s^2}{x_{\rm s}}\,{\rm H}_2$$

$$\Pi^{(4)}_{\rm AA\,;1}=4\,\frac{s^2}{x_{\rm s}}\,a_0^{\rm fin}\,(M)-\frac{8}{3}\sum_{\rm gen}\frac{x_{\rm l}^2}{x_{\rm s}}\,s^2\,a_0^{\rm fin}\left(M_{\rm l}\right)-\frac{32}{9}\sum_{\rm gen}\frac{x_{\rm u}^2}{x_{\rm s}}\,s^2\,a_0^{\rm fin}\left(M_{\rm u}\right)-\frac{8}{9}\sum_{\rm gen}\frac{x_{\rm d}^2}{x_{\rm s}}\,s^2\,a_0^{\rm fin}\left(M_{\rm d}\right)$$

$$\Pi^{(4)}_{\rm AA\,;2}=\frac{s^2}{x_{\rm s}}\,{\rm J}_{11}\,{\rm B}_0^{\rm fin}\,(M\,,M)-\frac{4}{3}\sum_{\rm gen}\frac{s^2}{x_{\rm s}}\,{\rm K}_2\,{\rm B}_0^{\rm fin}\left(M_{\rm l}\,,M_{\rm l}\right)-\frac{16}{9}\sum_{\rm gen}\frac{s^2}{x_{\rm s}}\,{\rm K}_0\,{\rm B}_0^{\rm fin}\left(M_{\rm u}\,,M_{\rm u}\right)-\frac{4}{9}\sum_{\rm gen}\frac{s^2}{x_{\rm s}}\,{\rm K}_1\,{\rm B}_0^{\rm fin}\left(M_{\rm d}\,,M_{\rm d}\right)$$

$$\Pi^{(6)}_{\rm AA\,;0}=\frac{16}{27}\,{\rm N_{gen}}\,a_{\phi\rm WAD}\,(1-3\,{\rm L_R})+2\,\frac{1}{x_{\rm s}}\,a_{\phi\rm WAD}-\frac{4}{9}\sum_{\rm gen}\frac{1}{x_{\rm s}}\,{\rm H}_2\,a_{\phi\rm WAD}-\frac{1}{2}\left[{\rm J}_{13}\,c^2\,a_{\phi\rm B}-{\rm J}_{15}\,s\,c^3\,a_{\phi\rm WB}+(3\,c^4\,a_{\phi\rm D}+s\,a_{\phi\rm WA})-({\rm J}_{12}\,a_{\phi\rm B}+{\rm J}_{18}\,a_{\phi\rm W})\,s^2\,c^2\right]\frac{\rm L_R}{c^2}+2\sum_{\rm gen}(-x_{\rm d}^2\,a_{\rm d\,WB}+2\,x_{\rm u}^2\,a_{\rm u\,WB}-x_{\rm l}^2\,a_{\rm l\,WB})\,s\,{\rm L_R}$$

$$\Pi^{(6)}_{\rm AA\,;1}=\frac{1}{2}\,\frac{1}{c^2}\,a_{\rm AA}\,a_0^{\rm fin}\,(M_0)+\frac{1}{2}\,x_{\rm H}^2\,a_{\rm AA}\,a_0^{\rm fin}\left(M_{\rm H}\right)-\frac{4}{3}\sum_{\rm gen}\frac{x_{\rm l}^2}{x_{\rm s}}\,a_{\phi\rm WAD}\,a_0^{\rm fin}\left(M_{\rm l}\right)-\frac{16}{9}\sum_{\rm gen}\frac{x_{\rm u}^2}{x_{\rm s}}\,a_{\phi\rm WAD}\,a_0^{\rm fin}\left(M_{\rm u}\right)-\frac{4}{9}\sum_{\rm gen}\frac{x_{\rm d}^2}{x_{\rm s}}\,a_{\phi\rm WAD}\,a_0^{\rm fin}\left(M_{\rm d}\right)+\left[{\rm J}_{16}\,s\,c\,a_{\phi\rm WB}+{\rm J}_{17}\,s^2\,a_{\phi\rm W}+(x_{\rm s}\,a_{\phi\rm B}-2\,a_{\phi\rm D})\,c^2\right]\frac{1}{x_{\rm s}}\,a_0^{\rm fin}\,(M)$$

$$\Pi^{(6)}_{\rm AA\,;2}=\frac{1}{2}\left[4\,{\rm J}_{14}\,s\,c\,a_{\phi\rm WB}+(-c^2\,a_{\phi\rm D}+4\,s^2\,a_{\phi\rm W})\,{\rm J}_{11}\right]\frac{1}{x_{\rm s}}\,{\rm B}_0^{\rm fin}\,(M\,,M)-\frac{2}{9}\sum_{\rm gen}(9\,s\,x_{\rm d}^2\,x_{\rm s}\,a_{\rm d\,WB}+{\rm K}_1\,a_{\phi\rm WAD})\,\frac{1}{x_{\rm s}}\,{\rm B}_0^{\rm fin}\left(M_{\rm d}\,,M_{\rm d}\right)+\frac{4}{9}\sum_{\rm gen}(9\,s\,x_{\rm u}^2\,x_{\rm s}\,a_{\rm u\,WB}-2\,{\rm K}_0\,a_{\phi\rm WAD})\,\frac{1}{x_{\rm s}}\,{\rm B}_0^{\rm fin}\left(M_{\rm u}\,,M_{\rm u}\right)-\frac{2}{3}\sum_{\rm gen}(3\,s\,x_{\rm l}^2\,x_{\rm s}\,a_{\rm l\,WB}+{\rm K}_2\,a_{\phi\rm WAD})\,\frac{1}{x_{\rm s}}\,{\rm B}_0^{\rm fin}\left(M_{\rm l}\,,M_{\rm l}\right)$$

- Z−A transition

$$\Pi^{(4)}_{\rm ZA\,;0}=-\frac{1}{9}\,\frac{s}{c}\,{\rm N_{gen}}\,v^{(2)}_{\rm gen}\,(1-3\,{\rm L_R})-\frac{1}{6}\,\frac{s}{c}\,{\rm F}_2^b\,{\rm L_R}+\frac{2}{3}\sum_{\rm gen}(x_{\rm l}^2\,{\rm v_l}+{\rm v_d}\,x_{\rm d}^2+2\,{\rm v_u}\,x_{\rm u}^2)\,\frac{s}{c\,x_{\rm s}}-\frac{1}{9}\,(36\,c^2+{\rm J}_{19})\,\frac{s}{c\,x_{\rm s}}$$

$$\Pi^{(4)}_{ZA\,;1} = -\frac{4}{3}\,\frac{s}{c\,x_S}\,F^b_1\,a^{fin}_0\,(M) + \frac{2}{3}\sum_{gen}\frac{s\,x^2_d}{c\,x_S}\,v_d\,a^{fin}_0\left(M_d\right) + \frac{4}{3}\sum_{gen}\frac{s\,x^2_u}{c\,x_S}\,v_u\,a^{fin}_0\left(M_u\right) + \frac{2}{3}\sum_{gen}\frac{s\,x^2_l}{c\,x_S}\,v_l\,a^{fin}_0\left(M_l\right)$$

$$\Pi^{(4)}_{ZA\,;2} = \frac{1}{3}\sum_{gen}\frac{s}{c\,x_S}\,K_2\,v_l\,B^{fin}_0\left(M_l\,,M_l\right) + \frac{2}{3}\sum_{gen}\frac{s}{c\,x_S}\,K_0\,v_u\,B^{fin}_0\left(M_u\,,M_u\right) + \frac{1}{3}\sum_{gen}\frac{s}{c\,x_S}\,K_1\,v_d\,B^{fin}_0\left(M_d\,,M_d\right) - \frac{1}{6}\left(6\,J_{11}\,c^2 + J_{17}\right)\frac{s}{c\,x_S}\,B^{fin}_0\,(M\,,M)$$

$$\begin{aligned}
\Pi^{(6)}_{ZA\,;0} = {} & \frac{1}{36}\Big[144\,s^3\,c^2\,a_{\phi WAB} - 4\,J_{26}\,s\,c\,a_{\phi WB} - 144\,F^b_3\,s^2\,c\,a_{\phi WZ} + 36\,F^b_5\,c^2\,a_{\phi D} \\
& + (a_{\phi D} - 2\,s^2\,a^{(+)}_{\phi WD})\,J_{19}\Big]\,\frac{1}{s\,c\,x_S} \\
& - \frac{1}{24}\Big[F^b_8\,c\,a_{\phi D} + 4\,(3\,a_{\phi B} - a_{\phi W} + 36\,s^2\,c^2\,a^{(a)}_{\phi WB})\,s^2\,c + 12\,(J_{12}\,a_{\phi B} + J_{18}\,a_{\phi W})\,s^2\,c^3 \\
& + 2\,(J_{20}\,c^2 - 6\,J_{23}\,s^2\,c^2 + 3\,F^b_6)\,s\,a_{\phi WB}\Big]\,\frac{L_R}{s\,c^2} \\
& + \frac{1}{108}\Big\{\Big[3\,c\,a_{\phi D}\,v^{(2)}_{gen} - 4\,(3\,a_{\phi WB}\,v^{(2)}_{gen} - 32\,(-c\,a_{\phi WZ} + s\,a_{\phi WAB})\,s\,c)\,s\Big]\,c \\
& + 4\,(G_3\,a_{\phi W} - F^b_{10}\,a_{\phi D})\,s^2\Big\}\,\frac{N_{gen}}{s\,c}\,(1 - 3\,L_R) \\
& + \frac{1}{18}\sum_{gen}\Big[4\,(a_{\phi D} + 4\,c\,a_{\phi WZ} - 4\,s\,a_{\phi WAB})\,H_2\,s^2\,c^2 + (-24\,x^2_d\,a_{\phi d} + 48\,x^2_u\,a_{\phi u} - 4\,G_0\,x^2_d\,a_{\phi W} \\
& - 12\,G_1\,x^2_l\,a_{\phi W} - 8\,G_2\,x^2_u\,a_{\phi W} - 24\,H_3\,a^{(1)}_{\phi q} + 24\,H_4\,a^{(3)}_{\phi q} + H_5\,a_{\phi D} - 4\,K_3\,a_{\phi l V})\,s^2 \\
& + 3\,(-c\,a_{\phi D} + 4\,s\,a_{\phi WB})\,(x^2_l\,v_l + v_d\,x^2_d + 2\,v_u\,x^2_u)\,c\Big]\,\frac{1}{s\,c\,x_S} \\
& + \frac{1}{12}\sum_{gen}\Big\{8\,s\,a_{\phi l V} - 3\,\Big[-(a_{l WB}\,v_l + 4\,s\,c\,a_{l BW})\,x^2_l - (3\,v_d\,a_{d WB} + 4\,s\,c\,a_{d BW})\,x^2_d \\
& + (3\,v_u\,a_{u WB} + 8\,s\,c\,a_{u BW})\,x^2_u\Big]\Big\}\,\frac{L_R}{c} \\
& - \frac{2}{9}\sum_{gen}(a_{\phi d V} + 2\,a_{\phi u V})\,(1 - 3\,L_R)\,\frac{s}{c}
\end{aligned}$$

$$\begin{aligned}
\Pi^{(6)}_{ZA\,;1} = {} & -\frac{1}{4}\,\frac{1}{c^2}\,a_{AZ}\,a^{fin}_0\,(M_0) - \frac{1}{4}\,x^2_H\,a_{AZ}\,a^{fin}_0\left(M_H\right) \\
& - \frac{1}{6}\Big\{2\,F^b_7\,a_{\phi D} + 16\,\Big[a_{\phi W} + 3\,(c\,a^{(a)}_{\phi WB} + s\,a_{\phi WB})\,s^2\,c\Big]\,s^2 - 6\,(x_S\,a_{\phi B} - J_{17}\,a_{\phi W})\,s^2\,c^2 \\
& - (6\,J_{21}\,s^2 - J_{24})\,s\,c\,a_{\phi WB}\Big\}\,\frac{1}{s\,c\,x_S}\,a^{fin}_0\,(M) \\
& - \frac{1}{6}\sum_{gen}\Big\{\Big[c^2\,a_{\phi D}\,v_l - 4\,(c\,a_{\phi WB}\,v_l + 2\,(a_{\phi l V} + 2\,c^3\,a_{\phi WZ} - 2\,s\,c^2\,a_{\phi WAB})\,s)\,s\Big] \\
& + (4\,G_1\,a_{\phi W} - F^b_9\,a_{\phi D})\,s^2\Big\}\,\frac{x^2_l}{s\,c\,x_S}\,a^{fin}_0\left(M_l\right) \\
& - \frac{1}{18}\sum_{gen}\Big\{\Big[3\,c^2\,v_d\,a_{\phi D} - 4\,(3\,c\,v_d\,a_{\phi WB} + 2\,(3\,a_{\phi d V} + 2\,c^3\,a_{\phi WZ} - 2\,s\,c^2\,a_{\phi WAB})\,s)\,s\Big] \\
& + (4\,G_0\,a_{\phi W} - F^b_4\,a_{\phi D})\,s^2\Big\}\,\frac{x^2_d}{s\,c\,x_S}\,a^{fin}_0\left(M_d\right) \\
& - \frac{1}{9}\sum_{gen}\Big\{\Big[3\,c^2\,v_u\,a_{\phi D} - 4\,(3\,c\,v_u\,a_{\phi WB} + 2\,(3\,a_{\phi u V} + 4\,c^3\,a_{\phi WZ} - 4\,s\,c^2\,a_{\phi WAB})\,s)\,s\Big]
\end{aligned}$$

$$+(4\,\mathrm{G}_2\,a_{\phi\mathrm{W}} - \mathrm{F}^b_{10}\,a_{\phi\mathrm{D}})\,s^2\Big\}\,\frac{x^2_{\mathrm{u}}}{s\,c\,x_{\mathrm{S}}}\,a^{\mathrm{fin}}_0\left(M_{\mathrm{u}}\right)$$

$$\begin{aligned}
\Pi^{(6)}_{\mathrm{ZA}\,;\,2} = \frac{1}{24}\Big\{&-48\left[c^3\,a_{\phi\mathrm{W}} + (c\,a_{\phi\mathrm{B}} + s\,a_{\phi\mathrm{WB}})\,s^2\right]\mathrm{J}_{11}\,s^2\,c + (a_{\phi\mathrm{D}} - 2\,s^2\,a^{(+)}_{\phi\mathrm{WD}})\,\mathrm{J}_{17} + 6\,(\mathrm{J}_{11}\,\mathrm{F}^b_5)\,c^2\,a_{\phi\mathrm{D}}\\
&+4\,(6\,\mathrm{J}_{22}\,s^2 - \mathrm{J}_{25})\,s\,c\,a_{\phi\mathrm{WB}}\Big\}\,\frac{1}{s\,c\,x_{\mathrm{S}}}\,\mathrm{B}^{\mathrm{fin}}_0\,(M\,,M)\\
&+\frac{1}{12}\sum_{\mathrm{gen}}\Big\{-\left[c^2\,a_{\phi\mathrm{D}}\,\mathrm{v}_{\mathrm{l}} - 4\,(c\,a_{\phi\mathrm{WB}}\,\mathrm{v}_{\mathrm{l}} + 2\,(a_{\phi\mathrm{l}\,\mathrm{V}} + 2\,c^3\,a_{\phi\mathrm{WZ}} - 2\,s\,c^2\,a_{\phi\mathrm{WAB}})\,s)\,s\right]\mathrm{K}_2\\
&+3\,(a_{\mathrm{l}\,\mathrm{WB}}\,\mathrm{v}_{\mathrm{l}} + 4\,s\,c\,a_{\mathrm{l}\,\mathrm{BW}})\,s\,x^2_{\mathrm{l}}\,x_{\mathrm{S}} - (4\,\mathrm{G}_1\,\mathrm{K}_2\,a_{\phi\mathrm{W}} - \mathrm{K}_2\,\mathrm{F}^b_9\,a_{\phi\mathrm{D}})\,s^2\Big\}\,\frac{1}{s\,c\,x_{\mathrm{S}}}\,\mathrm{B}^{\mathrm{fin}}_0\left(M_{\mathrm{l}}\,,M_{\mathrm{l}}\right)\\
&+\frac{1}{36}\sum_{\mathrm{gen}}\Big\{-\left[3\,c^2\,\mathrm{v}_{\mathrm{d}}\,a_{\phi\mathrm{D}} - 4\,(3\,c\,\mathrm{v}_{\mathrm{d}}\,a_{\phi\mathrm{WB}} + 2\,(3\,a_{\phi\mathrm{d}\,\mathrm{V}} + 2\,c^3\,a_{\phi\mathrm{WZ}} - 2\,s\,c^2\,a_{\phi\mathrm{WAB}})\,s)\,s\right]\mathrm{K}_1\\
&+9\,(3\,\mathrm{v}_{\mathrm{d}}\,a_{\mathrm{d}\,\mathrm{WB}} + 4\,s\,c\,a_{\mathrm{d}\,\mathrm{BW}})\,s\,x^2_{\mathrm{d}}\,x_{\mathrm{S}} - (4\,\mathrm{G}_0\,\mathrm{K}_1\,a_{\phi\mathrm{W}} - \mathrm{K}_1\,\mathrm{F}^b_4\,a_{\phi\mathrm{D}})\,s^2\Big\}\,\frac{1}{s\,c\,x_{\mathrm{S}}}\,\mathrm{B}^{\mathrm{fin}}_0\left(M_{\mathrm{d}}\,,M_{\mathrm{d}}\right)\\
&-\frac{1}{36}\sum_{\mathrm{gen}}\Big\{2\left[3\,c^2\,\mathrm{v}_{\mathrm{u}}\,a_{\phi\mathrm{D}} - 4\,(3\,c\,\mathrm{v}_{\mathrm{u}}\,a_{\phi\mathrm{WB}} + 2\,(3\,a_{\phi\mathrm{u}\,\mathrm{V}} + 4\,c^3\,a_{\phi\mathrm{WZ}} - 4\,s\,c^2\,a_{\phi\mathrm{WAB}})\,s)\,s\right]\mathrm{K}_0\\
&+9\,(3\,\mathrm{v}_{\mathrm{u}}\,a_{\mathrm{u}\,\mathrm{WB}} + 8\,s\,c\,a_{\mathrm{u}\,\mathrm{BW}})\,s\,x^2_{\mathrm{u}}\,x_{\mathrm{S}} + 2\,(4\,\mathrm{G}_2\,\mathrm{K}_0\,a_{\phi\mathrm{W}} - \mathrm{K}_0\,\mathrm{F}^b_{10}\,a_{\phi\mathrm{D}})\,s^2\Big\}\,\frac{1}{s\,c\,x_{\mathrm{S}}}\,\mathrm{B}^{\mathrm{fin}}_0\left(M_{\mathrm{u}}\,,M_{\mathrm{u}}\right)
\end{aligned}$$

- Z self-energy

$$\Pi^{(4)}_{\mathrm{ZZ}\,;\,0} = -3\,s^2\,\mathrm{L_R} + \frac{1}{36}\,\frac{\mathrm{N_{gen}}}{c^2}\,\mathrm{G}_7\,(1 - 3\,\mathrm{L_R}) + \frac{2}{9}\,(1 + 15\,\mathrm{L_R}) - \frac{1}{18}\,\frac{1}{c^2}\,(2 + 3\,\mathrm{L_R})$$

$$\Pi^{(4)}_{\mathrm{ZZ}\,;\,1} = 0$$

$$\begin{aligned}
\Pi^{(4)}_{\mathrm{ZZ}\,;\,2} = &-\frac{1}{12}\,\frac{1}{c^2}\,\mathrm{F}^b_{11}\,\mathrm{B}^{\mathrm{fin}}_0\,(M\,,M) - \frac{1}{12}\,\frac{1}{c^2}\,\mathrm{B}^{\mathrm{fin}}_0\left(M_{\mathrm{H}}\,,M_0\right) - \frac{1}{12}\sum_{\mathrm{gen}}\frac{1}{c^2}\,\mathrm{G}_6\,\mathrm{B}^{\mathrm{fin}}_0\left(M_{\mathrm{l}}\,,M_{\mathrm{l}}\right)\\
&-\frac{1}{4}\sum_{\mathrm{gen}}\frac{1}{c^2}\,\mathrm{G}_4\,\mathrm{B}^{\mathrm{fin}}_0\left(M_{\mathrm{u}}\,,M_{\mathrm{u}}\right) - \frac{1}{4}\sum_{\mathrm{gen}}\frac{1}{c^2}\,\mathrm{G}_5\,\mathrm{B}^{\mathrm{fin}}_0\left(M_{\mathrm{d}}\,,M_{\mathrm{d}}\right) - \frac{1}{6}\sum_{\mathrm{gen}}\frac{1}{c^2}\,\mathrm{B}^{\mathrm{fin}}_0\,(0,0)
\end{aligned}$$

$$\begin{aligned}
\Delta^{(4)}_{\mathrm{ZZ}\,;\,0} = &\frac{1}{6}\,\frac{1}{c^4}\,(1 - 6\,\mathrm{L_R}) - 2\,\frac{\mathrm{L_R}}{c^2} + \frac{1}{2}\sum_{\mathrm{gen}}\mathrm{H}_0\,\frac{\mathrm{L_R}}{c^2}\\
&+\frac{1}{6}\,(\mathrm{J}_{12} + 8\,\mathrm{F}^b_{14}\,c^2)\,\frac{1}{c^2} - \frac{1}{6}\sum_{\mathrm{gen}}(3\,\mathrm{G}_4\,x^2_{\mathrm{u}} + 3\,\mathrm{G}_5\,x^2_{\mathrm{d}} + \mathrm{G}_6\,x^2_{\mathrm{l}})\,\frac{1}{c^2}
\end{aligned}$$

$$\begin{aligned}
\Delta^{(4)}_{\mathrm{ZZ}\,;\,1} = &\frac{1}{3}\,\frac{1}{c^2}\,\mathrm{F}^b_{12}\,a^{\mathrm{fin}}_0\,(M) - \frac{1}{6}\sum_{\mathrm{gen}}\frac{x^2_{\mathrm{l}}}{c^2}\,\mathrm{G}_6\,a^{\mathrm{fin}}_0\left(M_{\mathrm{l}}\right) - \frac{1}{2}\sum_{\mathrm{gen}}\frac{x^2_{\mathrm{u}}}{c^2}\,\mathrm{G}_4\,a^{\mathrm{fin}}_0\left(M_{\mathrm{u}}\right)\\
&-\frac{1}{2}\sum_{\mathrm{gen}}\frac{x^2_{\mathrm{d}}}{c^2}\,\mathrm{G}_5\,a^{\mathrm{fin}}_0\left(M_{\mathrm{d}}\right) + \frac{1}{12}\,(1 + \mathrm{J}_{27}\,c^2)\,\frac{x^2_{\mathrm{H}}}{c^4\,x_{\mathrm{S}}}\,a^{\mathrm{fin}}_0\left(M_{\mathrm{H}}\right) - \frac{1}{12}\,(1 - \mathrm{J}_{28}\,c^2)\,\frac{1}{c^6\,x_{\mathrm{S}}}\,a^{\mathrm{fin}}_0\,(M_0)
\end{aligned}$$

$$\begin{aligned}
\Delta^{(4)}_{\mathrm{ZZ}\,;\,2} = &-\frac{1}{3}\,\frac{1}{c^2}\,\mathrm{F}^b_{13}\,\mathrm{B}^{\mathrm{fin}}_0\,(M\,,M) + \frac{1}{6}\sum_{\mathrm{gen}}\frac{x^2_{\mathrm{l}}}{c^2}\,\mathrm{G}_{10}\,\mathrm{B}^{\mathrm{fin}}_0\left(M_{\mathrm{l}}\,,M_{\mathrm{l}}\right) + \frac{1}{2}\sum_{\mathrm{gen}}\frac{x^2_{\mathrm{u}}}{c^2}\,\mathrm{G}_8\,\mathrm{B}^{\mathrm{fin}}_0\left(M_{\mathrm{u}}\,,M_{\mathrm{u}}\right)\\
&+\frac{1}{2}\sum_{\mathrm{gen}}\frac{x^2_{\mathrm{d}}}{c^2}\,\mathrm{G}_9\,\mathrm{B}^{\mathrm{fin}}_0\left(M_{\mathrm{d}}\,,M_{\mathrm{d}}\right) - \frac{1}{12}\,(1 - \mathrm{J}_{27}\,c^4\,x^2_{\mathrm{H}} + 2\,\mathrm{J}_{29}\,c^2)\,\frac{1}{c^6\,x_{\mathrm{S}}}\,\mathrm{B}^{\mathrm{fin}}_0\left(M_{\mathrm{H}}\,,M_0\right)
\end{aligned}$$

JHEP07(2015)175

$$
\begin{aligned}
\Pi^{(6)}_{ZZ;0} = {} & \frac{1}{9}\, a_{\phi D}\,(1+15 L_R) - \frac{1}{18}\,\frac{1}{c^2}\, a_{\phi\Box}\,(2+3 L_R) \\
& - \frac{1}{18}\Big[a_{\phi D} - 4 c^2 a_{ZZ} + 4\,(c\, a_{AZ} + s\, a_{AA})\, s\Big]\frac{1}{c^2} \\
& + \frac{1}{72}\Big[G_{22}\, a^{(-)}_{\phi WD} + 4\, v^{(2)}_{gen}\,(a_{\phi D} + 4 c\, a_{\phi WZ} - 4 s\, a_{\phi WAB})\, c^2\Big]\frac{N_{gen}}{c^2}\,(1-3 L_R) \\
& + \frac{1}{12}\Big\{2 J_{30}\, c^2 a_{\phi W} - \Big[a^{(+)}_{\phi WD} + 6\,(5 a_{\phi B} + 3 c^2 a_{\phi D} + 24 s^2 c^2 a^{(a)}_{\phi WB})\, s^2\Big] - 2\,(J_{31}\, c^2 - 9 F^{b}_{16})\, s\, c\, a_{\phi WB} \\
& + 2\,(J_{32}\, a_{\phi B} - J_{33}\, a_{\phi W})\, s^2 c^2\Big\}\frac{L_R}{c^2} \\
& - \frac{1}{9}\sum_{gen}\Big[3 G_{12}\, a_{\phi u} - 3 G_{14}\, a_{\phi d} - 3 G_{18}\, a^{(3)}_{\phi q} - G_{21}\, a^{(3)}_{\phi l} - 3 G_{23}\, a^{(1)}_{\phi q} - (a^{(3)}_{\phi l} - a_{\phi l V})\, G_{11}\Big]\frac{1}{c^2}\,(1-3 L_R) \\
& + \frac{1}{2}\sum_{gen}(-x^2_l\, v_l\, a_{l BW} - 3 v_d\, x^2_d\, a_{d BW} + 3 v_u\, x^2_u\, a_{u BW})\,\frac{L_R}{c}
\end{aligned}
$$

$$
\Pi^{(6)}_{ZZ;1} = \frac{1}{2}\,\frac{1}{c^2}\, a_{ZZ}\, a^{fin}_0(M_0) + \frac{1}{2}\, a_{ZZ}\, x^2_H\, a^{fin}_0\big(M_H\big) + \Big[c^2 a_{\phi W} + (c\, a_{\phi WB} + s\, a_{\phi B})\, s\Big]\, a^{fin}_0(M)
$$

$$
\begin{aligned}
\Pi^{(6)}_{ZZ;2} = {} & -\frac{1}{24}\,(a^{(+)}_{\phi WD} + 48 a_{ZZ} + 4 a_{\phi\Box})\,\frac{1}{c^2}\, B^{fin}_0\big(M_H, M_0\big) \\
& - \frac{1}{24}\,(F^{b}_{11}\, a_{\phi D} + 4 F^{b}_{15}\, s\, a_{\phi WA} + 4 F^{b}_{17}\, c\, a_{\phi WZ} - 16 F^{b}_{18}\, s^2 c^2 a_{\phi B})\,\frac{1}{c^2}\, B^{fin}_0(M, M) \\
& - \frac{1}{24}\sum_{gen}\Big[12 c\, x^2_l\, v_l\, a_{l BW} + 4\,(a_{\phi D} + 4 c\, a_{\phi WZ} - 4 s\, a_{\phi WAB})\, c^2 v_l + (8 G_{11}\, a_{\phi l} + G_{16}\, a^{(-)}_{\phi WD} \\
& + 4 G_{17}\, a_{\phi l VA})\Big]\frac{1}{c^2}\, B^{fin}_0\big(M_l, M_l\big) \\
& - \frac{1}{24}\sum_{gen}\Big[36 c\, v_d\, x^2_d\, a_{d BW} + 4\,(a_{\phi D} + 4 c\, a_{\phi WZ} - 4 s\, a_{\phi WAB})\, c^2 v_d \\
& + (24 G_{14}\, a_{\phi d} + 12 G_{15}\, a_{\phi d VA} + G_{20}\, a^{(-)}_{\phi WD})\Big]\frac{1}{c^2}\, B^{fin}_0\big(M_d, M_d\big) \\
& + \frac{1}{24}\sum_{gen}\Big[36 c\, v_u\, x^2_u\, a_{u BW} - 8\,(a_{\phi D} + 4 c\, a_{\phi WZ} - 4 s\, a_{\phi WAB})\, c^2 v_u \\
& + (24 G_{12}\, a_{\phi u} - 12 G_{13}\, a_{\phi u VA} - G_{19}\, a^{(-)}_{\phi WD})\Big]\frac{1}{c^2}\, B^{fin}_0\big(M_u, M_u\big) \\
& - \frac{1}{12}\sum_{gen}(4 a_{\phi v} + a^{(-)}_{\phi WD})\,\frac{1}{c^2}\, B^{fin}_0(0, 0)
\end{aligned}
$$

$$
\begin{aligned}
\Delta^{(6)}_{ZZ;0} = {} & \frac{1}{6}\,\frac{1}{c^4}\, a_{\phi\Box}\,(2-9 L_R) + \frac{1}{24}\,\frac{1}{c^4}\,(82-9 L_R)\, a_{\phi D} \\
& + \frac{1}{12}\Big[4 F^{b}_{20}\, s\, a_{\phi WA} + 4 F^{b}_{22}\, c\, a_{\phi WZ} + 64 F^{b}_{23}\, s^2 c^4 a_{\phi B} - 8 F^{b}_{26}\, s^2 a_{\phi D} + (4 a_{\phi\Box}\, x^2_H + J_{12}\, a^{(+)}_{\phi WD})\, c^2\Big]\frac{1}{c^4} \\
& - \frac{1}{8}\,(J_{36}\, c^2 a_{\phi D} + 16 F^{b}_{0}\, a_{\phi W})\,\frac{L_R}{c^4} \\
& - \frac{1}{12}\sum_{gen}\Big[4\,(a_{\phi D} + 4 c\, a_{\phi WZ} - 4 s\, a_{\phi WAB})\,(x^2_l\, v_l + v_d\, x^2_d + 2 v_u\, x^2_u)\, c^2 \\
& + (8 G_{11}\, x^2_l\, a_{\phi l} - 24 G_{12}\, x^2_u\, a_{\phi u} + 12 G_{13}\, x^2_u\, a_{\phi u VA} + 24 G_{14}\, x^2_d\, a_{\phi d} + 12 G_{15}\, x^2_d\, a_{\phi d VA} \\
& + G_{16}\, x^2_l\, a^{(-)}_{\phi WD} + 4 G_{17}\, x^2_l\, a_{\phi l VA} + G_{19}\, x^2_u\, a^{(-)}_{\phi WD} + G_{20}\, x^2_d\, a^{(-)}_{\phi WD})\Big]\frac{1}{c^2} \\
& - \frac{1}{4}\sum_{gen}(-24 x^2_d\, a_{\phi d} + 24 x^2_u\, a_{\phi u} - 8 x^2_l\, a_{\phi l A} - H_0\, a^{(-)}_{\phi WD} + 24 H_6\, a^{(1)}_{\phi q} - 24 H_7\, a^{(3)}_{\phi q})\,\frac{L_R}{c^2}
\end{aligned}
$$

$$
\Delta^{(6)}_{ZZ;1} = -\frac{1}{24}\Big\{\Big[48 a_{ZZ}\, x_s - 4 J_{28}\, a_{\phi W} + (a_{\phi D} + 4 a_{\phi\Box})\, J_{34}\Big]\, c^2 + (a^{(+)}_{\phi WD} + 4 a_{\phi\Box})\Big\}\frac{1}{c^6 x_s}\, a^{fin}_0(M_0)
$$

JHEP07(2015)175

$$
\begin{aligned}
&+\frac{1}{24}\Big\{\Big[48\,a_{\mathrm{ZZ}}\,x_{\mathrm{S}}+\mathrm{J}_{37}\,a_{\phi\mathrm{D}}+4\,(a_{\phi\mathrm{W}}+a_{\phi\Box})\,\mathrm{J}_{27}\Big]\,c^2+(a^{(+)}_{\phi\mathrm{WD}}+4\,a_{\phi\Box})\Big\}\,\frac{x_{\mathrm{H}}^2}{c^4\,x_{\mathrm{S}}}\,a_0^{\mathrm{fin}}\left(M_{\mathrm{H}}\right)\\
&+\frac{1}{6}\,(4\,\mathrm{F}^b_{19}\,s\,a_{\phi\mathrm{WA}}+4\,\mathrm{F}^b_{21}\,c\,a_{\phi\mathrm{WZ}}+32\,\mathrm{F}^b_{23}\,s^2\,c^2\,a_{\phi\mathrm{B}}+\mathrm{F}^b_{27}\,a_{\phi\mathrm{D}})\,\frac{1}{c^2}\,a_0^{\mathrm{fin}}\,(M)\\
&-\frac{1}{12}\sum_{\mathrm{gen}}\Big[4\,(a_{\phi\mathrm{D}}+4\,c\,a_{\phi\mathrm{WZ}}-4\,s\,a_{\phi\mathrm{WAB}})\,c^2\,\mathrm{v}_{\mathrm{l}}\\
&+(8\,\mathrm{G}_{11}\,a_{\phi\mathrm{l}}+\mathrm{G}_{16}\,a^{(-)}_{\phi\mathrm{WD}}+4\,\mathrm{G}_{17}\,a_{\phi\mathrm{l\,VA}})\Big]\,\frac{x_{\mathrm{l}}^2}{c^2}\,a_0^{\mathrm{fin}}\left(M_{\mathrm{l}}\right)\\
&-\frac{1}{12}\sum_{\mathrm{gen}}\Big[4\,(a_{\phi\mathrm{D}}+4\,c\,a_{\phi\mathrm{WZ}}-4\,s\,a_{\phi\mathrm{WAB}})\,c^2\,\mathrm{v}_{\mathrm{d}}\\
&+(24\,\mathrm{G}_{14}\,a_{\phi\mathrm{d}}+12\,\mathrm{G}_{15}\,a_{\phi\mathrm{d\,VA}}+\mathrm{G}_{20}\,a^{(-)}_{\phi\mathrm{WD}})\Big]\,\frac{x_{\mathrm{d}}^2}{c^2}\,a_0^{\mathrm{fin}}\left(M_{\mathrm{d}}\right)\\
&-\frac{1}{12}\sum_{\mathrm{gen}}\Big[8\,(a_{\phi\mathrm{D}}+4\,c\,a_{\phi\mathrm{WZ}}-4\,s\,a_{\phi\mathrm{WAB}})\,c^2\,\mathrm{v}_{\mathrm{u}}\\
&-(24\,\mathrm{G}_{12}\,a_{\phi\mathrm{u}}-12\,\mathrm{G}_{13}\,a_{\phi\mathrm{u\,VA}}-\mathrm{G}_{19}\,a^{(-)}_{\phi\mathrm{WD}})\Big]\,\frac{x_{\mathrm{u}}^2}{c^2}\,a_0^{\mathrm{fin}}\left(M_{\mathrm{u}}\right)
\end{aligned}
$$

$$
\begin{aligned}
\Delta^{(6)}_{\mathrm{ZZ};2}=\;&\frac{1}{24}\Big\{\Big[48\,\mathrm{J}_{35}\,x_{\mathrm{S}}\,a_{\phi\mathrm{B}}-4\,\mathrm{J}_{38}\,a_{\phi\mathrm{W}}+(a_{\phi\mathrm{D}}+4\,a_{\phi\Box})\,\mathrm{J}_{27}\,x_{\mathrm{H}}^2\Big]\,c^4\\
&-2\Big[24\,(a_{\phi\mathrm{B}}-s\,c\,a_{\phi\mathrm{WB}})\,x_{\mathrm{S}}+(a^{(+)}_{\phi\mathrm{WD}}+4\,a_{\phi\Box})\,\mathrm{J}_{29}\Big]\,c^2\\
&+48\,(a_{\phi\mathrm{WZ}}-c\,a_{\phi\mathrm{B}})\,c^5\,x_{\mathrm{H}}^2\,x_{\mathrm{S}}-(a^{(+)}_{\phi\mathrm{WD}}+4\,a_{\phi\Box})\Big\}\,\frac{1}{c^6\,x_{\mathrm{S}}}\,\mathrm{B}_0^{\mathrm{fin}}\left(M_{\mathrm{H}}\,,M_0\right)\\
&-\frac{1}{6}\,(\mathrm{F}^b_{13}\,a_{\phi\mathrm{D}}-32\,\mathrm{F}^b_{23}\,s^2\,c^2\,a_{\phi\mathrm{B}}+4\,\mathrm{F}^b_{24}\,s\,a_{\phi\mathrm{WA}}+4\,\mathrm{F}^b_{25}\,c\,a_{\phi\mathrm{WZ}})\,\frac{1}{c^2}\,\mathrm{B}_0^{\mathrm{fin}}\,(M\,,M)\\
&-\frac{1}{12}\sum_{\mathrm{gen}}\Big[4\,(a_{\phi\mathrm{D}}+4\,c\,a_{\phi\mathrm{WZ}}-4\,s\,a_{\phi\mathrm{WAB}})\,c^2\,\mathrm{v}_{\mathrm{l}}\\
&-(4\,\mathrm{G}_{28}\,a_{\phi\mathrm{l\,VA}}+8\,\mathrm{G}_{29}\,a_{\phi\mathrm{l}}+\mathrm{G}_{30}\,a^{(-)}_{\phi\mathrm{WD}})\Big]\,\frac{x_{\mathrm{l}}^2}{c^2}\,\mathrm{B}_0^{\mathrm{fin}}\left(M_{\mathrm{l}}\,,M_{\mathrm{l}}\right)\\
&-\frac{1}{12}\sum_{\mathrm{gen}}\Big[4\,(a_{\phi\mathrm{D}}+4\,c\,a_{\phi\mathrm{WZ}}-4\,s\,a_{\phi\mathrm{WAB}})\,c^2\,\mathrm{v}_{\mathrm{d}}\\
&-(12\,\mathrm{G}_{26}\,a_{\phi\mathrm{d\,VA}}+24\,\mathrm{G}_{27}\,a_{\phi\mathrm{d}}+\mathrm{G}_{32}\,a^{(-)}_{\phi\mathrm{WD}})\Big]\,\frac{x_{\mathrm{d}}^2}{c^2}\,\mathrm{B}_0^{\mathrm{fin}}\left(M_{\mathrm{d}}\,,M_{\mathrm{d}}\right)\\
&-\frac{1}{12}\sum_{\mathrm{gen}}\Big[8\,(a_{\phi\mathrm{D}}+4\,c\,a_{\phi\mathrm{WZ}}-4\,s\,a_{\phi\mathrm{WAB}})\,c^2\,\mathrm{v}_{\mathrm{u}}\\
&-(12\,\mathrm{G}_{24}\,a_{\phi\mathrm{u\,VA}}-24\,\mathrm{G}_{25}\,a_{\phi\mathrm{u}}+\mathrm{G}_{31}\,a^{(-)}_{\phi\mathrm{WD}})\Big]\,\frac{x_{\mathrm{u}}^2}{c^2}\,\mathrm{B}_0^{\mathrm{fin}}\left(M_{\mathrm{u}}\,,M_{\mathrm{u}}\right)
\end{aligned}
$$

- W self-energy

$$
\Pi^{(4)}_{\mathrm{WW};0}=\frac{4}{9}\,(1-3\,\mathrm{L_R})\,\mathrm{N_{gen}}+\frac{1}{18}\,(2+57\,\mathrm{L_R})
$$

$$
\Pi^{(4)}_{\mathrm{WW};1}=0
$$

$$
\begin{aligned}
\Pi^{(4)}_{\mathrm{WW};2}=&-\frac{1}{12}\,\mathrm{B}_0^{\mathrm{fin}}\left(M\,,M_{\mathrm{H}}\right)+\frac{1}{12}\,\mathrm{B}_0^{\mathrm{fin}}\,(M\,,M_0)\,\mathrm{F}^b_{28}\\
&+\frac{10}{3}\,\mathrm{B}_0^{\mathrm{fin}}\,(0\,,M)\,s^2-\sum_{\mathrm{gen}}\mathrm{B}_0^{\mathrm{fin}}\left(M_{\mathrm{u}}\,,M_{\mathrm{d}}\right)-\frac{1}{3}\sum_{\mathrm{gen}}\mathrm{B}_0^{\mathrm{fin}}\left(0\,,M_{\mathrm{l}}\right)
\end{aligned}
$$

JHEP07(2015)175

$$\Delta^{(4)}_{WW;0} = -2\,L_R + \frac{1}{6}\,\frac{1}{c^2}\,(1-6\,L_R) + \frac{1}{6}\,J_{47} - \frac{1}{6}\sum_{gen} H_0\,(2-3\,L_R)$$

$$\begin{aligned}\Delta^{(4)}_{WW;1} = {}& \frac{1}{12}\,\frac{x_H^2}{x_S}\,J_{41}\,a_0^{fin}(M_H) - \frac{1}{6}\sum_{gen}\frac{x_l^2}{x_S}\,K_5\,a_0^{fin}(M_l) \\ & - \frac{1}{12}\,(1+8\,J_{40}\,s^2c^2 - J_{44}\,c^2)\,\frac{1}{c^4 x_S}\,a_0^{fin}(M_0) + \frac{1}{12}\,(1-J_{45}\,c^2)\,\frac{1}{c^2 x_S}\,a_0^{fin}(M) \\ & - \frac{1}{2}\sum_{gen}(2\,x_S - H_6)\,\frac{x_d^2}{x_S}\,a_0^{fin}(M_d) - \frac{1}{2}\sum_{gen}(2\,x_S + H_6)\,\frac{x_u^2}{x_S}\,a_0^{fin}(M_u)\end{aligned}$$

$$\begin{aligned}\Delta^{(4)}_{WW;2} = {}& -\frac{2}{3}\,\frac{s^2}{x_S}\,J_{39}\,B_0^{fin}(0,M) - \frac{1}{12}\,\frac{1}{x_S}\,J_{43}\,B_0^{fin}(M,M_H) \\ & + \frac{1}{6}\sum_{gen}\frac{x_l^2}{x_S}\,K_4\,B_0^{fin}(0,M_l) + \frac{1}{2}\sum_{gen}(H_7\,x_S + H_8)\,\frac{1}{x_S}\,B_0^{fin}(M_u,M_d) \\ & - \frac{1}{12}\,(1-8\,J_{39}\,s^2c^4 - 7\,J_{42}\,c^4 + 2\,J_{46}\,c^2)\,\frac{1}{c^4 x_S}\,B_0^{fin}(M,M_0)\end{aligned}$$

$$\begin{aligned}\Pi^{(6)}_{WW;0} = {}& \frac{2}{9}\,s^2\,a_{AA}\,(1-9\,L_R) + \frac{8}{9}\,N_{gen}\,a_{\phi W}\,(1-3\,L_R) - \frac{1}{18}\,a_{\phi\Box}\,(2+3\,L_R) \\ & + \frac{1}{6}\left[6\,F_3^b\,s\,c\,a_{\phi WB} + (J_{54}\,c^2 - 3\,F_{29}^b)\,a_{\phi W}\right]\frac{L_R}{c^2} - \frac{2}{9}\,(-c\,a_{ZZ} + 2\,s\,a_{AZ})\,c \\ & + \frac{4}{9}\sum_{gen}(a^{(3)}_{\phi l} + 3\,a^{(3)}_{\phi q})\,(1-3\,L_R) + \frac{1}{2}\sum_{gen}(-3\,x_d^2\,a_{dW} + 3\,x_u^2\,a_{uW} - x_l^2\,a_{lW})\,L_R\end{aligned}$$

$$\begin{aligned}\Pi^{(6)}_{WW;1} = {}& a_{\phi W}\,a_0^{fin}(M) + \frac{1}{2}\,a_{\phi W}\,x_H^2\,a_0^{fin}(M_H) \\ & + \frac{1}{6}\left[F_{30}^b\,s\,c\,a_{AZ} + 3\,(c^2\,a_{ZZ} + s^2\,a_{AA})\right]\frac{1}{c^2}\,a_0^{fin}(M_0)\end{aligned}$$

$$\begin{aligned}\Pi^{(6)}_{WW;2} = {}& -\frac{1}{3}\left\{5\,c^2\,a_{\phi D} - J_{53}\,s\,c\,a_{\phi WB} - \left[2\,J_{49}\,a_{\phi W} + (2\,a_{AA} + s\,c\,a_{AZ})\,J_{48}\right]s^2\right\}B_0^{fin}(0,M) \\ & + \frac{1}{24}\left\{32\,J_{52}\,s^4\,c\,a^{(a)}_{\phi WB} + \left[39\,c\,a^{(+)}_{\phi WD} + 8\,(3\,a_{\phi WB} - 5\,s\,c\,a_{\phi D})\,s\right]\right. \\ & + 16\,(a_{\phi WA} - s\,a_{\phi B})\,J_{48}\,s^5\,c - 16\,(J_{46}\,a_{\phi W} + J_{51}\,a_{\phi B})\,s^2\,c \\ & \left. - 8\,(5\,J_{50} + J_{55}\,s^2)\,s\,c^2\,a_{\phi WB}\right\}\frac{1}{c}\,B_0^{fin}(M,M_0) \\ & + \frac{1}{24}\,(-52\,a_{\phi W} + a_{\phi D} - 4\,a_{\phi\Box})\,B_0^{fin}(M,M_H) \\ & - \frac{1}{2}\sum_{gen}(2\,a^{(3)}_{\phi q W} + 3\,x_d^2\,a_{dW} - 3\,x_u^2\,a_{uW})\,B_0^{fin}(M_u,M_d) \\ & - \frac{1}{6}\sum_{gen}(2\,a^{(3)}_{\phi l W} + 3\,x_l^2\,a_{lW})\,B_0^{fin}(0,M_l)\end{aligned}$$

$$\begin{aligned}\Delta^{(6)}_{WW;0} = {}& \frac{1}{3}\,\frac{1}{c^2}\,a_{\phi W}\,(1-6\,L_R) - \frac{1}{12}\,\frac{1}{c^2}\,a_{\phi D}\,(11-15\,L_R) \\ & + \frac{1}{6}\left[2\,c^3\,a_{\phi WB} + (3\,a_{\phi D} - 4\,c^2\,a_{AA} + 4\,c^2\,a_{\phi W})\,s\right]\frac{s}{c^2}\,(2-3\,L_R) \\ & - \frac{1}{12}\left[40\,s\,a_{\phi WB} - (4\,J_{35}\,a_{\phi\Box} + 4\,J_{47}\,a_{\phi W} + J_{75}\,a_{\phi D})\,c\right]\frac{1}{c} \\ & - \frac{1}{2}\,(8\,a_{\phi W} + 3\,a_{\phi\Box})\,L_R - \frac{1}{3}\sum_{gen}(2\,x_l^2\,a^{(3)}_{\phi l} + H_0\,a_{\phi W} + 6\,H_7\,a^{(3)}_{\phi q})\,(2-3\,L_R)\end{aligned}$$

$$\Delta^{(6)}_{\mathrm{WW};1} = \frac{1}{24}\Big[a^{(+)}_{\phi\mathrm{WD}} + 8\,\mathrm{J}_{61}\,s\,c^3\,a_{\mathrm{AZ}} - 8\,\mathrm{J}_{71}\,s\,c\,a_{\phi\mathrm{WB}}$$
$$-(12\,a_{\phi\mathrm{D}}\,x_{\mathrm{S}} + 4\,\mathrm{J}_{62}\,a_{\phi\Box} + 4\,\mathrm{J}_{69}\,a_{\phi\mathrm{W}} - \mathrm{J}_{74}\,a_{\phi\mathrm{D}})\,c^2\Big]\,\frac{1}{c^2\,x_{\mathrm{S}}}\,a_0^{\mathrm{fin}}(M)$$
$$+\frac{1}{24}\Big[16\,\mathrm{J}_{63}\,s^5\,c^2\,a_{\phi\mathrm{WA}} - 16\,\mathrm{J}_{64}\,s^4\,c^2\,a_{\phi\mathrm{W}} - 16\,\mathrm{F}^b_4\,s^2\,c^4\,x_{\mathrm{S}}\,a_{\phi\mathrm{B}} - (a^{(+)}_{\phi\mathrm{WD}} - 16\,s^4\,c^4\,a_{\phi\mathrm{B}})$$
$$-8\,(\mathrm{J}_{40}\,a_{\phi\mathrm{D}} + 2\,\mathrm{J}_{70}\,a_{\phi\mathrm{W}})\,s^2\,c^2 + (4\,\mathrm{J}_{44}\,a_{\phi\mathrm{W}} + \mathrm{J}_{65}\,a_{\phi\mathrm{D}})\,c^2$$
$$-8\,(\mathrm{J}_{66}\,s^2\,c^2 - \mathrm{J}_{71} + \mathrm{J}_{72}\,c^2)\,s\,c\,a_{\phi\mathrm{WB}}\Big]\,\frac{1}{c^4\,x_{\mathrm{S}}}\,a_0^{\mathrm{fin}}(M_0)$$
$$+\frac{1}{24}\Big[4\,\mathrm{J}_{67}\,a_{\phi\mathrm{W}} - (a_{\phi\mathrm{D}} - 4\,a_{\phi\Box})\,\mathrm{J}_{41}\Big]\,\frac{x_{\mathrm{H}}^2}{x_{\mathrm{S}}}\,a_0^{\mathrm{fin}}(M_{\mathrm{H}})$$
$$-\frac{1}{2}\sum_{\mathrm{gen}}(2\,x_{\mathrm{S}}\,a^{(3)}_{\phi\mathrm{q}\,\mathrm{W}} - 3\,x_{\mathrm{d}}^2\,x_{\mathrm{S}}\,a_{\mathrm{d}\,\mathrm{W}} - 3\,x_{\mathrm{u}}^2\,x_{\mathrm{S}}\,a_{\mathrm{u}\,\mathrm{W}} - \mathrm{H}_6\,a^{(3)}_{\phi\mathrm{q}\,\mathrm{W}})\,\frac{x_{\mathrm{d}}^2}{x_{\mathrm{S}}}\,a_0^{\mathrm{fin}}(M_{\mathrm{d}})$$
$$-\frac{1}{2}\sum_{\mathrm{gen}}(2\,x_{\mathrm{S}}\,a^{(3)}_{\phi\mathrm{q}\,\mathrm{W}} + 3\,x_{\mathrm{d}}^2\,x_{\mathrm{S}}\,a_{\mathrm{d}\,\mathrm{W}} + 3\,x_{\mathrm{u}}^2\,x_{\mathrm{S}}\,a_{\mathrm{u}\,\mathrm{W}} + \mathrm{H}_6\,a^{(3)}_{\phi\mathrm{q}\,\mathrm{W}})\,\frac{x_{\mathrm{u}}^2}{x_{\mathrm{S}}}\,a_0^{\mathrm{fin}}(M_{\mathrm{u}})$$
$$+\frac{1}{6}\sum_{\mathrm{gen}}(3\,x_{\mathrm{l}}^2\,x_{\mathrm{S}}\,a_{\mathrm{l}\,\mathrm{W}} - \mathrm{K}_5\,a^{(3)}_{\phi\mathrm{l}\,\mathrm{W}})\,\frac{x_{\mathrm{l}}^2}{x_{\mathrm{S}}}\,a_0^{\mathrm{fin}}(M_{\mathrm{l}})$$

$$\Delta^{(6)}_{\mathrm{WW};2} = \frac{1}{3}\Big[\mathrm{J}_{39}\,c^2\,a_{\phi\mathrm{D}} - (2\,a_{\mathrm{AA}} + s\,c\,a_{\mathrm{AZ}})\,\mathrm{J}_{56}\,s^2 - (c\,a_{\phi\mathrm{WB}} + 2\,s\,a_{\phi\mathrm{W}})\,\mathrm{J}_{57}\,s\Big]\,\frac{1}{x_{\mathrm{S}}}\,\mathrm{B}_0^{\mathrm{fin}}(0,M)$$
$$-\frac{1}{24}\Big[4\,\mathrm{J}_{68}\,a_{\phi\mathrm{W}} - (a_{\phi\mathrm{D}} - 4\,a_{\phi\Box})\,\mathrm{J}_{43}\Big]\,\frac{1}{x_{\mathrm{S}}}\,\mathrm{B}_0^{\mathrm{fin}}(M,M_{\mathrm{H}})$$
$$-\frac{1}{24}\Big\{-8\Big[\mathrm{J}_{39}\,a_{\phi\mathrm{D}} + 4\,\mathrm{J}_{60}\,a_{\phi\mathrm{W}} + 4\,(a_{\phi\mathrm{B}} - 3\,s^2\,a^{(a)}_{\phi\mathrm{WB}})\,x_{\mathrm{S}}\Big]\,s^2\,c^4 + (1 - 7\,\mathrm{J}_{42}\,c^4 + 2\,\mathrm{J}_{46}\,c^2)\,a^{(+)}_{\phi\mathrm{WD}}$$
$$+16\,(a_{\phi\mathrm{WA}} - s\,a_{\phi\mathrm{B}})\,\mathrm{J}_{56}\,s^5\,c^4 + 8\,(\mathrm{J}_{58}\,s^2\,c^4 - \mathrm{J}_{59}\,c^4 - \mathrm{J}_{71} + \mathrm{J}_{73}\,c^2)\,s\,c\,a_{\phi\mathrm{WB}}\Big\}\,\frac{1}{c^4\,x_{\mathrm{S}}}\,\mathrm{B}_0^{\mathrm{fin}}(M,M_0)$$
$$+\frac{1}{6}\sum_{\mathrm{gen}}(3\,x_{\mathrm{l}}^2\,x_{\mathrm{S}}\,a_{\mathrm{l}\,\mathrm{W}} + \mathrm{K}_4\,a^{(3)}_{\phi\mathrm{l}\,\mathrm{W}})\,\frac{x_{\mathrm{l}}^2}{x_{\mathrm{S}}}\,\mathrm{B}_0^{\mathrm{fin}}(0,M_{\mathrm{l}})$$
$$+\frac{1}{2}\sum_{\mathrm{gen}}(3\,\mathrm{H}_6\,x_{\mathrm{d}}^2\,x_{\mathrm{S}}\,a_{\mathrm{d}\,\mathrm{W}} + 3\,\mathrm{H}_6\,x_{\mathrm{u}}^2\,x_{\mathrm{S}}\,a_{\mathrm{u}\,\mathrm{W}} + \mathrm{H}_7\,x_{\mathrm{S}}\,a^{(3)}_{\phi\mathrm{q}\,\mathrm{W}} + \mathrm{H}_8\,a^{(3)}_{\phi\mathrm{q}\,\mathrm{W}})\,\frac{1}{x_{\mathrm{S}}}\,\mathrm{B}_0^{\mathrm{fin}}(M_{\mathrm{u}},M_{\mathrm{d}})$$

- neutrino (N) self-energy

$$V^{(4)}_{\mathrm{NN};0} = -\frac{1}{4} - \frac{1}{8}\,\frac{1}{c^2}\,(1 - \mathrm{L_R}) + \frac{1}{8}\,\mathrm{I}_0\,\mathrm{L_R}$$

$$V^{(4)}_{\mathrm{NN};1} = -\frac{1}{8}\,\frac{1}{c^4\,x_{\mathrm{S}}}\,a_0^{\mathrm{fin}}(M_0) - \frac{1}{8}\,\frac{1}{x_{\mathrm{S}}}\,\mathrm{I}_0\,a_0^{\mathrm{fin}}(M)$$

$$V^{(4)}_{\mathrm{NN};2} = -\frac{1}{8}\,\frac{1}{x_{\mathrm{S}}}\,\mathrm{I}_0\,\mathrm{J}_{61}\,\mathrm{B}_0^{\mathrm{fin}}(0,M) - \frac{1}{8}\,(1 - c^2\,x_{\mathrm{S}})\,\frac{1}{c^4\,x_{\mathrm{S}}}\,\mathrm{B}_0^{\mathrm{fin}}(0,M_0)$$

$$V^{(6)}_{\mathrm{NN};0} = -\frac{1}{4}\,a^{(3)}_{\phi\mathrm{L}\,\mathrm{W}} + \frac{1}{8}\,x_{\mathrm{L}}^2\,a_{\mathrm{L}\,\mathrm{W}}\,(2 - 3\,\mathrm{L_R})$$
$$-\frac{1}{16}\,(4\,a_{\phi\mathrm{N}} + a^{(-)}_{\phi\mathrm{WD}})\,\frac{1}{c^2}\,(1 - \mathrm{L_R}) + \frac{1}{4}\,(\mathrm{I}_0\,a_{\phi\mathrm{W}} + 2\,\mathrm{I}_1\,a^{(3)}_{\phi\mathrm{L}})\,\mathrm{L_R}$$

$$V^{(6)}_{\mathrm{NN};1} = -\frac{1}{16}\,(4\,a_{\phi\mathrm{N}} + a^{(-)}_{\phi\mathrm{WD}})\,\frac{1}{c^4\,x_{\mathrm{S}}}\,a_0^{\mathrm{fin}}(M_0)$$

$$-\frac{1}{8}\,(3\,x_{\rm L}^2\,a_{\rm L\,W} + {\rm I}_0\,a^{(3)}_{\phi\,\rm L\,W})\,\frac{1}{x_{\rm S}}\,a_0^{\rm fin}\,(M)$$

$$V^{(6)}_{\rm NN\,;\,2} = -\frac{1}{16}\,(4\,a_{\phi\,\rm N} + a^{(-)}_{\phi\,\rm WD})\,(1-c^2\,x_{\rm S})\,\frac{1}{c^4\,x_{\rm S}}\,{\rm B}_0^{\rm fin}\,(0\,,M_0)$$
$$-\frac{1}{8}\,(4\,{\rm I}_0\,a^{(3)}_{\phi\,\rm L} + 2\,{\rm I}_0\,{\rm J}_{61}\,a_{\phi\,\rm W} - 4\,{\rm I}_1\,x_{\rm S}\,a^{(3)}_{\phi\,\rm L} + 3\,{\rm J}_{76}\,x_{\rm L}^2\,a_{\rm L\,W})\,\frac{1}{x_{\rm S}}\,{\rm B}_0^{\rm fin}\,(0\,,M)$$

$$A^{(4)}_{\rm NN\,;\,0} = -\frac{1}{4} - \frac{1}{8}\,\frac{1}{c^2}\,(1-{\rm L_R}) + \frac{1}{8}\,{\rm I}_0\,{\rm L_R}$$

$$A^{(4)}_{\rm NN\,;\,1} = -\frac{1}{8}\,\frac{1}{c^4\,x_{\rm S}}\,a_0^{\rm fin}\,(M_0) - \frac{1}{8}\,\frac{1}{x_{\rm S}}\,{\rm I}_0\,a_0^{\rm fin}\,(M)$$

$$A^{(4)}_{\rm NN\,;\,2} = -\frac{1}{8}\,\frac{1}{x_{\rm S}}\,{\rm I}_0\,{\rm J}_{61}\,{\rm B}_0^{\rm fin}\,(0\,,M) - \frac{1}{8}\,(1-c^2\,x_{\rm S})\,\frac{1}{c^4\,x_{\rm S}}\,{\rm B}_0^{\rm fin}\,(0\,,M_0)$$

$$A^{(6)}_{\rm NN\,;\,0} = -\frac{1}{4}\,a^{(3)}_{\phi\,\rm L\,W} + \frac{1}{8}\,x_{\rm L}^2\,a_{\rm L\,W}\,(2-3\,{\rm L_R})$$
$$-\frac{1}{16}\,(4\,a_{\phi\,\rm N} + a^{(-)}_{\phi\,\rm WD})\,\frac{1}{c^2}\,(1-{\rm L_R})$$
$$+\frac{1}{4}\,({\rm I}_0\,a_{\phi\,\rm W} + 2\,{\rm I}_1\,a^{(3)}_{\phi\,\rm L})\,{\rm L_R}$$

$$A^{(6)}_{\rm NN\,;\,1} = -\frac{1}{16}\,(4\,a_{\phi\,\rm N} + a^{(-)}_{\phi\,\rm WD})\,\frac{1}{c^4\,x_{\rm S}}\,a_0^{\rm fin}\,(M_0)$$
$$-\frac{1}{8}\,(3\,x_{\rm L}^2\,a_{\rm L\,W} + {\rm I}_0\,a^{(3)}_{\phi\,\rm L\,W})\,\frac{1}{x_{\rm S}}\,a_0^{\rm fin}\,(M)$$

$$A^{(6)}_{\rm NN\,;\,2} = -\frac{1}{16}\,(4\,a_{\phi\,\rm N} + a^{(-)}_{\phi\,\rm WD})\,(1-c^2\,x_{\rm S})\,\frac{1}{c^4\,x_{\rm S}}\,{\rm B}_0^{\rm fin}\,(0\,,M_0)$$
$$-\frac{1}{8}\,(4\,{\rm I}_0\,a^{(3)}_{\phi\,\rm L} + 2\,{\rm I}_0\,{\rm J}_{61}\,a_{\phi\,\rm W} - 4\,{\rm I}_1\,x_{\rm S}\,a^{(3)}_{\phi\,\rm L} + 3\,{\rm J}_{76}\,x_{\rm L}^2\,a_{\rm L\,W})\,\frac{1}{x_{\rm S}}\,{\rm B}_0^{\rm fin}\,(0\,,M)$$

- lepton (L) self-energy

$$\Sigma^{(4)}_{\rm LL\,;\,0} = -\frac{1}{8}\,(16\,s^2\,c^2 - {\rm G}_{33})\,\frac{1}{c^2}\,x_{\rm L}\,(1-2\,{\rm L_R})$$

$$\Sigma^{(4)}_{\rm LL\,;\,1} = 0$$

$$\Sigma^{(4)}_{\rm LL\,;\,2} = -\frac{1}{4}\,x_{\rm L}^3\,{\rm B}_0^{\rm fin}\,\big(M_{\rm H}\,,M_{\rm L}\big) + 4\,s^2\,x_{\rm L}\,{\rm B}_0^{\rm fin}\,(0\,,M_{\rm L})$$
$$+\frac{1}{4}\,(c^2\,x_{\rm L}^2 - {\rm G}_{33})\,\frac{1}{c^2}\,x_{\rm L}\,{\rm B}_0^{\rm fin}\,(M_0\,,M_{\rm L})$$

$$\Sigma^{(6)}_{\rm LL\,;\,0} = -\frac{1}{8}\,\Big[c^2\,{\rm v_l}\,x_{\rm L}^2\,a_{\rm L\,BW} + 4\,{\rm F}_5^b\,s\,c^2\,a_{\phi\,\rm WB}\,{\rm v_l} + ({\rm v_l}\,a_{\rm L\,BW} + 2\,c^3\,a_{\rm L\,W})\Big]\,\frac{1}{c^3}\,x_{\rm L}\,(2-3\,{\rm L_R})$$
$$+\frac{1}{8}\,\Big\{s\,c\,x_{\rm S}\,{\rm v_l}\,x_{\rm L}\,a_{\rm L\,B} - 16\,{\rm G}_{29}\,s^2\,c^2\,a_{\phi\,\rm W}\,x_{\rm L} + 4\,{\rm L}_1\,s\,c^2\,x_{\rm L}\,a_{\rm L\,WB}$$
$$+\Big[{\rm G}_{29}\,a_{\rm L\,W}\,x_{\rm L} + 128\,(M\,\Delta_{\rm UV}\,{\rm C}^{\rm L}_{\rm UV})\Big]\,c^2\,x_{\rm S} + 2\,({\rm G}_{11}\,a_{\phi\,\rm L\,VA} + 2\,{\rm G}_{17}\,a_{\phi\,\rm L})\,x_{\rm L}\Big\}\,\frac{1}{c^2}$$

$$-\frac{1}{16}\Big\{32\,G_{28}\,s\,c^3\,a_{\phi WB}-16\,F^{b}_{31}\,s^2\,a_{\phi W}\,v_l$$
$$-\Big[4\,G_{11}\,a_{\phi W}-G_{36}\,a_{\phi D}+4\,(4\,c^4+s^2\,v_l)\,a_{\phi D}\Big]\Big\}\,\frac{1}{c^2}\,x_L\,(1-2\,L_R)$$
$$+\frac{1}{4}\Big\{4\,G_{39}\,s^2\,c^2\,a_{\phi W}+\Big[3\,x_H^2\,a_{L\phi}+2\,I_0\,a^{(3)}_{\phi L}+I_2\,a_{L\phi}-2\,(-a_{\phi L}+a^{(1)}_{\phi L}+a_{\phi\Box}-3\,s\,a_{LWB})\,x_L^2\Big]\,c^2$$
$$-\Big[G_{34}\,a_{\phi LVA}+2\,G_{35}\,a_{\phi L}-(a_{L\phi}+4\,s^2\,c^2\,a_{\phi B}\,v_l)\Big]\Big\}\,\frac{L_R}{c^2}\,x_L$$
$$+\frac{3}{2}\sum_{\text{gen}}(-x_d^2\,x_d\,a_{L1dQ}+x_u^2\,x_u\,a^{(1)}_{L1Qu})\,L_R$$

$$\Sigma^{(6)}_{LL;1}=-\frac{3}{4}\,x_H^2\,x_L\,a_{L\phi}\,a_0^{fin}(M_H)-\frac{3}{2}\sum_{\text{gen}}x_u^2\,x_u\,a^{(1)}_{L1Qu}\,a_0^{fin}(M_u)$$
$$+\frac{3}{2}\sum_{\text{gen}}x_d^2\,x_d\,a_{L1dQ}\,a_0^{fin}(M_d)-\frac{1}{8}\,(2\,a_{L\phi}+3\,a_{LW}+4\,a^{(3)}_{\phi L})\,x_L\,a_0^{fin}(M)$$
$$-\frac{1}{16}\,(3\,v_l\,a_{LBW}+4\,c\,a_{\phi LA}+4\,c\,a_{L\phi})\,\frac{1}{c^3}\,x_L\,a_0^{fin}(M_0)$$
$$-\frac{1}{16}\,(3\,v_l\,a_{LBW}+4\,c\,a_{\phi LA}+12\,s\,c\,a_{LWB})\,\frac{1}{c}\,x_L^3\,a_0^{fin}(M_L)$$

$$\Sigma^{(6)}_{LL;2}=\frac{1}{16}\Big\{2\,c^3\,a^{(-)}_{\phi WD}\,x_L^2-32\,F^{b}_{3}\,s^2\,c\,a_{AA}\,v_l-8\,F^{b}_{4}\,s\,c^2\,v_l\,a_{AZ}$$
$$+\Big[3\,a_{LBW}-8\,(a_{\phi D}-4\,c^2\,a_{ZZ})\,s^2\,c\Big]\,v_l-(3\,v_l\,a_{LBW}+4\,c\,a_{\phi LA})\,L_0\,c^2$$
$$-2\,(4\,G_{11}\,a_{\phi W}-G_{36}\,a_{\phi D}+G_{37}\,a_{\phi LVA}+2\,G_{38}\,a_{\phi L})\,c\Big\}\,\frac{1}{c^3}\,x_L\,B_0^{fin}(M_0,M_L)$$
$$+\frac{1}{8}\,(3\,a_{LW}+4\,a^{(3)}_{\phi L})\,J_{61}\,x_L\,B_0^{fin}(0,M)$$
$$+\frac{1}{4}\,(8\,a_{\phi WAD}-3\,L_0\,s\,a_{LWB})\,x_L\,B_0^{fin}(0,M_L)$$
$$-\frac{1}{8}\,(a^{(-)}_{\phi WD}-4\,a_{1\phi\Box})\,x_L^3\,B_0^{fin}(M_H,M_L)$$

$$V^{(4)}_{LL;0}=-\frac{1}{4}+\frac{1}{8}\,I_3\,L_R-\frac{1}{16}\,(16\,s^2\,c^2+G_6)\,\frac{1}{c^2}\,(1-L_R)$$

$$V^{(4)}_{LL;1}=-\frac{1}{8}\,\frac{x_L^2}{x_S}\,x_H^2\,a_0^{fin}(M_H)-\frac{1}{8}\,\frac{1}{x_S}\,I_0\,a_0^{fin}(M)$$
$$-\frac{1}{16}\,(2\,c^2\,x_L^2+G_6)\,\frac{1}{c^4\,x_S}\,a_0^{fin}(M_0)+\frac{1}{16}\,(4\,c^2\,x_L^2+16\,s^2\,c^2+G_6)\,\frac{x_L^2}{c^2\,x_S}\,a_0^{fin}(M_L)$$

$$V^{(4)}_{LL;2}=\frac{s^2}{x_S}\,L_2\,B_0^{fin}(0,M_L)-\frac{1}{8}\,\frac{1}{x_S}\,I_0\,J_{61}\,B_0^{fin}(0,M)$$
$$-\frac{1}{16}\Big[(G_6-2\,L_2\,c^4\,x_L^2)-(G_6\,x_S-G_{33}\,x_L^2)\,c^2\Big]\,\frac{1}{c^4\,x_S}\,B_0^{fin}(M_0,M_L)$$
$$+\frac{1}{8}\,(x_L^2+J_{34})\,\frac{x_L^2}{x_S}\,B_0^{fin}(M_H,M_L)$$

$$V^{(6)}_{LL;0}=-\frac{1}{32}\Big\{32\,G_{28}\,s\,c^3\,a_{\phi WB}-16\,F^{b}_{31}\,s^2\,a_{\phi W}\,v_l$$
$$+\Big[8\,G_{11}\,a_{\phi L}-G_{40}\,a_{\phi D}+4\,(a_{\phi LVA}+a_{\phi W})\,G_{17}-4\,(4\,c^4+s^2\,v_l)\,a_{\phi D}\Big]\Big\}\,\frac{1}{c^2}\,(1-L_R)$$
$$+\frac{1}{8}\Big\{\Big[2\,I_3\,a_{\phi W}+2\,I_4\,a^{(3)}_{\phi L}+(-2\,a_{\phi L}+2\,a^{(1)}_{\phi L}-a_{\phi D}-2\,a_{1\phi\Box})\,x_L^2\Big]+8\,(a_{\phi B}\,v_l+2\,a_{\phi W})\,s^2\Big\}\,L_R$$

$$
\begin{aligned}
&+\frac{1}{16}\left(\mathrm{v}_1\,a_{\mathrm{LBW}}+4\,s\,c\,a_{\mathrm{LWB}}\right)\frac{1}{c}\,x_{\mathrm{L}}^2\left(2-3\,\mathrm{L_R}\right)\\
&-\frac{1}{4}\left(c\,a^{(3)}_{\phi\mathrm{LW}}+4\,\mathrm{G}_{29}\,s^2\,c\,a_{\phi\mathrm{W}}+2\,\mathrm{F}^b_5\,s\,a_{\phi\mathrm{WB}}\,\mathrm{v}_1\right)\frac{1}{c}
\end{aligned}
$$

$$
\begin{aligned}
V^{(6)}_{\mathrm{LL}\,;\,1}=\;&\frac{1}{32}\Big\{4\,s^2\,a^{(+)}_{\phi\mathrm{WD}}\,\mathrm{v}_1-16\,\mathrm{F}^b_5\,s\,c\,a_{\phi\mathrm{WB}}\,\mathrm{v}_1\\
&-2\Big[3\,\mathrm{v}_1\,a_{\mathrm{LBW}}+4\,c\,a_{\phi\mathrm{LA}}+c\,a^{(-)}_{\phi\mathrm{WD}}+8\left(a_{\phi\mathrm{WZ}}-c\,a_{\phi\mathrm{B}}\right)s^2\,c^2\,\mathrm{v}_1\Big]\,c\,x_{\mathrm{L}}^2\\
&-\Big[8\,\mathrm{G}_{11}\,a_{\phi\mathrm{L}}-\mathrm{G}_{40}\,a_{\phi\mathrm{D}}+4\left(a_{\phi\mathrm{LVA}}+a_{\phi\mathrm{W}}\right)\mathrm{G}_{17}\Big]+8\left(x_{\mathrm{S}}\,a_{\mathrm{AZ}}+\mathrm{I}_4\,a_{\phi\mathrm{WB}}\right)s\,c^3\,\mathrm{v}_1\Big\}\,\frac{1}{c^4\,x_{\mathrm{S}}}\,a_0^{\mathrm{fin}}\left(M_0\right)\\
&+\frac{1}{32}\Big\{\Big[8\,\mathrm{G}_{11}\,a_{\phi\mathrm{L}}-\mathrm{G}_{40}\,a_{\phi\mathrm{D}}+4\left(a_{\phi\mathrm{LVA}}+a_{\phi\mathrm{W}}\right)\mathrm{G}_{17}-4\left(4\,c^4+s^2\,\mathrm{v}_1\right)a_{\phi\mathrm{D}}\Big]\\
&+2\left(3\,\mathrm{v}_1\,a_{\mathrm{LBW}}+4\,c\,a_{\phi\mathrm{LA}}+2\,c\,a^{(-)}_{\phi\mathrm{WD}}-4\,c\,a_{1\phi\square}+12\,s\,c\,a_{\mathrm{LWB}}\right)c\,x_{\mathrm{L}}^2+16\left(2\,\mathrm{G}_{28}\,c^2+\mathrm{F}^b_5\,\mathrm{v}_1\right)s\,c\,a_{\phi\mathrm{WB}}\\
&+16\left(2\,\mathrm{G}_{29}\,c^2-\mathrm{F}^b_{31}\,\mathrm{v}_1\right)s^2\,a_{\phi\mathrm{W}}\Big\}\,\frac{x_{\mathrm{L}}^2}{c^2\,x_{\mathrm{S}}}\,a_0^{\mathrm{fin}}\left(M_{\mathrm{L}}\right)\\
&-\frac{1}{4}\left(4\,a^{(3)}_{\phi\mathrm{L}}+\mathrm{I}_0\,a_{\phi\mathrm{W}}\right)\frac{1}{x_{\mathrm{S}}}\,a_0^{\mathrm{fin}}\left(M\right)\\
&-\frac{1}{16}\left(a^{(-)}_{\phi\mathrm{WD}}-4\,a_{1\phi\square}\right)\frac{x_{\mathrm{L}}^2}{x_{\mathrm{S}}}\,x_{\mathrm{H}}^2\,a_0^{\mathrm{fin}}\left(M_{\mathrm{H}}\right)
\end{aligned}
$$

$$
\begin{aligned}
V^{(6)}_{\mathrm{LL}\,;\,2}=\;&\frac{1}{16}\Big[\left(a^{(-)}_{\phi\mathrm{WD}}-4\,a_{1\phi\square}\right)x_{\mathrm{L}}^2+\left(a^{(-)}_{\phi\mathrm{WD}}-4\,a_{1\phi\square}\right)\mathrm{J}_{34}\Big]\,\frac{x_{\mathrm{L}}^2}{x_{\mathrm{S}}}\,\mathrm{B}_0^{\mathrm{fin}}\left(M_{\mathrm{H}}\,,M_{\mathrm{L}}\right)\\
&+\frac{1}{32}\Big\{2\,\mathrm{L}_2\,c^4\,a^{(-)}_{\phi\mathrm{WD}}\,x_{\mathrm{L}}^2-\Big[8\,\mathrm{G}_{11}\,a_{\phi\mathrm{L}}-\mathrm{G}_{40}\,a_{\phi\mathrm{D}}+4\left(a_{\phi\mathrm{LVA}}+a_{\phi\mathrm{W}}\right)\mathrm{G}_{17}\Big]\\
&+\Big[8\,\mathrm{G}_{11}\,x_{\mathrm{S}}\,a_{\phi\mathrm{L}}-4\,\mathrm{G}_{11}\,a_{\phi\mathrm{W}}\,x_{\mathrm{L}}^2+\mathrm{G}_{36}\,a_{\phi\mathrm{D}}\,x_{\mathrm{L}}^2-\mathrm{G}_{40}\,a_{\phi\mathrm{D}}\,x_{\mathrm{S}}+4\left(a_{\phi\mathrm{LVA}}+a_{\phi\mathrm{W}}\right)\mathrm{G}_{17}\,x_{\mathrm{S}}\Big]\,c^2\\
&-2\left(3\,a_{\mathrm{LBW}}-4\,c\,a_{\phi\mathrm{LV}}-8\,s^2\,c^3\,a_{\phi\mathrm{B}}\right)c\,\mathrm{v}_1\,x_{\mathrm{L}}^2+8\left(a_{\mathrm{AZ}}\,x_{\mathrm{S}}^2-2\,\mathrm{I}_0\,x_{\mathrm{S}}\,a_{\phi\mathrm{WB}}-\mathrm{I}_4\,a_{\phi\mathrm{WB}}\,x_{\mathrm{L}}^2\right)s\,c^5\,\mathrm{v}_1\\
&-16\left(a_{\phi\mathrm{WZ}}-c\,a_{\phi\mathrm{B}}\right)\mathrm{L}_3\,s^2\,c^5\,\mathrm{v}_1\,x_{\mathrm{L}}^2\\
&-2\left(3\,\mathrm{v}_1\,a_{\mathrm{LBW}}+4\,c\,a_{\phi\mathrm{LA}}\right)\mathrm{L}_0\,c^3\,x_{\mathrm{L}}^2+4\left(a_{\phi\mathrm{D}}+4\,\mathrm{F}^b_{31}\,a_{\phi\mathrm{W}}\right)s^2\,\mathrm{v}_1\\
&-8\left(-c\,a_{\phi\mathrm{WB}}-2\,s\,a_{\mathrm{AA}}+4\,s\,a_{\phi\mathrm{W}}\right)s\,c^2\,x_{\mathrm{S}}\,\mathrm{v}_1\\
&-4\left(4\,\mathrm{I}_3\,a_{\phi\mathrm{W}}+\mathrm{L}_2\,a_{\phi\mathrm{D}}-4\,\mathrm{F}^b_{32}\,a_{\phi\mathrm{W}}\,x_{\mathrm{L}}^2\right)s^2\,c^2\,\mathrm{v}_1\\
&+8\left(\mathrm{I}_5\,c^2-2\,\mathrm{L}_4\,s^2\,c^2-2\,\mathrm{F}^b_5\right)s\,c\,a_{\phi\mathrm{WB}}\,\mathrm{v}_1\Big\}\,\frac{1}{c^4\,x_{\mathrm{S}}}\,\mathrm{B}_0^{\mathrm{fin}}\left(M_0\,,M_{\mathrm{L}}\right)\\
&-\frac{1}{4}\left(\mathrm{I}_0\,\mathrm{J}_{61}\,a_{\phi\mathrm{W}}+4\,\mathrm{J}_{61}\,a^{(3)}_{\phi\mathrm{L}}\right)\frac{1}{x_{\mathrm{S}}}\,\mathrm{B}_0^{\mathrm{fin}}\left(0\,,M\right)\\
&-\frac{1}{4}\left(3\,\mathrm{L}_0\,s\,x_{\mathrm{L}}^2\,a_{\mathrm{LWB}}-2\,\mathrm{L}_2\,a_{\phi\mathrm{WAD}}+\mathrm{L}_5\,s\,c\,\mathrm{v}_1\,a_{\mathrm{AZ}}\right)\frac{1}{x_{\mathrm{S}}}\,\mathrm{B}_0^{\mathrm{fin}}\left(0\,,M_{\mathrm{L}}\right)
\end{aligned}
$$

$$
A^{(4)}_{\mathrm{LL}\,;\,0}=-\frac{1}{4}-\frac{1}{8}\,\frac{1}{c^2}\,\mathrm{v}_1\left(1-\mathrm{L_R}\right)+\frac{1}{8}\,\mathrm{I}_1\,\mathrm{L_R}
$$

$$
A^{(4)}_{\mathrm{LL}\,;\,1}=\frac{1}{8}\,\frac{x_{\mathrm{L}}^2}{c^2\,x_{\mathrm{S}}}\,\mathrm{v}_1\,a_0^{\mathrm{fin}}\left(M_{\mathrm{L}}\right)-\frac{1}{8}\,\frac{1}{c^4\,x_{\mathrm{S}}}\,\mathrm{v}_1\,a_0^{\mathrm{fin}}\left(M_0\right)-\frac{1}{8}\,\frac{1}{x_{\mathrm{S}}}\,\mathrm{I}_1\,a_0^{\mathrm{fin}}\left(M\right)
$$

$$
A^{(4)}_{\mathrm{LL}\,;\,2}=-\frac{1}{8}\,\frac{1}{x_{\mathrm{S}}}\,\mathrm{I}_1\,\mathrm{J}_{61}\,\mathrm{B}_0^{\mathrm{fin}}\left(0\,,M\right)-\frac{1}{8}\left(1-\mathrm{L}_2\,c^2\right)\frac{1}{c^4\,x_{\mathrm{S}}}\,\mathrm{v}_1\,\mathrm{B}_0^{\mathrm{fin}}\left(M_0\,,M_{\mathrm{L}}\right)
$$

$$
\begin{aligned}
A^{(6)}_{\mathrm{LL}\,;\,0}=\;&\frac{1}{16}\,\frac{1}{c}\,x_{\mathrm{L}}^2\,a_{\mathrm{LBW}}\left(2-3\,\mathrm{L_R}\right)\\
&+\frac{1}{32}\Big\{4\,s^2\,a_{\phi\mathrm{D}}+\Big[8\,\mathrm{G}_{11}\,a_{\phi\mathrm{L}}-\mathrm{G}_{41}\,a_{\phi\mathrm{D}}-4\left(a_{\phi\mathrm{LVA}}+a_{\phi\mathrm{W}}\right)\mathrm{G}_{17}\Big]\Big\}\,\frac{1}{c^2}\left(1-\mathrm{L_R}\right)
\end{aligned}
$$

$$-\frac{1}{4}\left\{2F^{b}_{31}\,s^2\,a_{\phi W}-\left[I_1\,a_{\phi W}+I_4\,a^{(3)}_{\phi L}+(-a_{\phi LV}+a^{(3)}_{\phi L})\,x^2_{L}\right]c^2-4\,(-c\,a_{\phi WB}+s\,a_{\phi B})\,s\,c^2\right\}\frac{L_R}{c^2}$$
$$+\frac{1}{2}\,(-2\,c^2\,a^{(3)}_{\phi L}-c^2\,a_{ZZ}+s^2\,a_{AA})\,\frac{1}{c^2}$$

$$A^{(6)}_{LL\,;1}=\frac{1}{32}\left\{4\,s^2\,a^{(+)}_{\phi WD}-16F^{b}_{5}\,s\,c\,a_{\phi WB}-2\left[3\,a_{LBW}+4\,c\,a_{\phi LV}+8\,(a_{\phi WZ}-c\,a_{\phi B})\,s^2\,c^2\right]c\,x^2_{L}\right.$$
$$\left.+\left[8\,G_{11}\,a_{\phi L}-G_{41}\,a_{\phi D}-4\,(a_{\phi LVA}+a_{\phi W})\,G_{17}\right]+8\,(x_S\,a_{AZ}+I_4\,a_{\phi WB})\,s\,c^3\right\}\frac{1}{c^4\,x_S}\,a^{fin}_{0}(M_0)$$
$$-\frac{1}{32}\left\{16F^{b}_{3}\,s^2\,a_{AA}+4\left[4\,c^3\,a_{AZ}+(a_{\phi D}-4\,c^2\,a_{ZZ})\,s\right]s\right.$$
$$\left.+\left[8\,G_{11}\,a_{\phi L}-G_{41}\,a_{\phi D}-4\,(a_{\phi LVA}+a_{\phi W})\,G_{17}\right]-2\,(3\,a_{LBW}+4\,c\,a_{\phi LV})\,c\,x^2_{L}\right\}\frac{x^2_{L}}{c^2\,x_S}\,a^{fin}_{0}(M_L)$$
$$-\frac{1}{4}\,(4\,a^{(3)}_{\phi L}+I_1\,a_{\phi W})\,\frac{1}{x_S}\,a^{fin}_{0}(M)$$

$$A^{(6)}_{LL\,;2}=-\frac{1}{4}\,\frac{1}{x_S}\,L_5\,s\,c\,a_{AZ}\,B^{fin}_{0}(0\,,M_L)$$
$$-\frac{1}{32}\left\{-\left[8\,G_{11}\,a_{\phi L}-G_{41}\,a_{\phi D}-4\,(a_{\phi LVA}+a_{\phi W})\,G_{17}\right]+2\,(3\,a_{LBW}+4\,c\,a_{\phi LV})\,L_0\,c^3\,x^2_{L}\right.$$
$$+2\,(3\,a_{LBW}-4\,c\,v_l\,a_{\phi LA}-8\,s^2\,c^3\,a_{\phi B})\,c\,x^2_{L}-8\,(a_{AZ}\,x^2_{S}-2\,I_0\,x_S\,a_{\phi WB}-I_4\,a_{\phi WB}\,x^2_{L})\,s\,c^5$$
$$+16\,(a_{\phi WZ}-c\,a_{\phi B})\,L_3\,s^2\,c^5\,x^2_{L}$$
$$-4\,(a_{\phi D}+4F^{b}_{31}\,a_{\phi W})\,s^2+8\,(-c\,a_{\phi WB}-2\,s\,a_{AA}+4\,s\,a_{\phi W})\,s\,c^2\,x_S$$
$$+(8\,G_{11}\,x_S\,a_{\phi L}-4\,G_{17}\,x_S\,a_{\phi LVA}-4\,G_{17}\,L_2\,a_{\phi W}-G_{41}\,L_2\,a_{\phi D})\,c^2$$
$$+4\,(4\,I_3\,a_{\phi W}+L_2\,a_{\phi D}-4F^{b}_{32}\,a_{\phi W}\,x^2_{L})\,s^2\,c^2$$
$$\left.-8\,(I_5\,c^2-2\,L_4\,s^2\,c^2-2F^{b}_{5})\,s\,c\,a_{\phi WB}\right\}\frac{1}{c^4\,x_S}\,B^{fin}_{0}(M_0\,,M_L)$$
$$-\frac{1}{4}\,(I_1\,J_{61}\,a_{\phi W}+4\,J_{61}\,a^{(3)}_{\phi L})\,\frac{1}{x_S}\,B^{fin}_{0}(0\,,M)$$

We have introduced

$$C^{L}_{UV}=-\frac{1}{256}\,\frac{M^2_L}{M}\left[3\,(s\,a_{LB}+c\,a_{LW})\,v_l\right.$$
$$\left.+4\,c\,(a_{\phi L}-a^{(1)}_{\phi L}+3\,a^{(3)}_{\phi L}+3\,c\,s\,a_{LB})+6\,(1+2\,s^2)\,c\,a_{LW}\right]\frac{1}{c}$$

- U quark self-energy

$$\Sigma^{(4)}_{UU\,;0}=\frac{1}{2}\,L_R\,x^2_{D}\,x_U-\frac{1}{72}\,(64\,s^2\,c^2-9\,G_{42})\,\frac{1}{c^2}\,x_U\,(1-2\,L_R)$$

$$\Sigma^{(4)}_{UU\,;1}=0$$

$$\Sigma^{(4)}_{UU\,;2}=\frac{1}{2}\,x^2_{D}\,x_U\,B^{fin}_{0}(M\,,M_D)-\frac{1}{4}\,x_U\,x^2_{U}\,B^{fin}_{0}\left(M_H\,,M_U\right)$$
$$+\frac{16}{9}\,s^2\,x_U\,B^{fin}_{0}(0\,,M_U)+\frac{1}{4}\,(c^2\,x^2_{U}-G_{42})\,\frac{1}{c^2}\,x_U\,B^{fin}_{0}(M_0\,,M_U)$$

$$\Sigma^{(6)}_{UU\,;0}=\frac{1}{3}\,\frac{s}{c}\,v_u\,a_{\phi WB}\,x_U\,(2-5\,L_R)$$

$$
\begin{aligned}
&+\frac{1}{8}\left[2\,\mathrm{H}_9\,c^3\,a_{\mathrm{UW}}+(1+c^2\,x_{\mathrm{U}}^2)\,\mathrm{v_u}\,a_{\mathrm{UBW}}\right]\frac{1}{c^3}\,x_{\mathrm{U}}\,(2-3\,\mathrm{L_R})\\
&+\frac{1}{72}\Big\{9\,s\,c\,\mathrm{v_u}\,x_{\mathrm{S}}\,x_{\mathrm{U}}\,a_{\mathrm{UB}}-32\,\mathrm{G}_{48}\,s^2\,c^2\,a_{\phi\mathrm{W}}\,x_{\mathrm{U}}-24\,\mathrm{L}_7\,s\,c^2\,x_{\mathrm{U}}\,a_{\mathrm{UWB}}\\
&-9\left[\mathrm{G}_{25}\,x_{\mathrm{U}}\,a_{\mathrm{UW}}-128\,(M\,\Delta_{\mathrm{UV}}\,\mathrm{C}^{\mathrm{U}}_{\mathrm{UV}})\right]c^2\,x_{\mathrm{S}}+18\,(\mathrm{G}_{12}\,a_{\phi\mathrm{UVA}}-2\,\mathrm{G}_{13}\,a_{\phi\mathrm{U}})\,x_{\mathrm{U}}\Big\}\,\frac{1}{c^2}\\
&+\frac{1}{36}\Big\{8\,\mathrm{G}_{49}\,s^2\,c^2\,a_{\phi\mathrm{W}}-9\left[3\,x_{\mathrm{H}}^2\,a_{\mathrm{U}\phi}-4\,x_{\mathrm{D}}^2\,a_{\phi\mathrm{W}}-4\,\mathrm{H}_9\,a^{(3)}_{\phi\mathrm{Q}}+\mathrm{I}_6\,a_{\mathrm{U}\phi}-2\,(a_{\phi\mathrm{UA}}-a_{\phi\Box}-2\,s\,a_{\mathrm{UWB}})\,x_{\mathrm{U}}^2\right]c^2\\
&-3\left[3\,\mathrm{G}_{43}\,a_{\phi\mathrm{UVA}}-6\,\mathrm{G}_{44}\,a_{\phi\mathrm{U}}+\left(3\,a_{\mathrm{U}\phi}-8\,(c\,a_{\phi\mathrm{B}}+s\,a_{\phi\mathrm{WB}})\,s^2\,c\,\mathrm{v_u}\right)\right]\Big\}\,\frac{\mathrm{L_R}}{c^2}\,x_{\mathrm{U}}\\
&+\frac{1}{144}\Big\{96\,\mathrm{F}^b_{31}\,s^2\,\mathrm{v_u}\,a_{\phi\mathrm{W}}+\Big[36\,\mathrm{G}_{12}\,a_{\phi\mathrm{W}}-3\,\mathrm{G}_{47}\,a_{\phi\mathrm{D}}+8\,(8\,c^4\,a_{\phi\mathrm{D}}\\
&-(-32\,c^3\,a_{\phi\mathrm{WB}}+3\,s\,\mathrm{v_u}\,a_{\phi\mathrm{D}})\,s)\Big]\Big\}\,\frac{1}{c^2}\,x_{\mathrm{U}}\,(1-2\,\mathrm{L_R})\\
&+\frac{1}{2}\sum_{\mathrm{gen}}(-3\,x_{\mathrm{d}}^3\,a^{(1)}_{\mathrm{QuQd}}+x_{\mathrm{l}}^2\,x_{\mathrm{l}}\,a^{(1)}_{\mathrm{LlQu}})\,\mathrm{L_R}
\end{aligned}
$$

$$
\begin{aligned}
\Sigma^{(6)}_{\mathrm{UU};1}=\;&\frac{3}{4}\,x_{\mathrm{H}}^2\,x_{\mathrm{U}}\,a_{\mathrm{U}\phi}\,a_0^{\mathrm{fin}}\left(M_{\mathrm{H}}\right)-\frac{1}{2}\sum_{\mathrm{gen}}x_{\mathrm{l}}^3\,a^{(1)}_{\mathrm{LlQu}}\,a_0^{\mathrm{fin}}\left(M_{\mathrm{l}}\right)+\frac{3}{2}\sum_{\mathrm{gen}}x_{\mathrm{d}}^3\,a^{(1)}_{\mathrm{QuQd}}\,a_0^{\mathrm{fin}}\left(M_{\mathrm{d}}\right)\\
&+\frac{1}{8}\,(3\,a_{\mathrm{UW}}-4\,a^{(3)}_{\phi\mathrm{Q}})\,x_{\mathrm{D}}^2\,x_{\mathrm{U}}\,a_0^{\mathrm{fin}}\,(M_{\mathrm{D}})+\frac{1}{8}\,(3\,a_{\mathrm{UW}}-4\,a^{(3)}_{\phi\mathrm{Q}}+2\,a_{\mathrm{U}\phi})\,x_{\mathrm{U}}\,a_0^{\mathrm{fin}}\,(M)\\
&+\frac{1}{16}\,(3\,\mathrm{v_u}\,a_{\mathrm{UBW}}-4\,c\,a_{\phi\mathrm{UA}}+4\,c\,a_{\mathrm{U}\phi})\,\frac{1}{c^3}\,x_{\mathrm{U}}\,a_0^{\mathrm{fin}}\,(M_0)\\
&+\frac{1}{16}\,(3\,\mathrm{v_u}\,a_{\mathrm{UBW}}-4\,c\,a_{\phi\mathrm{UA}}+8\,s\,c\,a_{\mathrm{UWB}})\,\frac{1}{c}\,x_{\mathrm{U}}\,x_{\mathrm{U}}^2\,a_0^{\mathrm{fin}}\,(M_{\mathrm{U}})
\end{aligned}
$$

$$
\begin{aligned}
\Sigma^{(6)}_{\mathrm{UU};2}=\;&\frac{1}{8}\left[8\,x_{\mathrm{D}}^2\,a_{\phi\mathrm{W}}+(3\,a_{\mathrm{UW}}-4\,a^{(3)}_{\phi\mathrm{Q}})\,x_{\mathrm{S}}-(3\,a_{\mathrm{UW}}-4\,a^{(3)}_{\phi\mathrm{Q}})\,\mathrm{H}_9\right]x_{\mathrm{U}}\,\mathrm{B}_0^{\mathrm{fin}}\,(M\,,M_{\mathrm{D}})\\
&+\frac{1}{48}\Big\{6\,c^3\,a^{(-)}_{\phi\mathrm{WD}}\,x_{\mathrm{U}}^2-64\,\mathrm{F}^b_3\,s^2\,c\,\mathrm{v_u}\,a_{\mathrm{AA}}-16\,\mathrm{F}^b_4\,s\,c^2\,\mathrm{v_u}\,a_{\mathrm{AZ}}\\
&-\left[9\,a_{\mathrm{UBW}}+16\,(a_{\phi\mathrm{D}}-4\,c^2\,a_{\mathrm{ZZ}})\,s^2\,c\right]\mathrm{v_u}+3\,(3\,\mathrm{v_u}\,a_{\mathrm{UBW}}-4\,c\,a_{\phi\mathrm{UA}})\,\mathrm{L}_6\,c^2\\
&-2\,(12\,\mathrm{G}_{12}\,a_{\phi\mathrm{W}}+3\,\mathrm{G}_{45}\,a_{\phi\mathrm{UVA}}-6\,\mathrm{G}_{46}\,a_{\phi\mathrm{U}}-\mathrm{G}_{47}\,a_{\phi\mathrm{D}})\,c\Big\}\,\frac{1}{c^3}\,x_{\mathrm{U}}\,\mathrm{B}_0^{\mathrm{fin}}\,(M_0\,,M_{\mathrm{U}})\\
&+\frac{1}{18}\,(16\,a_{\phi\mathrm{WAD}}+9\,\mathrm{L}_6\,s\,a_{\mathrm{UWB}})\,x_{\mathrm{U}}\,\mathrm{B}_0^{\mathrm{fin}}\,(0\,,M_{\mathrm{U}})\\
&-\frac{1}{8}\,(a^{(-)}_{\phi\mathrm{WD}}+4\,a_{\mathrm{u}\phi\Box})\,x_{\mathrm{U}}\,x_{\mathrm{U}}^2\,\mathrm{B}_0^{\mathrm{fin}}\left(M_{\mathrm{H}}\,,M_{\mathrm{U}}\right)
\end{aligned}
$$

$$
V^{(4)}_{\mathrm{UU};0}=-\frac{1}{4}+\frac{1}{8}\,(3\,x_{\mathrm{U}}^2+\mathrm{H}_{12})\,\mathrm{L_R}-\frac{1}{144}\,(64\,s^2\,c^2+9\,\mathrm{G}_4)\,\frac{1}{c^2}\,(1-\mathrm{L_R})
$$

$$
\begin{aligned}
V^{(4)}_{\mathrm{UU};1}=\;&-\frac{1}{8}\,\frac{x_{\mathrm{U}}^2}{x_{\mathrm{S}}}\,x_{\mathrm{H}}^2\,a_0^{\mathrm{fin}}\left(M_{\mathrm{H}}\right)+\frac{1}{8}\,(x_{\mathrm{U}}^2+\mathrm{H}_{12})\,\frac{x_{\mathrm{D}}^2}{x_{\mathrm{S}}}\,a_0^{\mathrm{fin}}\,(M_{\mathrm{D}})\\
&-\frac{1}{8}\,(x_{\mathrm{U}}^2+\mathrm{H}_{12})\,\frac{1}{x_{\mathrm{S}}}\,a_0^{\mathrm{fin}}\,(M)-\frac{1}{16}\,(2\,c^2\,x_{\mathrm{U}}^2+\mathrm{G}_4)\,\frac{1}{c^4\,x_{\mathrm{S}}}\,a_0^{\mathrm{fin}}\,(M_0)\\
&+\frac{1}{144}\,(36\,c^2\,x_{\mathrm{U}}^2+64\,s^2\,c^2+9\,\mathrm{G}_4)\,\frac{x_{\mathrm{U}}^2}{c^2\,x_{\mathrm{S}}}\,a_0^{\mathrm{fin}}\,(M_{\mathrm{U}})
\end{aligned}
$$

$$
\begin{aligned}
V^{(4)}_{\mathrm{UU};2}=\;&\frac{4}{9}\,\frac{s^2}{x_{\mathrm{S}}}\,\mathrm{L}_8\,\mathrm{B}_0^{\mathrm{fin}}\,(0\,,M_{\mathrm{U}})\\
&-\frac{1}{16}\left[(\mathrm{G}_4-2\,\mathrm{L}_8\,c^4\,x_{\mathrm{U}}^2)-(\mathrm{G}_4\,x_{\mathrm{S}}-\mathrm{G}_{42}\,x_{\mathrm{U}}^2)\,c^2\right]\frac{1}{c^4\,x_{\mathrm{S}}}\,\mathrm{B}_0^{\mathrm{fin}}\,(M_0\,,M_{\mathrm{U}})\\
&+\frac{1}{8}\,(x_{\mathrm{U}}^2+\mathrm{J}_{34})\,\frac{x_{\mathrm{U}}^2}{x_{\mathrm{S}}}\,\mathrm{B}_0^{\mathrm{fin}}\left(M_{\mathrm{H}}\,,M_{\mathrm{U}}\right)
\end{aligned}
$$

$$+\frac{1}{8}\,(x_{\rm S}\,x_{\rm U}^2-\mathrm{H}_{10}\,x_{\rm U}^2-\mathrm{H}_{11}+\mathrm{H}_{12}\,x_{\rm S})\,\frac{1}{x_{\rm S}}\,\mathrm{B}_0^{\rm fin}\,(M\,,M_{\rm D})$$

$$
\begin{aligned}
V^{(6)}_{\rm UU\,;0} = {}& \frac{1}{48}\Big[6\,c\,x_{\rm D}^2\,a_{\rm D\,W}-(3\,\mathrm{v_u}\,a_{\rm U\,BW}+8\,s\,c\,a_{\rm U\,WB})\,x_{\rm U}^2\Big]\,\frac{1}{c}\,(2-3\,\mathrm{L_R})\\
&+\frac{1}{96}\Big\{8\,s^2\,\mathrm{v_u}\,a_{\phi\rm D}+\Big[24\,\mathrm{G}_{12}\,a_{\phi\rm U}+\mathrm{G}_{50}\,a_{\phi\rm D}-12\,(a_{\phi\rm U\,VA}+a_{\phi\rm W})\,\mathrm{G}_{13}\Big]\Big\}\,\frac{1}{c^2}\,(1-\mathrm{L_R})\\
&-\frac{1}{72}\Big\{-\Big[18\,\mathrm{H}_{12}\,a_{\phi\rm W}+36\,\mathrm{H}_{13}\,a^{(3)}_{\phi\rm Q}-9\,(2\,a_{\phi\rm U\,A}-6\,a_{\phi\rm W}+a_{\phi\rm D}-2\,a_{\rm u\,\phi\square})\,x_{\rm U}^2\\
&+8\,(2\,a_{\phi\rm WAD}+3\,s^2\,\mathrm{v_u}\,a_{\rm ZZ})\Big]\,c^2+24\,(c\,a_{\rm AZ}+s\,a_{\rm AA})\,\mathrm{F}_3^b\,s\,\mathrm{v_u}\Big\}\,\frac{\mathrm{L_R}}{c^2}\\
&-\frac{1}{36}\Big\{\Big[(9\,a^{(3)}_{\phi\rm Q\,W}-8\,c^2\,a_{\phi\rm D})\,c-4\,(3\,\mathrm{v_u}-8\,c^2)\,s\,a_{\phi\rm WB}\Big]\,c+4\,(2\,\mathrm{G}_{48}\,c^2-3\,\mathrm{F}^b_{31}\,\mathrm{v_u})\,s^2\,a_{\phi\rm W}\Big\}\,\frac{1}{c^2}
\end{aligned}
$$

$$
\begin{aligned}
V^{(6)}_{\rm UU\,;1} = {}& \frac{1}{96}\Big\{16\,\mathrm{K}_7\,s\,c^3\,\mathrm{v_u}\,a_{\rm AZ}+\Big[24\,\mathrm{G}_{12}\,a_{\phi\rm U}+\mathrm{G}_{50}\,a_{\phi\rm D}-12\,(a_{\phi\rm U\,VA}+a_{\phi\rm W})\,\mathrm{G}_{13}\Big]\\
&+8\Big[4\,\mathrm{F}_3^b\,a_{\rm AA}+(a_{\phi\rm D}-4\,c^2\,a_{\rm ZZ})\Big]\,s^2\,\mathrm{v_u}+2\,(9\,\mathrm{v_u}\,a_{\rm U\,BW}-12\,c\,a_{\phi\rm U\,A}\\
&-3\,c\,a^{(-)}_{\phi\rm WD}-8\,s\,c^2\,\mathrm{v_u}\,a_{\rm AZ})\,c\,x_{\rm U}^2\Big\}\,\frac{1}{c^4\,x_{\rm S}}\,a_0^{\rm fin}\,(M_0)\\
&-\frac{1}{288}\Big\{\Big[72\,\mathrm{G}_{12}\,a_{\phi\rm U}+3\,\mathrm{G}_{50}\,a_{\phi\rm D}-36\,(a_{\phi\rm U\,VA}+a_{\phi\rm W})\,\mathrm{G}_{13}+8\,(8\,c^4\,a_{\phi\rm D}\\
&+(4\,c\,a_{\phi\rm WB}\,vta+3\,s\,\mathrm{v_u}\,a_{\phi\rm D})\,s)\Big]+18\,(3\,\mathrm{v_u}\,a_{\rm U\,BW}-4\,c\,a_{\phi\rm U\,A}-2\,c\,a^{(-)}_{\phi\rm WD}-4\,c\,a_{\rm u\,\phi\square}+8\,s\,c\,a_{\rm U\,WB})\,c\,x_{\rm U}^2\\
&-32\,(2\,\mathrm{G}_{48}\,c^2-3\,\mathrm{F}^b_{31}\,\mathrm{v_u})\,s^2\,a_{\phi\rm W}\Big\}\,\frac{x_{\rm U}^2}{c^2\,x_{\rm S}}\,a_0^{\rm fin}\,(M_{\rm U})\\
&-\frac{1}{16}\,(a^{(-)}_{\phi\rm WD}+4\,a_{\rm u\,\phi\square})\,\frac{x_{\rm U}^2}{x_{\rm S}}\,x_{\rm H}^2\,a_0^{\rm fin}\,(M_{\rm H})\\
&+\frac{1}{8}\,(2\,a_{\phi\rm W}\,x_{\rm U}^2+3\,x_{\rm D}^2\,a_{\rm D\,W}+\mathrm{H}_{12}\,a^{(3)}_{\phi\rm Q\,W})\,\frac{x_{\rm D}^2}{x_{\rm S}}\,a_0^{\rm fin}\,(M_{\rm D})\\
&-\frac{1}{8}\,(2\,a_{\phi\rm W}\,x_{\rm U}^2+3\,x_{\rm D}^2\,a_{\rm D\,W}+\mathrm{H}_{12}\,a^{(3)}_{\phi\rm Q\,W})\,\frac{1}{x_{\rm S}}\,a_0^{\rm fin}\,(M)
\end{aligned}
$$

$$
\begin{aligned}
V^{(6)}_{\rm UU\,;2} = {}& \frac{1}{16}\Big[(a^{(-)}_{\phi\rm WD}+4\,a_{\rm u\,\phi\square})\,x_{\rm U}^2+(a^{(-)}_{\phi\rm WD}+4\,a_{\rm u\,\phi\square})\,\mathrm{J}_{34}\Big]\,\frac{x_{\rm U}^2}{x_{\rm S}}\,\mathrm{B}_0^{\rm fin}\,(M_{\rm H}\,,M_{\rm U})\\
&+\frac{1}{96}\Big\{6\,\mathrm{L}_8\,c^4\,a^{(-)}_{\phi\rm WD}\,x_{\rm U}^2+32\,\mathrm{F}^b_{31}\,s^2\,\mathrm{v_u}\,a_{\phi\rm W}+16\,\mathrm{F}^b_{33}\,s\,c^2\,\mathrm{v_u}\,a_{\phi\rm WA}\,x_{\rm U}^2\\
&+8\Big[4\,c\,a_{\phi\rm WB}+(a_{\phi\rm D}-8\,c^2\,a_{\phi\rm B})\,s\Big]\,s\,\mathrm{v_u}+\Big[24\,\mathrm{G}_{12}\,a_{\phi\rm U}+\mathrm{G}_{50}\,a_{\phi\rm D}-12\,(a_{\phi\rm U\,VA}+a_{\phi\rm W})\,\mathrm{G}_{13}\Big]\\
&-\Big[24\,\mathrm{G}_{12}\,x_{\rm S}\,a_{\phi\rm U}+12\,\mathrm{G}_{12}\,a_{\phi\rm W}\,x_{\rm U}^2-\mathrm{G}_{47}\,a_{\phi\rm D}\,x_{\rm U}^2+\mathrm{G}_{50}\,a_{\phi\rm D}\,x_{\rm S}-12\,(a_{\phi\rm U\,VA}+a_{\phi\rm W})\,\mathrm{G}_{13}\,x_{\rm S}\Big]\,c^2\\
&+2\,(9\,a_{\rm U\,BW}+12\,c\,a_{\phi\rm U\,V}+40\,s^2\,c^2\,a_{\phi\rm WZ})\,c\,\mathrm{v_u}\,x_{\rm U}^2-16\,(a_{\rm AZ}-2\,s\,c\,a_{\rm ZZ})\,s\,c^3\,\mathrm{v_u}\,x_{\rm S}\\
&+6\,(3\,\mathrm{v_u}\,a_{\rm U\,BW}-4\,c\,a_{\phi\rm U\,A})\,\mathrm{L}_6\,c^3\,x_{\rm U}^2+8\,(8\,\mathrm{I}_7\,a_{\phi\rm B}-4\,\mathrm{I}_8\,a_{\phi\rm W}-\mathrm{L}_8\,a_{\phi\rm D}-4\,\mathrm{F}_3^b\,x_{\rm S}\,a_{\rm AA}-4\,\mathrm{F}^b_{32}\,a_{\phi\rm B}\,x_{\rm U}^2)\,s^2\,c^2\,\mathrm{v_u}\\
&-16\,(\mathrm{K}_6\,x_{\rm S}+\mathrm{L}_9\,x_{\rm U}^2)\,s\,c^5\,\mathrm{v_u}\,a_{\rm AZ}\Big\}\,\frac{1}{c^4\,x_{\rm S}}\,\mathrm{B}_0^{\rm fin}\,(M_0\,,M_{\rm U})\\
&+\frac{1}{8}\,(2\,a_{\phi\rm W}\,x_{\rm S}\,x_{\rm U}^2-3\,x_{\rm D}^2\,x_{\rm S}\,a_{\rm D\,W}-2\,\mathrm{H}_{10}\,a_{\phi\rm W}\,x_{\rm U}^2-3\,\mathrm{H}_{10}\,x_{\rm D}^2\,a_{\rm D\,W}-\mathrm{H}_{11}\,a^{(3)}_{\phi\rm Q\,W}+2\,\mathrm{H}_{12}\,a_{\phi\rm W}\,x_{\rm S}\\
&+4\,\mathrm{H}_{13}\,x_{\rm S}\,a^{(3)}_{\phi\rm Q})\,\frac{1}{x_{\rm S}}\,\mathrm{B}_0^{\rm fin}\,(M\,,M_{\rm D})\\
&+\frac{1}{18}\,(9\,\mathrm{L}_6\,s\,x_{\rm U}^2\,a_{\rm U\,WB}+4\,\mathrm{L}_8\,a_{\phi\rm WAD}-3\,\mathrm{L}_{10}\,s\,c\,\mathrm{v_u}\,a_{\rm AZ})\,\frac{1}{x_{\rm S}}\,\mathrm{B}_0^{\rm fin}\,(0\,,M_{\rm U})
\end{aligned}
$$

$$A^{(4)}_{\rm UU\,;0} = -\frac{1}{4}-\frac{1}{8}\,\frac{1}{c^2}\,\mathrm{v_u}\,(1-\mathrm{L_R})-\frac{1}{8}\,(x_{\rm U}^2-\mathrm{H}_{12})\,\mathrm{L_R}$$

$$
\begin{aligned}
A^{(4)}_{\mathrm{UU}\,;1} &= \frac{1}{8}\,\frac{x^2_{\mathrm{U}}}{c^2\,x_{\mathrm{S}}}\,\mathrm{v_u}\,a^{\mathrm{fin}}_0\,(M_{\mathrm{U}}) - \frac{1}{8}\,\frac{1}{c^4\,x_{\mathrm{S}}}\,\mathrm{v_u}\,a^{\mathrm{fin}}_0\,(M_0)\\
&\quad -\frac{1}{8}\,(x^2_{\mathrm{U}} - \mathrm{H}_{12})\,\frac{x^2_{\mathrm{D}}}{x_{\mathrm{S}}}\,a^{\mathrm{fin}}_0\,(M_{\mathrm{D}}) + \frac{1}{8}\,(x^2_{\mathrm{U}} - \mathrm{H}_{12})\,\frac{1}{x_{\mathrm{S}}}\,a^{\mathrm{fin}}_0\,(M)
\end{aligned}
$$

$$
\begin{aligned}
A^{(4)}_{\mathrm{UU}\,;2} &= -\frac{1}{8}\,(1 - \mathrm{L}_8\,c^2)\,\frac{1}{c^4\,x_{\mathrm{S}}}\,\mathrm{v_u}\,\mathrm{B}^{\mathrm{fin}}_0\,(M_0\,,M_{\mathrm{U}})\\
&\quad -\frac{1}{8}\,(x_{\mathrm{S}}\,x^2_{\mathrm{U}} - \mathrm{H}_{10}\,x^2_{\mathrm{U}} + \mathrm{H}_{11} - \mathrm{H}_{12}\,x_{\mathrm{S}})\,\frac{1}{x_{\mathrm{S}}}\,\mathrm{B}^{\mathrm{fin}}_0\,(M\,,M_{\mathrm{D}})
\end{aligned}
$$

$$
\begin{aligned}
A^{(6)}_{\mathrm{UU}\,;0} &= \frac{1}{6}\,\frac{s^2}{c^2}\,a_{\mathrm{AA}}\,(1 - 2\,\mathrm{L_R}) - \frac{1}{6}\,s\,c\,a_{\mathrm{AZ}}\,(1 + 2\,\mathrm{L_R})\\
&\quad -\frac{1}{6}\Big[\mathrm{F}^b_{34}\,c^2\,a_{\mathrm{ZZ}} - (-6\,c^2\,a^{(3)}_{\phi\mathrm{Q}} + s^4\,a_{\mathrm{AA}})\Big]\,\frac{1}{c^2}\\
&\quad +\frac{1}{96}\Big\{8\,s^2\,a_{\phi\mathrm{D}} - \Big[24\,\mathrm{G}_{12}\,a_{\phi\mathrm{U}} + \mathrm{G}_{51}\,a_{\phi\mathrm{D}} + 12\,(a_{\phi\mathrm{UVA}} + a_{\phi\mathrm{W}})\,\mathrm{G}_{13}\Big]\Big\}\,\frac{1}{c^2}\,(1 - \mathrm{L_R})\\
&\quad -\frac{1}{12}\Big\{-3\,\Big[\mathrm{H}_{12}\,a_{\phi\mathrm{W}} + 2\,\mathrm{H}_{13}\,a^{(3)}_{\phi\mathrm{Q}} - (a_{\phi\mathrm{UV}} + a_{\phi\mathrm{W}})\,x^2_{\mathrm{U}}\Big]\,c + 4\,(a_{\mathrm{AZ}} + s\,c\,a_{\mathrm{AA}} - s\,c\,a_{\mathrm{ZZ}})\,s\Big\}\,\frac{\mathrm{L_R}}{c}\\
&\quad -\frac{1}{16}\,(x^2_{\mathrm{U}}\,a_{\mathrm{UBW}} - 2\,c\,x^2_{\mathrm{D}}\,a_{\mathrm{DW}})\,(2 - 3\,\mathrm{L_R})\,\frac{1}{c}
\end{aligned}
$$

$$
\begin{aligned}
A^{(6)}_{\mathrm{UU}\,;1} &= \frac{1}{96}\Big\{16\,\mathrm{K}_7\,s\,c^3\,a_{\mathrm{AZ}} - \Big[24\,\mathrm{G}_{12}\,a_{\phi\mathrm{U}} + \mathrm{G}_{51}\,a_{\phi\mathrm{D}} + 12\,(a_{\phi\mathrm{UVA}} + a_{\phi\mathrm{W}})\,\mathrm{G}_{13}\Big]\\
&\quad +8\,\Big[4\,\mathrm{F}^b_3\,a_{\mathrm{AA}} + (a_{\phi\mathrm{D}} - 4\,c^2\,a_{\mathrm{ZZ}})\Big]\,s^2 + 2\,(9\,a_{\mathrm{UBW}} - 12\,c\,a_{\phi\mathrm{UV}} - 8\,s\,c^2\,a_{\mathrm{AZ}})\,c\,x^2_{\mathrm{U}}\Big\}\,\frac{1}{c^4\,x_{\mathrm{S}}}\,a^{\mathrm{fin}}_0\,(M_0)\\
&\quad -\frac{1}{96}\Big\{32\,\mathrm{F}^b_3\,s^2\,a_{\mathrm{AA}} + 8\,\Big[4\,c^3\,a_{\mathrm{AZ}} + (a_{\phi\mathrm{D}} - 4\,c^2\,a_{\mathrm{ZZ}})\,s\Big]\,s\\
&\quad -\Big[24\,\mathrm{G}_{12}\,a_{\phi\mathrm{U}} + \mathrm{G}_{51}\,a_{\phi\mathrm{D}} + 12\,(a_{\phi\mathrm{UVA}} + a_{\phi\mathrm{W}})\,\mathrm{G}_{13}\Big] + 6\,(3\,a_{\mathrm{UBW}} - 4\,c\,a_{\phi\mathrm{UV}})\,c\,x^2_{\mathrm{U}}\Big\}\,\frac{x^2_{\mathrm{U}}}{c^2\,x_{\mathrm{S}}}\,a^{\mathrm{fin}}_0\,(M_{\mathrm{U}})\\
&\quad -\frac{1}{8}\,(2\,a_{\phi\mathrm{W}}\,x^2_{\mathrm{U}} - 3\,x^2_{\mathrm{D}}\,a_{\mathrm{DW}} - \mathrm{H}_{12}\,a^{(3)}_{\phi\mathrm{QW}})\,\frac{x^2_{\mathrm{D}}}{x_{\mathrm{S}}}\,a^{\mathrm{fin}}_0\,(M_{\mathrm{D}})\\
&\quad +\frac{1}{8}\,(2\,a_{\phi\mathrm{W}}\,x^2_{\mathrm{U}} - 3\,x^2_{\mathrm{D}}\,a_{\mathrm{DW}} - \mathrm{H}_{12}\,a^{(3)}_{\phi\mathrm{QW}})\,\frac{1}{x_{\mathrm{S}}}\,a^{\mathrm{fin}}_0\,(M)
\end{aligned}
$$

$$
\begin{aligned}
A^{(6)}_{\mathrm{UU}\,;2} &= -\frac{1}{6}\,\frac{1}{x_{\mathrm{S}}}\,\mathrm{L}_{10}\,s\,c\,a_{\mathrm{AZ}}\,\mathrm{B}^{\mathrm{fin}}_0\,(0\,,M_{\mathrm{U}})\\
&\quad +\frac{1}{96}\Big\{32\,\mathrm{F}^b_{31}\,s^2\,a_{\phi\mathrm{W}} + 16\,\mathrm{F}^b_{33}\,s\,c^2\,a_{\phi\mathrm{WA}}\,x^2_{\mathrm{U}} + 8\,\Big[4\,c\,a_{\phi\mathrm{WB}} + (a_{\phi\mathrm{D}} - 8\,c^2\,a_{\phi\mathrm{B}})\,s\Big]\,s\\
&\quad -\Big[24\,\mathrm{G}_{12}\,a_{\phi\mathrm{U}} + \mathrm{G}_{51}\,a_{\phi\mathrm{D}} + 12\,(a_{\phi\mathrm{UVA}} + a_{\phi\mathrm{W}})\,\mathrm{G}_{13}\Big] + 6\,(3\,a_{\mathrm{UBW}} - 4\,c\,a_{\phi\mathrm{UV}})\,\mathrm{L}_6\,c^3\,x^2_{\mathrm{U}}\\
&\quad +2\,(9\,a_{\mathrm{UBW}} + 12\,c\,\mathrm{v_u}\,a_{\phi\mathrm{UA}} + 40\,s^2\,c^2\,a_{\phi\mathrm{WZ}})\,c\,x^2_{\mathrm{U}} - 16\,(a_{\mathrm{AZ}} - 2\,s\,c\,a_{\mathrm{ZZ}})\,s\,c^3\,x_{\mathrm{S}}\\
&\quad +(24\,\mathrm{G}_{12}\,x_{\mathrm{S}}\,a_{\phi\mathrm{U}} + 12\,\mathrm{G}_{13}\,x_{\mathrm{S}}\,a_{\phi\mathrm{UVA}} + 12\,\mathrm{G}_{13}\,\mathrm{L}_8\,a_{\phi\mathrm{W}} + \mathrm{G}_{51}\,\mathrm{L}_8\,a_{\phi\mathrm{D}})\,c^2\\
&\quad +8\,(8\,\mathrm{I}_7\,a_{\phi\mathrm{B}} - 4\,\mathrm{I}_8\,a_{\phi\mathrm{W}} - \mathrm{L}_8\,a_{\phi\mathrm{D}} - 4\,\mathrm{F}^b_3\,x_{\mathrm{S}}\,a_{\mathrm{AA}} - 4\,\mathrm{F}^b_{32}\,a_{\phi\mathrm{B}}\,x^2_{\mathrm{U}})\,s^2\,c^2\\
&\quad -16\,(\mathrm{K}_6\,x_{\mathrm{S}} + \mathrm{L}_9\,x^2_{\mathrm{U}})\,s\,c^5\,a_{\mathrm{AZ}}\Big\}\,\frac{1}{c^4\,x_{\mathrm{S}}}\,\mathrm{B}^{\mathrm{fin}}_0\,(M_0\,,M_{\mathrm{U}})\\
&\quad -\frac{1}{8}\,(2\,a_{\phi\mathrm{W}}\,x_{\mathrm{S}}\,x^2_{\mathrm{U}} + 3\,x^2_{\mathrm{D}}\,x_{\mathrm{S}}\,a_{\mathrm{DW}} - 2\,\mathrm{H}_{10}\,a_{\phi\mathrm{W}}\,x^2_{\mathrm{U}} + 3\,\mathrm{H}_{10}\,x^2_{\mathrm{D}}\,a_{\mathrm{DW}} + \mathrm{H}_{11}\,a^{(3)}_{\phi\mathrm{QW}} - 2\,\mathrm{H}_{12}\,a_{\phi\mathrm{W}}\,x_{\mathrm{S}}\\
&\quad -4\,\mathrm{H}_{13}\,x_{\mathrm{S}}\,a^{(3)}_{\phi\mathrm{Q}})\,\frac{1}{x_{\mathrm{S}}}\,\mathrm{B}^{\mathrm{fin}}_0\,(M\,,M_{\mathrm{D}})
\end{aligned}
$$

We have introduced

$$
\mathrm{C}^{\mathrm{U}}_{\mathrm{UV}} = -\frac{1}{256}\,\frac{M^2_{\mathrm{U}}}{M}\,\Big[3\,(s\,a_{\mathrm{UB}} - c\,a_{\mathrm{UW}})\,\mathrm{v_u}
$$

JHEP07(2015)175

$$+4\,c\,(a^{(1)}_{\phi Q} - a_{\phi U} + 3\,a^{(3)}_{\phi Q} + 2\,c\,s\,a_{UB}) - 2\,(3+4\,s^2)\,c\,a_{UW}\Big]\,\frac{1}{c}$$

- D quark self-energy

$$\Sigma^{(4)}_{DD\,;0} = \frac{1}{2}\,L_R\,x^2_U\,x_D - \frac{1}{72}\,(16\,s^2\,c^2 - 9\,G_{52})\,\frac{1}{c^2}\,x_D\,(1-2\,L_R)$$

$$\Sigma^{(4)}_{DD\,;1} = 0$$

$$\Sigma^{(4)}_{DD\,;2} = \frac{1}{2}\,x^2_U\,x_D\,B^{fin}_0\,(M\,,M_U) - \frac{1}{4}\,x_D\,x^2_D\,B^{fin}_0\,(M_H\,,M_D) + \frac{4}{9}\,s^2\,x_D\,B^{fin}_0\,(0\,,M_D) + \frac{1}{4}\,(c^2\,x^2_D - G_{52})\,\frac{1}{c^2}\,x_D\,B^{fin}_0\,(M_0\,,M_D)$$

$$\begin{aligned}\Sigma^{(6)}_{DD\,;0} = {} & \frac{1}{6}\,\frac{s}{c}\,v_d\,a_{\phi WB}\,x_D\,(2-5\,L_R) \\ & -\frac{1}{8}\Big[2\,H_{14}\,c^3\,a_{DW} + (1+c^2\,x^2_D)\,v_d\,a_{DBW}\Big]\,\frac{1}{c^3}\,x_D\,(2-3\,L_R) \\ & +\frac{1}{72}\Big\{9\,s\,c\,v_d\,x_s\,x_D\,a_{DB} - 16\,G_{55}\,s^2\,c^2\,a_{\phi W}\,x_D + 12\,L_{12}\,s\,c^2\,x_D\,a_{DWB} \\ & +9\Big[G_{27}\,a_{DW}\,x_D + 128\,(M\,\Delta_{UV}\,C^{D}_{UV})\Big]\,c^2\,x_s + 18\,(G_{14}\,a_{\phi DVA} + 2\,G_{15}\,a_{\phi D})\,x_D\Big\}\,\frac{1}{c^2} \\ & +\frac{1}{36}\Big\{4\,G_{59}\,s^2\,c^2\,a_{\phi W} + 9\Big[3\,x^2_H\,a_{D\phi} + 4\,x^2_U\,a_{\phi W} + 4\,H_{14}\,a^{(3)}_{\phi Q} + I_9\,a_{D\phi} \\ & +2\,(a_{\phi DA} - a_{\phi\Box} + s\,a_{DWB})\,x^2_D\Big]\,c^2 - 3\Big[3\,G_{53}\,a_{\phi DVA} + 6\,G_{54}\,a_{\phi D} \\ & -(3\,a_{D\phi} + 4\,(c\,a_{\phi B} + s\,a_{\phi WB})\,s^2\,c\,v_d)\Big]\Big\}\,\frac{L_R}{c^2}\,x_D \\ & +\frac{1}{144}\Big\{48\,F^b_{31}\,s^2\,v_d\,a_{\phi W} + \Big[36\,G_{14}\,a_{\phi W} - 3\,G_{58}\,a_{\phi D} + 4\,(4\,c^4\,a_{\phi D} \\ & +(-16\,c^3\,a_{\phi WB} + 3\,s\,v_d\,a_{\phi D})\,s)\Big]\Big\}\,\frac{1}{c^2}\,x_D\,(1-2\,L_R) \\ & -\frac{1}{2}\sum_{gen}(3\,x^3_u\,a^{(1)}_{QuQd} + x^2_l\,x_l\,a_{L1dQ})\,L_R\end{aligned}$$

$$\begin{aligned}\Sigma^{(6)}_{DD\,;1} = {} & -\frac{3}{4}\,x^2_H\,x_D\,a_{D\phi}\,a^{fin}_0\,(M_H) + \frac{1}{2}\sum_{gen} x^3_l\,a_{L1dQ}\,a^{fin}_0\,(M_l) + \frac{3}{2}\sum_{gen} x^3_u\,a^{(1)}_{QuQd}\,a^{fin}_0\,(M_u) \\ & -\frac{1}{8}\,(2\,a_{D\phi} + 3\,a_{DW} + 4\,a^{(3)}_{\phi Q})\,x_D\,a^{fin}_0\,(M) - \frac{1}{8}\,(3\,a_{DW} + 4\,a^{(3)}_{\phi Q})\,x^2_U\,x_D\,a^{fin}_0\,(M_U) \\ & -\frac{1}{16}\,(3\,v_d\,a_{DBW} + 4\,c\,a_{\phi DA} + 4\,c\,a_{D\phi})\,\frac{1}{c^3}\,x_D\,a^{fin}_0\,(M_0) \\ & -\frac{1}{16}\,(3\,v_d\,a_{DBW} + 4\,c\,a_{\phi DA} + 4\,s\,c\,a_{DWB})\,\frac{1}{c}\,x_D\,x^2_D\,a^{fin}_0\,(M_D)\end{aligned}$$

$$\begin{aligned}\Sigma^{(6)}_{DD\,;2} = {} & \frac{1}{8}\Big[8\,x^2_U\,a_{\phi W} - (3\,a_{DW} + 4\,a^{(3)}_{\phi Q})\,x_s + (3\,a_{DW} + 4\,a^{(3)}_{\phi Q})\,H_{14}\Big]\,x_D\,B^{fin}_0\,(M\,,M_U) \\ & +\frac{1}{48}\Big\{6\,c^3\,a^{(-)}_{\phi WD}\,x^2_D - 32\,F^b_3\,s^2\,c\,v_d\,a_{AA} - 8\,F^b_4\,s\,c^2\,v_d\,a_{AZ} \\ & +\Big[9\,a_{DBW} - 8\,(a_{\phi D} - 4\,c^2\,a_{ZZ})\,s^2\,c\Big]\,v_d - 3\,(3\,v_d\,a_{DBW} + 4\,c\,a_{\phi DA})\,L_{11}\,c^2 \\ & -2\,(12\,G_{14}\,a_{\phi W} + 3\,G_{56}\,a_{\phi DVA} + 6\,G_{57}\,a_{\phi D} - G_{58}\,a_{\phi D})\,c\Big\}\,\frac{1}{c^3}\,x_D\,B^{fin}_0\,(M_0\,,M_D) \\ & +\frac{1}{36}\,(8\,a_{\phi WAD} - 9\,L_{11}\,s\,a_{DWB})\,x_D\,B^{fin}_0\,(0\,,M_D)\end{aligned}$$

$$
-\frac{1}{8}\,(a^{(-)}_{\phi\,\mathrm{WD}} - 4\,a_{\mathrm{d}\,\phi\,\Box})\,x_{\mathrm{D}}\,x^2_{\mathrm{D}}\,\mathrm{B}^{\mathrm{fin}}_0\big(M_{\mathrm{H}}\,,M_{\mathrm{D}}\big)
$$

$$
V^{(4)}_{\mathrm{DD}\,;0} = -\frac{1}{4} + \frac{1}{8}\,(3\,x^2_{\mathrm{D}} + \mathrm{H}_{17})\,\mathrm{L}_{\mathrm{R}} - \frac{1}{144}\,(16\,s^2\,c^2 + 9\,\mathrm{G}_5)\,\frac{1}{c^2}\,(1 - \mathrm{L}_{\mathrm{R}})
$$

$$
\begin{aligned}
V^{(4)}_{\mathrm{DD}\,;1} = {} & -\frac{1}{8}\,\frac{x^2_{\mathrm{D}}}{x_{\mathrm{S}}}\,x^2_{\mathrm{H}}\,a^{\mathrm{fin}}_0\big(M_{\mathrm{H}}\big) + \frac{1}{8}\,(x^2_{\mathrm{D}} + \mathrm{H}_{17})\,\frac{x^2_{\mathrm{U}}}{x_{\mathrm{S}}}\,a^{\mathrm{fin}}_0\,(M_{\mathrm{U}}) \\
& -\frac{1}{8}\,(x^2_{\mathrm{D}} + \mathrm{H}_{17})\,\frac{1}{x_{\mathrm{S}}}\,a^{\mathrm{fin}}_0\,(M) - \frac{1}{16}\,(2\,c^2\,x^2_{\mathrm{D}} + \mathrm{G}_5)\,\frac{1}{c^4\,x_{\mathrm{S}}}\,a^{\mathrm{fin}}_0\,(M_0) \\
& +\frac{1}{144}\,(36\,c^2\,x^2_{\mathrm{D}} + 16\,s^2\,c^2 + 9\,\mathrm{G}_5)\,\frac{x^2_{\mathrm{D}}}{c^2\,x_{\mathrm{S}}}\,a^{\mathrm{fin}}_0\,(M_{\mathrm{D}})
\end{aligned}
$$

$$
\begin{aligned}
V^{(4)}_{\mathrm{DD}\,;2} = {} & \frac{1}{9}\,\frac{s^2}{x_{\mathrm{S}}}\,\mathrm{L}_{13}\,\mathrm{B}^{\mathrm{fin}}_0\,(0\,,M_{\mathrm{D}}) \\
& -\frac{1}{16}\Big[(\mathrm{G}_5 - 2\,\mathrm{L}_{13}\,c^4\,x^2_{\mathrm{D}}) - (\mathrm{G}_5\,x_{\mathrm{S}} - \mathrm{G}_{52}\,x^2_{\mathrm{D}})\,c^2\Big]\,\frac{1}{c^4\,x_{\mathrm{S}}}\,\mathrm{B}^{\mathrm{fin}}_0\,(M_0\,,M_{\mathrm{D}}) \\
& +\frac{1}{8}\,(x^2_{\mathrm{D}} + \mathrm{J}_{34})\,\frac{x^2_{\mathrm{D}}}{x_{\mathrm{S}}}\,\mathrm{B}^{\mathrm{fin}}_0\big(M_{\mathrm{H}}\,,M_{\mathrm{D}}\big) \\
& +\frac{1}{8}\,(x_{\mathrm{S}}\,x^2_{\mathrm{D}} - \mathrm{H}_{15}\,x^2_{\mathrm{D}} - \mathrm{H}_{16} + \mathrm{H}_{17}\,x_{\mathrm{S}})\,\frac{1}{x_{\mathrm{S}}}\,\mathrm{B}^{\mathrm{fin}}_0\,(M\,,M_{\mathrm{U}})
\end{aligned}
$$

$$
\begin{aligned}
V^{(6)}_{\mathrm{DD}\,;0} = {} & -\frac{1}{48}\Big[6\,c\,x^2_{\mathrm{U}}\,a_{\mathrm{U\,W}} - (3\,\mathrm{v_d}\,a_{\mathrm{D\,BW}} + 4\,s\,c\,a_{\mathrm{D\,WB}})\,x^2_{\mathrm{D}}\Big]\,\frac{1}{c}\,(2 - 3\,\mathrm{L}_{\mathrm{R}}) \\
& +\frac{1}{96}\Big\{4\,s^2\,\mathrm{v_d}\,a_{\phi\,\mathrm{D}} - \Big[24\,\mathrm{G}_{14}\,a_{\phi\,\mathrm{D}} - \mathrm{G}_{60}\,a_{\phi\,\mathrm{D}} + 12\,(a_{\phi\,\mathrm{D\,VA}} + a_{\phi\,\mathrm{W}})\,\mathrm{G}_{15}\Big]\Big\}\,\frac{1}{c^2}\,(1 - \mathrm{L}_{\mathrm{R}}) \\
& -\frac{1}{72}\Big\{-\Big[18\,\mathrm{H}_{17}\,a_{\phi\,\mathrm{W}} + 36\,\mathrm{H}_{18}\,a^{(3)}_{\phi\,\mathrm{Q}} - 9\,(2\,a_{\phi\,\mathrm{D\,A}} - 6\,a_{\phi\,\mathrm{W}} + a_{\phi\,\mathrm{D}} + 2\,a_{\mathrm{d}\,\phi\,\Box})\,x^2_{\mathrm{D}} \\
& +4\,(a_{\phi\,\mathrm{WAD}} + 3\,s^2\,\mathrm{v_d}\,a_{\mathrm{ZZ}})\Big]\,c^2 + 12\,(c\,a_{\mathrm{AZ}} + s\,a_{\mathrm{AA}})\,\mathrm{F}^b_3\,s\,\mathrm{v_d}\Big\}\,\frac{\mathrm{L}_{\mathrm{R}}}{c^2} \\
& -\frac{1}{36}\Big\{\Big[(9\,a^{(3)}_{\phi\,\mathrm{Q\,W}} - 2\,c^2\,a_{\phi\,\mathrm{D}})\,c - 2\,(3\,\mathrm{v_d} - 4\,c^2)\,s\,a_{\phi\,\mathrm{WB}}\Big]\,c + 2\,(2\,\mathrm{G}_{55}\,c^2 - 3\,\mathrm{F}^b_{31}\,\mathrm{v_d})\,s^2\,a_{\phi\,\mathrm{W}}\Big\}\,\frac{1}{c^2}
\end{aligned}
$$

$$
\begin{aligned}
V^{(6)}_{\mathrm{DD}\,;1} = {} & \frac{1}{96}\Big\{8\,\mathrm{K}_7\,s\,c^3\,\mathrm{v_d}\,a_{\mathrm{AZ}} - \Big[24\,\mathrm{G}_{14}\,a_{\phi\,\mathrm{D}} - \mathrm{G}_{60}\,a_{\phi\,\mathrm{D}} + 12\,(a_{\phi\,\mathrm{D\,VA}} + a_{\phi\,\mathrm{W}})\,\mathrm{G}_{15}\Big] \\
& +4\Big[4\,\mathrm{F}^b_3\,a_{\mathrm{AA}} + (a_{\phi\,\mathrm{D}} - 4\,c^2\,a_{\mathrm{ZZ}})\Big]\,s^2\,\mathrm{v_d} - 2\,(9\,\mathrm{v_d}\,a_{\mathrm{D\,BW}} + 12\,c\,a_{\phi\,\mathrm{D\,A}} + 3\,c\,a^{(-)}_{\phi\,\mathrm{WD}} \\
& +4\,s\,c^2\,\mathrm{v_d}\,a_{\mathrm{AZ}})\,c\,x^2_{\mathrm{D}}\Big\}\,\frac{1}{c^4\,x_{\mathrm{S}}}\,a^{\mathrm{fin}}_0\,(M_0) \\
& +\frac{1}{288}\Big\{\Big[72\,\mathrm{G}_{14}\,a_{\phi\,\mathrm{D}} - 3\,\mathrm{G}_{60}\,a_{\phi\,\mathrm{D}} + 36\,(a_{\phi\,\mathrm{D\,VA}} + a_{\phi\,\mathrm{W}})\,\mathrm{G}_{15} - 4\,(4\,c^4\,a_{\phi\,\mathrm{D}} \\
& +(4\,c\,a_{\phi\,\mathrm{WB}}\,vba + 3\,s\,\mathrm{v_d}\,a_{\phi\,\mathrm{D}})\,s)\Big] + 18\,(3\,\mathrm{v_d}\,a_{\mathrm{D\,BW}} + 4\,c\,a_{\phi\,\mathrm{D\,A}} + 2\,c\,a^{(-)}_{\phi\,\mathrm{WD}} - 4\,c\,a_{\mathrm{d}\,\phi\,\Box} + 4\,s\,c\,a_{\mathrm{D\,WB}})\,c\,x^2_{\mathrm{D}} \\
& +16\,(2\,\mathrm{G}_{55}\,c^2 - 3\,\mathrm{F}^b_{31}\,\mathrm{v_d})\,s^2\,a_{\phi\,\mathrm{W}}\Big\}\,\frac{x^2_{\mathrm{D}}}{c^2\,x_{\mathrm{S}}}\,a^{\mathrm{fin}}_0\,(M_{\mathrm{D}}) \\
& -\frac{1}{16}\,(a^{(-)}_{\phi\,\mathrm{WD}} - 4\,a_{\mathrm{d}\,\phi\,\Box})\,\frac{x^2_{\mathrm{D}}}{x_{\mathrm{S}}}\,x^2_{\mathrm{H}}\,a^{\mathrm{fin}}_0\big(M_{\mathrm{H}}\big) \\
& +\frac{1}{8}\,(2\,a_{\phi\,\mathrm{W}}\,x^2_{\mathrm{D}} - 3\,x^2_{\mathrm{U}}\,a_{\mathrm{U\,W}} + \mathrm{H}_{17}\,a^{(3)}_{\phi\,\mathrm{Q\,W}})\,\frac{x^2_{\mathrm{U}}}{x_{\mathrm{S}}}\,a^{\mathrm{fin}}_0\,(M_{\mathrm{U}}) \\
& -\frac{1}{8}\,(2\,a_{\phi\,\mathrm{W}}\,x^2_{\mathrm{D}} - 3\,x^2_{\mathrm{U}}\,a_{\mathrm{U\,W}} + \mathrm{H}_{17}\,a^{(3)}_{\phi\,\mathrm{Q\,W}})\,\frac{1}{x_{\mathrm{S}}}\,a^{\mathrm{fin}}_0\,(M)
\end{aligned}
$$

$$
V^{(6)}_{\mathrm{DD}\,;2} = \frac{1}{16}\Big[(a^{(-)}_{\phi\,\mathrm{WD}} - 4\,a_{\mathrm{d}\,\phi\,\Box})\,x^2_{\mathrm{D}} + (a^{(-)}_{\phi\,\mathrm{WD}} - 4\,a_{\mathrm{d}\,\phi\,\Box})\,\mathrm{J}_{34}\Big]\,\frac{x^2_{\mathrm{D}}}{x_{\mathrm{S}}}\,\mathrm{B}^{\mathrm{fin}}_0\big(M_{\mathrm{H}}\,,M_{\mathrm{D}}\big)
$$

JHEP07(2015)175

$$
\begin{aligned}
&+\frac{1}{96}\Big\{6\,L_{13}\,c^4\,a^{(-)}_{\phi W D}\,x_D^2+16\,F^b_{31}\,s^2\,v_d\,a_{\phi W}+8\,F^b_{33}\,s\,c^2\,v_d\,a_{\phi W A}\,x_D^2\\
&+4\Big[4\,c\,a_{\phi W B}+(a_{\phi D}-8\,c^2\,a_{\phi B})\,s\Big]\,s\,v_d+\Big[-12\,G_{14}\,a_{\phi W}\,x_D^2+24\,G_{14}\,a_{\phi D}\,x_S+G_{58}\,a_{\phi D}\,x_D^2-G_{60}\,a_{\phi D}\,x_S\\
&+12\,(a_{\phi D V A}+a_{\phi W})\,G_{15}\,x_S\Big]\,c^2\\
&-\Big[24\,G_{14}\,a_{\phi D}-G_{60}\,a_{\phi D}+12\,(a_{\phi D V A}+a_{\phi W})\,G_{15}\Big]-2\,(9\,a_{D B W}-12\,c\,a_{\phi D V}-20\,s^2\,c^2\,a_{\phi W Z})\,c\,v_d\,x_D^2\\
&-8\,(a_{AZ}-2\,s\,c\,a_{ZZ})\,s\,c^3\,v_d\,x_S-6\,(3\,v_d\,a_{D B W}+4\,c\,a_{\phi D A})\,L_{11}\,c^3\,x_D^2\\
&+4\,(8\,I_{10}\,a_{\phi B}-4\,I_{11}\,a_{\phi W}-L_{13}\,a_{\phi D}-4\,F^b_3\,x_S\,a_{AA}\\
&-4\,F^b_{32}\,a_{\phi B}\,x_D^2)\,s^2\,c^2\,v_d-8\,(K_6\,x_S+L_{14}\,x_D^2)\,s\,c^5\,v_d\,a_{AZ}\Big\}\,\frac{1}{c^4\,x_S}\,B_0^{fin}(M_0\,,M_D)\\
&+\frac{1}{8}\,(2\,a_{\phi W}\,x_S\,x_D^2+3\,x_U^2\,x_S\,a_{U W}-2\,H_{15}\,a_{\phi W}\,x_D^2+3\,H_{15}\,x_U^2\,a_{U W}-H_{16}\,a^{(3)}_{\phi Q W}\\
&+2\,H_{17}\,a_{\phi W}\,x_S+4\,H_{18}\,x_S\,a^{(3)}_{\phi Q})\,\frac{1}{x_S}\,B_0^{fin}(M\,,M_U)\\
&-\frac{1}{36}\,(9\,L_{11}\,s\,x_D^2\,a_{D W B}-2\,L_{13}\,a_{\phi W A D}+3\,L_{15}\,s\,c\,v_d\,a_{AZ})\,\frac{1}{x_S}\,B_0^{fin}(0\,,M_D)
\end{aligned}
$$

$$
A^{(4)}_{DD\,;0}=-\frac{1}{4}-\frac{1}{8}\,\frac{1}{c^2}\,v_d\,(1-L_R)-\frac{1}{8}\,(x_D^2-H_{17})\,L_R
$$

$$
\begin{aligned}
A^{(4)}_{DD\,;1}=&\;\frac{1}{8}\,\frac{x_D^2}{c^2\,x_S}\,v_d\,a_0^{fin}(M_D)-\frac{1}{8}\,\frac{1}{c^4\,x_S}\,v_d\,a_0^{fin}(M_0)\\
&-\frac{1}{8}\,(x_D^2-H_{17})\,\frac{x_U^2}{x_S}\,a_0^{fin}(M_U)+\frac{1}{8}\,(x_D^2-H_{17})\,\frac{1}{x_S}\,a_0^{fin}(M)
\end{aligned}
$$

$$
\begin{aligned}
A^{(4)}_{DD\,;2}=&-\frac{1}{8}\,(1-L_{13}\,c^2)\,\frac{1}{c^4\,x_S}\,v_d\,B_0^{fin}(M_0\,,M_D)\\
&-\frac{1}{8}\,(x_S\,x_D^2-H_{15}\,x_D^2+H_{16}-H_{17}\,x_S)\,\frac{1}{x_S}\,B_0^{fin}(M\,,M_U)
\end{aligned}
$$

$$
\begin{aligned}
A^{(6)}_{DD\,;0}=&-\frac{1}{6}\,\frac{s^2}{c^2}\,a_{AA}\,(1+L_R)\\
&-\frac{1}{6}\,s\,c\,a_{AZ}\,(2+L_R)\\
&-\frac{1}{6}\,\Big[F^b_0\,c^2\,a_{ZZ}-2\,(-3\,c^2\,a^{(3)}_{\phi Q}+s^4\,a_{AA})\Big]\,\frac{1}{c^2}\\
&+\frac{1}{96}\,\Big\{4\,s^2\,a_{\phi D}+\Big[24\,G_{14}\,a_{\phi D}-G_{61}\,a_{\phi D}-12\,(a_{\phi D V A}+a_{\phi W})\,G_{15}\Big]\Big\}\,\frac{1}{c^2}\,(1-L_R)\\
&-\frac{1}{12}\,\Big\{-3\,\Big[H_{17}\,a_{\phi W}+2\,H_{18}\,a^{(3)}_{\phi Q}-(a_{\phi D V}+a_{\phi W})\,x_D^2\Big]\,c+2\,(a_{AZ}+s\,c\,a_{AA}-s\,c\,a_{ZZ})\,s\Big\}\,\frac{L_R}{c}\\
&+\frac{1}{16}\,(x_D^2\,a_{D B W}-2\,c\,x_U^2\,a_{U W})\,(2-3\,L_R)\,\frac{1}{c}
\end{aligned}
$$

$$
\begin{aligned}
A^{(6)}_{DD\,;1}=&\;\frac{1}{96}\,\Big\{8\,K_7\,s\,c^3\,a_{AZ}+\Big[24\,G_{14}\,a_{\phi D}-G_{61}\,a_{\phi D}-12\,(a_{\phi D V A}+a_{\phi W})\,G_{15}\Big]\\
&+4\,\Big[4\,F^b_3\,a_{AA}+(a_{\phi D}-4\,c^2\,a_{ZZ})\Big]\,s^2-2\,(9\,a_{D B W}+12\,c\,a_{\phi D V}+4\,s\,c^2\,a_{AZ})\,c\,x_D^2\Big\}\,\frac{1}{c^4\,x_S}\,a_0^{fin}(M_0)\\
&-\frac{1}{96}\,\Big\{16\,F^b_3\,s^2\,a_{AA}+4\,\Big[4\,c^3\,a_{AZ}+(a_{\phi D}-4\,c^2\,a_{ZZ})\,s\Big]\,s\\
&+\Big[24\,G_{14}\,a_{\phi D}-G_{61}\,a_{\phi D}-12\,(a_{\phi D V A}+a_{\phi W})\,G_{15}\Big]-6\,(3\,a_{D B W}+4\,c\,a_{\phi D V})\,c\,x_D^2\Big\}\,\frac{x_D^2}{c^2\,x_S}\,a_0^{fin}(M_D)\\
&-\frac{1}{8}\,(2\,a_{\phi W}\,x_D^2+3\,x_U^2\,a_{U W}-H_{17}\,a^{(3)}_{\phi Q W})\,\frac{x_U^2}{x_S}\,a_0^{fin}(M_U)
\end{aligned}
$$

JHEP07(2015)175

$$+\frac{1}{8}\left(2\,a_{\phi\mathrm{W}}\,x_{\mathrm{D}}^2+3\,x_{\mathrm{U}}^2\,a_{\mathrm{UW}}-\mathrm{H}_{17}\,a_{\phi\mathrm{QW}}^{(3)}\right)\frac{1}{x_{\mathrm{S}}}\,a_0^{\mathrm{fin}}(M)$$

$$\begin{aligned}A_{\mathrm{DD};2}^{(6)}=&-\frac{1}{12}\frac{1}{x_{\mathrm{S}}}\mathrm{L}_{15}\,s\,c\,a_{\mathrm{AZ}}\,\mathrm{B}_0^{\mathrm{fin}}(0\,,M_{\mathrm{D}})\\&+\frac{1}{96}\Big\{16\,\mathrm{F}_{31}^b\,s^2\,a_{\phi\mathrm{W}}+8\,\mathrm{F}_{33}^b\,s\,c^2\,a_{\phi\mathrm{WA}}\,x_{\mathrm{D}}^2+4\Big[4\,c\,a_{\phi\mathrm{WB}}+(a_{\phi\mathrm{D}}-8\,c^2\,a_{\phi\mathrm{B}})\,s\Big]\,s\\&+\Big[24\,\mathrm{G}_{14}\,a_{\phi\mathrm{D}}-\mathrm{G}_{61}\,a_{\phi\mathrm{D}}-12\,(a_{\phi\mathrm{DVA}}+a_{\phi\mathrm{W}})\,\mathrm{G}_{15}\Big]-6\,(3\,a_{\mathrm{DBW}}+4\,c\,a_{\phi\mathrm{DV}})\,\mathrm{L}_{11}\,c^3\,x_{\mathrm{D}}^2\\&-2\,(9\,a_{\mathrm{DBW}}-12\,c\,\mathrm{v_d}\,a_{\phi\mathrm{DA}}-20\,s^2\,c^2\,a_{\phi\mathrm{WZ}})\,c\,x_{\mathrm{D}}^2-8\,(a_{\mathrm{AZ}}-2\,s\,c\,a_{\mathrm{ZZ}})\,s\,c^3\,x_{\mathrm{S}}\\&-(24\,\mathrm{G}_{14}\,a_{\phi\mathrm{D}}\,x_{\mathrm{S}}-12\,\mathrm{G}_{15}\,x_{\mathrm{S}}\,a_{\phi\mathrm{DVA}}-12\,\mathrm{G}_{15}\,\mathrm{L}_{13}\,a_{\phi\mathrm{W}}-\mathrm{G}_{61}\,\mathrm{L}_{13}\,a_{\phi\mathrm{D}})\,c^2\\&+4\,(8\,\mathrm{I}_{10}\,a_{\phi\mathrm{B}}-4\,\mathrm{I}_{11}\,a_{\phi\mathrm{W}}-\mathrm{L}_{13}\,a_{\phi\mathrm{D}}-4\,\mathrm{F}_3^b\,x_{\mathrm{S}}\,a_{\mathrm{AA}}-4\,\mathrm{F}_{32}^b\,a_{\phi\mathrm{B}}\,x_{\mathrm{D}}^2)\,s^2\,c^2\\&-8\,(\mathrm{K}_6\,x_{\mathrm{S}}+\mathrm{L}_{14}\,x_{\mathrm{D}}^2)\,s\,c^5\,a_{\mathrm{AZ}}\Big\}\frac{1}{c^4\,x_{\mathrm{S}}}\,\mathrm{B}_0^{\mathrm{fin}}(M_0\,,M_{\mathrm{D}})\\&-\frac{1}{8}\,(2\,a_{\phi\mathrm{W}}\,x_{\mathrm{S}}\,x_{\mathrm{D}}^2-3\,x_{\mathrm{U}}^2\,x_{\mathrm{S}}\,a_{\mathrm{UW}}-2\,\mathrm{H}_{15}\,a_{\phi\mathrm{W}}\,x_{\mathrm{D}}^2-3\,\mathrm{H}_{15}\,x_{\mathrm{U}}^2\,a_{\mathrm{UW}}+\mathrm{H}_{16}\,a_{\phi\mathrm{QW}}^{(3)}\\&-2\,\mathrm{H}_{17}\,a_{\phi\mathrm{W}}\,x_{\mathrm{S}}-4\,\mathrm{H}_{18}\,x_{\mathrm{S}}\,a_{\phi\mathrm{Q}}^{(3)})\,\frac{1}{x_{\mathrm{S}}}\,\mathrm{B}_0^{\mathrm{fin}}(M\,,M_{\mathrm{U}})\end{aligned}$$

We have introduced

$$\begin{aligned}\mathrm{C}_{\mathrm{UV}}^{\mathrm{D}}=&-\frac{1}{256}\frac{M_{\mathrm{D}}^2}{M}\Big[3\,(s\,a_{\mathrm{DB}}+c\,a_{\mathrm{DW}})\,\mathrm{v_d}\\&+4\,c\,(a_{\phi\mathrm{D}}-a_{\phi\mathrm{Q}}^{(1)}+3\,a_{\phi\mathrm{Q}}^{(3)}+c\,s\,a_{\mathrm{DB}})+2\,(3+2\,s^2)\,c\,a_{\mathrm{DW}}\Big]\frac{1}{c}\end{aligned}$$

C Listing the counterterms

In this appendix we give the full list of counterterms, dropping the ren-subscript for the parameters, $\mathrm{s}_\theta=s_{\theta\,\mathrm{ren}}$ etc. To keep the notation as compact as possible a number of auxiliary quantities are introduced. First we define the following set of polynomials:

$\boxed{\mathrm{A}(x)}$ where $x=\mathrm{s}_\theta^2$:

$$\begin{array}{lll}\mathrm{A}_0^a=1-x & \mathrm{A}_1^a=55-36x & \mathrm{A}_2^a=10-9x\\ \mathrm{A}_3^a=5-2x & \mathrm{A}_4^a=7-4x & \mathrm{A}_5^a=3-2x\end{array}$$

$$\begin{array}{lll}\mathrm{A}_0^b=19-72x & \mathrm{A}_1^b=19+9\,\mathrm{A}_0^a x & \mathrm{A}_2^b=29-2\,\mathrm{A}_1^a x\\ \mathrm{A}_3^b=2-x & \mathrm{A}_4^b=53-26x & \mathrm{A}_5^b=19-36x\\ \mathrm{A}_6^b=61+36\,\mathrm{A}_0^a x & \mathrm{A}_7^b=56-29x & \mathrm{A}_8^b=13+12\,\mathrm{A}_0^a x\\ \mathrm{A}_9^b=3+2\,\mathrm{A}_0^a x & \mathrm{A}_{10}^b=14-9x & \mathrm{A}_{11}^b=2-3x\\ \mathrm{A}_{12}^b=1-4\,\mathrm{A}_0^a x & \mathrm{A}_{13}^b=29+4\,\mathrm{A}_2^a x & \mathrm{A}_{14}^b=50-23x\\ \mathrm{A}_{15}^b=29+18\,\mathrm{A}_0^a x & \mathrm{A}_{16}^b=1-x & \mathrm{A}_{17}^b=3-\mathrm{A}_3^a x\\ \mathrm{A}_{18}^b=3-\mathrm{A}_4^a x & \mathrm{A}_{19}^b=1-\mathrm{A}_5^a x & \end{array}$$

$$\mathrm{A}^c_0 = 10-13\,x \qquad \mathrm{A}^c_1 = 3-8\,x \qquad \mathrm{A}^c_2 = 19-18\,x$$
$$\mathrm{A}^c_3 = 1-7\,x \qquad \mathrm{A}^c_4 = 1-4\,x \qquad \mathrm{A}^c_5 = 1-2\,x$$
$$\mathrm{A}^c_6 = 1-\mathrm{A}^b_0\,x \qquad \mathrm{A}^c_7 = 1-2\,\mathrm{A}^b_1\,x \qquad \mathrm{A}^c_8 = 2-\mathrm{A}^b_2\,x$$
$$\mathrm{A}^c_9 = 3-2\,x \qquad \mathrm{A}^c_{10} = 4+3\,x \qquad \mathrm{A}^c_{11} = 19-24\,\mathrm{A}^b_3\,x$$
$$\mathrm{A}^c_{12} = 24-\mathrm{A}^b_4\,x \qquad \mathrm{A}^c_{13} = 1+3\,x \qquad \mathrm{A}^c_{14} = 1-\mathrm{A}^b_5\,x$$
$$\mathrm{A}^c_{15} = 2-\mathrm{A}^b_6\,x \qquad \mathrm{A}^c_{16} = 3-4\,x \qquad \mathrm{A}^c_{17} = 3+x$$
$$\mathrm{A}^c_{18} = 3+2\,x \qquad \mathrm{A}^c_{19} = 41-48\,\mathrm{A}^b_3\,x \qquad \mathrm{A}^c_{20} = 97-4\,\mathrm{A}^b_7\,x$$
$$\mathrm{A}^c_{21} = 1-2\,\mathrm{A}^b_8\,x \qquad \mathrm{A}^c_{22} = 3-\mathrm{A}^b_9\,x \qquad \mathrm{A}^c_{23} = 97-4\,\mathrm{A}^b_4\,x$$
$$\mathrm{A}^c_{24} = 5-6\,x \qquad \mathrm{A}^c_{25} = 1+2\,x \qquad \mathrm{A}^c_{26} = 9-4\,x$$
$$\mathrm{A}^c_{27} = 11-6\,x \qquad \mathrm{A}^c_{28} = 13-8\,x \qquad \mathrm{A}^c_{29} = 19-4\,\mathrm{A}^b_{10}\,x$$
$$\mathrm{A}^c_{30} = 17+12\,\mathrm{A}^b_{11}\,x \qquad \mathrm{A}^c_{31} = 23-4\,x \qquad \mathrm{A}^c_{32} = 29-24\,x$$
$$\mathrm{A}^c_{33} = 73-72\,x \qquad \mathrm{A}^c_{34} = 1-2\,\mathrm{A}^b_{12}\,x \qquad \mathrm{A}^c_{35} = 2-\mathrm{A}^b_{13}\,x$$
$$\mathrm{A}^c_{36} = 19-18\,\mathrm{A}^b_{12}\,x \qquad \mathrm{A}^c_{37} = 83-96\,\mathrm{A}^b_3\,x \qquad \mathrm{A}^c_{38} = 293-12\,\mathrm{A}^b_{14}\,x$$
$$\mathrm{A}^c_{39} = 1-\mathrm{A}^b_{15}\,x \qquad \mathrm{A}^c_{40} = 7-6\,x \qquad \mathrm{A}^c_{41} = 1+2\,\mathrm{A}^b_{16}\,x^2$$
$$\mathrm{A}^c_{42} = 1-4\,\mathrm{A}^b_{17}\,x \qquad \mathrm{A}^c_{43} = 1-8\,\mathrm{A}^b_{18}\,x \qquad \mathrm{A}^c_{44} = 1-4\,\mathrm{A}^b_{19}\,x$$

$\boxed{\mathrm{B}(x)}$ where $x = x_{\mathrm{H}} = M_{\mathrm{H}}/M_{\mathrm{W}}$:

$$\mathrm{B}^a_0 = 2-3\,x^2 \qquad \mathrm{B}^a_1 = 11+15\,x^2 \qquad \mathrm{B}^a_2 = 22+9\,x^2$$
$$\mathrm{B}^a_3 = 106+9\,x^2 \qquad \mathrm{B}^a_4 = 74+9\,x^2 \qquad \mathrm{B}^a_5 = 2-11\,x^2$$
$$\mathrm{B}^a_6 = 4-21\,x^2 \qquad \mathrm{B}^a_7 = 11-3\,x^2$$

$$\mathrm{B}^b_0 = 6-\mathrm{B}^a_0\,x^2 \qquad \mathrm{B}^b_1 = 2+x^2 \qquad \mathrm{B}^b_2 = 7-x^2$$
$$\mathrm{B}^b_3 = 10-3\,x^2 \qquad \mathrm{B}^b_4 = 10-x^2 \qquad \mathrm{B}^b_5 = 11+6\,x^2$$
$$\mathrm{B}^b_6 = 31+15\,x^2 \qquad \mathrm{B}^b_7 = 32-3\,x^2 \qquad \mathrm{B}^b_8 = 96-\mathrm{B}^a_1\,x^2$$
$$\mathrm{B}^b_9 = 132-\mathrm{B}^a_2\,x^2 \qquad \mathrm{B}^b_{10} = 132-\mathrm{B}^a_3\,x^2 \qquad \mathrm{B}^b_{11} = 196-\mathrm{B}^a_4\,x^2$$
$$\mathrm{B}^b_{12} = 2+11\,x^2 \qquad \mathrm{B}^b_{13} = 4+x^2 \qquad \mathrm{B}^b_{14} = 6-\mathrm{B}^a_5\,x^2$$
$$\mathrm{B}^b_{15} = 12-x^2 \qquad \mathrm{B}^b_{16} = 12-\mathrm{B}^a_6\,x^2 \qquad \mathrm{B}^b_{17} = 30-\mathrm{B}^a_7\,x^2$$
$$\mathrm{B}^b_{18} = 1-9\,x^2 \qquad \mathrm{B}^b_{19} = 3-4\,x^2 \qquad \mathrm{B}^b_{20} = 7+8\,x^2$$
$$\mathrm{B}^b_{21} = 15+4\,x^2 \qquad \mathrm{B}^b_{22} = 20+9\,x^2 \qquad \mathrm{B}^b_{23} = 55-3\,x^2$$
$$\mathrm{B}^b_{24} = 80+27\,x^2 \qquad \mathrm{B}^b_{25} = 1-6\,x^2 \qquad \mathrm{B}^b_{26} = 2-x^2$$
$$\mathrm{B}^b_{27} = 10-11\,x^2 \qquad \mathrm{B}^b_{28} = 12+11\,x^2 \qquad \mathrm{B}^b_{29} = 23-3\,x^2$$
$$\mathrm{B}^b_{30} = 34+15\,x^2 \qquad \mathrm{B}^b_{31} = 56+9\,x^2 \qquad \mathrm{B}^b_{32} = 144-\mathrm{B}^a_2\,x^2$$
$$\mathrm{B}^b_{33} = 4+3\,x^2 \qquad \mathrm{B}^b_{34} = 3-x^2 \qquad \mathrm{B}^b_{35} = 6-x^2$$
$$\mathrm{B}^b_{36} = 9-x^2 \qquad \mathrm{B}^b_{37} = 10+3\,x^2 \qquad \mathrm{B}^b_{38} = 22-3\,x^2$$
$$\mathrm{B}^b_{39} = 82-9\,x^2 \qquad \mathrm{B}^b_{40} = 8+9\,x^2 \qquad \mathrm{B}^b_{41} = 22-x^2$$
$$\mathrm{B}^b_{42} = 34-x^2 \qquad \mathrm{B}^b_{43} = 9-11\,x^2 \qquad \mathrm{B}^b_{44} = 31-6\,x^2$$
$$\mathrm{B}^b_{45} = 32+3\,x^2 \qquad \mathrm{B}^b_{46} = 33-7\,x^2 \qquad \mathrm{B}^b_{47} = 40+33\,x^2$$
$$\mathrm{B}^b_{48} = 51-7\,x^2 \qquad \mathrm{B}^b_{49} = 204-\mathrm{B}^a_2\,x^2 \qquad \mathrm{B}^b_{50} = 204-\mathrm{B}^a_3\,x^2$$
$$\mathrm{B}^b_{51} = 5+4\,x^2$$

$\boxed{\mathrm{C}}$ where we have introduced $v_{\mathrm{f}} = 1-2\,\frac{Q_{\mathrm{f}}}{I^3_{\mathrm{f}}}\,\mathrm{s}^2_\theta$ and

$$v^{(1)}_{\mathrm{gen}} = v^2_{\mathrm{l}} + 3\left(v^2_{\mathrm{u}} + v_{\mathrm{d}}\right) \quad v^{(2)}_{\mathrm{gen}} = v^2_{\mathrm{l}} + 2\,v^2_{\mathrm{u}} + v_{\mathrm{d}} \quad v^{\pm}_{\mathrm{f}} = 1 \pm v_{\mathrm{f}} \tag{C.1}$$

JHEP07(2015)175

$$
\begin{array}{lll}
C^a_0 = 9 + v^{(1)}_{\rm gen} & C^a_1 = 17 + v^{(3)}_{\rm gen} & C^a_2 = v^+_{\rm u} - v^+_{\rm d} \\
C^a_3 = v^+_{\rm u} + v^+_{\rm d} & C^a_4 = 8 - v^{(2)}_{\rm gen} & C^a_5 = 16 - 3\, v^{(2)}_{\rm gen} \\
C^a_6 = 41 - 4\, v^{(2)}_{\rm gen} + v^{(1)}_{\rm gen} & C^a_7 = 53 - 12\, v^{(2)}_{\rm gen} - 3\, v^{(1)}_{\rm gen} & C^a_8 = 3 + v_{\rm l} \\
C^a_9 = 4 - v^{(2)}_{\rm gen} & C^a_{10} = 5\, v^-_{\rm u} + v^-_{\rm d} + 3\, v^-_{\rm L} & C^a_{11} = 2 + v^{(2)}_{\rm gen} \\
C^a_{12} = 9 + 4\, v^{(2)}_{\rm gen} + v^{(1)}_{\rm gen} & C^a_{13} = 17 + v^{(3)}_{\rm gen} - 2\, v^{(2)}_{\rm gen} &
\end{array}
$$

D where we have introduced

$$
x_{\rm f} = \frac{M_{\rm f}}{M_{\rm W}} \qquad x^{(1)}_{\rm gen} = x^2_{\rm l} + 3\left(x^2_{\rm u} + x^2_{\rm d}\right) \qquad x^{(2)}_{\rm gen} = x^4_{\rm l} + 3\left(x^4_{\rm u} + x^4_{\rm d}\right) \tag{C.2}
$$

$$
\begin{array}{lll}
D^a_0 = 2 - 9\, x^2_{\rm l} & D^a_1 = 2 - 9\, x^2_{\rm u} - 9\, x^2_{\rm d} & D^a_2 = -x^2_{\rm u} + x^2_{\rm d} \\
D^a_3 = x^{(1)}_{\rm gen} - 2\, x^{(2)}_{\rm gen} & D^a_4 = x^2_{\rm u} + x^2_{\rm d} & D^a_5 = 2 - 3\, x^2_{\rm l} \\
D^a_6 = 2 - 3\, x^2_{\rm u} - 3\, x^2_{\rm d} & &
\end{array}
$$

E

$$
\begin{array}{lll}
E^a_0 = 2 - 9 * x^2_{\rm U} + 9 * x^2_{\rm D} & E^a_1 = 2 - 9 * x^2_{\rm D} & E^a_2 = 26 + 9 * x^2_{\rm U} + 9 * x^2_{\rm D} \\
E^a_3 = 14 + 9 * x^2_{\rm U} - 9 * x^2_{\rm D} & E^a_4 = 8 - 9 * x^2_{\rm U} & E^a_5 = 14 + 3 * x^2_{\rm L} \\
E^a_6 = 2 - x^2_{\rm L} & E^a_7 = 2 + x^2_{\rm L} & E^a_8 = 1 + 3 * x^2_{\rm D} \\
E^a_9 = 4 + 4 * x^2_{\rm U} + 3 * x^2_{\rm D} & E^a_{10} = 4 + 6 * x^2_{\rm U} + 3 * x^2_{\rm D} & E^a_{11} = 4 - 3 * x^2_{\rm D} \\
E^a_{12} = 4 + 3 * x^2_{\rm D} & E^a_{13} = 8 - 3 * x^2_{\rm D} & E^a_{14} = 16 - 6 * x^2_{\rm U} - 3 * x^2_{\rm D} \\
E^a_{15} = 1 + 3 * x^2_{\rm U} & E^a_{16} = 4 + 3 * x^2_{\rm U} + 4 * x^2_{\rm D} & E^a_{17} = 8 - 3 * x^2_{\rm U} \\
E^a_{18} = 8 + 3 * x^2_{\rm U} & E^a_{19} = 8 + 3 * x^2_{\rm U} + 6 * x^2_{\rm D} & E^a_{20} = 16 - 15 * x^2_{\rm U} \\
E^a_{21} = 20 - 3 * x^2_{\rm U} - 6 * x^2_{\rm D} & E^a_{22} = 1 + 3 * x^2_{\rm L} & E^a_{23} = 4 - x^2_{\rm L} \\
E^a_{24} = 4 + x^2_{\rm L} & E^a_{25} = 4 + 3 * x^2_{\rm L} & E^a_{26} = 8 - 9 * x^2_{\rm L} \\
E^a_{27} = 8 - x^2_{\rm L} & &
\end{array}
$$

C.1 $\dim = 4$ counterterms

First we list the SM counterterms. In the following we use $s = {\rm s}_\theta$ and $c = {\rm c}_\theta$.

$$
{\rm dZ}^{(4)}_{\rm H} = \frac{4}{3}\,{\rm N_{gen}} - \frac{1}{2}\sum_{\rm gen} x^{(1)}_{\rm gen} - \frac{1}{6}\,\frac{{\rm A}^c_0}{c^2} \tag{C.3}
$$

$$
{\rm dZ}^{(4)}_{M_{\rm H}} = -\frac{1}{2}\left\{\sum_{\rm gen}(4\,x^{(2)}_{\rm gen} - x^{(1)}_{\rm gen}\,x^2_{\rm H}) - \left[3 - (x^2_{\rm H} - c^2\,{\rm B}^b_0)\,c^2\right]\frac{1}{c^4}\right\}\frac{1}{x^2_{\rm H}} \tag{C.4}
$$

$$
{\rm dZ}^{(4)}_{\rm A} = -\frac{1}{6}\,{\rm A}^c_2 + \frac{4}{9}\,{\rm N_{gen}}\,{\rm A}^c_1 \qquad {\rm dZ}^{(4)}_{\rm AZ} = \frac{1}{6}\,\frac{s}{c}\,{\rm A}^c_2 - \frac{1}{3}\,\frac{s}{c}\,{\rm N_{gen}}\,v^{(2)}_{\rm gen} \tag{C.5}
$$

$$
{\rm dZ}^{(4)}_{\rm W} = 0 \qquad {\rm dZ}^{(4)}_{M_{\rm W}} = \frac{4}{3}\,{\rm N_{gen}} - \frac{1}{2}\sum_{\rm gen} x^{(1)}_{\rm gen} - \frac{1}{6}\,\frac{{\rm A}^c_3}{c^2} \tag{C.6}
$$

$$
{\rm dZ}^{(4)}_{{\rm c}_\theta} = -\frac{1}{12}\,\frac{s^2}{c^2}\,{\rm A}^c_2 - \frac{1}{24}\,({\rm C}^a - 16\,c^2)\,\frac{\rm N_{gen}}{c^2} \qquad {\rm dZ}^{(4)}_{\rm Z} = -\frac{1}{6}\,\frac{s^2}{c^2}\,{\rm A}^c_2 - \frac{1}{12}\,({\rm C}^a - 16\,c^2)\,\frac{\rm N_{gen}}{c^2} \tag{C.7}
$$

$$
{\rm dZ}^{(4)}_{g} = -\frac{19}{12} + \frac{2}{3}\,{\rm N_{gen}} \tag{C.8}
$$

$$\mathrm{dZ}^{(4)}_{M_\mathrm{D}} = \frac{1}{48}\left[3\,\mathrm{C}^a_1 + 2\,(3\,\mathrm{E}^a_0 - 8\,s^2)\,c^2\right]\frac{1}{c^2} \tag{C.9}$$

$$\mathrm{dZ}^{(4)}_{\mathrm{RD}} = \frac{1}{144}\left[9\,\mathrm{C}^a_2 + 8\,(9\,x^2_\mathrm{d} + 2\,s^2)\,c^2\right]\frac{1}{c^2} \qquad \mathrm{dZ}^{(4)}_{\mathrm{LD}} = \frac{1}{144}\left[9\,\mathrm{C}^a + 4\,(9\,\mathrm{E}^a_1 + 4\,s^2)\,c^2\right]\frac{1}{c^2} \tag{C.10}$$

$$\mathrm{dZ}^{(4)}_{M_\mathrm{U}} = -\frac{1}{24}\,(5 - c^2\,\mathrm{E}^a_2)\,\frac{1}{c^2} \tag{C.11}$$

$$\mathrm{dZ}^{(4)}_{\mathrm{RU}} = \frac{1}{18}\,(8 - c^2\,\mathrm{E}^a_3)\,\frac{1}{c^2} \qquad \mathrm{dZ}^{(4)}_{\mathrm{LU}} = \frac{1}{36}\,(1 + c^2\,\mathrm{E}^a_4)\,\frac{1}{c^2} \tag{C.12}$$

$$\mathrm{dZ}^{(4)}_{M_\mathrm{L}} = -\frac{1}{8}\,(11 - c^2\,\mathrm{E}^a_5)\,\frac{1}{c^2} \tag{C.13}$$

$$\mathrm{dZ}^{(4)}_{\mathrm{RL}} = \frac{1}{2}\,(2 - c^2\,\mathrm{E}^a_6)\,\frac{1}{c^2} \qquad \mathrm{dZ}^{(4)}_{\mathrm{L1}} = \frac{1}{4}\,(1 + c^2\,\mathrm{E}^a_7)\,\frac{1}{c^2} \tag{C.14}$$

$$\mathrm{dZ}^{(4)}_{\mathrm{R}\nu} = 0 \qquad \mathrm{dZ}^{(4)}_{\mathrm{L}\nu} = \frac{1}{4}\,(1 + c^2\,\mathrm{E}^a_7)\,\frac{1}{c^2} \tag{C.15}$$

C.2 dim = 6 counterterms

To present dim = 6 counterterms we define vectors; for counterterms

$$\begin{array}{lllll}
\mathrm{CT}_1 = \mathrm{dZ}^{(6)}_{\mathrm{H}} & \mathrm{CT}_2 = \mathrm{dZ}^{(6)}_{M_\mathrm{H}} & \mathrm{CT}_3 = \mathrm{dZ}^{(6)}_{\mathrm{A}} & \mathrm{CT}_4 = \mathrm{dZ}^{(6)}_{\mathrm{W}} & \mathrm{CT}_5 = \mathrm{dZ}^{(6)}_{M_\mathrm{W}} \\
\mathrm{CT}_6 = \mathrm{dZ}^{(6)}_{\mathrm{AZ}} & \mathrm{CT}_7 = \mathrm{dZ}^{(6)}_{\hat{c}_\theta} & \mathrm{CT}_8 = \mathrm{dZ}^{(6)}_{\mathrm{Z}} & \mathrm{CT}_9 = \mathrm{dZ}^{(6)}_{g} & \mathrm{CT}_{10} = \mathrm{dZ}^{(6)}_{M_\mathrm{D}} \\
\mathrm{CT}_{11} = \mathrm{dZ}^{(6)}_{\mathrm{RD}} & \mathrm{CT}_{12} = \mathrm{dZ}^{(6)}_{\mathrm{LD}} & \mathrm{CT}_{13} = \mathrm{dZ}^{(6)}_{M_\mathrm{U}} & \mathrm{CT}_{14} = \mathrm{dZ}^{(6)}_{\mathrm{RU}} & \mathrm{CT}_{15} = \mathrm{dZ}^{(6)}_{\mathrm{LU}} \\
\mathrm{CT}_{16} = \mathrm{dZ}^{(6)}_{M_\mathrm{L}} & \mathrm{CT}_{17} = \mathrm{dZ}^{(6)}_{\mathrm{RL}} & \mathrm{CT}_{18} = \mathrm{dZ}^{(6)}_{\mathrm{LL}} & \mathrm{CT}_{19} = \mathrm{dZ}^{(6)}_{\mathrm{R}\nu} & \mathrm{CT}_{20} = \mathrm{dZ}^{(6)}_{\mathrm{L}\nu}
\end{array} \tag{C.16}$$

and for Wilson coefficients

$$\begin{array}{llll}
a_\phi = \mathrm{W}_1 & a_{\phi\Box} = \mathrm{W}_2 & a_{\phi\mathrm{D}} = \mathrm{W}_3 & a_{\phi\mathrm{W}} = \mathrm{W}_4 \\
a_{\phi\mathrm{B}} = \mathrm{W}_5 & a_{\phi\mathrm{WB}} = \mathrm{W}_6 & a_{\mathrm{u}\phi} = \mathrm{W}_7(\mathrm{q}\,,\mathrm{u}) & a_{\mathrm{d}\phi} = \mathrm{W}_8(\mathrm{q}\,,\mathrm{d}) \\
a_{\mathrm{L}\phi} = \mathrm{W}_9(\lambda\,,\mathrm{l}) & a^{(1)}_{\phi\mathrm{q}} = \mathrm{W}_{10}(\mathrm{q}) & a^{(1)}_{\phi\mathrm{l}} = \mathrm{W}_{11}(\mathrm{l}) & a_{\phi\mathrm{u}} = \mathrm{W}_{12}(\mathrm{u}) \\
a_{\phi\mathrm{d}} = \mathrm{W}_{13}(\mathrm{d}) & a_{\phi\mathrm{l}} = \mathrm{W}_{14}(\mathrm{l}) & a^{(3)}_{\phi\mathrm{q}} = \mathrm{W}_{15}(\mathrm{q}) & a^{(3)}_{\phi\mathrm{l}} = \mathrm{W}_{16}(\mathrm{l}) \\
a_{\mathrm{uW}} = \mathrm{W}_{17}(\mathrm{q}\,,\mathrm{u}) & a_{\mathrm{dW}} = \mathrm{W}_{18}(\mathrm{q}\,,\mathrm{d}) & a_{\mathrm{lW}} = \mathrm{W}_{19}(\lambda\,,\mathrm{l}) & a_{\mathrm{uB}} = \mathrm{W}_{20}(\mathrm{q}\,,\mathrm{u}) \\
a_{\mathrm{dB}} = \mathrm{W}_{21}(\mathrm{q}\,,\mathrm{d}) & a_{\mathrm{lB}} = \mathrm{W}_{22}(\Lambda,\mathrm{l}) & a_{\mathrm{L1dQ}} = \mathrm{W}_{23}(\Lambda,\mathrm{l},\mathrm{d},\mathrm{Q}) & a^{(1)}_{\mathrm{QuQd}} = \mathrm{W}_{24}(\mathrm{Q},\mathrm{u},\mathrm{Q},\mathrm{d}) \\
a^{(1)}_{\mathrm{L1Qu}} = \mathrm{W}_{25}(\Lambda,\mathrm{l},\mathrm{Q},\mathrm{u}) & & &
\end{array} \tag{C.17}$$

The result is given by introducing a matrix

$$\mathrm{CT}_i = \sum_{j=1,6} \mathrm{M}^{\mathrm{ct}}_{ij}\,\mathrm{W}_j + \sum_{j=7,25}\sum_{\mathrm{gen}} \mathrm{M}^{\mathrm{ct}}_{ij}(\mathrm{label})\,\mathrm{W}_j(\mathrm{label}) \tag{C.18}$$

where, without assuming universality, we have

$$\begin{aligned}
\sum_{\mathrm{gen}} \mathrm{M}^{\mathrm{ct}}_{i,10}(\mathrm{label})\,\mathrm{W}_{10}(\mathrm{label}) &= \mathrm{M}^{\mathrm{ct}}_{i,10}(\mathrm{u,d})\,\mathrm{W}_{10}(\mathrm{u,d}) + \mathrm{M}^{\mathrm{ct}}_{i,10}(\mathrm{c,s})\,\mathrm{W}_{10}(\mathrm{c,s}) + \mathrm{M}^{\mathrm{ct}}_{i,10}(\mathrm{t,b})\,\mathrm{W}_{10}(\mathrm{t,b}) \\
\sum_{\mathrm{gen}} \mathrm{M}^{\mathrm{ct}}_{i,12}(\mathrm{label})\,\mathrm{W}_{12}(\mathrm{label}) &= \mathrm{M}^{\mathrm{ct}}_{i,12}(\mathrm{u})\,\mathrm{W}_{12}(\mathrm{u}) + \mathrm{M}^{\mathrm{ct}}_{i,12}(\mathrm{c})\,\mathrm{W}_{12}(\mathrm{c}) + \mathrm{M}^{\mathrm{ct}}_{i,12}(\mathrm{t})\,\mathrm{W}_{12}(\mathrm{t})
\end{aligned} \tag{C.19}$$

etc. In the following we introduce all non-zero entries of the matrix M^{ct}.

JHEP07(2015)175

- $\underline{\mathrm{M}^{\mathrm{ct}}_{1,i}\text{ entries}}$

$$\mathrm{M}^{\mathrm{ct}}_{1,2} = -\frac{1}{6}\left\{4\,\mathrm{A}^{c}_{11} - \mathrm{B}^{b}_{3}\,c^2\right\}\frac{1}{c^2}$$

$$\mathrm{M}^{\mathrm{ct}}_{1,3} = \frac{1}{2}\sum_{\mathrm{gen}} x^{(1)}_{\mathrm{gen}} - \frac{1}{6}\left\{3\,\mathrm{A}^{c}_{12} - \mathrm{B}^{b}_{5}\,c^2\right\}\frac{1}{c^2}$$

$$\begin{aligned}\mathrm{M}^{\mathrm{ct}}_{1,4} = &-\sum_{\mathrm{gen}}\left\{x^{(1)}_{\mathrm{gen}} - \left[c^2\,x^{(1)}_{\mathrm{gen}}\,x^2_{\mathrm{H}} + 2\,(2\,s^2\,x^{(2)}_{\mathrm{gen}} + \mathrm{D}^{a}_{3})\right]c^2\right\}\\ &+\frac{1}{6}\left\{9\,\mathrm{A}^{c}_{9} - \left[-(\mathrm{A}^{c}_{8}\,x^2_{\mathrm{H}} + 8\,\mathrm{B}^{b}_{2}) + (-\mathrm{B}^{b}_{10}\,s^2 + \mathrm{B}^{b}_{11})\,c^2\right]c^2\right\}\frac{1}{c^2}\\ &+\frac{1}{3}\left\{\mathrm{C}^{a}_{1} + \left[8\,c^2\,x^2_{\mathrm{H}} - (16 + \mathrm{C}^{a}_{0}\,x^2_{\mathrm{H}})\right]c^2\right\}\mathrm{N_{gen}}\end{aligned}$$

$$\begin{aligned}\mathrm{M}^{\mathrm{ct}}_{1,5} = &\sum_{\mathrm{gen}}\left\{2\,x^{(1)}_{\mathrm{gen}} - \left[4\,x^{(2)}_{\mathrm{gen}} - x^{(1)}_{\mathrm{gen}}\,x^2_{\mathrm{H}}\right]c^2\right\}s^2\\ &+\frac{1}{6}\left\{6\,\mathrm{A}^{c}_{10} - \left[(\mathrm{A}^{c}_{8}\,x^2_{\mathrm{H}} + 2\,\mathrm{B}^{b}_{7}) - (4\,\mathrm{B}^{b}_{4} - \mathrm{B}^{b}_{9}\,s^2)\,c^2\right]c^2\right\}\frac{1}{c^2}\\ &-\frac{1}{6}\left\{-16\left[2 - c^2\,x^2_{\mathrm{H}}\right]c^2 + \left[2 - \mathrm{A}^{c}_{5}\,x^2_{\mathrm{H}}\right]\mathrm{C}^{a}_{0}\right\}\mathrm{N_{gen}}\end{aligned}$$

$$\begin{aligned}\mathrm{M}^{\mathrm{ct}}_{1,6} = &-\sum_{\mathrm{gen}}\left\{2\,x^{(1)}_{\mathrm{gen}} - \left[4\,x^{(2)}_{\mathrm{gen}} - x^{(1)}_{\mathrm{gen}}\,x^2_{\mathrm{H}}\right]c^2\right\}s\,c\\ &+\frac{1}{12}\left\{2\,\mathrm{A}^{c}_{5}\,\mathrm{C}^{a}_{0} + \left[16\,\mathrm{A}^{c}_{5}\,c^2\,x^2_{\mathrm{H}} - (\mathrm{A}^{c}_{4}\,\mathrm{C}^{a}_{0}\,x^2_{\mathrm{H}} + 32\,\mathrm{A}^{c}_{5})\right]c^2\right\}\frac{1}{s\,c}\,\mathrm{N_{gen}}\\ &+\frac{1}{6}\left\{2\,\mathrm{A}^{c}_{7} + \left[2\,\mathrm{B}^{b}_{6}\,s^2 - (-\mathrm{A}^{c}_{6}\,x^2_{\mathrm{H}} + \mathrm{B}^{b}_{1} - \mathrm{B}^{b}_{8}\,s^2)\,c^2\right]c^2\right\}\frac{1}{s\,c}\end{aligned}$$

$$\mathrm{M}^{\mathrm{ct}}_{1,7}(\mathrm{q},\mathrm{u}) = -3\,x^2_{\mathrm{u}} \qquad \mathrm{M}^{\mathrm{ct}}_{1,8}(\mathrm{q},\mathrm{d}) = 3\,x^2_{\mathrm{d}} \qquad \mathrm{M}^{\mathrm{ct}}_{1,9}(\lambda,\mathrm{l}) = x^2_{\mathrm{l}}$$

$$\mathrm{M}^{\mathrm{ct}}_{1,10}(\mathrm{q}) = 2\left\{\mathrm{C}^{a}_{2} + 6\,\mathrm{D}^{a}_{2}\,c^2\right\}\frac{1}{c^2} \qquad \mathrm{M}^{\mathrm{ct}}_{1,11}(\mathrm{l}) = -\frac{2}{3}\left\{\mathrm{v}^{+}_{\mathrm{l}} - 6\,c^2\,x^2_{\mathrm{l}}\right\}\frac{1}{c^2}$$

$$\mathrm{M}^{\mathrm{ct}}_{1,12}(\mathrm{u}) = -2\left\{\mathrm{v}^{-}_{\mathrm{u}} - 6\,c^2\,x^2_{\mathrm{u}}\right\}\frac{1}{c^2} \qquad \mathrm{M}^{\mathrm{ct}}_{1,13}(\mathrm{d}) = 2\left\{\mathrm{v}^{-}_{\mathrm{d}} - 6\,c^2\,x^2_{\mathrm{d}}\right\}\frac{1}{c^2}$$

$$\mathrm{M}^{\mathrm{ct}}_{1,14}(\mathrm{l}) = \frac{2}{3}\left\{\mathrm{v}^{-}_{\mathrm{l}} - 6\,c^2\,x^2_{\mathrm{l}}\right\}\frac{1}{c^2} \qquad \mathrm{M}^{\mathrm{ct}}_{1,15}(\mathrm{q}) = 2\left\{\mathrm{C}^{a}_{3} + \mathrm{D}^{a}_{1}\,c^2\right\}\frac{1}{c^2}$$

$$\mathrm{M}^{\mathrm{ct}}_{1,16}(\mathrm{l}) = \frac{2}{3}\left\{\mathrm{v}^{+}_{\mathrm{l}} + \mathrm{D}^{a}_{0}\,c^2\right\}\frac{1}{c^2}$$

$$\mathrm{M}^{\mathrm{ct}}_{1,17}(\mathrm{q},\mathrm{u}) = -\frac{3}{2}\,x^2_{\mathrm{u}} \qquad \mathrm{M}^{\mathrm{ct}}_{1,18}(\mathrm{q},\mathrm{d}) = \frac{3}{2}\,x^2_{\mathrm{d}} \qquad \mathrm{M}^{\mathrm{ct}}_{1,19}(\lambda,\mathrm{l}) = \frac{1}{2}\,x^2_{\mathrm{l}}$$

- $\underline{\mathrm{M}^{\mathrm{ct}}_{2,i}\text{ entries}}$

$$\mathrm{M}^{\mathrm{ct}}_{2,1} = -3\left\{1 + \mathrm{B}^{b}_{12}\,c^2\right\}\frac{1}{c^2\,x^2_{\mathrm{H}}}$$

$$\mathrm{M}^{\mathrm{ct}}_{2,2} = \left\{-\sum_{\mathrm{gen}}\left[4\,x^{(2)}_{\mathrm{gen}} - x^{(1)}_{\mathrm{gen}}\,x^2_{\mathrm{H}}\right] + \left[3 - (x^2_{\mathrm{H}} - \mathrm{B}^{b}_{14}\,c^2)\,c^2\right]\frac{1}{c^4}\right\}\frac{1}{x^2_{\mathrm{H}}}$$

$$M^{ct}_{2,3} = \frac{1}{8}\left\{2\sum_{gen}\left[4\,x^{(2)}_{gen} - x^{(1)}_{gen}\,x^2_{H}\right] + \left[18 - (5\,x^2_{H} + B^b_{16}\,c^2)\,c^2\right]\frac{1}{c^4}\right\}\frac{1}{x^2_{H}}$$

$$M^{ct}_{2,4} = \left\{-\sum_{gen}\left[4\,x^{(2)}_{gen} - x^{(1)}_{gen}\,x^2_{H}\right] + \left[3 + (B^b_{15} + B^b_{17}\,c^2)\,c^2\right]\frac{1}{c^4}\right\}\frac{1}{x^2_{H}}$$

$$M^{ct}_{2,5} = 3\left\{4 - \left[-c^2\,x^2_{H} + B^b_{13}\right]c^2\right\}\frac{1}{c^4\,x^2_{H}}$$

$$M^{ct}_{2,6} = -3\left\{4 - c^2\,x^2_{H}\right\}\frac{1}{x^2_{H}}\,\frac{s}{c^3} \qquad M^{ct}_{2,7}\,(q\,,u) = -3\left\{8\,x^2_{u} - x^2_{H}\right\}\frac{1}{x^2_{H}}\,x^2_{u}$$

$$M^{ct}_{2,8}\,(q\,,d) = 3\left\{8\,x^2_{d} - x^2_{H}\right\}\frac{1}{x^2_{H}}\,x^2_{d} \qquad M^{ct}_{2,9}\,(\lambda\,,l) = \left\{8\,x^2_{l} - x^2_{H}\right\}\frac{1}{x^2_{H}}\,x^2_{l}$$

- $M^{ct}_{3,i}$ entries

$$M^{ct}_{3,2} = \sum_{gen} x^{(1)}_{gen} - \frac{1}{3}\left\{A^c_{19} + B^b_{18}\,c^2\right\}\frac{1}{c^2}$$

$$M^{ct}_{3,3} = \frac{16}{9}\,N_{gen}\,c^2 + \frac{1}{4}\sum_{gen} x^{(1)}_{gen} - \frac{1}{24}\left\{3\,A^c_{20} - B^b_{22}\,c^2\right\}\frac{1}{c^2}$$

$$\begin{aligned}M^{ct}_{3,4} = {} & \sum_{gen}\left\{c^2\,x^{(1)}_{gen}\,x^2_{H} + 2\left[2\,s^2\,x^{(2)}_{gen} + D^a_3\right]\right\}c^2 \\ & + \frac{1}{6}\left\{\left[18 - B^b_{20} + 2\,B^b_{21}\,s^2\right] - \left[-2\,A^c_{14}\,x^2_{H} - B^b_{10}\,s^2 + B^b_{11}\right]c^2\right\} \\ & + \frac{1}{9}\left\{3\left[8\,c^2 - (C^a_0)\right]c^2\,x^2_{H} + \left[-16\,A^c_{17} + 3\,C^a_1\right]\right\}N_{gen}\end{aligned}$$

$$\begin{aligned}M^{ct}_{3,5} = {} & \sum_{gen}\left\{2\,x^{(1)}_{gen} - \left[4\,x^{(2)}_{gen} - x^{(1)}_{gen}\,x^2_{H}\right]c^2\right\}s^2 \\ & + \frac{1}{6}\left\{6\,A^c_{13} - \left[-(-2\,A^c_{14}\,x^2_{H} + 4\,B^b_4 - B^b_9\,s^2)\,c^2 + (-2\,B^b_{19}\,s^2 + B^b_{23})\right]c^2\right\}\frac{1}{c^2} \\ & - \frac{1}{6}\left\{-16\left[2 - c^2\,x^2_{H}\right]c^2 + \left[2 - A^c_5\,x^2_{H}\right]C^a_0\right\}N_{gen}\end{aligned}$$

$$\begin{aligned}M^{ct}_{3,6} = {} & -\sum_{gen}\left\{2\,x^{(1)}_{gen} - \left[4\,x^{(2)}_{gen} - x^{(1)}_{gen}\,x^2_{H}\right]c^2\right\}s\,c \\ & + \frac{1}{36}\left\{6\,A^c_5\,C^a_0 + \left[48\,A^c_5\,c^2\,x^2_{H} - (3\,A^c_4\,C^a_0\,x^2_{H} + 32\,A^c_{18})\right]c^2\right\}\frac{1}{s\,c}\,N_{gen} \\ & + \frac{1}{6}\left\{A^c_{15} + \left[B^b_{24}\,s^2 - (-A^c_6\,x^2_{H} + B^b_1 - B^b_8\,s^2)\,c^2\right]c^2\right\}\frac{1}{s\,c}\end{aligned}$$

$$M^{ct}_{3,10}\,(q) = 2\left\{C^a_2 + 6\,D^a_2\,c^2\right\}\frac{1}{c^2} \qquad M^{ct}_{3,11}\,(l) = -\frac{2}{3}\left\{v^+_l - 6\,c^2\,x^2_{l}\right\}\frac{1}{c^2}$$

$$M^{ct}_{3,12}\,(u) = -2\left\{v^-_u - 6\,c^2\,x^2_{u}\right\}\frac{1}{c^2} \qquad M^{ct}_{3,13}\,(d) = 2\left\{v^-_d - 6\,c^2\,x^2_{d}\right\}\frac{1}{c^2}$$

$$M^{ct}_{3,14}\,(l) = \frac{2}{3}\left\{v^-_l - 6\,c^2\,x^2_{l}\right\}\frac{1}{c^2} \qquad M^{ct}_{3,15}\,(q) = 2\left\{C^a_3 + D^a_1\,c^2\right\}\frac{1}{c^2} \qquad M^{ct}_{3,16}\,(l) = \frac{2}{3}\left\{v^+_l + D^a_0\,c^2\right\}\frac{1}{c^2}$$

$$M^{ct}_{3,17}\,(q\,,u) = -\frac{1}{2}\,A^c_1\,x^2_{u} \qquad M^{ct}_{3,18}\,(q\,,d) = \frac{1}{2}\,A^c_{16}\,x^2_{d} \qquad M^{ct}_{3,19}\,(\lambda\,,l) = \frac{1}{2}\,A^c_4\,x^2_{l}$$

$$M^{ct}_{3,20}\,(q\,,u) = 4\,s\,c\,x^2_{u} \qquad M^{ct}_{3,21}\,(q\,,d) = 2\,s\,c\,x^2_{d} \qquad M^{ct}_{3,22}\,(\lambda\,,l) = 2\,s\,c\,x^2_{l}$$

- $\mathrm{M}^{\rm ct}_{4,i}$ entries

$$\mathrm{M}^{\rm ct}_{4,2} = \sum_{\rm gen} x^{(1)}_{\rm gen} - \frac{1}{6}\left\{2\,\mathrm{A}^{c}_{19} + 3\,\mathrm{B}^{b}_{25}\,c^2\right\}\frac{1}{c^2}$$

$$\mathrm{M}^{\rm ct}_{4,3} = \frac{1}{4}\sum_{\rm gen} x^{(1)}_{\rm gen} - \frac{1}{24}\left\{3\,\mathrm{A}^{c}_{23} - \mathrm{B}^{b}_{31}\,c^2\right\}\frac{1}{c^2}$$

$$\begin{aligned}\mathrm{M}^{\rm ct}_{4,4} = &\sum_{\rm gen}\left\{c^2\,x^{(1)}_{\rm gen}\,x^2_{\rm H} + 2\left[2\,s^2\,x^{(2)}_{\rm gen} + \mathrm{D}^{a}_{3}\right]\right\}c^2\\ &+\frac{1}{6}\left\{6\,\mathrm{A}^{c}_{22} + \left[-(-2\,\mathrm{A}^{c}_{14}\,x^2_{\rm H} - \mathrm{B}^{b}_{10}\,s^2 + \mathrm{B}^{b}_{11})\,c^2 + (\mathrm{B}^{b}_{27} + \mathrm{B}^{b}_{28}\,s^2)\right]c^2\right\}\frac{1}{c^2}\\ &-\frac{1}{6}\left\{16\left[2 - c^2\,x^2_{\rm H}\right]c^2 - \left[-\mathrm{A}^{c}_{5}\,x^2_{\rm H} + \mathrm{B}^{b}_{26}\right]\mathrm{C}^{a}_{0}\right\}\mathrm{N_{gen}}\end{aligned}$$

$$\begin{aligned}\mathrm{M}^{\rm ct}_{4,5} = &\sum_{\rm gen}\left\{2\,x^{(1)}_{\rm gen} - \left[4\,x^{(2)}_{\rm gen} - x^{(1)}_{\rm gen}\,x^2_{\rm H}\right]c^2\right\}s^2\\ &+\frac{1}{6}\left\{6\,\mathrm{A}^{c}_{13} - \left[(\mathrm{A}^{c}_{8}\,x^2_{\rm H} + 2\,\mathrm{B}^{b}_{29}) - (4\,\mathrm{B}^{b}_{4} - \mathrm{B}^{b}_{32}\,s^2)\,c^2\right]c^2\right\}\frac{1}{c^2}\\ &-\frac{1}{6}\left\{-16\left[2 - c^2\,x^2_{\rm H}\right]c^2 + \left[2 - \mathrm{A}^{c}_{5}\,x^2_{\rm H}\right]\mathrm{C}^{a}_{0}\right\}\mathrm{N_{gen}}\end{aligned}$$

$$\begin{aligned}\mathrm{M}^{\rm ct}_{4,6} = &-\sum_{\rm gen}\left\{2\,x^{(1)}_{\rm gen} - \left[4\,x^{(2)}_{\rm gen} - x^{(1)}_{\rm gen}\,x^2_{\rm H}\right]c^2\right\}s\,c\\ &+\frac{1}{12}\left\{2\,\mathrm{A}^{c}_{5}\,\mathrm{C}^{a}_{0} + \left[16\,\mathrm{A}^{c}_{5}\,c^2\,x^2_{\rm H} - (\mathrm{A}^{c}_{4}\,\mathrm{C}^{a}_{0}\,x^2_{\rm H} + 32\,\mathrm{A}^{c}_{5})\right]c^2\right\}\frac{1}{s\,c}\mathrm{N_{gen}}\\ &+\frac{1}{6}\left\{2\,\mathrm{A}^{c}_{21} + \left[2\,\mathrm{B}^{b}_{30}\,s^2 - (-\mathrm{A}^{c}_{6}\,x^2_{\rm H} + \mathrm{B}^{b}_{1} - \mathrm{B}^{b}_{8}\,s^2)\,c^2\right]c^2\right\}\frac{1}{s\,c}\end{aligned}$$

$$\mathrm{M}^{\rm ct}_{4,10}(\mathrm{q}) = 2\left\{\mathrm{C}^{a}_{2} + 6\,\mathrm{D}^{a}_{2}\,c^2\right\}\frac{1}{c^2} \qquad \mathrm{M}^{\rm ct}_{4,11}(\mathrm{l}) = -\frac{2}{3}\left\{\mathrm{v}^{+}_{\rm l} - 6\,c^2\,x^2_{\rm l}\right\}\frac{1}{c^2}$$

$$\mathrm{M}^{\rm ct}_{4,12}(\mathrm{u}) = -2\left\{\mathrm{v}^{-}_{\rm u} - 6\,c^2\,x^2_{\rm u}\right\}\frac{1}{c^2} \qquad \mathrm{M}^{\rm ct}_{4,13}(\mathrm{d}) = 2\left\{\mathrm{v}^{-}_{\rm d} - 6\,c^2\,x^2_{\rm d}\right\}\frac{1}{c^2}$$

$$\mathrm{M}^{\rm ct}_{4,14}(\mathrm{l}) = \frac{2}{3}\left\{\mathrm{v}^{-}_{\rm l} - 6\,c^2\,x^2_{\rm l}\right\}\frac{1}{c^2} \qquad \mathrm{M}^{\rm ct}_{4,15}(\mathrm{q}) = 2\left\{\mathrm{C}^{a}_{3} - 9\,\mathrm{D}^{a}_{4}\,c^2\right\}\frac{1}{c^2} \qquad \mathrm{M}^{\rm ct}_{4,16}(\mathrm{l}) = \frac{2}{3}\left\{\mathrm{v}^{+}_{\rm l} - 9\,c^2\,x^2_{\rm l}\right\}\frac{1}{c^2}$$

- $\mathrm{M}^{\rm ct}_{5,i}$ entries

$$\mathrm{M}^{\rm ct}_{5,2} = \frac{5}{3} \qquad \mathrm{M}^{\rm ct}_{5,3} = -\frac{1}{4}\,\mathrm{A}^{c}_{24}\,\frac{1}{c^2}$$

$$\mathrm{M}^{\rm ct}_{5,4} = \frac{8}{3}\,\mathrm{N_{gen}} - \sum_{\rm gen} x^{(1)}_{\rm gen} + \frac{1}{6}\left\{15 + \mathrm{B}^{b}_{33}\,c^2\right\}\frac{1}{c^2}$$

$$\mathrm{M}^{\rm ct}_{5,6} = -\frac{s}{c} \qquad \mathrm{M}^{\rm ct}_{5,15}(\mathrm{q}) = 2\,\mathrm{D}^{a}_{6} \qquad \mathrm{M}^{\rm ct}_{5,16}(\mathrm{l}) = \frac{2}{3}\,\mathrm{D}^{a}_{5}$$

$$\mathrm{M}^{\rm ct}_{5,17}(\mathrm{q}\,,\mathrm{u}) = -\frac{3}{2}\,x^2_{\rm u} \qquad \mathrm{M}^{\rm ct}_{5,18}(\mathrm{q}\,,\mathrm{d}) = \frac{3}{2}\,x^2_{\rm d} \qquad \mathrm{M}^{\rm ct}_{5,19}(\lambda\,,\mathrm{l}) = \frac{1}{2}\,x^2_{\rm l}$$

- $\mathrm{M}^{\rm ct}_{6,i}$ entries

JHEP07(2015)175

$$M^{ct}_{6,3} = -\frac{1}{24}\,A^c_{29}\,\frac{1}{s\,c} - \frac{1}{36}\left\{-3\,c^2\,v^{(2)}_{gen} + 4\,A^c_{28}\,s^2\right\}\frac{1}{s\,c}\,N_{gen}$$

$$M^{ct}_{6,4} = \frac{1}{36}\left\{64\,A^c_{25}\,c^2 + \left[24\,s^2\,v^{(2)}_{gen} + C^a_7\right]\right\}\frac{s}{c}\,N_{gen} + \frac{1}{6}\left\{A^c_{27} - 6\left[A^c_{25}\,B^b_{15} - 2\,B^b_{35}\,s^2\right]c^2\right\}\frac{s}{c}$$

$$M^{ct}_{6,5} = \frac{1}{6}\left\{5\,A^c_{24} - 6\left[B^b_1\,c^2 - (-2\,B^b_{35} + B^b_{38})\,s^2\right]c^2\right\}\frac{s}{c} + \frac{1}{36}\left\{3\,C^a_0 - 8\left[16\,s^2 + 3\,C^a_4\right]c^2\right\}\frac{s}{c}\,N_{gen}$$

$$M^{ct}_{6,6} = -\frac{1}{72}\left\{3\,A^c_{16}\,C^a_0 - 2\left[128\,s^2\,c^2 + (-8\,C^a_5\,s^2 + 3\,C^a_6)\right]c^2\right\}\frac{1}{c^2}\,N_{gen} - \frac{1}{12}\left\{A^c_{26} - 2\left[-(3\,B^b_{13} + 12\,B^b_{34}\,s^4 - B^b_{39}\,s^2) + (-12\,B^b_{36}\,s^2 + B^b_{37})\,c^2\right]c^2\right\}\frac{1}{c^2}$$

$$M^{ct}_{6,10}(q) = -\frac{2}{3}\,\frac{s}{c} \qquad M^{ct}_{6,11}(l) = \frac{2}{3}\,\frac{s}{c} \qquad M^{ct}_{6,12}(u) = -\frac{4}{3}\,\frac{s}{c} \qquad M^{ct}_{6,13}(d) = \frac{2}{3}\,\frac{s}{c}$$

$$M^{ct}_{6,14}(l) = \frac{2}{3}\,\frac{s}{c} \qquad M^{ct}_{6,15}(q) = -2\,\frac{s}{c} \qquad M^{ct}_{6,16}(l) = -\frac{2}{3}\,\frac{s}{c}$$

$$M^{ct}_{6,17}(q\,,u) = \frac{1}{4}\left\{8\,c^2 + 3\,v_u\right\}\frac{s}{c}\,x^2_u \qquad M^{ct}_{6,18}(q\,,d) = -\frac{1}{4}\left\{4\,c^2 + 3\,v_d\right\}\frac{s}{c}\,x^2_d$$

$$M^{ct}_{6,19}(\lambda\,,l) = -\frac{1}{4}\left\{4\,c^2 + v_l\right\}\frac{s}{c}\,x^2_l \qquad M^{ct}_{6,20}(q\,,u) = \frac{1}{4}\left\{3\,v_u - 8\,s^2\right\}x^2_u$$

$$M^{ct}_{6,21}(q\,,d) = \frac{1}{4}\left\{3\,v_d - 4\,s^2\right\}x^2_d \qquad M^{ct}_{6,22}(\lambda\,,l) = \frac{1}{4}\left\{v_l - 4\,s^2\right\}x^2_l$$

- $M^{ct}_{7,i}$ entries

$$M^{ct}_{7,2} = -\frac{5}{6}\,\frac{s^2}{c^2}$$

$$M^{ct}_{7,3} = -\frac{1}{8}\sum_{gen} x^{(1)}_{gen} + \frac{1}{48}\left\{-4\,c^2\,v^{(2)}_{gen} + C^a_{10}\right\}\frac{1}{c^2}\,N_{gen} - \frac{1}{48}\left\{A^c_{30} + B^b_{40}\,c^2\right\}\frac{1}{c^2}$$

$$M^{ct}_{7,4} = \frac{1}{12}\left\{A^c_{33} - 3\,B^b_{42}\,c^2\right\}\frac{s^2}{c^2} - \frac{1}{12}\left\{-4\,C^a_9\,c^2 + C^a_{10}\right\}\frac{1}{c^2}\,N_{gen}$$

$$M^{ct}_{7,5} = -\frac{1}{4}\left\{A^c_{32} - B^b_{41}\,c^2\right\}\frac{s^2}{c^2} \qquad M^{ct}_{7,6} = \frac{1}{3}\,\frac{s}{c}\,N_{gen}\,v^{(2)}_{gen} + \frac{1}{12}\left\{A^c_{31} - B^b_{38}\,c^2\right\}\frac{s}{c}$$

$$M^{ct}_{7,10}(q) = -\frac{1}{2}\left\{C^a_2 + 6\,D^a_2\,c^2\right\}\frac{1}{c^2} \qquad M^{ct}_{7,11}(l) = -\frac{1}{6}\left\{v^-_l + 6\,c^2\,x^2_l\right\}\frac{1}{c^2}$$

$$M^{ct}_{7,12}(u) = \frac{1}{2}\left\{v^-_u - 6\,c^2\,x^2_u\right\}\frac{1}{c^2} \qquad M^{ct}_{7,13}(d) = -\frac{1}{2}\left\{v^-_d - 6\,c^2\,x^2_d\right\}\frac{1}{c^2}$$

$$M^{ct}_{7,14}(l) = -\frac{1}{6}\left\{v^-_l - 6\,c^2\,x^2_l\right\}\frac{1}{c^2} \qquad M^{ct}_{7,15}(q) = -\frac{1}{2}\left\{-4\,c^2 + C^a_3\right\}\frac{1}{c^2}$$

$$\mathrm{M}^{\mathrm{ct}}_{7,16}(\mathrm{l}) = -\frac{1}{6}\left\{-4c^2 + \mathrm{C}^a_8\right\}\frac{1}{c^2} \qquad \mathrm{M}^{\mathrm{ct}}_{7,17}(\mathrm{q},\mathrm{u}) = -\frac{3}{4}x^2_{\mathrm{u}}\,\mathrm{v}^-_{\mathrm{u}}$$

$$\mathrm{M}^{\mathrm{ct}}_{7,18}(\mathrm{q},\mathrm{d}) = \frac{3}{4}x^2_{\mathrm{d}}\,\mathrm{v}^-_{\mathrm{d}} \qquad \mathrm{M}^{\mathrm{ct}}_{7,19}(\lambda,\mathrm{l}) = \frac{1}{4}x^2_{\mathrm{l}}\,\mathrm{v}^-_{\mathrm{l}}$$

$$\mathrm{M}^{\mathrm{ct}}_{7,20}(\mathrm{q},\mathrm{u}) = -\frac{3}{4}\frac{s}{c}\,v_{\mathrm{u}}\,x^2_{\mathrm{u}} \qquad \mathrm{M}^{\mathrm{ct}}_{7,21}(\mathrm{q},\mathrm{d}) = -\frac{3}{4}\frac{s}{c}\,v_{\mathrm{d}}\,x^2_{\mathrm{d}}$$

$$\mathrm{M}^{\mathrm{ct}}_{7,22}(\lambda,\mathrm{l}) = -\frac{1}{4}\frac{s}{c}\,v_{\mathrm{l}}\,x^2_{\mathrm{l}}$$

- $\mathrm{M}^{\mathrm{ct}}_{8,i}$ entries

$$\mathrm{M}^{\mathrm{ct}}_{8,2} = \sum_{\mathrm{gen}} x^{(1)}_{\mathrm{gen}} - \frac{1}{6}\left\{\mathrm{A}^c_{37} + 2\,\mathrm{B}^b_{18}\,c^2\right\}\frac{1}{c^2}$$

$$\mathrm{M}^{\mathrm{ct}}_{8,3} = \frac{1}{4}\sum_{\mathrm{gen}} x^{(1)}_{\mathrm{gen}} + \frac{1}{24}\left\{-4c^2\,v^{(2)}_{\mathrm{gen}} + \mathrm{C}^a_{10}\right\}\frac{1}{c^2}\,\mathrm{N_{gen}} - \frac{1}{24}\left\{\mathrm{A}^c_{38} - 3\,\mathrm{B}^b_{45}\,c^2\right\}\frac{1}{c^2}$$

$$\begin{aligned}\mathrm{M}^{\mathrm{ct}}_{8,4} =& \sum_{\mathrm{gen}}\left\{c^2 x^{(1)}_{\mathrm{gen}} x^2_{\mathrm{H}} + 2\left[2s^2 x^{(2)}_{\mathrm{gen}} + \mathrm{D}^a_3\right]\right\}c^2\\ &+\frac{1}{6}\left\{\mathrm{A}^c_{36} + \left[-(-2\,\mathrm{A}^c_{14}x^2_{\mathrm{H}} + \mathrm{B}^b_{11} - \mathrm{B}^b_{50}s^2)\,c^2 + (\mathrm{B}^b_{43} - 2\,\mathrm{B}^b_{48}s^2)\right]c^2\right\}\frac{1}{c^2}\\ &-\frac{1}{6}\left\{\mathrm{C}^a_{10} + 2\left[(16 - 8c^2x^2_{\mathrm{H}} + \mathrm{C}^a_0 x^2_{\mathrm{H}})\,c^2 - (\mathrm{C}^a_{13})\right]c^2\right\}\frac{1}{c^2}\,\mathrm{N_{gen}}\end{aligned}$$

$$\begin{aligned}\mathrm{M}^{\mathrm{ct}}_{8,5} =& \sum_{\mathrm{gen}}\left\{2x^{(1)}_{\mathrm{gen}} - \left[4x^{(2)}_{\mathrm{gen}} - x^{(1)}_{\mathrm{gen}}x^2_{\mathrm{H}}\right]c^2\right\}s^2\\ &-\frac{1}{6}\left\{9\,\mathrm{A}^c_{34} + \left[-(-2\,\mathrm{A}^c_{14}x^2_{\mathrm{H}} + 4\,\mathrm{B}^b_4 - \mathrm{B}^b_{49}s^2)\,c^2 + (\mathrm{B}^b_{44} - 2\,\mathrm{B}^b_{46}s^2)\right]c^2\right\}\frac{1}{c^2}\\ &-\frac{1}{6}\left\{-16\left[2 - c^2x^2_{\mathrm{H}}\right]c^2 + \left[2 - \mathrm{A}^c_5 x^2_{\mathrm{H}}\right]\mathrm{C}^a_0\right\}\mathrm{N_{gen}}\end{aligned}$$

$$\begin{aligned}\mathrm{M}^{\mathrm{ct}}_{8,6} =& -\sum_{\mathrm{gen}}\left\{2x^{(1)}_{\mathrm{gen}} - \left[4x^{(2)}_{\mathrm{gen}} - x^{(1)}_{\mathrm{gen}}x^2_{\mathrm{H}}\right]c^2\right\}s\,c\\ &+\frac{1}{6}\left\{\mathrm{A}^c_{35} + \left[\mathrm{B}^b_{47}s^2 - (-\mathrm{A}^c_6 x^2_{\mathrm{H}} + \mathrm{B}^b_1 - \mathrm{B}^b_8 s^2)\,c^2\right]c^2\right\}\frac{1}{s\,c}\\ &-\frac{1}{12}\left\{\left[16\,(2 - \mathrm{A}^c_5 x^2_{\mathrm{H}})\,c^2 - (-\mathrm{A}^c_4\,\mathrm{C}^a_0 x^2_{\mathrm{H}} + 2\,\mathrm{C}^a_0 + 16\,\mathrm{C}^a_{11}s^2)\right]c^2\right.\\ &\left.+2\left[(-8s^2 v^{(2)}_{\mathrm{gen}} + \mathrm{C}^a_{12})\right]s^2\right\}\frac{1}{s\,c}\,\mathrm{N_{gen}}\end{aligned}$$

$$\mathrm{M}^{\mathrm{ct}}_{8,10}(\mathrm{q}) = \left\{\mathrm{C}^a_2 + 12\,\mathrm{D}^a_2 c^2\right\}\frac{1}{c^2} \qquad \mathrm{M}^{\mathrm{ct}}_{8,11}(\mathrm{l}) = -\frac{1}{3}\left\{-12c^2x^2_{\mathrm{l}} + \mathrm{C}^a_8\right\}\frac{1}{c^2}$$

$$\mathrm{M}^{\mathrm{ct}}_{8,12}(\mathrm{u}) = -\left\{\mathrm{v}^-_{\mathrm{u}} - 12c^2x^2_{\mathrm{u}}\right\}\frac{1}{c^2} \qquad \mathrm{M}^{\mathrm{ct}}_{8,13}(\mathrm{d}) = \left\{\mathrm{v}^-_{\mathrm{d}} - 12c^2x^2_{\mathrm{d}}\right\}\frac{1}{c^2}$$

$$\mathrm{M}^{\mathrm{ct}}_{8,14}(\mathrm{l}) = \frac{1}{3}\left\{\mathrm{v}^-_{\mathrm{l}} - 12c^2x^2_{\mathrm{l}}\right\}\frac{1}{c^2} \qquad \mathrm{M}^{\mathrm{ct}}_{8,15}(\mathrm{q}) = \left\{\mathrm{C}^a_3 + 2\,\mathrm{D}^a_1 c^2\right\}\frac{1}{c^2}$$

$$\mathrm{M}^{\mathrm{ct}}_{8,16}(\mathrm{l}) = -\frac{1}{3}\left\{\mathrm{v}^-_{\mathrm{l}} - 2\,\mathrm{D}^a_0 c^2\right\}\frac{1}{c^2} \qquad \mathrm{M}^{\mathrm{ct}}_{8,17}(\mathrm{q},\mathrm{u}) = -\frac{3}{2}x^2_{\mathrm{u}}\,\mathrm{v}^-_{\mathrm{u}}$$

JHEP07(2015)175

$$\mathrm{M}^{\mathrm{ct}}_{8,18}(\mathrm{q},\mathrm{d}) = \frac{3}{2}x_{\mathrm{d}}^2\,\mathrm{v}_{\mathrm{d}}^- \qquad \mathrm{M}^{\mathrm{ct}}_{8,19}(\lambda,\mathrm{l}) = \frac{1}{2}x_{\mathrm{l}}^2\,\mathrm{v}_{\mathrm{l}}^-$$

$$\mathrm{M}^{\mathrm{ct}}_{8,20}(\mathrm{q},\mathrm{u}) = -\frac{3}{2}\frac{s}{c}\,v_{\mathrm{u}}\,x_{\mathrm{u}}^2 \qquad \mathrm{M}^{\mathrm{ct}}_{8,21}(\mathrm{q},\mathrm{d}) = -\frac{3}{2}\frac{s}{c}\,v_{\mathrm{d}}\,x_{\mathrm{d}}^2$$

$$\mathrm{M}^{\mathrm{ct}}_{8,22}(\lambda,\mathrm{l}) = -\frac{1}{2}\frac{s}{c}\,v_{\mathrm{l}}\,x_{\mathrm{l}}^2$$

- $\mathrm{M}^{\mathrm{ct}}_{9,i}$ entries

$$\mathrm{M}^{\mathrm{ct}}_{9,2} = \frac{1}{2}\sum_{\mathrm{gen}} x^{(1)}_{\mathrm{gen}} - \frac{1}{6}\left\{\mathrm{A}^c_{19} + \mathrm{B}^b_{18}\,c^2\right\}\frac{1}{c^2}$$

$$\mathrm{M}^{\mathrm{ct}}_{9,3} = \frac{1}{8}\sum_{\mathrm{gen}} x^{(1)}_{\mathrm{gen}} - \frac{1}{48}\left\{3\,\mathrm{A}^c_{23} - \mathrm{B}^b_{31}\,c^2\right\}\frac{1}{c^2}$$

$$\begin{aligned}\mathrm{M}^{\mathrm{ct}}_{9,4} = {} & \frac{1}{2}\sum_{\mathrm{gen}}\left\{c^2\,x^{(1)}_{\mathrm{gen}}\,x_{\mathrm{H}}^2 + 2\left[2\,s^2\,x^{(2)}_{\mathrm{gen}} + \mathrm{D}^a_3\right]\right\}c^2\\ & + \frac{1}{12}\left\{3\,\mathrm{A}^c_{40} - \left[(-\mathrm{A}^c_8\,x_{\mathrm{H}}^2 + 2\,\mathrm{B}^b_{51}) + (-\mathrm{B}^b_{10}\,s^2 + \mathrm{B}^b_{11})\,c^2\right]c^2\right\}\frac{1}{c^2}\\ & + \frac{1}{6}\left\{\mathrm{C}^a_1 + \left[8\,c^2\,x_{\mathrm{H}}^2 - (16 + \mathrm{C}^a_0\,x_{\mathrm{H}}^2)\right]c^2\right\}\mathrm{N_{gen}}\end{aligned}$$

$$\begin{aligned}\mathrm{M}^{\mathrm{ct}}_{9,5} = {} & \frac{1}{2}\sum_{\mathrm{gen}}\left\{2\,x^{(1)}_{\mathrm{gen}} - \left[4\,x^{(2)}_{\mathrm{gen}} - x^{(1)}_{\mathrm{gen}}\,x_{\mathrm{H}}^2\right]c^2\right\}s^2\\ & + \frac{1}{12}\left\{6\,\mathrm{A}^c_{13} - \left[(\mathrm{A}^c_8\,x_{\mathrm{H}}^2 + 2\,\mathrm{B}^b_{29}) - (4\,\mathrm{B}^b_4 - \mathrm{B}^b_9\,s^2)\,c^2\right]c^2\right\}\frac{1}{c^2}\\ & - \frac{1}{12}\left\{-16\left[2 - c^2\,x_{\mathrm{H}}^2\right]c^2 + \left[2 - \mathrm{A}^c_5\,x_{\mathrm{H}}^2\right]\mathrm{C}^a_0\right\}\mathrm{N_{gen}}\end{aligned}$$

$$\begin{aligned}\mathrm{M}^{\mathrm{ct}}_{9,6} = {} & -\frac{1}{2}\sum_{\mathrm{gen}}\left\{2\,x^{(1)}_{\mathrm{gen}} - \left[4\,x^{(2)}_{\mathrm{gen}} - x^{(1)}_{\mathrm{gen}}\,x_{\mathrm{H}}^2\right]c^2\right\}s\,c\\ & + \frac{1}{24}\left\{2\,\mathrm{A}^c_5\,\mathrm{C}^a_0 + \left[16\,\mathrm{A}^c_5\,c^2\,x_{\mathrm{H}}^2 - (\mathrm{A}^c_4\,\mathrm{C}^a_0\,x_{\mathrm{H}}^2 + 32\,\mathrm{A}^c_5)\right]c^2\right\}\frac{1}{s\,c}\,\mathrm{N_{gen}}\\ & + \frac{1}{12}\left\{2\,\mathrm{A}^c_{39} + \left[2\,\mathrm{B}^b_6\,s^2 - (-\mathrm{A}^c_6\,x_{\mathrm{H}}^2 + \mathrm{B}^b_1 - \mathrm{B}^b_8\,s^2)\,c^2\right]c^2\right\}\frac{1}{s\,c}\end{aligned}$$

$$\mathrm{M}^{\mathrm{ct}}_{9,10}(\mathrm{q}) = \left\{\mathrm{C}^a_2 + 6\,\mathrm{D}^a_2\,c^2\right\}\frac{1}{c^2} \qquad \mathrm{M}^{\mathrm{ct}}_{9,11}(\mathrm{l}) = -\frac{1}{3}\left\{\mathrm{v}_{\mathrm{l}}^+ - 6\,c^2\,x_{\mathrm{l}}^2\right\}\frac{1}{c^2}$$

$$\mathrm{M}^{\mathrm{ct}}_{9,12}(\mathrm{u}) = -\left\{\mathrm{v}_{\mathrm{u}}^- - 6\,c^2\,x_{\mathrm{u}}^2\right\}\frac{1}{c^2} \qquad \mathrm{M}^{\mathrm{ct}}_{9,13}(\mathrm{d}) = \left\{\mathrm{v}_{\mathrm{d}}^- - 6\,c^2\,x_{\mathrm{d}}^2\right\}\frac{1}{c^2}$$

$$\mathrm{M}^{\mathrm{ct}}_{9,14}(\mathrm{l}) = \frac{1}{3}\left\{\mathrm{v}_{\mathrm{l}}^- - 6\,c^2\,x_{\mathrm{l}}^2\right\}\frac{1}{c^2} \qquad \mathrm{M}^{\mathrm{ct}}_{9,15}(\mathrm{q}) = \left\{\mathrm{C}^a_3 + \mathrm{D}^a_1\,c^2\right\}\frac{1}{c^2}$$

$$\mathrm{M}^{\mathrm{ct}}_{9,16}(\mathrm{l}) = \frac{1}{3}\left\{\mathrm{v}_{\mathrm{l}}^+ + \mathrm{D}^a_0\,c^2\right\}\frac{1}{c^2} \qquad \mathrm{M}^{\mathrm{ct}}_{9,17}(\mathrm{q},\mathrm{u}) = -\frac{3}{4}x_{\mathrm{u}}^2$$

$$\mathrm{M}^{\mathrm{ct}}_{9,18}(\mathrm{q},\mathrm{d}) = \frac{3}{4}x_{\mathrm{d}}^2 \qquad \mathrm{M}^{\mathrm{ct}}_{9,19}(\lambda,\mathrm{l}) = \frac{1}{4}x_{\mathrm{l}}^2$$

- $\mathrm{M}^{\mathrm{ct}}_{10,i}$ entries

$$\mathrm{M}^{\mathrm{ct}}_{10,2} = \frac{3}{4}\,x^2_{\mathrm{D}} \qquad \mathrm{M}^{\mathrm{ct}}_{10,3} = -\frac{1}{48}\left\{7+6\,c^2\,x^2_{\mathrm{D}}\right\}\frac{1}{c^2}$$

$$\mathrm{M}^{\mathrm{ct}}_{10,4} = \frac{1}{12}\left\{7+\mathrm{E}^a_0\,c^2\right\}\frac{1}{c^2} \qquad \mathrm{M}^{\mathrm{ct}}_{10,6} = -\frac{1}{6}\,\frac{s}{c}$$

$$\mathrm{M}^{\mathrm{ct}}_{10,8}\,(\mathrm{Q}\,,\mathrm{D}) = -\frac{1}{4}\left\{1+\left[3\,x^2_{\mathrm{H}}+\mathrm{E}^a_8\right]c^2\right\}\frac{1}{c^2} \qquad \mathrm{M}^{\mathrm{ct}}_{10,10}\,(\mathrm{Q}) = -\frac{1}{4}\left\{4-\mathrm{E}^a_{12}\,c^2\right\}\frac{1}{c^2}$$

$$\mathrm{M}^{\mathrm{ct}}_{10,13}\,(\mathrm{D}) = \frac{1}{4}\left\{2+\mathrm{E}^a_{11}\,c^2\right\}\frac{1}{c^2} \qquad \mathrm{M}^{\mathrm{ct}}_{10,15}\,(\mathrm{Q}) = \frac{1}{4}\left\{4-\mathrm{E}^a_{10}\,c^2\right\}\frac{1}{c^2}$$

$$\mathrm{M}^{\mathrm{ct}}_{10,17}\,(\mathrm{Q}\,,\mathrm{U}) = \frac{3}{8}\,x^2_{\mathrm{U}} \qquad \mathrm{M}^{\mathrm{ct}}_{10,18}\,(\mathrm{Q}\,,\mathrm{D}) = -\frac{1}{16}\left\{2\,\mathrm{A}^c_{16}+3\,\mathrm{E}^a_9\,c^2\right\}\frac{1}{c^2}$$

$$\mathrm{M}^{\mathrm{ct}}_{10,21}\,(\mathrm{Q}\,,\mathrm{D}) = \frac{1}{16}\left\{2-\mathrm{E}^a_{13}\,c^2\right\}\frac{s}{c^3} \qquad \mathrm{M}^{\mathrm{ct}}_{10,23}\,(\lambda\,,1\,,\mathrm{D}\,,\mathrm{Q}) = \frac{1}{2}\sum_{\mathrm{gen}}\frac{x^3_{\mathrm{l}}}{x_{\mathrm{D}}}$$

$$\mathrm{M}^{\mathrm{ct}}_{10,24}\,(\mathrm{q}\,,\mathrm{u}\,,\mathrm{Q}\,,\mathrm{D}) = \frac{3}{2}\sum_{\mathrm{gen}}\frac{x^3_{\mathrm{u}}}{x_{\mathrm{D}}}$$

- $\mathrm{M}^{\mathrm{ct}}_{11,i}$ entries

$$\mathrm{M}^{\mathrm{ct}}_{11,2} = \frac{1}{4}\,x^2_{\mathrm{D}} \qquad \mathrm{M}^{\mathrm{ct}}_{11,3} = -\frac{1}{72}\left\{4+9\,c^2\,x^2_{\mathrm{D}}\right\}\frac{1}{c^2}$$

$$\mathrm{M}^{\mathrm{ct}}_{11,4} = \frac{1}{9}\left\{2\,\mathrm{A}^c_{41}-\mathrm{E}^a_1\,c^2\right\}\frac{1}{c^2} \qquad \mathrm{M}^{\mathrm{ct}}_{11,5} = -\frac{4}{9}\,s^4$$

$$\mathrm{M}^{\mathrm{ct}}_{11,6} = \frac{2}{9}\,\mathrm{A}^c_{25}\,s\,c \qquad \mathrm{M}^{\mathrm{ct}}_{11,8}\,(\mathrm{Q}\,,\mathrm{D}) = -\frac{1}{4}\,x^2_{\mathrm{D}}$$

$$\mathrm{M}^{\mathrm{ct}}_{11,13}\,(\mathrm{D}) = \frac{1}{6}\left\{4-\mathrm{E}^a_{12}\,c^2\right\}\frac{1}{c^2} \qquad \mathrm{M}^{\mathrm{ct}}_{11,21}\,(\mathrm{Q}\,,\mathrm{D}) = \frac{1}{4}\,\frac{s}{c}\,x^2_{\mathrm{D}}$$

- $\mathrm{M}^{\mathrm{ct}}_{12,i}$ entries

$$\mathrm{M}^{\mathrm{ct}}_{12,2} = \frac{1}{4}\,x^2_{\mathrm{D}} \qquad \mathrm{M}^{\mathrm{ct}}_{12,3} = -\frac{1}{72}\left\{1+9\,c^2\,x^2_{\mathrm{D}}\right\}\frac{1}{c^2}$$

$$\mathrm{M}^{\mathrm{ct}}_{12,4} = \frac{1}{18}\left\{\mathrm{A}^c_{42}+\mathrm{E}^a_2\,c^2\right\}\frac{1}{c^2} \qquad \mathrm{M}^{\mathrm{ct}}_{12,5} = \frac{2}{9}\,\mathrm{A}^c_9\,s^2$$

$$\mathrm{M}^{\mathrm{ct}}_{12,6} = -\frac{4}{9}\,s\,c^3 \qquad \mathrm{M}^{\mathrm{ct}}_{12,8}\,(\mathrm{Q}\,,\mathrm{D}) = -\frac{1}{4}\,x^2_{\mathrm{D}}$$

$$\mathrm{M}^{\mathrm{ct}}_{12,10}\,(\mathrm{Q}) = -\frac{1}{6}\left\{2+\mathrm{E}^a_{11}\,c^2\right\}\frac{1}{c^2} \qquad \mathrm{M}^{\mathrm{ct}}_{12,15}\,(\mathrm{Q}) = \frac{1}{6}\left\{2+\mathrm{E}^a_{14}\,c^2\right\}\frac{1}{c^2}$$

$$\mathrm{M}^{\mathrm{ct}}_{12,17}\,(\mathrm{Q}\,,\mathrm{U}) = \frac{3}{4}\,x^2_{\mathrm{U}} \qquad \mathrm{M}^{\mathrm{ct}}_{12,18}\,(\mathrm{Q}\,,\mathrm{D}) = -\frac{3}{8}\,x^2_{\mathrm{D}}$$

$$\mathrm{M}^{\mathrm{ct}}_{12,21}\,(\mathrm{Q}\,,\mathrm{D}) = -\frac{1}{8}\,\frac{s}{c}\,x^2_{\mathrm{D}}$$

- $\mathrm{M}^{\mathrm{ct}}_{13,i}$ entries

$$M^{ct}_{13,2} = \frac{3}{4} x_U^2 \qquad M^{ct}_{13,3} = \frac{1}{48} \left\{ 5 - 6 c^2 x_U^2 \right\} \frac{1}{c^2}$$

$$M^{ct}_{13,4} = -\frac{1}{12} \left\{ 5 - E^a_3 c^2 \right\} \frac{1}{c^2} \qquad M^{ct}_{13,6} = -\frac{5}{3} \frac{s}{c}$$

$$M^{ct}_{13,7}(Q,U) = \frac{1}{4} \left\{ 1 + \left[3 x_H^2 + E^a_{15} \right] c^2 \right\} \frac{1}{c^2} \qquad M^{ct}_{13,10}(Q) = \frac{1}{4} \left\{ 8 - E^a_{18} c^2 \right\} \frac{1}{c^2}$$

$$M^{ct}_{13,12}(U) = \frac{1}{4} \left\{ 2 - E^a_{17} c^2 \right\} \frac{1}{c^2} \qquad M^{ct}_{13,15}(Q) = \frac{1}{4} \left\{ 8 - E^a_{19} c^2 \right\} \frac{1}{c^2}$$

$$M^{ct}_{13,17}(Q,U) = \frac{1}{16} \left\{ 2 A^c_1 + 3 E^a_{16} c^2 \right\} \frac{1}{c^2} \qquad M^{ct}_{13,18}(Q,D) = -\frac{3}{8} x_D^2$$

$$M^{ct}_{13,20}(Q,U) = \frac{1}{16} \left\{ 10 - E^a_{20} c^2 \right\} \frac{s}{c^3} \qquad M^{ct}_{13,24}(Q,U,q,d) = \frac{3}{2} \sum_{gen} \frac{x_d^3}{x_U}$$

$$M^{ct}_{13,25}(\lambda,1,Q,U) = -\frac{1}{2} \sum_{gen} \frac{x_l^3}{x_U}$$

- $M^{ct}_{14,i}$ entries

$$M^{ct}_{14,2} = \frac{1}{4} x_U^2 \qquad M^{ct}_{14,3} = -\frac{1}{72} \left\{ 16 + 9 c^2 x_U^2 \right\} \frac{1}{c^2}$$

$$M^{ct}_{14,4} = \frac{1}{9} \left\{ 8 A^c_{41} - E^a_4 c^2 \right\} \frac{1}{c^2} \qquad M^{ct}_{14,5} = -\frac{16}{9} s^4$$

$$M^{ct}_{14,6} = \frac{8}{9} A^c_{25} s c \qquad M^{ct}_{14,7}(Q,U) = \frac{1}{4} x_U^2$$

$$M^{ct}_{14,12}(U) = -\frac{1}{6} \left\{ 8 - E^a_{18} c^2 \right\} \frac{1}{c^2} \qquad M^{ct}_{14,20}(Q,U) = \frac{1}{2} \frac{s}{c} x_U^2$$

- $M^{ct}_{15,i}$ entries

$$M^{ct}_{15,2} = \frac{1}{4} x_U^2 \qquad M^{ct}_{15,3} = -\frac{1}{72} \left\{ 1 + 9 c^2 x_U^2 \right\} \frac{1}{c^2}$$

$$M^{ct}_{15,4} = \frac{1}{18} \left\{ A^c_{43} + E^a_2 c^2 \right\} \frac{1}{c^2} \qquad M^{ct}_{15,5} = \frac{4}{9} A^c_{16} s^2$$

$$M^{ct}_{15,6} = -\frac{4}{9} A^c_4 s c \qquad M^{ct}_{15,7}(Q,U) = \frac{1}{4} x_U^2$$

$$M^{ct}_{15,10}(Q) = -\frac{1}{6} \left\{ 2 - E^a_{17} c^2 \right\} \frac{1}{c^2} \qquad M^{ct}_{15,15}(Q) = -\frac{1}{6} \left\{ 2 - E^a_{21} c^2 \right\} \frac{1}{c^2}$$

$$M^{ct}_{15,17}(Q,U) = \frac{3}{8} x_U^2 \qquad M^{ct}_{15,18}(Q,D) = -\frac{3}{4} x_D^2$$

$$M^{ct}_{15,20}(Q,U) = \frac{1}{8} \frac{s}{c} x_U^2$$

- $M^{ct}_{16,i}$ entries

$$M^{ct}_{16,2} = \frac{3}{4} x_L^2 \qquad M^{ct}_{16,3} = \frac{1}{16}\left\{11 - 2c^2 x_L^2\right\}\frac{1}{c^2}$$

$$M^{ct}_{16,4} = -\frac{1}{4}\left\{11 - E^a_5 c^2\right\}\frac{1}{c^2} \qquad M^{ct}_{16,6} = -\frac{9}{2}\frac{s}{c}$$

$$M^{ct}_{16,9}(\Lambda, L) = -\frac{1}{4}\left\{1 + \left[3x_H^2 + E^a_{22}\right]c^2\right\}\frac{1}{c^2} \qquad M^{ct}_{16,11}(L) = -\frac{3}{4}\left\{4 - E^a_{24} c^2\right\}\frac{1}{c^2}$$

$$M^{ct}_{16,14}(L) = -\frac{3}{4}\left\{2 - E^a_{23} c^2\right\}\frac{1}{c^2} \qquad M^{ct}_{16,16}(L) = \frac{3}{4}\left\{4 - E^a_{24} c^2\right\}\frac{1}{c^2}$$

$$M^{ct}_{16,19}(\Lambda, L) = -\frac{3}{16}\left\{2A^c_4 + E^a_{25} c^2\right\}\frac{1}{c^2} \qquad M^{ct}_{16,22}(\Lambda, L) = \frac{3}{16}\left\{6 - E^a_{26} c^2\right\}\frac{s}{c^3}$$

$$M^{ct}_{16,23}(\Lambda, L, d, q) = \frac{3}{2}\sum_{gen}\frac{x_d^3}{x_L} \qquad M^{ct}_{16,25}(\Lambda, L, q, u) = -\frac{3}{2}\sum_{gen}\frac{x_u^3}{x_L}$$

- $M^{ct}_{17,i}$ entries

$$M^{ct}_{17,2} = \frac{1}{4} x_L^2 \qquad M^{ct}_{17,3} = -\frac{1}{8}\left\{4 + c^2 x_L^2\right\}\frac{1}{c^2}$$

$$M^{ct}_{17,4} = \left\{2A^c_{41} - E^a_6 c^2\right\}\frac{1}{c^2} \qquad M^{ct}_{17,5} = -4s^4$$

$$M^{ct}_{17,6} = 2A^c_{25}\, s\, c \qquad M^{ct}_{17,9}(\Lambda, L) = -\frac{1}{4} x_L^2$$

$$M^{ct}_{17,14}(L) = \frac{1}{2}\left\{4 - E^a_{24} c^2\right\}\frac{1}{c^2} \qquad M^{ct}_{17,22}(\Lambda, L) = \frac{3}{4}\frac{s}{c} x_L^2$$

- $M^{ct}_{18,i}$ entries

$$M^{ct}_{18,2} = \frac{1}{4} x_L^2 \qquad M^{ct}_{18,3} = -\frac{1}{8}\left\{1 + c^2 x_L^2\right\}\frac{1}{c^2}$$

$$M^{ct}_{18,4} = \frac{1}{2}\left\{A^c_{44} + E^a_7 c^2\right\}\frac{1}{c^2} \qquad M^{ct}_{18,5} = 2A^c_5 s^2$$

$$M^{ct}_{18,6} = 4s^3 c \qquad M^{ct}_{18,9}(\Lambda, L) = -\frac{1}{4} x_L^2$$

$$M^{ct}_{18,11}(L) = \frac{1}{2}\left\{2 - E^a_{23} c^2\right\}\frac{1}{c^2} \qquad M^{ct}_{18,16}(L) = -\frac{1}{2}\left\{2 - E^a_{27} c^2\right\}\frac{1}{c^2}$$

$$M^{ct}_{18,19}(\Lambda, L) = -\frac{3}{8} x_L^2 \qquad M^{ct}_{18,22}(\Lambda, L) = \frac{3}{8}\frac{s}{c} x_L^2$$

- $M^{ct}_{20,i}$ entries

$$M^{ct}_{20,3} = -\frac{1}{8}\frac{1}{c^2} \qquad M^{ct}_{20,4} = \frac{1}{2}\left\{1 + E^a_7 c^2\right\}\frac{1}{c^2}$$

$$M^{ct}_{20,11}(L) = \frac{1}{c^2} \qquad M^{ct}_{20,16}(L) = \left\{1 + E^a_6 c^2\right\}\frac{1}{c^2}$$

$$M^{ct}_{20,19}(\Lambda, L) = -\frac{3}{4} x_L^2 \tag{C.20}$$

D Self-energies at $s = 0$

In this appendix we present the full list of bosonic self energies evaluated at $s = 0$. We have introduced a simplified notation,

$$\mathrm{B}^{\mathrm{fin}}_{0\mathrm{p}}(m_1\,,m_1) = \mathrm{B}^{\mathrm{fin}}_{0\mathrm{p}}(0\,;m_1\,,m_2) \tag{D.1}$$

etc. We introduce the following polynomials:

M where $s = \mathrm{s}_\theta$, $c = \mathrm{c}_\theta$ and

$\mathrm{M}^a_0 = 5-3c$		
$\mathrm{M}^b_0 = 1-2c$	$\mathrm{M}^b_1 = 4-9c$	$\mathrm{M}^b_2 = 7-10c$
$\mathrm{M}^b_3 = 5+4c$	$\mathrm{M}^b_4 = 1-3s$	$\mathrm{M}^b_5 = 4-c$
$\mathrm{M}^b_6 = 17+16c$	$\mathrm{M}^b_7 = 31-11c$	$\mathrm{M}^b_8 = 4-s$
$\mathrm{M}^b_9 = 1+s$	$\mathrm{M}^b_{10} = 3+c$	$\mathrm{M}^b_{11} = 15+\mathrm{M}^a_0\,c$
$\mathrm{M}^b_{12} = 17-8c$	$\mathrm{M}^b_{13} = 8-5c$	$\mathrm{M}^b_{14} = 41-24s$

$\mathrm{M}^c_0 = 1+18c$	$\mathrm{M}^c_1 = 1+4c$	$\mathrm{M}^c_2 = 1+6c^2$
$\mathrm{M}^c_3 = 1+24s^2c$	$\mathrm{M}^c_4 = 1+3\mathrm{M}^b_0\,c$	$\mathrm{M}^c_5 = 1+4\mathrm{M}^b_1\,c$
$\mathrm{M}^c_6 = 2-\mathrm{M}^b_2\,c$	$\mathrm{M}^c_7 = 3-c$	$\mathrm{M}^c_8 = 3+4c$
$\mathrm{M}^c_9 = 5+8c$	$\mathrm{M}^c_{10} = 7-38c$	$\mathrm{M}^c_{11} = c-2$
$\mathrm{M}^c_{12} = 1-40c+36sc$	$\mathrm{M}^c_{13} = 3-2\mathrm{M}^b_3\,c$	$\mathrm{M}^c_{14} = 9-8s$
$\mathrm{M}^c_{15} = 11+4c$	$\mathrm{M}^c_{16} = 1+10s$	$\mathrm{M}^c_{17} = 1+2\mathrm{M}^b_4\,s$
$\mathrm{M}^c_{18} = 1-2\mathrm{M}^b_5\,c$	$\mathrm{M}^c_{19} = 2-c$	$\mathrm{M}^c_{20} = 3-\mathrm{M}^b_6\,c$

$\mathrm{M}^c_{21} = 4+c$	$\mathrm{M}^c_{22} = 5-2c$	$\mathrm{M}^c_{23} = 6-\mathrm{M}^b_7\,c$
$\mathrm{M}^c_{24} = 7-2\mathrm{M}^b_8\,s$	$\mathrm{M}^c_{25} = 9-2\mathrm{M}^b_9\,s$	$\mathrm{M}^c_{26} = 18-11c$
$\mathrm{M}^c_{27} = 5-35c+8sc$	$\mathrm{M}^c_{28} = 39-40s$	$\mathrm{M}^c_{29} = 1+c$
$\mathrm{M}^c_{30} = 1-4sc$	$\mathrm{M}^c_{31} = 2-3\mathrm{M}^b_{10}\,c$	$\mathrm{M}^c_{32} = 3-\mathrm{M}^b_{11}\,c$
$\mathrm{M}^c_{33} = 4+3c$	$\mathrm{M}^c_{34} = 5-2\mathrm{M}^b_{12}\,c$	$\mathrm{M}^c_{35} = 9-8\mathrm{M}^b_{13}\,c$
$\mathrm{M}^c_{36} = 29-16c$	$\mathrm{M}^c_{37} = 37-48s$	$\mathrm{M}^c_{38} = 37-2\mathrm{M}^b_{14}\,s$
$\mathrm{M}^c_{39} = 49-34c$	$\mathrm{M}^c_{40} = 79-40c$	

N

$\mathrm{N}_0 = 1-3*\mathrm{v_d}$	$\mathrm{N}_1 = 3-\mathrm{v_l}$	$\mathrm{N}_2 = 5-3*\mathrm{v_u}$
$\mathrm{N}_3 = 20-3*v^{(2)}_{\mathrm{gen}}$	$\mathrm{N}_4 = 1+\mathrm{v}^2_{\mathrm{u}}$	$\mathrm{N}_5 = 1+\mathrm{v}^2_{\mathrm{d}}$
$\mathrm{N}_6 = 1+\mathrm{v}^2_{\mathrm{l}}$	$\mathrm{N}_7 = 9+v^{(1)}_{\mathrm{gen}}$	$\mathrm{N}_8 = 38+3v^{(1)}_{\mathrm{gen}}$
$\mathrm{N}_9 = 1-\mathrm{v_l}$	$\mathrm{N}_{10} = 1-\mathrm{v_u}$	$\mathrm{N}_{11} = 1+\mathrm{v_u}$
$\mathrm{N}_{12} = 1-\mathrm{v_d}$	$\mathrm{N}_{13} = 1+\mathrm{v_d}$	$\mathrm{N}_{14} = 1-3\mathrm{v_l}$
$\mathrm{N}_{15} = 1+\mathrm{v_l}$	$\mathrm{N}_{16} = 2-\mathrm{v_u}$	$\mathrm{N}_{17} = 2+\mathrm{v_u}+\mathrm{v_d}$
$\mathrm{N}_{18} = 2-\mathrm{v_d}$	$\mathrm{N}_{19} = 2-\mathrm{v_l}$	$\mathrm{N}_{20} = 2+3\mathrm{v_l}$
$\mathrm{N}_{21} = 3-5\mathrm{v_u}$	$\mathrm{N}_{22} = 3-\mathrm{v_d}$	$\mathrm{N}_{23} = 3+\mathrm{v_l}$
$\mathrm{N}_{24} = 4+\mathrm{v_u}+\mathrm{v_d}$	$\mathrm{N}_{25} = 9-5\mathrm{v_u}-\mathrm{v_d}-3\mathrm{v_l}$	$\mathrm{N}_{26} = 10+3\mathrm{v_l}$
$\mathrm{N}_{27} = 38-15\mathrm{v_u}-3\mathrm{v_d}-9\mathrm{v_l}$	$\mathrm{N}_{28} = \mathrm{v_u}-\mathrm{v_d}$	

JHEP07(2015)175

O

$$\mathrm{O}_0 = x_{\mathrm{l}}^2 + 3x_{\mathrm{d}}^2 + 3x_{\mathrm{u}}^2 \quad \mathrm{O}_1 = x_{\mathrm{d}}^2 + x_{\mathrm{u}}^2 \quad \mathrm{O}_2 = x_{\mathrm{d}}^2 - 3x_{\mathrm{u}}^2$$
$$\mathrm{O}_3 = 3x_{\mathrm{d}}^2 - x_{\mathrm{u}}^2 \quad \mathrm{O}_4 = (x_{\mathrm{u}}^2 - x_{\mathrm{d}}^2)^2$$

P

$$\mathrm{P}_0 = 1 - x_{\mathrm{H}}^2 \quad \mathrm{P}_1 = 2 - x_{\mathrm{H}}^2 - x_{\mathrm{H}}^4 \quad \mathrm{P}_2 = 3 - 2x_{\mathrm{H}}^2 - x_{\mathrm{H}}^4$$
$$\mathrm{P}_3 = 6 - 7x_{\mathrm{H}}^2 + x_{\mathrm{H}}^4 \quad \mathrm{P}_4 = 10 - 11x_{\mathrm{H}}^2 + x_{\mathrm{H}}^4 \quad \mathrm{P}_5 = 2 - 5x_{\mathrm{H}}^2 + 3x_{\mathrm{H}}^4$$
$$\mathrm{P}_6 = 12 - 13x_{\mathrm{H}}^2 + x_{\mathrm{H}}^4 \quad \mathrm{P}_7 = 12 - 11x_{\mathrm{H}}^2 - x_{\mathrm{H}}^4 \quad \mathrm{P}_8 = 8 - 5x_{\mathrm{H}}^2 - 3x_{\mathrm{H}}^4$$
$$\mathrm{P}_9 = 1 - 3x_{\mathrm{H}}^2 + 3x_{\mathrm{H}}^4 - x_{\mathrm{H}}^6 \quad \mathrm{P}_{10} = 42 - 41x_{\mathrm{H}}^2 - x_{\mathrm{H}}^4 \quad \mathrm{P}_{11} = 1 - x_{\mathrm{H}}^4$$
$$\mathrm{P}_{12} = 7 - 6x_{\mathrm{H}}^2 \quad \mathrm{P}_{13} = 9 - x_{\mathrm{H}}^2 \quad \mathrm{P}_{14} = 20 - 21x_{\mathrm{H}}^2 + x_{\mathrm{H}}^4$$
$$\mathrm{P}_{15} = 5 - 6x_{\mathrm{H}}^2 + x_{\mathrm{H}}^4 \quad \mathrm{P}_{16} = 78 - 79x_{\mathrm{H}}^2 \quad \mathrm{P}_{17} = 10 + 3x_{\mathrm{H}}^2$$
$$\mathrm{P}_{18} = 11 - 18x_{\mathrm{H}}^2 + 7x_{\mathrm{H}}^4 \quad \mathrm{P}_{19} = 20 - 23x_{\mathrm{H}}^2 + 3x_{\mathrm{H}}^4 \quad \mathrm{P}_{20} = 32 - 45x_{\mathrm{H}}^2$$
$$\mathrm{P}_{21} = 80 - 79x_{\mathrm{H}}^2$$

With their help we derive the vector-vector transitions at $s = 0$

- A self-energy

$$\Pi^{(4)}_{\mathrm{AA}\,;0}(0) = -\frac{32}{9}\,s^2\,\mathrm{N_{gen}}\,(1 - \mathrm{L_R}) + \frac{1}{3}\,s^2\,(7 - 9\,\mathrm{L_R})$$

$$\Pi^{(4)}_{\mathrm{AA}\,;1}(0) = 3\,s^2\,a_0^{\mathrm{fin}}(M) - \frac{4}{3}\sum_{\mathrm{gen}} s^2\,a_0^{\mathrm{fin}}(M_{\mathrm{l}}) - \frac{16}{9}\sum_{\mathrm{gen}} s^2\,a_0^{\mathrm{fin}}(M_{\mathrm{u}}) - \frac{4}{9}\sum_{\mathrm{gen}} s^2\,a_0^{\mathrm{fin}}(M_{\mathrm{d}})$$

$$\Pi^{(4)}_{\mathrm{AA}\,;2}(0) = 0$$

$$\begin{aligned}\Pi^{(6)}_{\mathrm{AA}\,;0}(0) = &-\frac{16}{9}\,\mathrm{N_{gen}}\,a_{\phi\mathrm{WAD}}\,(1 - \mathrm{L_R}) - \frac{1}{6}\,c^2\,a_{\phi\mathrm{D}}\,(7 - 9\,\mathrm{L_R}) \\ &+ \frac{1}{2}\left[s\,a_{\phi\mathrm{WA}} - \frac{c^2}{x_{\mathrm{H}}^2 - 1}\,\mathrm{P}_2\,a_{\phi\mathrm{B}} + \frac{s\,c^3}{x_{\mathrm{H}}^2 - 1}\,\mathrm{P}_3\,a_{\phi\mathrm{WB}} + (\mathrm{P}_1\,a_{\phi\mathrm{B}} + \mathrm{P}_4\,a_{\phi\mathrm{W}})\,\frac{s^2\,c^2}{x_{\mathrm{H}}^2 - 1}\right]\frac{\mathrm{L_R}}{c^2} \\ &+ \frac{2}{3}\,(c\,a_{\phi\mathrm{WB}} + 7\,s\,a_{\phi\mathrm{W}})\,s - 2\sum_{\mathrm{gen}}(a_{\mathrm{d\,WB}}\,x_{\mathrm{d}}^2 - 2\,a_{\mathrm{u\,WB}}\,x_{\mathrm{u}}^2 + a_{\mathrm{l\,WB}}\,x_{\mathrm{l}}^2)\,s\,(1 - \mathrm{L_R})\end{aligned}$$

$$\begin{aligned}\Pi^{(6)}_{\mathrm{AA}\,;1}(0) = &\frac{1}{2}\,\frac{x_{\mathrm{H}}^2}{x_{\mathrm{H}}^2 - 1}\,\mathrm{P}_0\,a_{\mathrm{AA}}\,a_0^{\mathrm{fin}}(M_{\mathrm{H}}) - \frac{1}{2}\,\frac{1}{c^2}\,a_{\mathrm{AA}}\,a_0^{\mathrm{fin}}(M_0) \\ &- \frac{1}{2}\left[2\,c^2\,a_{\phi\mathrm{B}} + 3\,c^2\,a_{\phi\mathrm{D}} - 2\,(3\,c\,a_{\phi\mathrm{WB}} + 5\,s\,a_{\phi\mathrm{W}})\,s\right]a_0^{\mathrm{fin}}(M) - \frac{2}{9}\sum_{\mathrm{gen}}(a_{\phi\mathrm{WAD}} + 9\,s\,a_{\mathrm{d\,WB}}\,x_{\mathrm{d}}^2)\,a_0^{\mathrm{fin}}(M_{\mathrm{d}}) \\ &- \frac{2}{3}\sum_{\mathrm{gen}}(a_{\phi\mathrm{WAD}} + 3\,s\,a_{\mathrm{l\,WB}}\,x_{\mathrm{l}}^2)\,a_0^{\mathrm{fin}}(M_{\mathrm{l}}) - \frac{4}{9}\sum_{\mathrm{gen}}(2\,a_{\phi\mathrm{WAD}} - 9\,s\,a_{\mathrm{u\,WB}}\,x_{\mathrm{u}}^2)\,a_0^{\mathrm{fin}}(M_{\mathrm{u}})\end{aligned}$$

$$\Pi^{(6)}_{\mathrm{AA}\,;2}(0) = 0$$

JHEP07(2015)175

- Z−A transition

$$\Pi^{(4)}_{\mathrm{ZA}\,;0}(0) = -\frac{1}{3}\,\frac{s}{c}\,\mathrm{N_{gen}}\,v^{(2)}_{\mathrm{gen}}\,(1-\mathrm{L_R}) - \frac{1}{6}\,\frac{s}{c}\,(1+\mathrm{L_R}) + \frac{1}{3}\,s\,c\,(7-9\,\mathrm{L_R})$$

$$\begin{aligned}\Pi^{(4)}_{\mathrm{ZA}\,;1}(0) &= \frac{1}{6}\,\frac{s}{c}\,\mathrm{M}^c_0\,a^{\mathrm{fin}}_0\,(M) - \frac{1}{3}\sum_{\mathrm{gen}}\frac{s}{c}\,\mathrm{v_l}\,a^{\mathrm{fin}}_0\,(M_{\mathrm{l}}) \\ &\quad -\frac{2}{3}\sum_{\mathrm{gen}}\frac{s}{c}\,\mathrm{v_u}\,a^{\mathrm{fin}}_0\,(M_{\mathrm{u}}) - \frac{1}{3}\sum_{\mathrm{gen}}\frac{s}{c}\,\mathrm{v_d}\,a^{\mathrm{fin}}_0\,(M_{\mathrm{d}})\end{aligned}$$

$$\Pi^{(4)}_{\mathrm{ZA}\,;2}(0) = 0$$

$$\begin{aligned}\Pi^{(6)}_{\mathrm{ZA}\,;0}(0) &= \frac{2}{3}\,\frac{1}{s}\,c\,a_{\phi\mathrm{D}}\,(1-\mathrm{L_R}) - \frac{1}{24}\,\frac{1}{s\,c}\,a_{\phi\mathrm{D}}\,(1+\mathrm{L_R}) - \frac{1}{6}\,\frac{1}{s}\,c^3\,a_{\phi\mathrm{D}}\,(7-9\,\mathrm{L_R}) \\ &\quad -\frac{1}{12}\Big[3\,\mathrm{M}^c_3\,a_{\phi\mathrm{WB}} - 2\,(-3\,a_{\phi\mathrm{B}} + a_{\phi\mathrm{W}} - 36\,s^2\,c^2\,a^{(a)}_{\phi\mathrm{WB}})\,s\,c - 6\,(\mathrm{P}_1\,a_{\phi\mathrm{B}} + \mathrm{P}_4\,a_{\phi\mathrm{W}})\,\frac{s\,c^3}{x^2_{\mathrm{H}}-1} \\ &\quad -(\mathrm{P}_5 - 6\,\mathrm{P}_6\,s^2)\,\frac{c^2}{x^2_{\mathrm{H}}-1}\,a_{\phi\mathrm{WB}}\Big]\,\frac{\mathrm{L_R}}{c^2} \\ &\quad -\frac{1}{6}\Big[\mathrm{M}^c_6\,a_{\phi\mathrm{WA}} + \mathrm{M}^c_{10}\,s\,c\,a_{\phi\mathrm{WZ}} - 28\,s^3\,c\,a_{\phi\mathrm{B}}\,c\Big]\,\frac{1}{c} \\ &\quad +\frac{1}{36}\Big\{\Big[3\,c\,a_{\phi\mathrm{D}}\,v^{(2)}_{\mathrm{gen}} - 4\,(3\,a_{\phi\mathrm{WB}}\,v^{(2)}_{\mathrm{gen}} - 32\,(-c\,a_{\phi\mathrm{WZ}} + s\,a_{\phi\mathrm{WAB}})\,s\,c)\,s\Big]\,c \\ &\quad +4\,(\mathrm{N}_3\,a_{\phi\mathrm{W}} - \mathrm{M}^c_9\,a_{\phi\mathrm{D}})\,s^2\Big\}\,\frac{\mathrm{N_{gen}}}{s\,c}\,(1-\mathrm{L_R}) \\ &\quad -\frac{1}{12}\sum_{\mathrm{gen}}\Big\{-3\,\Big[-(a_{\mathrm{l\,WB}}\,\mathrm{v_l} + 4\,s\,c\,a_{\mathrm{l\,BW}})\,x^2_{\mathrm{l}} - (3\,\mathrm{v_d}\,a_{\mathrm{d\,WB}} + 4\,s\,c\,a_{\mathrm{d\,BW}})\,x^2_{\mathrm{d}} + (3\,\mathrm{v_u}\,a_{\mathrm{u\,WB}} \\ &\quad +8\,s\,c\,a_{\mathrm{u\,BW}})\,x^2_{\mathrm{u}}\Big] + 8\,(a_{\phi\mathrm{l\,V}} + a_{\phi\mathrm{d\,V}} + 2\,a_{\phi\mathrm{u\,V}})\,s\Big\}\,\frac{1}{c}\,(1-\mathrm{L_R})\end{aligned}$$

$$\begin{aligned}\Pi^{(6)}_{\mathrm{ZA}\,;1}(0) &= \frac{1}{4}\,\frac{x^2_{\mathrm{H}}}{x^2_{\mathrm{H}}-1}\,\mathrm{P}_0\,a_{\mathrm{AZ}}\,a^{\mathrm{fin}}_0\,(M_{\mathrm{H}}) - \frac{1}{4}\,\frac{1}{c^2}\,a_{\mathrm{AZ}}\,a^{\mathrm{fin}}_0\,(M_0) \\ &\quad +\frac{1}{24}\,(8\,\mathrm{M}^c_2\,s^2\,a_{\mathrm{AA}} - 8\,\mathrm{M}^c_4\,s\,c\,a_{\mathrm{AZ}} + \mathrm{M}^c_5\,a_{\phi\mathrm{D}} + 48\,\mathrm{M}^c_7\,s^2\,c^2\,a_{\mathrm{ZZ}})\,\frac{1}{s\,c}\,a^{\mathrm{fin}}_0\,(M) \\ &\quad -\frac{1}{12}\sum_{\mathrm{gen}}\Big\{-\Big[c^2\,a_{\phi\mathrm{D}}\,\mathrm{v_l} - 4\,(c\,a_{\phi\mathrm{WB}}\,\mathrm{v_l} + 2\,(a_{\phi\mathrm{l\,V}} + 2\,c^3\,a_{\phi\mathrm{WZ}} - 2\,s\,c^2\,a_{\phi\mathrm{WAB}})\,s)\,s\Big] \\ &\quad +3\,(a_{\mathrm{l\,WB}}\,\mathrm{v_l} + 4\,s\,c\,a_{\mathrm{l\,BW}})\,s\,x^2_{\mathrm{l}} - (4\,\mathrm{N}_1\,a_{\phi\mathrm{W}} - \mathrm{M}^c_8\,a_{\phi\mathrm{D}})\,s^2\Big\}\,\frac{1}{s\,c}\,a^{\mathrm{fin}}_0\,(M_{\mathrm{l}}) \\ &\quad -\frac{1}{36}\sum_{\mathrm{gen}}\Big\{-\Big[3\,c^2\,\mathrm{v_d}\,a_{\phi\mathrm{D}} - 4\,(3\,c\,\mathrm{v_d}\,a_{\phi\mathrm{WB}} + 2\,(3\,a_{\phi\mathrm{d\,V}} + 2\,c^3\,a_{\phi\mathrm{WZ}} - 2\,s\,c^2\,a_{\phi\mathrm{WAB}})\,s)\,s\Big] \\ &\quad +9\,(3\,\mathrm{v_d}\,a_{\mathrm{d\,WB}} + 4\,s\,c\,a_{\mathrm{d\,BW}})\,s\,x^2_{\mathrm{d}} - (4\,\mathrm{N}_0\,a_{\phi\mathrm{W}} - \mathrm{M}^c_1\,a_{\phi\mathrm{D}})\,s^2\Big\}\,\frac{1}{s\,c}\,a^{\mathrm{fin}}_0\,(M_{\mathrm{d}}) \\ &\quad +\frac{1}{36}\sum_{\mathrm{gen}}\Big\{2\,\Big[3\,c^2\,\mathrm{v_u}\,a_{\phi\mathrm{D}} - 4\,(3\,c\,\mathrm{v_u}\,a_{\phi\mathrm{WB}} + 2\,(3\,a_{\phi\mathrm{u\,V}} + 4\,c^3\,a_{\phi\mathrm{WZ}} - 4\,s\,c^2\,a_{\phi\mathrm{WAB}})\,s)\,s\Big] \\ &\quad +9\,(3\,\mathrm{v_u}\,a_{\mathrm{u\,WB}} + 8\,s\,c\,a_{\mathrm{u\,BW}})\,s\,x^2_{\mathrm{u}} + 2\,(4\,\mathrm{N}_2\,a_{\phi\mathrm{W}} - \mathrm{M}^c_9\,a_{\phi\mathrm{D}})\,s^2\Big\}\,\frac{1}{s\,c}\,a^{\mathrm{fin}}_0\,(M_{\mathrm{u}})\end{aligned}$$

$$\Pi^{(6)}_{\mathrm{ZA}\,;2}(0) = 0$$

- Z self-energy

$$\Delta^{(4)}_{ZZ;0}(0) = -\frac{1}{6}\frac{1}{c^4}(1-6\,L_R)+2\,\frac{L_R}{c^2} + \frac{1}{6}\frac{1}{c^2}\frac{1}{x_H^2-1}P_7+\frac{1}{2}\sum_{gen}\frac{1}{c^2}O_0(1-L_R)$$

$$\Delta^{(4)}_{ZZ;1}(0) = -2\,\frac{1}{c^2}a_0^{fin}(M)+\frac{1}{2}\sum_{gen}\frac{x_l^2}{c^2}a_0^{fin}(M_l)+\frac{3}{2}\sum_{gen}\frac{x_u^2}{c^2}a_0^{fin}(M_u) + \frac{3}{2}\sum_{gen}\frac{x_d^2}{c^2}a_0^{fin}(M_d) - \frac{2}{3}\left(c^2-\frac{1}{1-c^2x_H^2}M^c_{11}\right)\frac{1}{c^6}a_0^{fin}(M_H)-\frac{1}{3}\left(c^2+2\,\frac{1}{1-c^2x_H^2}M^c_{11}\right)\frac{1}{c^6}a_0^{fin}(M_0)$$

$$\Delta^{(4)}_{ZZ;2}(0) = -\frac{1}{12}\left[1+(2\,P_0-P_0\,c^2x_H^2)\,\frac{c^2}{x_H^2-1}\,x_H^2\right]\frac{1}{c^6}B^{fin}_{0p}(M_H\,,M_0)$$

$$\Delta^{(6)}_{ZZ;0}(0) = -\frac{1}{8}\frac{1}{x_H^2-1}P_8\,a_{\phi D}\frac{L_R}{c^2}-\frac{1}{24}(4\,a_{\phi\Box}+a_{\phi D})\frac{1}{c^4}(2-9\,L_R) + \frac{1}{12}(4\,P_0\,x_H^2\,a_{\phi\Box}+P_7\,a_{\phi D})\frac{1}{c^2}\frac{1}{x_H^2-1} + \frac{1}{4}\sum_{gen}(24\,x_d^2\,a_{\phi d}-24\,x_u^2\,a_{\phi u}+8\,x_l^2\,a_{\phi l\,A}-O_0\,a_{\phi D}+12\,O_1\,a_{\phi u\,VA})\frac{1}{c^2}(1-L_R)$$

$$\Delta^{(6)}_{ZZ;1}(0) = -\frac{1}{c^2}a_{\phi D}\,a_0^{fin}(M) + \frac{1}{24}\left[9\,\frac{c^4}{x_H^2-1}P_0\,a_{\phi D}\,x_H^2-8\,(4\,a_{\phi\Box}+a_{\phi D})\,c^2+8\,(4\,a_{\phi\Box}+a_{\phi D})\,\frac{1}{1-c^2x_H^2}M^c_{11}\right]\frac{1}{c^6}a_0^{fin}(M_H) - \frac{1}{24}\left[(4\,a_{\phi\Box}+a_{\phi D})\,c^2+8\,(4\,a_{\phi\Box}+a_{\phi D})\,\frac{1}{1-c^2x_H^2}M^c_{11}\right]\frac{1}{c^6}a_0^{fin}(M_0) + \frac{1}{4}\sum_{gen}(8\,a_{\phi l\,A}-a_{\phi D})\,\frac{x_l^2}{c^2}a_0^{fin}(M_l)+\frac{3}{4}\sum_{gen}(8\,a_{\phi d\,A}-a_{\phi D})\,\frac{x_d^2}{c^2}a_0^{fin}(M_d) + \frac{3}{4}\sum_{gen}(8\,a_{\phi u\,A}-a_{\phi D})\,\frac{x_u^2}{c^2}a_0^{fin}(M_u)$$

$$\Delta^{(6)}_{ZZ;2}(0) = -\frac{1}{24}\left[(4\,a_{\phi\Box}+a_{\phi D})+(4\,a_{\phi\Box}+a_{\phi D})\,(2\,P_0-P_0\,c^2x_H^2)\,\frac{c^2}{x_H^2-1}\,x_H^2\right]\frac{1}{c^6}B^{fin}_{0p}(M_H\,,M_0)$$

$$\Omega^{(4)}_{ZZ;0}(0) = \frac{2}{3}(3-5\,L_R)-\frac{1}{3}s^2(7-9\,L_R)+\frac{1}{36}\frac{1}{c^2}(11+6\,L_R) + \frac{1}{12}\frac{N_{gen}}{c^2}N_7\,L_R-\frac{1}{36}(N_8+6\,L_{ir})\frac{N_{gen}}{c^2}$$

$$\Omega^{(4)}_{ZZ;1}(0) = -\frac{1}{12}\frac{1}{c^2}M^c_{12}\,a_0^{fin}(M)-\frac{1}{12}\frac{1}{c^6}\frac{1}{1-c^2x_H^2}a_0^{fin}(M_0) - \frac{1}{12}\sum_{gen}\frac{1}{c^2}N_6\,a_0^{fin}(M_l)-\frac{1}{4}\sum_{gen}\frac{1}{c^2}N_4\,a_0^{fin}(M_u) - \frac{1}{4}\sum_{gen}\frac{1}{c^2}N_5\,a_0^{fin}(M_d)+\frac{1}{12}\left(-c^4+\frac{1}{1-c^2x_H^2}\right)\frac{1}{c^6}a_0^{fin}(M_H)$$

$$
\begin{aligned}
\Omega^{(4)}_{\mathrm{ZZ}\,;2}(0) = {}& \frac{1}{24}\Bigl[1+(2\,\mathrm{P}_0-\mathrm{P}_0\,c^2\,x_{\mathrm{H}}^2)\,\frac{c^2}{x_{\mathrm{H}}^2-1}\,x_{\mathrm{H}}^2\Bigr]\,\frac{1}{c^6}\,\mathrm{B}^{\mathrm{fin}}_{0\mathrm{s}}\left(M_{\mathrm{H}}\,,M_0\right) \\
& -\frac{1}{6}\,(5+\frac{c^2}{x_{\mathrm{H}}^2-1}\,\mathrm{P}_0\,x_{\mathrm{H}}^2)\,\frac{1}{c^4}\,\mathrm{B}^{\mathrm{fin}}_{0\mathrm{p}}\left(M_{\mathrm{H}}\,,M_0\right)
\end{aligned}
$$

$$
\begin{aligned}
\Omega^{(6)}_{\mathrm{ZZ}\,;0}(0) = {}& -\frac{1}{6}\,\mathrm{N_{gen}}\,a_{\phi\mathrm{D}}\,v^{(2)}_{\mathrm{gen}}\,(1-\mathrm{L_R})+\frac{1}{18}\,\frac{1}{c^2}\,a_{\phi\Box}\,(2+3\,\mathrm{L_R}) \\
& +\frac{1}{3}\,a_{\phi\mathrm{D}}\,(3-5\,\mathrm{L_R})-\frac{1}{6}\,s^2\,a_{\phi\mathrm{D}}\,(7-9\,\mathrm{L_R}) \\
& +\frac{1}{72}\,\frac{1}{c^2}\,a_{\phi\mathrm{D}}\,(11+6\,\mathrm{L_R})-\frac{1}{24}\,\frac{\mathrm{N_{gen}}}{c^2}\,\mathrm{N}_{25}\,\mathrm{L_R}\,a_{\phi\mathrm{D}} \\
& -\sum_{\mathrm{gen}}(1-\mathrm{L_R})\,\frac{1}{c^2}\,\mathrm{N}_{28}\,a^{(1)}_{\phi\mathrm{q}}+\frac{1}{72}\,(\mathrm{N}_{27}+6\,\mathrm{L_{ir}})\,\frac{\mathrm{N_{gen}}}{c^2}\,a_{\phi\mathrm{D}} \\
& -\frac{1}{3}\,\sum_{\mathrm{gen}}\Bigl[3\,\mathrm{N}_{10}\,a_{\phi\mathrm{u}}-3\,\mathrm{N}_{12}\,a_{\phi\mathrm{d}}-3\,\mathrm{N}_{17}\,a^{(3)}_{\phi\mathrm{q}}-\mathrm{N}_{23}\,a^{(3)}_{\phi\mathrm{l}}-(a^{(3)}_{\phi\mathrm{l}}-a_{\phi\mathrm{l\,V}})\,\mathrm{N}_9\Bigr]\,\frac{\mathrm{L_R}}{c^2} \\
& +\frac{1}{9}\,\sum_{\mathrm{gen}}\Bigl[9\,\mathrm{N}_{16}\,a_{\phi\mathrm{u}}-9\,\mathrm{N}_{18}\,a_{\phi\mathrm{d}}-3\,\mathrm{N}_{19}\,a_{\phi\mathrm{l}}-\mathrm{N}_{20}\,a^{(3)}_{\phi\mathrm{l}}-9\,\mathrm{N}_{24}\,a^{(3)}_{\phi\mathrm{q}}+\mathrm{N}_{26}\,a^{(1)}_{\phi\mathrm{l}}-3\,\mathrm{L_{ir}}\,a_{\phi\mathrm{v}}\Bigr]\,\frac{1}{c^2}
\end{aligned}
$$

$$
\begin{aligned}
\Omega^{(6)}_{\mathrm{ZZ}\,;1}(0) = {}& -\frac{1}{24}\,\frac{1}{c^2}\,\mathrm{M}^c_{12}\,a_{\phi\mathrm{D}}\,a^{\mathrm{fin}}_0\,(M) \\
& +\frac{1}{24}\,\Bigl[-(4\,a_{\phi\Box}+a_{\phi\mathrm{D}})\,c^4+(4\,a_{\phi\Box}+a_{\phi\mathrm{D}})\,\frac{1}{1-c^2\,x_{\mathrm{H}}^2}\Bigr]\,\frac{1}{c^6}\,a^{\mathrm{fin}}_0\left(M_{\mathrm{H}}\right) \\
& -\frac{1}{24}\,(4\,a_{\phi\Box}+a_{\phi\mathrm{D}})\,\frac{1}{c^6}\,\frac{1}{1-c^2\,x_{\mathrm{H}}^2}\,a^{\mathrm{fin}}_0\,(M_0) \\
& -\frac{1}{24}\,\sum_{\mathrm{gen}}\Bigl[4\,c^2\,a_{\phi\mathrm{D}}\,\mathrm{v_l}+(8\,\mathrm{N}_9\,a_{\phi\mathrm{l}}-\mathrm{N}_{14}\,a_{\phi\mathrm{D}}+4\,\mathrm{N}_{15}\,a_{\phi\mathrm{l\,VA}})\Bigr]\,\frac{1}{c^2}\,a^{\mathrm{fin}}_0\left(M_{\mathrm{l}}\right) \\
& -\frac{1}{24}\,\sum_{\mathrm{gen}}\Bigl[4\,c^2\,\mathrm{v_d}\,a_{\phi\mathrm{D}}+(24\,\mathrm{N}_{12}\,a_{\phi\mathrm{d}}+12\,\mathrm{N}_{13}\,a_{\phi\mathrm{d\,VA}}-\mathrm{N}_{22}\,a_{\phi\mathrm{D}})\Bigr]\,\frac{1}{c^2}\,a^{\mathrm{fin}}_0\left(M_{\mathrm{d}}\right) \\
& -\frac{1}{24}\,\sum_{\mathrm{gen}}\Bigl[8\,c^2\,\mathrm{v_u}\,a_{\phi\mathrm{D}}-(24\,\mathrm{N}_{10}\,a_{\phi\mathrm{u}}-12\,\mathrm{N}_{11}\,a_{\phi\mathrm{u\,VA}}+\mathrm{N}_{21}\,a_{\phi\mathrm{D}})\Bigr]\,\frac{1}{c^2}\,a^{\mathrm{fin}}_0\left(M_{\mathrm{u}}\right)
\end{aligned}
$$

$$
\begin{aligned}
\Omega^{(6)}_{\mathrm{ZZ}\,;2}(0) = {}& \frac{1}{48}\,\Bigl[(4\,a_{\phi\Box}+a_{\phi\mathrm{D}})+(4\,a_{\phi\Box}+a_{\phi\mathrm{D}})\,(2\,\mathrm{P}_0-\mathrm{P}_0\,c^2\,x_{\mathrm{H}}^2)\,\frac{c^2}{x_{\mathrm{H}}^2-1}\,x_{\mathrm{H}}^2\Bigr]\,\frac{1}{c^6}\,\mathrm{B}^{\mathrm{fin}}_{0\mathrm{s}}\left(M_{\mathrm{H}}\,,M_0\right) \\
& -\frac{1}{12}\,\Bigl[5\,(4\,a_{\phi\Box}+a_{\phi\mathrm{D}})+(4\,a_{\phi\Box}+a_{\phi\mathrm{D}})\,\frac{c^2}{x_{\mathrm{H}}^2-1}\,\mathrm{P}_0\,x_{\mathrm{H}}^2\Bigr]\,\frac{1}{c^4}\,\mathrm{B}^{\mathrm{fin}}_{0\mathrm{p}}\left(M_{\mathrm{H}}\,,M_0\right)
\end{aligned}
$$

- W self-energy

$$
\Delta^{(4)}_{\mathrm{WW}\,;0}(0) = 2\,\mathrm{L_R}-\frac{1}{6}\,\frac{1}{c^2}\,(1-6\,\mathrm{L_R})+\frac{1}{6}\,\frac{1}{x_{\mathrm{H}}^2-1}\,\mathrm{P}_{10}+\frac{1}{6}\,\sum_{\mathrm{gen}}\mathrm{O}_0\,(2-3\,\mathrm{L_R})
$$

$$
\begin{aligned}
\Delta^{(4)}_{\mathrm{WW}\,;1}(0) = {}& -\frac{2}{3}\,\frac{x_{\mathrm{H}}^2}{x_{\mathrm{H}}^2-1}\,a^{\mathrm{fin}}_0\left(M_{\mathrm{H}}\right)-\frac{1}{3}\,\frac{1}{s^2\,c^2}\,\mathrm{M}^c_{13}\,a^{\mathrm{fin}}_0\,(M_0) \\
& -\frac{1}{2}\,\sum_{\mathrm{gen}}\frac{x_{\mathrm{u}}^2}{x_{\mathrm{u}}^2-x_{\mathrm{d}}^2}\,\mathrm{O}_2\,a^{\mathrm{fin}}_0\left(M_{\mathrm{u}}\right)-\frac{1}{2}\,\sum_{\mathrm{gen}}\frac{x_{\mathrm{d}}^2}{x_{\mathrm{u}}^2-x_{\mathrm{d}}^2}\,\mathrm{O}_3\,a^{\mathrm{fin}}_0\left(M_{\mathrm{d}}\right) \\
& +\frac{1}{2}\,\sum_{\mathrm{gen}}x_{\mathrm{l}}^2\,a^{\mathrm{fin}}_0\left(M_{\mathrm{l}}\right)+\frac{1}{3}\,(2\,\frac{s^2}{x_{\mathrm{H}}^2-1}-\mathrm{M}^c_{15})\,\frac{1}{s^2}\,a^{\mathrm{fin}}_0\,(M)
\end{aligned}
$$

$$\Delta^{(4)}_{\mathrm{WW};2}(0) = -\frac{1}{12}\,\frac{s^4}{c^4}\,\mathrm{M}^c_{14}\,\mathrm{B}^{\mathrm{fin}}_{0\mathrm{p}}\,(M\,,M_0) + \frac{1}{12}\,\frac{1}{x^2_{\mathrm{H}}-1}\,\mathrm{P}_9\,\mathrm{B}^{\mathrm{fin}}_{0\mathrm{p}}\left(M\,,M_{\mathrm{H}}\right)$$
$$-\frac{2}{3}\,s^2\,\mathrm{B}^{\mathrm{fin}}_{0\mathrm{p}}\,(0\,,M) + \frac{1}{2}\sum_{\mathrm{gen}}\mathrm{O}_4\,\mathrm{B}^{\mathrm{fin}}_{0\mathrm{p}}\left(M_{\mathrm{u}}\,,M_{\mathrm{d}}\right) + \frac{1}{6}\sum_{\mathrm{gen}} x^4_{\mathrm{l}}\,\mathrm{B}^{\mathrm{fin}}_{0\mathrm{p}}\left(0\,,M_{\mathrm{l}}\right)$$

$$\Delta^{(6)}_{\mathrm{WW};0}(0) = -\frac{1}{3}\,\frac{1}{c^2}\,a_{\phi\mathrm{W}}\,(1-6\,\mathrm{L_R}) + \frac{1}{12}\,\frac{1}{c^2}\,a_{\phi\mathrm{D}}\,(11-15\,\mathrm{L_R})$$
$$-\frac{1}{6}\left[2\,c^3\,a_{\phi\mathrm{WB}} + (3\,a_{\phi\mathrm{D}} - 4\,c^2\,a_{\mathrm{AA}} + 4\,c^2\,a_{\phi\mathrm{W}})\,s\right]\frac{s}{c^2}\,(2-3\,\mathrm{L_R})$$
$$+\frac{1}{12}\left[40\,s\,a_{\phi\mathrm{WB}} + (4\,\mathrm{P}_{10}\,a_{\phi\mathrm{W}} + 4\,\mathrm{P}_{11}\,a_{\phi\Box} + \mathrm{P}_{14}\,a_{\phi\mathrm{D}})\,\frac{c}{x^2_{\mathrm{H}}-1}\right]\frac{1}{c}$$
$$+\frac{1}{2}\,(3\,a_{\phi\Box} + 8\,a_{\phi\mathrm{W}})\,\mathrm{L_R} + \frac{1}{3}\sum_{\mathrm{gen}}(2\,x^2_{\mathrm{l}}\,a^{(3)}_{\phi\mathrm{l}} + \mathrm{O}_0\,a_{\phi\mathrm{W}} + 6\,\mathrm{O}_1\,a^{(3)}_{\phi\mathrm{q}})\,(2-3\,\mathrm{L_R})$$

$$\Delta^{(6)}_{\mathrm{WW};1}(0) = -\frac{1}{2}\sum_{\mathrm{gen}}\frac{x^2_{\mathrm{u}}}{x^2_{\mathrm{u}}-x^2_{\mathrm{d}}}\,\mathrm{O}_2\,a^{(3)}_{\phi\mathrm{q}\,\mathrm{W}}\,a^{\mathrm{fin}}_0\left(M_{\mathrm{u}}\right)$$
$$-\frac{1}{2}\sum_{\mathrm{gen}}\frac{x^2_{\mathrm{d}}}{x^2_{\mathrm{u}}-x^2_{\mathrm{d}}}\,\mathrm{O}_3\,a^{(3)}_{\phi\mathrm{q}\,\mathrm{W}}\,a^{\mathrm{fin}}_0\left(M_{\mathrm{d}}\right) + \frac{1}{2}\sum_{\mathrm{gen}} x^2_{\mathrm{l}}\,a^{(3)}_{\phi\mathrm{l}\,\mathrm{W}}\,a^{\mathrm{fin}}_0\left(M_{\mathrm{l}}\right)$$
$$-\frac{1}{6}\Big[4\,\mathrm{M}^c_{16}\,s^2\,a_{\mathrm{AA}} + 3\,\mathrm{M}^c_{21}\,a_{\phi\mathrm{D}} + 20\,\mathrm{M}^c_{22}\,c^2\,a_{\mathrm{ZZ}} + 4\,\mathrm{M}^c_{26}\,s\,c\,a_{\mathrm{AZ}}$$
$$-(8\,a_{\phi\mathrm{W}} - 2\,\mathrm{P}_{12}\,a_{\phi\mathrm{D}} + \mathrm{P}_{13}\,a_{\phi\Box})\,\frac{s^2}{x^2_{\mathrm{H}}-1}\Big]\,\frac{1}{s^2}\,a^{\mathrm{fin}}_0\,(M)$$
$$-\frac{1}{3}\,(a^{(-)}_{\phi\mathrm{WD}} + 4\,a_{\phi\Box})\,\frac{x^2_{\mathrm{H}}}{x^2_{\mathrm{H}}-1}\,a^{\mathrm{fin}}_0\left(M_{\mathrm{H}}\right)$$
$$+\frac{1}{12}\,(8\,\mathrm{M}^c_{17}\,s^2\,a_{\mathrm{AA}} - 24\,\mathrm{M}^c_{18}\,c^2\,a_{\mathrm{ZZ}} - \mathrm{M}^c_{20}\,a_{\phi\mathrm{D}} - 4\,\mathrm{M}^c_{23}\,s\,c\,a_{\mathrm{AZ}})\,\frac{1}{s^2\,c^2}\,a^{\mathrm{fin}}_0\,(M_0)$$

$$\Delta^{(6)}_{\mathrm{WW};2}(0) = \frac{1}{2}\sum_{\mathrm{gen}}\mathrm{O}_4\,a^{(3)}_{\phi\mathrm{q}\,\mathrm{W}}\,\mathrm{B}^{\mathrm{fin}}_{0\mathrm{p}}\left(M_{\mathrm{u}}\,,M_{\mathrm{d}}\right) + \frac{1}{6}\sum_{\mathrm{gen}} x^4_{\mathrm{l}}\,a^{(3)}_{\phi\mathrm{l}\,\mathrm{W}}\,\mathrm{B}^{\mathrm{fin}}_{0\mathrm{p}}\left(0\,,M_{\mathrm{l}}\right)$$
$$-\frac{1}{3}\left[\mathrm{M}^c_{19}\,s\,c\,a_{\mathrm{AZ}} + (-c^2\,a_{\phi\mathrm{D}} + 4\,s^2\,a_{\mathrm{AA}})\right]\mathrm{B}^{\mathrm{fin}}_{0\mathrm{p}}\,(0\,,M)$$
$$+\frac{1}{24}\,(a^{(-)}_{\phi\mathrm{WD}} + 4\,a_{\phi\Box})\,\frac{1}{x^2_{\mathrm{H}}-1}\,\mathrm{P}_9\,\mathrm{B}^{\mathrm{fin}}_{0\mathrm{p}}\left(M\,,M_{\mathrm{H}}\right)$$
$$+\frac{1}{24}\,(16\,s^2\,c^4\,a_{\phi\mathrm{B}} - \mathrm{M}^c_{14}\,a_{\phi\mathrm{D}} - 4\,\mathrm{M}^c_{24}\,s\,a_{\phi\mathrm{WA}} - 4\,\mathrm{M}^c_{25}\,c\,a_{\phi\mathrm{WZ}})\,\frac{s^4}{c^4}\,\mathrm{B}^{\mathrm{fin}}_{0\mathrm{p}}\,(M\,,M_0)$$

$$\Omega^{(4)}_{\mathrm{WW};0}(0) = -\frac{4}{9}\,\mathrm{N_{gen}}\,(1-3\,\mathrm{L_R}) - \frac{1}{18}\,(2+57\,\mathrm{L_R})$$

$$\Omega^{(4)}_{\mathrm{WW};1}(0) = -\frac{1}{12}\,\frac{x^2_{\mathrm{H}}}{x^2_{\mathrm{H}}-1}\,a^{\mathrm{fin}}_0\left(M_{\mathrm{H}}\right) + \frac{1}{12}\,\frac{1}{s^2}\,\mathrm{M}^c_{28}\,a^{\mathrm{fin}}_0\,(M_0)$$
$$-\sum_{\mathrm{gen}}\frac{x^2_{\mathrm{u}}}{x^2_{\mathrm{u}}-x^2_{\mathrm{d}}}\,a^{\mathrm{fin}}_0\left(M_{\mathrm{u}}\right) + \sum_{\mathrm{gen}}\frac{x^2_{\mathrm{d}}}{x^2_{\mathrm{u}}-x^2_{\mathrm{d}}}\,a^{\mathrm{fin}}_0\left(M_{\mathrm{d}}\right)$$
$$-\frac{1}{3}\sum_{\mathrm{gen}} a^{\mathrm{fin}}_0\left(M_{\mathrm{l}}\right) - \frac{1}{12}\,(39 + \frac{s^2}{x^2_{\mathrm{H}}-1}\,\mathrm{P}_{16})\,\frac{1}{s^2}\,a^{\mathrm{fin}}_0\,(M)$$

$$\Omega^{(4)}_{\mathrm{WW};2}(0) = \frac{1}{24}\,\frac{s^4}{c^4}\,\mathrm{M}^c_{14}\,\mathrm{B}^{\mathrm{fin}}_{0\mathrm{s}}\,(M\,,M_0) + \frac{1}{6}\,\frac{1}{x^2_{\mathrm{H}}-1}\,\mathrm{P}_{15}\,\mathrm{B}^{\mathrm{fin}}_{0\mathrm{p}}\left(M\,,M_{\mathrm{H}}\right)$$
$$-\frac{1}{24}\,\frac{1}{x^2_{\mathrm{H}}-1}\,\mathrm{P}_9\,\mathrm{B}^{\mathrm{fin}}_{0\mathrm{s}}\left(M\,,M_{\mathrm{H}}\right) - \frac{1}{6}\,\frac{1}{c^2}\,\mathrm{M}^c_{27}\,\mathrm{B}^{\mathrm{fin}}_{0\mathrm{p}}\,(M\,,M_0)$$

$$
\begin{aligned}
&+\frac{4}{3}\,s^2\,\mathrm{B}^{\mathrm{fin}}_{0\mathrm{p}}\,(0\,,M)+\frac{1}{3}\,s^2\,\mathrm{B}^{\mathrm{fin}}_{0\mathrm{s}}\,(0\,,M)\\
&+\frac{1}{2}\sum_{\mathrm{gen}}\mathrm{O}_1\,\mathrm{B}^{\mathrm{fin}}_{0\mathrm{p}}\left(M_{\mathrm{u}}\,,M_{\mathrm{d}}\right)+\frac{1}{6}\sum_{\mathrm{gen}}x_{\mathrm{l}}^2\,\mathrm{B}^{\mathrm{fin}}_{0\mathrm{p}}\left(0\,,M_{\mathrm{l}}\right)\\
&-\frac{1}{4}\sum_{\mathrm{gen}}\mathrm{O}_4\,\mathrm{B}^{\mathrm{fin}}_{0\mathrm{s}}\left(M_{\mathrm{u}}\,,M_{\mathrm{d}}\right)-\frac{1}{12}\sum_{\mathrm{gen}}x_{\mathrm{l}}^4\,\mathrm{B}^{\mathrm{fin}}_{0\mathrm{s}}\left(0\,,M_{\mathrm{l}}\right)
\end{aligned}
$$

$$
\begin{aligned}
\Omega^{(6)}_{\mathrm{WW}\,;\,0}(0)=&-\frac{2}{9}\,s^2\,a_{\mathrm{AA}}\,(1-9\,\mathrm{L_R})-\frac{8}{9}\,\mathrm{N_{gen}}\,a_{\phi\,\mathrm{W}}\,(1-3\,\mathrm{L_R})\\
&+\frac{1}{18}\,a_{\phi\,\Box}\,(2+3\,\mathrm{L_R})+\frac{2}{9}\,(-c\,a_{\mathrm{ZZ}}+2\,s\,a_{\mathrm{AZ}})\,c\\
&+\frac{1}{6}\,(\frac{c^2}{x_{\mathrm{H}}^2-1}\,\mathrm{P}_{19}\,a_{\phi\,\mathrm{W}}-6\,\mathrm{M}^c_{29}\,s\,c\,a_{\phi\,\mathrm{WB}}+3\,\mathrm{M}^c_{30}\,a_{\phi\,\mathrm{W}})\,\frac{\mathrm{L_R}}{c^2}\\
&-\frac{4}{9}\sum_{\mathrm{gen}}(a^{(3)}_{\phi\,\mathrm{l}}+3\,a^{(3)}_{\phi\,\mathrm{q}})\,(1-3\,\mathrm{L_R})+\frac{1}{2}\sum_{\mathrm{gen}}(3\,x_{\mathrm{d}}^2\,a_{\mathrm{d\,W}}-3\,x_{\mathrm{u}}^2\,a_{\mathrm{u\,W}}+x_{\mathrm{l}}^2\,a_{\mathrm{l\,W}})\,\mathrm{L_R}
\end{aligned}
$$

$$
\begin{aligned}
\Omega^{(6)}_{\mathrm{WW}\,;\,1}(0)=&-\frac{1}{24}\left[4\,\mathrm{P}_{17}\,a_{\phi\,\mathrm{W}}+(4\,a_{\phi\,\Box}-a_{\phi\,\mathrm{D}})\right]\frac{x_{\mathrm{H}}^2}{x_{\mathrm{H}}^2-1}\,a^{\mathrm{fin}}_0\left(M_{\mathrm{H}}\right)\\
&-\frac{1}{24}\left[4\,\mathrm{M}^c_{35}\,s\,c\,a_{\mathrm{AZ}}+4\,\mathrm{M}^c_{38}\,s^2\,a_{\mathrm{AA}}-(\mathrm{M}^c_{28}\,a_{\phi\,\mathrm{D}}-12\,\mathrm{M}^c_{34}\,a_{\mathrm{ZZ}})\,c^2\right]\frac{1}{s^2\,c^2}\,a^{\mathrm{fin}}_0\,(M_0)\\
&-\frac{1}{24}\Big[12\,\mathrm{M}^c_{36}\,c^2\,a_{\mathrm{ZZ}}-4\,\mathrm{M}^c_{37}\,s^2\,a_{\mathrm{AA}}+4\,\mathrm{M}^c_{39}\,s\,c\,a_{\mathrm{AZ}}+\mathrm{M}^c_{40}\,a_{\phi\,\mathrm{D}}\\
&-(4\,a_{\phi\,\Box}-4\,\mathrm{P}_{20}\,a_{\phi\,\mathrm{W}}-\mathrm{P}_{21}\,a_{\phi\,\mathrm{D}})\,\frac{s^2}{x_{\mathrm{H}}^2-1}\Big]\,\frac{1}{s^2}\,a^{\mathrm{fin}}_0\,(M)\\
&-\frac{1}{2}\sum_{\mathrm{gen}}(2\,a^{(3)}_{\phi\,\mathrm{q\,W}}+3\,x_{\mathrm{d}}^2\,a_{\mathrm{d\,W}}-3\,x_{\mathrm{u}}^2\,a_{\mathrm{u\,W}})\,\frac{x_{\mathrm{u}}^2}{x_{\mathrm{u}}^2-x_{\mathrm{d}}^2}\,a^{\mathrm{fin}}_0\left(M_{\mathrm{u}}\right)\\
&+\frac{1}{2}\sum_{\mathrm{gen}}(2\,a^{(3)}_{\phi\,\mathrm{q\,W}}+3\,x_{\mathrm{d}}^2\,a_{\mathrm{d\,W}}-3\,x_{\mathrm{u}}^2\,a_{\mathrm{u\,W}})\,\frac{x_{\mathrm{d}}^2}{x_{\mathrm{u}}^2-x_{\mathrm{d}}^2}\,a^{\mathrm{fin}}_0\left(M_{\mathrm{d}}\right)\\
&-\frac{1}{6}\sum_{\mathrm{gen}}(2\,a^{(3)}_{\phi\,\mathrm{l\,W}}+3\,x_{\mathrm{l}}^2\,a_{\mathrm{l\,W}})\,a^{\mathrm{fin}}_0\left(M_{\mathrm{l}}\right)
\end{aligned}
$$

$$
\begin{aligned}
\Omega^{(6)}_{\mathrm{WW}\,;\,2}(0)=&-\frac{1}{4}\sum_{\mathrm{gen}}\mathrm{O}_4\,a^{(3)}_{\phi\,\mathrm{q\,W}}\,\mathrm{B}^{\mathrm{fin}}_{0\mathrm{s}}\left(M_{\mathrm{u}}\,,M_{\mathrm{d}}\right)-\frac{1}{12}\sum_{\mathrm{gen}}x_{\mathrm{l}}^4\,a^{(3)}_{\phi\,\mathrm{l\,W}}\,\mathrm{B}^{\mathrm{fin}}_{0\mathrm{s}}\left(0\,,M_{\mathrm{l}}\right)\\
&+\frac{1}{12}\left[4\,s^2\,c\,a_{\mathrm{AA}}-4\,\mathrm{M}^c_{32}\,s\,a_{\mathrm{AZ}}-(\mathrm{M}^c_{27}\,a_{\phi\,\mathrm{D}}+12\,\mathrm{M}^c_{31}\,a_{\mathrm{ZZ}})\,c\right]\frac{1}{c^3}\,\mathrm{B}^{\mathrm{fin}}_{0\mathrm{p}}\,(M\,,M_0)\\
&+\frac{1}{12}\left[4\,\mathrm{P}_{18}\,a_{\phi\,\mathrm{W}}+(4\,a_{\phi\,\Box}-a_{\phi\,\mathrm{D}})\,\mathrm{P}_{15}\right]\frac{1}{x_{\mathrm{H}}^2-1}\,\mathrm{B}^{\mathrm{fin}}_{0\mathrm{p}}\left(M\,,M_{\mathrm{H}}\right)\\
&+\frac{1}{6}\left[\mathrm{M}^c_{19}\,s\,c\,a_{\mathrm{AZ}}+(-c^2\,a_{\phi\,\mathrm{D}}+4\,s^2\,a_{\mathrm{AA}})\right]\mathrm{B}^{\mathrm{fin}}_{0\mathrm{s}}\,(0\,,M)\\
&+\frac{1}{3}\left[\mathrm{M}^c_{33}\,s\,c\,a_{\mathrm{AZ}}+2\,(-c^2\,a_{\phi\,\mathrm{D}}+4\,s^2\,a_{\mathrm{AA}})\right]\mathrm{B}^{\mathrm{fin}}_{0\mathrm{p}}\,(0\,,M)\\
&-\frac{1}{48}\,(a^{(-)}_{\phi\,\mathrm{WD}}+4\,a_{\phi\,\Box})\,\frac{1}{x_{\mathrm{H}}^2-1}\,\mathrm{P}_9\,\mathrm{B}^{\mathrm{fin}}_{0\mathrm{s}}\left(M\,,M_{\mathrm{H}}\right)\\
&-\frac{1}{48}\,(16\,s^2\,c^4\,a_{\phi\,\mathrm{B}}-\mathrm{M}^c_{14}\,a_{\phi\,\mathrm{D}}-4\,\mathrm{M}^c_{24}\,s\,a_{\phi\,\mathrm{WA}}-4\,\mathrm{M}^c_{25}\,c\,a_{\phi\,\mathrm{WZ}})\,\frac{s^4}{c^4}\,\mathrm{B}^{\mathrm{fin}}_{0\mathrm{s}}\,(M\,,M_0)\\
&+\frac{1}{6}\sum_{\mathrm{gen}}(a^{(3)}_{\phi\,\mathrm{l\,W}}+3\,x_{\mathrm{l}}^2\,a_{\mathrm{l\,W}})\,x_{\mathrm{l}}^2\,\mathrm{B}^{\mathrm{fin}}_{0\mathrm{p}}\left(0\,,M_{\mathrm{l}}\right)\\
&+\frac{1}{2}\sum_{\mathrm{gen}}(\mathrm{O}_1\,a^{(3)}_{\phi\,\mathrm{q\,W}}-3\,\mathrm{O}_1\,x_{\mathrm{d}}^2\,a_{\mathrm{d\,W}}-3\,\mathrm{O}_1\,x_{\mathrm{u}}^2\,a_{\mathrm{u\,W}})\,\mathrm{B}^{\mathrm{fin}}_{0\mathrm{p}}\left(M_{\mathrm{u}}\,,M_{\mathrm{d}}\right)
\end{aligned}
$$

E Finite counterterms

In this appendix we present the list of finite counterterms for fields and parameters, as defined in section 4.12. It should be understood that only the real part of the loop functions has to be included, i.e. $\mathrm{B}_0 \equiv \mathrm{Re}\,\mathrm{B}_0$ etc.

$$
\begin{aligned}
\mathrm{d}\mathscr{Z}^{(4)}_{M_{\mathrm{W}}} = & -\frac{1}{18}\left[3\,c^2\,x_{\mathrm{H}}^2+(3+128\,c^2)\right]\frac{1}{c^2}-\frac{4}{9}\,(1-3\,\mathrm{L_R})\,\mathrm{N_{gen}} \\
& +\frac{1}{6}\,(6-7\,c^2)\,\frac{1}{c^2}\,\mathrm{L_R}+\frac{1}{6}\sum_{\mathrm{gen}}(3\,x_{\mathrm{d}}^2+3\,x_{\mathrm{u}}^2+x_{\mathrm{l}}^2)\,(2-3\,\mathrm{L_R}) \\
& +\frac{1}{2}\sum_{\mathrm{gen}}(2-x_{\mathrm{d}}^2+x_{\mathrm{u}}^2)\,x_{\mathrm{d}}^2\,a_0^{\mathrm{fin}}\,(M_{\mathrm{b}})+\frac{1}{2}\sum_{\mathrm{gen}}(2+x_{\mathrm{d}}^2-x_{\mathrm{u}}^2)\,x_{\mathrm{u}}^2\,a_0^{\mathrm{fin}}\,(M_{\mathrm{t}}) \\
& +\frac{1}{6}\sum_{\mathrm{gen}}(2-x_{\mathrm{l}}^2)\,x_{\mathrm{l}}^2\,a_0^{\mathrm{fin}}\,(M_{\mathrm{l}})-\frac{1}{12}\left[c^2\,x_{\mathrm{H}}^2+(1+66\,c^2)\right]\frac{1}{c^2}\,a_0^{\mathrm{fin}}\,(M_{\mathrm{W}}) \\
& -\frac{1}{12}\,(3-x_{\mathrm{H}}^2)\,x_{\mathrm{H}}^2\,a_0^{\mathrm{fin}}\,(M_{\mathrm{H}})+\frac{1}{12}\,(1-19\,c^2+24\,s^2\,c^2)\,\frac{1}{c^4}\,a_0^{\mathrm{fin}}\,(M_{\mathrm{Z}}) \\
& -4\,s^2\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{W}}^2\,;0\,,M_{\mathrm{W}}\right) \\
& +\frac{1}{6}\sum_{\mathrm{gen}}\left[2-(1+x_{\mathrm{l}}^2)\,x_{\mathrm{l}}^2\right]\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{W}}^2\,;0\,,M_{\mathrm{l}}\right) \\
& +\frac{1}{2}\sum_{\mathrm{gen}}\left[2-x_{\mathrm{d}}^2-x_{\mathrm{u}}^2-(x_{\mathrm{u}}^2-x_{\mathrm{d}}^2)^2\right]\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{W}}^2\,;M_{\mathrm{t}}\,,M_{\mathrm{b}}\right) \\
& +\frac{1}{12}\left[1+48\,s^2\,c^4+4\,(4-29\,c^2)\,c^2\right]\frac{1}{c^4}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{W}}^2\,;M_{\mathrm{W}}\,,M_{\mathrm{Z}}\right) \\
& +\frac{1}{12}\left[12-(4-x_{\mathrm{H}}^2)\,x_{\mathrm{H}}^2\right]\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{W}}^2\,;M_{\mathrm{W}}\,,M_{\mathrm{H}}\right)
\end{aligned}
$$

$$
\begin{aligned}
\mathrm{d}\mathscr{Z}^{(4)}_{\mathrm{c}_\theta} = & -\frac{1}{36}\Big\{-3\sum_{\mathrm{gen}}(1-\mathrm{v}_{\mathrm{l}}^2)\,c^2\,x_{\mathrm{l}}^2-9\sum_{\mathrm{gen}}(1-\mathrm{v}_{\mathrm{d}}^2)\,c^2\,x_{\mathrm{d}}^2-9\sum_{\mathrm{gen}}(1-\mathrm{v}_{\mathrm{u}}^2)\,c^2\,x_{\mathrm{u}}^2 \\
& +2\left[97-12\,(11-3\,s^2)\,s^2\right]s^2\Big\}\,\frac{1}{c^2} \\
& -\frac{1}{12}\,(19-18\,s^2)\,\frac{s^2}{c^2}\,\mathrm{L_R}+\frac{1}{72}\left[(9-16\,c^2)+(\mathrm{v}_{\mathrm{l}}^2+3\,\mathrm{v}_{\mathrm{d}}^2+3\,\mathrm{v}_{\mathrm{u}}^2)\right]\frac{1}{c^2}\,(1-3\,\mathrm{L_R})\,\mathrm{N_{gen}} \\
& -\frac{1}{12}\sum_{\mathrm{gen}}\left[x_{\mathrm{l}}^2-(1-\mathrm{v}_{\mathrm{l}}^2)\right]x_{\mathrm{l}}^2\,a_0^{\mathrm{fin}}\,(M_{\mathrm{l}}) \\
& +\frac{1}{4}\sum_{\mathrm{gen}}\left[(1-\mathrm{v}_{\mathrm{d}}^2)-(x_{\mathrm{d}}^2-x_{\mathrm{u}}^2)\right]x_{\mathrm{d}}^2\,a_0^{\mathrm{fin}}\,(M_{\mathrm{b}}) \\
& +\frac{1}{4}\sum_{\mathrm{gen}}\left[(1-\mathrm{v}_{\mathrm{u}}^2)+(x_{\mathrm{d}}^2-x_{\mathrm{u}}^2)\right]x_{\mathrm{u}}^2\,a_0^{\mathrm{fin}}\,(M_{\mathrm{t}}) \\
& +\frac{1}{24}\left[c^4\,x_{\mathrm{H}}^2+(1-18\,c^2+24\,s^2\,c^2)\right]\frac{1}{c^4}\,a_0^{\mathrm{fin}}\,(M_{\mathrm{Z}}) \\
& -\frac{1}{24}\left\{c^2\,x_{\mathrm{H}}^2+\left[1+48\,s^2\,c^4+2\,(31-40\,c^2)\,c^2\right]\right\}\frac{1}{c^2}\,a_0^{\mathrm{fin}}\,(M_{\mathrm{W}}) \\
& -\frac{1}{24}\,(3-x_{\mathrm{H}}^2)\,x_{\mathrm{H}}^2\,a_0^{\mathrm{fin}}\,(M_{\mathrm{H}})+\frac{1}{24}\,(3-c^2\,x_{\mathrm{H}}^2)\,x_{\mathrm{H}}^2\,a_0^{\mathrm{fin}}\,(M_{\mathrm{H}}) \\
& -2\,s^2\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{W}}^2\,;0\,,M_{\mathrm{W}}\right)-\frac{1}{12}\,\frac{1}{c^2}\sum_{\mathrm{gen}}\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{Z}}^2\,;0\,,0\right) \\
& +\frac{1}{12}\sum_{\mathrm{gen}}\left[2-(1+x_{\mathrm{l}}^2)\,x_{\mathrm{l}}^2\right]\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{W}}^2\,;0\,,M_{\mathrm{l}}\right) \\
& -\frac{1}{24}\sum_{\mathrm{gen}}\left[(1+\mathrm{v}_{\mathrm{l}}^2)-2\,(2-\mathrm{v}_{\mathrm{l}}^2)\,c^2\,x_{\mathrm{l}}^2\right]\frac{1}{c^2}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{Z}}^2\,;M_{\mathrm{l}}\,,M_{\mathrm{l}}\right)
\end{aligned}
$$

$$
\begin{aligned}
&-\frac{1}{8}\sum_{\rm gen}\Big[(1+{\rm v}_{\rm d}^2)-2\,(2-{\rm v}_{\rm d}^2)\,c^2\,x_{\rm d}^2\Big]\,\frac{1}{c^2}\,{\rm B}_0^{\rm fin}\left(-M_{\rm Z}^2\,;M_{\rm b}\,,M_{\rm b}\right)\\
&-\frac{1}{8}\sum_{\rm gen}\Big[(1+{\rm v}_{\rm u}^2)-2\,(2-{\rm v}_{\rm u}^2)\,c^2\,x_{\rm u}^2\Big]\,\frac{1}{c^2}\,{\rm B}_0^{\rm fin}\left(-M_{\rm Z}^2\,;M_{\rm t}\,,M_{\rm t}\right)\\
&+\frac{1}{4}\sum_{\rm gen}\Big[2-x_{\rm d}^2-x_{\rm u}^2-(x_{\rm u}^2-x_{\rm d}^2)^2\Big]\,{\rm B}_0^{\rm fin}\left(-M_{\rm W}^2\,;M_{\rm t}\,,M_{\rm b}\right)\\
&+\frac{1}{24}\,\Big[1+48\,s^2\,c^4+4\,(4-29\,c^2)\,c^2\Big]\,\frac{1}{c^4}\,{\rm B}_0^{\rm fin}\left(-M_{\rm W}^2\,;M_{\rm W}\,,M_{\rm Z}\right)\\
&+\frac{1}{24}\,\Big[12-(4-x_{\rm H}^2)\,x_{\rm H}^2\Big]\,{\rm B}_0^{\rm fin}\left(-M_{\rm W}^2\,;M_{\rm W}\,,M_{\rm H}\right)\\
&-\frac{1}{24}\,\Big\{1+4\,\Big[4-(17+12\,c^2)\,c^2\Big]\,c^2\Big\}\,\frac{1}{c^2}\,{\rm B}_0^{\rm fin}\left(-M_{\rm Z}^2\,;M_{\rm W}\,,M_{\rm W}\right)\\
&-\frac{1}{24}\,(12-4\,c^2\,x_{\rm H}^2+c^4\,x_{\rm H}^4)\,\frac{1}{c^2}\,{\rm B}_0^{\rm fin}\left(-M_{\rm Z}^2\,;M_{\rm H}\,,M_{\rm Z}\right)
\end{aligned}
$$

$$
\begin{aligned}
{\rm d}\mathscr{Z}_g^{(4)}=&-\frac{1}{2}\,\delta_{\rm G}^{(4)}-\frac{2}{9}\,(1-3\,{\rm L_R})\,{\rm N_{gen}}-\frac{1}{36}\,(2+57\,{\rm L_R})\\
&+\frac{1}{4}\sum_{\rm gen}\left[2\,\frac{x_{\rm d}^2}{x_{\rm u}^2-x_{\rm d}^2}+(1-x_{\rm d}^2+x_{\rm u}^2)\right]\,x_{\rm d}^2\,a_0^{\rm fin}\left(M_{\rm b}\right)\\
&-\frac{1}{4}\sum_{\rm gen}\left\{2\,\frac{x_{\rm d}^4}{x_{\rm u}^2-x_{\rm d}^2}+\Big[2\,x_{\rm d}^2+(1-x_{\rm d}^2+x_{\rm u}^2)\,x_{\rm u}^2\Big]\right\}\,a_0^{\rm fin}\left(M_{\rm t}\right)\\
&-\frac{1}{12}\sum_{\rm gen}(1+x_{\rm l}^2)\,x_{\rm l}^2\,a_0^{\rm fin}\left(M_{\rm l}\right)\\
&+\frac{1}{24}\,\left[8\,\frac{x_{\rm H}^2}{x_{\rm H}^2-1}-(11-x_{\rm H}^2)\right]\,x_{\rm H}^2\,a_0^{\rm fin}\left(M_{\rm H}\right)\\
&+\frac{1}{24}\,\Big\{1+\Big[16-(69+8\,c^2)\,c^2\Big]\,c^2\Big\}\,\frac{1}{s^2\,c^4}\,a_0^{\rm fin}\left(M_{\rm Z}\right)\\
&-\frac{1}{24}\,\left\{-7\,s^2\,c^2\,x_{\rm H}^2+8\,\frac{x_{\rm H}^4}{x_{\rm H}^2-1}\,s^2\,c^2+\Big[1+(13-74\,c^2)\,c^2\Big]\right\}\,\frac{1}{s^2\,c^2}\,a_0^{\rm fin}\left(M_{\rm W}\right)\\
&-2\,s^2\,{\rm B}_0^{\rm fin}\left(-M_{\rm W}^2\,;0\,,M_{\rm W}\right)\\
&+\frac{1}{12}\sum_{\rm gen}\Big[2-(1+x_{\rm l}^2)\,x_{\rm l}^2\Big]\,{\rm B}_0^{\rm fin}\left(-M_{\rm W}^2\,;0\,,M_{\rm l}\right)\\
&+\frac{1}{4}\sum_{\rm gen}\Big[2-x_{\rm d}^2-x_{\rm u}^2-(x_{\rm u}^2-x_{\rm d}^2)^2\Big]\,{\rm B}_0^{\rm fin}\left(-M_{\rm W}^2\,;M_{\rm t}\,,M_{\rm b}\right)\\
&+\frac{1}{24}\,\Big[1+48\,s^2\,c^4+4\,(4-29\,c^2)\,c^2\Big]\,\frac{1}{c^4}\,{\rm B}_0^{\rm fin}\left(-M_{\rm W}^2\,;M_{\rm W}\,,M_{\rm Z}\right)\\
&+\frac{1}{24}\,\Big[12-(4-x_{\rm H}^2)\,x_{\rm H}^2\Big]\,{\rm B}_0^{\rm fin}\left(-M_{\rm W}^2\,;M_{\rm W}\,,M_{\rm H}\right)\\
&-\frac{1}{12}\sum_{\rm gen}x_{\rm l}^4\,{\rm B}_{\rm 0p}^{\rm fin}\left(0\,;0\,,M_{\rm l}\right)+\frac{1}{3}\,s^2\,{\rm B}_{\rm 0p}^{\rm fin}\left(0\,;0\,,M_{\rm W}\right)\\
&-\frac{1}{4}\sum_{\rm gen}(-x_{\rm d}^2+x_{\rm u}^2)^2\,{\rm B}_{\rm 0p}^{\rm fin}\left(0\,;M_{\rm t}\,,M_{\rm b}\right)\\
&+\frac{1}{24}\,(-1+x_{\rm H}^2)^2\,{\rm B}_{\rm 0p}^{\rm fin}\left(0\,;M_{\rm W}\,,M_{\rm H}\right)\\
&+\frac{1}{24}\,(9-8\,s^2)\,\frac{s^4}{c^4}\,{\rm B}_{\rm 0p}^{\rm fin}\left(0\,;M_{\rm W}\,,M_{\rm Z}\right)
\end{aligned}
$$

$$
\begin{aligned}
{\rm d}\mathscr{Z}_{M_{\rm H}}^{(4)}=\frac{1}{2}\,\Big\{&3\,c^2\,x_{\rm H}^2-\sum_{\rm gen}\Big[3\,(-x_{\rm H}^2+4\,x_{\rm d}^2)\,x_{\rm d}^2+3\,(-x_{\rm H}^2+4\,x_{\rm u}^2)\,x_{\rm u}^2\\
&+(-x_{\rm H}^2+4\,x_{\rm l}^2)\,x_{\rm l}^2\Big]\,\frac{1}{x_{\rm H}^2}\,c^2-(1+2\,c^2)\Big\}\,\frac{1}{c^2}\,{\rm L_R}
\end{aligned}
$$

$$
\begin{aligned}
&-\frac{1}{2}\,(1+2\,c^4)\,\frac{1}{c^4}\,\frac{1}{x_{\mathrm{H}}^2}\,(2-3\,\mathrm{L_R})\\
&+\frac{9}{8}\,x_{\mathrm{H}}^2\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{H}}\,,M_{\mathrm{H}}\right)\\
&-\frac{3}{2}\sum_{\mathrm{gen}}(-x_{\mathrm{H}}^2+4\,x_{\mathrm{d}}^2)\,\frac{x_{\mathrm{d}}^2}{x_{\mathrm{H}}^2}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{b}}\,,M_{\mathrm{b}}\right)\\
&-\frac{3}{2}\sum_{\mathrm{gen}}(-x_{\mathrm{H}}^2+4\,x_{\mathrm{u}}^2)\,\frac{x_{\mathrm{u}}^2}{x_{\mathrm{H}}^2}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{t}}\,,M_{\mathrm{t}}\right)\\
&-\frac{1}{2}\sum_{\mathrm{gen}}(-x_{\mathrm{H}}^2+4\,x_{\mathrm{l}}^2)\,\frac{x_{\mathrm{l}}^2}{x_{\mathrm{H}}^2}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{l}}\,,M_{\mathrm{l}}\right)\\
&+\frac{1}{4}\left[12-(4-x_{\mathrm{H}}^2)\,x_{\mathrm{H}}^2\right]\frac{1}{x_{\mathrm{H}}^2}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{W}}\,,M_{\mathrm{W}}\right)\\
&+\frac{1}{8}\,(-4\,c^2+c^4\,x_{\mathrm{H}}^2+12\,\frac{1}{x_{\mathrm{H}}^2})\,\frac{1}{c^4}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{Z}}\,,M_{\mathrm{Z}}\right)
\end{aligned}
$$

$$
\begin{aligned}
\mathrm{d}\mathscr{Z}^{(6)}_{M_{\mathrm{W}}} = {}& \frac{8}{9}\,a_{\phi\,\mathrm{W}}\,(1-3\,\mathrm{L_R})\,\mathrm{N_{gen}}\\
&-\frac{1}{36}\left[3\,c^2\,a^{(-)}_{\phi\,\mathrm{WD}}\,x_{\mathrm{H}}^2+4\,(2+3\,x_{\mathrm{H}}^2)\,c^2\,a_{\phi\,\square}+4\,(3+128\,c^2)\,a_{\phi\,\mathrm{W}}+3\,(9-8\,s^2)\,a_{\phi\,\mathrm{D}}\right]\frac{1}{c^2}\\
&+\frac{1}{12}\Big\{20\,c^2\,a_{\phi\,\square}+6\sum_{\mathrm{gen}}c^2\,a_{\mathrm{l\,W}}\,x_{\mathrm{l}}^2+18\sum_{\mathrm{gen}}c^2\,a_{\mathrm{d\,W}}\,x_{\mathrm{d}}^2-18\sum_{\mathrm{gen}}c^2\,a_{\mathrm{u\,W}}\,x_{\mathrm{u}}^2\\
&+2\left[3\,c^2\,x_{\mathrm{H}}^2+(15+4\,c^2)\right]a_{\phi\,\mathrm{W}}-3\,(5-6\,s^2)\,a_{\phi\,\mathrm{D}}\Big\}\,\frac{1}{c^2}\,\mathrm{L_R}+\frac{1}{3}\,\frac{s}{c}\,a_{\phi\,\mathrm{WB}}\,(10-3\,\mathrm{L_R})\\
&+\frac{1}{6}\sum_{\mathrm{gen}}\left[a^{(3)}_{\phi\,\mathrm{l\,W}}\,x_{\mathrm{l}}^2+3\,(x_{\mathrm{d}}^2+x_{\mathrm{u}}^2)\,a^{(3)}_{\phi\,\mathrm{q\,W}}\right](2-3\,\mathrm{L_R})-\frac{4}{9}\sum_{\mathrm{gen}}(a^{(3)}_{\phi\,\mathrm{l}}+3\,a^{(3)}_{\phi\,\mathrm{q}})\,(1-3\,\mathrm{L_R})\\
&-\frac{1}{6}\sum_{\mathrm{gen}}\left[3\,a_{\mathrm{l\,W}}\,x_{\mathrm{l}}^2-(2-x_{\mathrm{l}}^2)\,a^{(3)}_{\phi\,\mathrm{l\,W}}\right]x_{\mathrm{l}}^2\,a_0^{\mathrm{fin}}\left(M_{\mathrm{l}}\right)\\
&-\frac{1}{2}\sum_{\mathrm{gen}}\left[3\,a_{\mathrm{d\,W}}\,x_{\mathrm{d}}^2+3\,a_{\mathrm{u\,W}}\,x_{\mathrm{u}}^2-(2-x_{\mathrm{d}}^2+x_{\mathrm{u}}^2)\,a^{(3)}_{\phi\,\mathrm{q\,W}}\right]x_{\mathrm{d}}^2\,a_0^{\mathrm{fin}}\left(M_{\mathrm{b}}\right)\\
&+\frac{1}{2}\sum_{\mathrm{gen}}\left[3\,a_{\mathrm{d\,W}}\,x_{\mathrm{d}}^2+3\,a_{\mathrm{u\,W}}\,x_{\mathrm{u}}^2+(2+x_{\mathrm{d}}^2-x_{\mathrm{u}}^2)\,a^{(3)}_{\phi\,\mathrm{q\,W}}\right]x_{\mathrm{u}}^2\,a_0^{\mathrm{fin}}\left(M_{\mathrm{t}}\right)\\
&+\frac{1}{24}\left[a^{(-)}_{\phi\,\mathrm{WD}}\,x_{\mathrm{H}}^2-72\,a_{\phi\,\mathrm{W}}+3\,a_{\phi\,\mathrm{D}}-4\,(3-x_{\mathrm{H}}^2)\,a_{\phi\,\square}\right]x_{\mathrm{H}}^2\,a_0^{\mathrm{fin}}\left(M_{\mathrm{H}}\right)\\
&+\frac{1}{24}\left[-c^2\,a^{(-)}_{\phi\,\mathrm{WD}}\,x_{\mathrm{H}}^2+40\,s\,c\,a_{\phi\,\mathrm{WB}}-4\,(1+60\,c^2)\,a_{\phi\,\mathrm{W}}+4\,(2-x_{\mathrm{H}}^2)\,c^2\,a_{\phi\,\square}-(21-20\,s^2)\,a_{\phi\,\mathrm{D}}\right]\frac{1}{c^2}\,a_0^{\mathrm{fin}}\left(M_{\mathrm{W}}\right)\\
&+\frac{1}{24}\left[(1-13\,c^2+24\,s^2\,c^2)\,a_{\phi\,\mathrm{D}}+4\,(1-8\,c^2)\,s\,a_{\phi\,\mathrm{WA}}+4\,(11-32\,c^2)\,c\,a_{\phi\,\mathrm{WZ}}\right]\frac{1}{c^4}\,a_0^{\mathrm{fin}}\left(M_{\mathrm{Z}}\right)\\
&+\frac{1}{2}\sum_{\mathrm{gen}}\Big[3\,(1-x_{\mathrm{d}}^2+x_{\mathrm{u}}^2)\,a_{\mathrm{d\,W}}\,x_{\mathrm{d}}^2-3\,(1+x_{\mathrm{d}}^2-x_{\mathrm{u}}^2)\,a_{\mathrm{u\,W}}\,x_{\mathrm{u}}^2+(2-x_{\mathrm{d}}^2-x_{\mathrm{u}}^2-(x_{\mathrm{u}}^2-x_{\mathrm{d}}^2)^2)\,a^{(3)}_{\phi\,\mathrm{q\,W}}\Big]\\
&\times\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{W}}^2\,;M_{\mathrm{t}}\,,M_{\mathrm{b}}\right)\\
&+\frac{1}{6}\sum_{\mathrm{gen}}\Big\{\left[2-(1+x_{\mathrm{l}}^2)\,x_{\mathrm{l}}^2\right]a^{(3)}_{\phi\,\mathrm{l\,W}}+3\,(1-x_{\mathrm{l}}^2)\,a_{\mathrm{l\,W}}\,x_{\mathrm{l}}^2\Big\}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{W}}^2\,;0\,,M_{\mathrm{l}}\right)\\
&+\frac{1}{24}\Big\{a^{(-)}_{\phi\,\mathrm{WD}}\,x_{\mathrm{H}}^4+4\left[12-(4-x_{\mathrm{H}}^2)\,x_{\mathrm{H}}^2\right]a_{\phi\,\square}-4\,(3-x_{\mathrm{H}}^2)\,a_{\phi\,\mathrm{D}}+16\,(9-4\,x_{\mathrm{H}}^2)\,a_{\phi\,\mathrm{W}}\Big\}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{W}}^2\,;M_{\mathrm{W}}\,,M_{\mathrm{H}}\right)\\
&+\frac{1}{24}\Big\{\left[1+48\,s^2\,c^4+4\,(4-29\,c^2)\,c^2\right]a_{\phi\,\mathrm{D}}+44\left[1-2\,(1+4\,c^2)\,c^2\right]c\,a_{\phi\,\mathrm{WZ}}\\
&+4\left[1+2\,(3-20\,c^2)\,c^2\right]s\,a_{\phi\,\mathrm{WA}}\Big\}\,\frac{1}{c^4}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{W}}^2\,;M_{\mathrm{W}}\,,M_{\mathrm{Z}}\right)\\
&-2\,a_{\phi\,\mathrm{WAD}}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{W}}^2\,;0\,,M_{\mathrm{W}}\right)
\end{aligned}
$$

$$
\begin{aligned}
d\mathscr{Z}^{(6)}_{c_\theta} = {} & \frac{1}{18}\,\frac{s^2}{c^2}\,a_{\phi\Box}\,(2-15\,L_R) \\
&+\frac{1}{144}\Big\{9\,a^{(-)}_{\phi WD}-64\,c^2\,a_{\phi W}+\Big[(1+4\,c^2)\,v_d+(3+4\,c^2)\,v_l+(5+8\,c^2)\,v_u\Big]\,a_{\phi D} \\
&-4\Big[(1+8\,c^2)\,v_d+(3+8\,c^2)\,v_l+(5+16\,c^2)\,v_u\Big]\,s\,a_{\phi WA}-4\Big[(5-8\,c^2)\,v_d+(7-8\,c^2)\,v_l \\
&+(13-16\,c^2)\,v_u\Big]\,c\,a_{\phi WZ}+64\Big[(v_l+v_d+2\,v_u)\Big]\,s^2\,c^2\,a_{\phi B}\Big\}\,\frac{1}{c^2}\,(1-3\,L_R)\,N_{gen} \\
&+\frac{1}{72}\Big\{3\,c^2\,a^{(+)}_{\phi WD}\,x_H^2-3\,c^2\,a^{(-)}_{\phi WD}\,x_H^2+6\sum_{gen}c^2\,a^{(3)}_{\phi l W}\,x_l^2-24\sum_{gen}c^2\,a_{\phi l V}\,x_l^2\,v_l-72\sum_{gen}c^2\,v_d\,a_{\phi d V}\,x_d^2 \\
&-72\sum_{gen}c^2\,v_u\,a_{\phi u V}\,x_u^2+12\sum_{gen}\Big[(1+8\,c^2)\,v_d\,x_d^2+(3+8\,c^2)\,x_l^2\,v_l+(5+16\,c^2)\,v_u\,x_u^2\Big]\,s\,c^2\,a_{\phi WA} \\
&+12\sum_{gen}\Big[(5-8\,c^2)\,v_d\,x_d^2+(7-8\,c^2)\,x_l^2\,v_l+(13-16\,c^2)\,v_u\,x_u^2\Big]\,c^3\,a_{\phi WZ}+18\sum_{gen}(x_d^2+x_u^2)\,c^2\,a^{(3)}_{\phi q W} \\
&-192\sum_{gen}(x_l^2\,v_l+v_d\,x_d^2+2\,v_u\,x_u^2)\,s^2\,c^4\,a_{\phi B}-8\Big[1+(31+36\,c^4)\,c^2\Big]\,s^2\,a_{AA} \\
&-8\Big[17+(43+36\,(1+c^2)\,c^2)\,c^2\Big]\,s\,c\,a_{AZ}-8\Big[29+36\,(1-s^2)\,s^2\Big]\,s^2\,c^2\,a_{ZZ} \\
&-\Big[3\sum_{gen}(1+4\,c^2)\,c^2\,v_d\,x_d^2+3\sum_{gen}(3+4\,c^2)\,c^2\,x_l^2\,v_l \\
&+3\sum_{gen}(5+8\,c^2)\,c^2\,v_u\,x_u^2-2\,(52-(149-12\,(11-3\,s^2)\,s^2)\,s^2)\Big]\,a_{\phi D}\Big\}\,\frac{1}{c^2} \\
&+\frac{1}{72}\sum_{gen}\Big[4\,a_{\phi V}+4\,a_{\phi l A}+4\,a_{\phi l V}\,v_l+12\,a_{\phi d A}+12\,a_{\phi u A}+12\,v_d\,a_{\phi d V}+12\,v_u\,a_{\phi u V} \\
&-16\,c^2\,a^{(3)}_{\phi l}-48\,c^2\,a^{(3)}_{\phi q}-24\,c^2\,a_{\phi l}\,x_l^2-72\,c^2\,a_{\phi d}\,x_d^2+72\,c^2\,a_{\phi u}\,x_u^2+24\,c^2\,a^{(1)}_{\phi l}\,x_l^2 \\
&+72\,(x_d^2-x_u^2)\,c^2\,a^{(1)}_{\phi q}+3\,(3\,x_d^2+3\,x_u^2+x_l^2)\,c^2\,a_{\phi D}\Big]\,\frac{1}{c^2}\,(1-3\,L_R) \\
&+\frac{1}{48}\Big\{12\,c^2\,a_{\phi W}\,x_H^2-12\sum_{gen}c\,a_{l BW}\,x_l^2\,v_l-36\sum_{gen}c\,v_d\,a_{d BW}\,x_d^2+36\sum_{gen}c\,v_u\,a_{u BW}\,x_u^2 \\
&+12\sum_{gen}c^2\,a_{l W}\,x_l^2+36\sum_{gen}c^2\,a_{d W}\,x_d^2-36\sum_{gen}c^2\,a_{u W}\,x_u^2-4\Big[7+4\,(14+3\,c^2)\,c^2\Big]\,s\,c\,a_{AZ} \\
&-4\Big[19-4\,(8-3\,s^2)\,s^2\Big]\,s^2\,a_{AA}-4\Big[3\,c^2\,x_H^2+(31-4\,(1+3\,s^2)\,s^2)\,s^2\Big]\,a_{ZZ} \\
&-\Big[9\,c^2\,x_H^2+(25+4\,(4-9\,s^2)\,s^2)\Big]\,a_{\phi D}\Big\}\,\frac{1}{c^2}\,L_R \\
&+\frac{1}{24}\sum_{gen}\Big\{-8\,a_{\phi l V}\,v_l-6\,a_{l W}\,x_l^2-8\,a_{\phi l}+8\,a^{(1)}_{\phi l}-64\,s^2\,c^2\,a_{\phi B}\,v_l+\Big[1-(3+4\,c^2)\,v_l\Big]\,a_{\phi D} \\
&+2\,(1-x_l^2)\,a^{(3)}_{\phi l W}+4\,(3+8\,c^2)\,s\,a_{\phi WA}\,v_l+4\,(7-8\,c^2)\,c\,a_{\phi WZ}\,v_l\Big\}\,x_l^2\,a_0^{fin}\,(M_l) \\
&+\frac{1}{24}\sum_{gen}\Big\{-18\,a_{d W}\,x_d^2-18\,a_{u W}\,x_u^2-24\,a_{\phi d}+24\,a^{(1)}_{\phi q}-24\,v_d\,a_{\phi d V}-64\,s^2\,c^2\,v_d\,a_{\phi B} \\
&+\Big[3-(1+4\,c^2)\,v_d\Big]\,a_{\phi D}+6\,(1-x_d^2+x_u^2)\,a^{(3)}_{\phi q W}+4\,(1+8\,c^2)\,s\,v_d\,a_{\phi WA} \\
&+4\,(5-8\,c^2)\,c\,v_d\,a_{\phi WZ}\Big\}\,x_d^2\,a_0^{fin}\,(M_b) \\
&-\frac{1}{24}\sum_{gen}\Big\{-18\,a_{d W}\,x_d^2-18\,a_{u W}\,x_u^2-24\,a_{\phi u}+24\,a^{(1)}_{\phi q}+24\,v_u\,a_{\phi u V}+128\,s^2\,c^2\,v_u\,a_{\phi B} \\
&-\Big[3-(5+8\,c^2)\,v_u\Big]\,a_{\phi D}-6\,(1+x_d^2-x_u^2)\,a^{(3)}_{\phi q W}-4\,(5+16\,c^2)\,s\,v_u\,a_{\phi WA} \\
&-4\,(13-16\,c^2)\,c\,v_u\,a_{\phi WZ}\Big\}\,x_u^2\,a_0^{fin}\,(M_t) \\
&+\frac{1}{48}\Big[a^{(-)}_{\phi WD}\,x_H^2-72\,a_{\phi W}+3\,a_{\phi D}-4\,(3-x_H^2)\,a_{\phi\Box}\Big]\,x_H^2\,a_0^{fin}\,(M_H)
\end{aligned}
$$

JHEP07(2015)175

$$
\begin{aligned}
&+\frac{1}{48}\left[12\,a_{\phi\mathrm{D}}-c^2\,a^{(+)}_{\phi\mathrm{WD}}\,x_{\mathrm{H}}^2+12\,s\,c\,a_{\mathrm{AZ}}+12\,s^2\,a_{\mathrm{AA}}+4\,(3-c^2\,x_{\mathrm{H}}^2)\,a_{\phi\Box}+12\,(5+c^2)\,a_{\mathrm{ZZ}}\right]x_{\mathrm{H}}^2\,a_0^{\mathrm{fin}}\left(M_{\mathrm{H}}\right)\\
&-\frac{1}{48}\left\{c^2\,a^{(-)}_{\phi\mathrm{WD}}\,x_{\mathrm{H}}^2+4\left[11+8\,(8+3\,(1+2\,c^2)\,c^2)\,c^2\right]s\,c\,a_{\mathrm{AZ}}\right.\\
&+4\left[15+4\,(7-6\,(5-2\,c^2)\,c^2)\,c^2\right]c^2\,a_{\mathrm{ZZ}}+4\left[61-12\,(11-2\,(5-2\,s^2)\,s^2)\,s^2\right]s^2\,a_{\mathrm{AA}}\\
&\left.-\left[63-16\,(12-(11-3\,s^2)\,s^2)\,s^2\right]a_{\phi\mathrm{D}}-4\,(2-x_{\mathrm{H}}^2)\,c^2\,a_{\phi\Box}\right\}\frac{1}{c^2}\,a_0^{\mathrm{fin}}\left(M_{\mathrm{W}}\right)\\
&+\frac{1}{48}\left\{c^4\,a^{(+)}_{\phi\mathrm{WD}}\,x_{\mathrm{H}}^2+4\left[8-(31-24\,s^2)\,s^2\right]s^2\,a_{\mathrm{AA}}+4\left[11-(41-24\,c^2)\,c^2\right]s\,c\,a_{\mathrm{AZ}}\right.\\
&\left.+4\left[12-(65-24\,c^2)\,c^2\right]c^2\,a_{\mathrm{ZZ}}+(1-15\,c^2+24\,s^2\,c^2)\,a_{\phi\mathrm{D}}-4\,(2-c^2\,x_{\mathrm{H}}^2)\,c^2\,a_{\phi\Box}\right\}\frac{1}{c^4}\,a_0^{\mathrm{fin}}\left(M_{\mathrm{Z}}\right)\\
&+\frac{1}{4}\sum_{\mathrm{gen}}\left[3\,(1-x_{\mathrm{d}}^2+x_{\mathrm{u}}^2)\,a_{\mathrm{d\,W}}\,x_{\mathrm{d}}^2-3\,(1+x_{\mathrm{d}}^2-x_{\mathrm{u}}^2)\,a_{\mathrm{u\,W}}\,x_{\mathrm{u}}^2+(2-x_{\mathrm{d}}^2-x_{\mathrm{u}}^2-(x_{\mathrm{u}}^2-x_{\mathrm{d}}^2)^2)\,a^{(3)}_{\phi\mathrm{q\,W}}\right]\\
&\times\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{W}}^2\,;M_{\mathrm{t}}\,,M_{\mathrm{b}}\right)\\
&-\frac{1}{48}\sum_{\mathrm{gen}}\left\{12\,c\,a_{\mathrm{l\,BW}}\,x_{\mathrm{l}}^2\,\mathrm{v_l}+\left[(3+4\,c^2)+2\,(3+4\,c^2)\,c^2\,x_{\mathrm{l}}^2\right]a_{\phi\mathrm{D}}\,\mathrm{v_l}\right.\\
&-4\left[(3+8\,c^2)+2\,(3+8\,c^2)\,c^2\,x_{\mathrm{l}}^2\right]s\,a_{\phi\mathrm{WA}}\,\mathrm{v_l}-4\left[(7-8\,c^2)+2\,(7-8\,c^2)\,c^2\,x_{\mathrm{l}}^2\right]c\,a_{\phi\mathrm{WZ}}\,\mathrm{v_l}\\
&+(1-4\,c^2\,x_{\mathrm{l}}^2)\,a^{(-)}_{\phi\mathrm{WD}}+8\,(1-4\,c^2\,x_{\mathrm{l}}^2)\,a_{\phi\mathrm{l\,A}}+8\,(1+2\,c^2\,x_{\mathrm{l}}^2)\,a_{\phi\mathrm{l\,V}}\,\mathrm{v_l}\\
&\left.+64\,(1+2\,c^2\,x_{\mathrm{l}}^2)\,s^2\,c^2\,a_{\phi\mathrm{B}}\,\mathrm{v_l}\right\}\frac{1}{c^2}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{Z}}^2\,;M_{\mathrm{l}}\,,M_{\mathrm{l}}\right)\\
&-\frac{1}{48}\sum_{\mathrm{gen}}\left\{36\,c\,\mathrm{v_d}\,a_{\mathrm{d\,BW}}\,x_{\mathrm{d}}^2+\left[(1+4\,c^2)+2\,(1+4\,c^2)\,c^2\,x_{\mathrm{d}}^2\right]\mathrm{v_d}\,a_{\phi\mathrm{D}}-4\left[(1+8\,c^2)\right.\right.\\
&\left.+2\,(1+8\,c^2)\,c^2\,x_{\mathrm{d}}^2\right]s\,\mathrm{v_d}\,a_{\phi\mathrm{WA}}-4\left[(5-8\,c^2)+2\,(5-8\,c^2)\,c^2\,x_{\mathrm{d}}^2\right]c\,\mathrm{v_d}\,a_{\phi\mathrm{WZ}}+3\,(1-4\,c^2\,x_{\mathrm{d}}^2)\,a^{(-)}_{\phi\mathrm{WD}}\\
&\left.+24\,(1-4\,c^2\,x_{\mathrm{d}}^2)\,a_{\phi\mathrm{d\,A}}+24\,(1+2\,c^2\,x_{\mathrm{d}}^2)\,\mathrm{v_d}\,a_{\phi\mathrm{d\,V}}+64\,(1+2\,c^2\,x_{\mathrm{d}}^2)\,s^2\,c^2\,\mathrm{v_d}\,a_{\phi\mathrm{B}}\right\}\frac{1}{c^2}\\
&\times\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{Z}}^2\,;M_{\mathrm{b}}\,,M_{\mathrm{b}}\right)\\
&+\frac{1}{48}\sum_{\mathrm{gen}}\left\{36\,c\,\mathrm{v_u}\,a_{\mathrm{u\,BW}}\,x_{\mathrm{u}}^2-\left[(5+8\,c^2)+2\,(5+8\,c^2)\,c^2\,x_{\mathrm{u}}^2\right]\mathrm{v_u}\,a_{\phi\mathrm{D}}+4\left[(5+16\,c^2)\right.\right.\\
&\left.+2\,(5+16\,c^2)\,c^2\,x_{\mathrm{u}}^2\right]s\,\mathrm{v_u}\,a_{\phi\mathrm{WA}}+4\left[(13-16\,c^2)+2\,(13-16\,c^2)\,c^2\,x_{\mathrm{u}}^2\right]c\,\mathrm{v_u}\,a_{\phi\mathrm{WZ}}\\
&\left.-3\,(1-4\,c^2\,x_{\mathrm{u}}^2)\,a^{(-)}_{\phi\mathrm{WD}}-24\,(1-4\,c^2\,x_{\mathrm{u}}^2)\,a_{\phi\mathrm{u\,A}}-24\,(1+2\,c^2\,x_{\mathrm{u}}^2)\,\mathrm{v_u}\,a_{\phi\mathrm{u\,V}}-128\,(1+2\,c^2\,x_{\mathrm{u}}^2)\,s^2\,c^2\,\mathrm{v_u}\,a_{\phi\mathrm{B}}\right\}\frac{1}{c^2}\\
&\times\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{Z}}^2\,;M_{\mathrm{t}}\,,M_{\mathrm{t}}\right)\\
&+\frac{1}{12}\sum_{\mathrm{gen}}\left\{\left[2-(1+x_{\mathrm{l}}^2)\,x_{\mathrm{l}}^2\right]a^{(3)}_{\phi\mathrm{l\,W}}+3\,(1-x_{\mathrm{l}}^2)\,a_{\mathrm{l\,W}}\,x_{\mathrm{l}}^2\right\}\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{W}}^2\,;0\,,M_{\mathrm{l}}\right)\\
&-\frac{1}{24}\sum_{\mathrm{gen}}(a^{(-)}_{\phi\mathrm{WD}}+4\,a_{\phi\mathrm{v}})\,\frac{1}{c^2}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{Z}}^2\,;0\,,0\right)\\
&-\frac{1}{48}\left[48\,(2-c^2\,x_{\mathrm{H}}^2)\,a_{\mathrm{ZZ}}+(12-4\,c^2\,x_{\mathrm{H}}^2+c^4\,x_{\mathrm{H}}^4)\,a^{(+)}_{\phi\mathrm{WD}}+4\,(12-4\,c^2\,x_{\mathrm{H}}^2+c^4\,x_{\mathrm{H}}^4)\,a_{\phi\Box}\right]\frac{1}{c^2}\\
&\times\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{Z}}^2\,;M_{\mathrm{H}}\,,M_{\mathrm{Z}}\right)\\
&+\frac{1}{48}\left\{a^{(-)}_{\phi\mathrm{WD}}\,x_{\mathrm{H}}^4+4\left[12-(4-x_{\mathrm{H}}^2)\,x_{\mathrm{H}}^2\right]a_{\phi\Box}-4\,(3-x_{\mathrm{H}}^2)\,a_{\phi\mathrm{D}}+16\,(9-4\,x_{\mathrm{H}}^2)\,a_{\phi\mathrm{W}}\right\}\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{W}}^2\,;M_{\mathrm{W}}\,,M_{\mathrm{H}}\right)\\
&+\frac{1}{48}\left\{\left[1+48\,s^2\,c^4+4\,(4-29\,c^2)\,c^2\right]a_{\phi\mathrm{D}}+44\left[1-2\,(1+4\,c^2)\,c^2\right]c\,a_{\phi\mathrm{WZ}}\right.\\
&\left.+4\left[1+2\,(3-20\,c^2)\,c^2\right]s\,a_{\phi\mathrm{WA}}\right\}\frac{1}{c^4}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{W}}^2\,;M_{\mathrm{W}}\,,M_{\mathrm{Z}}\right)\\
&-\frac{1}{48}\left\{\left[1+4\,(4-(17+12\,c^2)\,c^2)\,c^2\right]a_{\phi\mathrm{D}}+12\left[5+4\,(6+(3+4\,c^2)\,c^2)\,c^2\right]s\,c\,a_{\mathrm{AZ}}\right.
\end{aligned}
$$

JHEP07(2015)175

$$
\begin{aligned}
&+12\left[7-4\,(5+(9-4\,c^2)\,c^2)\,c^2\right]c^2\,a_{\mathrm{ZZ}}+4\left[33-4\,(29-3\,(11-4\,s^2)\,s^2)\,s^2\right]s^2\,a_{\mathrm{AA}}\Big\}\,\frac{1}{c^2}\\
&\times \mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{Z}}^2\,;M_{\mathrm{W}}\,,M_{\mathrm{W}}\right)\\
&-a_{\phi\,\mathrm{WAD}}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{W}}^2\,;0\,,M_{\mathrm{W}}\right)
\end{aligned}
$$

$$
\begin{aligned}
\mathrm{d}\mathscr{Z}_g^{(6)} = &-\frac{1}{9}\,(c^2\,a_{\mathrm{ZZ}}-2\,s\,c\,a_{\mathrm{AZ}}+s^2\,a_{\mathrm{AA}})+\frac{1}{36}\,a_{\phi\,\square}\,(2+3\,\mathrm{L_R})\\
&-\frac{4}{9}\,a_{\phi\,\mathrm{W}}\,(1-3\,\mathrm{L_R})\,\mathrm{N_{gen}}-\frac{2}{9}\sum_{\mathrm{gen}}(a_{\phi\,\mathrm{l}}^{(3)}+3\,a_{\phi\,\mathrm{q}}^{(3)})\,(1-3\,\mathrm{L_R})\\
&+\frac{1}{12}\Big[3\,c^2\,a_{\phi\,\mathrm{W}}\,x_{\mathrm{H}}^2+3\sum_{\mathrm{gen}}c^2\,a_{\mathrm{l\,W}}\,x_{\mathrm{l}}^2+9\sum_{\mathrm{gen}}c^2\,a_{\mathrm{d\,W}}\,x_{\mathrm{d}}^2-9\sum_{\mathrm{gen}}c^2\,a_{\mathrm{u\,W}}\,x_{\mathrm{u}}^2+(9-38\,c^2)\,s\,c\,a_{\mathrm{AZ}}\\
&+(15-32\,c^2)\,c^2\,a_{\mathrm{ZZ}}-(29-32\,s^2)\,s^2\,a_{\mathrm{AA}}\Big]\,\frac{1}{c^2}\,\mathrm{L_R}\\
&-\frac{1}{12}\sum_{\mathrm{gen}}\left[3\,a_{\mathrm{l\,W}}\,x_{\mathrm{l}}^2+(1+x_{\mathrm{l}}^2)\,a_{\phi\,\mathrm{l\,W}}^{(3)}\right]x_{\mathrm{l}}^2\,a_0^{\mathrm{fin}}\left(M_{\mathrm{l}}\right)\\
&+\frac{1}{4}\sum_{\mathrm{gen}}\left[3\,(1-x_{\mathrm{d}}^2+x_{\mathrm{u}}^2)\,a_{\mathrm{d\,W}}\,x_{\mathrm{d}}^2-3\,(1+x_{\mathrm{d}}^2-x_{\mathrm{u}}^2)\,a_{\mathrm{u\,W}}\,x_{\mathrm{u}}^2+(2-x_{\mathrm{d}}^2-x_{\mathrm{u}}^2-(x_{\mathrm{u}}^2-x_{\mathrm{d}}^2)^2)\,a_{\phi\,\mathrm{q\,W}}^{(3)}\right]\\
&\times \mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{W}}^2\,;M_{\mathrm{t}}\,,M_{\mathrm{b}}\right)\\
&-\frac{1}{4}\sum_{\mathrm{gen}}\left\{3\,a_{\mathrm{d\,W}}\,x_{\mathrm{d}}^2+3\,a_{\mathrm{u\,W}}\,x_{\mathrm{u}}^2-\left[2\,\frac{x_{\mathrm{d}}^2}{x_{\mathrm{u}}^2-x_{\mathrm{d}}^2}+(1-x_{\mathrm{d}}^2+x_{\mathrm{u}}^2)\right]a_{\phi\,\mathrm{q\,W}}^{(3)}\right\}x_{\mathrm{d}}^2\,a_0^{\mathrm{fin}}\left(M_{\mathrm{b}}\right)\\
&+\frac{1}{4}\sum_{\mathrm{gen}}\left\{3\,a_{\mathrm{d\,W}}\,x_{\mathrm{u}}^2\,x_{\mathrm{d}}^2+3\,a_{\mathrm{u\,W}}\,x_{\mathrm{u}}^4-\left[2\,\frac{x_{\mathrm{d}}^4}{x_{\mathrm{u}}^2-x_{\mathrm{d}}^2}+(2\,x_{\mathrm{d}}^2+(1-x_{\mathrm{d}}^2+x_{\mathrm{u}}^2)\,x_{\mathrm{u}}^2)\right]a_{\phi\,\mathrm{q\,W}}^{(3)}\right\}a_0^{\mathrm{fin}}\left(M_{\mathrm{t}}\right)\\
&+\frac{1}{48}\left\{-104\,a_{\phi\,\mathrm{W}}+11\,a_{\phi\,\mathrm{D}}+4\left[8\,\frac{x_{\mathrm{H}}^2}{x_{\mathrm{H}}^2-1}-(11-x_{\mathrm{H}}^2)\right]a_{\phi\,\square}+(1+8\,\frac{1}{x_{\mathrm{H}}^2-1})\,a_{\phi\,\mathrm{WD}}^{(-)}\,x_{\mathrm{H}}^2\right\}x_{\mathrm{H}}^2\,a_0^{\mathrm{fin}}\left(M_{\mathrm{H}}\right)\\
&-\frac{1}{48}\Big\{\left[1+(27-88\,c^2)\,c^2\right]a_{\phi\,\mathrm{D}}-4\left[4+(3-8\,s^2)\,s^2\right]s^2\,a_{\mathrm{AA}}+4\left[11-3\,(17-4\,c^2)\,c^2\right]s\,c\,a_{\mathrm{AZ}}\\
&+4\left[21-(89-8\,c^2)\,c^2\right]c^2\,a_{\mathrm{ZZ}}+4\left[8\,\frac{x_{\mathrm{H}}^4}{x_{\mathrm{H}}^2-1}-(11+7\,x_{\mathrm{H}}^2)\right]s^2\,c^2\,a_{\phi\,\square}\\
&-(7-8\,\frac{x_{\mathrm{H}}^2}{x_{\mathrm{H}}^2-1})\,s^2\,c^2\,a_{\phi\,\mathrm{WD}}^{(-)}\,x_{\mathrm{H}}^2\Big\}\,\frac{1}{s^2\,c^2}\,a_0^{\mathrm{fin}}\left(M_{\mathrm{W}}\right)\\
&+\frac{1}{48}\Big\{\left[1+(16-(69+8\,c^2)\,c^2)\,c^2\right]a_{\phi\,\mathrm{D}}-4\left[4-(3+2\,s^2)\,s^2\right]s^2\,a_{\mathrm{AA}}+12\left[7-(25+2\,c^2)\,c^2\right]c^2\,a_{\mathrm{ZZ}}\\
&+4\left[11-(41-2\,(2-c^2)\,c^2)\,c^2\right]s\,c\,a_{\mathrm{AZ}}\Big\}\,\frac{1}{s^2\,c^4}\,a_0^{\mathrm{fin}}\left(M_{\mathrm{Z}}\right)\\
&+\frac{1}{12}\sum_{\mathrm{gen}}\left\{\left[2-(1+x_{\mathrm{l}}^2)\,x_{\mathrm{l}}^2\right]a_{\phi\,\mathrm{l\,W}}^{(3)}+3\,(1-x_{\mathrm{l}}^2)\,a_{\mathrm{l\,W}}\,x_{\mathrm{l}}^2\right\}\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{W}}^2\,;0\,,M_{\mathrm{l}}\right)\\
&+\frac{1}{48}\left\{a_{\phi\,\mathrm{WD}}^{(-)}\,x_{\mathrm{H}}^4+4\left[12-(4-x_{\mathrm{H}}^2)\,x_{\mathrm{H}}^2\right]a_{\phi\,\square}-4\,(3-x_{\mathrm{H}}^2)\,a_{\phi\,\mathrm{D}}+16\,(9-4\,x_{\mathrm{H}}^2)\,a_{\phi\,\mathrm{W}}\right\}\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{W}}^2\,;M_{\mathrm{W}}\,,M_{\mathrm{H}}\right)\\
&+\frac{1}{48}\Big\{\left[1+48\,s^2\,c^4+4\,(4-29\,c^2)\,c^2\right]a_{\phi\,\mathrm{D}}+44\left[1-2\,(1+4\,c^2)\,c^2\right]c\,a_{\phi\,\mathrm{WZ}}\\
&+4\left[1+2\,(3-20\,c^2)\,c^2\right]s\,a_{\phi\,\mathrm{WA}}\Big\}\,\frac{1}{c^4}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{W}}^2\,;M_{\mathrm{W}}\,,M_{\mathrm{Z}}\right)\\
&-a_{\phi\,\mathrm{WAD}}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{W}}^2\,;0\,,M_{\mathrm{W}}\right)\\
&-\frac{1}{4}\sum_{\mathrm{gen}}(-x_{\mathrm{d}}^2+x_{\mathrm{u}}^2)^2\,a_{\phi\,\mathrm{q\,W}}^{(3)}\,\mathrm{B}_{0\mathrm{p}}^{\mathrm{fin}}\left(0\,;M_{\mathrm{t}}\,,M_{\mathrm{b}}\right)\\
&-\frac{1}{12}\sum_{\mathrm{gen}}a_{\phi\,\mathrm{l\,W}}^{(3)}\,x_{\mathrm{l}}^4\,\mathrm{B}_{0\mathrm{p}}^{\mathrm{fin}}\left(0\,;0\,,M_{\mathrm{l}}\right)
\end{aligned}
$$

$$
\begin{aligned}
&+\frac{1}{6}\Big[-c^2 a_{\phi D}+4s^2 a_{AA}+(2-c^2)\,s\,c\,a_{AZ}\Big]\,\mathrm{B}^{\mathrm{fin}}_{0p}\left(0;0,M_{\mathrm{W}}\right)\\
&+\frac{1}{48}\,(x_{\mathrm{H}}^2-1)^2\,(a^{(-)}_{\phi WD}+4a_{\phi\square})\,\mathrm{B}^{\mathrm{fin}}_{0p}\left(0;M_{\mathrm{W}},M_{\mathrm{H}}\right)\\
&-\frac{1}{48}\Big\{16s^2c^4 a_{\phi B}-4\Big[7-2(4-s^2)s^2\Big]\,s\,a_{\phi WA}-4\Big[9-2(1+s^2)s^2\Big]\,c\,a_{\phi WZ}\\
&-(9-8s^2)\,a_{\phi D}\Big\}\,\frac{s^4}{c^4}\,\mathrm{B}^{\mathrm{fin}}_{0p}\left(0;M_{\mathrm{W}},M_{\mathrm{Z}}\right)
\end{aligned}
$$

$$
\begin{aligned}
\mathrm{d}\mathscr{Z}^{(6)}_{M_{\mathrm{H}}} = {}& 4a_{\phi W}\\
&-\frac{1}{4}\Big[4(1+2c^4)\,\frac{1}{x_{\mathrm{H}}^2}\,a_{\phi\square}+4(1+10c^4)\,\frac{1}{x_{\mathrm{H}}^2}\,a_{\phi W}+(3-2c^4)\,\frac{1}{x_{\mathrm{H}}^2}\,a_{\phi D}+4(-c^2+4\,\frac{1}{x_{\mathrm{H}}^2})\,a_{ZZ}\Big]\,\frac{1}{c^4}\,(2-3\mathrm{L_R})\\
&+\frac{1}{8}\Big\{192\,\frac{x_{\mathrm{d}}^2}{x_{\mathrm{H}}^2}\sum_{\mathrm{gen}}c^2 a_{\mathrm{d}\phi}x_{\mathrm{d}}^2-192\,\frac{x_{\mathrm{u}}^2}{x_{\mathrm{H}}^2}\sum_{\mathrm{gen}}c^2 a_{\mathrm{u}\phi}x_{\mathrm{u}}^2+64\,\frac{x_{\mathrm{l}}^2}{x_{\mathrm{H}}^2}\sum_{\mathrm{gen}}c^2 a_{\mathrm{L}\phi}x_{\mathrm{l}}^2\\
&-2\sum_{\mathrm{gen}}\Big[3(-x_{\mathrm{H}}^2+4x_{\mathrm{d}}^2)x_{\mathrm{d}}^2+3(-x_{\mathrm{H}}^2+4x_{\mathrm{u}}^2)x_{\mathrm{u}}^2+(-x_{\mathrm{H}}^2+4x_{\mathrm{l}}^2)x_{\mathrm{l}}^2\Big]\,\frac{1}{x_{\mathrm{H}}^2}\,c^2 a^{(-)}_{\phi WD}\\
&-8\sum_{\mathrm{gen}}(a_{\mathrm{l}\phi\square}x_{\mathrm{l}}^2+3a_{\mathrm{d}\phi\square}x_{\mathrm{d}}^2-3a_{\mathrm{u}\phi\square}x_{\mathrm{u}}^2)\,c^2-24\Big[11c^2+(1+2c^2)\,\frac{1}{x_{\mathrm{H}}^2}\Big]\,a_{\phi}+8\Big[3c^2x_{\mathrm{H}}^2-(1+8c^2)\Big]\,a_{\phi W}\\
&+8\Big[11c^2x_{\mathrm{H}}^2-4\sum_{\mathrm{gen}}(3x_{\mathrm{d}}^4+3x_{\mathrm{u}}^4+x_{\mathrm{l}}^4)\,\frac{1}{x_{\mathrm{H}}^2}\,c^2-(1+2c^2)\Big]\,a_{\phi\square}\\
&-\Big[21c^2x_{\mathrm{H}}^2+(5-4c^2)\Big]\,a_{\phi D}\Big\}\,\frac{1}{c^2}\,\mathrm{L_R}\\
&-12\,\frac{x_{\mathrm{d}}^2}{x_{\mathrm{H}}^2}\sum_{\mathrm{gen}}a_{\mathrm{d}\phi}x_{\mathrm{d}}^2\,a^{\mathrm{fin}}_0\left(M_{\mathrm{b}}\right)+12\,\frac{x_{\mathrm{u}}^2}{x_{\mathrm{H}}^2}\sum_{\mathrm{gen}}a_{\mathrm{u}\phi}x_{\mathrm{u}}^2\,a^{\mathrm{fin}}_0\left(M_{\mathrm{t}}\right)-4\,\frac{x_{\mathrm{l}}^2}{x_{\mathrm{H}}^2}\sum_{\mathrm{gen}}a_{\mathrm{L}\phi}x_{\mathrm{l}}^2\,a^{\mathrm{fin}}_0\left(M_{\mathrm{l}}\right)\\
&-\frac{3}{8}\Big[16\,\frac{1}{x_{\mathrm{H}}^2}\,a_{ZZ}-8\,\frac{1}{x_{\mathrm{H}}^2}\,c^2 a_{\phi}+(-c^2+4\,\frac{1}{x_{\mathrm{H}}^2})\,a_{\phi D}\Big]\,\frac{1}{c^4}\,a^{\mathrm{fin}}_0\left(M_{\mathrm{Z}}\right)\\
&+6(-2a_{\phi W}+a_{\phi})\,\frac{1}{x_{\mathrm{H}}^2}\,a^{\mathrm{fin}}_0\left(M_{\mathrm{W}}\right)+\frac{1}{8}\,(7a_{\phi D}x_{\mathrm{H}}^2-28a_{\phi\square}x_{\mathrm{H}}^2+120a_{\phi})\,a^{\mathrm{fin}}_0\left(M_{\mathrm{H}}\right)\\
&-\frac{3}{4}\sum_{\mathrm{gen}}\Big\{-4\Big[(-x_{\mathrm{H}}^2+4x_{\mathrm{d}}^2)\,a_{\mathrm{d}\phi\square}\Big]+(-x_{\mathrm{H}}^2+4x_{\mathrm{d}}^2)\,a^{(-)}_{\phi WD}\Big\}\,\frac{x_{\mathrm{d}}^2}{x_{\mathrm{H}}^2}\,\mathrm{B}^{\mathrm{fin}}_0\left(-M_{\mathrm{H}}^2;M_{\mathrm{b}},M_{\mathrm{b}}\right)\\
&-\frac{3}{4}\sum_{\mathrm{gen}}\Big\{4\Big[(-x_{\mathrm{H}}^2+4x_{\mathrm{u}}^2)\,a_{\mathrm{u}\phi\square}\Big]+(-x_{\mathrm{H}}^2+4x_{\mathrm{u}}^2)\,a^{(-)}_{\phi WD}\Big\}\,\frac{x_{\mathrm{u}}^2}{x_{\mathrm{H}}^2}\,\mathrm{B}^{\mathrm{fin}}_0\left(-M_{\mathrm{H}}^2;M_{\mathrm{t}},M_{\mathrm{t}}\right)\\
&-\frac{1}{4}\sum_{\mathrm{gen}}\Big\{-4\Big[(-x_{\mathrm{H}}^2+4x_{\mathrm{l}}^2)\,a_{\mathrm{l}\phi\square}\Big]+(-x_{\mathrm{H}}^2+4x_{\mathrm{l}}^2)\,a^{(-)}_{\phi WD}\Big\}\,\frac{x_{\mathrm{l}}^2}{x_{\mathrm{H}}^2}\,\mathrm{B}^{\mathrm{fin}}_0\left(-M_{\mathrm{H}}^2;M_{\mathrm{l}},M_{\mathrm{l}}\right)\\
&+\frac{1}{16}\Big[(-4c^2+c^4x_{\mathrm{H}}^2+12\,\frac{1}{x_{\mathrm{H}}^2})\,a^{(+)}_{\phi WD}+4(-4c^2+c^4x_{\mathrm{H}}^2+12\,\frac{1}{x_{\mathrm{H}}^2})\,a_{\phi\square}+48(-c^2+2\,\frac{1}{x_{\mathrm{H}}^2})\,a_{ZZ}\Big]\,\frac{1}{c^4}\\
&\times\mathrm{B}^{\mathrm{fin}}_0\left(-M_{\mathrm{H}}^2;M_{\mathrm{Z}},M_{\mathrm{Z}}\right)\\
&+\frac{1}{8}\Big\{a^{(-)}_{\phi WD}x_{\mathrm{H}}^2+4\Big[12-(4-x_{\mathrm{H}}^2)x_{\mathrm{H}}^2\Big]\,\frac{1}{x_{\mathrm{H}}^2}\,a_{\phi\square}-4(3-x_{\mathrm{H}}^2)\,\frac{1}{x_{\mathrm{H}}^2}\,a_{\phi D}+16(9-4x_{\mathrm{H}}^2)\,\frac{1}{x_{\mathrm{H}}^2}\,a_{\phi W}\Big\}\\
&\times\mathrm{B}^{\mathrm{fin}}_0\left(-M_{\mathrm{H}}^2;M_{\mathrm{W}},M_{\mathrm{W}}\right)\\
&-\frac{9}{16}\,(-4a_{\phi W}x_{\mathrm{H}}^2+3a_{\phi D}x_{\mathrm{H}}^2-12a_{\phi\square}x_{\mathrm{H}}^2+32a_{\phi})\,\mathrm{B}^{\mathrm{fin}}_0\left(-M_{\mathrm{H}}^2;M_{\mathrm{H}},M_{\mathrm{H}}\right)
\end{aligned}
$$

F Wave-function factors

In this appendix we present the full list of wave-function renormalization factors for H, Z and W fields. For the W factor we present only the IR finite part.

$$
\begin{aligned}
\mathrm{W}_{\mathrm{H}}^{(4)} = & -\frac{1}{2}\left[-\sum_{\text{gen}}(3\,x_{\mathrm{d}}^2+3\,x_{\mathrm{u}}^2+x_{\mathrm{l}}^2)\,c^2+(1+2\,c^2)\right]\frac{1}{c^2}\,\mathrm{L_R} \\
& +\frac{3}{2}\sum_{\text{gen}} x_{\mathrm{d}}^2\,\mathrm{B_0^{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{b}}\,,M_{\mathrm{b}}\right)+\frac{3}{2}\sum_{\text{gen}} x_{\mathrm{u}}^2\,\mathrm{B_0^{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{t}}\,,M_{\mathrm{t}}\right) \\
& +\frac{1}{2}\sum_{\text{gen}} x_{\mathrm{l}}^2\,\mathrm{B_0^{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{l}}\,,M_{\mathrm{l}}\right)-\frac{1}{2}\,\frac{1}{c^2}\,\mathrm{B_0^{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{Z}}\,,M_{\mathrm{Z}}\right) \\
& -\mathrm{B_0^{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{W}}\,,M_{\mathrm{W}}\right)+\frac{9}{8}\,x_{\mathrm{H}}^4\,\mathrm{B_{0p}^{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{H}}\,,M_{\mathrm{H}}\right) \\
& -\frac{3}{2}\sum_{\text{gen}}(-x_{\mathrm{H}}^2+4\,x_{\mathrm{d}}^2)\,x_{\mathrm{d}}^2\,\mathrm{B_{0p}^{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{b}}\,,M_{\mathrm{b}}\right) \\
& -\frac{3}{2}\sum_{\text{gen}}(-x_{\mathrm{H}}^2+4\,x_{\mathrm{u}}^2)\,x_{\mathrm{u}}^2\,\mathrm{B_{0p}^{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{t}}\,,M_{\mathrm{t}}\right) \\
& -\frac{1}{2}\sum_{\text{gen}}(-x_{\mathrm{H}}^2+4\,x_{\mathrm{l}}^2)\,x_{\mathrm{l}}^2\,\mathrm{B_{0p}^{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{l}}\,,M_{\mathrm{l}}\right) \\
& +\frac{1}{4}\left[12-(4-x_{\mathrm{H}}^2)\,x_{\mathrm{H}}^2\right]\mathrm{B_{0p}^{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{W}}\,,M_{\mathrm{W}}\right) \\
& +\frac{1}{8}\,(12-4\,c^2\,x_{\mathrm{H}}^2+c^4\,x_{\mathrm{H}}^4)\,\frac{1}{c^4}\,\mathrm{B_{0p}^{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{Z}}\,,M_{\mathrm{Z}}\right)
\end{aligned}
$$

$$
\begin{aligned}
\mathrm{W}_{\mathrm{Z}}^{(4)} = & \frac{1}{9}\,(1-2\,c^2)\,\frac{1}{c^2}-\frac{1}{36}\left[(9+\mathrm{v}_{\mathrm{l}}^2+3\,\mathrm{v}_{\mathrm{d}}^2+3\,\mathrm{v}_{\mathrm{u}}^2)\right]\frac{1}{c^2}\,(1-3\,\mathrm{L_R})\,\mathrm{N_{gen}} \\
& +\frac{1}{6}\,(1-20\,c^2+18\,s^2\,c^2)\,\frac{1}{c^2}\,\mathrm{L_R} \\
& +\frac{1}{12}\,(1-c^2\,x_{\mathrm{H}}^2)\,x_{\mathrm{H}}^2\,a_0^{\mathrm{fin}}\left(M_{\mathrm{H}}\right)-\frac{1}{12}\,(1-c^2\,x_{\mathrm{H}}^2)\,\frac{1}{c^2}\,a_0^{\mathrm{fin}}\left(M_{\mathrm{Z}}\right) \\
& +\frac{1}{12}\sum_{\text{gen}}\left[(1+\mathrm{v}_{\mathrm{l}}^2)\right]\frac{1}{c^2}\,\mathrm{B_0^{fin}}\left(-M_{\mathrm{Z}}^2\,;M_{\mathrm{l}}\,,M_{\mathrm{l}}\right) \\
& +\frac{1}{6}\,\frac{1}{c^2}\sum_{\text{gen}}\mathrm{B_0^{fin}}\left(-M_{\mathrm{Z}}^2\,;0\,,0\right) \\
& +\frac{1}{4}\sum_{\text{gen}}\left[(1+\mathrm{v}_{\mathrm{d}}^2)\right]\frac{1}{c^2}\,\mathrm{B_0^{fin}}\left(-M_{\mathrm{Z}}^2\,;M_{\mathrm{b}}\,,M_{\mathrm{b}}\right) \\
& +\frac{1}{4}\sum_{\text{gen}}\left[(1+\mathrm{v}_{\mathrm{u}}^2)\right]\frac{1}{c^2}\,\mathrm{B_0^{fin}}\left(-M_{\mathrm{Z}}^2\,;M_{\mathrm{t}}\,,M_{\mathrm{t}}\right) \\
& +\frac{1}{12}\,(1-40\,c^2+36\,s^2\,c^2)\,\frac{1}{c^2}\,\mathrm{B_0^{fin}}\left(-M_{\mathrm{Z}}^2\,;M_{\mathrm{W}}\,,M_{\mathrm{W}}\right) \\
& +\frac{1}{6}\,\frac{1}{c^4}\sum_{\text{gen}}\mathrm{B_{0p}^{fin}}\left(-M_{\mathrm{Z}}^2\,;0\,,0\right) \\
& +\frac{1}{12}\sum_{\text{gen}}\left[(1+\mathrm{v}_{\mathrm{l}}^2)-2\,(2-\mathrm{v}_{\mathrm{l}}^2)\,c^2\,x_{\mathrm{l}}^2\right]\frac{1}{c^4}\,\mathrm{B_{0p}^{fin}}\left(-M_{\mathrm{Z}}^2\,;M_{\mathrm{l}}\,,M_{\mathrm{l}}\right) \\
& +\frac{1}{4}\sum_{\text{gen}}\left[(1+\mathrm{v}_{\mathrm{d}}^2)-2\,(2-\mathrm{v}_{\mathrm{d}}^2)\,c^2\,x_{\mathrm{d}}^2\right]\frac{1}{c^4}\,\mathrm{B_{0p}^{fin}}\left(-M_{\mathrm{Z}}^2\,;M_{\mathrm{b}}\,,M_{\mathrm{b}}\right) \\
& +\frac{1}{4}\sum_{\text{gen}}\left[(1+\mathrm{v}_{\mathrm{u}}^2)-2\,(2-\mathrm{v}_{\mathrm{u}}^2)\,c^2\,x_{\mathrm{u}}^2\right]\frac{1}{c^4}\,\mathrm{B_{0p}^{fin}}\left(-M_{\mathrm{Z}}^2\,;M_{\mathrm{t}}\,,M_{\mathrm{t}}\right) \\
& +\frac{1}{12}\left\{1+4\left[4-(17+12\,c^2)\,c^2\right]c^2\right\}\frac{1}{c^4}\,\mathrm{B_{0p}^{fin}}\left(-M_{\mathrm{Z}}^2\,;M_{\mathrm{W}}\,,M_{\mathrm{W}}\right) \\
& +\frac{1}{12}\,(2-c^2\,x_{\mathrm{H}}^2)\,x_{\mathrm{H}}^2\,\mathrm{B_0^{fin}}\left(-M_{\mathrm{Z}}^2\,;M_{\mathrm{H}}\,,M_{\mathrm{Z}}\right) \\
& +\frac{1}{12}\,(12-4\,c^2\,x_{\mathrm{H}}^2+c^4\,x_{\mathrm{H}}^4)\,\frac{1}{c^4}\,\mathrm{B_{0p}^{fin}}\left(-M_{\mathrm{Z}}^2\,;M_{\mathrm{H}}\,,M_{\mathrm{Z}}\right)
\end{aligned}
$$

$$
\begin{aligned}
W_{W}^{(4)} = & -\frac{1}{9}(1-36s^2) - \frac{19}{6}L_R - \frac{4}{9}(1-3L_R)N_{gen} \\
& +\frac{1}{6}\sum_{gen} x_l^4\, a_0^{fin}(M_l) + \frac{1}{2}\sum_{gen}(x_d^2 - x_u^2)x_d^2\, a_0^{fin}(M_b) \\
& -\frac{1}{2}\sum_{gen}(x_d^2 - x_u^2)x_u^2\, a_0^{fin}(M_t) + \frac{1}{12}\left[c^2 x_H^2 + (1-2c^2)\right]\frac{1}{c^2}\, a_0^{fin}(M_W) \\
& +\frac{1}{12}(1-x_H^2)x_H^2\, a_0^{fin}(M_H) - \frac{1}{12}(9-8s^2)\frac{s^2}{c^4}\, a_0^{fin}(M_Z) \\
& -4s^2\, B_0^{fin}\left(-M_W^2; 0, M_W\right) \\
& +\frac{1}{6}\sum_{gen}(2+x_l^4)\, B_0^{fin}\left(-M_W^2; 0, M_l\right) \\
& +\frac{1}{2}\sum_{gen}(2+(x_u^2 - x_d^2)^2)\, B_0^{fin}\left(-M_W^2; M_t, M_b\right) \\
& -\frac{1}{12}\left[1-48s^2c^4 + 2(3+16c^2)c^2\right]\frac{1}{c^4}\, B_0^{fin}\left(-M_W^2; M_W, M_Z\right) \\
& +\frac{1}{12}(2-x_H^2)x_H^2\, B_0^{fin}\left(-M_W^2; M_W, M_H\right) \\
& +\frac{1}{6}\sum_{gen}\left[2-(1+x_l^2)x_l^2\right] B_{0p}^{fin}\left(-M_W^2; 0, M_l\right) \\
& +\frac{1}{2}\sum_{gen}(2-x_d^2-x_u^2-(x_u^2-x_d^2)^2)\, B_{0p}^{fin}\left(-M_W^2; M_t, M_b\right) \\
& +\frac{1}{12}\left[1+48s^2c^4 + 4(4-29c^2)c^2\right]\frac{1}{c^4}\, B_{0p}^{fin}\left(-M_W^2; M_W, M_Z\right) \\
& +\frac{1}{12}\left[12-(4-x_H^2)x_H^2\right] B_{0p}^{fin}\left(-M_W^2; M_W, M_H\right)
\end{aligned}
$$

$$
\begin{aligned}
W_{H}^{(6)} = & \; 4a_{\phi W} + \frac{1}{c^2}a_{ZZ}(2-3L_R) \\
& -\frac{1}{8}\Bigg\{-2\sum_{gen}(3x_d^2+3x_u^2+x_l^2)c^2 a_{\phi WD}^{(-)} + 8\sum_{gen}(a_{l\phi\Box}x_l^2 + 3a_{d\phi\Box}x_d^2 - 3a_{u\phi\Box}x_u^2)c^2 \\
& +\left[5c^2x_H^2+(1-4c^2)\right]a_{\phi D} - 4\left[7c^2x_H^2 - 2(1+2c^2)\right]a_{\phi\Box} + 8(1+8c^2)a_{\phi W}\Bigg\}\frac{1}{c^2}L_R \\
& +\frac{1}{8}\frac{1}{c^2}a_{\phi D}\, a_0^{fin}(M_Z) + \frac{1}{8}(a_{\phi D} - 4a_{\phi\Box})x_H^2\, a_0^{fin}(M_H) \\
& +\frac{3}{4}\sum_{gen}\left[a_{\phi WD}^{(-)} + 4a_{u\phi\Box}\right]x_u^2\, B_0^{fin}\left(-M_H^2; M_t, M_t\right) + \frac{3}{4}\sum_{gen}\left[a_{\phi WD}^{(-)} - 4a_{d\phi\Box}\right]x_d^2\, B_0^{fin}\left(-M_H^2; M_b, M_b\right) \\
& +\frac{1}{4}\sum_{gen}\left[a_{\phi WD}^{(-)} - 4a_{l\phi\Box}\right]x_l^2\, B_0^{fin}\left(-M_H^2; M_l, M_l\right) \\
& -\frac{1}{8}\left[24a_{ZZ} + 8a_{\phi W} - c^2a_{\phi D}x_H^2 + 4(2-c^2x_H^2)a_{\phi\Box}\right]\frac{1}{c^2}\, B_0^{fin}\left(-M_H^2; M_Z, M_Z\right) \\
& -\frac{1}{4}\left[32a_{\phi W} - (2-x_H^2)a_{\phi D} + 4(2-x_H^2)a_{\phi\Box}\right] B_0^{fin}\left(-M_H^2; M_W, M_W\right) \\
& -\frac{3}{8}(a_{\phi D} - 4a_{\phi\Box})x_H^2\, B_0^{fin}\left(-M_H^2; M_H, M_H\right) \\
& -\frac{3}{4}\sum_{gen}\left\{-4\left[(-x_H^2+4x_d^2)a_{d\phi\Box}\right] + (-x_H^2+4x_d^2)a_{\phi WD}^{(-)}\right\}x_d^2\, B_{0p}^{fin}\left(-M_H^2; M_b, M_b\right) \\
& -\frac{3}{4}\sum_{gen}\left\{4\left[(-x_H^2+4x_u^2)a_{u\phi\Box}\right] + (-x_H^2+4x_u^2)a_{\phi WD}^{(-)}\right\}x_u^2\, B_{0p}^{fin}\left(-M_H^2; M_t, M_t\right) \\
& -\frac{1}{4}\sum_{gen}\left\{-4\left[(-x_H^2+4x_l^2)a_{l\phi\Box}\right] + (-x_H^2+4x_l^2)a_{\phi WD}^{(-)}\right\}x_l^2\, B_{0p}^{fin}\left(-M_H^2; M_l, M_l\right) \\
& +\frac{1}{16}\left[48(2-c^2x_H^2)a_{ZZ} + (12-4c^2x_H^2+c^4x_H^4)a_{\phi WD}^{(+)} + 4(12-4c^2x_H^2+c^4x_H^4)a_{\phi\Box}\right]\frac{1}{c^4}
\end{aligned}
$$

$$
\begin{aligned}
&\times \mathrm{B}^{\mathrm{fin}}_{0\mathrm{p}}\left(-M^2_{\mathrm{H}}\,;M_{\mathrm{Z}}\,,M_{\mathrm{Z}}\right)\\
&+\frac{1}{8}\left\{a^{(-)}_{\phi\mathrm{WD}}\,x^4_{\mathrm{H}}+4\left[12-(4-x^2_{\mathrm{H}})\,x^2_{\mathrm{H}}\right]a_{\phi\Box}-4\,(3-x^2_{\mathrm{H}})\,a_{\phi\mathrm{D}}+16\,(9-4\,x^2_{\mathrm{H}})\,a_{\phi\mathrm{W}}\right\}\mathrm{B}^{\mathrm{fin}}_{0\mathrm{p}}\left(-M^2_{\mathrm{H}}\,;M_{\mathrm{W}}\,,M_{\mathrm{W}}\right)\\
&-\frac{9}{16}\,(-4\,a_{\phi\mathrm{W}}\,x^2_{\mathrm{H}}+3\,a_{\phi\mathrm{D}}\,x^2_{\mathrm{H}}-12\,a_{\phi\Box}\,x^2_{\mathrm{H}}+32\,a_{\phi})\,x^2_{\mathrm{H}}\,\mathrm{B}^{\mathrm{fin}}_{0\mathrm{p}}\left(-M^2_{\mathrm{H}}\,;M_{\mathrm{H}}\,,M_{\mathrm{H}}\right)
\end{aligned}
$$

$$
\begin{aligned}
\mathrm{W}^{(6)}_{\mathrm{Z}} = {} & \frac{1}{18}\,\frac{1}{c^2}\,a_{\phi\Box}\,(2+3\,\mathrm{L_R})\\
&-\frac{1}{9}\sum_{\mathrm{gen}}(a_{\phi\mathrm{v}}+a_{\phi\mathrm{l\,A}}+a_{\phi\mathrm{l\,V}}\,\mathrm{v_l}+3\,a_{\phi\mathrm{d\,A}}+3\,a_{\phi\mathrm{u\,A}}+3\,\mathrm{v_d}\,a_{\phi\mathrm{d\,V}}+3\,\mathrm{v_u}\,a_{\phi\mathrm{u\,V}})\,\frac{1}{c^2}\,(1-3\,\mathrm{L_R})\\
&-\frac{1}{72}\left\{9\,a^{(-)}_{\phi\mathrm{WD}}+\left[(1+4\,c^2)\,\mathrm{v_d}+(3+4\,c^2)\,\mathrm{v_l}+(5+8\,c^2)\,\mathrm{v_u}\right]a_{\phi\mathrm{D}}\right.\\
&-4\left[(1+8\,c^2)\,\mathrm{v_d}+(3+8\,c^2)\,\mathrm{v_l}+(5+16\,c^2)\,\mathrm{v_u}\right]s\,a_{\phi\mathrm{WA}}\\
&-4\left[(5-8\,c^2)\,\mathrm{v_d}+(7-8\,c^2)\,\mathrm{v_l}+(13-16\,c^2)\,\mathrm{v_u}\right]c\,a_{\phi\mathrm{WZ}}\\
&\left.+64\left[(\mathrm{v_l}+\mathrm{v_d}+2\,\mathrm{v_u})\right]s^2\,c^2\,a_{\phi\mathrm{B}}\right\}\frac{1}{c^2}\,(1-3\,\mathrm{L_R})\,\mathrm{N_{gen}}\\
&-\frac{1}{12}\left\{-6\sum_{\mathrm{gen}}c\,a_{\mathrm{l\,BW}}\,x^2_{\mathrm{l}}\,\mathrm{v_l}-18\sum_{\mathrm{gen}}c\,\mathrm{v_d}\,a_{\mathrm{d\,BW}}\,x^2_{\mathrm{d}}+18\sum_{\mathrm{gen}}c\,\mathrm{v_u}\,a_{\mathrm{u\,BW}}\,x^2_{\mathrm{u}}\right.\\
&-8\left[4+3\,(2+c^2)\,c^2\right]s\,c\,a_{\mathrm{AZ}}-2\left[3\,c^2\,x^2_{\mathrm{H}}+(15+4\,(7-3\,(6-c^2)\,c^2)\,c^2)\right]a_{\mathrm{ZZ}}\\
&\left.-(1-20\,c^2+18\,s^2\,c^2)\,a_{\phi\mathrm{D}}+4\,(5-6\,s^4)\,s^2\,a_{\mathrm{AA}}\right\}\frac{1}{c^2}\,\mathrm{L_R}\\
&+\frac{1}{18}\left[-4\,c^2\,a_{\mathrm{ZZ}}+8\,s\,c\,a_{\mathrm{AZ}}+4\,s^2\,a_{\mathrm{AA}}+(1-2\,c^2)\,a_{\phi\mathrm{D}}\right]\frac{1}{c^2}\\
&+\frac{1}{24}\left[a_{\phi\mathrm{D}}-8\,c\,a_{\phi\mathrm{WZ}}-c^2\,a^{(+)}_{\phi\mathrm{WD}}\,x^2_{\mathrm{H}}+4\,s\,a_{\phi\mathrm{WA}}-12\,s^2\,a_{\phi\mathrm{B}}+4\,(1-c^2\,x^2_{\mathrm{H}})\,a_{\phi\Box}\right]x^2_{\mathrm{H}}\,a^{\mathrm{fin}}_0\left(M_{\mathrm{H}}\right)\\
&-\frac{1}{24}\left[a_{\phi\mathrm{D}}+16\,c\,a_{\phi\mathrm{WZ}}-c^2\,a^{(+)}_{\phi\mathrm{WD}}\,x^2_{\mathrm{H}}+4\,s\,a_{\phi\mathrm{WA}}+12\,s^2\,a_{\phi\mathrm{B}}+4\,(1-c^2\,x^2_{\mathrm{H}})\,a_{\phi\Box}\right]\frac{1}{c^2}\,a^{\mathrm{fin}}_0\left(M_{\mathrm{Z}}\right)\\
&-(c^2\,a_{\phi\mathrm{W}}+s\,c\,a_{\phi\mathrm{WB}}+s^2\,a_{\phi\mathrm{B}})\,a^{\mathrm{fin}}_0\left(M_{\mathrm{W}}\right)\\
&+\frac{1}{24}\sum_{\mathrm{gen}}\left[a^{(-)}_{\phi\mathrm{WD}}+8\,a_{\phi\mathrm{l\,A}}+8\,a_{\phi\mathrm{l\,V}}\,\mathrm{v_l}+12\,c\,a_{\mathrm{l\,BW}}\,x^2_{\mathrm{l}}\,\mathrm{v_l}+64\,s^2\,c^2\,a_{\phi\mathrm{B}}\,\mathrm{v_l}+(3+4\,c^2)\,a_{\phi\mathrm{D}}\,\mathrm{v_l}\right.\\
&\left.-4\,(3+8\,c^2)\,s\,a_{\phi\mathrm{WA}}\,\mathrm{v_l}-4\,(7-8\,c^2)\,c\,a_{\phi\mathrm{WZ}}\,\mathrm{v_l}\right]\frac{1}{c^2}\,\mathrm{B}^{\mathrm{fin}}_0\left(-M^2_{\mathrm{Z}}\,;M_{\mathrm{l}}\,,M_{\mathrm{l}}\right)\\
&+\frac{1}{24}\sum_{\mathrm{gen}}\left[3\,a^{(-)}_{\phi\mathrm{WD}}+24\,a_{\phi\mathrm{d\,A}}+24\,\mathrm{v_d}\,a_{\phi\mathrm{d\,V}}+36\,c\,\mathrm{v_d}\,a_{\mathrm{d\,BW}}\,x^2_{\mathrm{d}}+64\,s^2\,c^2\,\mathrm{v_d}\,a_{\phi\mathrm{B}}+(1+4\,c^2)\,\mathrm{v_d}\,a_{\phi\mathrm{D}}\right.\\
&\left.-4\,(1+8\,c^2)\,s\,\mathrm{v_d}\,a_{\phi\mathrm{WA}}-4\,(5-8\,c^2)\,c\,\mathrm{v_d}\,a_{\phi\mathrm{WZ}}\right]\frac{1}{c^2}\,\mathrm{B}^{\mathrm{fin}}_0\left(-M^2_{\mathrm{Z}}\,;M_{\mathrm{b}}\,,M_{\mathrm{b}}\right)\\
&+\frac{1}{24}\sum_{\mathrm{gen}}\left[3\,a^{(-)}_{\phi\mathrm{WD}}+24\,a_{\phi\mathrm{u\,A}}+24\,\mathrm{v_u}\,a_{\phi\mathrm{u\,V}}-36\,c\,\mathrm{v_u}\,a_{\mathrm{u\,BW}}\,x^2_{\mathrm{u}}+128\,s^2\,c^2\,\mathrm{v_u}\,a_{\phi\mathrm{B}}+(5+8\,c^2)\,\mathrm{v_u}\,a_{\phi\mathrm{D}}\right.\\
&\left.-4\,(5+16\,c^2)\,s\,\mathrm{v_u}\,a_{\phi\mathrm{WA}}-4\,(13-16\,c^2)\,c\,\mathrm{v_u}\,a_{\phi\mathrm{WZ}}\right]\frac{1}{c^2}\,\mathrm{B}^{\mathrm{fin}}_0\left(-M^2_{\mathrm{Z}}\,;M_{\mathrm{t}}\,,M_{\mathrm{t}}\right)\\
&+\frac{1}{12}\sum_{\mathrm{gen}}(a^{(-)}_{\phi\mathrm{WD}}+4\,a_{\phi\mathrm{v}})\,\frac{1}{c^2}\,\mathrm{B}^{\mathrm{fin}}_0\left(-M^2_{\mathrm{Z}}\,;0\,,0\right)\\
&+\frac{1}{24}\left[48\,a_{\mathrm{ZZ}}+(2-c^2\,x^2_{\mathrm{H}})\,c^2\,a^{(+)}_{\phi\mathrm{WD}}\,x^2_{\mathrm{H}}+4\,(2-c^2\,x^2_{\mathrm{H}})\,c^2\,a_{\phi\Box}\,x^2_{\mathrm{H}}\right]\frac{1}{c^2}\,\mathrm{B}^{\mathrm{fin}}_0\left(-M^2_{\mathrm{Z}}\,;M_{\mathrm{H}}\,,M_{\mathrm{Z}}\right)\\
&+\frac{1}{24}\left\{12\left[5+4\,(3-c^2)\,c^2\right]s\,c\,a_{\mathrm{AZ}}+12\,(7-4\,(4+c^2)\,c^2\right]c^2\,a_{\mathrm{ZZ}}\\
&\left.-4\left[35-12\,(4-s^2)\,s^2\right]s^2\,a_{\mathrm{AA}}+(1-40\,c^2+36\,s^2\,c^2)\,a_{\phi\mathrm{D}}\right\}\frac{1}{c^2}\,\mathrm{B}^{\mathrm{fin}}_0\left(-M^2_{\mathrm{Z}}\,;M_{\mathrm{W}}\,,M_{\mathrm{W}}\right)\\
&+\frac{1}{24}\sum_{\mathrm{gen}}\left\{12\,c\,a_{\mathrm{l\,BW}}\,x^2_{\mathrm{l}}\,\mathrm{v_l}+\left[(3+4\,c^2)+2\,(3+4\,c^2)\,c^2\,x^2_{\mathrm{l}}\right]a_{\phi\mathrm{D}}\,\mathrm{v_l}\right.\\
&-4\left[(3+8\,c^2)+2\,(3+8\,c^2)\,c^2\,x^2_{\mathrm{l}}\right]s\,a_{\phi\mathrm{WA}}\,\mathrm{v_l}-4\left[(7-8\,c^2,rp)+2\,(7-8\,c^2)\,c^2\,x^2_{\mathrm{l}}\right]c\,a_{\phi\mathrm{WZ}}\,\mathrm{v_l}
\end{aligned}
$$

JHEP07(2015)175

$$
\begin{aligned}
&+(1-4c^2x_l^2)\,a^{(-)}_{\phi\,\mathrm{WD}}+8\,(1-4c^2x_l^2)\,a_{\phi\,l\,\mathrm{A}}+8\,(1+2c^2x_l^2)\,a_{\phi\,l\,\mathrm{V}}\,\mathrm{v}_l \\
&+64\,(1+2c^2x_l^2)\,s^2c^2\,a_{\phi\,\mathrm{B}}\,\mathrm{v}_l\Big\}\,\frac{1}{c^4}\,\mathrm{B}^{\mathrm{fin}}_{0\mathrm{p}}\left(-M_{\mathrm{Z}}^2\,;M_l\,,M_l\right) \\
&+\frac{1}{24}\sum_{\mathrm{gen}}\Big\{36\,c\,\mathrm{v_d}\,a_{\mathrm{d\,BW}}\,x_{\mathrm{d}}^2+\left[(1+4c^2)+2\,(1+4c^2)\,c^2x_{\mathrm{d}}^2\right]\mathrm{v_d}\,a_{\phi\,\mathrm{D}} \\
&-4\left[(1+8c^2)+2\,(1+8c^2)\,c^2x_{\mathrm{d}}^2\right]s\,\mathrm{v_d}\,a_{\phi\,\mathrm{WA}}-4\left[(5-8c^2,rp)+2\,(5-8c^2)\,c^2x_{\mathrm{d}}^2\right]c\,\mathrm{v_d}\,a_{\phi\,\mathrm{WZ}} \\
&+3\,(1-4c^2x_{\mathrm{d}}^2)\,a^{(-)}_{\phi\,\mathrm{WD}}+24\,(1-4c^2x_{\mathrm{d}}^2)\,a_{\phi\,\mathrm{d\,A}}+24\,(1+2c^2x_{\mathrm{d}}^2)\,\mathrm{v_d}\,a_{\phi\,\mathrm{d\,V}} \\
&+64\,(1+2c^2x_{\mathrm{d}}^2)\,s^2c^2\,\mathrm{v_d}\,a_{\phi\,\mathrm{B}}\Big\}\,\frac{1}{c^4}\,\mathrm{B}^{\mathrm{fin}}_{0\mathrm{p}}\left(-M_{\mathrm{Z}}^2\,;M_{\mathrm{b}}\,,M_{\mathrm{b}}\right) \\
&-\frac{1}{24}\sum_{\mathrm{gen}}\Big\{36\,c\,\mathrm{v_u}\,a_{\mathrm{u\,BW}}\,x_{\mathrm{u}}^2-\left[(5+8c^2)+2\,(5+8c^2)\,c^2x_{\mathrm{u}}^2\right]\mathrm{v_u}\,a_{\phi\,\mathrm{D}} \\
&+4\left[(5+16c^2)+2\,(5+16c^2)\,c^2x_{\mathrm{u}}^2\right]s\,\mathrm{v_u}\,a_{\phi\,\mathrm{WA}}+4\left[(13-16c^2)+2\,(13-16c^2)\,c^2x_{\mathrm{u}}^2\right]c\,\mathrm{v_u}\,a_{\phi\,\mathrm{WZ}} \\
&-3\,(1-4c^2x_{\mathrm{u}}^2)\,a^{(-)}_{\phi\,\mathrm{WD}}-24\,(1-4c^2x_{\mathrm{u}}^2)\,a_{\phi\,\mathrm{u\,A}}-24\,(1+2c^2x_{\mathrm{u}}^2)\,\mathrm{v_u}\,a_{\phi\,\mathrm{u\,V}} \\
&-128\,(1+2c^2x_{\mathrm{u}}^2)\,s^2c^2\,\mathrm{v_u}\,a_{\phi\,\mathrm{B}}\Big\}\,\frac{1}{c^4}\,\mathrm{B}^{\mathrm{fin}}_{0\mathrm{p}}\left(-M_{\mathrm{Z}}^2\,;M_{\mathrm{t}}\,,M_{\mathrm{t}}\right) \\
&+\frac{1}{12}\sum_{\mathrm{gen}}(a^{(-)}_{\phi\,\mathrm{WD}}+4\,a_{\phi\,\mathrm{V}})\,\frac{1}{c^4}\,\mathrm{B}^{\mathrm{fin}}_{0\mathrm{p}}\left(-M_{\mathrm{Z}}^2\,;0\,,0\right) \\
&+\frac{1}{24}\left[48\,(2-c^2x_{\mathrm{H}}^2)\,a_{\mathrm{ZZ}}+(12-4c^2x_{\mathrm{H}}^2+c^4x_{\mathrm{H}}^4)\,a^{(+)}_{\phi\,\mathrm{WD}}+4\,(12-4c^2x_{\mathrm{H}}^2+c^4x_{\mathrm{H}}^4)\,a_{\phi\,\Box}\right]\frac{1}{c^4} \\
&\times\mathrm{B}^{\mathrm{fin}}_{0\mathrm{p}}\left(-M_{\mathrm{Z}}^2\,;M_{\mathrm{H}}\,,M_{\mathrm{Z}}\right) \\
&+\frac{1}{24}\Big\{\left[1+4\,(4-(17+12c^2)\,c^2)\,c^2\right]a_{\phi\,\mathrm{D}}+12\left[5+4\,(6+(3+4c^2)\,c^2)\,c^2\right]s\,c\,a_{\mathrm{AZ}} \\
&+12\left[7-4\,(5+(9-4c^2)\,c^2)\,c^2\right]c^2\,a_{\mathrm{ZZ}}+4\left[33-4\,(29-3\,(11-4s^2)\,s^2)\,s^2\right]s^2\,a_{\mathrm{AA}}\Big\}\,\frac{1}{c^4} \\
&\times\mathrm{B}^{\mathrm{fin}}_{0\mathrm{p}}\left(-M_{\mathrm{Z}}^2\,;M_{\mathrm{W}}\,,M_{\mathrm{W}}\right)
\end{aligned}
$$

$$
\begin{aligned}
\mathrm{W}^{(6)}_{\mathrm{W}} = &-\frac{1}{9}\,(3\,a^{(3)}_{\phi\,\mathrm{q\,W}}+a^{(3)}_{\phi\,l\,\mathrm{W}})\,(1-3\,\mathrm{L_R})\,\mathrm{N_{gen}}+\frac{1}{18}\,a_{\phi\,\Box}\,(2+3\,\mathrm{L_R}) \\
&+\frac{1}{6}\Big[3\,c^2\,a_{\phi\,\mathrm{W}}\,x_{\mathrm{H}}^2+3\sum_{\mathrm{gen}}c^2\,a_{l\,\mathrm{W}}\,x_l^2+9\sum_{\mathrm{gen}}c^2\,a_{\mathrm{d\,W}}\,x_{\mathrm{d}}^2-9\sum_{\mathrm{gen}}c^2\,a_{\mathrm{u\,W}}\,x_{\mathrm{u}}^2+(9-38c^2)\,s\,c\,a_{\mathrm{AZ}} \\
&+(15-32c^2)\,c^2\,a_{\mathrm{ZZ}}-(29-32s^2)\,s^2\,a_{\mathrm{AA}}\Big]\,\frac{1}{c^2}\,\mathrm{L_R} \\
&-\frac{2}{9}\left[9\,c^2\,a_{\phi\,\mathrm{D}}-39\,s\,c\,a_{\phi\,\mathrm{WB}}+6\,s^2\,a_{\mathrm{AA}}+(1-42s^2)\,a_{\phi\,\mathrm{W}}\right] \\
&+\frac{1}{6}\sum_{\mathrm{gen}}a^{(3)}_{\phi\,l\,\mathrm{W}}\,x_l^4\,a^{\mathrm{fin}}_0\left(M_l\right) \\
&+\frac{1}{2}\sum_{\mathrm{gen}}(x_{\mathrm{d}}^2-x_{\mathrm{u}}^2)\,a^{(3)}_{\phi\,\mathrm{q\,W}}\,x_{\mathrm{d}}^2\,a^{\mathrm{fin}}_0\left(M_{\mathrm{b}}\right) \\
&-\frac{1}{2}\sum_{\mathrm{gen}}(x_{\mathrm{d}}^2-x_{\mathrm{u}}^2)\,a^{(3)}_{\phi\,\mathrm{q\,W}}\,x_{\mathrm{u}}^2\,a^{\mathrm{fin}}_0\left(M_{\mathrm{t}}\right) \\
&-\frac{1}{24}\left[a^{(-)}_{\phi\,\mathrm{WD}}\,x_{\mathrm{H}}^2+8\,a_{\phi\,\mathrm{W}}+a_{\phi\,\mathrm{D}}-4\,(1-x_{\mathrm{H}}^2)\,a_{\phi\,\Box}\right]x_{\mathrm{H}}^2\,a^{\mathrm{fin}}_0\left(M_{\mathrm{H}}\right) \\
&+\frac{1}{24}\Big[c^2\,a^{(-)}_{\phi\,\mathrm{WD}}\,x_{\mathrm{H}}^2-4\,(1-x_{\mathrm{H}}^2)\,c^2\,a_{\phi\,\Box}+(1+8c^2)\,a_{\phi\,\mathrm{D}}+4\,(5-14c^2)\,s\,c\,a_{\mathrm{AZ}} \\
&+4\,(9-16c^2)\,c^2\,a_{\mathrm{ZZ}}-4\,(15-16s^2)\,s^2\,a_{\mathrm{AA}}\Big]\,\frac{1}{c^2}\,a^{\mathrm{fin}}_0\left(M_{\mathrm{W}}\right) \\
&+\frac{1}{6}\sum_{\mathrm{gen}}\left[3\,a_{l\,\mathrm{W}}\,x_l^2+(2+x_l^4)\,a^{(3)}_{\phi\,l\,\mathrm{W}}\right]\mathrm{B}^{\mathrm{fin}}_0\left(-M_{\mathrm{W}}^2\,;0\,,M_l\right)
\end{aligned}
$$

$$
\begin{aligned}
&+\frac{1}{2}\sum_{\rm gen}\Big[3\,a_{\rm d\,w}\,x_{\rm d}^2-3\,a_{\rm u\,w}\,x_{\rm u}^2+(2+(x_{\rm u}^2-x_{\rm d}^2)^2)\,a^{(3)}_{\phi\rm q\,w}\Big]\,{\rm B}_0^{\rm fin}\left(-M_{\rm W}^2\,;M_{\rm t}\,,M_{\rm b}\right)\\
&+\frac{1}{24}\left[48\,a_{\phi\rm w}+(2-x_{\rm H}^2)\,a^{(-)}_{\phi\rm WD}\,x_{\rm H}^2+4\,(2-x_{\rm H}^2)\,a_{\phi\Box}\,x_{\rm H}^2\right]{\rm B}_0^{\rm fin}\left(-M_{\rm W}^2\,;M_{\rm W}\,,M_{\rm H}\right)\\
&-\frac{1}{24}\left\{\left[1-48\,s^2\,c^4+2\,(3+16\,c^2)\,c^2\right]a_{\phi\rm D}+4\left[1+2\,(1-4\,c^4)\,c^2\right]s\,a_{\phi\rm WA}\right.\\
&\left.+4\left[5-2\,(5-2\,(9+2\,c^2)\,c^2)\,c^2\right]c\,a_{\phi\rm WZ}+16\,(3-4\,s^2)\,s^2\,c^4\,a_{\phi\rm B}\right\}\frac{1}{c^4}\,{\rm B}_0^{\rm fin}\left(-M_{\rm W}^2\,;M_{\rm W}\,,M_{\rm Z}\right)\\
&-2\,a_{\phi\rm WAD}\,{\rm B}_0^{\rm fin}\left(-M_{\rm W}^2\,;0\,,M_{\rm W}\right)\\
&+\frac{1}{2}\sum_{\rm gen}\Big[3\,(1-x_{\rm d}^2+x_{\rm u}^2)\,a_{\rm d\,w}\,x_{\rm d}^2-3\,(1+x_{\rm d}^2-x_{\rm u}^2)\,a_{\rm u\,w}\,x_{\rm u}^2+(2-x_{\rm d}^2-x_{\rm u}^2-(x_{\rm u}^2-x_{\rm d}^2)^2)\,a^{(3)}_{\phi\rm q\,w}\Big]\\
&\times{\rm B}_{0\rm p}^{\rm fin}\left(-M_{\rm W}^2\,;M_{\rm t}\,,M_{\rm b}\right)\\
&+\frac{1}{6}\sum_{\rm gen}\Big\{\left[2-(1+x_{\rm l}^2)\,x_{\rm l}^2\right]a^{(3)}_{\phi\rm l\,w}+3\,(1-x_{\rm l}^2)\,a_{\rm l\,w}\,x_{\rm l}^2\Big\}\,{\rm B}_{0\rm p}^{\rm fin}\left(-M_{\rm W}^2\,;0\,,M_{\rm l}\right)\\
&-\frac{1}{24}\left[12\,(3-2\,c^2)\,c^2\,a_{\rm ZZ}+4\,(3-2\,s^2)\,s^2\,a_{\rm AA}+4\,(5-12\,c^4)\,s\,c\,a_{\rm AZ}+(9-8\,s^2)\,s^2\,a_{\phi\rm D}\right]\frac{1}{c^4}\,a_0^{\rm fin}\left(M_{\rm Z}\right)\\
&+\frac{1}{24}\left\{a^{(-)}_{\phi\rm WD}\,x_{\rm H}^4+4\left[12-(4-x_{\rm H}^2)\,x_{\rm H}^2\right]a_{\phi\Box}-4\,(3-x_{\rm H}^2)\,a_{\phi\rm D}+16\,(9-4\,x_{\rm H}^2)\,a_{\phi\rm w}\right\}{\rm B}_{0\rm p}^{\rm fin}\left(-M_{\rm W}^2\,;M_{\rm W}\,,M_{\rm H}\right)\\
&+\frac{1}{24}\left\{\left[1+48\,s^2\,c^4+4\,(4-29\,c^2)\,c^2\right]a_{\phi\rm D}+44\left[1-2\,(1+4\,c^2)\,c^2\right]c\,a_{\phi\rm WZ}\right.\\
&\left.+4\left[1+2\,(3-20\,c^2)\,c^2\right]s\,a_{\phi\rm WA}\right\}\frac{1}{c^4}\,{\rm B}_{0\rm p}^{\rm fin}\left(-M_{\rm W}^2\,;M_{\rm W}\,,M_{\rm Z}\right)
\end{aligned}
$$

G Mixing of Wilson coefficients

In this appendix we present the entries of the mixing matrix, eq. (5.9), that can be derived from the renormalization of $\rm H \to VV$.

G.1 Notations

First we define

R

$$
\begin{array}{lll}
{\rm R}^a_0 = 1+2\,c^2 & {\rm R}^a_1 = 7-12\,c^2 & {\rm R}^a_2 = 23-12\,c^2\\
{\rm R}^a_3 = 13-9\,c^2 & {\rm R}^a_4 = 1-12\,c^2 & {\rm R}^a_5 = 7+6\,c^2\\
{\rm R}^a_6 = 77+48\,c^2 & {\rm R}^a_7 = 5-12\,c^2 & {\rm R}^a_8 = 11-4\,c^2\\
{\rm R}^a_9 = 5+48\,c^2 & &
\end{array}
$$

$$
\begin{array}{lll}
{\rm R}^b_0 = 1+6\,s^2 & {\rm R}^b_1 = 1-s^2 & {\rm R}^b_2 = 11-12\,s^2\\
{\rm R}^b_3 = 1-c^2 & {\rm R}^b_4 = 13-18\,{\rm R}^a_0\,c^2 & {\rm R}^b_5 = 41+6\,{\rm R}^a_1\,c^2\\
{\rm R}^b_6 = 65-6\,{\rm R}^a_2\,c^2 & {\rm R}^b_7 = 9-4\,s^2 & {\rm R}^b_8 = 7-6\,s^2\\
{\rm R}^b_9 = 11-9\,s^2 & {\rm R}^b_{10} = 2-c^2 & {\rm R}^b_{11} = 43-18\,s^2\\
{\rm R}^b_{12} = 31-8\,{\rm R}^a_3\,c^2 & {\rm R}^b_{13} = 7-8\,c^4 & {\rm R}^b_{14} = 179+16\,{\rm R}^a_4\,c^2\\
{\rm R}^b_{15} = 77-12\,{\rm R}^a_5\,c^2 & {\rm R}^b_{16} = 79-4\,{\rm R}^a_6\,c^2 & {\rm R}^b_{17} = 7\,c^2+3\,s^2\\
{\rm R}^b_{18} = 35+3\,{\rm R}^a_7\,c^2 & {\rm R}^b_{19} = 107-32\,{\rm R}^a_8\,c^2 & {\rm R}^b_{20} = 267-4\,{\rm R}^a_9\,c^2\\
{\rm R}^b_{21} = 7-78\,c^2 & &
\end{array}
$$

$$
\begin{array}{lll}
R^c_0 = 1+2c^2-4R^b_0 s^2 c^2 & R^c_1 = 3-4R^b_1 s^2 & R^c_2 = 1-2s^2 \\
R^c_3 = 7+6R^b_2 s^2 & R^c_4 = 9-16c^2 & R^c_5 = 4-3s^2 \\
R^c_6 = 3-4R^b_3 c^2 & R^c_7 = 17+2R^b_4 c^2 & R^c_8 = 1-2c^2 \\
R^c_9 = 11-R^b_5 c^2 & R^c_{10} = 1+R^b_6 c^2 & R^c_{11} = 91-18R^b_7 s^2 \\
R^c_{12} = 1+8R^b_1 s^2 & R^c_{13} = 5+5c^2-12R^b_8 s^2 c^2 & R^c_{14} = 27+128 s^2 c^2 \\
R^c_{15} = 1-4s^2 & R^c_{16} = 19-8R^b_9 s^2 & R^c_{17} = 1-R^b_{10} c^2 \\
R^c_{18} = 117-4R^b_{11} s^2 & R^c_{19} = 1+4s^2 & R^c_{20} = 1+R^b_{12} c^2 \\
R^c_{21} = 1+8c^2 & R^c_{22} = 1+c^2 & R^c_{23} = 3-5c^2 \\
R^c_{24} = 1-7c^2 & R^c_{25} = 5-11c^2 & R^c_{26} = 1+R^b_{13} c^2 \\
R^c_{27} = 3-R^b_{14} c^2 & R^c_{28} = 27-48c^2+128s^4 & R^c_{29} = 9+8c^4 \\
R^c_{30} = 13-R^b_{15} c^2 & R^c_{31} = 58+R^b_{16} c^2 & R^c_{32} = 3c^2+R^b_{17} s^2 \\
R^c_{33} = 2+c^2 & R^c_{34} = 14-R^b_{18} c^2 & R^c_{35} = 54+R^b_{19} c^2 \\
R^c_{36} = 55-R^b_{20} c^2 & R^c_{37} = 7-2R^b_{21} c^2 &
\end{array}
$$

S

$$
\begin{array}{lll}
S_0 = 3x_d^2+3x_u^2+x_l^2 & S_1 = 5x_d^2+x_u^2 & S_2 = x_d^2+x_u^2 \\
S_3 = x_d^2+5x_u^2 & S_4 = 3x_d^4+3x_u^4+x_l^4 &
\end{array}
$$

With their help we derive the relevant elements of the mixing matrix.

G.2 Mixing matrix

$$dZ^W_{1,1} = \frac{32}{9} s^2 N_{gen} + \frac{1}{4}(R^c_0 + R^c_1 c^2 x_H^2)\frac{1}{c^2}$$

$$dZ^W_{1,2} = -(6-x_H^2)s^2c^2$$

$$dZ^W_{1,3} = -\frac{1}{24}(v^{(1)}_{gen} + R^c_4)\frac{1}{sc}N_{gen} - \frac{1}{12}(6R^c_2 c^2 x_H^2 + R^c_3)\frac{s}{c}$$

$$dZ^W_{2,1} = (c^2 x_H^2 - 2R^c_5)s^2$$

$$dZ^W_{2,2} = \frac{1}{12}(9+v^{(1)}_{gen})\frac{1}{c^2}N_{gen} + \frac{1}{12}(3R^c_6 c^2 x_H^2 + R^c_7)\frac{1}{c^2}$$

$$dZ^W_{2,3} = \frac{1}{24}(v^{(1)}_{gen} + 8s^2 v^{(2)}_{gen} + R^c_4)\frac{1}{sc}N_{gen} - \frac{1}{12}(6R^c_8 s^2 c^2 x_H^2 - R^c_9)\frac{1}{sc}$$

$$dZ^W_{3,1} = \frac{1}{12}(v^{(1)}_{gen} + 8s^2 v^{(2)}_{gen} + R^c_4)\frac{1}{sc}N_{gen} - \frac{1}{6}(6R^c_2 s^2 c^2 x_H^2 + R^c_{10})\frac{1}{sc}$$

$$dZ^W_{3,2} = -\frac{1}{12}(v^{(1)}_{gen} + R^c_4)\frac{1}{sc}N_{gen} + \frac{1}{6}(6R^c_2 c^2 x_H^2 - R^c_{11})\frac{s}{c}$$

$$dZ^W_{3,3} = \frac{1}{72}(3v^{(1)}_{gen} + R^c_{14})\frac{1}{c^2}N_{gen} + \frac{1}{12}(3R^c_{12} c^2 x_H^2 + 2R^c_{13})\frac{1}{c^2}$$

$$dZ^W_{4,1} = \frac{16}{3}s^2 N_{gen} - \frac{1}{3}(3R^c_{15} c^2 x_H^2 - R^c_{16})\frac{s^2}{c^2}$$

$$dZ^{W}_{4,2} = -\frac{80}{9}\,\frac{1}{c^2}\,R^c_{17}\,N_{gen} + \frac{1}{3}\,(3\,R^c_{15}\,c^2\,x_H^2 - R^c_{18})\,\frac{s^2}{c^2}$$

$$dZ^{W}_{4,3} = \frac{80}{9}\,\frac{s^3}{c}\,N_{gen} + \frac{1}{3}\,(3\,R^c_{19}\,s^2\,c^2\,x_H^2 - R^c_{20})\,\frac{1}{s\,c}$$

$$dZ^{W}_{4,4} = \frac{1}{2}\sum_{gen} S_0 + \frac{1}{12}\,(9\,c^2\,x_H^2 + 7\,R^c_{21})\,\frac{1}{c^2}$$

$$dZ^{W}_{4,5} = \frac{10}{3}\,\frac{s^2}{c^2}$$

$$dZ^{W}_{4,16} = -5\sum_{gen} x_l^2 + \frac{2}{3}\,\frac{1}{c^2}\,R^c_{22}\,N_{gen}$$

$$dZ^{W}_{4,17} = -\sum_{gen} x_l^2 - \frac{2}{3}\,\frac{1}{c^2}\,R^c_{23}\,N_{gen}$$

$$dZ^{W}_{4,18} = \frac{2}{3}\,N_{gen} - \sum_{gen} x_l^2$$

$$dZ^{W}_{4,19} = 2\,\frac{1}{c^2}\,R^c_{22}\,N_{gen} - 3\sum_{gen} S_1$$

$$dZ^{W}_{4,20} = -\frac{2}{3}\,\frac{1}{c^2}\,R^c_{24}\,N_{gen} - 3\sum_{gen} S_2$$

$$dZ^{W}_{4,21} = 2\,\frac{1}{c^2}\,R^c_{22}\,N_{gen} - 3\sum_{gen} S_3$$

$$dZ^{W}_{4,22} = -\frac{2}{3}\,\frac{1}{c^2}\,R^c_{25}\,N_{gen} - 3\sum_{gen} S_2$$

$$dZ^{W}_{5,1} = -\frac{1}{72}\,(3\,v^{(1)}_{gen} + 24\,s^2\,v^{(2)}_{gen} + R^c_{28})\,N_{gen} + \frac{1}{24}\,(12\,s^2\,c^6\,x_H^4 - 9\,R^c_{26}\,c^2\,x_H^2 - R^c_{27})\,\frac{1}{c^2}$$

$$\begin{aligned} dZ^{W}_{5,2} = &-\frac{1}{24}\,(2\,v^{(1)}_{gen} - 9\,c^2\,x_H^2 - c^2\,v^{(1)}_{gen}\,x_H^2 + 2\,R^c_{29})\,\frac{1}{c^2}\,N_{gen} \\ &-\frac{1}{24}\,(R^c_{30}\,c^2\,x_H^2 + R^c_{31} + 3\,R^c_{32}\,c^4\,x_H^4)\,\frac{1}{c^2} \\ &-\frac{1}{4}\sum_{gen}(2\,S_0 + S_0\,c^2\,x_H^2 - 4\,S_4\,c^2) \end{aligned}$$

$$\begin{aligned} dZ^{W}_{5,3} = &\frac{1}{144}\,(3\,c^2\,v^{(1)}_{gen}\,x_H^2 + 3\,R^c_4\,c^2\,x_H^2 - 3\,R^c_{33}\,v^{(1)}_{gen} - 24\,R^c_{33}\,s^2\,v^{(2)}_{gen} - R^c_{35})\,\frac{1}{s\,c}\,N_{gen} \\ &+\frac{1}{24}\,(6\,R^c_2\,s^2\,c^4\,x_H^4 + 2\,R^c_{34}\,c^2\,x_H^2 - R^c_{36})\,\frac{1}{s\,c} \end{aligned}$$

$$dZ^{W}_{5,4} = \frac{1}{48}\,\frac{1}{c^2}\,R^c_{37}$$

$$dZ^{W}_{5,5} = 4\,c^2$$

JHEP07(2015)175

H Non-factorizable amplitudes

In this appendix we present the explicit expressions for the non-factorizable part of the $\mathrm{H} \to \mathrm{AA}, \mathrm{AZ}, \mathrm{ZZ}$ and WW amplitudes.

H.1 Notations

It is useful to introduce the following sets of polynomials:

$\boxed{\mathrm{T}}$ where $s = \mathrm{s}_\theta$ and $c = \mathrm{c}_\theta$

$\mathrm{T}^a_0 = 81 - 56c^2$	$\mathrm{T}^a_1 = 53 - 39c^2$	$\mathrm{T}^a_2 = 35 - 26c^2$	$\mathrm{T}^a_3 = 35 - 18c^2$
$\mathrm{T}^a_4 = 19 - 10c^2$	$\mathrm{T}^a_5 = 21 - 11c^2$	$\mathrm{T}^a_6 = 5 + 4c^2$	$\mathrm{T}^a_7 = 1 - 6c^2$
$\mathrm{T}^a_8 = 7 - 12c^2$	$\mathrm{T}^a_9 = 47 + 12c^2$	$\mathrm{T}^a_{10} = 7 - c^2$	$\mathrm{T}^a_{11} = 37 + 4c^2$
$\mathrm{T}^a_{12} = 213 - 68c^2$	$\mathrm{T}^a_{13} = 29 - 4c^2$	$\mathrm{T}^a_{14} = 49 - 12c^2$	$\mathrm{T}^a_{15} = 173 - 192c^2$
$\mathrm{T}^a_{16} = 331 - 200c^2$	$\mathrm{T}^a_{17} = 33 - 16c^2$	$\mathrm{T}^a_{18} = 53 - 16c^2$	$\mathrm{T}^a_{19} = 8 - 3c^2$
$\mathrm{T}^a_{20} = 16 - 9c^2$	$\mathrm{T}^a_{21} = 3 - c^2$		

$\mathrm{T}^b_0 = 7 - 18c^2$	$\mathrm{T}^b_1 = 2 - 27c^2$	$\mathrm{T}^b_2 = 49 - 2\mathrm{T}^a_0 c^2$	$\mathrm{T}^b_3 = 11 - \mathrm{T}^a_1 c^2$
$\mathrm{T}^b_4 = 41 - 6\mathrm{T}^a_2 c^2$	$\mathrm{T}^b_5 = 37 - 2\mathrm{T}^a_3 c^2$	$\mathrm{T}^b_6 = 39 - 4\mathrm{T}^a_4 c^2$	$\mathrm{T}^b_7 = 11 - \mathrm{T}^a_5 c^2$
$\mathrm{T}^b_8 = 33 - 56c^2$	$\mathrm{T}^b_9 = 37 - 78c^2$	$\mathrm{T}^b_{10} = 6 - 13c^2$	$\mathrm{T}^b_{11} = 4 - 5c^2$
$\mathrm{T}^b_{12} = 7 - 9c^2$	$\mathrm{T}^b_{13} = 19 - 22c^2$	$\mathrm{T}^b_{14} = 1 - c^2$	$\mathrm{T}^b_{15} = 23 - 22c^2$
$\mathrm{T}^b_{16} = 1 + \mathrm{T}^a_6 c^2$	$\mathrm{T}^b_{17} = 1 + 4c^2$	$\mathrm{T}^b_{18} = 11 + 12c^2$	$\mathrm{T}^b_{19} = 1 + 2\mathrm{T}^a_7 c^2$
$\mathrm{T}^b_{20} = 7 - 12c^2$	$\mathrm{T}^b_{21} = 1 - 6c^2$	$\mathrm{T}^b_{22} = 3 - 2c^2$	$\mathrm{T}^b_{23} = 25 + 6\mathrm{T}^a_8 c^2$
$\mathrm{T}^b_{24} = 1 + 2c^2$	$\mathrm{T}^b_{25} = 7 - 6c^2$	$\mathrm{T}^b_{26} = 1 - 2c^2$	$\mathrm{T}^b_{27} = 1 + 3c^2$
$\mathrm{T}^b_{28} = 1 + 12c^2$	$\mathrm{T}^b_{29} = 7 + 6c^2$	$\mathrm{T}^b_{30} = 1 + c^2$	$\mathrm{T}^b_{31} = 3 - 4c^2$

$\mathrm{T}^b_{32} = 13 - 34c^2$	$\mathrm{T}^b_{33} = 1 - 5c^2$	$\mathrm{T}^b_{34} = 3 - 5c^2$	$\mathrm{T}^b_{35} = 1 + 20c^2$
$\mathrm{T}^b_{36} = 3 + 4c^2$	$\mathrm{T}^b_{37} = 27 + 68c^2$	$\mathrm{T}^b_{38} = 11 + 3c^2$	$\mathrm{T}^b_{39} = 13 - 3c^2$
$\mathrm{T}^b_{40} = 5 + 4c^2$	$\mathrm{T}^b_{41} = 12 + \mathrm{T}^a_9 c^2$	$\mathrm{T}^b_{42} = 1 - 4c^2$	$\mathrm{T}^b_{43} = 7 - 3c^2$
$\mathrm{T}^b_{44} = 13 - 12c^2$	$\mathrm{T}^b_{45} = 37 - 12\mathrm{T}^a_{10} c^2$	$\mathrm{T}^b_{46} = 11 - 23c^2$	$\mathrm{T}^b_{47} = 7 + c^2$
$\mathrm{T}^b_{48} = 7 - c^2$	$\mathrm{T}^b_{49} = 44 - \mathrm{T}^a_{11} c^2$	$\mathrm{T}^b_{50} = 11 + c^2$	$\mathrm{T}^b_{51} = 23 - 7c^2$
$\mathrm{T}^b_{52} = 78 - \mathrm{T}^a_{12} c^2$	$\mathrm{T}^b_{53} = 58 - 3\mathrm{T}^a_{13} c^2$	$\mathrm{T}^b_{54} = 37 - 3c^2$	$\mathrm{T}^b_{55} = 8 - \mathrm{T}^a_{14} c^2$
$\mathrm{T}^b_{56} = 55 - 56c^2$	$\mathrm{T}^b_{57} = 7 + 4c^2$	$\mathrm{T}^b_{58} = 1 - 36c^2$	$\mathrm{T}^b_{59} = 115 - 4\mathrm{T}^a_{15} c^2$
$\mathrm{T}^b_{60} = 77 - 192c^2$	$\mathrm{T}^b_{61} = 3 - 8c^2$	$\mathrm{T}^b_{62} = 119 + 360c^2$	$\mathrm{T}^b_{63} = 31 + 18c^2$

$\mathrm{T}^b_{64} = 37c^2 - s^2$	$\mathrm{T}^b_{65} = 14 - 11c^2$	$\mathrm{T}^b_{66} = 231 - 200c^2$	$\mathrm{T}^b_{67} = 184 - \mathrm{T}^a_{16} c^2$
$\mathrm{T}^b_{68} = 809 - 552c^2$	$\mathrm{T}^b_{69} = 365 - 496c^2$	$\mathrm{T}^b_{70} = 103 - 96c^2$	$\mathrm{T}^b_{71} = 185 - 52c^2$
$\mathrm{T}^b_{72} = 51 + 11c^2$	$\mathrm{T}^b_{73} = 22 - \mathrm{T}^a_{17} c^2$	$\mathrm{T}^b_{74} = 23 - 4c^2$	$\mathrm{T}^b_{75} = 45 - 16c^2$
$\mathrm{T}^b_{76} = 79 - 2\mathrm{T}^a_{18} c^2$	$\mathrm{T}^b_{77} = 121 - 40c^2$	$\mathrm{T}^b_{78} = 6 + c^2$	$\mathrm{T}^b_{79} = 11 - 8c^2$
$\mathrm{T}^b_{80} = 87 - 40c^2$	$\mathrm{T}^b_{81} = 3c^2 - s^2$	$\mathrm{T}^b_{82} = 31 - 36c^2$	$\mathrm{T}^b_{83} = 13 + 30c^2$
$\mathrm{T}^b_{84} = 47 - 40c^2$	$\mathrm{T}^b_{85} = 37 - 42c^2$	$\mathrm{T}^b_{86} = 1 + 45c^2$	$\mathrm{T}^b_{87} = 37 - 32c^2$
$\mathrm{T}^b_{88} = 1 + 16c^2$	$\mathrm{T}^b_{89} = 9 + 16c^2$	$\mathrm{T}^b_{90} = 2 - c^2$	$\mathrm{T}^b_{91} = 11 - 2\mathrm{T}^a_{19} c^2$
$\mathrm{T}^b_{92} = 5 - 2\mathrm{T}^a_{20} c^2$	$\mathrm{T}^b_{93} = 9 - 4c^2$	$\mathrm{T}^b_{94} = 13 - 6c^2$	$\mathrm{T}^b_{95} = 49 - 16c^2$
$\mathrm{T}^b_{96} = 69 - 32c^2$	$\mathrm{T}^b_{97} = 97 - 32\mathrm{T}^a_{21} c^2$	$\mathrm{T}^b_{98} = 1 - 2s^2$	

$T^c_0 = 1 - s^2$	$T^c_1 = 3 + 2T^b_0 c^2$	$T^c_2 = 3 + 2T^b_1 c^2$	$T^c_3 = 3 - T^b_2 c^2$
$T^c_4 = 5 - 6c^2$	$T^c_5 = 5 + 8T^b_3 c^2$	$T^c_6 = 6 - 7s^2$	$T^c_7 = 7 + 2T^b_4 c^2$
$T^c_8 = 9 - 2T^b_5 c^2$	$T^c_9 = 9 - 2T^b_6 c^2$	$T^c_{10} = 11 - 8T^b_7 c^2$	$T^c_{11} = 2 - c^2$
$T^c_{12} = 4 - 3s^2$	$T^c_{13} = 49 - 78s^2$	$T^c_{14} = 15 - 8c^2$	$T^c_{15} = 2 - T^b_8 c^2$
$T^c_{16} = 3 + 2T^b_9 c^2$	$T^c_{17} = 5 + 12T^b_{10} c^2$	$T^c_{18} = 7 - 8T^b_{11} c^2$	$T^c_{19} = 7 - 4T^b_{12} c^2$
$T^c_{20} = 9 - 2T^b_{13} c^2$	$T^c_{21} = 35 + 6c^2$	$T^c_{22} = 25 - 66c^2$	$T^c_{23} = 5 - 6s^2$
$T^c_{24} = 4 - T^b_8 c^2$	$T^c_{25} = 11 - 40T^b_{14} c^2$	$T^c_{26} = 11 - 36T^b_{14} c^2$	$T^c_{27} = 13 - 2T^b_{15} c^2$
$T^c_{28} = 1 - 2c^2$	$T^c_{29} = 1 - 12c^2$	$T^c_{30} = 5 - 4T^b_{16} c^2$	$T^c_{31} = 1 + 4c^2$

$T^c_{32} = 2 - 9T^b_{17} c^2$	$T^c_{33} = 11 + 16c^2$	$T^c_{34} = 12 - T^b_{18} c^2$	$T^c_{35} = 1 + c^2$
$T^c_{36} = 3 - 4c^2$	$T^c_{37} = 5 - 2T^b_{19} c^2$	$T^c_{38} = 11 - 36c^2$	$T^c_{39} = 11 + 12c^2$
$T^c_{40} = 2 + T^b_{20} c^2$	$T^c_{41} = 5 + T^b_{21} c^2$	$T^c_{42} = 29 - 18T^b_{22} c^2$	$T^c_{43} = 47 - 36c^4$
$T^c_{44} = 5 - 2T^b_{23} c^2$	$T^c_{45} = 19 - 36T^b_{24} c^2$	$T^c_{46} = 1 + 6c^2$	$T^c_{47} = 1 - 2T^b_{14} c^2$
$T^c_{48} = 1 - 3c^2$	$T^c_{49} = 1 - 4T^b_{25} c^2$	$T^c_{50} = 5 + 6c^2$	$T^c_{51} = 5 - 2T^b_{22} c^2$
$T^c_{52} = 4 + c^2$	$T^c_{53} = 1 - 4c^2$	$T^c_{54} = 1 - c^2$	$T^c_{55} = 1 + 4T^b_{14} c^2$
$T^c_{56} = 1 + T^b_{26} c^2$	$T^c_{57} = 2 - T^b_{27} c^2$	$T^c_{58} = 3 - T^b_{28} c^2$	$T^c_{59} = 5 - 2T^b_{29} c^2$
$T^c_{60} = 3 + 4c^2$	$T^c_{61} = 5 + 12T^b_{26} c^2$	$T^c_{62} = 1 + 16c^2$	$T^c_{63} = 2 - T^b_{20} c^2$

$T^c_{64} = 3 - 4T^b_{14} c^2$	$T^c_{65} = 31 - 12T^b_{30} c^2$	$T^c_{66} = 41 - 12T^b_{31} c^4$	$T^c_{67} = 5 + 2T^b_{32} c^2$
$T^c_{68} = 1 + 8c^2$	$T^c_{69} = 1 + 4T^b_{33} c^2$	$T^c_{70} = 59 + 12T^b_{34} c^2$	$T^c_{71} = 61 + 12T^b_{35} c^4$
$T^c_{72} = 2 - 3T^b_{36} c^2$	$T^c_{73} = 22 - T^b_{37} c^2$	$T^c_{74} = 1 + 12T^b_{30} c^2$	$T^c_{75} = 23 - 4T^b_{38} c^2$
$T^c_{76} = 3 + c^2$	$T^c_{77} = 11 - 7c^2$	$T^c_{78} = 15 + 4T^b_{39} c^2$	$T^c_{79} = 12 - T^b_{40} c^2$
$T^c_{80} = 55 + 117c^2$	$T^c_{81} = 15 - 4T^b_{41} c^2$	$T^c_{82} = 8 - 3s^2$	$T^c_{83} = 23 + 3c^2$
$T^c_{84} = 1 + 12T^b_{14} c^2$	$T^c_{85} = 1 + 3T^b_{42} c^2$	$T^c_{86} = 8 + 3c^2$	$T^c_{87} = 4 - 3c^2$
$T^c_{88} = 5 - 4c^2$	$T^c_{89} = 19 - 4T^b_{43} c^2$	$T^c_{90} = 13 + T^b_{44} c^2$	$T^c_{91} = 1 - 3c^4$
$T^c_{92} = 3 + 4T^b_{39} c^2$	$T^c_{93} = 17 - 2T^b_{45} c^2$	$T^c_{94} = 19 - 4T^b_{46} c^2$	$T^c_{95} = 35 - 4T^b_{47} c^2$

$T^c_{96} = 37 - 12T^b_{48} c^2$	$T^c_{97} = 37 - 4T^b_{49} c^2$	$T^c_{98} = 51 - 4T^b_{50} c^2$	$T^c_{99} = 67 - 4T^b_{51} c^2$
$T^c_{100} = 75 + 4T^b_{52} c^2$	$T^c_{101} = 77 - 4T^b_{53} c^2$	$T^c_{102} = 5 - 7c^2$	$T^c_{103} = 41 - 4T^b_{47} c^2$
$T^c_{104} = 53 - 4T^b_{54} c^2$	$T^c_{105} = 67 - 4T^b_{55} c^2$	$T^c_{106} = 1 - 24c^2$	$T^c_{107} = 13 - T^b_{56} c^2$
$T^c_{108} = 27 - 56c^2$	$T^c_{109} = 41 - 64c^2$	$T^c_{110} = 1 - 2T^b_{57} c^2$	$T^c_{111} = 2c^2 - s^2$
$T^c_{112} = 7 + 8c^2$	$T^c_{113} = 9 - 2T^b_{58} c^2$	$T^c_{114} = 11 + 36c^2$	$T^c_{115} = 17 - 72c^2$
$T^c_{116} = 20 + T^b_{59} c^2$	$T^c_{117} = 39 + 4T^b_{60} c^2$	$T^c_{118} = 41 - 156c^2$	$T^c_{119} = 49 - 204c^2$
$T^c_{120} = 79 + 228T^b_{61} c^2$	$T^c_{121} = 151 - 4T^b_{62} c^2$	$T^c_{122} = 5 - 12c^2$	$T^c_{123} = 25 - 8T^b_{63} c^2$
$T^c_{124} = 35c^2 - s^2$	$T^c_{125} = 36c^2 - s^2$	$T^c_{126} = 71c^4 - T^b_{64} s^2$	$T^c_{127} = 8 - 7T^b_{22} c^2$

$T^c_{128} = 12 - 11c^2$	$T^c_{129} = 11 - 6c^2$	$T^c_{130} = 13 - 24c^2$	$T^c_{131} = 17 - 22c^2$
$T^c_{132} = 19 - 286c^2$	$T^c_{133} = 23 - 4T^b_{65} c^2$	$T^c_{134} = 137 - 2T^b_{66} c^2$	$T^c_{135} = 143 - 4T^b_{67} c^2$
$T^c_{136} = 164 - T^b_{68} c^2$	$T^c_{137} = 251 - 152c^2$	$T^c_{138} = 19 - T^b_{69} c^2$	$T^c_{139} = 18 + T^b_{70} c^2$
$T^c_{140} = 55 + 2T^b_{71} c^2$	$T^c_{141} = 85 - 96c^2$	$T^c_{142} = 85 - 8T^b_{72} c^2$	$T^c_{143} = 3 - 11c^2$
$T^c_{144} = 3 + 13c^2$	$T^c_{145} = 9 - 16c^2$	$T^c_{146} = 21 - 40c^2$	$T^c_{147} = 21 - 4T^b_{73} c^2$
$T^c_{148} = 3 - 8c^2$	$T^c_{149} = 5 + 2c^2$	$T^c_{150} = 9 - 4c^2$	$T^c_{151} = 17 - 14c^2$
$T^c_{152} = 7 + T^b_{74} c^2$	$T^c_{153} = 31 - 8c^2$	$T^c_{154} = 17 - T^b_{75} c^2$	$T^c_{155} = 31 - 2T^b_{76} c^2$
$T^c_{156} = 69 - 2T^b_{77} c^2$	$T^c_{157} = 11 - 8T^b_{78} c^2$	$T^c_{158} = 19 + 2c^2$	$T^c_{159} = 4 - 7c^2$

$T^c_{160} = 13 + 2T^b_{79} c^2$	$T^c_{161} = 21 + 2T^b_{80} c^2$	$T^c_{162} = 11 - 8c^2$	$T^c_{163} = 3c^4 - T^b_{81} s^2$
$T^c_{164} = 1 - 8c^2$	$T^c_{165} = 5 - 24c^2$	$T^c_{166} = 4 - T^b_{82} c^2$	$T^c_{167} = 7 - 3c^2$
$T^c_{168} = 13 - 36c^2$	$T^c_{169} = 19 - 2T^b_{83} c^2$	$T^c_{170} = 25 - 112c^2$	$T^c_{171} = 105 - 8T^b_{84} c^2$
$T^c_{172} = 49 - 120c^2$	$T^c_{173} = 2 - 47c^2$	$T^c_{174} = 2 - 7c^2$	$T^c_{175} = 2 + 313c^2$
$T^c_{176} = 19 - 48c^2$	$T^c_{177} = 8 - 21c^2$	$T^c_{178} = 9 - 8c^2$	$T^c_{179} = 11 - 2T^b_{85} c^2$
$T^c_{180} = 13 - 56c^2$	$T^c_{181} = 13 - 2T^b_{86} c^2$	$T^c_{182} = 15 - 58c^2$	$T^c_{183} = 49 - 4T^b_{87} c^2$
$T^c_{184} = 2 - 77c^2$	$T^c_{185} = 2 - 251c^2$	$T^c_{186} = 1 + 2c^2$	$T^c_{187} = 3 - 2T^b_{22} c^2$
$T^c_{188} = 21 + 4T^b_{88} c^2$	$T^c_{189} = 7 - 4c^2$	$T^c_{190} = 17 - 18c^2$	$T^c_{191} = 15 + T^b_{89} c^2$

JHEP07(2015)175

$\mathrm{T}^c_{192}=41-16c^2$ $\mathrm{T}^c_{193}=23-16c^2$ $\mathrm{T}^c_{194}=39-34c^2$ $\mathrm{T}^c_{195}=23-10c^2$
$\mathrm{T}^c_{196}=53-4\mathrm{T}^b_{79}c^2$ $\mathrm{T}^c_{197}=3+16c^2$ $\mathrm{T}^c_{198}=5-4\mathrm{T}^b_{90}c^2$ $\mathrm{T}^c_{199}=1-2s^2$
$\mathrm{T}^c_{200}=1+3\mathrm{T}^b_{14}c^2$ $\mathrm{T}^c_{201}=2-\mathrm{T}^b_{91}c^2$ $\mathrm{T}^c_{202}=3+2\mathrm{T}^b_{92}c^2$ $\mathrm{T}^c_{203}=3-2\mathrm{T}^b_{93}c^2$
$\mathrm{T}^c_{204}=8-9c^2$ $\mathrm{T}^c_{205}=8+c^2$ $\mathrm{T}^c_{206}=9-2\mathrm{T}^b_{94}c^2$ $\mathrm{T}^c_{207}=10-13c^2$
$\mathrm{T}^c_{208}=10+c^2$ $\mathrm{T}^c_{209}=13-5c^2$ $\mathrm{T}^c_{210}=14-\mathrm{T}^b_{95}c^2$ $\mathrm{T}^c_{211}=18-\mathrm{T}^b_{96}c^2$
$\mathrm{T}^c_{212}=21-8c^2$ $\mathrm{T}^c_{213}=46-\mathrm{T}^b_{97}c^2$ $\mathrm{T}^c_{214}=37-16c^2$ $\mathrm{T}^c_{215}=c^2-\mathrm{T}^b_{98}s^2$

$\mathrm{T}^d_{0}=1-6s^2$ $\mathrm{T}^d_{1}=1-3s^2$ $\mathrm{T}^d_{2}=1-2s^2$ $\mathrm{T}^d_{3}=1-4\mathrm{T}^c_{0}s^2$
$\mathrm{T}^d_{4}=2-3s^2$ $\mathrm{T}^d_{5}=3-4\mathrm{T}^c_{0}s^2$ $\mathrm{T}^d_{6}=1-6c^2-72s^2c^2$ $\mathrm{T}^d_{7}=1-2c^2$
$\mathrm{T}^d_{8}=1+4c^2$ $\mathrm{T}^d_{9}=5+8c^2$ $\mathrm{T}^d_{10}=c^2-\mathrm{T}^c_{1}s^2$ $\mathrm{T}^d_{11}=3c^4-\mathrm{T}^c_{2}s^2$
$\mathrm{T}^d_{12}=1-4s^2$ $\mathrm{T}^d_{13}=1-8\mathrm{T}^c_{0}s^2$ $\mathrm{T}^d_{14}=1+8\mathrm{T}^c_{0}s^2$ $\mathrm{T}^d_{15}=1+2\mathrm{T}^c_{3}c^2$
$\mathrm{T}^d_{16}=1-4\mathrm{T}^c_{4}c^4$ $\mathrm{T}^d_{17}=1-\mathrm{T}^c_{5}c^2$ $\mathrm{T}^d_{18}=1+8\mathrm{T}^c_{6}s^2c^2$ $\mathrm{T}^d_{19}=1-\mathrm{T}^c_{7}c^2$
$\mathrm{T}^d_{20}=1+\mathrm{T}^c_{8}c^2$ $\mathrm{T}^d_{21}=1+\mathrm{T}^c_{9}c^2$ $\mathrm{T}^d_{22}=1+\mathrm{T}^c_{10}c^2$ $\mathrm{T}^d_{23}=3-4\mathrm{T}^c_{11}c^2$
$\mathrm{T}^d_{24}=3-4\mathrm{T}^c_{12}s^2$ $\mathrm{T}^d_{25}=5-8s^2$ $\mathrm{T}^d_{26}=5-6s^2$ $\mathrm{T}^d_{27}=5+\mathrm{T}^c_{13}s^2$
$\mathrm{T}^d_{28}=11-2\mathrm{T}^c_{14}c^2$ $\mathrm{T}^d_{29}=1-c^2$ $\mathrm{T}^d_{30}=1+2\mathrm{T}^c_{15}c^2$ $\mathrm{T}^d_{31}=1-\mathrm{T}^c_{16}c^2$

$\mathrm{T}^d_{32}=1-\mathrm{T}^c_{17}c^2$ $\mathrm{T}^d_{33}=1+\mathrm{T}^c_{18}c^2$ $\mathrm{T}^d_{34}=1+\mathrm{T}^c_{19}c^2$ $\mathrm{T}^d_{35}=1+\mathrm{T}^c_{20}c^2$
$\mathrm{T}^d_{36}=1+\mathrm{T}^c_{21}c^2$ $\mathrm{T}^d_{37}=2-3\mathrm{T}^c_{22}c^2$ $\mathrm{T}^d_{38}=3-2c^2$ $\mathrm{T}^d_{39}=5-21c^2$
$\mathrm{T}^d_{40}=5-4s^2$ $\mathrm{T}^d_{41}=7+6\mathrm{T}^c_{23}s^2$ $\mathrm{T}^d_{42}=11-8c^2$ $\mathrm{T}^d_{43}=13-8s^2$
$\mathrm{T}^d_{44}=20-39s^2$ $\mathrm{T}^d_{45}=1+2\mathrm{T}^c_{24}c^2$ $\mathrm{T}^d_{46}=1+\mathrm{T}^c_{25}c^2$ $\mathrm{T}^d_{47}=1+\mathrm{T}^c_{26}c^2$
$\mathrm{T}^d_{48}=1+\mathrm{T}^c_{27}c^2$ $\mathrm{T}^d_{49}=3+4s^2$ $\mathrm{T}^d_{50}=3+8s^2$ $\mathrm{T}^d_{51}=7-6s^2$
$\mathrm{T}^d_{52}=1-4s^2c^2$ $\mathrm{T}^d_{53}=1-14c^2$ $\mathrm{T}^d_{54}=1-11c^2$ $\mathrm{T}^d_{55}=1-8c^2$
$\mathrm{T}^d_{56}=1-2c^2-4\mathrm{T}^c_{28}s^2c^2$ $\mathrm{T}^d_{57}=1+6c^2$ $\mathrm{T}^d_{58}=1+8c^2$ $\mathrm{T}^d_{59}=1+10c^2$
$\mathrm{T}^d_{60}=1+18c^2$ $\mathrm{T}^d_{61}=1-4\mathrm{T}^c_{29}c^4$ $\mathrm{T}^d_{62}=1-\mathrm{T}^c_{30}c^2$ $\mathrm{T}^d_{63}=2-7c^2-6s^2c^2$

$\mathrm{T}^d_{64}=2-c^2$ $\mathrm{T}^d_{65}=3+10c^2-4\mathrm{T}^c_{31}s^2c^2$ $\mathrm{T}^d_{66}=3+192c^6+8\mathrm{T}^c_{32}s^2c^2$ $\mathrm{T}^d_{67}=3-4\mathrm{T}^c_{33}c^2$
$\mathrm{T}^d_{68}=7+4c^2-24s^2c^2$ $\mathrm{T}^d_{69}=13-4\mathrm{T}^c_{34}c^2$ $\mathrm{T}^d_{70}=1+3c^2$ $\mathrm{T}^d_{71}=1-4c^4$
$\mathrm{T}^d_{72}=1+12\mathrm{T}^c_{35}c^2$ $\mathrm{T}^d_{73}=1-6\mathrm{T}^c_{36}c^2$ $\mathrm{T}^d_{74}=1-\mathrm{T}^c_{37}c^2$ $\mathrm{T}^d_{75}=1-2\mathrm{T}^c_{38}c^2$
$\mathrm{T}^d_{76}=2-\mathrm{T}^c_{39}c^2$ $\mathrm{T}^d_{77}=3-8c^2$ $\mathrm{T}^d_{78}=3-4c^2$ $\mathrm{T}^d_{79}=5-4\mathrm{T}^c_{40}c^2$
$\mathrm{T}^d_{80}=5-24\mathrm{T}^c_{41}c^4$ $\mathrm{T}^d_{81}=7-2\mathrm{T}^c_{42}c^2$ $\mathrm{T}^d_{82}=11-\mathrm{T}^c_{43}c^2$ $\mathrm{T}^d_{83}=15-\mathrm{T}^c_{44}c^2$
$\mathrm{T}^d_{84}=17-12c^2$ $\mathrm{T}^d_{85}=25-24c^2$ $\mathrm{T}^d_{86}=45-2\mathrm{T}^c_{45}c^2$ $\mathrm{T}^d_{87}=1-6c^2$
$\mathrm{T}^d_{88}=1-4c^2$ $\mathrm{T}^d_{89}=1-2\mathrm{T}^c_{46}c^2$ $\mathrm{T}^d_{90}=1+4\mathrm{T}^c_{47}c^2$ $\mathrm{T}^d_{91}=2+\mathrm{T}^c_{48}c^2$
$\mathrm{T}^d_{92}=3+4c^2$ $\mathrm{T}^d_{93}=3-2s^2$ $\mathrm{T}^d_{94}=3+\mathrm{T}^c_{49}c^2$ $\mathrm{T}^d_{95}=3-2\mathrm{T}^c_{50}c^2$

$\mathrm{T}^d_{96}=3-\mathrm{T}^c_{51}c^2$ $\mathrm{T}^d_{97}=1-3c^6-\mathrm{T}^c_{52}s^2c^2$ $\mathrm{T}^d_{98}=1-2\mathrm{T}^c_{36}c^2$ $\mathrm{T}^d_{99}=1+\mathrm{T}^c_{53}c^2$
$\mathrm{T}^d_{100}=1-4\mathrm{T}^c_{54}c^2$ $\mathrm{T}^d_{101}=1-\mathrm{T}^c_{55}c^2$ $\mathrm{T}^d_{102}=1-2\mathrm{T}^c_{56}c^2$ $\mathrm{T}^d_{103}=1-4\mathrm{T}^c_{57}c^2$
$\mathrm{T}^d_{104}=1-2\mathrm{T}^c_{58}c^2$ $\mathrm{T}^d_{105}=1-\mathrm{T}^c_{59}c^2$ $\mathrm{T}^d_{106}=2+c^2$ $\mathrm{T}^d_{107}=3+c^2$
$\mathrm{T}^d_{108}=3-4\mathrm{T}^c_{54}c^2$ $\mathrm{T}^d_{109}=3-\mathrm{T}^c_{60}c^2$ $\mathrm{T}^d_{110}=4+c^2$ $\mathrm{T}^d_{111}=4+\mathrm{T}^c_{61}c^2$
$\mathrm{T}^d_{112}=7-4c^2$ $\mathrm{T}^d_{113}=1+8c^2-12s^2c^2$ $\mathrm{T}^d_{114}=1+32c^4-4\mathrm{T}^c_{62}s^2c^2$ $\mathrm{T}^d_{115}=1-4\mathrm{T}^c_{36}c^4$
$\mathrm{T}^d_{116}=1-4\mathrm{T}^c_{63}c^2$ $\mathrm{T}^d_{117}=2-3\mathrm{T}^c_{64}c^2$ $\mathrm{T}^d_{118}=3-16s^2c^2$ $\mathrm{T}^d_{119}=4-3\mathrm{T}^c_{64}c^2$
$\mathrm{T}^d_{120}=4-\mathrm{T}^c_{65}c^2$ $\mathrm{T}^d_{121}=8-\mathrm{T}^c_{66}c^2$ $\mathrm{T}^d_{122}=1-2\mathrm{T}^c_{67}c^2$ $\mathrm{T}^d_{123}=2-60s^2c^4+5\mathrm{T}^c_{68}c^2$
$\mathrm{T}^d_{124}=2-3\mathrm{T}^c_{69}c^2$ $\mathrm{T}^d_{125}=4-3\mathrm{T}^c_{69}c^2$ $\mathrm{T}^d_{126}=4+\mathrm{T}^c_{70}c^2$ $\mathrm{T}^d_{127}=8+\mathrm{T}^c_{71}c^2$

$\mathrm{T}^d_{128}=15-16s^2c^2$ $\mathrm{T}^d_{129}=17-24s^2c^2$ $\mathrm{T}^d_{130}=1+4\mathrm{T}^c_{72}c^2$ $\mathrm{T}^d_{131}=1+4\mathrm{T}^c_{73}c^2$
$\mathrm{T}^d_{132}=3+2\mathrm{T}^c_{74}c^2$ $\mathrm{T}^d_{133}=4-\mathrm{T}^c_{75}c^2$ $\mathrm{T}^d_{134}=5+4\mathrm{T}^c_{54}c^2$ $\mathrm{T}^d_{135}=7-4\mathrm{T}^c_{76}c^2$
$\mathrm{T}^d_{136}=11-2\mathrm{T}^c_{75}c^2$ $\mathrm{T}^d_{137}=15-4\mathrm{T}^c_{77}c^2$ $\mathrm{T}^d_{138}=16+\mathrm{T}^c_{78}c^2$ $\mathrm{T}^d_{139}=17-4\mathrm{T}^c_{79}c^2$
$\mathrm{T}^d_{140}=19-4\mathrm{T}^c_{80}c^2$ $\mathrm{T}^d_{141}=24-\mathrm{T}^c_{81}c^2$ $\mathrm{T}^d_{142}=55-12\mathrm{T}^c_{82}s^2$ $\mathrm{T}^d_{143}=73-12\mathrm{T}^c_{83}c^2$
$\mathrm{T}^d_{144}=1+2c^2$ $\mathrm{T}^d_{145}=1-12c^4$ $\mathrm{T}^d_{146}=1-\mathrm{T}^c_{84}c^2$ $\mathrm{T}^d_{147}=1-4\mathrm{T}^c_{85}c^2$
$\mathrm{T}^d_{148}=1-4\mathrm{T}^c_{86}c^2$ $\mathrm{T}^d_{149}=3+10c^2$ $\mathrm{T}^d_{150}=3-4\mathrm{T}^c_{87}c^2$ $\mathrm{T}^d_{151}=3-2\mathrm{T}^c_{88}c^2$
$\mathrm{T}^d_{152}=3-\mathrm{T}^c_{89}c^2$ $\mathrm{T}^d_{153}=4-3s^2$ $\mathrm{T}^d_{154}=5-2\mathrm{T}^c_{31}c^2$ $\mathrm{T}^d_{155}=7-4\mathrm{T}^c_{90}c^2$
$\mathrm{T}^d_{156}=1+2\mathrm{T}^c_{91}c^2$ $\mathrm{T}^d_{157}=1+2\mathrm{T}^c_{92}c^2$ $\mathrm{T}^d_{158}=2+\mathrm{T}^c_{92}c^2$ $\mathrm{T}^d_{159}=4-3c^2$

JHEP07(2015)175

$\mathrm{T}^d_{160} = 4+3c^2$ $\mathrm{T}^d_{161} = 5-2c^2$ $\mathrm{T}^d_{162} = 5+6c^2$ $\mathrm{T}^d_{163} = 6-c^2$
$\mathrm{T}^d_{164} = 8-3c^2$ $\mathrm{T}^d_{165} = 8+\mathrm{T}^c_{93}c^2$ $\mathrm{T}^d_{166} = 9-2c^2$ $\mathrm{T}^d_{167} = 10-3c^2$
$\mathrm{T}^d_{168} = 10-\mathrm{T}^c_{94}c^2$ $\mathrm{T}^d_{169} = 10-\mathrm{T}^c_{95}c^2$ $\mathrm{T}^d_{170} = 10-\mathrm{T}^c_{96}c^2$ $\mathrm{T}^d_{171} = 10+\mathrm{T}^c_{97}c^2$
$\mathrm{T}^d_{172} = 10-\mathrm{T}^c_{98}c^2$ $\mathrm{T}^d_{173} = 10-\mathrm{T}^c_{99}c^2$ $\mathrm{T}^d_{174} = 10-\mathrm{T}^c_{100}c^2$ $\mathrm{T}^d_{175} = 10-\mathrm{T}^c_{101}c^2$
$\mathrm{T}^d_{176} = 13-24s^2c^2+2\mathrm{T}^c_{102}c^4$ $\mathrm{T}^d_{177} = 14-3c^2$ $\mathrm{T}^d_{178} = 16-15c^2$ $\mathrm{T}^d_{179} = 30-\mathrm{T}^c_{103}c^2$
$\mathrm{T}^d_{180} = 32-21c^2$ $\mathrm{T}^d_{181} = 118+\mathrm{T}^c_{104}c^2$ $\mathrm{T}^d_{182} = 122+\mathrm{T}^c_{105}c^2$ $\mathrm{T}^d_{183} = 1+9c^2$
$\mathrm{T}^d_{184} = 1+8c^4$ $\mathrm{T}^d_{185} = 1+5\mathrm{T}^c_{106}c^2$ $\mathrm{T}^d_{186} = 1+4\mathrm{T}^c_{107}c^2$ $\mathrm{T}^d_{187} = 1+2\mathrm{T}^c_{108}c^2$
$\mathrm{T}^d_{188} = 3+158c^2$ $\mathrm{T}^d_{189} = 10-\mathrm{T}^c_{109}c^2$ $\mathrm{T}^d_{190} = 12+13c^2$ $\mathrm{T}^d_{191} = 12-\mathrm{T}^c_{110}c^2$

$\mathrm{T}^d_{192} = 23-146c^2$ $\mathrm{T}^d_{193} = 23-48c^2$ $\mathrm{T}^d_{194} = 49+8c^2$ $\mathrm{T}^d_{195} = c^2-s^2$
$\mathrm{T}^d_{196} = c^4-\mathrm{T}^c_{111}s^2$ $\mathrm{T}^d_{197} = 1-84c^2$ $\mathrm{T}^d_{198} = 1-12\mathrm{T}^c_{112}c^2$ $\mathrm{T}^d_{199} = 1-4\mathrm{T}^c_{113}c^2$
$\mathrm{T}^d_{200} = 1+\mathrm{T}^c_{114}c^2$ $\mathrm{T}^d_{201} = 1+4\mathrm{T}^c_{115}c^2$ $\mathrm{T}^d_{202} = 1-4\mathrm{T}^c_{116}c^2$ $\mathrm{T}^d_{203} = 1-2\mathrm{T}^c_{117}c^2$
$\mathrm{T}^d_{204} = 1-2\mathrm{T}^c_{118}c^2$ $\mathrm{T}^d_{205} = 1-2\mathrm{T}^c_{119}c^2$ $\mathrm{T}^d_{206} = 1-\mathrm{T}^c_{120}c^2$ $\mathrm{T}^d_{207} = 2-\mathrm{T}^c_{121}c^2$
$\mathrm{T}^d_{208} = 3+19\mathrm{T}^c_{122}c^2$ $\mathrm{T}^d_{209} = 23+2\mathrm{T}^c_{123}c^2$ $\mathrm{T}^d_{210} = 25+108c^2$ $\mathrm{T}^d_{211} = 4c^2+s^2$
$\mathrm{T}^d_{212} = 13c^2+s^2$ $\mathrm{T}^d_{213} = 29c^2+s^2$ $\mathrm{T}^d_{214} = 48c^2-\mathrm{T}^c_{124}s^2$ $\mathrm{T}^d_{215} = 59c^2+23s^2$
$\mathrm{T}^d_{216} = 61c^2+s^2$ $\mathrm{T}^d_{217} = 77c^2+s^2$ $\mathrm{T}^d_{218} = 83c^2-s^2$ $\mathrm{T}^d_{219} = 85c^2+s^2$
$\mathrm{T}^d_{220} = 93c^2+s^2$ $\mathrm{T}^d_{221} = 109c^2+s^2$ $\mathrm{T}^d_{222} = 115c^2-s^2$ $\mathrm{T}^d_{223} = 133c^2+s^2$

$\mathrm{T}^d_{224} = 157c^2+s^2$ $\mathrm{T}^d_{225} = 167c^2+3s^2$ $\mathrm{T}^d_{226} = 173c^2+s^2$ $\mathrm{T}^d_{227} = 35c^4-\mathrm{T}^c_{125}s^2$
$\mathrm{T}^d_{228} = 35c^6-\mathrm{T}^c_{126}s^2$ $\mathrm{T}^d_{229} = 1-3c^2$ $\mathrm{T}^d_{230} = 1+c^2$ $\mathrm{T}^d_{231} = 1-8\mathrm{T}^c_{28}c^2$
$\mathrm{T}^d_{232} = 1-2\mathrm{T}^c_{28}c^2$ $\mathrm{T}^d_{233} = 1-2\mathrm{T}^c_{31}c^2$ $\mathrm{T}^d_{234} = 1-\mathrm{T}^c_{127}c^2$ $\mathrm{T}^d_{235} = 1-\mathrm{T}^c_{128}c^2$
$\mathrm{T}^d_{236} = 3-131c^2$ $\mathrm{T}^d_{237} = 3-107c^2$ $\mathrm{T}^d_{238} = 3-83c^2$ $\mathrm{T}^d_{239} = 3-41c^2$
$\mathrm{T}^d_{240} = 3-11c^2$ $\mathrm{T}^d_{241} = 3-\mathrm{T}^c_{129}c^2$ $\mathrm{T}^d_{242} = 3+\mathrm{T}^c_{130}c^2$ $\mathrm{T}^d_{243} = 3-\mathrm{T}^c_{131}c^2$
$\mathrm{T}^d_{244} = 3+\mathrm{T}^c_{132}c^2$ $\mathrm{T}^d_{245} = 3-\mathrm{T}^c_{133}c^2$ $\mathrm{T}^d_{246} = 3-\mathrm{T}^c_{134}c^2$ $\mathrm{T}^d_{247} = 3-\mathrm{T}^c_{135}c^2$
$\mathrm{T}^d_{248} = 3-\mathrm{T}^c_{136}c^2$ $\mathrm{T}^d_{249} = 3-\mathrm{T}^c_{137}c^2$ $\mathrm{T}^d_{250} = 6+\mathrm{T}^c_{138}c^2$ $\mathrm{T}^d_{251} = 9+71c^2$
$\mathrm{T}^d_{252} = 15-23c^2$ $\mathrm{T}^d_{253} = 15-\mathrm{T}^c_{139}c^2$ $\mathrm{T}^d_{254} = 15+\mathrm{T}^c_{140}c^2$ $\mathrm{T}^d_{255} = 21-\mathrm{T}^c_{141}c^2$

$\mathrm{T}^d_{256} = 21-\mathrm{T}^c_{142}c^2$ $\mathrm{T}^d_{257} = 31-47c^2$ $\mathrm{T}^d_{258} = 24c^2-\mathrm{T}^c_{143}s^2$ $\mathrm{T}^d_{259} = 24c^2-\mathrm{T}^c_{144}s^2$
$\mathrm{T}^d_{260} = 1+22c^2$ $\mathrm{T}^d_{261} = 1-2\mathrm{T}^c_{145}c^2$ $\mathrm{T}^d_{262} = 1-\mathrm{T}^c_{146}c^2$ $\mathrm{T}^d_{263} = 1-\mathrm{T}^c_{147}c^2$
$\mathrm{T}^d_{264} = 2+\mathrm{T}^c_{148}c^2$ $\mathrm{T}^d_{265} = 3-4\mathrm{T}^c_{149}c^2$ $\mathrm{T}^d_{266} = 3-2\mathrm{T}^c_{150}c^2$ $\mathrm{T}^d_{267} = 3-\mathrm{T}^c_{151}c^2$
$\mathrm{T}^d_{268} = 7-40c^2$ $\mathrm{T}^d_{269} = 151-150s^2$ $\mathrm{T}^d_{270} = 4c^2+5s^2$ $\mathrm{T}^d_{271} = 1-44c^4$
$\mathrm{T}^d_{272} = 1-\mathrm{T}^c_{68}c^2$ $\mathrm{T}^d_{273} = 1+4\mathrm{T}^c_{152}c^2$ $\mathrm{T}^d_{274} = 1-2\mathrm{T}^c_{153}c^2$ $\mathrm{T}^d_{275} = 2-11c^2$
$\mathrm{T}^d_{276} = 3+130c^2$ $\mathrm{T}^d_{277} = 3+4\mathrm{T}^c_{154}c^2$ $\mathrm{T}^d_{278} = 3+2\mathrm{T}^c_{155}c^2$ $\mathrm{T}^d_{279} = 3+\mathrm{T}^c_{156}c^2$
$\mathrm{T}^d_{280} = 7-2\mathrm{T}^c_{157}c^2$ $\mathrm{T}^d_{281} = 8-5\mathrm{T}^c_{158}c^2$ $\mathrm{T}^d_{282} = 9+4\mathrm{T}^c_{159}c^2$ $\mathrm{T}^d_{283} = 9-\mathrm{T}^c_{160}c^2$
$\mathrm{T}^d_{284} = 10-\mathrm{T}^c_{161}c^2$ $\mathrm{T}^d_{285} = 11-2\mathrm{T}^c_{162}c^2$ $\mathrm{T}^d_{286} = c^2-2s^2$ $\mathrm{T}^d_{287} = 3c^2+s^2$

$\mathrm{T}^d_{288} = 6c^2-s^2$ $\mathrm{T}^d_{289} = 13c^2-s^2$ $\mathrm{T}^d_{290} = 17c^2-s^2$ $\mathrm{T}^d_{291} = 21c^2-s^2$
$\mathrm{T}^d_{292} = c^6-\mathrm{T}^c_{163}s^2$ $\mathrm{T}^d_{293} = 1+40c^2$ $\mathrm{T}^d_{294} = 1+4\mathrm{T}^c_{164}c^2$ $\mathrm{T}^d_{295} = 1+\mathrm{T}^c_{165}c^2$
$\mathrm{T}^d_{296} = 5-56c^2$ $\mathrm{T}^d_{297} = 5-8c^2$ $\mathrm{T}^d_{298} = 5+72c^2$ $\mathrm{T}^d_{299} = 5+88c^2$
$\mathrm{T}^d_{300} = 5+4\mathrm{T}^c_{166}c^2$ $\mathrm{T}^d_{301} = 5-8\mathrm{T}^c_{167}c^2$ $\mathrm{T}^d_{302} = 5+2\mathrm{T}^c_{168}c^2$ $\mathrm{T}^d_{303} = 5-4\mathrm{T}^c_{169}c^2$
$\mathrm{T}^d_{304} = 5+\mathrm{T}^c_{170}c^2$ $\mathrm{T}^d_{305} = 5+\mathrm{T}^c_{171}c^2$ $\mathrm{T}^d_{306} = 7-50c^2$ $\mathrm{T}^d_{307} = 7-18c^2$
$\mathrm{T}^d_{308} = 7-2c^2$ $\mathrm{T}^d_{309} = 9-8s^2$ $\mathrm{T}^d_{310} = 11+4\mathrm{T}^c_{172}c^2$ $\mathrm{T}^d_{311} = s^4-\mathrm{T}^c_{173}c^2$
$\mathrm{T}^d_{312} = s^4-\mathrm{T}^c_{174}c^2$ $\mathrm{T}^d_{313} = 7s^4+\mathrm{T}^c_{175}c^2$ $\mathrm{T}^d_{314} = 1-7c^2$ $\mathrm{T}^d_{315} = 1+14c^2$
$\mathrm{T}^d_{316} = 1+16c^2$ $\mathrm{T}^d_{317} = 1+2\mathrm{T}^c_{176}c^2$ $\mathrm{T}^d_{318} = 5-28c^2$ $\mathrm{T}^d_{319} = 5-12c^2$

$\mathrm{T}^d_{320} = 5+14c^2$ $\mathrm{T}^d_{321} = 5+66c^2$ $\mathrm{T}^d_{322} = 5-4\mathrm{T}^c_{86}c^2$ $\mathrm{T}^d_{323} = 5+8\mathrm{T}^c_{88}c^2$
$\mathrm{T}^d_{324} = 5+4\mathrm{T}^c_{177}c^2$ $\mathrm{T}^d_{325} = 5+4\mathrm{T}^c_{178}c^2$ $\mathrm{T}^d_{326} = 5+2\mathrm{T}^c_{179}c^2$ $\mathrm{T}^d_{327} = 5+2\mathrm{T}^c_{180}c^2$
$\mathrm{T}^d_{328} = 5-4\mathrm{T}^c_{181}c^2$ $\mathrm{T}^d_{329} = 5+2\mathrm{T}^c_{182}c^2$ $\mathrm{T}^d_{330} = 5+2\mathrm{T}^c_{183}c^2$ $\mathrm{T}^d_{331} = 9c^2+s^2$
$\mathrm{T}^d_{332} = s^4-\mathrm{T}^c_{184}c^2$ $\mathrm{T}^d_{333} = 5s^4-\mathrm{T}^c_{185}c^2$ $\mathrm{T}^d_{334} = 1-20c^2$ $\mathrm{T}^d_{335} = 1+5c^2$
$\mathrm{T}^d_{336} = 1-\mathrm{T}^c_{4}c^2$ $\mathrm{T}^d_{337} = 1-\mathrm{T}^c_{178}c^2$ $\mathrm{T}^d_{338} = 1-4\mathrm{T}^c_{186}c^2$ $\mathrm{T}^d_{339} = 1-2\mathrm{T}^c_{187}c^2$
$\mathrm{T}^d_{340} = 1-\mathrm{T}^c_{188}c^2$ $\mathrm{T}^d_{341} = 2-7\mathrm{T}^c_{54}c^2$ $\mathrm{T}^d_{342} = 3+2s^2$ $\mathrm{T}^d_{343} = 3-\mathrm{T}^c_{189}c^2$
$\mathrm{T}^d_{344} = 3-4\mathrm{T}^c_{190}c^2$ $\mathrm{T}^d_{345} = 4-9c^2$ $\mathrm{T}^d_{346} = 4-\mathrm{T}^c_{191}c^2$ $\mathrm{T}^d_{347} = 5-13c^2$
$\mathrm{T}^d_{348} = 5+c^2$ $\mathrm{T}^d_{349} = 6-13c^2$ $\mathrm{T}^d_{350} = 6-\mathrm{T}^c_{192}c^2$ $\mathrm{T}^d_{351} = 7-\mathrm{T}^c_{193}c^2$

JHEP07(2015)175

$$
\begin{array}{llll}
T^d_{352} = 7 - T^c_{194}\,c^2 & T^d_{353} = 8 - T^c_{195}\,c^2 & T^d_{354} = 9 - 35\,c^2 & T^d_{355} = 11 - 10\,c^2 \\
T^d_{356} = 14 - T^c_{196}\,c^2 & T^d_{357} = 1 + 68\,c^2 & T^d_{358} = 1 - T^c_{87}\,c^2 & T^d_{359} = 1 - T^c_{88}\,c^2 \\
T^d_{360} = 1 - 4\,T^c_{197}\,c^2 & T^d_{361} = 1 - T^c_{198}\,c^2 & T^d_{362} = 4 - c^2 & T^d_{363} = 9 - 16\,c^2 \\
T^d_{364} = 13 - 32\,c^2 & T^d_{365} = 13 - 8\,c^2 & T^d_{366} = 25 + 32\,c^4 & T^d_{367} = c^2 - T^c_{199}\,s^2 \\
T^d_{368} = 1 + 17\,c^2 & T^d_{369} = 1 + 8\,T^c_{11}\,c^2 & T^d_{370} = 1 - 8\,T^c_{200}\,c^2 & T^d_{371} = 1 + 8\,T^c_{201}\,c^2 \\
T^d_{372} = 1 - 4\,T^c_{202}\,c^2 & T^d_{373} = 1 + 4\,T^c_{203}\,c^2 & T^d_{374} = 1 + 2\,T^c_{204}\,c^2 & T^d_{375} = 1 + 2\,T^c_{205}\,c^2 \\
T^d_{376} = 1 + 2\,T^c_{206}\,c^2 & T^d_{377} = 1 + 2\,T^c_{207}\,c^2 & T^d_{378} = 1 + 2\,T^c_{208}\,c^2 & T^d_{379} = 1 - T^c_{209}\,c^2 \\
T^d_{380} = 1 + T^c_{210}\,c^2 & T^d_{381} = 1 + T^c_{211}\,c^2 & T^d_{382} = 1 + T^c_{212}\,c^2 & T^d_{383} = 1 + T^c_{213}\,c^2
\end{array}
$$

$$
\begin{array}{llll}
T^d_{384} = 3 + 4\,c^4 & T^d_{385} = 9 - 20\,c^2 & T^d_{386} = 17 - 8\,c^2 & T^d_{387} = 23 - 68\,c^2 \\
T^d_{388} = 23 - 4\,T^c_{214}\,c^2 & T^d_{389} = 9\,c^2 - 8\,s^2 & T^d_{390} = 8\,c^4 - T^c_{215}\,s^2 &
\end{array}
$$

U

$$
\begin{array}{llll}
U_0 = 2\,v_t + v_b + v_l & U_1 = 3 - v_t^2 & U_2 = 3 + v_t^2 & U_3 = 3 - v_b^2 \\
U_4 = 3 + v_b^2 & U_5 = 27 - 16\,v_t & U_6 = 27 - 8\,v_b & U_7 = 21 - v_t^2 \\
U_8 = 21 - v_b^2 & U_9 = 27 + v_t^2 & U_{10} = 27 + v_b^2 &
\end{array}
$$

V

$$V_0 = 2 - x_H^2 \qquad V_1 = 3 - x_H^2 \qquad V_2 = 6 - x_H^2$$

$$V_3 = 4x_t^2 - x_H^2 \qquad V_4 = 4x_b^2 - x_H^2 \qquad V_5 = 8 + x_H^2$$

$$V_6 = x_b^2 + x_t^2 \qquad V_7 = 6x_b^2 + 6x_t^2 + 7x_H^2$$

$$V_8 = -(2x_t^2 - x_H^2)\,\frac{1}{x_H^2} \qquad V_9 = \frac{1}{x_H^2}$$

$$V_{10} = (2x_t^2 + x_H^2)\,\frac{1}{x_H^2} \qquad V_{11} = -(2x_b^2 - x_H^2)\,\frac{1}{x_H^2}$$

$$V_{12} = (2x_b^2 + x_H^2)\,\frac{1}{x_H^2} \qquad V_{13} = (x_b^2 + x_t^2)\,\frac{1}{x_H^2}$$

$$V_{14} = 2 - x_b^2 - x_t^2 \qquad V_{15} = 2 - x_b^2 + x_t^2 \qquad V_{16} = 2 + x_b^2 - x_t^2$$

$$V_{17} = \Big[6 - (1 - 2x_b^2 + x_t^2)\,x_t^2 - (1 + x_b^2)\,x_b^2\Big] \qquad V_{18} = 1 + x_b^2 - x_t^2$$

$$V_{19} = \Big[1 + (2 + x_b^2)\,x_b^2 - (2 + 2x_b^2 - x_t^2)\,x_t^2\Big] \qquad V_{20} = \Big[1 - x_t^4 + (2 + x_b^2)\,x_b^2\Big]$$

$$V_{21} = \Big[2 - 2x_b^2 + 2x_t^2 - (1 + x_b^2 - x_t^2)\,x_H^2\Big] \qquad V_{22} = 2 + 2x_b^2 - 2x_t^2 - x_H^2$$

$$V_{23} = 2 + 2x_b^2 + 2x_t^2 - x_H^2 \qquad V_{24} = \Big[1 - x_t^4 - (2 - x_b^2)\,x_b^2\Big]$$

$$V_{25} = \Big[2 + 2x_b^4 + x_H^2 x_b^2 - 2\,(1 + x_b^2)\,x_t^2\Big] \qquad V_{26} = \Big\{\Big[2 - 2x_b^2 + (1 - x_b^2)\,x_H^2\Big]\,x_b^2 + (4 + 2x_b^2 + x_H^2 x_b^2)\,x_t^2\Big\}$$

$$V_{27} = \Big[4x_t^2 + (4 - x_H^2)\,x_b^2\Big] \qquad V_{28} = \Big[4 - (4 - x_H^2)\,x_H^2\Big]$$

$$V_{29} = \Big[32 - (81 - 8x_H^2)\,x_H^2\Big] \qquad V_{30} = \Big[61 - 2\,(4 - x_H^2)\,x_H^2\Big]$$

$$V_{31} = \Big[64 + (50 - 41x_H^2)\,x_H^2\Big] \qquad V_{32} = \Big[96 + (148 - 61x_H^2)\,x_H^2\Big]$$

$$V_{33} = \Big[100 - (50 + 49x_H^2)\,x_H^2\Big] \qquad V_{34} = \Big\{128 + \Big[36 - (132 - 41x_H^2)\,x_H^2\Big]\,x_H^2\Big\}$$

$$V_{35} = 146 + x_H^2 \qquad V_{36} = 4 - x_H^2 \qquad V_{37} = 4 + x_H^4$$

$$V_{38} = 2+x_H^2 \qquad V_{39} = 5-x_H^2 \qquad V_{40} = 10-x_H^2$$
$$V_{41} = 9-4x_H^2 \qquad V_{42} = 14-x_H^2$$
$$V_{43} = \left[14+(8+x_H^2)x_H^2\right] \qquad V_{44} = \left[18-(10-x_H^2)x_H^2\right]$$
$$V_{45} = 22+x_H^2 \qquad V_{46} = \left[28-9(2+x_H^2)x_H^2\right]$$
$$V_{47} = 3-x_b^2+x_t^2 \qquad V_{48} = 3+x_b^2-x_t^2$$
$$V_{49} = \left[5-(6+2x_b^2-x_t^2)x_t^2+(10+x_b^2)x_b^2\right] \qquad V_{50} = \left[1-(2-x_b^2)x_b^2-(2+2x_b^2-x_t^2)x_t^2\right]\frac{1}{x_H^2}$$
$$V_{51} = (1-x_b^2+x_t^2)\frac{1}{x_H^2} \qquad V_{52} = (1+x_b^2-x_t^2)\frac{1}{x_H^2}$$
$$V_{53} = 1-x_b^2+x_t^2 \qquad V_{54} = \left[1-x_t^4+(4+x_b^2)x_b^2\right]$$
$$V_{55} = x_b^2-x_t^2 \qquad V_{56} = (1+x_b^2-x_t^2+x_H^2)\frac{1}{x_H^2}$$
$$V_{57} = \left[3+(2-2x_b^2-x_t^2)x_t^2-3(2-x_b^2)x_b^2\right] \qquad V_{58} = 3-3x_b^2-x_t^2$$
$$V_{59} = 3+5x_b^2-x_t^2 \qquad V_{60} = \left[5-(6+6x_b^2-x_t^2)x_t^2+(14+5x_b^2)x_b^2\right]$$
$$V_{61} = \left[1-2x_H^2x_b^2-(2-x_b^2)x_b^2-(2+2x_b^2-x_t^2)x_t^2\right]\frac{1}{x_H^2} \qquad V_{62} = \left\{\left[1-x_b^2+(1-x_b^2)x_H^2\right]x_b^2+(1+2x_b^2-x_t^2+x_H^2x_b^2)x_t^2\right\}\frac{1}{x_H^2}$$
$$V_{63} = -\left[2x_t^2-(2+x_H^2)x_b^2\right]\frac{1}{x_H^2} \qquad V_{64} = \left[2x_t^2+(2-x_H^2)x_b^2\right]\frac{1}{x_H^2}$$
$$V_{65} = \left[3(1-x_b^2)x_b^2+(3+2x_b^2+x_t^2)x_t^2\right] \qquad V_{66} = -(2-x_H^2)\frac{1}{x_H^2}$$
$$V_{67} = \left[8-(4-x_H^2)x_H^2\right] \qquad V_{68} = 1-x_H^2$$
$$V_{69} = 2-5x_H^2 \qquad V_{70} = \left[16-5(4-x_H^2)x_H^2\right]$$
$$V_{71} = \left[16-(18-5x_H^2)x_H^2\right] \qquad V_{72} = \left[24-(2+5x_H^2)x_H^2\right]$$
$$V_{73} = \left\{32-\left[52-(28-5x_H^2)x_H^2\right]x_H^2\right\} \qquad V_{74} = \left[48-(32-5x_H^2)x_H^2\right]$$
$$V_{75} = \left[88-(6-5x_H^2)x_H^2\right] \qquad V_{76} = \left\{160-\left[168-(52-5x_H^2)x_H^2\right]x_H^2\right\}$$
$$V_{77} = \left[2-(4-x_H^2)x_H^2\right] \qquad V_{78} = \left[2-(3-x_H^2)x_H^2\right]$$
$$V_{79} = \left\{4-\left[8-(5-x_H^2)x_H^2\right]x_H^2\right\} \qquad V_{80} = \left[6-(4-x_H^2)x_H^2\right]$$
$$V_{81} = \left[8-(12-x_H^2)x_H^2\right] \qquad V_{82} = 12-x_H^2$$
$$V_{83} = 16-3x_H^4 \qquad V_{84} = \left\{20-\left[24-(8-x_H^2)x_H^2\right]x_H^2\right\}$$
$$V_{85} = \left[48-(12-x_H^2)x_H^2\right] \qquad V_{86} = 64+3x_H^4 \qquad V_{87} = 1+2x_H^2 \qquad V_{88} = 7-4x_H^2$$
$$V_{89} = 12+7x_H^2 \qquad V_{90} = 48-25x_H^2 \qquad V_{91} = 68+9x_H^2$$
$$V_{92} = \frac{1}{x_H^4} \qquad V_{93} = (9+2x_H^2)\frac{1}{x_H^2}$$
$$V_{94} = 3+2x_H^2 \qquad V_{95} = 4+x_H^2$$

W

$W_0 = 1 - 4\,\frac{x_t^2}{\lambda_{AZ}}$ $\quad W_1 = 1 - 4\,\frac{x_b^2}{\lambda_{AZ}}$ $\quad W_2 = 1 + \frac{x_H^2}{\lambda_{AZ}}$ $\quad W_3 = 1 + 2\,\frac{x_H^2}{\lambda_{AZ}}$

$W_4 = 2 + \frac{x_H^2}{\lambda_{AZ}}$ $\quad W_5 = 3 + 2\,\frac{x_H^2}{\lambda_{AZ}}$ $\quad W_6 = 1 - 6\,\frac{x_t^2}{\lambda_{ZZ}}$ $\quad W_7 = 1 - 6\,\frac{x_b^2}{\lambda_{ZZ}}$

$W_8 = 1 + 4\,\frac{x_H^2}{\lambda_{ZZ}}$ $\quad W_9 = 1 - \frac{x_H^2}{\lambda_{ZZ}}$ $\quad W_{10} = 1 + \frac{x_H^2}{\lambda_{ZZ}}$ $\quad W_{11} = 1 + 3\,\frac{x_H^2}{\lambda_{ZZ}}$

$W_{12} = 1 + 5\,\frac{x_H^2}{\lambda_{ZZ}}$ $\quad W_{13} = 1 + 6\,\frac{x_H^2}{\lambda_{ZZ}}$ $\quad W_{14} = 4 + 15\,\frac{x_H^2}{\lambda_{ZZ}}$ $\quad W_{15} = 5 + 6\,\frac{x_H^2}{\lambda_{ZZ}}$

$W_{16} = 5 + 8\,\frac{x_H^2}{\lambda_{ZZ}}$ $\quad W_{17} = 1 + 2\,\frac{x_H^2}{\lambda_{ZZ}}$ $\quad W_{18} = \frac{1}{\lambda_{ZZ}} - \mathscr{X}_9$ $\quad W_{19} = \frac{1}{\lambda_{ZZ}} + \mathscr{X}_9$

$W_{20} = 2\,\frac{x_t^2}{\lambda_{ZZ}} - \mathscr{X}_8$ $\quad W_{21} = 7\,\frac{1}{\lambda_{ZZ}} + \mathscr{X}_9$ $\quad W_{22} = 9\,\frac{1}{\lambda_{ZZ}} - \mathscr{X}_9$ $\quad W_{23} = 2\,\frac{x_t^2}{\lambda_{ZZ}} + \mathscr{X}_{10}$

$W_{24} = 2\,\frac{x_b^2}{\lambda_{ZZ}} - \mathscr{X}_{11}$ $\quad W_{25} = 2\,\frac{x_b^2}{\lambda_{ZZ}} + \mathscr{X}_{12}$ $\quad W_{26} = 1 + 3\,\frac{x_H^4}{\lambda_{ZZ}^2} - \frac{x_H^2}{\lambda_{ZZ}}$ $\quad W_{27} = 1 - 6\,\frac{x_H^2}{\lambda_{ZZ}}$

$W_{28} = 6\,\frac{x_H^2}{\lambda_{ZZ}^2} + \frac{1}{\lambda_{ZZ}} - \mathscr{X}_9$ $\quad W_{29} = 1 - 9\,\frac{x_H^4}{\lambda_{ZZ}^2} - \frac{x_H^2}{\lambda_{ZZ}}$ $\quad W_{30} = 1 - 6\,\frac{x_H^4}{\lambda_{ZZ}^2} - 6\,\frac{x_H^2}{\lambda_{ZZ}}$ $\quad W_{31} = 1 - 3\,\frac{x_H^4}{\lambda_{ZZ}^2} + 3\,\frac{x_H^2}{\lambda_{ZZ}}$

$W_{32} = 1 + 3\,\frac{x_H^4}{\lambda_{ZZ}^2} + \frac{x_H^2}{\lambda_{ZZ}}$ $\quad W_{33} = 1 + 6\,\frac{x_H^4}{\lambda_{ZZ}^2} - 9\,\frac{x_H^2}{\lambda_{ZZ}}$ $\quad W_{34} = 2 + 3\,\frac{x_H^2}{\lambda_{ZZ}}$ $\quad W_{35} = 5 - 6\,\frac{x_H^2}{\lambda_{ZZ}}$

$W_{36} = 1 - 96\,\frac{x_H^4}{\lambda_{ZZ}^2} + 9\,\frac{x_H^2}{\lambda_{ZZ}}$ $\quad W_{37} = 1 + 15\,\frac{x_H^4}{\lambda_{ZZ}^2} + 3\,\frac{x_H^2}{\lambda_{ZZ}}$ $\quad W_{38} = 1 + 30\,\frac{x_H^4}{\lambda_{ZZ}^2} - 9\,\frac{x_H^2}{\lambda_{ZZ}}$ $\quad W_{39} = 1 + 15\,\frac{x_H^2}{\lambda_{ZZ}}$

$W_{40} = 2 + 3\,\frac{x_H^4}{\lambda_{ZZ}^2} + 9\,\frac{x_H^2}{\lambda_{ZZ}}$ $\quad W_{41} = 4 + 51\,\frac{x_H^2}{\lambda_{ZZ}}$ $\quad W_{42} = 5 + 39\,\frac{x_H^2}{\lambda_{ZZ}}$ $\quad W_{43} = 6 + 17\,\frac{x_H^2}{\lambda_{ZZ}}$

$W_{44} = 17 + 51\,\frac{x_H^4}{\lambda_{ZZ}^2} - 13\,\frac{x_H^2}{\lambda_{ZZ}}$ $\quad W_{45} = 21 - 72\,\frac{x_H^4}{\lambda_{ZZ}^2} - 29\,\frac{x_H^2}{\lambda_{ZZ}}$ $\quad W_{46} = 6\,\frac{x_H^2}{\lambda_{ZZ}^2} + 15\,\frac{1}{\lambda_{ZZ}} + 2\,\mathscr{X}_9$ $\quad W_{47} = \mathscr{X}_6\,\frac{1}{\lambda_{ZZ}} + \mathscr{X}_{13}$

$W_{48} = 1 - 3\,\frac{x_H^4}{\lambda_{ZZ}^2} - \frac{x_H^2}{\lambda_{ZZ}}$ $\quad W_{49} = 1 + 3\,\frac{x_H^4}{\lambda_{ZZ}^2} + 5\,\frac{x_H^2}{\lambda_{ZZ}}$ $\quad W_{50} = 1 + 6\,\frac{x_H^4}{\lambda_{ZZ}^2} + 3\,\frac{x_H^2}{\lambda_{ZZ}}$ $\quad W_{51} = 6\,\frac{x_H^2}{\lambda_{ZZ}^2} + 7\,\frac{1}{\lambda_{ZZ}} + \mathscr{X}_9$

$W_{52} = 1 + 6\,\frac{x_H^2}{\lambda_{ZZ}^2} + 3\,\frac{x_H^2}{\lambda_{ZZ}}$ $\quad W_{53} = 1 + 3\,\frac{x_H^4}{\lambda_{ZZ}^2}$ $\quad W_{54} = 1 + 2\,\mathscr{X}_{18}\,\frac{1}{\lambda_{WW}}$ $\quad W_{55} = \mathscr{X}_{18} + 2\,\mathscr{X}_{19}\,\frac{1}{\lambda_{WW}}$

$W_{56} = 8\,\mathscr{X}_{18}\,\frac{1}{\lambda_{WW}} + \mathscr{X}_{21}$ $\quad W_{57} = 8\,\mathscr{X}_{18}\,\frac{1}{\lambda_{WW}} + \mathscr{X}_{23}$ $\quad W_{58} = 4\,\mathscr{X}_{19}\,\frac{1}{\lambda_{WW}} + \mathscr{X}_{20}$ $\quad W_{59} = x_b^2 + 2\,\mathscr{X}_{18}\,\frac{1}{\lambda_{WW}}$

$W_{60} = 8\,\mathscr{X}_{18}\,\frac{x_t^2}{\lambda_{WW}} + \mathscr{X}_{26}$ $\quad W_{61} = 4\,\mathscr{X}_{19}\,\frac{1}{\lambda_{WW}} + \mathscr{X}_{25}$ $\quad W_{62} = 1 - \mathscr{X}_{28}\,\frac{1}{\lambda_{WW}}$ $\quad W_{63} = 36 + \frac{x_H^2}{\lambda_{WW}}$

$W_{64} = 8\,\mathscr{X}_0 + \mathscr{X}_{31}\,\frac{1}{\lambda_{WW}}$ $\quad W_{65} = \mathscr{X}_{29} + \mathscr{X}_{34}\,\frac{1}{\lambda_{WW}}$ $\quad W_{66} = 2\,\mathscr{X}_{30} + \mathscr{X}_{32}\,\frac{1}{\lambda_{WW}}$

$W_{67} = \mathscr{X}_{33} - \mathscr{X}_{35}\,\frac{x_H^4}{\lambda_{WW}}$ $\quad W_{68} = 2 - \frac{x_H^4}{\lambda_{WW}}$ $\quad W_{69} = 8\,\frac{1}{\lambda_{WW}} + \mathscr{X}_0$

$W_{70} = 16\,\frac{1}{\lambda_{WW}} + \mathscr{X}_{37}$ $\quad W_{71} = 24\,\frac{1}{\lambda_{WW}} - \mathscr{X}_{36}\,x_H^2$ $\quad W_{72} = \frac{x_H^4}{\lambda_{WW}} + \mathscr{X}_{43}$

$W_{73} = 2\,\mathscr{X}_0\,\frac{1}{\lambda_{WW}} - \mathscr{X}_{40}$ $\quad W_{74} = \mathscr{X}_{28}\,\frac{1}{\lambda_{WW}} - \mathscr{X}_{41}$ $\quad W_{75} = \mathscr{X}_{42}\,\frac{x_H^2}{\lambda_{WW}} + \mathscr{X}_{44}$

$W_{76} = \mathscr{X}_{45}\,\frac{x_H^4}{\lambda_{WW}} - \mathscr{X}_{46}$ $\quad W_{77} = 8 + \frac{x_H^2}{\lambda_{WW}}$ $\quad W_{78} = \frac{1}{\lambda_{WW}} - \mathscr{X}_9$

$W_{79} = \frac{1}{\lambda_{WW}} + \mathscr{X}_9$ $\quad W_{80} = 12\,\mathscr{X}_{18}\,\frac{1}{\lambda_{WW}^2} + \mathscr{X}_{47}\,\frac{1}{\lambda_{WW}} + \mathscr{X}_{52}$ $\quad W_{81} = 12\,\mathscr{X}_{18}\,\frac{1}{\lambda_{WW}^2} + \mathscr{X}_{48}\,\frac{1}{\lambda_{WW}} + \mathscr{X}_{51}$

$W_{82} = 12\,\mathscr{X}_{19}\,\frac{1}{\lambda_{WW}^2} + \mathscr{X}_{49}\,\frac{1}{\lambda_{WW}} - \mathscr{X}_{50}$ $\quad W_{83} = 1 + 2\,\frac{1}{\lambda_{WW}}$ $\quad W_{84} = 1 - 2\,\mathscr{X}_6\,\frac{1}{\lambda_{WW}} - 12\,\mathscr{X}_{18}\,\frac{1}{\lambda_{WW}^2}$

$W_{85} = 1 + 2\,\mathscr{X}_{53}\,\frac{1}{\lambda_{WW}}$ $\quad W_{86} = \mathscr{X}_{18} - 12\,\mathscr{X}_{18}\,\frac{1}{\lambda_{WW}^2} + 4\,\mathscr{X}_{55}\,\frac{1}{\lambda_{WW}}$ $\quad W_{87} = 6\,\mathscr{X}_{19}\,\frac{1}{\lambda_{WW}} + \mathscr{X}_{54}$

$W_{88} = 2\,\frac{x_t^2}{\lambda_{WW}} + \mathscr{X}_{63}$ $\quad W_{89} = 2\,\frac{x_t^2}{\lambda_{WW}} + \mathscr{X}_{64}$ $\quad W_{90} = 12\,\mathscr{X}_{18}\,\frac{1}{\lambda_{WW}^2} + \mathscr{X}_{51} + \mathscr{X}_{59}\,\frac{1}{\lambda_{WW}}$

$W_{91} = 12\,\mathscr{X}_{18}\,\frac{x_t^2}{\lambda_{WW}^2} + \mathscr{X}_{62} + \mathscr{X}_{65}\,\frac{1}{\lambda_{WW}}$ $\quad W_{92} = 12\,\mathscr{X}_{19}\,\frac{1}{\lambda_{WW}^2} + \mathscr{X}_{60}\,\frac{1}{\lambda_{WW}} - \mathscr{X}_{61}$ $\quad W_{93} = \mathscr{X}_{50} - \mathscr{X}_{57}\,\frac{1}{\lambda_{WW}}$

$W_{94} = \mathscr{X}_{56} + \mathscr{X}_{58}\,\frac{1}{\lambda_{WW}}$ $\quad W_{95} = 1 - \frac{x_H^2}{\lambda_{WW}}$

JHEP07(2015)175

$W_{96} = 1 - \frac{x_H^2}{\lambda_{WW}} + 12\,\mathscr{X}_0\,\frac{1}{\lambda_{WW}^2}$ $\quad W_{97} = 12\,\mathscr{X}_0\,\frac{1}{\lambda_{WW}^2} - \mathscr{X}_0\,\frac{1}{\lambda_{WW}} - \mathscr{X}_{66}$ $\quad W_{98} = 12\,\mathscr{X}_{28}\,\frac{1}{\lambda_{WW}^2} + \mathscr{X}_{36} + \mathscr{X}_{67}\,\frac{1}{\lambda_{WW}}$

$W_{99} = 1 - 12\,\frac{x_H^2}{\lambda_{WW}^2} - \frac{x_H^2}{\lambda_{WW}}$ $\quad W_{100} = 1 + 12\,\frac{x_H^2}{\lambda_{WW}^2} - \frac{x_H^2}{\lambda_{WW}}$ $\quad W_{101} = 1 + 3\,\frac{x_H^2}{\lambda_{WW}}$

$W_{102} = 1 + \mathscr{X}_{36}\,\frac{1}{\lambda_{WW}} - 12\,\mathscr{X}_{68}\,\frac{1}{\lambda_{WW}^2}$ $\quad W_{103} = 5x_H^2 - 12\,\mathscr{X}_{71}\,\frac{1}{\lambda_{WW}^2} - \mathscr{X}_{74}\,\frac{1}{\lambda_{WW}}$ $\quad W_{104} = 12\,\mathscr{X}_{69}\,\frac{x_H^4}{\lambda_{WW}^2} - \mathscr{X}_{72} - \mathscr{X}_{75}\,\frac{x_H^2}{\lambda_{WW}}$

$W_{105} = \mathscr{X}_{70} + 12\,\mathscr{X}_{73}\,\frac{1}{\lambda_{WW}^2} + \mathscr{X}_{76}\,\frac{1}{\lambda_{WW}}$ $\quad W_{106} = 3 + 4\,\frac{x_H^2}{\lambda_{WW}}$ $\quad W_{107} = 36\,\frac{x_H^6}{\lambda_{WW}^2} + \mathscr{X}_{83} + \mathscr{X}_{86}\,\frac{x_H^2}{\lambda_{WW}}$

$W_{108} = x_H^2 - 12\,\mathscr{X}_{78}\,\frac{1}{\lambda_{WW}^2} - \mathscr{X}_{80}\,\frac{1}{\lambda_{WW}}$ $\quad W_{109} = \mathscr{X}_{36} - \mathscr{X}_{36}\,\frac{x_H^2}{\lambda_{WW}}$ $\quad W_{110} = \mathscr{X}_{77} + 12\,\mathscr{X}_{79}\,\frac{1}{\lambda_{WW}^2} + \mathscr{X}_{84}\,\frac{1}{\lambda_{WW}}$

$W_{111} = 12\,\mathscr{X}_{81}\,\frac{1}{\lambda_{WW}^2} - \mathscr{X}_{82} - \mathscr{X}_{85}\,\frac{1}{\lambda_{WW}}$ $\quad W_{112} = 1 - 8\,\frac{1}{\lambda_{WW}}$ $\quad W_{113} = 60\,\frac{x_H^2}{\lambda_{WW}^2} - \mathscr{X}_{88} + \mathscr{X}_{90}\,\frac{1}{\lambda_{WW}}$

$W_{114} = 60\,\frac{x_H^4}{\lambda_{WW}^2} + \mathscr{X}_{89} + \mathscr{X}_{91}\,\frac{x_H^2}{\lambda_{WW}}$ $\quad W_{115} = 5\,\frac{x_H^2}{\lambda_{WW}} - \mathscr{X}_{87}$ $\quad W_{116} = 60\,\frac{x_H^2}{\lambda_{WW}^2} + 17\,\frac{x_H^2}{\lambda_{WW}} + \mathscr{X}_{94}$

$W_{117} = 13\,\frac{1}{\lambda_{WW}} - \mathscr{X}_{93}$ $\quad W_{118} = 24\,\frac{1}{\lambda_{WW}} + \mathscr{X}_{36}$ $\quad W_{119} = 1 - \mathscr{X}_{95}\,\frac{1}{\lambda_{WW}}$

$W_{120} = 60\,\frac{x_H^2}{\lambda_{WW}^2} + \mathscr{X}_{94}$

X

Here $W_{\Phi|\phi}$ denotes the ϕ component of the Φ wave-function factor etc. Furthermore, $\sum_{gen}$ implies summing over all fermions and all generations, while $\overline{\sum}_{gen}$ excludes t and b from the sum.

$X_0 = W_H^{(4)} + 2W_A^{(4)} - 2d\mathscr{Z}_g^{(4)} + d\mathscr{Z}_{M_W}^{(4)}$ $\quad X_1 = 3 - W_Z^{(4)} - W_H^{(4)} - W_A^{(4)} + 2d\mathscr{Z}_g^{(4)} - d\mathscr{Z}_{M_W}^{(4)}$

$X_2 = 2W_{Z|t}^{(4)} + W_{H|t}^{(4)} + 4d\mathscr{Z}_{c_\theta|t}^{(4)}$ $\quad X_3 = 2W_{Z|b}^{(4)} + W_{H|b}^{(4)} + 4d\mathscr{Z}_{c_\theta|b}^{(4)}$

$X_4 = 2\sum_{gen} d\mathscr{Z}_{g|f}^{(4)} - 4\overline{\sum}_{gen} d\mathscr{Z}_{c_\theta|f}^{(4)} + \sum_{gen} d\mathscr{Z}_{M|f}^{(4)} - 2\overline{\sum}_{gen} W_{Z|f}^{(4)}$ $\quad X_5 = 4 - 2d\mathscr{Z}_{g|W}^{(4)} + 2W_{Z|W}^{(4)} + W_{H|W}^{(4)} - d\mathscr{Z}_{M|W}^{(4)} + 4d\mathscr{Z}_{c_\theta|W}^{(4)}$

$X_6 = 6 + 4d\mathscr{Z}_{g|W}^{(4)} - 4W_{Z|W}^{(4)} - 2W_{H|W}^{(4)} + 6W_{Z|b}^{(4)} + 3W_{H|b}^{(4)} + 6W_{Z|t}^{(4)} + 3W_{H|t}^{(4)} + 2d\mathscr{Z}_{M|W}^{(4)} - 8d\mathscr{Z}_{c_\theta|W}^{(4)} + 12d\mathscr{Z}_{c_\theta|b}^{(4)} + 12d\mathscr{Z}_{c_\theta|t}^{(4)}$

$X_7 = 11 + 30d\mathscr{Z}_{g|W}^{(4)} - 30W_{Z|W}^{(4)} - 15W_{H|W}^{(4)} + 15d\mathscr{Z}_{M|W}^{(4)} - 60d\mathscr{Z}_{c_\theta|W}^{(4)}$

$X_8 = 46 + 12d\mathscr{Z}_{g|W}^{(4)} - 12W_{Z|W}^{(4)} - 6W_{H|W}^{(4)} - 6\sum_{gen} d\mathscr{Z}_{g|f}^{(4)} + 6\overline{\sum}_{gen} d\mathscr{Z}_{c_\theta|f}^{(4)} - 3\sum_{gen} d\mathscr{Z}_{M|f}^{(4)} + 6\overline{\sum}_{gen} W_{Z|f}^{(4)} + 6W_{Z|b}^{(4)} + 3W_{H|b}^{(4)}$
$\quad + 6W_{Z|t}^{(4)} + 3W_{H|t}^{(4)} + 6d\mathscr{Z}_{M|W}^{(4)} - 30d\mathscr{Z}_{c_\theta|W}^{(4)} + 6d\mathscr{Z}_{c_\theta|b}^{(4)} + 6d\mathscr{Z}_{c_\theta|t}^{(4)}$

$X_9 = \overline{\sum}_{gen} d\mathscr{Z}_{c_\theta|f}^{(4)} + d\mathscr{Z}_{c_\theta|W}^{(4)} + d\mathscr{Z}_{c_\theta|b}^{(4)} + d\mathscr{Z}_{c_\theta|t}^{(4)}$ $\quad X_{10} = 1 - 2\sum_{gen} d\mathscr{Z}_{g|f}^{(4)} + 4\overline{\sum}_{gen} d\mathscr{Z}_{c_\theta|f}^{(4)} - \sum_{gen} d\mathscr{Z}_{M|f}^{(4)} + 2\overline{\sum}_{gen} W_{Z|f}^{(4)}$

$X_{11} = 5 + 4\overline{\sum}_{gen} d\mathscr{Z}_{c_\theta|f}^{(4)} + 4d\mathscr{Z}_{c_\theta|W}^{(4)} + 4d\mathscr{Z}_{c_\theta|b}^{(4)} + 4d\mathscr{Z}_{c_\theta|t}^{(4)}$

$X_{12} = 1 - 8\sum_{gen} d\mathscr{Z}_{g|f}^{(4)} + 16\overline{\sum}_{gen} d\mathscr{Z}_{c_\theta|f}^{(4)} + 8\overline{\sum}_{gen} W_{Z|f}^{(4)} + 4W_{Z|b}^{(4)} + 2W_{H|b}^{(4)} + 4W_{Z|t}^{(4)} + 2W_{H|t}^{(4)} + 4d\mathscr{Z}_{M|W}^{(4)} + 8d\mathscr{Z}_{c_\theta|b}^{(4)} + 8d\mathscr{Z}_{c_\theta|t}^{(4)}$

$X_{13} = 3 + 2d\mathscr{Z}_{g|W}^{(4)} - 2W_{Z|W}^{(4)} - W_{H|W}^{(4)} + 2\sum_{gen} d\mathscr{Z}_{g|f}^{(4)} - \sum_{gen} d\mathscr{Z}_{M|f}^{(4)} - 2\overline{\sum}_{gen} W_{Z|f}^{(4)} - 2W_{Z|b}^{(4)} - W_{H|b}^{(4)} - 2W_{Z|t}^{(4)} - W_{H|t}^{(4)} - d\mathscr{Z}_{M|W}^{(4)}$

$X_{14} = 44 - 2\sum_{gen} d\mathscr{Z}_{g|f}^{(4)} - \sum_{gen} d\mathscr{Z}_{M|f}^{(4)} + 2\overline{\sum}_{gen} W_{Z|f}^{(4)} + 2W_{Z|b}^{(4)} + W_{H|b}^{(4)} + 2W_{Z|t}^{(4)} + W_{H|t}^{(4)} - 4d\mathscr{Z}_{c_\theta|W}^{(4)}$

$X_{15} = W_H^{(4)}6 + 2W_Z^{(4)}6 + 4d\mathscr{Z}_c^{(4)}6 - d\mathscr{Z}_{M_W}^{(4)}6 - 2d\mathscr{Z}_g^{(4)}6$

$X_{16} = 1 - 8d\mathscr{Z}_{g|W}^{(4)} + 8W_{Z|W}^{(4)} + 4W_{H|W}^{(4)} - 8\sum_{gen} d\mathscr{Z}_{g|f}^{(4)} + 4\sum_{gen} d\mathscr{Z}_{M|f}^{(4)} + 8\overline{\sum}_{gen} W_{Z|f}^{(4)} + 8W_{Z|b}^{(4)} + 4W_{H|b}^{(4)} + 8W_{Z|t}^{(4)} + 4W_{H|t}^{(4)}$
$\quad + 4d\mathscr{Z}_{M|W}^{(4)}$

$X_{17} = 2 + 2d\mathscr{Z}_{g|t,b}^{(4)} + d\mathscr{Z}_{M|t,b}^{(4)} - 2W_{W|t,b}^{(4)} - W_{H|t,b}^{(4)}$ $\quad X_{18} = 2d\mathscr{Z}_{g|t,b}^{(4)} + d\mathscr{Z}_{M|t,b}^{(4)} - 2W_{W|t,b}^{(4)} - W_{H|t,b}^{(4)}$

$X_{19} = 103 + 144\sum_{gen} d\mathscr{Z}_{g|f}^{(4)} + 72\overline{\sum}_{gen} d\mathscr{Z}_{M|f}^{(4)} - 6W_{W|W}^{(4)} - 144\overline{\sum}_{gen} W_{W|f}^{(4)} + 6d\mathscr{Z}_{g|W}^{(4)} - 3W_{H|W}^{(4)} + 3d\mathscr{Z}_{M|W}^{(4)}$

JHEP07(2015)175

$$
\begin{aligned}
\mathrm{X}_{20} &= 17 - 2\,\mathrm{W}^{(4)}_{\mathrm{W}\,|\,\mathrm{W}} + 2\,\mathrm{d}\mathscr{Z}^{(4)}_{g\,|\,\mathrm{W}} - \mathrm{W}^{(4)}_{\mathrm{H}\,|\,\mathrm{W}} + \mathrm{d}\mathscr{Z}^{(4)}_{M\,|\,\mathrm{W}} \\
\mathrm{X}_{21} &= 163 - 96 \sum_{\mathrm{gen}} \mathrm{d}\mathscr{Z}^{(4)}_{g\,|\,\mathrm{f}} - 48\overline{\sum}_{\mathrm{gen}}\mathrm{d}\mathscr{Z}^{(4)}_{M\,|\,\mathrm{f}} + 26\,\mathrm{W}^{(4)}_{\mathrm{W}\,|\,\mathrm{W}} + 96\overline{\sum}_{\mathrm{gen}}\mathrm{W}^{(4)}_{\mathrm{W}\,|\,\mathrm{f}} - 26\,\mathrm{d}\mathscr{Z}^{(4)}_{g\,|\,\mathrm{W}} + 13\,\mathrm{W}^{(4)}_{\mathrm{H}\,|\,\mathrm{W}} - 13\,\mathrm{d}\mathscr{Z}^{(4)}_{M\,|\,\mathrm{W}} \\
\mathrm{X}_{22} &= 11 - 16 \sum_{\mathrm{gen}} \mathrm{d}\mathscr{Z}^{(4)}_{g\,|\,\mathrm{f}} + 8\overline{\sum}_{\mathrm{gen}}\mathrm{d}\mathscr{Z}^{(4)}_{M\,|\,\mathrm{f}} + 16\,\mathrm{W}^{(4)}_{\mathrm{W}\,|\,\mathrm{W}} + 16\overline{\sum}_{\mathrm{gen}}\mathrm{W}^{(4)}_{\mathrm{W}\,|\,\mathrm{f}} - 16\,\mathrm{d}\mathscr{Z}^{(4)}_{g\,|\,\mathrm{t,b}} + 8\,\mathrm{d}\mathscr{Z}^{(4)}_{M\,|\,\mathrm{t,b}} + 16\,\mathrm{W}^{(4)}_{\mathrm{W}\,|\,\mathrm{t,b}} + 8\,\mathrm{W}^{(4)}_{\mathrm{H}\,|\,\mathrm{t,b}} \\
&\quad - 16\,\mathrm{d}\mathscr{Z}^{(4)}_{g\,|\,\mathrm{W}} + 8\,\mathrm{W}^{(4)}_{\mathrm{H}\,|\,\mathrm{W}} + 8\,\mathrm{d}\mathscr{Z}^{(4)}_{M\,|\,\mathrm{W}} - 16\,\mathrm{d}\mathscr{Z}^{(4)}_{c} \\
\mathrm{X}_{23} &= 35 + 120 \sum_{\mathrm{gen}} \mathrm{d}\mathscr{Z}^{(4)}_{g\,|\,\mathrm{f}} + 12\overline{\sum}_{\mathrm{gen}}\mathrm{d}\mathscr{Z}^{(4)}_{M\,|\,\mathrm{f}} - 22\,\mathrm{W}^{(4)}_{\mathrm{W}\,|\,\mathrm{W}} - 120\overline{\sum}_{\mathrm{gen}}\mathrm{W}^{(4)}_{\mathrm{W}\,|\,\mathrm{f}} - 48\,\mathrm{d}\mathscr{Z}^{(4)}_{M\,|\,\mathrm{t,b}} + 22\,\mathrm{d}\mathscr{Z}^{(4)}_{g\,|\,\mathrm{W}} - 11\,\mathrm{W}^{(4)}_{\mathrm{H}\,|\,\mathrm{W}} - 37\,\mathrm{d}\mathscr{Z}^{(4)}_{M\,|\,\mathrm{W}} \\
&\quad + 120\,\mathrm{d}\mathscr{Z}^{(4)}_{c} \\
\mathrm{X}_{24} &= 293 + 12\,\mathrm{W}^{(4)}_{\mathrm{W}\,|\,\mathrm{W}} - 12\,\mathrm{d}\mathscr{Z}^{(4)}_{g\,|\,\mathrm{W}} + 6\,\mathrm{W}^{(4)}_{\mathrm{H}\,|\,\mathrm{W}} - 6\,\mathrm{d}\mathscr{Z}^{(4)}_{M\,|\,\mathrm{W}} \qquad \mathrm{X}_{25} = \mathrm{d}\mathscr{Z}^{(4)}_{c} \\
\mathrm{X}_{26} &= 3 - 4 \sum_{\mathrm{gen}} \mathrm{d}\mathscr{Z}^{(4)}_{g\,|\,\mathrm{f}} + 2\overline{\sum}_{\mathrm{gen}}\mathrm{d}\mathscr{Z}^{(4)}_{M\,|\,\mathrm{f}} + 4\,\mathrm{W}^{(4)}_{\mathrm{W}\,|\,\mathrm{W}} + 4\overline{\sum}_{\mathrm{gen}}\mathrm{W}^{(4)}_{\mathrm{W}\,|\,\mathrm{f}} - 4\,\mathrm{d}\mathscr{Z}^{(4)}_{g\,|\,\mathrm{t,b}} + 2\,\mathrm{d}\mathscr{Z}^{(4)}_{M\,|\,\mathrm{t,b}} + 4\,\mathrm{W}^{(4)}_{\mathrm{W}\,|\,\mathrm{t,b}} + 2\,\mathrm{W}^{(4)}_{\mathrm{H}\,|\,\mathrm{t,b}} - 4\,\mathrm{d}\mathscr{Z}^{(4)}_{g\,|\,\mathrm{W}} \\
&\quad + 2\,\mathrm{W}^{(4)}_{\mathrm{H}\,|\,\mathrm{W}} + 2\,\mathrm{d}\mathscr{Z}^{(4)}_{M\,|\,\mathrm{W}} \\
\mathrm{X}_{27} &= 72 - 10 \sum_{\mathrm{gen}} \mathrm{d}\mathscr{Z}^{(4)}_{g\,|\,\mathrm{f}} - \overline{\sum}_{\mathrm{gen}}\mathrm{d}\mathscr{Z}^{(4)}_{M\,|\,\mathrm{f}} + 2\,\mathrm{W}^{(4)}_{\mathrm{W}\,|\,\mathrm{W}} + 10\overline{\sum}_{\mathrm{gen}}\mathrm{W}^{(4)}_{\mathrm{W}\,|\,\mathrm{f}} + 4\,\mathrm{d}\mathscr{Z}^{(4)}_{M\,|\,\mathrm{t,b}} - 2\,\mathrm{d}\mathscr{Z}^{(4)}_{g\,|\,\mathrm{W}} + \mathrm{W}^{(4)}_{\mathrm{H}\,|\,\mathrm{W}} + 3\,\mathrm{d}\mathscr{Z}^{(4)}_{M\,|\,\mathrm{W}} \\
\mathrm{X}_{28} &= 3 - 8 \sum_{\mathrm{gen}} \mathrm{d}\mathscr{Z}^{(4)}_{g\,|\,\mathrm{f}} + 4\overline{\sum}_{\mathrm{gen}}\mathrm{d}\mathscr{Z}^{(4)}_{M\,|\,\mathrm{f}} + 8\,\mathrm{W}^{(4)}_{\mathrm{W}\,|\,\mathrm{W}} + 8\overline{\sum}_{\mathrm{gen}}\mathrm{W}^{(4)}_{\mathrm{W}\,|\,\mathrm{f}} - 8\,\mathrm{d}\mathscr{Z}^{(4)}_{g\,|\,\mathrm{t,b}} + 4\,\mathrm{d}\mathscr{Z}^{(4)}_{M\,|\,\mathrm{t,b}} + 8\,\mathrm{W}^{(4)}_{\mathrm{W}\,|\,\mathrm{t,b}} + 4\,\mathrm{W}^{(4)}_{\mathrm{H}\,|\,\mathrm{t,b}} \\
&\quad - 8\,\mathrm{d}\mathscr{Z}^{(4)}_{g\,|\,\mathrm{W}} + 4\,\mathrm{W}^{(4)}_{\mathrm{H}\,|\,\mathrm{W}} + 4\,\mathrm{d}\mathscr{Z}^{(4)}_{M\,|\,\mathrm{W}} - 16\,\mathrm{d}\mathscr{Z}^{(4)}_{c} \\
\mathrm{X}_{29} &= 11 - 20 \sum_{\mathrm{gen}} \mathrm{d}\mathscr{Z}^{(4)}_{g\,|\,\mathrm{f}} - 2\overline{\sum}_{\mathrm{gen}}\mathrm{d}\mathscr{Z}^{(4)}_{M\,|\,\mathrm{f}} + 2\,\mathrm{W}^{(4)}_{\mathrm{W}\,|\,\mathrm{W}} + 20\overline{\sum}_{\mathrm{gen}}\mathrm{W}^{(4)}_{\mathrm{W}\,|\,\mathrm{f}} + 8\,\mathrm{d}\mathscr{Z}^{(4)}_{M\,|\,\mathrm{t,b}} - 2\,\mathrm{d}\mathscr{Z}^{(4)}_{g\,|\,\mathrm{W}} + \mathrm{W}^{(4)}_{\mathrm{H}\,|\,\mathrm{W}} + 7\,\mathrm{d}\mathscr{Z}^{(4)}_{M\,|\,\mathrm{W}} - 40\,\mathrm{d}\mathscr{Z}^{(4)}_{c} \\
\mathrm{X}_{30} &= 2\,\mathrm{W}^{(6)}_{\mathrm{W}} + \mathrm{W}^{(6)}_{\mathrm{H}} - \mathrm{d}\mathscr{Z}^{(6)}_{M_\mathrm{W}} - 2\,\mathrm{d}\mathscr{Z}^{(6)}_{g} \qquad \mathrm{X}_{31} = 2\,\mathrm{W}^{(4)}_{\mathrm{W}} + \mathrm{W}^{(4)}_{\mathrm{H}} - 2\,\mathrm{d}\mathscr{Z}^{(4)}_{g} - 2\,\mathrm{d}\mathscr{Z}^{(4)}_{c} + \mathrm{d}\mathscr{Z}^{(4)}_{M_\mathrm{W}} \\
\mathrm{X}_{32} &= 2\,\mathrm{W}^{(4)}_{\mathrm{W}} + \mathrm{W}^{(4)}_{\mathrm{H}} - 2\,\mathrm{d}\mathscr{Z}^{(4)}_{g} + \mathrm{d}\mathscr{Z}^{(4)}_{M_\mathrm{W}} \qquad \mathrm{X}_{33} = 2\,\mathrm{W}^{(4)}_{\mathrm{W}} + \mathrm{W}^{(4)}_{\mathrm{H}} - 2\,\mathrm{d}\mathscr{Z}^{(4)}_{g} - 4\,\mathrm{d}\mathscr{Z}^{(4)}_{c} + \mathrm{d}\mathscr{Z}^{(4)}_{M_\mathrm{W}}
\end{aligned}
\tag{H.1}
$$

H.2 Amplitudes

We use the following notazion: $\mathscr{T}^{\mathrm{nfc}}_{\mathrm{AA}}(a_{\mathrm{u\,WB}})$ is the non-factorizable part of the $\mathscr{T}_{\mathrm{AA}}$ amplitude that is proportional to the Wilson coefficient $a_{\mathrm{u\,WB}}$ etc.

$$
\mathscr{D}^{\mathrm{nfc}}_{\mathrm{HVV}} = M_{\mathrm{W}}\,\mathscr{T}^{\mathrm{nfc}}_{\mathrm{D;VV}}\,, \qquad \mathscr{P}^{\mathrm{nfc}}_{\mathrm{HVV}} = \frac{1}{M_{\mathrm{W}}}\,\mathscr{T}^{\mathrm{nfc}}_{\mathrm{P;VV}}\,, \tag{H.2}
$$

with $\mathrm{V} = \mathrm{Z}, \mathrm{W}$, while $\mathscr{T}^{\mathrm{nfc}}_{\mathrm{HAA,HAZ}}$ should be multiplied by M_{W} to restore its dimensionality. Furthermore, λ_{AZ} is defined in eq. (5.34), λ_{ZZ} in eq. (5.50) and λ_{WW} in eq. (5.62). The function C_0 in this appendix is the scalar three-point function, scaled with M_{W}. The amplitudes are listed in the following equations:

- HAA Amplitudes

$$
\begin{aligned}
\mathscr{T}^{\mathrm{nfc}}_{\mathrm{AA}}(a_{\mathrm{u\,WB}}) &= -\frac{1}{8}\,s\,x^2_{\mathrm{H}}\,x^2_{\mathrm{t}} + \frac{1}{8}\,s\,x^2_{\mathrm{H}}\,x^2_{\mathrm{t}}\,a^{\mathrm{fin}}_0\,(M_{\mathrm{t}}) \\
&\quad + \frac{1}{8}\,s\,x^2_{\mathrm{H}}\,x^2_{\mathrm{t}}\,\mathrm{B}^{\mathrm{fin}}_0\left(-M^2_{\mathrm{H}}\,;M_{\mathrm{t}}\,,M_{\mathrm{t}}\right) \\
&\quad - \frac{1}{16}\,s\,x^4_{\mathrm{H}}\,x^2_{\mathrm{t}}\,\mathrm{C}_0\left(-M^2_{\mathrm{H}}\,,0\,,0;M_{\mathrm{t}}\,,M_{\mathrm{t}}\,,M_{\mathrm{t}}\right)
\end{aligned}
$$

$$
\begin{aligned}
\mathscr{T}^{\mathrm{nfc}}_{\mathrm{AA}}(a_{\mathrm{d\,WB}}) &= \frac{1}{16}\,s\,x^2_{\mathrm{H}}\,x^2_{\mathrm{b}} - \frac{1}{16}\,s\,x^2_{\mathrm{H}}\,x^2_{\mathrm{b}}\,a^{\mathrm{fin}}_0\,(M_{\mathrm{b}}) \\
&\quad - \frac{1}{16}\,s\,x^2_{\mathrm{H}}\,x^2_{\mathrm{b}}\,\mathrm{B}^{\mathrm{fin}}_0\left(-M^2_{\mathrm{H}}\,;M_{\mathrm{b}}\,,M_{\mathrm{b}}\right) \\
&\quad + \frac{1}{32}\,s\,x^4_{\mathrm{H}}\,x^2_{\mathrm{b}}\,\mathrm{C}_0\left(-M^2_{\mathrm{H}}\,,0\,,0;M_{\mathrm{b}}\,,M_{\mathrm{b}}\,,M_{\mathrm{b}}\right)
\end{aligned}
$$

JHEP07(2015)175

$$\mathscr{T}^{\rm nfc}_{\rm AA}(a_{\rm AZ}) = -\frac{1}{2}\,s^3\,c\,x^2_{\rm H}\,a^{\rm fin}_0\left(M_{\rm W}\right) + \frac{1}{4}\,{\rm T}^d_1\,s\,c\,x^2_{\rm H}
- \frac{1}{16}\,{\rm T}^d_2\,{\rm V}_0\,s\,c\,x^2_{\rm H}\,{\rm B}^{\rm fin}_0\left(-M^2_{\rm H}\,;M_{\rm W}\,,M_{\rm W}\right)
+ \frac{1}{2}\,(s^2\,x^2_{\rm H} + {\rm T}^d_1)\,s\,c\,x^2_{\rm H}\,{\rm C}_0\left(-M^2_{\rm H}\,,0\,,0\,;M_{\rm W}\,,M_{\rm W}\,,M_{\rm W}\right)
- \frac{1}{16}\,(2\,{\rm T}^d_0 - {\rm T}^d_2\,x^2_{\rm H})\,s\,c\,x^2_{\rm H}\,{\rm L_R}$$

$$\mathscr{T}^{\rm nfc}_{\rm AA}(a_{\rm AA}) = -\frac{1}{16}\,x^2_{\rm H}\,{\rm X}_0 + \frac{1}{4}\,{\rm T}^d_4\,s^2\,x^2_{\rm H} - \frac{1}{2}\,s^4\,x^2_{\rm H}\,a^{\rm fin}_0\left(M_{\rm W}\right)
- \frac{1}{64}\,x^4_{\rm H}\,{\rm B}^{\rm fin}_0\left(-M^2_{\rm H}\,;M_{\rm Z}\,,M_{\rm Z}\right)
- \frac{3}{64}\,x^4_{\rm H}\,{\rm B}^{\rm fin}_0\left(-M^2_{\rm H}\,;M_{\rm H}\,,M_{\rm H}\right)
+ \frac{1}{2}\,(s^2\,x^2_{\rm H} + {\rm T}^d_4)\,s^2\,x^2_{\rm H}\,{\rm C}_0\left(-M^2_{\rm H}\,,0\,,0\,;M_{\rm W}\,,M_{\rm W}\,,M_{\rm W}\right)
- \frac{1}{32}\,(8\,s^2\,c^2 + {\rm T}^d_3\,x^2_{\rm H})\,x^2_{\rm H}\,{\rm B}^{\rm fin}_0\left(-M^2_{\rm H}\,;M_{\rm W}\,,M_{\rm W}\right)
- \frac{1}{32}\,(8\,{\rm T}^d_1\,s^2 + {\rm T}^d_5\,x^2_{\rm H})\,x^2_{\rm H}\,{\rm L_R}$$

$$\mathscr{T}^{\rm nfc}_{\rm AA}(a_{\rm ZZ}) = -\frac{3}{4}\,s^2\,c^2\,x^2_{\rm H} - \frac{1}{2}\,s^2\,c^2\,x^2_{\rm H}\,a^{\rm fin}_0\left(M_{\rm W}\right)
+ \frac{1}{8}\,{\rm V}_0\,s^2\,c^2\,x^2_{\rm H}\,{\rm B}^{\rm fin}_0\left(-M^2_{\rm H}\,;M_{\rm W}\,,M_{\rm W}\right)
- \frac{1}{2}\,{\rm V}_1\,s^2\,c^2\,x^2_{\rm H}\,{\rm C}_0\left(-M^2_{\rm H}\,,0\,,0\,;M_{\rm W}\,,M_{\rm W}\,,M_{\rm W}\right)
+ \frac{1}{8}\,{\rm V}_2\,s^2\,c^2\,x^2_{\rm H}\,{\rm L_R}$$

- HAZ Amplitudes

$$\mathscr{T}^{\rm nfc}_{\rm AZ}(a_{\phi\,{\rm t\,v}}) = \frac{1}{2}\,\frac{s}{c^3}\,\frac{x^2_{\rm H}}{\lambda^2_{\rm AZ}}\,x^2_{\rm t}\,{\rm B}^{\rm fin}_0\left(-M^2_{\rm H}\,;M_{\rm t}\,,M_{\rm t}\right)
- \frac{1}{2}\,\frac{s}{c^3}\,\frac{x^2_{\rm H}}{\lambda^2_{\rm AZ}}\,x^2_{\rm t}\,{\rm B}^{\rm fin}_0\left(-M^2_{\rm Z}\,;M_{\rm t}\,,M_{\rm t}\right)
+ \frac{1}{2}\,\frac{s}{c}\,\frac{x^2_{\rm H}}{\lambda_{\rm AZ}}\,x^2_{\rm t}
+ \frac{1}{4}\,\frac{s}{c}\,{\rm W}_0\,x^2_{\rm H}\,x^2_{\rm t}\,{\rm C}_0\left(-M^2_{\rm H}\,,0\,,-M^2_{\rm Z}\,;M_{\rm t}\,,M_{\rm t}\,,M_{\rm t}\right)$$

$$\mathscr{T}^{\rm nfc}_{\rm AZ}(a_{\phi\,{\rm b\,v}}) = \frac{1}{4}\,\frac{s}{c^3}\,\frac{x^2_{\rm H}}{\lambda^2_{\rm AZ}}\,x^2_{\rm b}\,{\rm B}^{\rm fin}_0\left(-M^2_{\rm H}\,;M_{\rm b}\,,M_{\rm b}\right)
- \frac{1}{4}\,\frac{s}{c^3}\,\frac{x^2_{\rm H}}{\lambda^2_{\rm AZ}}\,x^2_{\rm b}\,{\rm B}^{\rm fin}_0\left(-M^2_{\rm Z}\,;M_{\rm b}\,,M_{\rm b}\right)
+ \frac{1}{4}\,\frac{s}{c}\,\frac{x^2_{\rm H}}{\lambda_{\rm AZ}}\,x^2_{\rm b}
+ \frac{1}{8}\,\frac{s}{c}\,{\rm W}_1\,x^2_{\rm H}\,x^2_{\rm b}\,{\rm C}_0\left(-M^2_{\rm H}\,,0\,,-M^2_{\rm Z}\,;M_{\rm b}\,,M_{\rm b}\,,M_{\rm b}\right)$$

$$\mathscr{T}^{\rm nfc}_{\rm AZ}(a_{\rm t\,B\,W}) = \frac{1}{16}\,s\,x^2_{\rm H}\,x^2_{\rm t}\,a^{\rm fin}_0\left(M_{\rm t}\right) - \frac{1}{8}\,\frac{s}{c^2}\,\frac{x^2_{\rm H}}{\lambda_{\rm AZ}}\,x^2_{\rm t}$$

$$-\frac{1}{16}\left[2\,\frac{1}{\lambda_{AZ}^2}+(-c^2+\frac{1}{\lambda_{AZ}})\,c^2\right]\frac{s}{c^4}\,x_H^2\,x_t^2\,B_0^{fin}\left(-M_H^2\,;M_t\,,M_t\right)$$
$$+\frac{1}{8}\,(-c^2+2\,\frac{1}{\lambda_{AZ}})\,\frac{s}{c^2}\,x_H^2\,x_t^4\,C_0\left(-M_H^2\,,0\,,-M_Z^2\,;M_t\,,M_t\,,M_t\right)$$
$$+\frac{1}{16}\,(c^2+2\,\frac{1}{\lambda_{AZ}})\,\frac{s}{c^4}\,\frac{x_H^2}{\lambda_{AZ}}\,x_t^2\,B_0^{fin}\left(-M_Z^2\,;M_t\,,M_t\right)$$

$$\begin{aligned}\mathscr{T}_{AZ}^{nfc}(a_{tWB}) = &-\frac{3}{128}\,\frac{v_t}{c}\,x_H^2\,x_t^2\\&-\frac{3}{64}\,\frac{v_t}{c}\,x_H^2\,x_t^4\,C_0\left(-M_H^2\,,0\,,-M_Z^2\,;M_t\,,M_t\,,M_t\right)\\&+\frac{3}{128}\,(c^2+\frac{1}{\lambda_{AZ}})\,\frac{v_t}{c^3}\,x_H^2\,x_t^2\,B_0^{fin}\left(-M_H^2\,;M_t\,,M_t\right)\\&-\frac{3}{128}\,(c^2+\frac{1}{\lambda_{AZ}})\,\frac{v_t}{c^3}\,x_H^2\,x_t^2\,B_0^{fin}\left(-M_Z^2\,;M_t\,,M_t\right)\end{aligned}$$

$$\begin{aligned}\mathscr{T}_{AZ}^{nfc}(a_{bBW}) = &-\frac{1}{32}\,s\,x_H^2\,x_b^2\,a_0^{fin}\left(M_b\right)+\frac{1}{16}\,\frac{s}{c^2}\,\frac{x_H^2}{\lambda_{AZ}}\,x_b^2\\&+\frac{1}{32}\left[2\,\frac{1}{\lambda_{AZ}^2}+(-c^2+\frac{1}{\lambda_{AZ}})\,c^2\right]\frac{s}{c^4}\,x_H^2\,x_b^2\,B_0^{fin}\left(-M_H^2\,;M_b\,,M_b\right)\\&-\frac{1}{16}\,(-c^2+2\,\frac{1}{\lambda_{AZ}})\,\frac{s}{c^2}\,x_H^2\,x_b^4\,C_0\left(-M_H^2\,,0\,,-M_Z^2\,;M_b\,,M_b\,,M_b\right)\\&-\frac{1}{32}\,(c^2+2\,\frac{1}{\lambda_{AZ}})\,\frac{s}{c^4}\,\frac{x_H^2}{\lambda_{AZ}}\,x_b^2\,B_0^{fin}\left(-M_Z^2\,;M_b\,,M_b\right)\end{aligned}$$

$$\begin{aligned}\mathscr{T}_{AZ}^{nfc}(a_{bWB}) = &\;\frac{3}{128}\,\frac{v_b}{c}\,x_H^2\,x_b^2\\&+\frac{3}{64}\,\frac{v_b}{c}\,x_H^2\,x_b^4\,C_0\left(-M_H^2\,,0\,,-M_Z^2\,;M_b\,,M_b\,,M_b\right)\\&-\frac{3}{128}\,(c^2+\frac{1}{\lambda_{AZ}})\,\frac{v_b}{c^3}\,x_H^2\,x_b^2\,B_0^{fin}\left(-M_H^2\,;M_b\,,M_b\right)\\&+\frac{3}{128}\,(c^2+\frac{1}{\lambda_{AZ}})\,\frac{v_b}{c^3}\,x_H^2\,x_b^2\,B_0^{fin}\left(-M_Z^2\,;M_b\,,M_b\right)\end{aligned}$$

$$\begin{aligned}\mathscr{T}_{AZ}^{nfc}(a_{\phi D}) = &\;\frac{1}{32}\left[2\,\frac{1}{\lambda_{AZ}}\,T_6^d\,c^2-(\frac{x_H^2}{\lambda_{AZ}}\,T_{10}^d-2\,T_{11}^d)\right]\frac{1}{s\,c^3}\,x_H^2\,C_0\left(-M_H^2\,,0\,,-M_Z^2\,;M_W\,,M_W\,,M_W\right)\\&+\frac{1}{192}\left\{3\,\frac{x_H^2}{\lambda_{AZ}}\,T_{10}^d-6\left[T_6^d+(x_b^2\,v_b+2\,x_t^2\,v_t)\,c^2\right]\frac{1}{\lambda_{AZ}}\,c^2\right.\\&\left.+2\left[(\frac{x_b^2}{\lambda_{AZ}}\,T_8^d+2\,\frac{x_t^2}{\lambda_{AZ}}\,T_9^d+9\,T_7^d)\right]s^2\,c^2\right\}\frac{1}{s\,c^3}\,x_H^2\\&-\frac{1}{192}\,(3\,c^2\,v_b-T_8^d\,s^2)\,\frac{1}{s\,c}\,W_1\,x_H^2\,x_b^2\,C_0\left(-M_H^2\,,0\,,-M_Z^2\,;M_b\,,M_b\,,M_b\right)\\&-\frac{1}{96}\,(3\,c^2\,v_b-T_8^d\,s^2)\,\frac{1}{s\,c^3}\,\frac{x_H^2}{\lambda_{AZ}^2}\,x_b^2\,B_0^{fin}\left(-M_H^2\,;M_b\,,M_b\right)\\&+\frac{1}{96}\,(3\,c^2\,v_b-T_8^d\,s^2)\,\frac{1}{s\,c^3}\,\frac{x_H^2}{\lambda_{AZ}^2}\,x_b^2\,B_0^{fin}\left(-M_Z^2\,;M_b\,,M_b\right)\\&-\frac{1}{96}\,(3\,c^2\,v_t-T_9^d\,s^2)\,\frac{1}{s\,c}\,W_0\,x_H^2\,x_t^2\,C_0\left(-M_H^2\,,0\,,-M_Z^2\,;M_t\,,M_t\,,M_t\right)\\&-\frac{1}{48}\,(3\,c^2\,v_t-T_9^d\,s^2)\,\frac{1}{s\,c^3}\,\frac{x_H^2}{\lambda_{AZ}^2}\,x_t^2\,B_0^{fin}\left(-M_H^2\,;M_t\,,M_t\right)\end{aligned}$$

$$
\begin{aligned}
&+\frac{1}{48}\,(3\,c^2\,\mathrm{v_t}-\mathrm{T}^d_9\,s^2)\,\frac{1}{s\,c^3}\,\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{AZ}}^2}\,x_{\mathrm{t}}^2\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{Z}}^2\,;M_{\mathrm{t}}\,,M_{\mathrm{t}}\right)\\
&-\frac{1}{64}\,(-\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{AZ}}}\,\mathrm{T}^d_{10}+2\,\frac{1}{\lambda_{\mathrm{AZ}}}\,\mathrm{T}^d_6\,c^2-6\,\mathrm{T}^d_7\,s^2\,c^2)\,\frac{1}{s\,c^5}\,\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{AZ}}}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{W}}\,,M_{\mathrm{W}}\right)\\
&+\frac{1}{64}\,(-\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{AZ}}}\,\mathrm{T}^d_{10}+2\,\frac{1}{\lambda_{\mathrm{AZ}}}\,\mathrm{T}^d_6\,c^2-6\,\mathrm{T}^d_7\,s^2\,c^2)\,\frac{1}{s\,c^5}\,\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{AZ}}}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{Z}}^2\,;M_{\mathrm{W}}\,,M_{\mathrm{W}}\right)
\end{aligned}
$$

$$
\begin{aligned}
\mathscr{T}^{\mathrm{nfc}}_{\mathrm{AZ}}(a_{\mathrm{AZ}}) ={}& \frac{1}{32}\,x_{\mathrm{H}}^2\,\mathrm{X}_1-\frac{1}{64}\,x_{\mathrm{H}}^4\,a_0^{\mathrm{fin}}\left(M_{\mathrm{H}}\right)+\frac{1}{64}\,\frac{1}{c^2}\,x_{\mathrm{H}}^2\,a_0^{\mathrm{fin}}\left(M_{\mathrm{Z}}\right)\\
&-\frac{1}{64}\left[2\,\frac{1}{\lambda_{\mathrm{AZ}}}-(c^2\,x_{\mathrm{H}}^2+2\,\mathrm{W}_4)\,c^2\right]\frac{1}{c^6}\,\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{AZ}}}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{Z}}^2\,;M_{\mathrm{H}}\,,M_{\mathrm{Z}}\right)\\
&+\frac{1}{16}\left[\frac{1}{\lambda_{\mathrm{AZ}}}\,\mathrm{T}^d_7+(\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{AZ}}}\,\mathrm{T}^d_2-\mathrm{T}^d_{26})\,c^2\right]\frac{s^2}{c^2}\,x_{\mathrm{H}}^2\,a_0^{\mathrm{fin}}\left(M_{\mathrm{W}}\right)\\
&+\frac{1}{32}\left\{16\,s^2\,c^6\,x_{\mathrm{H}}^2+8\,\frac{1}{\lambda_{\mathrm{AZ}}}\,\mathrm{T}^d_{27}\,c^4-\left[(-\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{AZ}}}\,\mathrm{T}^d_{22}+2\,\mathrm{T}^d_{15})\right]\right\}\frac{1}{c^4}\,x_{\mathrm{H}}^2\\
&\times\mathrm{C}_0\left(-M_{\mathrm{H}}^2\,,0\,,-M_{\mathrm{Z}}^2\,;M_{\mathrm{W}}\,,M_{\mathrm{W}}\,,M_{\mathrm{W}}\right)\\
&-\frac{1}{64}\left\{4\,\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{AZ}}}\,\mathrm{T}^d_2\,s^2\,c^6-\left[(2\,\mathrm{T}^d_{19}+\mathrm{T}^d_{20}\,x_{\mathrm{H}}^2)\right]\frac{1}{\lambda_{\mathrm{AZ}}^2}+2\,(3\,\frac{1}{\lambda_{\mathrm{AZ}}}\,\mathrm{T}^d_{23}+\mathrm{T}^d_{24}\,c^2)\,c^4\right\}\frac{1}{c^6}\,x_{\mathrm{H}}^2\\
&\times\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{Z}}^2\,;M_{\mathrm{W}}\,,M_{\mathrm{W}}\right)\\
&+\frac{1}{64}\left\{8\,\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{AZ}}}\,\mathrm{T}^d_2\,s^2\,c^6+\left[2\,\frac{1}{\lambda_{\mathrm{AZ}}}\,\mathrm{T}^d_{28}-(2\,\mathrm{T}^d_2-\mathrm{T}^d_{13}\,x_{\mathrm{H}}^2)\,c^2\right]c^4-\left[(2\,\mathrm{T}^d_{19}+\mathrm{T}^d_{20}\,x_{\mathrm{H}}^2)\right]\frac{1}{\lambda_{\mathrm{AZ}}^2}\right\}\frac{1}{c^6}\,x_{\mathrm{H}}^2\\
&\times\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{W}}\,,M_{\mathrm{W}}\right)\\
&+\frac{1}{32}\left\{\frac{1}{\lambda_{\mathrm{AZ}}^2}-\left[2\,\frac{1}{\lambda_{\mathrm{AZ}}}\,\mathrm{W}_2-(\frac{1}{\lambda_{\mathrm{AZ}}}\,\mathrm{W}_2+\mathrm{W}_2\,c^2)\,c^2\,x_{\mathrm{H}}^2\right]c^2\right\}\frac{1}{c^8}\,x_{\mathrm{H}}^2\,\mathrm{C}_0\left(-M_{\mathrm{H}}^2\,,0\,,-M_{\mathrm{Z}}^2\,;M_{\mathrm{Z}}\,,M_{\mathrm{H}}\,,M_{\mathrm{Z}}\right)\\
&+\frac{1}{128}\left\{4\,\frac{1}{\lambda_{\mathrm{AZ}}^2}-\left[2\,\frac{1}{\lambda_{\mathrm{AZ}}}\,\mathrm{W}_5+(c^2\,x_{\mathrm{H}}^2+2\,\mathrm{W}_3)\,c^2\right]c^2\right\}\frac{1}{c^6}\,x_{\mathrm{H}}^2\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{Z}}\,,M_{\mathrm{Z}}\right)\\
&-\frac{1}{192}\left\{3\left[\mathrm{T}^d_{18}-8\,(x_{\mathrm{b}}^2\,\mathrm{v_b}+2\,x_{\mathrm{t}}^2\,\mathrm{v_t})\,\frac{1}{\lambda_{\mathrm{AZ}}}\,c^2\right]c^2+3\left[(2\,\mathrm{T}^d_{17}+\mathrm{T}^d_{21}\,x_{\mathrm{H}}^2)\right]\frac{1}{\lambda_{\mathrm{AZ}}}\right.\\
&\left.+8\,(\mathrm{T}^d_{12}\,x_{\mathrm{b}}^2+2\,\mathrm{T}^d_{25}\,x_{\mathrm{t}}^2)\,\frac{1}{\lambda_{\mathrm{AZ}}}\,s^2\,c^4\right\}\frac{1}{c^4}\,x_{\mathrm{H}}^2\\
&-\frac{1}{64}\,(1-c^2\,x_{\mathrm{H}}^2)\,\frac{1}{c^4}\,\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{AZ}}}\,\mathrm{B}_0^{\mathrm{fin}}\left(0;M_{\mathrm{Z}}\,,M_{\mathrm{H}}\right)\\
&-\frac{3}{32}\,(1-c^2\,x_{\mathrm{H}}^2)\,\frac{1}{c^4}\,\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{AZ}}}\,x_{\mathrm{H}}^2\,\mathrm{C}_0\left(-M_{\mathrm{H}}^2\,,0\,,-M_{\mathrm{Z}}^2\,;M_{\mathrm{H}}\,,M_{\mathrm{Z}}\,,M_{\mathrm{H}}\right)\\
&+\frac{1}{24}\,(3\,\mathrm{v_b}-\mathrm{T}^d_{12}\,s^2)\,\frac{1}{c^2}\,\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{AZ}}^2}\,x_{\mathrm{b}}^2\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{b}}\,,M_{\mathrm{b}}\right)\\
&-\frac{1}{24}\,(3\,\mathrm{v_b}-\mathrm{T}^d_{12}\,s^2)\,\frac{1}{c^2}\,\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{AZ}}^2}\,x_{\mathrm{b}}^2\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{Z}}^2\,;M_{\mathrm{b}}\,,M_{\mathrm{b}}\right)\\
&+\frac{1}{48}\,(3\,\mathrm{v_b}-\mathrm{T}^d_{12}\,s^2)\,\mathrm{W}_1\,x_{\mathrm{H}}^2\,x_{\mathrm{b}}^2\,\mathrm{C}_0\left(-M_{\mathrm{H}}^2\,,0\,,-M_{\mathrm{Z}}^2\,;M_{\mathrm{b}}\,,M_{\mathrm{b}}\,,M_{\mathrm{b}}\right)\\
&+\frac{1}{12}\,(3\,\mathrm{v_t}-\mathrm{T}^d_{25}\,s^2)\,\frac{1}{c^2}\,\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{AZ}}^2}\,x_{\mathrm{t}}^2\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{t}}\,,M_{\mathrm{t}}\right)\\
&-\frac{1}{12}\,(3\,\mathrm{v_t}-\mathrm{T}^d_{25}\,s^2)\,\frac{1}{c^2}\,\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{AZ}}^2}\,x_{\mathrm{t}}^2\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{Z}}^2\,;M_{\mathrm{t}}\,,M_{\mathrm{t}}\right)\\
&+\frac{1}{24}\,(3\,\mathrm{v_t}-\mathrm{T}^d_{25}\,s^2)\,\mathrm{W}_0\,x_{\mathrm{H}}^2\,x_{\mathrm{t}}^2\,\mathrm{C}_0\left(-M_{\mathrm{H}}^2\,,0\,,-M_{\mathrm{Z}}^2\,;M_{\mathrm{t}}\,,M_{\mathrm{t}}\,,M_{\mathrm{t}}\right)
\end{aligned}
$$

JHEP07(2015)175

$$+\frac{3}{128}\,(-c^2+4\,\frac{1}{\lambda_{AZ}})\,\frac{1}{c^2}\,x_H^4\,B_0^{fin}\left(-M_H^2\,;M_H\,,M_H\right)$$

$$-\frac{1}{64}\,(c^2+6\,\frac{1}{\lambda_{AZ}})\,\frac{1}{c^2}\,x_H^4\,B_0^{fin}\left(-M_Z^2\,;M_Z\,,M_H\right)$$

$$-\frac{1}{64}\,(T^d_{14}\,c^2\,x_H^2+2\,T^d_{16})\,\frac{1}{c^2}\,x_H^2\,L_R$$

$$\mathscr{T}^{nfc}_{AZ}(a_{AA})=-\frac{1}{12}\,s\,c\,x_H^2\,x_b^2\,v_b\,a_0^{fin}\left(M_b\right)-\frac{1}{6}\,s\,c\,x_H^2\,x_t^2\,v_t\,a_0^{fin}\left(M_t\right)$$

$$-\frac{1}{24}\,\frac{s^3}{c^3}\,\frac{x_H^2}{\lambda_{AZ}^2}\,T^d_{40}\,x_b^2\,B_0^{fin}\left(-M_H^2\,;M_b\,,M_b\right)$$

$$-\frac{1}{12}\,\frac{s^3}{c^3}\,\frac{x_H^2}{\lambda_{AZ}^2}\,T^d_{43}\,x_t^2\,B_0^{fin}\left(-M_H^2\,;M_t\,,M_t\right)$$

$$-\frac{1}{48}\,\frac{s^3}{c}\,T^d_{40}\,W_1\,x_H^2\,x_b^2\,C_0\left(-M_H^2\,,0\,,-M_Z^2\,;M_b\,,M_b\,,M_b\right)$$

$$-\frac{1}{24}\,\frac{s^3}{c}\,T^d_{43}\,W_0\,x_H^2\,x_t^2\,C_0\left(-M_H^2\,,0\,,-M_Z^2\,;M_t\,,M_t\,,M_t\right)$$

$$-\frac{1}{24}\,\frac{s}{c}\,x_H^2\,v_l\,B_0^{fin}\left(-M_Z^2\,;0\,,0\right)$$

$$+\frac{1}{24}\,\frac{s}{c}\,U_0\,x_H^2\,(1-3\,L_R)$$

$$+\frac{1}{24}\left[\frac{x_b^2}{\lambda_{AZ}^2}\,T^d_{40}\,s^2-(1+2\,c^2\,x_b^2)\,c^2\,v_b\right]\frac{s}{c^3}\,x_H^2\,B_0^{fin}\left(-M_Z^2\,;M_b\,,M_b\right)$$

$$+\frac{1}{12}\left[\frac{x_t^2}{\lambda_{AZ}^2}\,T^d_{43}\,s^2-(1+2\,c^2\,x_t^2)\,c^2\,v_t\right]\frac{s}{c^3}\,x_H^2\,B_0^{fin}\left(-M_Z^2\,;M_t\,,M_t\right)$$

$$+\frac{1}{16}\left\{8\,s^2\,c^4\,x_H^2-8\,\frac{1}{\lambda_{AZ}}\,T^d_{44}\,c^4+\left[(-\frac{x_H^2}{\lambda_{AZ}}\,T^d_{35}+2\,T^d_{30})\right]\right\}\frac{s}{c^3}\,x_H^2$$

$$\times C_0\left(-M_H^2\,,0\,,-M_Z^2\,;M_W\,,M_W\,,M_W\right)$$

$$+\frac{1}{32}\left\{8\,\frac{x_H^2}{\lambda_{AZ}}\,s^2\,c^6-2\left[\frac{1}{\lambda_{AZ}}\,T^d_{42}+(1-T^d_2\,x_H^2)\,c^2\right]c^4+\left[(2\,T^d_{32}+T^d_{34}\,x_H^2)\right]\frac{1}{\lambda_{AZ}^2}\right\}\frac{s}{c^5}\,x_H^2$$

$$\times B_0^{fin}\left(-M_H^2\,;M_W\,,M_W\right)$$

$$-\frac{1}{96}\left\{12\,\frac{x_H^2}{\lambda_{AZ}}\,s^2\,c^6+3\left[(2\,T^d_{32}+T^d_{34}\,x_H^2)\right]\frac{1}{\lambda_{AZ}^2}-2\,(9\,\frac{1}{\lambda_{AZ}}\,T^d_{38}+T^d_{36})\,c^4\right\}\frac{s}{c^5}\,x_H^2$$

$$\times B_0^{fin}\left(-M_Z^2\,;M_W\,,M_W\right)$$

$$+\frac{1}{288}\left\{2\left[T^d_{37}-12\,(x_b^2\,v_b+2\,x_t^2\,v_t)\,c^2\right]c^2+9\left[(2\,T^d_{31}+T^d_{33}\,x_H^2)\right]\frac{1}{\lambda_{AZ}}\right.$$

$$\left.-12\,(T^d_{40}\,x_b^2+2\,T^d_{43}\,x_t^2)\,\frac{1}{\lambda_{AZ}}\,s^2\,c^2\right\}\frac{s}{c^3}\,x_H^2$$

$$+\frac{1}{24}\,(3\,\frac{x_H^2}{\lambda_{AZ}}\,s^2\,c^2-3\,\frac{1}{\lambda_{AZ}}\,T^d_{29}-T^d_{39}\,c^2)\,\frac{s}{c}\,x_H^2\,a_0^{fin}\left(M_W\right)$$

$$+\frac{1}{48}\,(3\,T^d_2\,c^2\,x_H^2+T^d_{41})\,\frac{s}{c}\,x_H^2\,L_R$$

$$\mathscr{T}^{nfc}_{AZ}(a_{ZZ})=\frac{1}{24}\,\frac{s}{c}\,\frac{x_H^2}{\lambda_{AZ}^2}\,T^d_{49}\,x_b^2\,B_0^{fin}\left(-M_H^2\,;M_b\,,M_b\right)$$

$$-\frac{1}{24}\,\frac{s}{c}\,\frac{x_H^2}{\lambda_{AZ}^2}\,T^d_{49}\,x_b^2\,B_0^{fin}\left(-M_Z^2\,;M_b\,,M_b\right)$$

$$+\frac{1}{12}\,\frac{s}{c}\,\frac{x_H^2}{\lambda_{AZ}^2}\,T^d_{50}\,x_t^2\,B_0^{fin}\left(-M_H^2\,;M_t\,,M_t\right)$$

$$-\frac{1}{12}\,\frac{s}{c}\,\frac{x_{\rm H}^2}{\lambda_{\rm AZ}^2}\,{\rm T}_{50}^{d}\,x_{\rm t}^2\,{\rm B}_0^{\rm fin}\left(-M_{\rm Z}^2\,;M_{\rm t}\,,M_{\rm t}\right)$$
$$+\frac{1}{48}\,{\rm T}_{49}^{d}\,{\rm W}_1\,s\,c\,x_{\rm H}^2\,x_{\rm b}^2\,{\rm C}_0\left(-M_{\rm H}^2\,,0\,,-M_{\rm Z}^2\,;M_{\rm b}\,,M_{\rm b}\,,M_{\rm b}\right)$$
$$+\frac{1}{24}\,{\rm T}_{50}^{d}\,{\rm W}_0\,s\,c\,x_{\rm H}^2\,x_{\rm t}^2\,{\rm C}_0\left(-M_{\rm H}^2\,,0\,,-M_{\rm Z}^2\,;M_{\rm t}\,,M_{\rm t}\,,M_{\rm t}\right)$$
$$+\frac{1}{32}\left\{4\,\frac{x_{\rm H}^2}{\lambda_{\rm AZ}}\,s^2\,c^6+\left[(2\,{\rm T}_{32}^{d}+{\rm T}_{47}^{d}\,x_{\rm H}^2)\right]\frac{1}{\lambda_{\rm AZ}^2}-2\,(3\,\frac{1}{\lambda_{\rm AZ}}\,{\rm T}_{38}^{d}-{\rm T}_{51}^{d}\,c^2)\,c^4\right\}\frac{s}{c^5}\,x_{\rm H}^2$$
$$\times{\rm B}_0^{\rm fin}\left(-M_{\rm Z}^2\,;M_{\rm W}\,,M_{\rm W}\right)$$
$$-\frac{1}{32}\left\{8\,\frac{x_{\rm H}^2}{\lambda_{\rm AZ}}\,s^2\,c^6-2\left[\frac{1}{\lambda_{\rm AZ}}\,{\rm T}_{42}^{d}+(1-{\rm T}_{2}^{d}\,x_{\rm H}^2)\,c^2\right]c^4+\left[(2\,{\rm T}_{32}^{d}+{\rm T}_{47}^{d}\,x_{\rm H}^2)\right]\frac{1}{\lambda_{\rm AZ}^2}\right\}\frac{s}{c^5}\,x_{\rm H}^2$$
$$\times{\rm B}_0^{\rm fin}\left(-M_{\rm H}^2\,;M_{\rm W}\,,M_{\rm W}\right)$$
$$-\frac{1}{96}\left\{2\left[(-2\,\frac{x_{\rm b}^2}{\lambda_{\rm AZ}}\,{\rm T}_{49}^{d}-4\,\frac{x_{\rm t}^2}{\lambda_{\rm AZ}}\,{\rm T}_{50}^{d}+21\,{\rm T}_{2}^{d})\right]c^4+3\left[(2\,{\rm T}_{31}^{d}+{\rm T}_{46}^{d}\,x_{\rm H}^2)\right]\frac{1}{\lambda_{\rm AZ}}\right\}\frac{s}{c^3}\,x_{\rm H}^2$$
$$+\frac{1}{16}\left\{-\left[(-\frac{x_{\rm H}^2}{\lambda_{\rm AZ}}\,{\rm T}_{48}^{d}+2\,{\rm T}_{45}^{d})\right]+8\,(c^2\,x_{\rm H}^2+\frac{1}{\lambda_{\rm AZ}}\,{\rm T}_{44}^{d})\,c^4\right\}\frac{s}{c^3}\,x_{\rm H}^2$$
$$\times{\rm C}_0\left(-M_{\rm H}^2\,,0\,,-M_{\rm Z}^2\,;M_{\rm W}\,,M_{\rm W}\,,M_{\rm W}\right)$$
$$+\frac{1}{16}\,(12\,c^2-{\rm T}_{2}^{d}\,x_{\rm H}^2)\,s\,c\,x_{\rm H}^2\,{\rm L}_{\rm R}$$
$$-\frac{1}{8}\,(\frac{x_{\rm H}^2}{\lambda_{\rm AZ}}\,s^2\,c^2-\frac{1}{\lambda_{\rm AZ}}\,{\rm T}_{29}^{d}+{\rm T}_{4}^{d}\,c^2)\,\frac{s}{c}\,x_{\rm H}^2\,a_0^{\rm fin}\left(M_{\rm W}\right)$$

- HZZ Amplitudes

$$\mathscr{T}^{\rm nfc}_{\rm D;ZZ}(a_{\phi\,{\rm t\,V}})=\frac{5}{16}\,\frac{{\rm v_t}}{c^2}\,x_{\rm t}^2+\frac{1}{8}\,\frac{{\rm v_t}}{c^2}\,x_{\rm t}^2\,a_0^{\rm fin}\left(M_{\rm t}\right)-\frac{1}{48}\,\frac{{\rm v_t}}{c^4}\,(1-3\,{\rm L_R})$$
$$+\frac{3}{8}\,\frac{{\rm v_t}}{c^4}\,\frac{x_{\rm t}^2}{\lambda_{\rm ZZ}}\,{\rm B}_0^{\rm fin}\left(-M_{\rm H}^2\,;M_{\rm t}\,,M_{\rm t}\right)$$
$$-\frac{3}{32}\left[4\,\frac{1}{\lambda_{\rm ZZ}}+(2+{\rm V}_3\,c^2)\,c^2\right]\frac{{\rm v_t}}{c^6}\,x_{\rm t}^2\,{\rm C}_0\left(-M_{\rm H}^2\,,-M_{\rm Z}^2\,,-M_{\rm Z}^2\,;M_{\rm t}\,,M_{\rm t}\,,M_{\rm t}\right)$$
$$+\frac{1}{16}\,(s{\rm W}_6+2\,c^2\,x_{\rm t}^2)\,\frac{{\rm v_t}}{c^4}\,{\rm B}_0^{\rm fin}\left(-M_{\rm Z}^2\,;M_{\rm t}\,,M_{\rm t}\right)$$

$$\mathscr{T}^{\rm nfc}_{\rm D;ZZ}(a_{\phi\,{\rm t\,A}})=\frac{1}{8}\,\frac{1}{c^2}\,x_{\rm t}^2\,a_0^{\rm fin}\left(M_{\rm t}\right)+\frac{1}{16}\,\frac{1}{c^2}\,x_{\rm t}^2\,(5-12\,{\rm L_R})-\frac{1}{48}\,\frac{1}{c^4}\,(1-3\,{\rm L_R})$$
$$+\frac{3}{8}\,\frac{1}{c^4}\,\frac{x_{\rm t}^2}{\lambda_{\rm ZZ}}\,{\rm B}_0^{\rm fin}\left(-M_{\rm H}^2\,;M_{\rm t}\,,M_{\rm t}\right)$$
$$-\frac{3}{32}\left[4\,\frac{1}{\lambda_{\rm ZZ}}+(2-{\rm V}_3\,c^2)\,c^2\right]\frac{1}{c^6}\,x_{\rm t}^2\,{\rm C}_0\left(-M_{\rm H}^2\,,-M_{\rm Z}^2\,,-M_{\rm Z}^2\,;M_{\rm t}\,,M_{\rm t}\,,M_{\rm t}\right)$$
$$+\frac{1}{16}\,(s{\rm W}_6-10\,c^2\,x_{\rm t}^2)\,\frac{1}{c^4}\,{\rm B}_0^{\rm fin}\left(-M_{\rm Z}^2\,;M_{\rm t}\,,M_{\rm t}\right)$$

$$\mathscr{T}^{\rm nfc}_{\rm D;ZZ}(a_{\phi\,{\rm b\,V}})=\frac{5}{16}\,\frac{{\rm v_b}}{c^2}\,x_{\rm b}^2+\frac{1}{8}\,\frac{{\rm v_b}}{c^2}\,x_{\rm b}^2\,a_0^{\rm fin}\left(M_{\rm b}\right)-\frac{1}{48}\,\frac{{\rm v_b}}{c^4}\,(1-3\,{\rm L_R})$$
$$+\frac{3}{8}\,\frac{{\rm v_b}}{c^4}\,\frac{x_{\rm b}^2}{\lambda_{\rm ZZ}}\,{\rm B}_0^{\rm fin}\left(-M_{\rm H}^2\,;M_{\rm b}\,,M_{\rm b}\right)$$
$$-\frac{3}{32}\left[4\,\frac{1}{\lambda_{\rm ZZ}}+(2+{\rm V}_4\,c^2)\,c^2\right]\frac{{\rm v_b}}{c^6}\,x_{\rm b}^2\,{\rm C}_0\left(-M_{\rm H}^2\,,-M_{\rm Z}^2\,,-M_{\rm Z}^2\,;M_{\rm b}\,,M_{\rm b}\,,M_{\rm b}\right)$$

$$+\frac{1}{16}\,(s\mathrm{W}_7+2\,c^2\,x_{\mathrm{b}}^2)\,\frac{\mathrm{v_b}}{c^4}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{Z}}^2\,;M_{\mathrm{b}}\,,M_{\mathrm{b}}\right)$$

$$\begin{aligned}\mathscr{T}^{\mathrm{nfc}}_{\mathrm{D;ZZ}}(a_{\phi\,\mathrm{b\,A}}) = {}& \frac{1}{8}\,\frac{1}{c^2}\,x_{\mathrm{b}}^2\,a_0^{\mathrm{fin}}\left(M_{\mathrm{b}}\right)+\frac{1}{16}\,\frac{1}{c^2}\,x_{\mathrm{b}}^2\,(5-12\,\mathrm{L_R})-\frac{1}{48}\,\frac{1}{c^4}\,(1-3\,\mathrm{L_R})\\ &+\frac{3}{8}\,\frac{1}{c^4}\,\frac{x_{\mathrm{b}}^2}{\lambda_{\mathrm{ZZ}}}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{b}}\,,M_{\mathrm{b}}\right)\\ &-\frac{3}{32}\left[4\,\frac{1}{\lambda_{\mathrm{ZZ}}}+(2-\mathrm{V}_4\,c^2)\,c^2\right]\frac{1}{c^6}\,x_{\mathrm{b}}^2\,\mathrm{C}_0\left(-M_{\mathrm{H}}^2\,,-M_{\mathrm{Z}}^2\,,-M_{\mathrm{Z}}^2\,;M_{\mathrm{b}}\,,M_{\mathrm{b}}\,,M_{\mathrm{b}}\right)\\ &+\frac{1}{16}\,(s\mathrm{W}_7-10\,c^2\,x_{\mathrm{b}}^2)\,\frac{1}{c^4}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{Z}}^2\,;M_{\mathrm{b}}\,,M_{\mathrm{b}}\right)\end{aligned}$$

$$\mathscr{T}^{\mathrm{nfc}}_{\mathrm{D;ZZ}}(a_{\phi\,\mathrm{l\,V}}) = \frac{1}{48}\,\frac{1}{c^4}\,\mathrm{v_l}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{Z}}^2\,;0\,,0\right)-\frac{1}{144}\,\frac{1}{c^4}\,\mathrm{v_l}\,(1-3\,\mathrm{L_R})$$

$$\mathscr{T}^{\mathrm{nfc}}_{\mathrm{D;ZZ}}(a_{\phi\,\mathrm{l\,A}}) = \frac{1}{48}\,\frac{1}{c^4}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{Z}}^2\,;0\,,0\right)-\frac{1}{144}\,\frac{1}{c^4}\,(1-3\,\mathrm{L_R})$$

$$\mathscr{T}^{\mathrm{nfc}}_{\mathrm{D;ZZ}}(a_{\mathrm{t}\,\phi}) = -\frac{1}{32}\,\frac{1}{c^2}\,\mathrm{X}_2$$

$$\mathscr{T}^{\mathrm{nfc}}_{\mathrm{D;ZZ}}(a_{\mathrm{b}\,\phi}) = \frac{1}{32}\,\frac{1}{c^2}\,\mathrm{X}_3$$

$$\begin{aligned}\mathscr{T}^{\mathrm{nfc}}_{\mathrm{D;ZZ}}(a_{\mathrm{t\,BW}}) = {}& -\frac{3}{128}\,\frac{\mathrm{v_t}}{c}\,x_{\mathrm{H}}^2\,x_{\mathrm{t}}^2\\ &-\frac{3}{128}\left[8\,\frac{1}{\lambda_{\mathrm{ZZ}}}+(2-c^2\,x_{\mathrm{H}}^2)\,c^2\right]\frac{\mathrm{v_t}}{c^5}\,x_{\mathrm{t}}^2\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{t}}\,,M_{\mathrm{t}}\right)\\ &+\frac{3}{128}\left[8\,\frac{1}{\lambda_{\mathrm{ZZ}}}+(2-c^2\,x_{\mathrm{H}}^2)\,c^2\right]\frac{\mathrm{v_t}}{c^5}\,x_{\mathrm{t}}^2\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{Z}}^2\,;M_{\mathrm{t}}\,,M_{\mathrm{t}}\right)\\ &+\frac{3}{64}\left\{4\,\frac{1}{\lambda_{\mathrm{ZZ}}}+\left[1+(4-c^2\,x_{\mathrm{H}}^2)\,c^2\,x_{\mathrm{t}}^2\right]c^2\right\}\frac{1}{c^7}\,x_{\mathrm{t}}^2\,\mathrm{v_t}\,\mathrm{C}_0\left(-M_{\mathrm{H}}^2\,,-M_{\mathrm{Z}}^2\,,-M_{\mathrm{Z}}^2\,;M_{\mathrm{t}}\,,M_{\mathrm{t}}\,,M_{\mathrm{t}}\right)\end{aligned}$$

$$\begin{aligned}\mathscr{T}^{\mathrm{nfc}}_{\mathrm{D;ZZ}}(a_{\mathrm{b\,BW}}) = {}& \frac{3}{128}\,\frac{\mathrm{v_b}}{c}\,x_{\mathrm{H}}^2\,x_{\mathrm{b}}^2\\ &+\frac{3}{128}\left[8\,\frac{1}{\lambda_{\mathrm{ZZ}}}+(2-c^2\,x_{\mathrm{H}}^2)\,c^2\right]\frac{\mathrm{v_b}}{c^5}\,x_{\mathrm{b}}^2\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{b}}\,,M_{\mathrm{b}}\right)\\ &-\frac{3}{128}\left[8\,\frac{1}{\lambda_{\mathrm{ZZ}}}+(2-c^2\,x_{\mathrm{H}}^2)\,c^2\right]\frac{\mathrm{v_b}}{c^5}\,x_{\mathrm{b}}^2\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{Z}}^2\,;M_{\mathrm{b}}\,,M_{\mathrm{b}}\right)\\ &-\frac{3}{64}\left\{4\,\frac{1}{\lambda_{\mathrm{ZZ}}}+\left[1+(4-c^2\,x_{\mathrm{H}}^2)\,c^2\,x_{\mathrm{b}}^2\right]c^2\right\}\frac{1}{c^7}\,x_{\mathrm{b}}^2\,\mathrm{v_b}\,\mathrm{C}_0\left(-M_{\mathrm{H}}^2\,,-M_{\mathrm{Z}}^2\,,-M_{\mathrm{Z}}^2\,;M_{\mathrm{b}}\,,M_{\mathrm{b}}\,,M_{\mathrm{b}}\right)\end{aligned}$$

$$\begin{aligned}\mathscr{T}^{\mathrm{nfc}}_{\mathrm{D;ZZ}}(a_{\phi}) = {}& \frac{3}{16}\,\frac{1}{c^2}\\ &-\frac{3}{8}\left[4\,\frac{1}{\lambda_{\mathrm{ZZ}}}+(\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{ZZ}}}\,c^2\,x_{\mathrm{H}}^2-\mathrm{W}_8)\,c^2\right]\frac{1}{c^6}\,\mathrm{C}_0\left(-M_{\mathrm{H}}^2\,,-M_{\mathrm{Z}}^2\,,-M_{\mathrm{Z}}^2\,;M_{\mathrm{H}}\,,M_{\mathrm{Z}}\,,M_{\mathrm{H}}\right)\\ &+\frac{3}{8}\,(2-c^2\,x_{\mathrm{H}}^2)\,\frac{1}{c^4\,\lambda_{\mathrm{ZZ}}}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{H}}\,,M_{\mathrm{H}}\right)\\ &-\frac{3}{8}\,(2-c^2\,x_{\mathrm{H}}^2)\,\frac{1}{c^4\,\lambda_{\mathrm{ZZ}}}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{Z}}^2\,;M_{\mathrm{H}}\,,M_{\mathrm{Z}}\right)\end{aligned}$$

$$\mathscr{T}^{\mathrm{nfc}}_{\mathrm{D;ZZ}}(a_{\phi\,\square}) = -\frac{1}{16}\,\frac{1}{c^2}\,\mathrm{X}_4-\frac{1}{192}\,\frac{1}{c^2}\,x_{\mathrm{H}}^2\,(25+3\,\mathrm{L_R})-\frac{1}{288}\,\frac{1}{c^4}\,(13-57\,\mathrm{L_R})$$

$$
\begin{aligned}
&-\frac{1}{16}\left[2-(c^2 x_{\rm H}^2+\mathrm{W}_{11})\,c^2 x_{\rm H}^2\right]\frac{1}{c^6}\,\mathrm{C}_0\left(-M_{\rm H}^2\,,-M_{\rm Z}^2\,,-M_{\rm Z}^2\,;M_{\rm Z}\,,M_{\rm H}\,,M_{\rm Z}\right)\\
&-\frac{1}{32}\left[8\,\frac{1}{\lambda_{\rm ZZ}}+(2\,\mathrm{W}_{11}-\mathrm{W}_{12}\,c^2 x_{\rm H}^2)\,c^2\right]\frac{1}{c^6}\,\mathrm{B}_0^{\rm fin}\left(-M_{\rm H}^2\,;M_{\rm H}\,,M_{\rm H}\right)\\
&+\frac{1}{32}\left\{16\,\frac{1}{\lambda_{\rm ZZ}}+\left[4\,\mathrm{W}_{10}+(\mathrm{W}_{12}\,c^2 x_{\rm H}^2-2\,\mathrm{W}_{16})\,c^2 x_{\rm H}^2\right]c^2\right\}\frac{1}{c^8}\\
&\times\mathrm{C}_0\left(-M_{\rm H}^2\,,-M_{\rm Z}^2\,,-M_{\rm Z}^2\,;M_{\rm H}\,,M_{\rm Z}\,,M_{\rm H}\right)\\
&+\frac{1}{96}\left\{24\,\frac{1}{\lambda_{\rm ZZ}}+\left[6\,\mathrm{W}_{15}+(c^2 x_{\rm H}^2-\mathrm{W}_{14})\,c^2 x_{\rm H}^2\right]c^2\right\}\frac{1}{c^6}\,\mathrm{B}_0^{\rm fin}\left(-M_{\rm Z}^2\,;M_{\rm H}\,,M_{\rm Z}\right)\\
&+\frac{1}{96}\,(2-c^2 x_{\rm H}^2)\,\frac{1}{c^4}\,a_0^{\rm fin}\,(M_{\rm Z})\\
&-\frac{1}{96}\,(3-c^2 x_{\rm H}^2)\,\frac{1}{c^2}\,x_{\rm H}^2\,a_0^{\rm fin}\,(M_{\rm H})\\
&-\frac{1}{64}\,(2\,s\mathrm{W}_{13}+3\,c^2 x_{\rm H}^2)\,\frac{1}{c^4}\,\mathrm{B}_0^{\rm fin}\left(-M_{\rm H}^2\,;M_{\rm Z}\,,M_{\rm Z}\right)\\
&-\frac{1}{16}\,(4\,\frac{1}{\lambda_{\rm ZZ}}\,\mathrm{T}^d_{52}+\mathrm{T}^d_{52}\,c^2\,s\mathrm{W}_9)\,\frac{1}{c^6}\,\mathrm{B}_0^{\rm fin}\left(-M_{\rm H}^2\,;M_{\rm W}\,,M_{\rm W}\right)\\
&+\frac{1}{16}\,(4\,\frac{1}{\lambda_{\rm ZZ}}\,\mathrm{T}^d_{52}+\mathrm{T}^d_{52}\,c^2\,s\mathrm{W}_9)\,\frac{1}{c^6}\,\mathrm{B}_0^{\rm fin}\left(-M_{\rm Z}^2\,;M_{\rm W}\,,M_{\rm W}\right)\\
&+\frac{1}{16}\,(4\,\frac{1}{\lambda_{\rm ZZ}}\,\mathrm{T}^d_{52}+\mathrm{T}^d_{52}\,c^2\,s\mathrm{W}_9)\,\frac{1}{c^8}\,\mathrm{C}_0\left(-M_{\rm H}^2\,,-M_{\rm Z}^2\,,-M_{\rm Z}^2\,;M_{\rm W}\,,M_{\rm W}\,,mw\right)
\end{aligned}
$$

$$
\begin{aligned}
\mathscr{T}^{\rm nfc}_{\rm D;ZZ}(a_{\phi\rm D})=&\;\frac{1}{192}\,\frac{1}{c^2}\,\mathrm{X}_6-\frac{1}{384}\,\frac{1}{c^4}\,\mathrm{X}_5\\
&-\frac{1}{384}\left[4\,\mathrm{T}^d_{63}\,c^2+(\mathrm{T}^d_{56}\,x_{\rm H}^2+2\,\mathrm{T}^d_{69})\,\frac{1}{\lambda_{\rm ZZ}}\right]\frac{1}{c^6}\,\mathrm{B}_0^{\rm fin}\left(-M_{\rm Z}^2\,;M_{\rm W}\,,M_{\rm W}\right)\\
&+\frac{1}{384}\left[\mathrm{T}^d_{68}\,c^2+(\mathrm{T}^d_{56}\,x_{\rm H}^2+2\,\mathrm{T}^d_{69})\,\frac{1}{\lambda_{\rm ZZ}}\right]\frac{1}{c^6}\,\mathrm{B}_0^{\rm fin}\left(-M_{\rm H}^2\,;M_{\rm W}\,,M_{\rm W}\right)\\
&-\frac{1}{384}\left[(\mathrm{T}^d_{56}\,x_{\rm H}^2+2\,\mathrm{T}^d_{69})\,\frac{1}{\lambda_{\rm ZZ}}-(\mathrm{T}^d_{61}\,c^2 x_{\rm H}^2-6\,\mathrm{T}^d_{62})\,c^2\right]\frac{1}{c^8}\\
&\times\mathrm{C}_0\left(-M_{\rm H}^2\,,-M_{\rm Z}^2\,,-M_{\rm Z}^2\,;M_{\rm W}\,,M_{\rm W}\,,M_{\rm W}\right)\\
&+\frac{1}{64}\left\{3\,c^2+\left[(3-\mathrm{T}^d_8\,\mathrm{v}_{\rm b})\right]\frac{1}{\lambda_{\rm ZZ}}\right\}\frac{1}{c^4}\,x_{\rm b}^2\,\mathrm{B}_0^{\rm fin}\left(-M_{\rm Z}^2\,;M_{\rm b}\,,M_{\rm b}\right)\\
&+\frac{1}{64}\left\{3\,c^2+\left[(3-\mathrm{T}^d_9\,\mathrm{v}_{\rm t})\right]\frac{1}{\lambda_{\rm ZZ}}\right\}\frac{1}{c^4}\,x_{\rm t}^2\,\mathrm{B}_0^{\rm fin}\left(-M_{\rm Z}^2\,;M_{\rm t}\,,M_{\rm t}\right)\\
&-\frac{1}{256}\left\{4\,\frac{1}{\lambda_{\rm ZZ}}\,\mathrm{V}_5+\left[(8-4\,\frac{x_{\rm H}^2}{\lambda_{\rm ZZ}}\,\mathrm{T}^d_{57}\,x_{\rm H}^2-\mathrm{T}^d_{60}\,x_{\rm H}^2)+(2\,c^2+\frac{x_{\rm H}^2}{\lambda_{\rm ZZ}}\,\mathrm{T}^d_{58})\,c^2 x_{\rm H}^4\right]c^2\right\}\frac{1}{c^8}\\
&\times\mathrm{C}_0\left(-M_{\rm H}^2\,,-M_{\rm Z}^2\,,-M_{\rm Z}^2\,;M_{\rm H}\,,M_{\rm Z}\,,M_{\rm H}\right)\\
&+\frac{1}{768}\left\{4\,\mathrm{T}^d_7-\left[(\frac{x_{\rm H}^2}{\lambda_{\rm ZZ}})\,\mathrm{T}^d_8+\mathrm{T}^d_{55})\,c^2 x_{\rm H}^2+2\,(\frac{x_{\rm H}^2}{\lambda_{\rm ZZ}}\,\mathrm{T}^d_{53}+\mathrm{T}^d_7)\right]c^2 x_{\rm H}^2\right\}\frac{1}{c^8}\\
&\times\mathrm{C}_0\left(-M_{\rm H}^2\,,-M_{\rm Z}^2\,,-M_{\rm Z}^2\,;M_{\rm Z}\,,M_{\rm H}\,,M_{\rm Z}\right)\\
&+\frac{1}{2304}\left\{\mathrm{T}^d_{66}+3\left[\mathrm{T}^d_{65}\,x_{\rm H}^2+6\,(\mathrm{T}^d_8\,x_{\rm b}^2\,\mathrm{v}_{\rm b}+\mathrm{T}^d_9\,x_{\rm t}^2\,\mathrm{v}_{\rm t}-3\,\mathrm{V}_6)\,c^2\right]c^2\right\}\frac{1}{c^6}\\
&+\frac{1}{256}\left\{\left[7\,c^2 x_{\rm H}^2+(4-\frac{x_{\rm H}^2}{\lambda_{\rm ZZ}}\,\mathrm{T}^d_{58}\,x_{\rm H}^2)\right]c^2+2\left[(8+\mathrm{T}^d_8\,x_{\rm H}^2)\right]\frac{1}{\lambda_{\rm ZZ}}\right\}\frac{1}{c^6}\,\mathrm{B}_0^{\rm fin}\left(-M_{\rm H}^2\,;M_{\rm H}\,,M_{\rm H}\right)\\
&+\frac{1}{384}\left\{\left[\frac{x_{\rm H}^2}{\lambda_{\rm ZZ}}\,\mathrm{T}^d_{59}-2\,(1-c^2 x_{\rm H}^2)\,c^2\right]c^2 x_{\rm H}^2-2\left[(\frac{x_{\rm H}^2}{\lambda_{\rm ZZ}}\,\mathrm{T}^d_{64}+12\,\frac{1}{\lambda_{\rm ZZ}}+\mathrm{T}^d_{54})\right]\right\}\frac{1}{c^6}\\
&\times\mathrm{B}_0^{\rm fin}\left(-M_{\rm Z}^2\,;M_{\rm H}\,,M_{\rm Z}\right)
\end{aligned}
$$

$$
\begin{aligned}
&+\frac{1}{256}\left\{4\left[(3-\mathrm{T}^d_8\,\mathrm{v_b})\right]\frac{1}{\lambda_{\mathrm{ZZ}}}+\left[2\,(3-\mathrm{T}^d_8\,\mathrm{v_b})-(\mathrm{T}^d_8\,\mathrm{V}_4\,\mathrm{v_b}+3\,\mathrm{V}_4)\,c^2\right]c^2\right\}\frac{1}{c^6}\,x^2_{\mathrm{b}}\\
&\times \mathrm{C}_0\left(-M^2_{\mathrm{H}}\,,-M^2_{\mathrm{Z}}\,,-M^2_{\mathrm{Z}}\,;M_{\mathrm{b}}\,,M_{\mathrm{b}}\,,M_{\mathrm{b}}\right)\\
&+\frac{1}{256}\left\{4\left[(3-\mathrm{T}^d_9\,\mathrm{v_t})\right]\frac{1}{\lambda_{\mathrm{ZZ}}}+\left[2\,(3-\mathrm{T}^d_9\,\mathrm{v_t})-(\mathrm{T}^d_9\,\mathrm{V}_3\,\mathrm{v_t}+3\,\mathrm{V}_3)\,c^2\right]c^2\right\}\frac{1}{c^6}\,x^2_{\mathrm{t}}\\
&\times \mathrm{C}_0\left(-M^2_{\mathrm{H}}\,,-M^2_{\mathrm{Z}}\,,-M^2_{\mathrm{Z}}\,;M_{\mathrm{t}}\,,M_{\mathrm{t}}\,,M_{\mathrm{t}}\right)\\
&-\frac{1}{768}\left\{-\left[(2\,\frac{x^2_{\mathrm{H}}}{\lambda_{\mathrm{ZZ}}}\,\mathrm{T}^d_{53}+\mathrm{T}^d_{55})\right]+(9\,c^2-\frac{x^2_{\mathrm{H}}}{\lambda_{\mathrm{ZZ}}})\,\mathrm{T}^d_8)\,c^2\,x^2_{\mathrm{H}}\right\}\frac{1}{c^6}\,\mathrm{B}^{\mathrm{fin}}_0\left(-M^2_{\mathrm{H}}\,;M_{\mathrm{Z}}\,,M_{\mathrm{Z}}\right)\\
&+\frac{1}{384}\,(1-2\,c^2\,x^2_{\mathrm{H}})\,\frac{1}{c^4}\,a^{\mathrm{fin}}_0\,(M_{\mathrm{Z}})\\
&-\frac{1}{64}\,(3-\mathrm{T}^d_8\,\mathrm{v_b})\,\frac{1}{c^4}\,\frac{x^2_{\mathrm{b}}}{\lambda_{\mathrm{ZZ}}}\,\mathrm{B}^{\mathrm{fin}}_0\left(-M^2_{\mathrm{H}}\,;M_{\mathrm{b}}\,,M_{\mathrm{b}}\right)\\
&-\frac{1}{64}\,(3-\mathrm{T}^d_9\,\mathrm{v_t})\,\frac{1}{c^4}\,\frac{x^2_{\mathrm{t}}}{\lambda_{\mathrm{ZZ}}}\,\mathrm{B}^{\mathrm{fin}}_0\left(-M^2_{\mathrm{H}}\,;M_{\mathrm{t}}\,,M_{\mathrm{t}}\right)\\
&-\frac{1}{384}\,(15-2\,c^2\,x^2_{\mathrm{H}})\,\frac{1}{c^2}\,x^2_{\mathrm{H}}\,a^{\mathrm{fin}}_0\,(M_{\mathrm{H}})\\
&-\frac{1}{768}\,(\mathrm{T}^d_{67}-6\,\mathrm{V}_7\,c^4)\,\frac{1}{c^6}\,\mathrm{L_R}
\end{aligned}
$$

$$
\begin{aligned}
\mathscr{T}^{\,\mathrm{nfc}}_{\mathrm{D;ZZ}}(a_{\mathrm{AZ}}) = {}&\frac{1}{288}\,\frac{s}{c^3}\,\mathrm{X}_7+\frac{1}{96}\,\frac{s}{c}\,\mathrm{X}_8+\frac{1}{16}\,\frac{c}{s}\,\mathrm{X}_9+\frac{1}{12}\,\mathrm{T}^d_{70}\,s\,c\,x^2_{\mathrm{H}}\,a^{\mathrm{fin}}_0\,(M_{\mathrm{W}})\\
&+\frac{5}{192}\left[4-(2\,\mathrm{W}_{10}+\mathrm{W}_{10}\,c^2\,x^2_{\mathrm{H}})\,c^2\,x^2_{\mathrm{H}}\right]\frac{s}{c^7}\,\mathrm{C}_0\left(-M^2_{\mathrm{H}}\,,-M^2_{\mathrm{Z}}\,,-M^2_{\mathrm{Z}}\,;M_{\mathrm{Z}}\,,M_{\mathrm{H}}\,,M_{\mathrm{Z}}\right)\\
&-\frac{5}{64}\left[4\,\frac{1}{\lambda_{\mathrm{ZZ}}}+(\frac{x^2_{\mathrm{H}}}{\lambda_{\mathrm{ZZ}}}\,c^2\,x^2_{\mathrm{H}}-\mathrm{W}_8)\,c^2\right]\frac{s}{c^7}\,x^2_{\mathrm{H}}\,\mathrm{C}_0\left(-M^2_{\mathrm{H}}\,,-M^2_{\mathrm{Z}}\,,-M^2_{\mathrm{Z}}\,;M_{\mathrm{H}}\,,M_{\mathrm{Z}}\,,M_{\mathrm{H}}\right)\\
&-\frac{1}{192}\left[2\,\mathrm{T}^d_{82}\,c^4\,x^2_{\mathrm{H}}+\mathrm{T}^d_{83}-6\,(\mathrm{T}^d_7\,c^2\,x^4_{\mathrm{H}}-9\,\mathrm{V}_6)\,s^2\,c^4\right]\frac{1}{s\,c^5}\,\mathrm{L_R}\\
&-\frac{1}{96}\left[4\,(\mathrm{T}^d_{72}+\mathrm{T}^d_{76}\,c^2\,x^2_{\mathrm{H}})\,c^2+(\mathrm{T}^d_{79}\,x^2_{\mathrm{H}}-2\,\mathrm{T}^d_{81})\,\frac{1}{\lambda_{\mathrm{ZZ}}}\right]\frac{s}{c^5}\,\mathrm{B}^{\mathrm{fin}}_0\left(-M^2_{\mathrm{Z}}\,;M_{\mathrm{W}}\,,M_{\mathrm{W}}\right)\\
&+\frac{1}{576}\left\{3\,\mathrm{T}^d_{80}+\left[\mathrm{T}^d_{86}\,x^2_{\mathrm{H}}-3\,(8\,c^2\,x^2_{\mathrm{H}}\,x^2_{\mathrm{b}}\,\mathrm{v_b}+16\,c^2\,x^2_{\mathrm{H}}\,x^2_{\mathrm{t}}\,\mathrm{v_t}-2\,\mathrm{T}^d_{84}\,x^2_{\mathrm{b}}\,\mathrm{v_b}-2\,\mathrm{T}^d_{85}\,x^2_{\mathrm{t}}\,\mathrm{v_t}\right.\right.\\
&\left.\left.-9\,\mathrm{U}_2\,x^2_{\mathrm{t}}-9\,\mathrm{U}_4\,x^2_{\mathrm{b}})\,c^2\right]c^2\right\}\frac{s}{c^5}\\
&-\frac{1}{96}\left\{\left[4\,c^2\,x^2_{\mathrm{H}}\,x^2_{\mathrm{b}}\,\mathrm{v_b}+(2\,x^2_{\mathrm{H}}\,\mathrm{v_b}+\mathrm{U}_6\,x^2_{\mathrm{b}})\right]c^2-\left[(4\,\mathrm{v_b}-6\,\frac{x^2_{\mathrm{b}}}{\lambda_{\mathrm{ZZ}}}\,\mathrm{T}^d_{78}\,\mathrm{v_b}-9\,\frac{x^2_{\mathrm{b}}}{\lambda_{\mathrm{ZZ}}}\,\mathrm{U}_4)\right]\right\}\frac{s}{c^3}\\
&\times \mathrm{B}^{\mathrm{fin}}_0\left(-M^2_{\mathrm{Z}}\,;M_{\mathrm{b}}\,,M_{\mathrm{b}}\right)\\
&-\frac{1}{96}\left\{\left[8\,c^2\,x^2_{\mathrm{H}}\,x^2_{\mathrm{t}}\,\mathrm{v_t}+(4\,x^2_{\mathrm{H}}\,\mathrm{v_t}+\mathrm{U}_5\,x^2_{\mathrm{t}})\right]c^2-\left[(8\,\mathrm{v_t}-6\,\frac{x^2_{\mathrm{t}}}{\lambda_{\mathrm{ZZ}}}\,\mathrm{T}^d_{77}\,\mathrm{v_t}-9\,\frac{x^2_{\mathrm{t}}}{\lambda_{\mathrm{ZZ}}}\,\mathrm{U}_2)\right]\right\}\frac{s}{c^3}\\
&\times \mathrm{B}^{\mathrm{fin}}_0\left(-M^2_{\mathrm{Z}}\,;M_{\mathrm{t}}\,,M_{\mathrm{t}}\right)\\
&-\frac{1}{96}\left\{\left[\mathrm{T}^d_{73}-3\,(\mathrm{T}^d_7\,c^2\,x^2_{\mathrm{H}}-\mathrm{T}^d_{71})\,c^2\,x^2_{\mathrm{H}}\right]c^2-(\mathrm{T}^d_{79}\,x^2_{\mathrm{H}}-2\,\mathrm{T}^d_{81})\,\frac{1}{\lambda_{\mathrm{ZZ}}}\right\}\frac{s}{c^5}\\
&\times \mathrm{B}^{\mathrm{fin}}_0\left(-M^2_{\mathrm{H}}\,;M_{\mathrm{W}}\,,M_{\mathrm{W}}\right)\\
&+\frac{1}{96}\left\{\left[6\,\mathrm{T}^d_{74}+(24\,c^6\,x^2_{\mathrm{H}}-\mathrm{T}^d_{75})\,c^2\,x^2_{\mathrm{H}}\right]c^2-(\mathrm{T}^d_{79}\,x^2_{\mathrm{H}}-2\,\mathrm{T}^d_{81})\,\frac{1}{\lambda_{\mathrm{ZZ}}}\right\}\frac{s}{c^7}\\
&\times \mathrm{C}_0\left(-M^2_{\mathrm{H}}\,,-M^2_{\mathrm{Z}}\,,-M^2_{\mathrm{Z}}\,;M_{\mathrm{W}}\,,M_{\mathrm{W}}\,,M_{\mathrm{W}}\right)\\
&-\frac{1}{128}\left\{4\left[(2\,\mathrm{T}^d_{77}\,\mathrm{v_t}+3\,\mathrm{U}_2)\right]\frac{1}{\lambda_{\mathrm{ZZ}}}+\left[2\,(2\,\mathrm{T}^d_{77}\,\mathrm{v_t}+3\,\mathrm{U}_2)+(2\,\mathrm{T}^d_{77}\,\mathrm{V}_3\,\mathrm{v_t}-3\,\mathrm{V}_3\,\mathrm{U}_1)\,c^2\right]c^2\right\}\frac{s}{c^5}\,x^2_{\mathrm{t}}\\
&\times \mathrm{C}_0\left(-M^2_{\mathrm{H}}\,,-M^2_{\mathrm{Z}}\,,-M^2_{\mathrm{Z}}\,;M_{\mathrm{t}}\,,M_{\mathrm{t}}\,,M_{\mathrm{t}}\right)
\end{aligned}
$$

$$
\begin{aligned}
&-\frac{1}{128}\left\{4\left[(2\,\mathrm{T}^d_{78}\,\mathrm{v}_\mathrm{b}+3\,\mathrm{U}_4)\right]\frac{1}{\lambda_{\mathrm{ZZ}}}+\left[2\,(2\,\mathrm{T}^d_{78}\,\mathrm{v}_\mathrm{b}+3\,\mathrm{U}_4)+(2\,\mathrm{T}^d_{78}\,\mathrm{V}_4\,\mathrm{v}_\mathrm{b}-3\,\mathrm{V}_4\,\mathrm{U}_3)\,c^2\right]c^2\right\}\frac{s}{c^5}\,x^2_\mathrm{b}\\
&\times \mathrm{C}_0\left(-M^2_\mathrm{H}\,,\,-M^2_\mathrm{Z}\,,\,-M^2_\mathrm{Z}\,;M_\mathrm{b}\,,M_\mathrm{b}\,,M_\mathrm{b}\right)\\
&+\frac{1}{48}\,(2-c^2\,x^2_\mathrm{H})\,\frac{s}{c^3}\,\mathrm{v}_\mathrm{l}\,\mathrm{B}^{\mathrm{fin}}_0\left(-M^2_\mathrm{Z}\,;0\,,0\right)\\
&+\frac{5}{64}\,(2-c^2\,x^2_\mathrm{H})\,\frac{s}{c^5}\,\frac{x^2_\mathrm{H}}{\lambda_{\mathrm{ZZ}}}\,\mathrm{B}^{\mathrm{fin}}_0\left(-M^2_\mathrm{H}\,;M_\mathrm{H}\,,M_\mathrm{H}\right)\\
&+\frac{1}{24}\,(2-c^2\,x^2_\mathrm{H})\,\frac{s}{c}\,x^2_\mathrm{b}\,\mathrm{v}_\mathrm{b}\,a^{\mathrm{fin}}_0\left(M_\mathrm{b}\right)\\
&+\frac{1}{12}\,(2-c^2\,x^2_\mathrm{H})\,\frac{s}{c}\,x^2_\mathrm{t}\,\mathrm{v}_\mathrm{t}\,a^{\mathrm{fin}}_0\left(M_\mathrm{t}\right)\\
&+\frac{5}{192}\,(s\mathrm{W}_{17}+\frac{x^2_\mathrm{H}}{\lambda_{\mathrm{ZZ}}}\,c^2\,x^2_\mathrm{H})\,\frac{s}{c^5}\,\mathrm{B}^{\mathrm{fin}}_0\left(-M^2_\mathrm{H}\,;M_\mathrm{Z}\,,M_\mathrm{Z}\right)\\
&-\frac{5}{96}\,(2\,s\mathrm{W}_{17}-\frac{x^2_\mathrm{H}}{\lambda_{\mathrm{ZZ}}}\,c^2\,x^2_\mathrm{H})\,\frac{s}{c^5}\,\mathrm{B}^{\mathrm{fin}}_0\left(-M^2_\mathrm{Z}\,;M_\mathrm{H}\,,M_\mathrm{Z}\right)\\
&+\frac{1}{32}\,(2\,\mathrm{T}^d_{77}\,\mathrm{v}_\mathrm{t}+3\,\mathrm{U}_2)\,\frac{s}{c^3}\,\frac{x^2_\mathrm{t}}{\lambda_{\mathrm{ZZ}}}\,\mathrm{B}^{\mathrm{fin}}_0\left(-M^2_\mathrm{H}\,;M_\mathrm{t}\,,M_\mathrm{t}\right)\\
&+\frac{1}{32}\,(2\,\mathrm{T}^d_{78}\,\mathrm{v}_\mathrm{b}+3\,\mathrm{U}_4)\,\frac{s}{c^3}\,\frac{x^2_\mathrm{b}}{\lambda_{\mathrm{ZZ}}}\,\mathrm{B}^{\mathrm{fin}}_0\left(-M^2_\mathrm{H}\,;M_\mathrm{b}\,,M_\mathrm{b}\right)\\
&-\frac{1}{48}\,(2\,\mathrm{U}_0-\mathrm{U}_0\,c^2\,x^2_\mathrm{H})\,\frac{s}{c^3}\,(1-3\,\mathrm{L}_\mathrm{R})
\end{aligned}
$$

$$
\begin{aligned}
\mathscr{T}^{\mathrm{nfc}}_{\mathrm{D;ZZ}}(a_{\mathrm{AA}}) = {}&\frac{1}{32}\,\mathrm{X}_{11}+\frac{1}{32}\,\frac{s^2}{c^2}\,\mathrm{X}_{10}\\
&+\frac{3}{32}\left[4\,\frac{1}{\lambda_{\mathrm{ZZ}}}+(\frac{x^2_\mathrm{H}}{\lambda_{\mathrm{ZZ}}}\,c^2\,x^2_\mathrm{H}-\mathrm{W}_8)\,c^2\right]\frac{s^2}{c^6}\,x^2_\mathrm{H}\,\mathrm{C}_0\left(-M^2_\mathrm{H}\,,-M^2_\mathrm{Z}\,,-M^2_\mathrm{Z}\,;M_\mathrm{H}\,,M_\mathrm{Z}\,,M_\mathrm{H}\right)\\
&-\frac{1}{32}\left[4\,\mathrm{T}^d_{29}-(2\,\mathrm{W}_{10}+\mathrm{W}_{10}\,c^2\,x^2_\mathrm{H})\,s^2\,c^2\,x^2_\mathrm{H}\right]\frac{1}{c^6}\,\mathrm{C}_0\left(-M^2_\mathrm{H}\,,-M^2_\mathrm{Z}\,,-M^2_\mathrm{Z}\,;M_\mathrm{Z}\,,M_\mathrm{H}\,,M_\mathrm{Z}\right)\\
&-\frac{1}{32}\left[\mathrm{T}^d_{90}+\mathrm{T}^d_{96}\,c^2\,x^2_\mathrm{H}+(\mathrm{T}^d_8\,x^2_\mathrm{b}\,\mathrm{v}_\mathrm{b}+\mathrm{T}^d_9\,x^2_\mathrm{t}\,\mathrm{v}_\mathrm{t})\,s^2\,c^2\right]\frac{1}{c^4}\\
&+\frac{1}{16}\left[(\mathrm{T}^d_{71}\,x^2_\mathrm{H}-4\,\mathrm{T}^d_{87})\,\frac{1}{\lambda_{\mathrm{ZZ}}}+(2\,\mathrm{T}^d_{88}+\mathrm{T}^d_{92}\,c^2\,x^2_\mathrm{H})\,c^2\right]\frac{s^2}{c^4}\,\mathrm{B}^{\mathrm{fin}}_0\left(-M^2_\mathrm{Z}\,;M_\mathrm{W}\,,M_\mathrm{W}\right)\\
&-\frac{1}{16}\left\{3\,c^2+\left[(3-\mathrm{T}^d_8\,\mathrm{v}_\mathrm{b})\right]\frac{1}{\lambda_{\mathrm{ZZ}}}\right\}\frac{s^2}{c^4}\,x^2_\mathrm{b}\,\mathrm{B}^{\mathrm{fin}}_0\left(-M^2_\mathrm{Z}\,;M_\mathrm{b}\,,M_\mathrm{b}\right)\\
&-\frac{1}{16}\left\{3\,c^2+\left[(3-\mathrm{T}^d_9\,\mathrm{v}_\mathrm{t})\right]\frac{1}{\lambda_{\mathrm{ZZ}}}\right\}\frac{s^2}{c^4}\,x^2_\mathrm{t}\,\mathrm{B}^{\mathrm{fin}}_0\left(-M^2_\mathrm{Z}\,;M_\mathrm{t}\,,M_\mathrm{t}\right)\\
&-\frac{1}{16}\left\{\left[c^2\,x^4_\mathrm{H}+(4-\mathrm{T}^d_{93}\,x^2_\mathrm{H})\right]c^4+(\mathrm{T}^d_{71}\,x^2_\mathrm{H}-4\,\mathrm{T}^d_{87})\,\frac{1}{\lambda_{\mathrm{ZZ}}}\right\}\frac{s^2}{c^4}\,\mathrm{B}^{\mathrm{fin}}_0\left(-M^2_\mathrm{H}\,;M_\mathrm{W}\,,M_\mathrm{W}\right)\\
&+\frac{1}{16}\left\{-\left[2\,\mathrm{T}^d_{89}-(4\,c^4\,x^2_\mathrm{H}+\mathrm{T}^d_{95})\,c^2\,x^2_\mathrm{H}\right]c^2+(\mathrm{T}^d_{71}\,x^2_\mathrm{H}-4\,\mathrm{T}^d_{87})\,\frac{1}{\lambda_{\mathrm{ZZ}}}\right\}\frac{s^2}{c^6}\\
&\times \mathrm{C}_0\left(-M^2_\mathrm{H}\,,-M^2_\mathrm{Z}\,,-M^2_\mathrm{Z}\,;M_\mathrm{W}\,,M_\mathrm{W}\,,M_\mathrm{W}\right)\\
&-\frac{1}{64}\left\{4\left[(3-\mathrm{T}^d_8\,\mathrm{v}_\mathrm{b})\right]\frac{1}{\lambda_{\mathrm{ZZ}}}+\left[2\,(3-\mathrm{T}^d_8\,\mathrm{v}_\mathrm{b})-(\mathrm{T}^d_8\,\mathrm{V}_4\,\mathrm{v}_\mathrm{b}+3\,\mathrm{V}_4)\,c^2\right]c^2\right\}\frac{s^2}{c^6}\,x^2_\mathrm{b}\\
&\times \mathrm{C}_0\left(-M^2_\mathrm{H}\,,-M^2_\mathrm{Z}\,,-M^2_\mathrm{Z}\,;M_\mathrm{b}\,,M_\mathrm{b}\,,M_\mathrm{b}\right)\\
&-\frac{1}{64}\left\{4\left[(3-\mathrm{T}^d_9\,\mathrm{v}_\mathrm{t})\right]\frac{1}{\lambda_{\mathrm{ZZ}}}+\left[2\,(3-\mathrm{T}^d_9\,\mathrm{v}_\mathrm{t})-(\mathrm{T}^d_9\,\mathrm{V}_3\,\mathrm{v}_\mathrm{t}+3\,\mathrm{V}_3)\,c^2\right]c^2\right\}\frac{s^2}{c^6}\,x^2_\mathrm{t}\\
&\times \mathrm{C}_0\left(-M^2_\mathrm{H}\,,-M^2_\mathrm{Z}\,,-M^2_\mathrm{Z}\,;M_\mathrm{t}\,,M_\mathrm{t}\,,M_\mathrm{t}\right)
\end{aligned}
$$

JHEP07(2015)175

$$-\frac{3}{32}\,(2-c^2\,x_{\rm H}^2)\,\frac{s^2}{c^4}\,\frac{x_{\rm H}^2}{\lambda_{\rm ZZ}}\,{\rm B}_0^{\rm fin}\left(-M_{\rm H}^2\,;M_{\rm H}\,,M_{\rm H}\right)$$
$$+\frac{1}{16}\,(3-{\rm T}_8^d\,{\rm v_b})\,\frac{s^2}{c^4}\,\frac{x_{\rm b}^2}{\lambda_{\rm ZZ}}\,{\rm B}_0^{\rm fin}\left(-M_{\rm H}^2\,;M_{\rm b}\,,M_{\rm b}\right)$$
$$+\frac{1}{16}\,(3-{\rm T}_9^d\,{\rm v_t})\,\frac{s^2}{c^4}\,\frac{x_{\rm t}^2}{\lambda_{\rm ZZ}}\,{\rm B}_0^{\rm fin}\left(-M_{\rm H}^2\,;M_{\rm t}\,,M_{\rm t}\right)$$
$$-\frac{1}{32}\,(s{\rm W}_{17}+\frac{x_{\rm H}^2}{\lambda_{\rm ZZ}}\,c^2\,x_{\rm H}^2)\,\frac{s^2}{c^4}\,{\rm B}_0^{\rm fin}\left(-M_{\rm H}^2\,;M_{\rm Z}\,,M_{\rm Z}\right)$$
$$+\frac{1}{16}\,(2\,s{\rm W}_{17}-\frac{x_{\rm H}^2}{\lambda_{\rm ZZ}}\,c^2\,x_{\rm H}^2)\,\frac{s^2}{c^4}\,{\rm B}_0^{\rm fin}\left(-M_{\rm Z}^2\,;M_{\rm H}\,,M_{\rm Z}\right)$$
$$-\frac{1}{32}\,(2\,s^2\,c^6\,x_{\rm H}^4-4\,{\rm T}_{91}^d\,c^4\,x_{\rm H}^2-{\rm T}_{94}^d)\,\frac{1}{c^4}\,{\rm L_R}$$

$$\mathscr{T}_{\rm D;ZZ}^{\rm nfc}(a_{\rm ZZ})=\frac{1}{32}\,{\rm X}_{14}+\frac{1}{32}\,x_{\rm H}^2\,{\rm X}_{13}+\frac{1}{32}\,\frac{1}{c^2}\,{\rm X}_{12}$$
$$+\frac{1}{32}\left[2\,\frac{x_{\rm H}^2}{\lambda_{\rm ZZ}}\,s^2\,c^2\,x_{\rm H}^2-(10-c^2\,x_{\rm H}^2)\,c^2\,x_{\rm H}^2+2\,(\frac{x_{\rm H}^2}{\lambda_{\rm ZZ}}\,{\rm T}_8^d+2\,{\rm T}_{107}^d)\right]\frac{1}{c^4}\,{\rm B}_0^{\rm fin}\left(-M_{\rm Z}^2\,;M_{\rm H}\,,M_{\rm Z}\right)$$
$$+\frac{1}{128}\left[4\,\frac{x_{\rm H}^2}{\lambda_{\rm ZZ}}\,s^2\,c^2\,x_{\rm H}^2-4\,{\rm T}_{110}^d\,s{\rm W}_{17}-(10+c^2\,x_{\rm H}^2)\,c^2\,x_{\rm H}^2\right]\frac{1}{c^4}\,{\rm B}_0^{\rm fin}\left(-M_{\rm H}^2\,;M_{\rm Z}\,,M_{\rm Z}\right)$$
$$-\frac{3}{32}\left[4\,\frac{1}{\lambda_{\rm ZZ}}\,{\rm T}_{29}^d-(4-c^2\,x_{\rm H}^2)\,\frac{x_{\rm H}^2}{\lambda_{\rm ZZ}}\,s^2\,c^2-(2\,c^2\,x_{\rm H}^2-{\rm T}_{107}^d)\,c^2\right]\frac{1}{c^6}\,x_{\rm H}^2$$
$$\times{\rm C}_0\left(-M_{\rm H}^2\,,-M_{\rm Z}^2\,,-M_{\rm Z}^2\,;M_{\rm H}\,,M_{\rm Z}\,,M_{\rm H}\right)$$
$$+\frac{3}{128}\left[4\,(2-c^2\,x_{\rm H}^2)\,\frac{1}{\lambda_{\rm ZZ}}\,s^2+(10-c^2\,x_{\rm H}^2)\,c^2\right]\frac{1}{c^4}\,x_{\rm H}^2\,{\rm B}_0^{\rm fin}\left(-M_{\rm H}^2\,;M_{\rm H}\,,M_{\rm H}\right)$$
$$-\frac{1}{32}\left\{9\,c^2+\left[(2\,{\rm T}_{42}^d\,{\rm v_t}+3\,{\rm U}_2)\right]\frac{1}{\lambda_{\rm ZZ}}\right\}\frac{1}{c^2}\,x_{\rm t}^2\,{\rm B}_0^{\rm fin}\left(-M_{\rm Z}^2\,;M_{\rm t}\,,M_{\rm t}\right)$$
$$-\frac{1}{32}\left\{9\,c^2+\left[(2\,{\rm T}_{112}^d\,{\rm v_b}+3\,{\rm U}_4)\right]\frac{1}{\lambda_{\rm ZZ}}\right\}\frac{1}{c^2}\,x_{\rm b}^2\,{\rm B}_0^{\rm fin}\left(-M_{\rm Z}^2\,;M_{\rm b}\,,M_{\rm b}\right)$$
$$-\frac{1}{32}\left\{\frac{x_{\rm H}^2}{\lambda_{\rm ZZ}}\,s^2\,c^4\,x_{\rm H}^4+4\,{\rm T}_{106}^d-\left[{\rm T}_{107}^d\,c^2\,x_{\rm H}^2+2\,(\frac{x_{\rm H}^2}{lzz}\,{\rm T}_{110}^d+{\rm T}_{107}^d)\right]c^2\,x_{\rm H}^2\right\}\frac{1}{c^6}$$
$$\times{\rm C}_0\left(-M_{\rm H}^2\,,-M_{\rm Z}^2\,,-M_{\rm Z}^2\,;M_{\rm Z}\,,M_{\rm H}\,,M_{\rm Z}\right)$$
$$+\frac{1}{64}\left\{4\,{\rm T}_{97}^d\,x_{\rm H}^2+\left[(2\,{\rm T}_{42}^d\,x_{\rm t}^2\,{\rm v_t}-32\,{\rm T}_{107}^d+2\,{\rm T}_{112}^d\,x_{\rm b}^2\,{\rm v_b}+3\,{\rm U}_2\,x_{\rm t}^2+3\,{\rm U}_4\,x_{\rm b}^2)\right]c^2\right\}\frac{1}{c^2}$$
$$+\frac{1}{64}\left\{2\,{\rm T}_{111}^d+\left[2\,{\rm T}_{103}^d\,x_{\rm H}^2-({\rm T}_{108}^d\,x_{\rm H}^4+18\,{\rm V}_6)\,c^2\right]c^2\right\}\frac{1}{c^4}\,{\rm L_R}$$
$$-\frac{1}{64}\left\{\left[{\rm T}_{100}^d\,c^2\,x_{\rm H}^4+2\,(2\,{\rm T}_{100}^d-{\rm T}_{102}^d\,x_{\rm H}^2)\right]c^2+4\left[(6\,{\rm T}_{98}^d-{\rm T}_{101}^d\,x_{\rm H}^2)\right]\frac{1}{\lambda_{\rm ZZ}}\right\}\frac{1}{c^4}$$
$$\times{\rm B}_0^{\rm fin}\left(-M_{\rm H}^2\,;M_{\rm W}\,,M_{\rm W}\right)$$
$$+\frac{1}{16}\left\{\left[2\,{\rm T}_{104}^d+(4\,c^6\,x_{\rm H}^2-{\rm T}_{105}^d)\,c^2\,x_{\rm H}^2\right]c^2+\left[(6\,{\rm T}_{98}^d-{\rm T}_{101}^d\,x_{\rm H}^2)\right]\frac{1}{\lambda_{\rm ZZ}}\right\}\frac{1}{c^6}$$
$$\times{\rm C}_0\left(-M_{\rm H}^2\,,-M_{\rm Z}^2\,,-M_{\rm Z}^2\,;M_{\rm W}\,,M_{\rm W}\,,M_{\rm W}\right)$$
$$-\frac{1}{128}\left\{4\left[(2\,{\rm T}_{42}^d\,{\rm v_t}+3\,{\rm U}_2)\right]\frac{1}{\lambda_{\rm ZZ}}+\left[2\,(2\,{\rm T}_{42}^d\,{\rm v_t}+3\,{\rm U}_2)+(2\,{\rm T}_{42}^d\,{\rm V}_3\,{\rm v_t}-3\,{\rm V}_3\,{\rm U}_1)\,c^2\right]c^2\right\}\frac{1}{c^4}\,x_{\rm t}^2$$
$$\times{\rm C}_0\left(-M_{\rm H}^2\,,-M_{\rm Z}^2\,,-M_{\rm Z}^2\,;M_{\rm t}\,,M_{\rm t}\,,M_{\rm t}\right)$$
$$+\frac{1}{16}\left\{\left[(6\,{\rm T}_{98}^d-{\rm T}_{101}^d\,x_{\rm H}^2)\right]\frac{1}{\lambda_{\rm ZZ}}+(2\,{\rm T}_{99}^d-{\rm T}_{109}^d\,c^2\,x_{\rm H}^2)\,c^2\right\}\frac{1}{c^4}\,{\rm B}_0^{\rm fin}\left(-M_{\rm Z}^2\,;M_{\rm W}\,,M_{\rm W}\right)$$

$$
\begin{aligned}
&- \frac{1}{128}\left\{4\left[(2\,\mathrm{T}^{d}_{112}\,\mathrm{v_b} + 3\,\mathrm{U}_4)\right]\frac{1}{\lambda_{\mathrm{ZZ}}} + \left[2\,(2\,\mathrm{T}^{d}_{112}\,\mathrm{v_b} + 3\,\mathrm{U}_4) + (2\,\mathrm{T}^{d}_{112}\,\mathrm{V}_4\,\mathrm{v_b} - 3\,\mathrm{V}_4\,\mathrm{U}_3)\,c^2\right]c^2\right\}\frac{1}{c^4}\,x_{\mathrm{b}}^2 \\
&\times \mathrm{C}_0\left(-M_{\mathrm{H}}^2\,,\,-M_{\mathrm{Z}}^2\,,\,-M_{\mathrm{Z}}^2\,;M_{\mathrm{b}}\,,M_{\mathrm{b}}\,,M_{\mathrm{b}}\right) \\
&- \frac{1}{32}\,(4 - c^2\,x_{\mathrm{H}}^2)\,\frac{1}{c^2}\,x_{\mathrm{H}}^2\,a_0^{\mathrm{fin}}\left(M_{\mathrm{H}}\right) \\
&+ \frac{1}{32}\,(4 - c^2\,x_{\mathrm{H}}^2)\,\frac{1}{c^4}\,a_0^{\mathrm{fin}}\left(M_{\mathrm{Z}}\right) \\
&+ \frac{1}{32}\,(2\,\mathrm{T}^{d}_{42}\,\mathrm{v_t} + 3\,\mathrm{U}_2)\,\frac{1}{c^2}\,\frac{x_{\mathrm{t}}^2}{\lambda_{\mathrm{ZZ}}}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{t}}\,,M_{\mathrm{t}}\right) \\
&+ \frac{1}{32}\,(2\,\mathrm{T}^{d}_{112}\,\mathrm{v_b} + 3\,\mathrm{U}_4)\,\frac{1}{c^2}\,\frac{x_{\mathrm{b}}^2}{\lambda_{\mathrm{ZZ}}}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{b}}\,,M_{\mathrm{b}}\right)
\end{aligned}
$$

$$
\mathscr{T}^{\mathrm{nfc}}_{\mathrm{D;ZZ}}(\mathrm{ren}) = \frac{1}{32}\,\frac{1}{c^2}\,\mathrm{X}_{15}
$$

$$
\begin{aligned}
\mathscr{T}^{\mathrm{nfc}}_{\mathrm{P;ZZ}}(a_{\phi\,\mathrm{t\,V}}) = &\ \frac{3}{16}\,\frac{\mathrm{v_t}}{c^2}\,\mathrm{W}_{19}\,x_{\mathrm{t}}^2 \\
&- \frac{3}{32}\left[12\,\frac{1}{\lambda_{\mathrm{ZZ}}^2} + (\mathrm{W}_{18} + 2\,\mathrm{W}_{20}\,c^2)\,c^2\right]\frac{\mathrm{v_t}}{c^6}\,x_{\mathrm{t}}^2\,\mathrm{C}_0\left(-M_{\mathrm{H}}^2\,,\,-M_{\mathrm{Z}}^2\,,\,-M_{\mathrm{Z}}^2\,;M_{\mathrm{t}}\,,M_{\mathrm{t}}\,,M_{\mathrm{t}}\right) \\
&+ \frac{3}{32}\,(-c^2\,s\mathrm{W}_{18} + 12\,\frac{1}{\lambda_{\mathrm{ZZ}}^2})\,\frac{\mathrm{v_t}}{c^4}\,x_{\mathrm{t}}^2\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{t}}\,,M_{\mathrm{t}}\right) \\
&- \frac{3}{32}\,(-c^2\,s\mathrm{W}_{18} + 12\,\frac{1}{\lambda_{\mathrm{ZZ}}^2})\,\frac{\mathrm{v_t}}{c^4}\,x_{\mathrm{t}}^2\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{Z}}^2\,;M_{\mathrm{t}}\,,M_{\mathrm{t}}\right)
\end{aligned}
$$

$$
\begin{aligned}
\mathscr{T}^{\mathrm{nfc}}_{\mathrm{P;ZZ}}(a_{\phi\,\mathrm{t\,A}}) = &\ \frac{3}{16}\,\frac{1}{c^2}\,\mathrm{W}_{19}\,x_{\mathrm{t}}^2 \\
&- \frac{3}{32}\left[12\,\frac{1}{\lambda_{\mathrm{ZZ}}^2} + (\mathrm{W}_{22} + 2\,\mathrm{W}_{23}\,c^2)\,c^2\right]\frac{1}{c^6}\,x_{\mathrm{t}}^2\,\mathrm{C}_0\left(-M_{\mathrm{H}}^2\,,\,-M_{\mathrm{Z}}^2\,,\,-M_{\mathrm{Z}}^2\,;M_{\mathrm{t}}\,,M_{\mathrm{t}}\,,M_{\mathrm{t}}\right) \\
&+ \frac{3}{32}\,(c^2\,s\mathrm{W}_{21} + 12\,\frac{1}{\lambda_{\mathrm{ZZ}}^2})\,\frac{1}{c^4}\,x_{\mathrm{t}}^2\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{t}}\,,M_{\mathrm{t}}\right) \\
&- \frac{3}{32}\,(c^2\,s\mathrm{W}_{21} + 12\,\frac{1}{\lambda_{\mathrm{ZZ}}^2})\,\frac{1}{c^4}\,x_{\mathrm{t}}^2\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{Z}}^2\,;M_{\mathrm{t}}\,,M_{\mathrm{t}}\right)
\end{aligned}
$$

$$
\begin{aligned}
\mathscr{T}^{\mathrm{nfc}}_{\mathrm{P;ZZ}}(a_{\phi\,\mathrm{b\,V}}) = &\ \frac{3}{16}\,\frac{\mathrm{v_b}}{c^2}\,\mathrm{W}_{19}\,x_{\mathrm{b}}^2 \\
&- \frac{3}{32}\left[12\,\frac{1}{\lambda_{\mathrm{ZZ}}^2} + (\mathrm{W}_{18} + 2\,\mathrm{W}_{24}\,c^2)\,c^2\right]\frac{\mathrm{v_b}}{c^6}\,x_{\mathrm{b}}^2\,\mathrm{C}_0\left(-M_{\mathrm{H}}^2\,,\,-M_{\mathrm{Z}}^2\,,\,-M_{\mathrm{Z}}^2\,;M_{\mathrm{b}}\,,M_{\mathrm{b}}\,,M_{\mathrm{b}}\right) \\
&+ \frac{3}{32}\,(-c^2\,s\mathrm{W}_{18} + 12\,\frac{1}{\lambda_{\mathrm{ZZ}}^2})\,\frac{\mathrm{v_b}}{c^4}\,x_{\mathrm{b}}^2\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{b}}\,,M_{\mathrm{b}}\right) \\
&- \frac{3}{32}\,(-c^2\,s\mathrm{W}_{18} + 12\,\frac{1}{\lambda_{\mathrm{ZZ}}^2})\,\frac{\mathrm{v_b}}{c^4}\,x_{\mathrm{b}}^2\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{Z}}^2\,;M_{\mathrm{b}}\,,M_{\mathrm{b}}\right)
\end{aligned}
$$

$$
\begin{aligned}
\mathscr{T}^{\mathrm{nfc}}_{\mathrm{P;ZZ}}(a_{\phi\,\mathrm{b\,A}}) = &\ \frac{3}{16}\,\frac{1}{c^2}\,\mathrm{W}_{19}\,x_{\mathrm{b}}^2 \\
&- \frac{3}{32}\left[12\,\frac{1}{\lambda_{\mathrm{ZZ}}^2} + (\mathrm{W}_{22} + 2\,\mathrm{W}_{25}\,c^2)\,c^2\right]\frac{1}{c^6}\,x_{\mathrm{b}}^2\,\mathrm{C}_0\left(-M_{\mathrm{H}}^2\,,\,-M_{\mathrm{Z}}^2\,,\,-M_{\mathrm{Z}}^2\,;M_{\mathrm{b}}\,,M_{\mathrm{b}}\,,M_{\mathrm{b}}\right) \\
&+ \frac{3}{32}\,(12\,\frac{1}{\lambda_{\mathrm{ZZ}}^2} + \mathrm{W}_{21}\,c^2)\,\frac{1}{c^4}\,x_{\mathrm{b}}^2\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{b}}\,,M_{\mathrm{b}}\right) \\
&- \frac{3}{32}\,(12\,\frac{1}{\lambda_{\mathrm{ZZ}}^2} + \mathrm{W}_{21}\,c^2)\,\frac{1}{c^4}\,x_{\mathrm{b}}^2\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{Z}}^2\,;M_{\mathrm{b}}\,,M_{\mathrm{b}}\right)
\end{aligned}
$$

$$
\begin{aligned}
\mathscr{T}^{\rm nfc}_{\rm P;ZZ}(a_{\rm t\,BW}) = {}& \frac{3}{32}\left\{6\,\frac{1}{\lambda^2_{\rm ZZ}} + \left[\frac{1}{\lambda_{\rm ZZ}} + (-c^2 + 2\,\frac{1}{\lambda_{\rm ZZ}})\,c^2\,x^2_{\rm t}\right]c^2\right\}\frac{1}{c^7}\,x^2_{\rm t}\,{\rm v_t} \\
& \times {\rm C}_0\left(-M^2_{\rm H}\,, -M^2_{\rm Z}\,, -M^2_{\rm Z}\,; M_{\rm t}\,, M_{\rm t}\,, M_{\rm t}\right) \\
& - \frac{3}{64}\,(c^2 + 2\,\frac{1}{\lambda_{\rm ZZ}})\,\frac{\rm v_t}{c^3}\,x^2_{\rm t} \\
& - \frac{3}{64}\,(-c^4 + 12\,\frac{1}{\lambda^2_{\rm ZZ}})\,\frac{\rm v_t}{c^5}\,x^2_{\rm t}\,{\rm B}^{\rm fin}_0\left(-M^2_{\rm H}\,; M_{\rm t}\,, M_{\rm t}\right) \\
& + \frac{3}{64}\,(-c^4 + 12\,\frac{1}{\lambda^2_{\rm ZZ}})\,\frac{\rm v_t}{c^5}\,x^2_{\rm t}\,{\rm B}^{\rm fin}_0\left(-M^2_{\rm Z}\,; M_{\rm t}\,, M_{\rm t}\right)
\end{aligned}
$$

$$
\begin{aligned}
\mathscr{T}^{\rm nfc}_{\rm P;ZZ}(a_{\rm b\,BW}) = {}& -\frac{3}{32}\left\{6\,\frac{1}{\lambda^2_{\rm ZZ}} + \left[\frac{1}{\lambda_{\rm ZZ}} + (-c^2 + 2\,\frac{1}{\lambda_{\rm ZZ}})\,c^2\,x^2_{\rm b}\right]c^2\right\}\frac{1}{c^7}\,x^2_{\rm b}\,{\rm v_b} \\
& \times {\rm C}_0\left(-M^2_{\rm H}\,, -M^2_{\rm Z}\,, -M^2_{\rm Z}\,; M_{\rm b}\,, M_{\rm b}\,, M_{\rm b}\right) \\
& + \frac{3}{64}\,(c^2 + 2\,\frac{1}{\lambda_{\rm ZZ}})\,\frac{\rm v_b}{c^3}\,x^2_{\rm b} \\
& + \frac{3}{64}\,(-c^4 + 12\,\frac{1}{\lambda^2_{\rm ZZ}})\,\frac{\rm v_b}{c^5}\,x^2_{\rm b}\,{\rm B}^{\rm fin}_0\left(-M^2_{\rm H}\,; M_{\rm b}\,, M_{\rm b}\right) \\
& - \frac{3}{64}\,(-c^4 + 12\,\frac{1}{\lambda^2_{\rm ZZ}})\,\frac{\rm v_b}{c^5}\,x^2_{\rm b}\,{\rm B}^{\rm fin}_0\left(-M^2_{\rm Z}\,; M_{\rm b}\,, M_{\rm b}\right)
\end{aligned}
$$

$$
\begin{aligned}
\mathscr{T}^{\rm nfc}_{\rm P;ZZ}(a_{\phi}) = {}& \frac{3}{16}\,\frac{1}{c^2}\,{\rm W}_{18}\,a^{\rm fin}_0\left(M_{\rm Z}\right) + \frac{3}{16}\,\frac{1}{c^2}\,{\rm W}_{19} + \frac{3}{16}\,{\rm W}_9\,a^{\rm fin}_0\left(M_{\rm H}\right) \\
& + \frac{3}{32}\left[24\,\frac{1}{\lambda^2_{\rm ZZ}} - (12\,\frac{x^2_{\rm H}}{\lambda^2_{\rm ZZ}} - {\rm W}_9\,c^2)\,c^2\right]\frac{1}{c^4}\,{\rm B}^{\rm fin}_0\left(-M^2_{\rm H}\,; M_{\rm H}\,, M_{\rm H}\right) \\
& - \frac{3}{32}\left[24\,\frac{1}{\lambda^2_{\rm ZZ}} - ({\rm W}_9\,c^2 + 2\,{\rm W}_{27})\,c^2\right]\frac{1}{c^4}\,{\rm B}^{\rm fin}_0\left(-M^2_{\rm Z}\,; M_{\rm H}\,, M_{\rm Z}\right) \\
& - \frac{3}{32}\left\{48\,\frac{1}{\lambda^2_{\rm ZZ}} + \left[8\,\frac{1}{\lambda_{\rm ZZ}}\,{\rm W}_{26} - ({\rm W}_9\,c^2\,x^2_{\rm H} - 4\,{\rm W}_{25})\,c^2\right]c^2\right\}\frac{1}{c^6}\,{\rm C}_0\left(-M^2_{\rm H}\,, -M^2_{\rm Z}\,, -M^2_{\rm Z}\,; M_{\rm H}\,, M_{\rm Z}\,, M_{\rm H}\right)
\end{aligned}
$$

$$
\begin{aligned}
\mathscr{T}^{\rm nfc}_{\rm P;ZZ}(a_{\phi\,\Box}) = {}& \frac{3}{64}\,\frac{1}{c^2}\,{\rm W}_9\,a^{\rm fin}_0\left(M_{\rm Z}\right) - \frac{3}{64}\,{\rm W}_9\,x^2_{\rm H}\,a^{\rm fin}_0\left(M_{\rm H}\right) \\
& + \frac{1}{128}\left[8\,\frac{1}{\lambda_{\rm ZZ}}\,s{\rm W}_{26} - ({\rm W}_9\,c^2\,x^2_{\rm H} - 2\,{\rm W}_{32})\,c^2\right]\frac{1}{c^4}\,{\rm B}^{\rm fin}_0\left(-M^2_{\rm H}\,; M_{\rm Z}\,, M_{\rm Z}\right) \\
& + \frac{1}{128}\left[16\,\frac{1}{\lambda_{\rm ZZ}}\,s{\rm W}_{11} + ({\rm W}_9\,c^2\,x^2_{\rm H} + 4\,{\rm W}_{30})\,c^2\right]\frac{1}{c^4}\,x^2_{\rm H}\,{\rm C}_0\left(-M^2_{\rm H}\,, -M^2_{\rm Z}\,, -M^2_{\rm Z}\,; M_{\rm Z}\,, M_{\rm H}\,, M_{\rm Z}\right) \\
& - \frac{1}{64}\left\{48\,\frac{1}{\lambda^2_{\rm ZZ}} + \left[12\,\frac{1}{\lambda_{\rm ZZ}} + (-4\,\frac{1}{\lambda_{\rm ZZ}}\,{\rm W}_{33} + {\rm W}_9\,c^2)\,c^2\,x^2_{\rm H}\right]c^2\right\}\frac{1}{c^6}\,{\rm B}^{\rm fin}_0\left(-M^2_{\rm H}\,; M_{\rm H}\,, M_{\rm H}\right) \\
& + \frac{1}{128}\left\{96\,\frac{1}{\lambda^2_{\rm ZZ}} + \left[16\,\frac{1}{\lambda_{\rm ZZ}}\,{\rm W}_{11} - (3\,{\rm W}_9\,c^2\,x^2_{\rm H} - 4\,{\rm W}_{28})\,c^2\right]c^2\right\}\frac{1}{c^6}\,{\rm B}^{\rm fin}_0\left(-M^2_{\rm Z}\,; M_{\rm H}\,, M_{\rm Z}\right) \\
& + \frac{1}{64}\left\{96\,\frac{1}{\lambda^2_{\rm ZZ}} + \left[8\,\frac{1}{\lambda_{\rm ZZ}}\,{\rm W}_{34} - ({\rm W}_9\,c^4\,x^4_{\rm H} - 4\,{\rm W}_{29} - 4\,{\rm W}_{31}\,c^2\,x^2_{\rm H})\,c^2\right]c^2\right\}\frac{1}{c^8} \\
& \times {\rm C}_0\left(-M^2_{\rm H}\,, -M^2_{\rm Z}\,, -M^2_{\rm Z}\,; M_{\rm H}\,, M_{\rm Z}\,, M_{\rm H}\right) \\
& - \frac{1}{32}\left\{12\,\frac{1}{\lambda^2_{\rm ZZ}}\,{\rm T}^d_{117} - \left[(12\,\frac{x^2_{\rm H}}{\lambda_{\rm ZZ}}\,{\rm T}^d_{52} - {\rm T}^d_{120})\,\frac{1}{\lambda_{\rm ZZ}} + ({\rm T}^d_{52}\,{\rm W}_9 + {\rm T}^d_{113}\,{\rm V}_9)\,c^2\right]c^2\right\}\frac{1}{c^6} \\
& \times {\rm B}^{\rm fin}_0\left(-M^2_{\rm H}\,; M_{\rm W}\,, M_{\rm W}\right) \\
& + \frac{1}{32}\left\{12\,\frac{1}{\lambda^2_{\rm ZZ}}\,{\rm T}^d_{117} - \left[(12\,\frac{x^2_{\rm H}}{\lambda_{\rm ZZ}}\,{\rm T}^d_{52} - {\rm T}^d_{120})\,\frac{1}{\lambda_{\rm ZZ}} + ({\rm T}^d_{52}\,{\rm W}_9 + {\rm T}^d_{113}\,{\rm V}_9)\,c^2\right]c^2\right\}\frac{1}{c^6}
\end{aligned}
$$

$$
\begin{aligned}
&\times \mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{Z}}^2\,;M_{\mathrm{W}}\,,M_{\mathrm{W}}\right)\\
&+\frac{1}{32}\left\{12\,\frac{1}{\lambda_{\mathrm{ZZ}}^2}\,\mathrm{T}^d_{117}-\left[(12\,\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{ZZ}}}\,\mathrm{T}^d_{52}-\mathrm{T}^d_{121})\,\frac{1}{\lambda_{\mathrm{ZZ}}}-(-\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{ZZ}}}\,\mathrm{T}^d_{115}+\mathrm{T}^d_{114}+\mathrm{T}^d_{116}\,\mathrm{V}_9)\,c^2\right]c^2\right\}\frac{1}{c^8}\\
&\times \mathrm{C}_0\left(-M_{\mathrm{H}}^2\,,-M_{\mathrm{Z}}^2\,,-M_{\mathrm{Z}}^2\,;M_{\mathrm{W}}\,,M_{\mathrm{W}}\,,M_{\mathrm{W}}\right)\\
&-\frac{1}{64}\left\{4\,\frac{1}{\lambda_{\mathrm{ZZ}}}\,\mathrm{T}^d_{119}+\left[(5-\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{ZZ}}}\,\mathrm{T}^d_{118}-4\,\mathrm{T}^d_{113}\,\mathrm{V}_9)\right]c^2\right\}\frac{1}{c^4}
\end{aligned}
$$

$$
\begin{aligned}
\mathscr{T}^{\mathrm{nfc}}_{\mathrm{P;ZZ}}(a_{\phi\mathrm{D}}) = {}&\frac{1}{512}\left[8\,s\mathrm{W}_{45}-(5\,\mathrm{W}_9\,c^2\,x_{\mathrm{H}}^2-2\,\mathrm{W}_{37})\,c^2\right]\frac{1}{c^4}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{Z}}\,,M_{\mathrm{Z}}\right)\\
&-\frac{1}{512}\left[16\,s\mathrm{W}_{39}-(5\,\mathrm{W}_9\,c^2\,x_{\mathrm{H}}^2-4\,\mathrm{W}_{36})\,c^2\,x_{\mathrm{H}}^2\right]\frac{1}{c^4}\,\mathrm{C}_0\left(-M_{\mathrm{H}}^2\,,-M_{\mathrm{Z}}^2\,,-M_{\mathrm{Z}}^2\,;M_{\mathrm{Z}}\,,M_{\mathrm{H}}\,,M_{\mathrm{Z}}\right)\\
&+\frac{1}{128}\left[(\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{ZZ}}}\,\mathrm{T}^d_{128}+\mathrm{T}^d_{8}\,\mathrm{W}_{19}\,x_{\mathrm{b}}^2\,\mathrm{v}_{\mathrm{b}}+\mathrm{T}^d_{9}\,\mathrm{W}_{19}\,x_{\mathrm{t}}^2\,\mathrm{v}_{\mathrm{t}}+\mathrm{T}^d_{129}-3\,\mathrm{W}_{47})\,c^2\right.\\
2\;&\left.(\frac{1}{\lambda_{\mathrm{ZZ}}}\,\mathrm{T}^d_{125}+\mathrm{T}^d_{123}\,\mathrm{V}_9)\right]\frac{1}{c^4}\\
&-\frac{1}{256}\left\{48\,\frac{1}{\lambda_{\mathrm{ZZ}}^2}+\left[12\,\frac{1}{\lambda_{\mathrm{ZZ}}}\,\mathrm{W}_{42}-(6\,\mathrm{W}_9\,c^2\,x_{\mathrm{H}}^2-\mathrm{W}_{44})\,c^2\right]c^2\right\}\frac{1}{c^6}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{Z}}^2\,;M_{\mathrm{H}}\,,M_{\mathrm{Z}}\right)\\
&+\frac{1}{512}\left\{96\,\frac{1}{\lambda_{\mathrm{ZZ}}^2}+\left[24\,\frac{1}{\lambda_{\mathrm{ZZ}}}\,\mathrm{W}_{38}+(-4\,\frac{1}{\lambda_{\mathrm{ZZ}}}\,\mathrm{W}_{40}+17\,\mathrm{W}_9\,c^2)\,c^2\,x_{\mathrm{H}}^2\right]c^2\right\}\frac{1}{c^6}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{H}}\,,M_{\mathrm{H}}\right)\\
&-\frac{1}{512}\left\{192\,\frac{1}{\lambda_{\mathrm{ZZ}}^2}+\left[16\,\frac{1}{\lambda_{\mathrm{ZZ}}}\,\mathrm{W}_{41}-(17\,\mathrm{W}_9\,c^4\,x_{\mathrm{H}}^4-8\,\mathrm{W}_{35}-4\,\mathrm{W}_{43}\,c^2\,x_{\mathrm{H}}^2)\,c^2\right]c^2\right\}\frac{1}{c^8}\\
&\times \mathrm{C}_0\left(-M_{\mathrm{H}}^2\,,-M_{\mathrm{Z}}^2\,,-M_{\mathrm{Z}}^2\,;M_{\mathrm{H}}\,,M_{\mathrm{Z}}\,,M_{\mathrm{H}}\right)\\
&+\frac{1}{128}\left\{12\,\frac{1}{\lambda_{\mathrm{ZZ}}^2}\,\mathrm{T}^d_{124}+\left[(24\,\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{ZZ}}}\,\mathrm{T}^d_{52}+\mathrm{T}^d_{126})\,\frac{1}{\lambda_{\mathrm{ZZ}}}+(2\,\mathrm{T}^d_{52}\,\mathrm{W}_9+5\,\mathrm{T}^d_{113}\,\mathrm{V}_9)\,c^2\right]c^2\right\}\frac{1}{c^6}\\
&\times \mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{W}}\,,M_{\mathrm{W}}\right)\\
&-\frac{1}{128}\left\{12\,\frac{1}{\lambda_{\mathrm{ZZ}}^2}\,\mathrm{T}^d_{124}+\left[(24\,\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{ZZ}}}\,\mathrm{T}^d_{52}+\mathrm{T}^d_{126})\,\frac{1}{\lambda_{\mathrm{ZZ}}}+(2\,\mathrm{T}^d_{52}\,\mathrm{W}_9+5\,\mathrm{T}^d_{113}\,\mathrm{V}_9)\,c^2\right]c^2\right\}\frac{1}{c^6}\\
&\times \mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{Z}}^2\,;M_{\mathrm{W}}\,,M_{\mathrm{W}}\right)\\
&-\frac{1}{128}\left\{12\,\frac{1}{\lambda_{\mathrm{ZZ}}^2}\,\mathrm{T}^d_{124}+\left[(24\,\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{ZZ}}}\,\mathrm{T}^d_{52}+\mathrm{T}^d_{127})\,\frac{1}{\lambda_{\mathrm{ZZ}}}+(2\,\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{ZZ}}}\,\mathrm{T}^d_{115}-5\,\mathrm{T}^d_{116}\,\mathrm{V}_9-2\,\mathrm{T}^d_{122})\,c^2\right]c^2\right\}\frac{1}{c^8}\\
&\times \mathrm{C}_0\left(-M_{\mathrm{H}}^2\,,-M_{\mathrm{Z}}^2\,,-M_{\mathrm{Z}}^2\,;M_{\mathrm{W}}\,,M_{\mathrm{W}}\,,M_{\mathrm{W}}\right)\\
&+\frac{1}{256}\left\{12\left[(3-\mathrm{T}^d_{8}\,\mathrm{v}_{\mathrm{b}})\right]\frac{1}{\lambda_{\mathrm{ZZ}}^2}-\left[(\mathrm{T}^d_{8}\,\mathrm{W}_{18}\,\mathrm{v}_{\mathrm{b}}-3\,\mathrm{W}_{22})+2\,(\mathrm{T}^d_{8}\,\mathrm{W}_{24}\,\mathrm{v}_{\mathrm{b}}-3\,\mathrm{W}_{46})\,c^2\right]c^2\right\}\frac{1}{c^6}\,x_{\mathrm{b}}^2\\
&\times \mathrm{C}_0\left(-M_{\mathrm{H}}^2\,,-M_{\mathrm{Z}}^2\,,-M_{\mathrm{Z}}^2\,;M_{\mathrm{b}}\,,M_{\mathrm{b}}\,,M_{\mathrm{b}}\right)\\
&-\frac{1}{256}\left\{12\left[(3-\mathrm{T}^d_{8}\,\mathrm{v}_{\mathrm{b}})\right]\frac{1}{\lambda_{\mathrm{ZZ}}^2}+(\mathrm{T}^d_{8}\,\mathrm{W}_{18}\,\mathrm{v}_{\mathrm{b}}+3\,\mathrm{W}_{21})\,c^2\right\}\frac{1}{c^4}\,x_{\mathrm{b}}^2\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{b}}\,,M_{\mathrm{b}}\right)\\
&+\frac{1}{256}\left\{12\left[(3-\mathrm{T}^d_{8}\,\mathrm{v}_{\mathrm{b}})\right]\frac{1}{\lambda_{\mathrm{ZZ}}^2}+(\mathrm{T}^d_{8}\,\mathrm{W}_{18}\,\mathrm{v}_{\mathrm{b}}+3\,\mathrm{W}_{21})\,c^2\right\}\frac{1}{c^4}\,x_{\mathrm{b}}^2\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{Z}}^2\,;M_{\mathrm{b}}\,,M_{\mathrm{b}}\right)\\
&+\frac{1}{256}\left\{12\left[(3-\mathrm{T}^d_{9}\,\mathrm{v}_{\mathrm{t}})\right]\frac{1}{\lambda_{\mathrm{ZZ}}^2}-\left[(\mathrm{T}^d_{9}\,\mathrm{W}_{18}\,\mathrm{v}_{\mathrm{t}}-3\,\mathrm{W}_{22})+2\,(\mathrm{T}^d_{9}\,\mathrm{W}_{20}\,\mathrm{v}_{\mathrm{t}}-3\,\mathrm{W}_{23})\,c^2\right]c^2\right\}\frac{1}{c^6}\,x_{\mathrm{t}}^2\\
&\times \mathrm{C}_0\left(-M_{\mathrm{H}}^2\,,-M_{\mathrm{Z}}^2\,,-M_{\mathrm{Z}}^2\,;M_{\mathrm{t}}\,,M_{\mathrm{t}}\,,M_{\mathrm{t}}\right)\\
&-\frac{1}{256}\left\{12\left[(3-\mathrm{T}^d_{9}\,\mathrm{v}_{\mathrm{t}})\right]\frac{1}{\lambda_{\mathrm{ZZ}}^2}+(\mathrm{T}^d_{9}\,\mathrm{W}_{18}\,\mathrm{v}_{\mathrm{t}}+3\,\mathrm{W}_{21})\,c^2\right\}\frac{1}{c^4}\,x_{\mathrm{t}}^2\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{t}}\,,M_{\mathrm{t}}\right)
\end{aligned}
$$

JHEP07(2015)175

$$+\frac{1}{256}\left\{12\left[(3-\mathrm{T}^d_9\,\mathrm{v_t})\right]\frac{1}{\lambda^2_{\mathrm{ZZ}}}+(\mathrm{T}^d_9\,\mathrm{W}_{18}\,\mathrm{v_t}+3\,\mathrm{W}_{21})\,c^2\right\}\frac{1}{c^4}\,x^2_\mathrm{t}\,\mathrm{B}^{\mathrm{fin}}_0\left(-M^2_\mathrm{Z}\,;M_\mathrm{t}\,,M_\mathrm{t}\right)$$
$$-\frac{1}{64}\,(2-3\,c^2\,s\mathrm{W}_9\,x^2_\mathrm{H})\,\frac{1}{c^2}\,a^{\mathrm{fin}}_0\,(M_\mathrm{H})$$
$$-\frac{1}{64}\,(3\,c^2\,s\mathrm{W}_9-2\,\mathrm{V}_9)\,\frac{1}{c^4}\,a^{\mathrm{fin}}_0\,(M_\mathrm{Z})$$

$$\mathscr{T}^{\mathrm{nfc}}_{\mathrm{P;ZZ}}(a_{\mathrm{AZ}})=-\frac{1}{12}\,s\,c\,x^2_\mathrm{b}\,\mathrm{v_b}\,a^{\mathrm{fin}}_0\,(M_\mathrm{b})-\frac{1}{6}\,s\,c\,x^2_\mathrm{t}\,\mathrm{v_t}\,a^{\mathrm{fin}}_0\,(M_\mathrm{t})$$
$$-\frac{1}{24}\,\frac{s}{c}\,\mathrm{v_l}\,\mathrm{B}^{\mathrm{fin}}_0\left(-M^2_\mathrm{Z}\,;0\,,0\right)+\frac{1}{24}\,\frac{s}{c}\,\mathrm{U}_0\,(1-3\,\mathrm{L_R})+\frac{1}{6}\,\mathrm{T}^d_{70}\,s\,c\,a^{\mathrm{fin}}_0\,(M_\mathrm{W})$$
$$-\frac{3}{256}\left[4\,s\mathrm{W}_{51}+(12\,\frac{x^2_\mathrm{H}}{\lambda^2_{\mathrm{ZZ}}}-\mathrm{W}_9\,c^2)\,c^2\,x^2_\mathrm{H}\right]\frac{s}{c^3}\,\mathrm{B}^{\mathrm{fin}}_0\left(-M^2_\mathrm{H}\,;M_\mathrm{Z}\,,M_\mathrm{Z}\right)$$
$$+\frac{3}{256}\left[8\,s\mathrm{W}_{49}-(\mathrm{W}_9\,c^2\,x^2_\mathrm{H}-2\,\mathrm{W}_{50})\,c^2\,x^2_\mathrm{H}\right]\frac{s}{c^3}\,\mathrm{C}_0\left(-M^2_\mathrm{H}\,,-M^2_\mathrm{Z}\,,-M^2_\mathrm{Z}\,;M_\mathrm{Z}\,,M_\mathrm{H}\,,M_\mathrm{Z}\right)$$
$$-\frac{9}{256}\left[24\,\frac{1}{\lambda^2_{\mathrm{ZZ}}}-(12\,\frac{x^2_\mathrm{H}}{\lambda^2_{\mathrm{ZZ}}}-\mathrm{W}_9\,c^2)\,c^2\right]\frac{s}{c^3}\,x^2_\mathrm{H}\,\mathrm{B}^{\mathrm{fin}}_0\left(-M^2_\mathrm{H}\,;M_\mathrm{H}\,,M_\mathrm{H}\right)$$
$$+\frac{3}{128}\left[16\,\frac{1}{\lambda_{\mathrm{ZZ}}}\,s\mathrm{W}_{11}-(\mathrm{W}_9\,c^2\,x^2_\mathrm{H}-4\,\mathrm{W}_{48})\,c^2\right]\frac{s}{c^3}\,\mathrm{B}^{\mathrm{fin}}_0\left(-M^2_\mathrm{Z}\,;M_\mathrm{H}\,,M_\mathrm{Z}\right)$$
$$+\frac{9}{256}\left\{48\,\frac{1}{\lambda^2_{\mathrm{ZZ}}}+\left[8\,\frac{1}{\lambda_{\mathrm{ZZ}}}\,\mathrm{W}_{26}-(\mathrm{W}_9\,c^2\,x^2_\mathrm{H}-4\,\mathrm{W}_{25})\,c^2\right]c^2\right\}\frac{s}{c^5}\,x^2_\mathrm{H}$$
$$\times\mathrm{C}_0\left(-M^2_\mathrm{H}\,,-M^2_\mathrm{Z}\,,-M^2_\mathrm{Z}\,;M_\mathrm{H}\,,M_\mathrm{Z}\,,M_\mathrm{H}\right)$$
$$+\frac{1}{128}\left\{24\,\frac{1}{\lambda^2_{\mathrm{ZZ}}}\,\mathrm{T}^d_{133}+\left[(64\,c^6\,x^2_\mathrm{H}-\frac{x^2_\mathrm{H}}{\lambda_{\mathrm{ZZ}}}\,\mathrm{T}^d_{139}-2\,\mathrm{T}^d_{130}\,\mathrm{V}_9+\mathrm{T}^d_{131})\,c^2\right.\right.$$
$$\left.\left.-2\,(6\,\frac{x^2_\mathrm{H}}{\lambda_{\mathrm{ZZ}}}\,\mathrm{T}^d_{100}-\mathrm{T}^d_{141})\,\frac{1}{\lambda_{\mathrm{ZZ}}}\right]c^2\right\}\frac{s}{c^7}\,\mathrm{C}_0\left(-M^2_\mathrm{H}\,,-M^2_\mathrm{Z}\,,-M^2_\mathrm{Z}\,;M_\mathrm{W}\,,M_\mathrm{W}\,,M_\mathrm{W}\right)$$
$$-\frac{1}{128}\left\{24\,\frac{1}{\lambda^2_{\mathrm{ZZ}}}\,\mathrm{T}^d_{133}-\left[2\,(6\,\frac{x^2_\mathrm{H}}{\lambda_{\mathrm{ZZ}}}\,\mathrm{T}^d_{100}-\mathrm{T}^d_{138})\,\frac{1}{\lambda_{\mathrm{ZZ}}}+(\frac{x^2_\mathrm{H}}{\lambda_{\mathrm{ZZ}}}\,\mathrm{T}^d_{137}+8\,\mathrm{T}^d_7\,c^2\,x^2_\mathrm{H}\right.\right.$$
$$\left.\left.-2\,\mathrm{T}^d_{72}\,\mathrm{V}_9-\mathrm{T}^d_{135})\,c^2\right]c^2\right\}\frac{s}{c^5}\,\mathrm{B}^{\mathrm{fin}}_0\left(-M^2_\mathrm{H}\,;M_\mathrm{W}\,,M_\mathrm{W}\right)$$
$$+\frac{1}{384}\left\{72\,\frac{1}{\lambda^2_{\mathrm{ZZ}}}\,\mathrm{T}^d_{133}+\left[-6\,(6\,\frac{x^2_\mathrm{H}}{\lambda_{\mathrm{ZZ}}}\,\mathrm{T}^d_{100}-\mathrm{T}^d_{138})\,\frac{1}{\lambda_{\mathrm{ZZ}}}\right.\right.$$
$$\left.\left.+(-3\,\frac{x^2_\mathrm{H}}{\lambda_{\mathrm{ZZ}}}\,\mathrm{T}^d_{137}+6\,\mathrm{T}^d_{72}\,\mathrm{V}_9-\mathrm{T}^d_{140})\,c^2\right]c^2\right\}\frac{s}{c^5}\,\mathrm{B}^{\mathrm{fin}}_0\left(-M^2_\mathrm{Z}\,;M_\mathrm{W}\,,M_\mathrm{W}\right)$$
$$-\frac{1}{384}\left\{\left[32\,c^2\,x^2_\mathrm{b}\,\mathrm{v_b}+(16\,\mathrm{v_b}+9\,\frac{x^2_\mathrm{b}}{\lambda_{\mathrm{ZZ}}}\,\mathrm{U}_8-6\,\mathrm{T}^d_{78}\,\mathrm{W}_{18}\,x^2_\mathrm{b}\,\mathrm{v_b}+9\,\mathrm{V}_9\,\mathrm{U}_4\,x^2_\mathrm{b})\right]c^2\right.$$
$$\left.+36\left[(2\,\mathrm{T}^d_{78}\,\mathrm{v_b}+3\,\mathrm{U}_4)\right]\frac{x^2_\mathrm{b}}{\lambda^2_{\mathrm{ZZ}}}\right\}\frac{s}{c^3}\,\mathrm{B}^{\mathrm{fin}}_0\left(-M^2_\mathrm{Z}\,;M_\mathrm{b}\,,M_\mathrm{b}\right)$$
$$-\frac{1}{384}\left\{\left[64\,c^2\,x^2_\mathrm{t}\,\mathrm{v_t}+(32\,\mathrm{v_t}+9\,\frac{x^2_\mathrm{t}}{\lambda_{\mathrm{ZZ}}}\,\mathrm{U}_7-6\,\mathrm{T}^d_{77}\,\mathrm{W}_{18}\,x^2_\mathrm{t}\,\mathrm{v_t}+9\,\mathrm{V}_9\,\mathrm{U}_2\,x^2_\mathrm{t})\right]c^2\right.$$
$$\left.+36\left[(2\,\mathrm{T}^d_{77}\,\mathrm{v_t}+3\,\mathrm{U}_2)\right]\frac{x^2_\mathrm{t}}{\lambda^2_{\mathrm{ZZ}}}\right\}\frac{s}{c^3}\,\mathrm{B}^{\mathrm{fin}}_0\left(-M^2_\mathrm{Z}\,;M_\mathrm{t}\,,M_\mathrm{t}\right)$$
$$-\frac{1}{576}\left\{\left[48\,(x^2_\mathrm{b}\,\mathrm{v_b}+2\,x^2_\mathrm{t}\,\mathrm{v_t})\,c^2-(-9\,\frac{x^2_\mathrm{H}}{\lambda_{\mathrm{ZZ}}}\,\mathrm{T}^d_{134}+18\,\mathrm{T}^d_{77}\,\mathrm{W}_{19}\,x^2_\mathrm{t}\,\mathrm{v_t}\right.\right.$$
$$\left.\left.+18\,\mathrm{T}^d_{78}\,\mathrm{W}_{19}\,x^2_\mathrm{b}\,\mathrm{v_b}-\mathrm{T}^d_{143}+27\,\mathrm{U}_2\,\mathrm{W}_{19}\,x^2_\mathrm{t}+27\,\mathrm{U}_4\,\mathrm{W}_{19}\,x^2_\mathrm{b})\right]c^2+9\,(\frac{1}{\lambda_{\mathrm{ZZ}}}\,\mathrm{T}^d_{136}+\mathrm{T}^d_{132}\,\mathrm{V}_9)\right\}\frac{s}{c^3}$$
$$+\frac{1}{128}\left\{-\left[(-3\,\frac{1}{\lambda_{\mathrm{ZZ}}}\,\mathrm{U}_7+2\,\mathrm{T}^d_{77}\,\mathrm{W}_{18}\,\mathrm{v_t}-3\,\mathrm{V}_9\,\mathrm{U}_2)\right]c^2+12\left[(2\,\mathrm{T}^d_{77}\,\mathrm{v_t}+3\,\mathrm{U}_2)\right]\frac{1}{\lambda^2_{\mathrm{ZZ}}}\right\}\frac{s}{c^3}\,x^2_\mathrm{t}$$

$$\times \mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2 ; M_{\mathrm{t}}, M_{\mathrm{t}}\right)$$
$$+\frac{1}{128}\left\{-\left[(-3 \frac{1}{\lambda_{\mathrm{ZZ}}} \mathrm{U}_8+2 \mathrm{T}_{78}^d \mathrm{W}_{18} \mathrm{v}_{\mathrm{b}}-3 \mathrm{V}_9 \mathrm{U}_4)\right] c^2+12\left[(2 \mathrm{T}_{78}^d \mathrm{v}_{\mathrm{b}}+3 \mathrm{U}_4)\right] \frac{1}{\lambda_{\mathrm{ZZ}}^2}\right\} \frac{s}{c^3} x_{\mathrm{b}}^2$$
$$\times \mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2 ; M_{\mathrm{b}}, M_{\mathrm{b}}\right)$$
$$-\frac{1}{128}\left\{\left[(3 \frac{1}{\lambda_{\mathrm{ZZ}}} \mathrm{U}_9+2 \mathrm{T}_{77}^d \mathrm{W}_{18} \mathrm{v}_{\mathrm{t}}-3 \mathrm{V}_9 \mathrm{U}_2)+2(2 \mathrm{T}_{77}^d \mathrm{W}_{20} \mathrm{v}_{\mathrm{t}}+3 \mathrm{U}_1+6 \mathrm{U}_2 \mathrm{W}_{19} x_{\mathrm{t}}^2) c^2\right] c^2\right.$$
$$\left.+12\left[(2 \mathrm{T}_{77}^d \mathrm{v}_{\mathrm{t}}+3 \mathrm{U}_2)\right] \frac{1}{\lambda_{\mathrm{ZZ}}^2}\right\} \frac{s}{c^5} x_{\mathrm{t}}^2 \mathrm{C}_0\left(-M_{\mathrm{H}}^2,-M_{\mathrm{Z}}^2,-M_{\mathrm{Z}}^2 ; M_{\mathrm{t}}, M_{\mathrm{t}}, M_{\mathrm{t}}\right)$$
$$-\frac{1}{128}\left\{\left[(3 \frac{1}{\lambda_{\mathrm{ZZ}}} \mathrm{U}_{10}+2 \mathrm{T}_{78}^d \mathrm{W}_{18} \mathrm{v}_{\mathrm{b}}-3 \mathrm{V}_9 \mathrm{U}_4)+2(2 \mathrm{T}_{78}^d \mathrm{W}_{24} \mathrm{v}_{\mathrm{b}}+3 \mathrm{U}_3+6 \mathrm{U}_4 \mathrm{W}_{19} x_{\mathrm{b}}^2) c^2\right] c^2\right.$$
$$\left.+12\left[(2 \mathrm{T}_{78}^d \mathrm{v}_{\mathrm{b}}+3 \mathrm{U}_4)\right] \frac{1}{\lambda_{\mathrm{ZZ}}^2}\right\} \frac{s}{c^5} x_{\mathrm{b}}^2 \mathrm{C}_0\left(-M_{\mathrm{H}}^2,-M_{\mathrm{Z}}^2,-M_{\mathrm{Z}}^2 ; M_{\mathrm{b}}, M_{\mathrm{b}}, M_{\mathrm{b}}\right)$$
$$+\frac{3}{64}(1-c^2 x_{\mathrm{H}}^2) \frac{s}{c} \mathrm{W}_9 a_0^{\mathrm{fin}}(M_{\mathrm{H}})$$
$$+\frac{3}{64}(s \mathrm{W}_{18}+c^2 s \mathrm{W}_9) \frac{s}{c^3} a_0^{\mathrm{fin}}(M_{\mathrm{Z}})$$
$$+\frac{1}{48}(3 \mathrm{T}_7^d c^2 x_{\mathrm{H}}^2+\mathrm{T}_{142}^d) \frac{s}{c} \mathrm{L}_{\mathrm{R}}$$

$$\mathscr{T}_{\mathrm{P;ZZ}}^{\mathrm{nfc}}(a_{\mathrm{AA}})=\frac{1}{32}\left\{12 \frac{1}{\lambda_{\mathrm{ZZ}}^2} \mathrm{T}_{150}^d-\left[2(2 c^2 x_{\mathrm{H}}^2+\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{ZZ}}} \mathrm{T}_{38}^d-\mathrm{T}_{144}^d) c^2+(24 \frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{ZZ}}^2} \mathrm{T}_7^d\right.\right.$$
$$\left.\left.-\frac{1}{\lambda_{\mathrm{ZZ}}} \mathrm{T}_{148}^d+\mathrm{T}_{145}^d \mathrm{V}_9)\right] c^2\right\} \frac{s^2}{c^4} \mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2 ; M_{\mathrm{W}}, M_{\mathrm{W}}\right)$$
$$-\frac{1}{32}\left\{12 \frac{1}{\lambda_{\mathrm{ZZ}}^2} \mathrm{T}_{150}^d-\left[2(8 c^4 x_{\mathrm{H}}^2+\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{ZZ}}} \mathrm{T}_{154}^d+\mathrm{T}_{151}^d) c^2+(24 \frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{ZZ}}^2} \mathrm{T}_7^d\right.\right.$$
$$\left.\left.-\frac{1}{\lambda_{\mathrm{ZZ}}} \mathrm{T}_{155}^d-\mathrm{T}_{147}^d \mathrm{V}_9)\right] c^2\right\} \frac{s^2}{c^6} \mathrm{C}_0\left(-M_{\mathrm{H}}^2,-M_{\mathrm{Z}}^2,-M_{\mathrm{Z}}^2 ; M_{\mathrm{W}}, M_{\mathrm{W}}, M_{\mathrm{W}}\right)$$
$$-\frac{1}{32}\left\{12 \frac{1}{\lambda_{\mathrm{ZZ}}^2} \mathrm{T}_{150}^d-\left[(24 \frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{ZZ}}^2} \mathrm{T}_7^d-\frac{1}{\lambda_{\mathrm{ZZ}}} \mathrm{T}_{148}^d+\mathrm{T}_{145}^d \mathrm{V}_9)+2(\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{ZZ}}} \mathrm{T}_{38}^d+\mathrm{T}_{149}^d) c^2\right] c^2\right\} \frac{s^2}{c^4}$$
$$\times \mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{Z}}^2 ; M_{\mathrm{W}}, M_{\mathrm{W}}\right)$$
$$-\frac{1}{32}\left\{8 \mathrm{T}_{29}^d c^4+\left[4 \frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{ZZ}}} \mathrm{T}_7^d c^2+(\mathrm{T}_8^d \mathrm{W}_{19} x_{\mathrm{b}}^2 \mathrm{v}_{\mathrm{b}}+\mathrm{T}_9^d \mathrm{W}_{19} x_{\mathrm{t}}^2 \mathrm{v}_{\mathrm{t}}-3 \mathrm{W}_{47})\right] s^2\right.$$
$$\left.+2(-\frac{1}{\lambda_{\mathrm{ZZ}}} \mathrm{T}_{152}^d+\mathrm{T}_{146}^d \mathrm{V}_9)\right\} \frac{1}{c^2}$$
$$-\frac{1}{64}\left\{12\left[(3-\mathrm{T}_8^d \mathrm{v}_{\mathrm{b}})\right] \frac{1}{\lambda_{\mathrm{ZZ}}^2}-\left[(\mathrm{T}_8^d \mathrm{W}_{18} \mathrm{v}_{\mathrm{b}}-3 \mathrm{W}_{22})+2(\mathrm{T}_8^d \mathrm{W}_{24} \mathrm{v}_{\mathrm{b}}-3 \mathrm{W}_{46}) c^2\right] c^2\right\} \frac{s^2}{c^6} x_{\mathrm{b}}^2$$
$$\times \mathrm{C}_0\left(-M_{\mathrm{H}}^2,-M_{\mathrm{Z}}^2,-M_{\mathrm{Z}}^2 ; M_{\mathrm{b}}, M_{\mathrm{b}}, M_{\mathrm{b}}\right)$$
$$+\frac{1}{64}\left\{12\left[(3-\mathrm{T}_8^d \mathrm{v}_{\mathrm{b}})\right] \frac{1}{\lambda_{\mathrm{ZZ}}^2}+(\mathrm{T}_8^d \mathrm{W}_{18} \mathrm{v}_{\mathrm{b}}+3 \mathrm{W}_{21}) c^2\right\} \frac{s^2}{c^4} x_{\mathrm{b}}^2 \mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2 ; M_{\mathrm{b}}, M_{\mathrm{b}}\right)$$
$$-\frac{1}{64}\left\{12\left[(3-\mathrm{T}_8^d \mathrm{v}_{\mathrm{b}})\right] \frac{1}{\lambda_{\mathrm{ZZ}}^2}+(\mathrm{T}_8^d \mathrm{W}_{18} \mathrm{v}_{\mathrm{b}}+3 \mathrm{W}_{21}) c^2\right\} \frac{s^2}{c^4} x_{\mathrm{b}}^2 \mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{Z}}^2 ; M_{\mathrm{b}}, M_{\mathrm{b}}\right)$$
$$-\frac{1}{64}\left\{12\left[(3-\mathrm{T}_9^d \mathrm{v}_{\mathrm{t}})\right] \frac{1}{\lambda_{\mathrm{ZZ}}^2}-\left[(\mathrm{T}_9^d \mathrm{W}_{18} \mathrm{v}_{\mathrm{t}}-3 \mathrm{W}_{22})+2(\mathrm{T}_9^d \mathrm{W}_{20} \mathrm{v}_{\mathrm{t}}-3 \mathrm{W}_{23}) c^2\right] c^2\right\} \frac{s^2}{c^6} x_{\mathrm{t}}^2$$
$$\times \mathrm{C}_0\left(-M_{\mathrm{H}}^2,-M_{\mathrm{Z}}^2,-M_{\mathrm{Z}}^2 ; M_{\mathrm{t}}, M_{\mathrm{t}}, M_{\mathrm{t}}\right)$$
$$+\frac{1}{64}\left\{12\left[(3-\mathrm{T}_9^d \mathrm{v}_{\mathrm{t}})\right] \frac{1}{\lambda_{\mathrm{ZZ}}^2}+(\mathrm{T}_9^d \mathrm{W}_{18} \mathrm{v}_{\mathrm{t}}+3 \mathrm{W}_{21}) c^2\right\} \frac{s^2}{c^4} x_{\mathrm{t}}^2 \mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2 ; M_{\mathrm{t}}, M_{\mathrm{t}}\right)$$

$$-\frac{1}{64}\left\{12\left[(3-\mathrm{T}^d_9\,\mathrm{v_t})\right]\frac{1}{\lambda^2_{\mathrm{ZZ}}}+(\mathrm{T}^d_9\,\mathrm{W}_{18}\,\mathrm{v_t}+3\,\mathrm{W}_{21})\,c^2\right\}\frac{s^2}{c^4}\,x_\mathrm{t}^2\,\mathrm{B}_0^{\mathrm{fin}}\left(-M^2_\mathrm{Z}\,;M_\mathrm{t}\,,M_\mathrm{t}\right)$$

$$-\frac{1}{8}\,(c^2\,x^2_{\mathrm{H}}-2\,\mathrm{T}^d_{153})\,s^2\,\mathrm{L_R}$$

$$\mathscr{T}^{\mathrm{nfc}}_{\mathrm{P;ZZ}}(a_{\mathrm{ZZ}})=-\frac{1}{64}\,\mathrm{X}_{16}$$

$$+\frac{3}{256}\left\{24\,\frac{1}{\lambda^2_{\mathrm{ZZ}}}\,\mathrm{T}^d_{167}+\left[4\,(8-3\,\frac{x^2_\mathrm{H}}{\lambda_{\mathrm{ZZ}}}\,\mathrm{T}^d_{167})\,\frac{1}{\lambda_{\mathrm{ZZ}}}+(-\frac{x^2_\mathrm{H}}{\lambda_{\mathrm{ZZ}}}\,\mathrm{T}^d_{167}+3\,\mathrm{T}^d_{64})\,c^2\right]c^2\right\}\frac{1}{c^4}\,x^2_\mathrm{H}$$

$$\times\mathrm{B}_0^{\mathrm{fin}}\left(-M^2_\mathrm{H}\,;M_\mathrm{H}\,,M_\mathrm{H}\right)$$

$$-\frac{3}{256}\left\{48\,\frac{1}{\lambda^2_{\mathrm{ZZ}}}\,\mathrm{T}^d_{167}+\left[-(12\,\frac{x^2_\mathrm{H}}{\lambda_{\mathrm{ZZ}}}\,\mathrm{T}^d_{163}+\mathrm{T}^d_{167}\,\mathrm{W}_9\,c^2\,x^2_\mathrm{H}-4\,\mathrm{T}^d_{167}\,\mathrm{W}_{53})\,c^2\right.\right.$$

$$\left.\left.+24\,(-2\,\frac{x^2_\mathrm{H}}{\lambda_{\mathrm{ZZ}}}\,\mathrm{T}^d_{167}+\mathrm{T}^d_{163})\,\frac{1}{\lambda_{\mathrm{ZZ}}}\right]c^2\right\}\frac{1}{c^6}\,x^2_\mathrm{H}\,\mathrm{C}_0\left(-M^2_\mathrm{H}\,,-M^2_\mathrm{Z}\,,-M^2_\mathrm{Z}\,;M_\mathrm{H}\,,M_\mathrm{Z}\,,M_\mathrm{H}\right)$$

$$-\frac{1}{64}\left\{\mathrm{T}^d_{164}+\left[(\frac{x^2_\mathrm{H}}{\lambda_{\mathrm{ZZ}}}\,\mathrm{T}^d_{167}+3\,\frac{1}{\lambda_{\mathrm{ZZ}}}-\mathrm{T}^d_{177})\right]c^2\,x^2_\mathrm{H}\right\}\frac{1}{c^2}\,a_0^{\mathrm{fin}}\left(M_\mathrm{H}\right)$$

$$+\frac{1}{64}\left\{\mathrm{T}^d_{164}\,\mathrm{V}_9+\left[(\frac{x^2_\mathrm{H}}{\lambda_{\mathrm{ZZ}}}\,\mathrm{T}^d_{167}+3\,\frac{1}{\lambda_{\mathrm{ZZ}}}-\mathrm{T}^d_{177})\right]c^2\right\}\frac{1}{c^4}\,a_0^{\mathrm{fin}}\left(M_\mathrm{Z}\right)$$

$$+\frac{1}{64}\left\{\mathrm{T}^d_{165}\,\mathrm{V}_9+\left[(\frac{x^2_\mathrm{H}}{\lambda_{\mathrm{ZZ}}}\,\mathrm{T}^d_{179}+\frac{1}{\lambda_{\mathrm{ZZ}}}\,\mathrm{T}^d_{157}+2\,\mathrm{T}^d_{176})+(2\,\mathrm{T}^d_{42}\,\mathrm{W}_{19}\,x^2_\mathrm{t}\,\mathrm{v_t}\right.\right.$$

$$\left.\left.+2\,\mathrm{T}^d_{112}\,\mathrm{W}_{19}\,x^2_\mathrm{b}\,\mathrm{v_b}+3\,\mathrm{U}_2\,\mathrm{W}_{19}\,x^2_\mathrm{t}+3\,\mathrm{U}_4\,\mathrm{W}_{19}\,x^2_\mathrm{b})\,c^2\right]c^2\right\}\frac{1}{c^4}$$

$$+\frac{1}{128}\left\{\left[64\,c^8\,x^2_\mathrm{H}-(\frac{x^2_\mathrm{H}}{\lambda_{\mathrm{ZZ}}}\,\mathrm{T}^d_{171}+2\,\frac{1}{\lambda_{\mathrm{ZZ}}}\,\mathrm{T}^d_{182}-\mathrm{T}^d_{174}-2\,\mathrm{T}^d_{175}\,\mathrm{V}_9)\right]c^2\right.$$

$$\left.-12\left[(2\,\mathrm{T}^d_{158}+\mathrm{T}^d_{169}\,x^2_\mathrm{H})\right]\frac{1}{\lambda^2_{\mathrm{ZZ}}}\right\}\frac{1}{c^6}\,\mathrm{C}_0\left(-M^2_\mathrm{H}\,,-M^2_\mathrm{Z}\,,-M^2_\mathrm{Z}\,;M_\mathrm{W}\,,M_\mathrm{W}\,,M_\mathrm{W}\right)$$

$$-\frac{1}{128}\left\{\left[4\,\mathrm{T}^d_{100}\,c^2\,x^2_\mathrm{H}-(-\frac{x^2_\mathrm{H}}{\lambda_{\mathrm{ZZ}}}\,\mathrm{T}^d_{173}+2\,\frac{1}{\lambda_{\mathrm{ZZ}}}\,\mathrm{T}^d_{181}+2\,\mathrm{T}^d_{170}\,\mathrm{V}_9+\mathrm{T}^d_{172})\right]c^2\right.$$

$$\left.-12\left[(2\,\mathrm{T}^d_{158}+\mathrm{T}^d_{169}\,x^2_\mathrm{H})\right]\frac{1}{\lambda^2_{\mathrm{ZZ}}}\right\}\frac{1}{c^4}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M^2_\mathrm{H}\,;M_\mathrm{W}\,,M_\mathrm{W}\right)$$

$$-\frac{1}{256}\left\{-\left[\mathrm{T}^d_{167}\,\mathrm{W}_9\,c^2\,x^2_\mathrm{H}+2\,(36\,\frac{x^2_\mathrm{H}}{\lambda^2_{\mathrm{ZZ}}}-6\,\frac{x^2_\mathrm{H}}{\lambda^2_{\mathrm{ZZ}}}\,\mathrm{T}^d_{167}\,x^2_\mathrm{H}-3\,\frac{x^2_\mathrm{H}}{\lambda_{\mathrm{ZZ}}}\,\mathrm{T}^d_{159}+\mathrm{T}^d_{160})\right]c^2\,x^2_\mathrm{H}\right.$$

$$\left.+8\,(\frac{x^2_\mathrm{H}}{\lambda_{\mathrm{ZZ}}}\,\mathrm{T}^d_{178}+\mathrm{T}^d_{159})\right\}\frac{1}{c^4}\,\mathrm{C}_0\left(-M^2_\mathrm{H}\,,-M^2_\mathrm{Z}\,,-M^2_\mathrm{Z}\,;M_\mathrm{Z}\,,M_\mathrm{H}\,,M_\mathrm{Z}\right)$$

$$-\frac{1}{128}\left\{\left[2\,(-6\,\frac{x^2_\mathrm{H}}{\lambda^2_{\mathrm{ZZ}}}\,\mathrm{T}^d_{167}\,x^2_\mathrm{H}+\frac{x^2_\mathrm{H}}{\lambda_{\mathrm{ZZ}}}\,\mathrm{T}^d_{162}+3\,\mathrm{T}^d_{166})-(-\frac{x^2_\mathrm{H}}{\lambda_{\mathrm{ZZ}}}\,\mathrm{T}^d_{167}+3\,\mathrm{T}^d_{163})\,c^2\,x^2_\mathrm{H}\right]c^2\right.$$

$$\left.+8\left[(9\,\frac{x^2_\mathrm{H}}{\lambda_{\mathrm{ZZ}}}\,\mathrm{T}^d_{161}+2\,\mathrm{T}^d_{159})\right]\frac{1}{\lambda_{\mathrm{ZZ}}}\right\}\frac{1}{c^4}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M^2_\mathrm{Z}\,;M_\mathrm{H}\,,M_\mathrm{Z}\right)$$

$$+\frac{1}{256}\left\{\left[12\,(\frac{x^2_\mathrm{H}}{\lambda^2_{\mathrm{ZZ}}}\,\mathrm{T}^d_{167}\,x^2_\mathrm{H}-\mathrm{W}_{52})+(\frac{x^2_\mathrm{H}}{\lambda_{\mathrm{ZZ}}}\,\mathrm{T}^d_{167}-\mathrm{T}^d_{177})\,c^2\,x^2_\mathrm{H}\right]c^2+4\,(\frac{1}{\lambda_{\mathrm{ZZ}}}\,\mathrm{T}^d_{180}+\mathrm{T}^d_{164}\,\mathrm{V}_9)\right\}\frac{1}{c^4}$$

$$\times\mathrm{B}_0^{\mathrm{fin}}\left(-M^2_\mathrm{H}\,;M_\mathrm{Z}\,,M_\mathrm{Z}\right)$$

$$+\frac{1}{128}\left\{-\left[(-3\,\frac{1}{\lambda_{\mathrm{ZZ}}}\,\mathrm{U}_7+2\,\mathrm{T}^d_{42}\,\mathrm{W}_{18}\,\mathrm{v_t}-3\,\mathrm{V}_9\,\mathrm{U}_2)\right]c^2+12\left[(2\,\mathrm{T}^d_{42}\,\mathrm{v_t}+3\,\mathrm{U}_2)\right]\frac{1}{\lambda^2_{\mathrm{ZZ}}}\right\}\frac{1}{c^2}\,x^2_\mathrm{t}$$

$$\times\mathrm{B}_0^{\mathrm{fin}}\left(-M^2_\mathrm{H}\,;M_\mathrm{t}\,,M_\mathrm{t}\right)$$

$$-\frac{1}{128}\left\{-\left[(-3\,\frac{1}{\lambda_{\mathrm{ZZ}}}\,\mathrm{U}_7+2\,\mathrm{T}^d_{42}\,\mathrm{W}_{18}\,\mathrm{v_t}-3\,\mathrm{V}_9\,\mathrm{U}_2)\right]c^2+12\left[(2\,\mathrm{T}^d_{42}\,\mathrm{v_t}+3\,\mathrm{U}_2)\right]\frac{1}{\lambda^2_{\mathrm{ZZ}}}\right\}\frac{1}{c^2}\,x^2_\mathrm{t}$$

$$
\begin{aligned}
&\times \mathrm{B}_0^{\mathrm{fin}}\Big(-M_{\mathrm{Z}}^2\,;M_{\mathrm{t}}\,,M_{\mathrm{t}}\Big)\\
&+\frac{1}{128}\Big\{-\Big[(-3\,\frac{1}{\lambda_{\mathrm{ZZ}}}\,\mathrm{U}_8+2\,\mathrm{T}^d_{112}\,\mathrm{W}_{18}\,\mathrm{v}_{\mathrm{b}}-3\,\mathrm{V}_9\,\mathrm{U}_4)\Big]\,c^2+12\,\Big[(2\,\mathrm{T}^d_{112}\,\mathrm{v}_{\mathrm{b}}+3\,\mathrm{U}_4)\Big]\,\frac{1}{\lambda^2_{\mathrm{ZZ}}}\Big\}\,\frac{1}{c^2}\,x_{\mathrm{b}}^2\\
&\times \mathrm{B}_0^{\mathrm{fin}}\Big(-M_{\mathrm{H}}^2\,;M_{\mathrm{b}}\,,M_{\mathrm{b}}\Big)\\
&-\frac{1}{128}\Big\{-\Big[(-3\,\frac{1}{\lambda_{\mathrm{ZZ}}}\,\mathrm{U}_8+2\,\mathrm{T}^d_{112}\,\mathrm{W}_{18}\,\mathrm{v}_{\mathrm{b}}-3\,\mathrm{V}_9\,\mathrm{U}_4)\Big]\,c^2+12\,\Big[(2\,\mathrm{T}^d_{112}\,\mathrm{v}_{\mathrm{b}}+3\,\mathrm{U}_4)\Big]\,\frac{1}{\lambda^2_{\mathrm{ZZ}}}\Big\}\,\frac{1}{c^2}\,x_{\mathrm{b}}^2\\
&\times \mathrm{B}_0^{\mathrm{fin}}\Big(-M_{\mathrm{Z}}^2\,;M_{\mathrm{b}}\,,M_{\mathrm{b}}\Big)\\
&-\frac{1}{128}\Big\{\Big[(3\,\frac{1}{\lambda_{\mathrm{ZZ}}}\,\mathrm{U}_9+2\,\mathrm{T}^d_{42}\,\mathrm{W}_{18}\,\mathrm{v}_{\mathrm{t}}-3\,\mathrm{V}_9\,\mathrm{U}_2)+2\,(2\,\mathrm{T}^d_{42}\,\mathrm{W}_{20}\,\mathrm{v}_{\mathrm{t}}+3\,\mathrm{U}_1+6\,\mathrm{U}_2\,\mathrm{W}_{19}\,x_{\mathrm{t}}^2)\,c^2\Big]\,c^2\\
&+12\,\Big[(2\,\mathrm{T}^d_{42}\,\mathrm{v}_{\mathrm{t}}+3\,\mathrm{U}_2)\Big]\,\frac{1}{\lambda^2_{\mathrm{ZZ}}}\Big\}\,\frac{1}{c^4}\,x_{\mathrm{t}}^2\,\mathrm{C}_0\Big(-M_{\mathrm{H}}^2\,,-M_{\mathrm{Z}}^2\,,-M_{\mathrm{Z}}^2\,;M_{\mathrm{t}}\,,M_{\mathrm{t}}\,,M_{\mathrm{t}}\Big)\\
&-\frac{1}{128}\Big\{\Big[(3\,\frac{1}{\lambda_{\mathrm{ZZ}}}\,\mathrm{U}_{10}+2\,\mathrm{T}^d_{112}\,\mathrm{W}_{18}\,\mathrm{v}_{\mathrm{b}}-3\,\mathrm{V}_9\,\mathrm{U}_4)+2\,(2\,\mathrm{T}^d_{112}\,\mathrm{W}_{24}\,\mathrm{v}_{\mathrm{b}}+3\,\mathrm{U}_3+6\,\mathrm{U}_4\,\mathrm{W}_{19}\,x_{\mathrm{b}}^2)\,c^2\Big]\,c^2\\
&+12\,\Big[(2\,\mathrm{T}^d_{112}\,\mathrm{v}_{\mathrm{b}}+3\,\mathrm{U}_4)\Big]\,\frac{1}{\lambda^2_{\mathrm{ZZ}}}\Big\}\,\frac{1}{c^4}\,x_{\mathrm{b}}^2\,\mathrm{C}_0\Big(-M_{\mathrm{H}}^2\,,-M_{\mathrm{Z}}^2\,,-M_{\mathrm{Z}}^2\,;M_{\mathrm{b}}\,,M_{\mathrm{b}}\,,M_{\mathrm{b}}\Big)\\
&-\frac{1}{128}\Big\{12\,\Big[(2\,\mathrm{T}^d_{158}+\mathrm{T}^d_{169}\,x_{\mathrm{H}}^2)\Big]\,\frac{1}{\lambda^2_{\mathrm{ZZ}}}+(-\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{ZZ}}}\,\mathrm{T}^d_{173}+2\,\frac{1}{\lambda_{\mathrm{ZZ}}}\,\mathrm{T}^d_{181}+\mathrm{T}^d_{168}+2\,\mathrm{T}^d_{170}\,\mathrm{V}_9)\,c^2,rc)\,\frac{1}{c^4}\\
&\times \mathrm{B}_0^{\mathrm{fin}}\Big(-M_{\mathrm{Z}}^2\,;M_{\mathrm{W}}\,,M_{\mathrm{W}}\Big)\\
&-\frac{1}{32}\,(\mathrm{T}^d_{108}\,c^2\,x_{\mathrm{H}}^2+4\,\mathrm{T}^d_{156})\,\frac{1}{c^2}\,\mathrm{L_R}
\end{aligned}
$$

- HWW Amplitudes

$$
\begin{aligned}
\mathscr{T}^{\mathrm{nfc}}_{\mathrm{D;WW}}(a_{\phi\,\mathrm{t\,V}}) = {}&\frac{1}{32}\,\mathrm{X}_{17}-\frac{1}{16}\,\mathrm{V}_6-\frac{3}{32}\,\mathrm{V}_{14}\,\mathrm{L_R}\\
&-\frac{1}{32}\,\mathrm{V}_{15}\,x_{\mathrm{b}}^2\,a_0^{\mathrm{fin}}\left(M_{\mathrm{b}}\right)-\frac{1}{32}\,\mathrm{V}_{16}\,x_{\mathrm{t}}^2\,a_0^{\mathrm{fin}}\left(M_{\mathrm{t}}\right)-\frac{1}{32}\,\mathrm{V}_{17}\,\mathrm{B}_0^{\mathrm{fin}}\Big(-M_{\mathrm{W}}^2\,;M_{\mathrm{t}}\,,M_{\mathrm{b}}\Big)
\end{aligned}
$$

$$
\begin{aligned}
\mathscr{T}^{\mathrm{nfc}}_{\mathrm{D;WW}}(a_{\phi\,\mathrm{t\,A}}) = {}&\frac{1}{32}\,\mathrm{X}_{17}-\frac{1}{16}\,\mathrm{V}_6-\frac{3}{32}\,\mathrm{V}_{14}\,\mathrm{L_R}\\
&-\frac{1}{32}\,\mathrm{V}_{15}\,x_{\mathrm{b}}^2\,a_0^{\mathrm{fin}}\left(M_{\mathrm{b}}\right)-\frac{1}{32}\,\mathrm{V}_{16}\,x_{\mathrm{t}}^2\,a_0^{\mathrm{fin}}\left(M_{\mathrm{t}}\right)-\frac{1}{32}\,\mathrm{V}_{17}\,\mathrm{B}_0^{\mathrm{fin}}\Big(-M_{\mathrm{W}}^2\,;M_{\mathrm{t}}\,,M_{\mathrm{b}}\Big)
\end{aligned}
$$

$$
\begin{aligned}
\mathscr{T}^{\mathrm{nfc}}_{\mathrm{D;WW}}(a_{\phi\,\mathrm{b\,V}}) = {}&\frac{1}{32}\,\mathrm{X}_{17}-\frac{1}{16}\,\mathrm{V}_6-\frac{3}{32}\,\mathrm{V}_{14}\,\mathrm{L_R}\\
&-\frac{1}{32}\,\mathrm{V}_{15}\,x_{\mathrm{b}}^2\,a_0^{\mathrm{fin}}\left(M_{\mathrm{b}}\right)-\frac{1}{32}\,\mathrm{V}_{16}\,x_{\mathrm{t}}^2\,a_0^{\mathrm{fin}}\left(M_{\mathrm{t}}\right)-\frac{1}{32}\,\mathrm{V}_{17}\,\mathrm{B}_0^{\mathrm{fin}}\Big(-M_{\mathrm{W}}^2\,;M_{\mathrm{t}}\,,M_{\mathrm{b}}\Big)
\end{aligned}
$$

$$
\begin{aligned}
\mathscr{T}^{\mathrm{nfc}}_{\mathrm{D;WW}}(a_{\phi\,\mathrm{b\,A}}) = {}&\frac{1}{32}\,\mathrm{X}_{17}-\frac{1}{16}\,\mathrm{V}_6-\frac{3}{32}\,\mathrm{V}_{14}\,\mathrm{L_R}\\
&-\frac{1}{32}\,\mathrm{V}_{15}\,x_{\mathrm{b}}^2\,a_0^{\mathrm{fin}}\left(M_{\mathrm{b}}\right)-\frac{1}{32}\,\mathrm{V}_{16}\,x_{\mathrm{t}}^2\,a_0^{\mathrm{fin}}\left(M_{\mathrm{t}}\right)-\frac{1}{32}\,\mathrm{V}_{17}\,\mathrm{B}_0^{\mathrm{fin}}\Big(-M_{\mathrm{W}}^2\,;M_{\mathrm{t}}\,,M_{\mathrm{b}}\Big)
\end{aligned}
$$

$$
\mathscr{T}^{\mathrm{nfc}}_{\mathrm{D;WW}}(a_{\phi\mathrm{V}}) = -\frac{1}{16}\,\mathrm{B}_0^{\mathrm{fin}}\Big(-M_{\mathrm{W}}^2\,;0\,,0\Big)+\frac{1}{48}\,(1-3\,\mathrm{L_R})
$$

$$
\mathscr{T}^{\mathrm{nfc}}_{\mathrm{D;WW}}(a_{\phi 1\mathrm{V}}) = -\frac{1}{16}\,\mathrm{B}_0^{\mathrm{fin}}\Big(-M_{\mathrm{W}}^2\,;0\,,0\Big)+\frac{1}{48}\,(1-3\,\mathrm{L_R})
$$

$$\mathscr{T}^{\rm nfc}_{\rm D;WW}(a_{\phi 1 \rm A}) = -\frac{1}{16}\,{\rm B}_0^{\rm fin}\left(-M^2_{\rm W}\,;0\,,0\right) + \frac{1}{48}\,(1-3\,{\rm L_R})$$

$$\begin{aligned}\mathscr{T}^{\rm nfc}_{\rm D;WW}(a_{\rm t\,\phi}) = {}& \frac{3}{32}\,x_{\rm t}^2\,(1-{\rm L_R})\\ &+\frac{3}{16}\,\frac{x_{\rm t}^2}{\lambda_{\rm WW}}\,{\rm V}_{18}\,{\rm B}_0^{\rm fin}\left(-M^2_{\rm H}\,;M_{\rm t}\,,M_{\rm t}\right)\\ &-\frac{3}{32}\,{\rm W}_{54}\,x_{\rm t}^2\,{\rm B}_0^{\rm fin}\left(-M^2_{\rm W}\,;M_{\rm t}\,,M_{\rm b}\right)\\ &-\frac{3}{32}\,{\rm W}_{55}\,x_{\rm t}^2\,{\rm C}_0\left(-M^2_{\rm H}\,,-M^2_{\rm W}\,,-M^2_{\rm W}\,;M_{\rm t}\,,M_{\rm b}\,,M_{\rm t}\right)\end{aligned}$$

$$\begin{aligned}\mathscr{T}^{\rm nfc}_{\rm D;WW}(a_{\rm b\,\phi}) = {}& -\frac{1}{32}\,{\rm X}_{18} + \frac{3}{32}\,x_{\rm t}^2\,(1-{\rm L_R})\\ &+\frac{3}{16}\,\frac{x_{\rm t}^2}{\lambda_{\rm WW}}\,{\rm V}_{18}\,{\rm B}_0^{\rm fin}\left(-M^2_{\rm H}\,;M_{\rm t}\,,M_{\rm t}\right)\\ &-\frac{3}{32}\,{\rm W}_{54}\,x_{\rm t}^2\,{\rm B}_0^{\rm fin}\left(-M^2_{\rm W}\,;M_{\rm t}\,,M_{\rm b}\right)\\ &-\frac{3}{32}\,{\rm W}_{55}\,x_{\rm t}^2\,{\rm C}_0\left(-M^2_{\rm H}\,,-M^2_{\rm W}\,,-M^2_{\rm W}\,;M_{\rm t}\,,M_{\rm b}\,,M_{\rm t}\right)\end{aligned}$$

$$\begin{aligned}\mathscr{T}^{\rm nfc}_{\rm D;WW}(a_{\rm t\,BW}) = {}& -\frac{3}{128}\,c\,x_{\rm H}^2\,x_{\rm t}^2\\ &-\frac{3}{128}\,c\,x_{\rm H}^2\,x_{\rm t}^2\,x_{\rm b}^2\,a_0^{\rm fin}\left(M_{\rm b}\right) + \frac{3}{128}\,c\,x_{\rm H}^2\,x_{\rm t}^4\,a_0^{\rm fin}\left(M_{\rm t}\right)\\ &+\frac{3}{32}\,c\,x_{\rm t}^2\,x_{\rm b}^2\,{\rm B}_0^{\rm fin}\left(-M^2_{\rm H}\,;M_{\rm b}\,,M_{\rm b}\right)\\ &+\frac{3}{64}\,{\rm V}_{22}\,c\,x_{\rm t}^2\,x_{\rm b}^2\,{\rm C}_0\left(-M^2_{\rm H}\,,-M^2_{\rm W}\,,-M^2_{\rm W}\,;M_{\rm b}\,,M_{\rm t}\,,M_{\rm b}\right)\\ &+\frac{3}{128}\,{\rm W}_{56}\,c\,x_{\rm t}^2\,{\rm B}_0^{\rm fin}\left(-M^2_{\rm W}\,;M_{\rm t}\,,M_{\rm b}\right)\\ &-\frac{3}{128}\,{\rm W}_{57}\,c\,x_{\rm t}^2\,{\rm B}_0^{\rm fin}\left(-M^2_{\rm H}\,;M_{\rm t}\,,M_{\rm t}\right)\\ &+\frac{3}{64}\,{\rm W}_{58}\,c\,x_{\rm t}^2\,{\rm C}_0\left(-M^2_{\rm H}\,,-M^2_{\rm W}\,,-M^2_{\rm W}\,;M_{\rm t}\,,M_{\rm b}\,,M_{\rm t}\right)\end{aligned}$$

$$\begin{aligned}\mathscr{T}^{\rm nfc}_{\rm D;WW}(a_{\rm t\,WB}) = {}& -\frac{3}{128}\,s\,x_{\rm H}^2\,x_{\rm t}^2\\ &-\frac{3}{128}\,s\,x_{\rm H}^2\,x_{\rm t}^2\,x_{\rm b}^2\,a_0^{\rm fin}\left(M_{\rm b}\right) + \frac{3}{128}\,s\,x_{\rm H}^2\,x_{\rm t}^4\,a_0^{\rm fin}\left(M_{\rm t}\right)\\ &+\frac{3}{32}\,s\,x_{\rm t}^2\,x_{\rm b}^2\,{\rm B}_0^{\rm fin}\left(-M^2_{\rm H}\,;M_{\rm b}\,,M_{\rm b}\right)\\ &+\frac{3}{64}\,{\rm V}_{22}\,s\,x_{\rm t}^2\,x_{\rm b}^2\,{\rm C}_0\left(-M^2_{\rm H}\,,-M^2_{\rm W}\,,-M^2_{\rm W}\,;M_{\rm b}\,,M_{\rm t}\,,M_{\rm b}\right)\\ &+\frac{3}{128}\,{\rm W}_{56}\,s\,x_{\rm t}^2\,{\rm B}_0^{\rm fin}\left(-M^2_{\rm W}\,;M_{\rm t}\,,M_{\rm b}\right)\\ &-\frac{3}{128}\,{\rm W}_{57}\,s\,x_{\rm t}^2\,{\rm B}_0^{\rm fin}\left(-M^2_{\rm H}\,;M_{\rm t}\,,M_{\rm t}\right)\\ &+\frac{3}{64}\,{\rm W}_{58}\,s\,x_{\rm t}^2\,{\rm C}_0\left(-M^2_{\rm H}\,,-M^2_{\rm W}\,,-M^2_{\rm W}\,;M_{\rm t}\,,M_{\rm b}\,,M_{\rm t}\right)\end{aligned}$$

$$\begin{aligned}\mathscr{T}^{\rm nfc}_{\rm D;WW}(a_{\rm b\,BW}) = {}& \frac{1}{32}\,c\,{\rm X}_{18} + \frac{3}{32}\,{\rm V}_6\,c\,{\rm L_R}\\ &-\frac{3}{128}\,c\,x_{\rm H}^2\,x_{\rm b}^4\,a_0^{\rm fin}\left(M_{\rm b}\right) + \frac{3}{128}\,c\,x_{\rm H}^2\,x_{\rm t}^2\,x_{\rm b}^2\,a_0^{\rm fin}\left(M_{\rm t}\right)\\ &+\frac{3}{128}\,{\rm V}_{23}\,c\,x_{\rm b}^2\,{\rm B}_0^{\rm fin}\left(-M^2_{\rm H}\,;M_{\rm b}\,,M_{\rm b}\right)\end{aligned}$$

$$
\begin{aligned}
&+\frac{3}{64}\,\mathrm{V}_{24}\,c\,x_{\mathrm{b}}^2\,\mathrm{C}_0\left(-M_{\mathrm{H}}^2\,,\,-M_{\mathrm{W}}^2\,,\,-M_{\mathrm{W}}^2\,;M_{\mathrm{b}}\,,M_{\mathrm{t}}\,,M_{\mathrm{b}}\right)\\
&-\frac{3}{128}\,\mathrm{V}_{27}\,c\\
&-\frac{3}{32}\,\mathrm{W}_{59}\,c\,x_{\mathrm{t}}^2\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{t}}\,,M_{\mathrm{t}}\right)\\
&+\frac{3}{128}\,\mathrm{W}_{60}\,c\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{W}}^2\,;M_{\mathrm{t}}\,,M_{\mathrm{b}}\right)\\
&+\frac{3}{64}\,\mathrm{W}_{61}\,c\,x_{\mathrm{t}}^2\,\mathrm{C}_0\left(-M_{\mathrm{H}}^2\,,\,-M_{\mathrm{W}}^2\,,\,-M_{\mathrm{W}}^2\,;M_{\mathrm{t}}\,,M_{\mathrm{b}}\,,M_{\mathrm{t}}\right)
\end{aligned}
$$

$$
\begin{aligned}
\mathscr{T}^{\mathrm{nfc}}_{\mathrm{D;WW}}(a_{\mathrm{bWB}}) = &\frac{1}{32}\,s\,\mathrm{X}_{18}+\frac{3}{32}\,\mathrm{V}_6\,s\,\mathrm{L_R}\\
&-\frac{3}{128}\,s\,x_{\mathrm{H}}^2\,x_{\mathrm{b}}^4\,a_0^{\mathrm{fin}}\left(M_{\mathrm{b}}\right)+\frac{3}{128}\,s\,x_{\mathrm{H}}^2\,x_{\mathrm{t}}^2\,x_{\mathrm{b}}^2\,a_0^{\mathrm{fin}}\left(M_{\mathrm{t}}\right)\\
&+\frac{3}{128}\,\mathrm{V}_{23}\,s\,x_{\mathrm{b}}^2\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{b}}\,,M_{\mathrm{b}}\right)\\
&+\frac{3}{64}\,\mathrm{V}_{24}\,s\,x_{\mathrm{b}}^2\,\mathrm{C}_0\left(-M_{\mathrm{H}}^2\,,\,-M_{\mathrm{W}}^2\,,\,-M_{\mathrm{W}}^2\,;M_{\mathrm{b}}\,,M_{\mathrm{t}}\,,M_{\mathrm{b}}\right)\\
&-\frac{3}{128}\,\mathrm{V}_{27}\,s\\
&-\frac{3}{32}\,\mathrm{W}_{59}\,s\,x_{\mathrm{t}}^2\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{t}}\,,M_{\mathrm{t}}\right)\\
&+\frac{3}{128}\,\mathrm{W}_{60}\,s\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{W}}^2\,;M_{\mathrm{t}}\,,M_{\mathrm{b}}\right)\\
&+\frac{3}{64}\,\mathrm{W}_{61}\,s\,x_{\mathrm{t}}^2\,\mathrm{C}_0\left(-M_{\mathrm{H}}^2\,,\,-M_{\mathrm{W}}^2\,,\,-M_{\mathrm{W}}^2\,;M_{\mathrm{t}}\,,M_{\mathrm{b}}\,,M_{\mathrm{t}}\right)
\end{aligned}
$$

$$
\begin{aligned}
\mathscr{T}^{\mathrm{nfc}}_{\mathrm{D;WW}}(a_{\phi\mathrm{B}}) = &\frac{3}{16}\\
&+\frac{3}{8}\,\frac{1}{\lambda_{\mathrm{WW}}}\,\mathrm{V}_0\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{H}}\,,M_{\mathrm{H}}\right)\\
&-\frac{3}{8}\,\frac{1}{\lambda_{\mathrm{WW}}}\,\mathrm{V}_0\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{W}}^2\,;M_{\mathrm{W}}\,,M_{\mathrm{H}}\right)\\
&+\frac{3}{8}\,\mathrm{W}_{62}\,\mathrm{C}_0\left(-M_{\mathrm{H}}^2\,,\,-M_{\mathrm{W}}^2\,,\,-M_{\mathrm{W}}^2\,;M_{\mathrm{H}}\,,M_{\mathrm{W}}\,,M_{\mathrm{H}}\right)
\end{aligned}
$$

$$
\begin{aligned}
\mathscr{T}^{\mathrm{nfc}}_{\mathrm{D;WW}}(a_{\phi\Box}) = &-\frac{1}{1152}\,\mathrm{X}_{19}-\frac{1}{96}\,x_{\mathrm{H}}^2\,a_0^{\mathrm{fin}}\left(M_{\mathrm{W}}\right)\\
&-\frac{1}{768}\,x_{\mathrm{H}}^2\,(103+12\,\mathrm{L_R})-\frac{1}{768}\,\frac{1}{c^2}+\frac{1}{768}\,\frac{1}{c^2}\,\mathrm{T}^d_{188}\,\mathrm{L_R}\\
&+\frac{1}{96}\,\mathrm{V}_0\,s^2\,\mathrm{C}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2\,,\,-M_{\mathrm{W}}^2\,,\,-M_{\mathrm{W}}^2\,;M_{\mathrm{W}}\,,0\,,M_{\mathrm{W}}\right)\\
&-\frac{1}{96}\,\mathrm{V}_1\,x_{\mathrm{H}}^2\,a_0^{\mathrm{fin}}\left(M_{\mathrm{H}}\right)\\
&-\frac{1}{256}\,\mathrm{W}_{64}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{H}}\,,M_{\mathrm{H}}\right)\\
&+\frac{1}{256}\,\mathrm{W}_{65}\,\mathrm{C}_0\left(-M_{\mathrm{H}}^2\,,\,-M_{\mathrm{W}}^2\,,\,-M_{\mathrm{W}}^2\,;M_{\mathrm{H}}\,,M_{\mathrm{W}}\,,M_{\mathrm{H}}\right)\\
&+\frac{1}{384}\,\mathrm{W}_{66}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{W}}^2\,;M_{\mathrm{W}}\,,M_{\mathrm{H}}\right)\\
&-\frac{1}{768}\,\mathrm{W}_{67}\,\mathrm{C}_0\left(-M_{\mathrm{H}}^2\,,\,-M_{\mathrm{W}}^2\,,\,-M_{\mathrm{W}}^2\,;M_{\mathrm{W}}\,,M_{\mathrm{H}}\,,M_{\mathrm{W}}\right)\\
&-\frac{1}{384}\left[\frac{1}{\lambda_{\mathrm{WW}}}\,\mathrm{T}^d_{185}+(23\,\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{WW}}}\,c^2-2\,\mathrm{T}^d_{183})\,c^2\right]\frac{1}{c^4}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{W}}^2\,;M_{\mathrm{W}}\,,M_{\mathrm{Z}}\right)\\
&+\frac{1}{768}\left[2\,\frac{1}{\lambda_{\mathrm{WW}}}\,\mathrm{T}^d_{187}+(23\,\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{WW}}}\,\mathrm{T}^d_{195}+\mathrm{T}^d_{193})\,c^2\right]\frac{1}{c^4}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{Z}}\,,M_{\mathrm{Z}}\right)
\end{aligned}
$$

$$-\frac{1}{768}\left\{c^2\,s\mathrm{W}_{63}\,x_{\mathrm{H}}^2+\left[(-\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{WW}}}\,\mathrm{T}^d_{192}+2\,\frac{1}{\lambda_{\mathrm{WW}}}\,\mathrm{T}^d_{194}+2\,\mathrm{T}^d_{190})\right]\right\}\frac{1}{c^2}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{W}}\,,M_{\mathrm{W}}\right)$$
$$+\frac{1}{768}\left\{2\,\frac{1}{\lambda_{\mathrm{WW}}}\,\mathrm{T}^d_{186}-\left[9\,c^4\,x_{\mathrm{H}}^2-(-23\,\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{WW}}}\,\mathrm{T}^d_{196}+2\,\mathrm{T}^d_{189})\right]c^2\right\}\frac{1}{c^6}$$
$$\times\mathrm{C}_0\left(-M_{\mathrm{H}}^2\,,-M_{\mathrm{W}}^2\,,-M_{\mathrm{W}}^2\,;M_{\mathrm{Z}}\,,M_{\mathrm{W}}\,,M_{\mathrm{Z}}\right)$$
$$-\frac{1}{768}\left\{\mathrm{T}^d_{184}\,c^2\,x_{\mathrm{H}}^2+\left[(23\,\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{WW}}}-2\,\frac{1}{\lambda_{\mathrm{WW}}}\,\mathrm{T}^d_{194}-2\,\mathrm{T}^d_{191})\right]\right\}\frac{1}{c^4}$$
$$\times\mathrm{C}_0\left(-M_{\mathrm{H}}^2\,,-M_{\mathrm{W}}^2\,,-M_{\mathrm{W}}^2\,;M_{\mathrm{W}}\,,M_{\mathrm{Z}}\,,M_{\mathrm{W}}\right)$$

$$\mathscr{T}^{\mathrm{nfc}}_{\mathrm{D;WW}}(a_{\phi\mathrm{D}})=-\frac{1}{3072}\,\mathrm{X}_{21}+\frac{1}{3072}\,\frac{s^2}{c^2}\,\mathrm{X}_{20}$$
$$+\frac{1}{384}\,x_{\mathrm{H}}^2\,a_0^{\mathrm{fin}}\left(M_{\mathrm{W}}\right)+\frac{1}{384}\,\frac{1}{c^4}\,\mathrm{T}^d_{211}\,a_0^{\mathrm{fin}}\left(M_{\mathrm{Z}}\right)+\frac{1}{384}\,\mathrm{V}_1\,x_{\mathrm{H}}^2\,a_0^{\mathrm{fin}}\left(M_{\mathrm{H}}\right)$$
$$+\frac{1}{3072}\left[\frac{1}{\lambda_{\mathrm{WW}}}\,\mathrm{T}^d_{206}+(\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{WW}}}\,\mathrm{T}^d_{215}\,c^2+2\,\mathrm{T}^d_{208})\,c^2\right]\frac{1}{c^6}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{W}}^2\,;M_{\mathrm{W}}\,,M_{\mathrm{Z}}\right)$$
$$-\frac{1}{6144}\left[(\mathrm{T}^d_{197}\,x_{\mathrm{H}}^2+2\,\mathrm{T}^d_{201})\,\frac{1}{\lambda_{\mathrm{WW}}}-(\mathrm{T}^d_{199}\,x_{\mathrm{H}}^2-2\,\mathrm{T}^d_{209})\,c^2\right]\frac{1}{c^6}$$
$$\times\mathrm{C}_0\left(-M_{\mathrm{H}}^2\,,-M_{\mathrm{W}}^2\,,-M_{\mathrm{W}}^2\,;M_{\mathrm{W}}\,,M_{\mathrm{Z}}\,,M_{\mathrm{W}}\right)$$
$$-\frac{1}{3072}\left\{8\,c^2\,s\mathrm{W}_{71}+\left[(4\,\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{WW}}}\,\mathrm{T}^d_{219}+\mathrm{T}^d_{223}\,\mathrm{W}_{68})\right]\right\}\frac{1}{c^2}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{W}}^2\,;M_{\mathrm{W}}\,,M_{\mathrm{H}}\right)$$
$$-\frac{1}{2048}\left\{16\,c^2\,s\mathrm{W}_{70}+\left[(-4\,\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{WW}}}\,\mathrm{T}^d_{217}+\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{WW}}}\,\mathrm{T}^d_{220}\,x_{\mathrm{H}}^2+4\,\frac{1}{\lambda_{\mathrm{WW}}}\,\mathrm{T}^d_{213}-\mathrm{T}^d_{226})\right]x_{\mathrm{H}}^2\right\}\frac{1}{c^2}$$
$$\times\mathrm{C}_0\left(-M_{\mathrm{H}}^2\,,-M_{\mathrm{W}}^2\,,-M_{\mathrm{W}}^2\,;M_{\mathrm{H}}\,,M_{\mathrm{W}}\,,M_{\mathrm{H}}\right)$$
$$+\frac{1}{2048}\left\{16\,c^2\,s\mathrm{W}_{69}+\left[(2\,\mathrm{T}^d_{216}-\mathrm{T}^d_{220}\,x_{\mathrm{H}}^2)\right]\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{WW}}}\right\}\frac{1}{c^2}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{H}}\,,M_{\mathrm{H}}\right)$$
$$-\frac{1}{6144}\left\{2\,\frac{1}{\lambda_{\mathrm{WW}}}\,\mathrm{T}^d_{202}+\left[9\,\mathrm{T}^d_{218}\,c^4\,x_{\mathrm{H}}^2-(\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{WW}}}\,\mathrm{T}^d_{228}+2\,\mathrm{T}^d_{207})\right]c^2\right\}\frac{1}{c^8}$$
$$\times\mathrm{C}_0\left(-M_{\mathrm{H}}^2\,,-M_{\mathrm{W}}^2\,,-M_{\mathrm{W}}^2\,;M_{\mathrm{Z}}\,,M_{\mathrm{W}}\,,M_{\mathrm{Z}}\right)$$
$$-\frac{1}{6144}\left\{2\,\frac{1}{\lambda_{\mathrm{WW}}}\,\mathrm{T}^d_{203}+\left[48\,c^4\,x_{\mathrm{H}}^2-(-\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{WW}}}\,\mathrm{T}^d_{227}+\mathrm{T}^d_{198})\right]c^2\right\}\frac{1}{c^6}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{Z}}\,,M_{\mathrm{Z}}\right)$$
$$+\frac{1}{6144}\left\{\left[144\,c^2\,x_{\mathrm{H}}^2+(\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{WW}}}\,\mathrm{T}^d_{212}\,x_{\mathrm{H}}^2+2\,\mathrm{T}^d_{210})\right]c^2+\left[(2\,\mathrm{T}^d_{201}+\mathrm{T}^d_{204}\,x_{\mathrm{H}}^2)\right]\frac{1}{\lambda_{\mathrm{WW}}}\right\}\frac{1}{c^4}$$
$$\times\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{W}}\,,M_{\mathrm{W}}\right)$$
$$+\frac{1}{2048}\,(16\,c^4\,x_{\mathrm{H}}^2-\mathrm{T}^d_{205})\,\frac{1}{c^4}\,\mathrm{L}_{\mathrm{R}}$$
$$-\frac{1}{6144}\,(\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{WW}}}\,\mathrm{T}^d_{212}\,x_{\mathrm{H}}^4+2\,\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{WW}}}\,\mathrm{T}^d_{224}\,x_{\mathrm{H}}^2-2\,\mathrm{T}^d_{216}\,\mathrm{V}_0+\mathrm{T}^d_{221}\,x_{\mathrm{H}}^4)\,\frac{1}{c^2}$$
$$\times\mathrm{C}_0\left(-M_{\mathrm{H}}^2\,,-M_{\mathrm{W}}^2\,,-M_{\mathrm{W}}^2\,;M_{\mathrm{W}}\,,M_{\mathrm{H}}\,,M_{\mathrm{W}}\right)$$
$$+\frac{1}{768}\,(\mathrm{T}^d_{200}\,x_{\mathrm{H}}^2-2\,\mathrm{T}^d_{214})\,\frac{1}{c^2}\,\mathrm{C}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2\,,-M_{\mathrm{W}}^2\,,-M_{\mathrm{W}}^2\,;M_{\mathrm{W}}\,,0\,,M_{\mathrm{W}}\right)$$
$$-\frac{1}{6144}\,(\mathrm{T}^d_{222}-\mathrm{T}^d_{225}\,c^2\,x_{\mathrm{H}}^2)\,\frac{1}{c^4}$$

$$\mathscr{T}^{\mathrm{nfc}}_{\mathrm{D;WW}}(a_{\mathrm{AZ}})=-\frac{1}{384}\,s\,c\,\mathrm{X}_{23}-\frac{1}{256}\,s\,c\,x_{\mathrm{H}}^2\,\mathrm{X}_{22}$$
$$-\frac{1}{768}\,\frac{s}{c}\,\mathrm{X}_{24}+\frac{1}{16}\,\frac{c^3}{s}\,\mathrm{V}_{39}\,\mathrm{X}_{25}+\frac{1}{64}\,\frac{s}{c}\,\mathrm{T}^d_{88}\,x_{\mathrm{H}}^2\,a_0^{\mathrm{fin}}\left(M_{\mathrm{W}}\right)$$

$$
\begin{aligned}
&+\frac{1}{8}\,\frac{1}{\lambda_{\mathrm{WW}}}\,\frac{s}{c^3}\,\mathrm{T}^d_{88}\,\mathrm{B}^{\mathrm{fin}}_0\left(-M^2_{\mathrm{H}}\,;0\,,M_{\mathrm{Z}}\right)\\
&-\frac{1}{32}\,\mathrm{V}_{36}\,s\,c\,x^2_{\mathrm{H}}\,a^{\mathrm{fin}}_0\left(M_{\mathrm{H}}\right)\\
&+\frac{1}{256}\left[48\,c^2\,x^2_{\mathrm{H}}+(-\frac{1}{\lambda_{\mathrm{WW}}}\,\mathrm{T}^d_{240}\,\mathrm{V}_{28}+\mathrm{T}^d_{237})\right]\frac{s}{c}\,x^2_{\mathrm{H}}\,\mathrm{C}_0\left(-M^2_{\mathrm{H}}\,,-M^2_{\mathrm{W}}\,,-M^2_{\mathrm{W}}\,;M_{\mathrm{H}}\,,M_{\mathrm{W}}\,,M_{\mathrm{H}}\right)\\
&+\frac{1}{96}\left[12\,s^2\,c^2\,x^4_{\mathrm{H}}-(\mathrm{T}^d_{258}\,x^2_{\mathrm{H}}-2\,\mathrm{T}^d_{259})\right]\frac{s}{c}\,\mathrm{C}^{\mathrm{fin}}_0\left(-M^2_{\mathrm{H}}\,,-M^2_{\mathrm{W}}\,,-M^2_{\mathrm{W}}\,;M_{\mathrm{W}}\,,0\,,M_{\mathrm{W}}\right)\\
&+\frac{1}{16}\left[2\,(c^2\,x^2_{\mathrm{H}}-\mathrm{T}^d_{232})\,c^2-(\frac{1}{\lambda_{\mathrm{WW}}}\,\mathrm{T}^d_{88}-\mathrm{V}_9)\right]\frac{s}{c^3}\,\mathrm{B}^{\mathrm{fin}}_0\left(-M^2_{\mathrm{W}}\,;0\,,M_{\mathrm{W}}\right)\\
&-\frac{1}{768}\left\{2\,\frac{1}{\lambda_{\mathrm{WW}}}\,\mathrm{T}^d_{246}+\left[6\,(c^2\,x^2_{\mathrm{H}}+2\,\mathrm{T}^d_{229})\,c^2\,x^2_{\mathrm{H}}+(\frac{x^2_{\mathrm{H}}}{\lambda_{\mathrm{WW}}}\,\mathrm{T}^d_{243}+\mathrm{T}^d_{255})\right]c^2\right\}\frac{s}{c^5}\\
&\times\mathrm{B}^{\mathrm{fin}}_0\left(-M^2_{\mathrm{H}}\,;M_{\mathrm{Z}}\,,M_{\mathrm{Z}}\right)\\
&-\frac{1}{768}\left\{2\,\frac{1}{\lambda_{\mathrm{WW}}}\,\mathrm{T}^d_{247}+\left[3\,\mathrm{T}^d_{257}\,c^4\,x^2_{\mathrm{H}}+(\frac{x^2_{\mathrm{H}}}{\lambda_{\mathrm{WW}}}\,\mathrm{T}^d_{245}+2\,\mathrm{T}^d_{250})\right]c^2\right\}\frac{s}{c^7}\\
&\times\mathrm{C}_0\left(-M^2_{\mathrm{H}}\,,-M^2_{\mathrm{W}}\,,-M^2_{\mathrm{W}}\,;M_{\mathrm{Z}}\,,M_{\mathrm{W}}\,,M_{\mathrm{Z}}\right)\\
&+\frac{1}{384}\left\{\frac{1}{\lambda_{\mathrm{WW}}}\,\mathrm{T}^d_{248}-\left[\frac{x^2_{\mathrm{H}}}{\lambda_{\mathrm{WW}}}\,\mathrm{T}^d_{252}\,c^2+2\,(3\,\mathrm{T}^d_{233}\,x^2_{\mathrm{H}}-\mathrm{T}^d_{253}+12\,\mathrm{V}_9)\right]c^2\right\}\frac{s}{c^5}\\
&\times\mathrm{B}^{\mathrm{fin}}_0\left(-M^2_{\mathrm{W}}\,;M_{\mathrm{W}}\,,M_{\mathrm{Z}}\right)\\
&-\frac{1}{384}\left\{12\,\mathrm{V}_{40}\,c^2\,x^2_{\mathrm{H}}+\left[(4\,\frac{x^2_{\mathrm{H}}}{\lambda_{\mathrm{WW}}}\,\mathrm{T}^d_{239}-\frac{x^2_{\mathrm{H}}}{\lambda_{\mathrm{WW}}}\,\mathrm{T}^d_{240}\,x^2_{\mathrm{H}}+2\,\mathrm{T}^d_{237})\right]\right\}\frac{s}{c})\\
&\times\mathrm{B}^{\mathrm{fin}}_0\left(-M^2_{\mathrm{W}}\,;M_{\mathrm{W}}\,,M_{\mathrm{H}}\right)\\
&-\frac{1}{768}\left\{\left[12\,c^2\,x^4_{\mathrm{H}}-(\frac{x^2_{\mathrm{H}}}{\lambda_{\mathrm{WW}}}\,\mathrm{T}^d_{240}\,x^2_{\mathrm{H}}+24\,\mathrm{T}^d_{88}\,x^2_{\mathrm{H}}-2\,\mathrm{T}^d_{251})\right]c^2-(\mathrm{T}^d_{244}\,x^2_{\mathrm{H}}+2\,\mathrm{T}^d_{249})\,\frac{1}{\lambda_{\mathrm{WW}}}\right\}\frac{s}{c^3}\\
&\times\mathrm{B}^{\mathrm{fin}}_0\left(-M^2_{\mathrm{H}}\,;M_{\mathrm{W}}\,,M_{\mathrm{W}}\right)\\
&+\frac{1}{768}\left\{\left[96\,c^6\,x^4_{\mathrm{H}}+(2\,\mathrm{T}^d_{254}-\mathrm{T}^d_{256}\,x^2_{\mathrm{H}})\right]c^2-(\mathrm{T}^d_{242}\,x^2_{\mathrm{H}}+2\,\mathrm{T}^d_{249})\,\frac{1}{\lambda_{\mathrm{WW}}}\right\}\frac{s}{c^5}\\
&\times\mathrm{C}_0\left(-M^2_{\mathrm{H}}\,,-M^2_{\mathrm{W}}\,,-M^2_{\mathrm{W}}\,;M_{\mathrm{W}}\,,M_{\mathrm{Z}}\,,M_{\mathrm{W}}\right)\\
&+\frac{1}{32}\left\{2\left[\mathrm{T}^d_8+(c^2\,x^2_{\mathrm{H}}-2\,\mathrm{T}^d_{230})\,c^2\,x^2_{\mathrm{H}}\right]c^2+(\frac{1}{\lambda_{\mathrm{WW}}}\,\mathrm{T}^d_{231}-\mathrm{V}_9)\right\}\frac{s}{c^5}\\
&\times\mathrm{C}_0\left(-M^2_{\mathrm{H}}\,,-M^2_{\mathrm{W}}\,,-M^2_{\mathrm{W}}\,;M_{\mathrm{Z}}\,,M_{\mathrm{W}}\,,0\right)\\
&+\frac{1}{32}\left\{2\left[\mathrm{T}^d_8+(c^2\,x^2_{\mathrm{H}}-2\,\mathrm{T}^d_{230})\,c^2\,x^2_{\mathrm{H}}\right]c^2+(\frac{1}{\lambda_{\mathrm{WW}}}\,\mathrm{T}^d_{231}-\mathrm{V}_9)\right\}\frac{s}{c^5}\\
&\times\mathrm{C}_0\left(-M^2_{\mathrm{H}}\,,-M^2_{\mathrm{W}}\,,-M^2_{\mathrm{W}}\,;0\,,M_{\mathrm{W}}\,,M_{\mathrm{Z}}\right)\\
&+\frac{1}{256}\,(1-c^2\,x^2_{\mathrm{H}})\,\frac{s}{c^3}\\
&-\frac{1}{256}\,(12\,s^2\,c^4\,x^4_{\mathrm{H}}+3\,\mathrm{T}^d_{234}+8\,\mathrm{T}^d_{235}\,c^2\,x^2_{\mathrm{H}})\,\frac{1}{s\,c^3}\,\mathrm{L_R}\\
&-\frac{1}{768}\,(2\,\frac{x^2_{\mathrm{H}}}{\lambda_{\mathrm{WW}}}\,\mathrm{T}^d_{236}\,x^2_{\mathrm{H}}+\frac{x^2_{\mathrm{H}}}{\lambda_{\mathrm{WW}}}\,\mathrm{T}^d_{240}\,x^4_{\mathrm{H}}+\mathrm{T}^d_{237}\,\mathrm{V}_{38}\,x^2_{\mathrm{H}}-4\,\mathrm{T}^d_{238})\,\frac{s}{c}\\
&\times\mathrm{C}_0\left(-M^2_{\mathrm{H}}\,,-M^2_{\mathrm{W}}\,,-M^2_{\mathrm{W}}\,;M_{\mathrm{W}}\,,M_{\mathrm{H}}\,,M_{\mathrm{W}}\right)\\
&+\frac{1}{256}\,(\frac{1}{\lambda_{\mathrm{WW}}}\,\mathrm{T}^d_{240}\,\mathrm{V}_0+6\,\mathrm{V}_{40}\,c^2)\,\frac{s}{c}\,x^2_{\mathrm{H}}\,\mathrm{B}^{\mathrm{fin}}_0\left(-M^2_{\mathrm{H}}\,;M_{\mathrm{H}}\,,M_{\mathrm{H}}\right)\\
&-\frac{1}{192}\,(3\,\mathrm{T}^d_{100}\,x^2_{\mathrm{H}}-4\,\mathrm{T}^d_{241})\,\frac{s}{c^3}\,a^{\mathrm{fin}}_0\left(M_{\mathrm{Z}}\right)
\end{aligned}
$$

$$
\begin{aligned}
\mathscr{T}^{\rm nfc}_{\rm D;WW}(a_{\rm AA}) = {} & \frac{1}{32}\,s^2\,{\rm X}_{27} - \frac{1}{64}\,s^2\,x_{\rm H}^2\,{\rm X}_{26} + \frac{1}{8}\,{\rm V}_{39}\,c^2\,{\rm X}_{25} \\
& - \frac{1}{16}\,s^2\,x_{\rm H}^2\,a_0^{\rm fin}\left(M_{\rm W}\right) \\
& - \frac{1}{32}\,\frac{s^2}{c^2}\,{\rm T}^d_7\,{\rm V}_{36}\,a_0^{\rm fin}\left(M_{\rm Z}\right) \\
& - \frac{1}{64}\,\frac{s^2}{c^2}\,{\rm T}^d_{269} \\
& - \frac{1}{8}\,{\rm V}_0\,s^2\,x_{\rm H}^2\,{\rm C}_0\left(-M_{\rm H}^2\,,\,-M_{\rm W}^2\,,\,-M_{\rm W}^2\,;\,0\,,\,M_{\rm W}\,,\,0\right) \\
& - \frac{1}{32}\,{\rm V}_{36}\,s^2\,x_{\rm H}^2\,a_0^{\rm fin}\left(M_{\rm H}\right) \\
& + \frac{1}{8}\,{\rm V}_{39}\,c^2\,{\rm d}\mathscr{Z}^{(4)}_c \\
& - \frac{3}{128}\,{\rm W}_{73}\,s^2\,x_{\rm H}^2\,{\rm B}_0^{\rm fin}\left(-M_{\rm H}^2\,;\,M_{\rm H}\,,\,M_{\rm H}\right) \\
& + \frac{3}{64}\,{\rm W}_{74}\,s^2\,x_{\rm H}^2\,{\rm C}_0\left(-M_{\rm H}^2\,,\,-M_{\rm W}^2\,,\,-M_{\rm W}^2\,;\,M_{\rm H}\,,\,M_{\rm W}\,,\,M_{\rm H}\right) \\
& + \frac{1}{32}\,{\rm W}_{75}\,s^2\,{\rm B}_0^{\rm fin}\left(-M_{\rm W}^2\,;\,M_{\rm W}\,,\,M_{\rm H}\right) \\
& + \frac{1}{64}\,{\rm W}_{76}\,s^2\,{\rm C}_0\left(-M_{\rm H}^2\,,\,-M_{\rm W}^2\,,\,-M_{\rm W}^2\,;\,M_{\rm W}\,,\,M_{\rm H}\,,\,M_{\rm W}\right) \\
& - \frac{1}{64}\left\{c^2\,s{\rm W}_{72} + \left[(2\,{\rm T}^d_{77} + {\rm T}^d_{260}\,x_{\rm H}^2)\right]\frac{1}{\lambda_{\rm WW}}\right\}\frac{s^2}{c^2}\,{\rm B}_0^{\rm fin}\left(-M_{\rm H}^2\,;\,M_{\rm W}\,,\,M_{\rm W}\right) \\
& + \frac{1}{8}\left\{s^2\,x_{\rm H}^4 + \left[(2\,{\rm T}^d_{107} - {\rm T}^d_{270}\,x_{\rm H}^2)\right]\right\}s^2\,{\rm C}_0^{\rm fin}\left(-M_{\rm H}^2\,,\,-M_{\rm W}^2\,,\,-M_{\rm W}^2\,;\,M_{\rm W}\,,\,0\,,\,M_{\rm W}\right) \\
& + \frac{1}{128}\left\{4\,\frac{1}{\lambda_{\rm WW}}\,{\rm T}^d_{261} + \left[{\rm V}_2\,c^2\,x_{\rm H}^2 + 2\,(-\frac{x_{\rm H}^2}{\lambda_{\rm WW}}\,{\rm T}^d_{195} + {\rm T}^d_{77})\right]c^2\right\}\frac{s^2}{c^4}\,{\rm B}_0^{\rm fin}\left(-M_{\rm H}^2\,;\,M_{\rm Z}\,,\,M_{\rm Z}\right) \\
& - \frac{1}{32}\left\{\frac{1}{\lambda_{\rm WW}}\,{\rm T}^d_{262} - \left[\frac{x_{\rm H}^2}{\lambda_{\rm WW}}\,c^2 + (x_{\rm H}^2 - 2\,{\rm T}^d_{264})\right]c^2\right\}\frac{s^2}{c^4}\,{\rm B}_0^{\rm fin}\left(-M_{\rm W}^2\,;\,M_{\rm W}\,,\,M_{\rm Z}\right) \\
& + \frac{1}{64}\left\{2\,\frac{1}{\lambda_{\rm WW}}\,{\rm T}^d_{263} + \left[\frac{x_{\rm H}^2}{\lambda_{\rm WW}}\,{\rm T}^d_{196} + (11\,c^2\,x_{\rm H}^2 + 2\,{\rm T}^d_{268})\,c^2\right]s^2\,c^2\right\}\frac{1}{c^6} \\
& \times{\rm C}_0\left(-M_{\rm H}^2\,,\,-M_{\rm W}^2\,,\,-M_{\rm W}^2\,;\,M_{\rm Z}\,,\,M_{\rm W}\,,\,M_{\rm Z}\right) \\
& + \frac{1}{64}\left\{\left[8\,c^4\,x_{\rm H}^4 + ({\rm T}^d_{265}\,x_{\rm H}^2 - 2\,{\rm T}^d_{266})\right]c^2 + (x_{\rm H}^2 + 2\,{\rm T}^d_{77})\,\frac{1}{\lambda_{\rm WW}}\right\}\frac{s^2}{c^4} \\
& \times{\rm C}_0\left(-M_{\rm H}^2\,,\,-M_{\rm W}^2\,,\,-M_{\rm W}^2\,;\,M_{\rm W}\,,\,M_{\rm Z}\,,\,M_{\rm W}\right) \\
& + \frac{1}{4}\,(x_{\rm H}^2 - 2\,c^2)\,s^2\,{\rm B}_0^{\rm fin}\left(-M_{\rm W}^2\,;\,0\,,\,M_{\rm W}\right) \\
& - \frac{1}{64}\,(3\,s^2\,c^2\,x_{\rm H}^4 - 22\,{\rm T}^d_{29}\,c^2\,x_{\rm H}^2 - {\rm T}^d_{267})\,\frac{1}{c^2}\,{\rm L_R}
\end{aligned}
$$

$$
\begin{aligned}
\mathscr{T}^{\rm nfc}_{\rm D;WW}(a_{\rm ZZ}) = {} & \frac{1}{64}\,c^2\,{\rm X}_{29} - \frac{1}{128}\,c^2\,x_{\rm H}^2\,{\rm X}_{28} + \frac{1}{64}\,s^2\,{\rm X}_{20} \\
& + \frac{1}{2}\,s^2\,c^2\,{\rm B}_0^{\rm fin}\left(-M_{\rm W}^2\,;\,0\,,\,M_{\rm W}\right) \\
& + \frac{1}{32}\,\frac{s^2}{c^2}\,{\rm T}^d_7\,{\rm V}_{36}\,a_0^{\rm fin}\left(M_{\rm Z}\right) \\
& - \frac{1}{32}\,{\rm T}^d_{195}\,x_{\rm H}^2\,a_0^{\rm fin}\left(M_{\rm W}\right) \\
& - \frac{1}{32}\,{\rm V}_{36}\,c^2\,x_{\rm H}^2\,a_0^{\rm fin}\left(M_{\rm H}\right) \\
& + \frac{3}{128}\left[8\,c^2\,x_{\rm H}^2 + (\frac{1}{\lambda_{\rm WW}}\,{\rm T}^d_{195}\,{\rm V}_{28} - {\rm T}^d_{290})\right]x_{\rm H}^2\,{\rm C}_0\left(-M_{\rm H}^2\,,\,-M_{\rm W}^2\,,\,-M_{\rm W}^2\,;\,M_{\rm H}\,,\,M_{\rm W}\,,\,M_{\rm H}\right)
\end{aligned}
$$

$$
\begin{aligned}
&+\frac{1}{16}\left[2\,c^2\,x_{\rm H}^4-(\mathrm{T}^d_{195}\,x_{\rm H}^2+2\,\mathrm{T}^d_{287})\right]s^2\,\mathrm{C}_0^{\rm fin}\left(-M_{\rm H}^2\,,\,-M_{\rm W}^2\,,\,-M_{\rm W}^2\,;M_{\rm W}\,,0\,,M_{\rm W}\right)\\
&+\frac{1}{128}\left[\mathrm{T}^d_{282}-2\,(3\,c^2\,x_{\rm H}^2+2\,\mathrm{T}^d_{275})\,c^2\,x_{\rm H}^2\right]\frac{1}{c^2}\,\mathrm{L_R}\\
&-\frac{1}{64}\left[2\,\mathrm{V}_{40}\,c^2\,x_{\rm H}^2+(\frac{x_{\rm H}^2}{\lambda_{\rm WW}}\,\mathrm{T}^d_{195}\,x_{\rm H}^2-4\,\frac{x_{\rm H}^2}{\lambda_{\rm WW}}\,\mathrm{T}^d_{288}-2\,\mathrm{T}^d_{290})\right]\mathrm{B}_0^{\rm fin}\left(-M_{\rm W}^2\,;M_{\rm W}\,,M_{\rm H}\right)\\
&+\frac{1}{128}\left\{2\,\frac{1}{\lambda_{\rm WW}}\,\mathrm{T}^d_{277}-\left[(c^2\,x_{\rm H}^2-2\,\mathrm{T}^d_{286})\,c^2\,x_{\rm H}^2+(\frac{x_{\rm H}^2}{\lambda_{\rm WW}}\,\mathrm{T}^d_{196}+\mathrm{T}^d_{285})\right]c^2\right\}\frac{1}{c^4}\,\mathrm{B}_0^{\rm fin}\left(-M_{\rm H}^2\,;M_{\rm Z}\,,M_{\rm Z}\right)\\
&+\frac{1}{128}\left\{2\,\frac{1}{\lambda_{\rm WW}}\,\mathrm{T}^d_{278}+\left[(16\,c^4\,x_{\rm H}^2+\mathrm{T}^d_{281})\,c^2\,x_{\rm H}^2-(-\frac{x_{\rm H}^2}{\lambda_{\rm WW}}\,\mathrm{T}^d_{292}+2\,\mathrm{T}^d_{284})\right]c^2\right\}\frac{1}{c^6}\\
&\times\mathrm{C}_0\left(-M_{\rm H}^2\,,\,-M_{\rm W}^2\,,\,-M_{\rm W}^2\,;M_{\rm Z}\,,M_{\rm W}\,,M_{\rm Z}\right)\\
&-\frac{1}{64}\left\{\frac{1}{\lambda_{\rm WW}}\,\mathrm{T}^d_{279}-\left[\frac{x_{\rm H}^2}{\lambda_{\rm WW}}\,\mathrm{T}^d_{195}\,c^2-2\,(\mathrm{T}^d_{272}\,x_{\rm H}^2-\mathrm{T}^d_{283})\right]c^2\right\}\frac{1}{c^4}\,\mathrm{B}_0^{\rm fin}\left(-M_{\rm W}^2\,;M_{\rm W}\,,M_{\rm Z}\right)\\
&-\frac{1}{128}\left\{\left[2\,c^2\,x_{\rm H}^4+(\mathrm{T}^d_{195}\,\mathrm{W}_{77}\,x_{\rm H}^2+2\,\mathrm{T}^d_{289})\right]c^2-(\mathrm{T}^d_{271}\,x_{\rm H}^2+2\,\mathrm{T}^d_{274})\,\frac{1}{\lambda_{\rm WW}}\right\}\frac{1}{c^2}\\
&\times\mathrm{B}_0^{\rm fin}\left(-M_{\rm H}^2\,;M_{\rm W}\,,M_{\rm W}\right)\\
&+\frac{1}{128}\left\{\left[16\,c^6\,x_{\rm H}^4+(2\,\mathrm{T}^d_{273}-\mathrm{T}^d_{280}\,x_{\rm H}^2)\right]c^2-(\mathrm{T}^d_{7}\,x_{\rm H}^2+2\,\mathrm{T}^d_{274})\,\frac{1}{\lambda_{\rm WW}}\right\}\frac{1}{c^4}\\
&\times\mathrm{C}_0\left(-M_{\rm H}^2\,,\,-M_{\rm W}^2\,,\,-M_{\rm W}^2\,;M_{\rm W}\,,M_{\rm Z}\,,M_{\rm W}\right)\\
&+\frac{1}{128}\,(\frac{x_{\rm H}^2}{\lambda_{\rm WW}}\,\mathrm{T}^d_{195}\,x_{\rm H}^4+2\,\frac{x_{\rm H}^2}{\lambda_{\rm WW}}\,\mathrm{T}^d_{291}\,x_{\rm H}^2-4\,\mathrm{T}^d_{289}+\mathrm{T}^d_{290}\,\mathrm{V}_{38}\,x_{\rm H}^2)\\
&\times\mathrm{C}_0\left(-M_{\rm H}^2\,,\,-M_{\rm W}^2\,,\,-M_{\rm W}^2\,;M_{\rm W}\,,M_{\rm H}\,,M_{\rm W}\right)\\
&-\frac{3}{128}\,(\frac{1}{\lambda_{\rm WW}}\,\mathrm{T}^d_{195}\,\mathrm{V}_0-\mathrm{V}_{40}\,c^2)\,x_{\rm H}^2\,\mathrm{B}_0^{\rm fin}\left(-M_{\rm H}^2\,;M_{\rm H}\,,M_{\rm H}\right)\\
&-\frac{1}{128}\,(\mathrm{T}^d_{153}\,c^2\,x_{\rm H}^2+\mathrm{T}^d_{276})\,\frac{1}{c^2}
\end{aligned}
$$

$$
\mathscr{T}^{\rm nfc}_{\rm D;\,WW}(\mathrm{ren})=\frac{1}{32}\,\mathrm{X}_{30}
$$

$$
\begin{aligned}
\mathscr{T}^{\rm nfc}_{\rm P;\,WW}(a_{\rm t\,\phi})=&\;\frac{3}{32}\,\mathrm{W}_{78}\,x_{\rm t}^2\,x_{\rm b}^2\,a_0^{\rm fin}\left(M_{\rm b}\right)-\frac{3}{32}\,\mathrm{W}_{78}\,x_{\rm t}^4\,a_0^{\rm fin}\left(M_{\rm t}\right)+\frac{3}{32}\,\mathrm{W}_{79}\,x_{\rm t}^2\\
&-\frac{3}{64}\,\mathrm{W}_{80}\,x_{\rm t}^2\,\mathrm{B}_0^{\rm fin}\left(-M_{\rm W}^2\,;M_{\rm t}\,,M_{\rm b}\right)\\
&+\frac{3}{64}\,\mathrm{W}_{81}\,x_{\rm t}^2\,\mathrm{B}_0^{\rm fin}\left(-M_{\rm H}^2\,;M_{\rm t}\,,M_{\rm t}\right)\\
&-\frac{3}{64}\,\mathrm{W}_{82}\,x_{\rm t}^2\,\mathrm{C}_0\left(-M_{\rm H}^2\,,\,-M_{\rm W}^2\,,\,-M_{\rm W}^2\,;M_{\rm t}\,,M_{\rm b}\,,M_{\rm t}\right)
\end{aligned}
$$

$$
\begin{aligned}
\mathscr{T}^{\rm nfc}_{\rm P;\,WW}(a_{\rm b\,\phi})=&\;\frac{3}{32}\,\mathrm{W}_{78}\,x_{\rm t}^2\,x_{\rm b}^2\,a_0^{\rm fin}\left(M_{\rm b}\right)-\frac{3}{32}\,\mathrm{W}_{78}\,x_{\rm t}^4\,a_0^{\rm fin}\left(M_{\rm t}\right)+\frac{3}{32}\,\mathrm{W}_{79}\,x_{\rm t}^2\\
&-\frac{3}{64}\,\mathrm{W}_{80}\,x_{\rm t}^2\,\mathrm{B}_0^{\rm fin}\left(-M_{\rm W}^2\,;M_{\rm t}\,,M_{\rm b}\right)\\
&+\frac{3}{64}\,\mathrm{W}_{81}\,x_{\rm t}^2\,\mathrm{B}_0^{\rm fin}\left(-M_{\rm H}^2\,;M_{\rm t}\,,M_{\rm t}\right)\\
&-\frac{3}{64}\,\mathrm{W}_{82}\,x_{\rm t}^2\,\mathrm{C}_0\left(-M_{\rm H}^2\,,\,-M_{\rm W}^2\,,\,-M_{\rm W}^2\,;M_{\rm t}\,,M_{\rm b}\,,M_{\rm t}\right)
\end{aligned}
$$

$$
\mathscr{T}^{\rm nfc}_{\rm P;\,WW}(a_{\rm t\,BW})=\frac{3}{16}\,\frac{x_{\rm t}^2}{\lambda_{\rm WW}}\,c\,x_{\rm b}^2\,\mathrm{B}_0^{\rm fin}\left(-M_{\rm H}^2\,;M_{\rm b}\,,M_{\rm b}\right)
$$

$$
\begin{aligned}
&+\frac{3}{32}\,\frac{x_t^2}{\lambda_{WW}}\,W_{87}\,c\,C_0\left(-M_H^2\,,\,-M_W^2\,,\,-M_W^2\,;M_t\,,M_b\,,M_t\right)\\
&-\frac{3}{64}\,W_{83}\,c\,x_t^2\\
&-\frac{3}{64}\,W_{83}\,c\,x_t^2\,x_b^2\,a_0^{fin}\left(M_b\right)\\
&+\frac{3}{64}\,W_{83}\,c\,x_t^4\,a_0^{fin}\left(M_t\right)\\
&+\frac{3}{64}\,W_{84}\,c\,x_t^2\,B_0^{fin}\left(-M_H^2\,;M_t\,,M_t\right)\\
&-\frac{3}{32}\,W_{85}\,c\,x_t^2\,x_b^2\,C_0\left(-M_H^2\,,\,-M_W^2\,,\,-M_W^2\,;M_b\,,M_t\,,M_b\right)\\
&-\frac{3}{64}\,W_{86}\,c\,x_t^2\,B_0^{fin}\left(-M_W^2\,;M_t\,,M_b\right)
\end{aligned}
$$

$$
\begin{aligned}
\mathcal{T}^{nfc}_{P;WW}(a_{tWB}) = &\ \frac{3}{16}\,\frac{x_t^2}{\lambda_{WW}}\,s\,x_b^2\,B_0^{fin}\left(-M_H^2\,;M_b\,,M_b\right)\\
&+\frac{3}{32}\,\frac{x_t^2}{\lambda_{WW}}\,W_{87}\,s\,C_0\left(-M_H^2\,,\,-M_W^2\,,\,-M_W^2\,;M_t\,,M_b\,,M_t\right)\\
&-\frac{3}{64}\,W_{83}\,s\,x_t^2\\
&-\frac{3}{64}\,W_{83}\,s\,x_t^2\,x_b^2\,a_0^{fin}\left(M_b\right)\\
&+\frac{3}{64}\,W_{83}\,s\,x_t^4\,a_0^{fin}\left(M_t\right)\\
&+\frac{3}{64}\,W_{84}\,s\,x_t^2\,B_0^{fin}\left(-M_H^2\,;M_t\,,M_t\right)\\
&-\frac{3}{32}\,W_{85}\,s\,x_t^2\,x_b^2\,C_0\left(-M_H^2\,,\,-M_W^2\,,\,-M_W^2\,;M_b\,,M_t\,,M_b\right)\\
&-\frac{3}{64}\,W_{86}\,s\,x_t^2\,B_0^{fin}\left(-M_W^2\,;M_t\,,M_b\right)
\end{aligned}
$$

$$
\begin{aligned}
\mathcal{T}^{nfc}_{P;WW}(a_{bBW}) = &-\frac{3}{64}\,W_{88}\,c\,x_b^2\,a_0^{fin}\left(M_b\right)\\
&+\frac{3}{64}\,W_{88}\,c\,x_t^2\,a_0^{fin}\left(M_t\right)\\
&-\frac{3}{64}\,W_{89}\,c\\
&-\frac{3}{64}\,W_{90}\,c\,x_t^2\,B_0^{fin}\left(-M_H^2\,;M_t\,,M_t\right)\\
&+\frac{3}{64}\,W_{91}\,c\,B_0^{fin}\left(-M_W^2\,;M_t\,,M_b\right)\\
&+\frac{3}{64}\,W_{92}\,c\,x_t^2\,C_0\left(-M_H^2\,,\,-M_W^2\,,\,-M_W^2\,;M_t\,,M_b\,,M_t\right)\\
&-\frac{3}{64}\,W_{93}\,c\,x_b^2\,C_0\left(-M_H^2\,,\,-M_W^2\,,\,-M_W^2\,;M_b\,,M_t\,,M_b\right)\\
&-\frac{3}{64}\,W_{94}\,c\,x_b^2\,B_0^{fin}\left(-M_H^2\,;M_b\,,M_b\right)
\end{aligned}
$$

$$
\begin{aligned}
\mathcal{T}^{nfc}_{P;WW}(a_{bWB}) = &-\frac{3}{64}\,W_{88}\,s\,x_b^2\,a_0^{fin}\left(M_b\right)\\
&+\frac{3}{64}\,W_{88}\,s\,x_t^2\,a_0^{fin}\left(M_t\right)\\
&-\frac{3}{64}\,W_{89}\,s\\
&-\frac{3}{64}\,W_{90}\,s\,x_t^2\,B_0^{fin}\left(-M_H^2\,;M_t\,,M_t\right)
\end{aligned}
$$

$$
\begin{aligned}
&+\frac{3}{64}\,W_{91}\,s\,B_0^{\rm fin}\left(-M_W^2\,;M_t\,,M_b\right)\\
&+\frac{3}{64}\,W_{92}\,s\,x_t^2\,C_0\left(-M_H^2\,,-M_W^2\,,-M_W^2\,;M_t\,,M_b\,,M_t\right)\\
&-\frac{3}{64}\,W_{93}\,s\,x_b^2\,C_0\left(-M_H^2\,,-M_W^2\,,-M_W^2\,;M_b\,,M_t\,,M_b\right)\\
&-\frac{3}{64}\,W_{94}\,s\,x_b^2\,B_0^{\rm fin}\left(-M_H^2\,;M_b\,,M_b\right)
\end{aligned}
$$

$$
\begin{aligned}
\mathscr{T}^{\rm nfc}_{\rm P;WW}(a_{\phi B}) = {}&\frac{3}{16}\,W_{78}\,a_0^{\rm fin}\left(M_W\right)\\
&+\frac{3}{16}\,W_{79}\\
&+\frac{3}{16}\,W_{95}\,a_0^{\rm fin}\left(M_H\right)\\
&+\frac{3}{32}\,W_{96}\,B_0^{\rm fin}\left(-M_H^2\,;M_H\,,M_H\right)\\
&-\frac{3}{32}\,W_{97}\,B_0^{\rm fin}\left(-M_W^2\,;M_W\,,M_H\right)\\
&-\frac{3}{32}\,W_{98}\,C_0\left(-M_H^2\,,-M_W^2\,,-M_W^2\,;M_H\,,M_W\,,M_H\right)
\end{aligned}
$$

$$
\begin{aligned}
\mathscr{T}^{\rm nfc}_{\rm P;WW}(a_{\phi\Box}) = {}&-\frac{5}{64}\,\frac{s^2}{c^4}\,T^d_{309}\,W_{78}\,a_0^{\rm fin}\left(M_Z\right)\\
&+\frac{1}{64}\,\frac{1}{c^2}\,T^d_{297}\,W_{78}\,a_0^{\rm fin}\left(M_W\right)\\
&-\frac{5}{2}\,\frac{1}{\lambda_{\rm WW}}\,s^2\,B_0^{\rm fin}\left(-M_W^2\,;0\,,M_W\right)\\
&-\frac{3}{64}\,W_{95}\,a_0^{\rm fin}\left(M_H\right)\\
&-\frac{1}{16}\,W_{102}\,B_0^{\rm fin}\left(-M_W^2\,;M_W\,,M_H\right)\\
&+\frac{1}{256}\,W_{103}\,B_0^{\rm fin}\left(-M_H^2\,;M_H\,,M_H\right)\\
&+\frac{1}{256}\,W_{104}\,C_0\left(-M_H^2\,,-M_W^2\,,-M_W^2\,;M_W\,,M_H\,,M_W\right)\\
&+\frac{1}{256}\,W_{105}\,C_0\left(-M_H^2\,,-M_W^2\,,-M_W^2\,;M_H\,,M_W\,,M_H\right)\\
&+\frac{1}{64}\left[4\,c^2\,s W_{101}+(\frac{1}{\lambda_{\rm WW}}\,T^d_{298}+T^d_{299}\,V_9)\right]\frac{1}{c^2}\\
&-\frac{1}{256}\left\{5\,c^2\,s W_{99}\,x_{\rm H}^2+\left[(-12\,\frac{x_{\rm H}^2}{\lambda_{\rm WW}^2}\,T^d_{308}-\frac{x_{\rm H}^2}{\lambda_{\rm WW}}\,T^d_{306}-24\,\frac{1}{\lambda_{\rm WW}^2}\,T^d_{293}\right.\right.\\
&\left.\left.+22\,\frac{1}{\lambda_{\rm WW}}\,T^d_{55}+2\,T^d_{296}\,V_9+T^d_{307})\right]\right\}\frac{1}{c^2}\,B_0^{\rm fin}\left(-M_H^2\,;M_W\,,M_W\right)\\
&-\frac{1}{128}\left\{7\,c^4\,s W_{100}-\left[(12\,\frac{1}{\lambda_{\rm WW}^2}\,T^d_{304}-\frac{1}{\lambda_{\rm WW}}\,T^d_{305}+5\,T^d_{295}\,V_9)\right]\right\}\frac{1}{c^4}\,B_0^{\rm fin}\left(-M_W^2\,;M_W\,,M_Z\right)\\
&+\frac{1}{256}\left\{7\left[(12\,\frac{x_{\rm H}^2}{\lambda_{\rm WW}^2}\,T^d_{195}+W_{95})\right]c^2+2\left[(-12\,\frac{1}{\lambda_{\rm WW}^2}\,T^d_{302}-\frac{1}{\lambda_{\rm WW}}\,T^d_{301}+5\,T^d_{58}\,V_9)\right]\right\}\frac{1}{c^4}\\
&\times B_0^{\rm fin}\left(-M_H^2\,;M_Z\,,M_Z\right)\\
&-\frac{1}{256}\left\{7\left[(12\,\frac{x_{\rm H}^2}{\lambda_{\rm WW}^2}\,T^d_{196}+\frac{x_{\rm H}^2}{\lambda_{\rm WW}}\,T^d_{312}-T^d_{311})\right]c^2\right.\\
&\left.-2\left[(-12\,\frac{1}{\lambda_{\rm WW}^2}\,T^d_{300}-\frac{1}{\lambda_{\rm WW}}\,T^d_{303}+5\,T^d_{294}\,V_9)\right]\right\}\frac{1}{c^6}\,C_0\left(-M_H^2\,,-M_W^2\,,-M_W^2\,;M_Z\,,M_W\,,M_Z\right)
\end{aligned}
$$

$$-\frac{1}{256}\,(84\,\frac{x_{\rm H}^2}{\lambda_{\rm WW}^2}+7\,\frac{x_{\rm H}^2}{\lambda_{\rm WW}}\,{\rm T}^d_{8}+24\,\frac{1}{\lambda_{\rm WW}^2}\,{\rm T}^d_{293}-2\,\frac{1}{\lambda_{\rm WW}}\,{\rm T}^d_{310}-10\,{\rm T}^d_{294}\,{\rm V}_9-{\rm T}^d_{313})\,\frac{1}{c^4}$$
$$\times{\rm C}_0\left(-M_{\rm H}^2\,,\,-M_{\rm W}^2\,,\,-M_{\rm W}^2\,;M_{\rm W}\,,M_{\rm Z}\,,M_{\rm W}\right)$$

$$\mathscr{T}^{\rm nfc}_{\rm P;WW}(a_{\phi{\rm D}})=-\frac{1}{4}\,\frac{1}{\lambda_{\rm WW}}\,{\rm T}^d_{12}\,{\rm B}_0^{\rm fin}\left(-M_{\rm W}^2\,;0\,,M_{\rm W}\right)$$
$$+\frac{1}{512}\,{\rm W}_{107}\,{\rm C}_0\left(-M_{\rm H}^2\,,\,-M_{\rm W}^2\,,\,-M_{\rm W}^2\,;M_{\rm W}\,,M_{\rm H}\,,M_{\rm W}\right)$$
$$-\frac{1}{128}\,{\rm W}_{108}\,{\rm B}_0^{\rm fin}\left(-M_{\rm H}^2\,;M_{\rm H}\,,M_{\rm H}\right)$$
$$+\frac{1}{256}\,{\rm W}_{109}\,a_0^{\rm fin}\left(M_{\rm H}\right)$$
$$-\frac{1}{128}\,{\rm W}_{110}\,{\rm C}_0\left(-M_{\rm H}^2\,,\,-M_{\rm W}^2\,,\,-M_{\rm W}^2\,;M_{\rm H}\,,M_{\rm W}\,,M_{\rm H}\right)$$
$$-\frac{1}{512}\,{\rm W}_{111}\,{\rm B}_0^{\rm fin}\left(-M_{\rm W}^2\,;M_{\rm W}\,,M_{\rm H}\right)$$
$$+\frac{1}{256}\left[c^2\,s{\rm W}_{95}+2\,(\frac{1}{\lambda_{\rm WW}}\,{\rm T}^d_{323}-{\rm T}^d_{325}\,{\rm V}_9)\right]\frac{1}{c^4}\,a_0^{\rm fin}\left(M_{\rm Z}\right)$$
$$+\frac{1}{512}\left[{\rm T}^d_{331}\,c^2\,s{\rm W}_{100}-2\,(12\,\frac{1}{\lambda_{\rm WW}^2}\,{\rm T}^d_{329}-\frac{1}{\lambda_{\rm WW}}\,{\rm T}^d_{330}+{\rm T}^d_{327}\,{\rm V}_9)\right]\frac{1}{c^4}\,{\rm B}_0^{\rm fin}\left(-M_{\rm W}^2\,;M_{\rm W}\,,M_{\rm Z}\right)$$
$$-\frac{1}{128}\left\{2\,c^2\,s{\rm W}_{106}+\left[(\frac{1}{\lambda_{\rm WW}}\,{\rm T}^d_{321}+5\,{\rm T}^d_{315}\,{\rm V}_9)\right]\right\}\frac{1}{c^2}$$
$$+\frac{1}{512}\left\{3\,c^2\,s{\rm W}_{99}\,x_{\rm H}^2-\left[(60\,\frac{x_{\rm H}^2}{\lambda_{\rm WW}^2}+\frac{x_{\rm H}^2}{\lambda_{\rm WW}}\,{\rm T}^d_{318}+48\,\frac{1}{\lambda_{\rm WW}^2}\,{\rm T}^d_{316}-8\,\frac{1}{\lambda_{\rm WW}}\,{\rm T}^d_{229}\right.\right.$$
$$\left.\left.-8\,{\rm T}^d_{314}\,{\rm V}_9-{\rm T}^d_{319})\right]\right\}\frac{1}{c^2}\,{\rm B}_0^{\rm fin}\left(-M_{\rm H}^2\,;M_{\rm W}\,,M_{\rm W}\right)$$
$$-\frac{1}{256}\left\{2\left[(12\,\frac{x_{\rm H}^2}{\lambda_{\rm WW}^2}\,{\rm T}^d_{195}+{\rm W}_{95})\right]c^2+\left[(-12\,\frac{1}{\lambda_{\rm WW}^2}\,{\rm T}^d_{324}-\frac{1}{\lambda_{\rm WW}}\,{\rm T}^d_{322}+5\,{\rm T}^d_{58}\,{\rm V}_9)\right]\right\}\frac{1}{c^4}$$
$$\times{\rm B}_0^{\rm fin}\left(-M_{\rm H}^2\,;M_{\rm Z}\,,M_{\rm Z}\right)$$
$$+\frac{1}{256}\left\{2\left[(12\,\frac{x_{\rm H}^2}{\lambda_{\rm WW}^2}\,{\rm T}^d_{196}+\frac{x_{\rm H}^2}{\lambda_{\rm WW}}\,{\rm T}^d_{312}-{\rm T}^d_{332})\right]c^2-\left[(-12\,\frac{1}{\lambda_{\rm WW}^2}\,{\rm T}^d_{326}-\frac{1}{\lambda_{\rm WW}}\,{\rm T}^d_{328}\right.\right.$$
$$\left.\left.+5\,{\rm T}^d_{294}\,{\rm V}_9)\right]\right\}\frac{1}{c^6}\,{\rm C}_0\left(-M_{\rm H}^2\,,\,-M_{\rm W}^2\,,\,-M_{\rm W}^2\,;M_{\rm Z}\,,M_{\rm W}\,,M_{\rm Z}\right)$$
$$+\frac{1}{512}\,(60\,\frac{x_{\rm H}^2}{\lambda_{\rm WW}^2}+5\,\frac{x_{\rm H}^2}{\lambda_{\rm WW}}\,{\rm T}^d_{8}+48\,\frac{1}{\lambda_{\rm WW}^2}\,{\rm T}^d_{316}-8\,\frac{1}{\lambda_{\rm WW}}\,{\rm T}^d_{317}-8\,{\rm T}^d_{294}\,{\rm V}_9-{\rm T}^d_{333})\,\frac{1}{c^4}$$
$$\times{\rm C}_0\left(-M_{\rm H}^2\,,\,-M_{\rm W}^2\,,\,-M_{\rm W}^2\,;M_{\rm W}\,,M_{\rm Z}\,,M_{\rm W}\right)$$
$$+\frac{1}{128}\,(-\frac{1}{\lambda_{\rm WW}}\,{\rm T}^d_{320}+5\,{\rm T}^d_{144}\,{\rm V}_9)\,\frac{1}{c^2}\,a_0^{\rm fin}\left(M_{\rm W}\right)$$

$$\mathscr{T}^{\rm nfc}_{\rm P;WW}(a_{\rm AZ})=-\frac{1}{16}\,s\,c\,{\rm X}_{31}-\frac{1}{8}\,\frac{c^3}{s}\,{\rm X}_{25}$$
$$-\frac{3}{8}\,\frac{x_{\rm H}^2}{\lambda_{\rm WW}}\,{\rm V}_0\,s\,c\,{\rm C}_0\left(-M_{\rm H}^2\,,\,-M_{\rm W}^2\,,\,-M_{\rm W}^2\,;M_{\rm H}\,,M_{\rm W}\,,M_{\rm H}\right)$$
$$-\frac{1}{8}\,\frac{1}{s}\,c^3\,{\rm d}\mathscr{Z}^{(4)}_c$$
$$-\frac{1}{4}\,{\rm V}_0\,s^3\,c\,{\rm C}_0^{\rm fin}\left(-M_{\rm H}^2\,,\,-M_{\rm W}^2\,,\,-M_{\rm W}^2\,;M_{\rm W}\,,0\,,M_{\rm W}\right)$$
$$-\frac{3}{64}\,{\rm W}_{112}\,s\,c\,x_{\rm H}^2\,{\rm B}_0^{\rm fin}\left(-M_{\rm H}^2\,;M_{\rm H}\,,M_{\rm H}\right)$$
$$+\frac{1}{64}\,{\rm W}_{113}\,s\,c\,{\rm B}_0^{\rm fin}\left(-M_{\rm W}^2\,;M_{\rm W}\,,M_{\rm H}\right)$$

$$
\begin{aligned}
&+\frac{1}{64}\,\mathrm{W}_{114}\,s\,c\,\mathrm{C}_0\left(-M_{\mathrm{H}}^2\,,-M_{\mathrm{W}}^2\,,-M_{\mathrm{W}}^2\,;M_{\mathrm{W}}\,,M_{\mathrm{H}}\,,M_{\mathrm{W}}\right)\\
&-\frac{1}{32}\,\mathrm{W}_{115}\,s\,c\,a_0^{\mathrm{fin}}\left(M_{\mathrm{H}}\right)\\
&-\frac{1}{128}\Big[12\,\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{WW}}^2}\,s^2\,c^2+\frac{x_{\mathrm{H}}^2}{lww}\,\mathrm{T}_{351}^d\,c^2+(24\,\frac{1}{\lambda_{\mathrm{WW}}^2}\,\mathrm{T}_{352}^d-2\,\frac{1}{\lambda_{\mathrm{WW}}}\,\mathrm{T}_{356}^d+\mathrm{T}_{346}^d\\
&+2\,\mathrm{T}_{350}^d\,\mathrm{V}_9+24\,\mathrm{V}_{92})\Big]\,\frac{s}{c^3}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{W}}^2\,;M_{\mathrm{W}}\,,M_{\mathrm{Z}}\right)\\
&+\frac{1}{64}\left[\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{WW}}}\,s^2\,c^2-(-2\,\frac{1}{\lambda_{\mathrm{WW}}}\,\mathrm{T}_{353}^d+\mathrm{T}_{341}^d+2\,\mathrm{T}_{349}^d\,\mathrm{V}_9)\right]\,\frac{s}{c^3}\,a_0^{\mathrm{fin}}\left(M_{\mathrm{Z}}\right)\\
&-\frac{1}{16}\left[(-18\,\frac{1}{\lambda_{\mathrm{WW}}^2}\,\mathrm{T}_{339}^d+\mathrm{T}_{98}^d\,\mathrm{V}_9)+(6\,\frac{1}{\lambda_{\mathrm{WW}}}\,\mathrm{T}_{336}^d+5\,\mathrm{T}_7^d\,c^2)\,c^2\right]\,\frac{s}{c^5}\\
&\times\mathrm{C}_0\left(-M_{\mathrm{H}}^2\,,-M_{\mathrm{W}}^2\,,-M_{\mathrm{W}}^2\,;M_{\mathrm{Z}}\,,M_{\mathrm{W}}\,,M_{\mathrm{Z}}\right)\\
&-\frac{1}{128}\Big\{4\,c^2\,x_{\mathrm{H}}^2-\Big[(12\,\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{WW}}^2}\,\mathrm{T}_{54}^d+\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{WW}}}\,\mathrm{T}_{354}^d-24\,\frac{1}{\lambda_{\mathrm{WW}}^2}\,\mathrm{T}_{355}^d+6\,\frac{1}{\lambda_{\mathrm{WW}}}\,\mathrm{T}_{334}^d\\
&+10\,\mathrm{T}_{88}^d\,\mathrm{V}_9-\mathrm{T}_{335}^d)\Big]\Big\}\,\frac{s}{c}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{W}}\,,M_{\mathrm{W}}\right)\\
&+\frac{1}{128}\Big\{32\,c^6\,x_{\mathrm{H}}^2-12\,\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{WW}}^2}\,s^2-\Big[(3\,\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{WW}}}\,\mathrm{T}_{343}^d-24\,\frac{1}{\lambda_{\mathrm{WW}}^2}\,\mathrm{T}_{355}^d+2\,\frac{1}{\lambda_{\mathrm{WW}}}\,\mathrm{T}_{344}^d\\
&+10\,\mathrm{T}_{88}^d\,\mathrm{V}_9-\mathrm{T}_{340}^d)\Big]\Big\}\,\frac{s}{c^3}\,\mathrm{C}_0\left(-M_{\mathrm{H}}^2\,,-M_{\mathrm{W}}^2\,,-M_{\mathrm{W}}^2\,;M_{\mathrm{W}}\,,M_{\mathrm{Z}}\,,M_{\mathrm{W}}\right)\\
&-\frac{1}{64}\left\{\left[c^2\,x_{\mathrm{H}}^2-2\,(-6\,\frac{1}{\lambda_{\mathrm{WW}}}\,\mathrm{T}_7^d+\mathrm{T}_2^d)\right]\,c^2+4\,(-18\,\frac{1}{\lambda_{\mathrm{WW}}^2}\,\mathrm{T}_{100}^d+\mathrm{T}_7^d\,\mathrm{V}_9)\right\}\,\frac{s}{c^3}\\
&\times\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{Z}}\,,M_{\mathrm{Z}}\right)\\
&+\frac{1}{32}\left\{-2\left[2\,(2-c^2\,x_{\mathrm{H}}^2)\,c^2+(\frac{1}{\lambda_{\mathrm{WW}}}\,\mathrm{T}_{88}^d-3\,\mathrm{V}_9)\right]\,c^2+3\,(\frac{1}{\lambda_{\mathrm{WW}}^2}\,\mathrm{T}_{231}^d-\mathrm{V}_{92})\right\}\,\frac{s}{c^5}\\
&\times\mathrm{C}_0\left(-M_{\mathrm{H}}^2\,,-M_{\mathrm{W}}^2\,,-M_{\mathrm{W}}^2\,;M_{\mathrm{Z}}\,,M_{\mathrm{W}}\,,0\right)\\
&+\frac{1}{32}\left\{-2\left[2\,(2-c^2\,x_{\mathrm{H}}^2)\,c^2+(\frac{1}{\lambda_{\mathrm{WW}}}\,\mathrm{T}_{88}^d-3\,\mathrm{V}_9)\right]\,c^2+3\,(\frac{1}{\lambda_{\mathrm{WW}}^2}\,\mathrm{T}_{231}^d-\mathrm{V}_{92})\right\}\,\frac{s}{c^5}\\
&\times\mathrm{C}_0\left(-M_{\mathrm{H}}^2\,,-M_{\mathrm{W}}^2\,,-M_{\mathrm{W}}^2\,;0\,,M_{\mathrm{W}}\,,M_{\mathrm{Z}}\right)\\
&-\frac{1}{16}\left\{-\left[(\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{WW}}}\,\mathrm{T}_2^d+\mathrm{T}_{342}^d)\,c^2-(\frac{1}{\lambda_{\mathrm{WW}}}\,\mathrm{T}_{338}^d+3\,\mathrm{V}_9)\right]\,c^2+3\,(\frac{1}{\lambda_{\mathrm{WW}}^2}\,\mathrm{T}_{88}^d-\mathrm{V}_{92})\right\}\,\frac{s}{c^3}\\
&\times\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{W}}^2\,;0\,,M_{\mathrm{W}}\right)\\
&-\frac{1}{32}\,(1+2\,\frac{1}{\lambda_{\mathrm{WW}}}\,\mathrm{T}_{348}^d+2\,\mathrm{T}_{110}^d\,\mathrm{V}_9)\,\frac{s}{c}\\
&+\frac{1}{32}\,(s\mathrm{W}_{78}+12\,\frac{1}{\lambda_{\mathrm{WW}}^2}\,\mathrm{T}_{88}^d)\,\frac{s}{c^3}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2\,;0\,,M_{\mathrm{Z}}\right)\\
&-\frac{1}{32}\,(3\,s^2\,c^2\,x_{\mathrm{H}}^2+2\,\mathrm{T}_{337}^d)\,\frac{1}{s\,c}\,\mathrm{L_R}\\
&+\frac{1}{32}\,(-2\,\frac{1}{\lambda_{\mathrm{WW}}}\,\mathrm{T}_{347}^d+\mathrm{T}_{88}^d+2\,\mathrm{T}_{345}^d\,\mathrm{V}_9)\,\frac{s}{c}\,a_0^{\mathrm{fin}}\left(M_{\mathrm{W}}\right)
\end{aligned}
$$

$$
\begin{aligned}
\mathscr{T}_{\mathrm{P;WW}}^{\mathrm{nfc}}(a_{\mathrm{AA}})=&-\frac{1}{4}\,c^2\,\mathrm{X}_{25}-\frac{1}{16}\,s^2\,\mathrm{X}_{32}\\
&+\frac{1}{4}\,s^2\,x_{\mathrm{H}}^2\,\mathrm{C}_0\left(-M_{\mathrm{H}}^2\,,-M_{\mathrm{W}}^2\,,-M_{\mathrm{W}}^2\,;0\,,M_{\mathrm{W}}\,,0\right)\\
&-\frac{3}{8}\,\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{WW}}}\,\mathrm{V}_0\,s^2\,\mathrm{C}_0\left(-M_{\mathrm{H}}^2\,,-M_{\mathrm{W}}^2\,,-M_{\mathrm{W}}^2\,;M_{\mathrm{H}}\,,M_{\mathrm{W}}\,,M_{\mathrm{H}}\right)
\end{aligned}
$$

$$
\begin{aligned}
&-\frac{1}{4}\,\mathrm{V}_0\,s^4\,\mathrm{C}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2\,,\,-M_{\mathrm{W}}^2\,,\,-M_{\mathrm{W}}^2\,;M_{\mathrm{W}}\,,0\,,M_{\mathrm{W}}\right)\\
&-\frac{1}{16}\,\mathrm{W}_{79}\,s^2\\
&-\frac{3}{64}\,\mathrm{W}_{112}\,s^2\,x_{\mathrm{H}}^2\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{H}}\,,M_{\mathrm{H}}\right)\\
&+\frac{1}{64}\,\mathrm{W}_{113}\,s^2\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{W}}^2\,;M_{\mathrm{W}}\,,M_{\mathrm{H}}\right)\\
&+\frac{1}{64}\,\mathrm{W}_{114}\,s^2\,\mathrm{C}_0\left(-M_{\mathrm{H}}^2\,,\,-M_{\mathrm{W}}^2\,,\,-M_{\mathrm{W}}^2\,;M_{\mathrm{W}}\,,M_{\mathrm{H}}\,,M_{\mathrm{W}}\right)\\
&-\frac{1}{32}\,\mathrm{W}_{115}\,s^2\,a_0^{\mathrm{fin}}\left(M_{\mathrm{H}}\right)\\
&+\frac{1}{16}\,\mathrm{W}_{117}\,s^2\,a_0^{\mathrm{fin}}\left(M_{\mathrm{W}}\right)\\
&+\frac{1}{8}\left[5\,s^2\,c^4+6\,\frac{1}{\lambda_{\mathrm{WW}}}\,\mathrm{T}_{358}^d\,c^2+(-18\,\frac{1}{\lambda_{\mathrm{WW}}^2}\,\mathrm{T}_{361}^d+\mathrm{T}_{359}^d\,\mathrm{V}_9)\right]\frac{1}{c^4}\\
&\times\mathrm{C}_0\left(-M_{\mathrm{H}}^2\,,\,-M_{\mathrm{W}}^2\,,\,-M_{\mathrm{W}}^2\,;M_{\mathrm{Z}}\,,M_{\mathrm{W}}\,,M_{\mathrm{Z}}\right)\\
&+\frac{1}{64}\left[8\,\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{WW}}}\,s^2\,c^2+(12\,\frac{1}{\lambda_{\mathrm{WW}}^2}\,\mathrm{T}_{364}^d-\frac{1}{\lambda_{\mathrm{WW}}}\,\mathrm{T}_{366}^d+\mathrm{T}_{363}^d\,\mathrm{V}_9+4\,\mathrm{T}_{367}^d)\right]\frac{s^2}{c^2}\\
&\times\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{W}}^2\,;M_{\mathrm{W}}\,,M_{\mathrm{Z}}\right)\\
&+\frac{1}{64}\left\{c^2\,s\mathrm{W}_{118}-8\left[(18\,\frac{1}{\lambda_{\mathrm{WW}}^2}\,\mathrm{T}_7^d-\mathrm{V}_9)\right]\right\}\frac{s^2}{c^2}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{Z}}\,,M_{\mathrm{Z}}\right)\\
&-\frac{1}{64}\left\{c^2\,s\mathrm{W}_{116}+\left[(12\,\frac{1}{\lambda_{\mathrm{WW}}^2}\,\mathrm{T}_{55}^d+\frac{1}{\lambda_{\mathrm{WW}}}\,\mathrm{T}_{357}^d-\mathrm{T}_{334}^d\,\mathrm{V}_9)\right]\right\}\frac{s^2}{c^2}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{W}}\,,M_{\mathrm{W}}\right)\\
&+\frac{1}{8}\left\{\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{WW}}}\,c^2+\left[(4\,\frac{1}{\lambda_{\mathrm{WW}}}\,\mathrm{T}_{106}^d+\mathrm{T}_{362}^d)\right]\right\}s^2\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{W}}^2\,;0\,,M_{\mathrm{W}}\right)\\
&+\frac{1}{64}\left\{8\,\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{WW}}}\,s^2\,c^2-16\,\mathrm{V}_0\,c^6+\left[(12\,\frac{1}{\lambda_{\mathrm{WW}}^2}\,\mathrm{T}_{55}^d+\frac{1}{\lambda_{\mathrm{WW}}}\,\mathrm{T}_{360}^d-\mathrm{T}_{88}^d\,\mathrm{V}_9)\right]\right\}\frac{s^2}{c^4}\\
&\times\mathrm{C}_0\left(-M_{\mathrm{H}}^2\,,\,-M_{\mathrm{W}}^2\,,\,-M_{\mathrm{W}}^2\,;M_{\mathrm{W}}\,,M_{\mathrm{Z}}\,,M_{\mathrm{W}}\right)\\
&-\frac{1}{32}\,(3\,s^2\,x_{\mathrm{H}}^2-16\,\mathrm{T}_{29}^d)\,\mathrm{L_R}\\
&+\frac{1}{32}\,(-\frac{1}{\lambda_{\mathrm{WW}}}\,\mathrm{T}_{365}^d+2\,\mathrm{T}_7^d+9\,\mathrm{V}_9)\,\frac{s^2}{c^2}\,a_0^{\mathrm{fin}}\left(M_{\mathrm{Z}}\right)
\end{aligned}
$$

$$
\begin{aligned}
\mathscr{T}_{\mathrm{P;WW}}^{\mathrm{nfc}}(a_{\mathrm{ZZ}})=&-\frac{1}{16}\,c^2\,\mathrm{X}_{33}\\
&-\frac{3}{8}\,\frac{x_{\mathrm{H}}^2}{\lambda_{\mathrm{WW}}}\,\mathrm{V}_0\,c^2\,\mathrm{C}_0\left(-M_{\mathrm{H}}^2\,,\,-M_{\mathrm{W}}^2\,,\,-M_{\mathrm{W}}^2\,;M_{\mathrm{H}}\,,M_{\mathrm{W}}\,,M_{\mathrm{H}}\right)\\
&-\frac{1}{4}\,\mathrm{V}_0\,s^2\,c^2\,\mathrm{C}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2\,,\,-M_{\mathrm{W}}^2\,,\,-M_{\mathrm{W}}^2\,;M_{\mathrm{W}}\,,0\,,M_{\mathrm{W}}\right)\\
&-\frac{3}{64}\,\mathrm{W}_{112}\,c^2\,x_{\mathrm{H}}^2\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{H}}\,,M_{\mathrm{H}}\right)\\
&+\frac{1}{64}\,\mathrm{W}_{113}\,c^2\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{W}}^2\,;M_{\mathrm{W}}\,,M_{\mathrm{H}}\right)\\
&+\frac{1}{64}\,\mathrm{W}_{114}\,c^2\,\mathrm{C}_0\left(-M_{\mathrm{H}}^2\,,\,-M_{\mathrm{W}}^2\,,\,-M_{\mathrm{W}}^2\,;M_{\mathrm{W}}\,,M_{\mathrm{H}}\,,M_{\mathrm{W}}\right)\\
&-\frac{1}{32}\,\mathrm{W}_{115}\,c^2\,a_0^{\mathrm{fin}}\left(M_{\mathrm{H}}\right)\\
&+\frac{1}{8}\,\mathrm{W}_{119}\,s^2\,c^2\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{W}}^2\,;0\,,M_{\mathrm{W}}\right)
\end{aligned}
$$

JHEP07(2015)175

$$-\frac{1}{32}\left[2\,c^2+(\frac{1}{\lambda_{\rm WW}}\,{\rm T}^d_{378}+{\rm T}^d_{375}\,{\rm V}_9)\right]\frac{1}{c^2}$$
$$-\frac{1}{64}\left[c^2\,s{\rm W}_{120}-(-\frac{x_{\rm H}^2}{\lambda_{\rm WW}}\,{\rm T}^d_{389}-12\,\frac{1}{\lambda^2_{\rm WW}}\,{\rm T}^d_{386}+\frac{1}{\lambda_{\rm WW}}\,{\rm T}^d_{387}+{\rm T}^d_{385}\,{\rm V}_9)\right]$$
$$\times{\rm B}_0^{\rm fin}\left(-M_{\rm H}^2\,;M_{\rm W}\,,M_{\rm W}\right)$$
$$-\frac{1}{64}\left[c^6\,x_{\rm H}^2+4\,s^2\,c^4+(-12\,\frac{1}{\lambda^2_{\rm WW}}\,{\rm T}^d_{376}-\frac{1}{\lambda_{\rm WW}}\,{\rm T}^d_{370}+{\rm T}^d_{369}\,{\rm V}_9)\right]\frac{1}{c^4}\,{\rm B}_0^{\rm fin}\left(-M_{\rm H}^2\,;M_{\rm Z}\,,M_{\rm Z}\right)$$
$$-\frac{1}{64}\left[8\,\frac{x_{\rm H}^2}{\lambda_{\rm WW}}\,s^4\,c^4-4\,{\rm T}^d_{390}\,c^2+(12\,\frac{1}{\lambda^2_{\rm WW}}\,{\rm T}^d_{381}-\frac{1}{\lambda_{\rm WW}}\,{\rm T}^d_{383}+{\rm T}^d_{380}\,{\rm V}_9)\right]\frac{1}{c^4}$$
$$\times{\rm B}_0^{\rm fin}\left(-M_{\rm W}^2\,;M_{\rm W}\,,M_{\rm Z}\right)$$
$$-\frac{1}{32}\left[2\,{\rm T}^d_7\,c^2+(-\frac{1}{\lambda_{\rm WW}}\,{\rm T}^d_{382}+{\rm T}^d_{368}\,{\rm V}_9)\right]\frac{s^2}{c^4}\,a_0^{\rm fin}\left(M_{\rm Z}\right)$$
$$-\frac{1}{32}\left[2\,{\rm T}^d_{195}\,c^2-(-\frac{1}{\lambda_{\rm WW}}\,{\rm T}^d_{377}+{\rm T}^d_{374}\,{\rm V}_9)\right]\frac{1}{c^2}\,a_0^{\rm fin}\left(M_{\rm W}\right)$$
$$-\frac{1}{64}\left\{8\,\frac{x_{\rm H}^2}{\lambda_{\rm WW}}\,s^4+\left[(-12\,\frac{1}{\lambda^2_{\rm WW}}\,{\rm T}^d_{386}+\frac{1}{\lambda_{\rm WW}}\,{\rm T}^d_{388}+9\,{\rm T}^d_{88}\,{\rm V}_9)\right]-8\,(2\,c^4\,x_{\rm H}^2-{\rm T}^d_{384})\,c^2\right\}\frac{1}{c^2}$$
$$\times{\rm C}_0\left(-M_{\rm H}^2\,,-M_{\rm W}^2\,,-M_{\rm W}^2\,;M_{\rm W}\,,M_{\rm Z}\,,M_{\rm W}\right)$$
$$+\frac{1}{64}\left\{\left[(12\,\frac{1}{\lambda^2_{\rm WW}}\,{\rm T}^d_{371}+\frac{1}{\lambda_{\rm WW}}\,{\rm T}^d_{372}-{\rm T}^d_{373}\,{\rm V}_9)\right]+8\,(2\,c^4\,x_{\rm H}^2+{\rm T}^d_{379})\,c^4\right\}\frac{1}{c^6}$$
$$\times{\rm C}_0\left(-M_{\rm H}^2\,,-M_{\rm W}^2\,,-M_{\rm W}^2\,;M_{\rm Z}\,,M_{\rm W}\,,M_{\rm Z}\right)$$
$$-\frac{1}{32}\,(3\,c^2\,x_{\rm H}^2+4\,{\rm T}^d_{88})\,{\rm L_R}$$

I dim = 4 sub-amplitudes

In this appendix we list the dim = 4 sub-amplitudes for $\rm H \to AZ, ZZ$ and WW.

I.1 $\rm H \to AZ$

$$\mathcal{T}^{\rm t}_{\rm HAZ\,;\,LO}=\frac{1}{4}\,\frac{M_{\rm H}^2\,M_{\rm t}^2}{M_{\rm W}\,(M_{\rm H}^2-M_{\rm Z}^2)}\,\frac{s}{c}\,{\rm v_t}+\frac{1}{8}\,(1-4\,\frac{M_{\rm t}^2}{M_{\rm H}^2-M_{\rm Z}^2})\,\frac{M_{\rm H}^2\,M_{\rm t}^2}{M_{\rm W}}\,\frac{s}{c}\,{\rm v_t}\,{\rm C}_0\left(-M_{\rm H}^2\,,0\,,-M_{\rm Z}^2\,;M_{\rm t}\,,M_{\rm t}\,,M_{\rm t}\right)$$
$$-\frac{1}{4}\,\frac{M_{\rm H}^2\,M_{\rm W}}{M_{\rm H}^2-M_{\rm Z}^2}\,\frac{M_{\rm t}^2}{M_{\rm H}^2-M_{\rm Z}^2}\,\frac{s}{c^3}\,{\rm v_t}\,{\rm B}_0^{\rm fin}\left(-M_{\rm Z}^2\,;M_{\rm t}\,,M_{\rm t}\right)$$
$$+\frac{1}{4}\,\frac{M_{\rm W}\,M_{\rm H}^2}{M_{\rm H}^2-M_{\rm Z}^2}\,\frac{M_{\rm t}^2}{M_{\rm H}^2-M_{\rm Z}^2}\,\frac{s}{c^3}\,{\rm v_t}\,{\rm B}_0^{\rm fin}\left(-M_{\rm H}^2\,;M_{\rm t}\,,M_{\rm t}\right)\qquad\text{(I.1)}$$

$$\mathcal{T}^{\rm b}_{\rm HAZ\,;\,LO}=\frac{1}{8}\,\frac{M_{\rm H}^2\,M_{\rm b}^2}{M_{\rm W}\,(M_{\rm H}^2-M_{\rm Z}^2)}\,\frac{s}{c}\,{\rm v_b}+\frac{1}{16}\,(1-4\,\frac{M_{\rm b}^2}{M_{\rm H}^2-M_{\rm Z}^2})\,\frac{M_{\rm H}^2\,M_{\rm b}^2}{M_{\rm W}}\,\frac{s}{c}\,{\rm v_b}\,{\rm C}_0\left(-M_{\rm H}^2\,,0\,,-M_{\rm Z}^2\,;M_{\rm b}\,,M_{\rm b}\,,M_{\rm b}\right)$$
$$-\frac{1}{8}\,\frac{M_{\rm H}^2\,M_{\rm W}}{M_{\rm H}^2-M_{\rm Z}^2}\,\frac{M_{\rm b}^2}{M_{\rm H}^2-M_{\rm Z}^2}\,\frac{s}{c^3}\,{\rm v_b}\,{\rm B}_0^{\rm fin}\left(-M_{\rm Z}^2\,;M_{\rm b}\,,M_{\rm b}\right)$$
$$+\frac{1}{8}\,\frac{M_{\rm W}\,M_{\rm H}^2}{M_{\rm H}^2-M_{\rm Z}^2}\,\frac{M_{\rm b}^2}{M_{\rm H}^2-M_{\rm Z}^2}\,\frac{s}{c^3}\,{\rm v_b}\,{\rm B}_0^{\rm fin}\left(-M_{\rm H}^2\,;M_{\rm b}\,,M_{\rm b}\right)\qquad\text{(I.2)}$$

$$\mathcal{T}^{\rm W}_{\rm HAZ\,;\,LO}=\frac{1}{16}\left[2\,(1-6\,c^2)\,M_{\rm W}+(1-2\,c^2)\,\frac{M_{\rm H}^2}{M_{\rm W}}\right]\frac{M_{\rm H}^2}{M_{\rm H}^2-M_{\rm Z}^2}\,\frac{s}{c}$$

$$
\begin{aligned}
&-\frac{1}{8}\left[2\,(1-6\,c^2)\,\frac{M_{\rm W}^3}{M_{\rm H}^2-M_{\rm Z}^2}-2\,(1-4\,c^2)\,M_{\rm W}+(1-2\,c^2)\,\frac{M_{\rm H}^2\,M_{\rm W}}{M_{\rm H}^2-M_{\rm Z}^2}\right]M_{\rm H}^2\,\frac{s}{c}\\
&\times \mathrm{C}_0\left(-M_{\rm H}^2\,,0\,,-M_{\rm Z}^2\,;M_{\rm W}\,,M_{\rm W}\,,M_{\rm W}\right)\\
&-\frac{1}{16}\left[2\,(1-6\,c^2)\,\frac{M_{\rm W}^3}{M_{\rm H}^2-M_{\rm Z}^2}+(1-2\,c^2)\,\frac{M_{\rm H}^2\,M_{\rm W}}{M_{\rm H}^2-M_{\rm Z}^2}\right]\frac{M_{\rm H}^2}{M_{\rm H}^2-M_{\rm Z}^2}\,\frac{s}{c^3}\,\mathrm{B}_0^{\rm fin}\left(-M_{\rm Z}^2\,;M_{\rm W}\,,M_{\rm W}\right)\\
&+\frac{1}{16}\left[2\,(1-6\,c^2)\,\frac{M_{\rm W}^3}{M_{\rm H}^2-M_{\rm Z}^2}+(1-2\,c^2)\,\frac{M_{\rm H}^2\,M_{\rm W}}{M_{\rm H}^2-M_{\rm Z}^2}\right]\frac{M_{\rm H}^2}{M_{\rm H}^2-M_{\rm Z}^2}\,\frac{s}{c^3}\,\mathrm{B}_0^{\rm fin}\left(-M_{\rm H}^2\,;M_{\rm W}\,,M_{\rm W}\right)
\end{aligned}
\tag{I.3}
$$

I.2 H → ZZ

$$
\begin{aligned}
\mathscr{D}^{\rm t}_{\rm HZZ\,;\,NLO}=&-\frac{3}{64}\left[2\,\mathrm{L_R}-(1+\mathrm{v}_{\rm t}^2)\right]\frac{1}{c^2}\,\frac{M_{\rm t}^2}{M_{\rm W}}\\
&+\frac{3}{32}\left[c^2+(1+\mathrm{v}_{\rm t}^2)\,\frac{M_{\rm W}^2}{\lambda_{\rm Z}}\right]\frac{1}{c^4}\,\frac{M_{\rm t}^2}{M_{\rm W}}\,\mathrm{B}_0^{\rm fin}\left(-M_{\rm Z}^2\,;M_{\rm t}\,,M_{\rm t}\right)\\
&+\frac{3}{32}\left[(1+\mathrm{v}_{\rm t}^2)\right]\frac{1}{c^4}\,\frac{M_{\rm W}\,M_{\rm t}^2}{\lambda_{\rm Z}}\,\mathrm{B}_0^{\rm fin}\left(-M_{\rm H}^2\,;M_{\rm t}\,,M_{\rm t}\right)\\
&+\frac{3}{128}\left[-4\,(1-\mathrm{v}_{\rm t}^2)\,c^4\,M_{\rm t}^2+(1-\mathrm{v}_{\rm t}^2)\,c^4\,M_{\rm H}^2+2\,(1+\mathrm{v}_{\rm t}^2)\,c^2\,M_{\rm W}^2+4\,(1+\mathrm{v}_{\rm t}^2)\,\frac{M_{\rm W}^4}{\lambda_{\rm Z}}\right]\frac{1}{c^6}\,\frac{M_{\rm t}^2}{M_{\rm W}}\\
&\times \mathrm{C}_0\left(-M_{\rm H}^2\,,-M_{\rm Z}^2\,,-M_{\rm Z}^2\,;M_{\rm t}\,,M_{\rm t}\,,M_{\rm t}\right)\\
&+\Delta\mathscr{D}^{\rm t}_{\rm HZZ\,;\,NLO}
\end{aligned}
\tag{I.4}
$$

$$
\begin{aligned}
\mathscr{D}^{\rm b}_{\rm HZZ\,;\,NLO}=&-\frac{3}{64}\left[2\,\mathrm{L_R}-(1+\mathrm{v}_{\rm b}^2)\right]\frac{1}{c^2}\,\frac{M_{\rm b}^2}{M_{\rm W}}\\
&+\frac{3}{32}\left[c^2+(1+\mathrm{v}_{\rm b}^2)\,\frac{M_{\rm W}^2}{\lambda_{\rm Z}}\right]\frac{1}{c^4}\,\frac{M_{\rm b}^2}{M_{\rm W}}\,\mathrm{B}_0^{\rm fin}\left(-M_{\rm Z}^2\,;M_{\rm b}\,,M_{\rm b}\right)\\
&+\frac{3}{32}\left[(1+\mathrm{v}_{\rm b}^2)\right]\frac{1}{c^4}\,\frac{M_{\rm b}^2\,M_{\rm W}}{\lambda_{\rm Z}}\,\mathrm{B}_0^{\rm fin}\left(-M_{\rm H}^2\,;M_{\rm b}\,,M_{\rm b}\right)\\
&+\frac{3}{128}\left[(1-\mathrm{v}_{\rm b}^2)\,c^4\,M_{\rm H}^2-4\,(1-\mathrm{v}_{\rm b}^2)\,M_{\rm b}^2\,c^4+2\,(1+\mathrm{v}_{\rm b}^2)\,c^2\,M_{\rm W}^2+4\,(1+\mathrm{v}_{\rm b}^2)\,\frac{M_{\rm W}^4}{\lambda_{\rm Z}}\right]\frac{1}{c^6}\,\frac{M_{\rm b}^2}{M_{\rm W}}\\
&\times \mathrm{C}_0\left(-M_{\rm H}^2\,,-M_{\rm Z}^2\,,-M_{\rm Z}^2\,;M_{\rm b}\,,M_{\rm b}\,,M_{\rm b}\right)\\
&+\Delta\mathscr{D}^{\rm b}_{\rm HZZ\,;\,NLO}
\end{aligned}
\tag{I.5}
$$

$$
\begin{aligned}
\mathscr{D}^{\rm W}_{\rm HZZ\,;\,NLO}=&-\frac{1}{4}\,a_0^{\rm fin}\left(M_{\rm W}\right)M_{\rm W}\\
&+\frac{1}{64}\left[3\,(1+2\,c^2)\,\mathrm{L_R}\,M_{\rm W}^2-(1+2\,c^2+32\,c^4-24\,s^2\,c^4)\,M_{\rm W}^2-(3-4\,s^2\,c^2)\,c^2\,M_{\rm H}^2\right]\frac{1}{M_{\rm W}}\,\frac{1}{c^4}\\
&+\frac{1}{32}\left[c^2+2\,(1+8\,c^2-12\,s^2\,c^2)\,\frac{M_{\rm W}^2}{\lambda_{\rm Z}}+(1-4\,s^2\,c^2)\,\frac{M_{\rm H}^2}{\lambda_{\rm Z}}\right]\frac{1}{c^4}\,M_{\rm W}\,\mathrm{B}_0^{\rm fin}\left(-M_{\rm H}^2\,;M_{\rm W}\,,M_{\rm W}\right)\\
&+\frac{1}{32}\left[4\,(1-2\,c^2)\,c^2+2\,(1+8\,c^2-12\,s^2\,c^2)\,\frac{M_{\rm W}^2}{\lambda_{\rm Z}}+(1-4\,s^2\,c^2)\,\frac{M_{\rm H}^2}{\lambda_{\rm Z}}\right]\frac{1}{c^4}\,M_{\rm W}\,\mathrm{B}_0^{\rm fin}\left(-M_{\rm Z}^2\,;M_{\rm W}\,,M_{\rm W}\right)\\
&+\frac{1}{64}\,(M_{\rm W}^2+\frac{M_{\rm H}^4}{\lambda_{\rm Z}}\,c^2+2\,\frac{M_{\rm W}^2\,M_{\rm H}^2}{\lambda_{\rm Z}})\,\frac{1}{M_{\rm W}}\,\frac{1}{c^4}\,\mathrm{B}_0^{\rm fin}\left(-M_{\rm H}^2\,;M_{\rm Z}\,,M_{\rm Z}\right)\\
&+\frac{3}{64}\,(2\,M_{\rm W}^2-c^2\,M_{\rm H}^2)\,\frac{1}{M_{\rm W}}\,\frac{1}{c^4}\,\frac{M_{\rm H}^2}{\lambda_{\rm Z}}\,\mathrm{B}_0^{\rm fin}\left(-M_{\rm H}^2\,;M_{\rm H}\,,M_{\rm H}\right)
\end{aligned}
$$

$$
\begin{aligned}
&+\frac{1}{32}\,(2\,M_{\mathrm{W}}^2-\frac{M_{\mathrm{H}}^4}{\lambda_{\mathrm{Z}}}\,c^2+4\,\frac{M_{\mathrm{W}}^2\,M_{\mathrm{H}}^2}{\lambda_{\mathrm{Z}}})\,\frac{1}{M_{\mathrm{W}}}\,\frac{1}{c^4}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{Z}}^2\,;M_{\mathrm{H}}\,,M_{\mathrm{Z}}\right)\\
&+\frac{1}{32}\left[6\,(1-4\,c^2-4\,c^4)\,c^4\,M_{\mathrm{W}}^2+(1-4\,c^2+12\,c^4)\,c^4\,M_{\mathrm{H}}^2-2\,(1+8\,c^2-12\,s^2\,c^2)\,\frac{M_{\mathrm{W}}^4}{\lambda_{\mathrm{Z}}}\right.\\
&\left.-(1-4\,s^2\,c^2)\,\frac{M_{\mathrm{W}}^2\,M_{\mathrm{H}}^2}{\lambda_{\mathrm{Z}}}\right]\frac{1}{c^6}\,M_{\mathrm{W}}\,\mathrm{C}_0\left(-M_{\mathrm{H}}^2\,,-M_{\mathrm{Z}}^2\,,-M_{\mathrm{Z}}^2\,;M_{\mathrm{W}}\,,M_{\mathrm{W}}\,,M_{\mathrm{W}}\right)\\
&+\frac{1}{64}\,(4\,M_{\mathrm{W}}^4-2\,c^2\,M_{\mathrm{W}}^2\,M_{\mathrm{H}}^2-c^4\,M_{\mathrm{H}}^4-\frac{M_{\mathrm{H}}^6}{\lambda_{\mathrm{Z}}}\,c^4-2\,\frac{M_{\mathrm{W}}^2\,M_{\mathrm{H}}^4}{\lambda_{\mathrm{Z}}}\,c^2)\,\frac{1}{M_{\mathrm{W}}}\,\frac{1}{c^6}\\
&\times\mathrm{C}_0\left(-M_{\mathrm{H}}^2\,,-M_{\mathrm{Z}}^2\,,-M_{\mathrm{Z}}^2\,;M_{\mathrm{Z}}\,,M_{\mathrm{H}}\,,M_{\mathrm{Z}}\right)\\
&+\frac{3}{64}\,(-c^2\,M_{\mathrm{W}}^2+\frac{M_{\mathrm{H}}^4}{\lambda_{\mathrm{Z}}}\,c^4-4\,\frac{M_{\mathrm{W}}^2\,M_{\mathrm{H}}^2}{\lambda_{\mathrm{Z}}}\,c^2+4\,\frac{M_{\mathrm{W}}^4}{\lambda_{\mathrm{Z}}})\,\frac{1}{c^6}\,\frac{M_{\mathrm{H}}^2}{M_{\mathrm{W}}}\\
&\times\mathrm{C}_0\left(-M_{\mathrm{H}}^2\,,-M_{\mathrm{Z}}^2\,,-M_{\mathrm{Z}}^2\,;M_{\mathrm{H}}\,,M_{\mathrm{Z}}\,,M_{\mathrm{H}}\right)\\
&+\Delta\mathscr{D}^{\mathrm{W}}_{\mathrm{HZZ\,;NLO}}
\end{aligned}
\tag{I.6}
$$

$$
\begin{aligned}
\Delta\mathscr{D}^{\mathrm{t}}_{\mathrm{HZZ\,;NLO}}&=\frac{1}{32}\,\frac{M_{\mathrm{W}}}{c^2}\,\left(\mathrm{W}^{(4)}_{\mathrm{H}\,;\mathrm{t}}+2\,\mathrm{W}^{(4)}_{\mathrm{Z}\,;\mathrm{t}}+4\,\mathrm{d}\mathscr{Z}^{(4)}_{c\,;\mathrm{t}}\right)\\
\Delta\mathscr{D}^{\mathrm{b}}_{\mathrm{HZZ\,;NLO}}&=\frac{1}{32}\,\frac{M_{\mathrm{W}}}{c^2}\,\left(\mathrm{W}^{(4)}_{\mathrm{H}\,;\mathrm{b}}+2\,\mathrm{W}^{(4)}_{\mathrm{Z}\,;\mathrm{b}}+4\,\mathrm{d}\mathscr{Z}^{(4)}_{c\,;\mathrm{b}}\right)\\
\Delta\mathscr{D}^{\mathrm{W}}_{\mathrm{HZZ\,;NLO}}&=\frac{1}{32}\,\frac{M_{\mathrm{W}}}{c^2}\,\left(\mathrm{W}^{(4)}_{\mathrm{H}\,;\mathrm{W}}+2\,\mathrm{W}^{(4)}_{\mathrm{Z}\,;\mathrm{W}}-\mathrm{d}\mathscr{Z}^{(4)}_{M_{\mathrm{W}}\,;\mathrm{W}}-2\,\mathrm{d}\mathscr{Z}^{(4)}_{g\,;\mathrm{W}}+4\,\mathrm{d}\mathscr{Z}^{(4)}_{c\,;\mathrm{W}}\right)
\end{aligned}
\tag{I.7}
$$

$$
\begin{aligned}
\mathscr{P}^{\mathrm{t}}_{\mathrm{HZZ\,;NLO}}=\;&\frac{3}{64}\left[(1+\mathrm{v}_{\mathrm{t}}^2)+(1+\mathrm{v}_{\mathrm{t}}^2)\,\frac{M_{\mathrm{H}}^2}{\lambda_{\mathrm{Z}}}\right]\frac{1}{c^2}\,\frac{M_{\mathrm{t}}^2}{M_{\mathrm{W}}\,M_{\mathrm{H}}^2}\\
&+\frac{3}{128}\left[(1+\mathrm{v}_{\mathrm{t}}^2)\,c^2+12\,(1+\mathrm{v}_{\mathrm{t}}^2)\,\frac{M_{\mathrm{W}}^2\,M_{\mathrm{H}}^2}{\lambda_{\mathrm{Z}}^2}+(7-\mathrm{v}_{\mathrm{t}}^2)\,\frac{M_{\mathrm{H}}^2}{\lambda_{\mathrm{Z}}}\,c^2\right]\frac{1}{c^4}\,\frac{M_{\mathrm{t}}^2}{M_{\mathrm{W}}\,M_{\mathrm{H}}^2}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{t}}\,,M_{\mathrm{t}}\right)\\
&+\frac{3}{128}\left[(1+\mathrm{v}_{\mathrm{t}}^2)\,c^2+12\,(1+\mathrm{v}_{\mathrm{t}}^2)\,\frac{M_{\mathrm{W}}^2\,M_{\mathrm{H}}^2}{\lambda_{\mathrm{Z}}^2}+(7-\mathrm{v}_{\mathrm{t}}^2)\,\frac{M_{\mathrm{H}}^2}{\lambda_{\mathrm{Z}}}\,c^2\right]\frac{1}{c^4}\,\frac{M_{\mathrm{t}}^2}{M_{\mathrm{W}}\,M_{\mathrm{H}}^2}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{Z}}^2\,;M_{\mathrm{t}}\,,M_{\mathrm{t}}\right)\\
&+\frac{3}{128}\left[2\,(1-\mathrm{v}_{\mathrm{t}}^2)\,c^4\,M_{\mathrm{H}}^2-(1+\mathrm{v}_{\mathrm{t}}^2)\,c^2\,M_{\mathrm{W}}^2+4\,(1+\mathrm{v}_{\mathrm{t}}^2)\,c^4\,M_{\mathrm{t}}^2+4\,(1+\mathrm{v}_{\mathrm{t}}^2)\,\frac{M_{\mathrm{H}}^2\,M_{\mathrm{t}}^2}{\lambda_{\mathrm{Z}}}\,c^4\right.\\
&\left.+12\,(1+\mathrm{v}_{\mathrm{t}}^2)\,\frac{M_{\mathrm{W}}^4\,M_{\mathrm{H}}^2}{\lambda_{\mathrm{Z}}^2}+(9+\mathrm{v}_{\mathrm{t}}^2)\,\frac{M_{\mathrm{W}}^2\,M_{\mathrm{H}}^2}{\lambda_{\mathrm{Z}}}\,c^2\right]\frac{1}{c^6}\,\frac{M_{\mathrm{t}}^2}{M_{\mathrm{W}}\,M_{\mathrm{H}}^2}\\
&\times\mathrm{C}_0\left(-M_{\mathrm{H}}^2\,,-M_{\mathrm{Z}}^2\,,-M_{\mathrm{Z}}^2\,;M_{\mathrm{t}}\,,M_{\mathrm{t}}\,,M_{\mathrm{t}}\right)
\end{aligned}
\tag{I.8}
$$

$$
\begin{aligned}
\mathscr{P}^{\mathrm{b}}_{\mathrm{HZZ\,;NLO}}=\;&\frac{3}{64}\left[(1+\mathrm{v}_{\mathrm{b}}^2)+(1+\mathrm{v}_{\mathrm{b}}^2)\,\frac{M_{\mathrm{H}}^2}{\lambda_{\mathrm{Z}}}\right]\frac{1}{c^2}\,\frac{M_{\mathrm{b}}^2}{M_{\mathrm{W}}\,M_{\mathrm{H}}^2}\\
&+\frac{3}{128}\left[(1+\mathrm{v}_{\mathrm{b}}^2)\,c^2+12\,(1+\mathrm{v}_{\mathrm{b}}^2)\,\frac{M_{\mathrm{W}}^2\,M_{\mathrm{H}}^2}{\lambda_{\mathrm{Z}}^2}+(7-\mathrm{v}_{\mathrm{b}}^2)\,\frac{M_{\mathrm{H}}^2}{\lambda_{\mathrm{Z}}}\,c^2\right]\frac{1}{c^4}\,\frac{M_{\mathrm{b}}^2}{M_{\mathrm{W}}\,M_{\mathrm{H}}^2}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{b}}\,,M_{\mathrm{b}}\right)\\
&+\frac{3}{128}\left[(1+\mathrm{v}_{\mathrm{b}}^2)\,c^2+12\,(1+\mathrm{v}_{\mathrm{b}}^2)\,\frac{M_{\mathrm{W}}^2\,M_{\mathrm{H}}^2}{\lambda_{\mathrm{Z}}^2}+(7-\mathrm{v}_{\mathrm{b}}^2)\,\frac{M_{\mathrm{H}}^2}{\lambda_{\mathrm{Z}}}\,c^2\right]\frac{1}{c^4}\,\frac{M_{\mathrm{b}}^2}{M_{\mathrm{W}}\,M_{\mathrm{H}}^2}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{Z}}^2\,;M_{\mathrm{b}}\,,M_{\mathrm{b}}\right)\\
&+\frac{3}{128}\left[2\,(1-\mathrm{v}_{\mathrm{b}}^2)\,c^4\,M_{\mathrm{H}}^2-(1+\mathrm{v}_{\mathrm{b}}^2)\,c^2\,M_{\mathrm{W}}^2+4\,(1+\mathrm{v}_{\mathrm{b}}^2)\,M_{\mathrm{b}}^2\,c^4+12\,(1+\mathrm{v}_{\mathrm{b}}^2)\,\frac{M_{\mathrm{W}}^4\,M_{\mathrm{H}}^2}{\lambda_{\mathrm{Z}}^2}\right.\\
&\left.+4\,(1+\mathrm{v}_{\mathrm{b}}^2)\,\frac{M_{\mathrm{b}}^2\,M_{\mathrm{H}}^2}{\lambda_{\mathrm{Z}}}\,c^4+(9+\mathrm{v}_{\mathrm{b}}^2)\,\frac{M_{\mathrm{W}}^2\,M_{\mathrm{H}}^2}{\lambda_{\mathrm{Z}}}\,c^2\right]\frac{1}{c^6}\,\frac{M_{\mathrm{b}}^2}{M_{\mathrm{W}}\,M_{\mathrm{H}}^2}
\end{aligned}
$$

$$\times \mathrm{C}_0\left(-M^2_{\mathrm{H}}\,,\,-M^2_{\mathrm{Z}}\,,\,-M^2_{\mathrm{Z}}\,;M_{\mathrm{b}}\,,M_{\mathrm{b}}\,,M_{\mathrm{b}}\right) \tag{I.9}$$

$$\begin{aligned}
\mathscr{P}^{\mathrm{W}}_{\mathrm{HZZ\,;NLO}} = &-\frac{1}{64}\Bigg[(1+2c^2+16c^4-24s^2c^4)\,M^2_{\mathrm{W}}+(1+2c^2+16c^4-24s^2c^4)\,\frac{M^2_{\mathrm{W}}M^2_{\mathrm{H}}}{\lambda_{\mathrm{Z}}}\\
&+(3-4s^2c^2)\,c^2M^2_{\mathrm{H}}+(3-4s^2c^2)\,\frac{M^4_{\mathrm{H}}}{\lambda_{\mathrm{Z}}}\,c^2\Bigg]\,\frac{1}{c^4}\,\frac{1}{M_{\mathrm{W}}M^2_{\mathrm{H}}}\\
&+\frac{1}{64}\,(M^2_{\mathrm{W}}-c^2M^2_{\mathrm{H}}+\frac{M^4_{\mathrm{H}}}{\lambda_{\mathrm{Z}}}\,c^2-\frac{M^2_{\mathrm{W}}M^2_{\mathrm{H}}}{\lambda_{\mathrm{Z}}})\,\frac{1}{c^2}\,\frac{1}{M^3_{\mathrm{W}}}\,a^{\mathrm{fin}}_0\left(M_{\mathrm{H}}\right)\\
&+\frac{1}{64}\,(M^2_{\mathrm{W}}-c^2M^2_{\mathrm{H}}+\frac{M^4_{\mathrm{H}}}{\lambda_{\mathrm{Z}}}\,c^2-\frac{M^2_{\mathrm{W}}M^2_{\mathrm{H}}}{\lambda_{\mathrm{Z}}})\,\frac{1}{c^4}\,\frac{1}{M_{\mathrm{W}}M^2_{\mathrm{H}}}\,a^{\mathrm{fin}}_0\left(M_{\mathrm{Z}}\right)\\
&+\frac{1}{128}\Bigg[2\,(1+8c^2-12s^2c^2)\,c^2M^2_{\mathrm{W}}+24\,(1+8c^2-12s^2c^2)\,\frac{M^4_{\mathrm{W}}M^2_{\mathrm{H}}}{\lambda^2_{\mathrm{Z}}}\\
&+(1-4s^2c^2)\,c^2M^2_{\mathrm{H}}-(1-4s^2c^2)\,\frac{M^4_{\mathrm{H}}}{\lambda_{\mathrm{Z}}}\,c^2+12\,(1-4s^2c^2)\,\frac{M^2_{\mathrm{W}}M^4_{\mathrm{H}}}{\lambda^2_{\mathrm{Z}}}\\
&+2\,(15-8c^2+12s^2c^2)\,\frac{M^2_{\mathrm{W}}M^2_{\mathrm{H}}}{\lambda_{\mathrm{Z}}}\,c^2\Bigg]\,\frac{1}{c^4}\,\frac{1}{M_{\mathrm{W}}M^2_{\mathrm{H}}}\,\mathrm{B}^{\mathrm{fin}}_0\left(-M^2_{\mathrm{H}}\,;M_{\mathrm{W}}\,,M_{\mathrm{W}}\right)\\
&+\frac{1}{128}\Bigg[2\,(1+8c^2-12s^2c^2)\,c^2M^2_{\mathrm{W}}+24\,(1+8c^2-12s^2c^2)\,\frac{M^4_{\mathrm{W}}M^2_{\mathrm{H}}}{\lambda^2_{\mathrm{Z}}}\\
&+(1-4s^2c^2)\,c^2M^2_{\mathrm{H}}-(1-4s^2c^2)\,\frac{M^4_{\mathrm{H}}}{\lambda_{\mathrm{Z}}}\,c^2+12\,(1-4s^2c^2)\,\frac{M^2_{\mathrm{W}}M^4_{\mathrm{H}}}{\lambda^2_{\mathrm{Z}}}\\
&+2\,(15-8c^2+12s^2c^2)\,\frac{M^2_{\mathrm{W}}M^2_{\mathrm{H}}}{\lambda_{\mathrm{Z}}}\,c^2\Bigg]\,\frac{1}{c^4}\,\frac{1}{M_{\mathrm{W}}M^2_{\mathrm{H}}}\,\mathrm{B}^{\mathrm{fin}}_0\left(-M^2_{\mathrm{Z}}\,;M_{\mathrm{W}}\,,M_{\mathrm{W}}\right)\\
&+\frac{1}{256}\,(4M^4_{\mathrm{W}}-c^4M^4_{\mathrm{H}}+\frac{M^6_{\mathrm{H}}}{\lambda_{\mathrm{Z}}}\,c^4+12\,\frac{M^2_{\mathrm{W}}M^6_{\mathrm{H}}}{\lambda^2_{\mathrm{Z}}}\,c^2+28\,\frac{M^4_{\mathrm{W}}M^2_{\mathrm{H}}}{\lambda_{\mathrm{Z}}}+24\,\frac{M^4_{\mathrm{W}}M^4_{\mathrm{H}}}{\lambda^2_{\mathrm{Z}}})\,\frac{1}{c^4}\,\frac{1}{M^3_{\mathrm{W}}M^2_{\mathrm{H}}}\\
&\times\mathrm{B}^{\mathrm{fin}}_0\left(-M^2_{\mathrm{H}}\,;M_{\mathrm{Z}}\,,M_{\mathrm{Z}}\right)\\
&+\frac{1}{128}\,(4c^2M^2_{\mathrm{W}}-c^4M^2_{\mathrm{H}}+\frac{M^4_{\mathrm{H}}}{\lambda_{\mathrm{Z}}}\,c^4-4\,\frac{M^2_{\mathrm{W}}M^2_{\mathrm{H}}}{\lambda_{\mathrm{Z}}}\,c^2-12\,\frac{M^2_{\mathrm{W}}M^4_{\mathrm{H}}}{\lambda^2_{\mathrm{Z}}}\,c^2+16\,\frac{M^4_{\mathrm{W}}}{\lambda_{\mathrm{Z}}}\\
&+48\,\frac{M^4_{\mathrm{W}}M^2_{\mathrm{H}}}{\lambda^2_{\mathrm{Z}}})\,\frac{1}{c^4}\,\frac{1}{M^3_{\mathrm{W}}}\,\mathrm{B}^{\mathrm{fin}}_0\left(-M^2_{\mathrm{Z}}\,;M_{\mathrm{H}}\,,M_{\mathrm{Z}}\right)\\
&+\frac{3}{256}\,(c^4-\frac{M^2_{\mathrm{H}}}{\lambda_{\mathrm{Z}}}\,c^4-12\,\frac{M^2_{\mathrm{W}}M^2_{\mathrm{H}}}{\lambda^2_{\mathrm{Z}}}\,c^2+24\,\frac{M^4_{\mathrm{W}}}{\lambda^2_{\mathrm{Z}}})\,\frac{1}{c^4}\,\frac{M^2_{\mathrm{H}}}{M^3_{\mathrm{W}}}\,\mathrm{B}^{\mathrm{fin}}_0\left(-M^2_{\mathrm{H}}\,;M_{\mathrm{H}}\,,M_{\mathrm{H}}\right)\\
&+\frac{1}{128}\Bigg[(1-8c^2-44c^4+112c^6)\,c^2M^2_{\mathrm{H}}+2\,(1-8c^2+28c^4-48c^6)\,c^2M^2_{\mathrm{W}}\\
&-24\,(1+8c^2-12s^2c^2)\,\frac{M^4_{\mathrm{W}}M^2_{\mathrm{H}}}{\lambda^2_{\mathrm{Z}}}-(1-12c^4+16c^6)\,\frac{M^4_{\mathrm{H}}}{\lambda_{\mathrm{Z}}}\,c^2-12\,(1-4s^2c^2)\,\frac{M^2_{\mathrm{W}}M^4_{\mathrm{H}}}{\lambda^2_{\mathrm{Z}}}\\
&-2\,(17-4c^4+48c^6)\,\frac{M^2_{\mathrm{W}}M^2_{\mathrm{H}}}{\lambda_{\mathrm{Z}}}\,c^2\Bigg]\,\frac{1}{c^6}\,\frac{M_{\mathrm{W}}}{M^2_{\mathrm{H}}}\,\mathrm{C}_0\left(-M^2_{\mathrm{H}}\,,\,-M^2_{\mathrm{Z}}\,,\,-M^2_{\mathrm{Z}}\,;M_{\mathrm{W}}\,,M_{\mathrm{W}}\,,M_{\mathrm{W}}\right)\\
&+\frac{1}{256}\,(8M^4_{\mathrm{W}}+2c^2M^2_{\mathrm{W}}M^2_{\mathrm{H}}-c^4M^4_{\mathrm{H}}+\frac{M^6_{\mathrm{H}}}{\lambda_{\mathrm{Z}}}\,c^4+6\,\frac{M^2_{\mathrm{W}}M^4_{\mathrm{H}}}{\lambda_{\mathrm{Z}}}\,c^2+12\,\frac{M^2_{\mathrm{W}}M^6_{\mathrm{H}}}{\lambda^2_{\mathrm{Z}}}\,c^2+40\,\frac{M^4_{\mathrm{W}}M^2_{\mathrm{H}}}{\lambda_{\mathrm{Z}}}\\
&+24\,\frac{M^4_{\mathrm{W}}M^4_{\mathrm{H}}}{\lambda^2_{\mathrm{Z}}})\,\frac{1}{c^4}\,\frac{1}{M^3_{\mathrm{W}}}\,\mathrm{C}_0\left(-M^2_{\mathrm{H}}\,,\,-M^2_{\mathrm{Z}}\,,\,-M^2_{\mathrm{Z}}\,;M_{\mathrm{Z}}\,,M_{\mathrm{H}}\,,M_{\mathrm{Z}}\right)
\end{aligned}$$

$$+\frac{3}{256}\,(4\,c^4\,M_{\rm W}^2 - c^6\,M_{\rm H}^2 + \frac{M_{\rm H}^4}{\lambda_{\rm Z}}\,c^6 - 4\,\frac{M_{\rm W}^2\,M_{\rm H}^2}{\lambda_{\rm Z}}\,c^4 + 12\,\frac{M_{\rm W}^2\,M_{\rm H}^4}{\lambda_{\rm Z}^2}\,c^4 + 8\,\frac{M_{\rm W}^4}{\lambda_{\rm Z}}\,c^2 - 48\,\frac{M_{\rm W}^4\,M_{\rm H}^2}{\lambda_{\rm Z}^2}\,c^2$$

$$+48\,\frac{M_{\rm W}^6}{\lambda_{\rm Z}^2})\,\frac{1}{c^6}\,\frac{M_{\rm H}^2}{M_{\rm W}^3}\,{\rm C}_0\left(-M_{\rm H}^2\,,\,-M_{\rm Z}^2\,,\,-M_{\rm Z}^2\,;\,M_{\rm H}\,,\,M_{\rm Z}\,,\,M_{\rm H}\right) \qquad \text{(I.10)}$$

I.3 $\mathrm{H} \to \mathrm{WW}$

$$\mathscr{D}^{\rm q}_{\rm HWW\,;\,NLO} = \frac{3}{32}\,(M_{\rm b}^2 + M_{\rm t}^2 - {\rm L_R}\,M_{\rm b}^2 - {\rm L_R}\,M_{\rm t}^2)\,\frac{1}{M_{\rm W}}$$

$$+\frac{3}{16}\,(M_{\rm b}^2 - M_{\rm t}^2 + M_{\rm W}^2)\,\frac{1}{M_{\rm W}}\,\frac{M_{\rm t}^2}{\lambda_{\rm w}}\,{\rm B}_0^{\rm fin}\left(-M_{\rm H}^2\,;\,M_{\rm t}\,,\,M_{\rm t}\right)$$

$$+\frac{3}{16}\,(-M_{\rm b}^2 + M_{\rm t}^2 + M_{\rm W}^2)\,\frac{1}{M_{\rm W}}\,\frac{M_{\rm b}^2}{\lambda_{\rm w}}\,{\rm B}_0^{\rm fin}\left(-M_{\rm H}^2\,;\,M_{\rm b}\,,\,M_{\rm b}\right)$$

$$-\frac{3}{32}\,(M_{\rm b}^2 + M_{\rm t}^2 - 2\,\frac{M_{\rm b}^4}{\lambda_{\rm w}} + 4\,\frac{M_{\rm t}^2\,M_{\rm b}^2}{\lambda_{\rm w}} - 2\,\frac{M_{\rm t}^4}{\lambda_{\rm w}} + 2\,\frac{M_{\rm W}^2\,M_{\rm b}^2}{\lambda_{\rm w}} + 2\,\frac{M_{\rm W}^2\,M_{\rm t}^2}{\lambda_{\rm w}})\,\frac{1}{M_{\rm W}}\,{\rm B}_0^{\rm fin}\left(-M_{\rm W}^2\,;\,M_{\rm t}\,,\,M_{\rm b}\right)$$

$$-\frac{3}{32}\,(-M_{\rm b}^2 + M_{\rm t}^2 + M_{\rm W}^2 + 2\,\frac{M_{\rm b}^4}{\lambda_{\rm w}} - 4\,\frac{M_{\rm t}^2\,M_{\rm b}^2}{\lambda_{\rm w}} + 2\,\frac{M_{\rm t}^4}{\lambda_{\rm w}} - 4\,\frac{M_{\rm W}^2\,M_{\rm b}^2}{\lambda_{\rm w}} + 4\,\frac{M_{\rm W}^2\,M_{\rm t}^2}{\lambda_{\rm w}} + 2\,\frac{M_{\rm W}^4}{\lambda_{\rm w}})\,\frac{M_{\rm b}^2}{M_{\rm W}}$$

$$\times{\rm C}_0\left(-M_{\rm H}^2\,,\,-M_{\rm W}^2\,,\,-M_{\rm W}^2\,;\,M_{\rm b}\,,\,M_{\rm t}\,,\,M_{\rm b}\right)$$

$$-\frac{3}{32}\,(M_{\rm b}^2 - M_{\rm t}^2 + M_{\rm W}^2 + 2\,\frac{M_{\rm b}^4}{\lambda_{\rm w}} - 4\,\frac{M_{\rm t}^2\,M_{\rm b}^2}{\lambda_{\rm w}} + 2\,\frac{M_{\rm t}^4}{\lambda_{\rm w}} + 4\,\frac{M_{\rm W}^2\,M_{\rm b}^2}{\lambda_{\rm w}} - 4\,\frac{M_{\rm W}^2\,M_{\rm t}^2}{\lambda_{\rm w}} + 2\,\frac{M_{\rm W}^4}{\lambda_{\rm w}})\,\frac{M_{\rm t}^2}{M_{\rm W}}$$

$$\times{\rm C}_0\left(-M_{\rm H}^2\,,\,-M_{\rm W}^2\,,\,-M_{\rm W}^2\,;\,M_{\rm t}\,,\,M_{\rm b}\,,\,M_{\rm t}\right)$$

$$+\Delta\mathscr{D}^{\rm q}_{\rm HWW\,;\,NLO} \qquad \text{(I.11)}$$

$$\mathscr{D}^{\rm W}_{\rm HWW\,;\,NLO} = -\frac{1}{4}\,a_0^{\rm fin}\,(M_{\rm W})\,M_{\rm W}$$

$$-\frac{1}{64}\left[3\,c^2\,M_{\rm H}^2 - 3\,(1+2\,c^2)\,{\rm L_R}\,M_{\rm W}^2 + (1+34\,c^2)\,M_{\rm W}^2\right]\frac{1}{M_{\rm W}}\,\frac{1}{c^2}$$

$$-\frac{1}{64}\left[c^2 - 2\,(1+6\,c^2-16\,c^4)\,\frac{M_{\rm W}^2}{\lambda_{\rm w}} - (-c^2+s^2)\,\frac{M_{\rm H}^2}{\lambda_{\rm w}}\,c^2\right]\frac{1}{c^4}\,M_{\rm W}\,{\rm B}_0^{\rm fin}\left(-M_{\rm H}^2\,;\,M_{\rm Z}\,,\,M_{\rm Z}\right)$$

$$-\frac{1}{64}\left[2\,c^2\,M_{\rm W}^2 + \frac{M_{\rm H}^4}{\lambda_{\rm w}}\,c^2 + (1+2\,c^2)\,\frac{M_{\rm W}^2\,M_{\rm H}^2}{\lambda_{\rm w}} + 2\,(1+8\,c^2)\,\frac{M_{\rm W}^4}{\lambda_{\rm w}}\right]\frac{1}{M_{\rm W}}\,\frac{1}{c^2}\,{\rm B}_0^{\rm fin}\left(-M_{\rm H}^2\,;\,M_{\rm W}\,,\,M_{\rm W}\right)$$

$$+\frac{1}{32}\left[\frac{M_{\rm H}^2}{\lambda_{\rm w}}\,c^4 + 2\,(1-3\,c^2)\,c^2 - (1+5\,c^2-24\,c^4)\,\frac{M_{\rm W}^2}{\lambda_{\rm w}}\right]\frac{1}{c^4}\,M_{\rm W}\,{\rm B}_0^{\rm fin}\left(-M_{\rm W}^2\,;\,M_{\rm W}\,,\,M_{\rm Z}\right)$$

$$+\frac{3}{64}\,(M_{\rm H}^2 - 2\,M_{\rm W}^2)\,\frac{1}{M_{\rm W}}\,\frac{M_{\rm H}^2}{\lambda_{\rm w}}\,{\rm B}_0^{\rm fin}\left(-M_{\rm H}^2\,;\,M_{\rm H}\,,\,M_{\rm H}\right)$$

$$-\frac{1}{32}\,(-2\,M_{\rm W}^2 + \frac{M_{\rm H}^4}{\lambda_{\rm w}} - 4\,\frac{M_{\rm W}^2\,M_{\rm H}^2}{\lambda_{\rm w}})\,\frac{1}{M_{\rm W}}\,{\rm B}_0^{\rm fin}\left(-M_{\rm W}^2\,;\,M_{\rm W}\,,\,M_{\rm H}\right)$$

$$-\frac{1}{64}\left[9\,c^6\,M_{\rm H}^2 - 2\,(1+4\,c^2-28\,c^4+32\,c^6)\,\frac{M_{\rm W}^4}{\lambda_{\rm w}} + 2\,(2-7\,c^2-16\,c^4)\,c^2\,M_{\rm W}^2\right.$$

$$\left.-(c^2-s^2)^2\,\frac{M_{\rm W}^2\,M_{\rm H}^2}{\lambda_{\rm w}}\,c^2\right]\frac{1}{c^6}\,M_{\rm W}\,{\rm C}_0\left(-M_{\rm H}^2\,,\,-M_{\rm W}^2\,,\,-M_{\rm W}^2\,;\,M_{\rm Z}\,,\,M_{\rm W}\,,\,M_{\rm Z}\right)$$

$$+\frac{1}{64}\left[\frac{M_{\rm W}^2\,M_{\rm H}^2}{\lambda_{\rm w}} - 2\,(1-22\,c^2+8\,s^2\,c^2)\,c^2\,M_{\rm W}^2 + 2\,(1+8\,c^2)\,\frac{M_{\rm W}^4}{\lambda_{\rm w}}\right.$$

$$\left.-(1+8\,c^4)\,c^2\,M_{\rm H}^2\right]\frac{1}{c^4}\,M_{\rm W}\,{\rm C}_0\left(-M_{\rm H}^2\,,\,-M_{\rm W}^2\,,\,-M_{\rm W}^2\,;\,M_{\rm W}\,,\,M_{\rm Z}\,,\,M_{\rm W}\right)$$

JHEP07(2015)175

$$
\begin{aligned}
&+\frac{1}{64}\,(M_{\rm H}^4+2\,M_{\rm W}^2\,M_{\rm H}^2-4\,M_{\rm W}^4+\frac{M_{\rm H}^6}{\lambda_{\rm w}}+2\,\frac{M_{\rm W}^2\,M_{\rm H}^4}{\lambda_{\rm w}})\,\frac{1}{M_{\rm W}}\,{\rm C}_0\left(-M_{\rm H}^2\,,-M_{\rm W}^2\,,-M_{\rm W}^2\,;M_{\rm W}\,,M_{\rm H}\,,M_{\rm W}\right)\\
&+\frac{3}{64}\,(-M_{\rm W}^2+\frac{M_{\rm H}^4}{\lambda_{\rm w}}-4\,\frac{M_{\rm W}^2\,M_{\rm H}^2}{\lambda_{\rm w}}+4\,\frac{M_{\rm W}^4}{\lambda_{\rm w}})\,\frac{M_{\rm H}^2}{M_{\rm W}}\,{\rm C}_0\left(-M_{\rm H}^2\,,-M_{\rm W}^2\,,-M_{\rm W}^2\,;M_{\rm H}\,,M_{\rm W}\,,M_{\rm H}\right)\\
&-\frac{1}{8}\,(M_{\rm H}^2-2\,M_{\rm W}^2)\,s^2\,M_{\rm W}\,{\rm C}_0^{\rm fin}\left(-M_{\rm H}^2\,,-M_{\rm W}^2\,,-M_{\rm W}^2\,;M_{\rm W}\,,0\,,M_{\rm W}\right)\\
&+\Delta\mathscr{D}^{\rm W}_{\rm HWW\,;\,NLO}
\end{aligned}
\tag{I.12}
$$

$$
\begin{aligned}
\mathscr{P}^{\rm q}_{\rm HWW\,;\,NLO}=&\;\frac{3}{32}\,(M_{\rm b}^2+M_{\rm t}^2+\frac{M_{\rm H}^2\,M_{\rm b}^2}{\lambda_{\rm w}}+\frac{M_{\rm H}^2\,M_{\rm t}^2}{\lambda_{\rm w}})\,\frac{1}{M_{\rm W}\,M_{\rm H}^2}\\
&+\frac{3}{32}\,(M_{\rm b}^2-M_{\rm t}^2-\frac{M_{\rm H}^2\,M_{\rm b}^2}{\lambda_{\rm w}}+\frac{M_{\rm H}^2\,M_{\rm t}^2}{\lambda_{\rm w}})\,\frac{1}{M_{\rm W}^2}\,\frac{M_{\rm b}^2}{M_{\rm W}\,M_{\rm H}^2}\,a_0^{\rm fin}\left(M_{\rm b}\right)\\
&-\frac{3}{32}\,(M_{\rm b}^2-M_{\rm t}^2-\frac{M_{\rm H}^2\,M_{\rm b}^2}{\lambda_{\rm w}}+\frac{M_{\rm H}^2\,M_{\rm t}^2}{\lambda_{\rm w}})\,\frac{1}{M_{\rm W}^2}\,\frac{M_{\rm t}^2}{M_{\rm W}\,M_{\rm H}^2}\,a_0^{\rm fin}\left(M_{\rm t}\right)\\
&+\frac{3}{64}\,(-M_{\rm b}^2+M_{\rm t}^2+M_{\rm W}^2+\frac{M_{\rm H}^2\,M_{\rm b}^2}{\lambda_{\rm w}}-\frac{M_{\rm H}^2\,M_{\rm t}^2}{\lambda_{\rm w}}+3\,\frac{M_{\rm W}^2\,M_{\rm H}^2}{\lambda_{\rm w}}+12\,\frac{M_{\rm W}^2\,M_{\rm H}^2\,M_{\rm b}^2}{\lambda_{\rm w}^2}\\
&-12\,\frac{M_{\rm W}^2\,M_{\rm H}^2\,M_{\rm t}^2}{\lambda_{\rm w}^2}+12\,\frac{M_{\rm W}^4\,M_{\rm H}^2}{\lambda_{\rm w}^2})\,\frac{1}{M_{\rm W}^2}\,\frac{M_{\rm t}^2}{M_{\rm W}\,M_{\rm H}^2}\,{\rm B}_0^{\rm fin}\left(-M_{\rm H}^2\,;M_{\rm t}\,,M_{\rm t}\right)\\
&+\frac{3}{64}\,(M_{\rm b}^2-M_{\rm t}^2+M_{\rm W}^2-\frac{M_{\rm H}^2\,M_{\rm b}^2}{\lambda_{\rm w}}+\frac{M_{\rm H}^2\,M_{\rm t}^2}{\lambda_{\rm w}}+3\,\frac{M_{\rm W}^2\,M_{\rm H}^2}{\lambda_{\rm w}}-12\,\frac{M_{\rm W}^2\,M_{\rm H}^2\,M_{\rm b}^2}{\lambda_{\rm w}^2}+12\,\frac{M_{\rm W}^2\,M_{\rm H}^2\,M_{\rm t}^2}{\lambda_{\rm w}^2}\\
&+12\,\frac{M_{\rm W}^4\,M_{\rm H}^2}{\lambda_{\rm w}^2})\,\frac{1}{M_{\rm W}^2}\,\frac{M_{\rm b}^2}{M_{\rm W}\,M_{\rm H}^2}\,{\rm B}_0^{\rm fin}\left(-M_{\rm H}^2\,;M_{\rm b}\,,M_{\rm b}\right)\\
&-\frac{3}{64}\,(-M_{\rm b}^4+2\,M_{\rm t}^2\,M_{\rm b}^2-M_{\rm t}^4+M_{\rm W}^2\,M_{\rm b}^2+M_{\rm W}^2\,M_{\rm t}^2+\frac{M_{\rm H}^2\,M_{\rm b}^4}{\lambda_{\rm w}}-2\,\frac{M_{\rm H}^2\,M_{\rm t}^2\,M_{\rm b}^2}{\lambda_{\rm w}}+\frac{M_{\rm H}^2\,M_{\rm t}^4}{\lambda_{\rm w}}\\
&+3\,\frac{M_{\rm W}^2\,M_{\rm H}^2\,M_{\rm b}^2}{\lambda_{\rm w}}-12\,\frac{M_{\rm W}^2\,M_{\rm H}^2\,M_{\rm b}^4}{\lambda_{\rm w}^2}+3\,\frac{M_{\rm W}^2\,M_{\rm H}^2\,M_{\rm t}^2}{\lambda_{\rm w}}+24\,\frac{M_{\rm W}^2\,M_{\rm H}^2\,M_{\rm t}^2\,M_{\rm b}^2}{\lambda_{\rm w}^2}\\
&-12\,\frac{M_{\rm W}^2\,M_{\rm H}^2\,M_{\rm t}^4}{\lambda_{\rm w}^2}+12\,\frac{M_{\rm W}^4\,M_{\rm H}^2\,M_{\rm b}^2}{\lambda_{\rm w}^2}+12\,\frac{M_{\rm W}^4\,M_{\rm H}^2\,M_{\rm t}^2}{\lambda_{\rm w}^2})\,\frac{1}{M_{\rm W}^3\,M_{\rm H}^2}\,{\rm B}_0^{\rm fin}\left(-M_{\rm W}^2\,;M_{\rm t}\,,M_{\rm b}\right)\\
&+\frac{3}{64}\,(M_{\rm b}^4-2\,M_{\rm t}^2\,M_{\rm b}^2+M_{\rm t}^4-2\,M_{\rm W}^2\,M_{\rm b}^2-2\,M_{\rm W}^2\,M_{\rm t}^2+M_{\rm W}^4-\frac{M_{\rm H}^2\,M_{\rm b}^4}{\lambda_{\rm w}}+2\,\frac{M_{\rm H}^2\,M_{\rm t}^2\,M_{\rm b}^2}{\lambda_{\rm w}}-\frac{M_{\rm H}^2\,M_{\rm t}^4}{\lambda_{\rm w}}\\
&-10\,\frac{M_{\rm W}^2\,M_{\rm H}^2\,M_{\rm b}^2}{\lambda_{\rm w}}-12\,\frac{M_{\rm W}^2\,M_{\rm H}^2\,M_{\rm b}^4}{\lambda_{\rm w}^2}+6\,\frac{M_{\rm W}^2\,M_{\rm H}^2\,M_{\rm t}^2}{\lambda_{\rm w}}+24\,\frac{M_{\rm W}^2\,M_{\rm H}^2\,M_{\rm t}^2\,M_{\rm b}^2}{\lambda_{\rm w}^2}-12\,\frac{M_{\rm W}^2\,M_{\rm H}^2\,M_{\rm t}^4}{\lambda_{\rm w}^2}\\
&-5\,\frac{M_{\rm W}^4\,M_{\rm H}^2}{\lambda_{\rm w}}-24\,\frac{M_{\rm W}^4\,M_{\rm H}^2\,M_{\rm b}^2}{\lambda_{\rm w}^2}+24\,\frac{M_{\rm W}^4\,M_{\rm H}^2\,M_{\rm t}^2}{\lambda_{\rm w}^2}\\
&-12\,\frac{M_{\rm W}^6\,M_{\rm H}^2}{\lambda_{\rm w}^2})\,\frac{1}{M_{\rm W}^2}\,\frac{M_{\rm t}^2}{M_{\rm W}\,M_{\rm H}^2}\,{\rm C}_0\left(-M_{\rm H}^2\,,-M_{\rm W}^2\,,-M_{\rm W}^2\,;M_{\rm t}\,,M_{\rm b}\,,M_{\rm t}\right)\\
&+\frac{3}{64}\,(M_{\rm b}^4-2\,M_{\rm t}^2\,M_{\rm b}^2+M_{\rm t}^4-2\,M_{\rm W}^2\,M_{\rm b}^2-2\,M_{\rm W}^2\,M_{\rm t}^2+M_{\rm W}^4-\frac{M_{\rm H}^2\,M_{\rm b}^4}{\lambda_{\rm w}}+2\,\frac{M_{\rm H}^2\,M_{\rm t}^2\,M_{\rm b}^2}{\lambda_{\rm w}}-\frac{M_{\rm H}^2\,M_{\rm t}^4}{\lambda_{\rm w}}\\
&+6\,\frac{M_{\rm W}^2\,M_{\rm H}^2\,M_{\rm b}^2}{\lambda_{\rm w}}-12\,\frac{M_{\rm W}^2\,M_{\rm H}^2\,M_{\rm b}^4}{\lambda_{\rm w}^2}-10\,\frac{M_{\rm W}^2\,M_{\rm H}^2\,M_{\rm t}^2}{\lambda_{\rm w}}+24\,\frac{M_{\rm W}^2\,M_{\rm H}^2\,M_{\rm t}^2\,M_{\rm b}^2}{\lambda_{\rm w}^2}-12\,\frac{M_{\rm W}^2\,M_{\rm H}^2\,M_{\rm t}^4}{\lambda_{\rm w}^2}\\
&-5\,\frac{M_{\rm W}^4\,M_{\rm H}^2}{\lambda_{\rm w}}+24\,\frac{M_{\rm W}^4\,M_{\rm H}^2\,M_{\rm b}^2}{\lambda_{\rm w}^2}-24\,\frac{M_{\rm W}^4\,M_{\rm H}^2\,M_{\rm t}^2}{\lambda_{\rm w}^2}-12\,\frac{M_{\rm W}^6\,M_{\rm H}^2}{\lambda_{\rm w}^2})\,\frac{1}{M_{\rm W}^2}\,\frac{M_{\rm b}^2}{M_{\rm W}\,M_{\rm H}^2}\\
&\times{\rm C}_0\left(-M_{\rm H}^2\,,-M_{\rm W}^2\,,-M_{\rm W}^2\,;M_{\rm b}\,,M_{\rm t}\,,M_{\rm b}\right)
\end{aligned}
\tag{I.13}
$$

$$
\begin{aligned}
\Delta\mathscr{D}^{\mathrm{q}}_{\mathrm{HWW\,;NLO}} &= \frac{1}{32}\,M_{\mathrm{W}}\,\Big(\mathrm{W}^{(4)}_{\mathrm{H\,;t,b}} + 2\,\mathrm{W}^{(4)}_{\mathrm{W\,;t,b}} - \mathrm{d}\mathscr{Z}^{(4)}_{M_{\mathrm{W}}\,;\mathrm{t,b}} - 2\,\mathrm{d}\mathscr{Z}^{(4)}_{g\,;\mathrm{t,b}}\Big) \\
\Delta\mathscr{D}^{\mathrm{W}}_{\mathrm{HWW\,;NLO}} &= \frac{1}{32}\,M_{\mathrm{W}}\,\Big(\mathrm{W}^{(4)}_{\mathrm{H\,;W}} + 2\,\mathrm{W}^{(4)}_{\mathrm{W\,;W}} - \mathrm{d}\mathscr{Z}^{(4)}_{M_{\mathrm{W}}\,;\mathrm{W}} - 2\,\mathrm{d}\mathscr{Z}^{(4)}_{g\,;\mathrm{W}}\Big)
\end{aligned}
\tag{I.14}
$$

$$
\begin{aligned}
\mathscr{P}^{\mathrm{W}}_{\mathrm{HWW\,;NLO}} = &-\frac{1}{64}\left[3\,c^2 M_{\mathrm{H}}^2 + 3\,\frac{M_{\mathrm{H}}^4}{\lambda_{\mathrm{w}}}\,c^2 + (1+18\,c^2)\,M_{\mathrm{W}}^2 + (1+18\,c^2)\,\frac{M_{\mathrm{W}}^2 M_{\mathrm{H}}^2}{\lambda_{\mathrm{w}}}\right]\frac{1}{c^2}\,\frac{1}{M_{\mathrm{W}} M_{\mathrm{H}}^2} \\
&+\frac{1}{64}\left[c^2 M_{\mathrm{H}}^2 - \frac{M_{\mathrm{H}}^4}{\lambda_{\mathrm{w}}}\,c^2 + (1-2\,c^2)\,M_{\mathrm{W}}^2 - (1-2\,c^2)\,\frac{M_{\mathrm{W}}^2 M_{\mathrm{H}}^2}{\lambda_{\mathrm{w}}}\right]\frac{1}{c^2}\,\frac{1}{M_{\mathrm{W}} M_{\mathrm{H}}^2}\,a_0^{\mathrm{fin}}\left(M_{\mathrm{W}}\right) \\
&-\frac{1}{64}\left[(9-8\,s^2) - (9-8\,s^2)\,\frac{M_{\mathrm{H}}^2}{\lambda_{\mathrm{w}}}\right]\frac{M_{\mathrm{W}}}{M_{\mathrm{H}}^2}\,\frac{s^2}{c^4}\,a_0^{\mathrm{fin}}\left(M_{\mathrm{Z}}\right) \\
&-\frac{1}{64}\,(M_{\mathrm{H}}^2 - M_{\mathrm{W}}^2 - \frac{M_{\mathrm{H}}^4}{\lambda_{\mathrm{w}}} + \frac{M_{\mathrm{W}}^2 M_{\mathrm{H}}^2}{\lambda_{\mathrm{w}}})\,\frac{1}{M_{\mathrm{W}}^3}\,a_0^{\mathrm{fin}}\left(M_{\mathrm{H}}\right) \\
&+\frac{1}{2}\,\frac{M_{\mathrm{W}}}{\lambda_{\mathrm{w}}}\,s^2\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{W}}^2\,;0\,,M_{\mathrm{W}}\right) \\
&-\frac{1}{256}\left[c^2 M_{\mathrm{H}}^2 - \frac{M_{\mathrm{H}}^4}{\lambda_{\mathrm{w}}}\,c^2 - 2\,(1-8\,c^2)\,\frac{M_{\mathrm{W}}^2 M_{\mathrm{H}}^2}{\lambda_{\mathrm{w}}} - 24\,(1+6\,c^2-16\,c^4)\,\frac{M_{\mathrm{W}}^4 M_{\mathrm{H}}^2}{\lambda_{\mathrm{w}}^2} + 2\,(1+8\,c^2)\,M_{\mathrm{W}}^2\right. \\
&\left.-12\,(-c^2+s^2)\,\frac{M_{\mathrm{W}}^2 M_{\mathrm{H}}^4}{\lambda_{\mathrm{w}}^2}\,c^2\right]\frac{1}{c^4}\,\frac{1}{M_{\mathrm{W}} M_{\mathrm{H}}^2}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{Z}}\,,M_{\mathrm{Z}}\right) \\
&+\frac{1}{256}\left[c^2 M_{\mathrm{H}}^4 - \frac{M_{\mathrm{H}}^6}{\lambda_{\mathrm{w}}}\,c^2 - 12\,\frac{M_{\mathrm{W}}^2 M_{\mathrm{H}}^6}{\lambda_{\mathrm{w}}^2}\,c^2 + 2\,(1-12\,c^2)\,M_{\mathrm{W}}^4 + (1-2\,c^2)\,M_{\mathrm{W}}^2 M_{\mathrm{H}}^2\right. \\
&-(1-2\,c^2)\,\frac{M_{\mathrm{W}}^2 M_{\mathrm{H}}^4}{\lambda_{\mathrm{w}}} - 12\,(1+2\,c^2)\,\frac{M_{\mathrm{W}}^4 M_{\mathrm{H}}^4}{\lambda_{\mathrm{w}}^2} - 24\,(1+8\,c^2)\,\frac{M_{\mathrm{W}}^6 M_{\mathrm{H}}^2}{\lambda_{\mathrm{w}}^2} \\
&\left.-2\,(1+20\,c^2)\,\frac{M_{\mathrm{W}}^4 M_{\mathrm{H}}^2}{\lambda_{\mathrm{w}}}\right]\frac{1}{c^2}\,\frac{1}{M_{\mathrm{W}}^3 M_{\mathrm{H}}^2}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{W}}\,,M_{\mathrm{W}}\right) \\
&+\frac{1}{128}\left[c^4 M_{\mathrm{H}}^2 - \frac{M_{\mathrm{H}}^4}{\lambda_{\mathrm{w}}}\,c^4 + 12\,\frac{M_{\mathrm{W}}^2 M_{\mathrm{H}}^4}{\lambda_{\mathrm{w}}^2}\,c^4 - (1+5\,c^2-24\,c^4)\,M_{\mathrm{W}}^2\right. \\
&\left.-12\,(1+5\,c^2-24\,c^4)\,\frac{M_{\mathrm{W}}^4 M_{\mathrm{H}}^2}{\lambda_{\mathrm{w}}^2} + (1+21\,c^2-72\,c^4+64\,c^6)\,\frac{M_{\mathrm{W}}^2 M_{\mathrm{H}}^2}{\lambda_{\mathrm{w}}}\right]\frac{1}{c^4}\,\frac{1}{M_{\mathrm{W}} M_{\mathrm{H}}^2} \\
&\times\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{W}}^2\,;M_{\mathrm{W}}\,,M_{\mathrm{Z}}\right) \\
&-\frac{3}{256}\,(1-\frac{M_{\mathrm{H}}^2}{\lambda_{\mathrm{w}}} - 12\,\frac{M_{\mathrm{W}}^2 M_{\mathrm{H}}^2}{\lambda_{\mathrm{w}}^2} + 24\,\frac{M_{\mathrm{W}}^4}{\lambda_{\mathrm{w}}^2})\,\frac{M_{\mathrm{H}}^2}{M_{\mathrm{W}}^3}\,\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{H}}^2\,;M_{\mathrm{H}}\,,M_{\mathrm{H}}\right) \\
&-\frac{1}{128}\,(M_{\mathrm{H}}^2 - 4\,M_{\mathrm{W}}^2 - \frac{M_{\mathrm{H}}^4}{\lambda_{\mathrm{w}}} + 4\,\frac{M_{\mathrm{W}}^2 M_{\mathrm{H}}^2}{\lambda_{\mathrm{w}}} + 12\,\frac{M_{\mathrm{W}}^2 M_{\mathrm{H}}^4}{\lambda_{\mathrm{w}}^2} - 16\,\frac{M_{\mathrm{W}}^4}{\lambda_{\mathrm{w}}} - 48\,\frac{M_{\mathrm{W}}^4 M_{\mathrm{H}}^2}{\lambda_{\mathrm{w}}^2})\,\frac{1}{M_{\mathrm{W}}^3} \\
&\times\mathrm{B}_0^{\mathrm{fin}}\left(-M_{\mathrm{W}}^2\,;M_{\mathrm{W}}\,,M_{\mathrm{H}}\right) \\
&+\frac{1}{256}\left[12\,\frac{M_{\mathrm{W}}^2 M_{\mathrm{H}}^4}{\lambda_{\mathrm{w}}^2} + 2\,(1-36\,c^2+96\,c^4)\,\frac{M_{\mathrm{W}}^2 M_{\mathrm{H}}^2}{\lambda_{\mathrm{w}}} + (1+4\,c^2)\,\frac{M_{\mathrm{H}}^4}{\lambda_{\mathrm{w}}}\right. \\
&-2\,(1+4\,c^2-32\,c^4)\,M_{\mathrm{W}}^2 + 24\,(1+8\,c^2)\,\frac{M_{\mathrm{W}}^4 M_{\mathrm{H}}^2}{\lambda_{\mathrm{w}}^2} \\
&\left.-(-2\,c^2+63\,c^4+s^4)\,M_{\mathrm{H}}^2\right]\frac{1}{c^4}\,\frac{M_{\mathrm{W}}}{M_{\mathrm{H}}^2}\,\mathrm{C}_0\left(-M_{\mathrm{H}}^2\,,-M_{\mathrm{W}}^2\,,-M_{\mathrm{W}}^2\,;M_{\mathrm{W}}\,,M_{\mathrm{Z}}\,,M_{\mathrm{W}}\right)
\end{aligned}
$$

$$
\begin{aligned}
&+\frac{1}{256}\Big[2\,(1-12\,c^2+8\,c^4+64\,c^6)\,\frac{M_W^2\,M_H^2}{\lambda_w}-2\,(1+4\,c^2-32\,c^4)\,M_W^2\\
&+24\,(1+4\,c^2-28\,c^4+32\,c^6)\,\frac{M_W^4\,M_H^2}{\lambda_w^2}+(-2\,c^2+7\,c^4+s^4)\,\frac{M_H^4}{\lambda_w}\,c^2-(-2\,c^2+63\,c^4+s^4)\,c^2\,M_H^2\\
&+12\,(c^4-2\,s^2\,c^2+s^4)\,\frac{M_W^2\,M_H^4}{\lambda_w^2}\,c^2\Big]\,\frac{1}{c^6}\,\frac{M_W}{M_H^2}\,C_0\left(-M_H^2\,,-M_W^2\,,-M_W^2\,;M_Z\,,M_W\,,M_Z\right)\\
&-\frac{3}{256}\,(M_H^2-4\,M_W^2-\frac{M_H^4}{\lambda_w}+4\,\frac{M_W^2\,M_H^2}{\lambda_w}-12\,\frac{M_W^2\,M_H^4}{\lambda_w^2}-8\,\frac{M_W^4}{\lambda_w}+48\,\frac{M_W^4\,M_H^2}{\lambda_w^2}\\
&-48\,\frac{M_W^6}{\lambda_w^2})\,\frac{M_H^2}{M_W^3}\,C_0\left(-M_H^2\,,-M_W^2\,,-M_W^2\,;M_H\,,M_W\,,M_H\right)\\
&-\frac{1}{256}\,(M_H^4-2\,M_W^2\,M_H^2-8\,M_W^4-\frac{M_H^6}{\lambda_w}-6\,\frac{M_W^2\,M_H^4}{\lambda_w}-12\,\frac{M_W^2\,M_H^6}{\lambda_w^2}-40\,\frac{M_W^4\,M_H^2}{\lambda_w}\\
&-24\,\frac{M_W^4\,M_H^4}{\lambda_w^2})\,\frac{1}{M_W^3}\,C_0\left(-M_H^2\,,-M_W^2\,,-M_W^2\,;M_W\,,M_H\,,M_W\right)
\end{aligned}
\tag{I.15}
$$

J Corrections for the W mass

In this appendix we present the full list of corrections for M_W in the α-scheme, as given in eq. (6.5). In this appendix we use $s=\hat{s}_\theta$ and $c=\hat{c}_\theta$ where $\hat{c}_\theta^2$ is defined in eq. (4.73). Furthermore, in this appendix, ratios of masses are defined according to

$$
x_H=\frac{M_H}{M_Z},\qquad x_f=\frac{M_f}{M_Z}
\tag{J.1}
$$

etc. We introduce the following polynomials:

$$
Q^a_0=23-4\,c^2 \qquad Q^a_1=77-12\,c^2
$$

$$
\begin{aligned}
&Q^b_0=21-4\,c^2 && Q^b_1=65-12\,c^2 && Q^b_2=109-6\,Q^a_0\,c^2\\
&Q^b_3=5-2\,c^2 && Q^b_4=62-Q^a_1\,c^2 &&
\end{aligned}
$$

$$
\begin{aligned}
&Q^c_0=2-c^2 && Q^c_1=12\,c^3+29\,s && Q^c_2=19-Q^b_0\,c^2\\
&Q^c_3=75-16\,c^2 && Q^c_4=22-Q^b_0\,c^2 && Q^c_5=52-Q^b_1\,c^2\\
&Q^c_6=5-2\,c^2 && Q^c_7=32-Q^b_2\,c^2 && Q^c_8=7-Q^b_3\,c^2\\
&Q^c_9=1+2\,Q^b_4\,c^2 && &&
\end{aligned}
$$

$$
\begin{aligned}
&Q^d_0=1-2\,c^2 && Q^d_1=119-128\,Q^c_0\,c^2 && Q^d_2=29-Q^c_1\,s\\
&Q^d_3=43-6\,Q^c_2\,c^2 && Q^d_4=15-Q^c_3\,c^2 && Q^d_5=61-12\,Q^c_4\,c^2\\
&Q^d_6=2+3\,Q^c_5\,c^2 && Q^d_7=1-s^2 && Q^d_8=1-s^2\,c^2\\
&Q^d_9=5-4\,c^2 && Q^d_{10}=7-4\,c^2 && Q^d_{11}=9-8\,c^2\\
&Q^d_{12}=13-8\,c^2 && Q^d_{13}=19+4\,Q^c_6\,c^2 && Q^d_{14}=1-2\,Q^c_7\,c^2\\
&Q^d_{15}=7-Q^c_8\,c^2 && Q^d_{16}=7-Q^c_9\,c^2 &&
\end{aligned}
$$

$$
\begin{array}{lll}
\mathrm{Q}^e_0 = 16\,\mathrm{Q}^d_0\, s - \mathrm{Q}^d_1\, c & \mathrm{Q}^e_1 = 1 + 16\,c^2 - 4\,\mathrm{Q}^d_2\, s\, c & \mathrm{Q}^e_2 = 1 + 62\,\mathrm{Q}^d_0\, s\, c - 2\,\mathrm{Q}^d_3\, c^2 \\
\mathrm{Q}^e_3 = 1 + \mathrm{Q}^d_4\, c^2 & \mathrm{Q}^e_4 = 9 - 8\,s^2 & \mathrm{Q}^e_5 = 20\,\mathrm{Q}^d_0\, s + \mathrm{Q}^d_5\, c \\
\mathrm{Q}^e_6 = 59\,\mathrm{Q}^d_0\, s + \mathrm{Q}^d_6\, c & \mathrm{Q}^e_7 = 5 - 8\,c^2 & \mathrm{Q}^e_8 = 9 - 128\,\mathrm{Q}^d_7\, s^2 \\
\mathrm{Q}^e_9 = 3\,\mathrm{Q}^d_0\, c + 32\,\mathrm{Q}^d_8\, s & \mathrm{Q}^e_{10} = 4\,\mathrm{Q}^d_0\, s - \mathrm{Q}^d_9\, c & \mathrm{Q}^e_{11} = 4\,\mathrm{Q}^d_0\, s - \mathrm{Q}^d_{10}\, c \\
\mathrm{Q}^e_{12} = 4\,\mathrm{Q}^d_0\, s - 3\,\mathrm{Q}^d_{11}\, c & \mathrm{Q}^e_{13} = 8\,\mathrm{Q}^d_0\, s - \mathrm{Q}^d_{12}\, c & \mathrm{Q}^e_{14} = 1 - 2\,c^2 \\
\mathrm{Q}^e_{15} = 1 - 2\,\mathrm{Q}^d_{13}\, c^2 & \mathrm{Q}^e_{16} = 12 - \mathrm{Q}^d_{14}\, s\, c - 6\,\mathrm{Q}^d_{15}\, c^2 & \mathrm{Q}^e_{17} = 12 - 6\,\mathrm{Q}^d_{15}\, c^2 + \mathrm{Q}^d_{16}\, s\, c
\end{array}
$$

With their help we derive the correction factors:

$$
\begin{aligned}
\Delta^{(4)}_{\mathrm{l}}\, M_{\mathrm{W}} = & -\frac{1}{24}\,\mathrm{B}^{\mathrm{fin}}_0\left(-M^2_{\mathrm{Z}}\,;0\,,0\right)\,\frac{1}{s^2}\,\frac{c^2}{s^2-c^2} + \frac{1}{24}\,\mathrm{B}^{\mathrm{fin}}_{0\mathrm{p}}\left(0;0\,,M_{\mathrm{l}}\right)\,\frac{1}{s^2-c^2}\,x^4_{\mathrm{l}} \\
& + \frac{1}{24}\,a^{\mathrm{fin}}_0\left(M_{\mathrm{l}}\right)\,\frac{1}{s^2\,c^2}\,x^4_{\mathrm{l}} + \frac{1}{24}\left[x^2_{\mathrm{l}} - \mathrm{v}^2_{\mathrm{l}}\,c^2\,x^2_{\mathrm{l}} - 8\,s^4\,c^2\right] a^{\mathrm{fin}}_0\left(M_{\mathrm{l}}\right)\,\frac{1}{s^2}\,\frac{1}{s^2-c^2} \\
& + \frac{1}{24}\left[x^4_{\mathrm{l}} + c^2\,x^2_{\mathrm{l}} - 2\,s\,c^3\right]\mathrm{B}^{\mathrm{fin}}_0\left(-M^2_{\mathrm{W}}\,;0\,,M_{\mathrm{l}}\right)\,\frac{1}{s^2\,c^2} \\
& + \frac{1}{144}\left[6\,c\,x^2_{\mathrm{l}} + \mathrm{Q}^e_0 + (1-6\,x^2_{\mathrm{l}})\,\mathrm{v}^2_{\mathrm{l}}\,c + 3\,(\mathrm{v}^2_{\mathrm{u}} + \mathrm{v}^2_{\mathrm{d}})\,c\right]\frac{1}{s^2}\,\frac{c}{s^2-c^2} \\
& - \frac{1}{48}\left[(1-4\,x^2_{\mathrm{l}}) + (1+2\,x^2_{\mathrm{l}})\,\mathrm{v}^2_{\mathrm{l}}\right]\mathrm{B}^{\mathrm{fin}}_0\left(-M^2_{\mathrm{Z}}\,;M_{\mathrm{l}}\,,M_{\mathrm{l}}\right)\,\frac{1}{s^2}\,\frac{c^2}{s^2-c^2}
\end{aligned}
\tag{J.2}
$$

$$
\begin{aligned}
\Delta^{(4)}_{\mathrm{q}}\, M_{\mathrm{W}} = & -\frac{1}{8}\left[x^2_{\mathrm{d}} - x^2_{\mathrm{u}}\right] a^{\mathrm{fin}}_0\left(M_{\mathrm{u}}\right)\,\frac{1}{s^2\,c^2}\,x^2_{\mathrm{u}} + \frac{1}{8}\,(x^2_{\mathrm{u}} - x^2_{\mathrm{d}})^2\,\mathrm{B}^{\mathrm{fin}}_{0\mathrm{p}}\left(0;M_{\mathrm{u}}\,,M_{\mathrm{d}}\right)\,\frac{1}{s^2-c^2} \\
& + \frac{1}{72}\left[9\,x^2_{\mathrm{u}} - 9\,\mathrm{v}^2_{\mathrm{u}}\,c^2\,x^2_{\mathrm{u}} + 18\,s^2\,x^2_{\mathrm{d}} - 32\,s^4\,c^2 + 18\,\frac{x^4_{\mathrm{d}}}{x^2_{\mathrm{u}} - x^2_{\mathrm{d}}}\,s^2\right] a^{\mathrm{fin}}_0\left(M_{\mathrm{u}}\right)\,\frac{1}{s^2}\,\frac{1}{s^2-c^2} \\
& - \frac{1}{8}\left[c^2 - (x^2_{\mathrm{d}} - x^2_{\mathrm{u}})\right] a^{\mathrm{fin}}_0\left(M_{\mathrm{d}}\right)\,\frac{1}{s^2\,c^2}\,x^2_{\mathrm{d}} - \frac{1}{8}\left[\mathrm{v}^2_{\mathrm{u}}\,x^2_{\mathrm{u}} + \mathrm{v}^2_{\mathrm{d}}\,x^2_{\mathrm{d}} - (x^2_{\mathrm{d}} + x^2_{\mathrm{u}})\right]\frac{1}{s^2}\,\frac{c^2}{s^2-c^2} \\
& - \frac{1}{72}\left[9\,\mathrm{v}^2_{\mathrm{d}}\,c^2\,x^2_{\mathrm{d}} + 8\,s^4\,c^2 + 18\,\frac{x^4_{\mathrm{d}}}{x^2_{\mathrm{u}} - x^2_{\mathrm{d}}}\,s^2\right] a^{\mathrm{fin}}_0\left(M_{\mathrm{d}}\right)\,\frac{1}{s^2}\,\frac{1}{s^2-c^2} \\
& - \frac{1}{8}\left[2\,s\,c^3 - (x^2_{\mathrm{d}} - x^2_{\mathrm{u}})^2 - (x^2_{\mathrm{d}} + x^2_{\mathrm{u}})\,c^2\right]\mathrm{B}^{\mathrm{fin}}_0\left(M^2_{\mathrm{W}}\,;M_{\mathrm{u}}\,,M_{\mathrm{d}}\right)\,\frac{1}{s^2\,c^2} \\
& - \frac{1}{16}\left[(1-4\,x^2_{\mathrm{d}}) + (1+2\,x^2_{\mathrm{d}})\,\mathrm{v}^2_{\mathrm{d}}\right]\mathrm{B}^{\mathrm{fin}}_0\left(M^2_{\mathrm{Z}}\,;M_{\mathrm{d}}\,,M_{\mathrm{d}}\right)\,\frac{1}{s^2}\,\frac{c^2}{s^2-c^2} \\
& - \frac{1}{16}\left[(1-4\,x^2_{\mathrm{u}}) + (1+2\,x^2_{\mathrm{u}})\,\mathrm{v}^2_{\mathrm{u}}\right]\mathrm{B}^{\mathrm{fin}}_0\left(-M^2_{\mathrm{Z}}\,;M_{\mathrm{u}}\,,M_{\mathrm{u}}\right)\,\frac{1}{s^2}\,\frac{c^2}{s^2-c^2}
\end{aligned}
\tag{J.3}
$$

$$
\begin{aligned}
\Delta^{(4)}_{\mathrm{B}}\, M_{\mathrm{W}} = & \,\mathrm{B}^{\mathrm{fin}}_0\left(-M^2_{\mathrm{W}}\,;0\,,M_{\mathrm{W}}\right)\,c^2 - \frac{1}{6}\,\mathrm{B}^{\mathrm{fin}}_{0\mathrm{p}}\left(0;0\,,M_{\mathrm{W}}\right)\,\frac{s^2\,c^4}{s^2-c^2} \\
& + \frac{1}{48}\,a^{\mathrm{fin}}_0\left(M_{\mathrm{W}}\right)\,\frac{1}{s^2}\,x^2_{\mathrm{H}} - \frac{1}{48}\,\mathrm{Q}^e_1\,\mathrm{B}^{\mathrm{fin}}_0\left(-M^2_{\mathrm{W}}\,;M_{\mathrm{W}}\,,M_{\mathrm{Z}}\right)\,\frac{1}{s^2\,c^2} \\
& - \frac{1}{48}\,\mathrm{Q}^e_4\,\mathrm{B}^{\mathrm{fin}}_{0\mathrm{p}}\left(0;M_{\mathrm{W}}\,,M_{\mathrm{Z}}\right)\,\frac{1}{s^2-c^2}\,s^4 - \frac{1}{48}\,\mathrm{Q}^e_5\,\mathrm{B}^{\mathrm{fin}}_0\left(-M^2_{\mathrm{Z}}\,;M_{\mathrm{W}}\,,M_{\mathrm{W}}\right)\,\frac{1}{s^2}\,\frac{c}{s^2-c^2} \\
& - \frac{1}{48}\left[12 - 4\,x^2_{\mathrm{H}} + x^4_{\mathrm{H}}\right]\mathrm{B}^{\mathrm{fin}}_0\left(-M^2_{\mathrm{Z}}\,;M_{\mathrm{H}}\,,M_{\mathrm{Z}}\right)\,\frac{1}{s^2}\,\frac{c^2}{s^2-c^2} \\
& - \frac{1}{48}\left[x^4_{\mathrm{H}} - 4\,c^2\,x^2_{\mathrm{H}} + 12\,s\,c^3\right]\mathrm{B}^{\mathrm{fin}}_0\left(-M^2_{\mathrm{W}}\,;M_{\mathrm{W}}\,,M_{\mathrm{H}}\right)\,\frac{1}{s^2\,c^2} \\
& - \frac{1}{48}\left[x^4_{\mathrm{H}} - 2\,c^2\,x^2_{\mathrm{H}} + c^4\right]\mathrm{B}^{\mathrm{fin}}_{0\mathrm{p}}\left(0;M_{\mathrm{W}}\,,M_{\mathrm{H}}\right)\,\frac{1}{s^2-c^2} \\
& + \frac{1}{48}\left[3\,c^2\,x^2_{\mathrm{H}} - 8\,c^4 - s^2\,x^4_{\mathrm{H}} - 8\,\frac{c^6}{x^2_{\mathrm{H}} - c^2}\right] a^{\mathrm{fin}}_0\left(M_{\mathrm{H}}\right)\,\frac{1}{c^2}\,\frac{1}{s^2-c^2} \\
& + \frac{1}{48}\left[c^4\,x^2_{\mathrm{H}} - \mathrm{Q}^e_3\right] a^{\mathrm{fin}}_0\left(M_{\mathrm{Z}}\right)\,\frac{1}{s^2\,c^2}\,\frac{1}{s^2-c^2}
\end{aligned}
$$

$$+\frac{1}{48}\left[8\,\frac{s^2\,c^4}{x_{\rm H}^2-c^2}+{\rm Q}_2^e\right]a_0^{\rm fin}\left(M_{\rm W}\right)\,\frac{1}{s^2}\,\frac{1}{s^2-c^2}$$
$$+\frac{1}{36}\left[{\rm Q}_6^e-(100-9\,\Delta_g)\,s^2\,c\right]\frac{1}{s^2}\,\frac{c}{s^2-c^2} \tag{J.4}$$

$$\Delta_{\rm l}^{(6)}\,M_{\rm W}=-\frac{1}{48}\left[8\,a_{\phi{\rm l}}^{(1)}-a_{\phi{\rm D}}\right]{\rm B}_0^{\rm fin}\left(-M_{\rm Z}^2\,;0\,,0\right)\,\frac{1}{s^2}\,\frac{c^2}{s^2-c^2}$$
$$-\frac{1}{144}\left[9\,x_{\rm l}^2\,a_{\phi{\rm D}}-8\,{\rm Q}_7^e\,a_{\phi{\rm D}}+48\,(a_{\phi{\rm l}}^{(3)}+a_{\phi{\rm l}}^{(1)}+a_{\phi{\rm l}})\,s^2+72\,(a_{\phi{\rm l}}^{(1)}-a_{\phi{\rm l}})\,x_{\rm l}^2\right]\frac{1}{s^2}\,\frac{c^2}{s^2-c^2}\,{\rm L_R}$$
$$+\frac{1}{48}\left[c\,x_{\rm l}^2\,a_{\phi{\rm D}}-8\,{\rm v_l}\,c\,x_{\rm l}^2\,a_{\phi{\rm l\,V}}+8\,{\rm v}_{\rm l}^2\,c\,x_{\rm l}^2\,a_{\phi{\rm l}}^{(3)}+8\,s^2\,c^3\,a_{\phi{\rm D}}+64\,s^4\,c\,a_{\phi{\rm l}}^{(3)}+{\rm Q}_{11}^e\,{\rm v_l}\,x_{\rm l}^2\,a_{\phi{\rm D}}\right.$$
$$\left.+8\,(a_{\phi{\rm l}}^{(1)}-a_{\phi{\rm l}})\,c\,x_{\rm l}^2\right]a_0^{\rm fin}\left(M_{\rm l}\right)\,\frac{1}{s^2}\,\frac{c}{s^2-c^2}$$
$$+\frac{1}{288}\left[6\,c^2\,x_{\rm l}^2\,a_{\phi{\rm D}}-{\rm Q}_8^e\,c^2\,a_{\phi{\rm D}}-32\,{\rm Q}_9^e\,s\,a_{\phi{\rm l}}^{(3)}-{\rm Q}_{10}^e\,{\rm v_d}\,c\,a_{\phi{\rm D}}-{\rm Q}_{13}^e\,{\rm v_u}\,c\,a_{\phi{\rm D}}\right.$$
$$+8\,(1-6\,x_{\rm l}^2)\,{\rm v_l}\,c^2\,a_{\phi{\rm l\,V}}-8\,(1-6\,x_{\rm l}^2)\,{\rm v}_{\rm l}^2\,c^2\,a_{\phi{\rm l}}^{(3)}$$
$$-(1-6\,x_{\rm l}^2)\,{\rm Q}_{11}^e\,{\rm v_l}\,c\,a_{\phi{\rm D}}+8\,(122\,a_{\phi{\rm l}}^{(3)}+a_{\phi{\rm l}}^{(1)}+a_{\phi{\rm l}})\,s^2+48\,(a_{\phi{\rm l}}^{(1)}-a_{\phi{\rm l}})\,c^2\,x_{\rm l}^2$$
$$\left.-24\,({\rm v}_{\rm u}^2+{\rm v}_{\rm d}^2)\,c^2\,a_{\phi{\rm l}}^{(3)}\right]\frac{1}{s^2}\,\frac{1}{s^2-c^2}$$
$$+\frac{1}{6}\,(a_{\phi{\rm l}}^{(3)}-a_{\phi{\rm l}}^{(1)}-a_{\phi{\rm l}})\,\frac{1}{s^2}+\frac{1}{288}\left[{\rm Q}_{10}^e\,{\rm v_d}+{\rm Q}_{13}^e\,{\rm v_u}\right]\frac{1}{s^2}\,\frac{c}{s^2-c^2}\,{\rm N_{gen}}\,a_{\phi{\rm D}}$$
$$+\frac{1}{96}\left[{\rm Q}_{11}^e\,{\rm v_l}\,a_{\phi{\rm D}}+2\,{\rm Q}_{12}^e\,{\rm v_l}\,x_{\rm l}^2\,a_{\phi{\rm D}}+(1-4\,x_{\rm l}^2)\,c\,a_{\phi{\rm D}}-8\,(1+2\,x_{\rm l}^2)\,{\rm v_l}\,c\,a_{\phi{\rm l\,V}}\right.$$
$$\left.+8\,(1+2\,x_{\rm l}^2)\,{\rm v}_{\rm l}^2\,c\,a_{\phi{\rm l}}^{(3)}+8\,(a_{\phi{\rm l}}^{(1)}-a_{\phi{\rm l}})\,(1-4\,x_{\rm l}^2)\,c\right]{\rm B}_0^{\rm fin}\left(-M_{\rm Z}^2\,;M_{\rm l}\,,M_{\rm l}\right)\,\frac{1}{s^2}\,\frac{c}{s^2-c^2} \tag{J.5}$$

$$\Delta_{\rm q}^{(6)}\,M_{\rm W}=\frac{1}{3}\left[c\,a_{\phi{\rm q}}^{(3)}-3\,s\,x_{\rm d}^2\right]\frac{1}{s}$$
$$+\frac{1}{144}\left[9\,c\,x_{\rm d}^2\,a_{\phi{\rm D}}-72\,{\rm v_d}\,c\,x_{\rm d}^2\,a_{\phi{\rm d\,V}}+72\,{\rm v}_{\rm d}^2\,c\,x_{\rm d}^2\,a_{\phi{\rm q}}^{(3)}+8\,s^2\,c^3\,a_{\phi{\rm D}}+64\,s^4\,c\,a_{\phi{\rm q}}^{(3)}+3\,{\rm Q}_{10}^e\,{\rm v_d}\,x_{\rm d}^2\,a_{\phi{\rm D}}\right.$$
$$\left.+72\,(a_{\phi{\rm q}}^{(1)}-a_{\phi{\rm d}})\,c\,x_{\rm d}^2\right]a_0^{\rm fin}\left(M_{\rm d}\right)\,\frac{1}{s^2}\,\frac{c}{s^2-c^2}$$
$$+\frac{1}{144}\left[9\,c\,x_{\rm u}^2\,a_{\phi{\rm D}}-72\,{\rm v_u}\,c\,x_{\rm u}^2\,a_{\phi{\rm u\,V}}+72\,{\rm v}_{\rm u}^2\,c\,x_{\rm u}^2\,a_{\phi{\rm q}}^{(3)}+32\,s^2\,c^3\,a_{\phi{\rm D}}+256\,s^4\,c\,a_{\phi{\rm q}}^{(3)}+3\,{\rm Q}_{13}^e\,{\rm v_u}\,x_{\rm u}^2\,a_{\phi{\rm D}}\right.$$
$$\left.-72\,(a_{\phi{\rm q}}^{(1)}-a_{\phi{\rm u}})\,c\,x_{\rm u}^2\right]a_0^{\rm fin}\left(M_{\rm u}\right)\,\frac{1}{s^2}\,\frac{c}{s^2-c^2}$$
$$+\frac{1}{48}\left[24\,{\rm v}_{\rm u}^2\,c\,x_{\rm u}^2\,a_{\phi{\rm q}}^{(3)}+24\,{\rm v}_{\rm d}^2\,c\,x_{\rm d}^2\,a_{\phi{\rm q}}^{(3)}+{\rm Q}_{10}^e\,{\rm v_d}\,x_{\rm d}^2\,a_{\phi{\rm D}}+{\rm Q}_{13}^e\,{\rm v_u}\,x_{\rm u}^2\,a_{\phi{\rm D}}\right.$$
$$+4\,(1-6\,x_{\rm d}^2)\,{\rm v_d}\,c\,a_{\phi{\rm d\,V}}+4\,(1-6\,x_{\rm u}^2)\,{\rm v_u}\,c\,a_{\phi{\rm u\,V}}$$
$$\left.+4\,(a_{\phi{\rm d\,A}}+a_{\phi{\rm u\,A}})\,c+24\,(a_{\phi{\rm q}}^{(1)}-a_{\phi{\rm d}})\,c\,x_{\rm d}^2-24\,(a_{\phi{\rm q}}^{(1)}-a_{\phi{\rm u}})\,c\,x_{\rm u}^2+3\,(x_{\rm d}^2+x_{\rm u}^2)\,c\,a_{\phi{\rm D}}\right]\frac{1}{s^2}\,\frac{c}{s^2-c^2}$$
$$-\frac{1}{288}\left[{\rm Q}_{10}^e\,{\rm v_d}+{\rm Q}_{13}^e\,{\rm v_u}\right]\frac{1}{s^2}\,\frac{c}{s^2-c^2}\,{\rm N_{gen}}\,a_{\phi{\rm D}}$$
$$+\frac{1}{96}\left[3\,(1-4\,x_{\rm d}^2)\,c\,a_{\phi{\rm D}}-24\,(1+2\,x_{\rm d}^2)\,{\rm v_d}\,c\,a_{\phi{\rm d\,V}}+24\,(1+2\,x_{\rm d}^2)\,{\rm v}_{\rm d}^2\,c\,a_{\phi{\rm q}}^{(3)}+(1+2\,x_{\rm d}^2)\,{\rm Q}_{10}^e\,{\rm v_d}\,a_{\phi{\rm D}}\right.$$
$$\left.+24\,(a_{\phi{\rm q}}^{(1)}-a_{\phi{\rm d}})\,(1-4\,x_{\rm d}^2)\,c\right]{\rm B}_0^{\rm fin}\left(-M_{\rm Z}^2\,;M_{\rm d}\,,M_{\rm d}\right)\,\frac{1}{s^2}\,\frac{c}{s^2-c^2}$$
$$+\frac{1}{96}\left[3\,(1-4\,x_{\rm u}^2)\,c\,a_{\phi{\rm D}}-24\,(1+2\,x_{\rm u}^2)\,{\rm v_u}\,c\,a_{\phi{\rm u\,V}}+24\,(1+2\,x_{\rm u}^2)\,{\rm v}_{\rm u}^2\,c\,a_{\phi{\rm q}}^{(3)}+(1+2\,x_{\rm u}^2)\,{\rm Q}_{13}^e\,{\rm v_u}\,a_{\phi{\rm D}}\right.$$
$$\left.-24\,(a_{\phi{\rm q}}^{(1)}-a_{\phi{\rm u}})\,(1-4\,x_{\rm u}^2)\,c\right]{\rm B}_0^{\rm fin}\left(-M_{\rm Z}^2\,;M_{\rm u}\,,M_{\rm u}\right)\,\frac{1}{s^2}\,\frac{c}{s^2-c^2}$$
$$-\frac{1}{48}\left[16\,(3\,a_{\phi{\rm q}}^{(3)}-a_{\phi{\rm q}}^{(1)}+a_{\phi{\rm d}}-2\,a_{\phi{\rm u}})\,s^2+72\,(a_{\phi{\rm q}}^{(1)}-a_{\phi{\rm d}})\,x_{\rm d}^2-72\,(a_{\phi{\rm q}}^{(1)}-a_{\phi{\rm u}})\,x_{\rm u}^2\right.$$

$$
+9\,(x_{\rm d}^2+x_{\rm u}^2)\,a_{\phi\rm D}\Big]\,\frac{1}{s^2}\,\frac{c^2}{s^2-c^2}\,{\rm L_R} \tag{J.6}
$$

$$
\begin{aligned}
\Delta^{(6)}_{\rm B}\,M_{\rm W} = &-\frac{1}{48}\,{\rm Q}^e_1\,{\rm B}^{\rm fin}_0\left(-M^2_{\rm W}\,;M_{\rm W}\,,M_{\rm Z}\right)\,\frac{1}{s^2\,c^2}\,a_{\phi\rm D}\\
&-\frac{1}{48}\,{\rm Q}^e_4\,{\rm B}^{\rm fin}_{0\rm p}\,(0;M_{\rm W}\,,M_{\rm Z})\,\frac{s^4}{s^2-c^2}\,a_{\phi\rm D}-\frac{1}{48}\,{\rm Q}^e_5\,{\rm B}^{\rm fin}_0\left(-M^2_{\rm Z}\,;M_{\rm W}\,,M_{\rm W}\right)\,\frac{1}{s^2}\,\frac{c}{s^2-c^2}\,a_{\phi\rm D}\\
&-\frac{1}{12}\,{\rm Q}^e_{14}\,{\rm B}^{\rm fin}_{0\rm p}\,(0;0\,,M_{\rm W})\,\frac{c^4}{s^2-c^2}\,a_{\phi\rm D}-\frac{1}{48}\Big[a_{\phi\rm D}\\
&+2\,a_{\phi\Box}\Big]\,\Big[12-4\,x^2_{\rm H}+x^4_{\rm H}\Big]\,{\rm B}^{\rm fin}_0\left(-M^2_{\rm Z}\,;M_{\rm H}\,,M_{\rm Z}\right)\,\frac{1}{s^2}\,\frac{c^2}{s^2-c^2}\\
&+\frac{1}{96}\Big[33\,a_{\phi\rm D}+8\,a_{\phi\Box}\Big]\,a^{\rm fin}_0\,(M_{\rm Z})\,\frac{1}{s^2}-\frac{1}{96}\Big[4\,x^2_{\rm H}\,a_{\phi\Box}+15\,c^2\,a_{\phi\rm D}\Big]\,a^{\rm fin}_0\,(M_{\rm H})\,\frac{1}{s^2\,c^2}\,x^2_{\rm H}\\
&-\frac{1}{24}\Big[x^4_{\rm H}-4\,c^2\,x^2_{\rm H}+12\,s\,c^3\Big]\,{\rm B}^{\rm fin}_0\left(-M^2_{\rm W}\,;M_{\rm W}\,,M_{\rm H}\right)\,\frac{1}{s^2\,c^2}\,a_{\phi\Box}\\
&-\frac{1}{24}\Big[x^4_{\rm H}-2\,c^2\,x^2_{\rm H}+c^4\Big]\,{\rm B}^{\rm fin}_{0\rm p}\,(0;M_{\rm W}\,,M_{\rm H})\,\frac{1}{s^2-c^2}\,a_{\phi\Box}\\
&+\frac{1}{48}\Big[2\,c\,x^2_{\rm H}\,a_{\phi\Box}-(39\,a_{\phi\rm D}-4\,a_{\phi\Box})\,s^3+(51\,a_{\phi\rm D}-4\,a_{\phi\Box})\,s\Big]\,a^{\rm fin}_0\,(M_{\rm W})\,\frac{1}{s^2\,c}\\
&+\frac{1}{72}\Big[3\,s\,c^3\,x^2_{\rm H}\,a_{\phi\rm D}-3\,{\rm Q}^e_{17}\,a_{\phi\rm D}+(19\,a_{\phi\rm D}+4\,a_{\phi\Box})\,s^3\,c-(182\,a_{\phi\rm D}+6\,a_{\phi\Box}-9\,\Delta_g\,a_{\phi\rm D})\,s^3\,c^3\Big]\,\frac{1}{s^3\,c}\,\frac{1}{s^2-c^2}\\
&-\frac{1}{96}\Big[32\,s^2\,c^2\,a_{\phi\Box}+32\,\frac{s^2\,c^4}{x^2_{\rm H}-c^2}\,a_{\phi\Box}+2\,(a_{\phi\rm D}+2\,a_{\phi\Box})\,c^2\,x^4_{\rm H}\\
&-3\,(5\,a_{\phi\rm D}+4\,a_{\phi\Box})\,s^2\,x^2_{\rm H}\Big]\,a^{\rm fin}_0\,(M_{\rm H})\,\frac{1}{s^2}\,\frac{1}{s^2-c^2}\\
&+\frac{1}{48}\Big[16\,\frac{s^3\,c^5}{x^2_{\rm H}-c^2}\,a_{\phi\Box}-{\rm Q}^e_{16}\,a_{\phi\rm D}-2\,(15\,a_{\phi\rm D}+a_{\phi\Box})\,s^3\,c^3\Big]\,a^{\rm fin}_0\,(M_{\rm W})\,\frac{1}{s^3\,c}\,\frac{1}{s^2-c^2}\\
&-\frac{1}{96}\Big[2\,{\rm Q}^e_{15}\,a_{\phi\rm D}-2\,(a_{\phi\rm D}+2\,a_{\phi\Box})\,c^4\,x^2_{\rm H}+(139\,a_{\phi\rm D}+8\,a_{\phi\Box})\,s^2\,c^2\Big]\,a^{\rm fin}_0\,(M_{\rm Z})\,\frac{1}{s^2\,c^2}\,\frac{1}{s^2-c^2}\\
&-\frac{1}{96}\Big[(25+9\,x^2_{\rm H})\,a_{\phi\rm D}-4\,(5\,a_{\phi\rm D}-11\,a_{\phi\Box})\,s^2\Big]\,\frac{1}{s^2}\,\frac{c^2}{s^2-c^2}\,{\rm L_R}\\
&+\frac{1}{36}\Big[(a_{\phi\rm D}-2\,a_{\phi\Box})\,c-(33\,a_{\phi\rm D}+2\,a_{\phi\Box})\,s^3+(51\,a_{\phi\rm D}+2\,a_{\phi\Box})\,s\Big]\,\frac{1}{s^2\,c}
\end{aligned} \tag{J.7}
$$

K T parameter

In this appendix we present explicit results for the T parameter of eq. (6.8). For simplicity we only include PTG operators in loops. We have introduced $s=\hat{s}_\theta\,, c=\hat{c}_\theta\,, c_2=\hat{c}_{2\theta}$ and

$$
\alpha\,{\rm T}=\frac{\alpha}{\pi}\,\frac{t}{s^2\,c^2\,c_2} \tag{K.1}
$$

- dim = 4 component

$$
\begin{aligned}
t^{(4)} = &\ \frac{5}{4}\,c^2\,c_2-\frac{1}{4}\sum_{\rm gen}a^{\rm fin}_0\,(M_{\rm u})\,\frac{x^2_{\rm u}\,x^2_{\rm d}}{x^2_{\rm u}-x^2_{\rm d}}\,c_2\\
&+\frac{1}{4}\sum_{\rm gen}a^{\rm fin}_0\,(M_{\rm d})\,\frac{x^2_{\rm u}\,x^2_{\rm d}}{x^2_{\rm u}-x^2_{\rm d}}\,c_2-\frac{1}{24}\,{\rm B}^{\rm fin}_{0\rm p}\,(0;0\,,M_{\rm l})\,c_2\sum_{\rm gen}x^4_{\rm l}\\
&+\frac{1}{6}\,{\rm B}^{\rm fin}_{0\rm p}\,(0;0\,,M_{\rm W})\,s^2\,c^4\,c_2-\frac{1}{48}\,(1-x^2_{\rm H})^2\,{\rm B}^{\rm fin}_{0\rm p}\,(0;M_{\rm H}\,,M_{\rm Z})\,c_2
\end{aligned}
$$

JHEP07(2015)175

$$
\begin{aligned}
&+\frac{1}{48}\,(5+4\,c_2)\,\mathrm{B}^{\mathrm{fin}}_{0\mathrm{p}}\left(0; M_{\mathrm{W}}\,, M_{\mathrm{Z}}\right)\,s^4\,c_2 - \frac{1}{8}\sum_{\mathrm{gen}}(x_{\mathrm{d}}^2-x_{\mathrm{u}}^2)^2\,\mathrm{B}^{\mathrm{fin}}_{0\mathrm{p}}\left(0; M_{\mathrm{u}}\,, M_{\mathrm{d}}\right)\,c_2\\
&+\frac{1}{24}\sum_{\mathrm{gen}}(3\,x_{\mathrm{d}}^2+3\,x_{\mathrm{u}}^2+x_{\mathrm{l}}^2)\,c_2 + \frac{1}{48}\,(x_{\mathrm{H}}^2-c^2)\,(x_{\mathrm{H}}^2-c^2)\,\mathrm{B}^{\mathrm{fin}}_{0\mathrm{p}}\left(0; M_{\mathrm{W}}\,, M_{\mathrm{H}}\right)\,c_2\\
&-\frac{1}{6}\left[-c^2-\frac{c^4}{x_{\mathrm{H}}^2-c^2}+\frac{x_{\mathrm{H}}^2}{x_{\mathrm{H}}^2-1}\right]a_0^{\mathrm{fin}}\left(M_{\mathrm{H}}\right)\,c_2\\
&+\frac{1}{24}\left[4\,\frac{s^2}{x_{\mathrm{H}}^2-1}-(9+17\,c_2+4\,c_2^2)\right]a_0^{\mathrm{fin}}\left(M_{\mathrm{Z}}\right)\,\frac{c_2}{s^2}\\
&-\frac{1}{12}\left[2\,\frac{s^2\,c^2}{x_{\mathrm{H}}^2-c^2}-5\,(2+c_2)\right]a_0^{\mathrm{fin}}\left(M_{\mathrm{W}}\right)\,\frac{c_2}{s^2}\,c^2
\end{aligned}
\qquad \text{(K.2)}
$$

- dim = 6 component

$$
\begin{aligned}
t^{(6)} = &-\frac{1}{6}\,\mathrm{B}^{\mathrm{fin}}_{0\mathrm{p}}\left(0; 0, M_{\mathrm{l}}\right)\,c_2\sum_{\mathrm{gen}}x_{\mathrm{l}}^4\,a^{(3)}_{\phi\mathrm{l}} - \frac{1}{12}\,\mathrm{B}^{\mathrm{fin}}_{0\mathrm{p}}\left(0; 0, M_{\mathrm{W}}\right)\,c^6\,c_2\,a_{\phi\mathrm{D}}\\
&+\frac{1}{96}\,(5+4\,c_2)\,\mathrm{B}^{\mathrm{fin}}_{0\mathrm{p}}\left(0; M_{\mathrm{W}}\,, M_{\mathrm{Z}}\right)\,s^4\,c_2\,a_{\phi\mathrm{D}} - \frac{1}{96}\,(a_{\phi\mathrm{D}}+4\,a_{\phi\Box})\,(1-x_{\mathrm{H}}^2)^2\,\mathrm{B}^{\mathrm{fin}}_{0\mathrm{p}}\left(0; M_{\mathrm{H}}\,, M_{\mathrm{Z}}\right)\,c_2\\
&-\frac{1}{2}\sum_{\mathrm{gen}}(x_{\mathrm{d}}^2-x_{\mathrm{u}}^2)^2\,\mathrm{B}^{\mathrm{fin}}_{0\mathrm{p}}\left(0; M_{\mathrm{u}}\,, M_{\mathrm{d}}\right)\,c_2\,a^{(3)}_{\phi\mathrm{q}} - \frac{1}{96}\,(x_{\mathrm{H}}^2-c^2)\,(x_{\mathrm{H}}^2-c^2)\,(a_{\phi\mathrm{D}}-4\,a_{\phi\Box})\,\mathrm{B}^{\mathrm{fin}}_{0\mathrm{p}}\left(0; M_{\mathrm{W}}\,, M_{\mathrm{H}}\right)\,c_2\\
&+\frac{1}{16}\sum_{\mathrm{gen}}\left[-3\,a_{\phi\mathrm{D}}+16\,\frac{x_{\mathrm{d}}^2}{x_{\mathrm{u}}^2-x_{\mathrm{d}}^2}\,a^{(3)}_{\phi\mathrm{q}}+8\,(2\,a^{(3)}_{\phi\mathrm{q}}-3\,a^{(1)}_{\phi\mathrm{q}}+3\,a_{\phi\mathrm{d}})\right]a_0^{\mathrm{fin}}\left(M_{\mathrm{d}}\right)\,c_2\,x_{\mathrm{d}}^2\\
&-\frac{1}{16}\sum_{\mathrm{gen}}\left[a_{\phi\mathrm{D}}+8\,(a^{(1)}_{\phi\mathrm{l}}-a_{\phi\mathrm{l}})\right]a_0^{\mathrm{fin}}\left(M_{\mathrm{l}}\right)\,c_2\,x_{\mathrm{l}}^2\\
&-\frac{1}{16}\sum_{\mathrm{gen}}\left[3\,a_{\phi\mathrm{D}}+16\,\frac{x_{\mathrm{d}}^2}{x_{\mathrm{u}}^2-x_{\mathrm{d}}^2}\,a^{(3)}_{\phi\mathrm{q}}-24\,(a^{(1)}_{\phi\mathrm{q}}-a_{\phi\mathrm{u}})\right]a_0^{\mathrm{fin}}\left(M_{\mathrm{u}}\right)\,c_2\,x_{\mathrm{u}}^2\\
&-\frac{1}{96}\left[9\,x_{\mathrm{H}}^2\,a_{\phi\mathrm{D}}+8\,(a_{\phi\mathrm{D}}-4\,a_{\phi\Box})\,c^2+8\,(a_{\phi\mathrm{D}}-4\,a_{\phi\Box})\,\frac{c^4}{x_{\mathrm{H}}^2-c^2}+8\,(a_{\phi\mathrm{D}}+4\,a_{\phi\Box})\,\frac{x_{\mathrm{H}}^2}{x_{\mathrm{H}}^2-1}\right]a_0^{\mathrm{fin}}\left(M_{\mathrm{H}}\right)\,c_2\\
&-\frac{1}{24}\left[c_2\,x_{\mathrm{H}}^2\,a_{\phi\mathrm{D}}-2\,c^4\,a_{\phi\Box}+2\,s^4\,a_{\phi\mathrm{D}}-2\,(a_{\phi\mathrm{D}}-a_{\phi\Box})\,s^2\,c^2+2\,(a_{\phi\mathrm{D}}+a_{\phi\Box})\,c_2\right]\\
&-\frac{1}{32}\left[6\,s^2\,x_{\mathrm{H}}^2\,a_{\phi\mathrm{D}}-3\,(7+x_{\mathrm{H}}^2)\,a_{\phi\mathrm{D}}-8\,(5\,a_{\phi\mathrm{D}}-3\,a_{\phi\Box})\,s^4+2\,(31\,a_{\phi\mathrm{D}}-6\,a_{\phi\Box})\,s^2\right]\mathrm{L_R}\\
&-\frac{1}{24}\Bigg[5\,(1-3\,c_2-c_2^2)\,a_{\phi\mathrm{D}}-2\,(a_{\phi\mathrm{D}}-4\,a_{\phi\Box})\,\frac{s^2\,c^2}{x_{\mathrm{H}}^2-c^2}\,c_2\\
&+(a_{\phi\mathrm{D}}-a_{\phi\Box})\,s^2\,c^2-(21\,a_{\phi\mathrm{D}}-a_{\phi\Box})\,s^4\Bigg]a_0^{\mathrm{fin}}\left(M_{\mathrm{W}}\right)\,\frac{c^2}{s^2}\\
&+\frac{1}{192}\Bigg[(51-152\,c_2-3\,c_2^2-16\,c_2^3)\,a_{\phi\mathrm{D}}+16\,(a_{\phi\mathrm{D}}+4\,a_{\phi\Box})\,\frac{s^2}{x_{\mathrm{H}}^2-1}\,c_2+2\,(11\,a_{\phi\mathrm{D}}-4\,a_{\phi\Box})\,s^2\,c^2\\
&-2\,(113\,a_{\phi\mathrm{D}}-4\,a_{\phi\Box})\,s^4\Bigg]a_0^{\mathrm{fin}}\left(M_{\mathrm{Z}}\right)\,\frac{1}{s^2}\\
&-\frac{1}{48}\sum_{\mathrm{gen}}\Bigg[-24\,(a^{(3)}_{\phi\mathrm{q}}-3\,a^{(1)}_{\phi\mathrm{q}}+3\,a_{\phi\mathrm{d}})\,x_{\mathrm{d}}^2-24\,(a^{(3)}_{\phi\mathrm{q}}+3\,a^{(1)}_{\phi\mathrm{q}}-3\,a_{\phi\mathrm{u}})\,x_{\mathrm{u}}^2-8\,(a^{(3)}_{\phi\mathrm{l}}-3\,a^{(1)}_{\phi\mathrm{l}}+3\,a_{\phi\mathrm{l}})\,x_{\mathrm{l}}^2\\
&+3\,(3\,x_{\mathrm{d}}^2+3\,x_{\mathrm{u}}^2+x_{\mathrm{l}}^2)\,a_{\phi\mathrm{D}}\Bigg]\,c_2\\
&+\frac{1}{16}\sum_{\mathrm{gen}}\left[24\,(a^{(1)}_{\phi\mathrm{q}}-a_{\phi\mathrm{d}})\,x_{\mathrm{d}}^2-24\,(a^{(1)}_{\phi\mathrm{q}}-a_{\phi\mathrm{u}})\,x_{\mathrm{u}}^2+8\,(a^{(1)}_{\phi\mathrm{l}}-a_{\phi\mathrm{l}})\,x_{\mathrm{l}}^2+(3\,x_{\mathrm{d}}^2+3\,x_{\mathrm{u}}^2+x_{\mathrm{l}}^2)\,a_{\phi\mathrm{D}}\right]\mathrm{L_R}\,c_2
\end{aligned}
\qquad \text{(K.3)}
$$

References

[1] CMS collaboration, *Observation of a new boson at a mass of* 125 *GeV with the CMS experiment at the LHC*, *Phys. Lett.* **B 716** (2012) 30 [arXiv:1207.7235] [INSPIRE].

[2] ATLAS collaboration, *Observation of a new particle in the search for the standard model Higgs boson with the ATLAS detector at the LHC*, *Phys. Lett.* **B 716** (2012) 1 [arXiv:1207.7214] [INSPIRE].

[3] S. Bolognesi et al., *On the spin and parity of a single-produced resonance at the LHC*, *Phys. Rev.* **D 86** (2012) 095031 [arXiv:1208.4018] [INSPIRE].

[4] LHC Higgs Cross section Working Group collaboration, A. David et al., *LHC HXSWG interim recommendations to explore the coupling structure of a Higgs-like particle*, arXiv:1209.0040 [INSPIRE].

[5] LHC Higgs Cross section Working Group collaboration, S. Heinemeyer et al., *Handbook of LHC Higgs cross sections:* 3. *Higgs properties*, arXiv:1307.1347 [INSPIRE].

[6] R. Contino, M. Ghezzi, C. Grojean, M. Muhlleitner and M. Spira, *Effective Lagrangian for a light Higgs-like scalar*, *JHEP* **07** (2013) 035 [arXiv:1303.3876] [INSPIRE].

[7] A. Azatov, C. Grojean, A. Paul and E. Salvioni, *Taming the off-shell Higgs boson*, *Zh. Eksp. Teor. Fiz.* **147** (2015) 410 [*J. Exp. Theor. Phys.* **120** (2015) 354] [arXiv:1406.6338] [INSPIRE].

[8] R. Contino, M. Ghezzi, C. Grojean, M. Mühlleitner and M. Spira, *eHDECAY: an implementation of the Higgs effective Lagrangian into HDECAY*, *Comput. Phys. Commun.* **185** (2014) 3412 [arXiv:1403.3381] [INSPIRE].

[9] L. Berthier and M. Trott, *Towards consistent electroweak precision data constraints in the SMEFT*, *JHEP* **05** (2015) 024 [arXiv:1502.02570] [INSPIRE].

[10] M. Trott, *On the consistent use of constructed observables*, *JHEP* **02** (2015) 046 [arXiv:1409.7605] [INSPIRE].

[11] R. Alonso, E.E. Jenkins, A.V. Manohar and M. Trott, *Renormalization group evolution of the standard model dimension six operators III: gauge coupling dependence and phenomenology*, *JHEP* **04** (2014) 159 [arXiv:1312.2014] [INSPIRE].

[12] E.E. Jenkins, A.V. Manohar and M. Trott, *Renormalization group evolution of the standard model dimension six operators II: Yukawa dependence*, *JHEP* **01** (2014) 035 [arXiv:1310.4838] [INSPIRE].

[13] E.E. Jenkins, A.V. Manohar and M. Trott, *Naive dimensional analysis counting of gauge theory amplitudes and anomalous dimensions*, *Phys. Lett.* **B 726** (2013) 697 [arXiv:1309.0819] [INSPIRE].

[14] E.E. Jenkins, A.V. Manohar and M. Trott, *Renormalization group evolution of the standard model dimension six operators I: formalism and λ dependence*, *JHEP* **10** (2013) 087 [arXiv:1308.2627] [INSPIRE].

[15] E.E. Jenkins, A.V. Manohar and M. Trott, *On gauge invariance and minimal coupling*, *JHEP* **09** (2013) 063 [arXiv:1305.0017] [INSPIRE].

JHEP07(2015)175

[16] P. Artoisenet et al., *A framework for Higgs characterisation*, *JHEP* **11** (2013) 043 [arXiv:1306.6464] [INSPIRE].

[17] A. Alloul, B. Fuks and V. Sanz, *Phenomenology of the Higgs effective Lagrangian via FEYNRULES*, *JHEP* **04** (2014) 110 [arXiv:1310.5150] [INSPIRE].

[18] J. Ellis, V. Sanz and T. You, *Complete Higgs sector constraints on dimension-6 operators*, *JHEP* **07** (2014) 036 [arXiv:1404.3667] [INSPIRE].

[19] A. Falkowski and F. Riva, *Model-independent precision constraints on dimension-6 operators*, *JHEP* **02** (2015) 039 [arXiv:1411.0669] [INSPIRE].

[20] I. Low, R. Rattazzi and A. Vichi, *Theoretical constraints on the Higgs effective couplings*, *JHEP* **04** (2010) 126 [arXiv:0907.5413] [INSPIRE].

[21] C. Degrande et al., *Effective field theory: a modern approach to anomalous couplings*, *Annals Phys.* **335** (2013) 21 [arXiv:1205.4231] [INSPIRE].

[22] C.-Y. Chen, S. Dawson and C. Zhang, *Electroweak effective operators and Higgs physics*, *Phys. Rev.* **D 89** (2014) 015016 [arXiv:1311.3107] [INSPIRE].

[23] R. Grober, M. Muhlleitner, M. Spira and J. Streicher, *NLO QCD corrections to Higgs pair production including dimension-6 operators*, arXiv:1504.06577 [INSPIRE].

[24] C. Englert, M. McCullough and M. Spannowsky, *Combining LEP and LHC to bound the Higgs width*, arXiv:1504.02458 [INSPIRE].

[25] C. Englert, I. Low and M. Spannowsky, *On-shell interference effects in Higgs boson final states*, *Phys. Rev.* **D 91** (2015) 074029 [arXiv:1502.04678] [INSPIRE].

[26] C. Englert et al., *Precision measurements of Higgs couplings: implications for new physics scales*, *J. Phys.* **G 41** (2014) 113001 [arXiv:1403.7191] [INSPIRE].

[27] A. Biekötter, A. Knochel, M. Krämer, D. Liu and F. Riva, *Vices and virtues of Higgs effective field theories at large energy*, *Phys. Rev.* **D 91** (2015) 055029 [arXiv:1406.7320] [INSPIRE].

[28] R.S. Gupta, A. Pomarol and F. Riva, *BSM primary effects*, *Phys. Rev.* **D 91** (2015) 035001 [arXiv:1405.0181] [INSPIRE].

[29] J. Elias-Miro, J.R. Espinosa, E. Masso and A. Pomarol, *Higgs windows to new physics through $D = 6$ operators: constraints and one-loop anomalous dimensions*, *JHEP* **11** (2013) 066 [arXiv:1308.1879] [INSPIRE].

[30] J. Elias-Miró, J.R. Espinosa, E. Masso and A. Pomarol, *Renormalization of dimension-six operators relevant for the Higgs decays $h \to \gamma\gamma, \gamma Z$*, *JHEP* **08** (2013) 033 [arXiv:1302.5661] [INSPIRE].

[31] A. Pomarol and F. Riva, *Towards the ultimate SM fit to close in on Higgs physics*, *JHEP* **01** (2014) 151 [arXiv:1308.2803] [INSPIRE].

[32] E. Masso, *An effective guide to beyond the standard model physics*, *JHEP* **10** (2014) 128 [arXiv:1406.6376] [INSPIRE].

[33] G. Passarino, *NLO inspired effective Lagrangians for Higgs physics*, *Nucl. Phys.* **B 868** (2013) 416 [arXiv:1209.5538] [INSPIRE].

[34] M. Ghezzi, G. Passarino and S. Uccirati, *Bounding the Higgs width using effective field theory*, PoS(LL2014)072 [arXiv:1405.1925] [INSPIRE].

JHEP07(2015)175

[35] G. Passarino, *Pseudo-observables: an independent safety assessment*, presented at the 9th *workshop of the LHC Higgs cross section working group*, http://indico.cern.ch/event/331452/, CERN, Geneva Switzerland (2015).

[36] G. Passarino, *POs@LEP: theory perspective*, presented at *Pseudo-observables: from LEP to LHC*, https://indico.cern.ch/event/373667/, CERN, Geneva Switzerland (2015).

[37] B. Henning, X. Lu and H. Murayama, *How to use the standard model effective field theory*, arXiv:1412.1837 [INSPIRE].

[38] S. Actis, G. Passarino, C. Sturm and S. Uccirati, *NNLO computational techniques: the cases $H \to \gamma\gamma$ and $H \to gg$*, Nucl. Phys. **B 811** (2009) 182 [arXiv:0809.3667] [INSPIRE].

[39] N. Kauer and G. Passarino, *Inadequacy of zero-width approximation for a light Higgs boson signal*, JHEP **08** (2012) 116 [arXiv:1206.4803] [INSPIRE].

[40] G. Passarino, *Higgs interference effects in $gg \to ZZ$ and their uncertainty*, JHEP **08** (2012) 146 [arXiv:1206.3824] [INSPIRE].

[41] G. Passarino, *Higgs CAT*, Eur. Phys. J. **C 74** (2014) 2866 [arXiv:1312.2397] [INSPIRE].

[42] F. Caola and K. Melnikov, *Constraining the Higgs boson width with ZZ production at the LHC*, Phys. Rev. **D 88** (2013) 054024 [arXiv:1307.4935] [INSPIRE].

[43] J.M. Campbell, R.K. Ellis and C. Williams, *Bounding the Higgs width at the LHC*, PoS(LL2014)008 [arXiv:1408.1723] [INSPIRE].

[44] D.Y. Bardin and G. Passarino, *The standard model in the making: precision study of the electroweak interactions*, International series of monographs on physics **104**, Oxford University Press, Oxford U.K. (1999).

[45] S. Actis, A. Ferroglia, M. Passera and G. Passarino, *Two-loop renormalization in the standard model. Part I: prolegomena*, Nucl. Phys. **B 777** (2007) 1 [hep-ph/0612122] [INSPIRE].

[46] G. Passarino, *Minimal and nonminimal standard models: universality of radiative corrections*, Nucl. Phys. **B 361** (1991) 351 [INSPIRE].

[47] W. Buchmüller and D. Wyler, *Effective Lagrangian analysis of new interactions and flavor conservation*, Nucl. Phys. **B 268** (1986) 621 [INSPIRE].

[48] B. Grzadkowski, M. Iskrzynski, M. Misiak and J. Rosiek, *Dimension-six terms in the standard model Lagrangian*, JHEP **10** (2010) 085 [arXiv:1008.4884] [INSPIRE].

[49] J.A. Aguilar-Saavedra, *A minimal set of top-Higgs anomalous couplings*, Nucl. Phys. **B 821** (2009) 215 [arXiv:0904.2387] [INSPIRE].

[50] J.A. Aguilar-Saavedra, *Effective four-fermion operators in top physics: a roadmap*, Nucl. Phys. **B 843** (2011) 638 [*Erratum ibid.* **B 851** (2011) 443] [arXiv:1008.3562] [INSPIRE].

[51] F. Bonnet, T. Ota, M. Rauch and W. Winter, *Interpretation of precision tests in the Higgs sector in terms of physics beyond the standard model*, Phys. Rev. **D 86** (2012) 093014 [arXiv:1207.4599] [INSPIRE].

[52] F. Bonnet, M.B. Gavela, T. Ota and W. Winter, *Anomalous Higgs couplings at the LHC and their theoretical interpretation*, Phys. Rev. **D 85** (2012) 035016 [arXiv:1105.5140] [INSPIRE].

[53] S. Kanemura and K. Tsumura, *Effects of the anomalous Higgs couplings on the Higgs boson production at the Large Hadron Collider*, Eur. Phys. J. **C 63** (2009) 11 [arXiv:0810.0433] [INSPIRE].

JHEP07(2015)175

- [54] J. Horejsi and K. Kampf, *Contribution of dimension-six bosonic operators to $H \to \gamma\gamma$ at one loop level*, Mod. Phys. Lett. **A 19** (2004) 1681 [hep-ph/0402147] [INSPIRE].
- [55] K. Hagiwara, R. Szalapski and D. Zeppenfeld, *Anomalous Higgs boson production and decay*, Phys. Lett. **B 318** (1993) 155 [hep-ph/9308347] [INSPIRE].
- [56] V. Hankele, G. Klamke, D. Zeppenfeld and T. Figy, *Anomalous Higgs boson couplings in vector boson fusion at the CERN LHC*, Phys. Rev. **D 74** (2006) 095001 [hep-ph/0609075] [INSPIRE].
- [57] C. Anastasiou, S. Buehler, F. Herzog and A. Lazopoulos, *Total cross-section for Higgs boson hadroproduction with anomalous standard model interactions*, JHEP **12** (2011) 058 [arXiv:1107.0683] [INSPIRE].
- [58] T. Corbett, O.J.P. Eboli, J. Gonzalez-Fraile and M.C. Gonzalez-Garcia, *Constraining anomalous Higgs interactions*, Phys. Rev. **D 86** (2012) 075013 [arXiv:1207.1344] [INSPIRE].
- [59] Y.-H. Qi, Y.-P. Kuang, B.-J. Liu and B. Zhang, *Anomalous gauge couplings of the Higgs boson at the CERN LHC: semileptonic mode in WW scatterings*, Phys. Rev. **D 79** (2009) 055010 [*Erratum ibid.* **D 82** (2010) 119902] [arXiv:0811.3099] [INSPIRE].
- [60] K. Hasegawa, N. Kurahashi, C.S. Lim and K. Tanabe, *Anomalous Higgs interactions in gauge-Higgs unification*, Phys. Rev. **D 87** (2013) 016011 [arXiv:1201.5001] [INSPIRE].
- [61] C. Degrande, J.M. Gerard, C. Grojean, F. Maltoni and G. Servant, *Probing top-Higgs non-standard interactions at the LHC*, JHEP **07** (2012) 036 [*Erratum ibid.* **03** (2013) 032] [arXiv:1205.1065] [INSPIRE].
- [62] A. Azatov et al., *Determining Higgs couplings with a model-independent analysis of $h \to \gamma\gamma$*, JHEP **06** (2012) 134 [arXiv:1204.4817] [INSPIRE].
- [63] M.C. Gonzalez-Garcia, *Anomalous Higgs couplings*, Int. J. Mod. Phys. **A 14** (1999) 3121 [hep-ph/9902321] [INSPIRE].
- [64] O.J.P. Eboli, M.C. Gonzalez-Garcia, S.M. Lietti and S.F. Novaes, *Bounds on Higgs and gauge boson interactions from LEP-2 data*, Phys. Lett. **B 434** (1998) 340 [hep-ph/9802408] [INSPIRE].
- [65] V. Barger, T. Han, P. Langacker, B. McElrath and P. Zerwas, *Effects of genuine dimension-six Higgs operators*, Phys. Rev. **D 67** (2003) 115001 [hep-ph/0301097] [INSPIRE].
- [66] F. del Aguila, J. de Blas and M. Pérez-Victoria, *Electroweak limits on general new vector bosons*, JHEP **09** (2010) 033 [arXiv:1005.3998] [INSPIRE].
- [67] M.J.G. Veltman, *Generalized Ward identities and Yang-Mills fields*, Nucl. Phys. **B 21** (1970) 288 [INSPIRE].
- [68] J.C. Taylor, *Ward identities and charge renormalization of the Yang-Mills field*, Nucl. Phys. **B 33** (1971) 436 [INSPIRE].
- [69] A.A. Slavnov, *Ward identities in gauge theories*, Theor. Math. Phys. **10** (1972) 99 [*Teor. Mat. Fiz.* **10** (1972) 153] [INSPIRE].
- [70] M.B. Einhorn and J. Wudka, *The bases of effective field theories*, Nucl. Phys. **B 876** (2013) 556 [arXiv:1307.0478] [INSPIRE].
- [71] G. Passarino, C. Sturm and S. Uccirati, *Higgs pseudo-observables, second Riemann sheet and all that*, Nucl. Phys. **B 834** (2010) 77 [arXiv:1001.3360] [INSPIRE].
- [72] S. Goria, G. Passarino and D. Rosco, *The Higgs boson lineshape*, Nucl. Phys. **B 864** (2012) 530 [arXiv:1112.5517] [INSPIRE].

[73] M. Gonzalez-Alonso, A. Greljo, G. Isidori and D. Marzocca, *Electroweak bounds on Higgs pseudo-observables and $h \to 4\ell$ decays*, arXiv:1504.04018 [INSPIRE].

[74] G. Passarino and R. Pittau, *M_W without Δr*, *Phys. Lett.* **B 228** (1989) 89 [INSPIRE].

[75] S. Actis and G. Passarino, *Two-loop renormalization in the standard model part II: renormalization procedures and computational techniques*, *Nucl. Phys.* **B 777** (2007) 35 [hep-ph/0612123] [INSPIRE].

[76] M.E. Peskin and T. Takeuchi, *A new constraint on a strongly interacting Higgs sector*, *Phys. Rev. Lett.* **65** (1990) 964 [INSPIRE].

[77] S. Actis and G. Passarino, *Two-loop renormalization in the standard model part III: renormalization equations and their solutions*, *Nucl. Phys.* **B 777** (2007) 100 [hep-ph/0612124] [INSPIRE].

[78] J. de Blas et al., *Global Bayesian analysis of the Higgs-boson couplings*, arXiv:1410.4204 [INSPIRE].

[79] G. Montagna, O. Nicrosini, F. Piccinini and G. Passarino, *TOPAZ0* 4.0*: a new version of a computer program for evaluation of deconvoluted and realistic observables at LEP-*1 *and LEP-*2, *Comput. Phys. Commun.* **117** (1999) 278 [hep-ph/9804211] [INSPIRE].

[80] G. Montagna, O. Nicrosini, G. Passarino and F. Piccinini, *TOPAZO* 2.0*: a program for computing deconvoluted and realistic observables around the Z^0 peak*, *Comput. Phys. Commun.* **93** (1996) 120 [hep-ph/9506329] [INSPIRE].

[81] G. Montagna, F. Piccinini, O. Nicrosini, G. Passarino and R. Pittau, *TOPAZ0: a program for computing observables and for fitting cross-sections and forward-backward asymmetries around the Z^0 peak*, *Comput. Phys. Commun.* **76** (1993) 328 [INSPIRE].

[82] A. Akhundov, A. Arbuzov, S. Riemann and T. Riemann, *The ZFITTER project*, *Phys. Part. Nucl.* **45** (2014) 529 [arXiv:1302.1395] [INSPIRE].

[83] A.B. Arbuzov et al., *ZFITTER: a semi-analytical program for fermion pair production in e^+e^- annihilation, from version* 6.21 *to version* 6.42, *Comput. Phys. Commun.* **174** (2006) 728 [hep-ph/0507146] [INSPIRE].

[84] D.A. Ross and M.J.G. Veltman, *Neutral currents in neutrino experiments*, *Nucl. Phys.* **B 95** (1975) 135 [INSPIRE].

[85] C. Hartmann and M. Trott, *On one-loop corrections in the standard model effective field theory; the $\Gamma(h \to \gamma\gamma)$ case*, arXiv:1505.02646 [INSPIRE].