

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.

$$\text{Mass } m_{B_s^0} = 5366.82 \pm 0.22 \text{ MeV}$$

$$m_{B_s^0} - m_B = 87.35 \pm 0.20 \text{ MeV}$$

$$\text{Mean life } \tau = (1.510 \pm 0.005) \times 10^{-12} \text{ s}$$

$$c\tau = 452.7 \text{ } \mu\text{m}$$

$$\Delta\Gamma_{B_s^0} = \Gamma_{B_{sL}^0} - \Gamma_{B_{sH}^0} = (0.082 \pm 0.007) \times 10^{12} \text{ s}^{-1}$$

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

$$\begin{aligned} \Delta m_{B_s^0} &= m_{B_{sH}^0} - m_{B_{sL}^0} = (17.757 \pm 0.021) \times 10^{12} \hbar \text{ s}^{-1} \\ &= (1.1688 \pm 0.0014) \times 10^{-8} \text{ MeV} \end{aligned}$$

$$x_s = \Delta m_{B_s^0} / \Gamma_{B_s^0} = 26.81 \pm 0.10$$

$$\chi_s = 0.499308 \pm 0.000005$$

CP violation parameters in B_s^0

$$\text{Re}(\epsilon_{B_s^0}) / (1 + |\epsilon_{B_s^0}|^2) = (-1.9 \pm 1.0) \times 10^{-3}$$

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

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

$$\gamma = (65 \pm 7)^\circ$$

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

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

$$\text{CP Violation phase } \beta_s = (0.6 \pm 1.9) \times 10^{-2} \text{ rad}$$

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

$$|\lambda| = 1.02 \pm 0.07$$

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

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

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

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

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

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

$$A_{CP}(B_s \rightarrow \pi^+ K^-) = 0.263 \pm 0.035$$

$$\begin{aligned}
 A_{CP}(B_s^0 \rightarrow [K^+ K^-]_D \bar{K}^*(892)^0) &= -0.04 \pm 0.07 \\
 A_{CP}(B_s^0 \rightarrow [\pi^+ K^-]_D K^*(892)^0) &= -0.01 \pm 0.04 \\
 A_{CP}(B_s^0 \rightarrow [\pi^+ \pi^-]_D K^*(892)^0) &= 0.06 \pm 0.13 \\
 \Delta a_\perp &< 1.2 \times 10^{-12} \text{ GeV, CL} = 95\%
 \end{aligned}$$

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 ± 0.5) × 10 ⁻⁴		1875
$D^+ D^-$	(2.2 ± 0.6) × 10 ⁻⁴		1925
$D^0 \bar{D}^0$	(1.9 ± 0.5) × 10 ⁻⁴		1930
$D_s^{*-} \pi^+$	(2.0 ± 0.5) × 10 ⁻³		2265
$D_s^{*\mp} K^\pm$	(1.33 ± 0.35) × 10 ⁻⁴		–

$D_s^{*-} \rho^+$	$(9.6 \pm 2.1) \times 10^{-3}$		2191
$D_s^{*+} D_s^- + D_s^{*-} D_s^+$	$(1.29 \pm 0.22) \%$	S=1.1	1742
$D_s^{*+} D_s^{*-}$	$(1.86 \pm 0.30) \%$		1655
$D_s^{(*)+} D_s^{(*)-}$	$(4.5 \pm 1.4) \%$		—
$\overline{D}^0 K^- \pi^+$	$(1.04 \pm 0.13) \times 10^{-3}$		2312
$\overline{D}^0 \overline{K}^*(892)^0$	$(4.4 \pm 0.6) \times 10^{-4}$		2264
$\overline{D}^0 \overline{K}^*(1410)$	$(3.9 \pm 3.5) \times 10^{-4}$		2117
$\overline{D}^0 \overline{K}_0^*(1430)$	$(3.0 \pm 0.7) \times 10^{-4}$		2113
$\overline{D}^0 \overline{K}_2^*(1430)$	$(1.1 \pm 0.4) \times 10^{-4}$		2113
$\overline{D}^0 \overline{K}^*(1680)$	$< 7.8 \times 10^{-5}$	CL=90%	1998
$\overline{D}^0 \overline{K}_0^*(1950)$	$< 1.1 \times 10^{-4}$	CL=90%	1890
$\overline{D}^0 \overline{K}_3^*(1780)$	$< 2.6 \times 10^{-5}$	CL=90%	1971
$\overline{D}^0 \overline{K}_4^*(2045)$	$< 3.1 \times 10^{-5}$	CL=90%	1837
$\overline{D}^0 K^- \pi^+$ (non-resonant)	$(2.1 \pm 0.8) \times 10^{-4}$		2312
$D_{s2}^*(2573)^- \pi^+$, $D_{s2}^* \rightarrow \overline{D}^0 K^-$	$(2.6 \pm 0.4) \times 10^{-4}$		—
$D_{s1}^*(2700)^- \pi^+$, $D_{s1}^* \rightarrow \overline{D}^0 K^-$	$(1.6 \pm 0.8) \times 10^{-5}$		—
$D_{s1}^*(2860)^- \pi^+$, $D_{s1}^* \rightarrow \overline{D}^0 K^-$	$(5 \pm 4) \times 10^{-5}$		—
$D_{s3}^*(2860)^- \pi^+$, $D_{s3}^* \rightarrow \overline{D}^0 K^-$	$(2.2 \pm 0.6) \times 10^{-5}$		—
$\overline{D}^0 K^+ K^-$	$(4.4 \pm 2.0) \times 10^{-5}$		2243
$\overline{D}^0 f_0(980)$	$< 3.1 \times 10^{-6}$	CL=90%	2242
$\overline{D}^0 \phi$	$(3.0 \pm 0.8) \times 10^{-5}$		2235
$D^{*\mp} \pi^\pm$	$< 6.1 \times 10^{-6}$	CL=90%	—
$J/\psi(1S) \phi$	$(1.07 \pm 0.08) \times 10^{-3}$		1588
$J/\psi(1S) \pi^0$	$< 1.2 \times 10^{-3}$	CL=90%	1786
$J/\psi(1S) \eta$	$(3.9 \pm 0.7) \times 10^{-4}$	S=1.4	1733
$J/\psi(1S) K_S^0$	$(1.89 \pm 0.12) \times 10^{-5}$		1743
$J/\psi(1S) \overline{K}^*(892)^0$	$(4.1 \pm 0.4) \times 10^{-5}$		1637
$J/\psi(1S) \eta'$	$(3.3 \pm 0.4) \times 10^{-4}$		1612
$J/\psi(1S) \pi^+ \pi^-$	$(2.13 \pm 0.18) \times 10^{-4}$		1775
$J/\psi(1S) f_0(500), f_0 \rightarrow \pi^+ \pi^-$	$< 1.7 \times 10^{-6}$	CL=90%	—
$J/\psi(1S) \rho, \rho \rightarrow \pi^+ \pi^-$	$< 1.2 \times 10^{-6}$	CL=90%	—
$J/\psi(1S) f_0(980), f_0 \rightarrow \pi^+ \pi^-$	$(1.34 \pm 0.15) \times 10^{-4}$		—
$J/\psi(1S) f_0(980)_0, f_0 \rightarrow \pi^+ \pi^-$	$(5.1 \pm 0.9) \times 10^{-5}$		—

$J/\psi(1S) f_2(1270)_0,$ $f_2 \rightarrow \pi^+ \pi^-$	$(2.6 \pm 0.7) \times 10^{-7}$	—	
$J/\psi(1S) f_2(1270)_\parallel,$ $f_2 \rightarrow \pi^+ \pi^-$	$(3.8 \pm 1.3) \times 10^{-7}$	—	
$J/\psi(1S) f_2(1270)_\perp,$ $f_2 \rightarrow \pi^+ \pi^-$	$(4.6 \pm 2.7) \times 10^{-7}$	—	
$J/\psi(1S) f_0(1500),$ $f_0 \rightarrow \pi^+ \pi^-$	$(7.3 \begin{smallmatrix} + 1.6 \\ - 1.4 \end{smallmatrix}) \times 10^{-6}$	—	
$J/\psi(1S) f'_2(1525)_0,$ $f'_2 \rightarrow \pi^+ \pi^-$	$(3.7 \pm 1.0) \times 10^{-7}$	—	
$J/\psi(1S) f'_2(1525)_\parallel,$ $f'_2 \rightarrow \pi^+ \pi^-$	$(4.3 \begin{smallmatrix} + 9.0 \\ - 3.1 \end{smallmatrix}) \times 10^{-8}$	—	
$J/\psi(1S) f'_2(1525)_\perp,$ $f'_2 \rightarrow \pi^+ \pi^-$	$(1.9 \pm 1.4) \times 10^{-7}$	—	
$J/\psi(1S) f_0(1790),$ $f_0 \rightarrow \pi^+ \pi^-$	$(1.7 \begin{smallmatrix} + 4.0 \\ - 0.4 \end{smallmatrix}) \times 10^{-6}$	—	
$J/\psi(1S) \bar{K}^0 \pi^+ \pi^-$	$< 4.4 \times 10^{-5}$	CL=90%	1675
$J/\psi(1S) K^+ K^-$	$(7.9 \pm 0.7) \times 10^{-4}$		1601
$J/\psi(1S) K^0 K^- \pi^+ + \text{c.c.}$	$(9.3 \pm 1.3) \times 10^{-4}$		1538
$J/\psi(1S) \bar{K}^0 K^+ K^-$	$< 1.2 \times 10^{-5}$	CL=90%	1333
$J/\psi(1S) f'_2(1525)$	$(2.6 \pm 0.6) \times 10^{-4}$		1304
$J/\psi(1S) \rho \bar{\rho}$	$< 4.8 \times 10^{-6}$	CL=90%	982
$J/\psi(1S) \gamma$	$< 7.3 \times 10^{-6}$	CL=90%	1790
$J/\psi(1S) \pi^+ \pi^- \pi^+ \pi^-$	$(7.9 \pm 0.9) \times 10^{-5}$		1731
$J/\psi(1S) f_1(1285)$	$(7.1 \pm 1.4) \times 10^{-5}$		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
$\psi(2S) \pi^+ \pi^-$	$(7.2 \pm 1.2) \times 10^{-5}$		1397
$\psi(2S) \phi$	$(5.4 \pm 0.5) \times 10^{-4}$		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
$\chi_{c1} \phi$	$(2.03 \pm 0.29) \times 10^{-4}$		1274
$\pi^+ \pi^-$	$(7.7 \pm 2.0) \times 10^{-7}$	S=1.4	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
$\eta' \eta'$	$(3.3 \pm 0.7) \times 10^{-5}$		2507
$\phi \rho^0$	$< 6.17 \times 10^{-4}$	CL=90%	2526
$\phi \phi$	$(1.87 \pm 0.15) \times 10^{-5}$		2482
$\pi^+ K^-$	$(5.6 \pm 0.6) \times 10^{-6}$		2659
$K^+ K^-$	$(2.52 \pm 0.17) \times 10^{-5}$		2638

$K^0 \bar{K}^0$		$< 6.6 \times 10^{-5}$	CL=90%	2637
$K^0 \pi^+ \pi^-$		$(1.5 \pm 0.4) \times 10^{-5}$		2653
$K^0 K^\pm \pi^\mp$		$(7.7 \pm 1.0) \times 10^{-5}$		2622
$K^*(892)^- \pi^+$		$(3.3 \pm 1.2) \times 10^{-6}$		2607
$K^*(892)^\pm K^\mp$		$(1.25 \pm 0.26) \times 10^{-5}$		2585
$K_S^0 \bar{K}^*(892)^0 + c.c.$		$(1.6 \pm 0.4) \times 10^{-5}$		2585
$K^0 K^+ K^-$		$< 3.5 \times 10^{-6}$	CL=90%	2568
$\bar{K}^*(892)^0 \rho^0$		$< 7.67 \times 10^{-4}$	CL=90%	2550
$\bar{K}^*(892)^0 K^*(892)^0$		$(1.11 \pm 0.27) \times 10^{-5}$		2531
$\phi K^*(892)^0$		$(1.14 \pm 0.30) \times 10^{-6}$		2507
$p \bar{p}$		$(2.8 \pm_{-1.7}^{+2.2}) \times 10^{-8}$		2514
$\Lambda_c^- \Lambda \pi^+$		$(3.6 \pm 1.6) \times 10^{-4}$		—
$\Lambda_c^- \Lambda_c^+$		$< 8.0 \times 10^{-5}$	CL=95%	—
$\gamma \gamma$	<i>B1</i>	$< 3.1 \times 10^{-6}$	CL=90%	2683
$\phi \gamma$		$(3.52 \pm 0.34) \times 10^{-5}$		2587

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

$\mu^+ \mu^-$	<i>B1</i>	$(2.9 \pm_{-0.6}^{+0.7}) \times 10^{-9}$		2681
$e^+ e^-$	<i>B1</i>	$< 2.8 \times 10^{-7}$	CL=90%	2683
$\mu^+ \mu^- \mu^+ \mu^-$	<i>B1</i>	$< 1.2 \times 10^{-8}$	CL=90%	2673
$SP, S \rightarrow \mu^+ \mu^-,$ $P \rightarrow \mu^+ \mu^-$	<i>B1</i>	$[b] < 1.2 \times 10^{-8}$	CL=90%	—
$\phi(1020) \mu^+ \mu^-$	<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



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

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

$$\text{Mass } m = 5415.4^{+1.8}_{-1.5} \text{ MeV} \quad (S = 3.0)$$

$$m_{B_s^*} - m_{B_s} = 48.6^{+1.8}_{-1.6} \text{ MeV} \quad (S = 2.8)$$

B_s^* DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$B_s \gamma$	dominant	—

$B_{s1}(5830)^0$

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

$$I, J, P \text{ need confirmation.}$$
Mass $m = 5828.63 \pm 0.27$ MeV $m_{B_{s1}^0} - m_{B^{*+}} = 503.98 \pm 0.18$ MeVFull width $\Gamma = 0.5 \pm 0.4$ MeV

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

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

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

$$I, J, P \text{ need confirmation.}$$
Mass $m = 5839.84 \pm 0.18$ MeV ($S = 1.1$) $m_{B_{s2}^{*0}} - m_{B_{s1}^0}$ $m_{B_{s2}^{*0}} - m_{B^+} = 560.53 \pm 0.18$ MeV ($S = 1.1$)Full width $\Gamma = 1.47 \pm 0.33$ MeV

$B_{s2}^*(5840)^0$ DECAY MODES	Fraction (Γ_i/Γ)	p (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.