1 Excited $D_{(s)}$ Mesons

Tables 1–3 represent a summary of recent results with an emphasis on information not provided in Ref. [1]. For a complete list of related publications, see Ref. [1]. All upper limits (U.L.) correspond to 90% confidence (C.L.) unless otherwise noted. The significances listed are approximate; they are calculated as either $\sqrt{-2\Delta \log \mathcal{L}}$ or $\sqrt{\Delta\chi^2}$, where Δ represents the change in the corresponding minimized function between two hypotheses, e.g., those for different spin states.

The broad charged $J^P = 1^+$ $c\bar{d}$ state is denoted $D_1(2430)^+$, although it has not yet been observed. The masses and widths of narrow states $D_1(2420)^\pm$, $D_1(2420)^0$, $D_2^*(2460)^0$, $D_2^*(2460)^\pm$ are well-measured, and thus only their averages are given [1]. The same holds for the wide state $D_0^*(2400)^0$. On the other hand for $D_0^*(2400)^\pm$ and $D_1(2430)^0$ the only dedicated measurements available are from [2] and [3], respectively, and hence these measurements are quoted separately. New precise measurements of masses and widths of $D_2^*(2460)^0$ and $D_0^*(2400)^0$ became available recently [4] and are included in the weighted averages[1] shown in Fig. 1. In these averages also the mass of $D_1(2420)^0$ from [5] is used[2].

The masses and widths of narrow ($\Gamma \sim$ 20–40 MeV) orbitally excited D mesons (denoted D^{**}), both neutral and charged, are well established. Measurements of broad states ($\Gamma \sim$ 200–400 MeV) are less abundant, as identifying the signal is more challenging. There is a slight discrepancy between the $D_0^*(2400)^0$ masses measured by the Belle [2] and FOCUS [3] experiments. No data exists yet for the $D_1(2430)^\pm$ state. Dalitz plot analyses of $B \to D^{(*)}\pi\pi$ decays strongly favor the assignments 0^+ and 1^+ for the spin-parity quantum numbers of the $D_0^*(2400)^0/D_0^*(2400)^\pm$ and $D_1(2430)^0$ states, respectively. The measured masses and widths, as well as the J^P values, are in agreement with theoretical predictions based on potential models [6–10]. The quantitative information on the values of branching fractions for all D^{**} mesons is scarce. In Fig. 1 we include the available measurements from [2, 11] for $D_1(2420)^0$ and from [2,4] for $D_2^*(2460)^0$. While the branching fractions for B mesons decaying to a narrow D^{**} state and a pion are similar for charged and neutral B initial states, the branching fractions to a broad D^{**} state and π^+ are much larger for B^+ than for B^0. This may be due to the fact that color-suppressed amplitudes contribute only to the B^+ decay and not to the B^0 decay (for a theoretical discussion, see Ref. [12, 13]).

The first observations of $D_{s1}(2460)^\pm$ and $D_{s0}^*(2317)^\pm$ states are described in Refs. [14] and [15], respectively. The discoveries of the $D_{s0}^*(2317)^\pm$ and $D_{s1}(2460)^\pm$ have triggered increased interest in properties of, and searches for, excited D_s mesons (here generically denoted D_s^{**}). While the masses and widths of $D_{s1}(2536)^\pm$ and $D_{s2}(2573)^\pm$ states are in relatively good agreement with potential model predictions, the masses of $D_{s0}^*(2317)^\pm$ and $D_{s1}(2460)^\pm$ states (and consequently their widths, less than around 5 MeV) are significantly lower than expected (see Ref. [16] for a discussion of $c\bar{s}$ models). Moreover, the mass splitting between these two states greatly exceeds that between the $D_{s1}(2536)^\pm$ and $D_{s2}(2573)^\pm$. These unexpected properties have led to interpretations of the $D_{s0}^*(2317)^\pm$ and $D_{s1}(2460)^\pm$ as exotic four-quark states. Measurements of masses (and the width of $D_{s2}(2573)^\pm$) are averaged by the PDG [1]. In the averages shown in Fig. 2 we include the mass measurement of $D_{s0}^*(2317)^\pm$ and $D_{s1}(2460)^\pm$ from [17][3]. Widths of other D_s^{**} mesons are below the current experimental sensitivity and the

[1]We calculate the weighted average of the PDG [1] and Ref. [4] values.

[2]PDG does not use values from [5] since they are measured relative to the mass of $D^{(*)\pm}$ mesons.

[3]We calculate the weighted average of PDG [1] and Ref. [17] values. The latter are excluded from the PDG

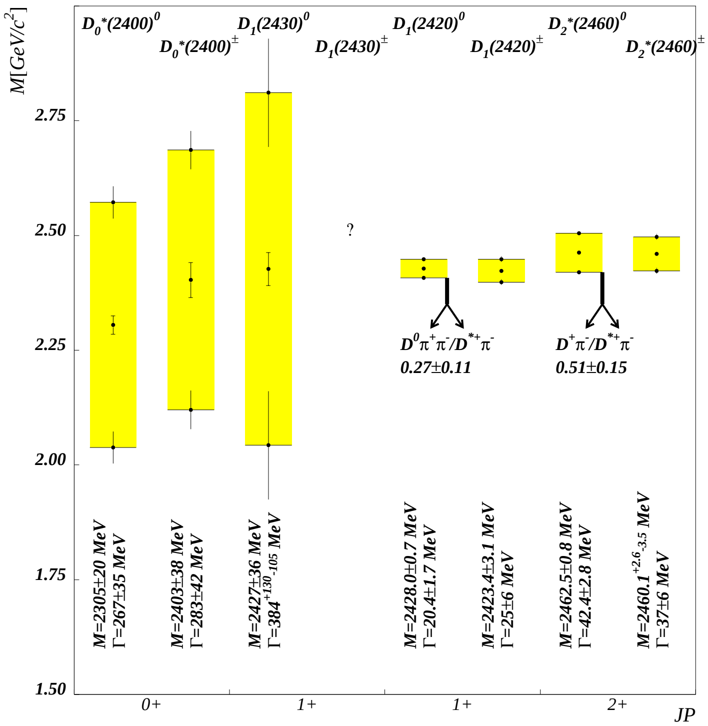

Figure 1: Masses, widths and some branching fractions of orbitally excited D mesons. Shaded regions show the masses and widths of individual states. The central point with error bars denotes the measured mass of each state. Error bars at the edges of the shaded regions denote the uncertainties of the width determination. Divided arrows denote relative branching ratios for the final states marked.

obtained upper limits are quoted separately.

While there are few measurements with respect to the J^P values of $D_{s0}^*(2317)^{\pm}$ and $D_{s1}(2460)^{\pm}$, the available data favors 0^+ and 1^+, respectively. A molecule-like (DK) interpretation of the $D_{s0}^*(2317)^{\pm}$ and $D_{s1}(2460)^{\pm}$ [18,19] that can account for their low masses and isospin-breaking decay modes is tested by searching for charged and neutral isospin partners of these states; thus far such searches have yielded negative results. Hence the subset of models that predict equal production rates for different charged states is nominally excluded. The molecular picture can also be tested by measuring the rates for the radiative processes $D_{s0}^*(2317)^{\pm}/D_{s1}(2460)^{\pm} \rightarrow D_s^{(*)}\gamma$ and comparing to theoretical predictions. The predicted rates, however, are below the sensitivity of current experiments. Another model successful in explaining the total widths and the $D_{s0}^*(2317)^{\pm}$-$D_{s1}(2460)^{\pm}$ mass splitting is based on the assumption that these states are chiral partners of the ground states $D_s^{\pm}$ and $D_s^{*\pm}$ [20]. While some measured branching fraction ratios agree with predicted values, further experimental tests with better sensitivity are needed to confirm or refute this scenario.

In addition to the $D_{s0}^*(2317)^{\pm}$ and $D_{s1}(2460)^{\pm}$ states, other excited D_s states may have been observed. SELEX has reported a $D_{sJ}(2632)^{\pm}$ candidate [21], but this has not been confirmed by other experiments. Belle and BaBar have observed $D_{s1}(2700)^{\pm}$ and $D_{sJ}(2860)^{\pm}$ states [22,23], which may be radial excitations of the $D_s^{*\pm}$ and $D_{s0}^*(2317)^{\pm}$, respectively (see for example [24]). However, the $D_{sJ}(2860)^{\pm}$ has been searched for in B decays and not observed, which may indicate that this state has higher spin. Recently new precise measurements of $D_{s1}(2700)^{\pm}$ and $D_{sJ}(2860)^{\pm}$ properties were performed by BaBar [25]. The weighted average of the results from [22,25] is $M(D_{s1}(2700)^{\pm}) = (2709 \pm 8)$ MeV/c^2 and $\Gamma(D_{s1}(2700)^{\pm}) = (126 \pm 31)$ MeV. In the same paper BaBar observes another state, denoted $D_{sJ}(3040)^{\pm}$, with a significance of 6 standard deviations. According to calculations of [24] this state is a candidate for the radial excitation of $D_{s1}(2460)^{\pm}$ or $D_{s1}(2536)^{\pm}$.

The existing studies of $D_{s1}(2460)^{\pm}$ provide for sufficient information that the individual branching fractions are calculated by HFAG; they are shown in Fig. 2. Beside this the relative branching ratios of $D_{s1}(2536)^{\pm}$ are shown [26,27]. Measurements of individual branching fractions of D_s^{**} are difficult due to the unknown fragmentation of $c\bar{c} \rightarrow D_s^{**}$ (in the studies where D_s^{**} mesons are produced in $c\bar{c}$ fragmentation) or due to the unknown $B \rightarrow D_s^{**}X$ branching fractions (in the studies where D_s^{**} are produced in B meson decays).

average since they are measured relative to the mass of $D_s^{(*)}$ mesons.

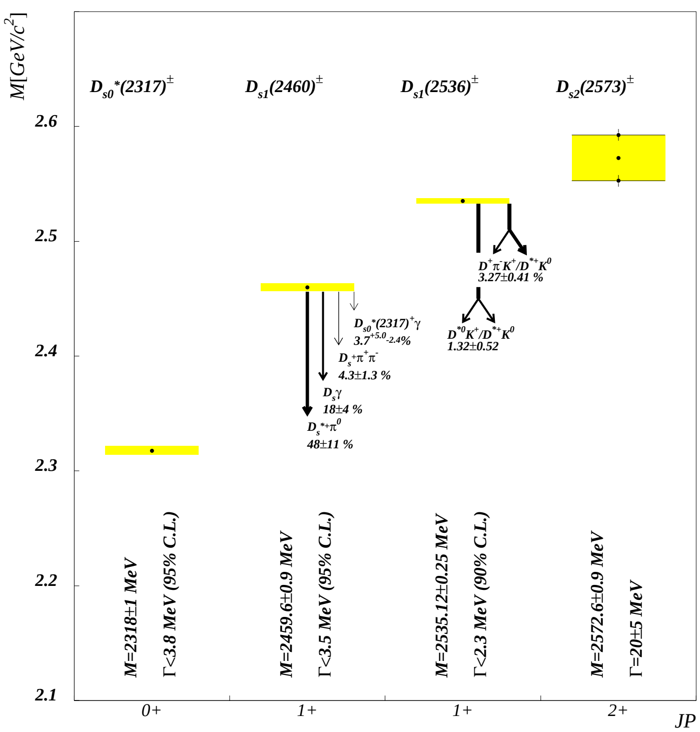

Figure 2: Masses, widths and some branching fractions of orbitally excited D_s mesons. Shaded regions show the masses and widths of individual states (U.L. on the widths in case of $D^*_{s0}(2317)^\pm$, $D_{s1}(2460)^\pm$, and $D_{s1}(2536)^\pm$). The central point with error bars denotes the measured mass of each state. Error bars at the edges of the shaded regions denote the uncertainties of the width determination. Arrows (divided arrows) denote branching fractions (relative branching ratios) for the final states marked.

Table 1: Recent results for properties of D^{**} mesons.

Main results		Reference	Comments
Masses [MeV/c^2], widths [MeV]	$M(D_0^*(2400)^0) : 2352 \pm 50$; $\Gamma(D_0^*(2400)^0) : 261 \pm 50$ $M(D_2^*(2460)^0) : 2461.1 \pm 1.6$; $\Gamma(D_2^*(2460)^0) : 43 \pm 4$ $M(D_2^*(2460)^\pm) : 2460.1\,^{+2.6}_{-3.5}$; $\Gamma(D_2^*(2460)^\pm) : 37 \pm 6$ $M(D_1(2420)^0) : 2422.3 \pm 1.3$; $\Gamma(D_1(2420)^0) : 20.4 \pm 1.7$ $M(D_1(2420)^\pm) : 2423.4 \pm 3.1$; $\Gamma(D_1(2420)^\pm) : 25 \pm 6$	[1]	PDG average; to $M(D_0^*(2400)^0)$ and $\Gamma(D_0^*(2400)^0)$ from [3] also $D_1(2430)^0$ may contribute
	$M(D_1(2430)^0) : 2427 \pm 26 \pm 20 \pm 15$ $\Gamma(D_1(2430)^0) : 384 \pm\,^{107}_{75} \pm 24 \pm 70$	[2]	last error due to Dalitz model
	$M(D_0^*(2400)^\pm/D_1(2430)^\pm) : 2403 \pm 14 \pm 35$ $\Gamma(D_0^*(2400)^\pm/D_1(2430)^\pm) : 283 \pm 24 \pm 34$	[3]	$D_0^*(2400)^\pm/D_1(2430)^\pm$ may contribute to signal
	$M(D_2^*(2460)^\pm) : 2463.3 \pm 0.6 \pm 0.8$ $M(D_1(2430)^0) : 2421.7 \pm 0.7 \pm 0.6$	[5]	M measured relative to $M^{(*)}\pm$
Branching fractions [10^{-4}]	$B^- \to D_0^*(2400)^0\pi^-$, $D_0^*(2400)^0 \to D^+\pi^- : 6.1 \pm 0.6 \pm 0.9 \pm 1.6$ $B^- \to D_2^*(2460)^0\pi^-$, $D_2^*(2460)^0 \to D^+\pi^- : 3.4 \pm 0.3 \pm 0.6 \pm 0.4$ $B^- \to D_1(2420)^0\pi^-$, $D_1(2420)^0 \to D^{*+}\pi^- : 6.8 \pm 0.7 \pm 1.3 \pm 0.3$ $B^- \to D_2^*(2460)^0\pi^-$, $D_2^*(2460)^0 \to D^{*+}\pi^- : 1.8 \pm 0.3 \pm 0.3 \pm 0.2$ $B^- \to D_1(2430)^0\pi^-$ $D_1(2430)^0 \to D^{*+}\pi^- : 5.0 \pm 0.4 \pm 1.0 \pm 0.4$	[2]	
	$\overline{B}^0 \to D_2^*(2460)^+\pi^-$, $D_2^*(2460)^+ \to D^0\pi^+ : 2.15 \pm 0.17 \pm 0.29 \pm 0.12$ $\overline{B}^0 \to D_0^*(2400)^+\pi^-$ $D_0^*(2400)^+ \to D^0\pi^+ : 0.60 \pm 0.13 \pm 0.15 \pm 0.22$	[28]	last error due to Dalitz model; $M(D_0^*(2400)^\pm) = M(D_0^*(2400)^0)$, $\Gamma(D_0^*(2400)^\pm) = \Gamma(D_0^*(2400)^0)$ assumed
	$B^- \to D_1(2420)^0\pi^-$, $D_1(2420)^0 \to D^0\pi^+\pi^- : 1.85 \pm 0.29 \pm 0.35 \pm\,^{0.00}_{0.43}$ $\overline{B}^0 \to D_1(2420)^+\pi^-$, $D_1(2420)^+ \to D^+\pi^+\pi^- : 0.89 \pm 0.15 \pm 0.17 \pm\,^{0.00}_{0.27}$	[11]	last error due to possible $D_2^*(2460)^0$, $D_2^*(2460)^\pm$ contr.
	$B^- \to D_2^*(2460)^0\pi^-$, $D_2^*(2460)^0 \to D^+\pi^- : 3.5 \pm 0.2 \pm 0.2 \pm 0.4$ $B^- \to D_0^*(2400)^0\pi^-$, $D_0^*(2400)^0 \to D^+\pi^- : 6.8 \pm 0.3 \pm 0.4 \pm 2.0$	[4]	last error due to Blatt-Weisskopf factors and sig./bkg. composition
Quantum numbers (J^P)	$D_0^*(2400)^0 : 0^+$	[2]	0^+ preferred over $1^-,\ 2^+$ with sign. $> 10\sigma$
	$D_1(2430)^0 : 1^+$		1^+ preferred over $0^-,\ 1^-,\ 2^+$ with sign. $> 10\sigma$
	$D_0^*(2400)^\pm : 0^+$	[28]	0^+ preferred over $1^-,\ 2^+$ with sign. $\sim 5\sigma$

Table 2: Recent results for masses and branching fractions of excited D_s mesons.

Main results		Reference	Comments
Masses [MeV/c^2], widths [MeV]	$M(D_{s0}^*(2317)^\pm) : 2318.0 \pm 1.0$ $M(D_{s1}(2460)^\pm) : 2459.6 \pm 0.9$ $M(D_{s1}(2536)^\pm) : 2353.12 \pm 0.25$ $M(D_{s2}(2573)^\pm) : 2572.6 \pm 0.9$ $\Gamma(D_{s2}(2573)^\pm) : 20 \pm 5$	[1]	PDG average
	$M(D_{s0}^*(2317)^\pm) : 2317.2 \pm 0.5 \pm 0.9$ $\Gamma(D_{s0}^*(2317)^\pm) :< 4.6$ $M(D_{s1}(2460)^\pm) : 2459.9 \pm 0.9 \pm 1.6$ $\Gamma(D_{s1}(2460)^\pm) :< 5.5$	[17]	M measured relative to $M(D_s^{(*)}$
	$\Gamma(D_{s0}^*(2317)^\pm) :< 3.8$ $\Gamma(D_{s1}(2460)^\pm) :< 3.5$	[29]	95% C.L. U.L.
	$\Gamma(D_{s1}(2536)^\pm) :< 2.3$	[30]	
	$M(D_{s1}(2700)^\pm) : 2710 \pm 2 \pm {}^{12}_{7}; \Gamma(D_{s1}(2700)^\pm) :\ 149 \pm 7 \pm {}^{39}_{52}$ $M(D_{sJ}(2860)^\pm) : 2862 \pm 2 \pm {}^{5}_{2}; \Gamma(D_{sJ}(2860)^\pm) :\ 48 \pm 3 \pm 6$ $M(D_{sJ}(3040)^\pm) : 3044 \pm 8 \pm {}^{30}_{5}; \Gamma(D_{sJ}(3040)^\pm) :\ 239 \pm 35 \pm {}^{46}_{42}$	[25]	$D_{sJ}(3040)^\pm$ sign. 6 σ
	$M(D_{s1}(2700)^\pm) : 2708 \pm 9 \pm {}^{11}_{10}; \Gamma(D_{s1}(2700)^\pm) :\ 108 \pm 23 \pm {}^{36}_{31}$	[22]	
	$M(D_{sJ}(2632)^\pm) : 2632.5 \pm 1.7; \Gamma(D_{s1}(2700)^\pm) :< 17$	[21]	not seen by other exp's; sys. err. not given
Branching fractions [10^{-4}] unless otherwise noted	$D_{s1}(2460)^\pm \to D_s^{*+}\pi^0 :\ (48 \pm 11)\%$ $D_{s1}(2460)^\pm \to D_s^+\gamma :\ (18 \pm 4)\%$ $D_{s1}(2460)^\pm \to D_s^+\pi^+\pi^- :\ (4.3 \pm 1.3)\%$ $D_{s1}(2460)^\pm \to D_{s0}^*(2317)^\pm\gamma :\ (3.7 \pm {}^{5.0}_{2.4})\%$	[1]	
	$B^0 \to D^- D_{s0}(2317)^+, D_{s0}(2317)^+ \to D_s^+\pi^0 :\ 8.6 \pm {}^{3.3}_{2.6} \pm 2.6$ $B^0 \to D^- D_{s1}(2460)^+, D_{s1}(2460)^+ \to D_s^{*+}\pi^0 :\ 22.7 \pm {}^{7.3}_{6.2} \pm 6.8$ $B^0 \to D^- D_{s1}(2460)^+, D_{s1}(2460)^+ \to D_s^+\gamma :\ 8.2 \pm {}^{2.2}_{1.9} \pm 2.5$	[31]	further br. frac. for B^0, $B^\pm$ in paper
	$B^0 \to D^- D_{s0}(2317)^+, D_{s0}(2317)^+ \to D_s^+\pi^0 :\ 18 \pm 4 \pm 3 \pm {}^{6}_{4}$ $B^0 \to D^- D_{s1}(2460)^+, D_{s1}(2460)^+ \to D_s^{*+}\pi^0 :\ 28 \pm 8 \pm 5 \pm {}^{10}_{6}$ $B^0 \to D^- D_{s1}(2460)^+, D_{s1}(2460)^+ \to D_s^+\gamma :\ 8 \pm 2 \pm 1 \pm {}^{3}_{2}$	[32]	further br. frac. for B^0, $B^\pm$ in paper; last error from $B(D, D_s^\pm)$
	$\frac{B(D_{s1}(2460)^\pm \to D_s^\pm\gamma)}{B(D_{s1}(2460)^\pm \to D_s^{*\pm}\pi^0)} = 0.55 \pm 0.13 \pm 0.08$ $\frac{B(D_{s1}(2460)^\pm \to D_s^\pm\pi^+\pi^-)}{B(D_{s1}(2460)^\pm \to D_s^{*\pm}\pi^0)} = 0.14 \pm 0.04 \pm 0.02$ $\frac{\sigma(D_{s1}(2536)^\pm)B(D_{s1}(2536)^\pm \to D_s^\pm\pi^+\pi^-)}{\sigma(D_{s1}(2460)^\pm)B(D_{s1}(2460)^\pm \to D_s^\pm\pi^+\pi^-)} = 1.05 \pm 0.32 \pm 0.06$	[17]	
	$B \to D_{s0}^*(2317)^\pm K^\mp,\ D_{s0}^*(2317)^\pm \to D_s^\pm\pi^0 :$ $0.53 \pm {}^{0.15}_{0.13} \pm 0.07 \pm 0.14$ $B \to D_{s1}(2460)^\pm K^\mp,\ D_{s1}(2460)^\pm \to D_s^\pm\gamma :\ < 0.094$	[33]	last error due to $B(D_s^\pm)$
	$\frac{\sigma(D_{s0}^*(2317)^\pm)B(D_{s0}^*(2317)^\pm \to D_s^\pm\pi^0)}{\sigma(D_s^\pm)} = (7.9 \pm 1.2 \pm 0.4) \cdot 10^{-2}$ $\frac{\sigma(D_{s1}(2460)^\pm)B(D_{s1}(2460)^\pm \to D_s^{*\pm}\pi^0)}{\sigma(D_s^\pm)} = (3.5 \pm 0.9 \pm 0.2) \cdot 10^{-2}$	[15]	
	$\frac{B(D_{s1}(2536)^\pm \to D^\pm\pi^\mp K^\pm)}{B(D_{s1}(2536)^\pm \to D^{*\pm}K^0)} = (3.27 \pm 0.18 \pm 0.37)\%$	[26]	
	$B \to D_{s1}(2536)^\pm D^\mp : 1.71 \pm 0.48 \pm 0.32$ $B \to D_{s1}(2536)^\pm D^{*\mp} : 3.32 \pm 0.88 \pm 0.66$ $B^+ \to D_{s1}(2536)^+\bar{D}^0 : 2.16 \pm 0.52 \pm 0.45$ $B^+ \to D_{s1}(2536)^+\bar{D}^{*0} : 5.46 \pm 1.17 \pm 1.04$	[34]	$D_{s1}(2536)^+ \to D^{*0}K^+$ used; br. frac. with $D_{s1}(2536)^+ \to D^{*+}K^0$ in paper
	$\frac{B(D_{s1}(2536)^+ \to D^{*0}K^+)}{B(D_{s1}(2536)^+ \to D^{*+}K^0)} = 1.32 \pm 0.47 \pm 0.23$	[27]	
	$B^+ \to D_{sJ}(2700)^+ D^0, D_{sJ}(2700)^+ \to D^0K^+ : 11.3 \pm 2.2 \pm {}^{1.4}_{2.8}$	[22]	
	$\frac{B(D_{s1}(2460)^\pm \to D_s^\pm\gamma)}{B(D_{s1}(2460)^\pm \to D_s^\pm\pi^0\gamma)} = 0.337 \pm 0.036 \pm 0.038$ $\frac{B(D_{s1}(2460)^\pm \to D_s^\pm\pi^+\pi^-)}{B(D_{s1}(2460)^\pm \to D_s^\pm\pi^0\gamma)} = 0.077 \pm 0.013 \pm 0.008$	[29]	95% C.L. U.L.
	$B(D_{s1}(2460)^\pm \to D_s^{*\pm}\pi^0) = (56 \pm 13 \pm 9)\%$ $B(D_{s1}(2460)^\pm \to D_s^\pm\gamma) = (16 \pm 4 \pm 3)\%$	[35]	
	$\frac{B(D_{sJ}(2632)^+ \to D^0K^+)}{B(D_{sJ}(2632)^+ \to D_s^+\eta)} = 0.14 \pm 0.06$	[21]	not seen by other exp's; sys. err. not given
	$\frac{B(D_{s1}(2700)^\pm \to D^{*0}K^+)}{D_{s1}(2700)^\pm \to D^0K^+)} = 0.91 \pm 0.13 \pm 0.12$ $\frac{B(D_{sJ}(2860)^\pm \to D^{*0}K^+)}{D_{sJ}(2860)^\pm \to D^0K^+)} = 1.10 \pm 0.15 \pm 0.19$	[25]	

Table 3: Recent results for quantum numbers of excited D_s mesons.

	Main results	Reference	Comments
Quantum numbers (J^P)	$\frac{\mathcal{A}_{L=2}(D_{s1}(2536)^{\pm}\to D^{*\pm}K_S)}{\mathcal{A}_{L=0}(D_{s1}(2536)^{\pm}\to D^{*\pm}K_S)} =$ $= (0.63 \pm 0.07 \pm 0.02) Exp[\pm i(0.76 \pm 0.03 \pm 0.01)]$	[33]	D-/S-wave amp. ratio
	$D_{s0}^{*}(2317)^{\pm} : 0^+, 1^-, 2^+, \ldots$	[14]	natural J^P based on J^P conserv.
	$D_{s1}(2536)^{\pm} : 1^+, 1^-$	[34]	1^- preferred over 2^+ with sign. $\sim 4\sigma$; 1^+ preferred over 2^- with sign. $\sim 3\sigma$;
	$D_{s1}(2700)^{\pm} : 1^-$	[22]	1^- preferred over $0^+, 2^+$ with sign. $> 10\sigma$
	$D_{s1}(2700)^{\pm},\ D_{sJ}(2860)^{\pm} : 1^-, 2^+, \ldots$	[25]	natural J^P preferred based on helicity angle distrib.; 0^+ ruled out due to $D_{sJ} \to D^*K$
	$D_{s1}(2460)^{\pm} : 1^+$	[31]	1^+ preferred over 2^- with sign. $\sim 6\sigma$
	$D_{s1}(2460)^{\pm} : J \neq 0$	[29]	0^- disfavored with sign. $\sim 5\sigma$; assuming decay $D_{s1}(2460)^{\pm} \to D_s^{*\pm}\pi^0$ $\to D_s^{\pm}\gamma\pi^0$

References

[1] Particle Data Group, C. Amsler *et al.*, Phys. Lett. **B667**, 1 (2008).

[2] Belle, K. Abe *et al.*, Phys. Rev. **D69**, 112002 (2004), hep-ex/0307021.

[3] FOCUS, J. M. Link *et al.*, Phys. Lett. **B586**, 11 (2004), hep-ex/0312060.

[4] BABAR, B. Aubert *et al.*, Phys. Rev. **D79**, 112004 (2009), 0901.1291.

[5] CDF, A. Abulencia *et al.*, Phys. Rev. **D73**, 051104 (2006), hep-ex/0512069.

[6] S. Godfrey and N. Isgur, Phys. Rev. **D32**, 189 (1985).

[7] J. L. Rosner, Comments Nucl. Part. Phys. **16**, 109 (1986).

[8] S. Godfrey and R. Kokoski, Phys. Rev. **D43**, 1679 (1991).

[9] N. Isgur and M. B. Wise, Phys. Rev. Lett. **66**, 1130 (1991).

[10] M. Di Pierro and E. Eichten, Phys. Rev. **D64**, 114004 (2001), hep-ph/0104208.

[11] Belle, K. Abe *et al.*, Phys. Rev. Lett. **94**, 221805 (2005), hep-ex/0410091.

[12] P. Colangelo, F. De Fazio, and R. Ferrandes, Mod. Phys. Lett. **A19**, 2083 (2004), hep-ph/0407137.

[13] F. Jugeau, A. Le Yaouanc, L. Oliver, and J. C. Raynal, Phys. Rev. **D72**, 094010 (2005), hep-ph/0504206.

[14] BABAR, B. Aubert *et al.*, Phys. Rev. Lett. **90**, 242001 (2003), hep-ex/0304021.

[15] CLEO, D. Besson *et al.*, Phys. Rev. **D68**, 032002 (2003), hep-ex/0305100.

[16] R. N. Cahn and J. D. Jackson, Phys. Rev. **D68**, 037502 (2003), hep-ph/0305012.

[17] Belle, K. Abe *et al.*, Phys. Rev. Lett. **92**, 012002 (2004), hep-ex/0307052.

[18] T. Barnes, F. E. Close, and H. J. Lipkin, Phys. Rev. **D68**, 054006 (2003), hep-ph/0305025.

[19] H. J. Lipkin, Phys. Lett. **B580**, 50 (2004), hep-ph/0306204.

[20] W. A. Bardeen, E. J. Eichten, and C. T. Hill, Phys. Rev. **D68**, 054024 (2003), hep-ph/0305049.

[21] SELEX, A. V. Evdokimov *et al.*, Phys. Rev. Lett. **93**, 242001 (2004), hep-ex/0406045.

[22] Belle, J. Brodzicka *et al.*, Phys. Rev. Lett. **100**, 092001 (2008), 0707.3491.

[23] BABAR, B. Aubert *et al.*, Phys. Rev. Lett. **97**, 222001 (2006), hep-ex/0607082.

[24] T. Matsuki, T. Morii, and K. Sudoh, Eur. Phys. J. **A31**, 701 (2007), hep-ph/0610186.

[25] BABAR, B. Aubert *et al.*, Phys. Rev. **D80**, 092003 (2009), 0908.0806.

[26] Belle, V. Balagura *et al.*, Phys. Rev. **D77**, 032001 (2008), 0709.4184.

[27] ALEPH, A. Heister *et al.*, Phys. Lett. **B526**, 34 (2002), hep-ex/0112010.

[28] Belle, A. Kuzmin *et al.*, Phys. Rev. **D76**, 012006 (2007), hep-ex/0611054.

[29] BABAR, B. Aubert *et al.*, Phys. Rev. **D74**, 032007 (2006), hep-ex/0604030.

[30] CLEO, J. P. Alexander *et al.*, Phys. Lett. **B303**, 377 (1993).

[31] Belle, P. Krokovny *et al.*, Phys. Rev. Lett. **91**, 262002 (2003), hep-ex/0308019.

[32] BABAR, B. Aubert *et al.*, Phys. Rev. Lett. **93**, 181801 (2004), hep-ex/0408041.

[33] Belle, A. Drutskoy *et al.*, Phys. Rev. Lett. **94**, 061802 (2005), hep-ex/0409026.

[34] BABAR, B. Aubert *et al.*, Phys. Rev. **D77**, 011102 (2008), 0708.1565.

[35] BABAR, B. Aubert *et al.*, Phys. Rev. **D74**, 031103 (2006), hep-ex/0605036.