Higgs-top interplay in EFTs

Higgs 2024

Uppsala University, Sweden

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Alejo N. Rossia

Università degli Studi di Padova

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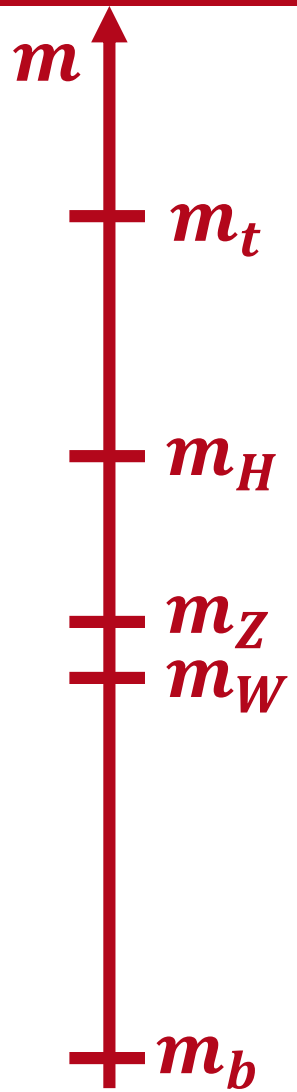
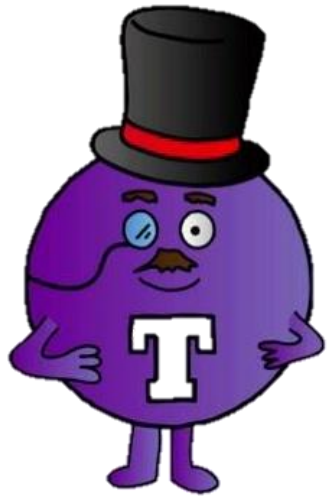
DI PADOVA

Higgs and top: a bond like no other





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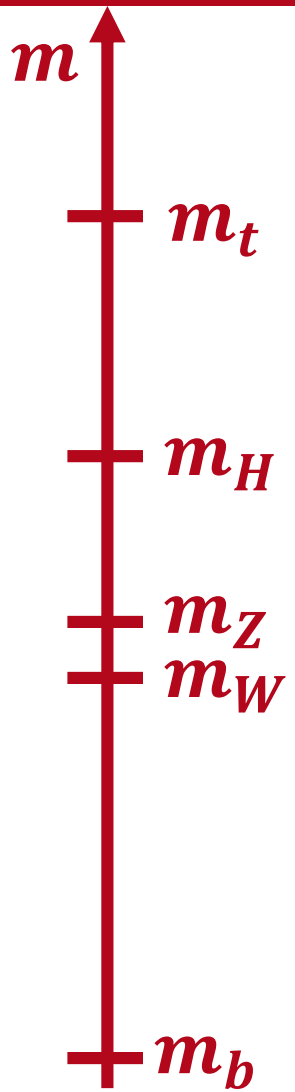

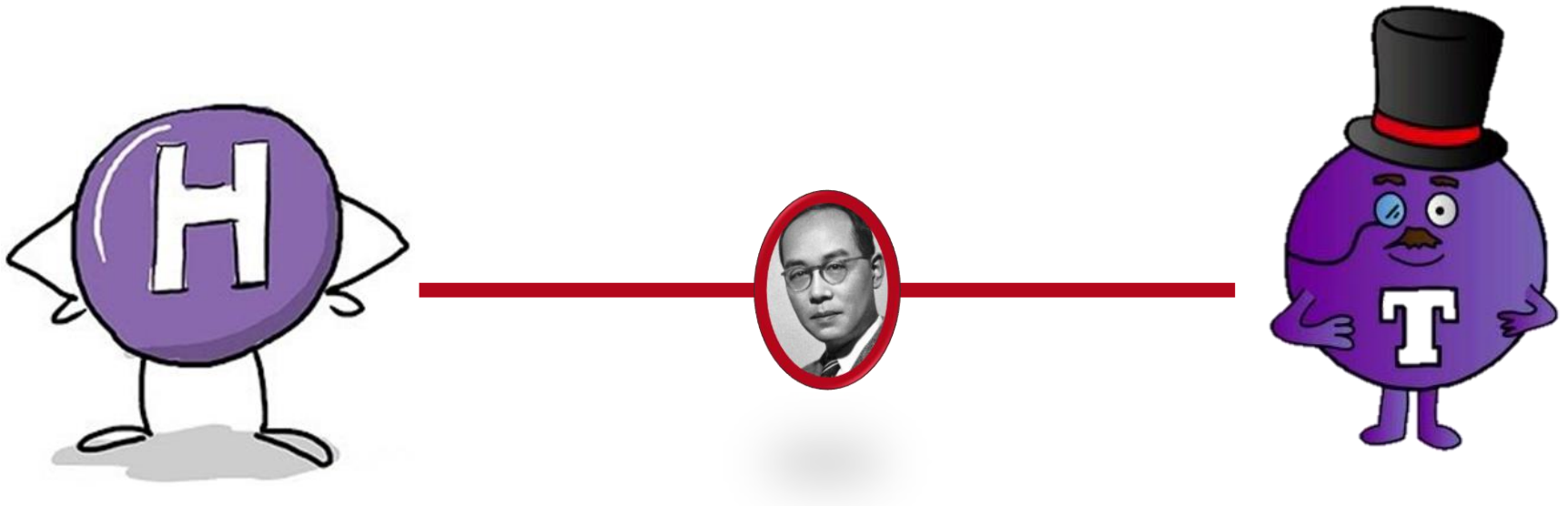

$$y_t = \sqrt{2}\,\frac{m_t}{v} \cong 0.99$$

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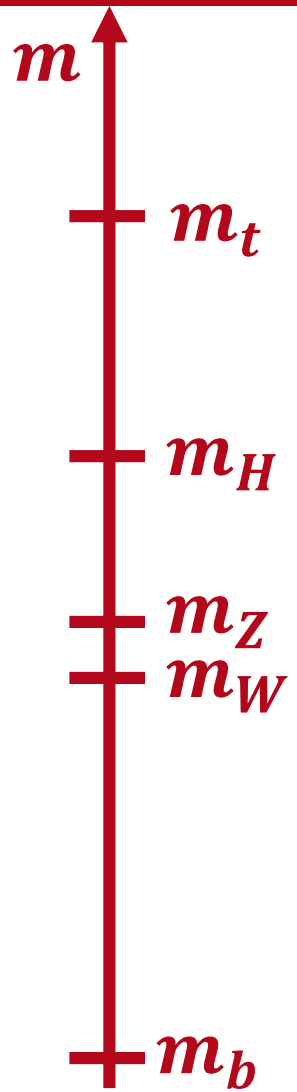
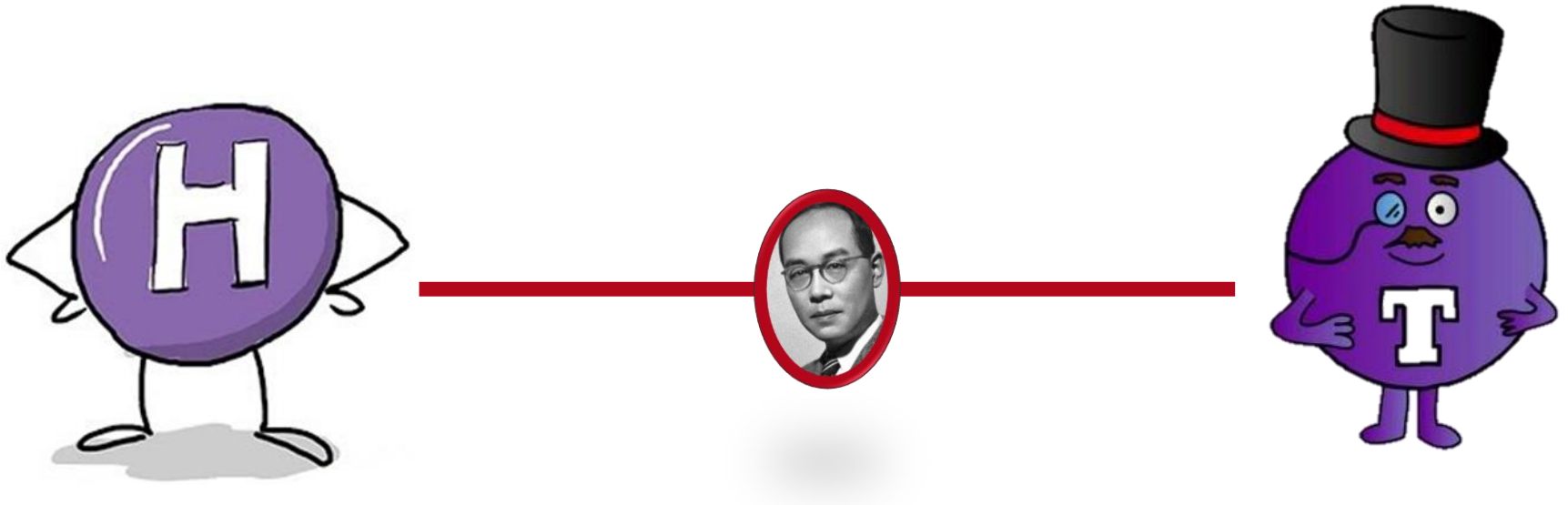
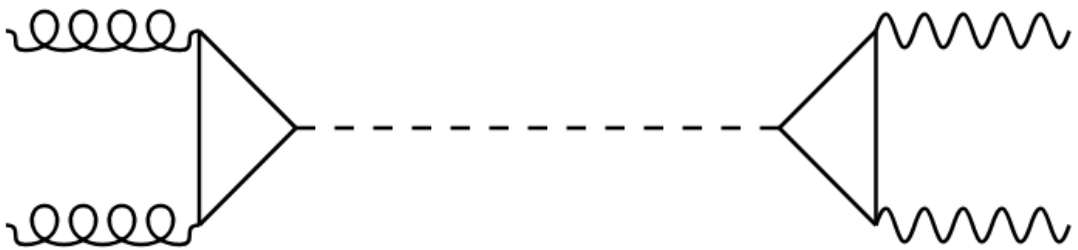


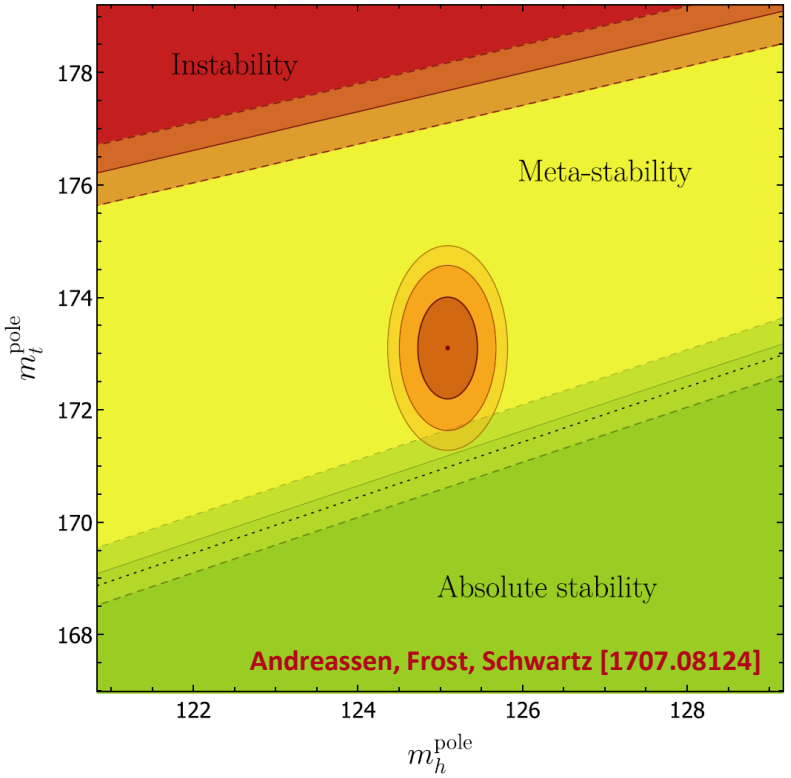


$$y_t = \sqrt{2}\,\frac{m_t}{v} \cong 0.99$$

Strongest SM Yukawa and key in many processes

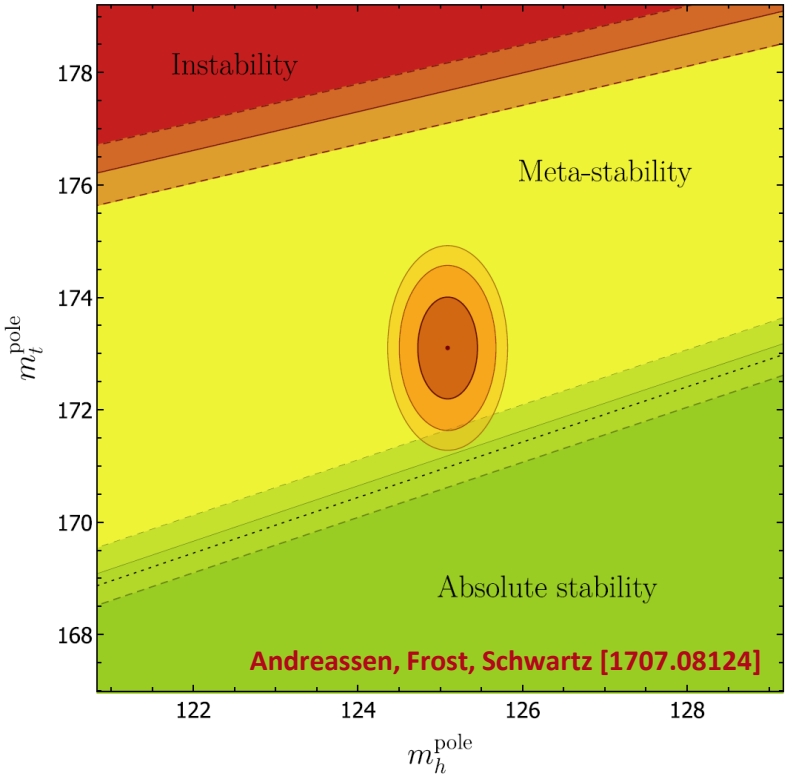


Higgs and top: a portal to the unknown



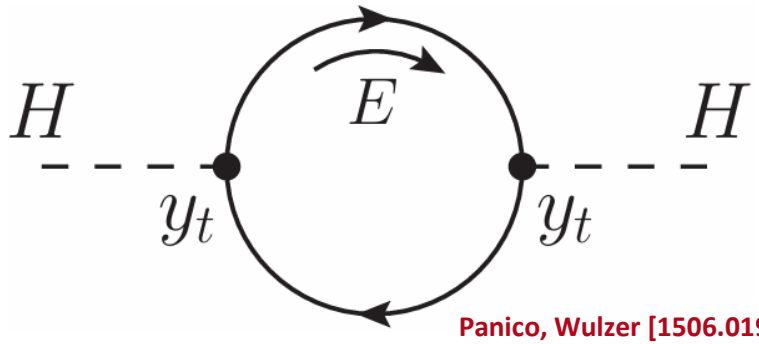
Key in vacuum stability

Higgs and top: a portal to the unknown



Andreassen, Frost, Schwartz [1707.08124]

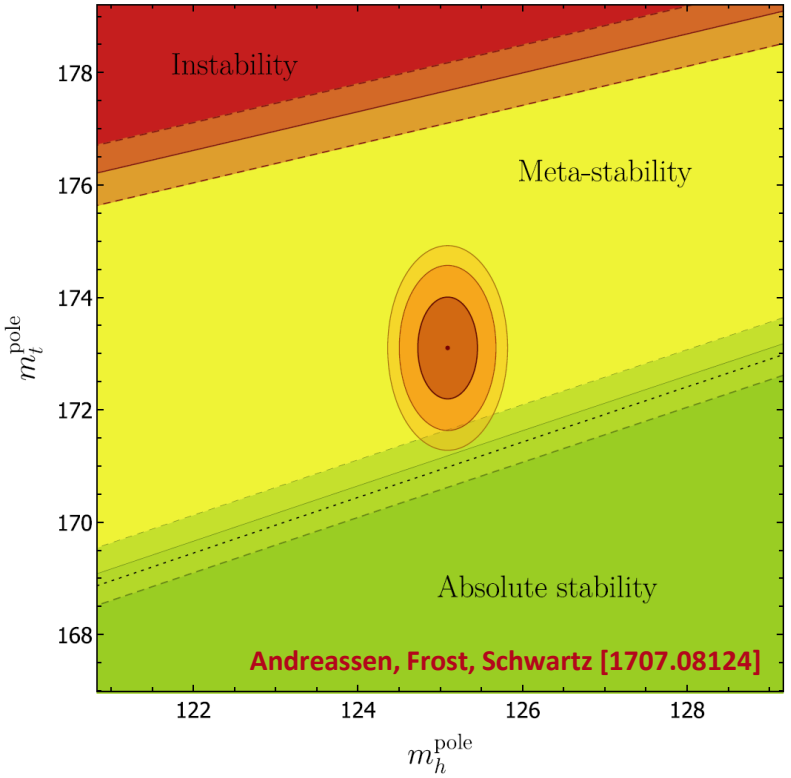
Key in vacuum stability



Panico, Wulzer [1506.01961]

The heart of the Hierarchy Problem

Higgs and top: a portal to the unknown



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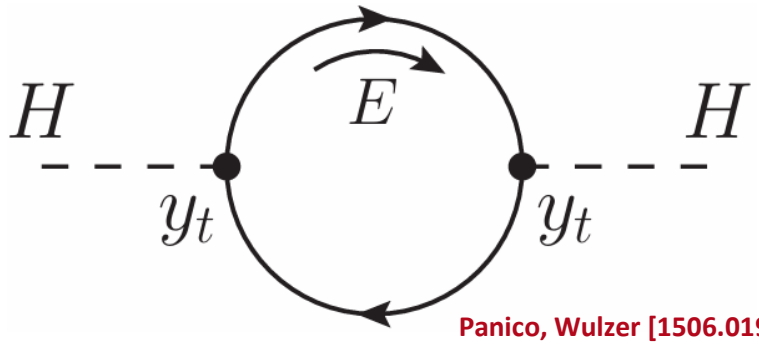
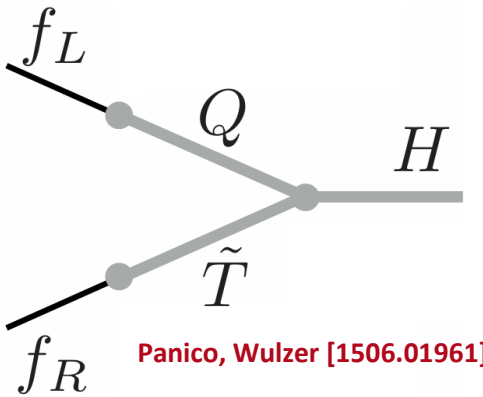


Panico, Wulzer [1506.01961]

The heart of the Hierarchy Problem

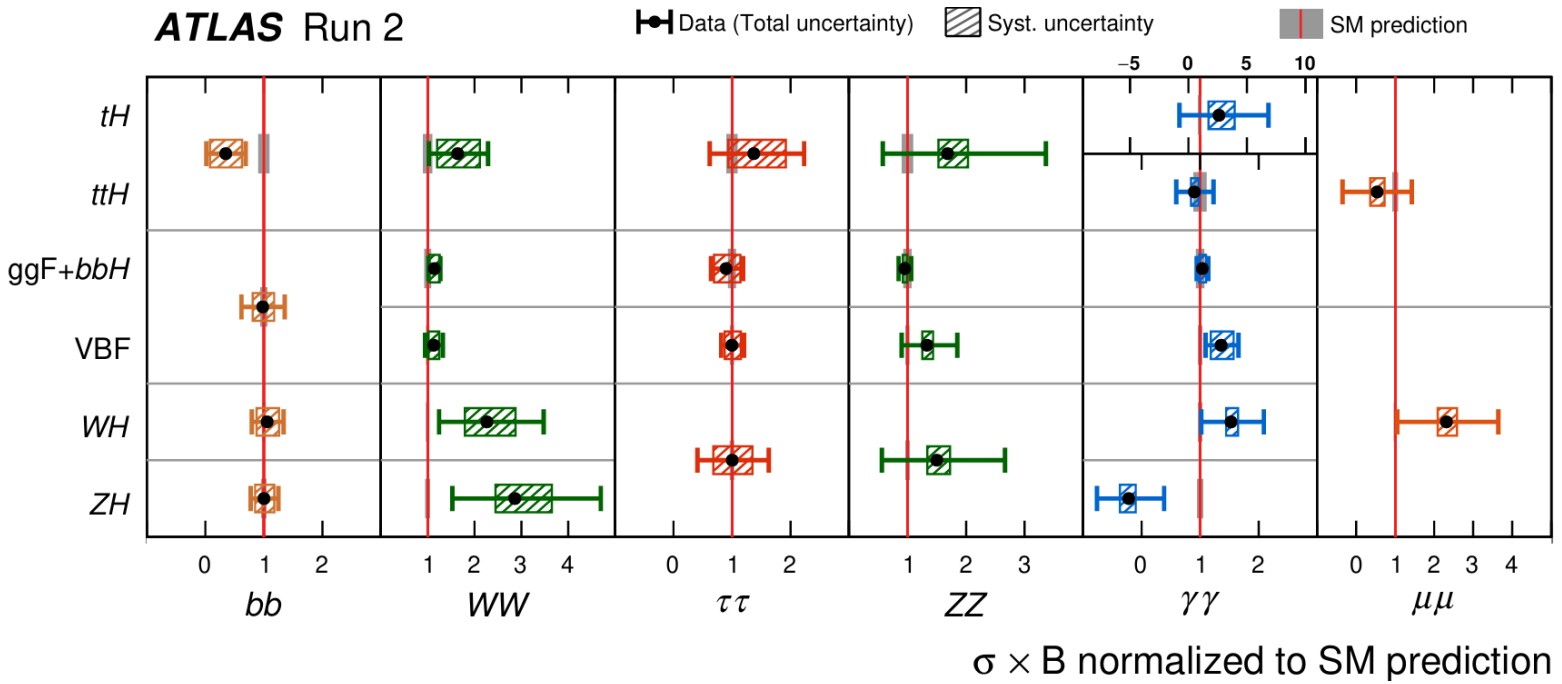
Link to Top Partners



Panico, Wulzer [1506.01961]

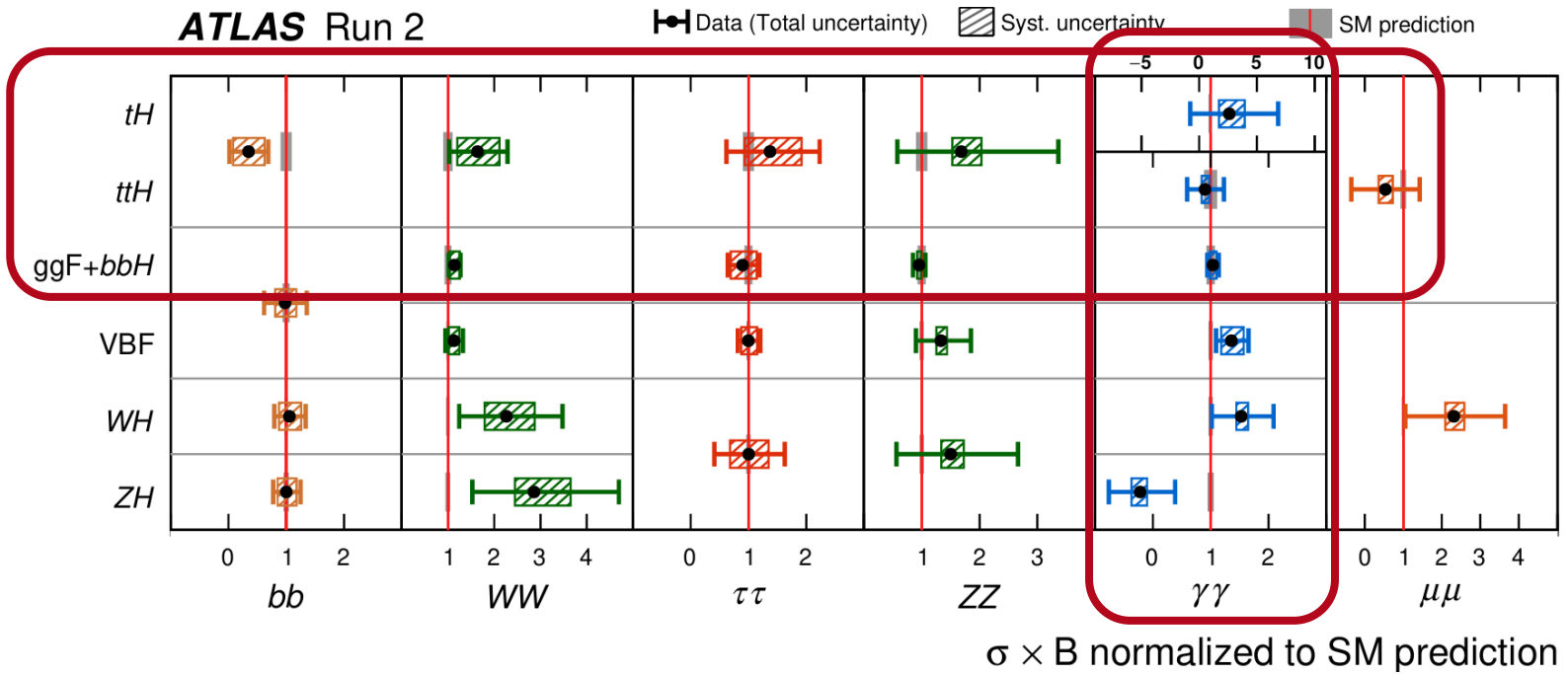
Top-Higgs is a key target for New Physics searches

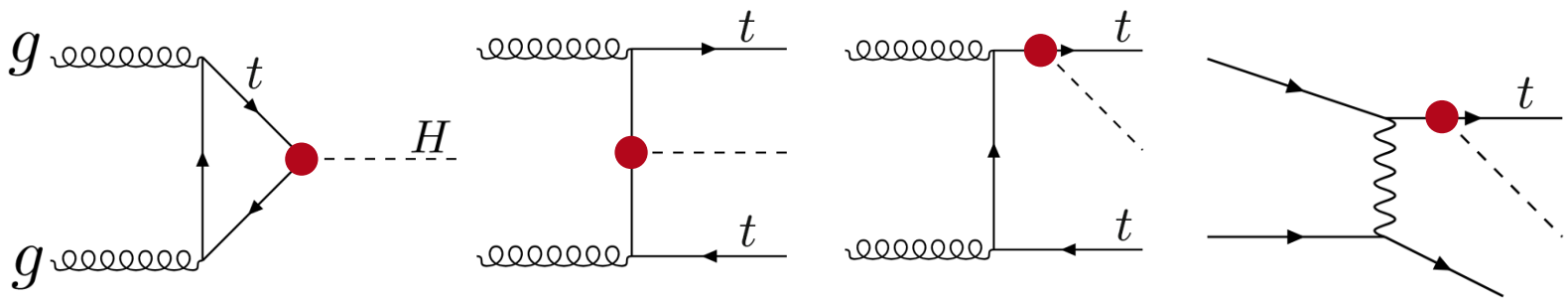
Top in Higgs measurements



ATLAS [2404.05498]

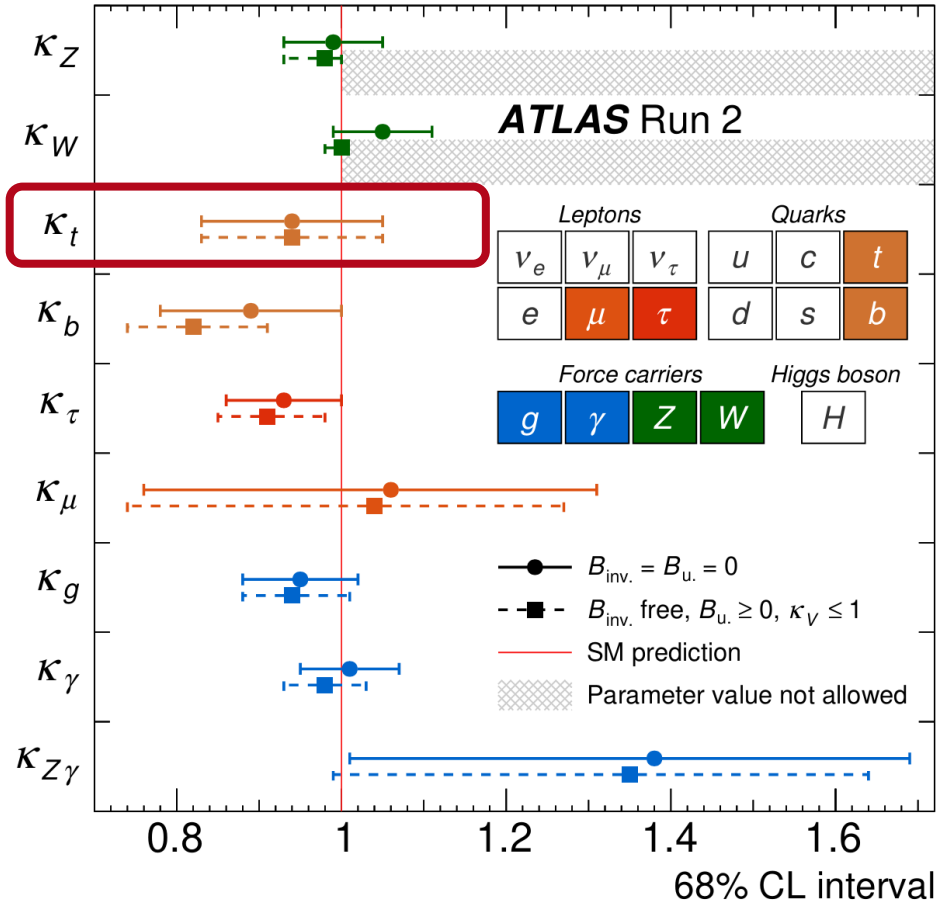
Top in Higgs measurements

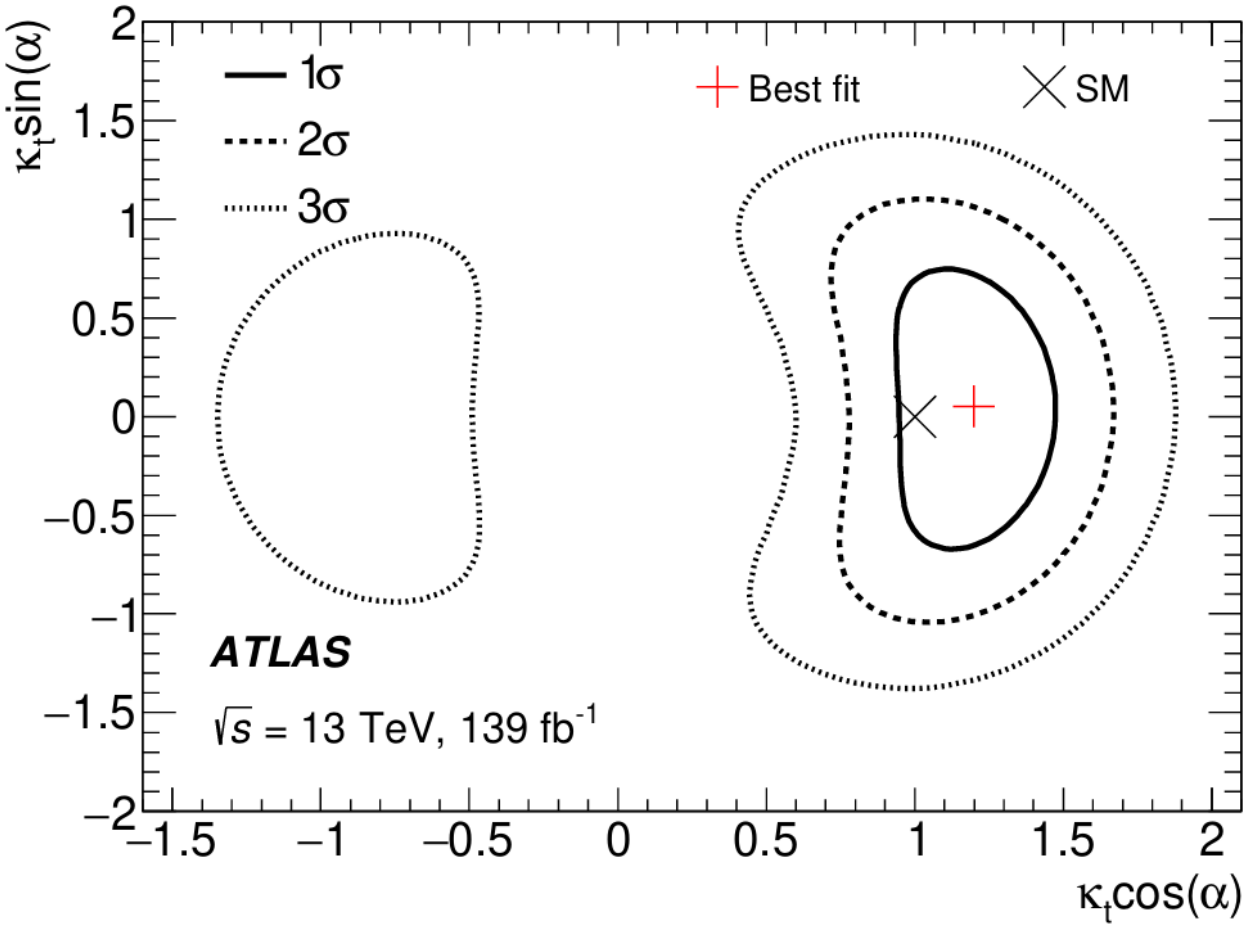




ATLAS [2404.05498]

Top lessons from the Higgs





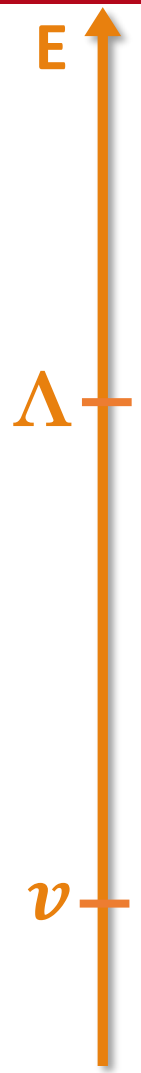
(See analogous CMS plots in P. Bokan's talk)

ATLAS [2404.05498]

The SM Effective Field Theory

$$\psi_{UV} =? \quad \mathcal{L}_{UV} =? \quad G_{UV} =?$$

The SM Effective Field Theory



$$\psi_{UV} =? \quad \mathcal{L}_{UV} =? \quad G_{UV} =?$$

$$\mathcal{L}_{\rm SMEFT} = \mathcal{L}_{\rm SM} + \frac{c_i^{(6)}}{\Lambda^2}\mathcal{O}_i^{(6)} + \frac{c_i^{(8)}}{\Lambda^4}\mathcal{O}_i^{(8)} + \dots$$

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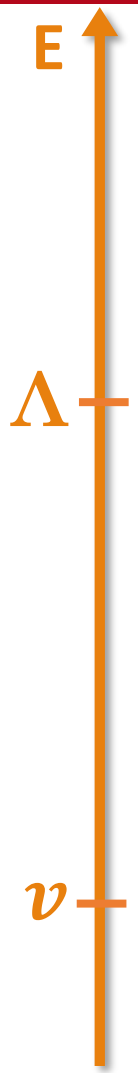

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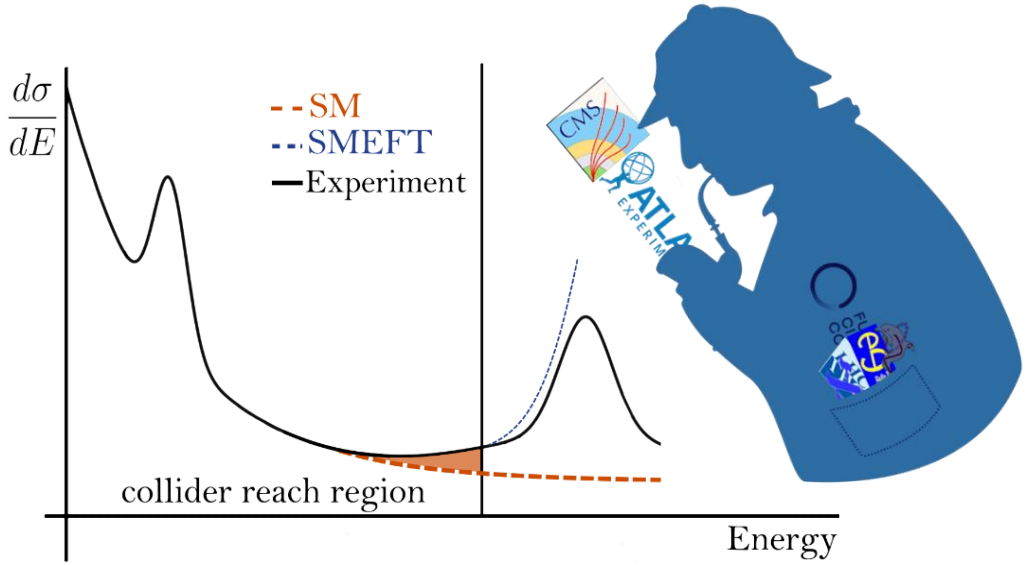
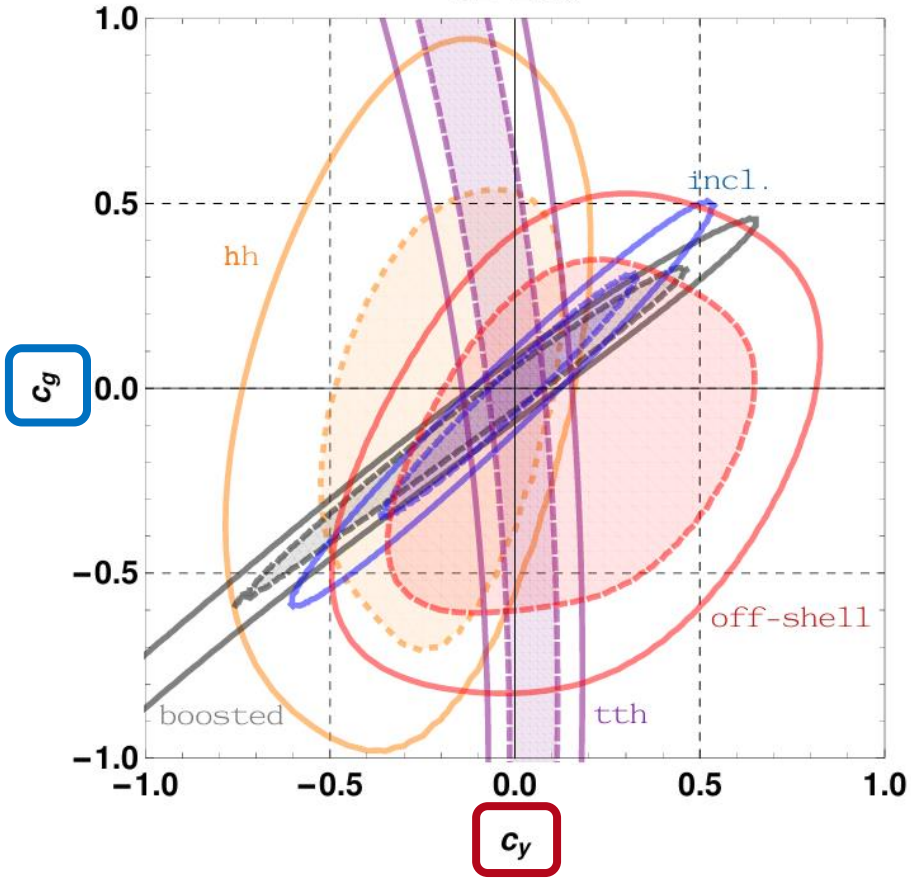
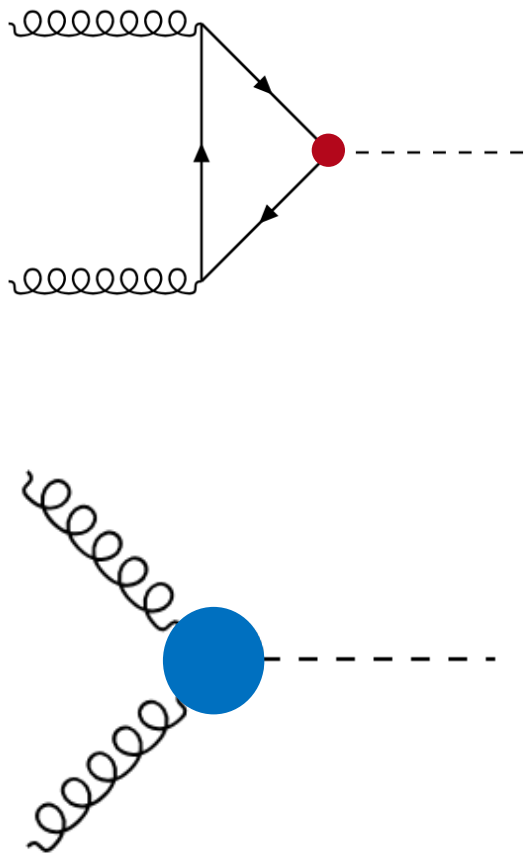
(Mostly) Model-independent phenomenology



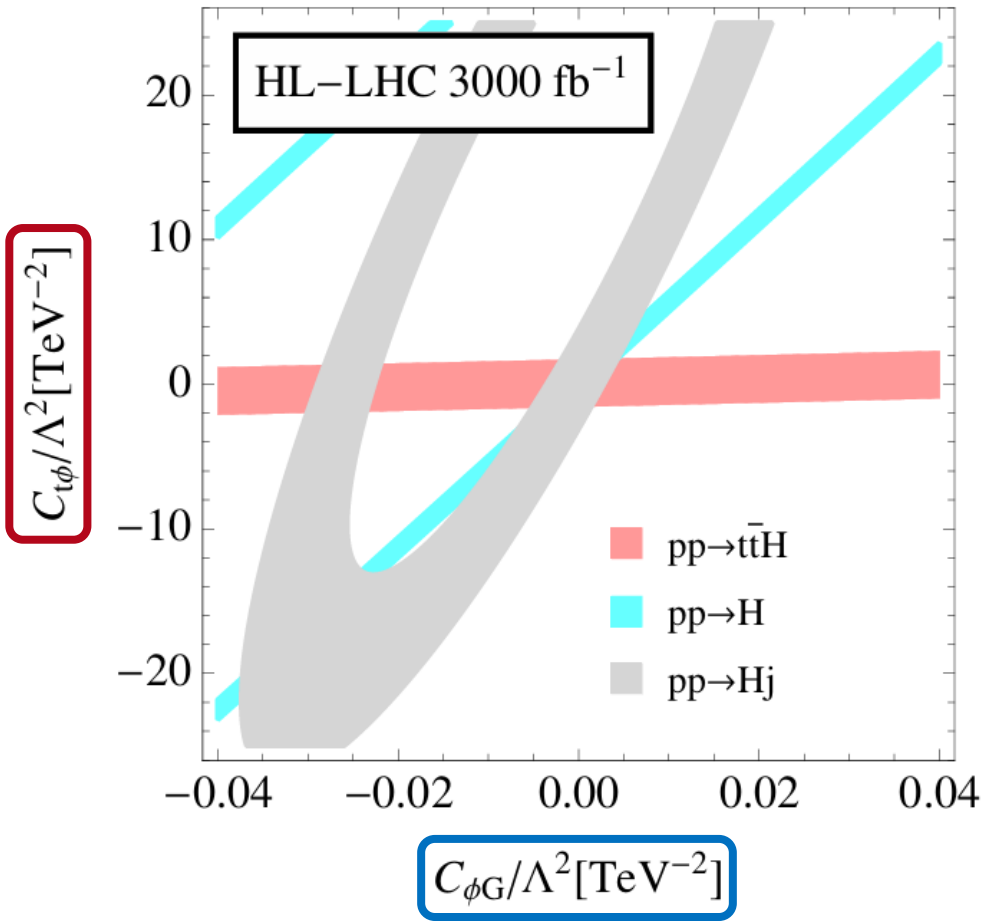
Complementarity in Top-Higgs

Azatov et al [1608.00977] HL–LHC

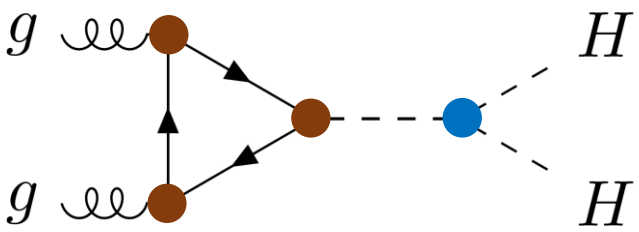


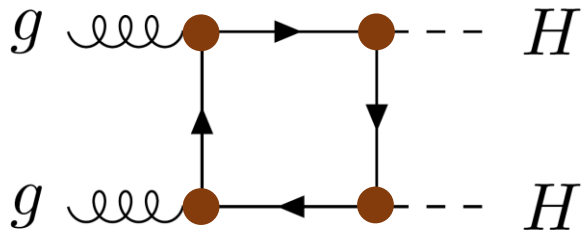


Maltoni, Vryonidou, Zhang [1607.05330]



A stepping stone into the next goal





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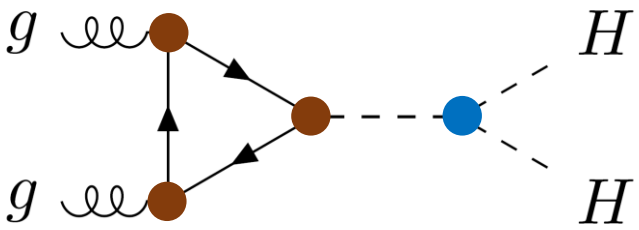

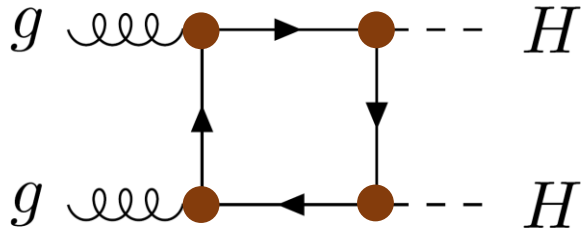

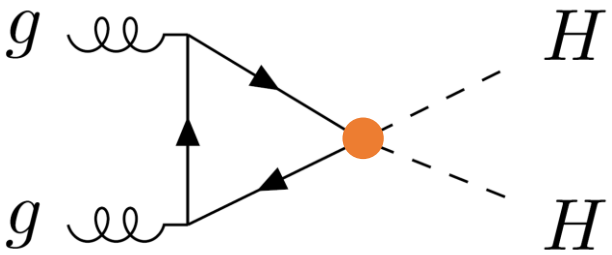

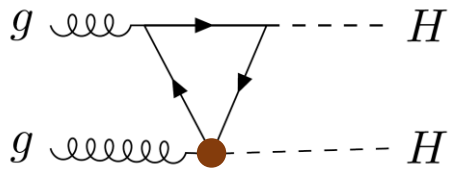

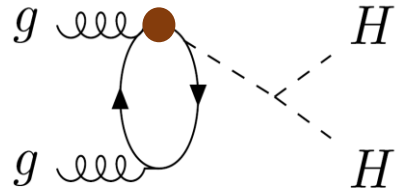

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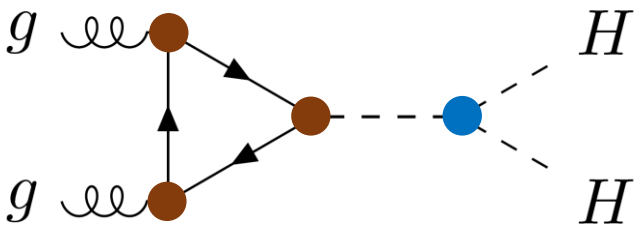
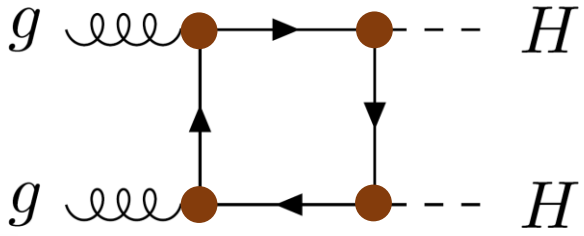
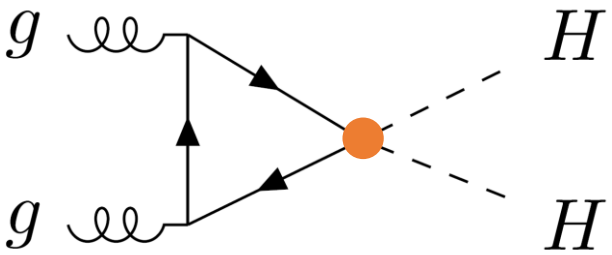
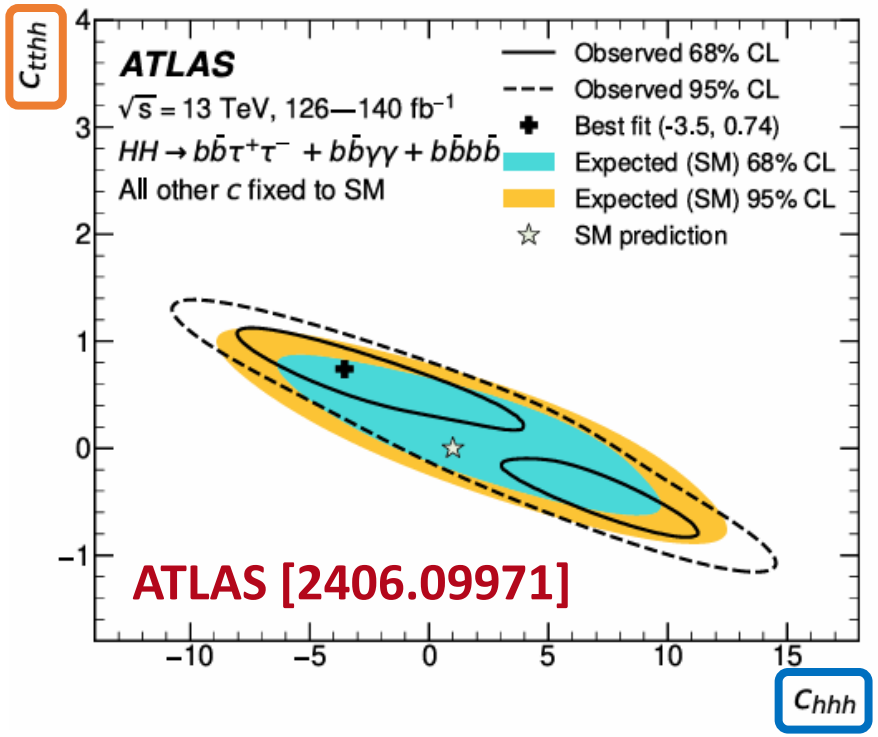
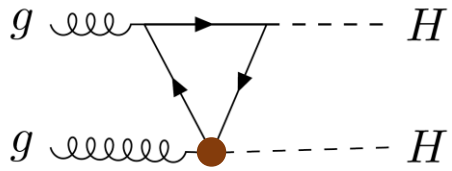
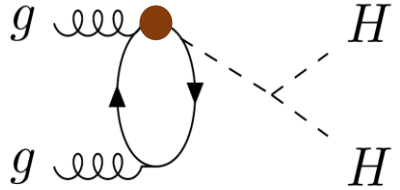










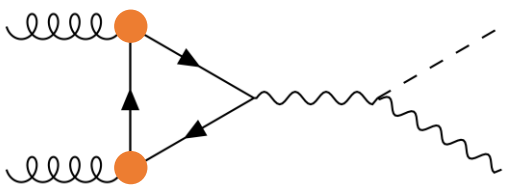


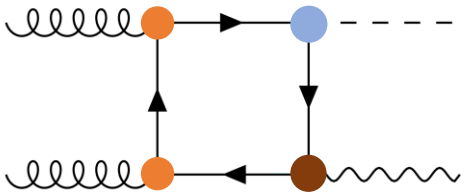
Disclaimer: ATLAS studied in HEFT framework

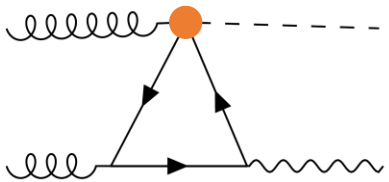
Knowing the Top-Higgs interaction is needed to know the self-interaction.

Top meets diboson: gluon-fusion ZH production

ANR, Thomas, Vryonidou [2306.09963]







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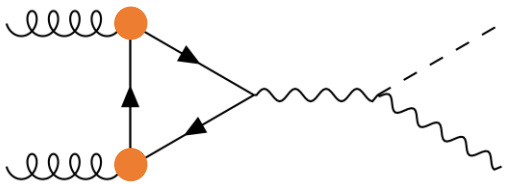
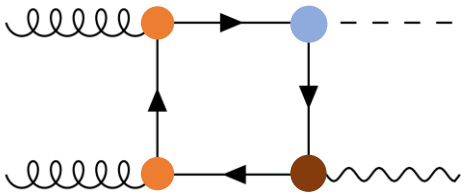
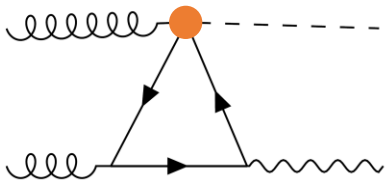
ANR, Thomas, Vryonidou [2306.09963]

$\lambda_{g_1}, \lambda_{g_2}, \lambda_H, \lambda_Z$	$\mathcal{O}_{tG}$
$+,+,0,+$	$\sqrt{s}\,\frac{m_t\, g_s^2\, g_{t,A}^Z}{\pi^2}\log\left(\frac{s}{m_t^2}\right)$
$+,+,0,-$	$\sqrt{s}\,\frac{m_t\, g_s^2\, g_{t,A}^Z}{\pi^2}\log\left(\frac{s}{m_t^2}\right)$
$+,+,0,0$	$\frac{m_t m_Z\, g_s^2\, g_{t,A}^Z}{\pi^2}\log^2\left(\frac{s}{m_t^2}\right)$
$+,-,0,+$	$\sqrt{s}\,\frac{m_t\, g_s^2\, g_{t,A}^Z}{\pi^2}$
$+,-,0,0$	$s\,\frac{m_t\, g_s^2\, g_{t,A}^Z}{\pi^2 m_Z}$







Top meets diboson: gluon-fusion ZH production

ANR, Thomas, Vryonidou [2306.09963]

(See also Thomas, Vryonidou [2411.00959])

$\lambda_{g_1}, \lambda_{g_2}, \lambda_H, \lambda_Z$	$\mathcal{O}_{tG}$
$+,+,0,+$	$\sqrt{s}\,\frac{m_t\, g_s^2\, g_{t,A}^Z}{\pi^2}\log\left(\frac{s}{m_t^2}\right)$
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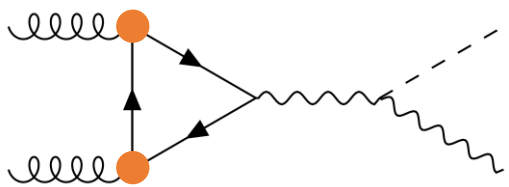
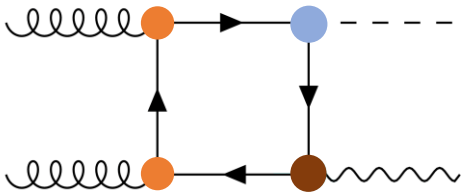
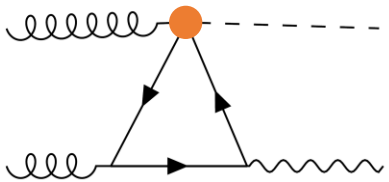
$+,+,0,0$	$\frac{m_t m_Z\, g_s^2\, g_{t,A}^Z}{\pi^2}\log^2\left(\frac{s}{m_t^2}\right)$
$+,-,0,+$	$\sqrt{s}\,\frac{m_t\, g_s^2\, g_{t,A}^Z}{\pi^2}$
$+,-,0,0$	$s\,\frac{m_t\, g_s^2\, g_{t,A}^Z}{\pi^2 m_Z}$

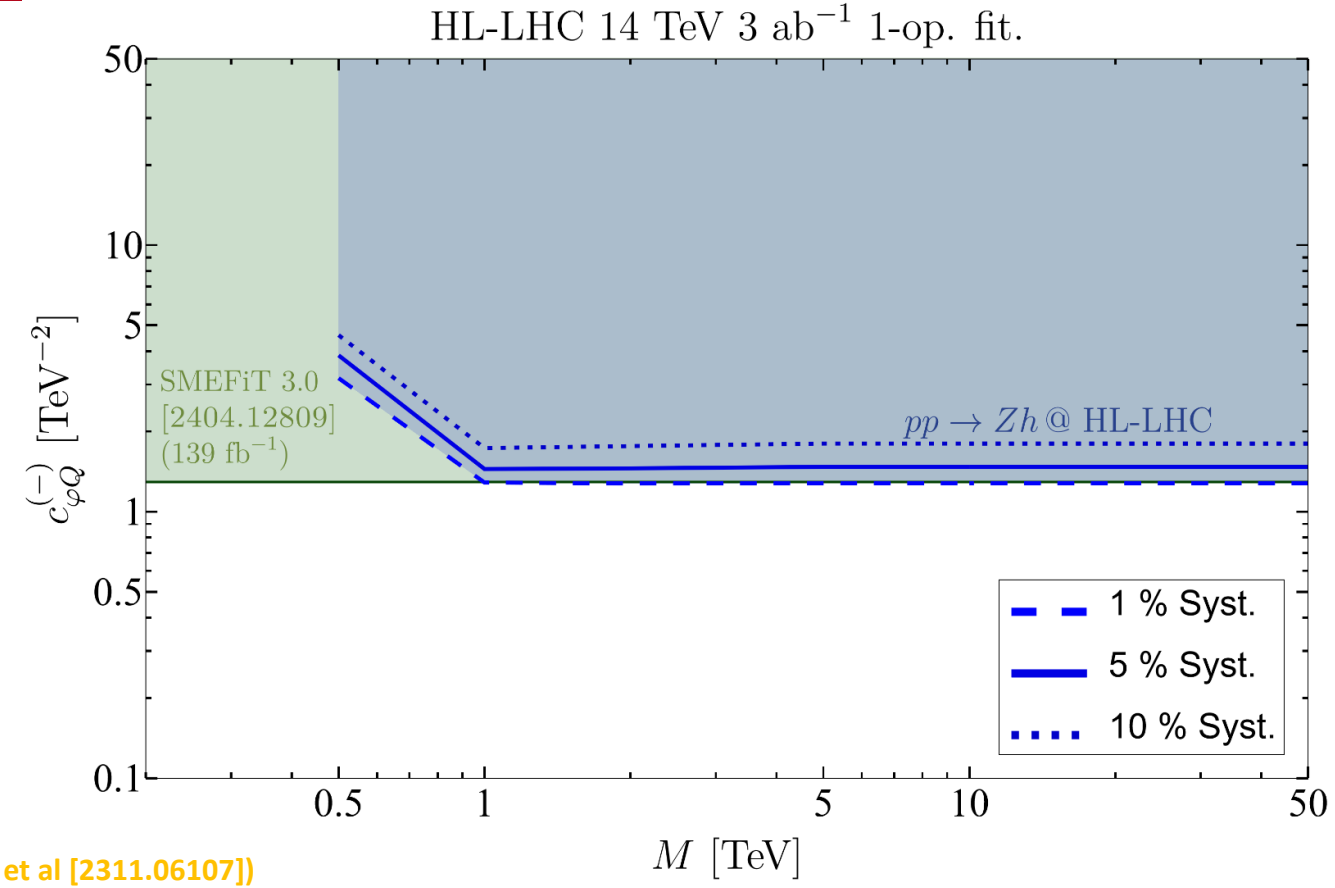






$\lambda_{g_1}, \lambda_{g_2}, \lambda_H, \lambda_Z$	$\mathcal{O}_{\varphi t}$	$\mathcal{O}_{\varphi Q}^{(-)}$	$\mathcal{O}_{t\varphi}$
$+,+,0,0$	$\frac{m_t^2\, v\, e\, g_s^2}{32\pi^2\, m_Z\, c_w\, s_w}\left[\log\left(\frac{s}{m_t^2}\right)-i\pi\right]^2$	$\frac{m_t^2\, v\, e\, g_s^2}{32\pi^2\, m_Z\, c_w\, s_w}\left[\log\left(\frac{s}{m_t^2}\right)-i\pi\right]^2$	$\frac{m_t\, v^2\, e\, g_s^2}{32\sqrt{2}\pi^2\, m_Z\, c_w\, s_w}\left[\log\left(\frac{s}{m_t^2}\right)-i\pi\right]^2$

Top meets diboson: gluon-fusion ZH production



(See also Gauld et al [2311.06107])

ANR, Thomas, Vryonidou [2306.09963]

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 level)
Probed by $qq \to ZH$ (tree level)

$p_{T,\min} = \min\{p_T^Z, p_T^H\}$

Categories		$p_{T,\min} \in$
0-lepton	boosted	$\{0, 300, 350, \infty\}$
	resolved	$\{0, 160, 200, 250, \infty\}$
2-lepton	boosted	$\{250, \infty\}$
	resolved	$\{175, 200, \infty\}$

A global view: Fisher matrix from SMEFiT 3.0

Celada et al [2404.12809]

- ✓ SMEFiT 3.0 is a toolbox for **global interpretations** of particle physics data in the **SMEFT framework**.

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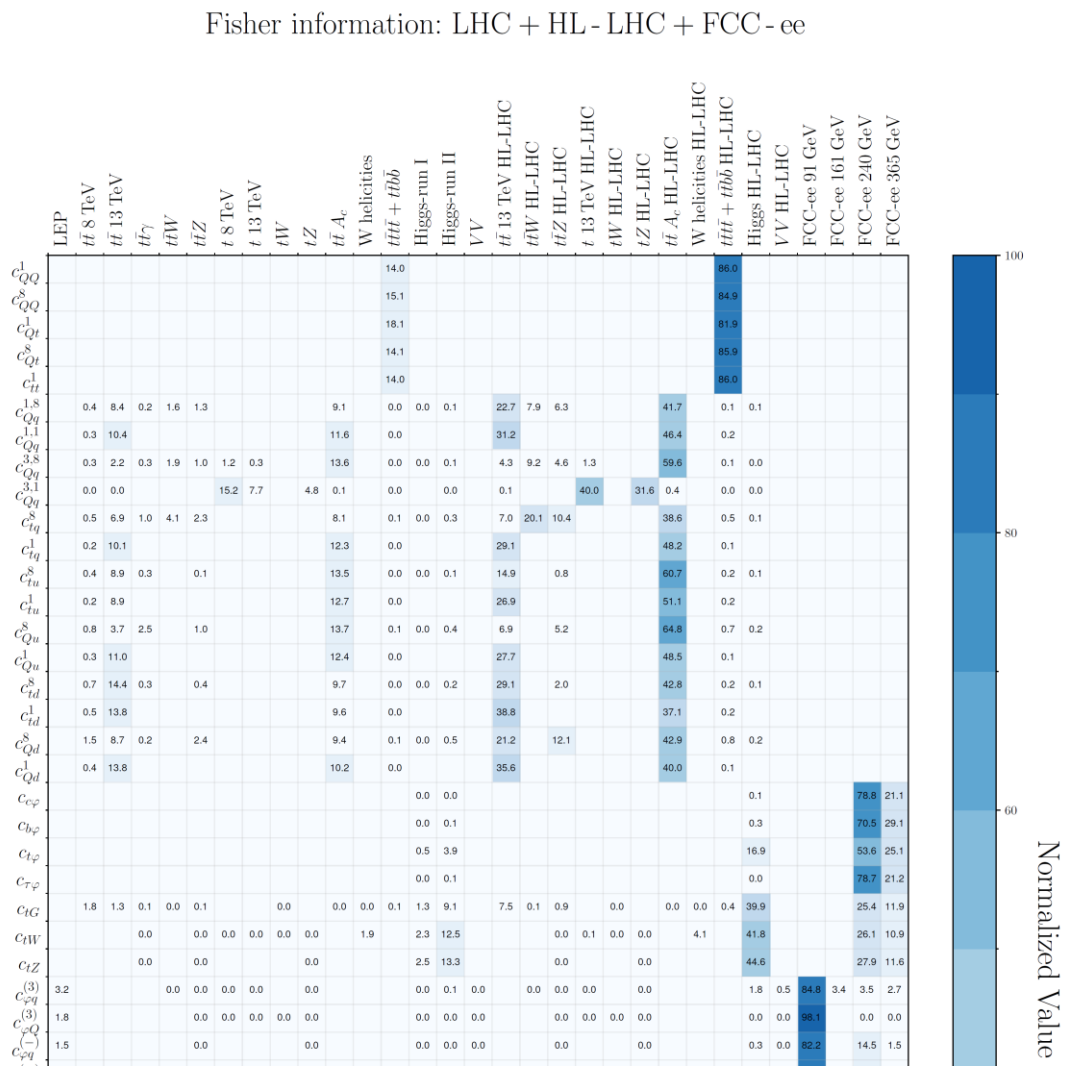

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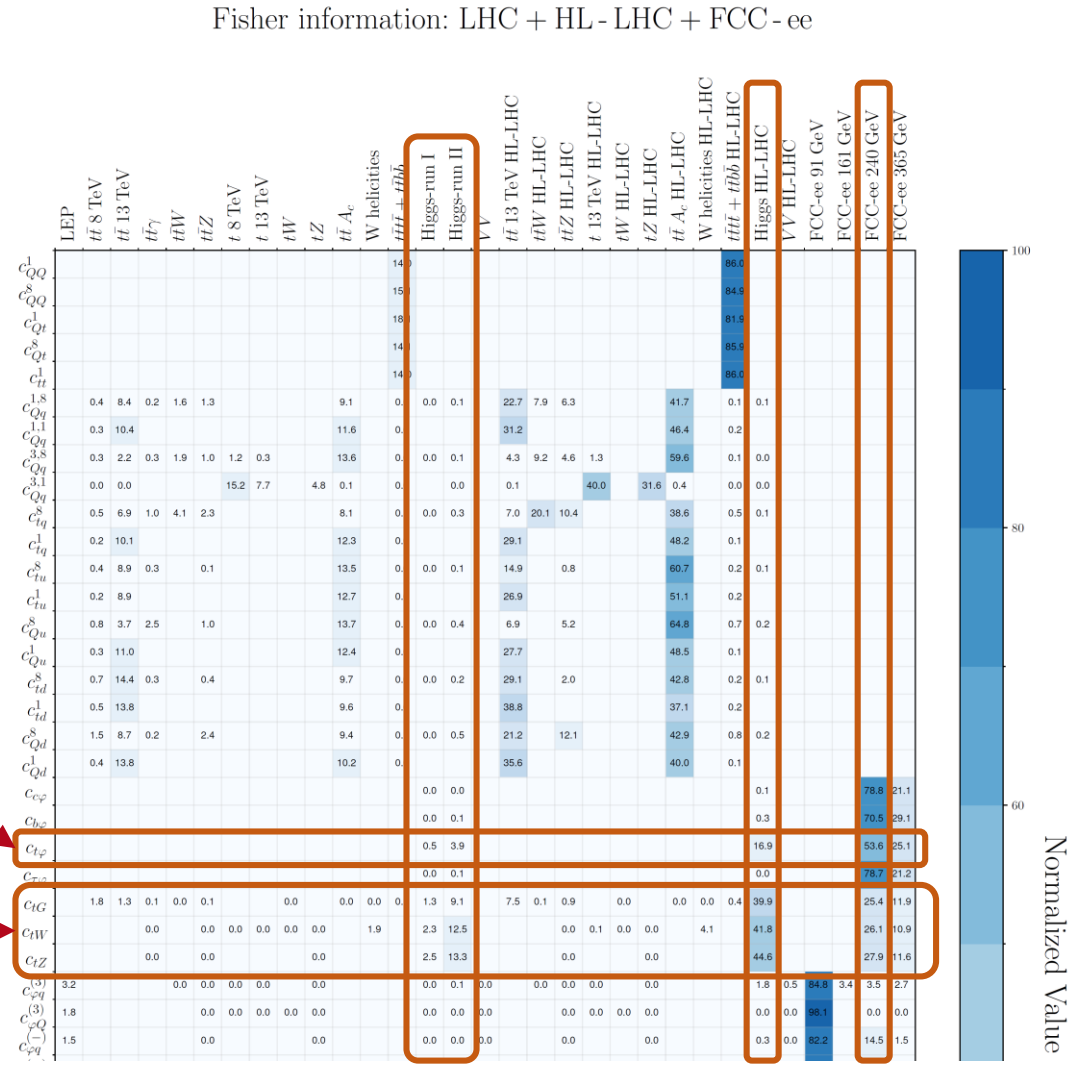
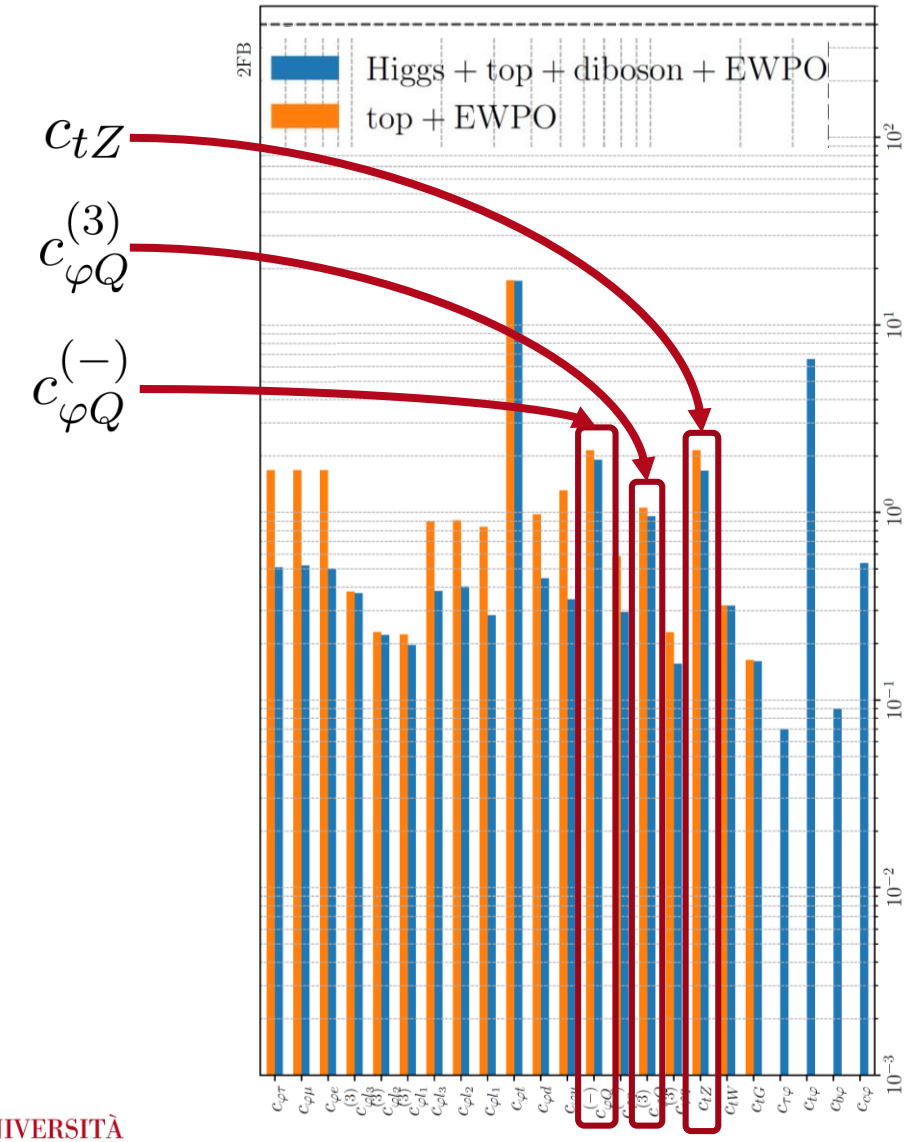
$c_{t\varphi}$

c_{tG}, c_{tW}, c_{tZ}



A global view: dataset complementarity

Celada et al [2404.12809]



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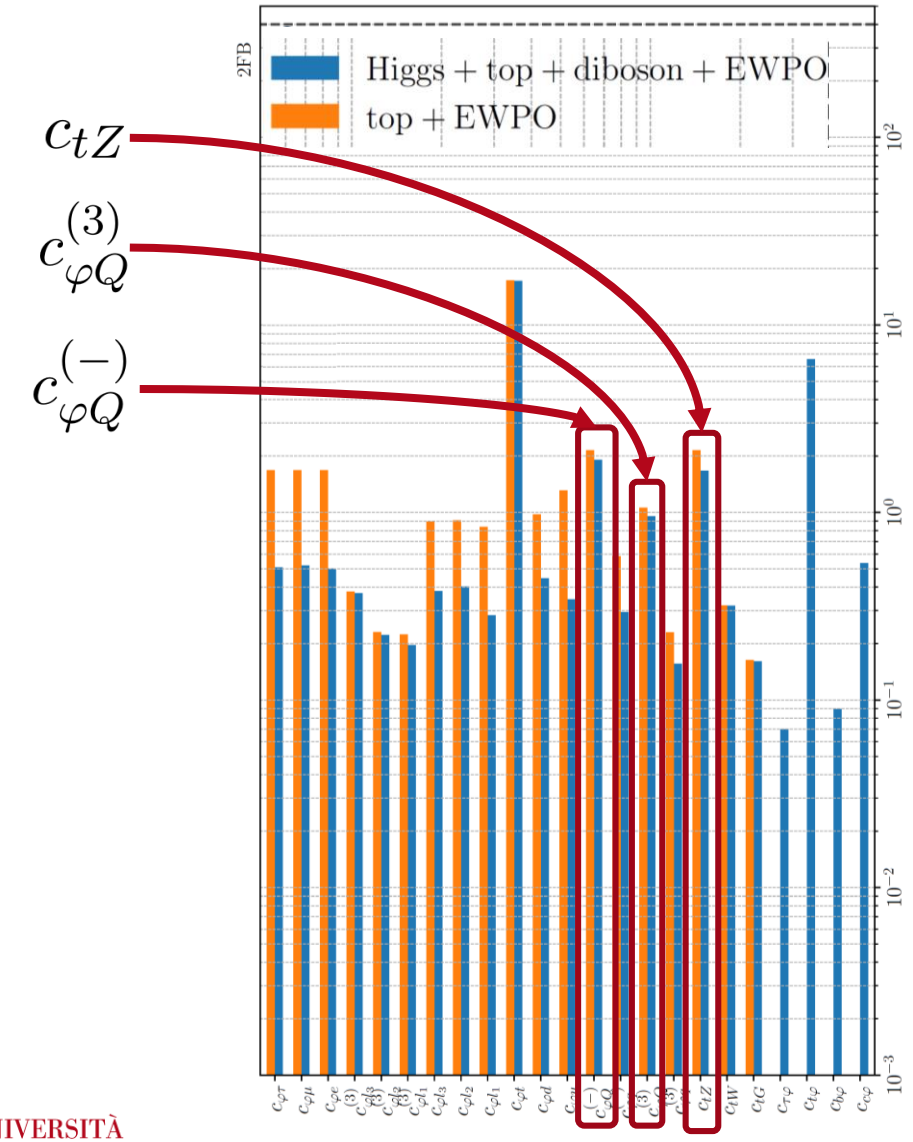
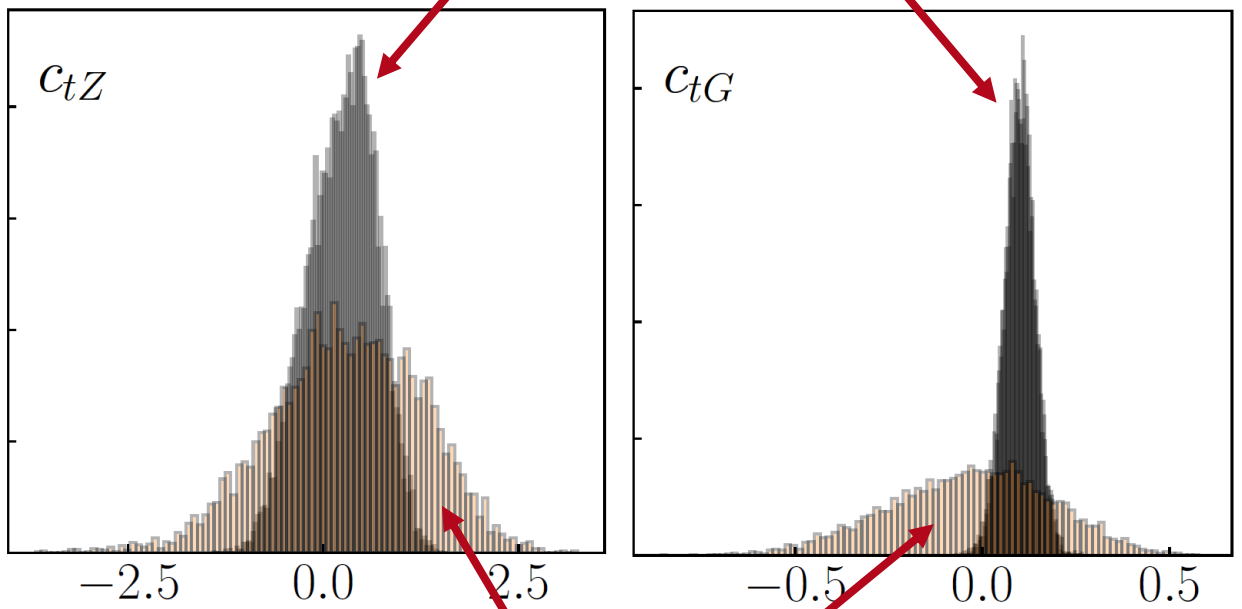


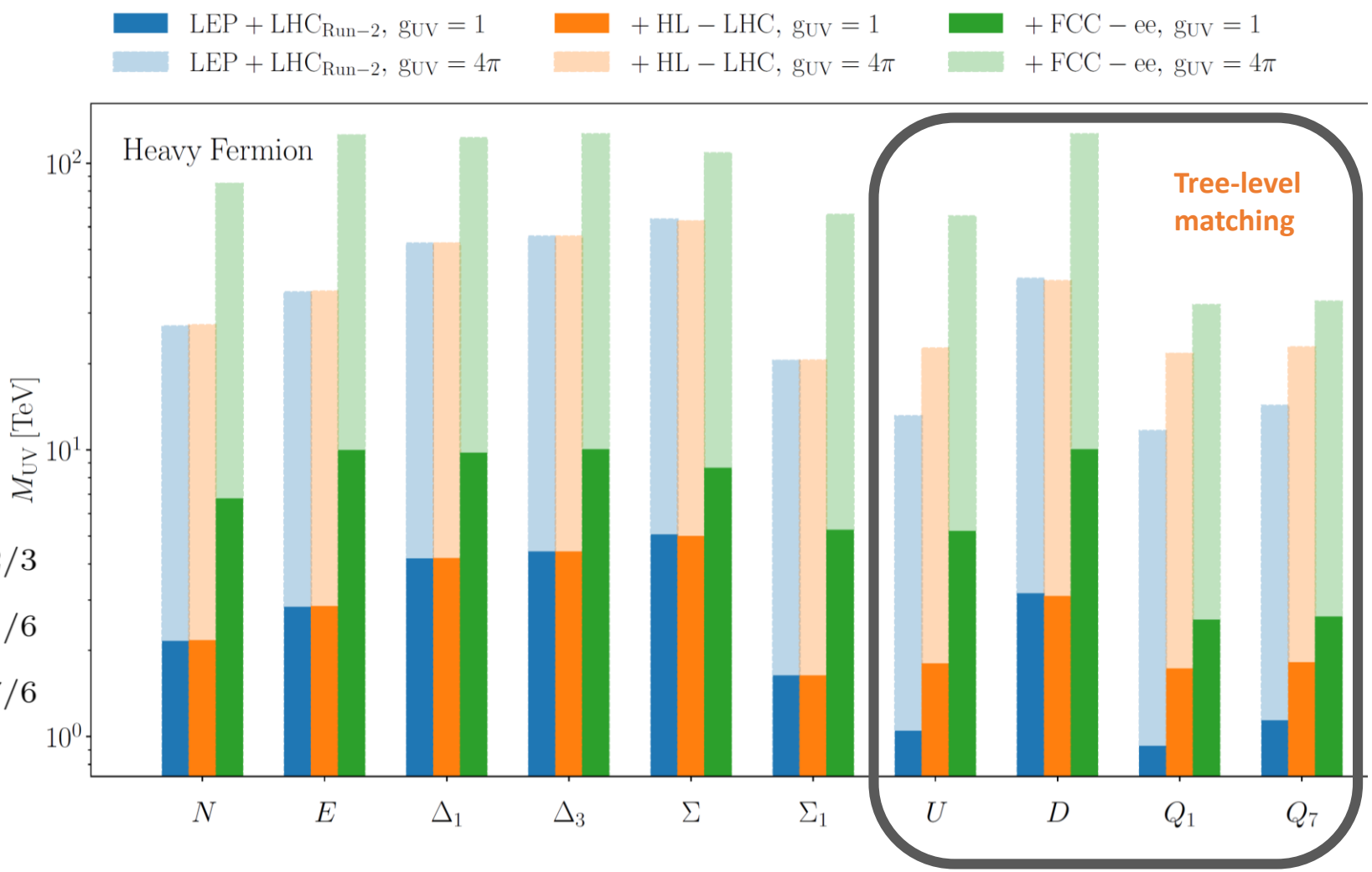
EWPOs + Higgs + VV + top



EWPOs + Higgs

A global view: hunting top partners

Celada et al [2404.12809]



Top partners

$U \sim (\mathbf{3}, \mathbf{1})_{2/3}$

$Q_1 \sim (\mathbf{3}, \mathbf{2})_{1/6}$

$Q_7 \sim (\mathbf{3}, \mathbf{2})_{7/6}$

(See also N. Selimovic's talk)

match2fit

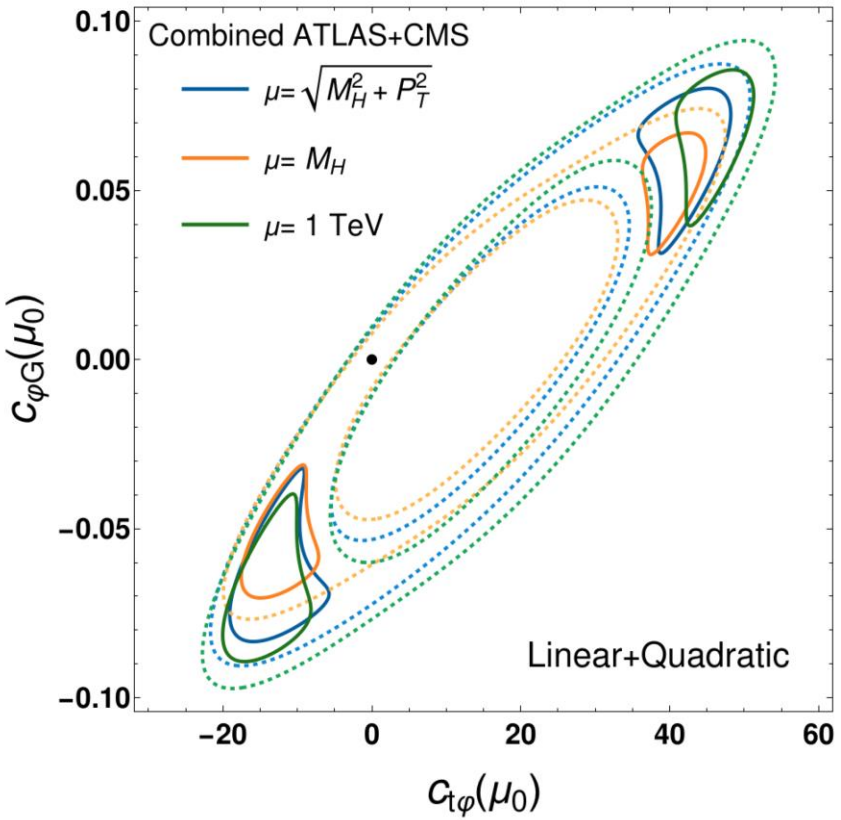
MEFiT

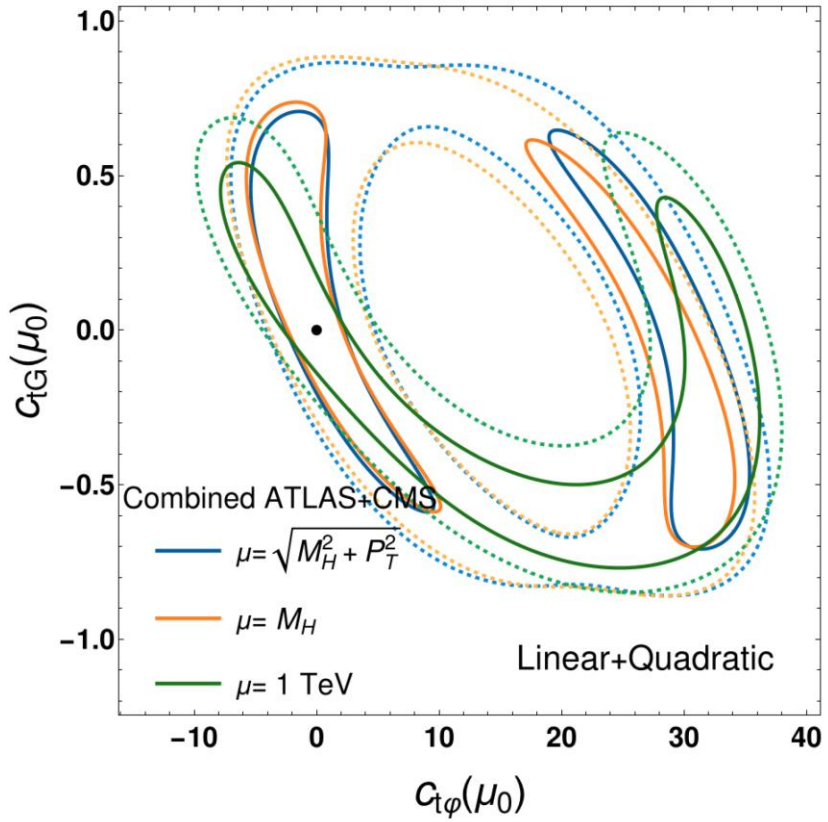
ter Hoeve et al [2309.04523]

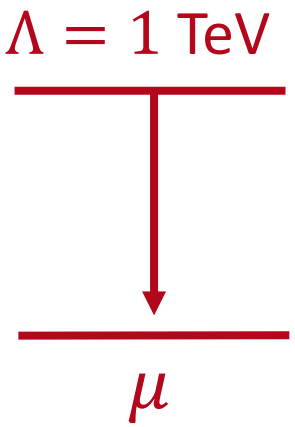
Running top operators in HH production

See G. Ventura's talk for details

Maltoni, Ventura, Vryonidou [2406.06670]

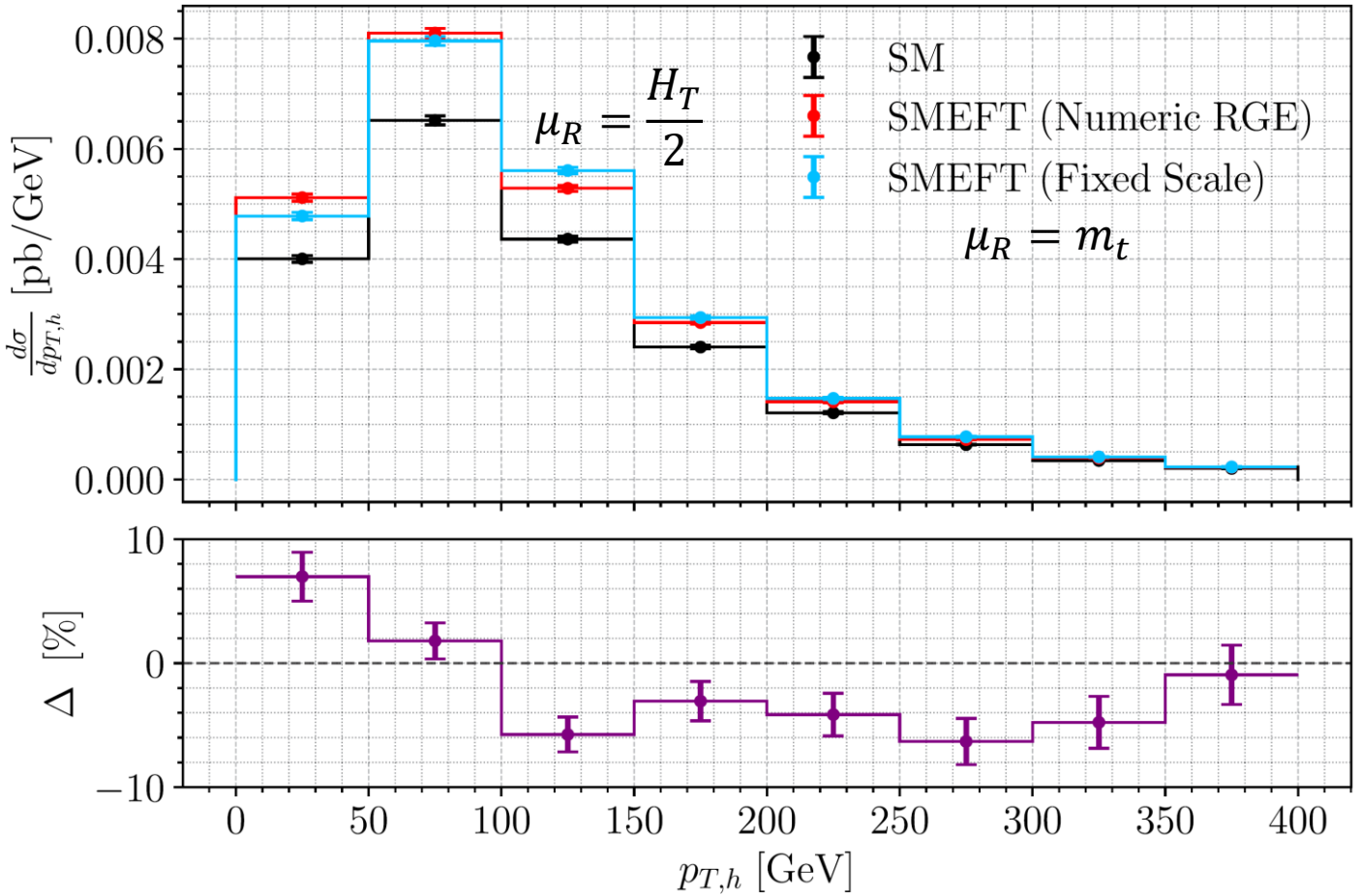




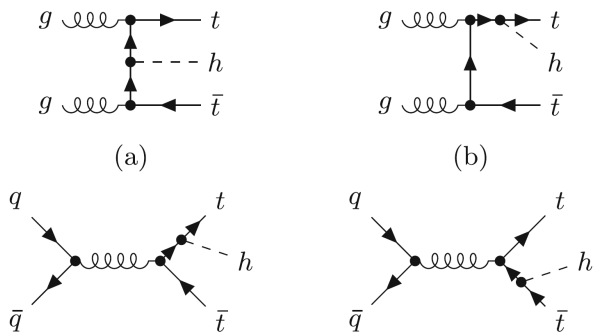


Bounds are sensitive to the RGE scale choice.

Top Yukawa running in ttH production



Di Noi and Gröber [2312.11327]



$$C_{Qt}^{(1)}(\Lambda) = \frac{4}{3} \times 20\,/\mathrm{TeV}^2$$

$\Lambda = 2$ TeV

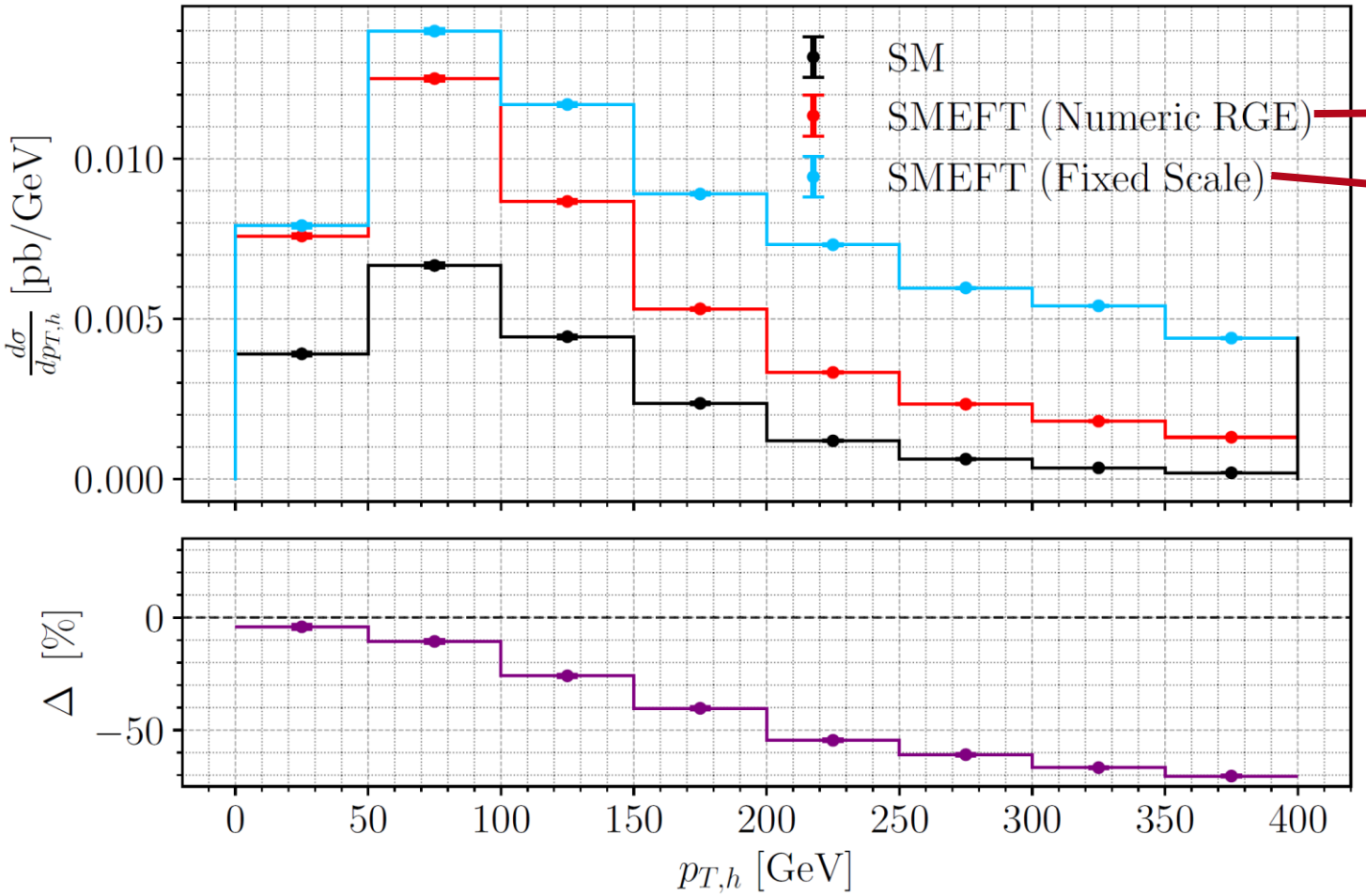
$$\mu \frac{dC_{tH}}{d\mu} \propto y_t^3\, C_{Qt}^{(1)}$$

μ_R

Top Yukawa-led running matters.

Top Yukawa running in ttH production

Di Noi and Gröber [2312.11327]



$\mu_R = \frac{H_T}{2}$

$\mu_R = m_t$

$\mathcal{C}_{4\text{tops}} = 25\ \text{TeV}^{-2}$

$\mathcal{C}_{2\text{t2q}} = 0.25\ \text{TeV}^{-2}$

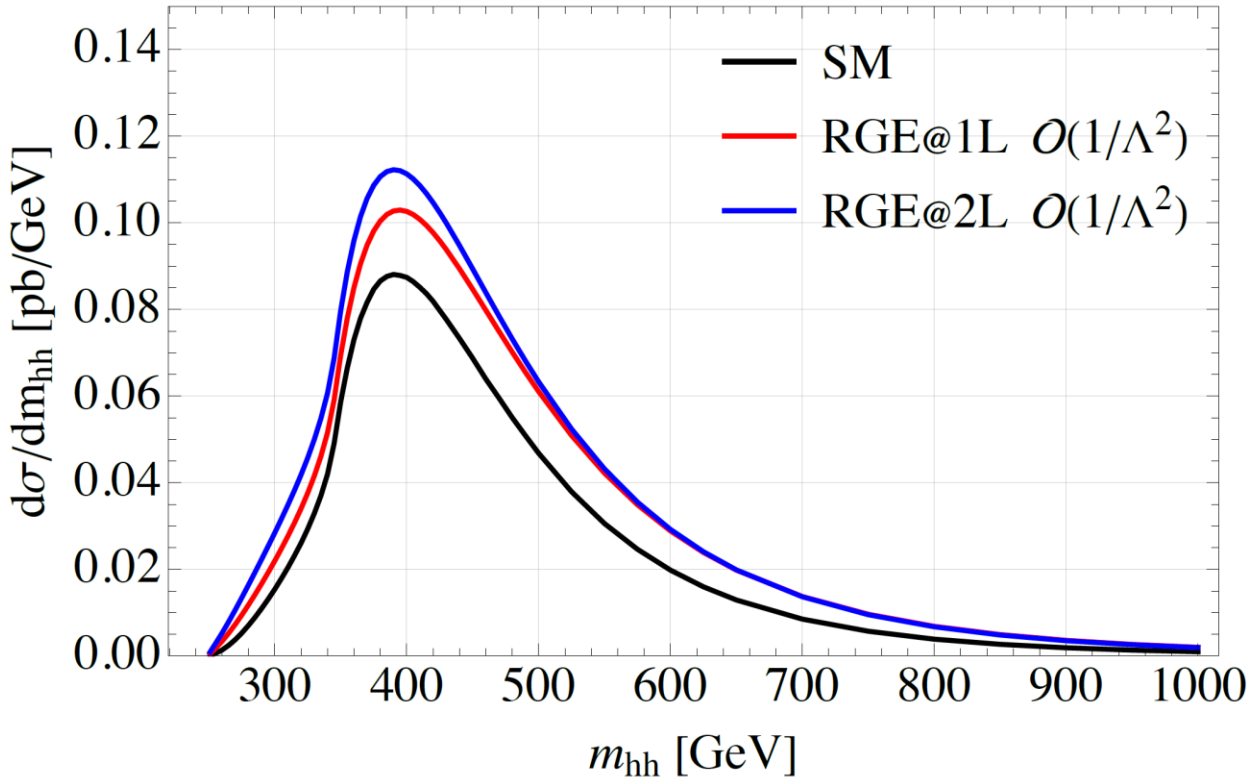
$\mathcal{C}_{\text{Others}} = \text{SMEFiT bound}$

$\Lambda = 2$ TeV

μ_R

Up to 70% difference between fixed-scale and dynamical RGE.

2-loop SMEFT RGE in HH production



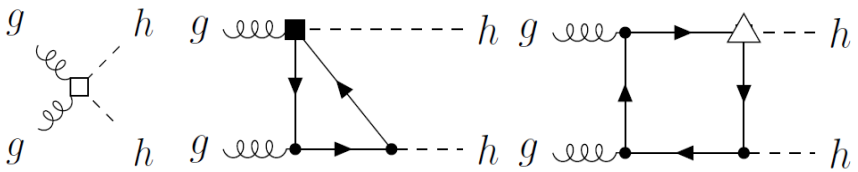
Di Noi, Gröber, Mandal [2408.03252]

$$\mathcal{C}_{tG}(\Lambda) = -\frac{1}{16\pi^2},\ \mathcal{C}_{Qt(1,8)}(\Lambda) = -10,\ \mathcal{C}_{H}(\Lambda) = 0$$

$$\mathcal{C}_{tH}(\Lambda) = 1,\ \mathcal{C}_{HG}(\Lambda) = \frac{1}{16\pi^2}$$

$\Lambda = 1$ TeV

m_h



Partial 2-loop RGE for $\mathcal{O}_{HG}$ and effect on HH/Hj production

$$\mu\frac{d\mathcal{C}_{HG}}{d\mu} \supset 3\left(\frac{1}{16\pi^2}\right)^2 g_s^2\left[\mathcal{C}_{tH}Y_t + \mathcal{C}_{tH}^*Y_t^* + \mathcal{C}_{bH}Y_b + \mathcal{C}_{bH}^*Y_b^*\right] - 4\left(\frac{1}{16\pi^2}\right)^2 g_s^2 Y_t Y_t^* \delta_{NDR}\left(\mathcal{C}_{Qt}^{(1)} - \frac{1}{6}\mathcal{C}_{Qt}^{(8)}\right)$$

Conclusions

- Top-Higgs interactions are fundamental for our understanding of the Universe
- Its importance is well motivated in both bottom-up and top-down approaches to NP
- Global fits that consider many processes at the same time are key
- A key stepping stone to probing the Higgs potential.
- RGE effects are relevant.
- Impressive progress in several directions. And more to come!

Thanks for your attention!

Alejo N. Rossia

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