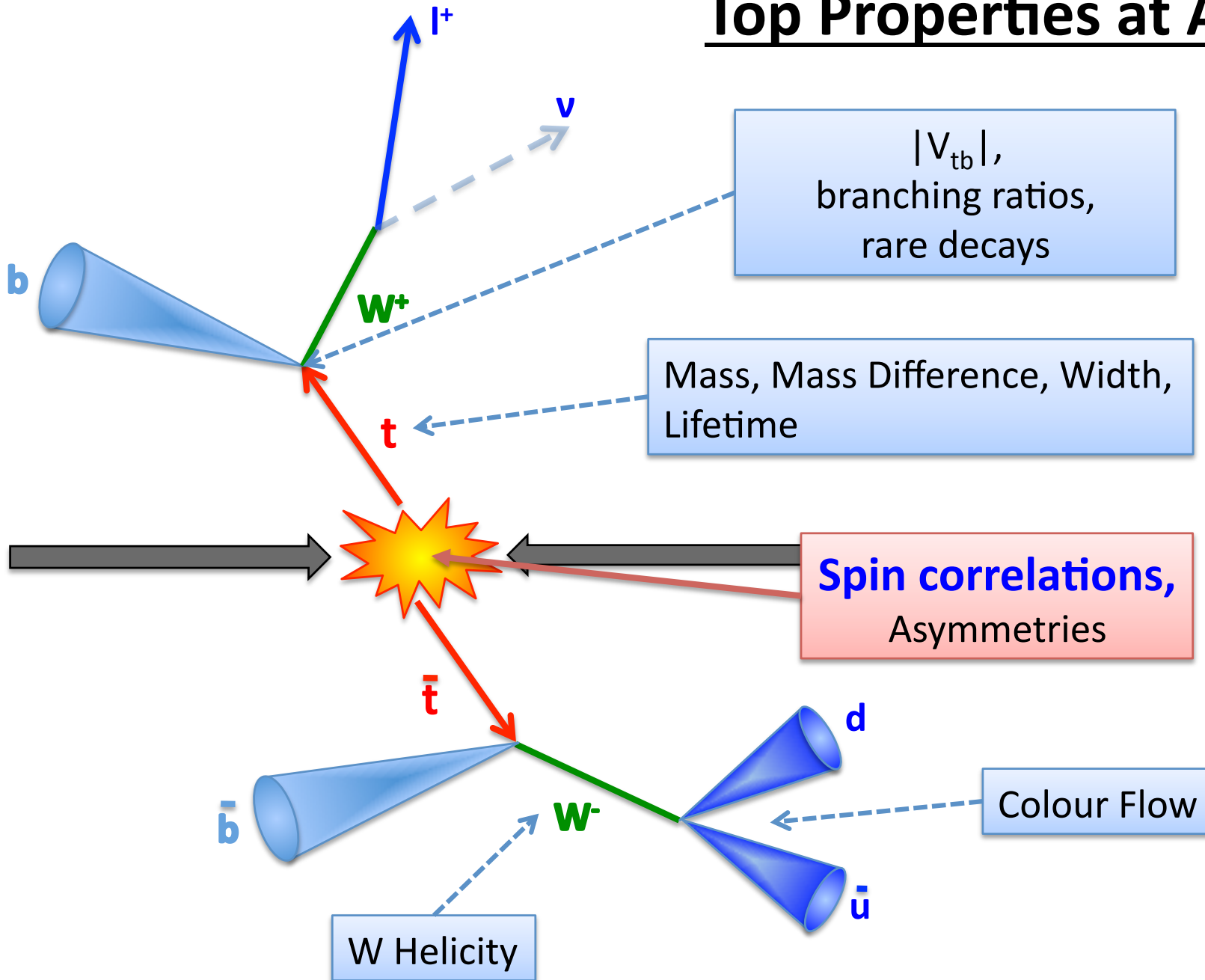




Spin Correlations in dilepton top decays

James Howarth
IOP QMUL 2012
03/04/12

Top Properties at ATLAS



Spin Correlation

$$A = \frac{N(\uparrow\uparrow) + N(\downarrow\downarrow) - N(\uparrow\downarrow) - N(\downarrow\uparrow)}{N(\uparrow\uparrow) + N(\downarrow\downarrow) + N(\uparrow\downarrow) + N(\downarrow\uparrow)},$$

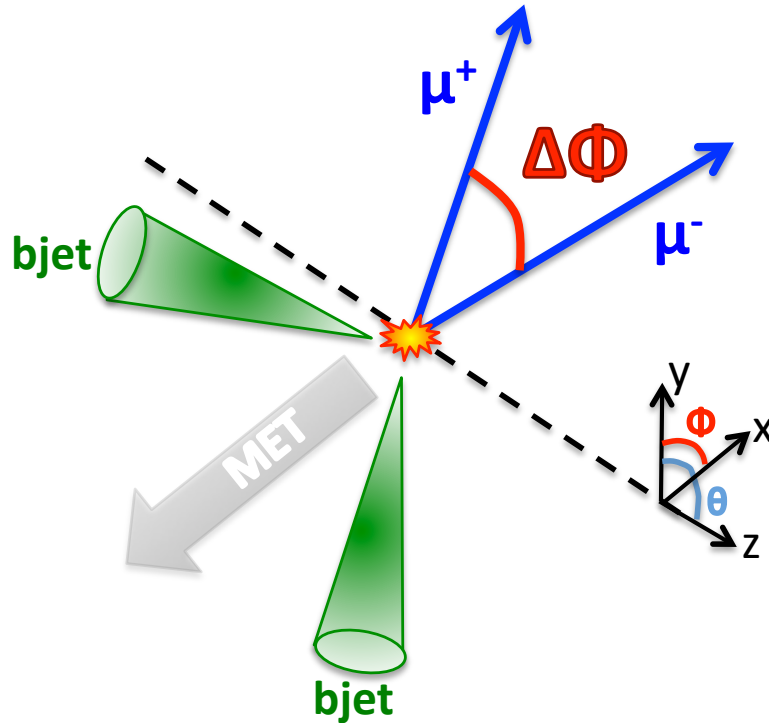
- In SM top quarks do not have polarized spin, but spins are correlated with anti-top.
- Measurement of this property is precision test of SM.

- Short lifetime implies no hadronisation, spin information transferred to decay particles.
- Spin correlation is sensitive to changes in top production and decay.
- **A** is different for Tevatron and LHC, hence results are complementary.
- Charged leptons allow for full access to this information, hence dilepton Channel most sensitive for observation.

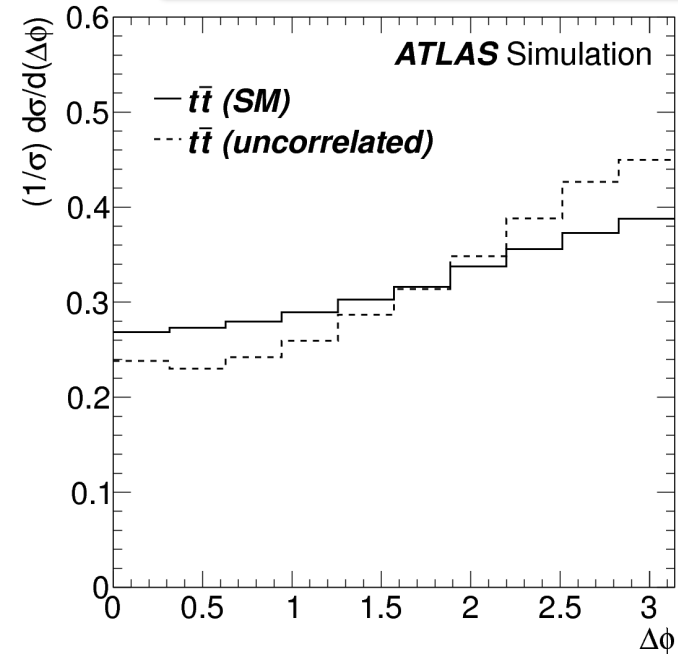
	<i>b</i> -quark	W^+	l^+	\bar{d} -quark or \bar{s} -quark	<i>u</i> -quark or <i>c</i> -quark
α_i (LO)	-0.41	0.41	1	1	-0.31
α_i (NLO)	-0.39	0.39	0.998	0.97	-0.32

Full Spin Info from Leptons

Observables



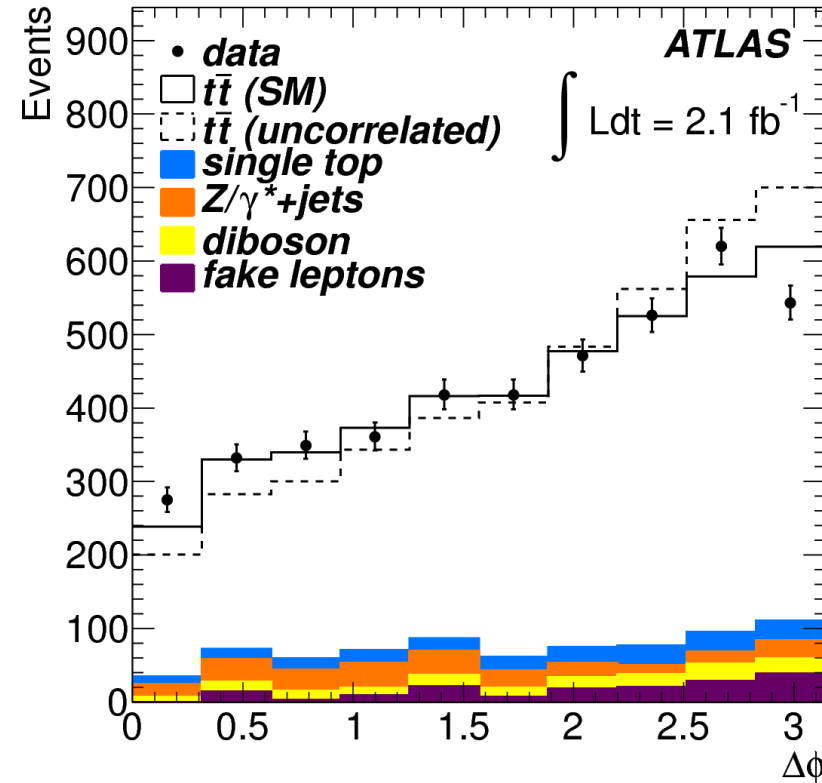
Parton Level MC@NLO (7TeV)



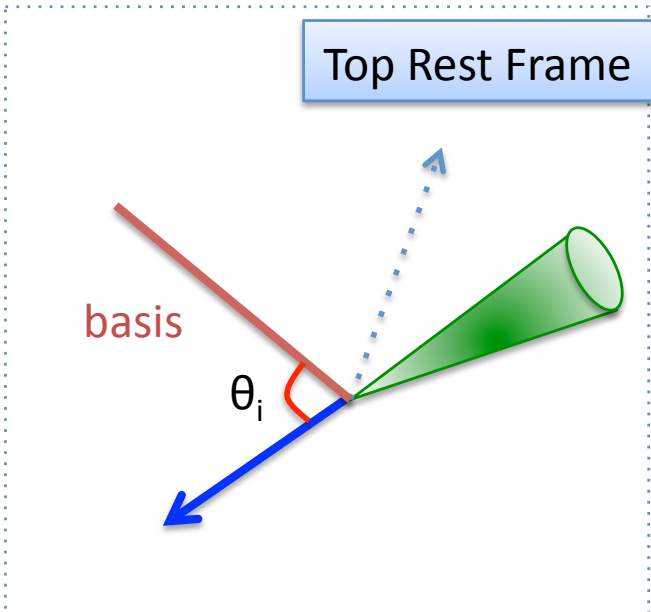
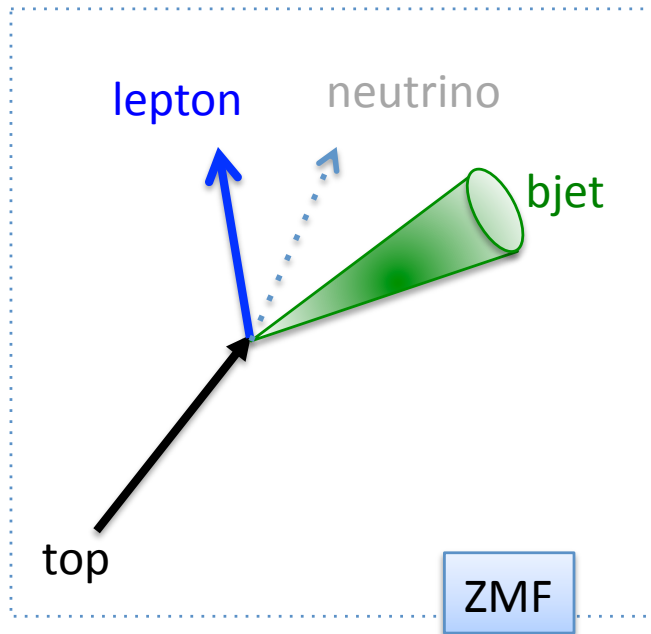
- Spin information from top pairs is accessible through angular distributions of decay particles.
- $\Delta\Phi$ = Difference in Azimuthal Angle of two leptons – Provides good sensitivity and does not require full event reconstruction!
- The two templates are full standard model spin correlation (f_{sm}) or uncorrelated spins.
- We assume full f_{sm} , zero spin, or a linear combination of the two cases.

2011 Result

- Binned Likelihood Fit performed in all channels simultaneously to extract f_{SM}
- Hypothesis of zero $t\bar{t}$ spin correlations excluded with significance of 5.1σ .
- **First observation of spin correlation!**
- Paper on arXiv (as of 20/03/12):
<http://de.arxiv.org/abs/1203.4081>
- Submitted to PRL

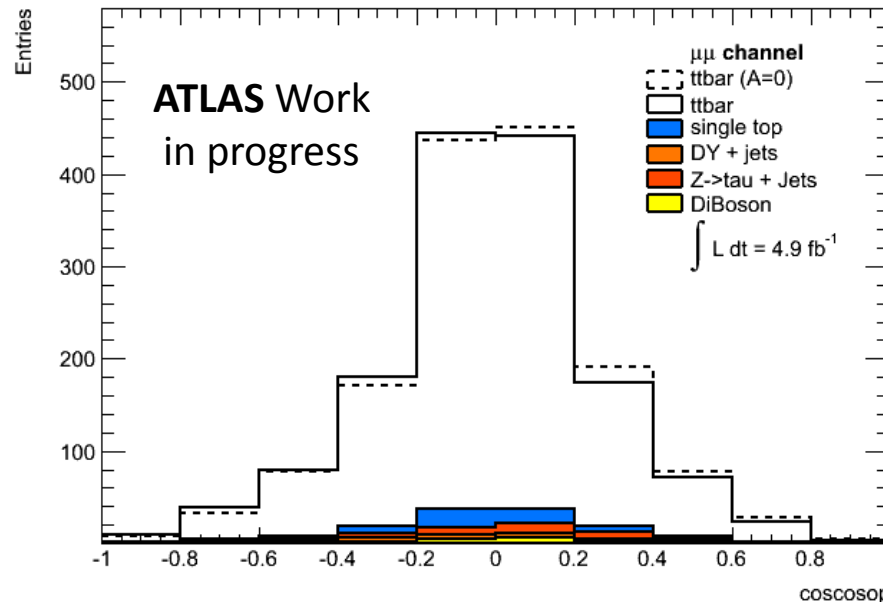


$$f^{\text{SM}} = 1.30 \pm 0.14 \text{ (stat)}^{+0.27}_{-0.22} \text{ (syst)}$$



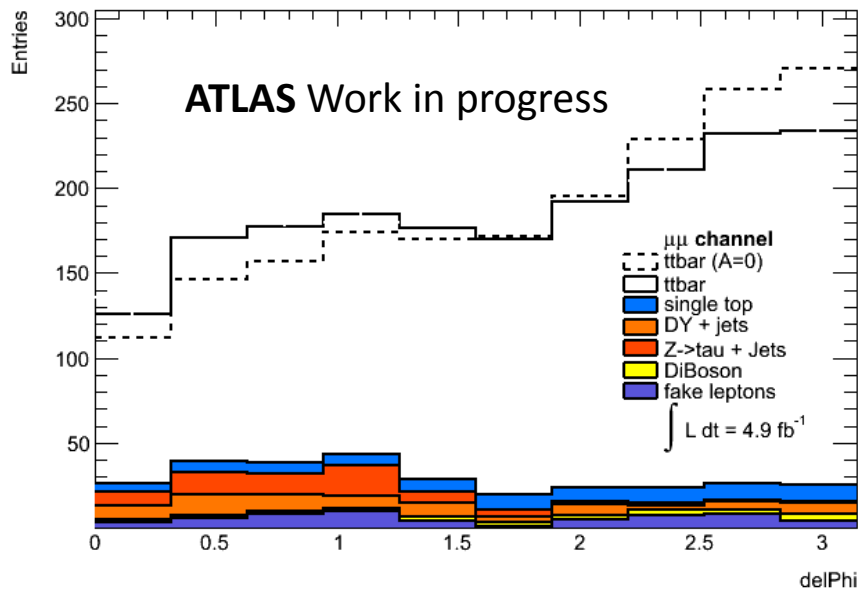
Observables

- $\cos(\theta^+) \cos(\theta^-)$ used for Tevatron Spin analyses.
- Requires full $t\bar{t}$ reconstruction
- Not trivial due to underconstrained event kinematics.
- Requires basis to measure lepton angular distributions.
- Three possible at LHC, beamline, helicity and maximal.

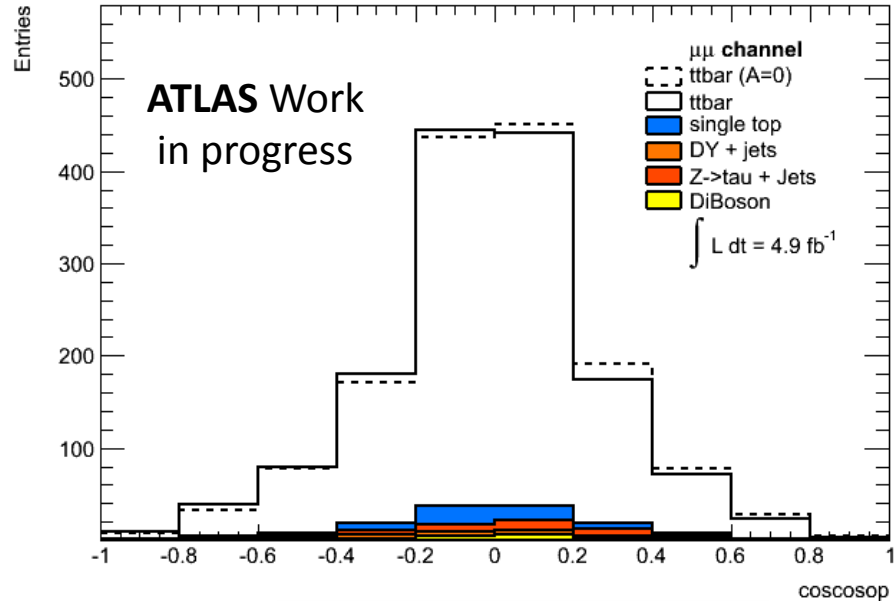


Spin Correlation 2012

- Now after observation, what's next?
- Different variables can be sensitive to different physics contributions (gg vs qqbar, helicity states etc).



Sensitive at low $M_{t\bar{t}}$

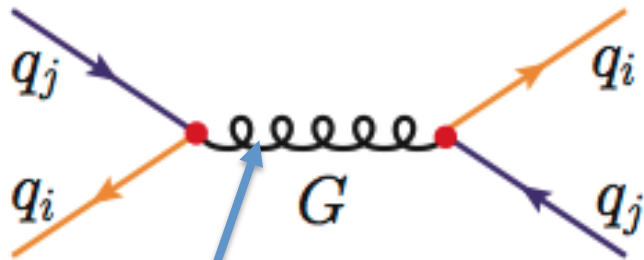


Sensitive at high $M_{t\bar{t}}$

- Sensitivity is highly dependent on the invariant mass of the system, would improve sensitivity, but loss of statistics and increase systematics could counteract this effect.

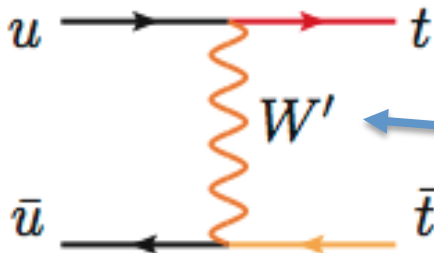
New physics models

- With 5fb^{-1} many new physics models are predicted to cause measureable asymmetries in $t\bar{t}$ events at $\geq 3\sigma$ (<http://prd.aps.org/pdf/PRD/v84/i7/e074034>)
- $\cos(\theta_+) \cos(\theta_-)$ variable sensitive to these models.



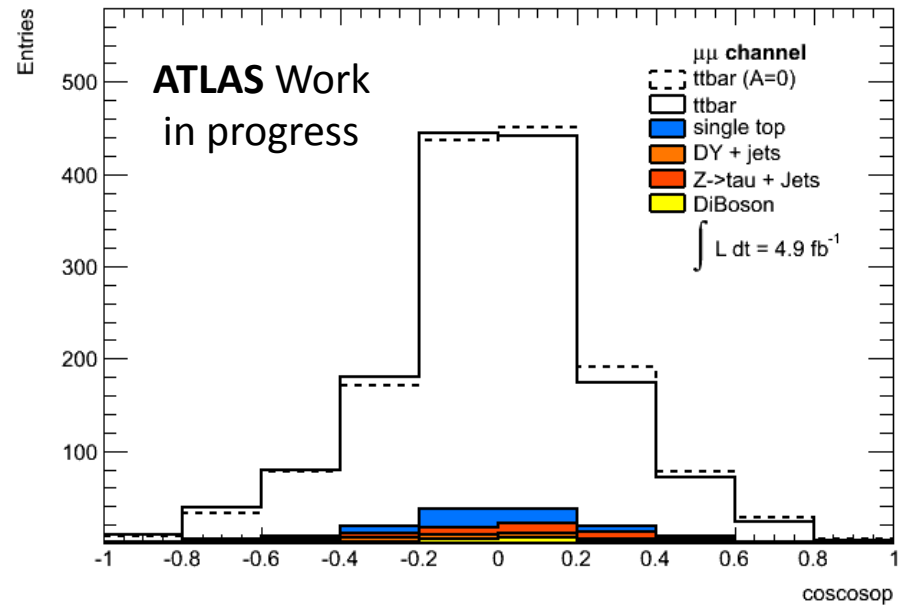
s-channel vector boson 'axi-gluon' Models

- Fully Axial coupling
- Left handed coupling
- Right handed coupling



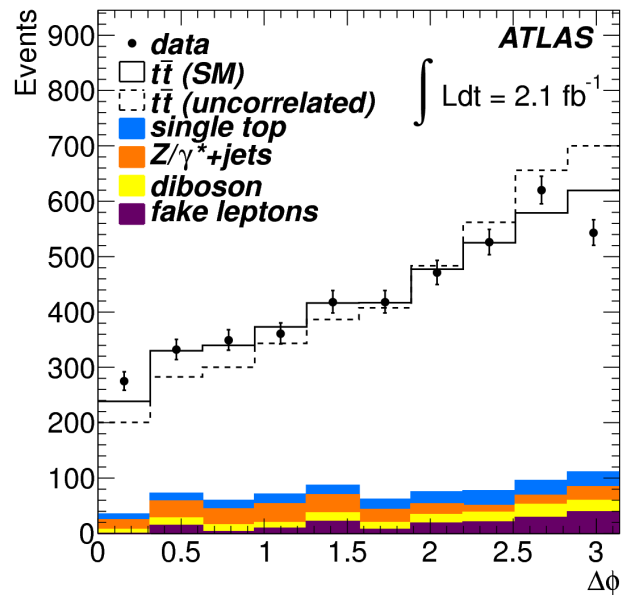
t-channel vector boson

- W' model



Summary

- First observation for non-vanishing spin correlation in dilepton $t\bar{t}$ events at ATLAS!
- Result on arXiv and submitted to PRL.



$$f^{\text{SM}} = 1.30 \pm 0.14 \text{ (stat)}^{+0.27}_{-0.21} \text{ (syst)}$$

- With full 5fb^{-1} data from ATLAS, results will be improved upon in 2012 and used to provide more detailed information on $t\bar{t}$ production and top properties.
- Spin correlation variable sensitive to new physics will also be studied.

Backup

Backup (Systematics)

Uncertainty source	Δf^{SM}
Data statistics	± 0.14
MC template statistics	± 0.09
Luminosity	± 0.01
Lepton	± 0.01
Jet	$-0.08 / +0.10$
NLO generator	± 0.10
Parton shower and fragmentation	± 0.09
ISR/FSR	± 0.06
PDF uncertainty	± 0.07
top quark mass	± 0.01
Z/ γ^* +jets method	± 0.00
Fake leptons	$-0.07 / +0.16$
Background normalisation	± 0.00
Calorimeter readout	± 0.01
All Systematics	$-0.21 / +0.26$
Statistical + Systematic	$-0.26 / +0.30$

Signal modeling systematics make large contribution to uncertainty.

This will be improved with more statistics

Systematics limited!

- Systematics limited, will hopefully be reduced with new techniques (ISR) and more data (Fakes) in 2012.