Weak annihilation decays $\bar{B}^0_{d,s} \to J/\psi\gamma$, $B^- \to \{D^{*-}, D_s^{*-}\}\gamma$

Anastasiia Kozachuk

Lomonosov Moscow State University
Faculty of Physics,
Scobeltsyn Institute of Nuclear Physics

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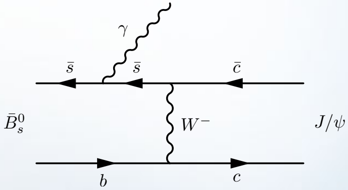
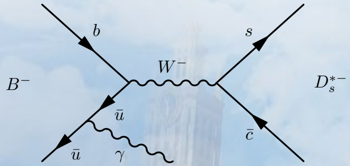
Introduction

- $\bar{B}^0_{d,s} \to J/\psi\gamma$



- $B^- \to \{D^{*-}, D_s^{*-}\}\gamma$



Introduction

	«Naive factirozation» in the $\frac{1}{m_b}$ leading order [1]	with the non-factorizable corrections[1]	pQCD [2]
$Br(\bar{B}_d^0 \to J/\psi\gamma)$	5.4×10^{-8}	$(2-3) \times 10^{-9}$	$4.5 \pm 0.7 \times 10^{-7}$
$Br(\bar{B}_s^0 \to J/\psi\gamma)$	1.4×10^{-6}	$(6-10) \times 10^{-8}$	$\sim 5 \times 10^{-6}$

The experiment upper limit $Br(\bar{B}_d^0 \to J/\psi\gamma) < 1.6 \times 10^{-6}$, Babar [3]

[1] Y.D.Yang, G.Lu and R.Wang, *Eur. Phys. J.* C 34, 291 (2004).

[2] Y.Li and C.-D.Lu, *Phys. Rev.* D 74, 097502 (2006).

[3] BaBar Collaboration, *Phys. Rev.* D 70, 091104(R) (2004).

Introduction

	HQET leading order [4, 5]	HQET higher order corrections [5]
$Br(B^0 \to \bar{D}^{*0}\gamma)$	$(0.7 - 4.6) \times 10^{-7}$	$(1.2 - 3.1) \times 10^{-5}$
$Br(B_s^0 \to \bar{D}^{*0}\gamma)$	$(1.5 - 3.0) \times 10^{-8}$	$(0.7 - 1.7) \times 10^{-6}$
$Br(B^+ \to D^{*+}\gamma)$	$(3.6 - 4.9) \times 10^{-9}$	$(0.6 - 1.0) \times 10^{-7}$
$Br(B^+ \to D_s^{*+}\gamma)$	$(0.7 - 1.0) \times 10^{-7}$	$(0.6 - 1.4) \times 10^{-6}$

The experiment upper limit $Br(B^0 \to \bar{D}^{*0}\gamma) < 2.5 \times 10^{-5}$, [7]

[4] B. Grinstein and R. F. Lebed, *Phys. Rev.* D 60, 031302 (1999)

[5] Oleg Antipin and G.Valencia, *Phys. Rev.* D 74, 054015 (2006)

[6] J. O. Eeg and J. A. Macdonald Sorensen, *Phys. Rev.* D 75, 034015 (2007)

[7] K.A.Olive at al. (Particle Data Group). *Chin. Phys.* C 38, 090001 (2014)

Effective Hamiltonian: Wilson Expansion

$$H_{eff} = \frac{G_F}{\sqrt{2}} V_{tb} V_{tq}^* \sum_i c_i(\mu) O_i(\mu),$$

$$O_1 = -\frac{\lambda_c}{\lambda_t}(\bar{q}_\alpha \gamma^\mu (1-\gamma_5) b_\alpha)(\bar{c}_\beta \gamma_\mu (1-\gamma_5) c_\beta) - \frac{\lambda_u}{\lambda_t}(\bar{q}_\alpha \gamma^\mu (1-\gamma_5) b_\alpha)(\bar{u}_\beta \gamma_\mu (1-\gamma_5) u_\beta),$$

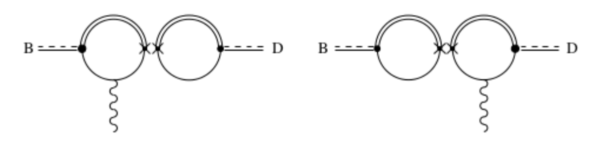
$$O_2 = -\frac{\lambda_c}{\lambda_t}(\bar{q}_\alpha \gamma^\mu (1-\gamma_5) b_\beta)(\bar{c}_\beta \gamma_\mu (1-\gamma_5) c_\alpha) s - \frac{\lambda_u}{\lambda_t}(\bar{q}_\alpha \gamma^\mu (1-\gamma_5) b_\beta)(\bar{u}_\beta \gamma_\mu (1-\gamma_5) u_\alpha),$$

$$O_{7\gamma} = \frac{e}{8\pi^2} \bar{q}_\alpha \sigma_{\mu\nu} [m_b(\mu)(1+\gamma_5) + m_q(\mu)(1-\gamma_5)] b_\alpha F^{\mu\nu},$$

$$O_{9V} = \frac{e}{8\pi^2}(\bar{q}_\alpha \gamma^\mu (1-\gamma_5) b_\alpha) \bar{l} \gamma_\mu l, O_{10A} = \frac{e}{8\pi^2}(\bar{q}_\alpha \gamma^\mu (1-\gamma_5) b_\alpha) \bar{l} \gamma_\mu \gamma_5 l,$$

where $\lambda_i = V_{iq}^* V_{ib}, i = \{u, c, t\}$

Factorization



$$H_{eff} = \frac{G_F}{\sqrt{2}} V_{ub} V_{cq}^* \left(c_1 + \frac{c_2}{N_c} \right) (\bar{u} O^\mu b)(\bar{q} O_\mu c),$$

$$\mathfrak{M}_{fi}^{(F)} = \frac{G_F}{\sqrt{2}} V_{ub} V_{cq}^* \left[c_1 + \frac{c_2}{N_c} \right] \Big(\langle D_q^{*-}(p_2) | \bar{q} O_\mu c | 0 \rangle \langle \gamma(q) | \bar{u} O^\mu b | B^-(p_1) \rangle +$$
$$+ \langle D_q^{*-}(p_2) \gamma(q) | \bar{q} O_\mu c | 0 \rangle \langle 0 | \bar{u} O^\mu b | B^-(p_1) \rangle \Big).$$

Partial Width

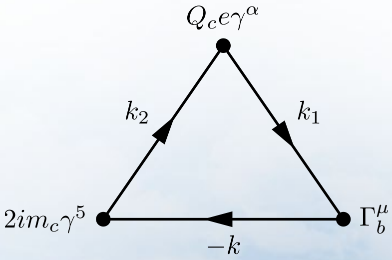
$$\Gamma(B \to V\gamma) = A^2\Big(\mid \tilde{F}_V \mid^2 + \mid \tilde{F}_A \mid^2 + BRe\tilde{F}_A + C\Big),$$

$$\tilde{F}_V = F_V + f_B \frac{m_q + m_c}{M_1 M_2} D_V,$$

$$\tilde{F}_A = F_A + f_B \frac{m_q - m_c}{M_1 M_2} D_A + (Q_q - Q_c) f_B \frac{2M_1}{M_1^2 - M_2^2}.$$

Dispersion Quark Model

- Form-factors are represented in the form of the dispersion integrals over the hadron mass



$$A^{\alpha\mu} \sim \varepsilon^{p_1 p_2 \alpha\mu} \int\limits_{4m_c^2}^{\infty} ds \frac{\phi(s)}{(s - M_1^2)} F(s)$$

Numerical Estimations: Branching Ratios

- $\bar{B}^0_{d,s} \to J/\psi\gamma$

$$Br(\bar{B}^0_d \to J/\psi\gamma) \approx 1.1 \times 10^{-8},$$

$$Br(\bar{B}^0_s \to J/\psi\gamma) \approx 1.9 \times 10^{-7}.$$

- In comparison with other results:

	«Naive factorization» in the $\frac{1}{m_b}$ leading order [1]	With the non-factorizable corrections [1]	pQCD [2]	Upper experimental limit, Babar[3]
$Br(\bar{B}^0_d \to J/\psi\gamma)$	5.4×10^{-8}	$(2-3) \times 10^{-9}$	$4.5 \pm 0.7 \times 10^{-7}$	$< 1.6 \times 10^{-6}$
$Br(\bar{B}^0_s \to J/\psi\gamma)$	1.4×10^{-6}	$(6-10) \times 10^{-8}$	$\sim 5 \times 10^{-6}$	

Numerical Estimations: Branching Ratios

- $B^- \to \{D^{*-}, D_s^{*-}\}\gamma$

$$Br(B^- \to D^{*-}\gamma) \approx 2 \times 10^{-7},$$

$$Br(B^- \to D_s^{*-}\gamma) \approx 1 \times 10^{-6}.$$

- In comparison with other results:

	HQET leading order [4, 5]	HQET higher order corrections [5]
$Br(B^+ \to D^{*+}\gamma)$	$(3.6 - 4.9) \times 10^{-9}$	$(0.6 - 1.0) \times 10^{-7}$
$Br(B^+ \to D_s^{*+}\gamma)$	$(0.7 - 1.0) \times 10^{-7}$	$(0.6 - 1.4) \times 10^{-6}$

Conclusion and Future Prospects

- Weak annihilation rare radiative decays were calculated in the framework of the dispersion quark model
- For the decays $\bar{B}^0_{d,s} \to J/\psi\gamma$ numerical estimations for the branching ratio are in agreement with some of the previous results in other models.
- For the decays $B^- \to \{D^{*-}, D_s^{*-}\}\gamma$ the obtained results are in agreement with the predictions obtained with HQET including higher order corrections.

- Calculation of the neutral modes of the corresponding B-decays $B_s^0 \to \bar{D}^{*0}\gamma$ is the next step.

Bibliography

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- BaBar Collaboration, *Phys. Rev.* D **70**, 091104(R) (2004).
- B. Grinstein and R. F. Lebed, *Phys. Rev.* D **60**, 031302 (1999).
- Oleg Antipin and G.Valencia, *Phys. Rev.* D **74**, 054015 (2006).
- J. O. Eeg and J. A. Macdonald Sorensen, *Phys. Rev.* D **75**, 034015 (2007).
- K.A.Olive at al. (Particle Data Group), *Chin. Phys.* C **38**, 090001 (2014).