Magnetic Dipole Decays of Heavy and Heavy-light Mesons

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Talk based on:

T.A. Lähde, hep-ph/0208110, submitted to NUCPHA
T.A. Lähde and D.O. Riska, hep-ph/0204230, NUCPHA, in press.

- M1 width for $J/\psi \to \eta_c \gamma$
- Other γ transitions in heavy quarkonia
- M1 widths of the heavy-light $Q\bar{q}$ mesons

Introduction

M1 transitions in $Q\bar{Q}$ systems

- Width for $J/\psi \longrightarrow \eta_c\gamma$ is not well described by nonrelativistic calculations - overestimated by factor $\sim 2-3$
- A nice explanation is obtained if the effective confining interaction has scalar Lorentz structure - the associated exchange current brings down the M1 width
- Relativistic treatment of single quark currents also required
- Realistic models for the forbidden $\psi' \longrightarrow \eta_c\gamma$ transition cannot be obtained by spin-averaged wavefunctions
- A few words about new results for the E1 transitions in heavy quarkonia

M1 transitions in $Q\bar{q}$ systems

- M1 widths for $D^{\pm *} \longrightarrow D^{\pm}\gamma$ and $D^{0*} \longrightarrow D^{0}\gamma$
- Exchange current and spin-flip operators for the $Q\bar{q}$ system

Widths for M1 transitions

- The width for an M1 transition between two heavy quarkonium states is given by

$$\Gamma \;=\; \frac{16}{2S_i\!+\!1}\, q^3 \alpha\, \frac{M_f}{M_i}\, |\mathcal{M}_\gamma|^2, \tag{1}$$

- The NRIA matrix element is given by

$$\mathcal{M}_\gamma = \int_0^\infty dr\; u_i(r) u_f(r)\, \frac{1}{4}\left[\frac{Q_1}{m_1} - \frac{Q_2}{m_2}\right] \tag{2}$$

- Insertion of $m_c = 1500$ MeV yields 2.85 keV ($\exp = 1.14 \pm 0.39$ keV) - too large by a factor ~ 3!
- Compute a relativistic spin-flip operator from the single quark current operators:
- K.Dannbom, L.Ya.Glozman, C.Helminen and D.O.Riska, NUCPHA **616:555** (1997)

$$\vec{\mu}_{\,\mathrm{sq}}^{\,\mathrm{Rel}} \;=\; \frac{e}{2}\left[\frac{Q_1}{2m_1} f_1^\gamma - \frac{Q_2}{2m_2} f_2^\gamma\right]\, (\vec{\sigma}_1 - \vec{\sigma}_2), \tag{3}$$

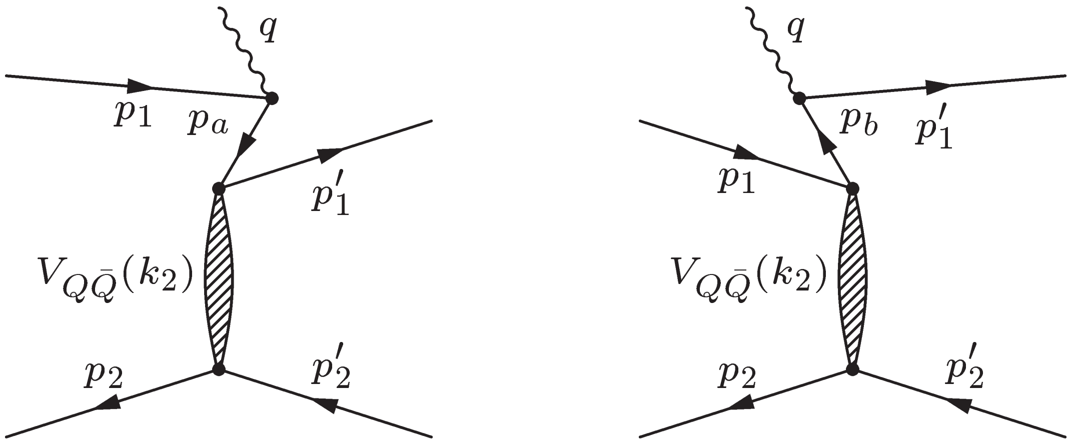
with

$$f_i^\gamma = \frac{m_i}{3E_i}\left[2 + \frac{m_i}{E_i}\right] \tag{4}$$

- Computation of the RIA matrix element yields 2.12 keV - still factor 2 too large!

- Two-quark exchange currents arise from elimination of the negative energy components of the Bethe-Salpeter equation - illustrated by Born diagrams:

- F.Coester and D.O.Riska, Ann.Phys. **234:141** (1994)
  K.Tsushima, D.O.Riska and P.G.Blunden, NUCPHA **559:543** (1993)



- The matrix element of the spin-flip operator associated with a scalar confining interaction is of the form

$$\mathcal{M}_\gamma^{\rm Conf} = -\int_0^\infty dr\, u_f(r)\, u_i(r)\, \frac{V_c(r)}{4}\left[\frac{Q_1}{m_1^2} - \frac{Q_2}{m_2^2}\right], \qquad (5)$$

- For $V_c(r) = cr$, addition of this matrix element brings the width for $J/\psi \to \eta_c\gamma$ down to 1.25 keV - in agreement with the experimental value 1.14 ± 0.39 keV.
- See also: J.Linde and H.Snellman, NUCPHA **619:346** (1997)

Other γ transitions

- "Forbidden" M1 transitions require that the spin-spin hyperfine interaction is treated nonperturbatively
- Blankenbecler-Sugar (BSLT) quasipotential reduction is a natural framework - others also commonly used
- The M1 transition $\psi' \longrightarrow \eta_c\gamma$ appears to be well described within the present model

- Two-quark diagrams also give rise to exchange charge density operators which may contribute to E1 transitions
- C.Helminen, PRC **59:2829** (1999)
- Exchange charge contributions to E1 transitions in heavy quarkonia found to be very small - 1% effects
- Employment of spin-averaged wavefunctions leads to unrealistic results where matrix elements are small - particularly important for several transitions in the bottomonium system
- Experimental situation, especially for the total widths of the $b\bar{b}$ and $c\bar{c}$ states could be improved!

M1 transitions in D mesons

- Total width of the $D^{\pm *}$ recently measured by CLEO - reported as $96 \pm 4 \pm 22$ keV - gives a width for $D^{\pm *} \to D^{\pm}\gamma$ of 1.5 ± 0.6 keV
- A.Anastassov *et al.*, (CLEO Coll.) PRD **65:032003** (2002)
- Models of π emission from the D^* states may constrain the total width of the D^{0*} - thus a width of ~ 25 keV is expected for the transition $D^{0*} \to D^0\gamma$
- K.O.E.Henriksson *et al.*, NUCPHA **686:355** (2001)
  J.L.Goity and W.Roberts, PRD **60:034001** (1999)
- Theoretical situation much more uncertain:
  - M1 transitions not well described by single quark (RIA) currents
  - Exchange current contributions large - even dominant, because of the small masses of the light constituent quarks
  - Magnitude of exchange currents uncertain - relativistic effects unknown
  - Structure of $Q\bar{q}$ interaction uncertain
  - Vector interactions (e.g. OGE) also give large contributions because of the large difference in quark masses
- Pure scalar confinement + OGE interaction model probably not the whole story - instanton induced interaction important?
- S.Chernyshev, M.A.Nowak and I.Zahed, PLB **350:238** (1995),
  PRD **53:5176** (1996)

Conclusions

- M1 transitions in heavy - heavy systems ($c\bar{c}$, $b\bar{b}$) well described by a scalar confining interaction
- D.Gromes, "An exact argument against an effective vector confining interaction", PLB **202:262** (1988)
- Situation for heavy - light $Q\bar{q}$ systems still uncertain, exchange current contributions are large in any case
- Relativistic treatment with realistic $Q\bar{q}$ interactions required