Top EFT fit: ATLAS+CMS

Baptiste Ravina (University of Göttingen)
Kirill Skovpen (Ghent University)

LHC EFT WG meeting

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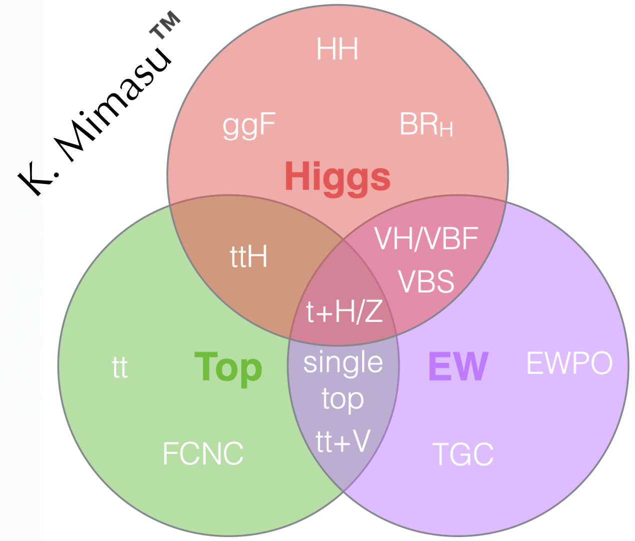
EFT in top sector

- Very rich in terms of potential new physics contributions
- Strong synergy with **EW** and **Higgs** sectors
- Combine ATLAS and CMS results at differential (**unfoldEFT**) and reconstruction (**recoEFT**) levels within **LHCtopWG**
- Use SMEFTsim; (m_W, m_Z, G_F); topU3l
- Consider a single insertion of an EFT operator
- Focus on 9 EFT operators that appear in the top EW processes (for now): C_{tG}, C^{I}_{tG}, C_{tW}, C^{I}_{tW}, C_{tB}, C^{I}_{tB}, C^{1}_{HQ}, C^{3}_{HQ}, C_{Ht}



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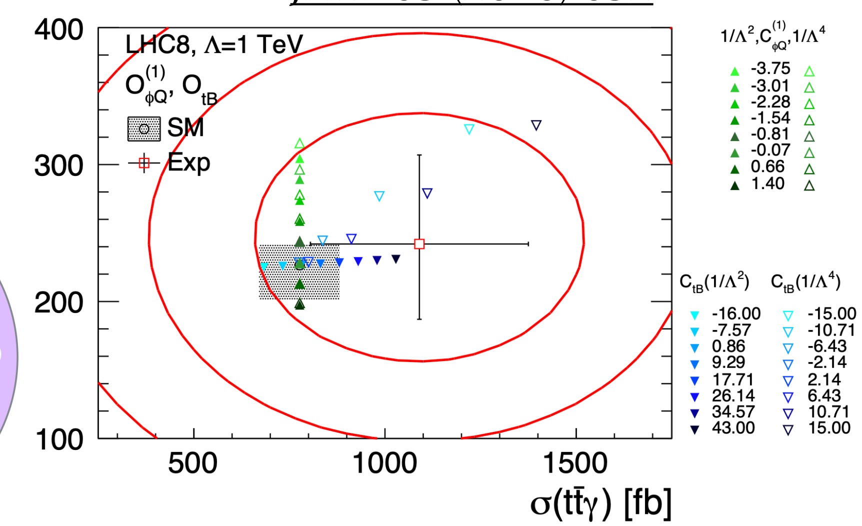

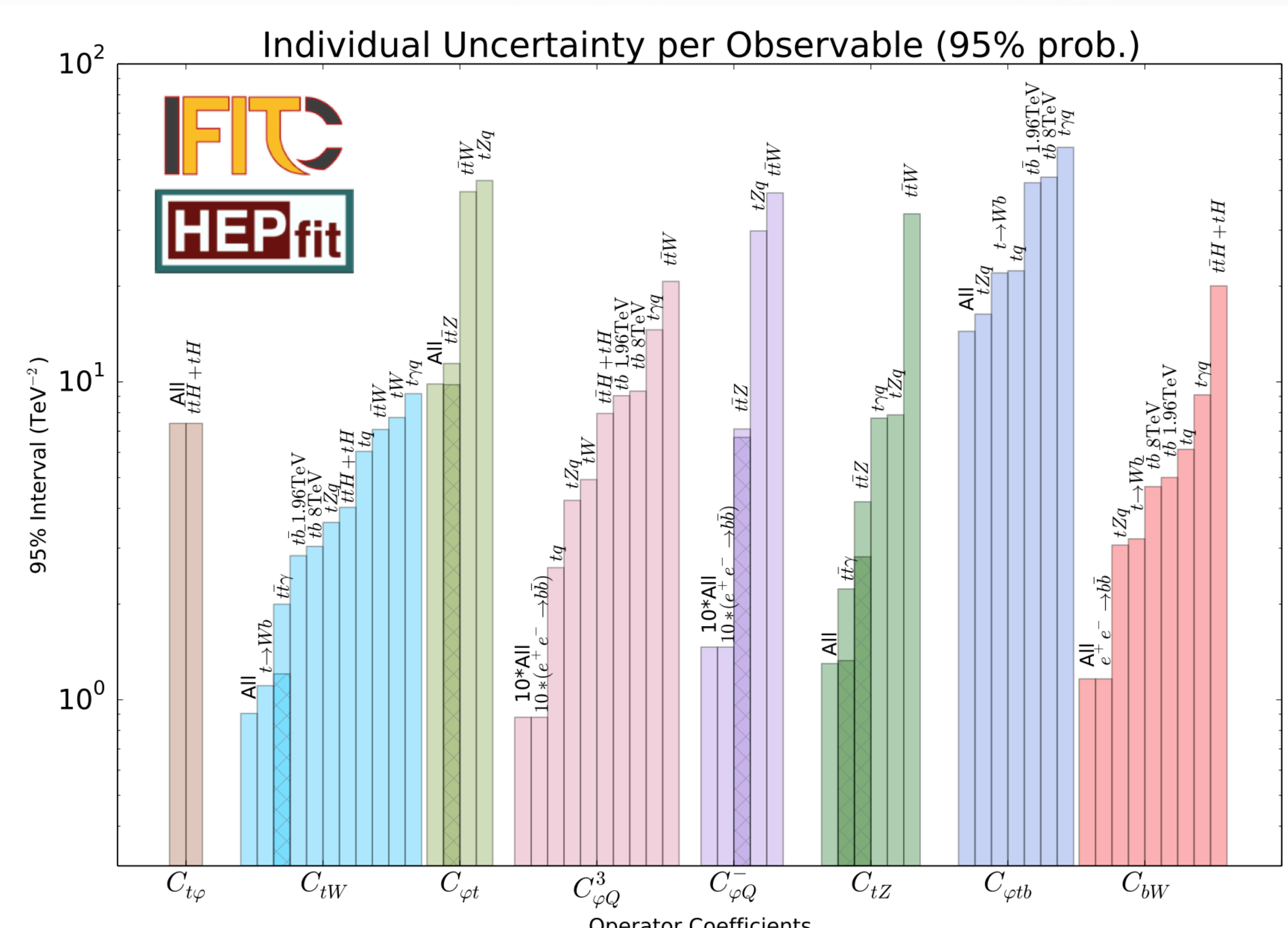

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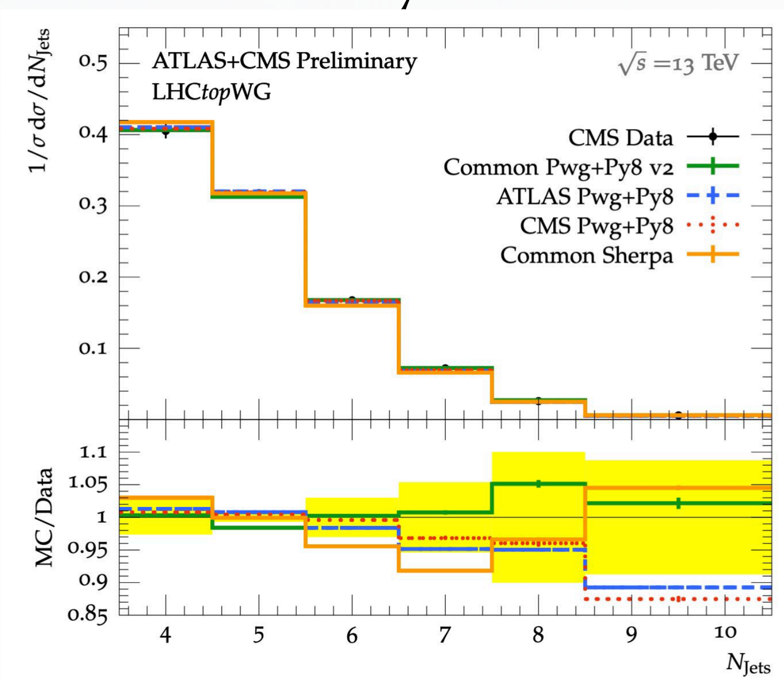
Common MC samples

- A dedicated effort within **LHCtopWG** to produce common **ttbar** samples (Powheg+Pythia, Sherpa)
- Understand the differences in how we generate samples, study correlations, and eventually use these samples as **baseline** prediction

CMS-DP-2022-056

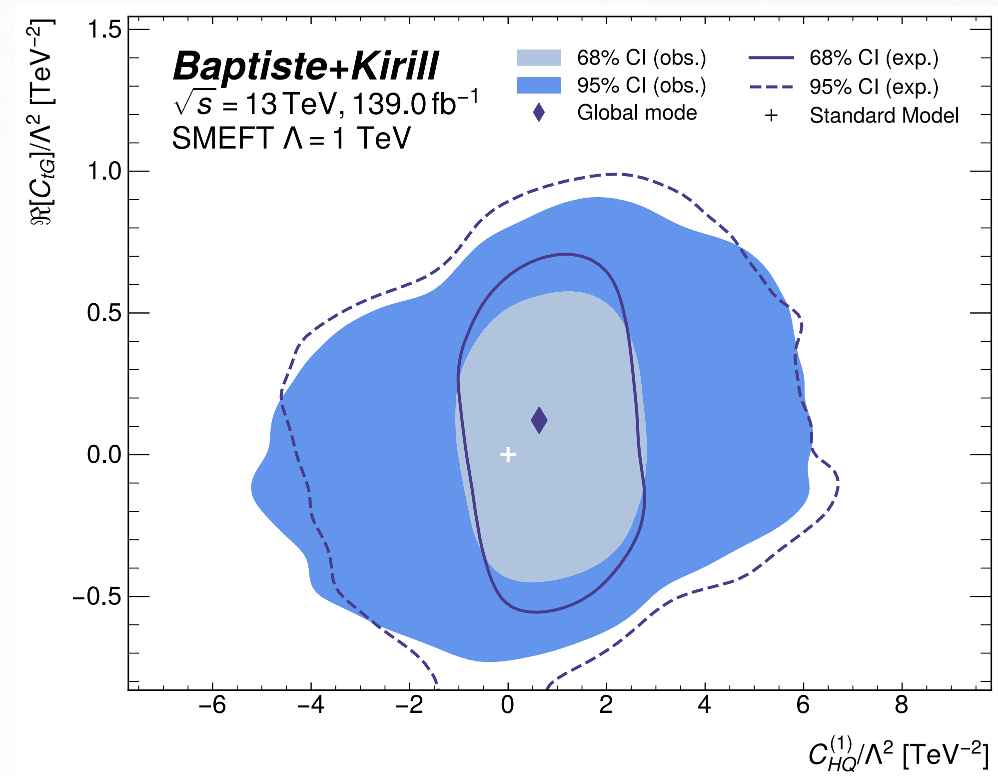


Setting name	Setting description	CMS default	ATLAS default	Common Pwg+Py8 v0.1	Common Pwg+Py8 v2
Powheg					
qmass	top-quark mass [GeV]	172.5	172.5	172.5	172.5
twidth	top-quark width [GeV]	1.31	1.32	1.315	1.311
hdamp	first emission damping parameter [GeV]	237.8775	258.75	250	250
wmass	$W^{\pm}$ mass [GeV]	80.4	80.3999	80.4	80.4
wwidth	$W^{\pm}$ width [GeV]	2.141	2.085	2.11	2.085
bmass	b-quark mass [GeV]	4.8	4.95	4.875	5.06
Pythia 8					
	Pythia 8 version	v240	v230	v240 (CMS) v244 (ATLAS)	v240 (CMS) v244 (ATLAS)
	Tune	CP5	A14	Monash	Monash-CMW
PDF:pSet	LHAPDF6 parton densities to be used for proton beams	NNPDF31_nnlo _as_0118	NNPDF23_lo _as_0130_qed	NNPDF23_lo _as_0130_qed	NNPDF23_lo _as_0130_qed
TimeShower:alphaSvalue	Value of α_s at Z mass scale for Final State Radiation	0.118	0.127	0.1365	0.118
SpaceShower:alphaSvalue	Value of α_s at Z mass scale for Initial State Radiation	0.118	0.127	0.1365	0.118
MPI:alphaSvalue	Value of α_s at Z mass scale for Multi-Parton Interaction	0.118	0.126	0.130	0.130
MPI:pT0ref	Reference p_T scale for regularizing soft QCD emissions	1.41	2.09	2.28	2.28
ColourReconnection:range	Parameter controlling colour reconnection probability	5.176	1.71	1.80	1.80

- Sharing a **common** MadGraph configuration to produce SMEFTsim samples (up to parton and particle levels) for **t(t)X** processes with all EFT/SM weights included
- **Validate** the predictions based on events weights by using additional samples produced at a given EFT point
- Using these samples in both **unfoldEFT** and **recoEFT** studies
- Extending the validation of **common MC samples** to **EFT studies** in **LHCtopWG**

Unfolded measurements

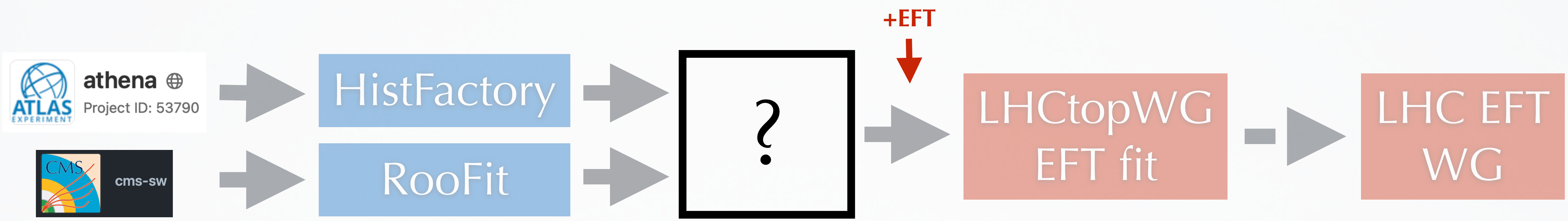
- Use **unfolded** differential **ttZ** cross sections measured by ATLAS and CMS
- A great **flexibility** for cross-experiment EFT studies with **many results available** in HEPData
- An established approach for a **global EFT fit** interpretations
- **Background** processes are subtracted under **SM assumption**
- A **strong dependence** of EFT interpretations on **background predictions** obtained from unfolded experimental results (there is no « background » when doing EFT!)
- Limited use for a proper **uncertainty correlation**

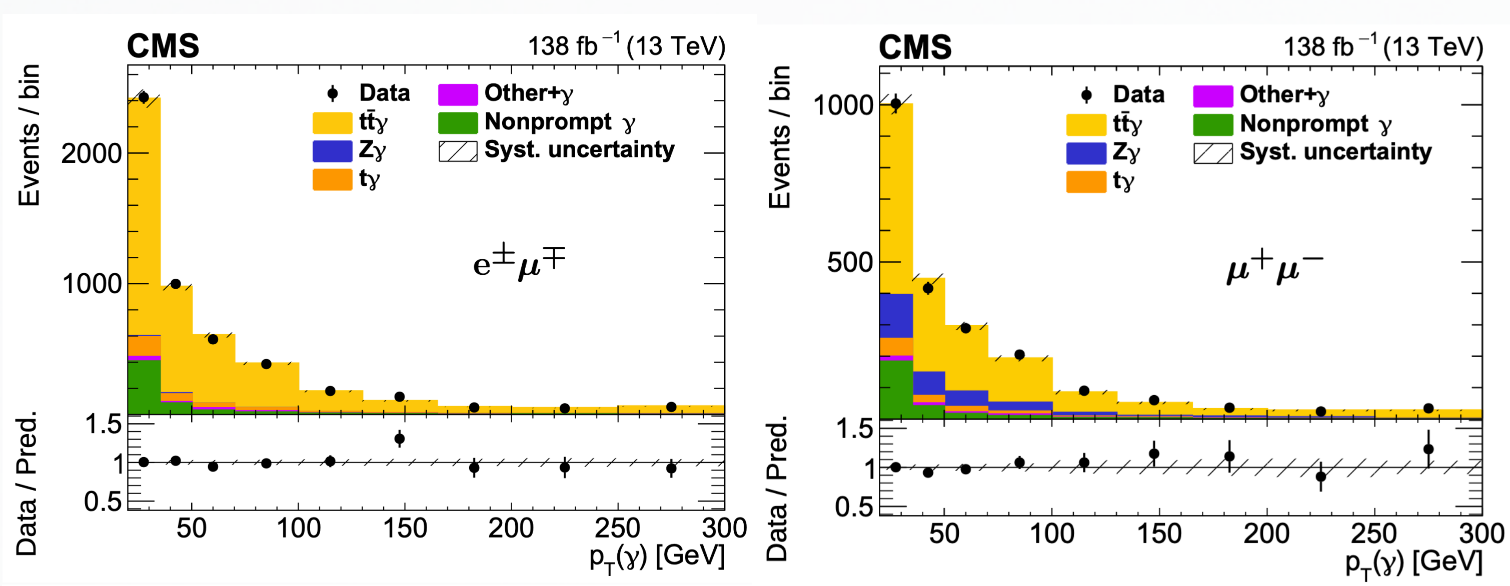


Baptiste+Kirill $\sqrt{s}$ = 13 TeV, 139 fb^{-1}

#	λ	$C_{HQ}^{(1)}$	$C_{HQ}^{(3)}$	C_{Ht}	$\Re[C_{tG}]$
1	0.02	0.37	-0.65	0.63	-0.20
2	30.17	0.29	-0.30	-0.19	0.89

Full reco information





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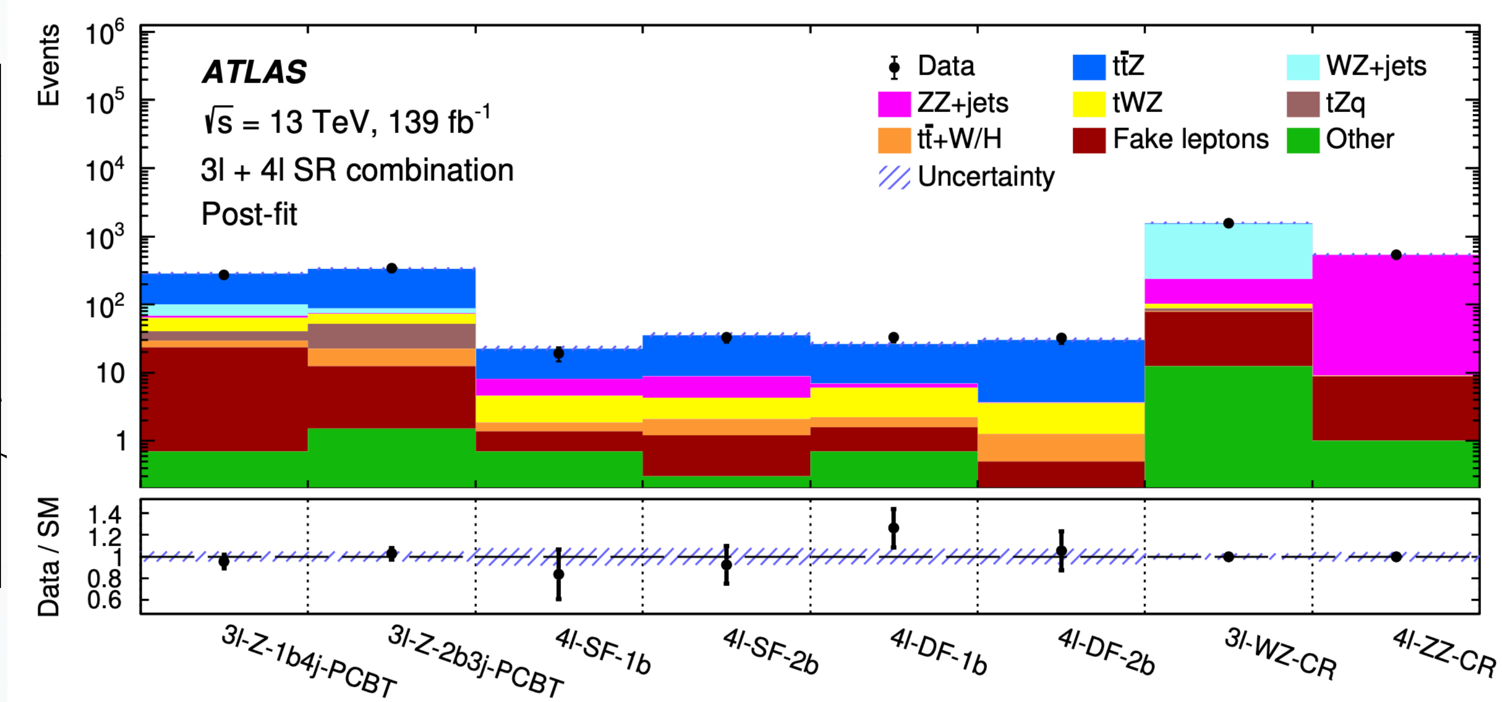

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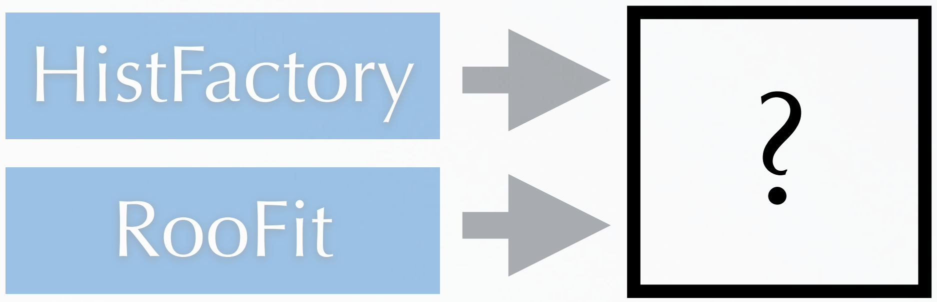
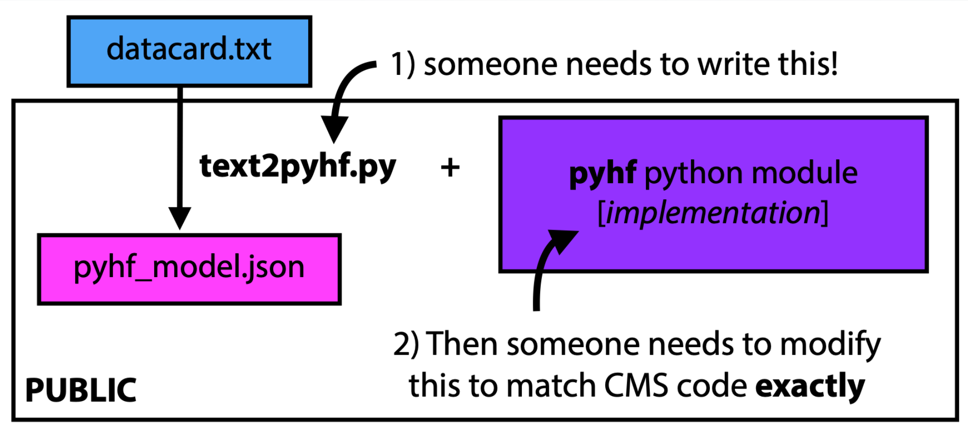
- Use measurements (**ttZ**, **ttγ**) with **full information** on all relevant processes
- Properly **correlate** systematic uncertainties
- Need a **common statistical model** for a combined ATLAS+CMS fit
- A **simultaneous** measurement of multiple processes using data from both experiments
- **Problem**: we do not possess a **common** format to systematically publish experimental results with full reconstruction information
- Important for **analysis preservation**, future **global fits**, and **reinterpretations**

Common fit model

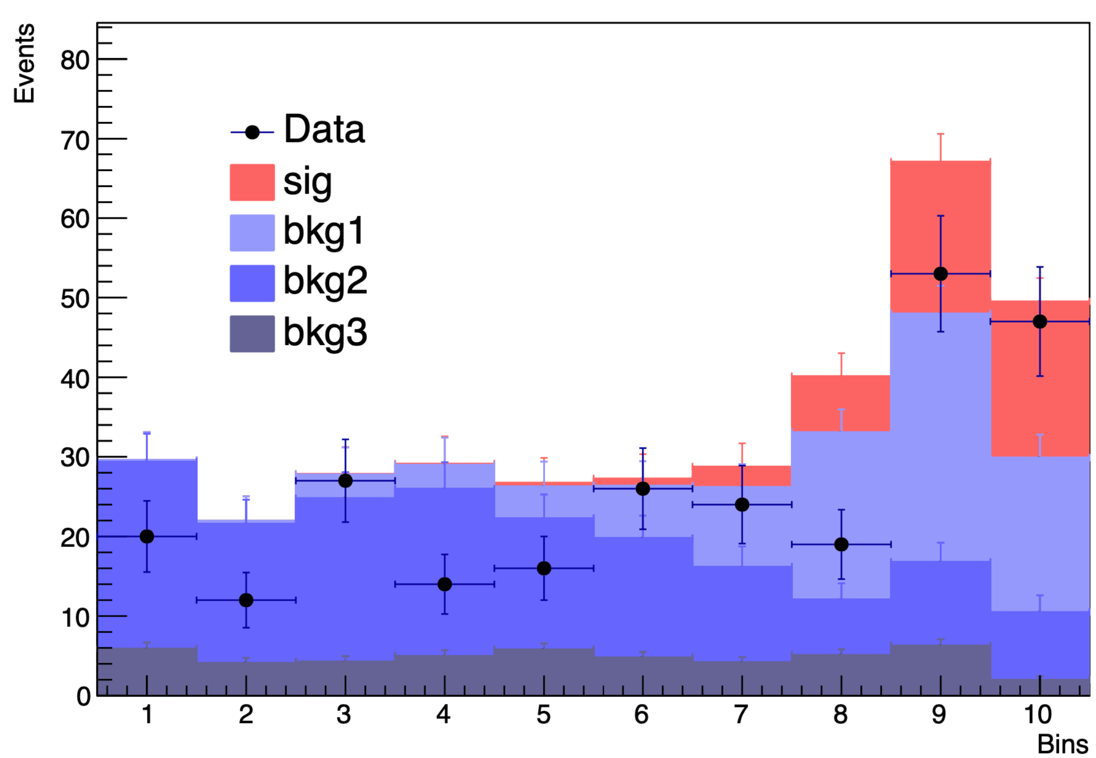
- Understand differences in the **treatment** of nuisance parameters in ATLAS and CMS
- Define **correlated nuisances** among various systematic variations
- Serialization of fit models (e.g. **JSON** in **pyhf**)
- A dedicated effort by pyhf team to create a bidirectional **pyhf-combine** converter
- Independently developed and cross-validated as part of **Combine** for a **combine→pyhf** translation
- **Good agreement** for **simple** models

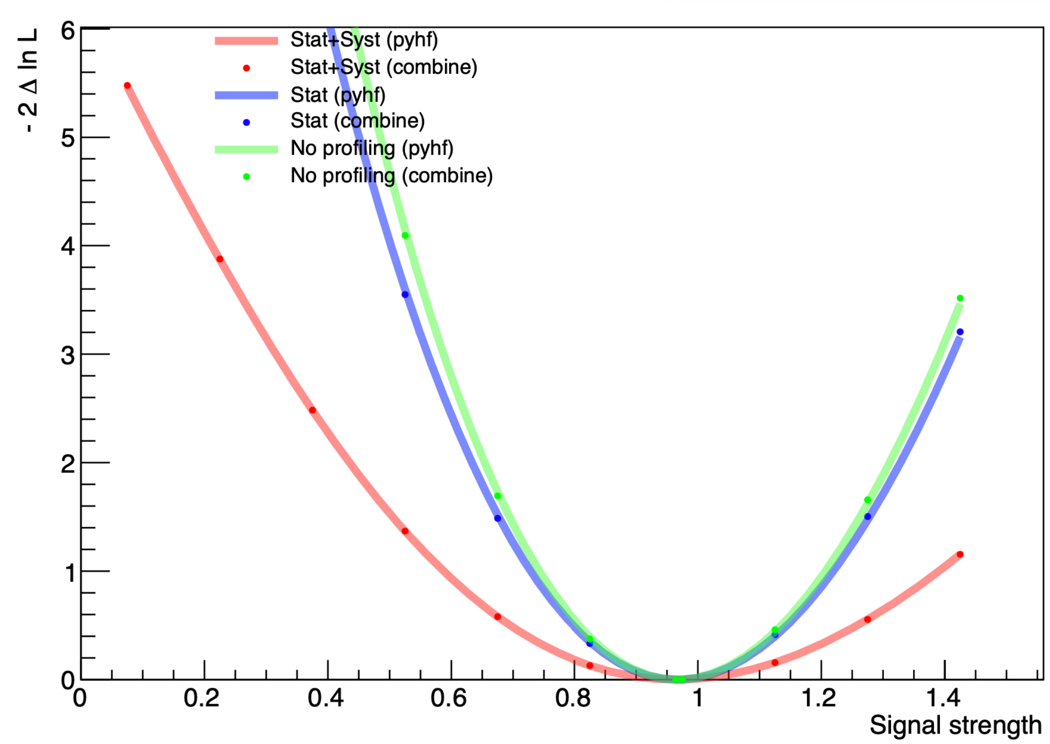




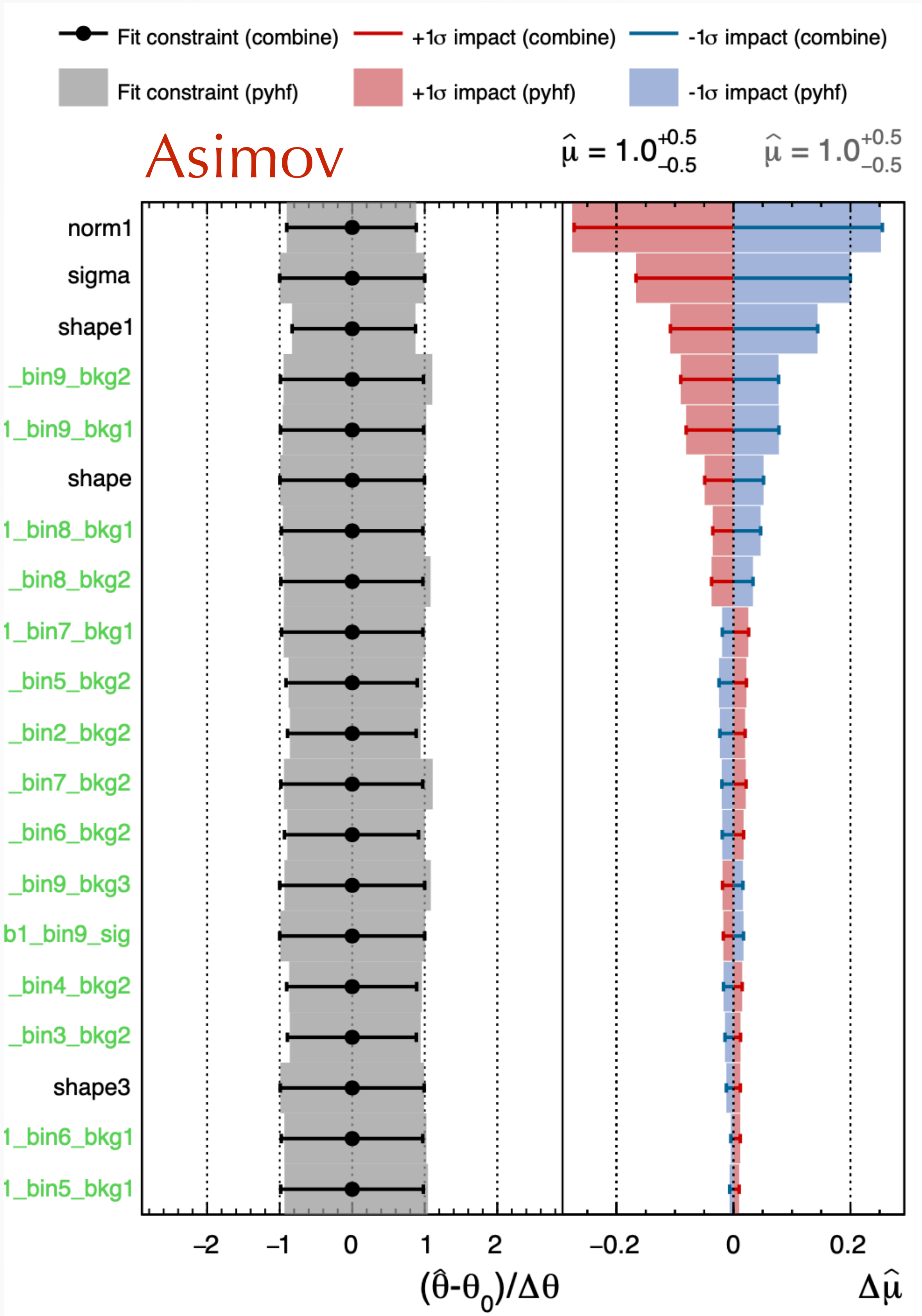
from A. Gilbert's talk

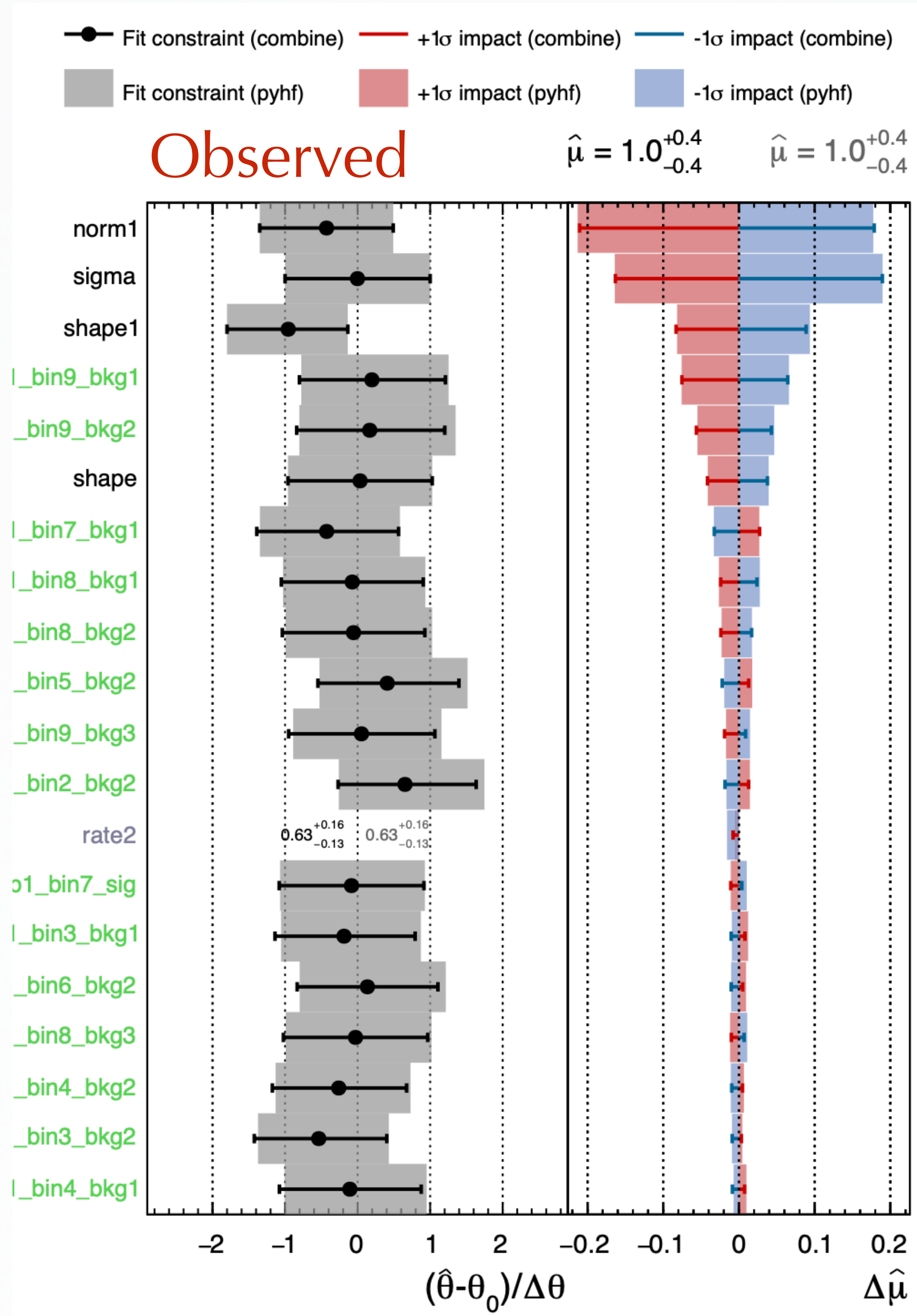
Thanks to N. Smith, N. Wardle (combine team) and A. Held, M. Feickert, G. Stark (pyhf team) for fruitful discussions





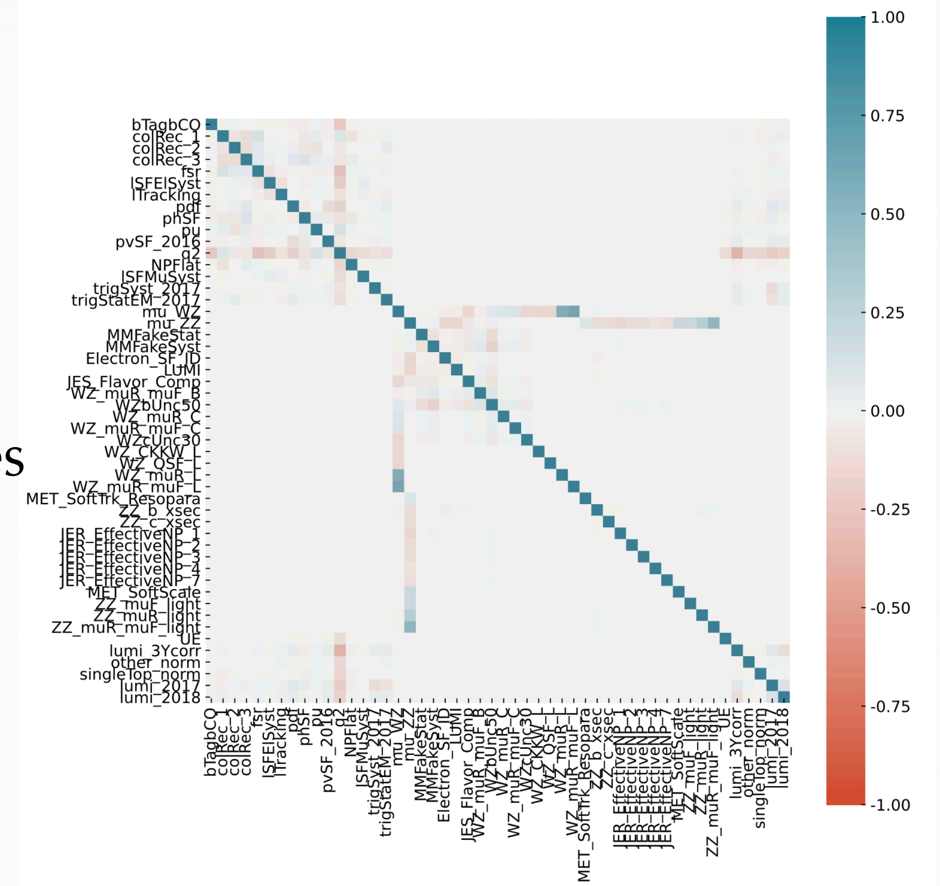
Common fit model

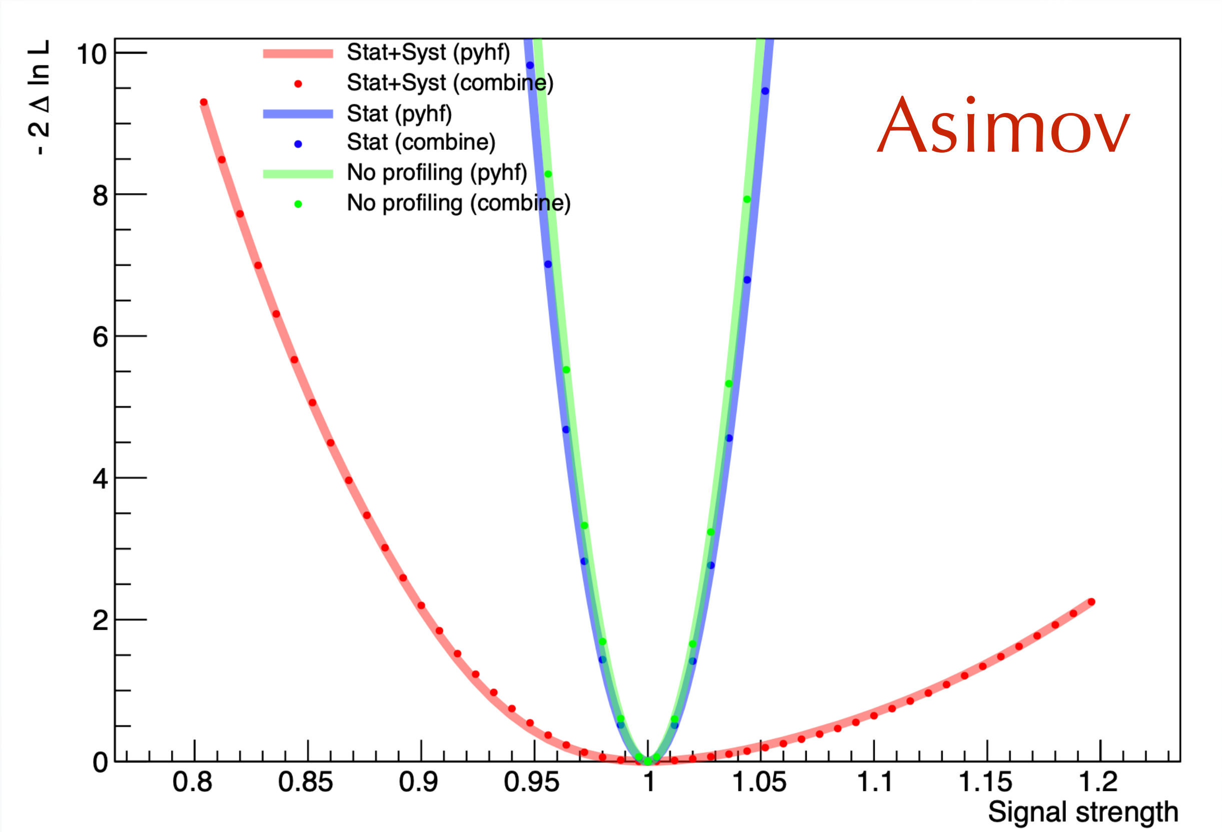


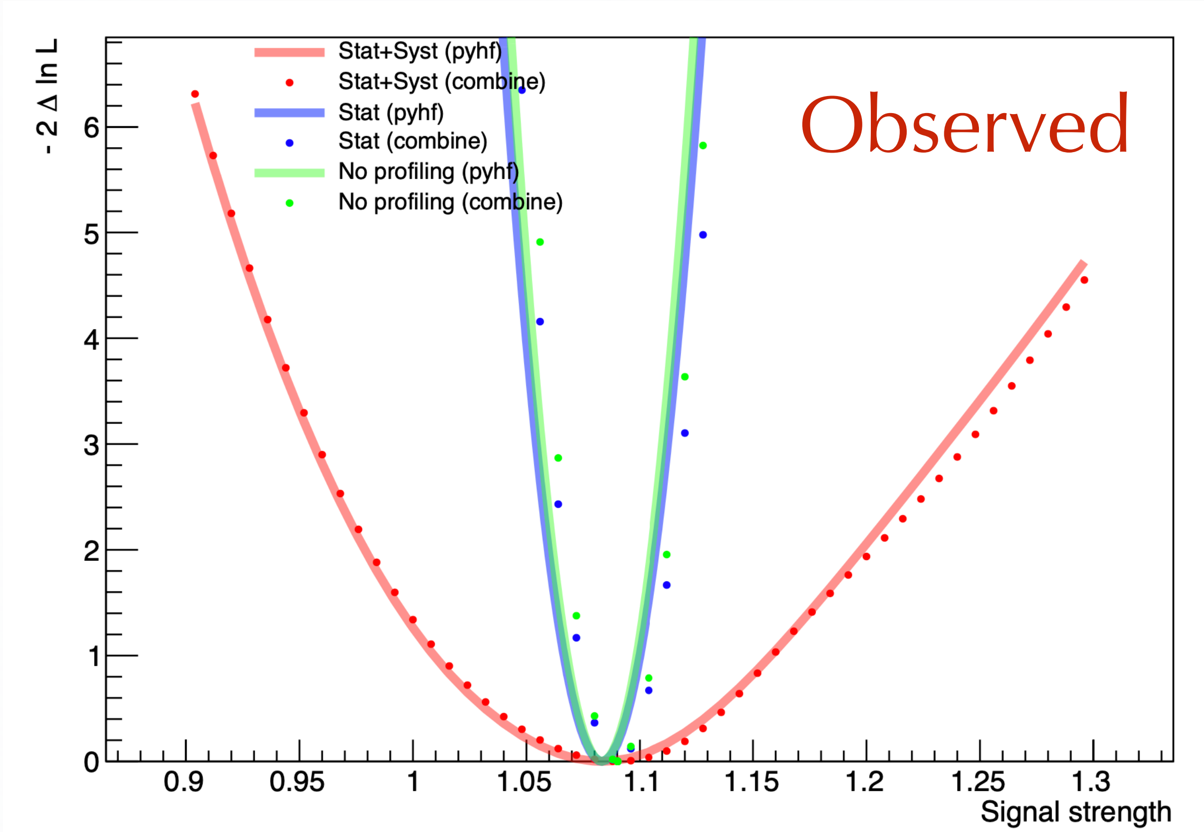


Common fit model

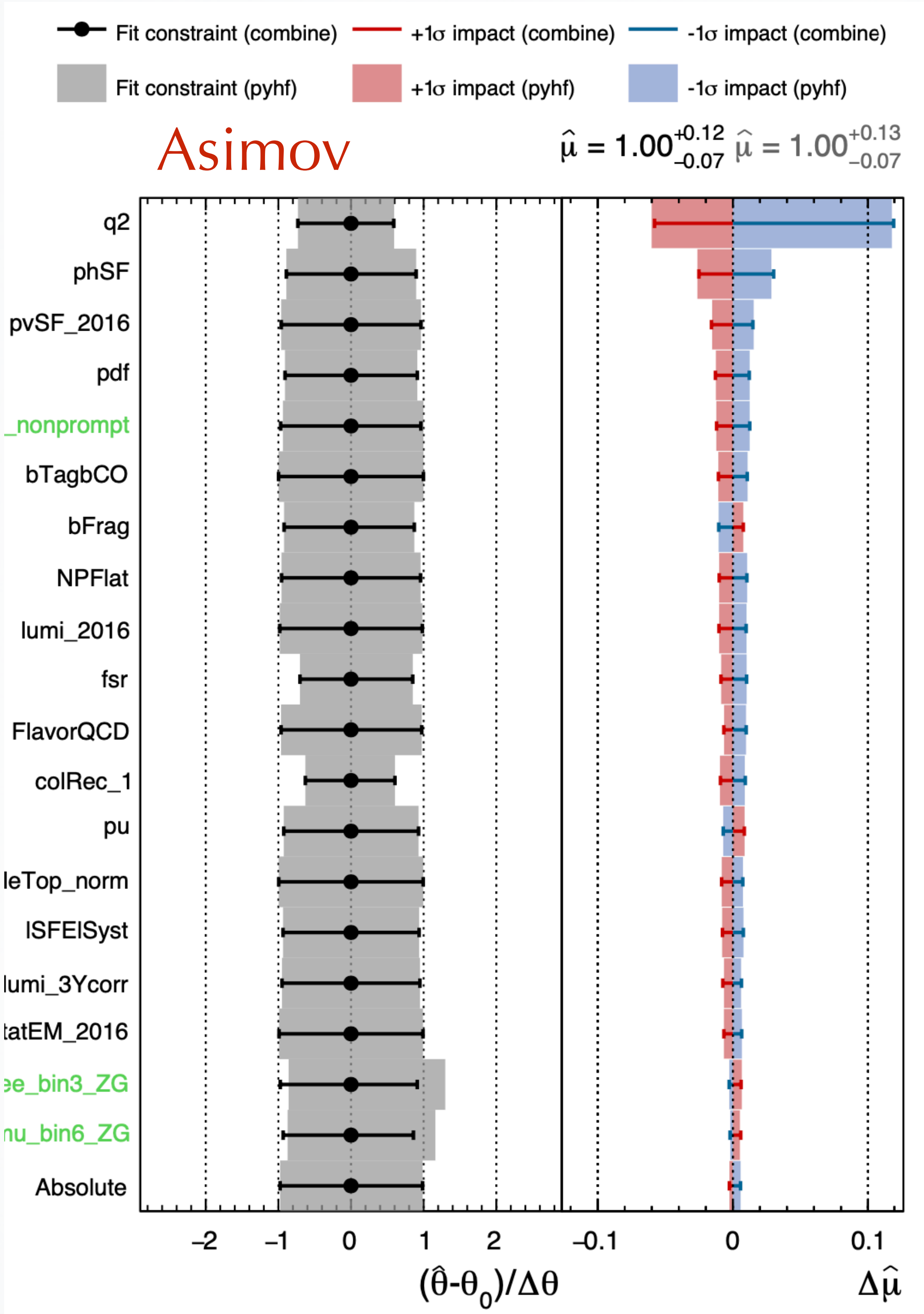
- Some differences observed when using **complex** models: ttZ (ATLAS) + ttγ (CMS)
- Generally reproducing **similar EFT sensitivities** with translated inputs, but needs further polishing for a perfect match
- Currently works with a **full BB** treatment of statistical uncertainties - need to understand why BB-lite does not give identical results
- Good progress on matching **minimization** procedures in both tools
- A **prototype** for the first full reco ATLAS+CMS combinations

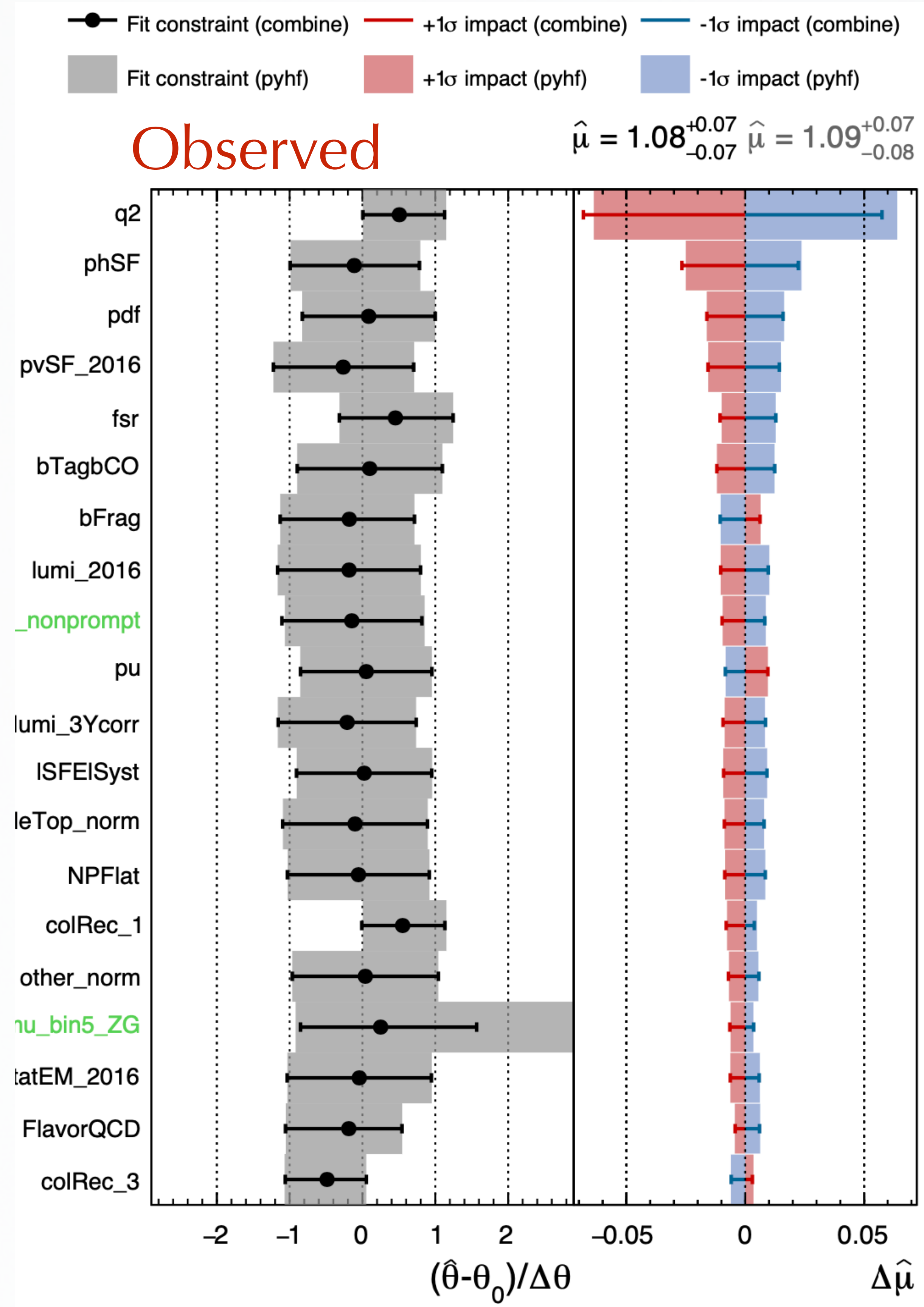




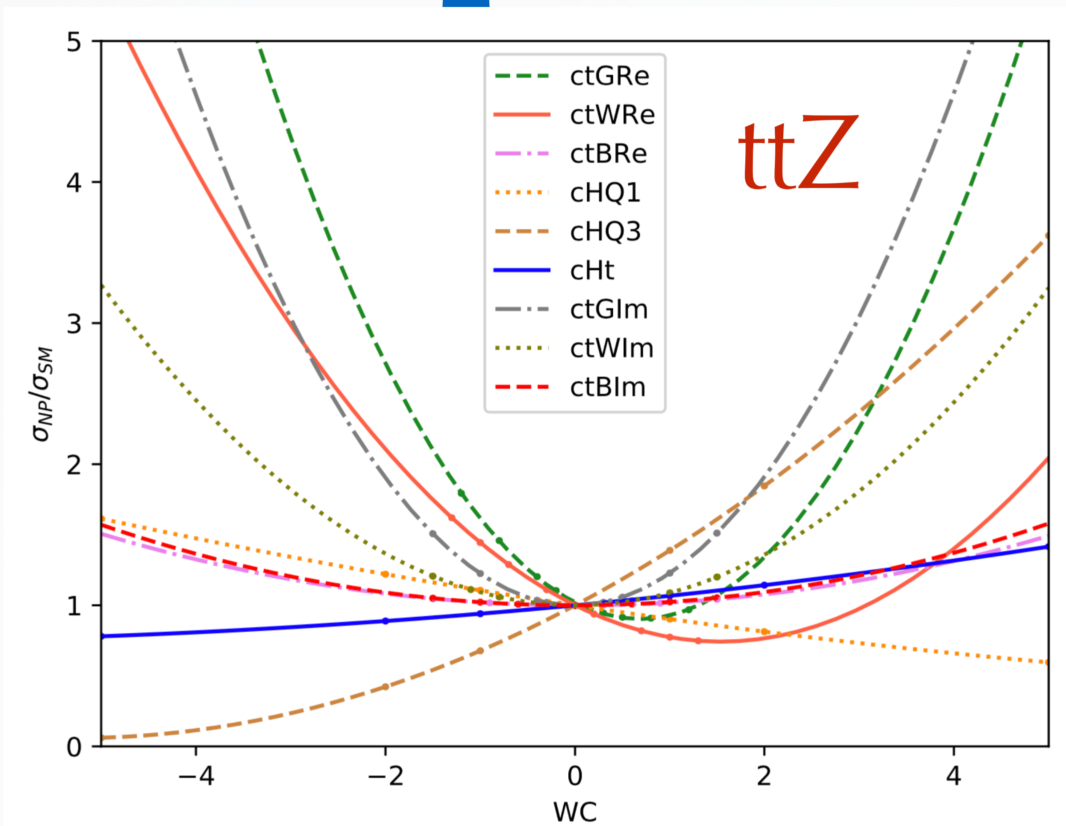


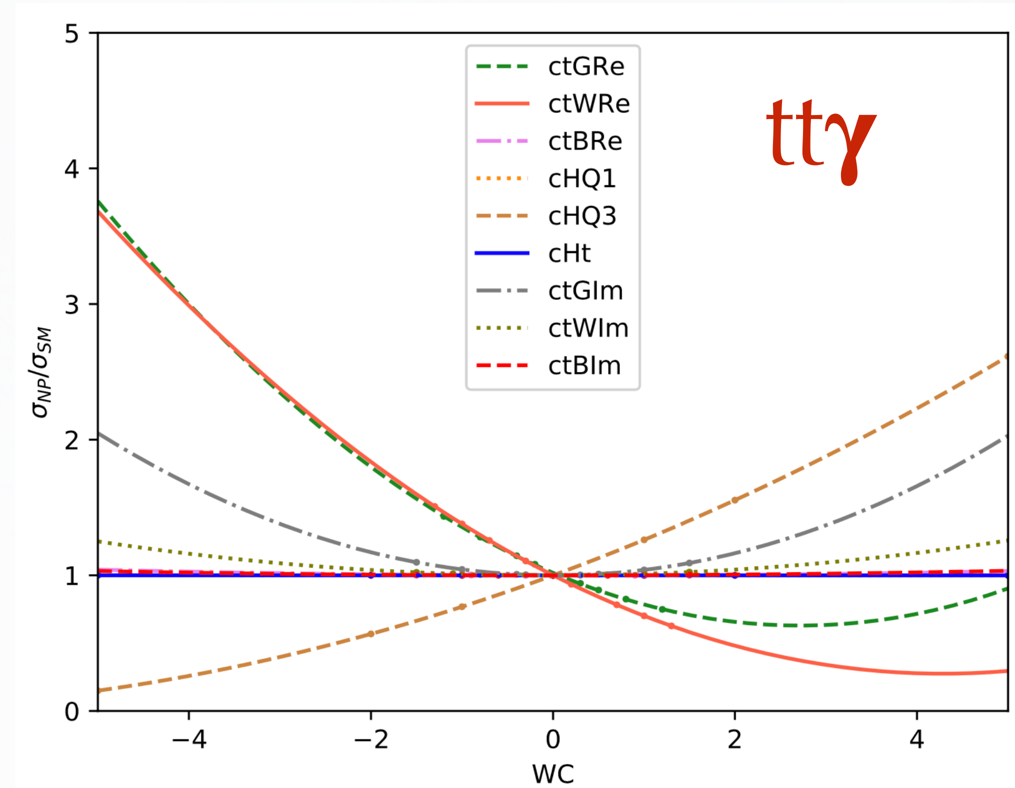
Common fit model





EFT parametrization

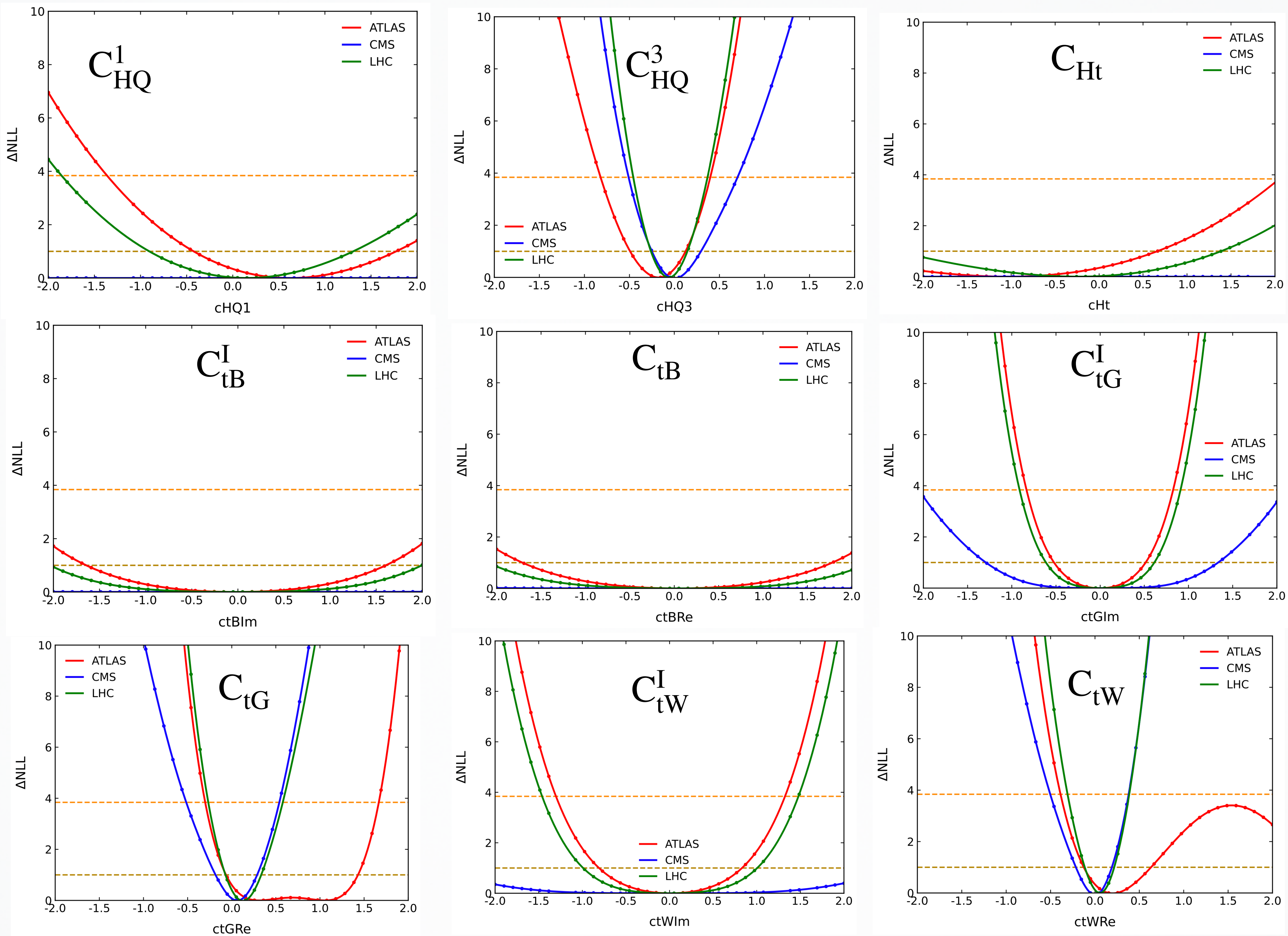




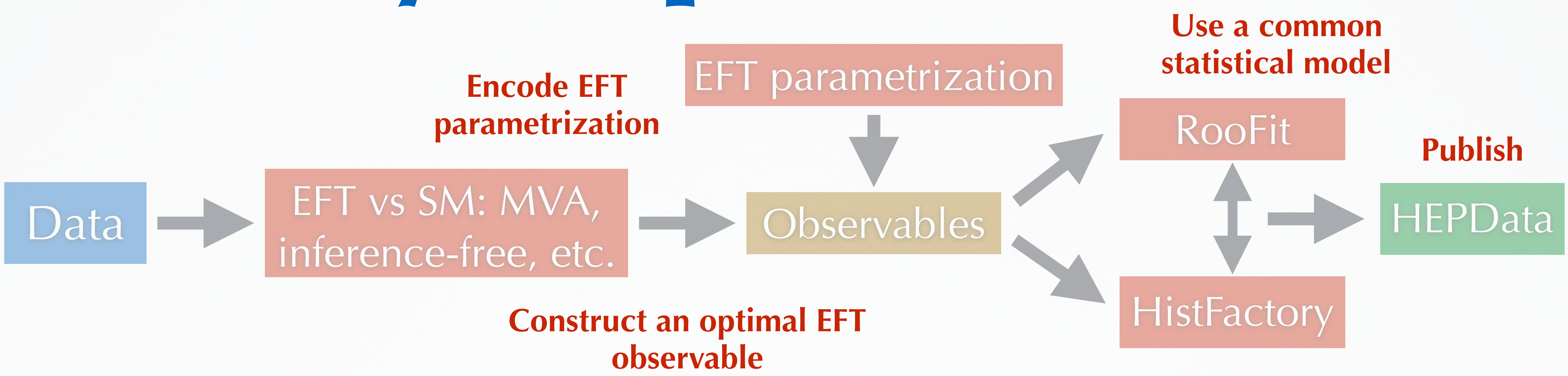
- Only likelihood scans are published for EFT results → **non-trivial to combine** (common systematic sources would be included multiple times)
- Derive a generator-level EFT parameterization and apply it in the bins of a **reco-level observable** (or cross section, if no corresponding observable is available at generator level)
- Such reweighing is only applicable to **simple** (one or two) kinematic variables
- **Proposal**: serialize to a bin-wise (and process-wise) EFT parameterization of event weights at reco-level and publish it to HEPData (e.g. as JSON, HDF5, etc.)

	bin	process	p_ctGRe	p_ctWRe	p_ctBRe	p_cHQ1	p_cHQ3	p_cHt	p_ctGIm	p_ctWIm	p_ctBIm	p_SM
0	pt25to50	ttZ	0.955115	-16.318899	-24.368322	1.217147	0.593863	22.704371	7.287961	34.34906	19.959084	178.957741
1	pt50to100	ttZ	1.049587	-2.443358	-7.818102	1.692363	-3.481057	14.057936	11.92833	43.699131	20.88683	77.626132

Likelihood scans



Analysis preservation



- What is the best way to **preserve** an analysis from an **EFT** point of view?
- How to **publish** a **statistical model**? See, for example: SciPost Phys. 12 (2022) 037
- **Unfolded differential measurements**: can serve as a viable option in some cases → no information about backgrounds
- **Inference-free likelihoods**: encode primary data, background estimates, and uncertainty correlations; e.g. as machine-learning proxy (e.g. DNNLikelihood, Inference-free, Tree boosting etc.) → combinations based on likelihood scans are non-trivial
- **Simplified likelihoods**: approximation to a full likelihood → must use a Gaussian approximation for uncertainties (see talks by N. Berger and N. Wardle)
- **Reco-level distributions / Full likelihoods**: include full information about all processes and uncertainties → need to agree on common publication format and fitting tools; complexity of inputs