$t\bar{t}$ Charge Asymmetry in 1.04 fb^{-1} at ATLAS

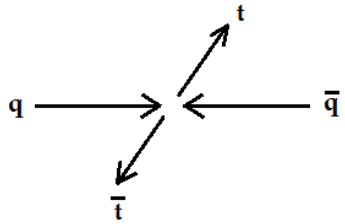
ESHEP

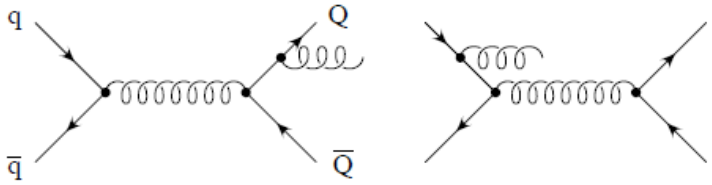
Anjou, France June 2012

Katie Malone, on behalf of Group C

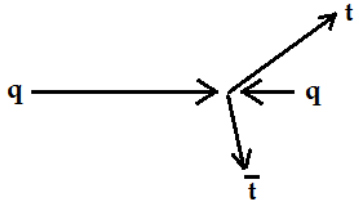
Introduction I

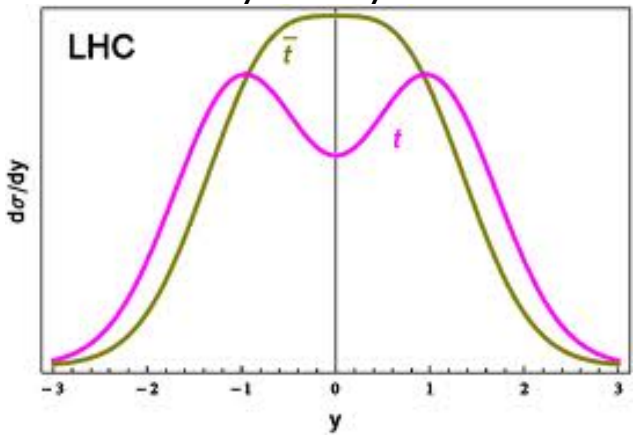
- In qqbar rest frame, top preferentially produced in quark direction
- Tevatron: measured asymmetry as a forward-backward asymmetry





- LHC: symmetric initial/final state, washes out effect
- However, t boosted in direction of valence quark → central-forward asymmetry



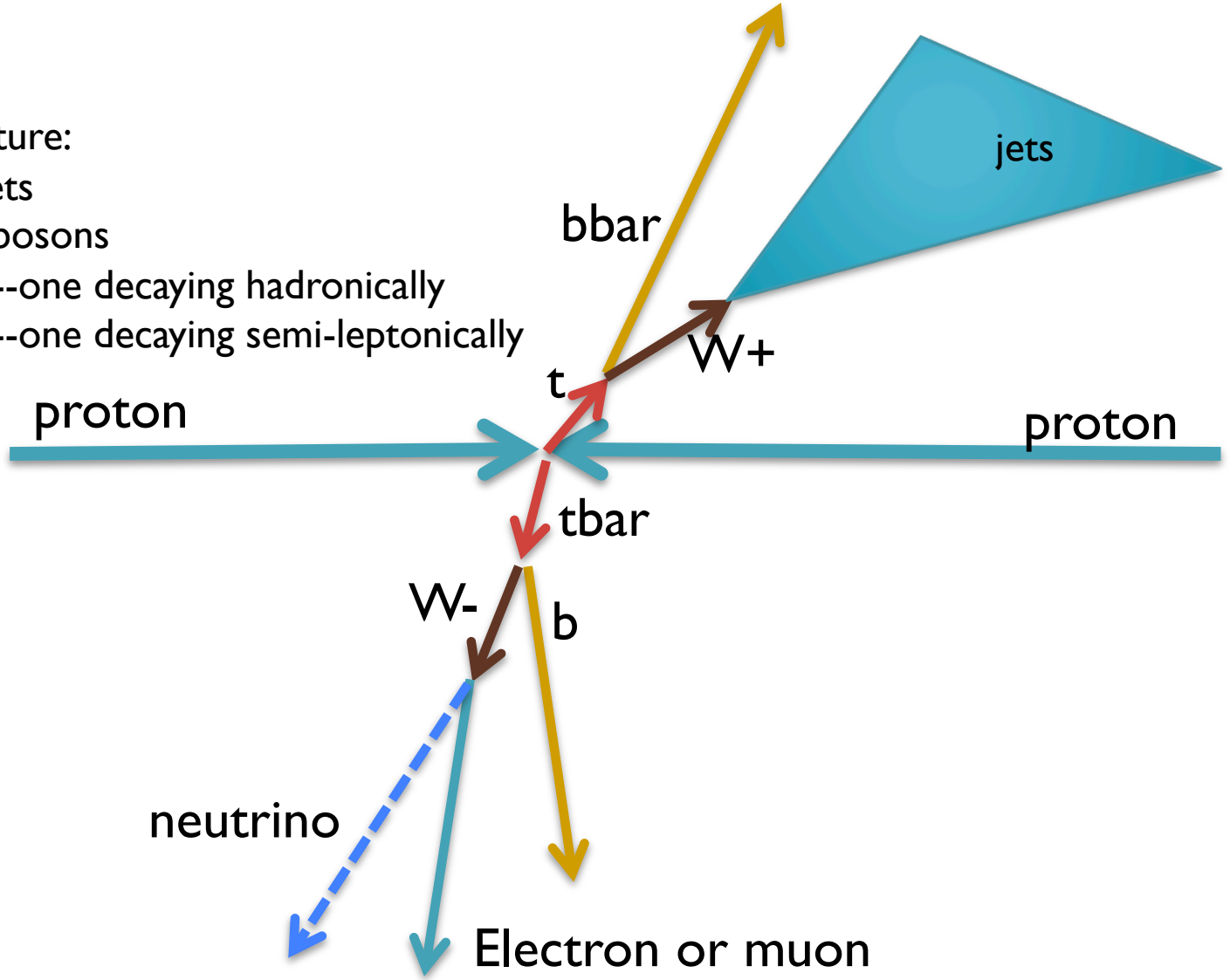


- Therefore, asymmetry taken as following ratio:

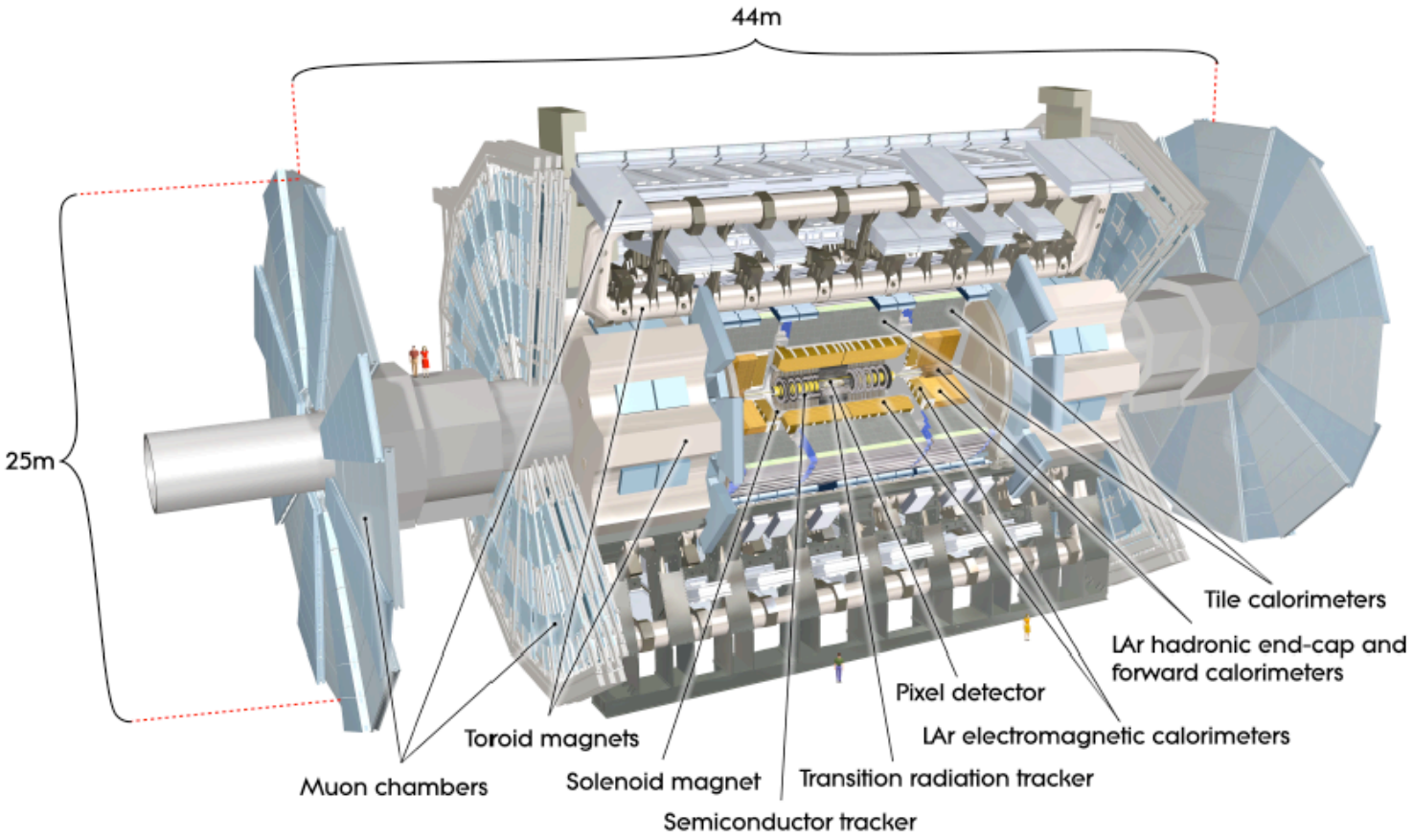
$$A_C = \frac{N(\Delta|y| > 0) - N(\Delta|y| < 0)}{N(\Delta|y| > 0) + N(\Delta|y| < 0)}, \qquad \Delta|y| \equiv |y_t| - |y_{\bar{t}}|$$

Introduction II

Signature:
2 b-jets
2 W bosons
--one decaying hadronically
--one decaying semi-leptonically



The ATLAS Detector



Coverage:

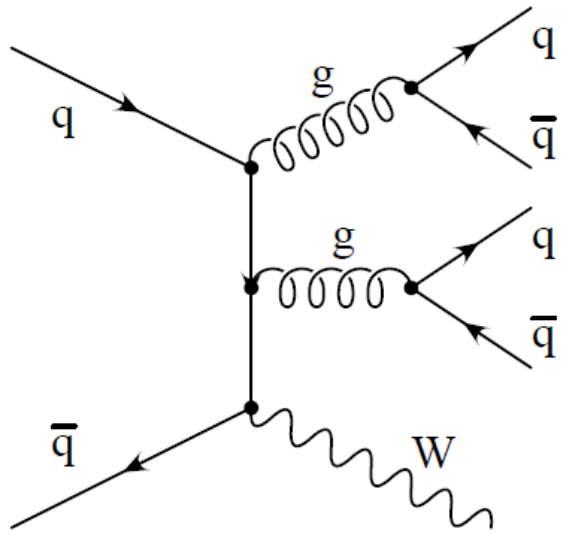
Tracker : $|\eta| < 2.5$

Calorimeter : $|\eta| < 4.9$

Muon system : $|\eta| < 2.7$

Backgrounds: W+jets

- W+jets estimation using charge asymmetry technique
- All other processes (except single top) symmetric in W+ and W- production.



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

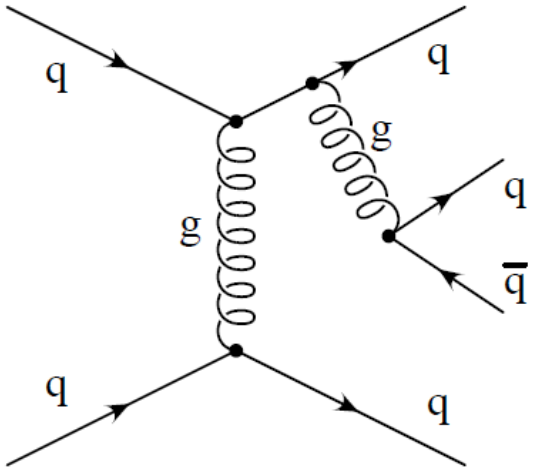
$D^+(D^-)$ total number of events in data passing all selection criteria (apart from b-tagging requirement)

$$r_{MC} \equiv \frac{N(pp \to W^+)}{N(pp \to W^-)}$$ evaluated from MC

Uncertainty: 21% (electron) or 23% (muons)
Other backgrounds are small

Backgrounds: Multijet BG

- Jets reconstructed as leptons
  - Tight leptons are defined using standard selection criteria
  - Loose leptons have looser identification criteria including no/reduced isolation requirements



$$N_{fake}^{tight} = \frac{\varepsilon_{fake}}{(\varepsilon_{real} - \varepsilon_{fake})}\left(N^{loose}\varepsilon_{real} - N^{tight}\right)$$

Where:

$$\varepsilon_{fake} = N_{fake}^{tight} \Big/ N_{fakel}^{loose}$$

$$\varepsilon_{real} = N_{real}^{tight} \Big/ N_{real}^{loose}$$

Uncertainty ~ 100%

Kinematic Fit

$$L = \mathcal{B}(\widetilde{E}_{\mathrm{p},1}, \widetilde{E}_{\mathrm{p},2} | m_W, \Gamma_W) \cdot \mathcal{B}(\widetilde{E}_{\mathrm{lep}}, \widetilde{E}_{\nu} | m_W, \Gamma_W) \cdot$$
$$\mathcal{B}(\widetilde{E}_{\mathrm{p},1}, \widetilde{E}_{\mathrm{p},2}, \widetilde{E}_{\mathrm{p},3} | m_t, \Gamma_t) \cdot \mathcal{B}(\widetilde{E}_{\mathrm{lep}}, \widetilde{E}_{\nu}, \widetilde{E}_{\mathrm{p},4} | m_t, \Gamma_t) \cdot$$
$$\mathcal{W}(\hat{E}_x^{\mathrm{miss}} | \widetilde{p}_{x,\nu}) \cdot \mathcal{W}(\hat{E}_y^{\mathrm{miss}} | \widetilde{p}_{y,\nu}) \cdot \mathcal{W}(\hat{E}_{\mathrm{lep}} | \widetilde{E}_{\mathrm{lep}}) \cdot$$
$$\prod_{\mathrm{i}=1}^{4} \mathcal{W}(\hat{E}_{\mathrm{jet,i}} | \widetilde{E}_{\mathrm{p,i}}) \cdot \prod_{\mathrm{i}=1}^{4} P(\mathrm{tagged} \mid \mathrm{parton\ flavour}),$$

Global Likelihood function with two main parts:

- -Breit-Wigner functions describing the physics distributions expected from the top and W particles
- -reconstruction efficiency functions and b-tagging efficiency, which describe how it will look in your detector when certain particles are produced

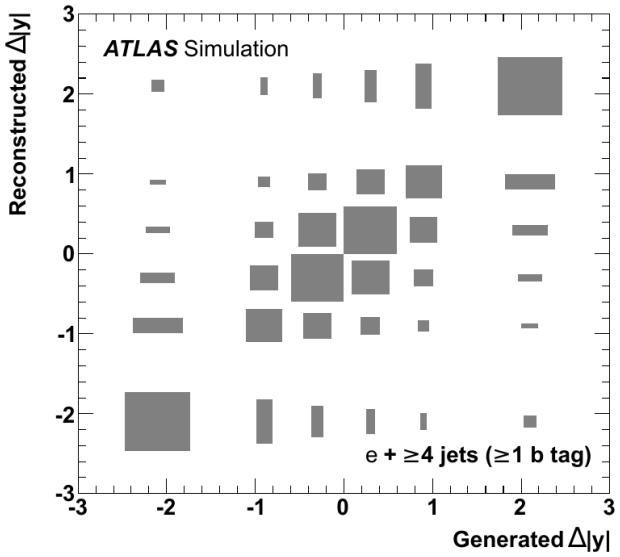
Minimized to select event topology most compatible with ttbar

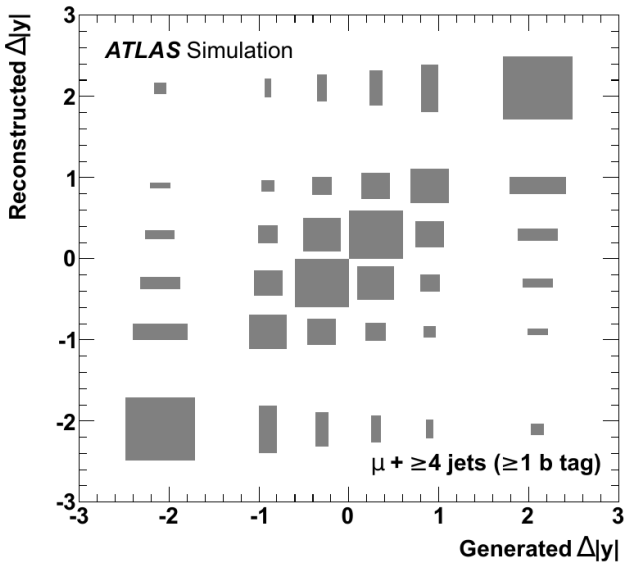
Unfolding

The measured distributions of top and anti-top rapidities are distorted by detector effects and event selection bias.

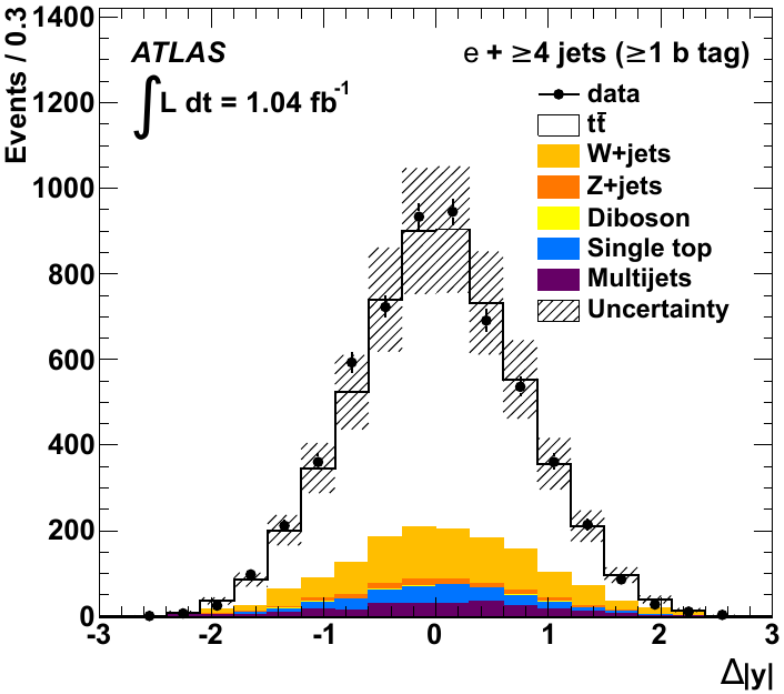
$$T_i = \sum_{j=1}^{n_{bins}} M_{ij} N_j$$

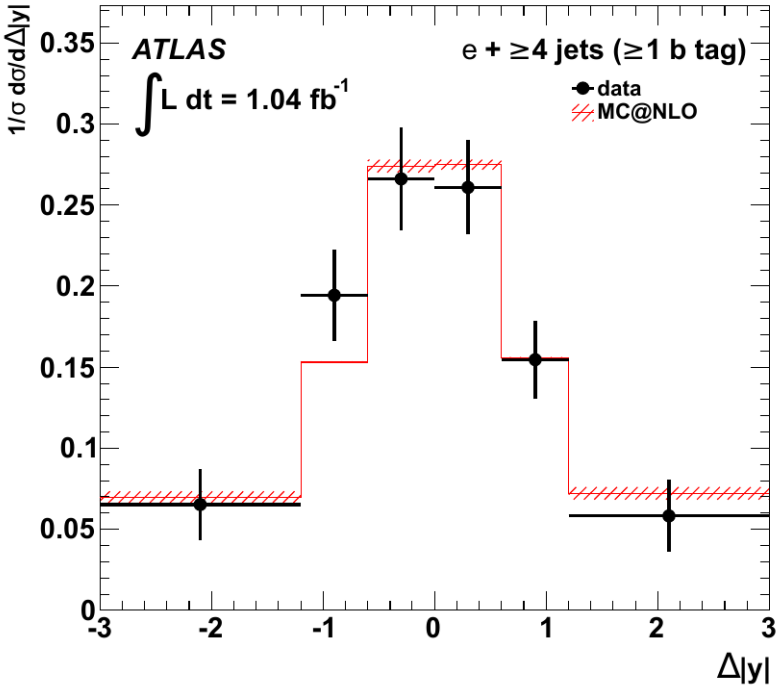
- T_i is the true distribution and N_j the reconstructed distribution after detector simulation and event selection.
- M_{ij} is the response matrix defined as the probability to observe an event in bin j when it is expected in bin i.
- M_{ij} is found using an interative Bayesian approach.





Results





Measured $\Delta|y|$ distribution before unfolding (left) and after applying the event selection, kinematic fit, and unfolding procedure (right), in the electron channel.

Asymmetry and Comparison with CDF

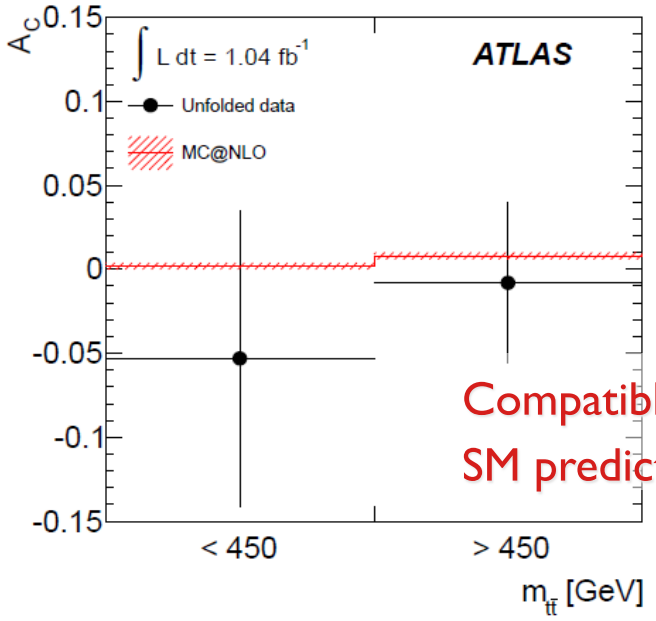
ATLAS

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

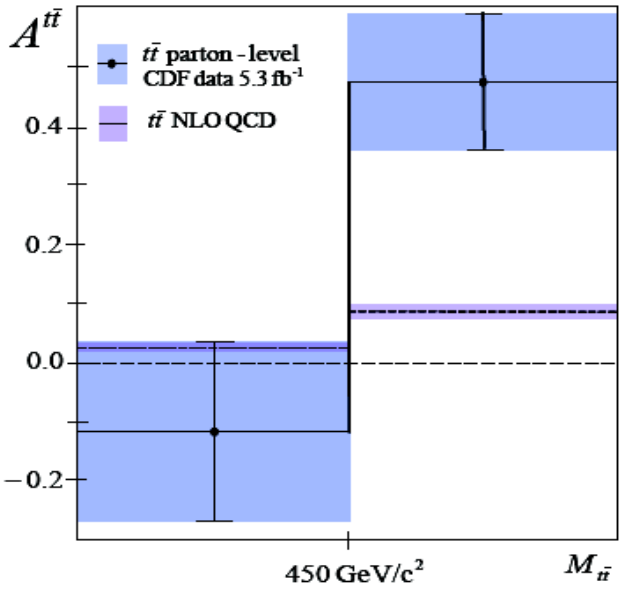
CDF

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

	ATLAS	CDF
$m_{\bar{t}t} < 450\,GeV$	-0.053 ± 0.088	-0.116 ± 0.153
$m_{\bar{t}t} > 450\,GeV$	-0.008 ± 0.047	0.475 ± 0.114
inclusive	-0.018 ± 0.036	0.158 ± 0.075



Compatible with SM predictions



Conclusions and Interpretation

ATLAS A_C measurement is a **test** of the unexpectedly large A_{FB} observed at **CDF**

LHC and Tevatron are really different machines

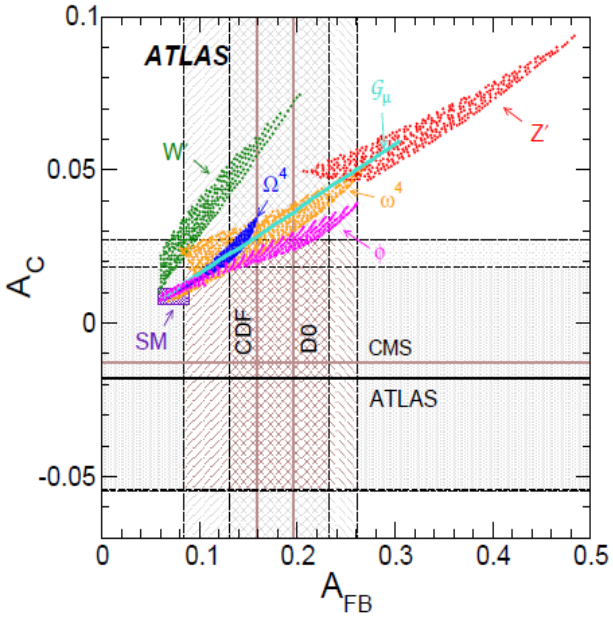
relations between A_C and A_{FB} are model dependent.

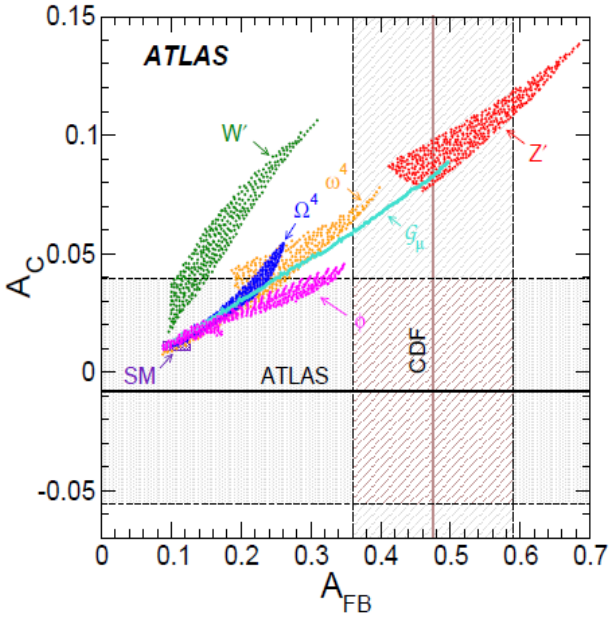
A few models were tested:

1) flavour-changing Z' exchanged in t-channel in $\bar{u}\,u \to \bar{t}\,t$

2) W' boson $\bar{d}\,d \to \bar{t}\,t$

…



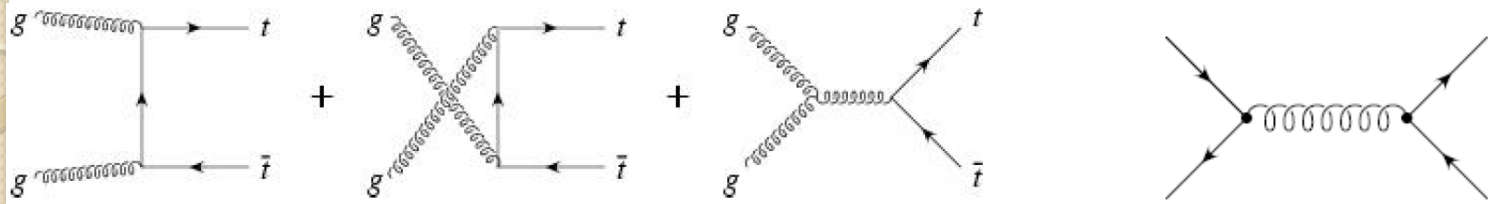


These measurement **disfavour** models with a new flavour-changing Z' and W' vector boson.

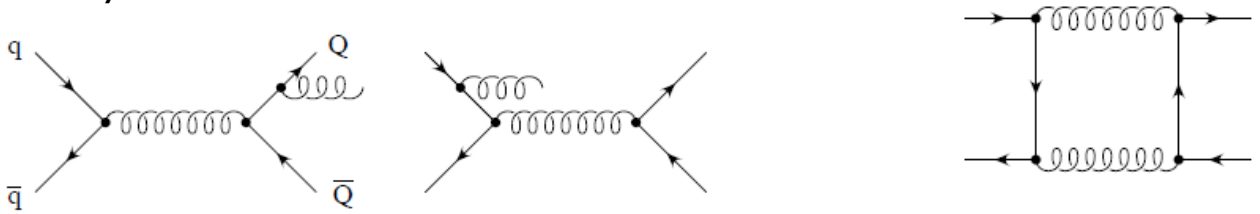
Backup Slides

$t\bar{t}$ production – sources of asymmetry

- Main LO contribution: gluon-gluon fusion, qq annihilation, completely symmetric



- At NLO, asymmetric states from ISR/FSR interferences, as well as box/Born



- Tevatron: mainly qqbar process, whereas at LHC, dominated by gluon fusion (85%)

- New physics might be source of additional charge asymmetry
  - Current measurement at Tevatron showing excess wrt SM about 2-3σ
  - CDF reports 3.4σ excess for M[tt]>450 GeV

Event Selection

- 1.04/fb of ATLAS data at sqrt(s) = 7 TeV
- AntiKt4 jets with p_T>25 and $|\eta|$<2.5 (at least 4 such jets in event)
- Electron channel:
  - Electron p_T > 25 GeV and $|\eta|$<2.47
  - $E_{T,miss}$ > 35 GeV (for electron) and $m_T(W)$ > 25 GeV
- Muon channel:
  - Muon p_T > 20 GeV and $|\eta|$<2.5
  - $E_{T,miss}$ > 20 GeV (for electron) and $E_{T,miss}+m_T(W)$ > 60 GeV
- At least one b-tag for tagged analysis
  - 70% efficiency point
- Top charge sign determined from lepton charge

Channel	μ + jets pretag	μ + jets tagged	e + jets pretag	e + jets tagged
Observed	19639	9124	12096	5829

Results

- **Systematics uncertainties**
  - ***Unfolding convergence***: a potential bias from the choice of the convergence is taken into account by adding a systematic uncertainty of 0.001.
  - ***Unfolding bias***: using pseudoexperiment a small bias (2-5%) is observed in the unfolded distribution. This is taken into account adding a systematic error (0.004 for e+jets and < 0.001 for μ+jets).
- **Results**
  - From the unfolded distributions the charge asymmetry after background subtraction is derived:

Asymmetry	reconstructed	detector and acceptance unfolded
A_C (electron)	-0.034 ± 0.019 (stat.) ± 0.010 (syst.)	-0.047 ± 0.045 (stat.) ± 0.028 (syst.)
A_C (muon)	-0.010 ± 0.015 (stat.) ± 0.008 (syst.)	-0.002 ± 0.036 (stat.) ± 0.023 (syst.)
Combined		-0.018 ± 0.028 (stat.) ± 0.023 (syst.)

Systematic errors

Source of systematic uncertainty on A_C	Electron channel	Muon channel
Detector modelling		
Jet energy scale	0.012	0.006
Jet efficiency and resolution	0.001	0.007
Muon efficiency and resolution	<0.001	0.001
Electron efficiency and resolution	0.003	0.001
b-tag scale factors	0.004	0.002
Calorimeter readout	0.001	0.004
Charge mis-ID	<0.001	<0.001
b-tag charge	0.001	0.001
Signal and background modelling		
Parton shower/fragmentation	0.010	0.010
Top mass	0.007	0.007
$t\bar{t}$ modelling	0.011	0.011
ISR and FSR	0.010	0.010
PDF	<0.001	<0.001
W+jets normalization and shape	0.008	0.005
Z+jets normalization and shape	0.005	0.001
Multijet background	0.011	0.001
Single top	<0.001	<0.001
Diboson	<0.001	<0.001
MC Statistics	0.006	0.005
Unfolding convergence	0.001	0.001
Unfolding bias	0.004	<0.001
Luminosity	0.001	0.001
Total systematic uncertainty	0.028	0.023

The unfolding method

$$M_{ij}^{k} = \frac{P\left(N_j|T_i\right)\pi^{k-1}\left(T_i\right)}{\epsilon_i \sum_{l=0}^{n_T} P\left(N_j|T_l\right)\pi^{k-1}\left(T_l\right)}$$

$$\epsilon_i = \sum_{l=0}^{n_D} P(N_l|T_i)$$

$$M_{ij} = \prod_{k=1}^{n_{iter}} M_{ij}^{k}$$

$$T_i = \sum_{j=1}^{n_{bins}} M_{ij} N_j$$

Data and Monte Carlo simulations

- 1.04 fb^{-1} of data collected in p-p collisions at $\sqrt{s}$ = 7 TeV
- MC samples:
  - tt pair events generated using MC@NLO (normalised to the cross section of 165 pb)
  - parton showering → HERWIG
  - underlying events → JIMMY
  - single top events → MC@NLO
  - W/Z bosons (jets) → ALPGEN generator + HERWIG + JIMMY
  - di-bosons WW, WZ, ZZ → HERWIG + MRST2007 lomod
- ATLAS detector simulated using GEANT4
- Events reconstructed using standard ATLAS reconstruction software