Bag Parameters Discussion

K. Keri Vos

Maastricht University & Nikhef

= More than a lifetime =

More than the lifetime calculation

Inclusive B Decays:

- $B \to X_c \ell \nu$ extract $\mu_G^2, \mu_\pi^2, \rho_D^3 \to$ lifetimes
- $B \to X_u \ell \nu$ and $B \to X_s \ell\ell$ depend on weak annihilation operators $\leftarrow$ Bag parameters
- Currently: input from charm studies Huber, Hurth, Qin, Lunghi, Jenkins, KKV
- Challenge: consistent treatment of masses, scales, perturbative corrections

More than the lifetime calculation

Inclusive B Decays:

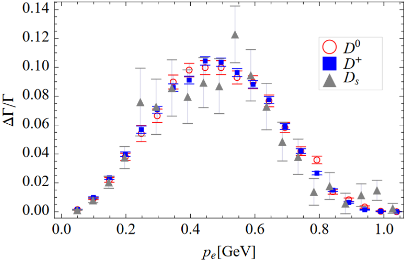
- $B \to X_c \ell\nu$ extract $\mu_G^2, \mu_\pi^2, \rho_D^3 \to$ lifetimes
- $B \to X_u \ell\nu$ and $B \to X_s \ell\ell$ depend on weak annihilation operators $\leftarrow$ Bag parameters
- Currently: input from charm studies Huber, Hurth, Qin, Lunghi, Jenkins, KKV
- Challenge: consistent treatment of masses, scales, perturbative corrections

Inclusive D Decays:

- HQE parameters less suppressed $\to$ larger sensitivity
- Inclusive $D \to X\ell\nu \to$ Bag parameters?
- Challenge: what mass to use for the charm?
- Challenge: perturbative corrections more important
- Currently: kinetic mass, 1S mass, MSbar..

Extracting weak annihilation from data

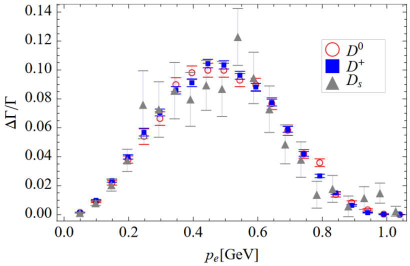
CLEO data, Gambino, Kamenik [1004.0114]



- Lepton energy moments extracted from spectrum
- Kinetic mass for charm at $\mu = 0.5$ GeV threshold, HQE parameters as input
- scaling $B^b_{\rm WA} = \frac{m_B f_B^2}{m_D f_D^2} B^c_{\rm WA}$ gives rough estimate
- Max 2% weak annihilation (WA) contribution to $B \to X_u \ell \nu$

Extracting weak annihilation from data

CLEO data, Gambino, Kamenik [1004.0114]



- Lepton energy moments extracted from spectrum
- Kinetic mass for charm at $\mu = 0.5$ GeV threshold, HQE parameters as input
- scaling $B^b_{\rm WA} = \frac{m_B f_B^2}{m_D f_D^2} B^c_{\rm WA}$ gives rough estimate
- Max 2% weak annihilation (WA) contribution to $B \to X_u \ell\nu$
- Feasibility study to measure q^2 moments at BESIII Bernlochner, Gilman, Malde, Prim, KKV, Wilkinson

Recent extractions from charm

Qin Qin; slide from CKM 2025

Weak-annihilation Uncertainty

❖ Redo the fits, adopting the HQET SR calculation for the weak annihilation contributions

$$\tau_0(D_d \to X_d) = \tau_0(D_s \to X_s) = \tau_{\text{val}} = (-0.18 \pm 0.65)\ \text{GeV}^3$$ [King, Lenz, Piscopo, Rauh,'19]

$$\tau_0(D_u \to X_{d,s}) = \tau_0(D_d \to X_s) = \tau_0(D_s \to X_d) = \tau_{\text{nonval}} = (0.45 \pm 2.10)\ \text{GeV}^3$$

$$\chi^2(\boldsymbol{\theta}) = \sum_{l=u,d,s} \sum_{i=1}^{5} \sum_{j=1}^{5} (y_{i,l} - \eta_{i,l})\, V^{-1}_{ij,l}\, (y_{j,l} - \eta_{j,l}) + \left(\frac{\tau_{\text{nonval}} - (-0.18)}{0.65}\right)^2 + \left(\frac{\tau_{\text{val}} - 0.45}{2.10}\right)^2$$

$$\mu_\pi^2(D^{0,+}) = 0.08\text{GeV}^2\ ,\ \mu_G^2(D^{0,+}) = 0.33\text{GeV}^2\ ,\ \rho_D^3(D^{0,+}) = -0.003\text{GeV}^3\ ,\ \rho_{LS}^3(D^{0,+}) = 0.004\text{GeV}^3$$
$$\mu_\pi^2(D_s) = 0.15\text{GeV}^2\ ,\ \mu_G^2(D_s) = 0.38\text{GeV}^2\ ,\ \rho_D^3(D_s) = -0.005\text{GeV}^3\ ,\ \rho_{LS}^3(D_s) = 0.006\text{GeV}^3\ ,$$
$$\tau_{\text{val}} = -0.11\text{GeV}^3,\ \tau_{\text{nonval}} = 0.002\text{GeV}^3\ .$$

The best-fit values only slightly change.

27

Quick estimate of weak annihilation in B

Piscopo, Fael, Lenz, Rusov et al. [2412.14035]

- $B^b_{\mathrm{WA}} = (-0.0004 \pm 0.0030)\mathrm{GeV}^3$ valence (uncertainty 2x smaller for non-valence)
- At 1σ level this is a 1% contribution to $B \to X_u \ell \nu$ rate
- in agreement with extracted values from D decays
- one of the dominant uncertainties in $B \to X_s \ell\ell$ at high q^2

Quick estimate of weak annihilation in B

Piscopo, Fael, Lenz, Rusov et al. [2412.14035]

- $B^b_{\mathrm{WA}} = (-0.0004 \pm 0.0030)\mathrm{GeV}^3$ valence (uncertainty 2x smaller for non-valence)
- At 1σ level this is a 1% contribution to $B \to X_u \ell \nu$ rate
- in agreement with extracted values from D decays
- one of the dominant uncertainties in $B \to X_s \ell\ell$ at high q^2
- Challenge: mixing with the ρ_D^3 parameter

How to proceed?

Input from Fabian, Zach, Matthew, Martin

- Which precision is needed?
- What is the timeline?
- What are the advantages and disadvantages of using QCD or HQET?
- Should we focus on lifetimes or lifetime differences?
- Should we focus on charm or bottom systems?

How to proceed?

Input from Fabian, Zach, Matthew, Martin

- Which precision is needed?
- What is the timeline?
- What are the advantages and disadvantages of using QCD or HQET?
- Should we focus on lifetimes or lifetime differences?
- Should we focus on charm or bottom systems?

- Can we obtain correlations?

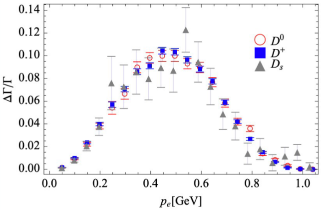
Backup

Qin Qin; slide from CKM 2025

Phenomenological Progress

❖ 4-quark operator matrix elements were extracted from electron energy spectrum

[Gambino,Kamenik, '10; Ligeti,Luke,Manohar, '10]



$$
\begin{aligned}
B_{\rm WA}^{(0),s}(D^0) &= -0.001(3)\mathrm{GeV}^3\,, & B_{\rm WA}^{(0),s}(D^+) &= -0.001(3)\mathrm{GeV}^3\,,\\
\bar{B}_{\rm WA}^{(1),s}(D^0) &= -0.0001(6)\mathrm{GeV}^3\,, & \bar{B}_{\rm WA}^{(1),s}(D^+) &= -0.0001(6)\mathrm{GeV}^3\,,\\
\bar{B}_{\rm WA}^{(2),s}(D^0) &= -0.0001(10)\mathrm{GeV}^3\,, & \bar{B}_{\rm WA}^{(2),s}(D^+) &= -0.0002(10)\mathrm{GeV}^3\,,\\
\bar{B}_{\rm WA}^{(\sigma),s}(D^0) &= -0.0000(7)\mathrm{GeV}^3\,, & \bar{B}_{\rm WA}^{(\sigma),s}(D^+) &= -0.0000(7)\mathrm{GeV}^3\,,
\end{aligned}
$$

2-quark operator matrix elements were assumed to be identical to the B meson ones, which is questionable.

16