Single top data in SMEFT fits

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PDF4BSM
Parton Distributions in the Higgs Boson Era

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Standard Model Effective Field Theory

Motivation

- Heavy BSM physics beyond the direct reach of the LHC can be parameterised in a model-independent way in terms of a complete basis of higher-dimensional operators

$$\mathscr{L}_{\mathrm{SMEFT}} = \mathscr{L}_{\mathrm{SM}} + \sum_{i}^{N_{d6}} \frac{c_i}{\Lambda^2}\mathcal{O}_i^{(6)} + \sum_{j}^{N_{d8}} \frac{b_j}{\Lambda^4}\mathcal{O}_j^{(8)} + \ldots$$

- Some operators induce growth with the partonic centre-of-mass energy: leads to increased sensitivity in LHC cross-sections in the TeV region

$$\sigma(E) = \sigma_{\mathrm{SM}}(E)\left(1 + \sum_{i}^{N_{d6}} \kappa_i \frac{c_i}{\Lambda^2} + \sum_{i,j}^{N_{d6}} \widetilde{\kappa}_{ij}\frac{c_i c_j}{\Lambda^4}\right)$$

- At dimension-6 we have 59 non-redundant operators assuming minimal flavour violation (2499 if no assumptions made)

- A global SMEFT analysis needs to explore a huge parameter space

Operator basis

Class	Notation	Degree of Freedom	Operator Definition
$QQQQ$	OQQ1	c^1_{QQ}	$2C^{1(3333)}_{qq} - \frac{2}{3}C^{3(3333)}_{qq}$
	OQQ8	c^8_{QQ}	$8C^{3(3333)}_{qq}$
	OQt1	c^1_{Qt}	$C^{1(3333)}_{qu}$
	OQt8	c^8_{Qt}	$C^{8(3333)}_{qu}$
	OQb1	c^1_{Qb}	$C^{1(3333)}_{qd}$
	OQb8	c^8_{Qb}	$C^{8(3333)}_{qd}$
	Ott1	c^1_{tt}	$C^{(3333)}_{uu}$
	Otb1	c^1_{tb}	$C^{1(3333)}_{ud}$
	Otb8	c^8_{tb}	$C^{8(3333)}_{ud}$
	OQtQb1	c^1_{QtQb}	$C^{1(3333)}_{quqd}$
	OQtQb8	c^8_{QtQb}	$C^{8(3333)}_{quqd}$
$QQqq$	O81qq	$c^{1,8}_{Qq}$	$C^{1(i33i)}_{qq} + 3C^{3(i33i)}_{qq}$
	O11qq	$c^{1,1}_{Qq}$	$C^{1(ii33)}_{qq} + \frac{1}{6}C^{1(i33i)}_{qq} + \frac{1}{2}C^{3(i33i)}_{qq}$
	O83qq	$c^{3,8}_{Qq}$	$C^{1(i33i)}_{qq} - C^{3(i33i)}_{qq}$
	O13qq	$c^{3,1}_{Qq}$	$C^{3(ii33)}_{qq} + \frac{1}{6}(C^{1(i33i)}_{qq} - C^{3(i33i)}_{qq})$
	O8qt	c^8_{tq}	$C^{8(ii33)}_{qu}$
	O1qt	c^1_{tq}	$C^{1(ii33)}_{qu}$
	O8ut	c^8_{tu}	$2C^{(i33i)}_{uu}$
	O1ut	c^1_{tu}	$C^{(ii33)}_{uu} + \frac{1}{3}C^{(i33i)}_{uu}$
	O8qu	c^8_{Qu}	$C^{8(33ii)}_{qu}$
	O1qu	c^1_{Qu}	$C^{1(33ii)}_{qu}$
	O8dt	c^8_{td}	$C^{8(33ii)}_{ud}$
	O1dt	c^1_{td}	$C^{1(33ii)}_{ud}$
	O8qd	c^8_{Qd}	$C^{8(33ii)}_{qd}$
	O1qd	c^1_{Qd}	$C^{1(33ii)}_{qd}$
$QQ+V,G,\varphi$	OtG	c_{tG}	$\mathrm{Re}\{C^{(33)}_{uG}\}$
	OtW	c_{tW}	$\mathrm{Re}\{C^{(33)}_{uW}\}$
	ObW	c_{bW}	$\mathrm{Re}\{C^{(33)}_{dW}\}$
	OtZ	c_{tZ}	$\mathrm{Re}\{-s_W C^{(33)}_{uB} + c_W C^{(33)}_{uW}\}$
	Off	$c_{\varphi tb}$	$\mathrm{Re}\{C^{(33)}_{\varphi ud}\}$
	Ofq3	$c^3_{\varphi Q}$	$C^{3(33)}_{\varphi q}$
	OpQM	$c^-_{\varphi Q}$	$C^{1(33)}_{\varphi q} - C^{3(33)}_{\varphi q}$
	Opt	$c_{\varphi t}$	$C^{(33)}_{\varphi u}$
	Otp	$c_{t\varphi}$	$\mathrm{Re}\{C^{(33)}_{u\varphi}\}$

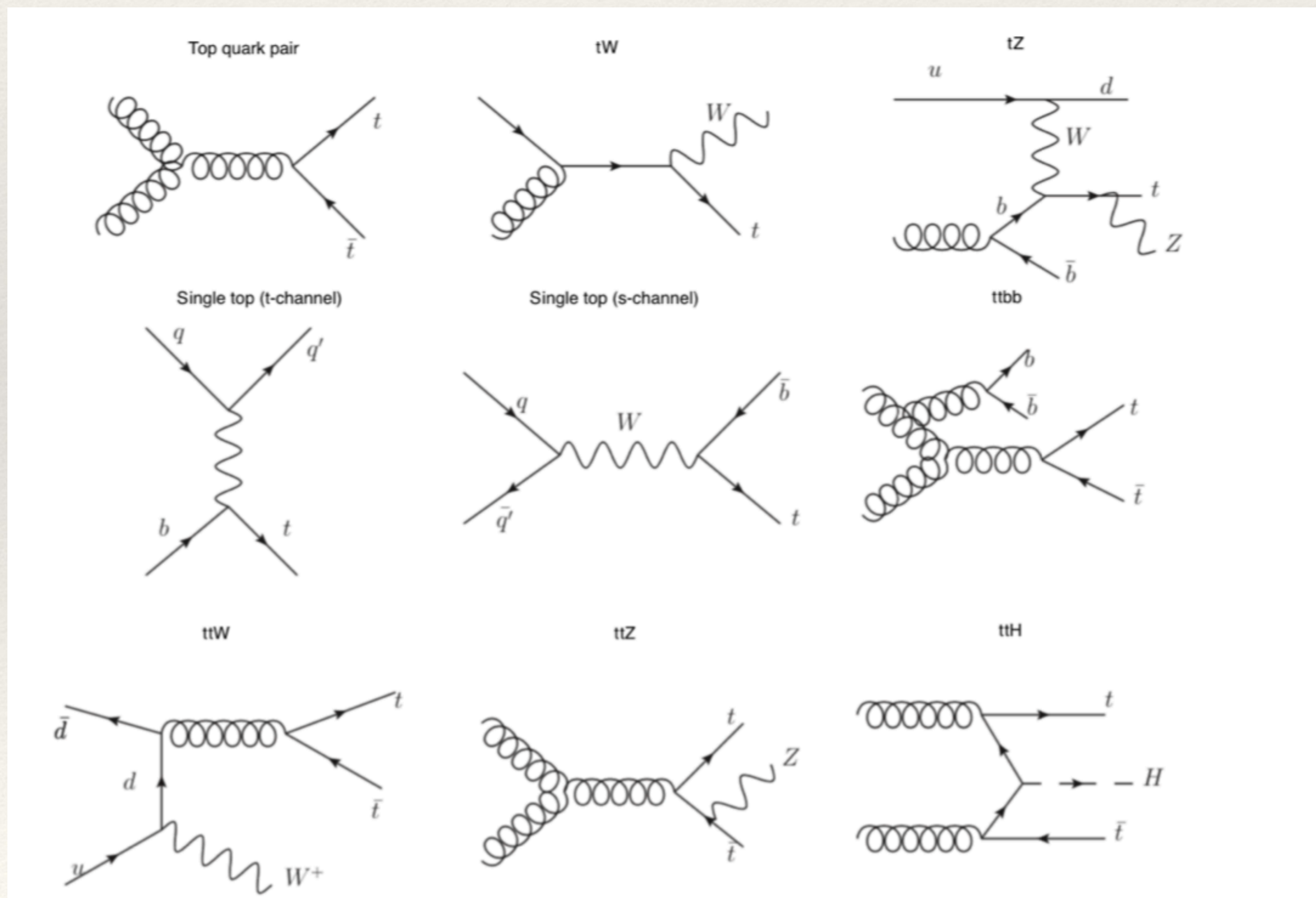
- We follow the same conventions as the LHC Top WG note [1802.07237] - linear combinations of Warsaw basis operators that appear in interferences with SM amplitudes
- Assume MFV, diagonal CKM matrix, zero Yukawas for 1st and 2nd generations
- CP conserving operators only
- Include all SMEFT dimension-6 operators which include at least 1 top quark
- Total of 34 independent degrees of freedom
- We include both the interference and quadratic contribution from all operators

Top quark sector of SMEFT

Notation	Sensitivity at $\mathcal{O}(\Lambda^{-2})$ ($\mathcal{O}(\Lambda^{-4})$)								
	$t\bar{t}$	single-top	tW	tZ	$t\bar{t}W$	$t\bar{t}Z$	$t\bar{t}H$	$t\bar{t}t\bar{t}$	$t\bar{t}b\bar{b}$
OQQ1								✓	✓
OQQ8								✓	✓
OQt1								✓	✓
OQt8								✓	✓
OQb1								(✓)	✓
OQb8								(✓)	✓
Ott1								✓	✓
Otb1								(✓)	✓
Otb8								✓	✓
OQtQb1									✓
OQtQb8									✓
O81qq	✓				✓	✓	✓	✓	✓
O11qq	✓				(✓)	(✓)	(✓)	✓	✓
O83qq	✓	✓		(✓)	✓	✓	✓	✓	✓
O13qq	✓	✓		✓	(✓)	(✓)	(✓)	✓	✓
O8qt	✓				✓	✓	✓	✓	✓
O1qt	✓				(✓)	(✓)	(✓)	✓	✓
O8ut	✓					✓	✓	✓	✓
O1ut	✓					(✓)	(✓)	✓	✓
O8qu	✓					✓	✓	✓	✓
O1qu	✓					(✓)	(✓)	✓	✓
O8dt	✓					✓	✓	✓	✓
O1dt	✓					(✓)	(✓)	✓	✓
O8qd	✓					✓	✓	✓	✓
O1qd	✓					(✓)	(✓)	✓	✓
OtG	✓				✓	✓	✓	✓	✓
OtW		✓	✓	✓					
ObW		(✓)	(✓)						
OtZ				✓		✓			
Off		(✓)	(✓)	(✓)					
Ofq3		✓	✓	✓		✓			
OpQM				✓		✓			
Opt				✓		✓	✓		
Otp							✓		

- A large number of operators modify single and double-top production at the LHC

$$\sigma(E) = \sigma_{\mathrm{SM}}(E)\left(1 + \sum_{i}^{N_{d6}} \kappa_i \frac{c_i}{\Lambda^2} + \sum_{i,j}^{N_{d6}} \widetilde{\kappa}_{ij} \frac{c_i c_j}{\Lambda^4}\right)$$



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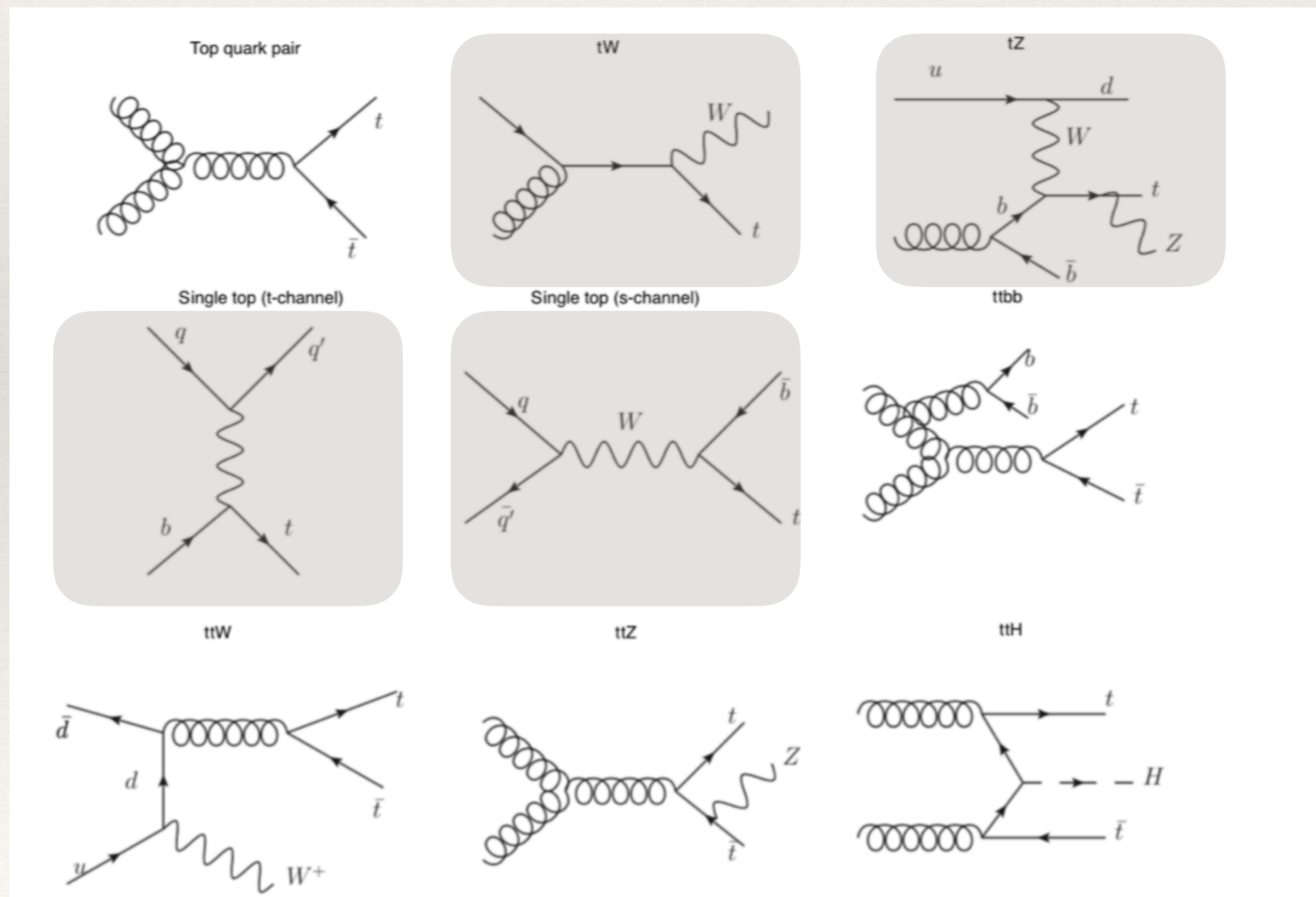
OQQ8								✓	✓
OQt1								✓	✓
OQt8								✓	✓
OQb1								(✓)	✓
OQb8								(✓)	✓
Ott1								✓	✓
Otb1								(✓)	✓
Otb8								✓	✓
OQtQb1									✓
OQtQb8									✓
O81qq	✓				✓	✓	✓	✓	✓
O11qq	✓				(✓)	(✓)	(✓)	✓	✓
O83qq	✓	✓		(✓)	✓	✓	✓	✓	✓
O13qq	✓	✓		✓	(✓)	(✓)	(✓)	✓	✓
O8qt	✓				✓	✓	✓	✓	✓
O1qt	✓				(✓)	(✓)	(✓)	✓	✓
O8ut	✓					✓	✓	✓	✓
O1ut	✓					(✓)	(✓)	✓	✓
O8qu	✓					✓	✓	✓	✓
O1qu	✓					(✓)	(✓)	✓	✓
O8dt	✓					✓	✓	✓	✓
O1dt	✓					(✓)	(✓)	✓	✓
O8qd	✓					✓	✓	✓	✓
O1qd	✓					(✓)	(✓)	✓	✓
OtG	✓				✓	✓	✓	✓	✓
OtW		✓	✓	✓					
ObW		(✓)	(✓)						
OtZ				✓		✓			
Off		(✓)	(✓)	(✓)					
Ofq3		✓	✓	✓		✓			
OpQM				✓		✓			
Opt				✓		✓	✓		
Otp							✓		

- A large number of operators modify single and double-top production at the LHC

$$\sigma(E) = \sigma_{\mathrm{SM}}(E)\left(1 + \sum_{i}^{N_{d6}} \kappa_i \frac{c_i}{\Lambda^2} + \sum_{i,j}^{N_{d6}} \widetilde{\kappa}_{ij} \frac{c_i c_j}{\Lambda^4}\right)$$



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	$t\bar{t}$	single-top	tW	tZ	$t\bar{t}W$	$t\bar{t}Z$	$t\bar{t}H$	$t\bar{t}t\bar{t}$	$t\bar{t}b\bar{b}$
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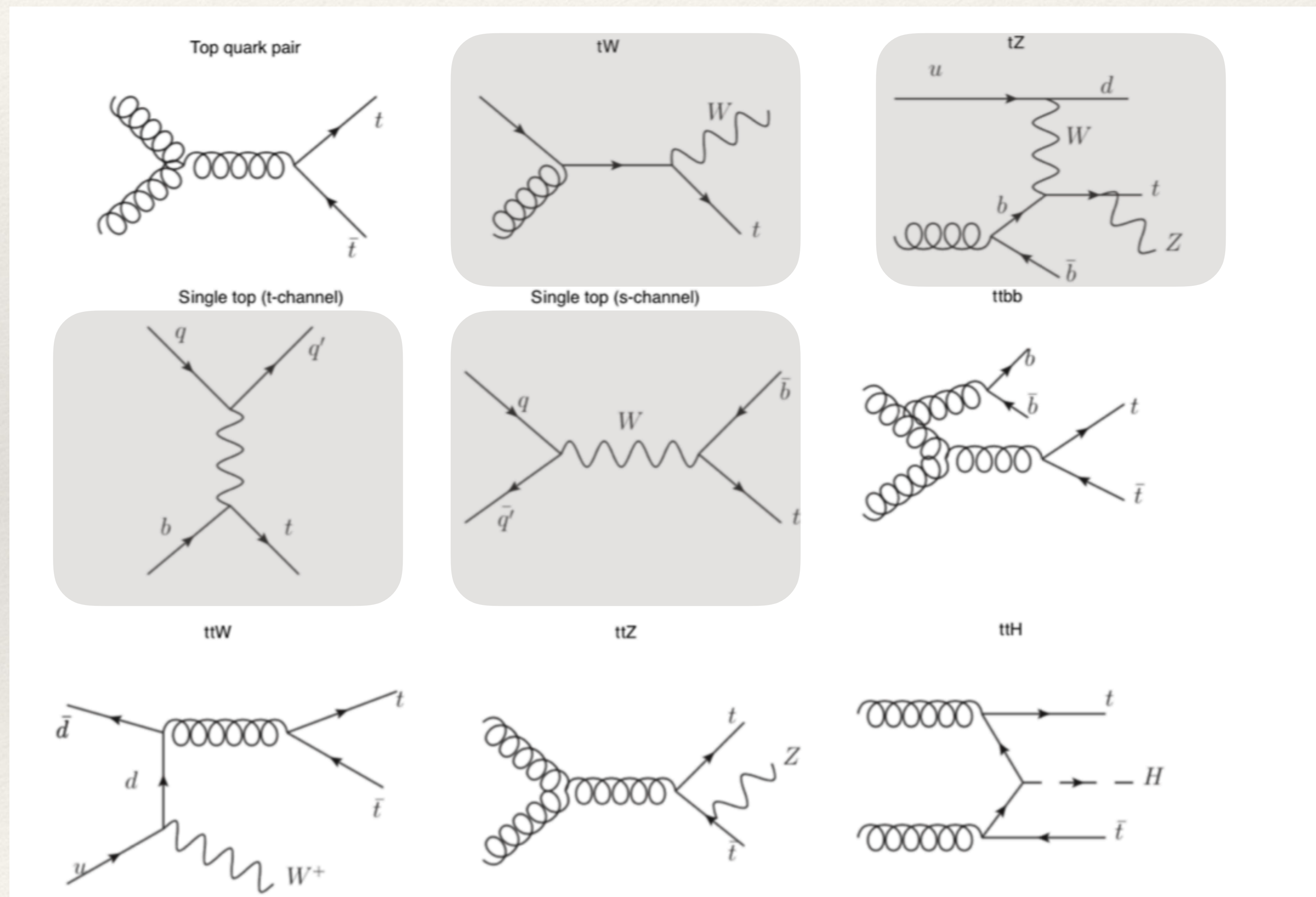
OQQ8								✓	✓
OQt1								✓	✓
OQt8								✓	✓
OQb1								(✓)	✓
OQb8								(✓)	✓
Ott1								✓	✓
Otb1								(✓)	✓
Otb8								✓	✓
OQtQb1									✓
OQtQb8									✓
O81qq	✓				✓	✓	✓	✓	✓
O11qq	✓				(✓)	(✓)	(✓)	✓	✓
O83qq	✓	✓		(✓)	✓	✓	✓	✓	✓
O13qq	✓	✓		✓	(✓)	(✓)	(✓)	✓	✓
O8qt	✓				✓	✓	✓	✓	✓
O1qt	✓				(✓)	(✓)	(✓)	✓	✓
O8ut	✓					✓	✓	✓	✓
O1ut	✓					(✓)	(✓)	✓	✓
O8qu	✓					✓	✓	✓	✓
O1qu	✓					(✓)	(✓)	✓	✓
O8dt	✓					✓	✓	✓	✓
O1dt	✓					(✓)	(✓)	✓	✓
O8qd	✓					✓	✓	✓	✓
O1qd	✓					(✓)	(✓)	✓	✓
OtG	✓				✓	✓	✓	✓	✓
OtW		✓	✓	✓					
ObW		(✓)	(✓)						
OtZ				✓		✓			
Off		(✓)	(✓)	(✓)					
Ofq3		✓	✓	✓		✓			
OpQM				✓		✓			
Opt				✓		✓	✓		
Otp							✓		

- Some operators ONLY constrained by single-top data



Top quark sector of SMEFT

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	$t\bar{t}$	single-top	tW	tZ	$t\bar{t}W$	$t\bar{t}Z$	$t\bar{t}H$	$t\bar{t}t\bar{t}$	$t\bar{t}b\bar{b}$
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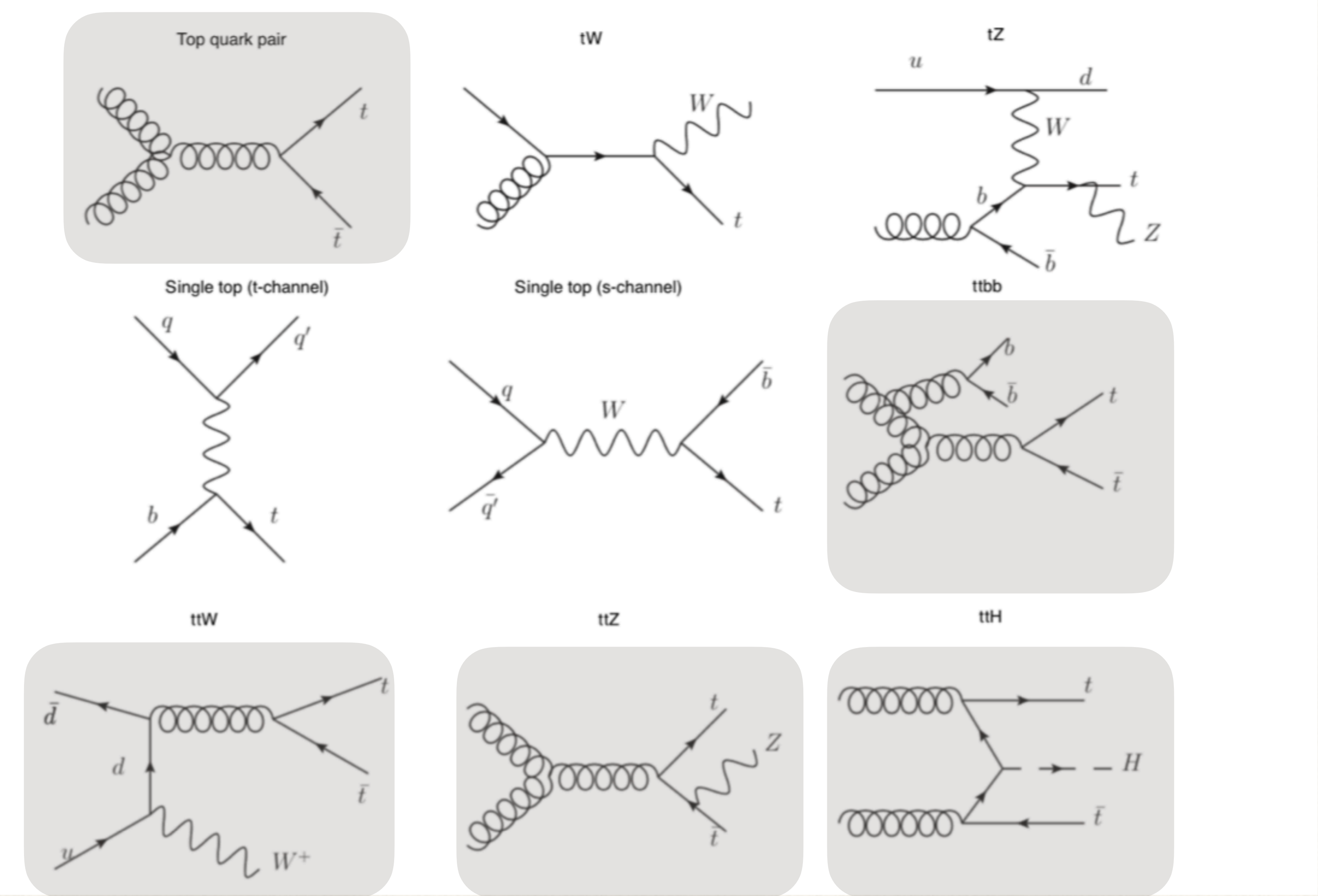
OQt1								✓	✓
OQt8								✓	✓
OQb1								(✓)	✓
OQb8								(✓)	✓
Ott1								✓	✓
Otb1								(✓)	✓
Otb8								✓	✓
OQtQb1									✓
OQtQb8									✓
O81qq	✓				✓	✓	✓	✓	✓
O11qq	✓				(✓)	(✓)	(✓)	✓	✓
O83qq	✓	✓		(✓)	✓	✓	✓	✓	✓
O13qq	✓	✓		✓	(✓)	(✓)	(✓)	✓	✓
O8qt	✓				✓	✓	✓	✓	✓
O1qt	✓				(✓)	(✓)	(✓)	✓	✓
O8ut	✓					✓	✓	✓	✓
O1ut	✓					(✓)	(✓)	✓	✓
O8qu	✓					✓	✓	✓	✓
O1qu	✓					(✓)	(✓)	✓	✓
O8dt	✓					✓	✓	✓	✓
O1dt	✓					(✓)	(✓)	✓	✓
O8qd	✓					✓	✓	✓	✓
O1qd	✓					(✓)	(✓)	✓	✓
OtG	✓				✓	✓	✓	✓	✓
OtW		✓	✓	✓					
ObW		(✓)	(✓)						
OtZ				✓		✓			
Off		(✓)	(✓)	(✓)					
Ofq3		✓	✓	✓		✓			
OpQM				✓		✓			
Opt				✓		✓	✓		
Otp							✓		

- Top quark pair production and associated production constrain many other operators



Input data

Input dataset

Process	Dataset	$\sqrt{s}$	Info	Observables	$N_{\rm dat}$
Single t	`CMS_t_tch_8TeV_inc`	**8 TeV**	t-channel	$\sigma_{\rm tot}(t), \sigma_{\rm tot}(\bar{t})$ (R_t)	2 (1)
Single t	`CMS_t_sch_8TeV`	**8 TeV**	s-channel	$\sigma_{\rm tot}(t+\bar{t})$	1
Single t	`ATLAS_t_sch_8TeV`	**8 TeV**	s-channel	$\sigma_{\rm tot}(t+\bar{t})$	1
Single t	`ATLAS_t_tch_8TeV`	**8 TeV**	t-channel	$d\sigma(tq)/dp_T^t, d\sigma(\bar{t}q)/dp_T^{\bar{t}}$ $d\sigma(tq)/dy_t, d\sigma(\bar{t}q)/dy_t$	5, 4 4, 4
Single t	`ATLAS_t_tch_13TeV`	**13 TeV**	t-channel	$\sigma_{\rm tot}(t), \sigma_{\rm tot}(\bar{t})$ (R_t)	2 (1)
Single t	`CMS_t_tch_13TeV_inc`	**13 TeV**	t-channel	$\sigma_{\rm tot}(t+\bar{t})$ (R_t)	1 (1)
Single t	`CMS_t_tch_8TeV_dif`	**8 TeV**	t-channel	$d\sigma/dp_T^{(t+\bar{t})}$, $d\sigma/d\|y^{(t+\bar{t})}\|$	6 6
Single t	`CMS_t_tch_13TeV_dif`	**13 TeV**	t-channel	$d\sigma/dp_T^{(t+\bar{t})}$, $d\sigma/d\|y^{(t+\bar{t})}\|$	4 4
tW	`ATLAS_tW_inc_8TeV`	**8 TeV**	inclusive	$\sigma_{\rm tot}(tW)$	1
tW	`CMS_tW_inc_8TeV`	**8 TeV**	inclusive	$\sigma_{\rm tot}(tW)$	1
tW	`ATLAS_tW_inc_13TeV`	**13 TeV**	inclusive	$\sigma_{\rm tot}(tW)$	1
tW	`CMS_tW_inc_13TeV`	**13 TeV**	inclusive	$\sigma_{\rm tot}(tW)$	1
tZ	`CMS_tZ_inc_13TeV`	**13 TeV**	inclusive	$\sigma_{\rm fid}(Wbl^+l^-q)$	1
tZ	`ATLAS_tZ_inc_13TeV`	**13 TeV**	inclusive	$\sigma_{\rm tot}(tZq)$	1

Input dataset

Process	Dataset	$\sqrt{s}$	Info	Observables	$N_{\rm dat}$
$t\bar{t}$	ATLAS_tt_8TeV_ljets	8 TeV	lepton+jets	$d\sigma/d\|y_t\|$, $d\sigma/dp_t^T$, $d\sigma/dm_{t\bar{t}}$, $d\sigma/d\|y_{t\bar{t}}\|$	5, 8, 7, 5
$t\bar{t}$	CMS_tt_8TeV_ljets	8 TeV	lepton+jets	$d\sigma/dy_t$, $d\sigma/dp_t^T$, $d\sigma/dm_{t\bar{t}}$, $d\sigma/dy_{t\bar{t}}$	10, 8, 7, 10
$t\bar{t}$	CMS_tt2D_8TeV_dilep	8 TeV	dileptons	$d^2\sigma/dy_t dp_t^T$, $d^2\sigma/dy_t dm_{t\bar{t}}$, $d^2\sigma/dp_{t\bar{t}}^T dm_{t\bar{t}}$, $d^2\sigma/dy_{t\bar{t}} dm_{t\bar{t}}$	16, 16, 16, 16
$t\bar{t}$	CMS_tt_13TeV_ljets	13 TeV	lepton+jets	$d\sigma/d\|y_t\|$, $d\sigma/dp_t^T$, $d\sigma/dm_{t\bar{t}}$, $d\sigma/d\|y_{t\bar{t}}\|$	7, 9, 8, 6
$t\bar{t}$	CMS_tt_13TeV_ljets2	13 TeV	lepton+jets	$d\sigma/d\|y_t\|$, $d\sigma/dp_t^T$, $d\sigma/dm_{t\bar{t}}$, $d\sigma/d\|y_{t\bar{t}}\|$	11, 12, 10, 10
$t\bar{t}$	CMS_tt_13TeV_dilep	13 TeV	dileptons	$d\sigma/dy_t$, $d\sigma/dp_t^T$, $d\sigma/dm_{t\bar{t}}$, $d\sigma/dy_{t\bar{t}}$	8, 6, 6, 8
$t\bar{t}$	ATLASCMS_AcMtt_8TeV	8 TeV	Asymm comb	$A_C(m_{t\bar{t}})$, Eq. (3.1)	6
$t\bar{t}$	ATLAS_WhelF_8TeV	8 TeV	W helicity fract	F_0, F_L, F_R	3
$t\bar{t}$	CMS_WhelF_8TeV	8 TeV	W helicity fract	F_0, F_L, F_R	3

Input dataset

Process	Dataset	$\sqrt{s}$	Info	Observables	$N_{\rm dat}$
$t\bar{t}b\bar{b}$	CMS_ttbb_13TeV	13 TeV	total xsec	$\sigma_{\rm tot}(t\bar{t}b\bar{b})$	1
$t\bar{t}t\bar{t}$	CMS_tttt_13TeV	13 TeV	total xsec	$\sigma_{\rm tot}(t\bar{t}t\bar{t})$	1
$t\bar{t}Z$	CMS_ttZ_8_13TeV	8+13 TeV	total xsec	$\sigma_{\rm tot}(t\bar{t}Z)$	2
$t\bar{t}Z$	ATLAS_ttZ_8_13TeV	8+13 TeV	total xsec	$\sigma_{\rm tot}(t\bar{t}Z)$	2
$t\bar{t}W$	CMS_ttW_8_13TeV	8+13 TeV	total xsec	$\sigma_{\rm tot}(t\bar{t}W)$	2
$t\bar{t}W$	ATLAS_ttW_8_13TeV	8+13 TeV	total xsec	$\sigma_{\rm tot}(t\bar{t}W)$	2
$t\bar{t}H$	CMS_tth_13TeV	13 TeV	signal strength	$\mu_{t\bar{t}H}$	1
$t\bar{t}H$	ATLAS_tth_13TeV	13 TeV	total xsec	$\sigma_{\rm tot}(t\bar{t}H)$	1

- Over 100 cross-section measurements at 8 and 13 TeV from 10 different top-quark production processes

SMEFiT methodology

Methodology

- Very strong similarity to PDF fits - in PDF fits, LHC cross-sections are used to constrain PDFs

$$\sigma^{\rm th}(Q,\{a_k\}) = \sum_{i,j} \Gamma_{ij}(\alpha_s, Q, Q_0) \otimes q_i(x, Q_0, \{a_k\}) \otimes q_j(x, Q_0, \{a_k\})$$

- The PDF parameters $\{a_k\}$ are determined via minimising some figure of merit

$$\chi^2(\{a_k\}) = \sum_{m,n}^{n_{\rm dat}} \left(\sigma_n^{\rm exp} - \sigma_n^{\rm th}\{a_k\}\right)({\rm cov})^{-1}_{mn}\left(\sigma_m^{\rm exp} - \sigma_m^{\rm th}\{a_k\}\right)$$

- If we instead keep the PDF set constant, determined from a different data set, one can fit the SMEFT Wilson coefficients using the same approach as in the NNPDF case

$$\sigma^{\rm th}(Q,\{c_k\}) = \sigma_{\rm SM}(E)\left(1 + \sum_{i}^{N_{d6}} \kappa_i \frac{c_i}{\Lambda^2} + \sum_{i,j}^{N_{d6}} \widetilde{\kappa}_{ij} \frac{c_i c_j}{\Lambda^4}\right) \sum_{i,j} \Gamma_{ij}(\alpha_s, Q, Q_0) \otimes q_i(x, Q_0, \{a_k\}) \otimes q_j(x, Q_0, \{a_k\})$$

$$\chi^2(\{c_k\}) = \sum_{m,n}^{n_{\rm dat}} \left(\sigma_n^{\rm exp} - \sigma_n^{\rm th}\{c_k\}\right)({\rm cov})^{-1}_{mn}\left(\sigma_m^{\rm exp} - \sigma_m^{\rm th}\{c_k\}\right)$$

SMEFiT code

NNPDF code

- Experimental data and covariance matrices
- NLO APPLgrids and NNLO K-factors

aMC@NLO

- NLO QCD for SM input
- LO, NLO SMEFT
- SMEFT operators both at $\mathcal{O}(\Lambda^{-2})$, $\mathcal{O}(\Lambda^{-4})$

MCFM

- NLO QCD for SM input
- Cross-check with aMC@NLO

Python code

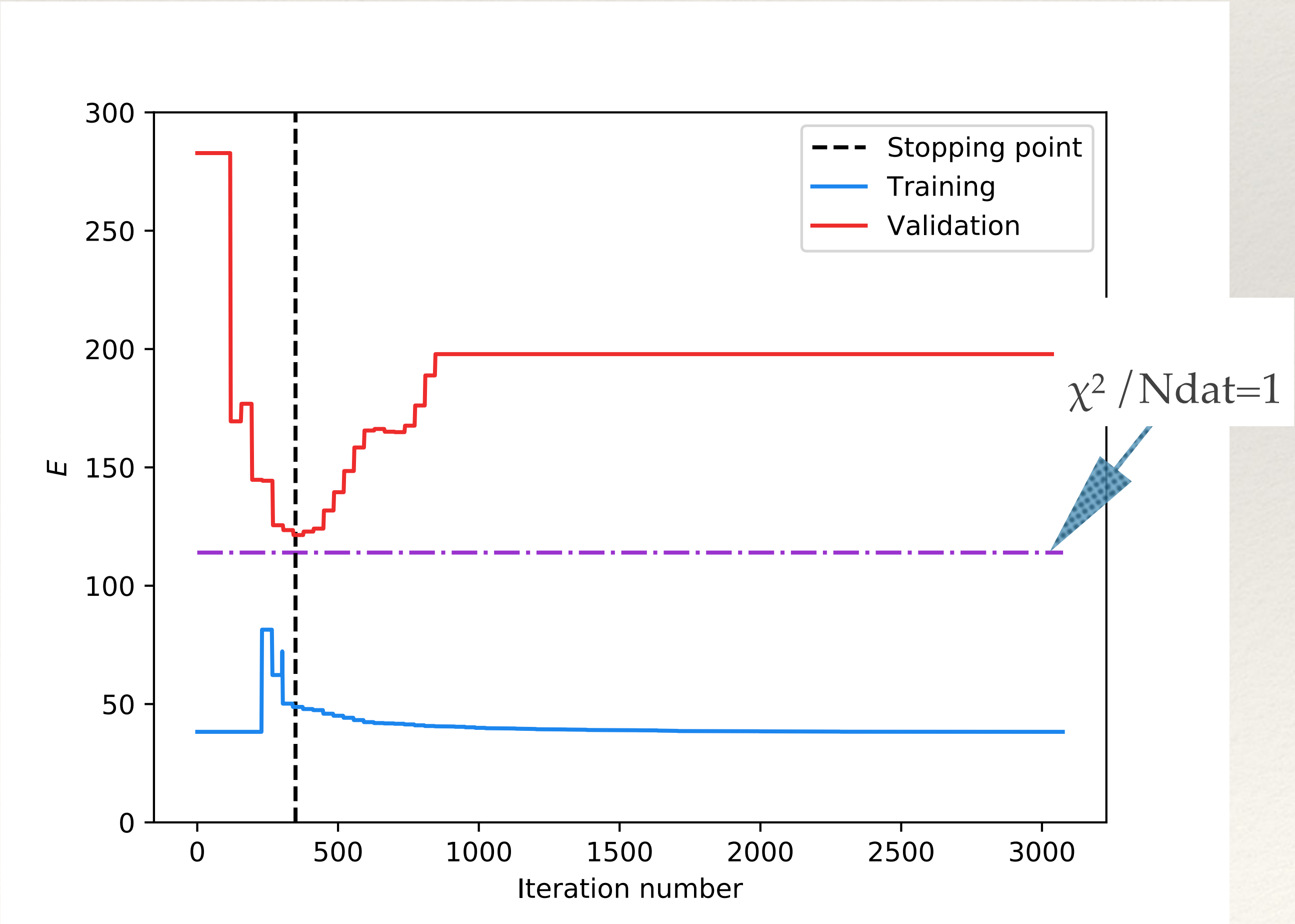
- Assemble SM and SMEFT theory predictions
- Optimisation using Sequential Quadratic Programming (SLSQP)
- Monte Carlo replicas for error propagation
- Monte Carlo cross-validation
- Closure testing

Fitting methodology

- We generate a large number of Monte Carlo replicas to construct the probability distribution in the space of experimental top-quark data

$$\mathcal{O}_i^{(\mathrm{art})(k)} = S_{i,N}^{(k)} \mathcal{O}_i^{(\mathrm{exp})} \left(1 + \sum_{\alpha=1}^{N_{\mathrm{sys}}} r_{i,\alpha}^{(k)} \sigma_{i,c}^{(\mathrm{sys})} + r_i^{(k)} \sigma_i^{(\mathrm{stat})}\right)$$

- We use cross-validation to avoid over-fitting to the data

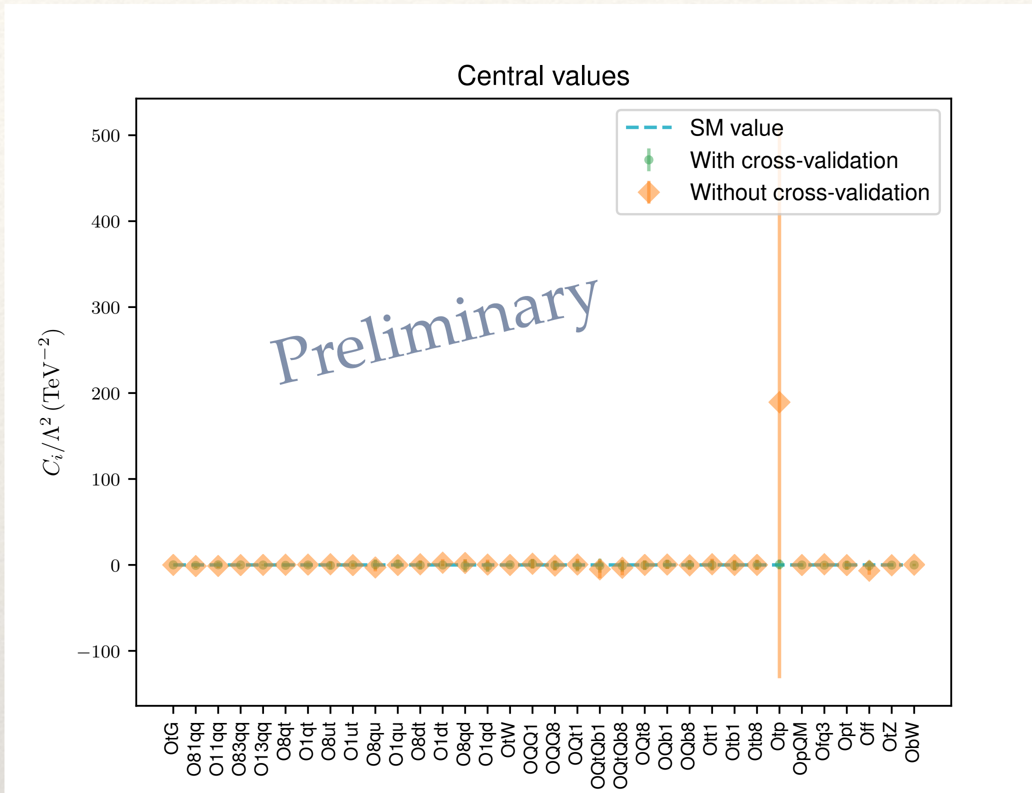


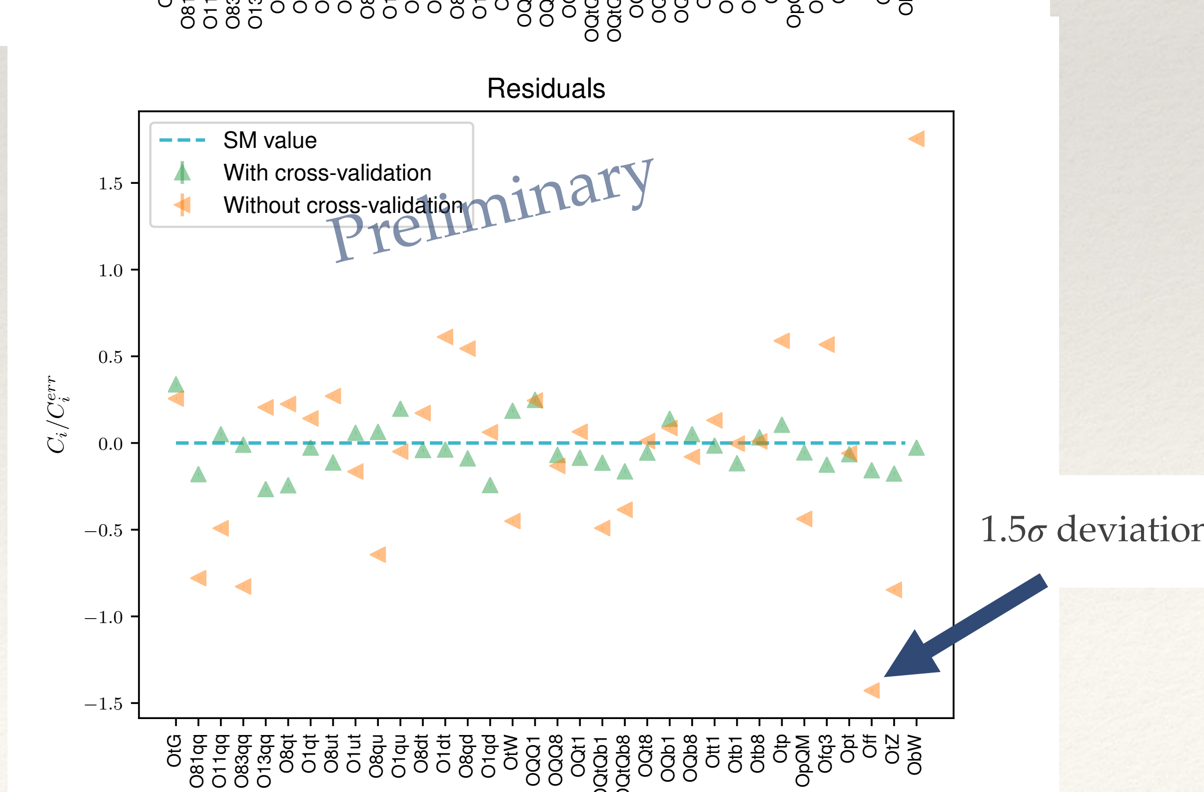
- PDF uncertainties included in the definition of the χ^2 as we use a NNPDF3.1 set without top-data to avoid double counting

- We see that without cross-validation the optimiser over-fits the data

Cross-validation

- The number of Wilson coefficients (34) is not to dissimilar to the total number of data points in the fit - so the optimiser will overfit the data
- We use cross-validation to avoid over-fitting to the data - artificial tensions with the SM are observed if we do not include cross-validation
- We can perform closure tests much as in the same way as in NNPDF: we generate pseudo-data based on a given scenario (SM or BSM) and check that the known (correct) results are reproduced after the fit
- Can test the impact of cross-validation within a closure test with pseudo-data generated with the SM
- Fit residuals only consistent with the SM if we include cross-validation



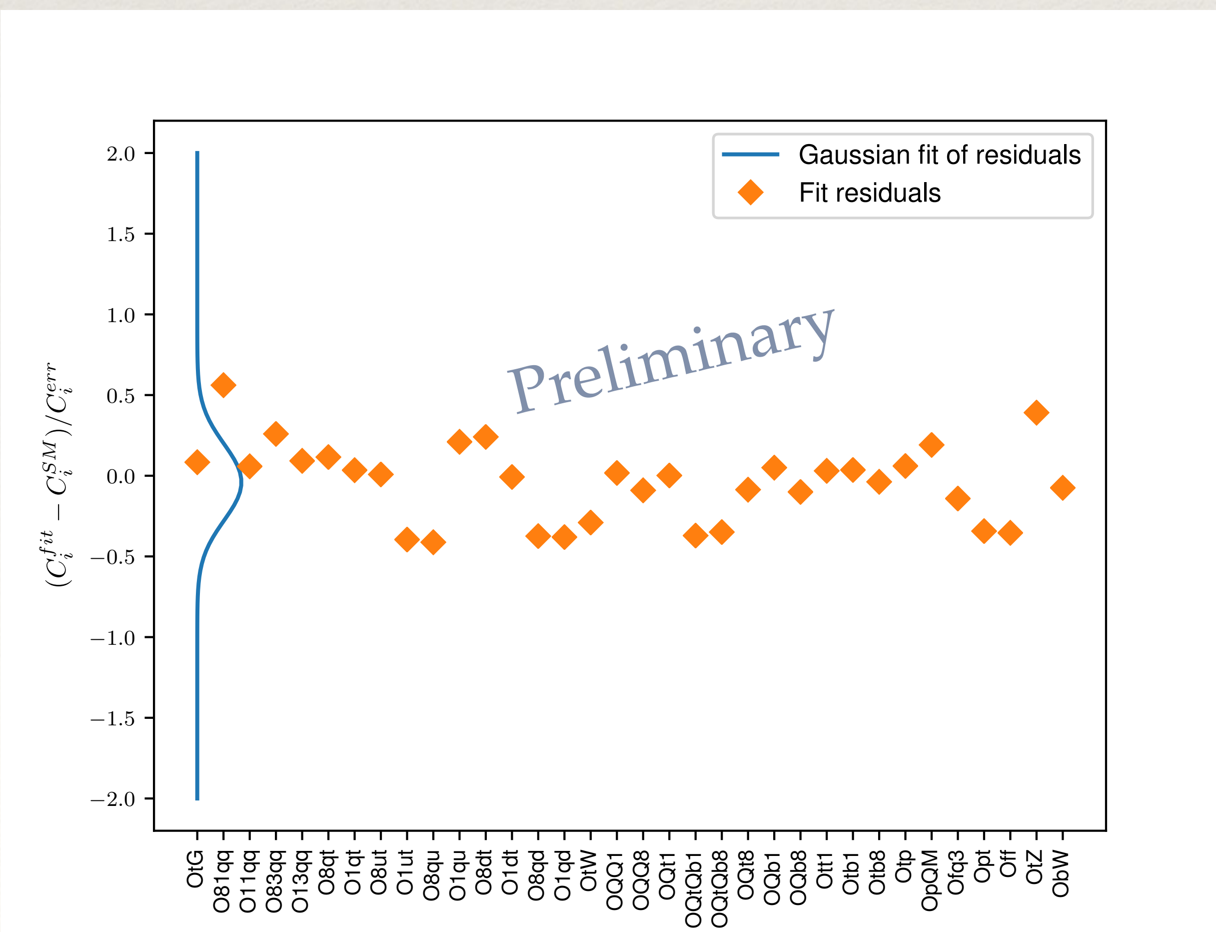


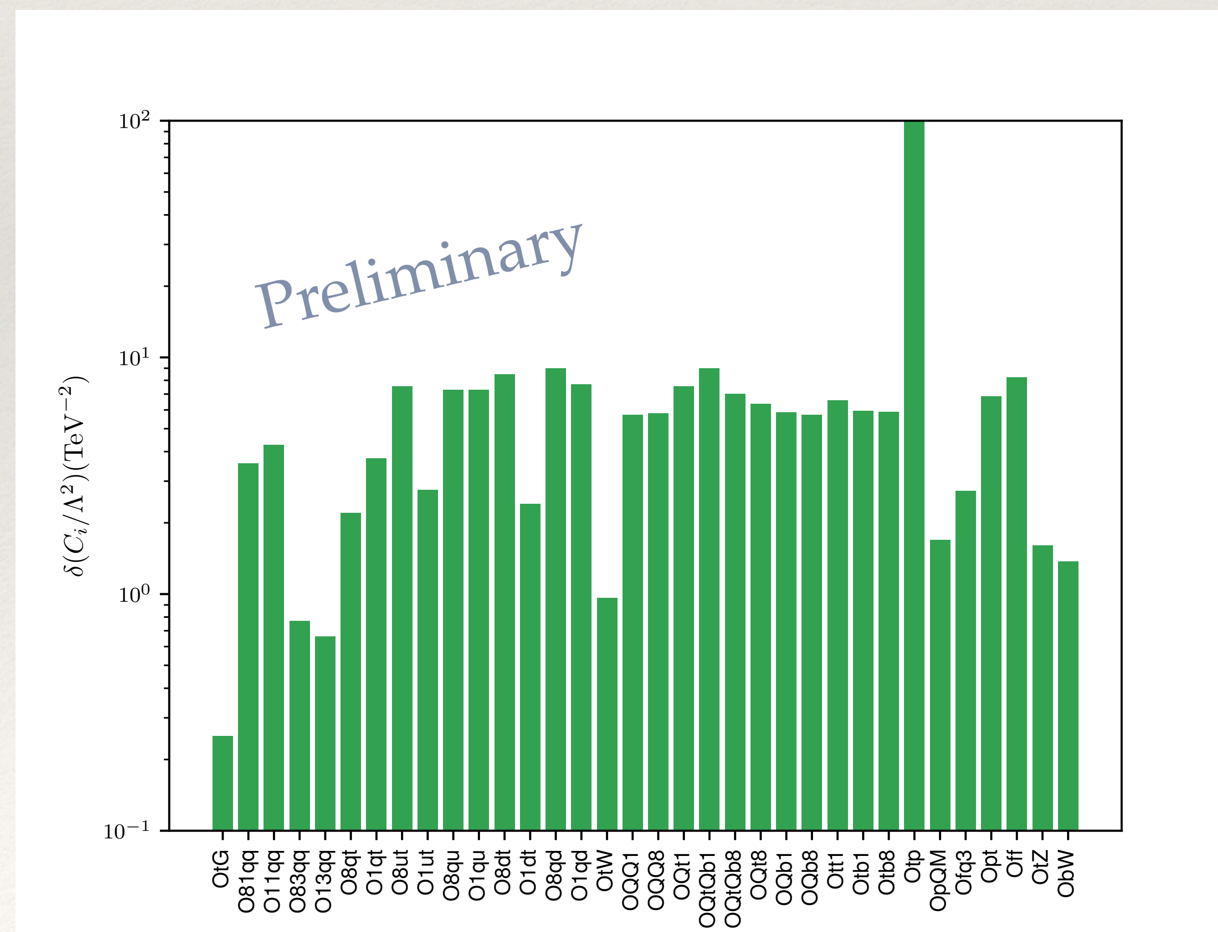
Results

Preliminary

Results

- We generate a large number of Monte Carlo replicas to construct the probability distribution in the space of experimental top-quark data
- We use cross-validation to avoid over-fitting to the data and use highest available perturbative order for all calculations
- We find all operators are constrained to be within 1 sigma of the SM





Results

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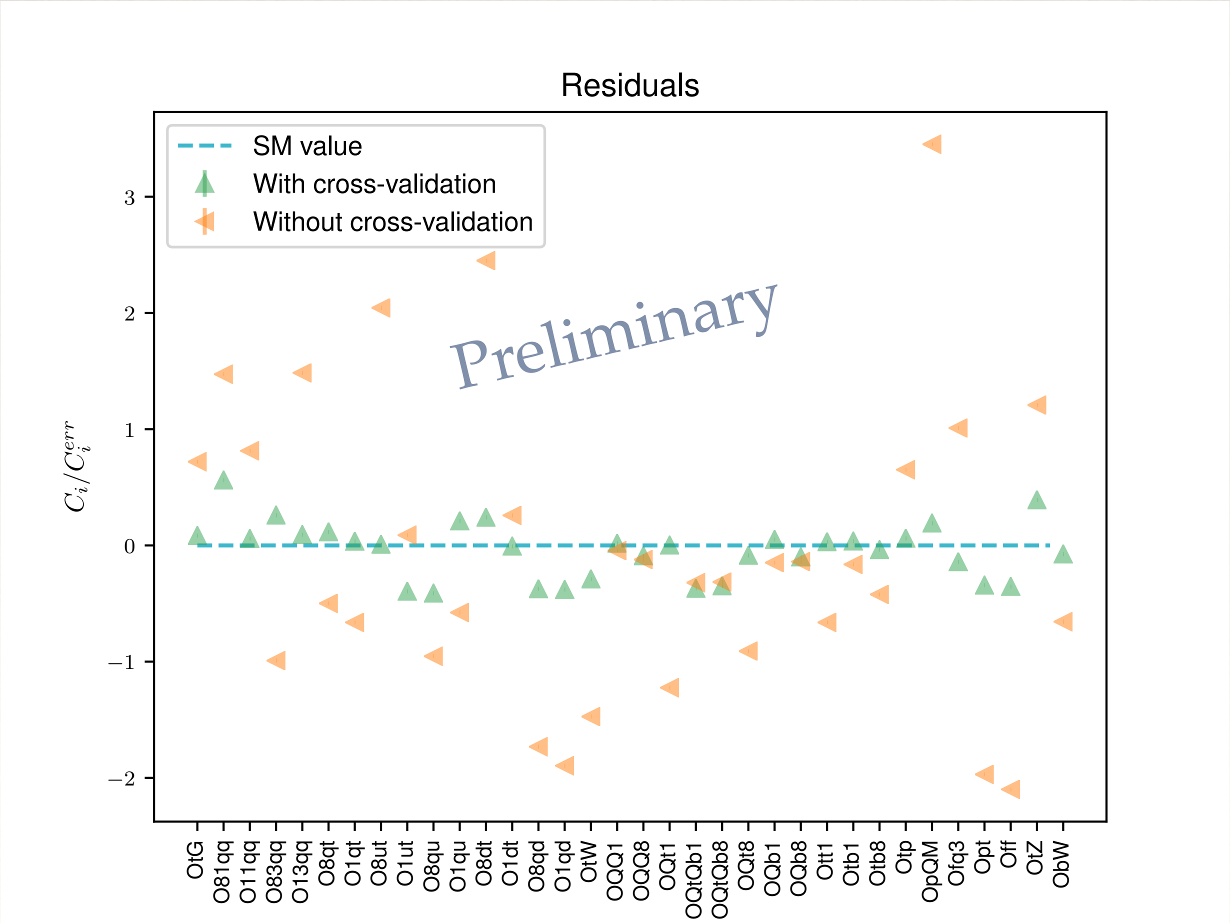
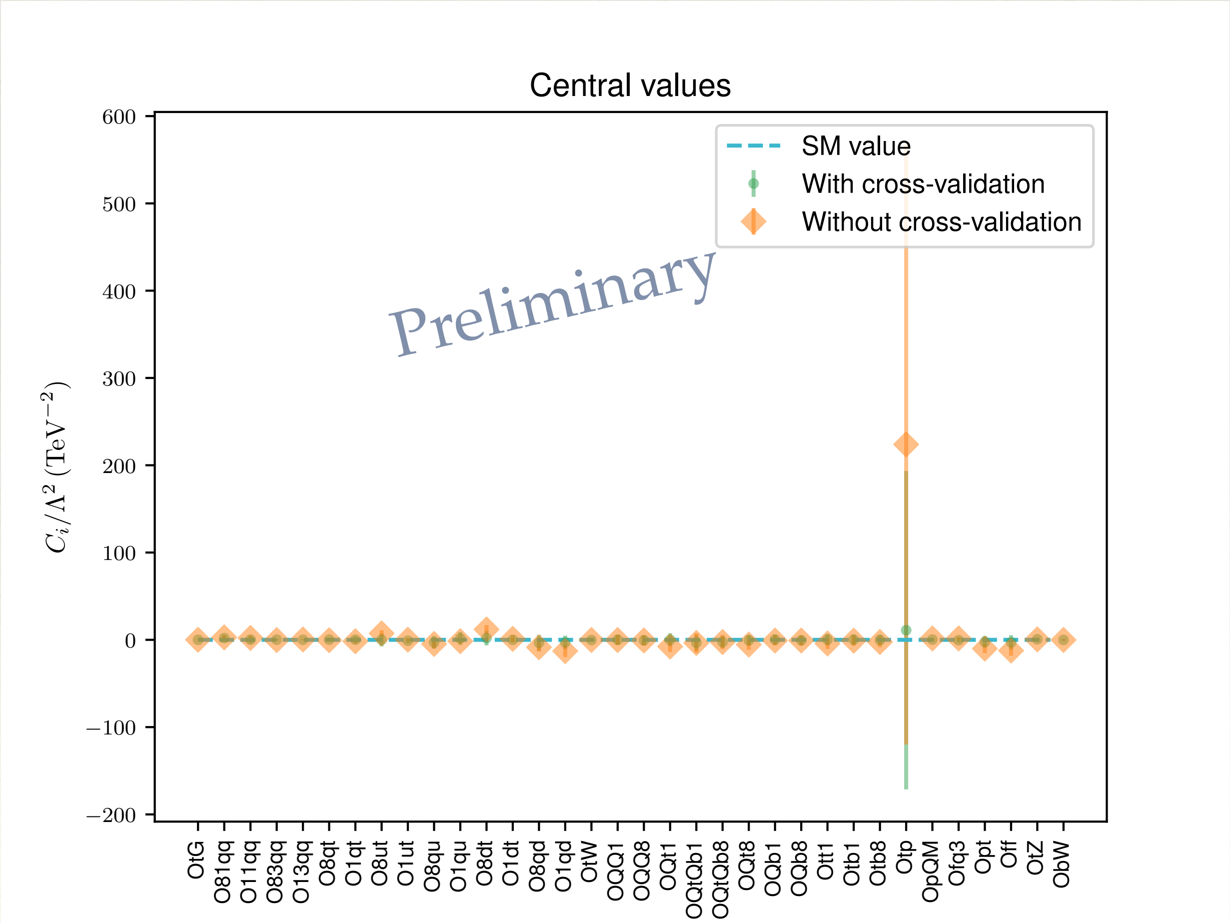
- We use cross-validation to avoid over-fitting to the data and use highest available perturbative order for all calculations
- Comparing to a fit without cross-validation we find >3 sigma discrepancies for some operators





Impact of single top

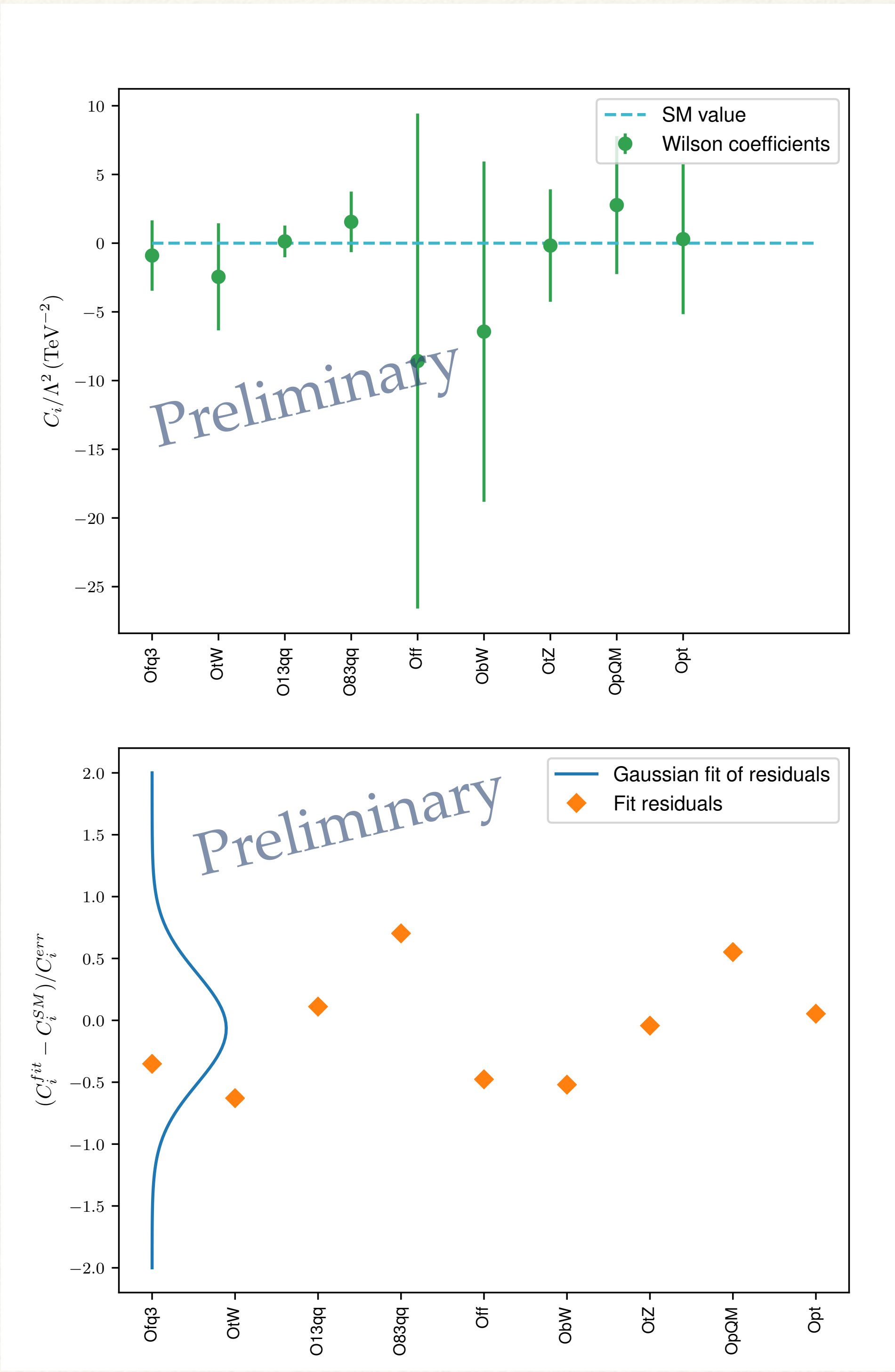
- Single-top data constrains 3 operators (OtW, ObW, Off) entirely, and contributes towards constraining 6 other operators

- With single-top alone we do obtain stringent bounds on a couple of operators, but several are loosely constrained

- Off and ObW are **only** constrained by the higher-order $\mathcal{O}(\Lambda^{-4})$ terms

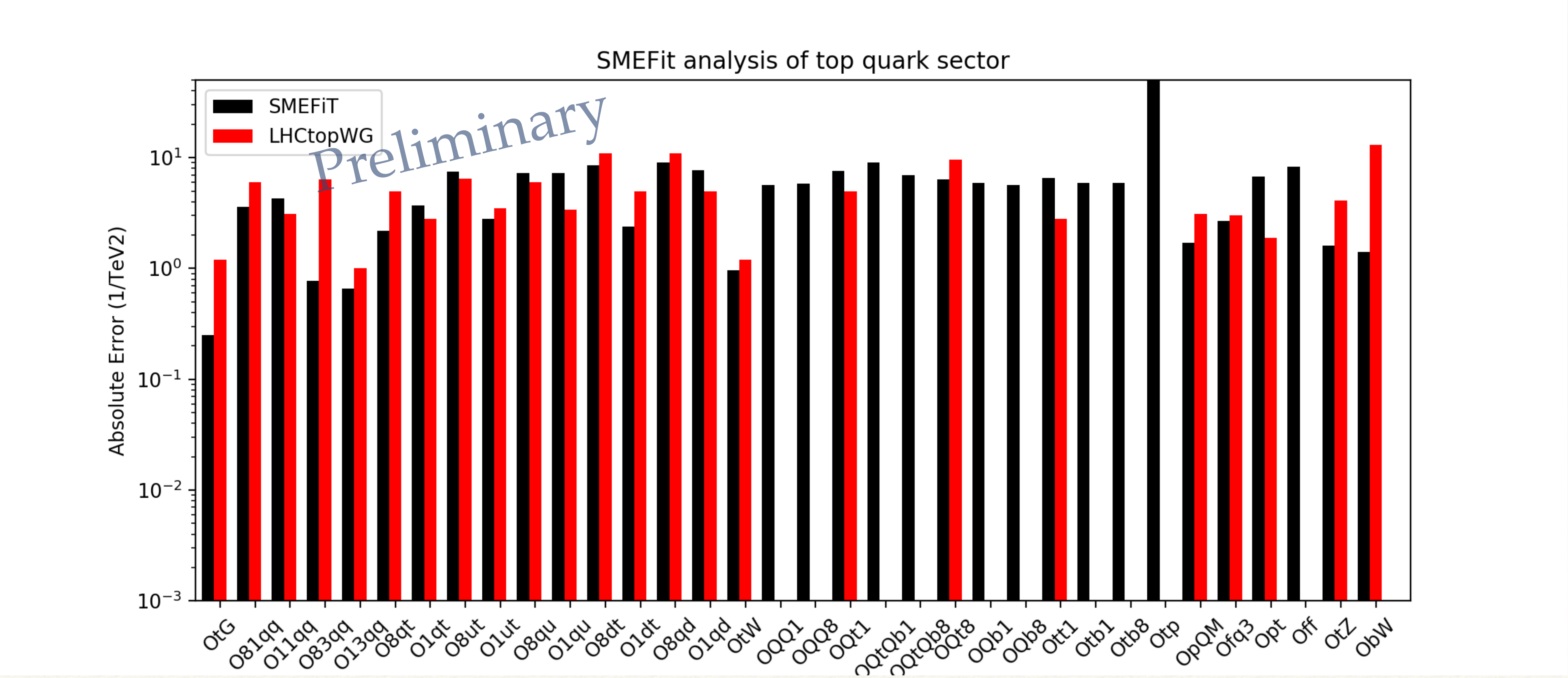
- All operators are within 1 sigma away from the standard model

- No new physics in the single-top sector?



Comparison with previous bounds

- Compare to bounds reported in LHC Top WG EFT note as they use same flavour assumptions
- Improvement in many degrees of freedom
- For a lot of operators, our bounds are the first to be reported



Summary and outlook

- We have presented a novel framework suitable for global analyses of the SMEFT using expertise in PDF fits
- Proof-of-concept of methodology applied to top sector
- Preliminary results indicate improved bounds on all parameters
- The code is entirely scalable - we can easily add new data and new operators to the fit

Next steps:

- Enlarge operator basis and add additional LHC cross-sections (Higgs, electroweak, jets)
- Ultimately we would like to perform a simultaneous fit of PDFs and SMEFT Wilson coefficients to ensure no overlap of data or kinematic regions

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Thanks for listening

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