

Impact of SMEFT renormalisation group running on Higgs production at the LHC

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with F. Maltoni and E. Vryonidou, based on 2406.06670

Higgs and Effective Field Theory 2024

Bologna, 13/06/2024



The University of Manchester

Effects of RGEs in the SMEFT

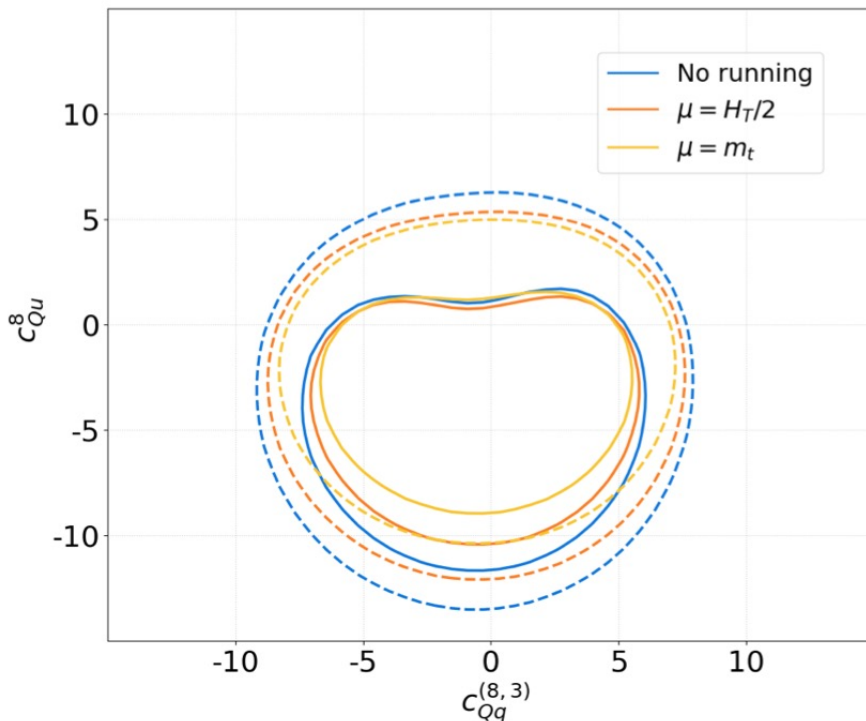
Upon renormalisation, operators run and mix as dictated by the RGEs

$$\sigma_{\text{SMEFT}} = \sigma_{\text{SM}} + \sum_i \frac{c_i(\mu)}{(\Lambda/1 \text{ TeV})^2} \sigma_i(\mu) + \sum_{i \leq j} \frac{c_i(\mu)c_j(\mu)}{(\Lambda/1 \text{ TeV})^4} \sigma_{ij}(\mu)$$

$$\frac{dc_i(\mu)}{d \log \mu^2} = \gamma_{ij} c_j(\mu)$$

Jenkins, Manohar and Trott
[1308.2627, 1310.4838, 1312.2014]

Bound for $O_{Qq}^{(8,3)}$ and O_{Qu}^8



Different choices of the renormalisation scale μ can impact observables and bounds on Wilson coefficients

Plot from Aoude, Maltoni, Mattelaer, Severi and Vryonidou
[arXiv:2212.05067]

See also:
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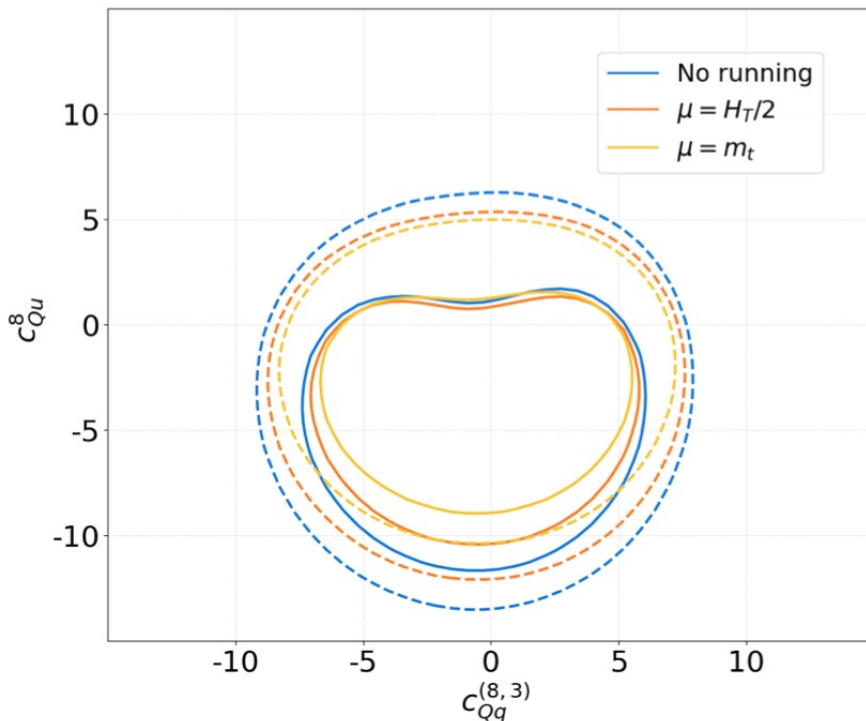
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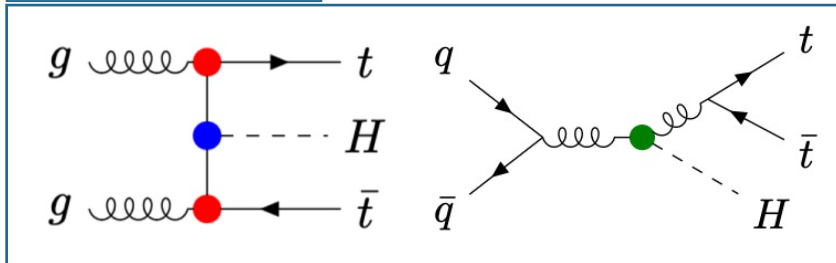
- We extend the study of (**QCD-induced**) RG effects by considering the impact on Higgs observables at the LHC, and on constraints of relevant Wilson coefficients

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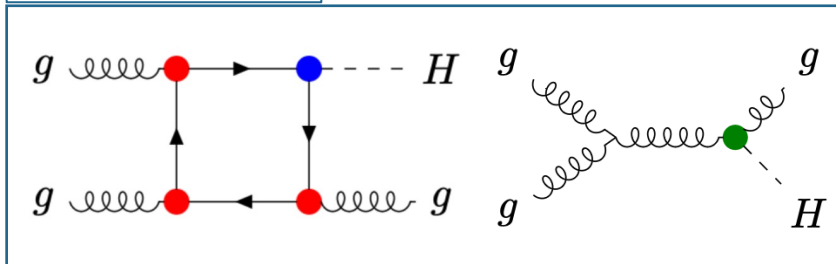
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SMEFT contribution to Higgs observables

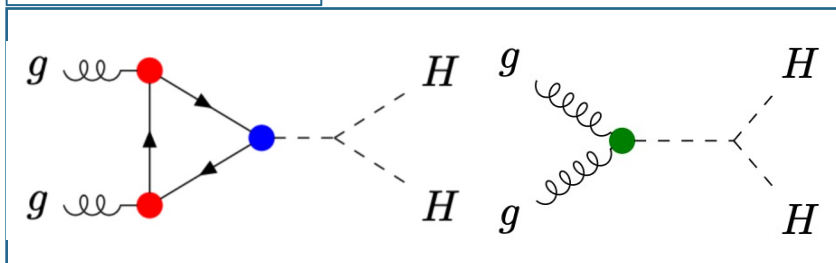
$pp \rightarrow t \bar{t} h$



$pp \rightarrow h j$



$pp \rightarrow h h$



Leading contribution from:

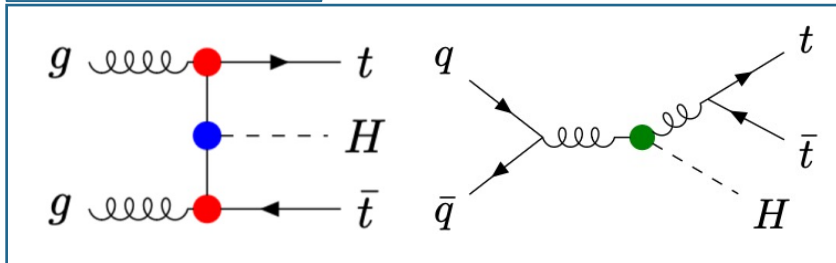
$$\mathcal{O}_{\varphi G} = \left(\varphi^\dagger \varphi - \frac{v^2}{2} \right) G_{\mu\nu}^a G_a^{\mu\nu}$$

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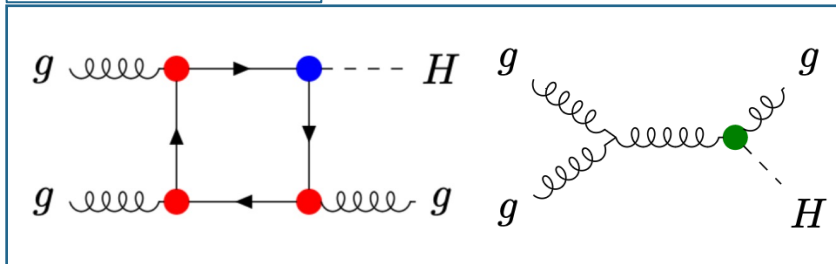
$$\mathcal{O}_{tG} = i g_s (\bar{Q} \tau^{\mu\nu} T^a \tilde{\varphi} t) G_{\mu\nu}^a + \text{h.c.}$$

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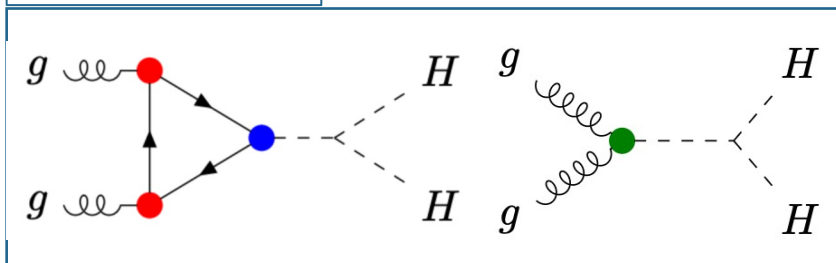
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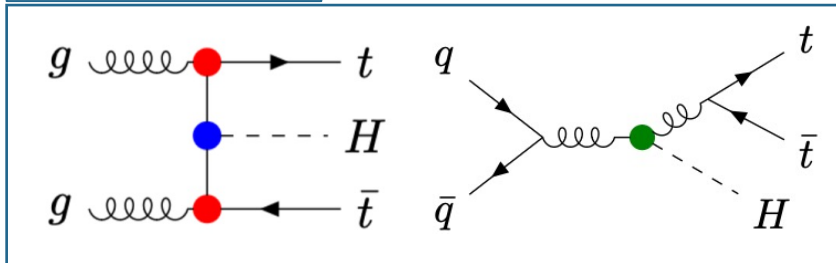
Induces tree-level diagrams for hh and hj

Divergences in hh and hj reabsorbed by $\mathcal{O}_{\varphi G}$

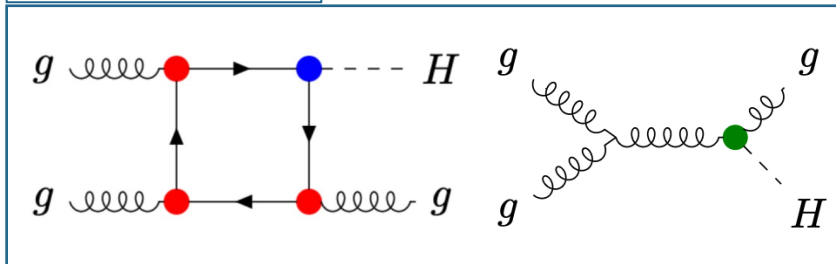
\mathcal{O}_{tG} -inserted cross-section terms will depend on the renormalisation scale μ

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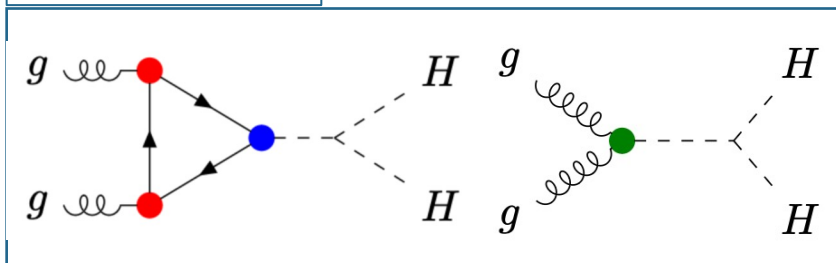
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Closed under QCD-induced
anomalous dimension matrix

Maltoni, Vryonidou and Zhang
[arXiv: 1607.05330]

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Impact of scale choice on distributions

SM and EFT cross-sections computed with MadGraph and SMEFT@NLO ($\mu_0 = 1 \text{ TeV}$)

Scale choices

- **Dynamical scale** (event-by-event variation)
- **Fixed scale** ($\mu_0 \rightarrow \mu$)
- **No running** ($\mu_0 = \mu = 1 \text{ TeV}$)

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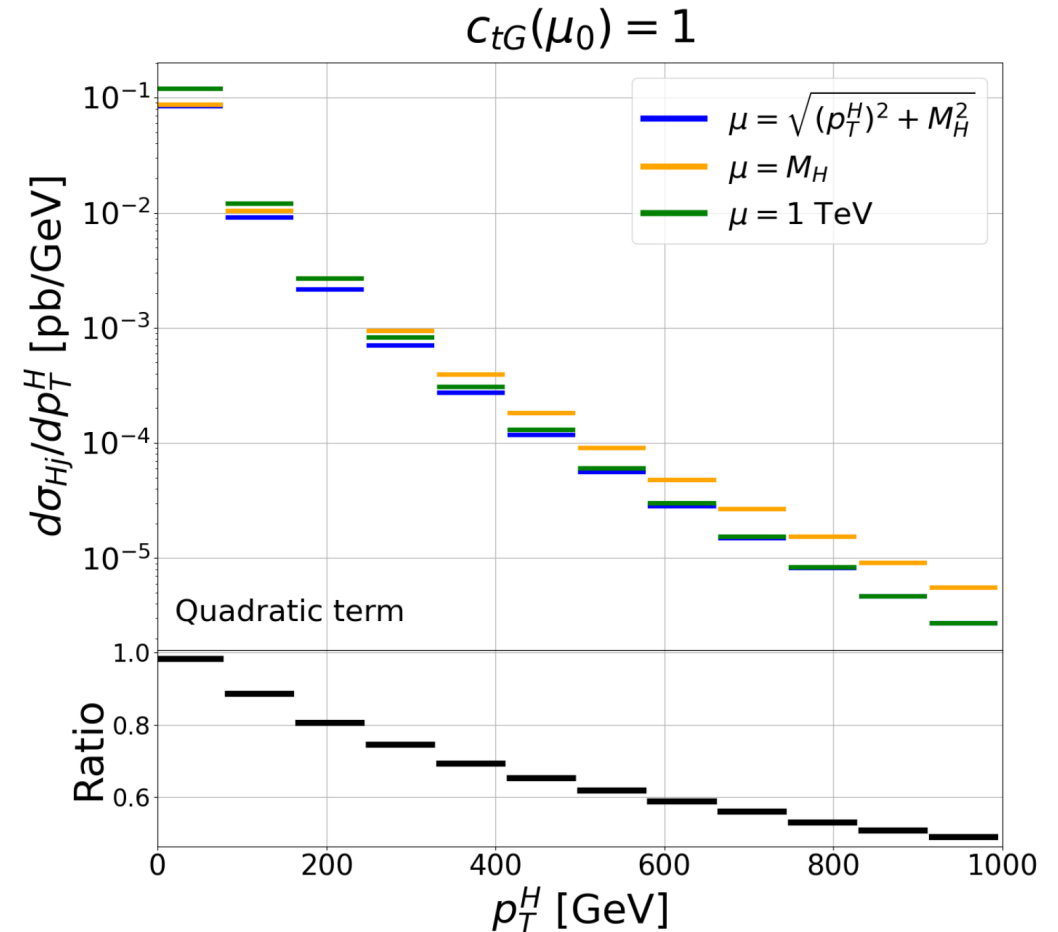
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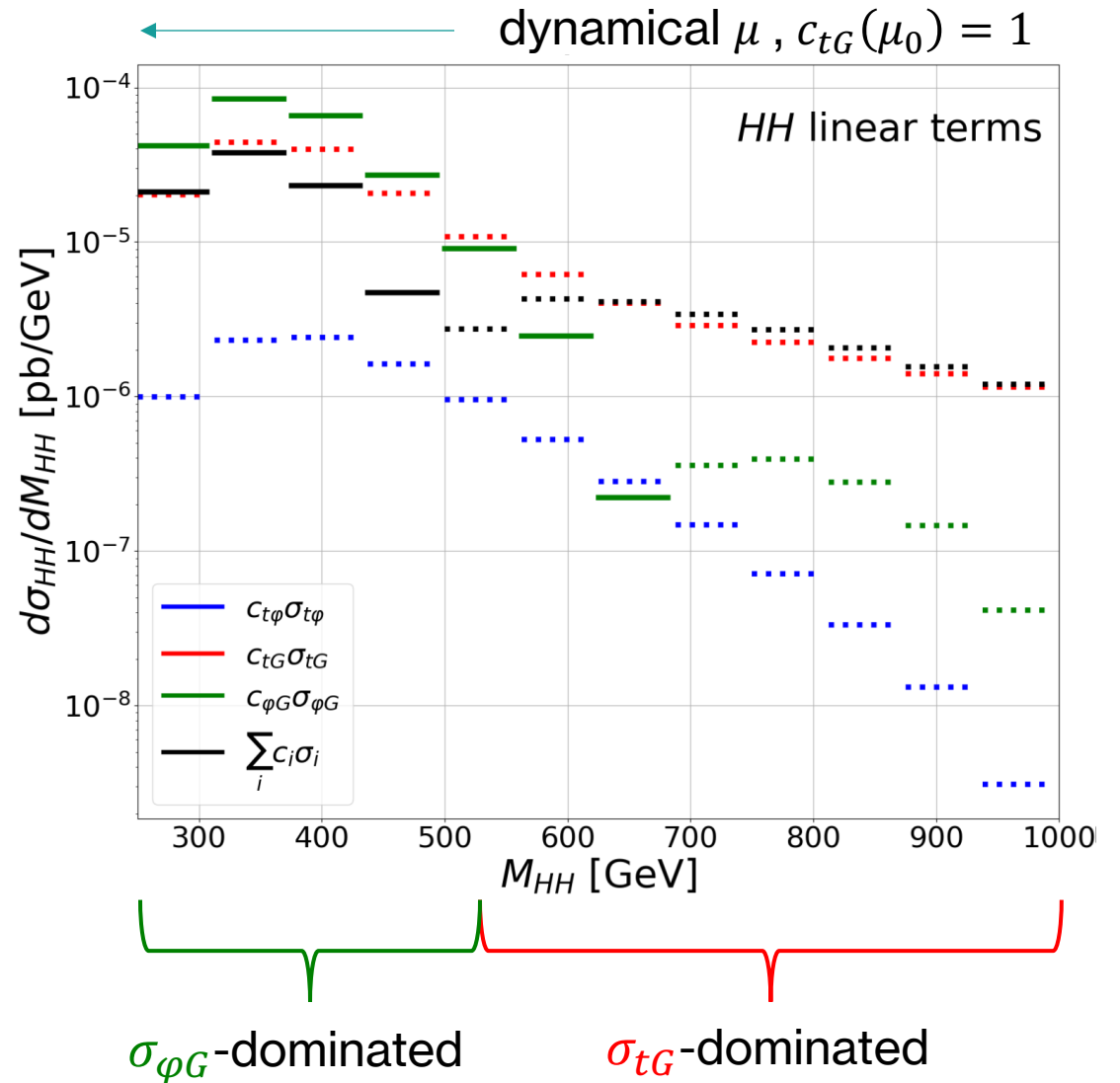
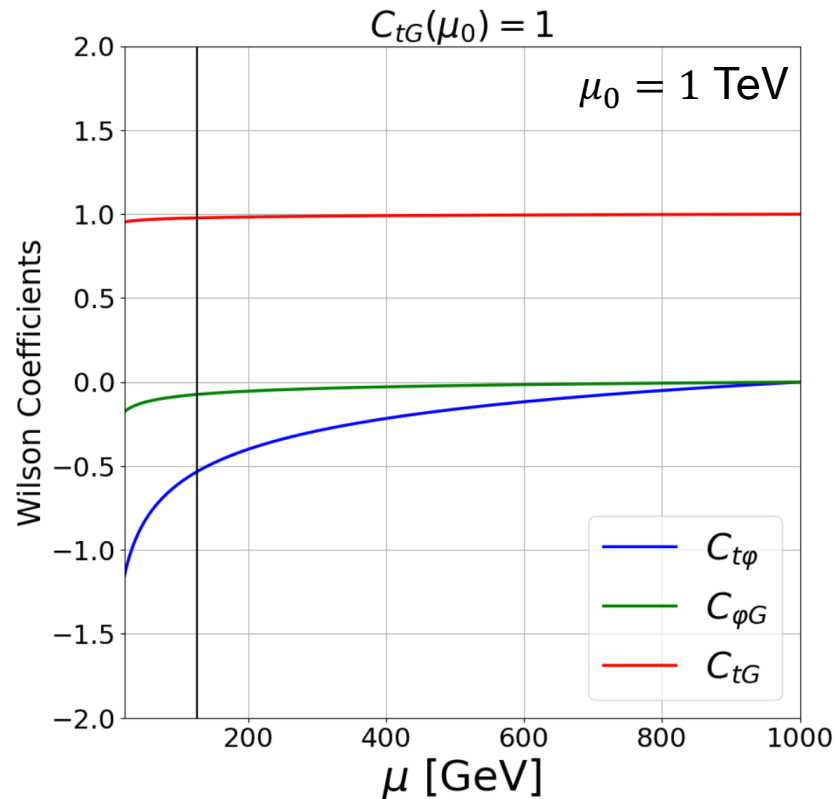
		Variation (up to)	
		Linear	Quadratic
Benchmarks	$pp \rightarrow h j$		
	$c_{t\phi}(\mu_0) = 1$	10%	20%
	$c_{\phi G}(\mu_0) = 1$	20%	35%
	$c_{tG}(\mu_0) = 1$	30%	50%

\mathcal{O}_{tG} causes the biggest impact in loop-induced processes



Mixing effects in loop-induced processes

When $c_{tG}(\mu_0) \neq 0$, the RGEs will activate $\mathcal{O}_{\varphi G}$ inducing tree-level contributions resulting in a strong mixing among different terms



Impact of RGEs on bounds : current data

Toy fit of differential p_T^H spectrum to inclusive data from ATLAS and CMS* ($p_T^H > 200$ GeV)

Constraints extracted at $\mu_0 = 1$ TeV

Marg.	μ dynamical	$\mu = M_H$	$\mu = 1$ TeV
$c_{t\varphi}$	[-21.00, 50.15]	[-19.56, 46.98]	[-21.17, 53.69]
$c_{\varphi G}$	[-0.095, 0.092]	[-0.085, 0.081]	[-0.10, 0.095]
c_{tG}	[-0.68, 0.69]	[-0.70, 0.65]	[-0.77, 0.49]

Enhanced constraints for $c_{t\varphi}$ and $c_{\varphi G}$

*[arXiv: 2006.13251, arXiv: 2111.08340]

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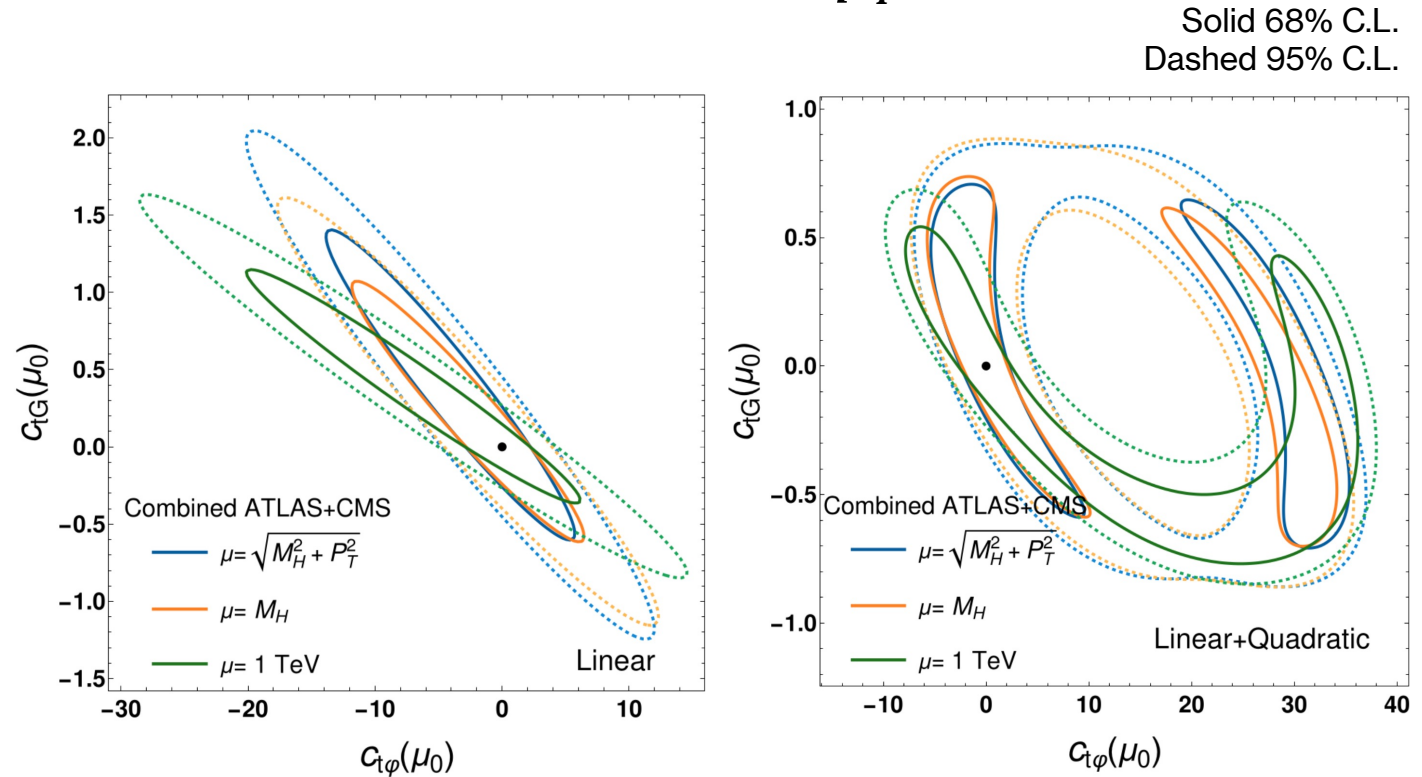
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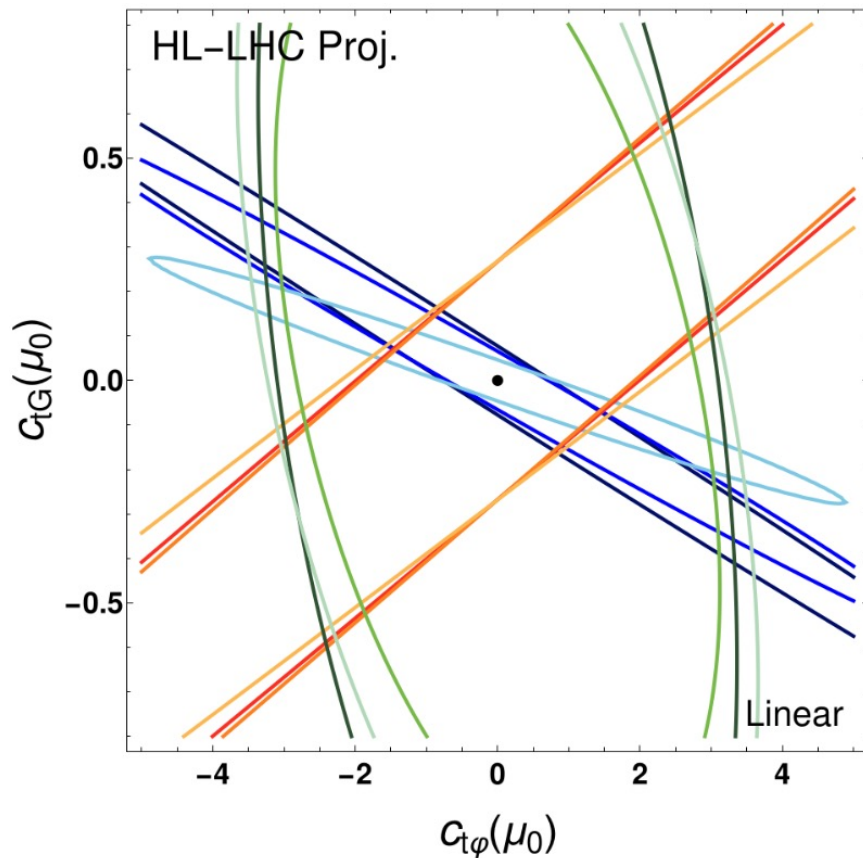
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Impact on correlations between coefficients, flat directions get rotated in the EFT parameter space

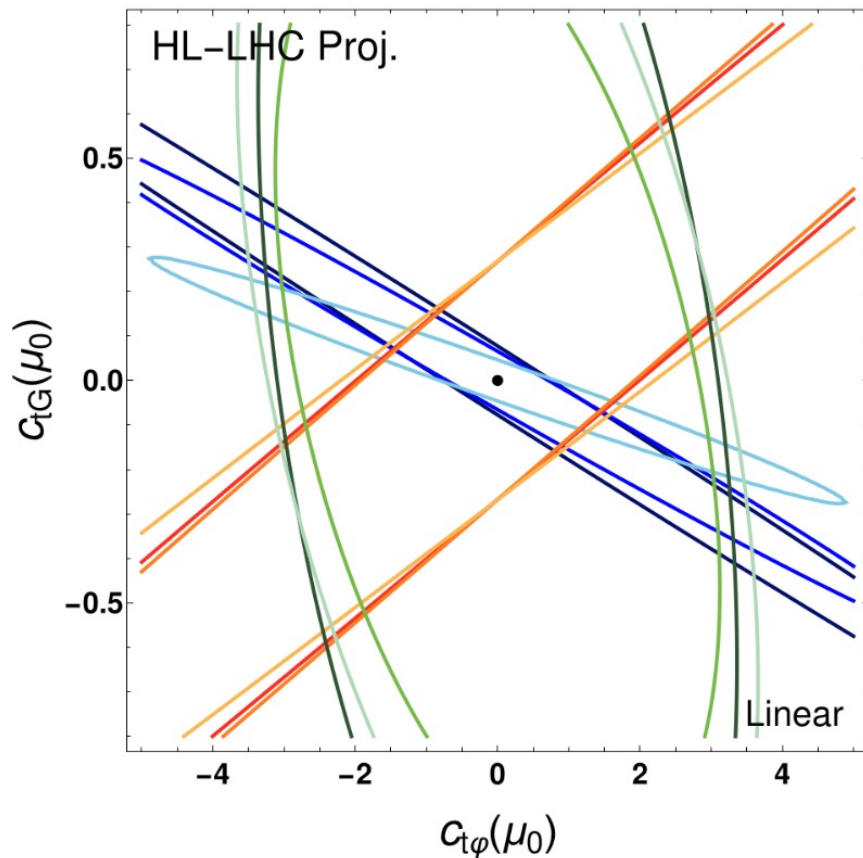
Impact of RGEs on bounds : HL-LHC

Toy fit with projected uncertainties for **inclusive p_T^H spectrum**, **$t \bar{t} h$ differential cross-section** and **HH invariant mass spectrum** [arXiv: 1902.00134]



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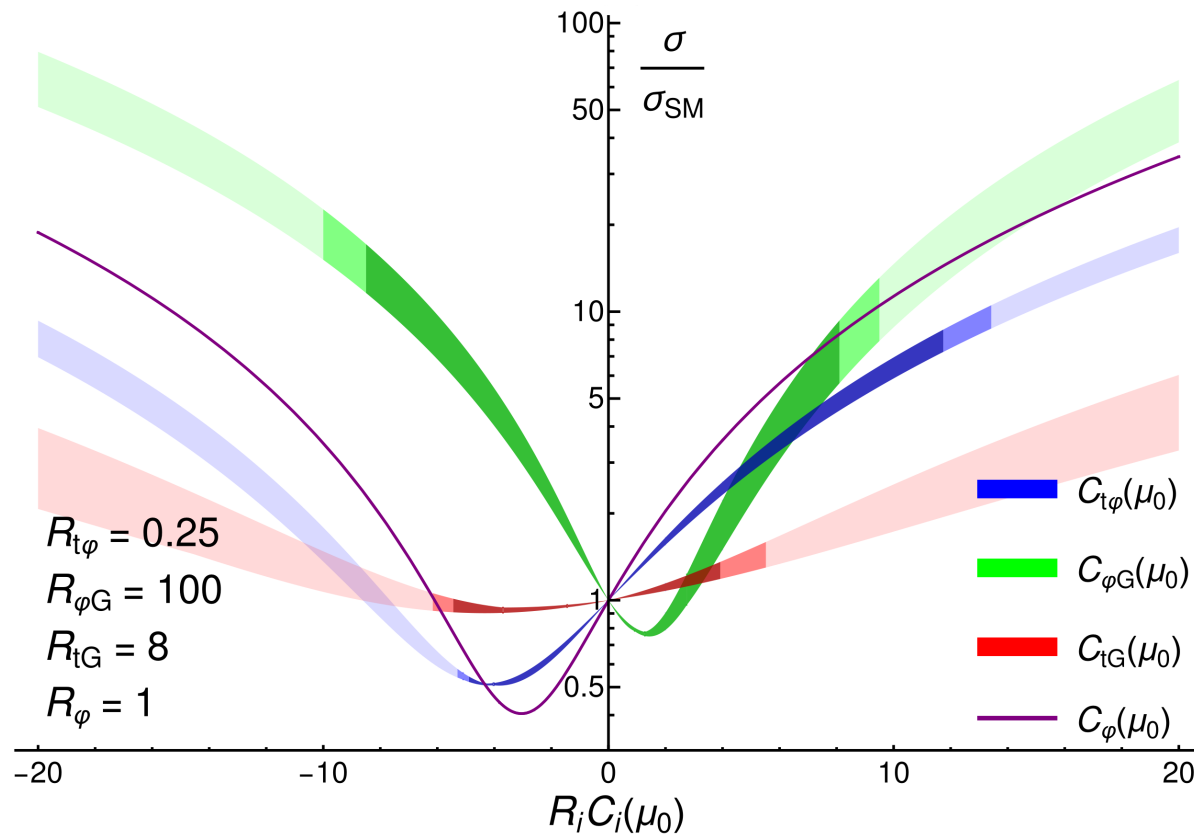
Marginalised	μ dynamical	$\mu = M_H$	$\mu = 1$ TeV (no running)
$c_{t\phi}$	[-2.02, 2.24]	[-1.95, 2.18]	[-1.69, 1.59]
$c_{\phi G}$	[-0.012, 0.012]	[-0.012, 0.012]	[-0.010, 0.0083]
c_{tG}	[-0.25, 0.21]	[-0.26, 0.22]	[-0.13, 0.11]

Bound for c_{tG} widened by a factor of 2 when running is activated

HH production and impact on Higgs self-interaction

Double Higgs production probes Higgs trilinear coupling at hadron colliders, which is modified by \mathcal{O}_φ

$$\mathcal{O}_\varphi = \left(\varphi^\dagger \varphi - \frac{v^2}{2} \right)^3$$

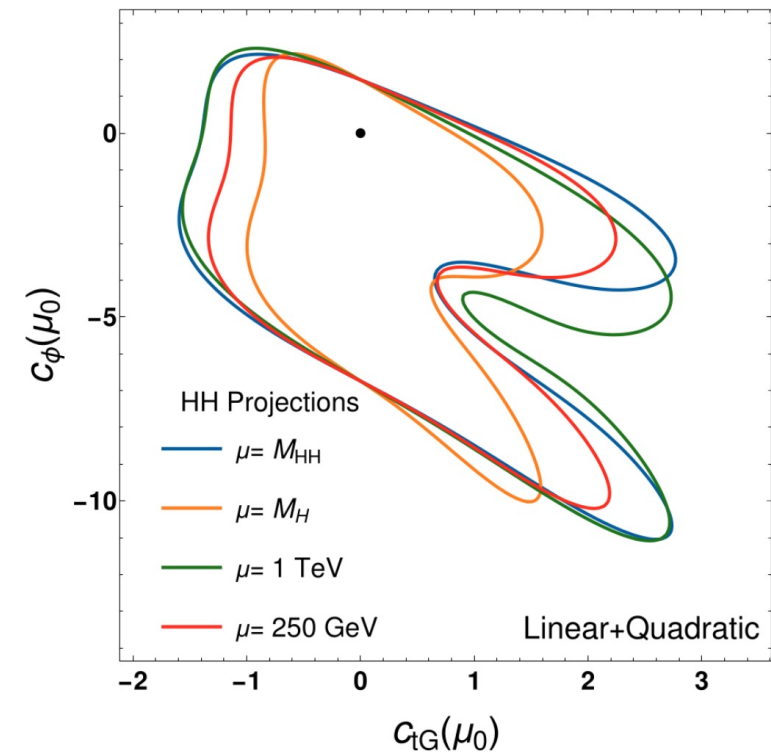
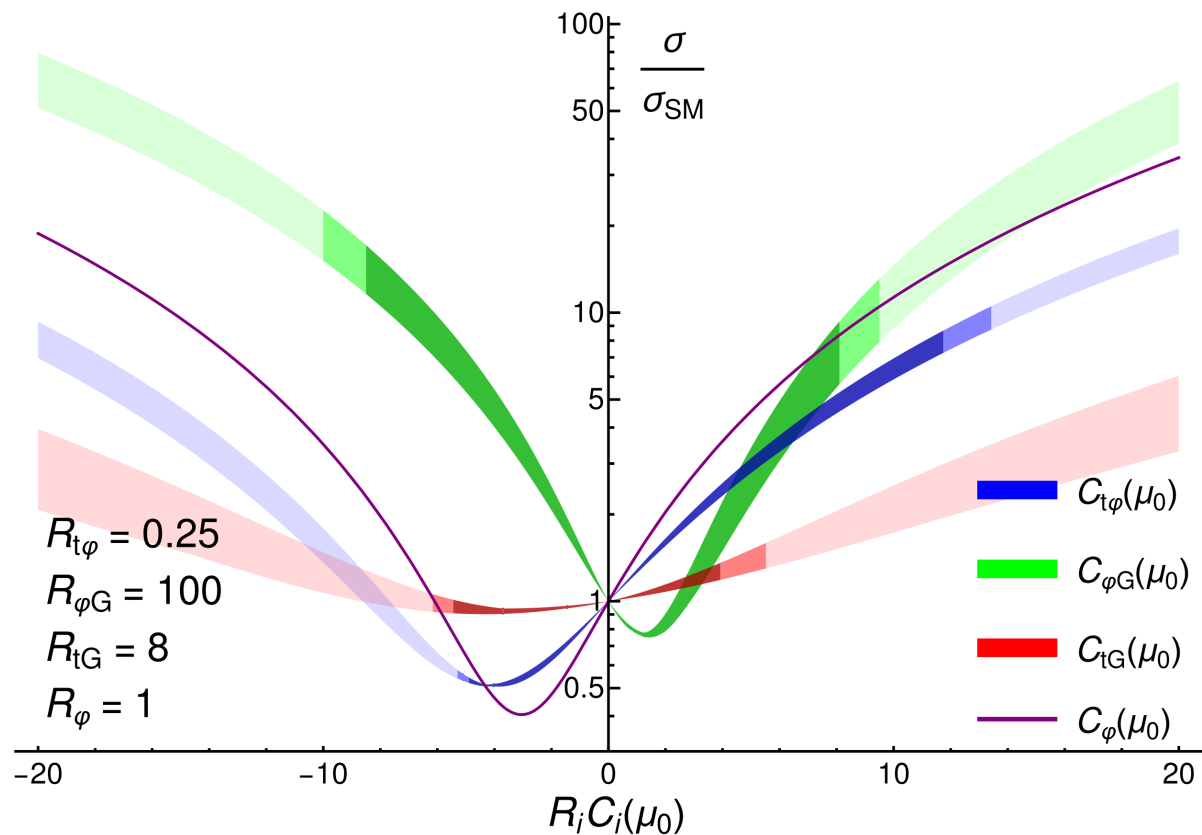


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Does not run under QCD, impact of scale choice through marginalisation



Conclusions

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➔ Motivation to include such effects in global fits

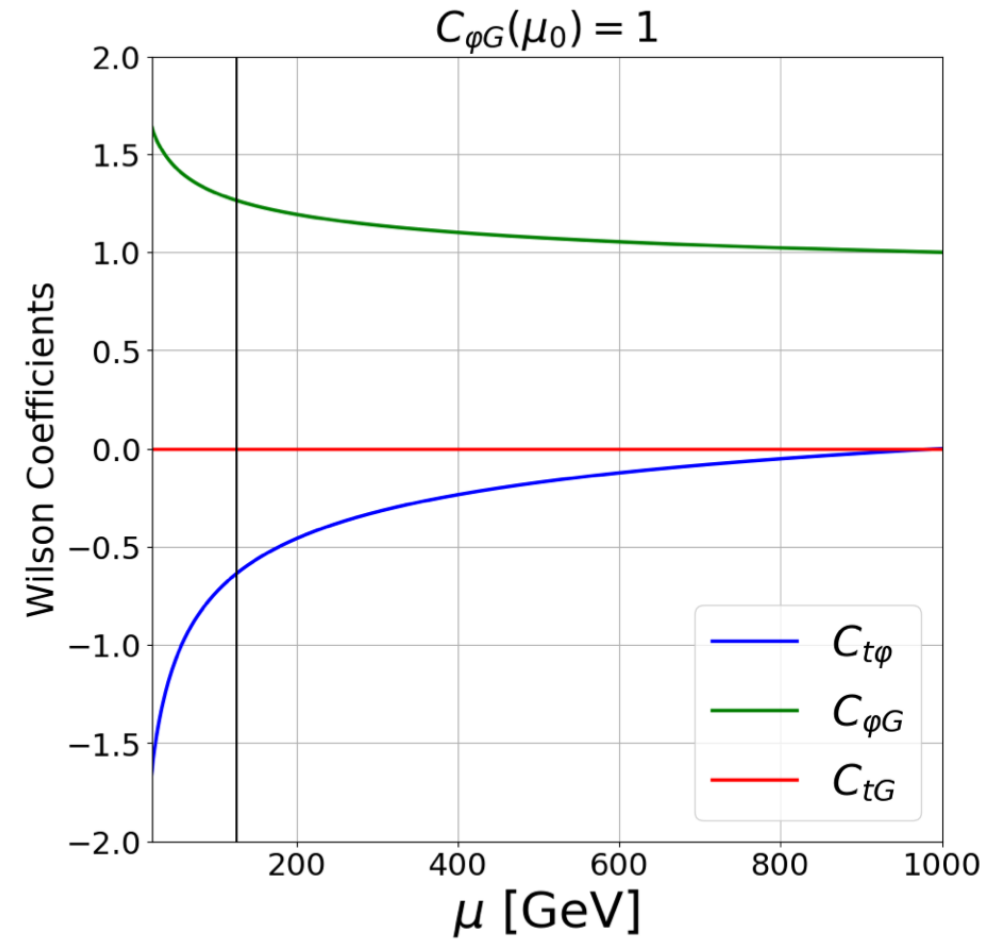
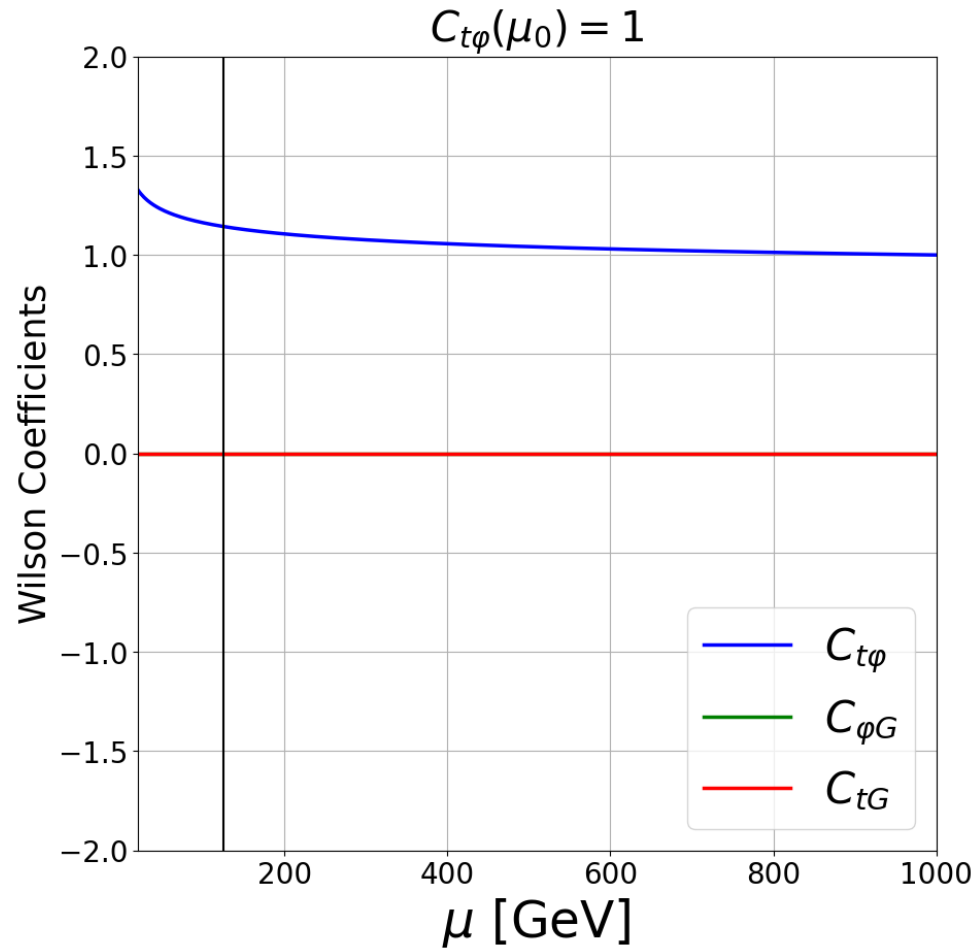
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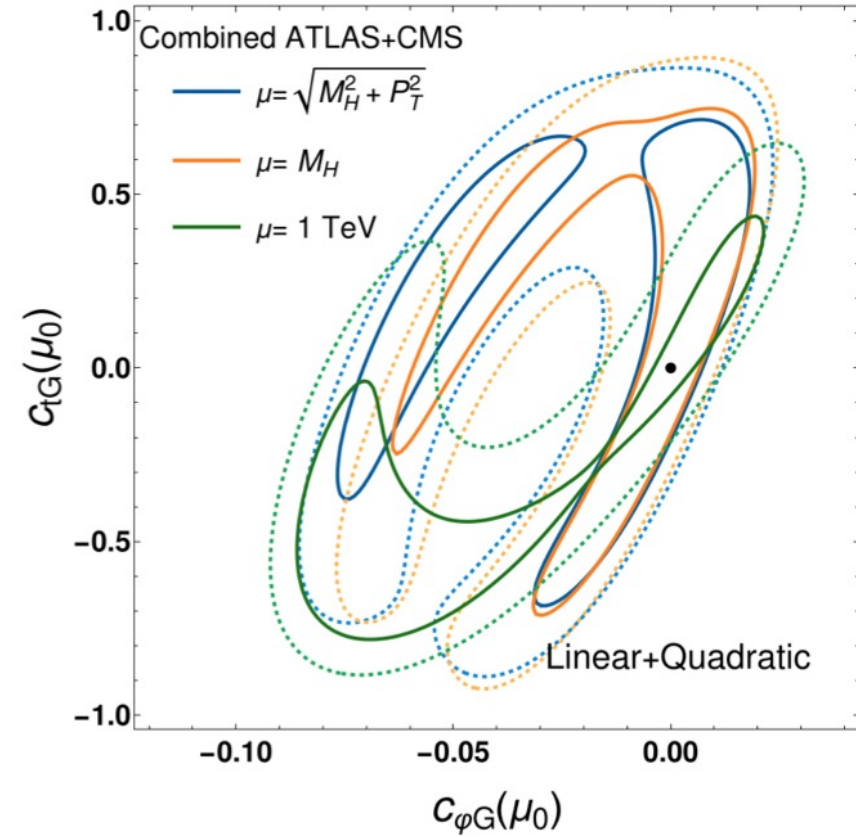
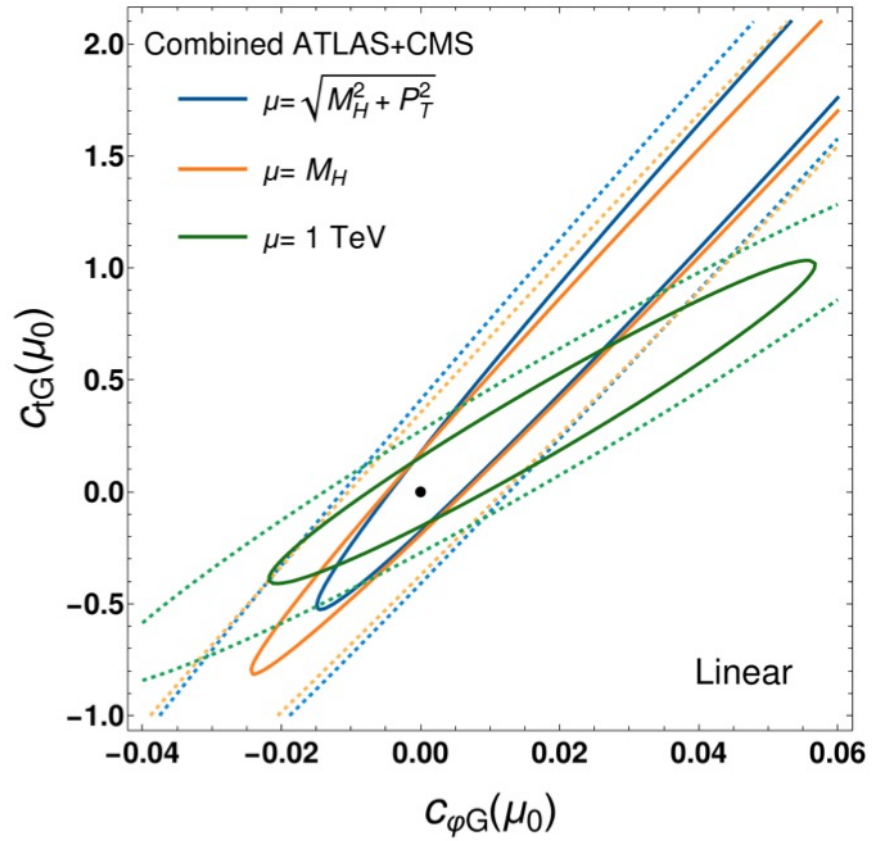
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Thank you

Backup: Running of the couplings



Backup: other 2D fits



Backup: more plots about mixing

