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Electric dipole transitions in potential nonrelativistic QCD

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Electric (E1) and magnetic (M1) dipole transitions have been studied since the early days of hadron spectroscopy because they allow to access heavy quarkonium states which are below open-flavour threshold. Moreover, these reactions are interesting by themselves because they are an important tool to check particular regions of the hadrons' wave function and thus to determine their internal structure and dynamics.

Electromagnetic transitions between heavy quarkonium states have been treated for a long time by means of potential models that use nonrelativistic reductions of phenomenological interactions. However, the progress made in effective field theories (EFTs) for studying heavy quarkonia and the new large set of accurate experimental data taken in the heavy quark sector by B-factories (BaBar, Belle and CLEO), τ-charm facilities (CLEO-c, BESIII) and even proton-proton colliders (CDF, D0, LHCb, ATLAS, CMS) ask for a systematic and model-independent analysis.

This contribution aims to present the first numerical determination of the electric dipole transitions: $\chi_{bJ}(1P) \to \gamma\Upsilon(1S)$ (with $J = 0, 1, 2$) and $h_b(1P) \to \gamma\eta_b(1S)$, using the low-energy EFT called potential nonrelativistic QCD (pNRQCD). At the first instance, we assume that the heavy mesons involved in the studied reactions lie in the strict weak-coupling regime of pNRQCD and thus a full perturbative calculation can be performed. Relativistic corrections of relative order $calO(v^2)$ are included. The analysis separates those contributions that account for the v^2-suppressed electromagnetic interaction terms in the pNRQCD Lagrangian and those that account for quarkonium state corrections of relative order $calO(v^2)$. Within the last ones, corrections come from higher-order potentials ($calO(1/m)$ and $calO(1/m^2)$ terms) and from higher Fock states which account for the coupling of the quark-antiquark state to other low-energy degrees of freedom and thus demand nonperturbative input.

Results within the former scheme show dramatic dependence on the renormalization scale, leading to final numbers with large theoretical uncertainties. We then repeat the calculation including exactly the static potential in the leading order Hamiltonian and also resuming the large logarithms associated with the heavy quark mass scale. The effect of the new power counting and the exact treatment of the soft logarithms of the static potential makes the factorization scale dependence much smaller. Since the convergence in the new scheme is found to be quite good, we give solid predictions for the E1 transitions studied.

Authors: Prof. BRAMBILLA, Nora (Technische Universität München); Dr SEGOVIA, Jorge (Technische Universität München); Mr STEINBEISSER, Sebastian (Technische Universität München); Dr VAIRO, Antonio (Technische Universität München)

Presenter: Dr SEGOVIA, Jorge (Technische Universität München)

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