

Combine ↔ Pyhf

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LHC Reinterpretation Forum

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Combining full likelihoods

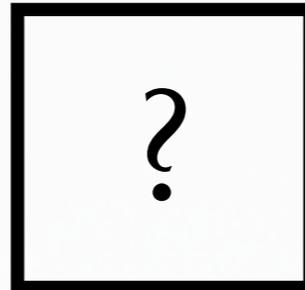
- ◆ Combining the full likelihood information represents the most **accurate** combination between the experiments
- ◆ Both ATLAS and CMS have many examples of publishing analyses that can be reinterpreted by using **simplified likelihoods**
- ◆ **Likelihood scans** based on full models are great for **reinterpretation** but impossible to combine
- ◆ **Full statistical model** descriptions (mainly for BSM searches) are made public by ATLAS; ATLAS and CMS fitting tools (**pyhf**, **combine**) are available publicly
- ◆ Compare the fitting tools to agree on a **common procedure** to **publish reconstruction-level results** for a full-likelihood combination (not just BSM!)
- ◆ Use **EFT fits in the top quark sector** as working example: predictions are based on SMEFTsim; BSM enters in multiple processes across various analyses

Full reco information



HistFactory

RooFit

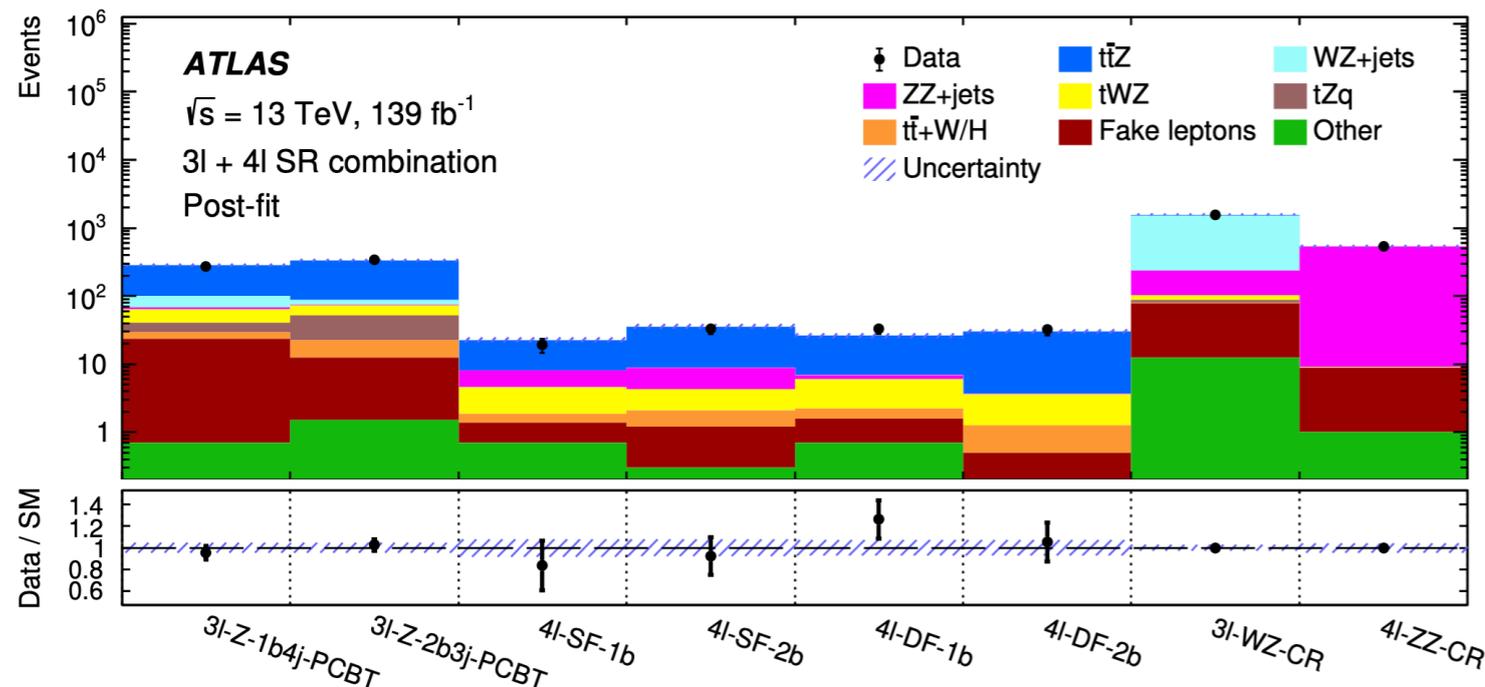
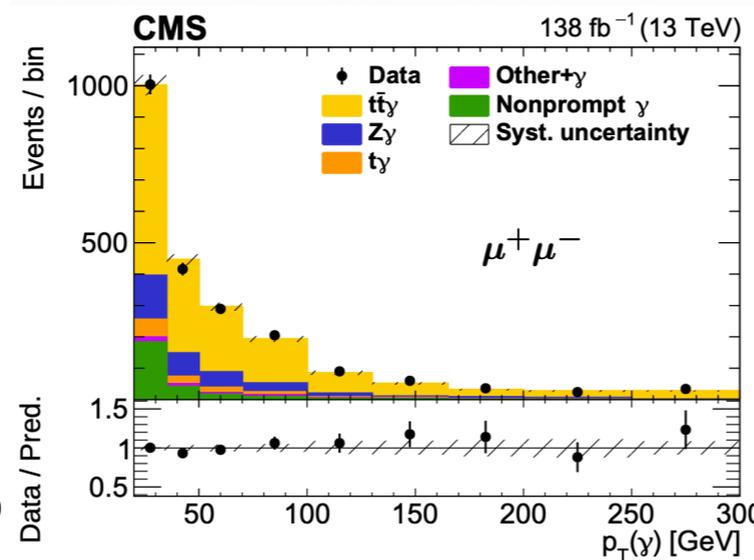
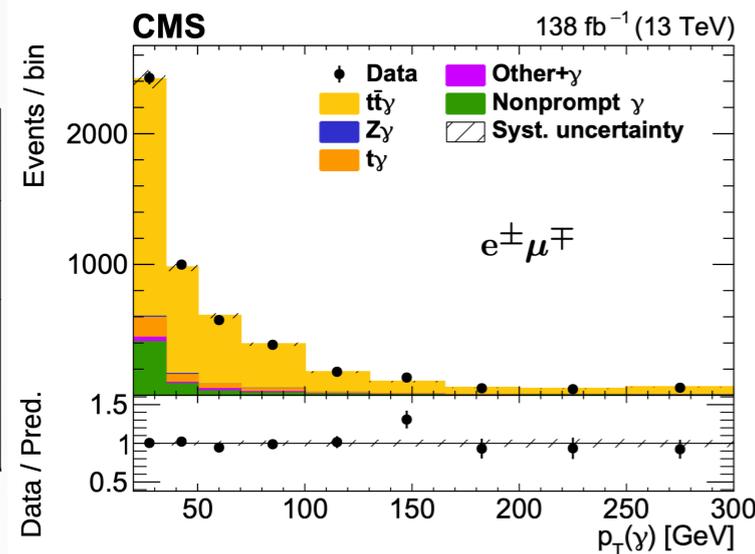


+EFT



LHCtopWG
EFT fit

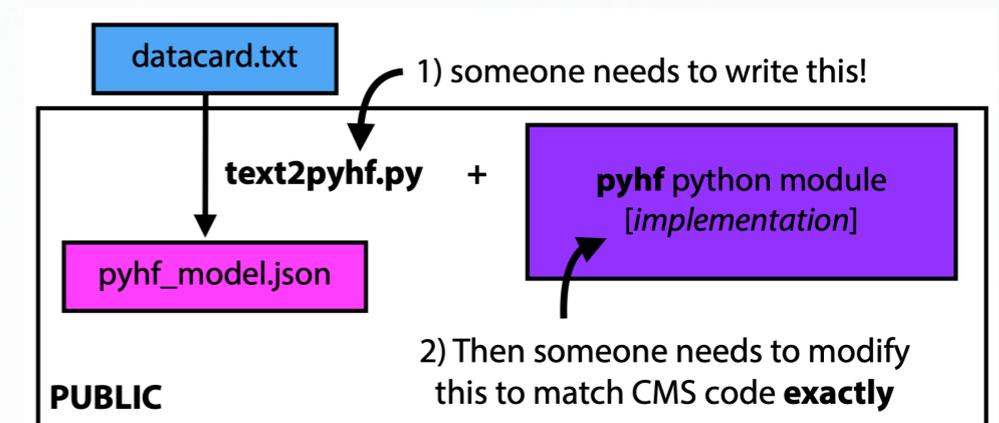
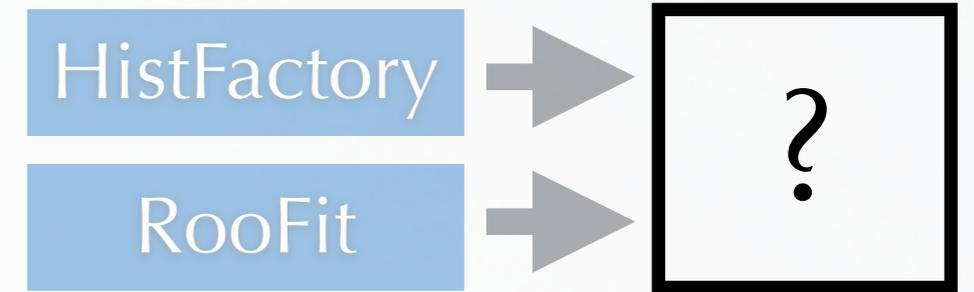
LHC EFT
WG



- ◆ Use measurements (ttZ , tty) 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**

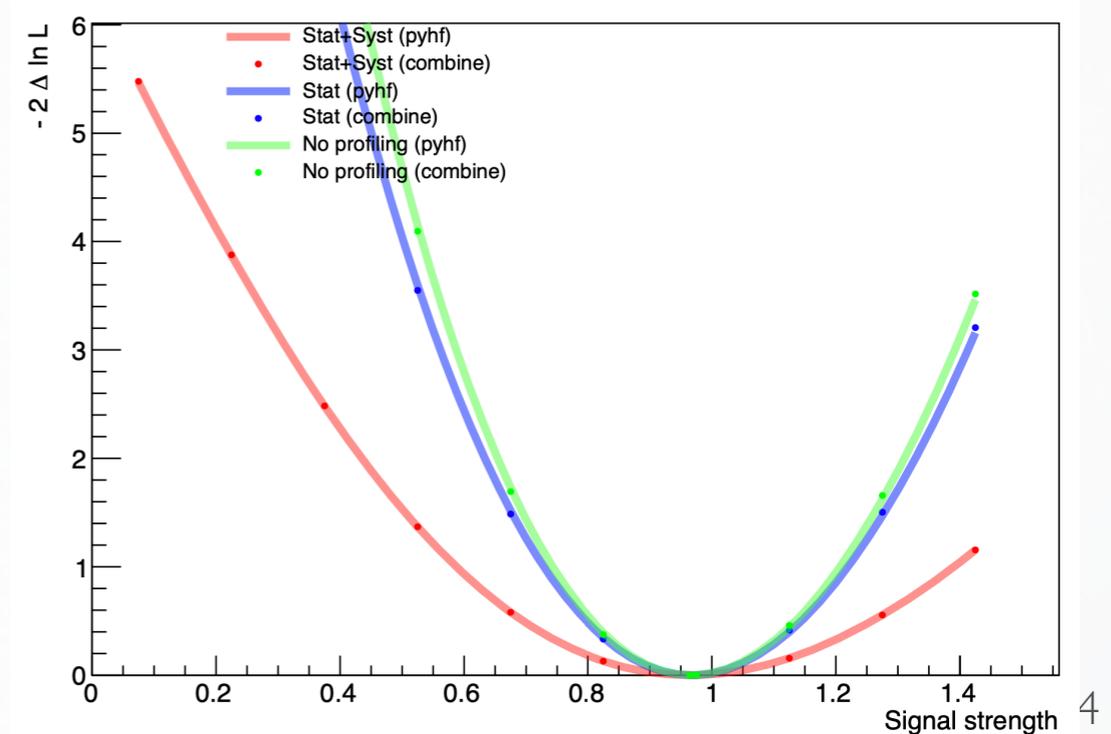
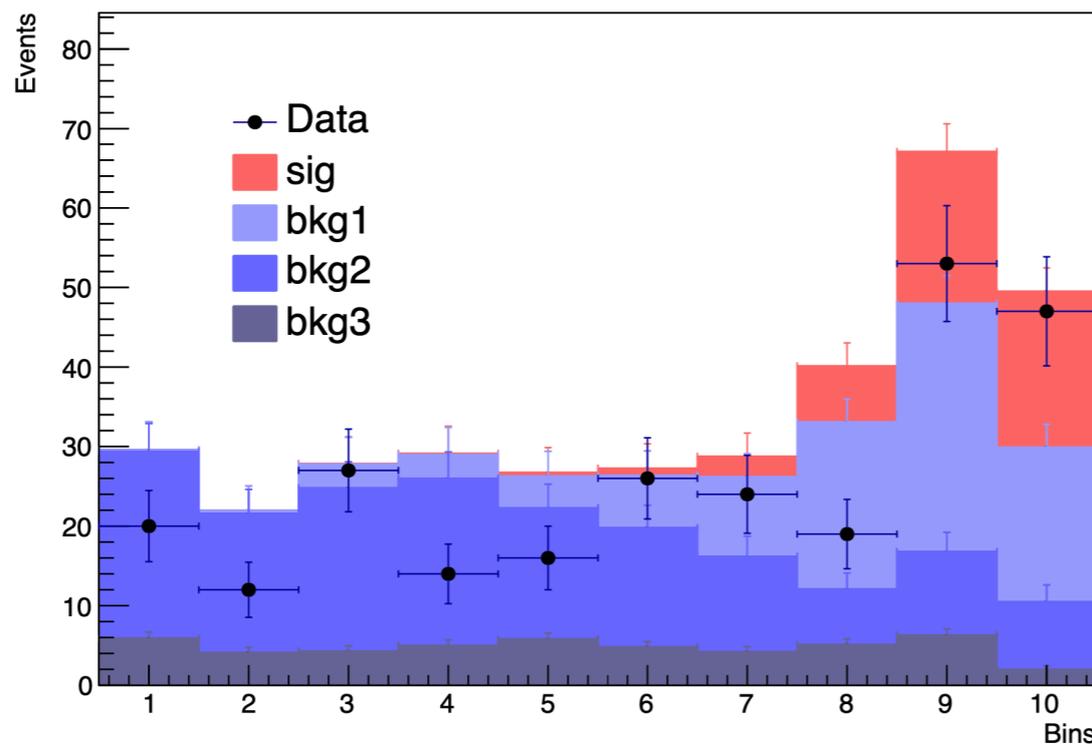
Common fit model

- ◆ 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, developed by Peter Ridolfi
- ◆ Independently developed and cross-validated as part of **Combine** for a **combine**→**pyhf** translation
- ◆ **Good agreement** for **simple** models

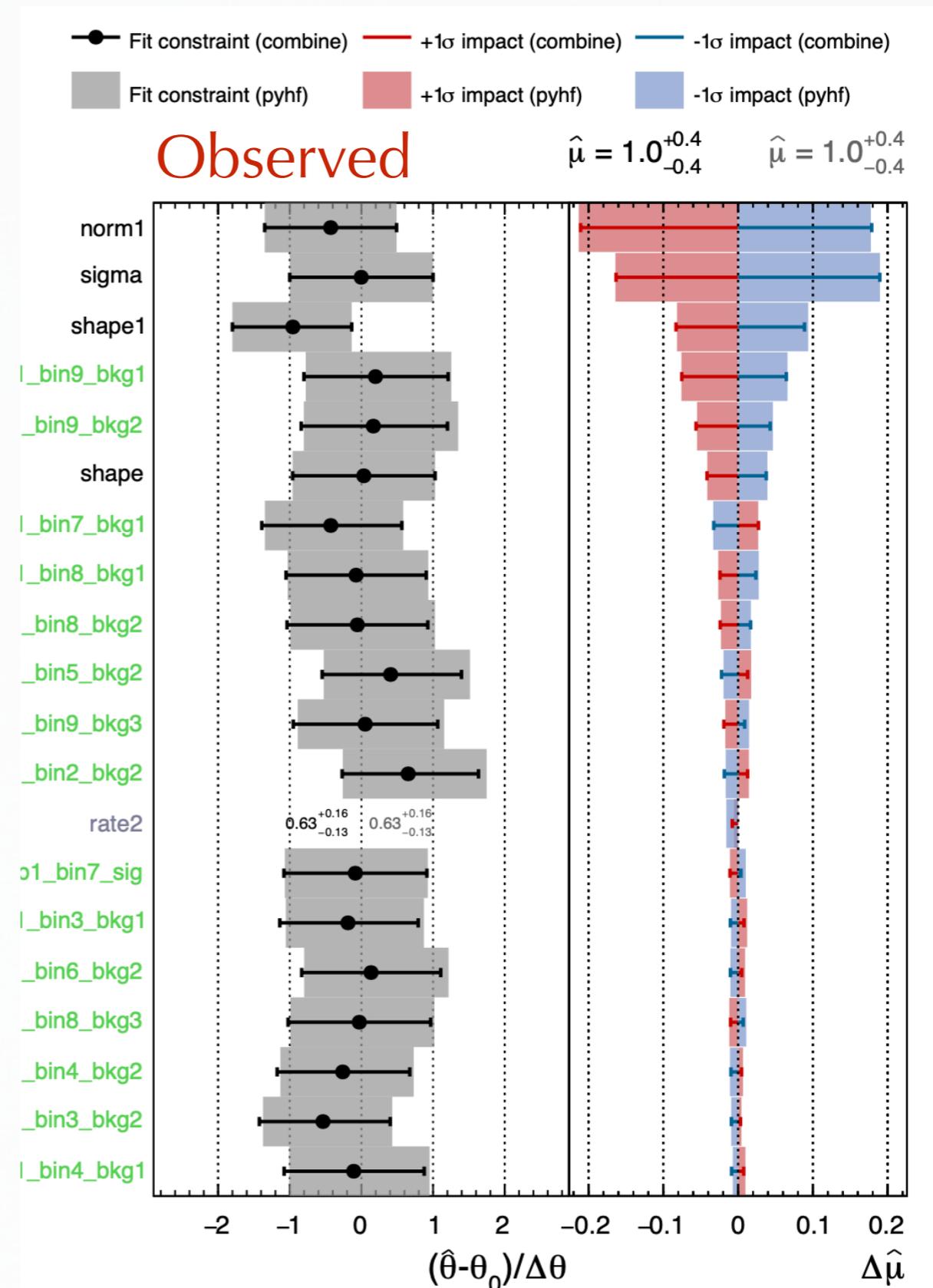
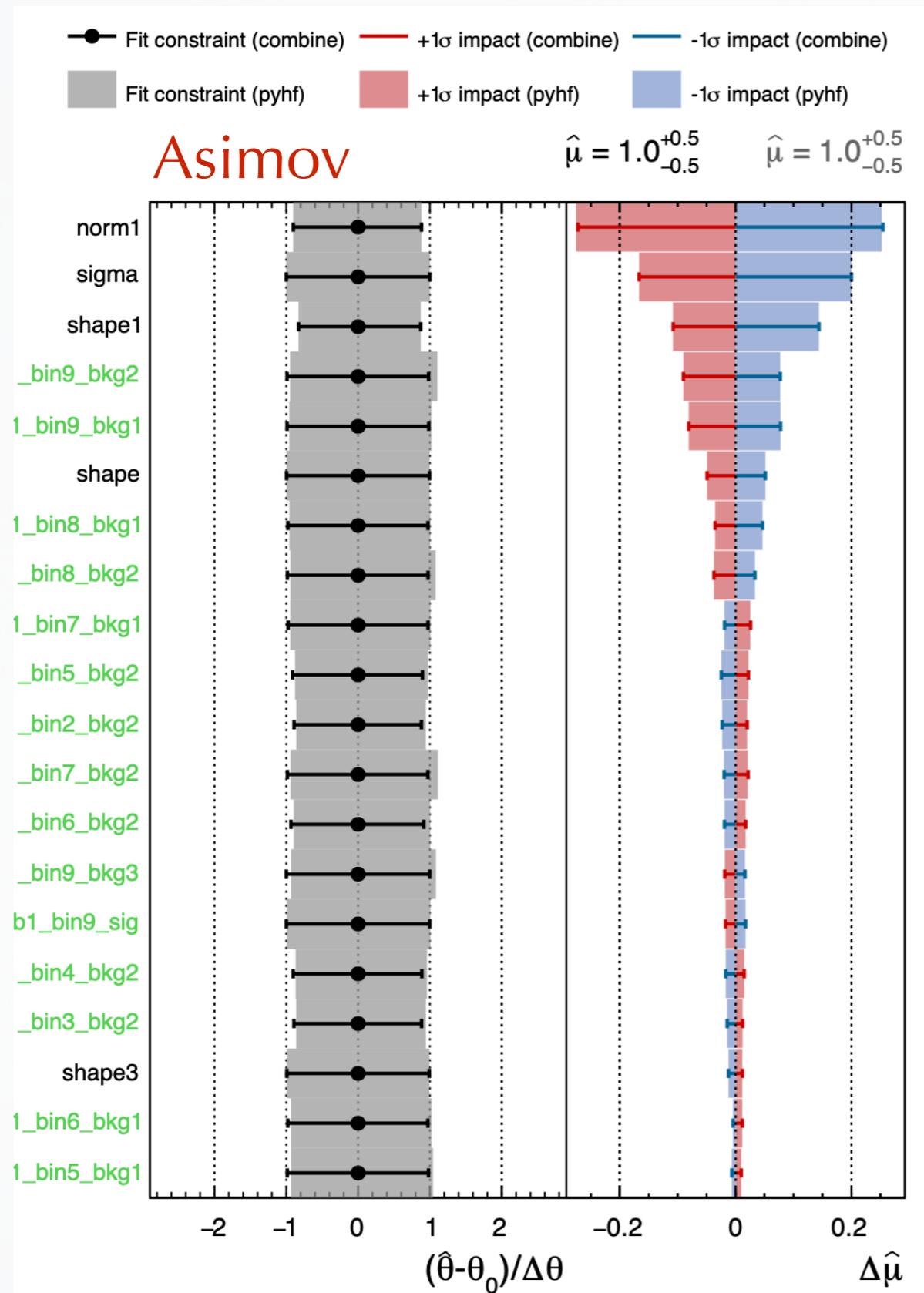


from A. Gilbert's talk

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

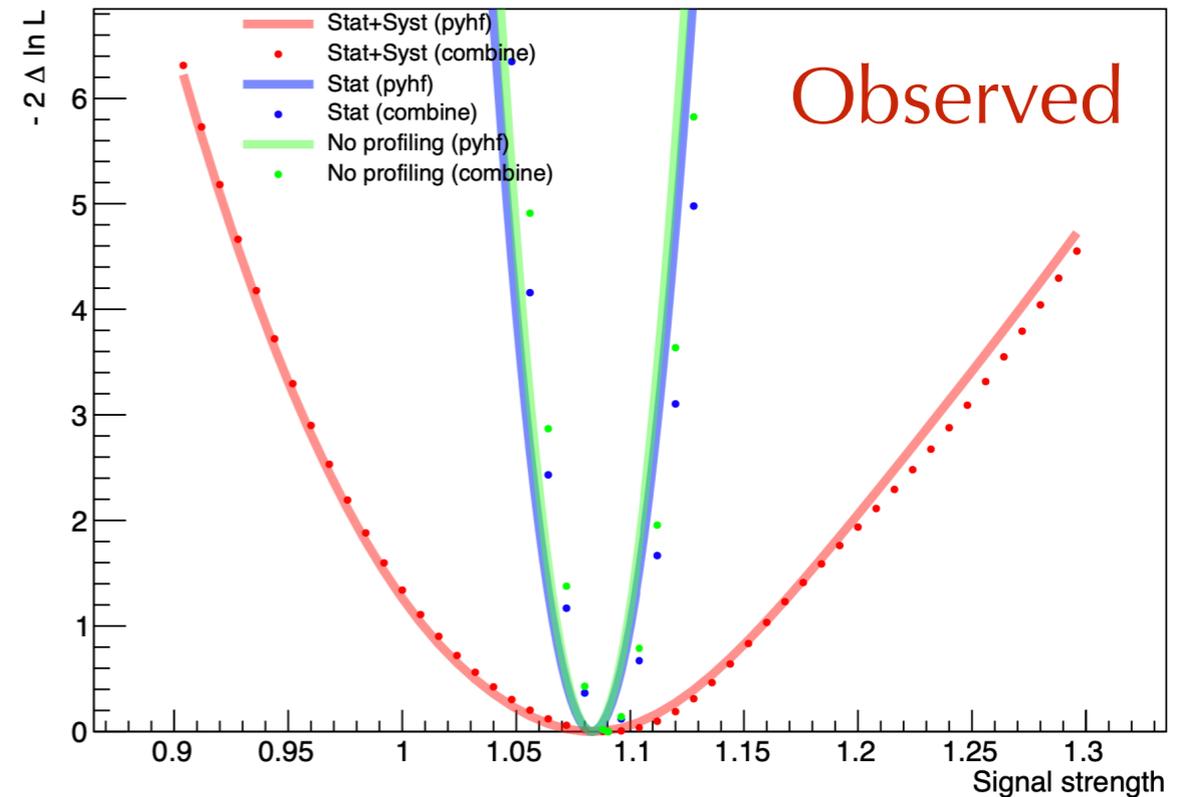
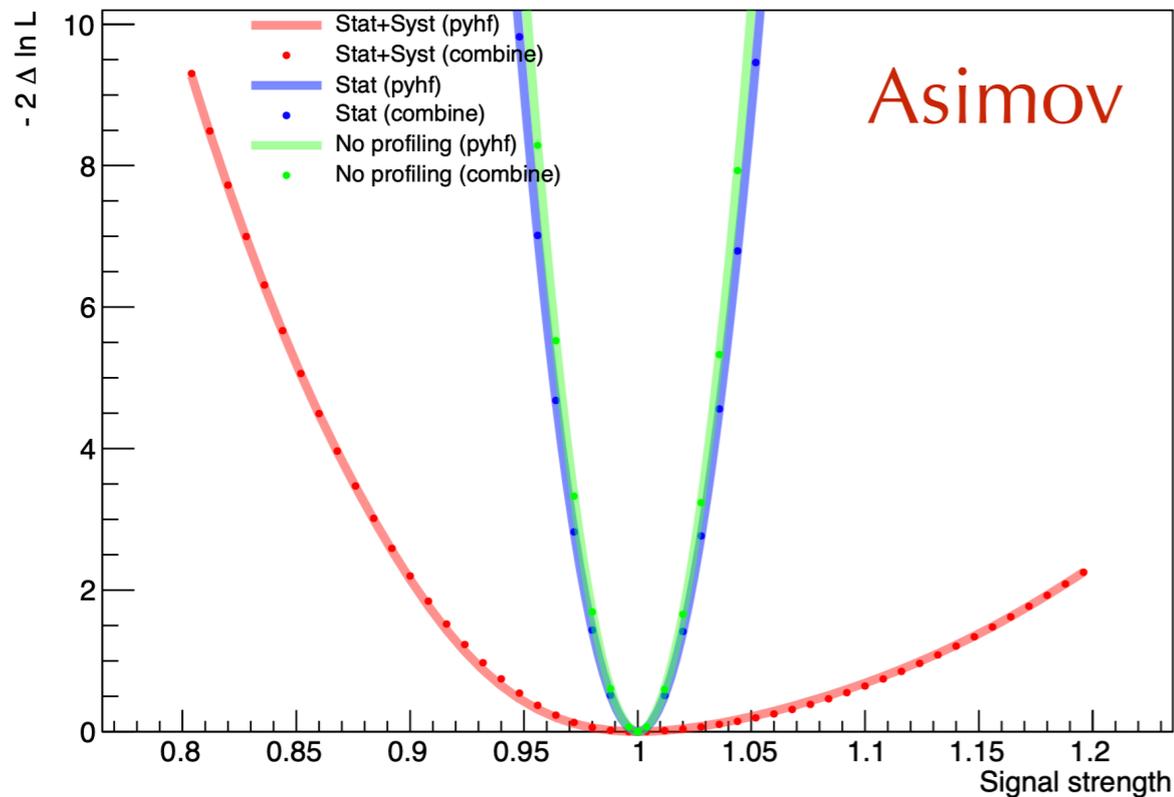
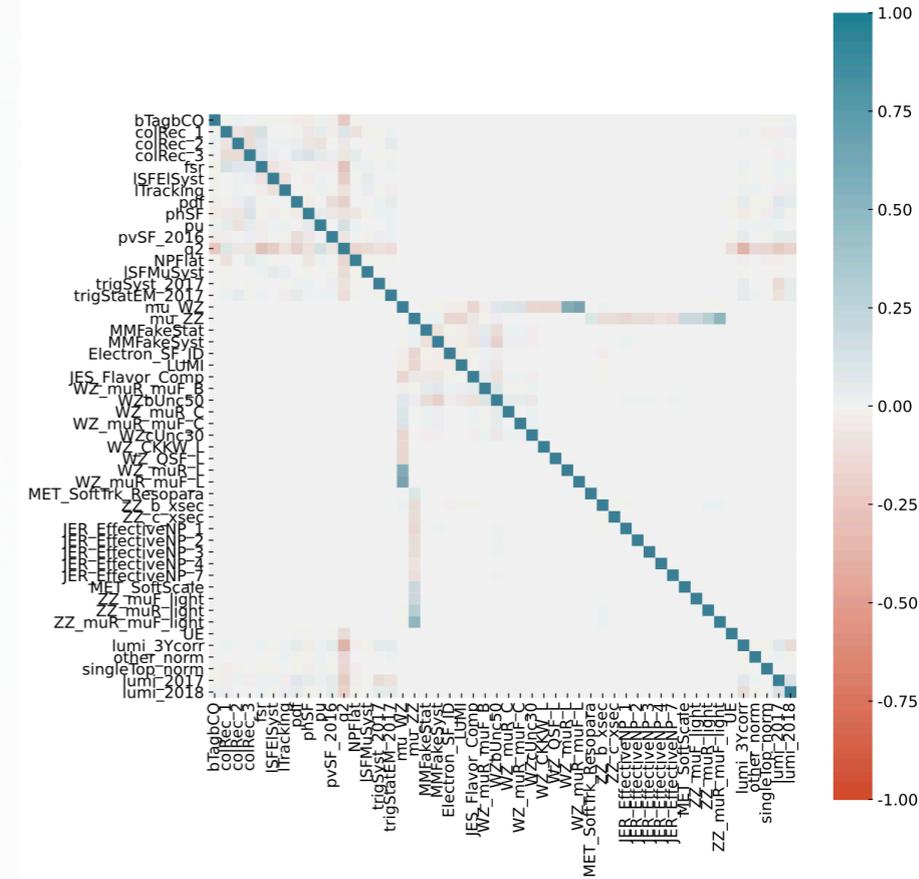


Common fit model

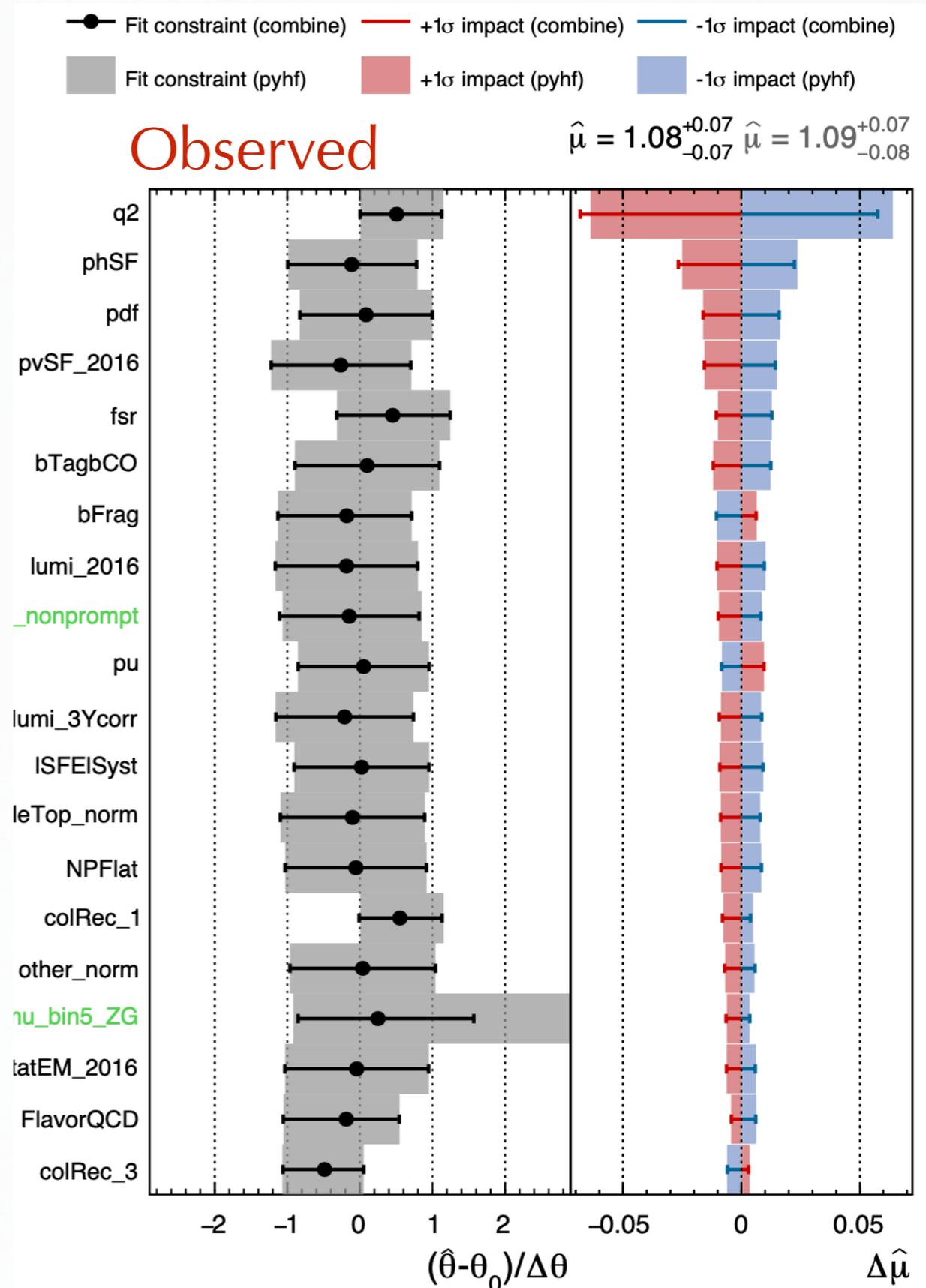
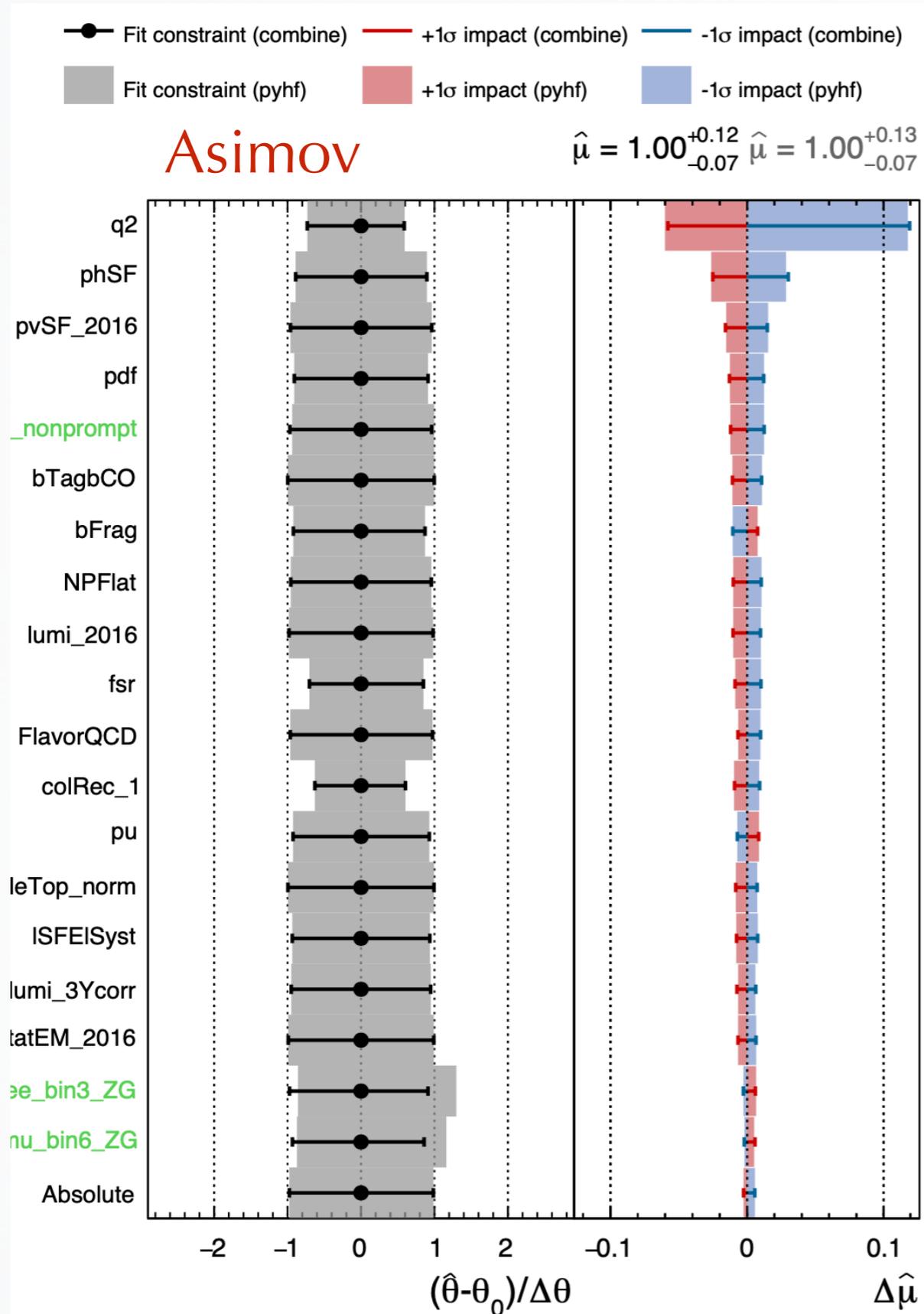


Common fit model

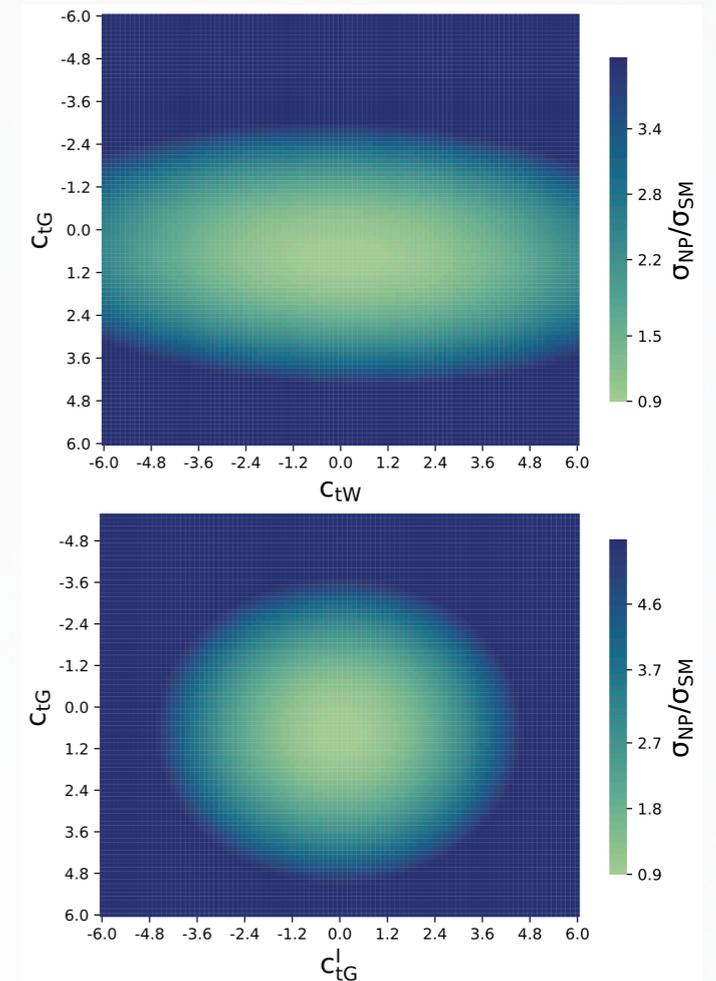
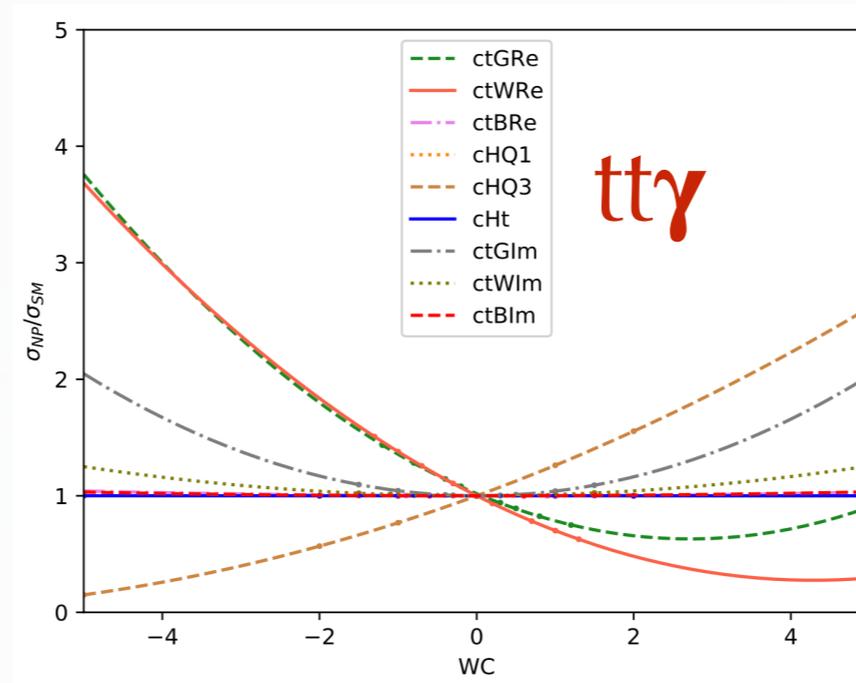
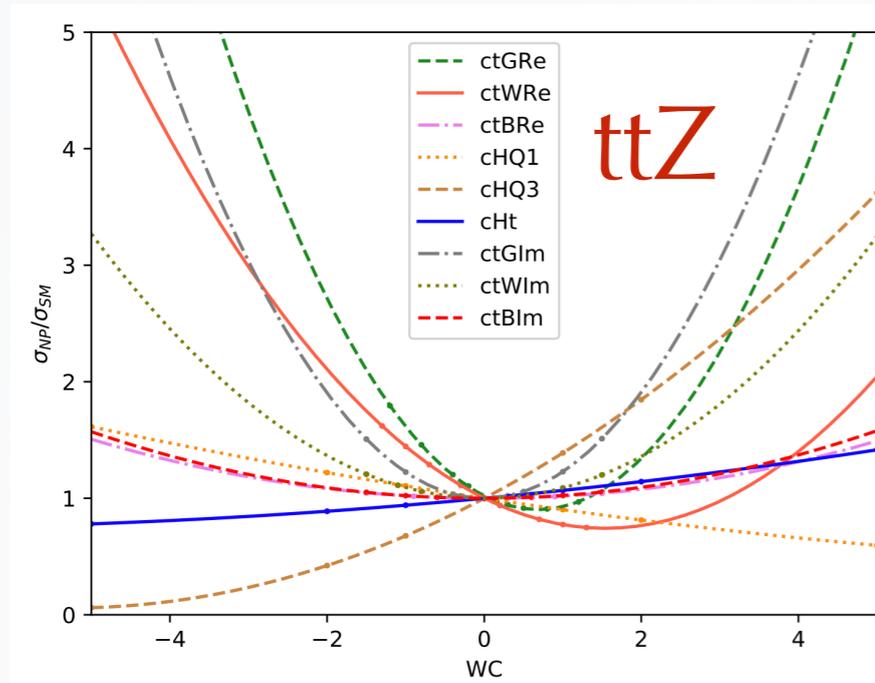
- ◆ Some differences observed when using **complex** models:
ttZ (ATLAS) + ttγ (CMS)
- ◆ Generally reproducing **similar EFT sensitivities** with translated inputs, but needs further polishing for a perfect match
- ◆ Currently works with a **full Barlow-Beeston (BB)** treatment of statistical uncertainties (more info [here](#)) - 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



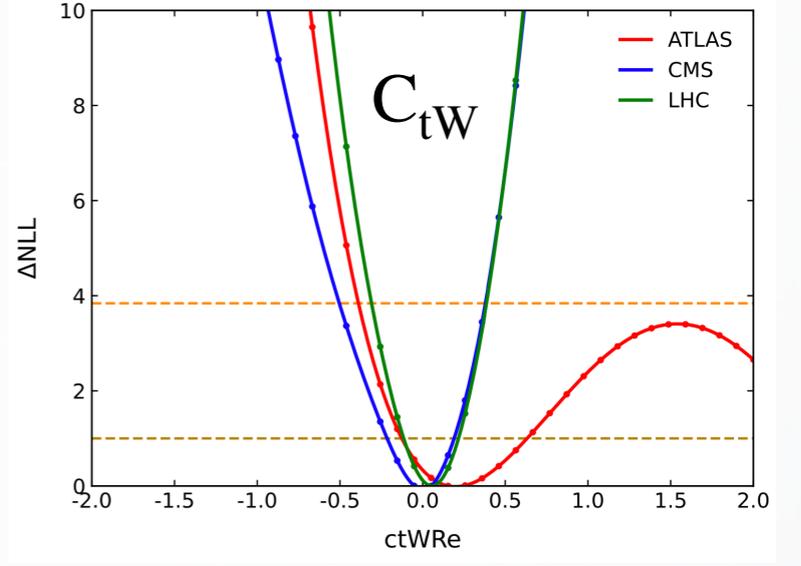
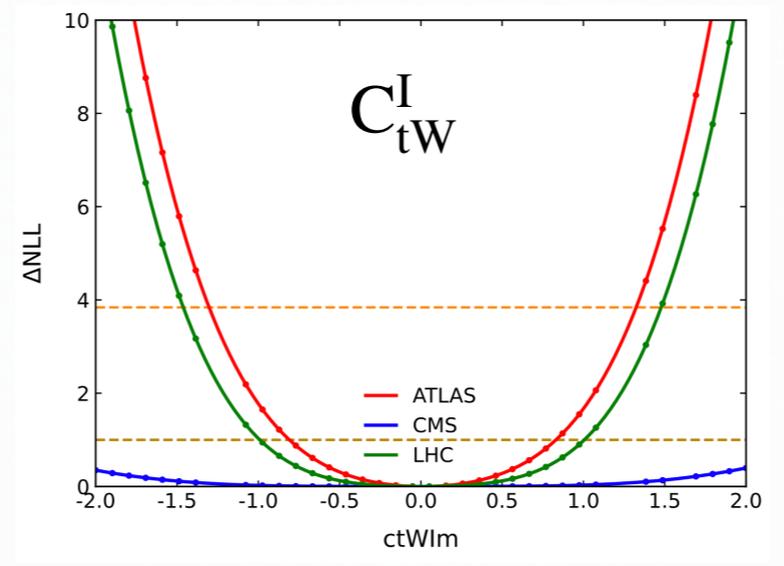
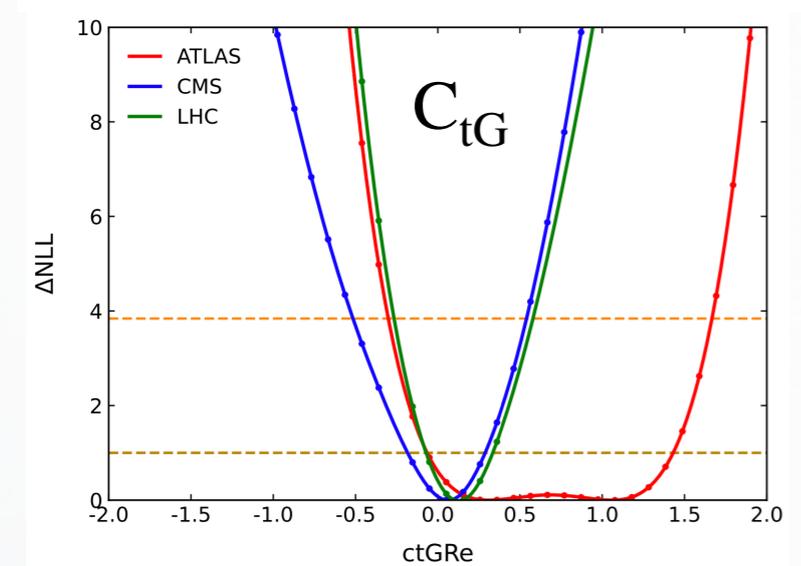
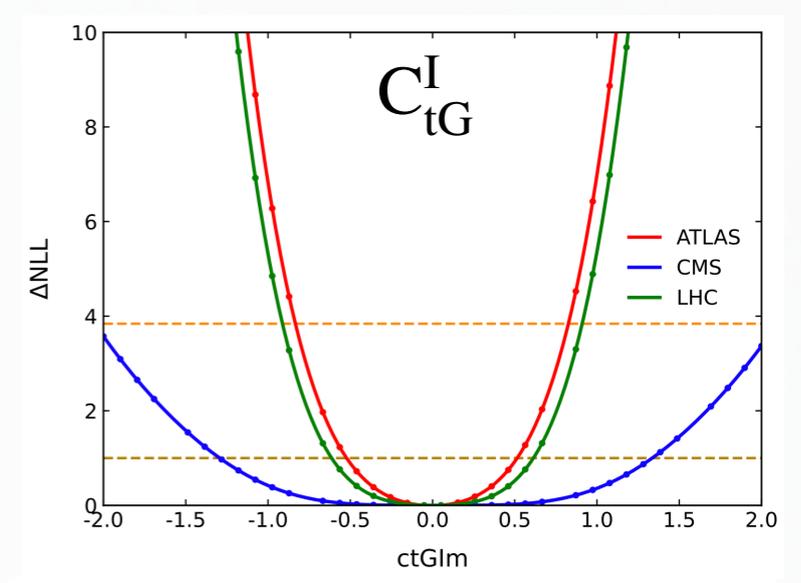
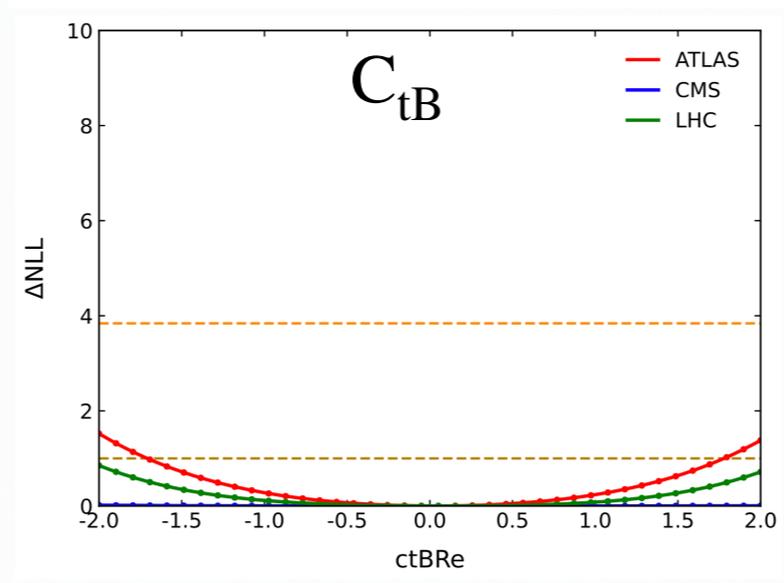
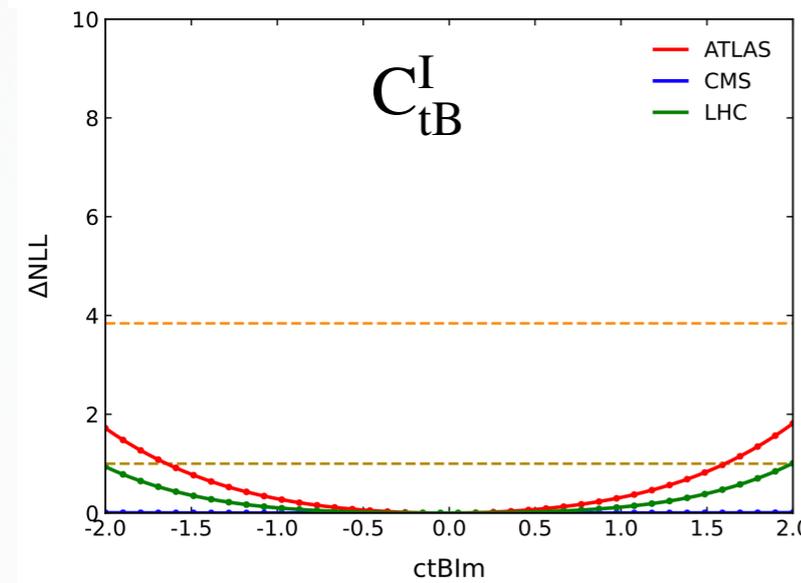
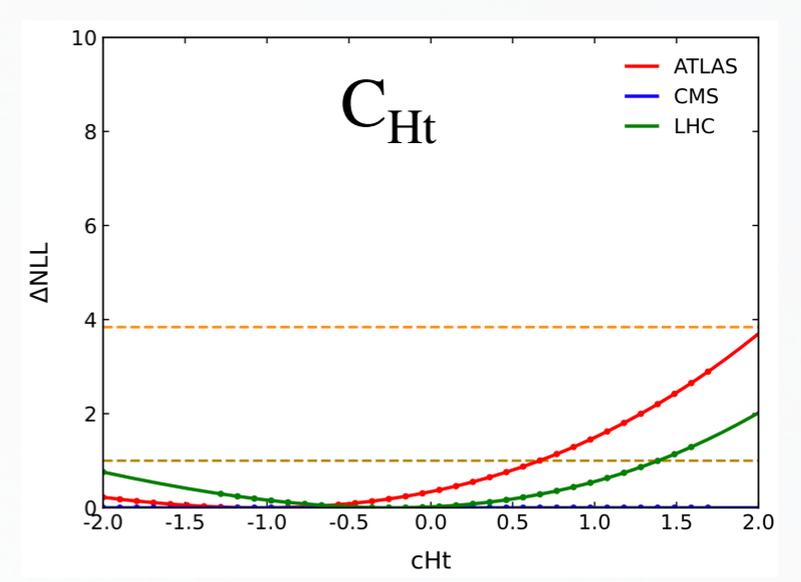
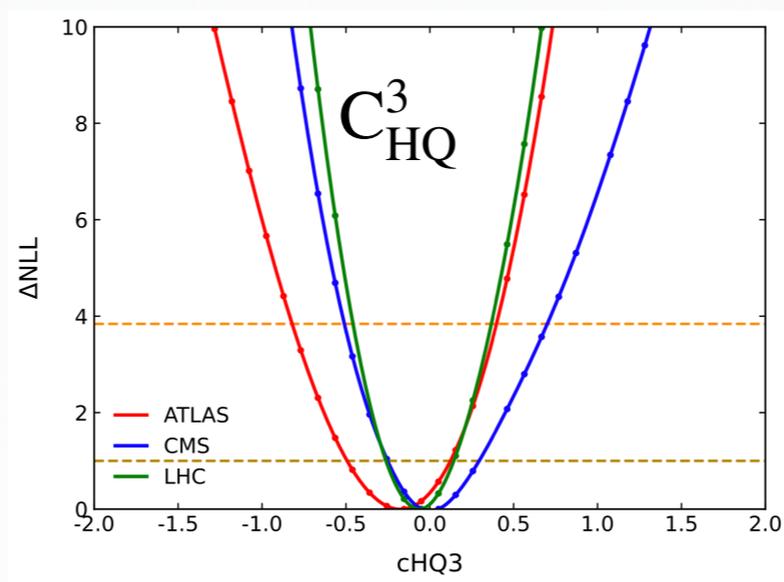
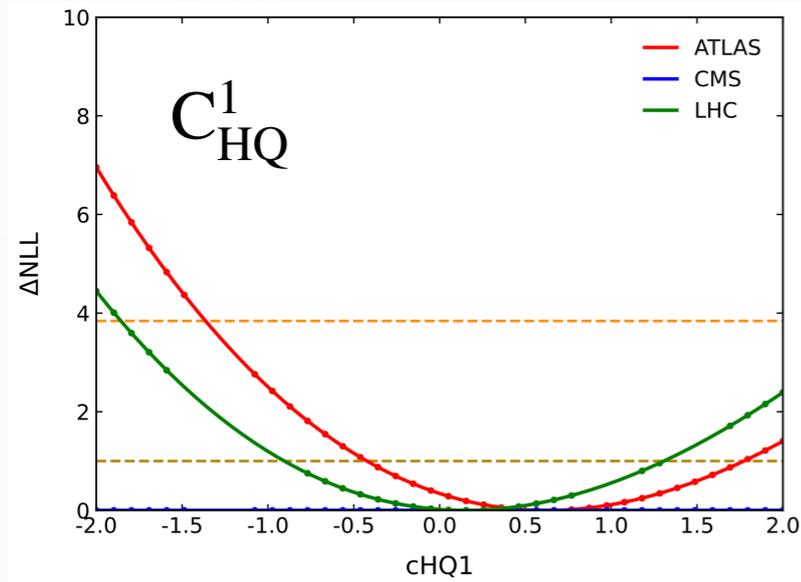
EFT parametrization



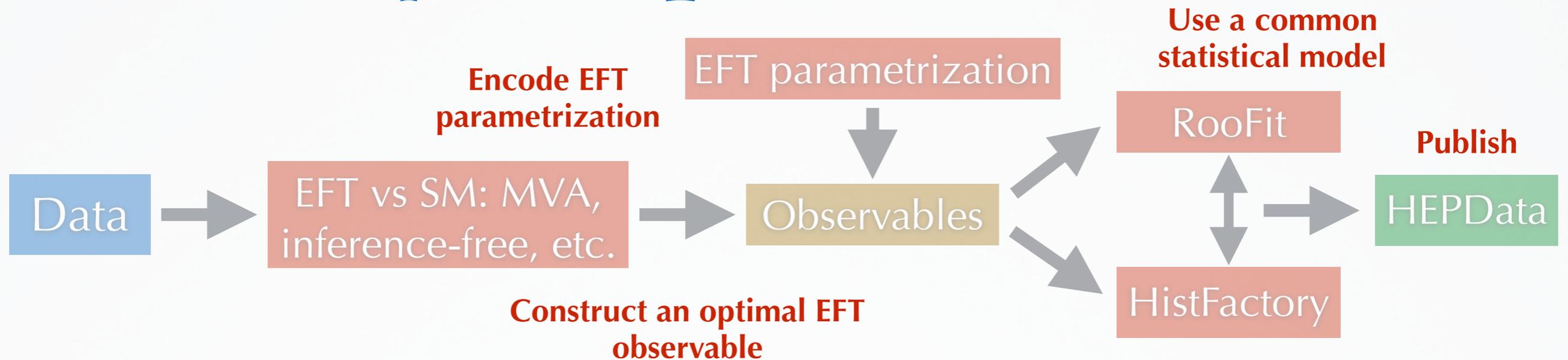
- ◆ Only likelihood scans are published for EFT results → **non-trivial to combine** (common systematic sources would be included multiple times)
- ◆ Derive a generator-level EFT parameterization and apply it in the bins of a **reco-level observable** (or cross section, if no corresponding observable 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 → backgrounds are subtracted under SM assumption
- ◆ **Simplified likelihoods**: approximation to a full likelihood → can use a Gaussian approximation for uncertainties (see talks by [N. Berger](#) and [N. Wardle](#))
- ◆ **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
- ◆ **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