# Report on LHC reinterpretation forum workshop

Ken Mimasu, Nick Wardle

LHC EFT WG General Meeting, 16th Nov 2023

# Re-interpretation forum

*"The LHC Re-interpretation forum discuss topics related to the BSM (re)interpretation of LHC data, including the development of the necessary public recasting tools and related infrastructure, and to provide a platform for continuous interaction between theorists and with the experiments."*

The forum holds regular workshops (8 at CERN, Fermilab, Imperial College London and Durham so far) focused on various topics around the re-interpretation of LHC (and beyond) measurements/searches

Most recent workshop (Durham https://conference.ippp.dur.ac.uk/event/1178/) focused on 3 main topics

1. **Storage and (re)usage of theoretical predictions, including event samples**
2. **The communication and reuse of statistical and machine-learned models**
3. **The combined/global interpretation of searches and measurements**

Included a **dedicated LHC EFT-WG** session discussing overlapping activities with our WG

Twiki: https://twiki.cern.ch/twiki/bin/view/LHCPhysics/InterpretingLHCresults , E-group: signup

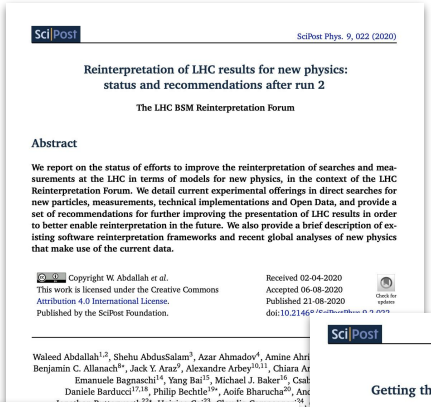
# Re-interpretation forum - Reports

Several community reports from the forum over the years

**Data and Analysis Preservation, Recasting, and Reinterpretation**
https://arxiv.org/abs/2203.10057

**Publishing statistical models: Getting the most out of particle physics experiments** https://arxiv.org/abs/2109.04981

**Reinterpretation of LHC Results for New Physics: Status and recommendations after Run 2**
https://scipost.org/10.21468/SciPostPhys.9.2.022

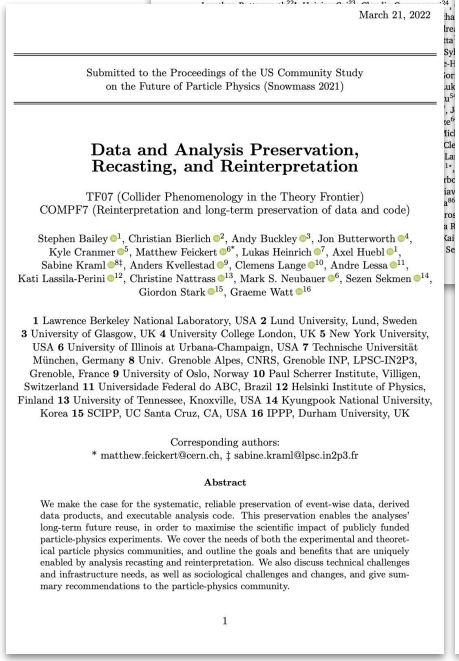

SciPost Phys. 9, 022 (2020)

Reinterpretation of LHC results for new physics: status and recommendations after run 2

The LHC BSM Reinterpretation Forum

Abstract

We report on the status of efforts to improve the reinterpretation of searches and measurements at the LHC in terms of models for new physics, in the context of the LHC Reinterpretation Forum. We detail current experimental offerings in direct searches for new particles, measurements, technical implementations and Open Data, and provide a set of recommendations for further improving the presentation of LHC results in order to better enable reinterpretation in the future. We also provide a brief description of existing software reinterpretation frameworks and recent global analyses of new physics that make use of the current data.


March 21, 2022

Submitted to the Proceedings of the US Community Study on the Future of Particle Physics (Snowmass 2021)

Data and Analysis Preservation, Recasting, and Reinterpretation

TF07 (Collider Phenomenology in the Theory Frontier)
COMPF7 (Reinterpretation and long-term preservation of data and code)

Abstract

We make the case for the systematic, reliable preservation of event-wise data, derived data products, and executable analysis code. This preservation enables the analyses' long-term future reuse, in order to maximise the scientific impact of publicly funded particle-physics experiments. We cover the needs of both the experimental and theoretical particle physics communities, and outline the goals and benefits that are uniquely enabled by analysis recasting and reinterpretation. We also discuss technical challenges and infrastructure needs, as well as sociological challenges and changes, and give summary recommendations to the particle-physics community.


SciPost Phys. 12, 037 (2022)

Publishing statistical models: Getting the most out of particle physics experiments

Abstract

The statistical models used to derive the results of experimental analyses are of incredible scientific value and are essential information for analysis preservation and reuse. In this paper, we make the scientific case for systematically publishing the full statistical models and discuss the technical developments that make this practical. By means of a variety of physics cases — including parton distribution functions, Higgs boson measurements, effective field theory interpretations, direct searches for new physics, heavy flavor physics, direct dark matter detection, world averages, and beyond the Standard Model global fits — we illustrate how detailed information on the statistical modelling can enhance the short- and long-term impact of experimental results.

# EFTWG & Re-interpretation forum

1. **Storage and (re)usage of theoretical predictions, including event samples**
2. **The communication and reuse of statistical and machine-learned models**
3. **The combined/global interpretation of searches and measurements**

## RIF historically more focused on concrete BSM searches

- SUSY, resonance searches, simplified models,...

## Reinterpretation of LHC data is a major part of EFT programme

Natural synergy between two groups: can we share expertise & work together?

- Recasting challenges, tools & techniques
- Optimal reporting of experimental data
- Shared theoretical predictions
- Developing machine-learning based searches

ADL/CutLang  Spey  MaPyDe

Contur  Checkmate  GAMBIT

HEPData  Lilith  SModelS

# EFT Day @ the RIF workshop

| | |
|---|---|
| **Off-the-shelf flavour constraints for your SMEFT fit** | *Dr Danny van Dyk* |
| **Interpreting HEP data in SMEFiT** | *Jaco ter Hoeve* |
| **Save the EFT: a primer for the ATLAS+CMS combination in the top sector** | *Kirill Skovpen* |
| **Global EFT fits within the ATLAS experiment** | *Rahul Balasubramanian* |
| **Summary of LHC EFT WG activities** | *Ken Mimasu* |
| **EFTs, models and matching: the necessity and caveats** | *Shankha Banerjee* |
| **Global view on SMEFT interpretations and UV connection** | *Maeve Madigan* |

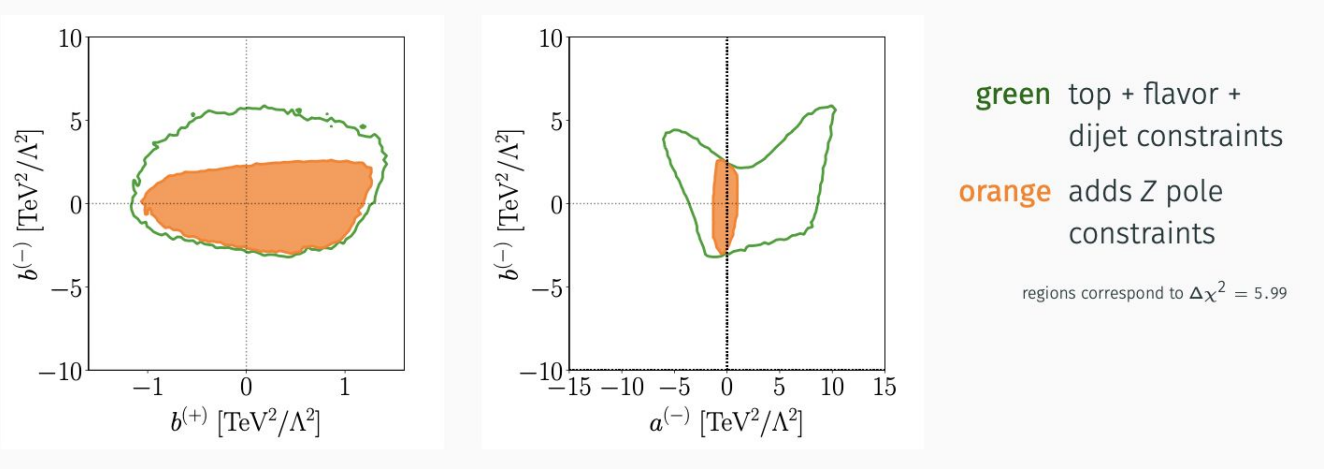
**+ Discussion session to gather feedback and discuss future common activities**

# Highlights

**Off-the-shelf flavour constraints for your SMEFT fit** — *Dr Danny van Dyk*

*PH8 (James Duff Lecture Theatre), Durham University* — 10:00 - 10:20

Update on interplay between top/Z-pole & Flavor data in the MFV-SMEFT




**Proof of concept:** public likelihood functions for flavour constraints on WET coefficients, marginalised over hadronic nuisance parameters, approximated by normalising flows

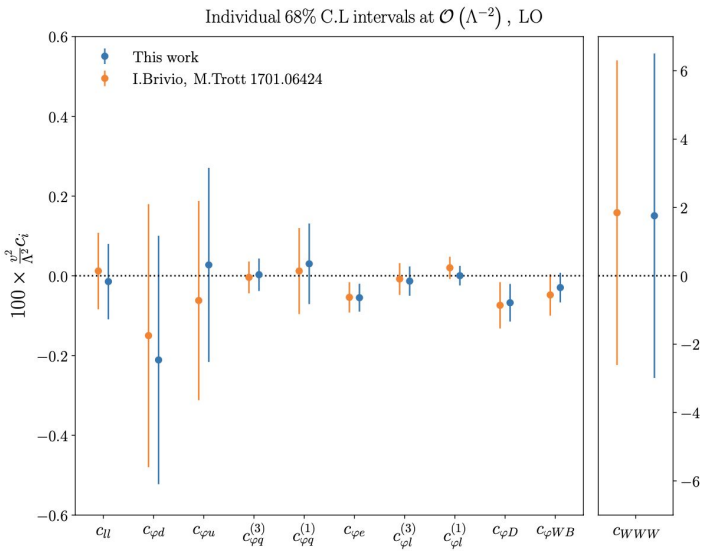
# Highlights

**Interpreting HEP data in SMEFiT** — *Jaco ter Hoeve*

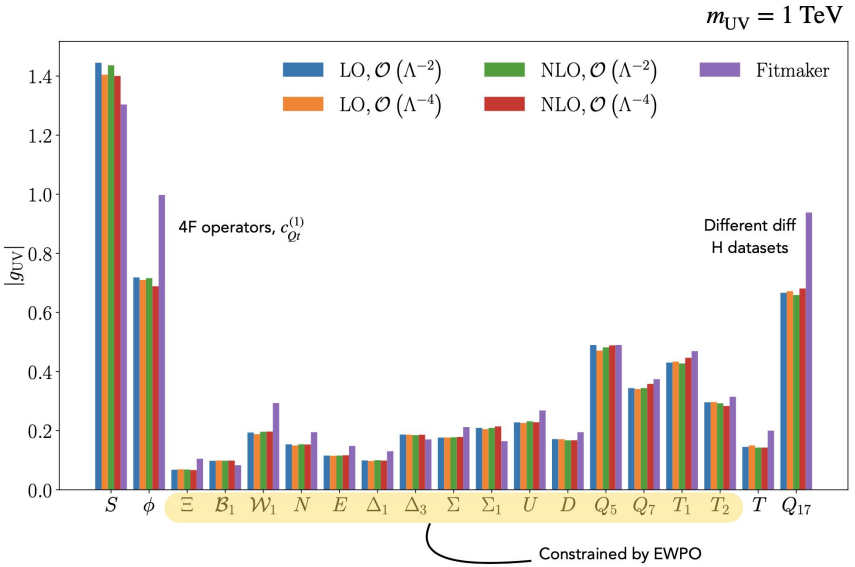
*PH8 (James Duff Lecture Theatre), Durham University* — 10:30 - 10:50

Latest results & plans from SMEFiT collaboration

## Exact EWPO implementation




## UV model interpretations



# Highlights

**Save the EFT: a primer for the ATLAS+CMS combination in the top sector** *Kirill Skovpen*

*PH8 (James Duff Lecture Theatre), Durham University* 11:20 - 11:40

## Combination exercise for CMS & ATLAS top data using full likelihood info

`Combine` (CMS) & `pyhf` (ATLAS) frameworks

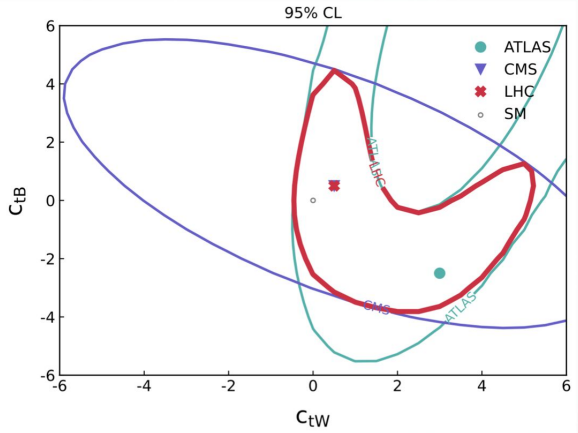
**Full likelihoods:**

- Full statistical model: correlations, nuisance parameters etc.
- EFT in background yields

**Ongoing study within LHCTopWG**

- EFT parameterizations not published
- Challenging for MVA-based analyses

- Combine **full likelihoods** from:
  - $t\bar{t}\gamma$ (single lepton): JHEP 12 (2021) 180
  - $t\bar{t}\gamma$ (di-lepton): JHEP 05 (2022) 091
  - $t\bar{t}Z$ (multilepton): EPJC 81 (2021) 737
- **Very complementary** sensitivity



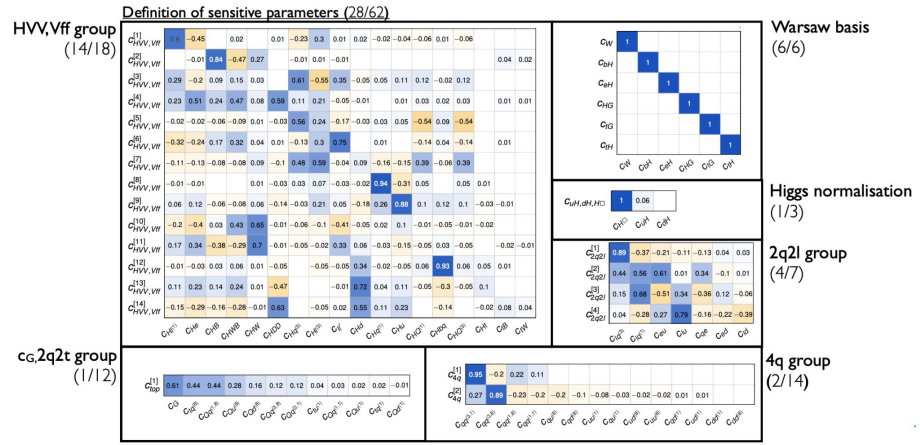
# Highlights

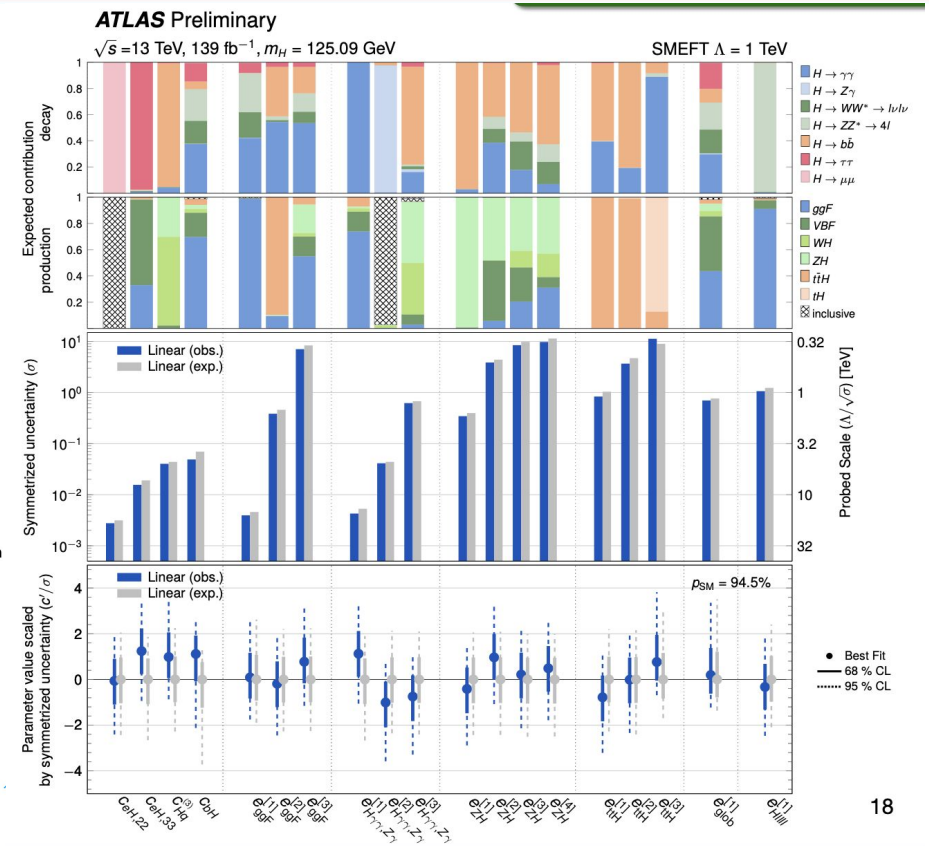
**Global EFT fits within the ATLAS experiment** — *Rahul Balasubramanian*

*PH8 (James Duff Lecture Theatre), Durham University* — 11:50 - 12:10

## Latest ATLAS SMEFT results

- Including global fit to Higgs, Diboson & EWPO



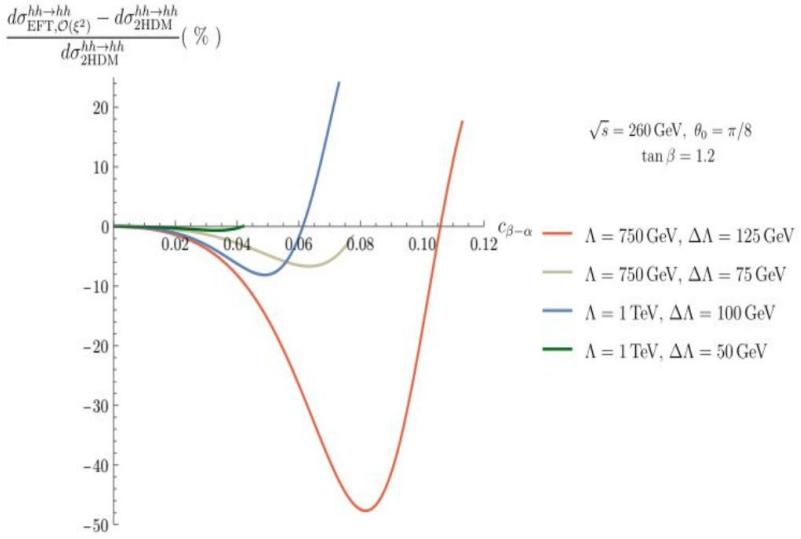



# Highlights

**EFTs, models and matching: the necessity and caveats** — *Shankha Banerjee*

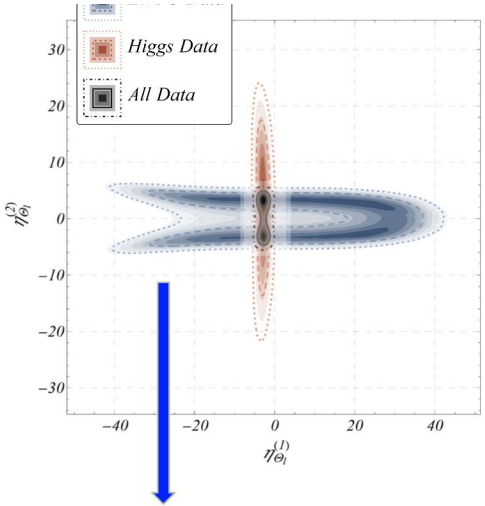
*PH8 (James Duff Lecture Theatre), Durham University* — 15:10 - 15:30

## Review on latest results in matching tools and fits




We extend SM by a colour-triplet isospin-doublet scalar $\Theta_1$ with hypercharge Y=1/6

$$\mathcal{L}_{\Theta_1} = \mathcal{L}^{d\leq 4}_{\mathrm{SM}} + (D_\mu \Theta_1)^\dagger (D^\mu \Theta_1) - m^2_{\Theta_1} \Theta_1^\dagger \Theta_1 - \eta^{(1)}_{\Theta_1} H^\dagger H\, \Theta_1^\dagger \Theta_1 - \eta^{(2)}_{\Theta_1} \left(H^\dagger \sigma^i H\right) \left(\Theta_1^\dagger \sigma^i \Theta_1\right) - \lambda^{(1)}_{\Theta_1} \left(\Theta_1^\dagger \Theta_1\right)^2 - \lambda^{(2)}_{\Theta_1} \left(\Theta_1^\dagger \sigma^i \Theta_1\right)^2 + \left\{ y_{\Theta_1} \Theta_1^\alpha \overline{d}^\alpha_R i\sigma^2 l_L + \mathrm{h.c.} \right\}$$




**2D marginalised posteriors**

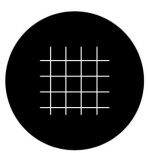
# Highlights

**Global view on SMEFT interpretations and UV connection** — *Maeve Madigan*

*PH8 (James Duff Lecture Theatre), Durham University* — 15:40 - 16:10

## ‘High-level’ overview of challenges/developments in SMEFT interpretations

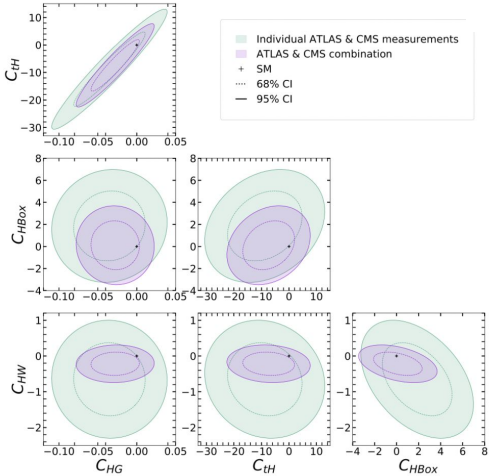
- Beware of assumptions!
- Unfolded vs. reco
- Exp vs. th. combinations

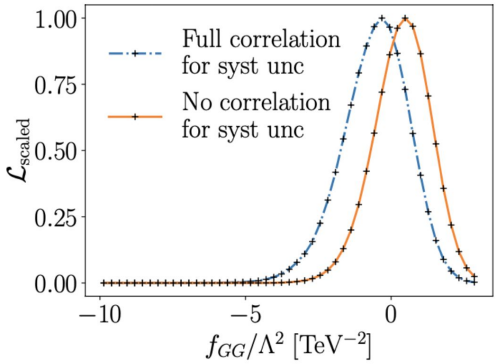


Datapoints & covariance matrices

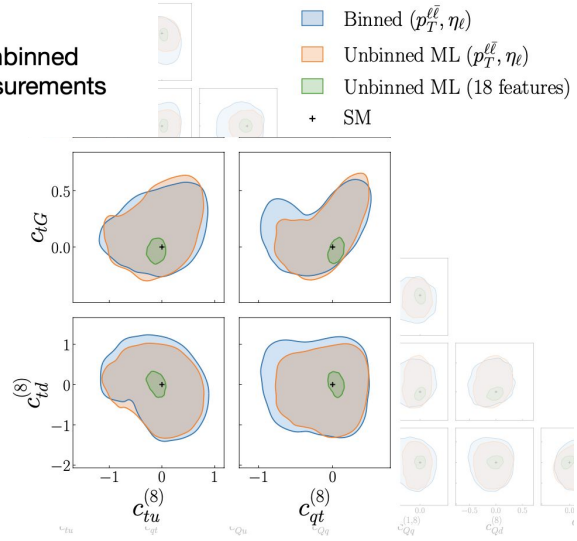
Likelihoods

Unbinned measurements




*I. Brivio et. al, 2208.08454*



# Outcomes of discussion session & future plans

**Reasonably enthusiastic response to EFT session**

- Some new signups to the EFTWG mailing list & future joint activities were welcomed

**Transfer of expertise on how best to reinterpret data**

- e.g. Asymmetric errors -> Full likelihood (pyhf, combine,...)
- Help with “forward folding” for global EFT fits (going beyond only unfolded data)
- EFT in backgrounds

**Idea:** publication of nominal signal & bkg samples from analyses

- e.g. SM MC samples used to perform experimental measurement
  - Can be used to determine EFT signal yields using reweighting
  - Allow for reinterpretation of complex, MVA-based templates by including e.g. BDT score per event
- Samples with EFT weights could also be published by th. community
- Or publish parametrisations (See update on Area 2 activity joint with WG2 on Friday)

**Comparing indirect v.s direct sensitivity**

- RIF would be ideal partner of EFTWG (Area 5) for this topic

**Unbinned unfolding for multi dimensional EFT interpretations:** potential future Area 2 study