THE NATURE OF THE ORBITALLY EXCITED CHARMED-STRANGE MESONS THROUGH NONLEPTONIC $B \to D^{(*)}D_{sJ}^{(*)}$ DECAYS

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12th International Workshop on Meson Production, Properties and Interaction

Kraków 31 May - 5 June 2012

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Experimental measurements

Nonleptonic decays of B mesons (at quark level $\bar{b} \to \bar{c}c\bar{s}$) have been used to search for new charmonium and charmed-strange mesons and to study their properties in detail.

- The BaBar Collaboration found the $D_{s0}^*(2317)$ in the inclusive $D_s^+\pi^0$ invariant mass distribution.
- The CLEO Collaboration observed its doublet partner $D_{s1}(2460)$ in the $D_s^{*+}\pi^0$ final state.

The properties of these states were not well known until the Belle Collaboration observed the $B \to \bar{D}D_{s0}^*(2317)$ and $B \to \bar{D}D_{s1}(2460)$ decays.

Last measurements: The Belle Collaboration in Phys. Rev. D83, 051102 (2011)

$$R_{D0} = \frac{\mathcal{B}(B \to DD_{s0}^*(2317))}{\mathcal{B}(B \to DD_s)} = 0.10 \pm 0.03, \quad R_{D^*0} = \frac{\mathcal{B}(B \to D^*D_{s0}^*(2317))}{\mathcal{B}(B \to D^*D_s)} = 0.15 \pm 0.06,$$

$$R_{D1} = \frac{\mathcal{B}(B \to DD_{s1}(2460))}{\mathcal{B}(B \to DD_s^*)} = 0.44 \pm 0.11, \quad R_{D^*1} = \frac{\mathcal{B}(B \to D^*D_{s1}(2460))}{\mathcal{B}(B \to D^*D_s^*)} = 0.58 \pm 0.12,$$

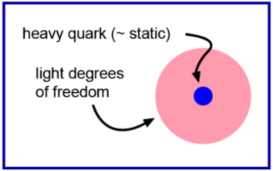
$$R_{D1'} = \frac{\mathcal{B}(B \to DD_{s1}(2536))}{\mathcal{B}(B \to DD_s^*)} = 0.049 \pm 0.010, \quad R_{D^*1'} = \frac{\mathcal{B}(B \to D^*D_{s1}(2536))}{\mathcal{B}(B \to D^*D_s^*)} = 0.044 \pm 0.010.$$

The study of nonleptonic decays can help to shed light on the structure of the P-wave charmed-strange mesons.

Heavy Quark Symmetry assumptions

- **Meson properties are characterized by the dynamics of the light quark:**

$$\vec{j}_q = \vec{L} + \vec{s}_q$$
$$\vec{J} = \vec{j}_q + \vec{s}_Q$$



- **The lowest D_s P-wave mesons can be grouped into two doublets:**

$$j_q^P = \frac{1}{2}^+ \rightarrow J^P = 0^+, 1^+$$
$$j_q^P = \frac{3}{2}^+ \rightarrow J^P = 1^+, 2^+$$

- **Properties:**
  - Doublets are degenerated.
  - Strong decays of the $D_{sJ}(j_q = 1/2)$ proceed only through S-waves $\Rightarrow$ Broad states.
  - Strong decays of the $D_{sJ}(j_q = 3/2)$ proceed only through D-waves $\Rightarrow$ Narrow states.

Heavy Quark Symmetry predictions

Spectroscopy of D_s P-wave mesons:

$j_q^P = \frac{1}{2}^+$			$j_q^P = \frac{3}{2}^+$		
$J^P = 0^+$	$D_{s0}^*(2317)$	2317.4 ± 0.9	$J^P = 1^+$	$D_{s1}(2536)$	2535.3 ± 0.6
$J^P = 1^+$	$D_{s1}(2460)$	2459.3 ± 1.3	$J^P = 2^+$	$D_{s2}^*(2573)$	2572.4 ± 1.5

Nonleptonic decay ratios of D_s P-wave mesons:

- **Factorization approximation:**

  $\rightarrow$ Matrix element of $B \rightarrow D^{(*)}D_{sJ}^{(*)}$ as a product of two matrix elements:

  i) The B weak transition into the $D^{(*)}$ mesons.

  ii) The weak creation of the $c\bar{s}$ pair which makes the $D_{sJ}^{(*)}$ meson $\propto f_{D_{sJ}^{(*)}}$.

- **Heavy quark limit:**

  i) PS effects are neglected: $R_{D0} = R_{D^*0} = \left|\frac{f_{D_{s0}^*(2317)}}{f_{D_s}}\right|^2, \quad R_{D1} = R_{D^*1} = \left|\frac{f_{D_{s1}(2460)}}{f_{D_s^*}}\right|^2.$

  ii) $f_{D_{s0}^*} = f_{D_{s1}}$ and $f_{D_s} = f_{D_s^*} \Rightarrow R_{D0} \approx R_{D1}$.

  iii) For P-wave $j_q = 1/2$ states $\rightarrow$ decay constants very similar to those of D_s and D_s^*.
  For P-wave $j_q = 3/2$ states $\rightarrow$ decay constants very small.

Ratios of order one for $D_{s0}^*(2317)$ and $D_{s1}(2460)$ $\rightarrow$ in strong disagreement

$\Downarrow$

We will concentrate in the influence of the effect of the finite c-quark mass

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Goldstone-boson exchange potentials

- QCD Lagrangian invariant under the chiral transformation

  Chiral symmetry is spontaneously broken

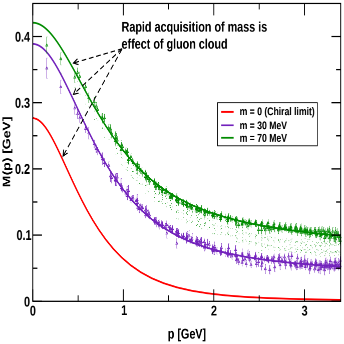
$$\mathcal{L} = \bar{\psi}\left(i\gamma^{\mu}\partial_{\mu} - M(q^2)U^{\gamma_5}\right)\psi$$

- Pseudo-Goldstone Bosons ($\vec{\pi}$, K_i and η_8)

$$U^{\gamma_5} = \exp\left(i\pi^a\lambda^a\gamma_5/f_\pi\right) \sim 1 + \frac{i}{f_\pi}\gamma^5\lambda^a\pi^a - \frac{1}{2f_\pi^2}\pi^a\pi^a + \ldots$$

- Constituent quark mass

$$M(q^2) = m_q F\left(q^2\right) = m_q\left[\frac{\Lambda^2}{\Lambda^2+q^2}\right]^{1/2}$$



C.D. Roberts, arXiv:1109.6325v1 [nucl-th].

One-gluon exchange potential

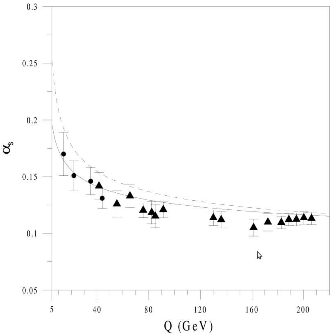
Beyond the chiral symmetry breaking scale
$\Downarrow$
Dynamics to be governed by QCD perturbative effects

- We take it into account through the one-gluon exchange (OGE) potential.
- The OGE is a standard color Fermi-Breit interaction obtained from the vertex Lagrangian:

$$\mathcal{L}_{\rm qqg} = i\sqrt{4\pi\alpha_s}\,\bar{\psi}\gamma_\mu G_c^\mu \lambda^c \psi$$

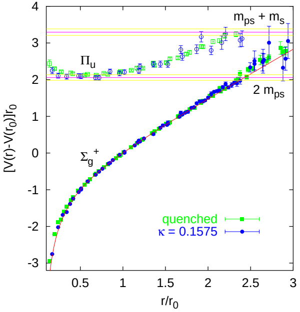
- Effective scale dependent strong coupling constant:

$$\alpha_s(\mu) = \frac{\alpha_0}{\ln\left(\frac{\mu^2+\mu_0^2}{\Lambda_0^2}\right)}$$

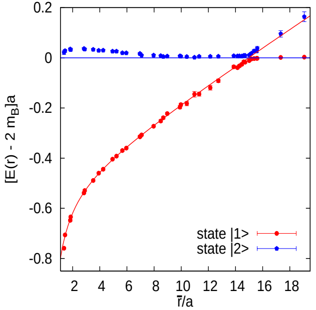


J. Vijande *et al.* J. Phys. G **31**, 481 (2005).

Confinement potential



G.S. Bali *et al.* Phys. Rep. **343**, 1 (2001).



G.S. Bali *et al.* Phys. Rev. D **71**, 114513 (2005).

LINEAR SCREENED POTENTIAL

$$V_{\rm CON}(r) = \left[-a_c(1-e^{-\mu_c r}) + \Delta\right](\vec{\lambda}_i \cdot \vec{\lambda}_j)$$

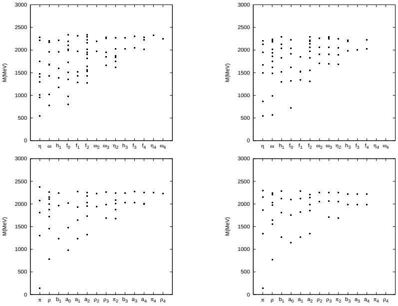
- *Flavor independent*
- $r \to 0 \;\; \Rightarrow V_{\rm CON}(r) \to (-a_c\mu_c r + \Delta)(\vec{\lambda}_i \cdot \vec{\lambda}_j)$
- $r \to \infty \Rightarrow V_{\rm CON}(r) \to (-a_c + \Delta)(\vec{\lambda}_i \cdot \vec{\lambda}_j)$

Some recent applications

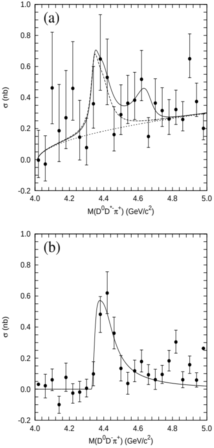
Deuteron

	CQM	NijmII	Bonn B	Exp.
ϵ_d (MeV)	-2.2242	-2.2246	-2.2246	-2.224575
P_D (%)	4.85	5.64	4.99	-
Q_d (fm^2)	0.276	0.271	0.278	0.2859 ± 0.0003
A_S (fm$^{-1/2}$)	0.891	0.8845	0.8860	0.8846 ± 0.0009
A_D/A_S	0.0257	0.0252	0.0264	0.0256 ± 0.0004

Light mesons



Reactions



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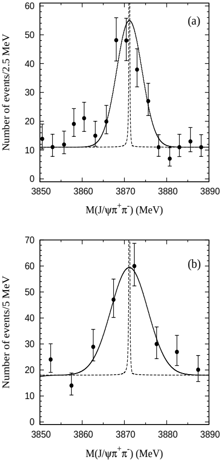

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$D_{s0}^*(2317)$ and the 1-loop corrections to OGE

What is the mechanism that explains the lower mass of the $D_{s0}^*(2317)$ meson?

- Addition of the one-loop QCD corrections to the spin-dependent terms of the potential.
- There is a spin-dependent term which affects only to mesons with different flavor quarks.
  - Lakhina and E. S. Swanson, Phys. Lett. B **650**, 159 (2007).

- **Our prediction:**

	Charmed-strange mesons					
	$j_q^P = 1/2^-$		$j_q^P = 1/2^+$		$j_q^P = 3/2^+$	
	0^-	1^-	0^+	1^+	1^+	2^+
This work (α_s)	1984	2110	2510	2593	2554	2591
This work (α_s^2)	1984	2104	2383	2570	2560	2609
Exp.	1969.0 ± 1.4	2112.3 ± 0.5	2318.0 ± 1.0	2459.6 ± 0.9	2535.12 ± 0.25	2572.6 ± 0.9

	Charmed mesons					
	$j_q^P = 1/2^-$		$j_q^P = 1/2^+$		$j_q^P = 3/2^+$	
	0^-	1^-	0^+	1^+	1^+	2^+
This work (α_s)	1896	2017	2516	2596	2466	2513
This work (α_s^2)	1896	2014	2362	2535	2499	2544
Exp.	1867.7 ± 0.3	2010.25 ± 0.14	2403 ± 38	2427 ± 36	2423.4 ± 3.1	2460.1 ± 4.4

The 0^+ states are more sensitive to the inclusion of the one-loop corrections.

$D_{s1}(2460)$ and $D_{s1}(2536)$. The tetraquark coupling

What is the mechanism that explains the lower mass of the $D_{s1}(2460)$ meson?

- **Possible molecular states.**
- **Tetraquark states.**
- **$c\bar{s}$ states in models with higher order corrections.**
- **Mixture of $c\bar{s}$ and $c\bar{s}n\bar{n}$.**

- **COUPLING PRESCRIPTION** J. Segovia *et al.*, Phys. Rev. D **80**, 054017 (2009).
  - **Working in HQS limit:**
    - Three different spin states for tetraquark: $|0\,1/2\rangle$, $|1\,1/2\rangle$ and $|1\,3/2\rangle$. The first index denotes the spin of the $n\bar{n}$ pair and the second one the coupling with the $\bar{s}$ spin.
  - **$^3P_0$ model to select the dominant couplings:**
    - The $n\bar{n}$ pair created is in a $J = 0$ state.
    - The coupling between D_s states and $|0\,1/2\rangle$ tetraquark component is dominant.
  - **This choice has several advantages:**
    - It has the correct heavy quark limit.
    - It can reproduce the narrow width of the $D_{s1}(2536)$ meson.
    - It is in agreement with the experimental situation which tells us that the prediction of the heavy quark limit is reasonable for the $j_q = 3/2$ states but not for the $j_q = 1/2$.

$D_{s1}(2460)$ and $D_{s1}(2536)$. The tetraquark coupling

Effective coupling between $c\bar{s}$ states and the tetraquark:

$$M = \begin{pmatrix} M_{^3P_1} & C_{SO} & \sqrt{\frac{2}{3}}C_S \\ C_{SO} & M_{^1P_1} & \sqrt{\frac{1}{3}}C_S \\ \sqrt{\frac{2}{3}}C_S & \sqrt{\frac{1}{3}}C_S & M_{c\bar{s}n\bar{n}} \end{pmatrix}$$

$M_{^3P_1}$	2571.5 MeV
$M_{^1P_1}$	2576.0 MeV
$M_{c\bar{s}n\bar{n}}$	2841 MeV
C_{SO}	19.6 MeV
C_S	224 MeV

Eigenstates are:

M (MeV)	$S(^3P_1)$	$P(^3P_1)$	$S(^1P_1)$	$P(^1P_1)$	$S(c\bar{s}n\bar{n})$	$P(c\bar{s}n\bar{n})$
2459	$-$	55.7	$-$	18.8	$+$	25.5
2557	$+$	27.7	$-$	72.1	$+$	0.2
2973	$+$	16.6	$+$	9.1	$+$	74.3

The doublets D_{sJ} with $j_q = 1/2,\ 3/2$ from HQS:

$$|1/2, 0^+\rangle = |^3P_0\rangle \qquad |3/2, 1^+\rangle = \sqrt{\frac{1}{3}}|^3P_1\rangle - \sqrt{\frac{2}{3}}|^1P_1\rangle$$

$$|1/2, 1^+\rangle = \sqrt{\frac{2}{3}}|^3P_1\rangle + \sqrt{\frac{1}{3}}|^1P_1\rangle \qquad |3/2, 2^+\rangle = |^3P_2\rangle$$

$D_{s1}(2460)$ and $D_{s1}(2536)$. The tetraquark coupling

- Calculation of the following physical observables:

$$\Gamma(D_{s1}(2536)^+) = \Gamma(D^{*0}K^+) + \Gamma(D^{*+}K^0)$$

$$R_1 = \frac{\Gamma(D_{s1}(2536)^+ \to D^{*0}K^+)}{\Gamma(D_{s1}(2536)^+ \to D^{*+}K^0)}$$

$$R_2 = \frac{\Gamma_S(D_{s1}(2536)^+ \to D^{*+}K^0)}{\Gamma(D_{s1}(2536)^+ \to D^{*+}K^0)}$$

$$R_3 = \frac{\Gamma(D_{s1}(2536)^+ \to D^+\pi^-K^+)}{\Gamma(D_{s1}(2536)^+ \to D^{*+}K^0)}$$

- $D_{s1}(2536)$ Eigenstate:

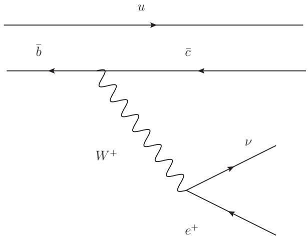
Mass (MeV)	Γ (MeV)	R_1	R_2	$R_3(\%)$
2557	0.46	1.31	0.66	4.00
Exp.	1.03	1.27	0.72	3.27

As the DK decay is zero the total width would be mainly given by the D^*K channel and is in the order of the experimental value.

Semileptonic B (B_s) decays into D^{**} (D_s^{**})

- *Different collaborations have recently reported semileptonic B decays into orbitally excited charmed mesons.*
- *The theoretical analysis of these data offers the possibility for a stringent test of meson models.*
- **Include a weak decay of the B meson and a strong decay of the D meson.**

- **Weak decays:**
  - Matrix elements $\Rightarrow$ parametrized in terms of form factors.
  - At the quark level $\Rightarrow$ light quark is an spectator.
  - We follow references bellow:
    - E. Hernández *et al.*, Phys. Rev. D **74**, 074008 (2006).
    - M.A. Ivanov *et al.*, Phys. Rev. D **73**, 054024 (2006).
- **Strong decays:**
  - The $^3P_0$ decay model.
  - The microscopic decay model.



Semileptonic B_s decays into D_s^{**}

	Experiment ($\times 10^{-3}$)	Theory ($\times 10^{-3}$)	
$D_{s0}^*(2317)$			
$\mathcal{B}(B_s^0 \to D_{s0}^*(2317)^- \mu^+ \nu_\mu)$	-	4.4282	
$D_{s1}(2460)$			
$\mathcal{B}(B_s^0 \to D_{s1}(2460)^- \mu^+ \nu_\mu)$	-	$1.74 - 5.70$	
$D_{s1}(2536)$		$^3P_0$	Mic.
$\mathcal{B}(B_s^0 \to D_{s1}(2536)^- \mu^+ \nu_\mu)\mathcal{B}(D_{s1}(2536)^- \to D^{*-}\bar{K}^0)$	2.4 ± 0.7	2.0491	2.2397
$D_{s2}^*(2573)$		$^3P_0$	Mic.
$\mathcal{B}(B_s^0 \to D_{s2}^*(2573)^- \mu^+ \nu_\mu)\mathcal{B}(D_{s2}^*(2573)^- \to D^-\bar{K}^0)$	-	1.7047	1.7680
$\mathcal{B}(B_s^0 \to D_{s2}^*(2573)^- \mu^+ \nu_\mu)\mathcal{B}(D_{s2}^*(2573)^- \to D^{*-}\bar{K}^0)$	-	0.1769	0.1136
$\mathcal{B}(B_s^0 \to D_{s2}^*(2573)^- \mu^+ \nu_\mu)\mathcal{B}(D_{s2}^*(2573)^- \to D^{(*)-}\bar{K}^0)$	-	1.8816	1.8816

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Remainder

These decays provide valuable information that makes possible to check the structure of the $D_{s0}^*(2317)$, $D_{s1}(2460)$ and $D_{s1}(2536)$ mesons

Heavy Quark Symmetry predictions

- Ratios of order one for $D_{s0}^*(2317)$ and $D_{s1}(2460)$ $\Rightarrow$ in strong disagreement.
- Ratios very small for $D_{s1}(2536)$ $\Rightarrow$ follow the expectations.

The disagreement $\Rightarrow$ an indication that $D_{s0}^*(2317)$ and $D_{s1}(2460)$ mesons could have a more complex structure

Expressions of the decay widths taking finite c-quark mass

- For $D_{sJ}^{(*)}$ a pseudoscalar or scalar meson:

$$\Gamma = \frac{G_F^2}{16\pi m_B^2}|V_{cb}|^2|V_{cs}|^2 a_1^2 \frac{\lambda^{1/2}(m_B^2, m_{D^{(*)}}^2, m_{D_{sJ}^{(*)}}^2)}{2m_B} m_{D_{sJ}^{(*)}}^2 f_{D_{sJ}^{(*)}}^2 \mathcal{H}_{tt}^{B\to D^{(*)}}(m_{D_{sJ}^{(*)}}^2)$$

- For $D_{sJ}^{(*)}$ a vector or axial-vector meson:

$$\Gamma = \frac{G_F^2}{16\pi m_B^2}|V_{cb}|^2|V_{cs}|^2 a_1^2 \frac{\lambda^{1/2}(m_B^2, m_{D^{(*)}}^2, m_{D_{sJ}^{(*)}}^2)}{2m_B} m_{D_{sJ}^{(*)}}^2 f_{D_{sJ}^{(*)}}^2 \times$$
$$\times \left[\mathcal{H}_{+1+1}^{B\to D^{(*)}}(m_{D_{sJ}^{(*)}}^2) + \mathcal{H}_{-1-1}^{B\to D^{(*)}}(m_{D_{sJ}^{(*)}}^2) + \mathcal{H}_{00}^{B\to D^{(*)}}(m_{D_{sJ}^{(*)}}^2)\right]$$

Discussion on the phase space

- Using experimental masses we obtain the ratios:

$D_{s0}^*(2317)$

$$R_{D0} = 0.9008 \times \left| \frac{f_{D_{s0}^*(2317)}}{f_{D_s}} \right|^2$$

$$R_{D^*0} = 0.7166 \times \left| \frac{f_{D_{s0}^*(2317)}}{f_{D_s}} \right|^2$$

$D_{s1}(2460)$

$$R_{D1} = 0.7040 \times \left| \frac{f_{D_{s1}(2460)}}{f_{D_s^*}} \right|^2$$

$$R_{D^*1} = 1.0039 \times \left| \frac{f_{D_{s1}(2460)}}{f_{D_s^*}} \right|^2$$

$D_{s1}(2536)$

$$R_{D1'} = 0.6370 \times \left| \frac{f_{D_{s1}(2536)}}{f_{D_s^*}} \right|^2$$

$$R_{D^*1'} = 0.9923 \times \left| \frac{f_{D_{s1}(2536)}}{f_{D_s^*}} \right|^2$$

- The double ratio does not depend on decay constants:

$$\frac{R_{D^*0}}{R_{D0}} = \begin{cases} 0.7955 \\ 1.50 \pm 0.75 \end{cases} \qquad \frac{R_{D^*1}}{R_{D1}} = \begin{cases} 1.4260 \\ 1.32 \pm 0.43 \end{cases} \qquad \frac{R_{D^*1'}}{R_{D1'}} = \begin{cases} 1.5578 \\ 0.90 \pm 0.27 \end{cases}$$

- *The quality of the experimental results does not allow to be very conclusive as to the goodness of the factorization approximation.*
- *But one can conclude that phase space and weak matrix element corrections cannot be ignored.*

Discussion on the decay constants

Approach	f_D (MeV)	f_{D_s} (MeV)	f_{D_s}/f_D
Ours	$297.019^{(\dagger)}$	$416.827^{(\dagger)}$	$1.40^{(\dagger)}$
	$214.613^{(\ddagger)}$	$286.382^{(\ddagger)}$	$1.33^{(\ddagger)}$
Experiment	206.7 ± 8.9	257.5 ± 6.1	1.25 ± 0.06

Approach	f_{D^*} (MeV)	$f_{D_s^*}$ (MeV)	$f_{D_s^*}/f_{D^*}$
Ours	$247.865^{(\dagger)}$	$329.441^{(\dagger)}$	$1.33^{(\dagger)}$
QL (Italy)	234	254	$1.04 \pm 0.01^{+2}_{-4}$
QL (UKQCD)	$245 \pm 20^{+0}_{-2}$	$272 \pm 16^{+0}_{-20}$	1.11 ± 0.03

- Decay constants of $^3S_1$ mesons agree.
- Decay constants of $^1S_0$ mesons are large:

i) A spin-spin contact hyperfine interaction regularized at $r = 0$.

ii) Hyperfine splittings in the different flavor sectors are well reproduced.

iii) Most of the physical observables are insensitive to the regularization → BUT → those related with annihilation processes are affected.

iv) The effect is:
  - Negligible for higher partial waves.
  - Small in the $^3S_1$ channel.
  - Sizable in the $^1S_0$ channel.

We will use for the pseudoscalar constant the experimental value.

	f_D (MeV)	$\sqrt{M_D}f_D$ $(\mathrm{GeV}^{3/2})$
$D_{s0}^*(2317)$	118.706	0.181
$D_{s1}(2460)$	165.097	0.259
$D_{s1}(2536)$	59.176	0.094

Comments

- From experiment:

$$f_{D_{s0}^*(2317)} \sim 1/3\, f_{D_s}$$

$$f_{D_{s0}^*(2317)} \sim f_{D_{s1}(2460)}$$

$$f_{D_{s1}(2536)} \to \mathrm{small}$$

- Our results:

$$f_{D_{s0}^*(2317)}/f_{D_s} = 0.36$$

$$f_{D_{s0}^*(2317)} \sim 0.72 f_{D_{s1}(2460)}$$

$$f_{D_{s1}(2536)} = 59.176\ \mathrm{MeV}$$

Our results

Ratios

	$X \equiv D_{s0}^*(2317)$ The.	Exp.	$X \equiv D_{s1}(2460)$ The.	Exp.	$X \equiv D_{s1}(2536)$ The.	Exp.
$\mathcal{B}(B \to DX)/\mathcal{B}(B \to DD_s)$	$0.19^{(*)}$	0.10 ± 0.03	-	-	-	-
$\mathcal{B}(B \to D^*X)/\mathcal{B}(B \to D^*D_s)$	$0.15^{(*)}$	0.15 ± 0.06	-	-	-	-
$\mathcal{B}(B \to DX)/\mathcal{B}(B \to DD_s^*)$	-	-	$\begin{bmatrix} 0.176^{(1)} \\ 0.177^{(2)} \end{bmatrix}$	0.44 ± 0.11	$\begin{bmatrix} 0.071^{(1)} \\ 0.021^{(2)} \end{bmatrix}$	0.049 ± 0.010
$\mathcal{B}(B \to D^*X)/\mathcal{B}(B \to D^*D_s^*)$	-	-	$\begin{bmatrix} 0.251^{(1)} \\ 0.252^{(2)} \end{bmatrix}$	0.58 ± 0.12	$\begin{bmatrix} 0.110^{(1)} \\ 0.032^{(2)} \end{bmatrix}$	0.044 ± 0.010

Comments

- Results close to or within the experimental error bars for the $D_{s0}^*(2317)$ meson.
  - 1-loop corrections to OGE has been introduced.
  - $(*)$ We are using the experimental value for f_{D_s}.
- The enhancement of the $j_q = 3/2$ component of the $D_{s1}(2536)$ meson gives rise to ratios in better agreement with experiment.
  - (1) Without coupling to non-$q\bar{q}$ degrees of freedom $\to$ second ratio in disagreement.
  - (2) With coupling to non-$q\bar{q}$ degrees of freedom $\to$ $D_{s1}(2536)$ remains almost a $q\bar{q}$.
- The $D_{s1}(2460)$ meson could have a sizable non-$q\bar{q}$ component.
  - (1) Without coupling to non-$q\bar{q}$ degrees of freedom $\to$ ratios in disagreement.
  - (2) With coupling to non-$q\bar{q}$ degrees of freedom $\to$ ratios in disagreement $\to$ We have not yet calculated the contribution of the non-$q\bar{q}$ degrees of freedom.

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Summary

- *Ratios of nonleptonic B decays into double charmed mesons have been recently reported by the Belle Collaboration.*
- *The strong disagreement found between the heavy quark limit predictions and the experimental data motivates the introduction of the finite c-quark mass effects.*
- *We have performed a calculation of the ratios working within the framework of the constituent quark model and in the factorization approximation.*

- The $D_{s0}(2317)$ meson:
  - The mass is lowered towards the experimental value with the inclusion of the 1-loop corrections to the OGE potential.
  - We obtain ratios compatible with the experimental data.
  - Our results indicate that this meson could be described as a canonical $c\bar{s}$ state.
- The $D_{s1}(2536)$ meson:
  - We incorporate the non-$q\bar{q}$ degrees of freedom in the $J^P = 1^+$ channel.
  - This meson remains almost a pure $q\bar{q}$ state and its $j_q = 3/2$ component is enhanced.
  - Correct ratios for this meson are predicted
- The $D_{s1}(2460)$ meson:
  - Has a sizable non-$q\bar{q}$ component.
  - The non-$q\bar{q}$ contribution has not been calculated.
  - The ratios are a factor 2 below the experimental ones.