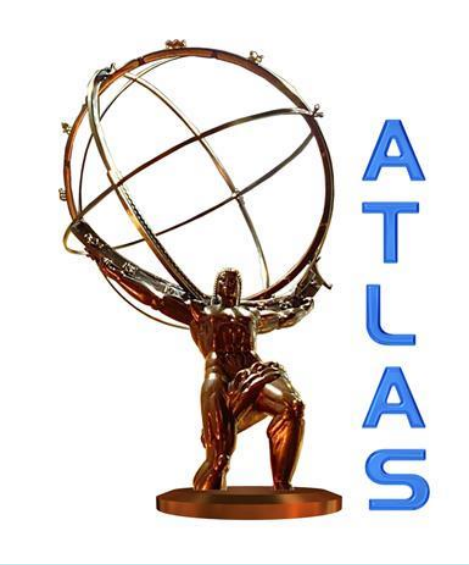
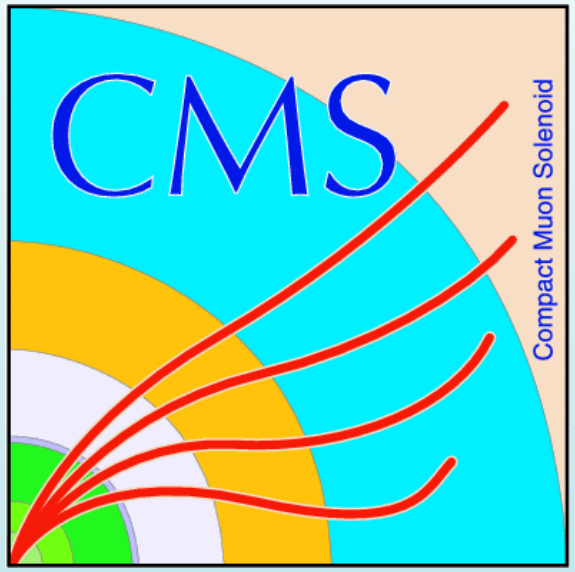
Top Spin & Wtb Couplings





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Outline

- Production properties
  - Spin Correlations
  - Top Polarization Measurements
- Decay properties
  - W Helicity
  - Anomalous Coupling Limits
- Conclusions

Spin Correlations

- The top lifetime is ~10^{-25}s, less than the timescale for QCD interactions.
  - The top spin at production is preserved through to the decay
- SM QCD production of $t\bar{t}$ predicts negligible polarization, but spins are correlated
  - Amount is sensitive to $q\bar{q}$ vs. gg vs. possible BSM

$$\frac{1}{N}\frac{d^2N}{d\cos\theta_1 d\cos\theta_2} = \frac{1}{4}\left(1 + B_1\cos\theta_1 + B_2\cos\theta_2 - C\cos\theta_1 \cdot \cos\theta_2\right)$$

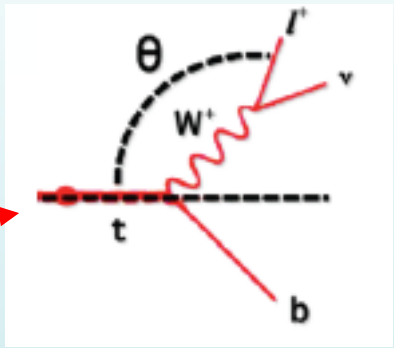
$$C = -A\alpha_1\alpha_2 \qquad A = \frac{N_{\text{like}} - N_{\text{unlike}}}{N_{\text{like}} + N_{\text{unlike}}}$$

Spin analyzing power

$$\alpha_{\ell^+} = +0.998$$
$$\alpha_d = -0.966$$
$$\alpha_b = -0.393$$

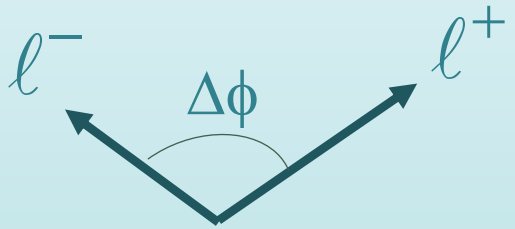
θ is defined with respect to a choice of spin quantization axis, e.g. "helicity basis"

t-tbar rest frame



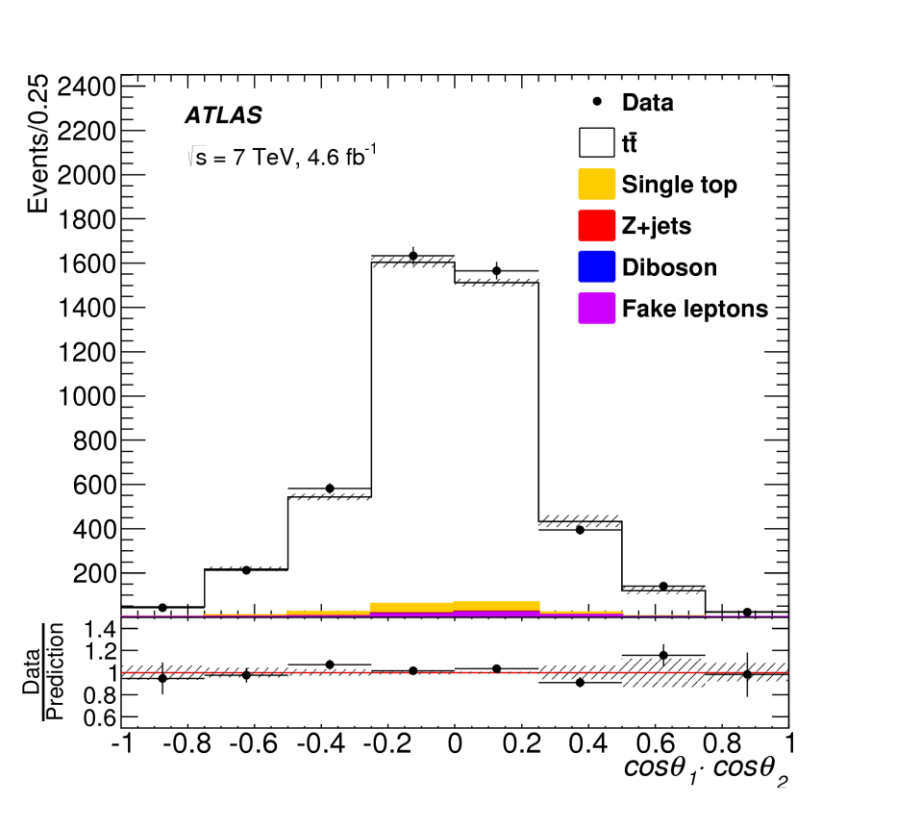
- Sensitivity also through $\Delta\phi$ between charged leptons

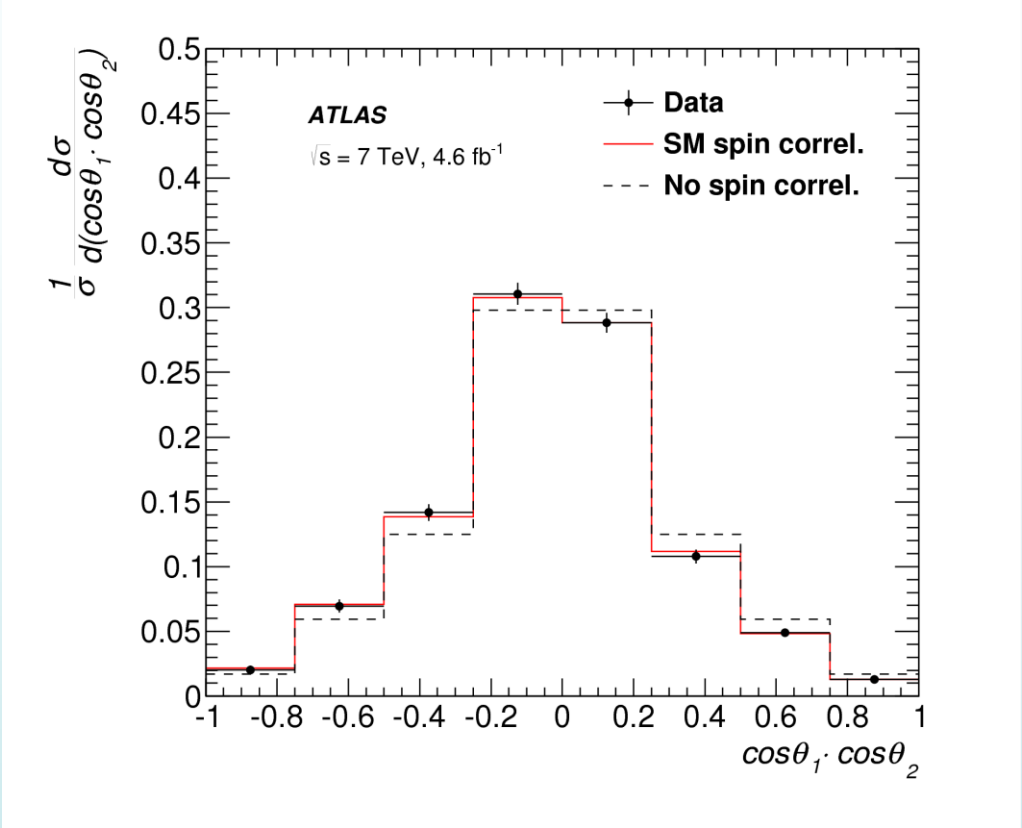
  Straightforward lab-frame measurement



7 TeV Dilepton

- "Topology reconstruction method" used to reconstruct top rest-frame angles
  - EtMiss x,y; Mw, Mt yield 6 constraints. Two b-tags identify b-jets (or Pt rank)
- Unfolded to parton level





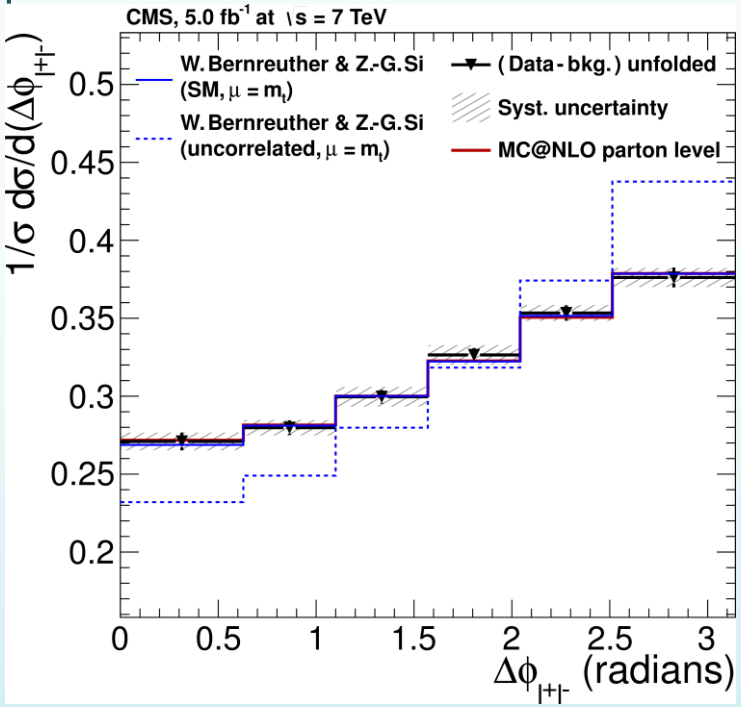
PRD 93, 012002 (2016)

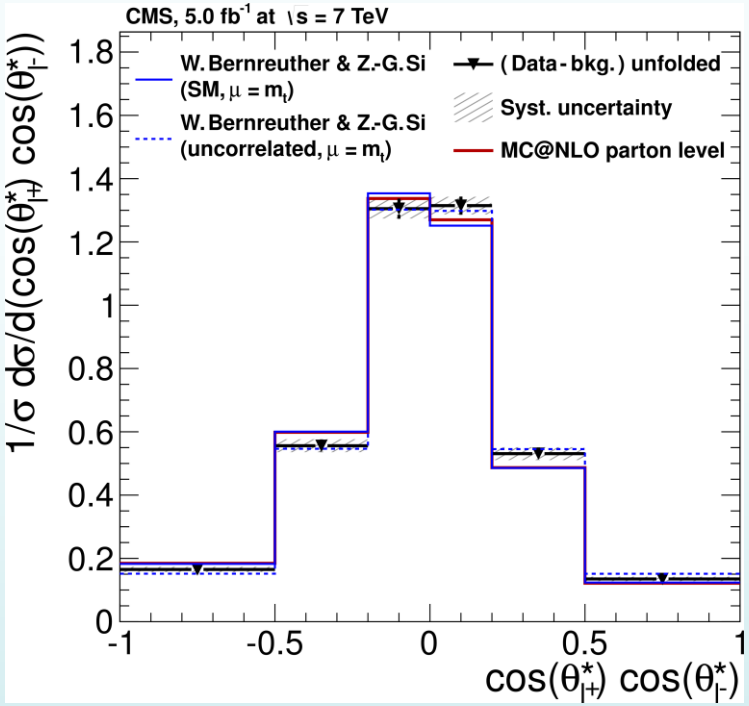
$$A_{\text{helicity}} = 0.315 \pm 0.061\,(\text{stat}) \pm 0.049\,(\text{sys})$$ (NLO QCD A=0.31)

7 TeV Dilepton

PRL 112, 182001 (2014)

- Matrix weighting technique used to reconstruct top rest-frame angles
  - Parton assignment chosen as largest ME weight – Integrated over Jet Pt & EtMiss
- Unfolded to parton level





$$A_{\Delta\phi} = \frac{N(\Delta\phi > \pi/2) - N(\Delta\phi < \pi/2)}{N(\Delta\phi > \pi/2) + N(\Delta\phi < \pi/2)} = 0.113 \pm 0.010 \pm 0.006 \pm 0.012$$

$$A_{c_1c_2} = \frac{N(\cos\theta^*_{\ell^+}\cos\theta^*_{\ell^-} > 0) - N(\cos\theta^*_{\ell^+}\cos\theta^*_{\ell^-} < 0)}{N(\cos\theta^*_{\ell^+}\cos\theta^*_{\ell^-} > 0) + N(\cos\theta^*_{\ell^+}\cos\theta^*_{\ell^-} < 0)} = -0.021 \pm 0.023 \pm 0.025 \pm 0.010$$

stat sys top P_T

NLO (SM, Correlated)

$$A_{\Delta\phi} = 0.115^{+0.014}_{-0.016}$$

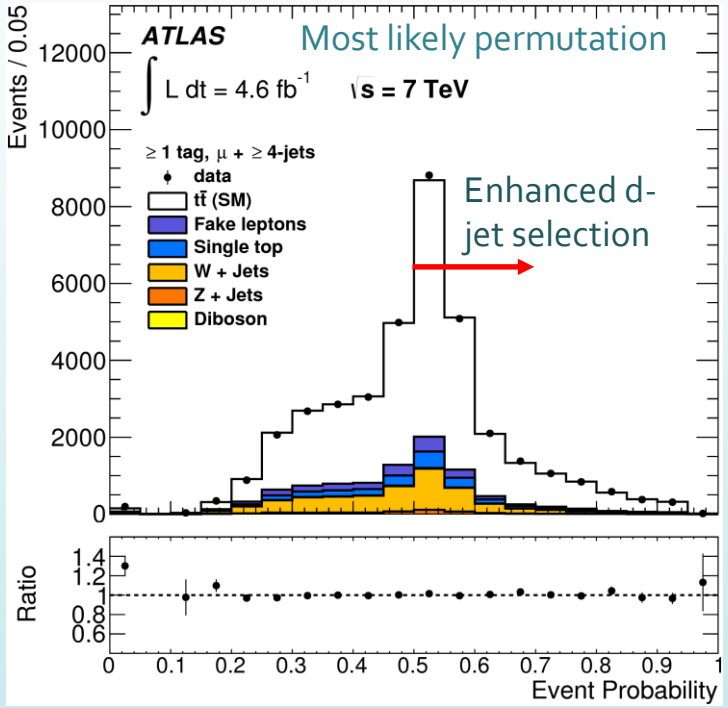
$$A_{c_1c_2} = -0.078 \pm 0.006$$

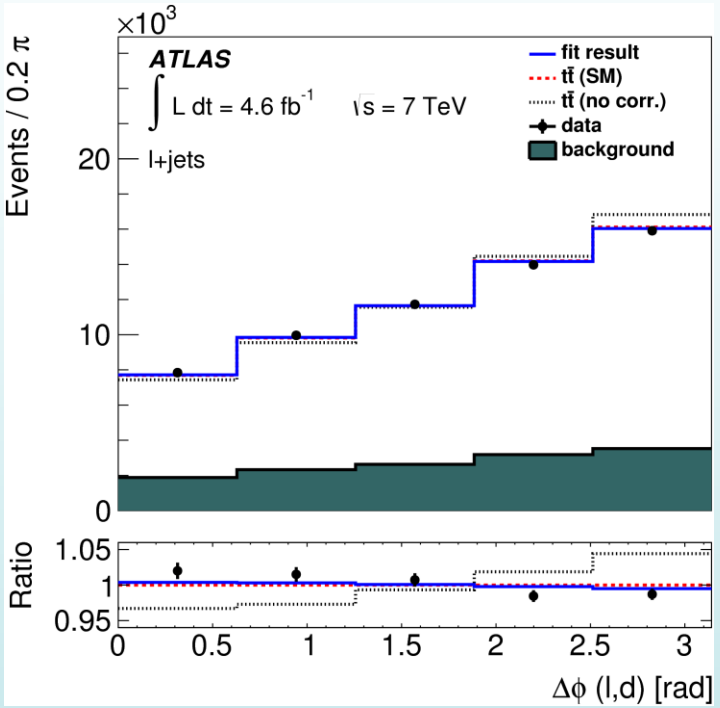
7 TeV e/μ+Jets

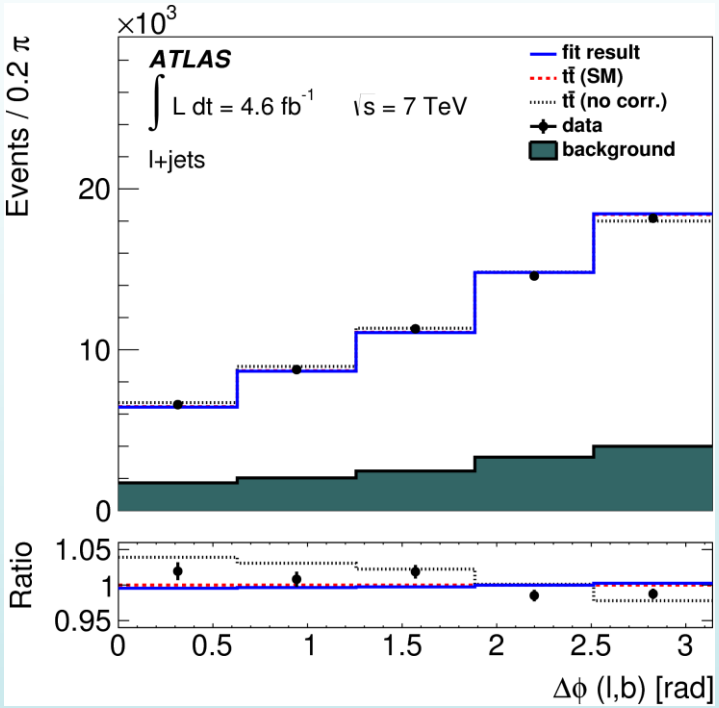
PRD 90, 112016 (2014)

- $\Delta\phi(\ell,d)$ & $\Delta\phi(\ell,b)$ analyzed (requires ID of down or appropriate bottom jet)
  - KL Fitter used for kinematic reconstruction
    - For d-jet ID likelihood includes b-tag weight (anti c-jet) and jet P_T (d-jet ~lower P_T)

f*(SM)+(1-f)*(A=0)+bkg







$$f = 1.12 \pm 0.09\ (\text{stat}) \pm 0.18\ (\text{sys})$$

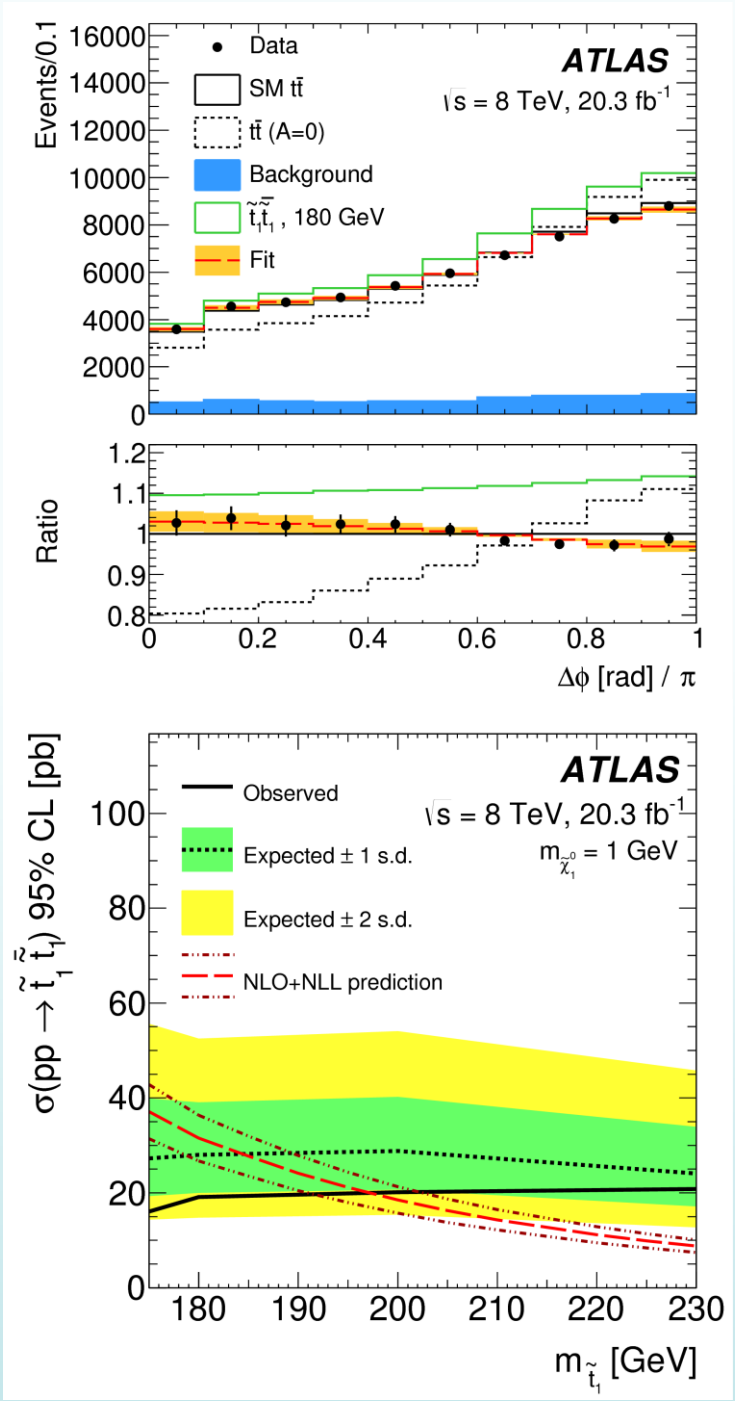
8 TeV Dilepton

- Fit $\Delta\phi$ distribution to f*SM+(1-f)*(*no correlation*)

$$f = 1.20 \pm 0.05\ (\text{stat}) \pm 0.13\ (\text{sys})$$
$$A_{\text{helicity}} = 0.38 \pm 0.04$$

Stop pair production masquerading as top pairs through $\tilde{t} \to t\chi^0$ can modify spin correlation measurement

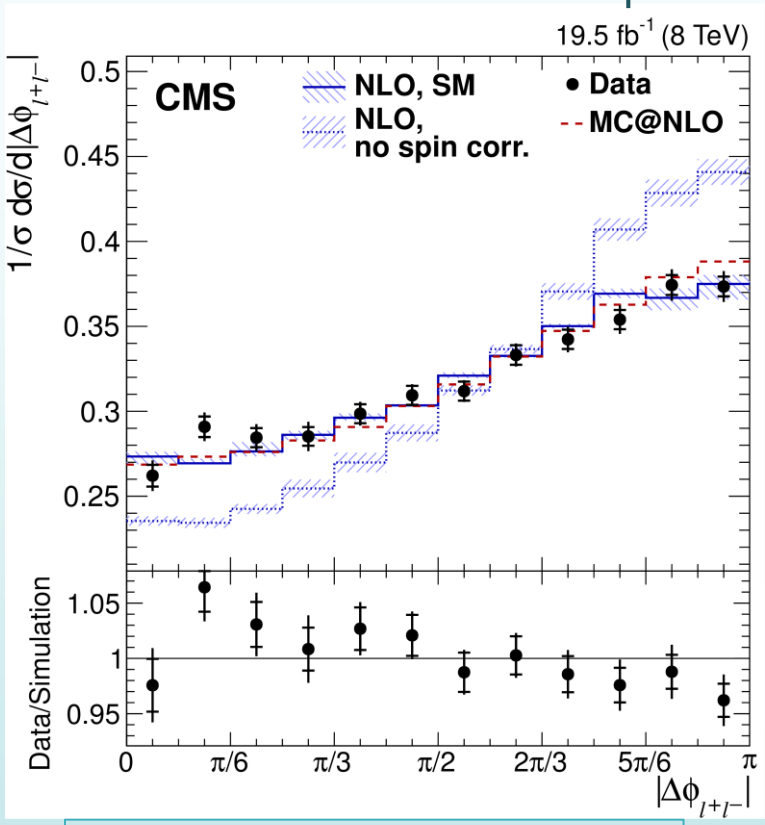
$M_{top} < M_{stop} < 191$ GeV excluded @ 95% C.L.



Phys. Rev. Lett. 114, 142001 (2015)

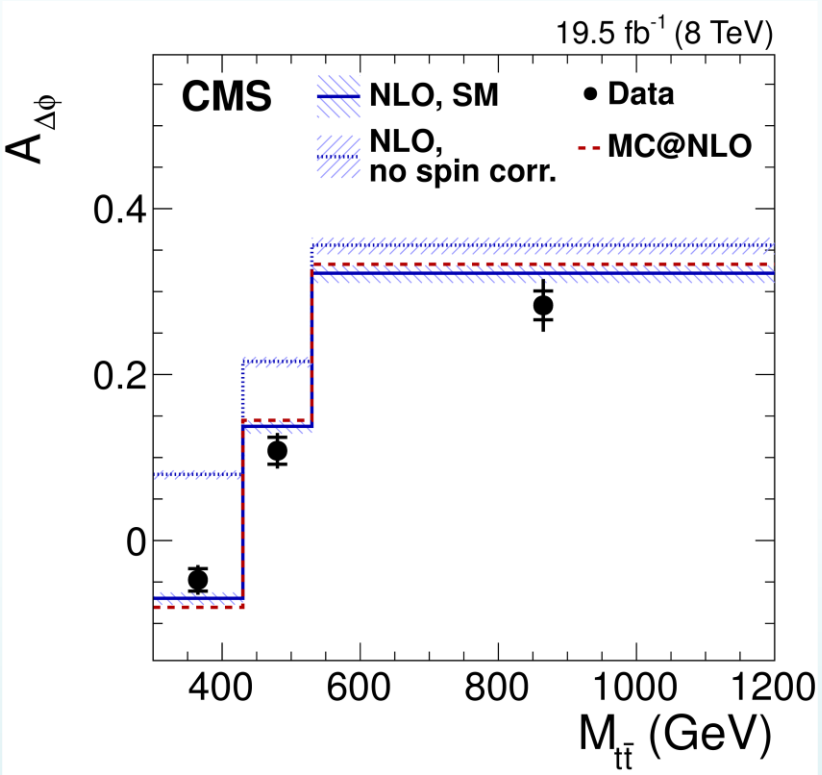
8 TeV Dilepton

- 8 possible solutions per event after using PtMiss and constraints on Mw and Mtop
- Solution chosen according to probability for extracted Bj x & lepton energies in top rest frames.
- Distributions unfolded to parton level.



PRD 93, 052007 (2016)

$A_{\Delta\phi}$ vs. $M_{t\bar{t}}$



Variable	$f_{SM} \pm$ (stat) $\pm$ (syst) $\pm$ (theor)	Total uncertainty
$A_{\Delta\phi}$	$1.14 \pm 0.06 \pm 0.13\,^{+0.08}_{-0.11}$	$^{+0.16}_{-0.18}$
$A_{\cos\varphi}$	$0.90 \pm 0.09 \pm 0.10 \pm 0.05$	± 0.15
$A_{c_1c_2}$	$0.87 \pm 0.17 \pm 0.21 \pm 0.04$	± 0.27
$A_{\Delta\phi}$ (vs. $M_{t\bar{t}}$)	$1.12 \pm 0.06 \pm 0.08\,^{+0.08}_{-0.11}$	$^{+0.12}_{-0.15}$

Chromo-mag dipole $-0.053 < \mathrm{Re}(\hat{\mu}_t) < 0.026$

Chromo-ele dipole $-0.068 < \mathrm{Im}(\hat{d}_t) < 0.067$

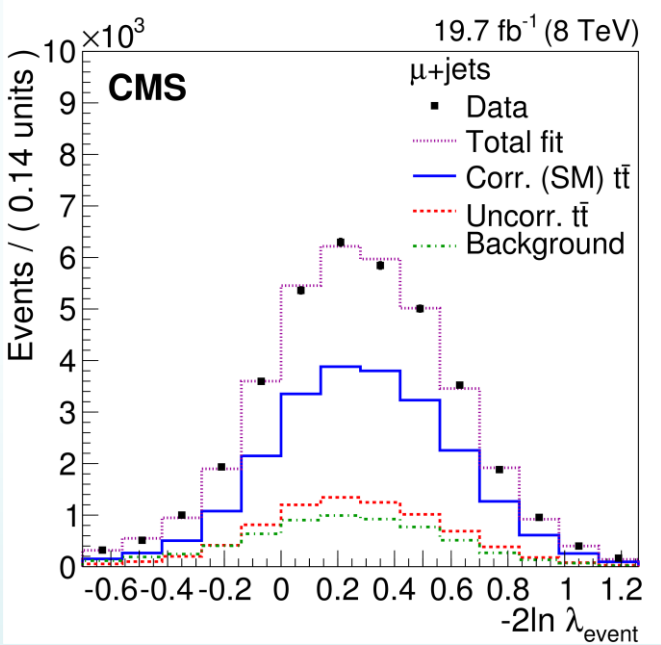
Excluded

8 TeV Muon+Jets

PLB 758, 321 (2016)

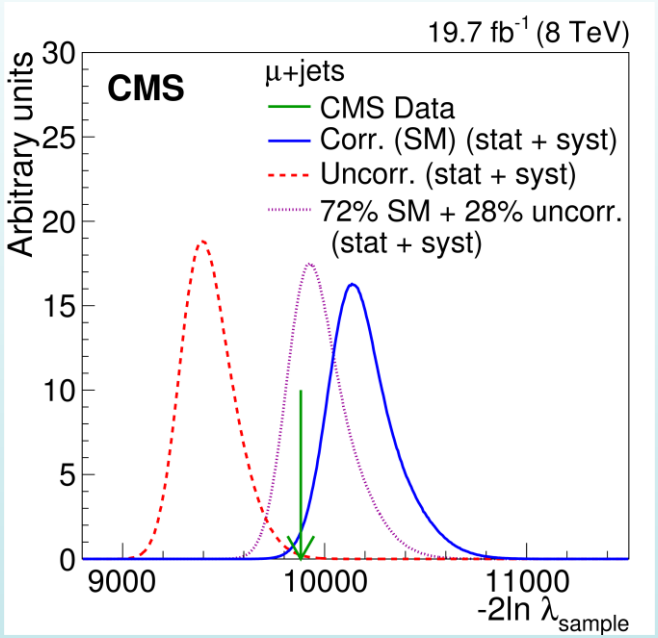
- LO matrix element method
- Calculate event probability for 2 hypotheses, H: correlated or uncorrelated

$$P(x_i \mid H) = \frac{1}{\sigma_{\text{obs}}(H)} \int f_{\text{PDF}}(q_1) f_{\text{PDF}}(q_2)\, dq_1 dq_2\, \frac{(2\pi)^4 \left|M(y,H)\right|^2}{q_1 q_2 s} W(x_i, y)\, d\Phi_6$$



- Calculate sample likelihood

$$L(x_1 \ldots, x_n \mid H) = \prod_{i=1}^{n} P(x_i \mid H)$$

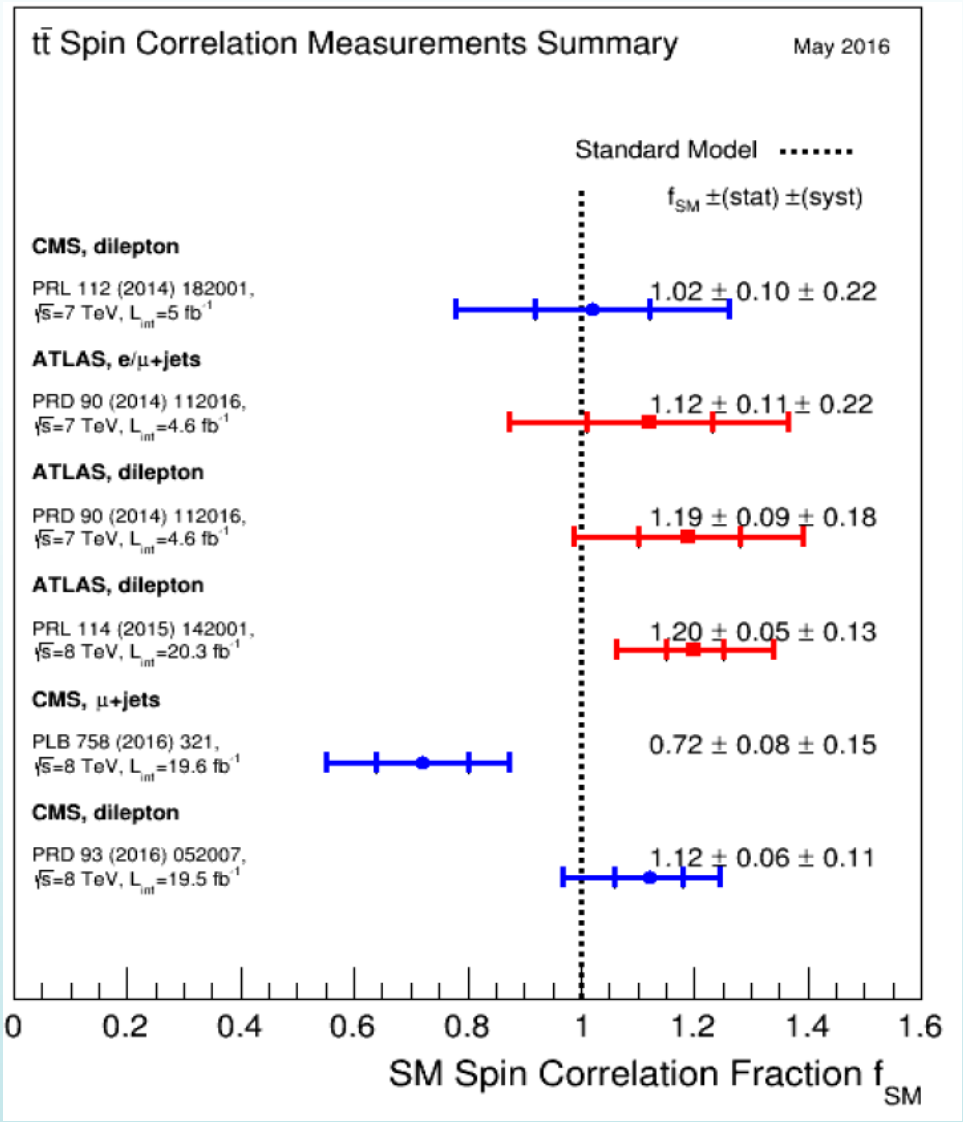


$$f = 0.72 \pm 0.08\ (\text{stat})^{+0.15}_{-0.13}\ (\text{sys})$$

2.2σ agreement with SM H

2.9σ agreement with uncorrelated H

Spin Correlations Summary



Top Quark Polarization

- Although spins are correlated, there is negligible polarization in the SM

$$\frac{1}{N}\frac{d^2N}{d\cos\theta_1 d\cos\theta_2} = \frac{1}{4}\left(1 + B_1\cos\theta_1 + B_2\cos\theta_2 - C\cos\theta_1 \bullet \cos\theta_2\right) \rightarrow \quad \frac{1}{N}\frac{dN}{d\cos\theta} = \frac{1}{2}\left(1 + B\cos\theta\right)$$

$$B = \alpha P$$

Spin quantization axis choices:

- *Helicity* axis: top direction in $t\bar{t}$ rest frame
- *Transverse* axis: transverse to plane defined by top direction and beam axis
- *r*-axis: Orthogonal to the helicity and transverse axes.

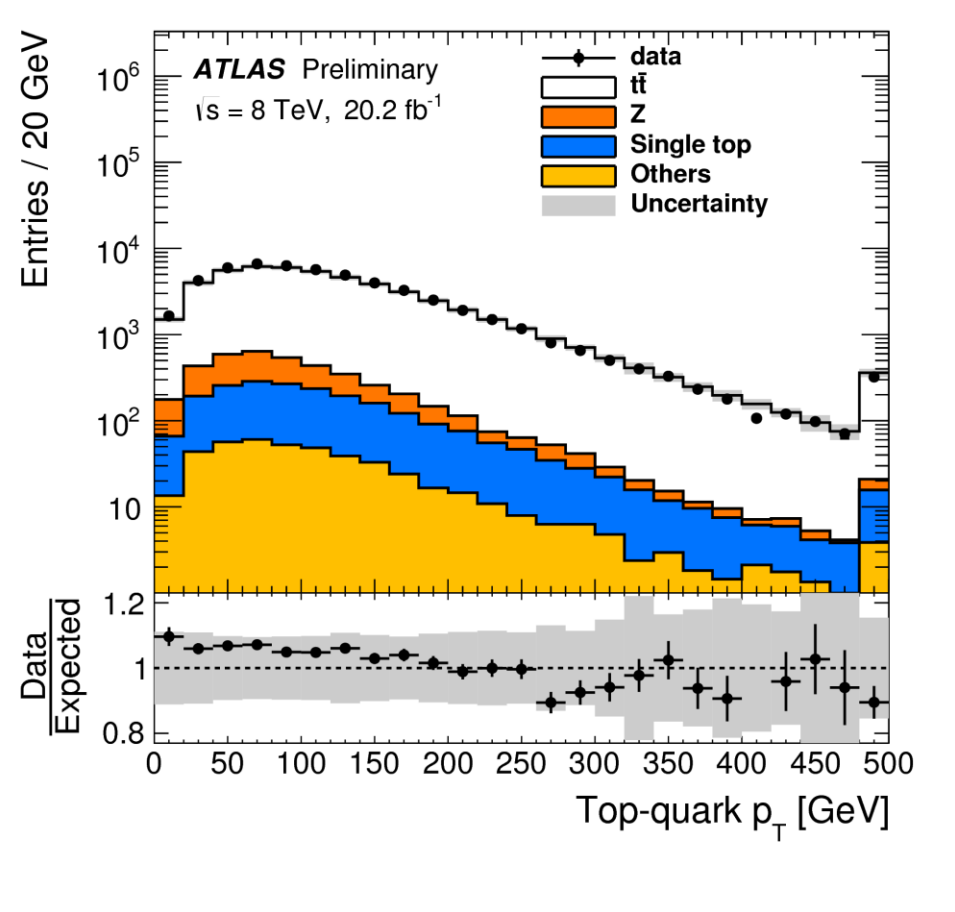
See Javier Jimenez Pena @ 15:00h for single-top results

Top Quark Polarization

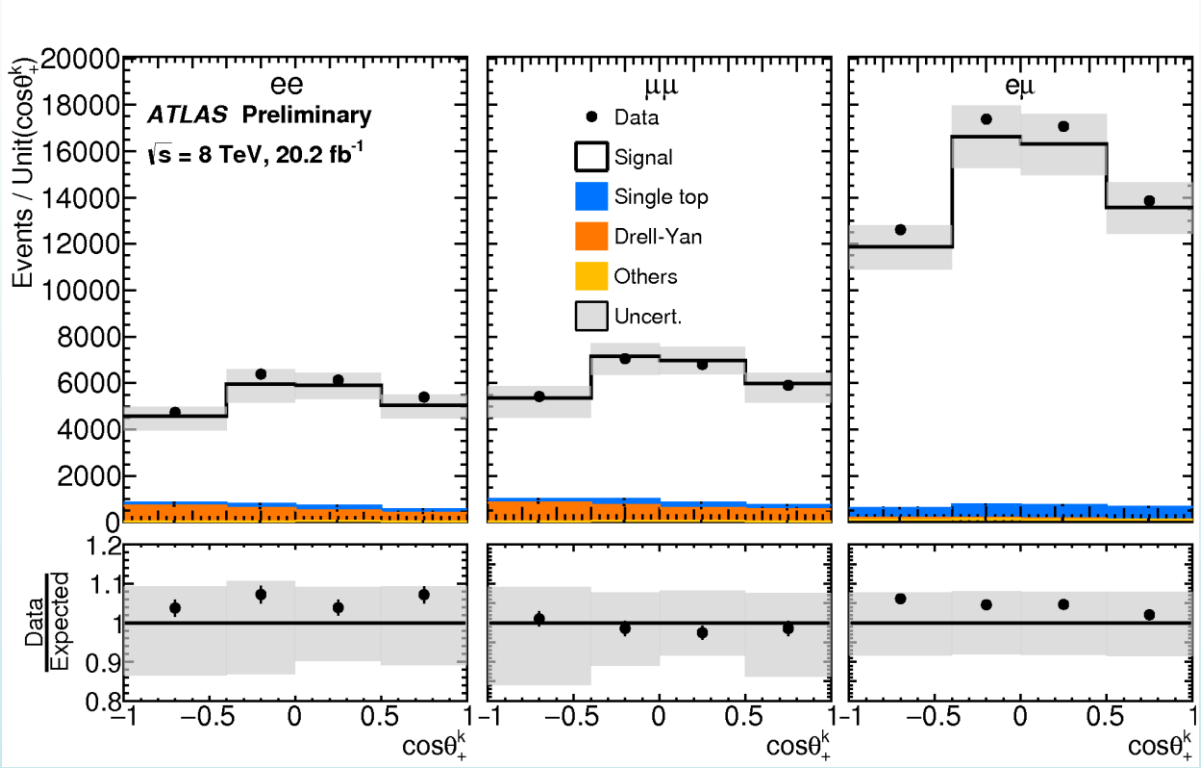
ATLAS-CONF-2016-099

- Dilepton final states with kinematic reconstruction via neutrino weighting
- Distributions unfolded to parton level and to stable-particle level

Data/MC agreement after reco

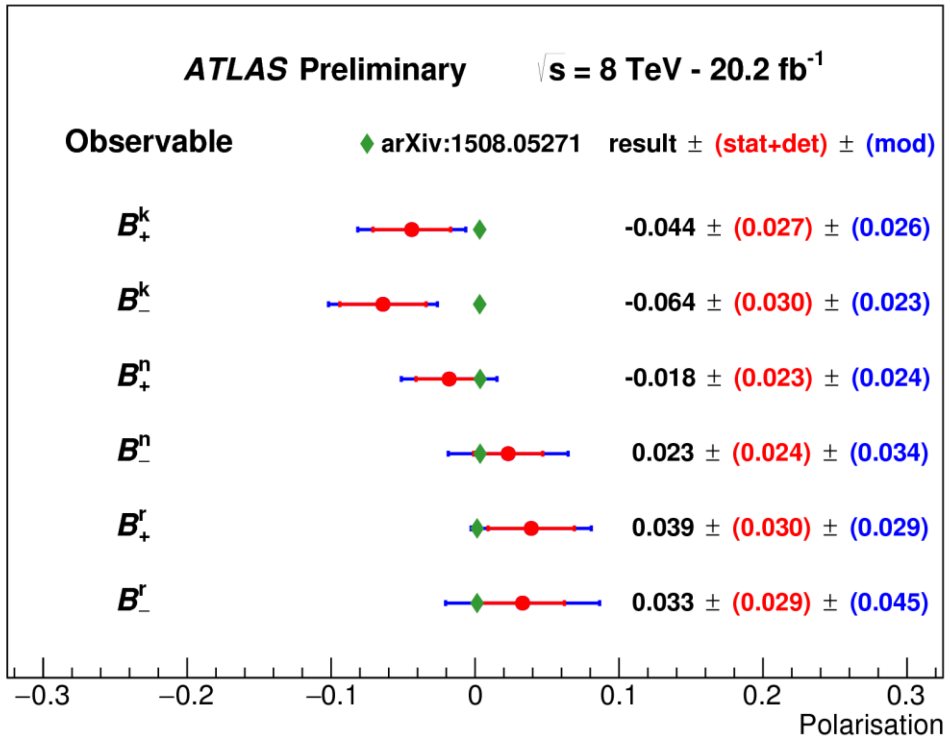


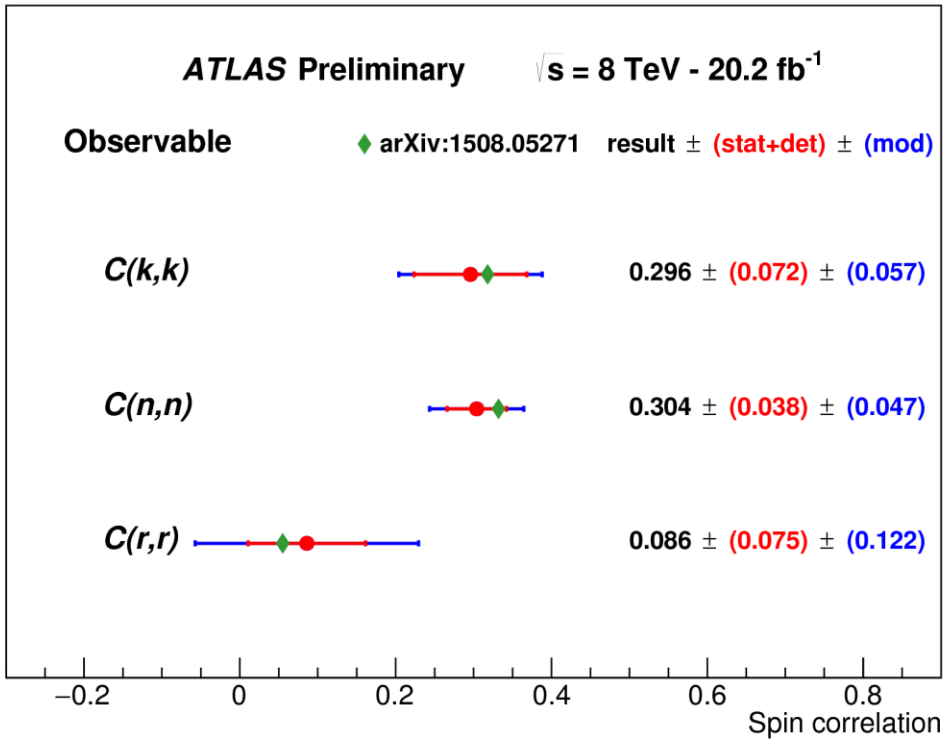
Input to unfolding of B_+^k



Top Quark Polarization

Parton-level results





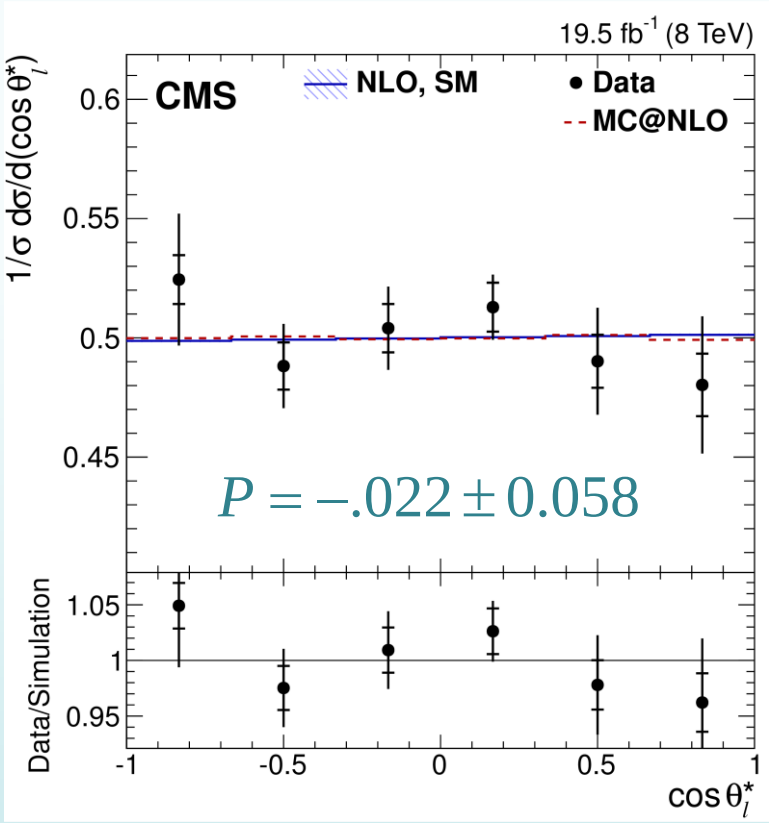
$$B_+^k = -0.044 \pm 0.027 \pm 0.026 \quad B_-^k = -0.64 \pm 0.030 \pm 0.023 \quad C(k,k) = 0.296 \pm 0.072 \pm 0.057$$

Top Quark Polarization

PRD 93, 052007 (2016)

$$A_{P^{\pm}} = \frac{N\left(\cos\theta^{*}_{\ell^{\pm}} > 0\right) - N\left(\cos\theta^{*}_{\ell^{\pm}} < 0\right)}{N\left(\cos\theta^{*}_{\ell^{\pm}} > 0\right) + N\left(\cos\theta^{*}_{\ell^{\pm}} < 0\right)}$$

- Assuming CP invariance $P = \left(A_{P^{+}} + A_{P^{-}}\right) = 2A_{P}$



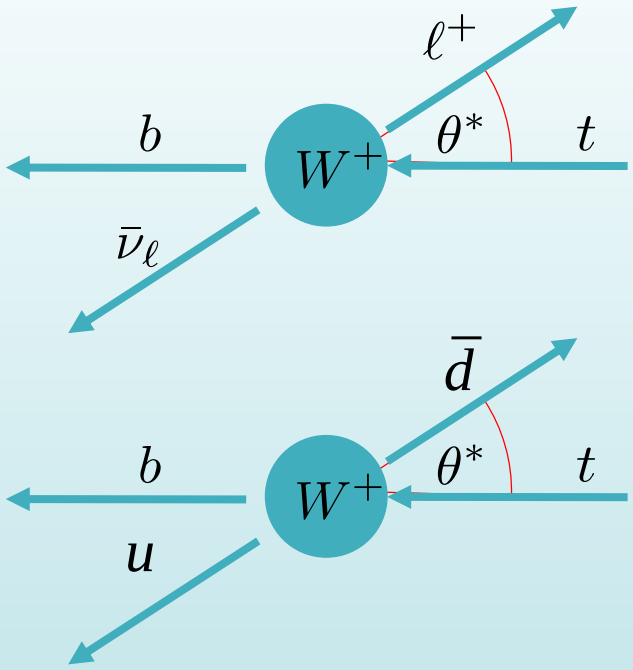
Helicity basis
Unfolded to parton level

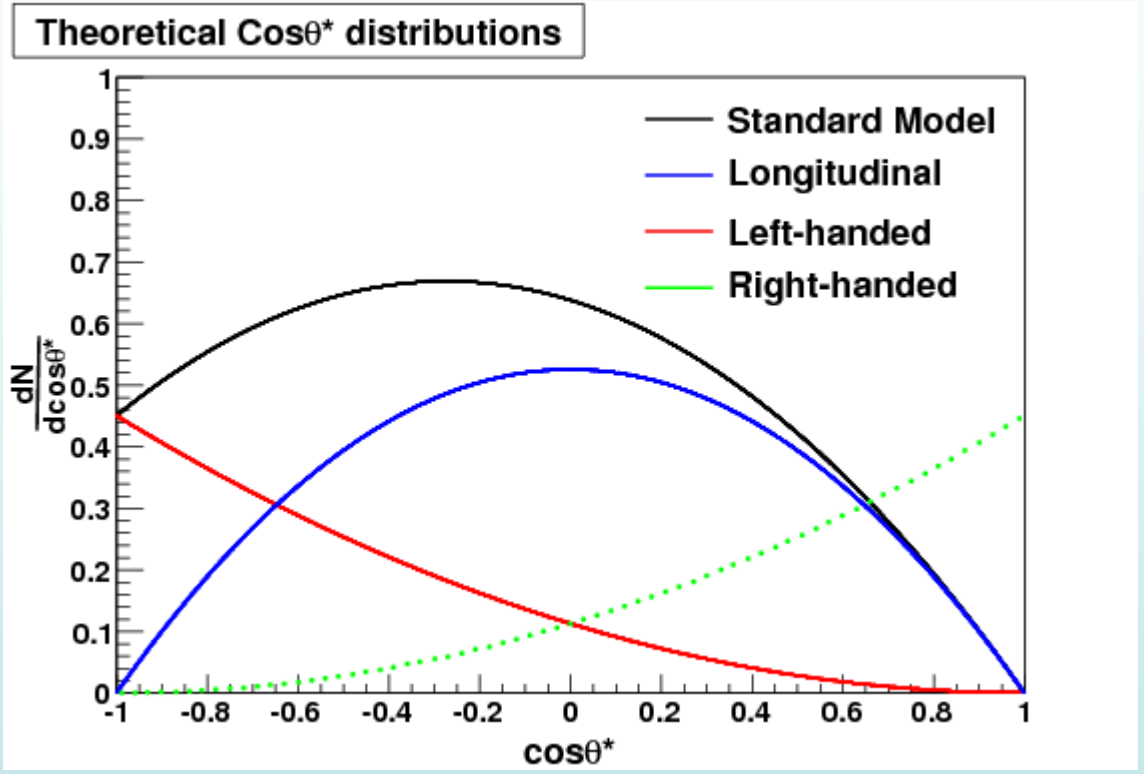
W-boson helicity in top decay

- W-boson helicity is sensitive to the (putative) V-A structure of the Wtb vertex

$$\frac{1}{\sigma}\frac{d\sigma}{d\cos\theta^*} = \frac{3}{8}\left(1-\cos\theta^*\right)^2 F_L + \frac{3}{4}\sin^2\theta^* F_0 + \frac{3}{8}\left(1+\cos\theta^*\right)^2 F_R$$

$$F_0 = \frac{M_t^2}{2M_W^2 + M_t^2}$$

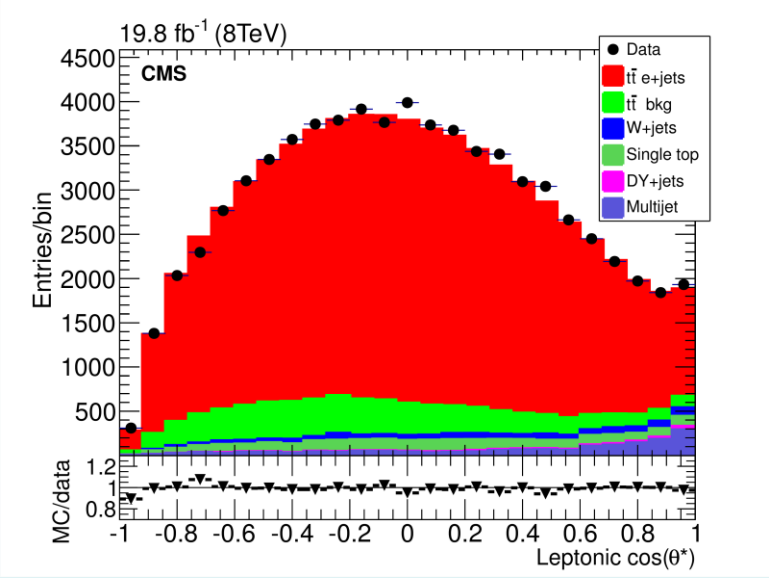


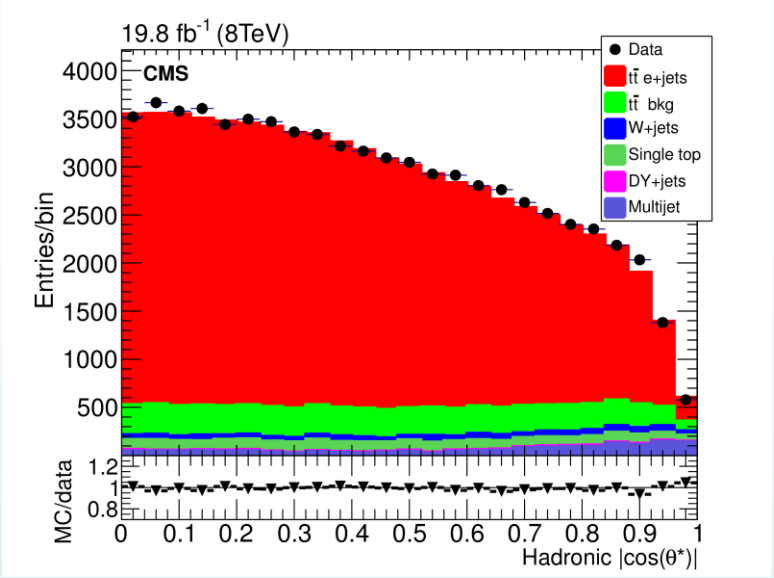


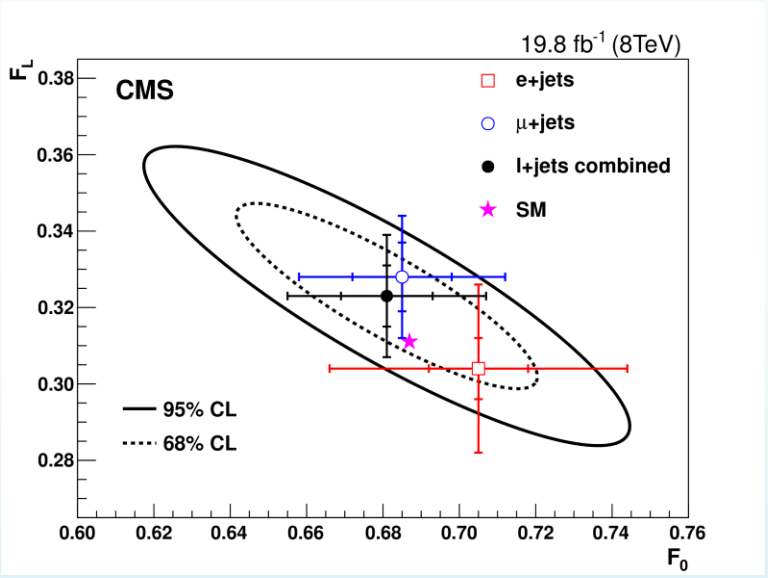
e/μ + Jets (8 TeV)

arXiv:1605.09047

- Kinematic reconstruction w/ χ^2 minimization





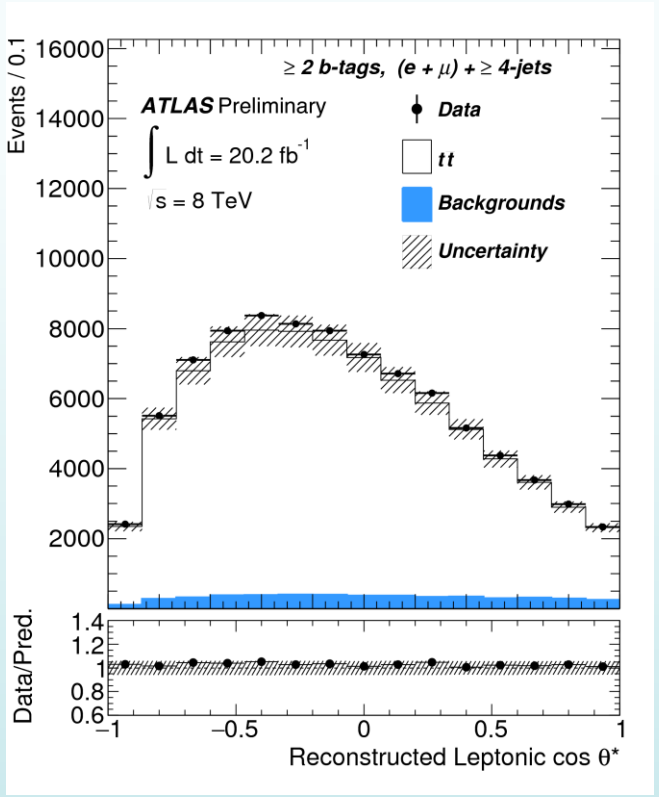


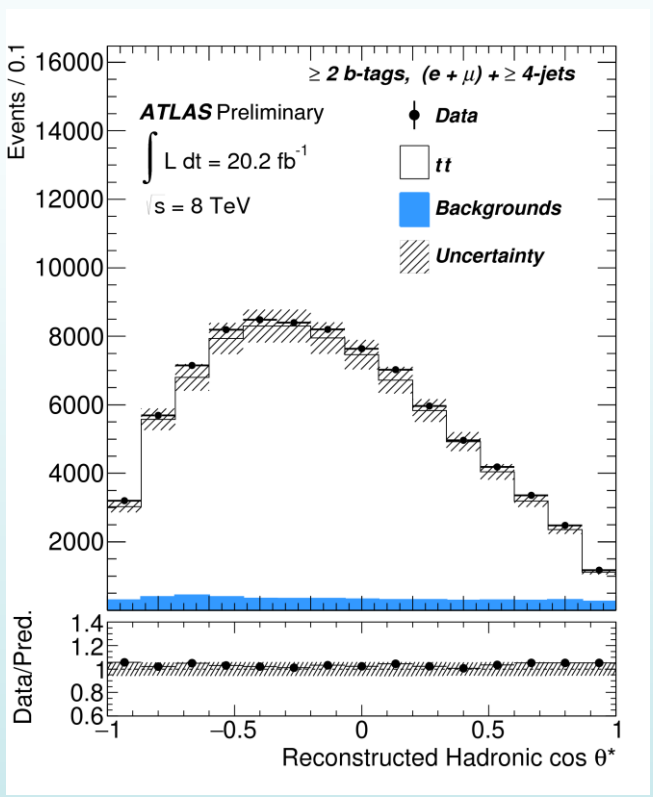
$$F_0 = 0.681 \pm 0.012\ (\text{stat}) \pm 0.023\ (\text{sys})$$
$$F_L = 0.323 \pm 0.008\ (\text{stat}) \pm 0.014\ (\text{sys})$$
$$F_R = -0.004 \pm 0.005\ (\text{stat}) \pm 0.014\ (\text{sys})$$

Primary systematic uncerts are t-tbar modeling (scales, matching, hadronization) & bkg norms.

e/μ + Jets (8 TeV)

- KL Fitter used for kinematic reconstruction
  - Both leptonic & hadronic side used
  - For d-jet ID likelihood includes b-tag weight (anti c-jet) and jet P_T (d-jet ~lower P_T)





$$F_0 = 0.709 \pm 0.012\ (\text{stat+bkg norm})^{+0.015}_{-0.014}\ (\text{sys})$$
$$F_L = 0.299 \pm 0.008\ (\text{stat+bkg norm})^{+0.013}_{-0.012}\ (\text{sys})$$
$$F_R = -0.008 \pm 0.006\ (\text{stat+bkg norm}) \pm 0.012\ (\text{sys})$$

Leptonic side

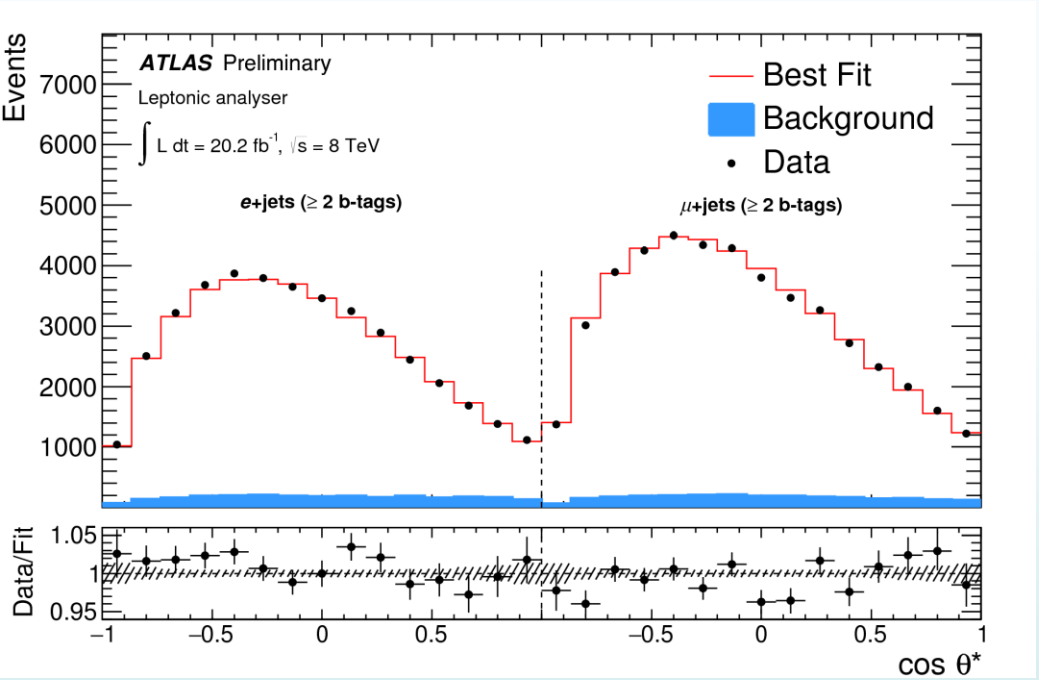
$$F_0 = 0.659 \pm 0.010\ (\text{stat+bkg norm})^{+0.052}_{-0.054}\ (\text{sys})$$
$$F_L = 0.281 \pm 0.021\ (\text{stat+bkg norm})^{+0.063}_{-0.067}\ (\text{sys})$$
$$F_R = 0.061 \pm 0.022\ (\text{stat+bkg norm})^{+0.101}_{-0.108}\ (\text{sys})$$

Hadronic side

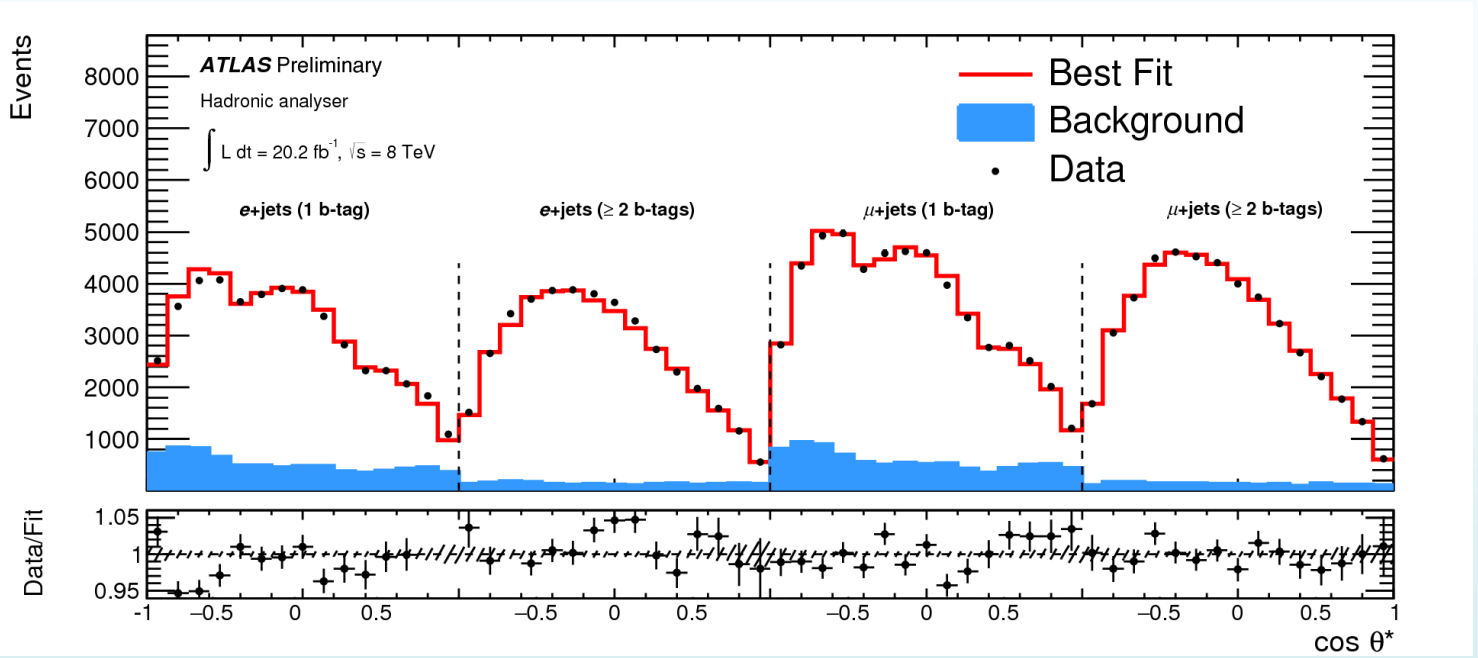
Main systematic uncerts are JES, JER, b-tagging, top modeling

e/μ + Jets (8 TeV) - Postfit

Leptonic analyzer (e, μ)

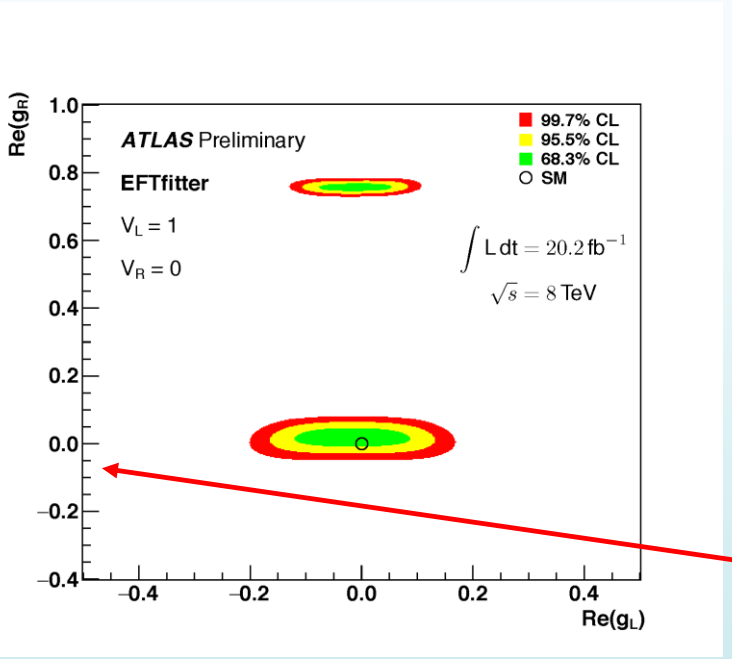


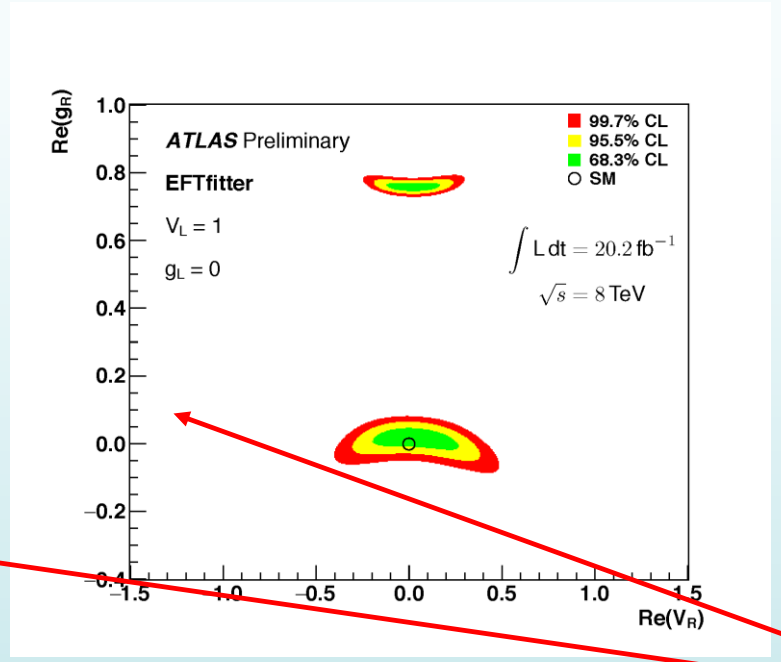
Hadronic analyzer (e 1 tag, 2 tag, μ 1 tag 2 tag)

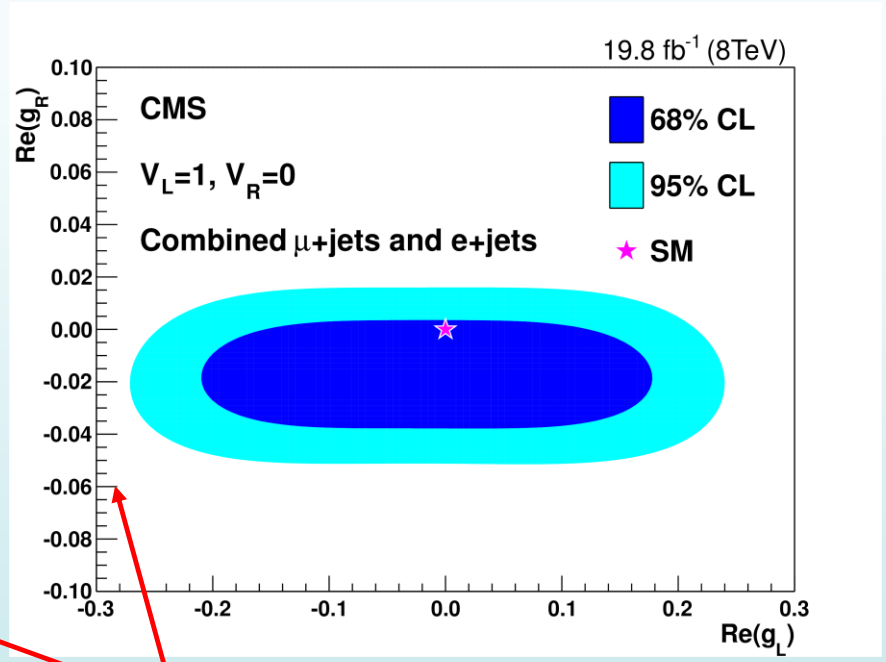


Limits on Wtb Anomalous Couplings

$$L = -\frac{g}{\sqrt{2}}\bar{b}\gamma^{\mu}\left(V_L P_L + V_R P_R\right)tW_{\mu}^{-} - \frac{g}{\sqrt{2}}\bar{b}\frac{i\sigma^{\mu\nu}q_{\nu}}{M_W}\left(g_L P_L + g_R P_R\right)tW_{\mu}^{-} + h.c.$$







N.B. 10X vertical scale difference!

Conclusions

- Top spin measurements at 7 & 8 TeV from ATLAS & CMS, including some new measurements at 8 TeV have been presented.
  - Spin correlations are now well established and comparisons between 7 & 8 TeV, and eventually 13 TeV will provide a new probe of top production dynamics.
  - Top polarization measurements are becoming more precise, but no deviations from the SM have been seen.

- W Helicity measurements at 8 TeV continue to probe the Wtb vertex.
  - Good consistency with SM for world-average top mass
  - EFTFitter used to set anomalous coupling limits

Backup

8 TeV Dilepton

$$f = 1.20 \pm 0.05\ (\text{stat}) \pm 0.13\ (\text{sys})$$

$$A_{\text{helicity}} = 0.38 \pm 0.04$$

TABLE II. Summary of systematic uncertainties on f_{SM} in the combined dilepton final state.

Source of uncertainty	Δf_{SM}
Detector modeling	
Lepton reconstruction	±0.01
Jet energy scale	±0.02
Jet reconstruction	±0.01
E_T^{miss}	< 0.01
Fake leptons	< 0.01
b tagging	< 0.01
Signal and background modeling	
Renormalization and factorization scale	±0.05
MC generator	±0.03
Parton shower and fragmentation	±0.06
ISR and FSR	±0.06
Underlying event	±0.04
Color reconnection	±0.01
PDF uncertainty	±0.05
Background	±0.01
MC statistics	±0.04
Total systematic uncertainty	±0.13
Data statistics	±0.05

Phys. Rev. Lett. 114, 142001 (2015)

8 TeV Dilepton

TABLE IV. Sources and values of the systematic uncertainties in the inclusive asymmetry variables.

Asymmetry variable	$A_{\Delta\phi}$	$A_{\cos\varphi}$	$A_{c_1c_2}$	A_P	A_P^{CPV}
		Experimental systematic uncertainties			
Jet energy scale	0.001	0.005	0.007	0.018	0.001
Jet energy resolution	<0.001	0.001	0.002	0.003	0.002
Lepton energy scale	0.001	0.002	0.005	0.003	<0.001
Background	0.001	0.001	0.001	0.002	<0.001
Pileup	<0.001	<0.001	<0.001	<0.001	<0.001
b tagging efficiency	<0.001	0.001	0.001	0.001	0.001
Lepton selection	0.001	<0.001	<0.001	0.002	<0.001
		$t\bar{t}$ modeling uncertainties			
Parton distribution functions	0.004	0.005	0.005	0.001	<0.001
Top quark p_{T}	0.011	0.006	0.006	0.004	<0.001
Factorization and renormalization scales	0.002	0.003	0.005	0.002	0.002
Top quark mass	0.001	0.001	0.007	0.008	0.001
Hadronization	0.001	0.004	0.005	0.019	0.003
Unfolding (simulation statistical)	0.002	0.005	0.006	0.003	0.003
Unfolding (regularization)	<0.001	<0.001	<0.001	<0.001	<0.001
Total systematic uncertainty	0.012	0.012	0.016	0.028	0.005

Variable	$f_{\mathrm{SM}} \pm (\mathrm{stat}) \pm (\mathrm{syst}) \pm (\mathrm{theor})$	Total uncertainty
$A_{\Delta\phi}$	$1.14 \pm 0.06 \pm 0.13\,^{+0.08}_{-0.11}$	$^{+0.16}_{-0.18}$
$A_{\cos\varphi}$	$0.90 \pm 0.09 \pm 0.10 \pm 0.05$	± 0.15
$A_{c_1c_2}$	$0.87 \pm 0.17 \pm 0.21 \pm 0.04$	± 0.27
$A_{\Delta\phi}$ (vs. $M_{\mathrm{t\bar{t}}}$)	$1.12 \pm 0.06 \pm 0.08\,^{+0.08}_{-0.11}$	$^{+0.12}_{-0.15}$

PRD 93, 052007 (2016)

8 TeV Muon+Jets

PLB 758, 321 (2016)

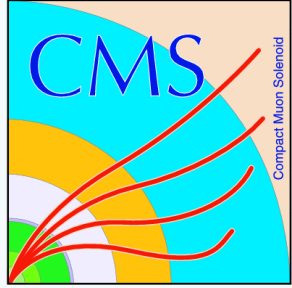


Table 3
Sources of systematic uncertainty in the fraction f of events with the SM spin correlation. There is no downward variation for the p_T^t modeling.

Source of syst. uncer.	Up variation	Down variation
Simulation stat.	0.042	−0.042
Scale	−0.068	0.124
JES	0.051	−0.090
JER	−0.023	−0.004
PDF	0.018	0.045
m_t	0.001	−0.034
top quark p_T^t modeling	0.023	–
Background modeling	0.017	−0.016
Pileup	0.012	−0.015
b tagging efficiency	−0.001	0.001
Mistag rate	0.005	−0.006
Trigger	<0.001	<0.001
Lepton ID/Iso	<0.001	<0.001
Calibration	0.003	−0.003
Total syst. uncer.	$^{+0.15}_{-0.13}$	

$$f = 0.72 \pm 0.08\ (\text{stat})^{+0.15}_{-0.13}\ (\text{sys})$$

Top Quark Polarization

ATLAS-CONF-2016-099

Observables	Central	Total	Statistical	Detector	Modelling	Others	Mass
Full phase space							
B_+^k	-0.044	± 0.038	± 0.018	± 0.001	± 0.026	± 0.007	± 0.027
B_-^k	-0.064	± 0.040	± 0.020	± 0.001	± 0.023	± 0.014	± 0.027
B_+^n	-0.018	± 0.034	± 0.020	± 0.001	± 0.024	± 0.005	-
B_-^n	0.023	± 0.042	± 0.020	± 0.001	± 0.034	± 0.005	-
B_+^r	0.039	± 0.042	± 0.026	± 0.001	± 0.029	± 0.005	-
B_-^r	0.033	± 0.054	± 0.023	± 0.002	± 0.045	± 0.006	± 0.016
$C(k,k)$	0.296	± 0.093	± 0.052	± 0.006	± 0.057	± 0.011	± 0.037
$C(n,n)$	0.304	± 0.060	± 0.028	± 0.001	± 0.047	± 0.001	± 0.010
$C(r,r)$	0.086	± 0.144	± 0.055	± 0.005	± 0.122	± 0.016	± 0.038
$C(n,k)+C(k,n)$	-0.012	± 0.128	± 0.072	± 0.005	± 0.087	± 0.029	-
$C(n,k)-C(k,n)$	-0.040	± 0.087	± 0.053	± 0.004	± 0.058	± 0.003	-
$C(n,r)+C(r,n)$	0.117	± 0.132	± 0.070	± 0.003	± 0.102	± 0.010	± 0.010
$C(n,r)-C(r,n)$	-0.006	± 0.108	± 0.069	± 0.005	± 0.070	± 0.004	± 0.043
$C(r,k)+C(k,r)$	-0.261	± 0.176	± 0.083	± 0.006	± 0.135	± 0.011	± 0.065
$C(r,k)-C(k,r)$	0.073	± 0.192	± 0.087	± 0.007	± 0.148	± 0.005	± 0.025

Top Quark Polarization

PRD 93, 052007 (2016)

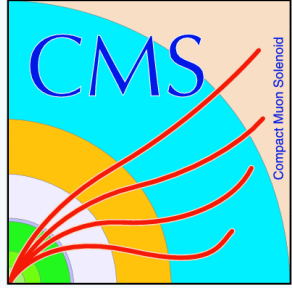


TABLE IV. Sources and values of the systematic uncertainties in the inclusive asymmetry variables.

Asymmetry variable	$A_{\Delta\phi}$	$A_{\cos\varphi}$	$A_{c_1c_2}$	A_P	A_P^{CPV}
		Experimental systematic uncertainties			
Jet energy scale	0.001	0.005	0.007	0.018	0.001
Jet energy resolution	<0.001	0.001	0.002	0.003	0.002
Lepton energy scale	0.001	0.002	0.005	0.003	<0.001
Background	0.001	0.001	0.001	0.002	<0.001
Pileup	<0.001	<0.001	<0.001	<0.001	<0.001
b tagging efficiency	<0.001	0.001	0.001	0.001	0.001
Lepton selection	0.001	<0.001	<0.001	0.002	<0.001
		$t\bar{t}$ modeling uncertainties			
Parton distribution functions	0.004	0.005	0.005	0.001	<0.001
Top quark p_{T}	0.011	0.006	0.006	0.004	<0.001
Factorization and renormalization scales	0.002	0.003	0.005	0.002	0.002
Top quark mass	0.001	0.001	0.007	0.008	0.001
Hadronization	0.001	0.004	0.005	0.019	0.003
Unfolding (simulation statistical)	0.002	0.005	0.006	0.003	0.003
Unfolding (regularization)	<0.001	<0.001	<0.001	<0.001	<0.001
Total systematic uncertainty	0.012	0.012	0.016	0.028	0.005

e/μ + Jets (8 TeV)

arXiv:1605.09047

	e+jets		μ+jets		ℓ+jets	
	Breakdown of systematic uncertainties					
	$\pm \Delta F_0$	$\pm \Delta F_L$	$\pm \Delta F_0$	$\pm \Delta F_L$	$\pm \Delta F_0$	$\pm \Delta F_L$
JES	0.004	0.003	0.005	0.003	0.005	0.003
JER	0.001	0.002	0.004	0.003	0.003	0.003
b tagging eff.	0.001	$<10^{-3}$	0.001	$<10^{-3}$	0.001	$<10^{-3}$
Lepton eff.	0.001	0.002	0.001	0.001	0.001	0.001
Single top normal.	0.002	$<10^{-3}$	0.003	0.001	0.003	0.001
W +jets bkg.	0.008	0.001	0.007	0.001	0.007	0.001
DY+jets bkg.	0.002	$<10^{-3}$	0.001	$<10^{-3}$	0.001	$<10^{-3}$
Multijet bkg.	0.023	0.007	0.007	0.003	0.008	0.001
Top quark mass	0.012	0.008	0.010	0.008	0.010	0.007
$t\bar{t}$ scales	0.011	0.008	0.014	0.007	0.012	0.007
$t\bar{t}$ match. scale	0.011	0.007	0.010	0.007	0.009	0.007
Hadronisation	0.015	0.009	0.005	0.003	0.006	0.004
Limited MC size	0.002	0.001	0.002	0.001	0.002	0.001
Pileup	0.001	0.001	$<10^{-3}$	$<10^{-3}$	0.001	$<10^{-3}$
$t\bar{t}$ p_T reweight	0.011	0.010	$<10^{-3}$	0.001	$<10^{-3}$	0.002
PDF	0.004	0.001	0.002	0.001	0.002	0.001

W helicty e/μ + Jets (8 TeV)

Systematic Uncertainty	Leptonic, ≥2 b-tags			Hadronic, 1 b-tag + ≥2 b-tags		
	F_0	F_L	F_R	F_0	F_L	F_R
Reconstructed Objects						
Electron	+0.003 -0.003	+0.002 -0.002	+0.001 -0.001	+0.003 -0.002	+0.003 -0.004	+0.005 -0.006
Muon	+0.002 -0.003	+0.001 -0.001	+0.001 -0.001	+0.003 -0.004	+0.005 -0.003	+0.007 -0.007
Jet Energy Scale	+0.006 -0.003	+0.003 -0.002	+0.004 -0.001	+0.007 -0.007	+0.012 -0.008	+0.014 -0.005
Jet Energy Resolution	+0.006 -0.006	+0.005 -0.002	+0.007 -0.007	+0.027 -0.031	+0.033 -0.041	+0.057 -0.071
Jet Vertex Fraction	+0.004 -0.002	+0.002 -0.001	+0.002 -0.001	+0.013 -0.009	+0.001 -0.005	+0.011 -0.004
Jet Reconstruction Efficiency	<0.001 <0.001	<0.001 <0.001	<0.001 <0.001	+0.001 -0.001	<0.001 <0.001	+0.001 -0.001
b tagging	+0.002 -0.002	+0.001 -0.001	+0.001 -0.001	+0.029 -0.031	+0.013 -0.014	+0.034 -0.035
Sum Reconstructed Objects	+0.010 -0.008	+0.006 -0.004	+0.009 -0.007	+0.043 -0.045	+0.038 -0.044	+0.069 -0.080

Signal Modelling						
Showering and Hadronisation	+0.002 -0.002	+0.002 -0.002	+0.004 -0.004	+0.015 -0.015	+0.001 -0.001	+0.014 -0.014
ME Generator	+0.003 -0.003	+0.003 -0.003	+0.006 -0.006	+0.016 -0.016	+0.024 -0.024	+0.04 -0.04
ISR/FSR	+0.003 -0.003	+0.006 -0.006	+0.003 -0.003	+0.018 -0.018	+0.039 -0.039	+0.057 -0.057
PDF	+0.003 -0.003	+0.004 -0.004	+0.001 -0.001	+0.001 -0.001	+0.002 -0.002	+0.002 -0.002
Top Mass	+0.002 -0.002	+0.005 -0.005	+0.003 -0.003	+0.003 -0.003	+0.009 -0.009	+0.006 -0.006
Sum Signal Modelling	+0.006 -0.006	+0.009 -0.009	+0.008 -0.008	+0.028 -0.028	+0.047 -0.047	+0.072 -0.072
Method Uncertainty						
Template Statistics	+0.009 -0.009	+0.006 -0.006	+0.004 -0.004	+0.008 -0.008	+0.016 -0.016	+0.016 -0.016
Total Systematic	+0.015 -0.014	+0.013 -0.012	+0.012 -0.012	+0.052 -0.054	+0.063 -0.067	+0.101 -0.108
Stat. + Bkg.	±0.012	±0.008	±0.006	±0.010	±0.021	±0.022