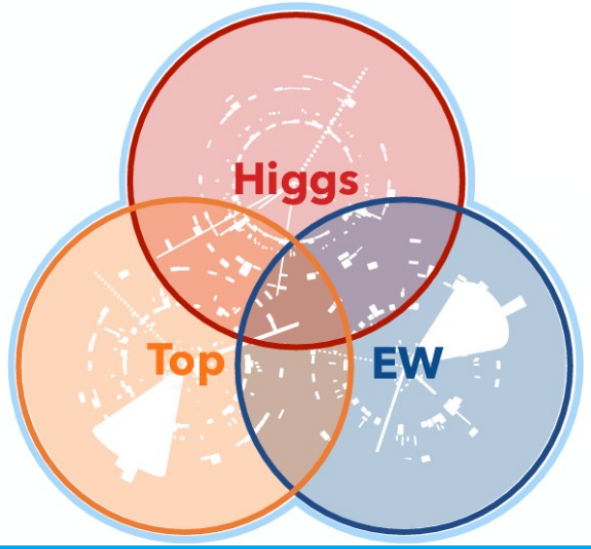
LHC EFT WG Area 4

Update on the ATLAS/CMS Global Fit



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On behalf of the WG collaborators

The University Of Sheffield.

General idea/plan of the Global Fit

- **Work towards EFT combination with inputs from top, Higgs and electroweak sector**
  - Use public measurements to setup the fits and validate parametrization between the different experiments in a simplified setup
    (no common final states, no common systematics)
  - Use validated fits to explore different questions from the other WG areas (and publish these in a WG note)
    (target areas 1,3,5)
  - Use this work as basis for a full combination between experiments

Potential studies

- **Area 1 Targets – testing the truncation and uncertainty prescriptions**
  - Public note contains 4/5 proposals , does not make recommendations
  - We can directly experiment with each proposal and make comparisons to converge towards the most robust approach(s)

- **Area 3 Target – testing pre-trained ML models for optimal observables**
  - This should be tested on single analyses / EFT coefficients first
  - But existing Area 4 combination fit is an ideal testing ground for extension to multiple processes

- **Area 5+6 Target – fit benchmark UV complete models mapped to SMEFT**
  - This should be tested on single analyses / EFT coefficients first
  - But existing Area 4 combination fit is an ideal testing ground for extension to multiple processes
  - Test flavour assumptions

Code setup

- **Agreed on SMEFT conventions:**
  - Single insertion of dimension 6 operators in Warsaw basis
  - (G F , mW , mZ) input parameter scheme
  - topU3l flavour symmetry: (q p , u p , d p) with p = 1, 2 and (Q, t, b)

- **Git repositories:**
  - CMS: https://github.com/ajgilbert/eft-exercise-cms
    → https://gitlab.cern.ch/lhc-eftwg/tools/eft-exercise-cms
  - ATLAS: https://gitlab.cern.ch/nberger/smeft-combination-exercise

General workflow

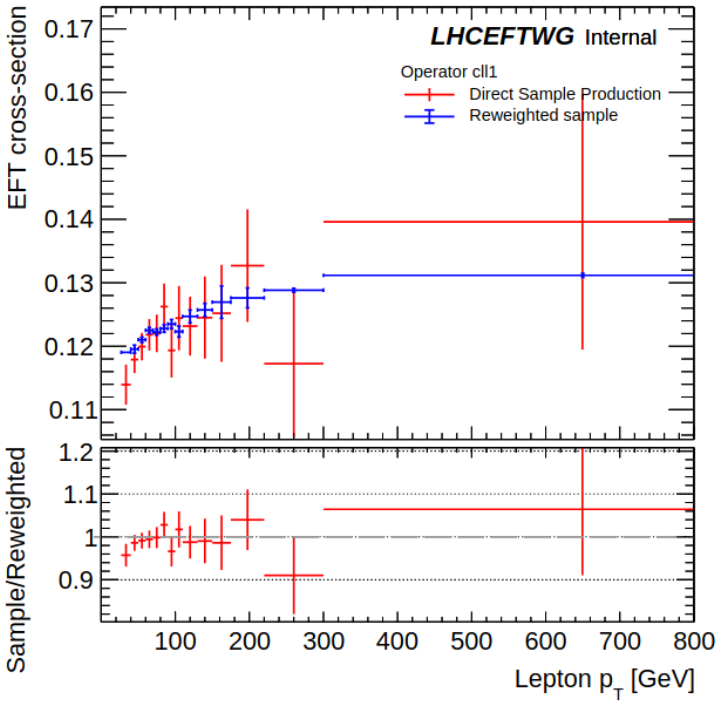
- **Use existing differential cross section measurements:**
  - **Higgs sector:**
    $H \to \gamma\gamma$ (CMS-HIG-19-015) - STXS
    $H \to \gamma\gamma + H \to 4\,\ell$ (ATLAS-CONF-2020-053) - STXS
  - **Electroweak sector:**
    WW (ATLAS-STDM-2017-24)
    WZ (ATLAS-STDM-2018-03)
    Zjj (ATLAS-STDM-2017-27)
    Wγ (CMS-SMP-20-005)
    arXiv:hep-ex/0509008 (Z-pole data from LEP and SLAC)
  - **Top sector:**
    single t, (t-chan) (CMS-TOP-17-023)
- Green: validated, orange: almost/newly validated, red: tbd

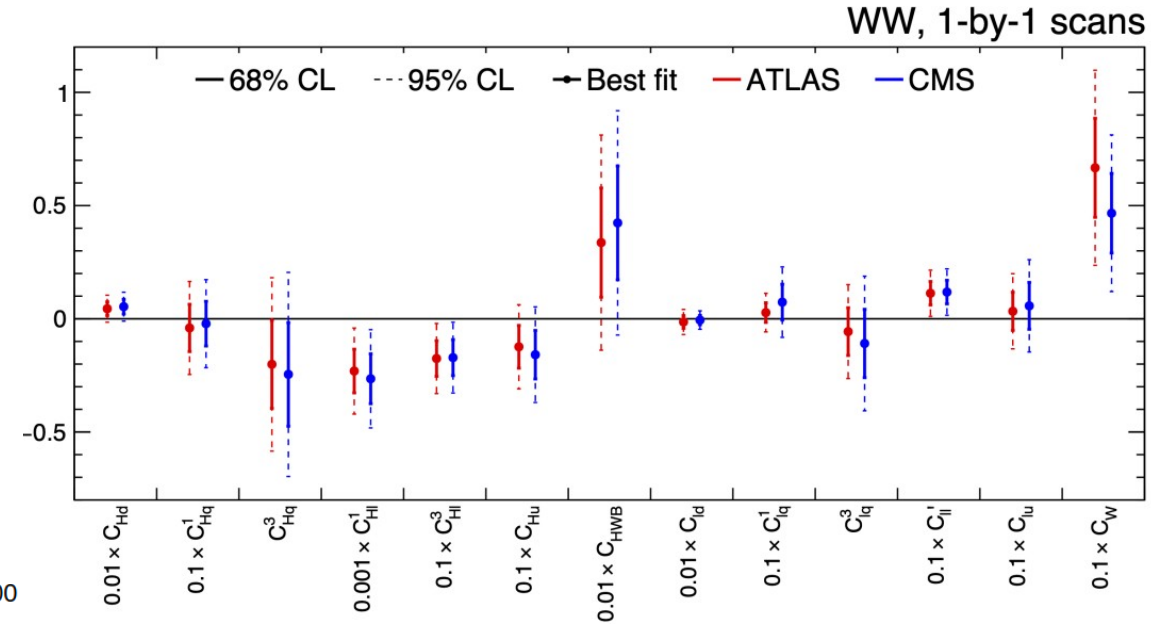
General workflow

- **Parametrisation of EFT cross sections**
  - MG5_aMC@NLO+Pythia with SMEFTsim3
  - Using (public) Rivet routines
- **Fit:**
  - Using multivariate Gaussian PDF using predicted and measured cross-sections (available on HEP data, partially also for theory predictions)
  - Derive constraints on Wilson operators
    → One-by-one
    → Principle Component analysis to determine orthogonal directions in Wilson space → e.g. fix flat directions to zero
- Fitting code from both sides setup, not yet validated each step

Recent progress: ATLAS/CMS EWK validation

- **Started validation of EWK parametrizations:**
  - Reweighted versus direct sample production agrees within uncertainties for relevant operators
  - Small effect on the results (same fitting code, different parametrization)





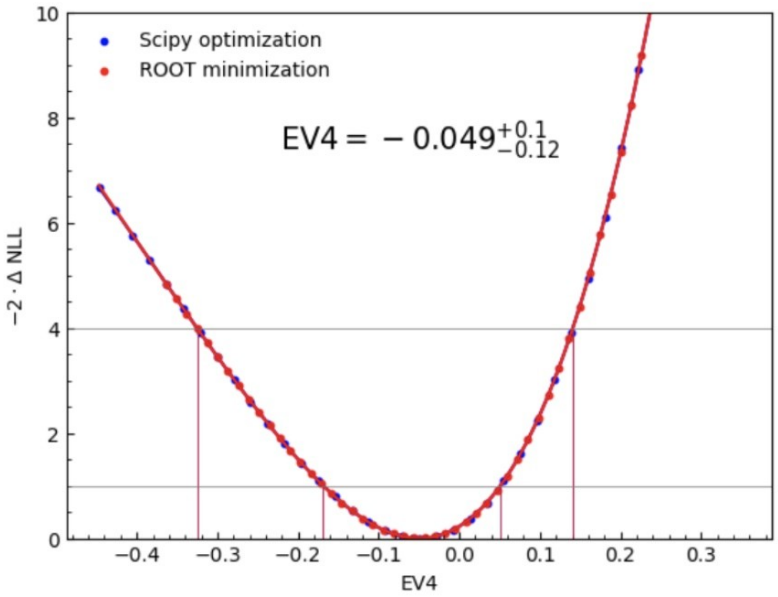
Recent progress: ATLAS/CMS EWK validation

- Progress with Zjj: Better agreement than in the past
- Need to compare with error bars

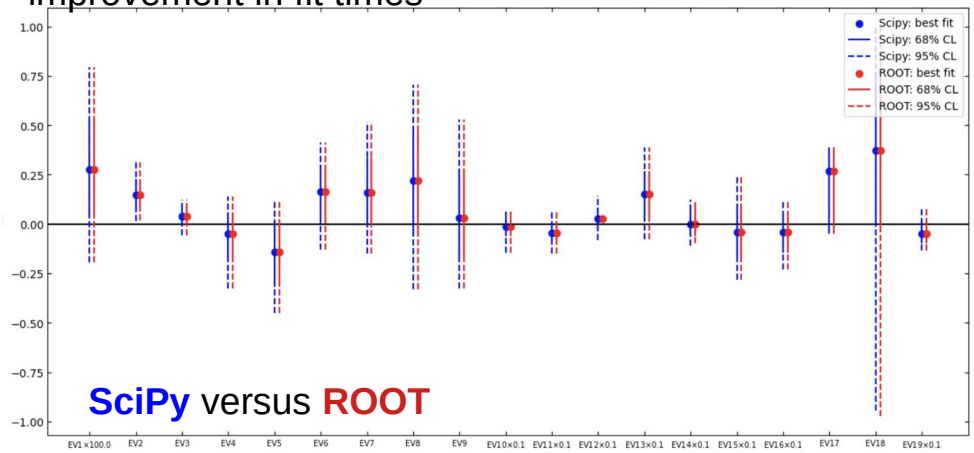
Recent progress: Improved Fitting Framework (CMS)

- **Updates to EFT Fit Code to improve accuracy and speed**
  - Python based implementation of likelihood function
    - Options for both Numpy and PyTorch optimizations
    - Various minimization algorithms tested with analytical gradients provided
  - Comparisons based on simple combination of cross-sections

Analysis	Process	# Measurement Bins
HIG 19-005	$H\gamma\gamma$	27
TOP-17-023	Single-top	5
SMP-20-005	$W\gamma$	12
ATLAS-STDM-2017-27	Zjj	11



Detailed comparison with ROOT based implementation shows excellent agreement but with 10-100x improvement in fit times



Recent progress: Improved Likelihood function (CMS)

Predictions of cross-sections based on usual EFT WC expansions

$$\mu(\vec{c}) = \frac{\sigma}{\sigma_{SM}}(\vec{c}) = 1 + \sum_i A_i c_i + \sum_{i,j} B_{ij} c_i c_j$$

Fits based on measured cross-sections + correlations

→ Profile likelihood (q) over WCs

$$q = -2\ln(L) = (\mu(\vec{c}) - \hat{\vec{\mu}})^T (\boldsymbol{V})^{-1} (\mu(\vec{c}) - \hat{\vec{\mu}})$$

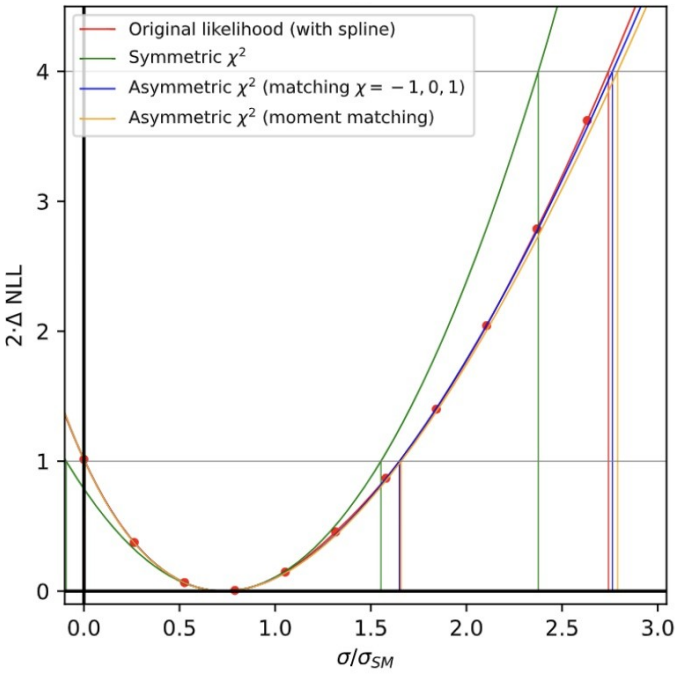
Can include **asymmetric uncertainties** in cross-section measurements by making the substitution(s) [1],[2]

$$\hat{\mu} = \alpha + \beta\chi + \gamma\chi^2$$

$$q \to \vec{\chi}(\boldsymbol{\rho})^{-1}\vec{\chi}$$

Several methods studied to obtain $\alpha,\ \beta,\ \gamma,\ \boldsymbol{\rho}$

CMS ttH(→γγ) low p_T(H)

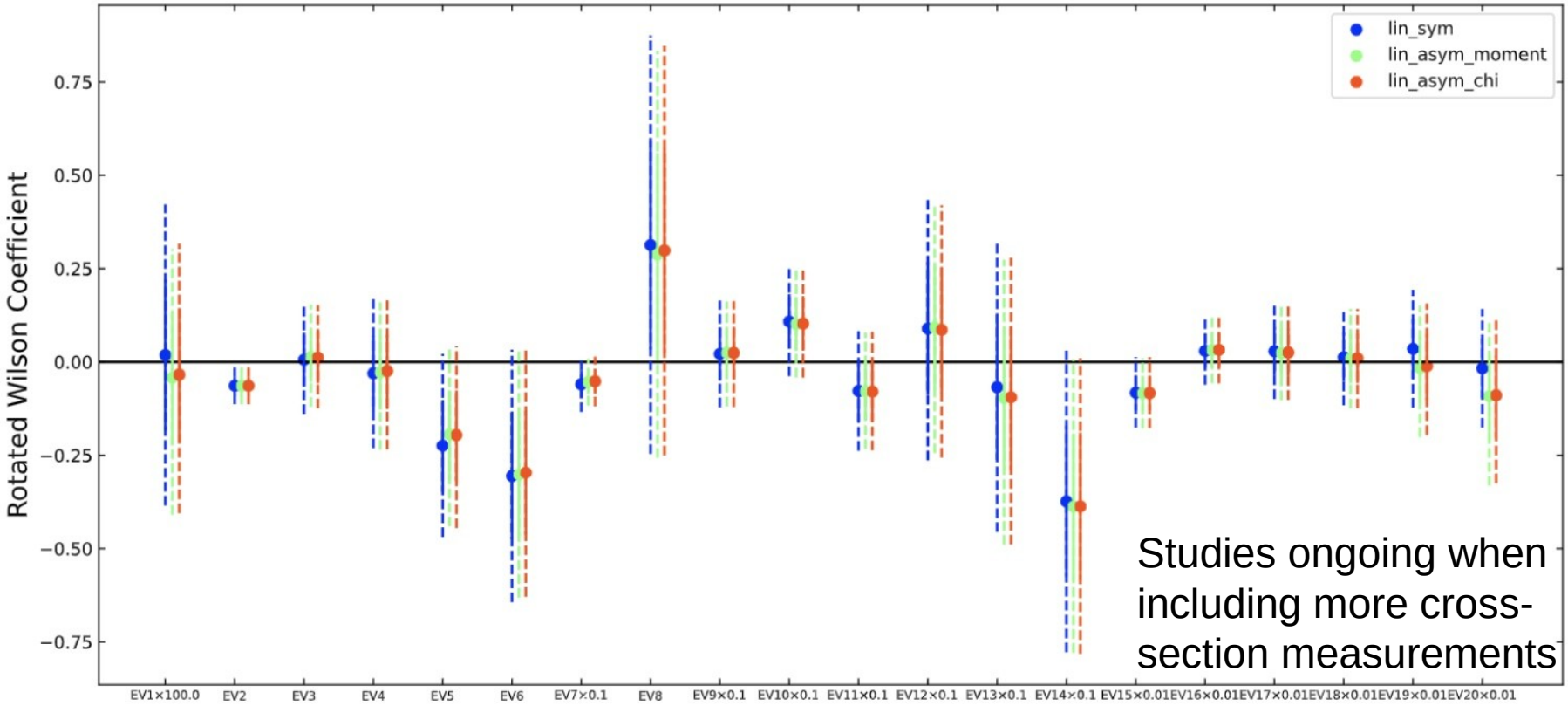


[1] https://doi.org/10.1007/jhep04(2019)064 , [2] https://arxiv.org/abs/2307.06996

Recent progress: Improved Likelihood function (CMS)

Results in fitted (rotated) WCs show differences when accounting for asymmetric uncertainties

Pieter Van Steenweghen



Studies ongoing when including more cross-section measurements

Conclusions

- **Slow but steady progress**
  - Higgs parametrizations validated within Higgs group
  - Progress on EWK side with validation
  - Update of CMS fitting code
- **Continue with**
  - Validating steps of the fitting code
    - Principle component analysis
    - Fits