Abstract

The inclusive semileptonic decay of the B meson serves as the "standard candle" process for the determination of the Cabibbo–Kobayashi–Maskawa matrix element V_{cb} in the Standard Model. It can also be used to fix values of the masses of the bottom and charm quarks and non-perturbative parameters used in the theory of all inclusive decays of the B meson. The recently developed techniques of reparametrization-invariance-improved Heavy Quark Expansion motivate the investigation of the leptonic invariant mass spectrum of this decay. In the present thesis, I describe the calculation of this spectrum in the leading order in the Heavy Quark Expansion and up to the next-to-next-to-leading order in Quantum Chromodynamics. The results contain the contribution from the $b \to cc\bar{c}l\bar{\nu}_l$ channel omitted in previous determinations, making the analysis fully inclusive. The spectrum is presented as a fit to precise numerical values obtained with the Auxiliary Mass Flow algorithm, and are followed by an examination of the impact of the Next-to-Next-to-Leading correction on its moments.

In the preparation of this dissertation, I placed an emphasis on the description of the field-theoretic framework used to obtain perturbative corrections in particle physics and of the contemporary methods of computing multi-loop, multi-scale Feynman diagrams. To this end, the calculation of a two loop diagram contributing to the considered process is presented in detail. The practical aspects of dimensional regularization, Clifford and $\mathfrak{su}(N)$ algebras are summarized with a subsequent overview of the techniques of Integration By Parts reduction, differential equations, ϵ-form, and Auxiliary Mass Flow.

The technical chapters of the thesis are followed by an outline of the modern theory of inclusive decays of hadrons containing a heavy quark. The leading order approximation of the semileptonic transition in the Standard Model is derived within the framework of an Effective Field Theory. The Heavy Quark Effective Theory and the resulting Heavy Quark Expansion are presented in the context of the semileptonic decay. The reparametrization invariance and its consequences are then reviewed. Finally, I construct the effective width technique for the leptonic invariant mass spectrum that greatly facilitates the computation of higher-order perturbative corrections.

The presented results can serve to improve the future extractions of phenomenologically significant quantities from the data provided by the Belle, Belle II, and LHCb experiments. The precision of these extractions is an important limiting factor of the predictions of rare processes that can guide the search for physics beyond the Standard Model.