

# Future Challenges in Non-Leptonic $B$ Decays: Theory and Experiment

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Testing the Standard Model (SM) and searching for New Physics (NP) are currently the main priorities in High-Energy Physics. Whether or not new particles are directly produced at the LHC, indirect searches will remain crucially important. If fingerprints of NP are found in indirect searches, many characteristics of new particles and interaction can be inferred.

Non-leptonic decays of  $B$  mesons are central to this enterprise and offer unique opportunities. With most of the  $3 \text{ fb}^{-1}$  of data recorded by the LHCb detector during run 1 of the LHC already analysed, the recent restart of the LHC with run 2, and the perspective of the upcoming the start of Belle-II, the flavour physics community finds itself in a very particular position to revisit and discuss theoretical and experimental issues, to create bridges between theory and experiment, and to devise new strategies for the interpretation of the new data. The aim of this workshop was thus to bring together theorists and experimentalists to discuss the future possibilities in non-leptonic  $B$  decays to make the most out of the expected experimental data.

The workshop consisted of a few general overview talks reviewing in depth the status of the field, given by world-leading top-class theorists and experimentalists. These were followed by extensive discussion sessions addressing the current challenges in the field. A particular focus was set on the interplay between theory and experiments. In addition, a few short presentations of significant recent results were given by PhD Students.

The program started with a session on flavor symmetries. A deep overview on the topic was presented by Martin Jung, after which some results related with the extraction of the CKM angle  $\gamma$  from three-body non-leptonic  $B$  decays were presented by Bhujyo Bhattacharya (theory) and Emilie Bertholet (who presented a recent analysis using BaBar data). In the afternoon Tim Gershon gave an overview talk about the experimental perspectives and vision concerning non-leptonic  $B$  decays, which extended for more than 90' due to extensive discussions involving all participants. After that, an inspiring short talk on the model-independent constraints on  $b \rightarrow \bar{c}cs$  operators was presented by Kirsten Leslie, a PhD student of Sebastian Jäger, who was also participating in the workshop. The day ended with a colloquium given remotely by Ikaros Bigi, on the grand issue of CP violation in multibody decays.

The second day was devoted entirely to the theory of non-leptonic  $B$  decays in QCD Factorization. In the morning we had two maximally comprehensive review talks on two-body (by Martin Beneke) and three-body (by Tobias Huber). The whole afternoon was reserved for a guided discussion session on the open issues in theory, chaired by Marco Ciuchini. This discussion focused primarily on three issues (1) charming penguins, (2) factorization in pQCD and (3) the FAT approach, and featured short contributions from Marco Ciuchini, Martin Beneke, Yuming Wang and Cai-Dian Lu.

On the third day of the workshop, there were two sessions: one discussing Light-Cone Sum Rules (morning), followed by a session on Dispersive Analyses (afternoon). Both sessions consisted of an overview talk and a discussion block. The morning session and discussion was chaired by Danny van Dyk, with an overview talk by Alex Khodjamirian who reviewed the LCSR approach to heavy-to-light transitions, and its applications to form factors and two-body non-leptonic decays. Many things were discussed during the discussion block, but an important element was introduced by Danny about the real perspectives for the determination of the inverse moment of the  $B$ -meson LCDA at Belle-2. The afternoon session was chaired by Emilie Passemar, and contained an overview talk by Bastian Kubis, where he described the applications of dispersive analyses to three-body  $B$  decays. Here the main challenge consists of bridging the gap between low-energy regime where dispersive analyses hold and the high-energy regime where QCD Factorization is the main framework. This requires a common language as a first step, and the many discussions following these talks certainly opened the way in this direction.

The fourth day of the workshop was devoted to three-body  $B$  decays and the challenges they pose. Ignacio de Bediaga and Jussara Miranda presented the previous and current analyses performed at LHCb, emphasizing the experimental and theoretical challenges in dealing with the fast increasing amount of statistics. In this endeavour, it is especially challenging to merge the needs and wishes of experimentalists and theorists. The question remains how to go beyond the well-established (and widely criticized) isobar model and how to interpret these results in a QCD-based theoretical framework. These issues were discussed in a lengthy discussion session, started by Patricia Magalhaes who presented a new model to describe final-state-interactions in  $B \rightarrow KKK$  using triangle loops. The discussion session contained contributions from Fabian Krinner, discussing the possibilities of performing a model-independent partial-wave analysis, Daniel O’Hanlon, about prospects at LHCb, and Bruno El-Bennich and Benoit Loiseau, who discussed the analyses of  $B \rightarrow K\pi\pi$  and  $B \rightarrow KKK$  in the "QCDF-inspired" naive factorization approach, paying attention to the analyticity and unitarity of the timelike form factors.

The last day contained only a morning session, where we had a couple of short talks by Maria Vieites, about a very interesting new LHC analysis of  $B \rightarrow K^*\rho$ , and Patricia Magalhaes, who discussed how pole positions and widths of resonances extracted from isobar fits to three-body decays may not coincide with the ones in the PDG. After these two talks, Sebastien Jäger and Thomas Mannel gave personal

summaries of the various sessions, highlighting the most relevant discussion points that happened during the workshop.

Overall, the workshop was very dynamic, very flexible, and with many discussions. Many new ideas have emerged as a result of this workshop, which will likely produce new collaborations among the participants, some of which are already ongoing.

Finally, we would like to thank the MITP for providing the infrastructure and the logistic support. The very fruitful and open atmosphere at MITP contributed a lot in making this workshop a great success.