Lifetimes and Inclusive Decay Rates of c and b Hadrons

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Data

Charm :

Hadron	Content	Mass (MeV)	$\Gamma_{tot}\ (ps^{-1})$	$B_{sl}\%$	$\Gamma_{sl}\ (ps^{-1})$
$D^{\pm}$	$c\overline{d}$	1869	0.95 ± 0.015	17.2 ± 1.9	0.16 ± 0.02
D^0	$c\overline{u}$	1865	2.41 ± 0.02	8.1 ± 1.1	0.20 ± 0.03
D_s	$c\overline{s}$	1969	2.14 ± 0.08	8^{+6}_{-5}	$0.17^{+0.12}_{-0.10}$
Λ_c^+	cud	2285	4.85 ± 0.28	4.5 ± 1.7	0.23 ± 0.09
Ξ_c^+	csu	2466	3.0 ± 0.5		
Ξ_c^0	csd	2472	10.2 ± 1.9		
Ω_c^0	css	2704	16 ± 5		

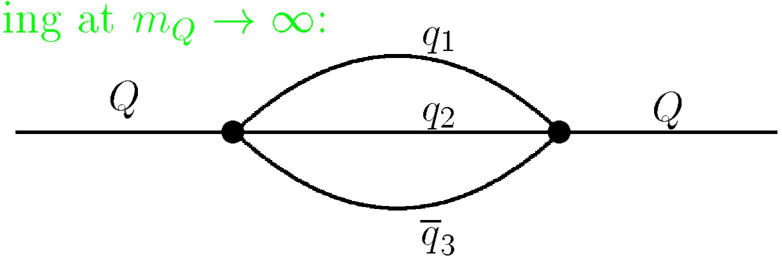
Beauty :

Hadron	Content	Mass (MeV)	$\Gamma_{tot}\ (ps^{-1})$
$B^{\pm}$	$b\overline{u}$	5279	0.606 ± 0.012
B^0	$b\overline{d}$	5279	0.649 ± 0.012
B_s	$b\overline{s}$	5369	0.65 ± 0.03
Λ_b	bud	5624	0.81 ± 0.05
Ξ_b (mixture)	bsq	~ 5800	$0.72^{+0.18}_{-0.14}$

$$\tau(B^{\pm})/\tau(B^0) = 1.07 \pm 0.03$$
$$\tau(B_s)/\tau(B^0) = 1.00 \pm 0.05$$
$$\tau(\Lambda_b)/\tau(B^0) = 0.81 \pm 0.05$$

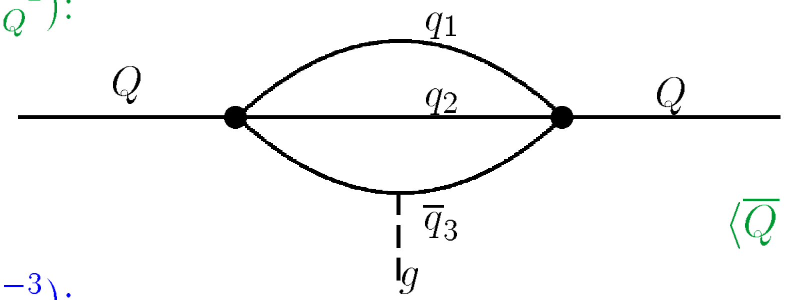
Mechanisms in heavy quark expansion for the weak decay rate

Leading at $m_Q \to \infty$:



m_Q^5

$O(m_Q^{-2})$:

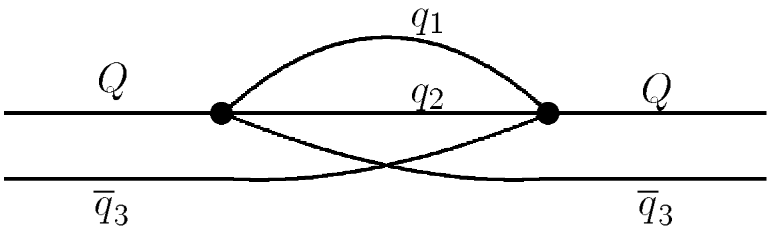


$\langle \overline{Q}\, \vec{\sigma} \cdot \vec{B}\, Q \rangle\, m_Q^3$

$\langle \overline{Q}\, \vec{\pi}^2\, Q \rangle\, m_Q^3$ (time dilation)

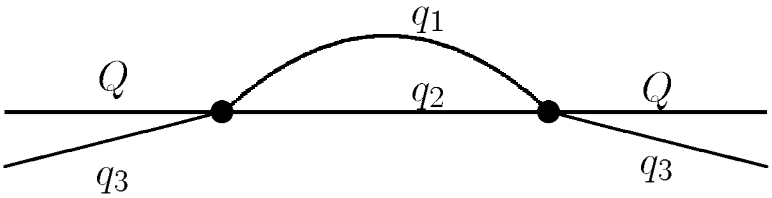
$O(m_Q^{-3})$:

Pauli interference (PI):



$\langle (\overline{q}\Gamma q)(\overline{Q}\Gamma' Q) \rangle\, m_Q^2$

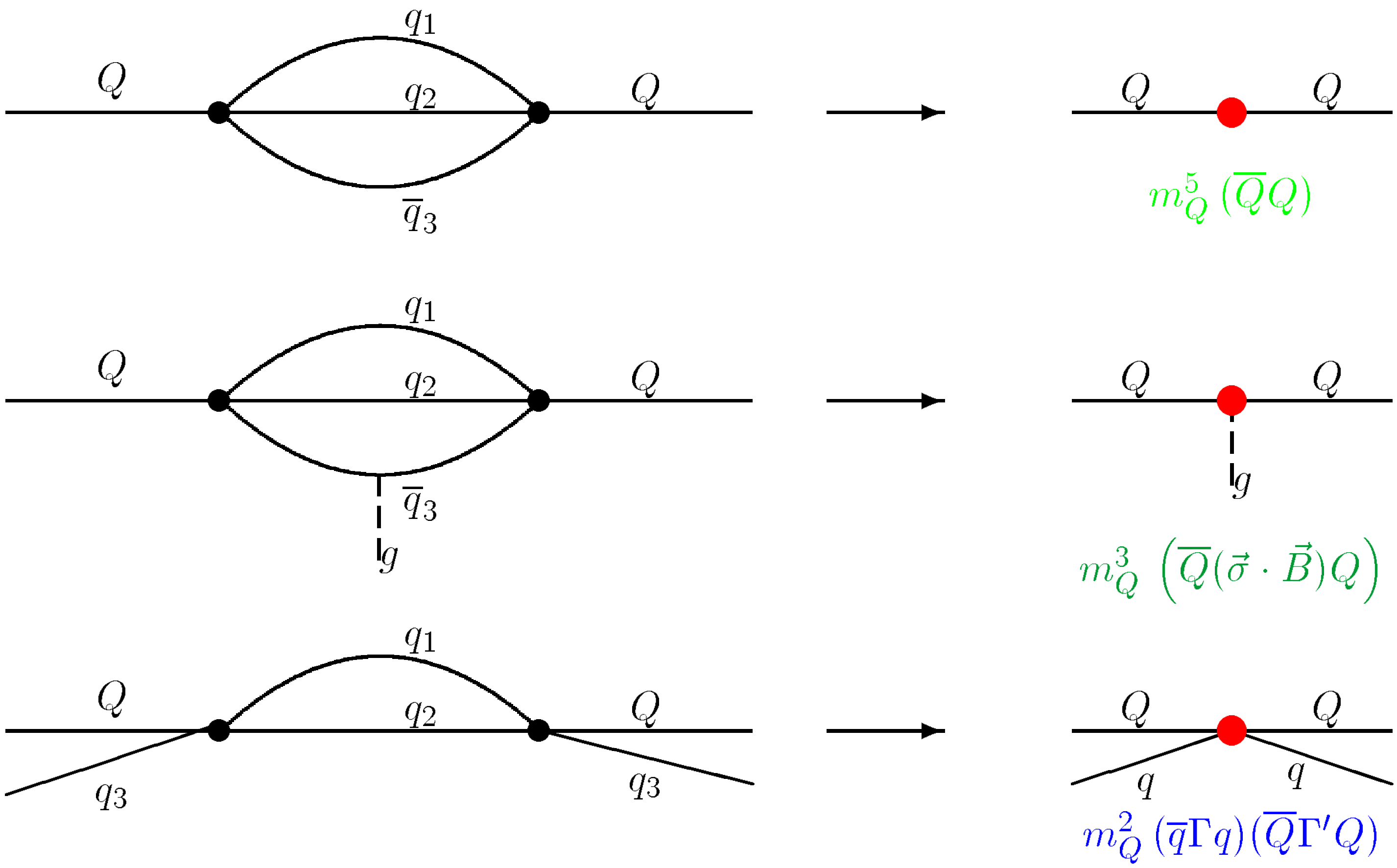
Weak scattering (WS, WA):



Operator Product Expansion (OPE)

$$L_{eff} = 2\,\mathrm{Im}\left[i\int d^4x\, e^{iqx}\, T\left\{L_W(x), L_W(0)\right\}\right] = L_{eff}^{(0)} + L_{eff}^{(2)} + L_{eff}^{(3)} =$$

$$const\cdot\frac{G_F^2\, m_Q^5}{192\,\pi^3}\left(\overline{Q}Q\right) + c_2\, m_Q^3\left(\overline{Q}(\vec{\sigma}\cdot\vec{B})Q\right) + \sum_i c_3^{(i)}\, m_Q^2\,(\overline{q}_i\Gamma_i q_i)(\overline{Q}\Gamma_i' Q)$$



$$\Gamma_H = \langle H_Q|\, L_{eff}\,|H_Q\rangle$$

$$(\overline{Q}Q) = Q^\dagger Q - \frac{(\overline{Q}\,\vec{\pi}^2 Q)}{2\,m_Q^2} + \frac{(\overline{Q}(\vec{\sigma}\cdot\vec{B})Q)}{2\,m_Q^2} \qquad \left(time\ dilation,\ \frac{mass}{energy}\right)$$

$\boxed{L_{eff}^{(0)}}$

In b hadrons the nonperturbative $O(m_b^{-2})$ and $O(m_b^{-3})$ terms are small. $L_{eff}^{(0)}$ is of interest on its own.

Problem of $B_{sl}(B)$:

experimentally $B_{sl}(B) = 10.45 \pm 0.21\%$;

theoretically: good to have $B_{sl}(B) \geq 11.5\%$

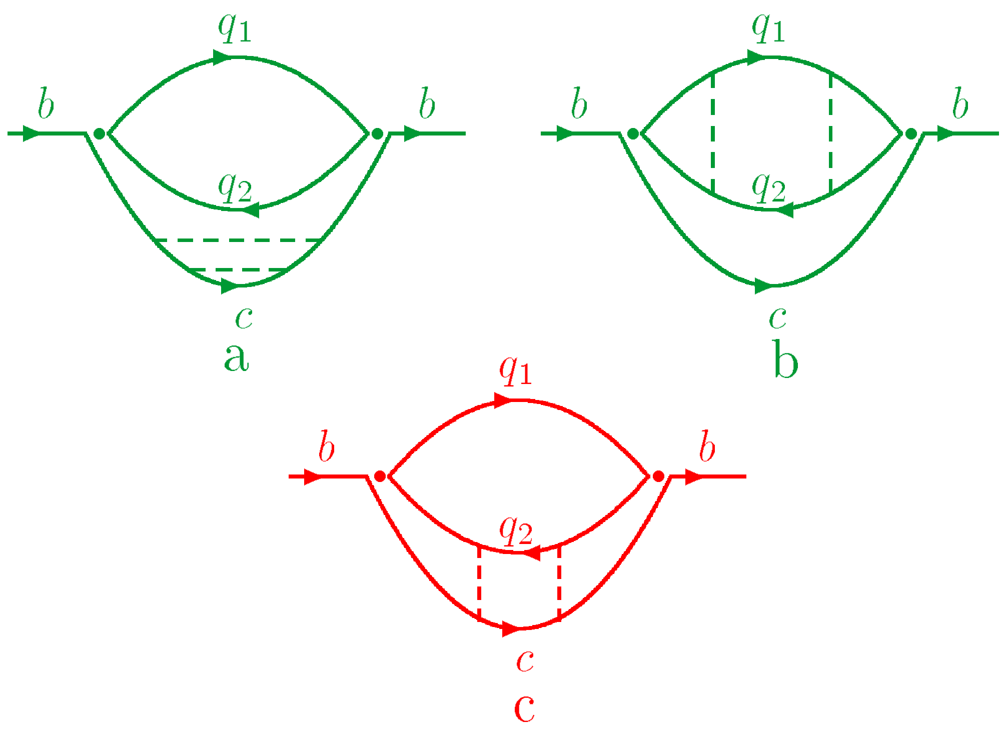
$\Rightarrow$ a (10 - 20) % enhancement of nonleptonic ($L_{eff}^{(0,\,nl)}$) vs. semileptonic decay rate ($L_{eff}^{(0,\,sl)}$) would be wellcome.

Perturbative QCD:

$$\frac{\Gamma(b \to c\bar{u}d) + \Gamma(b \to c\bar{u}s)}{3\,\Gamma(b \to ce\bar{\nu})} = 1 + \frac{\alpha_s}{\pi} + \frac{\alpha_s^2}{\pi^2}\left[4\,L^2 + \left(\frac{7}{6} + \frac{2}{3}\,9.0\right)\,L + X\,L^0\right] =$$

$$1 + \frac{\alpha_s}{\pi} + \frac{\alpha_s^2}{\pi^2}\,[32.5 + 20.4 + X],$$

where $L = \ln(m_W/m_b) \approx 2.85$, and X is not yet calculated. $X \approx 20 - 30$ would put the theoretical $B_{sl}(B)$ in line with the data.



$\boxed{L^{(2)}_{eff}}$

No SU(3) flavor dependence. Only splitting between decay rates of Λ_Q and P_Q, and (spin) between Λ_Q and Ω_Q.

$\mu_g^2 \equiv \langle P_Q| \left(\overline{Q}(\vec{\sigma}\cdot\vec{B})Q\right)|P_Q\rangle, \qquad \mu_\pi^2 \equiv \langle P_Q| \left(\overline{Q}\vec{\pi}^2 Q\right)|P_Q\rangle$

Spin symmetry: $M(V_Q)^2 - M(P_Q)^2 = \frac{4}{3}\,\mu_g^2$
$\Rightarrow \quad \mu_g^2 = \frac{3}{4}\,[M(B^*)^2 - M(B)^2] = 0.36\,GeV^2$

Quantum Mechanics: $(\vec{\sigma}\cdot\vec{\pi})^2 = \vec{\pi}^2 - \vec{\sigma}\cdot\vec{B} \;\;\Rightarrow\;\; \mu_\pi^2 \geq \mu_g^2$

- $\frac{\mu_g^2}{m_c^2} \approx 0.2 \quad \Rightarrow$ sizeable effect in charm decays: partly responcible for $\frac{\tau(\Lambda_c)}{\tau(D^0)} \approx 0.5$
- $\frac{\mu_g^2}{m_b^2} \approx 0.015 \quad \Rightarrow$ small in b decays

Λ_Q: no heavy-light spin correlation $\Rightarrow \quad \langle \Lambda_Q| \left(\overline{Q}(\vec{\sigma}\cdot\vec{B})Q\right)|\Lambda_Q\rangle = 0$

From mass formula, $M_H = m_Q + \overline{\Lambda}_H + \frac{\mu_\pi^2(H)}{2\,m_Q} - \frac{\langle\vec{\sigma}\cdot\vec{B}\rangle_H}{2\,m_Q}$:
$\mu_\pi^2(\Lambda_Q) - \mu_\pi^2(P_Q) = \frac{2\,m_b\,m_c}{m_b - m_c}\left[(\overline{M}_B - \overline{M}_D) - (M_{\Lambda_b} - M_{\Lambda_c})\right] =$
$0 \pm 0.04 GeV^2$ (interesting (?))

$\overline{M} = (M_P + 3\,M_V)/4.$

$\boxed{L_{eff}^{(3)}}$

To be discussed:

- Non CKM suppressed nonleptonic decays of charm, $c \to s\overline{d}u$, - $L_{eff,nl}^{(3,0)}$
- Once CKM suppressed nonleptonic decays of charm, $c \to d\overline{d}u,\ c \to s\overline{s}u$, - $L_{eff,nl}^{(3,1)}$
- Non CKM suppressed semileptonic decays of charm, $c \to s\ell\nu$, - $L_{eff,sl}^{(3,0)}$
- Once CKM suppressed semileptonic decays of charm, $c \to d\ell\nu$, - $L_{eff,sl}^{(3,1)}$
- CKM dominant decays of b, $b \to c\overline{u}d,\ b \to c\overline{c}s$, - $L_{eff,nl}^{(3,b)}$
- Relations between splittings of decay rates in the SU(3) triplet $(\Lambda_c,\, \Xi_c)$ and in $(\Lambda_b,\, \Xi_b)$

• $c \to s\overline{d}u$

$$L^{(3,0)}_{eff,\,nl} = \cos^4\theta_c \, \frac{G_F^2\, m_c^2}{4\pi} \, \Big\{ C_1\, (\overline{c}\Gamma_\mu c)(\overline{d}\Gamma_\mu d) + C_2\, (\overline{c}\Gamma_\mu d)(\overline{d}\Gamma_\mu c) +$$
$$C_3\, (\overline{c}\Gamma_\mu c + \tfrac{2}{3}\overline{c}\gamma_\mu\gamma_5 c)(\overline{s}\Gamma_\mu s) + C_4\, (\overline{c}_i\Gamma_\mu c_k + \tfrac{2}{3}\overline{c}_i\gamma_\mu\gamma_5 c_k)(\overline{s}_k\Gamma_\mu s_i) +$$
$$C_5\, (\overline{c}\Gamma_\mu c + \tfrac{2}{3}\overline{c}\gamma_\mu\gamma_5 c)(\overline{u}\Gamma_\mu u) + C_6\, (\overline{c}_i\Gamma_\mu c_k + \tfrac{2}{3}\overline{c}_i\gamma_\mu\gamma_5 c_k)(\overline{u}_k\Gamma_\mu u_i) +$$
$$\tfrac{1}{3}\,\kappa^{1/2}\,(\kappa^{-2/9} - 1)\, \Big[2\,(C_+^2 - C_-^2)\,(\overline{c}\Gamma_\mu t^a c)\, j^a_\mu -$$
$$(5C_+^2 + C_-^2)(\overline{c}\Gamma_\mu t^a c + \tfrac{2}{3}\overline{c}\gamma_\mu\gamma_5 t^a c) j^a_\mu \Big] \Big\}$$

$$\Gamma_\mu = \gamma_\mu\,(1 - \gamma_5)$$

$$C_- = C_+^{-2} = (\alpha_s(m_c)/\alpha_s(m_W))^{4/b}, \quad b = 11 - \tfrac{2}{3} n_f$$ UV logs

$$\kappa = (\alpha_s(\mu)/\alpha_s(m_c))$$ ‘Hybrid’ logs

$$j^a_\mu = \overline{u}\gamma_\mu t^a u + \overline{d}\gamma_\mu t^a d + \overline{s}\gamma_\mu t^a s, \quad t^a = \frac{\lambda^a}{2}$$

$$C_1 = C_+^2 + C_-^2 + \tfrac{1}{3}(1 - \kappa^{1/2})(C_+^2 - C_-^2)\ ,$$
$$C_2 = \kappa^{1/2}\,(C_+^2 - C_-^2)\ ,$$
$$C_3 = -\tfrac{1}{4}\, \Big[(C_+ - C_-)^2 + \tfrac{1}{3}(1 - \kappa^{1/2})(5C_+^2 + C_-^2 + 6C_+C_-) \Big]\ ,$$
$$C_4 = -\tfrac{1}{4}\,\kappa^{1/2}\,(5C_+^2 + C_-^2 + 6C_+C_-)\ ,$$
$$C_5 = -\tfrac{1}{4}\, \Big[(C_+ + C_-)^2 + \tfrac{1}{3}(1 - \kappa^{1/2})(5C_+^2 + C_-^2 - 6C_+C_-) \Big]\ ,$$
$$C_6 = -\tfrac{1}{4}\,\kappa^{1/2}\,(5C_+^2 + C_-^2 - 6C_+C_-)$$

- $b \to c\overline{u}d + b \to c\overline{c}s$

$$L^{(3,b)}_{eff,\,nl} = |V_{bc}|^2 \, \frac{G_F^2\, m_b^2}{4\pi} \, \Big\{ \tilde{C}_1 \, (\overline{b}\Gamma_\mu b)(\overline{u}\Gamma_\mu u) + \tilde{C}_2 \, (\overline{b}\Gamma_\mu u)(\overline{u}\Gamma_\mu b) +$$
$$\tilde{C}_5 \, (\overline{b}\Gamma_\mu b + \tfrac{2}{3}\overline{b}\gamma_\mu\gamma_5 b)(\overline{q}\Gamma_\mu q) + \tilde{C}_6 \, (\overline{b}_i\Gamma_\mu b_k + \tfrac{2}{3}\overline{b}_i\gamma_\mu\gamma_5 b_k)(\overline{q}_k\Gamma_\mu q_i) +$$
$$\tfrac{1}{3}\, \tilde{\kappa}^{1/2}\, (\tilde{\kappa}^{-2/9} - 1) \, \Big[2\, (\tilde{C}_+^2 - \tilde{C}_-^2)\, (\overline{b}\Gamma_\mu t^a b)\, j^a_\mu -$$
$$(5\tilde{C}_+^2 + \tilde{C}_-^2 - 6\, \tilde{C}_+\, \tilde{C}_-)(\overline{b}\Gamma_\mu t^a b + \tfrac{2}{3}\overline{b}\gamma_\mu\gamma_5 t^a b) j^a_\mu \Big] \Big\}$$

$\tilde{C}_a$, $\tilde{\kappa}$: same as C_a, κ with $m_c \to m_b$

Omitted terms of order $\frac{m_c^2}{m_b^2} \approx 0.09$. (These can be found e.g. in Neubert, Sachrajda '97 (NS))

Matrix Elements and Physical Effects

Mesons

$P_{Q\overline{q}} : Q\overline{q}$

$$\langle P_{Q\overline{q}} | (\overline{Q}\Gamma_\mu q)\, (\overline{q}\Gamma_\mu Q) | P_{Q\overline{q}} \rangle = \tfrac{1}{2}\, f_P^2\, M_P\, B$$

$$\langle P_{Q\overline{q}} | (\overline{Q}\Gamma_\mu Q)\, (\overline{q}\Gamma_\mu q) | P_{Q\overline{q}} \rangle = \tfrac{1}{6}\, f_P^2\, M_P\, \tilde{B}$$

B, $\tilde{B}$ - 'bag' constants. Naively $B = 1$, $\tilde{B} = 1$.

Differences of Decay Rates for Mesons

• D mesons

In this approximation $\Gamma(D^0) - \Gamma(D_s) = 0$. (Exp: $0.27 \pm 0.08\, ps^{-1}$ — might be due to higher terms in OPE(?))

$$\Gamma(D^{\pm}) - \Gamma(D^0) = \cos^4\theta_c \, \frac{G_F^2\, m_c^3\, f_D^2}{8\pi} \left[(C_+^2 - C_-^2)\, B + \frac{1}{3}\,(C_+^2 + C_-^2)\, \tilde{B} \right] \sim -0.8\, \left(\frac{f_D}{200\, MeV}\right)^2\, ps^{-1}$$

Exp: $-1.56 \pm 0.03 ps^{-1}$

• B mesons

$\Gamma(B^0) - \Gamma(B_s) = 0$ (Exp: $0. \pm 0.03\, ps^{-1}$). $\frac{\Delta\Gamma}{\Gamma} \approx few \times 10^{-3}$ due to: $O(\frac{m_c^2}{m_b^2})$ terms, higher terms in OPE, new physics: Keum, Nierste '97.

$$\Gamma(B^{\pm}) - \Gamma(B^0) = |V_{cb}|^2\, \frac{G_F^2\, m_b^3\, f_B^2}{8\pi} \left[(\tilde{C}_+^2 - \tilde{C}_-^2)\, B + \frac{1}{3}\,(\tilde{C}_+^2 + \tilde{C}_-^2)\, \tilde{B} \right] \approx -0.025\, \left(\frac{f_B}{200\, MeV}\right)^2\, ps^{-1}$$

Exp: $-0.043 \pm 0.017\, ps^{-1}$ (The sign and magnitude look correct.)

• Mesons look OK (so far).

$\boxed{\textit{Baryons}}$

SU(3) triplet $(\Lambda_Q, \Xi_Q^{up}, \Xi_Q^{down})$ and $\Omega_Q \sim Qss$.

In Λ_Q, Ξ_Q : $\;\; Q\,(q_1 q_2)_{s=0} \;\Rightarrow$ spin of Q is not correlated with spins of light components $\Rightarrow$ axial currents do not contribute. The only relavant structures are $(\overline{Q}\gamma_\mu Q)(\overline{q}\gamma_\mu q)$ and $(\overline{Q}_i\gamma_\mu Q_k)(\overline{q}_k\gamma_\mu q_i)$

Color antisymmetry:

$$\langle X_Q|\overline{Q}\gamma_\mu Q)(\overline{q}\gamma_\mu q)|X_Q\rangle = -\langle X_Q|\overline{Q}_i\gamma_\mu Q_k)(\overline{q}_k\gamma_\mu q_i)|X_Q\rangle_{\text{ naive}}$$

Non-relativistic model:

$$\langle P_Q|\overline{Q}\Gamma_\mu Q)(\overline{q}\Gamma_\mu q)|P_Q\rangle = -C\,(1+4\vec{s}_Q\cdot\vec{s}_{\overline{q}}) = 2C = \frac{f_P^2\, m_Q}{6}, \qquad C \propto |\psi(0)|^2$$

$$\langle \Lambda_Q|\overline{Q}\Gamma_\mu Q)(\overline{q}\Gamma_\mu q)|\Lambda_Q\rangle = C = \frac{f_P^2\, m_Q}{12}$$

assuming $|\psi(0)|^2_{baryon} = |\psi(0)|^2_{meson}$ extremely naive!

Ω_Q : $\;\; Q(ss)_s = 1$. Spin correlation enhances the (positive) effect of the s quark by a factor $\frac{10}{3}$.

Naive estimates of the matrix elements were successful in predicting the hierarchy of lifetimes of charmed hadrons:

$$\Gamma(\Omega_c) > \Gamma(\Xi_c^0) > \Gamma(\Lambda_c) > \Gamma(\Xi_c^+) > \Gamma(D_s) \approx \Gamma(D^0) > \Gamma(D^\pm)$$

(M. Sifman, M.V. '86)

but generally fail to quantitatively reproduce the splittings.

A (slightly) different approach:

- Abandon attempts at calculating absolute magnitude of the matrix elements.
- Relate, using symmetries (SU(3), Heavy Quark, ...), unknown differences to known.

'Known' differences: $\Delta\Gamma_{tot}$ in the SU(3) triplet (Λ_c, Ξ_c^+, Ξ_c^+).
Unknown: $\Delta\Gamma_{sl}, \Delta\Gamma_{nl}^{\Delta S=0}$ in the charm triplet, $\Delta\Gamma$ for b baryons,...

Rate Differences Within Baryon Triplet

Define:

$$x = \left\langle \frac{1}{2}\left(\overline{c}\,\gamma_\mu\, c\right)\left[\left(\overline{u}\,\gamma_\mu u\right) - \left(\overline{s}\,\gamma_\mu s\right)\right]\right\rangle_{\Xi_c^0-\Lambda_c} =$$
$$\left\langle \frac{1}{2}\left(\overline{c}\,\gamma_\mu\, c\right)\left[\left(\overline{s}\,\gamma_\mu s\right) - \left(\overline{d}\,\gamma_\mu d\right)\right]\right\rangle_{\Lambda_c-\Xi_c^+}$$

$$y = \left\langle \frac{1}{2}\left(\overline{c}_i\,\gamma_\mu\, c_k\right)\left[\left(\overline{u}_k\,\gamma_\mu u_i\right) - \left(\overline{s}_k\,\gamma_\mu s_i\right)\right]\right\rangle_{\Xi_c^0-\Lambda_c} =$$
$$\left\langle \frac{1}{2}\left(\overline{c}_i\,\gamma_\mu\, c_k\right)\left[\left(\overline{s}_k\,\gamma_\mu s_i\right) - \left(\overline{d}_k\,\gamma_\mu d_i\right)\right]\right\rangle_{\Lambda_c-\Xi_c^+}$$

The total decay rate differences $\Delta_1 \equiv \Gamma(\Xi_c^0) - \Gamma(\Lambda_c)$ and $\Delta_2 \equiv \Gamma(\Lambda_c) - \Gamma(\Xi_c^+)$ are expressed in terms of x and y. Solve for x and y and use in calculating unknown $\Delta\Gamma$'s. x and y are the same in c-baryons and in b-baryons.

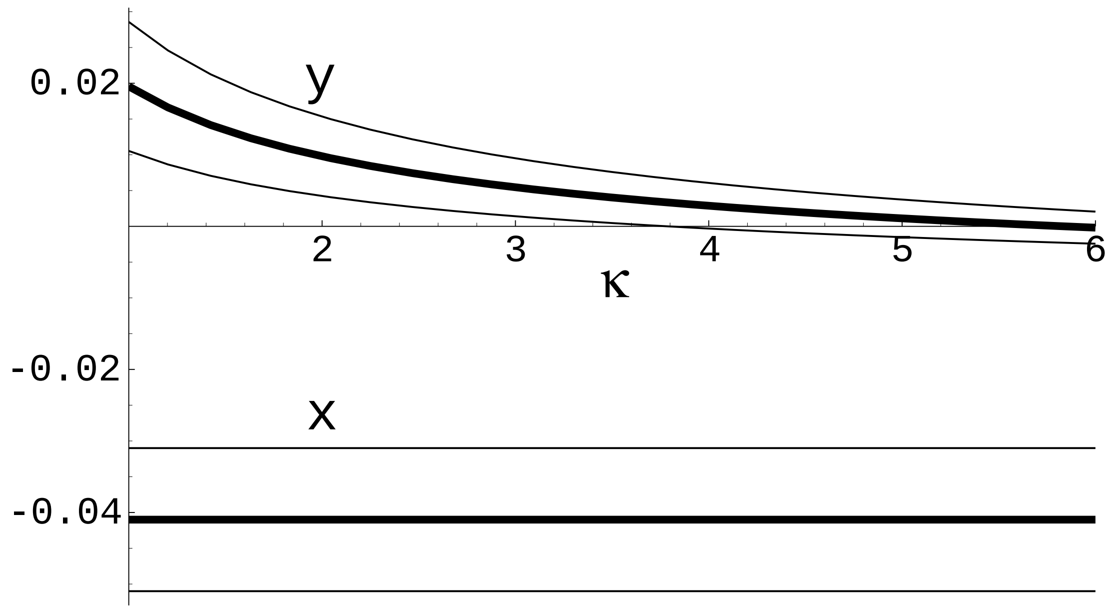


Figure 1: The values of the extracted matrix elements x and y in GeV^3 vs. the normalization point parameter $\kappa = \alpha_s(\mu)/\alpha_s(m_c)$. The thick lines correspond to the central value of the data on lifetimes of charmed baryons, and the thin lines show the error corridors. The extracted values of x and y scale as m_c^{-2} with the assumed mass of the charmed quark, and the plots are shown for $m_c = 1.4\,GeV$.

- The naive color antisymmetry relation $x = -y$ fails
- The value of $|x|$ is greatly enhanced compared to the naive estimate: $x = -f_D^2 m_D/12 \sim 0.006\,GeV^3$ (by factor $r = 5.5 \pm 1.5$).

Predictions for relations between differences of the rates do not depend on μ.

Predictions for Charm Baryons

- Semileptonic decay rates :

$\Gamma_{sl}(\Xi_c) - \Gamma_{sl}(\Lambda_c) =$
$0.13\ [\Gamma_{tot}(\Xi_c^0) - \Gamma_{tot}(\Lambda_c)] - 0.065\ [\Gamma_{tot}(\Lambda_c) - \Gamma_{tot}(\Xi_c^+)] = 0.59 \pm 0.32\, ps^{-1}$
Compare with $\Gamma_{sl}(\Lambda_c) = 0.23 \pm 0.09\, ps^{-1}$: possibly
$\Gamma_{sl}(\Xi_c) = (2-3)\Gamma(\Lambda_c)$.

- $\Delta S = 0$ nonleptonic decay rates ($\propto \sin^2\theta_c$):

$\Gamma_{\Delta S=0}(\Xi_c^+) = \Gamma_{\Delta S=0}(\Lambda_c)$
$\Gamma_{\Delta S=0}(\Xi_c^0) - \Gamma_{\Delta S=0}(\Lambda_c) =$
$0.082\ [\Gamma_{tot}(\Xi_c^0) - \Gamma_{tot}(\Lambda_c)] + 0.054\ [\Gamma_{tot}(\Lambda_c) - \Gamma_{tot}(\Xi_c^+)] = 0.55 \pm 0.22\, ps^{-1}$
Compare with $\Gamma_{tot}(\Xi_c^0) \cdot \tan^2\theta_c \approx 0.5 ps^{-1}$

Predictions for b Baryons

- $\Gamma(\Lambda_b) = \Gamma(\Xi_b^0)$ up to terms additionally suppressed by $\frac{m_c^2}{m_b^2}$

- $\Gamma(\Lambda_b) - \Gamma(\Xi_b^-) =$

$|V_{cb}|^2 \frac{m_b^2}{m_c^2}\ \{0.85\ [\Gamma_{tot}(\Xi_c^0) - \Gamma_{tot}(\Lambda_c)] + 0.91\ [\Gamma_{tot}(\Lambda_c) - \Gamma_{tot}(\Xi_c^+)]\} \approx$
$0.015\ [\Gamma_{tot}(\Xi_c^0) - \Gamma_{tot}(\Lambda_c)] + 0.016\ [\Gamma_{tot}(\Lambda_c) - \Gamma_{tot}(\Xi_c^+)] = 0.11 \pm 0.03\, ps^{-1}$
Compare with $\Gamma(\Lambda_b) = 0.81 \pm 0.05\, ps^{-1}$:
$\frac{\Delta\Gamma}{\Gamma} \approx 0.14$

Does this give us a chance to explain current $\tau(\Lambda_b)/\tau(B) = 0.81 \pm 0.05$?

(No)

$\boxed{\textit{Overall shift of } \Gamma_{tot} \textit{ of the b baryon triplet}}$

Introduce
$\overline{\Gamma}_Q = \frac{1}{3}\left(\Gamma(\Lambda_Q) + \Gamma(\Xi_Q^{(u)}) + \Gamma(\Xi_Q^{(d)})\right)$

From SU(3) singlet parts of $L_{eff}^{(3)}$:
$$\delta^{(3)}\overline{\Gamma}_b = \frac{|V_{bc}|^2}{\cos^4}\,\frac{m_b^2}{m_c^2}\,\frac{(\tilde{C}_+ - \tilde{C}_-)^2}{C_+^2 + C_-^2}\,\left[\frac{\alpha_s(m_c)}{\alpha_s(m_b)}\right]^{5/18}\,\delta_{nl}^{(3,0)}\overline{\Gamma}_c \approx 0.0025\,\delta_{nl}^{(3,0)}\overline{\Gamma}_c$$

$\frac{(\tilde{C}_+ - \tilde{C}_-)^2}{C_+^2 + C_-^2} \sim \left(\frac{\alpha_s}{\pi}\,\ln\frac{m_M}{m_b}\right)^2$: small.

$$\delta_{nl}^{(3,0)}\overline{\Gamma}_c < \overline{\Gamma}_c = 6.0 \pm 0.7\,ps^{-1} \quad \Rightarrow \quad \delta^{(3)}\overline{\Gamma}_b < 0.015 \pm 0.002\,ps^{-1}$$

Subtract from $\overline{\Gamma}_c$ the 'parton' term $\overline{\Gamma}_c^{(0)}$, the contribution of $L_{eff}^{(2)}$, and the semileptonic rate. Realistically $\delta_{nl}^{(3,0)}\overline{\Gamma}_c \approx 3\,ps^{-1} \quad \Rightarrow \quad \delta^{(3)}\overline{\Gamma}_b < 0.01\,ps^{-1}$.

- $\Gamma(\Lambda_b) - \Gamma(B^0) \approx 0.02\,ps^{-1}$ (from $\vec{\sigma}\cdot\vec{B}$)
$+\frac{1}{3}\,(0.11 \pm 0.03)\,ps^{-1} + (< 0.01 ps^{-1}) \approx 0.07\,ps^{-1}$

Conservatively: $\tau(\Lambda_b) > 0.9\,\tau(B^0)$.

- Prediction for the hierarchy:
$\tau(\Xi_b^0) \approx \tau(\Lambda_b) < \tau(B_d) < \tau(\Xi_b^-)$
is strengthened.

Conclusions

- OPE and HQ symmetry is in agreement with the data on charmed particles' lifetimes and on $\tau(B^{\pm})/\tau(B^0)$, $\quad \tau(B_s)/\tau(B^0)$

- The value $\tau(\Lambda_b)/\tau(B_d) = 0.81$ is hard or impossible to explain within the present knowledge/ignorance about OPE and hadronic matrix elements.

- Applicability of expansion in $1/m_c$ can be tested by measuring Γ_{sl} for Ξ_c (and Ω_c) and/or the differenece of the CKM-suppressed $\Gamma_{\Delta S=0}$ in the $(\Lambda_c,\, \Xi_c)$ triplet. $\Gamma_{sl}(\Xi_c) = (2-3)\,\Gamma_{sl}(\Lambda_c)$ is expected.

- The difference $\tau(\Xi_b^-) - \tau(\Lambda_b)$ is expected to be quite sizeable: 10-15 %.