



Hadronic and semileptonic decays of B_c meson

Issadykov Aidos

in collaboration with:

Mikhail A. Ivanov, S. Dubnicka, A.Z. Dubnickova, A. Liptaj

NEW TRENDS IN HIGH ENERGY PHYSICS,

Becici, Budva

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3,044

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[41,081](#)
[26,070](#)

1,221,911

1,100,730

29.7

42.2

[245](#)
[222](#)
[435](#)
[396](#)
[1,680](#)
[1,542](#)
[2,623](#)
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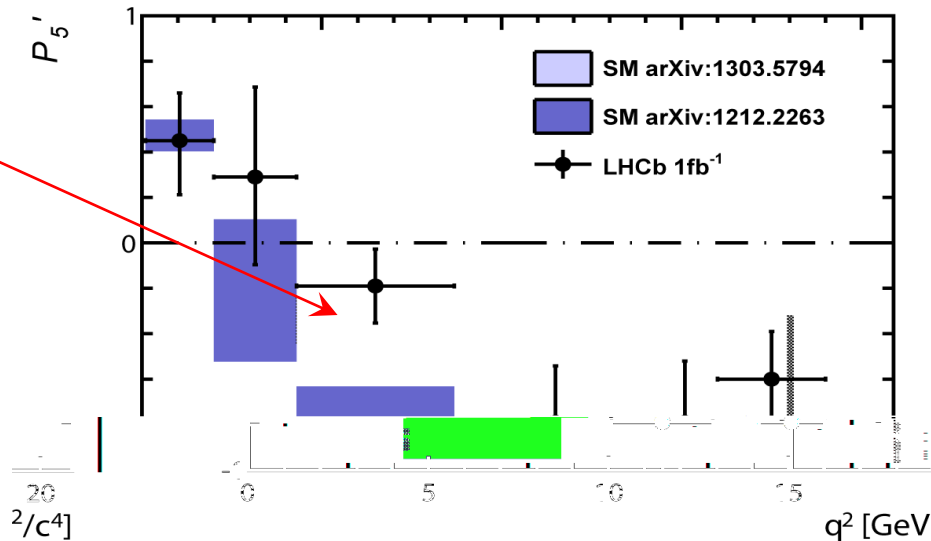
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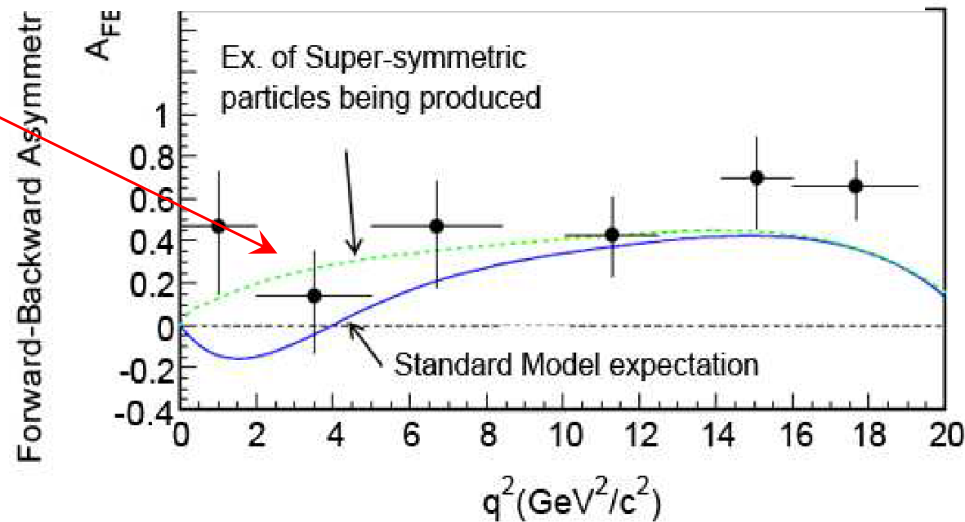
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THE LHCb COLLABORATION REPORT IN 2013

3.7 σ



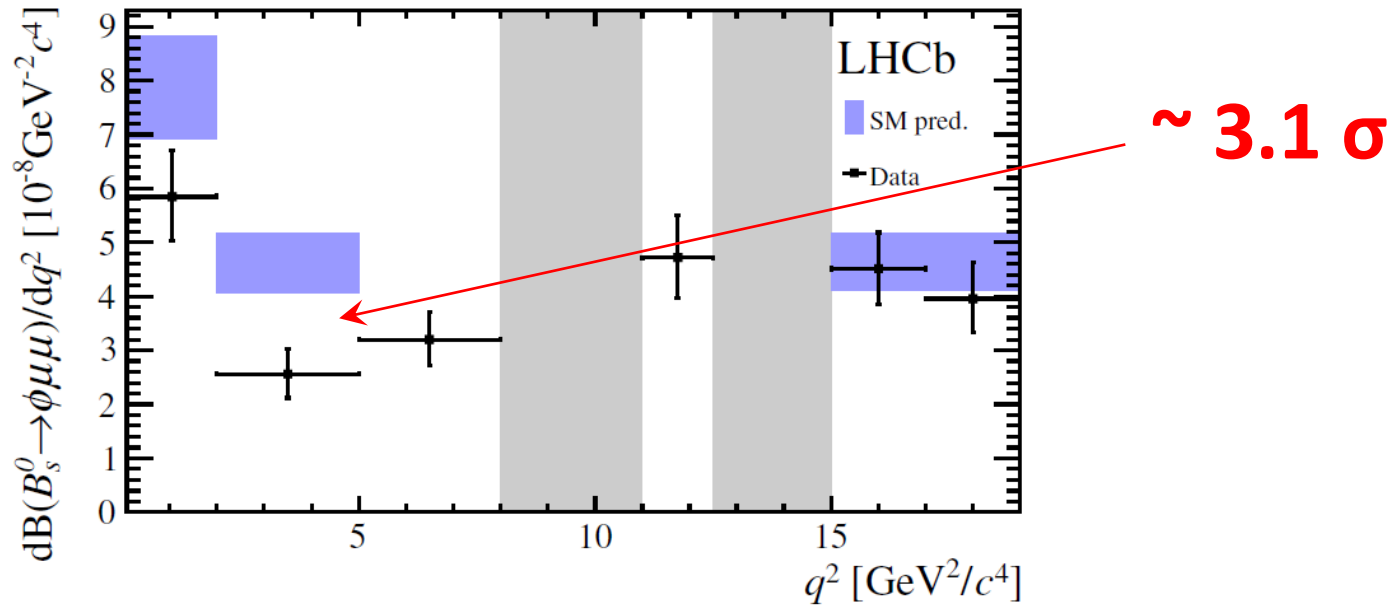
$\sim 3\sigma$



Invariant mass of lepton pair

*Phys.Rev.Lett. 111 (2013) 191801

$$B^0_s \rightarrow \varphi \ell^+ \ell^-$$

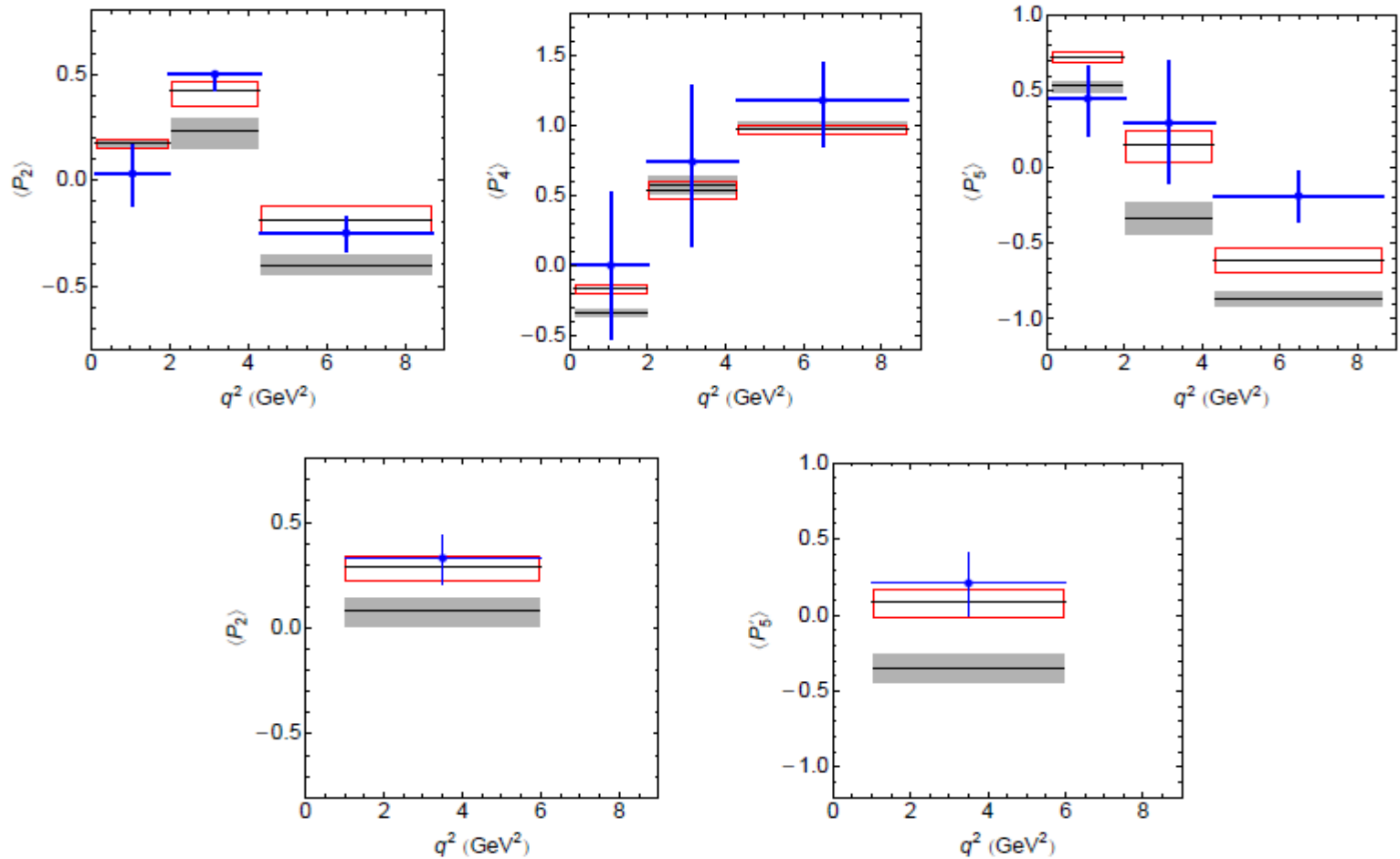


* R. Aaij *et al.* (LHCb Collaboration), J. High Energy Phys. 09 (2015) 179.

b-s anomaly

- $B \rightarrow K^* \mu^+ \mu^-$ • up to 3.7 σ
- $B_s \rightarrow \varphi \mu^+ \mu^-$ • up to 3.1 σ
- $B_s \rightarrow \mu^+ \mu^-$ • up to 5 σ !

New physics in $b \rightarrow s$



Comparison between the SM predictions (gray boxes), the experimental measurements (blue data points) and the predictions for the scenario with $C_9^{\text{NP}} = -1.5$ and other $C_i^{\text{NP}} = 0$ (red squares).

b-s anomaly

- $B \rightarrow K^* \mu^+ \mu^-$ • up to 3.7 σ
- $B_s \rightarrow \varphi \mu^+ \mu^-$ • up to 3.1 σ
- $B_s \rightarrow \mu^+ \mu^-$ • up to 5 σ !

b-s anomaly

- $B \rightarrow K^* \mu^+ \mu^-$ • up to 3.7 σ
- $B_s \rightarrow \varphi \mu^+ \mu^-$ • up to 3.1 σ
- $B_s \rightarrow \mu^+ \mu^-$ • less than 2 σ

Now*

b-s anomaly

- $B \rightarrow K^* \mu^+ \mu^-$ • up to 3.7σ
- $B_s \rightarrow \varphi \mu^+ \mu^-$ • about 2.2σ
- $B_s \rightarrow \mu^+ \mu^-$ • less than 2σ

Now*

b-s anomaly

- $B \rightarrow K^* \mu^+ \mu^-$
 - $B_s \rightarrow \varphi \mu^+ \mu^-$
 - $B_s \rightarrow \mu^+ \mu^-$
- up to 3.7σ ??
 - about 2.2σ
 - less than 2σ

Now*

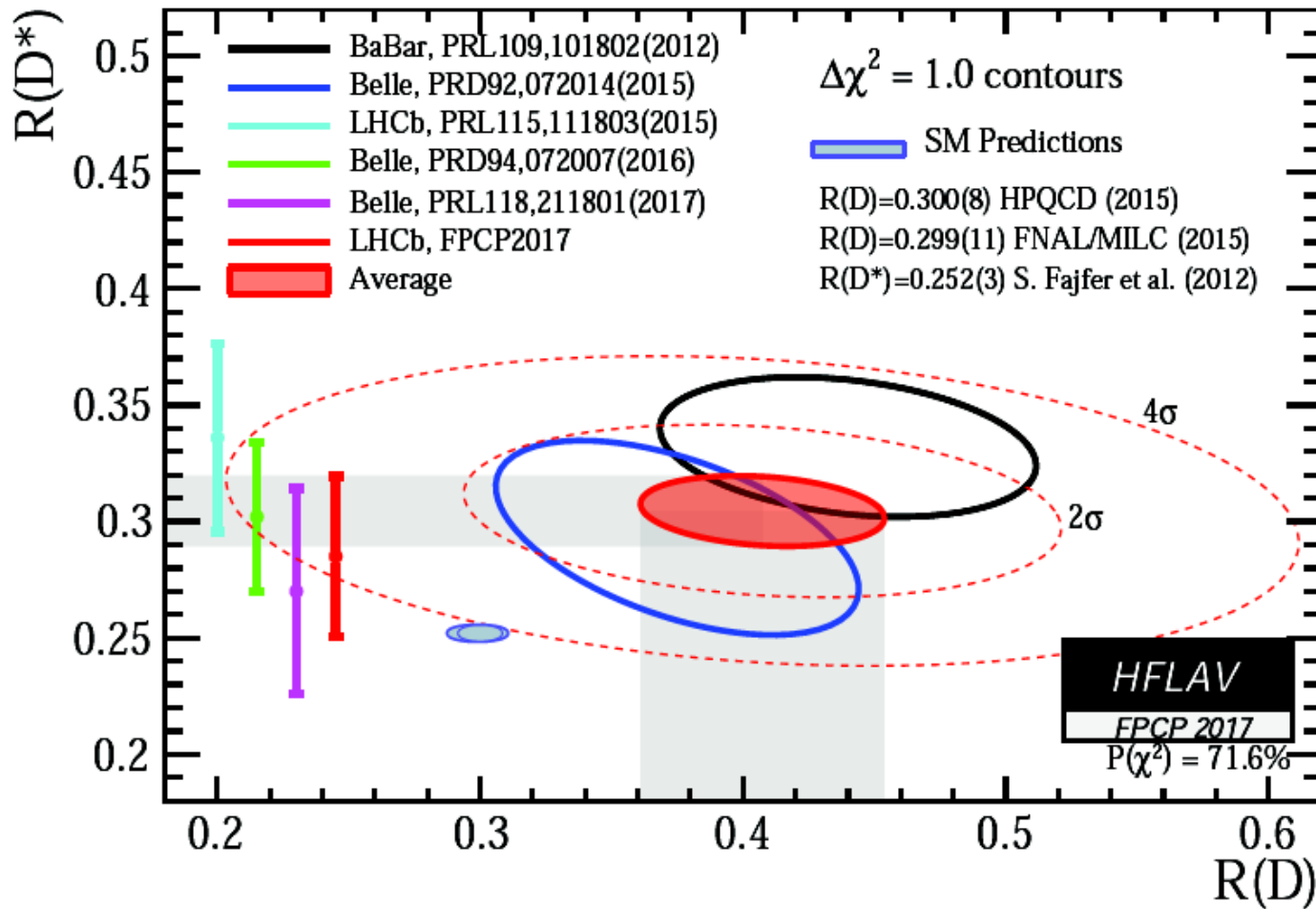
b-s anomaly

- $B \rightarrow K^* \mu^+ \mu^-$ • up to 3.7σ ??
- $B_s \rightarrow \varphi \mu^+ \mu^-$ • about 2.2σ
- $B_s \rightarrow \mu^+ \mu^-$ • less than 2σ

- Phys.Rev. D91 (2015) no.7, 074007 ([arXiv:1502.05280](#))
- Phys.Rev. D93 (2016) no.9, 094022 ([arXiv:1602.07864](#))
- Phys.Part.Nucl.Lett. 15 (2018) no.4, 393-396 ([arXiv:1807.04996](#))

Now*

b-c transition



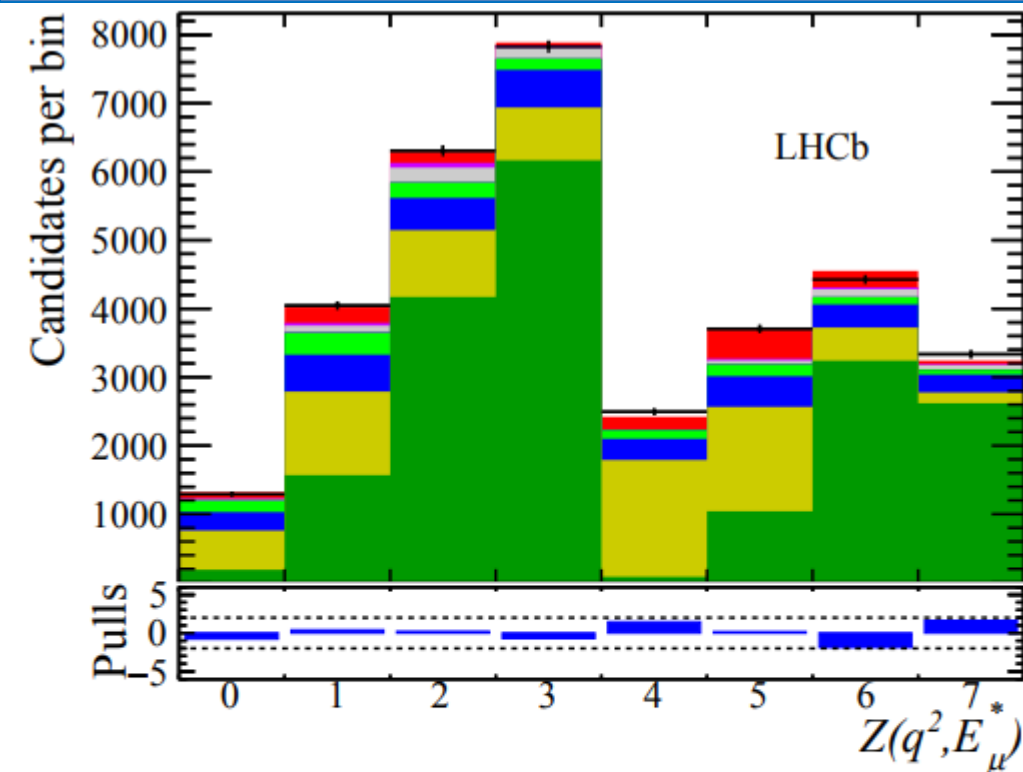
* Pavel KROKOVNY &
 Daniel CERVENKOV

Experimental data

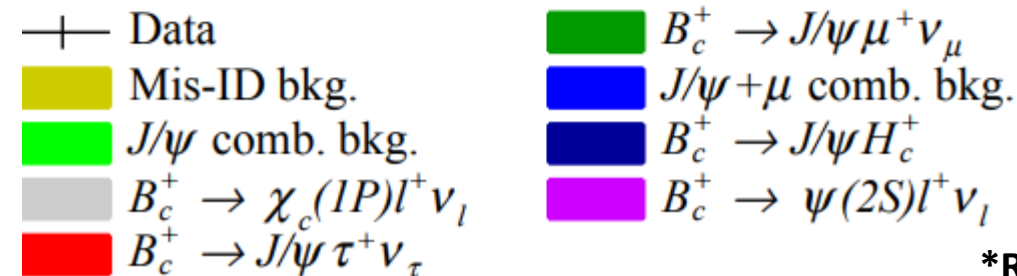
Relative decay rates of B_c meson.

Parameter	Measurements	Average
$\mathcal{B}(B_c^- \rightarrow J/\psi D_s^-)/\mathcal{B}(B_c^- \rightarrow J/\psi \pi^-)$	LHCb [5]: $2.90 \pm 0.57 \pm 0.24$ ATLAS [13]: $3.8 \pm 1.1 \pm 0.4$	3.09 ± 0.55
$\mathcal{B}(B_c^- \rightarrow J/\psi D_s^{*-})/\mathcal{B}(B_c^- \rightarrow J/\psi D_s^-)$	ATLAS [13]: $2.8^{+1.2}_{-0.8} \pm 0.3$ LHCb [5]: $2.37 \pm 0.56 \pm 0.10$	2.69 ± 0.78
$\mathcal{B}(B_c^- \rightarrow J/\psi D_s^{*-})/\mathcal{B}(B_c^- \rightarrow J/\psi \pi^-)$	ATLAS [13]: $10.4 \pm 3.1 \pm 1.6$	10.4 ± 3.5
$\mathcal{B}(B_c^- \rightarrow J/\psi K^-)/\mathcal{B}(B_c^- \rightarrow J/\psi \pi^-)$	LHCb [29]: $0.069 \pm 0.019 \pm 0.005$	0.069 ± 0.020
$\mathcal{B}(B_c^- \rightarrow J/\psi K^- K^+ \pi^-)/\mathcal{B}(B_c^- \rightarrow J/\psi \pi^-)$	LHCb [12]: $0.53 \pm 0.10 \pm 0.05$	0.53 ± 0.11
$\mathcal{B}(B_c^- \rightarrow J/\psi \pi^+ \pi^- \pi^-)/\mathcal{B}(B_c^- \rightarrow J/\psi \pi^-)$	LHCb [30]: $3.0 \pm 0.6 \pm 0.4$ LHCb [10]: $2.41 \pm 0.30 \pm 0.33$ CMS [31]: $2.55 \pm 0.80^{+0.33}_{-0.33}$	2.57 ± 0.35
$\mathcal{B}(B_c^- \rightarrow \psi(2S) \pi^-)/\mathcal{B}(B_c^- \rightarrow J/\psi \pi^-)$	LHCb [32]: $0.268 \pm 0.032 \pm 0.009$	0.268 ± 0.033

Semileptonic decays of B_c meson



$$\frac{\mathcal{B}(B_c^+ \rightarrow J/\psi \tau^+ \nu_\tau)}{\mathcal{B}(B_c^+ \rightarrow J/\psi \mu^+ \nu_\mu)} = 0.71 \pm 0.17(stat) \pm 0.18(syst).$$



*R. Aaij et al. Phys.Rev.Lett. 120 (2018) no.12, 121801
arXiv:1711.05623

Model parameters

$m_{u/d}$	m_s	m_c	m_b	λ	
0.241	0.428	1.67	5.05	0.181	GeV

Λ_{B_c}	Λ_{η_c}	$\Lambda_{J/\psi}$	Λ_D	Λ_{D^*}	Λ_{D_s}	$\Lambda_{D_s^*}$	Λ_B	Λ_{B^*}	Λ_{B_s}	
2.73	3.87	1.74	1.6	1.53	1.75	1.56	1.96	1.8	2.05	GeV

m_{B_c}	m_{η_c}	$m_{J/\psi}$	m_D	m_{D^*}	m_{D_s}	$m_{D_s^*}$		τ_{B_c}
6.275	2.984	3.097	1.869	2.010	1.968	2.112	GeV	0.507ps

***C. Patrignani et al. [Particle Data Group], Chin. Phys. C 40 (2016) no.10, 100001.**

Leptonic decay constants

$$M(H_{12} \rightarrow \bar{l}\nu) = \frac{G_F}{\sqrt{2}} V_{q_1 q_2} \mathcal{M}_H^\mu(p) \bar{u}_l(k_l) O^\mu u_\nu(k_\nu),$$

$$\mathcal{M}_H^\mu(p) = -3 g_{12} \int \frac{d^4 k}{(2\pi)^4 i} \widetilde{\Phi}_{12}(-k^2) \text{tr} \left[\Gamma_H \widetilde{S}_2(k - c_{12}^2 p) O^\mu \widetilde{S}_1(k + c_{12}^1 p) \right],$$

$$\Gamma_P = i\gamma^5, \quad \Gamma_V = \varepsilon_V \cdot \gamma,$$

$$\mathcal{M}_P^\mu(p) = -if_P p^\mu, \quad \mathcal{M}_V^\mu(p) = f_V m_V \varepsilon_V^\mu.$$

f_{B_c}	f_{η_c}	$f_{J/\psi}$	f_D	f_{D^*}	f_{D_s}	$f_{D_s^*}$
489	628	415	206	244	257	272

* Dubnicka, Dubnickova, Issadykov, Ivanov, Liptaj, Phys.Rev. D96 (2017) no.7, 076017

Form factors B_c decays

TABLE IV. $q^2 = 0$ results for the various form factors.

	$B_c \rightarrow D$	$B_c^+ \rightarrow D_s$	$B_c \rightarrow \eta_c$
$F_+(0)$	0.186	0.254	0.74
$F_-(0)$	-0.160	-0.202	-0.39
	$B_c \rightarrow D^*$	$B_c \rightarrow D_s^*$	$B_c \rightarrow J/\psi$
$A_0(0)$	0.276	0.365	1.65
$A_+(0)$	0.151	0.190	0.55
$A_-(0)$	-0.236	-0.293	-0.87
$V(0)$	0.230	0.282	0.78

* Dubnicka, Dubnickova, Issadykov, Ivanov, Liptaj, Phys.Rev. D96 (2017) no.7, 076017

Form factors B_c decays

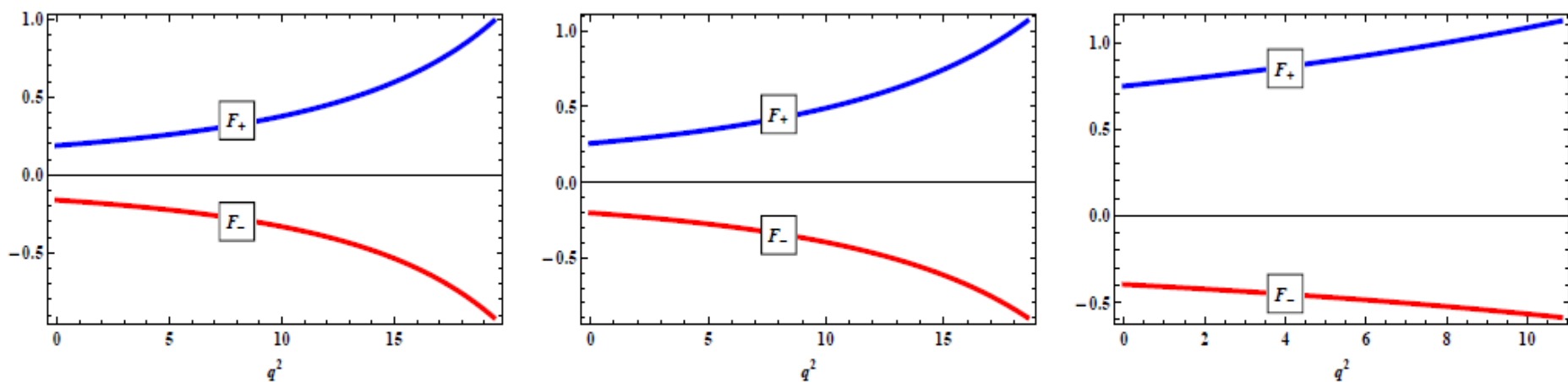


FIG. 1: The $F_+(q^2)$ and $F_-(q^2)$ form factors for $B_c \rightarrow D, B_c \rightarrow D_s$ and $B_c \rightarrow \eta_c$ transitions, respectively.

* Dubnicka, Dubnickova, Issadykov, Ivanov, Liptaj, Phys.Rev. D96 (2017) no.7, 076017

Form factors B_c decays

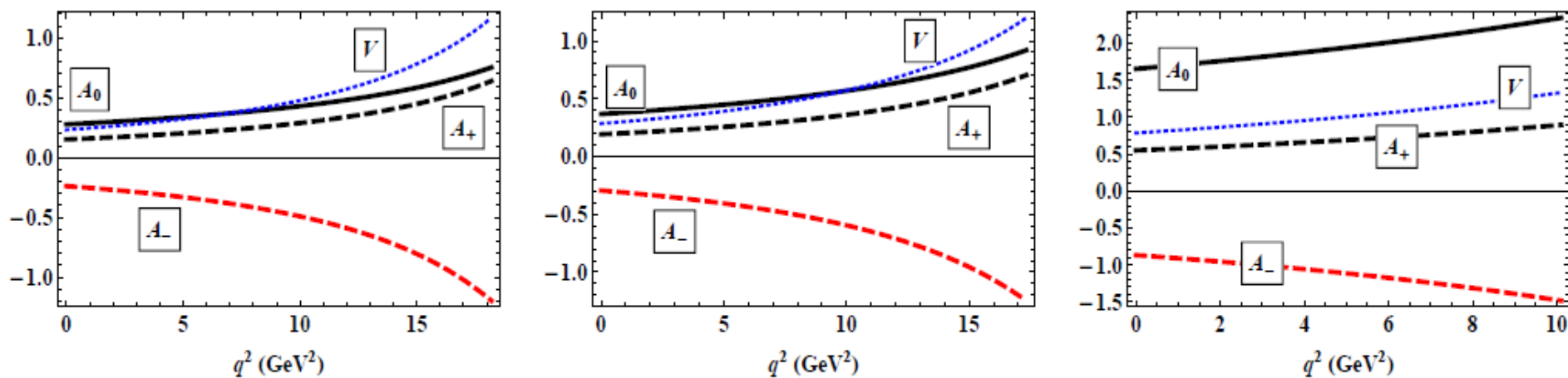


FIG. 2: The A_0, A_-, A_+ and V form factors for $B_c \rightarrow D^*$, $B_c \rightarrow D_s^*$ and $B_c \rightarrow J/\psi$ transitions, respectively.

* Dubnicka, Dubnickova, Issadykov, Ivanov, Liptaj, Phys.Rev. D96 (2017) no.7, 076017

Widths of semileptonic decays of B_c meson in terms of helicity amplitudes

The semileptonic B_c -decay widths are given by

$$\begin{aligned}\Gamma(B_c^- \rightarrow M_{\bar{c}c} l \bar{\nu}) &= \frac{G_F^2}{(2\pi)^3} |V_{cb}|^2 \int_{m_l^2}^{q_-^2} dq^2 \frac{(q^2 - m_l^2)^2 |\mathbf{p}_2|}{12 m_1^2 q^2} \\ &\quad \times \left\{ \left(1 + \frac{m_l^2}{2 q^2} \right) \sum_{i=\pm,0} \left(H_i^{B_c \rightarrow M_{\bar{c}c}}(q^2) \right)^2 + \frac{3 m_l^2}{2 q^2} \left(H_t^{B_c \rightarrow M_{\bar{c}c}}(q^2) \right)^2 \right\}, \\ \Gamma(B_c^- \rightarrow \bar{D}^0 l \bar{\nu}) &= \frac{G_F^2}{(2\pi)^3} |V_{ub}|^2 \int_{m_l^2}^{q_-^2} dq^2 \frac{(q^2 - m_l^2)^2 |\mathbf{p}_2|}{12 m_1^2 q^2} \\ &\quad \times \left\{ \left(1 + \frac{m_l^2}{2 q^2} \right) \sum_{i=\pm,0} \left(H_i^{B_c \rightarrow \bar{D}^0}(q^2) \right)^2 + \frac{3 m_l^2}{2 q^2} \left(H_t^{B_c \rightarrow \bar{D}^0}(q^2) \right)^2 \right\},\end{aligned}$$

where $q^2 = (m_1 - m_2)^2$, $m_1 \equiv m_{B_c}$, and $m_2 \equiv m_f$. Note that $M_{\bar{c}c}$ and $\bar{D}^0$ denote both the pseudoscalar and vector cases.

Semileptonic decays of B_c meson

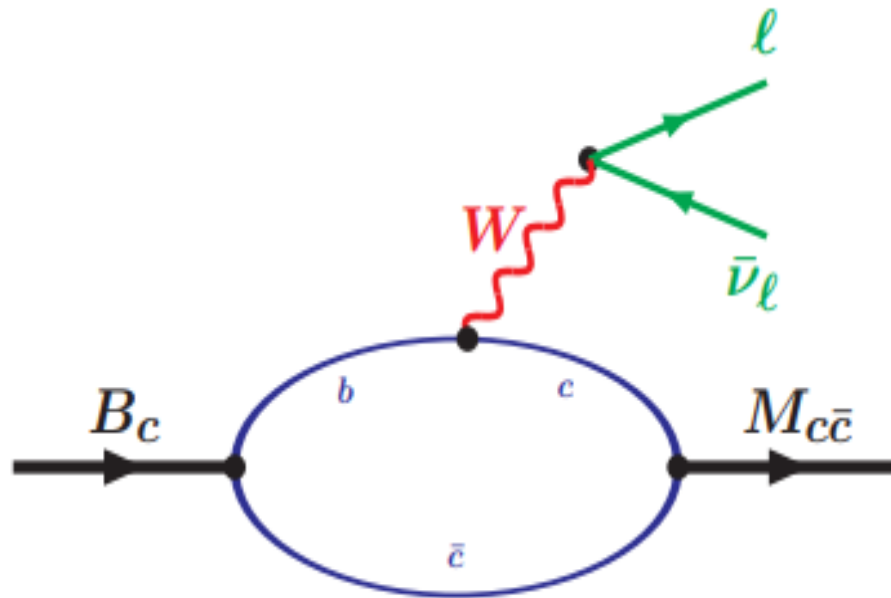


FIG. 3: Pictorial representation of the semileptonic B_c decays.

Branching ratios of semileptonic B_c decays

Table 3. Branching ratios (in %) of semileptonic B_c decays into ground state charmonium states.

Mode	This work	[23]	[7]	[24, 25]	[26]	[27]	[28]
$B_c^- \rightarrow \eta_c \ell \nu$	0.95	0.81	0.98	0.75	0.97	0.59	0.44
$B_c^- \rightarrow \eta_c \tau \nu$	0.24	0.22	0.27	0.23		0.20	0.14
$B_c^- \rightarrow J/\psi \ell \nu$	1.67	2.07	2.30	1.9	2.35	1.20	1.01
$B_c^- \rightarrow J/\psi \tau \nu$	0.40	0.49	0.59	0.48		0.34	0.29
$B_c^- \rightarrow \overline{D}^- \ell \nu$	0.0033	0.0035	0.018		0.004	0.006	0.0032
$B_c^- \rightarrow \overline{D}^- \tau \nu$	0.0021	0.0021	0.0094	0.002			0.0022
$B_c^- \rightarrow \overline{D}^{*-} \ell \nu$	0.006	0.0038	0.034		0.018	0.018	0.011
$B_c^- \rightarrow \overline{D}^{*-} \tau \nu$	0.0034	0.0022	0.019	0.008			0.006

Branching ratios of semileptonic B_c decays

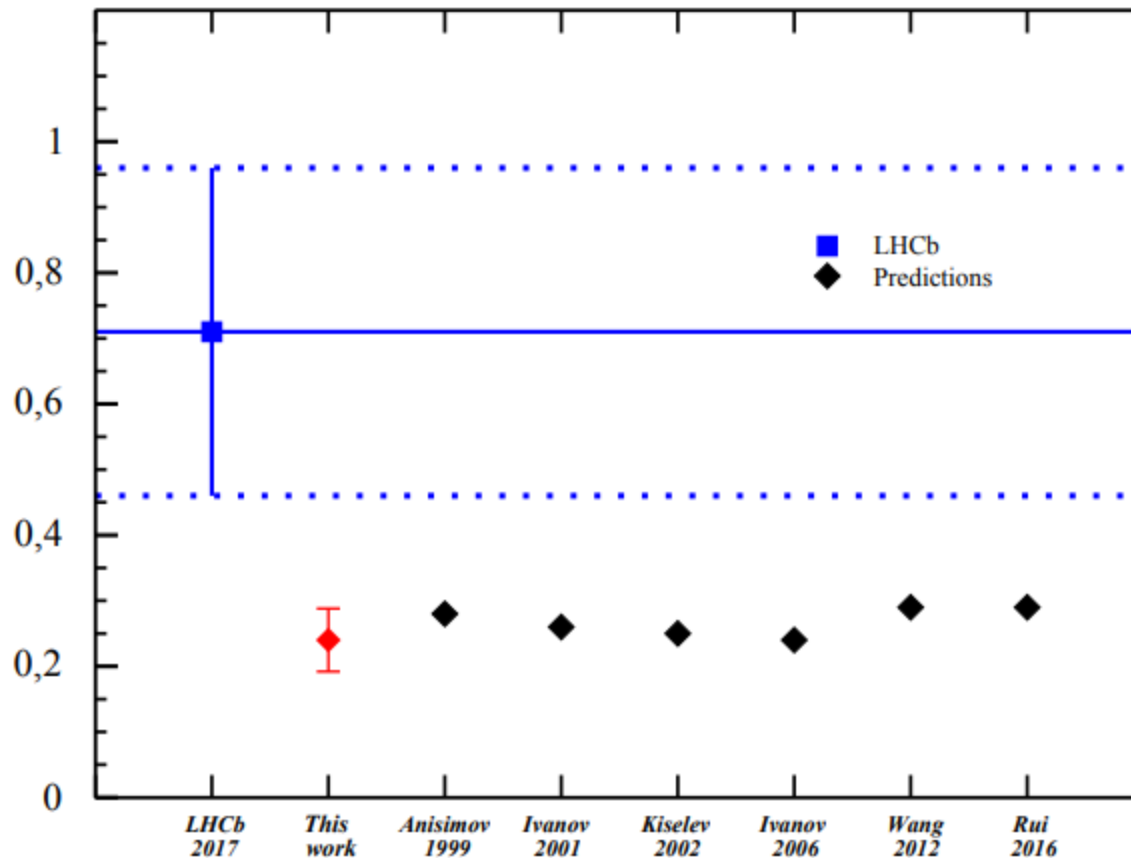
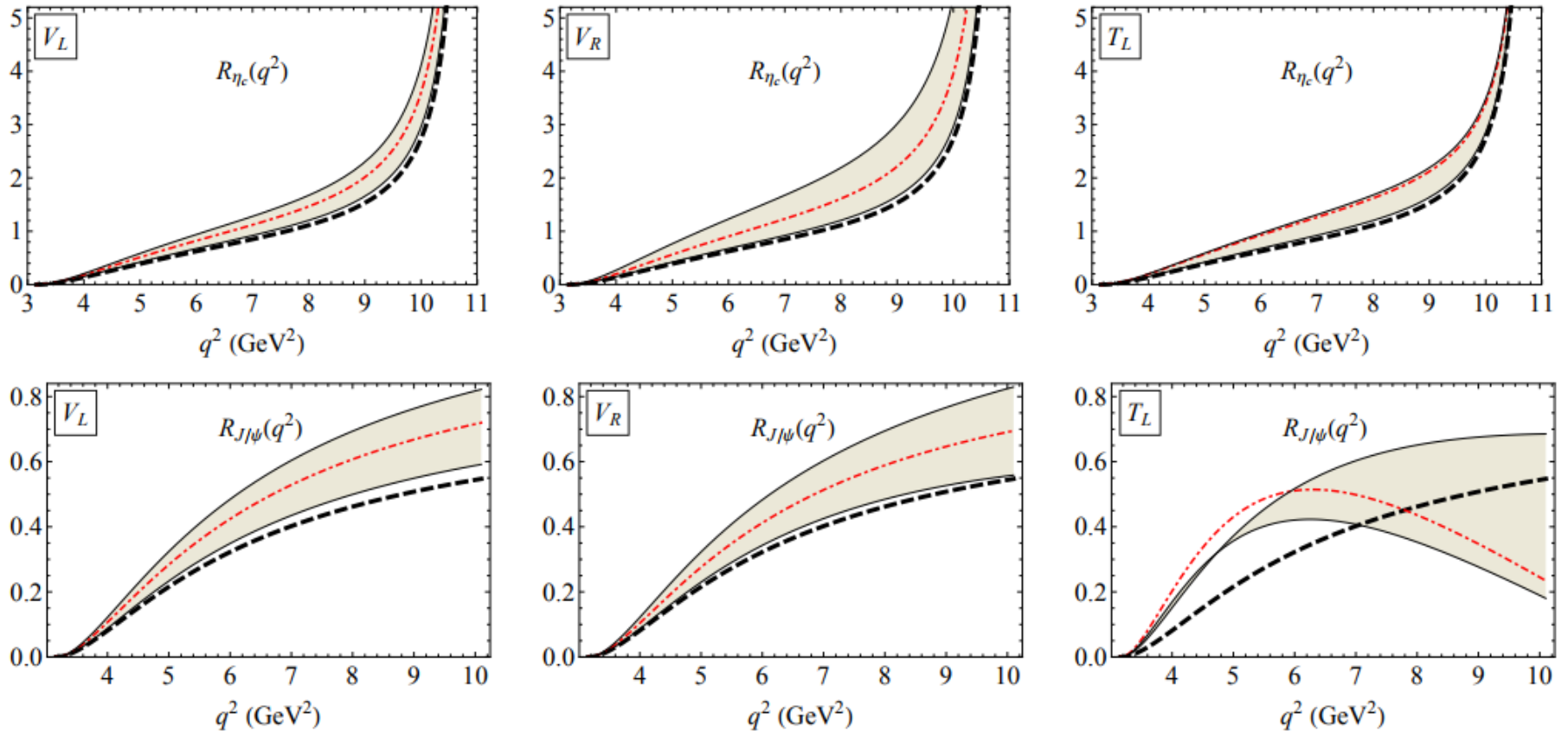


Figure 2: Theoretical predictions vs. LHCb data [15] for the ratio $\mathcal{R}_{\mathcal{J}/\psi}$. Solid line—central experimental value, dotted lines—experimental error bar.

New Physics effects in semileptonic B_c decays



*Tran, Ivanov, Körner, Santorelli, Phys.Rev. D97 (2018) no.5, 054014
arXiv:1801.06927

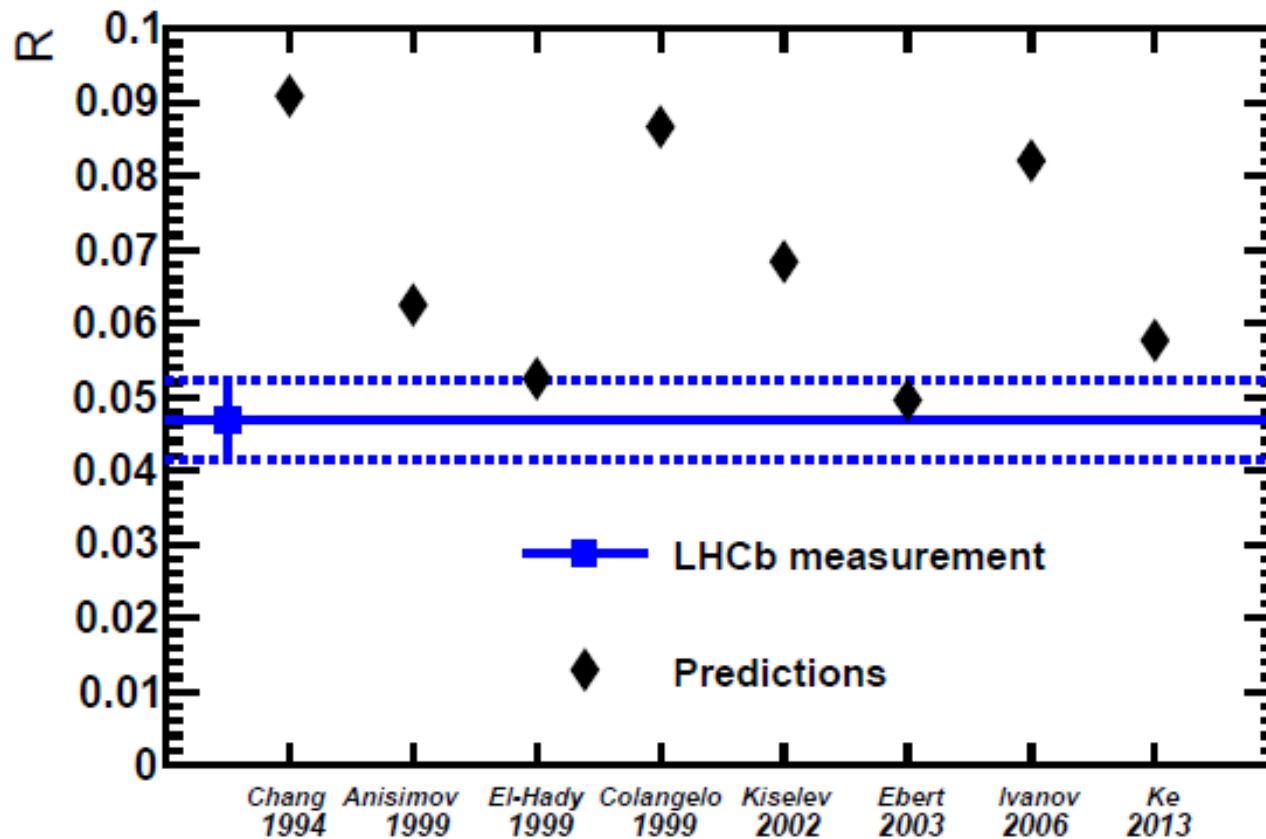
Nonleptonic decays of B_c meson

LHCb collaboration:

$$\frac{B(B_c^+ \rightarrow J/\psi \pi^+)}{B(B_c^+ \rightarrow J/\psi \ell^+ \nu)} = 0.0469 \pm 0.0028(stat) \pm 0.0046(syst).$$

***R. Aaij et al. [LHCb Collaboration], Phys. Rev. D 90 (2014) no.3, 032009**

LHCb data 2014



*R. Aaij et al. [LHCb Collaboration], Phys. Rev. D 90 (2014) no.3, 032009

Nonleptonic decays of B_c meson

LHCb collaboration(nonleptonic):

$$\frac{B(B_c^+ \rightarrow J/\psi K^+)}{B(B_c^+ \rightarrow J/\psi \pi^+)} = 0.069 \pm 0.0019(stat) \pm 0.005(syst).$$

***R. Aaij et al. [LHCb Collaboration], JHEP 1309 (2013) 075**

The predicted ratio of these branching fractions is proportional to

$$\frac{B(B_c^+ \rightarrow J/\psi K^+)}{B(B_c^+ \rightarrow J/\psi \pi^+)} \approx \left| \frac{V_{us} f_{K^+}}{V_{ud} f_{\pi^+}} \right|^2 = 0.077$$

$$\frac{B(B_c^+ \rightarrow J/\psi K^+)}{B(B_c^+ \rightarrow J/\psi \pi^+)} = 0.079 \pm 0.007(stat) \pm 0.003(syst).$$

***R. Aaij et al. [LHCb Collaboration], JHEP 1609 (2016) 153**

Nonleptonic decays of B_c meson

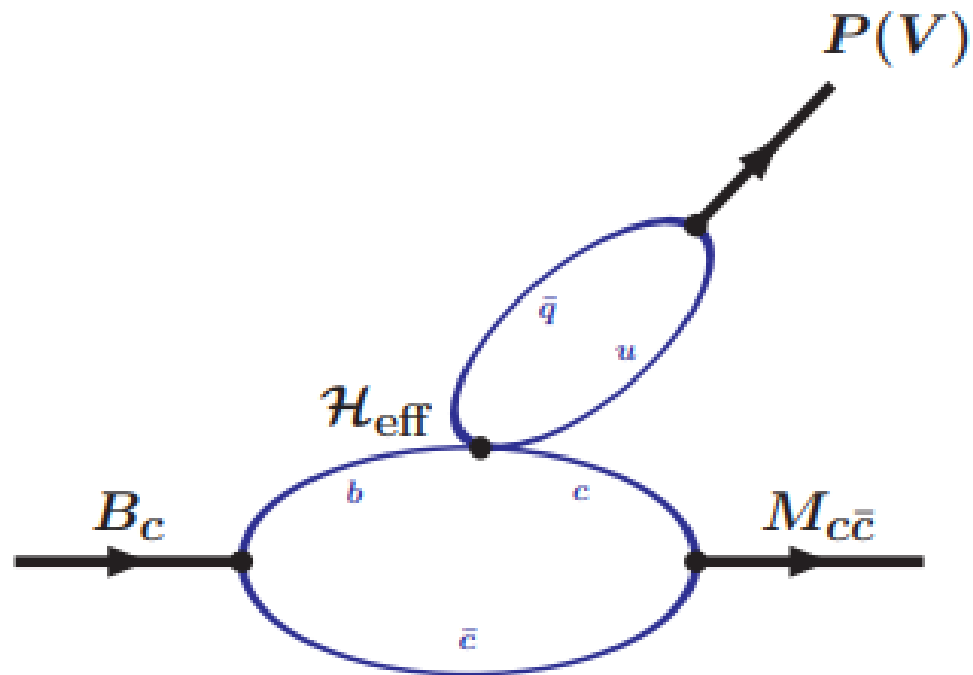


FIG. 2: Pictorial representation of the matrix elements of the nonleptonic B_c decays.

Nonleptonic decays of B_c meson

The nonleptonic B_c decay widths in terms of the helicity amplitudes are given by

$$\Gamma(B_c^+ \rightarrow P^+ M_{\bar{c}c}) = \frac{G_F^2}{16\pi} \frac{|\mathbf{p}_2|}{m_1^2} |V_{cb} V_{uq}^* \underline{a_1} f_P m_P|^2 \left(H_t^{B_c \rightarrow M_{\bar{c}c}}(m_P^2) \right)^2, \\ (P^+ = \pi^+, K^+, \text{ and } q = d, s, \text{ respectively}),$$

$$\Gamma(B_c^+ \rightarrow V^+ M_{\bar{c}c}) = \frac{G_F^2}{16\pi} \frac{|\mathbf{p}_2|}{m_1^2} |V_{cb} V_{uq}^* \underline{a_1} f_V m_V|^2 \sum_{i=0,\pm} \left(H_i^{B_c \rightarrow M_{\bar{c}c}}(m_V^2) \right)^2, \\ (V^+ = \rho^+, K^{*+}, \text{ and } q = d, s, \text{ respectively}).$$

Nonleptonic decays of B_c meson

Table 3: Nonleptonic decay widths of the B_c meson in units of $a_1^2 \cdot 10^{-15}$ GeV.

Mode	This work	[2]	[3]	[4]	[5]
$B_c^+ \rightarrow \eta_c \pi^+$	2.28 ± 0.46	2.07	1.59	0.28	1.47
$B_c^+ \rightarrow \eta_c \rho^+$	3.15 ± 0.63	5.48	3.74	0.75	3.35
$B_c^+ \rightarrow \eta_c K^+$	0.17 ± 0.03	0.16	0.12	0.023	0.15
$B_c^+ \rightarrow \eta_c K^{*+}$	0.19 ± 0.04	0.29	0.20	0.04	0.24
$B_c^+ \rightarrow J/\psi \pi^+$	1.22 ± 0.24	1.97	1.22	1.48	0.82
$B_c^+ \rightarrow J/\psi \rho^+$	2.03 ± 0.41	5.95	3.48	4.14	2.32
$B_c^+ \rightarrow J/\psi K^+$	0.09 ± 0.02	0.15	0.09	0.08	0.08
$B_c^+ \rightarrow J/\psi K^{*+}$	0.13 ± 0.03	0.32	0.20	0.23	0.18
Mode	[8]	[9]	[16]	[26]	
$B_c^+ \rightarrow \eta_c \pi^+$	0.93	2.11	1.18 ± 0.10	1.49	
$B_c^+ \rightarrow \eta_c \rho^+$	2.3	5.10	$2.89^{+0.51}_{-0.46}$	3.93	
$B_c^+ \rightarrow \eta_c K^+$	0.07	0.166	0.092 ± 0.0078	0.12	
$B_c^+ \rightarrow \eta_c K^{*+}$	0.12	0.276	0.17 ± 0.02	0.20	
$B_c^+ \rightarrow J/\psi \pi^+$	0.67	1.93	1.24 ± 0.11	1.01	
$B_c^+ \rightarrow J/\psi \rho^+$	1.8	5.49	$3.59^{+0.64}_{-0.58}$	3.25	
$B_c^+ \rightarrow J/\psi K^+$	0.05	0.15	0.095 ± 0.008	0.08	
$B_c^+ \rightarrow J/\psi K^{*+}$	0.11	0.31	0.226 ± 0.03	0.17	

Model parameters

f_π	f_K	f_ρ	f_{K^*}
130.3	156.0	221.0	226.8

We will use the numerical values of the Wilson coefficients from [24] obtained at the scale $\mu = 4$ GeV at leading order with $\Lambda_{MS}^{(5)} = 225$ MeV. One has $C_2 = 1.141$ and $C_1 = -0.310$ that gives $a_1 = C_2 + \xi C_1 = 1.038$. Note that this value has been also used in the paper [25]. It differs from the most old papers where the color-suppressed factor ξ was set to zero.

Nonleptonic decays of B_c meson

Table 5: The ratios of branching fractions.

Ref.	$\mathcal{R}_{\pi^+/\mu^+\nu}$	$\mathcal{R}_{K^+/\pi^+}$	$\mathcal{R}_{\eta_c}$	$\mathcal{R}_{J/\psi}$
LHCb [1]	0.0469 ± 0.0054	0.069 ± 0.019 0.079 ± 0.0076		0.71 ± 0.25
LHCb[10]				
LHCb [11]				
LHCb[15]				
This work	0.0605 ± 0.012	0.076 ± 0.015	0.26 ± 0.05	0.24 ± 0.05
[3]	0.0525	0.074		
[4]	0.0866	0.058		
[5]	0.0625	0.096		
[6]	0.058	0.075		
[7]	0.068	0.085	0.31	0.25
[8]	0.0496	0.077	0.27	0.24
[9]	0.082	0.076		
[14]		0.075		
[16]	$0.064^{+0.007}_{-0.008}$	$0.072^{+0.019}_{-0.008}$	0.63 ± 0.0	$0.29^{+0.01}_{-0.00}$
[18, 27]	$0.046^{+0.003}_{-0.002}$	0.082		
[19]			0.31	0.29
[22]			0.28	0.26

Ratios of branching fractions

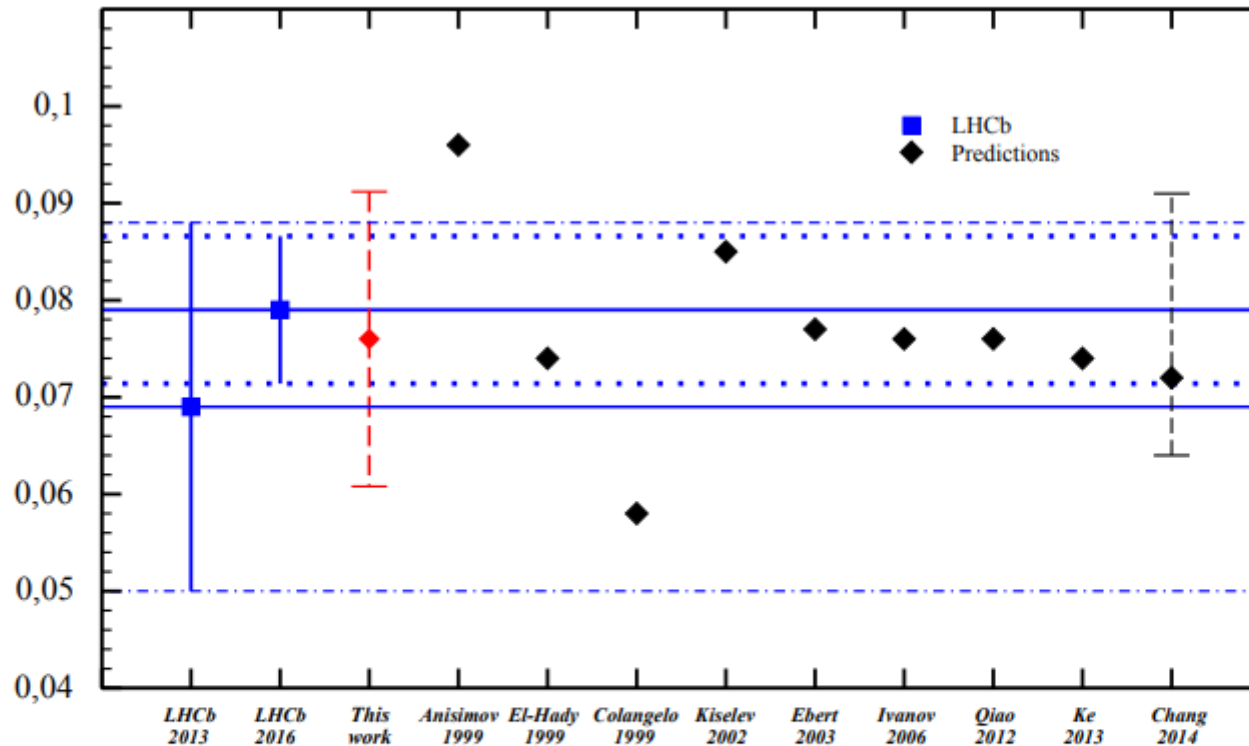


Figure 3: Theoretical predictions vs. LHCb data [10] and [11] for the ratio $\mathcal{R}_{K^+/\pi^+}$. Two solid lines—central experimental values, dash-dotted lines—experimental error bar from [10], dotted lines—experimental error bar from [11].

Ratios of branching fractions

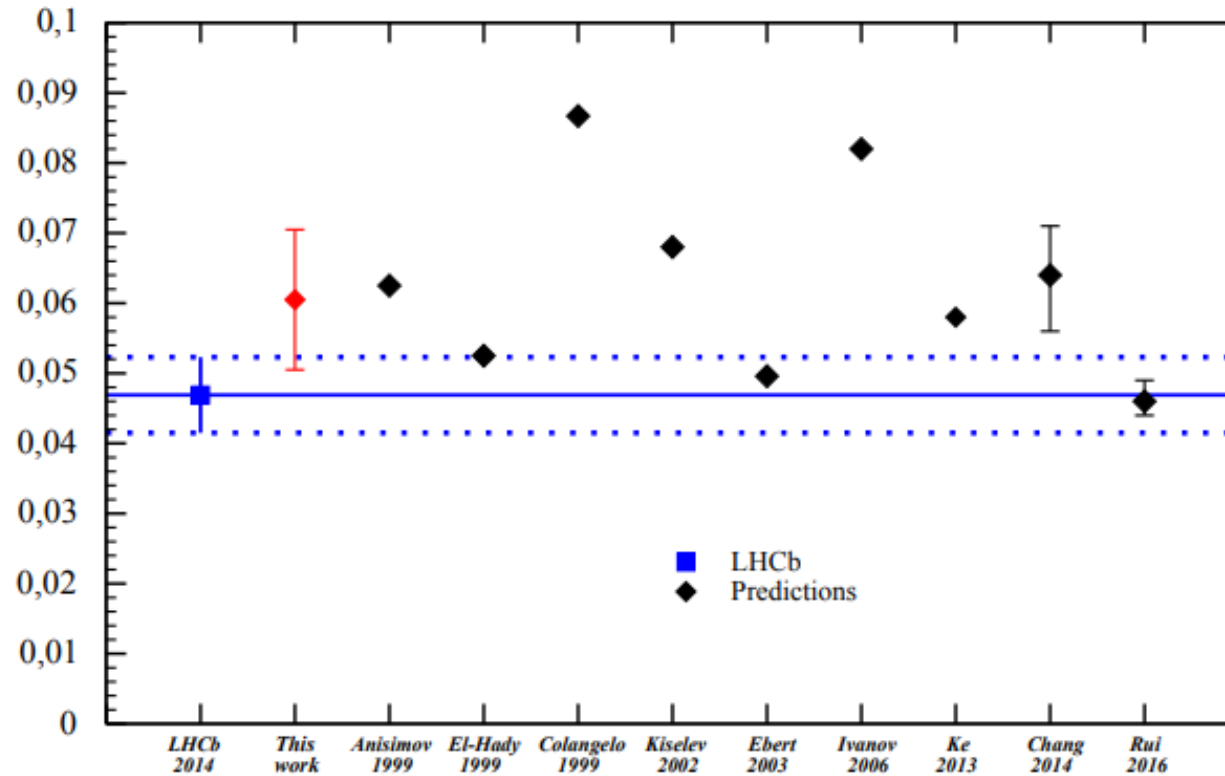


Figure 4: Theoretical predictions vs. LHCb data [1] for the ratio $\mathcal{R}_{\pi^+/\mu^+\nu_\mu}$. Solid line—central experimental value, dotted lines—experimental error bar.

Nonleptonic decays of B_c meson

$$\frac{\mathcal{B}(B_c^+ \rightarrow J/\psi D_s^+)}{\mathcal{B}(B_c^+ \rightarrow J/\psi \pi^+)} = 2.90 \pm 0.57(\text{stat}) \pm 0.24(\text{syst}).$$

$$\frac{\mathcal{B}(B_c^+ \rightarrow J/\psi D_s^{*+})}{\mathcal{B}(B_c^+ \rightarrow J/\psi D_s^+)} = 2.37 \pm 0.56(\text{stat}) \pm 0.10(\text{syst}).$$

*R. Aaij et al. (LHCb Collaboration), Phys. Rev. D 87, 112012 (2013); 89, 019901(E) (2014).

Nonleptonic decays of B_c meson

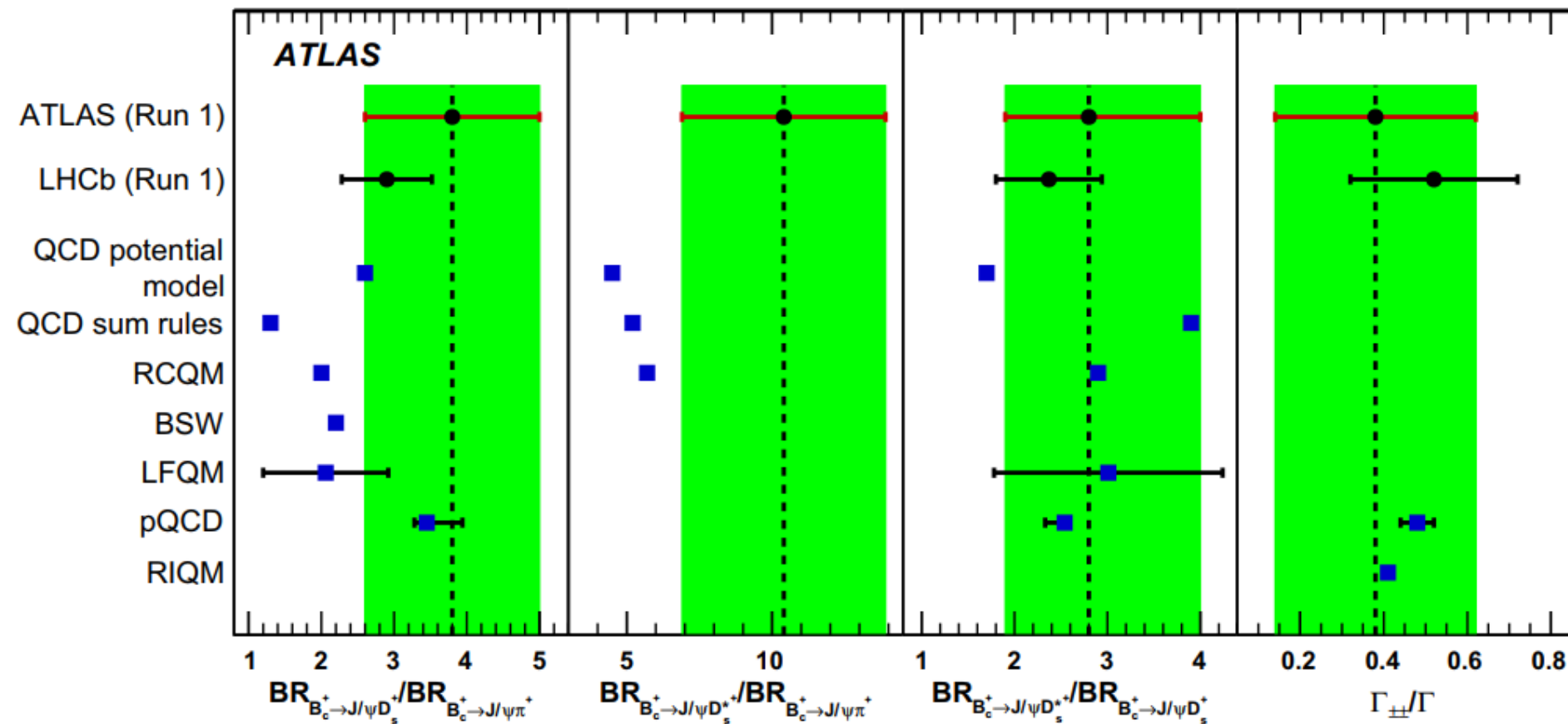
$$\mathcal{R}_{D_s^+/\pi^+} = \frac{\mathcal{B}_{B_c^+ \rightarrow J/\psi D_s^+}}{\mathcal{B}_{B_c^+ \rightarrow J/\psi \pi^+}} = 3.8 \pm 1.1(\text{stat.}) \pm 0.4(\text{syst.}) \pm 0.2(\text{BF}),$$

$$\mathcal{R}_{D_s^{*+}/\pi^+} = \frac{\mathcal{B}_{B_c^+ \rightarrow J/\psi D_s^{*+}}}{\mathcal{B}_{B_c^+ \rightarrow J/\psi \pi^+}} = 10.4 \pm 3.1(\text{stat.}) \pm 1.5(\text{syst.}) \pm 0.6(\text{BF}),$$

$$\mathcal{R}_{D_s^{*+}/D_s^+} = \frac{\mathcal{B}_{B_c^+ \rightarrow J/\psi D_s^{*+}}}{\mathcal{B}_{B_c^+ \rightarrow J/\psi D_s^+}} = 2.8_{-0.8}^{+1.2}(\text{stat.}) \pm 0.3(\text{syst.}),$$

***G. Aad et al. (ATLAS Collaboration), Eur. Phys. J. C 76, 4 (2016).**

Nonleptonic decays of B_c meson



*G. Aad et al. (ATLAS Collaboration), Eur. Phys. J. C 76, 4 (2016).

Nonleptonic decays of B_c meson

The nonleptonic B_c decay widths in terms of the helicity amplitudes are given by

$$\begin{aligned}\Gamma(B_c \rightarrow \eta_c D_q) &= N_W \{ a_1 f_{D_q^-} m_{D_q^-} H_t^{B_c \rightarrow \eta_c}(m_{D_q^-}^2) \\ &\quad + a_2 f_{\eta_c} m_{\eta_c} H_t^{B_c \rightarrow D_q^-}(m_{\eta_c}^2) \}^2, \\ \Gamma(B_c \rightarrow \eta_c D_q^*) &= N_W \{ a_1 f_{D_q^{*-}} m_{D_q^{*-}} H_0^{B_c \rightarrow \eta_c}(m_{D_q^{*-}}^2) \\ &\quad - a_2 f_{\eta_c} m_{\eta_c} H_t^{B_c \rightarrow D_q^{*-}}(m_{\eta_c}^2) \}^2, \\ \Gamma(B_c \rightarrow J/\psi D_q) &= N_W \{ -a_1 f_{D_q^-} m_{D_q^-} H_t^{B_c \rightarrow J/\psi}(m_{D_q^-}^2) \\ &\quad + a_2 f_{J/\psi} m_{J/\psi} H_0^{B_c \rightarrow D_q^-}(m_{J/\psi}^2) \}^2, \\ \Gamma(B_c \rightarrow J/\psi D_q^*) &= N_W \sum_{i=0,\pm} \{ a_1 f_{D_q^{*-}} m_{D_q^{*-}} H_i^{B_c \rightarrow J/\psi}(m_{D_q^{*-}}^2) \\ &\quad + a_2 f_{J/\psi} m_{J/\psi} H_i^{B_c \rightarrow D_q^{*-}}(m_{J/\psi}^2) \}^2,\end{aligned}$$

$$N_W \equiv \frac{G_F^2}{16\pi} \frac{|\mathbf{p}_2|}{m_1^2} |V_{cb} V_{cq}^\dagger|^2.$$

Nonleptonic decays of B_c meson

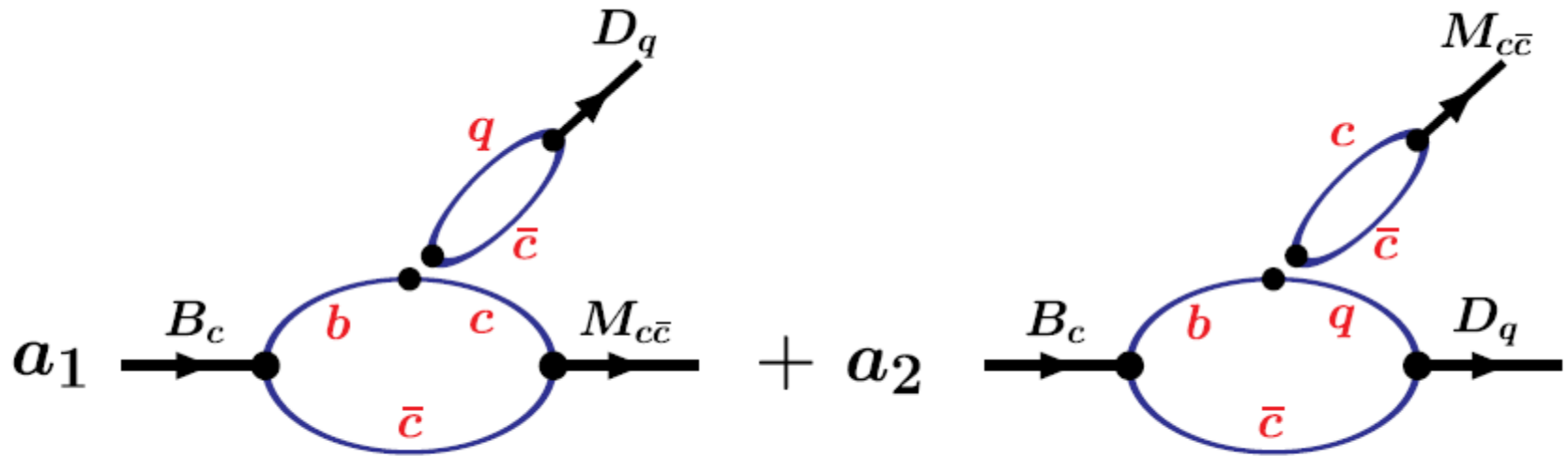


FIG. 1. Pictorial representation of the matrix elements of the nonleptonic B_c decays.

$$a_1 = C_2 + C_4 + \xi(C_1 + C_3) \text{ and } a_2 = C_1 + C_3 + \xi(C_2 + C_4)$$

$$a_1 = C_2 + C_4 = 0.93 \quad \text{and} \quad a_2 = C_1 + C_3 = -0.27$$

Nonleptonic decays of B_c meson

Mode	$a_1 = +0.93$ $a_2 = -0.27$	$a_1 = +1.14$ $a_2 = -0.20$
$B_c \rightarrow \eta_c D_s$	0.22	0.50
$B_c \rightarrow \eta_c D_s^*$	0.22	0.42
$B_c \rightarrow J/\psi D_s$	0.10	0.22
$B_c \rightarrow J/\psi D_s^*$	0.41	0.78
$B_c \rightarrow \eta_c D$	0.0073	0.016
$B_c \rightarrow \eta_c D^*$	0.0098	0.019
$B_c \rightarrow J/\psi D$	0.0035	0.0074
$B_c \rightarrow J/\psi D^*$	0.017	0.031

$$R_{D_s^{*+}/D_s^+} = \frac{B(B_c^+ \rightarrow J/\psi D_s^{*+})}{B(B_c^+ \rightarrow J/\psi D_s^+)} = \begin{cases} 3.55 & (a_1 = 1.14, a_2 = -0.20) \\ 3.96 & (a_1 = 0.93, a_2 = -0.27) \end{cases}$$

* Dubnicka, Dubnickova, Issadykov, Ivanov, Liptaj, Phys.Rev. D96 (2017) no.7, 076017

Ratios of branching fractions

$\mathcal{R}_{D_s^+/\pi^+}$	$\mathcal{R}_{D_s^{*+}/\pi^+}$	$\mathcal{R}_{D_s^{*+}/D_s^+}$	$\Gamma_{\pm\pm}/\Gamma$	Ref.
3.8 ± 1.2	10.4 ± 3.5	$2.8^{+1.2}_{-0.9}$	0.38 ± 0.24	ATLAS [1]
2.90 ± 0.62	...	2.37 ± 0.57	0.52 ± 0.20	LHCb [2]
1.29 ± 0.26	5.09 ± 1.02	3.96 ± 0.80	0.46 ± 0.09	CCQM
2.0	5.7	2.9	...	RCQM [3]
2.6	4.5	1.7	...	QCD PM [11]
1.3	5.2	3.9	...	QCD SR [12]
2.2	...	...	...	BSW RQM [16]
2.06 ± 0.86	...	3.01 ± 1.23	...	LFQM [17]
$3.45^{+0.49}_{-0.17}$	...	$2.54^{+0.07}_{-0.21}$	0.48 ± 0.04	pQCD [18]
...	...	...	0.410	RIQM [19]

$$\frac{\Gamma_{++}}{\Gamma} = \frac{\Gamma_{++}(B_c^+ \rightarrow J/\psi D_s^{*+})}{\Gamma(B_c^+ \rightarrow J/\psi D_s^{*+})}.$$

* Dubnicka, Dubnickova, Issadykov, Ivanov, Liptaj, Phys.Rev. D96 (2017) no.7, 076017

Conclusion

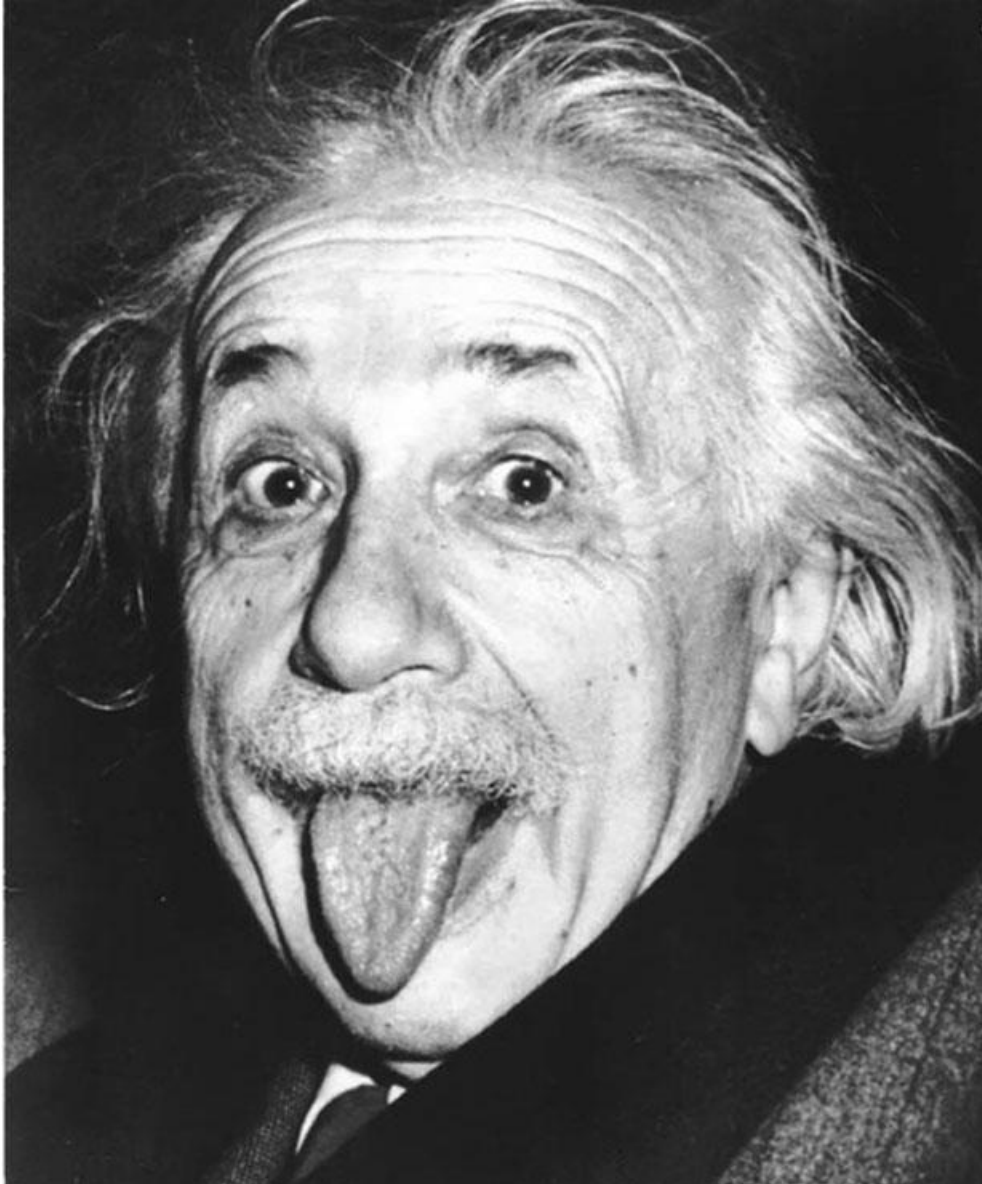
We have found that the theoretical predictions for the ratio $\mathcal{R}_{J/\psi}$ are more than 2σ less than the experimental data. This may indicate on the possibility of New physics effects in this decay.

At the same time the ratios of the branching fractions $\mathcal{R}_{\pi^+/\mu^+\nu}$ and $\mathcal{R}_{K^+/\pi^+}$ are in good agreement with the LHCb data and other theoretical approaches.

We found that our prediction for the ratios $\mathcal{R}_{D_s^*/D_s}$ and $\Gamma_{\pm\pm}/\Gamma$ are consistent with measurements and other approaches. The results for the ratios $\mathcal{R}_{D_s/\pi^+}$ and $\mathcal{R}_{D_s^*/\pi^+}$ are smaller than the measured values but the discrepancies do not exceed two standard deviations.

Since our result for $\mathcal{R}_{J/\psi}$ is different from the data at the level of 2σ , we can urge to more precise measurement of the $B_c \rightarrow J/\psi \ell \bar{\nu}_\ell$ channel which currently has quite large uncertainties. This might be very important since it may imply that the new physics (if there is any) has strong couplings to the leptons but not hadrons.

Thank you!



***A. Einstein**