ttX and top properties in ATLAS and CMS

Les Rencontres de Physique de la Vallée d'Aoste

<u>Bárbara Álvarez González</u> on behalf of the ATLAS and CMS Collaborations

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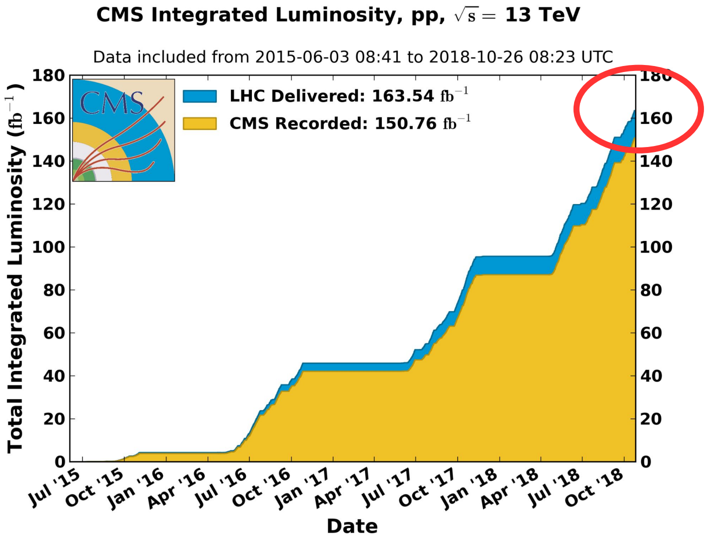
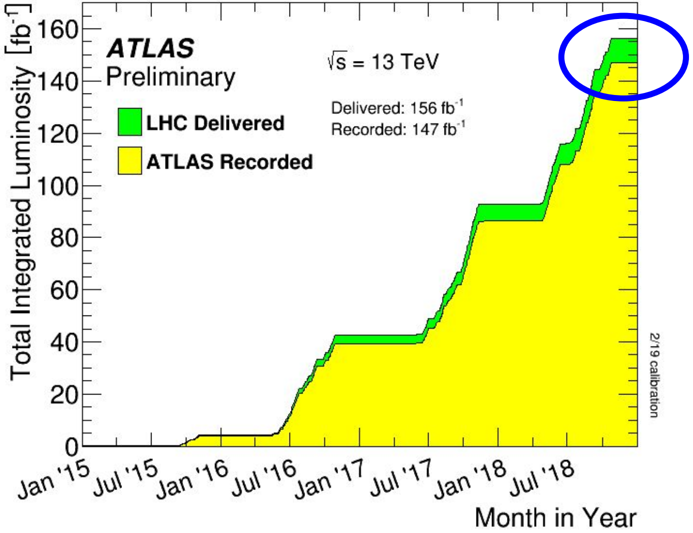
Introduction

- The **top quark** offers a **very rich physics program**
- Rare top production modes **(ttX)** become fully accessible with Run2 data *inclusively and differentially*
    - Precision measurements and searches (**EFT**) are carried out
- Searches for **FCNC** which are strongly suppressed in the SM but included in extensions of the SM
- The measurements and searches presented today are performed with the **full Run 2 of the LHC at 13 TeV** with the ATLAS and CMS experiments





Search for new physics using top quark pairs associated with a boosted Z or Higgs in EFT

NEW [CMS-PAS-TOP-21-003]

Probing EFT operators in the associated production of top quarks with a Z boson

[JHEP 12 (2021) 083]

Inclusive and differential $t\bar{t}\gamma$ cross sections

NEW [arxiv:2201.07301]

ROAD PATH

Search for FCNC couplings between the top quark and the photon

NEW [ATLAS-CONF-2022-003]

Search for FCNC interactions of a top quark and a gluon

NEW arxiv:2112.01302

Search for FCNC couplings between the top quark and the Z boson

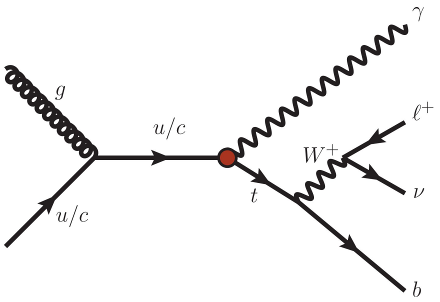
[ATLAS-CONF-2021-049]

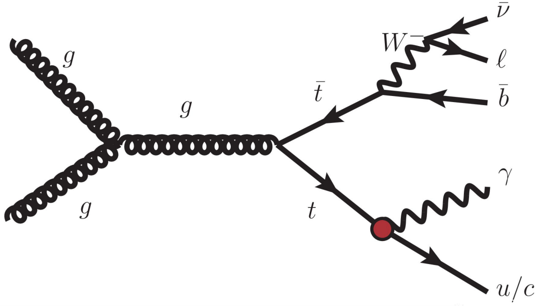
Search for FCNC couplings between the top quark and the photon

ATLAS-CONF-2022-003

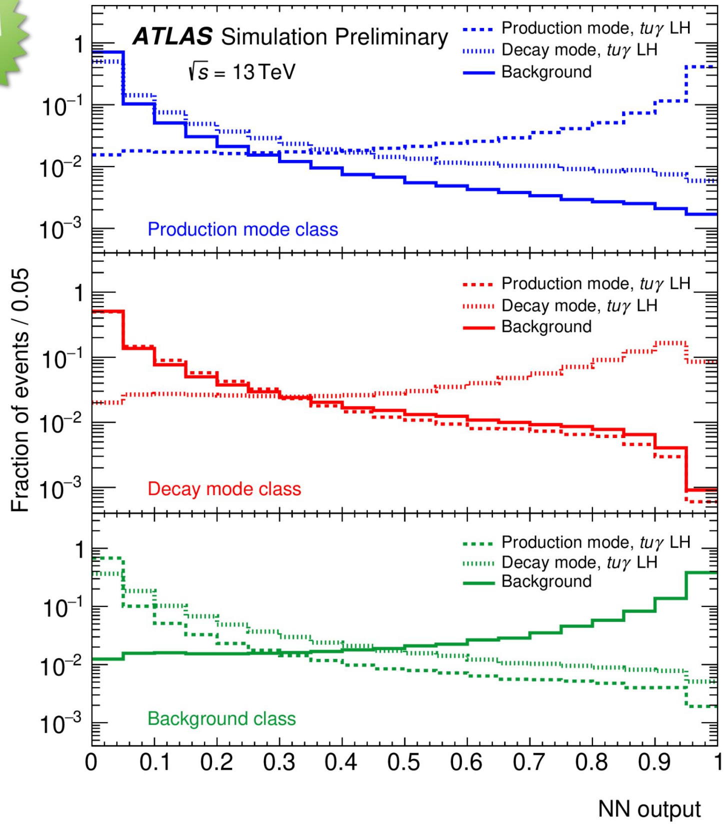
NEW

Both FCNC top-quark **production** and **decay** are considered



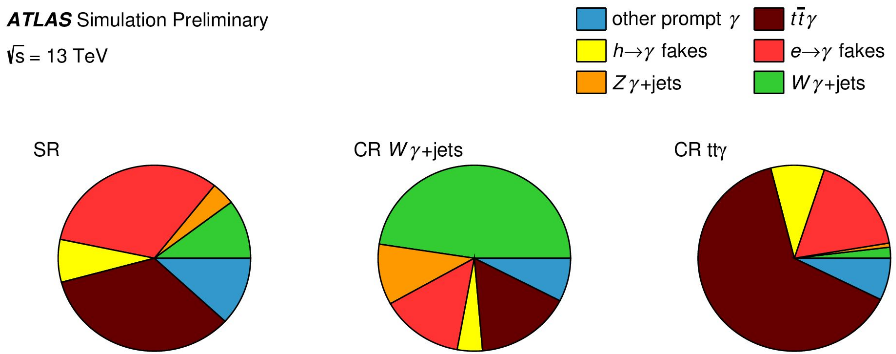


Object	SR	CR $t\bar{t}\gamma$	CR $W\gamma$+jets
Photon	$= 1$		
Lepton	$= 1$		
$E_{\mathrm{T}}^{\mathrm{miss}}$	> 30 GeV		
Jets	≥ 1	≥ 4	≥ 1
b-tagged jets (60% WP)	$= 1$	–	$= 0$
b-tagged jets (70% WP)	$= 1$	≥ 1	$= 0$
b-tagged jets (77% WP)	$= 1$	≥ 2	$= 1$
$m(e,\gamma)$	–	–	$\notin [80,100]$ GeV



A multiclass DNN is used to classify events as either one of the two signal categories or background

Search for FCNC couplings between the top quark and the photon

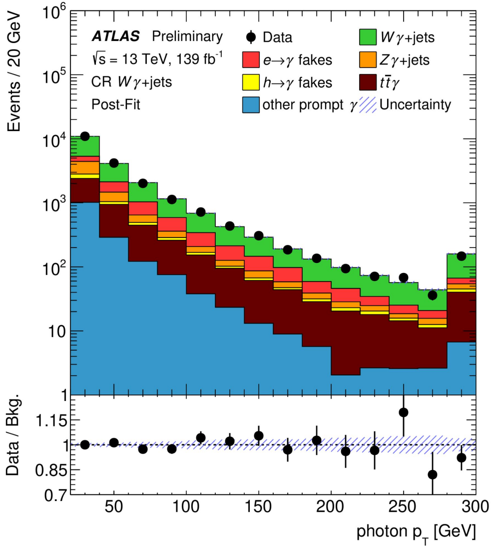


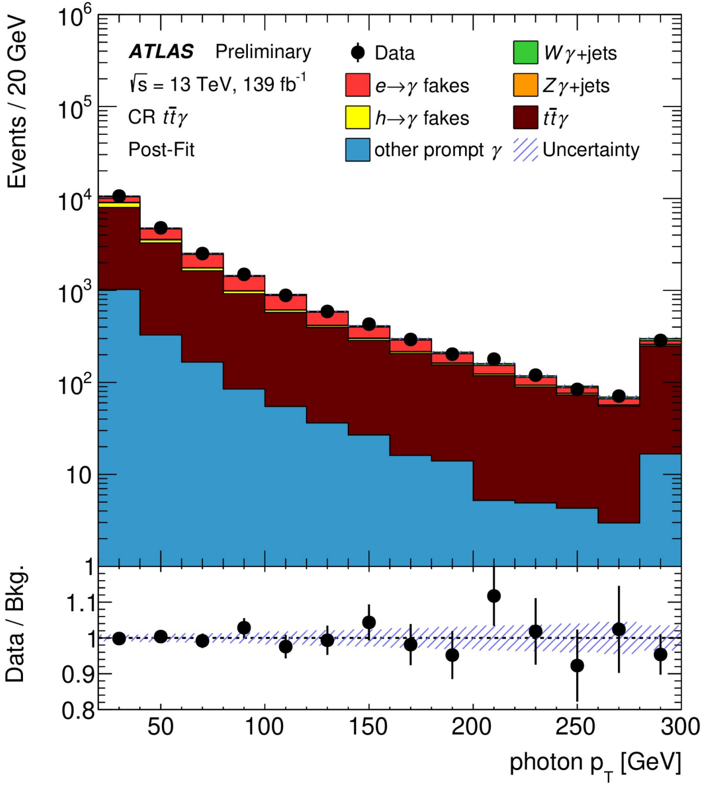
Main backgrounds:

- ttγ
- Wγ +jets
- Fakes

Backgrounds with **prompt photons** are modelled by MC and there are dedicated control regions (included in the fit)

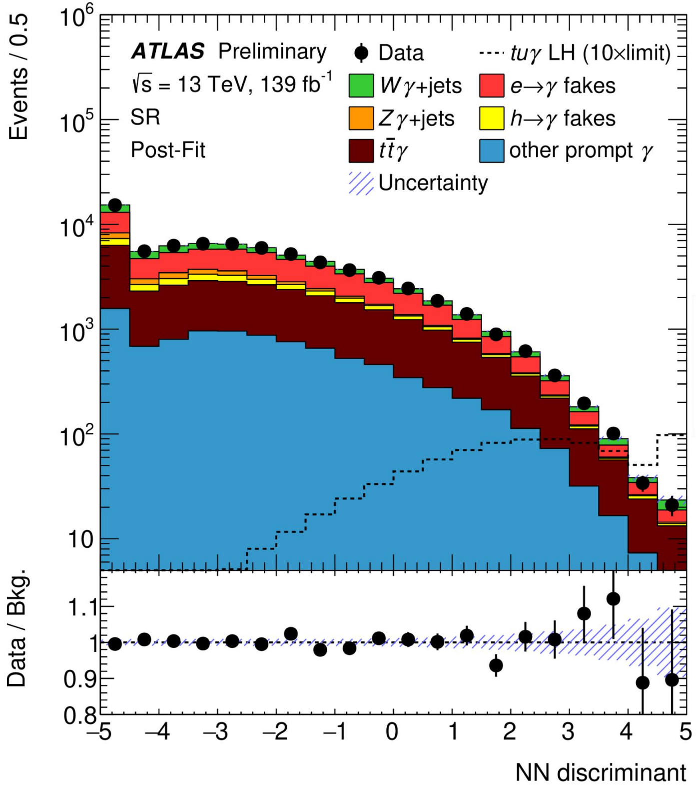
Fakes either from electrons or hadrons are modelled from MC but corrected with data-driven SFs





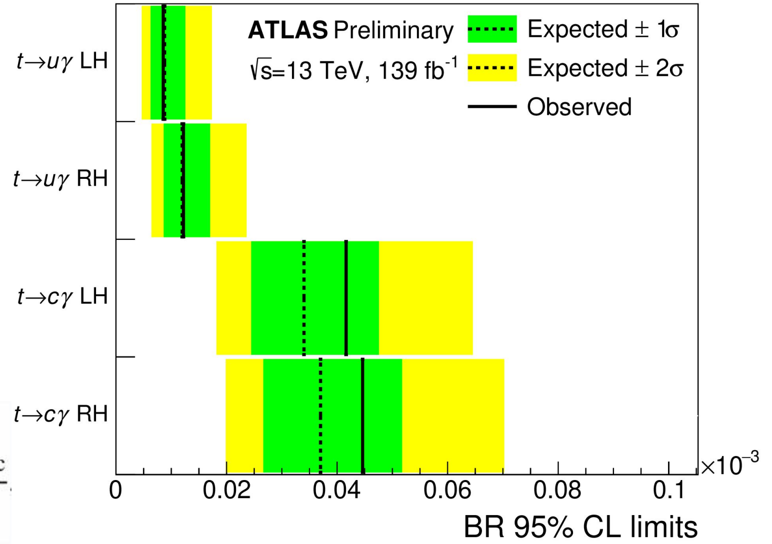
Search for FCNC couplings between the top quark and the photon

No significant excess of events over the background prediction is observed



95% CL upper limits on the **strength of left- and right-handed** FCNC interactions are set

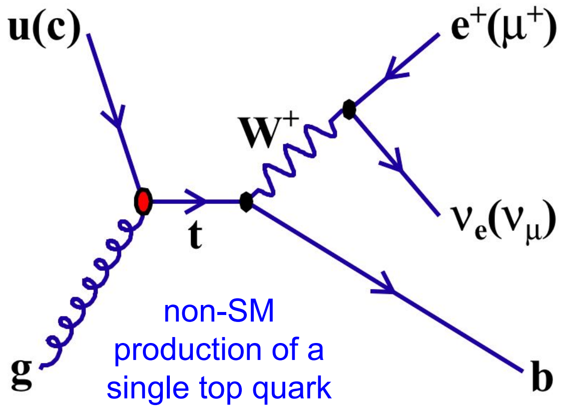
$$\mathcal{D} = \ln \frac{a \cdot y_{\text{prod}} + (1-a) \cdot y_{\text{dec}}}{y_{\text{bkg}}}$$



Effective coupling	Coefficient limits Expected	Coefficient limits Observed	Coupling	BRs $[10^{-5}]$ Expected	BRs $[10^{-5}]$ Observed
$\lvert C_{uW}^{(13)*} + C_{uB}^{(13)*}\rvert$	$0.104^{+0.020}_{-0.016}$	0.103	$t \to u\gamma$ LH	$0.88^{+0.37}_{-0.25}$	0.85
$\lvert C_{uW}^{(31)} + C_{uB}^{(31)}\rvert$	$0.122^{+0.023}_{-0.018}$	0.123	$t \to u\gamma$ RH	$1.20^{+0.50}_{-0.33}$	1.22
$\lvert C_{uW}^{(23)*} + C_{uB}^{(23)*}\rvert$	$0.205^{+0.037}_{-0.031}$	0.227	$t \to c\gamma$ LH	$3.40^{+1.35}_{-0.95}$	4.16
$\lvert C_{uW}^{(32)} + C_{uB}^{(32)}\rvert$	$0.214^{+0.039}_{-0.032}$	0.235	$t \to c\gamma$ RH	$3.70^{+1.47}_{-1.03}$	4.46

Search for FCNC interactions of a top quark and a gluon

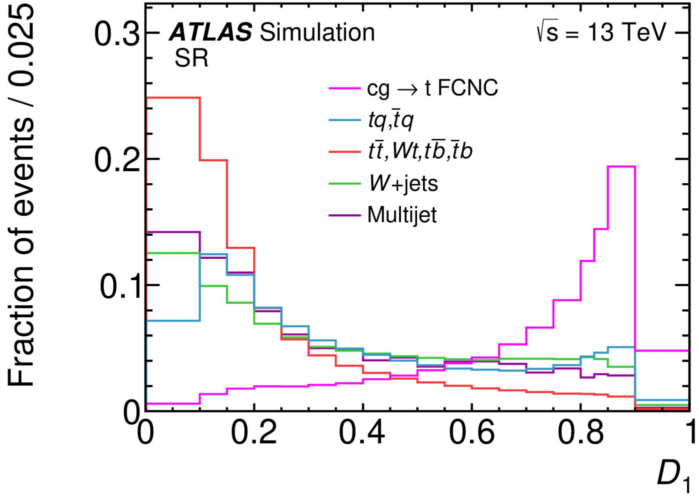
Submitted to ***EPJC*** *(2 December 2021)* arxiv:2112.01302

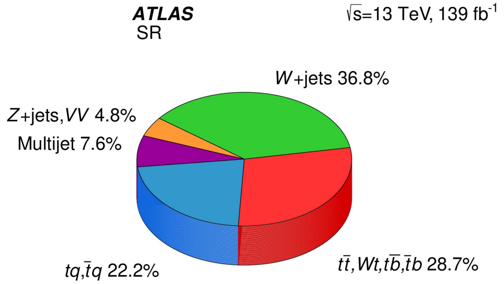


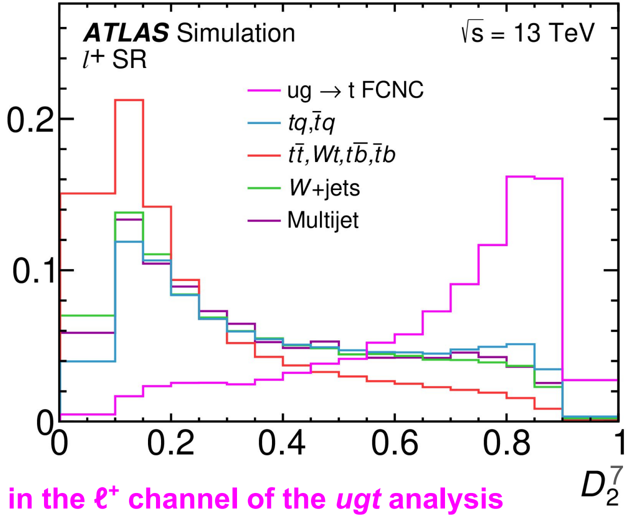
Signal region, event with:

- exactly one electron or muon
- exactly one *b*-tagged jet
- E_T^{miss} > 30 GeV and $m_T(W)$> 50 GeV

NNs based on kinematic variables to differentiate between events from the **two signal (cg→t and ug→t)** processes and events from background processes







D_1 was used for *cgt* analysis and the ℓ^- channel of the *ugt* analysis

D_2 used in the ℓ^+ channel of the *ugt* analysis

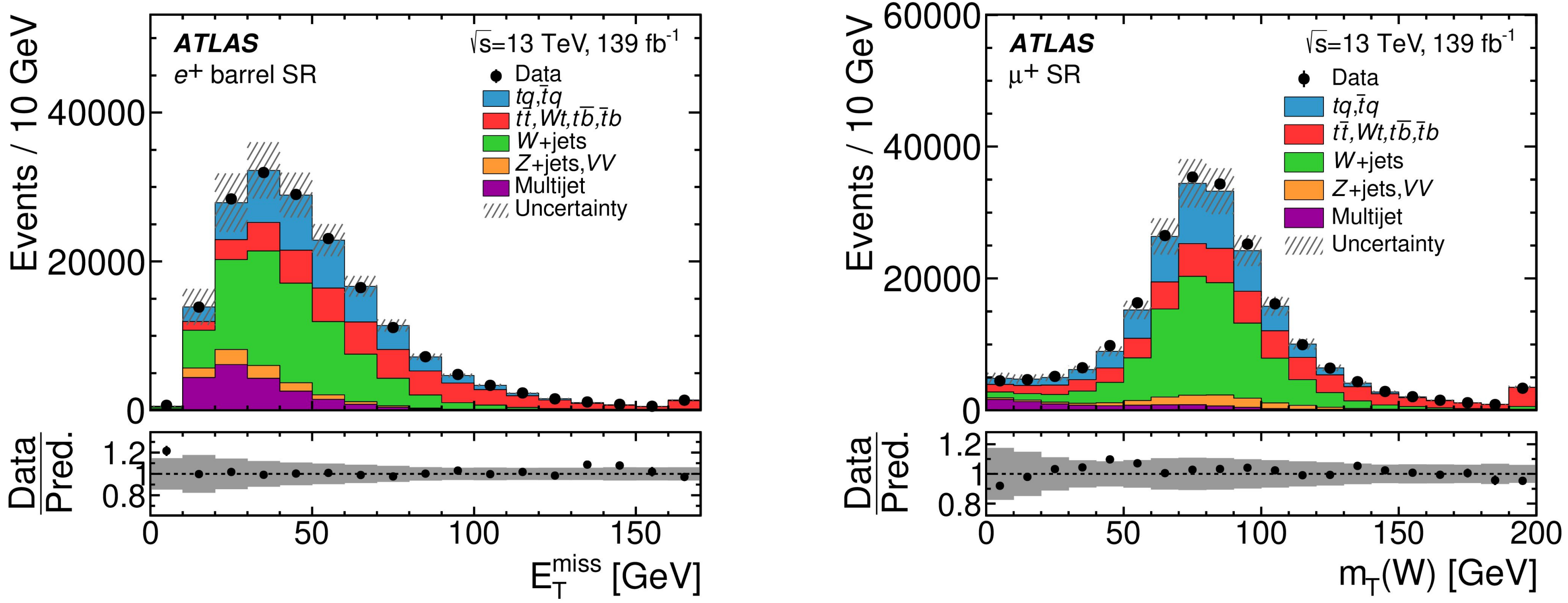
Search for FCNC interactions of a top quark and a gluon

Backgrounds with **prompt leptons** are modelled by MC and normalized to their expected cross section except **W+jets** extracted from the fit

The **multijet bkg** is modelled from MC simulation for electrons and from collision data for muons

The rate of the **multijet bkg** is determined in a data-driven way by **fitting**:

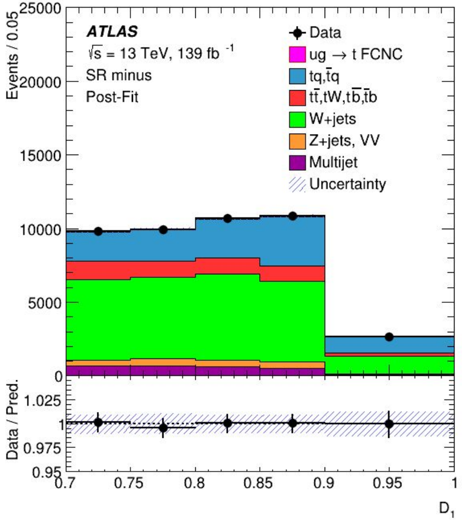
- the E_T^{miss} distribution for events with an electron
- the $m_T(W)$ distribution for events with a muon

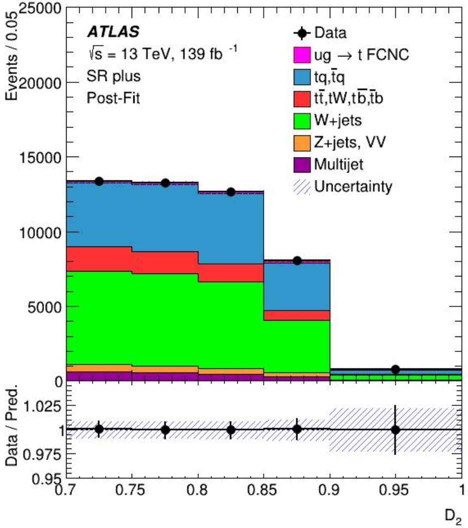


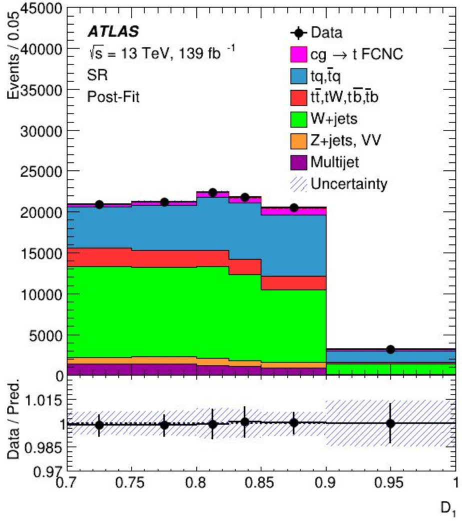
Search for FCNC interactions of a top quark and a gluon

Measurement consistent with the background-only hypothesis
Limits set on the production **cross-sections** of the signal processes:

$\sigma(u+g\to t)\times \mathrm{B}(t\to Wb)\times \mathrm{B}(W\to \ell\nu)$ < **3.0 pb** at the 95% C.L.
$\sigma(c+g\to t)\times \mathrm{B}(t\to Wb)\times \mathrm{B}(W\to \ell\nu)$ < **4.7 pb** at the 95% C.L.







Based on the framework of an **EFT**, the cross-section limits are translated into limits on the strengths of the ***tug*** and ***tcg*** **couplings** occurring in the theory:

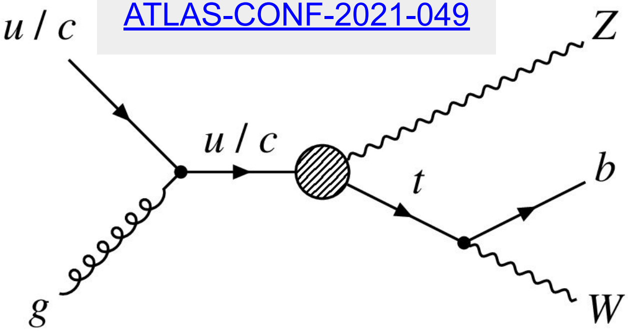
$|C^{ut}_{uG}|/\Lambda^2 < 0.057\ \mathrm{TeV}^{-2}$
$|C^{ct}_{uG}|/\Lambda^2 < 0.14\ \mathrm{TeV}^{-2}$

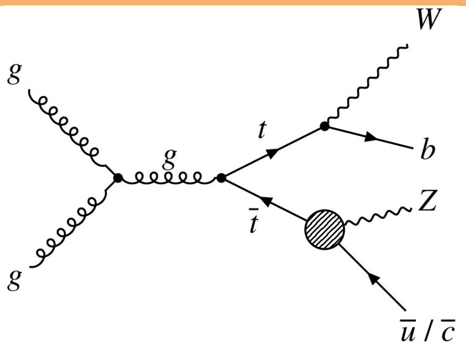
These bounds correspond to limits on the **branching ratios** of FCNC-induced top-quark decays:

$\mathrm{B}(t\to u+g) < 0.61\times 10^{-4}$
$\mathrm{B}(t\to c+g) < 3.7\times 10^{-4}$

Search for FCNC couplings between the top quark and the Z boson

ATLAS-CONF-2021-049



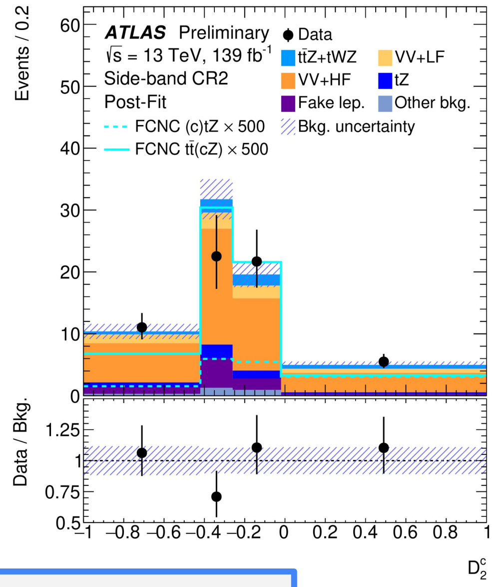


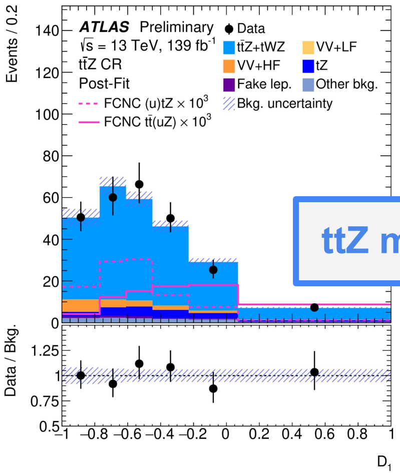
The search targets both events where a **single top quark** is produced as ***gq→tZ*** (with *q*=*u*,*c*) and **top-quark pair** events, with one top quark decaying through the ***t→qZ*** channel

Common selections		
Exactly 3 leptons with $p_T(\ell_1) > 27\,\mathrm{GeV}$, ≥ 1 OSSF pair, with $\lvert m_{\ell\ell} - m_Z\rvert < 15\,\mathrm{GeV}$		
SR1	SR2	
≥ 2 jets	1 jet	2 jets
1 b-jet	1 b-jet	1 b-jet
–	$m_T(\ell_W, \nu) > 40\,\mathrm{GeV}$	$m_T(\ell_W, \nu) > 40\,\mathrm{GeV}$
$\lvert m^{\mathrm{reco}}_{j_a\ell\ell} - m_t\rvert < 2\sigma_{t_{\mathrm{FCNC}}}$	–	$\lvert m^{\mathrm{reco}}_{j_a\ell\ell} - m_t\rvert > 2\sigma_{t_{\mathrm{FCNC}}}$
–	$\lvert m^{\mathrm{reco}}_{j_b\ell_W\nu} - m_t\rvert < 2\sigma_{t_{\mathrm{SM}}}$	$\lvert m^{\mathrm{reco}}_{j_b\ell_W\nu} - m_t\rvert < 2\sigma_{t_{\mathrm{SM}}}$

Several CRs to check the background contributions: side-band CR1, side-band CR2, tt CR and ttZ CR

VV+HF main bkg in SR2





ttZ main bkg in SR1

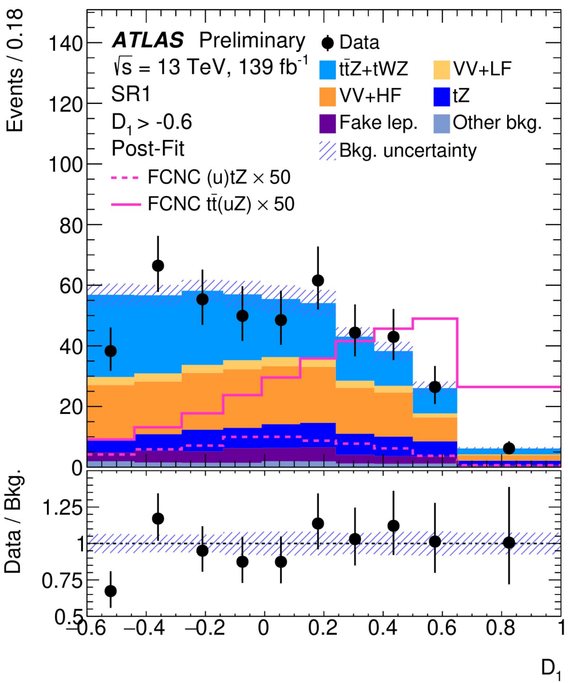
Search for FCNC couplings between the top quark and the Z boson

Measurement consistent with the background-only hypothesis
95% confidence-level limits on the branching ratios are:

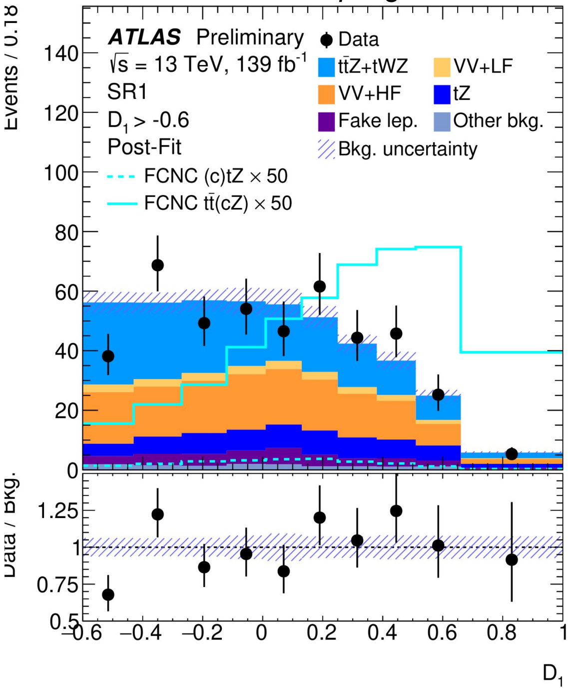
Left-handed coupling:
$B(t\rightarrow Z+u)$ 6.2×10^{-5}
$B(t\rightarrow Z+c)$ 13×10^{-5}

Right-handed coupling:
$B(t\rightarrow Z+u)$ 6.6×10^{-5}
$B(t\rightarrow Z+c)$ 12×10^{-5}

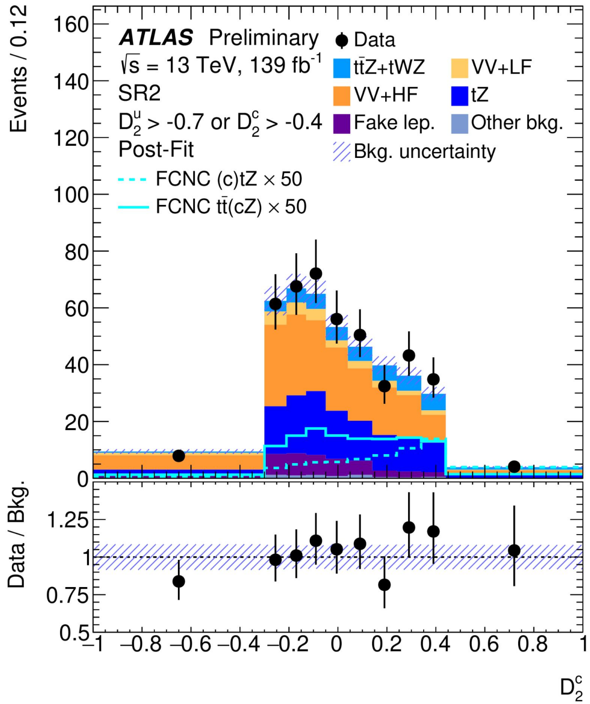
D_1 discriminant in SR1, for the FCNC tZu LH coupling



D_1 discriminant in SR1, for the FCNC tZc LH coupling



D_2^c discriminant in SR2, for the FCNC tZc LH coupling



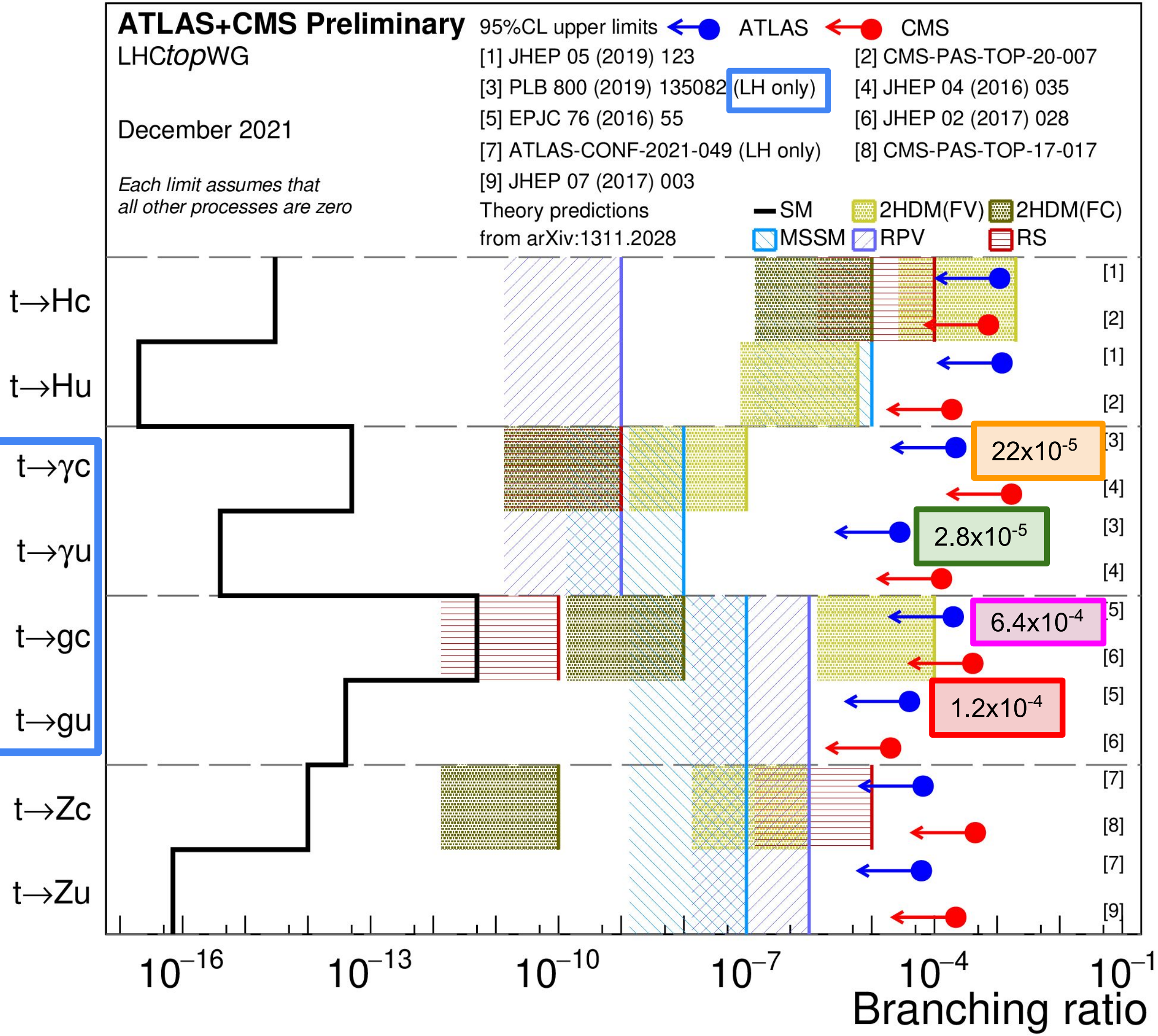
FCNC BR Summary

New results presented today supersede some of these results

Coupling	BRs $[10^{-5}]$ Expected	Observed
$t \to u\gamma$ LH	$0.88^{+0.37}_{-0.25}$	0.85
$t \to u\gamma$ RH	$1.20^{+0.50}_{-0.33}$	1.22
$t \to c\gamma$ LH	$3.40^{+1.35}_{-0.95}$	4.16
$t \to c\gamma$ RH	$3.70^{+1.47}_{-1.03}$	4.46

$B(t \to c+g) < 3.7\times10^{-4}$

$B(t \to u+g) < 0.61\times10^{-4}$

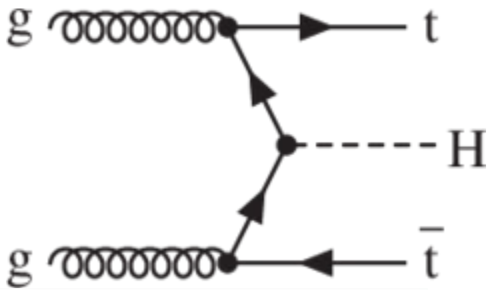


Search for new physics using top quark pairs associated with a boosted Z or Higgs in EFT

CMS-PAS-TOP-21-003

NEW

First search of new physics with **ttZ** and **ttH** events with a **boosted** Z/H boson using EFT at the LHC



EFT effects causes large deviations from the SM production of ttZ and ttH in the **boosted regime**

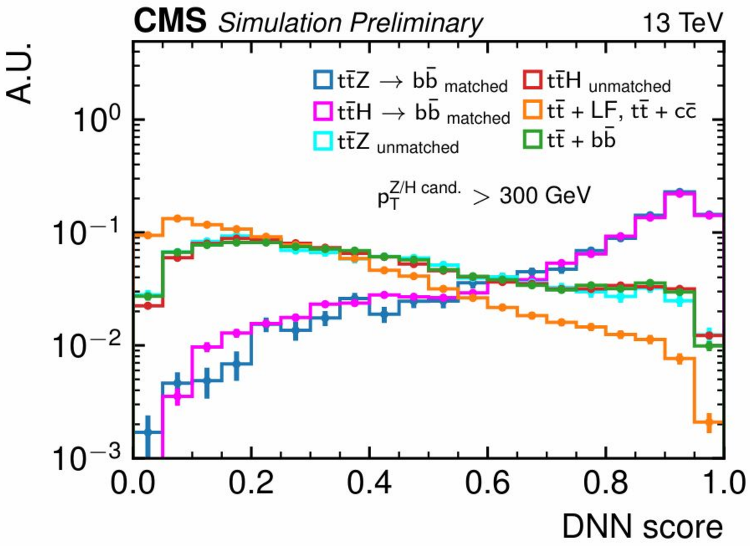
Signal region:

- 1 lepton (electron or moun)
- At least 1 (boosted) Z/H candidate
- At least 5 jets (p_T > 30 GeV)
- At least 2 b-tagged jets separated from the Z/H candidate
- E_T^{miss} > 20 GeV

This analysis targets the Z/H → bb

Built a deep multi-classifier neural network (**DNN**) trained to differentiate signal from bkg mainly (tt + bb)

Create analysis templates binned according to **DNN** score and reconstructed Z/H candidate mass



Search for new physics using top quark pairs associated with a boosted Z or Higgs in EFT

[CMS-PAS-TOP-21-003](CMS-PAS-TOP-21-003)

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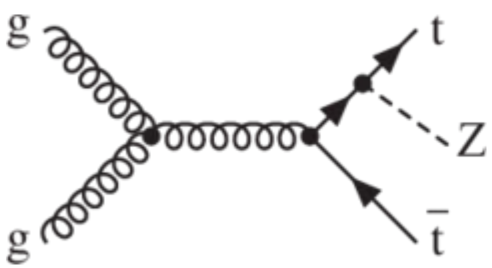

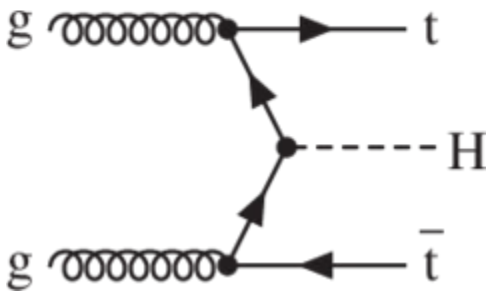

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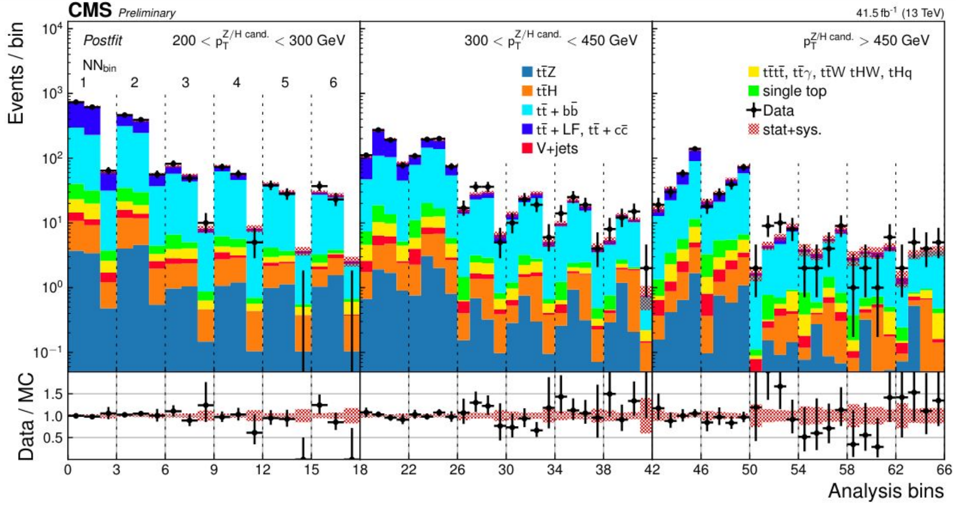

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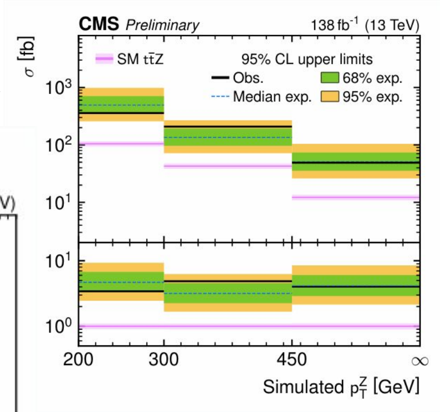
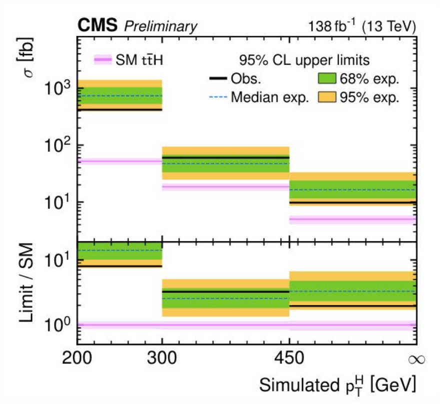
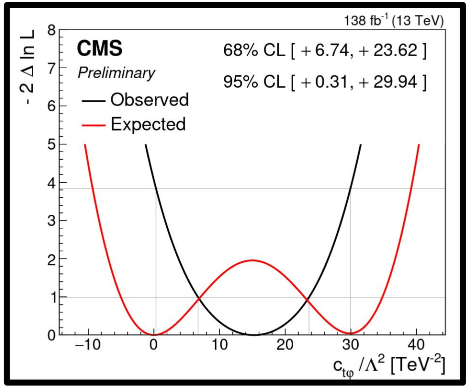
Search for new physics using top quark pairs associated with a boosted Z or Higgs in EFT

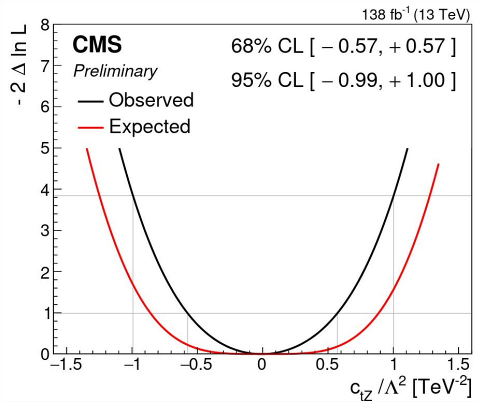
Used in a binned maximum-likelihood fit to extract the **best-fit values** of the model parameters

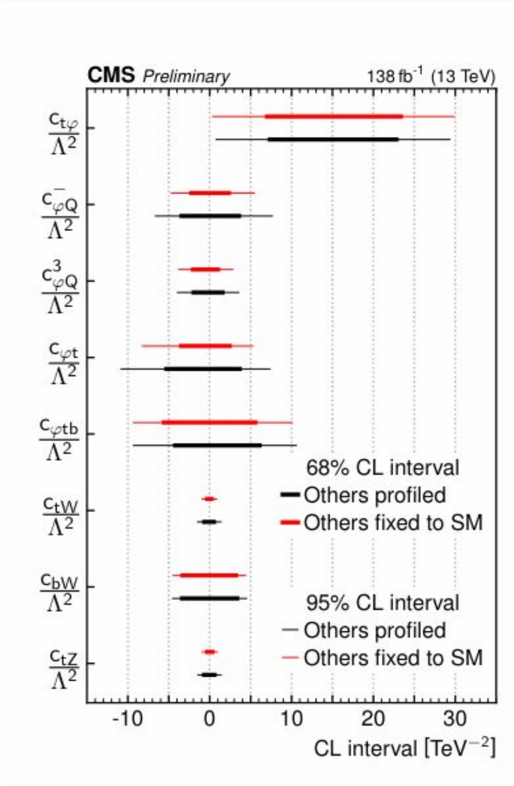
95% CL upper limits on the **differential cross section** of **ttZ** and **ttH** with respect to the boson p_T











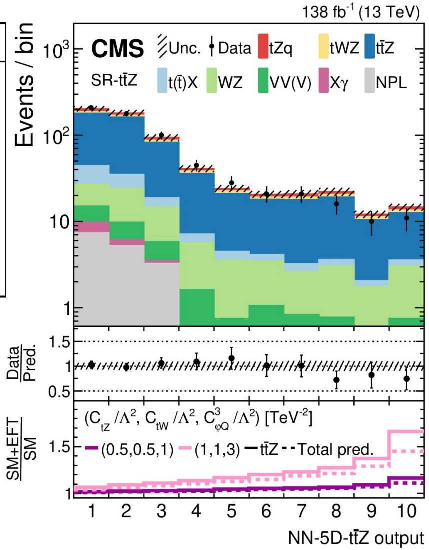
Provide competitive constraints on top+EW **EFT** Wilson coefficients in a previously **unexplored** phase space

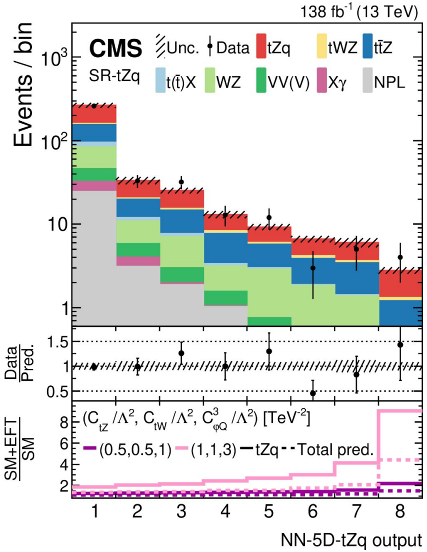
Probing EFT operators in the associated production of top quarks with a Z boson

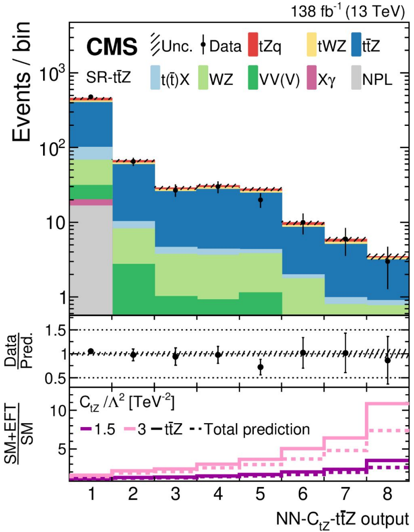
JHEP 12 (2021) 083

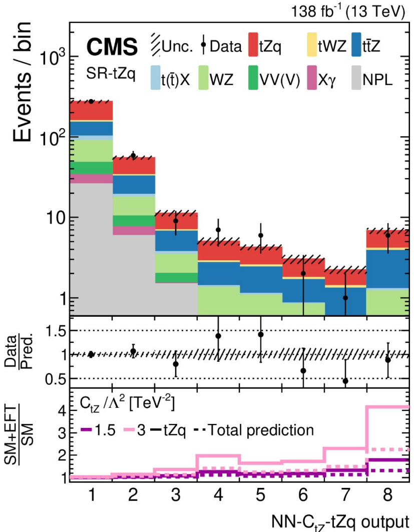
Search for **new top quark interactions** performed within the framework of an **EFT** theory using the t(t)Z events in multilepton final states with the full run 2 data

Selection requirement	SR-3ℓ	SR-$t\bar{t}$Z-4ℓ	WZ CR	ZZ CR
Lepton multiplicity	=3	=4	=3	=4
$m_{3\ell} - m_{Z}$	—	—	>15 GeV	—
Z boson candidates multiplicity	=1	=1	=1	=2
Jet multiplicity	≥2	≥2	—	—
b jet multiplicity	≥1	≥1	=0	—
p_{T}^{miss}	—	—	>50 GeV	—









Five dimension-six **operators** modifying the electroweak interactions of the top quark are considered

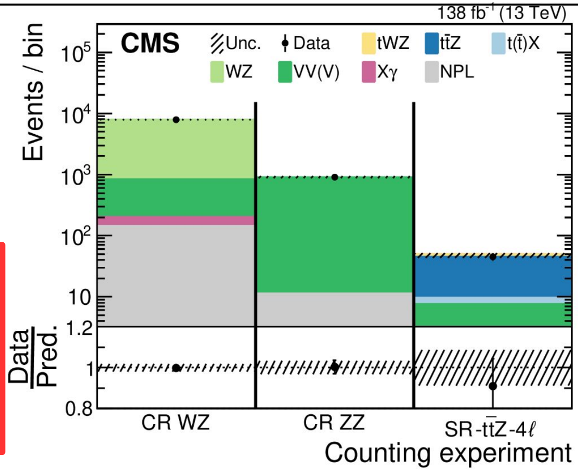
Probing EFT operators in the associated production of top quarks with a Z boson

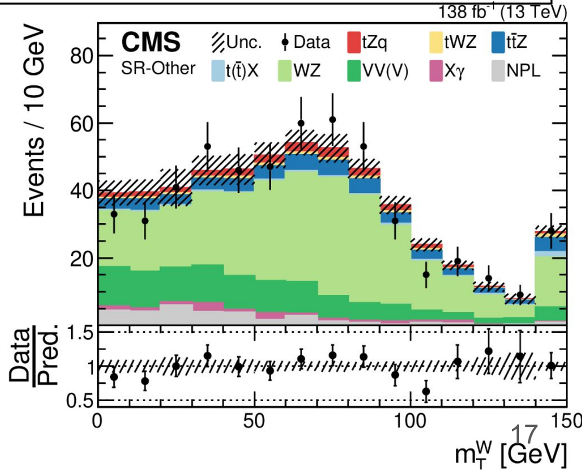
All five Wilson coefficients are simultaneously fit to data in six categories and 95% CL intervals are computed

Fit configuration	Region					
	SR-tZq	SR-t$\bar{t}$Z	SR-Others	SR-t$\bar{t}$Z-4ℓ	CR WZ	CR ZZ
1D c_{tZ}	NN-c_{tZ}-tZq	NN-c_{tZ}-t$\bar{t}$Z				
1D c_{tW}	NN-c_{tW}-tZq	NN-c_{tW}-t$\bar{t}$Z				
1D $c^{3}_{\varphi Q}$	NN-$c^{3}_{\varphi Q}$-tZq	NN-$c^{3}_{\varphi Q}$-t$\bar{t}$Z	m_T^W	Counting experiments		
1D $c^{-}_{\varphi Q}$	NN-SM (tZq node)	NN-SM (t$\bar{t}$Z node)				
1D $c_{\varphi t}$	NN-SM (tZq node)	NN-SM (t$\bar{t}$Z node)				
2D and 5D	NN-5D-tZq	NN-5D-t$\bar{t}$Z				

The **NN-SM** is trained to separate different SM processes, the other NNs include effects arising from one or more EFT operators

First time that **machine-learning techniques** accounting for the interference between EFT operators and the SM amplitude have been used in an LHC analysis

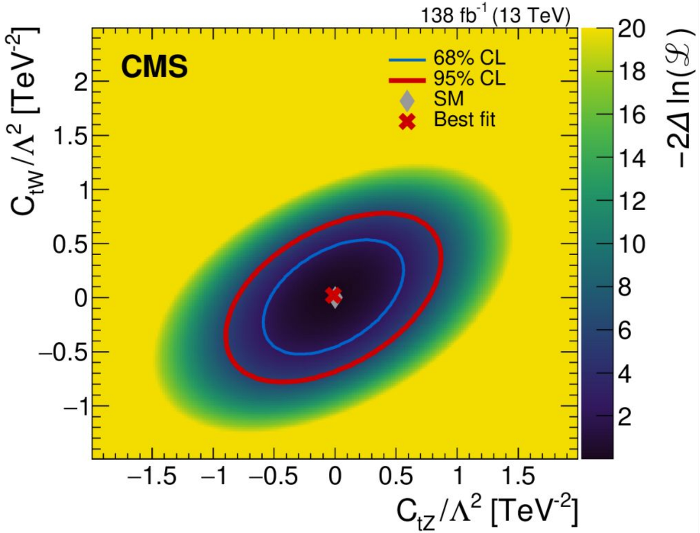


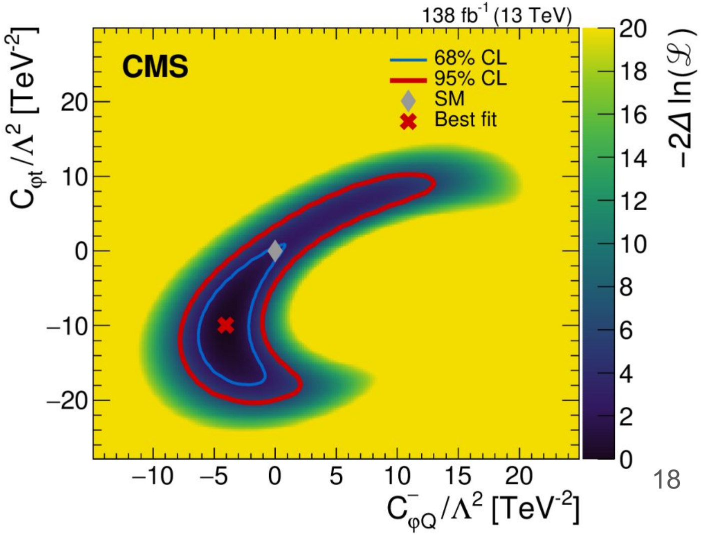


Probing EFT operators in the associated production of top quarks with a Z boson

WC/Λ^2 $[\mathrm{TeV}^{-2}]$	95% CL confidence intervals			
	Other WCs fixed to SM		5D fit	
	Expected	Observed	Expected	Observed
c_{tZ}	$[-0.97, 0.96]$	$[-0.76, 0.71]$	$[-1.24, 1.17]$	$[-0.85, 0.76]$
c_{tW}	$[-0.76, 0.74]$	$[-0.52, 0.52]$	$[-0.96, 0.93]$	$[-0.69, 0.70]$
$c^{3}_{\varphi Q}$	$[-1.39, 1.25]$	$[-1.10, 1.41]$	$[-1.91, 1.36]$	$[-1.26, 1.43]$
$c^{-}_{\varphi Q}$	$[-2.86, 2.33]$	$[-3.00, 2.29]$	$[-6.06, 14.09]$	$[-7.09, 14.76]$
$c_{\varphi t}$	$[-3.70, 3.71]$	$[-21.65, -14.61] \cup [-2.06, 2.69]$	$[-16.18, 10.46]$	$[-19.15, 10.34]$

All results are consistent with the SM expectations





Inclusive and differential $t\bar{t}\gamma$ cross sections

NEW

*Submitted to **JHEP** (18 January 2022)*

[arxiv:2201.07301](https://arxiv.org/abs/2201.07301)

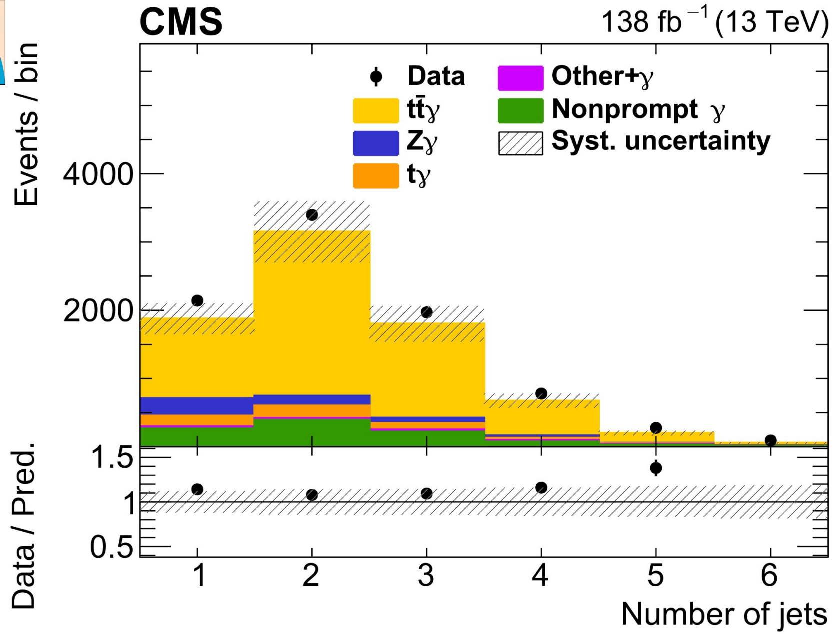
Measurement performed in the **dilepton channel** with the full run 2 data

Signal region:

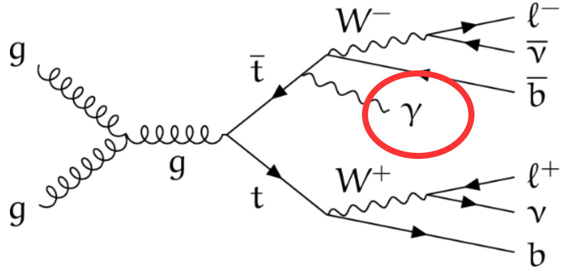
- exactly **two** oppositely charged leptons
- with at least **one** b-tagged jet
- exactly **one** isolated photon with p_T > 20 GeV

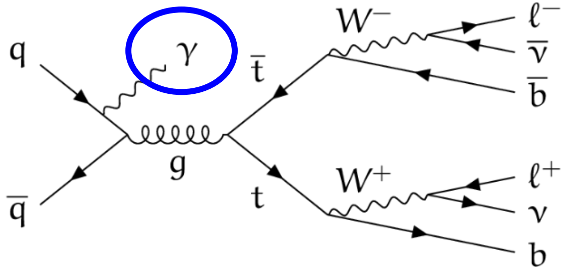
Measurement in the *fiducial region*

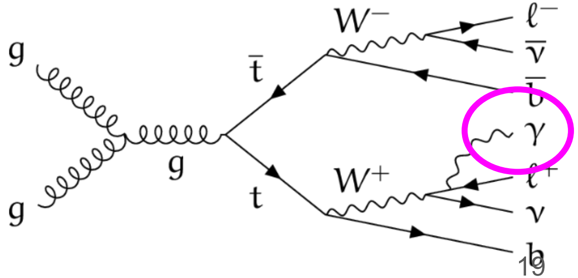
The inclusive cross section is extracted with a *profile likelihood fit* to the transverse momentum distribution of the reconstructed photon



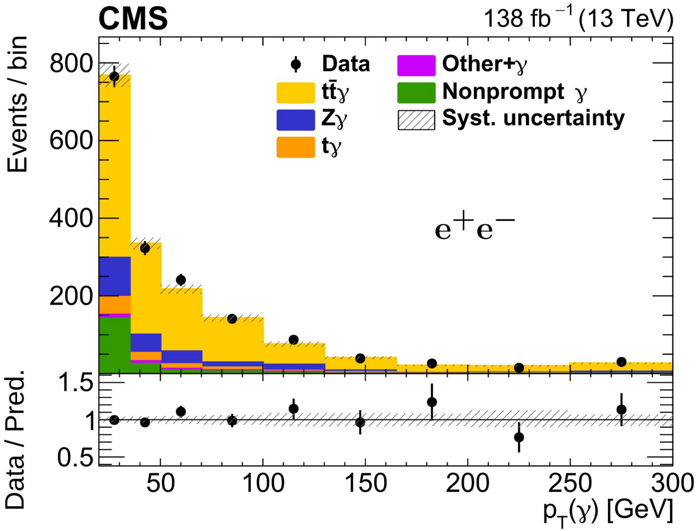
A fiducial phase space defined such that photons radiated by **top quarks**, **initial-state** particles, or any of their **decay products** are included

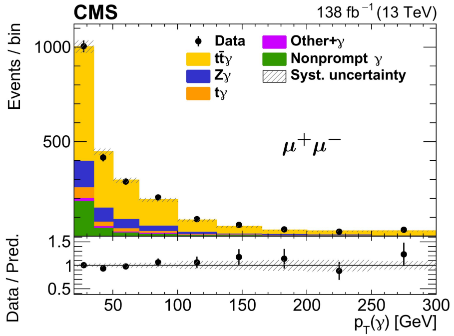




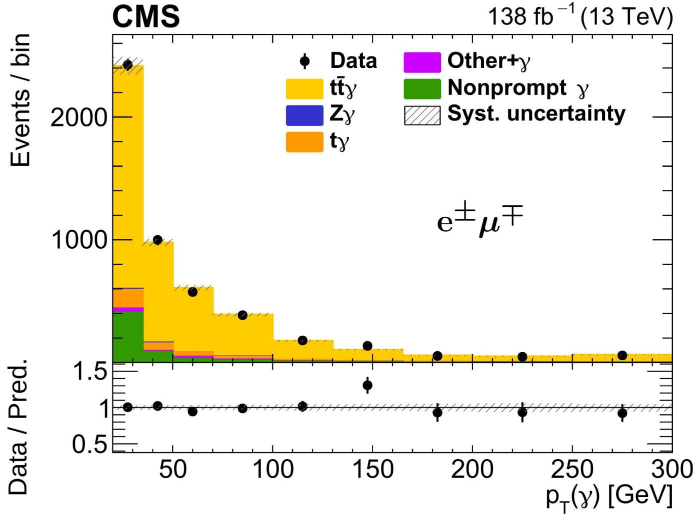


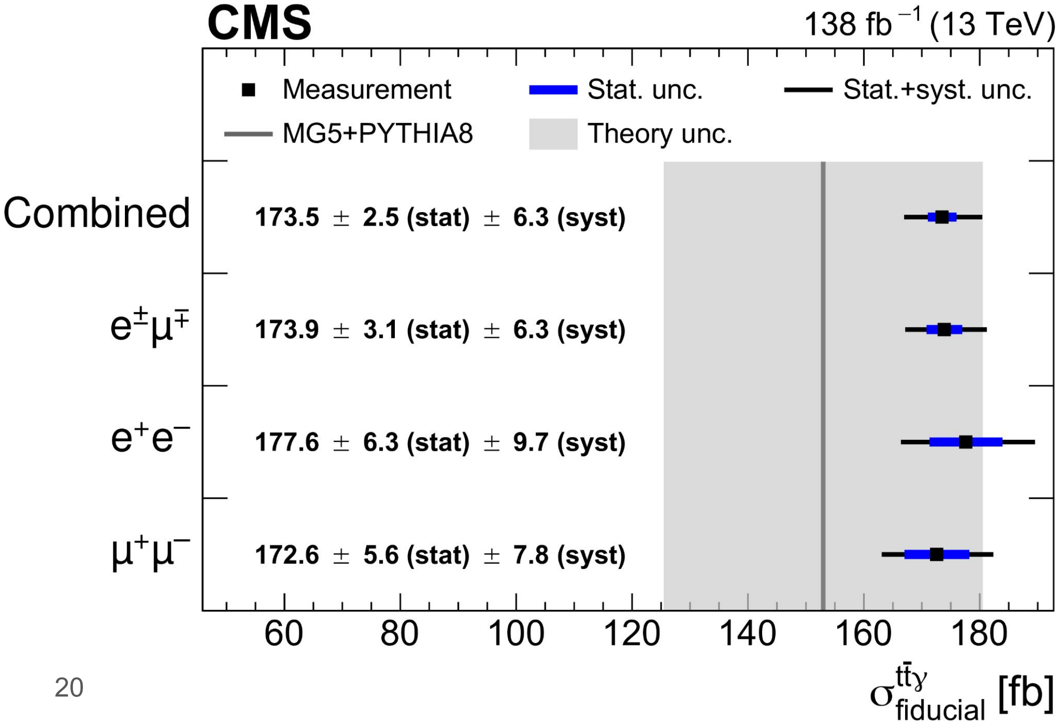
Inclusive





$\sigma_{SM}(pp\rightarrow tt\gamma)$=153 ± 27 fb



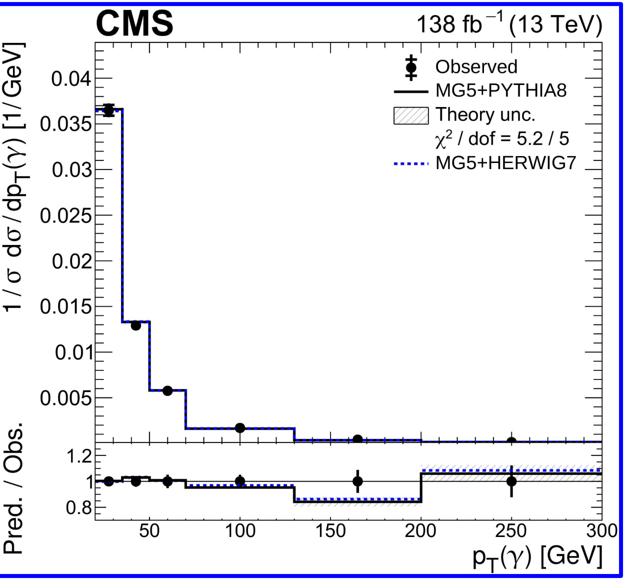


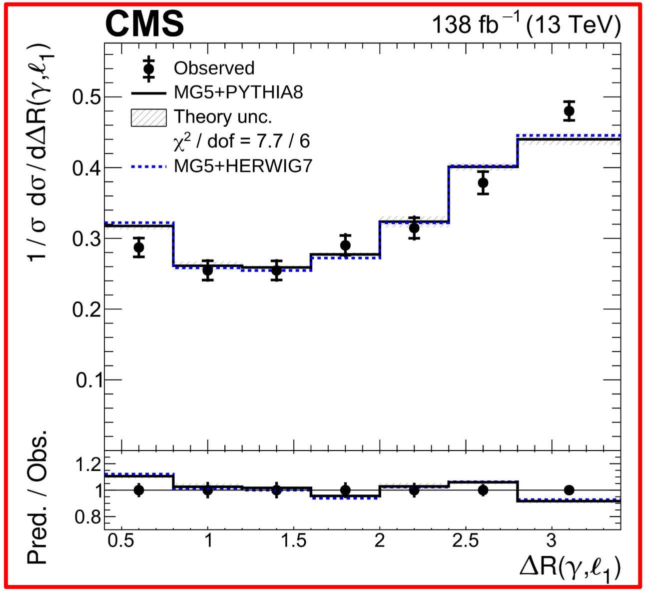
Inclusive and differential $t\bar{t}\gamma$ cross sections

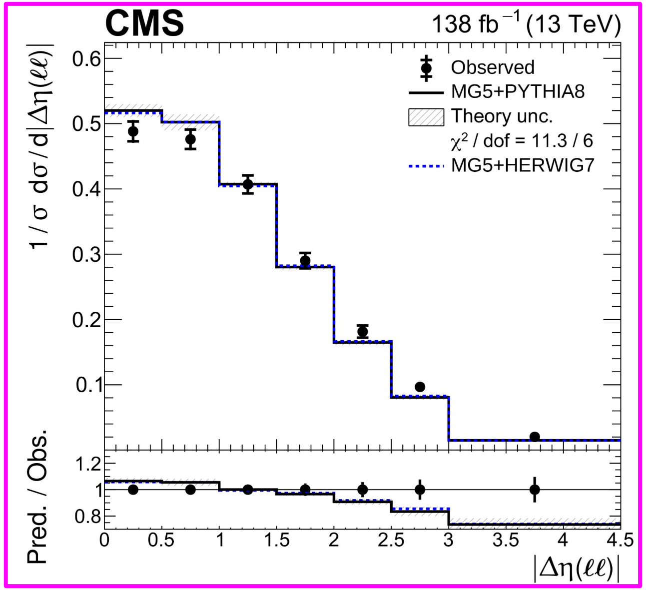
Differential

- Differential cross sections are measured as a function of several kinematic observables of the photon, leptons, and jets
- Compared to SM predictions obtained with the **MadGraph 5_aMC@NLO**+PYTHIA8 (**solid**) and HERWIG7 (**dotted**)

No significant deviations from the SM predictions are found





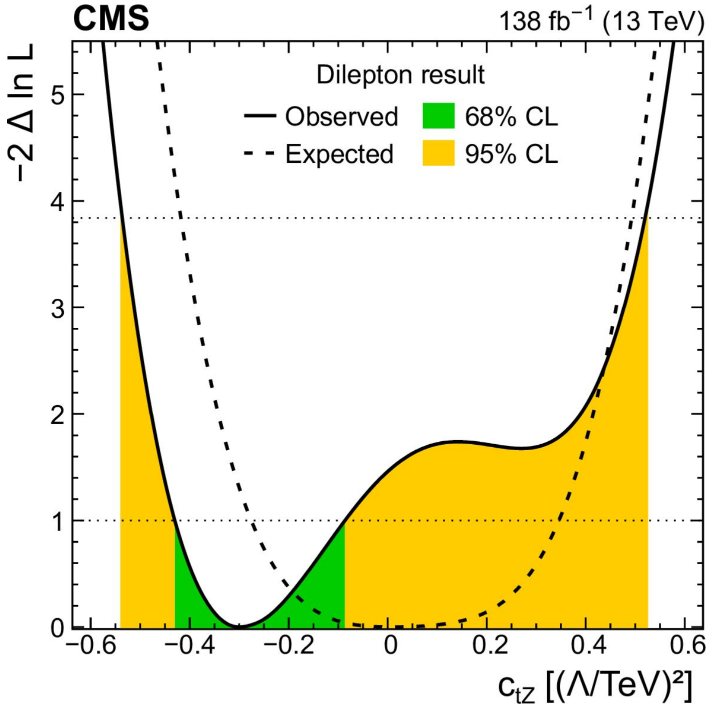


Normalized differential $t\bar{t}\gamma$ production cross sections as functions of $p_T(\gamma)$, $\Delta R(\gamma,\ell_1)$ and of $|\Delta\eta(\ell\ell)|$

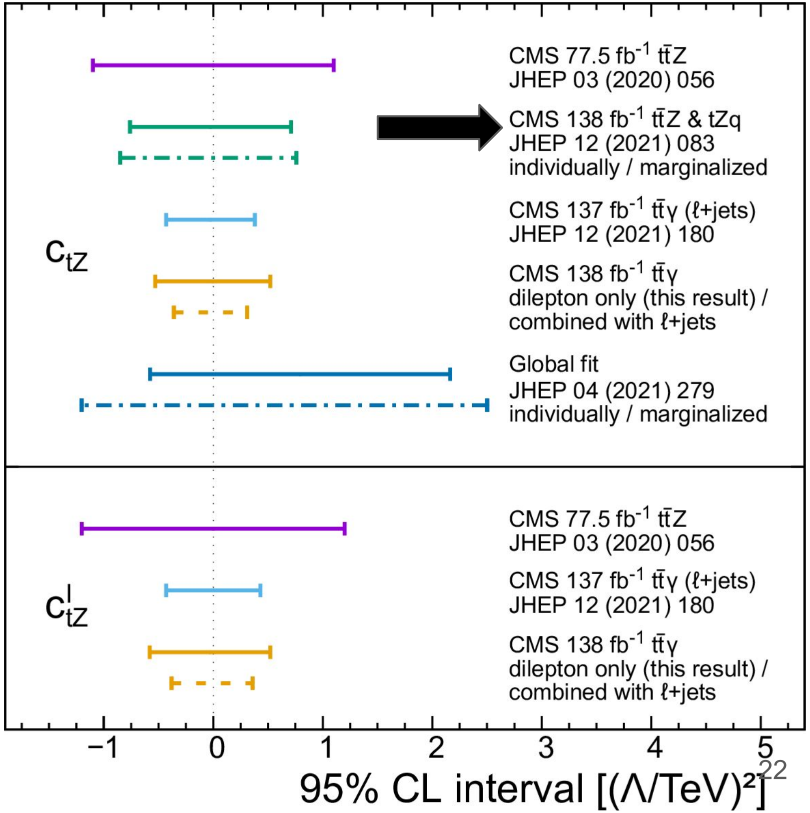
Inclusive and differential $t\bar{t}\gamma$ cross sections

EFT

Measurements are also interpreted in the **SM Effective Field Theory framework**
Limits are found on the $\mathbf{c_{tz}}$ and $\mathbf{c_{tz}^{I}}$ *Wilson coefficients* describing the modifications of the **ttZ** and **ttγ** interaction vertices



In the scan, the other **Wilson coefficient** is set to **zero**



Results using the photon p_T distribution from this analysis

Universidad de Oviedo
Universidá d'Uviéu
University of Oviedo

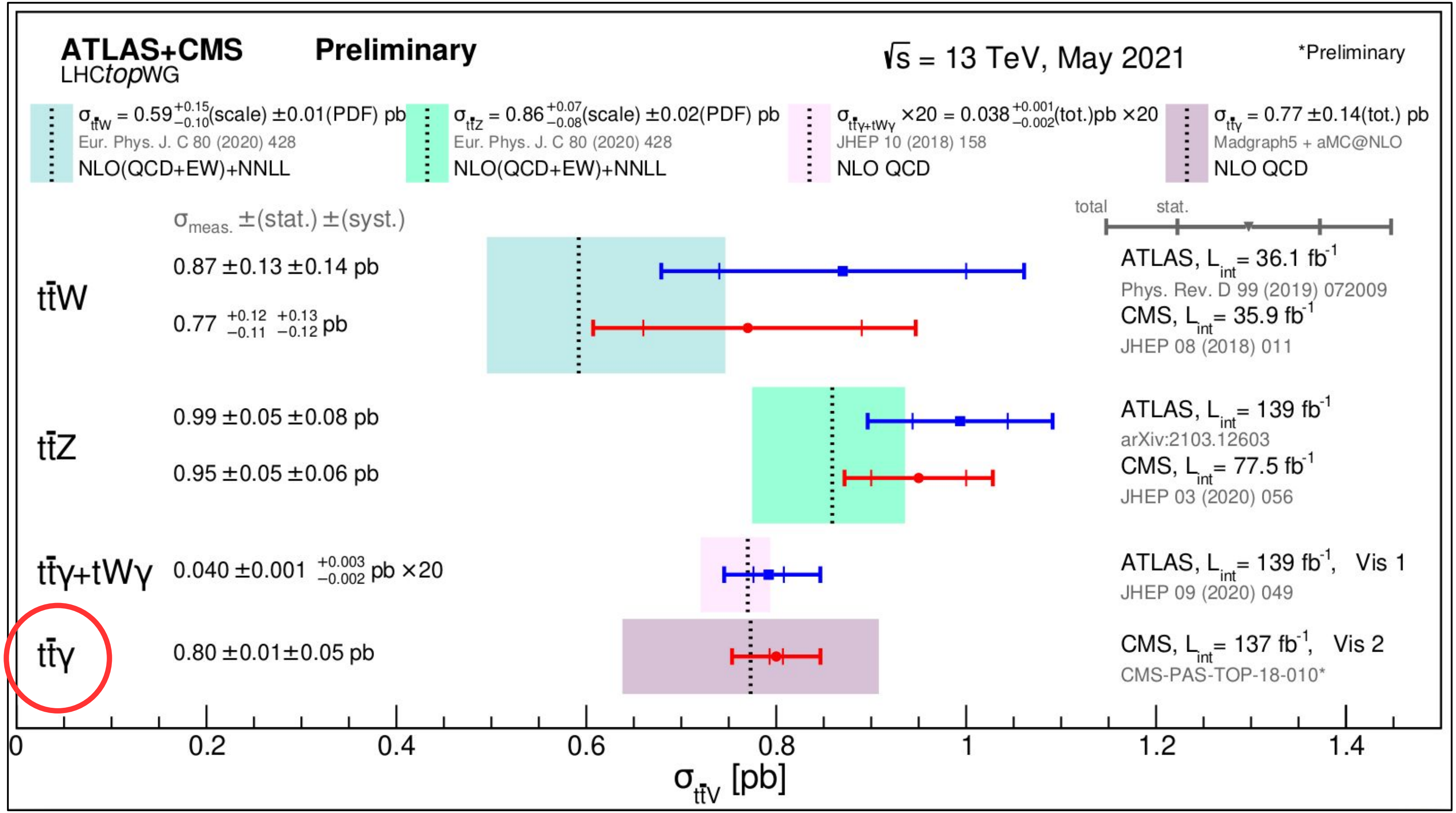
Summary

- The large amount of LHC data recorded up to date, ~140 fb^{-1} (full run2 LHC data), allows probing very rare SM processes, very small production cross sections
  - Even measurements of their differential cross sections
- Rare processes with top quarks are **sensitive** to beyond the SM interactions
  - Searches of FCNC
  - Using effective field theory
- All results are in good agreement with **SM** predictions
- **Stay tuned:** New results are on their way… this is just the first winter conference, few more to come

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/TopPublicResults

https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsTOP

BACK-UP SLIDES

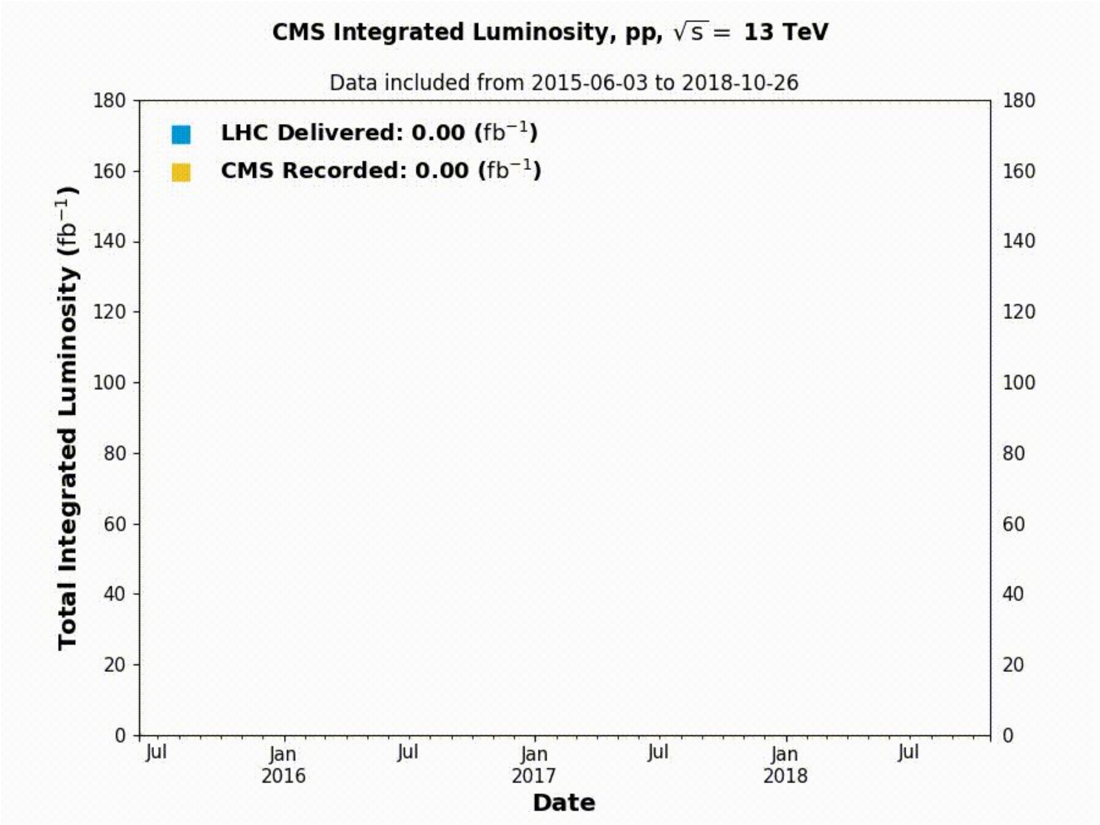


The large amount of LHC data recorded up to date allows probing rare SM processes

ttV among the **most massive** signatures that can be studied at the LHC with **high precision**

Overview

Measurements presented with the full run 2 of the LHC at 13 TeV



Other CMS results

Measurement of the inclusive and differential $t\bar{t}\gamma$ cross sections in the single-lepton channel and EFT interpretation TOP-18-010

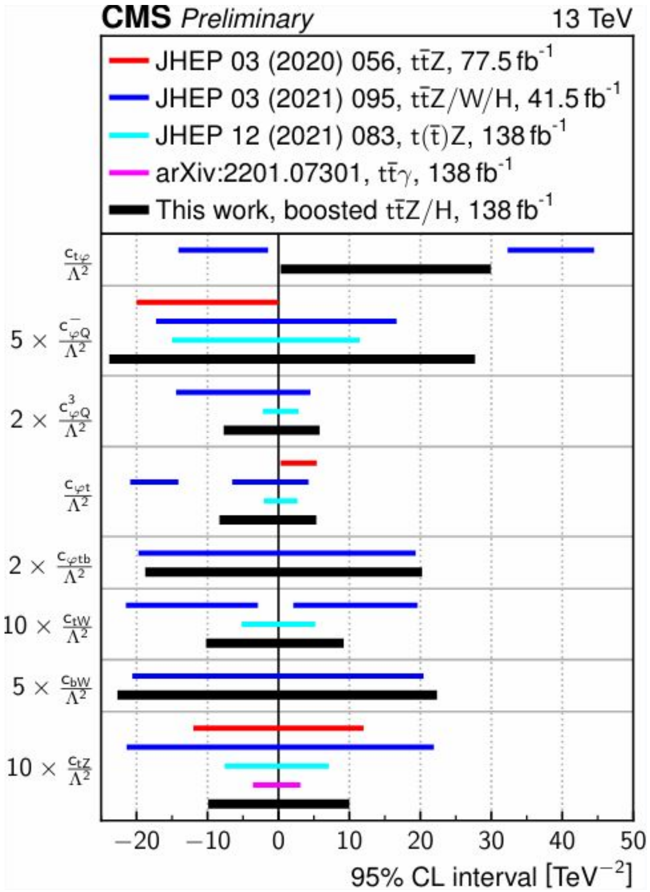
Measurement of the top quark mass using events with a single reconstructed top quark in pp collisions TOP-19-009

Search for CP violation in top quark pair events CMS-PAS-TOP-20-005

Measurement of the shape of the b quark fragmentation function CMS-PAS-TOP-18-012

Search for new physics using top quark pairs associated with a boosted Z or Higgs in EFT

Provide competitive constraints on top+EW EFT Wilson coefficients in a previously unexplored phase space



Search for CP violation in top quark pair events

CMS-PAS-TOP-20-005

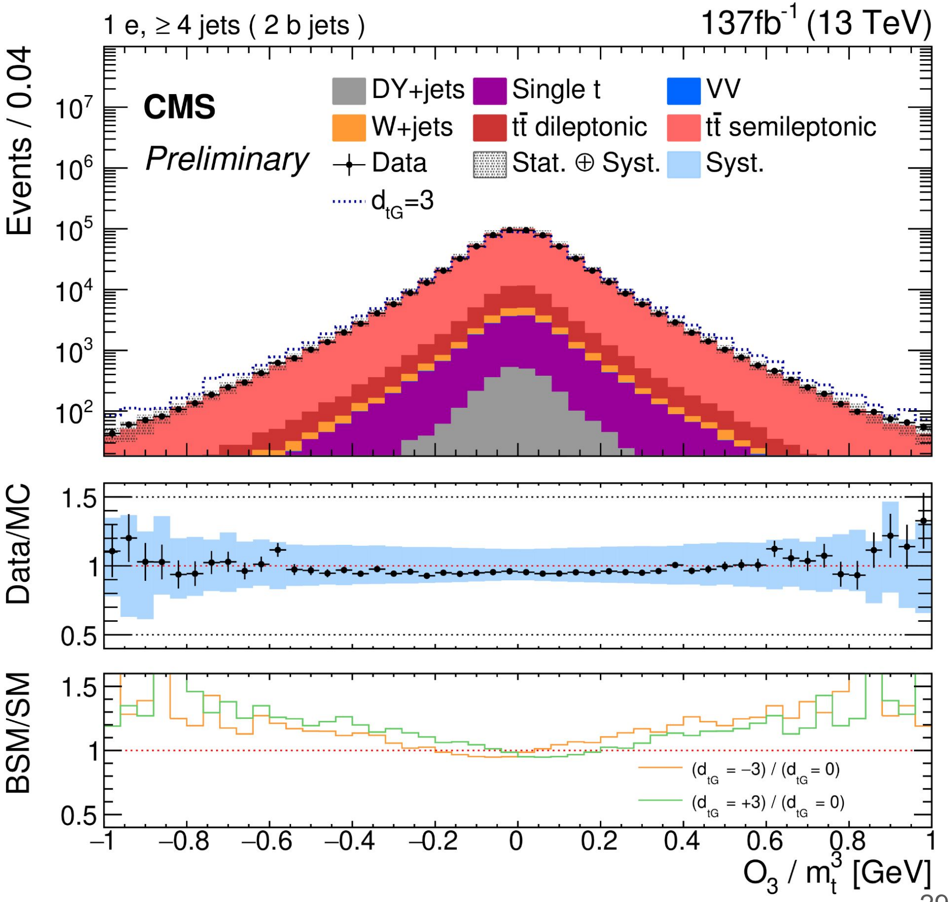
Search for CP violation in the **production** and **decay** of top quark-antiquark pairs using the semileptonic decay channel

The CP violating asymmetries are measured with the triple-product T-odd observables, constructed using linearly independent four-momentum vectors associated with the final state particles, where T is the time-reversal operator

Results of the effective asymmetries A'_{CP} for each observable

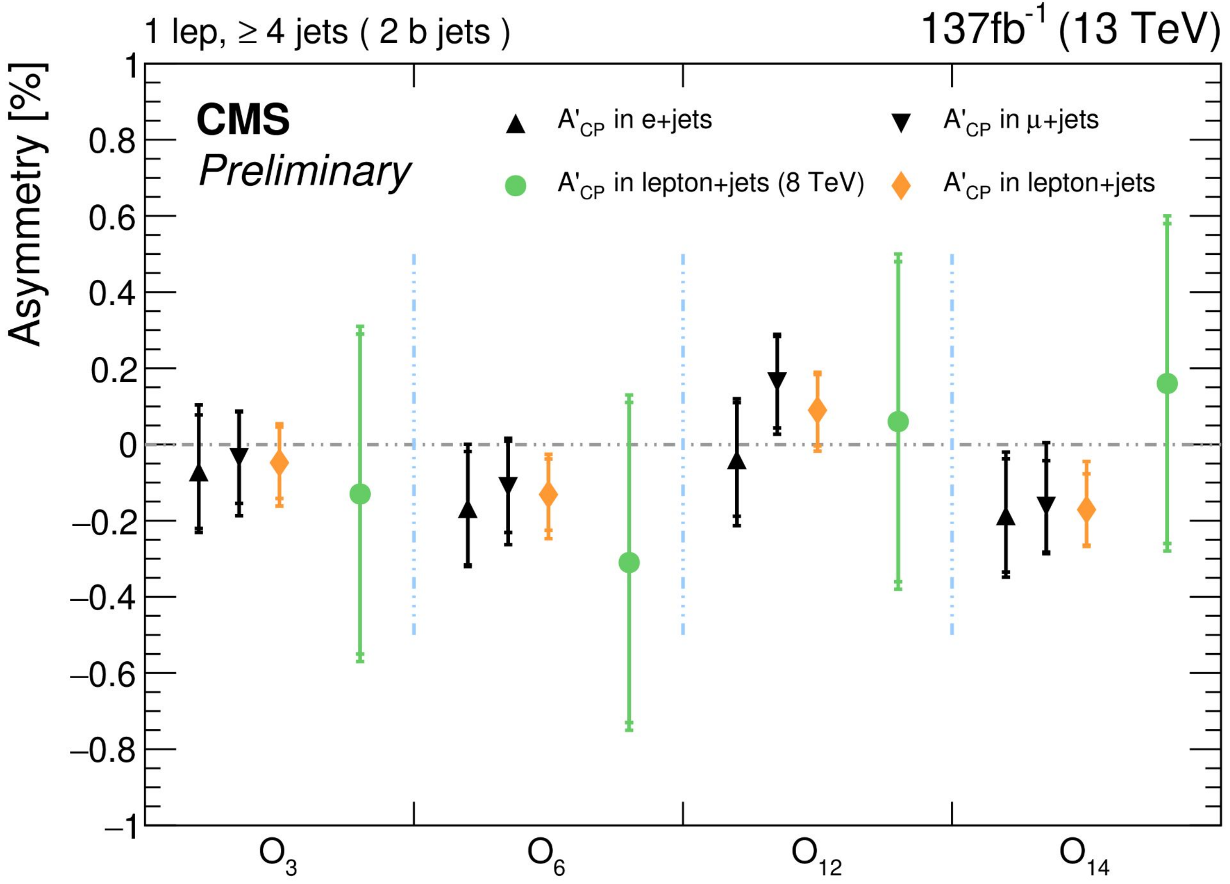
No evidence for CPV effects, consistent with the expectation from the SM

The 13 TeV results reduce the uncertainties by a factor of 3 compared with the 8 TeV results



Search for CP violation in top quark pair events

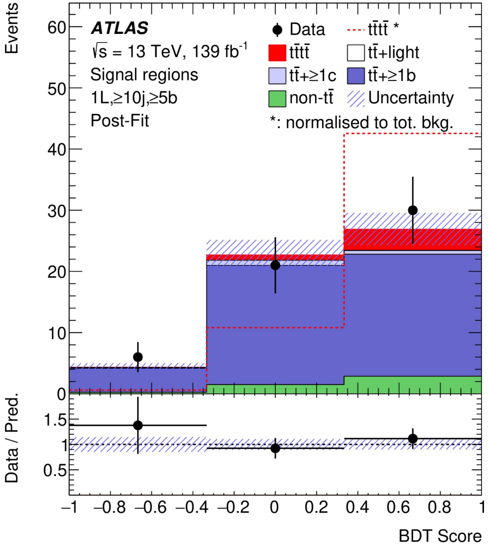
CMS-PAS-TOP-20-005

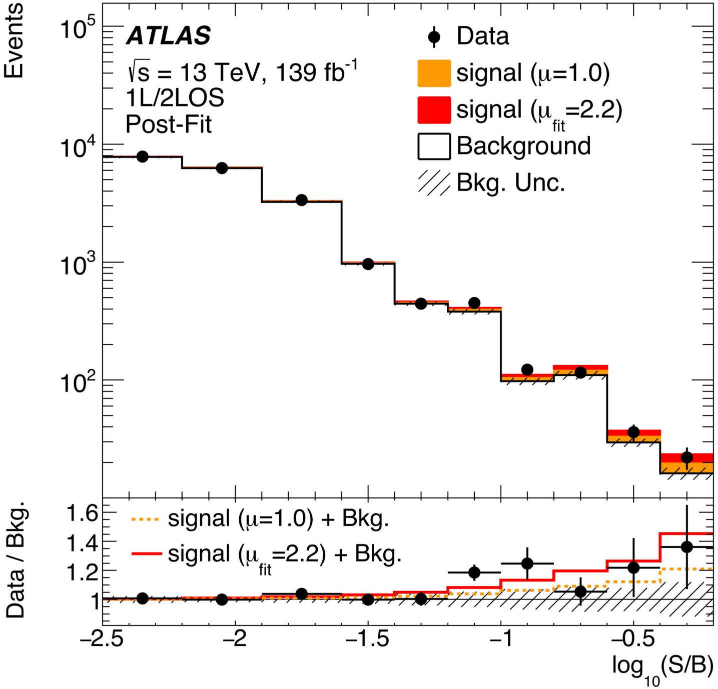


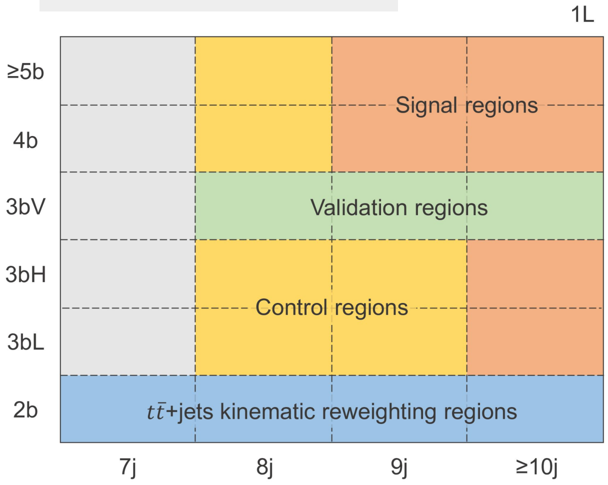
Measurement of the *tttt* production cross section

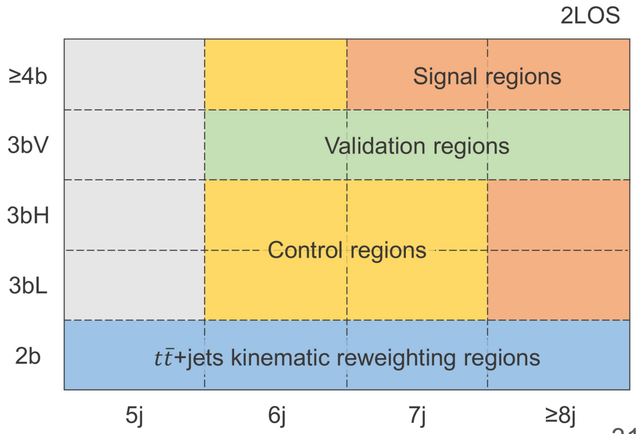
[JHEP11(2021)118]

- Events selected containing a **single lepton** (electron or muon) or an **opposite-sign lepton pair**, in association with multiple jets.
- Events categorised according to the **number of jets** and **b-jets**
- A BDT is used to discriminate between signal and background

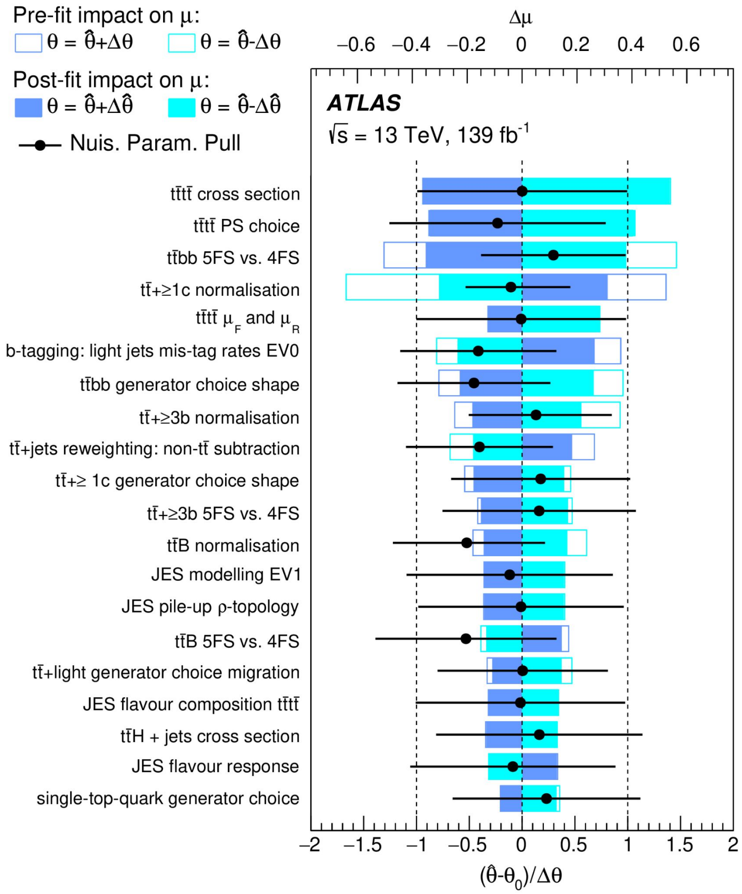




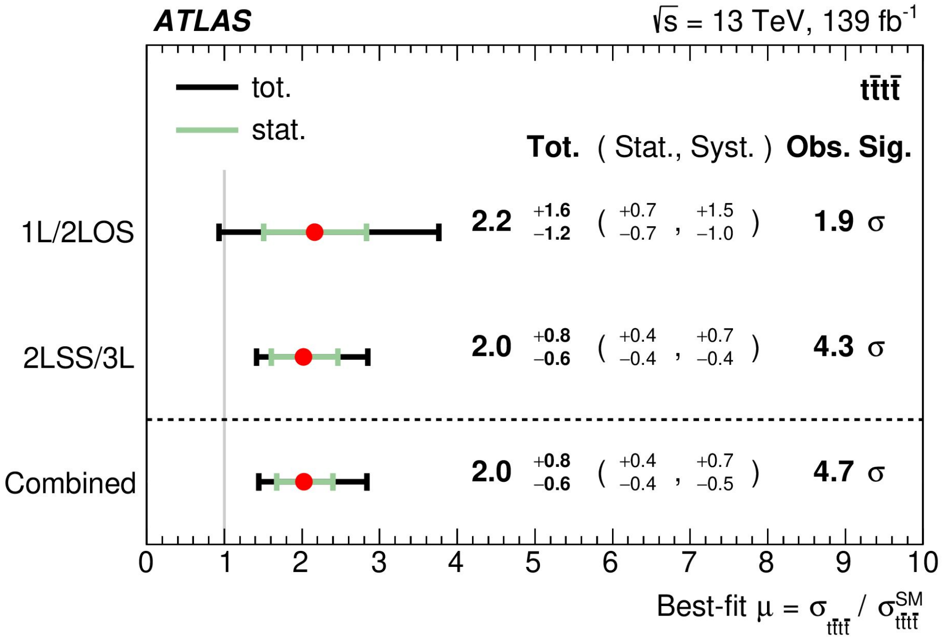




Measurement of the *tttt* production cross section



Cross section is found to be **26^{+17}_{-15} fb** corresponding to an observed significance of 1.9 standard deviations



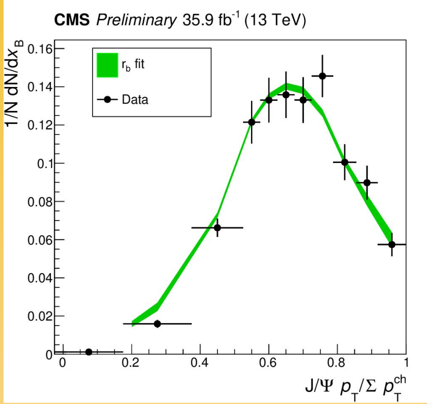
The result is **combined** with the previous measurement in the multilepton final state measuring **24^{+7}_{-6} fb** corresponding to an observed signal significance of 4.7 standard deviations

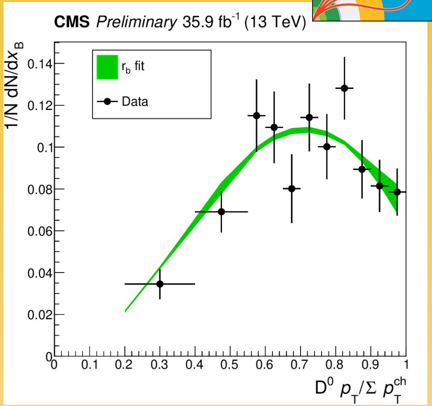
Measurement of the shape of the b quark fragmentation function

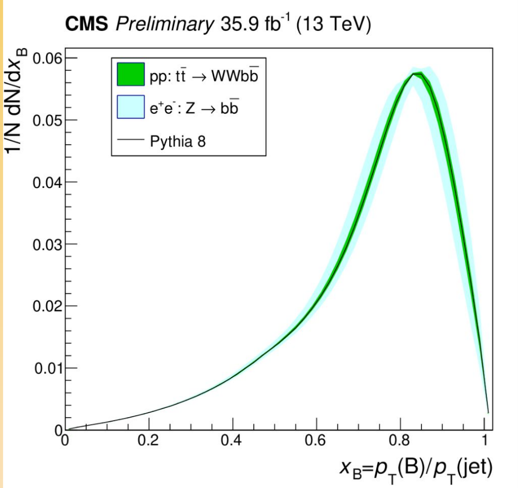
[CMS-PAS-TOP-18-012](CMS-PAS-TOP-18-012)

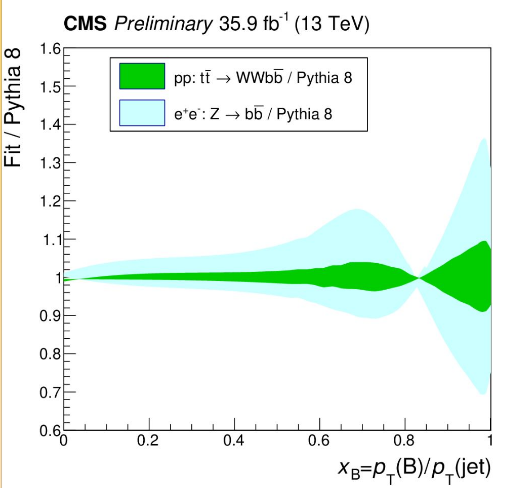
The measurement of Lund-Bowler fragmentation function for b quarks is performed using charmed mesons produced inside b jets from tt pair decays

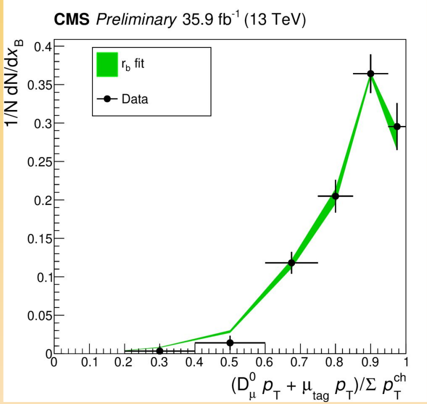
x_b is the fraction of the combined transverse momentum of the charged constituents of the jet carried by the charm meson, are fitted to extract the value of the shape parameter r_b











r_b = 0.858 ± 0.037 (stat) ±0.031 (syst)

The first measurement of the **b quark fragmentation function in tt events at the LHC**, and significantly improves the experimental constraints on the shape of the function

Inclusive and differential $t\bar{t}\gamma$ cross sections at 13 TeV

Leptons	Photons	Jets	b jets	Events
$p_T > 25\ (15)\,\text{GeV}$	$p_T > 20\,\text{GeV}$	$p_T > 30\,\text{GeV}$	$p_T > 30\,\text{GeV}$	$N_\ell = 2\ (\text{OC})$
$\lvert\eta\rvert < 2.4$	$\lvert\eta\rvert < 1.44$	$\lvert\eta\rvert < 2.4$	$\lvert\eta\rvert < 2.4$	$N_\gamma = 1$
	$\Delta R(\gamma, \ell) > 0.4$	$\Delta R(\text{jet}, \ell) > 0.4$	$\Delta R(\text{jet}, \ell) > 0.4$	$N_\text{b} \geq 1$
	isolated	$\Delta R(\text{jet}, \gamma) > 0.1$	$\Delta R(\text{jet}, \gamma) > 0.1$	$m(\ell\ell) > 20\,\text{GeV}$
			matched to b hadron	

Summary of the requirements at the particle level on the various physics objects in the fiducial phase space definition.

Inclusive and differential $t\bar{t}\gamma$ cross sections at 13 TeV

	Source	Correlation	Uncertainty [%] Prefit range	Uncertainty [%] Postfit
Experimental	Integrated luminosity	$\sim$	1.3–3.2	1.7
	Pileup	✓	0.1–1.4	0.7
	Trigger efficiency	$\times$	0.6–1.7	0.6
	Electron selection efficiency	$\sim$	1.0–1.3	1.0
	Muon selection efficiency	$\sim$	0.3–0.5	0.5
	Photon selection efficiency	$\sim$	0.4–3.6	1.1
	Electron & photon energy	✓	0.0–1.1	0.1
	Jet energy scale	$\sim$	0.1–1.3	0.5
	Jet energy resolution	✓	0.0–0.6	<0.1
	b tagging efficiency	$\sim$	0.9–1.4	1.1
	L1 prefiring	✓	0.0–0.8	0.3
Theoretical	Values of μ_F and μ_R	✓	0.3–3.5	1.3
	PDF choice	✓	0.3–4.5	0.3
	PS modelling: ISR & FSR scale	✓	0.3–3.5	1.3
	PS modelling: colour reconnection	✓	0.0–8.4	0.2
	PS modelling: b fragmentation	✓	0.0–2.2	0.7
	Underlying-event tune	✓	0.5	0.5
Background	$Z\gamma$ correction & normalization	✓	0.0–0.2	0.1
	$t\gamma$ normalization	✓	0.0–0.9	0.8
	Other+γ normalization	✓	0.3–1.0	0.8
	Nonprompt γ normalization	✓	0.0–1.8	0.7
	Size of simulated samples	$\times$	1.5–7.6	0.9
	Total systematic uncertainty			3.6
	Statistical uncertainty			1.4
	Total uncertainty			3.9

Summary of the systematic uncertainty sources in the cross section measurements

Inclusive and differential $t\bar{t}\gamma$ cross sections at 13 TeV

Summary of the one-dimensional 68 and 95% CL intervals obtained for the Wilson coefficients using the photon p_T distribution from this analysis or the combination of this analysis with the ℓ+jets analysis. The profiled results correspond to the fits where the other Wilson coefficient is left free in the fit, otherwise it is set to zero.

	Wilson coefficient		Dilepton result: 68% CL interval $[(\Lambda/\mathrm{TeV})^2]$	Dilepton result: 95% CL interval $[(\Lambda/\mathrm{TeV})^2]$	Dilepton & ℓ+jets combination: 68% CL interval $[(\Lambda/\mathrm{TeV})^2]$	Dilepton & ℓ+jets combination: 95% CL interval $[(\Lambda/\mathrm{TeV})^2]$
Expected	c_{tZ}	$c^I_{tZ} = 0$	$[-0.28, 0.35]$	$[-0.42, 0.49]$	$[-0.15, 0.19]$	$[-0.25, 0.29]$
		profiled	$[-0.28, 0.35]$	$[-0.42, 0.49]$	$[-0.15, 0.19]$	$[-0.25, 0.29]$
	c^I_{tZ}	$c_{tZ} = 0$	$[-0.33, 0.30]$	$[-0.47, 0.45]$	$[-0.17, 0.18]$	$[-0.27, 0.27]$
		profiled	$[-0.33, 0.30]$	$[-0.47, 0.45]$	$[-0.18, 0.18]$	$[-0.27, 0.27]$
Observed	c_{tZ}	$c^I_{tZ} = 0$	$[-0.43, -0.09]$	$[-0.53, 0.52]$	$[-0.30, -0.13]$	$[-0.36, 0.31]$
		profiled	$[-0.43, 0.17]$	$[-0.53, 0.51]$	$[-0.30, 0.00]$	$[-0.36, 0.31]$
	c^I_{tZ}	$c_{tZ} = 0$	$[-0.47, -0.03] \cup [0.07, 0.38]$	$[-0.58, 0.52]$	$[-0.32, -0.13] \cup [0.16, 0.29]$	$[-0.38, 0.36]$
		profiled	$[-0.43, 0.33]$	$[-0.56, 0.51]$	$[-0.28, 0.23]$	$[-0.36, 0.35]$

Search for FCNC interactions of a top quark and a gluon

arxiv:2112.01302

Analysis	$\mathcal{B}_{95}^{\text{obs}}(t \to u + g)$	$\mathcal{B}_{95}^{\text{exp}}(t \to u + g)$	$\mathcal{B}_{95}^{\text{obs}}(t \to c + g)$	$\mathcal{B}_{95}^{\text{exp}}(t \to c + g)$
ATLAS 13 TeV	6.1×10^{-5}	4.9×10^{-5}	37×10^{-5}	20×10^{-5}
ATLAS 8 TeV	12×10^{-5}	11×10^{-5}	64×10^{-5}	57×10^{-5}
CMS 7 TeV $\oplus$ 8 TeV	2.0×10^{-5}	2.8×10^{-5}	41×10^{-5}	28×10^{-5}

Search for FCNC couplings between the top quark and the Z boson

ATLAS-CONF-2021-049

	SR1 ($D_1 > -0.6$)	SR2 ($D_2^u > -0.7$ or $D_2^c > -0.4$)
$t\bar{t}Z + tWZ$	137 ± 12	36 ± 6
VV + LF	18 ± 7	24 ± 8
VV + HF	114 ± 19	162 ± 26
tZ	46 ± 7	108 ± 18
$t\bar{t} + tW$ fakes	14 ± 4	27 ± 8
Other fakes	7 ± 8	5 ± 6
$t\bar{t}W$	4.2 ± 2.1	3.1 ± 1.6
$t\bar{t}H$	4.8 ± 0.7	0.89 ± 0.17
Other bkg.	2.0 ± 1.0	2.5 ± 2.9
FCNC $(u)tZ$	0.9 ± 1.7	4 ± 8
FCNC $t\bar{t}(uZ)$	5 ± 9	0.8 ± 1.5
Total background	348 ± 15	369 ± 21
Data	345	380

Measurement of the polarisation of single (anti)top quarks produced in the *t*-channel

ATLAS-CONF-2021-027

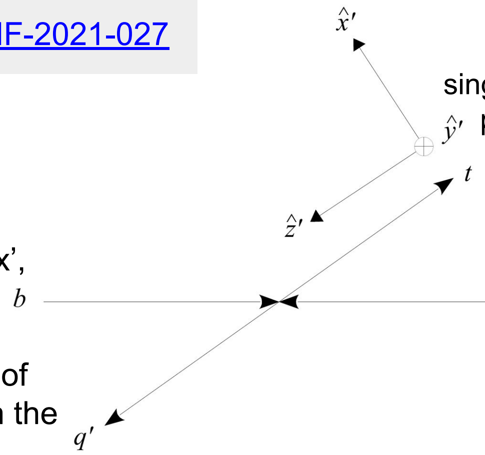
Signal region:

- exactly one isolated electron or muon
- large missing transverse momentum
- exactly two jets, one being b-tagged

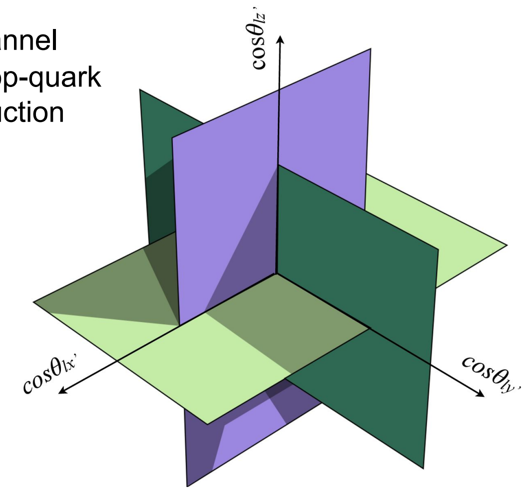
\+ stringent selection requirements

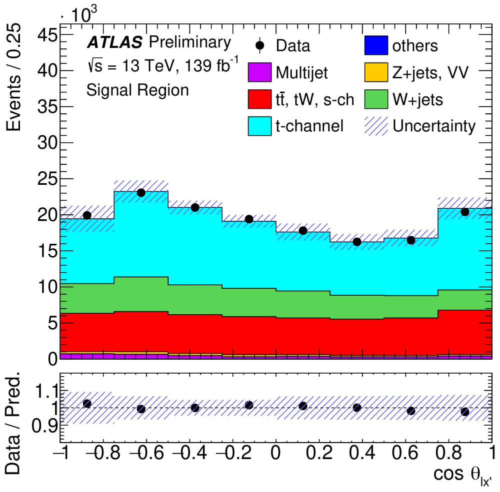
Simultaneous measurement of the three components (Px', Py', Pz') of the top and antitop polarisation vectors

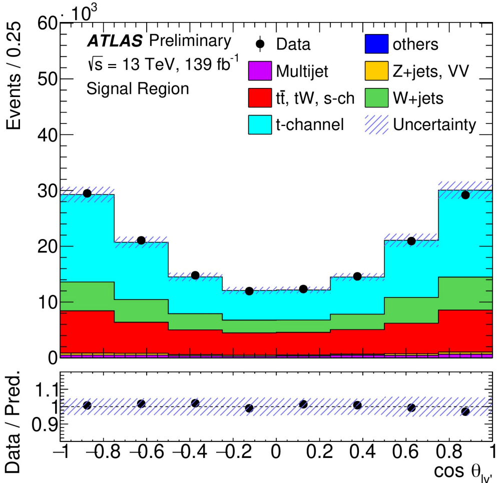
Polarisation vectors are measured from the distributions of the direction cosines of the charged lepton momentum in the top-quark rest frame

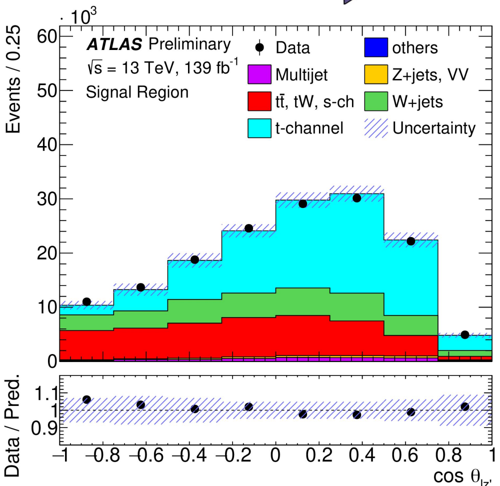


t-channel
single-top-quark
production

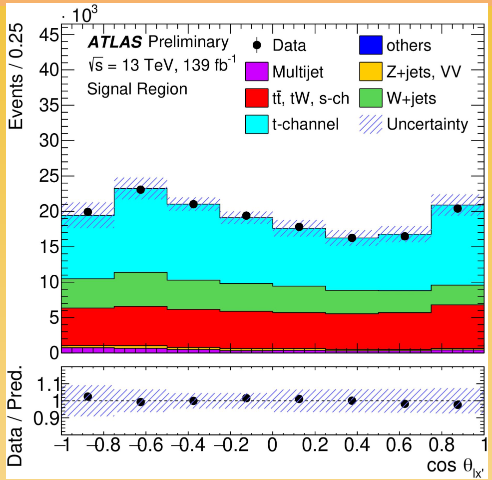


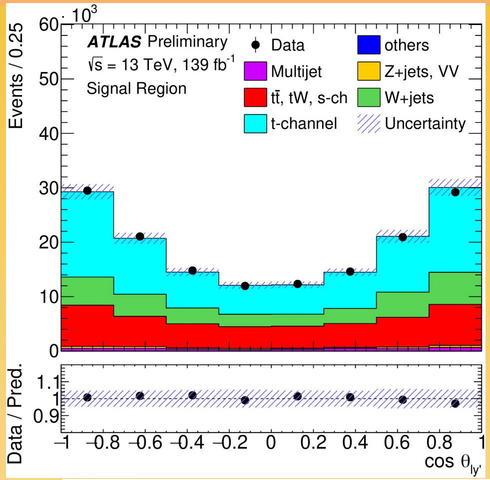


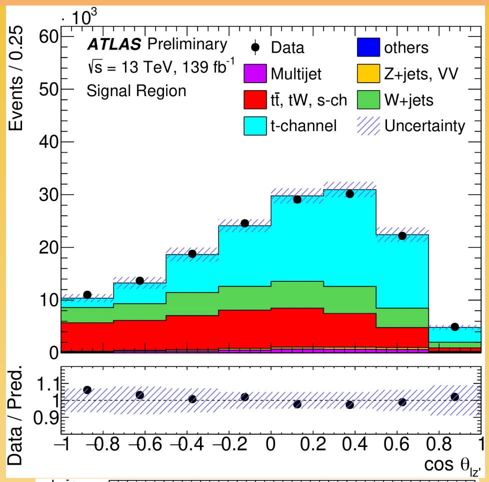




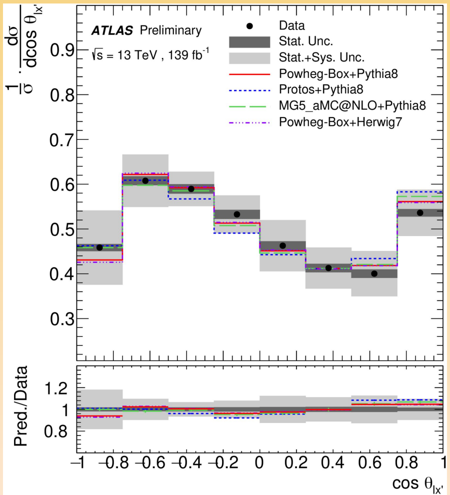
Measurement of the polarisation of single (anti)top quarks produced in the *t*-channel

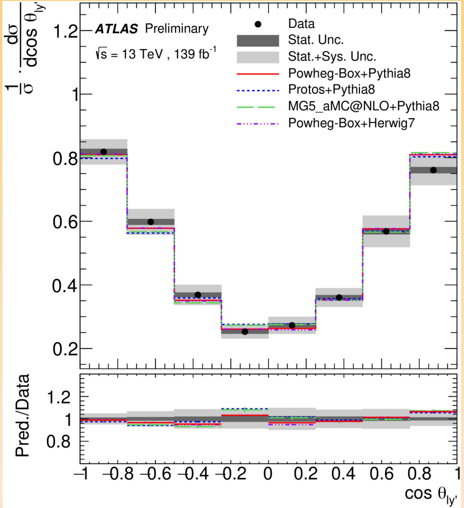


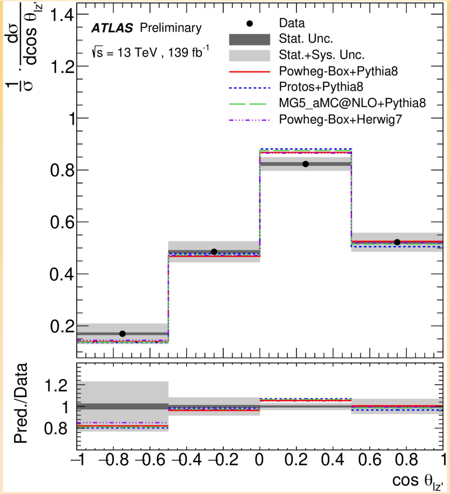




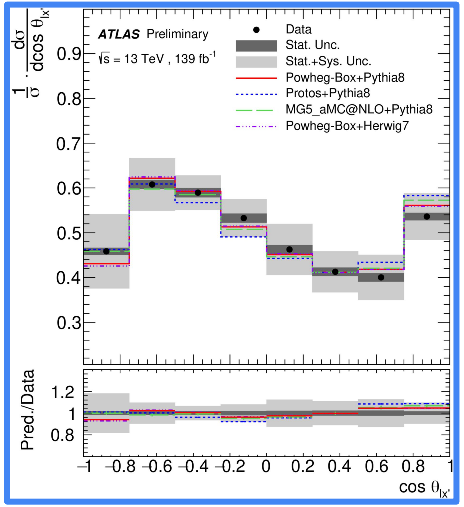
Normalised differential cross-sections corrected to a fiducial region at the stable-particle level are presented as a function of the charged lepton angles for top-quark and top-antiquark events inclusively in agreement with Standard Model predictions

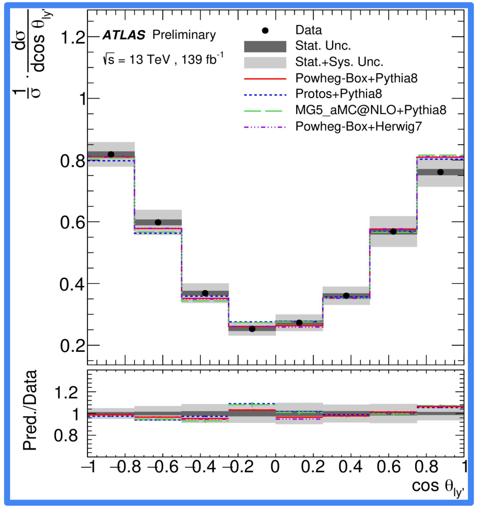


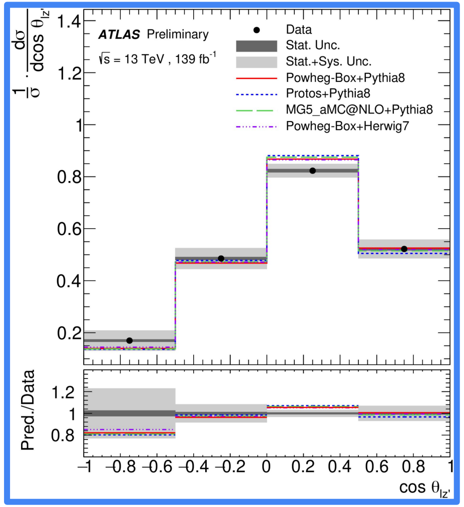




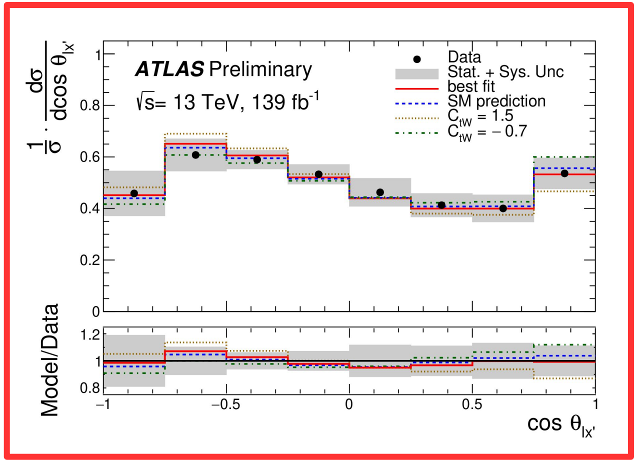
Measurement of the polarisation of single (anti)top quarks produced in the *t*-channel

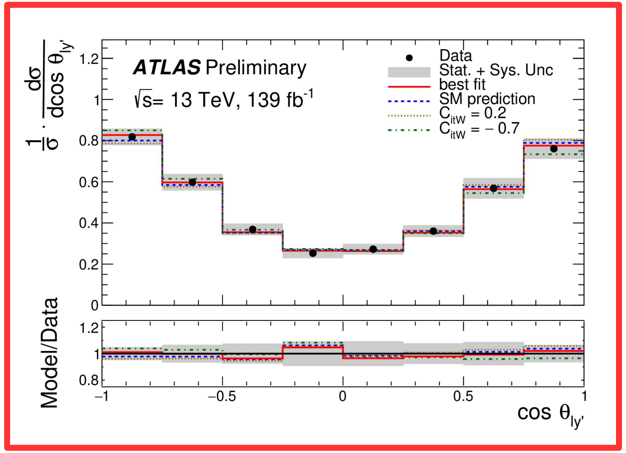






Normalised **differential cross-sections** corrected to a fiducial region at the **particle level** as a function of the charged lepton angles for top-quark and top-antiquark events in agreement with SM predictions





The **angular differential cross-sections** are used to derive bounds on the complex Wilson coefficient of the dimension-six O_{tW} operator in the **EFT** framework

Measurement of the polarisation of single (anti)top quarks produced in the *t*-channel