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 <u>continuous interaction between theorists and with the experiments</u>."

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

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

Sci Pos 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. Copyright W. Abdallah et al. Received 02-04-2020 Check & This work is licensed under the Creative Commons Accepted 06-08-2020 Attribution 4.0 International License. Published 21-08-2020 Published by the SciPost Foundation doi:10.21469/Collocation Sci Post SciPost Phys. 12, 037 (2022) Waleed Abdallah^{1,2}, Shehu AbdusSalam³, Azar Ahmadov⁴, Amine Ahri Benjamin C. Allanach8*, Jack Y. Araz9, Alexandre Arbev10,11, Chiara Ar Publishing statistical models: Emanuele Bagnaschi14, Yang Bai15, Michael J. Baker16, Csab Daniele Barducci17,18, Philip Bechtle19*, Aoife Bharucha20, An Getting the most out of particle physics experiments March 21, 2022 ha Kyle Cranmer^{1†*}, Sabine Kraml^{2†*}, Harrison B. Prosper ^{3°*}, Philip Bechtle⁴, Florian U. Bernlochner⁴, Itay M. Bloch⁵, Enzo Canonero⁶, Marcin Chrzaszcz⁷, Andrea Coccaro⁸, Jan Conrad⁹, Glen Cowan¹⁰, Matthew Feickert¹¹, Nahuel F. Iachellini^{12,13}, Andrew Fowlie¹⁴, Lukas Heinrich¹⁵, Alexander Held¹, Thomas Kuhr^{13,16}, Anders Kvellestad¹⁷, Maeve Madigan¹⁸, Farvah Mahmoudi¹⁵ Submitted to the Proceedings of the US Community Study Knut D. Morå²⁰, Mark S. Neubauer¹¹, Maurizio Pierini¹⁵, Juan Roio⁸, Sezen Sekmen²² on the Future of Particle Physics (Snowmass 2021) Luca Silvestrini²³, Veronica Sanz^{44,25}, Giordon Stark⁵⁶, Riccardo Torre⁸, Robert Thorne²⁷, Wolfgang Waltenberger²⁸, Nicholas Wardle²⁹ and Jonas Wittbrott³⁶ Cle Data and Analysis Preservation, Abstract Recasting, and Reinterpretation 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. TF07 (Collider Phenomenology in the Theory Frontier) In this paper, we make the scientific case for systematically publishing the full statistical COMPF7 (Reinterpretation and long-term preservation of data and code) models and discuss the technical developments that make this practical. By means of a variety of physics cases - including parton distribution functions, Higgs boson mea-Stephen Bailey ¹, Christian Bierlich ², Andy Buckley ³, Jon Butterworth ⁴, surements, effective field theory interpretations, direct searches for new physics, heavy Kyle Cranmer . Matthew Feickert . Lukas Heinrich . Axel Huebl . flavor physics, direct dark matter detection, world averages, and beyond the Standard Sabine Kraml ^{8‡}, Anders Kvellestad ⁹, Clemens Lange ¹⁰, Andre Lessa ¹¹, Model global fits - we illustrate how detailed information on the statistical modelling Kati Lassila-Perini ¹², Christine Nattrass ¹³, Mark S. Neubauer ⁶, Sezen Sekmen ¹⁴, can enhance the short- and long-term impact of experimental results Giordon Stark 915, Graeme Watt 916 Copyright K. Cranmer et al. Received 16-09-2021 1 Lawrence Berkelev National Laboratory, USA 2 Lund University, Lund, Sweden This work is licensed under the Creative Commons Accepted 08-12-2021 3 University of Glasgow, UK 4 University College London, UK 5 New York University, Attribution 4.0 International License Published 25-01-2022 USA 6 University of Illinois at Urbana-Champaign, USA 7 Technische Universität Published by the SciPost Foundation. doi:10.21468/SciPostPhys.12.1.037 München, Germany 8 Univ. Grenoble Alpes, CNRS, Grenoble INP, LPSC-IN2P3, Grenoble, France 9 University of Oslo, Norway 10 Paul Scherrer Institute, Villigen, Switzerland 11 Universidade Federal do ABC, Brazil 12 Helsinki Institute of Physics, 1 New York University, USA Finland 13 University of Tennessee, Knoxville, USA 14 Kyungpook National University, 2 LPSC Grenoble, France Korea 15 SCIPP, UC Santa Cruz, CA, USA 16 IPPP, Durham University, UK 3 Florida State University, USA 4 University of Bonn Germany Corresponding authors: 5 School of Physics and Astronomy, Tel-Aviv University, Israel * matthew.feickert@cern.ch, ‡ sabine.kraml@lpsc.in2p3.fr 6 University of Genova, Italy 7 Institute of Nuclear Physics, Polish Academy of Sciences, Krakow, Poland Abstract 8 INFN, Sezione di Genova, Italy 9 Oskar Klein Centre, Stockholm University, Sweden We make the case for the systematic, reliable preservation of event-wise data, derived 10 Royal Holloway, University of London, UK data products, and executable analysis code. This preservation enables the analyses 11 University of Illinois at Urbana-Champaign, USA long-term future reuse, in order to maximise the scientific impact of publicly funded 12 Max Planck Institute for Physics, Munich, Germany particle-physics experiments. We cover the needs of both the experimental and theoret-13 Exzellenzcluster ORIGINS, Garching, Germany ical particle physics communities, and outline the goals and benefits that are uniquely 14 Naniing Normal University, Naniing, PRC enabled by analysis recasting and reinterpretation. We also discuss technical challenges and infrastructure needs, as well as sociological challenges and changes, and give sum-15 CERN, Switzerland many recommendations to the particle-physics community. 16 Ludwig-Maximilians-Universität München, Germany 17 University of Oslo, Norway 3

18 DAMTP, University of Cambridge, UK

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	ADL/CutLan	a Spev	MaPyDe
•	Optimal reporting of experimental data			7
•	Shared theoretical predictions	Contur	Checkmate	GAMBIT
•	Developing machine-learning based searches			
		HEPData	Lilith	SModelS

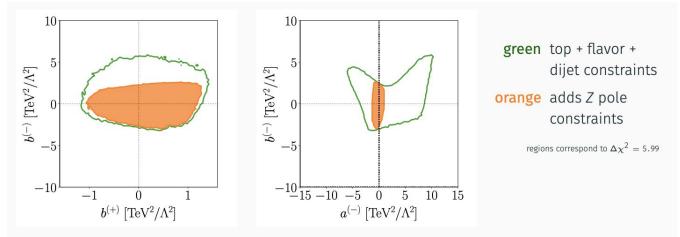
EFT Day @ the RIF workshop

Off-the-shelf flavour constraints for your SMEFT fit	Dr Danny van Dyk	Ø
Interpreting HEP data in SMEFiT	Jaco ter Hoeve	Ø
Save the EFT: a primer for the ATLAS+CMS combination in the top sector	Kirill Skovpen	Ø
Global EFT fits within the ATLAS experiment	Rahul Balasubramanian	Ø
Summary of LHC EFT WG activities	Ken Mimasu	0
EFTs, models and matching: the necessity and caveats	Shankha Banerjee	0
Global view on SMEFT interpretations and UV connection	Maeve Madigan	Ø

+ 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

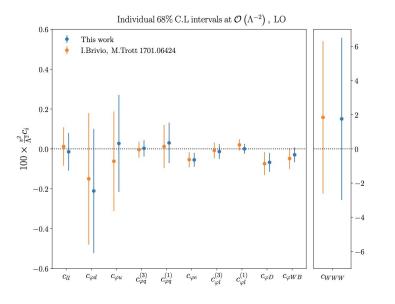


Proof of concept: public likelihood functions for flavour constraints on WET coefficients, marginalised over hadronic nuisance parameters, approximated by normalising flows

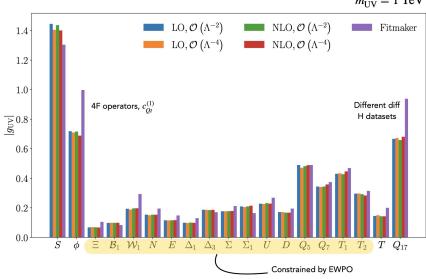
Interpreting HEP data in SMEFiT PH8 (James Duff Lecture Theatre), Durham University

Latest results & plans from SMEFiT collaboration

Exact EWPO implementation



UV model interpretations



Jaco ter Hoeve

10:30 - 10:50

Q

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

PH8 (James Duff Lecture Theatre), Durham University

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

Combine (CMS) & pyhf (ATLAS) frameworks

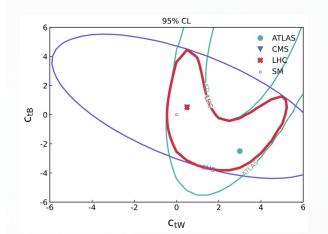
Full likelihoods:

- 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:
 - tīγ (single lepton): JHEP 12 (2021) 180
 - tīγ (di-lepton): JHEP 05 (2022) 091
 - ttZ (multilepton): EPJC 81 (2021) 737
- Very complementary sensitivity

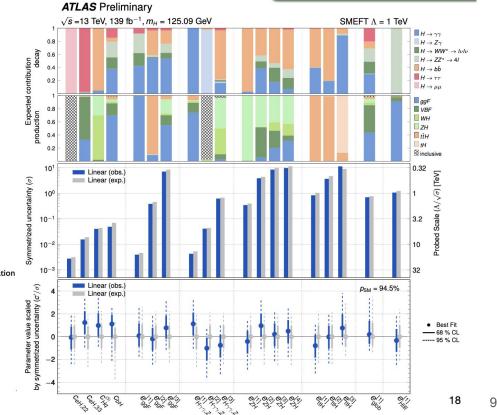


Global EFT fits within the ATLAS experiment

PH8 (James Duff Lecture Theatre), Durham University

Latest ATLAS SMEFT results

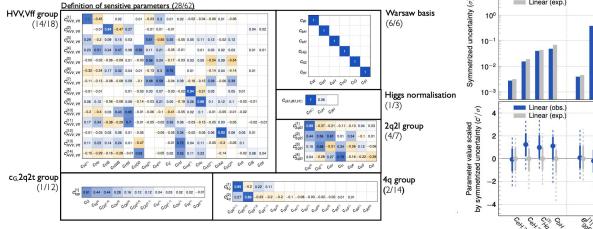
 Including global fit to Higgs, Diboson & EWPO



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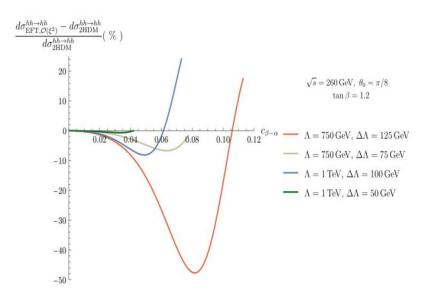
11:50 - 12:10

Rahul Balasubramanian



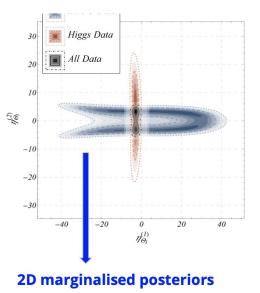
EFTs, models and matching: the necessity and caveats

Review on latest results in matching tools and fits



We extend SM by a colour-triplet isospin-doublet scalar Θ_1 with hypercharge Y=1/6

$$\begin{split} \mathcal{L}_{\Theta_{1}} &= \mathcal{L}_{\mathrm{SM}}^{d \leq 4} + (D_{\mu} \Theta_{1})^{\dagger} (D^{\mu} \Theta_{1}) - m_{\Theta_{1}}^{2} \Theta_{1}^{\dagger} \Theta_{1} - \\ \eta_{\Theta_{1}}^{(1)} H^{\dagger} H \Theta_{1}^{\dagger} \Theta_{1} - \eta_{\Theta_{1}}^{(2)} (H^{\dagger} \sigma^{i} H) \left(\Theta_{1}^{\dagger} \sigma^{i} \Theta_{1}\right) \\ &- \lambda_{\Theta_{1}}^{(1)} \left(\Theta_{1}^{\dagger} \Theta_{1}\right)^{2} - \lambda_{\Theta_{1}}^{(2)} \left(\Theta_{1}^{\dagger} \sigma^{i} \Theta_{1}\right)^{2} + \left\{ y_{\Theta_{1}} \Theta_{1}^{\alpha} \overline{d}_{R}^{\alpha} i \sigma^{2} l_{L} + \mathrm{h.c.} \right\} \end{split}$$

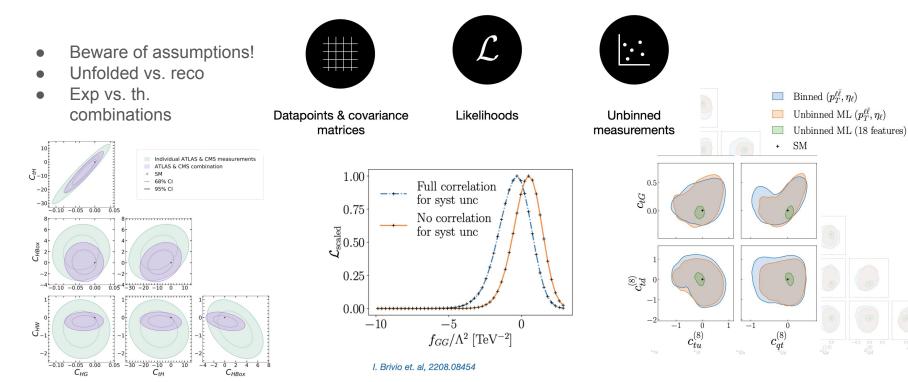


Shankha Banerjee 0

15:10 - 15:30

Maeve Madigan

'High-level' overview of challenges/developments in SMEFT interpretations



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,...)
- <u>Help</u> 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