Hints on $\tau_{\frac{1}{2}}(1)$ from the non-leptonic modes

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Puzzle

- Problem with broad $(1/2)^+$-states $[0^+, 1^+]$
  In QCD $1^+_{1/2}$ and $1^+_{3/2}$ mix $\rightarrow$ focus on $0^+ \equiv D_0^*$

- SL decays:

$$\begin{aligned} \mathcal{B}(B \rightarrow D_0^* \ell\nu) &\sim 10^{-3} \quad \text{[BaBar, Belle]} \\ &\sim 10^{-4} \quad \text{[predicted]} \end{aligned}$$

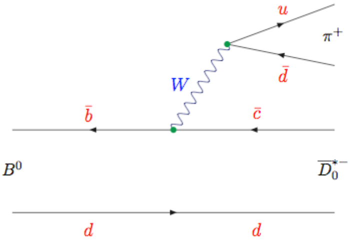
  combined with

$$\begin{array}{llcl} \text{BaBar} & \mathcal{B}(B \rightarrow D_0^* \ell\nu) & \approx & \mathcal{B}(B \rightarrow D^{**}_{3/2} \ell\nu) \\ & & & \tau_{1/2}(1) \approx \tau_{3/2}(1) \quad \text{Sic!} \\ \text{Belle} & \mathcal{B}(B \rightarrow D_0^* \ell\nu) & \gg & \mathcal{B}(B \rightarrow D_1^{1/2} \ell\nu) \end{array}$$

unprecedented HQS breaking – Sic!

Non-leptonics can help

- `F.Jugeau et al. 2005, H.Y.Cheng 2003`
  Class-I decays obey factorization – use it!
  [exact in $m_b \to \infty$, `Beneke et al. 2000`]



$$A(\bar{B}^0 \to D_0^{*+}\pi^-) = \frac{G_F}{\sqrt{2}} V_{cb} V_{ud}^* \times a_1 \times f_\pi (m_B^2 - m_{D_0^*}^2) F_0^{B\to D_0^*}(m_\pi^2)$$

- Works even for $B^0 \to D^{(*)+}\pi^-$ and $B^0 \to D^{(*)+}D^-$
  `D.B. et al. 2012`

$\tau_{\frac{1}{2}}(w_0)$

- $F_0^{B\to D_0^*}(m_\pi^2) \propto \tau_{\frac{1}{2}}(w_0)$, where $2m_B m_{D_0^*} w_0 = m_B + m_{D_0^*} - m_\pi^2$

$$A(\bar{B}^0 \to D_0^{*+}\pi^-) = \frac{G_F}{\sqrt{2}} V_{cb} V_{ud}^* a_1 f_\pi m_B^2 \, \frac{(1+r)(1-r)^2}{\sqrt{r}} \tau_{\frac{1}{2}}(w_0)\Big|_{r=\frac{m_{D_0^*}}{m_B}}$$

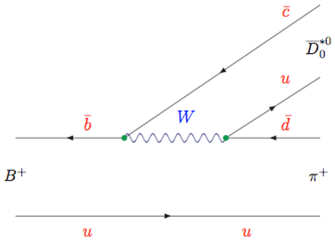
- $w_0 = 1.36(1) \to 1$, use `Morenas et al.` 1997 (confirmed by others)

$$\tau_{\frac{1}{2}}(w) = \tau_{\frac{1}{2}}(1)\left(\frac{2}{1+w}\right)^{5/3} \Rightarrow \tau_{\frac{1}{2}}(w_0) = 0.76(1) \times \tau_{\frac{1}{2}}(1)$$

- $\tau_{\frac{1}{2}}(1) \simeq 0.26$ for $a_1 = 1.15$ – indeed small

Class III can help too - New

- Extra diagram (OZI allowed)



$$A(\bar{B}^- \to D_0^{*0}\pi^-) = A_I + \frac{G_F}{\sqrt{2}} V_{cb} V_{ud}^* \times a_2 \times f_{D_0^*}(m_B^2 - m_\pi^2) F_0^{B\to\pi}(m_{D_0^*}^2)$$

Class III can help too - New (cont.)

- MtmQCD on the lattice has its own problems at $a \neq 0$, but once one takes the continuum limit, the results are safe and sound.
- With $N_{\rm f} = 2$, 4 latt.spacings, many sea quark masses

$$f_{D_0^*} = 141 \pm 17 \ \mathrm{MeV}$$

- Therefore,

$$\left[\frac{\mathcal{B}(B^- \to D_0^{*0}\pi^-)}{\mathcal{B}(\overline{B}^0 \to D_0^{*+}\pi^-)}\right]^{1/2} = 1 + \frac{a_2}{a_1}\frac{f_{D_0^*}}{f_\pi}\frac{\sqrt{r}}{(1+r)(1-r)^2}\frac{F_0^{B\to\pi}(m^2_{D_0^*})}{\tau_{\frac{1}{2}}(w_0)}\Bigg|_{r=\frac{m_{D_0^*}}{m_B}}$$

Class III can help too - New (cont.)

- Using $F_0^{B\to\pi}(m^2_{D_0^*}) = 0.30(3)$, $a_1 = 1.15$, $a_2 = 0.26$, we have

$$\left[\frac{\mathcal{B}(B^- \to D_0^{*0}\pi^-)}{\mathcal{B}(\overline{B}^0 \to D_0^{*+}\pi^-)}\right]^{1/2}_{\rm exp.} = 1 + \frac{a_2}{a_1}\frac{f_{D_0^*}}{f_\pi}\frac{\sqrt{r}}{(1+r)(1-r)^2}\frac{F_0^{B\to\pi}(m^2_{D_0^*})}{\tau_{\frac{1}{2}}(w_0)}$$

$$\left[\frac{(9.6\pm 2.7)\times 10^{-4}}{(1.0\pm 0.5)\times 10^{-4}}\right]^{1/2} = 1 + \frac{0.43(4)}{\tau_{\frac{1}{2}}(1)}$$

$$\Rightarrow \quad 0.15 \le \tau_{\frac{1}{2}}(1) \le 0.38$$

- Exp. errors dominant. D_0^* is broad and to discern it from the rest is difficult, often ambiguous if not impossible (continuum?)

B_s-decays – best environment for this research

- $B_s \to D_s^{**}\ell\nu$ would be the best (Super-Belle, Super-B)

Understand how $\mathcal{B}(B^0 \to X_c\ell\nu) = 10.1(2)\%$ is saturated via the similar study of $\mathcal{B}(B_s \to X_c\ell\nu)$.

- $B_s \to D_s^{**}\pi$ would be interesting too: D_{s0}^* and D_{s2}^* are narrow!
- The last can be studied at LHCb!

  Knowing that $\mathcal{B}(D_{s0}^{*+} \to D_s^+\pi^0) = (97 \pm 3)\%$, study

$$B_s \to D_{s0}^{*-}\pi^+$$
$$D_{s0}^{*-} \to D_s^-\pi^0$$
$$D_s^- \to K^+K^-\pi^-$$

Measure missing p_{π^0} using the known direction of B_s and 2 mass constraints, m_{π^0} and m_{B_s}

B_s-decays – best environment for this research [c.f. arXiv:1206.5869 [hep-ph]]

- $B_s \to D_s^{**}\pi$ from LHCb

Signal events: peak in $D_s^- \pi^0$ mass distribution

$$\mathcal{N}(B_s^0 \to D_{s0}^{*-}(2317)\pi^+) = 600 \times (1 \pm \frac{1}{2}) \times \mathcal{B}(D_{s0}^{*-} \to D_s^- \pi^0) \times \epsilon_{\pi^0}$$

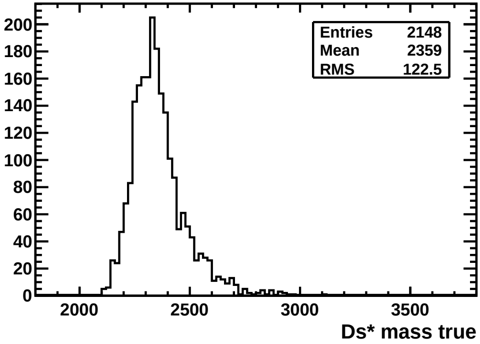
- LHCb see 6000 $B_s \to D_s^- \pi^+$ events $0.33\ \mathrm{fb}^{-1}$from LHCb

$\Rightarrow 18000 \quad 1\ \mathrm{fb}^{-1}$

Assume $\mathcal{B}(B_s^0 \to D_{s0}^{*-}\pi^+) = \mathcal{B}(B^0 \to D_0^{*-}\pi^+) = 1.0(5) \times 10^{-4}$, divide by $\mathcal{B}(B_s^0 \to D_s^{*-}\pi^+) \approx 3 \times 10^{-3}$ [LHCb]

B_s-decays – best environment for this research [c.f. arXiv:1206.5869 [hep-ph]]

- $B_s \to D_s^{**}\pi$ from LHCb [Monte Carlo test!]



- expect a couple of hundreds of signal events/fb^{-1}
  LHCb already have 3 fb^{-1}: possibility for a clean measure!
  Imploring our experimental friends: *Please measure this!*