IFIC INSTITUT DE FÍSICA CORPUSCULAR
CSIC CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS
VNIVERSITAT D VALÈNCIA

The $B_c \to J/\Psi KD$ weak decay and its relation with the $D^*_{s0}(2317)$ resonance

Pedro Fernandez-Soler
2 of june 2016. Presented at MESON 2016. Krakow, Poland

Table of contents

Based on:

"$D^*_{s0}(2317)^+$ in the decay of B_c into $J/\Psi DK$,"

Z. F. Sun, M. Bayar, P. Fernandez-Soler and E. Oset, Phys. Rev. D **93** (2016) no.5, 054028

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2. Several theoretical interpretations: $c\bar{s}$ state, molecular meson-meson, $K-D$-mixing, two meson and four quark state, four quark state
3. Lattice simulations have found the $D_{s0}^*(2317)$ state with a KD component of $\approx 70\%$

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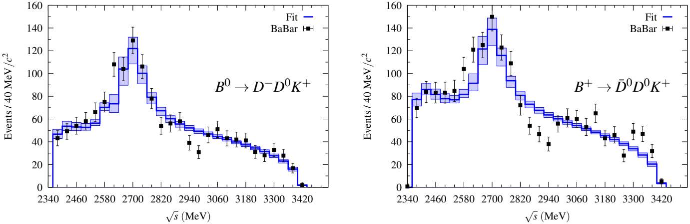

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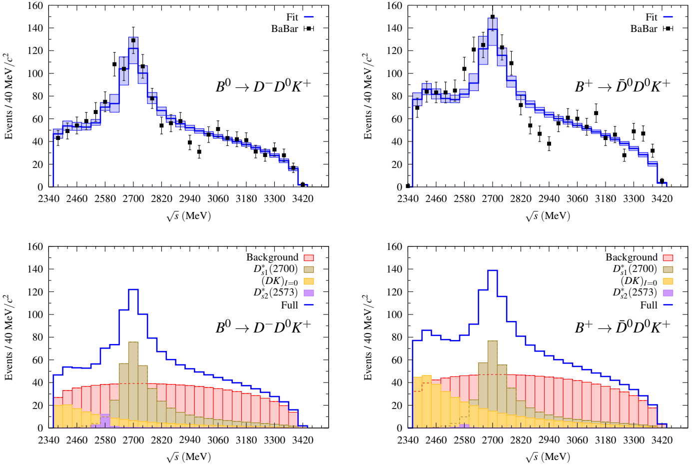

M. Albaladejo, D. Jido, J. Nieves and E. Oset, arXiv:1604.01193 [hep-ph].

II. Statement of the problem: weak decay of a heavy hadron

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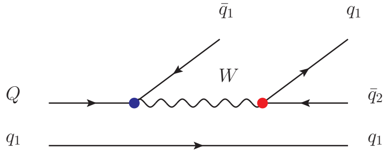

1. The dominant weak mechanism
   $H_W = \frac{G_F}{\sqrt{2}} V_{Qq_1} V_{q_1 q_2} \bar{q}_1 \gamma_\mu (1-\gamma_5) Q \bar{q}_2 \gamma^\mu (1-\gamma_5) q_1$

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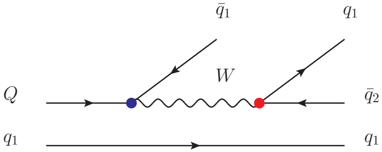

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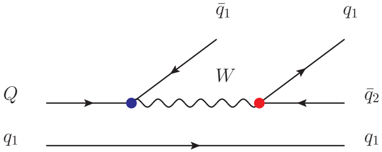

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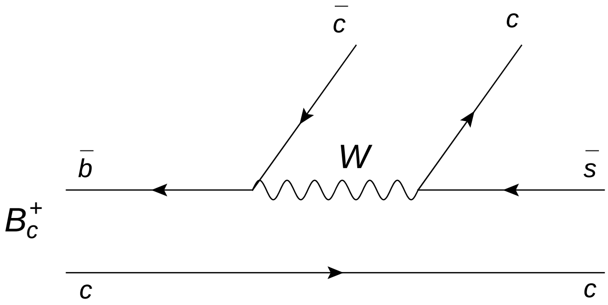
I. Weak decay of a heavy hadron. 2.



II. Theoretical approach: hadronization and rescattering.

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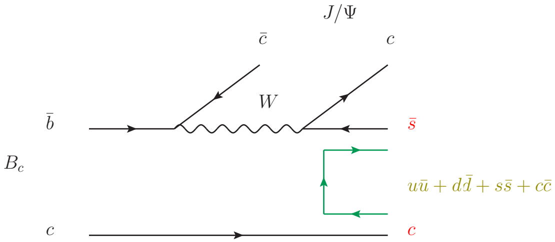

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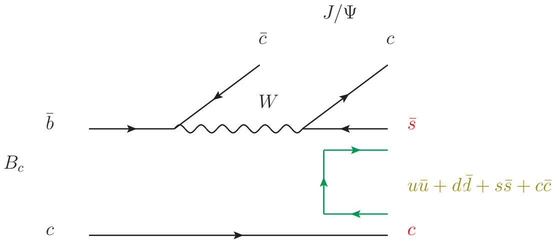

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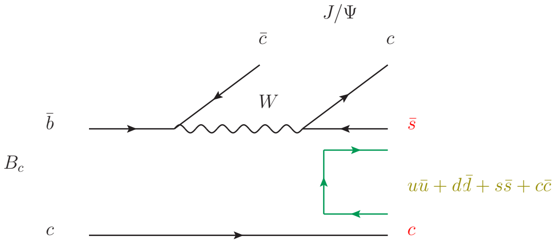

- An extra $q\bar{q}$ pair with the quantum numbers of the vacuum
- $c\bar{s}(u\bar{u} + d\bar{d} + c\bar{c} + s\bar{s})$
- Projection into meson-meson states is done with the M matrix

$$M = \begin{pmatrix} u\bar{u} & u\bar{d} & u\bar{s} & u\bar{c} \\ d\bar{u} & d\bar{d} & d\bar{s} & d\bar{c} \\ s\bar{u} & s\bar{d} & s\bar{s} & s\bar{c} \\ c\bar{u} & c\bar{d} & c\bar{s} & c\bar{c} \end{pmatrix} = \begin{pmatrix} u \\ d \\ s \\ c \end{pmatrix} \cdot \begin{pmatrix} \bar{u} & \bar{d} & \bar{s} & \bar{c} \end{pmatrix}$$

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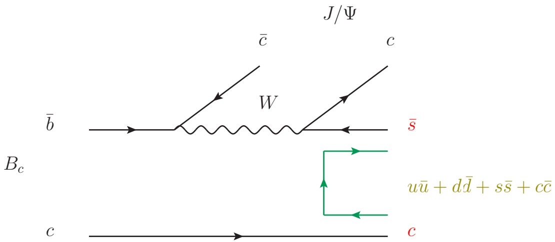

$$M^2 = \begin{pmatrix} u \\ d \\ s \\ c \end{pmatrix} \cdot \left[\begin{pmatrix} \bar{u} & \bar{d} & \bar{s} & \bar{c} \end{pmatrix} \cdot \begin{pmatrix} u \\ d \\ s \\ c \end{pmatrix} \right] \cdot \begin{pmatrix} \bar{u} & \bar{d} & \bar{s} & \bar{c} \end{pmatrix}$$

$$= M \left(u\bar{u} + d\bar{d} + s\bar{s} + c\bar{c} \right) \rightarrow (M^2)_{4,3} = c\bar{s}(u\bar{u} + d\bar{d} + c\bar{c} + s\bar{s})$$

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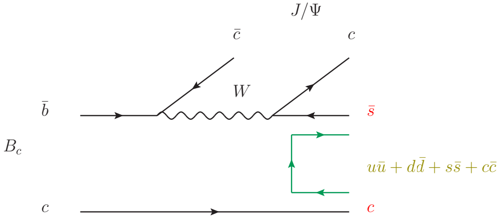
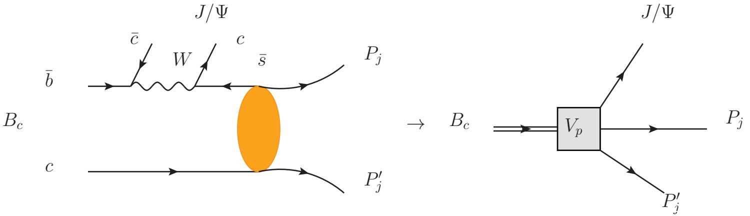


$$\phi = \begin{pmatrix} \frac{\eta}{\sqrt{3}} + \frac{\pi^0}{\sqrt{2}} + \frac{\eta'}{\sqrt{6}} & \pi^+ & K^+ & \bar{D}^0 \\ \pi^- & \frac{\eta}{\sqrt{3}} - \frac{\pi^0}{\sqrt{2}} + \frac{\eta'}{\sqrt{6}} & K^0 & D^- \\ K^- & \bar{K}^0 & \frac{2\eta'}{\sqrt{6}} - \frac{\eta}{\sqrt{3}} & D_s^- \\ D^0 & D^+ & D_s^+ & \eta_c \end{pmatrix}$$

$$(M^2)_{4,3} = c\bar{s}(u\bar{u} + d\bar{d} + c\bar{c} + s\bar{s})$$

$$(\phi^2)_{4,3} = D^0 K^+ + D^+ K^0 - \frac{1}{\sqrt{3}}\eta D_s^+ + \sqrt{\frac{2}{3}} D_s^+ \eta' + \eta_c D_s^+ \equiv \sum_j P_j P_j' h_j$$

II. Theoretical approach: *hadronization*. 3.



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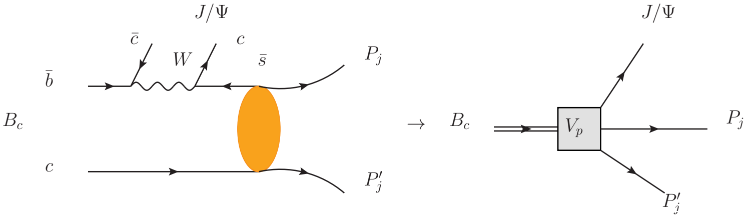

1. $t_{\text{Decay}}\left(B_c \rightarrow J/\Psi P_j P'_j\right) = V_p \times h_j$
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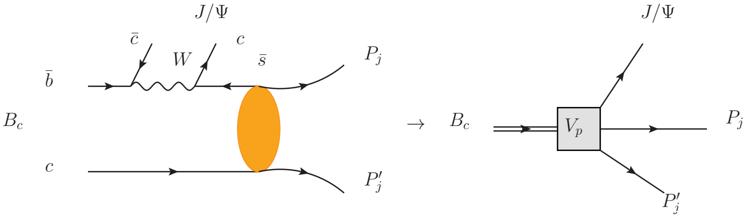
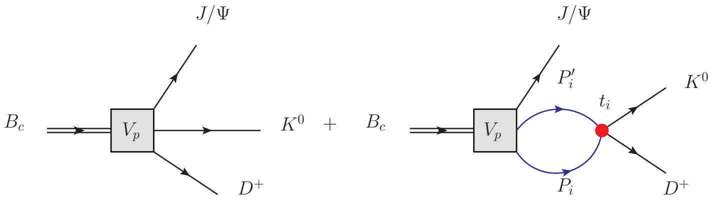


1. $t_{\text{Decay}}\left(B_c \rightarrow J/\Psi P_j P'_j\right) = V_p \times h_j$
2. The J/Ψ meson interaction will be neglected, OZI suppressed
3. There are more contributions to the final $J/\Psi P_j P'_j$ state



- $t_{\text{Decay}}\left(B_c \to J/\Psi K^0 D^+\right) = V_p \times \left(h_{K^0 D^+} + \sum_j G_j t_{j,K^0 D^+} h_j\right)$

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- The $t_{i,j}$ is the pseudoscalar interaction vertex relating channels i and j.

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- G is a diagonal matrix whose elements are the loop functions of the two mesons P_i, P'_i, in each channel

$$G_{i,i}(s = P^2) = \int_{\mathbb{R}^4} \frac{d^4q}{(2\pi)^4} \frac{1}{(P-q)^2 - m_i^2 + \mathrm{i}\epsilon} \frac{1}{q^2 - (m'_i)^2 + \mathrm{i}\epsilon}$$

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- $V_{i,j}$ is the kernel potential, L.O. S-wave amplitudes (GAMERMANN, OSET, STROTTMAN, VICENTE VACAS. PHYSICAL REVIEW D 76, 074016 (2007)), $\chi-$heavy-meson lagrangian

$$V_{i,j}(s) = \frac{1}{f_\pi}\left(A_{i,j}(m, m') + B_{i,j}(m, m')\, s + C_{i,j}(m, m')\,\frac{1}{s}\right)$$

III. Results and predictions for observables.

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- Fit the scattering free parameter α in order to have the $D^*_{s0}(2317)$ as a bound state. A pole in the t matrix, $t_{i,j} \approx \frac{g_i g_j}{s-(M_{D^*_{s0}(2317)})^2}$

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- The differential decay width $d\Gamma(B_c \to J/\Psi K D)/dM_{inv}$,

$$B_c \to J/\Psi K^0 D^+$$

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- The differential decay width $\mathrm{d}\Gamma(B_c \to J/\Psi KD)/\mathrm{d}M_{inv}$,

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-

$$\frac{\mathrm{d}\Gamma}{\mathrm{d}M_{\mathrm{inv}}} = A^2 \frac{p^3_{J/\Psi} p_{DK}}{(2\pi)^3 4 m^2_{B_c}} \left| \frac{t_{\mathrm{Decay}}\left(B_c \to J/\Psi D^+ K^0\right)}{V_p} \right|^2$$

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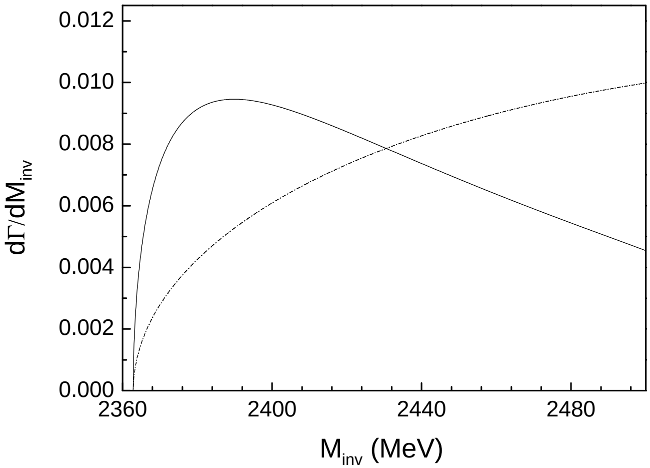
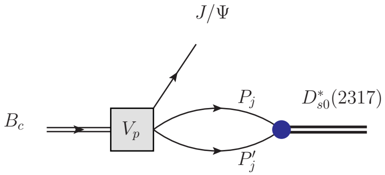


- $\Gamma(B_c \to J/\Psi D^*_{s0}(2317))$ Coalescence production of the $D^*_{s0}(2317)^+$: $t(B_c \to J/\Psi R) = V_p \sum_j h_j G_j g_j \Big|_{E=M_R}$



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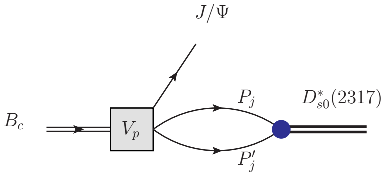

- $\frac{d\tilde{\Gamma}(B_c \to J/\Psi KD)}{dM_{inv}} = \frac{d\Gamma(B_c \to J/\Psi KD)}{dM_{inv}} \frac{1}{p^3_{J/\Psi} p_{DK}} \cdots$

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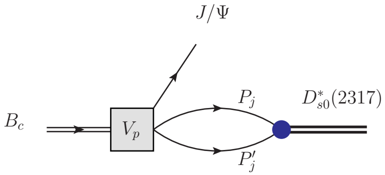

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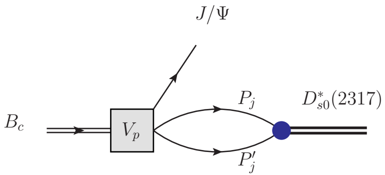

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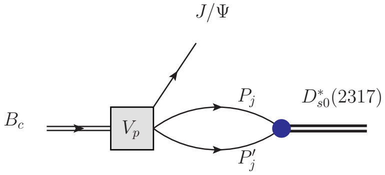

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$= \frac{M_R^2}{4\pi^2} \frac{\left| h_{D^+K^0} + \sum_i h_i G_i t_{i,D^+K^0} \right|^2}{\left| \sum_i h_i G_i g_i \right|^2 \Big|_{\text{pole}}},$
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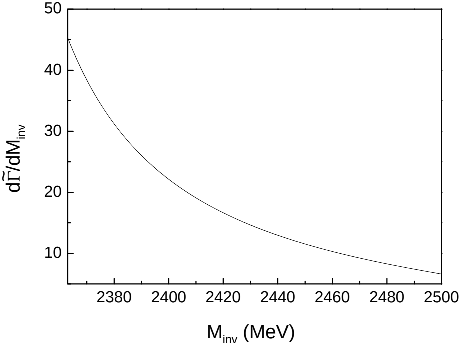

III. Results and predictions for observables. 3.

Possible $q\bar{q}$ component to the $D^*_{s0}(2317)$ generation (A. Martínez Torres, E. Oset, S. Prelovsek and A. Ramos, JHEP **1505** (2015) 153):

- The amount of KD from the lattice data

$$P(KD) = (72 \pm 14)\% \leftrightarrow P(KD) = -\sum_{i=K^+D^0,K^0D^+} g_i^2 \frac{\partial G_i}{\partial s}\bigg|_{\text{pole}}$$

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- We add a *Castillejo-Dalitz-Dyson* pole to the potential

$$V_{i,j} \to V_{i,j} + \delta V, \quad \delta V = \frac{\gamma}{M_{inv} - M_{q\bar{q}}}$$

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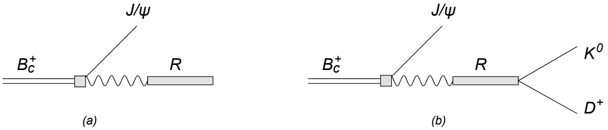

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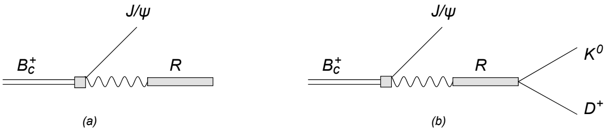

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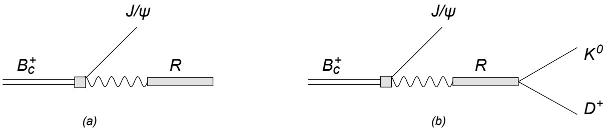
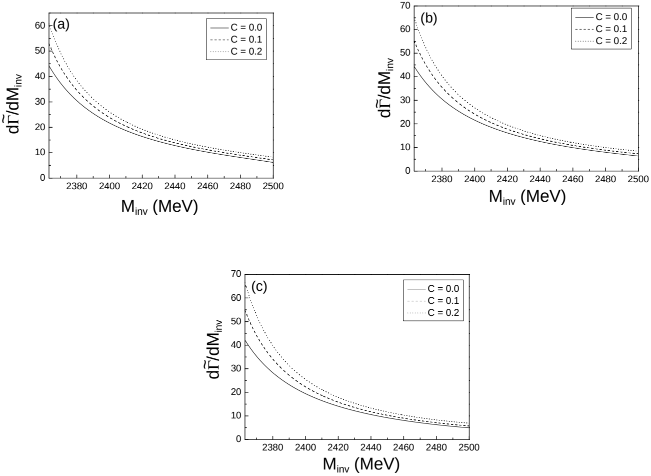


- For different cases $P(KD) = 58, 72, 86\%$, we consider a $q\bar{q}$ coupling to the resonance such that $\Rightarrow$ $0,\ 21,\ 44\%$ of increase in $\Gamma(B_c \to J/\Psi D^*_{s0}(2317))$

III. Results and predictions for observables. 3.



(a) $P(KD) = 0.68$. (b) $P(KD) = 0.72$. (c) $P(KD) = 0.86$.

V. Summary

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- The enhancement of events seen close to the KD threshold in B decays can be an experimental test of the molecular nature of the $D^*_{s0}(2317)$

V. Summary.

- The enhancement of events seen close to the *KD* threshold in *B* decays can be an experimental test of the molecular nature of the $D^*_{s0}(2317)$
- We have proposed an unmeasured weak decay process where, with the molecular *KD* hypothesis, this feature is also observed and due to the generation of the $D^*_{s0}(2317)$

Thank you for your attention

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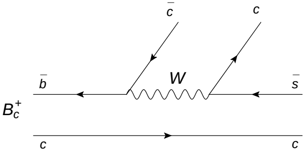
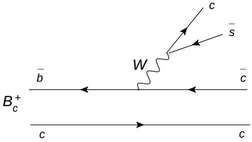
I. Weak decay of a heavy hadron. 2.





$$V_p + V_p'$$

Global constant factor