# $B_s^0$

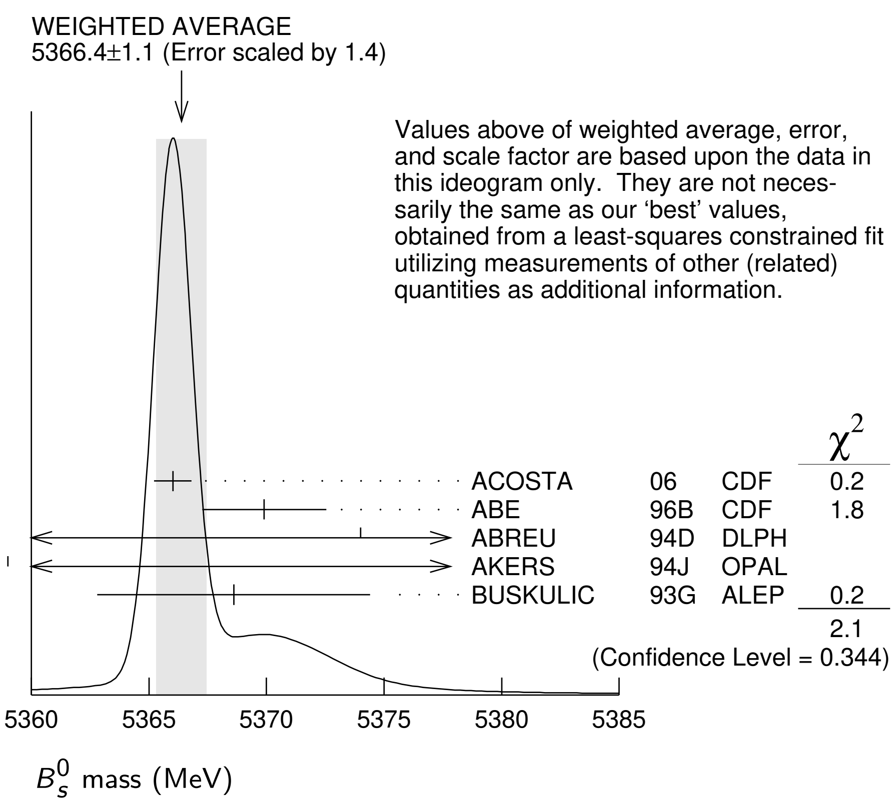
$I(J^P) = 0(0^-)$

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

## $B_s^0$ MASS

| *VALUE* (MeV) | *EVTS* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|
| **5366.1 ± 0.6 OUR FIT** | | | | | |
| **5366.4 ± 1.1 OUR AVERAGE** Error includes scale factor of 1.4. See the ideogram below. | | | | | |
| 5366.01 ± 0.73 ± 0.33 | | [1] ACOSTA | 06 | CDF | $p\overline{p}$ at 1.96 TeV |
| 5369.9 ± 2.3 ± 1.3 | 32 | [2] ABE | 96B | CDF | $p\overline{p}$ at 1.8 TeV |
| 5374 ± 16 ± 2 | 3 | ABREU | 94D | DLPH | $e^+e^- \rightarrow Z$ |
| 5359 ± 19 ± 7 | 1 | [2] AKERS | 94J | OPAL | $e^+e^- \rightarrow Z$ |
| 5368.6 ± 5.6 ± 1.5 | 2 | BUSKULIC | 93G | ALEP | $e^+e^- \rightarrow Z$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| 5370 ± 40 | 6 | [3] AKERS | 94J | OPAL | $e^+e^- \rightarrow Z$ |
| 5383.3 ± 4.5 ± 5.0 | 14 | ABE | 93F | CDF | Repl by ABE 96B |

[1] Uses exclusively reconstructed final states containing a $J/\psi \rightarrow \mu^+\mu^-$ decays.
[2] From the decay $B_s \rightarrow J/\psi(1S)\phi$.
[3] From the decay $B_s \rightarrow D_s^-\pi^+$.



## $m_{B_s^0} - m_B$

$m_B$ is the average of our $B$ masses $(m_{B^\pm}+m_{B^0})/2$.

| VALUE (MeV) | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **86.8 ±0.6 OUR FIT** | | | | | |
| **86.9 ±0.8 OUR AVERAGE** | | | | | |
| 86.64±0.80±0.08 | | [4] ACOSTA | 06 | CDF | $p\overline{p}$ at 1.96 TeV |
| 89.7 ±2.7 ±1.2 | | ABE | 96B | CDF | $p\overline{p}$ at 1.8 TeV |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| 80 to 130 | 68 | LEE-FRANZINI | 90 | CSB2 | $e^+ e^- \to \Upsilon(5S)$ |

[4] The reported result is $m_{B_s^0} - m_{B^0} = 86.38 \pm 0.90 \pm 0.06$ MeV. We convert it to the mass difference with respect to the average of $(m_{B^\pm} + m_{B^0})/2$.

## $m_{B^0_{sH}} - m_{B^0_{sL}}$

See the $B_s^0$-$\overline{B}_s^0$ MIXING section near the end of these $B_s^0$ Listings.

## $B_s^0$ MEAN LIFE

"OUR EVALUATION" is an average using rescaled values of the data listed below. The average and rescaling were performed by the Heavy Flavor Averaging Group (HFAG) and are described at http://www.slac.stanford.edu/xorg/hfag/. The averaging/rescaling procedure takes into account correlations between the measurements and asymmetric lifetime errors.

The First "OUR EVALUATION" is an average of 1 / [0.5 ($\Gamma_{B^0_{SL}}$ + $\Gamma_{B^0_{SL}}$)]. The Second "OUR EVALUATION" is the average of $B_s \to D_s X$ lifetimes.

| VALUE ($10^{-12}$ s) | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **$1.437^{+0.031}_{-0.030}$ OUR EVALUATION** | | First | | | |
| **1.425±0.041 OUR EVALUATION** | | Second | | | |
| $1.398 \pm 0.044 {}^{+0.028}_{-0.025}$ | | [5] ABAZOV | 06V | D0 | $p\overline{p}$ at 1.96 TeV |
| $1.42 {}^{+0.14}_{-0.13} \pm 0.03$ | | [6] ABREU | 00Y | DLPH | $e^+ e^- \to Z$ |
| $1.53 {}^{+0.16}_{-0.15} \pm 0.07$ | | [7] ABREU,P | 00G | DLPH | $e^+ e^- \to Z$ |
| $1.36 \pm 0.09 {}^{+0.06}_{-0.05}$ | | [8] ABE | 99D | CDF | $p\overline{p}$ at 1.8 TeV |
| $1.72 {}^{+0.20}_{-0.19} {}^{+0.18}_{-0.17}$ | | [9] ACKERSTAFF | 98F | OPAL | $e^+ e^- \to Z$ |
| $1.50 {}^{+0.16}_{-0.15} \pm 0.04$ | | [8] ACKERSTAFF | 98G | OPAL | $e^+ e^- \to Z$ |
| $1.47 \pm 0.14 \pm 0.08$ | | [7] BARATE | 98C | ALEP | $e^+ e^- \to Z$ |
| $1.54 {}^{+0.14}_{-0.13} \pm 0.04$ | | [8] BUSKULIC | 96M | ALEP | $e^+ e^- \to Z$ |

• • • We do not use the following data for averages, fits, limits, etc. • • •

| | | | | | |
|---|---|---|---|---|---|
| 1.51 $\pm 0.11$ | | [10] BARATE | 98C | ALEP | $e^+ e^- \rightarrow Z$ |
| 1.56 $^{+0.29}_{-0.26}$ $^{+0.08}_{-0.07}$ | | [8] ABREU | 96F | DLPH | Repl. by ABREU 00Y |
| 1.65 $^{+0.34}_{-0.31}$ $\pm 0.12$ | | [7] ABREU | 96F | DLPH | Repl. by ABREU 00Y |
| 1.76 $\pm 0.20$ $^{+0.15}_{-0.10}$ | | [11] ABREU | 96F | DLPH | Repl. by ABREU 00Y |
| 1.60 $\pm 0.26$ $^{+0.13}_{-0.15}$ | | [12] ABREU | 96F | DLPH | Repl. by ABREU,P 00G |
| 1.67 $\pm 0.14$ | | [13] ABREU | 96F | DLPH | $e^+ e^- \rightarrow Z$ |
| 1.61 $^{+0.30}_{-0.29}$ $^{+0.18}_{-0.16}$ | 90 | [7] BUSKULIC | 96E | ALEP | Repl. by BARATE 98C |
| 1.42 $^{+0.27}_{-0.23}$ $\pm 0.11$ | 76 | [8] ABE | 95R | CDF | Repl. by ABE 99D |
| 1.74 $^{+1.08}_{-0.69}$ $\pm 0.07$ | 8 | [14] ABE | 95R | CDF | Sup. by ABE 96N |
| 1.54 $^{+0.25}_{-0.21}$ $\pm 0.06$ | 79 | [8] AKERS | 95G | OPAL | Repl. by ACKERSTAFF 98G |
| 1.59 $^{+0.17}_{-0.15}$ $\pm 0.03$ | 134 | [8] BUSKULIC | 95O | ALEP | Sup. by BUSKULIC 96M |
| 0.96 $\pm 0.37$ | 41 | [15] ABREU | 94E | DLPH | Sup. by ABREU 96F |
| 1.92 $^{+0.45}_{-0.35}$ $\pm 0.04$ | 31 | [8] BUSKULIC | 94C | ALEP | Sup. by BUSKULIC 95O |
| 1.13 $^{+0.35}_{-0.26}$ $\pm 0.09$ | 22 | [8] ACTON | 93H | OPAL | Sup. by AKERS 95G |

[5] Measured using $D_s \mu^+$ vertices.
[6] Uses $D_s^- \ell^+$, and $\phi \ell^+$ vertices.
[7] Measured using $D_s$ hadron vertices.
[8] Measured using $D_s^- \ell^+$ vertices.
[9] ACKERSTAFF 98F use fully reconstructed $D_s^- \rightarrow \phi \pi^-$ and $D_s^- \rightarrow K^{*0} K^-$ in the inclusive $B_s^0$ decay.
[10] Combined results from $D_s^- \ell^+$ and $D_s$ hadron.
[11] Measured using $\phi \ell$ vertices.
[12] Measured using inclusive $D_s$ vertices.
[13] Combined result for the four ABREU 96F methods.
[14] Exclusive reconstruction of $B_s \rightarrow \psi \phi$.
[15] ABREU 94E uses the flight-distance distribution of $D_s$ vertices, $\phi$-lepton vertices, and $D_s \mu$ vertices.

## $B_s^0$ MEAN LIFE (Flavor specific)

| *VALUE* | *DOCUMENT ID* | *TECN* | *COMMENT* |
|---|---|---|---|
| **1.417 $\pm$ 0.042 OUR EVALUATION** | | | |
| **1.41 $\pm$ 0.04 OUR AVERAGE** | | | |
| 1.398 $\pm 0.044$ $^{+0.028}_{-0.025}$ | [16] ABAZOV 06V | D0 | $p\overline{p}$ at 1.96 TeV |
| 1.42 $^{+0.14}_{-0.13}$ $\pm 0.03$ | [17] ABREU 00Y | DLPH | $e^+ e^- \rightarrow Z$ |
| 1.36 $\pm 0.09$ $^{+0.06}_{-0.05}$ | [18] ABE 99D | CDF | $p\overline{p}$ at 1.8 TeV |
| 1.50 $^{+0.16}_{-0.15}$ $\pm 0.04$ | [19] ACKERSTAFF 98G | OPAL | $e^+ e^- \rightarrow Z$ |
| 1.54 $^{+0.14}_{-0.13}$ $\pm 0.04$ | [18] BUSKULIC 96M | ALEP | $e^+ e^- \rightarrow Z$ |

[16] Measured using $D_s^- \mu^+$ vertices.
[17] Uses $D_s^- \ell^+$, and $\phi \ell^+$ vertices.
[18] Measured using $D_s^- \ell^+$ vertices.
[19] ACKERSTAFF 98F use fully reconstructed $D_s^- \rightarrow \phi\pi^-$ and $D_s^- \rightarrow K^{*0} K^-$ in the inclusive $B_s^0$ decay.

## $B_s^0$ MEAN LIFE ($B_S \rightarrow J/\psi\phi$)

| VALUE | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **1.429±0.088 OUR EVALUATION** | | | | |
| **1.42 $^{+0.08}_{-0.07}$ OUR AVERAGE** | | | | |
| $1.444^{+0.098}_{-0.090}\pm0.020$ | [20] ABAZOV | 05B | D0 | $p\overline{p}$ at 1.96 TeV |
| $1.40\ ^{+0.15}_{-0.13}\ \pm0.02$ | [21] ACOSTA | 05 | CDF | $p\overline{p}$ at 1.96 TeV |
| $1.34\ ^{+0.23}_{-0.19}\ \pm0.05$ | [20] ABE | 98B | CDF | $p\overline{p}$ at 1.8 TeV |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| $1.39\ ^{+0.13}_{-0.16}\ ^{+0.01}_{-0.02}$ | [21] ABAZOV | 05W | D0 | $p\overline{p}$ at 1.96 TeV |
| $1.34\ ^{+0.23}_{-0.19}\ \pm0.05$ | [22] ABE | 96N | CDF | Repl. by ABE 98B |

[20] Measured using fully reconstructed $B_s \rightarrow J/\psi(1S)\phi$ decay.
[21] Measured using the time-dependent angular analysis of $B_s^0 \rightarrow J/\psi\phi$ decays.
[22] ABE 96N uses 58 ± 12 exclusive $B_s \rightarrow J/\psi(1S)\phi$ events.

## $\tau_{B_s^0}/\tau_{B^0}$ MEAN LIFE RATIO

### $\tau_{B_s^0}/\tau_{B^0}$ (direct measurements)

| VALUE | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **0.91 ±0.09 ±0.003** | [23] ABAZOV | 05W | D0 | $p\overline{p}$ at 1.96 TeV |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| $0.980^{+0.076}_{-0.071}\pm0.003$ | [24] ABAZOV | 05B | D0 | Repl. by ABAZOV 05W |

[23] Measured using the time-dependent angular analysis of $B_s^0 \rightarrow J/\psi\phi$ decays.
[24] Measured mean life ratio using fully reconstructed decays.

## $B_{sH}^0$ MEAN LIFE

$B_{sH}^0$ is the heavy mass state of two $B_s^0$ $CP$ eigenstates.

"OUR EVALUATION" is an average using rescaled values of the data listed below. The average and rescaling were performed by the Heavy Flavor Averaging Group (HFAG) and are described at http://www.slac.stanford.edu/xorg/hfag/. The averaging/rescaling procedure takes into account correlations between the measurements.

| *VALUE* ($10^{-12}$ s) | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|
| $\mathbf{1.530^{+0.077}_{-0.083}}$ **OUR EVALUATION** | | | | |
| $\mathbf{1.78 \pm 0.32}$ **OUR AVERAGE** | | | | |
| $1.58\ ^{+0.39}_{-0.42}\ ^{+0.01}_{-0.02}$ | [25] ABAZOV | 05W | D0 | $p\overline{p}$ at 1.96 TeV |
| $2.07\ ^{+0.58}_{-0.46}\ \pm 0.03$ | [25] ACOSTA | 05 | CDF | $p\overline{p}$ at 1.96 TeV |

[25] Measured using the time-dependent angular analysis of $B^0_s \rightarrow J/\psi\phi$ decays.

## $B^0_{sL}$ MEAN LIFE

$B^0_{sL}$ is the light state of two $B^0_s$ $CP$ eigenstates.

"OUR EVALUATION" is an average using rescaled values of the data listed below. The average and rescaling were performed by the Heavy Flavor Averaging Group (HFAG) and are described at http://www.slac.stanford.edu/xorg/hfag/. The averaging/rescaling procedure takes into account correlations between the measurements.

| *VALUE* ($10^{-12}$ s) | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|
| $\mathbf{1.355^{+0.063}_{-0.059}}$ **OUR EVALUATION** | | | | |
| $\mathbf{1.18\ ^{+0.10}_{-0.08}}$ **OUR AVERAGE** | | | | |
| $1.24\ ^{+0.14}_{-0.11}\ ^{+0.01}_{-0.02}$ | [26] ABAZOV | 05W | D0 | $p\overline{p}$ at 1.96 TeV |
| $1.05\ ^{+0.16}_{-0.13}\ \pm 0.02$ | [26] ACOSTA | 05 | CDF | $p\overline{p}$ at 1.96 TeV |
| $1.27\ \pm 0.33\ \pm 0.08$ | [27] BARATE | 00K | ALEP | $e^+e^- \rightarrow Z$ |

[26] Measured using the time-dependent angular analysis of $B^0_s \rightarrow J/\psi\phi$ decays.

[27] Uses $\phi\phi$ correlations from $B^0_s \rightarrow D_s^{(*)+} D_s^{(*)-}$.

## $\Delta\Gamma_{B^0_s}/\Gamma_{B^0_s}$

$\Gamma_{B^0_s}$ and $\Delta\Gamma_{B^0_s}$ are the decay rate average and difference between two $B^0_s$ $CP$ eigenstates (light − heavy).

"OUR EVALUATION" is an average of all available $B_s$ semi-leptonic lifetime measurements with the $\Delta\Gamma_{B^0_s}/\Gamma_s$ analyses performed by the Heavy Flavor Averaging Group (HFAG) as described in our "Review on $B$-$\overline{B}$ Mixing" in the $B^0$ Section of these Listings. The corresponding 95% CL is $-0.06 < \Delta\Gamma_{B^0_s}/\Gamma_{B^0_s} < 0.28$.

| VALUE | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **$0.121^{+0.083}_{-0.090}$ OUR EVALUATION** | | | | | |
| $0.24\ ^{+0.28}_{-0.38}\ ^{+0.03}_{-0.04}$ | | [28,29] ABAZOV | 05W | D0 | $p\overline{p}$ at 1.96 TeV |
| $0.65\ ^{+0.25}_{-0.33}\ \pm0.01$ | | [28] ACOSTA | 05 | CDF | $p\overline{p}$ at 1.96 TeV |
| $<0.46$ | 95 | [30] ABREU | 00Y | DLPH | $e^+e^- \rightarrow Z$ |
| $<0.69$ | 95 | [31] ABREU,P | 00G | DLPH | $e^+e^- \rightarrow Z$ |
| $0.25\ ^{+0.21}_{-0.14}$ | | [32] BARATE | 00K | ALEP | $e^+e^- \rightarrow Z$ |
| $<0.83$ | 95 | [33] ABE | 99D | CDF | $p\overline{p}$ at 1.8 TeV |
| $<0.67$ | 95 | [34] ACCIARRI | 98S | L3 | $e^+e^- \rightarrow Z$ |

[28] Measured using the time-dependent angular analysis of $B^0_s \rightarrow J/\psi\phi$ decays.

[29] Uses $|A_0|^2 - |A_{||}|^2$=0.355 ± 0.066 from ACOSTA 05.

[30] Uses $D^-_s\ell^+$, and $\phi\ell^+$ vertices.

[31] Measured using $D_s$ hadron vertices.

[32] Uses $\phi\phi$ correlations from $B^0_s \rightarrow D^{(*)+}_s D^{(*)-}_s$.

[33] ABE 99D assumes $\tau_{B^0_s}$= 1.55 ± 0.05 ps.

[34] ACCIARRI 98S assumes $\tau_{B^0_s}$= 1.49 ± 0.06 ps and PDG 98 values of $b$ production fraction.

## $\Delta\Gamma_{B^0_s}$

"OUR EVALUATION" is an average using rescaled values of the data listed below. The average and rescaling were performed by the Heavy Flavor Averaging Group (HFAG) and are described at http://www.slac.stanford.edu/xorg/hfag/. The averaging/rescaling procedure takes into account correlations between the measurements.

| VALUE ($10^{12}$ s$^{-1}$) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **$0.084^{+0.055}_{-0.050}$ OUR EVALUATION** | | | | |
| **$0.16\ ^{+0.10}_{-0.13}$ OUR AVERAGE** Error includes scale factor of 1.4. | | | | |
| $0.12\ ^{+0.08}_{-0.10}\ \pm0.02$ | [35,36] ABAZOV | 07 | D0 | $p\overline{p}$ at 1.96 TeV |
| $0.47\ ^{+0.19}_{-0.24}\ \pm0.01$ | [35] ACOSTA | 05 | CDF | $p\overline{p}$ at 1.96 TeV |

[35] Measured using the time-dependent angular analysis of $B^0_s \rightarrow J/\psi\phi$ decays and assuming $CP$-violating phase $\phi_s = 0$.

[36] ABAZOV 07 reports 0.17 ± 0.09 ± 0.02 with $CP$-violating phase $\phi_s$ as a free parameter.

# $B_s^0$ DECAY MODES

These branching fractions all scale with B($\overline{b} \rightarrow B_s^0$), the LEP $B_s^0$ production fraction. The first four were evaluated using B($\overline{b} \rightarrow B_s^0$) = (10.7 ± 1.4)% and the rest assume B($\overline{b} \rightarrow B_s^0$) = 12%.

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

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

| | Mode | | | Fraction ($\Gamma_i/\Gamma$) | Confidence level |
|---|---|---|---|---|---|
| $\Gamma_1$ | $D_s^-$ anything | | | (93 ±25 ) % | |
| $\Gamma_2$ | $D_s^- \ell^+ \nu_\ell$ anything | | [a] | ( 7.9 ± 2.4) % | |
| $\Gamma_3$ | $D_s^- \pi^+$ | | | ( 3.0 ± 0.7) × $10^{-3}$ | |
| $\Gamma_4$ | $D_s^- \pi^+ \pi^+ \pi^-$ | | | ( 8.4 ± 3.3) × $10^{-3}$ | |
| $\Gamma_5$ | $D_s^{(*)+} D_s^{(*)-}$ | | | (12 $^{+11}_{-6}$ ) % | |
| $\Gamma_6$ | $J/\psi(1S)\phi$ | | | ( 9.3 ± 3.3) × $10^{-4}$ | |
| $\Gamma_7$ | $J/\psi(1S)\pi^0$ | | | < 1.2 × $10^{-3}$ | 90% |
| $\Gamma_8$ | $J/\psi(1S)\eta$ | | | < 3.8 × $10^{-3}$ | 90% |
| $\Gamma_9$ | $\psi(2S)\phi$ | | | ( 4.8 ± 2.2) × $10^{-4}$ | |
| $\Gamma_{10}$ | $\pi^+\pi^-$ | | | < 1.7 × $10^{-6}$ | 90% |
| $\Gamma_{11}$ | $\pi^0\pi^0$ | | | < 2.1 × $10^{-4}$ | 90% |
| $\Gamma_{12}$ | $\eta\pi^0$ | | | < 1.0 × $10^{-3}$ | 90% |
| $\Gamma_{13}$ | $\eta\eta$ | | | < 1.5 × $10^{-3}$ | 90% |
| $\Gamma_{14}$ | $\rho^0\rho^0$ | | | < 3.20 × $10^{-4}$ | 90% |
| $\Gamma_{15}$ | $\phi\rho^0$ | | | < 6.17 × $10^{-4}$ | 90% |
| $\Gamma_{16}$ | $\phi\phi$ | | | ( 1.4 ± 0.8) × $10^{-5}$ | |
| $\Gamma_{17}$ | $\pi^+ K^-$ | | | < 5.6 × $10^{-6}$ | 90% |
| $\Gamma_{18}$ | $K^+ K^-$ | | | ( 3.3 ± 0.9) × $10^{-5}$ | |
| $\Gamma_{19}$ | $\overline{K}^*(892)^0 \rho^0$ | | | < 7.67 × $10^{-4}$ | 90% |
| $\Gamma_{20}$ | $\overline{K}^*(892)^0 K^*(892)^0$ | | | < 1.681 × $10^{-3}$ | 90% |
| $\Gamma_{21}$ | $\phi K^*(892)^0$ | | | < 1.013 × $10^{-3}$ | 90% |
| $\Gamma_{22}$ | $p\overline{p}$ | | | < 5.9 × $10^{-5}$ | 90% |
| $\Gamma_{23}$ | $\gamma\gamma$ | *B1* | | < 1.48 × $10^{-4}$ | 90% |
| $\Gamma_{24}$ | $\phi\gamma$ | | | < 1.2 × $10^{-4}$ | 90% |

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

| | | | | | | |
|---|---|---|---|---|---|---|
| $\Gamma_{25}$ | $\mu^+\mu^-$ | *B1* | | $< 1.5$ | $\times 10^{-7}$ | 90% |
| $\Gamma_{26}$ | $e^+e^-$ | *B1* | | $< 5.4$ | $\times 10^{-5}$ | 90% |
| $\Gamma_{27}$ | $e^\pm\mu^\mp$ | *LF* | [*b*] | $< 6.1$ | $\times 10^{-6}$ | 90% |
| $\Gamma_{28}$ | $\phi(1020)\mu^+\mu^-$ | *B1* | | $< 3.2$ | $\times 10^{-6}$ | 90% |
| $\Gamma_{29}$ | $\phi\nu\overline{\nu}$ | *B1* | | $< 5.4$ | $\times 10^{-3}$ | 90% |

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

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

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## $B_s^0$ BRANCHING RATIOS

### $\Gamma(D_s^-\text{ anything})/\Gamma_{\text{total}}$ $\qquad\Gamma_1/\Gamma$

| *VALUE* | *EVTS* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|
| **0.93±0.25 OUR AVERAGE** | | | | | |
| 0.91±0.18±0.41 | | [37] DRUTSKOY | 07 | BELL | $e^+e^- \to \Upsilon(4S)$ |
| 0.81±0.24±0.22 | 90 | [38] BUSKULIC | 96E | ALEP | $e^+e^- \to Z$ |
| 1.56±0.58±0.44 | 147 | [39] ACTON | 92N | OPAL | $e^+e^- \to Z$ |

[37] The extraction of this result takes into account the correlation between the measurements of B($\Upsilon(5S) \to D_s X$) and B($\Upsilon(5S) \to D^0 X$).

[38] BUSKULIC 96E separate $c\overline{c}$ and $b\overline{b}$ sources of $D_s^+$ mesons using a lifetime tag, subtract generic $\overline{b} \to W^+ \to D_s^+$ events, and obtain B($\overline{b} \to B_s^0$) × B($B_s^0 \to D_s^-$ anything) $= 0.088 \pm 0.020 \pm 0.020$ assuming B($D_s \to \phi\pi$) $= (3.5 \pm 0.4) \times 10^{-2}$ and PDG 1994 values for the relative partial widths to other $D_s$ channels. We evaluate using our current values B($\overline{b} \to B_s^0$) $= 0.107 \pm 0.014$ and B($D_s \to \phi\pi$) $= 0.036 \pm 0.009$. Our first error is their experiment's and our second error is that due to B($\overline{b} \to B_s^0$) and B($D_s \to \phi\pi$).

[39] ACTON 92N assume that excess of $147 \pm 48$ $D_s^0$ events over that expected from $B^0$, $B^+$, and $c\overline{c}$ is all from $B_s^0$ decay. The product branching fraction is measured to be B($\overline{b} \to B_s^0$)B($B_s^0 \to D_s^-$ anything)×B($D_s^- \to \phi\pi^-$) $= (5.9 \pm 1.9 \pm 1.1) \times 10^{-3}$. We evaluate using our current values B($\overline{b} \to B_s^0$) $= 0.107 \pm 0.014$ and B($D_s \to \phi\pi$) $= 0.036 \pm 0.009$. Our first error is their experiment's and our second error is that due to B($\overline{b} \to B_s^0$) and B($D_s \to \phi\pi$).

### $\Gamma(D_s^-\ell^+\nu_\ell\text{ anything})/\Gamma_{\text{total}}$ $\qquad\Gamma_2/\Gamma$

The values and averages in this section serve only to show what values result if one assumes our B($\overline{b} \to B_s^0$). They cannot be thought of as measurements since the underlying product branching fractions were also used to determine B($\overline{b} \to B_s^0$) as described in the note on "Production and Decay of *b*-Flavored Hadrons."

| VALUE | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **0.079±0.024 OUR AVERAGE** | | | | | |
| 0.076±0.012±0.021 | 134 | [40] BUSKULIC | 95O | ALEP | $e^+ e^- \rightarrow Z$ |
| 0.107±0.043±0.029 | | [41] ABREU | 92M | DLPH | $e^+ e^- \rightarrow Z$ |
| 0.103±0.036±0.028 | 18 | [42] ACTON | 92N | OPAL | $e^+ e^- \rightarrow Z$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| 0.13 ±0.04 ±0.04 | 27 | [43] BUSKULIC | 92E | ALEP | $e^+ e^- \rightarrow Z$ |

[40] BUSKULIC 95O use $D_s \ell$ correlations. The measured product branching ratio is B($\overline{b} \rightarrow B_s$) × B($B_s \rightarrow D_s^- \ell^+ \nu_\ell$anything) = ($0.82 \pm 0.09^{+0.13}_{-0.14}$)% assuming B($D_s \rightarrow \phi\pi$) = (3.5 ± 0.4) × $10^{-2}$ and PDG 1994 values for the relative partial widths to the six other $D_s$ channels used in this analysis. Combined with results from $\Upsilon(4S)$ experiments this can be used to extract B($\overline{b} \rightarrow B_s$) = ($11.0 \pm 1.2^{+2.5}_{-2.6}$)%. We evaluate using our current values B($\overline{b} \rightarrow B^0_s$) = 0.107 ± 0.014 and B($D_s \rightarrow \phi\pi$) = 0.036 ± 0.009. Our first error is their experiment's and our second error is that due to B($\overline{b} \rightarrow B^0_s$) and B($D_s \rightarrow \phi\pi$).

[41] ABREU 92M measured muons only and obtained product branching ratio B($Z \rightarrow b$or $\overline{b}$) × B($\overline{b} \rightarrow B_s$) × B($B_s \rightarrow D_s \mu^+ \nu_\mu$anything) × B($D_s \rightarrow \phi\pi$) = (18 ± 8) × $10^{-5}$. We evaluate using our current values B($\overline{b} \rightarrow B^0_s$) = 0.107 ± 0.014 and B($D_s \rightarrow \phi\pi$) = 0.036 ± 0.009. Our first error is their experiment's and our second error is that due to B($\overline{b} \rightarrow B^0_s$) and B($D_s \rightarrow \phi\pi$). We use B($Z \rightarrow b$or $\overline{b}$) = 2B($Z \rightarrow b\overline{b}$) = 2×(0.2212 ± 0.0019).

[42] ACTON 92N is measured using $D_s \rightarrow \phi\pi^+$ and $K^*(892)^0 K^+$ events. The product branching fraction measured is measured to be B($\overline{b} \rightarrow B^0_s$)B($B^0_s \rightarrow D_s^- \ell^+ \nu_\ell$anything) ×B($D_s^- \rightarrow \phi\pi^-$) = (3.9 ± 1.1 ± 0.8) × $10^{-4}$. We evaluate using our current values B($\overline{b} \rightarrow B^0_s$) = 0.107 ± 0.014 and B($D_s \rightarrow \phi\pi$) = 0.036 ± 0.009. Our first error is their experiment's and our second error is that due to B($\overline{b} \rightarrow B^0_s$) and B($D_s \rightarrow \phi\pi$).

[43] BUSKULIC 92E is measured using $D_s \rightarrow \phi\pi^+$ and $K^*(892)^0 K^+$ events. They use 2.7 ± 0.7% for the $\phi\pi^+$ branching fraction. The average product branching fraction is measured to be B($\overline{b} \rightarrow B^0_s$)B($B^0_s \rightarrow D_s^- \ell^+ \nu_\ell$anything) =$0.020 \pm 0.0055^{+0.005}_{-0.006}$. We evaluate using our current values B($\overline{b} \rightarrow B^0_s$) = 0.107 ± 0.014 and B($D_s \rightarrow \phi\pi$) = 0.036 ± 0.009. Our first error is their experiment's and our second error is that due to B($\overline{b} \rightarrow B^0_s$) and B($D_s \rightarrow \phi\pi$). Superseded by BUSKULIC 95O.

## $\Gamma(D_s^- \pi^+)/\Gamma_{\text{total}}$ $\Gamma_3/\Gamma$

| VALUE (units $10^{-3}$) | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **3.0±0.7±0.1** | | [44] ABULENCIA | 07C | CDF | $p\overline{p}$ at 1.96 TeV |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| 3.5±1.1±0.2 | | [45] ABULENCIA | 06J | CDF | Repl. by ABULENCIA 07C |
| <130 | 6 | [46] AKERS | 94J | OPAL | $e^+ e^- \rightarrow Z$ |
| seen | 1 | BUSKULIC | 93G | ALEP | $e^+ e^- \rightarrow Z$ |

[44] ABULENCIA 07C reports $[B(B^0_s \to D^-_s \pi^+) / B(B^0 \to D^- \pi^+)] = 1.13 \pm 0.08 \pm 0.23$. We multiply by our best value $B(B^0 \to D^- \pi^+) = (2.68 \pm 0.13) \times 10^{-3}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

[45] ABULENCIA 06J reports $[B(B^0_s \to D^-_s \pi^+) / B(B^0 \to D^- \pi^+)] = 1.32 \pm 0.18 \pm 0.38$. We multiply by our best value $B(B^0 \to D^- \pi^+) = (2.68 \pm 0.13) \times 10^{-3}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

[46] AKERS 94J sees $\leq 6$ events and measures the limit on the product branching fraction $f(\overline{b} \to B^0_s) \cdot B(B^0_s \to D^-_s \pi^+) < 1.3\%$ at CL = 90%. We divide by our current value $B(\overline{b} \to B^0_s) = 0.105$.

## $\Gamma(D^-_s \pi^+ \pi^+ \pi^-)/\Gamma_{\text{total}}$ — $\Gamma_4/\Gamma$

| *VALUE* (units $10^{-3}$) | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|
| **8.4±1.9±2.7** | [47] ABULENCIA | 07C | CDF | $p\overline{p}$ at 1.96 TeV |

[47] ABULENCIA 07C reports $[B(B^0_s \to D^-_s \pi^+ \pi^+ \pi^-) / B(B^0 \to D^- \pi^+ \pi^+ \pi^-)] = 1.05 \pm 0.10 \pm 0.22$. We multiply by our best value $B(B^0 \to D^- \pi^+ \pi^+ \pi^-) = (8.0 \pm 2.5) \times 10^{-3}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

## $\Gamma(D_s^{(*)+} D_s^{(*)-})/\Gamma_{\text{total}}$ — $\Gamma_5/\Gamma$

| *VALUE* | *CL%* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|
| **$0.12 \pm 0.05^{+0.10}_{-0.04}$** | | [48] BARATE | 00K | ALEP | $e^+ e^- \to Z$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| $<0.218$ | 90 | BARATE | 98Q | ALEP | $e^+ e^- \to Z$ |

[48] Uses $\phi\phi$ correlations from $B^0_s(\text{short}) \to D_s^{(*)+} D_s^{(*)-}$.

## $\Gamma(J/\psi(1S)\phi)/\Gamma_{\text{total}}$ — $\Gamma_6/\Gamma$

| *VALUE* (units $10^{-3}$) | *EVTS* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|
| **0.93±0.28±0.17** | | [49] ABE | 96Q | CDF | $p\overline{p}$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| $<6$ | 1 | [50] AKERS | 94J | OPAL | $e^+ e^- \to Z$ |
| seen | 14 | [51] ABE | 93F | CDF | $p\overline{p}$ at 1.8 TeV |
| seen | 1 | [52] ACTON | 92N | OPAL | Sup. by AKERS 94J |

[49] ABE 96Q assumes $f_u = f_d$ and $f_s/f_u = 0.40 \pm 0.06$. Uses $B \to J/\psi(1S) K$ and $B \to J/\psi(1S) K^*$ branching fractions from PDG 94. They quote two systematic errors, $\pm 0.10$ and $\pm 0.14$ where the latter is the uncertainty in $f_s$. We combine in quadrature.

[50] AKERS 94J sees one event and measures the limit on the product branching fraction $f(\overline{b} \to B^0_s) \cdot B(B^0_s \to J/\psi(1S)\phi) < 7 \times 10^{-4}$ at CL = 90%. We divide by $B(\overline{b} \to B^0_s) = 0.112$.

[51] ABE 93F measured using $J/\psi(1S) \to \mu^+ \mu^-$ and $\phi \to K^+ K^-$.

[52] In ACTON 92N a limit on the product branching fraction is measured to be $f(\overline{b} \to B^0_s) \cdot B(B^0_s \to J/\psi(1S)\phi) \leq 0.22 \times 10^{-2}$.

### $\Gamma(J/\psi(1S)\pi^0)/\Gamma_{total}$ — $\Gamma_7/\Gamma$

| VALUE | CL% | DOCUMENT ID | | TECN |
|---|---|---|---|---|
| **$<1.2 \times 10^{-3}$** | 90 | [53] ACCIARRI | 97C | L3 |

[53] ACCIARRI 97C assumes $B^0$ production fraction (39.5 ± 4.0%) and $B_s$ (12.0 ± 3.0%).

### $\Gamma(J/\psi(1S)\eta)/\Gamma_{total}$ — $\Gamma_8/\Gamma$

| VALUE | CL% | DOCUMENT ID | | TECN |
|---|---|---|---|---|
| **$<3.8 \times 10^{-3}$** | 90 | [54] ACCIARRI | 97C | L3 |

[54] ACCIARRI 97C assumes $B^0$ production fraction (39.5 ± 4.0%) and $B_s$ (12.0 ± 3.0%).

### $\Gamma(\psi(2S)\phi)/\Gamma_{total}$ — $\Gamma_9/\Gamma$

| VALUE (units $10^{-4}$) | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **4.8±1.4±1.7** | | [55] ABULENCIA | 06N | CDF | $p\overline{p}$ at 1.96 TeV |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| seen | 1 | BUSKULIC | 93G | ALEP | $e^+e^- \to Z$ |

[55] ABULENCIA 06N reports $[B(B_s^0 \to \psi(2S)\phi) / B(B_s^0 \to J/\psi(1S)\phi)] = 0.52 \pm 0.13 \pm 0.07$. We multiply by our best value $B(B_s^0 \to J/\psi(1S)\phi) = (9.3 \pm 3.3) \times 10^{-4}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

### $\Gamma(\pi^+\pi^-)/\Gamma_{total}$ — $\Gamma_{10}/\Gamma$

| VALUE (units $10^{-6}$) | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **< 1.7** | 90 | [56] ABULENCIA,A | 06D | CDF | $p\overline{p}$ at 1.96 TeV |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| <232 | 90 | [57] ABE | 00C | SLD | $e^+e^- \to Z$ |
| <170 | 90 | [58] BUSKULIC | 96V | ALEP | $e^+e^- \to Z$ |

[56] ABULENCIA,A 06D obtains this from $B(B_s \to \pi^+\pi^-) / B(B_s \to K^+K^-) < 0.05$ at 90% CL, assuming $B(B_s \to K^+K^-) = (33 \pm 6 \pm 7) \times 10^{-6}$.

[57] ABE 00C assumes $B(Z \to b\overline{b})$=(21.7 ± 0.1)% and the $B$ fractions $f_{B^0}=f_{B^+}=(39.7^{+1.8}_{-2.2})$% and $f_{B_s}=(10.5^{+1.8}_{-2.2})$%.

[58] BUSKULIC 96V assumes PDG 96 production fractions for $B^0$, $B^+$, $B_s$, $b$ baryons.

### $\Gamma(\pi^0\pi^0)/\Gamma_{total}$ — $\Gamma_{11}/\Gamma$

| VALUE | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **$<2.1 \times 10^{-4}$** | 90 | [59] ACCIARRI | 95H | L3 | $e^+e^- \to Z$ |

[59] ACCIARRI 95H assumes $f_{B^0} = 39.5 \pm 4.0$ and $f_{B_s} = 12.0 \pm 3.0$%.

### $\Gamma(\eta\pi^0)/\Gamma_{total}$ — $\Gamma_{12}/\Gamma$

| VALUE | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **$<1.0 \times 10^{-3}$** | 90 | [60] ACCIARRI | 95H | L3 | $e^+e^- \to Z$ |

[60] ACCIARRI 95H assumes $f_{B^0} = 39.5 \pm 4.0$ and $f_{B_s} = 12.0 \pm 3.0$%.

### $\Gamma(\eta\eta)/\Gamma_{total}$ $\Gamma_{13}/\Gamma$

| VALUE | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **$<1.5 \times 10^{-3}$** | 90 | [61] ACCIARRI | 95H | L3 | $e^+e^- \to Z$ |

[61] ACCIARRI 95H assumes $f_{B^0} = 39.5 \pm 4.0$ and $f_{B_s} = 12.0 \pm 3.0\%$.

### $\Gamma(\rho^0\rho^0)/\Gamma_{total}$ $\Gamma_{14}/\Gamma$

| VALUE | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **$<3.20 \times 10^{-4}$** | 90 | [62] ABE | 00C | SLD | $e^+e^- \to Z$ |

[62] ABE 00C assumes B($Z \to b\overline{b}$)=(21.7 $\pm$ 0.1)% and the $B$ fractions $f_{B^0}$=$f_{B^+}$=$(39.7^{+1.8}_{-2.2})$% and $f_{B_s}$=$(10.5^{+1.8}_{-2.2})$%.

### $\Gamma(\phi\rho^0)/\Gamma_{total}$ $\Gamma_{15}/\Gamma$

| VALUE | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **$<6.17 \times 10^{-4}$** | 90 | [63] ABE | 00C | SLD | $e^+e^- \to Z$ |

[63] ABE 00C assumes B($Z \to b\overline{b}$)=(21.7 $\pm$ 0.1)% and the $B$ fractions $f_{B^0}$=$f_{B^+}$=$(39.7^{+1.8}_{-2.2})$% and $f_{B_s}$=$(10.5^{+1.8}_{-2.2})$%.

### $\Gamma(\phi\phi)/\Gamma_{total}$ $\Gamma_{16}/\Gamma$

| VALUE (units $10^{-6}$) | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **$14^{+6}_{-5}\pm6$** | | [64] ACOSTA | 05J | CDF | $p\overline{p}$ at 1.96 TeV |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| $<1183$ | 90 | [65] ABE | 00C | SLD | $e^+e^- \to Z$ |

[64] Uses B($B^0 \to J/\psi\phi$) = (1.38 $\pm$ 0.49) $\times 10^{-3}$ and production cross-section ratio of $\sigma(B_s)/\sigma(B^0) = 0.26 \pm 0.04$.

[65] ABE 00C assumes B($Z \to b\overline{b}$)=(21.7 $\pm$ 0.1)% and the $B$ fractions $f_{B^0}$=$f_{B^+}$=$(39.7^{+1.8}_{-2.2})$% and $f_{B_s}$=$(10.5^{+1.8}_{-2.2})$%.

### $\Gamma(\pi^+K^-)/\Gamma_{total}$ $\Gamma_{17}/\Gamma$

| VALUE (units $10^{-6}$) | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **$<$ 5.6** | 90 | [66] ABULENCIA,A | 06D | CDF | $p\overline{p}$ at 1.96 TeV |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| $<261$ | 90 | [67] ABE | 00C | SLD | $e^+e^- \to Z$ |
| $<210$ | 90 | [68] BUSKULIC | 96V | ALEP | $e^+e^- \to Z$ |
| $<260$ | 90 | [69] AKERS | 94L | OPAL | $e^+e^- \to Z$ |

[66] ABULENCIA,A 06D obtains this from $(f_s/f_d)$ (B($B_s \to \pi^+K^-$) / B($B^0 \to K^+\pi^-$)) $< 0.08$ at 90% CL, assuming $f_s/f_d = 0.260 \pm 0.039$ and B($B^0 \to K^+\pi^-$) = (18.9 $\pm$ 0.7) $\times 10^{-6}$.

[67] ABE 00C assumes B($Z \to b\overline{b}$)=(21.7 $\pm$ 0.1)% and the $B$ fractions $f_{B^0}$=$f_{B^+}$=$(39.7^{+1.8}_{-2.2})$% and $f_{B_s}$=$(10.5^{+1.8}_{-2.2})$%.

[68] BUSKULIC 96V assumes PDG 96 production fractions for $B^0$, $B^+$, $B_s$, $b$ baryons.

[69] Assumes B($Z \to b\overline{b}$) = 0.217 and $B^0_d$ ($B^0_s$) fraction 39.5% (12%).

## $\Gamma(K^+ K^-)/\Gamma_{total}$ — $\Gamma_{18}/\Gamma$

| VALUE (units $10^{-5}$) | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **3.3±0.6±0.7** | | [70] ABULENCIA,A | 06D | CDF | $p\overline{p}$ at 1.96 TeV |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| <28.3 | 90 | [71] ABE | 00C | SLD | $e^+e^- \to Z$ |
| < 5.9 | 90 | [72] BUSKULIC | 96V | ALEP | $e^+e^- \to Z$ |
| <14 | 90 | [73] AKERS | 94L | OPAL | $e^+e^- \to Z$ |

[70] ABULENCIA,A 06D obtains this from $(f_s/f_d)$ (B($B_s \to K^+K^-$) / B($B^0 \to K^+\pi^-$)) $= 0.46 \pm 0.08 \pm 0.07$, assuming $f_s/f_d = 0.260 \pm 0.039$ and B($B^0 \to K^+\pi^-$) $= (18.9 \pm 0.7) \times 10^{-6}$.

[71] ABE 00C assumes B($Z \to b\overline{b}$)=(21.7 ± 0.1)% and the $B$ fractions $f_{B^0}=f_{B^+}=(39.7^{+1.8}_{-2.2})$% and $f_{B_s}=(10.5^{+1.8}_{-2.2})$%.

[72] BUSKULIC 96V assumes PDG 96 production fractions for $B^0$, $B^+$, $B_s$, $b$ baryons.

[73] Assumes B($Z \to b\overline{b}$) = 0.217 and $B^0_d$ ($B^0_s$) fraction 39.5% (12%).

## $\Gamma(\overline{K}^*(892)^0 \rho^0)/\Gamma_{total}$ — $\Gamma_{19}/\Gamma$

| VALUE | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **<7.67 × 10$^{-4}$** | 90 | [74] ABE | 00C | SLD | $e^+e^- \to Z$ |

[74] ABE 00C assumes B($Z \to b\overline{b}$)=(21.7 ± 0.1)% and the $B$ fractions $f_{B^0}=f_{B^+}=(39.7^{+1.8}_{-2.2})$% and $f_{B_s}=(10.5^{+1.8}_{-2.2})$%.

## $\Gamma(\overline{K}^*(892)^0 K^*(892)^0)/\Gamma_{total}$ — $\Gamma_{20}/\Gamma$

| VALUE | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **<16.81 × 10$^{-4}$** | 90 | [75] ABE | 00C | SLD | $e^+e^- \to Z$ |

[75] ABE 00C assumes B($Z \to b\overline{b}$)=(21.7 ± 0.1)% and the $B$ fractions $f_{B^0}=f_{B^+}=(39.7^{+1.8}_{-2.2})$% and $f_{B_s}=(10.5^{+1.8}_{-2.2})$%.

## $\Gamma(\phi K^*(892)^0)/\Gamma_{total}$ — $\Gamma_{21}/\Gamma$

| VALUE | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **<10.13 × 10$^{-4}$** | 90 | [76] ABE | 00C | SLD | $e^+e^- \to Z$ |

[76] ABE 00C assumes B($Z \to b\overline{b}$)=(21.7 ± 0.1)% and the $B$ fractions $f_{B^0}=f_{B^+}=(39.7^{+1.8}_{-2.2})$% and $f_{B_s}=(10.5^{+1.8}_{-2.2})$%.

## $\Gamma(p\overline{p})/\Gamma_{total}$ — $\Gamma_{22}/\Gamma$

Test for $\Delta B$=1 weak neutral current. Allowed by higher-order electroweak interactions.

| VALUE | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **<5.9 × 10$^{-5}$** | 90 | [77] BUSKULIC | 96V | ALEP | $e^+e^- \to Z$ |

[77] BUSKULIC 96V assumes PDG 96 production fractions for $B^0$, $B^+$, $B_s$, $b$ baryons.

## $\Gamma(\gamma\gamma)/\Gamma_{total}$ — $\Gamma_{23}/\Gamma$

Test for $\Delta B$=1 weak neutral current.

| VALUE | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **<14.8 × 10$^{-5}$** | 90 | [78] ACCIARRI | 95I | L3 | $e^+e^- \to Z$ |

[78] ACCIARRI 95I assumes $f_{B^0} = 39.5 \pm 4.0$ and $f_{B_s} = 12.0 \pm 3.0$%.

## $\Gamma(\phi\gamma)/\Gamma_{total}$ $\Gamma_{24}/\Gamma$

| VALUE | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **<1.2 × 10⁻⁴** | 90 | ACOSTA | 02G | CDF | $p\overline{p}$ at 1.8 TeV |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| $<7 \times 10^{-4}$ | 90 | [79] ADAM | 96D | DLPH | $e^+e^- \to Z$ |

[79] ADAM 96D assumes $f_{B^0} = f_{B^-} = 0.39$ and $f_{B_s} = 0.12$.

## $\Gamma(\mu^+\mu^-)/\Gamma_{total}$ $\Gamma_{25}/\Gamma$

Test for $\Delta B = 1$ weak neutral current.

| VALUE | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **$<1.5 \times 10^{-7}$** | 90 | [80] ABULENCIA | 05 | CDF | $p\overline{p}$ at 1.96 TeV |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| $<4.1 \times 10^{-7}$ | 90 | [81] ABAZOV | 05E | D0 | $p\overline{p}$ at 1.96 TeV |
| $<5.8 \times 10^{-7}$ | 90 | [82] ACOSTA | 04D | CDF | $p\overline{p}$ at 1.96 TeV |
| $<2.0 \times 10^{-6}$ | 90 | [83] ABE | 98 | CDF | $p\overline{p}$ at 1.8 TeV |
| $<3.8 \times 10^{-5}$ | 90 | [84] ACCIARRI | 97B | L3 | $e^+e^- \to Z$ |
| $<8.4 \times 10^{-6}$ | 90 | [85] ABE | 96L | CDF | Repl. by ABE 98 |

[80] Assumes production cross section $\sigma(B^+)/\sigma(B_s) = 3.71 \pm 0.41$ and $B(B^+ \to J/\psi K^+ \to \mu^+\mu^- K^+) = (5.88 \pm 0.26) \times 10^{-5}$.
[81] Assumes production cross-section $\sigma(B_s)/\sigma(B^+) = 0.270 \pm 0.034$.
[82] Assumes production cross-section $\sigma(B_s)/\sigma(B^+) = 0.100/0.391$ and the CDF measured value of $\sigma(B^+) = 3.6 \pm 0.6\ \mu$b.
[83] ABE 98 assumes production of $\sigma(B^0) = \sigma(B^+)$ and $\sigma(B_s)/\sigma(B^0) = 1/3$. They normalize to their measured $\sigma(B^0, p_T(B) > 6, |y| < 1.0) = 2.39 \pm 0.32 \pm 0.44\ \mu$b.
[84] ACCIARRI 97B assume PDG 96 production fractions for $B^+$, $B^0$, $B_s$, and $\Lambda_b$.
[85] ABE 96L assumes $B^+/B_s$ production ratio 3/1. They normalize to their measured $\sigma(B^+, p_T(B) > 6\ \text{GeV}/c, |y| < 1) = 2.39 \pm 0.54\ \mu$b.

## $\Gamma(e^+e^-)/\Gamma_{total}$ $\Gamma_{26}/\Gamma$

Test for $\Delta B = 1$ weak neutral current.

| VALUE | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **$<5.4 \times 10^{-5}$** | 90 | [86] ACCIARRI | 97B | L3 | $e^+e^- \to Z$ |

[86] ACCIARRI 97B assume PDG 96 production fractions for $B^+$, $B^0$, $B_s$, and $\Lambda_b$.

## $\Gamma(e^\pm\mu^\mp)/\Gamma_{total}$ $\Gamma_{27}/\Gamma$

Test of lepton family number conservation.

| VALUE | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **$<6.1 \times 10^{-6}$** | 90 | ABE | 98V | CDF | $p\overline{p}$ at 1.8 TeV |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| $<4.1 \times 10^{-5}$ | 90 | [87] ACCIARRI | 97B | L3 | $e^+e^- \to Z$ |

[87] ACCIARRI 97B assume PDG 96 production fractions for $B^+$, $B^0$, $B_s$, and $\Lambda_b$.

## $\Gamma(\phi(1020)\mu^+\mu^-)/\Gamma_{total}$ $\Gamma_{28}/\Gamma$

Test for $\Delta B = 1$ weak neutral current.

| VALUE | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **$<3.2 \times 10^{-6}$** | 90 | [88] ABAZOV | 06G | D0 | $p\overline{p}$ at 1.96 TeV |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| $<4.7 \times 10^{-5}$ | 90 | ACOSTA | 02D | CDF | $p\overline{p}$ at 1.8 TeV |

[88] Uses $B(B_s^0 \to J/\psi\phi) = 9.3 \times 10^{-4}$.

### $\Gamma(\phi\nu\overline{\nu})/\Gamma_{\text{total}}$ $\Gamma_{29}/\Gamma$

Test for $\Delta B = 1$ weak neutral current.

| VALUE | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **<5.4 × 10$^{-3}$** | 90 | [89] ADAM | 96D | DLPH | $e^+e^- \rightarrow Z$ |

[89] ADAM 96D assumes $f_{B^0} = f_{B^-} = 0.39$ and $f_{B_s} = 0.12$.

## POLARIZATION IN $B_s^0$ DECAY

### $\Gamma_L/\Gamma$ in $B_s^0 \rightarrow J/\psi(1S)\phi$

| VALUE | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **0.59±0.12 OUR AVERAGE** | | | | | |
| 0.61±0.14±0.02 | | [90] AFFOLDER | 00N | CDF | $p\overline{p}$ at 1.8 TeV |
| $0.56\pm0.21^{+0.02}_{-0.04}$ | 19 | ABE | 95Z | CDF | $p\overline{p}$ at 1.8 TeV |

[90] AFFOLDER 00N measurements are based on 40 $B_s^0$ candidates obtained from a data sample of 89 pb$^{-1}$. The $P$-wave fraction is found to be 0.23 ± 0.19 ± 0.04.

## $B_s^0$-$\overline{B}_s^0$ MIXING

For a discussion of $B_s^0$-$\overline{B}_s^0$ mixing see the note on "$B^0$-$\overline{B}^0$ Mixing" in the $B^0$ Particle Listings above.

$\chi_s$ is a measure of the time-integrated $B_s^0$-$\overline{B}_s^0$ mixing probability that produced $B_s^0(\overline{B}_s^0)$ decays as a $\overline{B}_s^0(B_s^0)$. Mixing violates $\Delta B \neq 2$ rule.

$$\chi_s = \frac{x_s^2}{2(1+x_s^2)}$$

$$x_s = \frac{\Delta m_{B_s^0}}{\Gamma_{B_s^0}} = (m_{B_{sH}^0} - m_{B_{sL}^0})\,\tau_{B_s^0}\,,$$

where $H$, $L$ stand for heavy and light states of two $B_s^0$ $CP$ eigenstates and $\tau_{B_s^0} = \frac{1}{0.5(\Gamma_{B_{sH}^0}+\Gamma_{B_{sL}^0})}$.

### $\Delta m_{B_s^0} = m_{B_{sH}^0} - m_{B_{sL}^0}$

$\Delta m_{B_s^0}$ is a measure of $2\pi$ times the $B_s^0$-$\overline{B}_s^0$ oscillation frequency in time-dependent mixing experiments.

| VALUE ($10^{12}$ $\hbar$ s$^{-1}$) | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **17.77±0.10±0.07** | | [91] ABULENCIA,A | 06G | CDF | $p\overline{p}$ at 1.96 TeV |

• • • We do not use the following data for averages, fits, limits, etc. • • •

| | | | | | |
|---|---|---|---|---|---|
| 17–21 | 90 | [92] ABAZOV | 06B | D0 | $p\overline{p}$ at 1.96 TeV |
| $17.31^{+0.33}_{-0.18}\pm0.07$ | | [93] ABULENCIA | 06Q | CDF | Repl. by ABULENCIA,A 06G |
| $>$ 8.0 | 95 | [94] ABDALLAH | 04J | DLPH | $e^+e^- \rightarrow Z^0$ |
| $>$ 4.9 | 95 | [95] ABDALLAH | 04J | DLPH | $e^+e^- \rightarrow Z^0$ |
| $>$ 8.5 | 95 | [96] ABDALLAH | 04J | DLPH | $e^+e^- \rightarrow Z^0$ |
| $>$ 5.0 | 95 | [97] ABDALLAH | 03B | DLPH | $e^+e^- \rightarrow Z$ |
| $>$10.3 | 95 | [98] ABE | 03 | SLD | $e^+e^- \rightarrow Z$ |
| $>$10.9 | 95 | [99] HEISTER | 03E | ALEP | $e^+e^- \rightarrow Z$ |
| $>$ 5.3 | 95 | [100] ABE | 02V | SLD | $e^+e^- \rightarrow Z$ |
| $>$ 1.0 | 95 | [101] ABBIENDI | 01D | OPAL | $e^+e^- \rightarrow Z$ |
| $>$ 7.4 | 95 | [102] ABREU | 00Y | DLPH | Repl. by ABDALLAH 04J |
| $>$ 4.0 | 95 | [103] ABREU,P | 00G | DLPH | $e^+e^- \rightarrow Z$ |
| $>$ 5.2 | 95 | [104] ABBIENDI | 99S | OPAL | $e^+e^- \rightarrow Z$ |
| $<$96 | 95 | [105] ABE | 99D | CDF | $p\overline{p}$ at 1.8 TeV |
| $>$ 5.8 | 95 | [106] ABE | 99J | CDF | $p\overline{p}$ at 1.8 TeV |
| $>$ 9.6 | 95 | [107] BARATE | 99J | ALEP | $e^+e^- \rightarrow Z$ |
| $>$ 7.9 | 95 | [108] BARATE | 98C | ALEP | Repl. by BARATE 99J |
| $>$ 3.1 | 95 | [109] ACKERSTAFF | 97U | OPAL | Repl. by ABBIENDI 99S |
| $>$ 2.2 | 95 | [110] ACKERSTAFF | 97V | OPAL | Repl. by ABBIENDI 99S |
| $>$ 6.5 | 95 | [111] ADAM | 97 | DLPH | Repl. by ABREU 00Y |
| $>$ 6.6 | 95 | [112] BUSKULIC | 96M | ALEP | Repl. by BARATE 98C |
| $>$ 2.2 | 95 | [110] AKERS | 95J | OPAL | Sup. by ACKERSTAFF 97V |
| $>$ 5.7 | 95 | [113] BUSKULIC | 95J | ALEP | $e^+e^- \rightarrow Z$ |
| $>$ 1.8 | 95 | [110] BUSKULIC | 94B | ALEP | $e^+e^- \rightarrow Z$ |

[91] Significance of oscillation signal is 5.4 $\sigma$. Also reports $|V_{td} / V_{ts}| = 0.2060 \pm 0.0007^{+0.0081}_{-0.0060}$.

[92] A likelihood scan over the oscillation frequency, $\Delta m_s$, gives a most probable value of 19 ps$^{-1}$ and a range of 17$<$ $\Delta m_s$ $<$21 (ps$^{-1}$) at 90% C.L. assuming Gaussian uncertainties. Also excludes $\Delta m_s$ $<$14.8 ps$^{-1}$ at 95% C.L

[93] Significance of oscillation signal is 0.2%. Also reported the value $|V_{td} / V_{ts}| = 0.208^{+0.001}_{-0.002}{}^{+0.008}_{-0.006}$.

[94] Uses leptons emitted with large momentum transverse to a jet and improved techniques for vertexing and flavor-tagging.

[95] Updates of $D_s$-lepton analysis.

[96] Combined results from all Delphi analyses.

[97] Events with a high transverse momentum lepton were removed and an inclusively reconstructed vertex was required.

[98] ABE 03 uses the novel "charge dipole" technique to reconstruct separate secondary and tertiary vertices originating from the $B \rightarrow D$ decay chain. The analysis excludes $\Delta m_s$ $<$4.9 ps$^{-1}$ and 7.9$<$ $\Delta m_s$ $<$10.3 ps$^{-1}$.

[99] Three analyses based on complementary event selections: (1) fully-reconstructed hadronic decays; (2) semileptonic decays with $D_s$ exclusively reconstructed; (3) inclusive semileptonic decays.

[100] ABE 02V uses exclusively reconstructed $D_s^-$ mesons and excludes $\Delta m_s$ $<$1.4 ps$^{-1}$ and 2.4$<$ $\Delta m_s$ $<$5.3 ps$^{-1}$ at 95%CL.

[101] Uses fully or partially reconstructed $D_s \ell$ vertices and a mixing tag as a flavor tagging.

[102] Replaced by ABDALLAH 04A. Uses $D_s^- \ell^+$, and $\phi\ell^+$ vertices, and a multi-variable discriminant as a flavor tagging.
[103] Uses inclusive $D_s$ vertices and fully reconstructed $B_s$ decays and a multi-variable discriminant as a flavor tagging.
[104] Uses $\ell$-$Q_{\text{hem}}$ and $\ell$-$\ell$.
[105] ABE 99D assumes $\tau_{B_s^0} = 1.55 \pm 0.05$ ps and $\Delta\Gamma/\Delta m = (5.6 \pm 2.6) \times 10^{-3}$.
[106] ABE 99J uses $\phi$ $\ell$-$\ell$ correlation.
[107] BARATE 99J uses combination of an inclusive lepton and $D_s^-$-based analyses.
[108] BARATE 98C combines results from $D_s\,h$-$\ell/Q_{\text{hem}}$, $D_s\,h$-$K$ in the same side, $D_s\,\ell$-$\ell/Q_{\text{hem}}$ and $D_s\,\ell$-$K$ in the same side.
[109] Uses $\ell$-$Q_{\text{hem}}$.
[110] Uses $\ell$-$\ell$.
[111] ADAM 97 combines results from $D_s\,\ell$-$Q_{\text{hem}}$, $\ell$-$Q_{\text{hem}}$, and $\ell$-$\ell$.
[112] BUSKULIC 96M uses $D_s$ lepton correlations and lepton, kaon, and jet charge tags.
[113] BUSKULIC 95J uses $\ell$-$Q_{\text{hem}}$. They find $\Delta m_s > 5.6$ [$> 6.1$] for $f_s$=10% [12%]. We interpolate to our central value $f_s$=10.5%.

## $x_s = \Delta m_{B_s^0}/\Gamma_{B_s^0}$

This is derived by the Heavy Flavor Averaging Group (HFAG) from the results on $\Delta m_{B_s^0}$ and "OUR EVALUATION" of the $B_s^0$ mean lifetime.

| *VALUE* | *DOCUMENT ID* |
|---|---|
| **25.5±0.6 OUR EVALUATION** | |

## $\chi_s$

This $B_s^0$-$\overline{B}_s^0$ integrated mixing parameter is derived from $x_s$ above.

| *VALUE* | *DOCUMENT ID* |
|---|---|
| **0.49924±0.00003 OUR EVALUATION** | |

# *CP* VIOLATION PARAMETERS in $B_s^0$

## $\text{Re}(\epsilon_{B_s^0}) / (1 + |\epsilon_{B_s^0}|^2)$

*CP* impurity in $B_s^0$ system. It is obtained from either $B_s^0$ decays or a mixture of the $B_d^0$ and $B_s^0$ decays where the effect from the $B_s^0$ is isolated by using the $B_d^0$ parameter obtained from the $B$ factories.

"OUR EVALUATION" is an average using rescaled values of the data listed below. The average and rescaling were performed by the Heavy Flavor Averaging Group (HFAG) and are described at http://www.slac.stanford.edu/xorg/hfag/. The averaging/scaling procedure takes into account correlation between the measurements.

| *VALUE* (units $10^{-3}$) | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|
| **−0.75±2.52 OUR EVALUATION** | | | | |
| **6.1 ±4.8 ±0.9** | [114] ABAZOV | 07A | D0 | $p\overline{p}$ at 1.96 TeV |

[114] The first direct measurement of the time integrated flavor untagged charge asymmetry in semileptonic $B_s^0$ decays is reported as 2xA$^s_{SL}$(untagged) = A$^s_{SL}$ = $(2.45 \pm 1.93 \pm 0.35) \times 10^{-2}$.

## $CP$ Violation phase $\phi_s$ in the $B_s^0$ System

$\phi_s$ is the $CP$-violating phase, defined as the relative phase of the off-diagonal elements of the mass and decay matrices in the $B_s^0 \overline{B}_s^0$ system.

| VALUE | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| $\mathbf{-0.79\pm0.56^{+0.14}_{-0.01}}$ | [115] ABAZOV | 07 | D0 | $p\overline{p}$ at 1.96 TeV |

[115] The first direct measurement of the $CP$-violating mixing phase is reported from the time-dependent analysis of flavor untagged $B_s^0 \rightarrow J/\psi\phi$ decays.

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