B Meson Light-Cone Wavefunctions and Heavy-Quark Symmetry

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We present the first systematic study of the B meson light-cone wavefunctions in the limit of infinite heavy-quark mass in QCD[1,2]. The light-cone wavefunctions are related to the usual Bethe-Salpeter wavefunctions at equal light-cone time $x^+ = (x^0 + x^3)/\sqrt{2}$. In the heavy-quark limit, the B meson light-cone wavefunctions obey the heavy-quark symmetry constraint, and can be introduced in terms of vacuum-to-meson matrix element of nonlocal operators in heavy-quark effective theory (HQET). We derive the integro-differential equations between the quark-antiquark wavefunctions and the quark-antiquark-gluon three-particle wavefunctions from the equations of motion in HQET[1,2]. Our integro-differential equations are exact in QCD in the heavy-quark limit.
As solution of these integro-differential equations, we construct representations for the quark-antiquark wavefunctions in terms of independent dynamical degrees of freedom. Firstly, we discuss analytic solution of the integro-differential equations for the case of light-like separation (zero transverse separation) between quark and antiquark[1]. We find that the "Wandzura-Wilczek-type" contributions corresponding to the valence Fock-state components are determined uniquely in analytic form in terms of $\bar{\Lambda}$, a fundamental mass parameter of HQET. We also find that both leading- and higher-twist wavefunctions receive the contributions of multi-particle states with additional gluons, and derive the exact integral representation for these contributions.
Secondly, we extend the analysis to the case of nonzero transverse separation of constituents, and investigate the transverse momentum distribution in the B mesons[2]. We give out the explicit analytic solution of our integro-differential equations with full account of the transverse momentum dependence, within the valence Fock states. We find that the result is expressed by one single nonperturbative parameter $\bar{\Lambda}$, and that the transverse momentum distribution strongly depends on the longitudinal momentum of the constituents. We also estimate the effects of higher Fock states on the transverse momentum distribution.
Our solutions exactly satisfy the equations of motion and constraints from heavy-quark symmetry, and thus provide powerful nonperturbative framework for building up the B meson light-cone wavefunctions. Our results are relevant for the QCD factorization approach for the hard exclusive processes, and are applicable to a range of phenomenologically interesting processes like the exclusive B meson decays and the heavy-meson pair production in e^+e^- collisions.

References

[1] H. Kawamura, J. Kodaira, C.-F. Qiao and K. Tanaka, Phys. Lett. B **523** (2001) 111.
[2] H. Kawamura, J. Kodaira, C.-F. Qiao and K. Tanaka, hep-ph/0112174.