

Fundamental Parameters of the Standard Model from Lattice QCD

- Executive Summary -

Aims of the Programme

Recent years have seen a significant increase in the overall accuracy of lattice QCD calculations of various hadronic observables. Results for quark and hadron masses, decay constants, form factors, the strong coupling constant and many other quantities are becoming increasingly important for testing the validity of the Standard Model. Prominent examples include calculations of Standard Model parameters, such as quark masses and the strong coupling constant, as well as the determination of CKM matrix elements, which is based on a variety of input quantities from experiment and theory. In order to make lattice QCD calculations more accessible to the entire particle physics community, two different initiatives (which have now merged) have sprung up, which collect the available lattice results and produce global averages. Also on the phenomenological side there are groups which produce global averages of flavour physics quantities, for which lattice input is crucial.

This scientific programme aimed to bring together lattice practitioners with members of the phenomenological and experimental communities who are using lattice estimates as input for phenomenological studies. In addition to sharing the expertise among several communities, the aim of the programme was to identify key quantities which allow for tests of the CKM paradigm with greater accuracy and to discuss the procedures in order to arrive at more reliable global estimates.

Format and Participation

The programme was attended by 19 members of the lattice community and seven phenomenologists, as well as one experimental physicist. The daily programme consisted of two one-hour talks each morning, and ample time for discussion in the afternoons.

This common programme was complemented by separate collaboration meetings of the CKMfitter collaboration (which performs fits to the CKM paradigm of the Standard Model and to New Physics models using precision flavour observables, relying on lattice inputs for many hadronic quantities) and of the Flavour Lattice Averaging Group (FLAG), which publishes averages of lattice determinations of numerous hadronic and fundamental quantities of relevance to flavour physics.

Framed by keynote talks from FLAG (presented by A. Vladikas) and the CKMfitter collaboration (presented by S. Descotes-Genon) on the first, and a summary talk (presented by G. von Hippel) on the last day, the programme of talks included reviews of the decay and mixing properties of heavy-light mesons (presented by P. Dimopoulos, P. Fritzsche, and S. Collins) and light mesons (presented by C. Kelly, and A. Jüttner), discussions of issues connected with the determination of quark masses (presented by G. Bali, M. Della Morte, and M. Creutz), and the interplay of electroweak and strong interactions (presented by T. Izubuchi, G. Herdoíza, and V. Lubicz). A special presentation of the PDG World Average of the strong coupling α_s (presented by S. Bethke) was complemented by a moderated community discussion, and by talks on determinations of α_s from heavy-quark potentials (presented by X. García i Tormo) and the role of

perturbation theory (presented by M. Lüscher). The core issue of data analysis in the presence of systematic errors, which was the topic of two discussion sessions, was addressed with new proposals in a special presentation (presented by J. Charles). The programme was rounded off with a talk on the topic of nucleon strange electromagnetic form factors (presented by J. Green).

The environment at the MITP fostered vigorous discussions also outside of dedicated sessions, both in the coffee room and in smaller groups meeting in individual offices, including those set aside for the purpose.

Central Topics

A topic that ran through most of the reviews and was addressed in a special presentation and separate discussions was the issue of how to average lattice results in the presence of the theoretical uncertainties which dominate over the statistical ones. This is of crucial importance in order to obtain reliable estimates of the overall systematic errors of lattice averages, which will be needed to constrain fits to the CKM paradigm and to probe the limits of the Standard Model. While no general consensus on a single unified way to estimate these uncertainties has been achieved so far, the discussions at the scientific programme have been helpful in identifying some of the ways in which the lattice community can better provide the information required by the CKM fitting communities, and in elucidating what are the pertinent theoretical and mathematical issues, such as the question of the nature (stochastic or otherwise) of systematic errors, which also influence the question of how these are to be treated in a maximum-likelihood framework.

Another important topic was the issue of including isospin breaking in lattice results, which will be required if sub-percent accuracy is to be achieved. The two major ways in which this problem can be tackled are direct simulations of QCD+QED with unequal-mass light quarks, and the incorporation of a systematic expansion around the isospin symmetric point into lattice calculations via a set of methods developed by the Rome-based RM123 collaboration. Either method will need to address the problem of infrared divergences associated with the lack of a mass gap in QED, and methods to deal with this in the spirit of the Bloch-Nordsieck treatment of IR divergences were discussed at the programme. Other sources of systematic error that may become significant at the sub-percent level, including the observables used for scale setting on the lattice, and the use of perturbative renormalization, were also the topic of some discussion.

Finally, the coordination of efforts and the improvement of communication channels between the lattice and phenomenological communities have been addressed, and it may be said that this programme represented a significant step in this direction.

Summary

This scientific programme connected the communities of the “producers” and “consumers” of lattice results for a discussion of the issues surrounding the use of lattice results in determining the fundamental parameters of the Standard Model, resulting in improved mutual understanding of relevant issues and methods.

The Organizers: *Gilberto Colangelo, Sébastien Descotes-Genon, Georg von Hippel, Heiko Lacker, Hartmut Wittig*