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

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In $qq\overline{q}$ 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:

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

$$\Delta|y| \equiv |y_t| - |y_{\overline{t}}|$$
Signature:  
2 b-jets  
2 W bosons  
--one decaying hadronically  
--one decaying semi-leptonically

Electron or muon
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)

\[
r_{MC} \equiv \frac{N(pp \rightarrow W^+)}{N(pp \rightarrow W^-)}
\]
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

\[
N_{\text{fake}}^{\text{tight}} = \frac{\varepsilon_{\text{fake}}}{(\varepsilon_{\text{real}} - \varepsilon_{\text{fake}})} (N_{\text{loose}} \varepsilon_{\text{real}} - N_{\text{tight}})
\]

Where:

\[
\varepsilon_{\text{fake}} = \frac{N_{\text{fake}}^{\text{tight}}}{N_{\text{fake}}^{\text{fake}}}
\]

\[
\varepsilon_{\text{real}} = \frac{N_{\text{tight}}^{\text{real}}}{N_{\text{loose}}^{\text{real}}}
\]

Uncertainty ~ 100%
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.

\[ T_i = \sum_{j=1}^{n_{\text{bins}}} M_{ij} N_j \]

- \( T_i \) 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 interactive 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

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

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

<table>
<thead>
<tr>
<th></th>
<th>ATLAS</th>
<th>CDF</th>
</tr>
</thead>
<tbody>
<tr>
<td>( m_{\tau\tau} &lt; 450 \text{ GeV} )</td>
<td>(-0.053 \pm 0.088)</td>
<td>(-0.116 \pm 0.153)</td>
</tr>
<tr>
<td>( m_{\tau\tau} &gt; 450 \text{ GeV} )</td>
<td>(-0.008 \pm 0.047)</td>
<td>(0.475 \pm 0.114)</td>
</tr>
<tr>
<td>inclusive</td>
<td>(-0.018 \pm 0.036)</td>
<td>(0.158 \pm 0.075)</td>
</tr>
</tbody>
</table>

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 $\bar{u}u \rightarrow \bar{t}t$
2) $W'$ boson $\bar{d}d \rightarrow \bar{t}t$

... These measurement disfavour models with a new flavour-changing $Z'$ and $W'$ vector boson.
Backup Slides
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. 1.04/fb of ATLAS data at $\sqrt{s} = 7$ TeV
2. AntiKt4 jets with $p_T > 25$ and $|\eta| < 2.5$ (at least 4 such jets in event)
3. Electron channel:
   - Electron $p_T > 25$ GeV and $|\eta| < 2.47$
   - $E_{T,\text{miss}} > 35$ GeV (for electron) and $m_T(W) > 25$ GeV
4. Muon channel:
   - Muon $p_T > 20$ GeV and $|\eta| < 2.5$
   - $E_{T,\text{miss}} > 20$ GeV (for electron) and $E_{T,\text{miss}} + m_T(W) > 60$ GeV
5. At least one $b$-tag for tagged analysis
   - 70% efficiency point
6. Top charge sign determined from lepton charge

<table>
<thead>
<tr>
<th>Channel</th>
<th>$\mu + \text{jets pretag}$</th>
<th>$\mu + \text{jets tagged}$</th>
<th>$e + \text{jets pretag}$</th>
<th>$e + \text{jets tagged}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observed</td>
<td>19639</td>
<td>9124</td>
<td>12096</td>
<td>5829</td>
</tr>
</tbody>
</table>
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:

<table>
<thead>
<tr>
<th>Asymmetry</th>
<th>reconstructed</th>
<th>detector and acceptance unfolded</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A_C$ (electron)</td>
<td>$-0.034 \pm 0.019$ (stat.) $\pm 0.010$ (syst.)</td>
<td>$-0.047 \pm 0.045$ (stat.) $\pm 0.028$ (syst.)</td>
</tr>
<tr>
<td>$A_C$ (muon)</td>
<td>$-0.010 \pm 0.015$ (stat.) $\pm 0.008$ (syst.)</td>
<td>$-0.002 \pm 0.036$ (stat.) $\pm 0.023$ (syst.)</td>
</tr>
<tr>
<td>Combined</td>
<td>$-0.018 \pm 0.028$ (stat.) $\pm 0.023$ (syst.)</td>
<td></td>
</tr>
</tbody>
</table>
## Systematic errors

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

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

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

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

\[ T_i = \sum_{j=1}^{n_{bins}} M_{ij} N_j \]
Data and Monte Carlo simulations

- 1.04 fb$^{-1}$ of data collected in p-p collisions at $\sqrt{s} = 7$ TeV

MC samples:

- $t\bar{t}$ pair events generated using MC@NLO (normalised to the cross section of 165 pb)
- parton showering $\rightarrow$ HERWIG
- underlying events $\rightarrow$ JIMMY
- single top events $\rightarrow$ MC@NLO
- W/Z bosons (jets) $\rightarrow$ ALPGEN generator + HERWIG + JIMMY
- $s$-bosons $WW, WZ, ZZ$ $\rightarrow$ HERWIG + MRST2007 lomod

- ATLAS detector simulated using GEANT4
- Events reconstructed using standard ATLAS reconstruction software