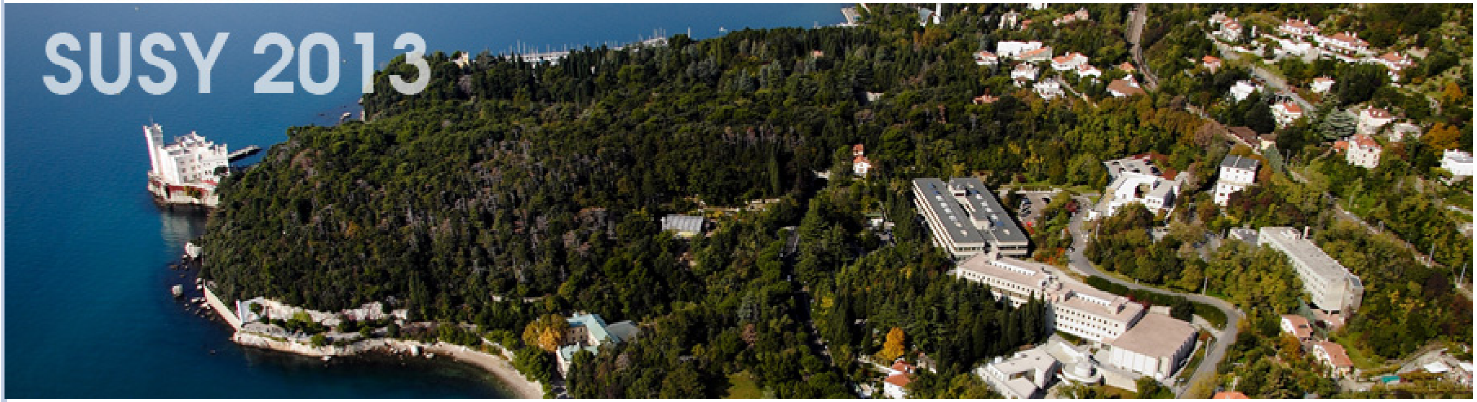


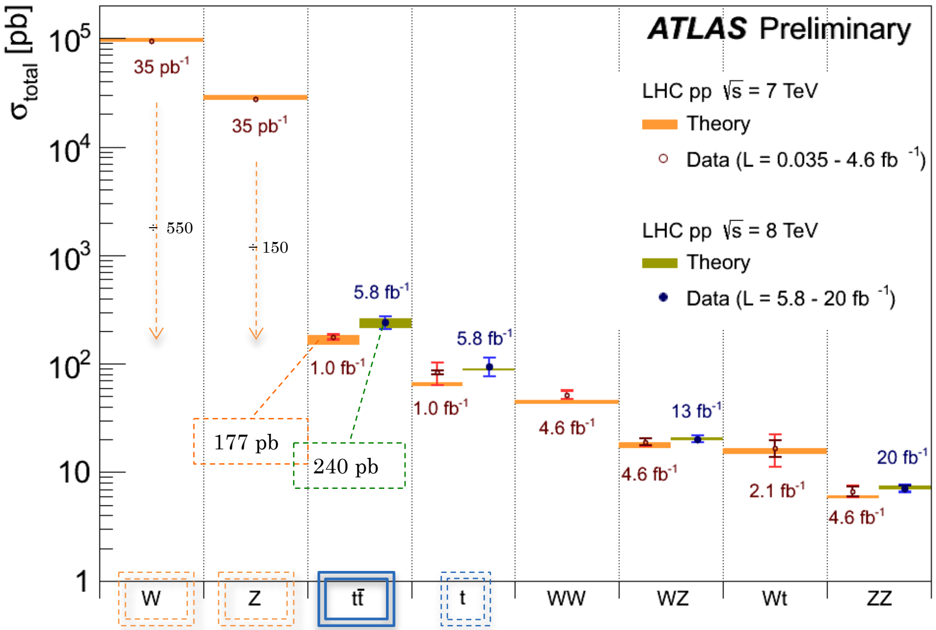
Top quark properties in ATLAS

M.Bosman (IFAE Barcelona)

on behalf of the ATLAS Collaboration

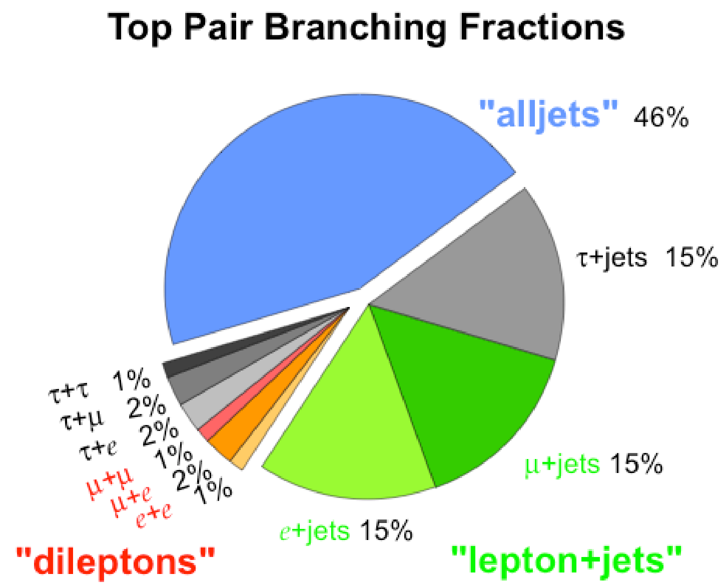
SUSY 2013 - ICTP Trieste

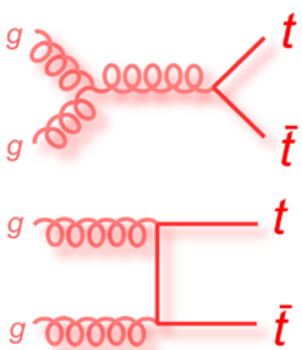
Top quark production in SM



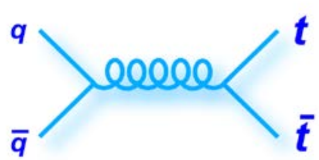
Br (t→Wb) ≅ 99.8%

W decays define the experimental signature





80 %



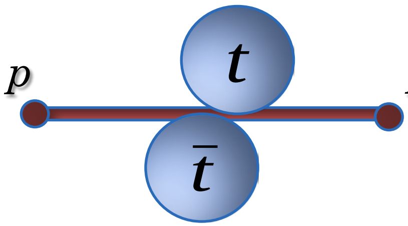
20%

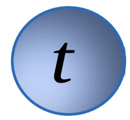
at the LHC

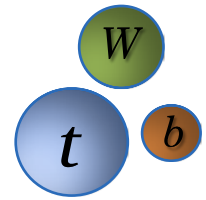
all jets: high rate, large QCD multijet background
lepton+jets: medium rate, accceptable background (W+jets)
dilepton: low rate, low background (Z+jets, Diboson)

OUTLINE

The properties presented are mostly measured in top-antitop events in the lepton+jets and dilepton channels with l=e,μ







in the properties of ttbar pairs

- charge asymmetry
- spin correlation
- top polarization
- couplings (ttγ/ Z)

in the properties of individual top quarks

- charge
- mass

in the properties of top quarks decays

- W polarization
- FCNC (t→Zq; t→cH)

top quark decays before hadronizing:
can measure "bare" quark" properties !

Event selection, background rejection and estimate

- Event selection (lepton+jets, dilepton)
  - single lepton trigger
  - 1 or 2 isolated high p_T leptons ($p_T > 20/25$ GeV, $|\eta| < 2.5$)
  - MET > 20/35 GeV, > 60 GeV
  - at least 4 or 2 anti-k_T (R=0.4) jets ($p_T > 25$ GeV, $|\eta| < 2.5$)
  - at least 1 b-tagged jet (70% efficiency for b-quark)
- Background rejection
  - QCD multijet: $m_T^W > 25$ GeV or MET+$m_T^W > 60$ GeV
  - Z+jets: m_{ll} veto or $H_T > 130$ GeV
- Background estimate
  - Fake leptons (multijet, W+jets): data-driven shape and normalization, usually from matrix method
  - W+jets: shape from MC and data-driven normalization from charge asymmetry: $N_{W^+ + W^-} = (r_{MC}+1)/(R_{MC}-1) \times (D^+ - D^-)$
  - Z+jets: shape from MC and data-driven normalization from m_{ll} around the Z mass

EVENT RECONSTRUCTION

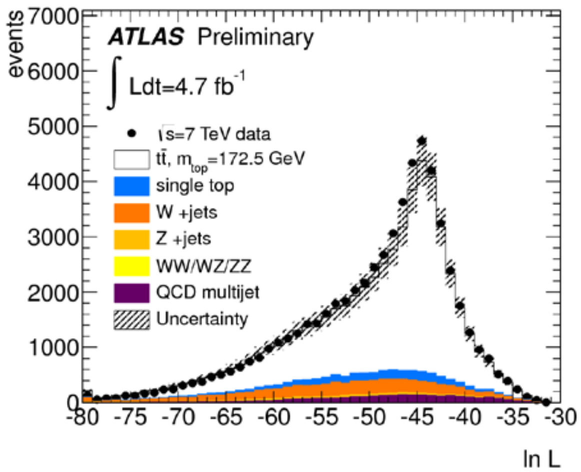
- reconstruction of the full kinematics of top pair in many analysis
- lepton + jets events: for example a kinematic likelihood fitter selects object topology that best fits top quark pair decay hypothesis

reco objects mapped to hard scatt. partons via LO transfert function (T)

Breit Wigner (B) constraints $\Gamma_{top}(\Gamma_W)$ for m_{top}^{reco} (m_W^{reco}) for had & lep sides

reduce combinatorics b-tagging info (P)

$$L = B(\tilde{E}_{p,1},\tilde{E}_{p,2}\,|\,m_W,\Gamma_W)\cdot B(\tilde{E}_{lep},\tilde{E}_{\nu}\,|\,m_W,\Gamma_W)\cdot$$
$$B(\tilde{E}_{p,1},\tilde{E}_{p,2},\tilde{E}_{p,3}\,|\,m_t,\Gamma_t)\cdot B(\tilde{E}_{lep},\tilde{E}_{\nu},\tilde{E}_{p,4}\,|\,m_t,\Gamma_t)\cdot$$
$$T(\hat{E}_x^{miss}\,|\,\tilde{p}_{x,\nu})\cdot T(\hat{E}_x^{miss}\,|\,\tilde{p}_{x,\nu})\cdot T(\hat{E}_{lep}\,|\,\tilde{E}_{lep})\cdot$$
$$\prod_{i=1}^{4} T(\hat{E}_{jet,i}\,|\,\tilde{E}_{p,i})\cdot \prod_{i=1}^{4} P(tagged\,|\,parton.flavour)$$



example: in the m_{top} analysis the reconstructed top mass done with correct assignment of jets to partons in more than 70% of the cases

- dilepton events: different methods used to select combination and determine neutrino momenta

SYSTEMATIC UNCERTAINTIES

All top analysis consider the following sources

- Detector modelling
  - Efficiency and resolution for reconstruction and identification of all physics objects

    Some of the most relevant are Jet Energy Scale for light jets (JES) and b-jets (bJES)
  - Luminosity and pile-up dependence

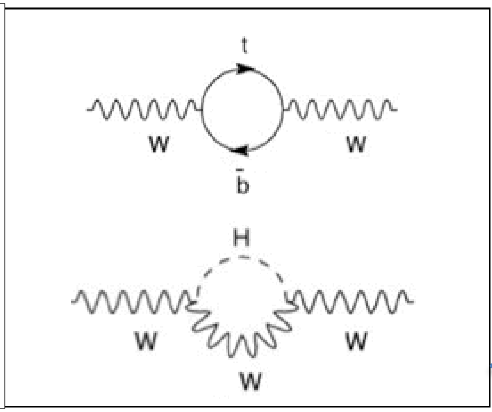
- Signal and background modelling
  - MC generators (NLO), QCD radiation, PDFs, top mass, etc.
    - improved MC description – constraints from data
  - Background normalization/shape (cross section or statistics of control sample), fraction of heavy flavour jets

- Analysis specific
  - Statistics of MC templates, charge misidentification, etc.

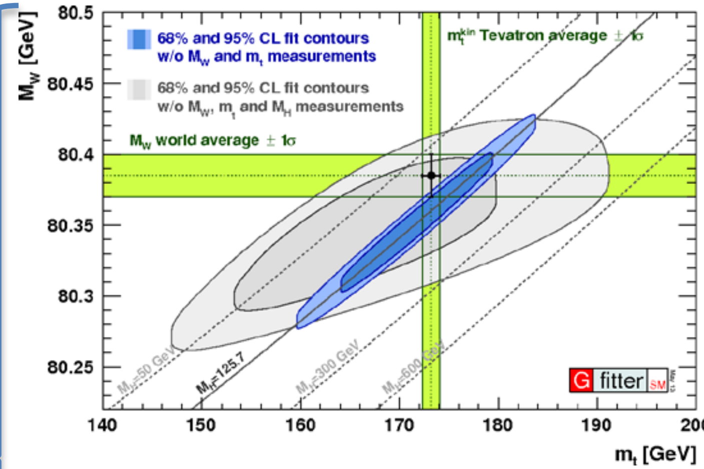
Top mass measurement

- top quark mass crucial input for consistency check of SM:

  top, W and H mass are related



http://gfitter.desy.de/Standard_Model/

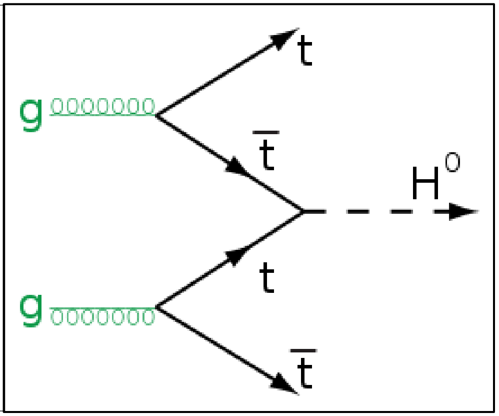


distinguish SM from possible extensions, like MSSM

SM: bring insight into stability of vacuum and the evolution of the universe

- check Higgs mechanism for fermion masses:

  measure independently mass and Yukawa coupling ttH

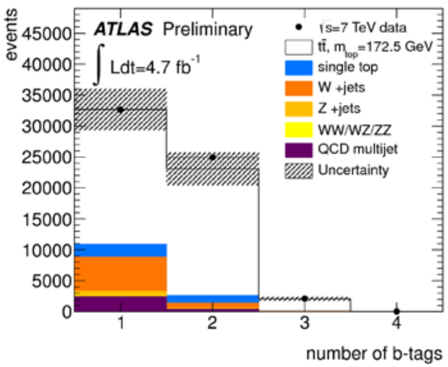


- top mass is also a source of uncertainty in the calculation of cross-section: 1% on top mass, 5% on cross-section

TOP MASS - *L*+JETS

ATLAS-CONF-2013-046

analyse events with 1 b-tag and ≥2 b-tags separately



events with ≥2 b-tags

$$R_{lb}^{reco} = \frac{p_T^{b-tag,1} + p_T^{b-tag,2}}{p_T^{light,1} + p_T^{light,2}}$$

events with 1 b-tag

$$R_{lb}^{reco} = \frac{p_T^{b-tag}}{(p_T^{light,1} + p_T^{light,2})/2}$$

observable 1 = m_{top}^{reco}

- sensitive to "input m_{top}"
- but also to

JSF: global jet energy scale factor

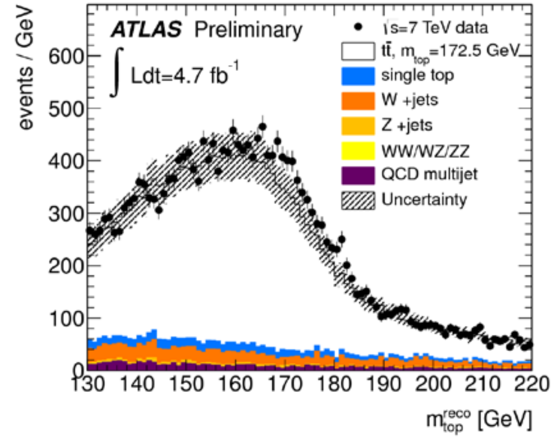
bJSF: relative b-jet to light jet scale factor

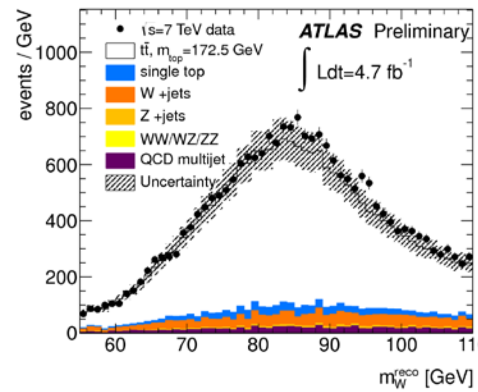
observable 2 = m_W^{reco}

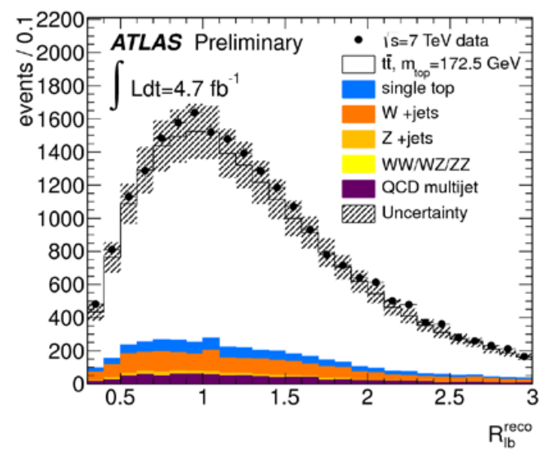
- sensitive to JSF

observable 3 = R_{lb}^{reco}

- sensitive to bJSF





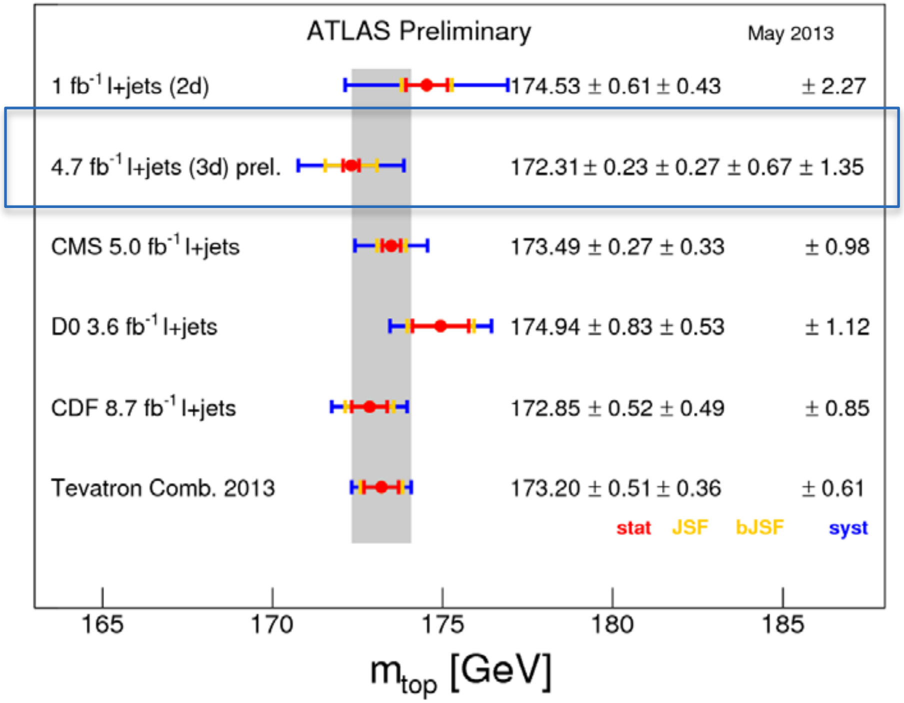


TOP MASS - *L*+JETS

ATLAS-CONF-2013-046

$$m_{top} = 172.31 \pm 0.75\,(\text{stat+JSF+bJSF}) \pm 1.35(\text{syst})\ \text{GeV},$$
$$\text{JSF} = 1.014 \pm 0.003\,(\text{stat}) \pm 0.021\,(\text{syst}),$$
$$\text{bJSF} = 1.006 \pm 0.008\,(\text{stat}) \pm 0.020\,(\text{syst})$$

compared to ATLAS 1 fb^{-1} paper: uncertainty has been reduced from 2.4 GeV to 1.5 GeV (40%) due to improvements in the analysis, MC modelling (constraint from data), detector understanding



total uncertainty dominated by:

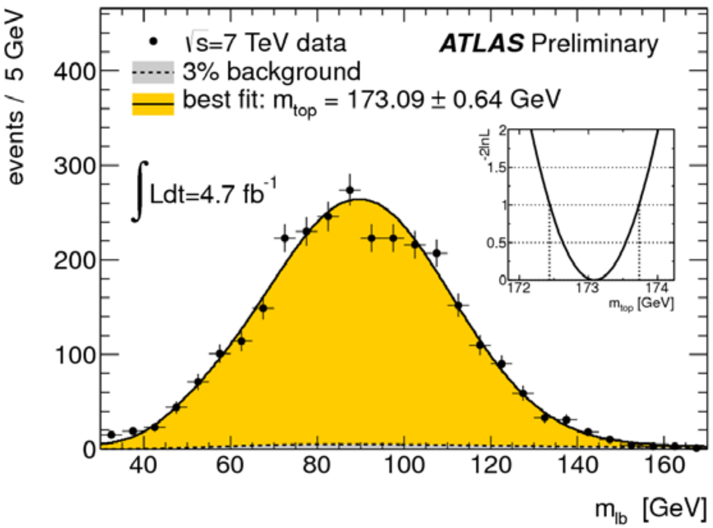
- residual JES
- b-tagging systematic

TOP MASS - DILEPTON

ATLAS-CONF-2013-077

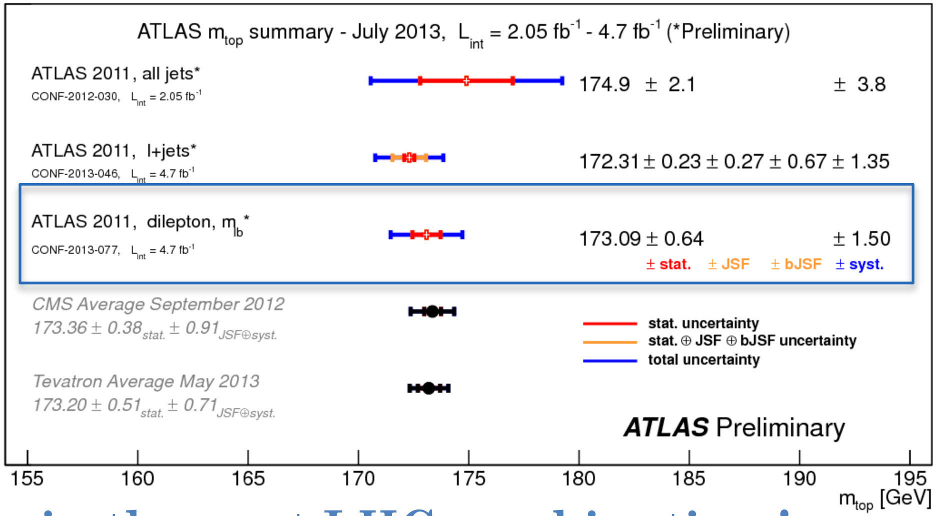
m_{top} = 173.0 ± 0.64 (stat) ± 1.50 (syst) GeV

m_{lb} = invariant mass of lepton and b-tagged jet:
2 leptons and 2 b-tagged jets combination leading to lowest average mass chosen
77% correct assignment



JSF,bJSF: largest contribution to systematic uncertainty – 80%
expected since no in-situ calibration

precision better than 1%, competitive with l+jets 3D analysis



Expect improved precision in the next LHC combination !

arxiv.org:1307.4568

TOP CHARGE

- l+jets events with 2 high purity b-jets
- b quark charge determined from weighted sum of tracks associated to b-jet:

$$Q_{b-jet} = \frac{\sum_i Q_i |\vec{j}\cdot\vec{p}_i|^{\kappa}}{\sum_i |\vec{j}\cdot\vec{p}_i|^{\kappa}}$$

- algorithm to pair l and b-jets:

$$m(l,b_{jet}(1,2)) < m_{cr} \quad m(l,b_{jet}(2,1)) > m_{cr} \qquad m_{cr} = 155 GeV$$

- top quark charge obtained from calibrated b-jet charge

$$Q_{top} = 1 + Q_{comb}^{data} \cdot C_b$$

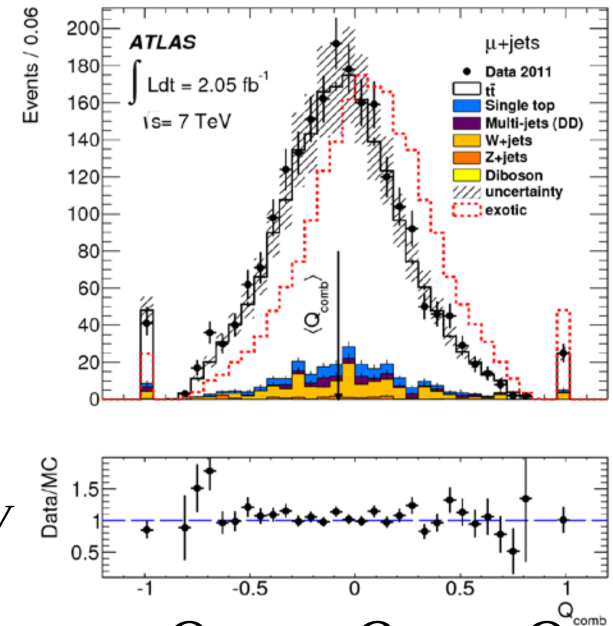
Q_{top}= 0.64 ± 0.02 (stat) ± 0.12 (syst)

dominating syst: JES and top modelling

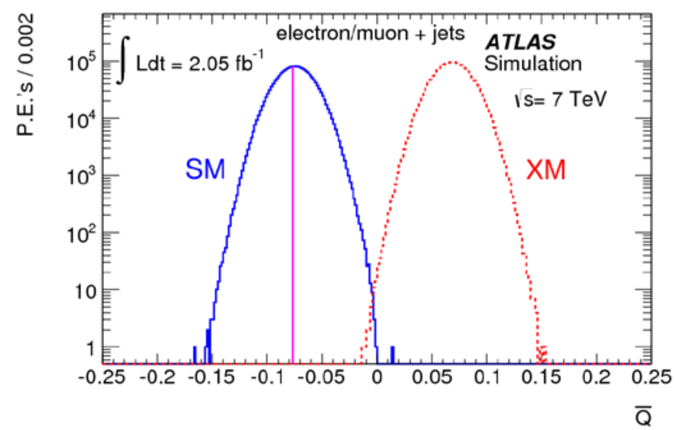
- compatibility with top or exotic quark from stat. model (pseudo-experiments)

$$t^{(2/3)} \rightarrow W^{(+1)} + b^{(-1/3)} \qquad t_X^{(-4/3)} \rightarrow W^{(-1)} + b^{(-1/3)}$$

Exotic model excluded > 8σ



$$Q_{comb} = Q_{b-jet} \cdot Q_l$$



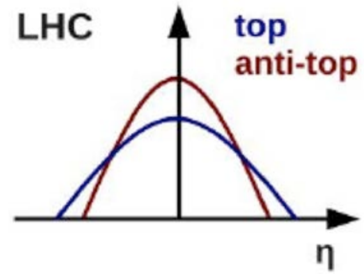
$$\overline{Q} = (1 - r_b - r_t) \cdot Q_s + r_b \cdot Q_b + r_t \cdot Q_t$$

r_b,r_t: frac. background, single top

Charge Asymmetry

ATLAS-CONF-2013-078

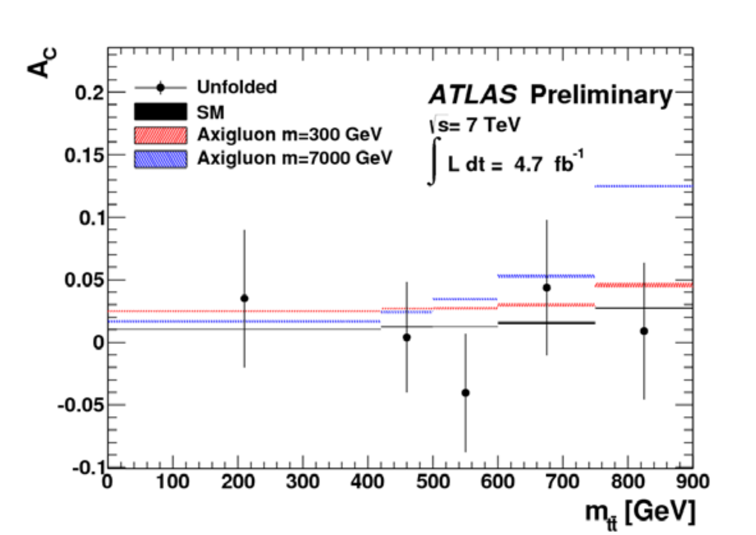
- $qg/q\bar{q}$ production of $t\bar{t}$
  - t emitted in direction of q and $\bar{t}$ of $\bar{q}$
- gg symmetric, $q\bar{q}$ asymmetric at NLO



$$A_c = \frac{N(\Delta|y|>0) - N(\Delta|y|<0)}{N(\Delta|y|>0) + N(\Delta|y|<0)}$$

$t\bar{t}$ asymmetry: $\Delta|y| = |y_t| - |y_{\bar{t}}|$

(l asymmetry: $\Delta|y| = |y_{l^+}| - |y_{l^-}|$)



***l*+jets events:** measure top quark based asymmetry with full bayesian unfolding of detector effects

Inclusive result $A_c^{t\bar{t}} = 0.006 \pm 0.010(stat + syst)$

SM $A_c^{t\bar{t}} = 0.0123 \pm 0.0005$

Differential measurement: $m(t\bar{t}), p_T(t\bar{t}), y(t\bar{t}), \beta_z(t\bar{t})$

Charge Asymmetry

ATLAS-CONF-2012-057

- **dilepton channel**

  measure lepton and top quark based asymmetry

  correct for detector effects using calibration

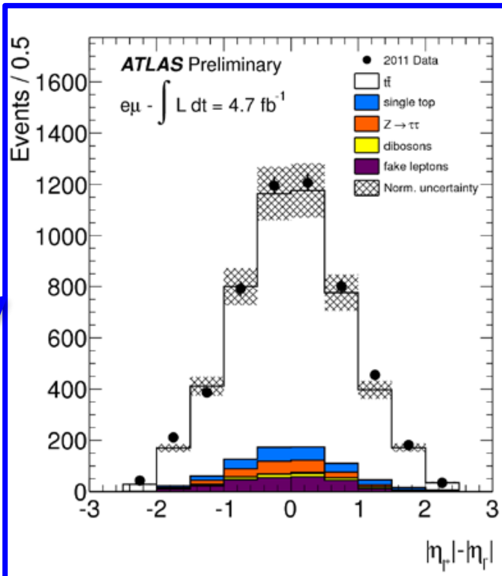
  use ME to reconstruct t and $\bar{t}$
- **Inclusive asymmetry results**

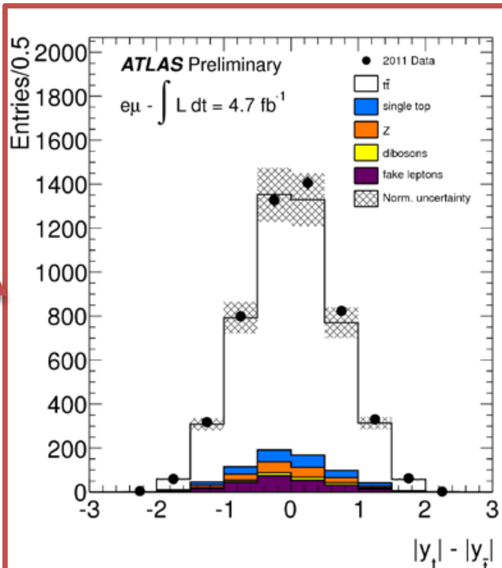
$$A_c^{ll} = 0.023 \pm 0.012(stat) \pm 0.008(syst)$$

$$A_c^{ll} = 0.004 \pm 0.001$$

$$A_c^{t\bar{t}} = 0.057 \pm 0.024(stat) \pm 0.015(syst)$$

$$A_c^{t\bar{t}} = 0.0123 \pm 0.0005$$





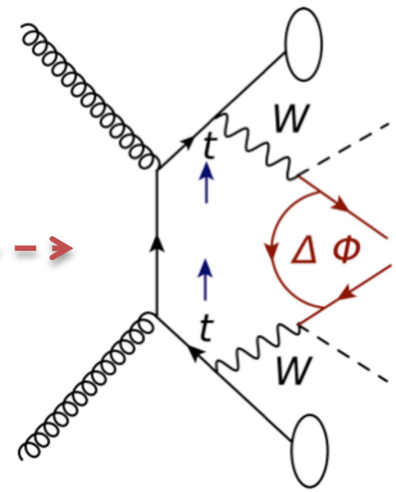
- dilepton - main systematic: QCD, calibration, $t\bar{t}$ modelling
- l+jets (syst < stat) – main systematic: JES and resolution

All measurements compatible with SM

SPIN CORRELATIONS

arXiv.1203.4081

- top quark decays before hadronizing; spin of the top quark at production is transferred to its decay products: azimuthal angle between leptons in dilepton events



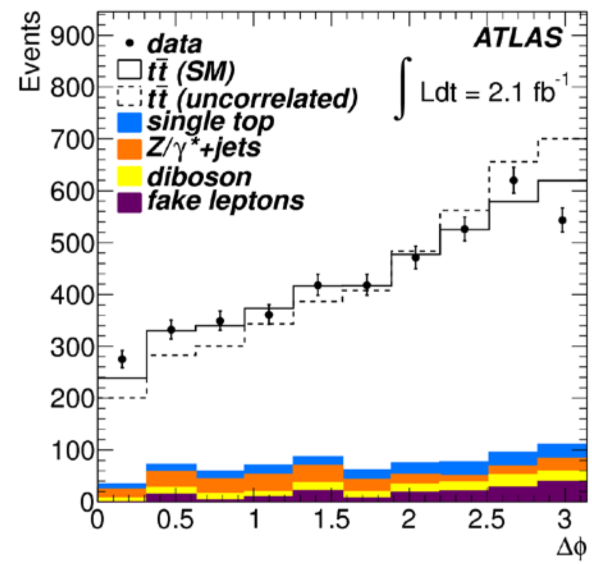
- **SM**: at low $m_{t\bar{t}}$ fusion of like-helicity gluons → top quarks in L-L or R-R helicity configuration

  BSM: exchange of a virtual heavy scalar Higgs boson → different spin correlation

- f_{SM} = fraction of events with SM-like spin correlation extracted from binned template fit of Δφ distribution to samples with ≠ fractions

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

- exclude no-correlation hypothesis with 5.1 significance



main systematics JES, fake lepton

TOP POLARIZATION

arXiv:1307.6511

- SM: top quarks produced unpolarized
  - test for polarization with ≠ assumptions: CP-violating/conserving
  - top/antitop with equal/opposite polarization
- full reconstruction to determine the top quark CM frame
- decay product distribution in helicity frame: p_{top}=quantization axis

$$W(\cos\theta_l) = 1/2(1 + \alpha_l P \cos\theta_l)$$

P = degree of polarization

α= analyzing power (=1 for lepton at tree level)

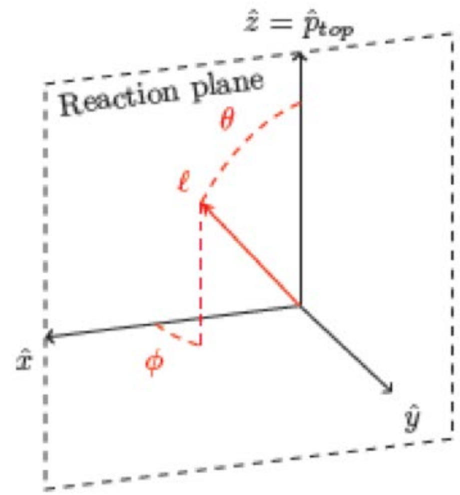
- template fit to $\cos\theta_l$ distribution

f = fraction of positively polarized top quarks

templates are generated with $\alpha P = 0.3$

➔ $$\alpha_l P = 0.6 f - 0.3$$

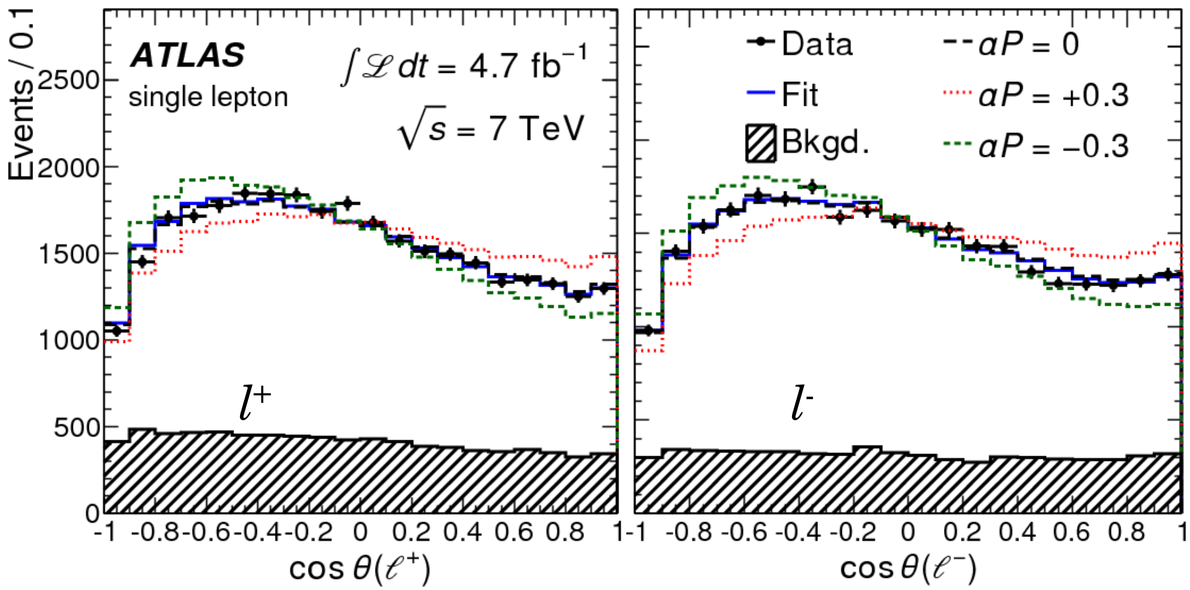
top C.M. frame



TOP POLARIZATION

arXiv:1307.6511

example: *e*,μ +jets CP Conserving



$$\alpha_l P_{CPC} = -0.035 \pm 0.014(stat) \pm 0.037(syst)$$

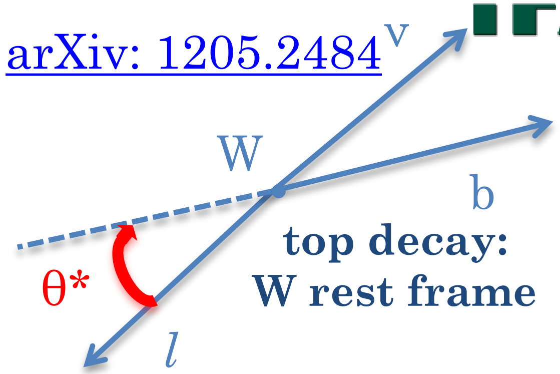
$$\alpha_l P_{CPV} = 0.020 \pm 0.016(stat)^{+0.013}_{-0.017}(syst)$$

data compatible with unpolarized top quarks

main systematics: jet reconstruction and top pair modelling

W POLARIZATION

arXiv: 1205.2484v



- **study Wtb vertex**

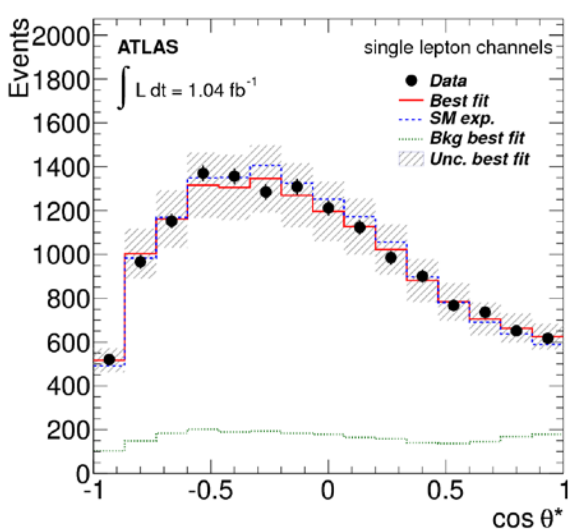
  measure fraction of longitudinally, left- and right-handed polarized Ws

  NNLO QCD: F_0=0.687±0.005 F_L=0.311±0.005 F_R=0.0017±0.0001

- l+jets and dilepton events, full reconstruction

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

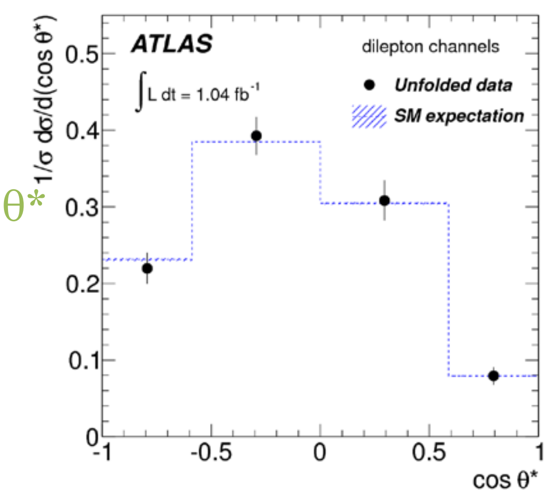
measured cosθ* distribution fitted to templates



$$z = \pm(1-2^{2/3})$$

$$A_\pm = \frac{N(\cos\theta^* > z) - N(\cos\theta^* < z)}{N(\cos\theta^* > z) + N(\cos\theta^* < z)}$$

$A_\pm$: unfolded cosθ* distribution

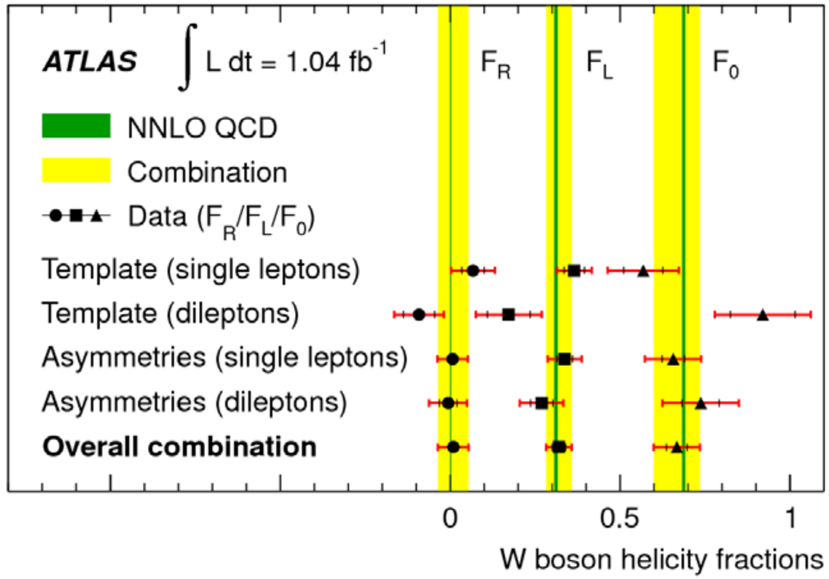


W POLARIZATION

arXiv: 1205.2484

- results of the 4 measurements combined with BLUE
- mostly dominated by systematic uncertainties: signal and background modelling, JES and jet reconstruction

  agreement with **SM** NNLO QCD more precise than CDF, D0

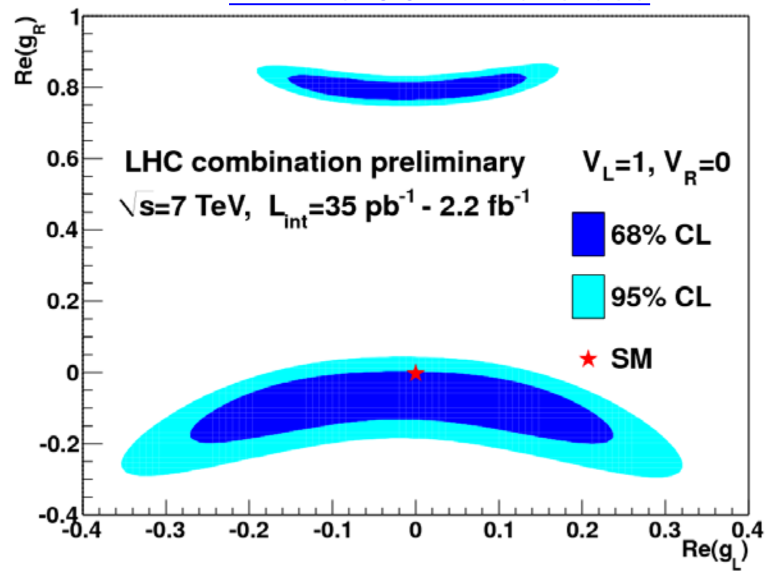


- results interpreted in terms of **BSM** physics introducing anomalous couplings in the effective Lagrangian: V_R, g_L, g_R

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

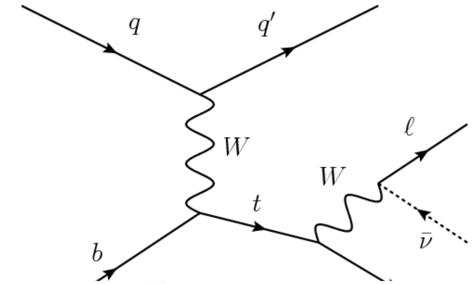
consistent with (V-A) structure

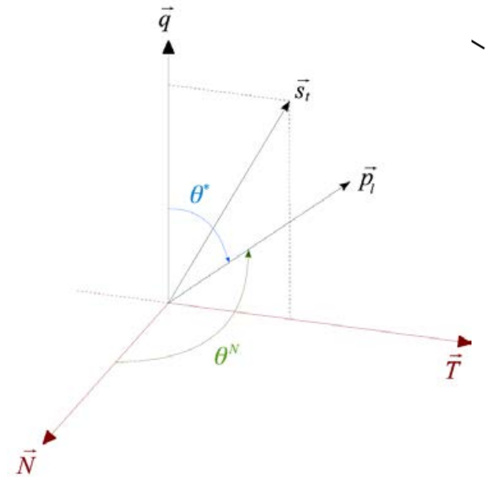
ATLAS-CONF-2013-033



SINGLE TOP – W POLARIZATION

ATLAS-CONF-2013-032

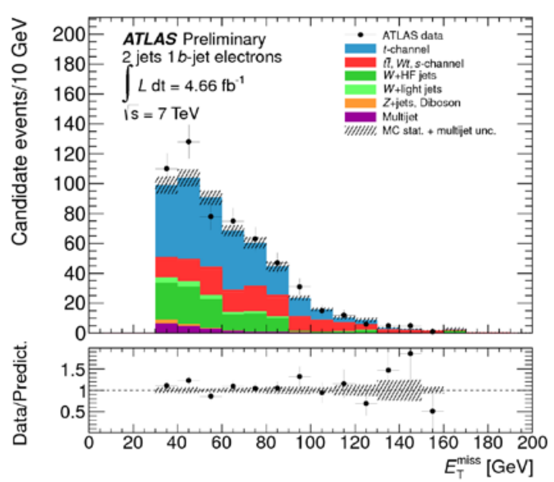


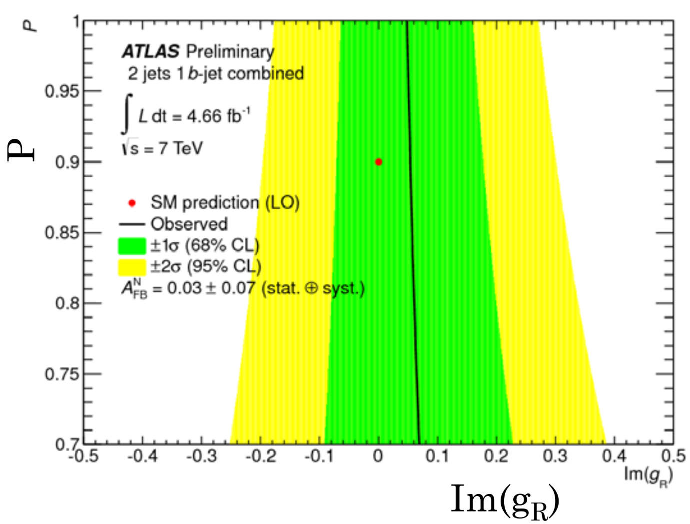


- EW single top production: top quark is polarized along direction of spectator quark (P≈0.9 in SM)
- other reference direction / angle can be defined (sensitive to complex phases)
- $A_{FB}^{N} = 0.64 \times P \times \mathrm{Im}(g_R)$

  $$A_{FB}^{N} = 0.031 \pm 0.065(stat) \pm^{+0.029}_{-0.031} (syst)$$
- first experimental limit on $\mathrm{Im}(g_R)$ [-0-20,0.30] at 95%C.L. (for P=0.9)

  SM prediction LO: P=0.9 and $\mathrm{Im}(g_R)$ =0





FCNC: t→Zq

[arXiv: 1206.0257]

- Search for t→Zq FCNC decay
  - Expected B.R. in SM: $O(10^{-14})$
  - Highest expected B.R. in BSM models $O(10^{-4})$
- trilepton final state:
  - 3 identified leptons (3ID)
  - 2 identified leptons + track lepton (2ID+TL)

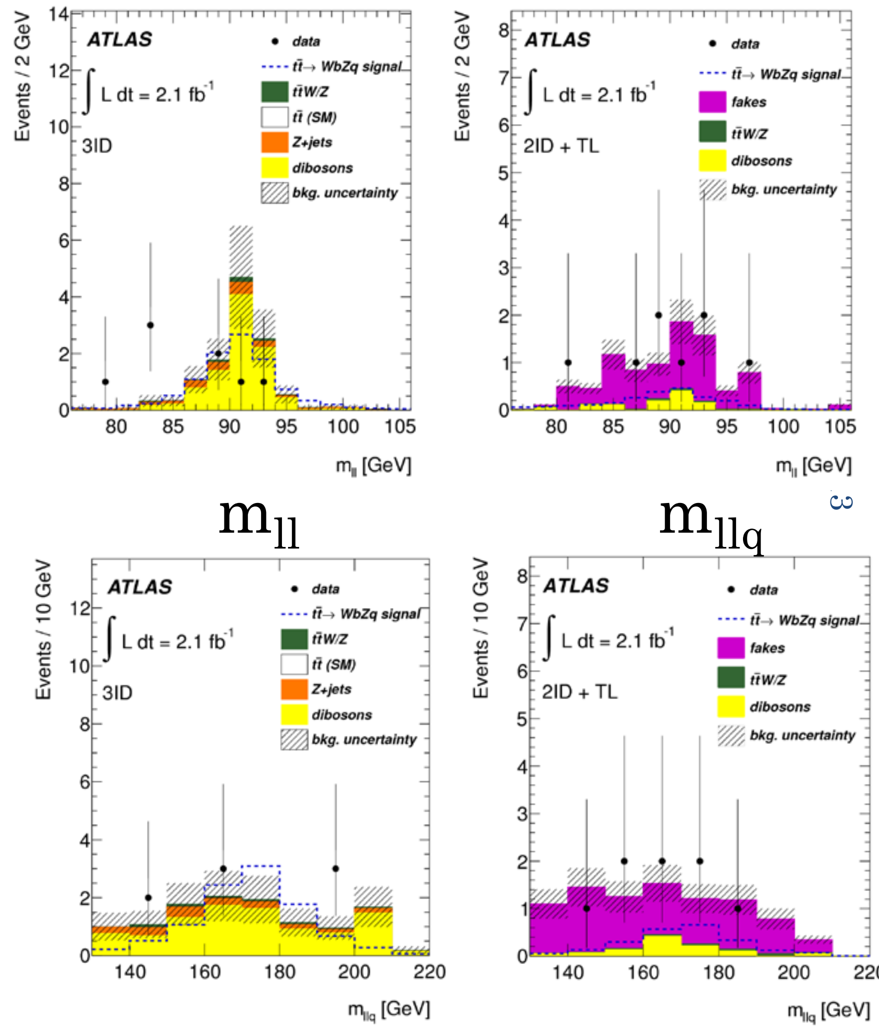
channel	observed	(-1σ)	expected	$(+1\sigma)$
3ID	0.81%	0.63%	0.95%	1.4%
2ID+TL	3.2%	2.15%	3.31%	4.9%
Combination	0.73%	0.61%	0.93%	1.4%

95% C.L. limit on FCNC BR(t→Zq)

observed 0.73%

(expected 0.93%)

- main systematics:
  - Diboson for 3ID
  - fake TL for 2ID+TL



FCNC: t→cH

ATLAS-CONF-2013-081

- Search for t→cH FCNC decay
  - Expected B.R. in SM: O(10^{-15})
  - Highest expected B.R. in BSM models O(10^{-3})
- H→γγ: Br = 0.23%, but clean signature

  other top: hadronic and *l*+jets decay modes

95% C.L. limit on FCNC BR(t→cH)

observed 0.83%

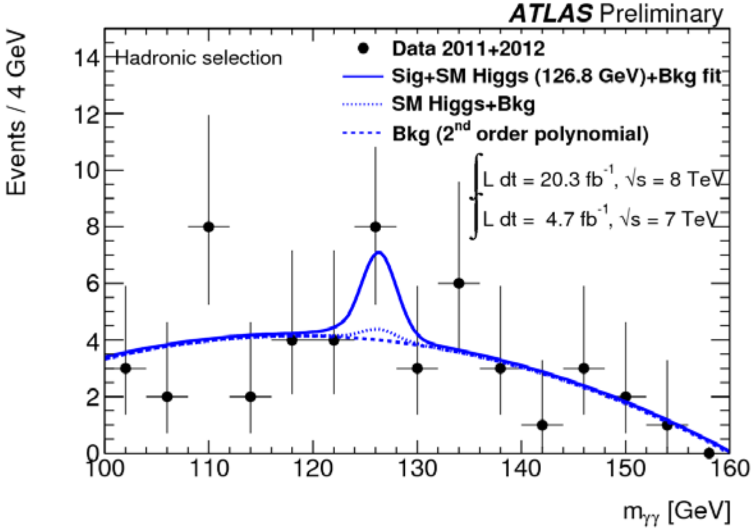
(expected 0.53%)

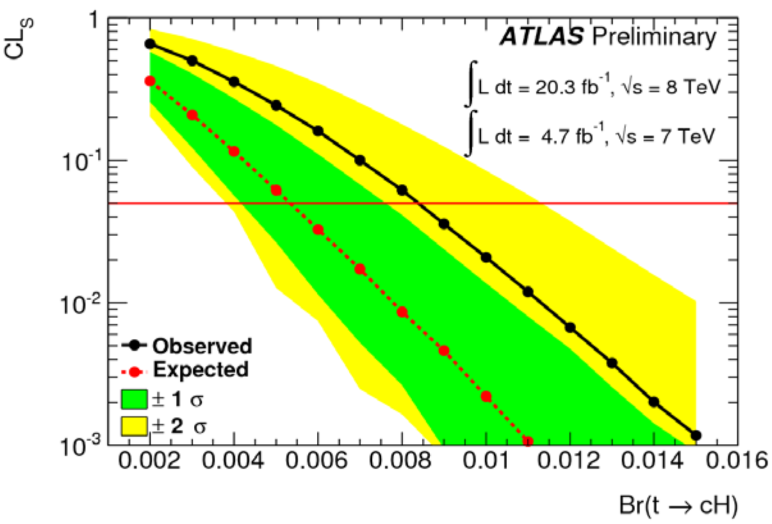
- for SM top width $\lambda_{tcH} = 1.91\sqrt{Br}$

  upper limit on tcH coupling

  observed 0.17

  (expected 0.14)
- main systematics PID, JES and b-tagging





ATLAS-CONF-2012-126

$t\bar{t}Z$ production

- trilepton final state

cut & count analysis

- 1 event observed

expected signal:

$0.85 \pm 0.04(\text{stat}) \pm 0.14(\text{syst})$

expected background:

$0.28 \pm 0.05(\text{stat}) \pm 0.14(\text{syst})$

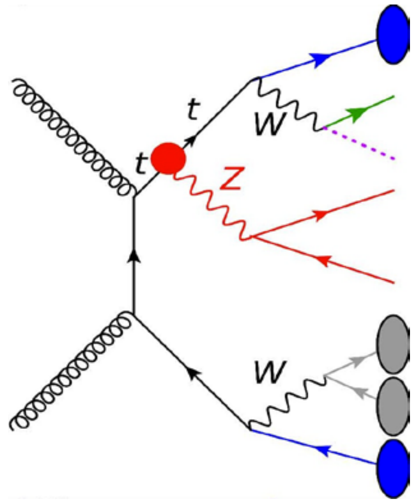
- result:

$$\sigma(t\bar{t}Z) < 0.71 pb \text{ @ } 95\% \text{ C.L.}$$

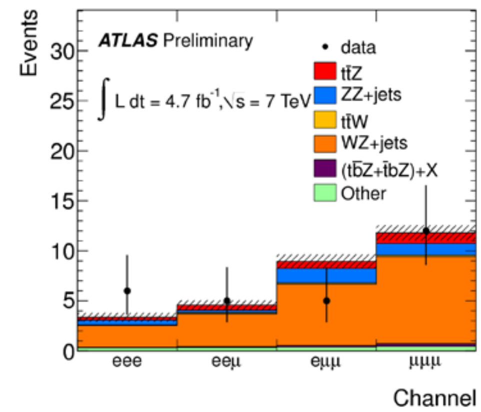
compatible with SM expectation

$$\sigma(t\bar{t}Z) = 0.14 pb \text{ @ NLO}$$

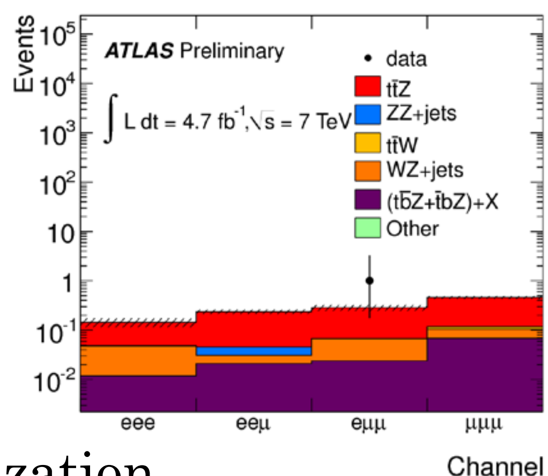
main systematics: background normalization



control region
no ll cut



signal region



N.B. measurement ($1fb^{-1}$) $t\bar{t}\gamma$ production compatible with SM

CONCLUSION

- many measurements of top quark properties performed at ATLAS exploiting large sample of top pairs *l*+jets and dilepton final states with low background
  - data-driven estimate of major background
  - full kinematic reconstruction used in many analysis
- results are compatible with SM
- many measurements already dominated by systematics
  - more sophisticated measurements and constraints from data help to improve the precision:
    - for example in the case of m_{top} measurement
  - further improvement in systematics needed for optimal exploitation of the large 2012 data sample

ATLAS top group public results available at:
https://twiki.cern.ch/twiki/bin/view/AtlasPublic/TopPublicResults

Background material

TOP MASS - *L*+JETS

ATLAS-CONF-2013-046

unbinned likelihood fit using template parameterizations as PDFs

observable 1 = m_{top}^{reco}

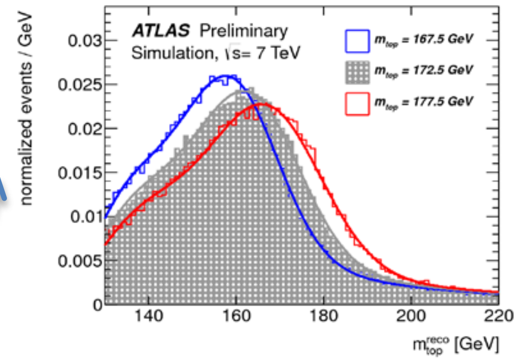
- sensitivity to “input m_{top}” ± 5 GeV

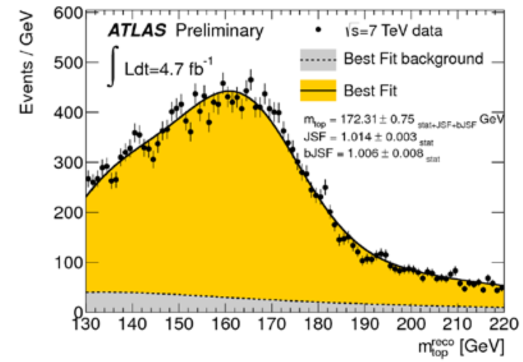
observable 2 = m_W^{reco}

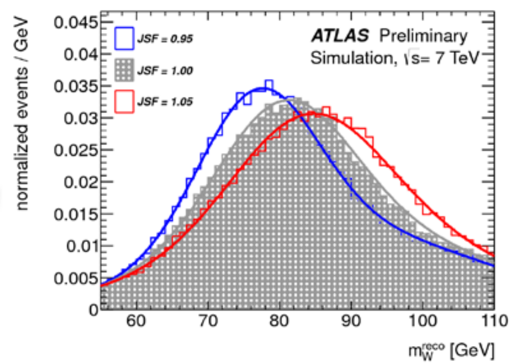
- sensitivity to JSF 0.95-1.05

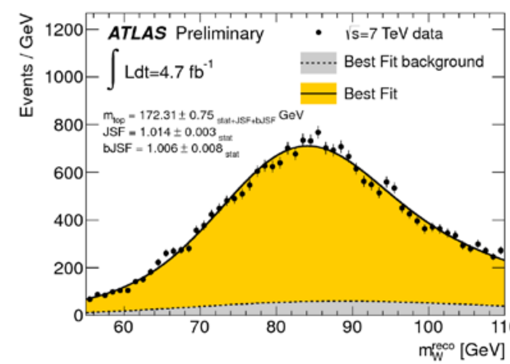
observable 3 = R_{lb}^{reco}

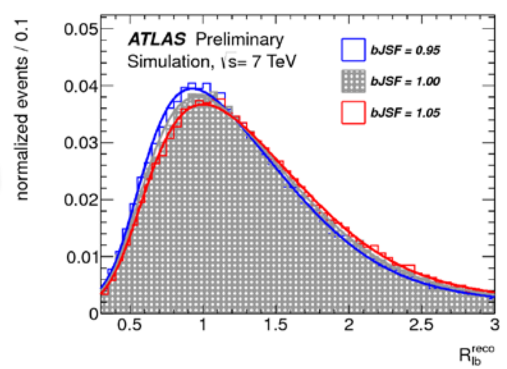
- sensitivity to bJSF 0.95-1.05

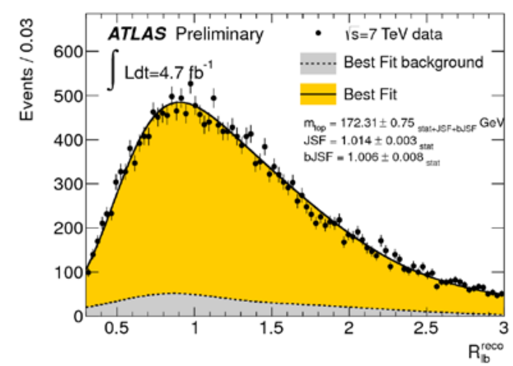












TOP MASS: *L*+JETS

- Systematic errors

	2d-analysis		3d-analysis		
	m_{top} [GeV]	JSF	m_{top} [GeV]	JSF	bJSF
Measured value	172.80	1.014	172.31	1.014	1.006
Data statistics	0.23	0.003	0.23	0.003	0.008
Jet energy scale factor (stat. comp.)	0.27	n/a	0.27	n/a	n/a
bJet energy scale factor (stat. comp.)	n/a	n/a	0.67	n/a	n/a
Method calibration	0.13	0.002	0.13	0.002	0.003
Signal MC generator	0.36	0.005	0.19	0.005	0.002
Hadronisation	1.30	0.008	0.27	0.008	0.013
Underlying event	0.02	0.001	0.12	0.001	0.002
Colour reconnection	0.03	0.001	0.32	0.001	0.004
ISR and FSR (signal only)	0.96	0.017	0.45	0.017	0.006
Proton PDF	0.09	0.000	0.17	0.000	0.001
single top normalisation	0.00	0.000	0.00	0.000	0.000
W+jets background	0.02	0.000	0.03	0.000	0.000
QCD multijet background	0.04	0.000	0.10	0.000	0.001
Jet energy scale	0.60	0.005	0.79	0.004	0.007
b-jet energy scale	0.92	0.000	0.08	0.000	0.002
Jet energy resolution	0.22	0.006	0.22	0.006	0.000
Jet reconstruction efficiency	0.03	0.000	0.05	0.000	0.000
b-tagging efficiency and mistag rate	0.17	0.001	0.81	0.001	0.011
Lepton energy scale	0.03	0.000	0.04	0.000	0.000
Missing transverse momentum	0.01	0.000	0.03	0.000	0.000
Pile-up	0.03	0.000	0.03	0.000	0.001
Total systematic uncertainty	2.02	0.021	1.35	0.021	0.020
Total uncertainty	2.05	0.021	1.55	0.021	0.022

TOP MASS: DILEPTON

- Systematic errors

Description	Value [GeV]
Measured value	173.09
Statistical uncertainty	0.64
Method calibration	0.07
Signal MC generator	0.20
Hadronisation	0.44
Underlying event	0.42
Colour reconnection	0.29
ISR/FSR	0.37
Proton PDF	0.12
Background	0.14
Jet energy scale	0.89
b-jet energy scale	0.71
b-tagging efficiency and mistag rate	0.46
Jet energy resolution	0.21
Missing transverse momentum	0.05
Pile-up	0.01
Electron uncertainties	0.11
Muon uncertainties	0.05
Total systematic uncertainty	1.50
Total uncertainty	1.63

TOP MASS: COMBINATION ATLAS-CMS 2011

- systematic errors

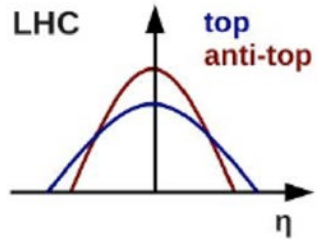
Uncertainty Categories			ATLAS / CMS	
Tevatron	ATLAS	CMS	2011 l+jets	2011 l+jets
Measured m_{top}			172.31	173.49
	Jet Scale Factor	Jet Scale Factor	0.27	0.33
	bJet Scale Factor		0.67	
iJES	Sum	Sum	0.72	0.33
bJES	JES_{b-jet}	JES_{b-jet}	0.08	0.61
dJES	$JES_{light-jet}$	$JES_{light-jet}$	0.79	0.28
Lepton p_T Scale			0.04	0.02
MC	MC Generator	MC Generator	0.19	
	Hadronisation		0.27	
	Sum	Sum	0.33	
Rad	ISR/FSR	ISR/FSR	0.45	
		Q-Scale		0.24
		Jet-Parton Scale		0.18
	Sum	Sum	0.45	0.30
CR	Colour Recon.		0.32	0.54
PDF	Proton PDF	Proton PDF	0.17	0.07
	Jet Energy Res.	Jet Energy Res.	0.22	0.23
	Jet Rec. Eff.		0.05	
	b-tagging	b-tagging	0.81	0.12
	E_T^{miss}	E_T^{miss}	0.03	0.06
DetMod	Sum	Sum	0.84	0.27
Underlying Event			0.12	0.15
BGMC				0.13
BGData			0.10	
Method	Method Calib.	Method Calib.	0.13	0.06
MHI	Pile-up	Pile-up	0.03	0.07
		Statistics	0.23	0.27
		Rest	1.53	1.03
		Total Uncertainty	1.55	1.07

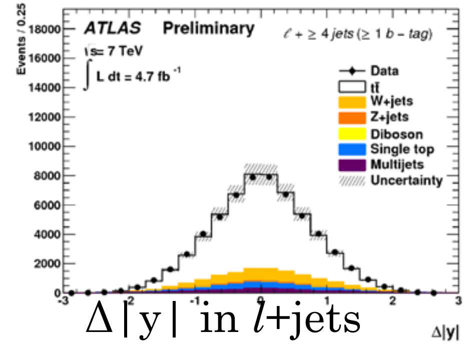
Charge Asymmetry

ATLAS-CONF-2013-078

- $qg / q\bar{q}$ production of $t\bar{t}$

  t emitted in direction of q and $\bar{t}$ of $\bar{q}$
- gg symmetric, $q\bar{q}$ asymmetric at NLO





$$A_c = \frac{N(\Delta|y|>0) - N(\Delta|y|<0)}{N(\Delta|y|>0) - N(\Delta|y|<0)}$$

$t\bar{t}$ asymmetry: $\Delta|y| = |y_t| - |y_{\bar{t}}|$

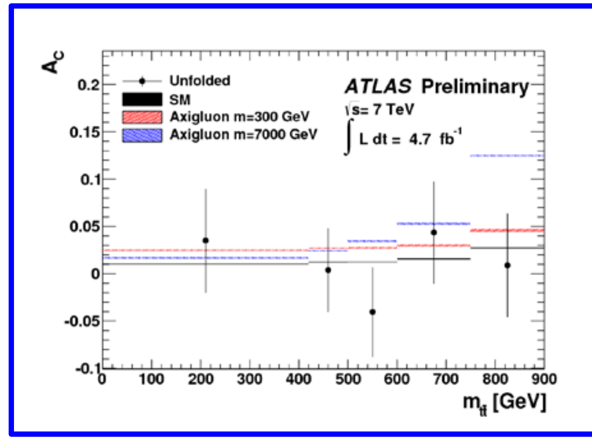
(lepton asymmetry: $\Delta|y| = |y_{l^+}| - |y_{l^-}|$)

- ***l*+jets events:** measure top quark based asymmetry with full bayesian unfolding of detector effects

Inclusive result $A_c^{t\bar{t}} = 0.006 \pm 0.010(stat + syst)$

SM $A_c^{t\bar{t}} = 0.0123 \pm 0.0005$

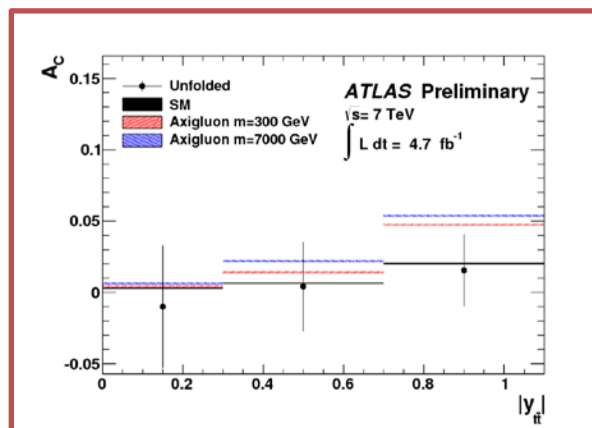
Differential measurement: $m(t\bar{t}), p_T(t\bar{t}), y(t\bar{t})$



BSM sensitive measurement

z-component of $t\bar{t}$ velocity β_z

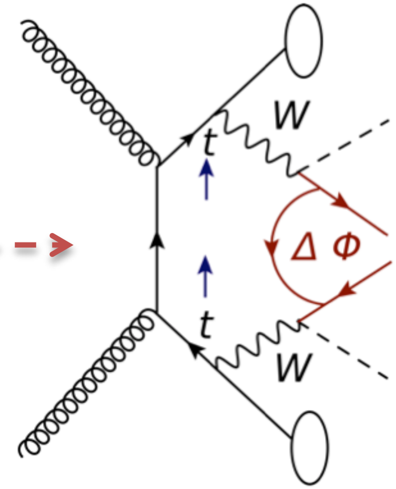
measure asymmetry for $\beta_z > 0.6$



SPIN CORRELATIONS

arXiv.1203.4081

- top quark decays before hadronizing; spin of the top quark at production is transferred to its decay products: azimuthal angle between leptons in dilepton events



- **SM**: at low $m_{t\bar{t}}$ fusion of like-helicity gluons → top quarks in L-L or R-R helicity configuration

  BSM: exchange of a virtual heavy scalar Higgs boson → different spin correlation

- f_{SM} = fraction of events with SM-like spin correlation extracted from binned template fit of Δφ distribution to samples with ≠ fractions

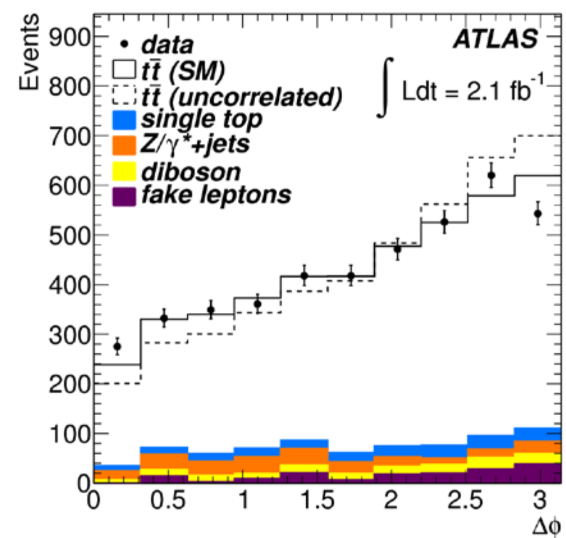
$$f_{SM} = 1.30 \pm 0.14(stat)^{+0.27}_{-0.22}(syst)$$

- degree of correlation:

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

helicity base $A = 0.40 \pm 0.04(stat)^{+0.08}_{-0.07}(syst)$

maximal base $A = 0.57 \pm 0.06(stat)^{+0.12}_{-0.10}(syst)$



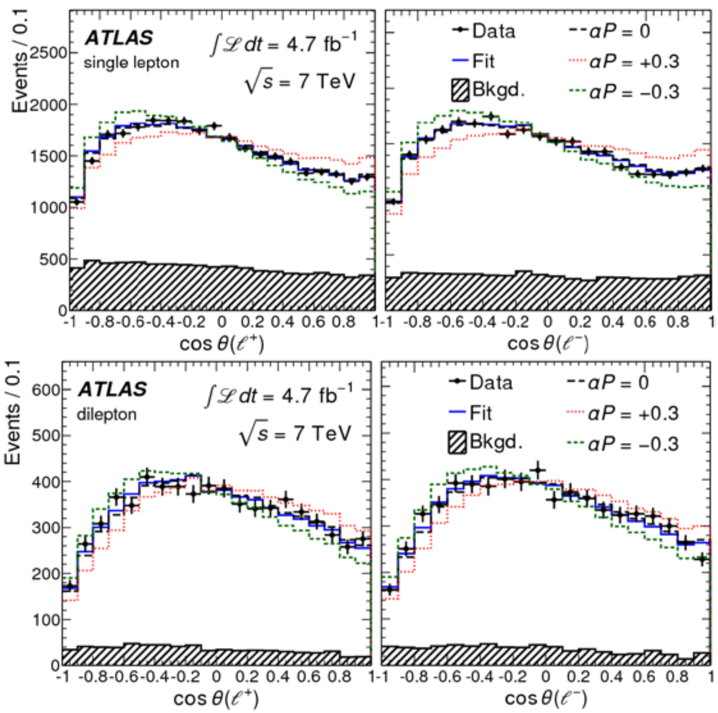
main systematics JES, fake lepton

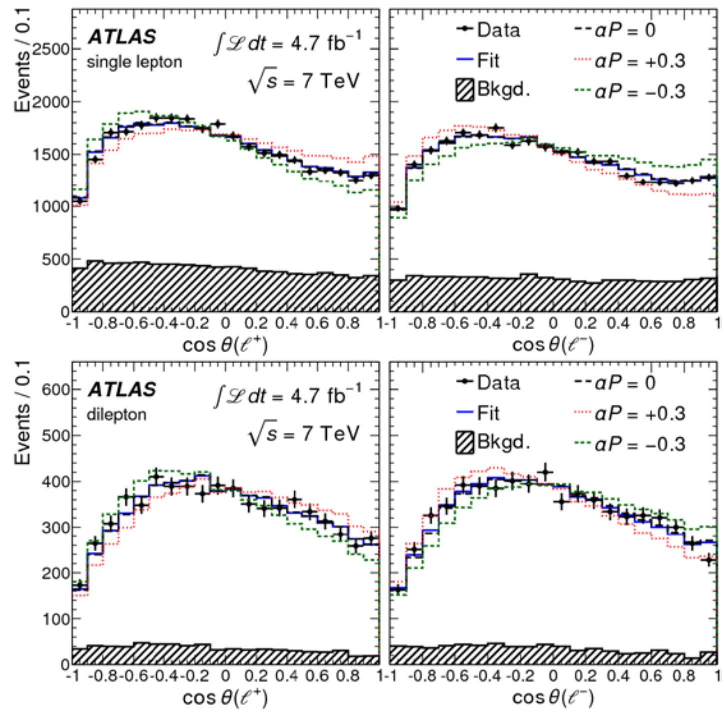
exclude no-correlation hypothesis with 5.1 significance

TOP POLARIZATION

arXiv:1307.6511

l+jets CP Conserving   dilepton CP Violating





$$\alpha_l P_{CPC} = -0.035 \pm 0.014(stat) \pm 0.037(syst)$$

$$\alpha_l P_{CPV} = 0.020 \pm 0.016(stat)^{+0.013}_{-0.017}(syst)$$

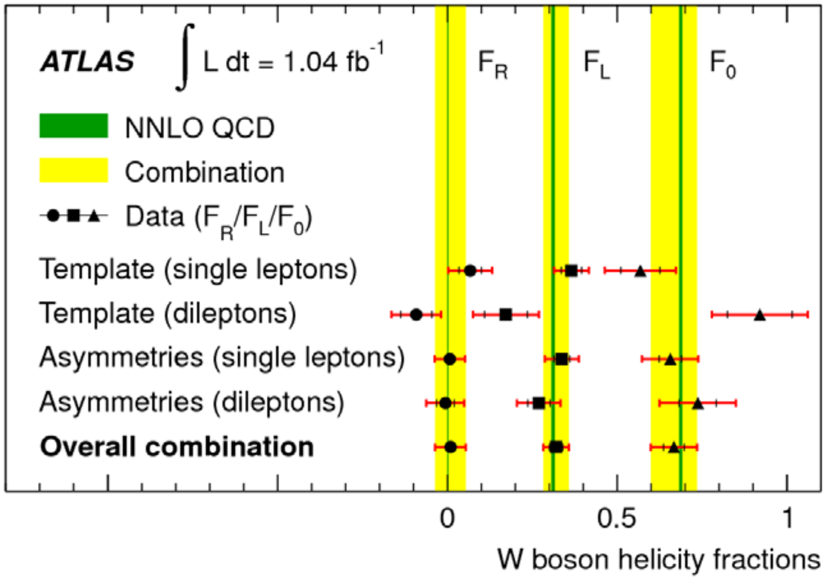
data compatible with unpolarized top quarks

main systematics: jet reconstruction and top pair modelling

W polarization

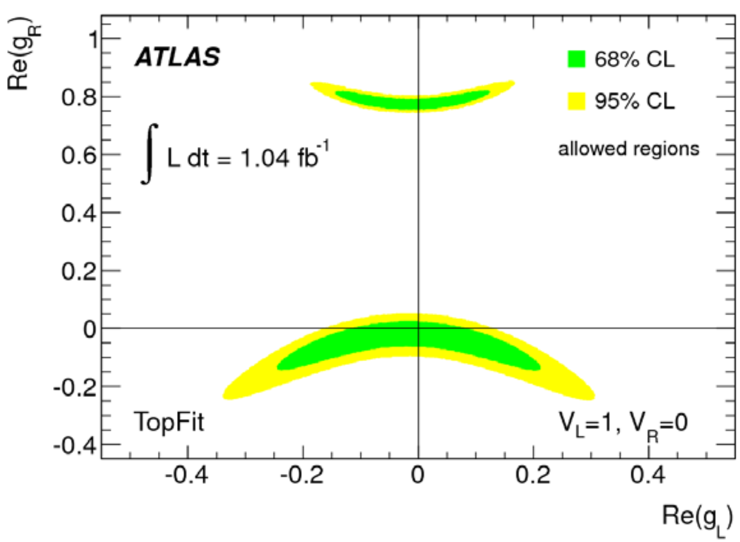
arXiv: 1205.2484

- results of the 4 measurements combined with BLUE
- mostly dominated by systematic uncertainties: signal and background modelling, JES and jet reconstruction
- agreement with NNLO QCD more precise than CDF, D0



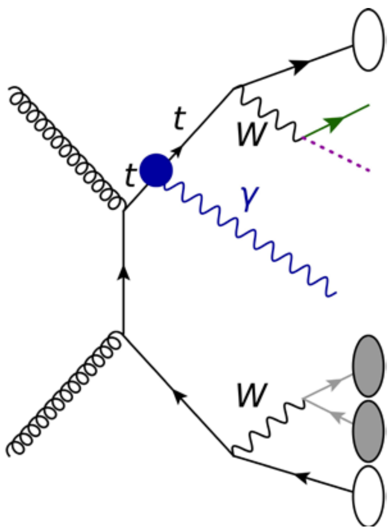
- results interpreted in terms of new physics introducing anomalous couplings in the effective lagrangian: V_R, g_L, g_R

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



- consistent with (V-A) structure

$t\bar{t}\gamma$ production



- l+jets, dilepton final states + 1 high pt Υ
- signal region 52(70) events in e(μ) channel

includes contributions from prompt & fake Υ

template fit to Υ track isolation variable

$p_T^{cone20} = \Sigma p_T(\text{track})$ for dR (Υ,track)<0.20

- result: σ.Br(l+jets+dilepton) for $p_T(\gamma)$>8 GeV

$$\sigma(t\bar{t}\gamma) = 2.0 \pm 0.5(stat) \pm 0.7(syst) \pm 0.08(lumi)\ \ pb$$

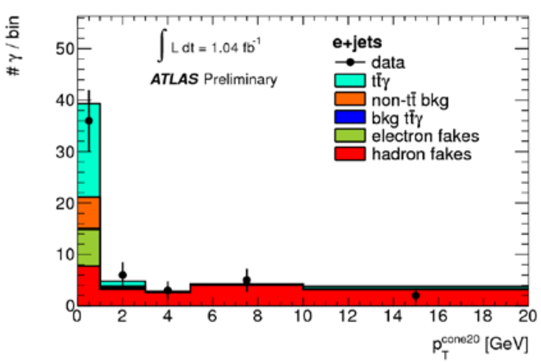
compatible with SM

$$\sigma(t\bar{t}\gamma) = 2.1 \pm 0.4\ \ pb$$

main systematics:

JES,modelling, pile-up

signal region (e)



isolation template