

Operator basis construction and projection for Effective Field Theories with AutoEFT

Young Scientists Meeting 2026

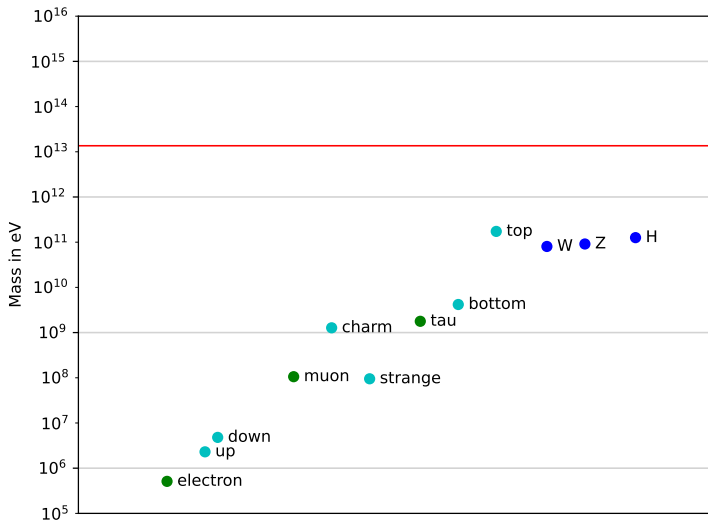
Lars Bündgen

Institute for Theoretical Particle Physics and Cosmology, RWTH Aachen University

21.09.2026

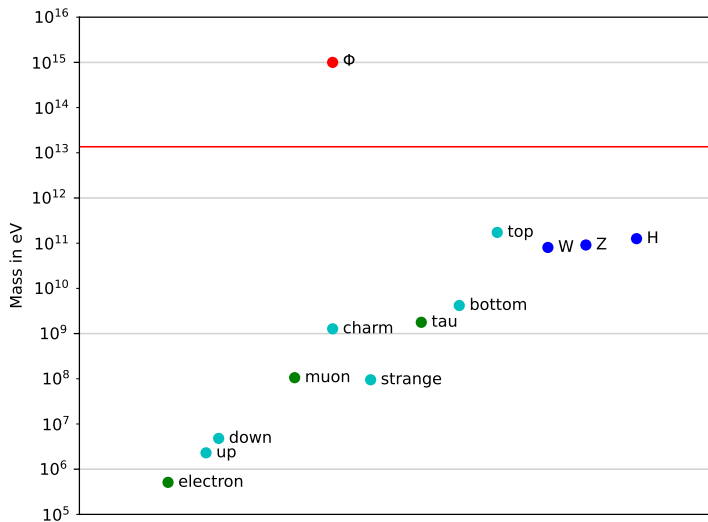
Effective field theories

Standard Model particles:



Effective field theories

BSM heavy scalar particle Φ :

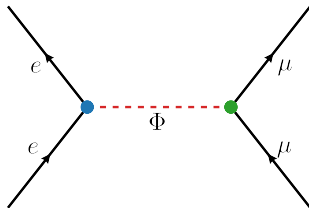


EFT interactions

$\mathcal{L}_{\text{BSM}}$ contains

$$\bar{e}e\Phi$$

$$\bar{\mu}\mu\Phi$$

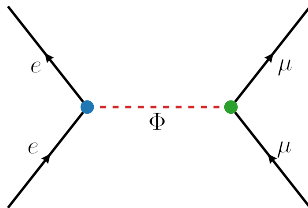


EFT interactions

$\mathcal{L}_{\text{BSM}}$ contains

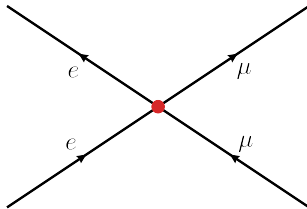
$$\bar{e}e\Phi$$

$$\bar{\mu}\mu\Phi$$



$\mathcal{L}_{\text{SMEFT}}$ contains

$$\frac{\bar{e}e\bar{\mu}\mu}{M_{\Phi}^2}$$

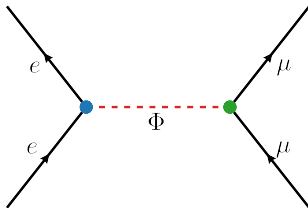


EFT interactions

$\mathcal{L}_{\text{BSM}}$ contains

$$\bar{e}e\Phi$$

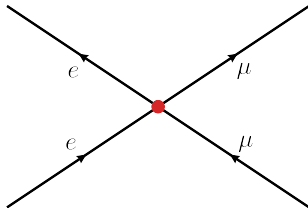
$$\bar{\mu}\mu\Phi$$



$\mathcal{L}_{\text{SMEFT}}$ contains

$$\frac{\bar{e}e\bar{\mu}\mu}{M_\Phi^2}$$

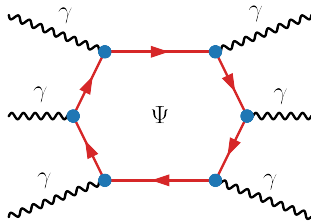
$$\left(\frac{1}{p^2 - M_\Phi^2} \xrightarrow{p \ll M_\Phi} \frac{1}{M_\Phi^2} \right)$$



EFT interactions

$\mathcal{L}_{\text{BSM}}$ contains

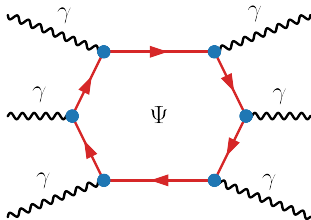
$$\bar{\Psi} \gamma^\mu A_\mu \Psi$$



EFT interactions

$\mathcal{L}_{\text{BSM}}$ contains

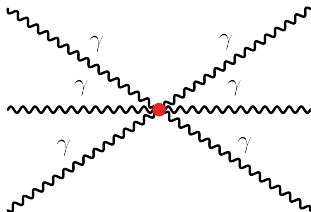
$$\bar{\Psi} \gamma^\mu A_\mu \Psi$$



$\mathcal{L}_{\text{SMEFT}}$ contains

$$\frac{A_\mu A^\mu A_\nu A^\nu A_\rho A^\rho}{M_\Psi^2}$$

+ ...



The EFT Lagrangian

Properties of the heavy particle(s) Φ (or Ψ) are unknown:

The EFT Lagrangian

Properties of the heavy particle(s) Φ (or Ψ) are unknown:

- Scalar Boson?
- Vector Boson?
- Fermion?

The EFT Lagrangian

Properties of the heavy particle(s) Φ (or Ψ) are unknown:

- Scalar Boson?
- Vector Boson?
- Fermion?
- $U(1)$ charge?
- $SU(2)$, $SU(3)$ representation?

The EFT Lagrangian

Properties of the heavy particle(s) Φ (or Ψ) are unknown:

- Scalar Boson?
- Vector Boson?
- Fermion?
- $U(1)$ charge?
- $SU(2)$, $SU(3)$ representation?
- How many heavy particles?
- Heavy particle masses?

The EFT Lagrangian

$$\mathcal{L}_{\text{SMEFT}} = \mathcal{L}_{\text{SM}} + \sum_{d=5}^{\infty} \frac{1}{\Lambda^{d-4}} \sum_i c_i \mathcal{O}_i$$

EFT operators $\mathcal{O}_i$ contain only SM fields.

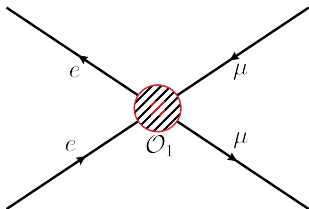
Terms are sorted by Mass dimension d .

The EFT Lagrangian

$$\mathcal{L}_{\text{SMEFT}} = \mathcal{L}_{\text{SM}} + \sum_{d=5}^{\infty} \frac{1}{\Lambda^{d-4}} \sum_i c_i \mathcal{O}_i$$

EFT operators $\mathcal{O}_i$ contain only SM fields.

Terms are sorted by Mass dimension d .

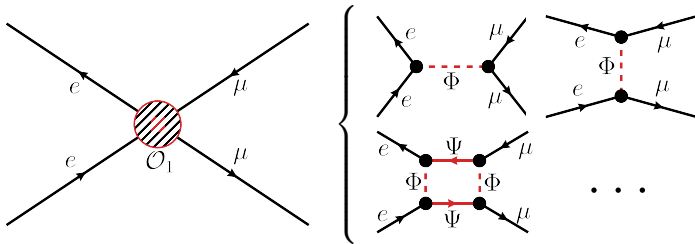


The EFT Lagrangian

$$\mathcal{L}_{\text{SMEFT}} = \mathcal{L}_{\text{SM}} + \sum_{d=5}^{\infty} \frac{1}{\Lambda^{d-4}} \sum_i c_i \mathcal{O}_i$$

EFT operators $\mathcal{O}_i$ contain only SM fields.

Terms are sorted by Mass dimension d .



The EFT Lagrangian

$$\mathcal{L}_{\text{SMEFT}} = \mathcal{L}_{\text{SM}} + \sum_{d=5}^{\infty} \frac{1}{\Lambda^{d-4}} \sum_i c_i \mathcal{O}_i$$

For fixed mass dimension d :

$$\mathcal{L}_{\text{SMEFT}}^{(d)} \propto \sum_i c_i \mathcal{O}_i$$

The EFT Lagrangian

$$\mathcal{L}_{\text{SMEFT}} = \mathcal{L}_{\text{SM}} + \sum_{d=5}^{\infty} \frac{1}{\Lambda^{d-4}} \sum_i c_i \mathcal{O}_i$$

For fixed mass dimension d :

$$\mathcal{L}_{\text{SMEFT}}^{(d)} \propto \sum_i c_i \mathcal{O}_i$$

↙ Basis vectors

↘ Vector components

- The observed BSM effects are one vector in the space spanned by all EFT operators.
- Diagrams with $\mathcal{O}_i$ inserted depend on c_i
- Need a set of operators with independent c_i (basis).

SMEFT operator bases

X^3		φ^6 and $\varphi^4 D^2$		$\psi^2 \varphi^3$	
Q_G	$f^{ABC} G_\mu^{A\nu} G_\nu^{B\rho} G_\rho^{C\mu}$	Q_φ	$(\varphi^\dagger \varphi)^3$	$Q_{e\varphi}$	$(\varphi^\dagger \varphi)(\bar{l}_p e_r \varphi)$
$Q_{\tilde{G}}$	$f^{ABC} \tilde{G}_\mu^{A\nu} G_\nu^{B\rho} G_\rho^{C\mu}$	$Q_{\varphi\Box}$	$(\varphi^\dagger \varphi)\Box(\varphi^\dagger \varphi)$	$Q_{u\varphi}$	$(\varphi^\dagger \varphi)(\bar{q}_p u_r \tilde{\varphi})$
Q_W	$\varepsilon^{IJK} W_\mu^{I\nu} W_\nu^{J\rho} W_\rho^{K\mu}$	$Q_{\varphi D}$	$(\varphi^\dagger D^\mu \varphi)^* (\varphi^\dagger D_\mu \varphi)$	$Q_{d\varphi}$	$(\varphi^\dagger \varphi)(\bar{q}_p d_r \varphi)$
$Q_{\tilde{W}}$	$\varepsilon^{IJK} \tilde{W}_\mu^{I\nu} W_\nu^{J\rho} W_\rho^{K\mu}$				
$X^2 \varphi^2$		$\psi^2 X \varphi$		$\psi^2 \varphi^2 D$	
$Q_{\varphi G}$	$\varphi^\dagger \varphi G_{\mu\nu}^A G^{A\mu\nu}$	Q_{eW}	$(\bar{l}_p \sigma^{\mu\nu} e_r) \tau^I \varphi W_{\mu\nu}^I$	$Q_{\varphi l}^{(1)}$	$(\varphi^\dagger i \overleftrightarrow{D}_\mu \varphi)(\bar{l}_p \gamma^\mu l_r)$
$Q_{\varphi \tilde{G}}$	$\varphi^\dagger \varphi \tilde{G}_{\mu\nu}^A G^{A\mu\nu}$	Q_{eB}	$(\bar{l}_p \sigma^{\mu\nu} e_r) \varphi B_{\mu\nu}$	$Q_{\varphi l}^{(3)}$	$(\varphi^\dagger i \overleftrightarrow{D}_\mu^I \varphi)(\bar{l}_p \tau^I \gamma^\mu l_r)$
$Q_{\varphi W}$	$\varphi^\dagger \varphi W_{\mu\nu}^I W^{I\mu\nu}$	Q_{uG}	$(\bar{q}_p \sigma^{\mu\nu} T^A u_r) \tilde{\varphi} G_{\mu\nu}^A$	$Q_{\varphi e}$	$(\varphi^\dagger i \overleftrightarrow{D}_\mu \varphi)(\bar{e}_p \gamma^\mu e_r)$
$Q_{\varphi \tilde{W}}$	$\varphi^\dagger \varphi \tilde{W}_{\mu\nu}^I W^{I\mu\nu}$	Q_{uW}	$(\bar{q}_p \sigma^{\mu\nu} u_r) \tau^I \tilde{\varphi} W_{\mu\nu}^I$	$Q_{\varphi q}^{(1)}$	$(\varphi^\dagger i \overleftrightarrow{D}_\mu \varphi)(\bar{q}_p \gamma^\mu q_r)$
$Q_{\varphi B}$	$\varphi^\dagger \varphi B_{\mu\nu} B^{\mu\nu}$	Q_{uB}	$(\bar{q}_p \sigma^{\mu\nu} u_r) \tilde{\varphi} B_{\mu\nu}$	$Q_{\varphi q}^{(3)}$	$(\varphi^\dagger i \overleftrightarrow{D}_\mu^I \varphi)(\bar{q}_p \tau^I \gamma^\mu q_r)$
$Q_{\varphi \tilde{B}}$	$\varphi^\dagger \varphi \tilde{B}_{\mu\nu} B^{\mu\nu}$	Q_{dG}	$(\bar{q}_p \sigma^{\mu\nu} T^A d_r) \varphi G_{\mu\nu}^A$	$Q_{\varphi u}$	$(\varphi^\dagger i \overleftrightarrow{D}_\mu \varphi)(\bar{u}_p \gamma^\mu u_r)$
$Q_{\varphi WB}$	$\varphi^\dagger \tau^I \varphi W_{\mu\nu}^I B^{\mu\nu}$	Q_{dW}	$(\bar{q}_p \sigma^{\mu\nu} d_r) \tau^I \varphi W_{\mu\nu}^I$	$Q_{\varphi d}$	$(\varphi^\dagger i \overleftrightarrow{D}_\mu \varphi)(\bar{d}_p \gamma^\mu d_r)$
$Q_{\varphi \tilde{W}B}$	$\varphi^\dagger \tau^I \varphi \tilde{W}_{\mu\nu}^I B^{\mu\nu}$	Q_{dB}	$(\bar{q}_p \sigma^{\mu\nu} d_r) \varphi B_{\mu\nu}$	$Q_{\varphi ud}$	$i(\tilde{\varphi}^\dagger D_\mu \varphi)(\bar{u}_p \gamma^\mu d_r)$

Some SMEFT Dimension 6 operators (Warsaw basis)

(Grzadkowski, Iskrzynski, Misiak, and Rosiek 2010)

SMEFT operator bases

$(\bar{L}L)(\bar{L}L)$		$(\bar{R}R)(\bar{R}R)$		$(\bar{L}L)(\bar{R}R)$	
Q_{ll}	$(\bar{l}_p \gamma_\mu l_r)(\bar{l}_s \gamma^\mu l_t)$	Q_{ee}	$(\bar{e}_p \gamma_\mu e_r)(\bar{e}_s \gamma^\mu e_t)$	Q_{le}	$(\bar{l}_p \gamma_\mu l_r)(\bar{e}_s \gamma^\mu e_t)$
$Q_{qq}^{(1)}$	$(\bar{q}_p \gamma_\mu q_r)(\bar{q}_s \gamma^\mu q_t)$	Q_{uu}	$(\bar{u}_p \gamma_\mu u_r)(\bar{u}_s \gamma^\mu u_t)$	Q_{lu}	$(\bar{l}_p \gamma_\mu l_r)(\bar{u}_s \gamma^\mu u_t)$
$Q_{qq}^{(3)}$	$(\bar{q}_p \gamma_\mu \tau^I q_r)(\bar{q}_s \gamma^\mu \tau^I q_t)$	Q_{dd}	$(\bar{d}_p \gamma_\mu d_r)(\bar{d}_s \gamma^\mu d_t)$	Q_{ld}	$(\bar{l}_p \gamma_\mu l_r)(\bar{d}_s \gamma^\mu d_t)$
$Q_{lq}^{(1)}$	$(\bar{l}_p \gamma_\mu l_r)(\bar{q}_s \gamma^\mu q_t)$	Q_{eu}	$(\bar{e}_p \gamma_\mu e_r)(\bar{u}_s \gamma^\mu u_t)$	Q_{qe}	$(\bar{q}_p \gamma_\mu q_r)(\bar{e}_s \gamma^\mu e_t)$
$Q_{lq}^{(3)}$	$(\bar{l}_p \gamma_\mu \tau^I l_r)(\bar{q}_s \gamma^\mu \tau^I q_t)$	Q_{ed}	$(\bar{e}_p \gamma_\mu e_r)(\bar{d}_s \gamma^\mu d_t)$	$Q_{qu}^{(1)}$	$(\bar{q}_p \gamma_\mu q_r)(\bar{u}_s \gamma^\mu u_t)$
		$Q_{ud}^{(1)}$	$(\bar{u}_p \gamma_\mu u_r)(\bar{d}_s \gamma^\mu d_t)$	$Q_{qu}^{(8)}$	$(\bar{q}_p \gamma_\mu T^A q_r)(\bar{u}_s \gamma^\mu T^A u_t)$
		$Q_{ud}^{(8)}$	$(\bar{u}_p \gamma_\mu T^A u_r)(\bar{d}_s \gamma^\mu T^A d_t)$	$Q_{qd}^{(1)}$	$(\bar{q}_p \gamma_\mu q_r)(\bar{d}_s \gamma^\mu d_t)$
				$Q_{qd}^{(8)}$	$(\bar{q}_p \gamma_\mu T^A q_r)(\bar{d}_s \gamma^\mu T^A d_t)$
$(\bar{L}R)(\bar{R}L)$ and $(\bar{L}R)(\bar{L}R)$		B -violating			
Q_{ledq}	$(\bar{l}_p^j e_r)(\bar{d}_s^j q_t^j)$	Q_{duq}	$\varepsilon^{\alpha\beta\gamma} \varepsilon_{jk} [(d_p^\alpha)^T C u_r^\beta] [(q_s^j)^T C l_t^k]$		
$Q_{quqd}^{(1)}$	$(\bar{q}_p^j u_r) \varepsilon_{jk} (\bar{q}_s^k d_t)$	Q_{qqqu}	$\varepsilon^{\alpha\beta\gamma} \varepsilon_{jk} [(q_p^{\alpha j})^T C q_r^{\beta k}] [(u_s^\gamma)^T C e_t]$		
$Q_{quqd}^{(8)}$	$(\bar{q}_p^j T^A u_r) \varepsilon_{jk} (\bar{q}_s^k T^A d_t)$	Q_{qqq}	$\varepsilon^{\alpha\beta\gamma} \varepsilon_{jn} \varepsilon_{km} [(q_p^{\alpha j})^T C q_r^{\beta k}] [(q_s^m)^T C l_t^n]$		
$Q_{lequ}^{(1)}$	$(\bar{l}_p^j e_r) \varepsilon_{jk} (\bar{q}_s^k u_t)$	Q_{duu}	$\varepsilon^{\alpha\beta\gamma} [(d_p^\alpha)^T C u_r^\beta] [(u_s^\gamma)^T C e_t]$		
$Q_{lequ}^{(3)}$	$(\bar{l}_p^j \sigma_{\mu\nu} e_r) \varepsilon_{jk} (\bar{q}_s^k \sigma^{\mu\nu} u_t)$				

More SMEFT Dimension 6 operators (Warsaw basis)

(Grzadkowski, Iskrzynski, Misiak, and Rosiek 2010)

SMEFT operator bases

Number of SMEFT operators by Mass dimension d

Mass dimension d (order $1/\Lambda^{d-4}$)	Onshell operators	Green's basis operators (offshell operators)
5	12	12
6	3045	3710
7	1542	2466
8	44 807	111 004
9	90 456	138 228
10	2 092 441	4 976 586

SMEFT operator bases

Number of SMEFT operators by Mass dimension d

Mass dimension d (order $1/\Lambda^{d-4}$)	Onshell operators	Green's basis operators (offshell operators)
5	12	12
6	3045	3710
7	1542	2466
8	44 807	111 004
9	90 456	138 228
10	2 092 441	4 976 586

Onshell basis: Used for $\mathcal{S}$ -matrix-elements $\langle p|\mathcal{S}|k\rangle$, cross-sections σ

Offshell basis: Used for calculations on correlation functions $\langle 0|\phi\dots|0\rangle$,
e.g. renormalization: $\mathcal{C}_{i,\text{bare}} = Z_{ji}\mathcal{C}_{j,\text{R}}$.



(Harlander and Schaaf 2024; Schaaf 2024)

EFT operator construction for many different models:

Supported fields

- Scalar fields
- Fermion fields (left/right Weyl spinors)
- Vector fields only as gauge fields
- Spin 2 Tensors (GRSMEFT)

Supported symmetries

- $U(1)$ symmetries
- $SU(n)$ symmetries

Symmetries can be either local (gauge) or global.

Only Lorentz- and Gauge-invariant operators are constructed.

AutoEFT



(Harlander and Schaaf 2024; Schaaf 2024)

EFT operator construction for many different models:

Supported fields

- Scalar fields
- Fermion fields (left/right Weyl spinors)
- Vector fields only as gauge fields
- Spin 2 Tensors (GRSMEFT)

Supported symmetries

- $U(1)$ symmetries
- $SU(n)$ symmetries

Symmetries can be either local (gauge) or global.

Only Lorentz- and Gauge-invariant operators are constructed.

Added support for offshell basis (Green's basis) construction.

Operator redundancies

Naive idea: Write down every valid operator.

→ **Overcomplete basis:** $\mathcal{C}_i$ cannot be fixed by experiments.

Operator redundancies

Naive idea: Write down every valid operator.

→ **Overcomplete basis**: $\mathcal{C}_i$ cannot be fixed by experiments.

Some examples of **redundancies**:

$$(\bar{\psi}\gamma^\mu P_L \psi)(\bar{\chi}\gamma_\mu P_L \chi) = (\bar{\psi}\gamma^\mu P_L \chi)(\bar{\chi}\gamma_\mu P_L \psi) \quad (\text{Fierz Identity})$$

$$D_\mu \bar{\psi} \gamma^\mu \psi \phi \simeq -\bar{\psi} \gamma^\mu D_\mu \psi \phi - \bar{\psi} \gamma^\mu \psi D_\mu \phi \quad (\text{Integration by Parts})$$

$$D_\mu D_\nu \phi - D_\nu D_\mu \phi = F_{\mu\nu} \phi \quad (\text{Commutator of Covariant Derivatives})$$

Operator redundancies

Naive idea: Write down every valid operator.

→ **Overcomplete basis**: $\mathcal{C}_i$ cannot be fixed by experiments.

Some examples of **redundancies**:

$$(\bar{\psi}\gamma^\mu P_L \psi)(\bar{\chi}\gamma_\mu P_L \chi) = (\bar{\psi}\gamma^\mu P_L \chi)(\bar{\chi}\gamma_\mu P_L \psi) \quad (\text{Fierz Identity})$$

$$D_\mu \bar{\psi} \gamma^\mu \psi \phi \simeq -\bar{\psi} \gamma^\mu D_\mu \psi \phi - \bar{\psi} \gamma^\mu \psi D_\mu \phi \quad (\text{Integration by Parts})$$

$$D_\mu D_\nu \phi - D_\nu D_\mu \phi = F_{\mu\nu} \phi \quad (\text{Commutator of Covariant Derivatives})$$

Only for onshell bases:

$$\square \phi \simeq 0, \quad D_\mu \gamma^\mu \psi \simeq 0, \quad D_\mu F^{\mu\nu} \simeq 0 \quad (\text{Equation of Motion})$$

Only for offshell bases:

$$\epsilon^{\alpha\beta} D_\alpha^{\dot{\alpha}} F_{L\beta\gamma} \simeq \epsilon_{\dot{\gamma}\dot{\alpha}} D_\gamma^{\dot{\gamma}} F_R^{\dot{\alpha}\dot{\beta}} \quad (\text{Bianchi identity})$$

Construction algorithm

Describe the field's representation in all symmetry groups:

- Lorentz group: $SO^+(3, 1) \simeq SL(2, \mathbb{C}) \simeq SU(2) \times SU(2)$
→ A tuple of $SU(2)$ -tableaux $(\mathcal{T}_L ; \mathcal{T}_R)$.
- $SU(n)$ groups: One $SU(n)$ -tableau $\mathcal{T}$.
- $U(1)$ groups: A charge q .

Construction algorithm

Describe the field's representation in all symmetry groups:

- Lorentz group: $SO^+(3, 1) \simeq SL(2, \mathbb{C}) \simeq SU(2) \times SU(2)$
 $\rightarrow$ A tuple of $SU(2)$ -tableaux $(\mathcal{T}_L; \mathcal{T}_R)$.
- $SU(n)$ groups: One $SU(n)$ -tableau $\mathcal{T}$.
- $U(1)$ groups: A charge q .

Example: SM Gluon field strength tensor $G_{\mu\nu}^I$:

$$G_{\mu\nu}^I \rightarrow \left\{ \begin{array}{ll} \text{Lorentz (Left):} & (G_L)_{\alpha\beta} = (\sigma^{\mu\nu})_{\alpha\beta} G_{\mu\nu} \rightarrow (\boxed{\alpha} \boxed{\beta}; 1) \\ \text{Lorentz (Right):} & (G_R)^{\dot{\alpha}\dot{\beta}} = (\bar{\sigma}^{\mu\nu})^{\dot{\alpha}\dot{\beta}} G_{\mu\nu} \rightarrow (1; \boxed{\dot{\alpha}} \boxed{\dot{\beta}}) \\ SU(3): & G^{abc} = \epsilon^{adc} (T^I)_d^b G^I \rightarrow \begin{array}{|c|c|} \hline a & b \\ \hline c & \\ \hline \end{array} \\ SU(2): & G \text{ (trivial)} \rightarrow 1 \\ U(1): & G \text{ (trivial)} \rightarrow 0 \end{array} \right.$$

Construction algorithm

Young Tableau product (*modified Littlewood-Richardson rule*):

$$G^I \cdot G^J \rightarrow G^{(I G^J)}, \quad \delta^{IJ} G^I G^J, \quad f^{IJK} G^I G^J, \quad \dots$$

$$\begin{array}{|c|c|} \hline a & b \\ \hline c & \\ \hline \end{array} \otimes \begin{array}{|c|c|} \hline d & e \\ \hline f & \\ \hline \end{array} = \begin{array}{|c|c|c|c|} \hline a & b & d & e \\ \hline c & f & & \\ \hline \end{array} \oplus \begin{array}{|c|c|} \hline a & b \\ \hline c & d \\ \hline e & f \\ \hline \end{array} \oplus \begin{array}{|c|c|c|} \hline a & b & d \\ \hline c & e & \\ \hline f & & \\ \hline \end{array} \oplus \dots$$

Construction algorithm

Young Tableau product (*modified Littlewood-Richardson rule*):

$$\begin{array}{c} G^I \quad \cdot \quad G^J \quad \rightarrow \quad G^{(I}G^J), \quad \delta^{IJ}G^IG^J, \quad f^{IJK}G^IG^J, \quad \dots \\
 \begin{array}{|c|c|} \hline a & b \\ \hline c & \\ \hline \end{array} \otimes \begin{array}{|c|c|} \hline d & e \\ \hline f & \\ \hline \end{array} = \begin{array}{|c|c|c|c|} \hline a & b & d & e \\ \hline c & f & & \\ \hline \end{array} \oplus \begin{array}{|c|c|} \hline a & b \\ \hline c & d \\ \hline e & f \\ \hline \end{array} \oplus \begin{array}{|c|c|c|} \hline a & b & d \\ \hline c & e & \\ \hline f & & \\ \hline \end{array} \oplus \dots
 \end{array}$$

One $SU(3)$ invariant contraction.

Construction algorithm

Young Tableau product (*modified Littlewood-Richardson rule*):

$$G^I \cdot G^J \rightarrow G^{(I G^J)}, \quad \delta^{IJ} G^I G^J, \quad f^{IJK} G^I G^J, \quad \dots$$

$$\begin{array}{|c|c|} \hline a & b \\ \hline c & \\ \hline \end{array} \otimes \begin{array}{|c|c|} \hline d & e \\ \hline f & \\ \hline \end{array} = \begin{array}{|c|c|c|c|} \hline a & b & d & e \\ \hline c & f & & \\ \hline \end{array} \oplus \begin{array}{|c|c|} \hline a & b \\ \hline c & d \\ \hline e & f \\ \hline \end{array} \oplus \begin{array}{|c|c|c|} \hline a & b & d \\ \hline c & e & \\ \hline f & & \\ \hline \end{array} \oplus \dots$$

One $SU(3)$ invariant contraction. Combine with fields G :

$$\begin{array}{|c|c|} \hline a & b \\ \hline c & d \\ \hline e & f \\ \hline \end{array} \rightarrow \mathcal{O} = \epsilon_{ace} \epsilon_{bdf} G^{abc} G^{def}$$

$$= \epsilon_{ace} \epsilon_{bdf} (\epsilon^{agc} (T^I)_g^b G^I) (\epsilon^{dhf} (T^J)_h^e G^J)$$

Projection

Two groups work with an EFT operator $\mathcal{A}$:

Projection

Two groups work with an EFT operator $\mathcal{A}$:

Group A uses a basis that contains $\mathcal{A}$:

$$\mathcal{A} = \mathcal{O}_1$$

Result is $\sigma(\mathcal{C}_1)$.

Projection

Two groups work with an EFT operator $\mathcal{A}$:

Group A uses a basis that contains $\mathcal{A}$:

$$\mathcal{A} = \mathcal{O}_1$$

Result is $\sigma(\mathcal{C}_1)$.

Group B uses basis that does not contain $\mathcal{A}$:

$$\mathcal{A} = \sum_n a'_n \mathcal{O}'_n$$

Result is $\sigma(\mathcal{C}'_1, \dots, \mathcal{C}'_n)$.

Projection

Two groups work with an EFT operator $\mathcal{A}$:

Group A uses a basis that contains $\mathcal{A}$:

$$\mathcal{A} = \mathcal{O}_1$$

Result is $\sigma(\mathcal{C}_1)$.

Group B uses basis that does not contain $\mathcal{A}$:

$$\mathcal{A} = \sum_n a'_n \mathcal{O}'_n$$

Result is $\sigma(\mathcal{C}'_1, \dots, \mathcal{C}'_n)$.

What are the expansion coefficients a'_n ?

What are the Wilson coefficients $\mathcal{C}'_i(\mathcal{C}_1, \dots, \mathcal{C}_n)$?

Projection

$$\delta c_z = -c_H - 3\delta v,$$

$$c_{gg} = c_{GG},$$

$$c_{ww} = c_{WW},$$

$$c_{zz} = \frac{g^4 c_{WW} + 4g^2 g'^2 c_{WB} + g'^4 c_{BB}}{(g^2 + g'^2)^2},$$

$$c_{z\gamma} = \frac{g^2 c_{WW} - 2(g^2 - g'^2) c_{WB} - g'^2 c_{BB}}{g^2 + g'^2},$$

$$c_{\gamma\gamma} = c_{WW} + c_{BB} - 4c_{WB},$$

$$c_{w\Box} = \frac{2}{g^2 - g'^2} [g'^2 c_{WB} - c_T + \delta v],$$

$$c_{z\Box} = -\frac{2}{g^2} [c_T - \delta v],$$

$$c_{\gamma\Box} = \frac{2}{g^2 - g'^2} [(g^2 + g'^2) c_{WB} - 2c_T + 2\delta v].$$

Relations between redundant Wilson coefficients in SMEFT
(Falkowski, Fuks, Mawatari, Mimasu, Riva, and Sanz 2015)

Projection

Projection algorithm: Find a general function

$$P : \mathcal{A} \rightarrow a_n \quad \text{such that} \quad \mathcal{A} = \sum_n a_n \mathcal{O}_n$$

Projection

Projection algorithm: Find a general function

$$P : \mathcal{A} \rightarrow a_n \quad \text{such that} \quad \mathcal{A} = \sum_n a_n \mathcal{O}_n$$

Inner product $\langle \mathcal{A} | \mathcal{B} \rangle$:

$$\langle \mathcal{A} | \mathcal{B} \rangle = \sum_{n,m} a_n b_m \langle \mathcal{O}_n | \mathcal{O}_m \rangle = \sum_{n,m} a_n g_{nm} a_m$$

Define $g_{nm} = \langle \mathcal{O}_n | \mathcal{O}_m \rangle = \delta_{nm}$ for one special basis.

Summary

- **General EFT operators** can be used to describe high-energy effects without having to decide on a specific high-energy model.
- The **Number of operators** of an EFT increases with mass dimension, and for SMEFT past dimension 7 the basis can not be constructed by hand.
- **AutoEFT** generates EFT operator bases for SMEFT, and any other model with $U(1)$ and $SU(N)$ symmetries.
- Both **Onshell** and **Offshell** bases are supported. Mass dimension is limited only by computation time.
- **Operator projection** enables us to deal with EFT operators just like ordinary vectors, including easy change of basis.

Backup

Backup