# $B_s^0$

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

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

## $B_s^0$ MASS

The fit uses $m_{B^+}$, $(m_{B^0} - m_{B^+})$, $m_{B_s^0}$, and $(m_{B_s^0} - (m_{B^+} + m_{B^0})/2)$ to determine $m_{B^+}$, $m_{B^0}$, $m_{B_s^0}$, and the mass differences.

| *VALUE* (MeV) | *EVTS* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|
| **5369.3± 2.0 OUR FIT** | | | | | |
| **5369.6± 2.4 OUR AVERAGE** | | | | | |
| 5369.9± 2.3±1.3 | 32 | [1] 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 | [1] 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 | [2] AKERS | 94J | OPAL | $e^+e^- \rightarrow Z$ |
| 5383.3± 4.5±5.0 | 14 | ABE | 93F | CDF | Repl by ABE 96B |

[1] From the decay $B_s \rightarrow J/\psi(1S)\phi$.

[2] From the decay $B_s \rightarrow D_s^- \pi^+$.

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

$m_B$ is the average of our $B$ masses $(m_{B^\pm}+m_{B^0})/2$. The fits uses $m_{B^+}$, $(m_{B^0} - m_{B^+})$, $m_{B_s^0}$, and $m_{B_s^0} - m_B$ to determine $m_{B^+}$, $m_{B^0}$, $m_{B_s^0}$, and the mass differences.

| *VALUE* (MeV) | *CL%* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|
| **90.2±2.2 OUR FIT** | | | | | |
| **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 | $e^+e^- \rightarrow \Upsilon(5S)$ |

## $m_{B_{sH}^0} - m_{B_{sL}^0}$

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 of the data listed below performed by the LEP $B$ Lifetimes Working Group as described in our review "Production and Decay of $b$-flavored Hadrons" in the $B^{\pm}$ Section of the Listings. The averaging procedure takes into account correlations between the measurements and asymmetric lifetime errors.

| VALUE ($10^{-12}$ s) | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **1.57±0.08 OUR EVALUATION** | | | | | |
| $1.34^{+0.23}_{-0.19}\pm0.05$ | | [3] ABE | 96N | CDF | $p\overline{p}$ |
| $1.56^{+0.29}_{-0.26}{}^{+0.08}_{-0.07}$ | | [4] ABREU | 96F | DLPH | $e^+e^- \rightarrow Z$ |
| $1.65^{+0.34}_{-0.31}\pm0.12$ | | [5] ABREU | 96F | DLPH | $e^+e^- \rightarrow Z$ |
| $1.76\pm0.20^{+0.15}_{-0.10}$ | | [6] ABREU | 96F | DLPH | $e^+e^- \rightarrow Z$ |
| $1.60\pm0.26^{+0.13}_{-0.15}$ | | [7] ABREU | 96F | DLPH | $e^+e^- \rightarrow Z$ |
| $1.61^{+0.30}_{-0.29}{}^{+0.18}_{-0.16}$ | 90 | [5] BUSKULIC | 96E | ALEP | $e^+e^- \rightarrow Z$ |
| $1.54^{+0.14}_{-0.13}\pm0.04$ | | [4] BUSKULIC | 96M | ALEP | $e^+e^- \rightarrow Z$ |
| $1.42^{+0.27}_{-0.23}\pm0.11$ | 76 | [4] ABE | 95R | CDF | $p\overline{p}$ at 1.8 TeV |
| $1.54^{+0.25}_{-0.21}\pm0.06$ | 79 | [4] AKERS | 95G | OPAL | $e^+e^- \rightarrow Z$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| $1.67\pm0.14$ | | [8] ABREU | 96F | DLPH | $e^+e^- \rightarrow Z$ |
| $1.74^{+1.08}_{-0.69}\pm0.07$ | 8 | [9] ABE | 95R | CDF | Sup. by ABE 96N |
| $1.59^{+0.17}_{-0.15}\pm0.03$ | 134 | [4] BUSKULIC | 95O | ALEP | Sup. by BUSKULIC 96M |
| $0.96\pm0.37$ | 41 | [10] ABREU | 94E | DLPH | Sup. by ABREU 96F |
| $1.92^{+0.45}_{-0.35}\pm0.04$ | 31 | [4] BUSKULIC | 94C | ALEP | Sup. by BUSKULIC 95O |
| $1.13^{+0.35}_{-0.26}\pm0.09$ | 22 | [4] ACTON | 93H | OPAL | Sup. by AKERS 95G |

[3] ABE 96N uses 58 ± 12 exclusive $B_s \rightarrow J/\psi(1S)\phi$ events.
[4] Measured using $D_s^-\ell^+$ vertices.
[5] Measured using $D_s$ hadron vertices.
[6] Measured using $\phi\ell$ vertices.
[7] Measured using inclusive $D_s$ vertices.
[8] Combined result for the four ABREU 96F methods.
[9] Exclusive reconstruction of $B_s \rightarrow \psi\phi$.
[10] ABREU 94E uses the flight-distance distribution of $D_s$ vertices, $\phi$-lepton vertices, and $D_s\mu$ vertices.

## $B_s^0$ DECAY MODES

These branching fractions all scale with $B(\overline{b} \to B_s^0)$, the LEP $B_s^0$ production fraction. The first four were evaluated using $B(\overline{b} \to B_s^0) = (11.2^{+1.8}_{-1.9})\%$ and the rest assume $B(\overline{b} \to B_s^0) = 12\%$.

The branching fraction $B(B_s^0 \to D_s^- \ell^+ \nu_\ell \text{ anything})$ is not a pure measurement since the measured product branching fraction $B(\overline{b} \to B_s^0) \times B(B_s^0 \to D_s^- \ell^+ \nu_\ell \text{ anything})$ was used to determine $B(\overline{b} \to B_s^0)$, as described in the note on "Production and Decay of $b$-Flavored Hadrons."

| | Mode | | Fraction ($\Gamma_i/\Gamma$) | | Confidence level |
|---|---|---|---|---|---|
| $\Gamma_1$ | $D_s^-$ anything | | (87 $\pm$31 ) % | | |
| $\Gamma_2$ | $D_s^- \ell^+ \nu_\ell$ anything | [a] | ( 7.6 $\pm$ 2.4) % | | |
| $\Gamma_3$ | $D_s^- \pi^+$ | | $< 12$ | % | |
| $\Gamma_4$ | $J/\psi(1S)\phi$ | | ( 9.3 $\pm$ 3.3) | $\times 10^{-4}$ | |
| $\Gamma_5$ | $\psi(2S)\phi$ | | seen | | |
| $\Gamma_6$ | $\pi^0\pi^0$ | | $<$ 2.1 | $\times 10^{-4}$ | 90% |
| $\Gamma_7$ | $\pi^+\pi^-$ | | $<$ 1.7 | $\times 10^{-4}$ | 90% |
| $\Gamma_8$ | $\eta\pi^0$ | | $<$ 1.0 | $\times 10^{-3}$ | 90% |
| $\Gamma_9$ | $\eta\eta$ | | $<$ 1.5 | $\times 10^{-3}$ | 90% |
| $\Gamma_{10}$ | $\pi^+ K^-$ | | $<$ 2.1 | $\times 10^{-4}$ | 90% |
| $\Gamma_{11}$ | $K^+ K^-$ | | $<$ 5.9 | $\times 10^{-5}$ | 90% |
| $\Gamma_{12}$ | $p\overline{p}$ | | $<$ 5.9 | $\times 10^{-5}$ | 90% |
| $\Gamma_{13}$ | $\gamma\gamma$ | | $<$ 1.48 | $\times 10^{-4}$ | 90% |
| | **$\Delta B = 1$ weak neutral current ($B1$) modes** | | | | |
| $\Gamma_{14}$ | $\mu^+\mu^-$ | $B1$ | $<$ 8.4 | $\times 10^{-6}$ | 90% |

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

## $B_s^0$ BRANCHING RATIOS

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

| VALUE | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **0.87$\pm$0.31 OUR AVERAGE** | | | | | |
| 0.76$\pm$0.23$\pm$0.23 | 90 | [11] BUSKULIC | 96E | ALEP | $e^+e^- \to Z$ |
| 1.46$\pm$0.54$\pm$0.44 | 147 | [12] ACTON | 92N | OPAL | $e^+e^- \to Z$ |

[11] 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 $B(\overline{b} \to B_s^0) \times B(B_s^0 \to D_s^- \text{anything}) = 0.088 \pm 0.020 \pm 0.020$ 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 $B(\overline{b} \to B_s^0) = 0.112^{+0.018}_{-0.019}$ 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 $B(D_s \to \phi\pi)$.

[12] ACTON 92N assume that excess of 147 ± 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$)\times B(D_s^- \to \phi\pi^-) = (5.9 \pm 1.9 \pm 1.1) \times 10^{-3}$. We evaluate using our current values $B(\overline{b} \to B_s^0) = 0.112^{+0.018}_{-0.019}$ 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 $B(D_s \to \phi\pi)$.

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

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 determinine $B(\overline{b} \to B_s^0)$ as described in the note on "Production and Decay of *b*-Flavored Hadrons."

| VALUE | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **0.076±0.024 OUR AVERAGE** | | | | | |
| $0.071^{+0.011}_{-0.012}\pm0.021$ | 134 | [13] BUSKULIC | 95O | ALEP | $e^+e^- \to Z$ |
| 0.14 ±0.06 ±0.04 | 7 | [14] ABREU | 92M | DLPH | $e^+e^- \to Z$ |
| 0.097±0.034±0.029 | 18 | [15] ACTON | 92N | OPAL | $e^+e^- \to Z$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| 0.13 ±0.04 ±0.04 | 27 | [16] BUSKULIC | 92E | ALEP | $e^+e^- \to Z$ |

[13] BUSKULIC 95O use $D_s\ell$ correlations. The measured product branching ratio is $B(\overline{b} \to B_s) \times B(B_s \to D_s^- \ell^+ \nu_\ell$ anything$) = (0.82 \pm 0.09^{+0.13}_{-0.14})\%$ 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 the six other $D_s$ channels used in this analysis. Combined with results from $\Upsilon(4S)$ experiments this can be used to extract $B(\overline{b} \to B_s) = (11.0 \pm 1.2^{+2.5}_{-2.6})\%$. We evaluate using our current values $B(\overline{b} \to B_s^0) = 0.112^{+0.018}_{-0.019}$ 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 $B(D_s \to \phi\pi)$.

[14] ABREU 92M measured muons only and obtained product branching ratio $B(Z \to b$ or $\overline{b}) \times B(\overline{b} \to B_s) \times B(B_s \to D_s \mu^+ \nu_\mu$ anything$) \times B(D_s \to \phi\pi) = (18 \pm 8) \times 10^{-5}$. We evaluate using our current values $B(\overline{b} \to B_s^0) = 0.112^{+0.018}_{-0.019}$ 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 $B(D_s \to \phi\pi)$. We use $B(Z \to b$ or $\overline{b}) = 2B(Z \to b\overline{b}) = 2\times(0.1546 \pm 0.0014)$.

[15] ACTON 92N is measured using $D_s \to \phi\pi^+$ and $K^*(892)^0 K^+$ events. The product branching fraction measured is measured to be $B(\overline{b} \to B_s^0)B(B_s^0 \to D_s^- \ell^+ \nu_\ell$ anything$)$ $\times B(D_s^- \to \phi\pi^-) = (3.9 \pm 1.1 \pm 0.8) \times 10^{-4}$. We evaluate using our current values $B(\overline{b} \to B_s^0) = 0.112^{+0.018}_{-0.019}$ 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 $B(D_s \to \phi\pi)$.

[16] BUSKULIC 92E is measured using $D_s \to \phi\pi^+$ 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 $B(\overline{b} \to B_s^0)B(B_s^0 \to D_s^- \ell^+ \nu_\ell$ anything$) = 0.020 \pm 0.0055^{+0.005}_{-0.006}$.

We evaluate using our current values $B(\overline{b} \rightarrow B_s^0) = 0.112^{+0.018}_{-0.019}$ and $B(D_s \rightarrow \phi\pi)$ $= 0.036 \pm 0.009$. Our first error is their experiment's and our second error is that due to $B(\overline{b} \rightarrow B_s^0)$ and $B(D_s \rightarrow \phi\pi)$. Superseded by BUSKULIC 95O.

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

| VALUE | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **<0.12** | 6 | [17] AKERS | 94J | OPAL | $e^+e^- \rightarrow Z$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| seen | 1 | BUSKULIC | 93G | ALEP | $e^+e^- \rightarrow Z$ |

[17] AKERS 94J sees $\leq 6$ events and measures the limit on the product branching fraction $f(\overline{b} \rightarrow B_s^0)\cdot B(B_s^0 \rightarrow D_s^- \pi^+) < 1.3\%$ at CL = 90%. We divide by our current value $B(\overline{b} \rightarrow B_s^0) = 0.112$.

## $\Gamma(J/\psi(1S)\phi)/\Gamma_{total}$ $\Gamma_4/\Gamma$

| VALUE (units $10^{-3}$) | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **0.93±0.28±0.17** | | [18] ABE | 96Q | CDF | $p\overline{p}$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| <6 | 1 | [19] AKERS | 94J | OPAL | $e^+e^- \rightarrow Z$ |
| seen | 14 | [20] ABE | 93F | CDF | $p\overline{p}$ at 1.8 TeV |
| seen | 1 | [21] ACTON | 92N | OPAL | Sup. by AKERS 94J |

[18] ABE 96Q assumes $f_u = f_d$ and $f_s/f_u = 0.40 \pm 0.06$. Uses $B \rightarrow J/\psi(1S)K$ and $B \rightarrow J/\psi(1S)K^*$ 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.

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

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

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

## $\Gamma(\psi(2S)\phi)/\Gamma_{total}$ $\Gamma_5/\Gamma$

| VALUE | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **seen** | 1 | BUSKULIC | 93G | ALEP | $e^+e^- \rightarrow Z$ |

## $\Gamma(\pi^+\pi^-)/\Gamma_{total}$ $\Gamma_7/\Gamma$

| VALUE | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **$<1.7 \times 10^{-4}$** | 90 | [22] BUSKULIC | 96V | ALEP | $e^+e^- \rightarrow Z$ |

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

## $\Gamma(\pi^0\pi^0)/\Gamma_{total}$ $\Gamma_6/\Gamma$

| VALUE | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **$<2.1 \times 10^{-4}$** | 90 | [23] ACCIARRI | 95H | L3 | $e^+e^- \rightarrow Z$ |

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

### $\Gamma(\eta\pi^0)/\Gamma_{total}$ $\Gamma_8/\Gamma$

| VALUE | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **$<1.0\times10^{-3}$** | 90 | [24] ACCIARRI | 95H | L3 | $e^+e^-\to Z$ |

[24] ACCIARRI 95H assumes $f_{B^0}=39.5\pm4.0$ and $f_{B_s}=12.0\pm3.0\%$.

### $\Gamma(\eta\eta)/\Gamma_{total}$ $\Gamma_9/\Gamma$

| VALUE | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **$<1.5\times10^{-3}$** | 90 | [25] ACCIARRI | 95H | L3 | $e^+e^-\to Z$ |

[25] ACCIARRI 95H assumes $f_{B^0}=39.5\pm4.0$ and $f_{B_s}=12.0\pm3.0\%$.

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

| VALUE | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **$<2.1\times10^{-4}$** | 90 | [26] BUSKULIC | 96V | ALEP | $e^+e^-\to Z$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| $<2.6\times10^{-4}$ | 90 | [27] AKERS | 94L | OPAL | $e^+e^-\to Z$ |

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

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

### $\Gamma(K^+K^-)/\Gamma_{total}$ $\Gamma_{11}/\Gamma$

| VALUE | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **$<5.9\times10^{-5}$** | 90 | [28] BUSKULIC | 96V | ALEP | $e^+e^-\to Z$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| $<1.4\times10^{-4}$ | 90 | [29] AKERS | 94L | OPAL | $e^+e^-\to Z$ |

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

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

### $\Gamma(p\overline{p})/\Gamma_{total}$ $\Gamma_{12}/\Gamma$

| VALUE | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **$<5.9\times10^{-5}$** | 90 | [30] BUSKULIC | 96V | ALEP | $e^+e^-\to Z$ |

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

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

| VALUE | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **$<14.8\times10^{-5}$** | 90 | [31] ACCIARRI | 95I | L3 | $e^+e^-\to Z$ |

[31] ACCIARRI 95I assumes $f_{B^0}=39.5\pm4.0$ and $f_{B_s}=12.0\pm3.0\%$.

### $\Gamma(\mu^+\mu^-)/\Gamma_{total}$ $\Gamma_{14}/\Gamma$

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

| VALUE | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **$<8.4\times10^{-6}$** | 90 | [32] ABE | 96L | CDF | $p\overline{p}$ at 1.8 TeV |

[32] ABE 96L assumes $B^+/B_s$ production ratio 3/1. They normalize to their measured $\sigma(B^+,\ p_T(B)>6$ GeV/$c$, $|y|<1)=2.39\pm0.54\ \mu$b.

## POLARIZATION IN $B_s^0$ DECAY

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

| VALUE | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| $0.56 \pm 0.21 \,^{+0.02}_{-0.04}$ | 19 | ABE | 95Z | CDF | $p\overline{p}$ at 1.8 TeV |

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

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

### $\chi_s$

This $B_s^0$-$\overline{B}_s^0$ mixing parameter measures the probability (integrated over time) that a produced $B_s^0$ ($\overline{B}_s^0$) decays as a $\overline{B}_s^0$ ($B_s^0$). It cannot exceed 0.50. Mixing violates $\Delta B \neq 2$ rule.

| VALUE | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **>0.495** | 95 | [33] BUSKULIC | 96M | ALEP | $e^+e^- \to Z$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| >0.494 | 95 | [33,34] BUSKULIC | 95J | ALEP | $e^+e^- \to Z$ |
| 0.74 ±0.27 | 95 | [35] ABREU | 94F | RVUE | $e^+e^- \to Z$ |
| $0.43 \,^{+0.26}_{-0.17}$ | | [36] ACCIARRI | 94D | RVUE | |
| 0.46 ±0.21 | | [37] ADEVA | 92C | RVUE | Sup. by ACCIARRI 94D |
| 0.53 ±0.15 | | [38] ALBAJAR | 91D | RVUE | |

[33] $\Delta m_{B_s^0}$ measurement combined with $\tau_{B_s^0} = 1.57$ ps, our central value.

[34] BUSKULIC 95J assumes $f_s = 11.2\%$.

[35] From a combination of DELPHI (ABREU 94F), CLEO (ARTUSO 89), and ARGUS (ALBRECHT 92L). Estimated from ABREU 94F figure 7.

[36] Uses BARTELT 93 to remove $B_d$ mixing contribution and assuming $f_d = 0.375 \pm 0.05$ and $f_s = 0.15 \pm 0.05$.

[37] From combination of L3 (ADEVA 92C), CLEO (ARTUSO 89), and ARGUS (ALBRECHT 92L). Corresponding limit is $> 0.16$ at 90%CL.

[38] From combination of UA1 (ALBAJAR 91D), CLEO (BEAN 87B), ARGUS (ALBRECHT 87I), ALEPH (DECAMP 91), and L3 (ADEVA 90P). Corresponding limits are $> 0.23$ at 95% CL and $> 0.27$ at 90% CL.

### $\chi_B$ at high energy

This is a $B$-$\overline{B}$ mixing measurement for an admixture of $B^0$ and $B_s^0$ at high energy.

$$\chi_B = f_d \chi_d + f_s \chi_s$$

where $f_d$ and $f_s$ are the production fractions of $B_d^0$ and $B_s^0$ mesons relative to all *b*-flavored hadrons. Only the measurements at the $Z$ and higher energy $p\overline{p}$ are averaged. Mixing violates $\Delta B \neq 2$ rule.

| VALUE | CL% | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|---|
| **0.118 ±0.006 OUR AVERAGE** | | | | | | |
| 0.1107±0.0062±0.0055 | | | [39] ALEXANDER | 96 | OPAL | $e^+e^- \to Z$ |
| 0.121 ±0.016 ±0.006 | | | [40] ABREU | 94J | DLPH | $e^+e^- \to Z$ |
| 0.123 ±0.012 ±0.008 | | | ACCIARRI | 94D | L3 | $e^+e^- \to Z$ |
| 0.114 ±0.014 ±0.008 | | | [41] BUSKULIC | 94G | ALEP | $e^+e^- \to Z$ |
| 0.129 ±0.022 | | | [42] BUSKULIC | 92B | ALEP | $e^+e^- \to Z$ |
| 0.176 ±0.031 ±0.032 | | 1112 | [43] ABE | 91G | CDF | $p\overline{p}$ 1.8 TeV |
| 0.148 ±0.029 ±0.017 | | | [44] ALBAJAR | 91D | UA1 | $p\overline{p}$ 630 GeV |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | | |
| 0.136 ±0.037 ±0.040 | | | [45] UENO | 96 | AMY | $e^+e^-$ at 57.9 GeV |
| 0.144 ±0.014 $^{+0.017}_{-0.011}$ | | | [46] ABREU | 94F | DLPH | Sup. by ABREU 94J |
| 0.131 ±0.014 | | | [47] ABREU | 94J | DLPH | $e^+e^- \to Z$ |
| 0.157 ±0.020 ±0.032 | | | [48] ALBAJAR | 94 | UA1 | $\sqrt{s}$ = 630 GeV |
| 0.121 $^{+0.044}_{-0.040}$ ±0.017 | | 1665 | [49] ABREU | 93C | DLPH | Sup. by ABREU 94J |
| 0.143 $^{+0.022}_{-0.021}$ ±0.007 | | | [50] AKERS | 93B | OPAL | Sup. by ALEXANDER 96 |
| 0.145 $^{+0.041}_{-0.035}$ ±0.018 | | | [51] ACTON | 92C | OPAL | $e^+e^- \to Z$ |
| 0.121 ±0.017 ±0.006 | | | [52] ADEVA | 92C | L3 | Sup. by ACCIARRI 94D |
| 0.132 ±0.22 $^{+0.015}_{-0.012}$ | | 823 | [53] DECAMP | 91 | ALEP | $e^+e^- \to Z$ |
| 0.178 $^{+0.049}_{-0.040}$ ±0.020 | | | [54] ADEVA | 90P | L3 | $e^+e^- \to Z$ |
| 0.17 $^{+0.15}_{-0.08}$ | | | [55,56] WEIR | 90 | MRK2 | $e^+e^-$ 29 GeV |
| 0.21 $^{+0.29}_{-0.15}$ | | | [55] BAND | 88 | MAC | $E^{ee}_{cm}$= 29 GeV |
| >0.02 | 90 | | [55] BAND | 88 | MAC | $E^{ee}_{cm}$= 29 GeV |
| 0.121 ±0.047 | | | [55,57] ALBAJAR | 87C | UA1 | Repl. by ALBAJAR 91D |
| <0.12 | 90 | | [55,58] SCHAAD | 85 | MRK2 | $E^{ee}_{cm}$= 29 GeV |

[39] ALEXANDER 96 uses a maximum likelihood fit to simultaneously extract $\chi$ as well as the forward-backward asymmetries in $e^+e^- \to Z \to b\overline{b}$ and $c\overline{c}$.

[40] This ABREU 94J result is from 5182 $\ell\ell$ and 279 $\Lambda\ell$ events. The systematic error includes 0.004 for model dependence.

[41] BUSKULIC 94G data analyzed using $ee$, $e\mu$, and $\mu\mu$ events.

[42] BUSKULIC 92B uses a jet charge technique combined with electrons and muons.

[43] ABE 91G measurement of $\chi$ is done with $e\mu$ and $ee$ events.

[44] ALBAJAR 91D measurement of $\chi$ is done with dimuons.

[45] UENO 96 extracted $\chi$ from the energy dependence of the forward-backward asymmetry.

[46] ABREU 94F uses the average electric charge sum of the jets recoiling against a $b$-quark jet tagged by a high $p_T$ muon. The result is for $\overline{\chi} = f_d\chi_d + 0.9 f_s\chi_s$.

[47] This ABREU 94J result combines $\ell\ell$, $\Lambda\ell$, and jet-charge $\ell$ (ABREU 94F) analyses. It is for $\overline{\chi} = f_d\chi_d + 0.96 f_s\chi_s$.

[48] ALBAJAR 94 uses dimuon events. Not independent of ALBAJAR 91D.

[49] ABREU 93C data analyzed using $ee$, $e\mu$, and $\mu\mu$ events.

[50] AKERS 93B analysis performed using dilepton events.

[51] ACTON 92C uses electrons and muons. Superseded by AKERS 93B.
[52] ADEVA 92C uses electrons and muons.
[53] DECAMP 91 done with opposite and like-sign dileptons. Superseded by BUSKULIC 92B.
[54] ADEVA 90P measurement uses $ee$, $\mu\mu$, and $e\mu$ events from 118k events at the $Z$. Superseded by ADEVA 92C.
[55] These experiments are not in the average because the combination of $B_s$ and $B_d$ mesons which they see could differ from those at higher energy.
[56] The WEIR 90 measurement supersedes the limit obtained in SCHAAD 85. The 90% CL are 0.06 and 0.38.
[57] ALBAJAR 87C measured $\chi = (\overline{B}^0 \rightarrow B^0 \rightarrow \mu^+ X)$ divided by the average production weighted semileptonic branching fraction for $B$ hadrons at 546 and 630 GeV.
[58] Limit is average probability for hadron containing $B$ quark to produce a positive lepton.

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

$\Delta m_{B_s^0}$ is a measure of 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 |
|---|---|---|---|---|---|
| **>6.6** | 95 | [59] BUSKULIC | 96M | ALEP | $e^+e^- \rightarrow Z$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| >2.2 | 95 | [60] AKERS | 95J | OPAL | $e^+e^- \rightarrow Z$ |
| >5.9 | 95 | [61] BUSKULIC | 95J | ALEP | $e^+e^- \rightarrow Z$ |
| >1.8 | 95 | [60] BUSKULIC | 94B | ALEP | $e^+e^- \rightarrow Z$ |

[59] BUSKULIC 96M uses $D_s$ lepton correlations and lepton, kaon, and jet charge tags.
[60] Uses dileptons.
[61] BUSKULIC 95J determine $\Delta m_{B_s^0}$ from time dependence of $B$ mixing using a jet charge technique to tag initial quark state and a lepton tag to determine flavor of the decaying $b$ quark. They find $\Delta m_s > 5.6$ [$> 6.1$] $\hbar$ ps$^{-1}$ when $f_s = 10\%$ [12%]. We interpolate to our central value $f_s = 11.2\%$.

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

This section combines the results from the previous two sections.

Time integrated mixing measurement of $\chi$ determine this quantity directly via

$$\frac{\Delta m_{B_s^0}}{\Gamma_{B_s^0}} = \left(\frac{\chi}{0.5-\chi}\right)^{1/2}$$

while time-dependent mixing measurements determine $\Delta m_{B_s^0} = m_{B_{sH}^0} - m_{B_{sL}^0}$ which are combined with $\tau_{B_s^0}$ to give

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

| VALUE | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **>10.4** | 95 | [62] BUSKULIC | 96M | ALEP | $e^+e^- \rightarrow Z$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| > 9.3 | 95 | [62,63] BUSKULIC | 95J | ALEP | $e^+e^- \rightarrow Z$ |

[62] $\Delta m_{B_s^0}$ measurement combined with $\tau_{B_s^0} = 1.57$ ps, our central value.
[63] BUSKULIC 95J assumes $f_s = 11.2\%$.

## $B_s^0$ REFERENCES


| | | | | |
|---|---|---|---|---|
| ABE | 96B | PR D53 3496 | +Albrow, Amendolia, Amidei+ | (CDF Collab.) |
| ABE | 96L | PRL 76 4675 | +Akimoto, Akopian, Albrow+ | (CDF Collab.) |
| ABE | 96N | PRL 77 1945 | +Akimoto, Akopian, Albrow+ | (CDF Collab.) |
| ABE | 96Q | PR D54 6596 | +Akimoto, Akopian, Albrow+ | (CDF Collab.) |
| ABREU | 96F | ZPHY C71 11 | +Adam, Adye, Agasi+ | (DELPHI Collab.) |
| ALEXANDER | 96 | ZPHY C70 357 | +Allison, Altekamp+ | (OPAL Collab.) |
| BUSKULIC | 96E | ZPHY C69 585 | +Casper, De Bonis, Decamp+ | (ALEPH Collab.) |
| BUSKULIC | 96M | PL B377 205 | +De Bonis, Decamp, Ghez+ | (ALEPH Collab.) |
| BUSKULIC | 96V | PL B384 471 | +De Bonis, Decamp, Ghez+ | (ALEPH Collab.) |
| PDG | 96 | PR D54 1 | | |
| UENO | 96 | PL B381 365 | +Kanda, Olsen, Kirk+ | (AMY Collab.) |
| ABE | 95R | PRL 74 4988 | +Albrow, Amendolia, Amidei+ | (CDF Collab.) |
| ABE | 95Z | PRL 75 3068 | +Albrow, Amendolia, Amidei+ | (CDF Collab.) |
| ACCIARRI | 95H | PL B363 127 | +Adam, Adriani, Aguilar-Benitez+ | (L3 Collab.) |
| ACCIARRI | 95I | PL B363 137 | +Adam, Adriani, Aguilar-Benitez+ | (L3 Collab.) |
| AKERS | 95G | PL B350 273 | +Alexander, Allison, Ametewee+ | (OPAL Collab.) |
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| BUSKULIC | 95J | PL B356 409 | +Casper, De Bonis, Decamp+ | (ALEPH Collab.) |
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| AKERS | 94J | PL B337 196 | +Alexander, Allison, Anderson, Arcelli+ | (OPAL Collab.) |
| AKERS | 94L | PL B337 393 | +Alexander, Allison, Anderson, Arcelli+ | (OPAL Collab.) |
| ALBAJAR | 94 | ZPHY C61 41 | +Ankoviak, Bartha, Bezaguet, Boehrer+ | (UA1 Collab.) |
| BUSKULIC | 94B | PL B322 441 | +De Bonis, Decamp, Ghez, Goy, Lees+ | (ALEPH Collab.) |
| BUSKULIC | 94C | PL B322 275 | +De Bonis, Decamp, Ghez, Goy, Lees+ | (ALEPH Collab.) |
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| ACTON | 92C | PL B276 379 | +Alexander, Allison, Allport, Anderson+ | (OPAL Collab.) |
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| ADEVA | 92C | PL B288 395 | +Adriani, Aguilar-Benitez, Ahlen+ | (L3 Collab.) |
| ALBRECHT | 92L | ZPHY C55 357 | +Ehrlichmann, Hamacher, Krueger, Nau+ | (ARGUS Collab.) |
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| SCHAAD | 85 | PL 160B 188 | +Nelson, Abrams, Amidei+ | (Mark II Collab.) |


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