Enhancing fits of SMEFT Wilson coefficients in the top-quark sector

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SMEFT - Standard Model Effective Field Theory

effective extension of the SM Lagrangian for energies much higher than the SM scale:

$$\mathcal{L}_{\mathrm{SMEFT}} = \mathcal{L}_{\mathrm{SM}} + \underbrace{\frac{1}{\Lambda} C^{(5)} O^{(5)}}_{\text{neutrino masses}} + \underbrace{\frac{1}{\Lambda^2} \sum_i C_i^{(6)} O_i^{(6)}}_{\text{BSM physics}} + \ldots$$

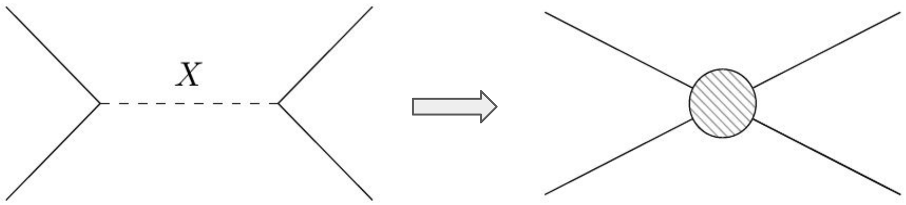
mass dimension = 4

Λ : energy scale

O_i : higher dimensional operators

C_i : Wilson coefficients

- higher dimensional operators based on SM symmetries & constructed from SM fields



⇨ model-independent probes of BSM phenomena by constraining values of the Wilson coefficients

Constraining SMEFT Wilson coefficients in the top-quark sector

- many BSM models predict deviations in top quark couplings
- efforts ongoing to constrain Wilson coefficients of dimension-six operators affecting the top quark

two studies investigating aspects for enhancing SMEFT fits in the top quark sector:

1) **including observables from *B* physics** [Eur. Phys. J. C 80 (2020) 136]

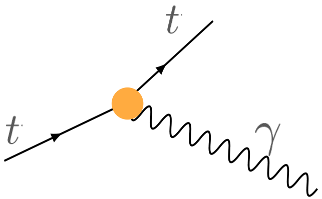
2) impact of correlations between uncertainties [1912.06090]

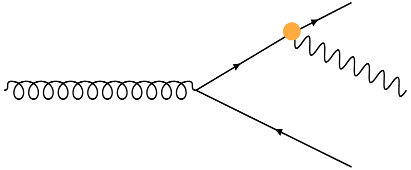
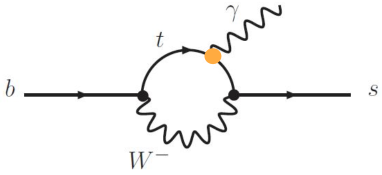
Combining measurements from top quark and *B* physics

- top quark related EFT operators also affect *B* physics processes

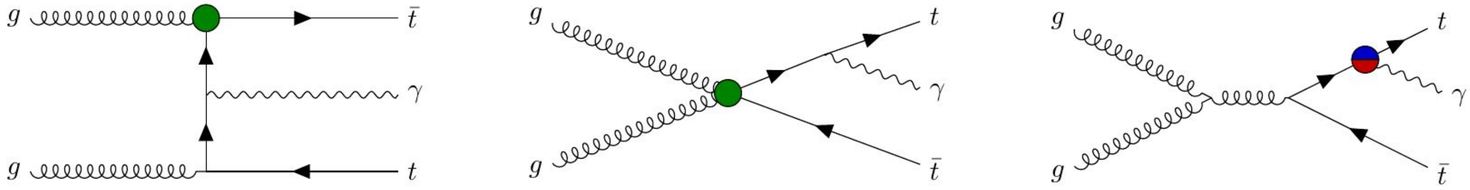
  ➩ combine measurements of top quark & *B* physics observables in one fit to constrain Wilson coefficients

- example: top-quark photon coupling



Top	***B***
$t\bar{t}\gamma$  production cross section	$b \to s + \gamma$  $\mathrm{BR}(\bar{B} \to X_s\gamma)$

$t\bar{t}\gamma$ production cross section



- Operators affecting top-boson interaction:

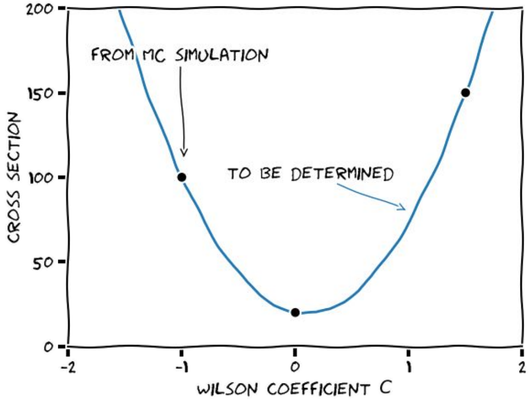
$$O_{uG} = \left(\bar{q}\sigma^{\mu\nu}T^{A}u\right)\tilde{\varphi}G^{A}_{\mu\nu}\,, \quad O_{uB} = \left(\bar{q}\sigma^{\mu\nu}u\right)\tilde{\varphi}B_{\mu\nu}\,, \quad O_{uW} = \left(\bar{q}\sigma^{\mu\nu}\tau^{I}u\right)\tilde{\varphi}W^{I}_{\mu\nu}$$

- consider fiducial cross section measurement by ATLAS @ 13TeV [Eur. Phys. J. C 79 (2019) 382]
- computation of BSM cross sections: *MadGraph* + *dim6top* UFO model
- interpolation using quadratic polynomial ⇨ parametrization of cross section as a function of Wilson coefficients

$$\sigma = \sigma^{\mathrm{SM}} + \frac{1}{\Lambda^2}\sum_i C_i \sigma_i^{\mathrm{interf.}} + \frac{1}{\Lambda^4}\sum_{i\leq j} C_i C_j \sigma_{ij}^{\mathrm{BSM}}$$

Madgraph

sampling points parameters



Parameterization of fiducial cross section

$$\tilde{C}_i = \frac{v^2}{\Lambda^2} C_i$$

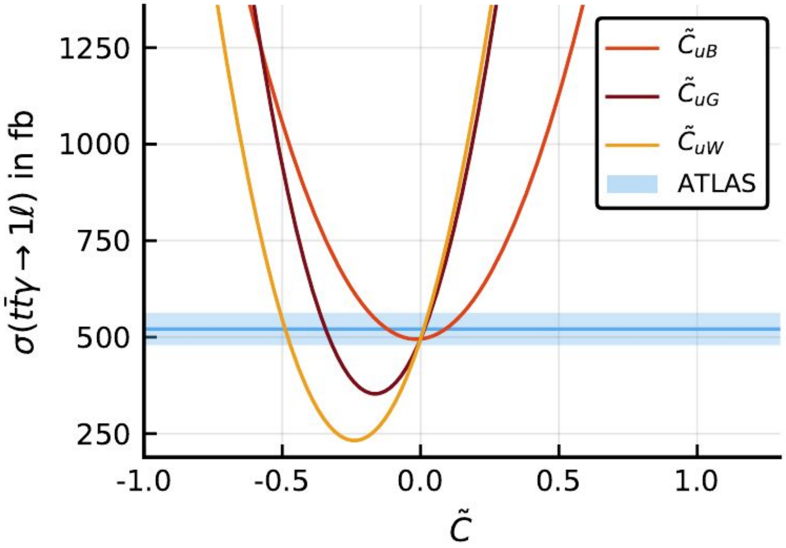
$$v = 246\,\mathrm{GeV}$$

$$\sigma_{\mathrm{fid}}(\tilde{C}_i) = \sigma_{\mathrm{tot}}(\tilde{C}_i) \cdot A_{\mathrm{fid}}(\tilde{C}_i)$$

MadGraph + dim6top + interpolation

event selection with MadAnalysis + interpolation

single-lepton channel



SMEFT vs. WET

- Top-Physics: **SMEFT**

$$\mathcal{L}_{\text{SMEFT}} = \mathcal{L}_{\text{SM}} + \sum_i \frac{C_i^{(6)}}{\Lambda^2} O_i^{(6)} + \mathcal{O}\left(\Lambda^{-4}\right)$$

- B-Physics: **WET** (Weak Effective Theory)

$$\mathcal{L}_{\text{WET}} = \frac{4G_F}{\sqrt{2}} V_{ts}^* V_{tb} \sum_{i=1}^{8} \bar{C}_i Q_i$$

Operators contributing to $t\gamma$-coupling:

$$O_{uW} = \left(\bar{q}\sigma^{\mu\nu}\tau^I u\right) \tilde{\varphi} W_{\mu\nu}^I \,,$$

$$O_{uB} = \left(\bar{q}\sigma^{\mu\nu} u\right) \tilde{\varphi} B_{\mu\nu} \,,$$

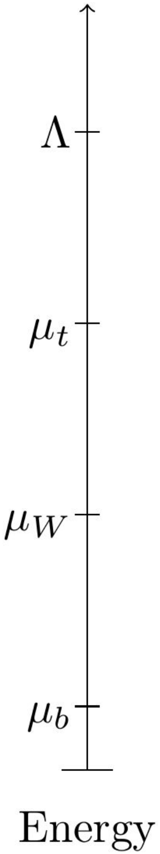
$$O_{uG} = \left(\bar{q}\sigma^{\mu\nu} T^A u\right) \tilde{\varphi} G_{\mu\nu}^A \,.$$

matching

$$Q_7 = \frac{e}{16\pi^2} m_b (\bar{s}_L \sigma^{\mu\nu} b_R) F_{\mu\nu} \,,$$

$$Q_8 = \frac{g_s}{16\pi^2} m_b (\bar{s}_L \sigma^{\mu\nu} T^a b_R) G_{\mu\nu}^a \,,$$

Energy scale

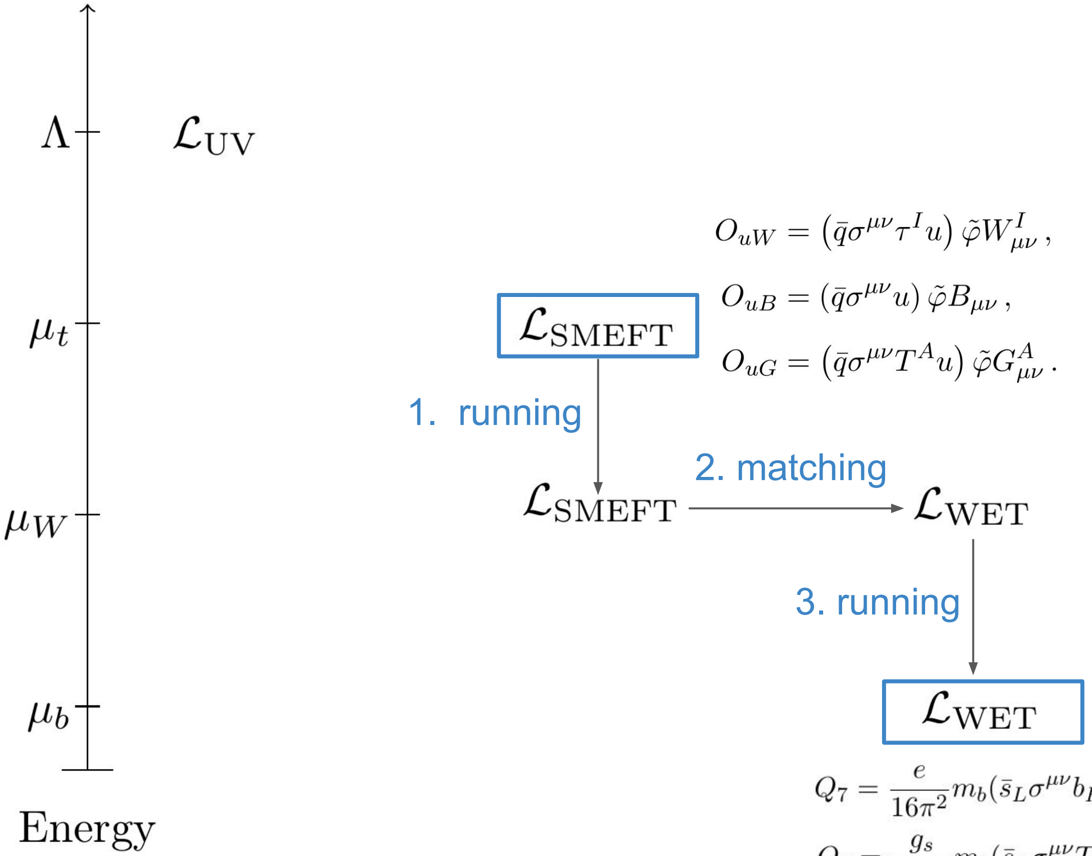


$\mathcal{L}_{\mathrm{UV}}$ $\longleftarrow$ Full theory of SM + BSM particles

$\mathcal{L}_{\mathrm{SMEFT}}$ $\longleftarrow$ SM particles

$\mathcal{L}_{\mathrm{WET}}$ $\longleftarrow$ SM particles without t, h, W, Z (integrated out)

Matching & Running



$$O_{uW} = (\bar{q}\sigma^{\mu\nu}\tau^I u)\,\tilde{\varphi}W^I_{\mu\nu}\,,$$
$$O_{uB} = (\bar{q}\sigma^{\mu\nu}u)\,\tilde{\varphi}B_{\mu\nu}\,,$$
$$O_{uG} = (\bar{q}\sigma^{\mu\nu}T^A u)\,\tilde{\varphi}G^A_{\mu\nu}\,.$$

$$Q_7 = \frac{e}{16\pi^2} m_b(\bar{s}_L\sigma^{\mu\nu}b_R)F_{\mu\nu}\,,$$
$$Q_8 = \frac{g_s}{16\pi^2} m_b(\bar{s}_L\sigma^{\mu\nu}T^a b_R)G^a_{\mu\nu}\,.$$

1. Running in SMEFT (RGE)
2. Matching SMEFT onto WET at scale μ_W
3. Running in WET (RGE)

$\mathrm{BR}(\bar{B} \to X_s\gamma)$

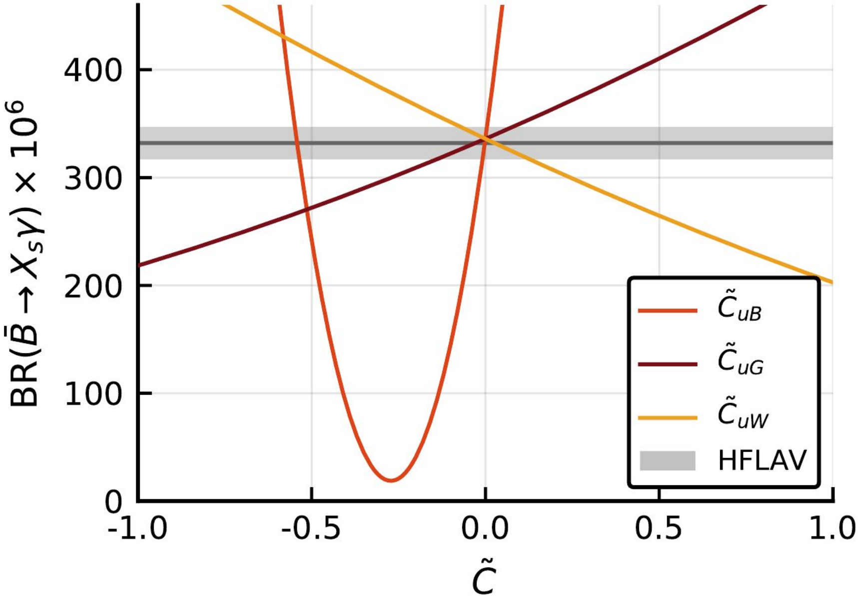
matching SMEFT onto WET:

$$\Delta C_7^{(0)} \sim \tilde{C}_{uW} A(x_t) + \tilde{C}_{uW}^* B(x_t) + \tilde{C}_{uB} C(x_t) + \tilde{C}_{uB}^* D(x_t)$$

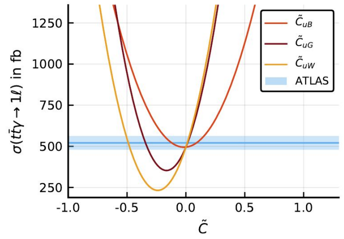
$$\Delta C_8^{(0)} \sim \tilde{C}_{uW} E(x_t) + \tilde{C}_{uW}^* F(x_t) - 2\frac{m_W}{v}\frac{(\tilde{C}_{uG} C(x_t) + \tilde{C}_{uG}^* D(x_t))}{\sqrt{4\pi\alpha_s(\mu_W)}}$$

calculation of BSM contributions is known in terms of **WET** operators [hep-ph/0609241, hep-ph/0104034]

$$\mathrm{BR}(\bar{B} \to X_s\gamma) = (332 \pm 15) \times 10^{-6}$$ [HFLAV 2019]

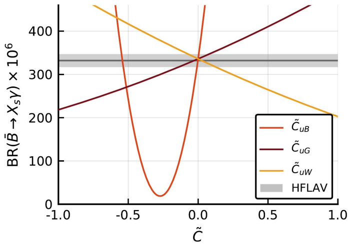


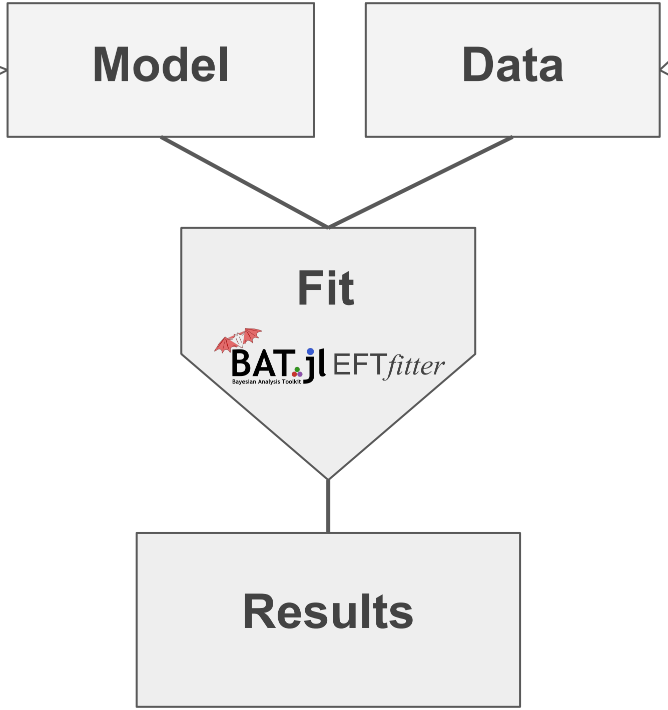
How to constrain Wilson coefficients?



MC Simulations

Theory calculations





ATLAS

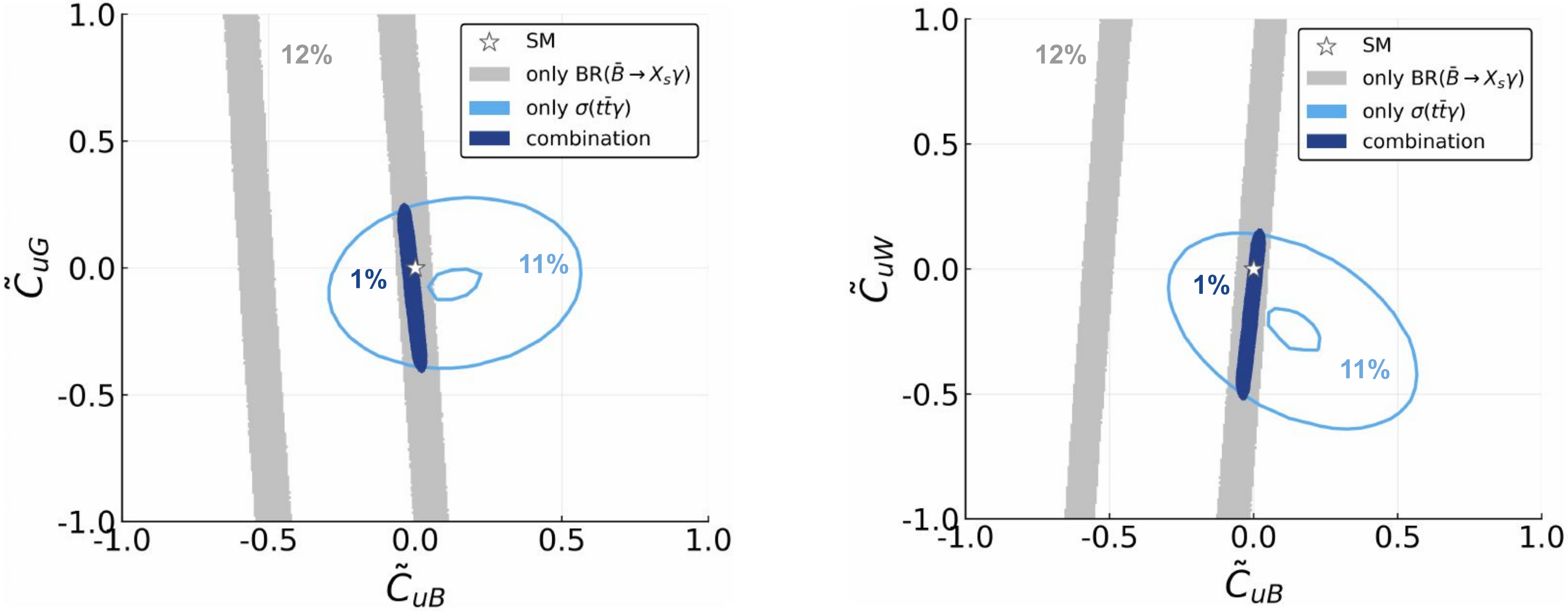
$$\sigma^{\text{fid}}_{\text{ATLAS}}(t\bar{t}\gamma, 1\ell) = 521 \pm 9\,(\text{stat.}) \pm 41\,(\text{syst.})\,\text{fb}\,,$$
$$\sigma^{\text{fid}}_{\text{ATLAS}}(t\bar{t}\gamma, 2\ell) = 69 \pm 3\,(\text{stat.}) \pm 4\,(\text{syst.})\,\text{fb}\,.$$

[Eur. Phys. J. C 79 (2019) 382]

HFLAV combination (BELLE, BaBar, CLEO)

$$\mathrm{BR}(\bar{B} \to X_s\gamma) = (332 \pm 15) \times 10^{-6}$$ [HFLAV 2019]

Combined fit: Top + *B*



smallest areas containing 90% posterior probability

⇨ combination of top quark & *B* observables improves the constraints by up to a factor of 10

How to enhance SMEFT fits in the top-quark sector ?

1) including observables from *B* physics [Eur. Phys. J. C 80 (2020) 136]

2) **impact of correlations between uncertainties** [1912.06090]

- global SMEFT fits usually include multiple measurements of several observables
- uncertainties of the included measurements are often correlated

problem: determining correlations between uncertainties is challenging, especially between different experiments ⇨ correlations are often neglected in SMEFT fits

Do correlations even matter in SMEFT fits ?

⇨ study the influence of correlations on the results of a SMEFT fit

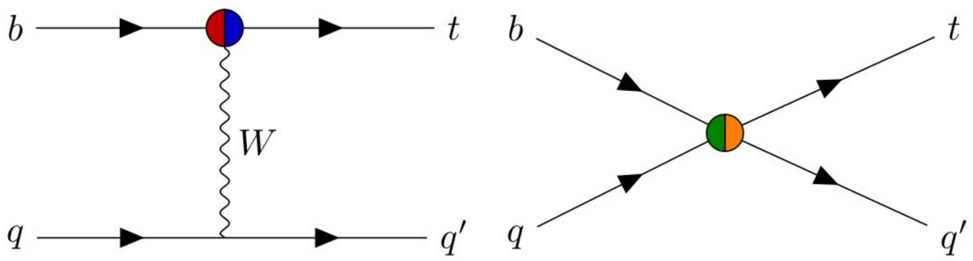
Setup of our study

- observables: **t-channel single-top** quark production and from **top-decay** (W-helicities & top-width)

  4 dimension-six operators of interest:

$$O_{\phi q}^{(3)} = i\left(\phi^\dagger \overleftrightarrow{D}^I_\mu \phi\right)\left(\bar{q}_L \gamma^\mu \tau^I q_L\right), \qquad O_{tW} = \left(\bar{q}_L \sigma^{\mu\nu} \tau^I t_R\right) \tilde{\phi} W^I_{\mu\nu},$$

$$O_{qq}^{(1)} = \left(\bar{q}_L \gamma_\mu q_L\right)\left(\bar{q}_L \gamma^\mu q_L\right), \qquad O_{qq}^{(3)} = \left(\bar{q}_L \gamma_\mu \tau^I q_L\right)\left(\bar{q}_L \gamma^\mu \tau^I q_L\right),$$



3 independent parameters in the fit: $\boxed{\tilde{C}_{\phi q}^{(3)},\ \tilde{C}_{tW},\ \tilde{C}_{qq}}$

Measurements included in the fit

55 measurements of 41 different observables:

$\sqrt{s}$	Luminosity	Experiment	Observable
7 TeV	$4.59\,\mathrm{fb}^{-1}$	ATLAS	$\sigma(tq)$, $\sigma(\bar{t}q)$, $d\sigma(tq)/dp_T$, $d\sigma(\bar{t}q)/dp_T$
	$1.17\,\mathrm{fb}^{-1}(\mu)$	CMS	$\sigma(tq+\bar{t}q)$
	$1.56\,\mathrm{fb}^{-1}(\mathrm{e})$	CMS	$\sigma(tq+\bar{t}q)$
8 TeV	$20.2\,\mathrm{fb}^{-1}$	ATLAS	$\sigma(tq)$, $\sigma(\bar{t}q)$, $d\sigma(tq)/dp_T$, $d\sigma(\bar{t}q)/dp_T$
	$19.7\,\mathrm{fb}^{-1}$	CMS	$\sigma(tq)$, $\sigma(\bar{t}q)$, $\sigma(tq+\bar{t}q)$, $d\sigma/d\|y(t/\bar{t})\|$
13 TeV	$3.2\,\mathrm{fb}^{-1}$	ATLAS	$\sigma(tq)$, $\sigma(\bar{t}q)$
	$2.2\,\mathrm{fb}^{-1}$	CMS	$\sigma(tq)$, $\sigma(\bar{t}q)$, $\sigma(tq+\bar{t}q)$
	$2.3\,\mathrm{fb}^{-1}$	CMS	$d\sigma/d\|y(t/\bar{t})\|$
1.96 TeV	$2.7\,\mathrm{fb}^{-1}$	CDF	F_0
	$8.7\,\mathrm{fb}^{-1}$	CDF	F_0
	$5.4\,\mathrm{fb}^{-1}$	D0	F_0
7 TeV	$1.04\,\mathrm{fb}^{-1}$	ATLAS	F_0, F_L
	$5.0\,\mathrm{fb}^{-1}$	CMS	F_0, F_L
8 TeV	$20.2\,\mathrm{fb}^{-1}$	ATLAS	Γ_t
	$20.2\,\mathrm{fb}^{-1}$	ATLAS	F_0, F_L
	$19.7\,\mathrm{fb}^{-1}$	CMS	F_0, F_L
13 TeV	$19.8\,\mathrm{fb}^{-1}$	CMS	F_0, F_L

total & differential t-channel cross sections

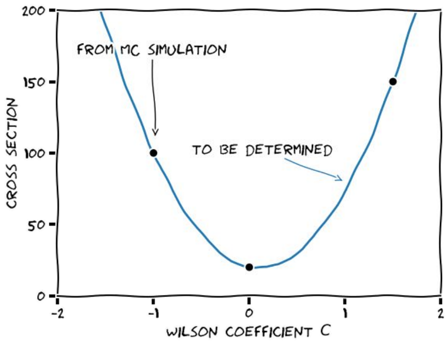
ATLAS, CMS

W-helicities & top-width

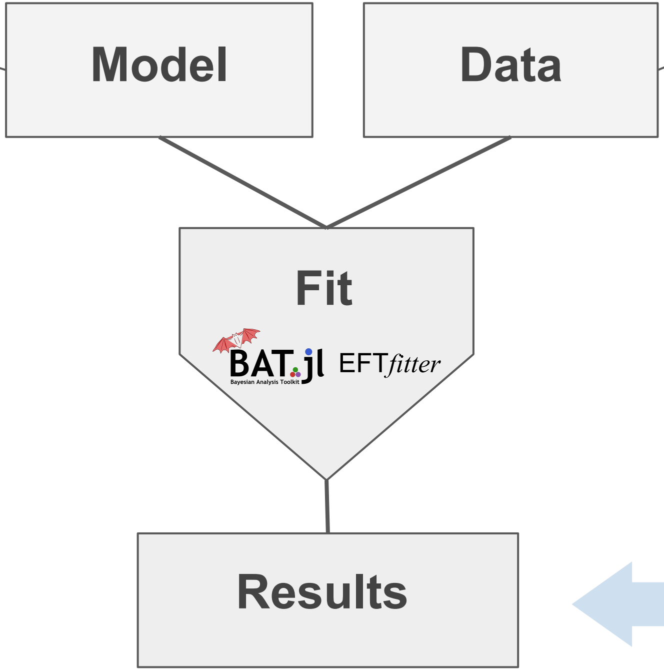
ATLAS, CMS, CDF, D0

- 3 types of uncertainties: statistical, systematic, theory

Setup of the fit



use both **linear** & **quadratic** parameterizations for cross sections



Process	$\sqrt{s}$	Luminosity	Experiment	Observable
Single top	7 TeV	$4.59\,\mathrm{fb}^{-1}$	ATLAS	$\sigma(tq)$, $\sigma(\bar{t}q)$, $d\sigma(tq)/dp_T$, $d\sigma(\bar{t}q)/dp_T$
		$1.17\,\mathrm{fb}^{-1}(\mu)$	CMS	$\sigma(tq+\bar{t}q)$
		$1.56\,\mathrm{fb}^{-1}(\mathrm{e})$	CMS	$\sigma(tq+\bar{t}q)$
Single top	8 TeV	$20.2\,\mathrm{fb}^{-1}$	ATLAS	$\sigma(tq)$, $\sigma(\bar{t}q)$, $d\sigma(tq)/dp_T$, $d\sigma(\bar{t}q)/dp_T$
		$19.7\,\mathrm{fb}^{-1}$	CMS	$\sigma(tq)$, $\sigma(\bar{t}q)$, $\sigma(tq+\bar{t}q)$, $d\sigma/d\lvert y(t/\bar{t})\rvert$
Single top	13 TeV	$3.2\,\mathrm{fb}^{-1}$	ATLAS	$\sigma(tq)$, $\sigma(\bar{t}q)$
		$2.2\,\mathrm{fb}^{-1}$	CMS	$\sigma(tq)$, $\sigma(\bar{t}q)$, $\sigma(tq+\bar{t}q)$
		$2.3\,\mathrm{fb}^{-1}$	CMS	$d\sigma/d\lvert y(t/\bar{t})\rvert$
Top decay	1.96 TeV	$2.7\,\mathrm{fb}^{-1}$	CDF	F_0
		$8.7\,\mathrm{fb}^{-1}$	CDF	F_0
		$5.4\,\mathrm{fb}^{-1}$	D0	F_0
Top decay	7 TeV	$1.04\,\mathrm{fb}^{-1}$	ATLAS	F_0, F_L
		$5.0\,\mathrm{fb}^{-1}$	CMS	F_0, F_L
Top decay	8 TeV	$20.2\,\mathrm{fb}^{-1}$	ATLAS	Γ_t
		$20.2\,\mathrm{fb}^{-1}$	ATLAS	F_0, F_L
		$19.7\,\mathrm{fb}^{-1}$	CMS	F_0, F_L
Top decay	13 TeV	$19.8\,\mathrm{fb}^{-1}$	CMS	F_0, F_L

$$\mathrm{Corr(stat.)}, \mathrm{Corr(syst.)}, \mathrm{Corr(theo.)}$$

How do correlations influence the results?

Correlations

55x55 correlation matrix for each of the 3 uncertainty categories

statistical correlations: given for bins of distributions, other statistical correlations assumed to vanish (independent events)

systematic & theory correlations: no information provided ➪ "**best guess" scenario** with simplifying parametrization

best guess:

systematic correlations:

$$
\begin{array}{c c}
 & \begin{array}{ccccc} \sigma(tq)_7^{\mathrm{A}} & \sigma(\bar{t}q)_7^{\mathrm{A}} & \sigma(tq)_8^{\mathrm{A}} & \sigma(tq)_8^{\mathrm{C}} & \Gamma_t \end{array} \\
\begin{array}{c} \sigma(tq)_7^{\mathrm{A}} \\ \sigma(\bar{t}q)_7^{\mathrm{A}} \\ \sigma(tq)_8^{\mathrm{A}} \\ \sigma(tq)_8^{\mathrm{C}} \\ \Gamma_t \end{array} &
\begin{pmatrix}
1 & \rho_{\mathrm{sys}} & \frac{\rho_{\mathrm{sys}}}{2} & 0 & 0 \\
\rho_{\mathrm{sys}} & 1 & \frac{\rho_{\mathrm{sys}}}{2} & 0 & 0 \\
\frac{\rho_{\mathrm{sys}}}{2} & \frac{\rho_{\mathrm{sys}}}{2} & 1 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 1
\end{pmatrix}
\end{array}
$$

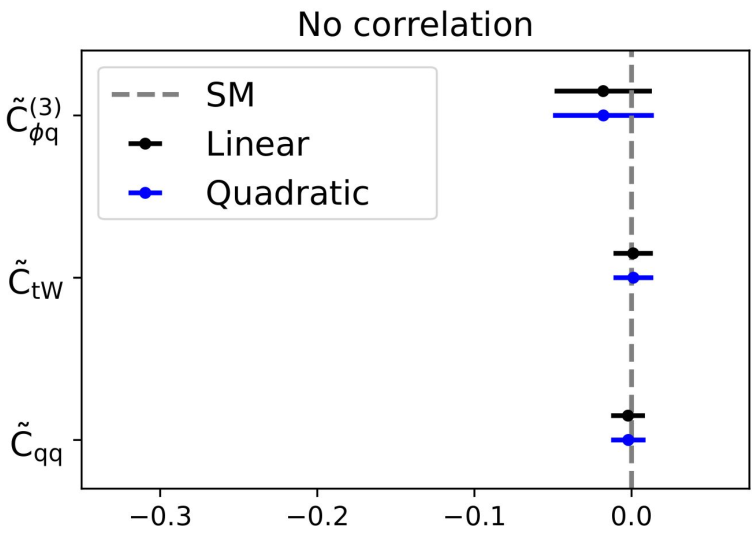
assumptions:

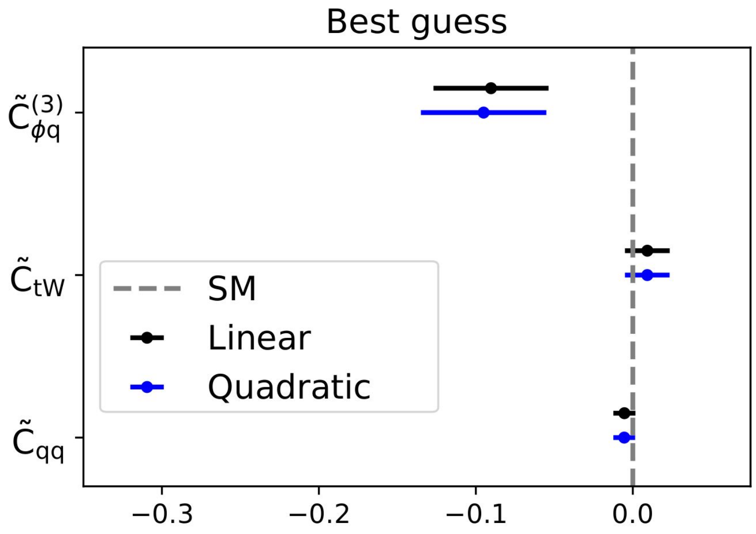
- same experiment & same energy ➪ strong corr.
- same experiment & different energy ➪ less strong corr.
- different experiments ➪ uncorrelated

similar assumptions for theory correlations

$$\rho_{\mathrm{sys}} = 0.9\,, \quad \rho_{\mathrm{th}} = 0.9$$

Fit results with & without correlations





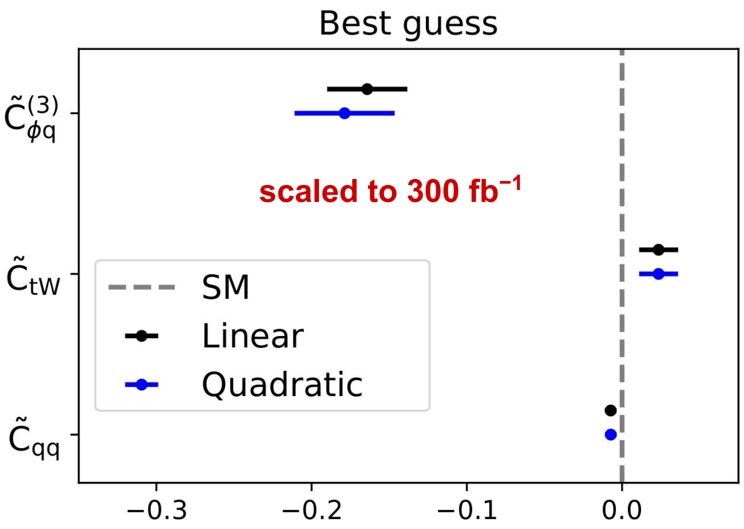
marginalized best fit values & smallest 95% intervals

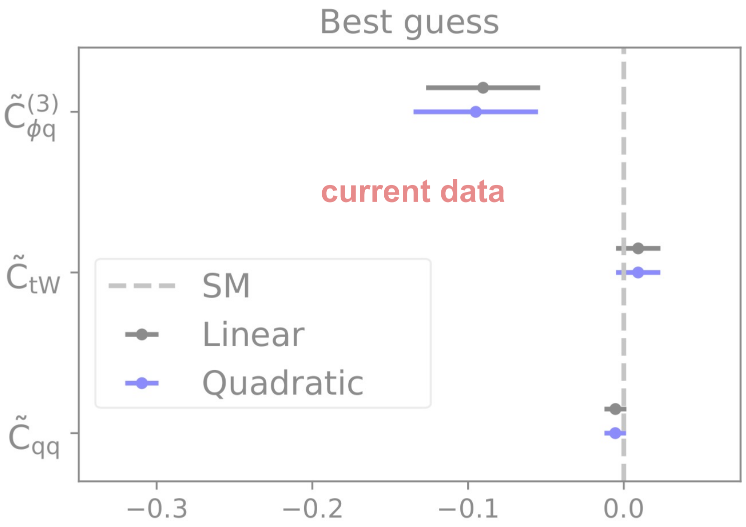
⇨ "best guess" correlations lead to significant deviations from SM for one of the Wilson coefficients

- varying values of $\rho_{\text{sys}}, \rho_{\text{th}}$: consistent behavior, larger correlations lead to stronger deviations

What about the future?

scaled statistical uncertainties to 300 fb^{-1} (LHC Run 3):





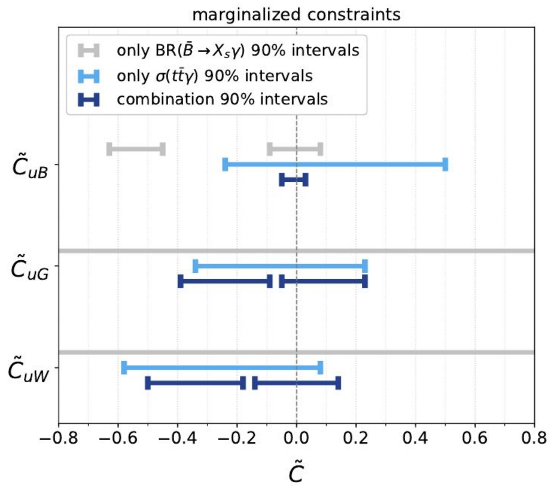
⇨ if statistical uncertainties decrease, correlations can lead to even stronger deviations from the SM

Summary & Conclusions

- first consistent fit of SMEFT Wilson coefficients using a combination of observables from top-quark and *B* physics
- combination leads to significant improvement of constraints

⇨ combination of observables from different energy scales are beneficial for global fits constraining top-quark related SMEFT Wilson coefficients

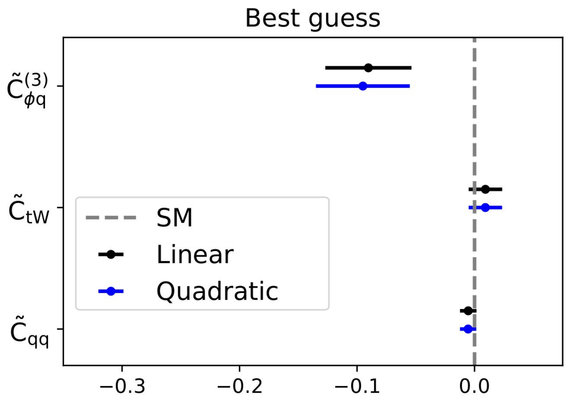
[Eur. Phys. J. C 80 (2020) 136]



- SMEFT fit of single-top & top-decay measurements
- studied the influence of correlations by comparing a no-correlation scenario to a best guess correlation scenario

⇨ correlations matter, in the future even more

[1912.06090]



Backup

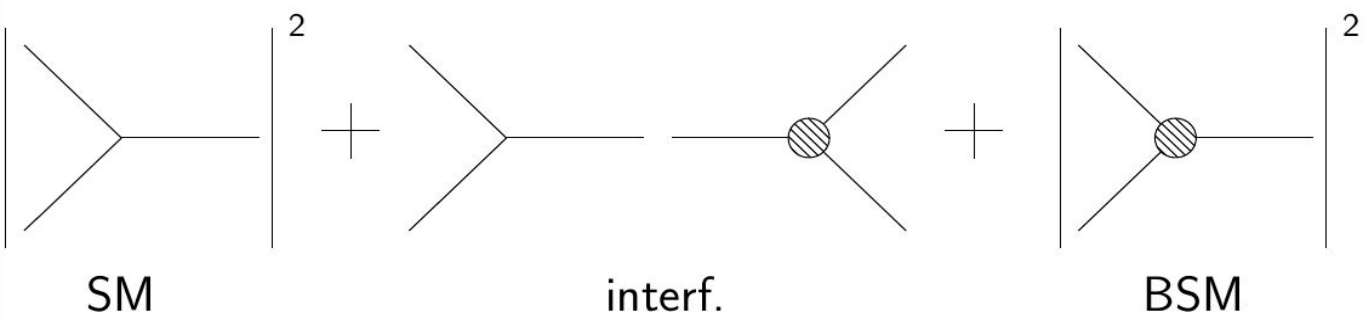
EFT cross sections

$$\mathcal{L} = \mathcal{L}_{\mathrm{SM}} + \tfrac{1}{\Lambda^2} \textstyle\sum_i C_i O$$

$$\mathcal{M} = \mathcal{M}^{\mathrm{SM}} + \tfrac{1}{\Lambda^2} \textstyle\sum_i C_i \mathcal{M}_i^{\mathrm{BSM}}$$

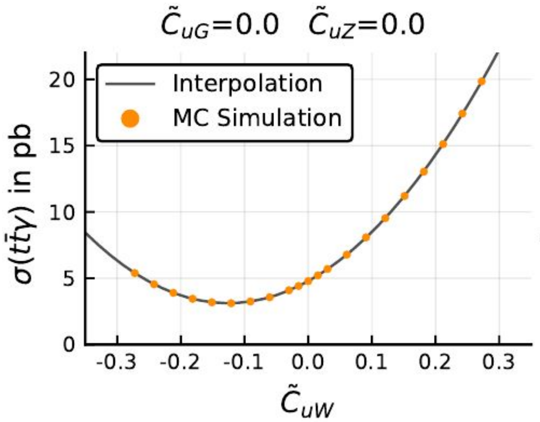
$$\sigma \propto |\mathcal{M}|^2$$

$$\boxed{\sigma = \sigma^{\mathrm{SM}} + \frac{1}{\Lambda^2} \sum_i C_i \sigma_i^{\mathrm{interf.}} + \frac{1}{\Lambda^4} \sum_{i \leq j} C_i C_j \sigma_{ij}^{\mathrm{BSM}}}$$

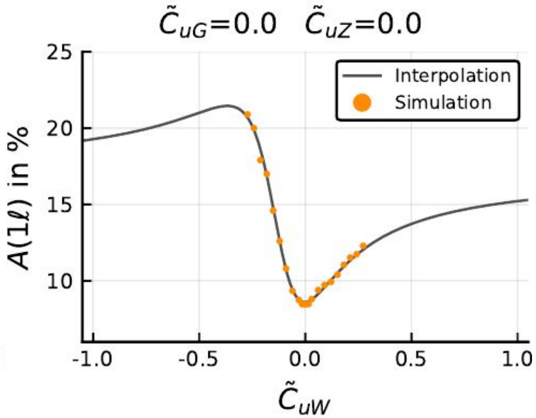


Dependence of fiducial cross section on Wilson coefficients

1) quadratic interpolation of total cross section:



2) interpolation of fiducial acceptance:



different degrees of freedom in *dim6top*:

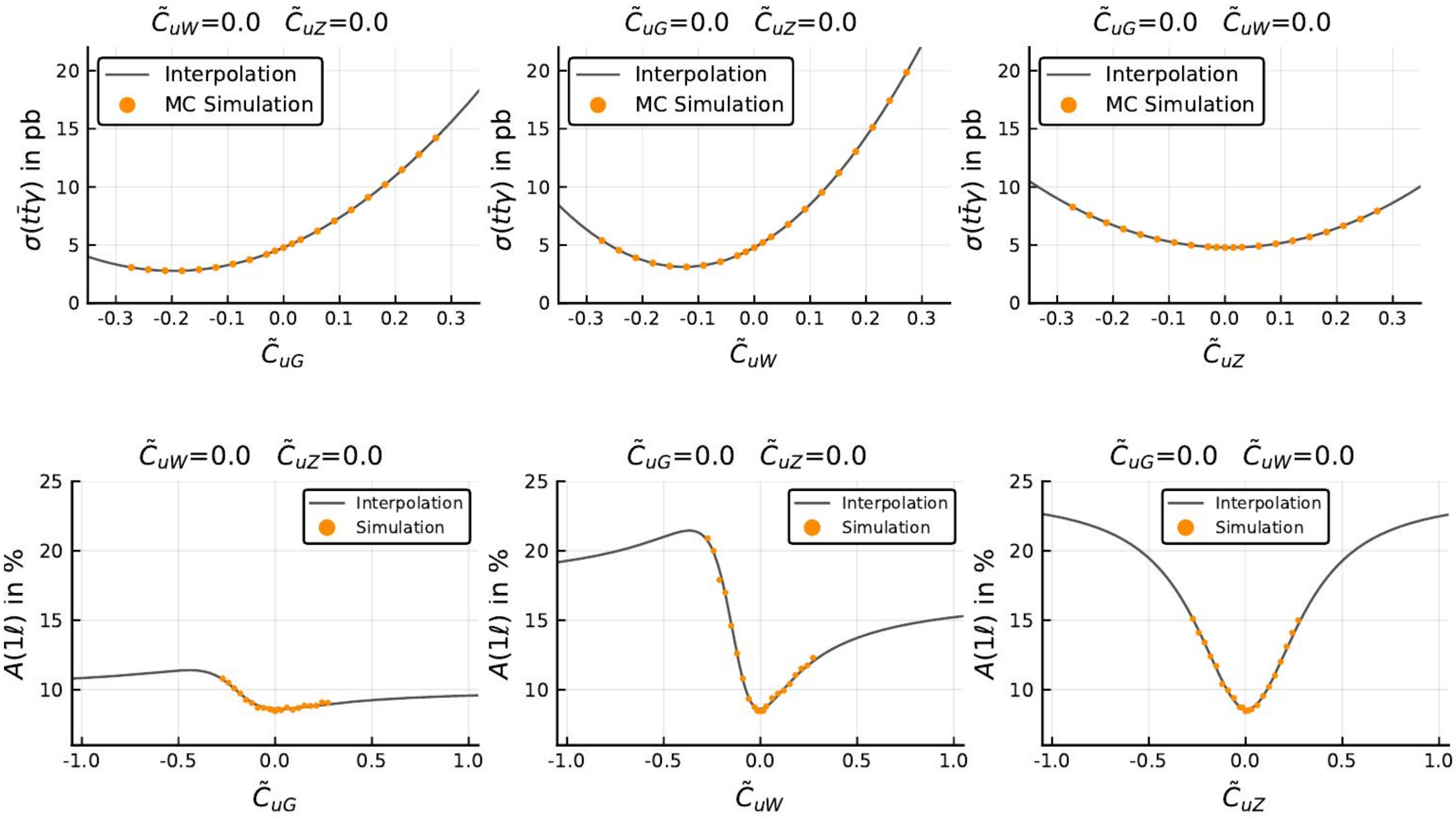
$$\tilde{C}_{uG},\ \tilde{C}_{uW},\ \tilde{C}_{uB} \xleftrightarrow{\tilde{C}_{uZ} = \cos\theta_W \tilde{C}_{uW} - \sin\theta_W \tilde{C}_{uB}} \tilde{C}_{uG},\ \tilde{C}_{uW},\ \tilde{C}_{uZ}$$

known from previous interpolation

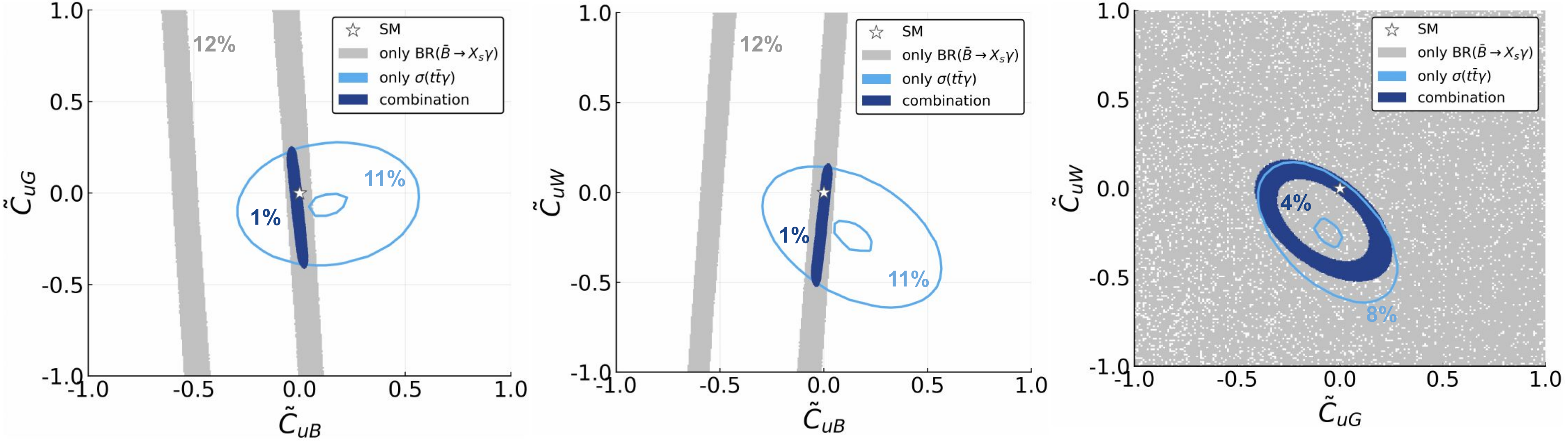
$$A_{\text{fid}} = \frac{\sigma_{\text{fid}}}{\sigma_{\text{tot}}} = \frac{\boxed{A^{\text{SM}}}\sigma^{\text{SM}} + \sum_i \tilde{C}_i \boxed{A_i^{\text{interf.}}}\sigma_i^{\text{interf.}} + \sum_{i\leq j}\tilde{C}_i\tilde{C}_j \boxed{A_{ij}^{\text{BSM}}}\sigma_{ij}^{\text{BSM}}}{\underbrace{\sigma^{\text{SM}} + \sum_i \tilde{C}_i \sigma_i^{\text{interf.}} + \sum_{i\leq j}\tilde{C}_i\tilde{C}_j\sigma_{ij}^{\text{BSM}}}_{\text{known from previous interpolation}}}$$

known from event selection

Interpolation of cross section & fiducial acceptance



Combined fit: Top + B

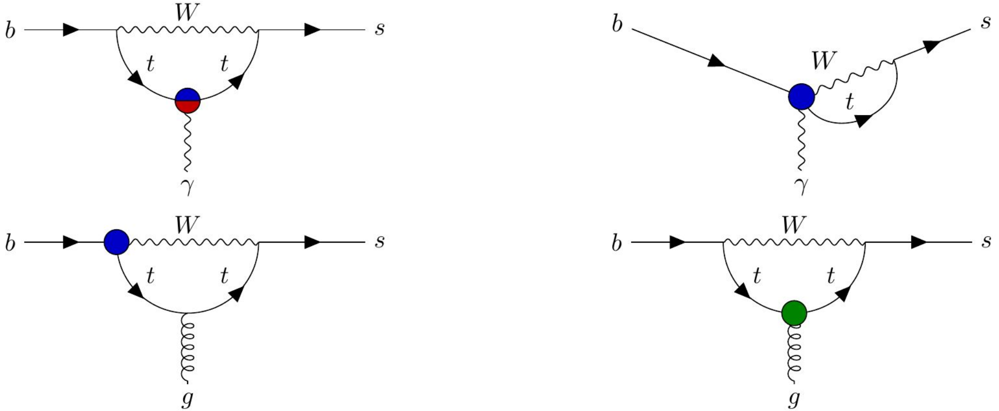


smallest areas containing 90% posterior probability

$\mathrm{BR}(\bar{B} \to X_s \gamma)$

$$\Delta C_7^{(0)} \sim \tilde{C}_{uW} A(x_t) + \tilde{C}_{uW}^* B(x_t) + \tilde{C}_{uB} C(x_t) + \tilde{C}_{uB}^* D(x_t)$$

$$\Delta C_8^{(0)} \sim \tilde{C}_{uW} E(x_t) + \tilde{C}_{uW}^* F(x_t) - 2\frac{m_W}{v} \frac{(\tilde{C}_{uG} C(x_t) + \tilde{C}_{uG}^* D(x_t))}{\sqrt{4\pi\alpha_s(\mu_W)}}$$



$$O_{uG} = \left(\bar{q}\sigma^{\mu\nu}T^A u\right)\tilde{\varphi}G^A_{\mu\nu}\,, \quad O_{uB} = \left(\bar{q}\sigma^{\mu\nu}u\right)\tilde{\varphi}B_{\mu\nu}\,, \quad O_{uW} = \left(\bar{q}\sigma^{\mu\nu}\tau^I u\right)\tilde{\varphi}W^I_{\mu\nu}$$

Correlations of best guess scenario

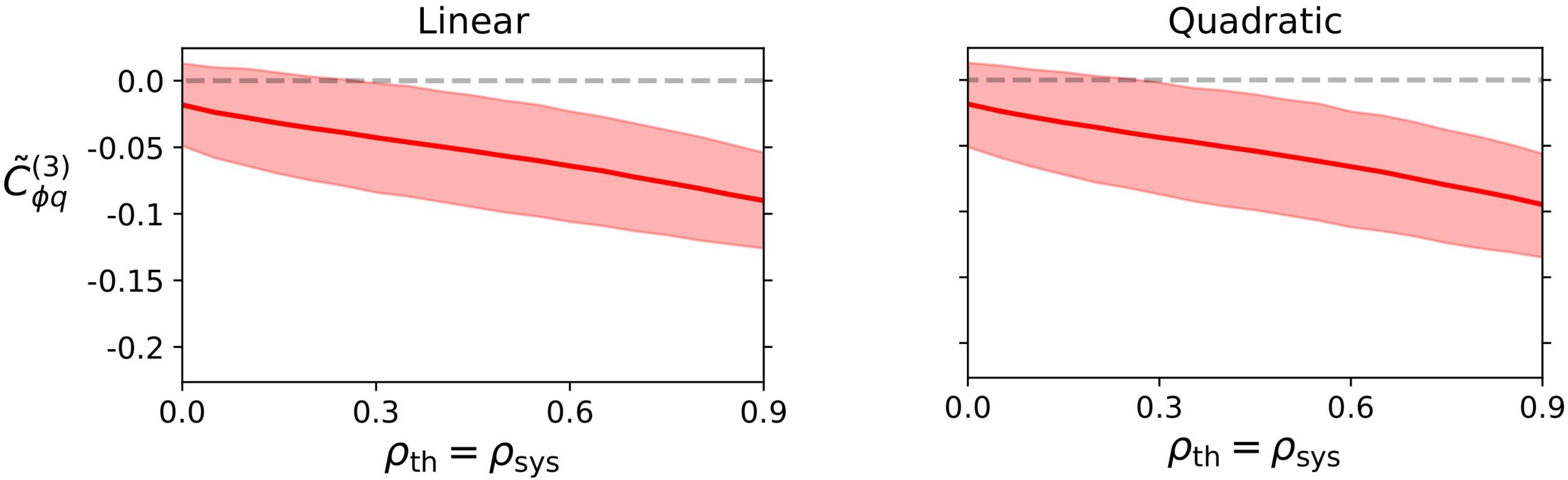
systematic correlations:

$$\begin{array}{c} \\ \sigma(tq)_7^{\mathrm{A}} \\ \sigma(\bar{t}q)_7^{\mathrm{A}} \\ \sigma(tq)_8^{\mathrm{A}} \\ \sigma(tq)_8^{\mathrm{C}} \\ \Gamma_t \end{array} \begin{array}{c} \begin{array}{ccccc} \sigma(tq)_7^{\mathrm{A}} & \sigma(\bar{t}q)_7^{\mathrm{A}} & \sigma(tq)_8^{\mathrm{A}} & \sigma(tq)_8^{\mathrm{C}} & \Gamma_t \end{array} \\ \begin{pmatrix} 1 & \rho_{\mathrm{sys}} & \frac{\rho_{\mathrm{sys}}}{2} & 0 & 0 \\ \rho_{\mathrm{sys}} & 1 & \frac{\rho_{\mathrm{sys}}}{2} & 0 & 0 \\ \frac{\rho_{\mathrm{sys}}}{2} & \frac{\rho_{\mathrm{sys}}}{2} & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{pmatrix} \end{array}$$

theory correlations:

$$\begin{array}{c} \\ \sigma(tq)_7^{\mathrm{A}} \\ \sigma(\bar{t}q)_7^{\mathrm{A}} \\ \sigma(tq)_8^{\mathrm{A}} \\ \sigma(tq)_8^{\mathrm{C}} \\ \Gamma_t \end{array} \begin{array}{c} \begin{array}{ccccc} \sigma(tq)_7^{\mathrm{A}} & \sigma(\bar{t}q)_7^{\mathrm{A}} & \sigma(tq)_8^{\mathrm{A}} & \sigma(tq)_8^{\mathrm{C}} & \Gamma_t \end{array} \\ \begin{pmatrix} 1 & \rho_{\mathrm{th}} & \frac{\rho_{\mathrm{th}}}{2} & \frac{\rho_{\mathrm{th}}}{2} & 0 \\ \rho_{\mathrm{th}} & 1 & \frac{\rho_{\mathrm{th}}}{2} & \frac{\rho_{\mathrm{th}}}{2} & 0 \\ \frac{\rho_{\mathrm{th}}}{2} & \frac{\rho_{\mathrm{th}}}{2} & 1 & \rho_{\mathrm{th}} & 0 \\ \frac{\rho_{\mathrm{th}}}{2} & \frac{\rho_{\mathrm{th}}}{2} & \rho_{\mathrm{th}} & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{pmatrix} \end{array}$$

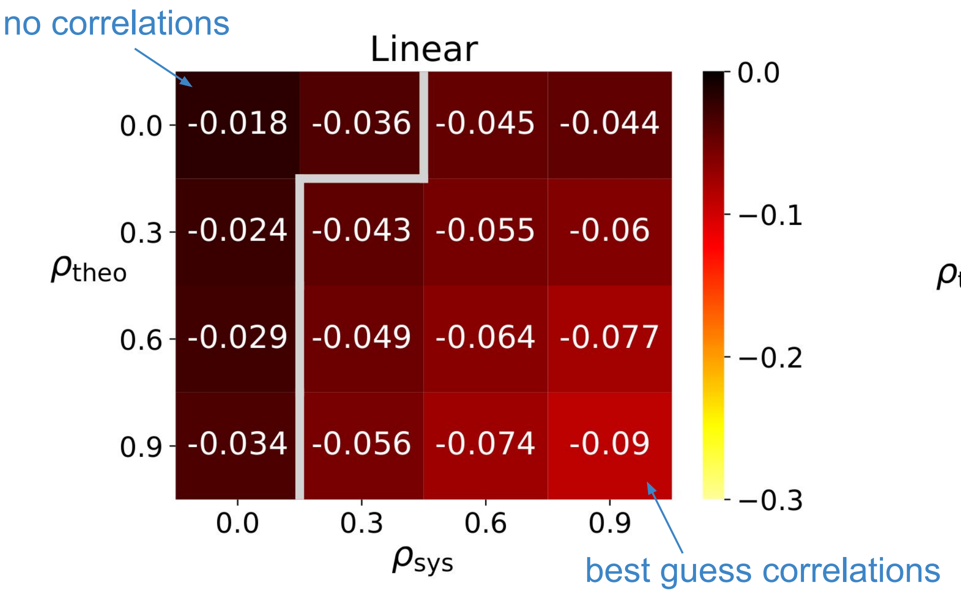
Varying the correlation coefficients

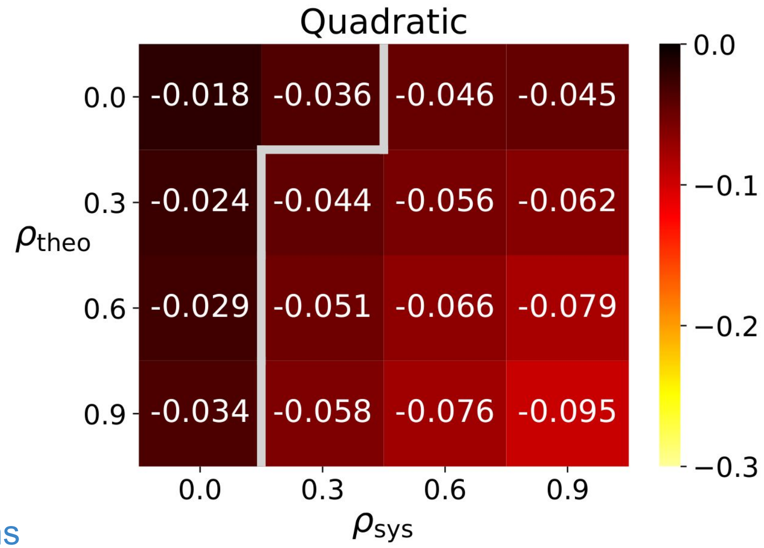


marginalized best fit value (line) & 95% interval (band)

- vary the correlation coefficients for theory and systematic correlations of the “best guess” scenario

Varying the correlation coefficients





- central values of $\tilde{C}_{\phi q}^{(3)}$ from a marginalized fit
- below and right of grey line: deviations from SM more than 2σ

Future vs. Current Data