



Searches for new physics with top quarks

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on behalf of the ATLAS and CMS Collaborations

Rencontres de Moriond EW 2026

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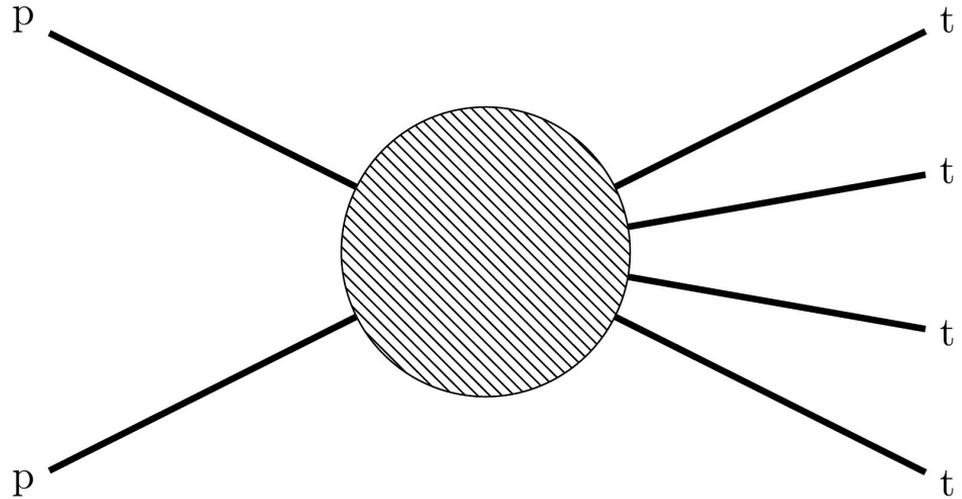


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$t\bar{t}$ resonance searches in a nutshell

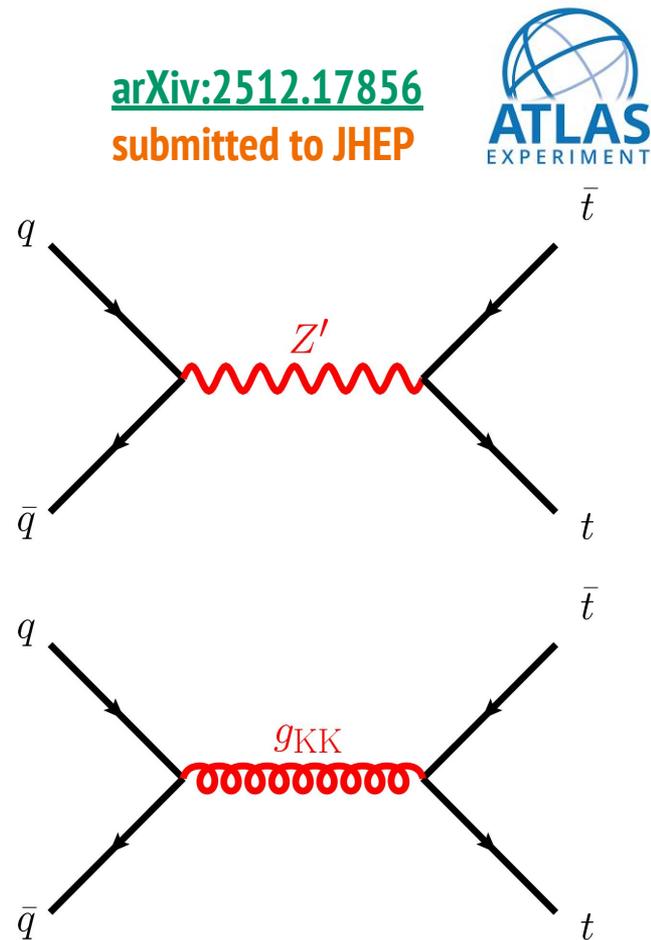
- **Abundant production of top quarks** at the LHC \rightarrow perfect place to **investigate new physics involving top quarks**
- Beyond Standard Model (BSM) theories predict **new heavy particles** coupling strongly to top quarks
- Can address open questions such as EW-Plank scale difference



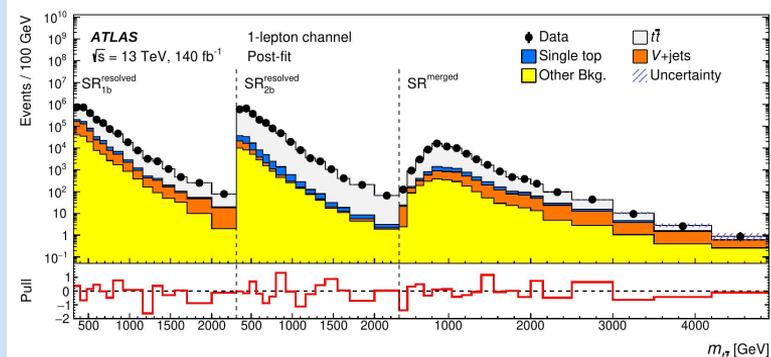
- SM **cross section for multi-top processes (like $t\bar{t}t\bar{t}$) is enhanced in many BSM models**
 - SUSY, compositeness, extra dimensions, ...

Heavy resonances $X \rightarrow t\bar{t}$

- Models such as Randall-Sundrum predict one or **several additional heavy bosons**
 - These can have preferential coupling to top quarks
- Produce results for
 - Topcolor-assisted-technicolor (TC2)
 - Kaluza-Klein graviton (G_{KK})
 - Kaluza-Klein gluon (g_{KK})
- Analyze LHC **Run2 dataset** (140 fb^{-1}) and $t\bar{t}b\bar{a}$ decays **in the 1L+2L final states**
- **Target both resolved and merged** hadronic top quark decays
 - [DNN-based method](#) to tag merged decays
- Observables:
 - 1L: $m_{t\bar{t}}$
 - 2L: m_{bbll}

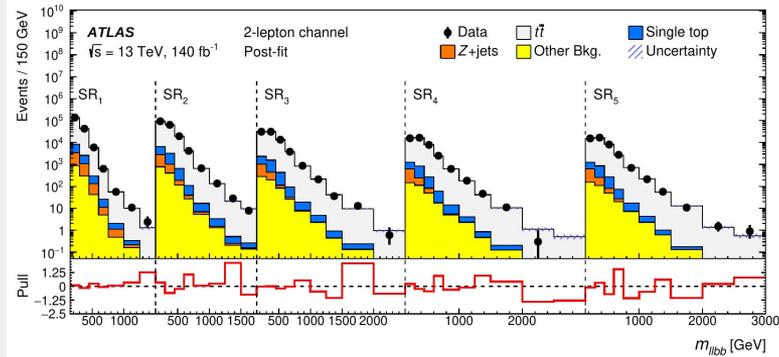


Heavy resonances $X \rightarrow t\bar{t}$



1-lepton channel

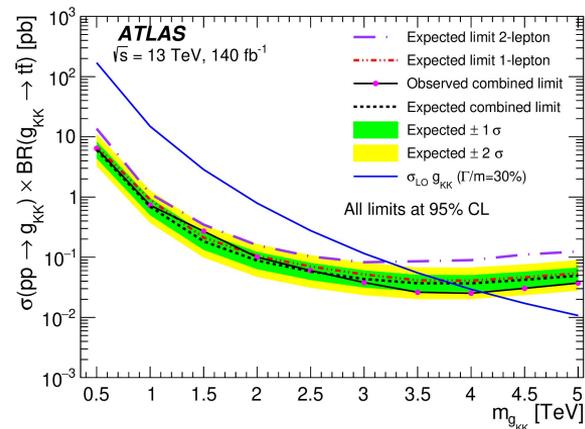
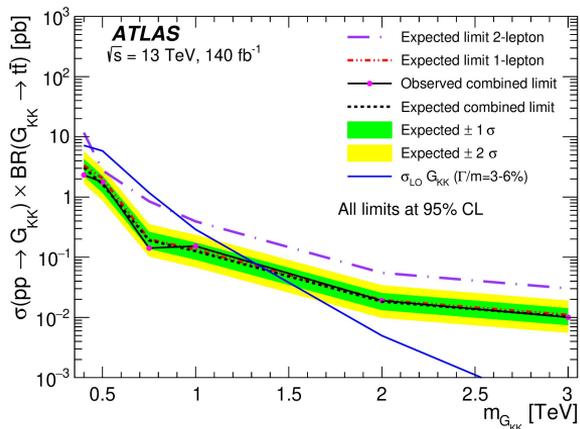
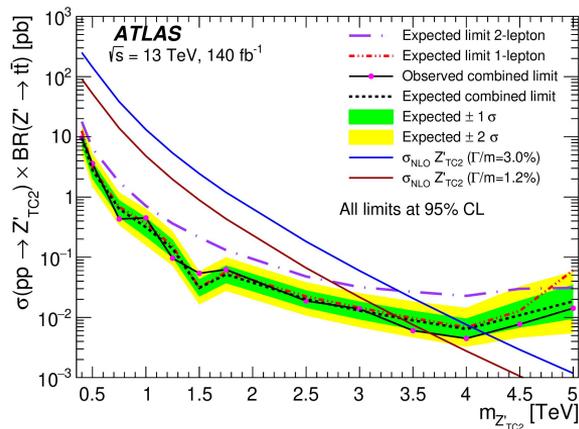
- **Analysis regions** defined along:
 - Presence of 1 lepton
 - Presence of large-radius jet
 - Number of b-tagged jets
- W+jets and “fake” backgrounds estimated with data-driven techniques



2-leptons channel

- **Analysis regions** defined along:
 - Presence of 2 OS leptons
 - Number of b-tagged jets
 - Angular separation between leptons $\Delta\Phi_{ll}/\pi$
- Z + jets background estimated with data-driven techniques

Heavy resonances $X \rightarrow t\bar{t}$



- **No significant excesses observed** across the $m_{t\bar{t}}$ or $m_{l\bar{l}b\bar{b}}$ spectra
- Upper limit derived for the considered signals
- Dominant systematics: modeling of $t\bar{t}$ background

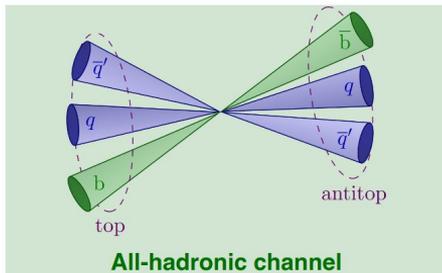
Heavy resonances $X \rightarrow t\bar{t}$

soon on the arXiv

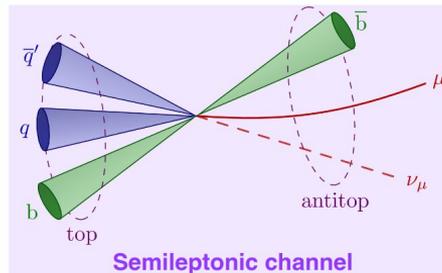


- Conceptually (motivation, signals under consideration) similar to previously mentioned ATLAS search

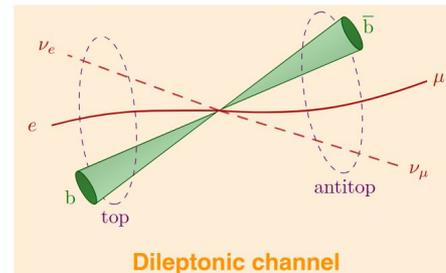
Adds 0L channel too



- Final state:**
 - 2 AK8 jets
- Dominant background:** QCD, SM $t\bar{t}$
 - $t\bar{t}$ modeled from MC simulation
 - QCD estimated from data using 2D parametric alphabet method

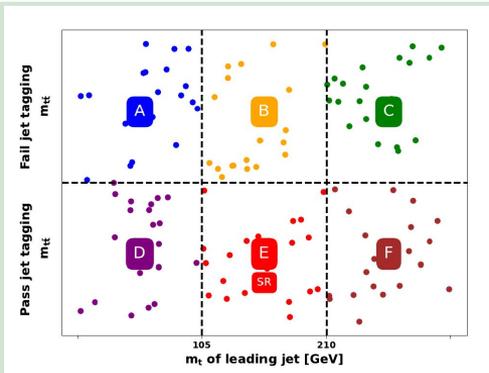


- Final state:**
 - *Leptonic top:*
 - Lepton + MET + AK4 jet
 - *Hadronic top:*
 - Boosted topology: AK8 top-tagged
 - Resolved topology: three AK4 jets
- Dominant background:** SM $t\bar{t}$, single top, W+jets
 - Dedicated DNN classifier to reject backgrounds



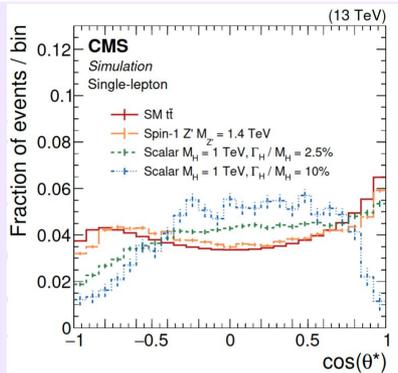
- Final state**
 - 2 AK4 jets
 - 2 leptons
 - MET
- Dominant background:** SM $t\bar{t}$, single top, DY
 - Modeled from MC simulation

Heavy resonances $X \rightarrow t\bar{t}$



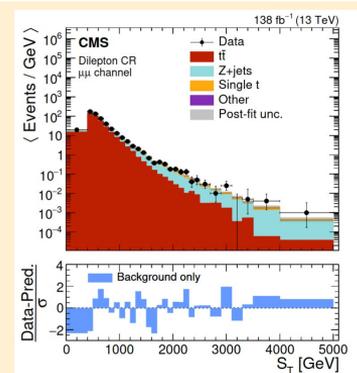
All-hadronic channel

- **Analysis regions** defined along:
 - subleading jet t -tagging requirement
 - leading jet mass above and below top mass window
- Simultaneous 2D fit across regions to determine contributions from QCD background and extract signal.
 - Done separately for central and forward rapidity regions



Semileptonic channel

- **Analysis regions** defined along:
 - DNN categorization
 - number of top tags
 - polarization variable ($\cos \theta^*$)
- Simultaneous ML fit of the top-antitop invariant mass across the regions

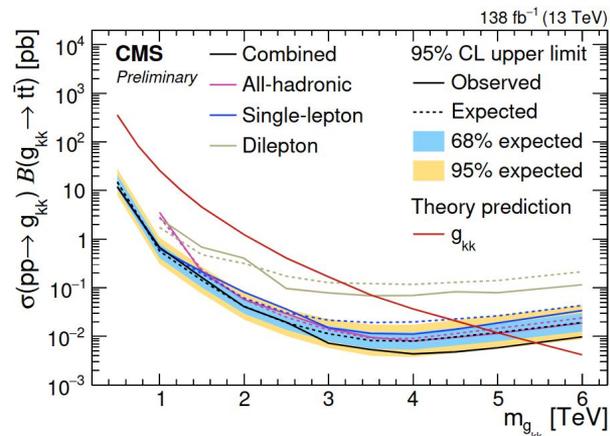
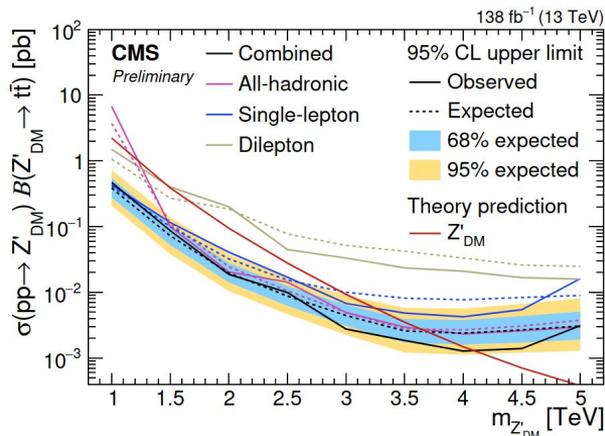
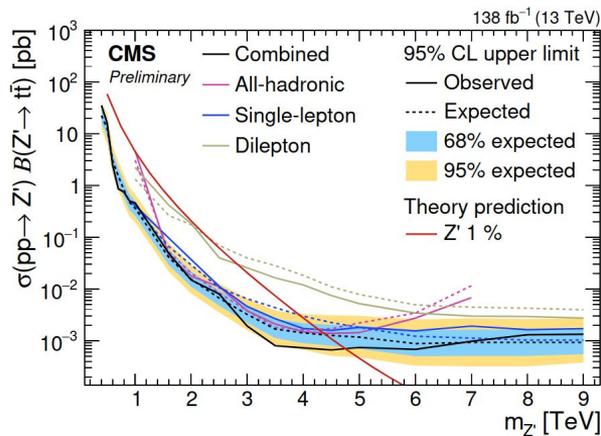


Dileptonic channel

- **Analysis regions** defined along:
 - sum of ΔR between the two leptons and the closest jet
 - (Boosted, resolved, control)
 - lepton flavor (ee, em, mm)
- Simultaneous ML fit of S_T variable^{*} across the regions

* scalar sum of the transverse momenta of the jets, leptons, and missing transverse momentum

Heavy resonances $X \rightarrow tt$



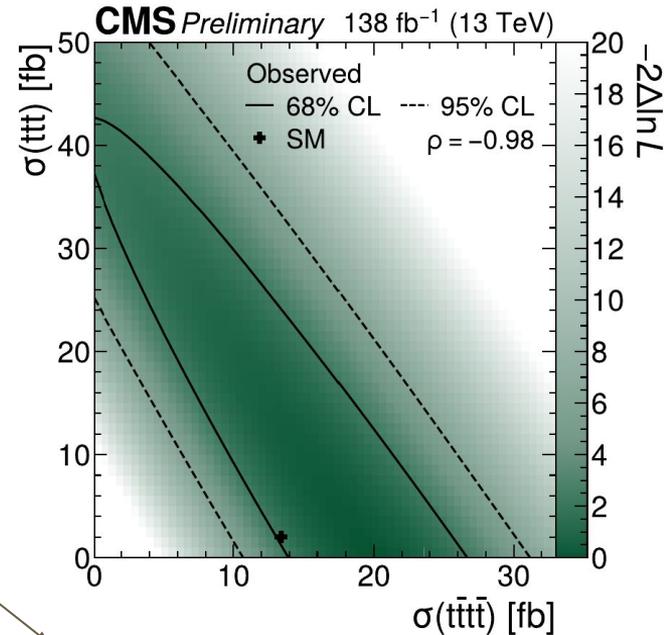
- With respect to ATLAS, include Z' dark-matter mediators, don't include G_{KK}
- **No significant excesses observed** across the m_{tt} or S_T spectra
- Dominant systematics: modeling of $t\bar{t}$ background

BSM interpretations of 4 tops

CMS-PAS-TOP-24-008

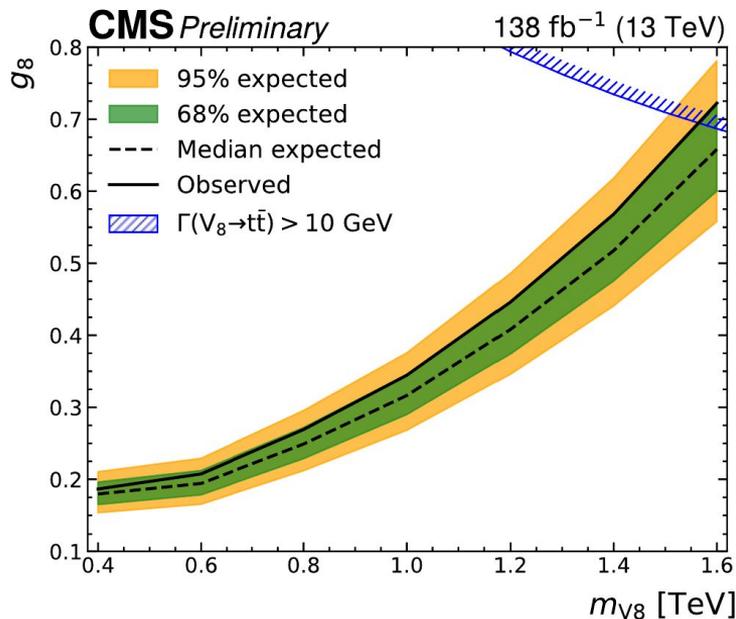


- **BSM interpretation of [previous CMS measurement](#)**
 - A few refinements in the treatment of backgrounds and uncertainties
- Study simultaneous production of $t\bar{t}t$ and $t\bar{t}W + t\bar{t}q$ (collectively called $t\bar{t}t$)
 - 2, 3 or 4 leptons + machine learning methods
- Cross section measurement slightly higher than predictions: $\sigma(t\bar{t}t) = 18.9^{+4.4}_{-4.0} \text{ fb}$
- **Interpret mild excess in three scenarios:**
 - Top-philic heavy resonances
 - Anomalous top quark Yukawa couplings
 - Standard Model Effective Field Theory (SMEFT)

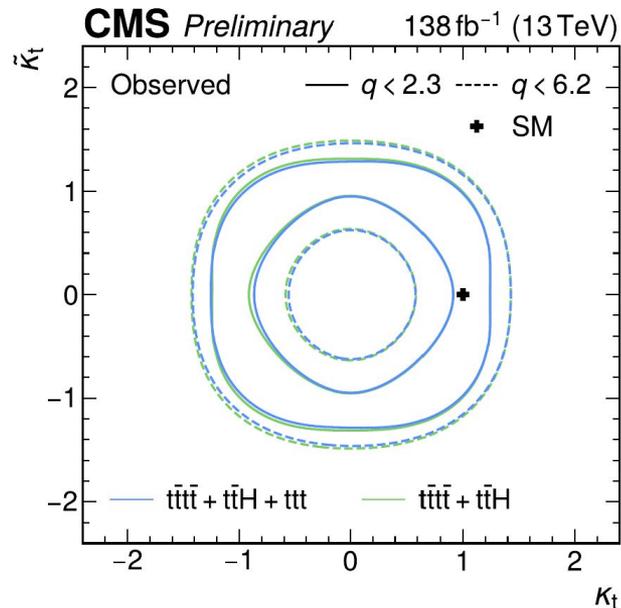


$\sigma(t\bar{t}t)_{\text{SM}} = 13.4^{+1.0}_{-1.8} \text{ fb}$ ([ref.](#))
 $\sigma(t\bar{t}t)_{\text{SM}} = 10.4^{+2.5}_{-2.2} \text{ fb}$ ([ref.](#))

BSM interpretations of 4 tops

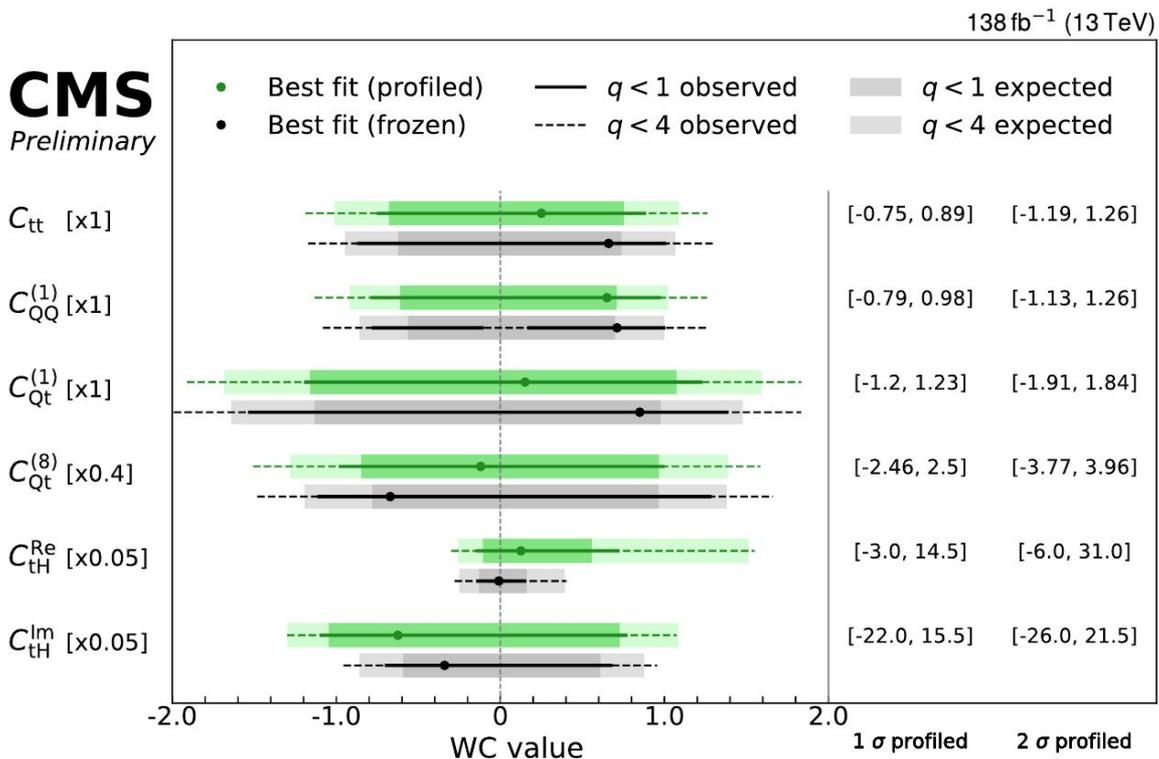


- Interpret results in terms of scalar, pseudoscalar, vector heavy resonances
- **Vector color octet (V8)** excluded for masses in [0.4, 1.5] TeV
- More interpretations in public document



- Interpret results in terms of **CP-violating anomalous Yukawa couplings**
- Enhanced magnitude of couplings allowed
- No preferred sign combination

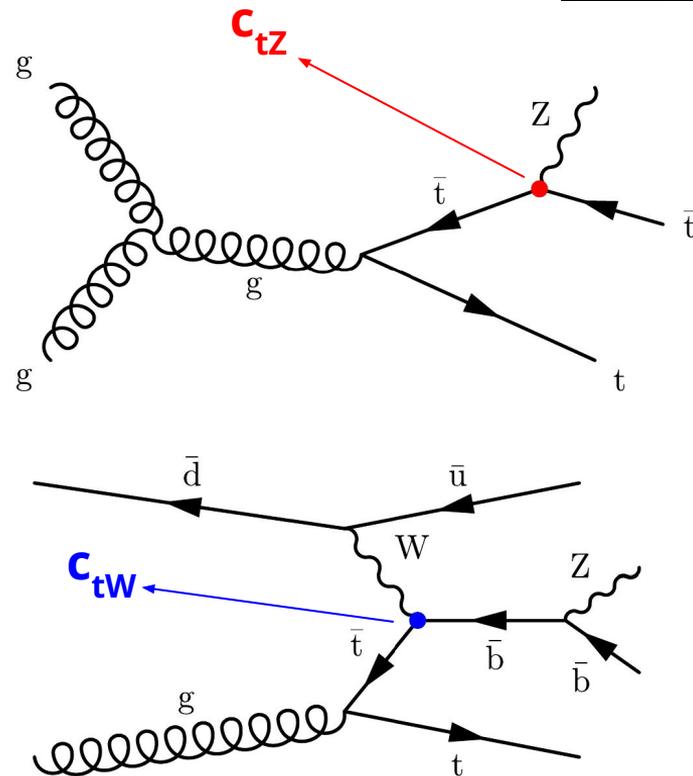
BSM interpretations of 4 tops



- Slight preference of non-zero values for four-heavy-quarks Wilson Coefficients
- Compatible with mild excess observed in SM fit
- **Within uncertainties, results compatible with SM expectation of 0**

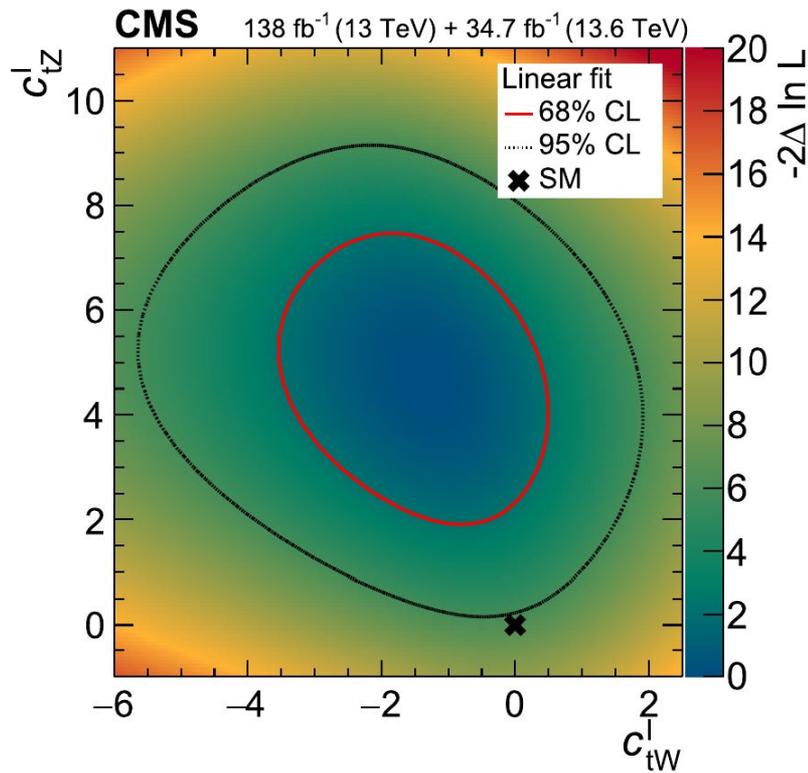
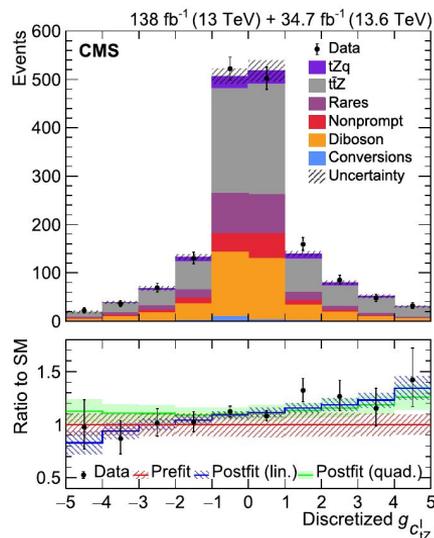
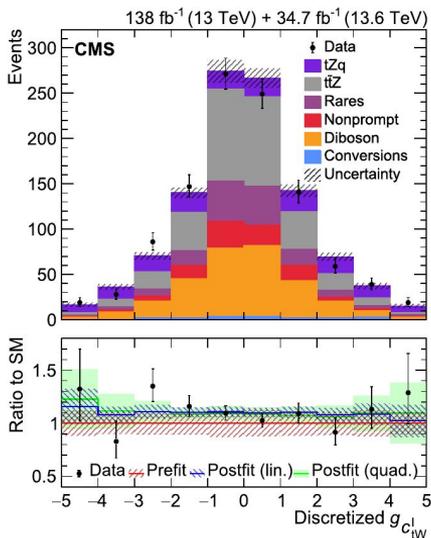
CP violation in ttZ

- Explore new sources of CP violation in the ttZ and tZq associated production
- Analyze LHC Run2 + **early Run3** (2022) **data**
- Previous ttZ analyses relied on CP-even observables (e.g. cross sections) → not sensitive to CP violation
 - **Here, employ CP-odd observables**
 - Observables built with machine learning using [CP-equivariant neural networks](#)
- Select events with at least three leptons + jets
 - One OSSF lepton pair, at least 1 b tag
- Study C_{tZ} and C_{tW}



CP violation in ttZ

- Simultaneous measurements of c_{tZ} and c_{tW} compatible with the SM prediction within 2σ
- Deviation explained by slight observed asymmetry in ML observables and slight excess of events



Conclusions



- Both ATLAS and CMS Collaborations are **actively searching for BSM physics using top quarks**
 - Looking directly for production of new particles
 - Looking for anomalous effects on top of SM
- **Both ATLAS and CMS** recently released searches for **heavy BSM particles decaying to $t\bar{t}$**
 - 1L + 2L channels for ATLAS
 - 0L + 1L + 2L channels for CMS
 - More BSM results by ATLAS in [Sergio's talk](#) on Saturday
- **CMS** also recently released **searches for new physics in multi-top final states**
 - BSM interpretations of 4-top cross section measurement (more about 4-top in [Dominic's talk](#))
 - CP violation in $t\bar{t}Z$
- **No strong hints of new physics** have emerged so far