



## The EFT Toolkit

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Manual: [arXiv:1704.04504](https://arxiv.org/abs/1704.04504) + [arXiv:2010.16341](https://arxiv.org/abs/2010.16341)

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

**SMEFT-Tools 2022**

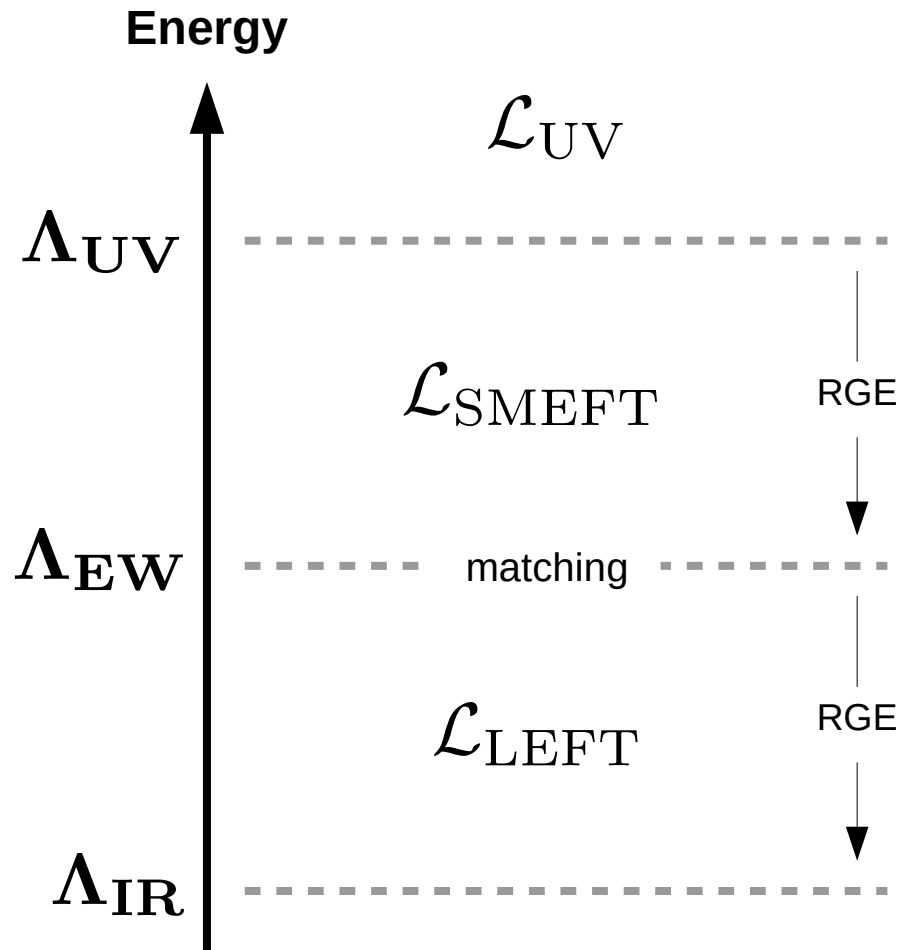
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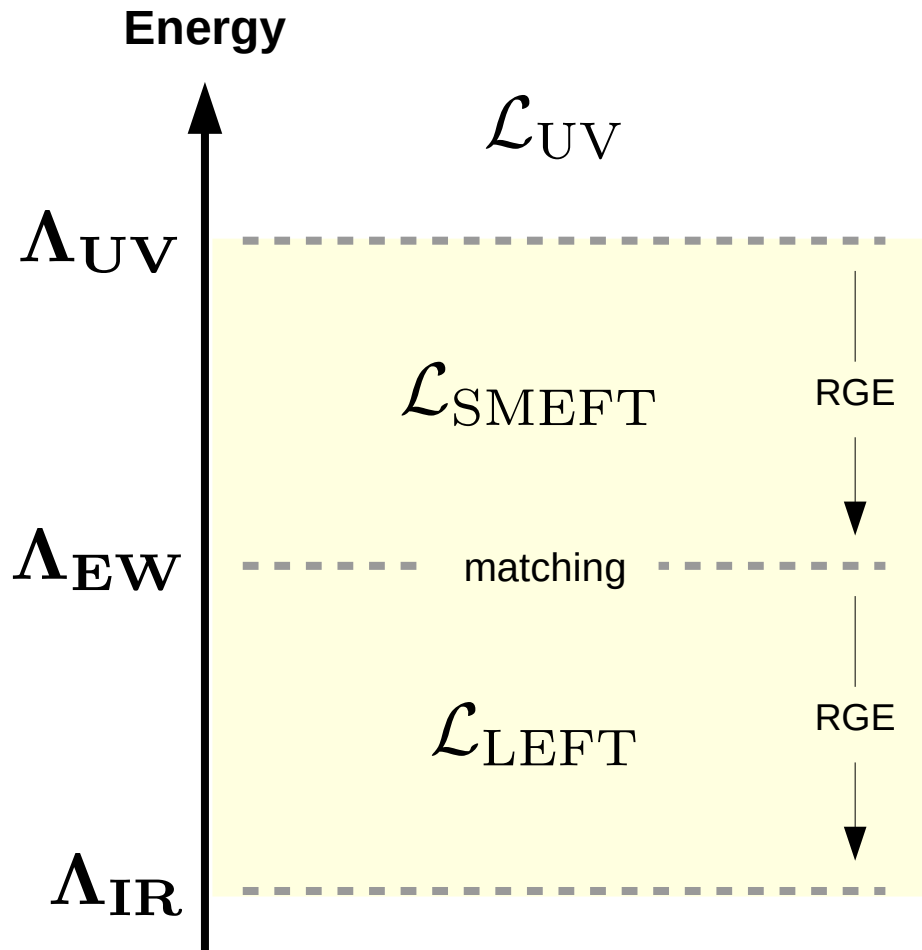
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# Problem we want to solve



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## 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.

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- <https://dsixtools.github.io/>
- [arXiv:1704.04504](https://arxiv.org/abs/1704.04504) (version **1.0**) and [arXiv:2010.16341](https://arxiv.org/abs/2010.16341) (version **2.0**)
- Mathematica package
- Installation: manual or automatic (recommended)
- It requires **Mathematica 9+**
- Alternative: **wilson** [talk by [Peter Stangl](#)]

# 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](#) [talk by [Achillefs Lazopoulos](#)]

Current version: **2.1**

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

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



**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'



# The SN model

right-handed  
neutrino



	$N$	$S$
$SU(3)_c$	<b>1</b>	<b>3</b>
$SU(2)_L$	<b>1</b>	<b>2</b>
$U(1)_Y$	0	$\frac{1}{6}$
GENERATIONS	1	1

scalar  
leptoquark



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

$$\mathcal{L}_{\text{NP}} = \mathcal{L}_N + \mathcal{L}_S + \mathcal{L}_{SH} + \mathcal{L}_Y$$

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

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

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

$$\mathcal{L}_Y = -Y_N^\alpha \bar{N} \ell_L^\alpha H - Y_S^\alpha \bar{q}_L^\alpha N S +$$



# SN model parameter point

$$M_N = 1 \text{ TeV} \quad M_S = 1.2 \text{ TeV} \quad \lambda_2 = \lambda_3 = 0.1$$

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

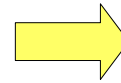
$$Y_S = \begin{pmatrix} -0.7 & 0.9 & -0.8 \end{pmatrix}$$

Note: phenomenologically excluded, but illustrative

# 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

$$d = 4 \quad \frac{d\hat{C}_i(t)}{dt} = \frac{1}{16\pi^2} \hat{\gamma}_{ij}(\hat{C}_k, C_k) \hat{C}_j(t) = \frac{1}{16\pi^2} \hat{\gamma}_{ij}(\hat{C}_k) \hat{C}_j(t) + \mathcal{O}(1/\Lambda^2)$$
$$\rightarrow \hat{C}_k^{\text{SM}}(t)$$

$$d = 6 \quad \frac{dC_i(t)}{dt} = \frac{1}{16\pi^2} \gamma_{ij}(\hat{C}_k) C_j(t) = \frac{1}{16\pi^2} \gamma_{ij}(\hat{C}_k^{\text{SM}}) C_j(t) + \mathcal{O}(1/\Lambda^2)$$

(analogous for d = 5)

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

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