Search for Leptonic Charge Asymmetry in the Trilepton Final State of $t\bar{t}W^{\pm}$

Marcos Miralles López[1] on behalf of the ATLAS Collaboration

[1]IFIC (UV-CSIC)

Introduction and strategy

ATLAS-CONF-2022-062

- **First** search for the **leptonic charge asymmetry** (A_c^l) of $t\bar{t}W$ in the $3l$ final state using the full Run2 dataset

$$A_c^l = \frac{N(\Delta\eta^l > 0) - N(\Delta\eta^l < 0)}{N(\Delta\eta^l > 0) + N(\Delta\eta^l < 0)}, \text{ with } \Delta\eta^l = |\eta_{\bar{l}}| - |\eta_l|$$

- Measured ATLAS and CMS $t\bar{t}W$ rate is consistently in tension with SM prediction ☞ATL-PHYS-PUB-2022-030
  - A_c^l insensitive to rate → independent way to probe $t\bar{t}W$
- This asymmetry is **sensitive to new physics** and is predicted to be **large** by the SM
- Binned max. likelihood fit is used to extract A_c^l at **reconstruction level** and **unfolded to particle level**

Process	$t\bar{t}$	$t\bar{t}W$
A_c^t [%]	$0.45^{+0.09}_{-0.06}$	$2.24^{+0.43}_{-0.32}$
A_c^ℓ [%]	–	$-13.16^{-0.81}_{+1.12}$

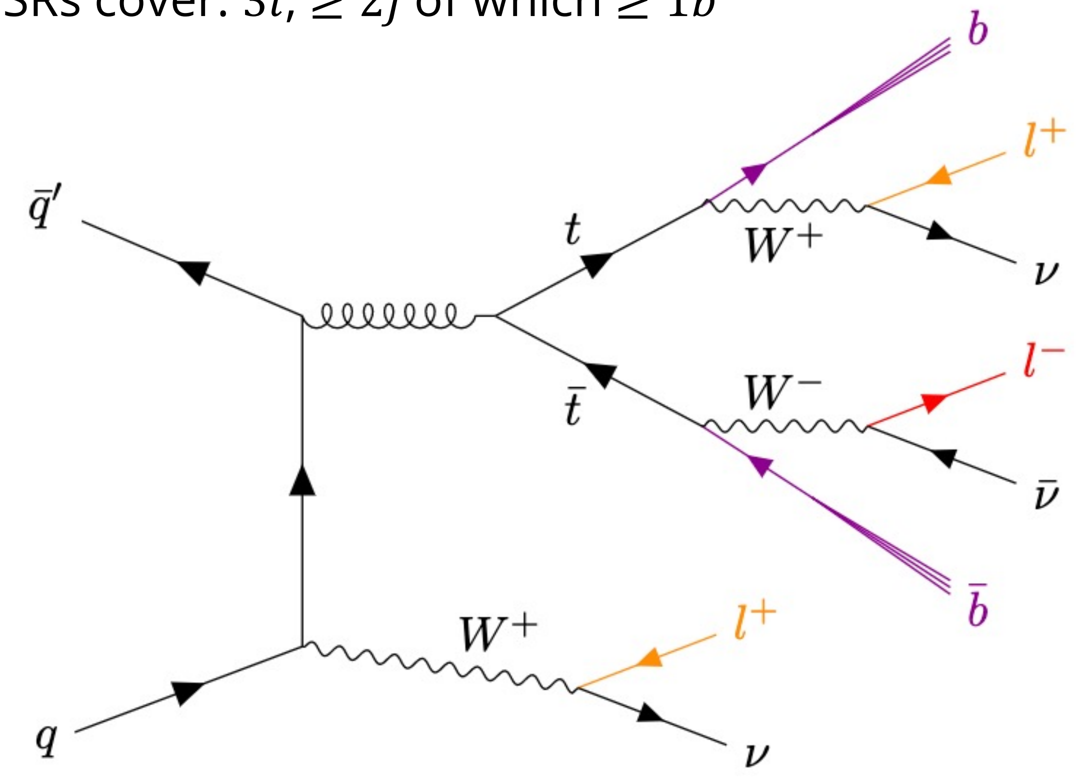
☞Phys. Lett. B **736** (2014) 252

☞ Eur. Phys. J. C **81** (2021) 675

Event selection

ATLAS-CONF-2022-062

SRs cover: $3l$, $\geq 2j$ of which $\geq 1b$

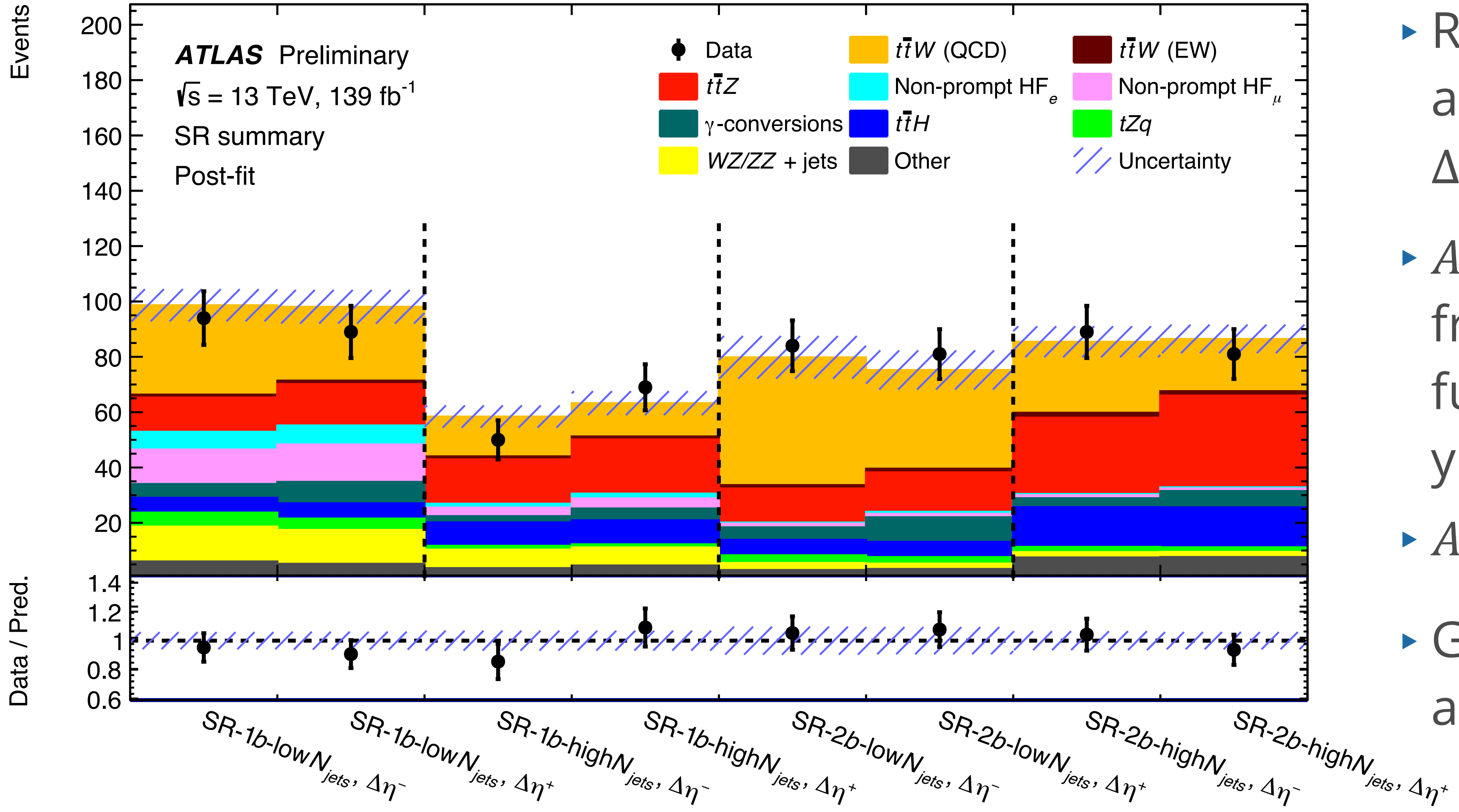


Odd lepton: always from (anti)top quark
Even leptons: need to select the correct one

- Selection of correct **even** lepton done using a BDT with 71% accuracy
- SRs are split into jet and b-jet (77% WP) multiplicity to improve S/B ratio
  - Veto of OSSF within ±10 GeV of the Z peak
  - Veto on electrons originating from γ-conv
- Main 4 backgrounds are constrained in enriched CRs
  - Prompt leptons from $\boldsymbol{t\bar{t}Z}$ – require one Z candidate
  - Non-prompt lepton from **heavy flavour decays** (mostly from $t\bar{t}$) – split in the flavour of the softest lepton
  - Non-prompt lepton from **γ-conv** (mostly from $t\bar{t}$) – select electrons originating from γ-conv

Signal regions and A_c^l extraction

ATLAS-CONF-2022-062

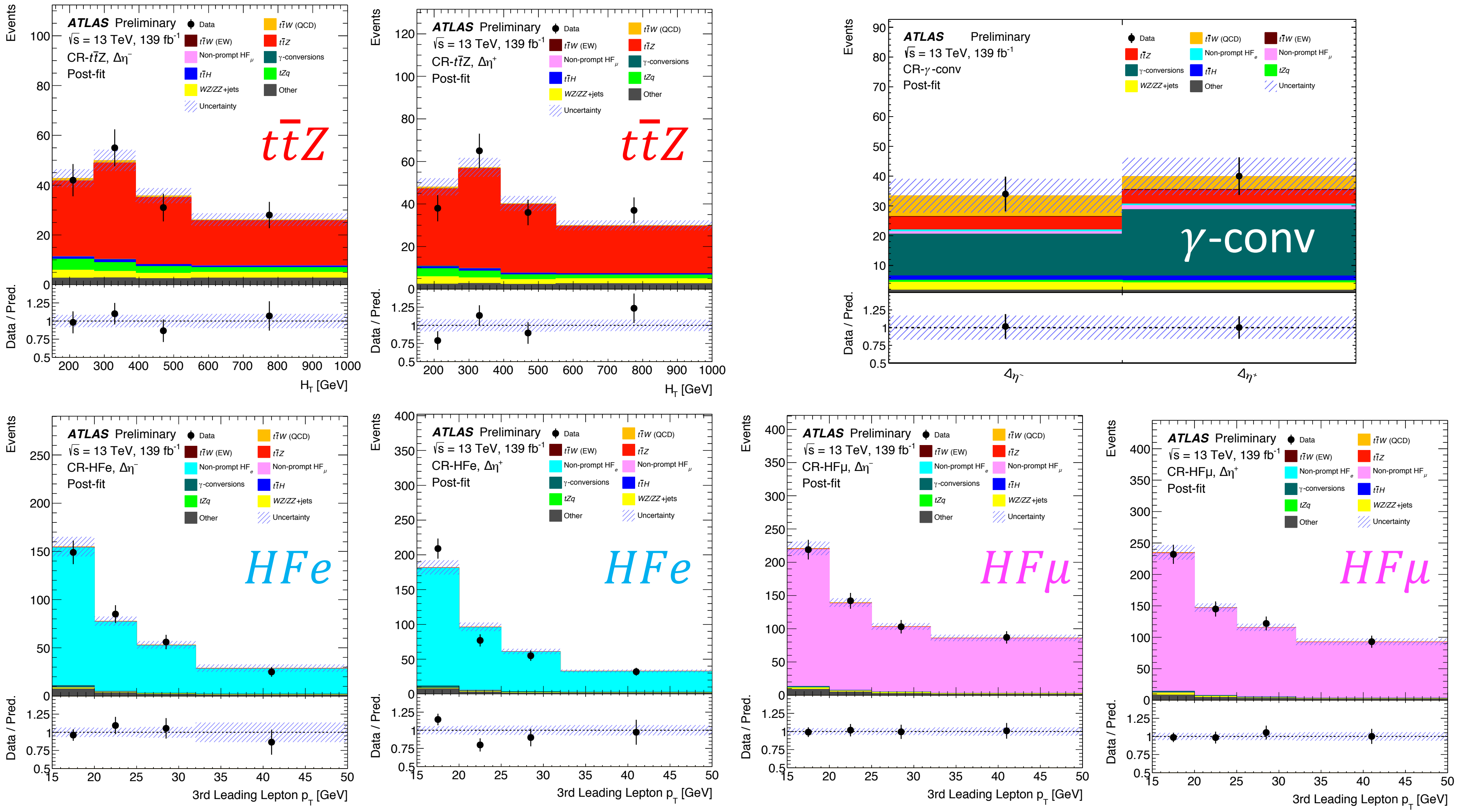


- Regions are split according to the sign of $\Delta\eta^l$
- A_c^l is extracted **directly** from the fit as a function of the event yields
- $A_c^l = \frac{N(\Delta\eta^l > 0) - N(\Delta\eta^l < 0)}{N(\Delta\eta^l > 0) + N(\Delta\eta^l < 0)}$
- Good post-fit agreement in SRs

ATLAS-CONF-2022-062

Control regions

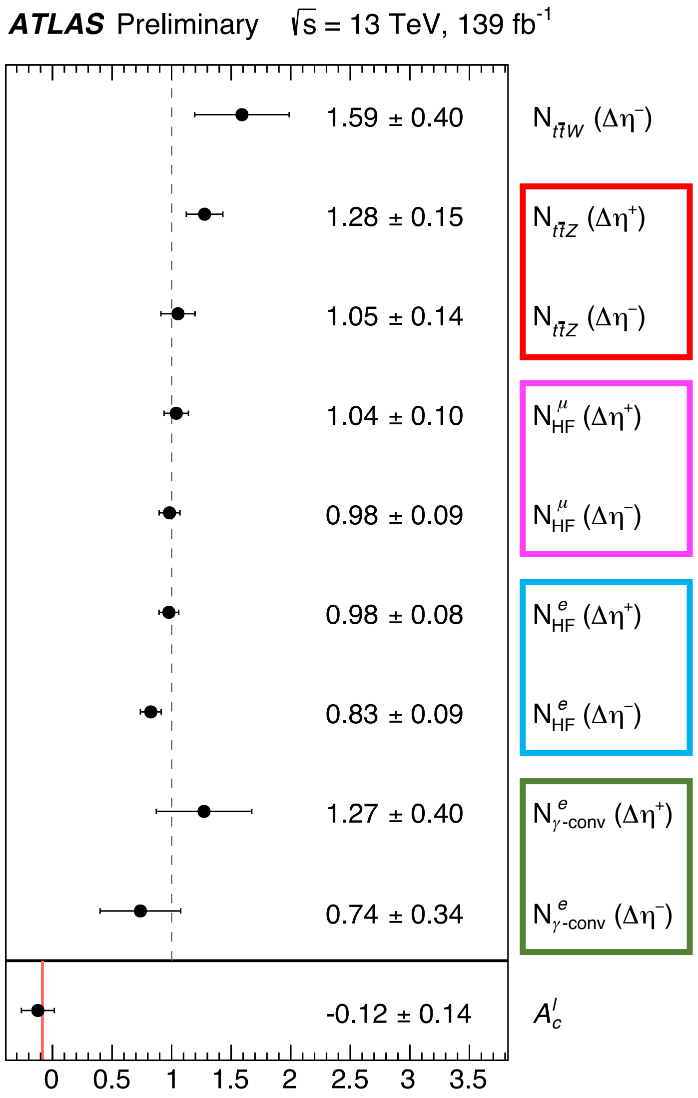
$\Delta\eta^{l} < 0$ $\Delta\eta^{l} > 0$ $\Delta\eta^{l} < 0$ $\Delta\eta^{l} > 0$



Reconstruction level fit

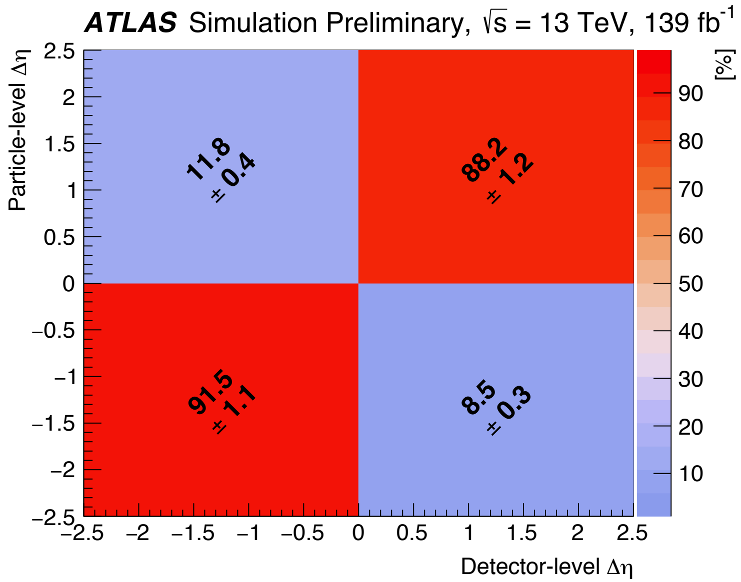
ATLAS-CONF-2022-062

- Total of 10 free-floating parameters extracted **simultaneously** from a binned max. likelihood fit to real data
- Background NFs are split in $\Delta\eta^l$ to avoid being biased by data asymmetries
  - An uncertainty is added to account for the potential spurious impact of these bkg. NFs in the A_c^l
  - Quantified by comparing fits (Asimov SR + data CR) with and without the bkg. NF splitting
- $A_c^l(t\bar{t}W) = -0.123 \pm 0.136\ (\text{stat.}) \pm 0.051\ (\text{syst.})$
  - Leading syst. unc. comes from $t\bar{t}W$ and $t\bar{t}Z$ modelling



Unfolding to particle level

- Unfolding is based on a **profile-likelihood approach**
  - Fitting particle level A_c^l of the truth bins by folding them and computing likelihood using data at reconstruction level
- No **regularisation** is used
- A **fiducial phase space** is defined which is close to the reco-level selection
  - Lepton-top association is based on m_{lb} discriminant (not the BDT)
  - Allows for easy phase space reconstruction, and independent MC generator implementation
- ***Injection* tests** are preformed to verify that non-SM asymmetries can be recovered after the unfolding
  - A small bias is observed and an unc. is assigned to account for it



Migration Matrix for the 2b-lowNjets SR

Summary

ATLAS-CONF-2022-062

- **First** search for the **leptonic charge asymmetry** of $t\bar{t}W$ in the $3l$ final state using the full Run2 dataset
- Lepton-top association is done using a BDT with 71% accuracy
- Observed A_c^l at **reconstruction level**:

$$A_c^l(t\bar{t}W) = -0.123 \pm 0.136\ (\text{stat.}) \pm 0.051\ (\text{syst.})$$

Expected: $A_c^l(t\bar{t}W)_{SM} = -0.084\ ^{+0.005}_{-0.003}\ (\text{scale}) \pm 0.006\ (\text{MC stat.})$

- **Unfolding** to particle level:

$$A_c^l(t\bar{t}W)^{PL} = -0.112 \pm 0.170\ (\text{stat.}) \pm 0.055\ (\text{syst.})$$

Expected: $A_c^l(t\bar{t}W)_{SM}^{PL} = -0.063\ ^{+0.007}_{-0.004}\ (\text{scale}) \pm 0.004\ (\text{MC stat.})$

- Observation in agreement with SM prediction
- Analysis is severely dominated by statistical uncertainties
  - Leading source of systematic uncertainty 8 times smaller than statistical uncertainty

Back-Up

Evolution of the A_c^l [%]

Inclusive Parton-Level

-11.8 ± 0.1

- Fiducial cuts are applied
- Truth matching for lepton-top association is used
- Main dilution comes from lepton p_T cuts

Fiducial Particle-Level (truth-matching)

-8.7 ± 0.4

- Truth matching (100% accuracy) is substituted by m_{lb} matching (65% accuracy) which dilutes the A_c^l

Fiducial Particle-Level (m_{lb}-matching)

-6.3 ± 0.4

Reconstruction-Level (m_{lb}-matching)

-6.6 ± 0.6

- m_{lb} matching (65% accuracy) is substituted by the BDT (71% accuracy) which enhances the A_c^l

Reconstruction-Level (BDT-matching)

-8.4 ± 0.6

- SM predictions are given for the $t\bar{t}W$ Sherpa2.2.10 sample, which has $0{,}1j$@NLO + $2{,}3{,}4j$@LO accuracy
- Shown errors include MC stat. unc.

Systematic impact on A_c^l

- Systematic impact for the reco-level and unfolded results
- Unc. due to the impact of the splitted bkg. NFs is the leading unc. in both cases
- Largest *fit* syst. unc. come mainly from MC modelling and
- Unfolding bias unc. is small in comparison

	$\Delta A_c^\ell(t\bar{t}W)$
Experimental uncertainties	
Jet energy resolution	0.013
Pile-up	0.007
b-tagging	0.005
Leptons	0.004
$E_{\mathrm{T}}^{\mathrm{miss}}$	0.004
Jet energy scale	0.003
Luminosity	0.001
MC modelling uncertainties	
$t\bar{t}W$ modelling	0.013
$t\bar{t}Z$ modelling	0.010
Non-prompt modelling	0.006
$t\bar{t}H$ modelling	0.005
Extra uncertainties	
$\Delta\eta^\pm$ dependency	0.046
MC statistical uncertainty	0.019
Data statistical uncertainty	0.136
Total uncertainty	0.145

	$\Delta A_c^\ell(t\bar{t}W)^{\mathrm{PL}}$
Experimental uncertainties	
Leptons	0.014
Jet energy resolution	0.011
Pile-up	0.008
Jet energy scale	0.004
$E_{\mathrm{T}}^{\mathrm{miss}}$	0.002
Luminosity	0.001
Jet vertex tagger	0.001
MC modelling uncertainties	
$t\bar{t}W$ modelling	0.022
$t\bar{t}Z$ modelling	0.017
Non-prompt modelling	0.015
Others modelling	0.015
$WZ/ZZ+$jets modelling	0.014
$t\bar{t}H$ modelling	0.006
Extra uncertainties	
Unfolding bias	0.011
$\Delta\eta^\pm$ dependency	0.039
MC statistical uncertainty	0.027
Response matrix	0.009
Data statistical uncertainty	0.170
Total uncertainty	0.179

Ranking of systematics for A_c^l

- Ranking of syst. unc. for the reco-level and unfolded results
- Ranking of syst. is very similar for both fits
- Leading syst. unc. (ttW alt. modelling) is about 10 times smaller than stat. unc.