DsixTools

Your EFT Toolkit

A. Celis, J. Fuentes-Martín, P. Ruiz-Femenía, A. Vicente, J. Virto

Manual: arXiv:1704.04504 + arXiv:2010.16341

Website: https://dsixtools.github.io/

SMEFT-Tools 2025

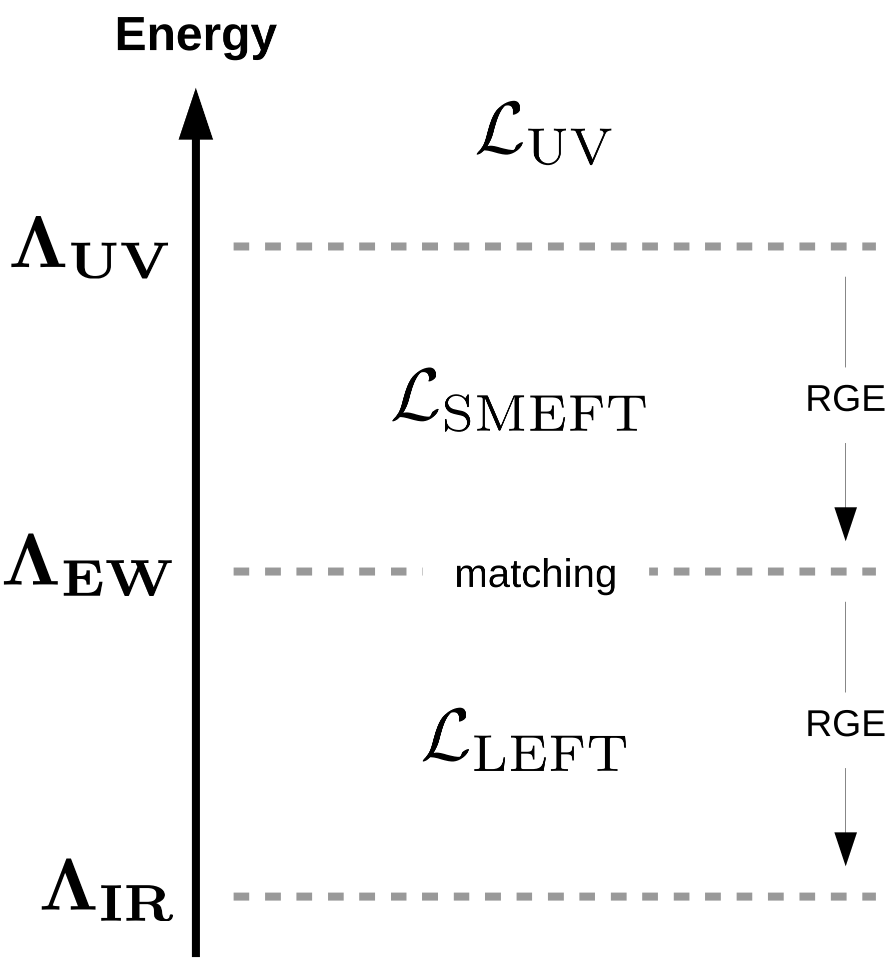
Mainz

IFIC INSTITUT DE FÍSICA CORPUSCULAR

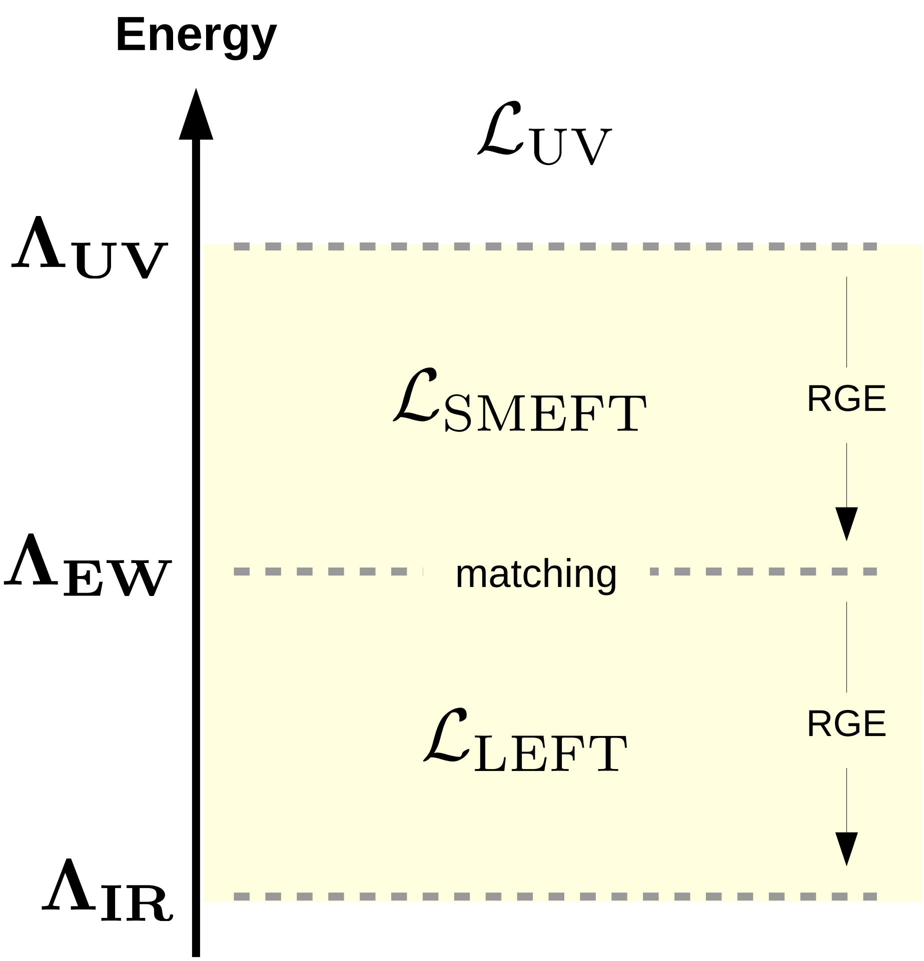
VNIVERSITAT DE VALÈNCIA

CSIC CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS

Problem we want to solve



Problem we want to solve



SMEFT

Warsaw basis

[Grzadkowski, Iskrzynski, Misiak, Rosiek, 2010]

Full 1-loop RGEs

[Alonso, Chang, Jenkins, Manohar, Shotwell, Trott, 2013-2014]

Full 1-loop matching

[Jenkins, Manohar, Stoffer, 2017]

[Dekens, Stoffer, 2019]

LEFT

San Diego basis

Full 1-loop RGEs

[Jenkins, Manohar, Stoffer, 2017]

DsixTools

DsixTools is a Mathematica package for the matching and RGE evolution from the new physics scale to the scale of low energy observables.

Alejandro Celis, Javier Fuentes-Martín,
Pedro Ruiz-Femenía, Avelino Vicente, Javier Virto

- https://dsixtools.github.io/
- arXiv:1704.04504 (version **1.0**) and arXiv:2010.16341 (version **2.0**)
- Current version: **2.1**
- Mathematica package
- Installation: manual or automatic (recommended)
- It requires **Mathematica** 9+

What DsixTools can do for you

- Full 1-loop RGE running in the SMEFT and the LEFT

Higher order for the SM parameters (5-loops for g_s, for instance)

- Full 1-loop SMEFT-LEFT matching
- Analytical and numerical routines
- Consistency check for SMEFT or LEFT parameter points
- Many useful resources for the study of the SMEFT and the LEFT
- Input from MatchMakerEFT

Current version: 2.1

Fast evolution matrix running

RGEs in **DsixTools 1.0**:

Method 1: NDSolve **Method 2:** leading log

→

RGEs in **DsixTools 2.0**:

Method 3: Evolution matrix

SMEFT RGEs

$d = 4$

$$\frac{d\hat{C}_i(t)}{dt} = \frac{1}{16\pi^2}\,\hat{\gamma}_{ij}(\hat{C}_k, C_k)\,\hat{C}_j(t) = \frac{1}{16\pi^2}\,\hat{\gamma}_{ij}(\hat{C}_k)\,\hat{C}_j(t) + \mathcal{O}(1/\Lambda^2)$$

$$\longrightarrow \hat{C}_k(t) = \hat{C}_k^{\text{SM}}(t) + \mathcal{O}(1/\Lambda^2)$$

$d = 6$

(analogous for d = 5)

$$\frac{dC_i(t)}{dt} = \frac{1}{16\pi^2}\,\gamma_{ij}(\hat{C}_k)\,C_j(t) = \frac{1}{16\pi^2}\,\gamma_{ij}(\hat{C}_k^{\text{SM}})\,C_j(t) + \mathcal{O}(1/\Lambda^2)$$

$$\equiv \bar{\gamma}_{ij}(t)\,C_j(t) + \mathcal{O}(1/\Lambda^2)$$

$$C_i(t) = U_{ij}(t, t_0)\,C_j(t_0)$$

$$(U \sim \exp\bar{\gamma})$$

Recent & future developments

[Aebischer, Morell, Pesut, Virto, arXiv: 2501.08384]

2-loop LEFT RGEs for 4-fermion operators

Install 2-loop version of DsixTools

```
In[•]:= Quit[];

In[1]:= Import["https://raw.githubusercontent.com/DsixTools/DsixTools/Two-loop-LEFT/install.m"]
Downloading DsixTools from https://github.com/DsixTools/DsixTools/archive/Two-loop-LEFT.zip
Extracting DsixTools zip file
Copying DsixTools to /home/jvirto/.Mathematica/Applications/DsixTools
Setting up the help system
Installation complete!

DsixTools 2.1

by Alejandro Celis, Javier Fuentes-Martin, Pedro Ruiz-Femenia, Avelino Vicente and Javier Virto
References: arXiv:1704.04504 and arXiv:2010.16341
Website: https://dsixtools.github.io/
Converting files: m to mx
Conversion complete!
```

← Already available
(soon in the master branch)

Test 2-loop version of DsixTools

```
In[2]:= β[LudS1RR[1, 1, 1, 1]]
```

Out[2]=

$$\frac{4}{27}\,\text{eQED}^2\,\text{LudduS1RR}[1,1,1,1]+\frac{64}{9}\,\text{gQCD}^2\,\text{LudduS1RR}[1,1,1,1]+\frac{49\,\text{eQED}^4\,\text{LoopParameter}^2\,\text{LudduS1RR}[1,1,1,1]}{5832\,\pi^2}+\frac{118\,\text{eQED}^2\,\text{gQCD}^2\,\text{LoopParameter}^2\,\text{LudduS1RR}[1,1,1,1]}{81\,\pi^2}+\frac{592\,\text{gQCD}^4\,\text{LoopParameter}^2\,\text{LudduS1RR}[1,1,1,1]}{81\,\pi^2}+$$
$$\frac{16}{81}\,\text{eQED}^2\,\text{LudduS8RR}[1,1,1,1]+\frac{112}{27}\,\text{gQCD}^2\,\text{LudduS8RR}[1,1,1,1]+\frac{49\,\text{eQED}^4\,\text{LoopParameter}^2\,\text{LudduS8RR}[1,1,1,1]}{4374\,\pi^2}+\frac{238\,\text{eQED}^2\,\text{gQCD}^2\,\text{LoopParameter}^2\,\text{LudduS8RR}[1,1,1,1]}{243\,\pi^2}+\frac{1036\,\text{gQCD}^4\,\text{LoopParameter}^2\,\text{LudduS8RR}[1,1,1,1]}{243\,\pi^2}-$$
$$\frac{46}{9}\,\text{eQED}^2\,\text{LudS1RR}[1,1,1,1]-16\,\text{gQCD}^2\,\text{LudS1RR}[1,1,1,1]+\frac{6391\,\text{eQED}^4\,\text{LoopParameter}^2\,\text{LudS1RR}[1,1,1,1]}{3888\,\pi^2}+\frac{17\,\text{eQED}^2\,\text{gQCD}^2\,\text{LoopParameter}^2\,\text{LudS1RR}[1,1,1,1]}{54\,\pi^2}-\frac{265\,\text{gQCD}^4\,\text{LoopParameter}^2\,\text{LudS1RR}[1,1,1,1]}{18\,\pi^2}+$$
$$\frac{16}{9}\,\text{gQCD}^2\,\text{LudS8RR}[1,1,1,1]+\frac{14\,\text{eQED}^2\,\text{gQCD}^2\,\text{LoopParameter}^2\,\text{LudS8RR}[1,1,1,1]}{81\,\pi^2}+\frac{58\,\text{gQCD}^4\,\text{LoopParameter}^2\,\text{LudS8RR}[1,1,1,1]}{81\,\pi^2}-\frac{128}{3}\,\text{gQCD}^2\,\text{LdG}[1,1]\times\text{LuG}[1,1]+\frac{128}{3}\,\text{eQED}^2\,\text{Ld}\gamma[1,1]\times\text{Lu}\gamma[1,1]$$

Thanks to Javier Virto
for the slide

Talk by Pol Morell tomorrow

Recent & future developments

- Input from Matchete
- Additional EFTs (including ALPs, for instance)
- Improvements in the evolution matrix formalism
- And more...

To be presented in
SMEFT-Tools 2028

Time to play

The SN model

right-handed neutrino

	N	S
$\mathrm{SU}(3)_c$	$\mathbf{1}$	$\mathbf{3}$
$\mathrm{SU}(2)_L$	$\mathbf{1}$	$\mathbf{2}$
$\mathrm{U}(1)_Y$	0	$\frac{1}{6}$
Generations	1	1

scalar leptoquark

$$\mathcal{L} = \mathcal{L}_{\mathrm{SM}} + \mathcal{L}_{\mathrm{NP}}$$

$$\mathcal{L}_{\mathrm{NP}} = \mathcal{L}_N + \mathcal{L}_S + \mathcal{L}_{SH} + \mathcal{L}_{\mathrm{Y}}$$

$$\mathcal{L}_N = i\overline{N}\,\gamma_\mu D^\mu N - \frac{1}{2} M_N \,\overline{N^c}\, N$$

$$\mathcal{L}_S = D_\mu S^\dagger\, D^\mu S - M_S^2\, S^\dagger\, S$$

$$\mathcal{L}_{SH} = -\lambda_2\, H^\dagger H\, S^\dagger S - \lambda_3\, H^\dagger S\, S^\dagger H$$

$$\mathcal{L}_{\mathrm{Y}} = -Y_N^\alpha\, \overline{N}\, \ell_L^\alpha H - Y_S^\alpha\, \overline{q}_L^\alpha\, N S +$$

SN model parameter point

$$M_N = 1\,\mathrm{TeV} \qquad M_S = 1.2\,\mathrm{TeV} \qquad \lambda_2 = \lambda_3 = 0.1$$

$$Y_N = \begin{pmatrix} 0.001 & 0.4 & -0.02 \end{pmatrix}$$

$$Y_S = \begin{pmatrix} -0.7 & 0.9 & -0.8 \end{pmatrix}$$

Note: phenomenologically excluded, but illustrative

Backup slides

Input: making the user's life easier

Even after fixing the operator basis (Warsaw & San Diego) the user must make sure that the input values lead to a consistent Lagrangian. This could be tricky...

Examples of inconsistencies:

Hermiticity: $\left(C_{\ell q}^{(1)}\right)_{2223} \neq \left(C_{\ell q}^{(1)}\right)^{*}_{2232}$

Antisimmetry: $\left(L_{\nu\gamma}\right)_{11} \neq 0$

Nooo!

DsixTools...

- Accepts input values for the Wilson coefficients of **any** set of operators
- Fixes all consistency problems
- Transforms all Wilson coefficients to the 'symmetric basis'