Non-leptonic *B* decays in QDC Factorisation

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I will review the theoretical understanding of non-leptonic two-body decays within the heavy quark expansion, highlighting the success as well as open questions of the factorisation approach. I will further discuss model-independent constraints on the B-meson light-cone distribution amplitude, which is the relevant hadronic input parameter for all exclusive charmless B decays, and I will present the status of the perturbative calculation of the underlying short-distance coefficient functions.

Experimental overview of hadronic *B* decays

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This talk gives an overview of the latest results and analysis methods of B→PP, B→VP and B→PP decays at the LHCb experiment and the B factories. The focus is on charmless transitions. In particular, the impact of these decays on the constraints of Standard Model (SM) parameters and their sensitivity to new physics are reviewed. The prospects of future measurements at LHCb and Belle II are discussed.

Loop dominated b→sqq (q=u,d) transitions such as B_d→η'K are potentially sensitive to new physics. A branching fraction or a *CP* asymmetry parameter deviating from its SM prediction can be due to a contribution from an unknown particle. The corresponding decays of the B_s meson, *e.g.* B_s→KK, can be used to search for new physics in a similar manner. Furthermore, B_s→VV decays proceeding through b→sss transitions, such as B_s→φφ, are pure penguin modes. The theoretical uncertainty on the phase from the interference of mixing and decay is low and thus B_s→φφ is an excellent mode to search for new physics.

The angle φ_2 of the unitarity triangle can be precisely determined in an isospin analysis of B_d→hh (h=K,π) decays. Other b→u transitions, such as B→ρρ and B_d→ρπ, can further constrain the φ_2 measurement. The polarization fractions of the B→VV decays allow an additional test of the SM.

Global CKM fits and non-leptonic *B* decays

Sébastien Descotes-Genon

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Some nonleptonic two-body B decays are particularly useful to constrain the CKM matrix, in particular through the determination of the angles alpha, beta, gamma. I will review the role played by these decays in the frequentist analysis performed by the CKMfitter group, discussing the sources of uncertainty in each case.

Precise predictions for penguin contributions to CP asymmetries in B decays

Ulrich Nierste

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The key modes to determine the fundamental CP phases in B_d and B_s mixing are B_d→J/psi K_s and B_s→J/psi phi, respectively . Both decay amplitudes receive corrections proportional to the CKM combination V_{ub}^* V_{us}, the so-called penguin pollution. I show that this contribution can be calculated in terms of an operator product expansion, which formalises the phenomenological ``Bander-Soni-Silverman mechanism''. I present numerical predictions for several CP asymmetries, including b → c c-bar d decays. Then I discuss branching ratios and CP asymmetries in B->DD decays, which can be treated in a similar way.

Precision determinations of the weak B meson mixing phases including "penguin pollution"

Martin Jung

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We discuss the model-independent precision determinations of the weak mixing phases phi_{d,s} from B → J/psi M decays, where M is a pseudoscalar or a vector meson. The framework is provided by an SU(3) flavour-symmetry analysis to first order in the symmetry breaking, including various subleading terms commonly neglected. Accounting for the various suppression factors in the analysis yields a predictive framework that allows for sufficient control of subleading effects in the foreseeable future.

Probing CP violation in two-body non-leptonic *B* decays

Alakabha Datta

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Oxford, MS 38677-1848, USA

I will discuss probes of CP violation in nonleptonic decays with special focus on vector-vector final states.

Lattice computations of nonleptonic kaon decay amplitudes and the lessons for hadronic *B*-decays

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I will review recent RBC-UKQCD studies of nonleptonic kaon decays and particularly the computation of ε'/ ε. It has taken many years of theoretical developments to make these calculations possible, as I will explain. The theoretical difficulties of extending these methods to *B*-decays will be discussed and the necessity of a new idea(s) highlighted.

Perturbative calculations for ε'/ ε

Martin Gorbahn

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The quantity ε'/ ε measures direct CP violation in kaons decaying into two pions. The theory prediction of ε'/ ε relies on perturbative and Lattice QCD calculations. In this talk I will discuss the standard model prediction and anatomy at NLO and present the status of the NNLO theory prediction.

Experimental results from *B* decays to charmless and open-charm 3-body final states

Tom Latham

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Amplitude analyses of 3-body decays of B mesons to both charmless and open-charm hadronic final states have the potential to provide excellent sensitivity to CP-violating phases. They also present great challenges, both in terms of satisfactorily describing the physics amplitudes but also the variation of the experimental acceptance and background processes over the phase space. We will discuss recent experimental results as well as the future potential of these decays.

Three-body non-leptonic *B* decays and QCD Factorization

Thomas Mannel

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We extend the framework of QCD factorization to non-leptonic B decays into three light mesons, taking as an example the decay $B^+ \to \pi^+\pi^+\pi^-$. We discuss the factorization properties of this decay in different regions of phase space. We argue that, in the limit of very large b-quark mass, the central region of the Dalitz plot can be described in terms of the $B\to\pi$ form factor and the B and π light-cone distribution amplitudes. The edges of the Dalitz plot, on the other hand, require different non-perturbative input: the $B \to \pi\pi$ form factor and the two-pion distribution amplitude. We present the set-up for both regions to leading order in both α_s and Λ_{QCD}/m_b and discuss how well the two descriptions merge. We argue that for realistic B-meson masses there is no perturbative center in the Dalitz plot, but that a systematic description might be possible in the context of two-pion states. As an example, we estimate the $B \to \rho\pi$ branching fraction beyond the quasi-particle approximation. We also discuss the prospects for studies of three-body and quasi-two-body non-leptonic B decays from QCD.

$B \to \pi\pi$ Form Factors: Overview and Results at Large Dipion Masses

Danny van Dyk

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I will review the B → pipi helicity form factors and highlight methods to calculate them in a number of regions of the B → pi pi ell nu phase space. I will then concentrate on the region of large dipion masses, in which QCD improved factorization can be applied. Numerical results and symmetry relations will be presented.

Form factors of $B \to \pi\pi$ transitions from QCD light-cone sum rules

Alex Khodjamirian

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I will present new results on the form factors of the B → pipi transitions, relevant for the semileptonic B → pi pi ell nu decays and for the factorization ansatz in three-body nonleptonic *B* decays. At small invariant dipion mass and, simultaneously, at large recoil, these form factors are calculated from QCD light-cone sum rules with the distribution amplitudes of dipion states. I will briefly discuss further development of this method and the alternative approach based on the sum rules with *B*-meson distribution amplitude.

Two-meson form factors from dispersion relations

Pablo Roig

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Two-meson form factors are required inputs for some non-leptonic B decays. I will discuss their building based on chiral perturbation theory, unitarity and analyticity constraints using dispersion relations.

Padé Theory: A toolkit for hadronic form factors

Pere Masjuan

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A model-independent and data-driven method to describe pseudoscalar meson form factors will be discussed within the context of Padé Theory. This method is a TOOLKIT suitable to provide precise parameterizations for non-leptonic (two-meson) B decays, exemplified in this talk by the pion vector form factor. Beyond that, the synergy between theory and experiment shall provide, as well, a precise determination of CKM parameters.

Dispersive methods in heavy-meson decays

Bastian Kubis

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The universality of final-state interactions can be exploited using methods from dispersion theory. In particular the (strong) phase motion of pion-pion and pion-kaon systems can be controlled accurately, building on very precise knowledge of the corresponding phase shifts at low energies. We apply dispersive techniques successfully in an analysis of LHCb data on B_{d/s} → J/psi pi pi [J/psi K \bar{K}]. The further complications of systems with strong rescattering between three decay particles is discussed in the context of a Dalitz plot study of D → K pi pi.

CP violation and CPT invariance in charmless three-body *B* decays

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The joint violation of the symmetries of parity and charge conjugation have been observed in high amount in charmless three body B decays. In this seminar we would like to discuss the different distribution of the CP asymmetry along the Dalitz phase space. It will be discussed evidences of new mechanisms to produce this type of asymmetry, directly related to the hadronic final state interactions. Finally we will discuss the relationship between these mechanisms and CPT invariance.

Branching fractions and CP violation in hadronic three-body *B* decays

Hai-Yang Cheng

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One of the salient features of hadronic charmless three-body B decays is the large fraction of nonresonant contributions. Nonresonant effects in penguin-dominated modes are found to be governed by the matrix elements of scalar densities. For resonant contributions to three-body decays, we consider the effects of vector and scalar mesons. Their contributions are essentially determined by strong couplings and decay constants. The predicted resonant and nonresonant rates are consistent with experiment.

We calculate inclusive and local CP asymmetries in various regions and investigate final-state interactions between pi+pi- and K+K- in the rescattering region of m_{\pi\pi} and m_{KK} between 1.0 and 1.5 GeV. We stress that CP asymmetries due to nonresonant terms alone are sizable.

Final state interaction on B+ → pi+pi-pi+

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The large localized CP asymmetries observed by LHCb in three-body charmless decays of *B* mesons brings new challenge for experimentalists and their traditional models to fit data. With higher statistics, rescattering and three-body effects, previously ignored on data analysis, become more visible.
The time is ripe to use better theoretical assumptions as an ingredient in order to improve the analysis.

In this talk we address the issue of rescattering effects in the charmless three-body decays of *B* mesons. In particular, we study the case of the *B* → pi pi pi decay and show that the presence of hadronic loops shifts the P-wave phase near threshold to below zero, and modifies the position of the rho-meson peak and its width, in the Dalitz plot.

Phenomenology of B->Kpipi modes and prospects with LHCb and Belle II data

Alejandro Perez

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Dalitz-plot analyses of B->Kpipi decays provide direct access to decay amplitudes, and thereby weak and strong phases can be disentangled by resolving the interference patterns in phase space between intermediate resonant states. An amplitude analysis provides interesting information on the dynamics of these resonances, which can be tested against models. These modes may also offer some sensitivity to NP contributions as they are dominated by high order diagrams(loops). In this contribution I will describe the amplitude analysis techniques for accessing interesting observables and the theoretical framework to interpret such measurements. Furthermore, some prospects for measurements at LHCb and Belle II will be also presented.

QCD factorization in non-leptonic B decays: status of phenomenology and challenges

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This abstract has been written by the organizers, not by the speaker:
In this talk, Martin will discuss the status and recent developments in the phenomenology of two-body non-leptonic B decays from the point of view of QCD factorization, and review the main challenges that remain ahead.

Power corrections in *B* decays

Yu-Ming Wang

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I will first illustrate the importance of power corrections in hard exclusive processes, particularly in B meson decays, and then discuss the theory challenges of computing the sub-leading power contributions on the conceptual aspects. I will further explain the QCD based techniques to evaluate power suppressed effects in several typical hard processes.

Charmless $B \to MM$ in QCDF: weak annihilation from data

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Charmless rare B → MM decays receive weak annihilation (WA) contributions, which are subleading in QCDF but enhanced by other factors. Currently, no factorization theorems are available for these contributions within QCDF (or SCET) and models are used to parametrize the corresponding hadronic effects. As WA is phenomenologically important, we present fits of the hadronic model parameters from the data of various $B \to PP$, PV and VV systems and compare them among the systems.