Chapter D

SMEFT

1 CoDEx : BSM physics being realised as an SMEFT

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Program Summary
Program Title: `CoDEx`
Version: `1.0.0`
Licensing provisions: `CC By 4.0`
Programming language: `Wolfram Language®`
Mathematica® Version: `10 +`
URL: `https://effexteam.github.io/CoDEx`
Send BUG reports and Questions: `effex.package@gmail.com`

1.1 Introduction

In spite of the non-observation of any new resonances after the discovery of the Standard Model (SM)-Higgs like particle, which announces the success of the SM, we have enough reason to believe the existence of theories beyond it (BSM), with the SM as a part. As any such theory will affect the electro-weak and the Higgs sector, and the sensitivity of these precision observables are bound to increase in near future, indirect estimation of allowed room left for BSM using Standard Model Effective Field Theory (SMEFT) is well-motivated.

Provided that the S-matrix can be expanded perturbatively in the inverse powers of the ultraviolet scale (Λ^{-1}), and the resultant series is convergent, we can integrate out heavy degrees of freedom and the higher mass dimensional operators capture their impact through – $\sum_i (1/\Lambda^{d_i-4}) C_i \mathcal{O}_i$, where d_i is the operator mass dimension (> 5), and C_i, a function of BSM parameters, is the corresponding Wilson coefficient. Among different choices of operator bases, we restrict ourselves to `"SILH"` [1, 2] and `"Warsaw"` [3–6] bases. All WCs are computed at the cut-of scale Λ, usually identified as the mass of the heavy field. The truncation the $1/\Lambda$ series depends on the experimental precision of the observables [7]. Already, there have been quite a progress in building packages and libraries in the literature, [8–13].

One can justifiably question the validity of choosing to use SMEFT over the full BSM Lagrangian and the answer lies in the trade-off between the computational challenge of the full BSM and precision of the observables. The choice of Λ ensures the convergence of M_Z/Λ series. Using the anomalous dimension matrix (γ) (which is basis dependent), the SMEFT WCs $C_i(\Lambda)$ (computed at Λ), are evolved to $C_i(M_Z)$, some of which are absent at the Λ scale as the matrix γ contains non-zero off-diagonal elements. See [4–6, 14] regarding the running of the SMEFT operators. We need to choose only those 'complete' bases, in which the precision observables are defined.

CoDEx, a *Mathematica*® package [15], in addition to integrating out the heavy field propagator(s) from tree and 1-loop processes and generating SMEFT operators up to dimension-6, provides the WCs as a function of BSM parameters. In this draft, we briefly discuss the underlying principle of **CoDEx**, and give one illustrative example of the work-flow. Details about downloading, installation, and detailed documentation of the functions are available in the website: https://effexteam.github.io/CoDEx.

1.2 The package, in detail

CoDEx is a Wilson coefficient calculator which is developed in Mathematica environment. The algorithm of this code is based on the "Covariant Derivative Expansion" method discussed in [16–30]. Each and every detail about this package can be found here :https://effexteam.github.io/CoDEx. The main functions based on which this program works are captured in Table D.1. Here, we have demonstrated the working methodology of **CoDEx** with an explicit example.

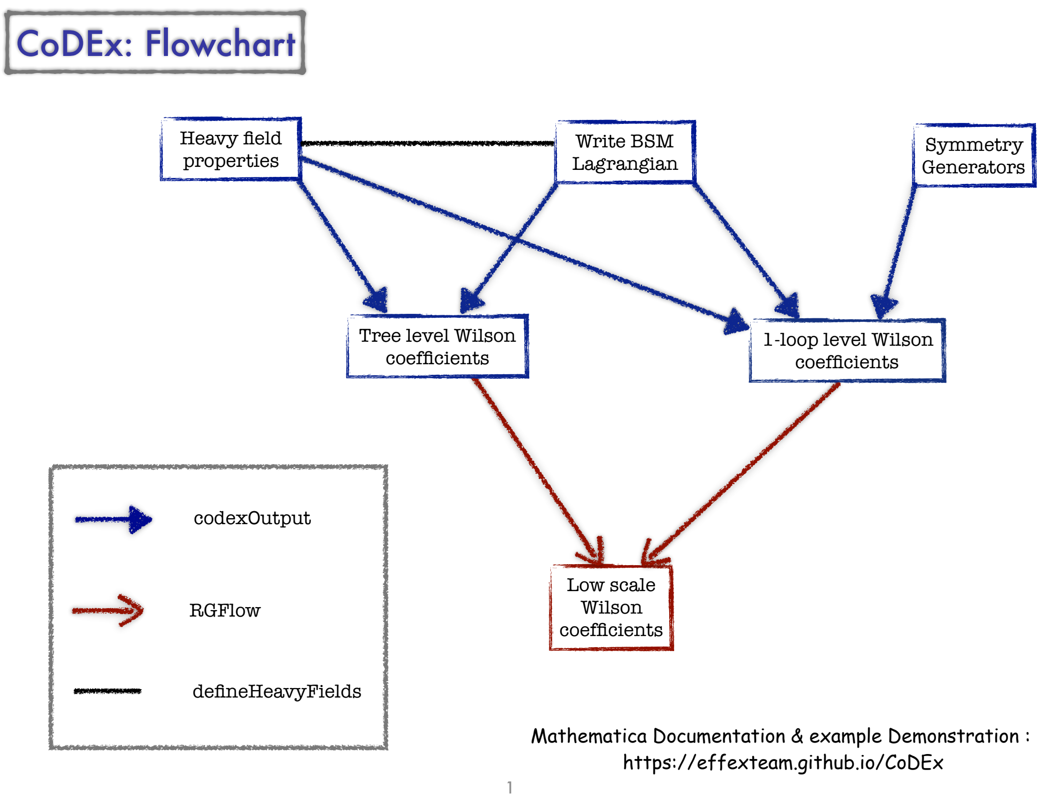

Fig. D.1: Flow-chart demonstrates the working principle of CoDEx

1.2.1 *Detailed example: Electro-weak $SU(2)_L$ Triplet Scalar with hypercharge $Y = 1$*

Here, we have demonstrated the work-flow of **CoDEx** with the help of a complete analysis of a representative model.

$$\mathcal{L}_{BSM} = \mathcal{L}_{SM} + Tr[(\mathcal{D}_\mu\Delta)^\dagger(\mathcal{D}^\mu\Delta)] - m_\Delta^2 Tr[\Delta^\dagger\Delta] + \mathcal{L}_Y - V(H,\Delta), \qquad (1.1)$$

Table D.1: Main functions provided by `CoDEx`

Function	*Details*
`CoDExHelp`	Opens the **`CoDEx`** guide, with all help files listed.
`treeOutput`	Calculates WCs generated from tree level processes.
`loopOutput`	Calculates WCs generated from 1-loop processes.
`codexOutput`	Generic function for WCs calculation with choices for level, bases etc. given with **`OptionValue`**s.
`defineHeavyFields`	Creates representation of heavy fields. Use the output to construct BSM Lagrangian.
`texTable`	Given a **`List`**, returns the LaTeX output of a tabular environment, displayed and/or copied to clipboard.*
`formPick`	Applied on a list of WCs from a specific operator basis, reformats the output in the specified style.
`RGFlow`	RG Flow of WCs of dim. 6 operators in `"Warsaw"` basis, from matching scale to a lower (arbitrary) scale.
`initializeLoop`	Prepares the Isospin and Color symmetry generators for a specific model with a specific heavy field content. `loopOutput` can only be run after this step is done.

where,

$$V(H,\Delta) =\zeta_1(H^\dagger H)Tr[\Delta^\dagger\Delta] + \zeta_2(H^\dagger\tau^i H)Tr[\Delta^\dagger\tau^i\Delta] + [\mu(H^T i\sigma^2\Delta^\dagger H) + h.c.], \tag{1.2}$$

$$\text{and} \quad \mathcal{L}_Y = y_\Delta L^T C i\tau^2 \Delta L + h.c. \tag{1.3}$$

Here, the heavy field is Δ. Once this heavy field, Δ, is integrated out using **`CoDEx`**, the effective operators upto dimension-6 for both bases are generated. The effective operators and their respective Wilson coefficients are listed in Table D.2-D.4. Below we have appended the exact steps one needs to follow to run the code and compute the desired results.

1. First, load the package:

```
In[1]:= Needs["CoDEx"]
```

2. We have to define the field Δ as:

```
fields =
{
{fieldName, components, colorDim, isoDim,
hyperCharge, spin,mass}
};
```

We follow the convention in above line.

```
In[2]:= fieldewcts=
        {
        {hf,3,1,3,1,0,mΔ}
        };

In[3]:= hfvecst2ss=defineHeavyFields[fieldewcts];

In[4]:= δ=hfvecst2ss[[1,1]]

Out[4]= {hf[1,1]+i ihf[1,1],hf[1,2]+i ihf[1,2],hf[1,3]+i ihf[1,3]}
```

3. Now, we will build the Lagrangian after defining the heavy field. We need to provide only those terms that contain the heavy fields. The kinetic terms (covariant derivative and mass terms) of the heavy field will not play any role in this construction, and thus can be ignored. The Lagrangian is written in the following way:

```
In[5]:= Δ=Σ_{i}^{3} δ[[i]] PauliMatrix[i];

In[6]:= Δc =i tau[2].Δ;

In[7]:= V=ζ1 dag[H].H Tr[dag[Δ].Δ]
           +ζ2 Σ_{i}^{3} dag[H].tau[i].H Tr[dag[Δ].tau[i].Δ]
           +μ H.(i tau[2].dag[Δ]).H
           +μ dag[H].(-i Δ.tau[2]).hermitianConjugate[H];

In[8]:= lyukawa=Expand[yΣ Σ_{i}^{2} Σ_{j}^{2} hermitianConjugate[lepb[1][[i]]].
             gamma[0].chargeC.(Δc[[i,j]] lep[1][[j]])
             +yΣ Σ_{i}^{2} Σ_{j}^{2} lepb[1][[i]].gamma[0].
             (dag[Δc][[i,j]] dag[chargeC].lep[1][[j]])];

In[9]:= Lpotent2ss=Expand[lyukawa-V];
```

```
In[10]:= initializeLoop["t2ss",fieldt2ss]

Out[10]= Check the documentation page CoDExParafernalia for details.

   » Isospin Symmetry Generators for the field 'hf' are
     isot2ss[1,a] = tauadj[a]

   » Color Symmetry Generators for the field 'hf' are colt2ss[1,a] = 0
```

(See the documentation of **initializeLoop** for details.)

```
In[13]:= wcT2SSwar=codexOutput[Lpotent2ss,fieldt2ss,model→"t2ss"];
         formPick["Warsaw","Detailed2",wcT2SSwar,FontSize→Medium,
         FontFamily→"Times New Roman",Frame→All]
```

4. The operators can be generated in both "SILH" and "Warsaw" bases along with their respective Wilson coefficients. This output can be exported into a LaTeX format as well, see Table D.3.

```
In[14]:= wcT2SSsilh=codexOutput[Lpotent2ss,fieldt2ss,model→"t2ss",
         operBasis→"SILH"];
         formPick["SILH","Detailed2",wcT2SSsilh,FontSize→Medium,
         FontFamily→"Times New Roman",Frame→All]
```

Output of this can be found in Table D.2.

```
In[15]:= wcT2SSdim5=codexOutput[Lpotent2ss,fieldt2ss,model→"t2ss",
                    operBasis→"Dim5"];
         formPick["Dim5","Detailed2",wcT2SSdim5,FontSize→Medium,
         FontFamily→"Times New Roman",Frame→All]
```

Output of this can be found in Table D.4.

5. The RG evolution of these WCs can be performed only in "Warsaw" basis as this is the complete one using **RGFlow** as:

```
In[16]:= RGFlow[wcT2SSwar,m,μ]
```

Let us consider that the **CoDEx** output which is the WCs at the high scale is generated, and saved as:

In[17]:= wcT2SSwar={{"qH", $-\frac{\zeta 1^3}{4\ m_\Delta{}^2\ \pi^2}-\frac{\zeta 1\ \zeta 2^2}{32\ m_\Delta{}^2\ \pi^2}-\frac{\zeta 1\ \mu^2}{m_\Delta{}^4}-\frac{\zeta 2\ \mu^2}{4\ m_\Delta{}^4}$},
{"qHbox", $\frac{\zeta 2^2}{192\ m_\Delta{}^2\ \pi^2}+\frac{\mu^2}{2\ m_\Delta{}^4}$},
{"qHD", $\frac{\zeta 1^2}{4\ m_\Delta{}^2\ \pi^2}+\frac{\zeta 2^2}{96\ m_\Delta{}^2\ \pi^2}-\frac{2\ \mu^2}{m_\Delta{}^4}$},{"qHW", $\frac{gW^2\ \zeta 1}{48\ m_\Delta{}^2\ \pi^2}$},
{"qHWB", $-\frac{gW\ gY\ \zeta 2}{48\ m_\Delta{}^2\ \pi^2}$},{"qll[1,1,1,1]", $\frac{y\Sigma^2}{4\ m_\Delta{}^2}$},{"qW", $\frac{gW^3}{1440\ m_\Delta{}^2\ \pi^2}$}}

Table D.2: Effective operators and Wilson Coefficients in "SILH" basis for Complex Triplet Scalar (Y=1) model.

O_{2B}	$\frac{g_Y^2}{160\pi^2 m_\Delta^2}$
O_{2W}	$\frac{g_W^2}{240\pi^2 m_\Delta^2}$
O_{3W}	$\frac{g_W^2}{240\pi^2 m_\Delta^2}$
O_6	$-\frac{\zeta_1\mu^2}{m_\Delta^4}-\frac{\zeta_2\mu^2}{4m_\Delta^4}-\frac{\zeta_1^3}{4\pi^2 m_\Delta^2}-\frac{\zeta_2^2\zeta_1}{32\pi^2 m_\Delta^2}$
$O_{\rm BB}$	$\frac{\zeta_1}{32\pi^2 m_\Delta^2}$
O_H	$\frac{\zeta_1^2}{8\pi^2 m_\Delta^2}+\frac{\mu^2}{2m_\Delta^4}$
O_R	$\frac{\zeta_2^2}{96\pi^2 m_\Delta^2}+\frac{\mu^2}{m_\Delta^4}$
O_T	$\frac{\zeta_2^2}{192\pi^2 m_\Delta^2}-\frac{\mu^2}{2m_\Delta^4}$
$O_{\rm WB}$	$-\frac{\zeta_2}{96\pi^2 m_\Delta^2}$
$O_{\rm WW}$	$\frac{\zeta_1}{48\pi^2 m_\Delta^2}$

Once we declare the matching scale (high scale) as the mass of the heavy particle ('**m**'), we need to recall the function **RGFlow** to generate the WCs at low scale as:

```
In[18]:= floRes1 = RGFlow[wcT2SSwar,m,μ]
```

Out[18]=

$$\Big\{\Big\{\text{qW},\frac{\text{gW}^3}{1440\,\text{m}_\Delta{}^2\,\pi^2}+\frac{29\,\text{gW}^5\,\text{Log}[\frac{\mu}{\text{m}}]}{46080\,\text{m}_\Delta{}^2\,\pi^4}\Big\},\Big\{\text{qH},-\frac{\zeta1^3}{4\,\text{m}_\Delta{}^2\,\pi^2}-\frac{\zeta1\,\zeta2^2}{32\,\text{m}_\Delta{}^2\,\pi^2}-\frac{\zeta1\,\mu^2}{\text{m}_\Delta{}^4}-\frac{\zeta2\,\mu^2}{4\,\text{m}_\Delta{}^4}-\frac{3\,\text{gW}^6\,\zeta1\,\text{Log}[\frac{\mu}{\text{m}}]}{256\,\text{m}_\Delta{}^2\,\pi^4}$$
$$-\frac{\text{gW}^4\,\text{gY}^2\,\zeta1\,\text{Log}[\frac{\mu}{\text{m}}]}{256\,\text{m}_\Delta{}^2\,\pi^4}-\frac{3\,\text{gW}^2\,\zeta1^2\,\text{Log}[\frac{\mu}{\text{m}}]}{32\,\text{m}_\Delta{}^2\,\pi^4}-\frac{3\,\text{gW}^4\,\zeta1^2\,\text{Log}[\frac{\mu}{\text{m}}]}{256\,\text{m}_\Delta{}^2\,\pi^4}+\frac{3\,\text{gY}^2\,\zeta1^2\,\text{Log}[\frac{\mu}{\text{m}}]}{32\,\text{m}_\Delta{}^2\,\pi^4}$$
$$-\frac{3\,\text{gW}^2\,\text{gY}^2\,\zeta1^2\,\text{Log}[\frac{\mu}{\text{m}}]}{128\,\text{m}_\Delta{}^2\,\pi^4}-\frac{3\,\text{gY}^4\,\zeta1^2\,\text{Log}[\frac{\mu}{\text{m}}]}{256\,\text{m}_\Delta{}^2\,\pi^4}+\frac{27\,\text{gW}^2\,\zeta1^3\,\text{Log}[\frac{\mu}{\text{m}}]}{128\,\text{m}_\Delta{}^2\,\pi^4}+\frac{9\,\text{gY}^2\,\zeta1^3\,\text{Log}[\frac{\mu}{\text{m}}]}{128\,\text{m}_\Delta{}^2\,\pi^4}$$
$$+\frac{\text{gW}^4\,\text{gY}^2\,\zeta2\,\text{Log}[\frac{\mu}{\text{m}}]}{256\,\text{m}_\Delta{}^2\,\pi^4}+\frac{\text{gW}^2\,\text{gY}^4\,\zeta2\,\text{Log}[\frac{\mu}{\text{m}}]}{256\,\text{m}_\Delta{}^2\,\pi^4}-\frac{\text{gW}^2\,\zeta2^2\,\text{Log}[\frac{\mu}{\text{m}}]}{256\,\text{m}_\Delta{}^2\,\pi^4}-\frac{\text{gW}^4\,\zeta2^2\,\text{Log}[\frac{\mu}{\text{m}}]}{2048\,\text{m}_\Delta{}^2\,\pi^4}+\frac{\text{gY}^2\,\zeta2^2\,\text{Log}[\frac{\mu}{\text{m}}]}{256\,\text{m}_\Delta{}^2\,\pi^4}$$
$$-\frac{\text{gW}^2\,\text{gY}^2\,\zeta2^2\,\text{Log}[\frac{\mu}{\text{m}}]}{1024\,\text{m}_\Delta{}^2\,\pi^4}-\frac{\text{gY}^4\,\zeta2^2\,\text{Log}[\frac{\mu}{\text{m}}]}{2048\,\text{m}_\Delta{}^2\,\pi^4}+\frac{27\,\text{gW}^2\,\zeta1\,\zeta2^2\,\text{Log}[\frac{\mu}{\text{m}}]}{1024\,\text{m}_\Delta{}^2\,\pi^4}$$
$$+\frac{9\,\text{gY}^2\,\zeta1\,\zeta2^2\,\text{Log}[\frac{\mu}{\text{m}}]}{1024\,\text{m}_\Delta{}^2\,\pi^4}+\frac{3\,\text{gW}^4\,\zeta1\,\lambda\,\text{Log}[\frac{\mu}{\text{m}}]}{64\,\text{m}_\Delta{}^2\,\pi^4}-\frac{\text{gW}^2\,\text{gY}^2\,\zeta2\,\lambda\,\text{Log}[\frac{\mu}{\text{m}}]}{64\,\text{m}_\Delta{}^2\,\pi^4}+\frac{5\,\text{gW}^2\,\zeta2^2\,\lambda\,\text{Log}[\frac{\mu}{\text{m}}]}{1152\,\text{m}_\Delta{}^2\,\pi^4}$$
$$+\frac{3\,\text{gW}^2\,\mu^2\,\text{Log}[\frac{\mu}{\text{m}}]}{4\,\text{m}_\Delta{}^4\,\pi^2}+\frac{3\,\text{gW}^4\,\mu^2\,\text{Log}[\frac{\mu}{\text{m}}]}{32\,\text{m}_\Delta{}^4\,\pi^2}-\frac{3\,\text{gY}^2\,\mu^2\,\text{Log}[\frac{\mu}{\text{m}}]}{4\,\text{m}_\Delta{}^4\,\pi^2}$$
$$+\frac{3\,\text{gW}^2\,\text{gY}^2\,\mu^2\,\text{Log}[\frac{\mu}{\text{m}}]}{16\,\text{m}_\Delta{}^4\,\pi^2}+\frac{3\,\text{gY}^4\,\mu^2\,\text{Log}[\frac{\mu}{\text{m}}]}{32\,\text{m}_\Delta{}^4\,\pi^2}+\frac{27\,\text{gW}^2\,\zeta1\,\mu^2\,\text{Log}[\frac{\mu}{\text{m}}]}{32\,\text{m}_\Delta{}^4\,\pi^2}$$
$$+\frac{9\,\text{gY}^2\,\zeta1\,\mu^2\,\text{Log}[\frac{\mu}{\text{m}}]}{32\,\text{m}_\Delta{}^4\,\pi^2}+\frac{27\,\text{gW}^2\,\zeta2\,\mu^2\,\text{Log}[\frac{\mu}{\text{m}}]}{128\,\text{m}_\Delta{}^4\,\pi^2}+\frac{9\,\text{gY}^2\,\zeta2\,\mu^2\,\text{Log}[\frac{\mu}{\text{m}}]}{128\,\text{m}_\Delta{}^4\,\pi^2}+\frac{5\,\text{gW}^2\,\lambda\,\mu^2\,\text{Log}[\frac{\mu}{\text{m}}]}{12\,\text{m}_\Delta{}^4\,\pi^2}\Big\},$$
$$\Big\{\text{qHbox},\frac{\zeta2^2}{192\,\text{m}_\Delta{}^2\,\pi^2}+\frac{\mu^2}{2\,\text{m}_\Delta{}^4}+\frac{5\,\text{gY}^2\,\zeta1^2\,\text{Log}[\frac{\mu}{\text{m}}]}{192\,\text{m}_\Delta{}^2\,\pi^4}-\frac{\text{gW}^2\,\zeta2^2\,\text{Log}[\frac{\mu}{\text{m}}]}{768\,\text{m}_\Delta{}^2\,\pi^4}$$
$$+\frac{\text{gY}^2\,\zeta2^2\,\text{Log}[\frac{\mu}{\text{m}}]}{1536\,\text{m}_\Delta{}^2\,\pi^4}-\frac{\text{gW}^2\,\mu^2\,\text{Log}[\frac{\mu}{\text{m}}]}{8\,\text{m}_\Delta{}^4\,\pi^2}-\frac{\text{gY}^2\,\mu^2\,\text{Log}[\frac{\mu}{\text{m}}]}{4\,\text{m}_\Delta{}^4\,\pi^2}\Big\},$$

Table D.3: Effective operators and Wilson Coefficients in “Warsaw” basis for Complex Triplet Scalar (Y=1) model.

Q_H	$-\frac{\zeta_1\mu^2}{m_\Delta^4} - \frac{\zeta_2\mu^{\ 2}}{4m_\Delta^4} - \frac{\zeta_1^3}{4\pi^2 m_\Delta^2} - \frac{\zeta_2^2\zeta_1}{32\pi^2 m_\Delta^2}$
$Q_{H\Box}$	$\frac{\zeta_2^2}{192\pi^2 m_\Delta^2} + \frac{\mu^2}{2m_\Delta^4}$
Q_{HD}	$\frac{\zeta_1^2}{4\pi^2 m_\Delta^2} + \frac{\zeta_2^2}{96\pi^2 m_\Delta^2} - \frac{2\mu^{\ 2}}{m_\Delta^4}$
Q_{HW}	$\frac{\zeta_1 g_W^2}{48\pi^2 m_\Delta^2}$
Q_{HWB}	$-\frac{\zeta_2 g_W g_Y}{48\pi^2\ m_\Delta^2}$
Q_{ll}	$\frac{\text{y}_\Delta^2}{4m_\Delta^2}$
Q_W	$\frac{g_W^3}{1440\pi^2 m_\Delta^2}$

Table D.4: Mass dimenion-5 Effective operators and Wilson Coefficients for Complex Triplet Scalar (Y=1) model.

Dimension-5 operator	Wilson Coefficient
$llHH$	$\frac{y_\Delta^2}{m_\Delta}$

$$\{\text{qHD}, \frac{\zeta 1^2}{4\ m_\Delta{}^2\ \pi^2} + \frac{\zeta 2^2}{96\ m_\Delta{}^2\ \pi^2} - \frac{2\ \mu^2}{m_\Delta{}^4} + \frac{9\ gW^2\ \zeta 1^2\ \text{Log}[\frac{\mu}{m}]}{128\ m_\Delta{}^2\ \pi^4} - \frac{5\ gY^2\ \zeta 1^2\ \text{Log}[\frac{\mu}{m}]}{384\ m_\Delta{}^2\ \pi^4}$$

$$+\frac{3\ gW^2\ \zeta 2^2\ \text{Log}[\frac{\mu}{m}]}{1024\ m_\Delta{}^2\ \pi^4} + \frac{5\ gY^2\ \zeta 2^2\ \text{Log}[\frac{\mu}{m}]}{3072\ m_\Delta{}^2\ \pi^4} - \frac{9\ gW^2\ \mu^2\ \text{Log}[\frac{\mu}{m}]}{16\ m_\Delta{}^4\ \pi^2} + \frac{5\ gY^2\ \mu^2\ \text{Log}[\frac{\mu}{m}]}{16\ m_\Delta{}^4\ \pi^2}\},$$

$$\{\text{qHW}, \frac{gW^2\ \zeta 1}{48\ m_\Delta{}^2\ \pi^2} - \frac{gW^6\ \text{Log}[\frac{\mu}{m}]}{1536\ m_\Delta{}^2\ \pi^4} - \frac{53\ gW^4\ \zeta 1\ \text{Log}[\frac{\mu}{m}]}{4608\ m_\Delta{}^2\ \pi^4}$$

$$-\frac{gW^2\ gY^2\ \zeta 1\ \text{Log}[\frac{\mu}{m}]}{512\ m_\Delta{}^2\ \pi^4} - \frac{gW^2\ gY^2\ \zeta 2\ \text{Log}[\frac{\mu}{m}]}{768\ m_\Delta{}^2\ \pi^4}\}, \{\text{qHB}, -\frac{gW^2\ gY^2\ \zeta 2\ \text{Log}[\frac{\mu}{m}]}{256\ m_\Delta{}^2\ \pi^4}\},$$

$$\{\text{qHWB}, -\frac{gW\ gY\ \zeta 2}{48\ m_\Delta{}^2\ \pi^2} + \frac{gW^5\ gY\ \text{Log}[\frac{\mu}{m}]}{7680\ m_\Delta{}^2\ \pi^4} + \frac{gW^3\ gY\ \zeta 1\ \text{Log}[\frac{\mu}{m}]}{384\ m_\Delta{}^2\ \pi^4} - \frac{gW^3\ gY\ \zeta 2\ \text{Log}[\frac{\mu}{m}]}{576\ m_\Delta{}^2\ \pi^4} - \frac{19\ gW\ gY^3\ \zeta 2\ \text{Log}[\frac{\mu}{m}]}{2304\ m_\Delta{}^2\ \pi^4}\},$$

$$\{\text{qeH}[1,1], \frac{3\ gW^4\ \zeta 1\ \text{Log}[\frac{\mu}{m}]\ \text{Yu}^\dagger[e]}{256\ m_\Delta{}^2\ \pi^4} - \frac{3\ gW^2\ \zeta 1^2\ \text{Log}[\frac{\mu}{m}]\ \text{Yu}^\dagger[e]}{128\ m_\Delta{}^2\ \pi^4}$$

$$+\frac{3\ gY^2\ \zeta 1^2\ \text{Log}[\frac{\mu}{m}]\ \text{Yu}^\dagger[e]}{128\ m_\Delta{}^2\ \pi^4} + \frac{gW^2\ gY^2\ \zeta 2\ \text{Log}[\frac{\mu}{m}]\ \text{Yu}^\dagger[e]}{256\ m_\Delta{}^2\ \pi^4}$$

$$+\frac{gW^2\ \zeta 2^2\ \text{Log}[\frac{\mu}{m}]\ \text{Yu}^\dagger[e]}{9216\ m_\Delta{}^2\ \pi^4} + \frac{gY^2\ \zeta 2^2\ \text{Log}[\frac{\mu}{m}]\ \text{Yu}^\dagger[e]}{1024\ m_\Delta{}^2\ \pi^4} + \frac{7\ gW^2\ \mu^2\ \text{Log}[\frac{\mu}{m}]\ \text{Yu}^\dagger[e]}{24\ m_\Delta{}^4\ \pi^2} - \frac{3\ gY^2\ \mu^2\ \text{Log}[\frac{\mu}{m}]\ \text{Yu}^\dagger[e]}{16\ m_\Delta{}^4\ \pi^2}\},$$

$$\{\text{quH}[1,1], \frac{3\ gW^4\ \zeta 1\ \text{Log}[\frac{\mu}{m}]\ \text{Yu}^\dagger[u]}{512\ m_\Delta{}^2\ \pi^4} - \frac{3\ gW^2\ \zeta 1^2\ \text{Log}[\frac{\mu}{m}]\ \text{Yu}^\dagger[u]}{128\ m_\Delta{}^2\ \pi^4}$$

$$+\frac{3\ gY^2\ \zeta 1^2\ \text{Log}[\frac{\mu}{m}]\ \text{Yu}^\dagger[u]}{128\ m_\Delta{}^2\ \pi^4} + \frac{gW^2\ gY^2\ \zeta 2\ \text{Log}[\frac{\mu}{m}]\ \text{Yu}^\dagger[u]}{768\ m_\Delta{}^2\ \pi^4} + \frac{gW^2\ \zeta 2^2\ \text{Log}[\frac{\mu}{m}]\ \text{Yu}^\dagger[u]}{9216\ m_\Delta{}^2\ \pi^4}$$

$$+\frac{gY^2\ \zeta 2^2\ \text{Log}[\frac{\mu}{m}]\ \text{Yu}^\dagger[u]}{1024\ m_\Delta{}^2\ \pi^4} + \frac{7\ gW^2\ \mu^2\ \text{Log}[\frac{\mu}{m}]\ \text{Yu}^\dagger[u]}{24\ m_\Delta{}^4\ \pi^2} - \frac{3\ gY^2\ \mu^2\ \text{Log}[\frac{\mu}{m}]\ \text{Yu}^\dagger[u]}{16\ m_\Delta{}^4\ \pi^2}\},$$

$$\{\text{qdH}[1,1], \frac{3\ gW^4\ \zeta 1\ \text{Log}[\frac{\mu}{m}]\ \text{Yu}^\dagger[d]}{512\ m_\Delta{}^2\ \pi^4} - \frac{3\ gW^2\ \zeta 1^2\ \text{Log}[\frac{\mu}{m}]\ \text{Yu}^\dagger[d]}{128\ m_\Delta{}^2\ \pi^4}$$

$$+\frac{3\ gY^2\ \zeta 1^2\ \text{Log}[\frac{\mu}{m}]\ \text{Yu}^\dagger[d]}{128\ m_\Delta{}^2\ \pi^4} - \frac{gW^2\ gY^2\ \zeta 2\ \text{Log}[\frac{\mu}{m}]\ \text{Yu}^\dagger[d]}{768\ m_\Delta{}^2\ \pi^4} + \frac{gW^2\ \zeta 2^2\ \text{Log}[\frac{\mu}{m}]\ \text{Yu}^\dagger[d]}{9216\ m_\Delta{}^2\ \pi^4}$$

$$+\frac{\text{gY}^2\ \zeta 2^2\ \text{Log}[\frac{\mu}{\text{m}}]\ \text{Yu}^\dagger[\text{d}]}{1024\ \text{m}_\triangle{}^2\ \pi^4}+\frac{7\ \text{gW}^2\ \mu^2\ \text{Log}[\frac{\mu}{\text{m}}]\ \text{Yu}^\dagger[\text{d}]}{24\ \text{m}_\triangle{}^4\ \pi^2}-\frac{3\ \text{gY}^2\ \mu^2\ \text{Log}[\frac{\mu}{\text{m}}]\ \text{Yu}^\dagger[\text{d}]}{16\ \text{m}_\triangle{}^4\ \pi^2}\},$$

$$\{\text{qeW}[1,1],-\frac{\text{gW}^3\ \zeta 1\ \text{Log}[\frac{\mu}{\text{m}}]\ \text{Yu}^\dagger[\text{e}]}{768\ \text{m}_\triangle{}^2\ \pi^4}-\frac{\text{gW}\ \text{gY}^2\ \zeta 2\ \text{Log}[\frac{\mu}{\text{m}}]\ \text{Yu}^\dagger[\text{e}]}{512\ \text{m}_\triangle{}^2\ \pi^4}\},$$

$$\{\text{qeB}[1,1],\frac{\text{gW}^2\ \text{gY}\ \zeta 2\ \text{Log}[\frac{\mu}{\text{m}}]\ \text{Yu}^\dagger[\text{e}]}{512\ \text{m}_\triangle{}^2\ \pi^4}\},$$

$$\{\text{quW}[1,1],-\frac{\text{gW}^3\ \zeta 1\ \text{Log}[\frac{\mu}{\text{m}}]\ \text{Yu}^\dagger[\text{u}]}{768\ \text{m}_\triangle{}^2\ \pi^4}-\frac{5\ \text{gW}\ \text{gY}^2\ \zeta 2\ \text{Log}[\frac{\mu}{\text{m}}]\ \text{Yu}^\dagger[\text{u}]}{4608\ \text{m}_\triangle{}^2\ \pi^4}\},$$

$$\{\text{quB}[1,1],-\frac{\text{gW}^2\ \text{gY}\ \zeta 2\ \text{Log}[\frac{\mu}{\text{m}}]\ \text{Yu}^\dagger[\text{u}]}{512\ \text{m}_\triangle{}^2\ \pi^4}\},$$

$$\{\text{qdW}[1,1],-\frac{\text{gW}^3\ \zeta 1\ \text{Log}[\frac{\mu}{\text{m}}]\ \text{Yu}^\dagger[\text{d}]}{768\ \text{m}_\triangle{}^2\ \pi^4}-\frac{\text{gW}\ \text{gY}^2\ \zeta 2\ \text{Log}[\frac{\mu}{\text{m}}]\ \text{Yu}^\dagger[\text{d}]}{4608\ \text{m}_\triangle{}^2\ \pi^4}\},$$

$$\{\text{qdB}[1,1],\frac{\text{gW}^2\ \text{gY}\ \zeta 2\ \text{Log}[\frac{\mu}{\text{m}}]\ \text{Yu}^\dagger[\text{u}]}{512\ \text{m}_\triangle{}^2\ \pi^4}\},$$

$$\{\text{q1Hl}[1,1],-\frac{\text{gY}^2\ \text{y}\Sigma^2\ \text{Log}[\frac{\mu}{\text{m}}]}{96\ \text{m}_\triangle{}^2\ \pi^2}-\frac{\text{gY}^2\ \zeta 1^2\ \text{Log}[\frac{\mu}{\text{m}}]}{384\ \text{m}_\triangle{}^2\ \pi^4}-\frac{\text{gY}^2\ \zeta 2^2\ \text{Log}[\frac{\mu}{\text{m}}]}{6144\ \text{m}_\triangle{}^2\ \pi^4}+\frac{\text{gY}^2\ \mu^2\ \text{Log}[\frac{\mu}{\text{m}}]}{64\ \text{m}_\triangle{}^4\ \pi^2}\},$$

$$\{\text{q3Hl}[1,1],\frac{\text{gW}^2\ \text{y}\Sigma^2\ \text{Log}[\frac{\mu}{\text{m}}]}{96\ \text{m}_\triangle{}^2\ \pi^2}+\frac{\text{gW}^2\ \zeta 2^2\ \text{Log}[\frac{\mu}{\text{m}}]}{18432\ \text{m}_\triangle{}^2\ \pi^4}+\frac{\text{gW}^2\ \mu^2\ \text{Log}[\frac{\mu}{\text{m}}]}{192\ \text{m}_\triangle{}^4\ \pi^2}\},$$

$$\{\text{qHe}[1,1],-\frac{\text{gY}^2\ \zeta 1^2\ \text{Log}[\frac{\mu}{\text{m}}]}{192\ \text{m}_\triangle{}^2\ \pi^4}-\frac{\text{gY}^2\ \zeta 2^2\ \text{Log}[\frac{\mu}{\text{m}}]}{3072\ \text{m}_\triangle{}^2\ \pi^4}+\frac{\text{gY}^2\ \mu^2\ \text{Log}[\frac{\mu}{\text{m}}]}{32\ \text{m}_\triangle{}^4\ \pi^2}\},$$

$$\{\text{q1Hq}[1,1],\frac{\text{gY}^2\ \zeta 1^2\ \text{Log}[\frac{\mu}{\text{m}}]}{1152\ \text{m}_\triangle{}^2\ \pi^4}+\frac{\text{gY}^2\ \zeta 2^2\ \text{Log}[\frac{\mu}{\text{m}}]}{18432\ \text{m}_\triangle{}^2\ \pi^4}-\frac{\text{gY}^2\ \mu^2\ \text{Log}[\frac{\mu}{\text{m}}]}{192\ \text{m}_\triangle{}^4\ \pi^2}\},$$

$$\{\text{q3Hq}[1,1],\frac{\text{gW}^2\ \zeta 2^2\ \text{Log}[\frac{\mu}{\text{m}}]}{18432\ \text{m}_\triangle{}^2\ \pi^4}+\frac{\text{gW}^2\ \mu^2\ \text{Log}[\frac{\mu}{\text{m}}]}{192\ \text{m}_\triangle{}^4\ \pi^2}\},$$

$$\{\text{qHu}[1,1],\frac{\text{gY}^2\ \zeta 1^2\ \text{Log}[\frac{\mu}{\text{m}}]}{288\ \text{m}_\triangle{}^2\ \pi^4}+\frac{\text{gY}^2\ \zeta 2^2\ \text{Log}[\frac{\mu}{\text{m}}]}{4608\ \text{m}_\triangle{}^2\ \pi^4}-\frac{\text{gY}^2\ \mu^2\ \text{Log}[\frac{\mu}{\text{m}}]}{48\ \text{m}_\triangle{}^4\ \pi^2}\},$$

$$\{\text{qHd}[1,1],-\frac{\text{gY}^2\ \zeta 1^2\ \text{Log}[\frac{\mu}{\text{m}}]}{576\ \text{m}_\triangle{}^2\ \pi^4}-\frac{\text{gY}^2\ \zeta 2^2\ \text{Log}[\frac{\mu}{\text{m}}]}{9216\ \text{m}_\triangle{}^2\ \pi^4}+\frac{\text{gY}^2\ \mu^2\ \text{Log}[\frac{\mu}{\text{m}}]}{96\ \text{m}_\triangle{}^4\ \pi^2}\},$$

$$\{\text{qll}[1,1,1,1],\frac{\text{y}\Sigma^2}{4\ \text{m}_\triangle{}^2}+\frac{11\ \text{gW}^2\ \text{y}\Sigma^2\ \text{Log}[\frac{\mu}{\text{m}}]}{192\ \text{m}_\triangle{}^2\ \pi^2}+\frac{5\ \text{gY}^2\ \text{y}\Sigma^2\ \text{Log}[\frac{\mu}{\text{m}}]}{64\ \text{m}_\triangle{}^2\ \pi^2}\},\{\text{q1lq}[1,1,1,1],-\frac{\text{gY}^2\ \text{y}\Sigma^2\ \text{Log}[\frac{\mu}{\text{m}}]}{96\ \text{m}_\triangle{}^2\ \pi^2}\},$$

$$\{\text{q3lq}[1,1,1,1],\frac{\text{gW}^2\ \text{y}\Sigma^2\ \text{Log}[\frac{\mu}{\text{m}}]}{96\ \text{m}_\triangle{}^2\ \pi^2}\},\{\text{qle}[1,1,1,1],\frac{\text{gY}^2\ \text{y}\Sigma^2\ \text{Log}[\frac{\mu}{\text{m}}]}{16\ \text{m}_\triangle{}^2\ \pi^2}\},$$

$$\{\text{qlu}[1,1,1,1],-\frac{\text{gY}^2\ \text{y}\Sigma^2\ \text{Log}[\frac{\mu}{\text{m}}]}{24\ \text{m}_\triangle{}^2\pi^2}\},\{\text{qld}[1,1,1,1],\frac{\text{gY}^2\ \text{y}\Sigma^2\ \text{Log}[\frac{\mu}{\text{m}}]}{48\ \text{m}_\triangle{}^2\ \pi^2}\}\}$$

We have provided the flexibility to the users to reformat, save, and/or export all these WCs corresponding to the effective operators at the electro-weak scale ($\boldsymbol{\mu}$) to LaTeX, using **formPick**. We have also provided an illustrative example:

```
In[19]:= formPick["Warsaw","Detailed2",floRes1,Frame→All,
           FontSize→Medium,FontFamily→"Times New Roman"]
```

Out[19]=

Q_W	$\epsilon^{\text{abc}} W_\rho{}^{a,\mu} W_\mu{}^{b,\nu} W_\nu{}^{c,\rho}$	$\frac{29 g_W{}^5 \log\left(\frac{\mu}{m_\Delta}\right)}{46080\pi^4 m_\Delta^2} + \frac{g_W{}^3}{1440\pi^2 m_\Delta^2}$
$\vdots$	$\vdots$	$\vdots$
Q_{ld}	$(\bar{l}\gamma_\mu\ \text{l})(\bar{d}\gamma_\mu\ \text{d})$	$\frac{g_Y{}^2 \text{y}_\Sigma{}^2 \log\left(\frac{\mu}{m_\Delta}\right)}{48\pi^2 m_\Delta^2}$

Acknowledgements

S. DasBakshi would like to thank the organizers of the 11th FCC-ee workshop: Theory and Experiments, CERN for the invitation and providing the opportunity to present this work.

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