

# BOTTOM, STRANGE MESONS

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

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

$B_s^0$

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

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

$$\text{Mass } m_{B_s^0} = 5366.93 \pm 0.10 \text{ MeV}$$

$$m_{B_s^0} - m_B = 87.37 \pm 0.12 \text{ MeV}$$

$$\text{Mean life } \tau = (1.516 \pm 0.006) \times 10^{-12} \text{ s}$$

$$c\tau = 454.5 \text{ } \mu\text{m}$$

$$\Delta\Gamma_{B_s^0} = \Gamma_{B_{sL}^0} - \Gamma_{B_{sH}^0} = (0.082 \pm 0.005) \times 10^{12} \text{ s}^{-1}$$

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

$$\Delta m_{B_s^0} = m_{B_{sH}^0} - m_{B_{sL}^0} = (17.765 \pm 0.006) \times 10^{12} \hbar \text{ s}^{-1}$$

$$= (1.1693 \pm 0.0004) \times 10^{-8} \text{ MeV}$$

$$x_s = \Delta m_{B_s^0} / \Gamma_{B_s^0} = 26.93 \pm 0.10$$

$$\chi_s (B_s^0 - \bar{B}_s^0 \text{ mixing parameter}) = 0.499314 \pm 0.000005$$

### CP violation parameters in $B_s^0$

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

$$C_{KK}(B_s^0 \rightarrow K^+ K^-) = 0.162 \pm 0.035$$

$$S_{KK}(B_s^0 \rightarrow K^+ K^-) = 0.14 \pm 0.05 \quad (S = 1.3)$$

$$r_B(B_s^0 \rightarrow D_s^\mp K^\pm) = 0.37^{+0.10}_{-0.09}$$

$$r_B(B_s^0 \rightarrow D_s^\mp K^\pm \pi^\pm \pi^\mp) = 0.47 \pm 0.08$$

$$\delta_B(B_s^0 \rightarrow D_s^\pm K^\mp) = (358 \pm 14)^\circ$$

$$\delta_B(B_s^0 \rightarrow D_s^\pm K^\mp \pi^\pm \pi^\mp) = (-6^{+10}_{-13})^\circ$$

$$\text{CP Violation phase } \beta_s (b \rightarrow c\bar{c}s) = (2.0 \pm 0.8) \times 10^{-2} \text{ rad}$$

$$\text{CP Violation phase } \beta_s (b \rightarrow s\bar{s}s) = (3.7 \pm 3.5) \times 10^{-2} \text{ rad}$$

$$|\lambda| (B_s^0 \rightarrow J/\psi(1S)\phi) = 0.988 \pm 0.009$$

$$|\lambda| (b \rightarrow c\bar{c}s) = 0.989 \pm 0.008$$

$$A, \text{ CP violation parameter} = -0.79 \pm 0.08$$

$$C, \text{ CP violation parameter} = 0.19 \pm 0.06$$

$$S, \text{ CP violation parameter} = 0.17 \pm 0.06$$

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

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

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

$$A_{CP}(B_s \rightarrow \pi^+ K^-) = 0.224 \pm 0.012$$

$$A_{CP}(B_s^0 \rightarrow [K^+ K^-]_D \bar{K}^*(892)^0) = 0.06 \pm 0.04$$

$$A_{CP}(B_s^0 \rightarrow [\pi^+ K^-]_D K^*(892)^0) = -0.009 \pm 0.023$$

$$A_{CP}(B_s^0 \rightarrow [\pi^+ \pi^-]_D K^*(892)^0) = 0.00 \pm 0.06$$

$$A_{CP}(B_s^0 \rightarrow [K^+ \pi^- \pi^+ \pi^-]_D \bar{K}^*(892)^0) = -0.029 \pm 0.024$$

$$A_{CP}(B_s^0 \rightarrow [\pi^+ \pi^- \pi^+ \pi^-]_D \bar{K}^*(892)^0) = 0.02 \pm 0.05$$

$$R_s^+ = \Gamma(B_s^0 \rightarrow [\pi^- K^+]_D \bar{K}^{*0}) / \Gamma(B_s^0 \rightarrow [\pi^+ K^-]_D \bar{K}^{*0}) = 0.004 \pm 0.006$$

$$R_s^- = \Gamma(\bar{B}_s^0 \rightarrow [\pi^+ K^-]_D K^{*0}) / \Gamma(\bar{B}_s^0 \rightarrow [\pi^- K^+]_D K^{*0}) = 0.004 \pm 0.006$$

$$R_s^+ = \Gamma(B_s^0 \rightarrow [\pi^- K^+ \pi^+ \pi^-]_D \bar{K}^{*0}) / \Gamma(B_s^0 \rightarrow [\pi^+ K^- \pi^+ \pi^-]_D \bar{K}^{*0}) = 0.019 \pm 0.008$$

NODE=MXXX046

NODE=S086

NODE=S086M;DTYPE=M

NODE=S086DM;DTYPE=D

NODE=S086T;DTYPE=T;OUR EVAL;  
→ UNCHECKED ←  
NODE=S086CTA;DTYPE=C;OUR EVAL

NODE=S086DGS;DTYPE=w;OUR EVAL;  
→ UNCHECKED ←

CLUMP=Y

NODE=S086D;DTYPE=y;CLUMP=Y;OUR  
EVAL;→ UNCHECKED ←  
NODE=S086D1;DTYPE=y;CLUMP=Y;OUR  
EVAL

NODE=S086DG;DTYPE=y;CLUMP=Y;OUR  
EVAL;→ UNCHECKED ←  
NODE=S086CHS;DTYPE=y;CLUMP=Y;  
OUR EVAL;→ UNCHECKED ←

CLUMP=C

NODE=S086EPS;DTYPE=v;CLUMP=C;  
OUR EVAL;→ UNCHECKED ←  
NODE=S086CK1;DTYPE=v;CLUMP=C

NODE=S086SK1;DTYPE=v;CLUMP=C

NODE=S086ARX;DTYPE=v;CLUMP=C

NODE=S086A28;DTYPE=v;CLUMP=C

NODE=S086DRX;DTYPE=v;CLUMP=C

NODE=S086A29;DTYPE=v;CLUMP=C

NODE=S086PHS;DTYPE=v;CLUMP=C;  
OUR EVAL;→ UNCHECKED ←  
NODE=S086PBS;DTYPE=v;CLUMP=C

NODE=S086LJP;DTYPE=v;CLUMP=C

NODE=S086LAM;DTYPE=v;CLUMP=C

NODE=S086JKA;DTYPE=v;CLUMP=C

NODE=S086JKC;DTYPE=v;CLUMP=C

NODE=S086JKS;DTYPE=v;CLUMP=C

NODE=S086PK4;DTYPE=v;CLUMP=C

NODE=S086PK5;DTYPE=v;CLUMP=C

NODE=S086PK6;DTYPE=v;CLUMP=C

NODE=S086CP1;DTYPE=v;CLUMP=C

NODE=S086CP2;DTYPE=v;CLUMP=C

NODE=S086CP3;DTYPE=v;CLUMP=C

NODE=S086CP4;DTYPE=v;CLUMP=C

NODE=S086A37;DTYPE=v;CLUMP=C

NODE=S086A41;DTYPE=v;CLUMP=C

NODE=S086A40;DTYPE=v;CLUMP=C

NODE=S086A42;DTYPE=v;CLUMP=C

NODE=S086A43;DTYPE=v;CLUMP=C

$$R_s^- = \Gamma(\bar{B}_s^0 \rightarrow [\pi^+ K^- \pi^+ \pi^-]_D K^{*0}) / \Gamma(\bar{B}_s^0 \rightarrow [\pi^- K^+ \pi^+ \pi^-]_D K^{*0}) = 0.015 \pm 0.008$$

$$S(B_s^0 \rightarrow \phi \gamma) = 0.43 \pm 0.32$$

$$C(B_s^0 \rightarrow \phi \gamma) = 0.11 \pm 0.31$$

$$A^\Delta(B_s^0 \rightarrow \phi \gamma) = -0.7 \pm 0.4$$

$$\Delta a_\perp < 1.2 \times 10^{-12} \text{ GeV}, \text{ CL} = 95\%$$

$$\Delta a_\parallel = (-0.9 \pm 1.5) \times 10^{-14} \text{ GeV}$$

$$\Delta a_X = (1.0 \pm 2.2) \times 10^{-14} \text{ GeV}$$

$$\Delta a_Y = (-3.8 \pm 2.2) \times 10^{-14} \text{ GeV}$$

$$\text{Re}(\xi) = -0.022 \pm 0.033$$

$$\text{Im}(\xi) = 0.004 \pm 0.011$$

NODE=S086A44;DTYPE=v;CLUMP=C

NODE=S086A23;DTYPE=v;CLUMP=C

NODE=S086A24;DTYPE=v;CLUMP=C

NODE=S086A07;DTYPE=v

NODE=S086CT1;DTYPE=t

NODE=S086CT0;DTYPE=t

NODE=S086A03;DTYPE=t

NODE=S086A04;DTYPE=t

NODE=S086A00;DTYPE=t

NODE=S086A01;DTYPE=t

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

NODE=S086215;NODE=S086

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 ( $\Gamma_i/\Gamma$ )       | Scale factor/<br>Confidence level | $p$<br>(MeV/c) |           |
|----------------------------------------------------------------------|--------------------------------------|-----------------------------------|----------------|-----------|
| $D_s^-$ anything                                                     | (62 $\pm$ 6 ) %                      |                                   | —              | DESIG=8   |
| $D_s^\pm$ anything                                                   | (92 $\pm$ 11 ) %                     |                                   | —              | DESIG=175 |
| $D^0/\bar{D}^0$ anything                                             | (38 $\pm$ 10 ) %                     |                                   | —              | DESIG=174 |
| $\ell \nu_\ell X$                                                    | ( 9.6 $\pm$ 0.8 ) %                  |                                   | —              | DESIG=49  |
| $e^+ \nu X^-$                                                        | ( 9.1 $\pm$ 0.8 ) %                  |                                   | —              | DESIG=98  |
| $\mu^+ \nu X^-$                                                      | (10.2 $\pm$ 1.0 ) %                  |                                   | —              | DESIG=99  |
| $D_s^- \ell^+ \nu_\ell \text{ anything}$                             | [a] ( 8.1 $\pm$ 1.3 ) %              |                                   | —              | DESIG=4   |
| $D_s^{*-} \ell^+ \nu_\ell \text{ anything}$                          | ( 5.4 $\pm$ 1.1 ) %                  |                                   | —              | DESIG=120 |
| $D_s^- \mu^+ \nu_\mu$                                                | ( 2.29 $\pm$ 0.21 ) %                |                                   | 2321           | DESIG=150 |
| $D_s^{*-} \mu^+ \nu_\mu$                                             | ( 5.2 $\pm$ 0.5 ) %                  |                                   | 2266           | DESIG=151 |
| $D_{s1}(2536)^- \mu^+ \nu_\mu, D_{s1}^- \rightarrow D^{*-} K_S^0$    | ( 2.7 $\pm$ 0.7 ) $\times 10^{-3}$   |                                   | —              | DESIG=36  |
| $D_{s1}(2536)^- X \mu^+ \nu, D_{s1}^- \rightarrow \bar{D}^0 K^+$     | ( 4.4 $\pm$ 1.3 ) $\times 10^{-3}$   |                                   | —              | DESIG=46  |
| $D_{s2}(2573)^- X \mu^+ \nu, D_{s2}^- \rightarrow \bar{D}^0 K^+$     | ( 2.7 $\pm$ 1.0 ) $\times 10^{-3}$   |                                   | —              | DESIG=47  |
| $K^- \mu^+ \nu_\mu$                                                  | ( 1.06 $\pm$ 0.09 ) $\times 10^{-4}$ |                                   | 2660           | DESIG=154 |
| $D_s^- \pi^+$                                                        | ( 2.98 $\pm$ 0.14 ) $\times 10^{-3}$ |                                   | 2320           | DESIG=5   |
| $D_s^- \rho^+$                                                       | ( 6.8 $\pm$ 1.4 ) $\times 10^{-3}$   |                                   | 2249           | DESIG=39  |
| $D_s^- \pi^+ \pi^+ \pi^-$                                            | ( 6.1 $\pm$ 1.0 ) $\times 10^{-3}$   |                                   | 2301           | DESIG=32  |
| $D_{s1}(2536)^- \pi^+, D_{s1}^- \rightarrow D_s^- \pi^+ \pi^-$       | ( 2.4 $\pm$ 0.8 ) $\times 10^{-5}$   |                                   | —              | DESIG=58  |
| $D_s^\mp K^\pm$                                                      | ( 2.25 $\pm$ 0.12 ) $\times 10^{-4}$ |                                   | 2293           | DESIG=37  |
| $D_{s1}(2536)^\mp K^\pm, D_{s1}^- \rightarrow \bar{D}^*(2007)^0 K^-$ | ( 2.48 $\pm$ 0.28 ) $\times 10^{-5}$ |                                   | —              | DESIG=180 |
| $D_s^- K^+ \pi^+ \pi^-$                                              | ( 3.2 $\pm$ 0.6 ) $\times 10^{-4}$   |                                   | 2249           | DESIG=57  |
| $D_s^+ D_s^-$                                                        | ( 4.5 $\pm$ 0.6 ) $\times 10^{-3}$   | S=1.3                             | 1824           | DESIG=33  |
| $D_s^- D^+$                                                          | ( 3.1 $\pm$ 0.5 ) $\times 10^{-4}$   |                                   | 1875           | DESIG=72  |
| $D^+ D^-$                                                            | ( 2.2 $\pm$ 0.6 ) $\times 10^{-4}$   |                                   | 1925           | DESIG=73  |
| $D^{*+} D^{*-}$                                                      | ( 2.14 $\pm$ 0.32 ) $\times 10^{-4}$ |                                   | 1778           | DESIG=177 |
| $D^0 \bar{D}^0$                                                      | ( 1.9 $\pm$ 0.5 ) $\times 10^{-4}$   |                                   | 1930           | DESIG=74  |
| $D_s^{*-} \pi^+$                                                     | ( 1.9 $\pm$ 0.5 ) $\times 10^{-3}$   |                                   | 2265           | DESIG=40  |

|                                                                  |                                         |             |           |
|------------------------------------------------------------------|-----------------------------------------|-------------|-----------|
| $D_s^{*\mp} K^\pm$                                               | $(1.32^{+0.40}_{-0.32}) \times 10^{-4}$ | —           | DESIG=113 |
| $D_s^{*-} \rho^+$                                                | $(9.5 \pm 2.0) \times 10^{-3}$          | 2191        | DESIG=41  |
| $D_s^{*+} D_s^- + D_s^{*-} D_s^+$                                | $(1.51 \pm 0.13) \%$                    | 1742        | DESIG=34  |
| $D_s^{*+} D_s^{*-}$                                              | $(1.58 \pm 0.20) \%$                    | S=1.3 1655  | DESIG=35  |
| $D_s^{(*)+} D_s^{(*)-}$                                          | $(4.5 \pm 1.4) \%$                      | —           | DESIG=24  |
| $D_s^{*-} D_s^+$                                                 | $(4.0 \pm 0.7) \times 10^{-4}$          | 1801        | DESIG=163 |
| $\bar{D}^{*0} \bar{K}^0$                                         | $(2.8 \pm 1.1) \times 10^{-4}$          | 2278        | DESIG=123 |
| $\bar{D}^0 \bar{K}^0$                                            | $(4.3 \pm 0.9) \times 10^{-4}$          | 2330        | DESIG=122 |
| $\bar{D}^0 K^- \pi^+$                                            | $(1.04 \pm 0.13) \times 10^{-3}$        | 2312        | DESIG=65  |
| $\bar{D}^{*}(2007)^0 K^- \pi^+$                                  | $(7.3 \pm 2.6) \times 10^{-4}$          | 2259        | DESIG=165 |
| $\bar{D}^0 \bar{K}^{*}(892)^0$                                   | $(4.4 \pm 0.6) \times 10^{-4}$          | 2264        | DESIG=48  |
| $\bar{D}^0 \bar{K}^{*}(1410)$                                    | $(3.9 \pm 3.5) \times 10^{-4}$          | 2117        | DESIG=84  |
| $\bar{D}^0 \bar{K}_0^{*}(1430)$                                  | $(3.0 \pm 0.7) \times 10^{-4}$          | 2113        | DESIG=85  |
| $\bar{D}^0 \bar{K}_2^{*}(1430)$                                  | $(1.1 \pm 0.4) \times 10^{-4}$          | 2112        | DESIG=86  |
| $\bar{D}^0 \bar{K}^{*}(1680)$                                    | $< 7.8 \times 10^{-5}$                  | CL=90% 1997 | DESIG=87  |
| $\bar{D}^0 \bar{K}_0^{*}(1950)$                                  | $< 1.1 \times 10^{-4}$                  | CL=90% 1884 | DESIG=88  |
| $\bar{D}^0 \bar{K}_3^{*}(1780)$                                  | $< 2.6 \times 10^{-5}$                  | CL=90% 1970 | DESIG=89  |
| $\bar{D}^0 \bar{K}_4^{*}(2045)$                                  | $< 3.1 \times 10^{-5}$                  | CL=90% 1835 | DESIG=90  |
| $\bar{D}^0 K^- \pi^+ (\text{non-resonant})$                      | $(2.1 \pm 0.8) \times 10^{-4}$          | 2312        | DESIG=91  |
| $[K^+ K^-]_D \bar{K}^{*}(892)^0$                                 | $(4.4 \pm 0.6) \times 10^{-4}$          | —           | DESIG=184 |
| $[\pi^+ \pi^-]_D \bar{K}^{*}(892)^0$                             | $(4.4 \pm 0.6) \times 10^{-4}$          | —           | DESIG=185 |
| $[\pi^+ \pi^- \pi^+ \pi^-]_D \bar{K}^{*}(892)^0$                 | $(4.4 \pm 0.6) \times 10^{-4}$          | —           | DESIG=188 |
| $D_{s2}^{*}(2573)^- \pi^+, D_{s2}^{*} \rightarrow \bar{D}^0 K^-$ | $(2.6 \pm 0.4) \times 10^{-4}$          | —           | DESIG=92  |
| $D_{s1}^{*}(2700)^- \pi^+, D_{s1}^{*} \rightarrow \bar{D}^0 K^-$ | $(1.6 \pm 0.8) \times 10^{-5}$          | —           | DESIG=93  |
| $D_{s1}^{*}(2860)^- \pi^+, D_{s1}^{*} \rightarrow \bar{D}^0 K^-$ | $(5 \pm 4) \times 10^{-5}$              | —           | DESIG=94  |
| $D_{s3}^{*}(2860)^- \pi^+, D_{s3}^{*} \rightarrow \bar{D}^0 K^-$ | $(2.2 \pm 0.6) \times 10^{-5}$          | —           | DESIG=95  |
| $\bar{D}^0 K^+ K^-$                                              | $(5.6 \pm 0.9) \times 10^{-5}$          | 2243        | DESIG=51  |
| $\bar{D}^0 f_0(980)$                                             | $< 3.1 \times 10^{-6}$                  | CL=90% 2242 | DESIG=114 |
| $\bar{D}^0 \phi$                                                 | $(2.30 \pm 0.25) \times 10^{-5}$        | 2235        | DESIG=75  |
| $\bar{D}^{*0} \phi$                                              | $(3.2 \pm 0.4) \times 10^{-5}$          | 2178        | DESIG=143 |
| $D^{*\mp} \pi^\pm$                                               | $< 6.1 \times 10^{-6}$                  | CL=90% —    | DESIG=70  |
| $\eta_c \phi$                                                    | $(5.0 \pm 0.9) \times 10^{-4}$          | 1663        | DESIG=131 |
| $\eta_c \pi^+ \pi^-$                                             | $(1.8 \pm 0.7) \times 10^{-4}$          | 1840        | DESIG=132 |
| $J/\psi(1S) \phi$                                                | $(1.03 \pm 0.04) \times 10^{-3}$        | 1588        | DESIG=7   |
| $J/\psi(1S) \phi \phi$                                           | $(1.18^{+0.14}_{-0.16}) \times 10^{-5}$ | 764         | DESIG=124 |
| $J/\psi(1S) \pi^0$                                               | $< 1.21 \times 10^{-5}$                 | CL=90% 1787 | DESIG=21  |
| $J/\psi(1S) \eta$                                                | $(4.0 \pm 0.7) \times 10^{-4}$          | S=1.4 1733  | DESIG=22  |
| $J/\psi(1S) K_S^0$                                               | $(1.92 \pm 0.14) \times 10^{-5}$        | 1743        | DESIG=44  |
| $J/\psi(1S) \bar{K}^{*}(892)^0$                                  | $(4.1 \pm 0.4) \times 10^{-5}$          | 1637        | DESIG=45  |
| $J/\psi(1S) \eta'$                                               | $(3.3 \pm 0.4) \times 10^{-4}$          | 1612        | DESIG=50  |
| $J/\psi(1S) \pi^+ \pi^-$                                         | $(2.02 \pm 0.17) \times 10^{-4}$        | S=1.7 1775  | DESIG=52  |
| $J/\psi(1S) f_0(500), f_0 \rightarrow \pi^+ \pi^-$               | $< 4 \times 10^{-6}$                    | CL=90% —    | DESIG=101 |
| $J/\psi(1S) \rho, \rho \rightarrow \pi^+ \pi^-$                  | $< 3.4 \times 10^{-6}$                  | CL=90% —    | DESIG=108 |
| $J/\psi(1S) f_0(980), f_0 \rightarrow \pi^+ \pi^-$               | $(1.24 \pm 0.15) \times 10^{-4}$        | S=2.1 —     | DESIG=42  |
| $J/\psi(1S) f_2(1270), f_2 \rightarrow \pi^+ \pi^-$              | $(1.0 \pm 0.4) \times 10^{-6}$          | —           | DESIG=53  |
| $J/\psi(1S) f_2(1270)_0, f_2 \rightarrow \pi^+ \pi^-$            | $(7.3 \pm 1.7) \times 10^{-7}$          | —           | DESIG=103 |
| $J/\psi(1S) f_2(1270)_\parallel, f_2 \rightarrow \pi^+ \pi^-$    | $(1.05 \pm 0.33) \times 10^{-6}$        | —           | DESIG=104 |
| $J/\psi(1S) f_2(1270)_\perp, f_2 \rightarrow \pi^+ \pi^-$        | $(1.3 \pm 0.7) \times 10^{-6}$          | —           | DESIG=105 |

|                                                                 |                                             |             |           |
|-----------------------------------------------------------------|---------------------------------------------|-------------|-----------|
| $J/\psi(1S) f_0(1370), f_0 \rightarrow \pi^+ \pi^-$             | $(4.4 \pm_{-4.0}^{+0.6}) \times 10^{-5}$    | —           | DESIG=43  |
| $J/\psi(1S) f_0(1500), f_0 \rightarrow \pi^+ \pi^-$             | $(2.04 \pm_{-0.24}^{+0.32}) \times 10^{-5}$ | —           | DESIG=106 |
| $J/\psi(1S) f'_2(1525)_0, f'_2 \rightarrow \pi^+ \pi^-$         | $(1.03 \pm 0.22) \times 10^{-6}$            | —           | DESIG=107 |
| $J/\psi(1S) f'_2(1525)_\parallel, f'_2 \rightarrow \pi^+ \pi^-$ | $(1.2 \pm_{-0.8}^{+2.6}) \times 10^{-7}$    | —           | DESIG=109 |
| $J/\psi(1S) f'_2(1525)_\perp, f'_2 \rightarrow \pi^+ \pi^-$     | $(5 \pm 4) \times 10^{-7}$                  | —           | DESIG=110 |
| $J/\psi(1S) f_0(1790), f_0 \rightarrow \pi^+ \pi^-$             | $(4.9 \pm_{-1.0}^{+10.0}) \times 10^{-6}$   | —           | DESIG=111 |
| $J/\psi(1S) \pi^+ \pi^-$ (nonresonant)                          | $(1.74 \pm_{-0.34}^{+1.10}) \times 10^{-5}$ | 1775        | DESIG=54  |
| $J/\psi(1S) \bar{K}^0 \pi^+ \pi^-$                              | $< 4.4 \times 10^{-5}$                      | CL=90% 1675 | DESIG=81  |
| $J/\psi(1S) K^+ K^-$                                            | $(7.9 \pm 0.7) \times 10^{-4}$              | 1601        | DESIG=71  |
| $J/\psi(1S) K^0 K^- \pi^+ + \text{c.c.}$                        | $(9.5 \pm 1.3) \times 10^{-4}$              | 1538        | DESIG=79  |
| $J/\psi(1S) \bar{K}^0 K^+ K^-$                                  | $< 1.2 \times 10^{-5}$                      | CL=90% 1333 | DESIG=80  |
| $J/\psi K^*(892)^0 \bar{K}^*(892)^0$                            | $(1.08 \pm 0.09) \times 10^{-4}$            | 1083        | DESIG=159 |
| $J/\psi(1S) f'_2(1525)$                                         | $(2.6 \pm 0.6) \times 10^{-4}$              | 1310        | DESIG=56  |
| $J/\psi(1S) \rho \bar{\rho}$                                    | $(3.6 \pm 0.4) \times 10^{-6}$              | 982         | DESIG=60  |
| $J/\psi(1S) \gamma$                                             | $< 7.3 \times 10^{-6}$                      | CL=90% 1790 | DESIG=112 |
| $J/\psi \mu^+ \mu^-, J/\psi \rightarrow \mu^+ \mu^-$            | $< 2.6 \times 10^{-9}$                      | CL=95% —    | DESIG=168 |
| $J/\psi(1S) \pi^+ \pi^- \pi^+ \pi^-$                            | $(7.5 \pm 0.8) \times 10^{-5}$              | 1731        | DESIG=77  |
| $J/\psi(1S) f_1(1285)$                                          | $(7.2 \pm 1.4) \times 10^{-5}$              | 1460        | DESIG=78  |
| $J/\psi(1S) \bar{D}^0$                                          | $< 1.0 \times 10^{-6}$                      | CL=90% 996  | DESIG=183 |
| $\psi(2S) \eta$                                                 | $(3.3 \pm 0.9) \times 10^{-4}$              | 1338        | DESIG=66  |
| $\psi(2S) \eta'$                                                | $(1.29 \pm 0.35) \times 10^{-4}$            | 1158        | DESIG=100 |
| $\psi(2S) \pi^+ \pi^-$                                          | $(6.9 \pm 1.2) \times 10^{-5}$              | 1397        | DESIG=67  |
| $\psi(2S) \phi$                                                 | $(5.2 \pm 0.4) \times 10^{-4}$              | 1120        | DESIG=6   |
| $\psi(2S) K^0$                                                  | $(1.9 \pm 0.5) \times 10^{-5}$              | 1352        | DESIG=166 |
| $\psi(2S) K^- \pi^+$                                            | $(3.1 \pm 0.4) \times 10^{-5}$              | 1310        | DESIG=118 |
| $\psi(2S) \bar{K}^*(892)^0$                                     | $(3.3 \pm 0.5) \times 10^{-5}$              | 1196        | DESIG=119 |
| $\chi_{c1} \phi$                                                | $(1.95 \pm 0.25) \times 10^{-4}$            | 1275        | DESIG=68  |
| $\chi_{c1}(3872) \phi$                                          | $(9.7 \pm 3.3) \times 10^{-5}$              | 936         | DESIG=152 |
| $\chi_{c1}(3872) (K^+ K^-)_{non-\phi}$                          | $(7.6 \pm 3.0) \times 10^{-5}$              | 961         | DESIG=160 |
| $\chi_{c1}(3872) \pi^+ \pi^-$                                   | $(3.7 \pm 1.5) \times 10^{-5}$              | 1264        | DESIG=173 |
| $\pi^+ \pi^-$                                                   | $(7.2 \pm 1.0) \times 10^{-7}$              | 2680        | DESIG=16  |
| $\pi^0 \pi^0$                                                   | $< 7.7 \times 10^{-6}$                      | CL=90% 2680 | DESIG=14  |
| $\eta \pi^0$                                                    | $< 1.0 \times 10^{-3}$                      | CL=90% 2654 | DESIG=13  |
| $\eta \eta$                                                     | $< 1.43 \times 10^{-4}$                     | CL=90% 2627 | DESIG=12  |
| $\rho^0 \rho^0$                                                 | $< 3.20 \times 10^{-4}$                     | CL=90% 2569 | DESIG=25  |
| $\eta' K_S^0$                                                   | $< 8.16 \times 10^{-6}$                     | CL=90% 2573 | DESIG=169 |
| $\eta' \eta$                                                    | $< 6.5 \times 10^{-5}$                      | CL=90% 2568 | DESIG=153 |
| $\eta' \eta'$                                                   | $(3.3 \pm 0.7) \times 10^{-5}$              | 2507        | DESIG=121 |
| $\eta' \phi$                                                    | $< 8.2 \times 10^{-7}$                      | CL=90% 2495 | DESIG=129 |
| $\phi f_0(980), f_0(980) \rightarrow \pi^+ \pi^-$               | $(1.12 \pm 0.21) \times 10^{-6}$            | —           | DESIG=126 |
| $\phi f_2(1270), f_2(1270) \rightarrow \pi^+ \pi^-$             | $(6.1 \pm_{-1.5}^{+1.8}) \times 10^{-7}$    | —           | DESIG=127 |
| $\phi \rho^0$                                                   | $(2.7 \pm 0.8) \times 10^{-7}$              | 2526        | DESIG=28  |
| $\phi \pi^+ \pi^-$                                              | $(3.5 \pm 0.5) \times 10^{-6}$              | 2579        | DESIG=125 |
| $\phi \phi$                                                     | $(1.84 \pm 0.14) \times 10^{-5}$            | 2482        | DESIG=30  |
| $\phi \phi \phi$                                                | $(2.2 \pm 0.6) \times 10^{-6}$              | 2165        | DESIG=136 |
| $\pi^+ K^-$                                                     | $(5.9 \pm 0.7) \times 10^{-6}$              | 2659        | DESIG=9   |
| $K^+ K^-$                                                       | $(2.72 \pm 0.23) \times 10^{-5}$            | 2638        | DESIG=10  |
| $K^0 \bar{K}^0$                                                 | $(1.76 \pm 0.31) \times 10^{-5}$            | 2637        | DESIG=38  |
| $K^0 \pi^+ \pi^-$                                               | $(9.5 \pm 2.1) \times 10^{-6}$              | 2653        | DESIG=61  |
| $K^0 K^\pm \pi^\mp$                                             | $(8.4 \pm 0.9) \times 10^{-5}$              | 2622        | DESIG=62  |
| $K^*(892)^- \pi^+$                                              | $(2.9 \pm 1.1) \times 10^{-6}$              | 2607        | DESIG=96  |

|                                         |                                  |             |           |
|-----------------------------------------|----------------------------------|-------------|-----------|
| $K^*(892)^\pm K^\mp$                    | $(1.9 \pm 0.5) \times 10^{-5}$   | 2585        | DESIG=97  |
| $K_0^*(1430)^\pm K^\mp$                 | $(3.1 \pm 2.5) \times 10^{-5}$   | —           | DESIG=144 |
| $K_2^*(1430)^\pm K^\mp$                 | $(1.0 \pm 1.7) \times 10^{-5}$   | —           | DESIG=145 |
| $K^*(892)^0 \bar{K}^0 + \text{c.c.}$    | $(2.0 \pm 0.6) \times 10^{-5}$   | 2585        | DESIG=146 |
| $K_0^*(1430) \bar{K}^0 + \text{c.c.}$   | $(3.3 \pm 1.0) \times 10^{-5}$   | 2468        | DESIG=147 |
| $K_2^*(1430)^0 \bar{K}^0 + \text{c.c.}$ | $(1.7 \pm 2.2) \times 10^{-5}$   | 2467        | DESIG=148 |
| $K_S^0 \bar{K}^*(892)^0 + \text{c.c.}$  | $(1.6 \pm 0.4) \times 10^{-5}$   | 2585        | DESIG=115 |
| $K_S^0 K^+ K^-$                         | $(1.3 \pm 0.6) \times 10^{-6}$   | 2568        | DESIG=63  |
| $\bar{K}^*(892)^0 \rho^0$               | $< 7.67 \times 10^{-4}$          | CL=90% 2550 | DESIG=26  |
| $\bar{K}^*(892)^0 K^*(892)^0$           | $(1.11 \pm 0.27) \times 10^{-5}$ | 2531        | DESIG=27  |
| $\phi K^*(892)^0$                       | $(1.14 \pm 0.30) \times 10^{-6}$ | 2507        | DESIG=29  |
| $p \bar{p}$                             | $< 4.4 \times 10^{-9}$           | CL=90% 2514 | DESIG=17  |
| $p \bar{p} K^+ K^-$                     | $(4.5 \pm 0.5) \times 10^{-6}$   | 2231        | DESIG=133 |
| $p \bar{p} K^+ \pi^-$                   | $(1.39 \pm 0.26) \times 10^{-6}$ | 2355        | DESIG=134 |
| $p \bar{p} \pi^+ \pi^-$                 | $(4.3 \pm 2.0) \times 10^{-7}$   | 2454        | DESIG=135 |
| $p \bar{p} p \bar{p}$                   | $(2.3 \pm 1.0) \times 10^{-8}$   | 1797        | DESIG=178 |
| $p \bar{\Lambda} K^- + \text{c.c.}$     | $(5.5 \pm 1.0) \times 10^{-6}$   | 2358        | DESIG=128 |
| $\Lambda_c^- \Lambda \pi^+$             | $(3.6 \pm 1.6) \times 10^{-4}$   | 1979        | DESIG=69  |
| $\Lambda_c^- \Lambda_c^+$               | $< 8.0 \times 10^{-5}$           | CL=95% 1405 | DESIG=76  |

**Lepton family (LF), lepton (L), baryon (B) number violating modes or  $\Delta B = 1$  weak neutral current (B1) modes**

NODE=S086;CLUMP=B

|                                                                 |     |                                            |        |      |           |
|-----------------------------------------------------------------|-----|--------------------------------------------|--------|------|-----------|
| $\gamma \gamma$                                                 | B1  | $< 3.1 \times 10^{-6}$                     | CL=90% | 2683 | DESIG=11  |
| $\phi \gamma$                                                   | B1  | $(3.4 \pm 0.4) \times 10^{-5}$             |        | 2587 | DESIG=18  |
| $f_2(1270) \gamma$                                              | B1  | $(9 \pm \frac{4}{5}) \times 10^{-6}$       |        | 2532 | DESIG=191 |
| $f_2'(1525) \gamma$                                             | B1  | $(6.6 \pm \frac{0.9}{0.8}) \times 10^{-6}$ |        | 2469 | DESIG=192 |
| $\phi(1680) \gamma, \phi \rightarrow K^+ K^-$                   | B1  | $(9.2 \pm 2.4) \times 10^{-7}$             |        | —    | DESIG=193 |
| $\phi_3(1850) \gamma, \phi_3 \rightarrow K^+ K^-$               | B1  | $(7 \pm \frac{6}{5}) \times 10^{-8}$       |        | —    | DESIG=194 |
| $f_2(2010) \gamma, f_2 \rightarrow K^+ K^-$                     | B1  | $(1.0 \pm \frac{0.7}{0.5}) \times 10^{-7}$ |        | —    | DESIG=195 |
| $\mu^+ \mu^-$                                                   | B1  | $(3.34 \pm 0.27) \times 10^{-9}$           |        | 2681 | DESIG=15  |
| $e^+ e^-$                                                       | B1  | $< 9.4 \times 10^{-9}$                     | CL=90% | 2683 | DESIG=20  |
| $\tau^+ \tau^-$                                                 | B1  | $< 6.8 \times 10^{-3}$                     | CL=95% | 2011 | DESIG=130 |
| $\mu^+ \mu^- \gamma$                                            | B1  | $< 4.2 \times 10^{-8}$                     | CL=95% | 2681 | DESIG=170 |
| $\mu^+ \mu^- \mu^+ \mu^-$                                       | B1  | $< 8.6 \times 10^{-10}$                    | CL=95% | 2673 | DESIG=59  |
| $SP, S \rightarrow \mu^+ \mu^-,$<br>$P \rightarrow \mu^+ \mu^-$ | B1  | $[b] < 2.2 \times 10^{-9}$                 | CL=95% | —    | DESIG=64  |
| $aa, a \rightarrow \mu^+ \mu^-$                                 | B1  | $< 5.8 \times 10^{-10}$                    | CL=95% | —    | DESIG=167 |
| $\phi(1020) \mu^+ \mu^-$                                        | B1  | $(8.3 \pm 0.4) \times 10^{-7}$             |        | 2582 | DESIG=31  |
| $f_2'(1525) \mu^+ \mu^-$                                        | B1  | $(1.60 \pm 0.22) \times 10^{-7}$           |        | 2464 | DESIG=164 |
| $\bar{K}^*(892)^0 \mu^+ \mu^-$                                  | B1  | $(2.9 \pm 1.1) \times 10^{-8}$             |        | 2605 | DESIG=137 |
| $\pi^+ \pi^- \mu^+ \mu^-$                                       | B1  | $(8.4 \pm 1.7) \times 10^{-8}$             |        | 2670 | DESIG=117 |
| $\bar{D}^0 \mu^+ \mu^-$                                         | B1  | $< 1.2 \times 10^{-7}$                     | CL=90% | 2354 | DESIG=182 |
| $\phi \nu \bar{\nu}$                                            | B1  | $< 5.4 \times 10^{-3}$                     | CL=90% | 2587 | DESIG=19  |
| $e^\pm \mu^\mp$                                                 | LF  | $[c] < 5.4 \times 10^{-9}$                 | CL=90% | 2682 | DESIG=23  |
| $e^\pm \tau^\mp$                                                | LF  | $< 1.4 \times 10^{-3}$                     | CL=90% | 2389 | DESIG=171 |
| $\mu^\pm \tau^\mp$                                              | LF  | $< 4.2 \times 10^{-5}$                     | CL=95% | 2388 | DESIG=149 |
| $\phi \mu^\pm e^\mp$                                            | LF  | $< 1.6 \times 10^{-8}$                     | CL=90% | 2586 | DESIG=176 |
| $\phi \mu^\pm \tau^\mp$                                         | LF  | $< 1.0 \times 10^{-5}$                     | CL=90% | 2241 | DESIG=196 |
| $p \mu^-$                                                       | L,B | $< 1.21 \times 10^{-8}$                    | CL=90% | 2600 | DESIG=179 |

**$B_s^*$**

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

NODE=S087

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

$$\text{Mass } m = 5415.4 \pm 1.4 \text{ MeV } (S = 2.6)$$

NODE=S087M;DTYPE=M

$$m_{B_s^*} - m_{B_s} = 48.5 \pm 1.4 \text{ MeV } (S = 2.6)$$

NODE=S087DM;DTYPE=D

| <b><math>B_s^*</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|---------------------------------------|--------------------------------|-------------|
| $B_s \gamma$                          | seen                           | 48          |

NODE=S087215;DESIG=1;OUR EST;  
→ UNCHECKED ←

**$B_{s1}(5830)^0$**

$I(J^P) = 0(1^+)$   
 $I, J, P$  need confirmation.

NODE=M187

Mass  $m = 5828.73 \pm 0.20$  MeV

NODE=M187M;DTYPE=M

$m_{B_{s1}^0} - m_{B^{*+}} = 503.98 \pm 0.17$  MeV

NODE=M187DM;DTYPE=D  
NODE=M187W;DTYPE=G

Full width  $\Gamma = 0.5 \pm 0.4$  MeV

| <b><math>B_{s1}(5830)^0</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|------------------------------------------------|--------------------------------|-------------|
| $B^{*+} K^-$                                   | seen                           | 97          |

NODE=M187215;DESIG=1

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

$I(J^P) = 0(2^+)$   
 $I, J, P$  need confirmation.

NODE=M186

Mass  $m = 5839.88 \pm 0.12$  MeV

NODE=M186M;DTYPE=M

$m_{B_{s2}^{*0}} - m_{B^+} = 560.48 \pm 0.12$  MeV

NODE=M186DM2;DTYPE=D  
NODE=M186W;DTYPE=G

Full width  $\Gamma = 1.49 \pm 0.27$  MeV

Branching fractions are given relative to the one **DEFINED AS 1**.

NODE=M186215;NODE=M186

| <b><math>B_{s2}^*(5840)^0</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|--------------------------------------------------|--------------------------------|-------------|
| $B^+ K^-$                                        | <b>DEFINED AS 1</b>            | 252         |
| $B^{*+} K^-$                                     | $0.093 \pm 0.018$              | 141         |
| $B^0 K_S^0$                                      | $0.43 \pm 0.11$                | 245         |
| $B^{*0} K_S^0$                                   | $0.04 \pm 0.04$                | —           |

DESIG=1

DESIG=2

DESIG=4

DESIG=3

## NOTES

[a] Not a pure measurement. See note at head of  $B_s^0$  Decay Modes.

LINKAGE=X86

[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.

LINKAGE=BSP

[c] The value is for the sum of the charge states or particle/antiparticle states indicated.

LINKAGE=SG