DIS2026
BOLOGNA, ITALY 4-8 MAY 2026
33rd INTERNATIONAL WORKSHOP ON
DEEP INELASTIC SCATTERING
AND RELATED SUBJECTS

Overview of EFT-based searches involving top quarks at ATLAS

Barbora Eckerova on behalf of the ATLAS Collaboration
5 May, DIS 2026 Bologna, Italy

FACULTY OF MATHEMATICS,
PHYSICS AND INFORMATICS
Comenius University
Bratislava

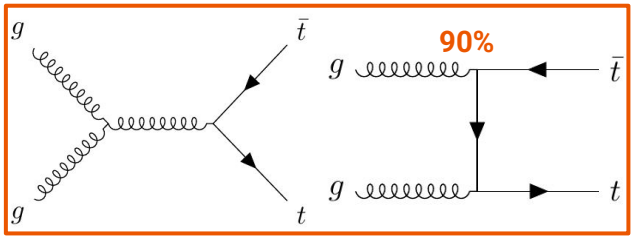
ATLAS EXPERIMENT

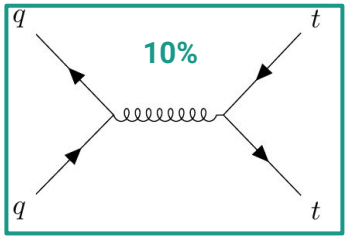
© 2021-2025 CERN

@

Top quark physics

In pp collision at 13TeV:





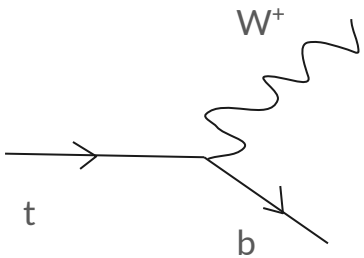
Top quark has unique properties

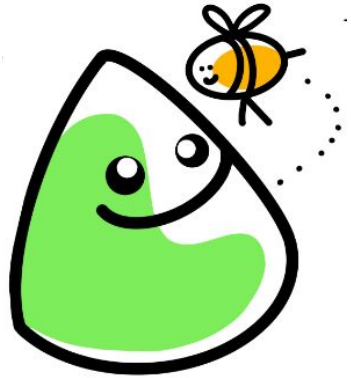
- The **heaviest** known fundamental particle, $m_t \approx 172.5$ GeV (Phys. Rev. Lett. 132 (2024) 261902)
- The **largest Yukawa** coupling to **Higgs** $\lambda_t \sim 1$
- Lifetime ~10^{-25}s smaller than hadronization time ~10^{-24}s = **possibility to study "bare" quark properties**, e.g. spin is transferred to decay products (leptons, down-type quarks)
- Plays important role in EWSB

LHC is a top-quark factory ~ **200M top quarks** produced in Run2!

- Top quark dominantly produced in $t\bar{t}$ pairs
- Allows to perform precise measurements

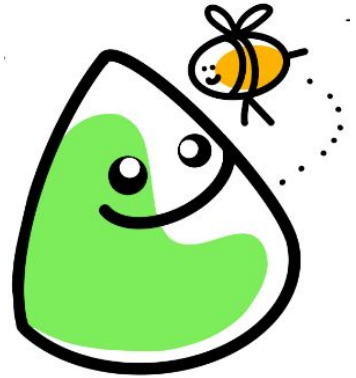
Top decays almost exclusively to **W** and **b quark**





© 2021-2025 CERN

@



Top quark and Effective Field Theory (EFT)

Effective theory = approximation to physics at a higher energy scale
(e.g. Standard Model effective field theory (SMEFT) (Phys. Rept. 793 (2019) 1)

- Standard Model (SM) treated as the EFT of an unknown BSM theory
- **BSM** effects can be **parameterised** by **higher-dimensional operators**

$$\mathcal{L}_{\text{eff}} = \mathcal{L}_{\text{SM}}^{(4)} + \frac{1}{\Lambda}\sum_i c_i^{(5)} O_i^{(5)} + \frac{1}{\Lambda^2}\sum_i c_i^{(6)} O_i^{(6)} + O\left(\frac{1}{\Lambda^3}\right) + \ldots,$$

Top quark is much **heavier** than other SM fermions!

- **BSM** physics at higher scales could **manifest** itself **at lower energies** through **effective interactions with top quark**

Let's search for **deviations from SM** predictions!

Eur. Phys. J. C 85 (2025) 1434

High mass $t\bar{t}\ell^+\ell^-$ and LFU-inspired EFT interpretation

Measure $t\bar{t}\ell^+\ell^-$ (ℓ = e,μ) & high mass: $m_{\ell\ell} > m_Z + 10$ GeV => **sensitivity to some 4-fermion EFT operators**

Operator	Definition
O_{te}	$(\bar{e}_p\gamma_\mu e_r)(\bar{t}\gamma^\mu t)$
O_{Qe}	$(\bar{Q}\gamma_\mu Q)(\bar{e}_p\gamma^\mu e_r)$
O_{tl}	$(\bar{l}_p\gamma_\mu l_r)(\bar{t}\gamma^\mu t)$
O^1_{Ql}	$(\bar{l}_p\gamma_\mu l_r)(\bar{Q}\gamma^\mu Q)$
O^3_{Ql}	$(\bar{l}_p\sigma^i\gamma_\mu l_r)(\bar{Q}\sigma^i\gamma^\mu Q)$
O^1_{leQt}	$(\bar{l}^j_p e_r)\epsilon_{jk}(\bar{Q}^k t)$
O^3_{leQt}	$(\bar{l}^j_p\sigma_{\mu\nu}e_r)\epsilon_{jk}(\bar{Q}^k\sigma^{\mu\nu}t)$

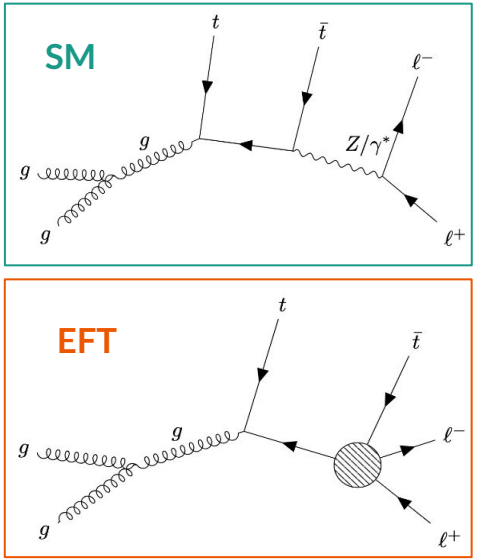
Each has 3 flavour-diagonal Wilson coefficients $c_{X,i}$ (i=flavour index)

Flavour-specific EFT operators can probe lepton flavour universality violation!

$$\mathcal{L}_{eff} = \mathcal{L}^{(4)}_{SM} + \frac{1}{\Lambda}\sum_i C_i^{(5)}O_i^{(5)} + \frac{1}{\Lambda^2}\sum_i C_i^{(6)}O_i^{(6)}) + \mathcal{O}\left(\Lambda^{-3}\right)$$

Large impact of EFT in high $m_{\ell\ell}$ bins, but very low $t\bar{t}\ell^+\ell^-$ statistics ($m_{\ell\ell}$ > 550 GeV)

→ CR to constrain backgrounds like $t\bar{t}W$, SM $t\bar{t}Z$, WZ+jets, fake leptons



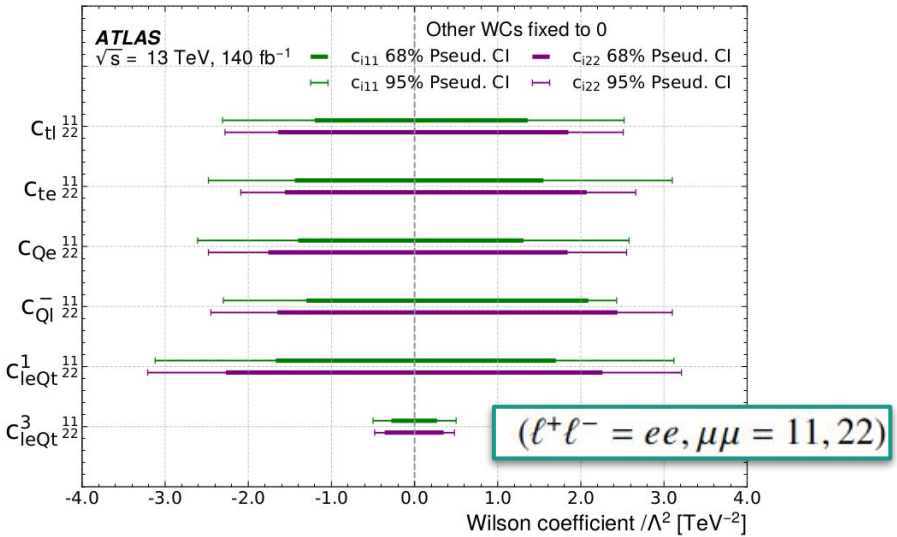
Maximum-likelihood fits of the signal and CR to data performed.

Eur. Phys. J. C 85 (2025) 1434

High mass $t\bar{t}\ell^+\ell^-$ and LFU-inspired EFT interpretation

Flavour-dependent scenario

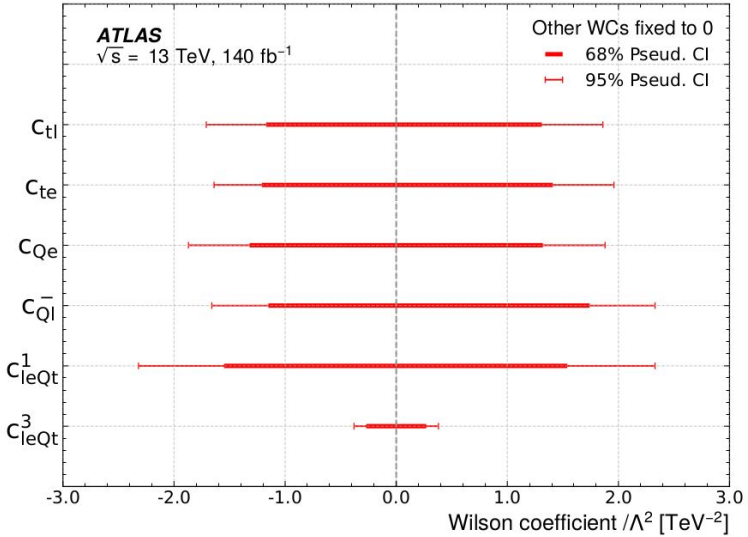
$$O^-_{Ql} = (O^1_{Ql} - O^3_{Ql})$$



Standard asymptotic method may not be valid
(when **pure-EFT terms dominant**)

→ **Pseudodata (toys) used to obtain true coverage!**
(arXiv:2207.01350**)**

Flavour-inclusive scenario



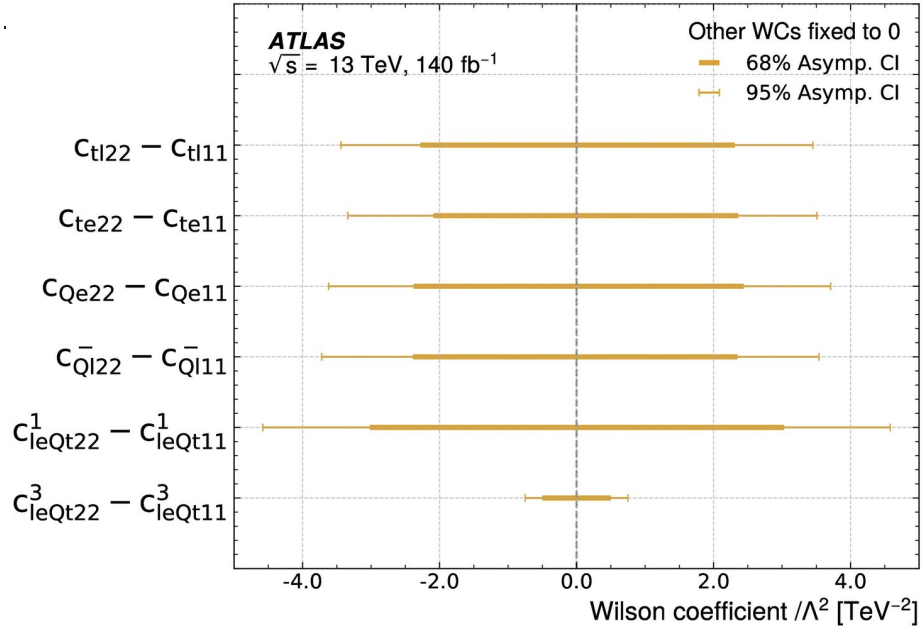
No significant deviations from **SM**

Limits **improved** wrt constraint from the CMS Collaboration (JHEP 12 (2023) 068)

Eur. Phys. J. C 85 (2025) 1434

High mass $t\bar{t}\ell^+\ell^-$ and LFU-inspired EFT interpretation

$(\ell^+\ell^- = ee, \mu\mu = 11, 22)$



LFU-violating signals tested by the difference between electron and muon WC for each operator, e.g.

$$\Delta(c_{tl(22)} - c_{tl(11)})$$

=> **Tested for the first time at the LHC!**

Limited by Run 2 statistical precision, but **cancellation of systematic uncertainties possible**

=> with more data higher-precision test of SM possible!

No deviations from the **SM** or **signs of lepton flavour universality violation!**

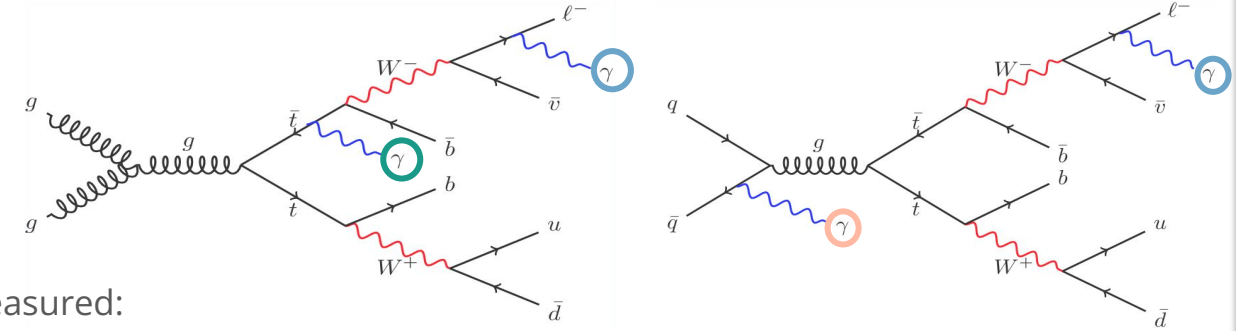
Phys. Lett. B 874 (2026) 140195

First observation of $t\bar{t}\gamma\gamma$ process

$t\bar{t}\gamma\gamma$ = Rare process with small Xsection in SM, **not studied before**

- γ from: **off-shell top**, **initial state radiation**, **charged top-decay products**

2→8 process



Measured:

- **$t\bar{t}\gamma\gamma$ fiducial Xsection** at particle level in single-lepton events with exactly 2 high-p_T isolated photons
- Measure **ratio of $t\bar{t}\gamma\gamma$ to $t\bar{t}\gamma$** ($R = \sigma_{t\bar{t}\gamma\gamma}/\sigma_{t\bar{t}\gamma}$) - test the impact of cancelation of systematics, **constrain to the CP-violating coupling terms**
  - $t\bar{t}\gamma$ already measured JHEP10(2024)191
    (here used for background estimates, synchronization of systematics between measurements)

Motivation:

Probe of t-γ coupling

Irreducible background to $t\bar{t}H$ ($H\to\gamma\gamma$)

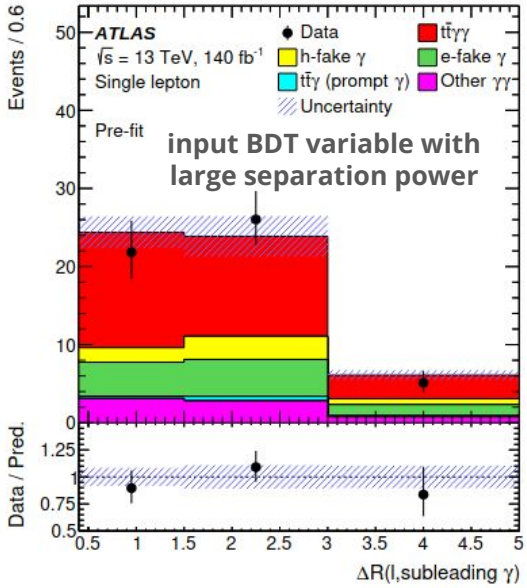
Sensitive to chromoelectric, chromomagnetic dipole moments = higher order corrections in many BSM [Phys. Rev. D 98, 035040, 2018,Chinese Phys. C 45 113101, (2021)]

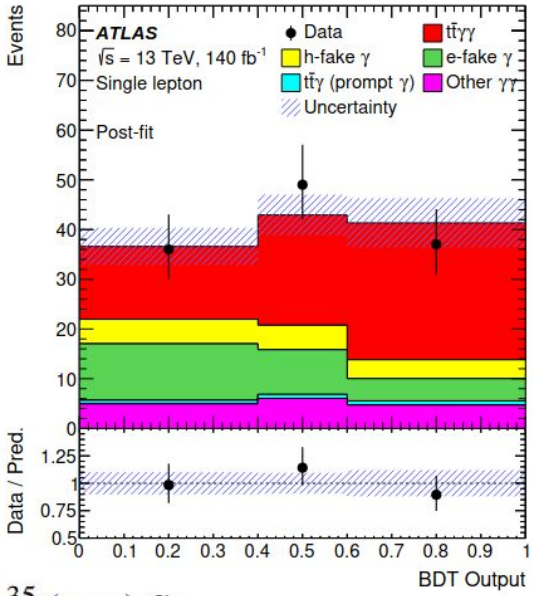
Phys. Lett. B 874 (2026) 140195

First observation of $t\bar{t}\gamma\gamma$ process

Inclusive $t\bar{t}\gamma\gamma$ Xsection obtained by **Profile Likelihood Unfolding** to Boosted Decision Tree (BDT) output

- BDT used for signal-background discrimination





Dominant systematic uncertainties:
jet related, fake photon estimates,
$W\gamma\gamma$ normalisation,
photon isolation and identification

$$\sigma_{t\bar{t}\gamma\gamma} = 2.42^{+0.58}_{-0.53}\ \text{fb} = 2.42^{+0.46}_{-0.38}\ (\text{stat})\ ^{+0.35}_{-0.38}\ (\text{syst})\ \text{fb}$$

Observed significance for $t\bar{t}\gamma\gamma$ process: 5.2σ

Relative total uncertainty is ~23%, **rel. statistical uncertainty dominant** ~17%

First observation of $t\bar{t}\gamma\gamma$ process!

Phys. Lett. B 874 (2026) 140195

First observation of $t\bar{t}\gamma\gamma$ process

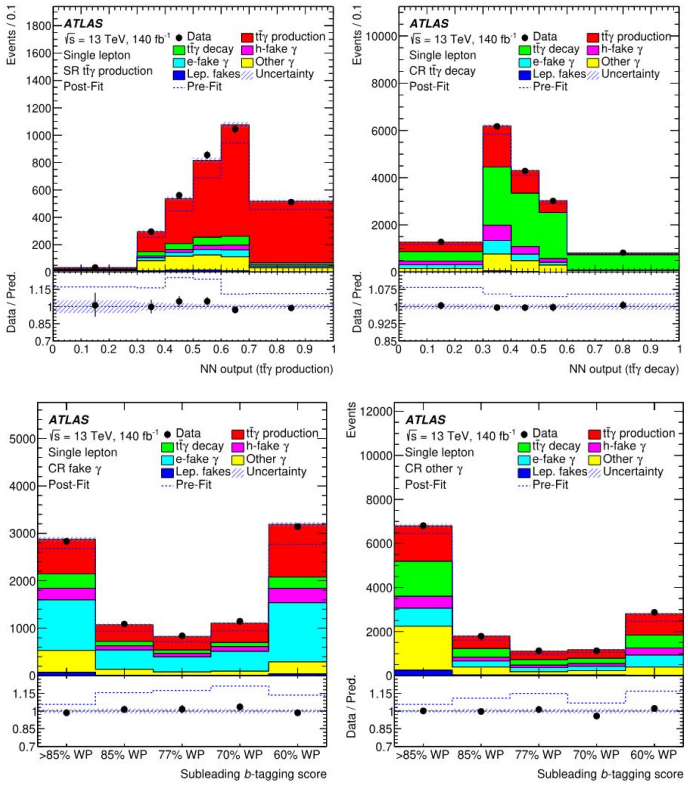
Simultaneous fit performed to the $t\bar{t}\gamma\gamma$ **BDT** and the variables used in **four regions from the $t\bar{t}\gamma$** measurement (JHEP10(2024)191).

$$R = (3.30^{+0.70}_{-0.65}) \times 10^{-3} = (3.30 \boxed{^{+0.63}_{-0.55}(\text{stat})} ^{+0.32}_{-0.34}(\text{syst})) \times 10^{-3}$$

All common sources of **systematic uncertainties** (experimental, background normalisation, modelling of common MC processes) **correlated.**

- **Cancelation of correlated systematics** in R wrt $t\bar{t}\gamma\gamma$ Xsection measurement
  - Mainly **experimental** source and **data-driven estimations of fake-photon backgrounds** cancel out significantly
- But **statistical uncertainty is prevailing** ~18% relative uncertainty

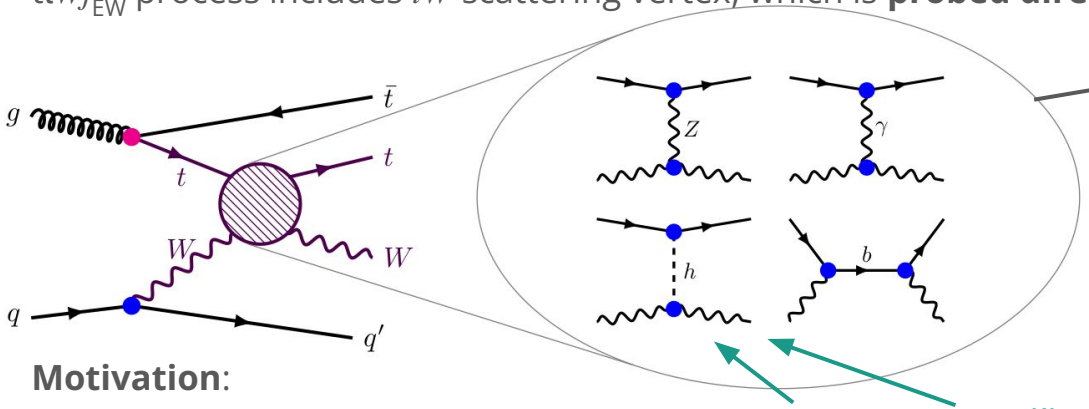
$t\bar{t}\gamma$ measurement (JHEP10(2024)191)



arXiv:2509.19038 (PRD)

Search for electroweak $t\bar{t}W$+jet and EFT interpretation

$t\bar{t}Wj_{EW}$ process includes tW-scattering vertex, which is **probed directly for the first time!**



Probes ***t–Z*** and **top Yukawa** (y_t) SM **couplings**

Motivation:
Probe EWSB in SM and beyond through EFT using O_{Ht} and $O_{HQ}^{(1)}$

$t\bar{t}Wj_{EW}$:

- Produces forward jet with higher η than QCD $t\bar{t}W$
  → good for experimental separation
- Higher-order effect of $t\bar{t}W$ (ease observed tension of $t\bar{t}W$ with SM)

- In $t\bar{t}Wj_{EW}$ the energy growth leads to a **significant quadratic dependence** in c_i/Λ^2
  - Linear interference term is strongly suppressed due to symmetries in SM amplitude
  - Helps to separate O_{Ht} and $O_{HQ}^{(1)}$ (suffer from degeneracies)
- In $t\bar{t}Z$ or $t\bar{t}H$, **linear** terms (in c_i/Λ^2) are **dominant**

$$\frac{c_{Ht}}{\Lambda^2}O_{Ht} = \frac{c_{Ht}}{\Lambda^2}(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar{t}_R\gamma^\mu t_R)$$

$$\frac{c_{HQ}^{(1)}}{\Lambda^2}O_{HQ}^{(1)} = \frac{c_{HQ}^{(1)}}{\Lambda^2}(H^\dagger \overleftrightarrow{D}_\mu H)(\bar{Q}_L\gamma^\mu Q_L)$$

=> modify EW couplings of top quark

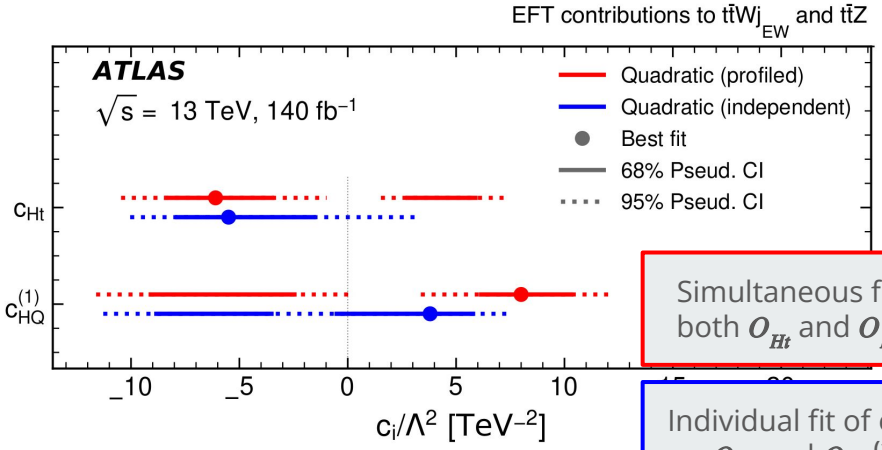
arXiv:2509.19038 (PRD)

Search for electroweak $t\bar{t}W$+jet and EFT interpretation

$t\bar{t}Wj_{EW}$ = single-lepton decay of $t\bar{t}$, leptonic decay of W + forward jet

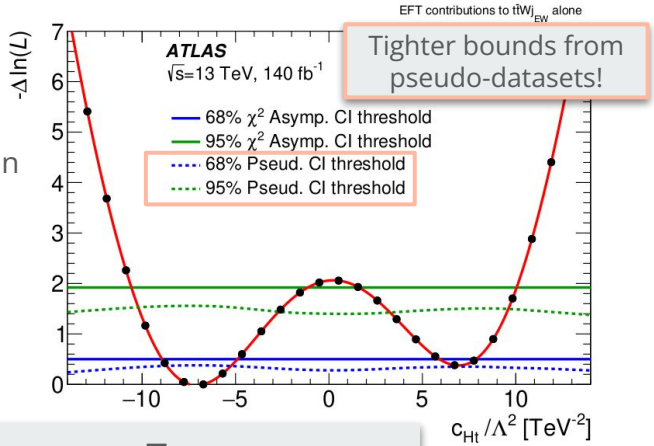
- At least 4 jets
- Same-charge pair of leptons (leptonic top and W of same charge)
- Expected high energy scale: high m_{ll} > 125 GeV, leading (subleading) lepton p_T ($l_{0(1)}$) > 80 GeV (40 GeV)

Signal in SR measured with **simultaneous binned profile-likelihood fit** of signal+background



Simultaneous fit of both O_{Ht} and $O_{HQ}^{(1)}$

Individual fit of each O_{Ht} and $O_{HQ}^{(1)}$



Tighter bounds from pseudo-datasets!

95% CL_S upper limit on σ ($t\bar{t}Wj_{EW}$) < 251 fb
→ consistent with SM cross section of 47.7 fb

Confidence intervals extracted using:
- Asymptotic likelihood approach (Wilk's theorem)
- **Pseudo-datasets**

Measurement **dominated** by **systematic uncertainties**
(normalization and modeling of QCD $t\bar{t}W$,
jet modeling and estimate of fake-lepton contributions)

arXiv:2509.19038 (PRD)

Search for electroweak $t\bar{t}W$+jet and EFT interpretation

$t\bar{t}Wj_{EW}$ alone

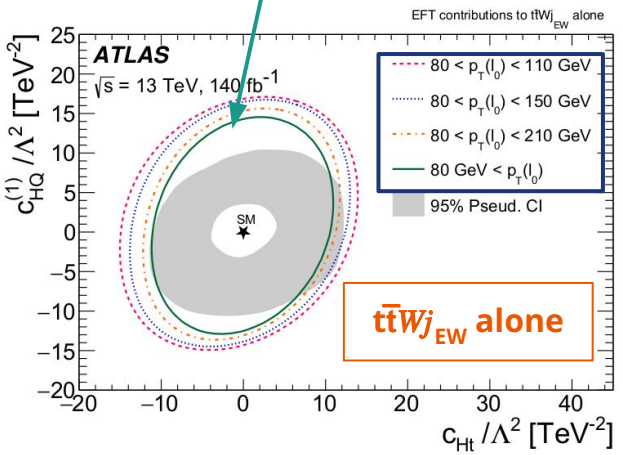
- Fits **prefer a non-zero value** for EFT Wilson coefficients

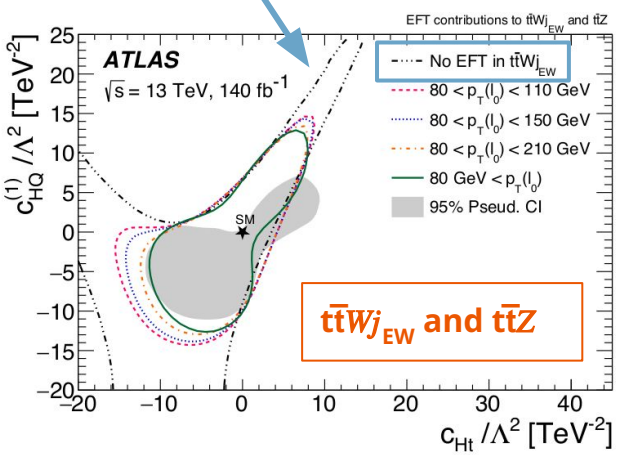
(data-MC difference observed in the highest p_T bin)

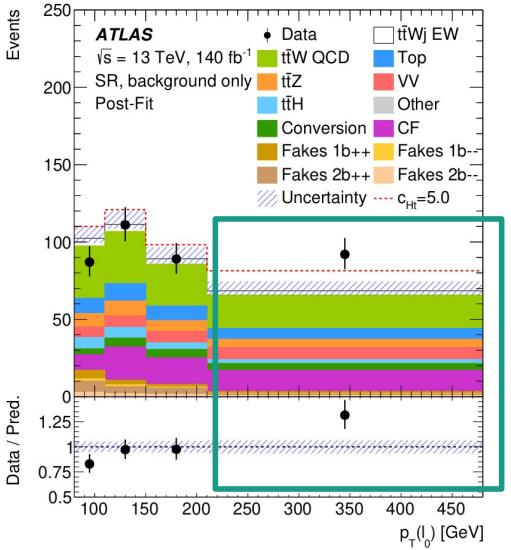
$t\bar{t}Wj_{EW}$ and $t\bar{t}Z$

- 95% confidence interval **contains the SM expectation**

Degeneracies btw operators present in limits from **$t\bar{t}Z$ alone reduced by inclusion of $t\bar{t}Wj_{EW}$**







Signal region is re-binned in $p_T(l_0)$ **to maximize the sensitivity** to the EFT operators
→ limits improving with larger p_T

The EFT sensitivity limited by statistics, especially at high p_T → increased sensitivity expected with Run 3

arXiv:2510.23372 (JHEP)

Constraints on EFT via quadruple-differential angular decay rates from t-channel single top

Single top t-channel = **largest rate** among all channels

- provides **unique access to the imaginary sector** of the Lagrangian (polarised top quark is produced)

Quadruple-differential decay spectrum determined by four angles (θ, ϕ, θ^*, ϕ^*) used to probe EFT contribution through Fourier analysis

5 EFT operators:

- 4-quark operator $O_{Qq}^{3,1} = \left(\bar{Q}\gamma_\mu\tau^I Q\right)\left(\bar{q}_i\gamma^\mu\tau^I q_i\right)$

SM structure, **only affects overall cross-section**

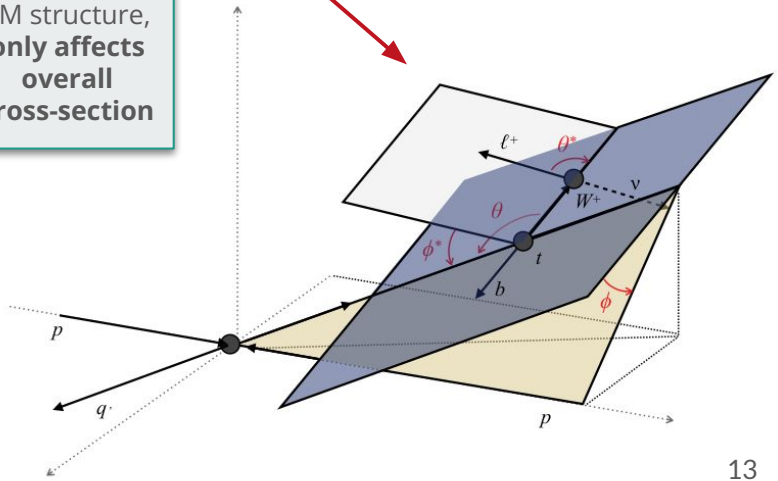
- Modifying tWb vertex: $O_{\varphi Q}^3 \supset -\frac{gv^2}{\sqrt{2}}\bar{b}_L\gamma^\mu t_L W_\mu^-,$

Imaginary Wilson coefficients considered for O_{bW} and O_{tW}: C_{tW} , C_{tW}^I , C_{bW} , C_{bW}^I

$$O_{\varphi tb} \supset \left[\frac{gv^2}{2\sqrt{2}}\bar{b}_R\gamma^\mu t_R W_\mu^-\right]^\dagger,$$

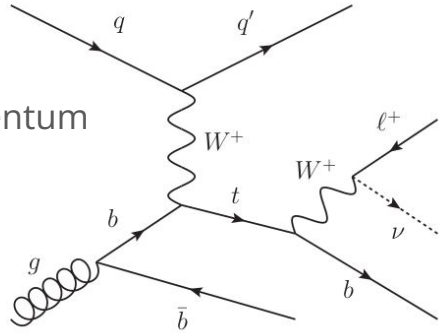
$$O_{tW} \supset 2v\bar{b}_L i\sigma^{\mu\nu} q_\nu t_R W_\mu^-,$$

$$O_{bW} \supset \left[2v\bar{b}_R i\sigma^{\mu\nu} q_\nu t_L W_\mu^-\right]^\dagger$$



arXiv:2510.23372 (JHEP)

Constraints on EFT via quadruple-differential angular decay rates from t-channel single top



Signal events = light spectator jet, b-jet, lepton and missing transverse momentum

- SR and 2 CRs (CR-W, CR-$t\bar{t}$) divided to 4 channels by lepton charge and top p_T (< 80 GeV; > 80 GeV)
  - *Improves sensitivity to EFT* (impact high/low-p_T regions differently)

Strategy = perform **Fourier analysis of quadruple-differential angular decay rate** at detector level, using a set of orthogonal basis functions (***M*-functions**)

$$\frac{1}{\Gamma}\frac{d\Gamma}{d\Omega d\Omega^*} = \sum_{j_1 j_2 m' m} c_{m' m}^{j_1 j_2} M_{m' m}^{j_1 j_2}(\cos\theta, \phi, \cos\theta^*, \phi^*)$$

Fourier coefficients obtained via simple average over dataset:

$$c_{m' m}^{j_1 j_2} = \frac{\sum_{i=1}^{N} w_i M_{m' m}^{j_1 j_2}(\cos\theta_i, \phi_i, \cos\theta_i^*, \phi_i^*)}{\sum_{i=1}^{N} w_i}$$

MC weight

Observables:

- M-function coefficients $c_{m' m}^{j1, j2}$
- SR and CRs event yields

-> **Gaussian likelihood maximized to extract Wilson coefficients**

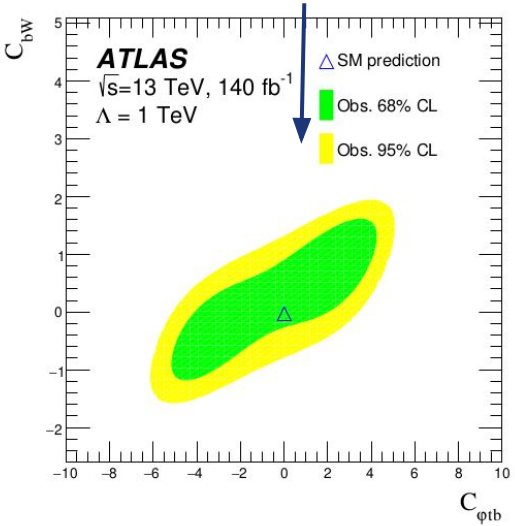
- Dependence on Wilson coefficients is modelled using **morphing** (except $C_{\varphi Q}$)
  (in both t-channel single-top and $t\bar{t}$ processes)

arXiv:2510.23372 (JHEP)

Constraints on EFT via quadruple-differential angular decay rates from t-channel single top

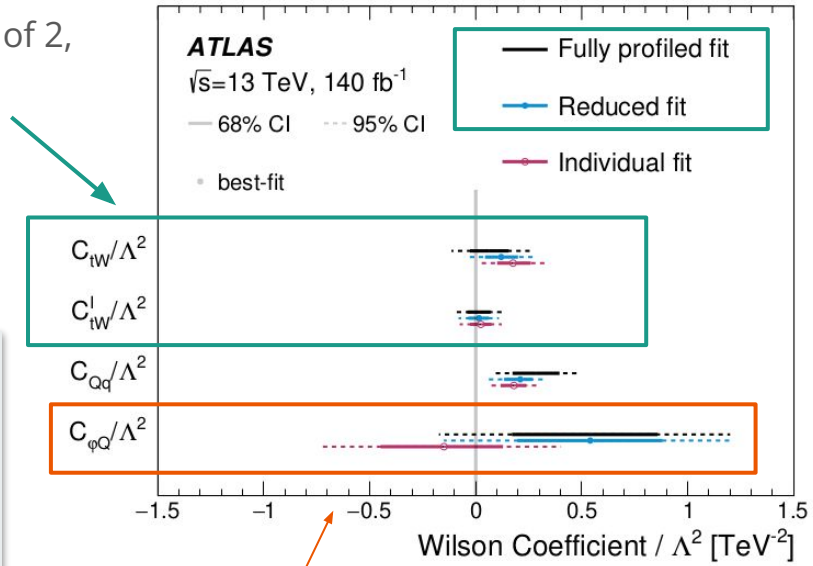
Bound for C_{tW} **improves** wrt (JHEP 08 (2020) 051) by a factor of 2, while assuming other WCs ≠ zero (**profiled/reduced fit**)

Limits on $C_{\varphi t\, b}$ **and** $C_{\,bW}$ **improve** with respect to measurement of F_R (JHEP 08 (2020) 051) by providing **constraints along the blind direction** of F_R



CMS (JHEP 12 (2023) 068) derived **mostly tighter constraints**,

- no information on the imaginary parts of WCs



Limit on $C_{\varphi Q}$ is improved by a factor of 2 with respect to (JHEP 05 (2024) 305).

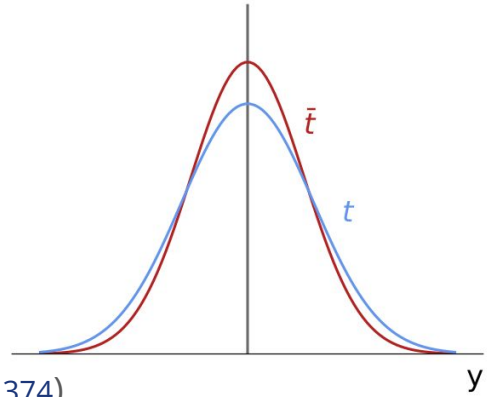
Systematic uncertainty is dominant

- No individual systematics larger than statistical uncertainty

All best-fit points are **consistent with the SM** expectation within 2σ.

ATL-PHYS-PUB-2025-037

Combined EFT interpretation of $t\bar{t}$ rapidity and energy asymmetry measurements



Combination of 2 published measurements of charge asymmetry A_C:

- **rapidity asymmetry A_Y** in $t\bar{t}$ as a function of $m^{t\bar{t}}$ (JHEP 08 (2023) 077) and

$$A_Y = \frac{N(\Delta|y| > 0) - N(\Delta|y| < 0)}{N(\Delta|y| > 0) + N(\Delta|y| < 0)} \qquad \Delta|y| = |y_t| - |y_{\bar{t}}|$$

- **energy asymmetry A_E** in $t\bar{t}$ + jet as a function of θ_j (Eur. Phys. J. C 82 (2022) 374)

$$A_E(\theta_j) = \frac{\sigma_{E,A}}{\sigma_{E,S}} = \frac{\sigma^{\text{opt}}(\theta_j|\Delta E > 0) - \sigma^{\text{opt}}(\theta_j|\Delta E < 0)}{\sigma^{\text{opt}}(\theta_j|\Delta E > 0) + \sigma^{\text{opt}}(\theta_j|\Delta E < 0)} \qquad \Delta E = E_t - E_{\bar{t}}$$

$$\sigma^{\text{opt}}(\theta_j) = \sigma(\theta_j|y_{t\bar{t}j} > 0) + \sigma(\pi - \theta_j|y_{t\bar{t}j} < 0), \quad \theta_j \in [0, \pi]$$

θ_j - scattering angle of associated jet w.r.t. z-axis

Measurements of A_Y and A_E **are complementary** (*sensitive differently to EFT operators*)
Strategy:

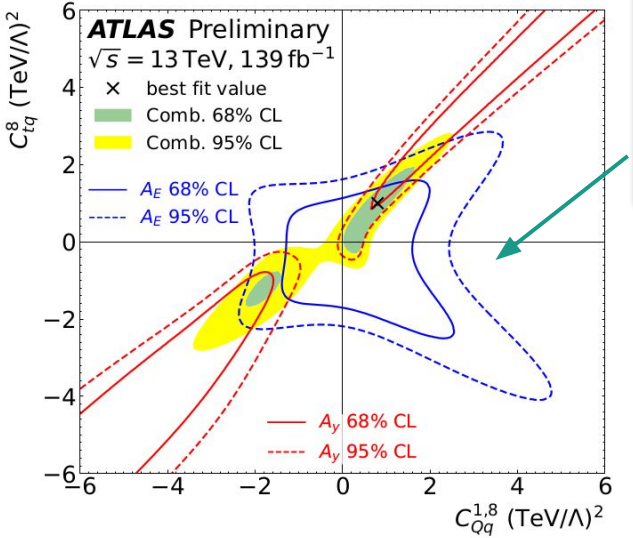
- Simultaneous extraction of A_Y in 5 $m^{t\bar{t}}$ bins and A_E in 3 θ_j bins with proper treatment of correlations (statistical and systematic) → asymmetries obtained by minimising a χ^2 likelihood function

ATL-PHYS-PUB-2025-037

Combined EFT interpretation of $t\bar{t}$ rapidity and energy asymmetry measurements

Sensitivity of combination similar to individual measurements = improvement of A_C uncertainties by about 1%

- Combination brings little improvement for constraints on single Wilson coefficients (other WCs set to 0 in fit)

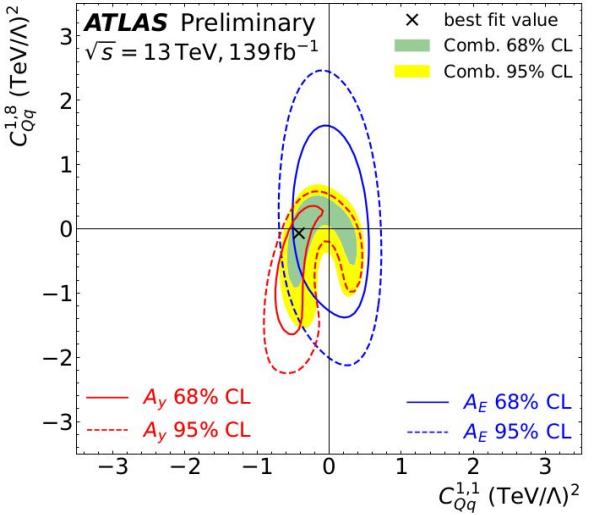


- But blind directions in the $(C_{Qq}^{1,8}, C_{tq}^{8})$ plane in A_Y measurement resolved by combination

6 EFT operators considered:

$$O_{Qq}^{1,8} = (\bar{Q}_L \gamma_\mu T^A Q_L)(\bar{q}_L \gamma^\mu T^A q_L)$$
$$O_{tq}^{8} = (\bar{q}_L \gamma_\mu T^A q_L)(\bar{t}_R \gamma^\mu T^A t_R)$$
$$O_{tu}^{8} = (\bar{t}_R \gamma_\mu T^A t_R)(\bar{u}_R \gamma^\mu T^A u_R)\,.$$

Different shape of bounds from A_Y and A_E due to different color-singlet/color-octet contribution to $t\bar{t}$ and $t\bar{t}$+j



$$O_{Qq}^{1,1} = (\bar{Q}_L \gamma_\mu Q_L)(\bar{q}_L \gamma^\mu q_L)$$
$$O_{tq}^{1} = (\bar{q}_L \gamma_\mu q_L)(\bar{t}_R \gamma^\mu t_R)$$
$$O_{tu}^{1} = (\bar{t}_R \gamma_\mu t_R)(\bar{u}_R \gamma^\mu u_R)$$

Feature different chiral and color structures

@

© 2021-2025 CERN

Summary

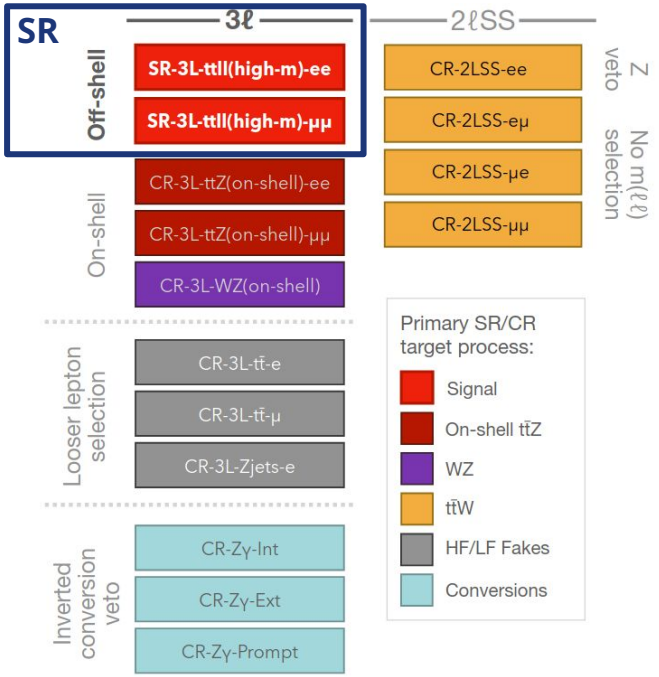
- Rare $t\bar{t}\gamma\gamma$ **process observed for the first time!**
- **Unique tW-scattering vertex** embedded in $t\bar{t}Wj_{EW}$ process **exploited to gain new sensitivity to EFT**
  - interplay btw $t\bar{t}Wj_{EW}$ and $t\bar{t}Z$ studied => degenerate direction in (O_{Ht} ,$O_{HQ}^{(1)}$) closed when both considered!
- **Blind directions** in ($C_{Qq}^{1,8}$, C_{tq}^{8}) plane in A_Y measurement **resolved by combination** of rapidity and energy asymmetry!
- High-precision probe of EFT through **Fourier-based angular analysis** in single-top t-channel
- **LFU violation tested** by difference between flavour-dependent EFT operators in $t\bar{t}\ell^+\ell^-$ process
- Increased sensitivity to EFT expected with Run 3 data
- **Many more results from ATLAS top quark group!**

Back up

Eur. Phys. J. C 85 (2025) 1434

High mass $t\bar{t}\ell^+\ell^-$ and LFU-inspired EFT interpretation

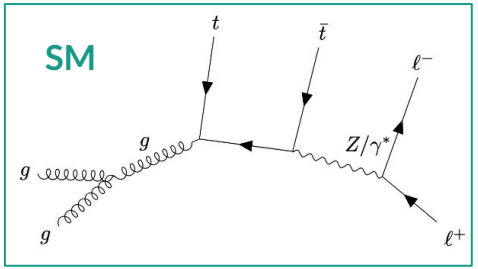
Measure $t\bar{t}\ell^+\ell^-$ (ℓ = e,μ) & high mass: $m_{\ell\ell} > m_Z + 10$ GeV => **sensitivity to some 4-fermion EFT operators**

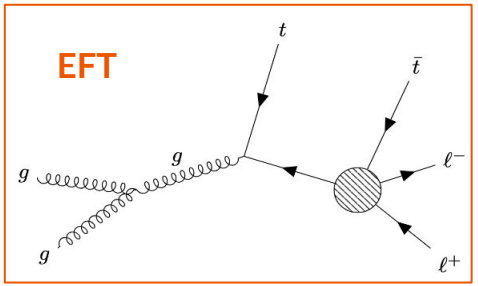


Flavour-specific EFT operators can probe flavour universality violation!

$$\mathcal{L}_{eff} = \mathcal{L}^{(4)}_{SM} + \frac{1}{\Lambda}\sum_i C_i^{(5)} O_i^{(5)} + \frac{1}{\Lambda^2}\sum_i C_i^{(6)} O_i^{(6)} + \mathcal{O}\left(\Lambda^{-3}\right)$$

Large impact of EFT in high $m_{\ell\ell}$ bins, but very low $t\bar{t}\ell^+\ell^-$ statistics ($m_{\ell\ell}$ > 550 GeV)
→ CR to constrain $t\bar{t}W$, SM $t\bar{t}Z$, WZ+jets, fake leptons



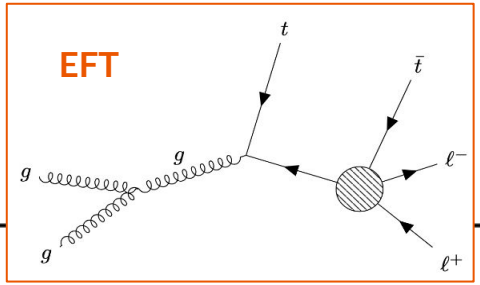


Maximum-likelihood fits of the signal and control categories to data performed.
Statistical uncertainties due to the limited size MC samples handled via dedicated parameters (the Beeston–Barlow "lite" technique)

Eur. Phys. J. C 85 (2025) 1434

High mass $t\bar{t}\ell^+\ell^-$ and LFU-inspired EFT interpretation

Measure $t\bar{t}\ell^+\ell^-$ & high mass: $m_{\ell\ell} > m_Z + 10$ GeV => **sensitivity to many 4-fermion operators in EFT** = some sensitive to flavour universality violation



$$\mathcal{L}_{eff} = \mathcal{L}_{SM}^{(4)} + \frac{1}{\Lambda}\sum_i C_i^{(5)} O_i^{(5)} + \frac{1}{\Lambda^2}\sum_i C_i^{(6)} O_i^{(6)} + \mathcal{O}\left(\Lambda^{-3}\right)$$

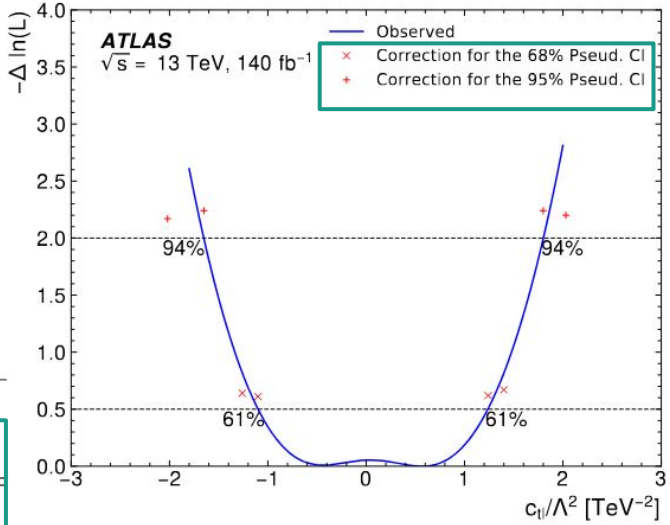
Operator	Definition	Description
O_{te}	$(\bar{e}_p\gamma_\mu e_r)(\bar{t}\gamma^\mu t)$	R-handed leptons and R-handed quarks in the $t\bar{t}\ell^+\ell^-$ vertex
O_{Qe}	$(\bar{Q}\gamma_\mu Q)(\bar{e}_p\gamma^\mu e_r)$	R-handed leptons and L-handed quarks in the $t\bar{t}\ell^+\ell^-$ and $b\bar{b}\ell^+\ell^-$ vertices
O_{tl}	$(\bar{l}_p\gamma_\mu l_r)(\bar{t}\gamma^\mu t)$	L-handed leptons and R-handed quarks in the $t\bar{t}\ell^+\ell^-$ vertex
O_{Ql}^1	$(\bar{l}_p\gamma_\mu l_r)(\bar{Q}\gamma^\mu Q)$	L-handed leptons and L-handed quarks in the $t\bar{t}\ell^+\ell^-$ and $b\bar{b}\ell^+\ell^-$ vertices, weak-singlet
O_{Ql}^3	$(\bar{l}_p\sigma^i\gamma_\mu l_r)(\bar{Q}\sigma^i\gamma^\mu Q)$	L-handed leptons and L-handed quarks in the $t\bar{t}\ell^+\ell^-$ and $b\bar{b}\ell^+\ell^-$ vertices, weak-triplet
O_{leQt}^1	$(\bar{l}_p^j e_r)\epsilon_{jk}(\bar{Q}^k t)$	Mixed L-/R-handed quarks and leptons in the $t\bar{t}\ell^+\ell^-$, $t\bar{b}\ell^+\ell^-$ and $b\bar{b}\ell^+\ell^-$ vertices, scalar
O_{leQt}^3	$(\bar{l}_p^j\sigma_{\mu\nu}e_r)\epsilon_{jk}(\bar{Q}^k\sigma^{\mu\nu}t)$	Mixed L-/R-handed quarks and leptons in the $t\bar{t}\ell^+\ell^-$, $t\bar{b}\ell\nu$, $\bar{t}b\ell\nu$ and $b\bar{b}\ell^+\ell^-$ vertices, tensor

Eur. Phys. J. C 85 (2025) 1434

High mass $t\bar{t}\ell^+\ell^-$ and LFU-inspired EFT interpretation

For the first time psedodata (toys) were used to calculate 68% (95%) coverage together with standard asymptotic assumption of profile-likelihood ratio

Wilks` theorem (standard asymptotic method) may not be valid to use in some cases (when **pure-EFT terms dominant**) => true coverage calculated from toy pseudodata!



$$O^{-}_{Ql} = (O^{1}_{Ql} - O^{3}_{Ql})$$

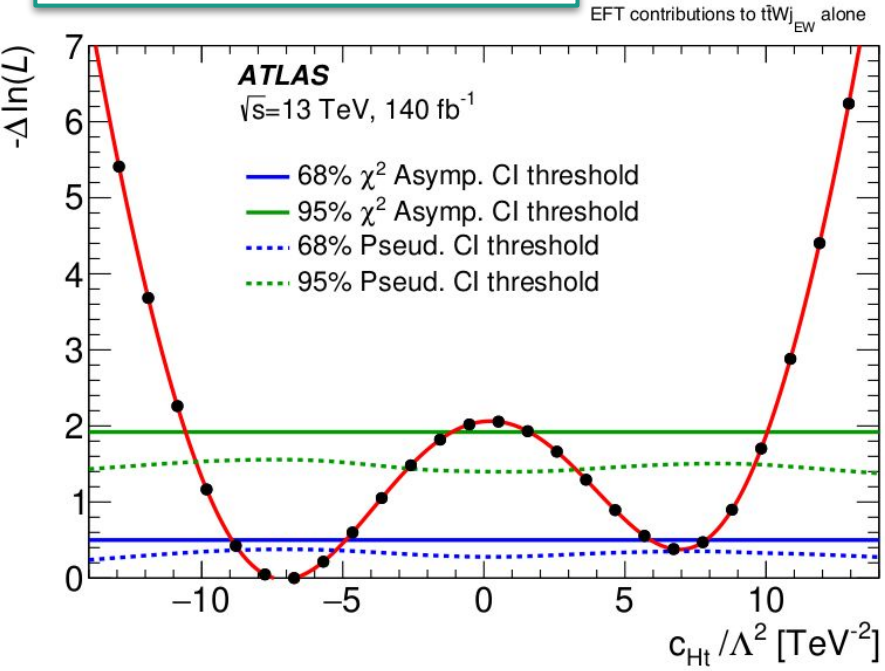
	$O(\Lambda^{-4})$ [TeV^{-2}]				
	Best fit	68% Asymp. CI	68% Pseud. CI	95% Asymp. CI	95% Pseud. CI
c_{tl}	−0.44	[−1.10, 1.24]	[−1.17, 1.31]	[−1.65, 1.80]	[−1.71, 1.86]
c_{te}	−0.45	[−1.05, 1.18]	[−1.21, 1.41]	[−1.57, 1.79]	[−1.64, 1.96]
c_{Qe}	−0.54	[−1.23, 1.19]	[−1.32, 1.32]	[−1.82, 1.83]	[−1.87, 1.88]
c^{-}_{Ql}	0.69	[−0.98, 1.41]	[−1.15, 1.74]	[−1.57, 2.03]	[−1.66, 2.33]
c^{1}_{leQt}	−0.61	[−1.51, 1.50]	[−1.55, 1.54]	[−2.27, 2.27]	[−2.32, 2.33]
c^{3}_{leQt}	−0.12	[−0.26, 0.26]	[−0.27, 0.27]	[−0.37, 0.37]	[−0.38, 0.38]

arXiv:2509.19038 (PRD)

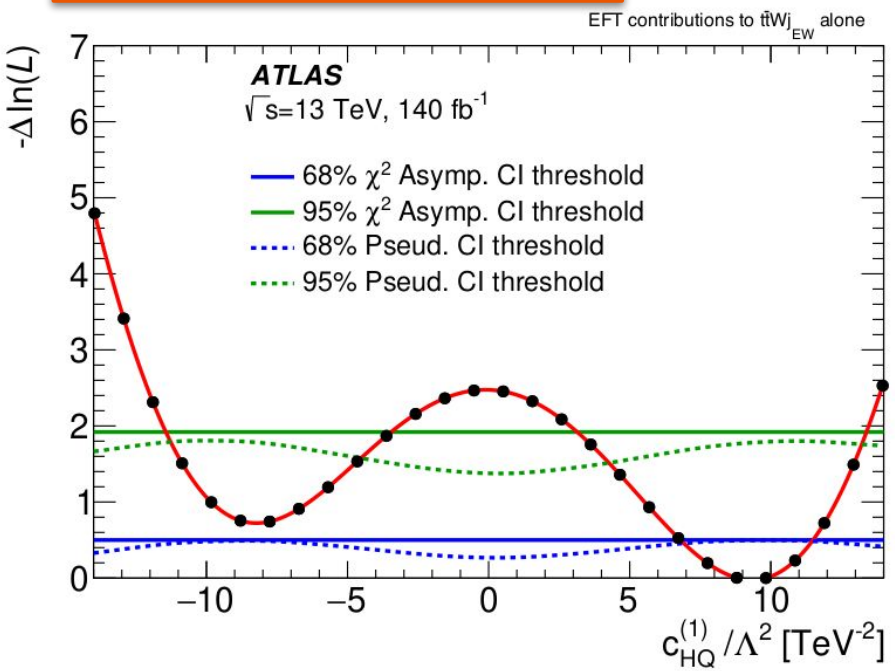
Search for electroweak $t\bar{t}W$+jet and EFT interpretation

Different bounds on EFT coefficients when using asymptotic approach and pseudo-datasets

EFT contributions to $t\bar{t}W_{EW}$ alone



EFT contributions to $t\bar{t}W_{EW}$ alone



Effective Field Theory (EFT)

Effective theory = approximation to physics at a higher energy scale

- Example: Standard Model effective field theory (SMEFT) (Phys. Rept. 793 (2019) 1)

In SMEFT:

- SM is treated as the EFT of an unknown BSM theory at a higher scale (Λ = 1 TeV)
- BSM effects can be parameterised by higher-dimensional operators in a power expansion

Effective SM Lagrangian $\mathcal{L}_{\text{eff}} = \mathcal{L}_{\text{SM}}^{(4)} + \frac{1}{\Lambda}\sum_i c_i^{(5)} O_i^{(5)} + \frac{1}{\Lambda^2}\sum_i c_i^{(6)} O_i^{(6)} + O\left(\frac{1}{\Lambda^3}\right) + \ldots,$

- where the c_i are the Wilson coefficients (WC) of operators O_i

Scale Λ = cut-off scale at which power expansion breaks down and BSM theory cannot be explained by the effective theory anymore

Because the top quark is much heavier than other SM fermions, BSM physics at higher scales could manifest itself at lower energies through its effective interactions, leading to detectable deviations from SM predictions