Abstract

In this dissertation, we obtain the renormalization group improved expressions of the Wilson coefficients associated to the $\mathcal{O}(1/m^3)$ HQET Lagrangian operators with leading-logarithmic (LL) approximation, in the Coulomb gauge. The Wilson coefficients include the heavy quark chromopolarizabilities. The analysis incorporates the effects induced by spectator quarks, which are considered to be massless. Special attention is paid to gauge independent combinations of Wilson coefficients.

The previous results are applied to pNRQCD at the weak coupling regime obtaining the renormalization group improved $\mathcal{O}(\alpha^2/m^3)$ and $\mathcal{O}(\alpha/m^4)$ spin-independent potentials in the off-shell Coulomb gauge matching scheme. The $\mathcal{O}(\alpha^3/m^2)$ potential is also computed, but in the off-shell Feynman gauge matching scheme, up to missing contributions proportional to c_k^2, d_{ss} and d_{vs}.

Such potentials are necessary to obtain the next-to-leading-logarithmic (NLL) potential and soft running of the Wilson coefficient $\tilde{D}_d^{(2)}$ associated to the spin-independent delta-like potential, which we also compute. The obtained result is complete up to missing contributions proportional to c_k^2, d_{ss}, d_{vs} and $\bar{c}_1^{hl\,(i)\,\mathrm{NLL}}$ of the NLL soft running. The first three are expected to be of the order of the computed contribution to the soft running, whereas the latter is of $\mathcal{O}(T_f n_f m\alpha^6 \ln\alpha)$, which is expected to be numerically subleading compared to the other contributions. The NLL ultrasoft running is also incorporated, as well as a contribution to the potential running of ultrasoft origin. The scheme independence of the potential renormalization group equation is explored via field redefinitions.

Presently, obtaining the NLL running of $\tilde{D}_d^{(2)}$ is the missing link to obtain the complete next-to-next-to-next-to-leading-logarithmic (N^{3}LL) pNRQCD Lagrangian. That is the necessary precision to obtain the spin-average (spin-independent part) heavy quarkonium spectrum relevant for S-wave (zero angular momentum) states with N^{3}LL ($\mathcal{O}(m\alpha^{5+n}\ln^n\alpha)$ with $n \in \mathbb{Z}$ and $n \geq 0$) accuracy. We carry out this computation up to a missing contribution coming from the missing contribution of $\tilde{D}_d^{(2)}$.