

BOTTOM, STRANGE MESONS

($B = \pm 1, S = \mp 1$)

$$B_s^0 = s\bar{b}, \bar{B}_s^0 = \bar{s}b, \quad \text{similarly for } B_s^{*'}s$$

B_s^0

$$I(J^P) = 0(0^-)$$

I, J, P need confirmation. Quantum numbers shown are quark-model predictions.

$$\text{Mass } m_{B_s^0} = 5366.89 \pm 0.19 \text{ MeV}$$

$$m_{B_s^0} - m_B = 87.42 \pm 0.19 \text{ MeV}$$

$$\text{Mean life } \tau = (1.509 \pm 0.004) \times 10^{-12} \text{ s}$$

$$c\tau = 452.4 \text{ } \mu\text{m}$$

$$\Delta\Gamma_{B_s^0} = \Gamma_{B_{sL}^0} - \Gamma_{B_{sH}^0} = (0.088 \pm 0.006) \times 10^{12} \text{ s}^{-1}$$

B_s^0 - \bar{B}_s^0 mixing parameters

$$\Delta m_{B_s^0} = m_{B_{sH}^0} - m_{B_{sL}^0} = (17.757 \pm 0.021) \times 10^{12} \hbar \text{ s}^{-1}$$

$$= (1.1688 \pm 0.0014) \times 10^{-8} \text{ MeV}$$

$$x_s = \Delta m_{B_s^0} / \Gamma_{B_s^0} = 26.72 \pm 0.09$$

$$\chi_s = 0.499304 \pm 0.000005$$

CP violation parameters in B_s^0

$$\text{Re}(\epsilon_{B_s^0}) / (1 + |\epsilon_{B_s^0}|^2) = (-0.15 \pm 0.70) \times 10^{-3}$$

$$C_{KK}(B_s^0 \rightarrow K^+ K^-) = 0.14 \pm 0.11$$

$$S_{KK}(B_s^0 \rightarrow K^+ K^-) = 0.30 \pm 0.13$$

$$r_B(B_s^0 \rightarrow D_s^\mp K^\pm) = 0.53 \pm 0.17$$

$$\delta_B(B_s^0 \rightarrow D_s^\pm K^\mp) = (3 \pm 20)^\circ$$

$$\text{CP Violation phase } \beta_s = (1.1 \pm 1.6) \times 10^{-2} \text{ rad}$$

$$|\lambda| (B_s^0 \rightarrow J/\psi(1S)\phi) = 0.964 \pm 0.020$$

$$|\lambda| = 1.001 \pm 0.017$$

$$A, \text{ CP violation parameter} = 0.5_{-0.7}^{+0.8}$$

$$C, \text{ CP violation parameter} = -0.3 \pm 0.4$$

$$S, \text{ CP violation parameter} = -0.1 \pm 0.4$$

$$A_{CP}^L(B_s \rightarrow J/\psi \bar{K}^*(892)^0) = -0.05 \pm 0.06$$

$$A_{CP}^{\parallel}(B_s \rightarrow J/\psi \bar{K}^*(892)^0) = 0.17 \pm 0.15$$

$$A_{CP}^{\perp}(B_s \rightarrow J/\psi \bar{K}^*(892)^0) = -0.05 \pm 0.10$$

$$\mathbf{A}_{CP}(B_s \rightarrow \pi^+ K^-) = 0.26 \pm 0.04$$

$$A_{CP}(B_s^0 \rightarrow [K^+ K^-]_D \bar{K}^*(892)^0) = -0.04 \pm 0.07$$

$$\begin{aligned}
 A_{CP}(B_s^0 \rightarrow [\pi^+ K^-]_D K^*(892)^0) &= -0.01 \pm 0.04 \\
 A_{CP}(B_s^0 \rightarrow [\pi^+ \pi^-]_D K^*(892)^0) &= 0.06 \pm 0.13 \\
 A^\Delta(B_s \rightarrow \phi \gamma) &= -1.0 \pm 0.5 \\
 \Delta a_\perp &< 1.2 \times 10^{-12} \text{ GeV, CL} = 95\% \\
 \Delta a_\parallel &= (-0.9 \pm 1.5) \times 10^{-14} \text{ GeV} \\
 \Delta a_X &= (1.0 \pm 2.2) \times 10^{-14} \text{ GeV} \\
 \Delta a_Y &= (-3.8 \pm 2.2) \times 10^{-14} \text{ GeV} \\
 \text{Re}(\xi) &= -0.022 \pm 0.033 \\
 \text{Im}(\xi) &= 0.004 \pm 0.011
 \end{aligned}$$

These branching fractions all scale with $B(\bar{b} \rightarrow B_s^0)$.

The branching fraction $B(B_s^0 \rightarrow D_s^- \ell^+ \nu_\ell \text{ anything})$ is not a pure measurement since the measured product branching fraction $B(\bar{b} \rightarrow B_s^0) \times B(B_s^0 \rightarrow D_s^- \ell^+ \nu_\ell \text{ anything})$ was used to determine $B(\bar{b} \rightarrow B_s^0)$, as described in the note on “ B^0 - \bar{B}^0 Mixing”

For inclusive branching fractions, *e.g.*, $B \rightarrow D^\pm \text{ anything}$, the values usually are multiplicities, not branching fractions. They can be greater than one.

B_s^0 DECAY MODES	Fraction (Γ_i/Γ)	Scale factor/ Confidence level	p (MeV/c)
D_s^- anything	(93 ± 25) %		—
$\ell \nu_\ell X^-$	(9.6 ± 0.8) %		—
$e^+ \nu X^-$	(9.1 ± 0.8) %		—
$\mu^+ \nu X^-$	(10.2 ± 1.0) %		—
$D_s^- \ell^+ \nu_\ell$ anything	[a] (8.1 ± 1.3) %		—
$D_s^{*-} \ell^+ \nu_\ell$ anything	(5.4 ± 1.1) %		—
$D_{s1}(2536)^- \mu^+ \nu_\mu, D_{s1}^- \rightarrow$ $D^{*-} K_S^0$	(2.6 ± 0.7) × 10 ⁻³		—
$D_{s1}(2536)^- X \mu^+ \nu, D_{s1}^- \rightarrow$ $\bar{D}^0 K^+$	(4.4 ± 1.3) × 10 ⁻³		—
$D_{s2}(2573)^- X \mu^+ \nu, D_{s2}^- \rightarrow$ $\bar{D}^0 K^+$	(2.7 ± 1.0) × 10 ⁻³		—
$D_s^- \pi^+$	(3.00 ± 0.23) × 10 ⁻³		2320
$D_s^- \rho^+$	(6.9 ± 1.4) × 10 ⁻³		2249
$D_s^- \pi^+ \pi^+ \pi^-$	(6.1 ± 1.0) × 10 ⁻³		2301
$D_{s1}(2536)^- \pi^+, D_{s1}^- \rightarrow$ $D_s^- \pi^+ \pi^-$	(2.5 ± 0.8) × 10 ⁻⁵		—
$D_s^\mp K^\pm$	(2.27 ± 0.19) × 10 ⁻⁴		2293
$D_s^- K^+ \pi^+ \pi^-$	(3.2 ± 0.6) × 10 ⁻⁴		2249
$D_s^+ D_s^-$	(4.4 ± 0.5) × 10 ⁻³		1824

$D_s^- D^+$	$(2.8 \pm 0.5) \times 10^{-4}$		1875
$D^+ D^-$	$(2.2 \pm 0.6) \times 10^{-4}$		1925
$D^0 \bar{D}^0$	$(1.9 \pm 0.5) \times 10^{-4}$		1930
$D_s^{*-} \pi^+$	$(2.0 \pm 0.5) \times 10^{-3}$		2265
$D_s^{*\mp} K^\pm$	$(1.33 \pm 0.35) \times 10^{-4}$		—
$D_s^{*-} \rho^+$	$(9.6 \pm 2.1) \times 10^{-3}$		2191
$D_s^{*+} D_s^- + D_s^{*-} D_s^+$	$(1.38 \pm 0.16) \%$		1742
$D_s^{*+} D_s^{*-}$	$(1.44 \pm 0.20) \%$	S=1.1	1655
$D_s^{(*)+} D_s^{(*)-}$	$(4.5 \pm 1.4) \%$		—
$\bar{D}^{*0} \bar{K}^0$	$(2.8 \pm 1.1) \times 10^{-4}$		2278
$\bar{D}^0 \bar{K}^0$	$(4.3 \pm 0.9) \times 10^{-4}$		2330
$\bar{D}^0 K^- \pi^+$	$(1.04 \pm 0.13) \times 10^{-3}$		2312
$\bar{D}^0 \bar{K}^*(892)^0$	$(4.4 \pm 0.6) \times 10^{-4}$		2264
$\bar{D}^0 \bar{K}^*(1410)$	$(3.9 \pm 3.5) \times 10^{-4}$		2114
$\bar{D}^0 \bar{K}_0^*(1430)$	$(3.0 \pm 0.7) \times 10^{-4}$		2113
$\bar{D}^0 \bar{K}_2^*(1430)$	$(1.1 \pm 0.4) \times 10^{-4}$		2113
$\bar{D}^0 \bar{K}^*(1680)$	$< 7.8 \times 10^{-5}$	CL=90%	1997
$\bar{D}^0 \bar{K}_0^*(1950)$	$< 1.1 \times 10^{-4}$	CL=90%	1890
$\bar{D}^0 \bar{K}_3^*(1780)$	$< 2.6 \times 10^{-5}$	CL=90%	1971
$\bar{D}^0 \bar{K}_4^*(2045)$	$< 3.1 \times 10^{-5}$	CL=90%	1837
$\bar{D}^0 K^- \pi^+ (\text{non-resonant})$	$(2.1 \pm 0.8) \times 10^{-4}$		2312
$D_{s2}^*(2573)^- \pi^+, D_{s2}^* \rightarrow \bar{D}^0 K^-$	$(2.6 \pm 0.4) \times 10^{-4}$		—
$D_{s1}^*(2700)^- \pi^+, D_{s1}^* \rightarrow \bar{D}^0 K^-$	$(1.6 \pm 0.8) \times 10^{-5}$		—
$D_{s1}^*(2860)^- \pi^+, D_{s1}^* \rightarrow \bar{D}^0 K^-$	$(5 \pm 4) \times 10^{-5}$		—
$D_{s3}^*(2860)^- \pi^+, D_{s3}^* \rightarrow \bar{D}^0 K^-$	$(2.2 \pm 0.6) \times 10^{-5}$		—
$\bar{D}^0 K^+ K^-$	$(4.4 \pm 2.0) \times 10^{-5}$		2243
$\bar{D}^0 f_0(980)$	$< 3.1 \times 10^{-6}$	CL=90%	2242
$\bar{D}^0 \phi$	$(3.0 \pm 0.8) \times 10^{-5}$		2235
$D^{*\mp} \pi^\pm$	$< 6.1 \times 10^{-6}$	CL=90%	—
$\eta_c \phi$	$(5.0 \pm 0.9) \times 10^{-4}$		1663
$\eta_c \pi^+ \pi^-$	$(1.8 \pm 0.7) \times 10^{-4}$		1840
$J/\psi(1S) \phi$	$(1.08 \pm 0.08) \times 10^{-3}$		1588
$J/\psi(1S) \phi \phi$	$(1.24 \pm_{-0.19}^{0.17}) \times 10^{-5}$		764
$J/\psi(1S) \pi^0$	$< 1.2 \times 10^{-3}$	CL=90%	1787
$J/\psi(1S) \eta$	$(4.0 \pm 0.7) \times 10^{-4}$	S=1.4	1733
$J/\psi(1S) K_S^0$	$(1.88 \pm 0.15) \times 10^{-5}$		1743
$J/\psi(1S) \bar{K}^*(892)^0$	$(4.1 \pm 0.4) \times 10^{-5}$		1637
$J/\psi(1S) \eta'$	$(3.3 \pm 0.4) \times 10^{-4}$		1612

$J/\psi(1S)\pi^+\pi^-$	$(2.09 \pm 0.23) \times 10^{-4}$	S=1.3	1775
$J/\psi(1S)f_0(500), f_0 \rightarrow \pi^+\pi^-$	$< 4 \times 10^{-6}$	CL=90%	—
$J/\psi(1S)\rho, \rho \rightarrow \pi^+\pi^-$	$< 4 \times 10^{-6}$	CL=90%	—
$J/\psi(1S)f_0(980), f_0 \rightarrow \pi^+\pi^-$	$(1.28 \pm 0.18) \times 10^{-4}$	S=1.7	—
$J/\psi(1S)f_2(1270), f_2 \rightarrow \pi^+\pi^-$	$(1.1 \pm 0.4) \times 10^{-6}$		—
$J/\psi(1S)f_2(1270)_0, f_2 \rightarrow \pi^+\pi^-$	$(7.5 \pm 1.8) \times 10^{-7}$		—
$J/\psi(1S)f_2(1270)_\parallel, f_2 \rightarrow \pi^+\pi^-$	$(1.09 \pm 0.34) \times 10^{-6}$		—
$J/\psi(1S)f_2(1270)_\perp, f_2 \rightarrow \pi^+\pi^-$	$(1.3 \pm 0.8) \times 10^{-6}$		—
$J/\psi(1S)f_0(1370), f_0 \rightarrow \pi^+\pi^-$	$(4.5 \pm_{-4.0}^{0.7}) \times 10^{-5}$		—
$J/\psi(1S)f_0(1500), f_0 \rightarrow \pi^+\pi^-$	$(2.11 \pm_{-0.29}^{0.40}) \times 10^{-5}$		—
$J/\psi(1S)f'_2(1525)_0, f'_2 \rightarrow \pi^+\pi^-$	$(1.07 \pm 0.24) \times 10^{-6}$		—
$J/\psi(1S)f'_2(1525)_\parallel, f'_2 \rightarrow \pi^+\pi^-$	$(1.3 \pm_{-0.9}^{2.7}) \times 10^{-7}$		—
$J/\psi(1S)f'_2(1525)_\perp, f'_2 \rightarrow \pi^+\pi^-$	$(5 \pm 4) \times 10^{-7}$		—
$J/\psi(1S)f_0(1790), f_0 \rightarrow \pi^+\pi^-$	$(5.0 \pm_{-1.1}^{11.0}) \times 10^{-6}$		—
$J/\psi(1S)\pi^+\pi^-$ (nonresonant)	$(1.8 \pm_{-0.4}^{1.1}) \times 10^{-5}$		1775
$J/\psi(1S)\bar{K}^0\pi^+\pi^-$	$< 4.4 \times 10^{-5}$	CL=90%	1675
$J/\psi(1S)K^+K^-$	$(7.9 \pm 0.7) \times 10^{-4}$		1601
$J/\psi(1S)K^0K^-\pi^+ + \text{c.c.}$	$(9.3 \pm 1.3) \times 10^{-4}$		1538
$J/\psi(1S)\bar{K}^0K^+K^-$	$< 1.2 \times 10^{-5}$	CL=90%	1333
$J/\psi(1S)f'_2(1525)$	$(2.6 \pm 0.6) \times 10^{-4}$		1304
$J/\psi(1S)p\bar{p}$	$< 4.8 \times 10^{-6}$	CL=90%	982
$J/\psi(1S)\gamma$	$< 7.3 \times 10^{-6}$	CL=90%	1790
$J/\psi(1S)\pi^+\pi^-\pi^+\pi^-$	$(7.8 \pm 1.0) \times 10^{-5}$		1731
$J/\psi(1S)f_1(1285)$	$(7.0 \pm 1.4) \times 10^{-5}$		1460
$\psi(2S)\eta$	$(3.3 \pm 0.9) \times 10^{-4}$		1338
$\psi(2S)\eta'$	$(1.29 \pm 0.35) \times 10^{-4}$		1158
$\psi(2S)\pi^+\pi^-$	$(7.1 \pm 1.3) \times 10^{-5}$		1397
$\psi(2S)\phi$	$(5.4 \pm 0.6) \times 10^{-4}$		1120
$\psi(2S)K^-\pi^+$	$(3.12 \pm 0.30) \times 10^{-5}$		1310
$\psi(2S)\bar{K}^*(892)^0$	$(3.3 \pm 0.5) \times 10^{-5}$		1196
$\chi_{c1}\phi$	$(2.04 \pm 0.30) \times 10^{-4}$		1274
$\pi^+\pi^-$	$(7.0 \pm 0.8) \times 10^{-7}$		2680

$\pi^0\pi^0$		< 2.1	$\times 10^{-4}$	CL=90%	2680
$\eta\pi^0$		< 1.0	$\times 10^{-3}$	CL=90%	2654
$\eta\eta$		< 1.5	$\times 10^{-3}$	CL=90%	2627
$\rho^0\rho^0$		< 3.20	$\times 10^{-4}$	CL=90%	2569
$\eta'\eta'$		(3.3 ± 0.7)	$\times 10^{-5}$		2507
$\eta'\phi$		< 8.2	$\times 10^{-7}$	CL=90%	2495
$\phi f_0(980), f_0(980) \rightarrow \pi^+\pi^-$		(1.12 ± 0.21)	$\times 10^{-6}$		–
$\phi f_2(1270), f_2(1270) \rightarrow \pi^+\pi^-$		$(6.1 \begin{smallmatrix} + \\ - \end{smallmatrix} \frac{1.8}{1.5})$	$\times 10^{-7}$		–
$\phi\rho^0$		(2.7 ± 0.8)	$\times 10^{-7}$		2526
$\phi\pi^+\pi^-$		(3.5 ± 0.5)	$\times 10^{-6}$		2579
$\phi\phi$		(1.87 ± 0.15)	$\times 10^{-5}$		2482
$\phi\phi\phi$		(2.2 ± 0.7)	$\times 10^{-6}$		2165
π^+K^-		(5.7 ± 0.6)	$\times 10^{-6}$		2659
K^+K^-		(2.59 ± 0.17)	$\times 10^{-5}$		2638
$K^0\bar{K}^0$		(2.0 ± 0.6)	$\times 10^{-5}$		2637
$K^0\pi^+\pi^-$		(9.4 ± 2.1)	$\times 10^{-6}$		2653
$K^0K^\pm\pi^\mp$		(8.4 ± 0.9)	$\times 10^{-5}$		2622
$K^*(892)^-\pi^+$		(3.3 ± 1.2)	$\times 10^{-6}$		2607
$K^*(892)^\pm K^\mp$		(1.25 ± 0.26)	$\times 10^{-5}$		2585
$K_S^0\bar{K}^*(892)^0 + c.c.$		(1.6 ± 0.4)	$\times 10^{-5}$		2585
$K_S^0K^+K^-$		(1.3 ± 0.6)	$\times 10^{-6}$		2568
$\bar{K}^*(892)^0\rho^0$		< 7.67	$\times 10^{-4}$	CL=90%	2550
$\bar{K}^*(892)^0K^*(892)^0$		(1.11 ± 0.27)	$\times 10^{-5}$		2531
$\phi K^*(892)^0$		(1.14 ± 0.30)	$\times 10^{-6}$		2507
$p\bar{p}$		< 1.5	$\times 10^{-8}$	CL=90%	2514
$p\bar{p}K^+K^-$		(4.5 ± 0.5)	$\times 10^{-6}$		2231
$p\bar{p}K^+\pi^-$		(1.39 ± 0.26)	$\times 10^{-6}$		2355
$p\bar{p}\pi^+\pi^-$		(4.3 ± 2.0)	$\times 10^{-7}$		2454
$p\bar{\Lambda}K^- + c.c.$		(5.5 ± 1.0)	$\times 10^{-6}$		2358
$\Lambda_c^-\Lambda\pi^+$		(3.6 ± 1.6)	$\times 10^{-4}$		–
$\Lambda_c^-\Lambda_c^+$		< 8.0	$\times 10^{-5}$	CL=95%	–

**Lepton Family number (LF) violating modes or
 $\Delta B = 1$ weak neutral current (B1) modes**

$\gamma\gamma$	B1	< 3.1	$\times 10^{-6}$	CL=90%	2683
$\phi\gamma$	B1	(3.4 ± 0.4)	$\times 10^{-5}$		2587
$\mu^+\mu^-$	B1	$(2.7 \begin{smallmatrix} + \\ - \end{smallmatrix} \frac{0.6}{0.5})$	$\times 10^{-9}$	S=1.2	2681
e^+e^-	B1	< 2.8	$\times 10^{-7}$	CL=90%	2683
$\tau^+\tau^-$	B1	< 6.8	$\times 10^{-3}$	CL=95%	2011
$\mu^+\mu^-\mu^+\mu^-$	B1	< 2.5	$\times 10^{-9}$	CL=95%	2673
$SP, S \rightarrow \mu^+\mu^-,$ $P \rightarrow \mu^+\mu^-$	B1	[b] < 2.2	$\times 10^{-9}$	CL=95%	–

$\phi(1020)\mu^+\mu^-$	<i>B1</i>	$(8.2 \pm 1.2) \times 10^{-7}$	2582
$\pi^+\pi^-\mu^+\mu^-$	<i>B1</i>	$(8.4 \pm 1.7) \times 10^{-8}$	2670
$\phi\nu\bar{\nu}$	<i>B1</i>	$< 5.4 \times 10^{-3}$	CL=90% 2587
$e^\pm\mu^\mp$	<i>LF</i>	$[c] < 1.1 \times 10^{-8}$	CL=90% 2682

B_s^*

$$I(J^P) = 0(1^-)$$

I, *J*, *P* need confirmation. Quantum numbers shown are quark-model predictions.

$$\text{Mass } m = 5415.4^{+1.8}_{-1.5} \text{ MeV} \quad (S = 2.9)$$

$$m_{B_s^*} - m_{B_s} = 48.5^{+1.8}_{-1.5} \text{ MeV} \quad (S = 2.8)$$

B_s^* DECAY MODES	Fraction (Γ_i/Γ)	<i>p</i> (MeV/c)
$B_s\gamma$	dominant	48

$B_{s1}(5830)^0$

$$I(J^P) = 0(1^+)$$

I, *J*, *P* need confirmation.

$$\text{Mass } m = 5828.63 \pm 0.27 \text{ MeV}$$

$$m_{B_{s1}^0} - m_{B^{*+}} = 503.98 \pm 0.18 \text{ MeV}$$

$$\text{Full width } \Gamma = 0.5 \pm 0.4 \text{ MeV}$$

$B_{s1}(5830)^0$ DECAY MODES	Fraction (Γ_i/Γ)	<i>p</i> (MeV/c)
$B^{*+}K^-$	dominant	97

$B_{s2}^*(5840)^0$

$$I(J^P) = 0(2^+)$$

I, *J*, *P* need confirmation.

$$\text{Mass } m = 5839.85 \pm 0.17 \text{ MeV} \quad (S = 1.1)$$

$$m_{B_{s2}^0} - m_{B^+} = 560.53 \pm 0.17 \text{ MeV} \quad (S = 1.1)$$

$$\text{Full width } \Gamma = 1.47 \pm 0.33 \text{ MeV}$$

$B_{s2}^*(5840)^0$ DECAY MODES	Fraction (Γ_i/Γ)	<i>p</i> (MeV/c)
B^+K^-	dominant	252

NOTES

- [a] Not a pure measurement. See note at head of B_s^0 Decay Modes.
- [b] Here S and P are the hypothetical scalar and pseudoscalar particles with masses of $2.5 \text{ GeV}/c^2$ and $214.3 \text{ MeV}/c^2$, respectively.
- [c] The value is for the sum of the charge states or particle/antiparticle states indicated.