Studying the Higgs boson in the SMEFT: gluon-induced ZH production

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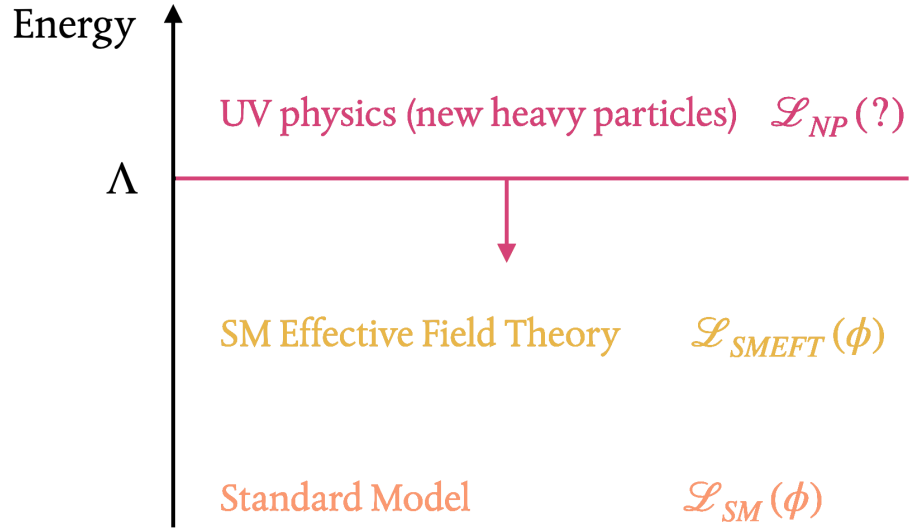
Based on arXiv: 2306.09963 (accepted in JHEP)
In collaboration with A. Rossia and E. Vryonidou

About the SMEFT framework



$$\mathscr{L}_{\text{SMEFT}} = \mathscr{L}^{(4)}_{\text{SM}} + \frac{1}{\Lambda} c^{(5)} \mathcal{O}^{(5)} + \frac{1}{\Lambda^2} \sum_k c^{(6)}_k \mathcal{O}^{(6)}_k + \mathcal{O}\left(\frac{1}{\Lambda^3}\right)$$

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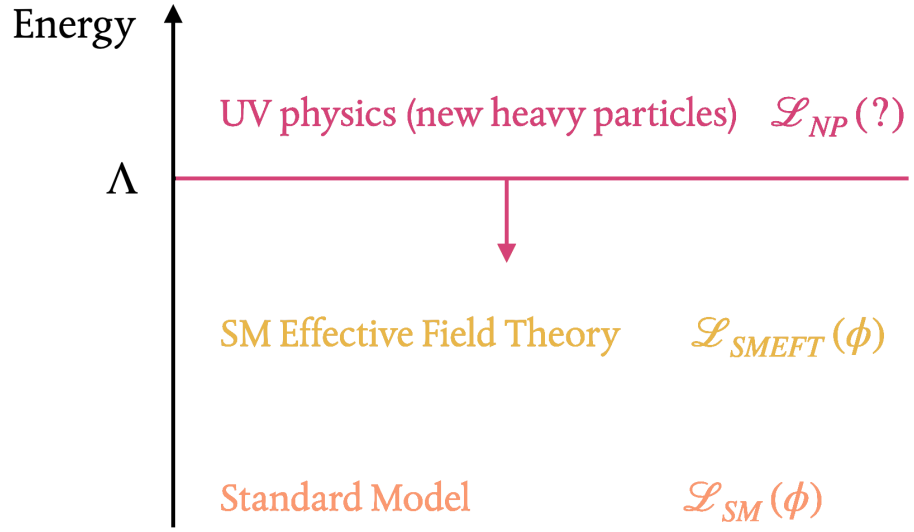

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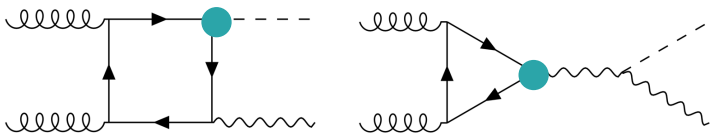
Focus on dimension-6 operators with Warsaw basis.

$gg \to ZH$: top quark loop → probes Higgs and top operators



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- Calculated analytical helicity amplitudes with **1 insertion of dim-6 SMEFT operators.**
- Studied high-energy behaviour of amplitudes → Which operators grow with energy?

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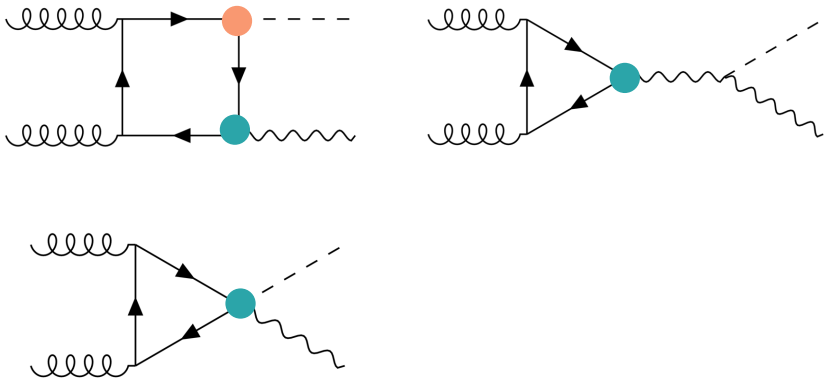
$+,+,0,0$	$\frac{m_t^2\, v\, e\, g_s^2}{32\pi^2\, m_Z\, c_w\, s_w}\left[\log\left(\frac{s}{m_t^2}\right) - i\pi\right]^2$	$\frac{m_t^2\, v\, e\, g_s^2}{32\pi^2\, m_Z\, c_w\, s_w}\left[\log\left(\frac{s}{m_t^2}\right) - i\pi\right]^2$	$\frac{m_t\, v^2\, e\, g_s^2}{32\sqrt{2}\pi^2\, m_Z\, c_w\, s_w}\left[\log\left(\frac{s}{m_t^2}\right) - i\pi\right]^2$



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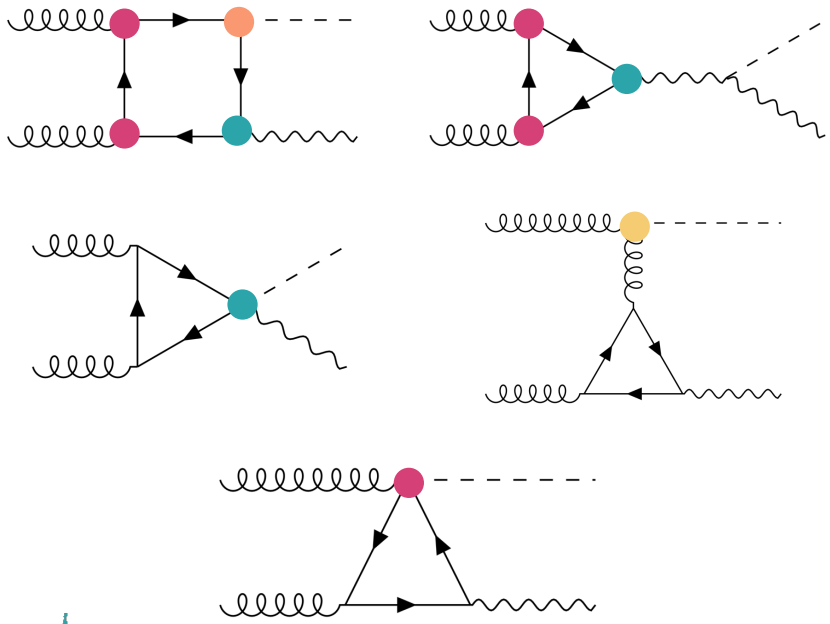
$\lambda_{g_1}, \lambda_{g_2}, \lambda_H, \lambda_Z$	$\mathcal{O}_{tG}$	$\mathcal{O}_{\varphi G}$
$+,+,0,+$	$\sqrt{s}\, m_t \log\left(\frac{s}{m_t^2}\right)$	$-$
$+,+,0,-$	$\sqrt{s}\, m_t \log^2\left(\frac{s}{m_t^2}\right)$	$-$
$+,+,0,0$	$\frac{m_t v^2}{m_Z} \log^2\left(\frac{s}{m_t^2}\right)$	$\frac{m_t^2\, v}{m_Z} \log^2\left(\frac{s}{m_t^2}\right)$
$+,-,0,+$	$\sqrt{s}\, m_t$	$-$
$+,-,0,0$	$s\, \frac{m_t}{m_Z}$	$\frac{m_t^2\, v}{m_Z} \log^2\left(\frac{s}{m_t^2}\right)$



Can measuring $pp \to ZH$ improve the bounds on Higgs and top operators?

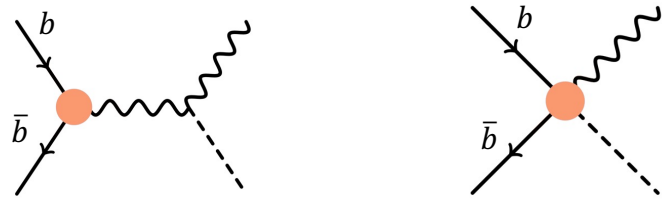
Third generation operators → Quark and gluon channels interplay

$\mathcal{O}_{\varphi Q}^{(1)}$	$c_{\varphi Q}^{(1)}$	$i\left(\varphi^\dagger \overleftrightarrow{D}_\mu \varphi\right)\left(\bar{Q}\,\gamma^\mu\, Q\right)$
$\mathcal{O}_{\varphi Q}^{(3)}$	$c_{\varphi Q}^{(3)}$	$i\left(\varphi^\dagger \overleftrightarrow{D}_\mu \tau_I \varphi\right)\left(\bar{Q}\,\gamma^\mu\, \tau^I Q\right)$
$\mathcal{O}_{\varphi Q}^{(-)}$	$c_{\varphi Q}^{(-)}$	$c_{\varphi Q}^{(1)} - c_{\varphi Q}^{(3)}$
$\mathcal{O}_{\varphi t}$	$c_{\varphi t}$	$i\left(\varphi^\dagger \overleftrightarrow{D}_\mu \varphi\right)\left(\bar{t}\,\gamma^\mu\, t\right)$
$\mathcal{O}_{t\varphi}$	$c_{t\varphi}$	$\left(\varphi^\dagger\varphi - \frac{v^2}{2}\right)\bar{Q}\,t\,\tilde{\varphi} + \text{h.c.}$

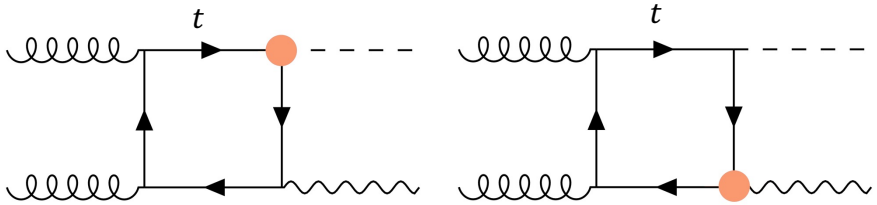
Probed by $gg \to ZH$

Probed by $qq \to ZH$

LO



NNLO



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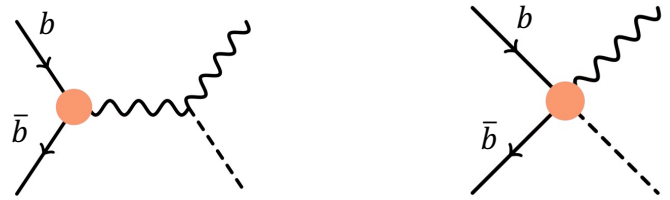

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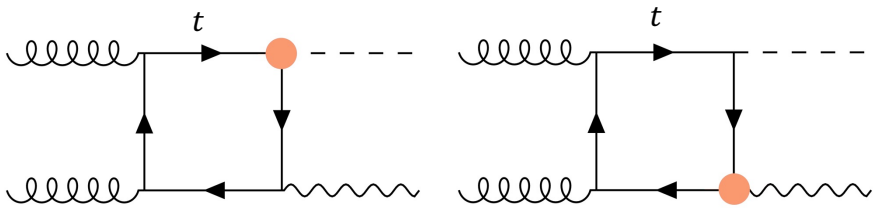

Probed by $gg \to ZH$
Probed by $qq \to ZH$

- Used $qq \to ZH$ analysis by Bishara, Englert, Grojean, Panico and Rossia, arXiv:2208.11134.
- Predictions obtained with Madgraph in the presence of one operator at a time.

HL-LHC projected bounds from $pp \to ZH$

WC [TeV^{-2}]	95% C.L. Bound (5% syst.)
$c_{\varphi Q}^{(3)}$	$[-0.72,\ 0.57]$
$c_{\varphi Q}^{(-)}$	$[-1.5,\ 1.1]$
$c_{\varphi t}$	$[-8.1,\ \ 19.6]$
$c_{t\varphi}$	$[-19.4,\ \ 8.0]$

Probed by $gg \to ZH$ (loop induced)
Probed by $qq \to ZH$ (tree-level)

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Compare to global fits of LHC data:

$|c_{\varphi Q}^{(3)}| \lesssim 0.6\ \text{TeV}^{-2} \quad c_{\varphi t} \in [-13.3, 4.0]\ \text{TeV}^{-2}$

$|c_{\varphi Q}^{(-)}| \lesssim 2.9\ \text{TeV}^{-2} \quad c_{t\varphi} \in [-2.3, 2.8]\ \text{TeV}^{-2}$

SMEFiT Collaboration, arXiv:2105.00006

Probed by $gg \to ZH$ (loop induced)
Probed by $qq \to ZH$ (tree-level)

Competitive against current bounds

→ Motivates precision measurements and inclusion in global fits.

Thank you!