

# LIGHT UNFLAVORED MESONS

## ( $S = C = B = 0$ )

For  $I = 1$  ( $\pi, \rho, \omega$ ):  $u\bar{d}, (u\bar{u}-d\bar{d})/\sqrt{2}, d\bar{u}$ ;  
 for  $I = 0$  ( $\eta, \eta', h, h', \omega, \phi, f, f'$ ):  $c_1(u\bar{u} + d\bar{d}) + c_2(s\bar{s})$

### $\pi^\pm$

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

Mass  $m = 139.57018 \pm 0.00035$  MeV ( $S = 1.2$ )

Mean life  $\tau = (2.6033 \pm 0.0005) \times 10^{-8}$  s ( $S = 1.2$ )

$$c\tau = 7.8045 \text{ m}$$

$\pi^\pm \rightarrow \ell^\pm \nu \gamma$  form factors [a]

$$F_V = 0.017 \pm 0.008$$

$$F_A = 0.0116 \pm 0.0016 \quad (S = 1.3)$$

$$R = 0.059^{+0.009}_{-0.008}$$

$\pi^-$  modes are charge conjugates of the modes below.

For decay limits to particles which are not established, see the appropriate Search sections (Massive Neutrino Peak Search Test,  $A^0$  (axion), and Other Light Boson ( $X^0$ ) Searches, etc.).

$\pi^+$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level	$p$ (MeV/c)
$\mu^+ \nu_\mu$	[b] (99.98770 $\pm$ 0.00004) %		30
$\mu^+ \nu_\mu \gamma$	[c] ( 2.00 $\pm$ 0.25 ) $\times 10^{-4}$		30
$e^+ \nu_e$	[b] ( 1.230 $\pm$ 0.004 ) $\times 10^{-4}$		70
$e^+ \nu_e \gamma$	[c] ( 1.61 $\pm$ 0.23 ) $\times 10^{-7}$		70
$e^+ \nu_e \pi^0$	( 1.025 $\pm$ 0.034 ) $\times 10^{-8}$		4
$e^+ \nu_e e^+ e^-$	( 3.2 $\pm$ 0.5 ) $\times 10^{-9}$		70
$e^+ \nu_e \nu \bar{\nu}$	< 5	$\times 10^{-6}$ 90%	70

#### Lepton Family number (LF) or Lepton number (L) violating modes

$\mu^+ \bar{\nu}_e$	L	[d] < 1.5	$\times 10^{-3}$ 90%	30
$\mu^+ \nu_e$	LF	[d] < 8.0	$\times 10^{-3}$ 90%	30
$\mu^- e^+ e^+ \nu$	LF	< 1.6	$\times 10^{-6}$ 90%	30



$$J^{PC} = 1^-(0^-+)$$

Mass  $m = 134.9766 \pm 0.0006$  MeV (S = 1.1)  
 $m_{\pi^\pm} - m_{\pi^0} = 4.5936 \pm 0.0005$  MeV  
 Mean life  $\tau = (8.4 \pm 0.6) \times 10^{-17}$  s (S = 3.0)  
 $c\tau = 25.1$  nm

For decay limits to particles which are not established, see the appropriate Search sections ( $A^0$  (axion), and Other Light Boson ( $X^0$ ) Searches, etc.).

$\pi^0$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor/ Confidence level	$p$ (MeV/c)
$2\gamma$	$(98.798 \pm 0.032) \%$	S=1.1	67
$e^+ e^- \gamma$	$(1.198 \pm 0.032) \%$	S=1.1	67
$\gamma$ positronium	$(1.82 \pm 0.29) \times 10^{-9}$		67
$e^+ e^+ e^- e^-$	$(3.14 \pm 0.30) \times 10^{-5}$		67
$e^+ e^-$	$(6.2 \pm 0.5) \times 10^{-8}$		67
$4\gamma$	$< 2$	$\times 10^{-8}$ CL=90%	67
$\nu \bar{\nu}$	$[e] < 8.3$	$\times 10^{-7}$ CL=90%	67
$\nu_e \bar{\nu}_e$	$< 1.7$	$\times 10^{-6}$ CL=90%	67
$\nu_\mu \bar{\nu}_\mu$	$< 3.1$	$\times 10^{-6}$ CL=90%	67
$\nu_\tau \bar{\nu}_\tau$	$< 2.1$	$\times 10^{-6}$ CL=90%	67
$\gamma \nu \bar{\nu}$	$< 6$	$\times 10^{-4}$ CL=90%	67

**Charge conjugation (C) or Lepton Family number (LF) violating modes**

$3\gamma$	C	$< 3.1$	$\times 10^{-8}$ CL=90%	67
$\mu^+ e^-$	LF	$< 3.8$	$\times 10^{-10}$ CL=90%	26
$\mu^- e^+$	LF	$< 3.4$	$\times 10^{-9}$ CL=90%	26
$\mu^+ e^- + \mu^- e^+$	LF	$< 1.72$	$\times 10^{-8}$ CL=90%	26



$$J^{PC} = 0^+(0^-+)$$

Mass  $m = 547.75 \pm 0.12$  MeV [ $f$ ] (S = 2.6)  
 Full width  $\Gamma = 1.29 \pm 0.07$  keV [ $g$ ]

**C-nonconserving decay parameters**

$\pi^+ \pi^- \pi^0$  Left-right asymmetry =  $(0.09 \pm 0.17) \times 10^{-2}$   
 $\pi^+ \pi^- \pi^0$  Sextant asymmetry =  $(0.18 \pm 0.16) \times 10^{-2}$   
 $\pi^+ \pi^- \pi^0$  Quadrant asymmetry =  $(-0.17 \pm 0.17) \times 10^{-2}$   
 $\pi^+ \pi^- \gamma$  Left-right asymmetry =  $(0.9 \pm 0.4) \times 10^{-2}$   
 $\pi^+ \pi^- \gamma$   $\beta$  (D-wave) =  $-0.02 \pm 0.07$  (S = 1.3)

**Dalitz plot parameter**

$$\pi^0 \pi^0 \pi^0 \quad \alpha = -0.031 \pm 0.004 \quad (S = 1.1)$$

$\eta$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor/ Confidence level	$p$ (MeV/c)
<b>Neutral modes</b>			
neutral modes	(72.0 $\pm$ 0.5 ) %	S=1.3	–
$2\gamma$	[ <i>g</i> ] (39.43 $\pm$ 0.26) %	S=1.2	274
$3\pi^0$	(32.51 $\pm$ 0.29) %	S=1.2	179
$\pi^0 2\gamma$	( 7.2 $\pm$ 1.4 ) $\times 10^{-4}$		257
other neutral modes	< 2.8 %	CL=90%	–
<b>Charged modes</b>			
charged modes	(28.0 $\pm$ 0.5 ) %	S=1.3	–
$\pi^+ \pi^- \pi^0$	(22.6 $\pm$ 0.4 ) %	S=1.3	174
$\pi^+ \pi^- \gamma$	( 4.68 $\pm$ 0.11) %	S=1.2	236
$e^+ e^- \gamma$	( 6.0 $\pm$ 0.8 ) $\times 10^{-3}$	S=1.4	274
$\mu^+ \mu^- \gamma$	( 3.1 $\pm$ 0.4 ) $\times 10^{-4}$		253
$e^+ e^-$	< 7.7 $\times 10^{-5}$	CL=90%	274
$\mu^+ \mu^-$	( 5.8 $\pm$ 0.8 ) $\times 10^{-6}$		253
$e^+ e^- e^+ e^-$	< 6.9 $\times 10^{-5}$	CL=90%	274
$\pi^+ \pi^- e^+ e^-$	( 4.0 $^{+14.0}_{-2.7}$ ) $\times 10^{-4}$	S=5.8	235
$\pi^+ \pi^- 2\gamma$	< 2.0 $\times 10^{-3}$		236
$\pi^+ \pi^- \pi^0 \gamma$	< 5 $\times 10^{-4}$	CL=90%	174
$\pi^0 \mu^+ \mu^- \gamma$	< 3 $\times 10^{-6}$	CL=90%	210
<b>Charge conjugation (C), Parity (P), Charge conjugation <math>\times</math> Parity (CP), or Lepton Family number (LF) violating modes</b>			
$\pi^+ \pi^-$	<i>P, CP</i> < 3.3	$\times 10^{-4}$	CL=90% 236
$\pi^0 \pi^0$	<i>P, CP</i> < 4.3	$\times 10^{-4}$	CL=90% 238
$3\gamma$	<i>C</i> < 5	$\times 10^{-4}$	CL=95% 274
$4\pi^0$	<i>P, CP</i> < 6.9	$\times 10^{-7}$	CL=90% 40
$\pi^0 e^+ e^-$	<i>C</i> [ <i>h</i> ] < 4	$\times 10^{-5}$	CL=90% 257
$\pi^0 \mu^+ \mu^-$	<i>C</i> [ <i>h</i> ] < 5	$\times 10^{-6}$	CL=90% 210
$\mu^+ e^- + \mu^- e^+$	<i>LF</i> < 6	$\times 10^{-6}$	CL=90% 264

**$f_0(600)$  [i]**  
or  $\sigma$

$$I^G(J^{PC}) = 0^+(0^{++})$$

Mass  $m = (400\text{--}1200)$  MeV

Full width  $\Gamma = (600\text{--}1000)$  MeV

<b><math>f_0(600)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\pi\pi$	dominant	—
$\gamma\gamma$	seen	—

**$\rho(770)$  [j]**

$$I^G(J^{PC}) = 1^+(1^{--})$$

Mass  $m = 775.8 \pm 0.5$  MeV

Full width  $\Gamma = 150.3 \pm 1.6$  MeV

$\Gamma_{ee} = 7.02 \pm 0.11$  keV

<b><math>\rho(770)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor/ Confidence level	$p$ (MeV/c)
$\pi\pi$	$\sim 100$	%	364
<b><math>\rho(770)^\pm</math> decays</b>			
$\pi^\pm\gamma$	$(4.5 \pm 0.5) \times 10^{-4}$	S=2.2	375
$\pi^\pm\eta$	$< 6 \times 10^{-3}$	CL=84%	153
$\pi^\pm\pi^+\pi^-\pi^0$	$< 2.0 \times 10^{-3}$	CL=84%	254
<b><math>\rho(770)^0</math> decays</b>			
$\pi^+\pi^-\gamma$	$(9.9 \pm 1.6) \times 10^{-3}$		362
$\pi^0\gamma$	$(6.0 \pm 1.3) \times 10^{-4}$	S=1.1	376
$\eta\gamma$	$(3.0 \pm 0.4) \times 10^{-4}$	S=1.4	195
$\pi^0\pi^0\gamma$	$(4.5 \pm 0.8) \times 10^{-5}$		364
$\mu^+\mu^-$	[k] $(4.55 \pm 0.28) \times 10^{-5}$		373
$e^+e^-$	[k] $(4.67 \pm 0.09) \times 10^{-5}$		388
$\pi^+\pi^-\pi^0$	$(1.01^{+0.54}_{-0.36} \pm 0.34) \times 10^{-4}$		323
$\pi^+\pi^-\pi^+\pi^-$	$(1.8 \pm 0.9) \times 10^{-5}$		251
$\pi^+\pi^-\pi^0\pi^0$	$< 4 \times 10^{-5}$	CL=90%	257

## $\omega(782)$

$$I^G(J^{PC}) = 0^-(1^{--})$$

Mass  $m = 782.59 \pm 0.11$  MeV ( $S = 1.7$ )

Full width  $\Gamma = 8.49 \pm 0.08$  MeV

$\Gamma_{ee} = 0.60 \pm 0.02$  keV

$\omega(782)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor/ Confidence level	$p$ (MeV/c)
$\pi^+\pi^-\pi^0$	(89.1 $\pm$ 0.7 ) %	S=1.1	327
$\pi^0\gamma$	( 8.92 <sup>+0.28</sup> <sub>-0.24</sub> ) %	S=1.1	380
$\pi^+\pi^-$	( 1.70 $\pm$ 0.27 ) %	S=1.4	366
neutrals (excluding $\pi^0\gamma$ )	( 1.4 <sup>+7.0</sup> <sub>-0.9</sub> ) $\times 10^{-3}$		—
$\eta\gamma$	( 4.9 $\pm$ 0.5 ) $\times 10^{-4}$		200
$\pi^0e^+e^-$	( 5.9 $\pm$ 1.9 ) $\times 10^{-4}$		380
$\pi^0\mu^+\mu^-$	( 9.6 $\pm$ 2.3 ) $\times 10^{-5}$		349
$e^+e^-$	( 7.14 $\pm$ 0.13 ) $\times 10^{-5}$	S=1.1	391
$\pi^+\pi^-\pi^0\pi^0$	< 2 %	CL=90%	262
$\pi^+\pi^-\gamma$	< 3.6 $\times 10^{-3}$	CL=95%	366
$\pi^+\pi^-\pi^+\pi^-$	< 1 $\times 10^{-3}$	CL=90%	256
$\pi^0\pi^0\gamma$	( 6.7 $\pm$ 1.1 ) $\times 10^{-5}$		367
$\eta\pi^0\gamma$	< 3.3 $\times 10^{-5}$	CL=90%	162
$\mu^+\mu^-$	( 9.0 $\pm$ 3.1 ) $\times 10^{-5}$		377
$3\gamma$	< 1.9 $\times 10^{-4}$	CL=95%	391
<b>Charge conjugation (C) violating modes</b>			
$\eta\pi^0$	C < 1 $\times 10^{-3}$	CL=90%	162
$3\pi^0$	C < 3 $\times 10^{-4}$	CL=90%	330

## $\eta'(958)$

$$I^G(J^{PC}) = 0^+(0^{-+})$$

Mass  $m = 957.78 \pm 0.14$  MeV

Full width  $\Gamma = 0.202 \pm 0.016$  MeV ( $S = 1.3$ )

$\eta'(958)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor/ Confidence level	$p$ (MeV/c)
$\pi^+\pi^-\eta$	(44.3 $\pm$ 1.5 ) %	S=1.2	232
$\rho^0\gamma$ (including non-resonant $\pi^+\pi^-\gamma$ )	(29.5 $\pm$ 1.0 ) %	S=1.2	165
$\pi^0\pi^0\eta$	(20.9 $\pm$ 1.2 ) %	S=1.2	239
$\omega\gamma$	( 3.03 $\pm$ 0.31 ) %		159
$\gamma\gamma$	( 2.12 $\pm$ 0.14 ) %	S=1.3	479
$3\pi^0$	( 1.56 $\pm$ 0.26 ) $\times 10^{-3}$		430
$\mu^+\mu^-\gamma$	( 1.04 $\pm$ 0.26 ) $\times 10^{-4}$		467
$\pi^+\pi^-\pi^0$	< 5 %	CL=90%	428

$\pi^0 \rho^0$	< 4	%	CL=90%	110
$\pi^+ \pi^+ \pi^- \pi^-$	< 1	%	CL=90%	372
$\pi^+ \pi^+ \pi^- \pi^-$ neutrals	< 1	%	CL=95%	–
$\pi^+ \pi^+ \pi^- \pi^- \pi^0$	< 1	%	CL=90%	298
$6\pi$	< 1	%	CL=90%	211
$\pi^+ \pi^- e^+ e^-$	< 6	$\times 10^{-3}$	CL=90%	458
$\gamma e^+ e^-$	< 9	$\times 10^{-4}$	CL=90%	479
$\pi^0 \gamma \gamma$	< 8	$\times 10^{-4}$	CL=90%	469
$4\pi^0$	< 5	$\times 10^{-4}$	CL=90%	380
$e^+ e^-$	< 2.1	$\times 10^{-7}$	CL=90%	479

**Charge conjugation (C), Parity (P),  
Lepton family number (LF) violating modes**

$\pi^+ \pi^-$	<i>P, CP</i>	< 2	%	CL=90%	458
$\pi^0 \pi^0$	<i>P, CP</i>	< 9	$\times 10^{-4}$	CL=90%	459
$\pi^0 e^+ e^-$	<i>C</i>	[ <i>h</i> ] < 1.4	$\times 10^{-3}$	CL=90%	469
$\eta e^+ e^-$	<i>C</i>	[ <i>h</i> ] < 2.4	$\times 10^{-3}$	CL=90%	322
$3\gamma$	<i>C</i>	< 1.0	$\times 10^{-4}$	CL=90%	479
$\mu^+ \mu^- \pi^0$	<i>C</i>	[ <i>h</i> ] < 6.0	$\times 10^{-5}$	CL=90%	445
$\mu^+ \mu^- \eta$	<i>C</i>	[ <i>h</i> ] < 1.5	$\times 10^{-5}$	CL=90%	273
$e\mu$	<i>LF</i>	< 4.7	$\times 10^{-4}$	CL=90%	473

**$f_0(980)$**  [<sup>1</sup>]

$$I^G(J^{PC}) = 0^+(0^{++})$$

Mass  $m = 980 \pm 10$  MeV

Full width  $\Gamma = 40$  to 100 MeV

<b><math>f_0(980)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\pi\pi$	dominant	471
$K\bar{K}$	seen	†
$\gamma\gamma$	seen	490

**$a_0(980)$**  [<sup>1</sup>]

$$I^G(J^{PC}) = 1^-(0^{++})$$

Mass  $m = 984.7 \pm 1.2$  MeV ( $S = 1.5$ )

Full width  $\Gamma = 50$  to 100 MeV

<b><math>a_0(980)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\eta\pi$	dominant	322
$K\bar{K}$	seen	†
$\gamma\gamma$	seen	492

**$\phi(1020)$**

$$I^G(J^{PC}) = 0^-(1^{--})$$

Mass  $m = 1019.456 \pm 0.020$  MeV (S = 1.1)

Full width  $\Gamma = 4.26 \pm 0.05$  MeV (S = 1.7)

<b><math>\phi(1020)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor/ Confidence level	$p$ (MeV/c)
$K^+ K^-$	(49.1 $\pm$ 0.6 ) %	S=1.2	127
$K_L^0 K_S^0$	(34.0 $\pm$ 0.5 ) %	S=1.1	110
$\rho\pi + \pi^+\pi^-\pi^0$	(15.4 $\pm$ 0.5 ) %	S=1.3	—
$\eta\gamma$	( 1.295 $\pm$ 0.025) %	S=1.1	363
$\pi^0\gamma$	( 1.23 $\pm$ 0.10 ) $\times 10^{-3}$		501
$e^+e^-$	( 2.98 $\pm$ 0.04 ) $\times 10^{-4}$	S=1.1	510
$\mu^+\mu^-$	( 2.85 $\pm$ 0.19 ) $\times 10^{-4}$		499
$\eta e^+e^-$	( 1.15 $\pm$ 0.10 ) $\times 10^{-4}$		363
$\pi^+\pi^-$	( 7.3 $\pm$ 1.3 ) $\times 10^{-5}$		490
$\omega\pi^0$	( 5.2 $\begin{smallmatrix} +1.3 \\ -1.1 \end{smallmatrix}$ ) $\times 10^{-5}$		172
$\omega\gamma$	< 5 %	CL=84%	209
$\rho\gamma$	< 1.2 $\times 10^{-5}$	CL=90%	215
$\pi^+\pi^-\gamma$	( 4.1 $\pm$ 1.3 ) $\times 10^{-5}$		490
$f_0(980)\gamma$	( 4.40 $\pm$ 0.21 ) $\times 10^{-4}$		39
$\pi^0\pi^0\gamma$	( 1.09 $\pm$ 0.06 ) $\times 10^{-4}$		492
$\pi^+\pi^-\pi^+\pi^-$	( 3.9 $\begin{smallmatrix} +2.8 \\ -2.2 \end{smallmatrix}$ ) $\times 10^{-6}$		410
$\pi^+\pi^+\pi^-\pi^-\pi^0$	< 4.6 $\times 10^{-6}$	CL=90%	342
$\pi^0 e^+ e^-$	( 1.12 $\pm$ 0.28 ) $\times 10^{-5}$		501
$\pi^0\eta\gamma$	( 8.3 $\pm$ 0.5 ) $\times 10^{-5}$		346
$a_0(980)\gamma$	( 7.6 $\pm$ 0.6 ) $\times 10^{-5}$		34
$\eta'(958)\gamma$	( 6.2 $\pm$ 0.7 ) $\times 10^{-5}$	S=1.1	60
$\eta\pi^0\pi^0\gamma$	< 2 $\times 10^{-5}$	CL=90%	293
$\mu^+\mu^-\gamma$	( 1.4 $\pm$ 0.5 ) $\times 10^{-5}$		499
$\rho\gamma\gamma$	< 5 $\times 10^{-4}$	CL=90%	215
$\eta\pi^+\pi^-$	< 1.8 $\times 10^{-5}$	CL=90%	288
$\eta\mu^+\mu^-$	< 9.4 $\times 10^{-6}$	CL=90%	321

**$h_1(1170)$**

$$I^G(J^{PC}) = 0^-(1^{+-})$$

Mass  $m = 1170 \pm 20$  MeV

Full width  $\Gamma = 360 \pm 40$  MeV

<b><math>h_1(1170)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\rho\pi$	seen	307

**$b_1(1235)$**

$$I^G(J^{PC}) = 1^+(1^+ -)$$

Mass  $m = 1229.5 \pm 3.2$  MeV (S = 1.6)

Full width  $\Gamma = 142 \pm 9$  MeV (S = 1.2)

<b><math>b_1(1235)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level	$p$ (MeV/c)
$\omega\pi$	dominant		348
[D/S amplitude ratio = $0.277 \pm 0.027$ ]			
$\pi^\pm\gamma$	$(1.6 \pm 0.4) \times 10^{-3}$		607
$\eta\rho$	seen		†
$\pi^+\pi^+\pi^-\pi^0$	< 50 %	84%	535
$(K\bar{K})^\pm\pi^0$	< 8 %	90%	248
$K_S^0 K_L^0 \pi^\pm$	< 6 %	90%	235
$K_S^0 K_S^0 \pi^\pm$	< 2 %	90%	235
$\phi\pi$	< 1.5 %	84%	147

**$a_1(1260)$  [ $m$ ]**

$$I^G(J^{PC}) = 1^-(1^{++})$$

Mass  $m = 1230 \pm 40$  MeV [ $n$ ]

Full width  $\Gamma = 250$  to  $600$  MeV

<b><math>a_1(1260)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$(\rho\pi)_{S\text{-wave}}$	seen	353
$(\rho\pi)_{D\text{-wave}}$	seen	353
$(\rho(1450)\pi)_{S\text{-wave}}$	seen	†
$(\rho(1450)\pi)_{D\text{-wave}}$	seen	†
$\sigma\pi$	seen	—
$f_0(980)\pi$	not seen	189
$f_0(1370)\pi$	seen	—
$f_2(1270)\pi$	seen	†
$K\bar{K}^*(892) + \text{c.c.}$	seen	†
$\pi\gamma$	seen	608

**$f_2(1270)$**

$$I^G(J^{PC}) = 0^+(2^{++})$$

Mass  $m = 1275.4 \pm 1.2$  MeV

Full width  $\Gamma = 185.1^{+3.5}_{-2.6}$  MeV (S = 1.5)

<b><math>f_2(1270)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor/ Confidence level	$p$ (MeV/c)
$\pi\pi$	$(84.8^{+2.5}_{-1.3})\%$	S=1.3	623
$\pi^+\pi^-\pi^0$	$(7.1^{+1.5}_{-2.7})\%$	S=1.3	563



$K\bar{K}$	( 4.6 ± 0.4 ) %	S=2.7	404
$2\pi^+ 2\pi^-$	( 2.8 ± 0.4 ) %	S=1.2	559
$\eta\eta$	( 4.5 ± 1.0 ) × 10 <sup>-3</sup>	S=2.4	327
$4\pi^0$	( 3.0 ± 1.0 ) × 10 <sup>-3</sup>		565
$\gamma\gamma$	( 1.41 ± 0.13 ) × 10 <sup>-5</sup>		638
$\eta\pi\pi$	< 8 × 10 <sup>-3</sup>	CL=95%	478
$K^0 K^- \pi^+ + \text{c.c.}$	< 3.4 × 10 <sup>-3</sup>	CL=95%	293
$e^+ e^-$	< 6 × 10 <sup>-10</sup>	CL=90%	638

## $f_1(1285)$

$$J^{PC} = 0^+(1^{++})$$

Mass  $m = 1281.8 \pm 0.6$  MeV (S = 1.6)

Full width  $\Gamma = 24.1 \pm 1.1$  MeV (S = 1.3)

$f_1(1285)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor/ Confidence level	$p$ (MeV/c)
$4\pi$	(33.1 <sup>+2.1</sup> <sub>-1.8</sub> ) %	S=1.3	568
$\pi^0 \pi^0 \pi^+ \pi^-$	(22.0 <sup>+1.4</sup> <sub>-1.2</sub> ) %	S=1.3	566
$2\pi^+ 2\pi^-$	(11.0 <sup>+0.7</sup> <sub>-0.6</sub> ) %	S=1.3	563
$\rho^0 \pi^+ \pi^-$	(11.0 <sup>+0.7</sup> <sub>-0.6</sub> ) %	S=1.3	336
$\rho^0 \rho^0$	seen		†
$4\pi^0$	< 7 × 10 <sup>-4</sup>	CL=90%	568
$\eta\pi\pi$	(52 ± 16 ) %		482
$a_0(980)\pi$ [ignoring $a_0(980) \rightarrow K\bar{K}$ ]	(36 ± 7 ) %		234
$\eta\pi\pi$ [excluding $a_0(980)\pi$ ]	(16 ± 7 ) %		482
$K\bar{K}\pi$	( 9.0 ± 0.4 ) %	S=1.1	308
$K\bar{K}^*(892)$	not seen		†
$\gamma\rho^0$	( 5.5 ± 1.3 ) %	S=2.8	406
$\phi\gamma$	( 7.4 ± 2.6 ) × 10 <sup>-4</sup>		236

**$\eta(1295)$**

$$I^G(J^{PC}) = 0^+(0^-+)$$

Mass  $m = 1294 \pm 4$  MeV ( $S = 1.6$ )

Full width  $\Gamma = 55 \pm 5$  MeV

<b><math>\eta(1295)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\eta\pi^+\pi^-$	seen	487
$a_0(980)\pi$	seen	244
$\eta\pi^0\pi^0$	seen	490
$\eta(\pi\pi)_{S\text{-wave}}$	seen	—

**$\pi(1300)$**

$$I^G(J^{PC}) = 1^-(0^-+)$$

Mass  $m = 1300 \pm 100$  MeV [ $\eta$ ]

Full width  $\Gamma = 200$  to  $600$  MeV

<b><math>\pi(1300)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\rho\pi$	seen	404
$\pi(\pi\pi)_{S\text{-wave}}$	seen	—

**$a_2(1320)$**

$$I^G(J^{PC}) = 1^-(2^{++})$$

Mass  $m = 1318.3 \pm 0.6$  MeV ( $S = 1.2$ )

Full width  $\Gamma = 107 \pm 5$  MeV [ $\eta$ ]

<b><math>a_2(1320)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor/ Confidence level	$p$ (MeV/c)
$\rho\pi$	(70.1 $\pm$ 2.7 ) %	S=1.2	416
$\eta\pi$	(14.5 $\pm$ 1.2 ) %		535
$\omega\pi\pi$	(10.6 $\pm$ 3.2 ) %	S=1.3	366
$K\bar{K}$	( 4.9 $\pm$ 0.8 ) %		437
$\eta'(958)\pi$	( 5.3 $\pm$ 0.9 ) $\times 10^{-3}$		288
$\pi^\pm\gamma$	( 2.68 $\pm$ 0.31 ) $\times 10^{-3}$		652
$\gamma\gamma$	( 9.4 $\pm$ 0.7 ) $\times 10^{-6}$		659
$\pi^+\pi^-\pi^-$	< 8 %	CL=90%	621
$e^+e^-$	< 6 $\times 10^{-9}$	CL=90%	659

**$f_0(1370)$**  [<sup>l</sup>]

$$I^G(J^{PC}) = 0^+(0^{++})$$

Mass  $m = 1200$  to  $1500$  MeV  
Full width  $\Gamma = 200$  to  $500$  MeV

<b><math>f_0(1370)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\pi\pi$	seen	—
$4\pi$	seen	—
$4\pi^0$	seen	—
$2\pi^+2\pi^-$	seen	—
$\pi^+\pi^-2\pi^0$	seen	—
$\rho\rho$	dominant	—
$2(\pi\pi)_{S\text{-wave}}$	seen	—
$\pi(1300)\pi$	seen	—
$a_1(1260)\pi$	seen	—
$\eta\eta$	seen	—
$K\bar{K}$	seen	—
$\gamma\gamma$	seen	—
$e^+e^-$	not seen	—

**$\pi_1(1400)$**  [<sup>o</sup>]

$$I^G(J^{PC}) = 1^-(1^{-+})$$

Mass  $m = 1376 \pm 17$  MeV  
Full width  $\Gamma = 300 \pm 40$  MeV

<b><math>\pi_1(1400)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\eta\pi^0$	seen	570
$\eta\pi^-$	seen	569

**$\eta(1405)$**  [<sup>p</sup>]  
was  $\eta(1440)$

$$I^G(J^{PC}) = 0^+(0^{-+})$$

Mass  $m = 1410.3 \pm 2.6$  MeV [<sup>n</sup>] ( $S = 2.2$ )  
Full width  $\Gamma = 51 \pm 4$  MeV [<sup>n</sup>] ( $S = 2.2$ )

<b><math>\eta(1405)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$K\bar{K}\pi$	seen	425
$\eta\pi\pi$	seen	563
$a_0(980)\pi$	seen	342

$\eta(\pi\pi)$ S-wave	seen	—
$f_0(980)\eta$	seen	†
$4\pi$	seen	639
$K^*(892)K$	seen	127

**$f_1(1420)$  [q]**

$$I^G(J^{PC}) = 0^+(1^{++})$$

Mass  $m = 1426.3 \pm 0.9$  MeV (S = 1.1)

Full width  $\Gamma = 54.9 \pm 2.6$  MeV

<b><math>f_1(1420)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$K\bar{K}\pi$	dominant	438
$K\bar{K}^*(892) + \text{c.c.}$	dominant	163
$\eta\pi\pi$	possibly seen	573
$\phi\gamma$	seen	349

**$\omega(1420)$  [r]**

$$I^G(J^{PC}) = 0^-(1^{--})$$

Mass  $m$  (1400–1450) MeV

Full width  $\Gamma$  (180–250) MeV

<b><math>\omega(1420)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\rho\pi$	dominant	488
$\omega\pi\pi$	seen	—
$b_1(1235)\pi$	seen	—
$e^+e^-$	seen	—

**$a_0(1450)$  [l]**

$$I^G(J^{PC}) = 1^-(0^{++})$$

Mass  $m = 1474 \pm 19$  MeV

Full width  $\Gamma = 265 \pm 13$  MeV

<b><math>a_0(1450)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\pi\eta$	seen	627
$\pi\eta'(958)$	seen	410
$K\bar{K}$	seen	547
$\omega\pi\pi$	seen	484

**$\rho(1450)$**  [s]

$$J^{PC} = 1^{+}(1^{-}-)$$

Mass  $m = 1465 \pm 25$  MeV [n]

Full width  $\Gamma = 400 \pm 60$  MeV [n]

<b><math>\rho(1450)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level	$p$ (MeV/c)
$\pi\pi$	seen		720
$4\pi$	seen		669
$\omega\pi$	<2.0 %	95%	512
$e^+e^-$	seen		732
$\eta\rho$	<4 %		310
$a_2(1320)\pi$	not seen		55
$\phi\pi$	<1 %		360
$K\bar{K}$	< $1.6 \times 10^{-3}$	95%	541
$\eta\gamma$	possibly seen		630

**$\eta(1475)$**  [ $\rho$ ]  
was  $\eta(1440)$

$$J^{PC} = 0^{+}(0^{-}+)$$

Mass  $m = 1476 \pm 4$  MeV (S = 1.4)

Full width  $\Gamma = 87 \pm 9$  MeV (S = 1.6)

<b><math>\eta(1475)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$K\bar{K}\pi$	dominant	477
$K\bar{K}^*(892)+$ c.c.	seen	245
$a_0(980)\pi$	seen	393
$\gamma\gamma$	seen	738

**$f_0(1500)$**  [o]

$$J^{PC} = 0^{+}(0^{++})$$

Mass  $m = 1507 \pm 5$  MeV (S = 1.2)

Full width  $\Gamma = 109 \pm 7$  MeV

<b><math>f_0(1500)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor	$p$ (MeV/c)
$\eta\eta'(958)$	( $1.9 \pm 0.8$ ) %	1.7	34
$\eta\eta$	( $5.1 \pm 0.9$ ) %	1.4	518
$4\pi$	( $49.5 \pm 3.3$ ) %	1.2	692
$4\pi^0$	seen		692
$2\pi^+2\pi^-$	seen		688

$\pi\pi$	$(34.9 \pm 2.3) \%$	1.2	741
$\pi^+\pi^-$	seen		741
$2\pi^0$	seen		741
$K\bar{K}$	$(8.6 \pm 1.0) \%$	1.1	569
$\gamma\gamma$	not seen		754

**$f'_2(1525)$**

$$I^G(J^{PC}) = 0^+(2^{++})$$

Mass  $m = 1525 \pm 5$  MeV [n]

Full width  $\Gamma = 73^{+6}_{-5}$  MeV [n]

<b><math>f'_2(1525)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$K\bar{K}$	$(88.8 \pm 3.1) \%$	581
$\eta\eta$	$(10.3 \pm 3.1) \%$	530
$\pi\pi$	$(8.2 \pm 1.5) \times 10^{-3}$	750
$\gamma\gamma$	$(1.11 \pm 0.14) \times 10^{-6}$	763

**$\pi_1(1600)$  [o]**

$$I^G(J^{PC}) = 1^-(1^{-+})$$

Mass  $m = 1596^{+25}_{-14}$  MeV

Full width  $\Gamma = 312^{+64}_{-24}$  MeV ( $S = 1.1$ )

<b><math>\pi_1(1600)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\pi\pi\pi$	seen	769
$\rho^0\pi^-$	seen	600
$f_2(1270)\pi^-$	not seen	259
$\eta'(958)\pi^-$	seen	497

**$\eta_2(1645)$**

$$I^G(J^{PC}) = 0^+(2^{-+})$$

Mass  $m = 1617 \pm 5$  MeV

Full width  $\Gamma = 181 \pm 11$  MeV

<b><math>\eta_2(1645)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$a_2(1320)\pi$	seen	242
$K\bar{K}\pi$	seen	580
$K^*\bar{K}$	seen	404
$\eta\pi^+\pi^-$	seen	685
$a_0(980)\pi$	seen	496
$f_2(1270)\eta$	not seen	†

**$\omega(1650)$  [<sup>t</sup>]**  
was  $\omega(1600)$

$$I^G(J^{PC}) = 0^-(1^{--})$$

Mass  $m = 1670 \pm 30$  MeV

Full width  $\Gamma = 315 \pm 35$  MeV

$\omega(1650)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\rho\pi$	seen	646
$\omega\pi\pi$	seen	617
$\omega\eta$	seen	500
$e^+e^-$	seen	835

**$\omega_3(1670)$**

$$I^G(J^{PC}) = 0^-(3^{--})$$

Mass  $m = 1667 \pm 4$  MeV

Full width  $\Gamma = 168 \pm 10$  MeV [<sup>n</sup>]

$\omega_3(1670)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\rho\pi$	seen	645
$\omega\pi\pi$	seen	615
$b_1(1235)\pi$	possibly seen	361

**$\pi_2(1670)$**

$$I^G(J^{PC}) = 1^-(2^{-+})$$

Mass  $m = 1672.4 \pm 3.2$  MeV [<sup>n</sup>] ( $S = 1.4$ )

Full width  $\Gamma = 259 \pm 9$  MeV [<sup>n</sup>] ( $S = 1.3$ )

$\pi_2(1670)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level	$p$ (MeV/c)
$3\pi$	$(95.8 \pm 1.4) \%$		809
$f_2(1270)\pi$	$(56.2 \pm 3.2) \%$		329
$\rho\pi$	$(31 \pm 4) \%$		648
$\sigma\pi$	$(10.9 \pm 3.4) \%$		—
$(\pi\pi)_{S\text{-wave}}$	$(8.7 \pm 3.4) \%$		—
$K\bar{K}^*(892) + \text{c.c.}$	$(4.2 \pm 1.4) \%$		455
$\omega\rho$	$(2.7 \pm 1.1) \%$		303
$\rho(1450)\pi$	$< 3.6 \times 10^{-3}$	97.7%	148
$b_1(1235)\pi$	$< 1.9 \times 10^{-3}$	97.7%	366

**$\phi(1680)$**

$$J^{PC} = 0^-(1^--)$$

Mass  $m = 1680 \pm 20$  MeV [ $n$ ]

Full width  $\Gamma = 150 \pm 50$  MeV [ $n$ ]

<b><math>\phi(1680)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$K\bar{K}^*(892) + \text{c.c.}$	dominant	462
$K_S^0 K \pi$	seen	621
$K\bar{K}$	seen	680
$e^+ e^-$	seen	840
$\omega \pi \pi$	not seen	623

**$\rho_3(1690)$**

$$J^{PC} = 1^+(3^--)$$

Mass  $m = 1688.8 \pm 2.1$  MeV [ $n$ ]

Full width  $\Gamma = 161 \pm 10$  MeV [ $n$ ] (S = 1.5)

<b><math>\rho_3(1690)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor	$p$ (MeV/c)
$4\pi$	(71.1 $\pm$ 1.9 ) %		790
$\pi^\pm \pi^+ \pi^- \pi^0$	(67 $\pm$ 22 ) %		787
$\omega \pi$	(16 $\pm$ 6 ) %		655
$\pi \pi$	(23.6 $\pm$ 1.3 ) %		834
$K\bar{K} \pi$	( 3.8 $\pm$ 1.2 ) %		629
$K\bar{K}$	( 1.58 $\pm$ 0.26) %	1.2	685
$\eta \pi^+ \pi^-$	seen		727
$\rho(770)\eta$	seen		520
$\pi \pi \rho$	seen		633
Excluding $2\rho$ and $a_2(1320)\pi$ .			
$a_2(1320)\pi$	seen		307
$\rho \rho$	seen		333

**$\rho(1700)$  [ $s$ ]**

$$J^{PC} = 1^+(1^--)$$

Mass  $m = 1720 \pm 20$  MeV [ $n$ ] ( $\eta \rho^0$  and  $\pi^+ \pi^-$  modes)

Full width  $\Gamma = 250 \pm 100$  MeV [ $n$ ] ( $\eta \rho^0$  and  $\pi^+ \pi^-$  modes)

<b><math>\rho(1700)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$2(\pi^+ \pi^-)$	large	803
$\rho \pi \pi$	dominant	653
$\rho^0 \pi^+ \pi^-$	large	650



$\rho^\pm \pi^\mp \pi^0$	large	651
$a_1(1260)\pi$	seen	404
$h_1(1170)\pi$	seen	447
$\pi(1300)\pi$	seen	349
$\rho\rho$	seen	371
$\pi^+\pi^-$	seen	849
$\pi\pi$	seen	849
$K\bar{K}^*(892) + \text{c.c.}$	seen	496
$\eta\rho$	seen	544
$a_2(1320)\pi$	not seen	334
$K\bar{K}$	seen	704
$e^+e^-$	seen	860
$\pi^0\omega$	seen	674

**$f_0(1710)$**  [*u*]

$$I^G(J^{PC}) = 0^+(0^{++})$$

Mass  $m = 1714 \pm 5$  MeV

Full width  $\Gamma = 140 \pm 10$  MeV ( $S = 1.2$ )

<b><math>f_0(1710)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$K\bar{K}$	seen	701
$\eta\eta$	seen	659
$\pi\pi$	seen	846

**$\pi(1800)$**

$$I^G(J^{PC}) = 1^-(0^{-+})$$

Mass  $m = 1812 \pm 14$  MeV ( $S = 2.3$ )

Full width  $\Gamma = 207 \pm 13$  MeV

<b><math>\pi(1800)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\pi^+\pi^-\pi^-$	seen	879
$f_0(600)\pi^-$	seen	—
$f_0(980)\pi^-$	seen	631
$f_0(1370)\pi^-$	seen	—
$f_0(1500)\pi^-$	not seen	248
$\rho\pi^-$	not seen	732
$\eta\eta\pi^-$	seen	661
$a_0(980)\eta$	seen	469
$f_0(1500)\pi^-$	seen	248

$\eta\eta'(958)\pi^-$	seen	376
$K_0^*(1430)K^-$	seen	†
$K^*(892)K^-$	not seen	570

### $\phi_3(1850)$

$$I^G(J^{PC}) = 0^-(3^{--})$$

Mass  $m = 1854 \pm 7$  MeV

Full width  $\Gamma = 87_{-23}^{+28}$  MeV (S = 1.2)

$\phi_3(1850)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$K\bar{K}$	seen	785
$K\bar{K}^*(892) + \text{c.c.}$	seen	602

### $f_2(1950)$

$$I^G(J^{PC}) = 0^+(2^{++})$$

Mass  $m = 1945 \pm 13$  MeV (S = 1.6)

Full width  $\Gamma = 475 \pm 19$  MeV

$f_2(1950)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$K^*(892)\bar{K}^*(892)$	seen	389
$\pi^+\pi^-$	seen	963
$4\pi$	seen	925
$\eta\eta$	seen	804
$K\bar{K}$	seen	838
$\gamma\gamma$	seen	973

### $f_2(2010)$

$$I^G(J^{PC}) = 0^+(2^{++})$$

Mass  $m = 2011_{-80}^{+60}$  MeV

Full width  $\Gamma = 202 \pm 60$  MeV

$f_2(2010)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\phi\phi$	seen	†

**$a_4(2040)$**

$$I^G(J^{PC}) = 1^-(4^{++})$$

Mass  $m = 2010 \pm 12$  MeV

Full width  $\Gamma = 353 \pm 40$  MeV

<b><math>a_4(2040)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$K \bar{K}$	seen	875
$\pi^+ \pi^- \pi^0$	seen	981
$\rho \pi$	seen	849
$f_2(1270) \pi$	seen	590
$\eta \pi^0$	seen	925
$\eta'(958) \pi$	seen	769

**$f_4(2050)$**

$$I^G(J^{PC}) = 0^+(4^{++})$$

Mass  $m = 2034 \pm 11$  MeV ( $S = 1.6$ )

Full width  $\Gamma = 222 \pm 19$  MeV ( $S = 1.8$ )

<b><math>f_4(2050)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\omega \omega$	not seen	650
$\pi \pi$	$(17.0 \pm 1.5) \%$	1008
$K \bar{K}$	$(6.8^{+3.4}_{-1.8}) \times 10^{-3}$	889
$\eta \eta$	$(2.1 \pm 0.8) \times 10^{-3}$	857
$4\pi^0$	$< 1.2 \%$	972
$a_2(1320) \pi$	seen	579

**$f_2(2300)$**

$$I^G(J^{PC}) = 0^+(2^{++})$$

Mass  $m = 2297 \pm 28$  MeV

Full width  $\Gamma = 149 \pm 40$  MeV

<b><math>f_2(2300)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\phi \phi$	seen	529
$K \bar{K}$	seen	1037
$\gamma \gamma$	seen	1149

**$f_2(2340)$**

$$I^G(J^{PC}) = 0^+(2^{++})$$

Mass  $m = 2339 \pm 60$  MeV

Full width  $\Gamma = 319^{+80}_{-70}$  MeV

**$f_2(2340)$  DECAY MODES**

	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\phi\phi$	seen	573

**STRANGE MESONS**  
**( $S = \pm 1, C = B = 0$ )**

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

**$K^\pm$**

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

Mass  $m = 493.677 \pm 0.016$  MeV <sup>[v]</sup> ( $S = 2.8$ )

Mean life  $\tau = (1.2384 \pm 0.0024) \times 10^{-8}$  s ( $S = 2.0$ )

$c\tau = 3.713$  m

**Slope parameter  $g$**  <sup>[w]</sup>

(See Particle Listings for quadratic coefficients)

$$K^+ \rightarrow \pi^+ \pi^+ \pi^- = -0.2154 \pm 0.0035 \quad (S = 1.4)$$

$$K^- \rightarrow \pi^- \pi^- \pi^+ = -0.217 \pm 0.007 \quad (S = 2.5)$$

$$K^\pm \rightarrow \pi^\pm \pi^0 \pi^0 = 0.638 \pm 0.020 \quad (S = 2.5)$$

**$K^\pm$  decay form factors** <sup>[a,x]</sup>

Assuming  $\mu$ - $e$  universality

$$\lambda_+(K_{\mu 3}^+) = \lambda_+(K_{e 3}^+) = (2.78 \pm 0.07) \times 10^{-2} \quad (S = 1.5)$$

$$\lambda_0(K_{\mu 3}^+) = (1.77 \pm 0.16) \times 10^{-2} \quad (S = 1.5)$$

Not assuming  $\mu$ - $e$  universality

$$\lambda_+(K_{e3}^+) = (2.77 \pm 0.05) \times 10^{-2}$$

$$\lambda_+(K_{\mu 3}^+) = (2.84 \pm 0.27) \times 10^{-2} \quad (S = 1.8)$$

$$\lambda_0(K_{\mu 3}^+) = (1.74 \pm 0.22) \times 10^{-2} \quad (S = 1.8)$$

$$K_{e3}^+ \quad |f_S/f_+| = (-0.3^{+0.8}_{-0.7}) \times 10^{-2}$$

$$K_{e3}^+ \quad |f_T/f_+| = (-1.2 \pm 2.3) \times 10^{-2}$$

$$K_{\mu 3}^+ \quad |f_S/f_+| = (0.2 \pm 0.6) \times 10^{-2}$$

$$K_{\mu 3}^+ \quad |f_T/f_+| = (-0.1 \pm 0.7) \times 10^{-2}$$

$$K^+ \rightarrow e^+ \nu_e \gamma \quad |F_A + F_V| = 0.148 \pm 0.010$$

$$K^+ \rightarrow \mu^+ \nu_\mu \gamma \quad |F_A + F_V| = 0.165 \pm 0.013$$

$$K^+ \rightarrow e^+ \nu_e \gamma \quad |F_A - F_V| < 0.49$$

$$K^+ \rightarrow \mu^+ \nu_\mu \gamma \quad |F_A - F_V| = -0.24 \text{ to } 0.04, \text{ CL} = 90\%$$

### Charge Radius

$$\langle r \rangle = 0.560 \pm 0.031 \text{ fm}$$

### CP violation parameters

$$\Delta(K_{\pi\mu\mu}^\pm) = -0.02 \pm 0.12$$

### T violation parameters

$$K^+ \rightarrow \pi^0 \mu^+ \nu_\mu \quad P_T = (-4 \pm 5) \times 10^{-3}$$

$$K^+ \rightarrow \mu^+ \nu_\mu \gamma \quad P_T = (-0.6 \pm 1.9) \times 10^{-2}$$

$$K^+ \rightarrow \pi^0 \mu^+ \nu_\mu \quad \text{Im}(\xi) = -0.014 \pm 0.014$$

$K^-$  modes are charge conjugates of the modes below.

<b><math>K^+</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor/ Confidence level	$p$ (MeV/c)
<b>Leptonic and semileptonic modes</b>			
$e^+ \nu_e$	$(1.55 \pm 0.07) \times 10^{-5}$		247
$\mu^+ \nu_\mu$	$(63.43 \pm 0.17) \%$	S=1.2	236
$\pi^0 e^+ \nu_e$	$(4.87 \pm 0.06) \%$	S=1.2	228
Called $K_{e3}^+$ .			
$\pi^0 \mu^+ \nu_\mu$	$(3.27 \pm 0.06) \%$	S=1.2	215
Called $K_{\mu 3}^+$ .			
$\pi^0 \pi^0 e^+ \nu_e$	$(2.1 \pm 0.4) \times 10^{-5}$		206
$\pi^+ \pi^- e^+ \nu_e$	$(4.08 \pm 0.09) \times 10^{-5}$		203
$\pi^+ \pi^- \mu^+ \nu_\mu$	$(1.4 \pm 0.9) \times 10^{-5}$		151
$\pi^0 \pi^0 \pi^0 e^+ \nu_e$	$< 3.5 \times 10^{-6}$	CL=90%	135

### Hadronic modes

$\pi^+ \pi^0$	(21.13 $\pm$ 0.14 ) %	S=1.1	205
$\pi^+ \pi^0 \pi^0$	( 1.73 $\pm$ 0.04 ) %	S=1.2	133
$\pi^+ \pi^+ \pi^-$	( 5.576 $\pm$ 0.031 ) %	S=1.1	125

### Leptonic and semileptonic modes with photons

$\mu^+ \nu_\mu \gamma$	[y,z] ( 5.50 $\pm$ 0.28 ) $\times 10^{-3}$		236
$\pi^0 e^+ \nu_e \gamma$	[y,z] ( 2.65 $\pm$ 0.20 ) $\times 10^{-4}$		228
$\pi^0 e^+ \nu_e \gamma$ (SD)	[aa] < 5.3 $\times 10^{-5}$	CL=90%	228
$\pi^0 \mu^+ \nu_\mu \gamma$	[y,z] < 6.1 $\times 10^{-5}$	CL=90%	215
$\pi^0 \pi^0 e^+ \nu_e \gamma$	< 5 $\times 10^{-6}$	CL=90%	206

### Hadronic modes with photons

$\pi^+ \pi^0 \gamma$	[y,z] ( 2.75 $\pm$ 0.15 ) $\times 10^{-4}$		205
$\pi^+ \pi^0 \gamma$ (DE)	[z,bb] ( 4.4 $\pm$ 0.8 ) $\times 10^{-6}$		205
$\pi^+ \pi^0 \pi^0 \gamma$	[y,z] ( 7.4 $\begin{smallmatrix} +5.5 \\ -2.9 \end{smallmatrix}$ ) $\times 10^{-6}$		133
$\pi^+ \pi^+ \pi^- \gamma$	[y,z] ( 1.04 $\pm$ 0.31 ) $\times 10^{-4}$		125
$\pi^+ \gamma \gamma$	[z] ( 1.10 $\pm$ 0.32 ) $\times 10^{-6}$		227
$\pi^+ 3\gamma$	[z] < 1.0 $\times 10^{-4}$	CL=90%	227

### Leptonic modes with $\ell\bar{\ell}$ pairs

$e^+ \nu_e \nu \bar{\nu}$	< 6 $\times 10^{-5}$	CL=90%	247
$\mu^+ \nu_\mu \nu \bar{\nu}$	< 6.0 $\times 10^{-6}$	CL=90%	236
$e^+ \nu_e e^+ e^-$	( 2.48 $\pm$ 0.20 ) $\times 10^{-8}$		247
$\mu^+ \nu_\mu e^+ e^-$	( 7.06 $\pm$ 0.31 ) $\times 10^{-8}$		236
$e^+ \nu_e \mu^+ \mu^-$	< 5 $\times 10^{-7}$	CL=90%	223
$\mu^+ \nu_\mu \mu^+ \mu^-$	< 4.1 $\times 10^{-7}$	CL=90%	185

### Lepton Family number (LF), Lepton number (L), $\Delta S = \Delta Q$ (SQ)

#### violating modes, or $\Delta S = 1$ weak neutral current (S1) modes

$\pi^+ \pi^+ e^- \bar{\nu}_e$	SQ	< 1.2 $\times 10^{-8}$	CL=90%	203
$\pi^+ \pi^+ \mu^- \bar{\nu}_\mu$	SQ	< 3.0 $\times 10^{-6}$	CL=95%	151
$\pi^+ e^+ e^-$	S1	( 2.88 $\pm$ 0.13 ) $\times 10^{-7}$		227
$\pi^+ \mu^+ \mu^-$	S1	( 8.1 $\pm$ 1.4 ) $\times 10^{-8}$	S=2.7	172
$\pi^+ \nu \bar{\nu}$	S1	( 1.6 $\begin{smallmatrix} +1.8 \\ -0.8 \end{smallmatrix}$ ) $\times 10^{-10}$		227
$\pi^+ \pi^0 \nu \bar{\nu}$	S1	< 4.3 $\times 10^{-5}$	CL=90%	205
$\mu^- \nu e^+ e^+$	LF	< 2.0 $\times 10^{-8}$	CL=90%	236
$\mu^+ \nu_e$	LF	[d] < 4 $\times 10^{-3}$	CL=90%	236
$\pi^+ \mu^+ e^-$	LF	< 2.8 $\times 10^{-11}$	CL=90%	214
$\pi^+ \mu^- e^+$	LF	< 5.2 $\times 10^{-10}$	CL=90%	214
$\pi^- \mu^+ e^+$	L	< 5.0 $\times 10^{-10}$	CL=90%	214
$\pi^- e^+ e^+$	L	< 6.4 $\times 10^{-10}$	CL=90%	227

$\pi^- \mu^+ \mu^+$	$L$	$[d] < 3.0$	$\times 10^{-9}$	CL=90%	172
$\mu^+ \bar{\nu}_e$	$L$	$[d] < 3.3$	$\times 10^{-3}$	CL=90%	236
$\pi^0 e^+ \bar{\nu}_e$	$L$	$< 3$	$\times 10^{-3}$	CL=90%	228
$\pi^+ \gamma$		$[cc] < 3.6$	$\times 10^{-7}$	CL=90%	227

$K^0$

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

50%  $K_S$ , 50%  $K_L$

Mass  $m = 497.648 \pm 0.022$  MeV

$m_{K^0} - m_{K^\pm} = 3.972 \pm 0.027$  MeV (S = 1.2)

**Mean Square Charge Radius**

$\langle r^2 \rangle = -0.076 \pm 0.018$  fm<sup>2</sup> (S = 1.1)

**T-violation parameters in  $K^0$ - $\bar{K}^0$  mixing** [x]

Asymmetry  $A_T$  in  $K^0$ - $\bar{K}^0$  mixing =  $(6.6 \pm 1.6) \times 10^{-3}$

**CPT-violation parameters** [x]

Re  $\delta = (2.9 \pm 2.7) \times 10^{-4}$

Im  $\delta = (0.02 \pm 0.05) \times 10^{-3}$

$|m_{K^0} - m_{\bar{K}^0}| / m_{\text{average}} < 10^{-18}$ , CL = 90% [dd]

$(\Gamma_{K^0} - \Gamma_{\bar{K}^0}) / m_{\text{average}} = (8 \pm 8) \times 10^{-18}$

$K_S^0$

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

Mean life  $\tau = (0.8953 \pm 0.0006) \times 10^{-10}$  s (S = 1.4) Assuming *CPT*

Mean life  $\tau = (0.8958 \pm 0.0006) \times 10^{-10}$  s (S = 1.2) Not assuming *CPT*

$c\tau = 2.6842$  cm Assuming *CPT*

**CP-violation parameters** [ee]

Im( $\eta_{+-0}$ ) =  $-0.002 \pm 0.009$

Im( $\eta_{000}$ ) =  $-0.05 \pm 0.13$

CP asymmetry  $A$  in  $\pi^+ \pi^- e^+ e^- = (-1 \pm 4)\%$

$K_S^0$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor/ Confidence level	$p$ (MeV/c)
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**Hadronic modes**

$\pi^0 \pi^0$	(31.05±0.14) %	S=1.1	209
$\pi^+ \pi^-$	(68.95±0.14) %	S=1.1	206
$\pi^+ \pi^- \pi^0$	( 3.2 $\begin{smallmatrix} +1.2 \\ -1.0 \end{smallmatrix}$ ) $\times 10^{-7}$		133

**Modes with photons or  $\ell\bar{\ell}$  pairs**

$\pi^+\pi^-\gamma$	[ <i>y,ff</i> ]	$(1.79 \pm 0.05) \times 10^{-3}$	206
$\pi^+\pi^-e^+e^-$		$(4.69 \pm 0.30) \times 10^{-5}$	206
$\pi^0\gamma\gamma$	[ <i>ff</i> ]	$(4.9 \pm 1.8) \times 10^{-8}$	231
$\gamma\gamma$		$(2.80 \pm 0.07) \times 10^{-6}$	249

**Semileptonic modes**

$\pi^\pm e^\mp \nu_e$	[ <i>gg</i> ]	$(6.9 \pm 0.4) \times 10^{-4}$	229
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**CP violating (CP) and  $\Delta S = 1$  weak neutral current (S1) modes**

$3\pi^0$	CP	$< 1.4 \times 10^{-5}$	CL=90%	139
$\mu^+\mu^-$	S1	$< 3.2 \times 10^{-7}$	CL=90%	225
$e^+e^-$	S1	$< 1.4 \times 10^{-7}$	CL=90%	249
$\pi^0 e^+ e^-$	S1 [ff]	$(3.0 \begin{smallmatrix} +1.5 \\ -1.2 \end{smallmatrix}) \times 10^{-9}$		231

**$K_L^0$**

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

$$m_{K_L} - m_{K_S}$$

$$= (0.5292 \pm 0.0010) \times 10^{10} \hbar s^{-1} \quad (S = 1.2) \quad \text{Assuming } CPT$$

$$= (3.483 \pm 0.006) \times 10^{-12} \text{ MeV} \quad \text{Assuming } CPT$$

$$= (0.5290 \pm 0.0016) \times 10^{10} \hbar s^{-1} \quad (S = 1.2) \quad \text{Not assuming } CPT$$

$$\text{Mean life } \tau = (5.18 \pm 0.04) \times 10^{-8} \text{ s} \quad (S = 1.1)$$

$$c\tau = 15.51 \text{ m}$$

**Slope parameter  $g$  [*w*]**

(See Particle Listings for quadratic coefficients)

$$K_L^0 \rightarrow \pi^+\pi^-\pi^0 = 0.678 \pm 0.008 \quad (S = 1.5)$$

**$K_L$  decay form factors [*x*]**

Assuming  $\mu$ - $e$  universality

$$\lambda_+(K_{\mu 3}^0) = \lambda_+(K_{e 3}^0) = 0.0300 \pm 0.0020 \quad (S = 2.0)$$

$$\lambda_0(K_{\mu 3}^0) = 0.030 \pm 0.005 \quad (S = 2.0)$$



Not assuming  $\mu$ - $e$  universality

$$\lambda_+(K_{e3}^0) = 0.0291 \pm 0.0018 \quad (S = 1.5)$$

$$\lambda_+(K_{\mu 3}^0) = 0.033 \pm 0.005 \quad (S = 2.3)$$

$$\lambda_0(K_{\mu 3}^0) = 0.027 \pm 0.006 \quad (S = 2.3)$$

$$K_{e3}^0 \quad |f_S/f_+| < 0.04, \text{ CL} = 68\%$$

$$K_{e3}^0 \quad |f_T/f_+| < 0.23, \text{ CL} = 68\%$$

$$K_{\mu 3}^0 \quad |f_T/f_+| = 0.12 \pm 0.12$$

$$K_L \rightarrow e^+ e^- \gamma: \quad \alpha_{K^*} = -0.33 \pm 0.05$$

$$K_L \rightarrow \mu^+ \mu^- \gamma: \quad \alpha_{K^*} = -0.158 \pm 0.027$$

$$K_L \rightarrow e^+ e^- e^+ e^-: \quad \alpha_{K^*}^{\text{eff}} = -0.14 \pm 0.22$$

$$K_L \rightarrow \pi^+ \pi^- e^+ e^-: \quad a_1/a_2 = -0.734 \pm 0.022 \text{ GeV}^2$$

$$K_L \rightarrow \pi^0 2\gamma: \quad a_V = -0.54 \pm 0.12 \quad (S = 2.8)$$

### **CP-violation parameters** <sup>[ee]</sup>

$$\delta_L = (0.327 \pm 0.012)\%$$

$$|\eta_{00}| = (2.276 \pm 0.014) \times 10^{-3}$$

$$|\eta_{+-}| = (2.288 \pm 0.014) \times 10^{-3}$$

$$|\epsilon| = (2.284 \pm 0.014) \times 10^{-3}$$

$$|\eta_{00}/\eta_{+-}| = 0.9950 \pm 0.0008 \text{ [hh]} \quad (S = 1.6)$$

$$\text{Re}(\epsilon'/\epsilon) = (1.67 \pm 0.26) \times 10^{-3} \text{ [hh]} \quad (S = 1.6)$$

Assuming *CPT*

$$\phi_{+-} = (43.52 \pm 0.06)^\circ \quad (S = 1.3)$$

$$\phi_{00} = (43.50 \pm 0.06)^\circ \quad (S = 1.3)$$

$$\phi_\epsilon = \phi_{\text{SW}} = (43.51 \pm 0.05)^\circ \quad (S = 1.2)$$

Not assuming *CPT*

$$\phi_{+-} = (43.4 \pm 0.7)^\circ \quad (S = 1.3)$$

$$\phi_{00} = (43.7 \pm 0.8)^\circ \quad (S = 1.2)$$

$$\phi_\epsilon = (43.5 \pm 0.7)^\circ \quad (S = 1.3)$$

$$CP \text{ asymmetry } A \text{ in } K_L^0 \rightarrow \pi^+ \pi^- e^+ e^- = (13.8 \pm 2.2)\%$$

$$\beta_{CP} \text{ from } K_L^0 \rightarrow e^+ e^- e^+ e^- = -0.23 \pm 0.09$$

$$\gamma_{CP} \text{ from } K_L^0 \rightarrow e^+ e^- e^+ e^- = -0.09 \pm 0.09$$

$$j \text{ for } K_L^0 \rightarrow \pi^+ \pi^- \pi^0 = 0.0012 \pm 0.0008$$

$$f \text{ for } K_L^0 \rightarrow \pi^+ \pi^- \pi^0 = 0.004 \pm 0.006$$

$$|\eta_{+-\gamma}| = (2.35 \pm 0.07) \times 10^{-3}$$

$$\phi_{+-\gamma} = (44 \pm 4)^\circ$$

$$|\epsilon'_{+-\gamma}|/\epsilon < 0.3, \text{ CL} = 90\%$$

### **T-violation parameters**

$$\text{Im}(\xi) \text{ in } K_{\mu 3}^0 = -0.007 \pm 0.026$$

### **CPT invariance tests**

$$\phi_{00} - \phi_{+-} = (0.2 \pm 0.4)^\circ$$

$$\text{Re}\left(\frac{2}{3}\eta_{+-} + \frac{1}{3}\eta_{00}\right) - \frac{\delta_L}{2} = (-3 \pm 35) \times 10^{-6}$$

### **$\Delta S = -\Delta Q$ in $K_{\ell 3}^0$ decay**

$$\text{Re } x = -0.002 \pm 0.006$$

$$\text{Im } x = 0.0012 \pm 0.0021$$

$K_L^0$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor/ Confidence level	$p$ (MeV/c)
<b>Semileptonic modes</b>			
$\pi^\pm e^\mp \nu_e$ Called $K_{e3}^0$ .	[gg] (38.81 $\pm$ 0.27) %	S=1.1	229
$\pi^\pm \mu^\mp \nu_\mu$ Called $K_{\mu 3}^0$ .	[gg] (27.19 $\pm$ 0.25) %	S=1.1	216
$(\pi \mu \text{ atom})\nu$	( 1.06 $\pm$ 0.11 ) $\times 10^{-7}$		188
$\pi^0 \pi^\pm e^\mp \nu$	[gg] ( 5.18 $\pm$ 0.29 ) $\times 10^{-5}$		207
<b>Hadronic modes, including Charge conjugation <math>\times</math> Parity Violating (CPV) modes</b>			
$3\pi^0$	(21.05 $\pm$ 0.23) %	S=1.1	139
$\pi^+ \pi^- \pi^0$	(12.59 $\pm$ 0.19) %	S=1.6	133
$\pi^+ \pi^-$	CPV ( 2.090 $\pm$ 0.025 ) $\times 10^{-3}$	S=1.1	206
$\pi^0 \pi^0$	CPV ( 9.32 $\pm$ 0.12 ) $\times 10^{-4}$	S=1.1	209

### Semileptonic modes with photons

$\pi^\pm e^\mp \nu_e \gamma$	$[y, gg, ii]$	$( 3.53 \pm 0.06 ) \times 10^{-3}$		229
$\pi^\pm \mu^\mp \nu_\mu \gamma$		$( 5.7 \begin{smallmatrix} +0.6 \\ -0.7 \end{smallmatrix} ) \times 10^{-4}$		216

### Hadronic modes with photons or $\ell\bar{\ell}$ pairs

$\pi^0 \pi^0 \gamma$		$< 5.6 \times 10^{-6}$		209
$\pi^+ \pi^- \gamma$	$[y, ii]$	$( 4.39 \pm 0.12 ) \times 10^{-5}$	S=1.8	206
$\pi^0 2\gamma$	$[ii]$	$( 1.41 \pm 0.12 ) \times 10^{-6}$	S=2.8	231
$\pi^0 \gamma e^+ e^-$		$( 2.3 \pm 0.4 ) \times 10^{-8}$		231

### Other modes with photons or $\ell\bar{\ell}$ pairs

$2\gamma$		$( 5.90 \pm 0.07 ) \times 10^{-4}$	S=1.1	249
$3\gamma$		$< 2.4 \times 10^{-7}$	CL=90%	249
$e^+ e^- \gamma$		$(10.0 \pm 0.5 ) \times 10^{-6}$	S=1.5	249
$\mu^+ \mu^- \gamma$		$( 3.59 \pm 0.11 ) \times 10^{-7}$	S=1.3	225
$e^+ e^- \gamma \gamma$	$[ii]$	$( 5.95 \pm 0.33 ) \times 10^{-7}$		249
$\mu^+ \mu^- \gamma \gamma$	$[ii]$	$( 1.0 \begin{smallmatrix} +0.8 \\ -0.6 \end{smallmatrix} ) \times 10^{-8}$		225

### Charge conjugation $\times$ Parity ( $CP$ ) or Lepton Family number ( $LF$ ) violating modes, or $\Delta S = 1$ weak neutral current ( $S1$ ) modes

$\mu^+ \mu^-$	$S1$	$( 7.27 \pm 0.14 ) \times 10^{-9}$		225
$e^+ e^-$	$S1$	$( 9 \begin{smallmatrix} +6 \\ -4 \end{smallmatrix} ) \times 10^{-12}$		249
$\pi^+ \pi^- e^+ e^-$	$S1 [ii]$	$( 3.11 \pm 0.19 ) \times 10^{-7}$		206
$\pi^0 \pi^0 e^+ e^-$	$S1$	$< 6.6 \times 10^{-9}$	CL=90%	209
$\mu^+ \mu^- e^+ e^-$	$S1$	$( 2.69 \pm 0.27 ) \times 10^{-9}$		225
$e^+ e^- e^+ e^-$	$S1$	$( 3.75 \pm 0.27 ) \times 10^{-8}$		249
$\pi^0 \mu^+ \mu^-$	$CP, S1 [jj]$	$< 3.8 \times 10^{-10}$	CL=90%	177
$\pi^0 e^+ e^-$	$CP, S1 [jj]$	$< 5.1 \times 10^{-10}$	CL=90%	231
$\pi^0 \nu \bar{\nu}$	$CP, S1 [kk]$	$< 5.9 \times 10^{-7}$	CL=90%	231
$e^\pm \mu^\mp$	$LF [gg]$	$< 4.7 \times 10^{-12}$	CL=90%	238
$e^\pm e^\pm \mu^\mp \mu^\mp$	$LF [gg]$	$< 4.12 \times 10^{-11}$	CL=90%	225
$\pi^0 \mu^\pm e^\mp$	$LF [gg]$	$< 6.2 \times 10^{-9}$	CL=90%	217

## **$K^*(892)$**

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

$K^*(892)^\pm$  mass  $m = 891.66 \pm 0.26$  MeV  
 $K^*(892)^0$  mass  $m = 896.10 \pm 0.27$  MeV (S = 1.4)  
 $K^*(892)^\pm$  full width  $\Gamma = 50.8 \pm 0.9$  MeV  
 $K^*(892)^0$  full width  $\Gamma = 50.7 \pm 0.6$  MeV (S = 1.1)

<b><math>K^*(892)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level	$p$ (MeV/c)
$K\pi$	$\sim 100$	%	289
$K^0\gamma$	$(2.30 \pm 0.20) \times 10^{-3}$		307
$K^\pm\gamma$	$(9.9 \pm 0.9) \times 10^{-4}$		309
$K\pi\pi$	$< 7$	$\times 10^{-4}$ 95%	223

## **$K_1(1270)$**

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

Mass  $m = 1273 \pm 7$  MeV [ $n$ ]  
 Full width  $\Gamma = 90 \pm 20$  MeV [ $n$ ]

<b><math>K_1(1270)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$K\rho$	$(42 \pm 6)$ %	43
$K_0^*(1430)\pi$	$(28 \pm 4)$ %	†
$K^*(892)\pi$	$(16 \pm 5)$ %	302
$K\omega$	$(11.0 \pm 2.0)$ %	†
$Kf_0(1370)$	$(3.0 \pm 2.0)$ %	–
$\gamma K^0$	seen	539

## **$K_1(1400)$**

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

Mass  $m = 1402 \pm 7$  MeV  
 Full width  $\Gamma = 174 \pm 13$  MeV (S = 1.6)

<b><math>K_1(1400)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$K^*(892)\pi$	$(94 \pm 6)$ %	402
$K\rho$	$(3.0 \pm 3.0)$ %	292
$Kf_0(1370)$	$(2.0 \pm 2.0)$ %	–
$K\omega$	$(1.0 \pm 1.0)$ %	284
$K_0^*(1430)\pi$	not seen	†
$\gamma K^0$	seen	613

**$K^*(1410)$**

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

Mass  $m = 1414 \pm 15$  MeV (S = 1.3)

Full width  $\Gamma = 232 \pm 21$  MeV (S = 1.1)

<b><math>K^*(1410)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level	$p$ (MeV/c)
$K^*(892)\pi$	> 40 %	95%	410
$K\pi$	(6.6±1.3) %		612
$K\rho$	< 7 %	95%	305
$\gamma K^0$	seen		619

**$K_0^*(1430)$  [//]**

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

Mass  $m = 1412 \pm 6$  MeV

Full width  $\Gamma = 294 \pm 23$  MeV

<b><math>K_0^*(1430)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$K\pi$	(93±10) %	611

**$K_2^*(1430)$**

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

$K_2^*(1430)^\pm$  mass  $m = 1425.6 \pm 1.5$  MeV (S = 1.1)

$K_2^*(1430)^0$  mass  $m = 1432.4 \pm 1.3$  MeV

$K_2^*(1430)^\pm$  full width  $\Gamma = 98.5 \pm 2.7$  MeV (S = 1.1)

$K_2^*(1430)^0$  full width  $\Gamma = 109 \pm 5$  MeV (S = 1.9)

<b><math>K_2^*(1430)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor/ Confidence level	$p$ (MeV/c)
$K\pi$	(49.9±1.2) %		619
$K^*(892)\pi$	(24.7±1.5) %		419
$K^*(892)\pi\pi$	(13.4±2.2) %		372
$K\rho$	(8.7±0.8) %	S=1.2	318
$K\omega$	(2.9±0.8) %		311
$K^+\gamma$	(2.4±0.5) × 10 <sup>-3</sup>	S=1.1	627
$K\eta$	(1.5 <sup>+3.4</sup> <sub>-1.0</sub> ) × 10 <sup>-3</sup>	S=1.3	486
$K\omega\pi$	< 7.2 × 10 <sup>-4</sup>	CL=95%	100
$K^0\gamma$	< 9 × 10 <sup>-4</sup>	CL=90%	626

### **$K^*(1680)$**

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

Mass  $m = 1717 \pm 27$  MeV (S = 1.4)

Full width  $\Gamma = 322 \pm 110$  MeV (S = 4.2)

<b><math>K^*(1680)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$K\pi$	$(38.7 \pm 2.5) \%$	781
$K\rho$	$(31.4^{+4.7}_{-2.1}) \%$	570
$K^*(892)\pi$	$(29.9^{+2.2}_{-4.7}) \%$	618

### **$K_2(1770)$ <sup>[mm]</sup>**

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

Mass  $m = 1773 \pm 8$  MeV

Full width  $\Gamma = 186 \pm 14$  MeV

<b><math>K_2(1770)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$K\pi\pi$		794
$K_2^*(1430)\pi$	dominant	288
$K^*(892)\pi$	seen	654
$Kf_2(1270)$	seen	53
$K\phi$	seen	441
$K\omega$	seen	607

### **$K_3^*(1780)$**

$$I(J^P) = \frac{1}{2}(3^-)$$

Mass  $m = 1776 \pm 7$  MeV (S = 1.1)

Full width  $\Gamma = 159 \pm 21$  MeV (S = 1.3)

<b><math>K_3^*(1780)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level	$p$ (MeV/c)
$K\rho$	$(31 \pm 9) \%$		613
$K^*(892)\pi$	$(20 \pm 5) \%$		656
$K\pi$	$(18.8 \pm 1.0) \%$		813
$K\eta$	$(30 \pm 13) \%$		719
$K_2^*(1430)\pi$	< 16 %	95%	291

## $K_2(1820)$ [ $nn$ ]

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

Mass  $m = 1816 \pm 13$  MeV

Full width  $\Gamma = 276 \pm 35$  MeV

$K_2(1820)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$K_2^*(1430)\pi$	seen	327
$K^*(892)\pi$	seen	681
$K f_2(1270)$	seen	185
$K\omega$	seen	638

## $K_4^*(2045)$

$$I(J^P) = \frac{1}{2}(4^+)$$

Mass  $m = 2045 \pm 9$  MeV ( $S = 1.1$ )

Full width  $\Gamma = 198 \pm 30$  MeV

$K_4^*(2045)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$K\pi$	$(9.9 \pm 1.2) \%$	958
$K^*(892)\pi\pi$	$(9 \pm 5) \%$	802
$K^*(892)\pi\pi\pi$	$(7 \pm 5) \%$	768
$\rho K\pi$	$(5.7 \pm 3.2) \%$	741
$\omega K\pi$	$(5.0 \pm 3.0) \%$	738
$\phi K\pi$	$(2.8 \pm 1.4) \%$	594
$\phi K^*(892)$	$(1.4 \pm 0.7) \%$	363

# CHARMED MESONS ( $C = \pm 1$ )

$D^+ = c\bar{d}$ ,  $D^0 = c\bar{u}$ ,  $\bar{D}^0 = \bar{c}u$ ,  $D^- = \bar{c}d$ , similarly for  $D^*$ 's

## $D^\pm$

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

Mass  $m = 1869.4 \pm 0.5$  MeV ( $S = 1.1$ )

Mean life  $\tau = (1040 \pm 7) \times 10^{-15}$  s

$c\tau = 311.8$   $\mu\text{m}$

### c-quark decays

$\Gamma(c \rightarrow \ell^+ \text{ anything})/\Gamma(c \rightarrow \text{ anything}) = 0.096 \pm 0.004$  [ $^{\circ\circ}$ ]

$\Gamma(c \rightarrow D^*(2010)^+ \text{ anything})/\Gamma(c \rightarrow \text{ anything}) = 0.255 \pm 0.017$

**CP-violation decay-rate asymmetries**

$$A_{CP}(K_S^0 \pi^\pm) = -0.016 \pm 0.017$$

$$A_{CP}(K_S^0 K^\pm) = 0.07 \pm 0.06$$

$$A_{CP}(K^+ K^- \pi^\pm) = 0.002 \pm 0.011$$

$$A_{CP}(K^\pm K^{*0}) = -0.02 \pm 0.05$$

$$A_{CP}(\phi \pi^\pm) = -0.014 \pm 0.033$$

$$A_{CP}(\pi^+ \pi^- \pi^\pm) = -0.02 \pm 0.04$$

**$D^+ \rightarrow \bar{K}^*(892)^0 \ell^+ \nu_\ell$  form factors**

$$r_V = 1.62 \pm 0.08 \quad (S = 1.5)$$

$$r_2 = 0.83 \pm 0.05$$

$$r_3 = 0.0 \pm 0.4$$

$$\Gamma_L/\Gamma_T = 1.13 \pm 0.08$$

$$\Gamma_+/\Gamma_- = 0.22 \pm 0.06 \quad (S = 1.6)$$

$D^-$  modes are charge conjugates of the modes below.

<b><math>D^+</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor/ Confidence level	$p$ (MeV/c)
<b>Inclusive modes</b>			
$e^+$ anything	(17.2 $\pm$ 1.9 ) %		—
$K^-$ anything	(27.5 $\pm$ 2.4 ) %		—
$\bar{K}^0$ anything + $K^0$ anything	(61 $\pm$ 8 ) %		—
$K^+$ anything	( 5.5 $\pm$ 1.6 ) %		—
$\eta$ anything	[ $pp$ ] < 13 %	CL=90%	—
$\phi$ anything	< 1.8 %	CL=90%	—
$\phi e^+$ anything	< 1.6 %	CL=90%	—
<b>Leptonic and semileptonic modes</b>			
$\mu^+ \nu_\mu$	( 8 $^{+17}_{-5}$ ) $\times 10^{-4}$		932
$\bar{K}^0 \ell^+ \nu_\ell$	[ $qq$ ] ( 6.8 $\pm$ 0.8 ) %		868
$\bar{K}^0 e^+ \nu_e$	( 6.7 $\pm$ 0.9 ) %		868
$\bar{K}^0 \mu^+ \nu_\mu$	( 7.0 $^{+3.0}_{-2.0}$ ) %		865
$K^- \pi^+ e^+ \nu_e$	( 4.5 $^{+1.0}_{-0.8}$ ) %	S=1.1	863
$\bar{K}^*(892)^0 e^+ \nu_e$	( 3.7 $\pm$ 0.5 ) %		722
$\times B(\bar{K}^*(892)^0 \rightarrow K^- \pi^+)$			
$K^- \pi^+ e^+ \nu_e$ nonresonant	< 7 $\times 10^{-3}$	CL=90%	863
$K^- \pi^+ \mu^+ \nu_\mu$	( 4.00 $\pm$ 0.32 ) %		851
$\bar{K}^*(892)^0 \mu^+ \nu_\mu$	( 3.7 $\pm$ 0.3 ) %		717
$\times B(\bar{K}^*(892)^0 \rightarrow K^- \pi^+)$			



$K^- \pi^+ \mu^+ \nu_\mu$ nonresonant	( 3.3 ± 1.3 ) × 10 <sup>-3</sup>		851
$(\bar{K}^*(892)\pi)^0 e^+ \nu_e$	< 1.2	% CL=90%	712
$(\bar{K}\pi\pi)^0 e^+ \nu_e$ non- $\bar{K}^*(892)$	< 9	× 10 <sup>-3</sup> CL=90%	846
$K^- \pi^+ \pi^0 \mu^+ \nu_\mu$	< 1.7	× 10 <sup>-3</sup> CL=90%	825
$\pi^0 \ell^+ \nu_\ell$	[rr] ( 3.1 ± 1.5 ) × 10 <sup>-3</sup>		930

Fractions of some of the following modes with resonances have already appeared above as submodes of particular charged-particle modes.

$\bar{K}^*(892)^0 \ell^+ \nu_\ell$	[qq] ( 5.73 ± 0.35 ) %		722
$\bar{K}^*(892)^0 e^+ \nu_e$	( 5.5 ± 0.7 ) %	S=1.4	722
$\bar{K}^*(892)^0 \mu^+ \nu_\mu$	( 5.5 ± 0.4 ) %		717
$\bar{K}_1(1270)^0 \mu^+ \nu_\mu$	< 4	% CL=95%	493
$\bar{K}_2^*(1430)^0 \mu^+ \nu_\mu$	< 1.0	% CL=95%	380
$\rho^0 e^+ \nu_e$	( 2.5 ± 1.0 ) × 10 <sup>-3</sup>		774
$\rho^0 \mu^+ \nu_\mu$	( 3.4 ± 0.8 ) × 10 <sup>-3</sup>		769
$\phi e^+ \nu_e$	< 2.09	% CL=90%	657
$\phi \mu^+ \nu_\mu$	< 3.72	% CL=90%	651
$\eta \ell^+ \nu_\ell$	< 5	× 10 <sup>-3</sup> CL=90%	854
$\eta'(958) \mu^+ \nu_\mu$	< 1.1	% CL=90%	684

### Hadronic modes with a $\bar{K}$ or $\bar{K}K\bar{K}$

$\bar{K}^0 \pi^+$	( 2.82 ± 0.19 ) %		862
$K^- \pi^+ \pi^+$	[ss] ( 9.2 ± 0.6 ) %		845
$\bar{K}^*(892)^0 \pi^+$	( 1.30 ± 0.13 ) %		714
× B( $\bar{K}^*(892)^0 \rightarrow K^- \pi^+$ )			
$\bar{K}_0^*(1430)^0 \pi^+$	( 2.3 ± 0.3 ) %		382
× B( $\bar{K}_0^*(1430)^0 \rightarrow K^- \pi^+$ )			
$\bar{K}^*(1680)^0 \pi^+$	( 3.8 ± 0.8 ) × 10 <sup>-3</sup>		58
× B( $\bar{K}^*(1680)^0 \rightarrow K^- \pi^+$ )			
$K^- \pi^+ \pi^+$ nonresonant	( 8.8 ± 0.9 ) %		845
$\bar{K}^0 \pi^+ \pi^0$	[ss] ( 9.7 ± 3.0 ) %	S=1.1	845
$\bar{K}^0 \rho^+$	( 6.6 ± 2.5 ) %		677
$\bar{K}^*(892)^0 \pi^+$	( 6.5 ± 0.6 ) × 10 <sup>-3</sup>		714
× B( $\bar{K}^*(892)^0 \rightarrow \bar{K}^0 \pi^0$ )			
$\bar{K}^0 \pi^+ \pi^0$ nonresonant	( 1.3 ± 1.1 ) %		845
$K^- \pi^+ \pi^+ \pi^0$	[ss] ( 6.5 ± 1.1 ) %		816
$\bar{K}^*(892)^0 \rho^+$ total	( 1.4 ± 0.9 ) %		422
× B( $\bar{K}^*(892)^0 \rightarrow K^- \pi^+$ )			
$\bar{K}_1(1400)^0 \pi^+$	( 2.2 ± 0.6 ) %		390
× B( $\bar{K}_1(1400)^0 \rightarrow K^- \pi^+ \pi^0$ )			
$K^- \rho^+ \pi^+$ total	( 3.1 ± 1.1 ) %		612
$K^- \rho^+ \pi^+$ 3-body	( 1.1 ± 0.4 ) %		612
$\bar{K}^*(892)^0 \pi^+ \pi^0$ total	( 4.5 ± 0.9 ) %		690
× B( $\bar{K}^*(892)^0 \rightarrow K^- \pi^+$ )			

$\bar{K}^*(892)^0 \pi^+ \pi^0$ 3-body $\times B(\bar{K}^*(892)^0 \rightarrow K^- \pi^+)$	( 2.9 ± 0.9 ) %		690
$K^*(892)^- \pi^+ \pi^+$ 3-body $\times B(K^*(892)^- \rightarrow K^- \pi^0)$	( 7 ± 3 ) × 10 <sup>-3</sup>		688
$K^- \pi^+ \pi^+ \pi^0$ nonresonant [tt]	( 1.2 ± 0.6 ) %		816
$\bar{K}^0 \pi^+ \pi^+ \pi^-$ [ss]	( 7.1 ± 1.0 ) %		814
$\bar{K}^0 a_1(1260)^+$ $\times B(a_1(1260)^+ \rightarrow \pi^+ \pi^+ \pi^-)$	( 4.0 ± 0.9 ) %		328
$\bar{K}_1(1400)^0 \pi^+$ $\times B(\bar{K}_1(1400)^0 \rightarrow \bar{K}^0 \pi^+ \pi^-)$	( 2.2 ± 0.6 ) %		390
$K^*(892)^- \pi^+ \pi^+$ 3-body $\times B(K^*(892)^- \rightarrow \bar{K}^0 \pi^-)$	( 1.4 ± 0.6 ) %		688
$\bar{K}^0 \rho^0 \pi^+$ total	( 4.3 ± 0.9 ) %		610
$\bar{K}^0 \rho^0 \pi^+$ 3-body	( 5 ± 5 ) × 10 <sup>-3</sup>		610
$\bar{K}^0 \pi^+ \pi^+ \pi^-$ nonresonant	( 9 ± 4 ) × 10 <sup>-3</sup>		814
$K^- 3\pi^+ \pi^-$ [ss]	( 6.2 ± 0.8 ) × 10 <sup>-3</sup>	S=1.3	772
$\bar{K}^*(892)^0 \pi^+ \pi^+ \pi^-$ $\times B(\bar{K}^*(892)^0 \rightarrow K^- \pi^+)$	( 2.1 ± 0.8 ) × 10 <sup>-3</sup>		645
$\bar{K}^*(892)^0 \rho^0 \pi^+$ $\times B(\bar{K}^*(892)^0 \rightarrow K^- \pi^+)$	( 2.0 ± 0.5 ) × 10 <sup>-3</sup>		239
$\bar{K}^*(892)^0 \pi^+ \pi^+ \pi^-$ no- $\rho$ $\times B(\bar{K}^*(892)^0 \rightarrow K^- \pi^+)$	( 2.9 ± 1.1 ) × 10 <sup>-3</sup>		645
$K^- \rho^0 \pi^+ \pi^+$	( 1.94 ± 0.35 ) × 10 <sup>-3</sup>	S=1.1	524
$K^- 3\pi^+ \pi^-$ nonresonant	( 4.3 ± 3.2 ) × 10 <sup>-4</sup>		772
$\bar{K}^0 \bar{K}^0 K^+$	( 1.8 ± 0.8 ) %		545
$K^+ K^- \bar{K}^0 \pi^+$	( 5.5 ± 1.4 ) × 10 <sup>-4</sup>		435

Fractions of some of the following modes with resonances have already appeared above as submodes of particular charged-particle modes.

$\bar{K}^0 \rho^+$	( 6.6 ± 2.5 ) %		677
$\bar{K}^0 a_1(1260)^+$	( 8.2 ± 1.7 ) %		328
$\bar{K}^0 a_2(1320)^+$	< 3 × 10 <sup>-3</sup>	CL=90%	199
$\bar{K}^*(892)^0 \pi^+$	( 1.95 ± 0.19 ) %		714
$\bar{K}^*(892)^0 \rho^+$ total [tt]	( 2.1 ± 1.4 ) %		422
$\bar{K}^*(892)^0 \rho^+$ S-wave [tt]	( 1.7 ± 1.6 ) %		422
$\bar{K}^*(892)^0 \rho^+$ P-wave	< 1 × 10 <sup>-3</sup>	CL=90%	422
$\bar{K}^*(892)^0 \rho^+$ D-wave	( 10 ± 7 ) × 10 <sup>-3</sup>		422
$\bar{K}^*(892)^0 \rho^+$ D-wave longitudinal	< 7 × 10 <sup>-3</sup>	CL=90%	422
$\bar{K}_1(1270)^0 \pi^+$	< 7 × 10 <sup>-3</sup>	CL=90%	487
$\bar{K}_1(1400)^0 \pi^+$	( 5.0 ± 1.3 ) %		390
$\bar{K}_0^*(1430)^0 \pi^+$	( 3.8 ± 0.4 ) %		382
$\bar{K}^*(1680)^0 \pi^+$	( 1.47 ± 0.31 ) %		58
$\bar{K}^*(892)^0 \pi^+ \pi^0$ total	( 6.8 ± 1.4 ) %		690

$\bar{K}^*(892)^0 \pi^+ \pi^0$ 3-body	[ <i>tt</i> ] ( 4.3 ± 1.4 ) %		690
$K^*(892)^- \pi^+ \pi^+$ total	—		688
$K^*(892)^- \pi^+ \pi^+$ 3-body	( 2.1 ± 0.9 ) %		688
$K^- \rho^+ \pi^+$ total	( 3.1 ± 1.1 ) %		612
$K^- \rho^+ \pi^+$ 3-body	( 1.1 ± 0.4 ) %		612
$\bar{K}^0 \rho^0 \pi^+$ total	( 4.3 ± 0.9 ) %	CL=90%	610
$\bar{K}^0 \rho^0 \pi^+$ 3-body	( 5 ± 5 ) × 10 <sup>-3</sup>		610
$\bar{K}^*(892)^0 \pi^+ \pi^+ \pi^-$	( 3.2 ± 1.2 ) × 10 <sup>-3</sup>	S=2.0	645
$\bar{K}^*(892)^0 \rho^0 \pi^+$	( 3.0 ± 0.7 ) × 10 <sup>-3</sup>	S=1.3	239
$\bar{K}^*(892)^0 \pi^+ \pi^+ \pi^-$ no- $\rho$	( 4.4 ± 1.7 ) × 10 <sup>-3</sup>		645
$K^- \rho^0 \pi^+ \pi^+$	( 1.94 ± 0.35 ) × 10 <sup>-3</sup>		524
$\bar{K}^*(892)^0 a_1(1260)^+$	( 9.1 ± 1.9 ) × 10 <sup>-3</sup>		†

### Pionic modes

$\pi^+ \pi^0$	( 2.6 ± 0.7 ) × 10 <sup>-3</sup>		925
$\pi^+ \pi^+ \pi^-$	( 3.1 ± 0.4 ) × 10 <sup>-3</sup>		908
$\sigma \pi^+$	( 2.2 ± 0.5 ) × 10 <sup>-3</sup>		—
$\rho^0 \pi^+$	( 1.05 ± 0.18 ) × 10 <sup>-3</sup>		766
$f_0(980) \pi^+$	[ <i>uu</i> ] ( 1.9 ± 0.5 ) × 10 <sup>-4</sup>		669
× B( $f_0 \rightarrow \pi^+ \pi^-$ )			
$f_2(1270) \pi^+$	( 6.1 ± 1.1 ) × 10 <sup>-4</sup>		485
× B( $f_2 \rightarrow \pi^+ \pi^-$ )			
$\pi^+ \pi^+ \pi^-$ nonresonant	( 2.4 ± 2.1 ) × 10 <sup>-4</sup>		908
$\pi^+ \pi^+ \pi^- \pi^0$	—		883
$\eta \pi^+ \times B(\eta \rightarrow \pi^+ \pi^- \pi^0)$	( 6.8 ± 1.4 ) × 10 <sup>-4</sup>		848
$\omega \pi^+ \times B(\omega \rightarrow \pi^+ \pi^- \pi^0)$	< 6 × 10 <sup>-3</sup>	CL=90%	763
$3\pi^+ 2\pi^-$	( 1.82 ± 0.25 ) × 10 <sup>-3</sup>	S=1.2	845

Fractions of some of the following modes with resonances have already appeared above as submodes of particular charged-particle modes.

$\eta \pi^+$	( 3.0 ± 0.6 ) × 10 <sup>-3</sup>		848
$\rho^0 \pi^+$	( 1.05 ± 0.18 ) × 10 <sup>-3</sup>		766
$\omega \pi^+$	< 7 × 10 <sup>-3</sup>	CL=90%	763
$\eta \rho^+$	< 7 × 10 <sup>-3</sup>	CL=90%	655
$\eta'(958) \pi^+$	( 5.1 ± 1.0 ) × 10 <sup>-3</sup>		680
$\eta'(958) \rho^+$	< 5 × 10 <sup>-3</sup>	CL=90%	348
$f_2(1270) \pi^+$	( 1.08 ± 0.20 ) × 10 <sup>-3</sup>		485

### Hadronic modes with a $K\bar{K}$ pair

$K^+ \bar{K}^0$	( 5.9 ± 0.6 ) × 10 <sup>-3</sup>	S=1.2	792
$K^+ K^- \pi^+$	[ <i>ss</i> ] ( 8.9 ± 0.8 ) × 10 <sup>-3</sup>		744
$\phi \pi^+ \times B(\phi \rightarrow K^+ K^-)$	( 3.1 ± 0.3 ) × 10 <sup>-3</sup>		647
$K^+ \bar{K}^*(892)^0$	( 2.9 ± 0.4 ) × 10 <sup>-3</sup>		613
× B( $\bar{K}^{*0} \rightarrow K^- \pi^+$ )			
$K^+ K^- \pi^+$ nonresonant	( 4.6 ± 0.9 ) × 10 <sup>-3</sup>		744

$K^0 \bar{K}^0 \pi^+$	—	741
$K^*(892)^+ \bar{K}^0$	( 2.1 ± 0.9 ) %	611
$\times B(K^{*+} \rightarrow K^0 \pi^+)$		
$K^+ K^- \pi^+ \pi^0$	—	682
$\phi \pi^+ \pi^0 \times B(\phi \rightarrow K^+ K^-)$	( 1.1 ± 0.5 ) %	619
$\phi \rho^+ \times B(\phi \rightarrow K^+ K^-)$	< 7 × 10 <sup>-3</sup> CL=90%	258
$K^+ K^- \pi^+ \pi^0$ non- $\phi$	( 1.5 $\pm$ $\frac{0.7}{0.6}$ ) %	682
$K^+ \bar{K}^0 \pi^+ \pi^-$	( 4.0 ± 0.7 ) × 10 <sup>-3</sup>	678
$K^0 K^- \pi^+ \pi^+$	( 5.5 ± 0.8 ) × 10 <sup>-3</sup>	678
$K^*(892)^+ \bar{K}^*(892)^0$	( 1.2 ± 0.5 ) %	280
$\times B^2(K^*(892)^+ \rightarrow K^0 \pi^+)$		
$K^0 K^- \pi^+ \pi^+ (\text{non-}K^* \bar{K}^{*0})$	< 7.9 × 10 <sup>-3</sup> CL=90%	678
$K^+ K^- \pi^+ \pi^+ \pi^-$	( 2.5 ± 1.3 ) × 10 <sup>-4</sup>	600

Fractions of the following modes with resonances have already appeared above as submodes of particular charged-particle modes.

$\phi \pi^+$	( 6.2 ± 0.6 ) × 10 <sup>-3</sup>	647
$\phi \pi^+ \pi^0$	( 2.3 ± 1.0 ) %	619
$\phi \rho^+$	< 1.5 % CL=90%	258
$K^+ \bar{K}^*(892)^0$	( 4.3 ± 0.6 ) × 10 <sup>-3</sup>	613
$K^*(892)^+ \bar{K}^0$	( 3.1 ± 1.4 ) %	611
$K^*(892)^+ \bar{K}^*(892)^0$	( 2.6 ± 1.1 ) %	280

**Doubly Cabibbo suppressed (DC) modes,  
 $\Delta C = 1$  weak neutral current (C1) modes, or  
 Lepton Family number (LF) or Lepton number (L) violating modes**

$K^+ \pi^+ \pi^-$	DC	( 7.0 ± 1.5 ) × 10 <sup>-4</sup>	845
$K^+ \rho^0$	DC	( 2.6 ± 1.2 ) × 10 <sup>-4</sup>	678
$K^*(892)^0 \pi^+$	DC [vv]	( 3.7 ± 1.7 ) × 10 <sup>-4</sup>	714
$K^+ \pi^+ \pi^-$ nonresonant	DC	( 2.5 ± 1.2 ) × 10 <sup>-4</sup>	845
$K^+ K^+ K^-$	DC	( 8.7 ± 2.1 ) × 10 <sup>-5</sup>	550
$\phi K^+$	DC [vv]	< 1.3 × 10 <sup>-4</sup> CL=90%	527
$\pi^+ e^+ e^-$	C1	< 5.2 × 10 <sup>-5</sup> CL=90%	929
$\pi^+ \mu^+ \mu^-$	C1	< 8.8 × 10 <sup>-6</sup> CL=90%	917
$\rho^+ \mu^+ \mu^-$	C1	< 5.6 × 10 <sup>-4</sup> CL=90%	757
$K^+ e^+ e^-$	[ww]	< 2.0 × 10 <sup>-4</sup> CL=90%	870
$K^+ \mu^+ \mu^-$	[ww]	< 9.2 × 10 <sup>-6</sup> CL=90%	856
$\pi^+ e^\pm \mu^\mp$	LF [gg]	< 3.4 × 10 <sup>-5</sup> CL=90%	926
$K^+ e^\pm \mu^\mp$	LF [gg]	< 6.8 × 10 <sup>-5</sup> CL=90%	866
$\pi^- e^+ e^+$	L	< 9.6 × 10 <sup>-5</sup> CL=90%	929
$\pi^- \mu^+ \mu^+$	L	< 4.8 × 10 <sup>-6</sup> CL=90%	917
$\pi^- e^+ \mu^+$	L	< 5.0 × 10 <sup>-5</sup> CL=90%	926
$\rho^- \mu^+ \mu^+$	L	< 5.6 × 10 <sup>-4</sup> CL=90%	757

$K^- e^+ e^+$	$L$	$< 1.2$	$\times 10^{-4}$	CL=90%	870
$K^- \mu^+ \mu^+$	$L$	$< 1.3$	$\times 10^{-5}$	CL=90%	856
$K^- e^+ \mu^+$	$L$	$< 1.3$	$\times 10^{-4}$	CL=90%	866
$K^*(892)^- \mu^+ \mu^+$	$L$	$< 8.5$	$\times 10^{-4}$	CL=90%	703

**$D^0$**

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

$$\text{Mass } m = 1864.6 \pm 0.5 \text{ MeV } (S = 1.1)$$

$$m_{D^\pm} - m_{D^0} = 4.78 \pm 0.10 \text{ MeV } (S = 1.1)$$

$$\text{Mean life } \tau = (410.3 \pm 1.5) \times 10^{-15} \text{ s}$$

$$c\tau = 123.0 \text{ } \mu\text{m}$$

$$|m_{D_1^0} - m_{D_2^0}| < 7 \times 10^{10} \hbar \text{ s}^{-1}, \text{ CL} = 95\% \text{ [xx]}$$

$$(\Gamma_{D_1^0} - \Gamma_{D_2^0})/\Gamma = 2y = 0.016 \pm 0.010$$

$$\Gamma(K^+ \ell^- \bar{\nu}_\ell \text{ (via } \bar{D}^0)) / \Gamma(K^- \ell^+ \nu_\ell) < 0.005, \text{ CL} = 90\%$$

$$\Gamma(K^+ \pi^- \text{ (via } \bar{D}^0)) / \Gamma(K^- \pi^+) < 4.1 \times 10^{-4}, \text{ CL} = 95\%$$

### CP-violation decay-rate asymmetries

$$A_{CP}(K^+ K^-) = 0.005 \pm 0.016$$

$$A_{CP}(K_S^0 K_S^0) = -0.23 \pm 0.19$$

$$A_{CP}(\pi^+ \pi^-) = 0.021 \pm 0.026$$

$$A_{CP}(\pi^0 \pi^0) = 0.00 \pm 0.05$$

$$A_{CP}(K_S^0 \phi) = -0.03 \pm 0.09$$

$$A_{CP}(K_S^0 \pi^0) = 0.001 \pm 0.013$$

$$A_{CP}(K^\pm \pi^\mp) = 0.08 \pm 0.09$$

$$A_{CP}(K^\mp \pi^\pm \pi^0) = -0.03 \pm 0.09$$

$$A_{CP}(K^\pm \pi^\mp \pi^0) = 0.09^{+0.25}_{-0.22}$$

### CPT-violation decay-rate asymmetry

$$A_{CPT}(K^\mp \pi^\pm) = 0.008 \pm 0.008$$

$\bar{D}^0$  modes are charge conjugates of the modes below.

<b><math>D^0</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor/ Confidence level	$p$ (MeV/c)
<b>Inclusive modes</b>			
$e^+$ anything	[ $y\gamma$ ] ( 6.87 ± 0.28 ) %		—
$\mu^+$ anything	( 6.5 ± 0.8 ) %		—
$K^-$ anything	(53 ± 4 ) %	S=1.3	—
$\bar{K}^0$ anything + $K^0$ anything	(42 ± 5 ) %		—
$K^+$ anything	( 3.4 $^{+0.6}_{-0.4}$ ) %		—
$\eta$ anything	[ $p\rho$ ] < 13 %	CL=90%	—
$\phi$ anything	( 1.7 ± 0.8 ) %		—

### Semileptonic modes

$K^- \ell^+ \nu_\ell$	[ <i>qq</i> ]	( 3.43 ± 0.14 ) %	S=1.2	867
$K^- e^+ \nu_e$		( 3.58 ± 0.18 ) %	S=1.1	867
$K^- \mu^+ \nu_\mu$		( 3.19 ± 0.17 ) %		864
$K^- \pi^0 e^+ \nu_e$		( 1.1 $\begin{smallmatrix} + \\ - \end{smallmatrix}$ 0.8 / 0.6 ) %	S=1.6	861
$\bar{K}^0 \pi^- e^+ \nu_e$		( 1.8 ± 0.8 ) %	S=1.6	860
$\bar{K}^*(892)^- e^+ \nu_e$		( 1.43 ± 0.23 ) %		719
$\times B(K^*(892)^- \rightarrow \bar{K}^0 \pi^-)$				
$K^- \pi^+ \pi^- \mu^+ \nu_\mu$		< 1.2	$\times 10^{-3}$ CL=90%	821
$(\bar{K}^*(892)\pi)^- \mu^+ \nu_\mu$		< 1.4	$\times 10^{-3}$ CL=90%	692
$\pi^- e^+ \nu_e$		( 3.6 ± 0.6 ) $\times 10^{-3}$		927

A fraction of the following resonance mode has already appeared above as a submode of a charged-particle mode.

$K^*(892)^- e^+ \nu_e$	( 2.15 ± 0.35 ) %	719
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### Hadronic modes with a $\bar{K}$ or $\bar{K}K\bar{K}$

$K^- \pi^+$	( 3.80 ± 0.09 ) %	861
$\bar{K}^0 \pi^0$	( 2.30 ± 0.22 ) %	860
$\bar{K}^0 \pi^+ \pi^-$	[ <i>ss</i> ] ( 5.97 ± 0.35 ) %	S=1.1 842
$\bar{K}^0 \rho^0$	( 1.55 $\begin{smallmatrix} + \\ - \end{smallmatrix}$ 0.12 / 0.16 ) %	673
$\bar{K}^0 \omega$	( 3.9 ± 0.9 ) $\times 10^{-4}$	670
$\times B(\omega \rightarrow \pi^+ \pi^-)$		
$\bar{K}^0 f_0(980)$	( 2.8 $\begin{smallmatrix} + \\ - \end{smallmatrix}$ 0.6 / 0.4 ) $\times 10^{-3}$	549
$\times B(f_0(980) \rightarrow \pi^+ \pi^-)$		
$\bar{K}^0 f_2(1270)$	( 2.6 $\begin{smallmatrix} + \\ - \end{smallmatrix}$ 2.3 / 1.4 ) $\times 10^{-4}$	262
$\times B(f_2(1270) \rightarrow \pi^+ \pi^-)$		
$\bar{K}^0 f_0(1370)$	( 5.1 $\begin{smallmatrix} + \\ - \end{smallmatrix}$ 1.2 / 1.3 ) $\times 10^{-3}$	—
$\times B(f_0(1370) \rightarrow \pi^+ \pi^-)$		
$K^*(892)^- \pi^+$	( 3.9 ± 0.3 ) %	711
$\times B(K^*(892)^- \rightarrow \bar{K}^0 \pi^-)$		
$K_0^*(1430)^- \pi^+$	( 6.1 $\begin{smallmatrix} + \\ - \end{smallmatrix}$ 1.2 / 0.8 ) $\times 10^{-3}$	378
$\times B(K_0^*(1430)^- \rightarrow \bar{K}^0 \pi^-)$		
$K_2^*(1430)^- \pi^+$	( 1.0 $\begin{smallmatrix} + \\ - \end{smallmatrix}$ 0.7 / 0.4 ) $\times 10^{-3}$	367
$\times B(K_2^*(1430)^- \rightarrow \bar{K}^0 \pi^-)$		
$K^*(1680)^- \pi^+$	( 2.1 $\begin{smallmatrix} + \\ - \end{smallmatrix}$ 1.0 / 0.9 ) $\times 10^{-3}$	46
$\times B(K^*(1680)^- \rightarrow \bar{K}^0 \pi^-)$		
$K^*(892)^+ \pi^-$	( 2.0 $\begin{smallmatrix} + \\ - \end{smallmatrix}$ 2.6 / 0.9 ) $\times 10^{-4}$	711
$\times B(K^*(892)^+ \rightarrow K^0 \pi^+)$		
$\bar{K}^0 \pi^+ \pi^-$ nonresonant	( 5.4 $\begin{smallmatrix} + \\ - \end{smallmatrix}$ 12.0 / 3.4 ) $\times 10^{-4}$	842

$K^- \pi^+ \pi^0$	[ss]	$(13.0 \pm 0.8) \%$	S=1.3	844
$K^- \rho^+$		$(10.1 \pm 0.8) \%$		675
$K^- \rho(1700)^+$		$(7.4 \pm 1.6) \times 10^{-3}$		†
$\times B(\rho(1700)^+ \rightarrow \pi^+ \pi^0)$				
$K^*(892)^- \pi^+$		$(1.97 \pm 0.13) \%$		711
$\times B(K^*(892)^- \rightarrow K^- \pi^0)$				
$\bar{K}^*(892)^0 \pi^0$		$(1.87 \pm 0.27) \%$		711
$\times B(\bar{K}^*(892)^0 \rightarrow K^- \pi^+)$				
$K_0^*(1430)^- \pi^+$		$(3.0 \pm 0.6) \times 10^{-3}$		378
$\times B(K_0^*(1430)^- \rightarrow K^- \pi^0)$				
$\bar{K}_0^*(1430)^0 \pi^0$		$(5.3 \pm 4.2) \times 10^{-3}$		379
$\times B(\bar{K}_0^*(1430)^0 \rightarrow K^- \pi^+)$				
$K^*(1680)^- \pi^+$		$(1.1 \pm 0.5) \times 10^{-3}$		46
$\times B(K^*(1680)^- \rightarrow K^- \pi^0)$				
$K^- \pi^+ \pi^0$ nonresonant		$(1.04 \pm 0.50) \%$		844
$\bar{K}^0 \pi^0 \pi^0$		—		843
$\bar{K}^*(892)^0 \pi^0$		$(9.3 \pm 1.3) \times 10^{-3}$		711
$\times B(\bar{K}^*(892)^0 \rightarrow \bar{K}^0 \pi^0)$				
$\bar{K}^0 \pi^0 \pi^0$ nonresonant		$(8.5 \pm 2.2) \times 10^{-3}$		843
$K^- \pi^+ \pi^+ \pi^-$	[ss]	$(7.46 \pm 0.31) \%$		812
$K^- \pi^+ \rho^0$ total		$(6.2 \pm 0.4) \%$		609
$K^- \pi^+ \rho^0$ 3-body		$(4.7 \pm 2.1) \times 10^{-3}$		609
$\bar{K}^*(892)^0 \rho^0$		$(9.7 \pm 2.1) \times 10^{-3}$		416
$\times B(\bar{K}^*(892)^0 \rightarrow K^- \pi^+)$				
$K^- a_1(1260)^+$		$(3.6 \pm 0.6) \%$		327
$\times B(a_1(1260)^+ \rightarrow \pi^+ \pi^+ \pi^-)$				
$\bar{K}^*(892)^0 \pi^+ \pi^-$ total		$(1.5 \pm 0.4) \%$		685
$\times B(\bar{K}^*(892)^0 \rightarrow K^- \pi^+)$				
$\bar{K}^*(892)^0 \pi^+ \pi^-$ 3-body		$(9.5 \pm 2.1) \times 10^{-3}$		685
$\times B(\bar{K}^*(892)^0 \rightarrow K^- \pi^+)$				
$K_1(1270)^- \pi^+$	[tt]	$(2.9 \pm 0.3) \times 10^{-3}$		484
$\times B(K_1(1270)^- \rightarrow K^- \pi^+ \pi^-)$				
$K^- \pi^+ \pi^+ \pi^-$ nonresonant		$(1.74 \pm 0.25) \%$		812
$\bar{K}^0 \pi^+ \pi^- \pi^0$	[ss]	$(10.9 \pm 1.3) \%$		812
$\bar{K}^0 \eta \times B(\eta \rightarrow \pi^+ \pi^- \pi^0)$		$(1.74 \pm 0.25) \times 10^{-3}$		772
$\bar{K}^0 \omega \times B(\omega \rightarrow \pi^+ \pi^- \pi^0)$		$(2.1 \pm 0.4) \%$		670
$K^*(892)^- \rho^+$		$(4.4 \pm 1.7) \%$		416
$\times B(K^*(892)^- \rightarrow \bar{K}^0 \pi^-)$				
$\bar{K}^*(892)^0 \rho^0$		$(4.8 \pm 1.1) \times 10^{-3}$		416
$\times B(\bar{K}^*(892)^0 \rightarrow \bar{K}^0 \pi^0)$				
$K_1(1270)^- \pi^+$	[tt]	$(4.5 \pm 1.2) \times 10^{-3}$		484
$\times B(K_1(1270)^- \rightarrow \bar{K}^0 \pi^- \pi^0)$				

$\bar{K}^*(892)^0 \pi^+ \pi^-$ 3-body $\times B(\bar{K}^*(892)^0 \rightarrow \bar{K}^0 \pi^0)$	$(4.7 \pm 1.0) \times 10^{-3}$		685
$\bar{K}^0 \pi^+ \pi^- \pi^0$ nonresonant	$(2.3 \pm 2.3) \%$		812
$K^- \pi^+ \pi^+ \pi^- \pi^0$	$(4.0 \pm 0.4) \%$		771
$\bar{K}^*(892)^0 \pi^+ \pi^- \pi^0$ $\times B(\bar{K}^*(892)^0 \rightarrow K^- \pi^+)$	$(1.2 \pm 0.6) \%$		643
$\bar{K}^*(892)^0 \eta$ $\times B(\bar{K}^*(892)^0 \rightarrow K^- \pi^+)$ $\times B(\eta \rightarrow \pi^+ \pi^- \pi^0)$	$(2.7 \pm 0.6) \times 10^{-3}$		582
$K^- \pi^+ \omega \times B(\omega \rightarrow \pi^+ \pi^- \pi^0)$	$(2.7 \pm 0.5) \%$		605
$\bar{K}^*(892)^0 \omega$ $\times B(\bar{K}^*(892)^0 \rightarrow K^- \pi^+)$ $\times B(\omega \rightarrow \pi^+ \pi^- \pi^0)$	$(6.5 \pm 2.4) \times 10^{-3}$		410
$\bar{K}^0 \pi^+ \pi^+ \pi^- \pi^-$	$(6.4 \pm 1.8) \times 10^{-3}$		768
$\bar{K}^0 K^+ K^-$ $\bar{K}^0 \phi \times B(\phi \rightarrow K^+ K^-)$	$(1.03 \pm 0.10) \%$		544
$\bar{K}^0 \phi \times B(\phi \rightarrow K^+ K^-)$	$(4.7 \pm 0.6) \times 10^{-3}$		520
$\bar{K}^0 K^+ K^-$ non- $\phi$	$(5.6 \pm 0.9) \times 10^{-3}$		544
$K_S^0 K_S^0 K_S^0$	$(9.2 \pm 1.6) \times 10^{-4}$		538
$K^+ K^- K^- \pi^+$	$(2.04 \pm 0.30) \times 10^{-4}$		434
$K^+ K^- \bar{K}^*(892)^0$ $\times B(\bar{K}^*(892)^0 \rightarrow K^- \pi^+)$	$(4.1 \pm 1.7) \times 10^{-5}$		†
$K^- \pi^+ \phi \times B(\phi \rightarrow K^+ K^-)$	$(3.8 \pm 1.6) \times 10^{-5}$		422
$\phi \bar{K}^*(892)^0$ $\times B(\phi \rightarrow K^+ K^-)$ $\times B(\bar{K}^*(892)^0 \rightarrow K^- \pi^+)$	$(1.0 \pm 0.2) \times 10^{-4}$		†
$K^+ K^- K^- \pi^+$ nonresonant	$(3.1 \pm 1.4) \times 10^{-5}$		434

Fractions of many of the following modes with resonances have already appeared above as submodes of particular charged-particle modes. (Modes for which there are only upper limits and  $\bar{K}^*(892)\rho$  submodes only appear below.)

$\bar{K}^0 \eta$	$(7.7 \pm 1.1) \times 10^{-3}$		772
$\bar{K}^0 \rho^0$	$(1.55^{+0.12}_{-0.16}) \%$		673
$K^- \rho^+$	$(10.1 \pm 0.8) \%$	S=1.2	675
$\bar{K}^0 \omega$	$(2.3 \pm 0.4) \%$		670
$\bar{K}^0 \eta'(958)$	$(1.88 \pm 0.28) \%$		565
$\bar{K}^0 \phi$	$(9.4 \pm 1.1) \times 10^{-3}$		520
$K^- a_1(1260)^+$	$(7.2 \pm 1.1) \%$		327
$\bar{K}^0 a_1(1260)^0$	$< 1.9 \%$	CL=90%	323
$\bar{K}^0 f_2(1270)$	$(4.7^{+4.1}_{-2.4}) \times 10^{-4}$		262
$K^- a_2(1320)^+$	$< 2 \times 10^{-3}$	CL=90%	197
$K^*(892)^- \pi^+$	$(5.9 \pm 0.4) \%$	S=1.1	711
$\bar{K}^*(892)^0 \pi^0$	$(2.8 \pm 0.4) \%$	S=1.1	711



$\bar{K}^*(892)^0 \pi^+ \pi^-$ total	( 2.2 ± 0.5 ) %		685
$\bar{K}^*(892)^0 \pi^+ \pi^-$ 3-body	( 1.42 ± 0.31 ) %		685
$K^- \pi^+ \rho^0$ total	( 6.2 ± 0.4 ) %		609
$K^- \pi^+ \rho^0$ 3-body	( 4.7 ± 2.1 ) × 10 <sup>-3</sup>		609
$\bar{K}^*(892)^0 \rho^0$	( 1.45 ± 0.32 ) %		416
$\bar{K}^*(892)^0 \rho^0$ transverse	( 1.5 ± 0.5 ) %		416
$\bar{K}^*(892)^0 \rho^0$ S-wave	( 2.8 ± 0.6 ) %		416
$\bar{K}^*(892)^0 \rho^0$ S-wave long.	< 3 × 10 <sup>-3</sup>	CL=90%	416
$\bar{K}^*(892)^0 \rho^0$ P-wave	< 3 × 10 <sup>-3</sup>	CL=90%	416
$\bar{K}^*(892)^0 \rho^0$ D-wave	( 1.9 ± 0.6 ) %		416
$K^*(892)^- \rho^+$	( 6.6 ± 2.6 ) %		416
$K^*(892)^- \rho^+$ longitudinal	( 3.2 ± 1.3 ) %		416
$K^*(892)^- \rho^+$ transverse	( 3.4 ± 2.0 ) %		416
$K^*(892)^- \rho^+$ P-wave	< 1.5 %	CL=90%	416
$K_1(1270)^- \pi^+$	[ <i>tt</i> ] ( 1.14 ± 0.31 ) %		484
$K_1(1400)^- \pi^+$	< 1.2 %	CL=90%	386
$\bar{K}_1(1400)^0 \pi^0$	< 3.7 %	CL=90%	387
$K_0^*(1430)^- \pi^+$	( 9.8 <sup>+2.0</sup> <sub>-1.3</sub> ) × 10 <sup>-3</sup>		378
$\bar{K}_0^*(1430)^0 \pi^0$	( 8.6 <sup>+6.8</sup> <sub>-2.3</sub> ) × 10 <sup>-3</sup>		379
$K_2^*(1430)^- \pi^+$	( 2.0 <sup>+1.3</sup> <sub>-0.7</sub> ) × 10 <sup>-3</sup>		367
$\bar{K}_2^*(1430)^0 \pi^0$	< 3.3 × 10 <sup>-3</sup>	CL=90%	368
$K^*(1680)^- \pi^+$	( 8.2 <sup>+3.9</sup> <sub>-3.5</sub> ) × 10 <sup>-3</sup>	S=1.2	46
$\bar{K}^*(892)^0 \pi^+ \pi^- \pi^0$	( 1.8 ± 0.9 ) %		643
$\bar{K}^*(892)^0 \eta$	( 1.8 ± 0.4 ) %		582
$K^- \pi^+ \omega$	( 3.0 ± 0.6 ) %		605
$\bar{K}^*(892)^0 \omega$	( 1.1 ± 0.4 ) %		410
$K^- \pi^+ \eta'(958)$	( 6.9 ± 1.8 ) × 10 <sup>-3</sup>		479
$\bar{K}^*(892)^0 \eta'(958)$	< 1.0 × 10 <sup>-3</sup>	CL=90%	119
$K^- \pi^+ \phi$	( 7.6 ± 3.1 ) × 10 <sup>-5</sup>		422
$K^+ K^- \bar{K}^*(892)^0$	( 6.1 ± 2.5 ) × 10 <sup>-5</sup>		†
$\phi \bar{K}^*(892)^0$	( 3.0 ± 0.6 ) × 10 <sup>-4</sup>		†
<b>Pionic modes</b>			
$\pi^+ \pi^-$	( 1.38 ± 0.05 ) × 10 <sup>-3</sup>		922
$\pi^0 \pi^0$	( 8.4 ± 2.2 ) × 10 <sup>-4</sup>		922
$\pi^+ \pi^- \pi^0$	( 1.1 ± 0.4 ) %		907
$\pi^+ \pi^+ \pi^- \pi^-$	( 7.3 ± 0.5 ) × 10 <sup>-3</sup>		880

### Hadronic modes with a $K\bar{K}$ pair

$K^+ K^-$	$( 3.89^{+0.12}_{-0.15} ) \times 10^{-3}$	S=1.2	791
$K^0 \bar{K}^0$	$( 7.1 \pm 1.9 ) \times 10^{-4}$	S=1.2	788
$K^0 K^- \pi^+$	$( 6.9 \pm 1.0 ) \times 10^{-3}$		739
$\bar{K}^*(892)^0 K^0$ $\times B(\bar{K}^{*0} \rightarrow K^- \pi^+)$	$< 1.1 \times 10^{-3}$	CL=90%	608
$K^*(892)^+ K^-$ $\times B(K^{*+} \rightarrow K^0 \pi^+)$	$( 2.5 \pm 0.5 ) \times 10^{-3}$		610
$K^0 K^- \pi^+$ nonresonant	$( 2.3 \pm 2.3 ) \times 10^{-3}$		739
$\bar{K}^0 K^+ \pi^-$	$( 5.3 \pm 1.0 ) \times 10^{-3}$		739
$K^*(892)^0 \bar{K}^0$ $\times B(K^{*0} \rightarrow K^+ \pi^-)$	$< 6 \times 10^{-4}$	CL=90%	608
$K^*(892)^- K^+$ $\times B(K^{*-} \rightarrow \bar{K}^0 \pi^-)$	$( 1.3 \pm 0.7 ) \times 10^{-3}$		610
$\bar{K}^0 K^+ \pi^-$ nonresonant	$( 3.8^{+2.3}_{-1.9} ) \times 10^{-3}$		739
$K^+ K^- \pi^0$	$( 1.24 \pm 0.35 ) \times 10^{-3}$		743
$K_S^0 K_S^0 \pi^0$	$< 5.9 \times 10^{-4}$		740
$K^+ K^- \pi^+ \pi^-$	[zz] $( 2.49 \pm 0.23 ) \times 10^{-3}$		677
$\phi \pi^+ \pi^- \times B(\phi \rightarrow K^+ K^-)$	$( 5.3 \pm 1.4 ) \times 10^{-4}$		614
$\phi \rho^0 \times B(\phi \rightarrow K^+ K^-)$	$( 2.9 \pm 1.5 ) \times 10^{-4}$		250
$K^+ K^- \rho^0$ 3-body	$( 9.0 \pm 2.3 ) \times 10^{-4}$		301
$K^*(892)^0 K^- \pi^+ + \text{c.c.}$	[aaa] $< 5 \times 10^{-4}$		531
$\times B(K^{*0} \rightarrow K^+ \pi^-)$			
$K^*(892)^0 \bar{K}^*(892)^0$ $\times B^2(K^{*0} \rightarrow K^+ \pi^-)$	$( 6 \pm 2 ) \times 10^{-4}$		272
$K^+ K^- \pi^+ \pi^-$ nonresonant	$< 8 \times 10^{-4}$	CL=90%	677
$K^0 \bar{K}^0 \pi^+ \pi^-$	$( 7.5 \pm 2.9 ) \times 10^{-3}$		673
$K^+ K^- \pi^+ \pi^- \pi^0$	$( 3.1 \pm 2.0 ) \times 10^{-3}$		600

Fractions of most of the following modes with resonances have already appeared above as submodes of particular charged-particle modes.

$\bar{K}^*(892)^0 K^0$	$< 1.7 \times 10^{-3}$	CL=90%	608
$K^*(892)^+ K^-$	$( 3.8 \pm 0.8 ) \times 10^{-3}$		610
$K^*(892)^0 \bar{K}^0$	$< 9 \times 10^{-4}$	CL=90%	608
$K^*(892)^- K^+$	$( 2.0 \pm 1.1 ) \times 10^{-3}$		610
$\phi \pi^0$	$( 7.5 \pm 0.5 ) \times 10^{-4}$		645
$\phi \eta$	$( 1.4 \pm 0.5 ) \times 10^{-4}$		489
$\phi \omega$	$< 2.1 \times 10^{-3}$	CL=90%	238
$\phi \pi^+ \pi^-$	$( 1.06 \pm 0.28 ) \times 10^{-3}$		614
$\phi \rho^0$	$( 5.7 \pm 3.0 ) \times 10^{-4}$		250
$\phi \pi^+ \pi^-$ 3-body	$( 7 \pm 5 ) \times 10^{-4}$		614
$K^*(892)^0 K^- \pi^+ + \text{c.c.}$	[aaa] $< 7 \times 10^{-4}$	CL=90%	531
$K^*(892)^0 \bar{K}^*(892)^0$	$( 1.4 \pm 0.5 ) \times 10^{-3}$		272

**Radiative modes**

$\rho^0 \gamma$		< 2.4	$\times 10^{-4}$	CL=90%	771
$\omega \gamma$		< 2.4	$\times 10^{-4}$	CL=90%	768
$\phi \gamma$		$( 2.5 \begin{smallmatrix} + \\ - \end{smallmatrix} \begin{smallmatrix} 0.7 \\ 0.6 \end{smallmatrix} ) \times 10^{-5}$			654
$\bar{K}^*(892)^0 \gamma$		< 7.6	$\times 10^{-4}$	CL=90%	719

**Doubly Cabibbo suppressed (DC) modes,  
 $\Delta C = 2$  forbidden via mixing (C2M) modes,  
 $\Delta C = 1$  weak neutral current (C1) modes,  
 Lepton Family number (LF) violating modes, or  
 Lepton number (L) violating modes**

$K^+ \ell^- \bar{\nu}_\ell$ (via $\bar{D}^0$ )	C2M	< 1.7	$\times 10^{-4}$	CL=90%	—
$K^+ \pi^-$	DC	$( 1.38 \pm 0.11 ) \times 10^{-4}$			861
$K^+ \pi^-$ (via $\bar{D}^0$ )	C2M	< 1.6	$\times 10^{-5}$	CL=95%	861
$K^*(892)^+ \pi^-$		$( 3.0 \begin{smallmatrix} + \\ - \end{smallmatrix} \begin{smallmatrix} 3.8 \\ 1.3 \end{smallmatrix} ) \times 10^{-4}$			711
$K^+ \pi^- \pi^0$		$( 5.6 \pm 1.7 ) \times 10^{-4}$			844
$K^+ \pi^- \pi^+ \pi^-$	DC	$( 3.1 \pm 1.0 ) \times 10^{-4}$			812
$K^+ \pi^- \pi^+ \pi^-$ (via $\bar{D}^0$ )	C2M	< 4	$\times 10^{-4}$	CL=90%	812
$K^+ \pi^-$ or $K^+ \pi^- \pi^+ \pi^-$ (via $\bar{D}^0$ )		< 1.0	$\times 10^{-3}$	CL=90%	—
$\mu^-$ anything (via $\bar{D}^0$ )	C2M	< 4	$\times 10^{-4}$	CL=90%	—
$\gamma \gamma$	C1	< 2.8	$\times 10^{-5}$	CL=90%	932
$e^+ e^-$	C1	< 6.2	$\times 10^{-6}$	CL=90%	932
$\mu^+ \mu^-$	C1	< 4.1	$\times 10^{-6}$	CL=90%	926
$\pi^0 e^+ e^-$	C1	< 4.5	$\times 10^{-5}$	CL=90%	927
$\pi^0 \mu^+ \mu^-$	C1	< 1.8	$\times 10^{-4}$	CL=90%	915
$\eta e^+ e^-$	C1	< 1.1	$\times 10^{-4}$	CL=90%	852
$\eta \mu^+ \mu^-$	C1	< 5.3	$\times 10^{-4}$	CL=90%	838
$\pi^+ \pi^- e^+ e^-$	C1	< 3.73	$\times 10^{-4}$	CL=90%	922
$\rho^0 e^+ e^-$	C1	< 1.0	$\times 10^{-4}$	CL=90%	771
$\pi^+ \pi^- \mu^+ \mu^-$	C1	< 3.0	$\times 10^{-5}$	CL=90%	894
$\rho^0 \mu^+ \mu^-$	C1	< 2.2	$\times 10^{-5}$	CL=90%	754
$\omega e^+ e^-$	C1	< 1.8	$\times 10^{-4}$	CL=90%	768
$\omega \mu^+ \mu^-$	C1	< 8.3	$\times 10^{-4}$	CL=90%	751
$K^- K^+ e^+ e^-$	C1	< 3.15	$\times 10^{-4}$	CL=90%	791
$\phi e^+ e^-$	C1	< 5.2	$\times 10^{-5}$	CL=90%	654
$K^- K^+ \mu^+ \mu^-$	C1	< 3.3	$\times 10^{-5}$	CL=90%	710
$\phi \mu^+ \mu^-$	C1	< 3.1	$\times 10^{-5}$	CL=90%	631
$\bar{K}^0 e^+ e^-$	[ww]	< 1.1	$\times 10^{-4}$	CL=90%	866
$\bar{K}^0 \mu^+ \mu^-$	[ww]	< 2.6	$\times 10^{-4}$	CL=90%	852
$K^- \pi^+ e^+ e^-$	C1	< 3.85	$\times 10^{-4}$	CL=90%	861
$\bar{K}^*(892)^0 e^+ e^-$	[ww]	< 4.7	$\times 10^{-5}$	CL=90%	719
$K^- \pi^+ \mu^+ \mu^-$	C1	< 3.59	$\times 10^{-4}$	CL=90%	829

$\bar{K}^*(892)^0 \mu^+ \mu^-$		$[ww] < 2.4$	$\times 10^{-5}$	CL=90%	700
$\pi^+ \pi^- \pi^0 \mu^+ \mu^-$	C1	$< 8.1$	$\times 10^{-4}$	CL=90%	863
$\mu^\pm e^\mp$	LF	$[gg] < 8.1$	$\times 10^{-6}$	CL=90%	929
$\pi^0 e^\pm \mu^\mp$	LF	$[gg] < 8.6$	$\times 10^{-5}$	CL=90%	924
$\eta e^\pm \mu^\mp$	LF	$[gg] < 1.0$	$\times 10^{-4}$	CL=90%	848
$\pi^+ \pi^- e^\pm \mu^\mp$	LF	$[gg] < 1.5$	$\times 10^{-5}$	CL=90%	911
$\rho^0 e^\pm \mu^\mp$	LF	$[gg] < 4.9$	$\times 10^{-5}$	CL=90%	767
$\omega e^\pm \mu^\mp$	LF	$[gg] < 1.2$	$\times 10^{-4}$	CL=90%	764
$K^- K^+ e^\pm \mu^\mp$	LF	$[gg] < 1.8$	$\times 10^{-4}$	CL=90%	754
$\phi e^\pm \mu^\mp$	LF	$[gg] < 3.4$	$\times 10^{-5}$	CL=90%	648
$\bar{K}^0 e^\pm \mu^\mp$	LF	$[gg] < 1.0$	$\times 10^{-4}$	CL=90%	862
$K^- \pi^+ e^\pm \mu^\mp$	LF	$[gg] < 5.53$	$\times 10^{-4}$	CL=90%	848
$\bar{K}^*(892)^0 e^\pm \mu^\mp$	LF	$[gg] < 8.3$	$\times 10^{-5}$	CL=90%	714
$\pi^- \pi^- e^+ e^+ + c.c.$	L	$< 1.12$	$\times 10^{-4}$	CL=90%	922
$\pi^- \pi^- \mu^+ \mu^+ + c.c.$	L	$< 2.9$	$\times 10^{-5}$	CL=90%	894
$K^- \pi^- e^+ e^+ + c.c.$	L	$< 2.06$	$\times 10^{-4}$	CL=90%	861
$K^- \pi^- \mu^+ \mu^+ + c.c.$	L	$< 3.9$	$\times 10^{-4}$	CL=90%	829
$K^- K^- e^+ e^+ + c.c.$	L	$< 1.52$	$\times 10^{-4}$	CL=90%	791
$K^- K^- \mu^+ \mu^+ + c.c.$	L	$< 9.4$	$\times 10^{-5}$	CL=90%	710
$\pi^- \pi^- e^+ \mu^+ + c.c.$	L	$< 7.9$	$\times 10^{-5}$	CL=90%	911
$K^- \pi^- e^+ \mu^+ + c.c.$	L	$< 2.18$	$\times 10^{-4}$	CL=90%	848
$K^- K^- e^+ \mu^+ + c.c.$	L	$< 5.7$	$\times 10^{-5}$	CL=90%	754

### $D^*(2007)^0$

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

$I, J, P$  need confirmation.

Mass  $m = 2006.7 \pm 0.5$  MeV ( $S = 1.1$ )

$m_{D^{*0}} - m_{D^0} = 142.12 \pm 0.07$  MeV

Full width  $\Gamma < 2.1$  MeV, CL = 90%

$\bar{D}^*(2007)^0$  modes are charge conjugates of modes below.

$D^*(2007)^0$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$D^0 \pi^0$	(61.9±2.9) %	43
$D^0 \gamma$	(38.1±2.9) %	137

### $D^*(2010)^\pm$

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

$I, J, P$  need confirmation.

Mass  $m = 2010.0 \pm 0.5$  MeV ( $S = 1.1$ )

$m_{D^*(2010)^+} - m_{D^+} = 140.64 \pm 0.10$  MeV ( $S = 1.1$ )

$m_{D^*(2010)^+} - m_{D^0} = 145.421 \pm 0.010$  MeV ( $S = 1.1$ )

Full width  $\Gamma = 96 \pm 22$  keV

$D^*(2010)^-$  modes are charge conjugates of the modes below.

$D^*(2010)^\pm$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$D^0 \pi^+$	$(67.7 \pm 0.5) \%$	39
$D^+ \pi^0$	$(30.7 \pm 0.5) \%$	38
$D^+ \gamma$	$(1.6 \pm 0.4) \%$	136

**$D_1(2420)^0$**

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

$I, J, P$  need confirmation.

Mass  $m = 2422.2 \pm 1.8$  MeV ( $S = 1.2$ )

Full width  $\Gamma = 18.9^{+4.6}_{-3.5}$  MeV

$\bar{D}_1(2420)^0$  modes are charge conjugates of modes below.

$D_1(2420)^0$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$D^*(2010)^+ \pi^-$	seen	355
$D^+ \pi^-$	not seen	474

**$D_2^*(2460)^0$**

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

$J^P = 2^+$  assignment strongly favored.

Mass  $m = 2458.9 \pm 2.0$  MeV ( $S = 1.2$ )

Full width  $\Gamma = 23 \pm 5$  MeV

$\bar{D}_2^*(2460)^0$  modes are charge conjugates of modes below.

$D_2^*(2460)^0$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$D^+ \pi^-$	seen	504
$D^*(2010)^+ \pi^-$	seen	387

**$D_2^*(2460)^\pm$**

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

$J^P = 2^+$  assignment strongly favored.

Mass  $m = 2459 \pm 4$  MeV ( $S = 1.7$ )

$m_{D_2^*(2460)^\pm} - m_{D_2^*(2460)^0} = 0.9 \pm 3.3$  MeV ( $S = 1.1$ )

Full width  $\Gamma = 25^{+8}_{-7}$  MeV

$D_2^*(2460)^-$  modes are charge conjugates of modes below.

$D_2^*(2460)^\pm$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$D^0 \pi^+$	seen	507
$D^{*0} \pi^+$	seen	390

## CHARMED, STRANGE MESONS

### ( $C = S = \pm 1$ )

$D_s^+ = c\bar{s}, D_s^- = \bar{c}s$ , similarly for  $D_s^{*}$ 's

$D_s^\pm$   
was  $F^\pm$

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

Mass  $m = 1968.3 \pm 0.5$  MeV ( $S = 1.2$ )  
 $m_{D_s^\pm} - m_{D^\pm} = 98.87 \pm 0.31$  MeV ( $S = 1.4$ )  
 Mean life  $\tau = (490 \pm 9) \times 10^{-15}$  s ( $S = 1.1$ )  
 $c\tau = 147.0$   $\mu\text{m}$

#### $D_s^+$ form factors

$r_2 = 1.60 \pm 0.24$   
 $r_V = 1.92 \pm 0.32$   
 $\Gamma_L/\Gamma_T = 0.72 \pm 0.18$

Unless otherwise noted, the branching fractions for modes with a resonance in the final state include all the decay modes of the resonance.  $D_s^-$  modes are charge conjugates of the modes below.

$D_s^+$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor/ Confidence level	$p$ (MeV/c)
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Inclusive modes			
$K^-$ anything	(13 $\begin{smallmatrix} +14 \\ -12 \end{smallmatrix}$ ) %		—
$\bar{K}^0$ anything + $K^0$ anything	(39 $\pm 28$ ) %		—
$K^+$ anything	(20 $\begin{smallmatrix} +18 \\ -14 \end{smallmatrix}$ ) %		—
(non- $K$ $\bar{K}$ ) anything	(64 $\pm 17$ ) %		—
$e^+$ anything	( 8 $\begin{smallmatrix} + 6 \\ - 5 \end{smallmatrix}$ ) %		—
$\phi$ anything	(18 $\begin{smallmatrix} +15 \\ -10 \end{smallmatrix}$ ) %		—

### Leptonic and semileptonic modes

$\mu^+ \nu_\mu$	( 5.0 ± 1.9 ) × 10 <sup>-3</sup>	S=1.3	981
$\tau^+ \nu_\tau$	( 6.4 ± 1.5 ) %		182
$\phi \ell^+ \nu_\ell$	[bbb] ( 2.0 ± 0.5 ) %		720
$\eta \ell^+ \nu_\ell + \eta'(958) \ell^+ \nu_\ell$	[bbb] ( 3.4 ± 1.0 ) %		—
$\eta \ell^+ \nu_\ell$	[bbb] ( 2.5 ± 0.7 ) %		908
$\eta'(958) \ell^+ \nu_\ell$	[bbb] ( 8.9 ± 3.3 ) × 10 <sup>-3</sup>		751

### Hadronic modes with a $K\bar{K}$ pair (including from a $\phi$ )

$K^+ \bar{K}^0$	( 3.6 ± 1.1 ) %		850
$K^+ K^- \pi^+$	[ss] ( 4.4 ± 1.2 ) %		805
$\phi \pi^+$	[ccc] ( 3.6 ± 0.9 ) %		712
$K^+ \bar{K}^*(892)^0$	[ccc] ( 3.3 ± 0.9 ) %		685
$f_0(980) \pi^+$	[ddd] ( 4.9 ± 2.3 ) × 10 <sup>-3</sup>		732
$\times B(f_0 \rightarrow K^+ K^-)$			
$K^+ \bar{K}_0^*(1430)^0$	[ccc] ( 7 ± 4 ) × 10 <sup>-3</sup>		218
$K^+ K^- \pi^+$ nonresonant	( 9 ± 4 ) × 10 <sup>-3</sup>		805
$K^0 \bar{K}^0 \pi^+$	—		802
$K^*(892)^+ \bar{K}^0$	[ccc] ( 4.3 ± 1.4 ) %		683
$K^+ K^- \pi^+ \pi^0$	—		748
$\phi \pi^+ \pi^0$	[ccc] ( 9 ± 5 ) %		686
$\phi \rho^+$	[ccc] ( 6.7 ± 2.3 ) %		400
$\phi \pi^+ \pi^0$ 3-body	[ccc] < 2.6 %	CL=90%	686
$K^+ K^- \pi^+ \pi^0$ non- $\phi$	< 9 %	CL=90%	748
$K^+ \bar{K}^0 \pi^+ \pi^-$	( 2.5 ± 0.9 ) %		744
$K^0 K^- \pi^+ \pi^+$	( 4.3 ± 1.5 ) %		744
$K^*(892)^+ \bar{K}^*(892)^0$	[ccc] ( 5.8 ± 2.5 ) %		416
$K^0 K^- \pi^+ \pi^+$ (non- $K^{*+} \bar{K}^{*0}$ )	< 2.9 %	CL=90%	744
$K^+ K^- \pi^+ \pi^+ \pi^-$	( 7.1 ± 2.2 ) × 10 <sup>-3</sup>		673
$\phi \pi^+ \pi^+ \pi^-$	[ccc] ( 9.7 ± 2.6 ) × 10 <sup>-3</sup>		640
$K^+ K^- \rho^0 \pi^+$ non- $\phi$	< 2.1 × 10 <sup>-4</sup>	CL=90%	248
$\phi \rho^0 \pi^+$	[ccc] ( 1.06 ± 0.35 ) %		180
$\phi a_1(1260)^+$	[ccc] ( 2.5 ± 0.8 ) %		†
$K^+ K^- \pi^+ \pi^+ \pi^-$ nonresonant	( 7 ± 6 ) × 10 <sup>-4</sup>		673

### Hadronic modes without $K$ 's

$\pi^+ \pi^+ \pi^-$	( 1.01 ± 0.28 ) %	S=1.1	959
$\rho^0 \pi^+$	< 7 × 10 <sup>-4</sup>	CL=90%	824
$f_0(980) \pi^+$	[uu] ( 5.7 ± 1.7 ) × 10 <sup>-3</sup>		732
$\times B(f_0 \rightarrow \pi^+ \pi^-)$			
$f_2(1270) \pi^+$	[ccc] ( 3.5 ± 1.2 ) × 10 <sup>-3</sup>		559
$f_0(1370) \pi^+$	[uu] ( 3.3 ± 1.2 ) × 10 <sup>-3</sup>		493
$\times B(f_0 \rightarrow \pi^+ \pi^-)$			
$\rho(1450)^0 \pi^+$	[uu] ( 4.4 ± 2.5 ) × 10 <sup>-4</sup>		421
$\times B(\rho^0 \rightarrow \pi^+ \pi^-)$			

$\pi^+ \pi^+ \pi^-$ nonresonant	( $5 \pm_{-5}^{+22}$ ) $\times 10^{-5}$		959
$\pi^+ \pi^+ \pi^- \pi^0$	< 12 %	CL=90%	935
$\eta \pi^+$	[ccc] ( $1.7 \pm 0.5$ ) %		902
$\omega \pi^+$	[ccc] ( $2.8 \pm 1.1$ ) $\times 10^{-3}$		822
$3\pi^+ 2\pi^-$	( $6.5 \pm 1.8$ ) $\times 10^{-3}$		899
$\pi^+ \pi^+ \pi^- \pi^0 \pi^0$	—		902
$\eta \rho^+$	[ccc] ( $10.8 \pm 3.1$ ) %		723
$\eta \pi^+ \pi^0$ 3-body	[ccc] < 4 %	CL=90%	885
$3\pi^+ 2\pi^- \pi^0$	( $4.9 \pm 3.2$ ) %		856
$\eta'(958) \pi^+$	[ccc] ( $3.9 \pm 1.0$ ) %		743
$3\pi^+ 2\pi^- 2\pi^0$	—		803
$\eta'(958) \rho^+$	[ccc] ( $10.1 \pm 2.8$ ) %		464
$\eta'(958) \pi^+ \pi^0$ 3-body	[ccc] < 1.4 %	CL=90%	720

**Modes with one or three K's**

$K^0 \pi^+$	< 8 $\times 10^{-3}$	CL=90%	916
$K^+ \pi^+ \pi^-$	( $1.0 \pm 0.4$ ) %		900
$K^+ \rho^0$	< 2.9 $\times 10^{-3}$	CL=90%	744
$K^*(892)^0 \pi^+$	[ccc] ( $6.5 \pm 2.8$ ) $\times 10^{-3}$		775
$K^+ K^+ K^-$	( $4.0 \pm 1.7$ ) $\times 10^{-4}$		627
$\phi K^+$	[ccc] < 5 $\times 10^{-4}$	CL=90%	607

**$\Delta C = 1$  weak neutral current (C1) modes,  
Lepton family number (LF), or  
Lepton number (L) violating modes**

$\pi^+ e^+ e^-$	[ww] < 2.7 $\times 10^{-4}$	CL=90%	979
$\pi^+ \mu^+ \mu^-$	[ww] < 2.6 $\times 10^{-5}$	CL=90%	968
$K^+ e^+ e^-$	C1 < 1.6 $\times 10^{-3}$	CL=90%	922
$K^+ \mu^+ \mu^-$	C1 < 3.6 $\times 10^{-5}$	CL=90%	909
$K^*(892)^+ \mu^+ \mu^-$	C1 < 1.4 $\times 10^{-3}$	CL=90%	765
$\pi^+ e^\pm \mu^\mp$	LF [gg] < 6.1 $\times 10^{-4}$	CL=90%	976
$K^+ e^\pm \mu^\mp$	LF [gg] < 6.3 $\times 10^{-4}$	CL=90%	919
$\pi^- e^+ e^+$	L < 6.9 $\times 10^{-4}$	CL=90%	979
$\pi^- \mu^+ \mu^+$	L < 2.9 $\times 10^{-5}$	CL=90%	968
$\pi^- e^+ \mu^+$	L < 7.3 $\times 10^{-4}$	CL=90%	976
$K^- e^+ e^+$	L < 6.3 $\times 10^{-4}$	CL=90%	922
$K^- \mu^+ \mu^+$	L < 1.3 $\times 10^{-5}$	CL=90%	909
$K^- e^+ \mu^+$	L < 6.8 $\times 10^{-4}$	CL=90%	919
$K^*(892)^- \mu^+ \mu^+$	L < 1.4 $\times 10^{-3}$	CL=90%	765



**$D_s^{*\pm}$**

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

$J^P$  is natural, width and decay modes consistent with  $1^-$ .

$$\text{Mass } m = 2112.1 \pm 0.7 \text{ MeV} \quad (S = 1.1)$$

$$m_{D_s^{*\pm}} - m_{D_s^\pm} = 143.8 \pm 0.4 \text{ MeV}$$

$$\text{Full width } \Gamma < 1.9 \text{ MeV, CL} = 90\%$$

$D_s^{*-}$  modes are charge conjugates of the modes below.

$D_s^{*+}$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$D_s^+ \gamma$	(94.2±2.5) %	139
$D_s^+ \pi^0$	( 5.8±2.5) %	48

**$D_{sJ}^*(2317)^\pm$**

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

$J, P$  need confirmation.

$J^P$  is natural, low mass consistent with  $0^+$ .

$$\text{Mass } m = 2317.4 \pm 0.9 \text{ MeV} \quad (S = 1.1)$$

$$m_{D_{sJ}^*(2317)^\pm} - m_{D_s^\pm} = 349.2 \pm 0.7 \text{ MeV}$$

$$\text{Full width } \Gamma < 4.6 \text{ MeV, CL} = 90\%$$

**$D_{sJ}(2460)^\pm$**

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

$$\text{Mass } m = 2459.3 \pm 1.3 \text{ MeV} \quad (S = 1.3)$$

$$m_{D_{sJ}^*(2460)^\pm} - m_{D_s^{*\pm}} = 347.2 \pm 1.2 \text{ MeV} \quad (S = 1.3)$$

$$m_{D_{sJ}(2460)^\pm} - m_{D_s^\pm} = 491.0 \pm 1.2 \text{ MeV} \quad (S = 1.3)$$

$$\text{Full width } \Gamma < 5.5 \text{ MeV, CL} = 90\%$$

**$D_{s1}(2536)^\pm$**

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

$J, P$  need confirmation.

$$\text{Mass } m = 2535.35 \pm 0.34 \pm 0.5 \text{ MeV}$$

$$\text{Full width } \Gamma < 2.3 \text{ MeV, CL} = 90\%$$

$D_{s1}(2536)^-$  modes are charge conjugates of the modes below.

$D_{s1}(2536)^+$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$D^*(2010)^+ K^0$	seen	150
$D^*(2007)^0 K^+$	seen	168

$D^+ K^0$	not seen	382
$D^0 K^+$	not seen	392
$D_s^{*+} \gamma$	possibly seen	388

### $D_{s2}(2573)^\pm$

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

$J^P$  is natural, width and decay modes consistent with  $2^+$ .

Mass  $m = 2572.4 \pm 1.5$  MeV

Full width  $\Gamma = 15_{-4}^{+5}$  MeV

$D_{s2}(2573)^-$  modes are charge conjugates of the modes below.

$D_{s2}(2573)^+$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$D^0 K^+$	seen	435
$D^*(2007)^0 K^+$	not seen	244

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

$B^+ = u\bar{b}, B^0 = d\bar{b}, \bar{B}^0 = \bar{d}b, B^- = \bar{u}b$ , 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.  $B^0$ - $\bar{B}^0$  mixing data are found in the  $B^0$  section, while  $B_s^0$ - $\bar{B}_s^0$  mixing data and  $B$ - $\bar{B}$  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,  $B^0-\bar{B}^0$  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,  $B_s^0-\bar{B}_s^0$  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.

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

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

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

### CP violation

$$\begin{aligned}
 A_{CP}(B^+ \rightarrow J/\psi(1S)K^+) &= -0.007 \pm 0.019 \\
 A_{CP}(B^+ \rightarrow J/\psi(1S)\pi^+) &= -0.01 \pm 0.13 \\
 A_{CP}(B^+ \rightarrow \psi(2S)K^+) &= -0.037 \pm 0.025 \\
 A_{CP}(B^+ \rightarrow \bar{D}^0 K^+) &= 0.04 \pm 0.07 \\
 A_{CP}(B^+ \rightarrow D_{CP(+1)} K^+) &= 0.06 \pm 0.19 \\
 A_{CP}(B^+ \rightarrow D_{CP(-1)} K^+) &= -0.19 \pm 0.18 \\
 A_{CP}(B^+ \rightarrow \pi^+ \pi^0) &= 0.05 \pm 0.15 \\
 A_{CP}(B^+ \rightarrow K^+ \pi^0) &= -0.10 \pm 0.08 \\
 A_{CP}(B^+ \rightarrow K_S^0 \pi^+) &= 0.03 \pm 0.08 \quad (S = 1.1) \\
 A_{CP}(B^+ \rightarrow \pi^+ \pi^- \pi^+) &= -0.39 \pm 0.35 \\
 A_{CP}(B^+ \rightarrow \rho^+ \rho^0) &= -0.09 \pm 0.16 \\
 A_{CP}(B^+ \rightarrow K^+ \pi^- \pi^+) &= 0.01 \pm 0.08 \\
 A_{CP}(B^+ \rightarrow K^+ K^- K^+) &= 0.02 \pm 0.08 \\
 A_{CP}(B^+ \rightarrow K^+ \eta') &= 0.009 \pm 0.035 \\
 A_{CP}(B^+ \rightarrow \omega \pi^+) &= -0.21 \pm 0.19 \\
 A_{CP}(B^+ \rightarrow \omega K^+) &= -0.21 \pm 0.28 \\
 A_{CP}(B^+ \rightarrow \phi K^+) &= 0.03 \pm 0.07 \\
 A_{CP}(B^+ \rightarrow \phi K^*(892)^+) &= 0.09 \pm 0.15 \\
 A_{CP}(B^+ \rightarrow \rho^0 K^*(892)^+) &= 0.20 \pm 0.31
 \end{aligned}$$

$B^-$  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)
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### Semileptonic and leptonic modes

$\ell^+ \nu_\ell$ anything	[ <i>rr</i> ] (10.2 ± 0.9) %	–
$\bar{D}^0 \ell^+ \nu_\ell$	[ <i>rr</i> ] (2.15 ± 0.22) %	2310
$\bar{D}^*(2007)^0 \ell^+ \nu_\ell$	[ <i>rr</i> ] (6.5 ± 0.5) %	2258
$\bar{D}_1(2420)^0 \ell^+ \nu_\ell$	(5.6 ± 1.6) × 10 <sup>-3</sup>	2084
$\bar{D}_2^*(2460)^0 \ell^+ \nu_\ell$	< 8 × 10 <sup>-3</sup>	CL=90% 2067
$\pi^0 e^+ \nu_e$	(9.0 ± 2.8) × 10 <sup>-5</sup>	2638
$\eta \ell^+ \nu_\ell$	(8 ± 4) × 10 <sup>-5</sup>	2611
$\omega \ell^+ \nu_\ell$	[ <i>rr</i> ] < 2.1 × 10 <sup>-4</sup>	CL=90% 2582
$\rho^0 \ell^+ \nu_\ell$	[ <i>rr</i> ] (1.34 <sup>+0.32</sup> <sub>-0.35</sub> ) × 10 <sup>-4</sup>	2583
$p\bar{p}e^+ \nu_e$	< 5.2 × 10 <sup>-3</sup>	CL=90% 2467
$e^+ \nu_e$	< 1.5 × 10 <sup>-5</sup>	CL=90% 2640
$\mu^+ \nu_\mu$	< 2.1 × 10 <sup>-5</sup>	CL=90% 2638
$\tau^+ \nu_\tau$	< 5.7 × 10 <sup>-4</sup>	CL=90% 2340
$e^+ \nu_e \gamma$	< 2.0 × 10 <sup>-4</sup>	CL=90% 2640
$\mu^+ \nu_\mu \gamma$	< 5.2 × 10 <sup>-5</sup>	CL=90% 2638

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

$\bar{D}^0 \pi^+$	(4.98 ± 0.29) × 10 <sup>-3</sup>	2308
$\bar{D}^0 \rho^+$	(1.34 ± 0.18) %	2236
$\bar{D}^0 K^+$	(3.7 ± 0.6) × 10 <sup>-4</sup>	S=1.1 2280
$\bar{D}^0 K^*(892)^+$	(6.1 ± 2.3) × 10 <sup>-4</sup>	2213
$\bar{D}^0 K^+ \bar{K}^0$	(5.5 ± 1.6) × 10 <sup>-4</sup>	2189
$\bar{D}^0 K^+ \bar{K}^*(892)^0$	(7.5 ± 1.7) × 10 <sup>-4</sup>	2071
$\bar{D}^0 \pi^+ \pi^+ \pi^-$	(1.1 ± 0.4) %	2289
$\bar{D}^0 \pi^+ \pi^+ \pi^-$ nonresonant	(5 ± 4) × 10 <sup>-3</sup>	2289
$\bar{D}^0 \pi^+ \rho^0$	(4.2 ± 3.0) × 10 <sup>-3</sup>	2207
$\bar{D}^0 a_1(1260)^+$	(5 ± 4) × 10 <sup>-3</sup>	2123
$\bar{D}^0 \omega \pi^+$	(4.1 ± 0.9) × 10 <sup>-3</sup>	2206
$D^*(2010)^- \pi^+ \pi^+$	(2.1 ± 0.6) × 10 <sup>-3</sup>	2247
$D^- \pi^+ \pi^+$	< 1.4 × 10 <sup>-3</sup>	CL=90% 2299
$\bar{D}^*(2007)^0 \pi^+$	(4.6 ± 0.4) × 10 <sup>-3</sup>	2256
$\bar{D}^*(2007)^0 \omega \pi^+$	(4.5 ± 1.2) × 10 <sup>-3</sup>	2149
$\bar{D}^*(2007)^0 \rho^+$	(9.8 ± 1.7) × 10 <sup>-3</sup>	2181
$\bar{D}^*(2007)^0 K^+$	(3.6 ± 1.0) × 10 <sup>-4</sup>	2227
$\bar{D}^*(2007)^0 K^*(892)^+$	(7.2 ± 3.4) × 10 <sup>-4</sup>	2156
$\bar{D}^*(2007)^0 K^+ \bar{K}^0$	< 1.06 × 10 <sup>-3</sup>	CL=90% 2132
$\bar{D}^*(2007)^0 K^+ K^*(892)^0$	(1.5 ± 0.4) × 10 <sup>-3</sup>	2008
$\bar{D}^*(2007)^0 \pi^+ \pi^+ \pi^-$	(9.4 ± 2.6) × 10 <sup>-3</sup>	2236
$\bar{D}^*(2007)^0 a_1(1260)^+$	(1.9 ± 0.5) %	2062
$\bar{D}^*(2007)^0 \pi^- \pi^+ \pi^+ \pi^0$	(1.8 ± 0.4) %	2219
$D^*(2010)^+ \pi^0$	< 1.7 × 10 <sup>-4</sup>	CL=90% 2255
$\bar{D}^*(2010)^+ K^0$	< 9.5 × 10 <sup>-5</sup>	CL=90% 2225
$D^*(2010)^- \pi^+ \pi^+ \pi^0$	(1.5 ± 0.7) %	2235

$D^*(2010)^- \pi^+ \pi^+ \pi^+ \pi^-$	< 1	%	CL=90%	2217
$\overline{D}_1^*(2420)^0 \pi^+$	( 1.5 ± 0.6 )	$\times 10^{-3}$	S=1.3	2081
$\overline{D}_1^*(2420)^0 \rho^+$	< 1.4	$\times 10^{-3}$	CL=90%	1995
$\overline{D}_2^*(2460)^0 \pi^+$	< 1.3	$\times 10^{-3}$	CL=90%	2064
$\overline{D}_2^*(2460)^0 \rho^+$	< 4.7	$\times 10^{-3}$	CL=90%	1977
$\overline{D}^0 D_s^+$	( 1.3 ± 0.4 )	%		1815
$\overline{D}^0 D_{sJ}(2317)^+$	seen			1605
$\overline{D}^0 D_{sJ}(2457)^+$	seen			—
$\overline{D}^0 D_{sJ}(2536)^+$	not seen			1447
$\overline{D}^*(2007)^0 D_{sJ}(2536)^+$	not seen			1338
$\overline{D}^0 D_{sJ}(2573)^+$	not seen			1417
$\overline{D}^*(2007)^0 D_{sJ}(2573)^+$	not seen			1306
$\overline{D}^0 D_s^{*+}$	( 9 ± 4 )	$\times 10^{-3}$		1734
$\overline{D}^*(2007)^0 D_s^+$	( 1.2 ± 0.5 )	%		1737
$\overline{D}^*(2007)^0 D_s^{*+}$	( 2.7 ± 1.0 )	%		1651
$D_s^{(*)+} \overline{D}^{*0}$	( 2.7 ± 1.2 )	%		—
$\overline{D}^*(2007)^0 D^*(2010)^+$	< 1.1	%	CL=90%	1713
$\overline{D}^0 D^*(2010)^+ +$ $\overline{D}^*(2007)^0 D^+$	< 1.3	%	CL=90%	1792
$\overline{D}^0 D^+$	< 6.7	$\times 10^{-3}$	CL=90%	1866
$\overline{D}^0 D^+ K^0$	< 2.8	$\times 10^{-3}$	CL=90%	1571
$\overline{D}^*(2007)^0 D^+ K^0$	< 6.1	$\times 10^{-3}$	CL=90%	1475
$\overline{D}^0 \overline{D}^*(2010)^+ K^0$	( 5.2 ± 1.2 )	$\times 10^{-3}$		1476
$\overline{D}^*(2007)^0 D^*(2010)^+ K^0$	( 7.8 ± 2.6 )	$\times 10^{-3}$		1362
$\overline{D}^0 D^0 K^+$	( 1.9 ± 0.4 )	$\times 10^{-3}$		1577
$\overline{D}^*(2010)^0 D^0 K^+$	< 3.8	$\times 10^{-3}$	CL=90%	—
$\overline{D}^0 D^*(2007)^0 K^+$	( 4.7 ± 1.0 )	$\times 10^{-3}$		1481
$\overline{D}^*(2007)^0 D^*(2007)^0 K^+$	( 5.3 ± 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 ± 0.4 )	$\times 10^{-3}$		1475
$D^*(2010)^- D^*(2010)^+ K^+$	< 1.8	$\times 10^{-3}$	CL=90%	1363
$(\overline{D} + \overline{D}^*)(D + D^*) K$	( 3.5 ± 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 $\begin{smallmatrix} +1.0 \\ -0.9 \end{smallmatrix}$ )	$\times 10^{-5}$		2534
$\omega K^+$	( 9.2 $\begin{smallmatrix} +2.8 \\ -2.5 \end{smallmatrix}$ )	$\times 10^{-6}$		2557
$\omega K^*(892)^+$	< 8.7	$\times 10^{-5}$	CL=90%	2503

$K^*(892)^0 \pi^+$	$( 1.9 \begin{smallmatrix} +0.6 \\ -0.8 \end{smallmatrix} ) \times 10^{-5}$		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
$K^+ \phi \phi$	$( 2.6 \begin{smallmatrix} +1.1 \\ -0.9 \end{smallmatrix} ) \times 10^{-6}$		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
$K^+ \pi^- \pi^+ \gamma$	$( 2.4 \begin{smallmatrix} +0.6 \\ -0.5 \end{smallmatrix} ) \times 10^{-5}$		2609
$K^*(892)^0 \pi^+ \gamma$	$( 2.0 \begin{smallmatrix} +0.7 \\ -0.6 \end{smallmatrix} ) \times 10^{-5}$		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 $\begin{smallmatrix} +0.9 \\ -1.1 \end{smallmatrix}$ )	$\times 10^{-6}$		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 $\begin{smallmatrix} +1.8 \\ -1.6 \end{smallmatrix}$ )	$\times 10^{-6}$	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 $\begin{smallmatrix} +0.7 \\ -0.6 \end{smallmatrix}$ )	$\times 10^{-5}$		2636
$\omega h^+$	( 1.38 $\begin{smallmatrix} +0.27 \\ -0.24 \end{smallmatrix}$ )	$\times 10^{-5}$		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	$\frac{+1.2}{-1.0}$ ) $\times 10^{-6}$		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	$\frac{+1.9}{-1.7}$ ) $\times 10^{-7}$		2616
$K^+ \mu^+ \mu^-$	B1	( 4.5	$\frac{+1.4}{-1.2}$ ) $\times 10^{-7}$		2612
$K^+ \ell^+ \ell^-$	B1 [rr]	( 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 [rr]	< 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

$\pi^- e^+ \mu^+$	$L$	$< 1.3$	$\times 10^{-6}$	CL=90%	2637
$\rho^- e^+ e^+$	$L$	$< 2.6$	$\times 10^{-6}$	CL=90%	2583
$\rho^- \mu^+ \mu^+$	$L$	$< 5.0$	$\times 10^{-6}$	CL=90%	2578
$\rho^- e^+ \mu^+$	$LF$	$< 3.3$	$\times 10^{-6}$	CL=90%	2581
$K^- e^+ e^+$	$L$	$< 1.0$	$\times 10^{-6}$	CL=90%	2616
$K^- \mu^+ \mu^+$	$L$	$< 1.8$	$\times 10^{-6}$	CL=90%	2612
$K^- e^+ \mu^+$	$L$	$< 2.0$	$\times 10^{-6}$	CL=90%	2615
$K^*(892)^- e^+ e^+$	$L$	$< 2.8$	$\times 10^{-6}$	CL=90%	2564
$K^*(892)^- \mu^+ \mu^+$	$L$	$< 8.3$	$\times 10^{-6}$	CL=90%	2560
$K^*(892)^- e^+ \mu^+$	$LF$	$< 4.4$	$\times 10^{-6}$	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	[rr] (10.5 $\pm$ 0.8 ) %		–
$D^- \ell^+ \nu_\ell$	[rr] ( 2.14 $\pm$ 0.20 ) %		2309
$D^*(2010)^- \ell^+ \nu_\ell$	[rr] ( 5.44 $\pm$ 0.23 ) %		2257
$\rho^- \ell^+ \nu_\ell$	[rr] ( 2.6 $\pm$ 0.7 ) $\times 10^{-4}$		2583
$\pi^- \ell^+ \nu_\ell$	[rr] ( 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
$K^-\pi^+\pi^+\pi^-$	[eee] $< 2.3 \times 10^{-4}$	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
$K^- a_1(1260)^+$	[eee] < 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
$\rho^\mp\pi^\pm$	[gg] ( 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
$a_1(1260)^\mp\pi^\pm$	[gg] < 4.9	$\times 10^{-4}$	CL=90%	2494
$a_2(1320)^\mp\pi^\pm$	[gg] < 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
$\pi^+\pi^+\pi^+\pi^-\pi^-\pi^-\pi^0$	< 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	[rr] $< 6.8 \times 10^{-7}$	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	[rr] $(1.17 \pm 0.30) \times 10^{-6}$		2564
$e^\pm \mu^\mp$	LF	[gg] $< 1.7 \times 10^{-7}$	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	[gg] $< 5.3 \times 10^{-4}$	CL=90%	2341
$\mu^\pm \tau^\mp$	LF	[gg] $< 8.3 \times 10^{-4}$	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	[fff]	( 10.73 ± 0.28 ) %		—
$B \rightarrow \bar{p} e^+ \nu_e$ anything		< 5.9	$\times 10^{-4}$	CL=90% —
$B \rightarrow \ell^+ \nu_\ell$ anything	[rr,fff]	( 10.73 ± 0.28 ) %		—
$B \rightarrow D^- \ell^+ \nu_\ell$ anything	[rr]	( 2.8 ± 0.9 ) %		—
$B \rightarrow \bar{D}^0 \ell^+ \nu_\ell$ anything	[rr]	( 7.2 ± 1.5 ) %		—
$B \rightarrow \bar{D}^{*+} \ell^+ \nu_\ell$	[rr,ggg]	( 2.7 ± 0.7 ) %		—
$B \rightarrow \bar{D}_1(2420) \ell^+ \nu_\ell$ anything		( 7.4 ± 1.6 ) $\times 10^{-3}$		—
$B \rightarrow D \pi \ell^+ \nu_\ell$ 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	$\times 10^{-3}$	CL=95% —
$B \rightarrow D^{*-} \pi^+ \ell^+ \nu_\ell$ anything		( 1.00 ± 0.34 ) %		—
$B \rightarrow D_s^- \ell^+ \nu_\ell$ anything	[rr]	< 9	$\times 10^{-3}$	CL=90% —
$B \rightarrow D_s^- \ell^+ \nu_\ell K^+$ anything	[rr]	< 6	$\times 10^{-3}$	CL=90% —
$B \rightarrow D_s^- \ell^+ \nu_\ell K^0$ anything	[rr]	< 9	$\times 10^{-3}$	CL=90% —
$B \rightarrow K^+ \ell^+ \nu_\ell$ anything	[rr]	( 6.2 ± 0.6 ) %		—
$B \rightarrow K^- \ell^+ \nu_\ell$ anything	[rr]	( 10 ± 4 ) $\times 10^{-3}$		—
$B \rightarrow K^0 / \bar{K}^0 \ell^+ \nu_\ell$ anything	[rr]	( 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	[gg]	( 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			—
$B \rightarrow D^{(*)} \bar{D}^{(*)} K^0 + D^{(*)} \bar{D}^{(*)} K^\pm$	[gg,hhh]	( 7.1 ± 2.7 / - 1.7 ) %		—
$b \rightarrow c \bar{c} s$		( 22 ± 4 ) %		—

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

### Charmonium modes

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

### K or K\* modes

$B \rightarrow K^\pm \text{ anything}$	$[gg]$	$( 78.9 \pm 2.5 ) \%$		—
$B \rightarrow K^+ \text{ anything}$		$( 66 \pm 5 ) \%$		—
$B \rightarrow K^- \text{ anything}$		$( 13 \pm 4 ) \%$		—
$B \rightarrow K^0 / \bar{K}^0 \text{ anything}$	$[gg]$	$( 64 \pm 4 ) \%$		—
$B \rightarrow K^*(892)^\pm \text{ anything}$		$( 18 \pm 6 ) \%$		—
$B \rightarrow K^*(892)^0 / \bar{K}^*(892)^0 \text{ anything}$	$[gg]$	$( 14.6 \pm 2.6 ) \%$		—
$B \rightarrow K^*(892)\gamma$		$( 4.2 \pm 0.6 ) \times 10^{-5}$		2564
$B \rightarrow K_1(1400)\gamma$		$< 1.27$	$\times 10^{-4}$	CL=90% 2453
$B \rightarrow K_2^*(1430)\gamma$		$( 1.7 \pm \frac{0.6}{0.5} ) \times 10^{-5}$		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
$B \rightarrow \pi^\pm\text{anything}$	[ <i>gg,iii</i> ] $(358 \pm 7) \%$		—
$B \rightarrow \pi^0\text{anything}$	$(235 \pm 11) \%$		—
$B \rightarrow \eta\text{anything}$	$( 17.6 \pm 1.6 ) \%$		—
$B \rightarrow \rho^0\text{anything}$	$( 21 \pm 5 ) \%$		—
$B \rightarrow \omega\text{anything}$	$< 81 \%$	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
$B \rightarrow \Xi_c^0 \text{anything}$	$( 1.4 \pm 0.5 ) \times 10^{-4}$		—
$\times B(\Xi_c^0 \rightarrow \Xi^- \pi^+)$			
$B \rightarrow \Xi_c^+ \text{anything}$	$( 4.5 \begin{smallmatrix} + 1.3 \\ - 1.2 \end{smallmatrix} ) \times 10^{-4}$		—
$\times B(\Xi_c^+ \rightarrow \Xi^- \pi^+ \pi^+)$			
$B \rightarrow p / \bar{p} \text{anything}$	[ <i>gg</i> ] $( 8.0 \pm 0.4 ) \%$		—
$B \rightarrow p / \bar{p}(\text{direct}) \text{anything}$	[ <i>gg</i> ] $( 5.5 \pm 0.5 ) \%$		—
$B \rightarrow \Lambda / \bar{\Lambda} \text{anything}$	[ <i>gg</i> ] $( 4.0 \pm 0.5 ) \%$		—
$B \rightarrow \Xi^- / \bar{\Xi}^+ \text{anything}$	[ <i>gg</i> ] $( 2.7 \pm 0.6 ) \times 10^{-3}$		—
$B \rightarrow \text{baryons anything}$	$( 6.8 \pm 0.6 ) \%$		—
$B \rightarrow p\bar{p} \text{anything}$	$( 2.47 \pm 0.23 ) \%$		—
$B \rightarrow \Lambda\bar{p} / \bar{\Lambda}p \text{anything}$	[ <i>gg</i> ] $( 2.5 \pm 0.4 ) \%$		—
$B \rightarrow \Lambda\bar{\Lambda} \text{anything}$	$< 5 \times 10^{-3}$	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 [rr]	( 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 [gg]	< 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	[ $rr$ ] ( 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	[ $rr$ ] ( 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	[ $rr$ ] ( 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	[ $rr$ ] ( 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	[ $rr, jjj$ ] seen	—
$D_2^*(2460)^- \ell^+ \nu_\ell$ anything	seen	—



charmless $\ell\bar{\nu}_\ell$	[ <i>rr</i> ]	( 1.7 ± 0.5 ) × 10 <sup>-3</sup>	—
$\tau^+ \nu_\tau$ anything		( 2.48 ± 0.26 ) %	—
$D^{*-} \tau \nu_\tau$ anything		( 9 ± 4 ) × 10 <sup>-3</sup>	—
$\bar{c} \rightarrow \ell^- \bar{\nu}_\ell$ anything	[ <i>rr</i> ]	( 8.0 ± 0.4 ) %	—
$c \rightarrow \ell^+ \nu$ anything		( 1.6 $\begin{smallmatrix} + \\ - \end{smallmatrix}$ 0.4 / 0.5 ) %	—

### Charmed meson and baryon modes

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

### Charmonium modes

$J/\psi(1S)$ anything		( 1.16 ± 0.10 ) %	—
$\psi(2S)$ anything		( 4.8 ± 2.4 ) × 10 <sup>-3</sup>	—
$\chi_{c1}(1P)$ anything		( 1.5 ± 0.5 ) %	—

### K or K\* modes

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

### Pion modes

$\pi^\pm$ anything		(397 ± 21) %	—
$\pi^0$ anything	[ <i>iii</i> ]	(278 ± 60) %	—
$\phi$ anything		( 2.82 ± 0.23 ) %	—

**Baryon modes**

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

**Other modes**

charged anything [iii] (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% —

**$B^*$**

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

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

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

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

**$B^*$  DECAY MODES**

	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$B\gamma$	dominant	45

**BOTTOM, STRANGE MESONS**  
**( $B = \pm 1, S = \mp 1$ )**  
 $B_s^0 = s\bar{b}, \bar{B}_s^0 = \bar{s}b$ , similarly for  $B_s^{*}$ 's

**$B_s^0$**

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

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

$$\text{Mass } m_{B_s^0} = 5369.6 \pm 2.4 \text{ MeV}$$

$$\text{Mean life } \tau = (1.461 \pm 0.057) \times 10^{-12} \text{ s}$$

$$c\tau = 438 \text{ } \mu\text{m}$$

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

$$\begin{aligned} \Delta m_{B_s^0} = m_{B_{sH}^0} - m_{B_{sL}^0} &> 14.4 \times 10^{12} \hbar s^{-1}, \text{ CL} = 95\% \\ &> 94.8 \times 10^{-10} \text{ MeV}, \text{ CL} = 95\% \\ x_s = \Delta m_{B_s^0} / \Gamma_{B_s^0} &> 20.6, \text{ CL} = 95\% \\ \chi_s &> 0.49883, \text{ CL} = 95\% \end{aligned}$$

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

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

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

$B_s^0$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level	$P$ (MeV/c)
$D_s^-$ anything	(94 $\pm$ 30 ) %		—
$D_s^- \ell^+ \nu_\ell$ anything	[kkk] ( 7.9 $\pm$ 2.4 ) %		—
$D_s^- \pi^+$	< 13 %		2322
$D_s^{(*)} + D_s^{(*)-}$	(23 $^{+21}_{-13}$ ) %		—
$J/\psi(1S)\phi$	( 9.3 $\pm$ 3.3 ) $\times 10^{-4}$		1590
$J/\psi(1S)\pi^0$	< 1.2 $\times 10^{-3}$	90%	1788
$J/\psi(1S)\eta$	< 3.8 $\times 10^{-3}$	90%	1735
$\psi(2S)\phi$	seen		1123
$\pi^+ \pi^-$	< 1.7 $\times 10^{-4}$	90%	2681
$\pi^0 \pi^0$	< 2.1 $\times 10^{-4}$	90%	2681
$\eta \pi^0$	< 1.0 $\times 10^{-3}$	90%	2655
$\eta \eta$	< 1.5 $\times 10^{-3}$	90%	2628
$\rho^0 \rho^0$	< 3.20 $\times 10^{-4}$	90%	2570
$\phi \rho^0$	< 6.17 $\times 10^{-4}$	90%	2528
$\phi \phi$	< 1.183 $\times 10^{-3}$	90%	2484
$\pi^+ K^-$	< 2.1 $\times 10^{-4}$	90%	2660
$K^+ K^-$	< 5.9 $\times 10^{-5}$	90%	2639
$\bar{K}^*(892)^0 \rho^0$	< 7.67 $\times 10^{-4}$	90%	2551
$\bar{K}^*(892)^0 K^*(892)^0$	< 1.681 $\times 10^{-3}$	90%	2532
$\phi K^*(892)^0$	< 1.013 $\times 10^{-3}$	90%	2508
$p\bar{p}$	< 5.9 $\times 10^{-5}$	90%	2516
$\gamma\gamma$	< 1.48 $\times 10^{-4}$	90%	2685
$\phi\gamma$	< 1.2 $\times 10^{-4}$	90%	2588

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

$\mu^+ \mu^-$	<i>B1</i>	< 2.0	$\times 10^{-6}$	90%	2683
$e^+ e^-$	<i>B1</i>	< 5.4	$\times 10^{-5}$	90%	2685
$e^\pm \mu^\mp$	<i>LF</i> [ <i>gg</i> ]	< 6.1	$\times 10^{-6}$	90%	2684
$\phi(1020) \mu^+ \mu^-$	<i>B1</i>	< 4.7	$\times 10^{-5}$	90%	2584
$\phi \nu \bar{\nu}$	<i>B1</i>	< 5.4	$\times 10^{-3}$	90%	2588

**BOTTOM, CHARMED MESONS  
 $(B = C = \pm 1)$**

$$B_c^+ = c\bar{b}, B_c^- = \bar{c}b, \text{ similarly for } B_c^{*'}\text{'s}$$

**$B_c^\pm$**

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

*I, J, P* need confirmation.

Quantum numbers shown are quark-model predictions.

Mass  $m = 6.4 \pm 0.4$  GeV

Mean life  $\tau = (0.46_{-0.16}^{+0.18}) \times 10^{-12}$  s

$B_c^-$  modes are charge conjugates of the modes below.

$B_c^+$ DECAY MODES $\times B(\bar{b} \rightarrow B_c)$	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level	$P$ (MeV/c)
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The following quantities are not pure branching ratios; rather the fraction  $\Gamma_i/\Gamma \times B(\bar{b} \rightarrow B_c)$ .

$J/\psi(1S) \ell^+ \nu_\ell$ anything	$(5.2_{-2.1}^{+2.4}) \times 10^{-5}$		—
$J/\psi(1S) \pi^+$	< 8.2	$\times 10^{-5}$	90% 2448
$J/\psi(1S) \pi^+ \pi^+ \pi^-$	< 5.7	$\times 10^{-4}$	90% 2429
$J/\psi(1S) a_1(1260)$	< 1.2	$\times 10^{-3}$	90% 2255
$D^*(2010)^+ \bar{D}^0$	< 6.2	$\times 10^{-3}$	90% 2546

# c $\bar{c}$ MESONS

**$\eta_c(1S)$**

$$I^G(J^{PC}) = 0^+(0^{-+})$$

Mass  $m = 2979.6 \pm 1.2$  MeV (S = 1.7)

Full width  $\Gamma = 17.3^{+2.7}_{-2.5}$  MeV (S = 1.1)

<b><math>\eta_c(1S)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level	$\rho$ (MeV/c)
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### Decays involving hadronic resonances

$\eta'(958)\pi\pi$	(4.1 $\pm$ 1.7 ) %		1321
$\rho\rho$	(2.6 $\pm$ 0.9 ) %		1272
$K^*(892)^0 K^- \pi^+ + \text{c.c.}$	(2.0 $\pm$ 0.7 ) %		1275
$K^*(892)\bar{K}^*(892)$	(8.5 $\pm$ 3.1 ) $\times 10^{-3}$		1194
$\phi K^+ K^-$	(2.9 $\pm$ 1.4 ) $\times 10^{-3}$		1101
$\phi\phi$	(2.6 $\pm$ 0.9 ) $\times 10^{-3}$		1086
$a_0(980)\pi$	< 2 %	90%	1323
$a_2(1320)\pi$	< 2 %	90%	1194
$K^*(892)\bar{K} + \text{c.c.}$	< 1.28 %	90%	1307
$f_2(1270)\eta$	< 1.1 %	90%	1143
$\omega\omega$	< 3.1 $\times 10^{-3}$	90%	1268

### Decays into stable hadrons

$K\bar{K}\pi$	(5.7 $\pm$ 1.6 ) %		1379
$\eta\pi\pi$	(4.9 $\pm$ 1.8 ) %		1426
$\pi^+\pi^- K^+ K^-$	(1.5 $\pm$ 0.6 ) %		1343
$2(K^+ K^-)$	(1.5 $\pm$ 0.7 ) $\times 10^{-3}$		1053
$2(\pi^+\pi^-)$	(1.20 $\pm$ 0.30) %		1457
$\rho\bar{\rho}$	(1.3 $\pm$ 0.4 ) $\times 10^{-3}$		1157
$K\bar{K}\eta$	< 3.1 %	90%	1263
$\pi^+\pi^- \rho\bar{\rho}$	< 1.2 %	90%	1024
$\Lambda\bar{\Lambda}$	< 2 $\times 10^{-3}$	90%	987

### Radiative decays

$\gamma\gamma$	(4.3 $\pm$ 1.5 ) $\times 10^{-4}$		1490
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# J/ψ(1S)

$$J^G(J^{PC}) = 0^-(1^{--})$$

Mass  $m = 3096.916 \pm 0.011$  MeV

Full width  $\Gamma = 91.0 \pm 3.2$  keV

$\Gamma_{ee} = 5.40 \pm 0.15 \pm 0.07$  keV

<b>J/ψ(1S) DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor/ Confidence level	$p$ (MeV/c)
hadrons	(87.7 ± 0.5) %		—
virtual $\gamma \rightarrow$ hadrons	(17.0 ± 2.0) %		—
$e^+ e^-$	( 5.93 ± 0.10) %		1548
$\mu^+ \mu^-$	( 5.88 ± 0.10) %		1545

### Decays involving hadronic resonances

$\rho\pi$	( 1.27 ± 0.09) %		1448
$\rho^0\pi^0$	( 4.2 ± 0.5) × 10 <sup>-3</sup>		1448
$a_2(1320)\rho$	( 1.09 ± 0.22) %		1123
$\omega\pi^+\pi^+\pi^-\pi^-$	( 8.5 ± 3.4) × 10 <sup>-3</sup>		1392
$\omega\pi^+\pi^-$	( 7.2 ± 1.0) × 10 <sup>-3</sup>		1435
$\omega f_2(1270)$	( 4.3 ± 0.6) × 10 <sup>-3</sup>		1142
$K^*(892)^0\bar{K}_2^*(1430)^0 + c.c.$	( 6.7 ± 2.6) × 10 <sup>-3</sup>		1012
$\omega K^*(892)\bar{K} + c.c.$	( 5.3 ± 2.0) × 10 <sup>-3</sup>		1097
$K^+\bar{K}^*(892)^- + c.c.$	( 5.0 ± 0.4) × 10 <sup>-3</sup>		1373
$K^0\bar{K}^*(892)^0 + c.c.$	( 4.2 ± 0.4) × 10 <sup>-3</sup>		1373
$K_1(1400)^\pm K^\mp$	( 3.8 ± 1.4) × 10 <sup>-3</sup>		1171
$\omega\pi^0\pi^0$	( 3.4 ± 0.8) × 10 <sup>-3</sup>		1436
$b_1(1235)^\pm\pi^\mp$	[gg] ( 3.0 ± 0.5) × 10 <sup>-3</sup>		1300
$\omega K^\pm K_S^0\pi^\mp$	[gg] ( 2.9 ± 0.7) × 10 <sup>-3</sup>		1210
$b_1(1235)^0\pi^0$	( 2.3 ± 0.6) × 10 <sup>-3</sup>		1300
$\phi K^*(892)\bar{K} + c.c.$	( 2.04 ± 0.28) × 10 <sup>-3</sup>		969
$\omega K\bar{K}$	( 1.9 ± 0.4) × 10 <sup>-3</sup>		1268
$\omega f_0(1710) \rightarrow \omega K\bar{K}$	( 4.8 ± 1.1) × 10 <sup>-4</sup>		878
$\phi 2(\pi^+\pi^-)$	( 1.60 ± 0.32) × 10 <sup>-3</sup>		1318
$\Delta(1232)^{++}\bar{p}\pi^-$	( 1.6 ± 0.5) × 10 <sup>-3</sup>		1030
$\omega\eta$	( 1.58 ± 0.16) × 10 <sup>-3</sup>		1394
$\phi K\bar{K}$	( 1.54 ± 0.21) × 10 <sup>-3</sup>		1179
$\phi f_0(1710) \rightarrow \phi K\bar{K}$	( 3.6 ± 0.6) × 10 <sup>-4</sup>		875
$p\bar{p}\omega$	( 1.30 ± 0.25) × 10 <sup>-3</sup>	S=1.3	768
$\Delta(1232)^{++}\bar{\Delta}(1232)^{--}$	( 1.10 ± 0.29) × 10 <sup>-3</sup>		938
$\Sigma(1385)^-\bar{\Sigma}(1385)^+ (or\ c.c.)$	[gg] ( 1.03 ± 0.13) × 10 <sup>-3</sup>		697
$p\bar{p}\eta'(958)$	( 9 ± 4 ) × 10 <sup>-4</sup>	S=1.7	596
$\phi f_2'(1525)$	( 8 ± 4 ) × 10 <sup>-4</sup>	S=2.7	871
$\phi\pi^+\pi^-$	( 8.0 ± 1.2) × 10 <sup>-4</sup>		1365
$\phi K^\pm K_S^0\pi^\mp$	[gg] ( 7.2 ± 0.9) × 10 <sup>-4</sup>		1114

$\omega f_1(1420)$	$( 6.8 \pm 2.4 ) \times 10^{-4}$		1062
$\phi\eta$	$( 6.5 \pm 0.7 ) \times 10^{-4}$		1320
$\Xi(1530)^- \Xi^+$	$( 5.9 \pm 1.5 ) \times 10^{-4}$		601
$\rho K^- \bar{\Sigma}(1385)^0$	$( 5.1 \pm 3.2 ) \times 10^{-4}$		646
$\omega\pi^0$	$( 4.2 \pm 0.6 ) \times 10^{-4}$	S=1.4	1446
$\phi\eta'(958)$	$( 3.3 \pm 0.4 ) \times 10^{-4}$		1192
$\phi f_0(980)$	$( 3.2 \pm 0.9 ) \times 10^{-4}$	S=1.9	1182
$\Xi(1530)^0 \Xi^0$	$( 3.2 \pm 1.4 ) \times 10^{-4}$		608
$\Sigma(1385)^- \bar{\Sigma}^+$ (or c.c.)	[gg] $( 3.1 \pm 0.5 ) \times 10^{-4}$		855
$\phi f_1(1285)$	$( 2.6 \pm 0.5 ) \times 10^{-4}$	S=1.1	1032
$\rho\eta$	$( 1.93 \pm 0.23 ) \times 10^{-4}$		1396
$\omega\eta'(958)$	$( 1.67 \pm 0.25 ) \times 10^{-4}$		1279
$\omega f_0(980)$	$( 1.4 \pm 0.5 ) \times 10^{-4}$		1271
$\rho\eta'(958)$	$( 1.05 \pm 0.18 ) \times 10^{-4}$		1281
$\rho\bar{\rho}\phi$	$( 4.5 \pm 1.5 ) \times 10^{-5}$		527
$a_2(1320)^\pm \pi^\mp$	[gg] $< 4.3 \times 10^{-3}$	CL=90%	1263
$K \bar{K}_2^*(1430) + \text{c.c.}$	$< 4.0 \times 10^{-3}$	CL=90%	1159
$K_1(1270)^\pm K^\mp$	$< 3.0 \times 10^{-3}$	CL=90%	1231
$K_2^*(1430)^0 \bar{K}_2^*(1430)^0$	$< 2.9 \times 10^{-3}$	CL=90%	604
$K^*(892)^0 \bar{K}^*(892)^0$	$< 5 \times 10^{-4}$	CL=90%	1266
$\phi f_2(1270)$	$< 3.7 \times 10^{-4}$	CL=90%	1036
$\rho\bar{\rho}\rho$	$< 3.1 \times 10^{-4}$	CL=90%	774
$\phi\eta(1405) \rightarrow \phi\eta\pi\pi$	$< 2.5 \times 10^{-4}$	CL=90%	946
$\omega f_2'(1525)$	$< 2.2 \times 10^{-4}$	CL=90%	1003
$\Sigma(1385)^0 \bar{\Lambda}$	$< 2 \times 10^{-4}$	CL=90%	912
$\Delta(1232)^+ \bar{p}$	$< 1 \times 10^{-4}$	CL=90%	1100
$\Sigma^0 \bar{\Lambda}$	$< 9 \times 10^{-5}$	CL=90%	1032
$\phi\pi^0$	$< 6.8 \times 10^{-6}$	CL=90%	1377

### Decays into stable hadrons

$2(\pi^+\pi^-)\pi^0$	$( 3.37 \pm 0.26 ) \%$		1496
$3(\pi^+\pi^-)\pi^0$	$( 2.9 \pm 0.6 ) \%$		1433
$\pi^+\pi^-\pi^0$	$( 1.50 \pm 0.20 ) \%$		1533
$\pi^+\pi^-\pi^0 K^+ K^-$	$( 1.20 \pm 0.30 ) \%$		1368
$4(\pi^+\pi^-)\pi^0$	$( 9.0 \pm 3.0 ) \times 10^{-3}$		1345
$\pi^+\pi^- K^+ K^-$	$( 7.2 \pm 2.3 ) \times 10^{-3}$		1407
$K \bar{K} \pi$	$( 6.1 \pm 1.0 ) \times 10^{-3}$		1442
$\rho\bar{\rho}\pi^+\pi^-$	$( 6.0 \pm 0.5 ) \times 10^{-3}$	S=1.3	1107
$2(\pi^+\pi^-)$	$( 4.0 \pm 1.0 ) \times 10^{-3}$		1517
$3(\pi^+\pi^-)$	$( 4.0 \pm 2.0 ) \times 10^{-3}$		1466
$n\bar{n}\pi^+\pi^-$	$( 4 \pm 4 ) \times 10^{-3}$		1106
$\Sigma^0 \bar{\Sigma}^0$	$( 1.27 \pm 0.17 ) \times 10^{-3}$		988
$2(\pi^+\pi^-) K^+ K^-$	$( 3.1 \pm 1.3 ) \times 10^{-3}$		1320
$\rho\bar{\rho}\pi^+\pi^-\pi^0$	[///] $( 2.3 \pm 0.9 ) \times 10^{-3}$	S=1.9	1033

$p\bar{p}$		$(2.12 \pm 0.10) \times 10^{-3}$		1232
$p\bar{p}\eta$		$(2.09 \pm 0.18) \times 10^{-3}$		948
$p\bar{n}\pi^{-}$		$(2.00 \pm 0.10) \times 10^{-3}$		1174
$n\bar{n}$		$(2.2 \pm 0.4) \times 10^{-3}$		1231
$\Xi\bar{\Xi}$		$(1.8 \pm 0.4) \times 10^{-3}$	S=1.8	818
$\Lambda\bar{\Lambda}$		$(1.30 \pm 0.12) \times 10^{-3}$	S=1.1	1074
$p\bar{p}\pi^0$		$(1.09 \pm 0.09) \times 10^{-3}$		1176
$\Lambda\bar{\Sigma}^{-}\pi^{+}$ (or c.c.)	[gg]	$(1.06 \pm 0.12) \times 10^{-3}$		950
$pK^{-}\bar{\Lambda}$		$(8.9 \pm 1.6) \times 10^{-4}$		876
$2(K^{+}K^{-})$		$(9.2 \pm 3.3) \times 10^{-4}$	S=1.3	1131
$pK^{-}\bar{\Sigma}^0$		$(2.9 \pm 0.8) \times 10^{-4}$		819
$K^{+}K^{-}$		$(2.37 \pm 0.31) \times 10^{-4}$		1468
$K_S^0 K_L^0$		$(1.46 \pm 0.26) \times 10^{-4}$	S=2.7	1466
$\Lambda\bar{\Lambda}\pi^0$		$(2.2 \pm 0.6) \times 10^{-4}$		998
$\pi^{+}\pi^{-}$		$(1.47 \pm 0.23) \times 10^{-4}$		1542
$\Lambda\bar{\Sigma} + \text{c.c.}$		$< 1.5 \times 10^{-4}$	CL=90%	1034
$K_S^0 K_S^0$		$< 5.2 \times 10^{-6}$	CL=90%	1466

### Radiative decays

$\gamma\eta_c(1S)$		$(1.3 \pm 0.4) \%$		115
$\gamma\pi^{+}\pi^{-}2\pi^0$		$(8.3 \pm 3.1) \times 10^{-3}$		1518
$\gamma\eta\pi\pi$		$(6.1 \pm 1.0) \times 10^{-3}$		1487
$\gamma\eta(1405/1475) \rightarrow \gamma K\bar{K}\pi$	[p]	$(2.8 \pm 0.6) \times 10^{-3}$	S=1.6	1223
$\gamma\eta(1405/1475) \rightarrow \gamma\gamma\rho^0$		$(6.4 \pm 1.4) \times 10^{-5}$		1223
$\gamma\eta(1405/1475) \rightarrow \gamma\eta\pi^{+}\pi^{-}$		$(3.0 \pm 0.5) \times 10^{-4}$		—
$\gamma\rho\rho$		$(4.5 \pm 0.8) \times 10^{-3}$		1340
$\gamma\eta_2(1870) \rightarrow \gamma\pi^{+}\pi^{-}$		$(6.2 \pm 2.4) \times 10^{-4}$		—
$\gamma\eta'(958)$		$(4.31 \pm 0.30) \times 10^{-3}$		1400
$\gamma 2\pi^{+}2\pi^{-}$		$(2.8 \pm 0.5) \times 10^{-3}$	S=1.9	1517
$\gamma K^{+}K^{-}\pi^{+}\pi^{-}$		$(2.1 \pm 0.6) \times 10^{-3}$		1407
$\gamma f_4(2050)$		$(2.7 \pm 0.7) \times 10^{-3}$		880
$\gamma\omega\omega$		$(1.59 \pm 0.33) \times 10^{-3}$		1336
$\gamma\eta(1405/1475) \rightarrow \gamma\rho^0\rho^0$		$(1.7 \pm 0.4) \times 10^{-3}$	S=1.3	1223
$\gamma f_2(1270)$		$(1.38 \pm 0.14) \times 10^{-3}$		1286
$\gamma f_0(1710) \rightarrow \gamma K\bar{K}$		$(8.5 \pm_{-0.9}^{+1.2}) \times 10^{-4}$	S=1.2	1075
$\gamma\eta$		$(8.6 \pm 0.8) \times 10^{-4}$		1500
$\gamma f_1(1420) \rightarrow \gamma K\bar{K}\pi$		$(7.9 \pm 1.3) \times 10^{-4}$		1220
$\gamma f_1(1285)$		$(6.1 \pm 0.8) \times 10^{-4}$		1283
$\gamma f_1(1510) \rightarrow \gamma\eta\pi^{+}\pi^{-}$		$(4.5 \pm 1.2) \times 10^{-4}$		—
$\gamma f_2'(1525)$		$(4.5 \pm_{-0.4}^{+0.7}) \times 10^{-4}$		1173
$\gamma f_2(1950) \rightarrow$		$(7.0 \pm 2.2) \times 10^{-4}$		—
$\gamma K^*(892)\bar{K}^*(892)$				
$\gamma K^*(892)\bar{K}^*(892)$		$(4.0 \pm 1.3) \times 10^{-3}$		1266



$\gamma\phi\phi$	$(4.0 \pm 1.2) \times 10^{-4}$	S=2.1	1166
$\gamma\rho\bar{\rho}$	$(3.8 \pm 1.0) \times 10^{-4}$		1232
$\gamma\eta(2225)$	$(2.9 \pm 0.6) \times 10^{-4}$		752
$\gamma\eta(1760) \rightarrow \gamma\rho^0\rho^0$	$(1.3 \pm 0.9) \times 10^{-4}$		1048
$\gamma(K\bar{K}\pi)_{JPC=0-+}$	$(7 \pm 4) \times 10^{-4}$	S=2.1	1442
$\gamma\pi^0$	$(3.9 \pm 1.3) \times 10^{-5}$		1546
$\gamma\rho\bar{\rho}\pi^+\pi^-$	$< 7.9 \times 10^{-4}$	CL=90%	1107
$\gamma\gamma$	$< 5 \times 10^{-4}$	CL=90%	1548
$\gamma\Lambda\bar{\Lambda}$	$< 1.3 \times 10^{-4}$	CL=90%	1074
$3\gamma$	$< 5.5 \times 10^{-5}$	CL=90%	1548
$\gamma f_J(2220)$	$> 2.50 \times 10^{-3}$	CL=99.9%	745
$\gamma f_J(2220) \rightarrow \gamma\pi\pi$	$(8 \pm 4) \times 10^{-5}$		—
$\gamma f_J(2220) \rightarrow \gamma K\bar{K}$	$(8.1 \pm 3.0) \times 10^{-5}$		—
$\gamma f_J(2220) \rightarrow \gamma\rho\bar{\rho}$	$(1.5 \pm 0.8) \times 10^{-5}$		—
$\gamma f_0(1500)$	$> (5.7 \pm 0.8) \times 10^{-4}$		1182
$\gamma e^+e^-$	$(8.8 \pm 1.4) \times 10^{-3}$		1548

### Lepton Family number (*LF*) violating modes

$e^\pm\mu^\mp$	<i>LF</i>	$< 1.1 \times 10^{-6}$	CL=90%	1547
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**$\chi_{c0}(1P)$**

$$I^G(J^{PC}) = 0^+(0^{++})$$

Mass  $m = 3415.19 \pm 0.34$  MeV

Full width  $\Gamma = 10.1 \pm 0.8$  MeV

<b><math>\chi_{c0}(1P)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level	$\frac{P}{\text{MeV}/c}$
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### Hadronic decays

$2(\pi^+\pi^-)$	$(2.58 \pm 0.31) \%$		1679
$\pi^+\pi^-K^+K^-$	$(2.1 \pm 0.5) \%$		1581
$\rho^0\pi^+\pi^-$	$(1.6 \pm 0.5) \%$		1607
$3(\pi^+\pi^-)$	$(1.27 \pm 0.22) \%$		1633
$K^+\bar{K}^*(892)^0\pi^- + \text{c.c.}$	$(1.2 \pm 0.4) \%$		1524
$K^+K^-$	$(6.0 \pm 0.9) \times 10^{-3}$		1635
$\pi\pi$	$(7.4 \pm 0.8) \times 10^{-3}$		1702
$\eta\eta$	$(2.1 \pm 1.1) \times 10^{-3}$		1617
$K^+K^-K^+K^-$	$(2.3 \pm 0.5) \times 10^{-3}$		1334
$K_S^0K_S^0$	$(2.1 \pm 0.6) \times 10^{-3}$		1633
$\pi^+\pi^-\rho\bar{\rho}$	$(2.2 \pm 0.8) \times 10^{-3}$		1320
$\phi\phi$	$(1.0 \pm 0.6) \times 10^{-3}$		1370
$\rho\bar{\rho}$	$(2.24 \pm 0.27) \times 10^{-4}$		1427
$\Lambda\bar{\Lambda}$	$(4.7 \pm 1.6) \times 10^{-4}$		1293
$K_S^0K^+\pi^- + \text{c.c.}$	$< 8 \times 10^{-4}$	90%	1610

### Radiative decays

$\gamma J/\psi(1S)$	$(1.18 \pm 0.14) \%$	303
$\gamma\gamma$	$(2.6 \pm 0.5) \times 10^{-4}$	1708

**$\chi_{c1}(1P)$**

$$J^G(J^{PC}) = 0^+(1^{++})$$

Mass  $m = 3510.59 \pm 0.10$  MeV ( $S = 1.1$ )

Full width  $\Gamma = 0.91 \pm 0.13$  MeV

**$\chi_{c1}(1P)$  DECAY MODES**                      Fraction ( $\Gamma_i/\Gamma$ )                       $p$  (MeV/c)

### Hadronic decays

$3(\pi^+\pi^-)$	$(6.2 \pm 1.6) \times 10^{-3}$	1683
$2(\pi^+\pi^-)$	$(8.2 \pm 2.9) \times 10^{-3}$	1727
$\pi^+\pi^-K^+K^-$	$(4.9 \pm 1.1) \times 10^{-3}$	1632
$\rho^0\pi^+\pi^-$	$(3.9 \pm 3.5) \times 10^{-3}$	1657
$K^+\bar{K}^*(892)^0\pi^- + \text{c.c.}$	$(3.2 \pm 2.1) \times 10^{-3}$	1577
$K_S^0K^+\pi^- + \text{c.c.}$	$(2.5 \pm 0.7) \times 10^{-3}$	1660
$\pi^+\pi^-\rho\bar{p}$	$(5.3 \pm 2.1) \times 10^{-4}$	1381
$K^+K^-K^+K^-$	$(4.2 \pm 1.9) \times 10^{-4}$	1393
$p\bar{p}$	$(7.2 \pm 1.3) \times 10^{-5}$	1483
$\Lambda\bar{\Lambda}$	$(2.6 \pm 1.2) \times 10^{-4}$	1355
$\pi^+\pi^- + K^+K^-$	$< 2.1 \times 10^{-3}$	—

### Radiative decays

$\gamma J/\psi(1S)$	$(31.6 \pm 3.3) \%$	389
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**$\chi_{c2}(1P)$**

$$J^G(J^{PC}) = 0^+(2^{++})$$

Mass  $m = 3556.26 \pm 0.11$  MeV

Full width  $\Gamma = 2.11 \pm 0.16$  MeV

**$\chi_{c2}(1P)$  DECAY MODES**                      Fraction ( $\Gamma_i/\Gamma$ )                      Confidence level ( $p$  (MeV/c))

### Hadronic decays

$2(\pi^+\pi^-)$	$(1.48 \pm 0.21) \%$	1751
$\pi^+\pi^-K^+K^-$	$(1.24 \pm 0.33) \%$	1656
$3(\pi^+\pi^-)$	$(1.07 \pm 0.24) \%$	1707
$\rho^0\pi^+\pi^-$	$(7 \pm 4) \times 10^{-3}$	1681
$K^+\bar{K}^*(892)^0\pi^- + \text{c.c.}$	$(4.8 \pm 2.8) \times 10^{-3}$	1602
$\phi\phi$	$(2.4 \pm 0.9) \times 10^{-3}$	1457
$\pi^+\pi^-$	$(1.77 \pm 0.27) \times 10^{-3}$	1773
$\pi^0\pi^0$	$(1.1 \pm 0.7) \times 10^{-3}$	1773

$\eta\eta$	$< 1.5 \times 10^{-3}$	90%	1692
$K^+ K^- K^+ K^-$	$(1.8 \pm 0.5) \times 10^{-3}$		1421
$\pi^+ \pi^- \rho \bar{\rho}$	$(1.7 \pm 0.4) \times 10^{-3}$		1410
$K^+ K^-$	$(9.4 \pm 2.1) \times 10^{-4}$		1708
$K_S^0 K_S^0$	$(7.2 \pm 2.7) \times 10^{-4}$		1707
$\rho \bar{\rho}$	$(6.8 \pm 0.7) \times 10^{-5}$		1510
$\Lambda \bar{\Lambda}$	$(3.4 \pm 1.7) \times 10^{-4}$		1385
$J/\psi(1S) \pi^+ \pi^- \pi^0$	$< 1.5 \%$	90%	186
$K_S^0 K^+ \pi^- + c.c.$	$< 1.3 \times 10^{-3}$	90%	1685

### Radiative decays

$\gamma J/\psi(1S)$	$(20.2 \pm 1.7) \%$		430
$\gamma\gamma$	$(2.46 \pm 0.23) \times 10^{-4}$		1778

## $\psi(2S)$

$$I^G(J^{PC}) = 0^-(1^{--})$$

Mass  $m = 3686.093 \pm 0.034$  MeV ( $S = 1.4$ )

Full width  $\Gamma = 281 \pm 17$  keV

$\Gamma_{ee} = 2.12 \pm 0.12$  keV

<b><math>\psi(2S)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor/ Confidence level	$\rho$ (MeV/c)
hadrons	$(97.85 \pm 0.13) \%$		—
virtual $\gamma \rightarrow$ hadrons	$(2.16 \pm 0.35) \%$	S=2.1	—
$e^+ e^-$	$(7.55 \pm 0.31) \times 10^{-3}$		1843
$\mu^+ \mu^-$	$(7.3 \pm 0.8) \times 10^{-3}$		1840
$\tau^+ \tau^-$	$(2.8 \pm 0.7) \times 10^{-3}$		489

### Decays into $J/\psi(1S)$ and anything

$J/\psi(1S)$ anything	$(57.6 \pm 2.0) \%$		—
$J/\psi(1S)$ neutrals	$(24.6 \pm 1.2) \%$		—
$J/\psi(1S) \pi^+ \pi^-$	$(31.7 \pm 1.1) \%$		477
$J/\psi(1S) \pi^0 \pi^0$	$(18.8 \pm 1.2) \%$		481
$J/\psi(1S) \eta$	$(3.16 \pm 0.22) \%$		199
$J/\psi(1S) \pi^0$	$(9.6 \pm 2.1) \times 10^{-4}$		528

### Hadronic decays

$3(\pi^+ \pi^-) \pi^0$	$(3.5 \pm 1.6) \times 10^{-3}$		1746
$2(\pi^+ \pi^-) \pi^0$	$(3.0 \pm 0.8) \times 10^{-3}$		1799
$\rho a_2(1320)$	$< 2.3 \times 10^{-4}$	CL=90%	1500
$\omega \pi^+ \pi^-$	$(4.8 \pm 0.9) \times 10^{-4}$		1748
$b_1^\pm \pi^\mp$	$(3.2 \pm 0.8) \times 10^{-4}$		1635
$\omega f_2(1270)$	$< 1.5 \times 10^{-4}$	CL=90%	1515
$\pi^+ \pi^- K^+ K^-$	$(1.6 \pm 0.4) \times 10^{-3}$		1726
$K^*(892) \bar{K}_2^*(1430)^0$	$< 1.2 \times 10^{-4}$	CL=90%	1418

$K_1(1270)^\pm K^\mp$	$( 1.00 \pm 0.28 ) \times 10^{-3}$		1581
$\pi^+ \pi^- p \bar{p}$	$( 8.0 \pm 2.0 ) \times 10^{-4}$		1491
$K^+ \bar{K}^*(892)^0 \pi^- + \text{c.c.}$	$( 6.7 \pm 2.5 ) \times 10^{-4}$		1674
$2(\pi^+ \pi^-)$	$( 4.5 \pm 1.0 ) \times 10^{-4}$		1817
$\rho^0 \pi^+ \pi^-$	$( 4.2 \pm 1.5 ) \times 10^{-4}$		1750
$\omega K^+ K^-$	$( 1.5 \pm 0.4 ) \times 10^{-4}$		1614
$\omega p \bar{p}$	$( 8.0 \pm 3.2 ) \times 10^{-5}$		1247
$\bar{p} p$	$( 2.07 \pm 0.31 ) \times 10^{-4}$		1586
$\Lambda \bar{\Lambda}$	$( 1.81 \pm 0.34 ) \times 10^{-4}$		1467
$3(\pi^+ \pi^-)$	$( 1.5 \pm 1.0 ) \times 10^{-4}$		1774
$\bar{p} p \pi^0$	$( 1.4 \pm 0.5 ) \times 10^{-4}$		1543
$\Delta^{++} \bar{\Delta}^{--}$	$( 1.28 \pm 0.35 ) \times 10^{-4}$		1371
$\Sigma^0 \bar{\Sigma}^0$	$( 1.2 \pm 0.6 ) \times 10^{-4}$		1405
$\Sigma^{*+} \bar{\Sigma}^{*-}$	$( 1.1 \pm 0.4 ) \times 10^{-4}$		1218
$K^+ K^-$	$( 1.0 \pm 0.7 ) \times 10^{-4}$		1776
$K_S^0 K_L^0$	$( 5.2 \pm 0.7 ) \times 10^{-5}$		1775
$\pi^+ \pi^- \pi^0$	$( 8 \pm 5 ) \times 10^{-5}$		1830
$\rho \pi$	$< 8.3 \times 10^{-5}$	CL=90%	1759
$\pi^+ \pi^-$	$( 8 \pm 5 ) \times 10^{-5}$		1838
$\Xi^- \bar{\Xi}^+$	$( 9.4 \pm 3.1 ) \times 10^{-5}$		1285
$K_1(1400)^\pm K^\mp$	$< 3.1 \times 10^{-4}$	CL=90%	1532
$\Xi^{*0} \bar{\Xi}^{*0}$	$< 8.1 \times 10^{-5}$	CL=90%	1025
$\Omega^- \bar{\Omega}^+$	$< 7.3 \times 10^{-5}$	CL=90%	774
$K^+ K^- \pi^0$	$< 2.96 \times 10^{-5}$	CL=90%	1754
$K^+ \bar{K}^*(892)^- + \text{c.c.}$	$< 5.4 \times 10^{-5}$	CL=90%	1698
$\phi \pi^+ \pi^-$	$( 1.50 \pm 0.28 ) \times 10^{-4}$		1690
$\phi f_0(980) \rightarrow \pi^+ \pi^-$	$( 6.0 \pm 2.2 ) \times 10^{-5}$		—
$\phi K^+ K^-$	$( 6.0 \pm 2.2 ) \times 10^{-5}$		1546
$\phi p \bar{p}$	$< 2.6 \times 10^{-5}$	CL=90%	1109
$\phi f_2'(1525)$	$< 4.5 \times 10^{-5}$	CL=90%	1321

### Radiative decays

$\gamma \chi_{c0}(1P)$	$( 8.6 \pm 0.7 ) \%$		261
$\gamma \chi_{c1}(1P)$	$( 8.4 \pm 0.8 ) \%$		171
$\gamma \chi_{c2}(1P)$	$( 6.4 \pm 0.6 ) \%$		128
$\gamma \eta_c(1S)$	$( 2.8 \pm 0.6 ) \times 10^{-3}$		639
$\gamma \eta'(958)$	$( 1.5 \pm 0.4 ) \times 10^{-4}$		1719
$\gamma f_2(1270)$	$( 2.1 \pm 0.4 ) \times 10^{-4}$		1622
$\gamma f_0(1710) \rightarrow \gamma \pi \pi$	$( 3.0 \pm 1.3 ) \times 10^{-5}$		—
$\gamma f_0(1710) \rightarrow \gamma K \bar{K}$	$( 6.0 \pm 1.6 ) \times 10^{-5}$		—
$\gamma \gamma$	$< 1.5 \times 10^{-4}$	CL=90%	1843
$\gamma \eta$	$< 9 \times 10^{-5}$	CL=90%	1802
$\gamma \eta(1405) \rightarrow \gamma K \bar{K} \pi$	$< 1.2 \times 10^{-4}$	CL=90%	1569

**$\psi(3770)$**

$$J^{PC} = 0^{-}(1^{- -})$$

Mass  $m = 3770.0 \pm 2.4$  MeV (S = 1.8)

Full width  $\Gamma = 23.6 \pm 2.7$  MeV (S = 1.1)

$\Gamma_{ee} = 0.26 \pm 0.04$  keV (S = 1.2)

$\psi(3770)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor	$p$ (MeV/c)
$D\bar{D}$	dominant		276
$e^+ e^-$	$(1.12 \pm 0.17) \times 10^{-5}$	1.2	1885

**$\psi(4040)$   $[mmm]$**

$$J^{PC} = 0^{-}(1^{- -})$$

Mass  $m = 4040 \pm 10$  MeV

Full width  $\Gamma = 52 \pm 10$  MeV

$\Gamma_{ee} = 0.75 \pm 0.15$  keV

$\psi(4040)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$e^+ e^-$	$(1.4 \pm 0.4) \times 10^{-5}$	2020
$D^0 \bar{D}^0$	seen	777
$D^*(2007)^0 \bar{D}^0 + c.c.$	seen	577
$D^*(2007)^0 \bar{D}^*(2007)^0$	seen	231

**$\psi(4160)$   $[mmm]$**

$$J^{PC} = 0^{-}(1^{- -})$$

Mass  $m = 4159 \pm 20$  MeV

Full width  $\Gamma = 78 \pm 20$  MeV

$\Gamma_{ee} = 0.77 \pm 0.23$  keV

$\psi(4160)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$e^+ e^-$	$(10 \pm 4) \times 10^{-6}$	2080

**$\psi(4415)$   $[mmm]$**

$$J^{PC} = 0^{-}(1^{- -})$$

Mass  $m = 4415 \pm 6$  MeV

Full width  $\Gamma = 43 \pm 15$  MeV (S = 1.8)

$\Gamma_{ee} = 0.47 \pm 0.10$  keV

$\psi(4415)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
hadrons	dominant	—
$e^+ e^-$	$(1.1 \pm 0.4) \times 10^{-5}$	2207

# $b\bar{b}$ MESONS

**$\Upsilon(1S)$**

$$I^G(J^{PC}) = 0^-(1^{--})$$

Mass  $m = 9460.30 \pm 0.26$  MeV (S = 3.3)

Full width  $\Gamma = 53.0 \pm 1.5$  keV

$\Gamma_{ee} = 1.314 \pm 0.029$  keV

<b><math>\Upsilon(1S)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level	$P$ (MeV/c)
$\tau^+ \tau^-$	$(2.67^{+0.14}_{-0.16}) \%$		4384
$e^+ e^-$	$(2.38 \pm 0.11) \%$		4730
$\mu^+ \mu^-$	$(2.48 \pm 0.06) \%$		4729

### Hadronic decays

$\eta'(958)$ anything	$(2.8 \pm 0.4) \%$		—
$J/\psi(1S)$ anything	$(1.1 \pm 0.4) \times 10^{-3}$		4223
$\rho\pi$	$< 2$	$\times 10^{-4}$	90% 4697
$\pi^+ \pi^-$	$< 5$	$\times 10^{-4}$	90% 4728
$K^+ K^-$	$< 5$	$\times 10^{-4}$	90% 4704
$p\bar{p}$	$< 5$	$\times 10^{-4}$	90% 4636
$\pi^0 \pi^+ \pi^-$	$< 1.84$	$\times 10^{-5}$	90% 4725

### Radiative decays

$\gamma \pi^+ \pi^-$	$(6.3 \pm 1.8) \times 10^{-5}$		4728
$\gamma \pi^0 \pi^0$	$(1.7 \pm 0.7) \times 10^{-5}$		4728
$\gamma 2h^+ 2h^-$	$(7.0 \pm 1.5) \times 10^{-4}$		4720
$\gamma 3h^+ 3h^-$	$(5.4 \pm 2.0) \times 10^{-4}$		4703
$\gamma 4h^+ 4h^-$	$(7.4 \pm 3.5) \times 10^{-4}$		4679
$\gamma \pi^+ \pi^- K^+ K^-$	$(2.9 \pm 0.9) \times 10^{-4}$		4686
$\gamma 2\pi^+ 2\pi^-$	$(2.5 \pm 0.9) \times 10^{-4}$		4720
$\gamma 3\pi^+ 3\pi^-$	$(2.5 \pm 1.2) \times 10^{-4}$		4703
$\gamma 2\pi^+ 2\pi^- K^+ K^-$	$(2.4 \pm 1.2) \times 10^{-4}$		4658
$\gamma \pi^+ \pi^- p\bar{p}$	$(1.5 \pm 0.6) \times 10^{-4}$		4604
$\gamma 2\pi^+ 2\pi^- p\bar{p}$	$(4 \pm 6) \times 10^{-5}$		4563
$\gamma 2K^+ 2K^-$	$(2.0 \pm 2.0) \times 10^{-5}$		4601
$\gamma \eta'(958)$	$< 1.6$	$\times 10^{-5}$	90% 4682
$\gamma \eta$	$< 2.1$	$\times 10^{-5}$	90% 4714
$\gamma f'_2(1525)$	$< 1.4$	$\times 10^{-4}$	90% 4607
$\gamma f_2(1270)$	$(8 \pm 4) \times 10^{-5}$		4644
$\gamma \eta(1405)$	$< 8.2$	$\times 10^{-5}$	90% 4625
$\gamma f_0(1710) \rightarrow \gamma K\bar{K}$	$< 2.6$	$\times 10^{-4}$	90% 4576

$\gamma f_0(2200) \rightarrow \gamma K^+ K^-$	$< 2$	$\times 10^{-4}$	90%	4475
$\gamma f_J(2220) \rightarrow \gamma K^+ K^-$	$< 1.5$	$\times 10^{-5}$	90%	4469
$\gamma f_J(2220) \rightarrow \gamma \pi^+ \pi^-$	$< 1.2$	$\times 10^{-5}$	90%	—
$\gamma f_J(2220) \rightarrow \gamma p \bar{p}$	$< 1.6$	$\times 10^{-5}$	90%	—
$\gamma \eta(2225) \rightarrow \gamma \phi \phi$	$< 3$	$\times 10^{-3}$	90%	4469
$\gamma X$	$< 3$	$\times 10^{-5}$	90%	—
(X = pseudoscalar with $m < 7.2$ GeV)				
$\gamma X \bar{X}$	$< 1$	$\times 10^{-3}$	90%	—
(X $\bar{X}$ = vectors with $m < 3.1$ GeV)				

**$\chi_{b0}(1P)$  <sup>[nnn]</sup>**

$I^G(J^{PC}) = 0^+(0^{++})$   
*J* needs confirmation.

Mass  $m = 9859.9 \pm 1.0$  MeV

<b><math>\chi_{b0}(1P)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level	$p$ (MeV/c)
$\gamma \Upsilon(1S)$	$< 6\%$	90%	391

**$\chi_{b1}(1P)$  <sup>[nnn]</sup>**

$I^G(J^{PC}) = 0^+(1^{++})$   
*J* needs confirmation.

Mass  $m = 9892.7 \pm 0.6$  MeV (S = 1.1)

<b><math>\chi_{b1}(1P)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\gamma \Upsilon(1S)$	$(35 \pm 8)\%$	423

**$\chi_{b2}(1P)$  <sup>[nnn]</sup>**

$I^G(J^{PC}) = 0^+(2^{++})$   
*J* needs confirmation.

Mass  $m = 9912.6 \pm 0.5$  MeV (S = 1.1)

<b><math>\chi_{b2}(1P)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\gamma \Upsilon(1S)$	$(22 \pm 4)\%$	442

**$\Upsilon(2S)$**

$$I^G(J^{PC}) = 0^-(1^{--})$$

Mass  $m = 10.02326 \pm 0.00031$  GeV

Full width  $\Gamma = 43 \pm 6$  keV

$\Gamma_{ee} = 0.576 \pm 0.024$  keV

<b><math>\Upsilon(2S)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level	$p$ (MeV/c)
$\Upsilon(1S)\pi^+\pi^-$	(18.8 $\pm$ 0.6) %		475
$\Upsilon(1S)\pi^0\pi^0$	( 9.0 $\pm$ 0.8 ) %		480
$\tau^+\tau^-$	( 1.7 $\pm$ 1.6 ) %		4686
$\mu^+\mu^-$	( 1.31 $\pm$ 0.21) %		5011
$e^+e^-$	( 1.34 $\pm$ 0.20) %		5012
$\Upsilon(1S)\pi^0$	< 1.1	$\times 10^{-3}$	90% 531
$\Upsilon(1S)\eta$	< 2	$\times 10^{-3}$	90% 126
$J/\psi(1S)$ anything	< 6	$\times 10^{-3}$	90% 4533

**Radiative decays**

$\gamma\chi_{b1}(1P)$	( 6.8 $\pm$ 0.7 ) %		130
$\gamma\chi_{b2}(1P)$	( 7.0 $\pm$ 0.6 ) %		110
$\gamma\chi_{b0}(1P)$	( 3.8 $\pm$ 0.6 ) %		162
$\gamma f_0(1710)$	< 5.9	$\times 10^{-4}$	90% 4865
$\gamma f'_2(1525)$	< 5.3	$\times 10^{-4}$	90% 4896
$\gamma f_2(1270)$	< 2.41	$\times 10^{-4}$	90% 4930

**$\chi_{b0}(2P)$  <sup>[nnn]</sup>**

$$I^G(J^{PC}) = 0^+(0^{++})$$

$J$  needs confirmation.

Mass  $m = 10.2321 \pm 0.0006$  GeV

<b><math>\chi_{b0}(2P)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\gamma\Upsilon(2S)$	(4.6 $\pm$ 2.1) %	207
$\gamma\Upsilon(1S)$	(9 $\pm$ 6 ) $\times 10^{-3}$	743

**$\chi_{b1}(2P)$  <sup>[nnn]</sup>**

$$I^G(J^{PC}) = 0^+(1^{++})$$

$J$  needs confirmation.

Mass  $m = 10.2552 \pm 0.0005$  GeV

$m_{\chi_{b1}(2P)} - m_{\chi_{b0}(2P)} = 23.5 \pm 1.0$  MeV

<b><math>\chi_{b1}(2P)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor	$p$ (MeV/c)
$\gamma\Upsilon(2S)$	(21 $\pm$ 4 ) %	1.5	229
$\gamma\Upsilon(1S)$	( 8.5 $\pm$ 1.3) %	1.3	764



**$\chi_{b2}(2P)$  [*nnn*]**

$$I^G(J^{PC}) = 0^+(2^{++})$$

*J* needs confirmation.

$$\text{Mass } m = 10.2685 \pm 0.0004 \text{ GeV}$$

$$m_{\chi_{b2}(2P)} - m_{\chi_{b1}(2P)} = 13.5 \pm 0.6 \text{ MeV}$$

<b><math>\chi_{b2}(2P)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	<i>p</i> (MeV/c)
$\gamma \Upsilon(2S)$	(16.2±2.4) %	242
$\gamma \Upsilon(1S)$	( 7.1±1.0) %	776

**$\Upsilon(3S)$**

$$I^G(J^{PC}) = 0^-(1^{--})$$

$$\text{Mass } m = 10.3552 \pm 0.0005 \text{ GeV}$$

$$\text{Full width } \Gamma = 26.3 \pm 3.4 \text{ keV}$$

<b><math>\Upsilon(3S)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor/ Confidence level	<i>p</i> (MeV/c)
$\Upsilon(2S)$ anything	(10.6 ± 0.8 ) %		296
$\Upsilon(2S) \pi^+ \pi^-$	( 2.8 ± 0.6 ) %	S=2.2	177
$\Upsilon(2S) \pi^0 \pi^0$	( 2.00±0.32) %		190
$\Upsilon(2S) \gamma \gamma$	( 5.0 ± 0.7 ) %		327
$\Upsilon(1S) \pi^+ \pi^-$	( 4.48±0.21) %		813
$\Upsilon(1S) \pi^0 \pi^0$	( 2.06±0.28) %		816
$\Upsilon(1S) \eta$	< 2.2	$\times 10^{-3}$ CL=90%	677
$\mu^+ \mu^-$	( 1.81±0.17) %		5177
$e^+ e^-$	seen		5178
<b>Radiative decays</b>			
$\gamma \chi_{b2}(2P)$	(11.4 ± 0.8 ) %	S=1.3	86
$\gamma \chi_{b1}(2P)$	(11.3 ± 0.6 ) %		100
$\gamma \chi_{b0}(2P)$	( 5.4 ± 0.6 ) %	S=1.1	122

**$\Upsilon(4S)$   
or  $\Upsilon(10580)$**

$$I^G(J^{PC}) = 0^-(1^{--})$$

$$\text{Mass } m = 10.5800 \pm 0.0035 \text{ GeV}$$

$$\text{Full width } \Gamma = 20 \pm 4 \text{ MeV}$$

$$\Gamma_{ee} = 0.248 \pm 0.031 \text{ keV} \quad (S = 1.3)$$

<b><math>\Upsilon(4S)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level	<i>p</i> (MeV/c)
$B \bar{B}$	> 96 %	95%	335
non- $B \bar{B}$	< 4 %	95%	—
$e^+ e^-$	( 2.8±0.7) $\times 10^{-5}$		5290

$J/\psi(1S)$ anything	< 1.9	$\times 10^{-4}$	95%	—
$D^{*+}$ anything + c.c.	< 7.4	%	90%	5099
$\phi$ anything	< 2.3	$\times 10^{-3}$	90%	5240
$\Upsilon(1S)$ anything	< 4	$\times 10^{-3}$	90%	1053
$\Upsilon(1S)\pi^+\pi^-$	< 1.2	$\times 10^{-4}$	90%	1027
$\Upsilon(2S)\pi^+\pi^-$	< 3.9	$\times 10^{-4}$	90%	469

### $\Upsilon(10860)$

$$I^G(J^{PC}) = 0^-(1^{--})$$

Mass  $m = 10.865 \pm 0.008$  GeV (S = 1.1)

Full width  $\Gamma = 110 \pm 13$  MeV

$\Gamma_{ee} = 0.31 \pm 0.07$  keV (S = 1.3)

$\Upsilon(10860)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$e^+e^-$	$(2.8 \pm 0.7) \times 10^{-6}$	5432

### $\Upsilon(11020)$

$$I^G(J^{PC}) = 0^-(1^{--})$$

Mass  $m = 11.019 \pm 0.008$  GeV

Full width  $\Gamma = 79 \pm 16$  MeV

$\Gamma_{ee} = 0.130 \pm 0.030$  keV

$\Upsilon(11020)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$e^+e^-$	$(1.6 \pm 0.5) \times 10^{-6}$	5510

## NOTES

- [a] See the “Note on  $\pi^\pm \rightarrow \ell^\pm \nu \gamma$  and  $K^\pm \rightarrow \ell^\pm \nu \gamma$  Form Factors” in the  $\pi^\pm$  Particle Listings for definitions and details.
- [b] Measurements of  $\Gamma(e^+ \nu_e)/\Gamma(\mu^+ \nu_\mu)$  always include decays with  $\gamma$ 's, and measurements of  $\Gamma(e^+ \nu_e \gamma)$  and  $\Gamma(\mu^+ \nu_\mu \gamma)$  never include low-energy  $\gamma$ 's. Therefore, since no clean separation is possible, we consider the modes with  $\gamma$ 's to be subreactions of the modes without them, and let  $[\Gamma(e^+ \nu_e) + \Gamma(\mu^+ \nu_\mu)]/\Gamma_{\text{total}} = 100\%$ .
- [c] See the  $\pi^\pm$  Particle Listings for the energy limits used in this measurement; low-energy  $\gamma$ 's are not included.
- [d] Derived from an analysis of neutrino-oscillation experiments.
- [e] Astrophysical and cosmological arguments give limits of order  $10^{-13}$ ; see the  $\pi^0$  Particle Listings.
- [f] Due to a new measurement in the average, this is 0.45 MeV larger than the mass we gave in our 2002 edition,  $547.30 \pm 0.12$  MeV.
- [g] Due to removing an old measurement from the average, this is 0.11 keV larger than the width we gave in our 2002 edition,  $1.18 \pm 0.11$  keV. See the  $\Gamma(2\gamma)$  data block in the Data Listings.
- [h]  $C$  parity forbids this to occur as a single-photon process.
- [i] See the “Note on scalar mesons” in the  $f_0(1370)$  Particle Listings . The interpretation of this entry as a particle is controversial.
- [j] See the “Note on  $\rho(770)$ ” in the  $\rho(770)$  Particle Listings .
- [k] The  $\omega\rho$  interference is then due to  $\omega\rho$  mixing only, and is expected to be small. If  $e\mu$  universality holds,  $\Gamma(\rho^0 \rightarrow \mu^+ \mu^-) = \Gamma(\rho^0 \rightarrow e^+ e^-) \times 0.99785$ .
- [l] See the “Note on scalar mesons” in the  $f_0(1370)$  Particle Listings .
- [m] See the “Note on  $a_1(1260)$ ” in the  $a_1(1260)$  Particle Listings .
- [n] This is only an educated guess; the error given is larger than the error on the average of the published values. See the Particle Listings for details.
- [o] See the “Note on non- $q\bar{q}$  mesons” in the Particle Listings (see the index for the page number).
- [p] See the “Note on the  $\eta(1405)$ ” in the  $\eta(1405)$  Particle Listings.
- [q] See the “Note on the  $f_1(1420)$ ” in the  $\eta(1405)$  Particle Listings.
- [r] See also the  $\omega(1650)$  Particle Listings.
- [s] See the “Note on the  $\rho(1450)$  and the  $\rho(1700)$ ” in the  $\rho(1700)$  Particle Listings.
- [t] See also the  $\omega(1420)$  Particle Listings.
- [u] See the “Note on  $f_0(1710)$ ” in the  $f_0(1710)$  Particle Listings .

[v] See the note in the  $K^\pm$  Particle Listings.

[w] The definition of the slope parameter  $g$  of the  $K \rightarrow 3\pi$  Dalitz plot is as follows (see also “Note on Dalitz Plot Parameters for  $K \rightarrow 3\pi$  Decays” in the  $K^\pm$  Particle Listings):

$$|M|^2 = 1 + g(s_3 - s_0)/m_{\pi^+}^2 + \dots$$

[x] For more details and definitions of parameters see the Particle Listings.

[y] Most of this radiative mode, the low-momentum  $\gamma$  part, is also included in the parent mode listed without  $\gamma$ 's.

[z] See the  $K^\pm$  Particle Listings for the energy limits used in this measurement.

[aa] Structure-dependent part.

[bb] Direct-emission branching fraction.

[cc] Violates angular-momentum conservation.

[dd] Derived from measured values of  $\phi_{+-}$ ,  $\phi_{00}$ ,  $|\eta|$ ,  $|m_{K_L^0} - m_{K_S^0}|$ , and  $\tau_{K_S^0}$ , as described in the introduction to “Tests of Conservation Laws.”

[ee] The  $CP$ -violation parameters are defined as follows (see also “Note on  $CP$  Violation in  $K_S \rightarrow 3\pi$ ” and “Note on  $CP$  Violation in  $K_L^0$  Decay” in the Particle Listings):

$$\eta_{+-} = |\eta_{+-}|e^{i\phi_{+-}} = \frac{A(K_L^0 \rightarrow \pi^+\pi^-)}{A(K_S^0 \rightarrow \pi^+\pi^-)} = \epsilon + \epsilon'$$

$$\eta_{00} = |\eta_{00}|e^{i\phi_{00}} = \frac{A(K_L^0 \rightarrow \pi^0\pi^0)}{A(K_S^0 \rightarrow \pi^0\pi^0)} = \epsilon - 2\epsilon'$$

$$\delta = \frac{\Gamma(K_L^0 \rightarrow \pi^-\ell^+\nu) - \Gamma(K_L^0 \rightarrow \pi^+\ell^-\nu)}{\Gamma(K_L^0 \rightarrow \pi^-\ell^+\nu) + \Gamma(K_L^0 \rightarrow \pi^+\ell^-\nu)},$$

$$\text{Im}(\eta_{+-0})^2 = \frac{\Gamma(K_S^0 \rightarrow \pi^+\pi^-\pi^0)^{CP \text{ viol.}}}{\Gamma(K_L^0 \rightarrow \pi^+\pi^-\pi^0)},$$

$$\text{Im}(\eta_{000})^2 = \frac{\Gamma(K_S^0 \rightarrow \pi^0\pi^0\pi^0)}{\Gamma(K_L^0 \rightarrow \pi^0\pi^0\pi^0)}.$$

where for the last two relations  $CPT$  is assumed valid, *i.e.*,  $\text{Re}(\eta_{+-0}) \simeq 0$  and  $\text{Re}(\eta_{000}) \simeq 0$ .

[ff] See the  $K_S^0$  Particle Listings for the energy limits used in this measurement.

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

- [hh]  $\text{Re}(\epsilon'/\epsilon) = \epsilon'/\epsilon$  to a very good approximation provided the phases satisfy *CPT* invariance.
- [ii] See the  $K_L^0$  Particle Listings for the energy limits used in this measurement.
- [jj] Allowed by higher-order electroweak interactions.
- [kk] Violates *CP* in leading order. Test of direct *CP* violation since the indirect *CP*-violating and *CP*-conserving contributions are expected to be suppressed.
- [ll] See the “Note on  $f_0(1370)$ ” in the  $f_0(1370)$  Particle Listings and in the 1994 edition.
- [mm] See the note in the  $L(1770)$  Particle Listings in Reviews of Modern Physics **56** No. 2 Pt. II (1984), p. S200. See also the “Note on  $K_2(1770)$  and the  $K_2(1820)$ ” in the  $K_2(1770)$  Particle Listings .
- [nn] See the “Note on  $K_2(1770)$  and the  $K_2(1820)$ ” in the  $K_2(1770)$  Particle Listings .
- [oo] This result applies to  $Z^0 \rightarrow c\bar{c}$  decays only. Here  $\ell^+$  is an average (not a sum) of  $e^+$  and  $\mu^+$  decays.
- [pp] This is a weighted average of  $D^\pm$  (44%) and  $D^0$  (56%) branching fractions. See “ $D^+$  and  $D^0 \rightarrow (\eta \text{ anything}) / (\text{total } D^+ \text{ and } D^0)$ ” under “ $D^+$  Branching Ratios” in the Particle Listings.
- [qq] This value averages the  $e^+$  and  $\mu^+$  branching fractions, after making a small phase-space adjustment to the  $\mu^+$  fraction to be able to use it as an  $e^+$  fraction; hence our  $\ell^+$  here is really an  $e^+$ .
- [rr] An  $\ell$  indicates an  $e$  or a  $\mu$  mode, not a sum over these modes.
- [ss] The branching fraction for this mode may differ from the sum of the submodes that contribute to it, due to interference effects. See the relevant papers in the Particle Listings.
- [tt] The two experiments measuring this fraction are in serious disagreement. See the Particle Listings.
- [uu] This value includes only  $\pi^+\pi^-$  decays of the intermediate resonance, because branching fractions of this resonance are not known.
- [vv] Unseen decay modes of the resonance are included.
- [ww] This mode is not a useful test for a  $\Delta C=1$  weak neutral current because both quarks must change flavor in this decay.
- [xx] This  $D_1^0 - D_2^0$  limit is inferred from the  $D^0 - \bar{D}^0$  mixing ratio  $\Gamma(K^+\pi^- \text{ (via } \bar{D}^0)) / \Gamma(K^-\pi^+)$  near the end of the  $D^0$  Listings.
- [yy] The exclusive  $e^+$  modes  $K^- e^+ \nu_e$ ,  $K^-\pi^0 e^+ \nu_e$ ,  $\bar{K}^0 \pi^- e^+ \nu_e$  and  $\pi^- e^+ \nu_e$  are constrained to equal this (well-measured) inclusive fraction.

- [zz] The experiments on the division of this charge mode amongst its sub-modes disagree, and the submode branching fractions here add up to considerably more than the charged-mode fraction.
- [aaa] However, these upper limits are in serious disagreement with values obtained in another experiment.
- [bbb] For now, we average together measurements of the  $X e^+ \nu_e$  and  $X \mu^+ \nu_\mu$  branching fractions. This is the *average*, not the *sum*.
- [ccc] This branching fraction includes all the decay modes of the final-state resonance.
- [ddd] This value includes only  $K^+ K^-$  decays of the intermediate resonance, because branching fractions of this resonance are not known.
- [eee]  $B^0$  and  $B_s^0$  contributions not separated. Limit is on weighted average of the two decay rates.
- [fff] These values are model dependent. See 'Note on Semileptonic Decays' in the  $B^+$  Particle Listings.
- [ggg]  $D^{**}$  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.
- [hhh]  $D^{(*)}\bar{D}^{(*)}$  stands for the sum of  $D^*\bar{D}^*$ ,  $D^*\bar{D}$ ,  $D\bar{D}^*$ , and  $D\bar{D}$ .
- [iii] Inclusive branching fractions have a multiplicity definition and can be greater than 100%.
- [jjj]  $D_j$  represents an unresolved mixture of pseudoscalar and tensor  $D^{**}$  ( $P$ -wave) states.
- [kkk] Not a pure measurement. See note at head of  $B_s^0$  Decay Modes.
- [lll] Includes  $p\bar{p}\pi^+\pi^-\gamma$  and excludes  $p\bar{p}\eta$ ,  $p\bar{p}\omega$ ,  $p\bar{p}\eta'$ .
- [mmm]  $J^{PC}$  known by production in  $e^+e^-$  via single photon annihilation.  $I^G$  is not known; interpretation of this state as a single resonance is unclear because of the expectation of substantial threshold effects in this energy region.
- [nnn] Spectroscopic labeling for these states is theoretical, pending experimental information.