

# BOTTOM MESONS ( $B = \pm 1$ )

$$B^+ = u\bar{b}, B^0 = d\bar{b}, \bar{B}^0 = \bar{d}b, B^- = \bar{u}b, \text{ similarly for } B^{*'}s$$

## **B-particle organization**

Many measurements of  $B$  decays involve admixtures of  $B$  hadrons. Previously we arbitrarily included such admixtures in the  $B^\pm$  section, but because of their importance we have created two new sections: “ $B^\pm/B^0$  Admixture” for  $\Upsilon(4S)$  results and “ $B^\pm/B^0/B_s^0/b$ -baryon Admixture” for results at higher energies. Most inclusive decay branching fractions and  $\chi_b$  at high energy are found in the Admixture sections.  $B^0\text{-}\bar{B}^0$  mixing data are found in the  $B^0$  section, while  $B_s^0\text{-}\bar{B}_s^0$  mixing data and  $B\text{-}\bar{B}$  mixing data for a  $B^0/B_s^0$  admixture are found in the  $B_s^0$  section.  $CP$ -violation data are found in the  $B^\pm$ ,  $B^0$ , and  $B^\pm/B^0$  Admixture sections.  $b$ -baryons are found near the end of the Baryon section.

The organization of the  $B$  sections is now as follows, where bullets indicate particle sections and brackets indicate reviews.

- $B^\pm$   
mass, mean life, branching fractions  $CP$  violation
- $B^0$   
mass, mean life, branching fractions  
polarization in  $B^0$  decay,  $B^0\text{-}\bar{B}^0$  mixing,  $CP$  violation
- $B^\pm/B^0$  Admixtures  
branching fractions,  $CP$  violation
- $B^\pm/B^0/B_s^0/b$ -baryon Admixtures  
mean life, production fractions, branching fractions  
 $\chi_b$  at high energy,  $V_{cb}$  measurements
- $B^*$   
mass
- $B_s^0$   
mass, mean life, branching fractions  
polarization in  $B_s^0$  decay,  $B_s^0\text{-}\bar{B}_s^0$  mixing
- $B_c^\pm$   
mass, mean life, branching fractions

At end of Baryon Listings:

- $\Lambda_b$   
mass, mean life, branching fractions
- $b$ -baryon Admixture  
mean life, branching fractions



$$I(J^P) = \frac{1}{2}(0^-)$$

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

$$\text{Mass } m_{B^\pm} = 5279.0 \pm 0.5 \text{ MeV}$$

$$\text{Mean life } \tau_{B^\pm} = (1.671 \pm 0.018) \times 10^{-12} \text{ s}$$

$$c\tau = 501 \text{ } \mu\text{m}$$

### CP violation

$$A_{CP}(B^+ \rightarrow J/\psi(1S)K^+) = -0.007 \pm 0.019$$

$$A_{CP}(B^+ \rightarrow J/\psi(1S)\pi^+) = -0.01 \pm 0.13$$

$$A_{CP}(B^+ \rightarrow \psi(2S)K^+) = -0.037 \pm 0.025$$

$$A_{CP}(B^+ \rightarrow \bar{D}^0 K^+) = 0.04 \pm 0.07$$

$$A_{CP}(B^+ \rightarrow D_{CP(+1)} K^+) = 0.06 \pm 0.19$$

$$A_{CP}(B^+ \rightarrow D_{CP(-1)} K^+) = -0.19 \pm 0.18$$

$$A_{CP}(B^+ \rightarrow \pi^+ \pi^0) = 0.05 \pm 0.15$$

$$A_{CP}(B^+ \rightarrow K^+ \pi^0) = -0.10 \pm 0.08$$

$$A_{CP}(B^+ \rightarrow K_S^0 \pi^+) = 0.03 \pm 0.08 \quad (S = 1.1)$$

$$A_{CP}(B^+ \rightarrow \pi^+ \pi^- \pi^+) = -0.39 \pm 0.35$$

$$A_{CP}(B^+ \rightarrow \rho^+ \rho^0) = -0.09 \pm 0.16$$

$$A_{CP}(B^+ \rightarrow K^+ \pi^- \pi^+) = 0.01 \pm 0.08$$

$$A_{CP}(B^+ \rightarrow K^+ K^- K^+) = 0.02 \pm 0.08$$

$$A_{CP}(B^+ \rightarrow K^+ \eta') = 0.009 \pm 0.035$$

$$A_{CP}(B^+ \rightarrow \omega \pi^+) = -0.21 \pm 0.19$$

$$A_{CP}(B^+ \rightarrow \omega K^+) = -0.21 \pm 0.28$$

$$A_{CP}(B^+ \rightarrow \phi K^+) = 0.03 \pm 0.07$$

$$A_{CP}(B^+ \rightarrow \phi K^*(892)^+) = 0.09 \pm 0.15$$

$$A_{CP}(B^+ \rightarrow \rho^0 K^*(892)^+) = 0.20 \pm 0.31$$

$B^-$  modes are charge conjugates of the modes below. Modes which do not identify the charge state of the  $B$  are listed in the  $B^\pm/B^0$  ADMIXTURE section.

The branching fractions listed below assume 50%  $B^0 \bar{B}^0$  and 50%  $B^+ B^-$  production at the  $\Upsilon(4S)$ . We have attempted to bring older measurements up to date by rescaling their assumed  $\Upsilon(4S)$  production ratio to 50:50 and their assumed  $D, D_S, D^*$ , and  $\psi$  branching ratios to current values whenever this would affect our averages and best limits significantly.

Indentation is used to indicate a subchannel of a previous reaction. All resonant subchannels have been corrected for resonance branching fractions to the final state so the sum of the subchannel branching fractions can exceed that of the final state.

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.

<b><math>B^+</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor/ Confidence level	$p$ (MeV/c)
<b>Semileptonic and leptonic modes</b>			
$\ell^+ \nu_\ell$ anything	[a] (10.2 $\pm$ 0.9) %		—
$\bar{D}^0 \ell^+ \nu_\ell$	[a] (2.15 $\pm$ 0.22) %		2310
$\bar{D}^*(2007)^0 \ell^+ \nu_\ell$	[a] (6.5 $\pm$ 0.5) %		2258
$\bar{D}_1(2420)^0 \ell^+ \nu_\ell$	(5.6 $\pm$ 1.6) $\times 10^{-3}$		2084
$\bar{D}_2^*(2460)^0 \ell^+ \nu_\ell$	< 8 $\times 10^{-3}$	CL=90%	2067
$\pi^0 e^+ \nu_e$	(9.0 $\pm$ 2.8) $\times 10^{-5}$		2638
$\eta \ell^+ \nu_\ell$	(8 $\pm$ 4) $\times 10^{-5}$		2611
$\omega \ell^+ \nu_\ell$	[a] < 2.1 $\times 10^{-4}$	CL=90%	2582
$\rho^0 \ell^+ \nu_\ell$	[a] (1.34 <sup>+0.32</sup> <sub>-0.35</sub> ) $\times 10^{-4}$		2583
$p \bar{p} e^+ \nu_e$	< 5.2 $\times 10^{-3}$	CL=90%	2467
$e^+ \nu_e$	< 1.5 $\times 10^{-5}$	CL=90%	2640
$\mu^+ \nu_\mu$	< 2.1 $\times 10^{-5}$	CL=90%	2638
$\tau^+ \nu_\tau$	< 5.7 $\times 10^{-4}$	CL=90%	2340
$e^+ \nu_e \gamma$	< 2.0 $\times 10^{-4}$	CL=90%	2640
$\mu^+ \nu_\mu \gamma$	< 5.2 $\times 10^{-5}$	CL=90%	2638
<b><math>D</math>, <math>D^*</math>, or <math>D_s</math> modes</b>			
$\bar{D}^0 \pi^+$	(4.98 $\pm$ 0.29) $\times 10^{-3}$		2308
$\bar{D}^0 \rho^+$	(1.34 $\pm$ 0.18) %		2236
$\bar{D}^0 K^+$	(3.7 $\pm$ 0.6) $\times 10^{-4}$	S=1.1	2280
$\bar{D}^0 K^*(892)^+$	(6.1 $\pm$ 2.3) $\times 10^{-4}$		2213
$\bar{D}^0 K^+ \bar{K}^0$	(5.5 $\pm$ 1.6) $\times 10^{-4}$		2189
$\bar{D}^0 K^+ \bar{K}^*(892)^0$	(7.5 $\pm$ 1.7) $\times 10^{-4}$		2071
$\bar{D}^0 \pi^+ \pi^+ \pi^-$	(1.1 $\pm$ 0.4) %		2289
$\bar{D}^0 \pi^+ \pi^+ \pi^-$ nonresonant	(5 $\pm$ 4) $\times 10^{-3}$		2289
$\bar{D}^0 \pi^+ \rho^0$	(4.2 $\pm$ 3.0) $\times 10^{-3}$		2207
$\bar{D}^0 a_1(1260)^+$	(5 $\pm$ 4) $\times 10^{-3}$		2123
$\bar{D}^0 \omega \pi^+$	(4.1 $\pm$ 0.9) $\times 10^{-3}$		2206
$D^*(2010)^- \pi^+ \pi^+$	(2.1 $\pm$ 0.6) $\times 10^{-3}$		2247
$D^- \pi^+ \pi^+$	< 1.4 $\times 10^{-3}$	CL=90%	2299
$\bar{D}^*(2007)^0 \pi^+$	(4.6 $\pm$ 0.4) $\times 10^{-3}$		2256
$\bar{D}^*(2007)^0 \omega \pi^+$	(4.5 $\pm$ 1.2) $\times 10^{-3}$		2149
$\bar{D}^*(2007)^0 \rho^+$	(9.8 $\pm$ 1.7) $\times 10^{-3}$		2181
$\bar{D}^*(2007)^0 K^+$	(3.6 $\pm$ 1.0) $\times 10^{-4}$		2227
$\bar{D}^*(2007)^0 K^*(892)^+$	(7.2 $\pm$ 3.4) $\times 10^{-4}$		2156
$\bar{D}^*(2007)^0 K^+ \bar{K}^0$	< 1.06 $\times 10^{-3}$	CL=90%	2132
$\bar{D}^*(2007)^0 K^+ K^*(892)^0$	(1.5 $\pm$ 0.4) $\times 10^{-3}$		2008

$\bar{D}^*(2007)^0 \pi^+ \pi^+ \pi^-$	$( 9.4 \pm 2.6 ) \times 10^{-3}$		2236
$\bar{D}^*(2007)^0 a_1(1260)^+$	$( 1.9 \pm 0.5 ) \%$		2062
$\bar{D}^*(2007)^0 \pi^- \pi^+ \pi^+ \pi^0$	$( 1.8 \pm 0.4 ) \%$		2219
$D^*(2010)^+ \pi^0$	$< 1.7 \times 10^{-4}$	CL=90%	2255
$\bar{D}^*(2010)^+ K^0$	$< 9.5 \times 10^{-5}$	CL=90%	2225
$D^*(2010)^- \pi^+ \pi^+ \pi^0$	$( 1.5 \pm 0.7 ) \%$		2235
$D^*(2010)^- \pi^+ \pi^+ \pi^+ \pi^-$	$< 1 \%$	CL=90%	2217
$\bar{D}_1^*(2420)^0 \pi^+$	$( 1.5 \pm 0.6 ) \times 10^{-3}$	S=1.3	2081
$\bar{D}_1^*(2420)^0 \rho^+$	$< 1.4 \times 10^{-3}$	CL=90%	1995
$\bar{D}_2^*(2460)^0 \pi^+$	$< 1.3 \times 10^{-3}$	CL=90%	2064
$\bar{D}_2^*(2460)^0 \rho^+$	$< 4.7 \times 10^{-3}$	CL=90%	1977
$\bar{D}^0 D_s^+$	$( 1.3 \pm 0.4 ) \%$		1815
$\bar{D}^0 D_{sJ}(2317)^+$	seen		1605
$\bar{D}^0 D_{sJ}(2457)^+$	seen		—
$\bar{D}^0 D_{sJ}(2536)^+$	not seen		1447
$\bar{D}^*(2007)^0 D_{sJ}(2536)^+$	not seen		1338
$\bar{D}^0 D_{sJ}(2573)^+$	not seen		1417
$\bar{D}^*(2007)^0 D_{sJ}(2573)^+$	not seen		1306
$\bar{D}^0 D_s^{*+}$	$( 9 \pm 4 ) \times 10^{-3}$		1734
$\bar{D}^*(2007)^0 D_s^+$	$( 1.2 \pm 0.5 ) \%$		1737
$\bar{D}^*(2007)^0 D_s^{*+}$	$( 2.7 \pm 1.0 ) \%$		1651
$D_s^{(*)+} \bar{D}^{*0}$	$( 2.7 \pm 1.2 ) \%$		—
$\bar{D}^*(2007)^0 D^*(2010)^+$	$< 1.1 \%$	CL=90%	1713
$\bar{D}^0 D^*(2010)^+ + \bar{D}^*(2007)^0 D^+$	$< 1.3 \%$	CL=90%	1792
$\bar{D}^0 D^+$	$< 6.7 \times 10^{-3}$	CL=90%	1866
$\bar{D}^0 D^+ K^0$	$< 2.8 \times 10^{-3}$	CL=90%	1571
$\bar{D}^*(2007)^0 D^+ K^0$	$< 6.1 \times 10^{-3}$	CL=90%	1475
$\bar{D}^0 \bar{D}^*(2010)^+ K^0$	$( 5.2 \pm 1.2 ) \times 10^{-3}$		1476
$\bar{D}^*(2007)^0 D^*(2010)^+ K^0$	$( 7.8 \pm 2.6 ) \times 10^{-3}$		1362
$\bar{D}^0 D^0 K^+$	$( 1.9 \pm 0.4 ) \times 10^{-3}$		1577
$\bar{D}^*(2010)^0 D^0 K^+$	$< 3.8 \times 10^{-3}$	CL=90%	—
$\bar{D}^0 D^*(2007)^0 K^+$	$( 4.7 \pm 1.0 ) \times 10^{-3}$		1481
$\bar{D}^*(2007)^0 D^*(2007)^0 K^+$	$( 5.3 \pm 1.6 ) \times 10^{-3}$		1368
$D^- D^+ K^+$	$< 4 \times 10^{-4}$	CL=90%	1571
$D^- D^*(2010)^+ K^+$	$< 7 \times 10^{-4}$	CL=90%	1475
$D^*(2010)^- D^+ K^+$	$( 1.5 \pm 0.4 ) \times 10^{-3}$		1475
$D^*(2010)^- D^*(2010)^+ K^+$	$< 1.8 \times 10^{-3}$	CL=90%	1363
$(\bar{D} + \bar{D}^*)(D + D^*)K$	$( 3.5 \pm 0.6 ) \%$		—
$D_s^+ \pi^0$	$< 2.0 \times 10^{-4}$	CL=90%	2270
$D_s^{*+} \pi^0$	$< 3.3 \times 10^{-4}$	CL=90%	2215
$D_s^+ \eta$	$< 5 \times 10^{-4}$	CL=90%	2235
$D_s^{*+} \eta$	$< 8 \times 10^{-4}$	CL=90%	2178

$D_s^+ \rho^0$	< 4	$\times 10^{-4}$	CL=90%	2197
$D_s^{*+} \rho^0$	< 5	$\times 10^{-4}$	CL=90%	2138
$D_s^+ \omega$	< 5	$\times 10^{-4}$	CL=90%	2195
$D_s^{*+} \omega$	< 7	$\times 10^{-4}$	CL=90%	2136
$D_s^+ a_1(1260)^0$	< 2.2	$\times 10^{-3}$	CL=90%	2079
$D_s^{*+} a_1(1260)^0$	< 1.6	$\times 10^{-3}$	CL=90%	2014
$D_s^+ \phi$	< 3.2	$\times 10^{-4}$	CL=90%	2141
$D_s^{*+} \phi$	< 4	$\times 10^{-4}$	CL=90%	2079
$D_s^+ \bar{K}^0$	< 1.1	$\times 10^{-3}$	CL=90%	2241
$D_s^{*+} \bar{K}^0$	< 1.1	$\times 10^{-3}$	CL=90%	2184
$D_s^+ \bar{K}^*(892)^0$	< 5	$\times 10^{-4}$	CL=90%	2172
$D_s^{*+} \bar{K}^*(892)^0$	< 4	$\times 10^{-4}$	CL=90%	2112
$D_s^- \pi^+ K^+$	< 8	$\times 10^{-4}$	CL=90%	2222
$D_s^{*-} \pi^+ K^+$	< 1.2	$\times 10^{-3}$	CL=90%	2164
$D_s^- \pi^+ K^*(892)^+$	< 6	$\times 10^{-3}$	CL=90%	2138
$D_s^{*-} \pi^+ K^*(892)^+$	< 8	$\times 10^{-3}$	CL=90%	2076

### Charmonium modes

$\eta_c K^+$	( 9.0 $\pm$ 2.7 )	$\times 10^{-4}$		1754
$J/\psi(1S) K^+$	( 1.00 $\pm$ 0.04 )	$\times 10^{-3}$		1683
$J/\psi(1S) K^+ \pi^+ \pi^-$	( 7.7 $\pm$ 2.0 )	$\times 10^{-4}$		1612
$X(3872) K^+$	seen			—
$J/\psi(1S) K^*(892)^+$	( 1.35 $\pm$ 0.10 )	$\times 10^{-3}$		1571
$J/\psi(1S) K(1270)^+$	( 1.8 $\pm$ 0.5 )	$\times 10^{-3}$		1390
$J/\psi(1S) K(1400)^+$	< 5	$\times 10^{-4}$	CL=90%	1308
$J/\psi(1S) \phi K^+$	( 5.2 $\pm$ 1.7 )	$\times 10^{-5}$	S=1.2	1227
$J/\psi(1S) \pi^+$	( 4.0 $\pm$ 0.5 )	$\times 10^{-5}$		1727
$J/\psi(1S) \rho^+$	< 7.7	$\times 10^{-4}$	CL=90%	1611
$J/\psi(1S) a_1(1260)^+$	< 1.2	$\times 10^{-3}$	CL=90%	1414
$J/\psi(1S) \rho \bar{\Lambda}$	( 1.2 $\begin{smallmatrix} +0.9 \\ -0.6 \end{smallmatrix}$ )	$\times 10^{-5}$		567
$\psi(2S) K^+$	( 6.8 $\pm$ 0.4 )	$\times 10^{-4}$		1284
$\psi(2S) K^*(892)^+$	( 9.2 $\pm$ 2.2 )	$\times 10^{-4}$		1115
$\psi(2S) K^+ \pi^+ \pi^-$	( 1.9 $\pm$ 1.2 )	$\times 10^{-3}$		1178
$\chi_{c0}(1P) K^+$	( 6.0 $\begin{smallmatrix} +2.4 \\ -2.1 \end{smallmatrix}$ )	$\times 10^{-4}$		1478
$\chi_{c1}(1P) K^+$	( 6.8 $\pm$ 1.2 )	$\times 10^{-4}$		1411
$\chi_{c1}(1P) K^*(892)^+$	< 2.1	$\times 10^{-3}$	CL=90%	1265

### K or K\* modes

$K^0 \pi^+$	( 1.88 $\pm$ 0.21 )	$\times 10^{-5}$		2614
$K^+ \pi^0$	( 1.29 $\pm$ 0.12 )	$\times 10^{-5}$		2615
$\eta' K^+$	( 7.8 $\pm$ 0.5 )	$\times 10^{-5}$		2528
$\eta' K^*(892)^+$	< 3.5	$\times 10^{-5}$	CL=90%	2472

$\eta K^+$	$< 6.9 \times 10^{-6}$	CL=90%	2588
$\eta K^*(892)^+$	$( 2.6^{+1.0}_{-0.9} ) \times 10^{-5}$		2534
$\omega K^+$	$( 9.2^{+2.8}_{-2.5} ) \times 10^{-6}$		2557
$\omega K^*(892)^+$	$< 8.7 \times 10^{-5}$	CL=90%	2503
$K^*(892)^0 \pi^+$	$( 1.9^{+0.6}_{-0.8} ) \times 10^{-5}$		2562
$K^*(892)^+ \pi^0$	$< 3.1 \times 10^{-5}$	CL=90%	2562
$K^+ \pi^- \pi^+$	$( 5.7 \pm 0.4 ) \times 10^{-5}$		2609
$K^+ \pi^- \pi^+$ nonresonant	$< 2.8 \times 10^{-5}$	CL=90%	2609
$K^+ \rho^0$	$< 1.2 \times 10^{-5}$	CL=90%	2558
$K_2^*(1430)^0 \pi^+$	$< 6.8 \times 10^{-4}$	CL=90%	2445
$K^- \pi^+ \pi^+$	$< 1.8 \times 10^{-6}$	CL=90%	2609
$K^- \pi^+ \pi^+$ nonresonant	$< 5.6 \times 10^{-5}$	CL=90%	2609
$K_1(1400)^0 \pi^+$	$< 2.6 \times 10^{-3}$	CL=90%	2451
$K^0 \pi^+ \pi^0$	$< 6.6 \times 10^{-5}$	CL=90%	2609
$K^0 \rho^+$	$< 4.8 \times 10^{-5}$	CL=90%	2558
$K^*(892)^+ \pi^+ \pi^-$	$< 1.1 \times 10^{-3}$	CL=90%	2556
$K^*(892)^+ \rho^0$	$( 1.1 \pm 0.4 ) \times 10^{-5}$		2504
$K^*(892)^+ K^*(892)^0$	$< 7.1 \times 10^{-5}$	CL=90%	2484
$K_1(1400)^+ \rho^0$	$< 7.8 \times 10^{-4}$	CL=90%	2387
$K_2^*(1430)^+ \rho^0$	$< 1.5 \times 10^{-3}$	CL=90%	2381
$K^+ \bar{K}^0$	$< 2.0 \times 10^{-6}$	CL=90%	2593
$\bar{K}^0 K^+ \pi^0$	$< 2.4 \times 10^{-5}$	CL=90%	2578
$K^+ K_S^0 K_S^0$	$( 1.34 \pm 0.24 ) \times 10^{-5}$		2521
$K_S^0 K_S^0 \pi^+$	$< 3.2 \times 10^{-6}$	CL=90%	2577
$K^+ K^- \pi^+$	$< 6.3 \times 10^{-6}$	CL=90%	2578
$K^+ K^- \pi^+$ nonresonant	$< 7.5 \times 10^{-5}$	CL=90%	2578
$K^+ K^+ \pi^-$	$< 1.3 \times 10^{-6}$	CL=90%	2578
$K^+ K^+ \pi^-$ nonresonant	$< 8.79 \times 10^{-5}$	CL=90%	2578
$K^+ K^*(892)^0$	$< 5.3 \times 10^{-6}$	CL=90%	2540
$K^+ K^- K^+$	$( 3.08 \pm 0.21 ) \times 10^{-5}$		2522
$K^+ \phi$	$( 9.3 \pm 1.0 ) \times 10^{-6}$	S=1.3	2516
$K^+ K^- K^+$ nonresonant	$< 3.8 \times 10^{-5}$	CL=90%	2522
$K^*(892)^+ K^+ K^-$	$< 1.6 \times 10^{-3}$	CL=90%	2466
$K^*(892)^+ \phi$	$( 9.6 \pm 3.0 ) \times 10^{-6}$	S=1.9	2460
$K_1(1400)^+ \phi$	$< 1.1 \times 10^{-3}$	CL=90%	2339
$K_2^*(1430)^+ \phi$	$< 3.4 \times 10^{-3}$	CL=90%	2332
$K^+ \phi \phi$	$( 2.6^{+1.1}_{-0.9} ) \times 10^{-6}$		2306
$K^*(892)^+ \gamma$	$( 3.8 \pm 0.5 ) \times 10^{-5}$		2564
$K_1(1270)^+ \gamma$	$< 9.9 \times 10^{-5}$	CL=90%	2486
$\phi K^+ \gamma$	$( 3.4 \pm 1.0 ) \times 10^{-6}$		2516
$K^+ \pi^- \pi^+ \gamma$	$( 2.4^{+0.6}_{-0.5} ) \times 10^{-5}$		2609

$K^*(892)^0 \pi^+ \gamma$	$( 2.0^{+0.7}_{-0.6} ) \times 10^{-5}$		2562
$K^+ \rho^0 \gamma$	$< 2.0$	$\times 10^{-5}$	CL=90% 2558
$K^+ \pi^- \pi^+ \gamma$ nonresonant	$< 9.2$	$\times 10^{-6}$	CL=90% 2609
$K_1(1400)^+ \gamma$	$< 5.0$	$\times 10^{-5}$	CL=90% 2453
$K_2^*(1430)^+ \gamma$	$< 1.4$	$\times 10^{-3}$	CL=90% 2447
$K^*(1680)^+ \gamma$	$< 1.9$	$\times 10^{-3}$	CL=90% 2360
$K_3^*(1780)^+ \gamma$	$< 5.5$	$\times 10^{-3}$	CL=90% 2341
$K_4^*(2045)^+ \gamma$	$< 9.9$	$\times 10^{-3}$	CL=90% 2243

### Light unflavored meson modes

$\rho^+ \gamma$	$< 2.1$	$\times 10^{-6}$	CL=90% 2583
$\pi^+ \pi^0$	$( 5.6^{+0.9}_{-1.1} ) \times 10^{-6}$		2636
$\pi^+ \pi^+ \pi^-$	$( 1.1 \pm 0.4 ) \times 10^{-5}$		2630
$\rho^0 \pi^+$	$( 8.6 \pm 2.0 ) \times 10^{-6}$		2581
$\pi^+ f_0(980)$	$< 1.4$	$\times 10^{-4}$	CL=90% 2547
$\pi^+ f_2(1270)$	$< 2.4$	$\times 10^{-4}$	CL=90% 2483
$\pi^+ \pi^- \pi^+$ nonresonant	$< 4.1$	$\times 10^{-5}$	CL=90% 2630
$\pi^+ \pi^0 \pi^0$	$< 8.9$	$\times 10^{-4}$	CL=90% 2631
$\rho^+ \pi^0$	$< 4.3$	$\times 10^{-5}$	CL=90% 2581
$\pi^+ \pi^- \pi^+ \pi^0$	$< 4.0$	$\times 10^{-3}$	CL=90% 2621
$\rho^+ \rho^0$	$( 2.6 \pm 0.6 ) \times 10^{-5}$		2523
$a_1(1260)^+ \pi^0$	$< 1.7$	$\times 10^{-3}$	CL=90% 2494
$a_1(1260)^0 \pi^+$	$< 9.0$	$\times 10^{-4}$	CL=90% 2494
$\omega \pi^+$	$( 6.4^{+1.8}_{-1.6} ) \times 10^{-6}$		S=1.3 2580
$\omega \rho^+$	$< 6.1$	$\times 10^{-5}$	CL=90% 2522
$\eta \pi^+$	$< 5.7$	$\times 10^{-6}$	CL=90% 2609
$\eta' \pi^+$	$< 7.0$	$\times 10^{-6}$	CL=90% 2551
$\eta' \rho^+$	$< 3.3$	$\times 10^{-5}$	CL=90% 2492
$\eta \rho^+$	$< 1.5$	$\times 10^{-5}$	CL=90% 2553
$\phi \pi^+$	$< 4.1$	$\times 10^{-7}$	CL=90% 2539
$\phi \rho^+$	$< 1.6$	$\times 10^{-5}$	2480
$\pi^+ \pi^+ \pi^+ \pi^- \pi^-$	$< 8.6$	$\times 10^{-4}$	CL=90% 2608
$\rho^0 a_1(1260)^+$	$< 6.2$	$\times 10^{-4}$	CL=90% 2433
$\rho^0 a_2(1320)^+$	$< 7.2$	$\times 10^{-4}$	CL=90% 2410
$\pi^+ \pi^+ \pi^+ \pi^- \pi^- \pi^0$	$< 6.3$	$\times 10^{-3}$	CL=90% 2592
$a_1(1260)^+ a_1(1260)^0$	$< 1.3$	%	CL=90% 2335

### Charged particle ( $h^\pm$ ) modes

$$h^\pm = K^\pm \text{ or } \pi^\pm$$

$h^+ \pi^0$	$( 1.6^{+0.7}_{-0.6} ) \times 10^{-5}$		2636
$\omega h^+$	$( 1.38^{+0.27}_{-0.24} ) \times 10^{-5}$		2580
$h^+ X^0$ (Familon)	$< 4.9$	$\times 10^{-5}$	CL=90% -

### Baryon modes

$p\bar{p}\pi^+$		< 3.7	$\times 10^{-6}$	CL=90%	2439
$p\bar{p}\pi^+$ nonresonant		< 5.3	$\times 10^{-5}$	CL=90%	2439
$p\bar{p}\pi^+\pi^+\pi^-$		< 5.2	$\times 10^{-4}$	CL=90%	2369
$p\bar{p}K^+$		( 4.3 $\begin{smallmatrix} +1.2 \\ -1.0 \end{smallmatrix}$ )	$\times 10^{-6}$		2348
$p\bar{p}K^+$ nonresonant		< 8.9	$\times 10^{-5}$	CL=90%	2348
$p\bar{\Lambda}$		< 1.5	$\times 10^{-6}$	CL=90%	2430
$p\bar{\Lambda}\pi^+\pi^-$		< 2.0	$\times 10^{-4}$	CL=90%	2367
$\Delta^0 p$		< 3.8	$\times 10^{-4}$	CL=90%	2402
$\Delta^{++}\bar{p}$		< 1.5	$\times 10^{-4}$	CL=90%	2402
$D^+ p\bar{p}$		< 1.5	$\times 10^{-5}$	CL=90%	1860
$D^*(2010)^+ p\bar{p}$		< 1.5	$\times 10^{-5}$	CL=90%	1786
$\bar{\Lambda}_c^- p\pi^+$		( 2.1 $\pm 0.7$ )	$\times 10^{-4}$		1981
$\bar{\Lambda}_c^- p\pi^+\pi^0$		( 1.8 $\pm 0.6$ )	$\times 10^{-3}$		1936
$\bar{\Lambda}_c^- p\pi^+\pi^+\pi^-$		( 2.3 $\pm 0.7$ )	$\times 10^{-3}$		1881
$\bar{\Lambda}_c^- p\pi^+\pi^+\pi^-\pi^0$		< 1.34	%	CL=90%	1823
$\bar{\Sigma}_c(2455)^0 p$		< 8	$\times 10^{-5}$	CL=90%	1939
$\bar{\Sigma}_c(2520)^0 p$		< 4.6	$\times 10^{-5}$	CL=90%	1905
$\bar{\Sigma}_c(2455)^0 p\pi^0$		( 4.4 $\pm 1.8$ )	$\times 10^{-4}$		1897
$\bar{\Sigma}_c(2455)^0 p\pi^-\pi^+$		( 4.4 $\pm 1.7$ )	$\times 10^{-4}$		1845
$\bar{\Sigma}_c(2455)^{--} p\pi^+\pi^+$		( 2.8 $\pm 1.2$ )	$\times 10^{-4}$		1845
$\bar{\Lambda}_c(2593)^- / \bar{\Lambda}_c(2625)^- p\pi^+$		< 1.9	$\times 10^{-4}$	CL=90%	—

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

$\pi^+ e^+ e^-$	B1	< 3.9	$\times 10^{-3}$	CL=90%	2638
$\pi^+ \mu^+ \mu^-$	B1	< 9.1	$\times 10^{-3}$	CL=90%	2633
$K^+ e^+ e^-$	B1	( 6.3 $\begin{smallmatrix} +1.9 \\ -1.7 \end{smallmatrix}$ )	$\times 10^{-7}$		2616
$K^+ \mu^+ \mu^-$	B1	( 4.5 $\begin{smallmatrix} +1.4 \\ -1.2 \end{smallmatrix}$ )	$\times 10^{-7}$		2612
$K^+ \ell^+ \ell^-$	B1 [a]	( 5.3 $\pm 1.1$ )	$\times 10^{-7}$		2616
$K^+ \bar{\nu}\nu$	B1	< 2.4	$\times 10^{-4}$	CL=90%	2616
$K^*(892)^+ e^+ e^-$	B1	< 4.6	$\times 10^{-6}$	CL=90%	2564
$K^*(892)^+ \mu^+ \mu^-$	B1	< 2.2	$\times 10^{-6}$	CL=90%	2560
$K^*(892)^+ \ell^+ \ell^-$	B1 [a]	< 2.2	$\times 10^{-6}$	CL=90%	2564
$\pi^+ e^+ \mu^-$	LF	< 6.4	$\times 10^{-3}$	CL=90%	2637
$\pi^+ e^- \mu^+$	LF	< 6.4	$\times 10^{-3}$	CL=90%	2637
$K^+ e^+ \mu^-$	LF	< 8	$\times 10^{-7}$	CL=90%	2615
$K^+ e^- \mu^+$	LF	< 6.4	$\times 10^{-3}$	CL=90%	2615
$K^*(892)^+ e^\pm \mu^\mp$	LF	< 7.9	$\times 10^{-6}$	CL=90%	2563
$\pi^- e^+ e^+$	L	< 1.6	$\times 10^{-6}$	CL=90%	2638
$\pi^- \mu^+ \mu^+$	L	< 1.4	$\times 10^{-6}$	CL=90%	2633



$\pi^- e^+ \mu^+$	<i>L</i>	< 1.3	$\times 10^{-6}$	CL=90%	2637
$\rho^- e^+ e^+$	<i>L</i>	< 2.6	$\times 10^{-6}$	CL=90%	2583
$\rho^- \mu^+ \mu^+$	<i>L</i>	< 5.0	$\times 10^{-6}$	CL=90%	2578
$\rho^- e^+ \mu^+$	<i>LF</i>	< 3.3	$\times 10^{-6}$	CL=90%	2581
$K^- e^+ e^+$	<i>L</i>	< 1.0	$\times 10^{-6}$	CL=90%	2616
$K^- \mu^+ \mu^+$	<i>L</i>	< 1.8	$\times 10^{-6}$	CL=90%	2612
$K^- e^+ \mu^+$	<i>L</i>	< 2.0	$\times 10^{-6}$	CL=90%	2615
$K^*(892)^- e^+ e^+$	<i>L</i>	< 2.8	$\times 10^{-6}$	CL=90%	2564
$K^*(892)^- \mu^+ \mu^+$	<i>L</i>	< 8.3	$\times 10^{-6}$	CL=90%	2560
$K^*(892)^- e^+ \mu^+$	<i>LF</i>	< 4.4	$\times 10^{-6}$	CL=90%	2563

**$B^0$**

$$I(J^P) = \frac{1}{2}(0^-)$$

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

$$\text{Mass } m_{B^0} = 5279.4 \pm 0.5 \text{ MeV}$$

$$m_{B^0} - m_{B^\pm} = 0.33 \pm 0.28 \text{ MeV} \quad (S = 1.1)$$

$$\text{Mean life } \tau_{B^0} = (1.536 \pm 0.014) \times 10^{-12} \text{ s}$$

$$c\tau = 460 \text{ } \mu\text{m}$$

$$\tau_{B^+}/\tau_{B^0} = 1.086 \pm 0.017 \quad (\text{direct measurements})$$

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

$$\chi_d = 0.186 \pm 0.004$$

$$\begin{aligned} \Delta m_{B^0} = m_{B_H^0} - m_{B_L^0} &= (0.502 \pm 0.007) \times 10^{12} \text{ } \hbar \text{ s}^{-1} \\ &= (3.304 \pm 0.046) \times 10^{-10} \text{ MeV} \end{aligned}$$

$$x_d = \Delta m_{B^0}/\Gamma_{B^0} = 0.771 \pm 0.012$$

### CP violation parameters

$$\begin{aligned} \text{Re}(\epsilon_{B^0})/(1+|\epsilon_{B^0}|^2) &= (0.5 \pm 3.1) \times 10^{-3} \\ A_{T/CP} &= 0.005 \pm 0.018 \\ A_{CP}(B^0 \rightarrow K^+ \pi^-) &= -0.09 \pm 0.04 \\ A_{CP}(B^0 \rightarrow \rho^+ \pi^-) &= -0.18 \pm 0.09 \\ A_{CP}(B^0 \rightarrow \rho^+ K^-) &= 0.28 \pm 0.19 \\ A_{CP}(B^0 \rightarrow K^*(892)^+ \pi^-) &= 0.26 \pm 0.35 \\ A_{CP}(B^0 \rightarrow K^*(892)^0 \phi) &= 0.05 \pm 0.10 \\ A_{CP}(B^0 \rightarrow D^*(2010)^+ D^-) &= -0.03 \pm 0.12 \\ C_{\pi\pi}(B^0 \rightarrow \pi^+ \pi^-) &= -0.51 \pm 0.23 \quad (S = 1.2) \\ S_{\pi\pi}(B^0 \rightarrow \pi^+ \pi^-) &= -0.5 \pm 0.6 \quad (S = 2.3) \\ C_{\rho\pi}(B^0 \rightarrow \rho^+ \pi^-) &= 0.36 \pm 0.18 \\ S_{\rho\pi}(B^0 \rightarrow \rho^+ \pi^-) &= 0.19 \pm 0.24 \\ C_{\eta'(958)K}(B^0 \rightarrow \eta'(958)K_S^0) &= 0.04 \pm 0.13 \\ S_{\eta'(958)K}(B^0 \rightarrow \eta'(958)K_S^0) &= 0.27 \pm 0.21 \\ C_{\phi K_S^0}(B^0 \rightarrow \phi K_S^0) &= 0.15 \pm 0.30 \\ S_{\phi K_S^0}(B^0 \rightarrow \phi K_S^0) &= -1.0 \pm 0.5 \\ C_{K^+ K^- K_S^0}(B^0 \rightarrow K^+ K^- K_S^0) &= 0.17 \pm 0.16 \\ S_{K^+ K^- K_S^0}(B^0 \rightarrow K^+ K^- K_S^0) &= -0.51 \pm 0.26 \\ C_{D^*(2010)^- D^+}(B^0 \rightarrow D^*(2010)^- D^+) &= -0.2 \pm 0.4 \\ S_{D^*(2010)^- D^+}(B^0 \rightarrow D^*(2010)^- D^+) &= -0.2 \pm 0.7 \\ C_{D^*(2010)^+ D^-}(B^0 \rightarrow D^*(2010)^+ D^-) &= -0.5 \pm 0.4 \\ S_{D^*(2010)^+ D^-}(B^0 \rightarrow D^*(2010)^+ D^-) &= -0.8 \pm 0.8 \\ C_{J/\psi(1S)\pi^0}(B^0 \rightarrow J/\psi(1S)\pi^0) &= 0.4 \pm 0.4 \\ S_{J/\psi(1S)\pi^0}(B^0 \rightarrow J/\psi(1S)\pi^0) &= 0.1 \pm 0.5 \\ \Delta C_{\rho\pi}(B^0 \rightarrow \rho^+ \pi^-) &= 0.28 \pm 0.19 \\ \Delta S_{\rho\pi}(B^0 \rightarrow \rho^+ \pi^-) &= 0.15 \pm 0.25 \\ |\lambda|(B^0 \rightarrow c\bar{c}K^0) &= 0.949 \pm 0.045 \\ |\lambda|(B^0 \rightarrow D^{*+} D^{*-}) &= 0.75 \pm 0.19 \\ \text{Im}(\lambda)(B^0 \rightarrow D^{*+} D^{*-}) &= 0.05 \pm 0.31 \\ \sin(2\beta) &= 0.731 \pm 0.056 \end{aligned}$$

$\bar{B}^0$  modes are charge conjugates of the modes below. Reactions indicate the weak decay vertex and do not include mixing. Modes which do not identify the charge state of the  $B$  are listed in the  $B^\pm/B^0$  ADMIXTURE section.

The branching fractions listed below assume 50%  $B^0 \bar{B}^0$  and 50%  $B^+ B^-$  production at the  $\Upsilon(4S)$ . We have attempted to bring older measurements up to date by rescaling their assumed  $\Upsilon(4S)$  production ratio to 50:50

and their assumed  $D$ ,  $D_s$ ,  $D^*$ , and  $\psi$  branching ratios to current values whenever this would affect our averages and best limits significantly.

Indentation is used to indicate a subchannel of a previous reaction. All resonant subchannels have been corrected for resonance branching fractions to the final state so the sum of the subchannel branching fractions can exceed that of the final state.

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.

<b><math>B^0</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor/ Confidence level	$p$ (MeV/c)
$\ell^+ \nu_\ell$ anything	[a] (10.5 $\pm$ 0.8) %		–
$D^- \ell^+ \nu_\ell$	[a] ( 2.14 $\pm$ 0.20) %		2309
$D^*(2010)^- \ell^+ \nu_\ell$	[a] ( 5.44 $\pm$ 0.23) %		2257
$\rho^- \ell^+ \nu_\ell$	[a] ( 2.6 $\pm$ 0.7) $\times 10^{-4}$		2583
$\pi^- \ell^+ \nu_\ell$	[a] ( 1.33 $\pm$ 0.22) $\times 10^{-4}$		2638
<b>Inclusive modes</b>			
$K^+$ anything	(78 $\pm$ 8) %		–
<b><math>D</math>, <math>D^*</math>, or <math>D_s</math> modes</b>			
$D^- \pi^+$	( 2.76 $\pm$ 0.25) $\times 10^{-3}$		2306
$D^- \rho^+$	( 7.7 $\pm$ 1.3) $\times 10^{-3}$		2235
$D^- K^*(892)^+$	( 3.7 $\pm$ 1.8) $\times 10^{-4}$		2211
$D^- \omega \pi^+$	( 2.8 $\pm$ 0.6) $\times 10^{-3}$		2204
$D^- K^+$	( 2.0 $\pm$ 0.6) $\times 10^{-4}$		2279
$D^- K^+ \bar{K}^0$	< 3.1 $\times 10^{-4}$	CL=90%	2188
$D^- K^+ \bar{K}^*(892)^0$	( 8.8 $\pm$ 1.9) $\times 10^{-4}$		2070
$\bar{D}^0 \pi^+ \pi^-$	( 8.0 $\pm$ 1.6) $\times 10^{-4}$		2301
$D^*(2010)^- \pi^+$	( 2.76 $\pm$ 0.21) $\times 10^{-3}$		2255
$D^- \pi^+ \pi^+ \pi^-$	( 8.0 $\pm$ 2.5) $\times 10^{-3}$		2287
( $D^- \pi^+ \pi^+ \pi^-$ ) nonresonant	( 3.9 $\pm$ 1.9) $\times 10^{-3}$		2287
$D^- \pi^+ \rho^0$	( 1.1 $\pm$ 1.0) $\times 10^{-3}$		2206
$D^- a_1(1260)^+$	( 6.0 $\pm$ 3.3) $\times 10^{-3}$		2121
$D^*(2010)^- \pi^+ \pi^0$	( 1.5 $\pm$ 0.5) %		2247
$D^*(2010)^- \rho^+$	( 6.8 $\pm$ 0.9) $\times 10^{-3}$		2180
$D^*(2010)^- K^+$	( 2.0 $\pm$ 0.5) $\times 10^{-4}$		2226
$D^*(2010)^- K^*(892)^+$	( 3.8 $\pm$ 1.5) $\times 10^{-4}$		2155
$D^*(2010)^- K^+ \bar{K}^0$	< 4.7 $\times 10^{-4}$	CL=90%	2131
$D^*(2010)^- K^+ \bar{K}^*(892)^0$	( 1.29 $\pm$ 0.33) $\times 10^{-3}$		2007
$D^*(2010)^- \pi^+ \pi^+ \pi^-$	( 7.6 $\pm$ 1.8) $\times 10^{-3}$	S=1.4	2235
( $D^*(2010)^- \pi^+ \pi^+ \pi^-$ ) non-resonant	( 0.0 $\pm$ 2.5) $\times 10^{-3}$		2235
$D^*(2010)^- \pi^+ \rho^0$	( 5.7 $\pm$ 3.2) $\times 10^{-3}$		2150

$D^*(2010)^- a_1(1260)^+$	( 1.30±0.27 ) %		2061
$D^*(2010)^- \pi^+ \pi^+ \pi^- \pi^0$	( 1.76±0.27 ) %		2218
$D^*(2010)^+ \pi^+ \pi^- \pi^- \pi^0$	( 1.8 ±0.7 ) %		2218
$D^*(2010)^- p \bar{p} \pi^+$	( 6.5 ±1.6 ) × 10 <sup>-4</sup>		1707
$D^*(2010)^- p \bar{n}$	( 1.5 ±0.4 ) × 10 <sup>-3</sup>		1785
$\bar{D}^*(2010)^- \omega \pi^+$	( 2.9 ±0.5 ) × 10 <sup>-3</sup>		2148
$\bar{D}_2^*(2460)^- \pi^+$	< 2.2 × 10 <sup>-3</sup>	CL=90%	2064
$\bar{D}_2^*(2460)^- \rho^+$	< 4.9 × 10 <sup>-3</sup>	CL=90%	1977
$D^- D^+$	< 9.4 × 10 <sup>-4</sup>	CL=90%	1864
$D^- D_s^+$	( 8.0 ±3.0 ) × 10 <sup>-3</sup>		1812
$D^*(2010)^- D_s^+$	( 1.07±0.29 ) %		1735
$D^- D_s^{*+}$	( 1.0 ±0.5 ) %		1732
$D^*(2010)^- D_s^{*+}$	( 1.9 ±0.5 ) %		1649
$D^- D_{sJ}(2317)^+$	seen		1602
$D^- D_{sJ}(2457)^+$	seen		—
$D^- D_{sJ}(2536)^+$	not seen		1444
$D^*(2010)^- D_{sJ}(2536)^+$	not seen		1336
$D^- D_{sJ}(2573)^+$	not seen		1414
$D^*(2010)^- D_{sJ}(2573)^+$	not seen		1303
$D_s^+ \pi^-$	( 2.7 ±1.0 ) × 10 <sup>-5</sup>		2270
$D_s^{*+} \pi^-$	< 4.1 × 10 <sup>-5</sup>	CL=90%	2215
$D_s^+ \rho^-$	< 7 × 10 <sup>-4</sup>	CL=90%	2197
$D_s^{*+} \rho^-$	< 8 × 10 <sup>-4</sup>	CL=90%	2138
$D_s^+ a_1(1260)^-$	< 2.6 × 10 <sup>-3</sup>	CL=90%	2080
$D_s^{*+} a_1(1260)^-$	< 2.2 × 10 <sup>-3</sup>	CL=90%	2015
$D_s^- K^+$	( 3.8 ±1.3 ) × 10 <sup>-5</sup>		2242
$D_s^{*-} K^+$	< 2.5 × 10 <sup>-5</sup>	CL=90%	2185
$D_s^- K^*(892)^+$	< 9.9 × 10 <sup>-4</sup>	CL=90%	2172
$D_s^{*-} K^*(892)^+$	< 1.1 × 10 <sup>-3</sup>	CL=90%	2112
$D_s^- \pi^+ K^0$	< 5 × 10 <sup>-3</sup>	CL=90%	2222
$D_s^{*-} \pi^+ K^0$	< 3.1 × 10 <sup>-3</sup>	CL=90%	2164
$D_s^- \pi^+ K^*(892)^0$	< 4 × 10 <sup>-3</sup>	CL=90%	2138
$D_s^{*-} \pi^+ K^*(892)^0$	< 2.0 × 10 <sup>-3</sup>	CL=90%	2076
$\bar{D}^0 K^0$	( 5.0 ±1.4 ) × 10 <sup>-5</sup>		2280
$\bar{D}^0 K^*(892)^0$	( 4.8 ±1.2 ) × 10 <sup>-5</sup>		2213
$\bar{D}^0 \pi^0$	( 2.91±0.28 ) × 10 <sup>-4</sup>		2308
$\bar{D}^0 \rho^0$	( 2.9 ±1.1 ) × 10 <sup>-4</sup>		2237
$\bar{D}^0 \eta$	( 2.2 ±0.5 ) × 10 <sup>-4</sup>	S=1.6	2274
$\bar{D}^0 \eta'$	( 1.7 ±0.4 ) × 10 <sup>-4</sup>		2198
$\bar{D}^0 \omega$	( 2.5 ±0.6 ) × 10 <sup>-4</sup>	S=1.5	2235
$D^0 K^*(892)^0$	< 1.8 × 10 <sup>-5</sup>	CL=90%	2213
$\bar{D}^{*0} \gamma$	< 5.0 × 10 <sup>-5</sup>	CL=90%	2258

$\bar{D}^*(2007)^0 \pi^0$	$( 2.7 \pm 0.5 ) \times 10^{-4}$		2256
$\bar{D}^*(2007)^0 \rho^0$	$< 5.1 \times 10^{-4}$	CL=90%	2181
$\bar{D}^*(2007)^0 \eta$	$( 2.6 \pm 0.6 ) \times 10^{-4}$		2220
$\bar{D}^*(2007)^0 \eta'$	$< 2.6 \times 10^{-4}$	CL=90%	2141
$\bar{D}^*(2007)^0 \pi^+ \pi^-$	$( 6.2 \pm 2.2 ) \times 10^{-4}$		2248
$\bar{D}^*(2007)^0 K^0$	$< 6.6 \times 10^{-5}$	CL=90%	2227
$\bar{D}^*(2007)^0 K^*(892)^0$	$< 6.9 \times 10^{-5}$	CL=90%	2157
$D^*(2007)^0 K^*(892)^0$	$< 4.0 \times 10^{-5}$	CL=90%	2157
$D^*(2007)^0 \pi^+ \pi^+ \pi^- \pi^-$	$( 3.0 \pm 0.9 ) \times 10^{-3}$		2219
$D^*(2010)^+ D^*(2010)^-$	$( 8.7 \pm 1.8 ) \times 10^{-4}$		1711
$\bar{D}^*(2007)^0 \omega$	$( 4.2 \pm 1.1 ) \times 10^{-4}$		2180
$D^*(2010)^+ D^-$	$< 6.3 \times 10^{-4}$	CL=90%	1790
$D^*(2010)^- D^+ +$ $D^*(2010)^+ D^-$	$( 9.3 \pm 1.5 ) \times 10^{-4}$		1790
$D^*(2007)^0 \bar{D}^*(2007)^0$	$< 2.7 \%$	CL=90%	1715
$D^- D^0 K^+$	$( 1.7 \pm 0.4 ) \times 10^{-3}$		1574
$D^- D^*(2007)^0 K^+$	$( 4.6 \pm 1.0 ) \times 10^{-3}$		1478
$D^*(2010)^- D^0 K^+$	$( 3.1 \pm_{-0.5}^{+0.6} ) \times 10^{-3}$		1479
$D^*(2010)^- D^*(2007)^0 K^+$	$( 1.18 \pm 0.20 ) \%$		1366
$D^- D^+ K^0$	$< 1.7 \times 10^{-3}$	CL=90%	1568
$D^*(2010)^- D^+ K^0 +$ $D^- D^*(2010)^+ K^0$	$( 6.5 \pm 1.6 ) \times 10^{-3}$		1473
$D^*(2010)^- D^*(2010)^+ K^0$	$( 8.8 \pm 1.9 ) \times 10^{-3}$		1360
$\bar{D}^0 D^0 K^0$	$< 1.4 \times 10^{-3}$	CL=90%	1575
$\bar{D}^0 D^*(2007)^0 K^0 +$ $\bar{D}^*(2007)^0 D^0 K^0$	$< 3.7 \times 10^{-3}$	CL=90%	1478
$\bar{D}^*(2007)^0 D^*(2007)^0 K^0$	$< 6.6 \times 10^{-3}$	CL=90%	1365
$(\bar{D} + \bar{D}^*)(D + D^*)K$	$( 4.3 \pm 0.7 ) \%$		—

### Charmonium modes

$\eta_c K^0$	$( 1.2 \pm 0.4 ) \times 10^{-3}$		1753
$\eta_c K^*(892)^0$	$( 1.6 \pm 0.7 ) \times 10^{-3}$		1648
$J/\psi(1S) K^0$	$( 8.5 \pm 0.5 ) \times 10^{-4}$		1683
$J/\psi(1S) K^+ \pi^-$	$( 1.2 \pm 0.6 ) \times 10^{-3}$		1652
$J/\psi(1S) K^*(892)^0$	$( 1.31 \pm 0.07 ) \times 10^{-3}$		1571
$J/\psi(1S) \phi K^0$	$( 9.4 \pm 2.6 ) \times 10^{-5}$		1224
$J/\psi(1S) K(1270)^0$	$( 1.3 \pm 0.5 ) \times 10^{-3}$		1390
$J/\psi(1S) \pi^0$	$( 2.2 \pm 0.4 ) \times 10^{-5}$		1728
$J/\psi(1S) \eta$	$< 2.7 \times 10^{-5}$	CL=90%	1672
$J/\psi(1S) \pi^+ \pi^-$	$( 4.6 \pm 0.9 ) \times 10^{-5}$		1716
$J/\psi(1S) \rho^0$	$( 1.6 \pm 0.7 ) \times 10^{-5}$		1611
$J/\psi(1S) \omega$	$< 2.7 \times 10^{-4}$	CL=90%	1609
$J/\psi(1S) \phi$	$< 9.2 \times 10^{-6}$	CL=90%	1519

$J/\psi(1S)\eta'(958)$	$< 6.3 \times 10^{-5}$	CL=90%	1546
$J/\psi(1S)K^0\pi^+\pi^-$	$(1.0 \pm 0.4) \times 10^{-3}$		1611
$J/\psi(1S)K^0\rho^0$	$(5.4 \pm 3.0) \times 10^{-4}$		1390
$J/\psi(1S)K^*(892)^+\pi^-$	$(8 \pm 4) \times 10^{-4}$		1514
$J/\psi(1S)K^*(892)^0\pi^+\pi^-$	$(6.6 \pm 2.2) \times 10^{-4}$		1447
$J/\psi(1S)\rho\bar{\rho}$	$< 1.9 \times 10^{-6}$	CL=90%	862
$\psi(2S)K^0$	$(6.2 \pm 0.7) \times 10^{-4}$		1283
$\psi(2S)K^+\pi^-$	$< 1 \times 10^{-3}$	CL=90%	1238
$\psi(2S)K^*(892)^0$	$(8.0 \pm 1.3) \times 10^{-4}$		1116
$\chi_{c0}(1P)K^0$	$< 5.0 \times 10^{-4}$	CL=90%	1477
$\chi_{c1}(1P)K^0$	$(4.0^{+1.2}_{-1.0}) \times 10^{-4}$		1411
$\chi_{c1}(1P)K^*(892)^0$	$(4.1 \pm 1.5) \times 10^{-4}$		1265

**K or K\* modes**

$K^+\pi^-$	$(1.85 \pm 0.11) \times 10^{-5}$	S=1.2	2615
$K^0\pi^0$	$(9.5^{+2.1}_{-1.9}) \times 10^{-6}$		2614
$\eta'K^0$	$(6.3 \pm 0.7) \times 10^{-5}$	S=1.1	2528
$\eta'K^*(892)^0$	$< 2.4 \times 10^{-5}$	CL=90%	2472
$\eta K^*(892)^0$	$(1.4^{+0.6}_{-0.5}) \times 10^{-5}$		2534
$\eta K^0$	$< 9.3 \times 10^{-6}$	CL=90%	2587
$\omega K^0$	$< 1.3 \times 10^{-5}$	CL=90%	2557
$K_S^0 X^0$ (Familon)	$< 5.3 \times 10^{-5}$	CL=90%	—
$\omega K^*(892)^0$	$< 2.3 \times 10^{-5}$	CL=90%	2503
$K^0\bar{K}^0$	$< 3.3 \times 10^{-6}$	CL=90%	2592
$K_S^0 K_S^0 K_S^0$	$(4.2^{+1.8}_{-1.5}) \times 10^{-6}$		2521
$K^+\pi^-\pi^0$	$< 4.0 \times 10^{-5}$	CL=90%	2609
$K^+\rho^-$	$(7.3 \pm 1.8) \times 10^{-6}$		2559
$K^0\pi^+\pi^-$	$(4.7 \pm 0.7) \times 10^{-5}$		2609
$K^0\rho^0$	$< 3.9 \times 10^{-5}$	CL=90%	2558
$K^0 f_0(980)$	$< 3.6 \times 10^{-4}$	CL=90%	2524
$K^*(892)^+\pi^-$	$(1.6^{+0.6}_{-0.5}) \times 10^{-5}$		2562
$K^*(892)^0\pi^0$	$< 3.6 \times 10^{-6}$	CL=90%	2563
$K_2^*(1430)^+\pi^-$	$< 1.8 \times 10^{-5}$	CL=90%	2445
$K^0 K^-\pi^+$	$< 2.1 \times 10^{-5}$	CL=90%	2578
$K^+ K^-\pi^0$	$< 1.9 \times 10^{-5}$	CL=90%	2579
$K^0 K^+ K^-$	$(2.8 \pm 0.5) \times 10^{-5}$		2522
$K^0\phi$	$(8.6^{+1.3}_{-1.1}) \times 10^{-6}$		2516
$K^-\pi^+\pi^+\pi^-$	[b] $< 2.3 \times 10^{-4}$	CL=90%	2600
$K^*(892)^0\pi^+\pi^-$	$< 1.4 \times 10^{-3}$	CL=90%	2557
$K^*(892)^0\rho^0$	$< 3.4 \times 10^{-5}$	CL=90%	2504

$K^*(892)^0 f_0(980)$	< 1.7	$\times 10^{-4}$	CL=90%	2468
$K_1(1400)^+ \pi^-$	< 1.1	$\times 10^{-3}$	CL=90%	2451
$K^- a_1(1260)^+$	[b] < 2.3	$\times 10^{-4}$	CL=90%	2471
$K^*(892)^0 K^+ K^-$	< 6.1	$\times 10^{-4}$	CL=90%	2466
$K^*(892)^0 \phi$	( 1.07 ± 0.11 )	$\times 10^{-5}$		2460
$\bar{K}^*(892)^0 K^*(892)^0$	< 2.2	$\times 10^{-5}$	CL=90%	2485
$K^*(892)^0 K^*(892)^0$	< 3.7	$\times 10^{-5}$	CL=90%	2485
$K^*(892)^+ K^*(892)^-$	< 1.41	$\times 10^{-4}$	CL=90%	2485
$K_1(1400)^0 \rho^0$	< 3.0	$\times 10^{-3}$	CL=90%	2388
$K_1(1400)^0 \phi$	< 5.0	$\times 10^{-3}$	CL=90%	2339
$K_2^*(1430)^0 \rho^0$	< 1.1	$\times 10^{-3}$	CL=90%	2381
$K_2^*(1430)^0 \phi$	< 1.4	$\times 10^{-3}$	CL=90%	2333
$K^*(892)^0 \gamma$	( 4.3 ± 0.4 )	$\times 10^{-5}$		2564
$K^0 \phi \gamma$	< 8.3	$\times 10^{-6}$	CL=90%	2516
$K^+ \pi^- \gamma$	( 4.6 ± 1.4 )	$\times 10^{-6}$		2615
$K^*(1410) \gamma$	< 1.3	$\times 10^{-4}$	CL=90%	2450
$K^+ \pi^- \gamma$ nonresonant	< 2.6	$\times 10^{-6}$	CL=90%	2615
$K_1(1270)^0 \gamma$	< 7.0	$\times 10^{-3}$	CL=90%	2486
$K_1(1400)^0 \gamma$	< 4.3	$\times 10^{-3}$	CL=90%	2453
$K_2^*(1430)^0 \gamma$	( 1.3 ± 0.5 )	$\times 10^{-5}$		2447
$K^*(1680)^0 \gamma$	< 2.0	$\times 10^{-3}$	CL=90%	2360
$K_3^*(1780)^0 \gamma$	< 1.0	%	CL=90%	2341
$K_4^*(2045)^0 \gamma$	< 4.3	$\times 10^{-3}$	CL=90%	2244

#### Light unflavored meson modes

$\rho^0 \gamma$	< 1.2	$\times 10^{-6}$	CL=90%	2583
$\omega \gamma$	< 1.0	$\times 10^{-6}$	CL=90%	2582
$\phi \gamma$	< 3.3	$\times 10^{-6}$	CL=90%	2541
$\pi^+ \pi^-$	( 4.8 ± 0.5 )	$\times 10^{-6}$		2636
$\pi^0 \pi^0$	( 1.9 ± 0.5 )	$\times 10^{-6}$		2636
$\eta \pi^0$	< 2.9	$\times 10^{-6}$	CL=90%	2610
$\eta \eta$	< 1.8	$\times 10^{-5}$	CL=90%	2582
$\eta' \pi^0$	< 5.7	$\times 10^{-6}$	CL=90%	2551
$\eta' \eta'$	< 4.7	$\times 10^{-5}$	CL=90%	2460
$\eta' \eta$	< 2.7	$\times 10^{-5}$	CL=90%	2522
$\eta' \rho^0$	< 1.2	$\times 10^{-5}$	CL=90%	2492
$\eta \rho^0$	< 1.0	$\times 10^{-5}$	CL=90%	2553
$\omega \eta$	< 1.2	$\times 10^{-5}$	CL=90%	2552
$\omega \eta'$	< 6.0	$\times 10^{-5}$	CL=90%	2491
$\omega \rho^0$	< 1.1	$\times 10^{-5}$	CL=90%	2522
$\omega \omega$	< 1.9	$\times 10^{-5}$	CL=90%	2521
$\phi \pi^0$	< 5	$\times 10^{-6}$	CL=90%	2539
$\phi \eta$	< 9	$\times 10^{-6}$	CL=90%	2511
$\phi \eta'$	< 3.1	$\times 10^{-5}$	CL=90%	2447

$\phi\rho^0$	< 1.3	$\times 10^{-5}$	CL=90%	2480
$\phi\omega$	< 2.1	$\times 10^{-5}$	CL=90%	2479
$\phi\phi$	< 1.2	$\times 10^{-5}$	CL=90%	2435
$\pi^+\pi^-\pi^0$	< 7.2	$\times 10^{-4}$	CL=90%	2631
$\rho^0\pi^0$	< 5.3	$\times 10^{-6}$	CL=90%	2581
$\rho^\mp\pi^\pm$	[c] ( 2.28±0.25)	$\times 10^{-5}$		2581
$\pi^+\pi^-\pi^+\pi^-$	< 2.3	$\times 10^{-4}$	CL=90%	2621
$\rho^0\rho^0$	< 2.1	$\times 10^{-6}$	CL=90%	2523
$a_1(1260)^\mp\pi^\pm$	[c] < 4.9	$\times 10^{-4}$	CL=90%	2494
$a_2(1320)^\mp\pi^\pm$	[c] < 3.0	$\times 10^{-4}$	CL=90%	2473
$\pi^+\pi^-\pi^0\pi^0$	< 3.1	$\times 10^{-3}$	CL=90%	2622
$\rho^+\rho^-$	< 2.2	$\times 10^{-3}$	CL=90%	2523
$a_1(1260)^0\pi^0$	< 1.1	$\times 10^{-3}$	CL=90%	2494
$\omega\pi^0$	< 3	$\times 10^{-6}$	CL=90%	2580
$\pi^+\pi^+\pi^-\pi^-\pi^0$	< 9.0	$\times 10^{-3}$	CL=90%	2609
$a_1(1260)^+\rho^-$	< 3.4	$\times 10^{-3}$	CL=90%	2433
$a_1(1260)^0\rho^0$	< 2.4	$\times 10^{-3}$	CL=90%	2433
$\pi^+\pi^+\pi^+\pi^-\pi^-\pi^-$	< 3.0	$\times 10^{-3}$	CL=90%	2592
$a_1(1260)^+a_1(1260)^-$	< 2.8	$\times 10^{-3}$	CL=90%	2336
$\pi^+\pi^+\pi^+\pi^-\pi^-\pi^0$	< 1.1	%	CL=90%	2572

### Baryon modes

$\rho\bar{p}$	< 1.2	$\times 10^{-6}$	CL=90%	2467
$\rho\bar{p}\pi^+\pi^-$	< 2.5	$\times 10^{-4}$	CL=90%	2406
$\rho\bar{p}K^0$	< 7.2	$\times 10^{-6}$	CL=90%	2347
$\rho\bar{\Lambda}\pi^-$	( 4.0 $\begin{smallmatrix} +1.1 \\ -1.0 \end{smallmatrix}$ )	$\times 10^{-6}$		2401
$\rho\bar{\Lambda}K^-$	< 8.2	$\times 10^{-7}$	CL=90%	2308
$\rho\bar{\Sigma}^0\pi^-$	< 3.8	$\times 10^{-6}$	CL=90%	2383
$\bar{\Lambda}\Lambda$	< 1.0	$\times 10^{-6}$	CL=90%	2392
$\Delta^0\bar{\Delta}^0$	< 1.5	$\times 10^{-3}$	CL=90%	2335
$\Delta^{++}\bar{\Delta}^{--}$	< 1.1	$\times 10^{-4}$	CL=90%	2335
$\bar{D}^0\rho\bar{p}$	( 1.18±0.22)	$\times 10^{-4}$		1862
$\bar{D}^*(2007)^0\rho\bar{p}$	( 1.2 ±0.4 )	$\times 10^{-4}$		1788
$\bar{\Sigma}_c^{--}\Delta^{++}$	< 1.0	$\times 10^{-3}$	CL=90%	1840
$\bar{\Lambda}_c^-\rho\pi^+\pi^-$	( 1.3 ±0.4 )	$\times 10^{-3}$		1934
$\bar{\Lambda}_c^-\rho$	( 2.2 ±0.8 )	$\times 10^{-5}$		2021
$\bar{\Lambda}_c^-\rho\pi^0$	< 5.9	$\times 10^{-4}$	CL=90%	1982
$\bar{\Lambda}_c^-\rho\pi^+\pi^-\pi^0$	< 5.07	$\times 10^{-3}$	CL=90%	1883
$\bar{\Lambda}_c^-\rho\pi^+\pi^-\pi^+\pi^-$	< 2.74	$\times 10^{-3}$	CL=90%	1821
$\bar{\Sigma}_c(2520)^{--}\rho\pi^+$	( 1.6 ±0.7 )	$\times 10^{-4}$		1861
$\bar{\Sigma}_c(2520)^0\rho\pi^-$	< 1.21	$\times 10^{-4}$	CL=90%	1861



$\overline{\Sigma}_c(2455)^0 p \pi^-$	$(10 \pm 8) \times 10^{-5}$	S=1.7	1896
$\overline{\Sigma}_c(2455)^{--} p \pi^+$	$(2.8 \pm 0.9) \times 10^{-4}$		1896
$\overline{\Lambda}_c(2593)^- / \overline{\Lambda}_c(2625)^- p$	$< 1.1 \times 10^{-4}$	CL=90%	–

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

$\gamma \gamma$	B1	$< 1.7 \times 10^{-6}$	CL=90%	2640
$e^+ e^-$	B1	$< 1.9 \times 10^{-7}$	CL=90%	2640
$\mu^+ \mu^-$	B1	$< 1.6 \times 10^{-7}$	CL=90%	2638
$K^0 e^+ e^-$	B1	$< 5.4 \times 10^{-7}$	CL=90%	2616
$K^0 \mu^+ \mu^-$	B1	$(5.6^{+2.9}_{-2.4}) \times 10^{-7}$		2612
$K^0 \ell^+ \ell^-$	B1	[a] $< 6.8 \times 10^{-7}$	CL=90%	2616
$K^*(892)^0 e^+ e^-$	B1	$< 2.4 \times 10^{-6}$	CL=90%	2564
$K^*(892)^0 \mu^+ \mu^-$	B1	$(1.3 \pm 0.4) \times 10^{-6}$		2560
$K^*(892)^0 \nu \bar{\nu}$	B1	$< 1.0 \times 10^{-3}$	CL=90%	2564
$K^*(892)^0 \ell^+ \ell^-$	B1	[a] $(1.17 \pm 0.30) \times 10^{-6}$		2564
$e^\pm \mu^\mp$	LF	[c] $< 1.7 \times 10^{-7}$	CL=90%	2639
$K^0 e^\pm \mu^\mp$	LF	$< 4.0 \times 10^{-6}$	CL=90%	2615
$K^*(892)^0 e^\pm \mu^\mp$	LF	$< 3.4 \times 10^{-6}$	CL=90%	2563
$e^\pm \tau^\mp$	LF	[c] $< 5.3 \times 10^{-4}$	CL=90%	2341
$\mu^\pm \tau^\mp$	LF	[c] $< 8.3 \times 10^{-4}$	CL=90%	2339

**$B^\pm / B^0$  ADMIXTURE**

**CP violation**

$$A_{CP}(B \rightarrow K^*(892)\gamma) = -0.01 \pm 0.07$$

$$A_{CP}(B \rightarrow s\gamma) = -0.08 \pm 0.11$$

The branching fraction measurements are for an admixture of  $B$  mesons at the  $\Upsilon(4S)$ . The values quoted assume that  $B(\Upsilon(4S) \rightarrow B\bar{B}) = 100\%$ .

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.

$\bar{B}$  modes are charge conjugates of the modes below. Reactions indicate the weak decay vertex and do not include mixing.

<b>B DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor/ Confidence level (MeV/c)
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### Semileptonic and leptonic modes

$B \rightarrow e^+ \nu_e$ anything	[d]	( 10.73 ± 0.28 ) %		—
$B \rightarrow \bar{p} e^+ \nu_e$ anything		< 5.9	× 10 <sup>-4</sup>	CL=90% —
$B \rightarrow \ell^+ \nu_\ell$ anything	[a,d]	( 10.73 ± 0.28 ) %		—
$B \rightarrow D^- \ell^+ \nu_\ell$ anything	[a]	( 2.8 ± 0.9 ) %		—
$B \rightarrow \bar{D}^0 \ell^+ \nu_\ell$ anything	[a]	( 7.2 ± 1.5 ) %		—
$B \rightarrow \bar{D}^{*0} \ell^+ \nu_\ell$	[a,e]	( 2.7 ± 0.7 ) %		—
$B \rightarrow \bar{D}_1(2420) \ell^+ \nu_\ell$ anything		( 7.4 ± 1.6 ) × 10 <sup>-3</sup>		—
$B \rightarrow D \pi \ell^+ \nu_\ell$ anything + $D^* \pi \ell^+ \nu_\ell$ anything		( 2.6 ± 0.5 ) %		S=1.5 —
$B \rightarrow D \pi \ell^+ \nu_\ell$ anything		( 1.5 ± 0.6 ) %		—
$B \rightarrow D^* \pi \ell^+ \nu_\ell$ anything		( 1.9 ± 0.4 ) %		—
$B \rightarrow \bar{D}_2^*(2460) \ell^+ \nu_\ell$ anything		< 6.5	× 10 <sup>-3</sup>	CL=95% —
$B \rightarrow D^{*-} \pi^+ \ell^+ \nu_\ell$ anything		( 1.00 ± 0.34 ) %		—
$B \rightarrow D_s^- \ell^+ \nu_\ell$ anything	[a]	< 9	× 10 <sup>-3</sup>	CL=90% —
$B \rightarrow D_s^- \ell^+ \nu_\ell K^+$ anything	[a]	< 6	× 10 <sup>-3</sup>	CL=90% —
$B \rightarrow D_s^- \ell^+ \nu_\ell K^0$ anything	[a]	< 9	× 10 <sup>-3</sup>	CL=90% —
$B \rightarrow K^+ \ell^+ \nu_\ell$ anything	[a]	( 6.2 ± 0.6 ) %		—
$B \rightarrow K^- \ell^+ \nu_\ell$ anything	[a]	( 10 ± 4 ) × 10 <sup>-3</sup>		—
$B \rightarrow K^0 / \bar{K}^0 \ell^+ \nu_\ell$ anything	[a]	( 4.5 ± 0.5 ) %		—

### D, D\*, or D<sub>s</sub> modes

$B \rightarrow D^\pm$ anything		( 23.5 ± 1.9 ) %		—
$B \rightarrow D^0 / \bar{D}^0$ anything		( 64.0 ± 3.0 ) %		S=1.1 —
$B \rightarrow D^*(2010)^\pm$ anything		( 22.5 ± 1.5 ) %		—
$B \rightarrow D^*(2007)^0$ anything		( 26.0 ± 2.7 ) %		—
$B \rightarrow D_s^\pm$ anything	[c]	( 10.5 ± 2.6 ) %		—
$B \rightarrow D_s^{*\pm}$ anything		( 7.9 ± 2.2 ) %		—
$B \rightarrow D_s^{*\pm} \bar{D}^{(*)}$		( 4.2 ± 1.2 ) %		—
$B \rightarrow \bar{D} D_{sJ}(2317)$	seen			1605
$B \rightarrow \bar{D} D_{sJ}(2457)$	seen			—
$B \rightarrow D^{(*)} \bar{D}^{(*)} K^0 + D^{(*)} \bar{D}^{(*)} K^\pm$	[c,f]	( 7.1 ± 2.7 / - 1.7 ) %		—
$b \rightarrow c \bar{c} s$		( 22 ± 4 ) %		—

$B \rightarrow D_s^{(*)} \bar{D}^{(*)}$	[c,f]	( 4.9 ± 1.2 ) %		—
$B \rightarrow D^* D^*(2010)^\pm$	[c]	< 5.9	$\times 10^{-3}$	CL=90% 1711
$B \rightarrow DD^*(2010)^\pm + D^* D^\pm$	[c]	< 5.5	$\times 10^{-3}$	CL=90% —
$B \rightarrow DD^\pm$	[c]	< 3.1	$\times 10^{-3}$	CL=90% 1866
$B \rightarrow D_s^{(*)\pm} \bar{D}^{(*)} \chi(n\pi^\pm)$	[c,f]	( 9 + — 4 ) %		—
$B \rightarrow D^*(2010)\gamma$		< 1.1	$\times 10^{-3}$	CL=90% 2257
$B \rightarrow D_s^+ \pi^-, D_s^{*+} \pi^-, D_s^+ \rho^-, D_s^{*+} \rho^-, D_s^+ \pi^0, D_s^{*+} \pi^0, D_s^+ \eta, D_s^{*+} \eta, D_s^+ \rho^0, D_s^{*+} \rho^0, D_s^+ \omega, D_s^{*+} \omega$	[c]	< 5	$\times 10^{-4}$	CL=90% —
$B \rightarrow D_{s1}(2536)^+ \text{ anything}$		< 9.5	$\times 10^{-3}$	CL=90% —

### Charmonium modes

$B \rightarrow J/\psi(1S) \text{ anything}$		( 1.094 ± 0.032 ) %		S=1.1 —
$B \rightarrow J/\psi(1S) \text{ (direct) anything}$		( 7.8 ± 0.4 ) $\times 10^{-3}$		S=1.1 —
$B \rightarrow \psi(2S) \text{ anything}$		( 3.07 ± 0.21 ) $\times 10^{-3}$		—
$B \rightarrow \chi_{c1}(1P) \text{ anything}$		( 3.86 ± 0.27 ) $\times 10^{-3}$		—
$B \rightarrow \chi_{c1}(1P) \text{ (direct) anything}$		( 3.34 ± 0.28 ) $\times 10^{-3}$		—
$B \rightarrow \chi_{c2}(1P) \text{ anything}$		( 1.3 ± 0.4 ) $\times 10^{-3}$		S=1.9 —
$B \rightarrow \chi_{c2}(1P) \text{ (direct) anything}$		( 1.65 ± 0.31 ) $\times 10^{-3}$		—
$B \rightarrow \eta_c(1S) \text{ anything}$		< 9	$\times 10^{-3}$	CL=90% —

### K or K\* modes

$B \rightarrow K^\pm \text{ anything}$	[c]	( 78.9 ± 2.5 ) %		—
$B \rightarrow K^+ \text{ anything}$		( 66 ± 5 ) %		—
$B \rightarrow K^- \text{ anything}$		( 13 ± 4 ) %		—
$B \rightarrow K^0 / \bar{K}^0 \text{ anything}$	[c]	( 64 ± 4 ) %		—
$B \rightarrow K^*(892)^\pm \text{ anything}$		( 18 ± 6 ) %		—
$B \rightarrow K^*(892)^0 / \bar{K}^*(892)^0 \text{ anything}$	[c]	( 14.6 ± 2.6 ) %		—
$B \rightarrow K^*(892)\gamma$		( 4.2 ± 0.6 ) $\times 10^{-5}$		2564
$B \rightarrow K_1(1400)\gamma$		< 1.27	$\times 10^{-4}$	CL=90% 2453
$B \rightarrow K_2^*(1430)\gamma$		( 1.7 + — 0.5 ) $\times 10^{-5}$		2447
$B \rightarrow K_2(1770)\gamma$		< 1.2	$\times 10^{-3}$	CL=90% 2342
$B \rightarrow K_3^*(1780)\gamma$		< 3.0	$\times 10^{-3}$	CL=90% 2341
$B \rightarrow K_4^*(2045)\gamma$		< 1.0	$\times 10^{-3}$	CL=90% 2244

$B \rightarrow K\eta'(958)$	$( 8.3 \pm 1.1 ) \times 10^{-5}$		2528
$B \rightarrow K^*(892)\eta'(958)$	$< 2.2 \times 10^{-5}$	CL=90%	2472
$B \rightarrow K\eta$	$< 5.2 \times 10^{-6}$	CL=90%	2588
$B \rightarrow K^*(892)\eta$	$( 1.8 \pm 0.5 ) \times 10^{-5}$		2534
$B \rightarrow K\phi\phi$	$( 2.3 \pm 0.9 ) \times 10^{-6}$		2306
$B \rightarrow \bar{b} \rightarrow \bar{s}\gamma$	$( 3.3 \pm 0.4 ) \times 10^{-4}$		—
$B \rightarrow \bar{b} \rightarrow \bar{s}\text{gluon}$	$< 6.8 \%$	CL=90%	—
$B \rightarrow \eta\text{anything}$	$< 4.4 \times 10^{-4}$	CL=90%	—
$B \rightarrow \eta'\text{anything}$	$( 4.6 \pm 1.3 ) \times 10^{-4}$		—

### Light unflavored meson modes

$B \rightarrow \rho\gamma$	$< 1.9 \times 10^{-6}$	CL=90%	2583
$B \rightarrow \pi^\pm\text{anything}$	[c,g] $(358 \pm 7) \%$		—
$B \rightarrow \pi^0\text{anything}$	$(235 \pm 11) \%$		—
$B \rightarrow \eta\text{anything}$	$( 17.6 \pm 1.6 ) \%$		—
$B \rightarrow \rho^0\text{anything}$	$( 21 \pm 5 ) \%$		—
$B \rightarrow \omega\text{anything}$	$< 81 \%$	CL=90%	—
$B \rightarrow \phi\text{anything}$	$( 3.5 \pm 0.7 ) \%$	S=1.8	—
$B \rightarrow \phi K^*(892)$	$< 2.2 \times 10^{-5}$	CL=90%	2460

### Baryon modes

$B \rightarrow \Lambda_c^+ / \bar{\Lambda}_c^- \text{anything}$	$( 6.4 \pm 1.1 ) \%$		—
$B \rightarrow \bar{\Lambda}_c^- e^+ \text{anything}$	$< 3.2 \times 10^{-3}$	CL=90%	—
$B \rightarrow \bar{\Lambda}_c^- p \text{anything}$	$( 3.6 \pm 0.7 ) \%$		—
$B \rightarrow \bar{\Lambda}_c^- p e^+ \nu_e$	$< 1.5 \times 10^{-3}$	CL=90%	2021
$B \rightarrow \bar{\Sigma}_c^- \text{anything}$	$( 4.2 \pm 2.4 ) \times 10^{-3}$		—
$B \rightarrow \bar{\Sigma}_c^- \text{anything}$	$< 9.6 \times 10^{-3}$	CL=90%	—
$B \rightarrow \bar{\Sigma}_c^0 \text{anything}$	$( 4.6 \pm 2.4 ) \times 10^{-3}$		—
$B \rightarrow \bar{\Sigma}_c^0 N (N = p \text{ or } n)$	$< 1.5 \times 10^{-3}$	CL=90%	1939
$B \rightarrow \Xi_c^0 \text{anything}$	$( 1.4 \pm 0.5 ) \times 10^{-4}$		—
$\times B(\Xi_c^0 \rightarrow \Xi^- \pi^+)$			
$B \rightarrow \Xi_c^+ \text{anything}$	$( 4.5 \begin{smallmatrix} + 1.3 \\ - 1.2 \end{smallmatrix} ) \times 10^{-4}$		—
$\times B(\Xi_c^+ \rightarrow \Xi^- \pi^+ \pi^+)$			
$B \rightarrow p/\bar{p} \text{anything}$	[c] $( 8.0 \pm 0.4 ) \%$		—
$B \rightarrow p/\bar{p}(\text{direct}) \text{anything}$	[c] $( 5.5 \pm 0.5 ) \%$		—
$B \rightarrow \Lambda/\bar{\Lambda} \text{anything}$	[c] $( 4.0 \pm 0.5 ) \%$		—
$B \rightarrow \Xi^-/\Xi^+ \text{anything}$	[c] $( 2.7 \pm 0.6 ) \times 10^{-3}$		—
$B \rightarrow \text{baryons anything}$	$( 6.8 \pm 0.6 ) \%$		—
$B \rightarrow p\bar{p} \text{anything}$	$( 2.47 \pm 0.23 ) \%$		—
$B \rightarrow \Lambda\bar{p}/\bar{\Lambda}p \text{anything}$	[c] $( 2.5 \pm 0.4 ) \%$		—
$B \rightarrow \Lambda\bar{\Lambda} \text{anything}$	$< 5 \times 10^{-3}$	CL=90%	—

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

$B \rightarrow s e^+ e^-$	B1	( 5.0 $\pm$ 2.6 )	$\times 10^{-6}$	–
$B \rightarrow s \mu^+ \mu^-$	B1	( 7.9 $\pm$ 3.0 – 2.6 )	$\times 10^{-6}$	–
$B \rightarrow s \ell^+ \ell^-$	B1 [a]	( 6.1 $\pm$ 2.0 – 1.8 )	$\times 10^{-6}$	–
$B \rightarrow K e^+ e^-$	B1	( 4.8 $\pm$ 1.5 – 1.3 )	$\times 10^{-7}$	2617
$B \rightarrow K^*(892) e^+ e^-$	B1	( 1.5 $\pm$ 0.5 )	$\times 10^{-6}$	2564
$B \rightarrow K \mu^+ \mu^-$	B1	( 4.8 $\pm$ 1.2 )	$\times 10^{-7}$	2612
$B \rightarrow K^*(892) \mu^+ \mu^-$	B1	( 1.17 $\pm$ 0.37 – 0.33 )	$\times 10^{-6}$	2560
$B \rightarrow K \ell^+ \ell^-$	B1	( 5.4 $\pm$ 0.8 )	$\times 10^{-7}$	2617
$B \rightarrow K^*(892) \ell^+ \ell^-$	B1	( 1.05 $\pm$ 0.20 )	$\times 10^{-6}$	2564
$B \rightarrow e^\pm \mu^\mp s$	LF [c]	< 2.2	$\times 10^{-5}$	CL=90% –
$B \rightarrow \pi e^\pm \mu^\mp$	LF	< 1.6	$\times 10^{-6}$	CL=90% 2637
$B \rightarrow \rho e^\pm \mu^\mp$	LF	< 3.2	$\times 10^{-6}$	CL=90% 2582
$B \rightarrow K e^\pm \mu^\mp$	LF	< 1.6	$\times 10^{-6}$	CL=90% 2616
$B \rightarrow K^*(892) e^\pm \mu^\mp$	LF	< 6.2	$\times 10^{-6}$	CL=90% 2563

**$B^\pm/B^0/B_s^0/b$ -baryon ADMIXTURE**

These measurements are for an admixture of bottom particles at high energy (LEP, Tevatron,  $S\bar{p}\bar{p}S$ ).

$$\text{Mean life } \tau = (1.564 \pm 0.014) \times 10^{-12} \text{ s}$$

$$\text{Mean life } \tau = (1.72 \pm 0.10) \times 10^{-12} \text{ s} \quad \text{Charged } b\text{-hadron admixture}$$

$$\text{Mean life } \tau = (1.58 \pm 0.14) \times 10^{-12} \text{ s} \quad \text{Neutral } b\text{-hadron admixture}$$

$$\tau_{\text{charged } b\text{-hadron}}/\tau_{\text{neutral } b\text{-hadron}} = 1.09 \pm 0.13$$

$$|\Delta\tau_b|/\tau_{b,\bar{b}} = -0.001 \pm 0.014$$

The branching fraction measurements are for an admixture of  $B$  mesons and baryons at energies above the  $\Upsilon(4S)$ . Only the highest energy results (LEP, Tevatron,  $S\bar{p}\bar{p}S$ ) are used in the branching fraction averages. In the following, we assume that the production fractions are the same at the LEP and at the Tevatron.

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.

The modes below are listed for a  $\bar{b}$  initial state.  $b$  modes are their charge conjugates. Reactions indicate the weak decay vertex and do not include mixing.

$\bar{b}$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor/ Confidence level	$p$ (MeV/c)
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### PRODUCTION FRACTIONS

The production fractions for weakly decaying  $b$ -hadrons at high energy have been calculated from the best values of mean lives, mixing parameters, and branching fractions in this edition by the Heavy Flavor Averaging Group (HFAG) as described in the note " $B^0$ - $\bar{B}^0$  Mixing" in the  $B^0$  Particle Listings. Values assume

$$B(\bar{b} \rightarrow B^+) = B(\bar{b} \rightarrow B^0)$$

$$B(\bar{b} \rightarrow B^+) + B(\bar{b} \rightarrow B^0) + B(\bar{b} \rightarrow B_s^0) + B(b \rightarrow b\text{-baryon}) = 100 \%$$

The notation for production fractions varies in the literature ( $f_d$ ,  $d_{B^0}$ ,  $f(b \rightarrow \bar{B}^0)$ ,  $\text{Br}(b \rightarrow \bar{B}^0)$ ). We use our own branching fraction notation here,  $B(\bar{b} \rightarrow B^0)$ .

$B^+$	( 39.7 $\pm$ 1.0 ) %	—
$B^0$	( 39.7 $\pm$ 1.0 ) %	—
$B_s^0$	( 10.7 $\pm$ 1.1 ) %	—
$b$ -baryon	( 9.9 $\pm$ 1.7 ) %	—
$B_c$	—	—

### DECAY MODES

#### Semileptonic and leptonic modes

$\nu$ anything	( 23.1 $\pm$ 1.5 ) %	—
$\ell^+ \nu_\ell$ anything	[a] ( 10.68 $\pm$ 0.22 ) %	—
$e^+ \nu_e$ anything	( 10.86 $\pm$ 0.35 ) %	—
$\mu^+ \nu_\mu$ anything	( 10.95 $^{+0.29}_{-0.25}$ ) %	—
$D^- \ell^+ \nu_\ell$ anything	[a] ( 2.3 $\pm$ 0.4 ) %	S=1.7 —
$D^- \pi^+ \ell^+ \nu_\ell$ anything	( 4.9 $\pm$ 1.9 ) $\times 10^{-3}$	—
$D^- \pi^- \ell^+ \nu_\ell$ anything	( 2.6 $\pm$ 1.6 ) $\times 10^{-3}$	—
$\bar{D}^0 \ell^+ \nu_\ell$ anything	[a] ( 6.90 $\pm$ 0.35 ) %	—
$\bar{D}^0 \pi^- \ell^+ \nu_\ell$ anything	( 1.07 $\pm$ 0.27 ) %	—
$\bar{D}^0 \pi^+ \ell^+ \nu_\ell$ anything	( 2.3 $\pm$ 1.6 ) $\times 10^{-3}$	—
$D^{*-} \ell^+ \nu_\ell$ anything	[a] ( 2.75 $\pm$ 0.19 ) %	—
$D^{*-} \pi^+ \ell^+ \nu_\ell$ anything	( 4.8 $\pm$ 1.0 ) $\times 10^{-3}$	—
$D^{*-} \pi^- \ell^+ \nu_\ell$ anything	( 6 $\pm$ 7 ) $\times 10^{-4}$	—
$D_j^- \ell^+ \nu_\ell$ anything	[a,h] seen	—
$D_2^*(2460)^- \ell^+ \nu_\ell$ anything	seen	—

charmless $\ell\bar{\nu}_\ell$	[a]	$(1.7 \pm 0.5) \times 10^{-3}$	—
$\tau^+ \nu_\tau$ anything		$(2.48 \pm 0.26) \%$	—
$D^{*-} \tau \nu_\tau$ anything		$(9 \pm 4) \times 10^{-3}$	—
$\bar{c} \rightarrow \ell^- \bar{\nu}_\ell$ anything	[a]	$(8.0 \pm 0.4) \%$	—
$c \rightarrow \ell^+ \nu$ anything		$(1.6 \pm_{-0.5}^{+0.4}) \%$	—

### Charmed meson and baryon modes

$\bar{D}^0$ anything		$(61.0 \pm 3.2) \%$	—
$D^0 D_s^\pm$ anything	[c]	$(9.1 \pm_{-2.8}^{+3.9}) \%$	—
$D^\mp D_s^\pm$ anything	[c]	$(4.0 \pm_{-1.8}^{+2.3}) \%$	—
$\bar{D}^0 D^0$ anything	[c]	$(5.1 \pm_{-1.8}^{+2.0}) \%$	—
$D^0 D^\pm$ anything	[c]	$(2.7 \pm_{-1.6}^{+1.8}) \%$	—
$D^\pm D^\mp$ anything	[c]	$< 9 \times 10^{-3}$ CL=90%	—
$D^-$ anything		$(23.1 \pm 2.2) \%$	—
$D^*(2010)^+$ anything		$(17.3 \pm 2.0) \%$	—
$D_1(2420)^0$ anything		$(5.0 \pm 1.5) \%$	—
$D^*(2010)^\mp D_s^\pm$ anything	[c]	$(3.3 \pm_{-1.3}^{+1.6}) \%$	—
$D^0 D^*(2010)^\pm$ anything	[c]	$(3.0 \pm_{-0.9}^{+1.1}) \%$	—
$D^*(2010)^\pm D^\mp$ anything	[c]	$(2.5 \pm_{-1.0}^{+1.2}) \%$	—
$D^*(2010)^\pm D^*(2010)^\mp$ anything	[c]	$(1.2 \pm 0.4) \%$	—
$D_2^*(2460)^0$ anything		$(4.7 \pm 2.7) \%$	—
$D_s^-$ anything		$(18 \pm 5) \%$	—
$D_s^+$ anything		$(10.1 \pm 3.1) \%$	—
$\Lambda_c^+$ anything		$(9.7 \pm 2.9) \%$	—
$\bar{c}/c$ anything	[g]	$(116.6 \pm 3.3) \%$	—

### Charmonium modes

$J/\psi(1S)$ anything		$(1.16 \pm 0.10) \%$	—
$\psi(2S)$ anything		$(4.8 \pm 2.4) \times 10^{-3}$	—
$\chi_{c1}(1P)$ anything		$(1.5 \pm 0.5) \%$	—

### K or K\* modes

$\bar{s}\gamma$		$(3.1 \pm 1.1) \times 10^{-4}$	—
$\bar{s}\bar{\nu}\nu$	<	$6.4 \times 10^{-4}$ CL=90%	—
$K^\pm$ anything		$(74 \pm 6) \%$	—
$K_S^0$ anything		$(29.0 \pm 2.9) \%$	—

### Pion modes

$\pi^\pm$ anything		$(397 \pm 21) \%$	—
$\pi^0$ anything	[g]	$(278 \pm 60) \%$	—
$\phi$ anything		$(2.82 \pm 0.23) \%$	—

**Baryon modes**

$p/\bar{p}$  anything ( 13.1 ± 1.1 ) % —

**Other modes**

charged anything [g] (497 ± 7 ) % —

hadron<sup>+</sup> hadron<sup>-</sup> ( 1.7  $\pm$   $\frac{1.0}{0.7}$  ) × 10<sup>-5</sup> —

charmless ( 7 ± 21 ) × 10<sup>-3</sup> —

**Baryon modes**

$\Lambda/\bar{\Lambda}$  anything ( 5.9 ± 0.6 ) % —

$b$ -baryon anything ( 10.2 ± 2.8 ) % —

**$\Delta B = 1$  weak neutral current ( $B1$ ) modes**

$\mu^+ \mu^-$  anything  $B1$  < 3.2 × 10<sup>-4</sup> CL=90% —

<b><math>B^*</math></b>	$I(J^P) = \frac{1}{2}(1^-)$
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$I, J, P$  need confirmation. Quantum numbers shown are quark-model predictions.

Mass  $m_{B^*} = 5325.0 \pm 0.6$  MeV

$m_{B^*} - m_B = 45.78 \pm 0.35$  MeV

<b><math>B^*</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$B\gamma$	dominant	45

NOTES

- [a] An  $\ell$  indicates an  $e$  or a  $\mu$  mode, not a sum over these modes.
- [b]  $B^0$  and  $B_s^0$  contributions not separated. Limit is on weighted average of the two decay rates.
- [c] The value is for the sum of the charge states or particle/antiparticle states indicated.
- [d] These values are model dependent. See 'Note on Semileptonic Decays' in the  $B^+$  Particle Listings.
- [e]  $D^{**}$  stands for the sum of the  $D(1^1P_1)$ ,  $D(1^3P_0)$ ,  $D(1^3P_1)$ ,  $D(1^3P_2)$ ,  $D(2^1S_0)$ , and  $D(2^1S_1)$  resonances.
- [f]  $D^{(*)}\bar{D}^{(*)}$  stands for the sum of  $D^*\bar{D}^*$ ,  $D^*\bar{D}$ ,  $D\bar{D}^*$ , and  $D\bar{D}$ .
- [g] Inclusive branching fractions have a multiplicity definition and can be greater than 100%.
- [h]  $D_j$  represents an unresolved mixture of pseudoscalar and tensor  $D^{**}$  ( $P$ -wave) states.