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Comment on "Heavy Hadron Chiral Perturbation Theory"

Peter Cho†
Lauritsen Laboratory
California Institute of Technology
Pasadena, CA 91125

Abstract

The form of the unique next-to-leading order operator which couples heavy antitriplet baryon fields to the axial vector Goldstone current in Heavy Hadron Chiral Perturbation Theory is clarified.

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A synthesis of Chiral Perturbation Theory and the Heavy Quark Effective Theory has recently been developed [1–4]. The interactions of low energy Goldstone bosons with hadrons containing a heavy quark may be studied in this new hybrid theory. In a recent article [5], we investigated some extensions of both the formalism and applications of Heavy Hadron Chiral Perturbation Theory (HHCPT). In particular, we identified a unique next-to-leading order operator which couples heavy antitriplet baryon fields to the axial vector Goldstone current. However, the form of the operator reported in ref. [5] is unfortunately incorrect. We therefore wish to present the correct operator and to clarify its discussion in this short note.

Antitriplet baryons are represented in HHCPT by velocity dependent fields $T_i(v)$ that transform as antitriplets under flavor $SU(3)$ and doublets under heavy quark spin symmetry $SU(2)_v$. Angular momentum and parity considerations prohibit an interaction between these baryons and the axial vector Goldstone field $A^\mu = i/2(\xi^\dagger\partial^\mu\xi - \xi\partial^\mu\xi^\dagger)$ from appearing in the leading order heavy hadron chiral Lagrangian [3,4]. However at next-to-leading order in the $1/m_Q$ expansion, there exists a unique operator O_{TTA} which generates such a coupling. In ref. [5], we specified this operator as

$$O_{TTA} = \frac{i}{m_Q}\epsilon_{\mu\nu\sigma\lambda}\overline{T}^j\sigma^{\mu\nu}D^\sigma T_i(A^\lambda)^i_j. \tag{1}$$

In this original definition of O_{TTA}, we erroneously regarded the iD^σ covariant derivative which acts on T_i as corresponding to the full momentum $p^\sigma = m_Q v^\sigma + k^\sigma$ of the antitriplet baryon field. But a derivative acting on a velocity dependent field pulls down just the residual momentum k^σ rather than full momentum p^σ of a heavy hadron. So to obtain the true form of O_{TTA}, we must make the following simple substitution in (1):

$$\left(\frac{iD^\sigma}{m_Q}\right)_{\substack{\text{full}\\ \text{momentum}}} \longrightarrow v^\sigma + \left(\frac{iD^\sigma}{m_Q}\right)_{\substack{\text{residual}\\ \text{momentum}}}. \tag{2}$$

The definition of O_{TTA} in ref. [5] should therefore be replaced by

$$O_{TTA} = \frac{\overline{\Lambda}}{m_Q}\epsilon_{\mu\nu\sigma\lambda}\overline{T}^j\sigma^{\mu\nu}\left(v^\sigma + \frac{iD^\sigma}{m_Q}\right)T_i(A^\lambda)^i_j. \tag{3}$$

We have incorporated a $\overline{\Lambda}/m_Q$ prefactor into this new operator's definition where $\overline{\Lambda} = M_Q - m_Q$ represents the residual mass of the light brown muck inside a T_Q baryon of mass M_Q. The prefactor ensures that all effects from the $SU(2)_v$ violating O_{TTA} operator vanish as the heavy quark spin symmetry becomes exact in the $m_Q \to \infty$ limit.

The Dirac algebra identity

$$\frac{1+\not{v}}{2}\sigma^{\mu\nu}\frac{1+\not{v}}{2} = -\epsilon^{\mu\nu\alpha\beta}\frac{1+\not{v}}{2}v_\alpha\gamma_\beta\gamma_5\frac{1+\not{v}}{2} \tag{4}$$

may be used to rewrite eqn. (3) in the equivalent form

$$O_{TTA} = \frac{2\overline{\Lambda}}{m_Q}\overline{\mathcal{T}}^j\gamma_\lambda\gamma_5\mathcal{T}_i(A^\lambda)^i_j \tag{5}$$

where $\mathcal{T} = (1+i\not{\mathcal{D}}/2m_Q)T$. This last expression is manifestly reparameterization invariant [6] and coincides with the result in eqn. (3.21) of ref. [7] by Cheng *et al.*

Although our prior interpretation of the covariant derivative in (1) as a full rather than residual momentum was incorrect, we should stress that our results based upon this interpretation remain unaltered when we adopt the new operator in (3). In particular, the $O(1/m_Q)$ Feynman rule that we used to compute the differential decay rate for the semileptonic process

$$T_b(v)_i \to T_c(v')_j + \ell + \overline{\nu}_\ell + \pi^a \tag{6}$$

is identical to that of (3). Therefore, the remaining results presented in section 4 of ref. [5] are unchanged.

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References

[1] M. Wise, Phys. Rev. **D45** (1992) R2188.

[2] G. Burdman and J. Donoghue, Phys. Lett. **B280** (1992) 287.

[3] T.M. Yan, H.Y. Cheng, C.Y. Cheung, G.L. Lin, Y.C. Lin and H.L. Yu, Phys. Rev. **D46** (1992) 1148.

[4] P. Cho, Phys. Lett. **B285** (1992) 145.

[5] P. Cho, Nucl Phys. **B396** (1993) 183.

[6] M. Luke and A. Manohar, Phys. Lett. **B286** (1992) 348.

[7] H. Y. Cheng, C. Y. Cheung, G. L. Lin, Y.C. Lin, T.M. Yan and H.L. Yu, CLNS-93/1192 (1993).