Lifetimes: $\tau = 1/\Gamma_{tot}$ (Exp)

$$\Gamma = \sum_x \int_{PS} (2\pi)^4 \delta(p_B - p_x) \frac{|\langle x|\mathcal{H}_{eff}|B\rangle|^2}{2m_B}$$

cpt. theorem ↓ =

$$\frac{\langle B|\,\mathrm{Im}_i \int dx\, T\{\mathcal{H}_{eff}(x)\mathcal{H}_{eff}(0)\}\,|B\rangle}{2m_B}$$

Mixing $B_s = (\bar{b}s)$ $\bar{B}_s = (b\bar{s})$

are not mass eigenstates

$$B_H = p\,B_s - q\,\bar{B}_s$$
$$B_L = p\,B_s + q\,\bar{B}_s$$

(Exp)

1) $\Delta m_B = m_{B_H} - m_{B_L} \equiv 2|M_{12}| =$ (off-shell)
2) $\Delta\Gamma_B = \Gamma_{B_L} - \Gamma_{B_H} = 2|\Gamma_{12}|\cos\phi_{12} =$ (on shell)
3) $a_{sl} = \frac{\Gamma(\bar{B}\to f) - \Gamma(B\to\bar{f})}{\text{—u—} \to \text{—u—}} = \left|\frac{\Gamma_{12}}{M_{12}}\right| \sin\phi_{12}$

Exp: (HFLAV ; PDG 2026 averages)

	τ	τ_x/τ_{B_s}
B_d	1.5113(27) ps	
B^+	1.637(4) ps	1.0832(34)
B_s	1.515(6) ps	1.003(4)
Λ_b	1.465(9) ps	0.970(6)

$\Delta m_s = 17.766(6)\ ps^{-1}$
$\Delta m_d = 0.5068(19)\ ps^{-1}$

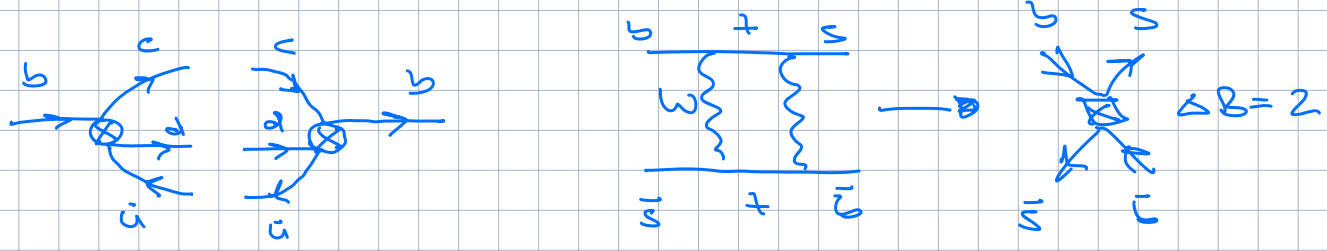
$\Delta\Gamma_s = 0.0783(35)\ ps^{-1}$
$\frac{\Delta\Gamma_d}{\Gamma_d} = 0.05 \pm 0.10$

$a_{sl}^s = (-60 \pm 250)\cdot 10^{-5}$
$a_{sl}^d = (-21 \pm 17)\cdot 10^{-4}$

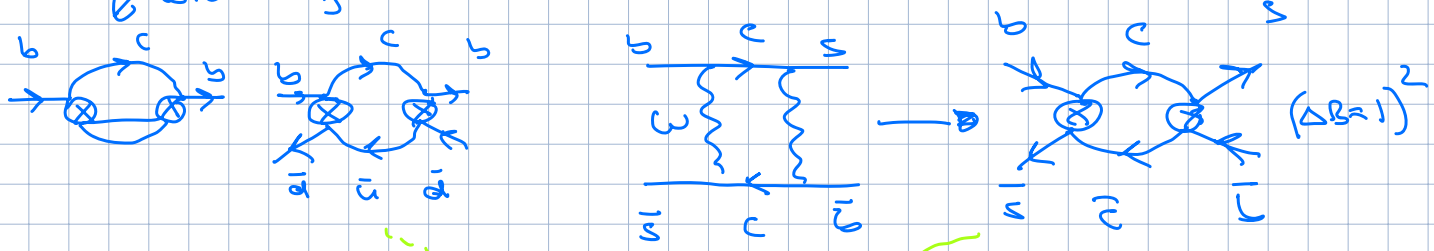
Theory ref. on webpage:

- Dieste, Reeck, Nod, Steinhauser
- Albrecht, Beneke, Buras, Russo

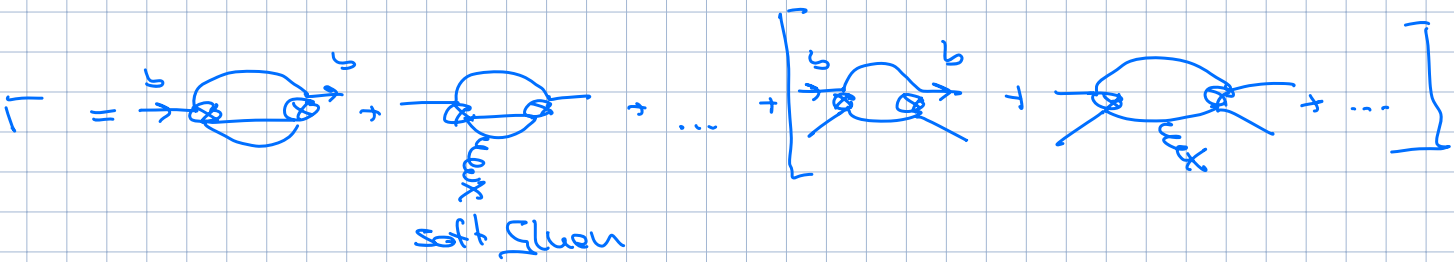
Diagrams:



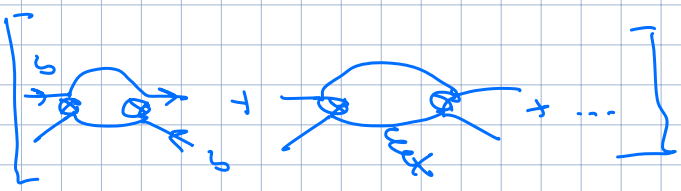
Wick



Heavy Quark Expansion



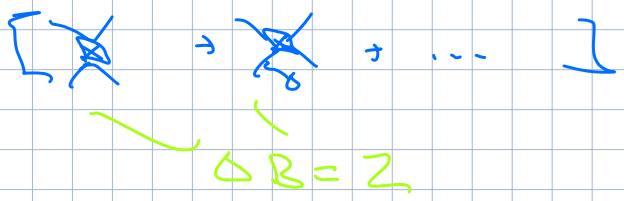
Γ_{12} =



$m_b \to \Lambda_{QCD}$

Γ =

Γ_{12} =



$$\Gamma = \Gamma_3 + \Gamma_5 \frac{\langle O_5 \rangle}{m_b^2} + \Gamma_6 \frac{\langle O_6 \rangle}{m_b^3} + \ldots + 16\pi^2 \left[\tilde{\Gamma}_6 \frac{\langle \tilde{Q}_6 \rangle}{m_b^3} + \tilde{\Gamma}_7 \frac{\langle \tilde{Q}_7 \rangle}{m_b^4} + \ldots \right]$$

$$\Gamma_{12} = 16\pi^2 \left[\tilde{\Gamma}_6 \frac{\langle \tilde{Q}_6 \rangle}{m_b^3} + \tilde{\Gamma}_7 \frac{\langle \tilde{Q}_7 \rangle}{m_b^4} + \ldots \right]$$

Wilson coefficients in pert. theory

$$\Gamma_i = \Gamma_i^{(0)} + \frac{\alpha_s}{4\pi} \Gamma_i^{(1)} + \left(\frac{\alpha_s}{4\pi}\right)^2 \Gamma_i^{(2)} + \left(\frac{\alpha_s}{4\pi}\right)^3 \Gamma_i^{(3)} + \ldots$$

<u>Non-pert. matrix elements:</u>

$Q_5 \to \bar{b} (i D_\mu)(i D^\mu) b$ kinetic operator

$Q_5 \to \bar{b} (i D_\mu)(i D_\nu)(-i \sigma^{\mu\nu}) b$ chromomagnetic operator

$Q_6 \longrightarrow \bar{b} (i D_\mu)(i v D)(i D^\mu) b$ Darwin operator

$\tilde{Q}_6 \longrightarrow \bar{b} \gamma_\mu (1-\gamma_5) q \quad \bar{q} \gamma^\mu (1-\gamma_5) b$

$(1-\gamma_5) \quad (1+\gamma_5)$

$\gamma_\mu (1-\gamma_5) T^a \quad \gamma^\mu (1-\gamma_5) T^a$

$(1-\gamma_5) T^a \quad (1+\gamma_5) T^a$

$\langle Q_5 \rangle \sim \mu_\pi^2$

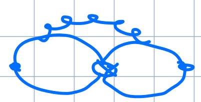
$\langle Q_6 \rangle \sim \mu_G^2$

$$\langle \tilde{Q}_6 \rangle \sim m_B^2 f_B^2 \cdot \begin{cases} B & \mathbb{1} \quad B \sim 1 \\ \varepsilon & T^a \quad \varepsilon \sim 1/N_c \end{cases}$$

C1b	C1c	C2c
pert. Coefficients $\Gamma_i^{(x)}$ (Ali)	non-pert. matrix elements $\langle \tilde{O}_x \rangle$ (Martin)	Charm physics ($m_c >> \Lambda_{QCD}$?) [Jian-Peng]

← Funding Period →

FP2: 2023 – 2026	FP3: 2027 – 2030
(C1a: $\Gamma_3^{(2)}$ for non-lept.) * SFB meeting 2020 Siegen	
C1b: $\Gamma_5^{(1)}$ Manuel, Moritz, Pivov.	$\Gamma_7^{(0)}$, $\Gamma_6^{(1)}$ → Siegen (PhD)
$\Delta B=2$ $\tilde{\Gamma}_6^{(2)}$ Nierste, Steinhauser	$\tilde{\Gamma}_7^{(1)}$ $\Delta B=0,2$ → KIT (Post-Doc)
$\Delta B=0$ $\tilde{\Gamma}_6^{(2)}$ Nierste, Steinhauser	$\tilde{\Gamma}_6^{(2)}$ penguins $\Delta B=0$
Gerlach, Reeck, Vlad, Marvin	$\tilde{\Gamma}_6^{(3)}$ first steps $\Delta B=0,2$
C1c: $\langle \tilde{O}_6 \rangle$ $\Delta B=0$ with HQET SR for general Dirac structures; Black, Lang, Lenz, Wüthrich	$\langle \hat{Q}_7 \rangle$ $\Delta B=0,2$ with HQET SR (PhD)
$\langle \tilde{O}_6 \rangle$ $\Delta B=0,2$ (CS) Lattice + Gradient-flow; Black, Harlander, Witzel	$\langle \hat{Q}_6 \rangle$, $\langle \hat{Q}_7 \rangle$ = $\Delta B=0,2$ Wesch, Baryon; PhD Aachen pert. grad; Post-doc Siegen Lattice
C2c	• $\tau(D^+)$, $\tau(D^0)$ • D-mixing • ΔA_{CP} (post-doc)



- $\Gamma(B_d)^{2019}_{HQE} = 0.63^{+0.11}_{-0.07}\,ps^{-1} \longrightarrow$ new $0.636^{+0.028}_{-0.037}\,ps^{-1}$ (domin. by μ-dep.)

- $\Delta\Gamma^{2025}_{HQE} = (7.8 \pm 1.5)\,ps^{-1}$ vs $(7.83 \pm 0.35)\,ps^{-1}$

  (domin. by D=7)

- $\dfrac{\tau(B^+)}{\tau(B_d)} = 1.072(24)$ vs $1.0832(34)$

  domin. by $\langle \tilde{Q}_6 \rangle$

  $\langle \tilde{Q}_7 \rangle$ unknown

$\Rightarrow$ BSM bounds

new decay channels modify $\tau(B)$

- e.g. B-mesogenesis

  Ali, Aitra, Alex K., ...

- e.g. model-indep.

  Jakob, ...

Alts $B_s \to D_s^+ \pi^-$