Towards a global EFT analysis

SM@LHC, 11-14th April 2022, CERN

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University of Sheffield

On behalf of the ATLAS and CMS collaborations and the LHC EFT WG

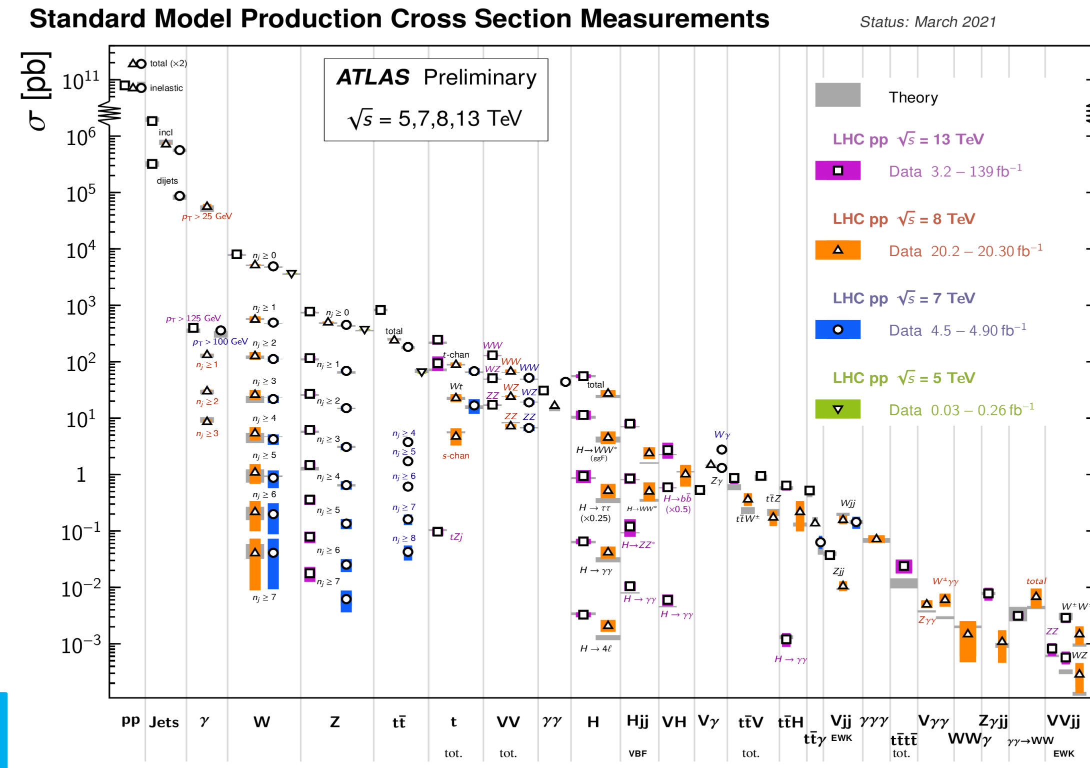
- Standard Model measurements can be grouped into

  – **High precision tests** (high statistics available)

  vs.

  – **High energy behaviour** as ultimate tests of the Standard Model

Consistent, complete but does not cover all we can observe in the universe

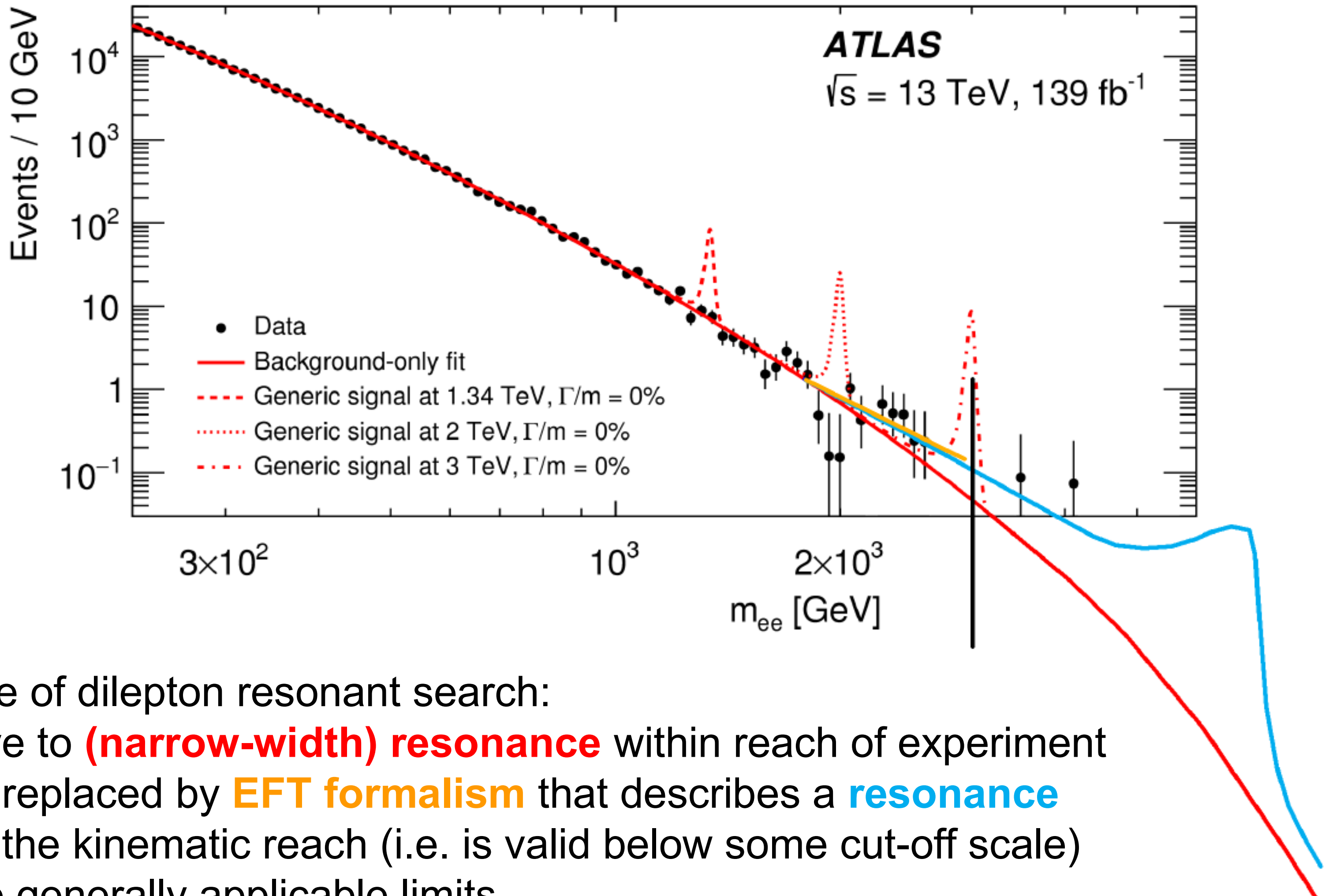


Large statistics → **High precision**

Rare processes → **High energy behaviour**

https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PUBNOTES/ATL-PHYS-PUB-2021-05/

The University Of Sheffield.

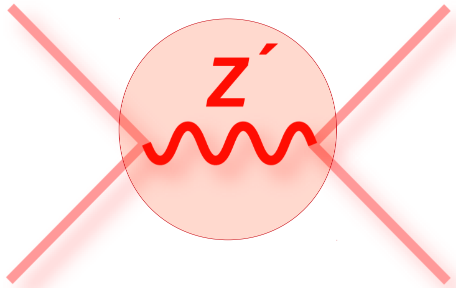


- Example of dilepton resonant search:
  Sensitive to **(narrow-width) resonance** within reach of experiment
- Can be replaced by **EFT formalism** that describes a **resonance** outside the kinematic reach (i.e. is valid below some cut-off scale)
  → more generally applicable limits
  → can find new physics beyond direct kinematic reach or narrow peaks

Sketch by Hannes Mildner using Phys. Lett. B 796 (2019) 68)

Effective Field theory (EFT): In a nutshell

$$\frac{1}{p^2 - M_{Z'}^2} = \frac{1}{-M_{Z'}^2}\left[1 + \frac{p^2}{M_{Z'}^2} + \left(\frac{p^2}{M_{Z'}^2}\right)^2 + \dots\right]$$



$$c' = -\frac{c}{M_{Z'}^2}$$

Effective Lagrangian as extension of SM Lagrangian

→ Taylor expansion in local operators of "light" degrees of freedom

→ removes explicit description of "heavy" / high energy physics
(suppressed by orders of energy scale Λ >> E_{CM})

$$\mathcal{L}^{(\mathrm{dim})} = \frac{1}{\Lambda}\sum_k C_k^{(\mathrm{dim})} Q_k^{(\mathrm{dim})}$$

Number of Operator — Wilson Coefficient — Operator

Systematic measure of SM deviations that can be linked to new physics phenomena

$$\mathcal{L}_{EFT} = \mathcal{L}_{SM}^{(4)} + \frac{1}{\Lambda}\sum_k C_k^{(5)} Q_k^{(5)} + \frac{1}{\Lambda^2}\sum_k C_k^{(6)} Q_k^{(6)} + \mathcal{O}\left(\frac{1}{\Lambda^4}\right)$$

- SM up to dim-4
- dim-5 (and dim-7): neutrino masses but lepton-flavour violating
- dim-6: most studied at LHC
- dim-8: studied for VBS processes

Dimension-6 EFT Bases

> SMEFT assumptions

- EFT should reduce to SM (if there are no undiscovered light particles)
- Higgs field is included (not the case for anomalous triple gauge couplings) and linearly realised (otherwise: Higgs-EFT)
- Wilson coefficients are arbitrary (and can differ between bases!)

> There are 2499 CP-even dimension-6 operators

- Need to reduce redundancy → also using some assumptions
- Usually: minimal flavour violation, no CP-violation, lepton/baryon numbers

> Most popular: Warsaw basis

- 59 operators (when considering only 1 generation)
- Renormalization Group and 1-loop finite renormalization (SMEFT@NLO)

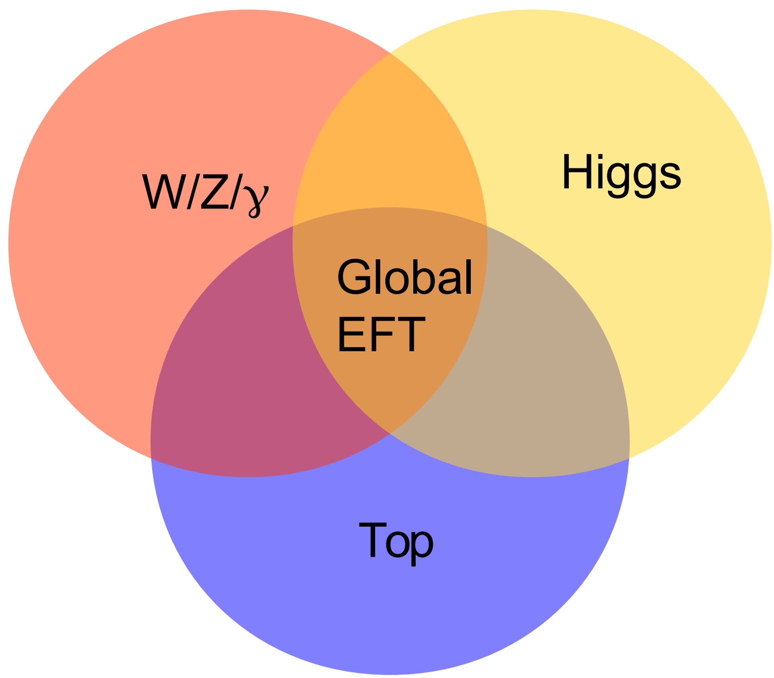
> Still not trivial: what is the order of the EFT expansion to be considered?

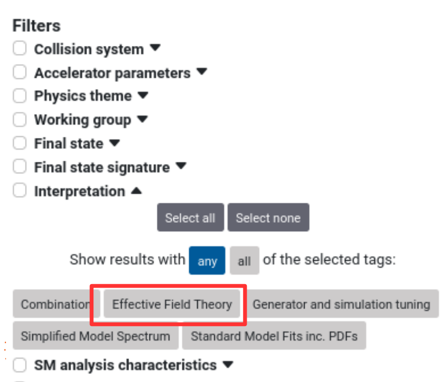
$$\sigma = \sigma_{\text{SM}} + \sum_i \frac{c_i}{\Lambda^2}\sigma_i^{\text{dim-6-interf}} + \sum_{ij} \frac{c_i c_j}{\Lambda^4}\sigma_{ij}^{(\text{dim-6})^2} + \sum_k \frac{c_k}{\Lambda^4}\sigma_k^{\text{dim-8-interf}} + \ldots$$

Linear quadratic dim-8

Global EFT fits

- Any final state is usually impacted by a number of Wilson coefficients: Combination allows to disentangle operators with similar effects on a single final state
- Can improve limits when the same operators affect many final states
- Major challenges are consistent treatment of measurements and correlations





- **Single final state "EFT interpretation"**

https://cms-results-search.web.cern.ch/
https://twiki.cern.ch/twiki/bin/view/AtlasPublic/HiggsPublicResults
https://twiki.cern.ch/twiki/bin/view/AtlasPublic/TopPublicResults
https://twiki.cern.ch/twiki/bin/view/AtlasPublic/StandardModelPublicResults

What is out there?

Theory Fitting groups
Overview of available codes: https://indico.cern.ch/event/971727/

- Provide bases, theoretical tools (feynrules)
- Use publicly available results

LHC EFT WG
https://lpcc.web.cern.ch/lhc-eft-wg

- Enhance comparability
- Common conventions and (conversion) tools
- Common standards for systematics

LHC top WG
https://twiki.cern.ch/twiki/bin/view/LHCPhysics/LHCTopWG

LHC Higgs XS WG
https://twiki.cern.ch/twiki/bin/view/LHCPhysics/LHCHXSWG

LHC EW (MB) WG
https://twiki.cern.ch/twiki/bin/view/LHCPhysics/LHCEW

- "Topical" EFT interpretations and combinations

CMS

ATLAS

- Long-term goal: accurate likelihood-level global EFT combination of ATLAS and CMS
- In parallel: more complex combinations planned within experiments

Global EFT fits

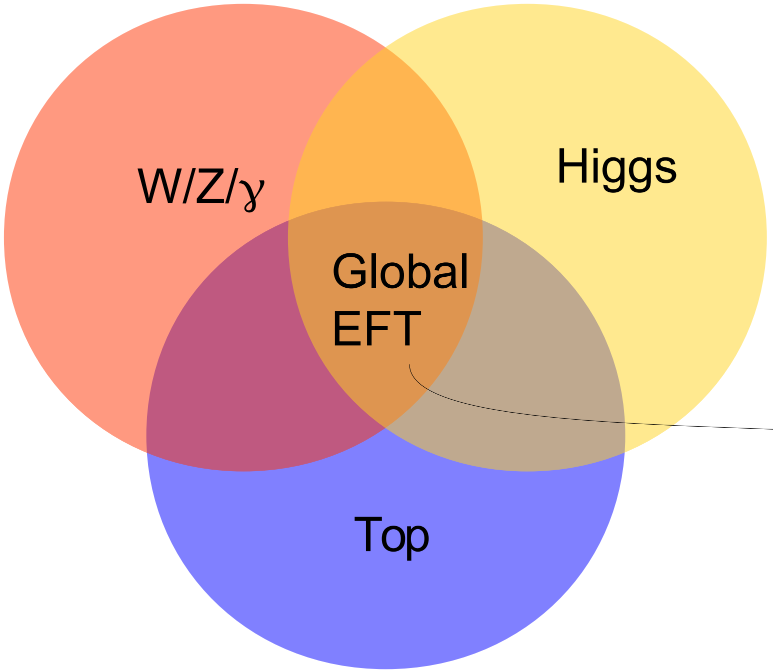
> Case for Fit by Experimental Collaborations:

- Most accurate interpretations
- Make optimal use of data
- Fit can guide measurements strategy
- Makes sure all relevant information is published

Combined EFT interpretation of H to WW and WW processes
ATL-PHYS-PUB-2021-010

Combined EFT analysis of WW, WZ, ZZ, VBF Z processes
ATL-PHYS-PUB-2021-022

EFT and MSSM interpretations of the STXS combination
ATLAS-CONF-2020-053
Update:
ATLAS-CONF-2021-053



Measurements of production cross sections of WZ and same-sign WW boson pairs in association with two jets in proton-proton collisions at s√= 13 TeV (dimension-8)
CMS-SMP-19-012

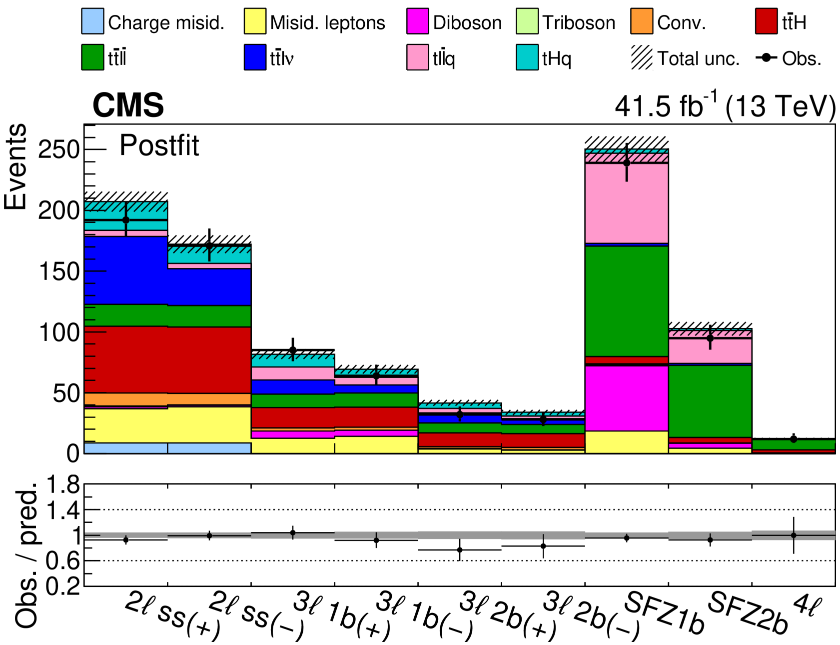
Planned by collaborations with guidance from LHC EFT group

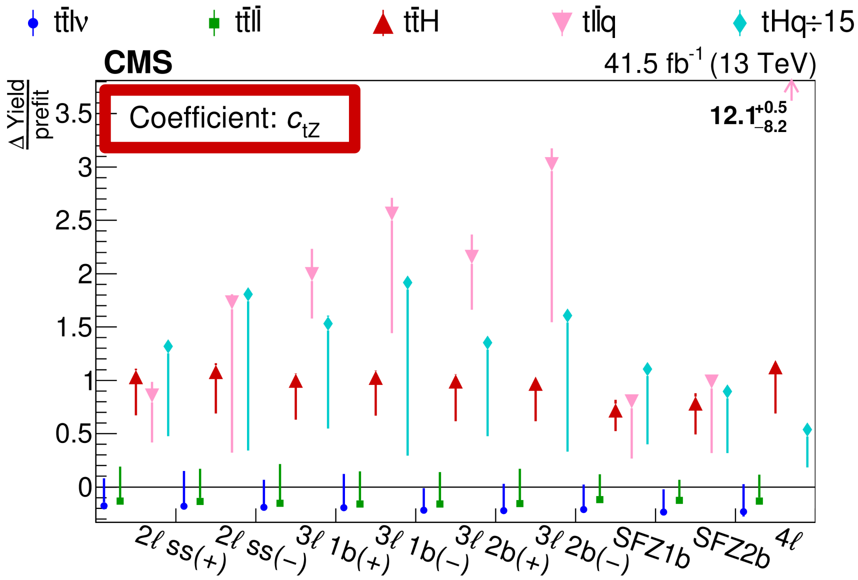
Search for new physics in top quark production with additional leptons in proton-proton collisions at s√= 13 TeV using effective field theory
CMS-TOP-19-001

Top EFT summary plots December 2021
ATL-PHYS-PUB-2021-043

The University Of Sheffield.

- EFT analysis of five signal processes: $t\bar{t}H$, $t\bar{t}\ell\bar{\ell}$, $t\bar{t}\ell\nu$, $t\ell\bar{\ell}q$, and tHq using tagged top events with different number of leptons
- Consistent analysis of categories with different fractions of contributing signal processes → no retrospective re-analysis!



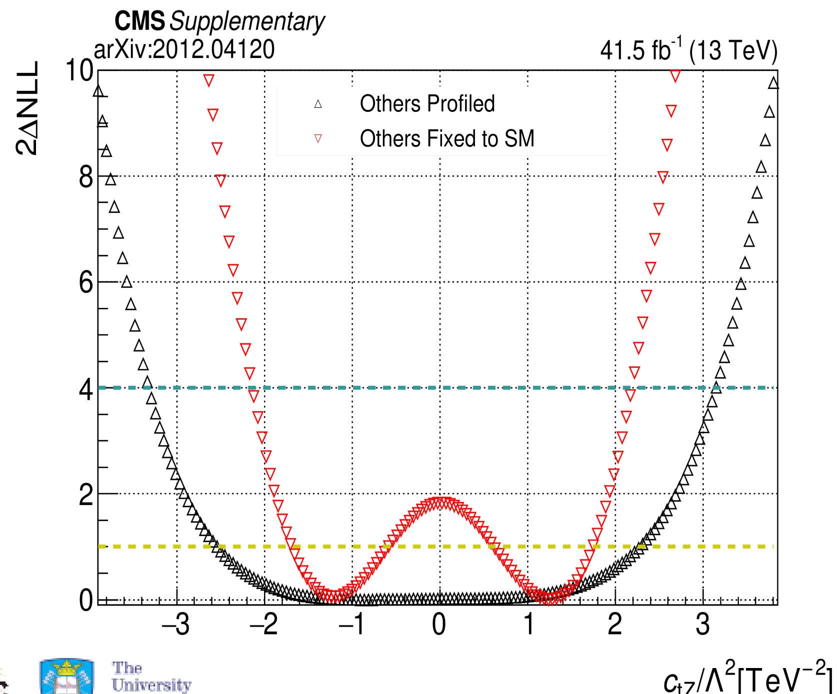


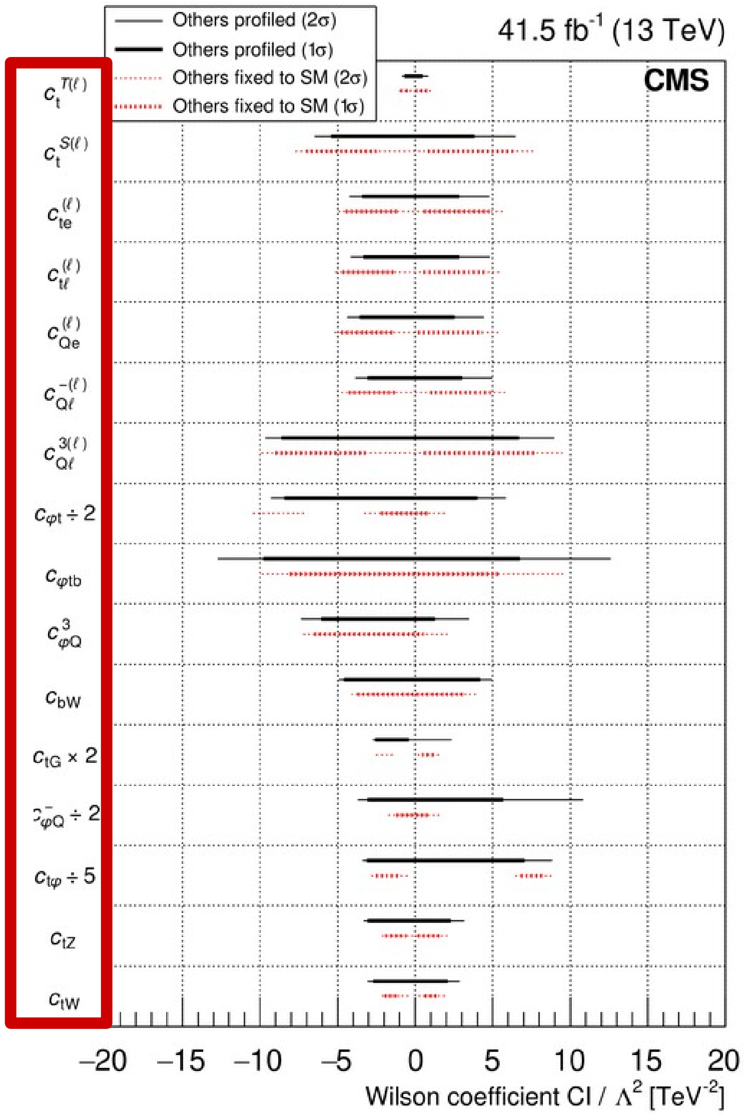
Fractional variation in expected yields for a given process and category after the fit and relative to the SM expectation

Search for new physics in top quark production with additional leptons in proton-proton collisions at s√= 13 TeV using effective field theory
CMS-TOP-19-001

CMS: Top EFT “combination”

- Results very dependent on whether other operators are profiled or fixed to SM values
  → need more channels to resolve this issue
- EFT parametrization based on Warsaw Basis, following https://arxiv.org/abs/1802.07237, considering linear interference terms
- Due to requirement of top quark, ***no*** direct interplay with EWK or Higgs sector

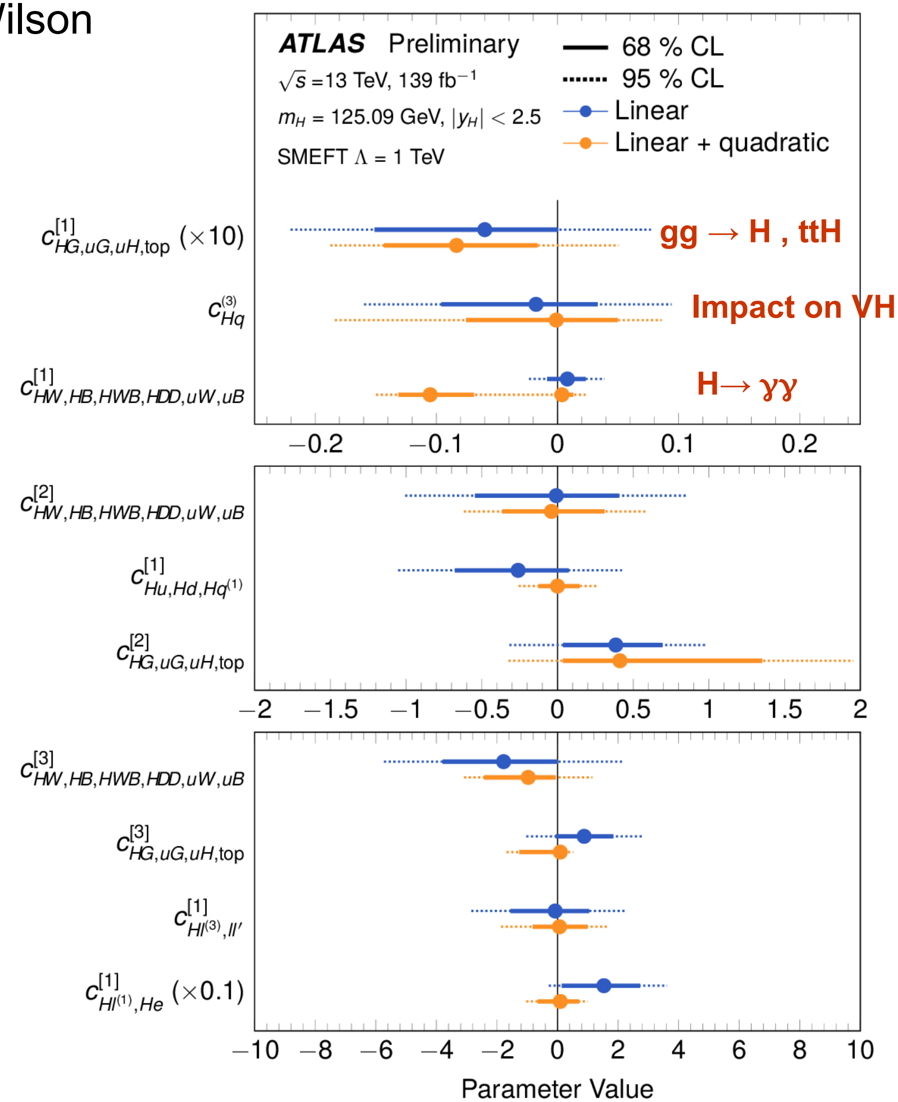




- Combination of measured signal strength for STXS categories → used before
- Not enough information to constrain all dim-6 Wilson coefficients → removing flat directions
- Rotate SMEFT basis using SM expected covariance matrix → Hessian eigenvectors giving ranking with highly un-constrained coefficients being pruned

Parameter		Definition	Eigenvalue	Fit Parameter
$c_{Hq}^{(3)}$		$c_{Hq}^{(3)}$	1900	✓
$c^{[i]}_{HW,HB,HWB,HDD,uW,uB}$	1	$-0.27c_{HW} - 0.84c_{HB} + 0.47c_{HWB} - 0.02c_{uW} - 0.05c_{uB}$	245000	✓
	2	$-0.96c_{HW} + 0.19c_{HB} - 0.20c_{HWB} + 0.02c_{uB}$	33	✓
	3	$-0.08c_{HW} + 0.50c_{HB} + 0.86c_{HWB} + 0.07c_{HDD} + 0.03c_{uW} + 0.06c_{uB}$	4	✓
	4	$0.03c_{HWB} - 0.85c_{HDD} + 0.32c_{uW} + 0.43c_{uB}$	0.017	
	5	$-0.01c_{HW} + 0.07c_{HB} + 0.05c_{HWB} - 0.44c_{HDD} - 0.86c_{uW} - 0.23c_{uB}$	0.0077	
	6	$-0.01c_{HW} + 0.06c_{HB} + 0.04c_{HWB} - 0.29c_{HDD} + 0.39c_{uW} - 0.87c_{uB}$	0.0025	

2020 version



EFT and MSSM interpretations of the STXS combination
ATLAS-CONF-2020-053
Update:
ATLAS-CONF-2021-053

ATLAS: Higgs STXS combination

- Combination of measured signal strength for STXS categories → used before
- Not enough information to constrain all dim-6 Wilson coefficients → removing flat directions
- Rotate SMEFT basis using SM expected covariance matrix → Hessian eigenvectors giving ranking with highly un-constrained coefficients being pruned

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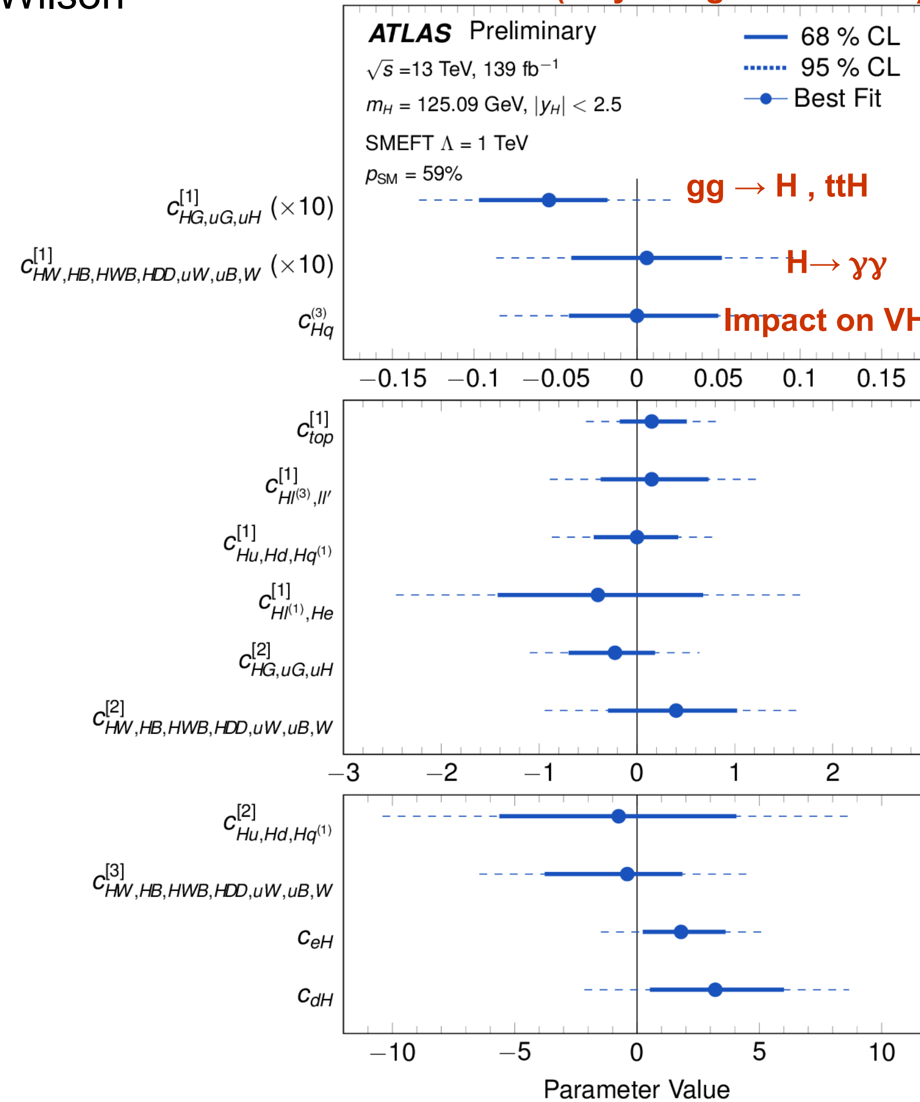
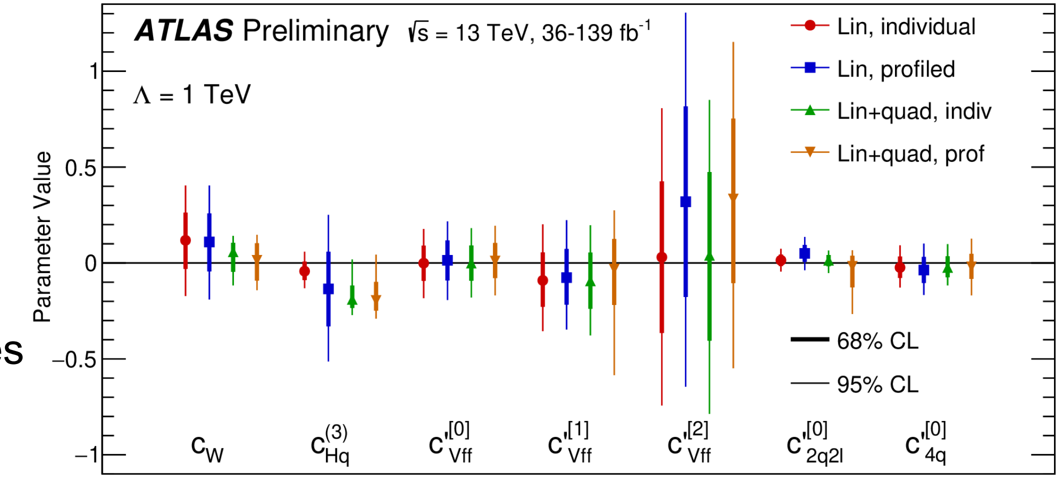
EFT and MSSM interpretations of the STXS combination
ATLAS-CONF-2020-053
Update:
ATLAS-CONF-2021-053

2021 Update (only using linear terms)



ATLAS: SM cross-section combination

- Post-mortem combination of unfolded differential cross-sections of WW, WZ, 4-lepton and Z+2jets
- Combined likelihood function accounts for experimental uncertainties and correlation as well as theory uncertainties
- Sensitive to 33 operators – constrained are 2 operators (cW, $cHq^{(3)}$) and 13 linear combinations
- Correlations lead to degradation of profiled limits → will improve once more measurements are included
- Comparison of linear and quadratic limits can give estimate of convergence of SMEFT extension and uncertainties



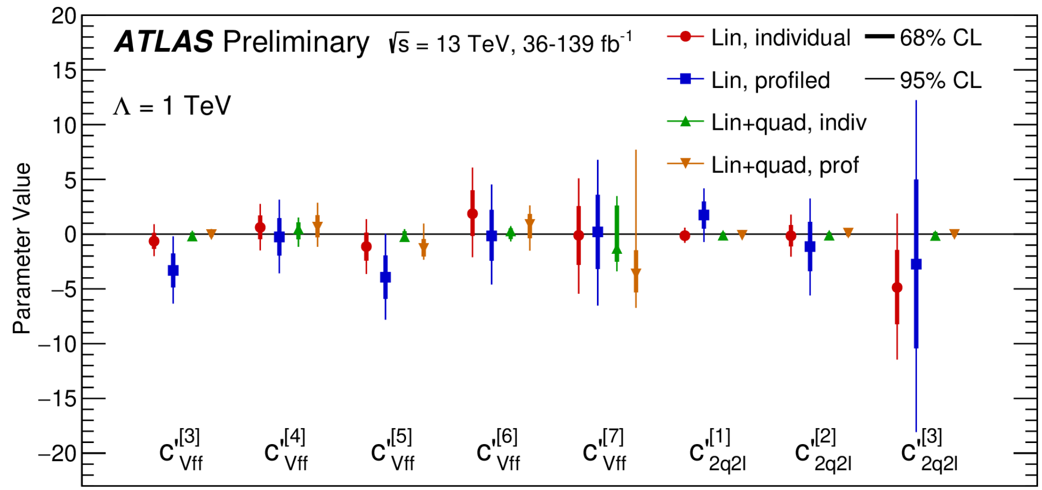
$c'^{[0]}_{Vff} \approx 0.81c_{HWB} + 0.38c_{HD} + 0.13c^{(1)}_{Hl} + 0.37c^{(3)}_{Hl} - 0.14c^{(1)}_{ll} + 0.12c^{(1)}_{Hq}$

$c'^{[1]}_{Vff} \approx 0.73c^{(1)}_{Hl} - 0.28c^{(3)}_{Hl} - 0.48c_{He} + 0.38c^{(1)}_{ll} + 0.13c^{(1)}_{Hq}$

$c'^{[2]}_{Vff} \approx 0.37c_{HWB} + 0.17c_{HD} - 0.31c^{(1)}_{Hl} - 0.53c^{(3)}_{Hl} + 0.25c_{He} + 0.59c^{(1)}_{ll} - 0.21c^{(1)}_{Hq}$

$c'^{[0]}_{2q2l} \approx -0.37c^{(1)}_{lq} + 0.89c^{(3)}_{lq} - 0.11c_{lu} - 0.21c_{eu} - 0.13c_{qe}$

$c'^{[0]}_{4q} \approx 0.11c^{(11)}_{qq} + 0.22c^{(18)}_{qq} + 0.95c^{(31)}_{qq} - 0.2c^{(38)}_{qq}$



$c'^{[3]}_{Vff} \approx -0.19c^{(1)}_{Hl} - 0.14c^{(3)}_{Hl} + 0.86c^{(1)}_{Hq} + 0.41c_{Hu} - 0.17c_{Hd}$

$c'^{[4]}_{Vff} \approx -0.35c_{HWB} + 0.49c_{HD} + 0.26c^{(1)}_{Hl} + 0.35c^{(3)}_{Hl} + 0.51c_{He} + 0.38c^{(1)}_{ll} + 0.18c^{(1)}_{Hq}$

$c'^{[5]}_{Vff} \approx 0.25c_{HD} + 0.33c^{(1)}_{Hl} - 0.22c^{(3)}_{Hl} + 0.18c_{He} - 0.35c^{(1)}_{ll} - 0.3c^{(1)}_{Hq} + 0.71c_{Hu} - 0.16c_{Hd}$

$c'^{[6]}_{Vff} \approx -0.22c^{(1)}_{Hl} + 0.52c^{(3)}_{Hl} - 0.39c_{He} + 0.44c^{(1)}_{ll} - 0.22c^{(1)}_{Hq} + 0.52c_{Hu}$

$c'^{[7]}_{Vff} \approx -0.28c_{HWB} + 0.71c_{HD} - 0.31c^{(1)}_{Hl} - 0.21c^{(3)}_{Hl} - 0.5c_{He} - 0.14c^{(1)}_{ll}$

$c'^{[1]}_{2q2l} \approx 0.56c^{(1)}_{lq} + 0.44c^{(3)}_{lq} + 0.61c_{eu} - 0.1c_{ed} + 0.34c_{qe}$

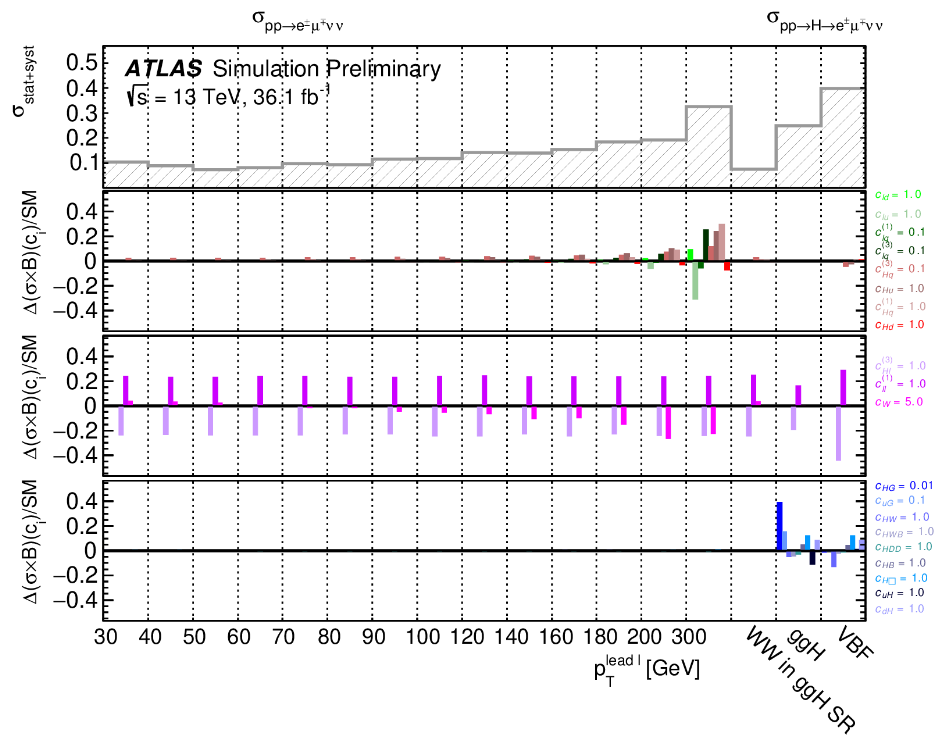
$c'^{[2]}_{2q2l} \approx 0.68c^{(1)}_{lq} + 0.15c^{(3)}_{lq} + 0.33c_{lu} - 0.51c_{eu} + 0.13c_{ed} - 0.37c_{qe}$

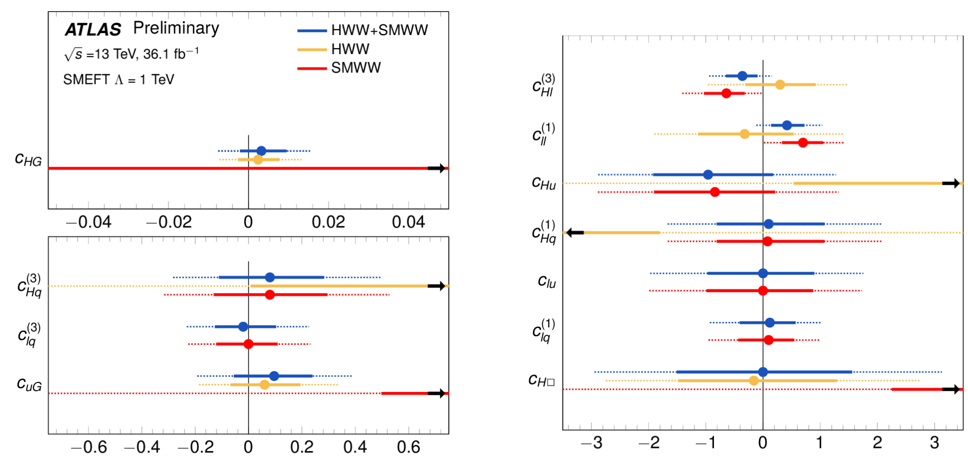
$c'^{[3]}_{2q2l} \approx -0.27c^{(1)}_{lq} + 0.79c_{lu} - 0.39c_{ld} + 0.26c_{eu} - 0.22c_{ed} - 0.16c_{qe}$

Combined EFT analysis of WW, WZ, ZZ, VBF Z processes
ATL-PHYS-PUB-2021-022

ATLAS: HWW and WW cross-section combination

- Combination uses the **likelihood function obtained in the signal strength fit** of the Higgs measurement together with the **unfolded differential cross-sections** for the WW process
- Technically ambitious combination and proof of principle of feasibility due to combination of different “flavours” of measurements and overlaps (signal definition however orthogonal)
- Partial overlap with the control regions (CR) used in the Higgs analysis
  → WW CR replaced by measurement
  → Degradation of 10% of ggH measurement
- 8 eigenvectors of Wilson coefficients can be measured





Parameter value (single operator fit)

Combined EFT interpretation of H to WW and WW processes
ATL-PHYS-PUB-2021-010

Towards a global fit: LHC EFT WG

- Goal of the LHC EFT WG: provide guidance for the interpretation of LHC data in the context of effective field theories (EFTs). https://lpcc.web.cern.ch/lhc-eft-wg

- **Areas of interest:**
  → Basics / EFT formalism
  → Predictions and tools
  → Experimental measurements and observables
  → **Fits and related systematics**
  → Benchmark scenarios from UV models
  → Interplay/connection with flavour

- **Experimental combination between ATLAS and CMS**
  → Kick-off: https://indico.cern.ch/event/1007581/ **(Feb 22, 2021)**
  - Use combination project to get feedback and advice from the LHC WG but also to help focus the WG discussions on something concrete and help those discussions converge, in some cases break the symmetry

Scope of combination:
- Cross-experimental (ATLAS+CMS)
- Cross-topical (i.e. including top, Higgs and EWK measurements)

A common EFT fit between ATLAS and CMS

- Examples of such combinations exist:

  → **ATLAS/CMS Higgs combination (Run-1) (JHEP 08 (2016) 045)**

  Maximized sensitivity of LHC in extraction of Higgs properties

- **Current plans foresee**
  - to concentrate on dimension-6 operators using the Warsaw basis
  - Use (and test) recommendations of LHC EFT WG, e.g. **recommended default input scheme (GF, mZ, mW)**
  - Use (and test) flavour assumptions (enhances cross-talk between top and Higgs/EW)

→ https://twiki.cern.ch/twiki/bin/view/LHCPhysics/LHCEFTExpCombinationConventions

Interim Conventions for a first EFT Combination between LHC experiments

⚠ Recently proposed ATLAS evolutions are in red text below and still need to be singed off by CMS.

Conclusion

- Steps towards *experimental* global fits have been taken

  → various partial examples published from ATLAS and CMS

  → Generally: Global fits are being prepared **within** the collaborations

- Within the scope of the LHC EFT Working group

  → First steps towards ATLAS/CMS combined global EFT fit

    - playground for validity scheme investigations
    - playground for flavour assumptions

  → General Recommendations on global fits

    - conventions on electroweak parameter schemes
    - others being actively discussed (flavour assumptions, truncations of SMEFT expansion, ….)

Backup slides.

So what is being done at the LHC?

- official CERN/LHC groups

LHC EFT WG https://lpcc.web.cern.ch/lhc-eft-wg (new!)

LHC top WG
https://twiki.cern.ch/twiki/bin/view/LHCPhysics/LHCTopWG

LHC Higgs XS WG
https://twiki.cern.ch/twiki/bin/view/LHCPhysics/LHCHXSWG

LHC EW (MB) WG
https://twiki.cern.ch/twiki/bin/view/LHCPhysics/LHCEW

CMS

ATLAS

- Other

European strategy

Snowmass (here/now!)

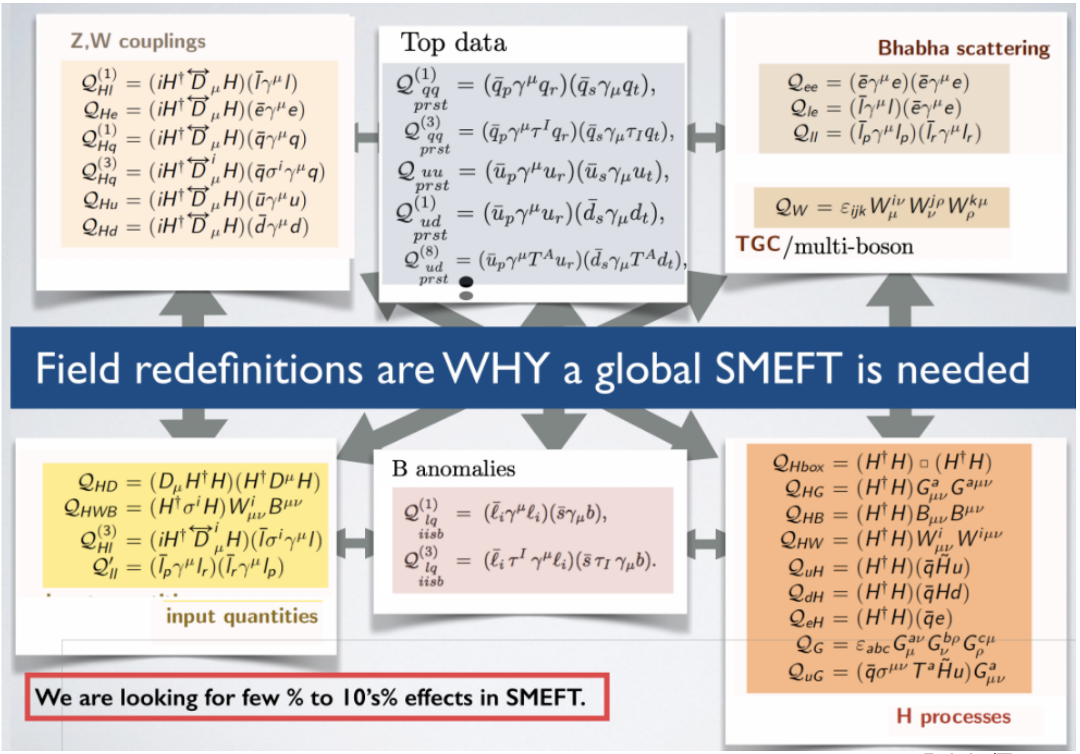
VBScan
EU/ERC-sponsored network

https://vbscanaction.web.cern.ch/

. . . potential others

Dimension-6 effective field theory: SMEFT

- Dim-6: 2499 parameters reduced to 81 ($U(3)^5$ flavour symm.)
  → Warsaw basis:
  orthogonal, complete,
  renormalisable
  → https://arxiv.org/abs/1008.4884,
  https://arxiv.org/abs/1709.06492,
  https://arxiv.org/abs/2005.05366



Brivio/Trott

- Dim-8: complete basis available since recently
  →https://arxiv.org/abs/2005.00059
  → https://arxiv.org/abs/2005.00008
  relevant for VBS+tribosons (and available in MG5)
  → https://arxiv.org/abs/1604.03555

- Not entirely trivial interplay:

$$\sigma = \sigma_{\mathrm{SM}} + \sum_i \frac{c_i}{\Lambda^2}\sigma_i^{\text{dim-6-interf}} + \sum_{ij} \frac{c_i c_j}{\Lambda^4}\sigma_{ij}^{(\text{dim-6})^2} + \sum_k \frac{c_k}{\Lambda^4}\sigma_k^{\text{dim-8-interf}} + \ldots$$

erc The University Of Sheffield.

CMS: EWK EFT interpretations

- From: https://cms-results-search.web.cern.ch/

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- Physics theme ▲

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- Working group ▼
- Final state ▼
- Final state signature ▼
- Interpretation ▲

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Show results with any all of the selected tags:

Combination | Effective Field Theory | Generator and simulation tuning | Simplified Model Spectrum | Standard Model Fits inc. PDFs

- SM analysis characteristics ▲

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Show 10 entries

Previous 1 2 3 4 5 6 Next

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Code	Title	Status/Link	Date
HIG-20-005	Search for Higgs boson pair production in the four b quark final state in proton-proton collisions at $\sqrt{s} = 13$ TeV	Submitted to Phys. Rev. Lett.	February 19, 2022
SMP-20-005	Measurement of $W^{\pm}\gamma$ differential cross sections in proton-proton collisions at $\sqrt{s} = 13$ TeV and effective field theory constraints	Phys. Rev. D 105 (2022) 052003	November 27, 2021
SMP-20-014	Measurement of the inclusive and differential WZ production cross sections, polarization angles, and triple gauge couplings in pp collisions at $\sqrt{s} =$ 13 TeV	Submitted to J. High Energy Phys.	October 21, 2021
TOP-18-010	Measurement of the inclusive and differential $t\bar{t}\gamma$ cross sections in the single-lepton channel and EFT interpretation at $\sqrt{s} = 13$ TeV	JHEP 12 (2021) 180	July 3, 2021
SMP-20-016	Measurement of the electroweak production of Zγ and two jets in proton-proton collisions at $\sqrt{s} = 13$ TeV and constraints on anomalous quartic gauge couplings	Phys. Rev. D 104 (2021) 072001	June 21, 2021
SMP-19-013	Measurements of the $pp \to W^{\pm}\gamma\gamma$ and $pp \to Z\gamma\gamma$ cross sections at $\sqrt{s} = 13$ TeV and limits on anomalous quartic gauge couplings	JHEP 10 (2021) 174	May 26, 2021
HIG-19-009	Constraints on anomalous Higgs boson couplings to vector bosons and fermions in its production and decay using the four-lepton final state	Phys. Rev. D 104 (2021) 052004	April 25, 2021
SMP-19-002	Measurement of Wγ production cross section in proton-proton collisions at $\sqrt{s} = 13$ TeV and constraints on effective field theory coefficients	Phys. Rev. Lett. 126 (2021) 252002	February 3, 2021
HIG-19-018	Search for nonresonant Higgs boson pair production in final states with two bottom quarks and two photons in proton-proton collisions at $\sqrt{s} = 13$ TeV	JHEP 03 (2021) 257	November 24, 2020
SMP-19-008	Observation of electroweak production of Wγ with two jets in proton-proton collisions at $\sqrt{s} = 13$ TeV	Phys. Lett. B 811 (2020) 135988	August 24, 2020

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Previous 1 2 3 4 5 6 Next

ATLAS: EWK EFT interpretations - SM

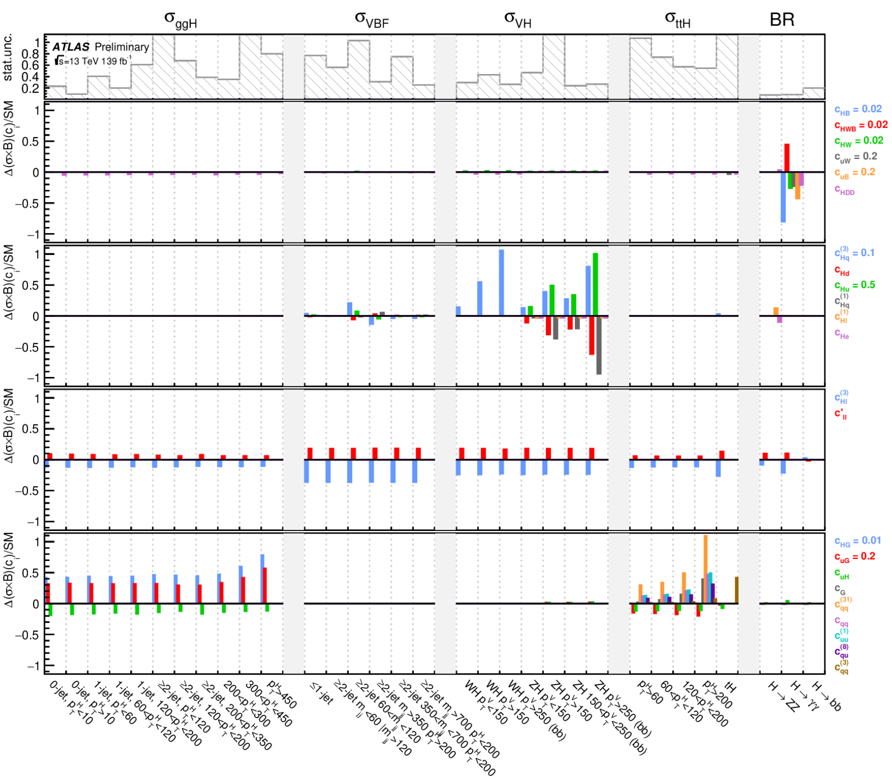
- https://twiki.cern.ch/twiki/bin/view/AtlasPublic/StandardModelPublicResults

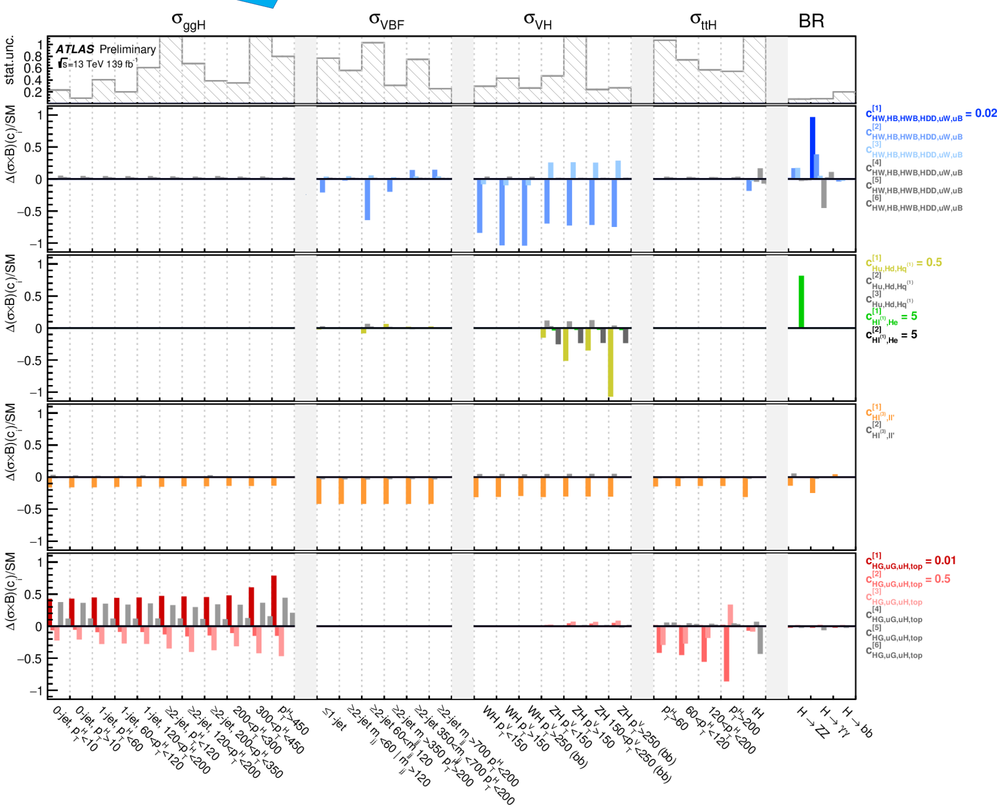
Short Title	Journal Reference	Date	√s (TeV)	L	Links
WW+1jet differential cross sections	JHEP 06 (2021) 003	18-MAR-21	13	139 fb^{-1}	Documents | 2103.10319 | Inspire Rivet | HepData | Internal
Inclusive four-lepton lepton differential cross sections	JHEP 07 (2021) 005	02-MAR-21	13	139 fb^{-1}	Documents | 2103.01918 | Inspire Rivet | HepData | Internal
EW Zjj differential cross sections	Eur. Phys. J. C 81 (2021) 163	27-JUN-20	13	139 fb^{-1}	Documents | 2006.15458 | Inspire Rivet | HepData | Internal
ZZ production with two neutrinos in the final state at 13 TeV	JHEP 10 (2019) 127	17-MAY-19	13	36 fb^{-1}	Documents | 1905.07163 | Inspire Internal
WZ boson pair production at 13 TeV	Eur. Phys. J. C 79 (2019) 535	15-FEB-19	13	36.1 fb^{-1}	Documents | 1902.05759 | Inspire HepData | Internal
ZZ cross-section measurement and aTGC limits at 13 TeV	Phys. Rev. D 97 (2018) 032005	22-SEP-17	13	36 fb^{-1}	Documents | 1709.07703 | Inspire Rivet | HepData | Internal
WVγ cross sections and limits on aGCs at 8 TeV	Eur. Phys. J. C 77 (2017) 646	18-JUL-17	8	20.2 fb^{-1}	Documents | 1707.05597 | Inspire HepData | Internal
Semileptonic WW/WZ cross-section at 8 TeV	Eur. Phys. J. C 77 (2017) 563	06-JUN-17	8	20.2 fb^{-1}	Documents | 1706.01702 | Inspire HepData | Internal
Electroweak $Z\gamma$ production 8 TeV	JHEP 07 (2017) 107	04-MAY-17	8	20.2 pb^{-1}	Documents | 1705.01966 | Inspire HepData | Briefing | Internal
Electroweak Wjj cross section and aGC Limits at 7 and 8 TeV	Eur. Phys. J. C 77 (2017) 474	13-MAR-17	7 , 8	4.7 fb^{-1}, 20.2 fb^{-1}	Documents | 1703.04362 | Inspire HepData | Internal
Same-sign WW cross-section and aQGC Limits at 8 TeV	Phys. Rev. D 96 (2017) 012007	08-NOV-16	8	20.3 fb^{-1}	Documents | 1611.02428 | Inspire Internal
ZZ cross-section and aTGC limits at 8 TeV	JHEP 01 (2017) 099	24-OCT-16	8	20.3 fb^{-1}	Documents | 1610.07585 | Inspire HepData | Internal
Search for semileptonic WW/WZ VBS at 8 TeV	Phys. Rev. D 95 (2017) 032001	16-SEP-16	8	20.3 fb^{-1}	Documents | 1609.05122 | Inspire Internal
Exclusive WW cross-section at 8 TeV	Phys. Rev. D 94 (2016) 032011	13-JUL-16	8	20.3 fb^{-1}	Documents | 1607.03745 | Inspire Internal

ATLAS: STXS EFT basis

Parameter		Definition	Eigenvalue	Fit Parameter
$c_{Hq}^{(3)}$		$c_{Hq}^{(3)}$	1900	✓
$c^{[i]}_{HW,HB,HWB,HDD,uW,uB}$	1	$-0.27c_{HW} - 0.84c_{HB} + 0.47c_{HWB} - 0.02c_{uW} - 0.05c_{uB}$	245000	✓
	2	$-0.96c_{HW} + 0.19c_{HB} - 0.20c_{HWB} + 0.02c_{uB}$	33	✓
	3	$-0.08c_{HW} + 0.50c_{HB} + 0.86c_{HWB} + 0.07c_{HDD} + 0.03c_{uW} + 0.06c_{uB}$	4	✓
	4	$0.03c_{HWB} - 0.85c_{HDD} + 0.32c_{uW} + 0.43c_{uB}$	0.017	
	5	$-0.01c_{HW} + 0.07c_{HB} + 0.05c_{HWB} - 0.44c_{HDD} - 0.86c_{uW} - 0.23c_{uB}$	0.0077	
	6	$-0.01c_{HW} + 0.06c_{HB} + 0.04c_{HWB} - 0.29c_{HDD} + 0.39c_{uW} - 0.87c_{uB}$	0.0025	
$c^{[i]}_{HG,uG,uH,\text{top}}$	1	$+0.999c_{HG} + 0.038c_{uG}$	176000	✓
	2	$-0.03c_{HG} + 0.73c_{uG} - 0.03c_{qq}^{(1)} - 0.23c_{qq} - 0.05c_{qq}^{(3)} - 0.54c_{qq}^{(31)} - 0.02c_{uu} - 0.24c_{uu}^{(1)} - 0.04c_{ud}^{(8)} - 0.01c_{qu}^{(1)} - 0.15c_{qu}^{(8)} - 0.04c_{qd}^{(8)} - 0.18c_{G} + 0.06c_{uH}$	20	✓
	3	$-0.03c_{HG} + 0.67c_{uG} + 0.04c_{qq}^{(1)} + 0.25c_{qq} + 0.05c_{qq}^{(3)} + 0.55c_{qq}^{(31)} + 0.02c_{uu} + 0.26c_{uu}^{(1)} + 0.03c_{ud}^{(8)} + 0.01c_{qu}^{(1)} + 0.16c_{qu}^{(8)} + 0.03c_{qd}^{(8)} + 0.29c_{G} + 0.1c_{uH}$	1.3	✓
	4	$+0.11c_{uG} + 0.01c_{qq} - 0.018c_{qq}^{(3)} + 0.029c_{qq}^{(31)} + 0.012c_{uu}^{(1)} - 0.993c_{uH}$	0.14	
	5	$+0.02c_{qq} - 1.0c_{qq}^{(3)} + 0.06c_{qq}^{(31)} + 0.03c_{uu}^{(1)} + 0.02c_{qu}^{(8)} + 0.02c_{uH}$	0.02	
	6	$+0.07c_{uG} - 0.02c_{qq}^{(1)} + 0.07c_{qq} + 0.03c_{qq}^{(3)} + 0.32c_{qq}^{(31)} + 0.06c_{uu}^{(1)} + 0.04c_{ud}^{(8)} + 0.08c_{qu}^{(8)} + 0.04c_{qd}^{(8)} - 0.94c_{G} + 0.02c_{uH}$	0.0092	
$c^{[1]}_{Hl^{(1)},He}$		$+0.78c_{Hl}^{(1)} - 0.62c_{He}$	2.6	✓
$c^{[2]}_{Hl^{(1)},He}$		$+0.62c_{Hl}^{(1)} + 0.78c_{He}$	0.056	
$c^{[1]}_{Hu,Hd,Hq^{(1)}}$		$-0.87c_{Hu} + 0.26c_{Hd} + 0.42c_{Hq}^{(1)}$	59	✓
$c^{[2]}_{Hu,Hd,Hq^{(1)}}$		$+0.41c_{Hu} - 0.09c_{Hd} + 0.91c_{Hq}^{(1)}$	0.10	
$c^{[3]}_{Hu,Hd,Hq^{(1)}}$		$-0.28c_{Hu} - 0.96c_{Hd} + 0.03c_{Hq}^{(1)}$	0.0018	
$c^{[1]}_{Hl^{(3)},ll'}$		$0.87c_{Hl}^{(3)} - 0.50c'_{ll}$	27	✓
$c^{[2]}_{Hl^{(3)},ll'}$		$0.50c_{Hl}^{(3)} + 0.87c'_{ll}$	0.33	

ATLAS: STXS EFT basis rotation





Area 1: EWK Input parameter scheme

- **Recommendations presented in LHC EFT note: https://arxiv.org/abs/2111.12515**

- **Common set of electroweak parameters for SMEFT predictions for LHC observables eases comparisons and combinations**
  → Implementation of different schemes in tools desirable for comparing different choices

- **Considerations:**
  → Input parameters are precisely measured (impact negligible in SMEFT fit)
  → Experimental measurement of input parameters is independent of SMEFT effects
  → Choice does not introduce dependence of the fit on other unrelated operators (i.e. those that are not included in the fit) [or at least minimizes this effect]

- **Choices reviewed:**
  → (1) $\{\alpha , G\mu , m_Z\}$
  → (2) $\{G\mu , m_Z, m_W\}$ → favoured as it reduced dependence on propagators, but needs to care when combining LHC and LEP results (which use (1) – however no large numerical impact is expected)
  → (3) $\{\alpha , m_Z, m_W\}$

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Area 1: Validity

- **What is "validity"?**

  → An estimate of how valid or correct the used EFT parametrization is

  → Answers the question on how reliable the EFT constrain is when translated to a concrete model (→ see quote)

A Quote from a Model Builder

- "Whatever bound you get from your EFT, I can always write down a model that passes the test against data and violates the bound you claim to have." – Bhaskar Dutta

Slide by William Shepherd

- **Breakdown of validity (at large scale)**

$$\sigma = \sigma_{\text{SM}} + \sum_i \frac{c_i}{\Lambda^2}\sigma_i^{\text{dim-6-interf}} + \sum_{ij} \frac{c_i c_j}{\Lambda^4}\sigma_{ij}^{(\text{dim-6})^2} + \sum_k \frac{c_k}{\Lambda^4}\sigma_k^{\text{dim-8-interf}} + \ldots$$

- Most general description of violation of validity: EFT expansion does not describe the model underlying the actual data (anymore)
  → Does the dim-6 terms match the underlying new physics (and for which NP scenarios?)
  (1) general consideration: growth with energy cannot go on forever
  (2) Dim-6 terms are not necessarily smaller than Dim-8 (and quadratic Dim-6) terms, especially at large energy scales (→ truncation after linear Dim-6 is incorrect, example: WW)
  (3) Correspondence between UV model and EFT breaks down above certain energy threshold

- **Interpretation of EFT fits can be misleading (overconstraints, wrongly excluded models...)**

Area 1: Validity

- **Possible solutions / Proposals discussed**

→ Proposals are presented in LHC EFT note: https://arxiv.org/abs/2201.04974v1

→ based on dedicated meeting January 19, 2021 (https://indico.cern.ch/event/980681/)
→ follow-up in general meeting on May 3, 2021 (https://indico.cern.ch/event/1016713/)
→ Comment collection: https://docs.google.com/document/d/13gLoLsELfBaifcTwhSXkcj6z152uz-xlB_WDx2HirFo/edit
→ Feedback from the collaborations June 28, 2021 (https://indico.cern.ch/event/1048848/)

- **Proposal C**

→ using quadratic dim-6 as proxies for missing dim-8 terms (of same order) *where needed* (dim-8 functional form unknown)
→ employing a power-counting rule to estimate dim-8 contributions from quadratic dim-6 (general on power counting: https://arxiv.org/abs/1601.07551 → which are dominant term depending on which aspect of the theory is more relevant)
→ Use as uncertainties quadratic dim-6 and dim-8 terms
→ Directly use in experimental analysis

Pro: best "mapping" → correspondence between 'error' and dim-6-quad / dim-8 model
Contra: Difficult to apply a posteriori (and concrete implementation not quite known)
Difficult to find consist choice of variables and cuts across different processes

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