



# Combination of 7TeV tt charge asymmetry results First steps

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# CHARGE SYMMETRY MS TLAS COMBINATION

KIT – University of the State of Baden-Wuerttemberg and National Research Center of the Helmholtz Association

#### Published and preliminary results @7TeV

#### Lepton+jets

ATLAS (4.7fb<sup>-1</sup>) arXiv:1311.6724 (sub. to JHEP)
A<sub>c</sub> = 0.006 ±0.010 (stat. + syst.)

CMS (5.0fb<sup>-1</sup>) Phys. Lett. B 7171 (2012) 129 A<sub>c</sub> = 0.004 ±0.010 (stat.) ±0.011(syst.)

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

#### Dilepton

- ATLAS (4.7fb<sup>-1</sup>) ATLAS-CONF-2012-057 A<sub>c</sub> = 0.057 ±0.024 (stat.) ±0.015 (syst.)
- CMS (5.0fb<sup>-1</sup>) TOP-12-010

 $A_c = 0.050 \pm 0.043 \text{ (stat.)} + 0.010 - 0.039 \text{ (syst.)}$ 

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







# Published and preliminary results @7TeV



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

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#### Dilepton

ATLAS (4.7fb<sup>-1</sup>) ATLAS-CONF-2012-057 A<sub>c</sub> = 0.057 ±0.024 (stat.) ±0.015 (syst.)



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 $A_c = 0.050 \pm 0.043 \text{ (stat.)} + 0.010 - 0.039 \text{ (syst.)}$ 



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# Lepton+jets results @7TeV



top

anti-top

LHC

- $A_c = 0.006 \pm 0.010$  (stat.+syst.)
- $A_c = 0.004 \pm 0.010 \text{ (stat.)} \pm 0.011 \text{ (syst.)}$
- 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<sub>c</sub> 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 the top quark p

where the set of th

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CLE INFO	ABSTRACT	
91   Jaco 2012 revised form 30 August 2012 (Soptember 2012 skan 17 September 2012 Josef	The ti charge asymmetry is measured in events containing a ch at heart loss jets, one of which is identified as originating from diarat corresponds to an integrated leminosity of 50 fb <sup>-1</sup> calcula- An inclusive and three differential measurements of the ti spiner are charge asymmetry in $A_{ee} = 0.604 \pm 0.010$ (state) and 10 ± 0.011 (syst).	

ntroduction

be top space to determine a neucline representative to search for  $d_{\rm eff}$  . The energy of the search of the s

a procession on the parts at seeing street (LD) (B yHHReff): a procession of the parts at seeing street (LD) (B yHHReff): so there are asymmetry in the differential distributions of ands: and antipacts. The interference between initial-state linal-state radiation (UR and PSR) processes as well as the encode between the line and also diagrams generate a comsense between the lines and how diagrams generate a comtensive field of the line of the discovery of the line is indiced by the line of the discovery of the line of the interms is related to the of the incension of the top-antipact terms is related to the of the incension gamingan (LL). While

cision is  $A_c^{\rm Distry} = 0.0115 \pm 0.0006$  [5]. Recently, the Compact Nuon Solenaid (CMS) and ATLAS Colneations have published first measurements of the charge





#### Inclusive lepton+jets results @7TeV







 $A_{c} = 0.006 \pm 0.010 \text{ (stat.+syst.)}$ 

 $A_c = 0.004 \pm 0.010 \text{ (stat.)} \pm 0.011 \text{ (syst.)}$ 

- 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**





 $A_c = 0.006 \pm 0.010$  (stat.+syst.)



 $A_c = 0.004 \pm 0.010 \text{ (stat.)} \pm 0.011 \text{ (syst.)}$ 

- 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

- 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**





 $A_{c} = 0.006 \pm 0.010 \text{ (stat.+syst.)}$ 

#### $A_c = 0.004 \pm 0.010 \text{ (stat.)} \pm 0.011 \text{ (syst.)}$

# 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 <sup>2</sup> 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**







 $A_c = 0.006 \pm 0.010$  (stat.+syst.)

 $A_c = 0.004 \pm 0.010 \text{ (stat.)} \pm 0.011 \text{ (syst.)}$ 

- 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)



# "Detector-modelling" (correlation: 0)



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	
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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 <sup>2</sup> 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 (2)



#### "Detector-modelling" (correlation: 0)

0.000

0 002



#### "Signal-modelling" (correlation: 1)

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
<i>b</i> -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 <sup>2</sup> 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)



#### "Detector-modelling" (correlation: 0)

0.000

0 0 0 2



#### "Signal-modelling" (correlation: 1)

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

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 $0.002$ Model dependence $0.007$ Total $0.011$	_	Systematic uncertainty	Shift $(\pm)$ in inclusive $A_C$
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 $0.002$ Model dependence $0.007$ Total $0.011$		JES	0.003
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 $0.002$ Model dependence $0.007$ Total $0.011$		JER	0.002
Generator       0.001         Hadronization       0.001 $Q^2$ scale       0.002         PDF       0.002         Pileup       < 0.001		Lepton ID/sel. efficiency	0.006
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 $0.011$		Generator	0.001
$Q^2$ scale         0.002           PDF         0.002           Pileup         < 0.001		Hadronization	0.001
PDF         0.002           Pileup         < 0.001		Q <sup>2</sup> scale	0.002
Pileup< 0.001W + jets0.004Multijet0.001Migration matrix0.002Model dependence0.007Total0.011		PDF	0.002
W + jets0.004Multijet0.001Migration matrix0.002Model dependence0.007Total0.011		Pileup	< 0.001
Multijet0.001Migration matrix0.002Model dependence0.007Total0.011		W + jets	0.004
Migration matrix0.002Model dependence0.007Total0.011		Multijet	0.001
Model dependence0.007Total0.011		Migration matrix	0.002
Total 0.011		Model dependence	0.007
	-	Total	0.011

# "Modelling of W+jets" (correlation: 1) $\frac{0.002}{0.004}$



# Mapping of systematic uncertainties (4)



#### "Detector-modelling" (correlation: 0)

0.000

0 0 0 2



#### "Signal-modelling" (correlation: 1)

Source of systematic uncertainty		
Lepton reconstruction/identification		
Lepton energy scale and resolution		
Jet energy scale and resolution		

	Inclusive
Lepton reconstruction/identification	< 0.001
Lepton energy scale and resolution	0.003
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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 <sup>2</sup> 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)





# Mapping of systematic uncertainties (5)



#### "Detector-modelling" (correlation: 0)

0.000

0.002



#### "Signal-modelling" (correlation: 1)

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
<i>b</i> -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

"Pileup" (correlation: 0)

"PDF" (correlation: 1)



0.001

0.002

Systematic uncertainty	Shift $(\pm)$ in inclusive $A_0$
JES	0.003
JER	0.002
Lepton ID/sel. efficiency	0.006
Generator	0.001
Hadronization	0.001
Q <sup>2</sup> 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

# Mapping of systematic uncertainties (6)



#### "Detector-modelling" (correlation: 0)

0.000

0 0 0 2



#### "Signal-modelling" (correlation: 1)

Inclusive
< 0.001
0.003
0.003
0.002
< 0.001
< 0.001
< 0.001
< 0.001
0.002
0.001
0.002
0.010

_	Systematic uncertainty	Shift (±) in inclusive $A_C$
ſ	JES	0.003
	JER	0.002
	Lepton ID/sel. efficiency	0.006
ſ	Generator	0.001
I	Hadronization	0.001
	Q <sup>2</sup> 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)





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





		]	Reweigh	ted in m	ŧ	
	$m_{t\bar{t}}$ bin 1		m <sub>tī</sub> bin 2		$m_{\rm ff}$ bin 3	
Scenario	$A_C^{gen}$	$A_C^{meas}$	A <sub>C</sub> <sup>gen</sup>	ACmeas	$A_C^{gen}$	A <sub>C</sub> <sup>meas</sup>
A	0.013	0.010	0.040	0.038	0.101	0.104
В	-0.003	0.000	-0.026	-0.024	-0.081	-0.083
С	-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 <sub>Ltī</sub>					11
$m_{\rm tf}$ bin 1		oin 1	m <sub>tī</sub> l	oin 2	m <sub>ff</sub> bin 3	
Scenario	$A_C^{gen}$	$A_C^{meas}$	$A_C^{gen}$	Areas	AC	A <sub>C</sub> meas
A	0.031	0.031	0.050	0.053	0.071	0.088
В	-0.021	-0.021	-0.037	-0.039	-0.051	-0.067
С	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
/	$\sim$	) F	Reweight	ed in yt		
$m_{\rm tf}$ bin 1		mtil	oin 2	$m_{\rm ff}$ bin 3		
Scenario	Agen	Ameas	Ac	Areas	$A_C^{gen}$	A <sub>C</sub> meas
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)  $\rightarrow$  no bias in the linearity check (For the 1fb<sup>-1</sup> paper several physics models have been used  $\rightarrow$  also no bias in the linearity check