Combination of 7TeV $t\bar{t}$ charge asymmetry results

First steps

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CHARGE ASYMMETRY
CMS ATLAS COMBINATION

Published and preliminary results @7TeV

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- **Lepton+jets**
  - ATLAS (4.7fb^{-1}) arXiv:1311.6724 (sub. to JHEP)

    A_c = 0.006 ±0.010 (stat. + syst.)
  - CMS (5.0fb^{-1}) Phys. Lett. B 7171 (2012) 129

    A_c = 0.004 ±0.010 (stat.) ±0.011(syst.)

Theory prediction (Kühn, Rodrigo) A_c = 0.0115 ±0.006

- **Dilepton**
  - ATLAS (4.7fb^{-1}) ATLAS-CONF-2012-057

    A_c = 0.057 ±0.024 (stat.) ±0.015 (syst.)
  - CMS (5.0fb^{-1}) TOP-12-010

    A_c = 0.050 ±0.043 (stat.) +0.010 – 0.039 (syst.)

    A paper is currently in internal review with a different method yielding a different result

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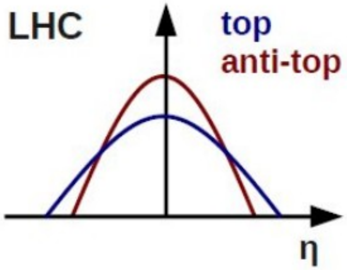
- **Lepton+jets**
  - ATLAS ($4.7fb^{-1}$) arXiv:1311.6724 (sub. to JHEP)
    $A_c = 0.006 \pm 0.010$ (stat. + syst.)
  - CMS ($5.0fb^{-1}$) Phys. Lett. B 7171 (2012) 129
    $A_c = 0.004 \pm 0.010$ (stat.) ± 0.011(syst.)

Start with the combination of **lepton+jets** results

Theory prediction (Kühn, Rodrigo) $A_c = 0.0115 \pm 0.006$

- **Dilepton**
  - ATLAS ($4.7fb^{-1}$) ATLAS-CONF-2012-057
    $A_c = 0.057 \pm 0.024$ (stat.) ± 0.015 (syst.)
  - CMS ($5.0fb^{-1}$) TOP-12-010
    $A_c = 0.050 \pm 0.043$ (stat.) $+0.010 - 0.039$ (syst.)
    A paper is currently in internal review with a different method yielding a different result

Lepton+jets results @7TeV



$$\Delta|y| = |y_t| - |y_{\bar{t}}| \qquad A_C = \frac{N^+ - N^-}{N^+ + N^-}$$

A_c = 0.006 ± 0.010 (stat.+syst.)

A_c = 0.004 ± 0.010 (stat.) ± 0.011 (syst.)

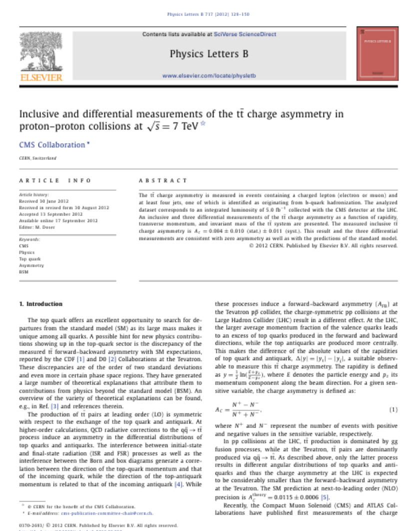
- Both analyses use the same sensitive variable
- Central values are very close
- Both comparable within the uncertainties with ...
  - ...the SM predictions
  - ...zero asymmetry
- In addition: both analyses measure A_c differentially
  - ...but with different binnings
  - Focus on **inclusive results** for the combination


ATLAS NOTE
ATLAS-CONF-2013-078
July 18, 2013

Measurement of the top quark pair production charge asymmetry in proton-proton collisions at $\sqrt{s}$ = 7 TeV using the ATLAS detector

The ATLAS Collaboration

Abstract


Physics Letters B

Inclusive and differential measurements of the $t\bar{t}$ charge asymmetry in proton–proton collisions at $\sqrt{s} = 7$ TeV

CMS Collaboration

Inclusive lepton+jets results @7TeV

A_c = 0.006 ± 0.010 (stat.+syst.)

A_c = 0.004 ± 0.010 (stat.) ± 0.011 (syst.)

- Main difference: size of the uncertainties
- Stat. uncertainty is ~0.010 in both analyses
- Syst. uncertainty for ATLAS is much smaller (due to marginalization procedure)

Estimation of systematic uncertainties

A_c = 0.006 ± 0.010 (stat.+syst.)

- Systematics are taken into account using a **marginalization** procedure
- **Posterior distributions** for signal and BG corresponding to each syst. variation are computed
- Likelihood used in the unfolding is **marginalized by integrating out** its dependence on the nuisance parameters
- Priors for all nuisances are Gaussian without correlation between them
- The **resulting posterior** is used to extract the systematic uncertainty

A_c = 0.004 ± 0.010 (stat.) ± 0.011 (syst.)

- For **each source** of systematic uncertainty the **measurement on data is repeated**
- Instead of the default MC templates the **systematically shifted** ones are used for BG-estimation, BG-subtraction and unfolding
- The resulting asymmetry is compared to the central result
- The **difference** is quoted as systematic uncertainty
- The individual contributions are **added in quadrature** yielding the total systematic uncertainty

Closer look at the individual systematics

A_c = 0.006 ± 0.010 (stat.+syst.)

A_c = 0.004 ± 0.010 (stat.) ± 0.011 (syst.)

For illustration only: calculated one-by-one **before** marginalization

Source of systematic uncertainty	Inclusive
Lepton reconstruction/identification	< 0.001
Lepton energy scale and resolution	0.003
Jet energy scale and resolution	0.003
Missing transverse momentum and pile-up modelling	0.002
Multijet background normalisation	< 0.001
b-tagging/mis-tag efficiency	< 0.001
Signal modelling	< 0.001
Parton shower/hadronisation	< 0.001
Monte Carlo statistics	0.002
PDF	0.001
W+jets normalisation and shape	0.002
Statistical uncertainty	0.010

Systematic uncertainty	Shift (±) in inclusive A_C
JES	0.003
JER	0.002
Lepton ID/sel. efficiency	0.006
Generator	0.001
Hadronization	0.001
Q^2 scale	0.002
PDF	0.002
Pileup	< 0.001
W + jets	0.004
Multijet	0.001
Migration matrix	0.002
Model dependence	0.007
Total	0.011

Closer look at systematics

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A_c = 0.006 ± 0.010 (stat.+syst.)

A_c = 0.004 ± 0.010 (stat.) ± 0.011 (syst.)

- List of considered systematics is **almost identical**
- CMS has **one additional uncertainty** on the **model dependence** of the default signal sample used for the unfolding
  - **Largest single uncertainty** → drives the total
- ATLAS numbers are **only for illustration**: for this cross-check the syst. uncertainties are calculated one-by-one before marginalization
  - For the final result, the stat.+syst. uncertainty is estimated using a marginalization procedure
  - Total uncertainty is ~ statistical uncertainty (0.010)
- The **different methods** to estimate the **impact of systematic** uncertainties yield **different total syst. uncertainties** of the final results

Mapping of systematic uncertainties (1)

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“Detector-modelling” (correlation: 0)

0.004 ATLAS
0.007 CMS

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Multijet	0.001
Migration matrix	0.002
Model dependence	0.007
Total	0.011

We group together systematic uncertainties of related sources by adding them in quadrature

Mapping of systematic uncertainties (2)

“Detector-modelling” (correlation: 0)

0.004 (ATLAS)
0.007 (CMS)

“Signal-modelling” (correlation: 1)

0.000 (ATLAS)
0.002 (CMS)

Source of systematic uncertainty	Inclusive
Lepton reconstruction/identification	< 0.001
Lepton energy scale and resolution	0.003
Jet energy scale and resolution	0.003
Missing transverse momentum and pile-up modelling	0.002
Multijet background normalisation	< 0.001
b-tagging/mis-tag efficiency	< 0.001
Signal modelling	< 0.001
Parton shower/hadronisation	< 0.001
Monte Carlo statistics	0.002
PDF	0.001
W+jets normalisation and shape	0.002
Statistical uncertainty	0.010

Systematic uncertainty	Shift (±) in inclusive A_C
JES	0.003
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Lepton ID/sel. efficiency	0.006
Generator	0.001
Hadronization	0.001
Q^2 scale	0.002
PDF	0.002
Pileup	< 0.001
W + jets	0.004
Multijet	0.001
Migration matrix	0.002
Model dependence	0.007
Total	0.011

We group together systematic uncertainties of related sources by adding them in quadrature

Mapping of systematic uncertainties (3)

Karlsruhe Institute of Technology

“Detector-modelling” (correlation: 0) 0.004 (ATLAS) 0.007 (CMS)

“Signal-modelling” (correlation: 1) 0.000 (ATLAS) 0.002 (CMS)

Source of systematic uncertainty	Inclusive
Lepton reconstruction/identification	< 0.001
Lepton energy scale and resolution	0.003
Jet energy scale and resolution	0.003
Missing transverse momentum and pile-up modelling	0.002
Multijet background normalisation	< 0.001
b-tagging/mis-tag efficiency	< 0.001
Signal modelling	< 0.001
Parton shower/hadronisation	< 0.001
Monte Carlo statistics	0.002
PDF	0.001
W+jets normalisation and shape	0.002
Statistical uncertainty	0.010

Systematic uncertainty	Shift ($\pm$) in inclusive A_C
JES	0.003
JER	0.002
Lepton ID/sel. efficiency	0.006
Generator	0.001
Hadronization	0.001
Q^2 scale	0.002
PDF	0.002
Pileup	< 0.001
W + jets	0.004
Multijet	0.001
Migration matrix	0.002
Model dependence	0.007
Total	0.011

“Modelling of W+jets” (correlation: 1) 0.002 (ATLAS) 0.004 (CMS)

Mapping of systematic uncertainties (4)

"Detector-modelling" (correlation: 0) 0.004 (ATLAS) 0.007 (CMS)

"Signal-modelling" (correlation: 1) 0.000 (ATLAS) 0.002 (CMS)

Source of systematic uncertainty	Inclusive
Lepton reconstruction/identification	< 0.001
Lepton energy scale and resolution	0.003
Jet energy scale and resolution	0.003
Missing transverse momentum and pile-up modelling	0.002
Multijet background normalisation	< 0.001
b-tagging/mis-tag efficiency	< 0.001
Signal modelling	< 0.001
Parton shower/hadronisation	< 0.001
Monte Carlo statistics	0.002
PDF	0.001
W+jets normalisation and shape	0.002
Statistical uncertainty	0.010

Systematic uncertainty	Shift (±) in inclusive A_C
JES	0.003
JER	0.002
Lepton ID/sel. efficiency	0.006
Generator	0.001
Hadronization	0.001
Q^2 scale	0.002
PDF	0.002
Pileup	< 0.001
W + jets	0.004
Multijet	0.001
Migration matrix	0.002
Model dependence	0.007
Total	0.011

"Modelling of W+jets" (correlation: 1) 0.002 (ATLAS) 0.004 (CMS)

"Modelling of QCD" (correlation: 0) 0.000 (ATLAS) 0.001 (CMS)

Mapping of systematic uncertainties (5)

Karlsruhe Institute of Technology

"Detector-modelling" (correlation: 0) 0.004 (ATLAS) 0.007 (CMS)

"Signal-modelling" (correlation: 1) 0.000 (ATLAS) 0.002 (CMS)

Source of systematic uncertainty	Inclusive
Lepton reconstruction/identification	< 0.001
Lepton energy scale and resolution	0.003
Jet energy scale and resolution	0.003
Missing transverse momentum and pile-up modelling	0.002
Multijet background normalisation	< 0.001
b-tagging/mis-tag efficiency	< 0.001
Signal modelling	< 0.001
Parton shower/hadronisation	< 0.001
Monte Carlo statistics	0.002
PDF	0.001
W+jets normalisation and shape	0.002
Statistical uncertainty	0.010

Systematic uncertainty	Shift (±) in inclusive A_C
JES	0.003
JER	0.002
Lepton ID/sel. efficiency	0.006
Generator	0.001
Hadronization	0.001
Q^2 scale	0.002
PDF	0.002
Pileup	< 0.001
W + jets	0.004
Multijet	0.001
Migration matrix	0.002
Model dependence	0.007
Total	0.011

"Pileup" (correlation: 0) 0.002 (ATLAS) 0.000 (CMS)

"PDF" (correlation: 1) 0.001 (ATLAS) 0.002 (CMS)

Mapping of systematic uncertainties (6)

Karlsruhe Institute of Technology

“Detector-modelling” (correlation: 0)

0.004
0.007

“Signal-modelling” (correlation: 1)

0.000
0.002

Source of systematic uncertainty	Inclusive
Lepton reconstruction/identification	< 0.001
Lepton energy scale and resolution	0.003
Jet energy scale and resolution	0.003
Missing transverse momentum and pile-up modelling	0.002
Multijet background normalisation	< 0.001
b-tagging/mis-tag efficiency	< 0.001
Signal modelling	< 0.001
Parton shower/hadronisation	< 0.001
Monte Carlo statistics	0.002
PDF	0.001
W+jets normalisation and shape	0.002
Statistical uncertainty	0.010

Systematic uncertainty	Shift (±) in inclusive A_C
JES	0.003
JER	0.002
Lepton ID/sel. efficiency	0.006
Generator	0.001
Hadronization	0.001
Q^2 scale	0.002
PDF	0.002
Pileup	< 0.001
W + jets	0.004
Multijet	0.001
Migration matrix	0.002
Model dependence	0.007
Total	0.011

“MC statistics of the migration matrix” (correlation: 0)

0.002
0.002

Summary of systematics

Systematic	ATLAS	CMS	Correlation
Detector modelling	0.004	0.007	0
Signal modelling	0.000	0.002	1
W+jets	0.002	0.004	1
QCD	0.000	0.001	0
Pileup	0.002	0.000	0
PDF	0.001	0.002	1
MC stats pf Migmatrix	0.002	0.002	0
Model dependence	---	0.007	---

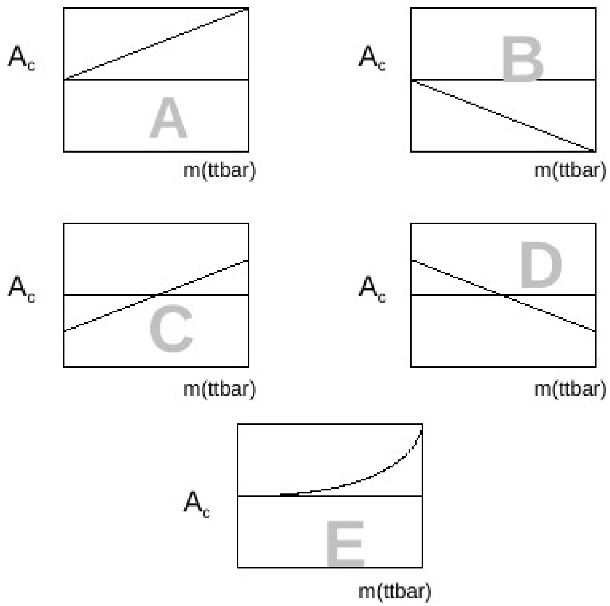
Conclusion and outlook

- Identified corresponding systematics in ATLAS and CMS
  - But: mapping of systematics shown in this presentation mainly for illustration purpose
  - ATLAS uses marginalization procedure
  - Have to define a strategy of how to treat these uncertainties
- Next step:
  - Combination of the lepton+jets results
  - ...using the BLUE method
  - ...considering ATLAS' marginalization procedure
  - Add dilepton results

BACKUP

CMS: Model dependence systematic

- Reweight events to produce asymmetry depending on the secondary variable
- The errors of the unfolding procedure give an estimate of the unfolding reliability in scenarios deviating significantly from Powheg simulation



Results for |y(ttbar)| and pT(ttbar) in the backup

Scenario	$m_{t\bar{t}}$ bin 1 A_C^{gen}	$m_{t\bar{t}}$ bin 1 A_C^{meas}	$m_{t\bar{t}}$ bin 2 A_C^{gen}	$m_{t\bar{t}}$ bin 2 A_C^{meas}	$m_{t\bar{t}}$ bin 3 A_C^{gen}	$m_{t\bar{t}}$ bin 3 A_C^{meas}
Reweighted in $m_{t\bar{t}}$						
A	0.013	0.010	0.040	0.038	0.101	0.104
B	-0.003	0.000	-0.026	-0.024	-0.081	-0.083
C	-0.012	-0.016	-0.002	-0.004	0.047	0.051
D	0.022	0.026	0.015	0.017	-0.027	-0.030
E	0.008	0.003	0.034	0.037	0.112	0.113
Reweighted in $p_{T,t\bar{t}}$						
A	0.031	0.031	0.050	0.053	0.071	0.088
B	-0.021	-0.021	-0.037	-0.039	-0.051	-0.067
C	0.005	0.005	0.009	0.012	0.017	0.035
D	0.005	0.006	0.005	0.002	0.003	-0.014
E	0.030	0.030	0.049	0.053	0.070	0.090
Reweighted in $\|y_{t\bar{t}}\|$						
A	0.040	0.036	0.065	0.059	0.085	0.081
B	-0.030	-0.027	-0.051	-0.046	-0.065	-0.060
C	0.014	0.011	0.023	0.018	0.031	0.028
D	-0.004	0.000	-0.010	-0.005	-0.011	-0.007
E	0.041	0.037	0.067	0.063	0.090	0.088

ATLAS: uses axigluon models to reweight the partonic asymmetry from MC@NLO (not linear nor quadratic, but coming from a physics model) → no bias in the linearity check (For the 1fb^{-1} paper several physics models have been used → also no bias in the linearity check