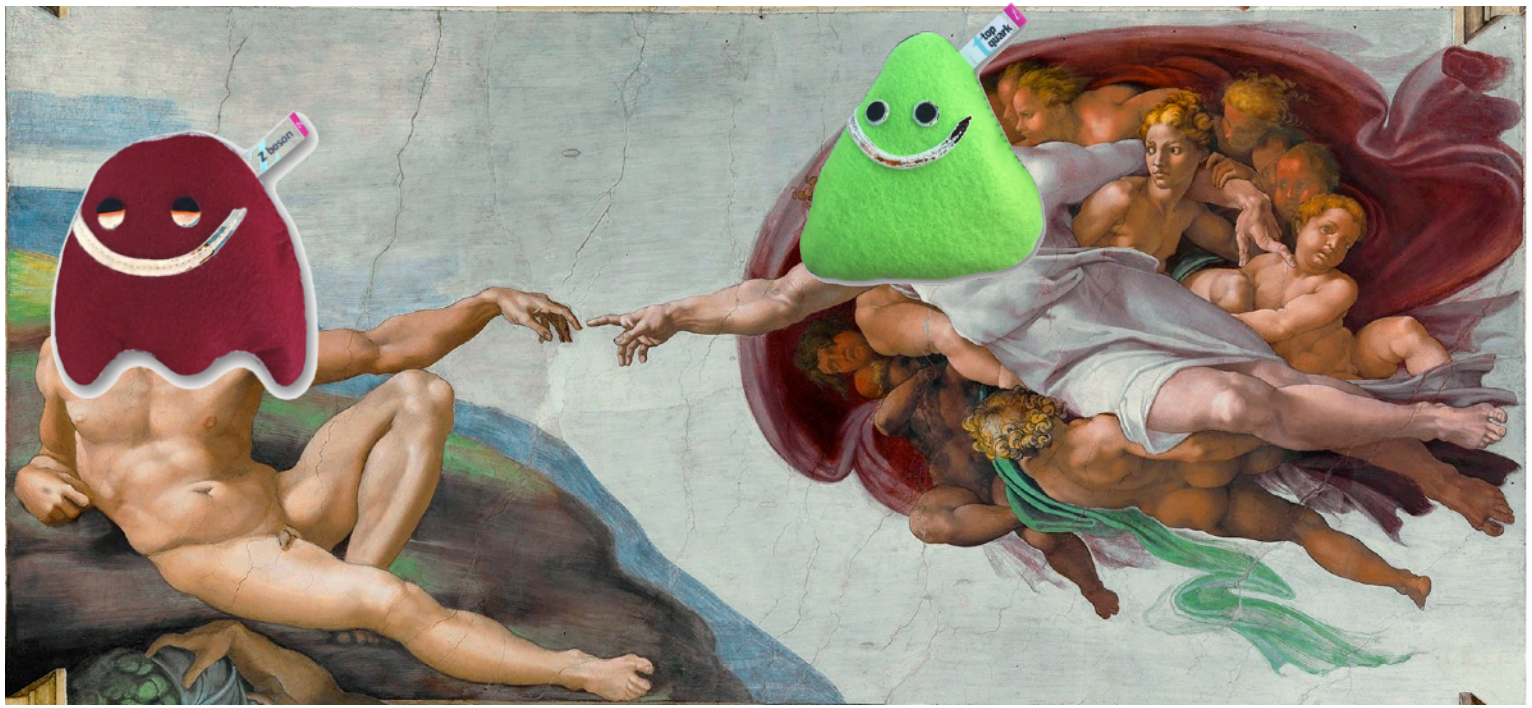


Effective field theory constraints from the top quark sector

Sergio Sánchez Cruz on behalf of the ATLAS and CMS Collaborations

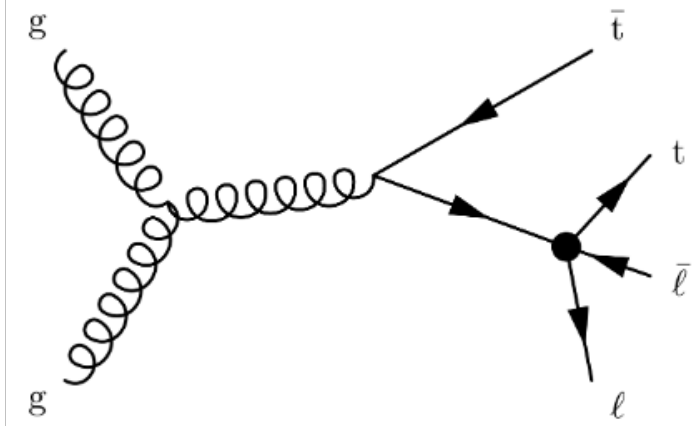
SM@LHC Workshop - Rome

08.05.2024

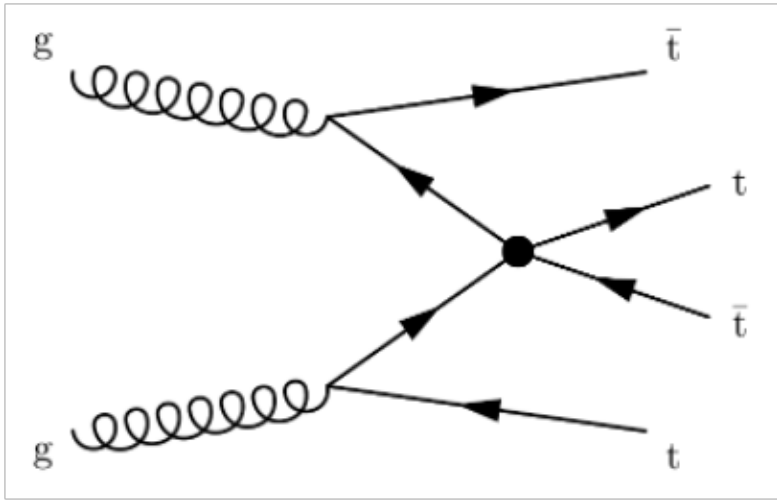
The top EFT basis

arXiv:1802.07237

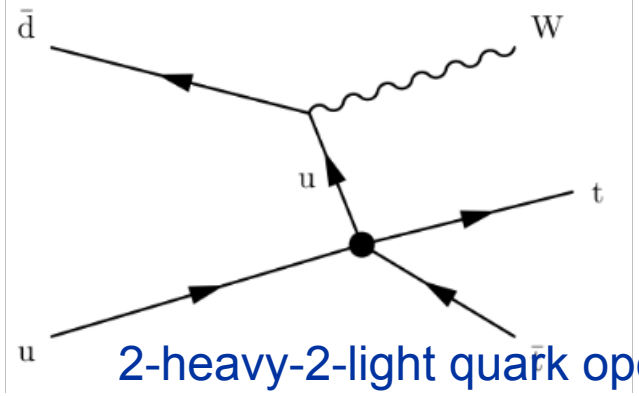
- Set of flavour assumptions used by convention for top quark studies
- 42 CP-conserving and 11 CP-violating operators



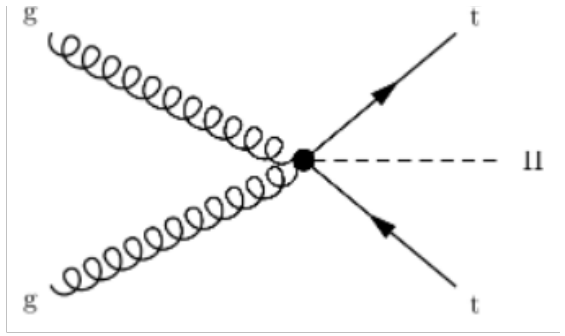
Heavy quark + lepton operators
(8 + 3 CPV) x 3 lep generations

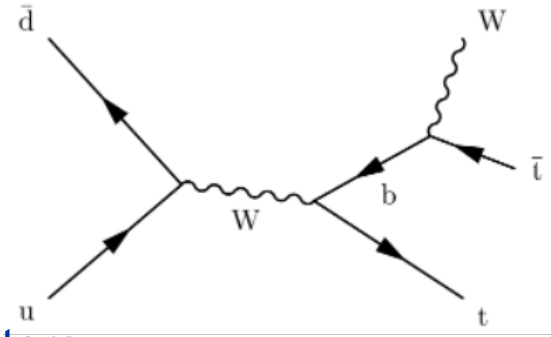


4-heavy quark operators
11 + 2 CPV operators



2-heavy-2-light quark operators
14 operators

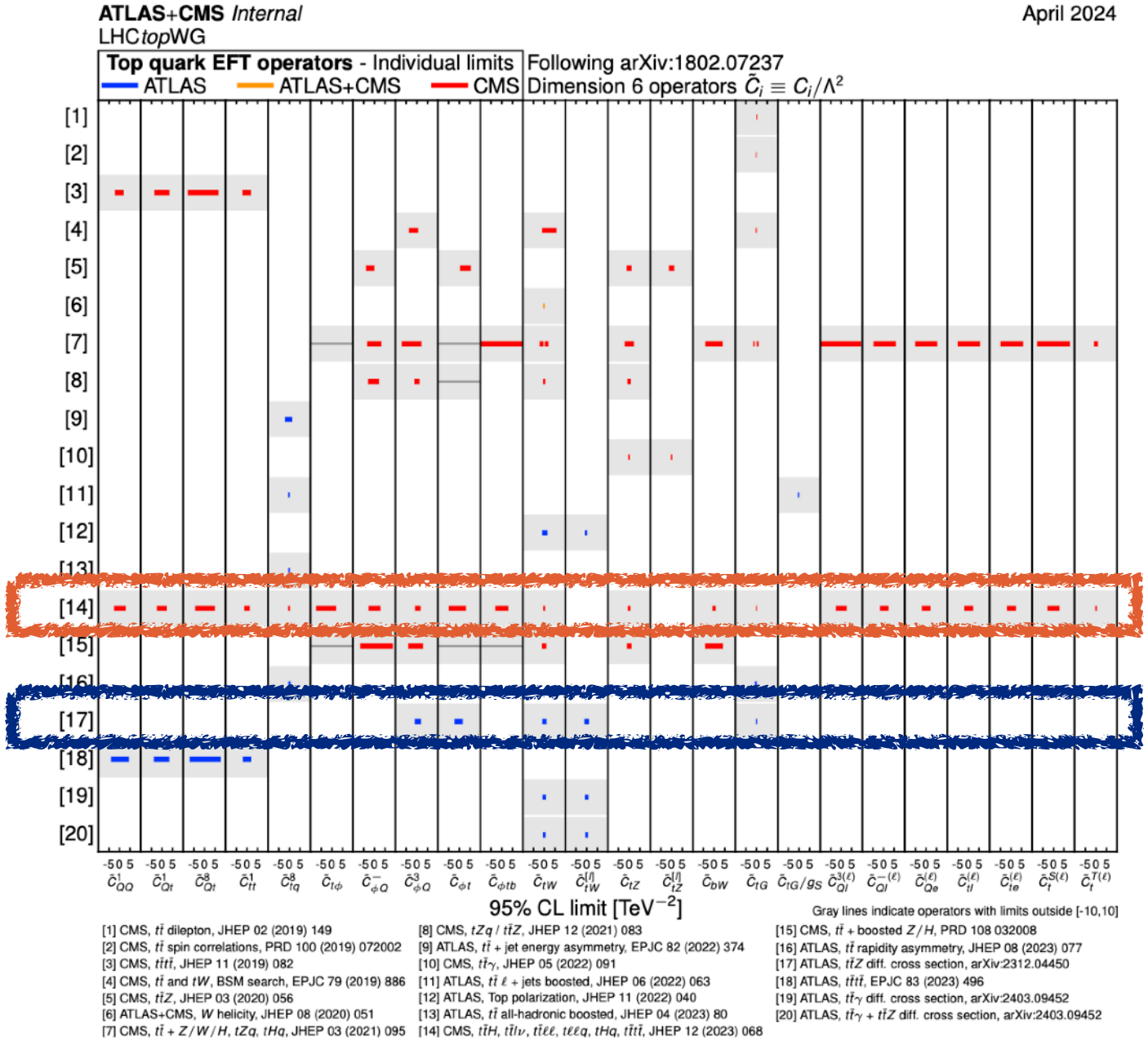




2-heavy quark+ boson operators
9 + 6 CPV operators

Programme of measurements by ATLAS and CMS

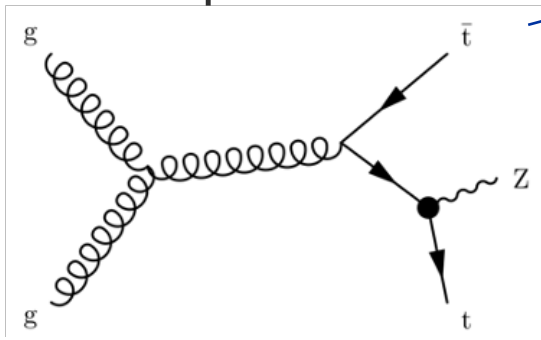
- Order of 30 operators probed in the top EFT basis
- Complementary search programme in ATLAS and CMS
- I will cover:
  - Newest results by ATLAS and CMS in the “canonical” flavour symmetry scenario
  - Results going beyond the usual flavour assumptions (LFV, BNV)
- For measurements in top physics see:
  - Tae Jeong’s talk on tt+bb/tt+tt
  - Jonathan’s talk on ttW, ttZ, ttgamma
- FCNCs in Efe’s talk



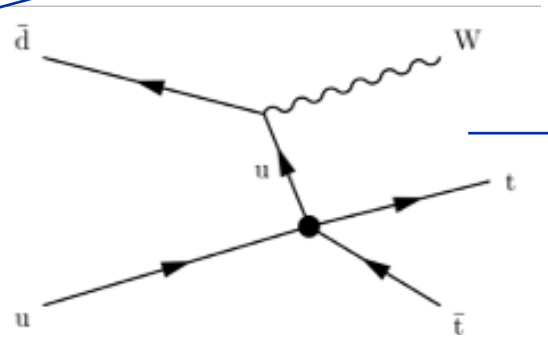
Measurement of ttZ production

arXiv:2312.04450

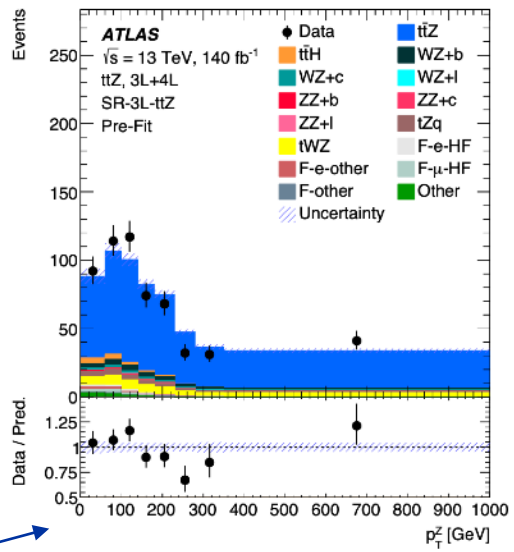
- ttZ production measured as function of observables in regions with 3 and 4 leptons
  - Signal/background discriminated using DNNs
  - Differential measurements as functions of $\mathbf{p_T^Z}$, $\mathbf{p_T^{top}}$, y^{top}, p_T^{ttbar}, …
  - Inclusive cross section, spin correlations also measured
  - Results consistent with the NLO **reference models**
- Measurement of **all variables** interpreted in terms of EFT operators

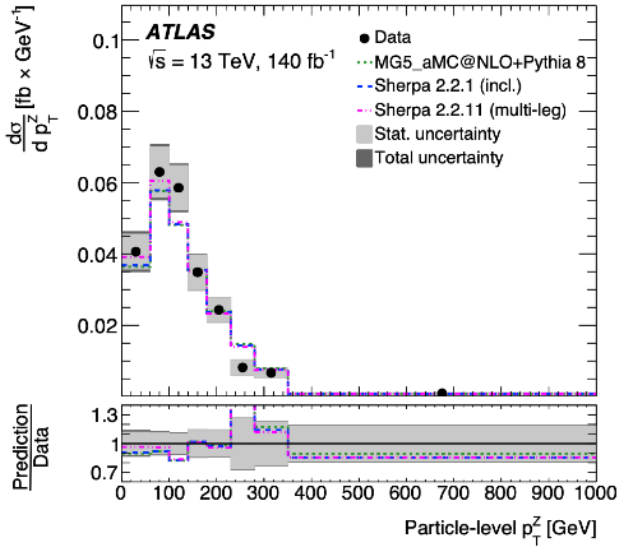


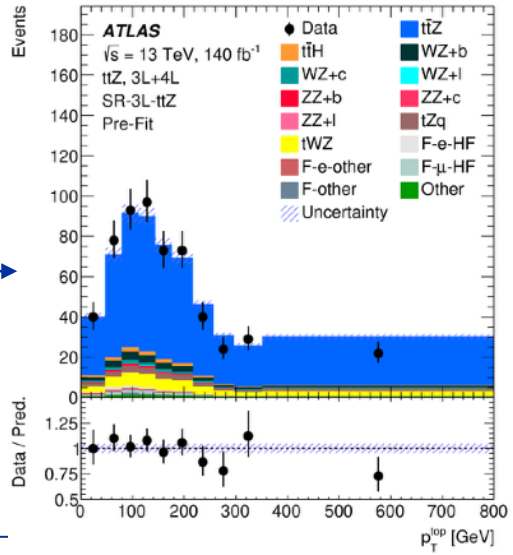
Top+boson operators

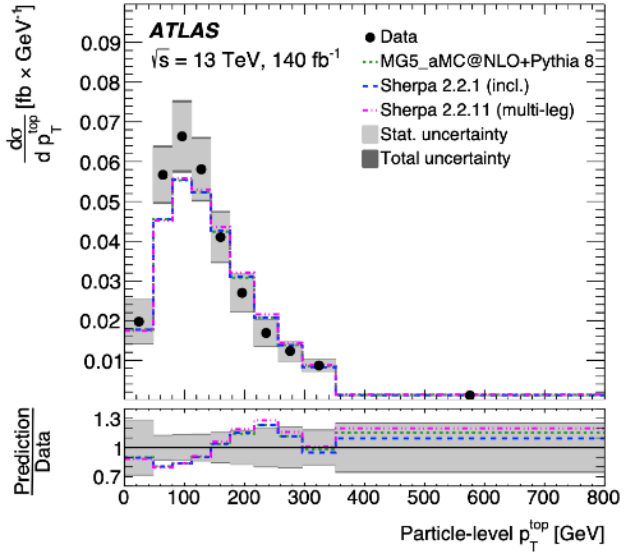


4-quark operators



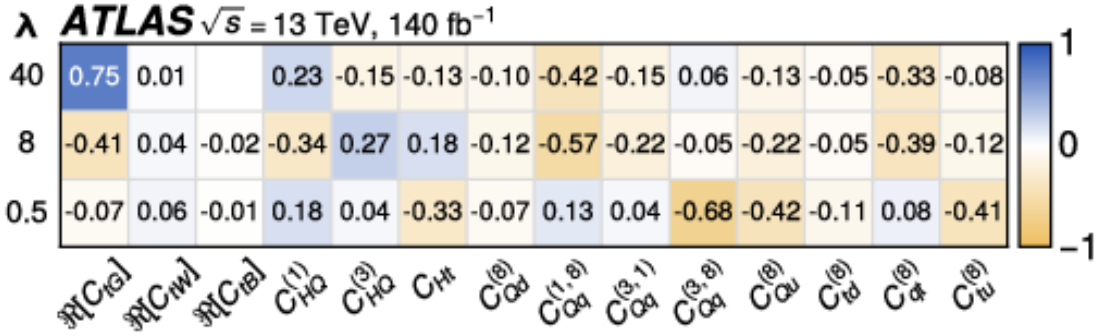


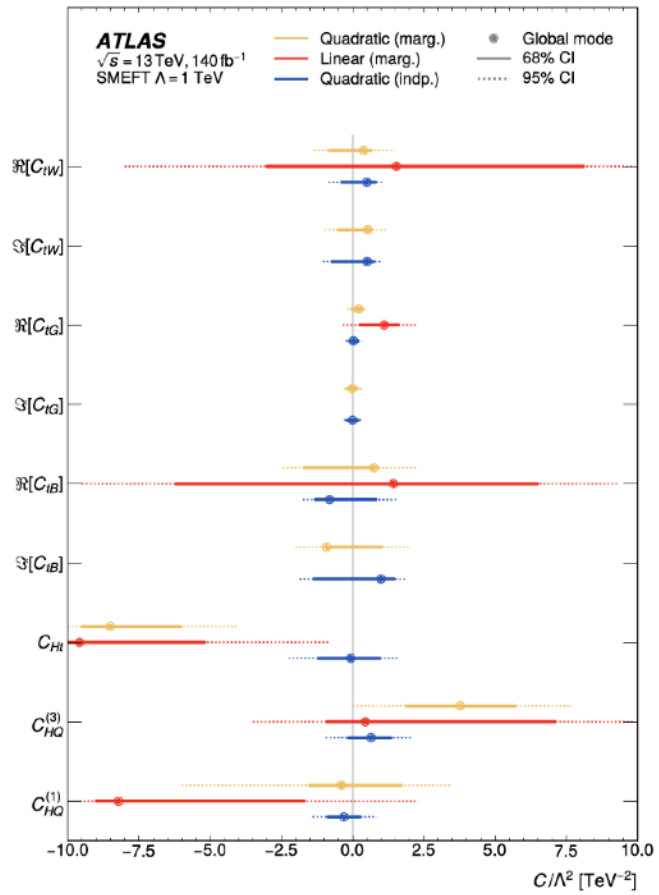


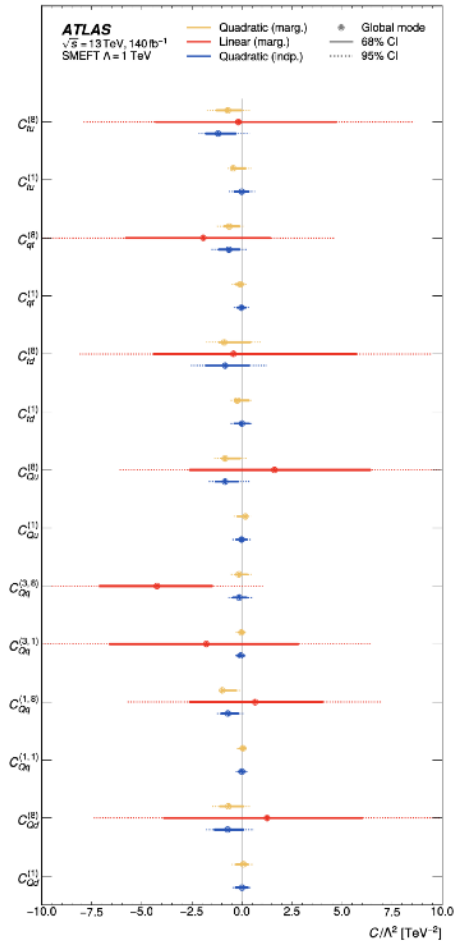


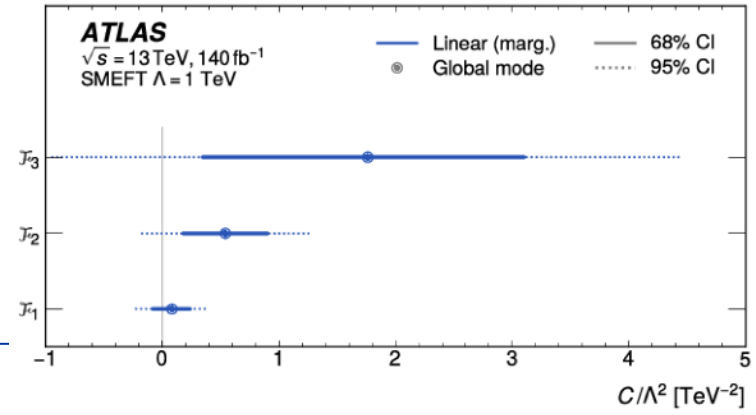
ttZ - EFT interpretation

- **Two scenarios considered:**
  - Top+boson scenario
  - Four-quark scenario
- Three types of fits:
  - BSM/SM interference only, marginalised
  - Quadratic marginalised + independent
- Results consistent with the SM, slight deviations from zero due to degenerate modes
- PCA used to determine combinations of WCs with sensitivity → **3 sensitive directions** ($C/\Lambda^2 < 3.15$ TeV^{-2})





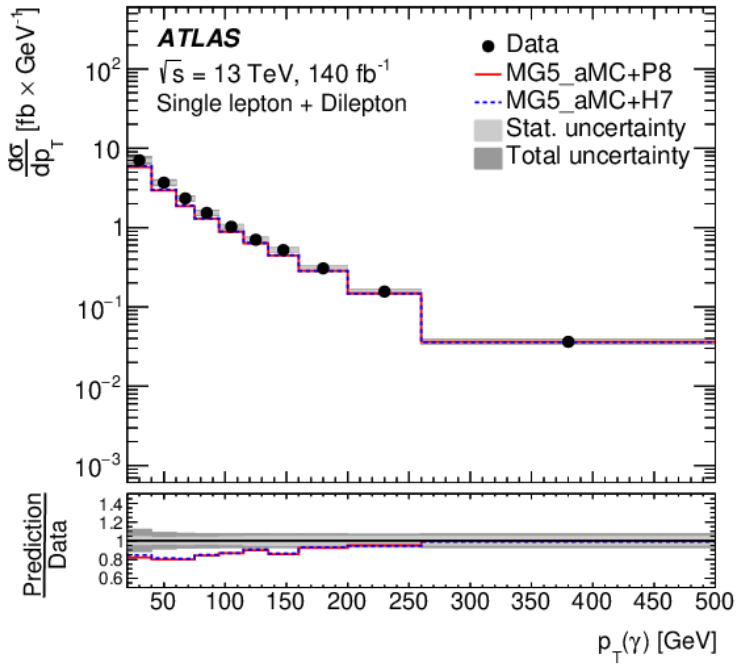


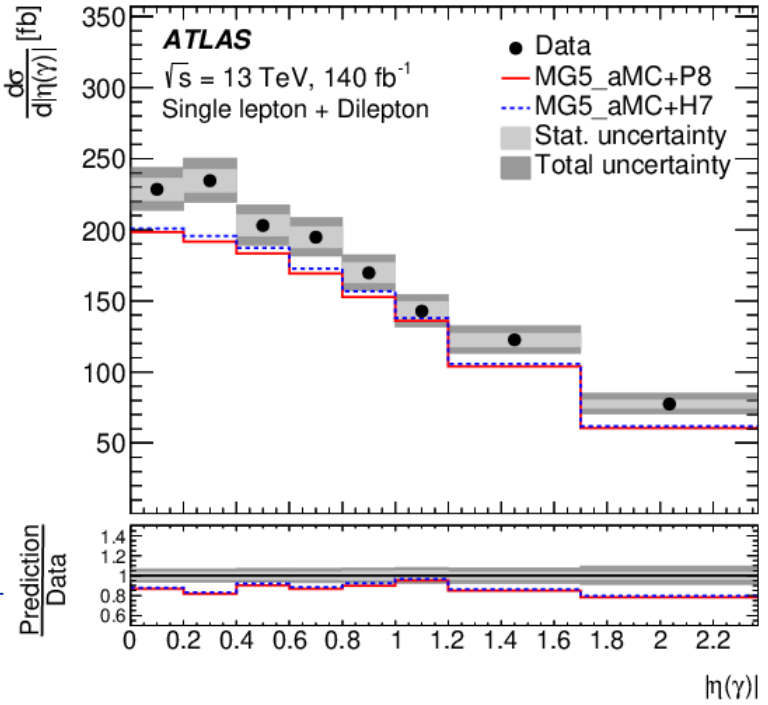


arXiv:2312.04450

Measurement of ttγ production

- ttγ production measured in single and di-lepton channels
- DNNs used to discriminate backgrounds against ttγ production, regardless of the origin of the photon
- Measurements performed as a function of p_T^γ, η^γ, p_T(j1) ΔR(γ, lep), …
  - η^γ well described by state-of-the-art MC
  - p_T^γ slightly softer than predicted
- Measurements also performed for ttγ production and decay separately





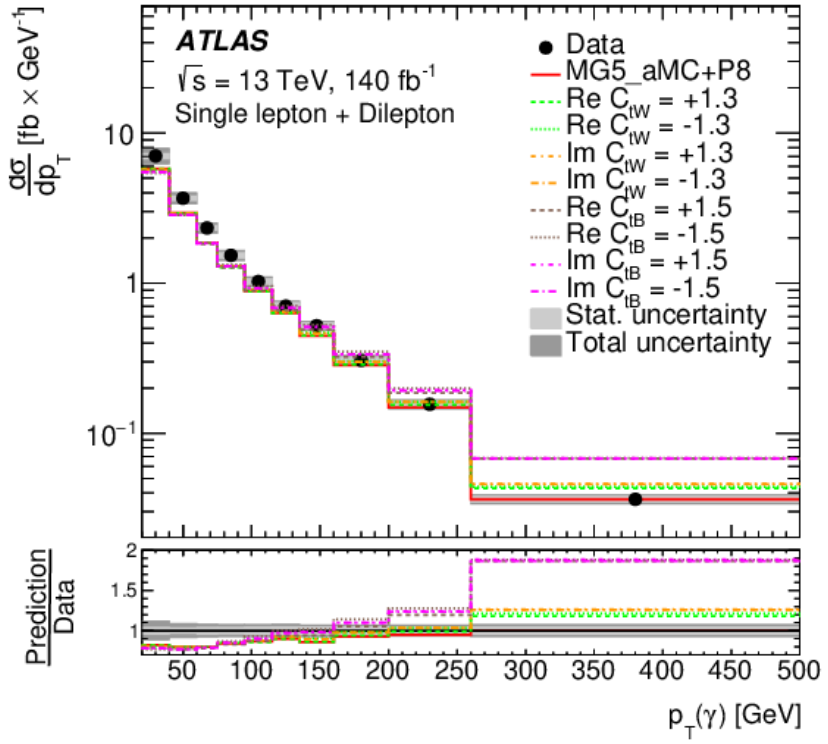
arXiv:2403.09452

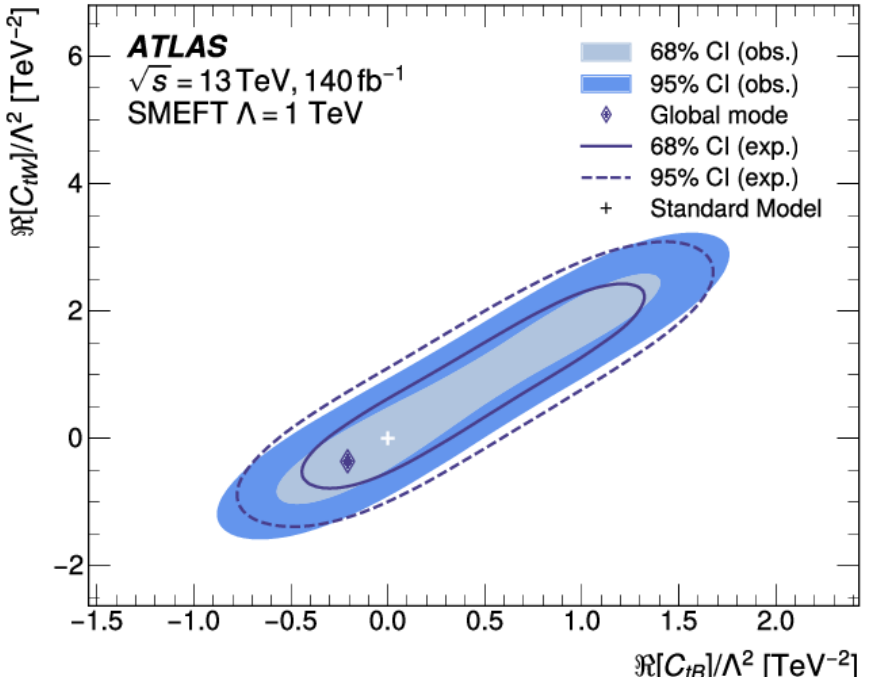
Measurement of tty production

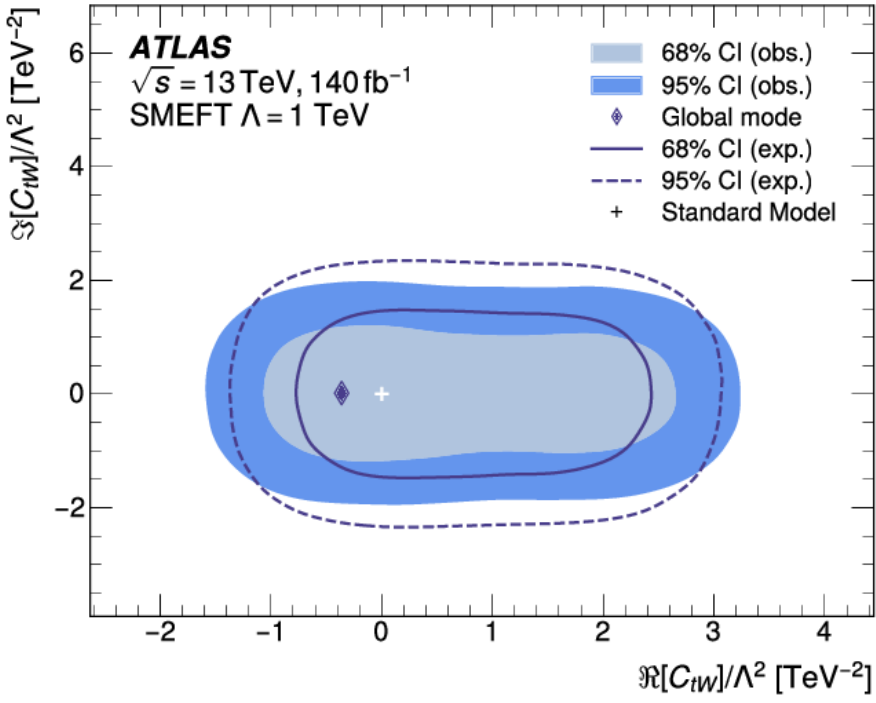
- Limits on EFT operators using the **unfolded photon pT** distribution
- Setting limits on the top quark electroweak dipole moments

$$(\bar{q}_i \sigma^{\mu\nu} u_j)\, \tilde{\varphi} B_{\mu\nu}$$

$$(\bar{q}_i \sigma^{\mu\nu} \tau^I u_j)\, \tilde{\varphi} W^I_{\mu\nu}$$





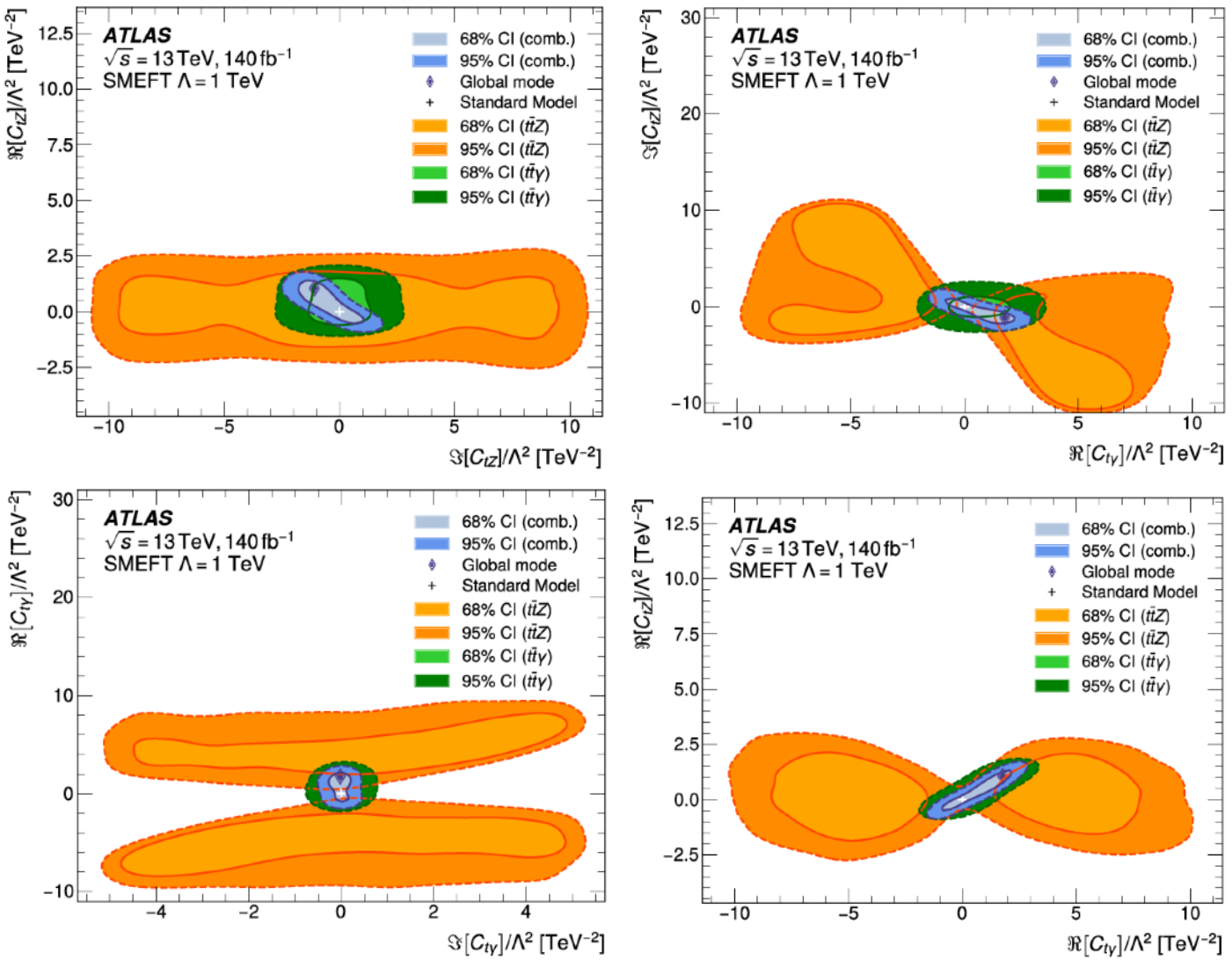


CERN ATLAS EXPERIMENT

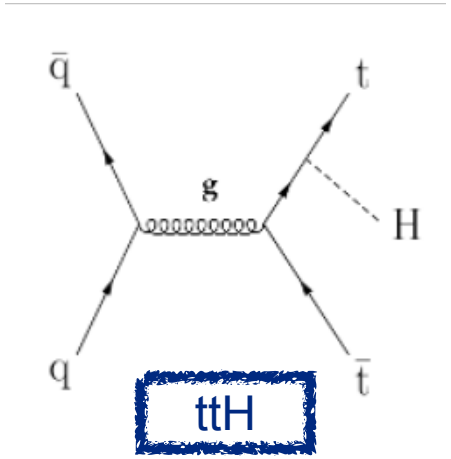
arXiv:2403.09452

Combination of ttZ and ttγ measurements

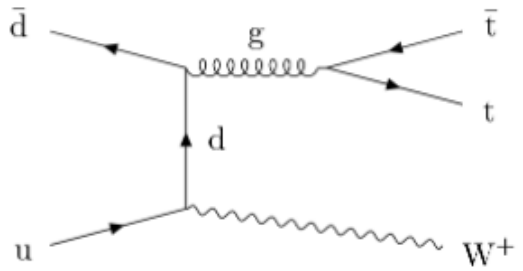
- **EFT interpretation from the simultaneous ttZ and ttγ** measurements
  - Using the **boson p_T distributions**
  - Measuring top electroweak dipole moments
  - **Sensitivity dominated by ttγ**
- Some complementarity between analyses, different regions of the boson p_T spectrum are probed



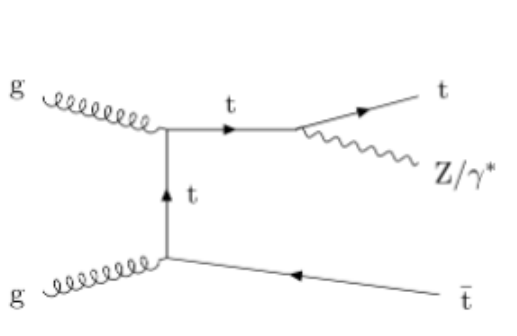
EFT in top quark production in association with leptons



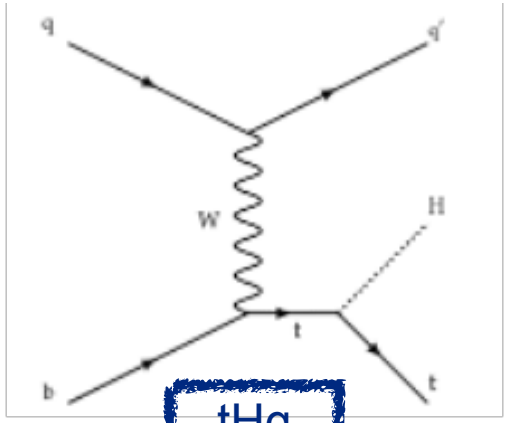
ttH



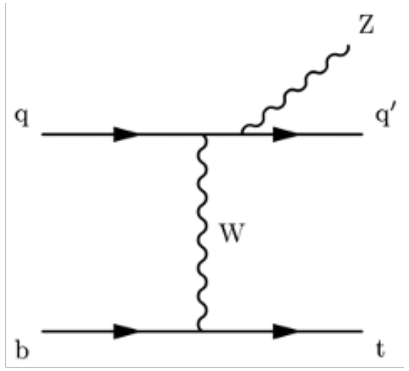
ttW



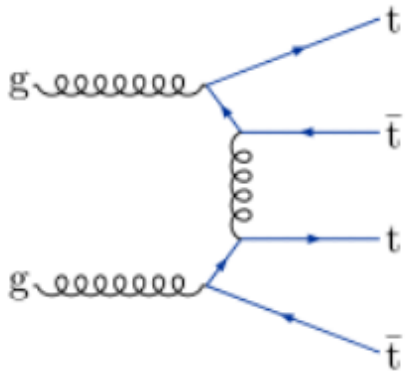
ttZ



tHq



tZq



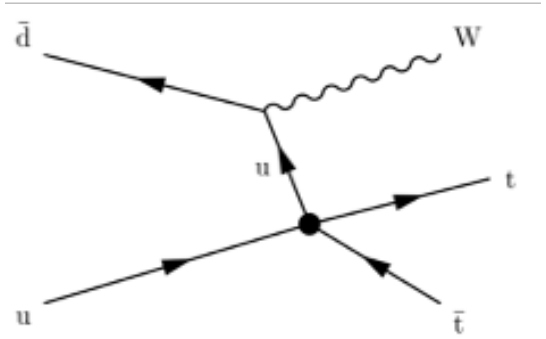
tttt

JHEP 12 (2023) 068

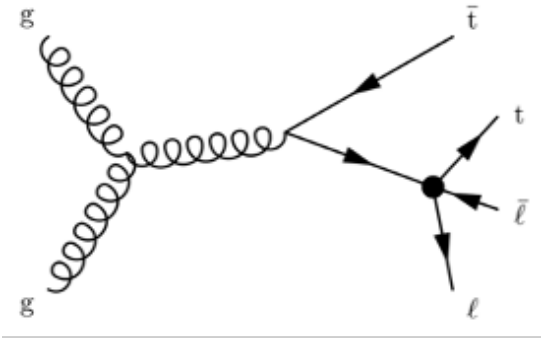
- tt+X processes populate the multilepton final state (two-same sign, three, four leptons)

Observables considered

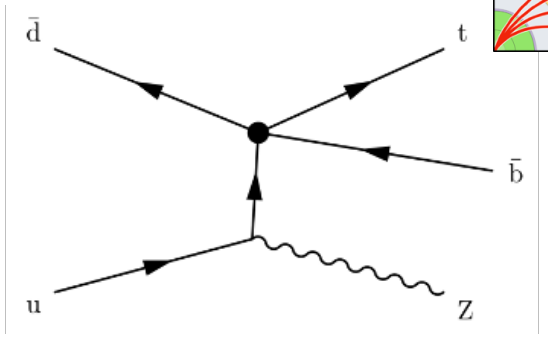
JHEP 12 (2023) 068



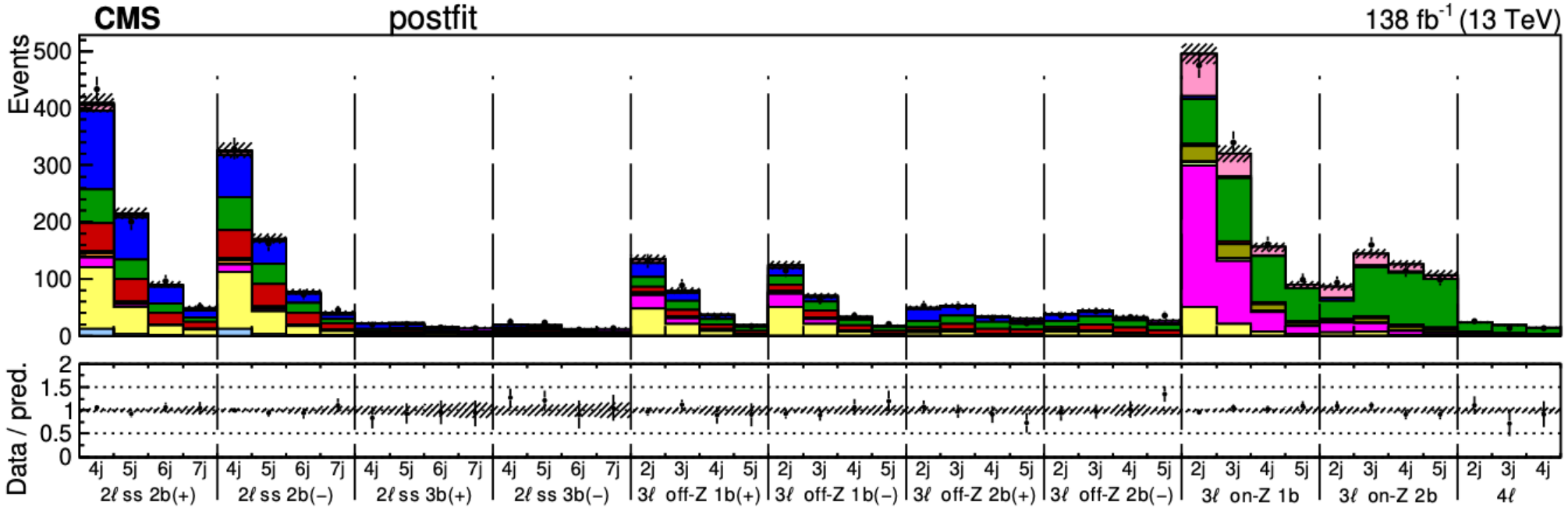
2-heavy-2-light quarks op.



2-top-2-lepton op.



2-heavy-2-light quark op.



Observables considered

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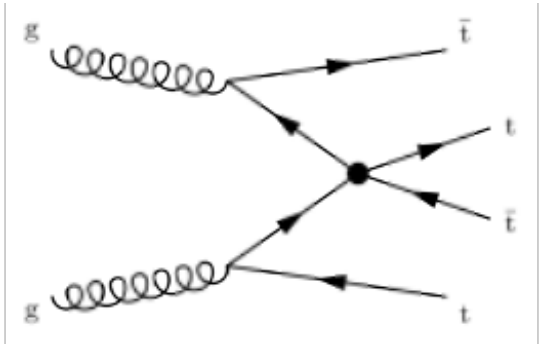

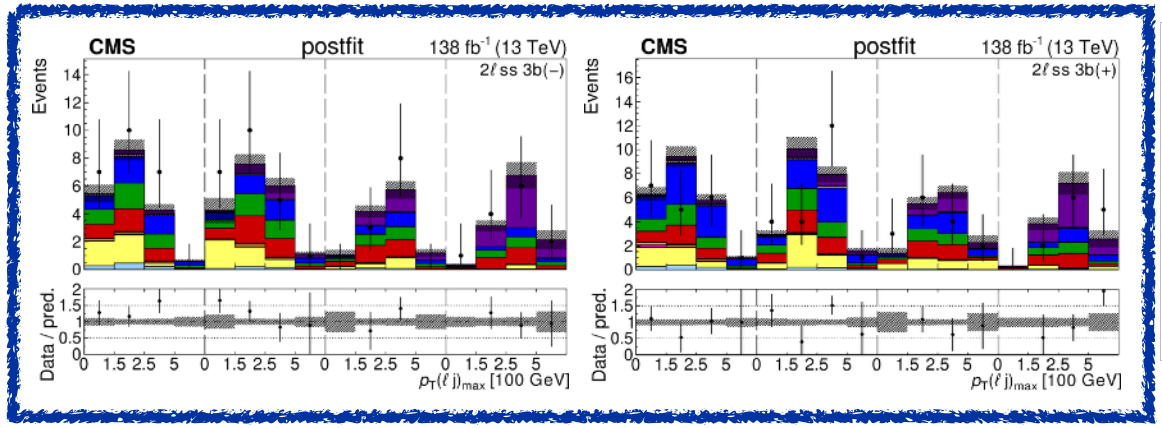

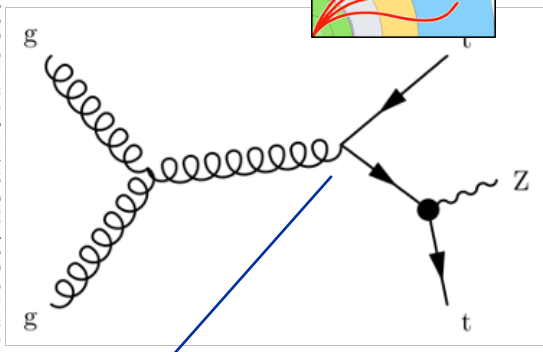

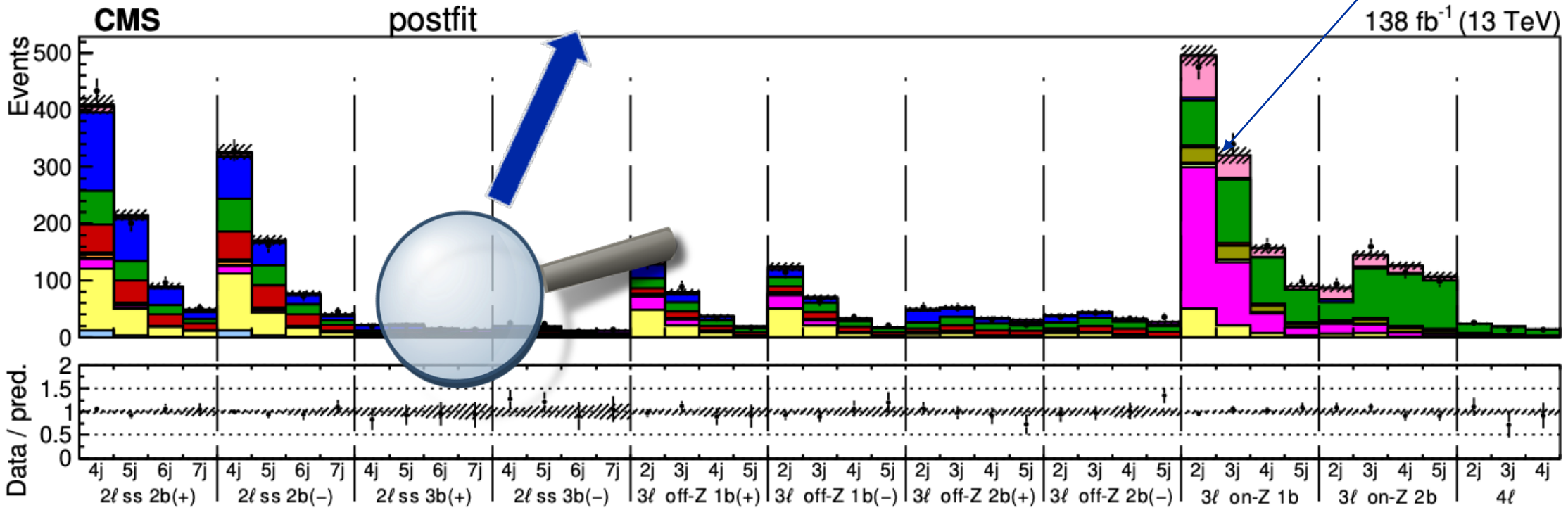

Results

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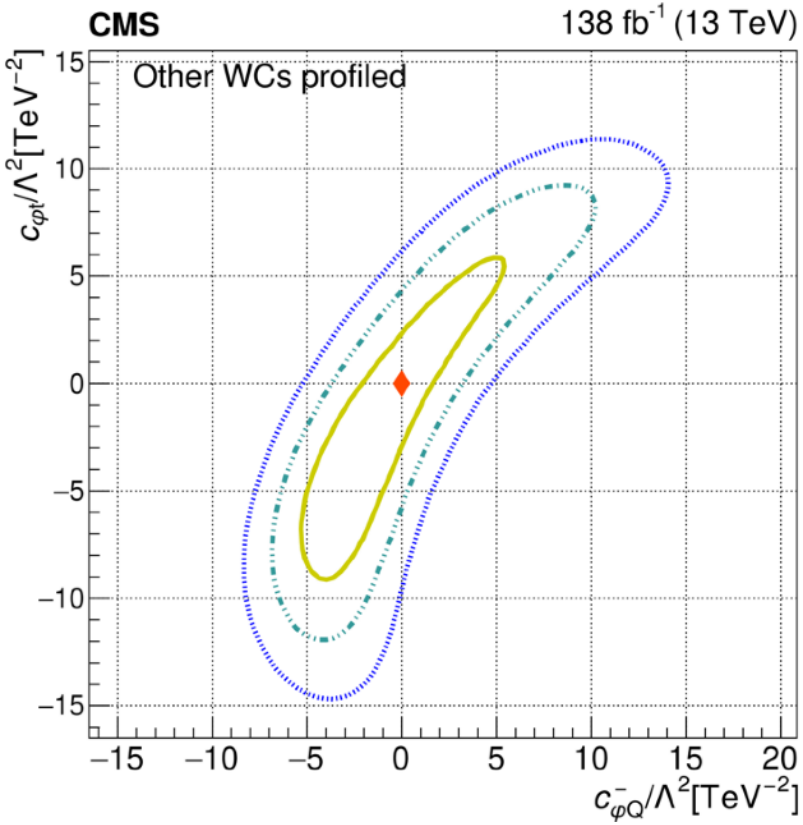
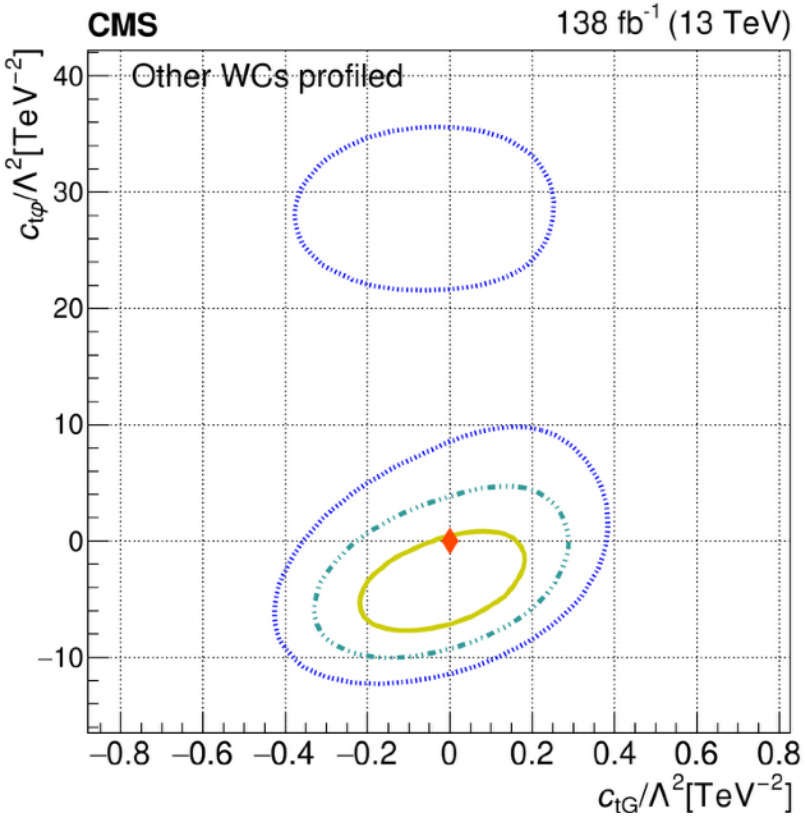
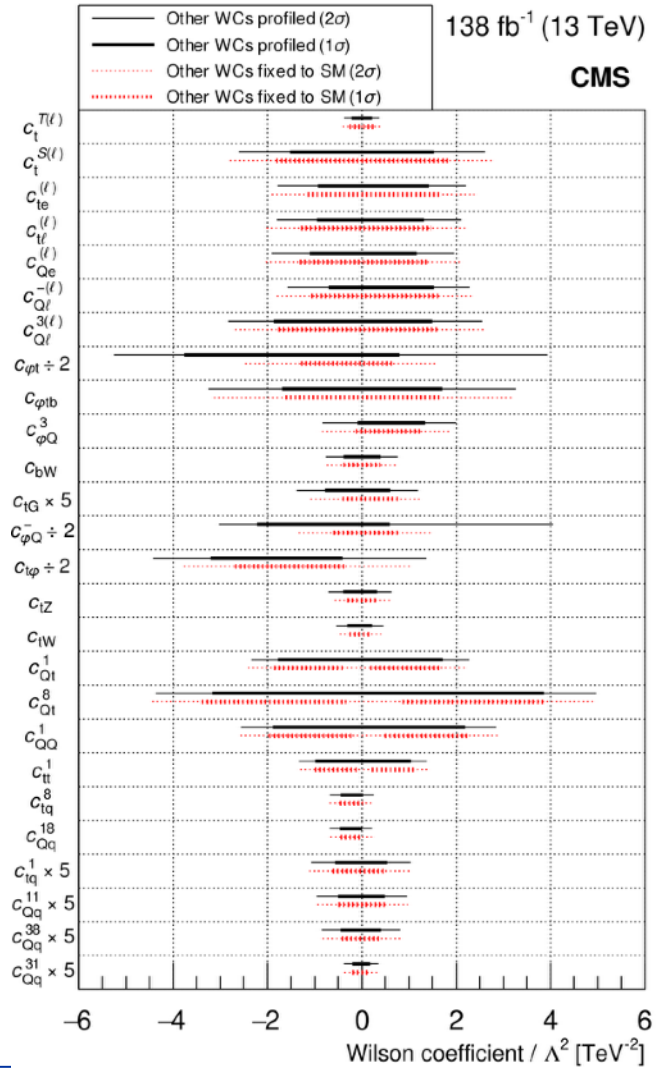
- Results consistent with the SM
- Setting limits on 26 independent Wilson coefficients

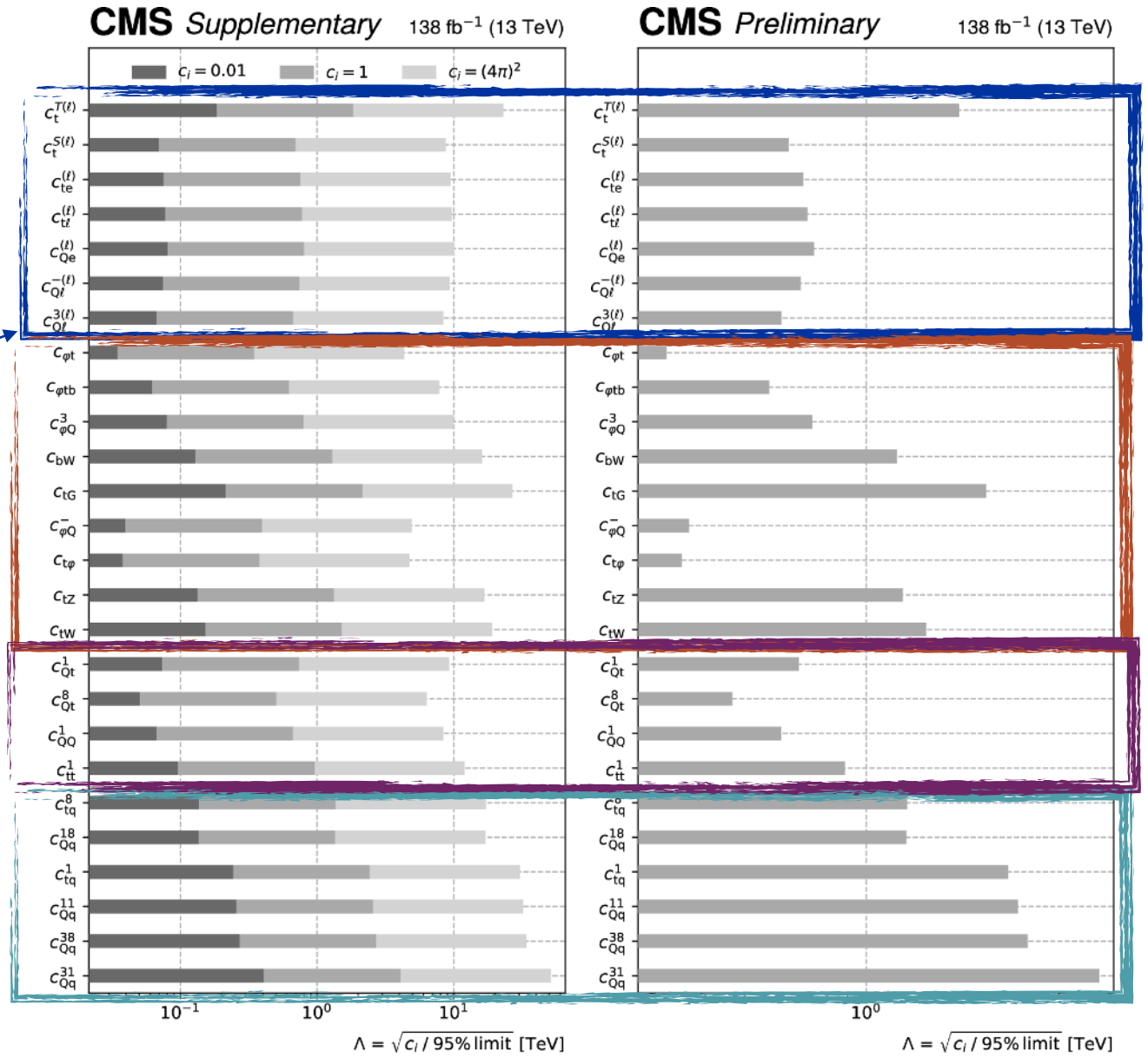






Results

- Limits on Wilson coefficients are translated to limits in the new physics scale
- 2-top-2-lepton operators: Λ > O(800 GeV) - O(1 TeV)
- top+boson operators: Λ > O(300 GeV) - O(1 TeV)
- 4-heavy-quark-operators: Λ > O(700 GeV) - O(1 TeV)
- 2-light-2-heavy operators: Λ > O(1 - 3 TeV)



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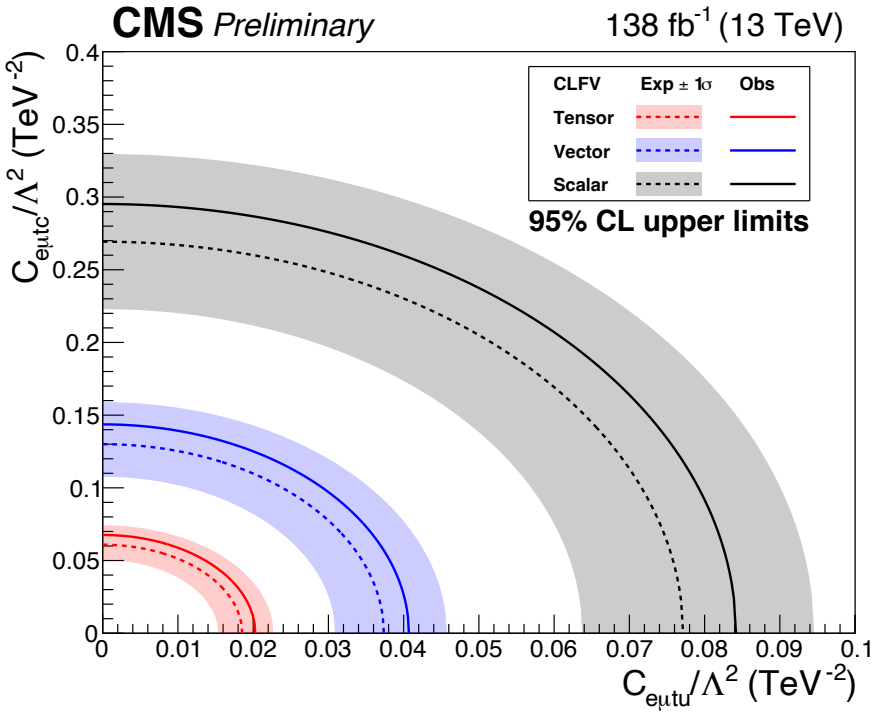
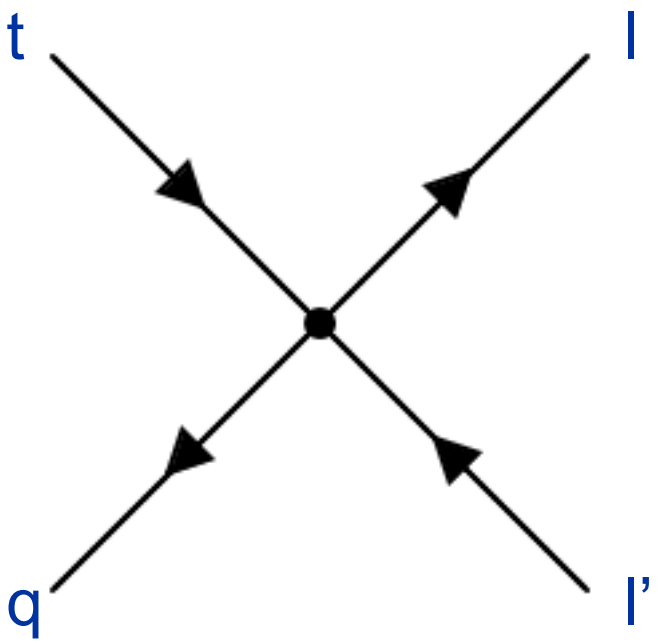
Top quark probing lepton flavour violation

- Four-fermion contact interactions may introduce LFV
- Different LFV couplings studied by ATLAS and CMS:
  - tqeμ by CMS in arXiv:2312.03199 and JHEP 06 (2022) 082
  - Covering latest result by ATLAS on tqμτ arXiv:2403.06742

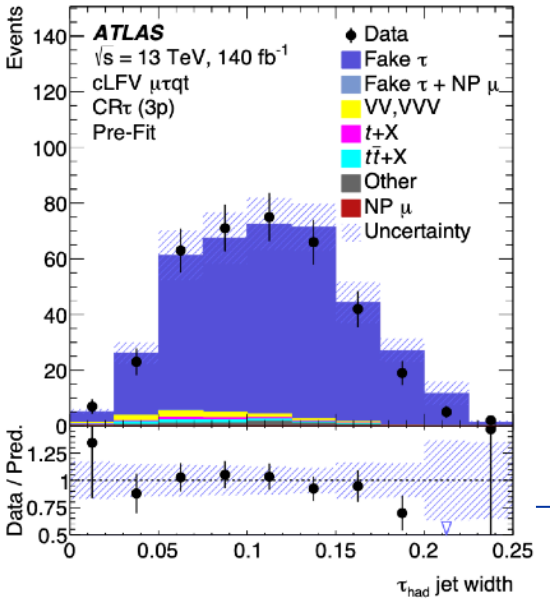


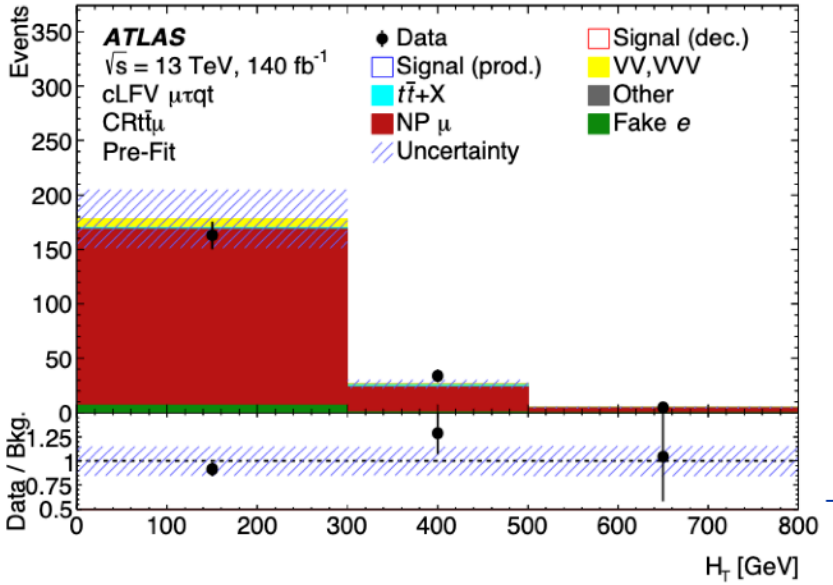


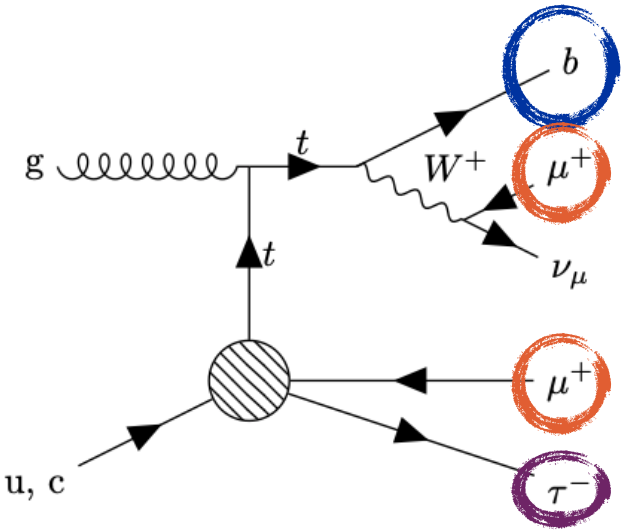
Lepton flavour violation

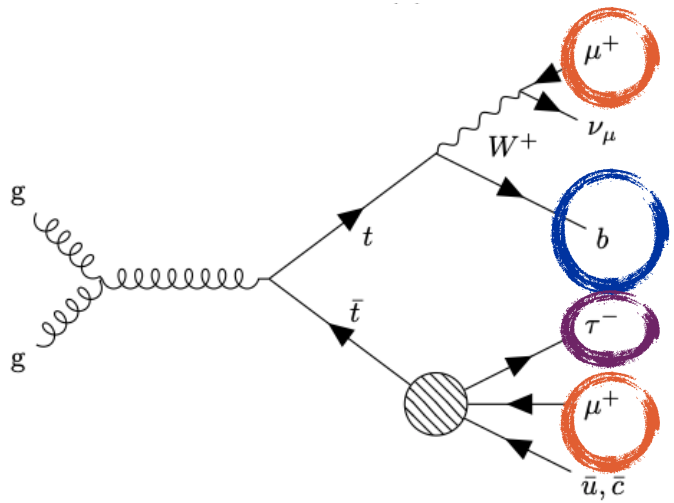
arXiv:2403.06742

- Sensitivity coming from **tll production** and **t→ll'q decay**
  - Fully dominated in production for tuμτ
  - More balanced between the two channels for tcμτ
- Using events with two same-sign muons, a hadronically decaying τ candidate and at least one jet
- Backgrounds dominated by tt+X (ttW, ttZ, ttH) and WZ production
- Semi data-driven estimation of nonprompt μ and jets faking τ

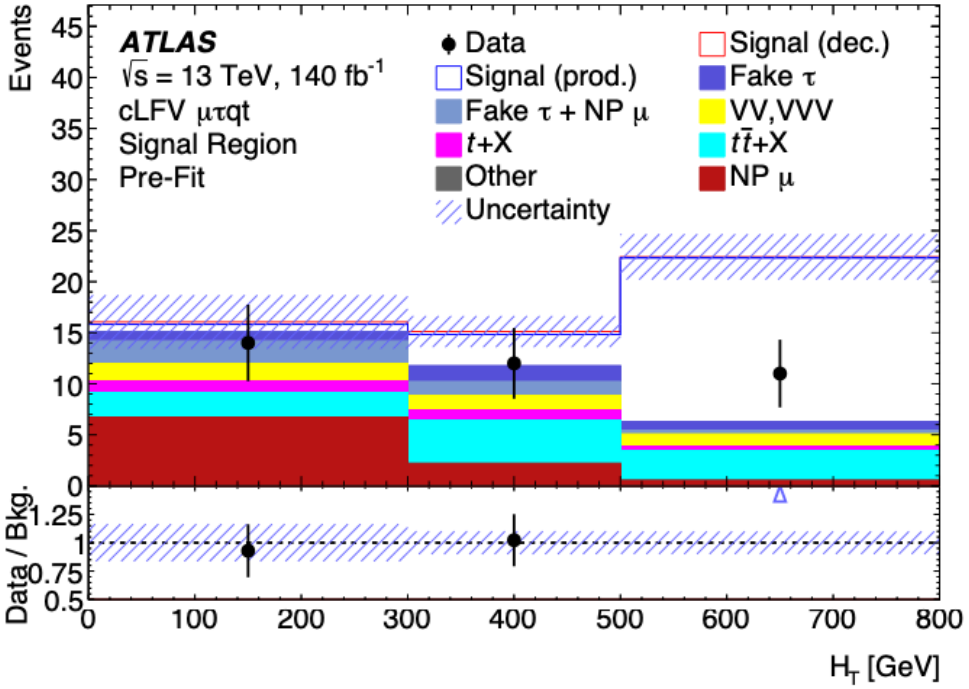


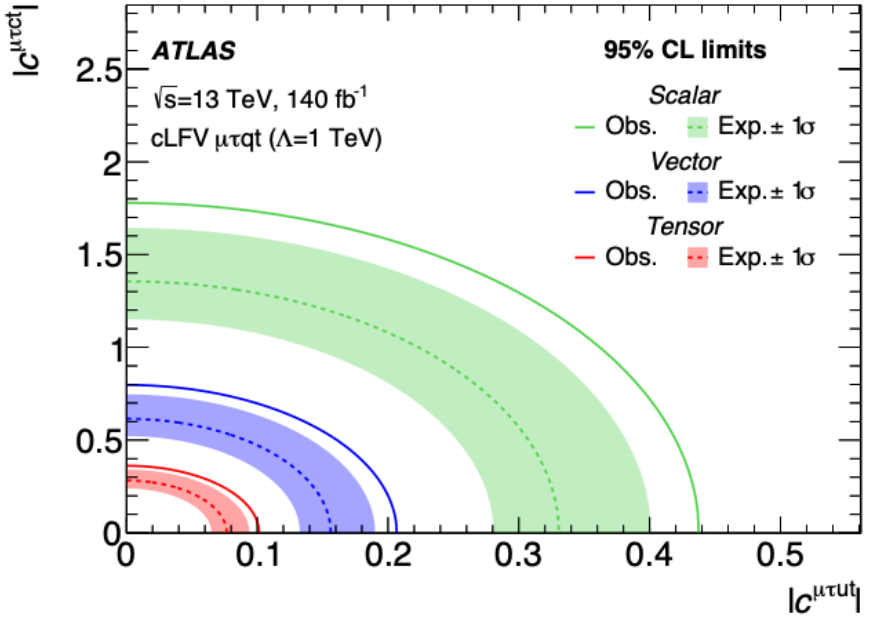


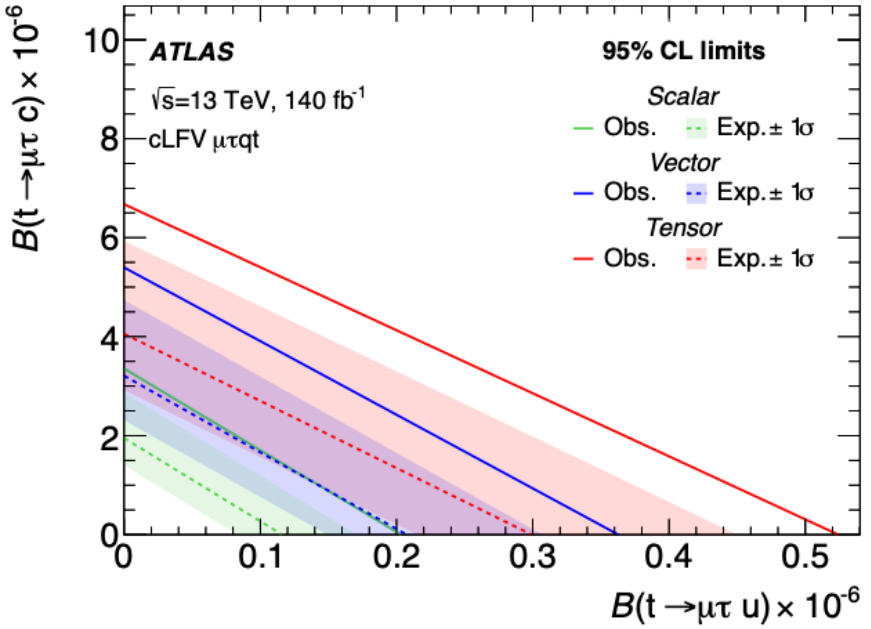




Lepton flavour violation







- **Results compatible with SM expectations within 1.6σ**
- Slight excess driven by the last HT bin in the signal region
- Setting limits on LFV for fermion operators, translated to 10^{-6} - 10^{-7} limits in LFV top quark decay modes
- Analysis also interpreted in terms of leptoquarks

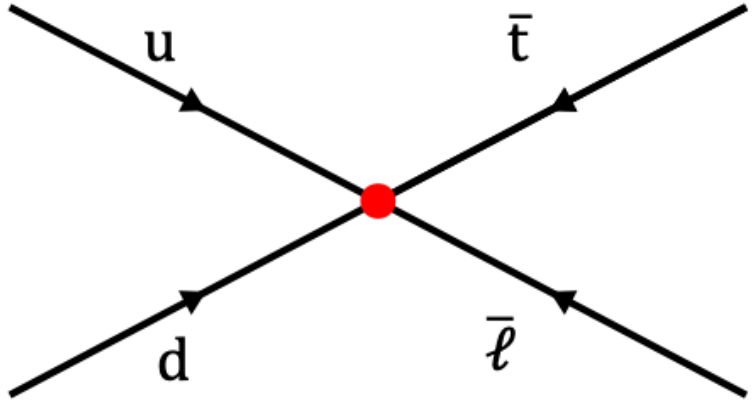
arXiv:2403.06742

Baryon number violation

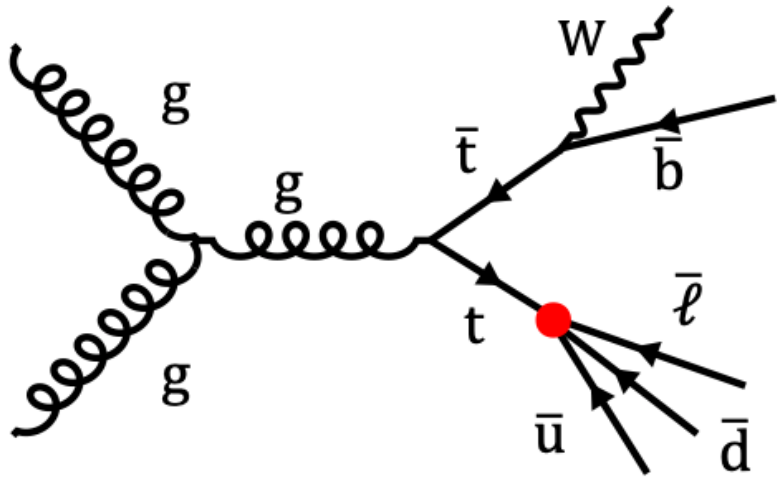
arXiv:2402.18461

- Baryon number violation can be induced by 4-fermion operators
- Introducing **top + lepton production** and **t→lqq** decay

$$\mathcal{L}_{\text{eff}} = \frac{C_s}{\Lambda^2}\epsilon^{\alpha\beta\gamma}[\overline{t^c_\alpha} d_\gamma][\overline{u^c_\beta}\ell] + \frac{C_t}{\Lambda^2}\epsilon^{\alpha\beta\gamma}[\overline{t^c_\alpha}\ell][\overline{u^c_\beta} d_\gamma] + \text{h.c.}$$

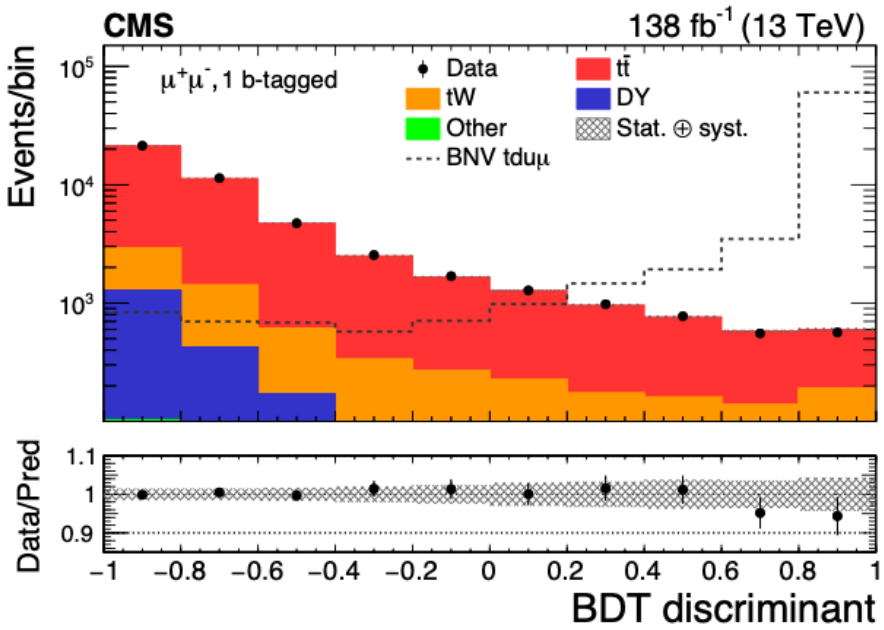


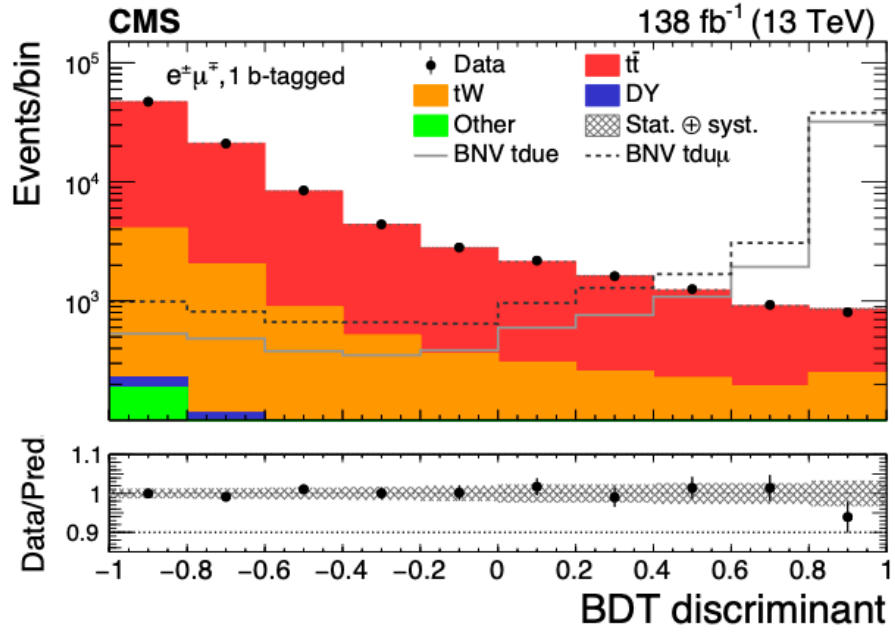
- Probing tlqq' couplings with l=e,μ, q=u,c, q'=d,s, b
- Probing scalar and tensor Lorentz structure
- Studying the dilepton channel (ee, eμ, μμ) in events with exactly one b-tagged jet

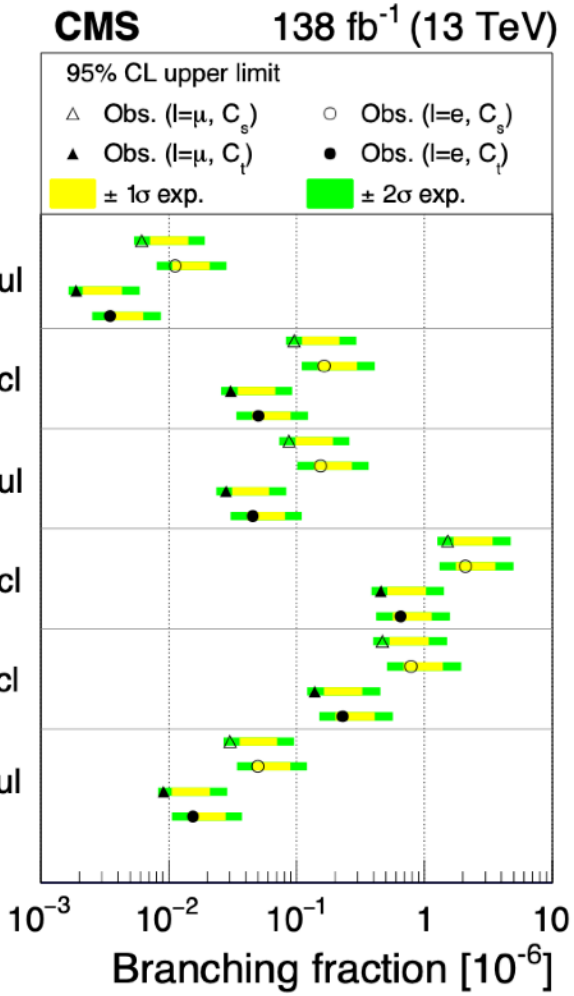


Baryon number violation

- **BDT** used to discriminate between **top+lepton BNV production signal and SM backgrounds**
- Rely mostly on lepton and top quark **p_T and $\Delta\Phi$(l,l)**
- Results consistent with the SM within 2 sigma
- Setting limits in top branching fraction between 10^{-9}-10^{-6}







arXiv:2402.18461

Conclusions

- Overview of latest results on EFTs involving the top quark
  - **Showed an snapshot of a broader on-going programme**
- ATLAS and CMS study both the **“canonical" flavour symmetry and violations of accidental symmetries** (BNV, LFV)
- **Complementary programmes** followed by both collaborations, both in methodology and observables used
- **All results are compatible with the SM**
- **More analyses and combinations are ongoing**
  - See talks on combinations by Alessandro (Higgs combinations) and Andrea (all sectors)
- **Keep posted for more interesting results**