Report from the EFT Working Group

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

General Meeting 10 days ago: indico.cern.ch/event/1201401/
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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- **2 notes released within Area 1**

**“Electroweak input parameters”**

- 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”**

- Collect proposals for ensuring EFT validity and assessing \( d \geq 8 \) impact
  - e.g. clipping data, clipping prediction, introducing uncertainty band...
- No recommendation, main ideas and pros + cons are discussed

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- 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

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- 1 note released within **Area 5**

“Precision matching of microscopic physics to SMEFT”

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

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- 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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- “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
  - LEP + SLC
  - [A+C] STXS $h \rightarrow \gamma \gamma$, $h \rightarrow 4l$, $VH(bb)$
  - [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 \textbf{SM prediction}: higher order, updated PDFs...
  - combine several past/present/future LHC measurements consistently

Further requirements

- retain as much \textbf{information} as possible \textbf{in parameterization}
  - maximize constraining+discriminating power
- retain as much \textbf{information} as possible \textbf{in measurement}
  (uncertainty dependence, potential correlations with other meas. . .)
- make predictions \textbf{reproducible outside Collaborations}
EFT analysis workflow

operators (Area 1)

processes

observables

measurements

global fit (Area 4)

all steps are relevant for Reproducibility + Reinterpretability of the final results

adapted from A. Gritsan
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**

- ✗ hard to reproduce a posteriori
- ✔ requires weaker modeling assumptions
- ✔ preserves all measurement features

**Unfolded**

- ✔ easier to reinterpret
- ✗ often assume SM for acceptance, efficiencies, backgrounds...
- ✗ information loss
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
**Goals**

- 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
- ...