

Measurement of the top quark charge asymmetry with the ATLAS detector

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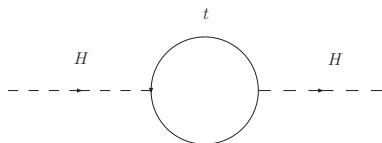
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Introduction

The top quark is the heaviest known elementary particle, with a mass of 173.2 GeV.

Its $\mathcal{O}(1)$ Yukawa coupling y_t means that the top plays an important role in EW symmetry breaking.

Loop diagram



also implies relevance to the hierarchy problem (why is $m_H \ll m_{GUT} \sim 10^{16}$ GeV): correction to m_H of order $|y_t|^2 \Lambda_{\text{cutoff}}^2$.

Most new physics models which attempt to solve the hierarchy problem have a partner of the top quark which is expected to be light (e.g. the stop in supersymmetry).

More top quark properties

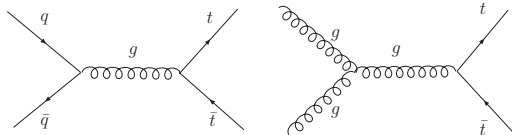
Top has a width of $\Gamma_t \sim 1.5$ GeV, compared to the QCD scale of $\Lambda_{QCD} \sim 1$ GeV \rightarrow the top decays before QCD effects set in - closest one can get to a **bare quark**.

CKM matrix elements: $|V_{td}|, |V_{ts}| \approx 10^{-3}$ and $|V_{tb}| \approx 1$, and therefore the top almost always decays as $t \rightarrow Wb$.

Very rich physics:

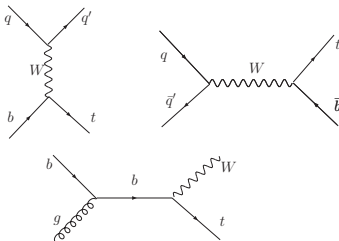
- deviations of $t\bar{t}$ cross-section from SM prediction could indicate BSM production modes.
- spin correlations preserved (QCD has no time to flip spins) by the decay products.
- can **directly** measure V_{tb} by measuring the top production rate.
- precision measurements of top mass very important for EW global fits.
- plenty more, including **charge asymmetry** which we focus on today.

Top production at the LHC



Dominant production modes are $gg \rightarrow t\bar{t}$ ($\sim 80\%$) and $q\bar{q} \rightarrow t\bar{t}$ ($\sim 20\%$) with a small $qg \rightarrow t\bar{t}$ component at NLO. These are all **top pair** production modes.

Also **single top** production:
EW cross-sections,
considerably smaller than $t\bar{t}$.



Top charge asymmetry: introduction

The top/antitop differential distributions in $t\bar{t}$ events are predicted to be **different** in perturbative QCD (Kühn, Rodrigo: hep-ph/9807420, hep-ph/9802268).

This is an NLO (therefore small!) effect; only $q\bar{q} \rightarrow t\bar{t}$ and $qg \rightarrow t\bar{t}q$ events exhibit an asymmetry. Due to **interference** of amplitudes with relative sign under the exchange of t and \bar{t} .

Manifests as a forward-backward asymmetry A_{FB} at Tevatron, where initial state quark direction is known.

$$A_{FB} = \frac{N(\Delta Y > 0) - N(\Delta Y < 0)}{N(\Delta Y > 0) + N(\Delta Y < 0)},$$

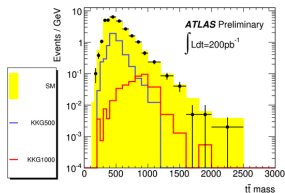
with $\Delta Y = Y_t - Y_{\bar{t}}$, and $Y_{t,\bar{t}}$ are top/antitop rapidities.

Both D0 and CDF observe discrepancies from SM prediction, in particular for large $m_{t\bar{t}}$.

3.4σ at CDF ([arXiv:1101.0034](https://arxiv.org/abs/1101.0034)): $A_{FB} = 0.475 \pm 0.114$ compared to QCD prediction of 0.088.

An indication of BSM physics?

Not straightforward to come up with models to explain this: resonances usually don't do the job, since they would have shown up in differential cross section measurements.



(plot from ATLAS-CONF-2011-087)

Alternative proposals (mostly phenomenological):

- new particles being exchanged in t -channel, e.g. axigluons. The axial couplings generate the required asymmetry. Evade $d\sigma/dm_{t\bar{t}}$ limits by considering broad resonances. Differential cross-sections look like:

$$\frac{d\sigma(q\bar{q} \rightarrow t\bar{t})}{dm_{t\bar{t}}} = \alpha_s^2 \frac{\pi}{\hat{s}} (A + Bc + Cc^2) \quad (1)$$

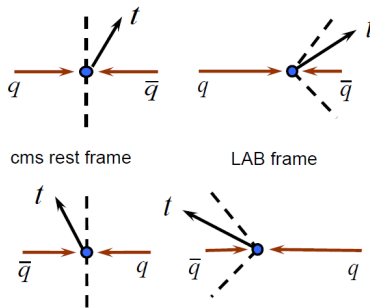
where $c = \cos \theta$ and θ the angle between q and t in the centre of mass frame. The Bc term is responsible for the charge asymmetry.

BSM models for explaining the Tevatron measurements

- t - and u - channel exchanges. E.g. non-universally coupled Z' or W' bosons. These tend to be constrained by searches for same sign top quarks (e.g. if $(w\bar{u} \rightarrow t\bar{t})$ by Z' exchange in t -channel, $uu \rightarrow tt$ also allowed), but some regions of parameter space still survive.
- plenty of others - top partners in modified SUSY models etc. Possibilities have been classified in an effective theory approach.

Charge asymmetry at LHC

At the LHC, the asymmetry is diluted (mostly $gg \rightarrow t\bar{t}$), and $A_{FB} = 0$. Charge asymmetry \leftrightarrow tops preferentially emitted in quark direction. Since quarks generally carry a larger momentum fraction of the proton than antiquarks, tops tend to be **more forward** than antitops in the lab frame:



Consider instead the observable:

$$A_C = \frac{N(\Delta|Y| > 0) - N(\Delta|Y| < 0)}{N(\Delta|Y| > 0) + N(\Delta|Y| < 0)}, \quad (2)$$

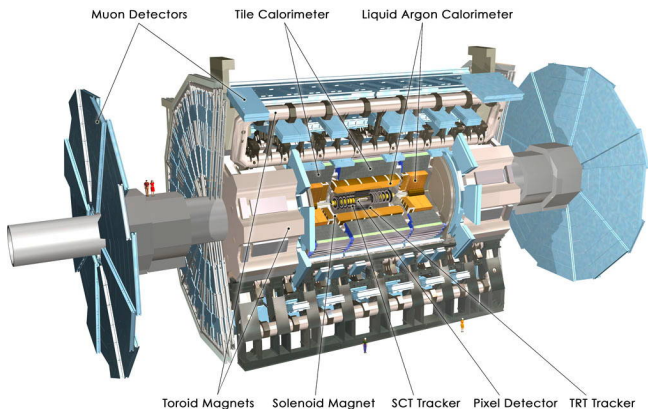
with $\Delta|Y| = |Y_t| - |Y_{\bar{t}}|$. MC@NLO prediction is 0.006.

Overview of ATLAS

One of two general purpose detectors at the LHC.

Calorimeters for energy measurements of e/γ and jets; tracking system immersed in magnetic field for precision measurement of momenta.

Separate muon system in toroidal magnetic field.



Components and their coverage

Coordinate system: θ angle from the beam axis, ϕ azimuthal angle in x, y plane transverse to beam axis. Pseudorapidity defined as $\eta = -\ln(\tan \theta/2)$; 5° translates into $\eta = 3.13$ while 45° corresponds to $\eta = 0.88$.

Detector Component	η coverage
Tracking	$ \eta < 2.5$
EM calorimetry	$ \eta < 3.2$
Hadronic calorimetry	
barrel and end-cap	$ \eta < 3.2$
forward	$3.1 < \eta < 4.9$
Muon spectrometer	$ \eta < 2.7$

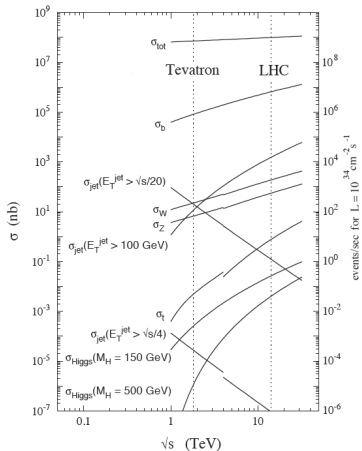
Forward regions of the detectors generally not as finely granulated as the central ones (so larger uncertainties); also, tracking only extends up to $|\eta| < 2.5$. Consequently, at present requiring $|\eta| < 2.5$ on all objects.

What does ATLAS measure?

ATLAS reconstructs the following objects emerging from collisions:

- jets (tracks + energy deposits which result from quark fragmentation and hadronisation)
- leptons - usually by this one means only e, μ , since τ either decays hadronically (giving a 'tau-jet') or $\tau \rightarrow l\nu_l\nu_\tau$ which is indistinguishable from e or μ .
- photons - similar to e , but no tracks associated
- missing transverse energy - essentially reconstructed as $\cancel{E}_T = -\sum E_T$ of all visible objects. Can be **real** (if there were neutrinos or BSM invisible particles in the event) or **fake** (a result of mismeasurements).
- B -hadrons have lifetimes measured in picoseconds \implies can travel millimeters before decaying - **secondary vertices** may be seen inside jets, thanks to the very precise tracking system. These are then tagged as b-jets.

Cross-sections and triggering



Cross-sections for ‘interesting’ processes very small compared to total cross-section at LHC. Use 3-level **triggering system** to pick out the interesting ones:

- L1: hardware based, reduces rate to (at most) 75kHz
- L2: reduce further to 3kHz
- Event Filter (EF): 200Hz final output rate.

Trigger on muons, electrons, photons, taus, jets, b-jets, \cancel{E}_T and event level quantities (e.g. total E_T).

ATLAS top physics results

- cross-section, in various channels. Most precise result thus far: $\sigma_{t\bar{t}} = 179 \pm 11.8$ pb, in agreement with approximate NNLO SM computation. Errors already comparable to PDF+scale uncertainties on theoretical prediction!
- top mass: $175.9 \pm 0.9(\text{stat.}) \pm 2.7(\text{syst.})$ GeV - Tevatron combined result has a 0.9GeV total uncertainty.
- t -channel single top quark cross section
- searches for FCNC processes $t \rightarrow q\gamma, t \rightarrow qZ, t \rightarrow qg$ (various models predict increased increased BRs for these)
- $t\bar{t}$ spin correlations
- searches for $t\bar{t}$ resonances
- searches for tt production
- ...many others - listed [here](#)
- [top charge asymmetry](#) ([ATLAS-CONF-2011-106](#))

$t\bar{t}$ channel classification

Almost always have $t\bar{t} \rightarrow WWb\bar{b}$. The W branching ratios are $BR(W \rightarrow l\nu) \approx 11\%$ with $l = e, \mu, \tau$ and $BR(W \rightarrow q\bar{q}') \approx 68\%$.

Threefold classification of $t\bar{t}$ decays:

- **all-hadronic**: $t\bar{t} \rightarrow q_1\bar{q}'_2 q_3\bar{q}'_4 b\bar{b}$. $BR \sim 4/9$. 6 jets in final state!
Difficult to trigger on, large background from multijet QCD, very hard to reconstruct the top quarks.
- **single lepton**: $t\bar{t} \rightarrow q_1\bar{q}'_2 l\nu b\bar{b}$. $BR \sim 4/9$. 4 jets in final state; can trigger on the lepton (τ much more tricky than e, μ however), hadronically decaying top easily reconstructed. e +jets and μ +jets channels.
- **dilepton**: $t\bar{t} \rightarrow l_1\nu_1 l_2\nu_2 b\bar{b}$. $BR \sim 1/9$. 2 jets in final state; two leptons to trigger on, however two neutrinos escaping the detector \implies reconstruction difficult.

Charge asymmetry: outline of measurement

The approach is as follows:

- Need to reconstruct the top and antitop - use the **single lepton** channel.
- Use an event selection to pick $t\bar{t}$ candidates.
- Dominant backgrounds:
 - ① $W \rightarrow l\nu + \text{jets}$
 - ② single top
 - ③ $Z \rightarrow ll + \text{jets}$ with one lepton outside detector coverage or unidentified
 - ④ multijet QCD (usually just 'QCD') with leptons coming from heavy hadron decays ($BR(B \rightarrow l\nu X) \approx 20\%$ or 'fake' leptons, e.g. $\pi^0\pi^+$ with $\pi^0 \rightarrow \gamma\gamma$).
 - ⑤ diboson: WW, WZ, ZZ .
- Once t, \bar{t} candidates are reconstructed, can plot $\Delta|Y| \equiv |Y_t| - |Y_{\bar{t}}|$.
- Backgrounds must then be subtracted to obtain the distribution for $t\bar{t}$ events only.
- Finally, A_C may be computed (caveat: **unfolding**).

Samples used

Data collected in 2011 with an integrated luminosity of 0.70fb^{-1} was used. $t\bar{t}$ signal simulated using MC@NLO; Herwig used for modelling hadron showers.

W/Z +jets simulated with Alpgen + Herwig. Alpgen can do up to $W+5$ partons to LO, important since we are dealing with large jet multiplicities. single top from MC@NLO.

Diboson ($WW/ZZ/WZ$) with Herwig.

Typically, multiple $p-p$ interactions in one bunch crossing ('pile-up') - can get e.g. extra energy deposits in detector in this way. The extra interactions are simulated and the MC simulation reweighted to match the average number of interactions per bunch crossing.

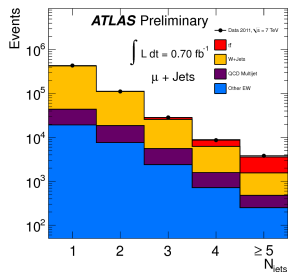
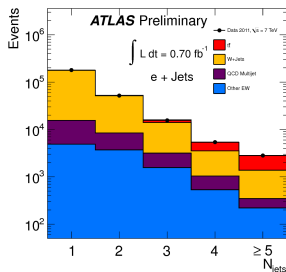
Event Selection

- appropriate electron and muon triggers
- one **isolated** lepton required ($p_T > 25$ GeV for e , $p_T > 20$ GeV for μ)
- $\cancel{E}_T > 20$ GeV and $\cancel{E}_T + m_T(W) > 60$ GeV (μ channel) (to remove QCD background) (removes a lot of the QCD and Z +jets background)
- $\cancel{E}_T > 35$ GeV and $m_T(W) > 25$ GeV (e channel)
- ≥ 4 jets with $p_T > 25$ GeV ($t\bar{t}$ should have 4 hard jets in the single lepton channel)
- at least one b -tagged jet ($t\bar{t}$ should always have two!)

b -tagging such that 50% of 'true' b -jets tagged as such; around 10% and 1% of c - and l -jets also b -tagged. Decay length significance $L/\sigma(L)$ used as the discriminant, with L the distance from the primary vertex to the secondary vertex.

Single lepton channel

Jet multiplicities in single lepton channel (from ATLAS-CONF-2011-121):



Background estimation

Rely on **data driven** methods as much as possible (rather than Monte Carlo).

This is particularly important for W +jets and QCD.

W + ≥ 4 jets hard to model - we only have LO simulation of this background; overall normalisation particularly difficult to compute on the theoretical level (8% uncertainty only from α_s).

multijet QCD: huge cross sections and tiny efficiencies: the probability of an isolated energetic lepton arising from a jet very small. Would need very large MC samples to estimate this background correctly.

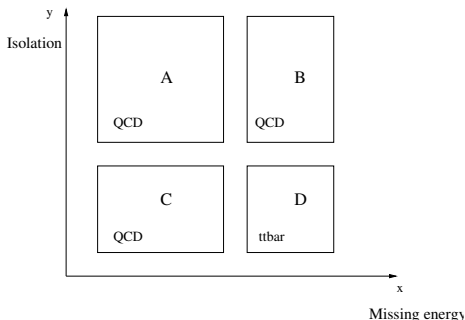
Also, do not trust MC with modelling fake lepton rates.

⇒ use **data-driven** methods for estimating these two important backgrounds.

Background estimation: multijet QCD

QCD estimated using the so-called Matrix Method technique, for both channels.

Take two uncorrelated variables which discriminate between QCD and $t\bar{t}$ - e.g., lepton isolation (i.e. energy in cone around lepton) and \cancel{E}_T .



Estimate the number of QCD events in signal region D as $N_D = \frac{N_C}{N_A} \times N_B$.

In reality, things somewhat more subtle:

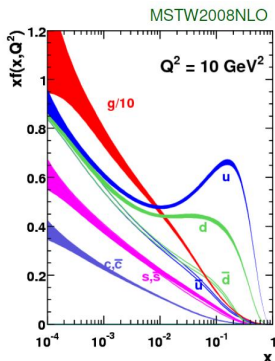
- there is signal (and non-QCD background) contamination in A, B and C. Need to subtract those off - use MC estimates for that purpose.
- Need not just the total number of events, but [distributions](#).

Background estimation: W^+ jets

W^+ jets normalisation determined using the fact that there are more W^+ produced at a pp collider than W^- , and that the ratio is theoretically known very precisely (Kom, Stirling: arXiv:1004.3404).

Schematically, $\sigma(W^+)$ depends on $u(x)\bar{d}(x)$, and $\sigma(W^-)$ on $d(x)\bar{u}(x)$. The ratio of production cross sections depends on $u(x)/d(x)$.

The idea is that all other backgrounds, as well as $t\bar{t}$ signal, give equal numbers of events with $+$ and $-$ leptons (in the single lepton channel). Things different for different x , i.e. selection cuts and centre of mass energies (works better at 7TeV than 14TeV).



Background estimation: W +jets

Done in two steps:

- First the number W_{pretag} of W +jets events before the b-tagging requirement is determined using the equation

$$N_{W^+} + N_{W^-} = \left(\frac{r_{MC} + 1}{r_{MC} - 1} \right) (D^+ - D^-),$$

D^+ , (D^-) are numbers of events in data with positively (negatively) charged leptons, and $r_{MC} \equiv \frac{\sigma(pp \rightarrow W^+)}{\sigma(pp \rightarrow W^-)}$. $r_{MC} = 1.56 \pm 0.07$ (e channel), 1.66 ± 0.06 (μ channel)

- Now estimate the number of tagged W +jet events:

$$W_{\text{tagged}} = W_{\text{pretag}} \cdot f_{4,\text{tagged}}$$

Here $f_{4,\text{tagged}}$ is the 4-jet tag fraction from MC.

Heavy flavour fractions

Since we are using a b-tagging requirement in the selection, the W +jets background dominated by 'heavy flavour' components, $W + bb$ +jets, $W + cc$ +jets, $W + c$ +jets. These processes modelled separately in MC (massive quarks!) and their individual normalisations not well known.

Tevatron previously observed large discrepancies for W +HF cross-section from SM prediction.

Heavy flavour scale factors derived from auxiliary measurements in 1- and 2-jet bins: relate number of events before tagging to number of tagged events, using tagging probabilities for each type of flavour as derived from simulation.

Obtain 1.63 ± 0.76 for $Wb\bar{b}$ +jet and $Wc\bar{c}$ +jet events and 1.11 ± 0.35 for Wc +jets.

These are applied everywhere and their uncertainties propagated to the measurement.

Large effect on $f_{4,\text{tagged}}$.

Other backgrounds (single top, Z +jets, $WW/WZ/ZZ$) taken from MC.

Data/MC event yields

Channel	μ + jets pretag	μ + jets tagged	e + jets pretag	e + jets tagged
$t\bar{t}$	4784 \pm 5	3247 \pm 4	3293 \pm 4	2218 \pm 4
Single top	306 \pm 2	171 \pm 2	219 \pm 2	124 \pm 2
Z+jets	632 \pm 7	43 \pm 2	535 \pm 7	35 \pm 1
Diboson	90 \pm 2	8 \pm 1	56 \pm 1	5 \pm 0
W+jets	5741 \pm 915	494 \pm 234	3436 \pm 628	309 \pm 144
QCD	1103 \pm 552	227 \pm 227	665 \pm 332	84 \pm 84
Total background	7871 \pm 1068	943 \pm 326	4910 \pm 711	557 \pm 167
Signal + background	12655 \pm 1068	4189 \pm 326	8203 \pm 711	2775 \pm 167
Observed	12705	4392	8193	2997

More events in μ channel due to harder \cancel{E}_T cuts in e channel, necessary because of higher QCD levels.

Uncertainties on signal/background from limited sizes of MC samples only - systematics not included (except W +jets and QCD).

Good agreement between data and MC is observed.

Use kinematic likelihood fitter, based on the following likelihood:

$$\begin{aligned}
 \mathcal{L} = & \mathcal{B}(\tilde{E}_{p,1}, \tilde{E}_{p,2} | m_W, \Gamma_W) \cdot \mathcal{B}(\tilde{E}_{lep}, \tilde{E}_\nu | m_W, \Gamma_W) \cdot \\
 & \mathcal{B}(\tilde{E}_{p,1}, \tilde{E}_{p,2}, \tilde{E}_{p,3} | m_t, \Gamma_t) \cdot \mathcal{B}(\tilde{E}_{lep}, \tilde{E}_\nu, \tilde{E}_{p,4} | m_t, \Gamma_t) \cdot \\
 & \mathcal{W}(\tilde{E}_x^{miss} | \hat{p}_{x,\nu}) \cdot \mathcal{W}(\tilde{E}_y^{miss} | \hat{p}_{y,\nu}) \cdot \mathcal{W}(\tilde{E}_{lep} | \hat{E}_{lep}) \cdot \\
 & \prod_{i=1}^4 \mathcal{W}(\tilde{E}_{p,i} | \hat{E}_{jet,i}) \cdot \prod_{i=1}^4 \mathcal{W}(\tilde{\eta}_{p,i} | \hat{\eta}_{jet,i}) \cdot \prod_{i=1}^4 \mathcal{W}(\tilde{\phi}_{p,i} | \hat{\phi}_{jet,i}) \cdot \prod_{i=1}^4 P(\text{tagged} | \text{parton flavour}) \quad (3)
 \end{aligned}$$

\tilde{X} are partonic quantities; \hat{X} corresponding reconstructed values.

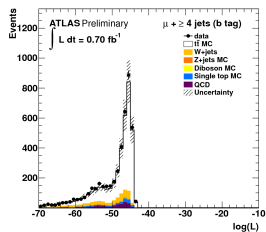
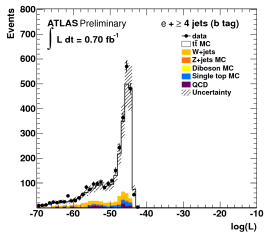
\mathcal{B} represent Breit-Wigner functions.

Transfer functions $\mathcal{W} \equiv$ probability of observing a jet with $\hat{\eta}_{jet,i}$ from a parton with $\tilde{\eta}_{p,i}$ derived from MC.

Using up to 5 leading jets in p_T in the fit; b -tagging information made use of via $P(\text{tagged} | \text{parton flavour})$ term.

Likelihood maximised wrt the jet energies, the lepton energy or transverse momentum, and the neutrino momentum components over all jet permutations.

$t\bar{t}$ system reconstruction

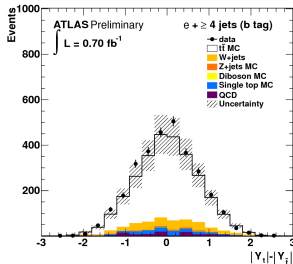
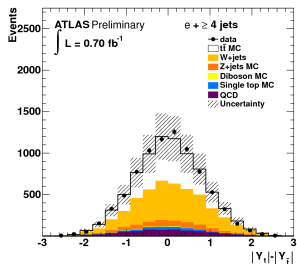


Likelihood for (left) muon and (right) electron channel.

For events in which the jets are matched to partons, the probability of getting the right combination is 62% (74%) for selections with/without b-tagging.

Charge assignment and $|Y_t| - |Y_{\bar{t}}|$

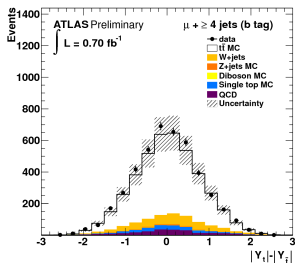
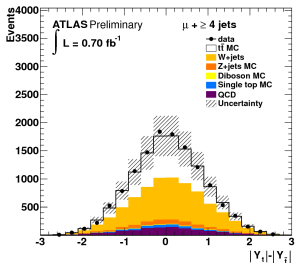
We can tell t from \bar{t} by the charge of the lepton in the leptonically decaying top ($t \rightarrow bW \rightarrow bl\nu$). This allows us to reconstruct the sought distribution, $|Y_t| - |Y_{\bar{t}}|$.



Results from these **cannot** be directly compared to theoretical predictions for A_C :

- 1 distributions smeared and distorted by detector effects
- 2 acceptance: gaps in detector; problematic parts of detector also affect the distribution.

$|Y_t| - |Y_{\bar{t}}|$ in the muon channel



Same distributions, in the muon channel.

Unfolding

Detector and acceptance effects distort the 'true' asymmetry distribution.

In order to compare the results with theoretical computations and other experiments, results need to be [unfolded](#).

$$\mathbf{n} = R\mu + \beta \quad (4)$$

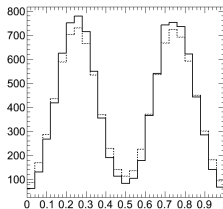
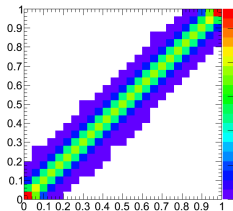
\mathbf{n} is the data, μ the expectation values for the true histogram, and β the background. R is a [response](#) matrix, derived from MC simulation.

Can do $\mu = R^{-1}(\mathbf{n} - \beta)$. However, this problem is susceptible to numerical instability due to fluctuations in \mathbf{n} .

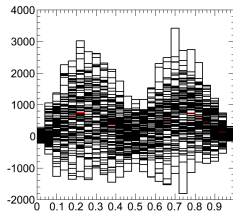
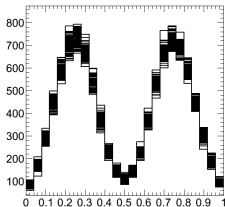
Belongs to a class of so-called 'ill posed' problems - results highly sensitive to changes in data.

Why matrix inversion doesn't work

Take a simple example with a double gaussian and a somewhat off-diagonal response.



Left: response matrix. Right: true and reconstructed distributions.



Left: ensemble of statistical fluctuations of the reconstructed histogram. Right: unfolded results. **Large fluctuations are evident.**

Regularised unfolding

Need to **regularise** to avoid small the large fluctuations in the unfolded result.

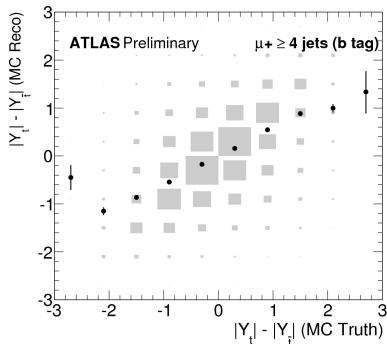
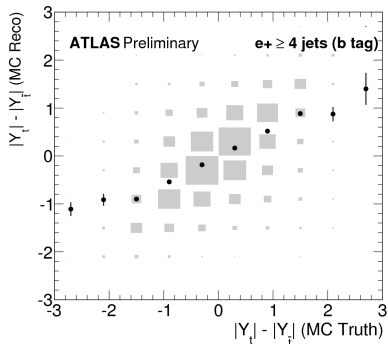
We use an iterative method to do this, based on Bayes' theorem:

$$P(C_i|E_j) = \frac{P(E_j|C_i)P(C_i)}{\sum_l P(E_j|C_l)P(C_l)} \quad (5)$$

Here C_i are 'causes' (the 'truth'), and E_j are effects (the reconstructed distribution). $P(E_j|C_i)$ is just the response matrix, and $P(C_i)$ is a prior distribution for the observable in question.

Iteratively apply formula (5) to obtain an improved guess for $P(C_i)$ at each step.

Unfolding $d|Y|$



Response matrices for the $d|Y|$ distribution. Good correlation and linearity, although considerable off-diagonal elements. Things break down near $|\eta| = 2.5$ as one would expect.

Various sources of systematic uncertainty were considered in the measurement. The first group is detector modelling uncertainties:

- Jet energy scale (JES): uncertainty in measured jet energies, due to energy outside jet cone, dead calorimeter cells, etc. p_T and η dependent, from 2.5% to 8%. Can be measured in e.g. Z +jet events.
- Jet energy resolution: measured from dijet balance, 10%.
- Lepton reconstruction efficiencies: estimate from $Z \rightarrow ll$ events using tag and probe method.
- Lepton energy scale and resolution: from shape of $Z \rightarrow ll$ peak.
- Charge misidentification: sometimes identify $+$ as $-$ leptons and vice versa. E.g. due to 'tridents' $e^+ \rightarrow e^+e^+e^-$, or mismeasured tracks for high p_T .
- b-tagging scale factors: derived to match b-tagging performance in simulation to data.

Signal/background systematics

- Signal modelling: use alternative generator: POWHEG - also NLO.
- Parton shower: compare POWHEG + Herwig and POWHEG + Pythia.
- ISR/FSR: modelling of extra gluon radiation. More radiation \iff more jets. Depends on Monte Carlo parameters - vary these to assess the size of the effect.
- Background normalisation: the important ones are W +jets and QCD - 50% and 100% from data-driven methods.
- Small uncertainties from normalisation of MC driven backgrounds: single top, Z +jets, diboson.
- Parton distribution function (PDF) uncertainty: this is one of the dominant sources of theoretical uncertainty in A_C . Evaluate effect by using alternative PDF sets.
- Top mass: use signal samples with varying top mass.

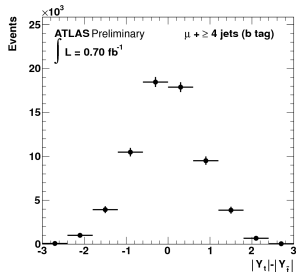
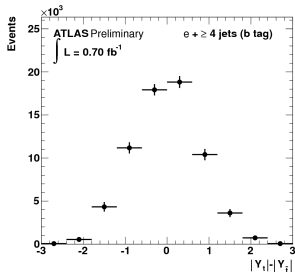
Systematics: summary table

	Electron channel	Muon channel
Source of systematic uncertainty	ΔA_C	
<i>Signal and background modelling</i>		
$t\bar{t}$ generator	0.0243	0.0100
Parton shower/fragmentation	0.0108	0.0079
ISR/FSR	0.0074	0.0074
PDF uncertainty	0.0008	0.0008
Top mass	0.0059	0.0059
QCD normalisation	0.0062	0.0059
W+jets normalisation	0.0054	0.0097
W+jets shape	0.0043	0.0043
Z+jets normalisation	0.0002	0.0002
Z+jets shape	0.0010	0.0010
Single Top normalisation	0.0002	0.0002
Diboson normalisation	0.00001	0.00001
MC sample sizes	0.0043	0.0029
<i>Detector modelling</i>		
Muon efficiencies	(n.a.)	0.0002
Muon momentum scale and resolution	0.0004	0.0004
Electron efficiencies	0.0004	(n.a.)
Electron energy scale and resolution	0.0004	0.0004
Lepton charge misidentification	0.0002	0.0002
Jet energy scale	0.0041	0.0046
Jet energy resolution	0.0105	0.0040
Jet reconstruction efficiency	0.0003	0.0003
b -tagging scale factors	0.0038	0.0038
Charge asymmetry in b -tagging efficiency	0.0007	0.0007
Calorimeter readout	0.0015	0.0029
Combined uncertainty	0.032	0.022

Unfolded results

Asymmetry	detector unfolded	detector and acceptance unfolded
A_C (muon pretag)	-0.020 ± 0.026 (stat.) ± 0.062 (syst.)	-0.016 ± 0.028 (stat.) ± 0.064 (syst.)
A_C (muon b -tag)	-0.030 ± 0.021 (stat.) ± 0.020 (syst.)	-0.028 ± 0.019 (stat.) ± 0.022 (syst.)
A_C (electron pretag)	-0.017 ± 0.031 (stat.) ± 0.067 (syst.)	-0.023 ± 0.034 (stat.) ± 0.065 (syst.)
A_C (electron b -tag)	-0.012 ± 0.026 (stat.) ± 0.030 (syst.)	-0.009 ± 0.023 (stat.) ± 0.032 (syst.)

Table: The measured charge asymmetry values for the electron and muon channels before and after the b -tagging requirement is applied for different levels of unfolding. The quoted uncertainties are statistical and systematic, respectively.



Unfolded $\Delta|Y|$ distributions; uncertainties shown are statistical only.

Channel combination

Combine e and μ channels using the best linear unbiased estimator (BLUE) method.

This takes into account correlations between the two channels.

Essentially obtained by minimising $\text{Var}(y)$ with $y = \sum \alpha_i y_i$ for measurements y_i of a single quantity, over α_i , with $\sum \alpha_i = 1$.

After unfolding, one has:

$$A_C = -0.009 \pm 0.023 \text{ (stat.)} \pm 0.032 \text{ (syst.)} \quad (\text{e+jets channel})$$

$$A_C = -0.028 \pm 0.019 \text{ (stat.)} \pm 0.022 \text{ (syst.)} \quad (\mu\text{+jets channel}).$$

Combining the channels, we get:

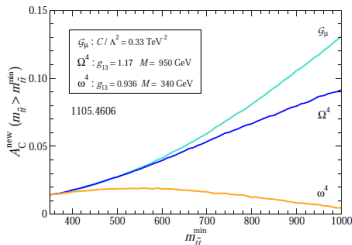
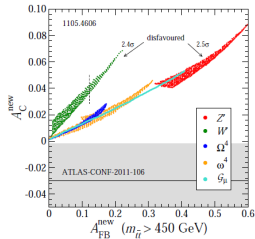
$$A_C = -0.024 \pm 0.016 \text{ (stat.)} \pm 0.023 \text{ (syst.)}.$$

which is compatible with the SM prediction.

Implications for theory

Strong interaction between theory and experiment: theorists already taken into account latest measurements from ATLAS/CMS and assessed their impact on parameter spaces of various models compatible with the observed Tevatron asymmetry.

81 dedicated papers on the topic in 2011! Quite a few models ruled out already by various ATLAS/CMS measurements.



(from talk of J.A. Aguilar Saavedra at Top2011)

Conclusions

Described a measurement of the charge asymmetry with 0.70fb^{-1} of data collected by the ATLAS detector.

Precision measurement of a top quark property.

Systematics are of order $\sim 2 - 3\%$, dominated by signal modelling (POWHEG vs MC@NLO), parton shower and ISR/FSR modelling.

Measured values are compatible with the MC@NLO predictions - no sign yet of any beyond Standard Model physics.

Further improvements expected in near future - plenty more data ($\sim 5\text{fb}^{-1}$ collected in 2011), and some of the systematics may be improved upon.