Bottom Baryons

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Recently CDF Collaboration observed four bottom baryons $\Sigma_b^{\pm}$ and $\Sigma_b^{*\pm}$ [1, 2]. D0 Collaboration announced the observation of Ξ_b [3], which was confirmed by CDF collaboration later [4, 5]. Very recently, Babar Collaboration reported the observation of Ω_c^* with the mass splitting $m_{\Omega_c^*} - m_{\Omega_c} = 70.8 \pm 1.0 \pm 1.1$ MeV [6].

Heavy hadrons containing a single heavy quark are particularly interesting. The light degrees of freedom (u, d, s quarks and gluons) circle around the nearly static heavy quark. Such a system behaves as a QCD analogue of the familiar hydrogen bounded by electromagnetic interaction. The heavy quark expansion provides a systematic tool for heavy hadrons. When the heavy quark mass $m_Q \to \infty$, the chromo-magnetic spin-spin interaction between the light and heavy quarks can be neglected. Therefore heavy hadrons form doublets. For example, Ω_b and Ω_b^* will be degenerate in the heavy quark limit. At finite m_Q, the chromo-magnetic interaction at the order $\mathcal{O}(1/m_Q)$ can be taken into account systematically in the framework of heavy quark effective field theory (HQET).

In order to extract the chromo-magnetic splitting between the bottom baryon doublets reliably, we derive the mass sum rules up to the order of $1/m_Q$ in the heavy quark effective field theory in this work. We perform a systematic study of the masses of Ξ_b, Ξ_b', Ξ_b^*, Ω_b and Ω_b^* through the inclusion of the strange quark mass correction. The resulting chromo-magnetic mass splittings agree well with the available experimental data. As a cross-check, we reproduce the mass sum rules of Λ_b, Σ_b and Σ_b^* which have been derived in literature previously. We have also extended the same formalism to the case of charmed baryons while keeping in mind that the heavy quark expansion does not work well for the charmed hadrons. We collect the extracted $\bar{\Lambda}$, $\mathcal{K}_i$, $\mathcal{S}_i$ and mass splitting $m_{B_c^*} - m_{B_c'}$ in Table 1.

Table 1: The central values in this table are extracted at $T = 0.5$ GeV, $\omega_i = 1.3$ GeV for $\Sigma_b^{(*)}$, $\omega_i = 1.4$ GeV for $\Xi_b^{'(*)}$, $\omega_i = 1.55$ GeV for $\Omega_b^{(*)}$, $\omega_i = 1.1$ GeV for Λ_b and $\omega_i = 1.25$ GeV for Ξ_b (in MeV).

	Σ_b	Ξ_b'	Ω_b^0	Λ_b	Ξ_b
$\bar{\Lambda}$	950^{+78}_{-74}	1042^{+76}_{-74}	1169 ± 74	773^{+68}_{-59}	908^{+72}_{-67}
δm	59^{+4}_{-2}	60^{+6}_{-4}	67^{+7}_{-3}	65^{+2}_{-1}	72 ± 1
mass splitting	$m_{\Sigma_b^*} - m_{\Sigma_b}$	$m_{\Xi_b^*} - m_{\Xi_b'}$	$m_{\Omega_b^*} - m_{\Omega_b}$	-	-
this work	26 ± 1	26 ± 1	28^{+8}_{-2}	-	-
experiment [1, 2]	21	-	-	-	-

In short summary, we have investigated the masses of heavy baryons systematically using the QCD sum rule approach in HQET. The chromo-magnetic splitting of the bottom baryon doublet from the present work agrees well with the recent experimental data. Recently $\Xi_b^{(*)}$ was observed by CDF collaboration [1, 2]. Our results are also consistent with their experimental values. Our prediction of the masses of Ξ_b', Ξ_b^*, Ω_b and Ω_b^* can be tested through the future discovery of these interesting states at Tevatron at Fermi Lab.

References

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