Constraints From Global Fits

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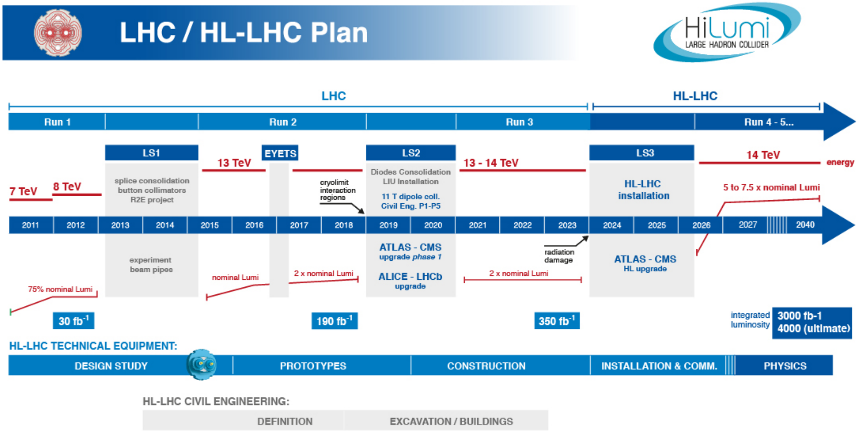
The Outline

- Constraints from Global Fits of Data
  - ☞ Improvements from Machine/Experiments
  - ☞ Improvements from Theory
- Global Fits @ the HL-LHC
  - fitting several observables @ high lumi
- Conclusions

Constraints from Global Fits

☞ The High Luminosity Phase of the LHC (HL-LHC Schedule)



- pp collisions @ 14 TeV, L=5-7.5$\times 10^{34}$cm^{-2}s^{-1}
- integrated luminosity: 3000 to 4000 fb^{-1}
- pile-up: 140 $\rightarrow$ 200 / bunch crossing

[Improvements from Machine/Experiments]

☞ Projections @ HL-LHC based on:

- **Full simulation** of reconstructed objects
- **Extrapolations** of existing results (scale factors applied)
- **Parametrizations** of detector sresponses (particle-leve objects reconstruction i.e., resolution effects, fake rates, etc.)

[Improvements from Machine/Experiments]

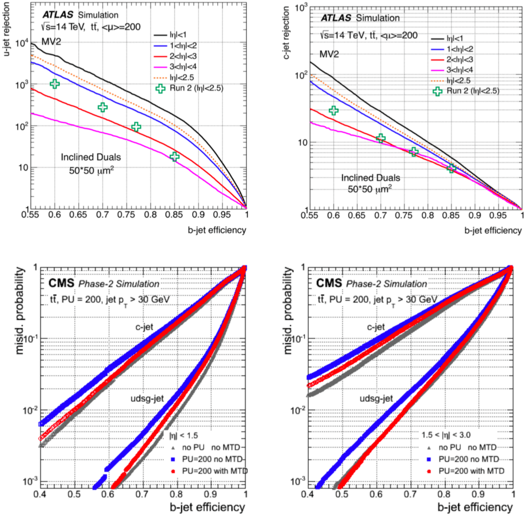
☞ Systematic Uncertainties @ HL-LHC:

- **No MC simulation** uncertainty, in general
- **Statistical uncertainties**, scale with luminosity, $1/\sqrt{L}$
- **Theoretical uncertainties** $\rightarrow$ reduce by $\times 2$, if unavailable
- **Analysis methods uncertainties** $\rightarrow$ keep the same
- **Intrinsic detector response** $\rightarrow$ keep the same
- **Flavour-tag** $\rightarrow$ reduce by 2 (due to improved tracker, resolution and coverage)

[Imp ... riments]

☞ Syst ... C:

- No M
- Stati ... ty, $1/\sqrt{L}$
- Theo ... f unavailable
- Anal ... e same
- Intri ... ne
- Flav ... tracker,
  reso

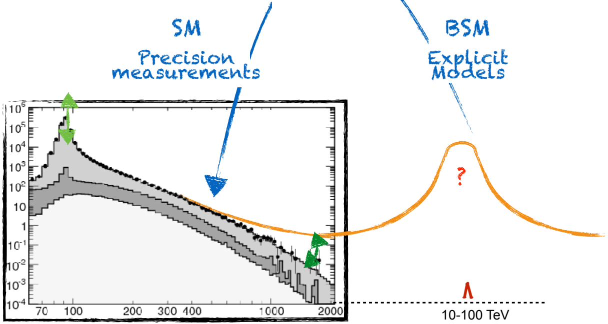


[Improvements from Theory]

☞ Effective Field Theory approach (EFT):

EFT

$$\mathcal{L}_{EFT} = \mathcal{L}_{SM} + \sum_i c_i \frac{\mathcal{O}_i}{\Lambda^2} + \cdots \quad (*)$$



[Improvements from Theory]

☞ Effective Field Theory approach (EFT):

- Dimension 6 Operators:

X^3		φ^6 and $\varphi^4 D^2$		$\psi^2\varphi^3$	
Q_G	$f^{ABC} G_\mu^{A\nu} G_\nu^{B\rho} G_\rho^{C\mu}$	Q_φ	$(\varphi^\dagger\varphi)^3$	$Q_{e\varphi}$	$(\varphi^\dagger\varphi)(\bar l_p e_r \varphi)$
$Q_{\widetilde G}$	$f^{ABC} \widetilde G_\mu^{A\nu} G_\nu^{B\rho} G_\rho^{C\mu}$	$Q_{\varphi\Box}$	$(\varphi^\dagger\varphi)\Box(\varphi^\dagger\varphi)$	$Q_{u\varphi}$	$(\varphi^\dagger\varphi)(\bar q_p u_r \widetilde\varphi)$
Q_W	$\varepsilon^{IJK} W_\mu^{I\nu} W_\nu^{J\rho} W_\rho^{K\mu}$	$Q_{\varphi D}$	$\left(\varphi^\dagger D^\mu\varphi\right)^\star \left(\varphi^\dagger D_\mu\varphi\right)$	$Q_{d\varphi}$	$(\varphi^\dagger\varphi)(\bar q_p d_r \varphi)$
$Q_{\widetilde W}$	$\varepsilon^{IJK} \widetilde W_\mu^{I\nu} W_\nu^{J\rho} W_\rho^{K\mu}$				
$X^2\varphi^2$		$\psi^2 X\varphi$		$\psi^2\varphi^2 D$	
$Q_{\varphi G}$	$\varphi^\dagger\varphi\, G_{\mu\nu}^A G^{A\mu\nu}$	Q_{eW}	$(\bar l_p \sigma^{\mu\nu} e_r)\tau^I \varphi W_{\mu\nu}^I$	$Q_{\varphi l}^{(1)}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu \varphi)(\bar l_p \gamma^\mu l_r)$
$Q_{\varphi\widetilde G}$	$\varphi^\dagger\varphi\, \widetilde G_{\mu\nu}^A G^{A\mu\nu}$	Q_{eB}	$(\bar l_p \sigma^{\mu\nu} e_r)\varphi B_{\mu\nu}$	$Q_{\varphi l}^{(3)}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu^I \varphi)(\bar l_p \tau^I \gamma^\mu l_r)$
$Q_{\varphi W}$	$\varphi^\dagger\varphi\, W_{\mu\nu}^I W^{I\mu\nu}$	Q_{uG}	$(\bar q_p \sigma^{\mu\nu} T^A u_r)\widetilde\varphi\, G_{\mu\nu}^A$	$Q_{\varphi e}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu \varphi)(\bar e_p \gamma^\mu e_r)$
$Q_{\varphi\widetilde W}$	$\varphi^\dagger\varphi\, \widetilde W_{\mu\nu}^I W^{I\mu\nu}$	Q_{uW}	$(\bar q_p \sigma^{\mu\nu} u_r)\tau^I \widetilde\varphi\, W_{\mu\nu}^I$	$Q_{\varphi q}^{(1)}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu \varphi)(\bar q_p \gamma^\mu q_r)$
$Q_{\varphi B}$	$\varphi^\dagger\varphi\, B_{\mu\nu} B^{\mu\nu}$	Q_{uB}	$(\bar q_p \sigma^{\mu\nu} u_r)\widetilde\varphi\, B_{\mu\nu}$	$Q_{\varphi q}^{(3)}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu^I \varphi)(\bar q_p \tau^I \gamma^\mu q_r)$
$Q_{\varphi\widetilde B}$	$\varphi^\dagger\varphi\, \widetilde B_{\mu\nu} B^{\mu\nu}$	Q_{dG}	$(\bar q_p \sigma^{\mu\nu} T^A d_r)\varphi\, G_{\mu\nu}^A$	$Q_{\varphi u}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu \varphi)(\bar u_p \gamma^\mu u_r)$
$Q_{\varphi WB}$	$\varphi^\dagger\tau^I\varphi\, W_{\mu\nu}^I B^{\mu\nu}$	Q_{dW}	$(\bar q_p \sigma^{\mu\nu} d_r)\tau^I \varphi\, W_{\mu\nu}^I$	$Q_{\varphi d}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu \varphi)(\bar d_p \gamma^\mu d_r)$
$Q_{\varphi\widetilde WB}$	$\varphi^\dagger\tau^I\varphi\, \widetilde W_{\mu\nu}^I B^{\mu\nu}$	Q_{dB}	$(\bar q_p \sigma^{\mu\nu} d_r)\varphi\, B_{\mu\nu}$	$Q_{\varphi ud}$	$i(\widetilde\varphi^\dagger D_\mu\varphi)(\bar u_p \gamma^\mu d_r)$

$(\bar LL)(\bar LL)$		$(\bar RR)(\bar RR)$		$(\bar LL)(\bar RR)$	
Q_{ll}	$(\bar l_p\gamma_\mu l_r)(\bar l_s\gamma^\mu l_t)$	Q_{ee}	$(\bar e_p\gamma_\mu e_r)(\bar e_s\gamma^\mu e_t)$	Q_{le}	$(\bar l_p\gamma_\mu l_r)(\bar e_s\gamma^\mu e_t)$
$Q_{qq}^{(1)}$	$(\bar q_p\gamma_\mu q_r)(\bar q_s\gamma^\mu q_t)$	Q_{uu}	$(\bar u_p\gamma_\mu u_r)(\bar u_s\gamma^\mu u_t)$	Q_{lu}	$(\bar l_p\gamma_\mu l_r)(\bar u_s\gamma^\mu u_t)$
$Q_{qq}^{(3)}$	$(\bar q_p\gamma_\mu\tau^I q_r)(\bar q_s\gamma^\mu\tau^I q_t)$	Q_{dd}	$(\bar d_p\gamma_\mu d_r)(\bar d_s\gamma^\mu d_t)$	Q_{ld}	$(\bar l_p\gamma_\mu l_r)(\bar d_s\gamma^\mu d_t)$
$Q_{lq}^{(1)}$	$(\bar l_p\gamma_\mu l_r)(\bar q_s\gamma^\mu q_t)$	Q_{eu}	$(\bar e_p\gamma_\mu e_r)(\bar u_s\gamma^\mu u_t)$	Q_{qe}	$(\bar q_p\gamma_\mu q_r)(\bar e_s\gamma^\mu e_t)$
$Q_{lq}^{(3)}$	$(\bar l_p\gamma_\mu\tau^I l_r)(\bar q_s\gamma^\mu\tau^I q_t)$	Q_{ed}	$(\bar e_p\gamma_\mu e_r)(\bar d_s\gamma^\mu d_t)$	$Q_{qu}^{(1)}$	$(\bar q_p\gamma_\mu q_r)(\bar u_s\gamma^\mu u_t)$
		$Q_{ud}^{(1)}$	$(\bar u_p\gamma_\mu u_r)(\bar d_s\gamma^\mu d_t)$	$Q_{qu}^{(8)}$	$(\bar q_p\gamma_\mu T^A q_r)(\bar u_s\gamma^\mu T^A u_t)$
		$Q_{ud}^{(8)}$	$(\bar u_p\gamma_\mu T^A u_r)(\bar d_s\gamma^\mu T^A d_t)$	$Q_{qd}^{(1)}$	$(\bar q_p\gamma_\mu q_r)(\bar d_s\gamma^\mu d_t)$
				$Q_{qd}^{(8)}$	$(\bar q_p\gamma_\mu T^A q_r)(\bar d_s\gamma^\mu T^A d_t)$

$(\bar LR)(\bar RL)$ and $(\bar LR)(\bar LR)$		B-violating	
Q_{ledq}	$(\bar l_p^j e_r)(\bar d_s q_t^j)$	Q_{duq}	$\varepsilon^{\alpha\beta\gamma}\varepsilon_{jk}\left[(d_p^\alpha)^T C u_r^\beta\right]\left[(q_s^{\gamma j})^T C l_t^k\right]$
$Q_{quqd}^{(1)}$	$(\bar q_p^j u_r)\varepsilon_{jk}(\bar q_s^k d_t)$	Q_{qqu}	$\varepsilon^{\alpha\beta\gamma}\varepsilon_{jk}\left[(q_p^{\alpha j})^T C q_r^{\beta k}\right]\left[(u_s^\gamma)^T C e_t\right]$
$Q_{quqd}^{(8)}$	$(\bar q_p^j T^A u_r)\varepsilon_{jk}(\bar q_s^k T^A d_t)$	$Q_{qqq}^{(1)}$	$\varepsilon^{\alpha\beta\gamma}\varepsilon_{jk}\varepsilon_{mn}\left[(q_p^{\alpha j})^T C q_r^{\beta k}\right]\left[(q_s^{\gamma m})^T C l_t^n\right]$
$Q_{lequ}^{(1)}$	$(\bar l_p^j e_r)\varepsilon_{jk}(\bar q_s^k u_t)$	$Q_{qqq}^{(3)}$	$\varepsilon^{\alpha\beta\gamma}(\tau^I\varepsilon)_{jk}(\tau^I\varepsilon)_{mn}\left[(q_p^{\alpha j})^T C q_r^{\beta k}\right]\left[(q_s^{\gamma m})^T C l_t^n\right]$
$Q_{lequ}^{(3)}$	$(\bar l_p^j \sigma_{\mu\nu} e_r)\varepsilon_{jk}(\bar q_s^k \sigma^{\mu\nu} u_t)$	Q_{duu}	$\varepsilon^{\alpha\beta\gamma}\left[(d_p^\alpha)^T C u_r^\beta\right]\left[(u_s^\gamma)^T C e_t\right]$

- Buchmuller, Wyler Nucl.Phys. **B268** (1986) 621-653, Grzadkowski et al arxiv:1008.4884

[Improvements from Theory]

☞ Effective Field Theory approach (EFT):

- Example of top quark operators:

$$O_{\varphi Q}^{(3)} = i\frac{1}{2}y_t^2\left(\varphi^\dagger \overleftrightarrow{D}^I_\mu \varphi\right)\left(\bar{Q}\gamma^\mu \tau^I Q\right)$$

$$O_{\varphi Q}^{(1)} = i\frac{1}{2}y_t^2\left(\varphi^\dagger \overleftrightarrow{D}_\mu \varphi\right)\left(\bar{Q}\gamma^\mu Q\right)$$

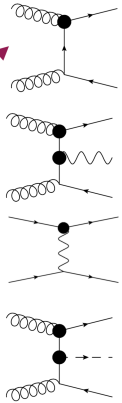
$$O_{\varphi t} = i\frac{1}{2}y_t^2\left(\varphi^\dagger \overleftrightarrow{D}_\mu \varphi\right)\left(\bar{t}\gamma^\mu t\right)$$

$$O_{tW} = y_t g_w(\bar{Q}\sigma^{\mu\nu}\tau^I t)\tilde{\varphi}W^I_{\mu\nu}$$

$$O_{tB} = y_t g_Y(\bar{Q}\sigma^{\mu\nu} t)\tilde{\varphi}B_{\mu\nu}$$

$$O_{tG} = y_t g_s(\bar{Q}\sigma^{\mu\nu}T^A t)\tilde{\varphi}G^A_{\mu\nu}\,,$$

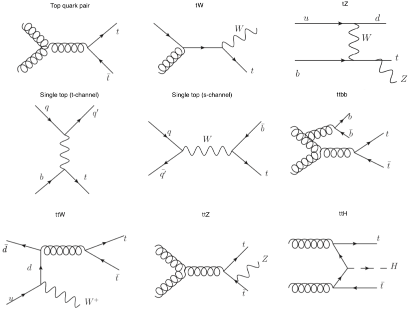
$$O_{t\phi} = y_t^3\left(\phi^\dagger\phi\right)\left(\bar{Q}t\right)\tilde{\phi}$$



+ Four-Fermion Operators
+ non-top operators (mixing)

[Improvements from Theory]

☞ Towards a Global SMEFT Fit:

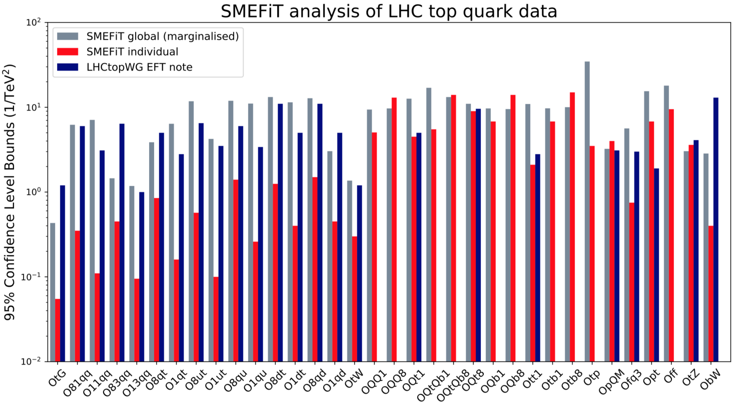


- Maltoni et al., arXiv:1901.05965
- 34 d.o.f., $\geq$ 100 observables

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							✓		

[Improvements from Theory]

☞ Towards a Global SMEFT Fit: Results



- Maltoni et al., arXiv:1901.05965 [LHCTopWG EFT note, arXiv:1802.07237]

Extrapolation test, from 13 to 14 TeV:

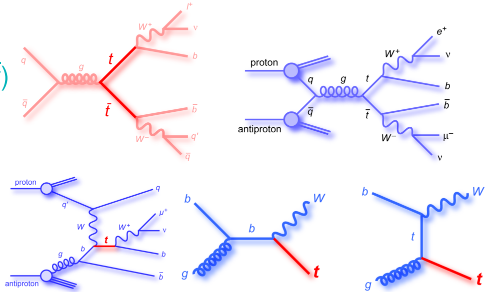
- Constraints from Global Fits of Data
  ☞ @ HL-LHC

Global Fits of Data

The objective: extend the studies already performed at the LHC on top quark Anomalous Couplings/EFT in $t \to Wb$ decays to HL-LHC

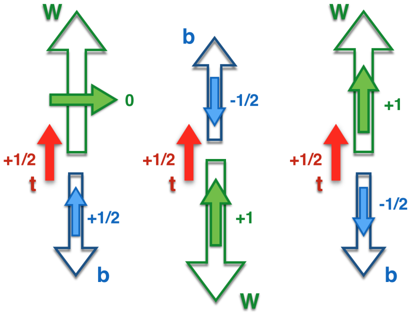
Several processes under study to probe the *Wtb* vertex[1]:

- Top quark pair production ($t\bar{t}$)
  - (i) semileptonic channel
  - (ii) dileptonic decays
- single top quark physics
  - (i) *t*-channel (single lepton)
  - (ii) *Wt*-channel (dileptonic decay)
- EFT/anomalous couplings studied associated to the *Wtb* vertex



[1] JHEP**1206**(2012)088, EPJC**77**(2017)264, JHEP**04**(2017)124, JHEP**04**(2016)023, JHEP**12**(2017)017, PLB**717**(2012)330, PRD**90**(2014)112006, PLB**716**(2012)142, PLB**756**(2016)228, EPJC**77**(2017)531, JHEP**01**(2016)064, JHEP**04**(2017)086, JHEP**01**(2018)63, EPJC**78**(2018)186

☞ Observable(s): angular distribution(s) $\cos\theta^*_\ell$ $[F_0, F_L, F_R]$



F_0
W Longitudinal fraction

F_L
W Left-Handed fraction

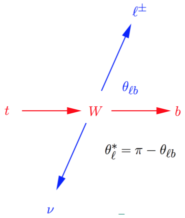
F_R
W Right-Handed fraction

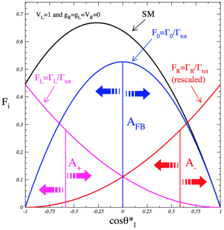
$F_0^{SM} = 0.687 \pm 0.005$

$F_L^{SM} = 0.311 \pm 0.005$

$F_R^{SM} = 0.0017 \pm 0.0001$

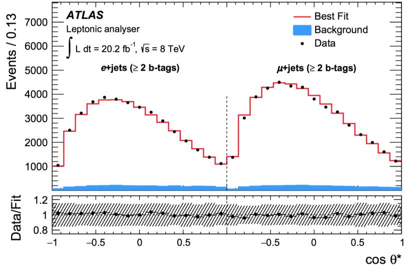
@ NNLO QCD calculation, PRD**81**(2010)111503
($F_0 + F_L + F_R = 1$)



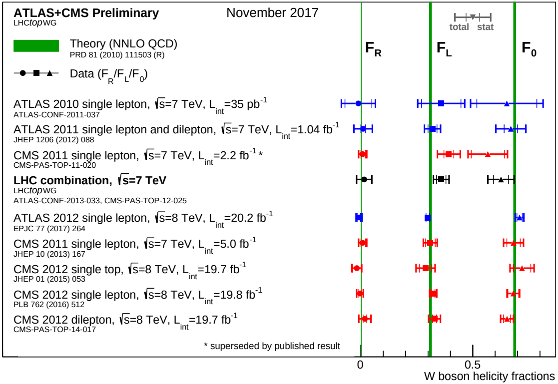


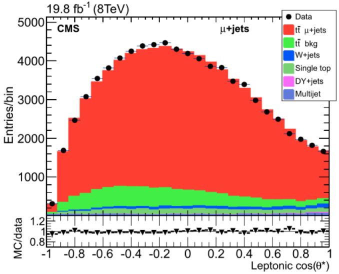
$$\frac{1}{N}\frac{dN}{d\cos\theta^*_\ell} = \frac{3}{2}\left[F_0\left(\frac{\sin\theta^*_\ell}{\sqrt{2}}\right)^2 + F_L\left(\frac{1-\cos\theta^*_\ell}{2}\right)^2 + F_R\left(\frac{1+\cos\theta^*_\ell}{2}\right)^2\right]$$

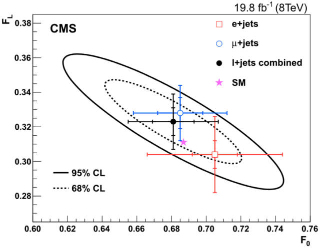
EPJC**77**(2017)264



Summary of W-boson helicity meas. @ LHC







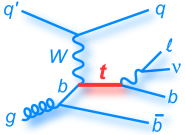
$$\Delta F_0/F_0 \sim 2.7\% \ (3.7\times \text{ theo. unc.})$$

$$\Delta F_L/F_L \sim 5\% \ (3.1\times \text{ theo. unc.})$$

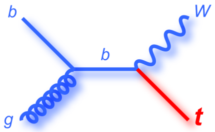
$$F_R = -0.008 \pm 0.014$$

Single top quark production

- Processes currently under study:

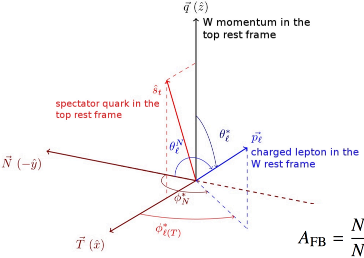


t-channel



(*Wt*-prod.)

☞ Observables: 2D angular distributions in *t*-channel production as a function of 6 spin observabels $< S_{1,2,3} >$, $< T_0 >$, $< A_{1,2} >$ [PRD **93** (2016) 011301]



1) Double-differential distribution:

$$\frac{1}{\Gamma}\frac{\mathrm{d}\Gamma}{\mathrm{d}(\cos\theta_\ell^*)\mathrm{d}\phi_\ell^*} = \frac{3}{8\pi}\left\{\frac{2}{3} + \frac{1}{\sqrt{6}}\langle T_0\rangle\left(3\cos^2\theta_\ell^* - 1\right) + \langle S_3\rangle\cos\theta_\ell^* \right.$$
$$+ \langle S_1\rangle\cos\phi_\ell^*\sin\theta_\ell^* + \langle S_2\rangle\sin\phi_\ell^*\sin\theta_\ell^*$$
$$\left. - \langle A_1\rangle\cos\phi_\ell^*\sin 2\theta_\ell^* - \langle A_2\rangle\sin\phi_\ell^*\sin 2\theta_\ell^* \right\}.$$

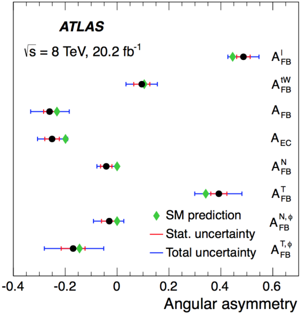
2) A_{FB} and A_{EC} Asymmetries:

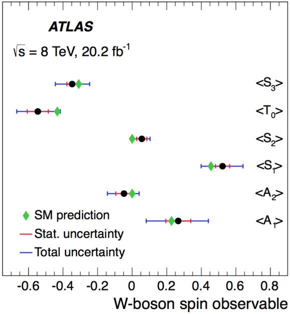
$$A_{\mathrm{FB}} = \frac{N(\cos\theta > 0) - N(\cos\theta < 0)}{N(\cos\theta > 0) + N(\cos\theta < 0)} \qquad A_{\mathrm{EC}} = \frac{N(|\cos\theta| > \frac{1}{2}) - N(|\cos\theta| < \frac{1}{2})}{N(|\cos\theta| > \frac{1}{2}) + N(|\cos\theta| < \frac{1}{2})}$$

- Asymmetries with associated angular distributions [JHEP**04**(2017)124]:

Asymmetry	Angular observable	Polarisation observable	SM prediction
$A^{\ell}_{\rm FB}$	$\cos\theta_\ell$	$\frac{1}{2}\alpha_\ell P$	0.45
$A^{tW}_{\rm FB}$	$\cos\theta_W \cos\theta^*_\ell$	$\frac{3}{8}P\,(F_{\rm R}+F_{\rm L})$	0.10
$A_{\rm FB}$	$\cos\theta^*_\ell$	$\frac{3}{4}\langle S_3\rangle = \frac{3}{4}\,(F_{\rm R}-F_{\rm L})$	−0.23
$A_{\rm EC}$	$\cos\theta^*_\ell$	$\frac{3}{8}\sqrt{\frac{3}{2}}\langle T_0\rangle = \frac{3}{16}\,(1-3F_0)$	−0.20
$A^{T}_{\rm FB}$	$\cos\theta^T_\ell$	$\frac{3}{4}\langle S_1\rangle$	0.34
$A^{N}_{\rm FB}$	$\cos\theta^N_\ell$	$-\frac{3}{4}\langle S_2\rangle$	0
$A^{T,\phi}_{\rm FB}$	$\cos\theta^*_\ell \cos\phi^*_T$	$-\frac{2}{\pi}\langle A_1\rangle$	−0.14
$A^{N,\phi}_{\rm FB}$	$\cos\theta^*_\ell \cos\phi^*_N$	$\frac{2}{\pi}\langle A_2\rangle$	0

$$A^{\ell}_{\rm FB} = 0.49 \pm 0.03\ (\text{stat.}) \pm 0.05\ (\text{syst.}) = 0.49 \pm 0.06\,,$$
$$A^{tW}_{\rm FB} = 0.10 \pm 0.03\ (\text{stat.}) \pm 0.05\ (\text{syst.}) = 0.10 \pm 0.06\,,$$
$$A_{\rm FB} = -0.26 \pm 0.02\ (\text{stat.}) \pm 0.07\ (\text{syst.}) = -0.26 \pm 0.08\,,$$
$$A_{\rm EC} = -0.25 \pm 0.03\ (\text{stat.}) \pm 0.05\ (\text{syst.}) = -0.25 \pm 0.06\,,$$
$$A^{T}_{\rm FB} = 0.39 \pm 0.03\ (\text{stat.}) \pm 0.09\ (\text{syst.}) = 0.39 \pm 0.09\,,$$
$$A^{N,\phi}_{\rm FB} = -0.03 \pm 0.03\ (\text{stat.}) \pm 0.05\ (\text{syst.}) = -0.03 \pm 0.06\,,$$
$$A^{T,\phi}_{\rm FB} = -0.17 \pm 0.05\ (\text{stat.})^{+0.11}_{-0.10}\ (\text{syst.}) = -0.17^{+0.12}_{-0.11}\,.$$





Spin Measurements:

$< S_3 >= -0.35 \pm 0.10$

$< T_0 >= -0.55 \pm 0.13$

$< S_2 >= +0.06 \pm 0.05$

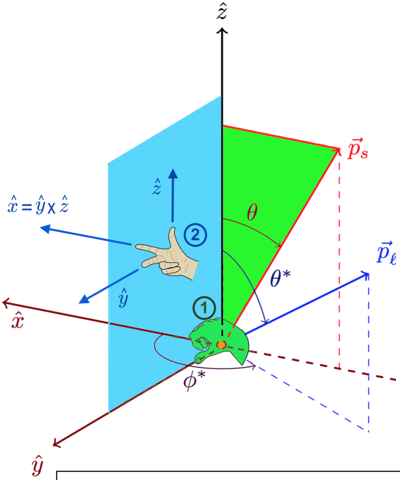
$< S_1 >= +0.52 \pm 0.12$

$< A_2 >= -0.05 \pm 0.10$

$< A_1 >= +0.27\ ^{+0.17}_{-0.19}$

Single top quark production

- Triple-differential (3D) decay rates of polarised top quarks
  - ☞ define specific coordinate system (in t centre-of-mass):



1) System Definition (in t-system):

$\hat{z} = \hat{p}^*_W = \vec{p}^{\,*}_W / |\vec{p}^{\,*}_W|$, $\vec{p}^{\,*}_s$=spectator quark mom.

$\hat{y} = \hat{p}^*_s \times \hat{p}^*_W$, $\hat{x} = \hat{y} \times \hat{p}^*_W$

2) Triple-differential distribution:

$$\varrho(\theta,\theta^*,\phi^*;P) = \frac{1}{N}\frac{\mathrm{d}^3N}{\mathrm{d}(\cos\theta)\mathrm{d}\Omega^*} = \frac{1}{8\pi}\left\{\frac{3}{4}\left|A_{1,\frac{1}{2}}\right|^2(1+P\cos\theta)(1+\cos\theta^*)^2\right.$$
$$+ \frac{3}{4}\left|A_{-1,-\frac{1}{2}}\right|^2(1-P\cos\theta)(1-\cos\theta^*)^2$$
$$+ \frac{3}{2}\left(\left|A_{0,\frac{1}{2}}\right|^2(1-P\cos\theta)+\left|A_{0,-\frac{1}{2}}\right|^2(1+P\cos\theta)\right)\sin^2\theta^*$$
$$- \frac{3\sqrt{2}}{2}P\sin\theta\sin\theta^*(1+\cos\theta^*)\,\mathrm{Re}\left[e^{i\phi^*}A_{1,\frac{1}{2}}A^*_{0,\frac{1}{2}}\right]$$
$$\left.- \frac{3\sqrt{2}}{2}P\sin\theta\sin\theta^*(1-\cos\theta^*)\,\mathrm{Re}\left[e^{-i\phi^*}A_{-1,-\frac{1}{2}}A^*_{0,-\frac{1}{2}}\right]\right\}$$
$$= \sum_{k=0}^{1}\sum_{l=0}^{2}\sum_{m=-k}^{k} a_{k,l,m}M^m_{k,l}(\theta,\theta^*,\phi^*)\,,$$

A_{λ_W,λ_b} = helicity amplitudes

$$M^m_{k,l}(\theta,\theta^*,\phi^*) = \sqrt{2\pi}Y^m_k(\theta,0)Y^m_l(\theta^*,\phi^*)$$

Results Interpreted in Terms of Anomalous Couplings (V_R, g_L, g_R)

☞ **next slide**

Anomalous couplings/EFT parameters in global fits

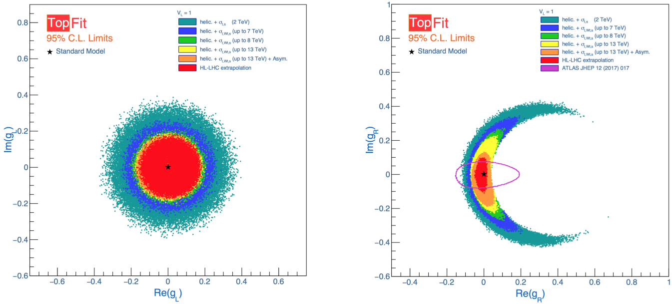
General Wtb vertex — Eur.Phys.J. C50 (2007) 519-533

$$\mathcal{L} = -\frac{g}{\sqrt{2}}\bar{b}\gamma^{\mu}\left(V_{\rm L}P_{\rm L} + V_{\rm R}P_{\rm R}\right)t\,W_{\mu}^{-} - \frac{g}{\sqrt{2}}\bar{b}\,\frac{i\sigma^{\mu\nu}q_{\nu}}{M_W}\left(g_{\rm L}P_{\rm L} + g_{\rm R}P_{\rm R}\right)t\,W_{\mu}^{-}$$

vector ($V_{\rm R}$) and tensor like couplings ($g_{\rm L}$, $g_{\rm R}$) zero @ tree level in SM

☞ EFT parameters: anomalous couplings described by effective operators $\mathcal{O}_{uW}$,$\mathcal{O}_{dW}$, $\mathcal{O}_{\phi q}^{(3)}$ and $\mathcal{O}_{\phi ud}$ i.e., constraints on anomalous couplings equivalent to constraints on EFT parameters (a more integrating framework) [arXiv:1802.07237]

PRD 97 (2018) 1, 013007 (TopFit), arXiv:1811.02492



Fits Using:

σ, W_{hel}, A_{FB} @ 7,8,13 TeV

Conclusions

Global SMEFT Fits to Data:

1) SMEFT is a consistent way to look for BSM and test the SM (a bit á la Fermi Physics)
2) going global has a direct impact on the Wilson coefficients sensitivity: including more observables is mandatory
3) including NLO and $O(1/\Lambda^4)$ have an impact and can be different operator-by-operator
4) SMEFT in the top sector, in the interface of the Higgs sector and including EW effects, important
5) need to go global

SMEFT Fits @ HL-LHC (the real future):

1) the gains from RUN 2 to the HL-LHC exist but,
2) new data analysis strategies to improve sensitivity need to be considered
3) Gaining less than 1 order of magnitude over a period of 20 years?