

Executive Summary of MITP Programme “Effective Field Theories as Discovery Tools”

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The goal of the three-week programme was to lay out and discuss the new physics discovery potential of Run II of the LHC from the effective field theory (EFT) approach. The participants had a strong background on the use of EFTs in the context of flavour, Higgs and/or dark matter physics. The exchange between these various fields was one of the fundamental scopes of the programme.

During the three week programme, we had a total of 26 presentations, which were scheduled to be 45 min each. They usually took place in the mornings, leaving the afternoons free for discussions and collaborations among participants. On Thursdays, instead of presentations, we had scheduled discussion sessions on the topics of flavour physics, Higgs physics and dark matter physics, respectively.

Flavour Physics

Most of the current theoretical efforts in flavour physics are driven by the various anomalies observed recently in the flavour sector. These are on the one hand the deviations from standard model predictions observed by the LHCb experiment and the B factories in the semi-leptonic B meson decays $B \rightarrow K^{(*)}\ell^+\ell^-$ and $B \rightarrow D^{(*)}\tau\bar{\nu}$, but on the other hand also the indications by recent lattice QCD results for tensions in the CP-violating observable ϵ'/ϵ in $K \rightarrow \pi\pi$ decays and in neutral $B_{d,s}$ meson mixing. The discussion session during the first week of the workshop provided an overview over the current experimental and theoretical status. The description of all these observables is conveniently done in the EFT picture, collecting both the SM electroweak effects and possible beyond the SM (BSM) contributions in higher-dimensional operators. We also had a number of presentations related to flavour physics. Siavash Neshatpour presented the status of $b \rightarrow s$ anomalies, and David Straub discussed possible new physics in radiative B decays and gave a brief introduction to the software package ‘flavio’. Danny van Dyk in his presentation revisited the known $B \rightarrow D^{(*)}$ form factor calculations with the aim to re-assess the underlying uncertainties. Admir Greljo presented recent work, in which he connected the various BSM explanations of the $R(D^{(*)})$ anomalies to observable deviations in high- p_T $\tau^+\tau^-$ data at the LHC. Concerning BSM flavour model building, Sho Iwamoto presented a supersymmetric model, in which gauge mediation is introduced in a flavour violating manner.

Dark Matter

EFTs are also ubiquitous in dark matter phenomenology. For searches at colliders, one has to be aware of the EFT limitations when considering particles recoiling with transverse momenta of the order of the dark matter mass (which led to the use of simplified models). Several presentations scattered throughout the three weeks tackled on many of these aspects. Anibal Medina discussed the validity of using EFT for co-annihilating dark matter in collider searches. Matthew Dolan presented a new algorithm to maximize the sensitivity of jets plus missing

energy searches at the LHC. Swasti Belwal discussed the interplay between simplified models and EFT at colliders for WIMP dark matter, while Oleg Antipin and Mikael Chala analyzed the dark matter phenomenology of models with new strong interactions (Composite Higgs and hypercolor). Christian Gross discussed the collider phenomenology of multi-component dark matter, which arises naturally when considering additional (non-SM) gauge interactions. For direct detection experiments, where the dark matter particle recoils with keV energies the application of the EFT is well understood, but yet the traditional approach is to consider only vector and axial currents. In the discussion session led by James Dent and Will Shepherd, it was indeed discussed that those two operators might be insufficient and additional operators are needed. They also discussed the status of indirect searches, and gave an overview of the experimental prospects for the next generation of experiments, and reviewed the current hints for dark matter.

Higgs and Top Physics

The use of EFTs in Higgs Physics has become of utmost importance in order to parameterize deviations from the SM Higgs case, where all couplings are known. Oscar Cata discussed in detail the case of linearly versus non-linearly realized EFTs in the Higgs sector, while Shao-Feng Ge showed the expected accuracy to extract these couplings at lepton colliders. Due to the large value of the top-Yukawa, considering effective operators in the top sector is also important. The status of top EFTs was reviewed by Durieux Gauthier in his presentation. The current efforts to automatize the inclusion of NLO QCD corrections in MC generators were presented by Cen Zhang for the case of top-antitop resonances (including interference effects) and by Hai Tao Li on SCET resummation of top pair production. Christian Schwinn presented a generic framework to properly include these NLO QCD effects in the whole SM+EFT Lagrangian, while Minho Son reviewed a recent result that states the “non-interference” between QCD and dimension 6 operators corrections, which he applied to anomalous gauge couplings at the LHC. The discussion on Higgs Physics was led by Benjamin Fuks and Markus Schulze, who summarized the latest results in Higgs physics presented at ICHEP and the content of the new Higgs Yellow Report 4, paying special attention to the prospects of measuring multi-Higgs interactions at the LHC and at the FCC, which are crucial for the stability of the vacuum of our Universe.

Emerging topics and discussions

In addition to the presentations reviewed above, additional topics related to physics beyond the Standard Model were also discussed in a number of talks, displaying the enthusiasm for the prospect that the LHC will discover new physics.

Last but not least, the *leit-motiv* of the program, namely the question of the role of EFTs in a pre-discovery vs. post-discovery era, was revisited many times during coffee breaks and in presentations. One particularly interesting discussion revolved around the validity of truncation methods for generating Monte Carlo and the sensitivity to new physics from tails of kinematic distributions in an EFT context.

Summary

The three week programme provided the basis for the exchange of knowledge and very fruitful discussions among the participants. The timing of the workshop, at the early stages of Run

II at the LHC, has been extremely appropriate.

The format of the workshop has been chosen to maximally encourage and facilitate interactions among participants, to foster discussion by raising topics during in-depth technical presentations followed by ample time for public and private debates. Discussions over lunch and coffee on site and dinner in town followed in smaller groups. The atmosphere has been very informal throughout the workshop, something that has played a role in making the younger researchers immediately comfortable and triggered discussions right away.

Let us conclude by expressing our gratitude to the MITP (starting from an amazingly kind, warm and helpful staff to the board and director) for making our lives as programme coordinators extremely easy and for having given us the chance to organize and run this programme. Our programme was successful, inspiring, and timely, and we expect that future scientific collaborations and results initiated at our programme are forthcoming.