Search for leptonic charge asymmetry in $t\bar{t}W$ in final states with three charged leptons with the ATLAS detector

LHCC meeting poster session – 29 Nov 2022

- The top-antitop quark pair production in association with a W boson ($t\bar{t}W$) is one of the most **phenomenologically rich** and **intriguing** processes
- The charge asymmetry in $t\bar{t}W$ is **enhanced** with respect to $t\bar{t}$ production at the expense of low statistics [1, 2]
- Analysis event selection: $N_\ell(e/\mu) = 3$, p_T^ℓ: $\geq 30, \geq 20, \geq 15$ GeV, $|\eta^\ell| < 2.5$, $\sum$charges $= \pm 1$, $m_{\ell\ell}^{\text{OSSF}} > 30$ GeV, $p_T^j > 20$ GeV, $|\eta^j| < 2.5$, DL1r 77% WP

NLO+PS		13 TeV
$t\bar{t}$	σ [pb]	$661^{+15\%}_{-13\%}$
	A_c^t [%]	$0.45^{+0.09}_{-0.06}$
$t\bar{t}W$	σ [fb]	$587^{+13\%}_{-12\%}$
	A_c^t [%]	$2.24^{+0.43\ (19\%)}_{-0.32\ (14\%)}$
	A_c^ℓ [%]	$-13.16^{-0.81\ (6\%)}_{-1.12\ (9\%)}$

Anatomy of $t\bar{t}W$ production

$t\bar{t}W$ Production

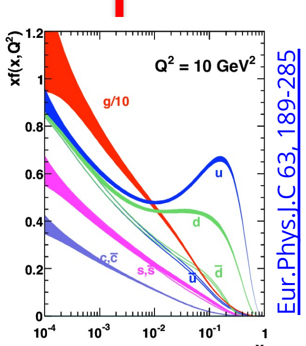
- At LO QCD it can only occur via $q\bar{q}'$ annihilation, qg diagrams open at NLO
- Absence of symmetric gg initial state + emission of $W^\pm$ gauge boson = **large** A_c^ℓ prediction
- A_c^ℓ is independent from $t\bar{t}W$ production rate

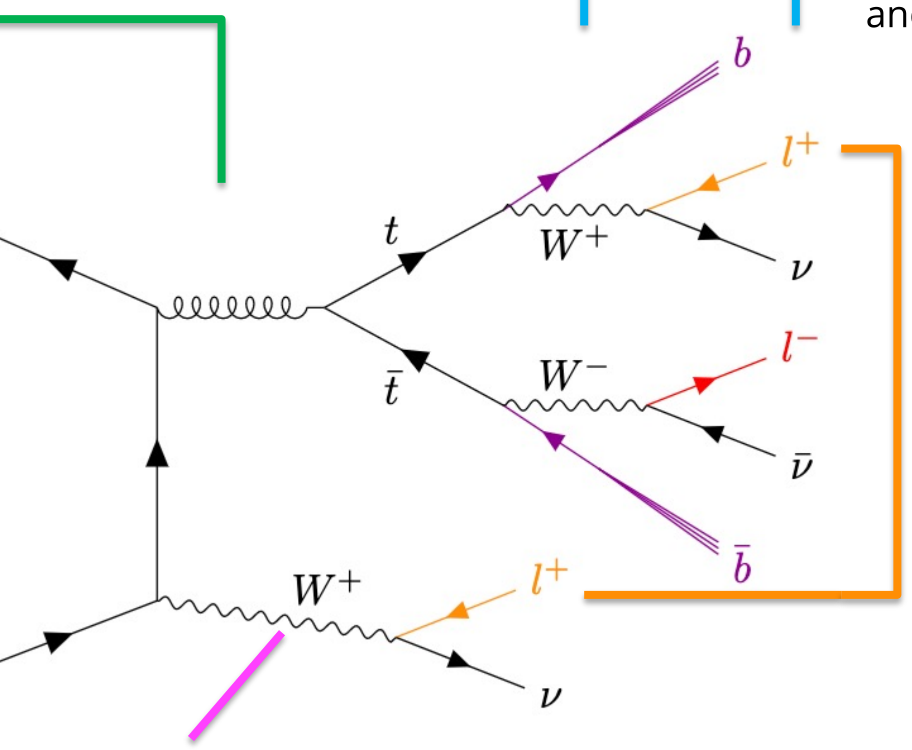
$t\bar{t}W$ Signature: $3\ell + 2b\text{–jets} + E_T^{\text{miss}}$

- 3ℓ channel $\mathcal{BR} \sim 1.1\%$ of total $t\bar{t}W$ cross-section
- Only channel with **dileptonic** decay of top-antitop quark pair
- Main background processes are $t\bar{t}Z$ and $t\bar{t}$ (non-prompt leptons)

$t\bar{t}W^+$ vs $t\bar{t}W^-$

- $t(\bar{t})$ quark momentum is connected to $q(\bar{q})$ longitudinal momentum
- Typically $p_u > p_d > p_{\bar{u}} \approx p_{\bar{d}}$
- Therefore, top quarks have on average larger $|\eta_t|$ values
- Thus, $u\bar{d} \to t\bar{t}W^+$ has a **larger** charge asymmetry than $d\bar{u} \to t\bar{t}W^-$ production





Improved assignment of even lepton using **ML techniques**

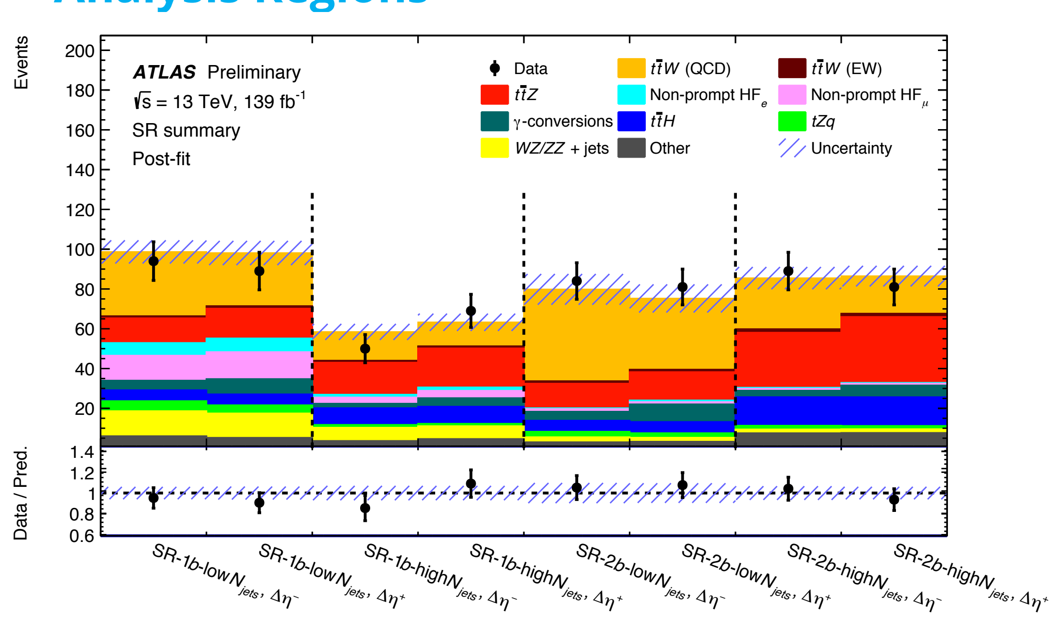
- Odd lepton: always from (anti)top quark
- Even leptons: need to select the correct one
- We make use of a k-fold cross validation with 5 folds
- $\boldsymbol{m_{lb0}}, m_{lb1}, \Delta R_{lb0}, \Delta R_{lb1}, p_T$
- Accuracy of BDT ~71% across all folds

- $W^\pm$ boson **polarises** $q\bar{q}'$ pair = asymmetric top decay products at LO

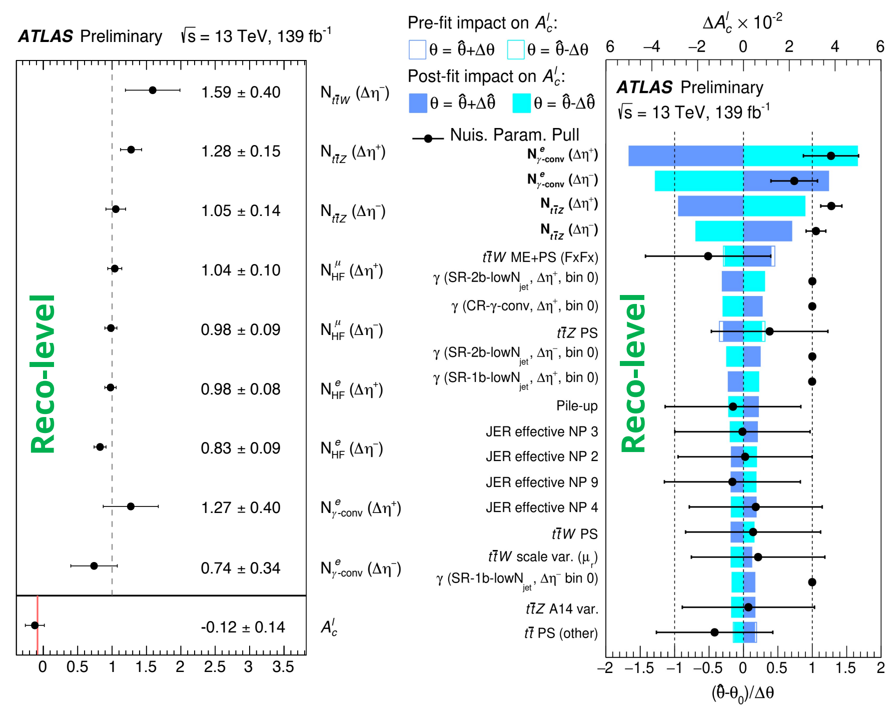
Analysis Strategy

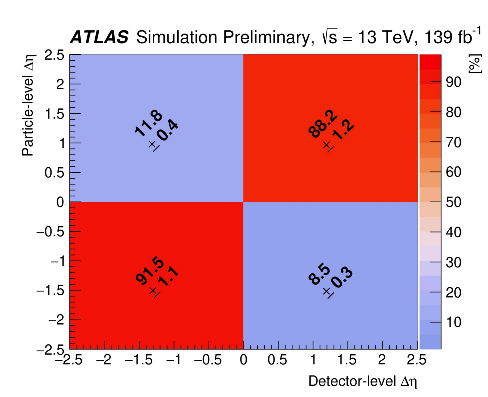
Leptonic Charge Asymmetry: $A_c^\ell = \dfrac{N(\Delta_\eta^\ell > 0) - N(\Delta_\eta^\ell < 0)}{N(\Delta_\eta^\ell > 0) + N(\Delta_\eta^\ell < 0)}$, with $\Delta_\eta^\ell = |\eta_{\bar{\ell}}| - |\eta_\ell|$

Analysis Regions



- Regions split into jet/b-jet multiplicity, $\Delta_\eta^\ell > 0$ and $\Delta_\eta^\ell < 0$
- Free-floating NFs for main backgrounds: N_{ttZ}, N_{HF}^{e}, N_{HF}^{μ} and $N_{\gamma-conv}^{e}$ (splitted in Δ_η^ℓ)
- 2 signal NFs splitted in Δ_η^ℓ are **reparameterised** to extract A_c^ℓ directly from the fit
- **Binned Maximum Profile-Likelihood fit**
- **Unfolding** to particle-level (PL) fiducial phase-space





SR-2b-lowNjets
Migration Matrix

- SRs and CR-γ-conv are unfolded via **response matrices** along with all signal systematic variations in those regions
- Analysis strongly limited by data statistics

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

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

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

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

CONF-Note: ATLAS-CONF-2022-062

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[1] F. Maltoni et al. *Top-quark charge asymmetry and polarization in $t\bar{t}W^\pm$ production at the LHC.* Phys. Lett. B 736 (2014) 252
[2] G. Bevilacqua et al. *NLO QCD corrections to off-shell $t\bar{t}W^\pm$ production at the LHC: Correlations and Asymmetries.* Eur. Phys. J. C 81 (2021) 675