

Recent differential measurements of top+ χ production and rare SM top processes from ATLAS and CMS

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Overview

Top quark + X and rare SM processes **at a center-of-mass energy of 13 TeV** (13.6 TeV)
Run 2 (early Run 3)

All measurements using full Run 2 data (**2016-2018**), 138-140 fb⁻¹ (62 fb⁻¹ for Run 3)

A **top-antitop pair** produced with **an additional object X**: ttZ, ttW, tty,...

- Used for differential measurements
- Sensitive to QCD + EW + EFT effects

Rare top processes, processes with **very small cross sections** in the Standard Model:
4top, 3top, tWZ, tZq,...

- **Statistically limited**
- **Recently observed or still being established**
- Sensitive to **new physics**

4tops with a hadronic tau decay

TOP-24-017



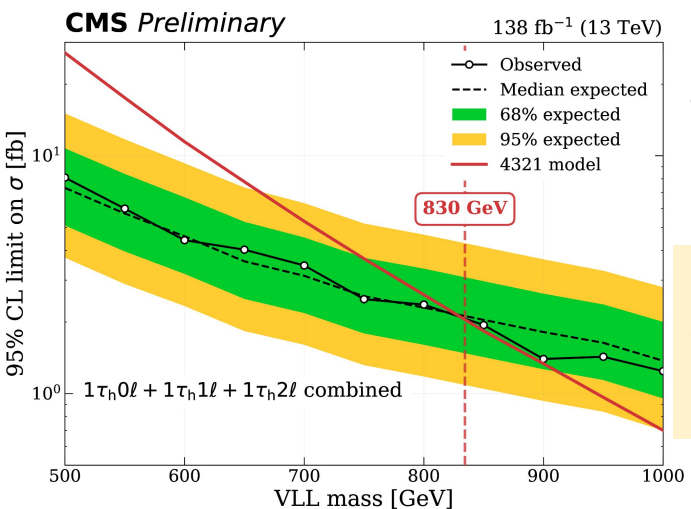
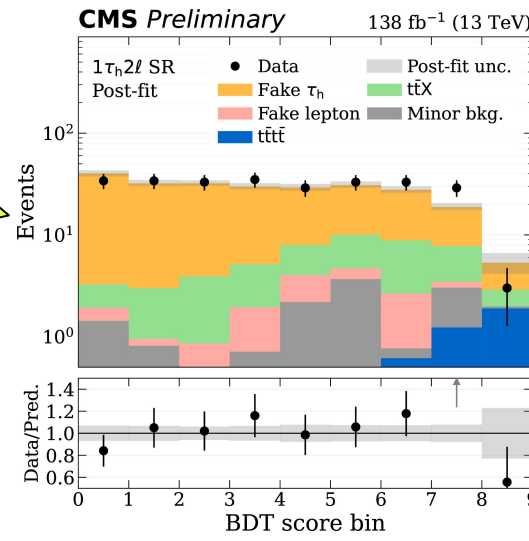
Targets final states with hadronically decaying tau leptons ($\tau \rightarrow \text{hadrons}$)

- **At least one hadronically decaying tau (+ 0l, 1l, or 2l)**
- Multiple jets and b-tagged jets (from top decays)

A ML discriminant (BDT) used to separate: signal and bkg (tt and Wjets)

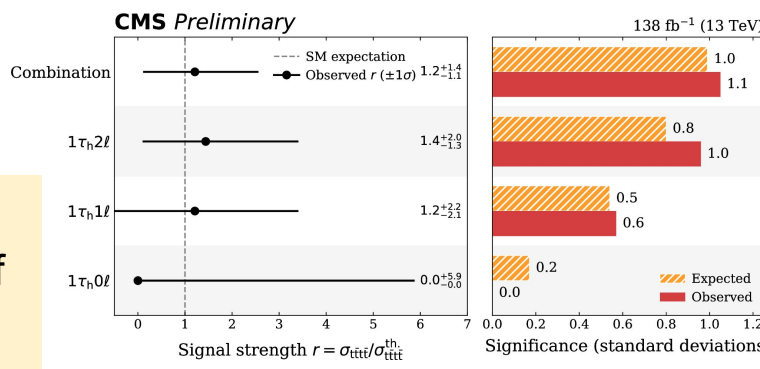
Independent and complementary confirmation of 4top production compared to multilepton analyses

$$\sigma(tttt) = 16^{+18}_{-15} \text{ fb}$$



Search for **Vector-Like Leptons (VLLs)** also performed

No significant excess is found, exclusion limits of **830 GeV at 95% C.L.**



Search for 3top production

TOP-24-006



Very rare production mode, **expected cross section ~ 2 fb**

Employing two channels: **single lepton and multilepton**:

- 1, 2 same-sign or at least 3 leptons
- Additional jets and b-tagged jets



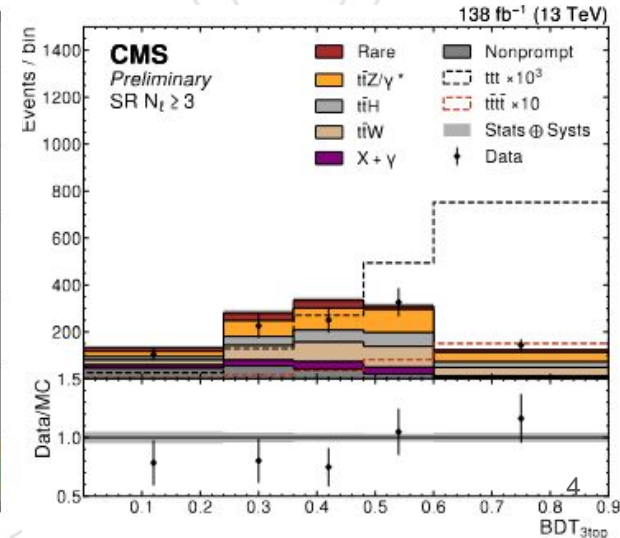
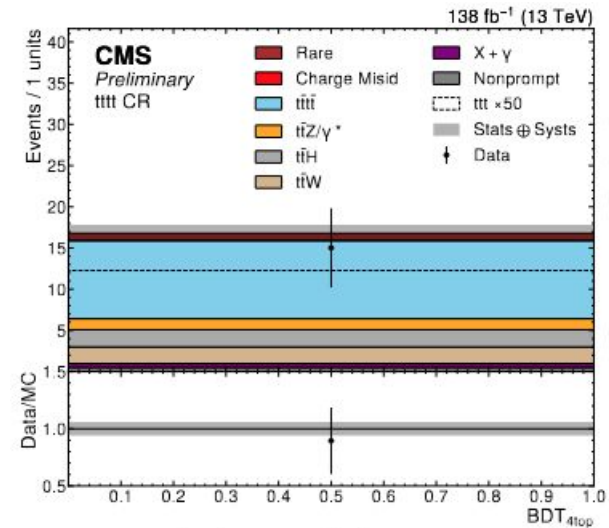
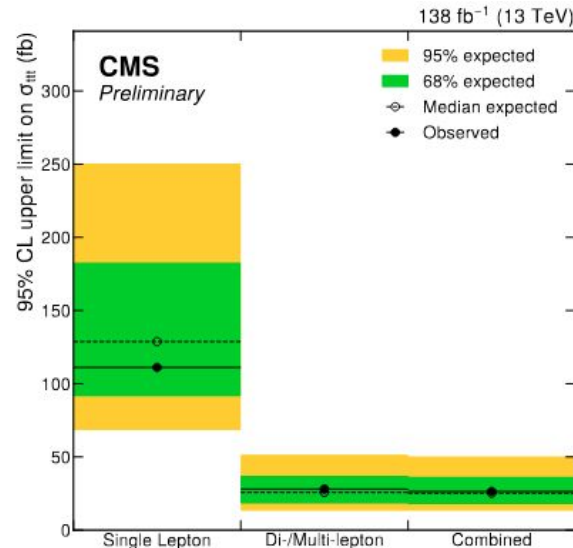
Multilepton is the **most sensitive** channel

BDT: 4tops vs background+3top

BDT: 3tops vs background

An upper limit of **25 fb** is set on the signal cross section at 95% C.L

Measurement limited by statistical uncertainty



First Observation of $t\bar{t}\gamma\gamma$



Phys. Lett. B 874 (2026) 140195

Extremely rare SM process

Focuses on **single-lepton final state**:

- 1 lepton (e/μ)
- 2 isolated photons
- jets (including b-jets)

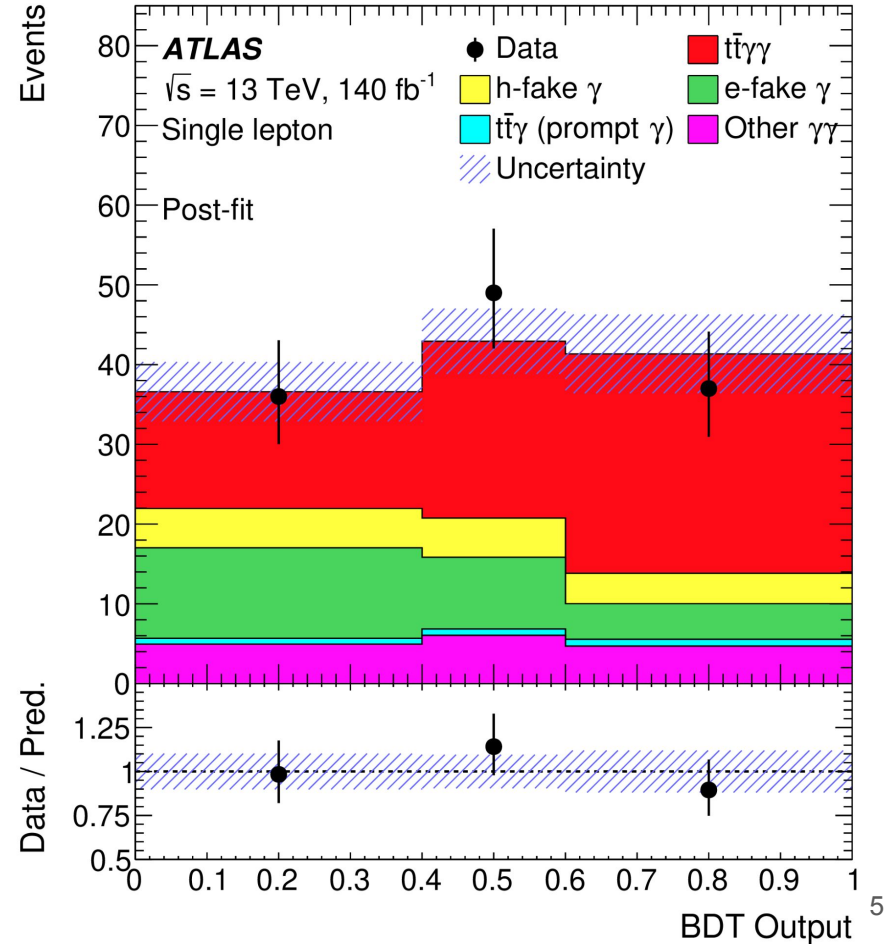
BDT is performed to separate the $t\bar{t}\gamma\gamma$ signal from the background

Observed significance: $\sim 5.2\sigma$

$$\sigma(t\bar{t}\gamma\gamma) = 2.4^{+0.58}_{-0.53} \text{ fb}$$

Results are consistent with SM predictions (MadGraph):

$$1.5^{+0.5}_{-0.4} \text{ fb @ LO (K-factor } \sim 1.7)$$



Observation of tWZ

Phys. Rev. Lett. 136 (2026) 081802



Run 2 + Run 3 (2022 and 2023) data, total of 200 fb⁻¹

Events with 3 or 4 charged leptons

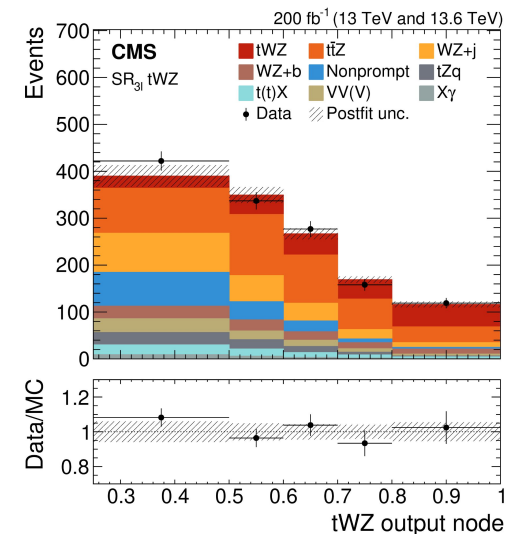
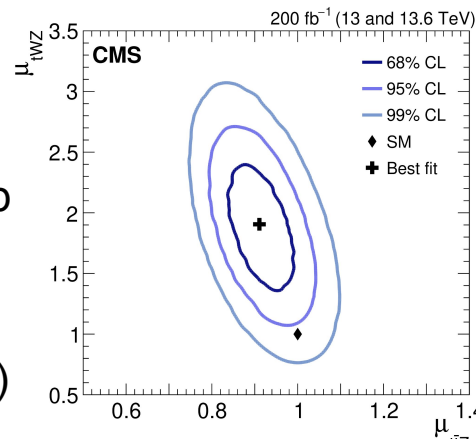
ML algorithm based on the **particle transformer** employed to discriminate between signal and background, mainly **ttZ** and **WZ**

The measured cross sections for tWZ:

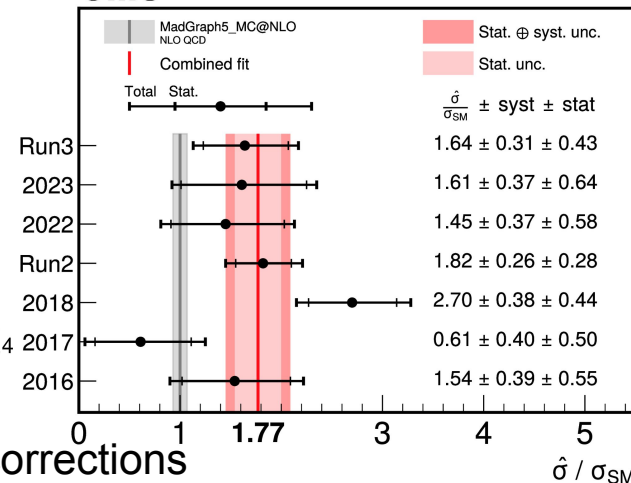
$\sigma(13 \text{ TeV}) = 248 \pm 38 \text{ (stat)} \pm 35 \text{ (syst)} \text{ fb}$

$\sigma(13.6 \text{ TeV}) = 242 \pm 62 \text{ (stat)} \pm 46 \text{ (syst)} \text{ fb}$

Observed significance: 5.8 σ (3.5 σ exp)



CMS



Dominant syst. unc.: normalization of the ttZ, WZ and jet energy corrections

$\hat{\sigma} / \sigma_{SM}$

Rare SM process with a **tW -scattering vertex** (direct probe of top EW couplings)

Signature (multilepton final states)

- Same-sign dileptons (e/μ)
- ≥ 1 b -tagged jet
- Additional forward jet characteristic of EW production

Analysis strategy:

- Dedicated control regions to constrain backgrounds
- Separate **EW $t\bar{t}W_j$** from dominant **QCD $t\bar{t}W$** background

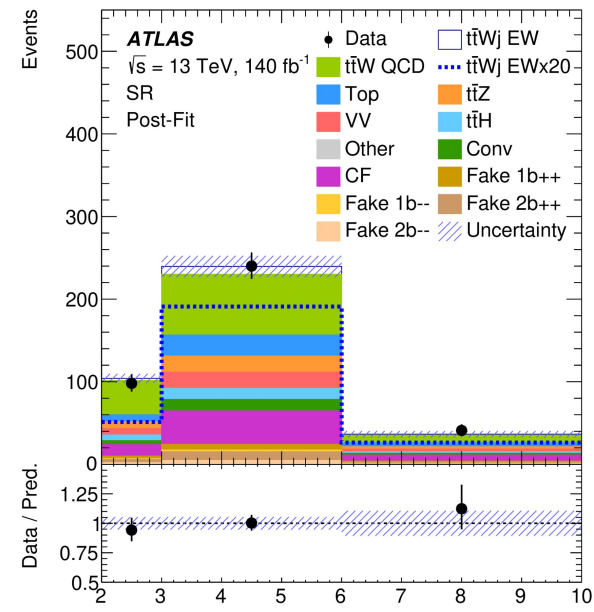
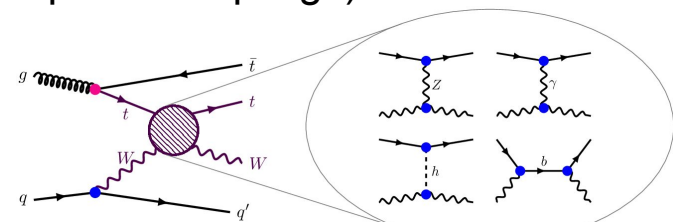
Set upper limit on EW production cross section:

$\sigma_{t\bar{t}W_j} < 251 \text{ fb (observed) at 95\% C.L.}$

SM expectation $\approx 47.7 \text{ fb}$

Analysis also includes an EFT interpretation (back-up)

Difference in η between the most forward non b -tagged jet and the jet with which it forms the largest invariant mass

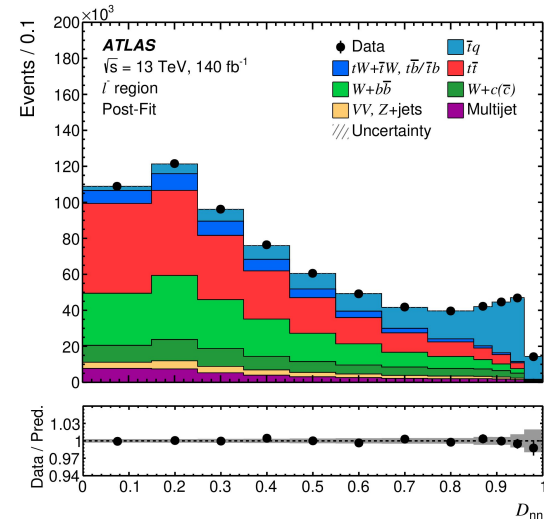


t-channel differential cross section

arXiv:2601.04938



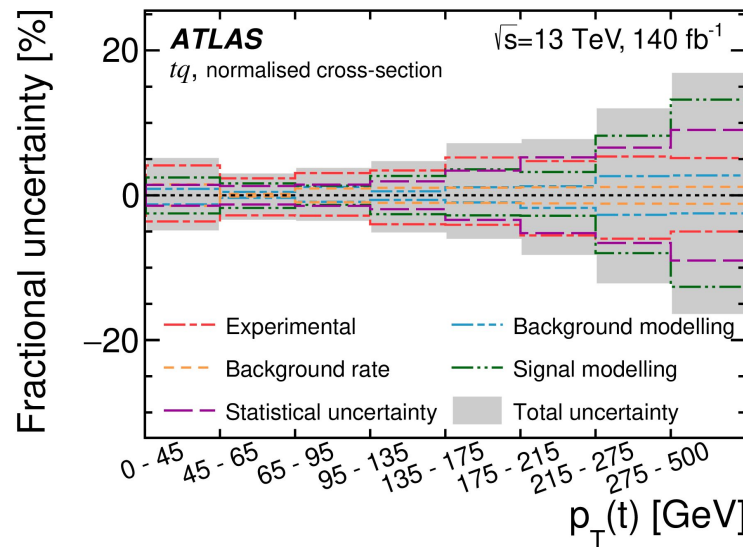
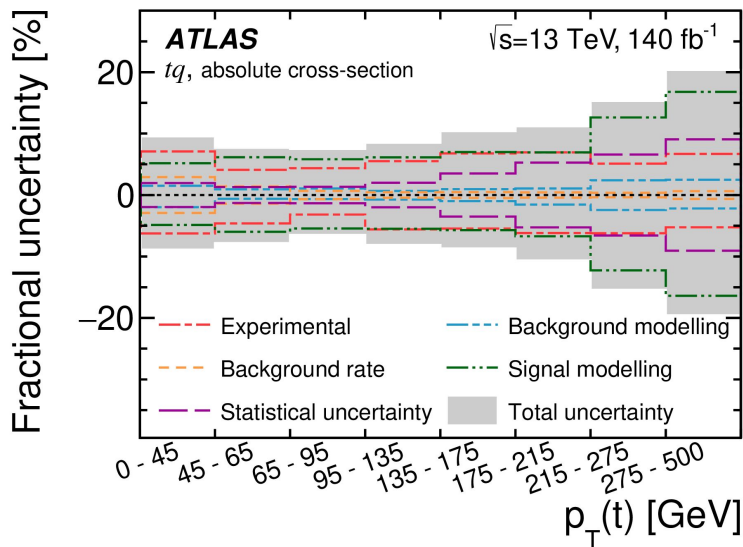
+ $D_{NN} > 0.93$



Signal region definition:

- 1 lepton and 2 jets (1 b-tagged)
- $E_{T}^{\text{miss}} > 30 \text{ GeV}$ and $m_{T}(W) > 50 \text{ GeV}$
- $p_{T}(\ell) > 40 \text{ GeV} \cdot |\Delta\phi(j_1, \ell)|/\pi$ and $m(\ell b) < 160 \text{ GeV}$

Measurements: absolute and normalised production cross sections differentially as a function of: $p_{T}(\mathbf{t})$, $p_{T}(\mathbf{\bar{t}})$, $|\mathbf{y}(\mathbf{t})|$ and $|\mathbf{y}(\mathbf{\bar{t}})|$

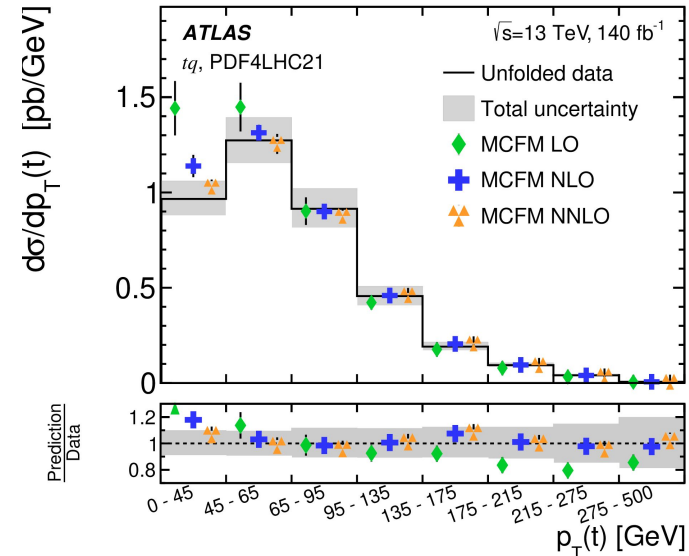
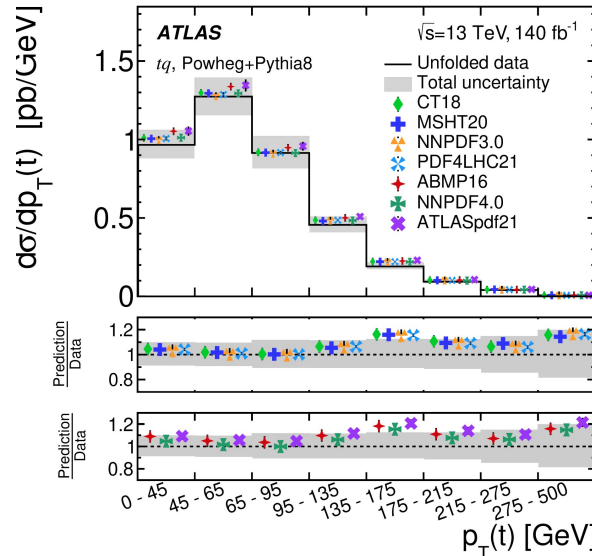
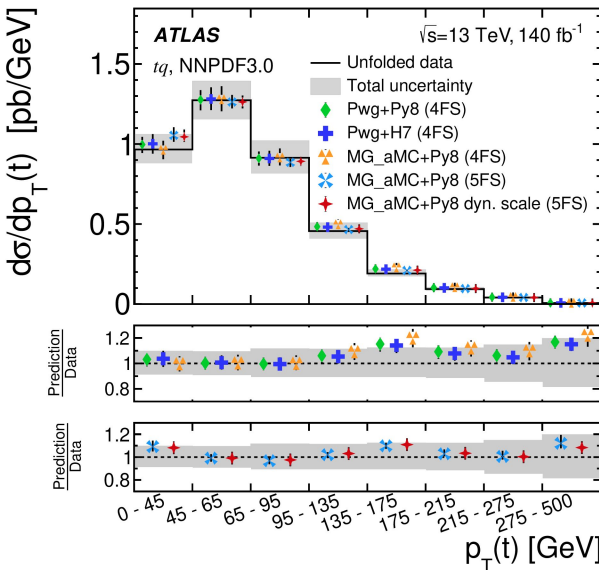


Main uncertainties:

- Signal modelling
- Statistical
- Experimental

Measurements: absolute and normalized unfolded differential tq and $\bar{t}q$ cross sections as a function of the same observables

Compared with NLO obtained with different combinations of **matrix-element generators**, **parton-shower programs** and **proton PDFs**, as well as to **LO**, **NLO** and **NNLO** calculations



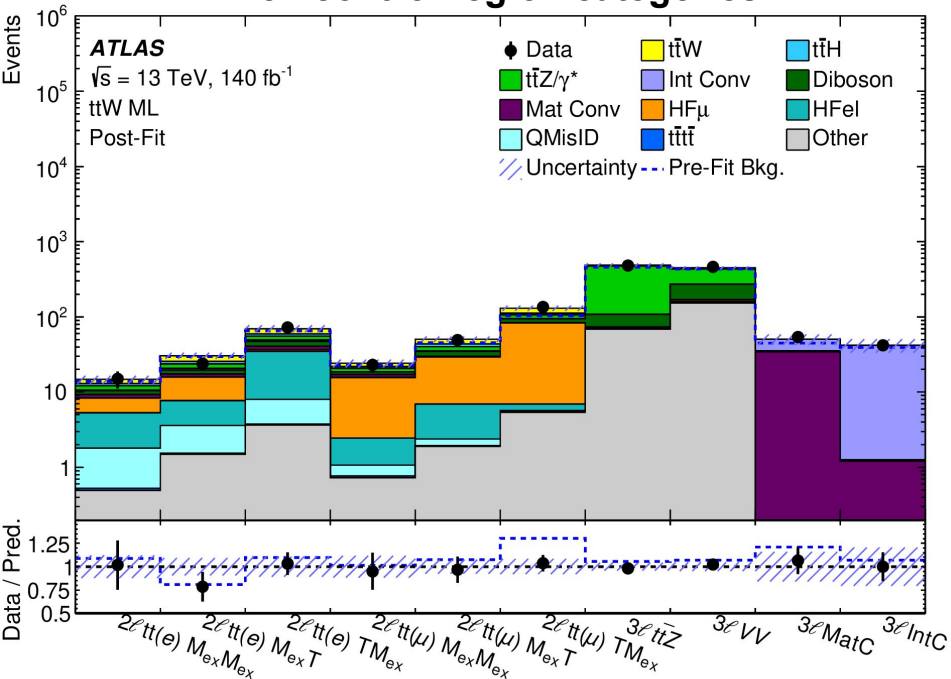
Good agreement, **sensitivity** limited by the **systematic uncertainties**



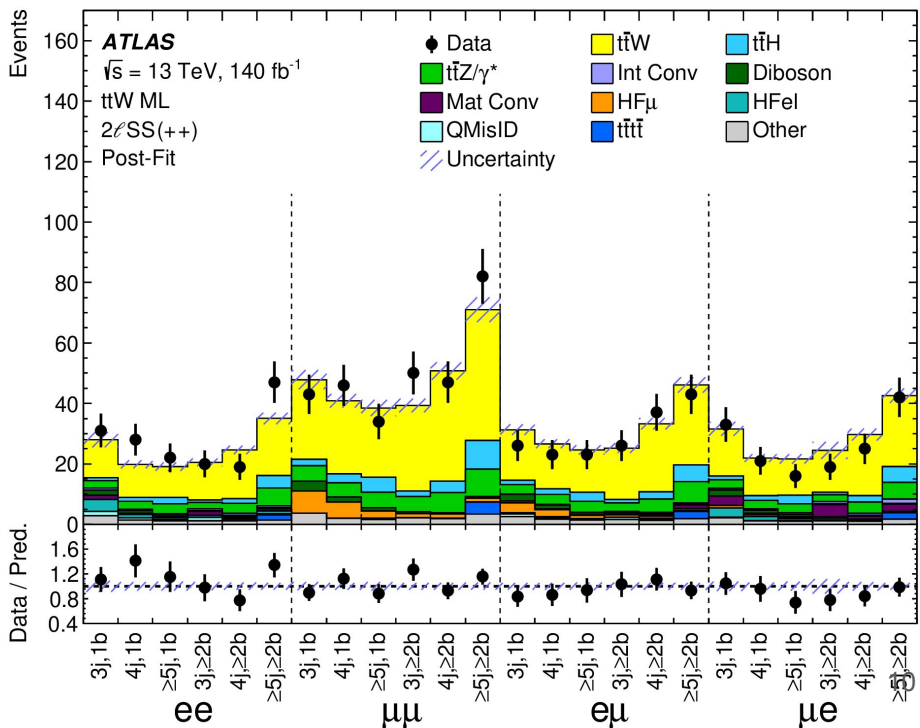
Combination of **signal and control regions** to extract the ttW cross section

Measurement performed by targeting final states with **2 same-sign** or **3 isolated leptons**

Ten control region categories

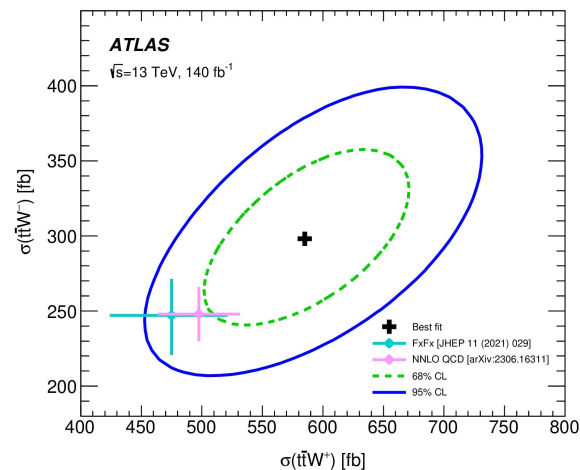
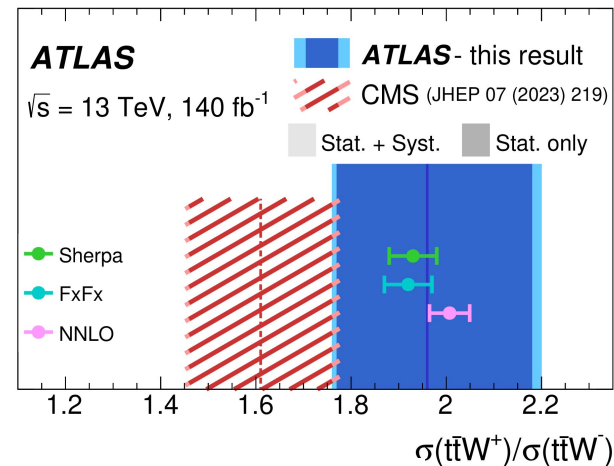
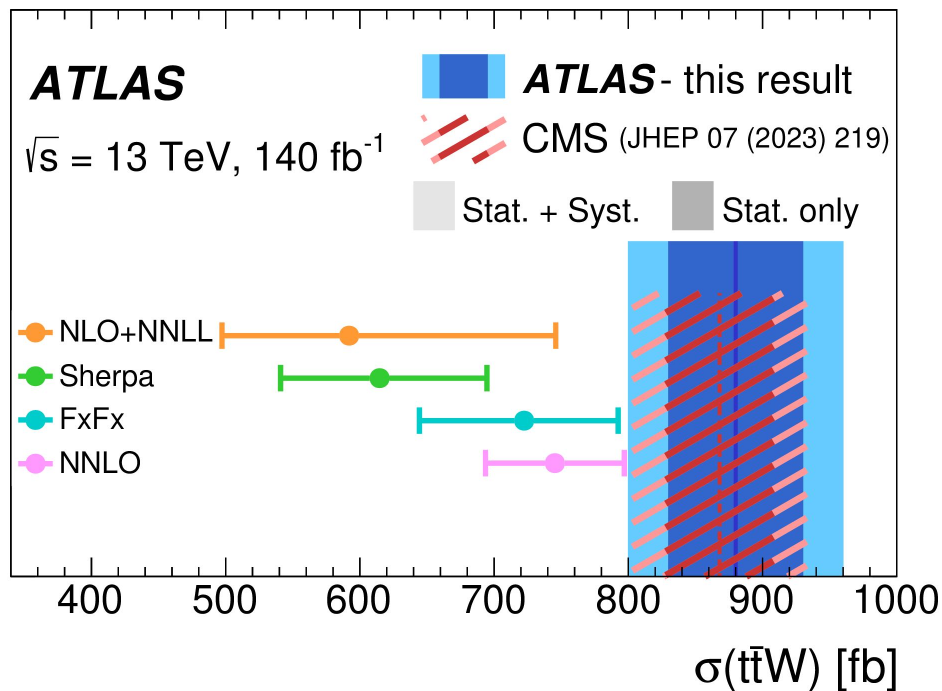


Four signal region categories: 2ISS (++,--) or 3I (+,-)



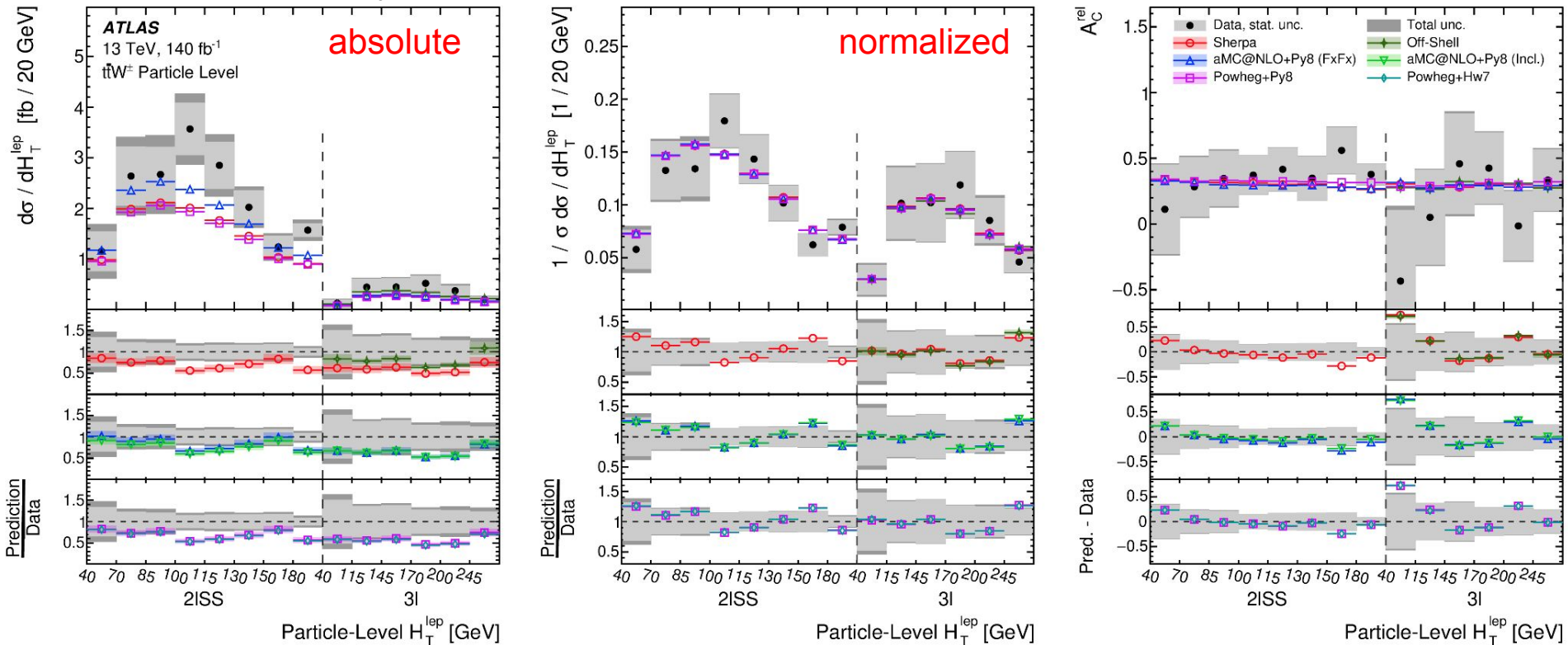
Inclusive cross section and ratio

2D likelihood scan of ttW⁺ and ttW⁻ cross sections



6 particle-level observables: $jet\ multiplicity, H_{T,jets}, H_{T,lep}, \Delta R_{lb, lead}, \Delta\phi_{ll, SS}$ and $\Delta\eta_{ll, SS}$

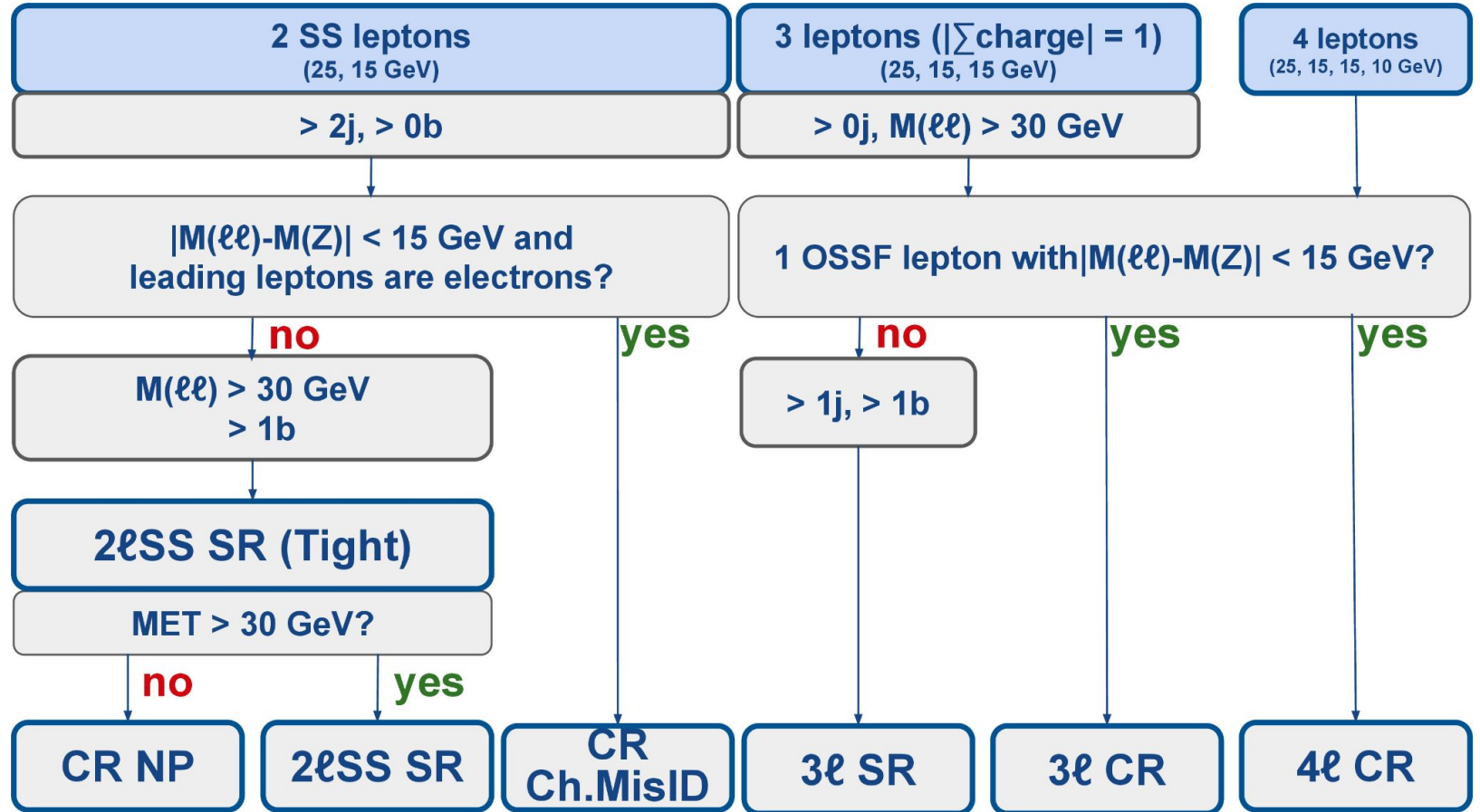
Compared with a variety of theoretical predictions



Good agreement observed with the normalised differential cross section results

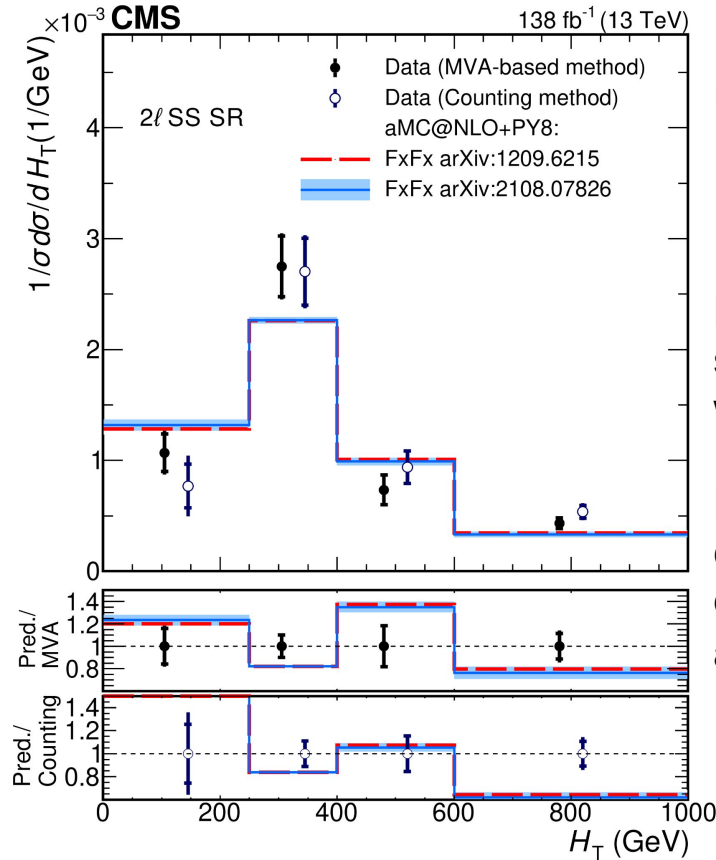
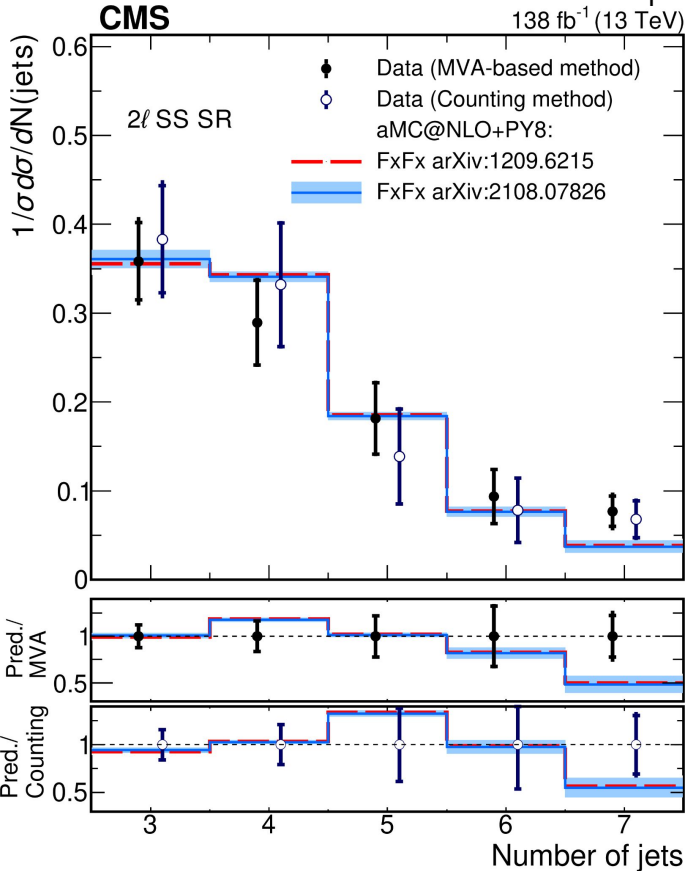


Control regions (CR) and signal regions (SR) used in the analysis





Measured 14 observables: Njet, H_T , (sub)leading jet p_T & $|\eta|$, (sub)leading lepton p_T , maximum $|\eta|$ of selected leptons, the sum of their p_T , invariant mass of the leptons, $|\Delta\eta(\ell_1, \ell_2)$, $\Delta R(\ell_1, \ell_2)$ and $\Delta R(\ell_1, \text{jet})_{\min}$



Using two methods:

- MVA based
- Counting

Normalized cross section are consistent with expectations

Larger values observed compared to the expectations in the absolute cross section

Inclusive cross section of ttZ, tWZ and tZq



A first simultaneous measurement of single and pair production of top quarks in association with a Z boson: ttZ, tWZ and tZq

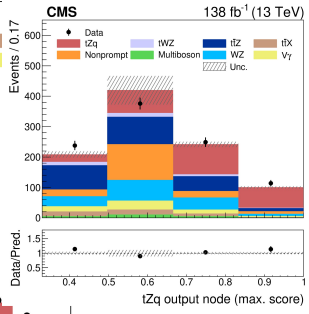
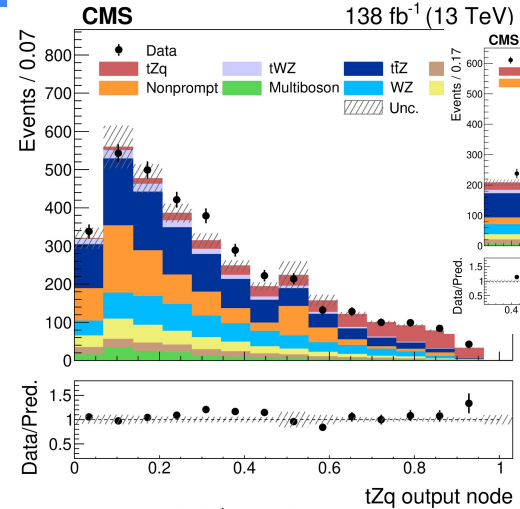
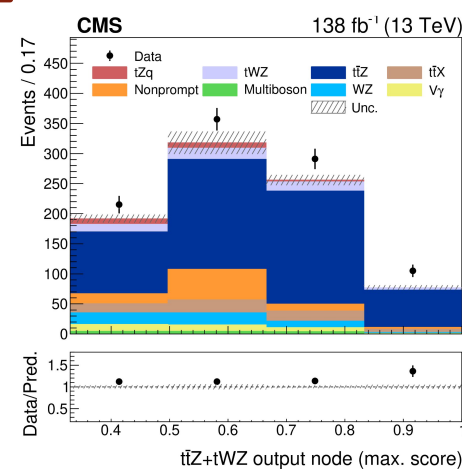
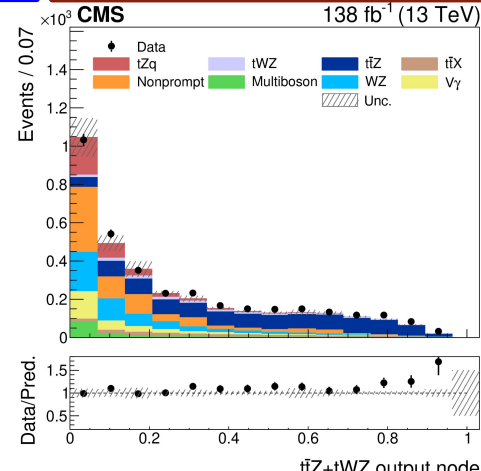
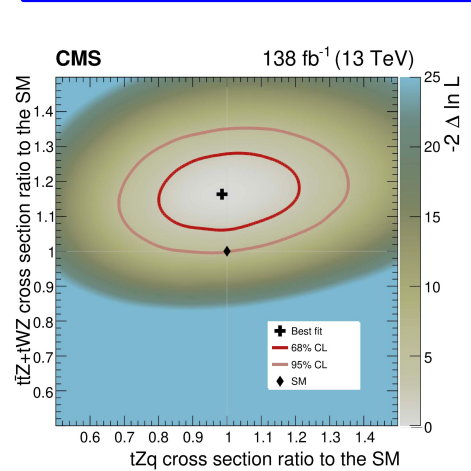
Final states: ≥ 3 leptons (e/ μ), targeting $Z \rightarrow \ell\ell$ decays

Deep neural network classifier with three output nodes

Measured cross sections (in a Z-mass window 70-110 GeV):

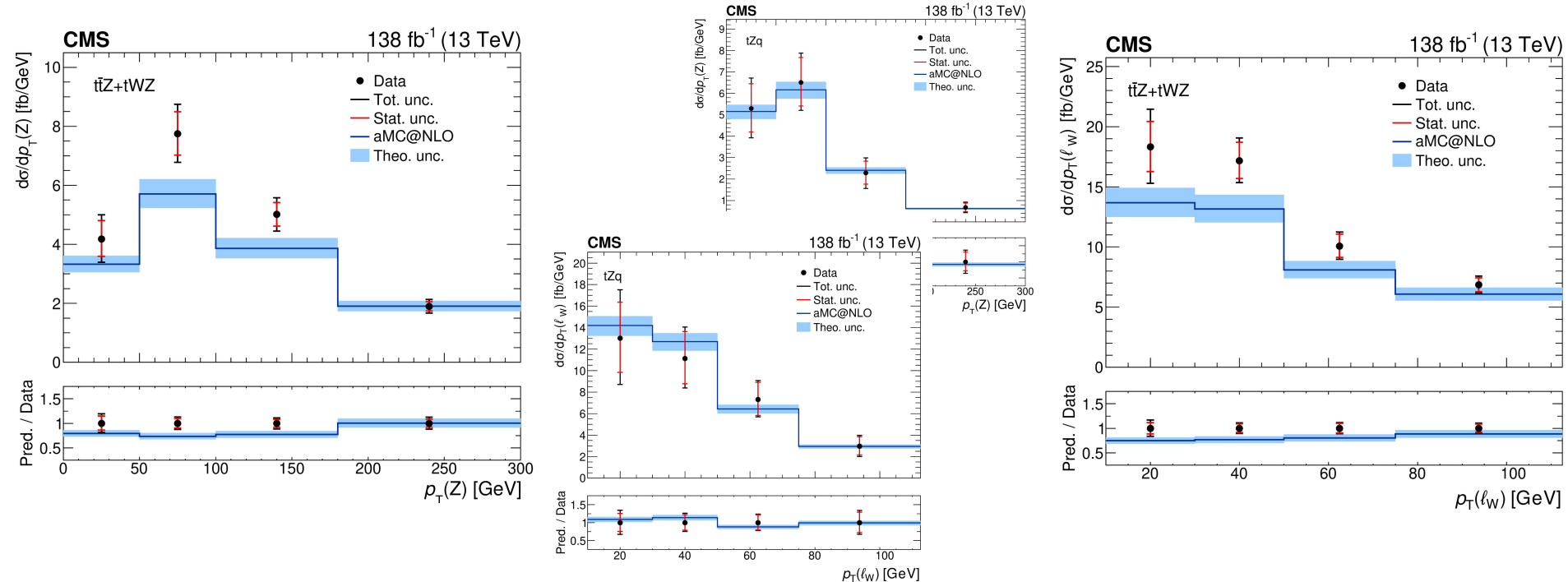
$$\sigma(\text{ttZ}+\text{tWZ}) = 1.14 \pm 0.07 \text{ pb}$$

$$\sigma(\text{tZq}) = 0.81 \pm 0.10 \text{ pb}$$





The cross sections are measured differentially (normalized and absolute) as functions of 5 observables: $p_T(Z)$, $p_T(\ell_W)$, $\Delta\phi(\ell^+, \ell^-)$, $\Delta R(Z, \ell_W)$, and $\cos\Theta_z^*$



Good agreement with theoretical predictions is found for the **tZq process**, while for **$t\bar{t}Z+tWZ$ production**, the slope in the transverse momentum of the lepton (from the W) is found to be **steeper than predicted**

Inclusive and differential cross section and tt̄/tt̄ ratio

Final state:

- Dilepton channel (two e/μ)
- ≥1 isolated high-p_T photon
- Jets (including b-jets from top decays)

Separating production vs decay radiation is a key feature of this analysis

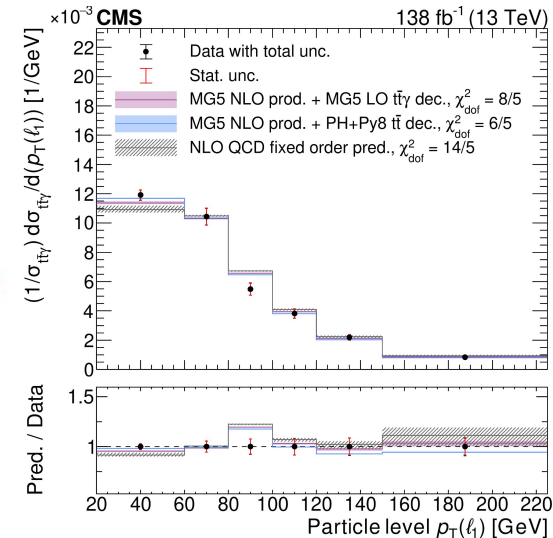
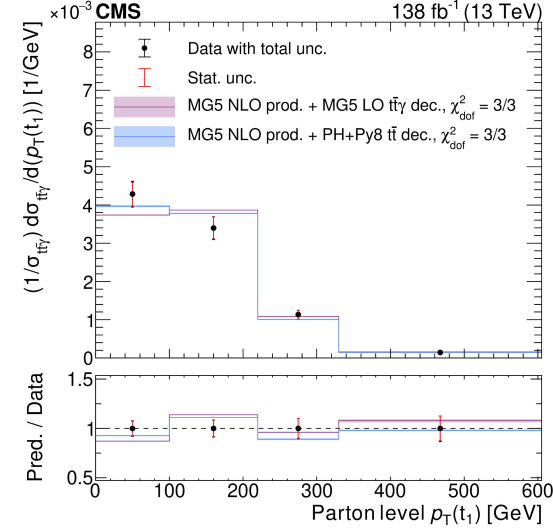
All measurements are consistent with SM predictions

$$\sigma_{fid}(t\bar{t}\gamma) = 137 \pm 3(\text{stat}) \pm 7(\text{syst}) \text{ fb } p_T(\gamma) > 20 \text{ GeV}$$

$$\sigma_{fid}(t\bar{t}\gamma) = 56 \pm 2(\text{stat}) \pm 4(\text{syst}) \text{ fb } p_T(\gamma) > 20 \text{ GeV, } \gamma \text{ from production process}$$

$$R_\gamma \equiv \frac{\sigma_{fid}(t\bar{t}\gamma)}{\sigma_{fid}(t\bar{t}) + \sigma_{fid}(t\bar{t}\gamma)} = 0.0133 \pm 0.0002(\text{stat}) \pm 0.0005(\text{syst})$$

$$A_C = -1.2 \pm 4.1(\text{stat}) \pm 0.9(\text{syst})\%$$



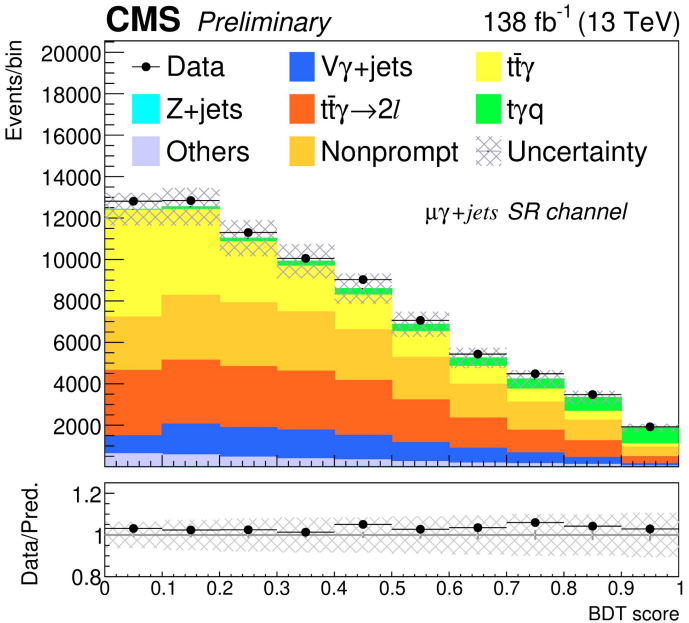
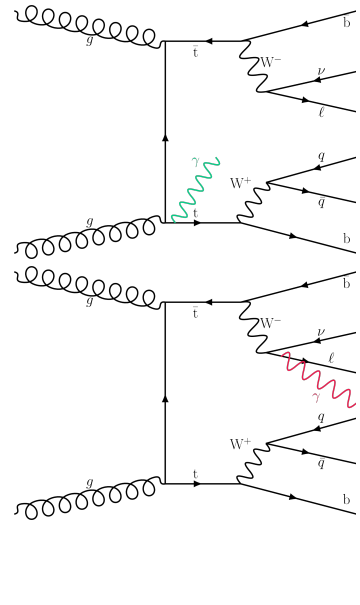
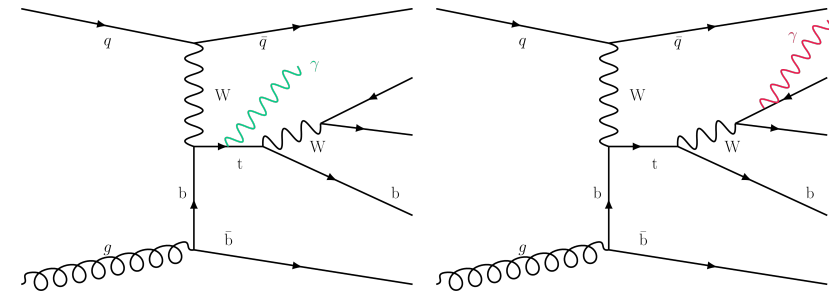
Single and pair top quark production in association with a photon

First **observation** of $tq\gamma$ by CMS and first differential measurement ever

TOP-25-003

Signature (lepton+jets channel):

- 1 isolated high p_T lepton (e/μ)
- 1 isolated photon
- At least 2 jets, 1 b tagged



Dedicated BDT trained to separate $t\bar{t}\gamma$ and $tq\gamma$

$$\sigma_{t\gamma q} = 236 \pm 17 \text{ fb}$$

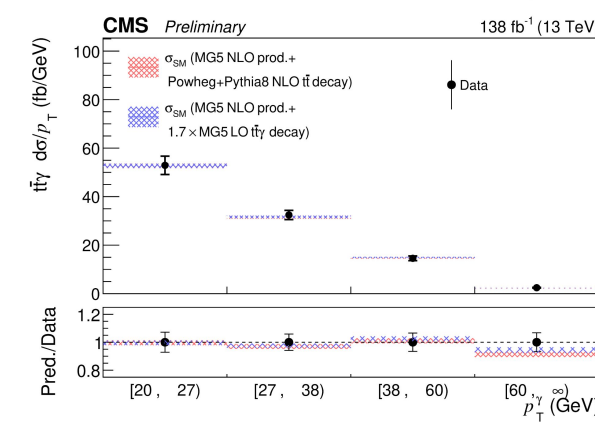
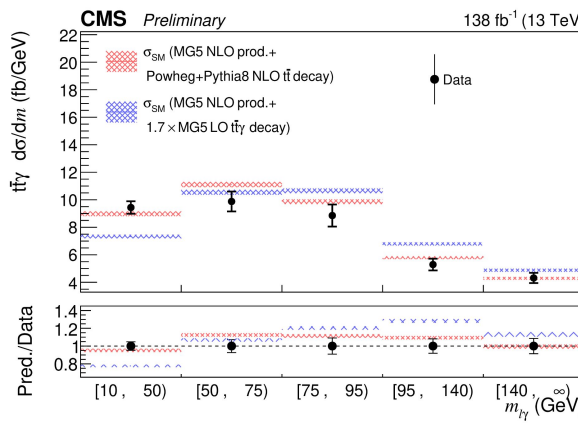
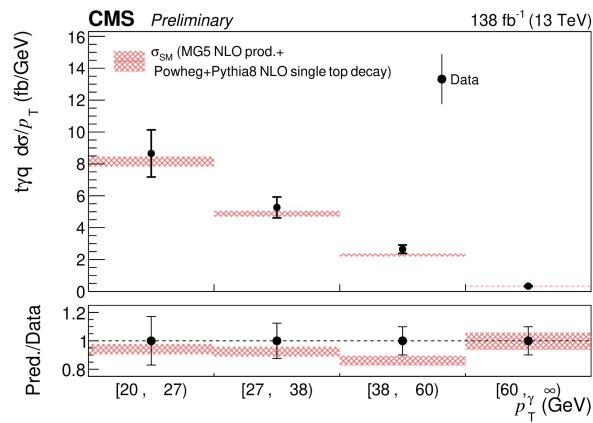
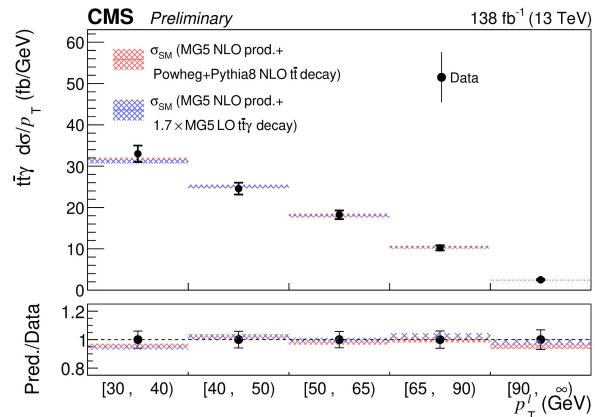
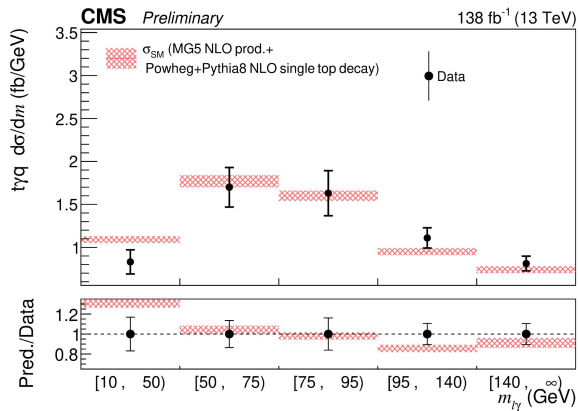
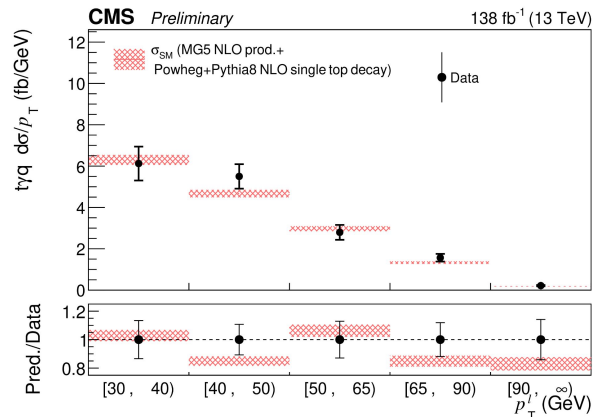
$$\sigma_{t\bar{t}\gamma} = 1445 \pm 80 \text{ fb}$$

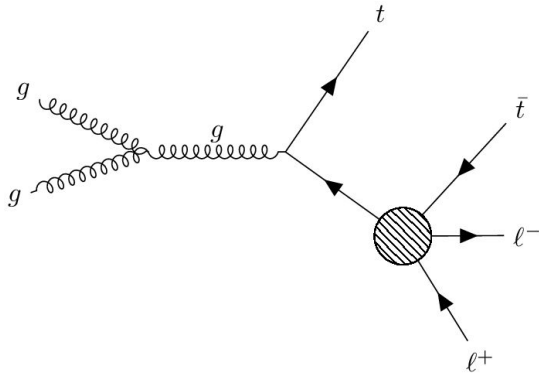
$$\sigma_{t\gamma q}^{(SM)} = 207 \pm 9 \text{ fb}$$

$$\sigma_{t\bar{t}\gamma}^{(SM)} = 1369 \pm 23 \text{ fb}$$

Single and pair top quark production in association with a photon

Differential cross sections measured as functions of $p_T^{\ell}, p_T^{\gamma}, m_{\ell\gamma}, \Delta R(\ell, \gamma), \eta_{light}, N_{jets}$ in the fiducial region at the particle level, and as functions of $\Delta R(t, \gamma)$ and the top quark charge at parton





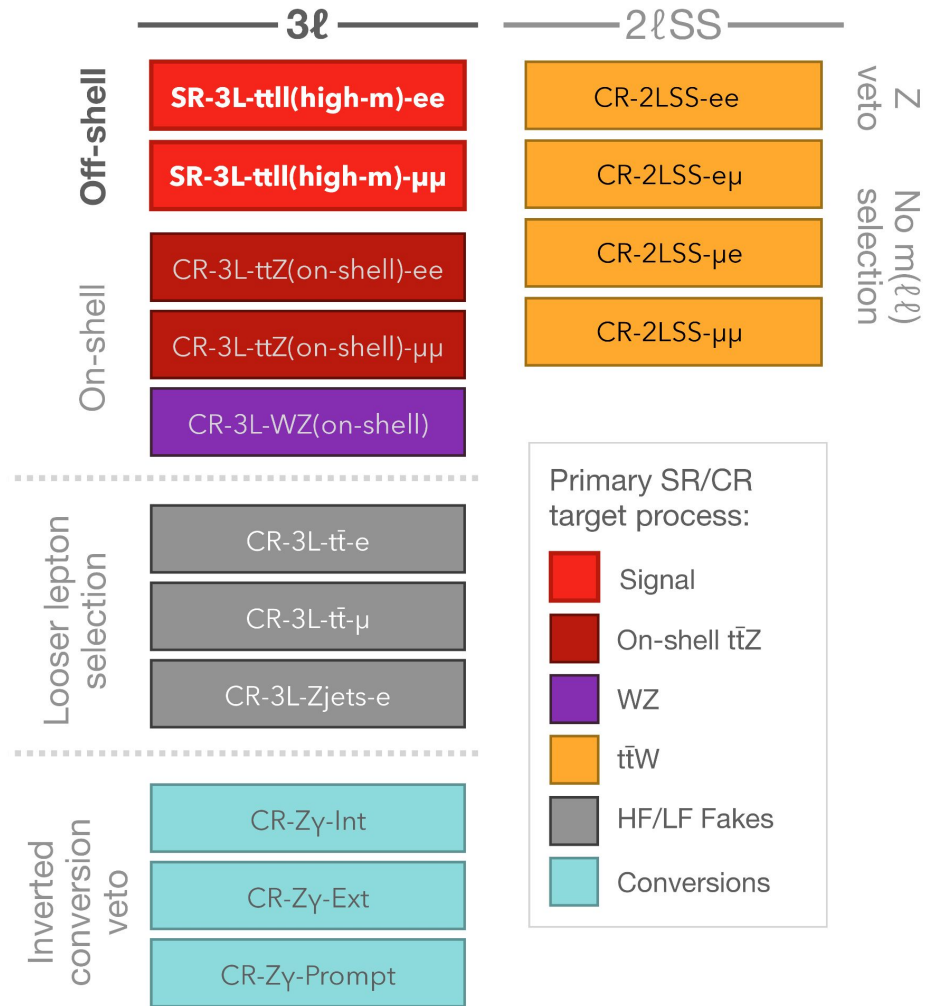
Sensitivity to new physics coupling to **leptons** and **top quarks**

Searching for events with 3 leptons:

- 1 from one top quark
- 2 not compatible with a Z boson

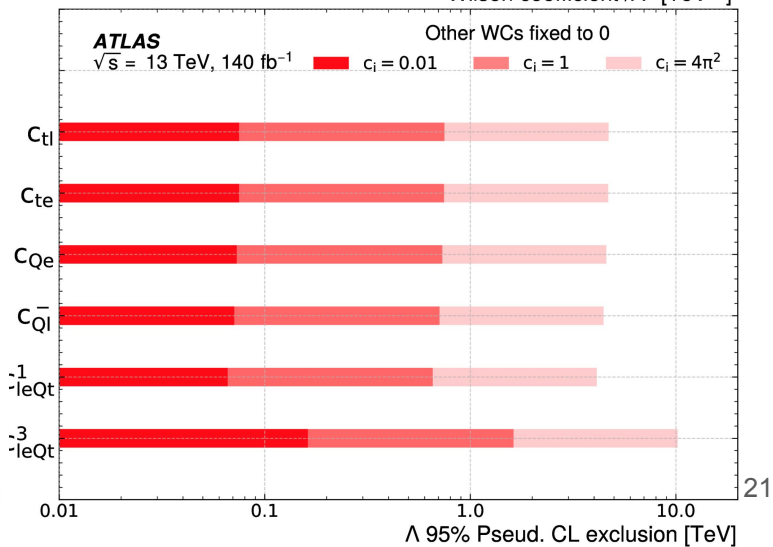
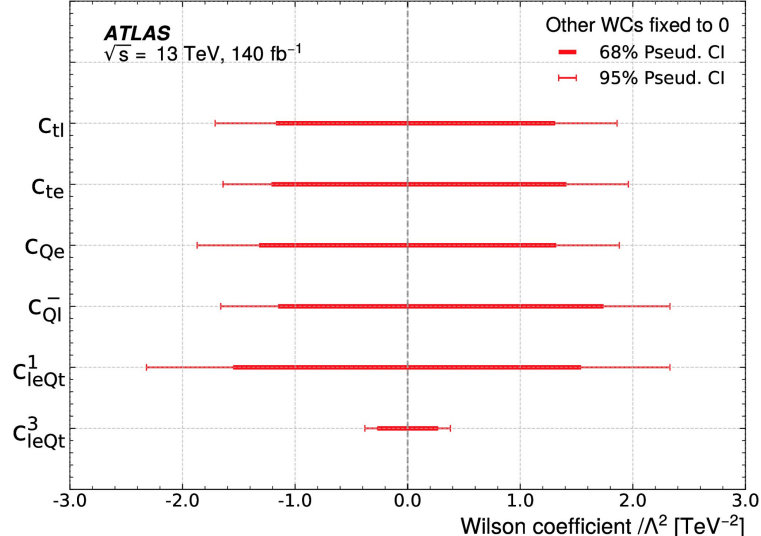
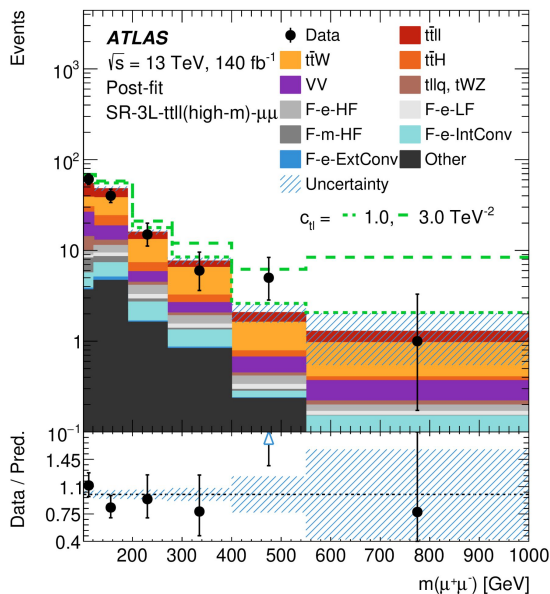
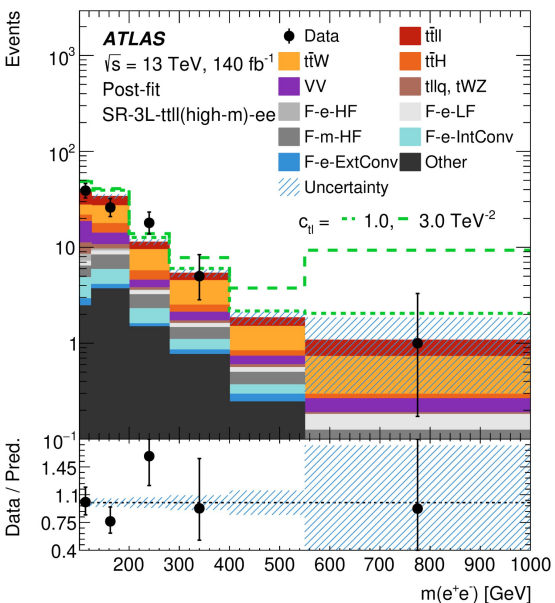
With additional (b)-jets

ttZ and **ttW** are the dominant backgrounds



Analysis used to probe different top+lepton contact interactions

Sensitivity separately for *electrons* and *muon*



Summary

Presented results from ATLAS and CMS Collaborations, based mainly on Run 2 ($\sim 140 \text{ fb}^{-1}$) + early Run 3

Top quark as a probe of:

- QCD in extreme regimes
- Electroweak couplings
- BSM sensitivity via rare processes

List of results:



- **4tops** with a hadronic tau decay: [TOP-24-017](#)



- Search for **3top** production: [TOP-24-006](#)



- A search for electroweak **ttWj** production: [arxiv:2509.19038](#)



- Differential **t-channel** cross section: [arXiv:2601.04938](#)



- Differential cross sections of **ttW**: [JHEP 05 \(2024\) 131](#)



- Differential cross sections of **ttW**: [JHEP 03 \(2026\) 083](#)



- **ttl+l-** high mass measurement: [Eur. Phys. J. C 85 \(2025\) 1434](#)



- Differential cross section of **ttZ**, **tWZ** and **tZq**: [JHEP 02 \(2025\) 177](#)

- Inclusive and differential **ttY** cross sections: [arxiv:2511.01995](#)

- Inclusive and differential **ttY** and **ttq** cross sections: [TOP-25-003](#)

- Observation of **ttty**: [Phys. Lett. B 874 \(2026\) 140195](#)

- Observation of **ttWZ**: [Phys. Rev. Lett. 136 \(2026\) 081802](#)

BACK-UP

<https://arxiv.org/pdf/2403.02126> *Measurement of t -channel production of single top quarks and antiquarks in pp collisions at 13 TeV using the full ATLAS Run 2 data sample*

Systematic uncertainty	$\Delta\sigma(tq)/\sigma(tq)$	$\Delta\sigma(\bar{t}q)/\sigma(\bar{t}q)$	$\Delta\sigma(tq + \bar{t}q)/\sigma(tq + \bar{t}q)$
tq matching scale definition, rate	+3.1 / -2.9	+2.8 / -2.6	+2.9 / -2.8
tq parton shower, rate	+2.6 / -2.5	+3.3 / -3.2	+2.9 / -2.8
tq final-state radiation	+2.1 / -2.0	+2.2 / -2.1	+2.1 / -2.0
tq matching scale definition, shape	+1.6 / -1.5	+1.2 / -1.2	+1.5 / -1.4
JES η intercalibration modelling	+1.2 / -1.2	+1.6 / -1.5	+1.4 / -1.3
b -tagging NP B1	+1.0 / -0.9	+1.0 / -1.0	+1.0 / -0.9
b -tagging NP B0	+1.0 / -0.9	+1.0 / -1.0	+1.0 / -0.9
Luminosity	+0.9 / -0.8	+0.9 / -0.9	+0.9 / -0.8

Table 4: The impact of the eight most important systematic uncertainties on $\sigma(tq)$, $\sigma(\bar{t}q)$ and $\sigma(tq + \bar{t}q)$ given in %. The sequence of the uncertainties is given by the impact on $\sigma(tq + \bar{t}q)$.

Measurements of inclusive and differential production cross-sections of $t\bar{t}W$



[JHEP 05 \(2024\) 131](#)

	Electron				Muon			
Lepton definition	<i>L</i>	<i>M</i>	<i>M_{ex}</i>	<i>T</i>	<i>L</i>	<i>M</i>	<i>M_{ex}</i>	<i>T</i>
Identification	Loose	Tight			Loose	Medium		
Transverse impact parameter significance $ d_0 /\sigma_{d_0}$	< 5				< 3			
Longitudinal impact parameter z_0	$ z_0 \sin \theta < 0.5 \text{ mm}$							
Isolation	Yes				Yes			
Non-prompt lepton WP	No	<i>Tight</i>	<i>Tight-not-VeryTight</i>	<i>VeryTight</i>	No	<i>Tight</i>	<i>Tight-not-VeryTight</i>	<i>VeryTight</i>
Electron charge-misassignment veto	No	Yes			–			
Electron conversion candidate veto	No	Yes (except e^*)			–			

Description of the loose inclusive (L), medium inclusive (M), medium exclusive (M_{ex}), and tight (T) lepton definitions

Measurements of inclusive and differential production cross-sections of ttW

Event selection summary in the signal and control regions



Signal region preselection	$2\ell SS$	3ℓ
Lepton definition	TT	LTT
Lepton p_T [GeV]	(20, 20)	(10, 20, 20)
$m_{\ell^+\ell^-}^{SF}$ [GeV]	–	> 12
$ m_{\ell^+\ell^-}^{SF} - m_Z $ [GeV]	–	> 10
$ m_{3\ell} - m_Z $ [GeV]	–	> 10
N_{jets}		≥ 2
$N_{b\text{-jets}}$		$\geq 1 b^{60\%}$ or $\geq 2 b^{77\%}$
Inclusive cross-section measurement		
Lepton charge split	$(\ell^+\ell^+, \ell^-\ell^-)$	$(\ell^+\ell^-\ell^-, \ell^-\ell^+\ell^+)$
Lepton flavour split	$(\mu\mu, e\mu, \mu e, ee)$	–
Jet multiplicity split	(3, 4, ≥ 5)	(2, ≥ 3)
b -jet multiplicity split		(1, ≥ 2)
Total inclusive SRs	48	8
Differential cross-section measurement		
Lepton charge split	$(\ell^+\ell^+, \ell^-\ell^-)$	$(\ell^+\ell^-\ell^-, \ell^-\ell^+\ell^+)$
Number of OS-SF pairs split	–	(0, 1, 2)
Total differential SRs	2	6

Control regions for:	Diboson	$t\bar{t}Z$	Conversions	HF non-prompt
Lepton requirement		3ℓ	$\mu\mu e^*$	$2\ell SS$
Lepton definition		(L, M, M)		$(T, M_{\text{ex}}) \parallel (M_{\text{ex}}, T) \parallel (M_{\text{ex}}, M_{\text{ex}})$
Lepton p_T [GeV]		(10, 20, 20)		(20, 20)
$m_{\ell^+\ell^-}^{SF}$ [GeV]		> 12	> 12	–
$ m_{\ell^+\ell^-}^{SF} - m_Z $ [GeV]		< 10	> 10	–
$ m_{3\ell} - m_Z $ [GeV]		> 10	< 10	–
$m_T(\ell_0, E_T^{\text{miss}})$ [GeV]		–		< 250 for TM_{ex} and $M_{\text{ex}}T$ pairs
N_{jets}	2 or 3	≥ 4	≥ 0	≥ 2
$N_{b\text{-jets}}$	$1 b^{60\%}$	$\geq 1 b^{60\%}$ or $\geq 2 b^{77\%}$	$0 b^{77\%}$	$1 b^{77\%}$
Region split	–	–	internal / material	sub-leading $e/\mu \times (TM_{\text{ex}}, M_{\text{ex}}T, M_{\text{ex}}M_{\text{ex}})$
Region naming	$3\ell VV$	$3\ell t\bar{t}Z$	$3\ell \text{IntC} /$ $3\ell \text{MatC}$	$2\ell \text{tt}(e)_{TM_{\text{ex}}}, 2\ell \text{tt}(e)_{M_{\text{ex}}T}, 2\ell \text{tt}(e)_{M_{\text{ex}}M_{\text{ex}}}$ $2\ell \text{tt}(\mu)_{TM_{\text{ex}}}, 2\ell \text{tt}(\mu)_{M_{\text{ex}}T}, 2\ell \text{tt}(\mu)_{M_{\text{ex}}M_{\text{ex}}}$

Measurements of inclusive and differential production cross-sections of $t\bar{t}W$



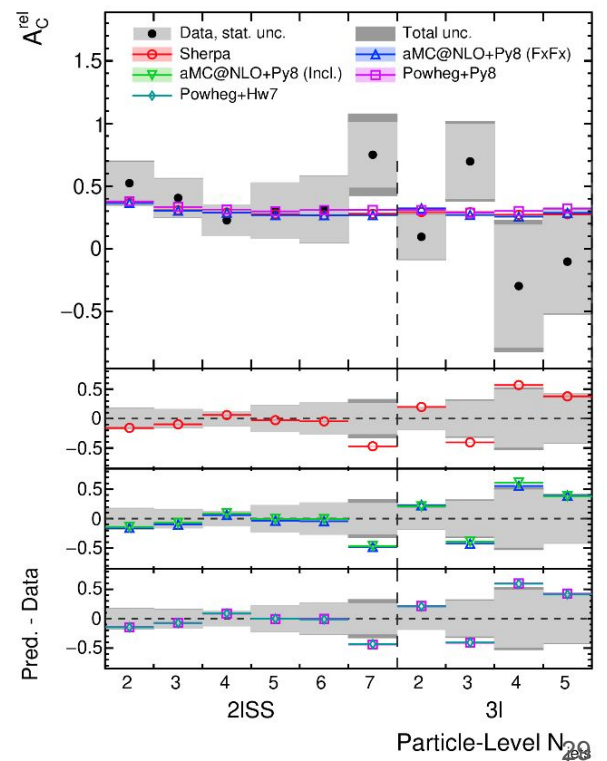
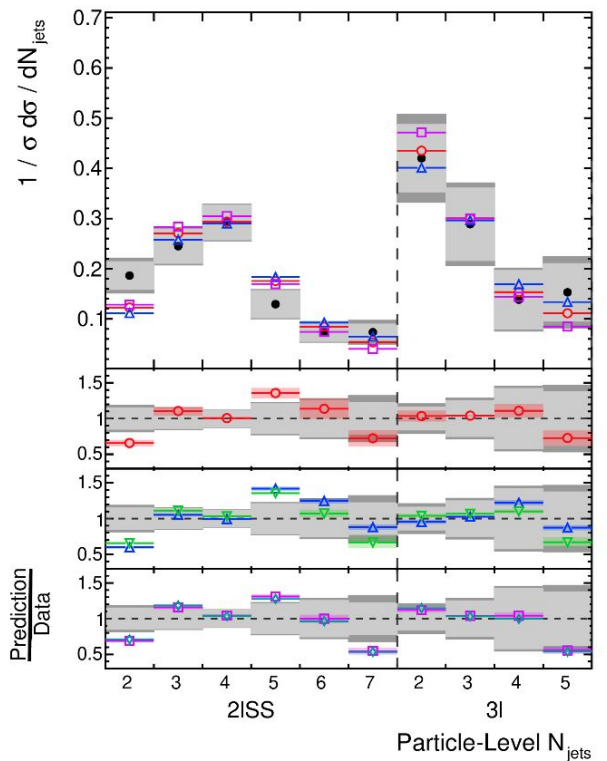
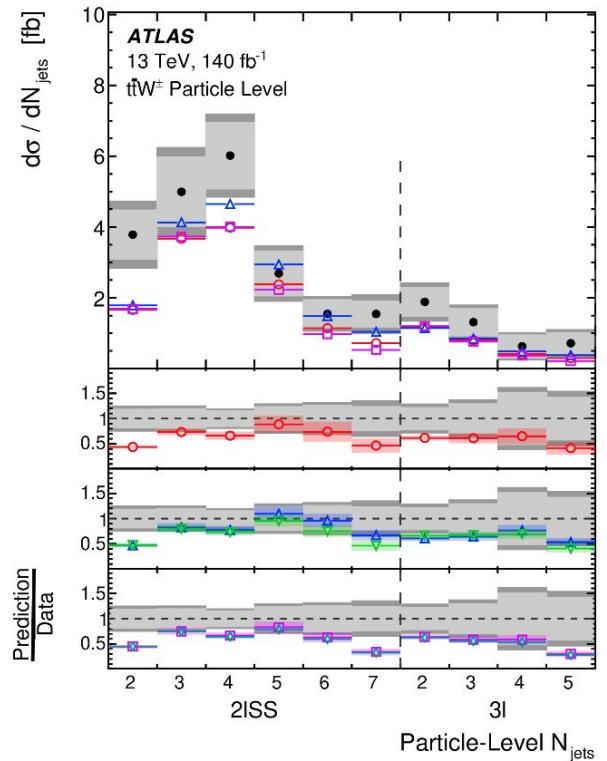
Definition of objects and selections for fiducial regions

Objects	
Electrons	$p_T \geq 10$ GeV and $ \eta < 2.47$ (excluding the LAr transition region $1.37 < \eta < 1.52$)
Muons	$p_T \geq 10$ GeV and $ \eta < 2.5$
Jets	Anti- k_r $R = 0.4$ jets with $p_T \geq 25$ GeV and $ \eta < 2.5$
b -jets	Tagged if jet contains a ghost-associated b -hadron with $p_T > 5$ GeV
E_T^{miss}	Vector sum of p_T for all neutrinos ($p_T(\nu)$) in the event not from hadron decays
Overlap removal	
Electron–jet	If $\Delta R(e, \text{jet}) < 0.2$ (excluding b -jets with $p_T < 200$ GeV) remove jet
Jet–lepton	If $\Delta R(\ell, \text{jet}) < \min(0.4, 0.04 + 10 \text{ GeV}/p_{T,\ell})$ remove lepton
Selections	
$2\ell\text{SS}$	Exactly two leptons with the same charge Both leptons have $p_T \geq 20$ GeV $N_{\text{jets}} \geq 3$ ($N_{\text{jets}} \geq 2$) with at least one b -jet for inclusive (differential) fit $m_{\ell\ell} > 12$ GeV for same-flavour pairs
3ℓ	Exactly three leptons with a total charge of ± 1 Both leptons from the same-sign lepton pair are required to have $p_T \geq 20$ GeV $N_{\text{jets}} \geq 1$ with at least one b -jet $m_{\ell\ell} > 12$ GeV & $ m_{\ell\ell} - m_Z > 10$ GeV (for OS-SF $\ell\ell$) $ m_{\ell\ell\ell} - m_Z > 10$ GeV

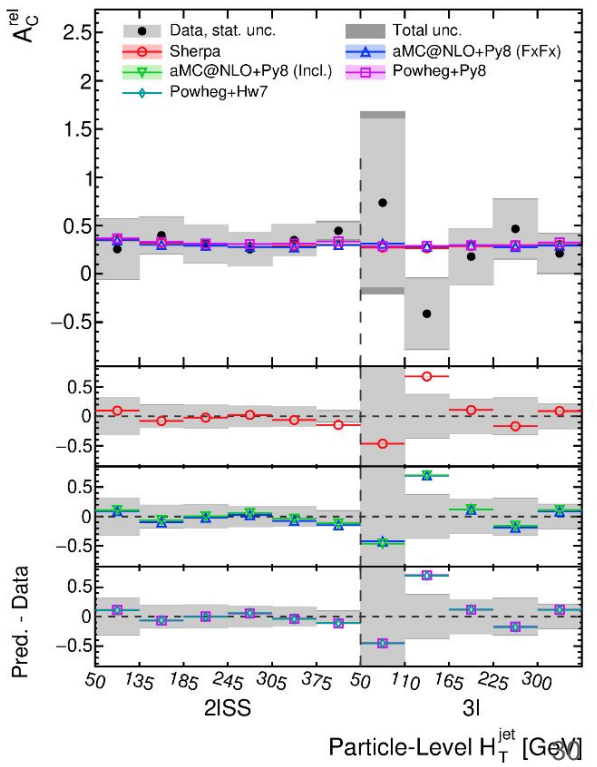
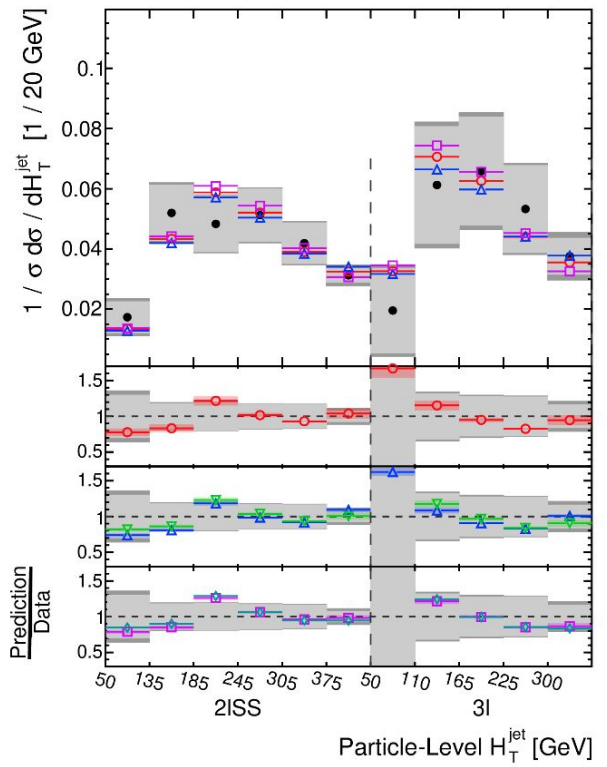
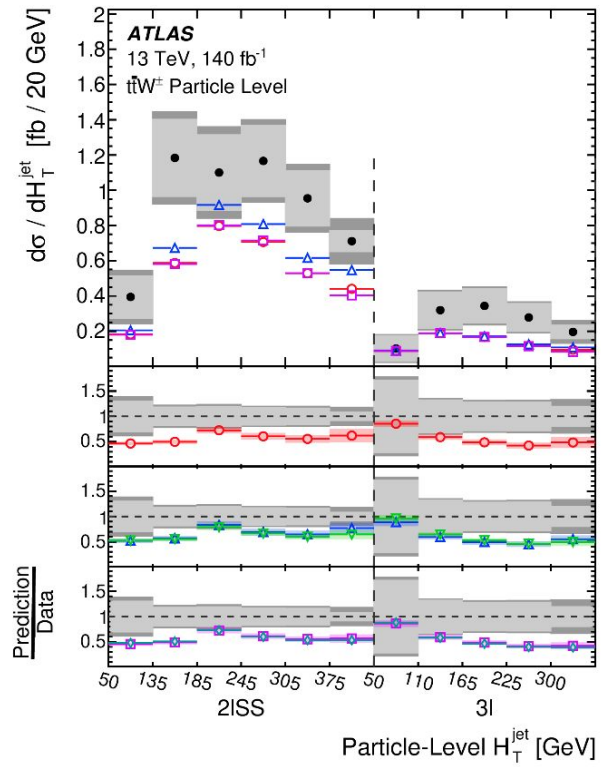


Variable	Definition
N_{jets}	Number of selected jets with $p_{\text{T}} > 25$ GeV and $ \eta < 2.5$
$H_{\text{T}}^{\text{jet}}$	Scalar sum of the transverse momenta of selected jets with $p_{\text{T}} > 25$ GeV and $ \eta < 2.5$
$H_{\text{T}}^{\text{lep}}$	Scalar sum of the transverse momenta of selected leptons
$\Delta R_{\ell b, \text{lead}}$	Angular separation between the leading lepton and the leading b -tagged jet
$ \Delta\phi_{\ell\ell, \text{ss}} $	Absolute azimuthal separation between the two leptons of the same-sign pair
$ \Delta\eta_{\ell\ell, \text{ss}} $	Absolute pseudorapidity separation between the two leptons of the same-sign pair

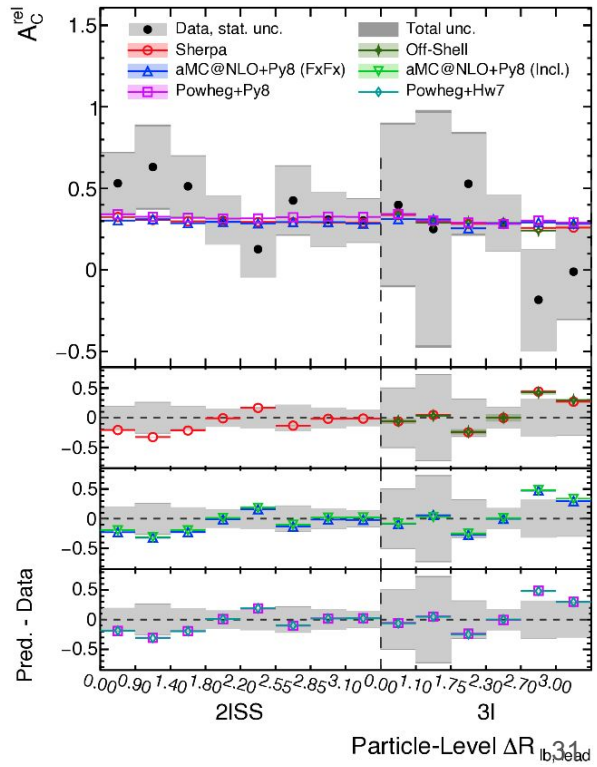
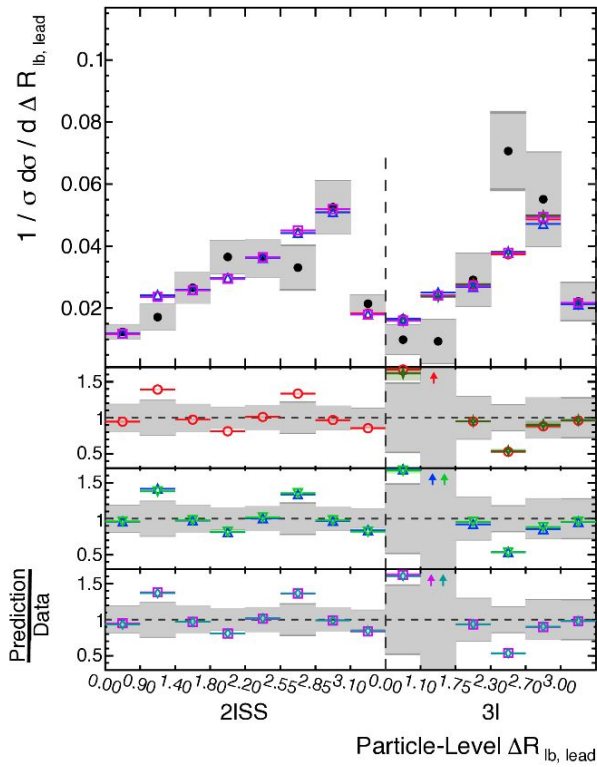
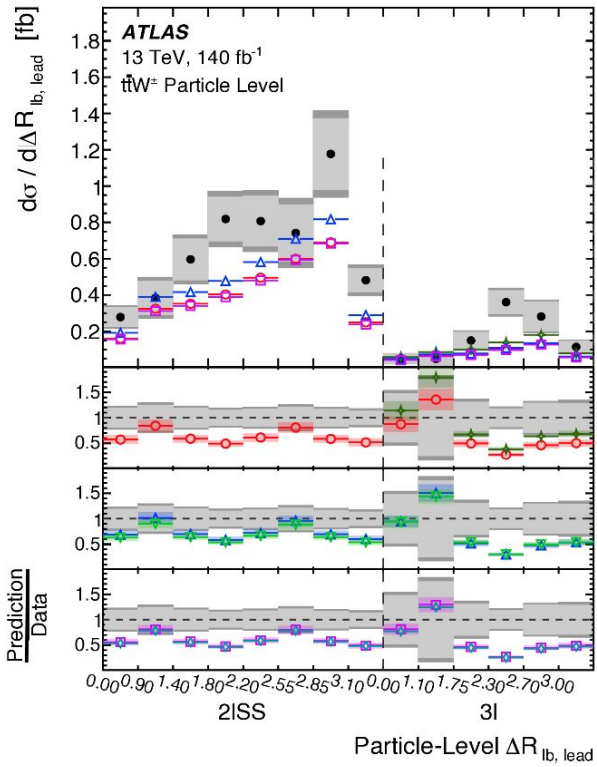
Measurements of inclusive and differential production cross-sections of $t\bar{t}W$



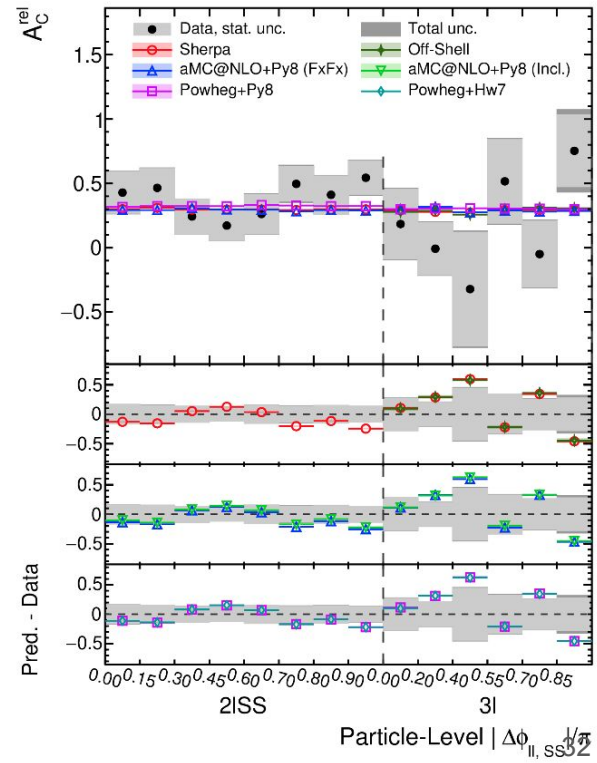
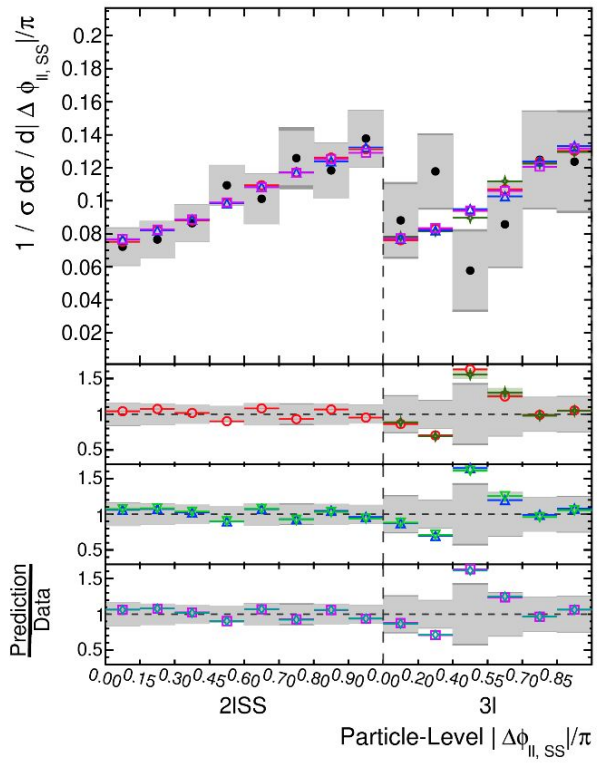
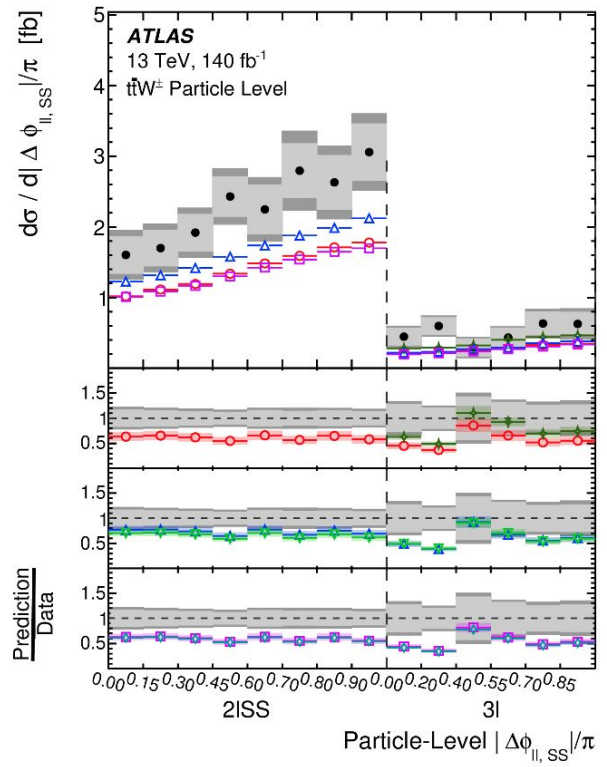
Measurements of inclusive and differential production cross-sections of $t\bar{t}W$



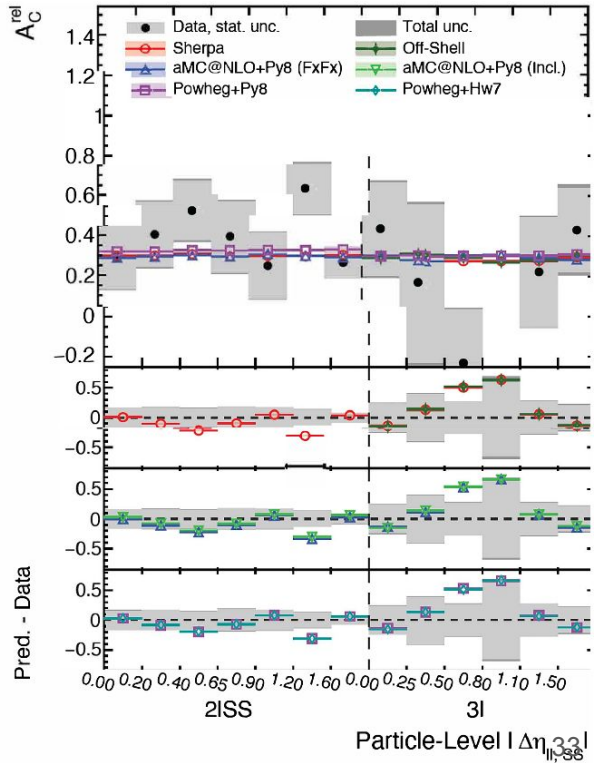
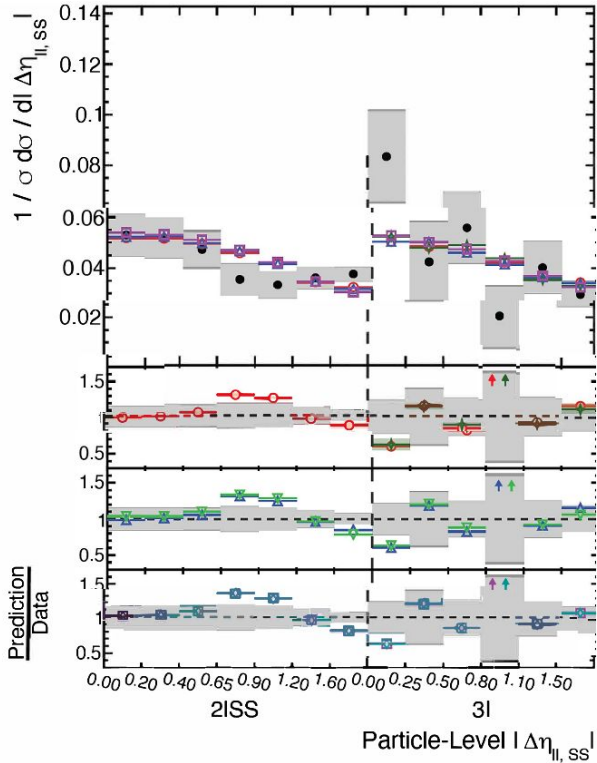
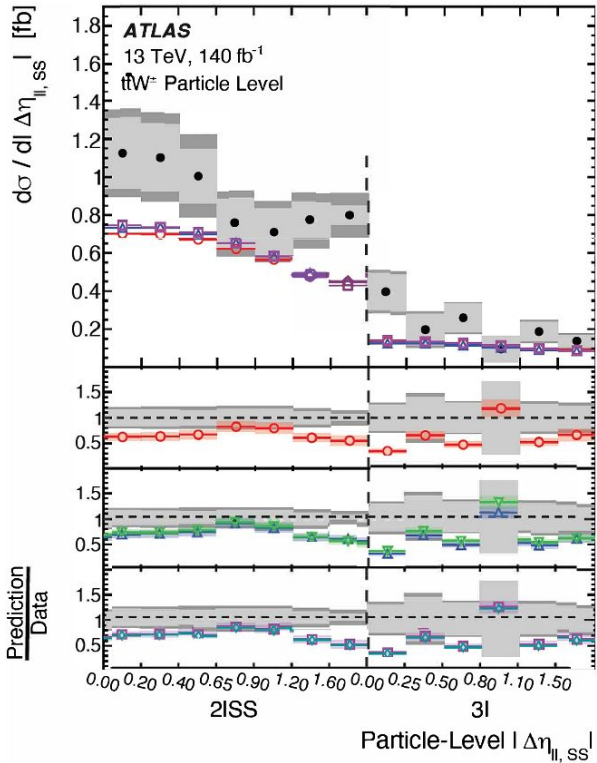
Measurements of inclusive and differential production cross-sections of $t\bar{t}W$



Measurements of inclusive and differential production cross-sections of $t\bar{t}W$



Measurements of inclusive and differential production cross-sections of $t\bar{t}W$



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 $t\bar{t}l^+l^-$ vertex
O_{Qe}	$(\bar{Q} \gamma_\mu Q)(\bar{e}_p \gamma^\mu e_r)$	R-handed leptons and L-handed quarks in the $t\bar{t}l^+l^-$ and $b\bar{b}l^+l^-$ vertices
O_{tl}	$(\bar{l}_p \gamma_\mu l_r)(\bar{t} \gamma^\mu t)$	L-handed leptons and R-handed quarks in the $t\bar{t}l^+l^-$ 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 $t\bar{t}l^+l^-$ and $b\bar{b}l^+l^-$ 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 $t\bar{t}l^+l^-$ and $b\bar{b}l^+l^-$ 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 $t\bar{t}l^+l^-$, $t\bar{b}l^+l^-$ and $b\bar{b}l^+l^-$ 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 $t\bar{t}l^+l^-$, $t\bar{b}l\nu$, $\bar{t}b l\nu$ and $b\bar{b}l^+l^-$ vertices, tensor

A search for electroweak ttWj production

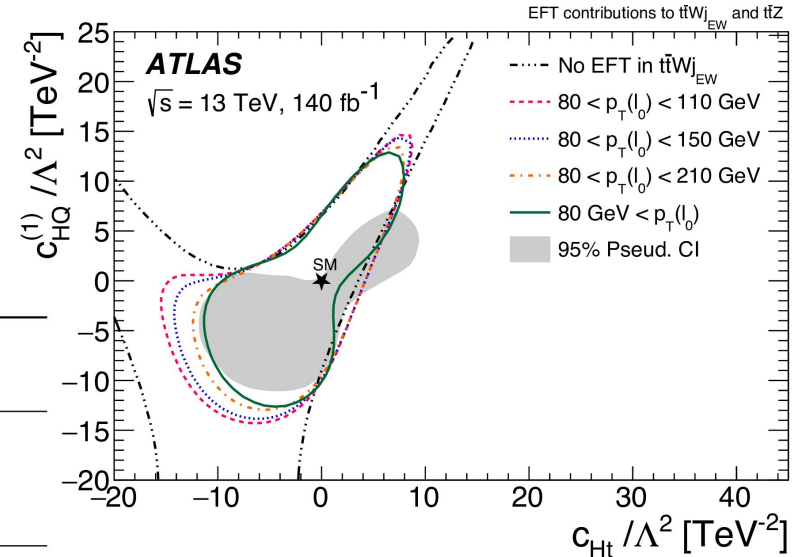
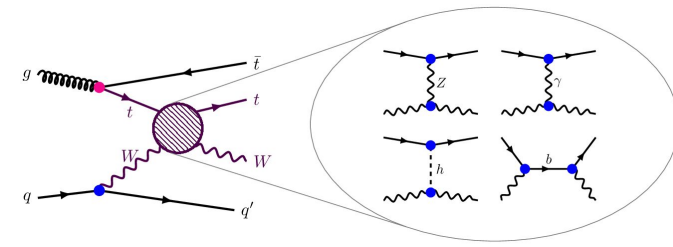
Analysis also interpreted in the framework of EFT

Floating the operators in both ttWj and ttZ is responsible for the sensitivity

Allowing constraints on **dimension-6 EFT operators**

- O_{Ht}
- O_{HQ}

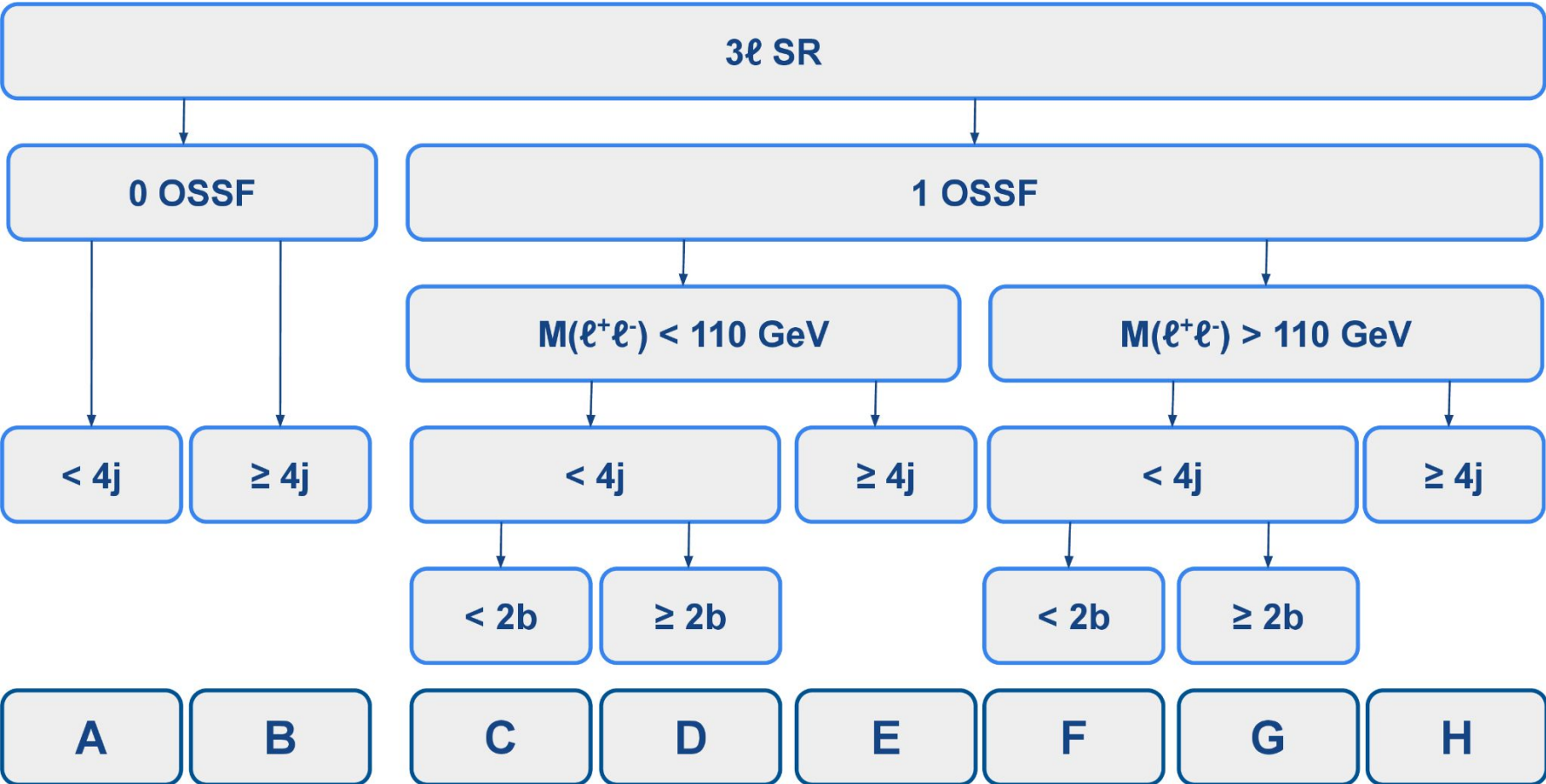
Operators	Processes	95% CI (observed) [TeV^{-2}]	
		c_{Ht}	$c_{HQ}^{(1)}$
O_{Ht}	$t\bar{t}Wj_{EW}$	$[-10, -2.7] \cup [3.3, 9.6]$	-
$O_{HQ}^{(1)}$	$t\bar{t}Wj_{EW}$	-	$[-11, -4.5] \cup [4.3, 13]$
$O_{Ht} + O_{HQ}^{(1)}$	$t\bar{t}Wj_{EW}$	$[-9.9, 9.3]$	$[-12, 14]$
O_{Ht}	$t\bar{t}Wj_{EW} + t\bar{t}Z$	$[-10, 3.2]$	-
$O_{HQ}^{(1)}$	$t\bar{t}Wj_{EW} + t\bar{t}Z$	-	$[-11, 7.4]$
$O_{Ht} + O_{HQ}^{(1)}$	$t\bar{t}Wj_{EW} + t\bar{t}Z$	$[-10, -0.96] \cup [1.5, 7.3]$	$[-12, 0.33] \cup [3.4, 12]$

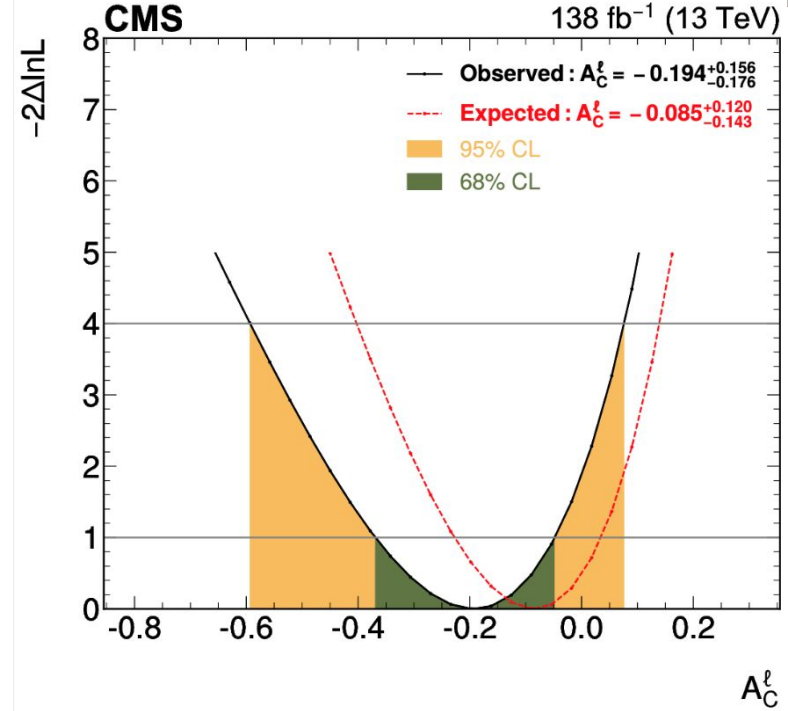
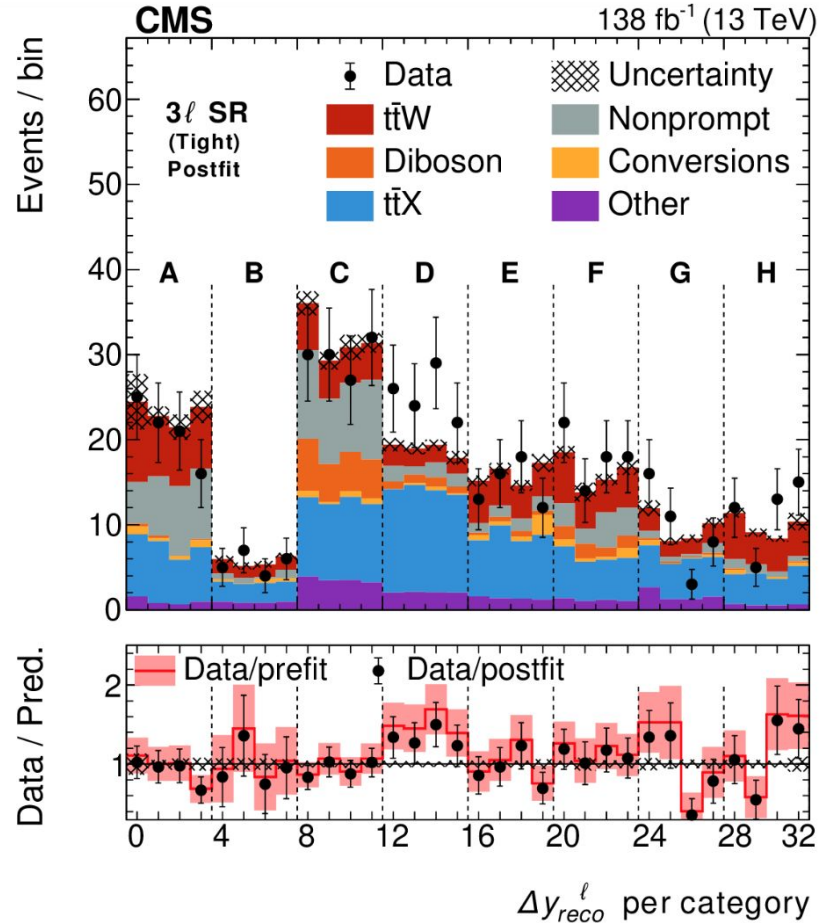


[arxiv:2509.19038](https://arxiv.org/abs/2509.19038)



Categorization of three-lepton events for the measurement of the leptonic charge asymmetry





Observed value consistent with the expectation predicted by NLO simulations