# Report from the EFT Working Group

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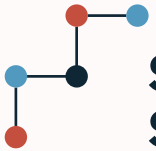


Swiss National Science Foundation

ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

# The LHC EFT Working Group

| | |
|---|---|
| **Website** | `lpcc.web.cern.ch/lhc-eft-wg` |
| **Meetings** | `indico.cern.ch/category/12671/` |
| **Twiki** | `twiki.cern.ch/twiki/bin/view/LHCPhysics/LHCEFT` [CDS documents] |
| **Contact** | `lhc-eftwg-admin@cern.ch` [sign up] |

**Conveners**

| | | |
|---|---|---|
| **ATLAS** | Sandra Kortner | Pierre Savard |
| | Sarah Heim (Higgs) | Nicolas Berger |
| | Jacob Kempster (Top) | Nuno Castro |
| | Kristin Lohwasser (EW) | |
| **CMS** | Nadjieh Jafari | Andrei Gritsan |
| | Nicholas Wardle (Higgs) | Giovanni Petrucciani |
| | Robert Schöfbeck (Top) | |
| | Matteo Presilla (EW) | Andrew Gilbert |
| **LHCb** | Patrick Owen | |
| **Theory** | Ilaria Brivio | |
| | Gauthier Durieux | |
| | Admir Greljo | |
| | Anke Biekötter (Higgs) | Jorge De Blas |
| | Shankha Banerjee (EW) | Céline Degrande |
| | Ken Mimasu (Top) | Eleni Vryonidou |

established 2020, currently having a conveners turnover and refreshing activities plan

General Meeting 10 days ago: `indico.cern.ch/event/1201401/`

# LHC EFT WG Structure

overview of targets: 2020 doc + Twiki

**Area 1.** EFT Formalism

Ilaria, Gauthier, Matteo

**Area 2.** Predictions and Tools

Ken, Ilaria, Sarah, Robert

**Area 3.** Experimental measurements and observables

Anke, Shankha, Jacob, Kristin, Nadjieh

**Area 4.** Fits and related systematics

Anke, Ken, Kristin, Jacob, Nicholas

**Area 5.** Benchmark scenarios from UV models

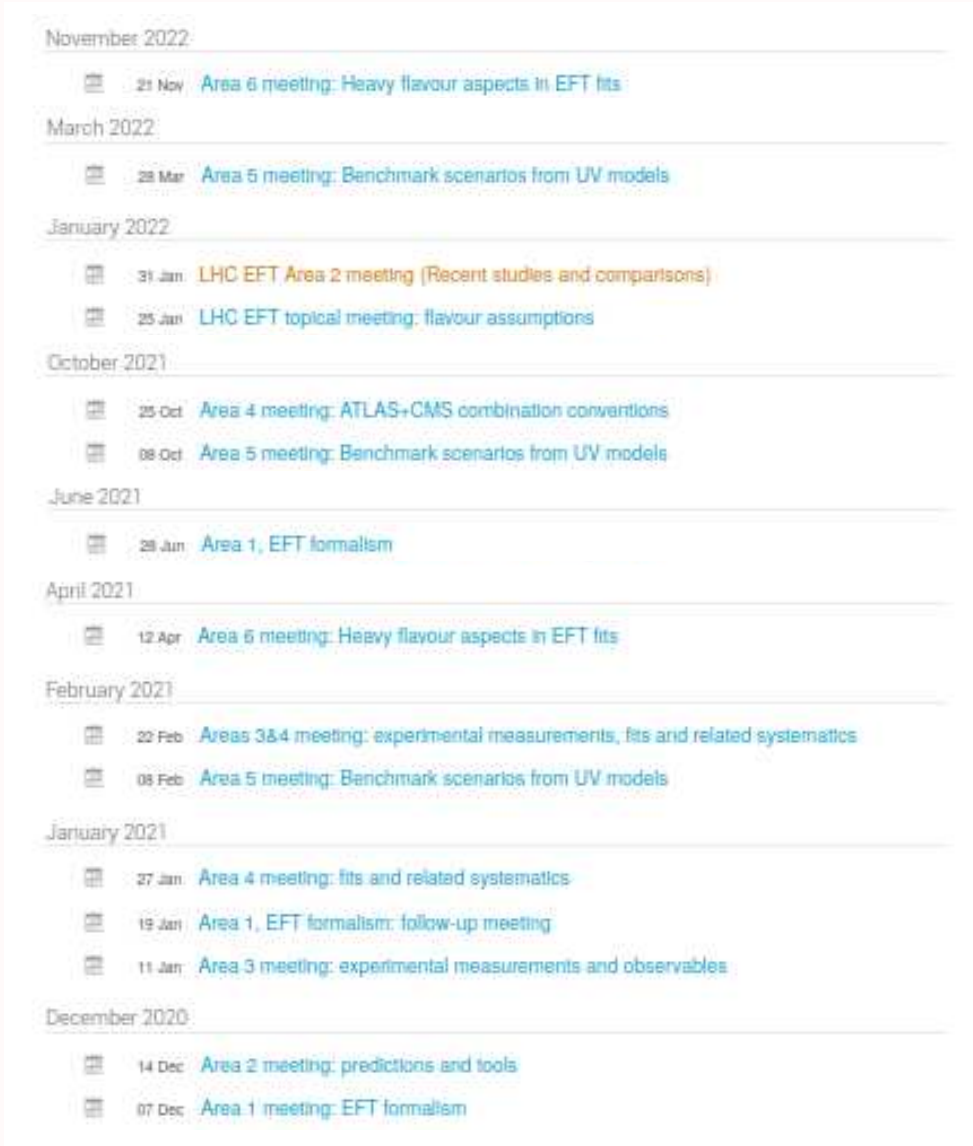
Shankha, Admir, Sandra

**Area 6.** Interplay with (heavy) flavour

Admir, Gauthier, Patrick

# Wrap-up of WG activities so far

- **15 topical meetings**, covering all areas



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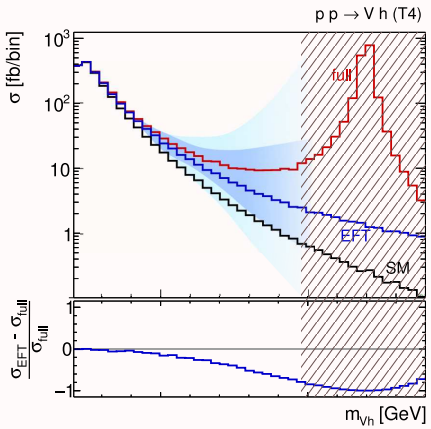
- **15 topical meetings**, covering all areas
- 2 notes released within **Area 1**

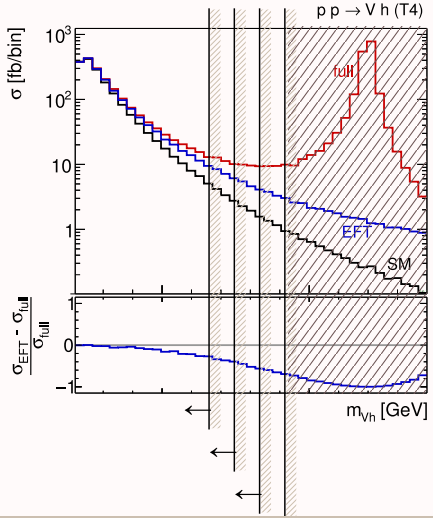
"Electroweak input parameters" CERN-LHCEFTWG-2021-001 2111.12515

- recommend $\{m_W, m_Z, G_F\}$ as input parameters for EW sector
- discuss pros+cons of adopting other options (e.g. with $\alpha$)

"Truncation, validity, uncertainties" CERN-LHCEFTWG-2021-002 2201.04974

- collect proposals for ensuring EFT validity and assessing $d \geqslant 8$ impact e.g. clipping data, clipping prediction, introducing uncertainty band...
- no recommendation, main ideas and pros+cons are discussed



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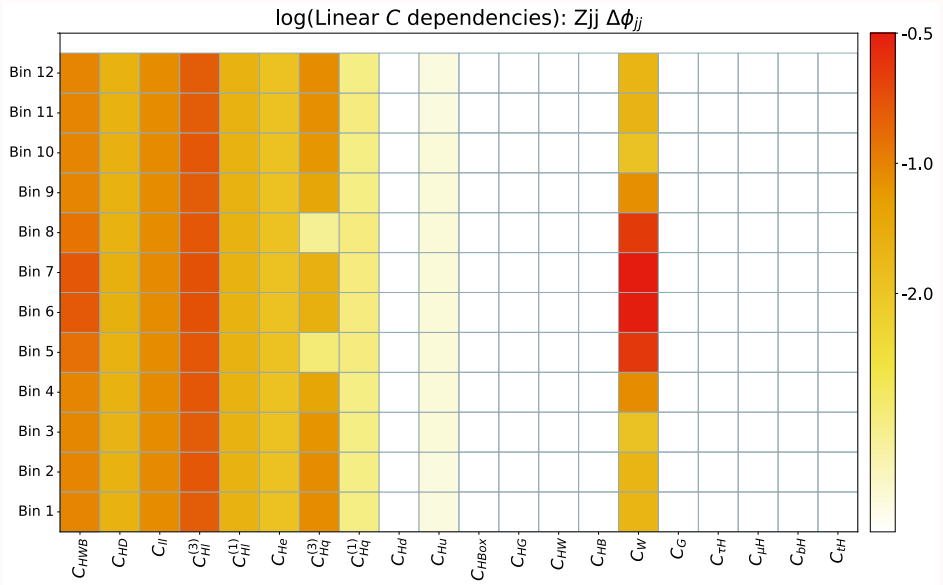
- 2 notes released within **Area 1**
- 1 note released within **Area 3**

"Experimental Measurements and Observables" CERN-LHCEFTWG-2022-001 2211.08353

👉 review options for definition of optimal observables
👉 report and compare results from theory fits, focusing on who constrains what
(Fisher information, comparison of linear and quadratic. . . )




Fitmaker team:
Ellis, Madigan, Mimasu, Sanz, You

# Wrap-up of WG activities so far

- **15 topical meetings**, covering all areas
- 2 notes released within **Area 1**
- 1 note released within **Area 3**
- 1 note released within **Area 5**

"Precision matching of microscopic physics to SMEFT" CERN-LHCEFTWG-2022-002 2212.02905

👉 Overview of tools for 1-loop matching of models to SMEFT
matching of SMEFT to LEFT
RGE running

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- **15 topical meetings**, covering all areas
- 2 notes released within **Area 1**
- 1 note released within **Area 3**
- 1 note released within **Area 5**
- 1 note in progress within **Areas 1+3+6**

"Benchmarks for Flavour assumptions"

👉 estimate nr of relevant parameters for well-defined observables sets, varying flavor symmetry assumptions between 5 benchmarks

👉 roadmap for future fits and LHC targets

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- **15 topical meetings**, covering all areas
- 2 notes released within **Area 1**
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- 1 note in progress within **Areas 1+3+6**
- "Fitting exercise" organized and currently ongoing (**Area 4**)

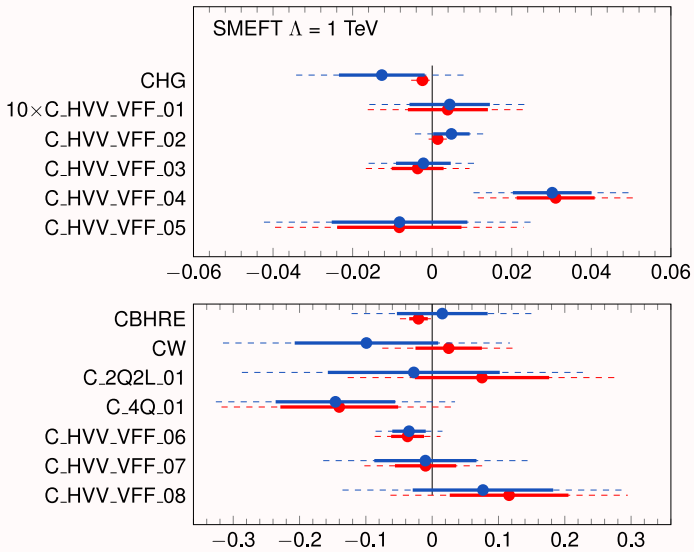
# ATLAS + CMS "Fitting exercise"

- **main goal:** harmonize workspaces and conventions, iron out differences between ATLAS and CMS, identify potential issues

- done with **public data**, public combination code [ATLAS repo] [CMS repo]

- dataset encompasses Higgs + EW + top

  included so far:
  - LEP + SLC
  - [A+C] STXS $h \to \gamma\gamma$, $h \to 4l$, $VH(bb)$
  - [C] single top ($p_T^t$)
  - diboson: [C] $W\gamma$ ($p_T^\gamma \times \Delta\phi$)
    [A] WW ($p_T^l$)
    [A] WZ ($m_T^{WZ}$)
  - [A] $Zjj$ ($\Delta\phi_{jj}$)




- statistical combination: RooFit model with multi-variate Gaussian pdf

- will be used also as **playground for studies of other areas**: truncation benchmarking, using ML observables, matching to models...

# Reinterpreting EFT measurements

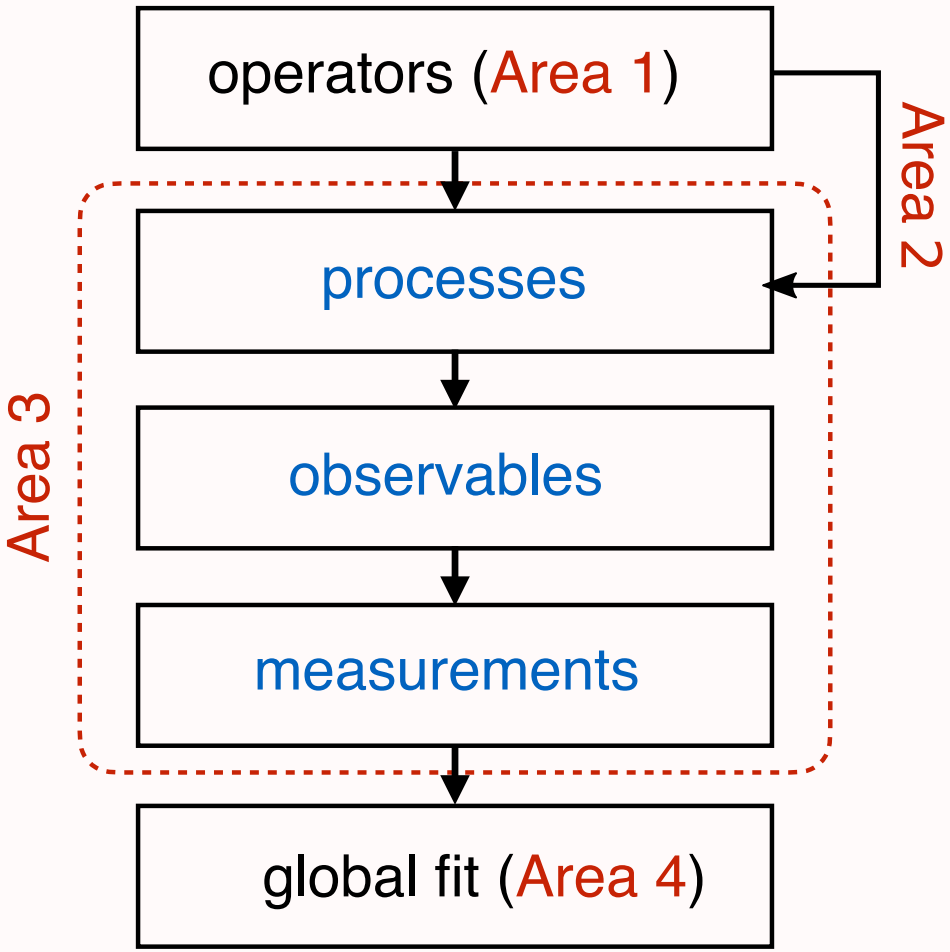
## Things we want to be able to do in the (far) future

- update theory prediction
  - **EFT signal**
    → more operators, higher order in loop or dimension, refined flavor indices...
    → more UV-specific (e.g. if discovery or anomalies):
    restricted operators set, map EFT to model parameters
  - **EFT in backgrounds**
  - reference **SM prediction**: higher order, updated PDFs...
- combine several past/present/future LHC measurements consistently

## Further requirements

- retain as much **information** as possible **in parameterization**
  → maximize constraining+discriminating power
- retain as much **information** as possible **in measurement**
  (uncertainty dependence, potential correlations with other meas. ...)
- make predictions **reproducible outside Collaborations**

# EFT analysis workflow




adapted from A. Gritsan

all steps are relevant for

Reproducibility + Reinterpretability

of the final results

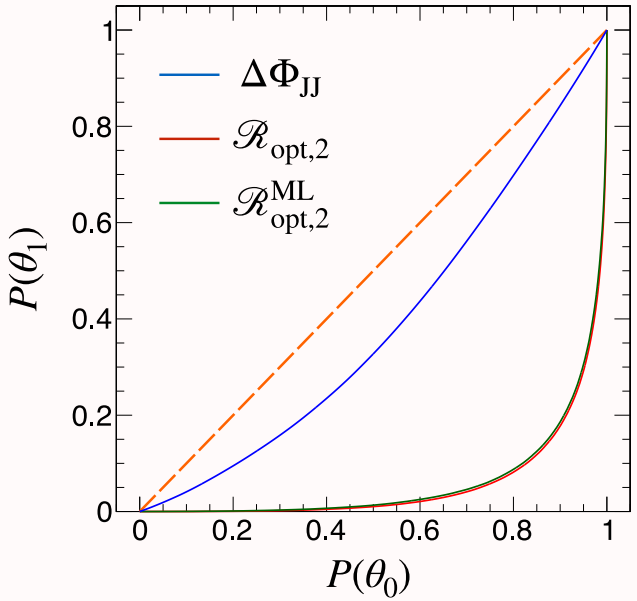
# Definition of optimal observables

tasks:

- **maximize sensitivity**
  → discriminate SM vs EFT, EFT operators among each other
- ensure **reproducibility** of likelihood ratio outside collaborations
  → by theorists, other experiment, future users . . .

options to evaluate: (*)

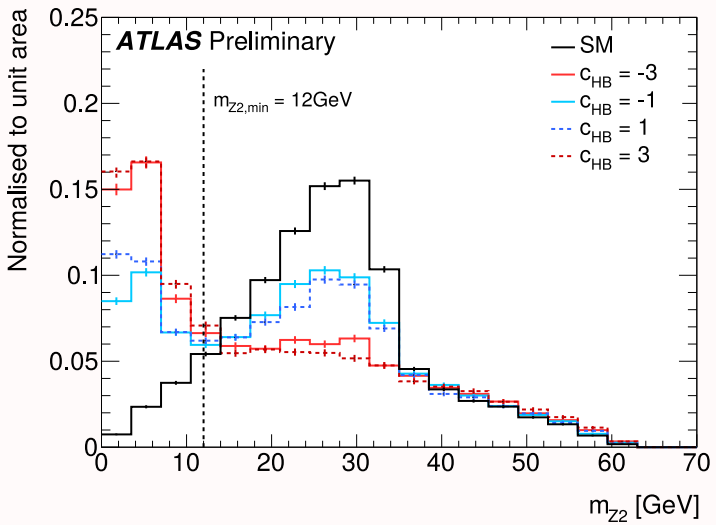
- folded / unfolded
- binned / unbinned ⇝ Jaco's talk
- ME or ML-based
- . . .




(*) putting together the steps of defining observables and measurements ("fitted" quantities)

# Folded/Unfolded observables

| Folded | Unfolded |
|---|---|
| ✖ hard to reproduce a posteriori | ✔ easier to reinterpret |
| ✔ requires weaker modeling assumptions | ✖ often assume SM for acceptance, efficiencies, backgrounds... |
| ✔ preserves all measurement features | ✖ information loss |

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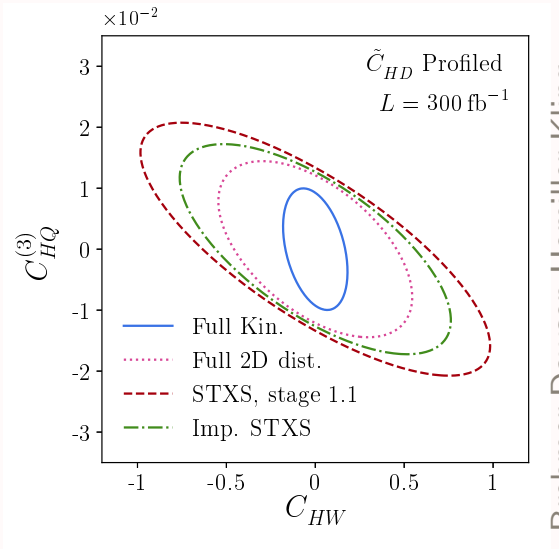


Brehmer, Dawson, Homiller, Kling, Plehn 1908.06980

# Reuse of event samples

Basic idea: re-do exp. analyses in the future with different theory model by adapting=reweighting existing MC samples

→ in principle applies to any sample: S/B, SR/CR...

## What would be needed

- **storing samples** in some format (LHE?)
- streamlined and validated **reweighting procedures**

## Reweighting for EFT [for concreteness: in MG5]

✔ already much used to derive parameterizations

✖ not always an effective method for EFT: new Lorentz structures!

- initial sample must populate all phase space relevant to final sample
- matching to PS depends on final state momenta + helicity + color conn. if any is changed by EFT, PS must be re-run
- default: helicity-specific rwgt.
  preserves PS matching but problematic for helicity-changing EFT operators

# Reporting (combined) analysis results

## Goals

⇝ Tilman's talk

- enable combinations among several measurements, ensuring **proper treatment of uncertainties and correlations**
- minimize loss of information that can steer EFT fit (correlations, dependence on syst., operator discriminants...) → retain as much as possible of the likelihood

## Options:

- publish approximate likelihood → oversimplifying?
- publish "full" likelihood (i.e. full workspaces) → too expensive?
- publish EFT templates
- likelihood-free inference?
- ...

👉 preferred solution generally depends on observables definition

# Potential future tasks, relevant for reinterpretation

some proposals for next steps within EFT WG put forth and discussed at latest General Meeting:

- Database of **predictions** for univocally defined observables (STXS. . . )
- Preparation of **shared samples** for some measurements
- Adding **EFT weights to HEPdata** for reco-level observables (bin by bin)
- Validation of (helicity aware) **reweighting** techniques
- Explore concrete applications of **ML-optimised** observables
- Start a **full-likelihood combination** in parallel to fitting ex
- Database of 1-loop **matching** results for UV benchmark models
- . . .