

Area 4 Report: Fits and Related Systematics

Jorge de Blas
University of Granada

with N. Berger, F. Canelli, N. Castro,
P. Govoni and G. Petrucciani
on behalf of the WG conveners



ugr

Universidad
de **Granada**



Funded by: FEDER/Junta de Andalucía-Consejería de Transformación
Económica, Industria, Conocimiento y Universidades/Proyect P18-FRJ-3735

LHC EFT WG Area 4: Fits and Related Systematics

- Area 4 covers issues concerning the interpretation, preparation and performance of LHC global fits:
 - ✓ Experimental EFT fits: ATLAS, CMS, ATLAS+CMS combinations of EW+H+Top
 - ✓ Inputs/Output, fitting procedures and tools
 - ▶ Treatment of EXP inputs
 - ▶ EFT capabilities
 - ▶ Validation of different tools
 - ✓ Combination with non-LHC constraints (LEP, Tevatron, Flavor, etc)
 - ✓ Systematics and their correlations:
 - ▶ Theory (Area 2)
 - ▶ Experimental (Area 3)
 - ✓ Presentation of EFT fit results: likelihoods, covariances, treatment of flat directions, etc.
 - ✓ Future projections of EFT constraints

LHC EFT WG Area 4: Fits and Related Systematics

- Area 4 covers issues concerning the interpretation, preparation and performance of LHC global fits:
 - ✓ Experimental EFT fits: ATLAS, CMS, ATLAS+CMS combinations of EW+H+Top
 - ✓ Inputs/Output, fitting procedures and tools
 - ▶ Treatment of EXP inputs
 - ▶ EFT capabilities
 - ▶ Validation of different tools
 - ✓ Combination with non-LHC constraints (LEP, Tevatron, Flavor, etc)
 - ✓ Systematics and their correlations:
 - ▶ Theory (Area 2)
 - ▶ Experimental (Area 3)
 - ✓ Presentation of EFT fit results: likelihoods, covariances, treatment of flat directions, etc.
 - ✓ Future projections of EFT constraints

LHC EFT WG Area 4 Meetings

Area 4 meeting: fits and related systematics

miércoles 27 ene. 2021 15:00 → 19:00 Europe/Zurich

Florencia Canelli (Universitaet Zuerich (CH)), Giovanni Petrucciani (CERN), Jorge de Blas (Universidad de Granada (ES)), Nicolas Berger (Centre National de la Recherche Scientifique (FR)), Nuno Castro (LIP and University of Minho (PT)), Pietro Govoni (Universita & INFN, Milano-Bicocca (IT))

15:00 → 15:10 Introduction

LHCEFTWG-Area3-i...

15:10 → 16:25 Fitting Frameworks (I)

15:10 Fitmaker

Ponente: Maeve Madigan (University of Cambridge)

eft-area4-madigan... Fitmaker_MM.pdf

15:35 SMEFit

Ponente: Juan Rojo (VU Amsterdam and Nikhef)

eft-area4-rojo.mp4 rojo-SMEFIT-LHCEF...

16:00 EFTFitter

Ponentes: Cornelius Grunwald (Technische Universitaet Dortmund (DE)), Cornelius Grunwald (TU Dortmund)

eft-area4-grunwald... EFTfitter.pdf

16:25 → 16:45

Coffee Break

16:45 → 17:35 Fitting Frameworks (II)

16:45 HEPfit

Ponente: Luca Silvestrini (INFN Rome)

eft-area4-silvestrini... silvestrini@Area4.p...

17:10 Sfitter

Ponente: Sebastian Bruggisser (University Heidelberg)

Bruggisser_SFITTE... eft-area4-bruggisse...

17:35 → 19:00 Discussion

afte-area4-dicussio... Area4_Discussion...

Jan 27, 2021

<https://indico.cern.ch/event/971727/>

Areas 3&4 meeting: experimental measurements, fits and related systematics

lunes 22 feb. 2021 14:00 → 18:00 Europe/Zurich

Andrei Gritsan (Johns Hopkins University (US)), Eleni Vryonidou (University of Manchester (GB)), Florencia Canelli (Universitaet Zuerich (CH)), Giovanni Petrucciani (CERN), Jorge de Blas (Universidad de Granada (ES)), Nicolas Berger (Centre National de la Recherche Scientifique (FR)), Nuno Castro (LIP and University of Minho (PT)), Pietro Govoni (Universita & INFN, Milano-Bicocca (IT))

14:00 → 14:05 Introduction

Ponente: Nuno Castro (LIP and University of Minho (PT))

LHCEFTWG-Area3-...

14:05 → 14:35 Fitting experience and plans in ATLAS: focus on the technical aspects

Ponente: Nicolas Berger (Centre National de la Recherche Scientifique (FR))

EFTWG_ATLAS_Ex...

14:40 → 15:10 Fitting experience and plans in CMS: focus on the technical aspects

Ponentes: Adinda De Wit (Universitaet Zuerich (CH)), Kevin Patrick Lannon (University of Notre Dame (US))

Higgs

Ponente: Adinda De Wit (Universitaet Zuerich (CH))

EFTWG_CMSHiggs_A...

Top

Ponente: Kevin Patrick Lannon (University of Notre Dame (US))

LHCEFTWG_2020-02-...

15:20 → 15:35 The ATLAS + CMS Higgs combination

Ponentes: Andrew Gilbert (Northwestern University (US)), Roberto Di Nardo (Universita e INFN Roma Tre (IT))

EFTWG-LHC-HCom...

15:45 → 16:05 On the presentation of public experimental results: A theorist point of view

Ponente: Jorge de Blas (Universidad de Granada)

Presentation_ExpR...

16:15 → 16:25 Towards a technical combination exercise

Ponente: Pierre Savard (University of Toronto (CA))

savard_eftwg_22fe...

Feb 22, 2021

<https://indico.cern.ch/event/1007581/>

LHC EFT WG Area 4 Meetings

Area 4 meeting: fits and related systematics

miércoles 27 ene. 2021 15:00 → 19:00 Europe/Zurich

Florencia Canelli (Universitaet Zuerich (CH)), Giovanni Petrucciani (CERN), Jorge de Blas (Universidad de Granada (ES)), Nicolas Berger (Centre National de la Recherche Scientifique (FR)), Nuno Castro (LIP and University of Minho (PT)), Pietro Govoni (Universita & INFN, Milano-Bicocca (IT))

15:00 → 15:10 Introduction

LHCEFTWG-Area3-I...

15:10 → 16:25 Fitting Frameworks (I)

15:10 Fitmaker

Ponente: Maeve Madigan (University of Cambridge)

eft-area4-madigan... Fitmaker_MM.pdf

15:35 SMEFit

Reviewing public fitting frameworks with capacities for EFT studies

16:45 → 17:35 Fitting Frameworks (II)

16:45 HEPfit

Ponente: Luca Silvestrini (INFN Rome)

eft-area4-silvestrini... silvestrini@Area4.p...

17:10 Sfitter

Ponente: Sebastian Bruggisser (University Heidelberg)

Bruggisser_SFITTE... eft-area4-bruggisse...

17:35 → 19:00 Discussion

afte-area4-dicussio... Area4_Discussion...

Jan 27, 2021

<https://indico.cern.ch/event/971727/>

Areas 3&4 meeting: experimental measurements, fits and related systematics

lunes 22 feb. 2021 14:00 → 18:00 Europe/Zurich

Andrei Gritsan (Johns Hopkins University (US)), Eleni Vryonidou (University of Manchester (GB)), Florencia Canelli (Universitaet Zuerich (CH)), Giovanni Petrucciani (CERN), Jorge de Blas (Universidad de Granada (ES)), Nicolas Berger (Centre National de la Recherche Scientifique (FR)), Nuno Castro (LIP and University of Minho (PT)), Pietro Govoni (Universita & INFN, Milano-Bicocca (IT))

14:00 → 14:05 Introduction

Ponente: Nuno Castro (LIP and University of Minho (PT))

LHCEFTWG-Area3-...

14:05 → 14:35 Fitting experience and plans in ATLAS: focus on the technical aspects

Ponente: Nicolas Berger (Centre National de la Recherche Scientifique (FR))

EFTWG_ATLAS_Ex...

14:40 → 15:10 Fitting experience and plans in CMS: focus on the technical aspects

Ponentes: Adinda De Wit (Universitaet Zuerich (CH)), Kevin Patrick Lannon (University of Notre Dame (US))

Higgs

Ponente: Adinda De Wit (Universitaet Zuerich (CH))

EFTWG_CMSHiggs_A...

Top

Ponente: Kevin Patrick Lannon (University of Notre Dame (US))

LHCEFTWG_2020-02-...

15:20 → 15:35 The ATLAS + CMS Higgs combination

Ponentes: Andrew Gilbert (Northwestern University (US)), Roberto Di Nardo (Università e INFN Roma Tre (IT))

EFTWG-LHC-HCom...

15:45 → 16:05 On the presentation of public experimental results: A theorist point of view

Ponente: Jorge de Blas (University of Granada)

Presentation_ExpR...

16:15 → 16:25 Towards a technical combination exercise

Ponente: Pierre Savard (University of Toronto (CA))

savard_eftwg_22fe...

Feb 22, 2021

<https://indico.cern.ch/event/1007581/>

LHC EFT WG Area 4 Meetings

Area 4 meeting: fits and related systematics

miércoles 27 ene. 2021 15:00 → 19:00 Europe/Zurich

Florencia Canelli (Universitaet Zuerich (CH)), Giovanni Petrucciani (CERN), Jorge de Blas (Universidad de Granada (ES)), Nicolas Berger (Centre National de la Recherche Scientifique (FR)), Nuno Castro (LIP and University of Minho (PT)), Pietro Govoni (Universita & INFN, Milano-Bicocca (IT))

15:00 → 15:10 Introduction

LHCEFTWG-Area3-I...

15:10 → 16:25 Fitting Frameworks (I)

15:10 Fitmaker

Ponente: Maeve Madigan (University of Cambridge)

eft-area4-madigan..., Fitmaker_MM.pdf

15:35 SMEFit

Ponente: Juan Rojo (VU Amsterdam and Nikhef)

eft-area4-rojo.mp4, rojo-SMEFIT-LHCEF...

16:00 EFTFitter

Ponentes: Cornelius Grunwald (Technische Universitaet Dortmund (DE)), Cornelius Grunwald (TU Dortmund)

eft-area4-grunwald..., EFTfitter.pdf

16:25 → 16:45

Coffee Break

16:45 → 17:35 Fitting Frameworks (II)

16:45 HEPfit

Ponente: Luca Silvestrini (INFN Rome)

eft-area4-silvestrini..., silvestrini@Area4.p...

17:10 Sfitter

Ponente: Sebastian Bruggisser (University Heidelberg)

Bruggisser_SFITTE..., eft-area4-bruggisse...

17:35 → 19:00 Discussion

afte-area4-dicussio..., Area4_Discussion...

Jan 27, 2021

<https://indico.cern.ch/event/971727/>

Areas 3&4 meeting: experimental measurements, fits and related systematics

lunes 22 feb. 2021 14:00 → 18:00 Europe/Zurich

Andrei Gritsan (Johns Hopkins University (US)), Eleni Vryonidou (University of Manchester (GB)), Florencia Canelli (Universitaet Zuerich (CH)), Giovanni Petrucciani (CERN), Jorge de Blas (Universidad de Granada (ES)), Nicolas Berger (Centre National de la Recherche Scientifique (FR)), Nuno Castro (LIP and University of Minho (PT)), Pietro Govoni (Universita & INFN, Milano-Bicocca (IT))

14:00 → 14:05 Introduction

Ponente: Nuno Castro (LIP and University of Minho (PT))

Reviewing ATLAS & CMS fitting experience in the SMEFT framework

Higgs

Ponente: Adinda De Wit (Universitaet Zuerich (CH))

Discussing usability and improvements in presentation of public EXP data (for external EFT interpret. & global combinations)

Ponentes: Andrew Gilbert (Northwestern University (US)), Roberto Di Narzo (Universita' di Roma Tre (IT))

EFTWG-LHC-HCom...

15:45 → 16:05 On the presentation of public experimental results: A theorist point of view

Ponente: Jorge de Blas (University of Granada)

Presentation_ExpR...

16:15 → 16:25 Towards a technical combination exercise

Ponente: Pierre Savard (University of Toronto (CA))

savard_eftwg_22fe...

Feb 22, 2021

<https://indico.cern.ch/event/1007581/>

SMEFT fitting frameworks

Summary of fitting frameworks

- Several fitting frameworks available in the “market” (with different scopes):

EFT*fitter*

Fitmaker



Summary of fitting frameworks

- Several fitting frameworks available in the “market” (with different scopes):

EFT*fitter*

Fitmaker



- Summary of features (not available in all of them):
 - ✓ Wide range of observables available in the EFT framework: EW, Higgs, Top, Flavor
 - ✓ Possibility of Bayesian or frequentist statistical interpretations
 - ✓ Different levels in the EFT implementation: Linear/Quadratic, LO/NLO
 - ✓ Possibility of modeling (correlated) theory uncertainties
 - ✓ Admit different forms of Exp. Inputs: (Correlated) observables, Histograms, DNN (WIP), ...

Summary of fitting frameworks

- Several fitting frameworks available in the “market” (with different scopes):

EFT*fitter*

Fitmaker



- Some issues of potential relevance discussed in Area 4 meeting:
 - I. Requirements from experiments so that these tools can be implemented in the EXP workflow?

Summary of fitting frameworks

- Several fitting frameworks available in the “market” (with different scopes):

EFT*fit*ter

Fitmaker



- Some issues of potential relevance discussed in Area 4 meeting:
 1. Requirements from experiments so that these tools can be implemented in the EXP workflow?
 2. Difficulties coming from the compact format used for publications by Exp. Coll.

Summary of fitting frameworks

- Several fitting frameworks available in the “market” (with different scopes):

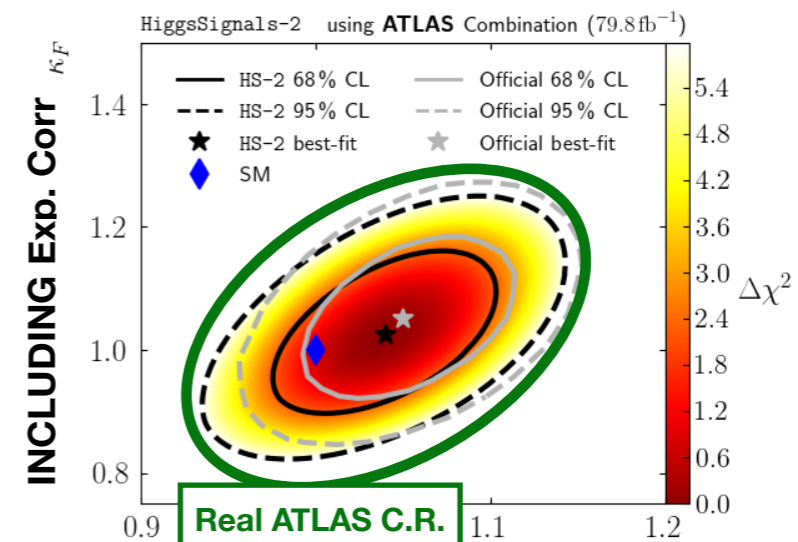
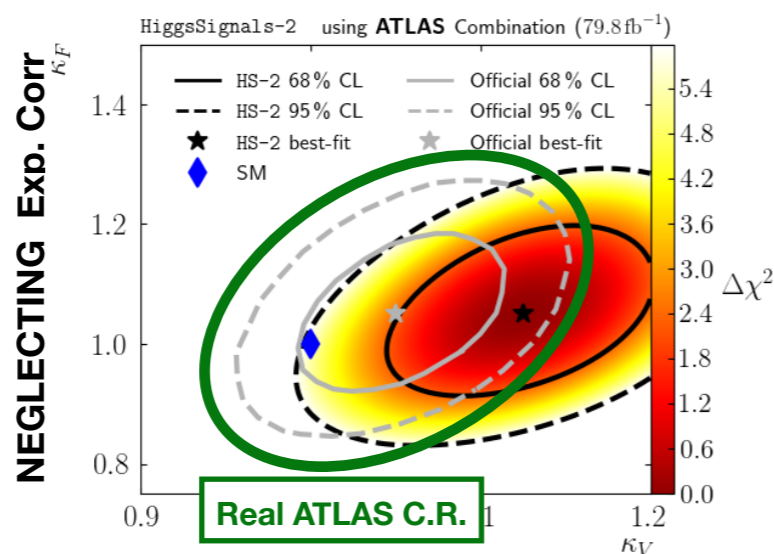
EFTfitter

Fitmaker



- Some issues of potential relevance discussed in Area 4 meeting:
 - Requirements from experiments so that these tools can be implemented in the EXP workflow?
 - Difficulties coming from the compact format used for publications by Exp. Coll. \Rightarrow Decent approx. to likelihood needed for interpretation

Correlations:
STXS
Re-Interpretation



P. Bechtle et al., E. P. J.C 81 (2021) 2. 145


Summary of fitting frameworks

- Several fitting frameworks available in the “market” (with different scopes):

EFTfitter

Fitmaker



- Some issues of potential relevance discussed in Area 4 meeting:
 1. Requirements from experiments so that these tools can be implemented in the EXP workflow?
 2. Difficulties coming from the compact format used for publications by Exp. Coll. \Rightarrow Decent approx. to likelihood needed for interpretation
 - ▶ Always provide fit mode and covariance matrices (V) for the POI...
 - ▶ ...separating sources of errors: $V = V_{\text{stat}} + V_{\text{sys}} + V_{\text{th}}$ \leftarrow Important for combination and treatment of TH unc.
 - ▶ Provide full likelihoods?  DNNLikelihoods

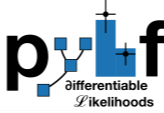
Summary of fitting frameworks

- Several fitting frameworks available in the “market” (with different scopes):

EFTfitter

Fitmaker



- Some issues of potential relevance discussed in Area 4 meeting:
 1. Requirements from experiments so that these tools can be implemented in the EXP workflow?
 2. Difficulties coming from the compact format used for publications by Exp. Coll. \Rightarrow Decent approx. to likelihood needed for interpretation
 - ▶ Always provide fit mode and covariance matrices (V) for the POI...
 - ▶ ...separating sources of errors: $V = V_{\text{stat}} + V_{\text{sys}} + V_{\text{th}}$ \leftarrow Important for combination and treatment of TH unc.
 - ▶ Provide full likelihoods?  DNNLikelihoods
 3. Need of cross-checking SMEFT implementations across tools (validation, systematics) \Rightarrow WG activity

Cross-checking SMEFT fitting frameworks

- Define fit benchmarks to cross-check results from different codes:
 1. Identify overlaps in subsets of processes/operators implemented in several codes \Rightarrow Use these to define basic benchmark setups
 2. Choose sensible SMEFT assumptions, according to the processes in each benchmark, e.g. flavor universality
- Focus first on testing the basic SMEFT implementation:
 - ▶ Compare results neglecting $O(1/\Lambda^4)$ effects
 - ▶ Use trivial (flat) priors on the SMEFT effects
 - ▶ Neglect theory uncertainties
- Comparison:
 1. Compare results from fits to both:
 - ▶ Global fit results (mode + covariance matrix)
 - ▶ Fits to individual operators (to easily identify possible issues, if discrepancies are present)
 2. More in-depth comparison could be done if common output format is adopted

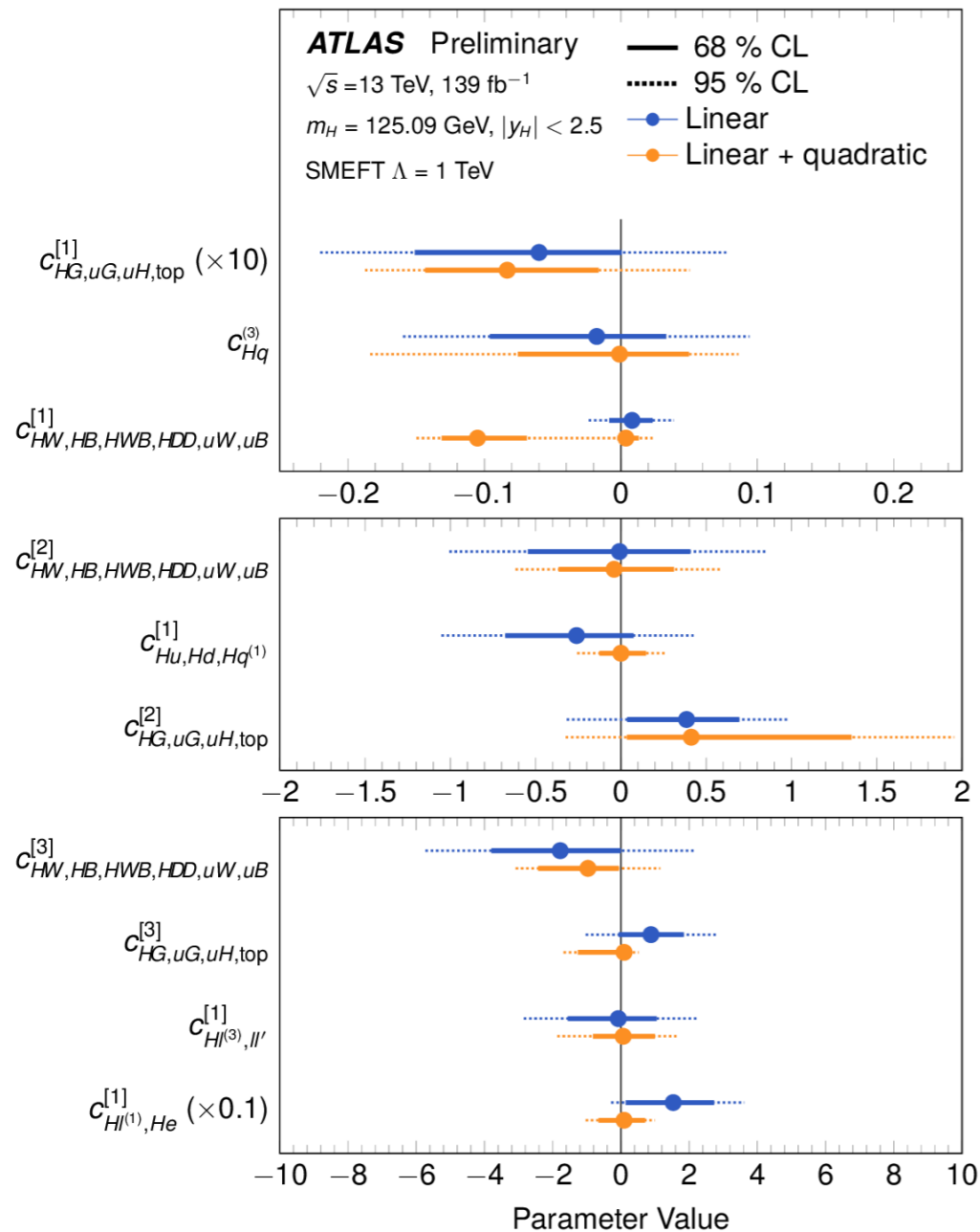
Thanks to J. Rojo for input

LHC fitting experience

ATLAS and CMS EFT fitting experience

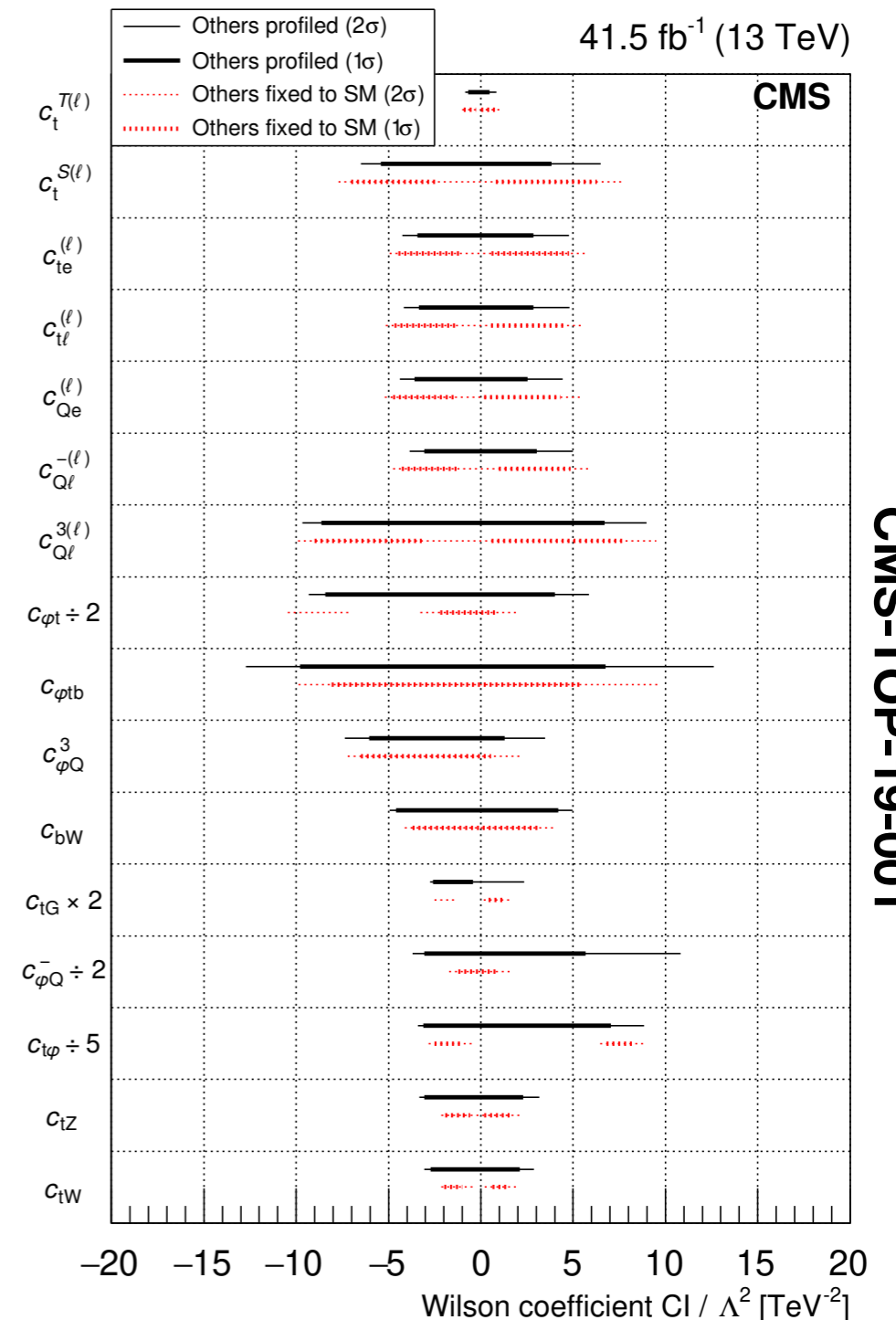
- Several existing studies using the EFT interpretation by ATLAS (in EW/H/Top) and CMS (H/Top), e.g.

ATLAS Higgs STXS combination



ATLAS-CONF-2020-053

CMS Top multi-lepton



CMS-TOP-19-001

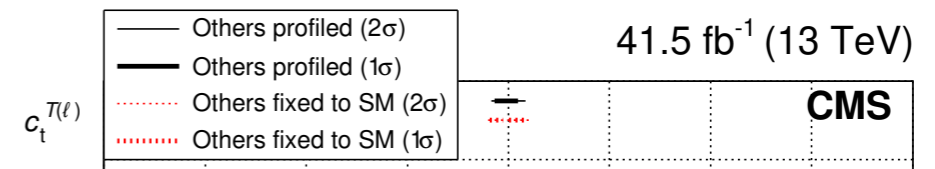
ATLAS and CMS EFT fitting experience

- Several existing studies using the EFT interpretation by ATLAS (in EW/H/Top) and CMS (H/Top), e.g.

ATLAS Higgs STXS combination

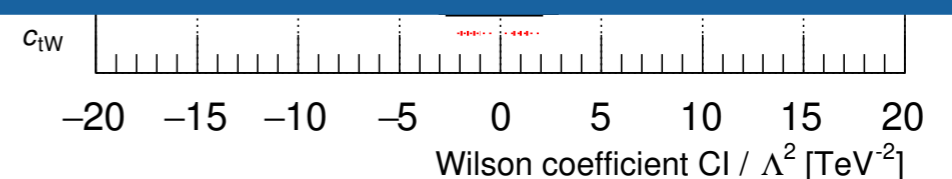
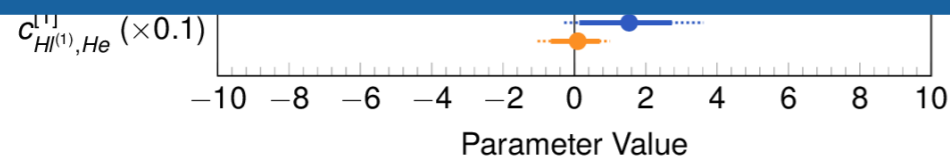


CMS Top multi-lepton



Some general remarks

- ▶ Consensus toward adopting Warsaw basis by both ATLAS and CMS
 - ▶ Plans reported from both ATLAS and CMS to perform EW+Higgs+Top EFT combinations
 - ▶ **Long term goal:** ATLAS+CMS combination
 - ▶ **Issue:** Current studies restricted to incomplete sets of dim-6 operators (not global). Problematic for global combinations with other processes
- ⇒ **Go global, then report bounds on non-flat combinations, via e.g. PCA**



ATLAS and CMS combinations

- Discussed the issues of ATLAS + CMS combinations in the context of the Run I combination of Higgs results
 - ▶ No EFT interpretation in Run I combination
- **Currently:** preparatory steps for the ATLAS+CMS Run 2 combination of Higgs results
 - ▶ EFT interpretation is expected, based in the combination of STXS measurements
- **Long term goal:** ATLAS and CMS combination of EW+Higgs+Top
- This will require to align EFT assumptions to be implemented in Workspaces:
 1. Operator basis and subsets of operators to be considered (if not global)
 2. SM EW input scheme
 3. Truncation of EFT results
 4. Scheme describing uncertainties on EFT predictions
 5. Etc

ATLAS and CMS combinations

- Discussed the issues of ATLAS + CMS combinations in the context of the Run I combination of Higgs results
 - ▶ No EFT interpretation in Run I combination
- **Currently:** preparatory steps for the ATLAS+CMS Run 2 combination of Higgs results
 - ▶ EFT interpretation is expected, based in the combination of STXS measurements
- **Long term goal:** ATLAS and CMS combination of EW+Higgs+Top
- This will require to align EFT assumptions to be implemented in Workspaces:

1. Operator basis and subsets of operators to be considered (if not global)
2. SM EW input scheme
3. Truncation of EFT results
4. Scheme describing uncertainties on EFT predictions
5. Etc

**Covered in this WG
Area 1**

LHC SMEFT fitting exercise

LHC fitting exercise

- One prime objective of Area 4 is to bring ATLAS and CMS to the level where a robust procedure for a combination is built
- We propose a technical exercise to identify key aspects that may need to be addressed in future LHC combinations. The goal is:
 1. To examine the viability of implementing the conventions and recommendations from the WG
 2. To identify possible technical difficulties in the combination process and determine the optimal configuration of the fitting techniques for the future
- Focus of the last part of this 2nd general meeting:

17:00	→ 17:10	Fitting exercise: Introduction Ponente: Pierre Savard (University of Toronto (CA))	🕒 10m
17:15	→ 17:30	Fitting exercise: ATLAS vision Ponente: Ana Rosario Cueto Gomez (CERN)	🕒 15m
17:30	→ 17:45	Fitting exercise: CMS vision ¶ Ponente: Alexander Josef Grohsjean (Deutsches Elektronen-Synchrotron (DE))	🕒 15m
17:45	→ 18:00	Fitting exercise: Discussion	🕒 15m

Summary

Summary

- Current Area 4 meetings focused on:
 - ✓ Fitting tools, their validation and interplay with EXP inputs
 - ✓ Reviewing the status of the fitting experience by ATLAS and CMS
 - ✓ Paving the way towards a general & realistic ATLAS/CMS combined EFT fit

- Several work items identified:
 - ✓ Definition of fit benchmark scenarios for cross-checking fitting tools
 - ✓ Recommendation for a common output format for fitting tools?
 - ✓ Work with ATLAS and CMS in defining a robust procedure for EFT combinations, using the recommendations of the LHC EFT WG

⇒ LHC global fit combination exercise (see next talks)

Summary

- Check preliminary Area 4 note (attached to indico page):

PRELIMINARY

LHC EFT WG Area 4 - Fits and related systematics

Editors: N. Berger, J. de Blas, F. Canelli, N. Castro,
P. Govoni and G. Petrucciani

May 1, 2021

So far, the activities of this Area 4 have focused on:

1. Identifying different computational fitting frameworks publicly available with capabilities for performing EFT studies.
2. Reviewing the fitting experience in the SMEFT framework by the LHC ATLAS and CMS collaborations, and discussing/exploring the possibility of combined analyses.
3. Discussing the usability and possible improvements in the presentation of public experimental results, so they can be efficiently used for global studies combining information from different processes.

- Please send your comments, corrections, suggestions for activities, etc using the [link to the Area 4 google doc](#) in the indico page