FTAE
High Energy Theory

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Evanescent operators in one-loop matching computations

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Based on 2211.0914 done with M. König, A. E. Thomsen, J. Pagès, and F. Wilsch

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The EFT approach

EFTs are essential to interpret experimental observations

UV physics

$$\mathscr{L}_{\rm EFT}(\eta_L) = \mathscr{L}_{d=4}(\eta_L) + \sum_{\ell=0}^{\infty}\sum_{n=5}^{\infty}\sum_{k} \frac{C_{n,k}^{(\ell)}}{(16\pi^2)^{\ell}\,\Lambda^{n-4}}\, O_{n,k}(\eta_L)$$

- Bottom → Up

  Comprehensive approach: Large classes of UV physics covered by a single Lagrangian (“model independence”), written in terms of an expansion in loops and powers of Λ

- Top → Down

  Reusability: EFT computations can be shared among different BSM models (“compute once for all”)

  BSM computations of experimental observables are multi-scale problems: Precision requires the use of EFTs (RG resummation of large logarithms)

The repetitive nature of EFT computations call for new approaches and automated solutions

[See Anders’ and José’s talks]

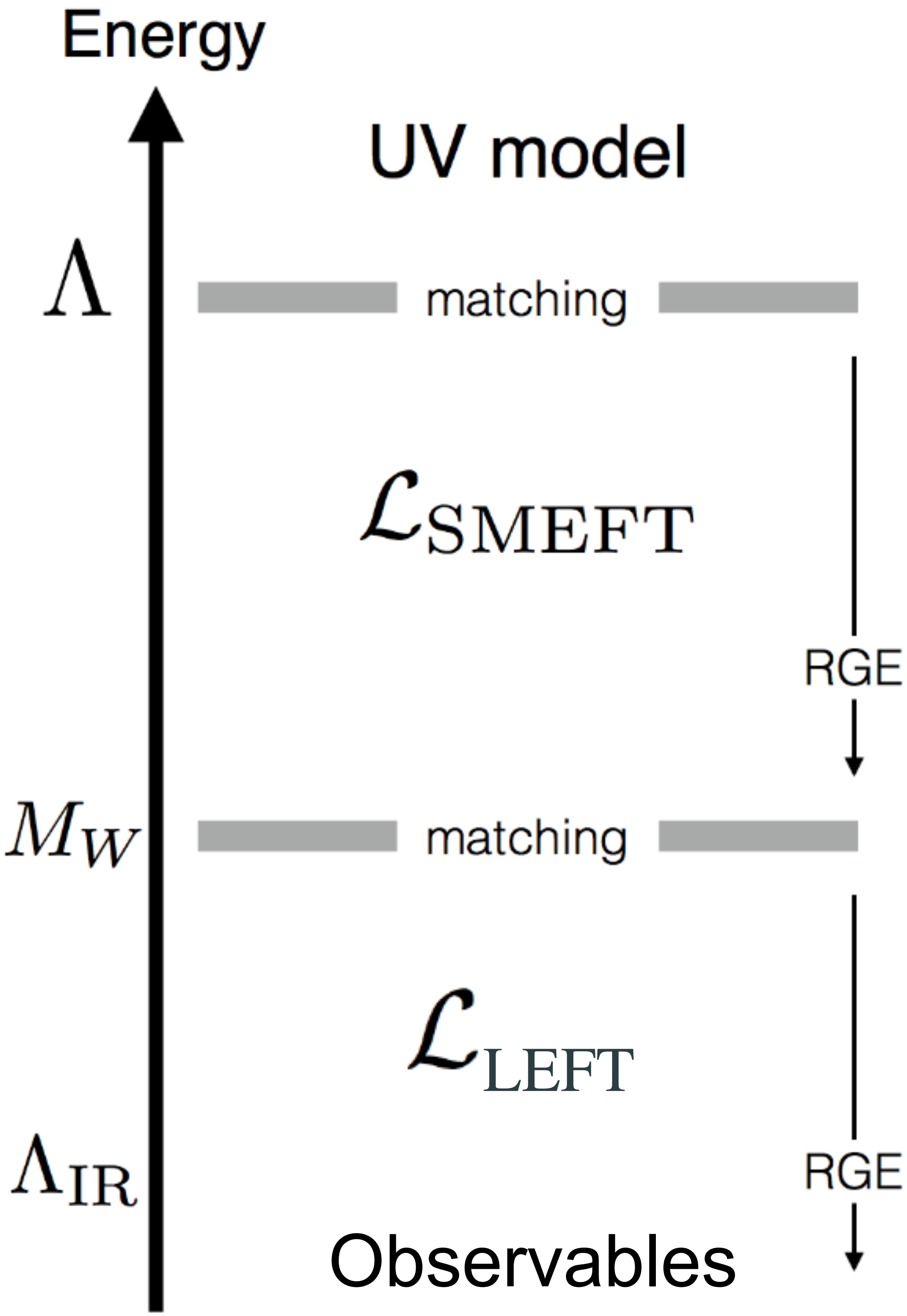
The EFT approach: recent progress

Much progress has been made:

- Tree-level matching to the SMEFT is a solved problem

  [de Blas, Criado, Pérez-Victoria, Santiago, 1711.10391]

  MatchingTools: [Criado, 1710.06445]



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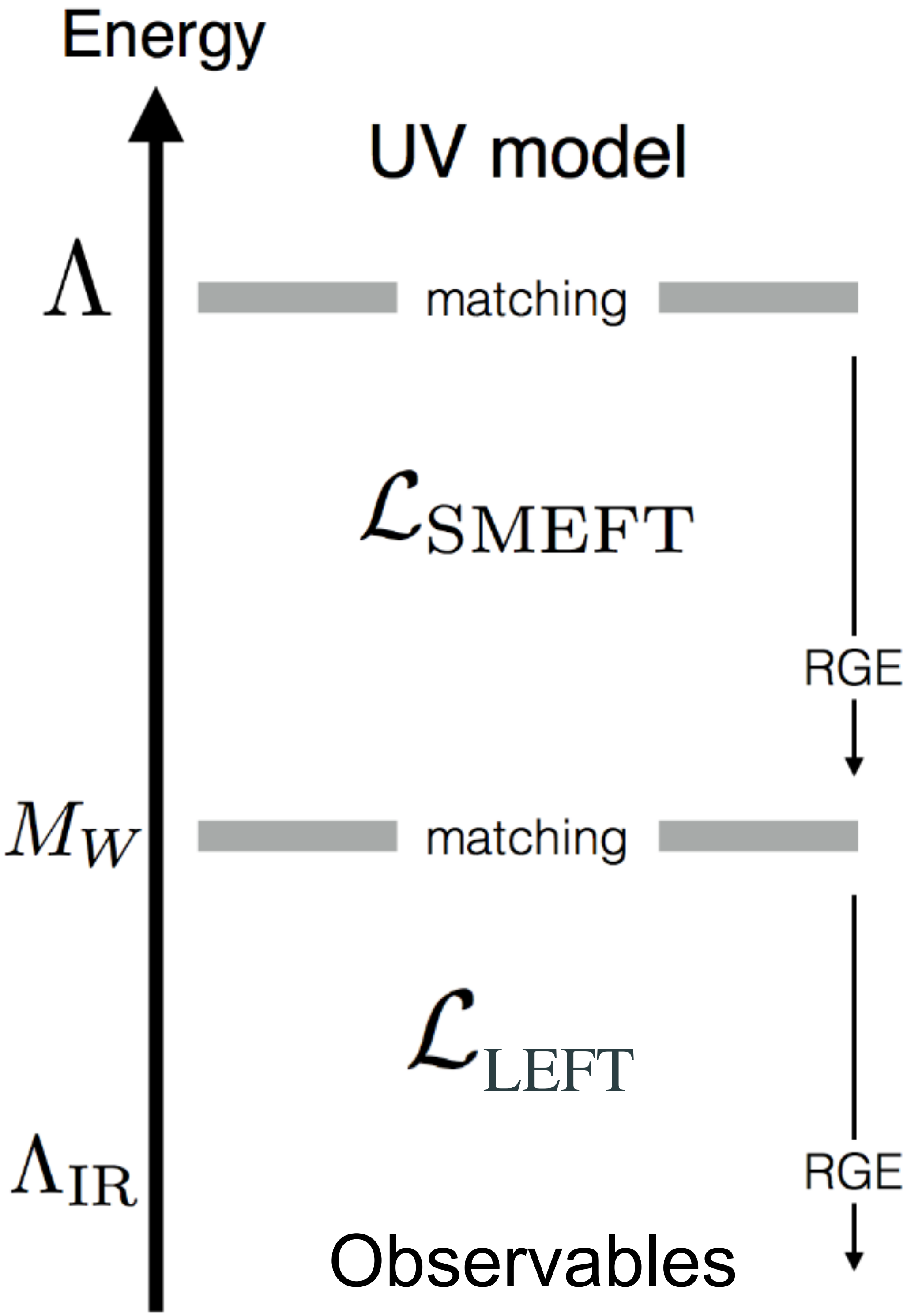
  MatchingTools: [Criado, 1710.06445]

- RGE evolution in the SMEFT and LEFT, and one-loop matching of the SMEFT to the LEFT is also known

  [Jenkins, Manohar, Trott, 1308.2627, 1310.4838, Alonso et al., 1312.2014, Jenkins, Manohar, Stoffer, 1709.04486, 1711.05270; Dekens, Stoffer, 1908.05295]

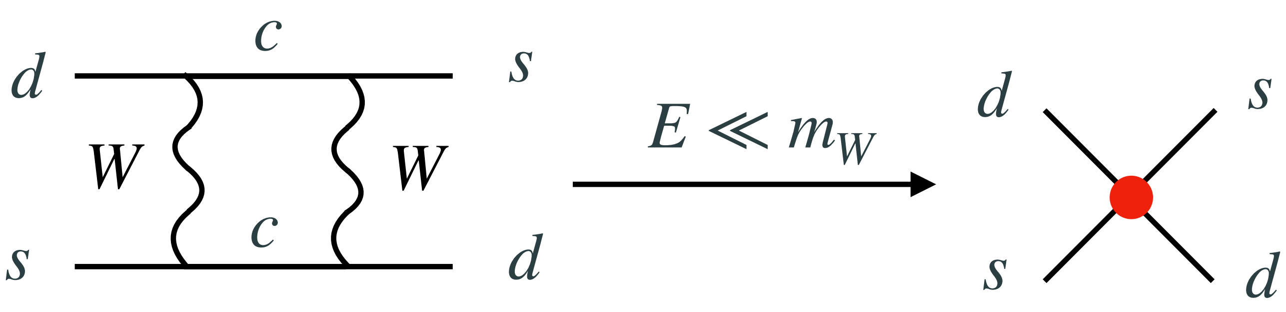
  DsixTools and Wilson:
  [JFM, Ruiz-Femenía, Vicente, Virto, 2010.16341; Aebischer, Kumar, Straub, 1804.05033]



The EFT approach: recent progress

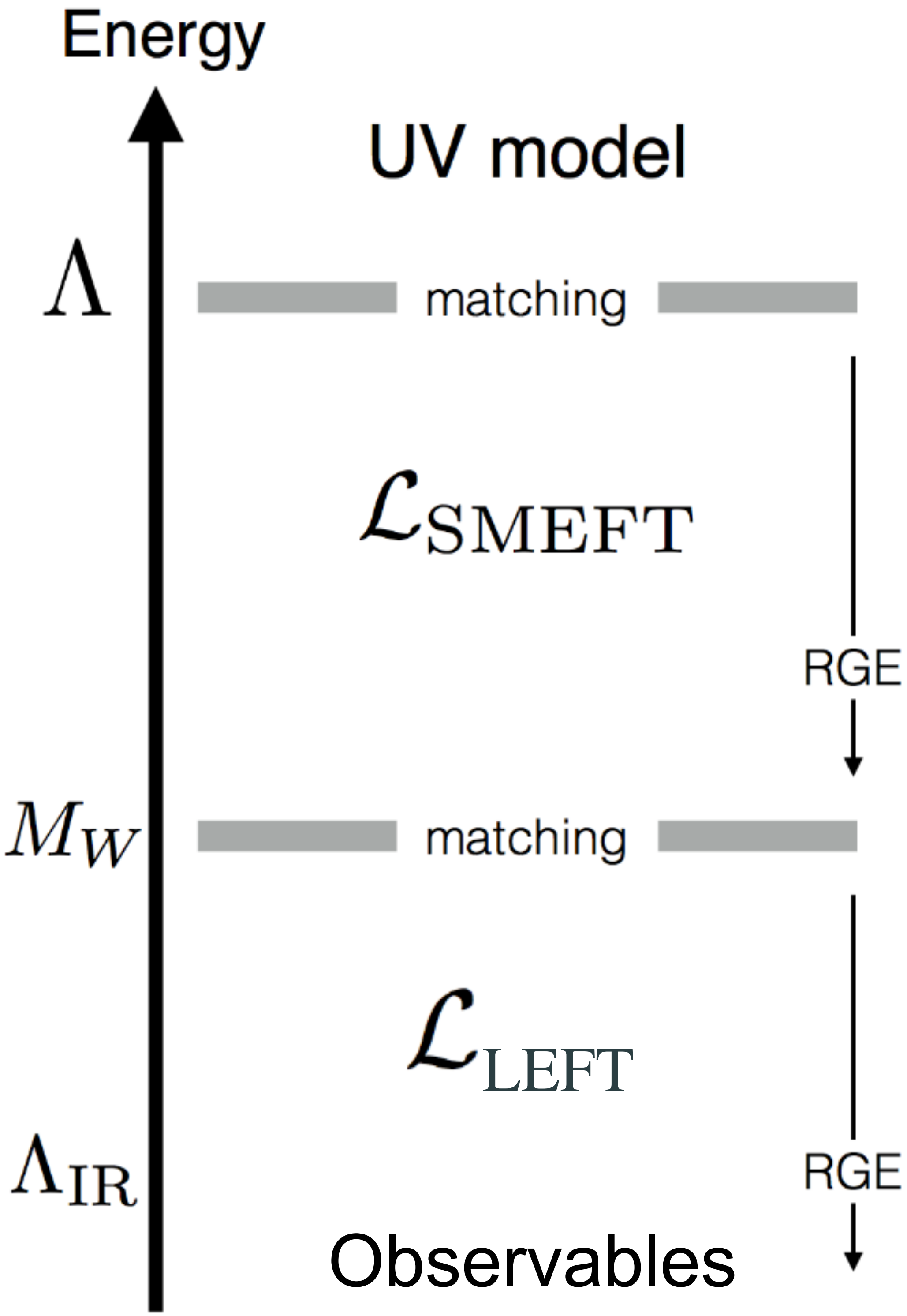
However, we need to go beyond:

- One-loop can be the leading effect in important processes. E.g., in the SM



- Recent progress in one-loop matching automation (both diagrammatic and functional approaches)

[Carmona, Lazopoulos, Olgoso, Santiago, 2112.10787; JFM, König, Thomsen, Pagès, Wilsch, 2212.04510]



Energy

UV model

Λ matching

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

RGE

M_W matching

$\mathcal{L}_{\text{LEFT}}$

Λ_{IR}

RGE

Observables

Evanescent operators

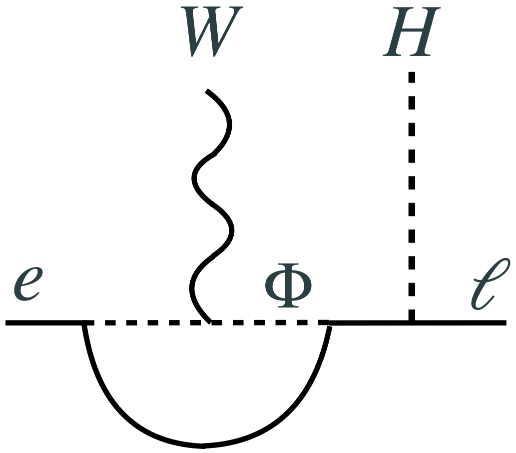
Addressing an important subtlety in the EFT basis reduction

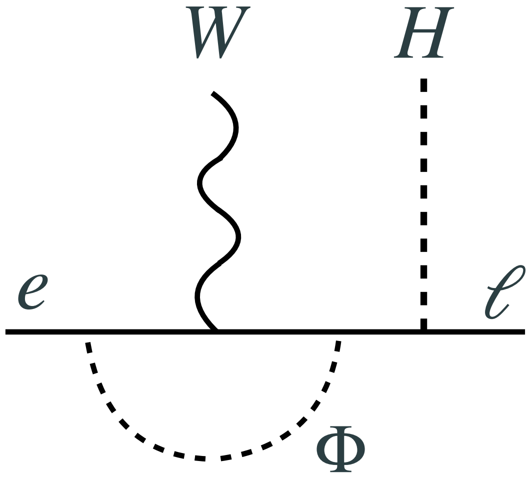
A 2HDM example

Take the SM + leptophilic Higgs doublet, $\Phi \sim (\mathbf{1},\mathbf{2})_{1/2}$

$$\mathscr{L}_{\rm UV} = \mathscr{L}_{\rm SM} + |D_\mu \Phi|^2 - M_\Phi^2 |\Phi|^2 - \left(y_{\Phi e}^{pr}\, \bar{\ell}_p \Phi\, e_r + \mathrm{h.c.} \right)$$

Say we want to compute $e_r H \to \ell_p W$ [contribution to e.g. the LFV process $\mu \to e\gamma$]





The amplitude in the full model reads

$$iA_{e_r H \to \ell_p W} = \frac{g_L}{384\pi^2 M_\Phi^2} [y_{\Phi e} y_{\Phi e}^\dagger y_e]^{pr} \left(\bar{u}\, \tau^I \sigma_{\mu\nu} P_R\, u \right) q^\mu \varepsilon^{*\nu}$$

A 2HDM example: EFT matching

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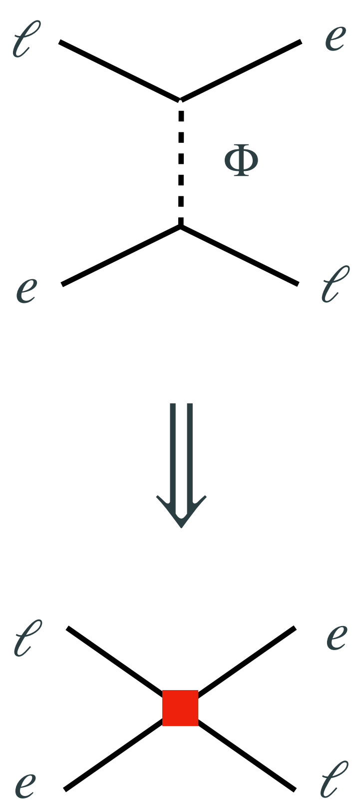
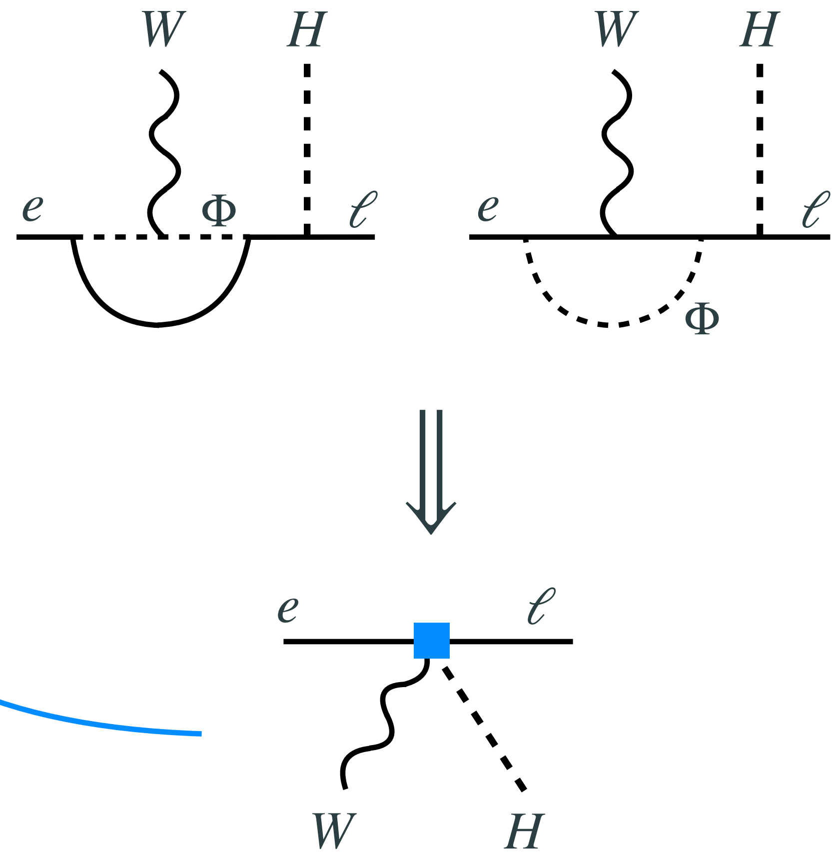
Below the scale $M_\Phi \gg v_{\rm EW}$ we can match to the SMEFT



$$\mathscr{L}_{\rm EFT} \supset \underline{C_{\ell e}^{prst}\,R_{\ell e}^{prst}} + \underline{C_{eW}^{pr}\,Q_{eW}^{pr}}$$



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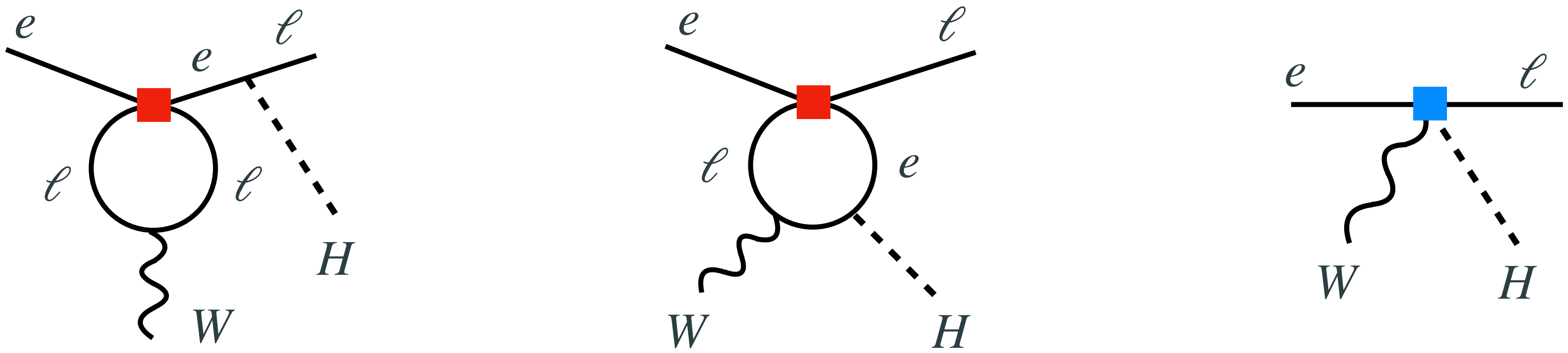
From the EFT point of view, the $e_r H \to \ell_p W$ amplitude is now given by

$$\mathscr{L}_{\rm EFT} \supset C_{\ell e}^{prst} R_{\ell e}^{prst} + C_{eW}^{pr} Q_{eW}^{pr}$$



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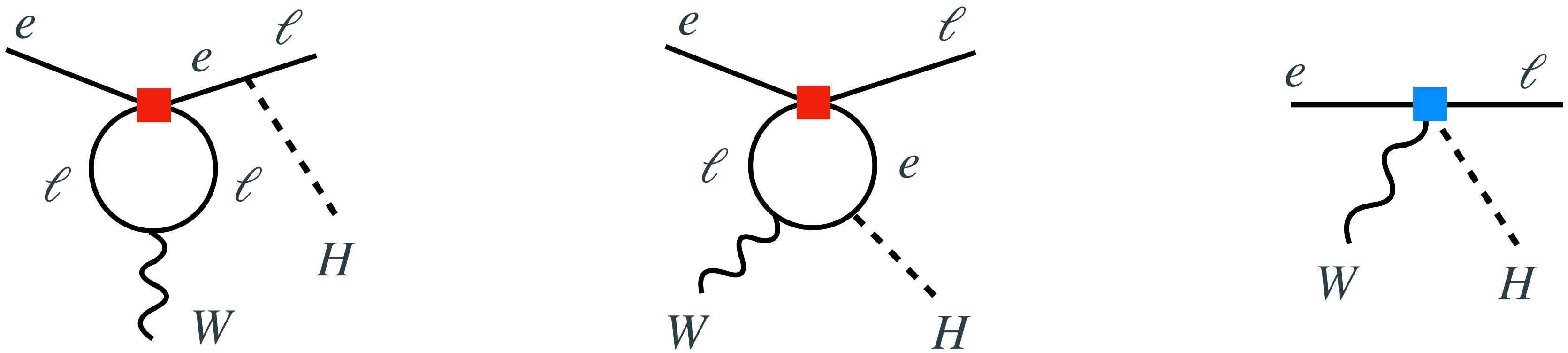

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but the tree-level-generated operator $R_{\ell e}$ is not part of the Warsaw basis (standard SMEFT basis)

A 2HDM example: Changing EFT basis

In $d = 4$, we can use the Fierz identity $R_{\ell e} = -\frac{1}{2} Q_{\ell e}$

$$\mathscr{L}_{\text{EFT}} \supset C_{eW}^{pr} Q_{eW}^{pr} + C_{\ell e}^{prst} R_{\ell e}^{prst} \qquad R_{\ell e}^{prst} = (\bar{\ell}_p e_r)(\bar{e}_s \ell_t)$$

$$\mathscr{L}'_{\text{EFT}} \supset C_{eW}^{pr} Q_{eW}^{pr} - \frac{1}{2} C_{\ell e}^{prst} Q_{\ell e}^{prst} \qquad Q_{\ell e}^{prst} = (\bar{\ell}_p \gamma_\mu \ell_t)(\bar{e}_s \gamma^\mu e_r)$$

so that $\mathscr{L}_{\text{EFT}} = \mathscr{L}'_{\text{EFT}}$ at tree level.

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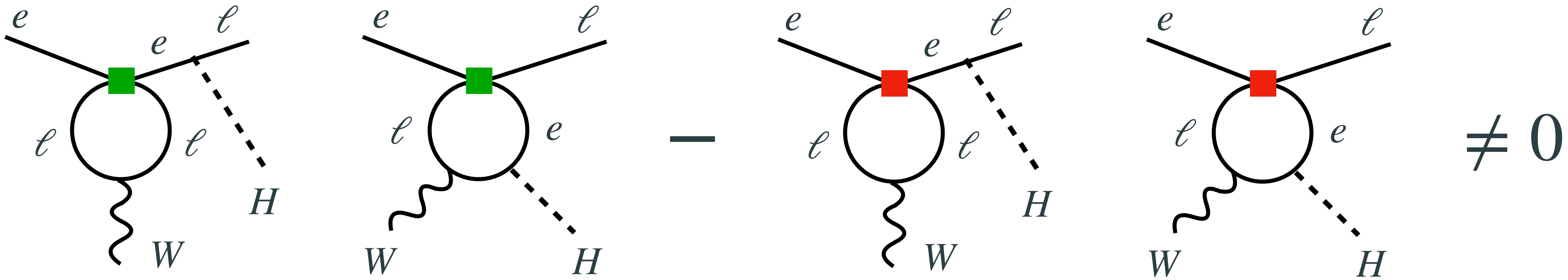

Different flavor structure than $A_{e_r H\to \ell_p W}$!

$$i\,(A_{e_r H\to \ell_p W} - A'_{e_r H\to \ell_p W}) = \frac{g_L}{64\pi^2 M_\Phi^2}\, y_{\Phi e}^{pr}\, {\rm tr}\{y_{\Phi e}^\dagger y_e\}\left(\bar{u}\, \tau^I \sigma_{\mu\nu} P_R\, u\right) q^\mu \varepsilon^{*\nu}$$

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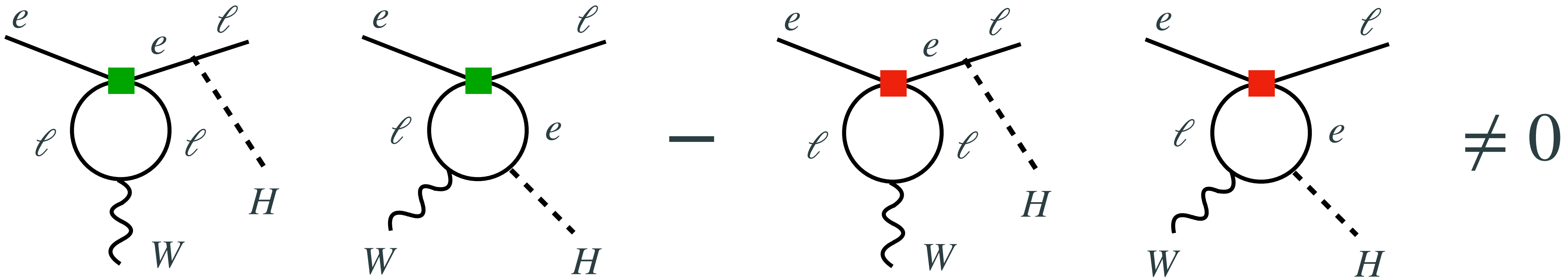

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In $d = 4-2\epsilon$, there is an evanescent operator that also contributes to the amplitude

$$R_{\ell e}^{prst} = -\frac{1}{2}\,Q_{\ell e}^{prst} + E_{\ell e}^{prst} \qquad\qquad E_{\ell e}^{prst} \xrightarrow{\epsilon\,\to\,0} 0$$

Evanescent operators

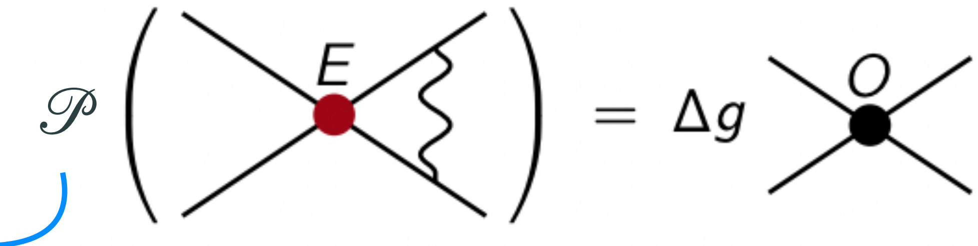
An evanescent operator E is an operator that satisfies

$$E = \text{rank}(\epsilon) \xrightarrow{d \to 4} 0$$

Evanescent contributions have long been accounted for in Weak Effective Theory calculations, but not so much in a BSM-to-SMEFT context

[Buras, Weisz ‘90; Dugan, Grinstein, ’91; Herrlich, Nierste, hep-ph/9412375;…]

The physical contributions from evanescent operators are finite and local



Physical (or $d = 4$) projection

e.g., in the 2HDM example

$$E_{\ell e}^{prst} \to -\frac{g_L\, y_e^{ts}}{128\pi^2}\, Q_{eW}^{pr} + [\text{ many other contributions }]$$

Defining the physical projection

Choosing a set of identities defines the physical projector $\mathscr{P}$:

$$O_d = \underbrace{\mathscr{P}\, O_d}_{\text{Physical part}} + \underbrace{\overset{Id - \mathscr{P}}{\mathscr{E}}\, O_d}_{\text{Evanescent part}}$$

- Fierz identities for 4-fermion operators, e.g.,

$$(P_R) \otimes [P_L] = -\frac{1}{2}\,(\gamma_\mu P_L] \otimes [\gamma^\mu P_R) \; + \; E_{\text{Fierz}}^{(P_R,\,P_L)}$$

- Reduction of Dirac structures in 4-fermion operators, e.g.,

$$(\gamma^\mu \gamma^\nu \gamma^\rho P_L) \otimes [\gamma_\mu \gamma_\nu \gamma_\rho P_L] = 4\,(1 - \overset{\text{Compatibility with NDR}}{2\epsilon})\,(\gamma_\mu P_L) \otimes [\gamma^\mu P_L] \; + \; E_{LL}^{(3\gamma)}$$

- Other identities (e.g involving γ_5 and/or the Levi-Civita tensor)

$$\epsilon_{\mu\nu\rho\sigma}\,\sigma^{\rho\sigma} = 2i\,\sigma_{\mu\nu}\gamma_5 \; + \; E_{\mu\nu}^{(\epsilon\cdot\sigma)} \qquad\qquad \epsilon_{\mu\nu\rho\sigma}\,\epsilon^{\mu\nu\rho\sigma} = -\,24 \; + \; E^{(\epsilon\cdot\epsilon)}$$

Evanescence-free schemes

For an EFT Lagrangian $\mathscr{L} = \bar{g}_a O_a + \bar{\eta}_i E_i$, the 1-loop effective action is

$$\Gamma = \int_x \big(\underbrace{\bar{g}_a O^a + \bar{\eta}_i E^i}_{\text{bare couplings}}\big) + \overbrace{\bar{\Gamma}(g,\eta)}^{\text{1-loop diagrams, tree-level couplings}} .$$

Scheme	$\overline{\text{MS}}$
Action $\mathscr{P} : O^a$	$\bar{g}_a = g_a + \delta g_a$
$\mathscr{E} : E^i$	$\bar{\eta}_i = \eta_i + \delta\eta_i$
Eff. action $\mathscr{P}\Gamma$	$\int_x \bar{g}_a O^a + \mathscr{P}\bar{\Gamma}(g,\eta)$

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Scheme		$\overline{\text{MS}}$	Compensated
Action	$\mathscr{P}: O^a$	$\bar{g}_a = g_a + \delta g_a$	$(\bar{g}_a + \Delta g_a) - \boxed{\Delta g_a}$
	$\mathscr{E}\ :\ E^i$	$\bar{\eta}_i = \eta_i + \delta\eta_i$	$\delta\eta_i + \boxed{\eta_i}$
Eff. action $\mathscr{P}\Gamma$		$\int_x \bar{g}_a O^a + \mathscr{P}\bar{\Gamma}(g,\eta)$	$\int_x (\bar{g}_a + \Delta g_a) O^a$ $+ \mathscr{P}\bar{\Gamma}(g,\eta) - \int_x \Delta g_a O^a$

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The evanescent contribution is defined by

$$\int_x \Delta g_a O^a \equiv \mathscr{P}\left[\bar{\Gamma}(g, \eta) - \bar{\Gamma}(g, 0)\right]$$

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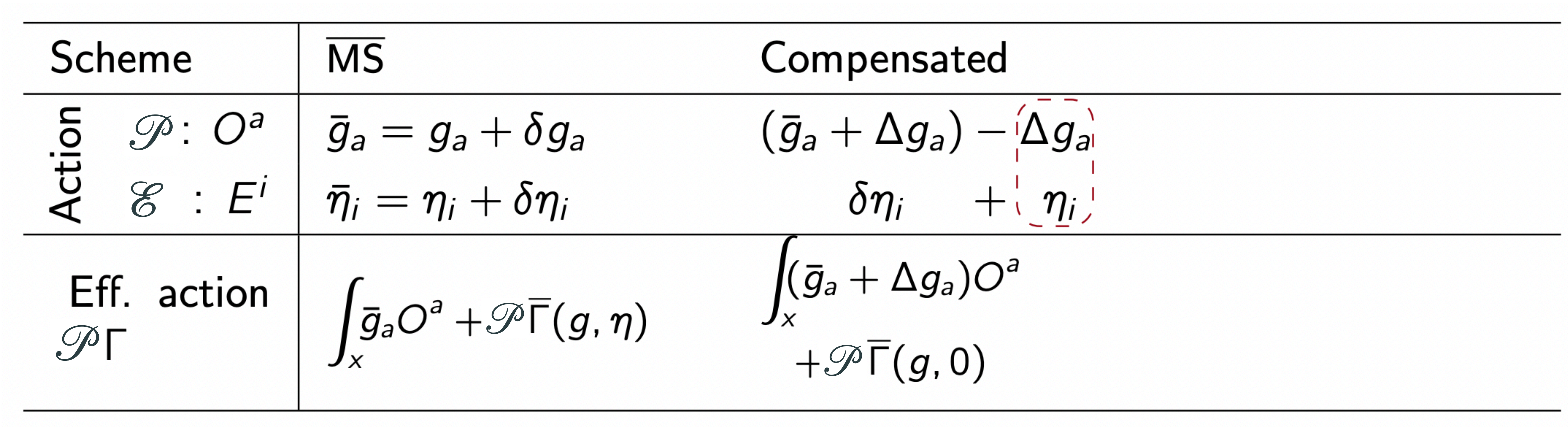

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Handling evanescent contributions means computing Δg

Evanescence-free schemes

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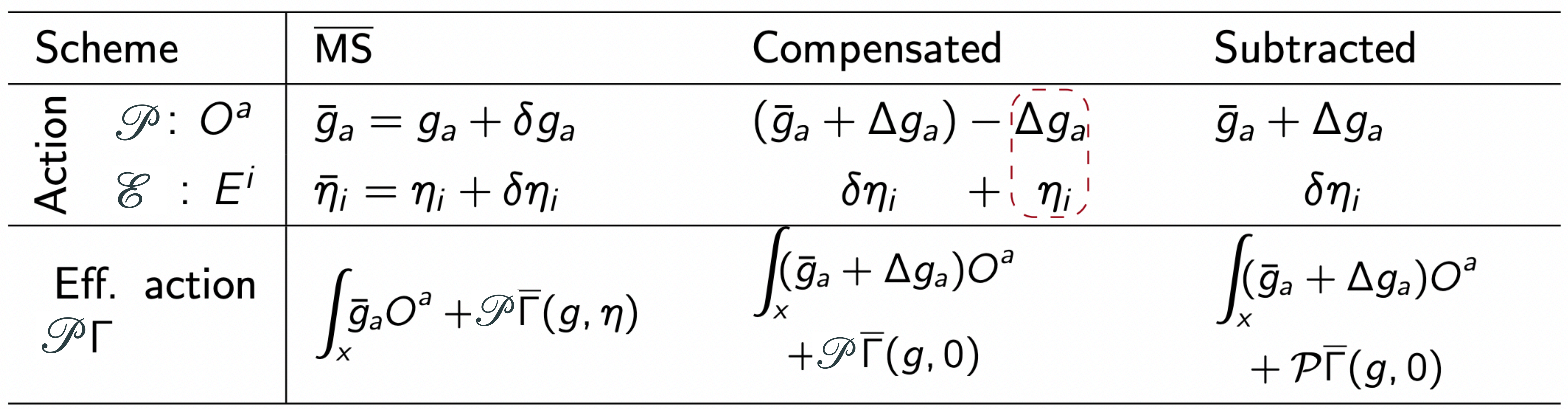
1-loop diagrams, tree-level couplings

bare couplings



Scheme	$\overline{\text{MS}}$	Compensated	Subtracted
Action $\mathscr{P}: O^a$	$\bar{g}_a = g_a + \delta g_a$	$(\bar{g}_a + \Delta g_a) - \Delta g_a$	$\bar{g}_a + \Delta g_a$
$\mathscr{E} : E^i$	$\bar{\eta}_i = \eta_i + \delta\eta_i$	$\delta\eta_i + \eta_i$	$\delta\eta_i$
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Handling evanescent contributions means computing Δg

Application to the SMEFT

d-dimensional SMEFT basis and reduction to Warsaw basis

Application to the SMEFT

EFT bases in $d = 4 - 2\epsilon$ spacetime dimensions typically have infinite elements!

$$(\bar{\ell}\gamma_{\mu_1}\ldots\gamma_{\mu_n}\ell)\,(\bar{\ell}\gamma^{\mu_1}\ldots\gamma^{\mu_n}\ell)$$

However, the *d-dimensional SMEFT (d-SMEFT)* is finite once we impose some UV restrictions:

- Generated by the exchange of tree-level NP mediators (one-loop evanescent contributions)
- Any NP mediator of spin 0, 1/2 and 1 (excl. antisymmetric rank-2 tensors)
- NP Lagrangian with arbitrary (physical) interactions up to dimension 5

It follows:

1) BSM scalars generate 23 (+ 2 BNV) new operators. E.g. $(\bar{\ell}^c_i\,\ell_j)\,(\bar{\ell}_j\,\ell^c_i)$

2) BSM fermions do not generate any new operators

3) BSM vectors generate 21 (+ 3 BNV) new operators. E.g. $(\bar{\ell}\gamma_\mu\tau^I\ell)\,(\bar{\ell}\gamma^\mu\tau^I\ell)$

New SMEFT operators: Scalar mediators

$(\bar{L}R)(\bar{R}L)$ & $(\bar{L}R)(\bar{L}R)$		$(\bar{R}^c R)(\bar{R}R^c)$	
$R_{\ell e}$	$(\bar{\ell}_p e_r)(\bar{e}_s \ell_t)$	$R_{e^c e}$	$(\bar{e}^c_p e_r)(\bar{e}_s e^c_t)$
$R_{\ell u}$	$(\bar{\ell}_p u_r)(\bar{u}_s \ell_t)$	$R_{u^c u}$	$(\bar{u}^c_{\alpha p} u_{\beta r})(\bar{u}_{\beta s} u^c_{\alpha t})$
$R_{\ell d}$	$(\bar{\ell}_p d_r)(\bar{d}_s \ell_t)$	$R_{d^c d}$	$(\bar{d}^c_{\alpha p} d_{\beta r})(\bar{d}_{\beta s} d^c_{\alpha t})$
R_{qe}	$(\bar{q}_p e_r)(\bar{e}_s q_t)$	$R_{e^c u}$	$(\bar{e}^c_p u_r)(\bar{u}_s e^c_t)$
$R^{(1)}_{qu}$	$(\bar{q}_p u_r)(\bar{u}_s q_t)$	$R_{e^c d}$	$(\bar{e}^c_p d_r)(\bar{d}_s e^c_t)$
$R^{(8)}_{qu}$	$(\bar{q}_p T^A u_r)(\bar{u}_s T^A q_t)$	$R_{u^c d}$	$(\bar{u}^c_{\alpha p} d_{\beta r})(\bar{d}_{\beta s} u^c_{\alpha t})$
$R^{(1)}_{qd}$	$(\bar{q}_p d_r)(\bar{d}_s q_t)$	$R'_{u^c d}$	$(\bar{u}^c_{\alpha p} d_{\beta r})(\bar{d}_{\alpha s} u^c_{\beta t})$
$R^{(8)}_{qd}$	$(\bar{q}_p T^A d_r)(\bar{d}_s T^A q_t)$		
$R_{\ell uqe}$	$(\bar{\ell}_{ip} u_r)\varepsilon^{ij}(\bar{q}_{js} e_t)$		
$(\bar{L}^c L)(\bar{L}L^c)$		$(\bar{R}^c R)(\bar{L}L^c)$	
$R_{\ell^c \ell}$	$(\bar{\ell}^c_{ip} \ell_{jr})(\bar{\ell}_{js} \ell^c_{it})$	$R_{u^c dqq^c}$	$(\bar{u}^c_{\alpha p} d_{\beta r})\varepsilon^{ij}(\bar{q}_{\beta is} q^c_{\alpha jt})$
$R_{q^c q}$	$(\bar{q}^c_{\alpha ip} q_{\beta jr})(\bar{q}_{\beta js} q^c_{\alpha it})$	$R_{u^c e\ell q^c}$	$(\bar{u}^c_p e_r)\varepsilon^{ij}(\bar{\ell}_{is} q^c_{jt})$
$R'_{q^c q}$	$(\bar{q}^c_{\alpha ip} q_{\beta jr})(\bar{q}_{\beta is} q^c_{\alpha jt})$	Baryon number violating	
$R_{q^c \ell}$	$(\bar{q}^c_{ip} \ell_{jr})(\bar{\ell}_{js} q^c_{it})$	$R_{q^c qq^c \ell}$	$\varepsilon_{\alpha\beta\gamma}\varepsilon_{ij}\varepsilon_{kl}(\bar{q}^c_{\alpha ip} q_{\beta jr})(\bar{q}^c_{\gamma ks} \ell_{lt})$
$R'_{q^c \ell}$	$(\bar{q}^c_{ip} \ell_{jr})(\bar{\ell}_{is} q^c_{jt})$	$R_{u^c ud^c e}$	$\varepsilon_{\alpha\beta\gamma}(\bar{u}^c_{\alpha p} u_{\beta r})(\bar{d}^c_{\gamma s} e_t)$

New SMEFT operators: Vector mediators

$(\bar{L}L)(\bar{L}L)$	
$R_{\ell\ell}^{(3)}$	$(\bar{\ell}_p\gamma_\mu\tau^I\ell_r)(\bar{\ell}_s\gamma^\mu\tau^I\ell_t)$
$R_{qq}^{(1,8)}$	$(\bar{q}_p\gamma_\mu T^A q_r)(\bar{q}_s\gamma^\mu T^A q_t)$
$R_{qq}^{(3,8)}$	$(\bar{q}_p\gamma_\mu\tau^I T^A q_r)(\bar{q}_s\gamma^\mu\tau^I T^A q_t)$
$R_{\ell q}^{(1)}$	$(\bar{\ell}_p\gamma_\mu q_r)(\bar{q}_s\gamma^\mu\ell_t)$
$R_{\ell q}^{(3)}$	$(\bar{\ell}_p\gamma_\mu\tau^I q_r)(\bar{q}_s\gamma^\mu\tau^I\ell_t)$
$(\bar{R}R)(\bar{R}R)$	
$R_{uu}^{(8)}$	$(\bar{u}_p\gamma_\mu T^A u_r)(\bar{u}_s\gamma^\mu T^A u_t)$
$R_{dd}^{(8)}$	$(\bar{d}_p\gamma_\mu T^A d_r)(\bar{d}_s\gamma^\mu T^A d_t)$
R_{eu}	$(\bar{e}_p\gamma_\mu u_r)(\bar{u}_s\gamma^\mu e_t)$
R_{ed}	$(\bar{e}_p\gamma_\mu d_r)(\bar{d}_s\gamma^\mu e_t)$
$R_{ud}^{(1)}$	$(\bar{u}_p\gamma_\mu d_r)(\bar{d}_s\gamma^\mu u_t)$
$R_{ud}^{(8)}$	$(\bar{u}_p\gamma_\mu T^A d_r)(\bar{d}_s\gamma^\mu T^A u_t)$
$(\bar{L}L)(\bar{R}R)$	
$R_{\ell qde}$	$(\bar{\ell}_p\gamma_\mu q_r)(\bar{d}_s\gamma^\mu e_t)$

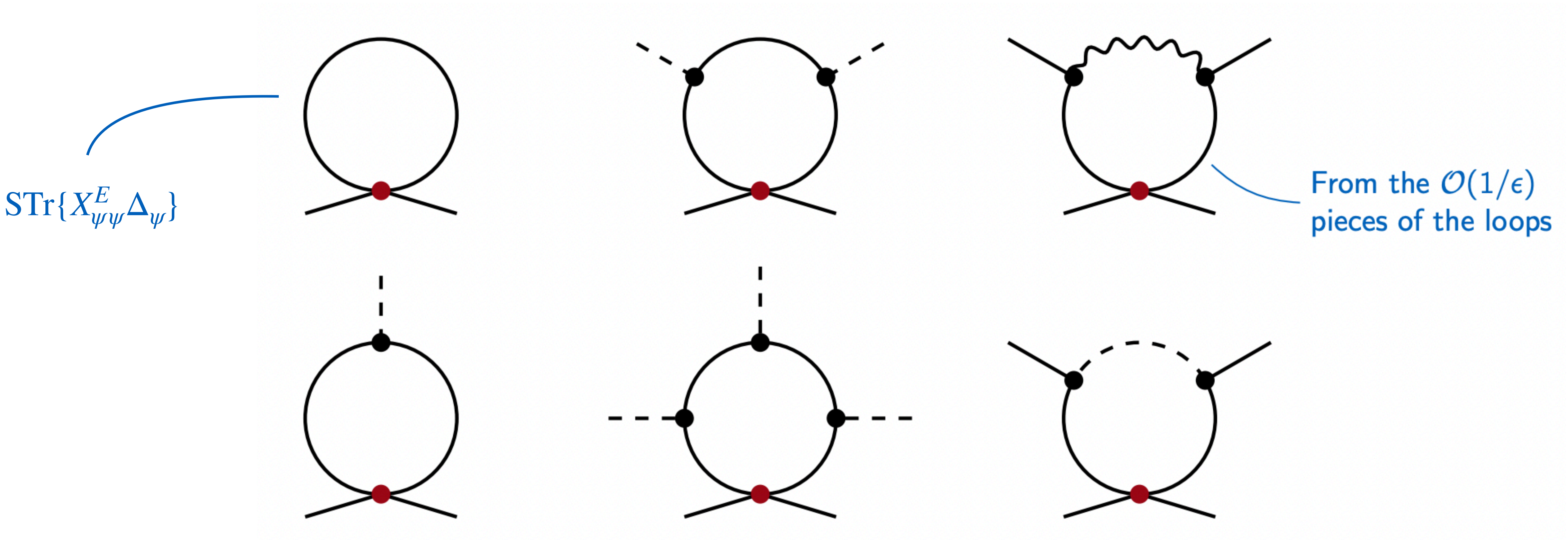
$(\bar{L}^cR)(\bar{R}L^c)$	
$R_{\ell^c e}$	$(\bar{\ell}^c_p\gamma_\mu e_r)(\bar{e}_s\gamma^\mu\ell^c_t)$
$R_{\ell^c u}$	$(\bar{\ell}^c_p\gamma_\mu u_r)(\bar{u}_s\gamma^\mu\ell^c_t)$
$R_{\ell^c d}$	$(\bar{\ell}^c_p\gamma_\mu d_r)(\bar{d}_s\gamma^\mu\ell^c_t)$
$R_{q^c ed\ell^c}$	$(\bar{q}^c_p\gamma^\mu e_r)(\bar{d}_s\gamma_\mu\ell^c_t)$
$R_{q^c e}$	$(\bar{q}^c_p\gamma_\mu e_r)(\bar{e}_s\gamma^\mu q^c_t)$
$R_{q^c u}$	$(\bar{q}^c_{\alpha p}\gamma_\mu u_{\beta r})(\bar{u}_{\beta s}\gamma^\mu q^c_{\alpha t})$
$R'_{q^c u}$	$(\bar{q}^c_{\alpha p}\gamma_\mu u_{\beta r})(\bar{u}_{\alpha s}\gamma^\mu q^c_{\beta t})$
$R_{q^c d}$	$(\bar{q}^c_{\alpha p}\gamma_\mu d_{\beta r})(\bar{d}_{\beta s}\gamma^\mu q^c_{\alpha t})$
$R'_{q^c d}$	$(\bar{q}^c_{\alpha p}\gamma_\mu d_{\beta r})(\bar{d}_{\alpha s}\gamma^\mu q^c_{\beta t})$
Baryon number violating	
$R_{d^c\ell q^c u}$	$\varepsilon_{\alpha\beta\gamma}\varepsilon_{ij}(\bar{d}^c_{\alpha p}\gamma_\mu\ell_{ir})(\bar{q}^c_{\beta js}\gamma^\mu u_{\gamma t})$
$R_{u^c\ell q^c d}$	$\varepsilon_{\alpha\beta\gamma}\varepsilon_{ij}(\bar{u}^c_{\alpha p}\gamma_\mu\ell_{ir})(\bar{q}^c_{\beta js}\gamma^\mu d_{\gamma t})$
$R_{q^c eu^c q}$	$\varepsilon_{\alpha\beta\gamma}\varepsilon_{ij}(\bar{q}^c_{\alpha ip}\gamma_\mu e_r)(\bar{u}^c_{\beta s}\gamma^\mu q_{\gamma jt})$

Reduction of the d-SMEFT to the physical basis

Once the d-dimensional basis has been established, we can reduce to the Warsaw basis by applying physical projections and subsequently computing the evanescent shifts

This is done using functional methods with a modified version of MATCHETE

Evanescent operators contribute through six covariant trace structures/topologies $^{(*)}$



$\mathrm{STr}\{X^E_{\psi\psi}\Delta_\psi\}$

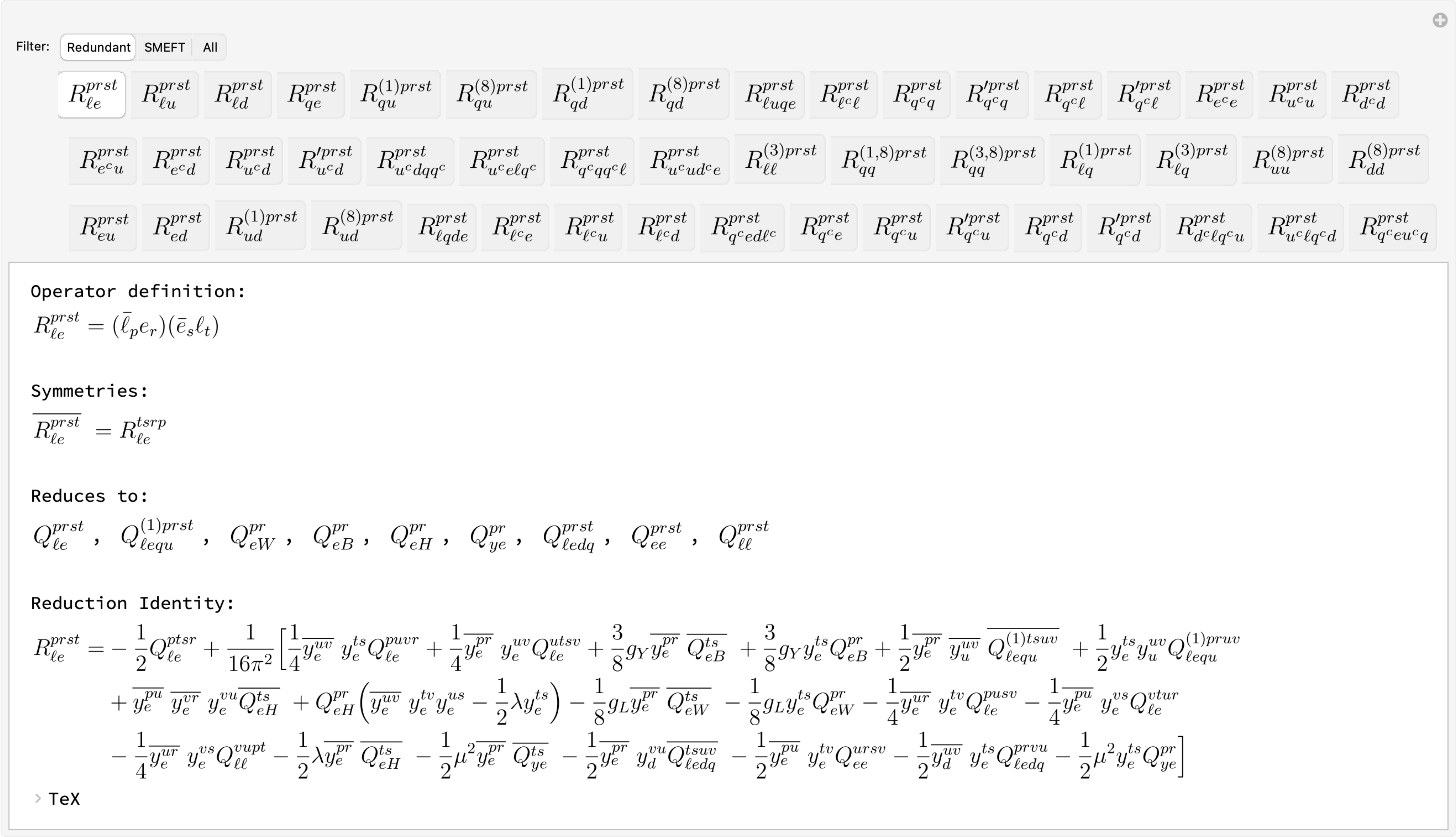
From the $\mathcal{O}(1/\epsilon)$ pieces of the loops

$^{(*)}$ N.B.: Analogous to Feynman diagrams, but including (arbitrary) gauge boson radiation

Mathematica interface

`OperatorView[]`

[JFM, König, Pagès, Thomsen, Wilsch, 2211.0914]



Operator definition:

$$R_{\ell e}^{prst} = (\bar{\ell}_p e_r)(\bar{e}_s \ell_t)$$

Symmetries:

$$\overline{R_{\ell e}^{prst}} = R_{\ell e}^{tsrp}$$

Reduction to:

$$Q_{\ell e}^{prst}\,,\quad Q_{\ell equ}^{(1)prst}\,,\quad Q_{eW}^{pr}\,,\quad Q_{eB}^{pr}\,,\quad Q_{eH}^{pr}\,,\quad Q_{ye}^{pr}\,,\quad Q_{\ell edq}^{prst}\,,\quad Q_{ee}^{prst}\,,\quad Q_{\ell\ell}^{prst}$$

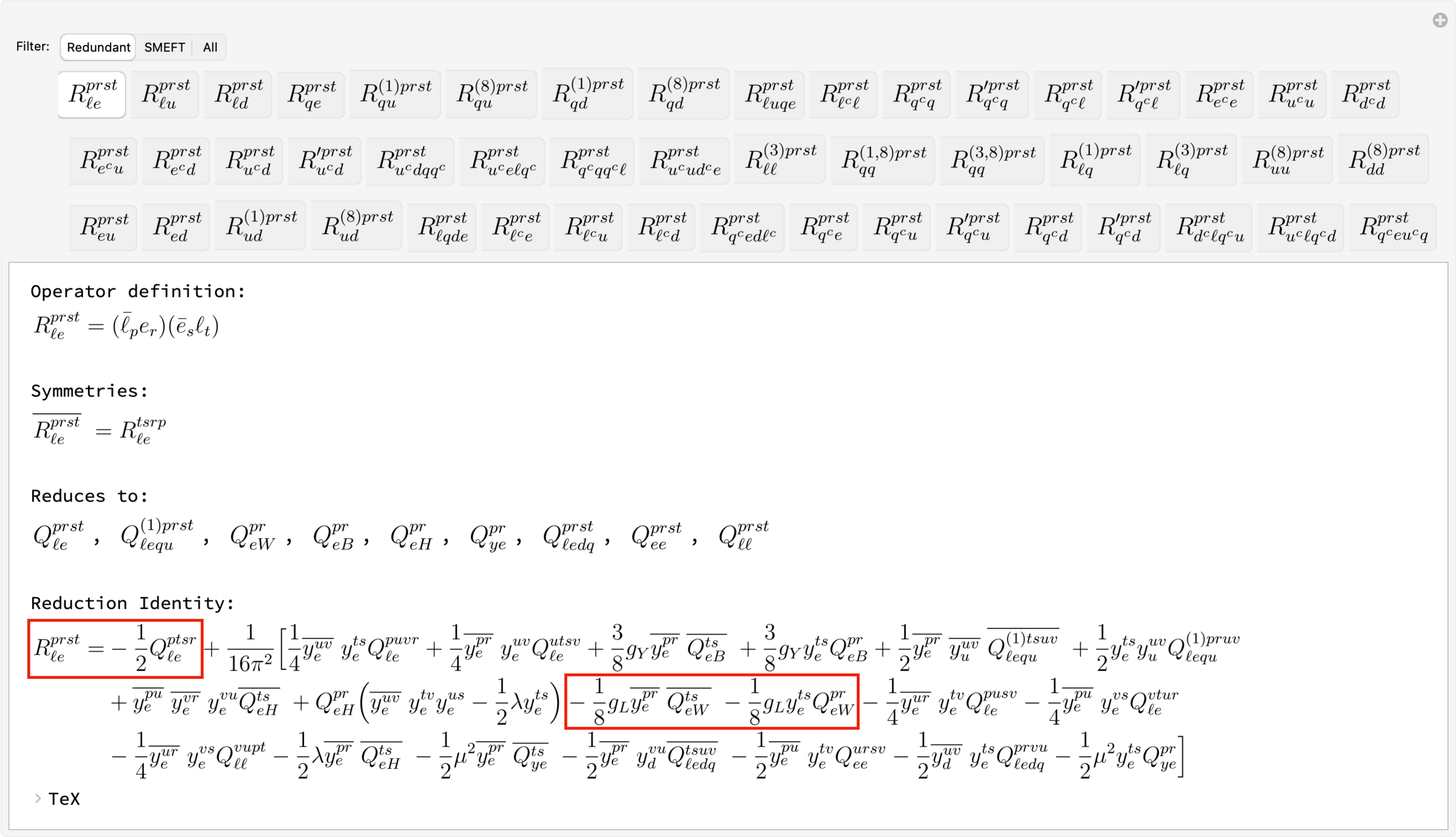
Reduction Identity:

$$\begin{aligned} R_{\ell e}^{prst} = &-\frac{1}{2}Q_{\ell e}^{ptsr} + \frac{1}{16\pi^2}\Big[\frac{1}{4}\overline{y_e^{uv}}\; y_e^{ts}Q_{\ell e}^{puvr} + \frac{1}{4}\overline{y_e^{pr}}\; y_e^{uv}Q_{\ell e}^{utsv} + \frac{3}{8}g_Y\overline{y_e^{pr}}\;\overline{Q_{eB}^{ts}} + \frac{3}{8}g_Y y_e^{ts}Q_{eB}^{pr} + \frac{1}{2}\overline{y_e^{pr}}\;\overline{y_u^{uv}}\;\overline{Q_{\ell equ}^{(1)tsuv}} + \frac{1}{2}y_e^{ts}y_u^{uv}Q_{\ell equ}^{(1)pruv} \\ &+ \overline{y_e^{pu}}\;\overline{y_e^{vr}}\; y_e^{vu}\overline{Q_{eH}^{ts}} + Q_{eH}^{pr}\left(\overline{y_e^{uv}}\; y_e^{tv}y_e^{us} - \frac{1}{2}\lambda y_e^{ts}\right) - \frac{1}{8}g_L\overline{y_e^{pr}}\;\overline{Q_{eW}^{ts}} - \frac{1}{8}g_L y_e^{ts}Q_{eW}^{pr} - \frac{1}{4}\overline{y_e^{ur}}\; y_e^{tv}Q_{\ell e}^{pusv} - \frac{1}{4}\overline{y_e^{pu}}\; y_e^{vs}Q_{\ell e}^{vtur} \\ &- \frac{1}{4}\overline{y_e^{ur}}\; y_e^{vs}Q_{\ell\ell}^{vupt} - \frac{1}{2}\lambda\overline{y_e^{pr}}\;\overline{Q_{eH}^{ts}} - \frac{1}{2}\mu^2\overline{y_e^{pr}}\;\overline{Q_{ye}^{ts}} - \frac{1}{2}\overline{y_e^{pr}}\; y_d^{vu}\overline{Q_{\ell edq}^{tsuv}} - \frac{1}{2}\overline{y_e^{pu}}\; y_e^{tv}Q_{ee}^{ursv} - \frac{1}{2}\overline{y_d^{uv}}\; y_e^{ts}Q_{\ell edq}^{prvu} - \frac{1}{2}\mu^2 y_e^{ts}Q_{ye}^{pr}\Big] \end{aligned}$$

Mathematica interface

`OperatorView[]`

[JFM, König, Pagès, Thomsen, Wilsch, 2211.0914]



Operator definition:

$$R_{\ell e}^{prst} = (\bar{\ell}_p e_r)(\bar{e}_s \ell_t)$$

Symmetries:

$$\overline{R_{\ell e}^{prst}} = R_{\ell e}^{tsrp}$$

Reduces to:

$Q_{\ell e}^{prst}$, $Q_{\ell equ}^{(1)prst}$, Q_{eW}^{pr} , Q_{eB}^{pr} , Q_{eH}^{pr} , Q_{ye}^{pr} , $Q_{\ell edq}^{prst}$, Q_{ee}^{prst} , $Q_{\ell\ell}^{prst}$

Reduction Identity:

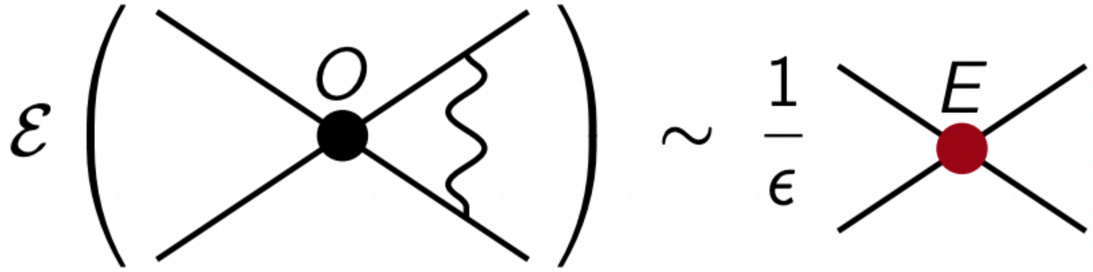
$$\begin{aligned}&\boxed{R_{\ell e}^{prst} = -\frac{1}{2}Q_{\ell e}^{ptsr}} + \frac{1}{16\pi^2}\Big[\frac{1}{4}\overline{y_e^{uv}}\; y_e^{ts}Q_{\ell e}^{puvr} + \frac{1}{4}\overline{y_e^{pr}}\; y_e^{uv}Q_{\ell e}^{utsv} + \frac{3}{8}g_Y\overline{y_e^{pr}}\;\overline{Q_{eB}^{ts}} + \frac{3}{8}g_Y y_e^{ts}Q_{eB}^{pr} + \frac{1}{2}\overline{y_e^{pr}}\;\overline{y_u^{uv}}\;\overline{Q_{\ell equ}^{(1)tsuv}} + \frac{1}{2}y_e^{ts}y_u^{uv}Q_{\ell equ}^{(1)pruv}\\&\quad + \overline{y_e^{pu}}\;\overline{y_e^{vr}}\; y_e^{vu}\overline{Q_{eH}^{ts}} + Q_{eH}^{pr}\left(\overline{y_e^{uv}}\; y_e^{tv}y_e^{us} - \frac{1}{2}\lambda y_e^{ts}\right)\boxed{-\frac{1}{8}g_L\overline{y_e^{pr}}\;\overline{Q_{eW}^{ts}} - \frac{1}{8}g_L y_e^{ts}Q_{eW}^{pr}} - \frac{1}{4}\overline{y_e^{ur}}\; y_e^{tv}Q_{\ell e}^{pusv} - \frac{1}{4}\overline{y_e^{pu}}\; y_e^{vs}Q_{\ell e}^{vtur}\\&\quad - \frac{1}{4}\overline{y_e^{ur}}\; y_e^{vs}Q_{\ell\ell}^{vupt} - \frac{1}{2}\lambda\overline{y_e^{pr}}\;\overline{Q_{eH}^{ts}} - \frac{1}{2}\mu^2\overline{y_e^{pr}}\;\overline{Q_{ye}^{ts}} - \frac{1}{2}\overline{y_e^{pr}}\; y_d^{vu}\overline{Q_{\ell edq}^{tsuv}} - \frac{1}{2}\overline{y_e^{pu}}\; y_e^{tv}Q_{ee}^{ursv} - \frac{1}{2}\overline{y_d^{uv}}\; y_e^{ts}Q_{\ell edq}^{prvu} - \frac{1}{2}\mu^2 y_e^{ts}Q_{ye}^{pr}\Big]\end{aligned}$$

› TeX

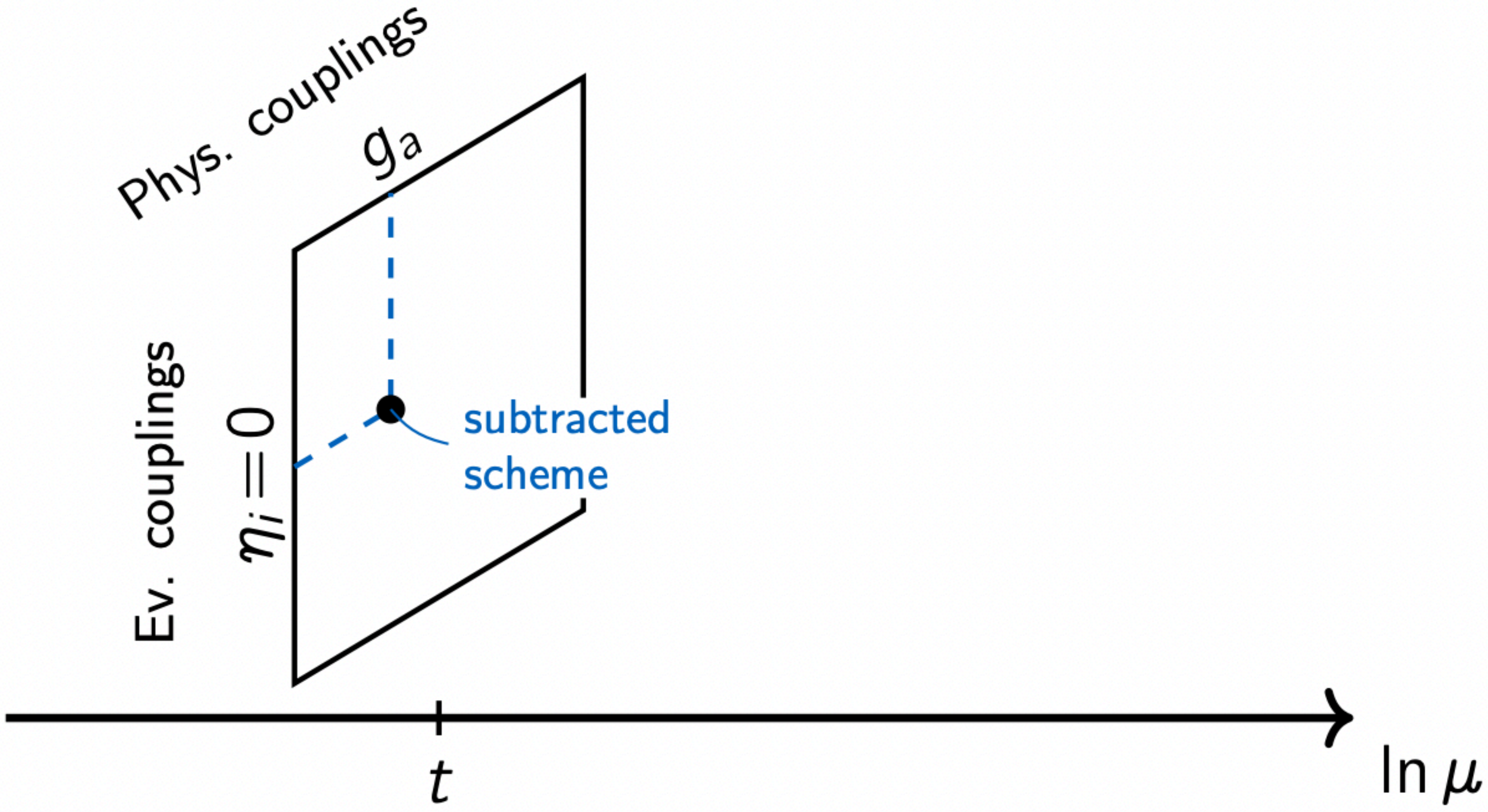
RG evolution

in evanescence-free schemes

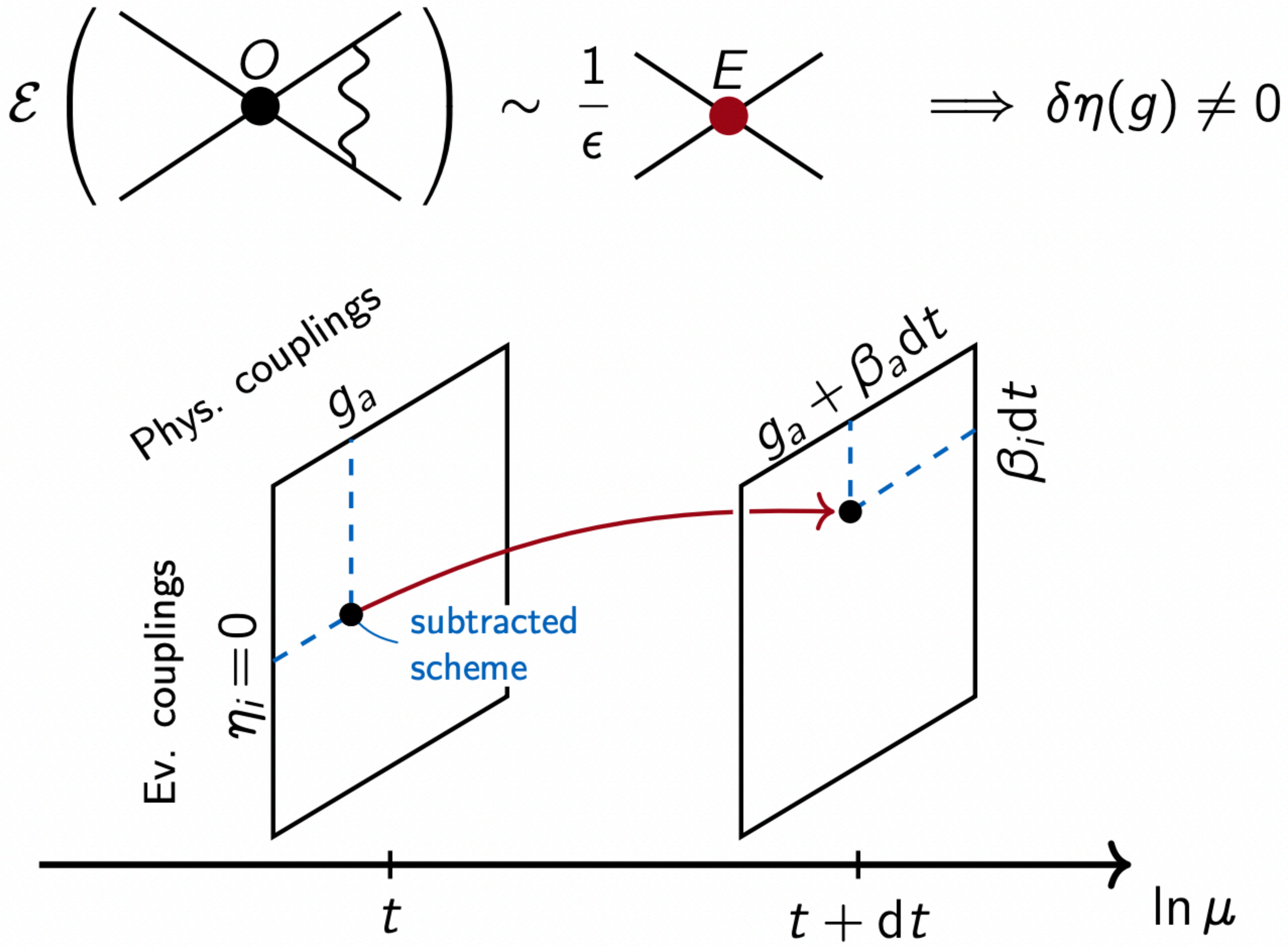
RG evolution in evanescent schemes



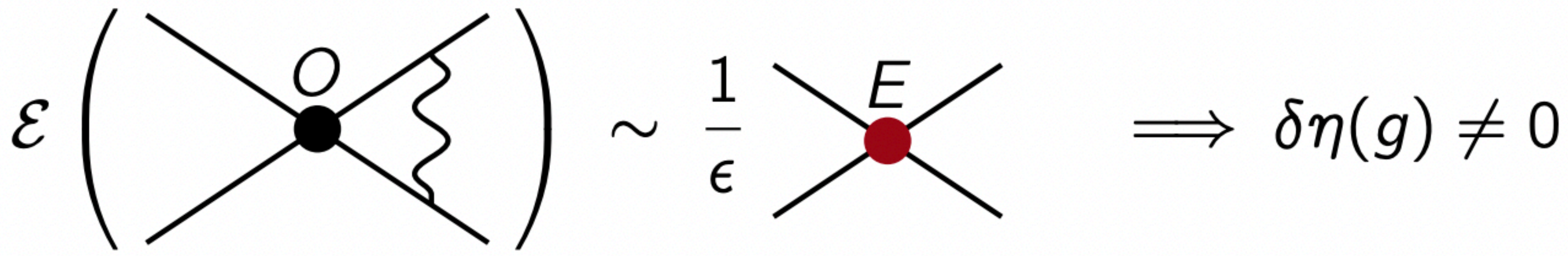
$\Longrightarrow \delta\eta(g) \neq 0$

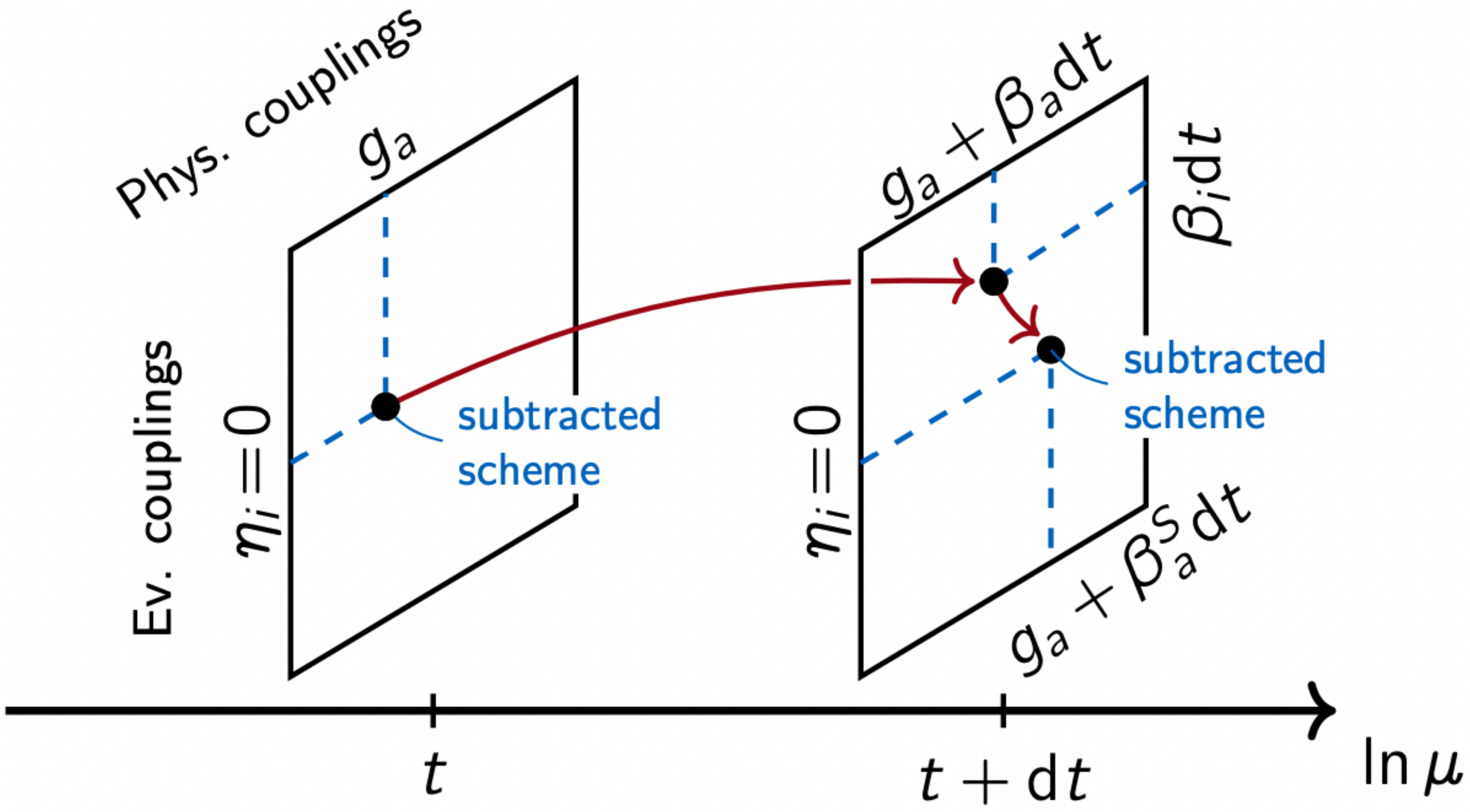


RG evolution in evanescent schemes

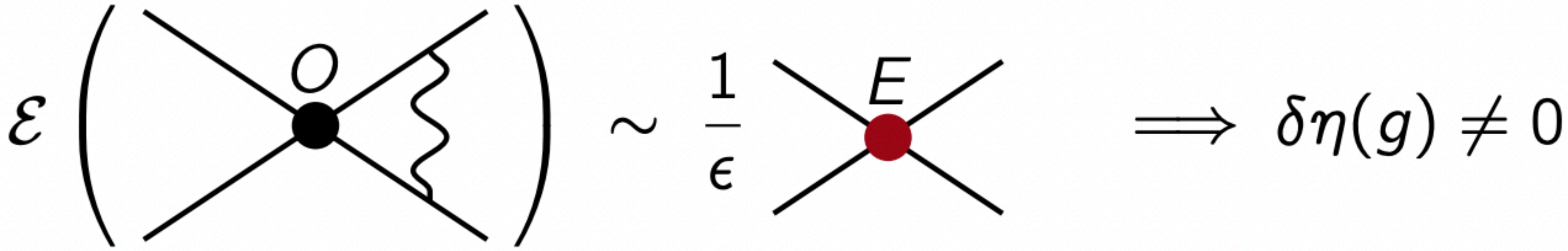


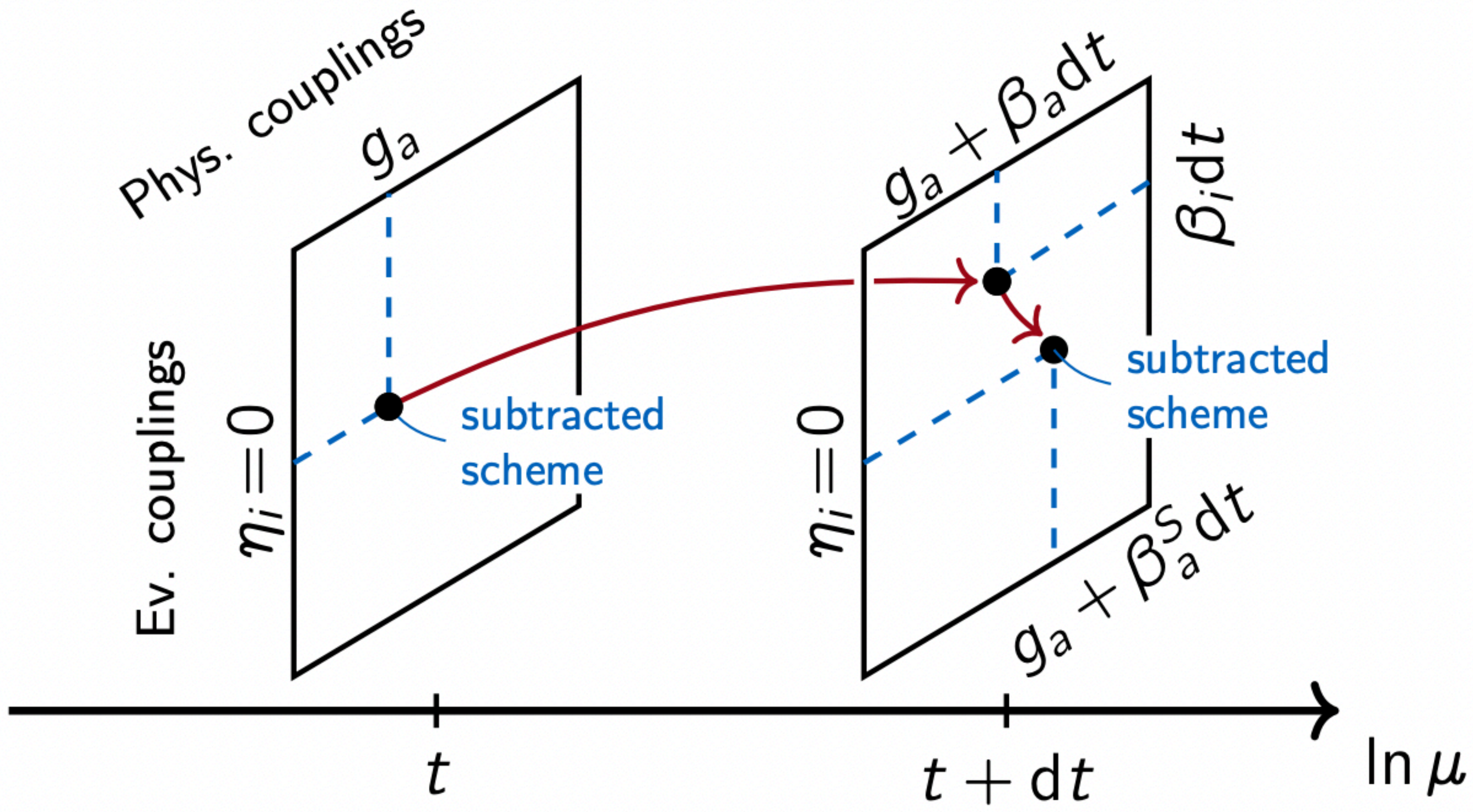
RG evolution in evanescent schemes





RG evolution in evanescent schemes





In the subtracted evanescent scheme

$$\frac{\mathrm{d}g_a}{\mathrm{d}t} = \beta_a^S = \beta_a + \beta_i \overbrace{\frac{\partial \Delta g_a}{\partial \eta_i}}^{\text{2-loop}}\Bigg|_{\eta=0}$$

Outlook

- One-loop UV-to-EFT matching is crucial for BSM phenomenology

- Recent progress in the automation of the process (using different approaches)

https://gitlab.com/matchete/matchete

… but there is still a long road ahead before this endeavor is complete

- Evanescent contributions in the BSM-to-SMEFT are now available (obtained with the help of Matchete)

- We plan to develop an automated implementation (as part of Matchete) for the reduction to (arbitrary) EFT basis including evanescent contributions

Thank you