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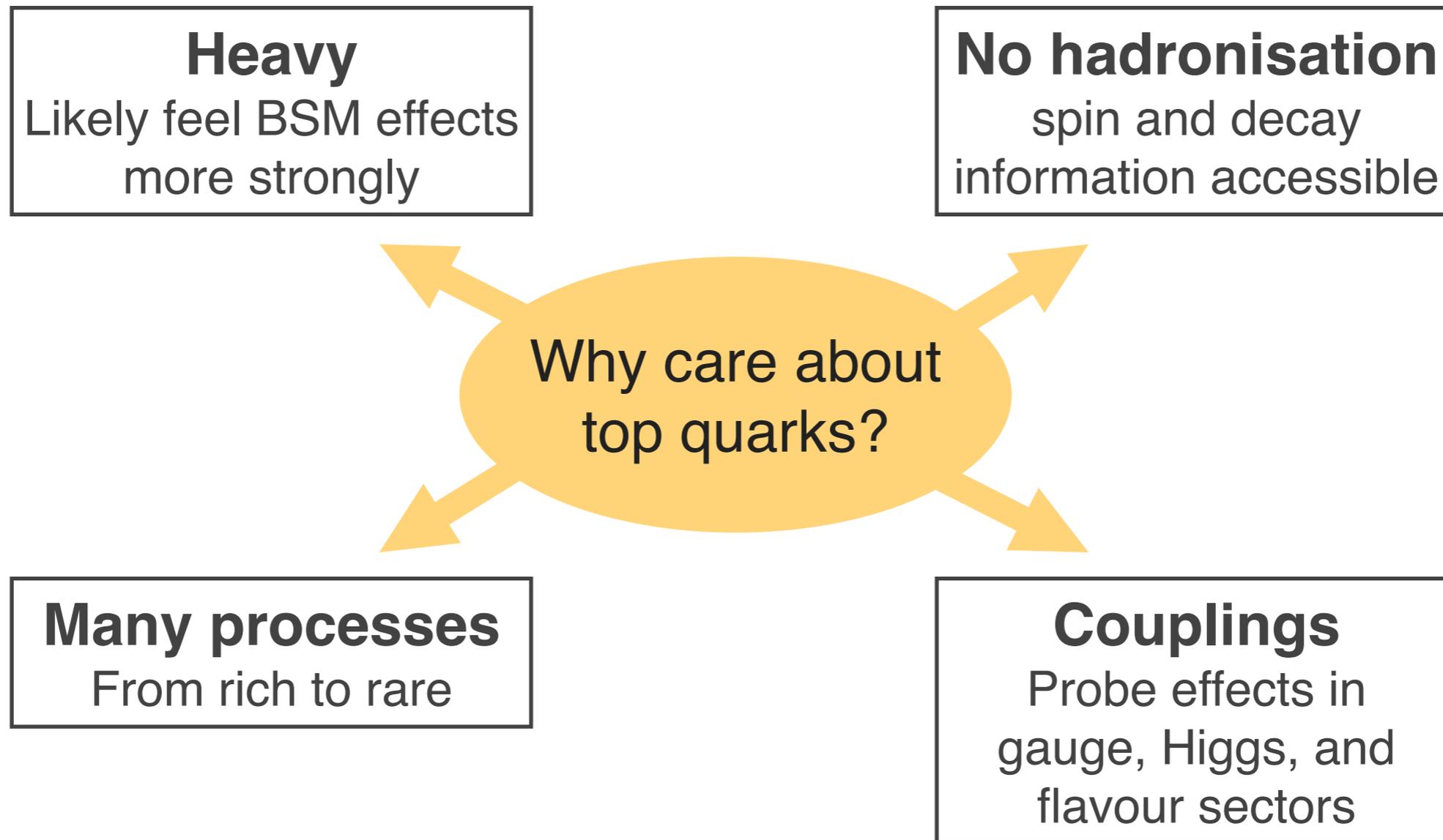
ATLAS EFT results in the top sector

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on behalf of the ATLAS Collaboration

32nd International Symposium on Lepton Photon Interactions at High Energies (LP2025)

25–30 Aug 2025

Top quark in ATLAS

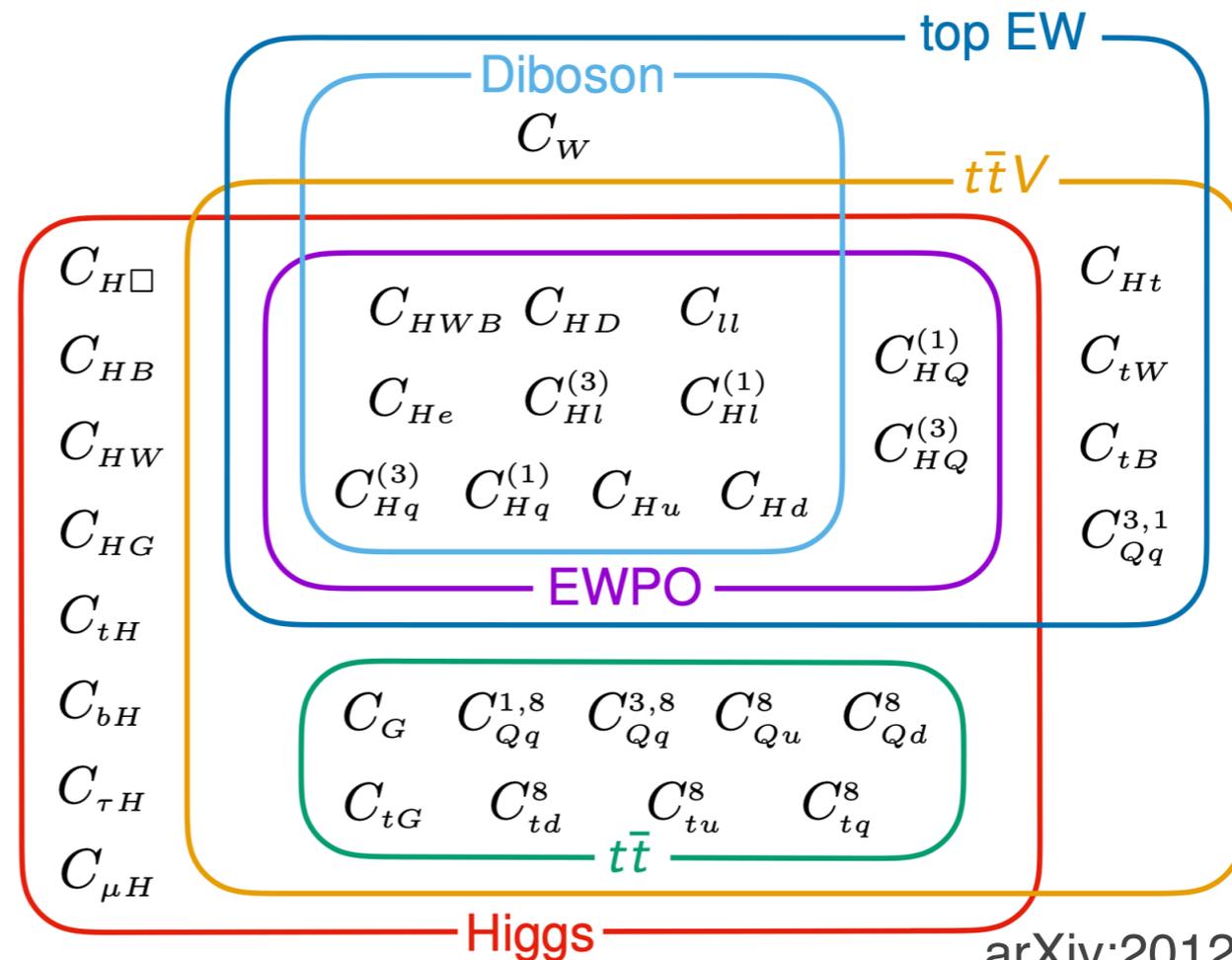


Effective Field Theory in ATLAS

- SMEFT: extension of Standard Model (SM) by adding higher-dimensional operators built upon SM fields

$$\mathcal{L}_{\text{SMEFT}} = \mathcal{L}_{\text{SM}} + \sum_i^{N_{d=6}} \frac{c_i}{\Lambda^2} O_i^{(6)} + \sum_j^{N_{d=8}} \frac{b_j}{\Lambda^4} O_j^{(8)} + \dots$$

- c_i : Wilson coefficients (WC) that parameterise effect of new physics. $c_i \neq 0 \Rightarrow$ new physics
- $\Lambda = 1\text{TeV}$ by convention



arXiv:2012.02779

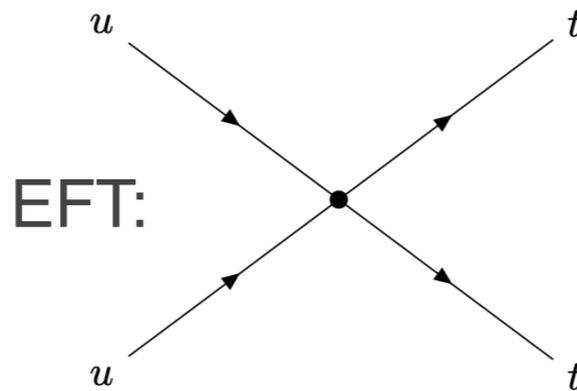
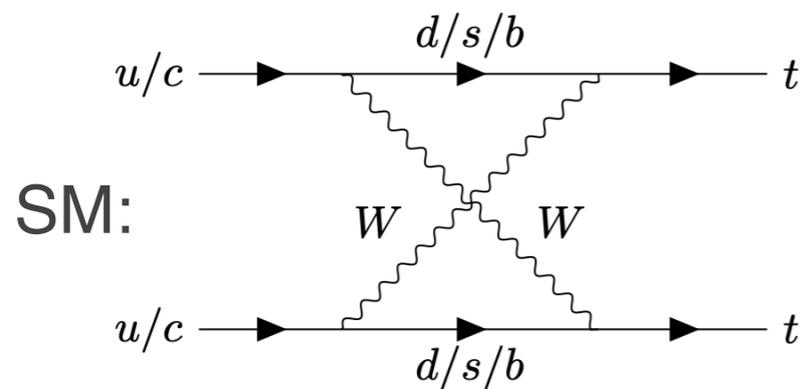
Search for same sign top pair production

JHEP 02 (2025) 084

Analysis overview

- Same-sign (SS) top-quark pair production is forbidden at leading order in the SM

- $\sigma_{\text{SM}}(pp \rightarrow tt) \approx 4 \cdot 10^{-15} \text{ pb @LHC}$



$$O_{tu}^{(1)} = [\bar{t}_R \gamma^\mu u_R] [\bar{t}_R \gamma_\mu u_R],$$

$$O_{Qu}^{(1)} = [\bar{Q}_L \gamma^\mu q_L] [\bar{t}_R \gamma_\mu u_R],$$

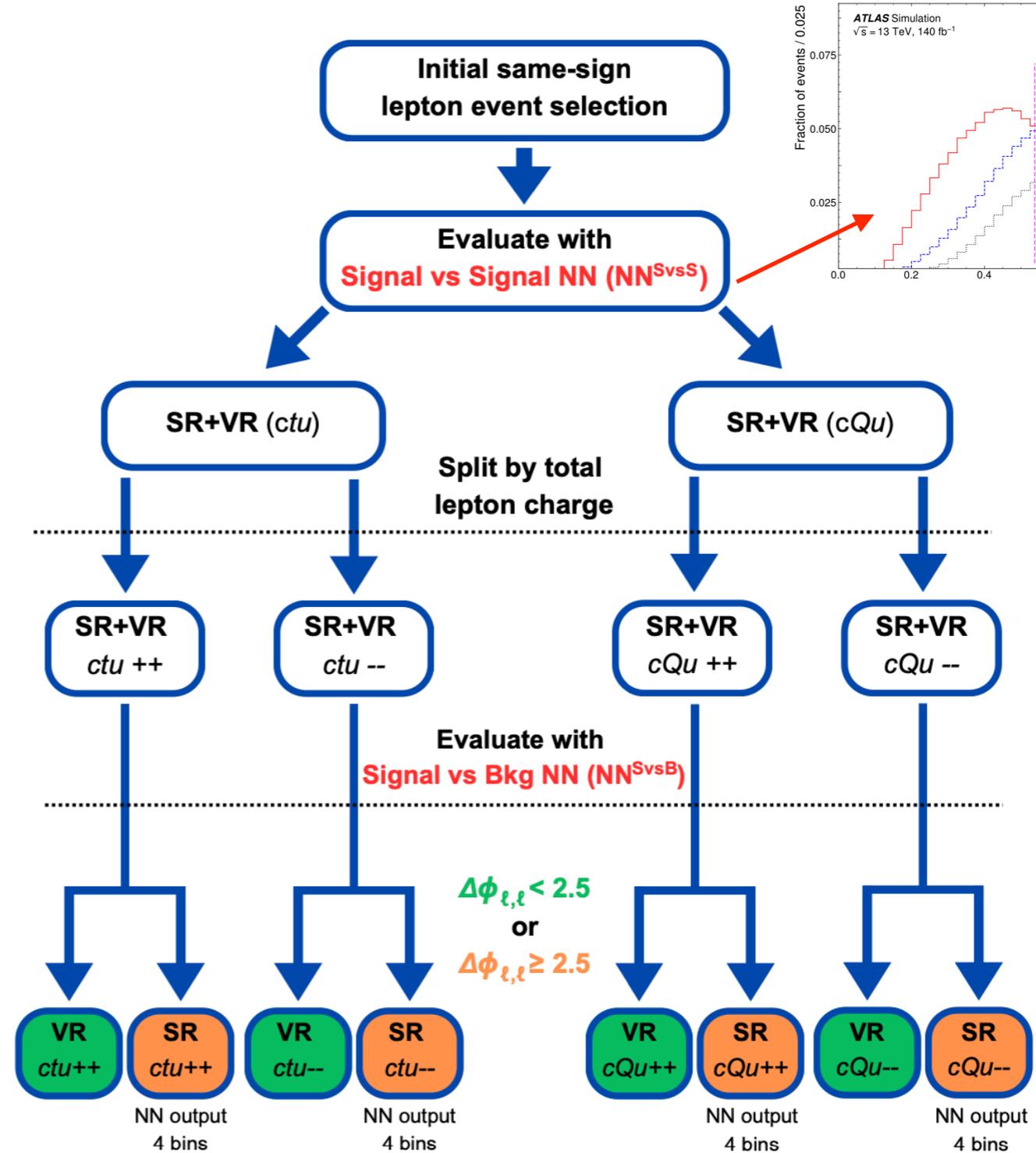
$$O_{Qu}^{(8)} = [\bar{Q}_L \gamma^\mu T^A q_L] [\bar{t}_R \gamma_\mu T^A u_R]$$

$O_{Qq}^{(1)}$ $O_{Qq}^{(3)}$ also enter but constrained previously in JHEP 03 (2008) 049

- Ideal playground to search for Beyond SM (BSM) physics
- Final states: two SS leptons and two jets
- Major backgrounds:
 - ttW production; Diboson production (VBS); ttZ&ttH production
 - Nine control regions (CR) defined to target non-prompt leptons, diboson and ttZ backgrounds

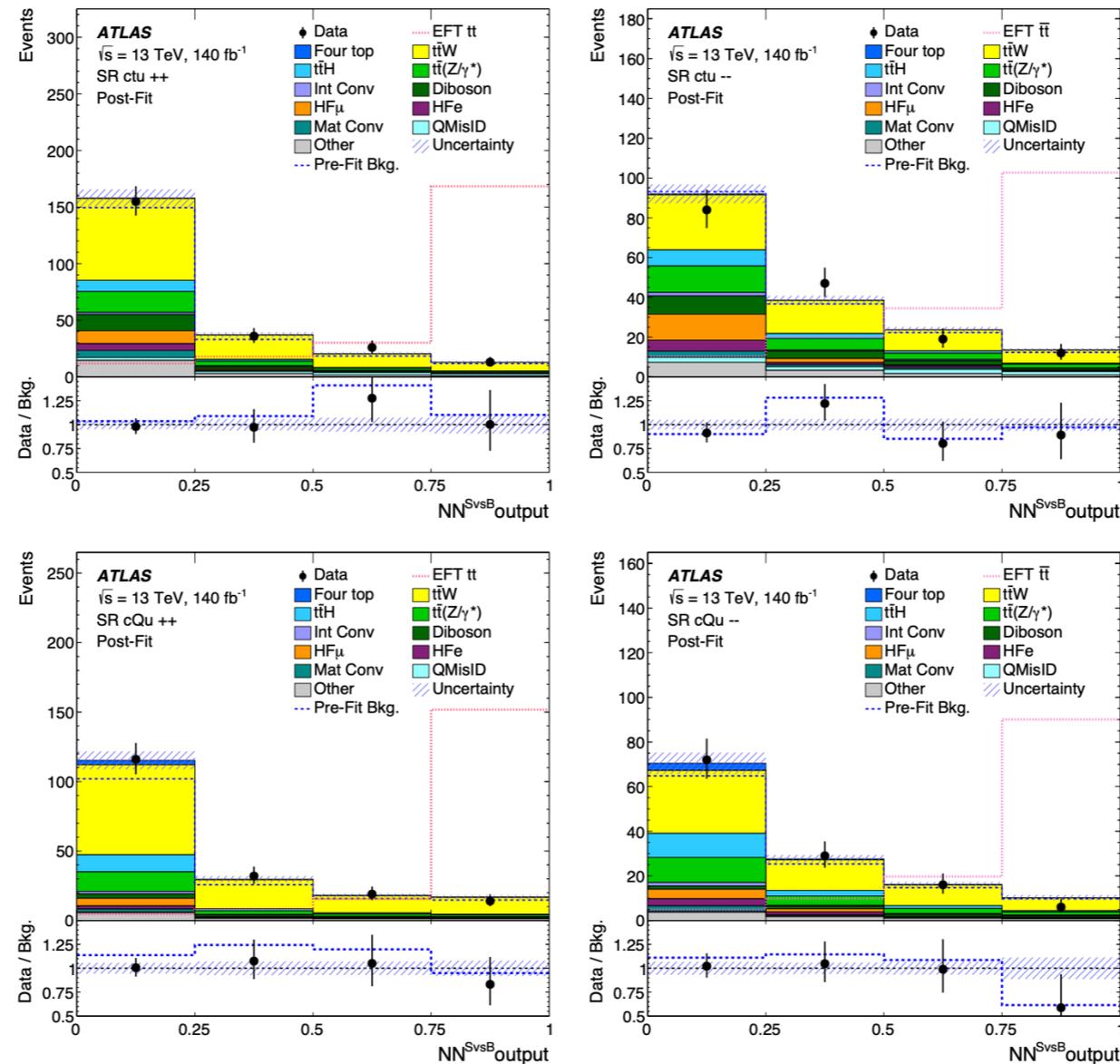
Analysis strategy

- Signal vs signal neural network (NN) to enhance the C_{Qu} and C_{tu} events
 - C_{Qu} and C_{tu} introduce different kinematics due to different chirality
- A neural network (NN) to distinguish signal from background
 - Normalisation of the dominant background ttW is constrained by the low NN output score in the SRs



Results

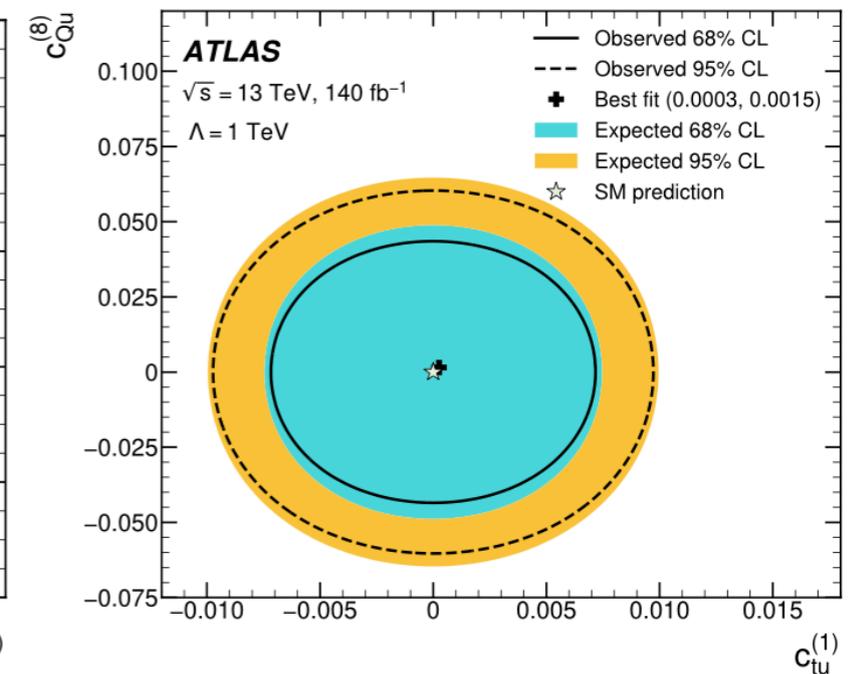
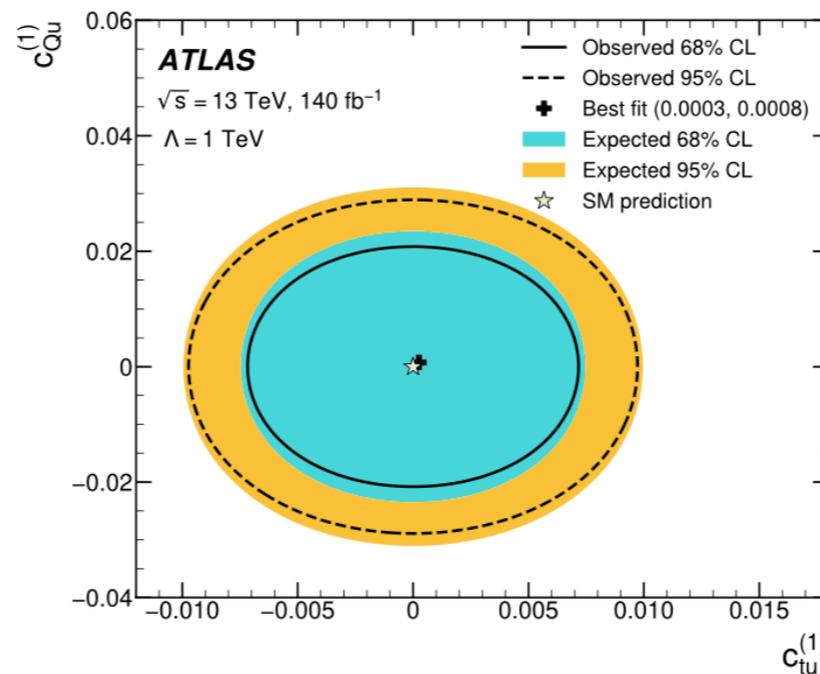
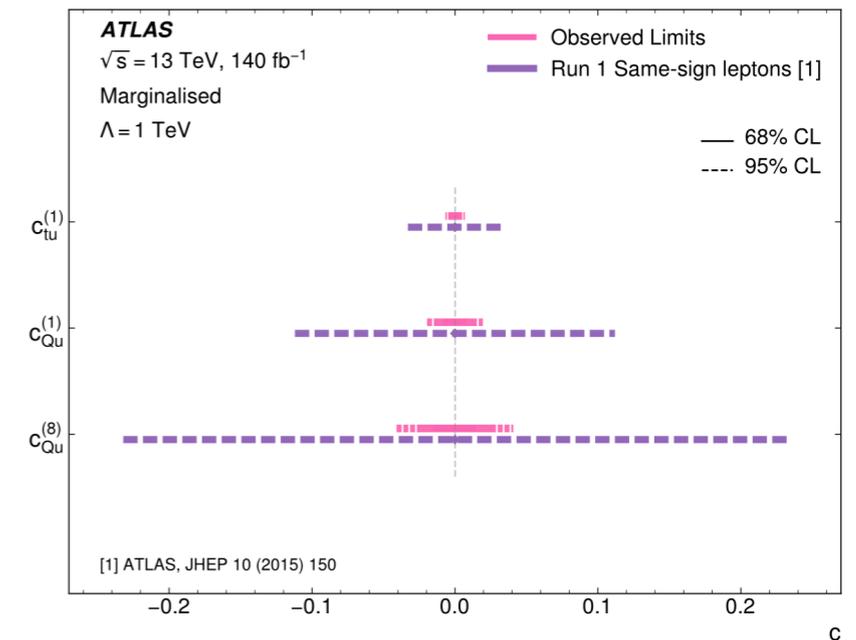
- Combined binned profile-likelihood fit over the **SRs+CRs** simultaneously



- The fitted signal yield in each of the four SRs is found to be ≤ 0.001
 - Upper limit of $\sigma(\text{pp} \rightarrow \text{tt}) < 1.6 \text{ fb}$.

EFT interpretation

- 1D likelihood scan for each WC to extract upper limit.
 - Other two WCs are floated in the fit
 - Improve from the previous Run 1 results by a factor of ~ 10
- 2D likelihood scans shows no strong correlations among the 3 measured WCs
- Precision limited by statistical uncertainties
 - Besides statistical uncertainties, modelling uncertainties on ttW have the largest impact on the final results

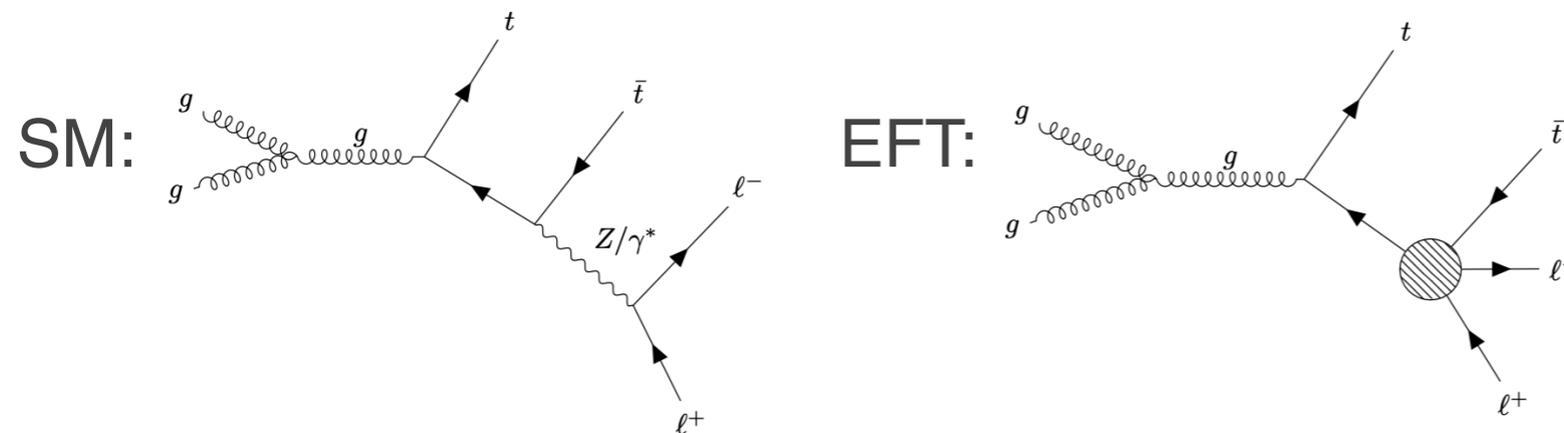


Measurement of high-mass $t\bar{t}l^+l^-$

[arXiv: 2504.05919](https://arxiv.org/abs/2504.05919) (Submitted to EPJC)

Analysis overview

- Extension of refined $t\bar{t}Z$: Measurement of $t\bar{t}l^+l^-$ production in high mass region - not previously measured in ATLAS
- $m_{ll} > m_Z + 10$ GeV: special sensitivity to **four-fermion top-lepton** operators through effective coupling:
 - Relevant Wilson Coefficients previously poorly constrained
 - Sensitivity to many four-fermion operators grows with the energy



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_{Ql}^1	$(\bar{l}_p \gamma_\mu l_r)(\bar{Q} \gamma^\mu Q)$
O_{Ql}^3	$(\bar{l}_p \sigma^i \gamma_\mu l_r)(\bar{Q} \sigma^i \gamma^\mu Q)$
O_{leQt}^1	$(\bar{l}_p^j e_r) \epsilon_{jk} (\bar{Q}^k t)$
O_{leQt}^3	$(\bar{l}_p^j \sigma_{\mu\nu} e_r) \epsilon_{jk} (\bar{Q}^k \sigma^{\mu\nu} t)$

- EFT effects quadratically dominated

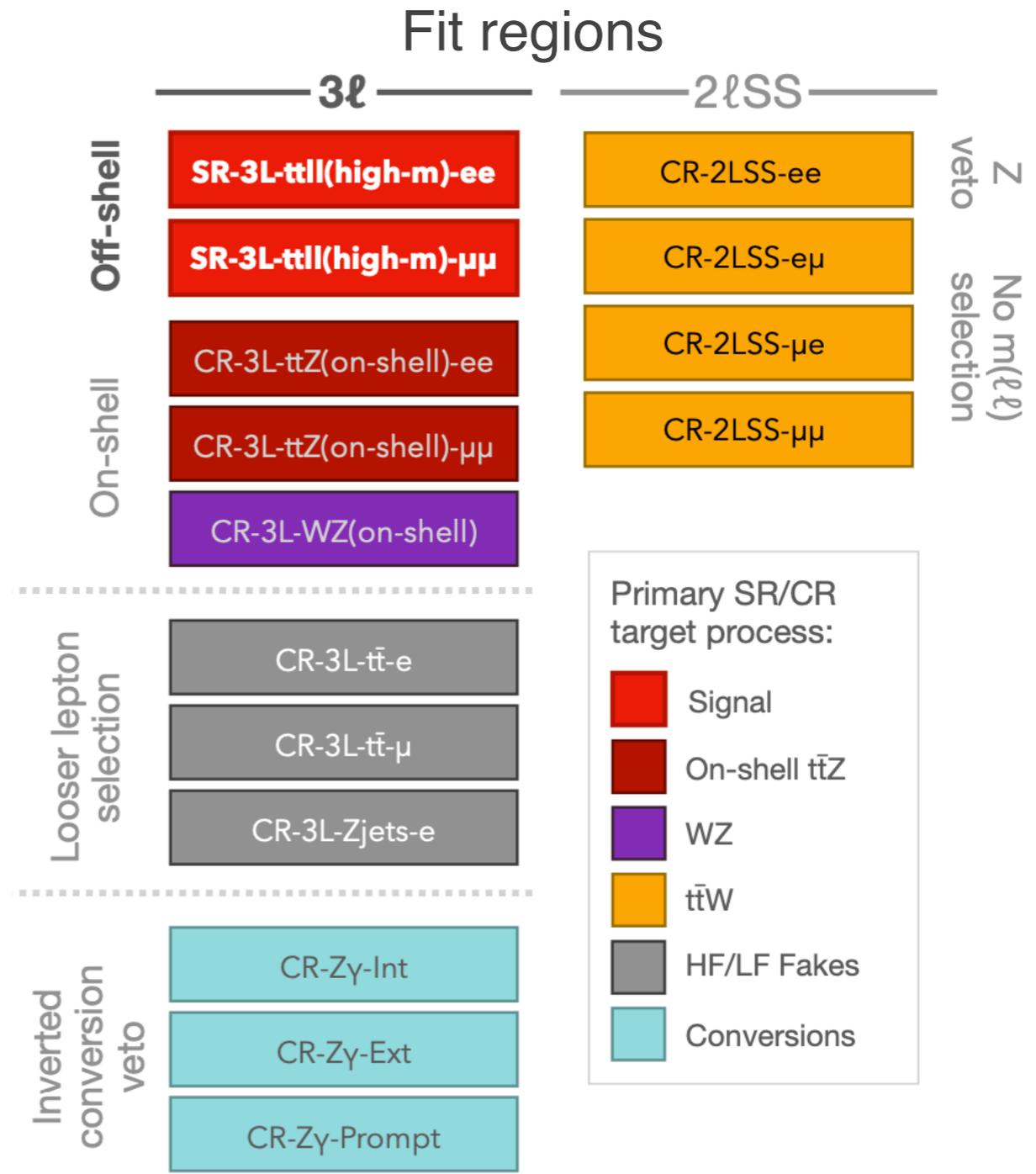
Analysis strategy

- Signal selection:

- 3-lepton final state, ≥ 1 opposite-sign, same-flavour (OSSF) pair
- ≥ 3 jets (≥ 1 b-jet)
- Split by lepton flavour ($t\bar{t}e^+e^-$ and $t\bar{t}\mu^+\mu^-$) - gain sensitivity to flavour-split WCs
- Aggressive binning in m_{ll} in SRs to benefit from large increase in quadratic EFT effects in high mass bins

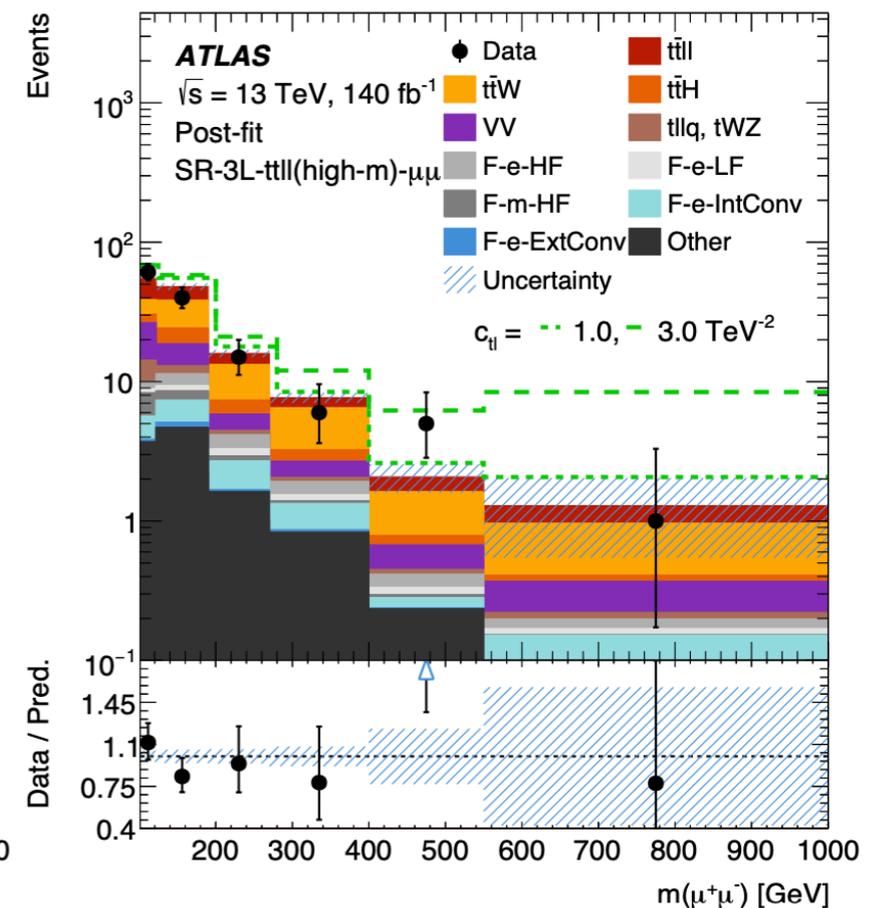
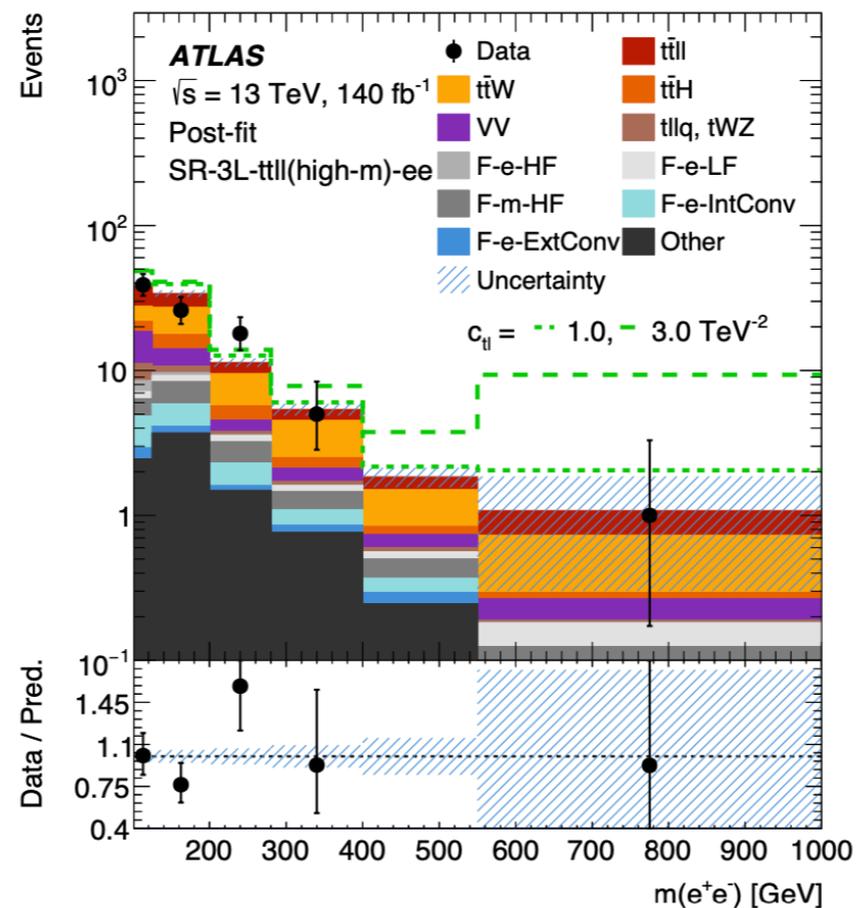
- Major background:

- ttV: on-shell ttZ and ttW; Di-boson: WZ; Non-prompt: fakes and photon conversions
- 13 Control Regions to constrain dominant ttW, ttZ, WZ, and fake-lepton backgrounds



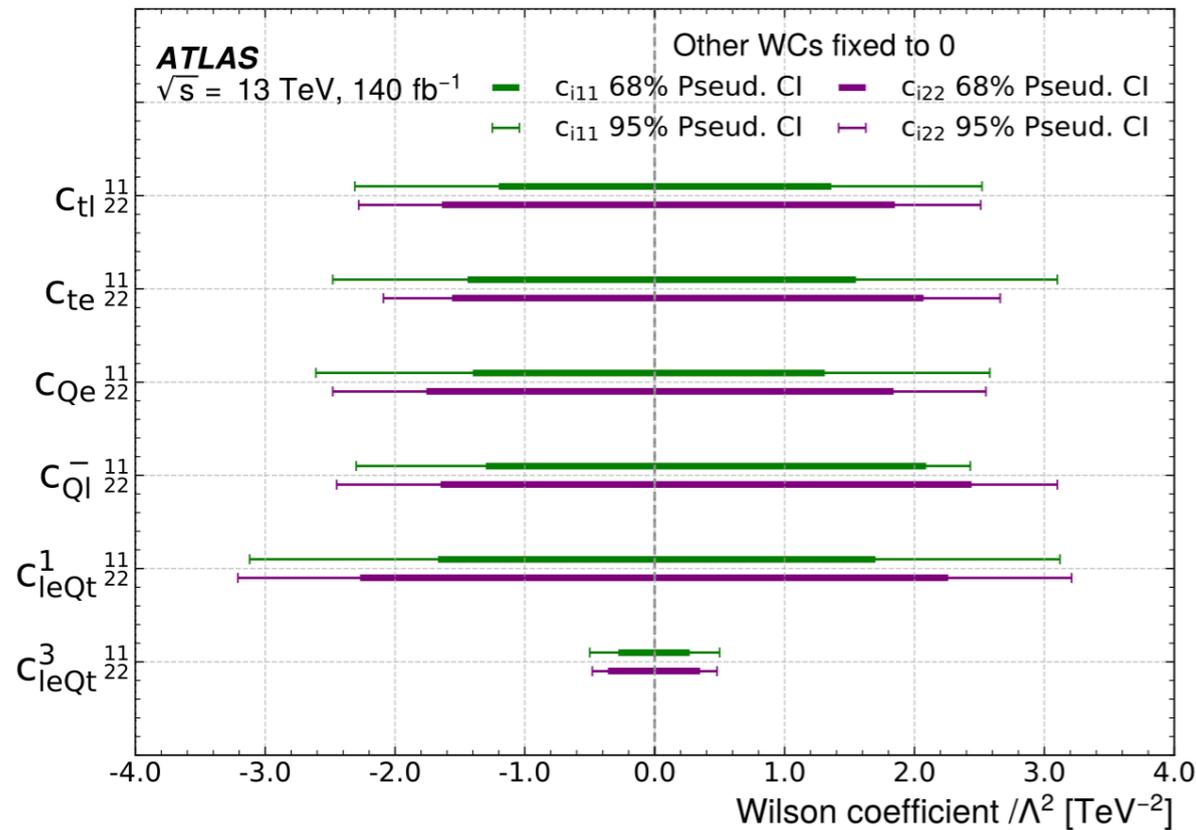
Results

- Inclusion of EFT effects
 - EFT effects only considered in signal
- Combined binned profile-likelihood fit performed in all regions with WCs free-floating
 - Final discrimination: dilepton mass m_{ll}
- Fits one WC at a time (other WCs = 0) - **results compatible with SM expectation**
- Statistically dominated



EFT interpretation

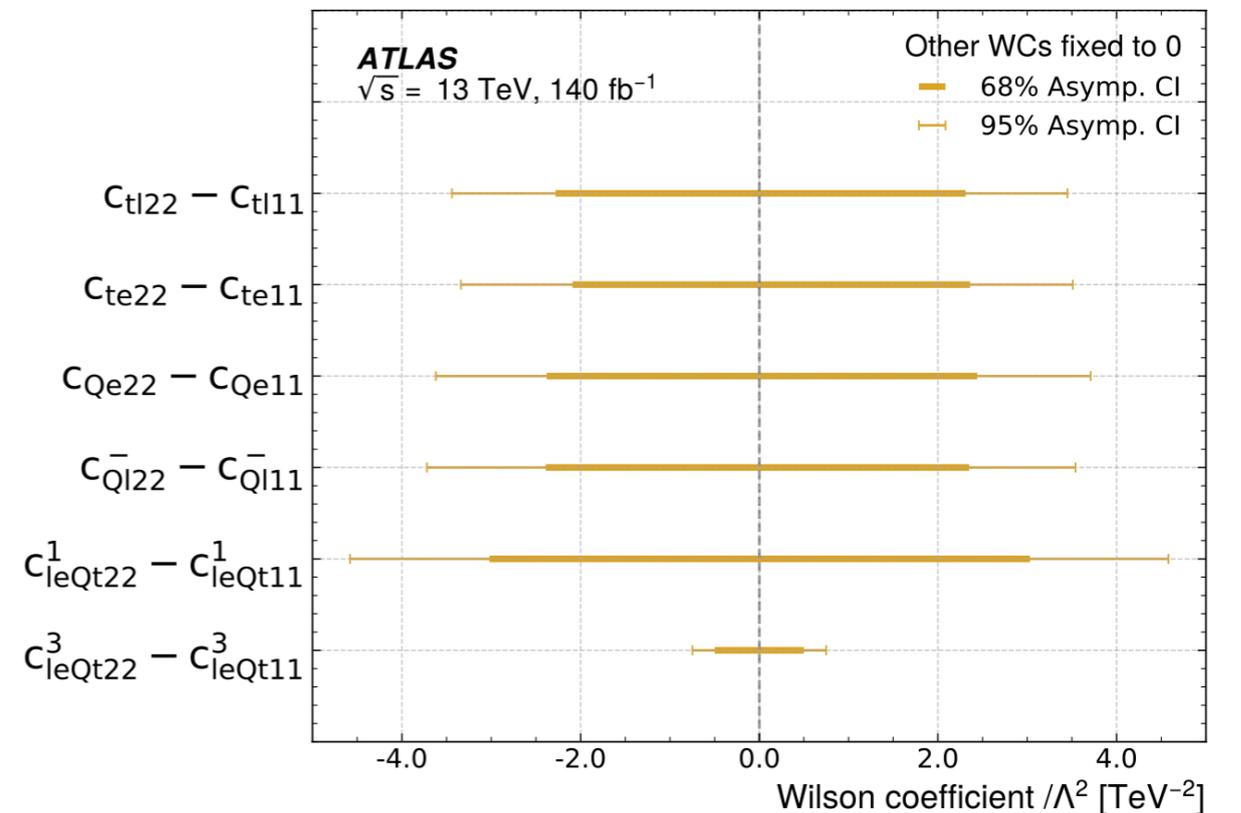
- Flavour inclusive



Results derived from pseudo-experiments

- Flavour separate

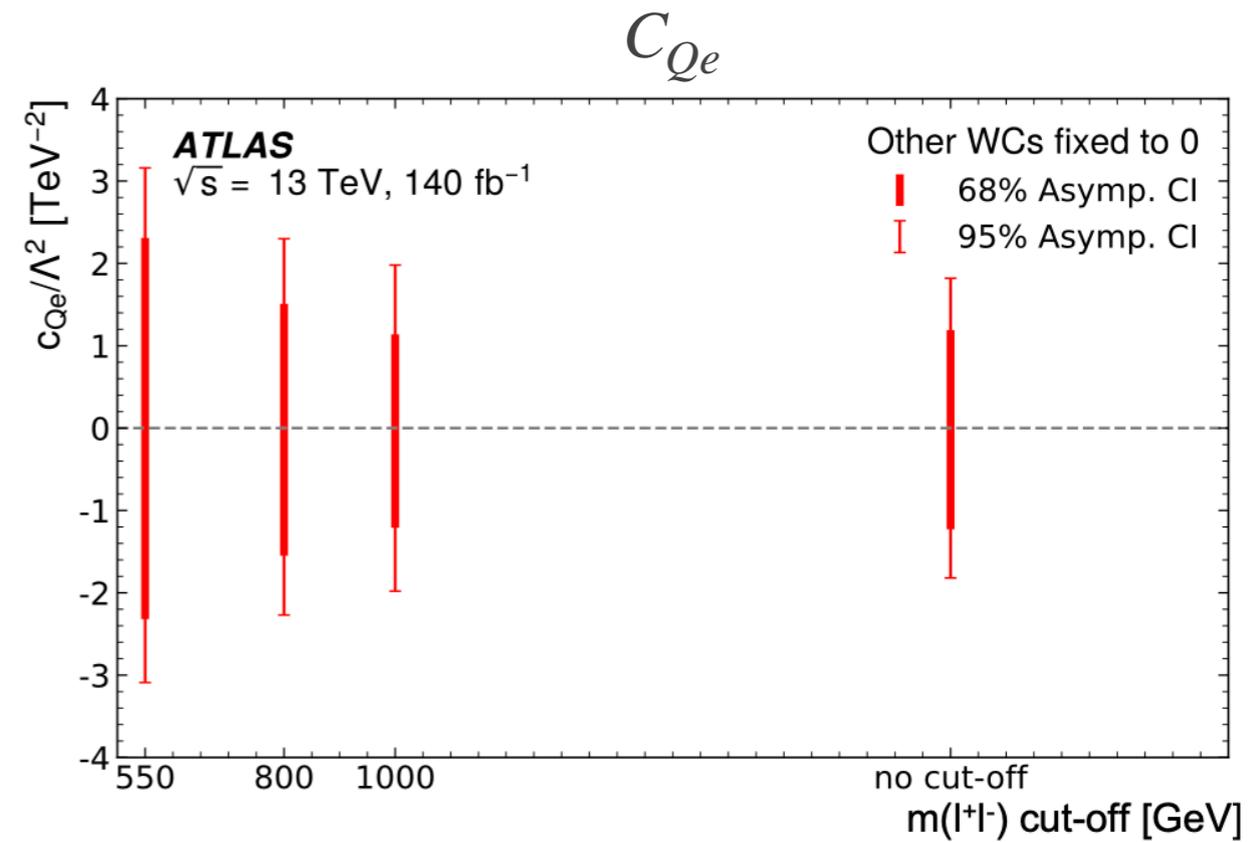
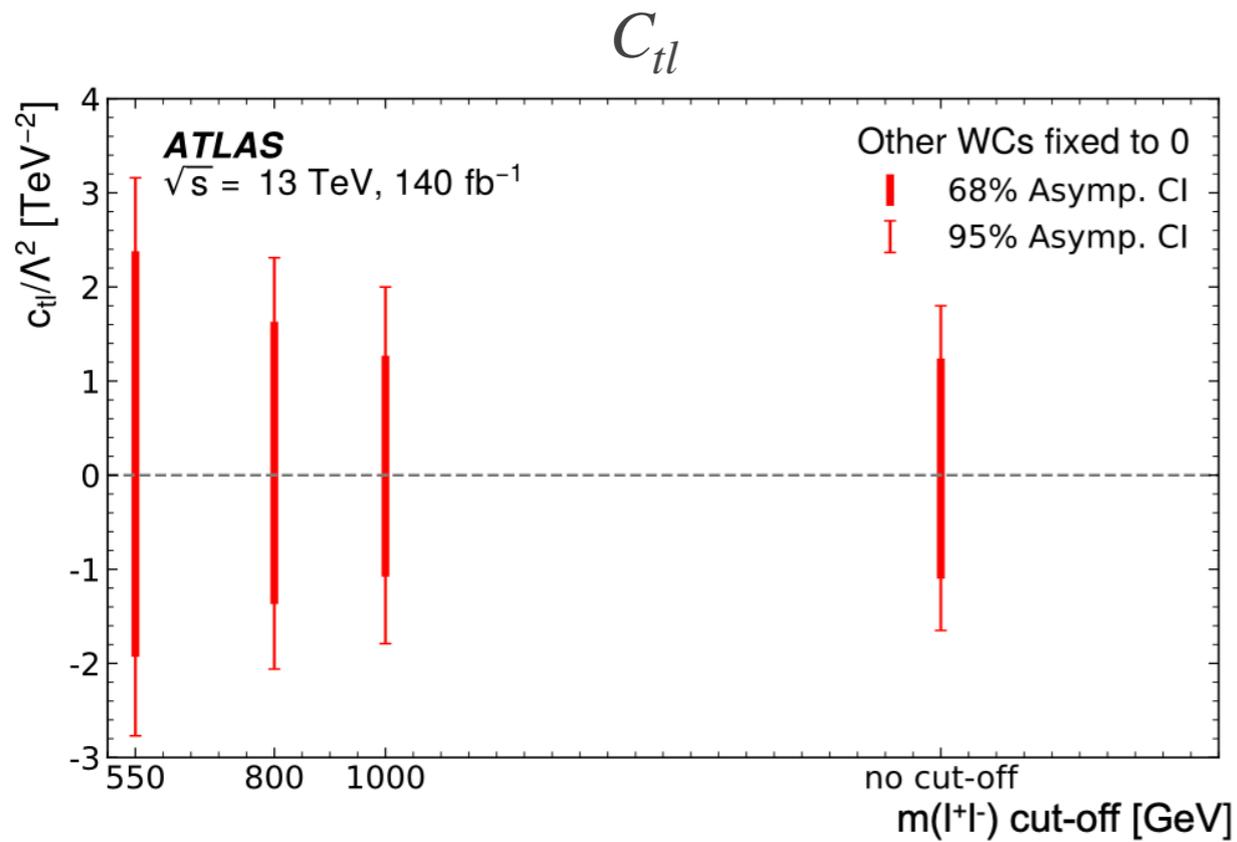
- The correlation between C_{11} and C_{22} is preserved.



Results derived from asymptotic method

- A test on lepton flavour universality in this final state with large systematics cancellation: valuable for future analysis
- Results limited by statistics

EFT interpretation



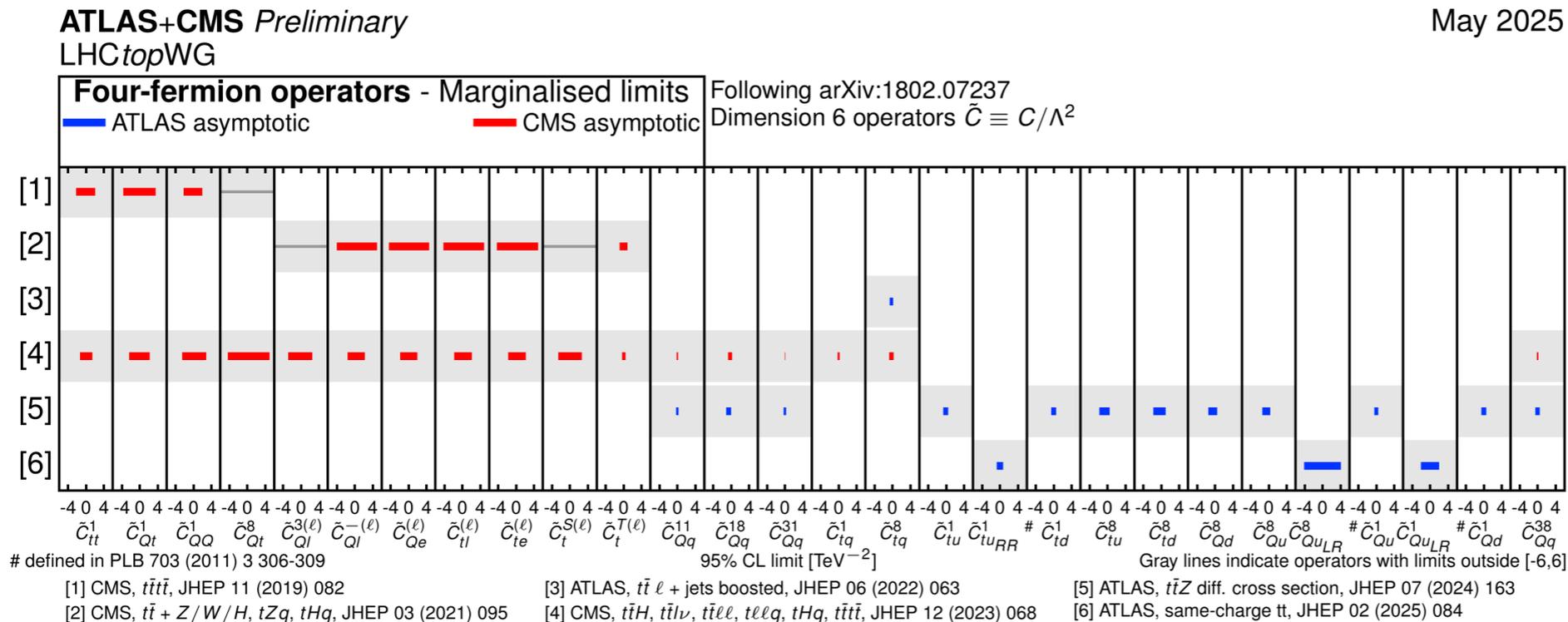
- Restrict range with when applying higher cut on $m(ll)$

Summary

Summary

- EFT is a stress-test for the SM

- Wide array of top quark related processes being measured in ATLAS to place more stringent limits on new physics through the SMEFT framework



Summary of obs limits of 4-fermion interactions in dimension-6

- Future analyses will benefit from:

- More data and advanced analysis techniques are the potential
 - The searches are only Run 2
- Larger combinations to resolve degeneracies and investigate correlations
 - Efforts of combination are under discussion [[ATL-PHYS-PUB-2023-030](#)]

Thank you for listening!

Backup

Search for same sign top pair production

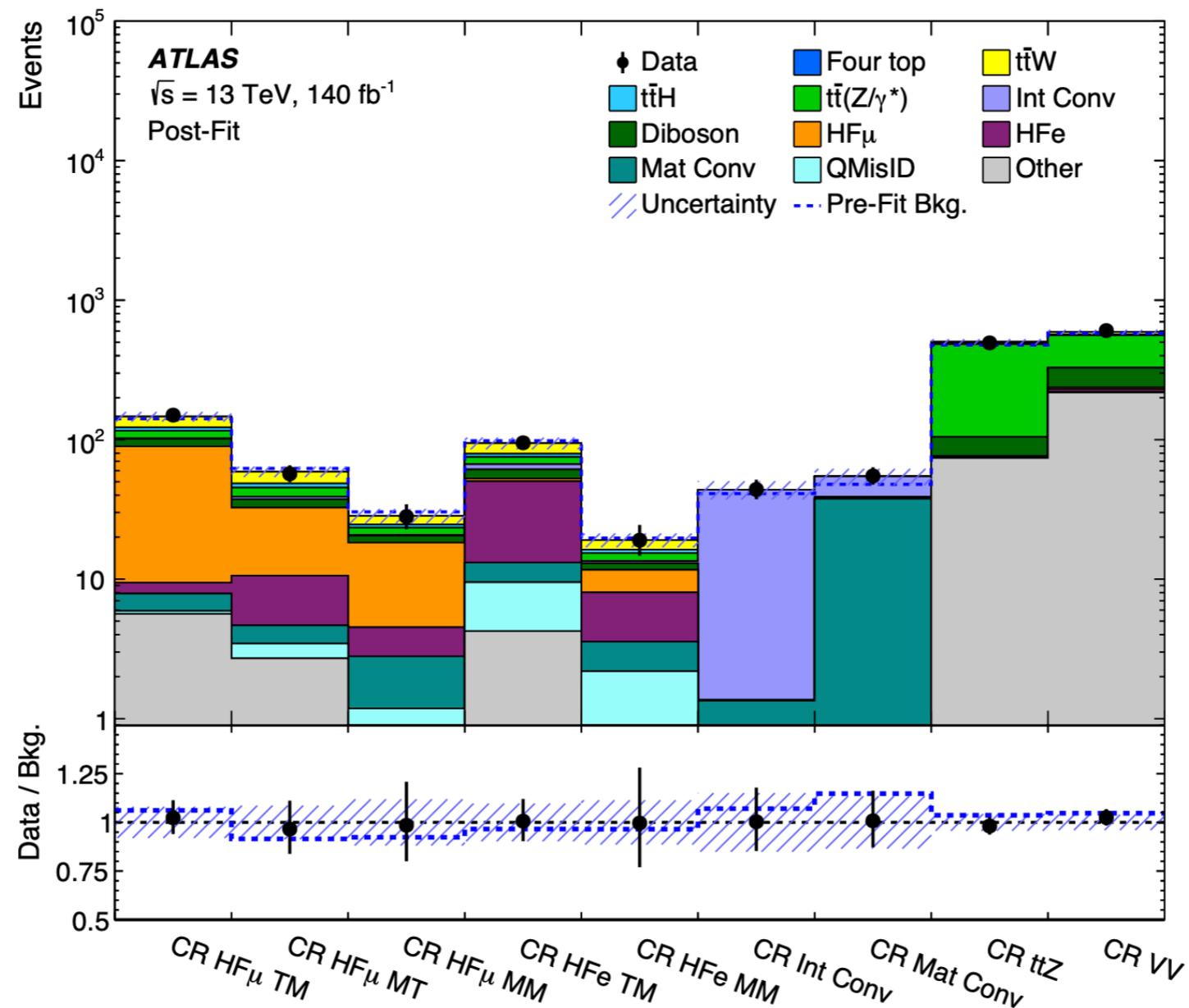
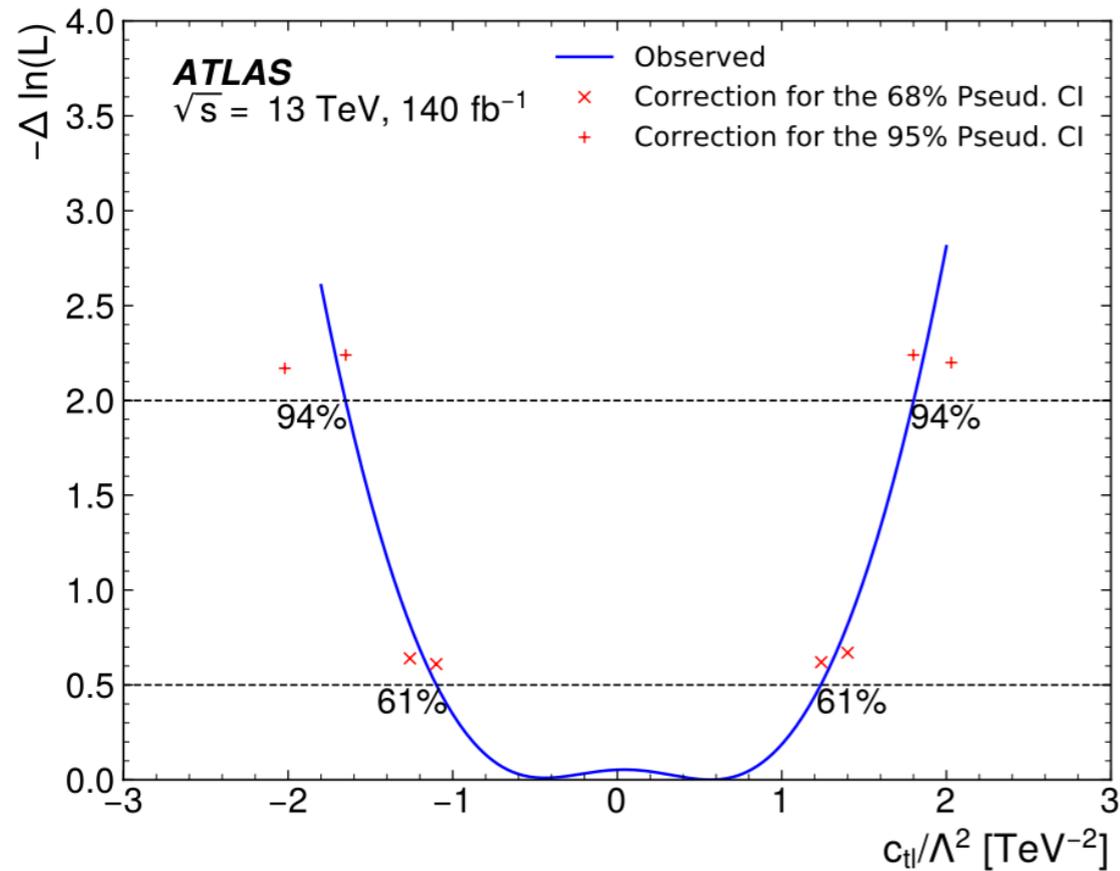
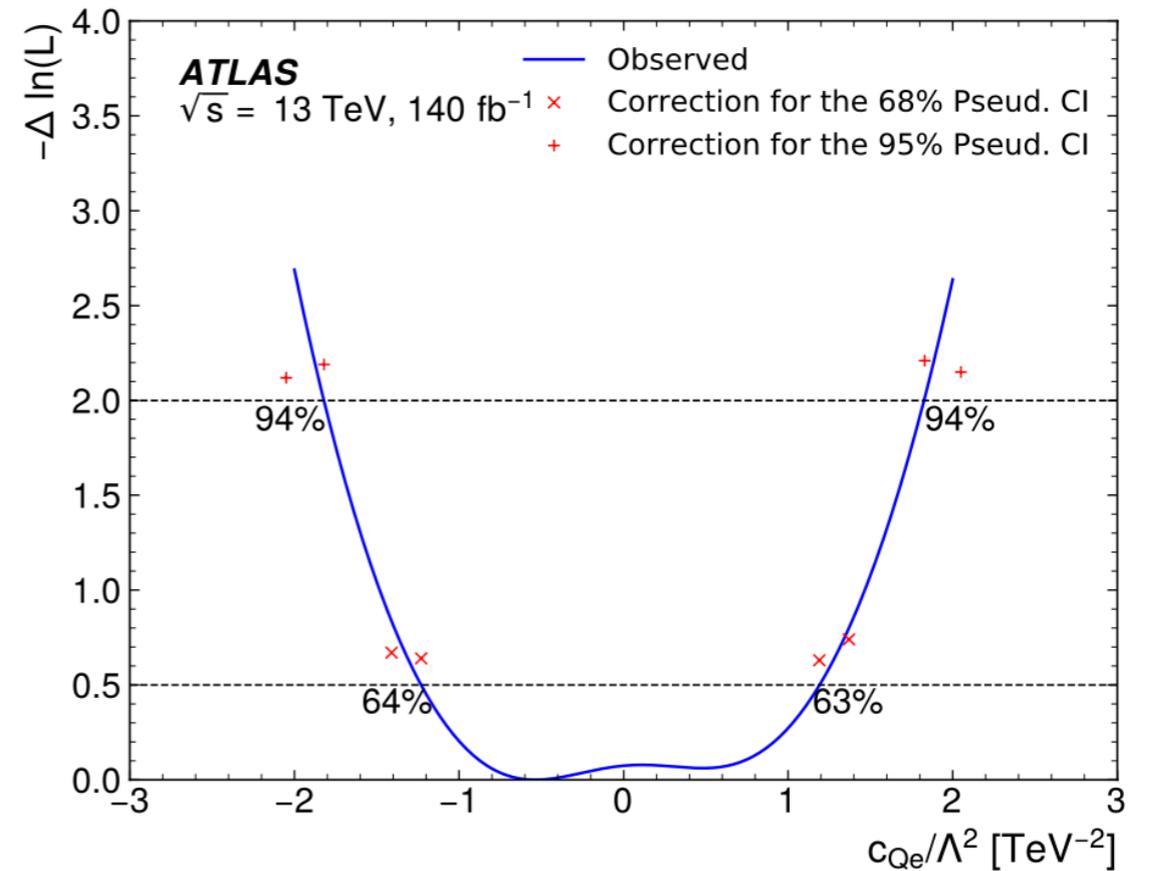


Figure 5: Comparison between the event yields in data and the background expectation after the likelihood fit for the nine control regions. The post-fit background expectations are shown as filled histograms, the combined pre-fit background expectations are shown as dashed lines. The ratio of the data to the total post-fit background is shown in the lower panel. The combined statistical and systematic uncertainty in the simulation is indicated by the hatched band, while the vertical error bars represent the statistical uncertainty in the data.

Measurement of high-mass $ttll$



(a)



(b)

Figure 5: Scans of the fitted negative log-likelihood value as a function of the WC value for (a) c_{tl} and (b) c_{Qe} . The solid line shows the standard profile likelihood ratio approach, the cross and plus markers show the values of the 68% and 95% coverage, respectively, calculated from the fits to pseudodata (Pseud.).