Study of $\Lambda_b \to \Lambda\phi$ and $\Lambda_b \to \Lambda\eta^{(\prime)}$

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Outline

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$\Lambda_b(bud),\ \Lambda(sud),\ \phi(s\bar{s}),\ \eta^q(u\bar{u}+d\bar{d})/\sqrt{2},\ \eta^s(s\bar{s})$

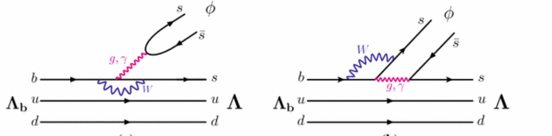
Motivation

1. The recent measurements of $\Lambda_b \to \Lambda\phi$ and $\Lambda_b \to \Lambda\eta^{(\prime)}$ from LHCb are given as
   $\mathcal{B}(\Lambda_b \to \Lambda\phi) = (5.18 \pm 1.29)x10^{-6}$,
   $\mathcal{B}(\Lambda_b \to \Lambda\eta) = (9.3^{+7.3}_{-5.3},\ )x10^{-6}$, 3$\sigma$-significance,
   $\mathcal{B}(\Lambda_b \to \Lambda\eta') < 3.1x10^{-6}$, (90% C.L.)
   (R. Aaij et al. [LHCb Collaboration],Phys.Lett. B759 (2016) 282-292)
   (R. Aaij et al. [LHCb Collaboration], JHEP 1509, 006 (2015))

2. The decay of $\Lambda_b \to \Lambda\phi$ has not been well explored.

3. The first work on $\Lambda_b \to \Lambda\eta^{(\prime)}$ predicted the branching ratios with uncertain form factors to be $\mathcal{B}(\Lambda_b \to \Lambda\eta, \Lambda\eta') = (5.0 - 14.5, 5.8 - 13.7)x10^{-6}$.
   (M.R. Ahmady, C.S. Kim, S. Oh, C. Yu, Phys. Lett. B 598, 203(2004))

$\Lambda_b \to \Lambda\phi$

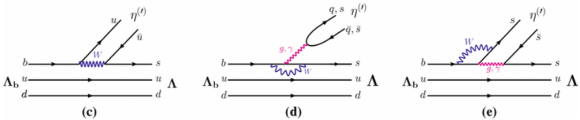


According to the diagrams above, the amplitude can be derived as

$\mathcal{A}(\Lambda_b \to \Lambda\phi) = \frac{G_F}{\sqrt{2}}\alpha_3\langle\phi|\bar{s}\gamma_\mu s|0\rangle\langle\Lambda|\bar{s}\gamma_\mu(1-\gamma_5)b|\Lambda_b\rangle$ with

- $\alpha_3 = V_{tb}V_{ts}^*(a_3 + a_4 + a_5 - \frac{1}{2}a_9)$
- $V_{q_1 q_2}$ is the Cabibbo-Kpbayashi-Maskawa (CKM) Matrix elements.
- $a_i = c_i^{eff} + c_{i\pm1}^{eff}/N_c$ are composed of the effective Wilson coefficients.

$\Lambda_b \to \Lambda\eta^{(\prime)}$



Similarly, the amplitude of $\Lambda_b \to \Lambda\eta^{(\prime)}$ are given by :

$$\mathcal{A}(\Lambda_b \to \Lambda\eta^{(\prime)}) = \frac{G_F}{\sqrt{2}}\left\{\left[\beta_2\langle\eta^{(\prime)}|\bar{q}\gamma_\mu\gamma_5 q|0\rangle + \beta_3\langle\eta^{(\prime)}|\bar{s}\gamma_\mu\gamma_5 s|0\rangle\right]\right.$$
$$\left.\langle\Lambda|\bar{s}\gamma_\mu(1-\gamma_5)b|\Lambda_b\rangle + \beta_6\langle\eta^{(\prime)}|\bar{s}\gamma_5 s|0\rangle\langle\Lambda|\bar{s}(1-\gamma_5)b|\Lambda_b\rangle\right\}$$

with $q = u$ or d, $\beta_2 = -V_{ub}V_{us}^*\, a_2 + V_{tb}V_{ts}^*(2a_3 - 2a_5 + a_9/2)$, $\beta_3 = V_{tb}V_{ts}^*(a_3 + a_4 - a_5 - a_9/2)$, and $\beta_6 = V_{tb}V_{ts}^*\, 2a_6$

The meson production matrix element

$$\langle\phi|\bar{s}\gamma_\mu s|0\rangle = m_\phi f_\phi \epsilon^*_\mu \qquad \langle\eta^{(\prime)}|\bar{q}\gamma_\mu\gamma_5 q|0\rangle = -\frac{i}{\sqrt{2}} f^q_{\eta^{(\prime)}} q_\mu \,,$$

$$\langle\eta^{(\prime)}|\bar{s}\gamma_\mu\gamma_5 s|0\rangle = -i f^s_{\eta^{(\prime)}} q_\mu \qquad 2m_s\langle\eta^{(\prime)}|\bar{s}\gamma_5 s|0\rangle = -i h^s_{\eta^{(\prime)}} \,,$$

f_ϕ, $f^q_{\eta^{(\prime)}}$, $f^s_{\eta^{(\prime)}}$, $h^s_{\eta^{(\prime)}}$ is the decay constant, and ϵ^* is the polarization, $q = u, d$, and q_μ is the four momentum

the $\eta - \eta'$ mixing is adopted as :

$$\begin{pmatrix} \eta \\ \eta' \end{pmatrix} = \begin{pmatrix} \cos\phi & -\sin\phi \\ \sin\phi & \cos\phi \end{pmatrix} \begin{pmatrix} \eta_q \\ \eta_s \end{pmatrix},$$

with mixing angle $\phi = (39.3 \pm 1.0)^o$. As a result, $f^q_{\eta^{(\prime)}}$ and $f^s_{\eta^{(\prime)}}$ mix with the decay constants f_q and f_s.

The matrix element of $\Lambda_b \to \Lambda$ baryon transition have been parameterized as :

$$\langle\Lambda|\bar{s}\gamma_\mu(1-\gamma_5)b|\Lambda_b\rangle = \bar{u_\Lambda}(f_1\gamma_\mu - g_1\gamma_\mu\gamma_5)u_{\Lambda_b}$$

$$\langle\Lambda|\bar{s}(1-\gamma_5)b|\Lambda_b\rangle = \bar{u}_\Lambda(f_S\gamma_\mu - g_P\gamma_\mu\gamma_5)u_{\Lambda_b}$$

where f_1, g_1 are the momentum dependent form factors

$f_1 = \frac{f_1(0)}{(1-q^2/m_{\Lambda_b}^2)^2}$, $g_1 = \frac{g_1(0)}{(1-q^2/m_{\Lambda_b}^2)^2}$,

and $f_S = (\frac{m_{\Lambda_b}-m_\Lambda}{m_b-m_s})f_1$, $g_P = (\frac{m_{\Lambda_b}+m_\Lambda}{m_b+m_s})g_1$

Theoretical Inputs

The CKM matrix elements are given by
$(V_{ub},\, V_{us},\, V_{tb},\, V_{ts}) = (A\lambda^3(\rho - i\eta), \lambda, 1, -A\lambda^2)$,
with $(\lambda,\, A,\, \rho,\, \eta) = (0.225,\, 0.814,\, 0.120 \pm 0.022,\, 0.362 \pm 0.013)$.

The decay constants are
$f_\phi = 0.231$ GeV, $(f^q_\eta, f^q_{\eta'}, f^s_\eta, f^s_{\eta'}) = (0.108, 0.089, -0.111, 0.136) GeV$,
$(h^s_\eta, h^s_{\eta'}) = (-0.055,\, 0.068) GeV^3$.

The form factors are
$f_1(0) = g_1(0) = -\sqrt{2/3}(0.136)$

Results

We fixed N_c=3 for a_i, and our results show as

decay mode	data	our results
$10^6\mathcal{B}(\Lambda_b \to \Lambda\phi)$	5.18 ± 1.29	$1.77^{+1.76}_{-1.71} \pm 0.24$
$10^6\mathcal{B}(\Lambda_b \to \Lambda\eta)$	$9.3^{+7.3}_{-5.3}$	$1.47^{+0.29}_{-0.13} \pm 0.20$
$10^6\mathcal{B}(\Lambda_b \to \Lambda\eta')$	< 3.1	$1.83^{+0.55}_{-0.18} \pm 0.25$

- The $\Lambda_b \to \Lambda\phi$ decay is judged to receive the non-factorizable effects with $N_c = 2$,
  such that $\mathcal{B}(\Lambda_b \to \Lambda\phi)$ =(3.53 ± 0.24)x10^{-6}.
- We prefer a smaller $\mathcal{B}(\Lambda_b \to \Lambda\eta)$.
- The relation of $\mathcal{B}(\Lambda_b \to \Lambda\eta) \simeq \mathcal{B}(\Lambda_b \to \Lambda\eta')$ holds as in the previous work.

Thank You