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Status of the joint ATLAS/CMS top-EFT interpretation effort

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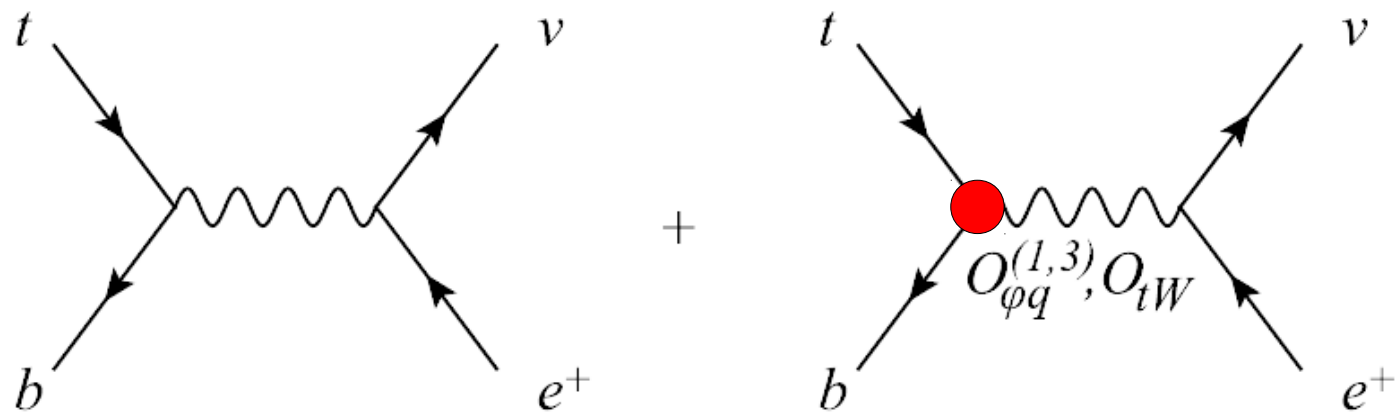
Top working group meeting (07.06.2017)

Motivation

Search for new physics based on EFTs

- Expand SM Lagrangian by all possible and allowed terms
  - additional operators with at least dimension 6 (for the top sector)
  - strengths of the different operators: Wilson coefficient
- **Example:**

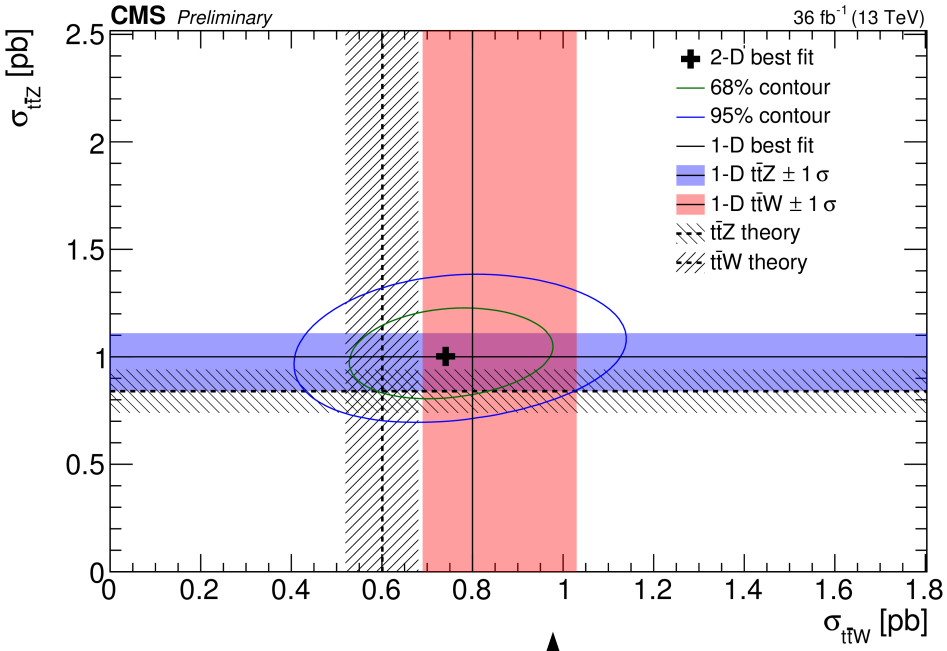


- Different nomenclature (anomalous couplings, Wilson coefficients)
- Individual interpretations (W-helicity, ttV, single top, etc.)
- **Our aim: go for a unified approach including consistent models and measurements**

Individual interpretations

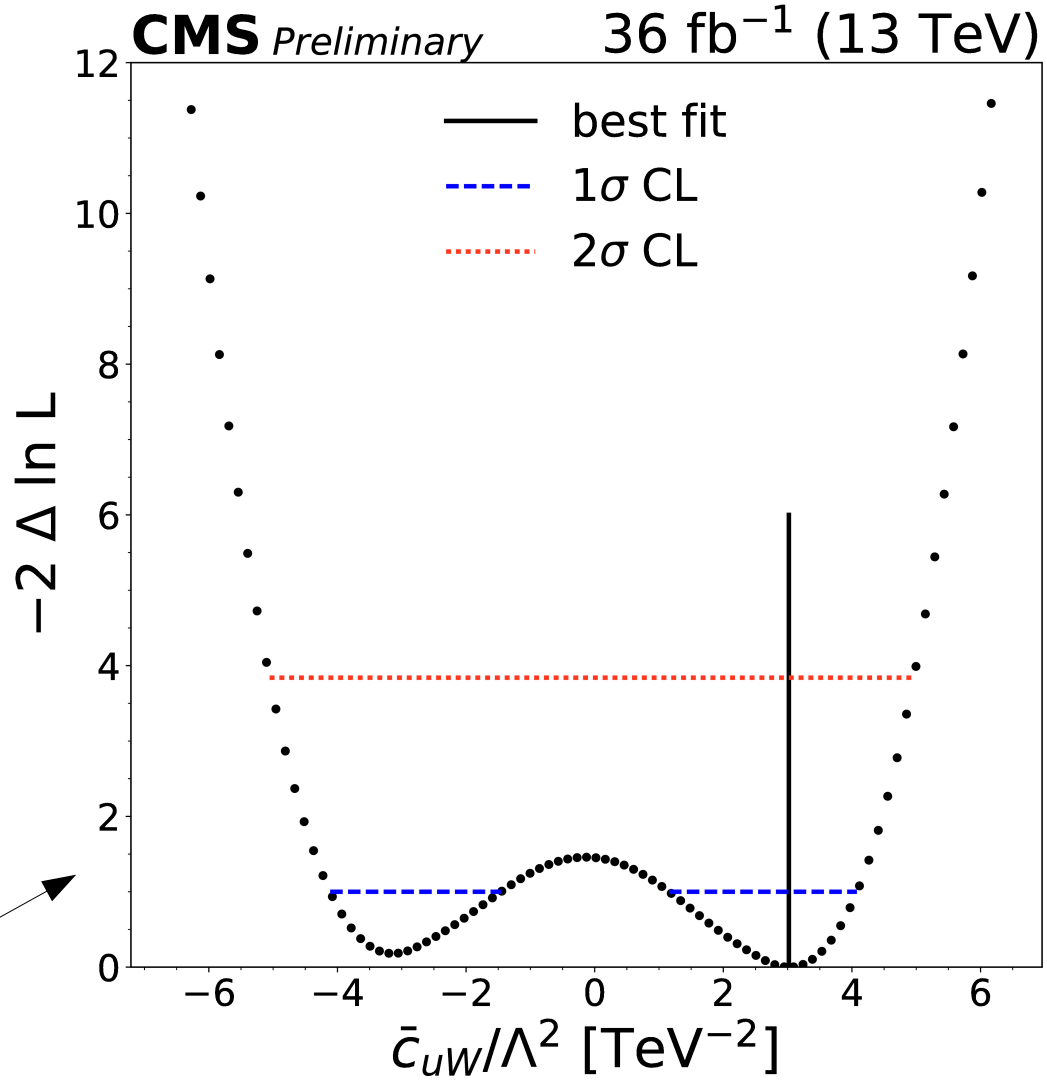
Example: ttV in CMS

- See [CMS-PAS-TOP-17-005]



measurement

interpretation



Way to an interpretation

Follow two different paths

- Simple and easy [**default**]:
  - Perform measurements of observables in different analysis groups and optimize for minimum uncertainty of observables
  - Estimate uncertainties and combine measurements of observables
  - Interpret the measurements in terms of EFT operators
  - **EFT parameter estimates are a byproduct**
- More focused, but more difficult:
  - Prepare a global analysis with an optimization w.r.t. EFT parameters
  - Put everything into a common likelihood
  - **Measurements of observables are byproducts** (in a sense)

Roadmap

Following the simple ansatz

- Perform measurements of different **observables** in different analysis groups and experiments
- Define a model: calculate predictions for observables as a function of the EFT parameters. Use a **parameterization**
- For each measurement, quote:
  - One or more measured values, e.g. a total cross-section or a differential distribution
  - A **breakdown of uncertainties**
  - List of **corrections** for acceptance and efficiencies (if necessary)
- Collect all measurements and build overall covariance matrix
- Put everything into a **tool** to do the calculation
- **Example in the following: differential t-channel measurement** (provided by Cornelius Grunwald)

Definition of observables

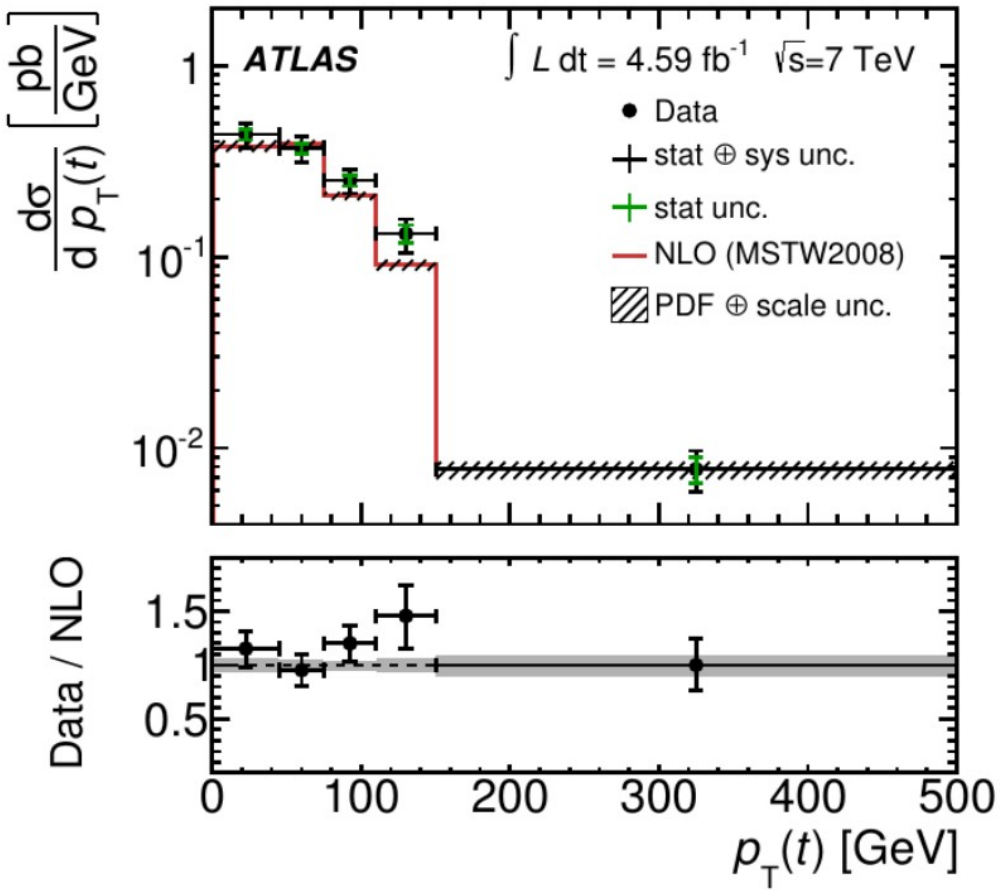
What should be measured

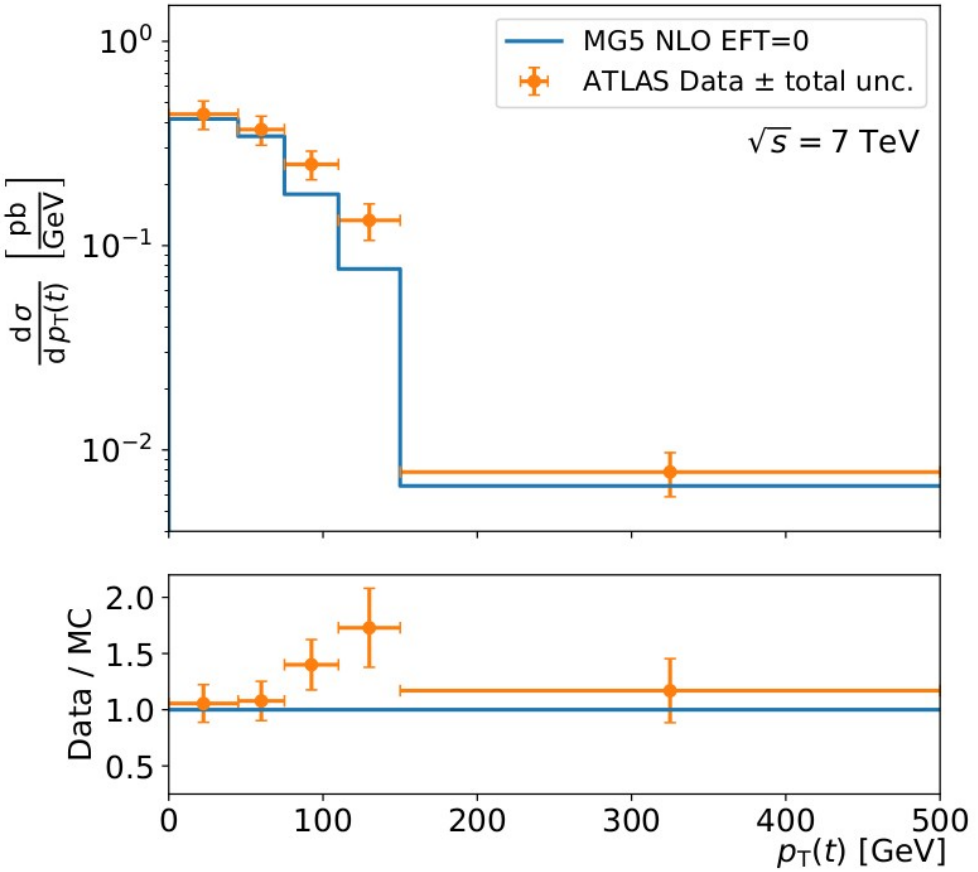
- Observables should be
  - well defined
  - calculable using MC generators
  - predicted to sufficient precision (LO or NLO or whatever is there)
- Need guidance from theory, which observables are more sensitive to EFT parameters than others
- Consensus on details would be helpful, e.g.
  - variables for differential distributions
  - choice of binning for those
  - unfolding level
  - ...

Definition of observables

Example: differential t-channel measurement

- Measured values from [Phys.Rev. D **90** (2014) no.11, 112006]





Parameterizations

Models, obserables, parameters

- Once a model is agreed upon:
  - define unique set of parameters used in the interpretation (C, Λ, C/Λ^2, gA, gV, ...)
  - fix the ranges of the parameters (e.g. for Λ and c)
  - fix all other settings, e.g. particle masses (e.g. b and top mass)
- Use MG to calculate the set of observables for different values of the EFT parameters
- Fit a 2nd order polynomial to the supporting points

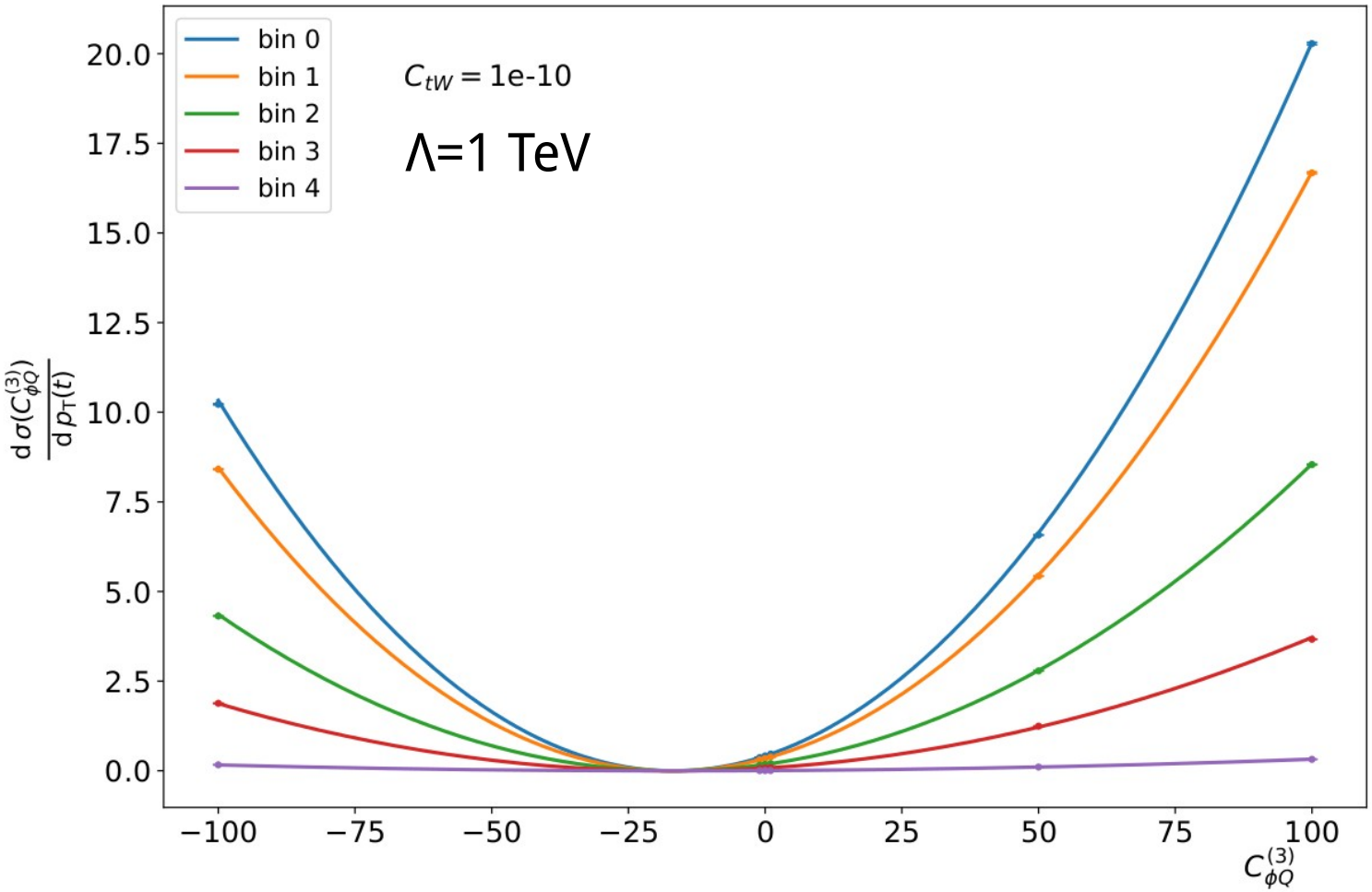
Example: t-channel cross section

$$\sigma_{t,\text{t-ch.}} = \sigma_{\text{SM}} + C_{\phi Q}\frac{\sigma_{\phi Q}}{\Lambda^2} + C_{tW}\frac{\sigma_{tW}}{\Lambda^2} + C_{\phi Q}^2\frac{\sigma_{\phi Q\phi Q}}{\Lambda^4} + C_{tW}^2\frac{\sigma_{tWtW}}{\Lambda^4} + C_{\phi Q}C_{tW}\frac{\sigma_{\phi Q,\,tW}}{\Lambda^4}$$

linear terms quadratic terms mixed terms

Parameterizations

Example: differential t-channel measurement



Categories of uncertainty

Uncertainties, correlations and all that

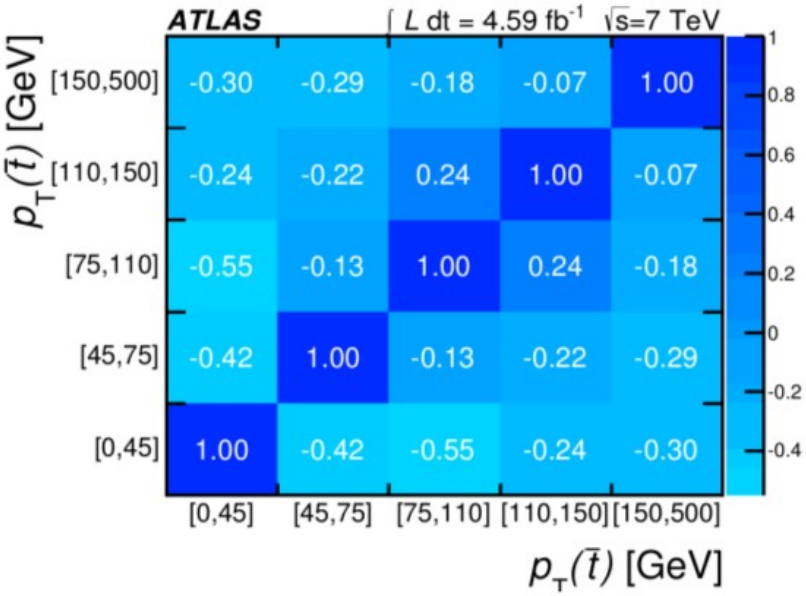
- Need to make sure that uncertainties are assigned in a similar way among measurements and experiments
- Lot's of experience from ongoing combination work
- Suggestion:
  - Simplify categories of uncertainty, e.g. one per detector object, modeling, etc.
  - Quote uncertainty and sign, e.g. cross-section estimate goes „up“ if JES goes „down“
  - Build covariance matrix

Categories of uncertainty

Example: differential t-channel measurement

- Input uncertainties per bin and covariance matrix

$p_T(\bar{t})$ [GeV]	$\frac{d\sigma}{dp_T(\bar{t})}$ [$\frac{fb}{GeV}$]	total [%]	stat. [%]	syst. [%]
[0,45]	190 ± 50	± 28	± 12	± 25
[45,75]	230 ± 40	± 18	± 8.2	± 17
[75,110]	97 ± 27	± 27	± 13	± 24
[110,150]	13.0 ± 9.7	± 74	± 26	± 70
[150,500]	1.4 ± 0.9	± 59	± 26	± 53



Corrections

What else needs to be considered?

- If measurements include large extrapolations, e.g. total cross section, the found estimate might depend on SM assumptions
- Unfolded fiducial measurements should have a minimal dependence on non-SM contributions (stress test, additional uncertainties for non-closure) → **discuss**
- Some quantities do not need to be corrected, e.g. W-helicity fractions
- Whatever needs to be done, develop a common recipe
- Might require a lot of MC samples to be produced (this „correction grid“ is usually larger than the grid used for the parameterization of the observables)

Statistical tools

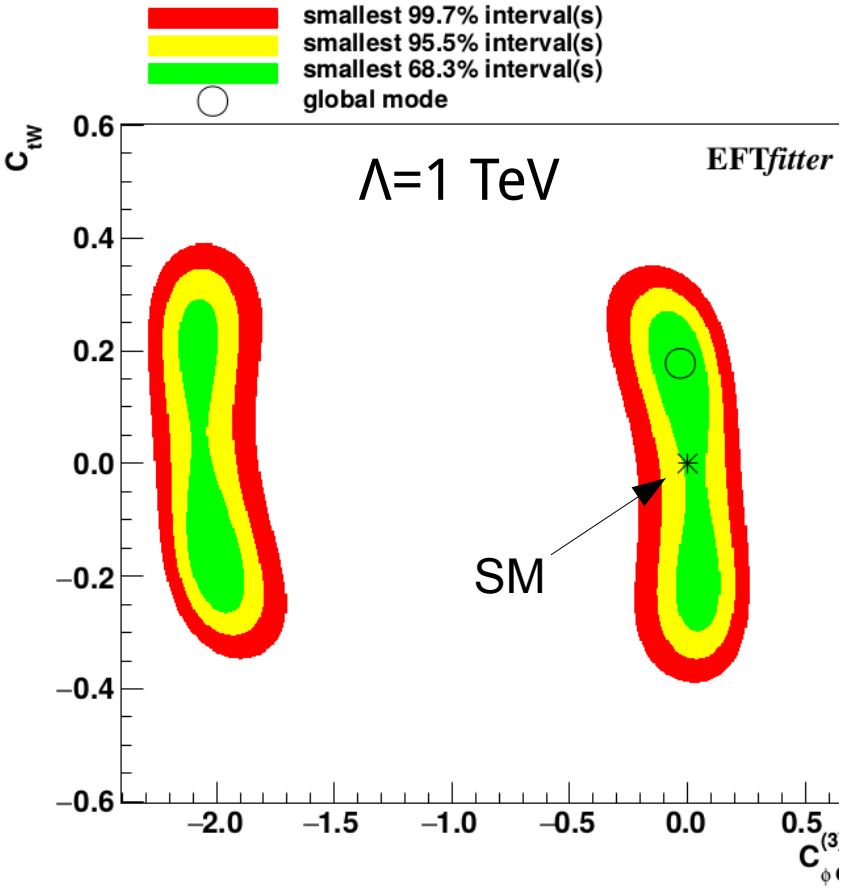
How to do the interpretation?

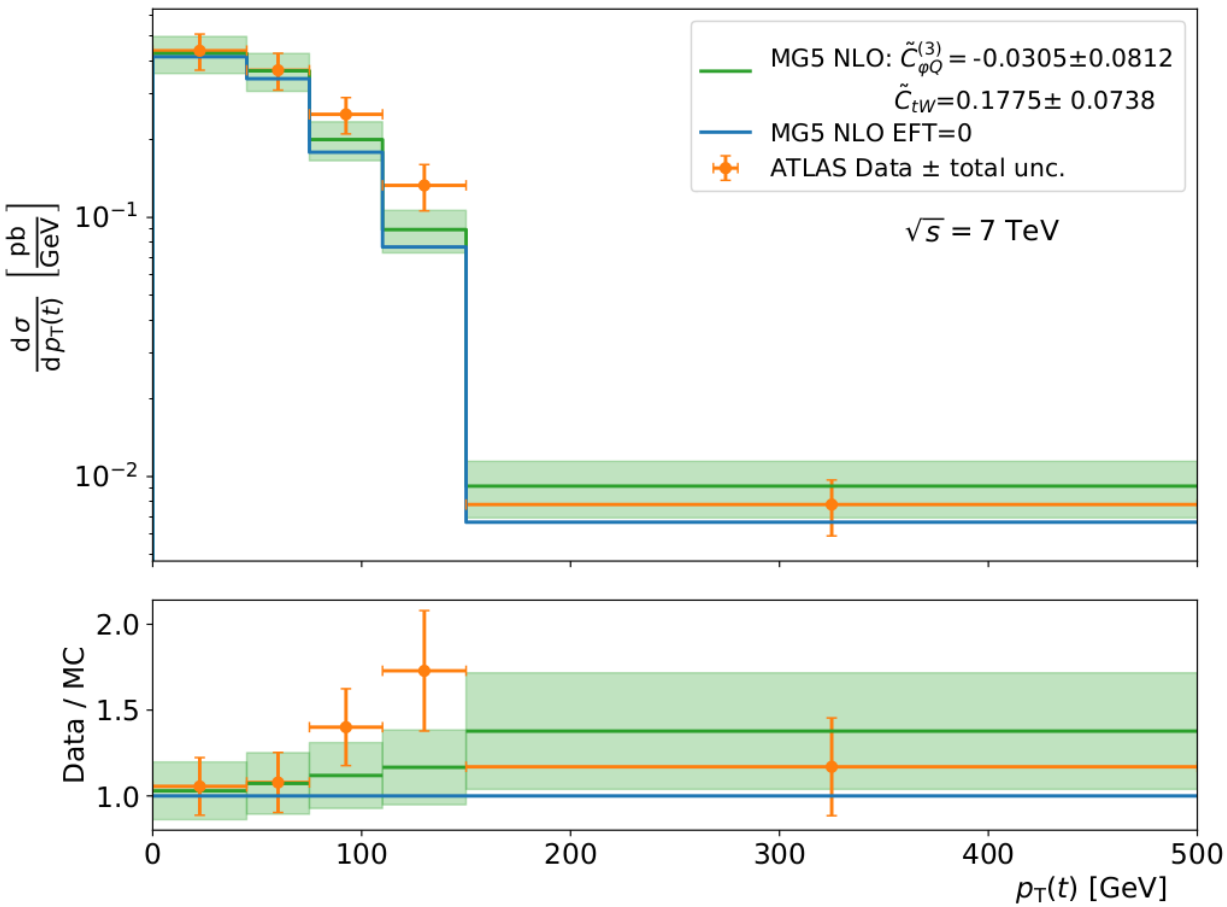
- Use a tool which implements all the aspects discussed above, i.e.
  - EFT model, parameters and parameterization of observables
  - Measurements, uncertainties and correlations
  - Inclusion of prior knowledge, e.g. physical boundaries, results from *b*-physics, etc.
  - Proper statistical interpretation
  - Meta analysis: ranking of uncertainties and measurements, etc.
- Working codes are available, e.g. combine, professor, EFTfitter

Statistical tools

Example: differential t-channel measurement

- Interpretation with EFTfitter [Eur.Phys.J. C **76** (2016) 432]





Harmonization effort

Where can ATLAS and CMS use the same things?

- **Definition of observables**, e.g. fiducial cross sections, differential distributions, etc. → **necessary**
- **EFT model**, e.g. EFT parameters, settings, etc. Can use the same parameterization for calculating observables as a function of the EFT parameters → **necessary** → **discussion after theory talk (?)**
- **Categories of uncertainty**, e.g. coarse categories for detector and theory uncertainties → **necessary**
- **Strategies for estimating corrections**, e.g. using the same MC files and a similar level of precision → **nice to have**
- **Tool for statistical inference**, e.g. pick one to implement the things mentioned above, maybe cross-check with another → **nice to have**

Status

Where are we?

- **We have**
  - built a strategy how to interpret measurements
  - Implemented a working example on how this could work
- **We need**
  - a unique MG model for the parameterization
  - guidance on the parameter intervals and settings
- **We will**
  - write up the strategy and a recipe for analysers
  - clarify details, e.g. categories of uncertainties and corrections