EXCLUSIVE $c \to u\gamma$ TRANSITIONS OF B_C MESON

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Abstract

We study the rare decays of the B_c meson induced by the flavour changing neutral current $c \to u\gamma$ transition. In the Standard Model they are strongly suppressed by the Glashow-Iliopoulos-Maiani mechanism, therefore they are sensitive to new physics effects. The difficulty is to get rid of long-distance hadronic effects. We study such effects in radiative B_c transitions both to B^* and to the axial-vector B_1' mesons.

Introduction

Flavour changing neutral current $c \to u$ fundamental in the search for new physics (NP) phenomena:

- SM weak Hamiltonian involves small Wilson coefficients from GIM mechanism

$\Rightarrow$ hadronic amplitudes highly suppressed.
$\Rightarrow$ suitable for looking at enhancements from non-SM contributions.
Theoretical difficulty:

- long-distance (LD) contributions from purely hadronic processes

$\Rightarrow$ LD precise determination to access the short-distance part using measurements.
How to deal with LD:

- consider processes in which the LD contribution is reduced due to kinematics

$\Rightarrow B_c^+ \to B_1'^+\gamma$ (new) and $B_c^+ \to B^{*+}\gamma$ (already analysed).

Effective Weak Hamiltonian

Effective weak Hamiltonian governing the $c \to u\gamma$ transition

$$\mathcal{H}_{eff} = 4\frac{G_F}{\sqrt{2}}\Big[\sum_{q=d,s} V_{cq}^* V_{uq}\Big(C_1\mathcal{O}_1^{(q)} + C_2\mathcal{O}_2^{(q)}\Big) + \sum_{i=3}^{6} C_1\mathcal{O}_i + \sum_{i=7}^{8}\big(C_i\mathcal{O}_i + C_i'\mathcal{O}_i'\big)\Big]$$

- $\mathcal{O}_{1,2}^{(q)}$ current-current operators
- $\mathcal{O}_{3,\dots 6}$ QCD penguins operators
- $\mathcal{O}_{7,8}^{(\prime)}$ electromagnetic and gluon dipole operators

$C_7' \sim m_u/m_c \Rightarrow \mathcal{O}_7'$ neglected in SM.
$\mathcal{O}_7$ GIM suppressed in SM, $C_7 \sim 10^{-3} \Rightarrow$ significantly enhanced in a beyond SM (BSM) scenario.
General bounds:

$$|C_7|, |C_7'| \lesssim 0.5.$$

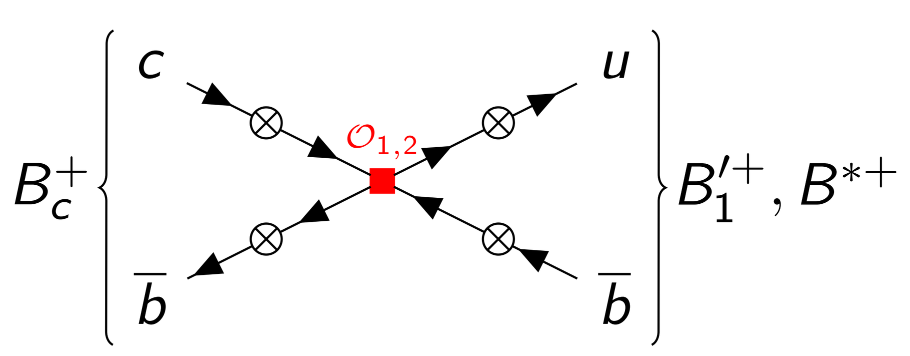
Radiative B_c decays to beauty mesons decays need also operators $\mathcal{O}_{1,2}^{(b)}$ involving the b quark
Amplitude for $B_c(p) \to A(p',\epsilon)\gamma(q,\lambda)$, A a 1^+ state:

$$\mathcal{A}(B_c(p) \to A(p',\epsilon)\gamma(q,\lambda)) = \Big\{A_{PC}\big[p\cdot q g^{\alpha\beta} - q^\alpha p^\beta\big] + iA_{PV}\varepsilon^{\alpha\beta\mu\nu}p_\mu q_\nu\Big\}\epsilon_\alpha^*\lambda_\beta^*$$

Short distance

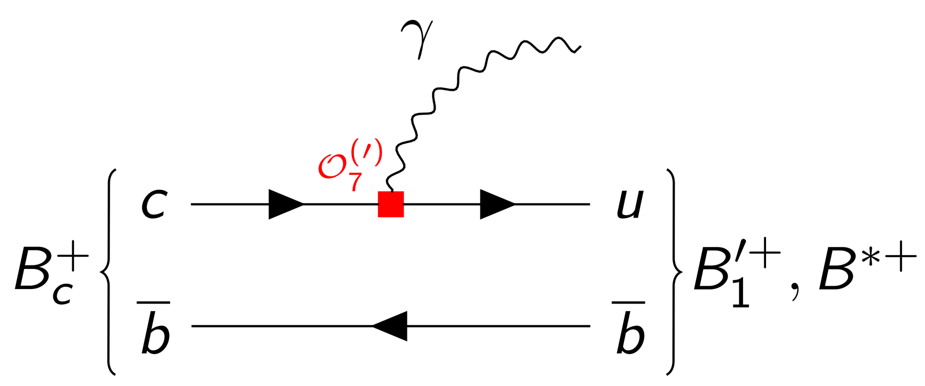
Short-distance (SD) contributions:

- Weak annihilation (WA)



Doubly-Cabibbo suppressed $\Rightarrow$ ignored.

- $\mathcal{O}_7^{(\prime)}$ electromagnetic dipole operator



$\mathcal{O}_7^{(\prime)} \propto \bar{u}\sigma_{\mu\nu}c \Rightarrow$ hadronic matrix element for the 1^+ channel

$$\langle B_1'(p',\epsilon)|\,\bar{u}\sigma_{\mu\nu}c\,|B_c(p)\rangle = \frac{\epsilon^*\cdot q}{\Big(m_{B_c}+m_{B_1^{(\prime)}}\Big)^2}\left(p_\mu p_\nu' - p_\nu p_\mu'\right)T_0'(q^2) + \left(p_\mu\epsilon_\nu^* - p_\nu\epsilon_\mu^*\right)T_1'(q^2) + \left(p_\mu'\epsilon_\nu^* - p_\nu'\epsilon_\mu^*\right)T_2'(q^2).$$

Therefore

$$A_{PC}^{SD} = i\frac{G_F}{(2\pi)^{3/2}}m_c\alpha^{1/2}(C_7^{eff}+C_7')(T_1'(0)+T_2'(0)),$$
$$A_{PV}^{SD} = -i\frac{G_F}{(2\pi)^{3/2}}m_c\alpha^{1/2}(C_7^{eff}-C_7')(T_1'(0)+T_2'(0)).$$

Heavy spin symmetry to relate T_i to universal form factors

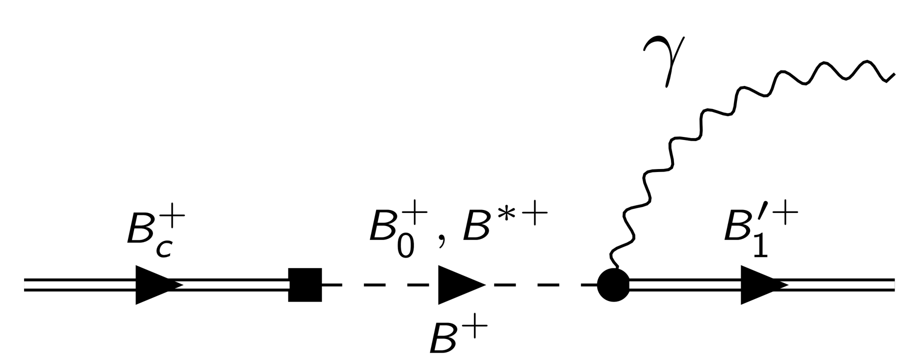
$$T_0'(q^2) = 2i\frac{(m_{B_c}+m_{B_1'})^2\sqrt{m_{B_1'}}}{m_{B_c}^{3/2}}a_0\,\Omega_2'$$
$$T_1'(q^2) = -\frac{m_{B_1'}}{m_{B_c}}T_2'(q^2)$$
$$T_2'(q^2) = -i\sqrt{\frac{m_{B_c}}{m_{B_1'}}}\Omega_1'$$

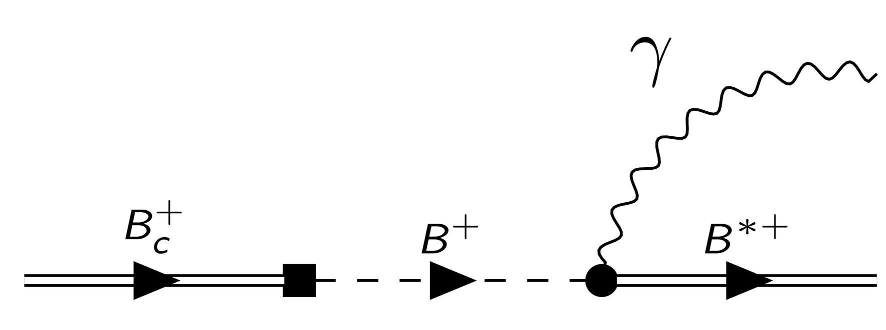
$a_0\,\Omega_2'$ and Ω_1' from form factors computed by using covariant light-front approach.

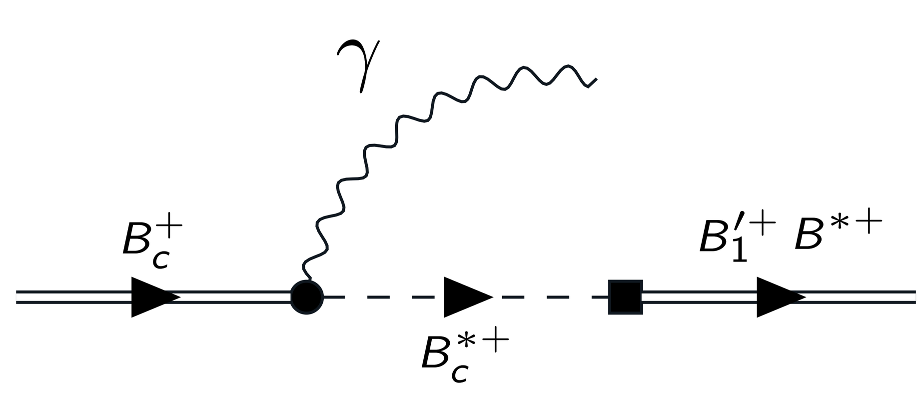
Long distance

Long-distance (LD) contributions:

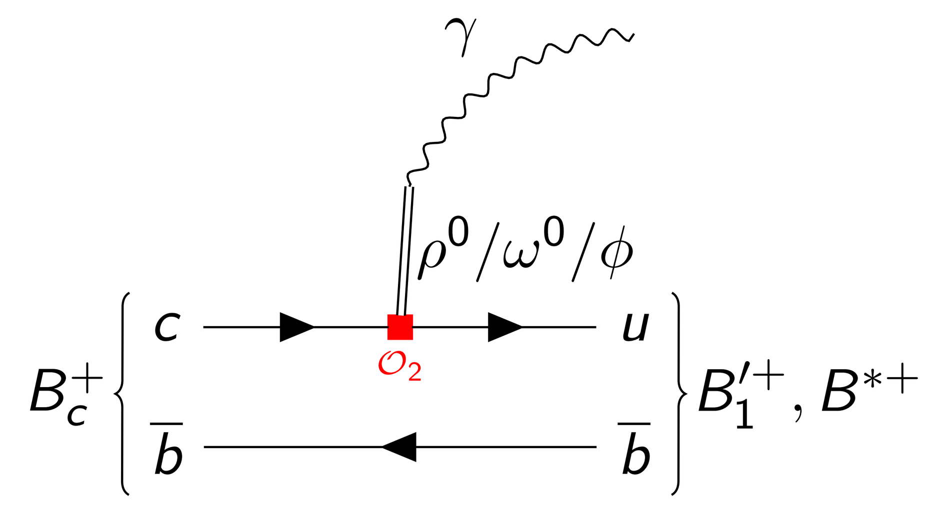
- WA with intermediate hadrons







- pole contribution

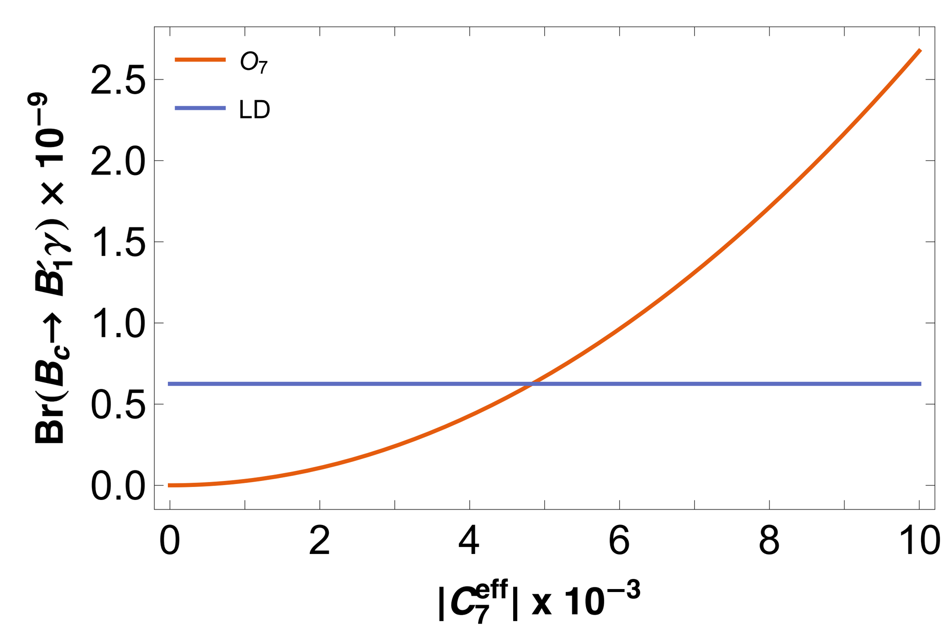


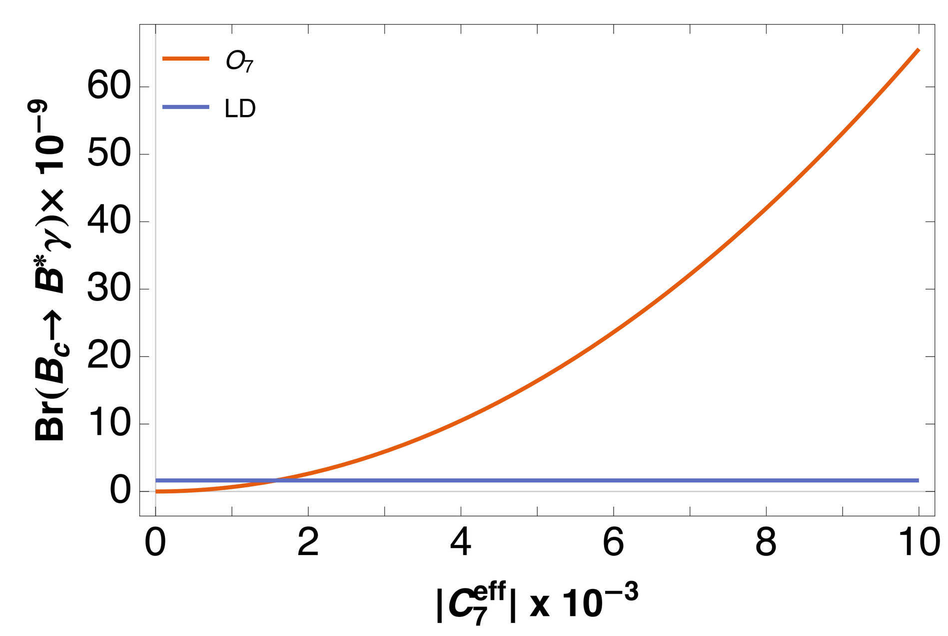
Parameters in the amplitudes of the WA contributions evaluated using:

- Light-cone QCD sum rules + HQET for B_1' case
- ISGW quark model for B^* case

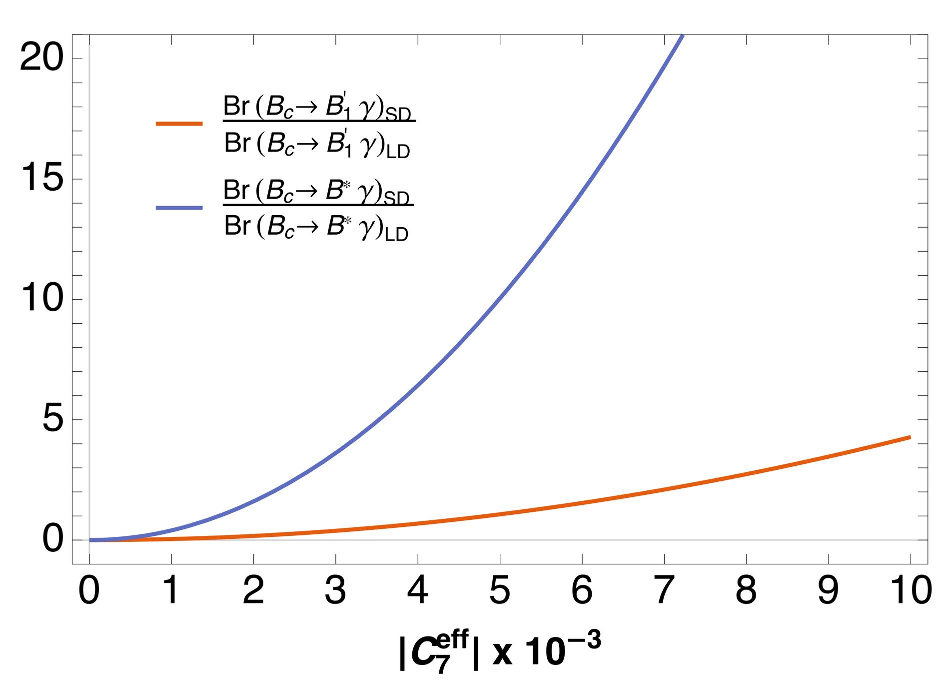
Results

Comparison between LD and SD contributions for both channels varying $|C_7^{eff}|$





Ratio of LD and SD contributions for both channels varying $|C_7^{eff}|$



LD contributions prevail in the B_1' channel $\Rightarrow B^*$ channel more suitable for searching NP in C_7^{eff}.
This is due to the hadronic cancellation in the SD amplitude for B_1' channel
$\Rightarrow T_1'(0) + T_2'(0) \propto m_{B_c} - m_{B_1'}$.