S. Di Noi

Higgs-gluon coupling in the SMEFT (and EFT $h + hh$ plans)

Based on arXiv:2310.18221

with R. Gröber, G. Heinrich, J. Lang, M. Vitti

Higgs+EFT Joint session

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Istituto Nazionale di Fisica Nucleare

Introduction

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- The **Standard Model** (**SM**) is one of the biggest scientific successes of our time, but leaves some phenomena unexplained (massive neutrinos, dark matter...)
- Many **New Physics** (**NP**) theories have been proposed, but it is not clear which is the correct direction.
- **Effective Field Theories** (**EFTs**) offer a powerful and pragmatic approach to the search for NP with minimal UV assumptions.

EFT $h + hh$ plans (Courtesy of R. Gröber)

- Common initiative: WG2 + WG4.
- Whoever wants to join is welcome! **Please contact the conveners if interested!**

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5. Understand which operators are relevant and how to treat them in a fit.

The SMEFT

- Parametrise heavy NP effects with a tower of gauge/Lorentz invariant operators:

$$\mathcal{L}_{\text{SMEFT}} = \mathcal{L}_{\text{SM}} + \sum_{\mathfrak{D}_i > 4} \frac{\mathcal{C}_i}{\Lambda^{\mathfrak{D}_i - 4}} \mathcal{O}_i,$$

$$O_i \sim \partial^{n_d^i} \phi^{n_\phi^i} A^{n_A^i} \psi^{n_\psi^i}, \qquad \mathfrak{D}_i = n_d^i + n_\phi^i + n_A^i + \frac{3}{2} n_\psi^i.$$

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- ϕ, A, ψ: SM fields.
- Gauge group: $\mathrm{SU}(3)_{\mathrm{C}} \otimes \mathrm{SU}(2)_{\mathrm{W}} \otimes \mathrm{U}(1)_{\mathrm{Y}}$.

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- The dominant effects in collider physics arise at $\mathfrak{D} = 6$ (**Warsaw basis**, ([Grzadkowski,Iskrzynski,Misiak,Rosiek,'10])).

SMEFT: how should we use it?

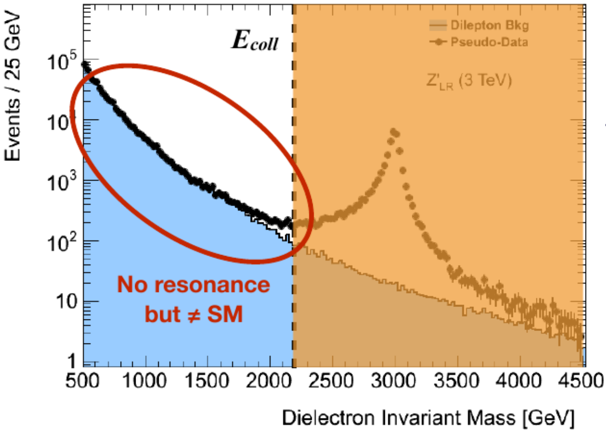

Figure: Courtesy of P. Azzi.

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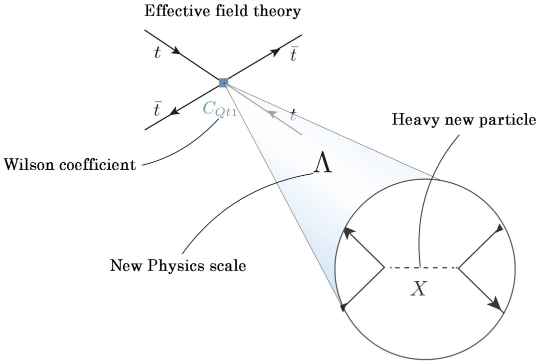

Figure: courtesy of L. Alasfar

- Information on UV mediator from IR dynamics: see [Altmannshofer, Gori, Lehmann, Zuo,'23]

Status of the Higgs-gluon coupling in the SMEFT

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Several groups have studied the Higgs-gluon coupling with different subsets of the SMEFT operators:

- $\mathcal{O}_{tG}$ [Choudhury,Saha,'12].
- $\mathcal{O}_{tG}, \mathcal{O}_{t\phi}, \mathcal{O}_{\phi\Box/\phi D}$ [Degrande et al.,'12].
- $\mathcal{O}_{t\phi/b\phi}, \mathcal{O}_{\phi G}, \mathcal{O}_{tG}$ [Grazzini,Ilnicka,Spira,Wiesemann,'16], [Grazzini,Ilnicka,Spira,'18], [Battaglia,Grazzini,Spira,Wiesemann,'21].
- geoSMEFT approach: [Corbett,Martin,Trott,'21],[Martin,Trott,'23].
- $\mathcal{O}_{4\mathrm{t}}$@2 loop in $pp \to h$ [Alasfar,de Blas,Gröber,'22] .

Four-top operators in Higgs-gluon coupling.

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- We focus on four-top operators:

$$\mathcal{L}_{4t} = \frac{\mathcal{C}_{QQ}^{(1)}}{\Lambda^2}\left(\bar{Q}_L\gamma_\mu Q_L\right)\left(\bar{Q}_L\gamma^\mu Q_L\right) + \frac{\mathcal{C}_{QQ}^{(3)}}{\Lambda^2}\left(\bar{Q}_L\tau^I\gamma_\mu Q_L\right)\left(\bar{Q}_L\tau^I\gamma^\mu Q_L\right)$$
$$+ \frac{\mathcal{C}_{Qt}^{(1)}}{\Lambda^2}\left(\bar{Q}_L\gamma_\mu Q_L\right)\left(\bar{t}_R\gamma^\mu t_R\right) + \frac{\mathcal{C}_{Qt}^{(8)}}{\Lambda^2}\left(\bar{Q}_L T^A\gamma_\mu Q_L\right)\left(\bar{t}_R T^A\gamma^\mu t_R\right)$$
$$+ \frac{\mathcal{C}_{tt}}{\Lambda^2}\left(\bar{t}_R\gamma_\mu t_R\right)\left(\bar{t}_R\gamma^\mu t_R\right) .$$

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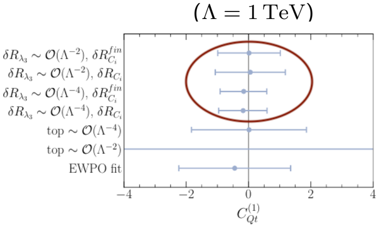
- Direct probes are difficult due to the small cross section.

- Alternative methods are possible.

State of the art

- Indirect bounds from single Higgs production are competitive with
  - Top quark data ([Ethier et. al.,'21]),
  - EWPO ([Dawson,Giardino,'22], [de Blas, Chala, Santiago,'15]).



$\langle C_{Qt}^{(1)} \rangle$	95% CI
0.0	[-1.0, 1.0]
0.1	[-1.1, 1.2]
-0.2	[-0.9, 0.6]
-0.2	[-1.0, 0.6]
0.0	[-1.8, 1.9]
-18.0	[-195.0, 159.0]
-0.4	[-2.2, 1.4]

[Alasfar,de Blas,Gröber,'22]

- Possible bounds also from flavour observables ([Silvestrini,Valli,'18]).
- Four-top operators affect the extraction of λ_3.

Are the log-enhanced terms enough?

- For every observable we can define $(R = \Gamma, \sigma)$:

$$\delta R = \frac{R}{R_{\mathrm{SM}}} - 1, \quad \delta R(\mathcal{C}_i) = \frac{\mathcal{C}_i}{\Lambda^2}\left(\delta R^{\mathrm{fin}}(\mathcal{C}_i) + \delta R^{\log}(\mathcal{C}_i)\log\frac{\mu_R^2}{\Lambda^2}\right)$$

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Operator	Process	μ_R	$\delta R^{fin}_{C_i}$ [TeV^2]	$\delta R^{log}_{C_i}$ [TeV^2]
$\mathcal{O}^{(1)}_{Qt}$	ggF	$\frac{m_h}{2}$	$9.91 \cdot 10^{-3}$	$2.76 \cdot 10^{-3}$
	$h \to gg$	m_h	$6.08 \cdot 10^{-3}$	$2.76 \cdot 10^{-3}$
	$h \to \gamma\gamma$		$-1.76 \cdot 10^{-3}$	$-0.80 \cdot 10^{-3}$
	$t\bar{t}h$ 13 TeV	$m_t + \frac{m_h}{2}$	$-4.20 \cdot 10^{-1}$	$-2.78 \cdot 10^{-3}$
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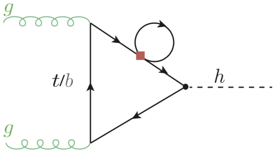
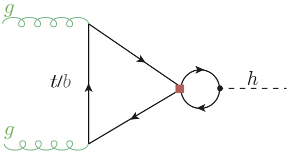
[Alasfar,de Blas,Gröber,'22]





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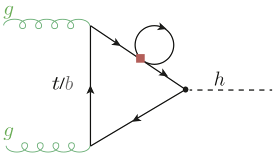

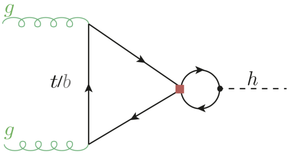

- **Finite terms are comparable with the log-enhanced ones if $\Lambda = \mathcal{O}(\text{TeV})$!**

Dimensional regularisation and chiral couplings

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- γ_5 is a purely 4-dimensional object: **a continuation scheme must be chosen**.
- For the details, see [Di Noi et al.,'23].

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Continuation to D dimensions schemes for γ_5

- **Naive Dimensional Regularisation (NDR)**: assumes that the 4-dimensional relations hold also in D dimensions:

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Algebraically consistent.

May break Ward identities (e.g., [Larin,'93]).

Computationally demanding.

Higgs-gluon coupling with four-top operators

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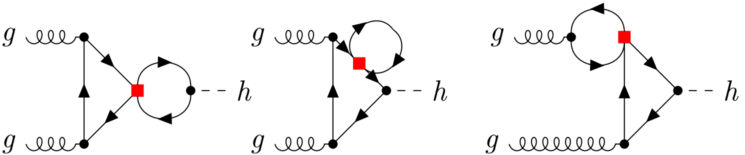

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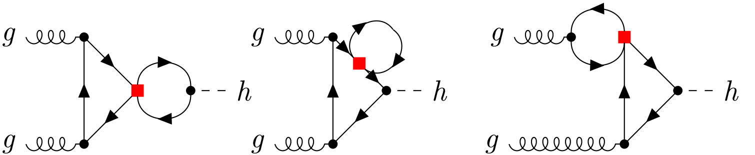

- Poles in $ht\bar{t}$, m_t corrections are **scheme-independent**.

Poles and Anomalous Dimension I

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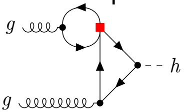

$$\Big|_{\mathrm{DIV}} = K_{tG} \times \left(\mathcal{C}_{Qt}^{(1)} - \tfrac{1}{6}\mathcal{C}_{Qt}^{(8)} \right) \frac{1}{\Lambda^2} g_s m_t \frac{1}{\epsilon} \frac{\sqrt{2}}{4\pi^2} \left(\frac{m_h^2}{2}\, g^{\mu_1\mu_2} - p_1^{\mu_2} p_2^{\mu_1} \right),$$

$$K_{tG} = \begin{cases} \frac{\sqrt{2} m_t g_s}{16\pi^2 v} & \text{(NDR)} \\ 0 & \text{(BMHV)}. \end{cases}$$

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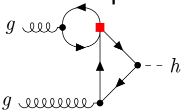

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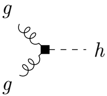
- **The anomalous dimension (AD) of $\mathcal{O}_{\phi G}$ depends on the scheme! $\rightarrow$ log terms scheme-dependent!**



$$= -4iv \frac{\mathcal{C}_{\phi G}}{\Lambda^2} \left(\frac{m_h^2}{2}\, g^{\mu_1\mu_2} - p_1^{\mu_2} p_2^{\mu_1}\right), \qquad \mathcal{O}_{\phi G} = \phi^\dagger \phi G_{\mu\nu} G^{\mu\nu},$$

$$16\pi^2 \mu \frac{d\mathcal{C}_{\phi G}}{d\mu} = -4\sqrt{2} g_{h\bar{t}t} g_s \Bigg(\underbrace{\mathcal{C}_{tG}}_{\text{1L}} + \underbrace{K_{tG} \left(\mathcal{C}^{(1)}_{Qt} - \frac{1}{6}\mathcal{C}^{(8)}_{Qt}\right)}_{\text{2L, new}} \Bigg).$$

Poles and Anomalous Dimension II

- The scheme-dependence of the LO AD involving $(\bar{L}L)(\bar{R}R)$ is known (e.g., $b \to sg, s\gamma$, [M. Ciuchini et al.,'93]).

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- **Idea**: the coefficient of the chromomagnetic operator $\mathcal{O}_{tG} = \bar{Q}_L \sigma^{\mu\nu} T^A t_R \tilde{\phi} G^A_{\mu\nu}$ (which enters at one-loop) depends on the scheme :

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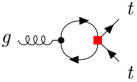
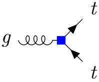
- $\mathcal{C}_{tG}, K_{tG}$ **depend on the scheme,** $\tilde{\mathcal{C}}_{tG}$ **does not.**
- K_{tG} **can be computed via a one-loop diagram:**



$= \frac{\mathcal{C}^{(1)}_{Qt} - \frac{1}{6}\mathcal{C}^{(8)}_{Qt}}{\mathcal{C}_{tG}} K_{tG} \times$



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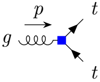

$= -\frac{\mathcal{C}_{tG}}{\Lambda^2}\sqrt{2} v T^A \sigma^{\mu\nu} p_\nu.$

Poles and Anomalous Dimension II

- The scheme-dependence of the LO AD involving $(\bar{L}L)(\bar{R}R)$ is known (e.g., $b \to sg, s\gamma$, [M. Ciuchini et al.,'93]).
- **Idea**: the coefficient of the chromomagnetic operator $\mathcal{O}_{tG} = \bar{Q}_L \sigma^{\mu\nu} T^A t_R \tilde{\phi} G^A_{\mu\nu}$ (which enters at one-loop) depends on the scheme :

$$16\pi^2 \mu \frac{d\mathcal{C}_{\phi G}}{d\mu} = -4\sqrt{2} g_{h\bar{t}t} g_s \underbrace{\left(\mathcal{C}_{tG} + K_{tG} \left(\mathcal{C}^{(1)}_{Qt} - \frac{1}{6} \mathcal{C}^{(8)}_{Qt} \right) \right)}_{\tilde{\mathcal{C}}_{tG}} .$$

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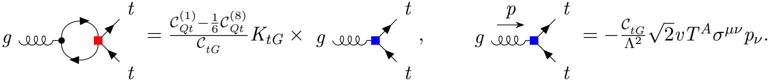

- $\mathcal{O}_{tG}, \mathcal{O}_{4t}$ **enter at the same order** [G. Buchalla et al.,'22].

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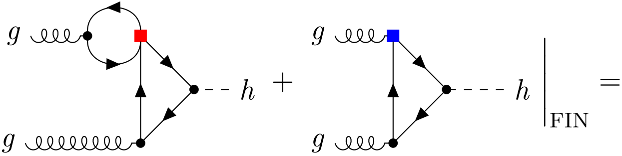

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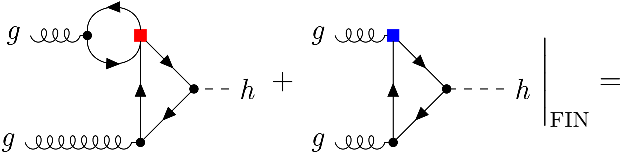

$$= \left[\mathcal{C}_{tG} + \left(\mathcal{C}^{(1)}_{Qt} - \frac{1}{6}\mathcal{C}^{(8)}_{Qt} \right) K_{tG} \right] \frac{1}{\Lambda^2} \mathcal{M}_{tG}|_{\mathrm{FIN}} \equiv \frac{\tilde{\mathcal{C}}_{tG}}{\Lambda^2} \mathcal{M}_{tG}|_{\mathrm{FIN}}$$

- … **Yes.**

SMEFT in NDR vs BMHV

- With this set of redefinitions, the two schemes give the same result (both for the finite parts and the AD).

$$\mathcal{C}_{tG}^{\rm NDR} = \mathcal{C}_{tG}^{\rm BMHV} - \left(\mathcal{C}_{Qt}^{(1)} - \frac{1}{6}\mathcal{C}_{Qt}^{(8)}\right)\frac{\sqrt{2}g_{h\bar{t}t}g_s}{16\pi^2},$$

$$g_{h\bar{t}t}^{\rm NDR} = g_{h\bar{t}t}^{\rm BMHV} - g_{h\bar{t}t}\left(\mathcal{C}_{Qt}^{(1)} + \frac{4}{3}\mathcal{C}_{Qt}^{(8)}\right)\frac{(m_h^2 - 6m_t^2)}{16\pi^2\Lambda^2},$$

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- Computed via one-loop diagrams.
- Validated by a matching with a UV model (top-down approach).

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- Not only four-top: other operators show this interplay (e.g., $\mathcal{O}_{\phi Q}^{(1)} = \bar{Q}_L \gamma_\mu Q_L \left(\phi^\dagger i \overleftrightarrow{D}^\mu \phi\right)$).

Thank you for your attention!

Backup

EFT notation

$$
\begin{aligned}
\mathcal{L}_{\mathcal{D}=6} &= \mathcal{L}_{\rm SM} + \mathcal{L}_{\rm 4t} + \mathcal{L}_{\rm 2t} + \mathcal{L}_{\rm s}, \\
\mathcal{L}_{\rm SM} &= -\frac{1}{4} G^A_{\mu\nu} G^{A\mu\nu} - \frac{1}{4} W^I_{\mu\nu} W^{I\mu\nu} - \frac{1}{4} B_{\mu\nu} B^{\mu\nu} + \sum_\psi \bar{\psi} i \not{D} \psi \\
&\quad + (D_\mu \phi)^\dagger (D^\mu \phi) - \lambda \left(\phi^\dagger \phi - \frac{1}{2} v^2 \right)^2 - Y_u \tilde{\phi}^\dagger \bar{u}_R Q_L + \text{H.c.}, \\
\mathcal{L}_{\rm 2t} &= \left[\frac{\mathcal{C}_{t\phi}}{\Lambda^2} (\bar{Q}_L \tilde{\phi} t_R) \phi^\dagger \phi + \frac{\mathcal{C}_{tG}}{\Lambda^2} \bar{Q}_L \sigma^{\mu\nu} T^A t_R \tilde{\phi} G^A_{\mu\nu} + \text{H.c.} \right], \\
\mathcal{L}_{\rm s} &= \frac{\mathcal{C}_{\phi G}}{\Lambda^2} \phi^\dagger \phi G_{\mu\nu} G^{\mu\nu}.
\end{aligned}
\tag{6.1}
$$

- In unitary gauge $\phi = (1/\sqrt{2})(0, (v+h))^T$:

$$
\mathcal{L}_{\mathcal{D}=6} \supset -m_t \bar{t} t - g_{h\bar{t}t} h \bar{t} t, \quad
\begin{cases}
m_t = \frac{v}{\sqrt{2}} \left(Y_t - \frac{v^2}{2} \frac{\mathcal{C}_{t\phi}}{\Lambda^2} \right), \\
g_{h\bar{t}t} = \frac{1}{\sqrt{2}} \left(Y_t - \frac{3v^2}{2} \frac{\mathcal{C}_{t\phi}}{\Lambda^2} \right) = \frac{m_t}{v} - \frac{v^2}{\sqrt{2}} \frac{\mathcal{C}_{t\phi}}{\Lambda^2}.
\end{cases}
$$

Renormalised matrix element

- The renormalised matrix element is:

$$\mathcal{M}^{\text{Ren}}_{\text{TOT}} = \left(\mathcal{C}^{(1)}_{Qt} + \frac{4}{3}\mathcal{C}^{(8)}_{Qt}\right)\frac{1}{\Lambda^2}\mathcal{M}^{\text{S.I.}}_{g_{h\bar{t}t}+m_t} + \left[\mathcal{C}_{tG} + \left(\mathcal{C}^{(1)}_{Qt} - \frac{1}{6}\mathcal{C}^{(8)}_{Qt}\right)K_{tG}\right]\frac{1}{\Lambda^2}\mathcal{M}_{tG}|_{\text{FIN}}$$
$$+\left[1 + \left(\mathcal{C}^{(1)}_{Qt} + \frac{4}{3}\mathcal{C}^{(8)}_{Qt}\right)\frac{1}{\Lambda^2}K_{h\bar{t}t}\right]\mathcal{M}_{\text{SM}}(g_{h\bar{t}t}, m_t) + \left(\mathcal{C}^{(1)}_{Qt} + \frac{4}{3}\mathcal{C}^{(8)}_{Qt}\right)\frac{1}{\Lambda^2}K_{m_t}\frac{\partial\mathcal{M}_{\text{SM}}}{\partial m_t} \times m_t + \mathcal{C}_{\phi G}\mathcal{M}_{\phi G}\frac{1}{\Lambda^2}.$$

- We define:

$$\tilde{\mathcal{C}}_{tG} = \mathcal{C}_{tG} + \left(\mathcal{C}^{(1)}_{Qt} - \frac{1}{6}\mathcal{C}^{(8)}_{Qt}\right)K_{tG},$$
$$\tilde{g}_{h\bar{t}t} = g_{h\bar{t}t}\left[1 + \left(\mathcal{C}^{(1)}_{Qt} + \frac{4}{3}\mathcal{C}^{(8)}_{Qt}\right)\frac{1}{\Lambda^2}K_{h\bar{t}t}\right],$$
$$\tilde{m}_t = m_t\left[1 + \left(\mathcal{C}^{(1)}_{Qt} + \frac{4}{3}\mathcal{C}^{(8)}_{Qt}\right)\frac{1}{\Lambda^2}K_{m_t}\right].$$

$$\mathcal{M}^{\text{Ren}}_{\text{TOT}} = \left(\mathcal{C}^{(1)}_{Qt} + \frac{4}{3}\mathcal{C}^{(8)}_{Qt}\right)\frac{1}{\Lambda^2}\mathcal{M}^{\text{S.I.}}_{g_{h\bar{t}t}+m_t}$$
$$+\frac{\tilde{\mathcal{C}}_{tG}}{\Lambda^2}\mathcal{M}_{tG}|_{\text{FIN}} + \mathcal{M}_{\text{SM}}(\tilde{g}_{h\bar{t}t}, \tilde{m}_t) + \frac{\mathcal{C}_{\phi G}}{\Lambda^2}\mathcal{M}_{\phi G}.$$

Matching with a UV model: $\Phi \sim (8,2)_{\frac{1}{2}}$

- We can test the relations between the parameters in NDR and BMHV matching the SMEFT with a UV toy model:

$$\mathcal{L}_\Phi = (D_\mu \Phi)^\dagger D^\mu \Phi - M_\Phi^2 \Phi^\dagger \Phi - Y_\Phi \left(\Phi^{A,\dagger} \varepsilon \bar{Q}_L^T T^A t_R + \text{H.c.} \right).$$

- Tree-level matching (in both schemes):

$$\frac{\mathcal{C}_{Qt}^{(1)}}{\Lambda^2} = -\frac{2}{9} \frac{Y_\Phi^2}{M_\Phi^2}, \quad \frac{\mathcal{C}_{Qt}^{(8)}}{\Lambda^2} = \frac{1}{6} \frac{Y_\Phi^2}{M_\Phi^2}.$$

- One-loop matching + Fierz identities ([Fuentes-Martin et al.,'22]):

$$\frac{\mathcal{C}_{tG}^{\text{NDR}}}{\Lambda^2} = \frac{1}{16\pi^2} \frac{Y_\Phi^2}{M_\Phi^2} \frac{\sqrt{2} g_{h\bar{t}t} g_s}{4}, \qquad \frac{\mathcal{C}_{tG}^{\text{BMHV}}}{\Lambda^2} = 0.$$

- Using the tree-level matching for $\mathcal{C}_{Qt}^{(1,8)}$, we can verify:

$$\mathcal{C}_{tG}^{\text{NDR}} = \mathcal{C}_{tG}^{\text{BMHV}} - \left(\mathcal{C}_{Qt}^{(1)} - \frac{1}{6} \mathcal{C}_{Qt}^{(8)} \right) \frac{\sqrt{2} g_{h\bar{t}t} g_s}{16\pi^2}.$$

$h \to \bar{b}b$ rate in the SMEFT

$$\mathcal{L}_\mathrm{b} = \frac{\mathcal{C}_{Qb}^{(1)}}{\Lambda^2}\left(\bar{Q}_L\gamma_\mu Q_L\right)\left(\bar{b}_R\gamma^\mu b_R\right) + \frac{\mathcal{C}_{Qb}^{(8)}}{\Lambda^2}\left(\bar{Q}_L T^A\gamma_\mu Q_L\right)\left(\bar{b}_R T^A\gamma^\mu b_R\right) + \left[\frac{\mathcal{C}_{b\phi}}{\Lambda^2}(\phi^\dagger\phi)\bar{Q}_L\phi b_R + \mathrm{H.c.}\right] .$$

- The one-loop amplitude depends on the scheme:

$$\frac{\Gamma^{\mathrm{NDR,1L}}_{h\to b\bar{b}} - \Gamma^{\mathrm{BMHV,1L}}_{h\to b\bar{b}}}{\Gamma^{\mathrm{SM}}_{h\to b\bar{b}}} = \frac{\mathcal{C}_{Qb}^{(1)} + \frac{4}{3}\mathcal{C}_{Qb}^{(8)}}{8\pi^2\,\Lambda^2}(m_h^2 - 6m_b^2) + \mathcal{O}\left(\frac{1}{\Lambda^4}\right) .$$

- Using $\Gamma^{\mathrm{X,TL}}_{h\to b\bar{b}} \propto (g^{\mathrm{X}}_{h\bar{b}b})^2$, $\mathrm{X} = \mathrm{NDR}, \mathrm{BMHV}$.

$$g^{\mathrm{NDR}}_{h\bar{b}b} = g^{\mathrm{BMHV}}_{h\bar{b}b} - g_{h\bar{b}b}\left(\mathcal{C}_{Qb}^{(1)} + \frac{4}{3}\mathcal{C}_{Qb}^{(8)}\right)\frac{(m_h^2 - 6m_b^2)}{16\pi^2\Lambda^2},$$

$$\frac{\Gamma^{\mathrm{NDR,TL}}_{h\to b\bar{b}} - \Gamma^{\mathrm{BMHV,TL}}_{h\to b\bar{b}}}{\Gamma^{\mathrm{SM}}_{h\to b\bar{b}}} = -\frac{\mathcal{C}_{Qb}^{(1)} + \frac{4}{3}\mathcal{C}_{Qb}^{(8)}}{8\pi^2\,\Lambda^2}(m_h^2 - 6m_b^2) + \mathcal{O}\left(\frac{1}{\Lambda^4}\right) .$$

- $\Gamma^{\mathrm{NDR,TL}}_{h\to b\bar{b}} + \Gamma^{\mathrm{NDR,1L}}_{h\to b\bar{b}}$ is scheme-independent!

2-parameters fit results

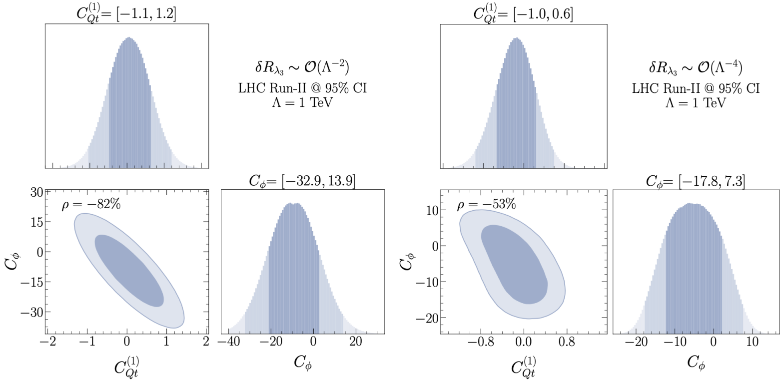
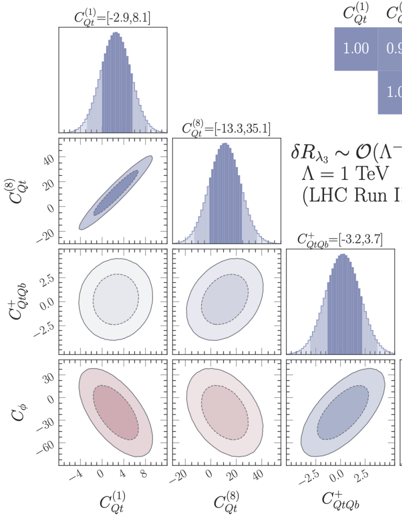


Figure: from [Alasfar,de Blas,Gröber,'22]

4-parameters fit results



	$C_{Qt}^{(1)}$	$C_{Qt}^{(8)}$	C_{QtQb}^{+}	C_ϕ
$C_{Qt}^{(1)}$	1.00	0.96	0.08	-0.60
$C_{Qt}^{(8)}$		1.00	0.30	-0.37
C_{QtQb}^{+}			1.00	0.64
C_ϕ				1.00

Figure: from [Alasfar,de Blas,Gröber,'22]

Is the SMEFT general enough?

- The SMEFT assumes a SM-like Higgs boson:

$$(\tilde{\varphi}, \varphi) = \frac{v+h}{\sqrt{2}} \cdot U, \qquad U = \exp\left(i\frac{\pi^I \tau^I}{v}\right).$$

- The Higgs EFT (HEFT) instead assumes a more general scenario: U and h are treated separately.
- SM$\subset$SMEFT$\subset$HEFT.
- Less correlations between coefficients in HEFT: (e.g., in SMEFT $g_{5h} = v g_{6h}$ but not in HEFT).
- Measure correlation$\rightarrow$ insights about EW SSB.
- More about this topic in [Brivio, Trott, '17].

RGESolver

- A `C++` library that performs RG evolution of SMEFT coefficients ([S.D.N.,Silvestrini,'22]).

- General flavour structure (assuming L, B conservation).

- Numerical and approximate solutions of the RGEs with unprecedented efficiency.

- Back-rotation effects easily implemented.

- Authors:
  - Stefano Di Noi,
  - Luca Silvestrini.