

Report on the Needs and Goals of the LHC EFT Group

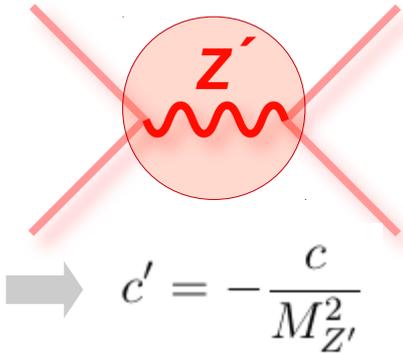


The
University
Of
Sheffield.

Kristin Lohwasser
University of Sheffield

Effective Field theory: A motivation

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



Effective Lagrangian as extension of SM Lagrangian

- Taylor expansion of local operators of “light” degrees of freedom
- removes explicit description of “heavy” / high energy physics (suppressed by orders of energy scale $\Lambda \gg E_{CM}$)

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

Number of Operator Wilson Coefficient Operator

→ easier calculation of low energy physics by “skipping” complicated terms without large effects on final state

→ systematic measure of SM deviations that can be linked to possible new physics phenomena (→ <https://arxiv.org/abs/1711.10391>, <https://arxiv.org/abs/2009.01249>)

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

▪ SM up to dim-4

▪ dim-5:
neutrino masses
but lepton flavour
violating

▪ dim-6:
most studied at
the LHC

▪ dim-8:
not complete,
studied for VBS
processes

Dimension-6 effective field theory: SMEFT

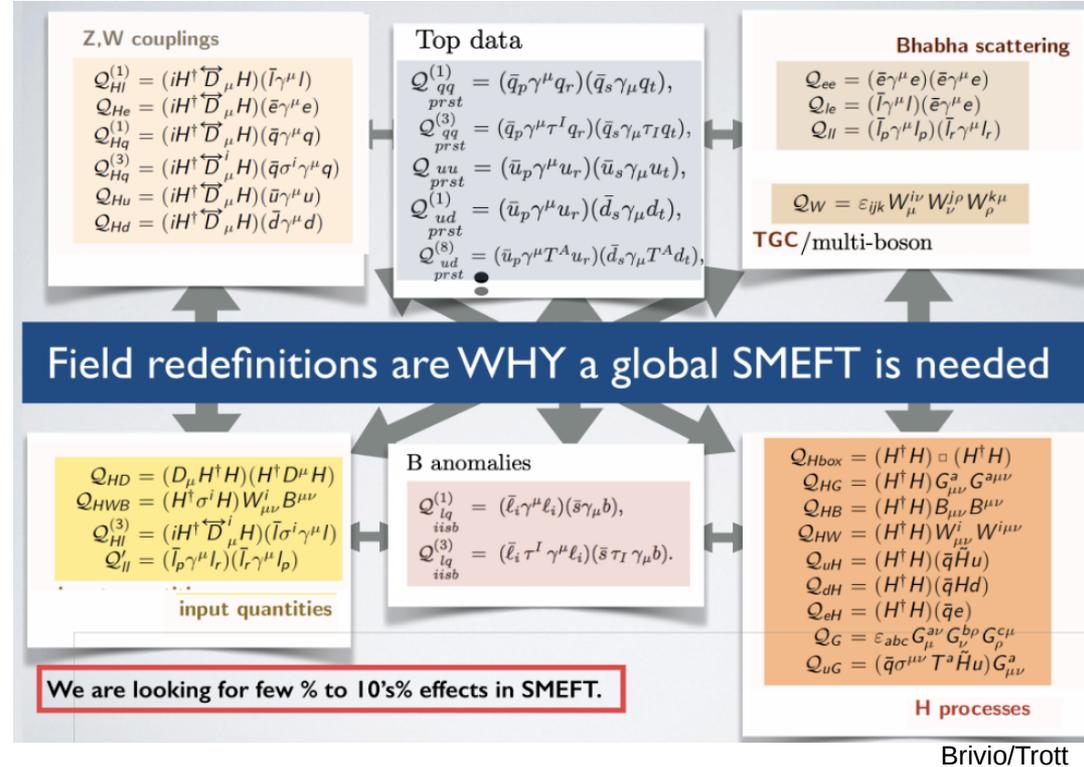
- Dim-6: 2499 parameters reduced to 81 ($U(3)^5$ flavour symm.)

→ Warsaw basis:
orthogonal, complete,
renormalisable

→ <https://arxiv.org/abs/1008.4884>,
<https://arxiv.org/abs/1709.06492>,
<https://arxiv.org/abs/2005.05366>

- 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:



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

So what is being done at the LHC?

- official CERN/LHC groups

LHC EFT WG <https://lpsc.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

VBScan

EU/ERC-sponsored
network

[https://vbscanaction
.web.cern.ch/](https://vbscanaction.web.cern.ch/)

... potential others

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

- New groups (after first discussion last year)
 - First open meeting: 19 Oct - 20 Oct
 - <https://indico.cern.ch/event/943996/>
 - Summary of:
 - experimental (ATLAS+CMS) + theory efforts
 - EFT summary of Higgs/Top/EW
 - 2nd day: discussion on EFT WG targets and goals
 - Working group discussion then
 - General plan has been discussed amongst the convenors with different topics
 - Basics / EFT formalism
 - Predictions and tools
 - Experimental measurements and observables
 - Fits and related systematics
 - Benchmark scenarios from UV models
- Discussed in the following in a bit more details**
- **General split with other LHC groups → more global fits**

- **Conveners:**
 - ATLAS:
 - Nicolas Berger (Higgs WG contact)
 - Nuno Castro (Top WG contact)
 - Kristin Lohwasser (EW WG contact)
 - Pierre Savard
 - CMS:
 - Florencia Canelli (Top WG contact)
 - Pietro Govoni (EW WG contact)
 - Andrei Gritsan
 - Giovanni Petrucciani (Higgs WG contact)
 - Theory:
 - Ilaria Brivio
 - Sally Dawson
 - Jorge De Blas (Higgs WG contact)
 - Celine Degrande (EW WG contact)
 - Gauthier Durieux
 - Admir Greljo
 - Eleni Vryonidou (Top WG contact)
- Reach all conveners through lhc-eftwg-admin@cern.ch

LHC EFT WG: Topics (shortened)

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

■ EFT formalism and implementation

→ *establish common conventions on possible SMEFT bases/normalization/input schemes*

(e.g. currently little overlap between Top and diboson and Higgs → everything used consistently?)

e.g. translation dim6 ← → aTGC in MG5 vs. seminal paper with different sign (flipped limits in WW results between ATLAS and CMS)

→ Assumptions on symmetries (CP, flavour)

→ Definition of scenarios (for fit with limited data / benchmark)

→ **some standalone scenarios exist to some extent for Higgs and top ; less for multibosons**

→ Truncations, dim8 contributions, validity

→ Theory constraints (unitarity, positivity) and how to use in fit

■ Predictions and tools

→ *Guidance: what is available, how to use → reweighting techniques?*

→ Deliverables: Cross-validation at tree and loop levels, **common MC generator/settings (exp)**

Interplay with best-practice recommendations of LHC-EW group

→ Specific theory developments: treatment of unstable particles, EFT in PDFs, α_s , ...



- **Experimental measurements and observables**

- *Study observable, channel, process sensitivities and complementarities*

- Differential distributions, optimal observables, including machine learning, and dedicated EFT measurements ...

- What observables are most sensitive to new physics? Exploit energy growing effects, non-interferences, and other TH knowledge

- Analysis strategies & experimental outputs

- legacy measurements and their possible reinterpretation

Interplay with LHC MB WG: Recommendations to analysis / study of processes

- **Fits and related systematics**

- *Experimental EFT fits: ATLAS+CMS+... combination of H+EW+Top*

- Inputs and outputs, fitting procedures and tools (focus on practical considerations!)

- Comparison to, and inclusion of, non-LHC constraints (LEP, Tevatron, flavor, g-2, EDM, etc.)

- Future projections

- **Benchmark scenarios from UV models**

- Matching to specific models, BSM-driven subsets of operators, benchmarks beyond SMEFT,

- Comparison of EFT constraints vs. direct BSM searches beyond EFT

Topical LHC groups

LHC top WG

<https://twiki.cern.ch/twiki/bin/view/LHCPhysics/LHCTopWG>

- EFT subgroup
- Official recommendations:
<https://arxiv.org/abs/1802.07237>
- A variety of global fits on the market

LHC Higgs WG

<https://twiki.cern.ch/twiki/bin/view/LHCPhysics/LHCHXSWG>

- Technically there are 2 groups:
Higgs (XS) WG
Higgs Combination
- EFT subgroup
- Various EFT publication (different frameworks)
- Next general meeting in November:
<https://indico.cern.ch/event/922192/>

LHC EW (MB) WG

<https://twiki.cern.ch/twiki/bin/view/LHCPhysics/LHCEW>

- Multiboson
Subgroup of general EW group
- Traditionally working with (higgsless) anomalous couplings
→ transition to SMEFT in Run-2
- Work on YR ongoing

Conclusion

- LHC EFT group just founded → general goals and interests briefly outlined (as relationship with other LHC (sub)groups)
- More detailed discussion planned for the first open meetings
- Some Interplay with LHC MB working group:
 - Main split discussed as “single” process/group (e.g. top or MB) versus global view/fit
 - more focus on EFT aspects and commonalities between top/MB/Higgs
- Experimental LHC EFT contacts with ties to LHC EW group selected