Weak decays of heavy hadrons in light of search for new physics

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This series of works is devoted to the analysis of semileptonic and nonleptonic decays of both heavy mesons and baryons. This analysis is highly relevant in light of emerging experimental data at the LHC collider, the Belle II super B-factory and the BESIII-particle physics experiment at the Beijing Electron-Positron Collider. Theoretically, much interest in studying the weak decays of heavy hadrons containing b- or c-quarks has arisen due to a number of experimental data indicating the possible emergence of new physics beyond the standard model. Various theoretical models are being intensively developed, in which either new particles or new interactions are introduced. The most promising is the effective theory of the standard model, based on the construction of an effective Lagrangian that preserves symmetry of the standard model. At energies significantly lower than the electroweak scale (246 GeV), the so-called effective low-energy theory is used, the main elements of which are 4-fermion operators of mass dimension 6. In this cycle works developed an approach called the covariant quark model, which allows one to calculate the matrix elements of such operators from a unified position. This series of papers presents a wide range of results on weak decays of heavy hadrons, including the effects of new physics. The most significant results are briefly summarized below.

- For the first time, a technique has been developed for calculating three-loop diagrams in the covariant quark model taking into account confinement and applied for calculations of W-exchange diagrams for two-particle nonleptonic decays of doubly charmed baryons Ξ^{++}_{cc} and Ω^{+}_{cc} have been calculated. It is shown that these contributions are not suppressed compared to factorable contributions.
- Two-particle nonleptonic decays have been systematically studied as a light Λ-hyperon $\Lambda \to p\pi^-(n\pi^0)$, and the charmed Ξ^0_c-baryon $\Xi^0_c \to \Lambda_c^+\pi^-$ without changing the charm $\Delta C = 0$. Both pure quark diagrams (contribution of short distances) and pole diagrams with intermediate resonances (contribution of long distances) are consistently taken into account. It has been established that the contributions of quark diagrams are significantly suppressed compared to the contributions of pole diagrams.
- The widths of semileptonic and two-body nonleptonic decays of doubly charmed baryons Ξ^{++}_{cc}, Ξ^{+}_{cc}, and Ω^{+}_{cc} have been calculated.

- In semileptonic decays of heavy mesons and baryons the dependence on the lepton mass is factorized before by the quadratic coefficient $\cos^2(\theta)$, where θ is the angle of expansion in the differential distribution. We call the corresponding normalized coefficient the convexity parameter. This observation opens a way to test the universality of leptons in semileptonic decays of heavy mesons and baryons, which is independent of form factor effects. The so-called optimized partial widths, which in the standard model are the same for all three (e, μ, τ) decay modes, are proposed for measurement and theoretically calculated. Specifically, semileptonic decays of heavy mesons are considered $B^0 \to D^* + l^- \nu^-_l$ and $B^-_c \to J/\psi(\eta_c) l^- \nu^-_l$ and heavy baryons $\Lambda_b \to \Lambda_c l^- \nu^-_l$.
- Semileptonic decays of the Bc meson into final charmonium states were studied both within the standard model and beyond by introducing a complete set of four- fermion operators describing $b \to c\tau\nu_\tau$ transition. Experimental restrictions on the corresponding Wilson coefficients are obtained.

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