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Journeys in Effective Field Theories

GRK 2497 | **Exercise session 2** | **Date: 26.09.2025**

Exercise 1: Integrating out a heavy field at tree-level

Consider a heavy scalar field ϕ with quantum numbers $\phi \sim (\mathbf{3}, \mathbf{1}, -1/3)$ under $SU(3)_c \times SU(2)_L \times U(1)_Y$.

a) Write down the Lagrangian for ϕ at the renormalisable level, keeping up to linear terms in ϕ.

b) Compute the tree-level matching onto the SMEFT in the Warsaw basis analytically (use equations of motion or diagrammatic matching).

c) Check your result using `Matchete`.

Exercise 2: Constraining single-particle extensions of the Standard Model

Consider the Standard Model Lagrangian, extended by a single copy of a BSM field X in the gauge representation shown in the table below, and with mass $M \gg v_{ew}$:

$$\mathcal{L} = \mathcal{L}_{SM}^{d\leq 4} + \mathcal{L}_{X}^{d\leq 4} \,.$$

Referring to the bounds in Figure 1, and the PDG if needed, try to come up with an estimate of the best current bound on M, under the specified flavour assumption for its couplings to the SM fermions, and otherwise $O(1)$ couplings.

Group	$(SU(3)_c, SU(2)_L, U(1)_Y)$	Spin	Flavour assumption
I	(**3**,**1**,-1/3)	0	$U(2)^5$
II	(**8**,**2**,1/2)	0	$U(2)_q$
III	(**1**,**1**,-1)	1/2	Froggatt-Nielsen
IV	(**3**,**2**,-5/6)	1/2	Anarchy
V	(**1**,**1**,0)	1	MFV
VI	(**3**,**1**,2/3)	1	$U(2)_q \times U(2)_u \times U(2)_d$

Tabelle 1: Quantum number and flavour assumption assignments by group.

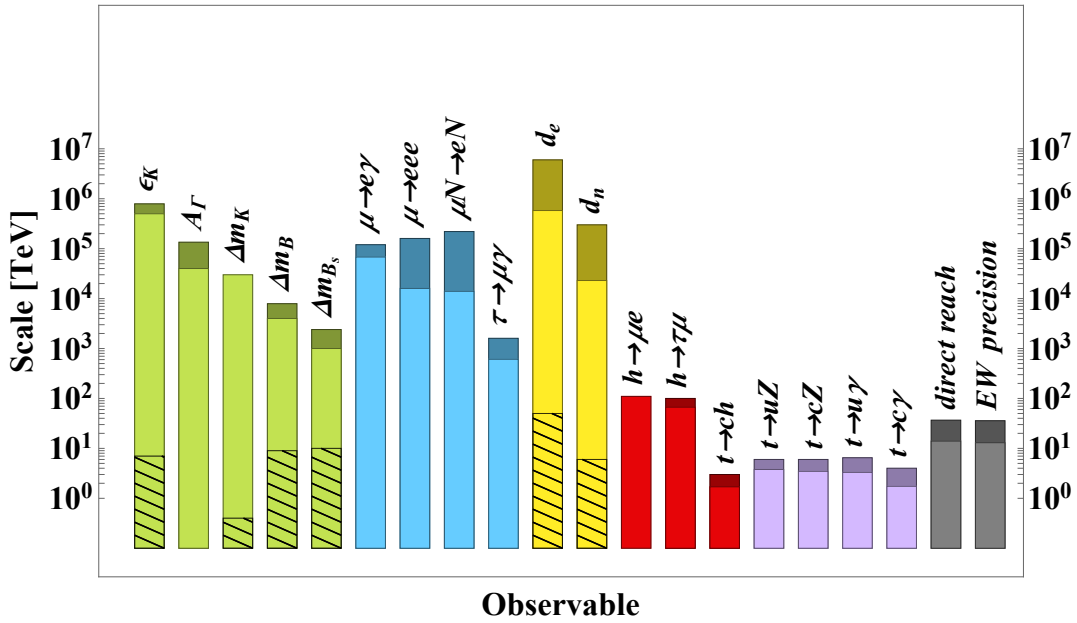

Abbildung 1: Current constraints on the effective New Physics scale from different observables.