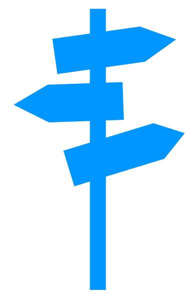
Measurements and EFT fits on detector level

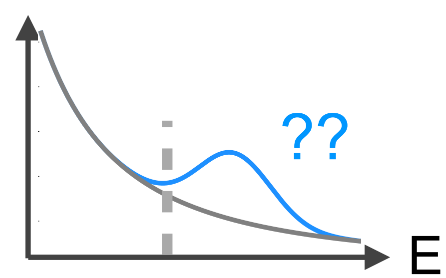
Kelci Mohrman, University of Florida
On behalf of ATLAS and CMS

Motivation for indirect searches for new physics:
New physics has to be out there, but ...

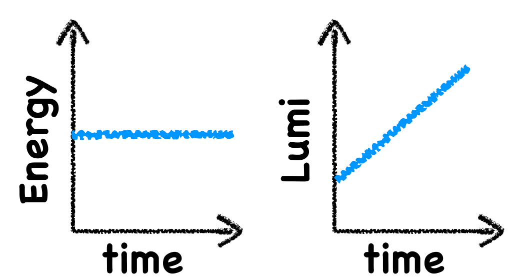
No conclusive indication of which direction to look



No guarantee BSM particles light enough to be produced at LHC



Energy not going up much (but stats are!)



Effective field theory (EFT) provides a relatively model independent way to describe possible effects of heavy new physics

Brief introduction to SM EFT*

- Treats SM as lowest order term in an expansion of higher-dimensional operators, describes BSM at a scale Λ, interacting with strength given by Wilson coefficient
- If all Wilson coefficients (WCs) are 0, the SM is recovered
  −> a non-zero WC would indicate new physics

Wilson Coefficient (strength of interaction)

Energy scale of the new physics

Operators are built of products of SM fields and their derivatives

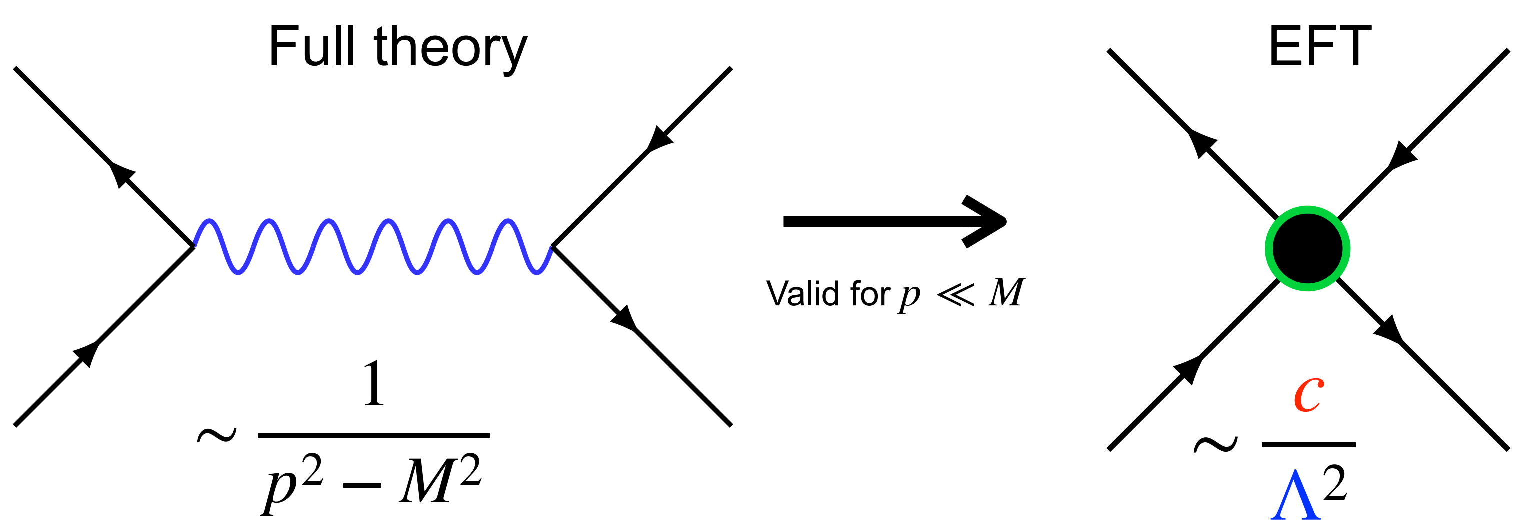
$$\mathscr{L}_{\mathrm{EFT}} = \mathscr{L}_{\mathrm{SM}} + \sum_i \frac{c_i}{\Lambda}\mathcal{O}_i^{(5)} + \sum_i \frac{c_i}{\Lambda^2}\mathcal{O}_i^{(6)} + \dots$$

TOP focusses on **dim 6** (lowest order terms that contribute)

*In this talk, when we write "EFT" we are referring to "SMEFT" in particular, see backup slides for more on this

Using $\mathscr{L}_{\mathrm{EFT}} = \mathscr{L}_{\mathrm{SM}} + \sum_i \frac{c_i}{\Lambda^2} \mathcal{O}_i^{(6)}$ to describe interactions

- Example: If a heavy particle can't be produced on-shell at the LHC, would be hard to find via direct search
- Can describe the interaction with an EFT operator, interaction strength determined by the WC



EFT is not new, e.g. historical example of an EFT is Fermi theory for beta decay

$$\mathscr{L}_{\text{EFT}} = \mathscr{L}_{\text{SM}} + \sum_i \frac{1}{\Lambda^2} c_i \mathcal{O}_i^{(6)}$$

How many of these are there?

$$\mathscr{L}_{\mathrm{EFT}} = \mathscr{L}_{\mathrm{SM}} + \sum_i \frac{1}{\Lambda^2} c_i \mathcal{O}_i^{(6)}$$

How many of these are there?

Depends on how you count...

- Flavor assumptions?
- Include or exclude B/L number violating operators?
- Count hermitian conjugates separately?
- …

Some ballpark numbers:

- With fewest assumptions, 1000s of operators
- With a flavor universality assumption, ~O(60)

$$\mathscr{L}_{\rm EFT} = \mathscr{L}_{\rm SM} + \sum_i \frac{1}{\Lambda^2} c_i \mathcal{O}_i^{(6)}$$

How many of these are there?

Depends on how you count...

- Flavor assumptions?
- Include or exclude B/L number violating operators?
- Count hermitian conjugates separately?
- …

Some ballpark numbers:

- With fewest assumptions, 1000s of operators
- With a flavor universality assumption, ~O(60)

The dim-6 EFT operators in the Warsaw basis (1008.4884)

$(\bar{L}L)(\bar{L}L)$		$(\bar{R}R)(\bar{R}R)$		$(\bar{L}L)(\bar{R}R)$	
Q_{ll}	$(\bar{l}_p\gamma_\mu l_r)(\bar{l}_s\gamma^\mu l_t)$	Q_{ee}	$(\bar{e}_p\gamma_\mu e_r)(\bar{e}_s\gamma^\mu e_t)$	Q_{le}	$(\bar{l}_p\gamma_\mu l_r)(\bar{e}_s\gamma^\mu e_t)$
$Q_{qq}^{(1)}$	$(\bar{q}_p\gamma_\mu q_r)(\bar{q}_s\gamma^\mu q_t)$	Q_{uu}	$(\bar{u}_p\gamma_\mu u_r)(\bar{u}_s\gamma^\mu u_t)$	Q_{lu}	$(\bar{l}_p\gamma_\mu l_r)(\bar{u}_s\gamma^\mu u_t)$
$Q_{qq}^{(3)}$	$(\bar{q}_p\gamma_\mu\tau^I q_r)(\bar{q}_s\gamma^\mu\tau^I q_t)$	Q_{dd}	$(\bar{d}_p\gamma_\mu d_r)(\bar{d}_s\gamma^\mu d_t)$	Q_{ld}	$(\bar{l}_p\gamma_\mu l_r)(\bar{d}_s\gamma^\mu d_t)$
$Q_{lq}^{(1)}$	$(\bar{l}_p\gamma_\mu l_r)(\bar{q}_s\gamma^\mu q_t)$	Q_{eu}	$(\bar{e}_p\gamma_\mu e_r)(\bar{u}_s\gamma^\mu u_t)$	Q_{qe}	$(\bar{q}_p\gamma_\mu q_r)(\bar{e}_s\gamma^\mu e_t)$
$Q_{lq}^{(3)}$	$(\bar{l}_p\gamma_\mu\tau^I l_r)(\bar{q}_s\gamma^\mu\tau^I q_t)$	Q_{ed}	$(\bar{e}_p\gamma_\mu e_r)(\bar{d}_s\gamma^\mu d_t)$	$Q_{qu}^{(1)}$	$(\bar{q}_p\gamma_\mu q_r)(\bar{u}_s\gamma^\mu u_t)$
		$Q_{ud}^{(1)}$	$(\bar{u}_p\gamma_\mu u_r)(\bar{d}_s\gamma^\mu d_t)$	$Q_{qu}^{(8)}$	$(\bar{q}_p\gamma_\mu T^A q_r)(\bar{u}_s\gamma^\mu T^A u_t)$
		$Q_{ud}^{(8)}$	$(\bar{u}_p\gamma_\mu T^A u_r)(\bar{d}_s\gamma^\mu T^A d_t)$	$Q_{qd}^{(1)}$	$(\bar{q}_p\gamma_\mu q_r)(\bar{d}_s\gamma^\mu d_t)$
				$Q_{qd}^{(8)}$	$(\bar{q}_p\gamma_\mu T^A q_r)(\bar{d}_s\gamma^\mu T^A d_t)$

$(\bar{L}R)(\bar{R}L)$ and $(\bar{L}R)(\bar{L}R)$		B-violating	
Q_{ledq}	$(\bar{l}_p^j e_r)(\bar{d}_s q_t^j)$	Q_{duq}	$\varepsilon^{\alpha\beta\gamma}\varepsilon_{jk}\left[(d_p^\alpha)^T C u_r^\beta\right]\left[(q_s^{\gamma j})^T C l_t^k\right]$
$Q_{quqd}^{(1)}$	$(\bar{q}_p^j u_r)\varepsilon_{jk}(\bar{q}_s^k d_t)$	Q_{qqu}	$\varepsilon^{\alpha\beta\gamma}\varepsilon_{jk}\left[(q_p^{\alpha j})^T C q_r^{\beta k}\right]\left[(u_s^\gamma)^T C e_t\right]$
$Q_{quqd}^{(8)}$	$(\bar{q}_p^j T^A u_r)\varepsilon_{jk}(\bar{q}_s^k T^A d_t)$	Q_{qqq}	$\varepsilon^{\alpha\beta\gamma}\varepsilon_{jn}\varepsilon_{km}\left[(q_p^{\alpha j})^T C q_r^{\beta k}\right]\left[(q_s^{\gamma m})^T C l_t^n\right]$
$Q_{lequ}^{(1)}$	$(\bar{l}_p^j e_r)\varepsilon_{jk}(\bar{q}_s^k u_t)$	Q_{duu}	$\varepsilon^{\alpha\beta\gamma}\left[(d_p^\alpha)^T C u_r^\beta\right]\left[(u_s^\gamma)^T C e_t\right]$
$Q_{lequ}^{(3)}$	$(\bar{l}_p^j \sigma_{\mu\nu} e_r)\varepsilon_{jk}(\bar{q}_s^k \sigma^{\mu\nu} u_t)$		

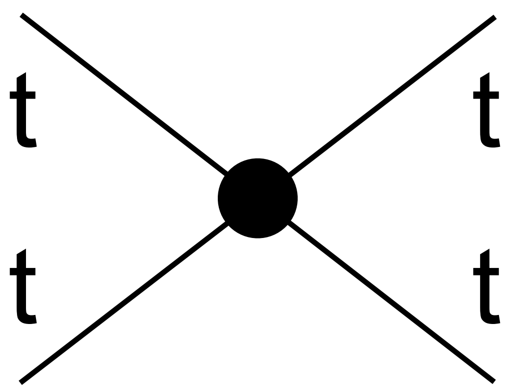
X^3		φ^6 and $\varphi^4 D^2$		$\psi^2\varphi^3$	
Q_G	$f^{ABC}G_\mu^{A\nu}G_\nu^{B\rho}G_\rho^{C\mu}$	Q_φ	$(\varphi^\dagger\varphi)^3$	$Q_{e\varphi}$	$(\varphi^\dagger\varphi)(\bar{l}_p e_r\varphi)$
$Q_{\widetilde{G}}$	$f^{ABC}\widetilde{G}_\mu^{A\nu}G_\nu^{B\rho}G_\rho^{C\mu}$	$Q_{\varphi\Box}$	$(\varphi^\dagger\varphi)\Box(\varphi^\dagger\varphi)$	$Q_{u\varphi}$	$(\varphi^\dagger\varphi)(\bar{q}_p u_r\widetilde{\varphi})$
Q_W	$\varepsilon^{IJK}W_\mu^{I\nu}W_\nu^{J\rho}W_\rho^{K\mu}$	$Q_{\varphi D}$	$\left(\varphi^\dagger D^\mu\varphi\right)^\star\left(\varphi^\dagger D_\mu\varphi\right)$	$Q_{d\varphi}$	$(\varphi^\dagger\varphi)(\bar{q}_p d_r\varphi)$
$Q_{\widetilde{W}}$	$\varepsilon^{IJK}\widetilde{W}_\mu^{I\nu}W_\nu^{J\rho}W_\rho^{K\mu}$				

$X^2\varphi^2$		$\psi^2 X\varphi$		$\psi^2\varphi^2 D$	
$Q_{\varphi G}$	$\varphi^\dagger\varphi\, G_{\mu\nu}^A G^{A\mu\nu}$	Q_{eW}	$(\bar{l}_p\sigma^{\mu\nu}e_r)\tau^I\varphi W_{\mu\nu}^I$	$Q_{\varphi l}^{(1)}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu\varphi)(\bar{l}_p\gamma^\mu l_r)$
$Q_{\varphi\widetilde{G}}$	$\varphi^\dagger\varphi\,\widetilde{G}_{\mu\nu}^A G^{A\mu\nu}$	Q_{eB}	$(\bar{l}_p\sigma^{\mu\nu}e_r)\varphi B_{\mu\nu}$	$Q_{\varphi l}^{(3)}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu^I\varphi)(\bar{l}_p\tau^I\gamma^\mu l_r)$
$Q_{\varphi W}$	$\varphi^\dagger\varphi\, W_{\mu\nu}^I W^{I\mu\nu}$	Q_{uG}	$(\bar{q}_p\sigma^{\mu\nu}T^A u_r)\widetilde{\varphi}\, G_{\mu\nu}^A$	$Q_{\varphi e}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu\varphi)(\bar{e}_p\gamma^\mu e_r)$
$Q_{\varphi\widetilde{W}}$	$\varphi^\dagger\varphi\,\widetilde{W}_{\mu\nu}^I W^{I\mu\nu}$	Q_{uW}	$(\bar{q}_p\sigma^{\mu\nu}u_r)\tau^I\widetilde{\varphi}\, W_{\mu\nu}^I$	$Q_{\varphi q}^{(1)}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu\varphi)(\bar{q}_p\gamma^\mu q_r)$
$Q_{\varphi B}$	$\varphi^\dagger\varphi\, B_{\mu\nu}B^{\mu\nu}$	Q_{uB}	$(\bar{q}_p\sigma^{\mu\nu}u_r)\widetilde{\varphi}\, B_{\mu\nu}$	$Q_{\varphi q}^{(3)}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu^I\varphi)(\bar{q}_p\tau^I\gamma^\mu q_r)$
$Q_{\varphi\widetilde{B}}$	$\varphi^\dagger\varphi\,\widetilde{B}_{\mu\nu}B^{\mu\nu}$	Q_{dG}	$(\bar{q}_p\sigma^{\mu\nu}T^A d_r)\varphi\, G_{\mu\nu}^A$	$Q_{\varphi u}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu\varphi)(\bar{u}_p\gamma^\mu u_r)$
$Q_{\varphi WB}$	$\varphi^\dagger\tau^I\varphi\, W_{\mu\nu}^I B^{\mu\nu}$	Q_{dW}	$(\bar{q}_p\sigma^{\mu\nu}d_r)\tau^I\varphi\, W_{\mu\nu}^I$	$Q_{\varphi d}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu\varphi)(\bar{d}_p\gamma^\mu d_r)$
$Q_{\varphi\widetilde{W}B}$	$\varphi^\dagger\tau^I\varphi\,\widetilde{W}_{\mu\nu}^I B^{\mu\nu}$	Q_{dB}	$(\bar{q}_p\sigma^{\mu\nu}d_r)\varphi\, B_{\mu\nu}$	$Q_{\varphi ud}$	$i(\widetilde{\varphi}^\dagger D_\mu\varphi)(\bar{u}_p\gamma^\mu d_r)$

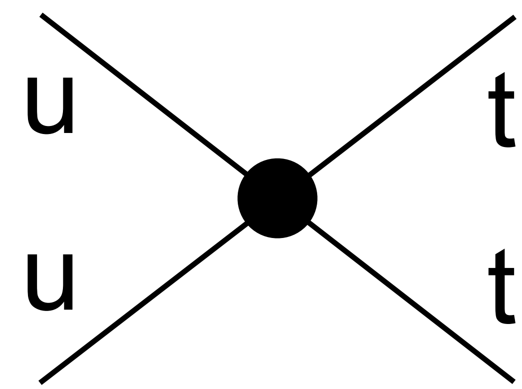
EFT operators involving top quarks

Focus on operators involving tops → ~40 operators[1]

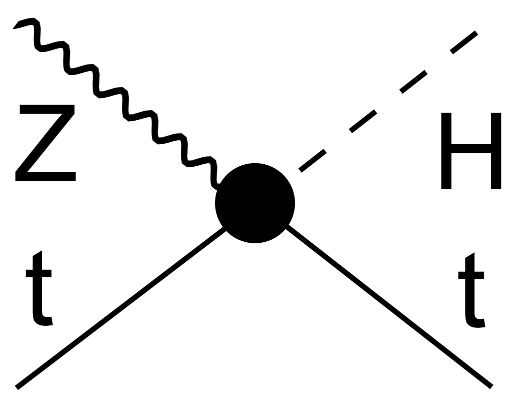
Generally these fall into 4 categories[2]



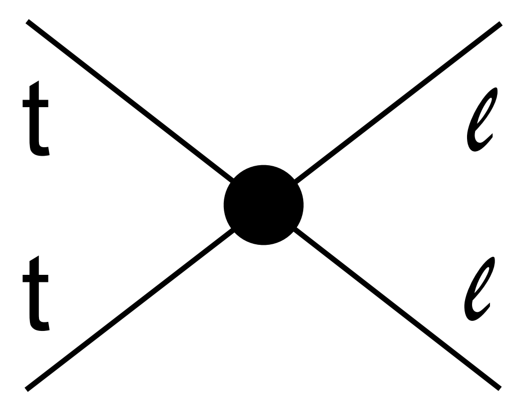
4 heavy[3] quarks



2 heavy quarks
and 2 light quarks



2 heavy quarks
and bosons



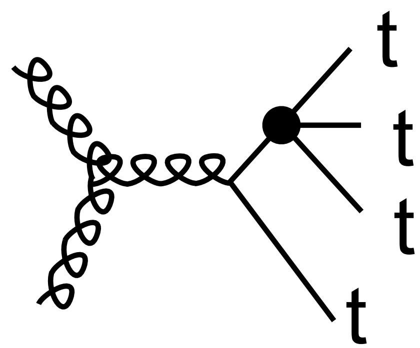
2 heavy quarks
and 2 leptons

[1] The number quoted here is from the dim6top note (1802.07237) assumption described in the "baseline" section i.e. 4.1

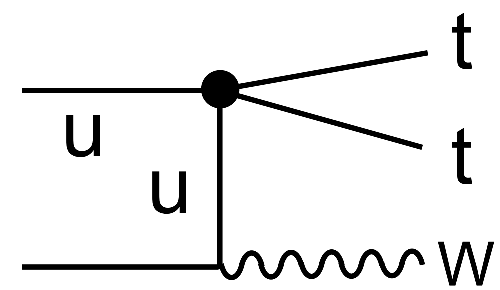
[2] In general an operator will give rise to multiple EFT vertices, here we just show an example vertex for an operator from each category

[3] Note: "heavy" means top or bottom, "light" is everything else, see dim6top model paper (1802.07237) for more details on the operators, also note the operators in the ~40 number quoted here does not include the FCNC operators

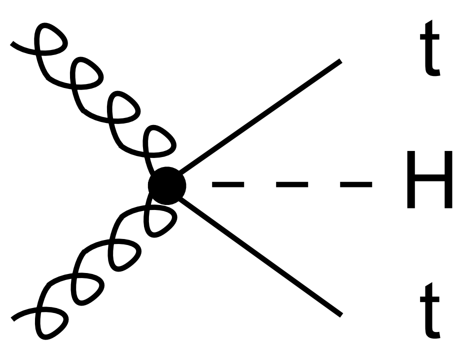
The EFT vertices can impact observables, where the strengths of the impacts are determined by the WCs that scale the vertices



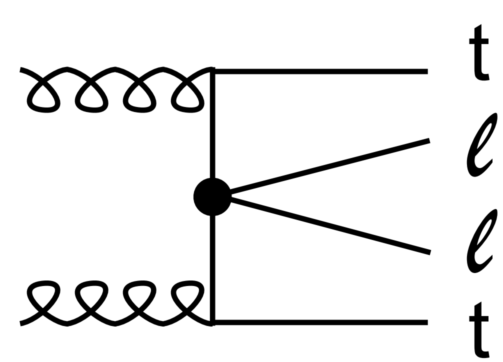
4 heavy[3] quarks



2 heavy quarks
and 2 light quarks



2 heavy quarks
and bosons



2 heavy quarks
and 2 leptons

[3]Note: "heavy" means top or bottom, "light" is everything else, see dim6top model paper (1802.07237) for more details on the operators, also note the operators in the ~40 number quoted here does not include the FCNC operators

Note: In general an operator will give rise to multiple EFT vertices, and there are also multiple types of vertices in each category, which can impact multiple signal processes. Here we just show an example vertex for an operator from each category impacting an example process.

The goal of EFT analyses

What:

- Find the best fit values (and uncertainties) for the WCs

Why:

- A non zero WC would be a sign of new physics![1]

How:

- Parameterize some prediction in terms of the WCs
- Compare observation to the prediction and extract the best fit values and corresponding uncertainties for the WCs

[1]Absent a signal, the WC intervals are also useful, as they can be interpreted in terms of the energy scale probed, and can also help constrain theory models

The goal of EFT analyses

What:

- Find the best fit values (and uncertainties) for the WCs

Why:

- A non zero WC would be a sign of new physics![1]

How:

- Parameterize some prediction in terms of the WCs
- Compare observation to the prediction and extract the best fit values and corresponding uncertainties for the WCs

[1]Absent a signal, the WC intervals are also useful, as they can be interpreted in terms of the energy scale probed, and can also help constrain theory models

How do observables depend on EFT? Let's start with σ

If the EFT is modeled linearly in amplitude,

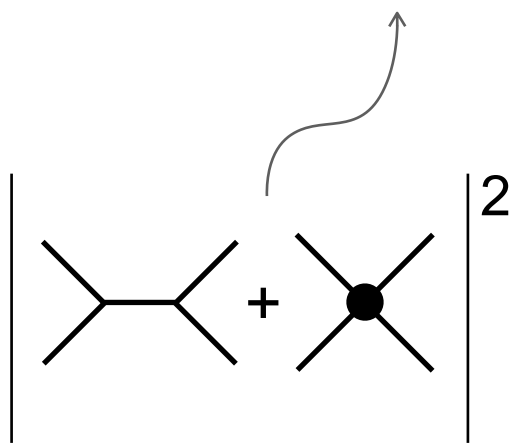
$$\sigma \propto |\mathscr{M}_{SM} + \frac{c_i}{\Lambda^2} \mathscr{M}_i|^2$$

How do observables depend on EFT? Let's start with σ

If the EFT is modeled linearly in amplitude,

$$\sigma \;\propto\; |\mathscr{M}_{SM} + \frac{c_i}{\Lambda^2}\mathscr{M}_i|^2$$

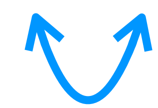
$\sigma \;\propto$

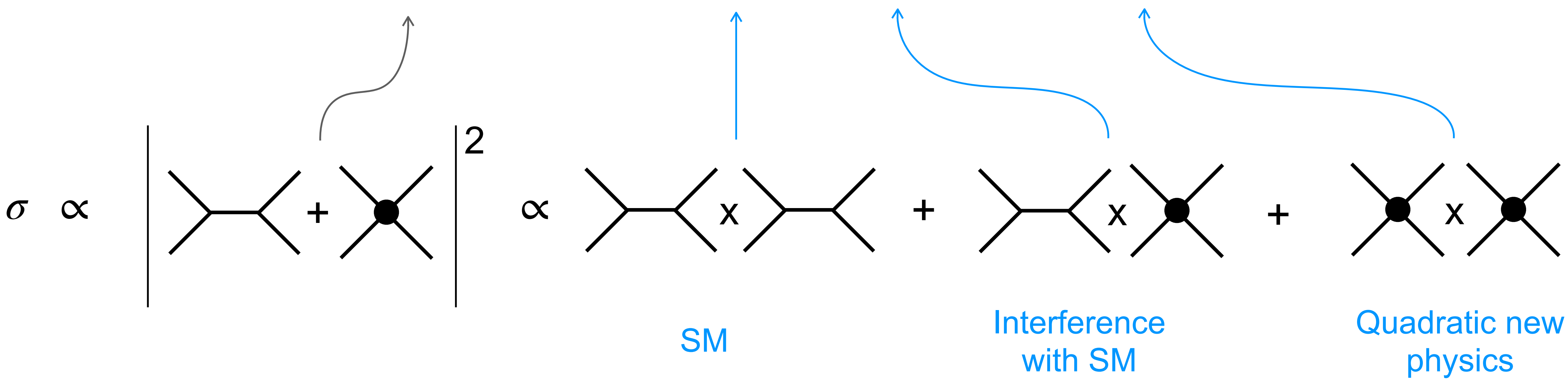


How do observables depend on EFT? Let's start with σ

If the EFT is modeled linearly in amplitude, the cross section is an *n*-quadratic in terms of the WCs (where *n* is number of WCs)

$$\sigma \propto \left| \mathscr{M}_{SM} + \frac{c_i}{\Lambda^2} \mathscr{M}_i \right|^2 \propto s_0 + s_i \frac{c_i}{\Lambda^2} + s_{ij} \frac{c_i}{\Lambda^2} \frac{c_j}{\Lambda^2} =$$

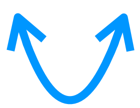


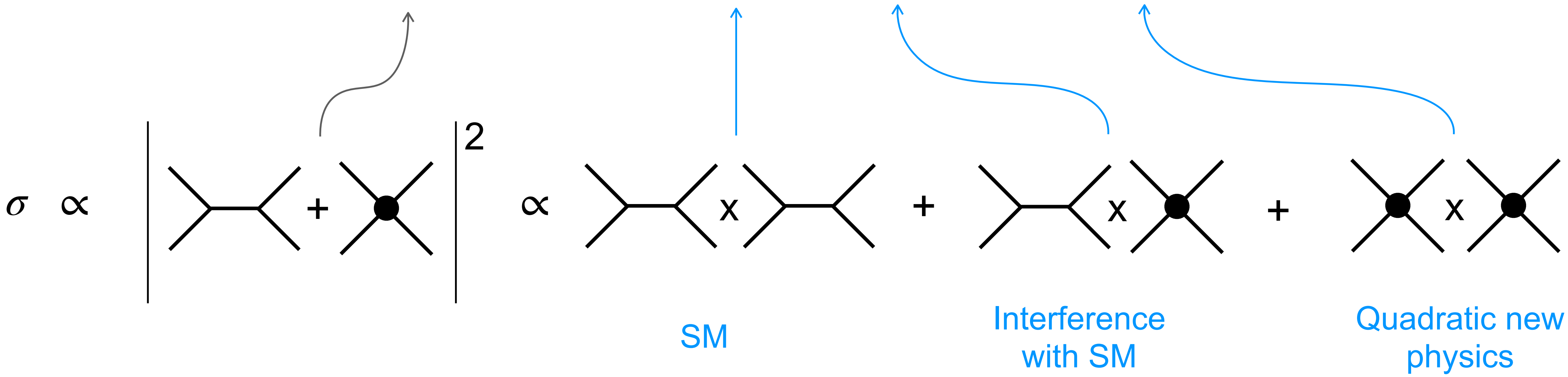


How do observables depend on EFT? Let's start with σ

If the EFT is modeled linearly in amplitude, the cross section is an *n*-quadratic in terms of the WCs (where *n* is number of WCs)

$$\sigma \propto \left|\mathcal{M}_{SM} + \frac{c_i}{\Lambda^2}\mathcal{M}_i\right|^2 \propto s_0 + s_i \frac{c_i}{\Lambda^2} + s_{ij}\frac{c_i}{\Lambda^2}\frac{c_j}{\Lambda^2} =$$





This holds for any cross section, inclusive or differential

The goal of EFT analyses

What:

- Find the best fit values (and uncertainties) for the WCs

Why:

- A non zero WC would be a sign of new physics

We've covered how the xsec depends on EFT

Now let's cover different analysis approaches

i.e. how do you use this to search for non-zero WCs

How:

- Parameterize some prediction in terms of the WCs
- Compare observation to the prediction and extract the best fit values and corresponding uncertainties for the WCs

[1]Absent a signal, the WC intervals are also useful, as they can be interpreted in terms of the energy scale probed, and can also help constrain theory models

The spectrum of approaches to EFT measurements

Indirect ⟷ Direct

The spectrum of approaches to EFT measurements

Indirect ⟷ Direct

Reinterpretation

Perform a fit to a cross-section or
to unfolded differential distributions

The spectrum of approaches to EFT measurements

Indirect — Direct

Reinterpretation

Perform a fit to a cross-section or to unfolded differential distributions

See Peter Onyisi's upcoming talk!

The spectrum of approaches to EFT measurements

Indirect ⟷ Direct

Reinterpretation

Perform a fit to a cross-section or to unfolded differential distributions

See Peter Onyisi's upcoming talk!

Direct detector-level

Perform fit directly with number of observed events with EFT fully simulated at detector level

The spectrum of approaches to EFT measurements

Indirect ⟷ Direct

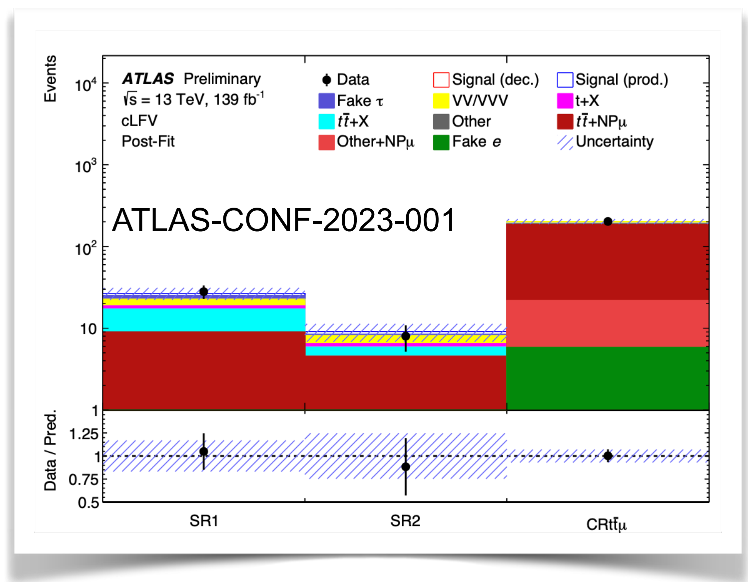
Reinterpretation

Perform a fit to a cross-section or to unfolded differential distributions

See Peter Onyisi's upcoming talk!

Direct detector-level

Perform fit directly with number of observed events with EFT fully simulated at detector level



Recent examples:
CMS PAS TOP-22-005
ATLAS-CONF-2023-001
CMS TOP-22-006 (2307.15761)

The spectrum of approaches to EFT measurements

Indirect ⟷ Direct

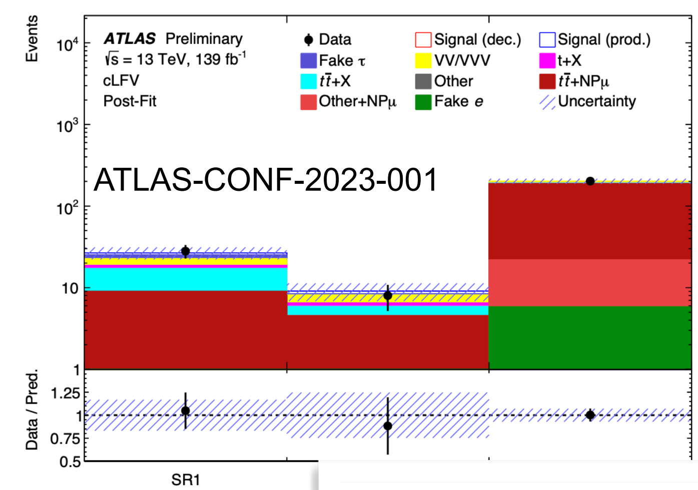
Reinterpretation

Perform a fit to a cross-section or to unfolded differential distributions

See Peter Onyisi's upcoming talk!

Direct detector-level

Perform fit directly with number of observed events with EFT fully simulated at detector level



Recent examples:
CMS PAS TOP-22-005
ATLAS-CONF-2023-001
CMS TOP-22-006 (2307.15761)

Observed yields to WC limits

	95% CL upper limits on Wilson coefficients c/Λ^2 [TeV^{-2}]							
	$c_{lq}^{-(ijk3)}$	$c_{eq}^{(ijk3)}$	$c_{lu}^{(ijk3)}$	$c_{eu}^{(ijk3)}$	$c_{lequ}^{1(ijk3)}$	$c_{lequ}^{1(ij3k)}$	$c_{lequ}^{3(ijk3)}$	$c_{lequ}^{3(ij3k}$
Previous (u) [22]	12	12	12	12	26	26	3.4	3.4
Expected (u)	0.47	0.44	0.43	0.46	0.49	0.49	0.11	0.11
Observed (u)	0.49	0.47	0.46	0.48	0.51	0.51	0.11	0.11
Previous (c) [22]	14	14	14	14	29	29	3.7	3.7
Expected (c)	1.6	1.6	1.5	1.6	1.8	1.8	0.35	0.35
Observed (c)	1.7	1.6	1.6	1.6	1.9	1.9	0.37	0.37

ATLAS-CONF-2023-001

The spectrum of approaches to EFT measurements

Indirect ⟷ Direct

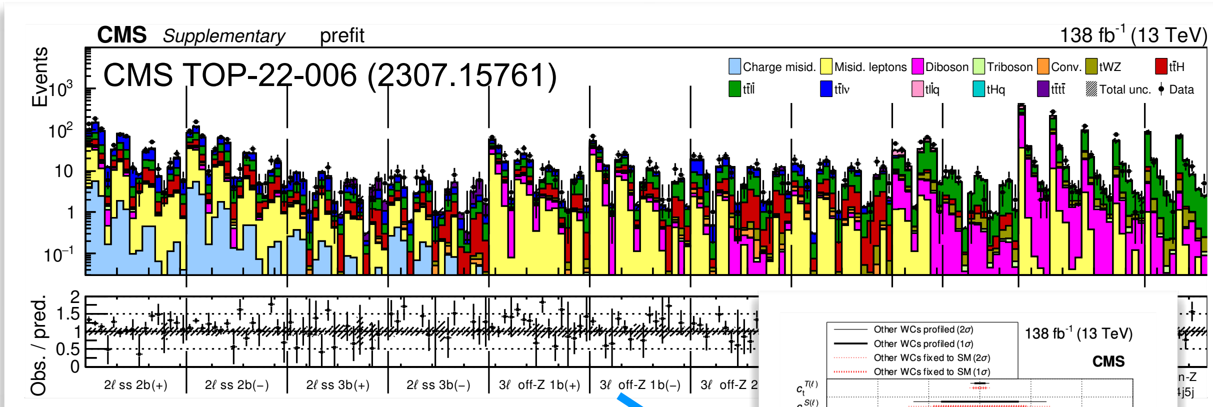
Reinterpretation

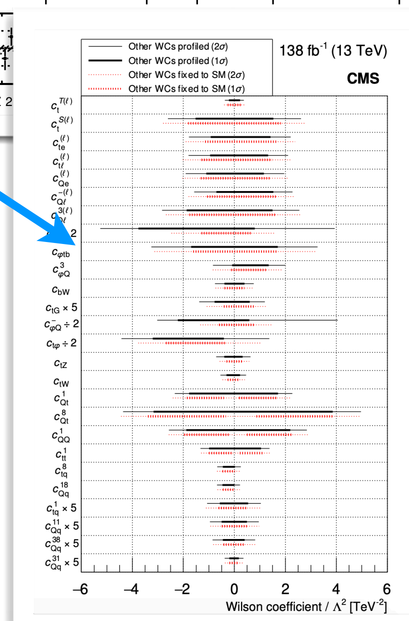
Perform a fit to a cross-section or to unfolded differential distributions

See Peter Onyisi's <u>upcoming talk</u>!

Direct detector-level

Perform fit directly with number of observed events with EFT fully simulated at detector level





Observed yields to WC limits

Recent examples:
CMS PAS TOP-22-005
ATLAS-CONF-2023-001
CMS TOP-22-006 (2307.15761)

The spectrum of approaches to EFT measurements

Indirect ⟵⟶ Direct

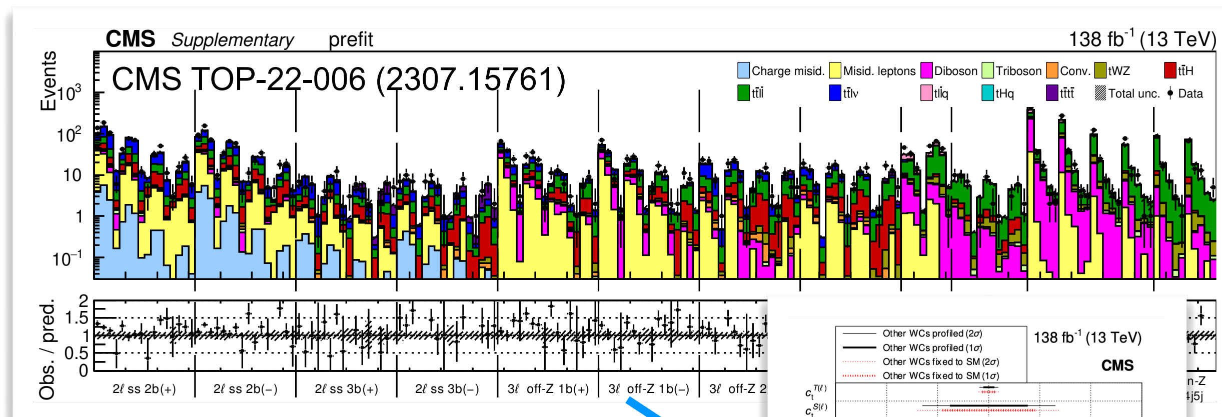
Reinterpretation

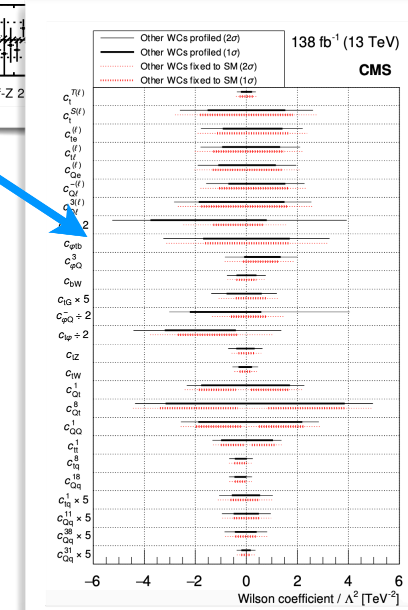
Perform a fit to a cross-section or to unfolded differential distributions

See Peter Onyisi's <u>upcoming talk</u>!

Direct detector-level

Perform fit directly with number of observed events with EFT fully simulated at detector level





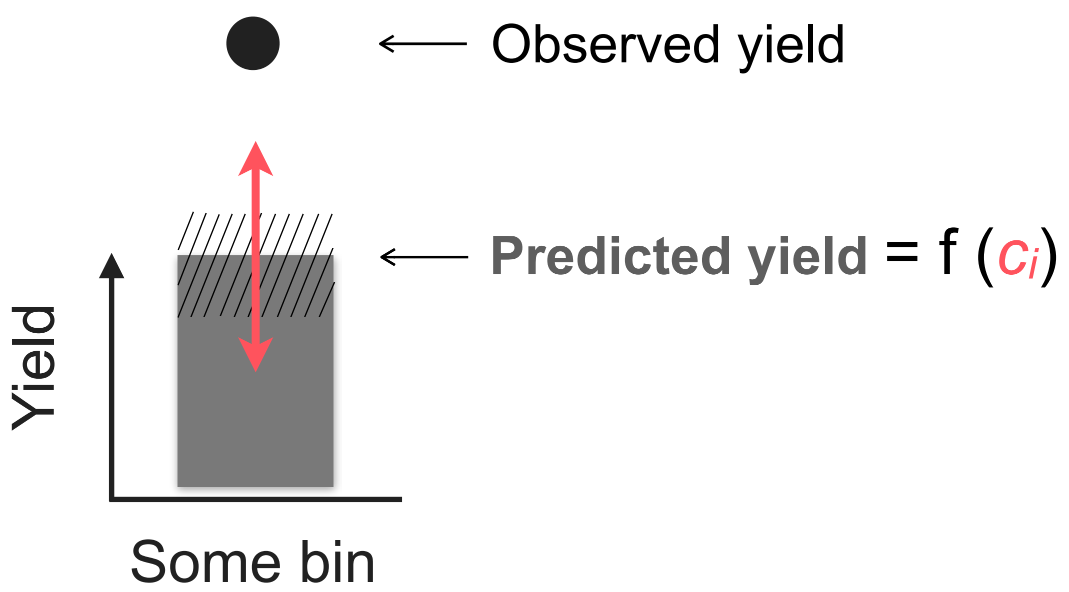
Observed yields to WC limits

Recent examples:
CMS PAS TOP-22-005
ATLAS-CONF-2023-001
CMS TOP-22-006 (2307.15761)

This talk is on direct approaches

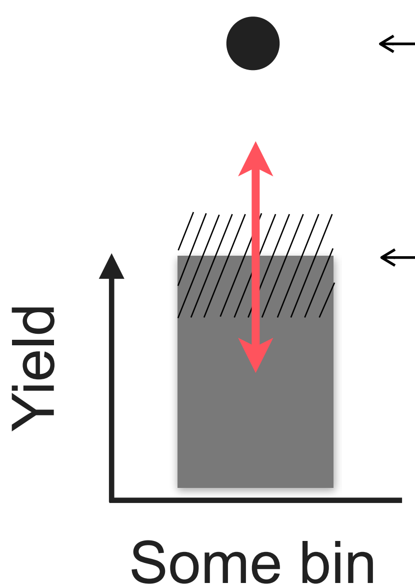
The direct detector-level approach

1. Write the **prediction** in the observable bins as a function of WCs
2. Compare that to the observation to extract limits for the WCs

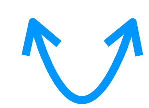


The direct detector-level approach

1. Write the **prediction** in the observable bins as a function of WCs
2. Compare that to the observation to extract limits for the WCs

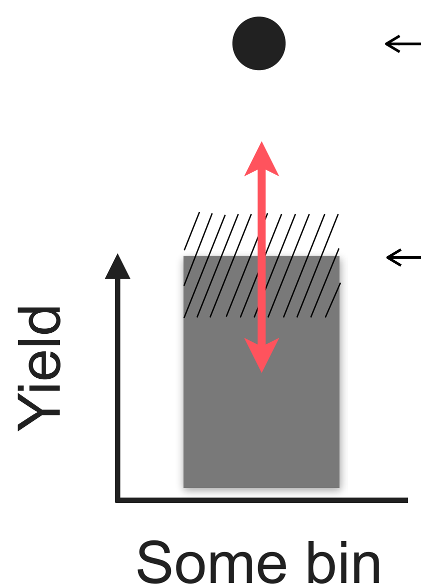


⟵ Observed yield

⟵ **Predicted yield** $= f\,(c_i) = s_0 + s_i\, c_i + s_{ij}\, c_i\, c_j =$ 

The direct detector-level approach

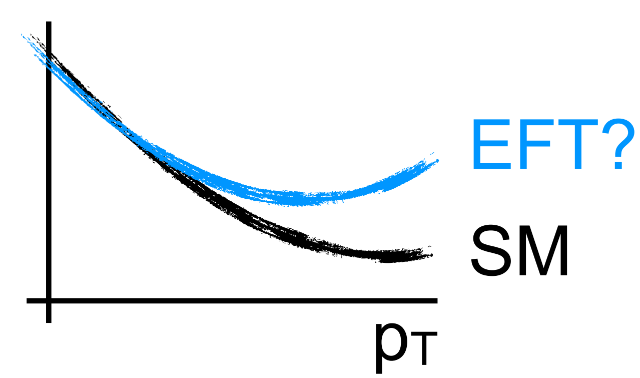
1. Write the **prediction** in the observable bins as a function of WCs
2. Compare that to the observation to extract limits for the WCs



← Observed yield

← **Predicted yield** = $f\,(c_i) = s_0 + s_i\, c_i + s_{ij}\, c_i\, c_j =$

But we'd expect the dependence to vary from bin to bin



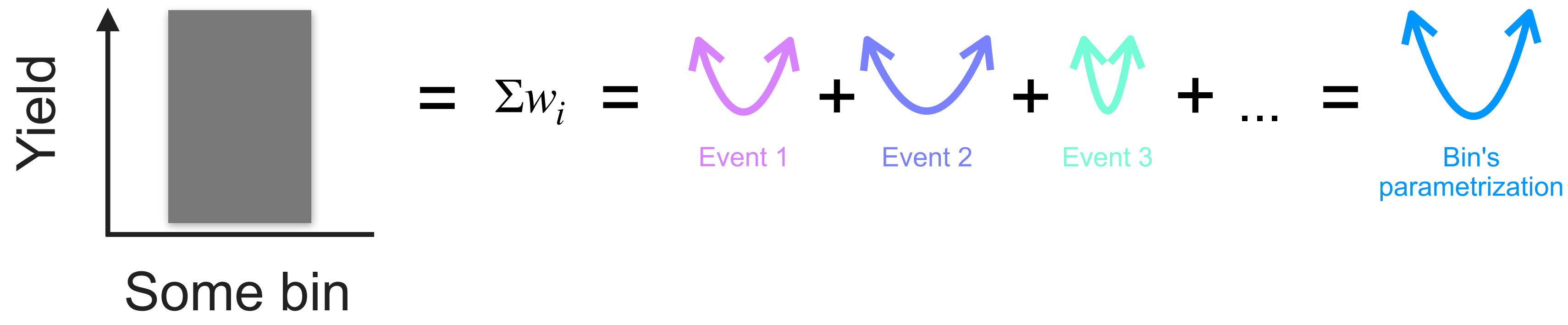
How do we find the quadratic parametrization for each bin's yield?

- The key is to parametrize the weight of each simulated event as a quadratic in terms of the WCs*

*The quadratic for each event is extracted using MadGraph reweighing, as described in this LPC EFT Workshop tutorial
**These are drawn as 1-dimensional, but really are *n*-dimensional quadratics for each event, where *n* = number of WCs (so e.g. 26d for CMS TOP-22-006), some more technical details on analysis approach in LHC EFT WG presentation

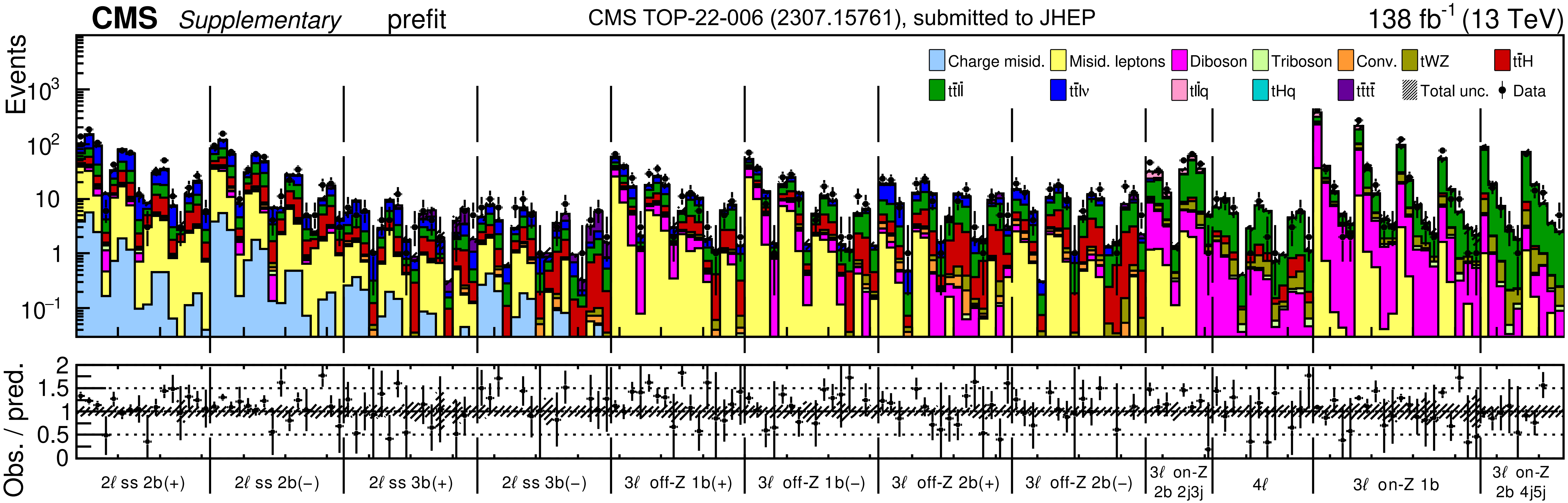
How do we find the quadratic parametrization for each bin's yield?

- The key is to parametrize the weight of each simulated event as a quadratic in terms of the WCs*
- Can then find any arbitrary bin's yield as a function of the WCs by summing the quadratics** of the events that fall in the bin



*The quadratic for each event is extracted using MadGraph reweighing, as described in this LPC EFT Workshop tutorial
**These are drawn as 1-dimensional, but really are *n*-dimensional quadratics for each event, where *n* = number of WCs (so e.g. 26d for CMS TOP-22-006), some more technical details on analysis approach in LHC EFT WG presentation

What this looks like in practice in a real analysis



- The predicted yield for each signal processes in each bin is a 26-d quadratic
- The statistical fit can turn the 26 knobs (changing shape and normalization across all 178 bins) to extract the WC ranges that agree with the observations

For the results, see Aashwin Basnet's upcoming YSF talk!

Advantageous vs more challenging aspects of the direct approach

Challenging ← → Advantageous

Challenging	Advantageous
Analysis preservation/longevity	More information available → potential for more sensitivity
Reinterpretations	Can handle final states with complicated admixtures of processes all affected differently by EFT
Need to produce detector-level EFT simulations	Account for all relevant correlations

↑ These challenging aspects for direct approaches are generally advantages of the indirect approach

Some recent TOP EFT analyses

CMS

- Search for CLFV with trileptons, 6 WCs (fit individually) ← **New! (since Top22), see FCNC/LFV CMS talk on Wednesday**
  CMS PAS TOP-22-005
- t(t)X multilepton, 26 WCs (fit individually and simultaneously) ← **New! (since Top22), see YSF talk Tuesday afternoon**
  CMS TOP-22-006 (2307.15761)
- Search for CLFV in $e\mu$ final states, 6 WCs (fit individually)
  JHEP 06 (2022) 082
- $t\bar{t}$ with boosted Z or H, singe lepton + jets, 8 WCs (fit individually and simultaneously)
  PRD 108 (2023) 032008
- $t\bar{t}Z$ multilepton, 5 WCs (fit individually and simultaneously)
  JHEP 12 (2021) 083
- $t\bar{t}\gamma$ dilepton, Re and Im part of 1 WC (fit individually and together)
  JHEP 05 (2022) 091

ATLAS

- $t\bar{t}Z$ multilepton, 20 WCs plus 3 Im parts of WCs included (fit individually and simultaneously) ← **New! (since Top22), see ttX talk Monday**
  ATLAS-CONF-2023-065
- Single top t-channel leptonic, 1 WC ← **New! (since Top22), see YSF talk Tuesday afternoon**
  ATLAS-CONF-2023-026
- Search for CLFV $t \rightarrow \mu\tau q$, 8 WCs (fit individually) ← **New! (since Top22), see FCNC/LFV ATLAS talk on Wednesday**
  ATLAS-CONF-2023-001
- $t\bar{t}t\bar{t}$ multilepton, 4 WCs (fit individually) ← **New! (since Top22), see 4t measurement and interpretation talks from Monday**
  Eur. Phys. J. C 83 (2023) 496
- $t\bar{t}$ all-hadronic, 8 WCs (fit individually and in pairs)
  JHEP 04 (2023) 80
- $t\bar{t}$ charge asymmetry, single and di-lepton, 15 WCs (fit individually)
  JHEP 08 (2023) 077
- $t\bar{t}$ semi-leptonic, 2 WCs (fit individually and together),
  JHEP 06 (2022) 063
- Single top polarization, leptonic, Re and Im part of 1 WC (fit individually and together),
  JHEP 11 (2022) 040

Some recent TOP EFT analyses

CMS

(Direct)
- Search for CLFV with trileptons, 6 WCs (fit individually) ← **New! (since Top22), see FCNC/LFV CMS talk on Wednesday**
  CMS PAS TOP-22-005

(Direct)
- t(t)X multilepton, 26 WCs (fit individually and simultaneously) ← **New! (since Top22), see YSF talk Tuesday afternoon**
  CMS TOP-22-006 (2307.15761)

(Direct)
- Search for CLFV in eμ final states, 6 WCs (fit individually)
  JHEP 06 (2022) 082

(Direct)
- $t\bar{t}$ with boosted Z or H, singe lepton + jets, 8 WCs (fit individually and simultaneously)
  PRD 108 (2023) 032008

(Direct)
- $t\bar{t}Z$ multilepton, 5 WCs (fit individually and simultaneously)
  JHEP 12 (2021) 083

(Semi direct)
- $t\bar{t}\gamma$ dilepton, Re and Im part of 1 WC (fit individually and together)
  JHEP 05 (2022) 091

ATLAS

- $t\bar{t}Z$ multilepton, 20 WCs plus 3 Im parts of WCs included (fit individually and simultaneously) ← **New! (since Top22), see ttX talk Monday**
  ATLAS-CONF-2023-065

(Direct)
- Single top t-channel leptonic, 1 WC ← **New! (since Top22), see YSF talk Tuesday afternoon**
  ATLAS-CONF-2023-026

(Direct)
- Search for CLFV $t\rightarrow\mu\tau q$, 8 WCs (fit individually) ← **New! (since Top22), see FCNC/LFV ATLAS talk on Wednesday**
  ATLAS-CONF-2023-001

- $t\bar{t}t\bar{t}$ multilepton, 4 WCs (fit individually) ← **New! (since Top22), see 4t measurement and interpretation talks from Monday**
  Eur. Phys. J. C 83 (2023) 496
- $t\bar{t}$ all-hadronic, 8 WCs (fit individually and in pairs)
  JHEP 04 (2023) 80
- $t\bar{t}$ charge asymmetry, single and di-lepton, 15 WCs (fit individually)
  JHEP 08 (2023) 077
- $t\bar{t}$ semi-leptonic, 2 WCs (fit individually and together),
  JHEP 06 (2022) 063
- Single top polarization, leptonic, Re and Im part of 1 WC (fit individually and together),
  JHEP 11 (2022) 040

Some recent TOP EFT analyses

CMS

- (Direct) Search for CLFV with trileptons, 6 WCs (fit individually) ← **New! (since Top22), see FCNC/LFV CMS talk on Wednesday**
  CMS PAS TOP-22-005
- (Direct) t(t)X multilepton, 26 WCs (fit individually and simultaneously) ← **New! (since Top22), see YSF talk Tuesday afternoon**
  CMS TOP-22-006 (2307.15761)
- (Direct) Search for CLFV in $e\mu$ final states, 6 WCs (fit individually)
  JHEP 06 (2022) 082
- (Direct) $t\bar{t}$ with boosted Z or H, si
  PRD 108 (2023) 032008
- (Direct) $t\bar{t}Z$ multilepton, 5 WCs (fit individually and simultaneously)
  JHEP 12 (2021) 083
- (Semi direct) $t\bar{t}\gamma$ dilepton, Re and Im part of 1 WC (fit individually and together)
  JHEP 05 (2022) 091

All new detector-level analyses since Top22 have dedicated talks at Top23

We'll briefly show their results here, but see the dedicated talks for full details!

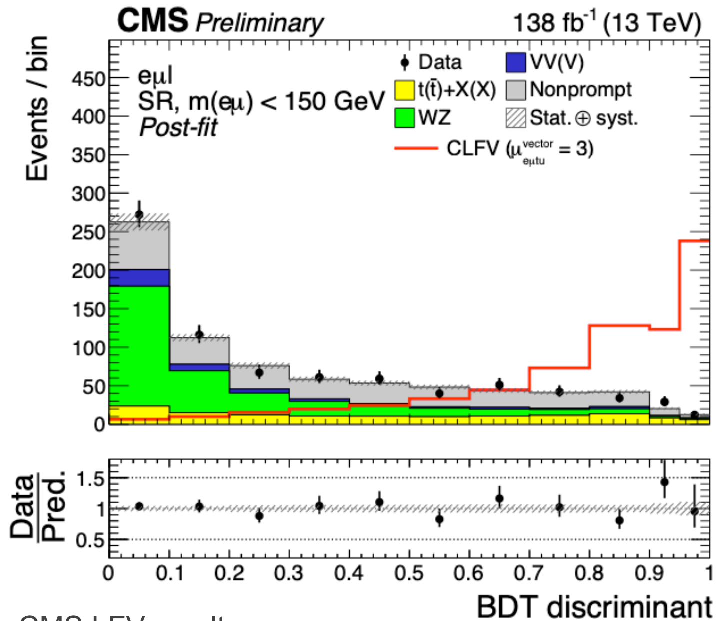
ATLAS

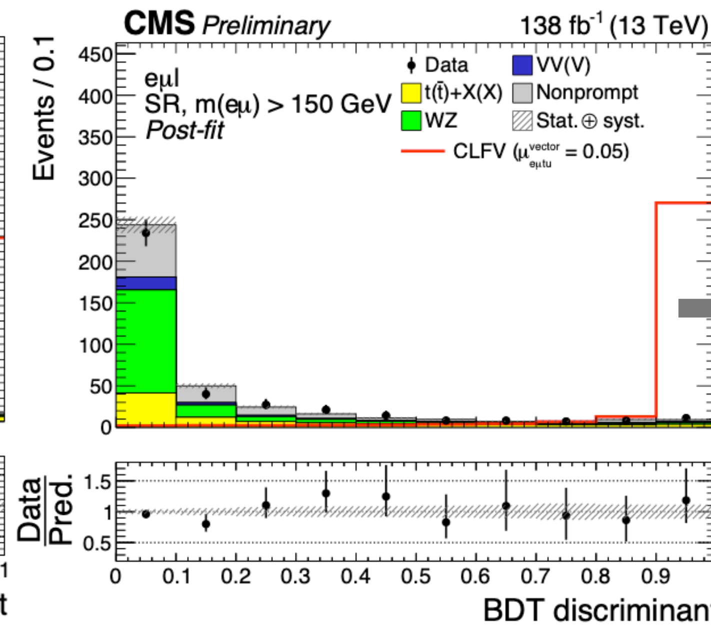
- $t\bar{t}Z$ multilepton, 20 WCs plus 3 Im parts of WCs included (fit individually and simultaneously) ← **New! (since Top22), see ttX talk Monday**
  ATLAS-CONF-2023-065
- (Direct) Single top t-channel leptonic, 1 WC ← **New! (since Top22), see YSF talk Tuesday afternoon**
  ATLAS-CONF-2023-026
- (Direct) Search for CLFV $t \to \mu\tau q$, 8 WCs (fit individually) ← **New! (since Top22), see FCNC/LFV ATLAS talk on Wednesday**
  ATLAS-CONF-2023-001
- $t\bar{t}t\bar{t}$ multilepton, 4 WCs (fit individually) ← **New! (since Top22), see 4t measurement and interpretation talks from Monday**
  Eur. Phys. J. C 83 (2023) 496
- $t\bar{t}$ all-hadronic, 8 WCs (fit individually and in pairs)
  JHEP 04 (2023) 80
- $t\bar{t}$ charge asymmetry, single and di-lepton, 15 WCs (fit individually)
  JHEP 08 (2023) 077
- $t\bar{t}$ semi-leptonic, 2 WCs (fit individually and together),
  JHEP 06 (2022) 063
- Single top polarization, leptonic, Re and Im part of 1 WC (fit individually and together),
  JHEP 11 (2022) 040

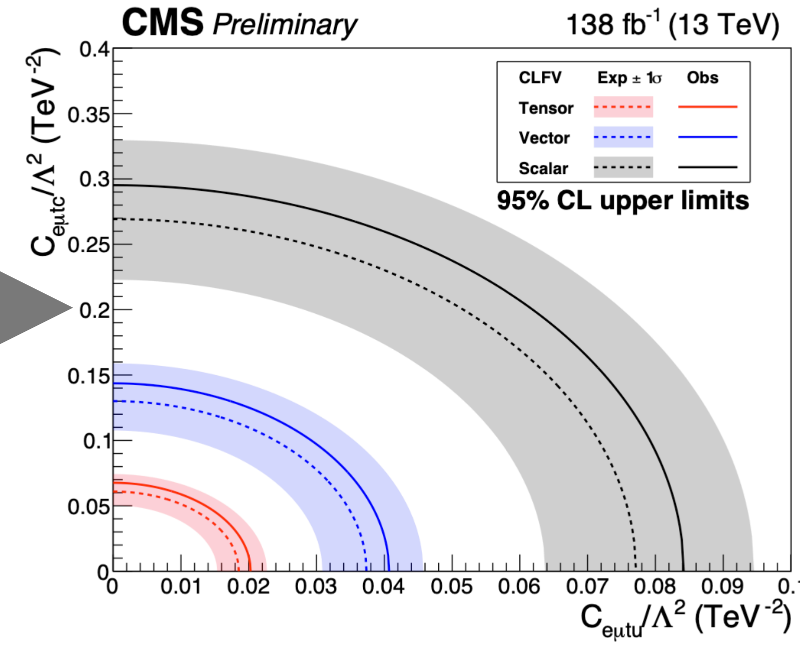
PAS TOP-22-005 : Search for CLFV in trilepton final states

Targets os eμ pair + extra ℓ + jet(s) + at most 1 b jet → results consistent with SM

Train BDTs to separate between SM background and possible LFV signal

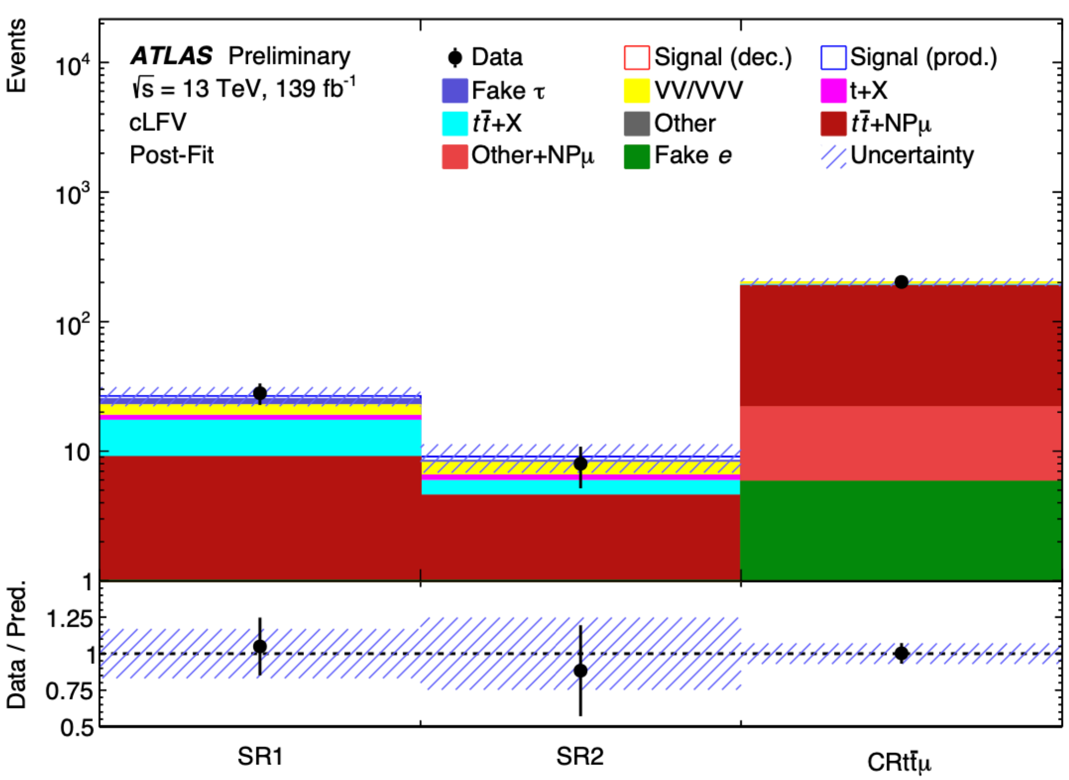






See also JHEP 06 (2022) 082 for CMS LFV results

CONF-2023-001: Search for charged LFV $\mu\tau qt$ interaction



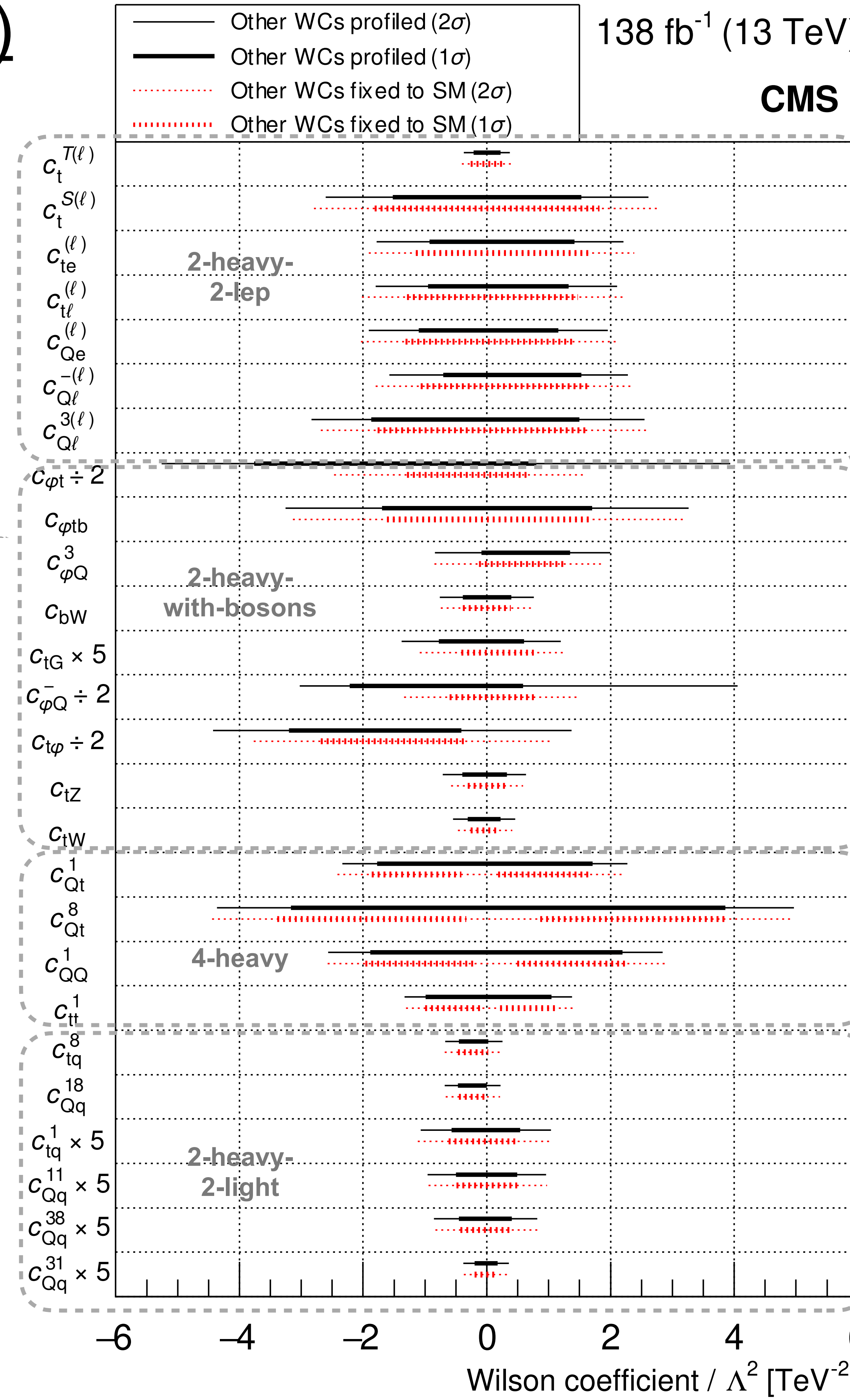
- Events with 2μ (ss), a hadronic tau, jet(s), 1 btag
- Profile-likelihood fit across 2 SR bins and a non-prompt muon CR (binned in H_T)

	95% CL upper limits on Wilson coefficients c/Λ^2 [TeV^{-2}]							
	$c_{lq}^{-(ijk3)}$	$c_{eq}^{(ijk3)}$	$c_{lu}^{(ijk3)}$	$c_{eu}^{(ijk3)}$	$c_{lequ}^{1(ijk3)}$	$c_{lequ}^{1(ij3k)}$	$c_{lequ}^{3(ijk3)}$	$c_{lequ}^{3(ij3k)}$
Previous (u) [22]	12	12	12	12	26	26	3.4	3.4
Expected (u)	0.47	0.44	0.43	0.46	0.49	0.49	0.11	0.11
Observed (u)	0.49	0.47	0.46	0.48	0.51	0.51	0.11	0.11
Previous (c) [22]	14	14	14	14	29	29	3.7	3.7
Expected (c)	1.6	1.6	1.5	1.6	1.8	1.8	0.35	0.35
Observed (c)	1.7	1.6	1.6	1.6	1.9	1.9	0.37	0.37

CMS TOP-22-006 (2307.15761)

- Signal processes: ttH, ttll, ttlν, tHq, tllq, tttt
- Multilepton final states (2lss or 3 or more ℓ)
- Fit 26 WCs simultaneously
- Result is consistent with SM

See Aashwin Basnet's YSF talk today!



ATLAS-CONF-2023-026

- Event selection targets 1 lep, 2 jets, 1 bjet
- Event yields in each bin in the DNN distributions in the SRs parameterized by quadratic in terms of 1 WC
- 95% CI result: $-0.25 < C_{qQ}^{(1,3)} < 0.12.$

See Joshua Aaron Reidelsturz's YSF talk today!

Some recent TOP EFT analyses

CMS

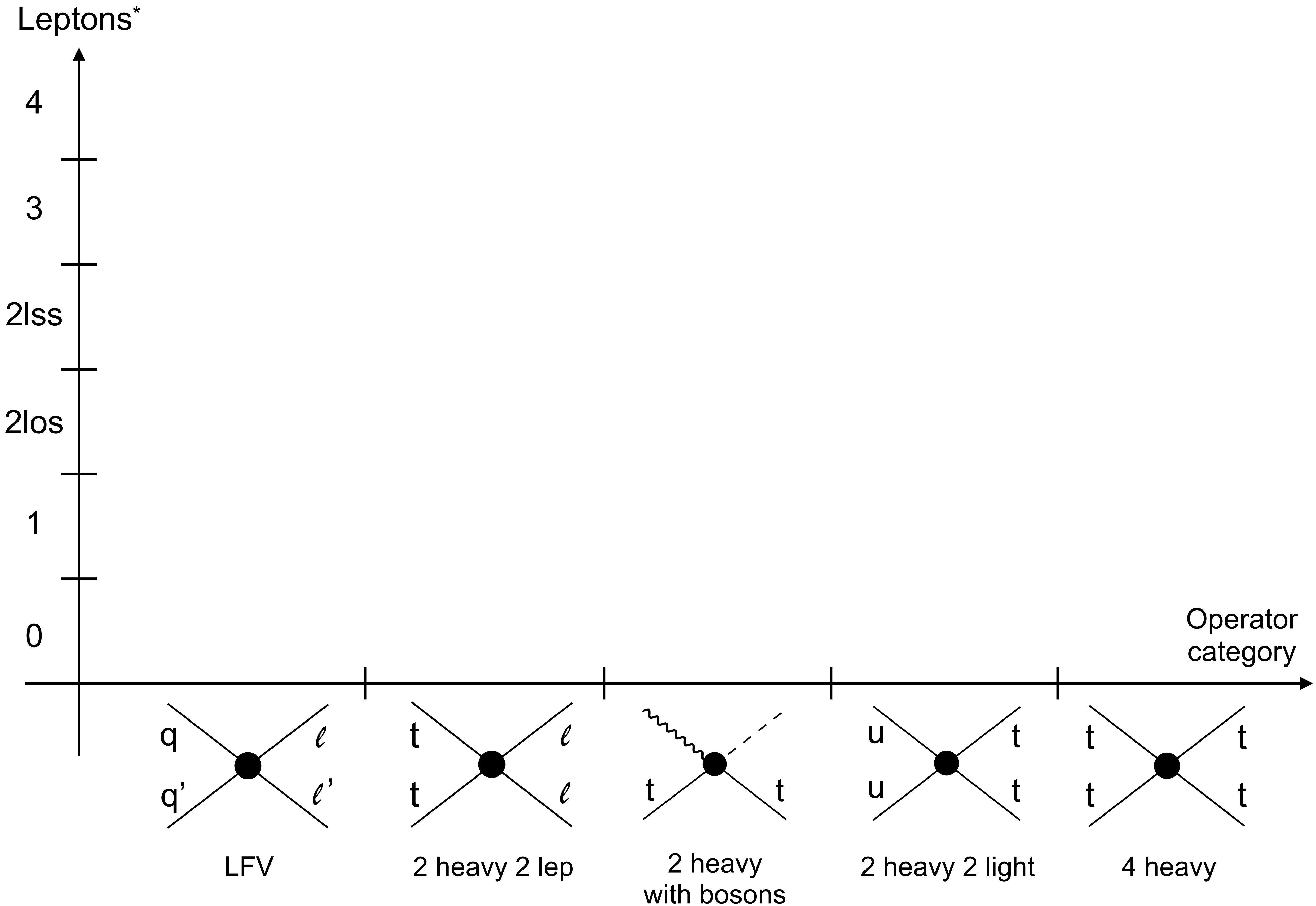
- (Direct) Search for CLFV with trileptons, 6 WCs (fit individually) ← **New! (since Top22), see FCNC/LFV CMS talk on Wednesday**
  CMS PAS TOP-22-005
- (Direct) t(t)X multilepton, 26 WCs (fit individually and simultaneously) ← **New! (since Top22), see YSF talk Tuesday afternoon**
  CMS TOP-22-006 (2307.15761)
- (Direct) Search for CLFV in $e\mu$ final states, 6 WCs (fit individually)
  JHEP 06 (2022) 082
- (Direct) $t\bar{t}$ with boosted Z or H, singe lepton + jets, 8 WCs (fit individually and simultaneously)
  PRD 108 (2023) 032008
- (Direct) $t\bar{t}Z$ multilepton, 5 WCs (fit individually and simultaneously)
  JHEP 12 (2021) 083
- (Semi direct) $t\bar{t}\gamma$ dilepton, Re and Im part of 1 WC (fit individually and together)
  JHEP 05 (2022) 091

ATLAS

- $t\bar{t}Z$ multilepton, 20 WCs plus 3 Im parts of WCs included (fit individually and simultaneously) ← **New! (since Top22), see ttX talk Monday**
  ATLAS-CONF-2023-065
- (Direct) Single top t-channel leptonic, 1 WC ← **New! (since Top22), see YSF talk Tuesday afternoon**
  ATLAS-CONF-2023-026
- (Direct) Search for CLFV $t\to\mu\tau q$, 8 WCs (fit individually) ← **New! (since Top22), see FCNC/LFV ATLAS talk on Wednesday**
  ATLAS-CONF-2023-001
- $t\bar{t}t\bar{t}$ multilepton, 4 WCs (fit individually) ← **New! (since Top22), see 4t measurement and interpretation talks from Monday**
  Eur. Phys. J. C 83 (2023) 496
- $t\bar{t}$ all-hadronic, 8 WCs (fit individually and pairs)
  JHEP 04 (2023) 80
- $t\bar{t}$ charge asymmetry, single and di-lepton, 15 WCs (fit individually)
  JHEP 08 (2023) 077
- $t\bar{t}$ semi-leptonic, 2 WCs (fit individually and together),
  JHEP 06 (2022) 063
- Single top polarization, leptonic, Re and Im part of 1 WC (fit individually and together),
  JHEP 11 (2022) 040

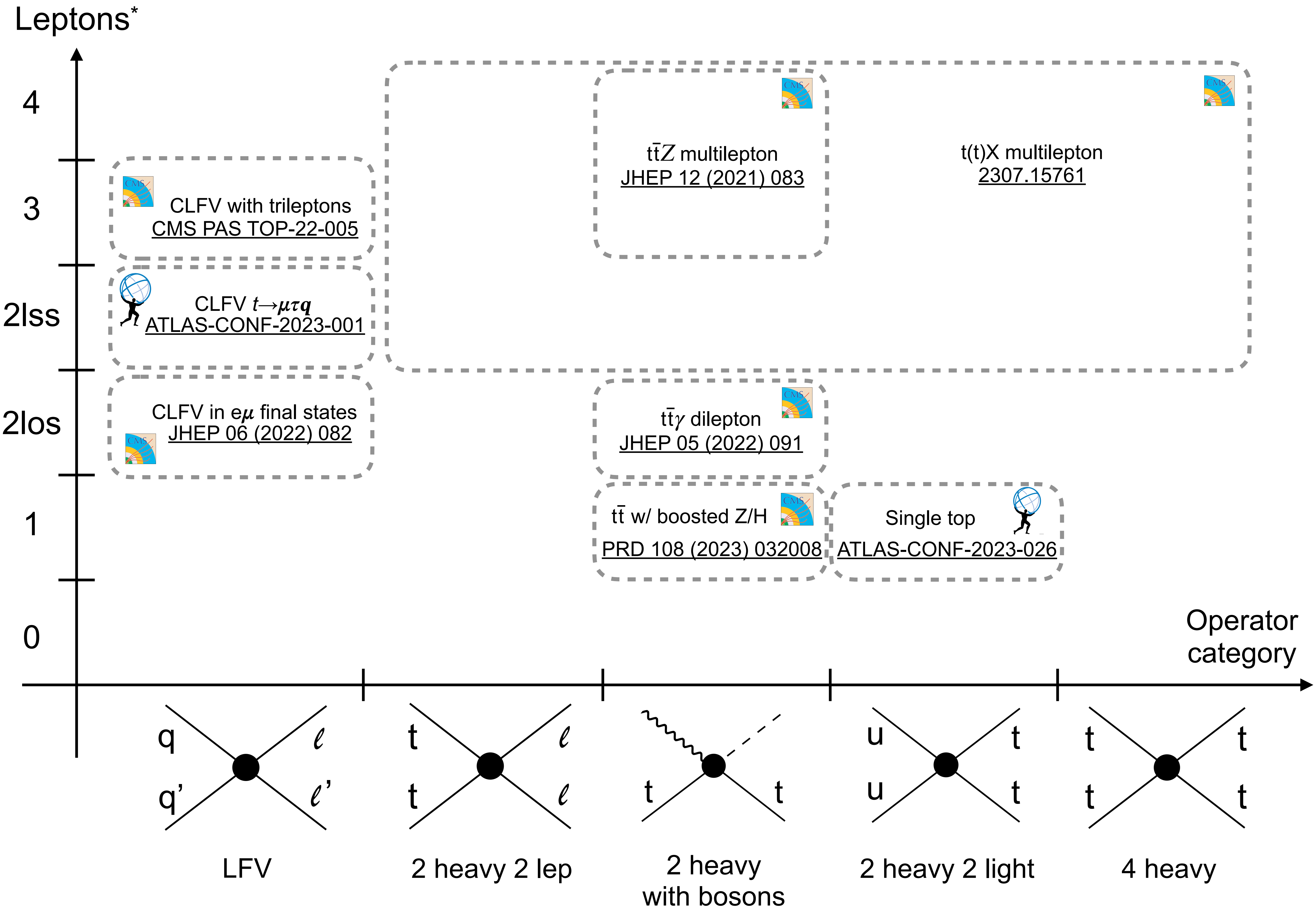
Now let's talk about how the analyses fit together into the Top EFT landscape

A map of detector-level top EFT analyses[1]



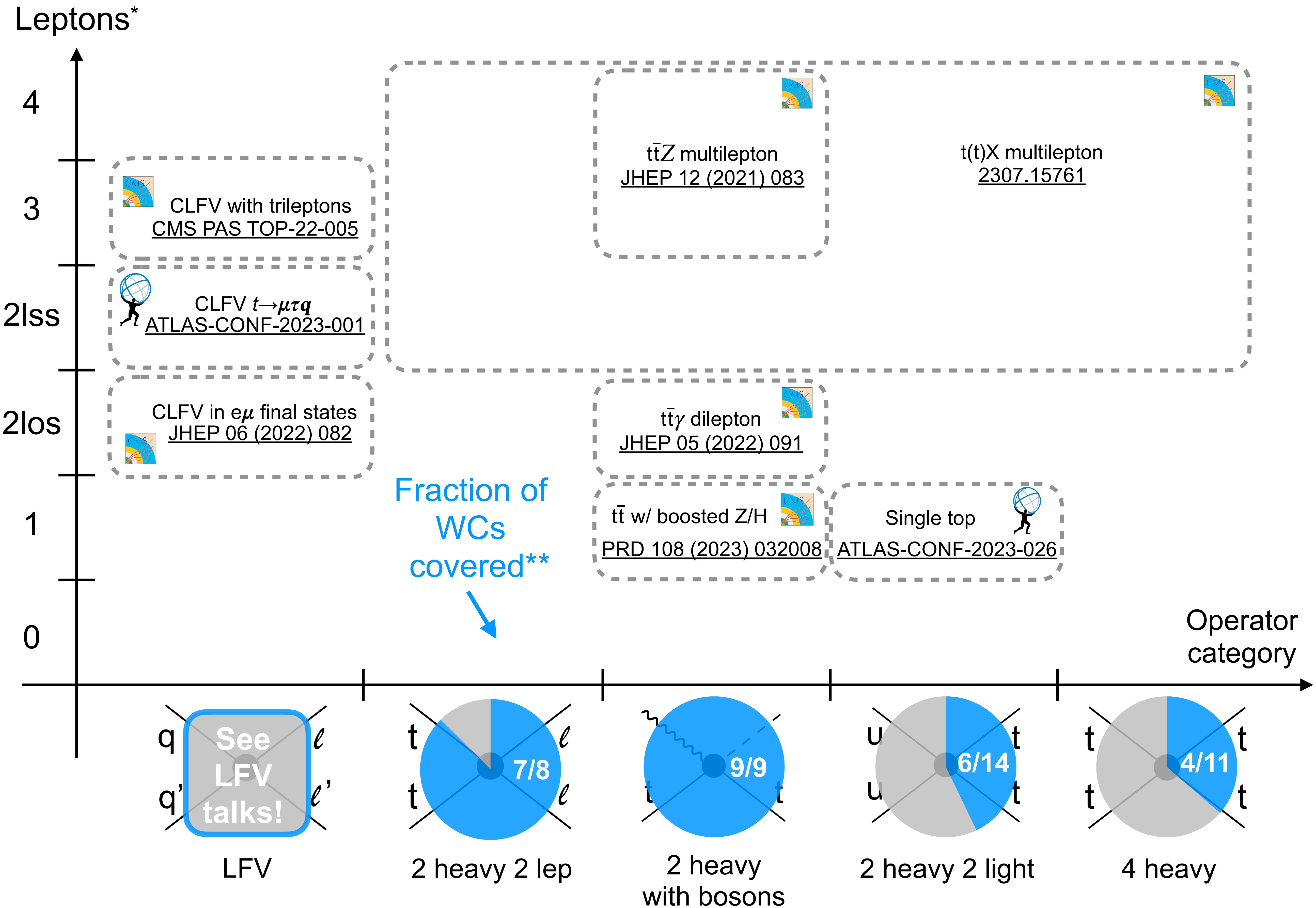
[1]Only analyses from the past ~couple years of analyses (i.e. detector-level analyses listed on the “Some recent TOP EFT analyses” slide) are included here
*The upper edge of the analyses’ y axis placement is based on the selection category with highest lep multiplicity, which can be inclusive

A map of detector-level top EFT analyses[1]



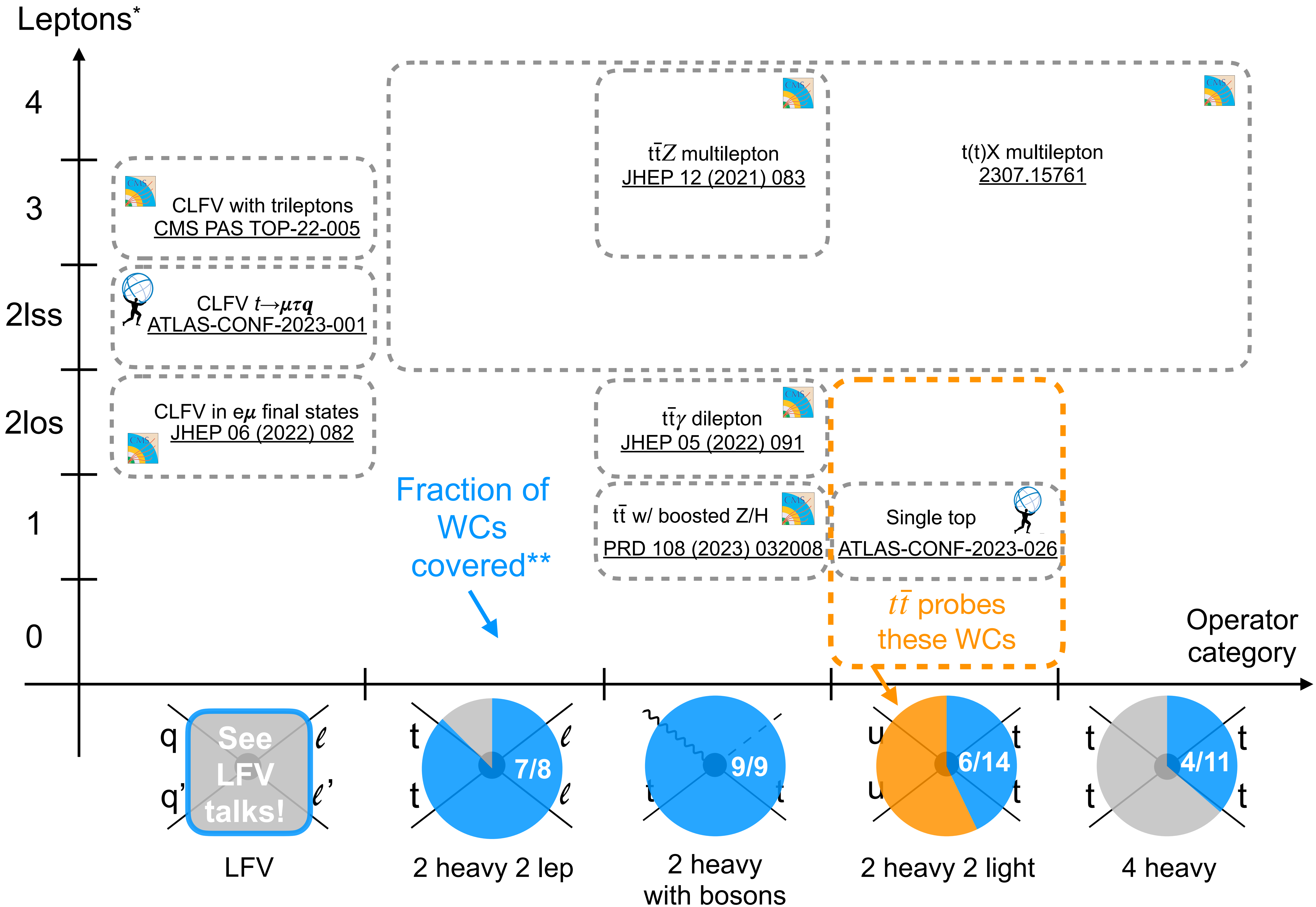
[1]Only analyses from the past ~couple years of analyses (i.e. detector-level analyses listed on the “Some recent TOP EFT analyses” slide) are included here
*The upper edge of the analyses' y axis placement is based on the selection category with highest lep multiplicity, which can be inclusive

A map of detector-level top EFT analyses[1]



[1]Only analyses from the past ~couple years of analyses (i.e. detector-level analyses listed on the "Some recent TOP EFT analyses" slide) are included here
*The upper edge of the analyses' y axis placement is based on the selection category with highest lep multiplicity, which can be inclusive
**Note: The number of WCs quoted for each category does not include the CP violating Im parts of WCs

A map of detector-level top EFT analyses[1]

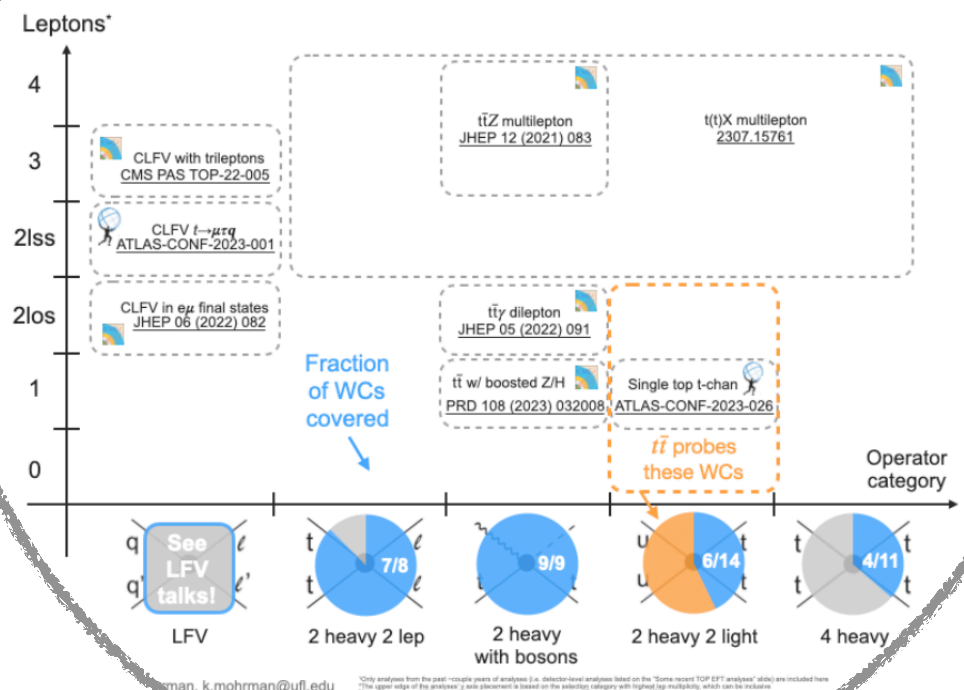


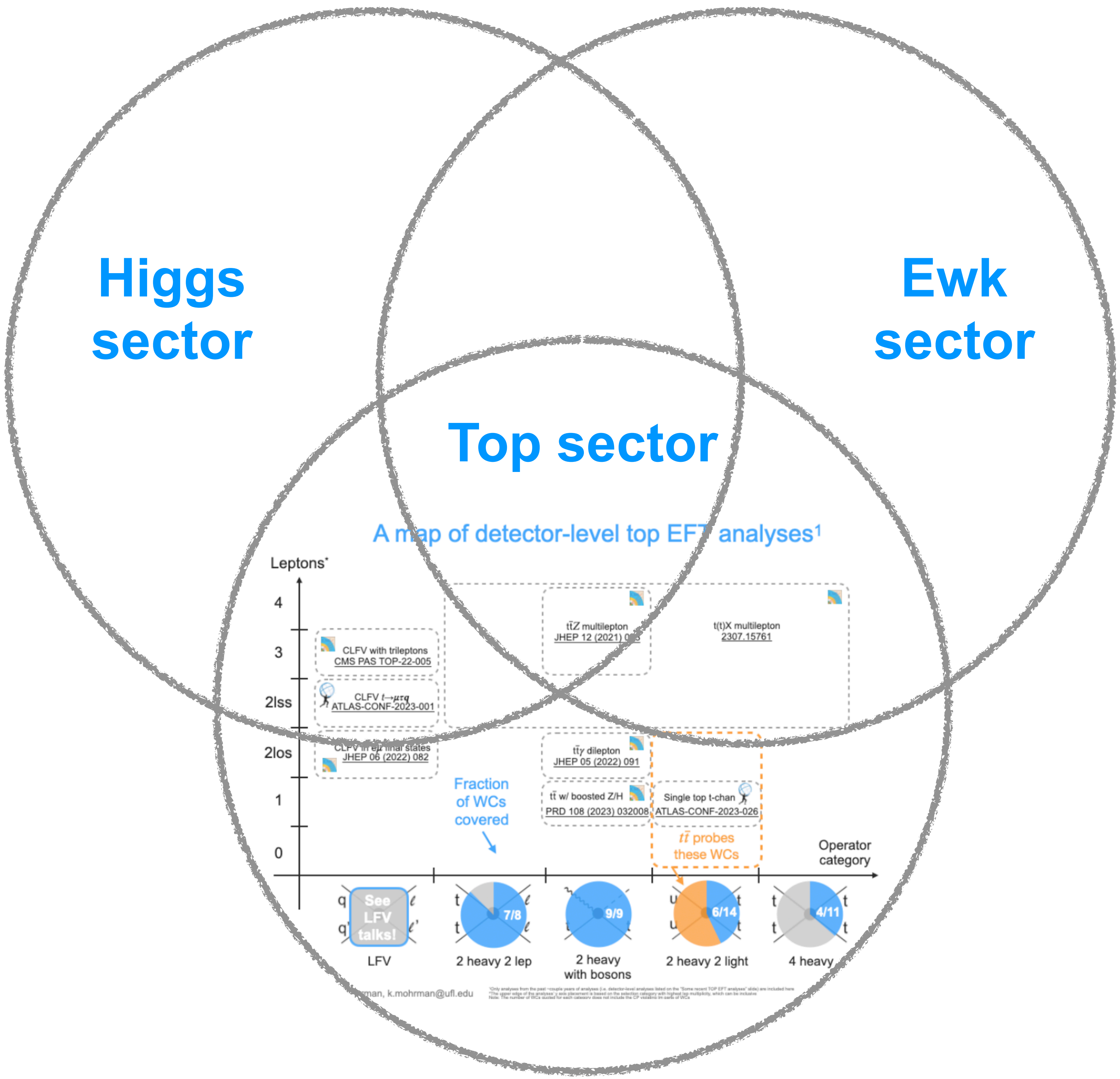
Kelci Mohrman, k.mohrman@ufl.edu

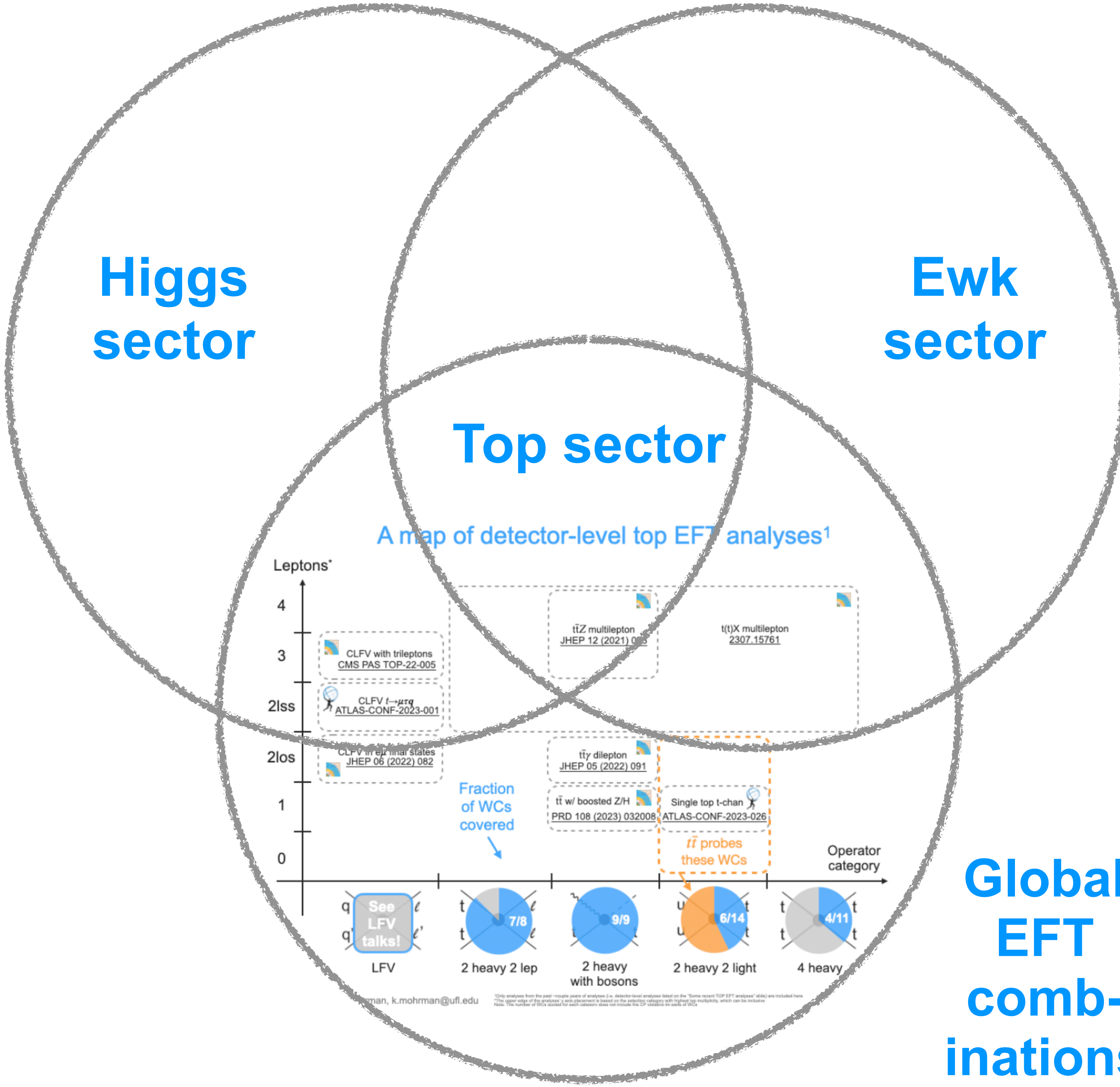
[1]Only analyses from the past ~couple years of analyses (i.e. detector-level analyses listed on the "Some recent TOP EFT analyses" slide) are included here
*The upper edge of the analyses' y axis placement is based on the selection category with highest lep multiplicity, which can be inclusive
**Note: The number of WCs quoted for each category does not include the CP violating Im parts of WCs

Top sector

A map of detector-level top EFT analyses[1]




Higgs sector
Ewk sector
Top sector
A map of detector-level top EFT analyses[1]
Leptons*
4
3
2lss
2los
1
0
CLFV with trileptons
CMS PAS TOP-22-005
CLFV t→μτq
ATLAS-CONF-2023-001
JHEP 06 (2022) 082
tt̄Z multilepton
t(t)X multilepton
2307.15761
tt̄γ dilepton
JHEP 05 (2022) 091
tt̄ w/ boosted Z/H
PRD 108 (2023) 032008
Single top t-chan
ATLAS-CONF-2023-026
Fraction of WCs covered
tt̄ probes these WCs
Operator category
See LFV talks!
7/8
9/9
6/14
4/11
LFV
2 heavy 2 lep
2 heavy with bosons
2 heavy 2 light
4 heavy

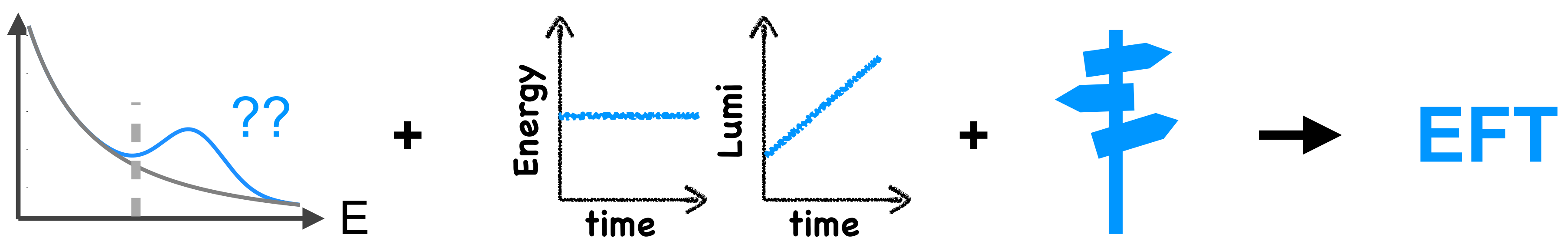


Global EFT comb-inations

→ **Hopefully to new physics discoveries!**

Summary and outlook

- BSM is out there, but might not be light enough to make at the LHC => EFT aims to discover new physics via its off shell effects



- CMS and ATLAS employ a variety of direct and indirect EFT approaches to search for new physics in the TOP sector
- While no signal yet observed, still many new directions to improve and expanded, and combinations will be especially exciting:
  - More data
  - Improvements in EFT modeling
  - Combinations within TOP
  - Combinations across sectors

Hopefully leading to new physics discoveries!

Sleeping Bear Dunes National Lakeshore, MI

Backup

Constraints on CP violating operators in dim6top (1802.07237 i.e. dim6top note)

Four-heavy				
$c_{QtQb}^{1I} \equiv \text{Im}\{C_{quqd}^{1(3333)}\}$	$[-3.4, 3.4] \cdot 10^{-3}$	(d_n)		
$c_{QtQb}^{8I} \equiv \text{Im}\{C_{quqd}^{8(3333)}\}$	$[-2.2, 2.2] \cdot 10^{-2}$	(d_n)		
Two-heavy				
$c_{t\varphi}^{I} \equiv \text{Im}\{C_{u\varphi}^{(33)}\}$	$[-3.7, 3.7]$	(d_n)	$[-0.18, 0.18]$	(d_e)
$c_{\varphi tb}^{I} \equiv \text{Im}\{C_{\varphi ud}^{(33)}\}$	$[-0.019, 0.019]$	(d_n)	$[-0.052, 0.052]$	$(B \to X_s\gamma)$
$c_{tW}^{I} \equiv \text{Im}\{C_{uW}^{(33)}\}$	$[-8.1, 8.1] \cdot 10^{-3}$	(d_e)	$[-2.4, 4.5]$	$(B \to X_s\gamma)$
$c_{tA}^{I} \equiv \text{Im}\{c_W C_{uB}^{(33)} + s_W C_{uW}^{(33)}\}$	$[-6.3, 6.3] \cdot 10^{-3}$	(d_e)	$[-9.0, 5.0]$	$(B \to X_s\gamma)$
$c_{bW}^{I} \equiv \text{Im}\{C_{dW}^{(33)}\}$	$[-5.5, 5.5] \cdot 10^{-4}$	(d_n)	$[-4.3, 2.3] \cdot 10^{-2}$	$(B \to X_s\gamma)$
$c_{tG}^{I} \equiv \text{Im}\{C_{uG}^{(33)}\}$	$[-6.9, 6.9] \cdot 10^{-3}$	(d_n)		
Two-heavy-two-lepton				
$c_{t}^{SI(e)} \equiv \text{Im}\{C_{lequ}^{1(1133)}\}$	$[-5.5, 5.5] \cdot 10^{-8}$	(d_e)		
$c_{t}^{TI(e)} \equiv \text{Im}\{C_{lequ}^{3(1133)}\}$	$[-8.0, 8.0] \cdot 10^{-11}$	(d_e)		
$c_{b}^{SI(e)} \equiv \text{Im}\{C_{ledq}^{(1133)}\}$	$[-2.5, 2.5] \cdot 10^{-4}$	(d_e)		

Table 5: Constraints from the electron and neutron EDMs as well as $A_{CP}(B \to X_s\gamma)$. Here we turn on one coupling at a time and assume $\Lambda = 1$ TeV. The source of the constraints are indicated in brackets.

We've been saying "model agnostic" a lot…
But, what about this model?

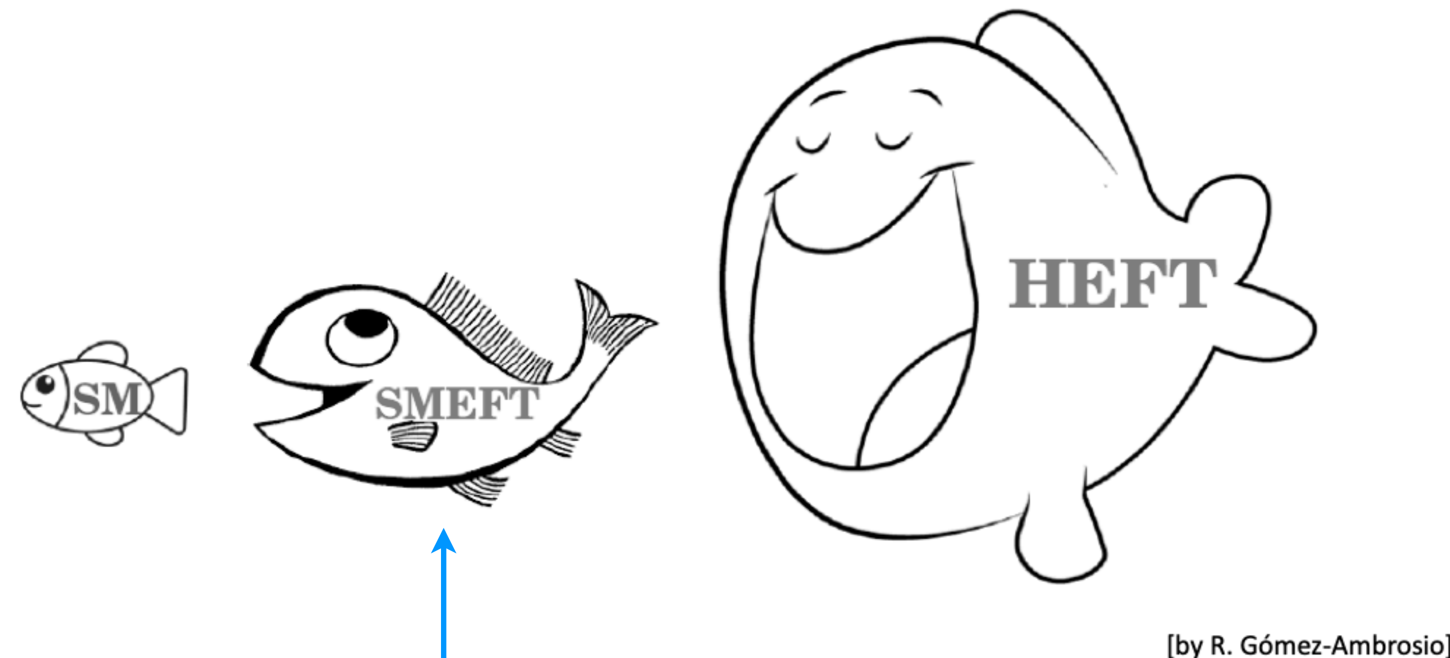
$$\mathscr{L}_{\text{EFT}} = \boxed{\mathscr{L}_{\text{SM}}} + \sum_i \frac{c_i}{\Lambda^2} \mathcal{O}_i^{(6)}$$

This assumption means that so far in this presentation we have actually been talking about a special case of EFT, known as "SM EFT"

Assumptions that go into SM EFT $\left(\mathscr{L}_{\text{SMEFT}} = \mathscr{L}_{\text{SM}} + \sum_i \frac{c_i}{\Lambda^2}\mathcal{O}_i^{(6)}\right)$

- TOP mainly uses SM EFT, i.e. assumes SM is correct and complete description of everything we can produce on shell
- Other EFTs (e.g. HEFT) can be more general

Image credit: Juan José Sanz-Cillero ("Reasons for HEFT: why we may need more than SMEFT", Higgs 2022)



So for this talk, when we say "EFT" we generally mean "SM EFT"

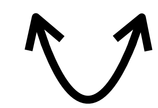
SMEFT is a special case of HEFT in which the resonance at 125GeV is the SM Higgs*

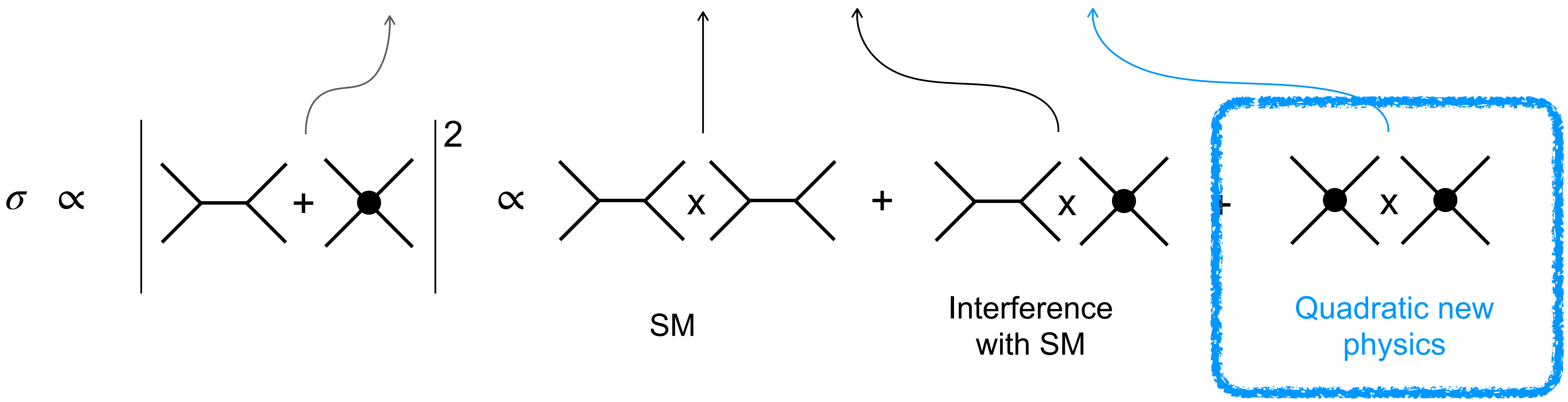
*I.e., SMEFT assumes the SM Higgs complex doublet

How do observables depend on EFT? Let's start with σ

If the EFT is modeled linearly in amplitude, the cross section is an *n*-quadratic in terms of the WCs (where *n* is number of WCs)

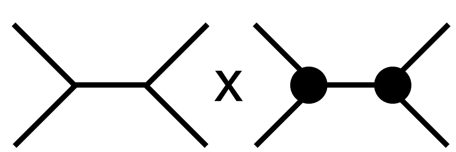
$$\sigma \propto |\mathcal{M}_{SM} + \frac{c_i}{\Lambda^2}\mathcal{M}_i|^2 \propto s_0 + s_i \frac{c_i}{\Lambda^2} + s_{ij}\frac{c_i}{\Lambda^2}\frac{c_j}{\Lambda^2} =$$





Other contributions at the same Λ^{-4} order: dim-8 interfering with the SM, and double insertions of dim-6 interfering with the SM

e.g.:



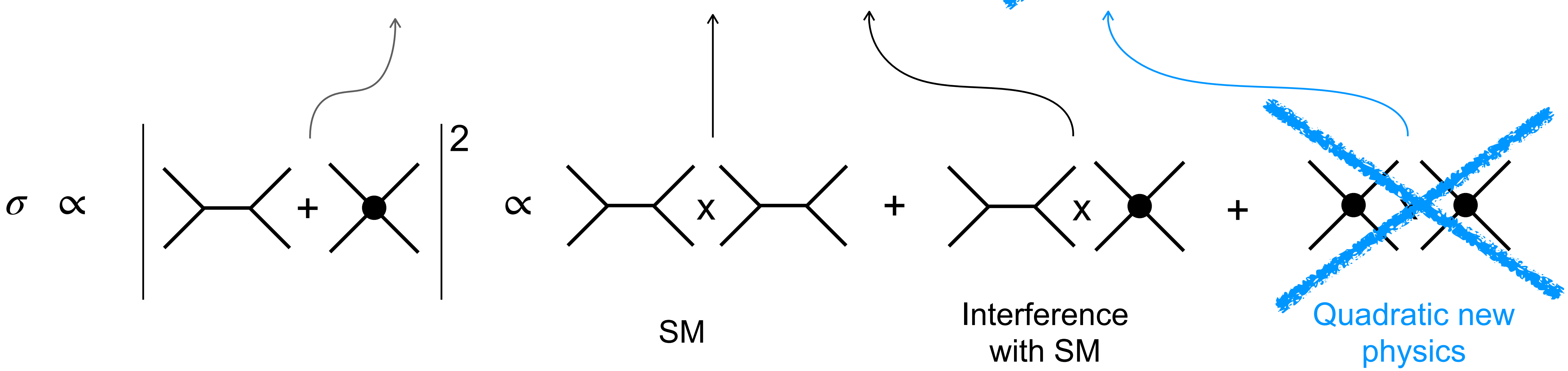
$\sim \Lambda^{-4}$ ←

This double insertion example is possible (though challenging) to incorporate into the simulation, while on the other hand dim8 is currently not really possible (for TOP), though there are ideas like geoSMEFT (2001.01453) that might help to make this doable

How do observables depend on EFT? Let's start with σ

If the EFT is modeled linearly in amplitude, the cross section is an *n*-quadratic in terms of the WCs (where *n* is number of WCs)

$$\sigma \propto \left| \mathscr{M}_{SM} + \frac{c_i}{\Lambda^2} \mathscr{M}_i \right|^2 \propto s_0 + s_i \frac{c_i}{\Lambda^2} + s_{ij} \frac{c_i}{\Lambda^2} \frac{c_j}{\Lambda^2} =$$



So some analyses include only up to the linear term, though this can be challenging in cases where there is not strong interference, or where most of the sensitivity comes from the quadratic piece

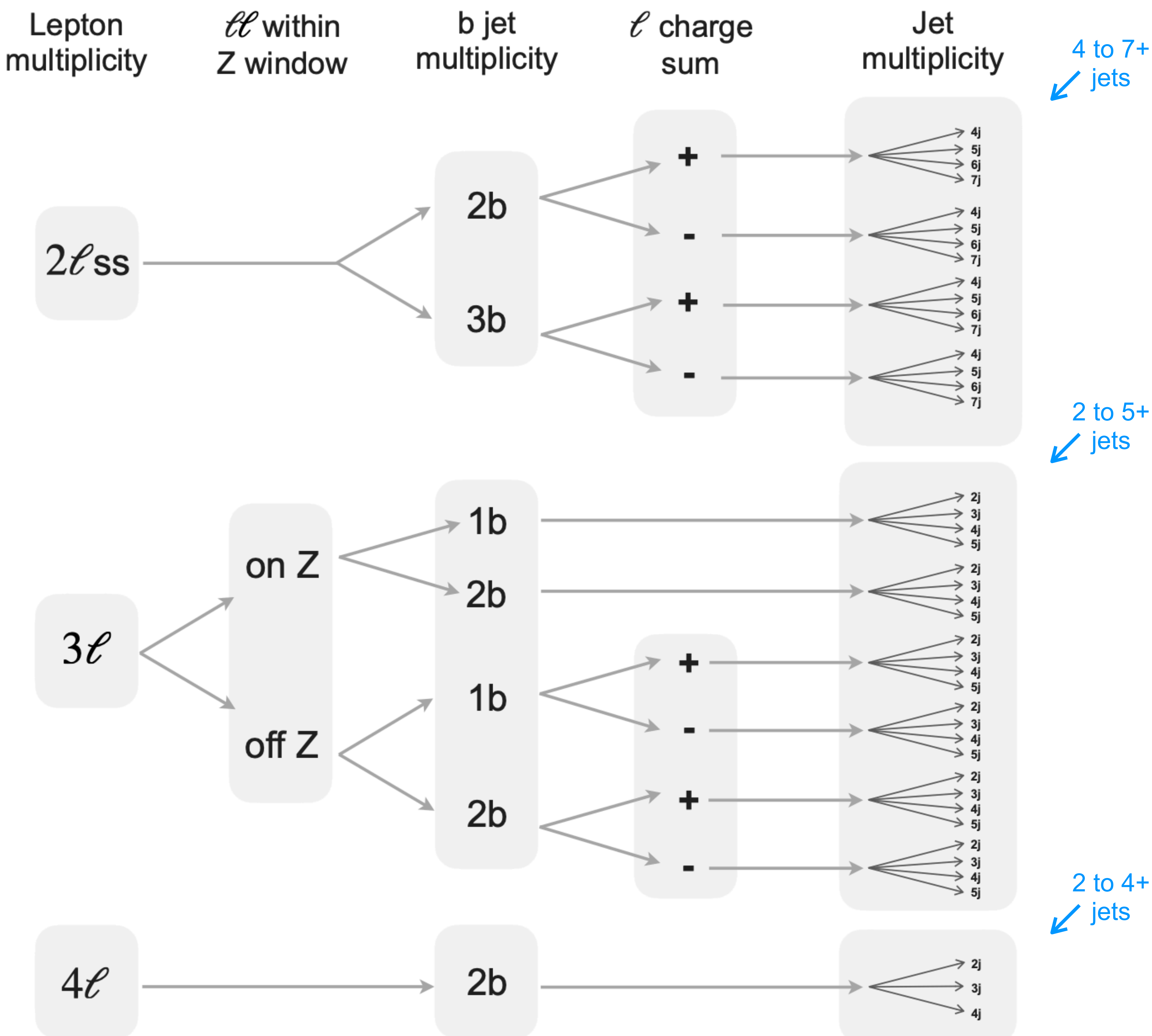
More info on the CMS and ATLAS analyses

TOP-22-006 SM cross sections used

Table 2: Theoretical cross sections at next-to-LO (NLO) used for normalization of simulated signal samples. The uncertainties are broken into normalization components due to modeling the parton distribution functions (PDFs) and QCD order. Entries without a value are negligible.

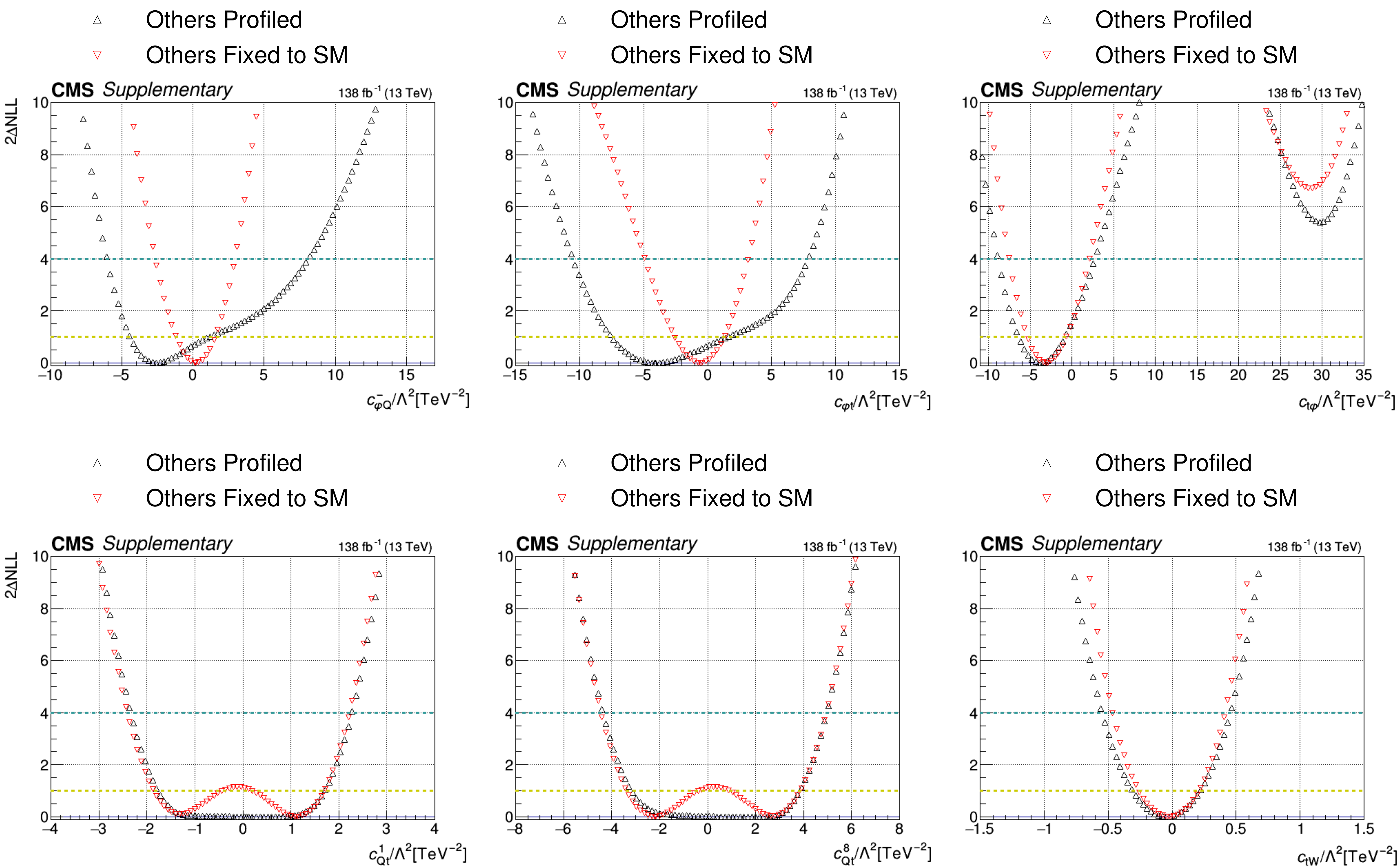
Process	Cross section (pb)	Accuracy	Ref.
$t\bar{t}H$	$0.5071 \pm 2.4\%$ (PDF) $^{+7.6\%}_{-7.1\%}$ (QCD)	NLO (QCD + EWK)	[28]
$t\bar{t}\ell\bar{\ell}$ ($m_{\ell\ell} > 10\,GeV$)	0.281 $^{+12\%}_{-10\%}$ (QCD)	NLO (QCD + EWK)	[28]
$t\bar{t}\ell\nu$	0.235 $^{+10\%}_{-11\%}$ (QCD)	NLO (QCD + EWK) (incl. $\alpha_S\alpha^4$ terms and multijet merging)	[29]
$t\ell\bar{\ell}q$ ($m_{\ell\ell} > 30\,GeV$)	$0.076 \pm 2.7\%$ (PDF) $\pm 2.0\%$ (QCD)	NLO QCD	[19–21]
tHq	$0.071 \pm 5.1\%$ (PDF) $^{+6.5\%}_{-15\%}$ (QCD)	NLO QCD	[28]
$t\bar{t}t\bar{t}$	$0.01337 \pm 6.9\%$ (PDF) $^{+3.6\%}_{-11\%}$ (QCD)	NLO (QCD + EWK) + NLL′	[30]

TOP-22-006 event selection summary



(Note: All highest multiplicity categories (for lep and jets) are inclusive)

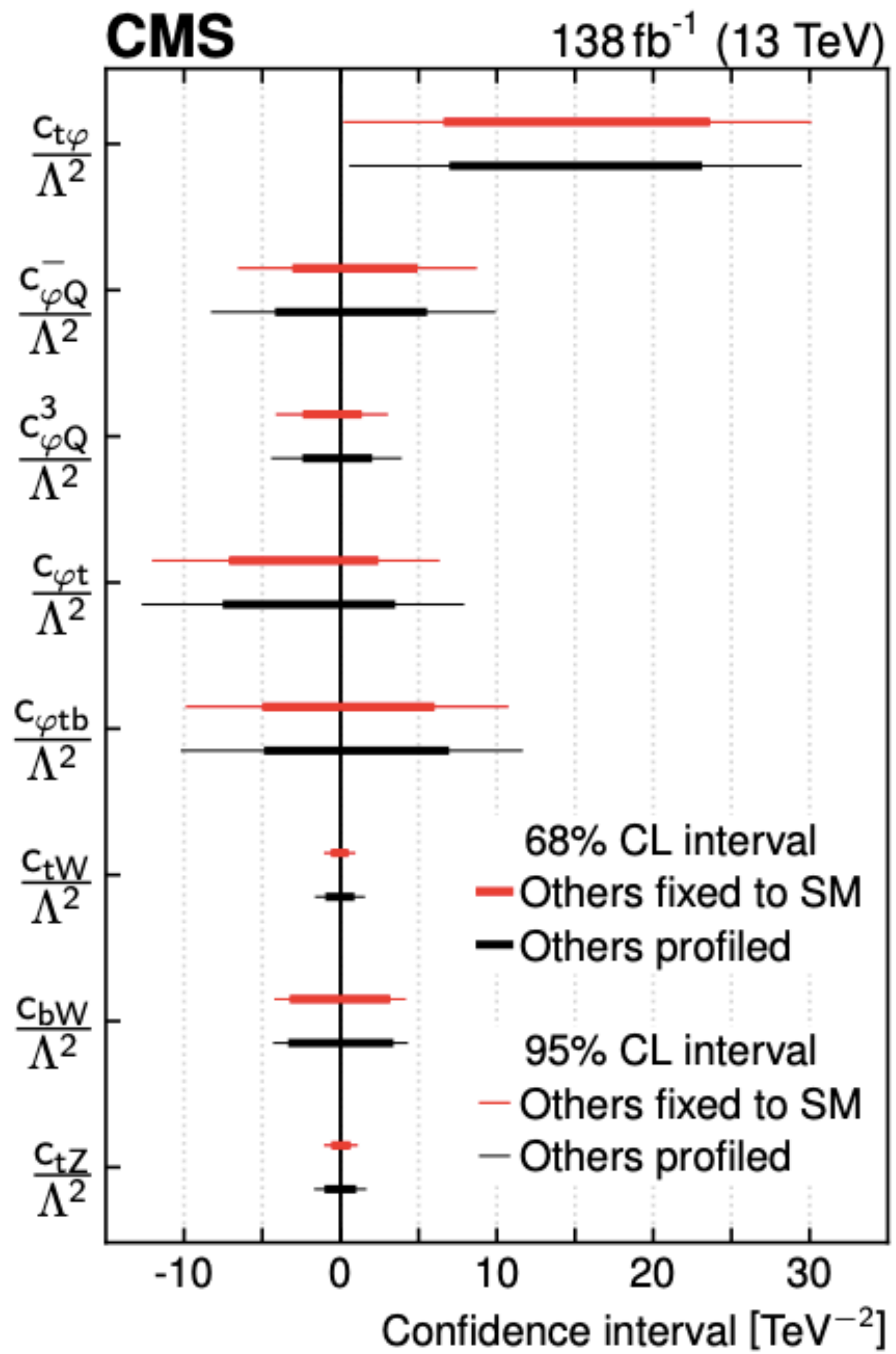
Example one-dimensional scans TOP-22-006



Summary: CMS TOP-21-003

- "Search for new physics using effective field theory in 13 TeV pp collision events that contain a top quark pair and a boosted Z or Higgs boson"
    - Target ttZ/H where the Z/H is boosted
    - Single lepton signatures

- EFT modeling:
    - Detector level approach (parameterize event weights in terms of the WCs in order to obtain detector level yields as a function of the WCs)
    - Fit 8 WCs (2heavy-with-bosons) individually and profiled



Summary: CMS TOP-21-004

- "Measurement of the inclusive and differential ttγ cross sections in the dilepton channel and effective field theory interpretation in proton-proton collisions at $\sqrt{s}$ = 13 TeV"
    - Target leptonic decays of $t\bar{t}\gamma$
    - Final states: Opposite sign leptons and a photon
- EFT modeling:
    - Studied in bins of photon pt
    - Model operator effects using gen-sample reweighting to estimate the expected SMEFT modifications at the reconstructed level
    - Real and imaginary part of ctZ is studied

	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	$[-0.43, 0.33]$	$[-0.56, 0.51]$	$[-0.28, 0.23]$	$[-0.36, 0.35]$

Summary: CMS TOP-21-001

- "Probing effective field theory operators in the associated production of top quarks with a Z boson in multilepton final states at $\sqrt{s}$ = 13 TeV"
  - Target ttZ and tZq
  - Multilepton final states (3 or 4 leptons)
- EFT modeling:
  - Detector level approach (parameterize event weights in terms of the WCs in order to obtain detector level yields as a function of the WCs)
  - Probe 5 WCs, fit individually and profiled

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}	$[-0.76, 0.74]$	$[-0.52, 0.52]$	$[-0.96, 0.93]$	$[-0.69, 0.70]$
$c^{3}_{\varphi\mathrm{Q}}$	$[-1.39, 1.25]$	$[-1.10, 1.41]$	$[-1.91, 1.36]$	$[-1.26, 1.43]$
$c^{-}_{\varphi\mathrm{Q}}$	$[-2.86, 2.33]$	$[-3.00, 2.29]$	$[-6.06, 14.09]$	$[-7.09, 14.76]$
$c_{\varphi\mathrm{t}}$	$[-3.70, 3.71]$	$[-21.65, -14.61] \cup [-2.06, 2.69]$	$[-16.18, 10.46]$	$[-19.15, 10.34]$

Summary: ATLAS-CONF-2023-001

- "Search for charged-lepton-flavour violating $\mu\tau qt$ interaction in top-quark production and decay with the ATLAS detector at the LHC"
    - The analysis targets events containing two muons, a hadronically decaying tau lepton and at least one jet, with exactly one b-tagged jet, produced by a $\mu\tau qt$ interaction in top-quark production or decay
    - No excess above the Standard Model background is observed
    - "The dominant source of uncertainty in all the limits extracted in this analysis is statistical, while the largest sources of systematic uncertainty relate to the $t\bar{t}$ modelling and the NP muon estimation"

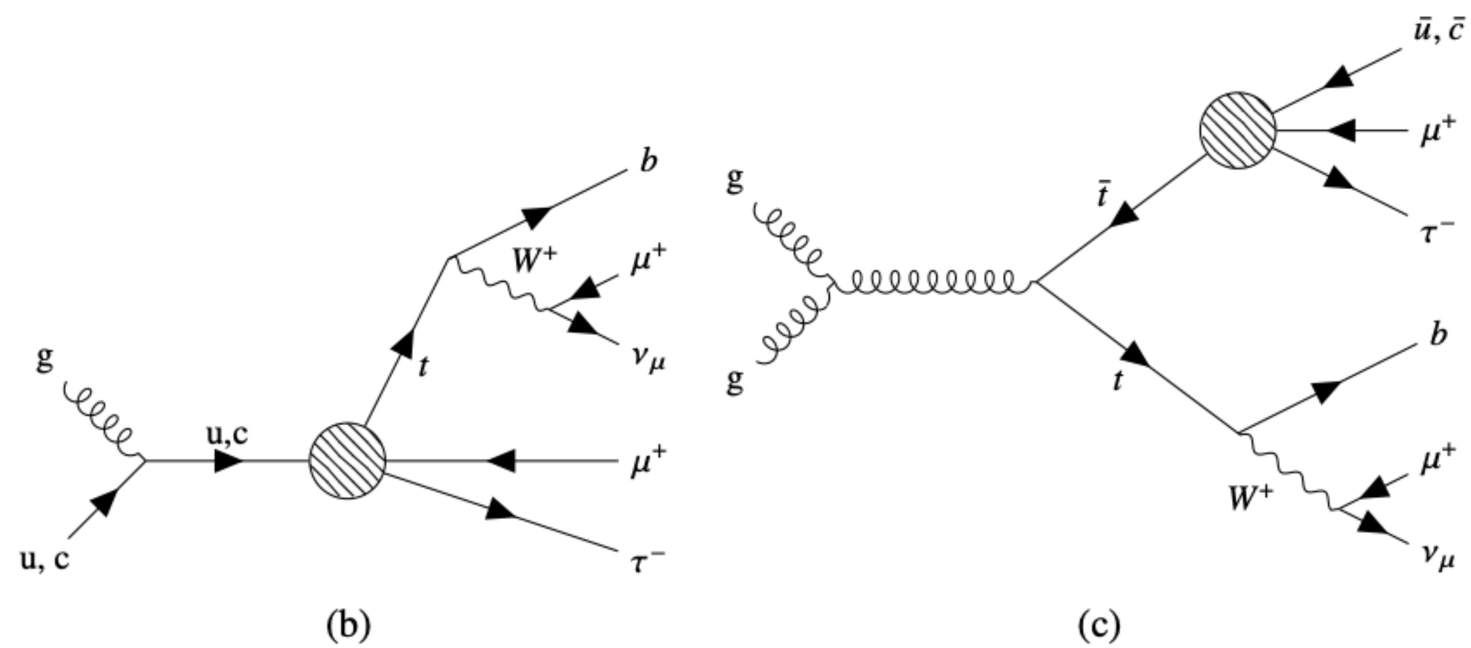


Table 7: Expected and observed 95% CL upper limits on Wilson coefficients corresponding to 2Q2L EFT operators which could introduce cLFV top decay in the $\mu\tau$ channel, and existing limits from Ref. [22] (previous). Results are shown separately for $\mu\tau ut$ and $\mu\tau ct$ interactions. The lepton generations are denoted by $i, j = 2, 3$ for μ and τ (where $i \neq j$) and the quark generations are denoted by $k = 1, 2$ for u and c, respectively.

	95% CL upper limits on Wilson coefficients c/Λ^2 [TeV^{-2}]							
	$c_{lq}^{-(ijk3)}$	$c_{eq}^{(ijk3)}$	$c_{lu}^{(ijk3)}$	$c_{eu}^{(ijk3)}$	$c_{lequ}^{1(ijk3)}$	$c_{lequ}^{1(ij3k)}$	$c_{lequ}^{3(ijk3)}$	$c_{lequ}^{3(ij3k)}$
Previous (u) [22]	12	12	12	12	26	26	3.4	3.4
Expected (u)	0.47	0.44	0.43	0.46	0.49	0.49	0.11	0.11
Observed (u)	0.49	0.47	0.46	0.48	0.51	0.51	0.11	0.11
Previous (c) [22]	14	14	14	14	29	29	3.7	3.7
Expected (c)	1.6	1.6	1.5	1.6	1.8	1.8	0.35	0.35
Observed (c)	1.7	1.6	1.6	1.6	1.9	1.9	0.37	0.37