

# 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  $m = 139.57039 \pm 0.00018$  MeV ( $S = 1.8$ )

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]

$$F_V = 0.0254 \pm 0.0017$$

$$F_A = 0.0119 \pm 0.0001$$

$$F_V \text{ slope parameter } a = 0.10 \pm 0.06$$

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

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

For decay limits to particles which are not established, see the section on Searches for Axions and Other Very Light Bosons.

| $\pi^+$ DECAY MODES   | Fraction ( $\Gamma_i/\Gamma$ )           | Confidence level       | $P$<br>(MeV/c) |
|---|--|------------------------|----------------|
| $\mu^+ \nu_\mu$   | [b] (99.98770 ± 0.00004) %               |                        | 30             |
| $\mu^+ \nu_\mu \gamma$  | [c] ( 2.00 ± 0.25 ) × 10 <sup>-4</sup>   |                        | 30             |
| $e^+ \nu_e$   | [b] ( 1.230 ± 0.004 ) × 10 <sup>-4</sup> |                        | 70             |
| $e^+ \nu_e \gamma$  | [c] ( 7.39 ± 0.05 ) × 10 <sup>-7</sup>   |                        | 70             |
| $e^+ \nu_e \pi^0$   | ( 1.036 ± 0.006 ) × 10 <sup>-8</sup>     |                        | 4              |
| $e^+ \nu_e e^+ e^-$   | ( 3.2 ± 0.5 ) × 10 <sup>-9</sup>         |                        | 70             |
| $\mu^+ \nu_\mu \nu \bar{\nu}$   | < 9                                      | × 10 <sup>-6</sup> 90% | 30             |
| $e^+ \nu_e \nu \bar{\nu}$   | < 1.6                                    | × 10 <sup>-7</sup> 90% | 70             |
| <b>Lepton Family number (LF) or Lepton number (L) violating modes</b> |  |                        |                |
| $\mu^+ \bar{\nu}_e$   | L [d] < 1.5                              | × 10 <sup>-3</sup> 90% | 30             |
| $\mu^+ \nu_e$   | LF [d] < 8.0                             | × 10 <sup>-3</sup> 90% | 30             |
| $\mu^- e^+ e^+ \nu$   | LF < 1.6                                 | × 10 <sup>-6</sup> 90% | 30             |



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

Mass  $m = 134.9768 \pm 0.0005$  MeV (S = 1.1)

$m_{\pi^\pm} - m_{\pi^0} = 4.5936 \pm 0.0005$  MeV

Mean life  $\tau = (8.43 \pm 0.13) \times 10^{-17}$  s (S = 1.2)

$c\tau = 25.3$  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/<br>Confidence level | $p$<br>(MeV/c)           |    |
|--|----------------------------------|-----------------------------------|--------------------------|----|
| $2\gamma$  | $(98.823 \pm 0.034) \%$          | S=1.5                             | 67                       |    |
| $e^+ e^- \gamma$   | $(1.174 \pm 0.035) \%$           | S=1.5                             | 67                       |    |
| $\gamma$ positronium   | $(1.82 \pm 0.29) \times 10^{-9}$ |                                   | 67                       |    |
| $e^+ e^+ e^- e^-$  | $(3.34 \pm 0.16) \times 10^{-5}$ |                                   | 67                       |    |
| $e^+ e^-$  | $(6.46 \pm 0.33) \times 10^{-8}$ |                                   | 67                       |    |
| $4\gamma$  | $< 2$                            | $\times 10^{-8}$ CL=90%           | 67                       |    |
| $\nu\bar{\nu}$   | $[e] < 2.7$                      | $\times 10^{-7}$ CL=90%           | 67                       |    |
| $\nu_e\bar{\nu}_e$   | $< 1.7$                          | $\times 10^{-6}$ CL=90%           | 67                       |    |
| $\nu_\mu\bar{\nu}_\mu$   | $< 1.6$                          | $\times 10^{-6}$ CL=90%           | 67                       |    |
| $\nu_\tau\bar{\nu}_\tau$   | $< 2.1$                          | $\times 10^{-6}$ CL=90%           | 67                       |    |
| $\gamma\nu\bar{\nu}$   | $< 1.9$                          | $\times 10^{-7}$ CL=90%           | 67                       |    |
| <b>Charge conjugation (C) or Lepton Family number (LF) violating modes</b> |                                  |                                   |                          |    |
| $3\gamma$  | 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                               | $< 3.6$                           | $\times 10^{-10}$ CL=90% | 26 |



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

Mass  $m = 547.862 \pm 0.017$  MeV

Full width  $\Gamma = 1.31 \pm 0.05$  keV

**C-nonconserving decay parameters**

$\pi^+ \pi^- \pi^0$  left-right asymmetry =  $(0.09^{+0.11}_{-0.12}) \times 10^{-2}$

$\pi^+ \pi^- \pi^0$  sextant asymmetry =  $(0.12^{+0.10}_{-0.11}) \times 10^{-2}$

$\pi^+ \pi^- \pi^0$  quadrant asymmetry =  $(-0.09 \pm 0.09) \times 10^{-2}$

$\pi^+ \pi^- \gamma$  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)

**CP-nonconserving decay parameters**

$\pi^+ \pi^- e^+ e^-$  decay-plane asymmetry  $A_\phi = (-0.6 \pm 3.1) \times 10^{-2}$

### Other decay parameters

$\pi^0\pi^0\pi^0$  Dalitz plot  $\alpha = -0.0288 \pm 0.0012$  ( $S = 1.1$ )

Parameter  $\Lambda$  in  $\eta \rightarrow \ell^+\ell^-\gamma$  decay =  $0.716 \pm 0.011$  GeV/ $c^2$

| $\eta$ DECAY MODES | Fraction ( $\Gamma_i/\Gamma$ ) | Scale factor/<br>Confidence level | $p$<br>(MeV/ $c$ ) |
|--------------------|--------------------------------|-----------------------------------|--------------------|
|--------------------|--------------------------------|-----------------------------------|--------------------|

#### Neutral modes

|                   |                               |        |     |
|-------------------|-------------------------------|--------|-----|
| neutral modes     | (72.12±0.34) %                | S=1.2  | —   |
| 2 $\gamma$        | (39.41±0.20) %                | S=1.1  | 274 |
| 3 $\pi^0$         | (32.68±0.23) %                | S=1.1  | 179 |
| $\pi^0 2\gamma$   | ( 2.56±0.22) $\times 10^{-4}$ |        | 257 |
| 2 $\pi^0 2\gamma$ | < 1.2 $\times 10^{-3}$        | CL=90% | 238 |
| 4 $\gamma$        | < 2.8 $\times 10^{-4}$        | CL=90% | 274 |
| invisible         | < 1.0 $\times 10^{-4}$        | CL=90% | —   |

#### Charged modes

|                                     |                               |        |     |
|-------------------------------------|-------------------------------|--------|-----|
| charged modes                       | (27.89±0.29) %                | S=1.2  | —   |
| $\pi^+\pi^-\pi^0$                   | (22.92±0.28) %                | S=1.2  | 174 |
| $\pi^+\pi^-\gamma$                  | ( 4.22±0.08) %                | S=1.1  | 236 |
| $e^+e^-\gamma$                      | ( 6.9 ±0.4 ) $\times 10^{-3}$ | S=1.3  | 274 |
| $\mu^+\mu^-\gamma$                  | ( 3.1 ±0.4 ) $\times 10^{-4}$ |        | 253 |
| $e^+e^-$                            | < 7 $\times 10^{-7}$          | CL=90% | 274 |
| $\mu^+\mu^-$                        | ( 5.8 ±0.8 ) $\times 10^{-6}$ |        | 253 |
| 2 $e^+2e^-$                         | ( 2.40±0.22) $\times 10^{-5}$ |        | 274 |
| $\pi^+\pi^-e^+e^-(\gamma)$          | ( 2.68±0.11) $\times 10^{-4}$ |        | 235 |
| $e^+e^-\mu^+\mu^-$                  | < 1.6 $\times 10^{-4}$        | CL=90% | 253 |
| 2 $\mu^+2\mu^-$                     | < 3.6 $\times 10^{-4}$        | CL=90% | 161 |
| $\mu^+\mu^-\pi^+\pi^-$              | < 3.6 $\times 10^{-4}$        | CL=90% | 113 |
| $\pi^+e^-\bar{\nu}_e + \text{c.c.}$ | < 1.7 $\times 10^{-4}$        | CL=90% | 256 |
| $\pi^+\pi^-2\gamma$                 | < 2.1 $\times 10^{-3}$        |        | 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 |

#### Charge conjugation (C), Parity (P), Charge conjugation $\times$ Parity (CP), or Lepton Family number (LF) violating modes

|                 |      |         |                  |        |     |
|-----------------|------|---------|------------------|--------|-----|
| $\pi^0\gamma$   | C    | [f] < 9 | $\times 10^{-5}$ | CL=90% | 257 |
| $\pi^+\pi^-$    | P,CP | < 4.4   | $\times 10^{-6}$ | CL=90% | 236 |
| 2 $\pi^0$       | P,CP | < 3.5   | $\times 10^{-4}$ | CL=90% | 238 |
| 2 $\pi^0\gamma$ | C    | < 5     | $\times 10^{-4}$ | CL=90% | 238 |
| 3 $\pi^0\gamma$ | C    | < 6     | $\times 10^{-5}$ | CL=90% | 179 |
| 3 $\gamma$      | C    | < 1.6   | $\times 10^{-5}$ | CL=90% | 274 |
| 4 $\pi^0$       | P,CP | < 6.9   | $\times 10^{-7}$ | CL=90% | 40  |
| $\pi^0e^+e^-$   | C    | [g] < 8 | $\times 10^{-6}$ | CL=90% | 257 |

|                         |    |           |                  |        |     |
|-------------------------|----|-----------|------------------|--------|-----|
| $\pi^0 \mu^+ \mu^-$     | C  | $[g] < 5$ | $\times 10^{-6}$ | CL=90% | 210 |
| $\mu^+ e^- + \mu^- e^+$ | LF | $< 6$     | $\times 10^{-6}$ | CL=90% | 264 |

### $f_0(500)$

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

also known as  $\sigma$ ; was  $f_0(600)$

See the review on "Scalar Mesons below 2 GeV."

Mass (T-Matrix Pole  $\sqrt{s}$ ) = (400–550)– $i$ (200–350) MeV

Mass (Breit-Wigner) = 400 to 800 MeV

Full width (Breit-Wigner) = 100 to 800 MeV

| $f_0(500)$ DECAY MODES | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|------------------------|--------------------------------|-------------|
| $\pi \pi$              | seen                           | –           |
| $\gamma \gamma$        | seen                           | –           |

### $\rho(770)$

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

See the note in  $\rho(770)$  Particle Listings.

Mass  $m = 775.26 \pm 0.23$  MeV

Full width  $\Gamma = 149.1 \pm 0.8$  MeV

| $\rho(770)$ DECAY MODES                  | Fraction ( $\Gamma_i/\Gamma$ )                       | Scale factor/<br>Confidence level | $p$<br>(MeV/c) |
|--|--|-----------------------------------|----------------|
| $\pi \pi$                                | $\sim 100$   | %                                 | 363            |
| <b><math>\rho(770)^\pm</math> decays</b> |  |                                   |                |
| $\pi^\pm \gamma$                         | ( $4.5 \pm 0.5$ ) $\times 10^{-4}$                   | S=2.2                             | 375            |
| $\pi^\pm \eta$                           | $< 6$  | CL=84%                            | 152            |
| $\pi^\pm \pi^+ \pi^- \pi^0$              | $< 2.0$  | CL=84%                            | 254            |
| <b><math>\rho(770)^0</math> decays</b>   |  |                                   |                |
| $\pi^+ \pi^- \gamma$                     | ( $9.9 \pm 1.6$ ) $\times 10^{-3}$                   |                                   | 362            |
| $\pi^0 \gamma$                           | ( $4.7 \pm 0.8$ ) $\times 10^{-4}$                   | S=1.7                             | 376            |
| $\eta \gamma$                            | ( $3.00 \pm 0.21$ ) $\times 10^{-4}$                 |                                   | 194            |
| $\pi^0 \pi^0 \gamma$                     | ( $4.5 \pm 0.8$ ) $\times 10^{-5}$                   |                                   | 363            |
| $\mu^+ \mu^-$                            | [h] ( $4.55 \pm 0.28$ ) $\times 10^{-5}$             |                                   | 373            |
| $e^+ e^-$                                | [h] ( $4.72 \pm 0.05$ ) $\times 10^{-5}$             |                                   | 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            |
| $\pi^+ \pi^- \pi^0 \pi^0$                | ( $1.6 \pm 0.8$ ) $\times 10^{-5}$                   |                                   | 257            |
| $\pi^0 e^+ e^-$                          | $< 1.2$  | CL=90%                            | 376            |

**$\omega(782)$**

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

Mass  $m = 782.66 \pm 0.13$  MeV ( $S = 2.0$ )

Full width  $\Gamma = 8.68 \pm 0.13$  MeV

| <b><math>\omega(782)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ )      | Scale factor/<br>Confidence level | $\rho$<br>(MeV/c) |
|---|-------------------------------------|-----------------------------------|-------------------|
| $\pi^+\pi^-\pi^0$                           | (89.2 $\pm$ 0.7 ) %                 |                                   | 327               |
| $\pi^0\gamma$                               | ( 8.34 $\pm$ 0.26) %                | S=2.1                             | 380               |
| $\pi^+\pi^-$                                | ( 1.53 $^{+0.11}_{-0.13}$ ) %       | S=1.2                             | 366               |
| neutrals (excluding $\pi^0\gamma$ )         | ( 7 $^{+7}_{-5}$ ) $\times 10^{-3}$ | S=1.1                             | –                 |
| $\eta\gamma$                                | ( 4.5 $\pm$ 0.4 ) $\times 10^{-4}$  | S=1.1                             | 200               |
| $\pi^0e^+e^-$                               | ( 7.7 $\pm$ 0.6 ) $\times 10^{-4}$  |                                   | 380               |
| $\pi^0\mu^+\mu^-$                           | ( 1.34 $\pm$ 0.18) $\times 10^{-4}$ | S=1.5                             | 349               |
| $e^+e^-$                                    | ( 7.39 $\pm$ 0.19) $\times 10^{-5}$ | S=1.7                             | 391               |
| $\pi^+\pi^-\pi^0\pi^0$                      | < 2 $\times 10^{-4}$                | 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               |
| $\mu^+\mu^-$                                | ( 7.4 $\pm$ 1.8 ) $\times 10^{-5}$  |                                   | 377               |
| $3\gamma$                                   | < 1.9 $\times 10^{-4}$              | CL=95%                            | 391               |

**Charge conjugation (C) violating modes**

|             |   |                        |        |     |
|-------------|---|------------------------|--------|-----|
| $\eta\pi^0$ | C | < 2.1 $\times 10^{-4}$ | CL=90% | 162 |
| $2\pi^0$    | C | < 2.2 $\times 10^{-4}$ | CL=90% | 367 |
| $3\pi^0$    | C | < 2.3 $\times 10^{-4}$ | CL=90% | 330 |
| invisible   |   | < 7 $\times 10^{-5}$   | CL=90% | –   |

**$\eta'(958)$**

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

Mass  $m = 957.78 \pm 0.06$  MeV

Full width  $\Gamma = 0.188 \pm 0.006$  MeV

| <b><math>\eta'(958)</math> DECAY MODES</b>                     | Fraction ( $\Gamma_i/\Gamma$ )       | Confidence level | $\rho$<br>(MeV/c) |
|--|--------------------------------------|------------------|-------------------|
| $\pi^+\pi^-\eta$   | (42.5 $\pm$ 0.5 ) %                  |                  | 232               |
| $\rho^0\gamma$ (including non-resonant<br>$\pi^+\pi^-\gamma$ ) | (29.5 $\pm$ 0.4 ) %                  |                  | 165               |
| $\pi^0\pi^0\eta$   | (22.4 $\pm$ 0.5 ) %                  |                  | 239               |
| $\omega\gamma$   | ( 2.52 $\pm$ 0.07 ) %                |                  | 159               |
| $\omega e^+e^-$  | ( 2.0 $\pm$ 0.4 ) $\times 10^{-4}$   |                  | 159               |
| $\gamma\gamma$   | ( 2.307 $\pm$ 0.033) %               |                  | 479               |
| $3\pi^0$   | ( 2.50 $\pm$ 0.17 ) $\times 10^{-3}$ |                  | 430               |

|                                      |   |     |     |
|--------------------------------------|---|-----|-----|
| $\mu^+ \mu^- \gamma$                 | $( 1.13 \pm 0.28 ) \times 10^{-4}$  |     | 467 |
| $\pi^+ \pi^- \mu^+ \mu^-$            | $< 2.9 \times 10^{-5}$  | 90% | 401 |
| $\pi^+ \pi^- \pi^0$                  | $( 3.61 \pm 0.17 ) \times 10^{-3}$  |     | 428 |
| $(\pi^+ \pi^- \pi^0)$ S-wave         | $( 3.8 \pm 0.5 ) \times 10^{-3}$  |     | 428 |
| $\pi^\mp \rho^\pm$                   | $( 7.4 \pm 2.3 ) \times 10^{-4}$  |     | 106 |
| $\pi^0 \rho^0$                       | $< 4 \%$  | 90% | 111 |
| $2(\pi^+ \pi^-)$                     | $( 8.4 \pm 0.9 ) \times 10^{-5}$  |     | 372 |
| $\pi^+ \pi^- 2\pi^0$                 | $( 1.8 \pm 0.4 ) \times 10^{-4}$  |     | 376 |
| $2(\pi^+ \pi^-)$ neutrals            | $< 1 \%$  | 95% | –   |
| $2(\pi^+ \pi^-) \pi^0$               | $< 1.8 \times 10^{-3}$  | 90% | 298 |
| $2(\pi^+ \pi^-) 2\pi^0$              | $< 1 \%$  | 95% | 197 |
| $3(\pi^+ \pi^-)$                     | $< 3.1 \times 10^{-5}$  | 90% | 189 |
| $K^\pm \pi^\mp$                      | $< 4 \times 10^{-5}$  | 90% | 334 |
| $\pi^+ \pi^- e^+ e^-$                | $( 2.4 \begin{smallmatrix} +1.3 \\ -1.0 \end{smallmatrix} ) \times 10^{-3}$ |     | 458 |
| $\pi^+ e^- \nu_e + \text{c.c.}$      | $< 2.1 \times 10^{-4}$  | 90% | 469 |
| $\gamma e^+ e^-$                     | $( 4.91 \pm 0.27 ) \times 10^{-4}$  |     | 479 |
| $\pi^0 \gamma \gamma$                | $( 3.20 \pm 0.24 ) \times 10^{-3}$  |     | 469 |
| $\pi^0 \gamma \gamma$ (non resonant) | $( 6.2 \pm 0.9 ) \times 10^{-4}$  |     | –   |
| $\eta \gamma \gamma$                 | $< 1.33 \times 10^{-4}$   | 90% | 322 |
| $4\pi^0$                             | $< 4.94 \times 10^{-5}$   | 90% | 380 |
| $e^+ e^-$                            | $< 5.6 \times 10^{-9}$  | 90% | 479 |
| invisible                            | $< 6 \times 10^{-4}$  | 90% | –   |

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

|                     |         |                        |     |     |
|---------------------|---------|------------------------|-----|-----|
| $\pi^+ \pi^-$       | $P, CP$ | $< 1.8 \times 10^{-5}$ | 90% | 458 |
| $\pi^0 \pi^0$       | $P, CP$ | $< 4 \times 10^{-4}$   | 90% | 459 |
| $\pi^0 e^+ e^-$     | $C$ [g] | $< 1.4 \times 10^{-3}$ | 90% | 469 |
| $\eta e^+ e^-$      | $C$ [g] | $< 2.4 \times 10^{-3}$ | 90% | 322 |
| $3\gamma$           | $C$     | $< 1.0 \times 10^{-4}$ | 90% | 479 |
| $\mu^+ \mu^- \pi^0$ | $C$ [g] | $< 6.0 \times 10^{-5}$ | 90% | 445 |
| $\mu^+ \mu^- \eta$  | $C$ [g] | $< 1.5 \times 10^{-5}$ | 90% | 273 |
| $e\mu$              | $LF$    | $< 4.7 \times 10^{-4}$ | 90% | 473 |

**$f_0(980)$**

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

See the review on "Scalar Mesons below 2 GeV."

Mass  $m = 990 \pm 20$  MeV

Full width  $\Gamma = 10$  to 100 MeV

| <b><math>f_0(980)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|--|--------------------------------|-------------|
| $\pi \pi$                                | seen                           | 476         |
| $K \bar{K}$                              | seen                           | 36          |

**$a_0(980)$** 

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

See the review on "Scalar Mesons below 2 GeV."

 Mass  $m = 980 \pm 20$  MeV

 Full width  $\Gamma = 50$  to 100 MeV

| <b><math>a_0(980)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|--|--------------------------------|-------------|
| $\eta\pi$                                | seen                           | 319         |
| $K\bar{K}$                               | seen                           | †           |
| $\eta'\pi$                               | seen                           | †           |
| $\rho\pi$                                | not seen                       | 137         |
| $\gamma\gamma$                           | seen                           | 490         |

 **$\phi(1020)$** 

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

 Mass  $m = 1019.461 \pm 0.016$  MeV

 Full width  $\Gamma = 4.249 \pm 0.013$  MeV ( $S = 1.1$ )

| <b><math>\phi(1020)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ )                                  | Scale factor/<br>Confidence level | $p$<br>(MeV/c) |
|--|---|-----------------------------------|----------------|
| $K^+K^-$                                   | (49.2 ± 0.5 ) %   | S=1.3                             | 127            |
| $K_L^0 K_S^0$                              | (34.0 ± 0.4 ) %   | S=1.3                             | 110            |
| $\rho\pi + \pi^+\pi^-\pi^0$                | (15.24 ± 0.33 ) %   | S=1.2                             | —              |
| $\eta\gamma$                               | ( 1.303±0.025 ) %   | S=1.2                             | 363            |
| $\pi^0\gamma$                              | ( 1.32 ± 0.06 ) × 10 <sup>-3</sup>                              |                                   | 501            |
| $\ell^+\ell^-$                             | —   |                                   | 510            |
| $e^+e^-$                                   | ( 2.974±0.034 ) × 10 <sup>-4</sup>                              | S=1.3                             | 510            |
| $\mu^+\mu^-$                               | ( 2.86 ± 0.19 ) × 10 <sup>-4</sup>                              |                                   | 499            |
| $\eta e^+e^-$                              | ( 1.08 ± 0.04 ) × 10 <sup>-4</sup>                              |                                   | 363            |
| $\pi^+\pi^-$                               | ( 7.3 ± 1.3 ) × 10 <sup>-5</sup>                                |                                   | 490            |
| $\omega\pi^0$                              | ( 4.7 ± 0.5 ) × 10 <sup>-5</sup>                                |                                   | 171            |
| $\omega\gamma$                             | < 5 %   | CL=84%                            | 209            |
| $\rho\gamma$                               | < 1.2 × 10 <sup>-5</sup>  | CL=90%                            | 215            |
| $\pi^+\pi^-\gamma$                         | ( 4.1 ± 1.3 ) × 10 <sup>-5</sup>                                |                                   | 490            |
| $f_0(980)\gamma$                           | ( 3.22 ± 0.19 ) × 10 <sup>-4</sup>                              | S=1.1                             | 29             |
| $\pi^0\pi^0\gamma$                         | ( 1.12 ± 0.06 ) × 10 <sup>-4</sup>                              |                                   | 492            |
| $\pi^+\pi^-\pi^+\pi^-$                     | ( 3.9 <sup>+2.8</sup> / <sub>-2.2</sub> ) × 10 <sup>-6</sup>    |                                   | 410            |
| $\pi^+\pi^+\pi^-\pi^-\pi^0$                | < 4.6 × 10 <sup>-6</sup>  | CL=90%                            | 342            |
| $\pi^0 e^+e^-$                             | ( 1.33 <sup>+0.07</sup> / <sub>-0.10</sub> ) × 10 <sup>-5</sup> |                                   | 501            |

|                                   |                                    |                         |     |
|-----------------------------------|------------------------------------|-------------------------|-----|
| $\pi^0 \eta \gamma$               | $( 7.27 \pm 0.30 ) \times 10^{-5}$ | $S=1.5$                 | 346 |
| $a_0(980) \gamma$                 | $( 7.6 \pm 0.6 ) \times 10^{-5}$   |                         | 39  |
| $K^0 \bar{K}^0 \gamma$            | $< 1.9$                            | $\times 10^{-8}$ CL=90% | 110 |
| $\eta'(958) \gamma$               | $( 6.22 \pm 0.21 ) \times 10^{-5}$ |                         | 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 |
| $\rho \gamma \gamma$              | $< 1.2$                            | $\times 10^{-4}$ 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 |
| $\eta U \rightarrow \eta e^+ e^-$ | $< 1$                              | $\times 10^{-6}$ CL=90% | —   |
| invisible                         | $< 1.7$                            | $\times 10^{-4}$ CL=90% | —   |

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

|                 |    |       |                         |     |
|-----------------|----|-------|-------------------------|-----|
| $e^\pm \mu^\mp$ | LF | $< 2$ | $\times 10^{-6}$ CL=90% | 504 |
|-----------------|----|-------|-------------------------|-----|

**$h_1(1170)$**

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

Mass  $m = 1166 \pm 6$  MeV  
 Full width  $\Gamma = 375 \pm 35$  MeV

| <b><math>h_1(1170)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|---|--------------------------------|-------------|
| $\rho \pi$                                | seen                           | 305         |

**$b_1(1235)$**

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

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) |
|---|--|------------------|-------------|
| $\omega \pi$                              | seen                                       |                  | 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         |
| $K^*(892)^\pm K^\mp$                      | seen                                       |                  | †           |
| $(K\bar{K})^\pm \pi^0$                    | $< 8$ %                                    | 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         |



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

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

Mass  $m = 1230 \pm 40$  MeV [i]Full width  $\Gamma = 250$  to  $600$  MeV

| <b><math>a_1(1260)</math> DECAY MODES</b>                  | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|--|--------------------------------|-------------|
| $3\pi$   | seen                           | 577         |
| $(\rho\pi)_{S\text{-wave}}, \rho \rightarrow \pi\pi$       | seen                           | 353         |
| $(\rho\pi)_{D\text{-wave}}, \rho \rightarrow \pi\pi$       | seen                           | 353         |
| $(\rho(1450)\pi)_{S\text{-wave}}, \rho \rightarrow \pi\pi$ | seen                           | †           |
| $(\rho(1450)\pi)_{D\text{-wave}}, \rho \rightarrow \pi\pi$ | seen                           | †           |
| $f_0(500)\pi, f_0 \rightarrow \pi\pi$                      | seen                           | —           |
| $f_0(980)\pi, f_0 \rightarrow \pi\pi$                      | not seen                       | 179         |
| $f_0(1370)\pi, f_0 \rightarrow \pi\pi$                     | seen                           | †           |
| $f_2(1270)\pi, f_2 \rightarrow \pi\pi$                     | seen                           | †           |
| $\pi^+\pi^-\pi^0$  | seen                           | 576         |
| $\pi^0\pi^0\pi^0$  | not seen                       | 577         |
| $KK\pi$  | seen                           | 250         |
| $K^*(892)K$  | seen                           | †           |
| $\pi\gamma$  | seen                           | 608         |

 **$f_2(1270)$** 

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

Mass  $m = 1275.5 \pm 0.8$  MeVFull width  $\Gamma = 186.7^{+2.2}_{-2.5}$  MeV ( $S = 1.4$ )

| <b><math>f_2(1270)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ )   | Scale factor/<br>Confidence level | $p$<br>(MeV/c) |
|---|----------------------------------|-----------------------------------|----------------|
| $\pi\pi$                                  | $(84.2^{+2.9}_{-0.9})\%$         | S=1.1                             | 623            |
| $\pi^+\pi^-\pi^0$                         | $(7.7^{+1.1}_{-3.2})\%$          | S=1.2                             | 563            |
| $K\bar{K}$                                | $(4.6^{+0.5}_{-0.4})\%$          | S=2.7                             | 404            |
| $2\pi^+2\pi^-$                            | $(2.8 \pm 0.4)\%$                | S=1.2                             | 560            |
| $\eta\eta$                                | $(4.0 \pm 0.8) \times 10^{-3}$   | S=2.1                             | 326            |
| $4\pi^0$                                  | $(3.0 \pm 1.0) \times 10^{-3}$   |                                   | 565            |
| $\gamma\gamma$                            | $(1.42 \pm 0.24) \times 10^{-5}$ | S=1.4                             | 638            |
| $\eta\pi\pi$                              | $< 8 \times 10^{-3}$             | CL=95%                            | 478            |
| $K^0K^-\pi^+ + \text{c.c.}$               | $< 3.4 \times 10^{-3}$           | CL=95%                            | 293            |
| $e^+e^-$                                  | $< 6 \times 10^{-10}$            | CL=90%                            | 638            |

**$f_1(1285)$**

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

Mass  $m = 1281.9 \pm 0.5$  MeV (S = 1.8)  
 Full width  $\Gamma = 22.7 \pm 1.1$  MeV (S = 1.5)

| <b><math>f_1(1285)</math> DECAY MODES</b>                 | Fraction ( $\Gamma_i/\Gamma$ ) | Scale factor/<br>Confidence level | $p$<br>(MeV/c) |
|---|--------------------------------|-----------------------------------|----------------|
| $4\pi$  | (32.7 ± 1.9) %                 | S=1.2                             | 568            |
| $\pi^0\pi^0\pi^+\pi^-$                                    | (21.8 ± 1.3) %                 | S=1.2                             | 566            |
| $2\pi^+2\pi^-$  | (10.9 ± 0.6) %                 | S=1.2                             | 563            |
| $\rho^0\pi^+\pi^-$  | (10.9 ± 0.6) %                 | S=1.2                             | 336            |
| $\rho^0\rho^0$  | seen                           |                                   | †              |
| $4\pi^0$  | < 7 × 10 <sup>-4</sup>         | CL=90%                            | 568            |
| $\eta\pi^+\pi^-$  | (35 ± 15) %                    |                                   | 479            |
| $\eta\pi\pi$  | (52.2 ± 2.0) %                 | S=1.2                             | 482            |
| $a_0(980)\pi$ [ignoring $a_0(980) \rightarrow K\bar{K}$ ] | (38 ± 4) %                     |                                   | 238            |
| $\eta\pi\pi$ [excluding $a_0(980)\pi$ ]                   | (14 ± 4) %                     |                                   | 482            |
| $K\bar{K}\pi$   | (9.0 ± 0.4) %                  | S=1.1                             | 308            |
| $K\bar{K}^*(892)$   | not seen                       |                                   | †              |
| $\pi^+\pi^-\pi^0$   | (3.0 ± 0.9) × 10 <sup>-3</sup> |                                   | 603            |
| $\rho^\pm\pi^\mp$   | < 3.1 × 10 <sup>-3</sup>       | CL=95%                            | 390            |
| $\gamma\rho^0$  | (6.1 ± 1.0) %                  | S=1.7                             | 406            |
| $\phi\gamma$  | (7.4 ± 2.6) × 10 <sup>-4</sup> |                                   | 236            |
| $e^+e^-$  | < 9.4 × 10 <sup>-9</sup>       | CL=90%                            | 641            |

**$\eta(1295)$**

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

See the review on "Pseudoscalar and pseudovector mesons in the 1400 MeV region."

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                           | 248         |
| $\eta\pi^0\pi^0$                           | seen                           | 490         |
| $\eta(\pi\pi)_{S\text{-wave}}$             | seen                           | —           |

**$\pi(1300)$**

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

Mass  $m = 1300 \pm 100$  MeV [J]  
 Full width  $\Gamma = 200$  to 600 MeV

| $\pi(1300)$ DECAY MODES | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|-------------------------|--------------------------------|-------------|
| $\rho\pi$               | seen                           | 404         |
| $\pi(\pi\pi)$ S-wave    | seen                           | —           |

### $a_2(1320)$

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

Mass  $m = 1318.2 \pm 0.6$  MeV (S = 1.2)

Full width  $\Gamma = 107 \pm 5$  MeV [1]

| $a_2(1320)$ DECAY MODES | Fraction ( $\Gamma_i/\Gamma$ )       | Scale factor/<br>Confidence level | $p$<br>(MeV/c) |
|-------------------------|--------------------------------------|-----------------------------------|----------------|
| $3\pi$                  | (70.1 $\pm$ 2.7 ) %                  | S=1.2                             | 624            |
| $\eta\pi$               | (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            |
| $\eta'(958)\pi$         | ( 5.5 $\pm$ 0.9 ) $\times 10^{-3}$   |                                   | 288            |
| $\pi^\pm\gamma$         | ( 2.91 $\pm$ 0.27 ) $\times 10^{-3}$ |                                   | 652            |
| $\gamma\gamma$          | ( 9.4 $\pm$ 0.7 ) $\times 10^{-6}$   |                                   | 659            |
| $e^+e^-$                | < 5 $\times 10^{-9}$                 | CL=90%                            | 659            |

### $f_0(1370)$

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

See the review on "Scalar Mesons below 2 GeV."

Mass  $m = 1200$  to 1500 MeV

Full width  $\Gamma = 200$  to 500 MeV

| $f_0(1370)$ DECAY MODES | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|-------------------------|--------------------------------|-------------|
| $\pi\pi$                | seen                           | 672         |
| $4\pi$                  | seen                           | 617         |
| $4\pi^0$                | seen                           | 617         |
| $2\pi^+2\pi^-$          | seen                           | 612         |
| $\pi^+\pi^-2\pi^0$      | seen                           | 615         |
| $\rho\rho$              | seen                           | †           |
| $2(\pi\pi)$ S-wave      | seen                           | —           |
| $\pi(1300)\pi$          | seen                           | †           |
| $a_1(1260)\pi$          | seen                           | 35          |
| $\eta\eta$              | seen                           | 411         |
| $K\bar{K}$              | seen                           | 475         |
| $K\bar{K}n\pi$          | not seen                       | †           |
| $6\pi$                  | not seen                       | 508         |
| $\omega\omega$          | not seen                       | †           |

|                |          |     |
|----------------|----------|-----|
| $\gamma\gamma$ | seen     | 685 |
| $e^+e^-$       | not seen | 685 |

 **$\pi_1(1400)$** 

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

See the review on "Non- $q\bar{q}$  Mesons." See also  $\pi_1(1600)$ .

Mass  $m = 1354 \pm 25$  MeV (S = 1.8)

Full width  $\Gamma = 330 \pm 35$  MeV

| <b><math>\pi_1(1400)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|---|--------------------------------|-------------|
| $\eta\pi^0$                                 | seen                           | 557         |
| $\eta\pi^-$                                 | seen                           | 556         |
| $\rho(770)\pi$                              | not seen                       | 442         |

 **$\eta(1405)$** 

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

See the review on "Pseudoscalar and Pseudovector Mesons in the 1400 MeV Region." See also  $\eta(1475)$ .

Mass  $m = 1408.8 \pm 2.0$  MeV (S = 2.2)

Full width  $\Gamma = 50.1 \pm 2.6$  MeV (S = 1.7)

| <b><math>\eta(1405)</math> DECAY MODES</b>  | Fraction ( $\Gamma_i/\Gamma$ ) | Confidence level | $p$ (MeV/c) |
|---|--------------------------------|------------------|-------------|
| $K\bar{K}\pi$                               | seen                           |                  | 424         |
| $\eta\pi\pi$                                | seen                           |                  | 562         |
| $a_0(980)\pi$                               | seen                           |                  | 345         |
| $\eta(\pi\pi)$ S-wave                       | seen                           |                  | —           |
| $f_0(980)\pi^0 \rightarrow \pi^+\pi^-\pi^0$ | not seen                       |                  | —           |
| $f_0(980)\eta$                              | seen                           |                  | †           |
| $4\pi$                                      | seen                           |                  | 639         |
| $\rho\rho$                                  | <58 %                          | 99.85%           | †           |
| $\rho^0\gamma$                              | seen                           |                  | 491         |
| $K^*(892)K$                                 | seen                           |                  | 123         |

 **$h_1(1415)$** 

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

was  $h_1(1380)$

Mass  $m = 1416 \pm 8$  MeV (S = 1.5)

Full width  $\Gamma = 90 \pm 15$  MeV

**$f_1(1420)$** 

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

See the review on "Pseudoscalar and Pseudovector Mesons in the 1400 MeV Region."

$$\text{Mass } m = 1426.3 \pm 0.9 \text{ MeV} \quad (S = 1.1)$$

$$\text{Full width } \Gamma = 54.5 \pm 2.6 \text{ MeV}$$

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

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

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

$$\text{Mass } m = 1410 \pm 60 \text{ MeV} [j]$$

$$\text{Full width } \Gamma = 290 \pm 190 \text{ MeV} [j]$$

| <b><math>\omega(1420)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|--|--------------------------------|-------------|
| $\rho \pi$                                   | seen                           | 480         |
| $\omega \pi \pi$                             | seen                           | 437         |
| $b_1(1235) \pi$                              | seen                           | 112         |
| $e^+ e^-$                                    | seen                           | 705         |

 **$a_0(1450)$** 

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

See the review on "Scalar Mesons below 2 GeV."

$$\text{Mass } m = 1474 \pm 19 \text{ MeV}$$

$$\text{Full width } \Gamma = 265 \pm 13 \text{ MeV}$$

| <b><math>a_0(1450)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|---|--------------------------------|-------------|
| $\pi \eta$                                | $0.093 \pm 0.020$              | 627         |
| $\pi \eta'(958)$                          | $0.033 \pm 0.017$              | 410         |
| $K \bar{K}$                               | $0.082 \pm 0.028$              | 547         |
| $\omega \pi \pi$                          | <b>DEFINED AS 1</b>            | 484         |
| $a_0(980) \pi \pi$                        | seen                           | 342         |
| $\gamma \gamma$                           | seen                           | 737         |

**$\rho(1450)$** 

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

See the note in  $\rho(1450)$  Particle Listings.

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

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

| <b><math>\rho(1450)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|--|--------------------------------|-------------|
| $\pi\pi$                                   | seen                           | 720         |
| $\pi^+\pi^-$                               | seen                           | 719         |
| $4\pi$                                     | seen                           | 669         |
| $e^+e^-$                                   | seen                           | 732         |
| $\eta\rho$                                 | seen                           | 311         |
| $a_2(1320)\pi$                             | not seen                       | 55          |
| $K\bar{K}$                                 | seen                           | 541         |
| $K^+K^-$                                   | seen                           | 541         |
| $K\bar{K}^*(892)+\text{c.c.}$              | possibly seen                  | 229         |
| $\eta\gamma$                               | seen                           | 630         |
| $f_0(500)\gamma$                           | not seen                       | —           |
| $f_0(980)\gamma$                           | not seen                       | 398         |
| $f_0(1370)\gamma$                          | not seen                       | 92          |
| $f_2(1270)\gamma$                          | not seen                       | 177         |

 **$\eta(1475)$** 

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

See the review on "Pseudoscalar and Pseudovector Mesons in the 1400 MeV Region." See also  $\eta(1405)$ .

Mass  $m = 1475 \pm 4$  MeV ( $S = 1.4$ )

Full width  $\Gamma = 90 \pm 9$  MeV ( $S = 1.6$ )

| <b><math>\eta(1475)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|--|--------------------------------|-------------|
| $K\bar{K}\pi$                              | seen                           | 477         |
| $K\bar{K}^*(892)+\text{c.c.}$              | seen                           | 244         |
| $a_0(980)\pi$                              | seen                           | 396         |
| $\gamma\gamma$                             | seen                           | 738         |
| $K_S^0 K_S^0 \eta$                         | possibly seen                  | †           |
| $\gamma\phi(1020)$                         | possibly seen                  | 385         |

**$f_0(1500)$** 

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

See the reviews on "Scalar Mesons below 2 GeV" and on "Non- $q\bar{q}$  Mesons".

$$\text{Mass } m = 1506 \pm 6 \text{ MeV} \quad (S = 1.4)$$

$$\text{Full width } \Gamma = 112 \pm 9 \text{ MeV}$$

| <b><math>f_0(1500)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ ) | Scale factor | $P$<br>(MeV/c) |
|---|--------------------------------|--------------|----------------|
| $\pi\pi$                                  | $(34.5 \pm 2.2) \%$            | 1.2          | 741            |
| $\pi^+\pi^-$                              | seen                           |              | 740            |
| $2\pi^0$                                  | seen                           |              | 741            |
| $4\pi$                                    | $(48.9 \pm 3.3) \%$            | 1.2          | 692            |
| $4\pi^0$                                  | seen                           |              | 692            |
| $2\pi^+2\pi^-$                            | seen                           |              | 687            |
| $2(\pi\pi)_{S\text{-wave}}$               | seen                           |              | —              |
| $\rho\rho$                                | seen                           |              | †              |
| $\pi(1300)\pi$                            | seen                           |              | 145            |
| $a_1(1260)\pi$                            | seen                           |              | 219            |
| $\eta\eta$                                | $(6.0 \pm 0.9) \%$             | 1.1          | 517            |
| $\eta\eta'(958)$                          | $(2.2 \pm 0.8) \%$             | 1.4          | 20             |
| $K\bar{K}$                                | $(8.5 \pm 1.0) \%$             | 1.1          | 569            |
| $\gamma\gamma$                            | not seen                       |              | 753            |

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

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

$$\text{Mass } m = 1517.4 \pm 2.5 \text{ MeV} \quad (S = 2.8)$$

$$\text{Full width } \Gamma = 86 \pm 5 \text{ MeV} \quad (S = 2.2)$$

| <b><math>f'_2(1525)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ ) | Scale factor | $P$<br>(MeV/c) |
|--|--------------------------------|--------------|----------------|
| $K\bar{K}$                                 | $(87.6 \pm 2.2) \%$            | 1.1          | 576            |
| $\eta\eta$                                 | $(11.6 \pm 2.2) \%$            | 1.1          | 525            |
| $\pi\pi$                                   | $(8.3 \pm 1.6) \times 10^{-3}$ |              | 747            |
| $\gamma\gamma$                             | $(9.5 \pm 1.1) \times 10^{-7}$ | 1.1          | 759            |

**$\pi_1(1600)$** 

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

See the review on "Non- $q\bar{q}$  Mesons" and a note in PDG 06, Journal of Physics **G33** 1 (2006). See also  $\pi_1(1400)$ .

$$\text{Mass } m = 1661_{-11}^{+15} \text{ MeV} \quad (S = 1.2)$$

$$\text{Full width } \Gamma = 240 \pm 50 \text{ MeV} \quad (S = 1.7)$$

| <b><math>\pi_1(1600)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|---|--------------------------------|-------------|
| $\pi\pi\pi$                                 | seen                           | 803         |
| $\rho^0\pi^-$                               | seen                           | 641         |
| $f_2(1270)\pi^-$                            | not seen                       | 318         |
| $b_1(1235)\pi$                              | seen                           | 357         |
| $\eta'(958)\pi^-$                           | seen                           | 543         |
| $f_1(1285)\pi$                              | seen                           | 314         |

 **$a_1(1640)$** 

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

$$\text{Mass } m = 1655 \pm 16 \text{ MeV} \quad (S = 1.2)$$

$$\text{Full width } \Gamma = 254 \pm 40 \text{ MeV} \quad (S = 1.8)$$

| <b><math>a_1(1640)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|---|--------------------------------|-------------|
| $\pi\pi\pi$                               | seen                           | 800         |
| $f_2(1270)\pi$                            | seen                           | 314         |
| $\sigma\pi$                               | seen                           | —           |
| $\rho\pi$ <i>S-wave</i>                   | seen                           | 638         |
| $\rho\pi$ <i>D-wave</i>                   | seen                           | 638         |
| $\omega\pi\pi$                            | seen                           | 607         |
| $f_1(1285)\pi$                            | seen                           | 309         |
| $a_1(1260)\eta$                           | not seen                       | †           |

 **$\eta_2(1645)$** 

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

$$\text{Mass } m = 1617 \pm 5 \text{ MeV}$$

$$\text{Full width } \Gamma = 181 \pm 11 \text{ MeV}$$

| <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     | 499 |
| $f_2(1270)\eta$  | not seen | †   |

 **$\omega(1650)$  [1]**

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

 Mass  $m = 1670 \pm 30$  MeV [1]

 Full width  $\Gamma = 315 \pm 35$  MeV [1]

| <b><math>\omega(1650)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|--|--------------------------------|-------------|
| $\rho\pi$                                    | seen                           | 647         |
| $\rho(1450)\pi$                              | seen                           | 145         |
| $\omega\pi\pi$                               | seen                           | 617         |
| $\omega\eta$                                 | seen                           | 500         |
| $e^+e^-$                                     | seen                           | 835         |
| $\pi^0\gamma$                                | not seen                       | 830         |

 **$\omega_3(1670)$** 

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

 Mass  $m = 1667 \pm 4$  MeV

 Full width  $\Gamma = 168 \pm 10$  MeV

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

 **$\pi_2(1670)$** 

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

 Mass  $m = 1670.6^{+2.9}_{-1.2}$  MeV ( $S = 1.3$ )

 Full width  $\Gamma = 258^{+8}_{-9}$  MeV ( $S = 1.2$ )

| <b><math>\pi_2(1670)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ ) | Confidence level | $p$ (MeV/c) |
|---|--------------------------------|------------------|-------------|
| $3\pi$                                      | (95.8±1.4) %                   |                  | 808         |
| $f_2(1270)\pi$                              | (56.3±3.2) %                   |                  | 327         |
| $\rho\pi$                                   | (31 ±4 ) %                     |                  | 647         |
| $\sigma\pi$                                 | (10 ±4 ) %                     |                  | –           |
| $\pi(\pi\pi)_{S\text{-wave}}$               | ( 8.7±3.4) %                   |                  | –           |
| $\pi^\pm\pi^+\pi^-$                         | (53 ±4 ) %                     |                  | 806         |
| $K\bar{K}^*(892)+\text{c.c.}$               | ( 4.2±1.4) %                   |                  | 453         |

|                         |                                |       |     |
|-------------------------|--------------------------------|-------|-----|
| $\omega\rho$            | $(2.7 \pm 1.1)\%$              |       | 302 |
| $\pi^\pm\gamma$         | $(7.0 \pm 1.2) \times 10^{-4}$ |       | 829 |
| $\gamma\gamma$          | $< 2.8 \times 10^{-7}$         | 90%   | 835 |
| $\eta\pi$               | $< 5\%$                        |       | 739 |
| $\pi^\pm 2\pi^+ 2\pi^-$ | $< 5\%$                        |       | 735 |
| $\rho(1450)\pi$         | $< 3.6 \times 10^{-3}$         | 97.7% | 145 |
| $b_1(1235)\pi$          | $< 1.9 \times 10^{-3}$         | 97.7% | 364 |
| $f_1(1285)\pi$          | possibly seen                  |       | 322 |
| $a_2(1320)\pi$          | not seen                       |       | 291 |

### $\phi(1680)$

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

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

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

| $\phi(1680)$ DECAY MODES        | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|---------------------------------|--------------------------------|-------------|
| $K\bar{K}^*(892) + \text{c.c.}$ | seen                           | 462         |
| $K_S^0 K\pi$                    | seen                           | 621         |
| $K\bar{K}$                      | seen                           | 680         |
| $e^+e^-$                        | seen                           | 840         |
| $\omega\pi\pi$                  | not seen                       | 623         |
| $K^+K^-\pi^+\pi^-$              | seen                           | 544         |
| $\eta\phi$                      | seen                           | 290         |
| $\eta\gamma$                    | seen                           | 751         |

### $\rho_3(1690)$

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

Mass  $m = 1688.8 \pm 2.1$  MeV

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

| $\rho_3(1690)$ DECAY MODES | 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         |
| $a_2(1320)\pi$             | seen                           |              | 307         |
| $\rho\rho$                 | seen                           |              | 335         |

**$\rho(1700)$** 

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

See the note in  $\rho(1700)$  Particle Listings.Mass  $m = 1720 \pm 20$  MeV [ $J$ ] ( $\eta\rho^0$  and  $\pi^+\pi^-$  modes)Full width  $\Gamma = 250 \pm 100$  MeV [ $J$ ] ( $\eta\rho^0$  and  $\pi^+\pi^-$  modes)

| <b><math>\rho(1700)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|--|--------------------------------|-------------|
| $2(\pi^+\pi^-)$                            | seen                           | 803         |
| $\rho\pi\pi$                               | seen                           | 653         |
| $\rho^0\pi^+\pi^-$                         | seen                           | 651         |
| $\rho^\pm\pi^\mp\pi^0$                     | seen                           | 652         |
| $a_1(1260)\pi$                             | seen                           | 404         |
| $h_1(1170)\pi$                             | seen                           | 450         |
| $\pi(1300)\pi$                             | seen                           | 349         |
| $\rho\rho$                                 | seen                           | 372         |
| $\pi^+\pi^-$                               | seen                           | 849         |
| $\pi\pi$                                   | seen                           | 849         |
| $K\bar{K}^*(892) + \text{c.c.}$            | seen                           | 496         |
| $\eta\rho$                                 | seen                           | 545         |
| $a_2(1320)\pi$                             | not seen                       | 334         |
| $K\bar{K}$                                 | seen                           | 704         |
| $e^+e^-$                                   | seen                           | 860         |
| $\pi^0\omega$                              | seen                           | 674         |
| $\pi^0\gamma$                              | not seen                       | 855         |

 **$a_2(1700)$** 

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

Mass  $m = 1698 \pm 40$  MeVFull width  $\Gamma = 265 \pm 60$  MeV

| <b><math>a_2(1700)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ )   | $p$ (MeV/c) |
|---|----------------------------------|-------------|
| $\eta\pi$                                 | $(3.6 \pm 1.1) \%$               | 754         |
| $\gamma\gamma$                            | $(1.13 \pm 0.30) \times 10^{-6}$ | 849         |
| $\rho\pi$                                 | seen                             | 664         |
| $f_2(1270)\pi$                            | seen                             | 350         |
| $K\bar{K}$                                | $(1.9 \pm 1.2) \%$               | 691         |
| $\omega\pi^-\pi^0$                        | seen                             | 634         |
| $\omega\rho$                              | seen                             | 338         |

**$f_0(1710)$** 

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

See the review on "Non- $q\bar{q}$  Mesons."Mass  $m = 1704 \pm 12$  MeVFull width  $\Gamma = 123 \pm 18$  MeV

| <b><math>f_0(1710)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|---|--------------------------------|-------------|
| $K\bar{K}$                                | seen                           | 694         |
| $\eta\eta$                                | seen                           | 652         |
| $\pi\pi$                                  | seen                           | 841         |
| $\gamma\gamma$                            | seen                           | 852         |
| $\omega\omega$                            | seen                           | 337         |

 **$\pi(1800)$** 

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

Mass  $m = 1810^{+9}_{-11}$  MeV ( $S = 2.2$ )Full width  $\Gamma = 215^{+7}_{-8}$  MeV

| <b><math>\pi(1800)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|---|--------------------------------|-------------|
| $\pi^+\pi^-\pi^-$                         | seen                           | 878         |
| $f_0(500)\pi^-$                           | seen                           | —           |
| $f_0(980)\pi^-$                           | seen                           | 624         |
| $f_0(1370)\pi^-$                          | seen                           | 366         |
| $f_0(1500)\pi^-$                          | not seen                       | 247         |
| $\rho\pi^-$                               | not seen                       | 731         |
| $\eta\eta\pi^-$                           | seen                           | 660         |
| $a_0(980)\eta$                            | seen                           | 471         |
| $a_2(1320)\eta$                           | not seen                       | †           |
| $f_2(1270)\pi$                            | not seen                       | 441         |
| $f_0(1370)\pi^-$                          | not seen                       | 366         |
| $f_0(1500)\pi^-$                          | seen                           | 247         |
| $\eta\eta'(958)\pi^-$                     | seen                           | 373         |
| $K_0^*(1430)K^-$                          | seen                           | †           |
| $K^*(892)K^-$                             | not seen                       | 568         |

 **$\phi_3(1850)$** 

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

Mass  $m = 1854 \pm 7$  MeVFull width  $\Gamma = 87^{+28}_{-23}$  MeV ( $S = 1.2$ )

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

 **$\eta_2(1870)$** 

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

Mass  $m = 1842 \pm 8$  MeVFull width  $\Gamma = 225 \pm 14$  MeV

| $\eta_2(1870)$ DECAY MODES | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|----------------------------|--------------------------------|-------------|
| $\gamma\gamma$             | seen                           | 921         |

 **$\pi_2(1880)$** 

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

Mass  $m = 1874^{+26}_{-5}$  MeV ( $S = 1.6$ )Full width  $\Gamma = 237^{+33}_{-30}$  MeV ( $S = 1.2$ ) **$f_2(1950)$** 

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

Mass  $m = 1936 \pm 12$  MeV ( $S = 1.3$ )Full width  $\Gamma = 464 \pm 24$  MeV

| $f_2(1950)$ DECAY MODES  | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|--------------------------|--------------------------------|-------------|
| $K^*(892)\bar{K}^*(892)$ | seen                           | 377         |
| $\pi^+\pi^-$             | seen                           | 958         |
| $\pi^0\pi^0$             | seen                           | 959         |
| $4\pi$                   | seen                           | 921         |
| $\eta\eta$               | seen                           | 798         |
| $K\bar{K}$               | seen                           | 833         |
| $\gamma\gamma$           | seen                           | 968         |
| $p\bar{p}$               | seen                           | 238         |

 **$a_4(1970)$** 

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

was  $a_4(2040)$ Mass  $m = 1967 \pm 16$  MeV ( $S = 2.1$ )Full width  $\Gamma = 324^{+15}_{-18}$  MeV

| <b><math>a_4(1970)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|---|--------------------------------|-------------|
| $K\bar{K}$                                | seen                           | 851         |
| $\pi^+\pi^-\pi^0$                         | seen                           | 959         |
| $\rho\pi$                                 | seen                           | 825         |
| $f_2(1270)\pi$                            | seen                           | 559         |
| $\omega\pi^-\pi^0$                        | seen                           | 801         |
| $\omega\rho$                              | seen                           | 601         |
| $\eta\pi$                                 | seen                           | 902         |
| $\eta'(958)\pi$                           | seen                           | 743         |

**$f_2(2010)$**

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

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

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

| <b><math>f_2(2010)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|---|--------------------------------|-------------|
| $\phi\phi$                                | seen                           | †           |
| $K\bar{K}$                                | seen                           | 876         |

**$f_4(2050)$**

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

Mass  $m = 2018 \pm 11$  MeV ( $S = 2.1$ )

Full width  $\Gamma = 237 \pm 18$  MeV ( $S = 1.9$ )

| <b><math>f_4(2050)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ )       | $p$ (MeV/c) |
|---|--------------------------------------|-------------|
| $\omega\omega$                            | seen                                 | 637         |
| $\pi\pi$                                  | $(17.0 \pm 1.5)\%$                   | 1000        |
| $K\bar{K}$                                | $(6.8^{+3.4}_{-1.8}) \times 10^{-3}$ | 880         |
| $\eta\eta$                                | $(2.1 \pm 0.8) \times 10^{-3}$       | 848         |
| $4\pi^0$                                  | $< 1.2\%$                            | 964         |
| $a_2(1320)\pi$                            | seen                                 | 567         |

**$\phi(2170)$**

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

Mass  $m = 2159 \pm 17$  MeV [ $j$ ] ( $S = 1.4$ )

Full width  $\Gamma = 137 \pm 16$  MeV [ $j$ ]

| $\phi(2170)$ DECAY MODES                                | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|---|--------------------------------|-------------|
| $e^+ e^-$   | seen                           | 1080        |
| $\phi f_0(980)$   | seen                           | 395         |
| $K^+ K^- f_0(980) \rightarrow$<br>$K^+ K^- \pi^+ \pi^-$ | seen                           | —           |
| $K^+ K^- f_0(980) \rightarrow K^+ K^- \pi^0 \pi^0$      | seen                           | —           |
| $K^{*0} K^\pm \pi^\mp$                                  | not seen                       | 759         |
| $K^*(892)^0 \bar{K}^*(892)^0$                           | not seen                       | 609         |

## $f_2(2300)$

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

Mass  $m = 2297 \pm 28$  MeV

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

| $f_2(2300)$ DECAY MODES | 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  $m = 2345^{+50}_{-40}$  MeV

Full width  $\Gamma = 322^{+70}_{-60}$  MeV

| $f_2(2340)$ DECAY MODES | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|-------------------------|--------------------------------|-------------|
| $\phi\phi$              | seen                           | 580         |
| $\eta\eta$              | seen                           | 1037        |

# 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 [ $n$ ] ( $S = 2.8$ )

Mean life  $\tau = (1.2380 \pm 0.0020) \times 10^{-8}$  s ( $S = 1.8$ )

$c\tau = 3.711$  m

**CPT violation parameters ( $\Delta = \text{rate difference/sum}$ )**

$$\Delta(K^\pm \rightarrow \mu^\pm \nu_\mu) = (-0.27 \pm 0.21)\%$$

$$\Delta(K^\pm \rightarrow \pi^\pm \pi^0) = (0.4 \pm 0.6)\% \text{ [o]}$$

**CP violation parameters ( $\Delta = \text{rate difference/sum}$ )**

$$\Delta(K^\pm \rightarrow \pi^\pm e^+ e^-) = (-2.2 \pm 1.6) \times 10^{-2}$$

$$\Delta(K^\pm \rightarrow \pi^\pm \mu^+ \mu^-) = 0.010 \pm 0.023$$

$$\Delta(K^\pm \rightarrow \pi^\pm \pi^0 \gamma) = (0.0 \pm 1.2) \times 10^{-3}$$

$$\Delta(K^\pm \rightarrow \pi^\pm \pi^+ \pi^-) = (0.04 \pm 0.06)\%$$

$$\Delta(K^\pm \rightarrow \pi^\pm \pi^0 \pi^0) = (-0.02 \pm 0.28)\%$$

**T violation parameters**

$$K^+ \rightarrow \pi^0 \mu^+ \nu_\mu \quad P_T = (-1.7 \pm 2.5) \times 10^{-3}$$

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

$$K^+ \rightarrow \pi^0 \mu^+ \nu_\mu \quad \text{Im}(\xi) = -0.006 \pm 0.008$$

**Slope parameter  $g$  [p]**

(See Particle Listings for quadratic coefficients and alternative parametrization related to  $\pi\pi$  scattering)

$$K^\pm \rightarrow \pi^\pm \pi^+ \pi^- \quad g = -0.21134 \pm 0.00017$$

$$(g_+ - g_-) / (g_+ + g_-) = (-1.5 \pm 2.2) \times 10^{-4}$$

$$K^\pm \rightarrow \pi^\pm \pi^0 \pi^0 \quad g = 0.626 \pm 0.007$$

$$(g_+ - g_-) / (g_+ + g_-) = (1.8 \pm 1.8) \times 10^{-4}$$

 **$K^\pm$  decay form factors [a,q]**

Assuming  $\mu$ - $e$  universality

$$\lambda_+(K_{\mu 3}^+) = \lambda_+(K_{e 3}^+) = (2.959 \pm 0.025) \times 10^{-2}$$

$$\lambda_0(K_{\mu 3}^+) = (1.76 \pm 0.25) \times 10^{-2} \quad (S = 2.7)$$

Not assuming  $\mu$ - $e$  universality

$$\lambda_+(K_{e 3}^+) = (2.956 \pm 0.025) \times 10^{-2}$$

$$\lambda_+(K_{\mu 3}^+) = (3.09 \pm 0.25) \times 10^{-2} \quad (S = 1.5)$$

$$\lambda_0(K_{\mu 3}^+) = (1.73 \pm 0.27) \times 10^{-2} \quad (S = 2.6)$$

$K_{e 3}$  form factor quadratic fit

$$\lambda'_+(K_{e 3}^\pm) \text{ linear coeff.} = (2.59 \pm 0.04) \times 10^{-2}$$

$$\lambda''_+(K_{e 3}^\pm) \text{ quadratic coeff.} = (0.186 \pm 0.021) \times 10^{-2}$$

$$\lambda'_+(K_{\mu 3}^\pm) \text{ (LINEAR FORM FACTOR FROM QUADRATIC FIT)}$$

$$= (24 \pm 4) \times 10^{-3}$$



$$\lambda''_+ \text{ (QUADRATIC } K_{\mu 3}^\pm \text{ FORM FACTOR)} = (1.8 \pm 1.5) \times 10^{-3}$$

$$M_V \text{ (VECTOR POLE MASS FOR } K_{e3}^\pm \text{ DECAY)} = 890.3 \pm 2.8 \text{ MeV}$$

$$M_V \text{ (VECTOR POLE MASS FOR } K_{\mu 3}^\pm \text{ DECAY)} = 878 \pm 12 \text{ MeV}$$

$$M_S \text{ (SCALAR POLE MASS FOR } K_{\mu 3}^\pm \text{ DECAY)} = 1215 \pm 50 \text{ MeV}$$

$$\Lambda_+ \text{ (DISPERSIVE VECTOR FORM FACTOR IN } K_{e3}^\pm \text{ DECAY)} = (2.460 \pm 0.017) \times 10^{-2}$$

$$\Lambda_+ \text{ (DISPERSIVE VECTOR FORM FACTOR IN } K_{\mu 3}^\pm \text{ DECAY)} = (25.4 \pm 0.9) \times 10^{-3}$$

$$\ln(C) \text{ (DISPERSIVE SCALAR FORM FACTOR IN } K_{\mu 3}^\pm \text{ decays)} = (182 \pm 16) \times 10^{-3}$$

$$K_{e3}^+ \quad |f_S/f_+| = (-0.08^{+0.34}_{-0.40}) \times 10^{-2}$$

$$K_{e3}^+ \quad |f_T/f_+| = (-1.2^{+1.3}_{-1.1}) \times 10^{-2}$$

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

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

$$K^+ \rightarrow e^+ \nu_e \gamma \quad |F_A + F_V| = 0.133 \pm 0.008 \quad (S = 1.3)$$

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

$$K^+ \rightarrow e^+ \nu_e \gamma \quad |F_A - F_V| < 0.49, \text{ CL} = 90\%$$

$$K^+ \rightarrow \mu^+ \nu_\mu \gamma \quad |F_A - F_V| = -0.153 \pm 0.033 \quad (S = 1.1)$$

### Charge radius

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

### Forward-backward asymmetry

$$A_{FB}(K_{\pi\mu\mu}^\pm) = \frac{\Gamma(\cos(\theta_{K\mu}) > 0) - \Gamma(\cos(\theta_{K\mu}) < 0)}{\Gamma(\cos(\theta_{K\mu}) > 0) + \Gamma(\cos(\theta_{K\mu}) < 0)} < 2.3 \times 10^{-2}, \text{ CL} = 90\%$$

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

| <b><math>K^+</math> DECAY MODES</b>    | Fraction ( $\Gamma_i/\Gamma$ )     | Scale factor/<br>Confidence level (MeV/c) | $p$ |
|--|------------------------------------|---|-----|
| <b>Leptonic and semileptonic modes</b> |                                    |   |     |
| $e^+ \nu_e$                            | $(1.582 \pm 0.007) \times 10^{-5}$ |   | 247 |
| $\mu^+ \nu_\mu$                        | $(63.56 \pm 0.11) \%$              | S=1.2                                     | 236 |
| $\pi^0 e^+ \nu_e$                      | $(5.07 \pm 0.04) \%$               | S=2.1                                     | 228 |
| Called $K_{e3}^+$ .                    |                                    |   |     |
| $\pi^0 \mu^+ \nu_\mu$                  | $(3.352 \pm 0.033) \%$             | S=1.9                                     | 215 |
| Called $K_{\mu 3}^+$ .                 |                                    |   |     |
| $\pi^0 \pi^0 e^+ \nu_e$                | $(2.55 \pm 0.04) \times 10^{-5}$   | S=1.1                                     | 206 |

|                               |   |                   |                         |     |
|-------------------------------|---|-------------------|-------------------------|-----|
| $\pi^+ \pi^- e^+ \nu_e$       | ( | $4.247 \pm 0.024$ | ) $\times 10^{-5}$      | 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

|                     |   |                   |     |       |     |
|---------------------|---|-------------------|-----|-------|-----|
| $\pi^+ \pi^0$       | ( | $20.67 \pm 0.08$  | ) % | S=1.2 | 205 |
| $\pi^+ \pi^0 \pi^0$ | ( | $1.760 \pm 0.023$ | ) % | S=1.1 | 133 |
| $\pi^+ \pi^+ \pi^-$ | ( | $5.583 \pm 0.024$ | ) % |       | 125 |

### Leptonic and semileptonic modes with photons

|  |       |               |                         |                         |     |
|--|-------|---------------|-------------------------|-------------------------|-----|
| $\mu^+ \nu_\mu \gamma$                   | [r,s] | (             | $6.2 \pm 0.8$           | ) $\times 10^{-3}$      | 236 |
| $\mu^+ \nu_\mu \gamma (SD^+)$            | [a,t] | (             | $1.33 \pm 0.22$         | ) $\times 10^{-5}$      | —   |
| $\mu^+ \nu_\mu \gamma (SD^+ INT)$        | [a,t] | <             | 2.7                     | $\times 10^{-5}$ CL=90% | —   |
| $\mu^+ \nu_\mu \gamma (SD^- + SD^- INT)$ | [a,t] | <             | 2.6                     | $\times 10^{-4}$ CL=90% | —   |
| $e^+ \nu_e \gamma$                       | (     | $9.4 \pm 0.4$ | ) $\times 10^{-6}$      | 247                     |     |
| $\pi^0 e^+ \nu_e \gamma$                 | [r,s] | (             | $2.56 \pm 0.16$         | ) $\times 10^{-4}$      | 228 |
| $\pi^0 e^+ \nu_e \gamma (SD)$            | [a,t] | <             | 5.3                     | $\times 10^{-5}$ CL=90% | 228 |
| $\pi^0 \mu^+ \nu_\mu \gamma$             | [r,s] | (             | $1.25 \pm 0.25$         | ) $\times 10^{-5}$      | 215 |
| $\pi^0 \pi^0 e^+ \nu_e \gamma$           | <     | 5             | $\times 10^{-6}$ CL=90% | 206                     |     |

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

|                            |       |                 |                         |                         |     |
|----------------------------|-------|-----------------|-------------------------|-------------------------|-----|
| $\pi^+ \pi^0 \gamma (INT)$ | (     | $-4.2 \pm 0.9$  | ) $\times 10^{-6}$      | —                       |     |
| $\pi^+ \pi^0 \gamma (DE)$  | [r,u] | (               | $6.0 \pm 0.4$           | ) $\times 10^{-6}$      | 205 |
| $\pi^+ \pi^0 e^+ e^-$      | (     | $4.24 \pm 0.14$ | ) $\times 10^{-6}$      | 205                     |     |
| $\pi^+ \pi^0 \pi^0 \gamma$ | [r,s] | (               | $7.6 \pm_{-3.0}^{+6.0}$ | ) $\times 10^{-6}$      | 133 |
| $\pi^+ \pi^+ \pi^- \gamma$ | [r,s] | (               | $7.1 \pm 0.5$           | ) $\times 10^{-6}$      | 125 |
| $\pi^+ \gamma \gamma$      | [r]   | (               | $1.01 \pm 0.06$         | ) $\times 10^{-6}$      | 227 |
| $\pi^+ 3\gamma$            | [r]   | <               | 1.0                     | $\times 10^{-4}$ CL=90% | 227 |
| $\pi^+ e^+ e^- \gamma$     | (     | $1.19 \pm 0.13$ | ) $\times 10^{-8}$      | 227                     |     |

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

|                               |   |                 |                         |     |
|-------------------------------|---|-----------------|-------------------------|-----|
| $e^+ \nu_e \nu \bar{\nu}$     | < | 6               | $\times 10^{-5}$ CL=90% | 247 |
| $\mu^+ \nu_\mu \nu \bar{\nu}$ | < | 2.4             | $\times 10^{-6}$ 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 |
| $e^+ \nu_e \mu^+ \mu^-$       | ( | $1.7 \pm 0.5$   | ) $\times 10^{-8}$      | 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 | < | 1.3             | $\times 10^{-8}$ CL=90%  | 203 |
| $\pi^+ \pi^+ \mu^- \bar{\nu}_\mu$ | SQ | < | 3.0             | $\times 10^{-6}$ CL=95%  | 151 |
| $\pi^+ e^+ e^-$                   | S1 | ( | $3.00 \pm 0.09$ | ) $\times 10^{-7}$       | 227 |
| $\pi^+ \mu^+ \mu^-$               | S1 | ( | $9.4 \pm 0.6$   | ) $\times 10^{-8}$ S=2.6 | 172 |

|                             |               |  |            |
|-----------------------------|---------------|--|------------|
| $\pi^+ \nu \bar{\nu}$       | <i>SI</i>     | $( 8 \begin{smallmatrix} +6 \\ -4 \end{smallmatrix} ) \times 10^{-11}$ | 227        |
| $\pi^+ \pi^0 \nu \bar{\nu}$ | <i>SI</i>     | $< 4.3 \times 10^{-5}$   | CL=90% 205 |
| $\mu^- \nu e^+ e^+$         | <i>LF</i>     | $< 2.1 \times 10^{-8}$   | CL=90% 236 |
| $\mu^+ \nu_e$               | <i>LF</i> [d] | $< 4 \times 10^{-3}$   | CL=90% 236 |
| $\pi^+ \mu^+ e^-$           | <i>LF</i>     | $< 1.3 \times 10^{-11}$  | CL=90% 214 |
| $\pi^+ \mu^- e^+$           | <i>LF</i>     | $< 5.2 \times 10^{-10}$  | CL=90% 214 |
| $\pi^- \mu^+ e^+$           | <i>L</i>      | $< 5.0 \times 10^{-10}$  | CL=90% 214 |
| $\pi^- e^+ e^+$             | <i>L</i>      | $< 2.2 \times 10^{-10}$  | CL=90% 227 |
| $\pi^- \mu^+ \mu^+$         | <i>L</i>      | $< 4.2 \times 10^{-11}$  | CL=90% 172 |
| $\mu^+ \bar{\nu}_e$         | <i>L</i> [d]  | $< 3.3 \times 10^{-3}$   | CL=90% 236 |
| $\pi^0 e^+ \bar{\nu}_e$     | <i>L</i>      | $< 3 \times 10^{-3}$   | CL=90% 228 |
| $\pi^+ \gamma$              | [v]           | $< 2.3 \times 10^{-9}$   | CL=90% 227 |

**$K^0$**

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

50%  $K_S$ , 50%  $K_L$

$$\text{Mass } m = 497.611 \pm 0.013 \text{ MeV} \quad (S = 1.2)$$

$$m_{K^0} - m_{K^\pm} = 3.934 \pm 0.020 \text{ MeV} \quad (S = 1.6)$$

#### Mean square charge radius

$$\langle r^2 \rangle = -0.077 \pm 0.010 \text{ fm}^2$$

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

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

#### *CP*-violation parameters

$$\text{Re}(\epsilon) = (1.596 \pm 0.013) \times 10^{-3}$$

#### *CPT*-violation parameters [q]

$$\text{Re } \delta = (2.5 \pm 2.3) \times 10^{-4}$$

$$\text{Im } \delta = (-1.5 \pm 1.6) \times 10^{-5}$$

$$\text{Re}(y), K_{e3} \text{ parameter} = (0.4 \pm 2.5) \times 10^{-3}$$

$$\text{Re}(x_-), K_{e3} \text{ parameter} = (-2.9 \pm 2.0) \times 10^{-3}$$

$$|m_{K^0} - m_{\bar{K}^0}| / m_{\text{average}} < 6 \times 10^{-19}, \text{ CL} = 90\% \text{ [x]}$$

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

#### Tests of $\Delta S = \Delta Q$

$$\text{Re}(x_+), K_{e3} \text{ parameter} = (-0.9 \pm 3.0) \times 10^{-3}$$



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

Mean life  $\tau = (0.8954 \pm 0.0004) \times 10^{-10}$  s (S = 1.1) Assuming *CPT*

Mean life  $\tau = (0.89564 \pm 0.00033) \times 10^{-10}$  s Not assuming *CPT*

$c\tau = 2.6844$  cm Assuming *CPT*

**CP-violation parameters** [ $\chi$ ]

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

$$\text{Im}(\eta_{000}) = -0.001 \pm 0.016$$

$$|\eta_{000}| = |A(K_S^0 \rightarrow 3\pi^0)/A(K_L^0 \rightarrow 3\pi^0)| < 0.0088, \text{ CL} = 90\%$$

$$\text{CP asymmetry } A \text{ in } \pi^+ \pi^- e^+ e^- = (-0.4 \pm 0.8)\%$$

| $K_S^0$ DECAY MODES  | Fraction ( $\Gamma_i/\Gamma$ )   | Scale factor/<br>Confidence level | $p$<br>(MeV/c) |
|--|--|-----------------------------------|----------------|
| <b>Hadronic modes</b>  |  |                                   |                |
| $\pi^0 \pi^0$  | $(30.69 \pm 0.05) \%$  |                                   | 209            |
| $\pi^+ \pi^-$  | $(69.20 \pm 0.05) \%$  |                                   | 206            |
| $\pi^+ \pi^- \pi^0$  | $(3.5 \begin{smallmatrix} +1.1 \\ -0.9 \end{smallmatrix}) \times 10^{-7}$        |                                   | 133            |
| <b>Modes with photons or <math>\ell\bar{\ell}</math> pairs</b>                         |  |                                   |                |
| $\pi^+ \pi^- \gamma$   | [s,z] $(1.79 \pm 0.05) \times 10^{-3}$   |                                   | 206            |
| $\pi^+ \pi^- e^+ e^-$  | $(4.79 \pm 0.15) \times 10^{-5}$   |                                   | 206            |
| $\pi^0 \gamma \gamma$  | [z] $(4.9 \pm 1.8) \times 10^{-8}$   |                                   | 230            |
| $\gamma \gamma$  | $(2.63 \pm 0.17) \times 10^{-6}$   | S=3.1                             | 249            |
| <b>Semileptonic modes</b>  |  |                                   |                |
| $\pi^\pm e^\mp \nu_e$  | [aa] $(7.04 \pm 0.08) \times 10^{-4}$  |                                   | 229            |
| <b>CP violating (CP) and <math>\Delta S = 1</math> weak neutral current (S1) modes</b> |  |                                   |                |
| $3\pi^0$   | CP $< 2.6 \times 10^{-8}$  | CL=90%                            | 139            |
| $\mu^+ \mu^-$  | S1 $< 2.1 \times 10^{-10}$   | CL=90%                            | 225            |
| $e^+ e^-$  | S1 $< 9 \times 10^{-9}$  | CL=90%                            | 249            |
| $\pi^0 e^+ e^-$  | S1 [z] $(3.0 \begin{smallmatrix} +1.5 \\ -1.2 \end{smallmatrix}) \times 10^{-9}$ |                                   | 230            |
| $\pi^0 \mu^+ \mu^-$  | S1 $(2.9 \begin{smallmatrix} +1.5 \\ -1.2 \end{smallmatrix}) \times 10^{-9}$     |                                   | 177            |



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

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

$$= (0.5293 \pm 0.0009) \times 10^{10} \hbar s^{-1} \quad (S = 1.3) \quad \text{Assuming } CPT$$

$$= (3.484 \pm 0.006) \times 10^{-12} \text{ MeV} \quad \text{Assuming } CPT$$

$$= (0.5289 \pm 0.0010) \times 10^{10} \hbar s^{-1} \quad \text{Not assuming } CPT$$

$$\text{Mean life } \tau = (5.116 \pm 0.021) \times 10^{-8} \text{ s} \quad (S = 1.1)$$

$$c\tau = 15.34 \text{ m}$$

### Slope parameters [p]

(See Particle Listings for other linear and quadratic coefficients)

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

$$K_S^0 \rightarrow \pi^+ \pi^- \pi^0: h = 0.076 \pm 0.006$$

$$K_S^0 \rightarrow \pi^+ \pi^- \pi^0: k = 0.0099 \pm 0.0015$$

$$K_L^0 \rightarrow \pi^0 \pi^0 \pi^0: h = (0.6 \pm 1.2) \times 10^{-3}$$

### $K_L$ decay form factors [q]

Linear parametrization assuming  $\mu$ -e universality

$$\lambda_+(K_{\mu 3}^0) = \lambda_+(K_{e 3}^0) = (2.82 \pm 0.04) \times 10^{-2} \quad (S = 1.1)$$

$$\lambda_0(K_{\mu 3}^0) = (1.38 \pm 0.18) \times 10^{-2} \quad (S = 2.2)$$

Quadratic parametrization assuming  $\mu$ -e universality

$$\lambda'_+(K_{\mu 3}^0) = \lambda'_+(K_{e 3}^0) = (2.40 \pm 0.12) \times 10^{-2} \quad (S = 1.2)$$

$$\lambda''_+(K_{\mu 3}^0) = \lambda''_+(K_{e 3}^0) = (0.20 \pm 0.05) \times 10^{-2} \quad (S = 1.2)$$

$$\lambda_0(K_{\mu 3}^0) = (1.16 \pm 0.09) \times 10^{-2} \quad (S = 1.2)$$

Pole parametrization assuming  $\mu$ -e universality

$$M_V^\mu(K_{\mu 3}^0) = M_V^e(K_{e 3}^0) = 878 \pm 6 \text{ MeV} \quad (S = 1.1)$$

$$M_S^\mu(K_{\mu 3}^0) = 1252 \pm 90 \text{ MeV} \quad (S = 2.6)$$

Dispersive parametrization assuming  $\mu$ -e universality

$$\Lambda_+ = (2.51 \pm 0.06) \times 10^{-2} \quad (S = 1.5)$$

$$\ln(C) = (1.75 \pm 0.18) \times 10^{-1} \quad (S = 2.0)$$

$$K_{e 3}^0 \quad |f_S/f_+| = (1.5_{-1.6}^{+1.4}) \times 10^{-2}$$

$$K_{e 3}^0 \quad |f_T/f_+| = (5_{-5}^{+4}) \times 10^{-2}$$

$$K_{\mu 3}^0 \quad |f_T/f_+| = (12 \pm 12) \times 10^{-2}$$

$$K_L \rightarrow \ell^+ \ell^- \gamma, K_L \rightarrow \ell^+ \ell^- \ell'^+ \ell'^-: \alpha_{K^*} = -0.205 \pm 0.022 \quad (S = 1.8)$$

$$K_L^0 \rightarrow \ell^+ \ell^- \gamma, K_L^0 \rightarrow \ell^+ \ell^- \ell'^+ \ell'^-: \alpha_{DIP} = -1.69 \pm 0.08 \quad (S = 1.7)$$

$$K_L \rightarrow \pi^+ \pi^- e^+ e^-: a_1/a_2 = -0.737 \pm 0.014 \text{ GeV}^2$$

$$K_L \rightarrow \pi^0 2\gamma: a_V = -0.43 \pm 0.06 \quad (S = 1.5)$$

**CP-violation parameters** [ $\nu$ ]

$$A_L = (0.332 \pm 0.006)\%$$

$$|\eta_{00}| = (2.220 \pm 0.011) \times 10^{-3} \quad (S = 1.8)$$

$$|\eta_{+-}| = (2.232 \pm 0.011) \times 10^{-3} \quad (S = 1.8)$$

$$|\epsilon| = (2.228 \pm 0.011) \times 10^{-3} \quad (S = 1.8)$$

$$|\eta_{00}/\eta_{+-}| = 0.9950 \pm 0.0007 \text{ [}bb\text{]} \quad (S = 1.6)$$

$$\text{Re}(\epsilon'/\epsilon) = (1.66 \pm 0.23) \times 10^{-3} \text{ [}bb\text{]} \quad (S = 1.6)$$

Assuming *CPT*

$$\phi_{+-} = (43.51 \pm 0.05)^\circ \quad (S = 1.2)$$

$$\phi_{00} = (43.52 \pm 0.05)^\circ \quad (S = 1.3)$$

$$\phi_\epsilon = \phi_{SW} = (43.52 \pm 0.05)^\circ \quad (S = 1.2)$$

$$\text{Im}(\epsilon'/\epsilon) = -(\phi_{00} - \phi_{+-})/3 = (-0.002 \pm 0.005)^\circ \quad (S = 1.7)$$

Not assuming *CPT*

$$\phi_{+-} = (43.4 \pm 0.5)^\circ \quad (S = 1.2)$$

$$\phi_{00} = (43.7 \pm 0.6)^\circ \quad (S = 1.2)$$

$$\phi_\epsilon = (43.5 \pm 0.5)^\circ \quad (S = 1.3)$$

$$\text{CP asymmetry } A \text{ in } K_L^0 \rightarrow \pi^+ \pi^- e^+ e^- = (13.7 \pm 1.5)\%$$

$$\beta_{CP} \text{ from } K_L^0 \rightarrow e^+ e^- e^+ e^- = -0.19 \pm 0.07$$

$$\gamma_{CP} \text{ from } K_L^0 \rightarrow e^+ e^- e^+ e^- = 0.01 \pm 0.11 \quad (S = 1.6)$$

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

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

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

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

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

$$|g_{E1}| \text{ for } K_L^0 \rightarrow \pi^+ \pi^- \gamma < 0.21, \text{ CL} = 90\%$$

**T-violation parameters**

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

**CPT invariance tests**

$$\phi_{00} - \phi_{+-} = (0.34 \pm 0.32)^\circ$$

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

**$\Delta S = -\Delta Q$  in  $K_{l3}^0$  decay**

Re  $x = -0.002 \pm 0.006$

Im  $x = 0.0012 \pm 0.0021$

| <b><math>K_L^0</math> DECAY MODES</b>  | Fraction ( $\Gamma_i/\Gamma$ )                  | Scale factor/<br>Confidence level (MeV/c) | $p$ |
|--|---|---|-----|
| <b>Semileptonic modes</b>  |   |   |     |
| $\pi^\pm e^\mp \nu_e$<br>Called $K_{e3}^0$ .   | [aa] (40.55 $\pm$ 0.11 ) %                      | S=1.7                                     | 229 |
| $\pi^\pm \mu^\mp \nu_\mu$<br>Called $K_{\mu3}^0$ .   | [aa] (27.04 $\pm$ 0.07 ) %                      | S=1.1                                     | 216 |
| $(\pi \mu \text{atom}) \nu$  | ( 1.05 $\pm$ 0.11 ) $\times 10^{-7}$            |   | 188 |
| $\pi^0 \pi^\pm e^\mp \nu$  | [aa] ( 5.20 $\pm$ 0.11 ) $\times 10^{-5}$       |   | 207 |
| $\pi^\pm e^\mp \nu e^+ e^-$  | [aa] ( 1.26 $\pm$ 0.04 ) $\times 10^{-5}$       |   | 229 |
| <b>Hadronic modes, including Charge conjugation <math>\times</math> Parity Violating (CPV) modes</b>   |   |   |     |
| $3\pi^0$   | (19.52 $\pm$ 0.12 ) %                           | S=1.6                                     | 139 |
| $\pi^+ \pi^- \pi^0$  | (12.54 $\pm$ 0.05 ) %                           |   | 133 |
| $\pi^+ \pi^-$  | CPV [cc] ( 1.967 $\pm$ 0.010 ) $\times 10^{-3}$ | S=1.5                                     | 206 |
| $\pi^0 \pi^0$  | CPV ( 8.64 $\pm$ 0.06 ) $\times 10^{-4}$        | S=1.8                                     | 209 |
| <b>Semileptonic modes with photons</b>   |   |   |     |
| $\pi^\pm e^\mp \nu_e \gamma$   | [s,aa,dd] ( 3.79 $\pm$ 0.06 ) $\times 10^{-3}$  |   | 229 |
| $\pi^\pm \mu^\mp \nu_\mu \gamma$   | ( 5.65 $\pm$ 0.23 ) $\times 10^{-4}$            |   | 216 |
| <b>Hadronic modes with photons or <math>l\bar{l}</math> pairs</b>  |   |   |     |
| $\pi^0 \pi^0 \gamma$   | < 2.43 $\times 10^{-7}$                         | CL=90%                                    | 209 |
| $\pi^+ \pi^- \gamma$   | [s,dd] ( 4.15 $\pm$ 0.15 ) $\times 10^{-5}$     | S=2.8                                     | 206 |
| $\pi^+ \pi^- \gamma$ (DE)  | ( 2.84 $\pm$ 0.11 ) $\times 10^{-5}$            | S=2.0                                     | 206 |
| $\pi^0 2\gamma$  | [dd] ( 1.273 $\pm$ 0.033 ) $\times 10^{-6}$     |   | 230 |
| $\pi^0 \gamma e^+ e^-$   | ( 1.62 $\pm$ 0.17 ) $\times 10^{-8}$            |   | 230 |
| <b>Other modes with photons or <math>l\bar{l}</math> pairs</b>   |   |   |     |
| $2\gamma$  | ( 5.47 $\pm$ 0.04 ) $\times 10^{-4}$            | S=1.1                                     | 249 |
| $3\gamma$  | < 7.4 $\times 10^{-8}$                          | CL=90%                                    | 249 |
| $e^+ e^- \gamma$   | ( 9.4 $\pm$ 0.4 ) $\times 10^{-6}$              | S=2.0                                     | 249 |
| $\mu^+ \mu^- \gamma$   | ( 3.59 $\pm$ 0.11 ) $\times 10^{-7}$            | S=1.3                                     | 225 |
| $e^+ e^- \gamma \gamma$  | [dd] ( 5.95 $\pm$ 0.33 ) $\times 10^{-7}$       |   | 249 |
| $\mu^+ \mu^- \gamma \gamma$  | [dd] ( 1.0 $^{+0.8}_{-0.6}$ ) $\times 10^{-8}$  |   | 225 |
| <b>Charge conjugation <math>\times</math> Parity (CP) or Lepton Family number (LF) violating modes, or <math>\Delta S = 1</math> weak neutral current (S1) modes</b> |   |   |     |
| $\mu^+ \mu^-$  | S1 ( 6.84 $\pm$ 0.11 ) $\times 10^{-9}$         |   | 225 |
| $e^+ e^-$  | S1 ( 9 $^{+6}_{-4}$ ) $\times 10^{-12}$         |   | 249 |

|                             |         |        |                                  |                   |            |
|-----------------------------|---------|--------|----------------------------------|-------------------|------------|
| $\pi^+\pi^-\mu^+\mu^-$      | $S1$    | $[dd]$ | $(3.11 \pm 0.19) \times 10^{-7}$ |                   | 206        |
| $\pi^0\pi^0e^+e^-$          | $S1$    |        | $< 6.6$                          | $\times 10^{-9}$  | CL=90% 209 |
| $\pi^0\pi^0\mu^+\mu^-$      | $S1$    |        | $< 9.2$                          | $\times 10^{-11}$ | CL=90% 57  |
| $\mu^+\mu^-e^+e^-$          | $S1$    |        | $(2.69 \pm 0.27) \times 10^{-9}$ |                   | 225        |
| $e^+e^-e^+e^-$              | $S1$    |        | $(3.56 \pm 0.21) \times 10^{-8}$ |                   | 249        |
| $\pi^0\mu^+\mu^-$           | $CP,S1$ | $[ee]$ | $< 3.8$                          | $\times 10^{-10}$ | CL=90% 177 |
| $\pi^0e^+e^-$               | $CP,S1$ | $[ee]$ | $< 2.8$                          | $\times 10^{-10}$ | CL=90% 230 |
| $\pi^0\nu\bar{\nu}$         | $CP,S1$ | $[ff]$ | $< 3.0$                          | $\times 10^{-9}$  | CL=90% 230 |
| $\pi^0\pi^0\nu\bar{\nu}$    | $S1$    |        | $< 8.1$                          | $\times 10^{-7}$  | CL=90% 209 |
| $e^\pm\mu^\mp$              | $LF$    | $[aa]$ | $< 4.7$                          | $\times 10^{-12}$ | CL=90% 238 |
| $e^\pm e^\pm\mu^\mp\mu^\mp$ | $LF$    | $[aa]$ | $< 4.12$                         | $\times 10^{-11}$ | CL=90% 225 |
| $\pi^0\mu^\pm e^\mp$        | $LF$    | $[aa]$ | $< 7.6$                          | $\times 10^{-11}$ | CL=90% 217 |
| $\pi^0\pi^0\mu^\pm e^\mp$   | $LF$    |        | $< 1.7$                          | $\times 10^{-10}$ | CL=90% 159 |

**Lorentz invariance violating modes**

|               |  |  |         |                  |            |
|---------------|--|--|---------|------------------|------------|
| $\pi^0\gamma$ |  |  | $< 1.7$ | $\times 10^{-7}$ | CL=90% 230 |
|---------------|--|--|---------|------------------|------------|

**$K_0^*(700)$**

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

also known as  $\kappa$ ; was  $K_0^*(800)$

Mass (T-Matrix Pole  $\sqrt{s}$ ) =  $(630-730) - i(260-340)$  MeV

Mass (Breit-Wigner) =  $845 \pm 17$  MeV

Full width (Breit-Wigner) =  $468 \pm 30$  MeV

| <b><math>K_0^*(700)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|--|--------------------------------|-------------|
| $K\pi$                                     | 100 %                          | 256         |

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

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

Mass (T-Matrix Pole  $\sqrt{s}$ ) =  $(890 \pm 14) - i(26 \pm 6)$  MeV

$K^*(892)^\pm$  hadroproduced mass  $m = 891.67 \pm 0.26$  MeV

$K^*(892)^\pm$  in  $\tau$  decays mass  $m = 895.5 \pm 0.8$  MeV

$K^*(892)^0$  mass  $m = 895.55 \pm 0.20$  MeV ( $S = 1.7$ )

$K^*(892)^\pm$  hadroproduced full width  $\Gamma = 51.4 \pm 0.8$  MeV

$K^*(892)^\pm$  in  $\tau$  decays full width  $\Gamma = 46.2 \pm 1.3$  MeV

$K^*(892)^0$  full width  $\Gamma = 47.3 \pm 0.5$  MeV ( $S = 1.9$ )

| <b><math>K^*(892)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ )   | Confidence level | $p$ (MeV/c) |
|--|----------------------------------|------------------|-------------|
| $K\pi$                                   | $\sim 100$                       | %                | 289         |
| $K^0\gamma$                              | $(2.46 \pm 0.21) \times 10^{-3}$ |                  | 307         |



|                |                                  |     |     |
|----------------|----------------------------------|-----|-----|
| $K^\pm \gamma$ | $( 9.8 \pm 0.9 ) \times 10^{-4}$ |     | 309 |
| $K \pi \pi$    | $< 7 \times 10^{-4}$             | 95% | 223 |

 **$K_1(1270)$** 

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

Mass  $m = 1253 \pm 7$  MeV [1] (S = 2.2)Full width  $\Gamma = 90 \pm 20$  MeV [1]

| <b><math>K_1(1270)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|---|--------------------------------|-------------|
| $K \rho$                                  | $(42 \pm 6) \%$                | †           |
| $K_0^*(1430)\pi$                          | $(28 \pm 4) \%$                | †           |
| $K^*(892)\pi$                             | $(16 \pm 5) \%$                | 286         |
| $K \omega$                                | $(11.0 \pm 2.0) \%$            | †           |
| $K f_0(1370)$                             | $( 3.0 \pm 2.0) \%$            | †           |
| $\gamma K^0$                              | seen                           | 528         |

 **$K_1(1400)$** 

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

Mass  $m = 1403 \pm 7$  MeVFull 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         |
| $K \rho$                                  | $( 3.0 \pm 3.0) \%$            | 293         |
| $K f_0(1370)$                             | $( 2.0 \pm 2.0) \%$            | †           |
| $K \omega$                                | $( 1.0 \pm 1.0) \%$            | 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         |
| $K \pi$                                   | $( 6.6 \pm 1.3) \%$            |                  | 612         |
| $K \rho$                                  | $< 7 \%$                       | 95%              | 305         |
| $\gamma K^0$                              | $< 2.3 \times 10^{-4}$         | 90%              | 619         |

**$K_0^*(1430)$** 

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

Mass  $m = 1425 \pm 50$  MeVFull width  $\Gamma = 270 \pm 80$  MeV

| <b><math>K_0^*(1430)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|---|--------------------------------|-------------|
| $K\pi$                                      | (93 $\pm$ 10) %                | 619         |
| $K\eta$                                     | ( 8.6 $^{+2.7}_{-3.4}$ ) %     | 486         |
| $K\eta'(958)$                               | seen                           | †           |

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

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

 $K_2^*(1430)^\pm$  mass  $m = 1427.3 \pm 1.5$  MeV (S = 1.3) $K_2^*(1430)^0$  mass  $m = 1432.4 \pm 1.3$  MeV $K_2^*(1430)^\pm$  full width  $\Gamma = 100.0 \pm 2.1$  MeV $K_2^*(1430)^0$  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/<br>Confidence level | $p$<br>(MeV/c) |
|---|---|-----------------------------------|----------------|
| $K\pi$                                      | (49.9 $\pm$ 1.2) %                        |                                   | 620            |
| $K^*(892)\pi$                               | (24.7 $\pm$ 1.5) %                        |                                   | 420            |
| $K^*(892)\pi\pi$                            | (13.4 $\pm$ 2.2) %                        |                                   | 373            |
| $K\rho$                                     | ( 8.7 $\pm$ 0.8) %                        | S=1.2                             | 320            |
| $K\omega$                                   | ( 2.9 $\pm$ 0.8) %                        |                                   | 313            |
| $K^+\gamma$                                 | ( 2.4 $\pm$ 0.5) $\times 10^{-3}$         | S=1.1                             | 628            |
| $K\eta$                                     | ( 1.5 $^{+3.4}_{-1.0}$ ) $\times 10^{-3}$ | S=1.3                             | 488            |
| $K\omega\pi$                                | < 7.2 $\times 10^{-4}$                    | CL=95%                            | 106            |
| $K^0\gamma$                                 | < 9 $\times 10^{-4}$                      | CL=90%                            | 627            |

 **$K(1460)$** 

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

| <b><math>K(1460)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|---|--------------------------------|-------------|
| $K^*(892)\pi$                           | seen                           | —           |
| $K\rho$                                 | seen                           | —           |
| $K_0^*(1430)\pi$                        | seen                           | —           |

**$K_1(1650)$**

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

Mass  $m = 1672 \pm 50$  MeV (S = 1.1)  
 Full width  $\Gamma = 158 \pm 50$  MeV

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

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

Mass  $m = 1718 \pm 18$  MeV  
 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) |
|---|--------------------------------|-------------|
| $K\pi$                                    | $(38.7 \pm 2.5) \%$            | 782         |
| $K\rho$                                   | $(31.4^{+5.0}_{-2.1}) \%$      | 571         |
| $K^*(892)\pi$                             | $(29.9^{+2.2}_{-5.0}) \%$      | 618         |
| $K\phi$                                   | seen                           | 387         |
| $K\eta$                                   | $(1.4^{+1.0}_{-0.8}) \%$       | 683         |

**$K_2(1770)$  [gg]**

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

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         |
| $K_2^*(1430)\pi$                          | seen                           | 287         |
| $K^*(892)\pi$                             | 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  $m = 1779 \pm 8$  MeV (S = 1.2)  
 Full width  $\Gamma = 161 \pm 17$  MeV (S = 1.1)

| <b><math>K_3^*(1780)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ ) | Confidence level | $p$ (MeV/c) |
|---|--------------------------------|------------------|-------------|
| $K\rho$                                     | $(31 \pm 9) \%$                |                  | 616         |
| $K^*(892)\pi$                               | $(20 \pm 5) \%$                |                  | 657         |

|                  |                     |         |
|------------------|---------------------|---------|
| $K\pi$           | $(18.8 \pm 1.0) \%$ | 815     |
| $K\eta$          | $(30 \pm 13) \%$    | 721     |
| $K_2^*(1430)\pi$ | $< 16 \%$           | 95% 292 |

**$K_2(1820)$  [gg]**

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

Mass  $m = 1819 \pm 12$  MeV

Full width  $\Gamma = 264 \pm 34$  MeV

| <b><math>K_2(1820)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|---|--------------------------------|-------------|
| $K_2^*(1430)\pi$                          | seen                           | 328         |
| $K^*(892)\pi$                             | seen                           | 683         |
| $K f_2(1270)$                             | seen                           | 191         |
| $K\omega$                                 | seen                           | 640         |
| $K\phi$                                   | seen                           | 483         |

**$K_2^*(1980)$**

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

Mass  $m = 1995^{+60}_{-50}$  MeV ( $S = 2.8$ )

Full width  $\Gamma = 349^{+50}_{-30}$  MeV ( $S = 1.3$ )

| <b><math>K_2^*(1980)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|---|--------------------------------|-------------|
| $K^*(892)\pi$                               | possibly seen                  | 791         |
| $K\rho$                                     | possibly seen                  | 762         |
| $K f_2(1270)$                               | possibly seen                  | 424         |
| $K\phi$                                     | seen                           | 627         |
| $K\eta$                                     | seen                           | 850         |

**$K_4^*(2045)$**

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

Mass  $m = 2048^{+8}_{-9}$  MeV ( $S = 1.1$ )

Full width  $\Gamma = 199^{+27}_{-19}$  MeV

| <b><math>K_4^*(2045)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|---|--------------------------------|-------------|
| $K\pi$                                      | $(9.9 \pm 1.2) \%$             | 960         |
| $K^*(892)\pi\pi$                            | $(9 \pm 5) \%$                 | 804         |
| $K^*(892)\pi\pi\pi$                         | $(7 \pm 5) \%$                 | 770         |
| $\rho K\pi$                                 | $(5.7 \pm 3.2) \%$             | 744         |
| $\omega K\pi$                               | $(5.0 \pm 3.0) \%$             | 740         |

|                 |                    |     |
|-----------------|--------------------|-----|
| $\phi K \pi$    | $(2.8 \pm 1.4) \%$ | 597 |
| $\phi K^*(892)$ | $(1.4 \pm 0.7) \%$ | 368 |

## 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  $m = 1869.66 \pm 0.05$  MeV

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

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

### c-quark decays

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

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

### CP-violation decay-rate asymmetries

$$A_{CP}(\mu^\pm \nu) = (8 \pm 8)\%$$

$$A_{CP}(K_L^0 e^\pm \nu) = (-0.6 \pm 1.6)\%$$

$$A_{CP}(K_S^0 \pi^\pm) = (-0.41 \pm 0.09)\%$$

$$A_{CP}(K_L^0 K^\pm) \text{ in } D^\pm \rightarrow K_L^0 K^\pm = (-4.2 \pm 3.4) \times 10^{-2}$$

$$A_{CP}(K^\mp 2\pi^\pm) = (-0.18 \pm 0.16)\%$$

$$A_{CP}(K^\mp \pi^\pm \pi^\pm \pi^0) = (-0.3 \pm 0.7)\%$$

$$A_{CP}(K_S^0 \pi^\pm \pi^0) = (-0.1 \pm 0.7)\%$$

$$A_{CP}(K_S^0 \pi^\pm \eta) \text{ in } D^\pm \rightarrow K_S^0 \pi^\pm \eta = (-0.9 \pm 3.1) \times 10^{-2}$$

$$A_{CP}(K_S^0 \pi^\pm \pi^+ \pi^-) = (0.0 \pm 1.2)\%$$

$$A_{CP}(K^\pm \pi^+ \pi^- \pi^0) \text{ in } D^\pm \rightarrow K^\pm \pi^+ \pi^- \pi^0 = -0.04 \pm 0.06$$

$$A_{CP}(\pi^\pm \pi^0) = (2.4 \pm 1.2)\%$$

$$A_{CP}(\pi^\pm \eta) = (1.0 \pm 1.5)\% \quad (S = 1.4)$$

$$A_{CP}(\pi^\pm \eta'(958)) = (-0.6 \pm 0.7)\%$$

$$A_{CP}(\bar{K}^0 / K^0 K^\pm) = (0.11 \pm 0.17)\%$$

$$A_{CP}(K_S^0 K^\pm) = (-0.01 \pm 0.07)\%$$

$$A_{CP}(K_S^0 K^\pm \pi^0) \text{ in } D^\pm \rightarrow K_S^0 K^\pm \pi^0 = (1 \pm 4) \times 10^{-2}$$

$$A_{CP}(K_L^0 K^\pm \pi^0) \text{ in } D^\pm \rightarrow K_L^0 K^\pm \pi^0 = (-1 \pm 4) \times 10^{-2}$$

$$A_{CP}(K^+ K^- \pi^\pm) = (0.37 \pm 0.29)\%$$

$$A_{CP}(K^\pm K^{*0}) = (-0.3 \pm 0.4)\%$$

$$A_{CP}(\phi \pi^\pm) = (0.01 \pm 0.09)\% \quad (S = 1.8)$$

$$A_{CP}(K^\pm K_0^*(1430)^0) = (8_{-6}^{+7})\%$$

$$A_{CP}(K^\pm K_2^*(1430)^0) = (43_{-26}^{+20})\%$$

$$\begin{aligned}
 A_{CP}(K^\pm K_0^*(700)) &= (-12^{+18}_{-13})\% \\
 A_{CP}(a_0(1450)^0 \pi^\pm) &= (-19^{+14}_{-16})\% \\
 A_{CP}(\phi(1680) \pi^\pm) &= (-9 \pm 26)\% \\
 A_{CP}(\pi^+ \pi^- \pi^\pm) &= (-2 \pm 4)\% \\
 A_{CP}(\pi^+ \pi^- \pi^\pm \eta) \text{ in } D^\pm &\rightarrow \pi^+ \pi^- \pi^\pm \eta = (3 \pm 5) \times 10^{-2} \\
 A_{CP}(K_S^0 K^\pm \pi^+ \pi^-) &= (-4 \pm 7)\% \\
 A_{CP}(K^\pm \pi^0) &= (-4 \pm 11)\%
 \end{aligned}$$

### $\chi^2$ tests of CP-violation (CPV)

$$\begin{aligned}
 \text{Local CPV in } D^\pm &\rightarrow \pi^+ \pi^- \pi^\pm = 78.1\% \\
 \text{Local CPV in } D^\pm &\rightarrow K^+ K^- \pi^\pm = 31\%
 \end{aligned}$$

### CP violating asymmetries of P-odd (T-odd) moments

$$A_T(K_S^0 K^\pm \pi^+ \pi^-) = (-12 \pm 11) \times 10^{-3} [ii]$$

### $D^+$ form factors

$$\begin{aligned}
 f_+(0) |V_{cs}| \text{ in } \bar{K}^0 \ell^+ \nu_\ell &= 0.719 \pm 0.011 \quad (S = 1.6) \\
 r_1 \equiv a_1/a_0 \text{ in } \bar{K}^0 \ell^+ \nu_\ell &= -2.13 \pm 0.14 \\
 r_2 \equiv a_2/a_0 \text{ in } \bar{K}^0 \ell^+ \nu_\ell &= -3 \pm 12 \quad (S = 1.5) \\
 f_+(0) |V_{cd}| \text{ in } \pi^0 \ell^+ \nu_\ell &= 0.1407 \pm 0.0025 \\
 r_1 \equiv a_1/a_0 \text{ in } \pi^0 \ell^+ \nu_\ell &= -2.00 \pm 0.13 \\
 r_2 \equiv a_2/a_0 \text{ in } \pi^0 \ell^+ \nu_\ell &= -4 \pm 5 \\
 f_+(0) |V_{cd}| \text{ in } D^+ \rightarrow \eta \ell^+ \nu_\ell \ (\ell = e \text{ or } \nu) &= (8.4 \pm 0.4) \times 10^{-2} \\
 r_1 \equiv a_1/a_0 \text{ in } D^+ \rightarrow \eta e^+ \nu_e &= -5.3 \pm 2.7 \quad (S = 1.9) \\
 r_v \equiv V(0)/A_1(0) \text{ in } D^+ \rightarrow \omega e^+ \nu_e &= 1.24 \pm 0.11 \\
 r_2 \equiv A_2(0)/A_1(0) \text{ in } D^+ \rightarrow \omega e^+ \nu_e &= 1.06 \pm 0.16 \\
 r_v \equiv V(0)/A_1(0) \text{ in } D^+, D^0 \rightarrow \rho e^+ \nu_e &= 1.64 \pm 0.10 \quad (S = 1.2) \\
 r_2 \equiv A_2(0)/A_1(0) \text{ in } D^+, D^0 \rightarrow \rho e^+ \nu_e &= 0.84 \pm 0.06 \\
 r_v \equiv V(0)/A_1(0) \text{ in } \bar{K}^*(892)^0 \ell^+ \nu_\ell &= 1.49 \pm 0.05 \quad (S = 2.1) \\
 r_2 \equiv A_2(0)/A_1(0) \text{ in } \bar{K}^*(892)^0 \ell^+ \nu_\ell &= 0.802 \pm 0.021 \\
 r_3 \equiv A_3(0)/A_1(0) \text{ in } \bar{K}^*(892)^0 \ell^+ \nu_\ell &= 0.0 \pm 0.4 \\
 \Gamma_L/\Gamma_T \text{ in } \bar{K}^*(892)^0 \ell^+ \nu_\ell &= 1.13 \pm 0.08 \\
 \Gamma_+/\Gamma_- \text{ in } \bar{K}^*(892)^0 \ell^+ \nu_\ell &= 0.22 \pm 0.06 \quad (S = 1.6)
 \end{aligned}$$

Most decay modes (other than the semileptonic modes) that involve a neutral  $K$  meson are now given as  $K_S^0$  modes, not as  $\bar{K}^0$  modes. Nearly always it is a  $K_S^0$  that is measured, and interference between Cabibbo-allowed and doubly Cabibbo-suppressed modes can invalidate the assumption that  $2\Gamma(K_S^0) = \Gamma(\bar{K}^0)$ .

| $D^+$ DECAY MODES | Fraction ( $\Gamma_i/\Gamma$ ) | Scale factor/<br>Confidence level | $p$<br>(MeV/c) |
|-------------------|--------------------------------|-----------------------------------|----------------|
|-------------------|--------------------------------|-----------------------------------|----------------|

| <b>Inclusive modes</b> |                       |  |   |
|------------------------|-----------------------|--|---|
| $e^+$ semileptonic     | (16.07 $\pm$ 0.30 ) % |  | — |

|                                       |                       |          |
|---------------------------------------|-----------------------|----------|
| $\mu^+$ anything                      | (17.6 $\pm$ 3.2 ) %   | —        |
| $K^-$ anything                        | (25.7 $\pm$ 1.4 ) %   | —        |
| $\bar{K}^0$ anything + $K^0$ anything | (61 $\pm$ 5 ) %       | —        |
| $K^+$ anything                        | ( 5.9 $\pm$ 0.8 ) %   | —        |
| $K^*(892)^-$ anything                 | ( 6 $\pm$ 5 ) %       | —        |
| $\bar{K}^*(892)^0$ anything           | (23 $\pm$ 5 ) %       | —        |
| $K^*(892)^0$ anything                 | < 6.6 %               | CL=90% — |
| $\eta$ anything                       | ( 6.3 $\pm$ 0.7 ) %   | —        |
| $\eta'$ anything                      | ( 1.04 $\pm$ 0.18 ) % | —        |
| $\phi$ anything                       | ( 1.12 $\pm$ 0.04 ) % | —        |

### Leptonic and semileptonic modes

|   |                       |                         |     |
|---|-----------------------|-------------------------|-----|
| $e^+ \nu_e$   | < 8.8                 | $\times 10^{-6}$ CL=90% | 935 |
| $\gamma e^+ \nu_e$  | < 3.0                 | $\times 10^{-5}$ CL=90% | 935 |
| $\mu^+ \nu_\mu$   | ( 3.74 $\pm$ 0.17 )   | $\times 10^{-4}$        | 932 |
| $\tau^+ \nu_\tau$   | ( 1.20 $\pm$ 0.27 )   | $\times 10^{-3}$        | 90  |
| $\bar{K}^0 e^+ \nu_e$   | ( 8.73 $\pm$ 0.10 ) % |                         | 869 |
| $\bar{K}^0 \mu^+ \nu_\mu$   | ( 8.76 $\pm$ 0.19 ) % |                         | 865 |
| $K^- \pi^+ e^+ \nu_e$   | ( 4.02 $\pm$ 0.18 ) % | S=3.2                   | 864 |
| $\bar{K}^*(892)^0 e^+ \nu_e, \bar{K}^*(892)^0 \rightarrow$<br>$K^- \pi^+$       | ( 3.77 $\pm$ 0.17 ) % |                         | 722 |
| $(K^- \pi^+) [0.8-1.0] \text{GeV} e^+ \nu_e$                                    | ( 3.39 $\pm$ 0.09 ) % |                         | 864 |
| $(K^- \pi^+)_{S\text{-wave}} e^+ \nu_e$   | ( 2.28 $\pm$ 0.11 )   | $\times 10^{-3}$        | —   |
| $\bar{K}^*(1410)^0 e^+ \nu_e,$<br>$\bar{K}^*(1410)^0 \rightarrow K^- \pi^+$     | < 6                   | $\times 10^{-3}$ CL=90% | —   |
| $\bar{K}_2^*(1430)^0 e^+ \nu_e,$<br>$\bar{K}_2^*(1430)^0 \rightarrow K^- \pi^+$ | < 5                   | $\times 10^{-4}$ CL=90% | —   |
| $K^- \pi^+ e^+ \nu_e$ nonresonant   | < 7                   | $\times 10^{-3}$ CL=90% | 864 |
| $\bar{K}^*(892)^0 e^+ \nu_e$  | ( 5.40 $\pm$ 0.10 ) % | S=1.1                   | 722 |
| $K^- \pi^+ \mu^+ \nu_\mu$   | ( 3.65 $\pm$ 0.34 ) % |                         | 851 |
| $\bar{K}^*(892)^0 \mu^+ \nu_\mu,$<br>$\bar{K}^*(892)^0 \rightarrow K^- \pi^+$   | ( 3.52 $\pm$ 0.10 ) % |                         | 717 |
| $K^- \pi^+ \mu^+ \nu_\mu$ nonresonant   | ( 1.9 $\pm$ 0.5 )     | $\times 10^{-3}$        | 851 |
| $\bar{K}^*(892)^0 \mu^+ \nu_\mu$  | ( 5.27 $\pm$ 0.15 ) % |                         | 717 |
| $K^- \pi^+ \pi^0 \mu^+ \nu_\mu$   | < 1.5                 | $\times 10^{-3}$ CL=90% | 825 |
| $\bar{K}_1(1270)^0 e^+ \nu_e, \bar{K}_1^0 \rightarrow$<br>$K^- \pi^+ \pi^0$     | ( 1.06 $\pm$ 0.15 )   | $\times 10^{-3}$        | —   |
| $\bar{K}_0^*(1430)^0 \mu^+ \nu_\mu$   | < 2.3                 | $\times 10^{-4}$ CL=90% | 380 |
| $\bar{K}^*(1680)^0 \mu^+ \nu_\mu$   | < 1.5                 | $\times 10^{-3}$ CL=90% | 105 |
| $\pi^0 e^+ \nu_e$   | ( 3.72 $\pm$ 0.17 )   | $\times 10^{-3}$ S=2.0  | 930 |
| $\pi^0 \mu^+ \nu_\mu$   | ( 3.50 $\pm$ 0.15 )   | $\times 10^{-3}$        | 927 |
| $\eta e^+ \nu_e$  | ( 1.11 $\pm$ 0.07 )   | $\times 10^{-3}$        | 855 |
| $\eta \mu^+ \nu_\mu$  | ( 1.04 $\pm$ 0.11 )   | $\times 10^{-3}$        | 851 |

|   |   |     |
|---|---|-----|
| $\pi^- \pi^+ e^+ \nu_e$   | $( 2.45 \pm 0.10 ) \times 10^{-3}$            | 924 |
| $f_0(500)^0 e^+ \nu_e, f_0(500)^0 \rightarrow$<br>$\pi^+ \pi^-$ | $( 6.3 \pm 0.5 ) \times 10^{-4}$              | —   |
| $\rho^0 e^+ \nu_e$  | $( 2.18 \pm_{-0.25}^{+0.17} ) \times 10^{-3}$ | 774 |
| $\rho^0 \mu^+ \nu_\mu$  | $( 2.4 \pm 0.4 ) \times 10^{-3}$              | 770 |
| $\omega e^+ \nu_e$  | $( 1.69 \pm 0.11 ) \times 10^{-3}$            | 771 |
| $\omega \mu^+ \nu_\mu$  | $( 1.77 \pm 0.21 ) \times 10^{-3}$            | 767 |
| $\eta'(958) e^+ \nu_e$  | $( 2.0 \pm 0.4 ) \times 10^{-4}$              | 690 |
| $a(980)^0 e^+ \nu_e, a(980)^0 \rightarrow \eta \pi^0$           | $( 1.7 \pm_{-0.7}^{+0.8} ) \times 10^{-4}$    | —   |
| $b_1(1235)^0 e^+ \nu_e, b_1^0 \rightarrow \omega \pi^0$         | $< 1.75 \times 10^{-4}$ CL=90%                | —   |
| $\phi e^+ \nu_e$  | $< 1.3 \times 10^{-5}$ CL=90%                 | 657 |
| $D^0 e^+ \nu_e$   | $< 1.0 \times 10^{-4}$ CL=90%                 | 5   |

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

|  |  |       |     |
|--|--|-------|-----|
| $K_S^0 \pi^+$  | $( 1.562 \pm 0.031 ) \%$                       | S=1.7 | 863 |
| $K_L^0 \pi^+$  | $( 1.46 \pm 0.05 ) \%$                         |       | 863 |
| $K^- 2\pi^+$   | [ <i>jj</i> ] $( 9.38 \pm 0.16 ) \%$           | S=1.6 | 846 |
| $(K^- \pi^+)_{S\text{-wave}} \pi^+$                                      | $( 7.52 \pm 0.17 ) \%$                         |       | 846 |
| $\bar{K}_0^*(1430)^0 \pi^+,$   | [ <i>kk</i> ] $( 1.25 \pm 0.06 ) \%$           |       | 382 |
| $\bar{K}_0^*(1430)^0 \rightarrow K^- \pi^+$                              |  |       |     |
| $\bar{K}^*(892)^0 \pi^+,$  | $( 1.04 \pm 0.12 ) \%$                         |       | 714 |
| $\bar{K}^*(892)^0 \rightarrow K^- \pi^+$                                 |  |       |     |
| $\bar{K}^*(1410)^0 \pi^+, \bar{K}^{*0} \rightarrow$<br>$K^- \pi^+$       | not seen                                       |       | 381 |
| $\bar{K}_2^*(1430)^0 \pi^+,$   | [ <i>kk</i> ] $( 2.3 \pm 0.7 ) \times 10^{-4}$ |       | 371 |
| $\bar{K}_2^*(1430)^0 \rightarrow K^- \pi^+$                              |  |       |     |
| $\bar{K}^*(1680)^0 \pi^+,$   | [ <i>kk</i> ] $( 2.2 \pm 1.1 ) \times 10^{-4}$ |       | 58  |
| $\bar{K}^*(1680)^0 \rightarrow K^- \pi^+$                                |  |       |     |
| $K^-(2\pi^+)_{I=2}$  | $( 1.45 \pm 0.26 ) \%$                         |       | —   |
| $K_S^0 \pi^+ \pi^0$  | [ <i>jj</i> ] $( 7.36 \pm 0.21 ) \%$           |       | 845 |
| $K_S^0 \rho^+$   | $( 6.14 \pm_{-0.35}^{+0.60} ) \%$              |       | 677 |
| $K_S^0 \rho(1450)^+, \rho^+ \rightarrow \pi^+ \pi^0$                     | $( 1.5 \pm_{-1.4}^{+1.2} ) \times 10^{-3}$     |       | —   |
| $\bar{K}^*(892)^0 \pi^+,$  | $( 2.64 \pm 0.32 ) \times 10^{-3}$             |       | 714 |
| $\bar{K}^*(892)^0 \rightarrow K_S^0 \pi^0$                               |  |       |     |
| $\bar{K}_0^*(1430)^0 \pi^+, \bar{K}_0^{*0} \rightarrow$<br>$K_S^0 \pi^0$ | $( 2.7 \pm 0.9 ) \times 10^{-3}$               |       | —   |
| $\bar{K}_0^*(1680)^0 \pi^+, \bar{K}_0^{*0} \rightarrow$<br>$K_S^0 \pi^0$ | $( 10 \pm_{-10}^{+7} ) \times 10^{-4}$         |       | —   |
| $\bar{\kappa}^0 \pi^+, \bar{\kappa}^0 \rightarrow K_S^0 \pi^0$           | $( 6 \pm_{-4}^{+5} ) \times 10^{-3}$           |       | —   |
| $K_S^0 \pi^+ \pi^0$ nonresonant  | $( 3 \pm 4 ) \times 10^{-3}$                   |       | 845 |



|   |   |              |
|---|---|--------------|
| $K_S^0 \pi^+ \pi^0$ nonresonant and $\bar{K}^0 \pi^+$ | ( 1.37 $\pm$ 0.21 $\pm$ 0.40 ) %        | –            |
| $(K_S^0 \pi^0)_{S\text{-wave}} \pi^+$                 | ( 1.27 $\pm$ 0.27 $\pm$ 0.33 ) %        | 845          |
| $K_S^0 \pi^+ \eta$                                    | ( 1.31 $\pm$ 0.05 ) %                   | 722          |
| $K_S^0 \pi^+ \eta'(958)$                              | ( 1.90 $\pm$ 0.21 ) $\times 10^{-3}$    | 481          |
| $K^- 2\pi^+ \pi^0$                                    | [//] ( 6.25 $\pm$ 0.18 ) %              | 817          |
| $K_S^0 2\pi^+ \pi^-$                                  | [//] ( 3.10 $\pm$ 0.09 ) %              | 814          |
| $K^- 2\pi^+ \eta$                                     | ( 1.35 $\pm$ 0.12 ) $\times 10^{-3}$    | 657          |
| $K_S^0 \pi^+ \pi^0 \eta$                              | ( 1.22 $\pm$ 0.25 ) $\times 10^{-3}$    | 657          |
| $K^- 3\pi^+ \pi^-$                                    | [jj] ( 5.7 $\pm$ 0.5 ) $\times 10^{-3}$ | S=1.1<br>772 |
| $\bar{K}^*(892)^0 2\pi^+ \pi^-$ ,                     | ( 1.2 $\pm$ 0.4 ) $\times 10^{-3}$      | 645          |
| $\bar{K}^*(892)^0 \rightarrow K^- \pi^+$              |   |              |
| $\bar{K}^*(892)^0 \rho^0 \pi^+$ ,                     | ( 2.3 $\pm$ 0.4 ) $\times 10^{-3}$      | 239          |
| $\bar{K}^*(892)^0 \rightarrow K^- \pi^+$              |   |              |
| $\bar{K}^*(892)^0 a_1(1260)^+$                        | [nn] ( 9.3 $\pm$ 1.9 ) $\times 10^{-3}$ | †            |
| $K^- \rho^0 2\pi^+$                                   | ( 1.72 $\pm$ 0.28 ) $\times 10^{-3}$    | 524          |
| $K^- 3\pi^+ \pi^-$ nonresonant                        | ( 4.0 $\pm$ 2.9 ) $\times 10^{-4}$      | 772          |
| $K^+ 2K_S^0$  | ( 2.54 $\pm$ 0.13 ) $\times 10^{-3}$    | 545          |
| $K^+ K^- K_S^0 \pi^+$                                 | ( 2.4 $\pm$ 0.5 ) $\times 10^{-4}$      | 436          |

### Pionic modes

|   |  |     |
|---|--|-----|
| $\pi^+ \pi^0$                                     | ( 1.247 $\pm$ 0.033 ) $\times 10^{-3}$ | 925 |
| $2\pi^+ \pi^-$                                    | ( 3.27 $\pm$ 0.18 ) $\times 10^{-3}$   | 909 |
| $\rho^0 \pi^+$                                    | ( 8.3 $\pm$ 1.5 ) $\times 10^{-4}$     | 767 |
| $\pi^+ (\pi^+ \pi^-)_{S\text{-wave}}$             | ( 1.83 $\pm$ 0.16 ) $\times 10^{-3}$   | 909 |
| $\sigma \pi^+$ , $\sigma \rightarrow \pi^+ \pi^-$ | ( 1.38 $\pm$ 0.12 ) $\times 10^{-3}$   | –   |
| $f_0(980) \pi^+$ ,                                | ( 1.56 $\pm$ 0.33 ) $\times 10^{-4}$   | 669 |
| $f_0(980) \rightarrow \pi^+ \pi^-$                |  |     |
| $f_0(1370) \pi^+$ ,                               | ( 8 $\pm$ 4 ) $\times 10^{-5}$         | –   |
| $f_0(1370) \rightarrow \pi^+ \pi^-$               |  |     |
| $f_2(1270) \pi^+$ ,                               | ( 5.0 $\pm$ 0.9 ) $\times 10^{-4}$     | 485 |
| $f_2(1270) \rightarrow \pi^+ \pi^-$               |  |     |
| $\rho(1450)^0 \pi^+$ ,                            | < 8 $\times 10^{-5}$ CL=95%            | 338 |
| $\rho(1450)^0 \rightarrow \pi^+ \pi^-$            |  |     |
| $f_0(1500) \pi^+$ ,                               | ( 1.1 $\pm$ 0.4 ) $\times 10^{-4}$     | –   |
| $f_0(1500) \rightarrow \pi^+ \pi^-$               |  |     |
| $f_0(1710) \pi^+$ ,                               | < 5 $\times 10^{-5}$ CL=95%            | –   |
| $f_0(1710) \rightarrow \pi^+ \pi^-$               |  |     |
| $f_0(1790) \pi^+$ ,                               | < 7 $\times 10^{-5}$ CL=95%            | –   |
| $f_0(1790) \rightarrow \pi^+ \pi^-$               |  |     |
| $(\pi^+ \pi^+)_{S\text{-wave}} \pi^-$             | < 1.2 $\times 10^{-4}$ CL=95%          | 909 |
| $2\pi^+ \pi^-$ nonresonant                        | < 1.1 $\times 10^{-4}$ CL=95%          | 909 |
| $\pi^+ 2\pi^0$                                    | ( 4.7 $\pm$ 0.4 ) $\times 10^{-3}$     | 910 |

|                        |                                    |       |     |
|------------------------|------------------------------------|-------|-----|
| $2\pi^+\pi^-\pi^0$     | ( 1.16 ± 0.08 ) %                  |       | 883 |
| $3\pi^+2\pi^-$         | ( 1.66 ± 0.16 ) × 10 <sup>-3</sup> | S=1.1 | 845 |
| $\eta\pi^+$            | ( 3.77 ± 0.09 ) × 10 <sup>-3</sup> |       | 848 |
| $\eta\pi^+\pi^0$       | ( 2.05 ± 0.35 ) × 10 <sup>-3</sup> | S=2.2 | 831 |
| $\eta2\pi^+\pi^-$      | ( 3.41 ± 0.20 ) × 10 <sup>-3</sup> |       | 798 |
| $\eta\pi^+2\pi^0$      | ( 3.20 ± 0.33 ) × 10 <sup>-3</sup> |       | 801 |
| $\eta\eta\pi^+$        | ( 2.96 ± 0.26 ) × 10 <sup>-3</sup> |       | 700 |
| $\omega\pi^+$          | ( 2.8 ± 0.6 ) × 10 <sup>-4</sup>   |       | 764 |
| $\omega\pi^+\pi^0$     | ( 3.9 ± 0.9 ) × 10 <sup>-3</sup>   |       | 742 |
| $\eta'(958)\pi^+$      | ( 4.97 ± 0.19 ) × 10 <sup>-3</sup> |       | 681 |
| $\eta'(958)\pi^+\pi^0$ | ( 1.6 ± 0.5 ) × 10 <sup>-3</sup>   |       | 654 |

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

|  |   |       |     |
|--|---|-------|-----|
| $K^+K_S^0$   | ( 3.04 ± 0.09 ) × 10 <sup>-3</sup>  | S=2.2 | 793 |
| $K_L^0K^+$   | ( 3.21 ± 0.16 ) × 10 <sup>-3</sup>  |       | 793 |
| $K_S^0K^+\pi^0$  | ( 5.07 ± 0.30 ) × 10 <sup>-3</sup>  |       | 744 |
| $K_L^0K^+\pi^0$  | ( 5.24 ± 0.31 ) × 10 <sup>-3</sup>  |       | 744 |
| $K^+K^-\pi^+$  | [ij] ( 9.68 ± 0.18 ) × 10 <sup>-3</sup>   |       | 744 |
| $K^+K^-\pi^+\pi^0$   | ( 6.62 ± 0.32 ) × 10 <sup>-3</sup>  |       | 682 |
| $\phi\pi^+$  | ( 5.70 ± 0.14 ) × 10 <sup>-3</sup>  |       | 647 |
| $\phi\pi^+, \phi \rightarrow K^+K^-$                               | ( 2.69 $\begin{smallmatrix} + \\ - \end{smallmatrix}$ $\begin{smallmatrix} 0.07 \\ 0.08 \end{smallmatrix}$ ) × 10 <sup>-3</sup> |       | 647 |
| $K^+\bar{K}^*(892)^0, \bar{K}^*(892)^0 \rightarrow K^-\pi^+$       | ( 2.49 $\begin{smallmatrix} + \\ - \end{smallmatrix}$ $\begin{smallmatrix} 0.08 \\ 0.13 \end{smallmatrix}$ ) × 10 <sup>-3</sup> |       | 613 |
| $K^+\bar{K}_0^*(1430)^0, \bar{K}_0^*(1430)^0 \rightarrow K^-\pi^+$ | ( 1.82 ± 0.35 ) × 10 <sup>-3</sup>  |       | —   |
| $K^+\bar{K}_2^*(1430)^0, \bar{K}_2^* \rightarrow K^-\pi^+$         | ( 1.6 $\begin{smallmatrix} + \\ - \end{smallmatrix}$ $\begin{smallmatrix} 1.2 \\ 0.8 \end{smallmatrix}$ ) × 10 <sup>-4</sup>    |       | —   |
| $K^+\bar{K}_0^*(700), \bar{K}_0^* \rightarrow K^-\pi^+$            | ( 6.8 $\begin{smallmatrix} + \\ - \end{smallmatrix}$ $\begin{smallmatrix} 3.5 \\ 2.1 \end{smallmatrix}$ ) × 10 <sup>-4</sup>    |       | —   |
| $a_0(1450)^0\pi^+, a_0^0 \rightarrow K^+K^-$                       | ( 4.5 $\begin{smallmatrix} + \\ - \end{smallmatrix}$ $\begin{smallmatrix} 7.0 \\ 1.8 \end{smallmatrix}$ ) × 10 <sup>-4</sup>    |       | —   |
| $\phi(1680)\pi^+, \phi \rightarrow K^+K^-$                         | ( 4.9 $\begin{smallmatrix} + \\ - \end{smallmatrix}$ $\begin{smallmatrix} 4.0 \\ 1.9 \end{smallmatrix}$ ) × 10 <sup>-5</sup>    |       | —   |
| $K_S^0K_S^0\pi^+$  | ( 2.70 ± 0.13 ) × 10 <sup>-3</sup>  |       | 741 |
| $K_S^0K_S^0\pi^+\pi^0$   | ( 1.34 ± 0.21 ) × 10 <sup>-3</sup>  |       | 679 |
| $K_S^0K^+\eta$   | ( 1.8 ± 0.5 ) × 10 <sup>-4</sup>  |       | 516 |
| $K^+K_S^0\pi^+\pi^-$   | ( 1.89 ± 0.13 ) × 10 <sup>-3</sup>  |       | 678 |
| $K_S^0K^+\pi^0\pi^0$   | ( 5.8 ± 1.3 ) × 10 <sup>-4</sup>  |       | 683 |
| $K_S^0K^-2\pi^+$   | ( 2.27 ± 0.13 ) × 10 <sup>-3</sup>  |       | 678 |
| $K^+K^-2\pi^+\pi^-$  | ( 2.3 ± 1.2 ) × 10 <sup>-4</sup>  |       | 601 |

A few poorly measured branching fractions:

|                  |                 |        |     |
|------------------|-----------------|--------|-----|
| $\phi\pi^+\pi^0$ | ( 2.3 ± 1.0 ) % |        | 619 |
| $\phi\rho^+$     | < 1.5 %         | CL=90% | 260 |

|                                   |                               |     |
|-----------------------------------|-------------------------------|-----|
| $K^+ K^- \pi^+ \pi^0$ non- $\phi$ | ( 1.5 $\pm$ 0.7 $\pm$ 0.6 ) % | 682 |
| $K^*(892)^+ K_S^0$                | ( 1.7 $\pm$ 0.8 ) %           | 612 |

**Doubly Cabibbo-suppressed modes**

|  |  |       |     |
|--|--|-------|-----|
| $K^+ \pi^0$  | ( 2.08 $\pm$ 0.21 ) $\times 10^{-4}$         | S=1.4 | 864 |
| $K^+ \eta$   | ( 1.25 $\pm$ 0.16 ) $\times 10^{-4}$         | S=1.1 | 776 |
| $K^+ \eta'(958)$   | ( 1.85 $\pm$ 0.20 ) $\times 10^{-4}$         |       | 571 |
| $K^+ \pi^+ \pi^-$  | ( 4.91 $\pm$ 0.09 ) $\times 10^{-4}$         |       | 846 |
| $K^+ \rho^0$   | ( 1.9 $\pm$ 0.5 ) $\times 10^{-4}$           |       | 679 |
| $K^*(892)^0 \pi^+, K^*(892)^0 \rightarrow K^+ \pi^-$       | ( 2.3 $\pm$ 0.4 ) $\times 10^{-4}$           |       | 714 |
| $K^+ f_0(980), f_0(980) \rightarrow \pi^+ \pi^-$           | ( 4.4 $\pm$ 2.6 ) $\times 10^{-5}$           |       | —   |
| $K_2^*(1430)^0 \pi^+, K_2^*(1430)^0 \rightarrow K^+ \pi^-$ | ( 3.9 $\pm$ 2.7 ) $\times 10^{-5}$           |       | —   |
| $K^+ \pi^+ \pi^-$ nonresonant                              | not seen                                     |       | 846 |
| $K^+ \pi^+ \pi^- \pi^0$                                    | ( 1.21 $\pm$ 0.09 ) $\times 10^{-3}$         |       | 817 |
| $K^+ \omega$   | ( 5.7 $\pm$ 2.5 $\pm$ 2.1 ) $\times 10^{-5}$ |       | 675 |
| $2K^+ K^-$   | ( 6.14 $\pm$ 0.11 ) $\times 10^{-5}$         |       | 550 |
| $\phi(1020)^0 K^+$   | < 2.1 $\times 10^{-5}$ CL=90%                |       | —   |
| $K^+ \phi(1020), \phi \rightarrow K^+ K^-$                 | ( 4.4 $\pm$ 0.6 ) $\times 10^{-6}$           |       | —   |
| $K^+ (K^+ K^-) S\text{-wave}$                              | ( 5.77 $\pm$ 0.12 ) $\times 10^{-5}$         |       | 550 |

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

|  |              |  |     |
|--|--------------|--|-----|
| $\pi^+ e^+ e^-$                            | C1           | < 1.1 $\times 10^{-6}$ CL=90%                | 930 |
| $\pi^+ \pi^0 e^+ e^-$                      |              | < 1.4 $\times 10^{-5}$ CL=90%                | 925 |
| $\pi^+ \phi, \phi \rightarrow e^+ e^-$     | [ $\infty$ ] | ( 1.7 $\pm$ 1.4 $\pm$ 0.9 ) $\times 10^{-6}$ | —   |
| $\pi^+ \mu^+ \mu^-$                        | C1           | < 7.3 $\times 10^{-8}$ CL=90%                | 918 |
| $\pi^+ \phi, \phi \rightarrow \mu^+ \mu^-$ | [ $\infty$ ] | ( 1.8 $\pm$ 0.8 ) $\times 10^{-6}$           | —   |
| $\rho^+ \mu^+ \mu^-$                       | C1           | < 5.6 $\times 10^{-4}$ CL=90%                | 757 |
| $K^+ e^+ e^-$                              | [ $pp$ ]     | < 1.0 $\times 10^{-6}$ CL=90%                | 870 |
| $K^+ \pi^0 e^+ e^-$                        |              | < 1.5 $\times 10^{-5}$ CL=90%                | 864 |
| $K_S^0 \pi^+ e^+ e^-$                      |              | < 2.6 $\times 10^{-5}$ CL=90%                | —   |
| $K_S^0 K^+ e^+ e^-$                        |              | < 1.1 $\times 10^{-5}$ CL=90%                | —   |
| $K^+ \mu^+ \mu^-$                          | [ $pp$ ]     | < 4.3 $\times 10^{-6}$ CL=90%                | 856 |
| $\pi^+ e^+ \mu^-$                          | LF           | < 2.9 $\times 10^{-6}$ CL=90%                | 927 |
| $\pi^+ e^- \mu^+$                          | LF           | < 3.6 $\times 10^{-6}$ CL=90%                | 927 |
| $K^+ e^+ \mu^-$                            | LF           | < 1.2 $\times 10^{-6}$ CL=90%                | 866 |
| $K^+ e^- \mu^+$                            | LF           | < 2.8 $\times 10^{-6}$ CL=90%                | 866 |
| $\pi^- 2e^+$                               | L            | < 1.1 $\times 10^{-6}$ CL=90%                | 930 |
| $\pi^- 2\mu^+$                             | L            | < 2.2 $\times 10^{-8}$ CL=90%                | 918 |
| $\pi^- e^+ \mu^+$                          | L            | < 2.0 $\times 10^{-6}$ CL=90%                | 927 |

|                      |        |         |                         |     |
|----------------------|--------|---------|-------------------------|-----|
| $\rho^- 2\mu^+$      | $L$    | $< 5.6$ | $\times 10^{-4}$ CL=90% | 757 |
| $K^- 2e^+$           | $L$    | $< 9$   | $\times 10^{-7}$ CL=90% | 870 |
| $K_S^0 \pi^- 2e^+$   |        | $< 3.3$ | $\times 10^{-6}$ CL=90% | 863 |
| $K^- \pi^0 2e^+$     |        | $< 8.5$ | $\times 10^{-6}$ CL=90% | 864 |
| $K^- 2\mu^+$         | $L$    | $< 1.0$ | $\times 10^{-5}$ CL=90% | 856 |
| $K^- e^+ \mu^+$      | $L$    | $< 1.9$ | $\times 10^{-6}$ CL=90% | 866 |
| $K^*(892)^- 2\mu^+$  | $L$    | $< 8.5$ | $\times 10^{-4}$ CL=90% | 703 |
| $\Lambda e^+$        | $L, B$ | $< 1.1$ | $\times 10^{-6}$ CL=90% | 602 |
| $\bar{\Lambda} e^+$  | $L, B$ | $< 6.5$ | $\times 10^{-7}$ CL=90% | 602 |
| $\Sigma^0 e^+$       | $L, B$ | $< 1.7$ | $\times 10^{-6}$ CL=90% | 554 |
| $\bar{\Sigma}^0 e^+$ | $L, B$ | $< 1.3$ | $\times 10^{-6}$ CL=90% | 554 |

**$D^0$**

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

Mass  $m = 1864.84 \pm 0.05$  MeV

$m_{D^\pm} - m_{D^0} = 4.822 \pm 0.015$  MeV

Mean life  $\tau = (410.1 \pm 1.5) \times 10^{-15}$  s

$c\tau = 122.9$   $\mu\text{m}$

### Mixing and related parameters

$$|m_{D_1^0} - m_{D_2^0}| = (0.95^{+0.41}_{-0.44}) \times 10^{10} \hbar \text{ s}^{-1}$$

$$(\Gamma_{D_1^0} - \Gamma_{D_2^0})/\Gamma = 2y = (1.29^{+0.14}_{-0.18}) \times 10^{-2}$$

$$|q/p| = 0.92^{+0.12}_{-0.09}$$

$$A_\Gamma = (-0.125 \pm 0.526) \times 10^{-3}$$

$$\phi^{K_S^0 \pi \pi} = -0.09^{+0.10}_{-0.13}$$

$K^+ \pi^-$  relative strong phase:  $\cos \delta = 0.97 \pm 0.11$

$K^- \pi^+ \pi^0$  coherence factor  $R_{K \pi \pi^0} = 0.82 \pm 0.06$

$K^- \pi^+ \pi^0$  average relative strong phase  $\delta^{K \pi \pi^0} = (199 \pm 14)^\circ$

$K^- \pi^- 2\pi^+$  coherence factor  $R_{K 3\pi} = 0.53^{+0.18}_{-0.21}$

$K^- \pi^- 2\pi^+$  average relative strong phase  $\delta^{K 3\pi} = (125^{+22}_{-14})^\circ$

$D^0 \rightarrow K^- \pi^- 2\pi^+$ ,  $R_{K 3\pi} (y \cos \delta^{K 3\pi} - x \sin \delta^{K 3\pi}) = (-3.0 \pm 0.7) \times 10^{-3} \text{ TeV}^{-1}$

$K_S^0 K^+ \pi^-$  coherence factor  $R_{K_S^0 K \pi} = 0.70 \pm 0.08$

$K_S^0 K^+ \pi^-$  average relative strong phase  $\delta^{K_S^0 K \pi} = (0 \pm 16)^\circ$

$K^* K$  coherence factor  $R_{K^* K} = 0.94 \pm 0.12$

$K^* K$  average relative strong phase  $\delta^{K^* K} = (-17 \pm 18)^\circ$

### CP-violation decay-rate asymmetries (labeled by the $D^0$ decay)

$$A_{CP}(K^+ K^-) = (-0.07 \pm 0.11)\%$$

$$A_{CP}(2K_S^0) = (0.4 \pm 1.4)\%$$

$$\begin{aligned}
A_{CP}(\pi^+\pi^-) &= (0.13 \pm 0.14)\% \\
A_{CP}(\pi^0\pi^0) &= (0.0 \pm 0.6)\% \\
A_{CP}(\rho\gamma) &= (6 \pm 15) \times 10^{-2} \\
A_{CP}(\phi\gamma) &= (-9 \pm 7) \times 10^{-2} \\
A_{CP}(\overline{K}^*(892)^0\gamma) &= (-0.3 \pm 2.0) \times 10^{-2} \\
A_{CP}(\pi^+\pi^-\pi^0) &= (0.3 \pm 0.4)\% \\
A_{CP}(\rho(770)^+\pi^- \rightarrow \pi^+\pi^-\pi^0) &= (1.2 \pm 0.9)\% [qq] \\
A_{CP}(\rho(770)^0\pi^0 \rightarrow \pi^+\pi^-\pi^0) &= (-3.1 \pm 3.0)\% [qq] \\
A_{CP}(\rho(770)^-\pi^+ \rightarrow \pi^+\pi^-\pi^0) &= (-1.0 \pm 1.7)\% [qq] \\
A_{CP}(\rho(1450)^+\pi^- \rightarrow \pi^+\pi^-\pi^0) &= (0 \pm 70)\% [qq] \\
A_{CP}(\rho(1450)^0\pi^0 \rightarrow \pi^+\pi^-\pi^0) &= (-20 \pm 40)\% [qq] \\
A_{CP}(\rho(1450)^-\pi^+ \rightarrow \pi^+\pi^-\pi^0) &= (6 \pm 9)\% [qq] \\
A_{CP}(\rho(1700)^+\pi^- \rightarrow \pi^+\pi^-\pi^0) &= (-5 \pm 14)\% [qq] \\
A_{CP}(\rho(1700)^0\pi^0 \rightarrow \pi^+\pi^-\pi^0) &= (13 \pm 9)\% [qq] \\
A_{CP}(\rho(1700)^-\pi^+ \rightarrow \pi^+\pi^-\pi^0) &= (8 \pm 11)\% [qq] \\
A_{CP}(f_0(980)\pi^0 \rightarrow \pi^+\pi^-\pi^0) &= (0 \pm 35)\% [qq] \\
A_{CP}(f_0(1370)\pi^0 \rightarrow \pi^+\pi^-\pi^0) &= (25 \pm 18)\% [qq] \\
A_{CP}(f_0(1500)\pi^0 \rightarrow \pi^+\pi^-\pi^0) &= (0 \pm 18)\% [qq] \\
A_{CP}(f_0(1710)\pi^0 \rightarrow \pi^+\pi^-\pi^0) &= (0 \pm 24)\% [qq] \\
A_{CP}(f_2(1270)\pi^0 \rightarrow \pi^+\pi^-\pi^0) &= (-4 \pm 6)\% [qq] \\
A_{CP}(\sigma(400)\pi^0 \rightarrow \pi^+\pi^-\pi^0) &= (6 \pm 8)\% [qq] \\
A_{CP}(\text{nonresonant } \pi^+\pi^-\pi^0) &= (-13 \pm 23)\% [qq] \\
A_{CP}(a_1(1260)^+\pi^- \rightarrow 2\pi^+2\pi^-) &= (5 \pm 6)\% \\
A_{CP}(a_1(1260)^-\pi^+ \rightarrow 2\pi^+2\pi^-) &= (14 \pm 18)\% \\
A_{CP}(\pi(1300)^+\pi^- \rightarrow 2\pi^+2\pi^-) &= (-2 \pm 15)\% \\
A_{CP}(\pi(1300)^-\pi^+ \rightarrow 2\pi^+2\pi^-) &= (-6 \pm 30)\% \\
A_{CP}(a_1(1640)^+\pi^- \rightarrow 2\pi^+2\pi^-) &= (9 \pm 26)\% \\
A_{CP}(\pi_2(1670)^+\pi^- \rightarrow 2\pi^+2\pi^-) &= (7 \pm 18)\% \\
A_{CP}(\sigma f_0(1370) \rightarrow 2\pi^+2\pi^-) &= (-15 \pm 19)\% \\
A_{CP}(\sigma\rho(770)^0 \rightarrow 2\pi^+2\pi^-) &= (3 \pm 27)\% \\
A_{CP}(2\rho(770)^0 \rightarrow 2\pi^+2\pi^-) &= (-6 \pm 6)\% \\
A_{CP}(2f_2(1270) \rightarrow 2\pi^+2\pi^-) &= (-28 \pm 24)\% \\
A_{CP}(\pi^+\pi^-\pi^0\eta) \text{ in } D^0, \overline{D}^0 \rightarrow \pi^+\pi^-\pi^0\eta &= (-6 \pm 6) \times 10^{-2} \\
A_{CP}(K^+K^-\pi^0) &= (-1.0 \pm 1.7)\% \\
A_{CP}(K^*(892)^+K^- \rightarrow K^+K^-\pi^0) &= (-0.9 \pm 1.3)\% [qq] \\
A_{CP}(K^*(1410)^+K^- \rightarrow K^+K^-\pi^0) &= (-21 \pm 24)\% [qq] \\
A_{CP}((K^+\pi^0)_{S\text{-wave}}K^- \rightarrow K^+K^-\pi^0) &= (7 \pm 15)\% [qq] \\
A_{CP}(\phi(1020)\pi^0 \rightarrow K^+K^-\pi^0) &= (1.1 \pm 2.2)\% [qq] \\
A_{CP}(f_0(980)\pi^0 \rightarrow K^+K^-\pi^0) &= (-3 \pm 19)\% [qq] \\
A_{CP}(a_0(980)^0\pi^0 \rightarrow K^+K^-\pi^0) &= (-5 \pm 16)\% [qq] \\
A_{CP}(f'_2(1525)\pi^0 \rightarrow K^+K^-\pi^0) &= (0 \pm 160)\% [qq] \\
A_{CP}(K^*(892)^-K^+ \rightarrow K^+K^-\pi^0) &= (-5 \pm 4)\% [qq]
\end{aligned}$$

$$\begin{aligned}
A_{CP}(K^*(1410)^- K^+ \rightarrow K^+ K^- \pi^0) &= (-17 \pm 29)\% \text{ [qq]} \\
A_{CP}((K^- \pi^0)_{S\text{-wave}} K^+ \rightarrow K^+ K^- \pi^0) &= (-10 \pm 40)\% \text{ [qq]} \\
A_{CP}(K_S^0 \pi^0) &= (-0.20 \pm 0.17)\% \\
A_{CP}(K_S^0 \eta) &= (0.5 \pm 0.5)\% \\
A_{CP}(K_S^0 \eta') &= (1.0 \pm 0.7)\% \\
A_{CP}(K_S^0 \phi) &= (-3 \pm 9)\% \\
A_{CP}(K^- \pi^+) &= (0.2 \pm 0.5)\% \\
A_{CP}(K^+ \pi^-) &= (-0.9 \pm 1.4)\% \\
A_{CP}(D_{CP(\pm 1)} \rightarrow K^\mp \pi^\pm) &= (12.7 \pm 1.5)\% \\
A_{CP}(K^- \pi^+ \pi^0) &= (0.1 \pm 0.5)\% \\
A_{CP}(K^+ \pi^- \pi^0) &= (0 \pm 5)\% \\
A_{CP}(K_S^0 \pi^+ \pi^-) &= (-0.1 \pm 0.8)\% \\
A_{CP}(K^\mp \pi^\pm \eta) \text{ in } D^0, \bar{D}^0 \rightarrow K^\mp \pi^\pm \eta &= (-1.9 \pm 1.6) \times 10^{-2} \\
A_{CP}(K_S^0 \pi^0 \eta) \text{ in } D^0, \bar{D}^0 \rightarrow K_S^0 \pi^0 \eta &= (-3.9 \pm 3.3) \times 10^{-2} \\
A_{CP}(K^\mp \pi^\pm \pi^0 \eta) \text{ in } D^0, \bar{D}^0 \rightarrow K^\mp \pi^\pm \pi^0 \eta &= (-8 \pm 5) \times 10^{-2} \\
A_{CP}(K^*(892)^- \pi^+ \rightarrow K_S^0 \pi^+ \pi^-) &= (0.4 \pm 0.5)\% \\
A_{CP}(K^*(892)^+ \pi^- \rightarrow K_S^0 \pi^+ \pi^-) &= (1 \pm 6)\% \\
A_{CP}(\bar{K}^0 \rho^0 \rightarrow K_S^0 \pi^+ \pi^-) &= (-0.1 \pm 0.5)\% \\
A_{CP}(\bar{K}^0 \omega \rightarrow K_S^0 \pi^+ \pi^-) &= (-13 \pm 7)\% \\
A_{CP}(\bar{K}^0 f_0(980) \rightarrow K_S^0 \pi^+ \pi^-) &= (-0.4 \pm 2.7)\% \\
A_{CP}(\bar{K}^0 f_2(1270) \rightarrow K_S^0 \pi^+ \pi^-) &= (-4 \pm 5)\% \\
A_{CP}(\bar{K}^0 f_0(1370) \rightarrow K_S^0 \pi^+ \pi^-) &= (-1 \pm 9)\% \\
A_{CP}(\bar{K}^0 \rho^0(1450) \rightarrow K_S^0 \pi^+ \pi^-) &= (-4 \pm 10)\% \\
A_{CP}(\bar{K}^0 f_0(600) \rightarrow K_S^0 \pi^+ \pi^-) &= (-3 \pm 5)\% \\
A_{CP}(K^*(1410)^- \pi^+ \rightarrow K_S^0 \pi^+ \pi^-) &= (-2 \pm 9)\% \\
A_{CP}(K_0^*(1430)^- \pi^+ \rightarrow K_S^0 \pi^+ \pi^-) &= (4 \pm 4)\% \\
A_{CP}(K_0^*(1430)^+ \pi^- \rightarrow K_S^0 \pi^+ \pi^-) &= (12 \pm 15)\% \\
A_{CP}(K_2^*(1430)^- \pi^+ \rightarrow K_S^0 \pi^+ \pi^-) &= (3 \pm 6)\% \\
A_{CP}(K_2^*(1430)^+ \pi^- \rightarrow K_S^0 \pi^+ \pi^-) &= (-10 \pm 32)\% \\
A_{CP}(K^- \pi^+ \pi^+ \pi^-) &= (0.2 \pm 0.5)\% \\
A_{CP}(K^+ \pi^- \pi^+ \pi^-) &= (-2 \pm 4)\% \\
A_{CP}(K^+ K^- \pi^+ \pi^-) &= (1.3 \pm 1.7)\% \\
A_{CP}(K_1^*(1270)^+ K^- \rightarrow K^+ K^- \pi^+ \pi^-) &= (-2.3 \pm 1.7)\% \\
A_{CP}(K_1^*(1270)^+ K^- \rightarrow K^{*0} \pi^+ K^-) &= (-1 \pm 10)\% \\
A_{CP}(K_1^*(1270)^- K^+ \rightarrow \bar{K}^{*0} \pi^- K^+) &= (-10 \pm 32)\% \\
A_{CP}(K_1^*(1270)^- K^+ \rightarrow K^+ K^- \pi^+ \pi^-) &= (1.7 \pm 3.5)\% \\
A_{CP}(K_1^*(1270)^+ K^- \rightarrow \rho^0 K^+ K^-) &= (-7 \pm 17)\% \\
A_{CP}(K_1^*(1270)^- K^+ \rightarrow \rho^0 K^- K^+) &= (10 \pm 13)\% \\
A_{CP}(K_1(1400)^+ K^- \rightarrow K^+ K^- \pi^+ \pi^-) &= (-4.4 \pm 2.1)\% \\
A_{CP}(K^*(1410)^+ K^- \rightarrow K^{*0} \pi^+ K^-) &= (-20 \pm 17)\% \\
A_{CP}(K^*(1410)^- K^+ \rightarrow \bar{K}^{*0} \pi^- K^+) &= (-1 \pm 14)\% \\
A_{CP}(K^*(1680)^+ K^- \rightarrow K^+ K^- \pi^+ \pi^-) &= (-17 \pm 29)\%
\end{aligned}$$

$$\begin{aligned}
 A_{CP}(K^{*0}\bar{K}^{*0}) \text{ in } D^0, \bar{D}^0 \rightarrow K^{*0}\bar{K}^{*0} &= (-5 \pm 14)\% \\
 A_{CP}(K^{*0}\bar{K}^{*0} \text{ S-wave}) &= (-3.9 \pm 2.2)\% \\
 A_{CP}(\phi\rho^0) \text{ in } D^0, \bar{D}^0 \rightarrow \phi\rho^0 &= (1 \pm 9)\% \\
 A_{CP}(\phi\rho^0 \text{ S-wave}) &= (-3 \pm 5)\% \\
 A_{CP}(\phi\rho^0 \text{ D-wave}) &= (-37 \pm 19)\% \\
 A_{CP}(\phi(\pi^+\pi^-)_{S\text{-wave}}) &= (6 \pm 6)\% \\
 A_{CP}(K^*(892)^0(K^-\pi^+)_{S\text{-wave}}) &= (-10 \pm 40)\% \\
 A_{CP}(K^+K^-\pi^+\pi^- \text{ non-resonant}) &= (8 \pm 20)\% \\
 A_{CP}((K^-\pi^+)_{P\text{-wave}}(K^+\pi^-)_{S\text{-wave}}) &= (3 \pm 11)\% \\
 A_{CP}(K^+K^-\mu^+\mu^-) \text{ in } D^0, \bar{D}^0 \rightarrow K^+K^-\mu^+\mu^- &= (0 \pm 11)\% \\
 A_{CP}(\pi^+\pi^-\mu^+\mu^-) \text{ in } D^0, \bar{D}^0 \rightarrow \pi^+\pi^-\mu^+\mu^- &= (5 \pm 4)\%
 \end{aligned}$$

### CP-even fractions (labeled by the $D^0$ decay)

$$\begin{aligned}
 \text{CP-even fraction in } D^0 \rightarrow \pi^+\pi^-\pi^0 \text{ decays} &= (97.3 \pm 1.7)\% \\
 \text{CP-even fraction in } D^0 \rightarrow K^+K^-\pi^0 \text{ decays} &= (73 \pm 6)\% \\
 \text{CP-even fraction in } D^0 \rightarrow \pi^+\pi^-\pi^+\pi^- \text{ decays} &= (76.9 \pm 2.3)\% \\
 \text{CP-even fraction in } D^0 \rightarrow K_S^0\pi^+\pi^-\pi^0 \text{ decays} &= (23.8 \pm 1.7)\% \\
 \text{CP-even fraction in } D^0 \rightarrow K^+K^-\pi^+\pi^- \text{ decays} &= (75 \pm 4)\%
 \end{aligned}$$

### CP-violation asymmetry difference

$$\Delta A_{CP} = A_{CP}(K^+K^-) - A_{CP}(\pi^+\pi^-) = (-0.154 \pm 0.029)\%$$

### $\chi^2$ tests of CP-violation (CPV) p-values

$$\begin{aligned}
 \text{Local CPV in } D^0, \bar{D}^0 \rightarrow \pi^+\pi^-\pi^0 &= 4.9\% \\
 \text{Local CPV in } D^0, \bar{D}^0 \rightarrow \pi^+\pi^-\pi^+\pi^- &= (0.6 \pm 0.2)\% \\
 \text{Local CPV in } D^0, \bar{D}^0 \rightarrow K_S^0\pi^+\pi^- &= 96\% \\
 \text{Local CPV in } D^0, \bar{D}^0 \rightarrow K^+K^-\pi^0 &= 16.6\% \\
 \text{Local CPV in } D^0, \bar{D}^0 \rightarrow K^+K^-\pi^+\pi^- &= 9.1\%
 \end{aligned}$$

### T-violation decay-rate asymmetry

$$\begin{aligned}
 A_T(K^+K^-\pi^+\pi^-) &= (2.9 \pm 2.2) \times 10^{-3} [ii] \\
 A_{T\text{viol}}(K_S\pi^+\pi^-\pi^0) \text{ in } D^0, \bar{D}^0 \rightarrow K_S\pi^+\pi^-\pi^0 &= (-0.3^{+1.4}_{-1.6}) \times 10^{-3}
 \end{aligned}$$

### CPT-violation decay-rate asymmetry

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

### Form factors

$$\begin{aligned}
 r_V &\equiv V(0)/A_1(0) \text{ in } D^0 \rightarrow K^*(892)^-\ell^+\nu_\ell = 1.46 \pm 0.07 \\
 r_2 &\equiv A_2(0)/A_1(0) \text{ in } D^0 \rightarrow K^*(892)^-\ell^+\nu_\ell = 0.68 \pm 0.06 \\
 f_+(0) &\text{ in } D^0 \rightarrow K^-\ell^+\nu_\ell = 0.736 \pm 0.004 \\
 f_+(0)|V_{cs}| &\text{ in } D^0 \rightarrow K^-\ell^+\nu_\ell = 0.7166 \pm 0.0030 \\
 r_1 &\equiv a_1/a_0 \text{ in } D^0 \rightarrow K^-\ell^+\nu_\ell = -2.40 \pm 0.16 \\
 r_2 &\equiv a_2/a_0 \text{ in } D^0 \rightarrow K^-\ell^+\nu_\ell = 5 \pm 4
 \end{aligned}$$

$$\begin{aligned}
 f_+(0) \text{ in } D^0 \rightarrow \pi^- \ell^+ \nu_\ell &= 0.637 \pm 0.009 \\
 f_+(0) |V_{cd}| \text{ in } D^0 \rightarrow \pi^- \ell^+ \nu_\ell &= 0.1436 \pm 0.0026 \quad (S = 1.5) \\
 r_1 \equiv a_1/a_0 \text{ in } D^0 \rightarrow \pi^- \ell^+ \nu_\ell &= -1.97 \pm 0.28 \quad (S = 1.4) \\
 r_2 \equiv a_1/a_0 \text{ in } D^0 \rightarrow \pi^- \ell^+ \nu_\ell &= -0.2 \pm 2.2 \quad (S = 1.7)
 \end{aligned}$$

Most decay modes (other than the semileptonic modes) that involve a neutral  $K$  meson are now given as  $K_S^0$  modes, not as  $\bar{K}^0$  modes. Nearly always it is a  $K_S^0$  that is measured, and interference between Cabibbo-allowed and doubly Cabibbo-suppressed modes can invalidate the assumption that  $2\Gamma(K_S^0) = \Gamma(\bar{K}^0)$ .

| <b><math>D^0</math> DECAY MODES</b>           | Fraction ( $\Gamma_i/\Gamma$ )   | Scale factor/<br>Confidence level | $p$<br>(MeV/c) |
|---|--|-----------------------------------|----------------|
| <b>Topological modes</b>                      |  |                                   |                |
| 0-prongs                                      | [ $rr$ ] (15 ± 6 ) %   |                                   | —              |
| 2-prongs                                      | (71 ± 6 ) %  |                                   | —              |
| 4-prongs                                      | [ $ss$ ] (14.6 ± 0.5 ) %   |                                   | —              |
| 6-prongs                                      | [ $tt$ ] ( 6.5 ± 1.3 ) × 10 <sup>-4</sup>  |                                   | —              |
| <b>Inclusive modes</b>                        |  |                                   |                |
| $e^+$ anything                                | [ $uu$ ] ( 6.49 ± 0.11 ) %   |                                   | —              |
| $\mu^+$ anything                              | ( 6.8 ± 0.6 ) %  |                                   | —              |
| $K^-$ anything                                | (54.7 ± 2.8 ) %  | S=1.3                             | —              |
| $\bar{K}^0$ anything + $K^0$ anything         | (47 ± 4 ) %  |                                   | —              |
| $K^+$ anything                                | ( 3.4 ± 0.4 ) %  |                                   | —              |
| $K^*(892)^-$ anything                         | (15 ± 9 ) %  |                                   | —              |
| $\bar{K}^*(892)^0$ anything                   | ( 9 ± 4 ) %  |                                   | —              |
| $K^*(892)^+$ anything                         | < 3.6 %  | CL=90%                            | —              |
| $K^*(892)^0$ anything                         | ( 2.8 ± 1.3 ) %  |                                   | —              |
| $\eta$ anything                               | ( 9.5 ± 0.9 ) %  |                                   | —              |
| $\eta'$ anything                              | ( 2.48 ± 0.27 ) %  |                                   | —              |
| $\phi$ anything                               | ( 1.08 ± 0.04 ) %  |                                   | —              |
| invisibles                                    | < 9.4 × 10 <sup>-5</sup>   | CL=90%                            | —              |
| <b>Semileptonic modes</b>                     |  |                                   |                |
| $K^- e^+ \nu_e$                               | ( 3.541 ± 0.034 ) %  | S=1.3                             | 867            |
| $K^- \mu^+ \nu_\mu$                           | ( 3.41 ± 0.04 ) %  |                                   | 864            |
| $K^*(892)^- e^+ \nu_e$                        | ( 2.15 ± 0.16 ) %  |                                   | 719            |
| $K^*(892)^- \mu^+ \nu_\mu$                    | ( 1.89 ± 0.24 ) %  |                                   | 714            |
| $K^- \pi^0 e^+ \nu_e$                         | ( 1.6 $\begin{smallmatrix} + \\ - \end{smallmatrix}$ $\begin{smallmatrix} 1.3 \\ 0.5 \end{smallmatrix}$ ) %                  |                                   | 861            |
| $\bar{K}^0 \pi^- e^+ \nu_e$                   | ( 1.44 ± 0.04 ) %  |                                   | 860            |
| $(\bar{K}^0 \pi^-)_{S\text{-wave}} e^+ \nu_e$ | ( 7.9 ± 1.7 ) × 10 <sup>-4</sup>   |                                   | 860            |
| $K^- \pi^+ \pi^- e^+ \nu_e$                   | ( 2.8 $\begin{smallmatrix} + \\ - \end{smallmatrix}$ $\begin{smallmatrix} 1.4 \\ 1.1 \end{smallmatrix}$ ) × 10 <sup>-4</sup> |                                   | 843            |
| $K_1(1270)^- e^+ \nu_e$                       | ( 7.6 $\begin{smallmatrix} + \\ - \end{smallmatrix}$ $\begin{smallmatrix} 4.0 \\ 3.1 \end{smallmatrix}$ ) × 10 <sup>-4</sup> |                                   | 511            |



|   |  |                  |        |     |
|---|--|------------------|--------|-----|
| $K^- \pi^+ \pi^- \mu^+ \nu_\mu$                         | $< 1.3$  | $\times 10^{-3}$ | CL=90% | 821 |
| $(\bar{K}^*(892)\pi)^- \mu^+ \nu_\mu$                   | $< 1.5$  | $\times 10^{-3}$ | CL=90% | 692 |
| $\pi^- e^+ \nu_e$                                       | $(2.91 \pm 0.04)$  | $\times 10^{-3}$ |        | 927 |
| $\pi^- \mu^+ \nu_\mu$                                   | $(2.67 \pm 0.12)$  | $\times 10^{-3}$ | S=1.3  | 924 |
| $\pi^- \pi^0 e^+ \nu_e$                                 | $(1.45 \pm 0.07)$  | $\times 10^{-3}$ |        | 922 |
| $\rho^- e^+ \nu_e$                                      | $(1.50 \pm 0.12)$  | $\times 10^{-3}$ | S=1.9  | 771 |
| $a(980)^- e^+ \nu_e, a^- \rightarrow \eta \pi^-$        | $(1.33 \begin{smallmatrix} + \\ - \end{smallmatrix} \begin{smallmatrix} 0.34 \\ 0.30 \end{smallmatrix})$ | $\times 10^{-4}$ |        | –   |
| $b_1(1235)^- e^+ \nu_e, b_1^- \rightarrow \omega \pi^-$ | $< 1.12$   | $\times 10^{-4}$ | CL=90% | –   |

### Hadronic modes with one $\bar{K}$

|   |  |                  |        |     |
|---|--|------------------|--------|-----|
| $K^- \pi^+$   | $(3.946 \pm 0.030)$  | %                | S=1.2  | 861 |
| $K_S^0 \pi^0$   | $(1.239 \pm 0.022)$  | %                |        | 860 |
| $K_L^0 \pi^0$   | $(10.0 \pm 0.7)$   | $\times 10^{-3}$ |        | 860 |
| $K_S^0 \pi^+ \pi^-$                                     | [ij] $(2.80 \pm 0.18)$   | %                | S=1.1  | 842 |
| $K_S^0 \rho^0$  | $(6.3 \begin{smallmatrix} + \\ - \end{smallmatrix} \begin{smallmatrix} 0.6 \\ 0.8 \end{smallmatrix})$        | $\times 10^{-3}$ |        | 674 |
| $K_S^0 \omega, \omega \rightarrow \pi^+ \pi^-$          | $(2.0 \pm 0.6)$  | $\times 10^{-4}$ |        | 670 |
| $K_S^0 (\pi^+ \pi^-)_{S\text{-wave}}$                   | $(3.3 \pm 0.8)$  | $\times 10^{-3}$ |        | 842 |
| $K_S^0 f_0(980), f_0 \rightarrow \pi^+ \pi^-$           | $(1.20 \begin{smallmatrix} + \\ - \end{smallmatrix} \begin{smallmatrix} 0.40 \\ 0.23 \end{smallmatrix})$     | $\times 10^{-3}$ |        | 549 |
| $K_S^0 f_0(1370), f_0 \rightarrow \pi^+ \pi^-$          | $(2.8 \begin{smallmatrix} + \\ - \end{smallmatrix} \begin{smallmatrix} 0.9 \\ 1.3 \end{smallmatrix})$        | $\times 10^{-3}$ |        | †   |
| $K_S^0 f_2(1270), f_2 \rightarrow \pi^+ \pi^-$          | $(9 \begin{smallmatrix} + \\ - \end{smallmatrix} \begin{smallmatrix} 10 \\ 6 \end{smallmatrix})$             | $\times 10^{-5}$ |        | 262 |
| $K^*(892)^- \pi^+, K^{*-} \rightarrow K_S^0 \pi^-$      | $(1.64 \begin{smallmatrix} + \\ - \end{smallmatrix} \begin{smallmatrix} 0.14 \\ 0.17 \end{smallmatrix})$     | %                |        | 711 |
| $K_0^*(1430)^- \pi^+, K_0^{*-} \rightarrow K_S^0 \pi^-$ | $(2.67 \begin{smallmatrix} + \\ - \end{smallmatrix} \begin{smallmatrix} 0.40 \\ 0.33 \end{smallmatrix})$     | $\times 10^{-3}$ |        | 378 |
| $K_2^*(1430)^- \pi^+, K_2^{*-} \rightarrow K_S^0 \pi^-$ | $(3.4 \begin{smallmatrix} + \\ - \end{smallmatrix} \begin{smallmatrix} 1.9 \\ 1.0 \end{smallmatrix})$        | $\times 10^{-4}$ |        | 367 |
| $K^*(1680)^- \pi^+, K^{*-} \rightarrow K_S^0 \pi^-$     | $(4.4 \pm 3.5)$  | $\times 10^{-4}$ |        | 46  |
| $K^*(892)^+ \pi^-, K^{*+} \rightarrow K_S^0 \pi^+$      | [v] $(1.13 \begin{smallmatrix} + \\ - \end{smallmatrix} \begin{smallmatrix} 0.60 \\ 0.34 \end{smallmatrix})$ | $\times 10^{-4}$ |        | 711 |
| $K_0^*(1430)^+ \pi^-, K_0^{*+} \rightarrow K_S^0 \pi^+$ | [v] $< 1.4$  | $\times 10^{-5}$ | CL=95% | –   |
| $K_2^*(1430)^+ \pi^-, K_2^{*+} \rightarrow K_S^0 \pi^+$ | [v] $< 3.4$  | $\times 10^{-5}$ | CL=95% | –   |
| $K_S^0 \pi^+ \pi^-$ nonresonant                         | $(2.5 \begin{smallmatrix} + \\ - \end{smallmatrix} \begin{smallmatrix} 6.0 \\ 1.6 \end{smallmatrix})$        | $\times 10^{-4}$ |        | 842 |
| $K^- \pi^+ \pi^0$                                       | [ij] $(14.4 \pm 0.5)$  | %                | S=2.0  | 844 |
| $K^- \rho^+$  | $(11.2 \pm 0.7)$   | %                |        | 675 |
| $K^- \rho(1700)^+, \rho^+ \rightarrow \pi^+ \pi^0$      | $(8.2 \pm 1.8)$  | $\times 10^{-3}$ |        | †   |

|   |   |       |     |
|---|---|-------|-----|
| $K^*(892)^- \pi^+$ , $K^*(892)^- \rightarrow$                                 | $( 2.31 \begin{smallmatrix} + 0.40 \\ - 0.20 \end{smallmatrix} ) \%$          |       | 711 |
| $\bar{K}^*(892)^0 \pi^0$ , $\bar{K}^*(892)^0 \rightarrow$                     | $( 1.95 \pm 0.24 ) \%$  |       | 711 |
| $K_0^*(1430)^- \pi^+$ , $K_0^{*-} \rightarrow$                                | $( 4.8 \pm 2.2 ) \times 10^{-3}$  |       | 378 |
| $\bar{K}_0^*(1430)^0 \pi^0$ , $\bar{K}_0^{*0} \rightarrow$                    | $( 5.9 \begin{smallmatrix} + 5.0 \\ - 1.6 \end{smallmatrix} ) \times 10^{-3}$ |       | 379 |
| $K^*(1680)^- \pi^+$ , $K^{*-} \rightarrow$                                    | $( 1.9 \pm 0.7 ) \times 10^{-3}$  |       | 46  |
| $K^- \pi^+ \pi^0$ nonresonant   | $( 1.15 \begin{smallmatrix} + 0.60 \\ - 0.20 \end{smallmatrix} ) \%$          |       | 844 |
| $K_S^0 2\pi^0$  | $( 9.1 \pm 1.1 ) \times 10^{-3}$  | S=2.2 | 843 |
| $K_S^0 (2\pi^0)_{S\text{-wave}}$  | $( 2.6 \pm 0.7 ) \times 10^{-3}$  |       | —   |
| $\bar{K}^*(892)^0 \pi^0$ , $\bar{K}^{*0} \rightarrow K_S^0 \pi^0$             | $( 8.1 \pm 0.7 ) \times 10^{-3}$  |       | 711 |
| $\bar{K}^*(1430)^0 \pi^0$ , $\bar{K}^{*0} \rightarrow$                        | $( 4 \pm 23 ) \times 10^{-5}$   |       | —   |
| $\bar{K}^*(1680)^0 \pi^0$ , $\bar{K}^{*0} \rightarrow$                        | $( 1.0 \pm 0.4 ) \times 10^{-3}$  |       | —   |
| $K_S^0 f_2(1270)$ , $f_2 \rightarrow 2\pi^0$                                  | $( 2.3 \pm 1.1 ) \times 10^{-4}$  |       | —   |
| $2K_S^0$ , one $K_S^0 \rightarrow 2\pi^0$                                     | $( 3.2 \pm 1.1 ) \times 10^{-4}$  |       | —   |
| $K^- 2\pi^+ \pi^-$  | [ij] $( 8.22 \pm 0.14 ) \%$   | S=1.1 | 813 |
| $K^- \pi^+ \rho^0$ total  | $( 6.86 \pm 0.31 ) \%$  |       | 609 |
| $K^- \pi^+ \rho^0$ 3-body   | $( 6.1 \pm 1.6 ) \times 10^{-3}$  |       | 609 |
| $\bar{K}^*(892)^0 \rho^0$ , $\bar{K}^{*0} \rightarrow$                        | $( 1.01 \pm 0.05 ) \%$  |       | 416 |
| $\bar{K}^*(892)^0 \rho^0$ transverse,<br>$\bar{K}^{*0} \rightarrow K^- \pi^+$ | $( 1.2 \pm 0.4 ) \%$  |       | 417 |
| $K^- a_1(1260)^+$ , $a_1^+ \rightarrow$                                       | $( 4.32 \pm 0.32 ) \%$  |       | 327 |
| $\rho^0 \pi^+$  |   |       |     |
| $K_1(1270)^- \pi^+$ , $K_1^- \rightarrow$                                     | $( 3.9 \pm 0.4 ) \times 10^{-3}$  |       | —   |
| $K^- \pi^+ \pi^-$ total   |   |       |     |
| $K_1(1270)^- \pi^+$ , $K_1^- \rightarrow$                                     | $( 6.6 \pm 2.3 ) \times 10^{-4}$  |       | 484 |
| $\bar{K}^*(892)^0 \pi^-$ , $\bar{K}^{*0} \rightarrow$                         |   |       |     |
| $K^- \pi^+$   |   |       |     |
| $K^- 2\pi^+ \pi^-$ nonresonant  | $( 1.81 \pm 0.07 ) \%$  |       | 813 |
| $K_S^0 \pi^+ \pi^- \pi^0$   | [xx] $( 5.2 \pm 0.6 ) \%$   |       | 813 |
| $K_S^0 \eta$ , $\eta \rightarrow \pi^+ \pi^- \pi^0$                           | $( 1.17 \pm 0.03 ) \times 10^{-3}$  |       | 772 |
| $K_S^0 \omega$ , $\omega \rightarrow \pi^+ \pi^- \pi^0$                       | $( 9.9 \pm 0.6 ) \times 10^{-3}$  |       | 670 |
| $K^- \pi^+ 2\pi^0$  | $( 8.86 \pm 0.23 ) \%$  |       | 815 |
| $K^- 2\pi^+ \pi^- \pi^0$  | $( 4.3 \pm 0.4 ) \%$  |       | 771 |
| $\bar{K}^*(892)^0 \pi^+ \pi^- \pi^0$ , $\bar{K}^{*0} \rightarrow$             | $( 1.3 \pm 0.6 ) \%$  |       | 643 |
| $K^- \pi^+$   |   |       |     |
| $K^- \pi^+ \omega$ , $\omega \rightarrow \pi^+ \pi^- \pi^0$                   | $( 2.8 \pm 0.5 ) \%$  |       | 605 |

|   |   |        |     |
|---|---|--------|-----|
| $\bar{K}^*(892)^0 \omega, \bar{K}^{*0} \rightarrow$<br>$K^- \pi^+, \omega \rightarrow$<br>$\pi^+ \pi^- \pi^0$ | $( 6.5 \pm 3.0 ) \times 10^{-3}$  |        | 410 |
| $K_S^0 \eta \pi^0$  | $( 1.01 \pm 0.05 ) \%$  |        | 721 |
| $K_S^0 a_0(980), a_0 \rightarrow \eta \pi^0$  | $( 1.20 \pm 0.28 ) \%$  |        | –   |
| $\bar{K}^*(892)^0 \eta, \bar{K}^{*0} \rightarrow K_S^0 \pi^0$   | $( 2.9 \pm 0.7 ) \times 10^{-3}$  |        | –   |
| $K^- \pi^+ \eta$  | $( 1.88 \pm 0.05 ) \%$  | S=1.4  | 721 |
| $K^*(892)^0 \eta, K^{*0} \rightarrow K^- \pi^+$   | $( 8.9 \begin{smallmatrix} + 0.8 \\ - 0.6 \end{smallmatrix} ) \times 10^{-3}$ |        | –   |
| $a_0(980)^+ K^-, a_0^+ \rightarrow \eta \pi^+$  | $( 7.4 \begin{smallmatrix} + 0.9 \\ - 0.7 \end{smallmatrix} ) \times 10^{-3}$ |        | –   |
| $K_2^*(1980)^- \pi^+, K_2^{*-} \rightarrow$<br>$K^- \eta$   | $( 2.2 \begin{smallmatrix} + 1.7 \\ - 1.9 \end{smallmatrix} ) \times 10^{-4}$ |        | –   |
| $K^- \pi^+ \pi^0 \eta$  | $( 4.49 \pm 0.27 ) \times 10^{-3}$  |        | 656 |
| $K_S^0 \pi^+ \pi^- \eta$  | $( 2.80 \pm 0.21 ) \times 10^{-3}$  |        | 651 |
| $K_S^0 2\pi^0 \eta$   | $( 1.76 \pm 0.26 ) \times 10^{-3}$  |        | 656 |
| $K_S^0 2\pi^+ 2\pi^-$   | $( 2.66 \pm 0.30 ) \times 10^{-3}$  |        | 768 |
| $K_S^0 \rho^0 \pi^+ \pi^-, \text{ no } K^*(892)^-$  | $( 1.1 \pm 0.7 ) \times 10^{-3}$  |        | –   |
| $K^*(892)^- 2\pi^+ \pi^-,$<br>$K^*(892)^- \rightarrow K_S^0 \pi^-,$<br>no $\rho^0$                            | $( 5 \pm 7 ) \times 10^{-4}$  |        | 642 |
| $K^*(892)^- \rho^0 \pi^+,$<br>$K^*(892)^- \rightarrow K_S^0 \pi^-$  | $( 1.6 \pm 0.6 ) \times 10^{-3}$  |        | 230 |
| $K_S^0 2\pi^+ 2\pi^- \text{ nonresonant}$   | $< 1.2 \times 10^{-3}$  | CL=90% | 768 |
| $K^- 3\pi^+ 2\pi^-$   | $( 2.2 \pm 0.6 ) \times 10^{-4}$  |        | 713 |

Fractions of some of the following modes with resonances have already appeared above as submodes of particular charged-particle modes. These nine modes below are all corrected for unseen decays of the resonances.

|                                      |                                    |        |     |
|--------------------------------------|------------------------------------|--------|-----|
| $K_S^0 \eta$                         | $( 5.08 \pm 0.13 ) \times 10^{-3}$ |        | 772 |
| $K_S^0 \omega$                       | $( 1.11 \pm 0.06 ) \%$             |        | 670 |
| $K_S^0 \eta'(958)$                   | $( 9.49 \pm 0.32 ) \times 10^{-3}$ |        | 565 |
| $\bar{K}^*(892)^0 \pi^+ \pi^- \pi^0$ | $( 1.9 \pm 0.9 ) \%$               |        | 643 |
| $\bar{K}^*(892)^0 \eta$              | $( 1.41 \pm 0.12 ) \%$             |        | 583 |
| $K^- \pi^+ \omega$                   | $( 3.1 \pm 0.6 ) \%$               |        | 605 |
| $\bar{K}^*(892)^0 \omega$            | $( 1.1 \pm 0.5 ) \%$               |        | 410 |
| $K^- \pi^+ \eta'(958)$               | $( 6.43 \pm 0.34 ) \times 10^{-3}$ |        | 479 |
| $K_S^0 \eta'(958) \pi^0$             | $( 2.52 \pm 0.27 ) \times 10^{-3}$ |        | 479 |
| $\bar{K}^*(892)^0 \eta'(958)$        | $< 1.0 \times 10^{-3}$             | CL=90% | 119 |

#### Hadronic modes with three K's

|   |                                    |  |     |
|---|------------------------------------|--|-----|
| $K_S^0 K^+ K^-$                               | $( 4.42 \pm 0.32 ) \times 10^{-3}$ |  | 544 |
| $K_S^0 a_0(980)^0, a_0^0 \rightarrow K^+ K^-$ | $( 2.9 \pm 0.4 ) \times 10^{-3}$   |  | –   |

|   |                                    |                  |           |
|---|------------------------------------|------------------|-----------|
| $K^- a_0(980)^+, a_0^+ \rightarrow K^+ K_S^0$   | $( 5.9 \pm 1.8 ) \times 10^{-4}$   |                  | —         |
| $K^+ a_0(980)^-, a_0^- \rightarrow K^- K_S^0$   | $< 1.1$                            | $\times 10^{-4}$ | CL=95% —  |
| $K_S^0 f_0(980), f_0 \rightarrow K^+ K^-$   | $< 9$                              | $\times 10^{-5}$ | CL=95% —  |
| $K_S^0 \phi, \phi \rightarrow K^+ K^-$  | $( 2.03 \pm 0.15 ) \times 10^{-3}$ |                  | 520       |
| $K_S^0 f_0(1370), f_0 \rightarrow K^+ K^-$  | $( 1.7 \pm 1.1 ) \times 10^{-4}$   |                  | —         |
| $3K_S^0$  | $( 7.5 \pm 0.7 ) \times 10^{-4}$   |                  | S=1.4 539 |
| $K^+ 2K^- \pi^+$  | $( 2.25 \pm 0.32 ) \times 10^{-4}$ |                  | 434       |
| $K^+ K^- \bar{K}^*(892)^0, \bar{K}^{*0} \rightarrow K^- \pi^+$                        | $( 4.5 \pm 1.8 ) \times 10^{-5}$   |                  | †         |
| $K^- \pi^+ \phi, \phi \rightarrow K^+ K^-$  | $( 4.0 \pm 1.7 ) \times 10^{-5}$   |                  | 422       |
| $\phi \bar{K}^*(892)^0, \phi \rightarrow K^+ K^-, \bar{K}^{*0} \rightarrow K^- \pi^+$ | $( 1.08 \pm 0.20 ) \times 10^{-4}$ |                  | †         |
| $K^+ 2K^- \pi^+$ nonresonant  | $( 3.4 \pm 1.5 ) \times 10^{-5}$   |                  | 434       |
| $2K_S^0 K^\pm \pi^\mp$  | $( 5.9 \pm 1.3 ) \times 10^{-4}$   |                  | 427       |

### Pionic modes

|  |                                      |  |           |
|--|--------------------------------------|--|-----------|
| $\pi^+ \pi^-$  | $( 1.453 \pm 0.024 ) \times 10^{-3}$ |  | S=1.4 922 |
| $2\pi^0$   | $( 8.26 \pm 0.25 ) \times 10^{-4}$   |  | 923       |
| $\pi^+ \pi^- \pi^0$  | $( 1.49 \pm 0.06 ) \%$               |  | S=2.1 907 |
| $\rho^+ \pi^-$   | $( 1.01 \pm 0.04 ) \%$               |  | 764       |
| $\rho^0 \pi^0$   | $( 3.86 \pm 0.23 ) \times 10^{-3}$   |  | 764       |
| $\rho^- \pi^+$   | $( 5.15 \pm 0.25 ) \times 10^{-3}$   |  | 764       |
| $\rho(1450)^+ \pi^-, \rho^+ \rightarrow \pi^+ \pi^0$       | $( 1.6 \pm 2.1 ) \times 10^{-5}$     |  | —         |
| $\rho(1450)^0 \pi^0, \rho^0 \rightarrow \pi^+ \pi^-$       | $( 4.5 \pm 1.9 ) \times 10^{-5}$     |  | —         |
| $\rho(1450)^- \pi^+, \rho^- \rightarrow \pi^- \pi^0$       | $( 2.7 \pm 0.4 ) \times 10^{-4}$     |  | —         |
| $\rho(1700)^+ \pi^-, \rho^+ \rightarrow \pi^+ \pi^0$       | $( 6.1 \pm 1.5 ) \times 10^{-4}$     |  | —         |
| $\rho(1700)^0 \pi^0, \rho^0 \rightarrow \pi^+ \pi^-$       | $( 7.4 \pm 1.8 ) \times 10^{-4}$     |  | —         |
| $\rho(1700)^- \pi^+, \rho^- \rightarrow \pi^- \pi^0$       | $( 4.8 \pm 1.1 ) \times 10^{-4}$     |  | —         |
| $f_0(980) \pi^0, f_0 \rightarrow \pi^+ \pi^-$              | $( 3.7 \pm 0.9 ) \times 10^{-5}$     |  | —         |
| $f_0(500) \pi^0, f_0 \rightarrow \pi^+ \pi^-$              | $( 1.22 \pm 0.22 ) \times 10^{-4}$   |  | —         |
| $f_0(1370) \pi^0, f_0 \rightarrow \pi^+ \pi^-$             | $( 5.5 \pm 2.1 ) \times 10^{-5}$     |  | —         |
| $f_0(1500) \pi^0, f_0 \rightarrow \pi^+ \pi^-$             | $( 5.8 \pm 1.6 ) \times 10^{-5}$     |  | —         |
| $f_0(1710) \pi^0, f_0 \rightarrow \pi^+ \pi^-$             | $( 4.6 \pm 1.6 ) \times 10^{-5}$     |  | —         |
| $f_2(1270) \pi^0, f_2 \rightarrow \pi^+ \pi^-$             | $( 1.96 \pm 0.21 ) \times 10^{-4}$   |  | —         |
| $\pi^+ \pi^- \pi^0$ nonresonant                            | $( 1.3 \pm 0.4 ) \times 10^{-4}$     |  | 907       |
| $3\pi^0$   | $( 2.0 \pm 0.5 ) \times 10^{-4}$     |  | 908       |
| $2\pi^+ 2\pi^-$  | $( 7.55 \pm 0.20 ) \times 10^{-3}$   |  | 880       |
| $a_1(1260)^+ \pi^-, a_1^+ \rightarrow 2\pi^+ \pi^-$ total  | $( 4.53 \pm 0.31 ) \times 10^{-3}$   |  | —         |
| $a_1(1260)^+ \pi^-, a_1^+ \rightarrow \rho^0 \pi^+$ S-wave | $( 3.13 \pm 0.21 ) \times 10^{-3}$   |  | —         |

|   |                                  |            |
|---|----------------------------------|------------|
| $a_1(1260)^+ \pi^-$ , $a_1^+ \rightarrow \rho^0 \pi^+$ <i>D-wave</i>                              | $(1.9 \pm 0.5) \times 10^{-4}$   | —          |
| $a_1(1260)^+ \pi^-$ , $a_1^+ \rightarrow \sigma \pi^+$  | $(6.4 \pm 0.7) \times 10^{-4}$   | —          |
| $a_1(1260)^- \pi^+$ , $a_1^- \rightarrow \rho^0 \pi^-$ <i>S-wave</i>                              | $(2.3 \pm 0.9) \times 10^{-4}$   | —          |
| $a_1(1260)^- \pi^+$ , $a_1^- \rightarrow \sigma \pi^-$  | $(6.0 \pm 3.4) \times 10^{-5}$   | —          |
| $\pi(1300)^+ \pi^-$ , $\pi(1300)^+ \rightarrow \sigma \pi^+$                                      | $(5.1 \pm 2.7) \times 10^{-4}$   | —          |
| $\pi(1300)^- \pi^+$ , $\pi(1300)^- \rightarrow \sigma \pi^-$                                      | $(2.3 \pm 2.2) \times 10^{-4}$   | —          |
| $a_1(1640)^+ \pi^-$ , $a_1^+ \rightarrow \rho^0 \pi^+$ <i>D-wave</i>                              | $(3.2 \pm 1.6) \times 10^{-4}$   | —          |
| $a_1(1640)^+ \pi^-$ , $a_1^+ \rightarrow \sigma \pi^+$  | $(1.8 \pm 1.4) \times 10^{-4}$   | —          |
| $\pi_2(1670)^+ \pi^-$ , $\pi_2^+ \rightarrow f_2(1270)^0 \pi^+$ , $f_2^0 \rightarrow \pi^+ \pi^-$ | $(2.0 \pm 0.9) \times 10^{-4}$   | —          |
| $\pi_2(1670)^+ \pi^-$ , $\pi_2^+ \rightarrow \sigma \pi^+$  | $(2.6 \pm 1.0) \times 10^{-4}$   | —          |
| $2\rho^0$ total   | $(1.85 \pm 0.13) \times 10^{-3}$ | 518        |
| $2\rho^0$ , parallel helicities   | $(8.3 \pm 3.2) \times 10^{-5}$   | —          |
| $2\rho^0$ , perpendicular helicities  | $(4.8 \pm 0.6) \times 10^{-4}$   | —          |
| $2\rho^0$ , longitudinal helicities   | $(1.27 \pm 0.10) \times 10^{-3}$ | —          |
| $2\rho(770)^0$ , <i>S-wave</i>  | $(1.8 \pm 1.3) \times 10^{-4}$   | —          |
| $2\rho(770)^0$ , <i>P-wave</i>  | $(5.3 \pm 1.3) \times 10^{-4}$   | —          |
| $2\rho(770)^0$ , <i>D-wave</i>  | $(6.2 \pm 3.0) \times 10^{-4}$   | —          |
| Resonant $(\pi^+ \pi^-) \pi^+ \pi^-$ 3-body total   | $(1.51 \pm 0.12) \times 10^{-3}$ | —          |
| $\sigma \pi^+ \pi^-$  | $(6.2 \pm 0.9) \times 10^{-4}$   | —          |
| $\sigma \rho(770)^0$  | $(5.0 \pm 2.5) \times 10^{-4}$   | —          |
| $f_0(980) \pi^+ \pi^-$ , $f_0 \rightarrow \pi^+ \pi^-$  | $(1.8 \pm 0.5) \times 10^{-4}$   | —          |
| $f_2(1270) \pi^+ \pi^-$ , $f_2 \rightarrow \pi^+ \pi^-$   | $(3.7 \pm 0.6) \times 10^{-4}$   | —          |
| $2f_2(1270)$ , $f_2 \rightarrow \pi^+ \pi^-$  | $(1.6 \pm 1.8) \times 10^{-4}$   | —          |
| $f_0(1370) \sigma$ , $f_0 \rightarrow \pi^+ \pi^-$  | $(1.6 \pm 0.5) \times 10^{-3}$   | —          |
| $\pi^+ \pi^- 2\pi^0$  | $(1.02 \pm 0.09) \%$             | 882        |
| $\eta \pi^0$ [yy]   | $(6.3 \pm 0.6) \times 10^{-4}$   | S=1.1 846  |
| $\omega \pi^0$ [yy]   | $(1.17 \pm 0.35) \times 10^{-4}$ | 761        |
| $\omega \eta$   | $(1.98 \pm 0.18) \times 10^{-3}$ | S=1.1 648  |
| $2\pi^+ 2\pi^- \pi^0$   | $(4.2 \pm 0.5) \times 10^{-3}$   | 844        |
| $\eta \pi^+ \pi^-$ [yy]   | $(1.16 \pm 0.07) \times 10^{-3}$ | 827        |
| $\omega \pi^+ \pi^-$ [yy]   | $(1.33 \pm 0.20) \times 10^{-3}$ | 738        |
| $\omega \pi^0 \pi^0$  | $< 1.10 \times 10^{-3}$          | CL=90% 740 |

|                          |                                    |        |     |
|--------------------------|------------------------------------|--------|-----|
| $\eta 2\pi^0$            | $( 3.8 \pm 1.3 ) \times 10^{-4}$   |        | 829 |
| $\pi^+ \pi^- \pi^0 \eta$ | $( 3.23 \pm 0.22 ) \times 10^{-3}$ |        | 797 |
| $3\pi^+ 3\pi^-$          | $( 4.3 \pm 1.2 ) \times 10^{-4}$   |        | 795 |
| $\eta'(958)\pi^0$        | $( 9.2 \pm 1.0 ) \times 10^{-4}$   |        | 678 |
| $\eta'(958)\pi^+ \pi^-$  | $( 4.5 \pm 1.7 ) \times 10^{-4}$   |        | 650 |
| $2\eta$                  | $( 2.11 \pm 0.19 ) \times 10^{-3}$ | S=2.3  | 754 |
| $2\eta\pi^0$             | $( 7.3 \pm 2.2 ) \times 10^{-4}$   |        | 699 |
| $3\eta$                  | $< 1.3 \times 10^{-4}$             | CL=90% | 421 |
| $\eta\eta'(958)$         | $( 1.01 \pm 0.19 ) \times 10^{-3}$ |        | 537 |

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

|  |                                    |       |     |
|--|------------------------------------|-------|-----|
| $K^+ K^-$  | $( 4.08 \pm 0.06 ) \times 10^{-3}$ | S=1.6 | 791 |
| $2K_S^0$   | $( 1.41 \pm 0.05 ) \times 10^{-4}$ | S=1.1 | 789 |
| $K_S^0 K^- \pi^+$  | $( 3.3 \pm 0.5 ) \times 10^{-3}$   | S=1.1 | 739 |
| $\bar{K}^*(892)^0 K_S^0, \bar{K}^{*0} \rightarrow$<br>$K^- \pi^+$  | $( 8.2 \pm 1.6 ) \times 10^{-5}$   |       | 608 |
| $K^*(892)^+ K^-, K^{*+} \rightarrow$<br>$K_S^0 \pi^+$              | $( 1.89 \pm 0.30 ) \times 10^{-3}$ |       | —   |
| $\bar{K}^*(1410)^0 K_S^0, \bar{K}^{*0} \rightarrow$<br>$K^- \pi^+$ | $( 1.3 \pm 1.9 ) \times 10^{-4}$   |       | —   |
| $K^*(1410)^+ K^-, K^{*+} \rightarrow$<br>$K_S^0 \pi^+$             | $( 3.2 \pm 1.9 ) \times 10^{-4}$   |       | —   |
| $(K^- \pi^+)_{S\text{-wave}} K_S^0$                                | $( 6.0 \pm 2.9 ) \times 10^{-4}$   |       | 739 |
| $(K_S^0 \pi^+)_{S\text{-wave}} K^-$                                | $( 3.9 \pm 1.0 ) \times 10^{-4}$   |       | 739 |
| $a_0(980)^- \pi^+, a_0^- \rightarrow K_S^0 K^-$                    | $( 1.3 \pm 1.4 ) \times 10^{-4}$   |       | —   |
| $a_0(1450)^- \pi^+, a_0^- \rightarrow$<br>$K_S^0 K^-$              | $( 2.5 \pm 2.0 ) \times 10^{-5}$   |       | —   |
| $a_2(1320)^- \pi^+, a_2^- \rightarrow$<br>$K_S^0 K^-$              | $( 5 \pm 5 ) \times 10^{-6}$       |       | —   |
| $\rho(1450)^- \pi^+, \rho^- \rightarrow K_S^0 K^-$                 | $( 4.6 \pm 2.5 ) \times 10^{-5}$   |       | —   |
| $K_S^0 K^+ \pi^-$  | $( 2.17 \pm 0.34 ) \times 10^{-3}$ | S=1.1 | 739 |
| $K^*(892)^0 K_S^0, K^{*0} \rightarrow$<br>$K^+ \pi^-$              | $( 1.12 \pm 0.21 ) \times 10^{-4}$ |       | 608 |
| $K^*(892)^- K^+, K^{*-} \rightarrow$<br>$K_S^0 \pi^-$              | $( 6.2 \pm 1.0 ) \times 10^{-4}$   |       | —   |
| $K^*(1410)^0 K_S^0, K^{*0} \rightarrow$<br>$K^+ \pi^+$             | $( 5 \pm 8 ) \times 10^{-5}$       |       | —   |
| $K^*(1410)^- K^+, K^{*-} \rightarrow$<br>$K_S^0 \pi^-$             | $( 2.6 \pm 2.0 ) \times 10^{-4}$   |       | —   |
| $(K^+ \pi^-)_{S\text{-wave}} K_S^0$                                | $( 3.7 \pm 1.9 ) \times 10^{-4}$   |       | 739 |
| $(K_S^0 \pi^-)_{S\text{-wave}} K^+$                                | $( 1.4 \pm 0.6 ) \times 10^{-4}$   |       | 739 |
| $a_0(980)^+ \pi^-, a_0^+ \rightarrow K_S^0 K^+$                    | $( 6 \pm 4 ) \times 10^{-4}$       |       | —   |

|  |                                    |     |
|--|------------------------------------|-----|
| $a_0(1450)^+ \pi^-$ , $a_0^+ \rightarrow$<br>$K_S^0 K^+$   | $( 3.2 \pm 2.5 ) \times 10^{-5}$   | —   |
| $\rho(1700)^+ \pi^-$ , $\rho^+ \rightarrow$ $K_S^0 K^+$  | $( 1.1 \pm 0.6 ) \times 10^{-5}$   | —   |
| $K^+ K^- \pi^0$  | $( 3.42 \pm 0.14 ) \times 10^{-3}$ | 743 |
| $K^*(892)^+ K^-$ , $K^*(892)^+ \rightarrow$<br>$K^+ \pi^0$   | $( 1.52 \pm 0.07 ) \times 10^{-3}$ | —   |
| $K^*(892)^- K^+$ , $K^*(892)^- \rightarrow$<br>$K^- \pi^0$   | $( 5.4 \pm 0.4 ) \times 10^{-4}$   | —   |
| $(K^+ \pi^0)_{S-wave} K^-$   | $( 2.43 \pm 0.18 ) \times 10^{-3}$ | 743 |
| $(K^- \pi^0)_{S-wave} K^+$   | $( 1.3 \pm 0.5 ) \times 10^{-4}$   | 743 |
| $f_0(980) \pi^0$ , $f_0 \rightarrow$ $K^+ K^-$   | $( 3.6 \pm 0.6 ) \times 10^{-4}$   | —   |
| $\phi \pi^0$ , $\phi \rightarrow$ $K^+ K^-$  | $( 6.6 \pm 0.4 ) \times 10^{-4}$   | —   |
| $2K_S^0 \pi^0$   | $< 5.9 \times 10^{-4}$             | 740 |
| $K^+ K^- \eta$   | $( 5.9 \pm 1.9 ) \times 10^{-5}$   | 514 |
| $2K_S^0 \eta$  | $( 1.3 \pm 0.6 ) \times 10^{-4}$   | 508 |
| $K^+ K^- \pi^0 \pi^0$  | $( 6.9 \pm 0.8 ) \times 10^{-4}$   | 681 |
| $K^+ K^- \pi^+ \pi^-$  | $( 2.47 \pm 0.11 ) \times 10^{-3}$ | 677 |
| $\phi(\pi^+ \pi^-)_{S-wave}$ , $\phi \rightarrow$<br>$K^+ K^-$                                       | $( 10 \pm 5 ) \times 10^{-5}$      | 614 |
| $(\phi \rho^0)_{S-wave}$ , $\phi \rightarrow$ $K^+ K^-$  | $( 6.9 \pm 0.6 ) \times 10^{-4}$   | 250 |
| $(\phi \rho^0)_{P-wave}$ , $\phi \rightarrow$ $K^+ K^-$  | $( 4.0 \pm 1.9 ) \times 10^{-5}$   | —   |
| $(\phi \rho^0)_{D-wave}$ , $\phi \rightarrow$ $K^+ K^-$  | $( 4.2 \pm 1.4 ) \times 10^{-5}$   | —   |
| $(K^*(892)^0 \bar{K}^*(892)^0)_{S-wave}$ ,<br>$K^{*0} \rightarrow$ $K^\pm \pi^\mp$                   | $( 2.24 \pm 0.13 ) \times 10^{-4}$ | —   |
| $(K^*(892)^0 \bar{K}^*(892)^0)_{P-wave}$ ,<br>$K^* \rightarrow$ $K^\pm \pi^\mp$                      | $( 1.20 \pm 0.08 ) \times 10^{-4}$ | —   |
| $(K^*(892)^0 \bar{K}^*(892)^0)_{D-wave}$ ,<br>$K^* \rightarrow$ $K^\pm \pi^\mp$                      | $( 4.7 \pm 0.4 ) \times 10^{-5}$   | —   |
| $K^*(892)^0 (K^- \pi^+)_{S-wave}$<br>3-body, $K^{*0} \rightarrow$ $K^+ \pi^-$                        | $( 1.4 \pm 0.6 ) \times 10^{-4}$   | —   |
| $K_1(1270)^+ K^-$ , $K_1^+ \rightarrow$<br>$K^{*0} \pi^+$  | $( 1.4 \pm 0.9 ) \times 10^{-4}$   | —   |
| $K_1(1270)^+ K^-$ , $K_1^+ \rightarrow$<br>$K^*(1430)^0 \pi^+$ , $K^{*0} \rightarrow$<br>$K^+ \pi^-$ | $( 1.5 \pm 0.5 ) \times 10^{-4}$   | —   |
| $K_1(1270)^+ K^-$ , $K_1^+ \rightarrow$<br>$\rho^0 K^+$  | $( 2.2 \pm 0.6 ) \times 10^{-4}$   | —   |
| $K_1(1270)^+ K^-$ , $K_1^+ \rightarrow$<br>$\omega(782) K^+$ , $\omega \rightarrow$ $\pi^+ \pi^-$    | $( 1.5 \pm 1.2 ) \times 10^{-5}$   | —   |
| $K_1(1270)^- K^+$ , $K_1^- \rightarrow$<br>$\rho^0 K^-$  | $( 1.3 \pm 0.4 ) \times 10^{-4}$   | —   |
| $K_1(1400)^+ K^-$ , $K_1^+ \rightarrow$<br>$K^*(892)^0 \pi^+$ , $K^{*0} \rightarrow$<br>$K^+ \pi^-$  | $( 4.6 \pm 0.4 ) \times 10^{-4}$   | —   |

|   |                                    |            |
|---|------------------------------------|------------|
| $K^*(1410)^- K^+, K^{*-} \rightarrow \bar{K}^{*0} \pi^-$                        | $( 7.0 \pm 1.1 ) \times 10^{-5}$   | —          |
| $K_1(1680)^+ K^-, K_1^+ \rightarrow K^{*0} \pi^+, K^{*0} \rightarrow K^+ \pi^-$ | $( 8.9 \pm 3.2 ) \times 10^{-5}$   | —          |
| $K^+ K^- \pi^+ \pi^-$ non-resonant  | $( 2.7 \pm 0.6 ) \times 10^{-4}$   | —          |
| $2K_S^0 \pi^+ \pi^-$  | $( 5.3 \pm 0.9 ) \times 10^{-4}$   | 673        |
| $K_S^0 K^- \pi^+ \pi^0$   | $( 1.32 \pm 0.16 ) \times 10^{-3}$ | 677        |
| $K_S^0 K^+ \pi^- \pi^0$   | $( 6.5 \pm 0.7 ) \times 10^{-4}$   | 677        |
| $K_S^0 K^- 2\pi^+ \pi^-$  | $< 1.4 \times 10^{-4}$             | CL=90% 595 |
| $K^+ K^- \pi^+ \pi^- \pi^0$   | $( 3.1 \pm 2.0 ) \times 10^{-3}$   | 600        |

Other  $K\bar{K}X$  modes. They include all decay modes of the  $\phi$ ,  $\eta$ , and  $\omega$ .

|               |                                    |            |
|---------------|------------------------------------|------------|
| $\phi \pi^0$  | $( 1.17 \pm 0.04 ) \times 10^{-3}$ | 645        |
| $\phi \eta$   | $( 1.8 \pm 0.5 ) \times 10^{-4}$   | 489        |
| $\phi \omega$ | $< 2.1 \times 10^{-3}$             | CL=90% 238 |

### Radiative modes

|                     |                                    |            |
|---------------------|------------------------------------|------------|
| $\rho^0 \gamma$     | $( 1.82 \pm 0.32 ) \times 10^{-5}$ | 771        |
| $\omega \gamma$     | $< 2.4 \times 10^{-4}$             | CL=90% 768 |
| $\phi \gamma$       | $( 2.81 \pm 0.19 ) \times 10^{-5}$ | 654        |
| $K^*(892)^0 \gamma$ | $( 4.1 \pm 0.7 ) \times 10^{-4}$   | 719        |

### Doubly Cabibbo suppressed (DC) modes or $\Delta C = 2$ forbidden via mixing (C2M) modes

|  |   |            |
|--|---|------------|
| $K^+ \ell^- \bar{\nu}_\ell$ via $\bar{D}^0$                | $< 2.2 \times 10^{-5}$                        | CL=90% —   |
| $K^+$ or $K^*(892)^+$ $e^- \bar{\nu}_e$ via $\bar{D}^0$    | $< 6 \times 10^{-5}$                          | CL=90% —   |
| $K^+ \pi^-$ DC   | $( 1.50 \pm 0.07 ) \times 10^{-4}$            | S=3.0 861  |
| $K^+ \pi^-$ via DCS  | $( 1.363 \pm 0.025 ) \times 10^{-4}$          | —          |
| $K^+ \pi^-$ via $\bar{D}^0$                                | $< 1.6 \times 10^{-5}$                        | CL=95% 861 |
| $K_S^0 \pi^+ \pi^-$ in $D^0 \rightarrow \bar{D}^0$         | $< 1.8 \times 10^{-4}$                        | CL=95% —   |
| $K^*(892)^+ \pi^-, K^{*+} \rightarrow K_S^0 \pi^+$ DC      | $( 1.13 \pm_{-0.34}^{+0.60} ) \times 10^{-4}$ | 711        |
| $K_0^*(1430)^+ \pi^-, K_0^{*+} \rightarrow K_S^0 \pi^+$ DC | $< 1.4 \times 10^{-5}$                        | —          |
| $K_2^*(1430)^+ \pi^-, K_2^{*+} \rightarrow K_S^0 \pi^+$ DC | $< 3.4 \times 10^{-5}$                        | —          |
| $K^+ \pi^- \pi^0$ DC                                       | $( 3.05 \pm 0.15 ) \times 10^{-4}$            | 844        |
| $K^+ \pi^- \pi^0$ via $\bar{D}^0$                          | $( 7.6 \pm_{-0.6}^{+0.5} ) \times 10^{-4}$    | —          |
| $K^+ \pi^+ 2\pi^-$ via DCS                                 | $( 2.49 \pm 0.07 ) \times 10^{-4}$            | —          |
| $K^+ \pi^+ 2\pi^-$ DC                                      | $( 2.65 \pm 0.06 ) \times 10^{-4}$            | 813        |
| $K^+ \pi^+ 2\pi^-$ via $\bar{D}^0$                         | $( 7.9 \pm 3.0 ) \times 10^{-6}$              | 812        |
| $\mu^-$ anything via $\bar{D}^0$                           | $< 4 \times 10^{-4}$                          | CL=90% —   |



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

|   |      |                     |                  |        |     |
|---|------|---------------------|------------------|--------|-----|
| $\gamma\gamma$  | C1   | < 8.5               | $\times 10^{-7}$ | CL=90% | 932 |
| $e^+e^-$  | C1   | < 7.9               | $\times 10^{-8}$ | CL=90% | 932 |
| $\mu^+\mu^-$  | C1   | < 6.2               | $\times 10^{-9}$ | CL=90% | 926 |
| $\pi^0 e^+e^-$  | C1   | < 4                 | $\times 10^{-6}$ | CL=90% | 928 |
| $\pi^0 \mu^+\mu^-$                                      | C1   | < 1.8               | $\times 10^{-4}$ | CL=90% | 915 |
| $\eta e^+e^-$   | C1   | < 3                 | $\times 10^{-6}$ | CL=90% | 852 |
| $\eta \mu^+\mu^-$                                       | C1   | < 5.3               | $\times 10^{-4}$ | CL=90% | 838 |
| $\pi^+\pi^- e^+e^-$                                     | C1   | < 7                 | $\times 10^{-6}$ | CL=90% | 922 |
| $\rho^0 e^+e^-$   | C1   | < 1.0               | $\times 10^{-4}$ | CL=90% | 771 |
| $\pi^+\pi^-\mu^+\mu^-$                                  | C1   | ( 9.6 $\pm$ 1.2 )   | $\times 10^{-7}$ |        | 894 |
| $\pi^+\pi^-\mu^+\mu^-$ (non-res)                        |      | < 5.5               | $\times 10^{-7}$ | CL=90% | –   |
| $\rho^0 \mu^+\mu^-$                                     | C1   | < 2.2               | $\times 10^{-5}$ | CL=90% | 754 |
| $\omega e^+e^-$   | C1   | < 6                 | $\times 10^{-6}$ | CL=90% | 768 |
| $\omega \mu^+\mu^-$                                     | C1   | < 8.3               | $\times 10^{-4}$ | CL=90% | 751 |
| $K^-K^+ e^+e^-$   | C1   | < 1.1               | $\times 10^{-5}$ | CL=90% | 791 |
| $\phi e^+e^-$   | C1   | < 5.2               | $\times 10^{-5}$ | CL=90% | 654 |
| $K^-K^+ \mu^+\mu^-$                                     | C1   | ( 1.54 $\pm$ 0.32 ) | $\times 10^{-7}$ |        | 710 |
| $K^-K^+ \mu^+\mu^-$ (non-res)                           |      | < 3.3               | $\times 10^{-5}$ | CL=90% | –   |
| $\phi \mu^+\mu^-$                                       | C1   | < 3.1               | $\times 10^{-5}$ | CL=90% | 631 |
| $\overline{K}^0 e^+e^-$                                 | [pp] | < 2.4               | $\times 10^{-5}$ | CL=90% | 866 |
| $\overline{K}^0 \mu^+\mu^-$                             | [pp] | < 2.6               | $\times 10^{-4}$ | CL=90% | 852 |
| $K^-\pi^+ e^+e^-$ , 675 <<br>$m_{ee} < 875$ MeV         |      | ( 4.0 $\pm$ 0.5 )   | $\times 10^{-6}$ |        | –   |
| $K^-\pi^+ e^+e^-$ , 1.005 <<br>$m_{ee} < 1.035$ GeV     |      | < 5                 | $\times 10^{-7}$ | CL=90% | –   |
| $\overline{K}^*(892)^0 e^+e^-$                          | [pp] | < 4.7               | $\times 10^{-5}$ | CL=90% | 719 |
| $K^-\pi^+ \mu^+\mu^-$                                   | C1   | < 3.59              | $\times 10^{-4}$ | CL=90% | 829 |
| $K^-\pi^+ \mu^+\mu^-$ , 675 <<br>$m_{\mu\mu} < 875$ MeV |      | ( 4.2 $\pm$ 0.4 )   | $\times 10^{-6}$ |        | –   |
| $\overline{K}^*(892)^0 \mu^+\mu^-$                      | [pp] | < 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   | [aa] < 1.3          | $\times 10^{-8}$ | CL=90% | 929 |
| $\pi^0 e^\pm \mu^\mp$                                   | LF   | [aa] < 8.0          | $\times 10^{-7}$ | CL=90% | 924 |
| $\eta e^\pm \mu^\mp$                                    | LF   | [aa] < 2.25         | $\times 10^{-6}$ | CL=90% | 848 |
| $\pi^+\pi^- e^\pm \mu^\mp$                              | LF   | [aa] < 1.71         | $\times 10^{-6}$ | CL=90% | 911 |
| $\rho^0 e^\pm \mu^\mp$                                  | LF   | [aa] < 5.0          | $\times 10^{-7}$ | CL=90% | 767 |
| $\omega e^\pm \mu^\mp$                                  | LF   | [aa] < 1.71         | $\times 10^{-6}$ | CL=90% | 764 |
| $K^-K^+ e^\pm \mu^\mp$                                  | LF   | [aa] < 1.00         | $\times 10^{-6}$ | CL=90% | 754 |
| $\phi e^\pm \mu^\mp$                                    | LF   | [aa] < 5.1          | $\times 10^{-7}$ | CL=90% | 648 |
| $\overline{K}^0 e^\pm \mu^\mp$                          | LF   | [aa] < 1.74         | $\times 10^{-6}$ | CL=90% | 863 |
| $K^-\pi^+ e^\pm \mu^\mp$                                | LF   | [aa] < 1.90         | $\times 10^{-6}$ | CL=90% | 848 |

|                                  |       |               |                  |        |     |
|----------------------------------|-------|---------------|------------------|--------|-----|
| $\bar{K}^*(892)^0 e^\pm \mu^\mp$ | $LF$  | $[aa] < 1.25$ | $\times 10^{-6}$ | CL=90% | 714 |
| $2\pi^- 2e^+$                    | $L$   | $< 9.1$       | $\times 10^{-7}$ | CL=90% | 922 |
| $2\pi^- 2\mu^+$                  | $L$   | $< 1.52$      | $\times 10^{-6}$ | CL=90% | 894 |
| $K^- \pi^- 2e^+$                 | $L$   | $< 5.0$       | $\times 10^{-7}$ | CL=90% | 861 |
| $K^- \pi^- 2\mu^+$               | $L$   | $< 5.3$       | $\times 10^{-7}$ | CL=90% | 829 |
| $2K^- 2e^+$                      | $L$   | $< 3.4$       | $\times 10^{-7}$ | CL=90% | 791 |
| $2K^- 2\mu^+$                    | $L$   | $< 1.0$       | $\times 10^{-7}$ | CL=90% | 710 |
| $\pi^- \pi^- e^+ \mu^+$          | $L$   | $< 3.06$      | $\times 10^{-6}$ | CL=90% | 911 |
| $K^- \pi^- e^+ \mu^+$            | $L$   | $< 2.10$      | $\times 10^{-6}$ | CL=90% | 848 |
| $2K^- e^+ \mu^+$                 | $L$   | $< 5.8$       | $\times 10^{-7}$ | CL=90% | 754 |
| $p e^-$                          | $L,B$ | $[zz] < 1.0$  | $\times 10^{-5}$ | CL=90% | 696 |
| $\bar{p} e^+$                    | $L,B$ | $[aaa] < 1.1$ | $\times 10^{-5}$ | CL=90% | 696 |

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

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

$I, J, P$  need confirmation.

$$\text{Mass } m = 2006.85 \pm 0.05 \text{ MeV} \quad (S = 1.1)$$

$$m_{D^{*0}} - m_{D^0} = 142.014 \pm 0.030 \text{ MeV} \quad (S = 1.5)$$

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

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

| $D^*(2007)^0$ DECAY MODES | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|---------------------------|--------------------------------|-------------|
| $D^0 \pi^0$               | $(64.7 \pm 0.9) \%$            | 43          |
| $D^0 \gamma$              | $(35.3 \pm 0.9) \%$            | 137         |

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

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

$I, J, P$  need confirmation.

$$\text{Mass } m = 2010.26 \pm 0.05 \text{ MeV}$$

$$m_{D^{*(2010)^+}} - m_{D^+} = 140.603 \pm 0.015 \text{ MeV}$$

$$m_{D^{*(2010)^+}} - m_{D^0} = 145.4258 \pm 0.0017 \text{ MeV}$$

$$\text{Full width } \Gamma = 83.4 \pm 1.8 \text{ keV}$$

$D^*(2010)^-$  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         |

**$D_0^*(2300)$**

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

was  $D_0^*(2400)$

Mass  $m = 2343 \pm 10$  MeV (S = 1.5)

Full width  $\Gamma = 229 \pm 16$  MeV

| <b><math>D_0^*(2300)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|---|--------------------------------|-------------|
| $D\pi^\pm$                                  | seen                           | 411         |

**$D_1(2420)$**

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

Mass  $m = 2422.1 \pm 0.6$  MeV (S = 1.7)

$m_{D_1(2420)^0} - m_{D^{*+}} = 411.8 \pm 0.6$  MeV (S = 1.7)

$m_{D_1(2420)^\pm} - m_{D_1(2420)^0} = 4 \pm 4$  MeV

Full width  $\Gamma = 31.3 \pm 1.9$  MeV (S = 2.8)

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

| <b><math>D_1(2420)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|---|--------------------------------|-------------|
| $D^*(2007)^0\pi$                          | seen                           | 359         |

**$D_1(2430)^0$**

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

Mass  $m = 2412 \pm 9$  MeV

Full width  $\Gamma = 314 \pm 29$  MeV

| <b><math>D_1(2430)^0</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|---|--------------------------------|-------------|
| $D^*(2010)^+\pi^-$                          | seen                           | 345         |

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

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

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

Mass  $m = 2461.1^{+0.7}_{-0.8}$  MeV (S = 6.2)

$m_{D_2^*(2460)^0} - m_{D^+} = 591.5^{+0.7}_{-0.8}$  MeV (S = 5.9)

$m_{D_2^*(2460)^0} - m_{D^{*+}} = 450.9^{+0.7}_{-0.8}$  MeV (S = 5.9)

$m_{D_2^*(2460)^\pm} - m_{D_2^*(2460)^0} = 2.4 \pm 1.7$  MeV

Full width  $\Gamma = 47.3 \pm 0.8$  MeV (S = 1.5)

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

| $D_2^*(2460)$ DECAY MODES | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|---------------------------|--------------------------------|-------------|
| $D\pi^-$                  | seen                           | 509         |
| $D^*(2010)\pi^-$          | seen                           | 389         |

**$D_3^*(2750)$**

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

Mass  $m = 2763.1 \pm 3.2$  MeV ( $S = 2.1$ )

Full width  $\Gamma = 66 \pm 5$  MeV

| $D_3^*(2750)$ DECAY MODES | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|---------------------------|--------------------------------|-------------|
| $D\pi$                    | seen                           | 743         |
| $D^+\pi^-$                | seen                           | 739         |
| $D^0\pi^\pm$              | seen                           | 743         |
| $D^*\pi$                  | seen                           | 639         |
| $D^{*+}\pi^-$             | seen                           | 639         |

## CHARMED, STRANGE MESONS ( $C = S = \pm 1$ ) (including possibly non- $q\bar{q}$ states)

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

**$D_s^\pm$**

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

Mass  $m = 1968.35 \pm 0.07$  MeV

$m_{D_s^\pm} - m_{D^\pm} = 98.69 \pm 0.05$  MeV

Mean life  $\tau = (504 \pm 4) \times 10^{-15}$  s ( $S = 1.2$ )

$c\tau = 151.2$   $\mu\text{m}$

### CP-violating decay-rate asymmetries

$$A_{CP}(\mu^\pm\nu) = (5 \pm 6)\%$$

$$A_{CP}(K^\pm K_S^0) = (0.09 \pm 0.26)\%$$

$$A_{CP}(K^\pm K_L^0) \text{ in } D_s^\pm \rightarrow K^\pm K_L^0 = (-1.1 \pm 2.7) \times 10^{-2}$$

$$A_{CP}(K^+ K^- \pi^\pm) = (-0.5 \pm 0.9)\%$$

$$A_{CP}(\phi\pi^\pm) = (-0.38 \pm 0.27)\%$$

$$A_{CP}(K^\pm K_S^0 \pi^0) = (-2 \pm 6)\%$$

$$\begin{aligned}
 A_{CP}(2K_S^0 \pi^\pm) &= (3 \pm 5)\% \\
 A_{CP}(K^+ K^- \pi^\pm \pi^0) &= (0.0 \pm 3.0)\% \\
 A_{CP}(K^\pm K_S^0 \pi^+ \pi^-) &= (-6 \pm 5)\% \\
 A_{CP}(K_S^0 K^\mp 2\pi^\pm) &= (4.1 \pm 2.8)\% \\
 A_{CP}(\pi^+ \pi^- \pi^\pm) &= (-0.7 \pm 3.1)\% \\
 A_{CP}(\pi^\pm \eta) &= (1.1 \pm 3.1)\% \\
 A_{CP}(\pi^\pm \eta') &= (-0.9 \pm 0.5)\% \\
 A_{CP}(\eta \pi^\pm \pi^0) &= (-1 \pm 4)\% \\
 A_{CP}(\eta' \pi^\pm \pi^0) &= (0 \pm 8)\% \\
 A_{CP}(K^\pm \pi^0) &= (-27 \pm 24)\% \\
 A_{CP}(\bar{K}^0 / K^0 \pi^\pm) &= (0.4 \pm 0.5)\% \\
 A_{CP}(K_S^0 \pi^\pm) &= (0.20 \pm 0.18)\% \\
 A_{CP}(K^\pm \pi^+ \pi^-) &= (4 \pm 5)\% \\
 A_{CP}(K^\pm \eta) &= (9 \pm 15)\% \\
 A_{CP}(K^\pm \eta'(958)) &= (6 \pm 19)\%
 \end{aligned}$$

**CP violating asymmetries of P-odd (T-odd) moments**

$$A_T(K_S^0 K^\pm \pi^+ \pi^-) = (-14 \pm 8) \times 10^{-3} [ii]$$

**$D_s^+ \rightarrow \phi \ell^+ \nu_\ell$  form factors**

$$\begin{aligned}
 r_2 &= 0.84 \pm 0.11 \quad (S = 2.4) \\
 r_V &= 1.80 \pm 0.08 \\
 \Gamma_L / \Gamma_T &= 0.72 \pm 0.18 \\
 f_+(0) |V_{cs}| \text{ in } D_s^+ \rightarrow \eta e^+ \nu_e &= 0.446 \pm 0.007 \\
 f_+(0) |V_{cs}| \text{ in } D_s^+ \rightarrow \eta' e^+ \nu_e &= 0.48 \pm 0.05 \\
 f_+(0) |V_{cd}| \text{ in } D_s^+ \rightarrow K^0 e^+ \nu_e &= 0.162 \pm 0.019 \\
 r_V \equiv V(0)/A_1(0) \text{ in } D_s^+ \rightarrow K^*(892)^0 e^+ \nu_e &= 1.7 \pm 0.4 \\
 r_2 \equiv A_2(0)/A_1(0) \text{ in } D_s^+ \rightarrow K^*(892)^0 e^+ \nu_e &= 0.77 \pm 0.29 \\
 f_{D_s^+} |V_{cs}| \text{ in } D_s^+ \rightarrow \mu^+ \nu_\mu &= 246 \pm 5 \text{ MeV}
 \end{aligned}$$

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/<br>Confidence level | $p$<br>(MeV/c) |
|------------------------|--------------------------------|-----------------------------------|----------------|
| <b>Inclusive modes</b> |                                |                                   |                |
| $e^+$ semileptonic     | [bbb] ( 6.5 $\pm$ 0.4 ) %      |                                   | —              |
| $\pi^+$ anything       | (119.3 $\pm$ 1.4 ) %           |                                   | —              |
| $\pi^-$ anything       | ( 43.2 $\pm$ 0.9 ) %           |                                   | —              |
| $\pi^0$ anything       | (123 $\pm$ 7 ) %               |                                   | —              |
| $K^-$ anything         | ( 18.7 $\pm$ 0.5 ) %           |                                   | —              |
| $K^+$ anything         | ( 28.9 $\pm$ 0.7 ) %           |                                   | —              |
| $K_S^0$ anything       | ( 19.0 $\pm$ 1.1 ) %           |                                   | —              |

|  |       |                          |        |   |
|--|-------|--------------------------|--------|---|
| $\eta$ anything                                    | [ccc] | ( 29.9 ± 2.8 ) %         |        | — |
| $\omega$ anything                                  |       | ( 6.1 ± 1.4 ) %          |        | — |
| $\eta'$ anything                                   | [ddd] | ( 10.3 ± 1.4 ) %         | S=1.1  | — |
| $f_0(980)$ anything, $f_0 \rightarrow \pi^+ \pi^-$ |       | < 1.3 %                  | CL=90% | — |
| $\phi$ anything                                    |       | ( 15.7 ± 1.0 ) %         |        | — |
| $K^+ K^-$ anything                                 |       | ( 15.8 ± 0.7 ) %         |        | — |
| $K_S^0 K^+$ anything                               |       | ( 5.8 ± 0.5 ) %          |        | — |
| $K_S^0 K^-$ anything                               |       | ( 1.9 ± 0.4 ) %          |        | — |
| $2K_S^0$ anything                                  |       | ( 1.70 ± 0.32 ) %        |        | — |
| $2K^+$ anything                                    |       | < 2.6 × 10 <sup>-3</sup> | CL=90% | — |
| $2K^-$ anything                                    |       | < 6 × 10 <sup>-4</sup>   | CL=90% | — |

### Leptonic and semileptonic modes

|   |       |                                    |        |     |
|---|-------|------------------------------------|--------|-----|
| $e^+ \nu_e$                             |       | < 8.3 × 10 <sup>-5</sup>           | CL=90% | 984 |
| $\mu^+ \nu_\mu$                         |       | ( 5.49 ± 0.16 ) × 10 <sup>-3</sup> |        | 981 |
| $\tau^+ \nu_\tau$                       |       | ( 5.48 ± 0.23 ) %                  |        | 182 |
| $\gamma e^+ \nu_e$                      |       | < 1.3 × 10 <sup>-4</sup>           | CL=90% | 984 |
| $K^+ K^- e^+ \nu_e$                     |       | —                                  |        | 851 |
| $\phi e^+ \nu_e$                        | [eee] | ( 2.39 ± 0.16 ) %                  | S=1.3  | 720 |
| $\phi \mu^+ \nu_\mu$                    |       | ( 1.9 ± 0.5 ) %                    |        | 715 |
| $\eta e^+ \nu_e + \eta'(958) e^+ \nu_e$ | [eee] | ( 3.03 ± 0.24 ) %                  |        | —   |
| $\eta e^+ \nu_e$                        | [eee] | ( 2.32 ± 0.08 ) %                  |        | 908 |
| $\eta'(958) e^+ \nu_e$                  | [eee] | ( 8.0 ± 0.7 ) × 10 <sup>-3</sup>   |        | 751 |
| $\eta \mu^+ \nu_\mu$                    |       | ( 2.4 ± 0.5 ) %                    |        | 905 |
| $\eta'(958) \mu^+ \nu_\mu$              |       | ( 1.1 ± 0.5 ) %                    |        | 747 |
| $\omega e^+ \nu_e$                      | [fff] | < 2.0 × 10 <sup>-3</sup>           | CL=90% | 829 |
| $K^0 e^+ \nu_e$                         |       | ( 3.4 ± 0.4 ) × 10 <sup>-3</sup>   |        | 921 |
| $K^*(892)^0 e^+ \nu_e$                  | [eee] | ( 2.15 ± 0.28 ) × 10 <sup>-3</sup> | S=1.1  | 782 |

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

|  |           |                                  |       |     |
|--|-----------|----------------------------------|-------|-----|
| $K^+ K_S^0$  |           | ( 1.46 ± 0.04 ) %                | S=1.1 | 850 |
| $K^+ K_L^0$  |           | ( 1.49 ± 0.06 ) %                |       | 850 |
| $K^+ \bar{K}^0$  |           | ( 2.95 ± 0.14 ) %                |       | 850 |
| $K^+ K^- \pi^+$  | [jj]      | ( 5.39 ± 0.15 ) %                | S=1.2 | 805 |
| $\phi \pi^+$   | [eee,ggg] | ( 4.5 ± 0.4 ) %                  |       | 712 |
| $\phi \pi^+, \phi \rightarrow K^+ K^-$                       | [ggg]     | ( 2.24 ± 0.08 ) %                |       | 712 |
| $K^+ \bar{K}^*(892)^0, \bar{K}^{*0} \rightarrow K^- \pi^+$   |           | ( 2.58 ± 0.08 ) %                |       | 416 |
| $f_0(980) \pi^+, f_0 \rightarrow K^+ K^-$                    |           | ( 1.14 ± 0.31 ) %                |       | 732 |
| $f_0(1370) \pi^+, f_0 \rightarrow K^+ K^-$                   |           | ( 7 ± 5 ) × 10 <sup>-4</sup>     |       | —   |
| $f_0(1710) \pi^+, f_0 \rightarrow K^+ K^-$                   |           | ( 6.6 ± 2.8 ) × 10 <sup>-4</sup> |       | 198 |
| $K^+ \bar{K}_0^*(1430)^0, \bar{K}_0^* \rightarrow K^- \pi^+$ |           | ( 1.8 ± 0.4 ) × 10 <sup>-3</sup> |       | 218 |
| $K^+ K_S^0 \pi^0$  |           | ( 1.52 ± 0.22 ) %                |       | 805 |

|  |   |        |     |
|--|---|--------|-----|
| $2K_S^0\pi^+$  | ( 7.7 ±0.6 ) × 10 <sup>-3</sup>                 |        | 802 |
| $K^0\bar{K}^0\pi^+$  | —   |        | 802 |
| $K^*(892)^+\bar{K}^0$  | [eee] ( 5.4 ±1.2 ) %                            |        | 683 |
| $K^+K^-\pi^+\pi^0$   | ( 6.2 ±0.6 ) %                                  | S=1.1  | 748 |
| $\phi\rho^+$   | [eee] ( 8.4 <sup>+1.9</sup> <sub>-2.3</sub> ) % |        | 401 |
| $K_S^0K^-2\pi^+$   | ( 1.65±0.10 ) %                                 |        | 744 |
| $K^*(892)^+\bar{K}^*(892)^0$   | [eee] ( 7.2 ±2.6 ) %                            |        | 417 |
| $K^+K_S^0\pi^+\pi^-$   | ( 9.9 ±0.8 ) × 10 <sup>-3</sup>                 |        | 744 |
| $K^+K^-2\pi^+\pi^-$  | ( 8.6 ±1.5 ) × 10 <sup>-3</sup>                 |        | 673 |
| $\phi2\pi^+\pi^-$  | [eee] ( 1.21±0.16 ) %                           |        | 640 |
| $\phi\rho^0\pi^+, \phi \rightarrow K^+K^-$                                 | ( 6.5 ±1.3 ) × 10 <sup>-3</sup>                 |        | 181 |
| $\phi a_1(1260)^+, \phi \rightarrow K^+K^-, a_1^+ \rightarrow \rho^0\pi^+$ | ( 7.4 ±1.2 ) × 10 <sup>-3</sup>                 |        | †   |
| $\phi2\pi^+\pi^- \text{ non-}\rho, \phi \rightarrow K^+K^-$                | ( 1.8 ±0.7 ) × 10 <sup>-3</sup>                 |        | —   |
| $K^+K^-\rho^0\pi^+ \text{ non-}\phi$                                       | < 2.6 × 10 <sup>-4</sup>                        | CL=90% | 249 |
| $K^+K^-2\pi^+\pi^- \text{ nonresonant}$                                    | ( 9 ±7 ) × 10 <sup>-4</sup>                     |        | 673 |
| $2K_S^02\pi^+\pi^-$  | ( 8.4 ±3.5 ) × 10 <sup>-4</sup>                 |        | 669 |

### Hadronic modes without K's

|   |  |        |     |
|---|--|--------|-----|
| $\pi^+\pi^0$  | < 3.4 × 10 <sup>-4</sup>               | CL=90% | 975 |
| $2\pi^+\pi^-$   | ( 1.08±0.04 ) %                        | S=1.1  | 959 |
| $\rho^0\pi^+$   | ( 1.9 ±1.2 ) × 10 <sup>-4</sup>        |        | 825 |
| $\pi^+(\pi^+\pi^-)_{S\text{-wave}}$                           | [hhh] ( 9.0 ±0.4 ) × 10 <sup>-3</sup>  |        | 959 |
| $f_2(1270)\pi^+, f_2 \rightarrow \pi^+\pi^-$                  | ( 1.09±0.20 ) × 10 <sup>-3</sup>       |        | 559 |
| $\rho(1450)^0\pi^+, \rho^0 \rightarrow \pi^+\pi^-$            | ( 3.0 ±1.9 ) × 10 <sup>-4</sup>        |        | 421 |
| $\pi^+2\pi^0$   | ( 6.5 ±1.3 ) × 10 <sup>-3</sup>        |        | 961 |
| $2\pi^+\pi^-\pi^0$  | —                                      |        | 935 |
| $\eta\pi^+$   | [eee] ( 1.68±0.10 ) %                  | S=1.2  | 902 |
| $\omega\pi^+$   | [eee] ( 1.92±0.30 ) × 10 <sup>-3</sup> |        | 822 |
| $3\pi^+2\pi^-$  | ( 7.9 ±0.8 ) × 10 <sup>-3</sup>        |        | 899 |
| $2\pi^+\pi^-2\pi^0$   | —                                      |        | 902 |
| $\eta\rho^+$  | [eee] ( 8.9 ±0.8 ) %                   |        | 724 |
| $\eta\pi^+\pi^0$  | ( 9.5 ±0.5 ) %                         |        | 885 |
| $\eta(\pi^+\pi^0)_{P\text{-wave}}$                            | ( 5.1 ±3.1 ) × 10 <sup>-3</sup>        |        | 885 |
| $a_0(980)^{+0}\pi^{0+}, a_0(980)^{+0} \rightarrow \eta\pi^+0$ | ( 2.2 ±0.4 ) %                         |        | —   |
| $\omega\pi^+\pi^0$  | [eee] ( 2.8 ±0.7 ) %                   |        | 802 |
| $3\pi^+2\pi^-\pi^0$   | ( 4.9 ±3.2 ) %                         |        | 856 |
| $\omega2\pi^+\pi^-$   | [eee] ( 1.6 ±0.5 ) %                   |        | 766 |
| $\eta'(958)\pi^+$   | [ddd,eee] ( 3.94±0.25 ) %              |        | 743 |
| $3\pi^+2\pi^-2\pi^0$  | —                                      |        | 803 |

|                                    |                           |        |     |
|------------------------------------|---------------------------|--------|-----|
| $\omega\eta\pi^+$                  | [eee] < 2.13 %            | CL=90% | 654 |
| $\eta'(958)\rho^+$                 | [ddd,eee] ( 5.8 ± 1.5 ) % |        | 465 |
| $\eta'(958)\pi^+\pi^0$             | ( 5.6 ± 0.8 ) %           |        | 720 |
| $\eta'(958)\pi^+\pi^0$ nonresonant | < 5.1 %                   | CL=90% | 720 |

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

|  |  |        |     |
|--|--|--------|-----|
| $K^+\pi^0$                                       | ( 7.4 ± 0.6 ) × 10 <sup>-4</sup>         |        | 917 |
| $K_S^0\pi^+$                                     | ( 1.10 ± 0.05 ) × 10 <sup>-3</sup>       |        | 916 |
| $K^+\eta$  | [eee] ( 1.60 ± 0.11 ) × 10 <sup>-3</sup> |        | 835 |
| $K^+\omega$                                      | [eee] ( 8.7 ± 2.5 ) × 10 <sup>-4</sup>   |        | 741 |
| $K^+\eta'(958)$                                  | [eee] ( 2.65 ± 0.25 ) × 10 <sup>-3</sup> |        | 646 |
| $K^+\pi^+\pi^-$                                  | ( 6.5 ± 0.4 ) × 10 <sup>-3</sup>         |        | 900 |
| $K^+\rho^0$                                      | ( 2.5 ± 0.4 ) × 10 <sup>-3</sup>         |        | 745 |
| $K^+\rho(1450)^0, \rho^0 \rightarrow \pi^+\pi^-$ | ( 6.9 ± 2.4 ) × 10 <sup>-4</sup>         |        | —   |
| $K^*(892)^0\pi^+, K^{*0} \rightarrow$            | ( 1.41 ± 0.24 ) × 10 <sup>-3</sup>       |        | 775 |
| $K^+\pi^-$                                       |  |        |     |
| $K^*(1410)^0\pi^+, K^{*0} \rightarrow$           | ( 1.23 ± 0.28 ) × 10 <sup>-3</sup>       |        | —   |
| $K^+\pi^-$                                       |  |        |     |
| $K^*(1430)^0\pi^+, K^{*0} \rightarrow$           | ( 5.0 ± 3.5 ) × 10 <sup>-4</sup>         |        | —   |
| $K^+\pi^-$                                       |  |        |     |
| $K^+\pi^+\pi^-$ nonresonant                      | ( 1.03 ± 0.34 ) × 10 <sup>-3</sup>       |        | 900 |
| $K^0\pi^+\pi^0$                                  | ( 1.00 ± 0.18 ) %                        |        | 899 |
| $K_S^0 2\pi^+\pi^-$                              | ( 3.0 ± 1.1 ) × 10 <sup>-3</sup>         |        | 870 |
| $K^+\omega\pi^0$                                 | [eee] < 8.2 × 10 <sup>-3</sup>           | CL=90% | 684 |
| $K^+\omega\pi^+\pi^-$                            | [eee] < 5.4 × 10 <sup>-3</sup>           | CL=90% | 603 |
| $K^+\omega\eta$                                  | [eee] < 7.9 × 10 <sup>-3</sup>           | CL=90% | 366 |
| $2K^+K^-$  | ( 2.16 ± 0.20 ) × 10 <sup>-4</sup>       |        | 628 |
| $\phi K^+, \phi \rightarrow K^+K^-$              | ( 8.8 ± 2.0 ) × 10 <sup>-5</sup>         |        | —   |

**Doubly Cabibbo-suppressed modes**

|                                     |                                    |  |     |
|-------------------------------------|------------------------------------|--|-----|
| $2K^+\pi^-$                         | ( 1.28 ± 0.04 ) × 10 <sup>-4</sup> |  | 805 |
| $K^+K^*(892)^0, K^{*0} \rightarrow$ | ( 6.0 ± 3.4 ) × 10 <sup>-5</sup>   |  | —   |
| $K^+\pi^-$                          |                                    |  |     |

**Baryon-antibaryon mode**

|                    |                                    |        |     |
|--------------------|------------------------------------|--------|-----|
| $p\bar{n}$         | ( 1.22 ± 0.11 ) × 10 <sup>-3</sup> |        | 295 |
| $p\bar{p}e^+\nu_e$ | < 2.0 × 10 <sup>-4</sup>           | CL=90% | 296 |

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

|                                      |  |        |     |
|--------------------------------------|--|--------|-----|
| $\pi^+e^+e^-$                        | [pp] < 1.3 × 10 <sup>-5</sup>  | CL=90% | 979 |
| $\pi^+\phi, \phi \rightarrow e^+e^-$ | [oo] ( 6 $\begin{smallmatrix} +8 \\ -4 \end{smallmatrix}$ ) × 10 <sup>-6</sup> |        | —   |
| $\pi^+\mu^+\mu^-$                    | [pp] < 4.1 × 10 <sup>-7</sup>  | CL=90% | 968 |
| $K^+e^+e^-$                          | C1 < 3.7 × 10 <sup>-6</sup>  | CL=90% | 922 |
| $K^+\mu^+\mu^-$                      | C1 < 2.1 × 10 <sup>-5</sup>  | CL=90% | 909 |



|                          |    |       |                  |        |     |
|--------------------------|----|-------|------------------|--------|-----|
| $K^*(892)^+ \mu^+ \mu^-$ | CI | < 1.4 | $\times 10^{-3}$ | CL=90% | 765 |
| $\pi^+ e^+ \mu^-$        | LF | < 1.2 | $\times 10^{-5}$ | CL=90% | 976 |
| $\pi^+ e^- \mu^+$        | LF | < 2.0 | $\times 10^{-5}$ | CL=90% | 976 |
| $K^+ e^+ \mu^-$          | LF | < 1.4 | $\times 10^{-5}$ | CL=90% | 919 |
| $K^+ e^- \mu^+$          | LF | < 9.7 | $\times 10^{-6}$ | CL=90% | 919 |
| $\pi^- 2e^+$             | L  | < 4.1 | $\times 10^{-6}$ | CL=90% | 979 |
| $\pi^- 2\mu^+$           | L  | < 1.2 | $\times 10^{-7}$ | CL=90% | 968 |
| $\pi^- e^+ \mu^+$        | L  | < 8.4 | $\times 10^{-6}$ | CL=90% | 976 |
| $K^- 2e^+$               | L  | < 5.2 | $\times 10^{-6}$ | CL=90% | 922 |
| $K^- 2\mu^+$             | L  | < 1.3 | $\times 10^{-5}$ | CL=90% | 909 |
| $K^- e^+ \mu^+$          | L  | < 6.1 | $\times 10^{-6}$ | CL=90% | 919 |
| $K^*(892)^- 2\mu^+$      | 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  $1^-$ .

Mass  $m = 2112.2 \pm 0.4$  MeV

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

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

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

| $D_s^{*+}$ DECAY MODES | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|------------------------|--------------------------------|-------------|
| $D_s^+ \gamma$         | (93.5±0.7) %                   | 139         |
| $D_s^+ \pi^0$          | ( 5.8±0.7) %                   | 48          |
| $D_s^+ e^+ e^-$        | ( 6.7±1.6) $\times 10^{-3}$    | 139         |

### $D_{s0}^*(2317)^\pm$

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

$J, P$  need confirmation.

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

Mass  $m = 2317.8 \pm 0.5$  MeV

$m_{D_{s0}^*(2317)^\pm} - m_{D_s^\pm} = 349.4 \pm 0.5$  MeV

Full width  $\Gamma < 3.8$  MeV, CL = 95%

$D_{s0}^*(2317)^-$  modes are charge conjugates of modes below.

| $D_{s0}^*(2317)^\pm$ DECAY MODES | Fraction ( $\Gamma_i/\Gamma$ ) | Confidence level | $p$ (MeV/c) |
|----------------------------------|--------------------------------|------------------|-------------|
| $D_s^+ \pi^0$                    | (100 $^{+0}_{-20}$ ) %         |                  | 298         |
| $D_s^+ \gamma$                   | < 5 %                          | 90%              | 323         |

|                        |                      |     |     |
|------------------------|----------------------|-----|-----|
| $D_s^*(2112)^+ \gamma$ | < 6 %                | 90% | —   |
| $D_s^+ \gamma \gamma$  | < 18 %               | 95% | 323 |
| $D_s^*(2112)^+ \pi^0$  | < 11 %               | 90% | —   |
| $D_s^+ \pi^+ \pi^-$    | < 4 $\times 10^{-3}$ | 90% | 194 |
| $D_s^+ \pi^0 \pi^0$    | not seen             |     | 205 |

### $D_{s1}(2460)^\pm$

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

Mass  $m = 2459.5 \pm 0.6$  MeV ( $S = 1.1$ )

$m_{D_{s1}(2460)^\pm} - m_{D_s^{*\pm}} = 347.3 \pm 0.7$  MeV ( $S = 1.2$ )

$m_{D_{s1}(2460)^\pm} - m_{D_s^\pm} = 491.1 \pm 0.6$  MeV ( $S = 1.1$ )

Full width  $\Gamma < 3.5$  MeV, CL = 95%

$D_{s1}(2460)^-$  modes are charge conjugates of the modes below.

| $D_{s1}(2460)^+$ DECAY MODES | Fraction ( $\Gamma_i/\Gamma$ ) | Scale factor/<br>Confidence level | $p$<br>(MeV/c) |
|------------------------------|--------------------------------|-----------------------------------|----------------|
| $D_s^{*+} \pi^0$             | (48 $\pm$ 11 ) %               |                                   | 297            |
| $D_s^+ \gamma$               | (18 $\pm$ 4 ) %                |                                   | 442            |
| $D_s^+ \pi^+ \pi^-$          | ( 4.3 $\pm$ 1.3 ) %            | S=1.1                             | 363            |
| $D_s^{*+} \gamma$            | < 8 %                          | CL=90%                            | 323            |
| $D_{s0}^*(2317)^+ \gamma$    | ( 3.7 $^{+5.0}_{-2.4}$ ) %     |                                   | 138            |

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

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

$J, P$  need confirmation.

Mass  $m = 2535.11 \pm 0.06$  MeV

Full width  $\Gamma = 0.92 \pm 0.05$  MeV

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

| $D_{s1}(2536)^+$ DECAY MODES | Fraction ( $\Gamma_i/\Gamma$ ) | Confidence level | $p$<br>(MeV/c) |
|------------------------------|--------------------------------|------------------|----------------|
| $D^*(2010)^+ K^0$            | 0.85 $\pm$ 0.12                |                  | 149            |
| $(D^*(2010)^+ K^0)_{S-wave}$ | 0.61 $\pm$ 0.09                |                  | 149            |
| $D^+ \pi^- K^+$              | 0.028 $\pm$ 0.005              |                  | 176            |
| $D^*(2007)^0 K^+$            | <b>DEFINED AS 1</b>            |                  | 167            |
| $D^+ K^0$                    | <0.34                          | 90%              | 381            |
| $D^0 K^+$                    | <0.12                          | 90%              | 391            |
| $D_s^{*+} \gamma$            | possibly seen                  |                  | 388            |
| $D_s^+ \pi^+ \pi^-$          | seen                           |                  | 437            |

**$D_{s2}^*(2573)$** 

$$I(J^P) = 0(2^+)$$

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

Mass  $m = 2569.1 \pm 0.8$  MeV ( $S = 2.4$ )

Full width  $\Gamma = 16.9 \pm 0.7$  MeV

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

| <b><math>D_{s2}^*(2573)^+</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|--|--------------------------------|-------------|
| $D^0 K^+$  | seen                           | 431         |
| $D^*(2007)^0 K^+$                                | not seen                       | 238         |

 **$D_{s1}^*(2700)^\pm$** 

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

Mass  $m = 2714 \pm 5$  MeV ( $S = 1.5$ )

Full width  $\Gamma = 122 \pm 10$  MeV

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

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

### **$B$ -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,  $CP$  violation, branching fractions
- $B^0$   
mass, mean life,  $B^0-\bar{B}^0$  mixing,  $CP$  violation, branching fractions
- $B^\pm/B^0$  Admixtures  
 $CP$  violation, branching fractions
- $B^\pm/B^0/B_s^0/b$ -baryon Admixtures  
mean life, production fractions, branching fractions
- $B^*$   
mass
- $B_1(5721)^+$   
mass
- $B_1(5721)^0$   
mass
- $B_2^*(5747)^+$   
mass
- $B_2^*(5747)^0$   
mass
- $B_J^*(5970)^+$   
mass
- $B_J^*(5970)^0$   
mass
- $B_s^0$   
mass, mean life,  $B_s^0-\bar{B}_s^0$  mixing,  $CP$  violation, branching fractions
- $B_s^*$   
mass
- $B_{s1}(5830)^0$   
mass
- $B_{s2}^*(5840)^0$   
mass

- $B_c^\pm$   
mass, mean life, branching fractions

At the end of Baryon Listings:

- $\Lambda_b$   
mass, mean life, branching fractions
- $\Lambda_b(5912)^0$   
mass, mean life
- $\Lambda_b(5920)^0$   
mass, mean life
- $\Sigma_b$   
mass
- $\Sigma_b^*$   
mass
- $\Xi_b^0, \Xi_b^-$   
mass, mean life, branching fractions
- $\Xi_b'(5935)^-$   
mass
- $\Xi_b(5945)^0$   
mass
- $\Xi_b^*(5955)^-$   
mass
- $\Omega_b^-$   
mass, 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.

$$\text{Mass } m_{B^\pm} = 5279.34 \pm 0.12 \text{ MeV}$$

$$\text{Mean life } \tau_{B^\pm} = (1.638 \pm 0.004) \times 10^{-12} \text{ s}$$

$$c\tau = 491.1 \text{ } \mu\text{m}$$

### CP violation

$$A_{CP}(B^+ \rightarrow J/\psi(1S)K^+) = (1.8 \pm 3.0) \times 10^{-3} \quad (S = 1.5)$$

$$\begin{aligned}
 A_{CP}(B^+ \rightarrow J/\psi(1S)\pi^+) &= (1.8 \pm 1.2) \times 10^{-2} \quad (S = 1.3) \\
 A_{CP}(B^+ \rightarrow J/\psi\rho^+) &= -0.05 \pm 0.05 \\
 A_{CP}(B^+ \rightarrow J/\psi K^*(892)^+) &= -0.048 \pm 0.033 \\
 A_{CP}(B^+ \rightarrow \eta_c K^+) &= 0.01 \pm 0.07 \quad (S = 2.2) \\
 A_{CP}(B^+ \rightarrow \psi(2S)\pi^+) &= 0.03 \pm 0.06 \\
 A_{CP}(B^+ \rightarrow \psi(2S)K^+) &= 0.012 \pm 0.020 \quad (S = 1.5) \\
 A_{CP}(B^+ \rightarrow \psi(2S)K^*(892)^+) &= 0.08 \pm 0.21 \\
 A_{CP}(B^+ \rightarrow \chi_{c1}(1P)\pi^+) &= 0.07 \pm 0.18 \\
 A_{CP}(B^+ \rightarrow \chi_{c0}K^+) &= -0.20 \pm 0.18 \quad (S = 1.5) \\
 A_{CP}(B^+ \rightarrow \chi_{c1}K^+) &= -0.009 \pm 0.033 \\
 A_{CP}(B^+ \rightarrow \chi_{c1}K^*(892)^+) &= 0.5 \pm 0.5 \\
 A_{CP}(B^+ \rightarrow D^0\ell^+\nu_\ell) &= (-0.14 \pm 0.20) \times 10^{-2} \\
 A_{CP}(B^+ \rightarrow \bar{D}^0\pi^+) &= -0.007 \pm 0.007 \\
 A_{CP}(B^+ \rightarrow D_{CP(+1)}\pi^+) &= -0.0080 \pm 0.0026 \\
 A_{CP}(B^+ \rightarrow D_{CP(-1)}\pi^+) &= 0.017 \pm 0.026 \\
 A_{CP}([K^\mp\pi^\pm\pi^+\pi^-]_D\pi^+) &= 0.02 \pm 0.05 \\
 A_{CP}(B^+ \rightarrow [\pi^+\pi^+\pi^-\pi^-]_D K^+) &= 0.10 \pm 0.04 \\
 A_{CP}(B^+ \rightarrow [\pi^+\pi^-\pi^+\pi^-]_D K^*(892)^+) &= 0.02 \pm 0.11 \\
 A_{CP}(B^+ \rightarrow \bar{D}^0 K^+) &= -0.017 \pm 0.005 \\
 A_{CP}([K^\mp\pi^\pm\pi^+\pi^-]_D K^+) &= -0.31 \pm 0.11 \\
 A_{CP}(B^+ \rightarrow [\pi^+\pi^+\pi^-\pi^-]_D\pi^+) &= (-4 \pm 8) \times 10^{-3} \\
 A_{CP}(B^+ \rightarrow [K^-\pi^+]_D K^+) &= -0.58 \pm 0.21 \\
 A_{CP}(B^+ \rightarrow [K^-\pi^+\pi^0]_D K^+) &= 0.07 \pm 0.30 \quad (S = 1.5) \\
 A_{CP}(B^+ \rightarrow [K^+K^-\pi^0]_D K^+) &= 0.30 \pm 0.20 \\
 A_{CP}(B^+ \rightarrow [\pi^+\pi^-\pi^0]_D K^+) &= 0.05 \pm 0.09 \\
 A_{CP}(B^+ \rightarrow \bar{D}^0 K^*(892)^+) &= -0.007 \pm 0.019 \\
 A_{CP}(B^+ \rightarrow [K^-\pi^+]_{\bar{D}} K^*(892)^+) &= -0.75 \pm 0.16 \\
 A_{CP}(B^+ \rightarrow [K^-\pi^+\pi^-\pi^+]_{\bar{D}} K^*(892)^+) &= -0.45 \pm 0.25 \\
 A_{CP}(B^+ \rightarrow [K^-\pi^+]_D\pi^+) &= 0.00 \pm 0.09 \\
 A_{CP}(B^+ \rightarrow [K^-\pi^+\pi^0]_D\pi^+) &= 0.35 \pm 0.16 \\
 A_{CP}(B^+ \rightarrow [K^+K^-\pi^0]_D\pi^+) &= -0.03 \pm 0.04 \\
 A_{CP}(B^+ \rightarrow [\pi^+\pi^-\pi^0]_D\pi^+) &= -0.016 \pm 0.020 \\
 A_{CP}(B^+ \rightarrow [K^-\pi^+]_{(D\pi)}\pi^+) &= -0.09 \pm 0.27 \\
 A_{CP}(B^+ \rightarrow [K^-\pi^+]_{(D\gamma)}\pi^+) &= -0.7 \pm 0.6 \\
 A_{CP}(B^+ \rightarrow [K^-\pi^+]_{(D\pi)}K^+) &= 0.8 \pm 0.4 \\
 A_{CP}(B^+ \rightarrow [K^-\pi^+]_{(D\gamma)}K^+) &= 0.4 \pm 1.0 \\
 A_{CP}(B^+ \rightarrow [\pi^+\pi^-\pi^0]_D K^+) &= -0.02 \pm 0.15 \\
 A_{CP}(B^+ \rightarrow [K_S^0 K^+\pi^-]_D K^+) &= 0.10 \pm 0.09 \\
 A_{CP}(B^+ \rightarrow [K_S^0 K^-\pi^+]_D K^+) &= -0.04 \pm 0.08 \\
 A_{CP}(B^+ \rightarrow [K_S^0 K^-\pi^+]_D\pi^+) &= 0.003 \pm 0.015 \\
 A_{CP}(B^+ \rightarrow [K_S^0 K^+\pi^-]_D\pi^+) &= -0.034 \pm 0.020
 \end{aligned}$$

$$\begin{aligned}
A_{CP}(B^+ \rightarrow [K^*(892)^- K^+]_D K^+) &= 0.08 \pm 0.05 \\
A_{CP}(B^+ \rightarrow [K^*(892)^+ K^-]_D K^+) &= 0.02 \pm 0.10 \\
A_{CP}(B^+ \rightarrow [K^*(892)^+ K^-]_D \pi^+) &= 0.007 \pm 0.017 \\
A_{CP}(B^+ \rightarrow [K^*(892)^- K^+]_D \pi^+) &= -0.020 \pm 0.011 \\
\mathbf{A_{CP}(B^+ \rightarrow D_{CP(+1)} K^+) = 0.120 \pm 0.014} \quad (S = 1.4) \\
A_{ADS}(B^+ \rightarrow D K^+) &= -0.40 \pm 0.06 \\
A_{ADS}(B^+ \rightarrow D \pi^+) &= 0.100 \pm 0.032 \\
A_{ADS}(B^+ \rightarrow [K^- \pi^+]_D K^+ \pi^- \pi^+) &= -0.33 \pm 0.35 \\
A_{ADS}(B^+ \rightarrow [K^- \pi^+]_D \pi^+ \pi^- \pi^+) &= -0.01 \pm 0.09 \\
A_{CP}(B^+ \rightarrow D_{CP(-1)} K^+) &= -0.10 \pm 0.07 \\
A_{CP}(B^+ \rightarrow [K^+ K^-]_D K^+ \pi^- \pi^+) &= -0.04 \pm 0.06 \\
A_{CP}(B^+ \rightarrow [\pi^+ \pi^-]_D K^+ \pi^- \pi^+) &= -0.05 \pm 0.10 \\
A_{CP}(B^+ \rightarrow [K^- \pi^+]_D K^+ \pi^- \pi^+) &= 0.013 \pm 0.023 \\
A_{CP}(B^+ \rightarrow [K^+ K^-]_D \pi^+ \pi^- \pi^+) &= -0.019 \pm 0.015 \\
A_{CP}(B^+ \rightarrow [\pi^+ \pi^-]_D \pi^+ \pi^- \pi^+) &= -0.013 \pm 0.019 \\
A_{CP}(B^+ \rightarrow [K^- \pi^+]_D \pi^+ \pi^- \pi^+) &= -0.002 \pm 0.011 \\
A_{CP}(B^+ \rightarrow \bar{D}^{*0} \pi^+) &= 0.0010 \pm 0.0028 \\
A_{CP}(B^+ \rightarrow (D_{CP(+1)}^*)^0 \pi^+) &= 0.016 \pm 0.010 \quad (S = 1.2) \\
A_{CP}(B^+ \rightarrow (D_{CP(-1)}^*)^0 \pi^+) &= -0.09 \pm 0.05 \\
A_{CP}(B^+ \rightarrow D^{*0} K^+) &= -0.001 \pm 0.011 \quad (S = 1.1) \\
A_{CP}(B^+ \rightarrow D_{CP(+1)}^{*0} K^+) &= -0.11 \pm 0.08 \quad (S = 2.7) \\
A_{CP}(B^+ \rightarrow D_{CP(-1)}^* K^+) &= 0.07 \pm 0.10 \\
A_{CP}(B^+ \rightarrow D_{CP(+1)} K^*(892)^+) &= 0.08 \pm 0.06 \\
A_{CP}(B^+ \rightarrow D_{CP(-1)} K^*(892)^+) &= -0.23 \pm 0.22 \\
A_{CP}(B^+ \rightarrow D_s^+ \phi) &= 0.0 \pm 0.4 \\
A_{CP}(B^+ \rightarrow D_s^+ \bar{D}^0) &= (-0.4 \pm 0.7)\% \\
A_{CP}(B^+ \rightarrow D^{*+} \bar{D}^{*0}) &= -0.15 \pm 0.11 \\
A_{CP}(B^+ \rightarrow D^{*+} \bar{D}^0) &= -0.06 \pm 0.13 \\
A_{CP}(B^+ \rightarrow D^+ \bar{D}^{*0}) &= 0.13 \pm 0.18 \\
A_{CP}(B^+ \rightarrow D^+ \bar{D}^0) &= 0.016 \pm 0.025 \\
A_{CP}(B^+ \rightarrow K_S^0 \pi^+) &= -0.017 \pm 0.016 \\
A_{CP}(B^+ \rightarrow K^+ \pi^0) &= 0.037 \pm 0.021 \\
A_{CP}(B^+ \rightarrow \eta' K^+) &= 0.004 \pm 0.011 \\
A_{CP}(B^+ \rightarrow \eta' K^*(892)^+) &= -0.26 \pm 0.27 \\
A_{CP}(B^+ \rightarrow \eta' K_0^*(1430)^+) &= 0.06 \pm 0.20 \\
A_{CP}(B^+ \rightarrow \eta' K_2^*(1430)^+) &= 0.15 \pm 0.13 \\
\mathbf{A_{CP}(B^+ \rightarrow \eta K^+) = -0.37 \pm 0.08} \\
A_{CP}(B^+ \rightarrow \eta K^*(892)^+) &= 0.02 \pm 0.06 \\
A_{CP}(B^+ \rightarrow \eta K_0^*(1430)^+) &= 0.05 \pm 0.13 \\
A_{CP}(B^+ \rightarrow \eta K_2^*(1430)^+) &= -0.45 \pm 0.30
\end{aligned}$$

$$\begin{aligned}
 A_{CP}(B^+ \rightarrow \omega K^+) &= -0.02 \pm 0.04 \\
 A_{CP}(B^+ \rightarrow \omega K^{*+}) &= 0.29 \pm 0.35 \\
 A_{CP}(B^+ \rightarrow \omega (K\pi)_0^{*+}) &= -0.10 \pm 0.09 \\
 A_{CP}(B^+ \rightarrow \omega K_2^*(1430)^+) &= 0.14 \pm 0.15 \\
 A_{CP}(B^+ \rightarrow K^{*0} \pi^+) &= -0.04 \pm 0.09 \quad (S = 2.1) \\
 A_{CP}(B^+ \rightarrow K^*(892)^+ \pi^0) &= -0.39 \pm 0.21 \quad (S = 1.6) \\
 \mathbf{A_{CP}(B^+ \rightarrow K^+ \pi^- \pi^+)} &= 0.027 \pm 0.008 \\
 A_{CP}(B^+ \rightarrow K^+ K^- K^+ \text{ nonresonant}) &= 0.06 \pm 0.05 \\
 A_{CP}(B^+ \rightarrow f(980)^0 K^+) &= -0.08 \pm 0.09 \\
 \mathbf{A_{CP}(B^+ \rightarrow f_2(1270) K^+)} &= -0.68^{+0.19}_{-0.17} \\
 A_{CP}(B^+ \rightarrow f_0(1500) K^+) &= 0.28 \pm 0.30 \\
 A_{CP}(B^+ \rightarrow f_2'(1525)^0 K^+) &= -0.08^{+0.05}_{-0.04} \\
 \mathbf{A_{CP}(B^+ \rightarrow \rho^0 K^+)} &= 0.37 \pm 0.10 \\
 A_{CP}(B^+ \rightarrow K^0 \pi^+ \pi^0) &= 0.07 \pm 0.06 \\
 A_{CP}(B^+ \rightarrow K_0^*(1430)^0 \pi^+) &= 0.061 \pm 0.032 \\
 A_{CP}(B^+ \rightarrow K_0^*(1430)^+ \pi^0) &= 0.26^{+0.18}_{-0.14} \\
 A_{CP}(B^+ \rightarrow K_2^*(1430)^0 \pi^+) &= 0.05^{+0.29}_{-0.24} \\
 A_{CP}(B^+ \rightarrow K^+ \pi^0 \pi^0) &= -0.06 \pm 0.07 \\
 A_{CP}(B^+ \rightarrow K^0 \rho^+) &= -0.03 \pm 0.15 \\
 A_{CP}(B^+ \rightarrow K^{*+} \pi^+ \pi^-) &= 0.07 \pm 0.08 \\
 A_{CP}(B^+ \rightarrow \rho^0 K^*(892)^+) &= 0.31 \pm 0.13 \\
 A_{CP}(B^+ \rightarrow K^*(892)^+ f_0(980)) &= -0.15 \pm 0.12 \\
 A_{CP}(B^+ \rightarrow a_1^+ K^0) &= 0.12 \pm 0.11 \\
 A_{CP}(B^+ \rightarrow b_1^+ K^0) &= -0.03 \pm 0.15 \\
 A_{CP}(B^+ \rightarrow K^*(892)^0 \rho^+) &= -0.01 \pm 0.16 \\
 A_{CP}(B^+ \rightarrow b_1^0 K^+) &= -0.46 \pm 0.20 \\
 A_{CP}(B^+ \rightarrow K^0 K^+) &= 0.04 \pm 0.14 \\
 A_{CP}(B^+ \rightarrow K_S^0 K^+) &= -0.21 \pm 0.14 \\
 A_{CP}(B^+ \rightarrow K^+ K_S^0 K_S^0) &= 0.025 \pm 0.031 \\
 \mathbf{A_{CP}(B^+ \rightarrow K^+ K^- \pi^+)} &= -0.122 \pm 0.021 \\
 A_{CP}(B^+ \rightarrow K^+ K^- \pi^+ \text{ nonresonant}) &= -0.11 \pm 0.06 \\
 A_{CP}(B^+ \rightarrow K^+ \bar{K}^*(892)^0) &= 0.12 \pm 0.10 \\
 A_{CP}(B^+ \rightarrow K^+ \bar{K}_0^*(1430)^0) &= 0.10 \pm 0.17 \\
 A_{CP}(B^+ \rightarrow \phi \pi^+) &= 0.1 \pm 0.5 \\
 A_{CP}(B^+ \rightarrow \pi^+ (K^+ K^-)_{S\text{-wave}}) &= -0.66 \pm 0.04 \\
 \mathbf{A_{CP}(B^+ \rightarrow K^+ K^- K^+)} &= -0.033 \pm 0.008 \\
 A_{CP}(B^+ \rightarrow \phi K^+) &= 0.024 \pm 0.028 \quad (S = 2.3) \\
 A_{CP}(B^+ \rightarrow X_0(1550) K^+) &= -0.04 \pm 0.07 \\
 A_{CP}(B^+ \rightarrow K^{*+} K^+ K^-) &= 0.11 \pm 0.09 \\
 A_{CP}(B^+ \rightarrow \phi K^*(892)^+) &= -0.01 \pm 0.08 \\
 A_{CP}(B^+ \rightarrow \phi (K\pi)_0^{*+}) &= 0.04 \pm 0.16
 \end{aligned}$$



$$\begin{aligned}
A_{CP}(B^+ \rightarrow \phi K_1(1270)^+) &= 0.15 \pm 0.20 \\
A_{CP}(B^+ \rightarrow \phi K_2^*(1430)^+) &= -0.23 \pm 0.20 \\
A_{CP}(B^+ \rightarrow K^+ \phi \phi) &= -0.10 \pm 0.08 \\
A_{CP}(B^+ \rightarrow K^+ [\phi \phi]_{\eta_c}) &= 0.09 \pm 0.10 \\
A_{CP}(B^+ \rightarrow K^*(892)^+ \gamma) &= 0.014 \pm 0.018 \\
A_{CP}(B^+ \rightarrow X_S \gamma) &= 0.028 \pm 0.019 \\
A_{CP}(B^+ \rightarrow \eta K^+ \gamma) &= -0.12 \pm 0.07 \\
A_{CP}(B^+ \rightarrow \phi K^+ \gamma) &= -0.13 \pm 0.11 \quad (S = 1.1) \\
A_{CP}(B^+ \rightarrow \rho^+ \gamma) &= -0.11 \pm 0.33 \\
A_{CP}(B^+ \rightarrow \pi^+ \pi^0) &= 0.03 \pm 0.04 \\
\mathbf{A_{CP}(B^+ \rightarrow \pi^+ \pi^- \pi^+)} &= 0.057 \pm 0.013 \\
A_{CP}(B^+ \rightarrow \rho^0 \pi^+) &= 0.009 \pm 0.019 \\
A_{CP}(B^+ \rightarrow f_2(1270) \pi^+) &= 0.40 \pm 0.06 \\
A_{CP}(B^+ \rightarrow \rho^0(1450) \pi^+) &= -0.11 \pm 0.05 \\
A_{CP}(B^+ \rightarrow \rho_3(1690) \pi^+) &= -0.80 \pm 0.28 \\
\mathbf{A_{CP}(B^+ \rightarrow f_0(1370) \pi^+)} &= 0.72 \pm 0.22 \\
A_{CP}(B^+ \rightarrow \pi^+ \pi^- \pi^+ \text{ nonresonant}) &= -0.14^{+0.23}_{-0.16} \\
A_{CP}(B^+ \rightarrow \rho^+ \pi^0) &= 0.02 \pm 0.11 \\
A_{CP}(B^+ \rightarrow \rho^+ \rho^0) &= -0.05 \pm 0.05 \\
A_{CP}(B^+ \rightarrow \omega \pi^+) &= -0.04 \pm 0.05 \\
A_{CP}(B^+ \rightarrow \omega \rho^+) &= -0.20 \pm 0.09 \\
A_{CP}(B^+ \rightarrow \eta \pi^+) &= -0.14 \pm 0.07 \quad (S = 1.4) \\
A_{CP}(B^+ \rightarrow \eta \rho^+) &= 0.11 \pm 0.11 \\
A_{CP}(B^+ \rightarrow \eta' \pi^+) &= 0.06 \pm 0.16 \\
A_{CP}(B^+ \rightarrow \eta' \rho^+) &= 0.26 \pm 0.17 \\
A_{CP}(B^+ \rightarrow b_1^0 \pi^+) &= 0.05 \pm 0.16 \\
A_{CP}(B^+ \rightarrow \rho \bar{p} \pi^+) &= 0.00 \pm 0.04 \\
A_{CP}(B^+ \rightarrow \rho \bar{p} K^+) &= 0.00 \pm 0.04 \quad (S = 2.2) \\
A_{CP}(B^+ \rightarrow \rho \bar{p} K^*(892)^+) &= 0.21 \pm 0.16 \quad (S = 1.4) \\
A_{CP}(B^+ \rightarrow \rho \bar{\Lambda} \gamma) &= 0.17 \pm 0.17 \\
A_{CP}(B^+ \rightarrow \rho \bar{\Lambda} \pi^0) &= 0.01 \pm 0.17 \\
A_{CP}(B^+ \rightarrow K^+ \ell^+ \ell^-) &= -0.02 \pm 0.08 \\
A_{CP}(B^+ \rightarrow K^+ e^+ e^-) &= 0.14 \pm 0.14 \\
A_{CP}(B^+ \rightarrow K^+ \mu^+ \mu^-) &= 0.011 \pm 0.017 \\
A_{CP}(B^+ \rightarrow \pi^+ \mu^+ \mu^-) &= -0.11 \pm 0.12 \\
A_{CP}(B^+ \rightarrow K^{*+} \ell^+ \ell^-) &= -0.09 \pm 0.14 \\
A_{CP}(B^+ \rightarrow K^* e^+ e^-) &= -0.14 \pm 0.23 \\
A_{CP}(B^+ \rightarrow K^* \mu^+ \mu^-) &= -0.12 \pm 0.24 \\
\gamma &= (71.1^{+4.6}_{-5.3})^\circ \\
\mathbf{r_B(B^+ \rightarrow D^0 K^+)} &= 0.0993 \pm 0.0046 \\
\mathbf{\delta_B(B^+ \rightarrow D^0 K^+)} &= (129.6^{+5.0}_{-6.0})^\circ
\end{aligned}$$

$$r_B(B^+ \rightarrow D^0 K^{*+}) = 0.076 \pm 0.020$$

$$\delta_B(B^+ \rightarrow D^0 K^{*+}) = (98_{-37}^{+18})^\circ$$

$$r_B(B^+ \rightarrow D^{*0} K^+) = 0.140 \pm 0.019$$

$$\delta_B(B^+ \rightarrow D^{*0} K^+) = (319.2_{-8.7}^{+7.7})^\circ$$

$B^-$  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.,  $B \rightarrow D^\pm X$ , the values usually are multiplicities, not branching fractions. They can be greater than one.

| $B^+$ DECAY MODES  | Fraction ( $\Gamma_i/\Gamma$ )       | Scale factor/<br>Confidence level(MeV/c) | $p$  |
|--|--------------------------------------|--|------|
| <b>Semileptonic and leptonic modes</b>   |                                      |  |      |
| $\ell^+ \nu_\ell X$  | [iii] ( 10.99 $\pm$ 0.28 ) %         |  | –    |
| $e^+ \nu_e X_c$  | ( 10.8 $\pm$ 0.4 ) %                 |  | –    |
| $D \ell^+ \nu_\ell X$  | ( 9.7 $\pm$ 0.7 ) %                  |  | –    |
| $\bar{D}^0 \ell^+ \nu_\ell$  | [iii] ( 2.35 $\pm$ 0.09 ) %          |  | 2310 |
| $\bar{D}^0 \tau^+ \nu_\tau$  | ( 7.7 $\pm$ 2.5 ) $\times 10^{-3}$   |  | 1911 |
| $\bar{D}^*(2007)^0 \ell^+ \nu_\ell$  | [iii] ( 5.66 $\pm$ 0.22 ) %          |  | 2258 |
| $\bar{D}^*(2007)^0 \tau^+ \nu_\tau$  | ( 1.88 $\pm$ 0.20 ) %                |  | 1839 |
| $D^- \pi^+ \ell^+ \nu_\ell$  | ( 4.4 $\pm$ 0.4 ) $\times 10^{-3}$   |  | 2306 |
| $\bar{D}_0^*(2420)^0 \ell^+ \nu_\ell, \bar{D}_0^{*0} \rightarrow$                    | ( 2.5 $\pm$ 0.5 ) $\times 10^{-3}$   |  | –    |
| $D^- \pi^+$<br>$\bar{D}_2^*(2460)^0 \ell^+ \nu_\ell, \bar{D}_2^{*0} \rightarrow$     | ( 1.53 $\pm$ 0.16 ) $\times 10^{-3}$ |  | 2065 |
| $D^- \pi^+$<br>$D^{(*)} n \pi \ell^+ \nu_\ell (n \geq 1)$                            | ( 1.88 $\pm$ 0.25 ) %                |  | –    |
| $D^{*-} \pi^+ \ell^+ \nu_\ell$   | ( 6.0 $\pm$ 0.4 ) $\times 10^{-3}$   |  | 2254 |
| $\bar{D}_1(2420)^0 \ell^+ \nu_\ell, \bar{D}_1^0 \rightarrow$                         | ( 3.03 $\pm$ 0.20 ) $\times 10^{-3}$ |  | 2084 |
| $D^{*-} \pi^+$<br>$\bar{D}'_1(2430)^0 \ell^+ \nu_\ell, \bar{D}'_1{}^0 \rightarrow$   | ( 2.7 $\pm$ 0.6 ) $\times 10^{-3}$   |  | –    |
| $D^{*-} \pi^+$<br>$\bar{D}_2^*(2460)^0 \ell^+ \nu_\ell,$                             | ( 1.01 $\pm$ 0.24 ) $\times 10^{-3}$ | S=2.0                                    | 2065 |
| $\bar{D}_2^{*0} \rightarrow D^{*-} \pi^+$<br>$\bar{D}^0 \pi^+ \pi^- \ell^+ \nu_\ell$ | ( 1.7 $\pm$ 0.4 ) $\times 10^{-3}$   |  | 2301 |

|   |  |      |
|---|--|------|
| $\overline{D}^{*0} \pi^+ \pi^- \ell^+ \nu_\ell$ | ( 8 ± 5 ) × 10 <sup>-4</sup>                               | 2248 |
| $D_s^{(*)-} K^+ \ell^+ \nu_\ell$                | ( 6.1 ± 1.0 ) × 10 <sup>-4</sup>                           | —    |
| $D_s^- K^+ \ell^+ \nu_\ell$                     | ( 3.0 <sup>+1.4</sup> <sub>-1.2</sub> ) × 10 <sup>-4</sup> | 2242 |
| $D_s^{*-} K^+ \ell^+ \nu_\ell$                  | ( 2.9 ± 1.9 ) × 10 <sup>-4</sup>                           | 2185 |
| $\pi^0 \ell^+ \nu_\ell$                         | ( 7.80 ± 0.27 ) × 10 <sup>-5</sup>                         | 2638 |
| $\eta \ell^+ \nu_\ell$                          | ( 3.9 ± 0.5 ) × 10 <sup>-5</sup>                           | 2611 |
| $\eta' \ell^+ \nu_\ell$                         | ( 2.3 ± 0.8 ) × 10 <sup>-5</sup>                           | 2553 |
| $\omega \ell^+ \nu_\ell$                        | [iii] ( 1.19 ± 0.09 ) × 10 <sup>-4</sup>                   | 2582 |
| $\rho^0 \ell^+ \nu_\ell$                        | [iii] ( 1.58 ± 0.11 ) × 10 <sup>-4</sup>                   | 2583 |
| $p \bar{p} \ell^+ \nu_\ell$                     | ( 5.8 <sup>+2.6</sup> <sub>-2.3</sub> ) × 10 <sup>-6</sup> | 2467 |
| $p \bar{p} \mu^+ \nu_\mu$                       | ( 5.32 ± 0.34 ) × 10 <sup>-6</sup>                         | 2446 |
| $p \bar{p} e^+ \nu_e$                           | ( 8.2 <sup>+4.0</sup> <sub>-3.3</sub> ) × 10 <sup>-6</sup> | 2467 |
| $e^+ \nu_e$                                     | < 9.8 × 10 <sup>-7</sup> CL=90%                            | 2640 |
| $\mu^+ \nu_\mu$                                 | < 8.6 × 10 <sup>-7</sup> CL=90%                            | 2639 |
| $\tau^+ \nu_\tau$                               | ( 1.09 ± 0.24 ) × 10 <sup>-4</sup> S=1.2                   | 2341 |
| $\ell^+ \nu_\ell \gamma$                        | < 3.0 × 10 <sup>-6</sup> CL=90%                            | 2640 |
| $e^+ \nu_e \gamma$                              | < 4.3 × 10 <sup>-6</sup> CL=90%                            | 2640 |
| $\mu^+ \nu_\mu \gamma$                          | < 3.4 × 10 <sup>-6</sup> CL=90%                            | 2639 |
| $\mu^+ \mu^- \mu^+ \nu_\mu$                     | < 1.6 × 10 <sup>-8</sup> CL=95%                            | 2634 |

### Inclusive modes

|                            |  |   |
|----------------------------|--|---|
| $D^0 X$                    | ( 8.6 ± 0.7 ) %                              | — |
| $\overline{D}^0 X$         | ( 79 ± 4 ) %                                 | — |
| $D^+ X$                    | ( 2.5 ± 0.5 ) %                              | — |
| $D^- X$                    | ( 9.9 ± 1.2 ) %                              | — |
| $D_s^+ X$                  | ( 7.9 <sup>+1.4</sup> <sub>-1.3</sub> ) %    | — |
| $D_s^- X$                  | ( 1.10 <sup>+0.40</sup> <sub>-0.32</sub> ) % | — |
| $\Lambda_c^+ X$            | ( 2.1 <sup>+0.9</sup> <sub>-0.6</sub> ) %    | — |
| $\overline{\Lambda}_c^- X$ | ( 2.8 <sup>+1.1</sup> <sub>-0.9</sub> ) %    | — |
| $\bar{c} X$                | ( 97 ± 4 ) %                                 | — |
| $c X$                      | ( 23.4 <sup>+2.2</sup> <sub>-1.8</sub> ) %   | — |
| $c / \bar{c} X$            | ( 120 ± 6 ) %                                | — |

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

|                         |  |      |
|-------------------------|--|------|
| $\overline{D}^0 \pi^+$  | ( 4.68 ± 0.13 ) × 10 <sup>-3</sup>       | 2308 |
| $D_{CP(+1)} \pi^+$      | [jjj] ( 2.05 ± 0.18 ) × 10 <sup>-3</sup> | —    |
| $D_{CP(-1)} \pi^+$      | [jjj] ( 2.0 ± 0.4 ) × 10 <sup>-3</sup>   | —    |
| $\overline{D}^0 \rho^+$ | ( 1.34 ± 0.18 ) %                        | 2237 |
| $\overline{D}^0 K^+$    | ( 3.63 ± 0.12 ) × 10 <sup>-4</sup>       | 2281 |

|   |                |                                    |            |
|---|----------------|------------------------------------|------------|
| $D_{CP(+1)} K^+$  | [ <i>jjj</i> ] | $( 1.80 \pm 0.07 ) \times 10^{-4}$ | —          |
| $D_{CP(-1)} K^+$  | [ <i>jjj</i> ] | $( 1.96 \pm 0.18 ) \times 10^{-4}$ | —          |
| $D^0 K^+$   |                | $( 3.57 \pm 0.35 ) \times 10^{-6}$ | 2281       |
| $[K^- \pi^+]_D K^+$   | [ <i>kkk</i> ] | $< 2.8 \times 10^{-7}$             | CL=90% —   |
| $[K^+ \pi^-]_D K^+$   | [ <i>kkk</i> ] | $< 1.5 \times 10^{-5}$             | CL=90% —   |
| $[K^- \pi^+ \pi^0]_D K^+$   |                | seen                               | —          |
| $[K^+ \pi^- \pi^0]_D K^+$   |                | seen                               | —          |
| $[K^- \pi^+ \pi^+ \pi^-]_D K^+$   |                | seen                               | —          |
| $[K^+ \pi^- \pi^+ \pi^-]_D K^+$   |                | seen                               | —          |
| $[K^- \pi^+]_D \pi^+$   | [ <i>kkk</i> ] | $( 6.3 \pm 1.1 ) \times 10^{-7}$   | —          |
| $[K^+ \pi^-]_D \pi^+$   |                | $( 1.78 \pm 0.32 ) \times 10^{-4}$ | —          |
| $[K^- \pi^+ \pi^0]_D \pi^+$   |                | seen                               | —          |
| $[K^+ \pi^- \pi^0]_D \pi^+$   |                | seen                               | —          |
| $[K^- \pi^+ \pi^+ \pi^-]_D \pi^+$   |                | seen                               | —          |
| $[K^+ \pi^- \pi^+ \pi^-]_D \pi^+$   |                | seen                               | —          |
| $[\pi^+ \pi^- \pi^0]_D K^-$   |                | $( 4.6 \pm 0.9 ) \times 10^{-6}$   | —          |
| $[K_S^0 K^+ \pi^-]_D K^+$   |                | seen                               | —          |
| $[K_S^0 K^- \pi^+]_D K^+$   |                | seen                               | —          |
| $[K^*(892)^+ K^-]_D K^+$  |                | seen                               | —          |
| $[K_S^0 K^- \pi^+]_D \pi^+$   |                | seen                               | —          |
| $[K^*(892)^+ K^-]_D \pi^+$  |                | seen                               | —          |
| $[K_S^0 K^+ \pi^-]_D \pi^+$   |                | seen                               | —          |
| $[K^*(892)^- K^+]_D \pi^+$  |                | seen                               | —          |
| $\bar{D}^0 K^*(892)^+$  |                | $( 5.3 \pm 0.4 ) \times 10^{-4}$   | 2213       |
| $D_{CP(-1)} K^*(892)^+$   | [ <i>jjj</i> ] | $( 2.7 \pm 0.8 ) \times 10^{-4}$   | —          |
| $D_{CP(+1)} K^*(892)^+$   | [ <i>jjj</i> ] | $( 6.2 \pm 0.7 ) \times 10^{-4}$   | —          |
| $D^0 K^*(892)^+$  |                | $( 3.1 \pm 1.6 ) \times 10^{-6}$   | 2213       |
| $\bar{D}^0 K^+ \pi^+ \pi^-$   |                | $( 5.2 \pm 2.1 ) \times 10^{-4}$   | 2237       |
| $\bar{D}^0 K^+ \bar{K}^0$   |                | $( 5.5 \pm 1.6 ) \times 10^{-4}$   | 2189       |
| $\bar{D}^0 K^+ \bar{K}^*(892)^0$  |                | $( 7.5 \pm 1.7 ) \times 10^{-4}$   | 2072       |
| $\bar{D}^0 \pi^+ \pi^+ \pi^-$   |                | $( 5.6 \pm 2.1 ) \times 10^{-3}$   | S=3.6 2289 |
| $\bar{D}^0 \pi^+ \pi^+ \pi^-$ nonresonant                                 |                | $( 5 \pm 4 ) \times 10^{-3}$       | 2289       |
| $\bar{D}^0 \pi^+ \rho^0$  |                | $( 4.2 \pm 3.0 ) \times 10^{-3}$   | 2208       |
| $\bar{D}^0 a_1(1260)^+$   |                | $( 4 \pm 4 ) \times 10^{-3}$       | 2123       |
| $\bar{D}^0 \omega \pi^+$  |                | $( 4.1 \pm 0.9 ) \times 10^{-3}$   | 2206       |
| $D^*(2010)^- \pi^+ \pi^+$   |                | $( 1.35 \pm 0.22 ) \times 10^{-3}$ | 2247       |
| $D^*(2010)^- K^+ \pi^+$   |                | $( 8.2 \pm 1.4 ) \times 10^{-5}$   | 2206       |
| $\bar{D}_1(2420)^0 \pi^+, \bar{D}_1^0 \rightarrow$<br>$D^*(2010)^- \pi^+$ |                | $( 8.4 \pm 1.5 ) \times 10^{-4}$   | 2081       |
| $D^- \pi^+ \pi^+$   |                | $( 1.07 \pm 0.05 ) \times 10^{-3}$ | 2299       |
| $D^- K^+ \pi^+$   |                | $( 7.7 \pm 0.5 ) \times 10^{-5}$   | 2260       |
| $D_0^*(2300)^0 K^+, D_0^{*0} \rightarrow$<br>$D^- \pi^+$                  |                | $( 6.1 \pm 2.4 ) \times 10^{-6}$   | —          |

|  |   |             |
|--|---|-------------|
| $D_2^*(2460)^0 K^+, D_2^{*0} \rightarrow$                  | $( 2.32 \pm 0.23 ) \times 10^{-5}$            | —           |
| $D_1^*(2760)^0 K^+, D_1^{*0} \rightarrow$                  | $( 3.6 \pm 1.2 ) \times 10^{-6}$              | —           |
| $D^+ K^0$  | $< 2.9 \times 10^{-6}$                        | CL=90% 2278 |
| $D^+ K^+ \pi^-$  | $( 5.6 \pm 1.1 ) \times 10^{-6}$              | 2260        |
| $D_2^*(2460)^0 K^+, D_2^{*0} \rightarrow$                  | $< 6.3 \times 10^{-7}$                        | CL=90% —    |
| $D^+ K^{*0}$   | $< 4.9 \times 10^{-7}$                        | CL=90% 2211 |
| $D^+ \bar{K}^{*0}$   | $< 1.4 \times 10^{-6}$                        | CL=90% 2211 |
| $\bar{D}^*(2007)^0 \pi^+$                                  | $( 4.90 \pm 0.17 ) \times 10^{-3}$            | 2256        |
| $\bar{D}_{CP(+1)}^{*0} \pi^+$                              | [///] $( 2.7 \pm 0.6 ) \times 10^{-3}$        | —           |
| $\bar{D}_{CP(-1)}^{*0} \pi^+$                              | [///] $( 2.4 \pm 0.9 ) \times 10^{-3}$        | —           |
| $\bar{D}^*(2007)^0 \omega \pi^+$                           | $( 4.5 \pm 1.2 ) \times 10^{-3}$              | 2149        |
| $\bar{D}^*(2007)^0 \rho^+$                                 | $( 9.8 \pm 1.7 ) \times 10^{-3}$              | 2181        |
| $\bar{D}^*(2007)^0 K^+$                                    | $( 3.97 \pm_{-0.28}^{+0.31} ) \times 10^{-4}$ | 2227        |
| $\bar{D}_{CP(+1)}^{*0} K^+$                                | [///] $( 2.60 \pm 0.33 ) \times 10^{-4}$      | —           |
| $\bar{D}_{CP(-1)}^{*0} K^+$                                | [///] $( 2.19 \pm 0.30 ) \times 10^{-4}$      | —           |
| $\bar{D}^*(2007)^0 K^+$                                    | $( 7.8 \pm 2.2 ) \times 10^{-6}$              | 2227        |
| $\bar{D}^*(2007)^0 K^*(892)^+$                             | $( 8.1 \pm 1.4 ) \times 10^{-4}$              | 2156        |
| $\bar{D}^*(2007)^0 K^+ \bar{K}^0$                          | $< 1.06 \times 10^{-3}$                       | CL=90% 2132 |
| $\bar{D}^*(2007)^0 K^+ \bar{K}^*(892)^0$                   | $( 1.5 \pm 0.4 ) \times 10^{-3}$              | 2009        |
| $\bar{D}^*(2007)^0 \pi^+ \pi^+ \pi^-$                      | $( 1.03 \pm 0.12 ) \%$                        | 2236        |
| $\bar{D}^*(2007)^0 a_1(1260)^+$                            | $( 1.9 \pm 0.5 ) \%$                          | 2063        |
| $\bar{D}^*(2007)^0 \pi^- \pi^+ \pi^+ \pi^0$                | $( 1.8 \pm 0.4 ) \%$                          | 2219        |
| $\bar{D}^{*0} 3\pi^+ 2\pi^-$                               | $( 5.7 \pm 1.2 ) \times 10^{-3}$              | 2196        |
| $D^*(2010)^+ \pi^0$  | $< 3.6 \times 10^{-6}$                        | 2255        |
| $D^*(2010)^+ K^0$  | $< 9.0 \times 10^{-6}$                        | CL=90% 2225 |
| $D^*(2010)^- \pi^+ \pi^+ \pi^0$                            | $( 1.5 \pm 0.7 ) \%$                          | 2235        |
| $D^*(2010)^- \pi^+ \pi^+ \pi^+ \pi^-$                      | $( 2.6 \pm 0.4 ) \times 10^{-3}$              | 2217        |
| $\bar{D}^{*0} \pi^+$                                       | [nnn] $( 5.7 \pm 1.2 ) \times 10^{-3}$        | —           |
| $\bar{D}_1^*(2420)^0 \pi^+$                                | $( 1.5 \pm 0.6 ) \times 10^{-3}$              | S=1.3 2081  |
| $\bar{D}_1(2420)^0 \pi^+ \times B(\bar{D}_1^0 \rightarrow$ | $( 2.5 \pm_{-1.4}^{+1.6} ) \times 10^{-4}$    | S=3.9 2081  |
| $\bar{D}^0 \pi^+ \pi^-)$                                   |   |             |
| $\bar{D}_1(2420)^0 \pi^+ \times B(\bar{D}_1^0 \rightarrow$ | $( 2.2 \pm 1.0 ) \times 10^{-4}$              | 2081        |
| $\bar{D}^0 \pi^+ \pi^- (\text{nonresonant}))$              |   |             |
| $\bar{D}_1(2430)^0 \pi^+, \bar{D}_1^0 \rightarrow$         | $( 3.5 \pm 0.6 ) \times 10^{-4}$              | 2079        |
| $D^*(2010)^- \pi^+$  |   |             |
| $\bar{D}(2550)^0 \pi^+, \bar{D}^0 \rightarrow$             | $( 7.2 \pm 1.4 ) \times 10^{-5}$              | —           |
| $D^*(2010)^- \pi^+$  |   |             |
| $\bar{D}_J^*(2600)^0 \pi^+, \bar{D}_J^{*0} \rightarrow$    | $( 6.8 \pm 1.3 ) \times 10^{-5}$              | —           |
| $D^*(2010)^- \pi^+$  |   |             |

|   |  |             |
|---|--|-------------|
| $\bar{D}_2^*(2462)^0 \pi^+, \bar{D}_2^{*0} \rightarrow D^- \pi^+$                                       | $( 3.56 \pm 0.24 ) \times 10^{-4}$         | —           |
| $\bar{D}_2^*(2462)^0 \pi^+, \bar{D}_2^{*0} \rightarrow$<br>$\bar{D}^0 \pi^- \pi^+$                      | $( 2.2 \pm 1.0 ) \times 10^{-4}$           | —           |
| $\bar{D}_2^*(2462)^0 \pi^+, \bar{D}_2^{*0} \rightarrow$<br>$\bar{D}^0 \pi^- \pi^+ (\text{nonresonant})$ | $< 1.7 \times 10^{-4}$                     | CL=90% —    |
| $\bar{D}_2^*(2462)^0 \pi^+, \bar{D}_2^{*0} \rightarrow$<br>$D^*(2010)^- \pi^+$                          | $( 2.2 \pm 1.1 ) \times 10^{-4}$           | —           |
| $\bar{D}_0^*(2400)^0 \pi^+$<br>$\times B(\bar{D}_0^*(2400)^0 \rightarrow D^- \pi^+)$                    | $( 6.4 \pm 1.4 ) \times 10^{-4}$           | 2136        |
| $\bar{D}_1(2421)^0 \pi^+, \bar{D}_1^0 \rightarrow D^{*-} \pi^+$   | $( 7.4 \pm 1.0 ) \times 10^{-4}$           | —           |
| $\bar{D}_2^*(2462)^0 \pi^+, \bar{D}_2^{*0} \rightarrow$<br>$D^{*-} \pi^+$                               | $( 1.98 \pm 0.30 ) \times 10^{-4}$         | —           |
| $\bar{D}_1'(2427)^0 \pi^+, \bar{D}_1'^0 \rightarrow$<br>$D^{*-} \pi^+$                                  | $( 3.5 \pm 0.9 ) \times 10^{-4}$           | S=1.5 —     |
| $\bar{D}_1(2420)^0 \pi^+ \times B(\bar{D}_1^0 \rightarrow$<br>$\bar{D}^{*0} \pi^+ \pi^-)$               | $< 6 \times 10^{-6}$                       | CL=90% 2081 |
| $\bar{D}_1^*(2420)^0 \rho^+$  | $< 1.4 \times 10^{-3}$                     | CL=90% 1996 |
| $\bar{D}_2^*(2460)^0 \pi^+$   | $< 1.3 \times 10^{-3}$                     | CL=90% 2063 |
| $\bar{D}_2^*(2460)^0 \pi^+ \times B(\bar{D}_2^{*0} \rightarrow$<br>$\bar{D}^{*0} \pi^+ \pi^-)$          | $< 2.2 \times 10^{-5}$                     | CL=90% 2063 |
| $\bar{D}_1^*(2680)^0 \pi^+, \bar{D}_1^*(2680)^0 \rightarrow$<br>$D^- \pi^+$                             | $( 8.4 \pm 2.1 ) \times 10^{-5}$           | —           |
| $\bar{D}(2740)^0 \pi^+, \bar{D}^0 \rightarrow$<br>$D^*(2010)^- \pi^+$                                   | $( 3.3 \pm 1.5 ) \times 10^{-5}$           | —           |
| $\bar{D}_3^*(2750)^0 \pi^+, \bar{D}_3^{*0} \rightarrow$<br>$D^*(2010)^- \pi^+$                          | $( 1.10 \pm 0.32 ) \times 10^{-5}$         | 1913        |
| $\bar{D}_3^*(2760)^0 \pi^+,$<br>$\bar{D}_3^*(2760)^0 \pi^+ \rightarrow D^- \pi^+$                       | $( 1.00 \pm 0.22 ) \times 10^{-5}$         | —           |
| $\bar{D}_2^*(3000)^0 \pi^+,$<br>$\bar{D}_2^*(3000)^0 \pi^+ \rightarrow D^- \pi^+$                       | $( 2.0 \pm 1.4 ) \times 10^{-6}$           | —           |
| $\bar{D}_2^*(2460)^0 \rho^+$  | $< 4.7 \times 10^{-3}$                     | CL=90% 1977 |
| $\bar{D}^0 D_s^+$   | $( 9.0 \pm 0.9 ) \times 10^{-3}$           | 1815        |
| $D_{s0}^*(2317)^+ \bar{D}^0, D_{s0}^{*+} \rightarrow$<br>$D_s^+ \pi^0$                                  | $( 8.0 \pm_{-1.3}^{+1.6} ) \times 10^{-4}$ | 1605        |
| $D_{s0}(2317)^+ \bar{D}^0 \times$<br>$B(D_{s0}(2317)^+ \rightarrow D_s^{*+} \gamma)$                    | $< 7.6 \times 10^{-4}$                     | CL=90% 1605 |
| $D_{s0}(2317)^+ \bar{D}^*(2007)^0 \times$<br>$B(D_{s0}(2317)^+ \rightarrow D_s^+ \pi^0)$                | $( 9 \pm 7 ) \times 10^{-4}$               | 1511        |
| $D_{sJ}(2457)^+ \bar{D}^0$  | $( 3.1 \pm_{-0.9}^{+1.0} ) \times 10^{-3}$ | —           |

|  |   |             |
|--|---|-------------|
| $D_{sJ}(2457)^+ \bar{D}^0 \times$<br>$B(D_{sJ}(2457)^+ \rightarrow D_s^+ \gamma)$                                | $( 4.6 \begin{smallmatrix} + 1.3 \\ - 1.1 \end{smallmatrix} ) \times 10^{-4}$ | –           |
| $D_{sJ}(2457)^+ \bar{D}^0 \times$<br>$B(D_{sJ}(2457)^+ \rightarrow$<br>$D_s^+ \pi^+ \pi^-)$                      | $< 2.2 \quad \times 10^{-4}$  | CL=90% –    |
| $D_{sJ}(2457)^+ \bar{D}^0 \times$<br>$B(D_{sJ}(2457)^+ \rightarrow D_s^+ \pi^0)$                                 | $< 2.7 \quad \times 10^{-4}$  | CL=90% –    |
| $D_{sJ}(2457)^+ \bar{D}^0 \times$<br>$B(D_{sJ}(2457)^+ \rightarrow D_s^{*+} \gamma)$                             | $< 9.8 \quad \times 10^{-4}$  | CL=90% –    |
| $D_{sJ}(2457)^+ \bar{D}^*(2007)^0$   | $( 1.20 \pm 0.30 ) \%$  | –           |
| $D_{sJ}(2457)^+ \bar{D}^*(2007)^0 \times$<br>$B(D_{sJ}(2457)^+ \rightarrow D_s^+ \gamma)$                        | $( 1.4 \begin{smallmatrix} + 0.7 \\ - 0.6 \end{smallmatrix} ) \times 10^{-3}$ | –           |
| $\bar{D}^0 D_{s1}(2536)^+ \times$<br>$B(D_{s1}(2536)^+ \rightarrow$<br>$D^*(2007)^0 K^+ +$<br>$D^*(2010)^+ K^0)$ | $( 4.0 \pm 1.0 ) \times 10^{-4}$  | 1447        |
| $\bar{D}^0 D_{s1}(2536)^+ \times$<br>$B(D_{s1}(2536)^+ \rightarrow$<br>$D^*(2007)^0 K^+)$                        | $( 2.2 \pm 0.7 ) \times 10^{-4}$  | 1447        |
| $\bar{D}^*(2007)^0 D_{s1}(2536)^+ \times$<br>$B(D_{s1}(2536)^+ \rightarrow$<br>$D^*(2007)^0 K^+)$                | $( 5.5 \pm 1.6 ) \times 10^{-4}$  | 1339        |
| $\bar{D}^0 D_{s1}(2536)^+ \times$<br>$B(D_{s1}(2536)^+ \rightarrow D^{*+} K^0)$                                  | $( 2.3 \pm 1.1 ) \times 10^{-4}$  | 1447        |
| $\bar{D}^0 D_{sJ}(2700)^+ \times$<br>$B(D_{sJ}(2700)^+ \rightarrow D^0 K^+)$                                     | $( 5.6 \pm 1.8 ) \times 10^{-4}$  | S=1.7 –     |
| $\bar{D}^{*0} D_{s1}(2536)^+, D_{s1}^+ \rightarrow$<br>$D^{*+} K^0$  | $( 3.9 \pm 2.6 ) \times 10^{-4}$  | 1339        |
| $\bar{D}^0 D_{sJ}(2573)^+, D_{sJ}^+ \rightarrow$<br>$D^0 K^+$  | $( 8 \pm 15 ) \times 10^{-6}$   | –           |
| $\bar{D}^{*0} D_{sJ}(2573), D_{sJ}^+ \rightarrow$<br>$D^0 K^+$   | $< 2 \quad \times 10^{-4}$  | CL=90% 1306 |
| $\bar{D}^*(2007)^0 D_{sJ}(2573), D_{sJ}^+ \rightarrow$<br>$D^0 K^+$  | $< 5 \quad \times 10^{-4}$  | CL=90% 1306 |
| $\bar{D}^0 D_s^{*+}$   | $( 7.6 \pm 1.6 ) \times 10^{-3}$  | 1734        |
| $\bar{D}^*(2007)^0 D_s^+$  | $( 8.2 \pm 1.7 ) \times 10^{-3}$  | 1737        |
| $\bar{D}^*(2007)^0 D_s^{*+}$   | $( 1.71 \pm 0.24 ) \%$  | 1651        |
| $D_s^{(*)+} \bar{D}^{*0}$  | $( 2.7 \pm 1.2 ) \%$  | –           |
| $\bar{D}^*(2007)^0 D^*(2010)^+$  | $( 8.1 \pm 1.7 ) \times 10^{-4}$  | 1713        |
| $\bar{D}^0 D^*(2010)^+ +$<br>$\bar{D}^*(2007)^0 D^+$   | $< 1.30 \quad \%$   | CL=90% 1792 |
| $\bar{D}^0 D^*(2010)^+$  | $( 3.9 \pm 0.5 ) \times 10^{-4}$  | 1792        |

|   |                                    |                         |      |
|---|------------------------------------|-------------------------|------|
| $\bar{D}^0 D^+$                               | $( 3.8 \pm 0.4 ) \times 10^{-4}$   |                         | 1866 |
| $\bar{D}^0 D^+ K^0$                           | $( 1.55 \pm 0.21 ) \times 10^{-3}$ |                         | 1571 |
| $D^+ \bar{D}^*(2007)^0$                       | $( 6.3 \pm 1.7 ) \times 10^{-4}$   |                         | 1791 |
| $\bar{D}^*(2007)^0 D^+ K^0$                   | $( 2.1 \pm 0.5 ) \times 10^{-3}$   |                         | 1475 |
| $\bar{D}^0 D^*(2010)^+ K^0$                   | $( 3.8 \pm 0.4 ) \times 10^{-3}$   |                         | 1476 |
| $\bar{D}^*(2007)^0 D^*(2010)^+ K^0$           | $( 9.2 \pm 1.2 ) \times 10^{-3}$   |                         | 1362 |
| $\bar{D}^0 D^0 K^+$                           | $( 1.45 \pm 0.33 ) \times 10^{-3}$ | S=2.6                   | 1577 |
| $\bar{D}^*(2007)^0 D^0 K^+$                   | $( 2.26 \pm 0.23 ) \times 10^{-3}$ |                         | 1481 |
| $\bar{D}^0 D^*(2007)^0 K^+$                   | $( 6.3 \pm 0.5 ) \times 10^{-3}$   |                         | 1481 |
| $\bar{D}^*(2007)^0 D^*(2007)^0 K^+$           | $( 1.12 \pm 0.13 ) \%$             |                         | 1368 |
| $D^- D^+ K^+$                                 | $( 2.2 \pm 0.7 ) \times 10^{-4}$   |                         | 1571 |
| $X_0(2900) D^+, X_0 \rightarrow$<br>$D^- K^+$ | $( 1.2 \pm 0.5 ) \times 10^{-5}$   |                         | —    |
| $X_1(2900) D^+, X_1 \rightarrow$<br>$D^- K^+$ | $( 6.7 \pm 2.3 ) \times 10^{-5}$   |                         | —    |
| $D^- D^+ K^+$ nonresonant                     | $( 5.3 \pm 1.8 ) \times 10^{-5}$   |                         | 1571 |
| $D^- D^*(2010)^+ K^+$                         | $( 6.3 \pm 1.1 ) \times 10^{-4}$   |                         | 1475 |
| $D^*(2010)^- D^+ K^+$                         | $( 6.0 \pm 1.3 ) \times 10^{-4}$   |                         | 1475 |
| $D^*(2010)^- D^*(2010)^+ K^+$                 | $( 1.32 \pm 0.18 ) \times 10^{-3}$ |                         | 1363 |
| $(\bar{D} + \bar{D}^*)(D + D^*) K$            | $( 4.05 \pm 0.30 ) \%$             |                         | —    |
| $D_s^+ \pi^0$                                 | $( 1.6 \pm 0.5 ) \times 10^{-5}$   |                         | 2270 |
| $D_s^{*+} \pi^0$                              | $< 2.6$                            | $\times 10^{-4}$ CL=90% | 2215 |
| $D_s^+ \eta$                                  | $< 4$                              | $\times 10^{-4}$ CL=90% | 2235 |
| $D_s^{*+} \eta$                               | $< 6$                              | $\times 10^{-4}$ CL=90% | 2178 |
| $D_s^+ \rho^0$                                | $< 3.0$                            | $\times 10^{-4}$ CL=90% | 2197 |
| $D_s^{*+} \rho^0$                             | $< 4$                              | $\times 10^{-4}$ CL=90% | 2138 |
| $D_s^+ \omega$                                | $< 4$                              | $\times 10^{-4}$ CL=90% | 2195 |
| $D_s^{*+} \omega$                             | $< 6$                              | $\times 10^{-4}$ CL=90% | 2136 |
| $D_s^+ a_1(1260)^0$                           | $< 1.8$                            | $\times 10^{-3}$ CL=90% | 2079 |
| $D_s^{*+} a_1(1260)^0$                        | $< 1.3$                            | $\times 10^{-3}$ CL=90% | 2015 |
| $D_s^+ K^+ K^-$                               | $( 7.2 \pm 1.1 ) \times 10^{-6}$   |                         | 2149 |
| $D_s^+ \phi$                                  | $< 4.2$                            | $\times 10^{-7}$ CL=90% | 2141 |
| $D_s^{*+} \phi$                               | $< 1.2$                            | $\times 10^{-5}$ CL=90% | 2079 |
| $D_s^+ \bar{K}^0$                             | $< 8$                              | $\times 10^{-4}$ CL=90% | 2242 |
| $D_s^{*+} \bar{K}^0$                          | $< 9$                              | $\times 10^{-4}$ CL=90% | 2185 |
| $D_s^+ \bar{K}^*(892)^0$                      | $< 4.4$                            | $\times 10^{-6}$ CL=90% | 2172 |
| $D_s^+ K^{*0}$                                | $< 3.5$                            | $\times 10^{-6}$ CL=90% | 2172 |
| $D_s^{*+} \bar{K}^*(892)^0$                   | $< 3.5$                            | $\times 10^{-4}$ CL=90% | 2112 |
| $D_s^- \pi^+ K^+$                             | $( 1.80 \pm 0.22 ) \times 10^{-4}$ |                         | 2222 |
| $D_s^{*-} \pi^+ K^+$                          | $( 1.45 \pm 0.24 ) \times 10^{-4}$ |                         | 2164 |
| $D_s^- \pi^+ K^*(892)^+$                      | $< 5$                              | $\times 10^{-3}$ CL=90% | 2138 |



|                             |                   |                  |        |      |
|-----------------------------|-------------------|------------------|--------|------|
| $D_s^{*-} \pi^+ K^*(892)^+$ | $< 7$             | $\times 10^{-3}$ | CL=90% | 2076 |
| $D_s^- K^+ K^+$             | $( 9.7 \pm 2.1 )$ | $\times 10^{-6}$ |        | 2149 |
| $D_s^{*-} K^+ K^+$          | $< 1.5$           | $\times 10^{-5}$ | CL=90% | 2088 |

### Charmonium modes

|   |  |                  |        |      |
|---|--|------------------|--------|------|
| $\eta_c K^+$  | $( 1.09 \pm 0.08 )$  | $\times 10^{-3}$ |        | 1751 |
| $\eta_c K^+, \eta_c \rightarrow K_S^0 K^\mp \pi^\pm$          | $( 2.7 \pm 0.6 )$  | $\times 10^{-5}$ |        | —    |
| $\eta_c K^*(892)^+$   | $( 1.1 \begin{smallmatrix} + 0.5 \\ - 0.4 \end{smallmatrix} )$ | $\times 10^{-3}$ |        | 1646 |
| $\eta_c K^+ \pi^+ \pi^-$                                      | $< 3.9$  | $\times 10^{-4}$ | CL=90% | 1684 |
| $\eta_c K^+ \omega(782)$                                      | $< 5.3$  | $\times 10^{-4}$ | CL=90% | 1475 |
| $\eta_c K^+ \eta$   | $< 2.2$  | $\times 10^{-4}$ | CL=90% | 1588 |
| $\eta_c K^+ \pi^0$  | $< 6.2$  | $\times 10^{-5}$ | CL=90% | 1723 |
| $\eta_c(2S) K^+$  | $( 4.4 \pm 1.0 )$  | $\times 10^{-4}$ |        | 1320 |
| $\eta_c(2S) K^+, \eta_c \rightarrow p\bar{p}$                 | $( 3.5 \pm 0.8 )$  | $\times 10^{-8}$ |        | —    |
| $\eta_c(2S) K^+, \eta_c \rightarrow K_S^0 K^\mp \pi^\pm$      | $( 3.4 \begin{smallmatrix} + 2.3 \\ - 1.6 \end{smallmatrix} )$ | $\times 10^{-6}$ |        | —    |
| $\eta_c(2S) K^+, \eta_c \rightarrow p\bar{p} \pi^+ \pi^-$     | $( 1.12 \pm 0.18 )$  | $\times 10^{-6}$ |        | —    |
| $h_c(1P) K^+, h_c \rightarrow J/\psi \pi^+ \pi^-$             | $< 3.4$  | $\times 10^{-6}$ | CL=90% | 1401 |
| $X(3730)^0 K^+, X^0 \rightarrow \eta_c \eta$                  | $< 4.6$  | $\times 10^{-5}$ | CL=90% | —    |
| $X(3730)^0 K^+, X^0 \rightarrow \eta_c \pi^0$                 | $< 5.7$  | $\times 10^{-6}$ | CL=90% | —    |
| $\eta_{c2}(1D) K^+, \eta_{c2} \rightarrow h_c \gamma$         | $< 3.7$  | $\times 10^{-5}$ | CL=90% | —    |
| $\eta_{c2}(1D) \pi^+ K_S^0, \eta_{c2} \rightarrow h_c \gamma$ | $< 1.1$  | $\times 10^{-4}$ | CL=90% | —    |
| $\psi_2(3823) K^+, \psi_2 \rightarrow J/\psi \pi^+ \pi^-$     | $( 2.8 \pm 0.6 )$  | $\times 10^{-7}$ |        | —    |
| $\chi_{c1}(3872) K^+$   | $( 2.1 \pm 0.7 )$  | $\times 10^{-4}$ |        | 1141 |
| $X(3915) K^+$   | $< 2.8$  | $\times 10^{-4}$ | CL=90% | 1101 |
| $X(3915) K^+, X \rightarrow D^+ D^-$                          | $( 8.1 \pm 3.3 )$  | $\times 10^{-6}$ |        | —    |
| $X(3915)^0 K^+, X^0 \rightarrow \eta_c \eta$                  | $< 4.7$  | $\times 10^{-5}$ | CL=90% | —    |
| $X(3915)^0 K^+, X^0 \rightarrow \eta_c \pi^0$                 | $< 1.7$  | $\times 10^{-5}$ | CL=90% | —    |
| $X(4014)^0 K^+, X^0 \rightarrow \eta_c \eta$                  | $< 3.9$  | $\times 10^{-5}$ | CL=90% | —    |
| $X(4014)^0 K^+, X^0 \rightarrow \eta_c \pi^0$                 | $< 1.2$  | $\times 10^{-5}$ | CL=90% | —    |
| $Z_c(3900)^0 K^+, Z_c^0 \rightarrow \eta_c \pi^+ \pi^-$       | $< 4.7$  | $\times 10^{-5}$ | CL=90% | —    |
| $X(4020)^0 K^+, X^0 \rightarrow \eta_c \pi^+ \pi^-$           | $< 1.6$  | $\times 10^{-5}$ | CL=90% | —    |
| $\chi_{c1}(3872) K^*(892)^+$                                  | $< 6$  | $\times 10^{-4}$ | CL=90% | 940  |
| $\chi_{c1}(3872)^+ K^0, \chi_{c1}^+ \rightarrow [ooo]$        | $< 6.1$  | $\times 10^{-6}$ | CL=90% | —    |
| $J/\psi(1S) \pi^+ \pi^0$                                      |  |                  |        |      |
| $\chi_{c1}(3872) K^0 \pi^+$                                   | $( 2.8 \pm 1.2 )$  | $\times 10^{-4}$ |        | 1085 |
| $Z_c(4430)^+ K^0, Z_c^+ \rightarrow J/\psi \pi^+$             | $< 1.5$  | $\times 10^{-5}$ | CL=95% | —    |
| $Z_c(4430)^+ K^0, Z_c^+ \rightarrow \psi(2S) \pi^+$           | $< 4.7$  | $\times 10^{-5}$ | CL=95% | —    |

|   |   |                  |        |      |
|---|---|------------------|--------|------|
| $\psi(4260)^0 K^+, \psi^0 \rightarrow$<br>$J/\psi \pi^+ \pi^-$        | < 1.56  | $\times 10^{-5}$ | CL=95% | —    |
| $X(3915) K^+, X \rightarrow J/\psi \gamma$                            | < 1.4   | $\times 10^{-5}$ | CL=90% | —    |
| $X(3915) K^+, X \rightarrow$<br>$\chi_{c1}(1P) \pi^0$                 | < 3.8   | $\times 10^{-5}$ | CL=90% | —    |
| $X(3930)^0 K^+, X^0 \rightarrow J/\psi \gamma$                        | < 2.5   | $\times 10^{-6}$ | CL=90% | —    |
| $J/\psi(1S) K^+$  | ( 1.020 ± 0.019 )   | $\times 10^{-3}$ |        | 1684 |
| $J/\psi(1S) K^0 \pi^+$  | ( 1.14 ± 0.11 )   | $\times 10^{-3}$ |        | 1651 |
| $J/\psi(1S) K^+ \pi^+ \pi^-$  | ( 8.1 ± 1.3 )   | $\times 10^{-4}$ | S=2.5  | 1612 |
| $J/\psi(1S) K^+ K^- K^+$  | ( 3.37 ± 0.29 )   | $\times 10^{-5}$ |        | 1252 |
| $X(3915) K^+, X \rightarrow p \bar{p}$                                | < 7.1   | $\times 10^{-8}$ | CL=95% | —    |
| $J/\psi(1S) K^*(892)^+$   | ( 1.43 ± 0.08 )   | $\times 10^{-3}$ |        | 1571 |
| $J/\psi(1S) K(1270)^+$  | ( 1.8 ± 0.5 )   | $\times 10^{-3}$ |        | 1402 |
| $J/\psi(1S) K(1400)^+$  | < 5   | $\times 10^{-4}$ | CL=90% | 1308 |
| $J/\psi(1S) \eta K^+$   | ( 1.24 ± 0.14 )   | $\times 10^{-4}$ |        | 1510 |
| $\chi_{c1-odd}(3872) K^+,$<br>$\chi_{c1-odd} \rightarrow J/\psi \eta$ | < 3.8   | $\times 10^{-6}$ | CL=90% | —    |
| $\psi(4160) K^+, \psi \rightarrow J/\psi \eta$                        | < 7.4   | $\times 10^{-6}$ | CL=90% | —    |
| $J/\psi(1S) \eta' K^+$  | < 8.8   | $\times 10^{-5}$ | CL=90% | 1273 |
| $J/\psi(1S) \phi K^+$   | ( 5.0 ± 0.4 )   | $\times 10^{-5}$ |        | 1227 |
| $J/\psi(1S) K_1(1650), K_1 \rightarrow$<br>$\phi K^+$                 | ( 6 $\begin{smallmatrix} +10 \\ -6 \end{smallmatrix}$ )         | $\times 10^{-6}$ |        | —    |
| $J/\psi(1S) K^*(1680)^+, K^* \rightarrow$<br>$\phi K^+$               | ( 3.4 $\begin{smallmatrix} +1.9 \\ -2.2 \end{smallmatrix}$ )    | $\times 10^{-6}$ |        | —    |
| $J/\psi(1S) K_2^*(1980), K_2^* \rightarrow$<br>$\phi K^+$             | ( 1.5 $\begin{smallmatrix} +0.9 \\ -0.5 \end{smallmatrix}$ )    | $\times 10^{-6}$ |        | —    |
| $J/\psi(1S) K(1830)^+,$<br>$K(1830)^+ \rightarrow \phi K^+$           | ( 1.3 $\begin{smallmatrix} +1.3 \\ -1.1 \end{smallmatrix}$ )    | $\times 10^{-6}$ |        | —    |
| $\chi_{c1}(4140) K^+, \chi_{c1} \rightarrow$<br>$J/\psi(1S) \phi$     | ( 10 ± 4 )  | $\times 10^{-6}$ |        | —    |
| $\chi_{c1}(4274) K^+, \chi_{c1} \rightarrow$<br>$J/\psi(1S) \phi$     | ( 3.6 $\begin{smallmatrix} +2.2 \\ -1.8 \end{smallmatrix}$ )    | $\times 10^{-6}$ |        | —    |
| $\chi_{c0}(4500) K^+, \chi_c^0 \rightarrow$<br>$J/\psi(1S) \phi$      | ( 3.3 $\begin{smallmatrix} +2.1 \\ -1.7 \end{smallmatrix}$ )    | $\times 10^{-6}$ |        | —    |
| $\chi_{c0}(4700) K^+, \chi_{c0} \rightarrow$<br>$J/\psi(1S) \phi$     | ( 6 $\begin{smallmatrix} +5 \\ -4 \end{smallmatrix}$ )          | $\times 10^{-6}$ |        | —    |
| $J/\psi(1S) \omega K^+$   | ( 3.20 $\begin{smallmatrix} +0.60 \\ -0.32 \end{smallmatrix}$ ) | $\times 10^{-4}$ |        | 1388 |
| $X(3915) K^+, X \rightarrow J/\psi \omega$                            | ( 3.0 $\begin{smallmatrix} +0.9 \\ -0.7 \end{smallmatrix}$ )    | $\times 10^{-5}$ |        | 1103 |
| $J/\psi(1S) \pi^+$  | ( 3.92 ± 0.08 )   | $\times 10^{-5}$ |        | 1728 |
| $J/\psi(1S) \pi^+ \pi^+ \pi^+ \pi^- \pi^-$                            | ( 1.17 ± 0.13 )   | $\times 10^{-5}$ |        | 1635 |
| $\psi(2S) \pi^+ \pi^+ \pi^-$  | ( 1.9 ± 0.4 )   | $\times 10^{-5}$ |        | 1304 |

|   |   |        |      |
|---|---|--------|------|
| $J/\psi(1S)\rho^+$  | $(4.1 \pm 0.5) \times 10^{-5}$              | S=1.4  | 1611 |
| $J/\psi(1S)\pi^+\pi^0$ nonresonant                                    | $< 7.3 \times 10^{-6}$                      | CL=90% | 1717 |
| $J/\psi(1S)a_1(1260)^+$   | $< 1.2 \times 10^{-3}$                      | CL=90% | 1415 |
| $J/\psi(1S)p\bar{p}\pi^+$   | $< 5.0 \times 10^{-7}$                      | CL=90% | 643  |
| $J/\psi(1S)p\bar{\Lambda}$  | $(1.46 \pm 0.12) \times 10^{-5}$            |        | 567  |
| $J/\psi(1S)\bar{\Sigma}^0 p$  | $< 1.1 \times 10^{-5}$                      | CL=90% | —    |
| $J/\psi(1S)D^+$   | $< 1.2 \times 10^{-4}$                      | CL=90% | 871  |
| $J/\psi(1S)\bar{D}^0\pi^+$  | $< 2.5 \times 10^{-5}$                      | CL=90% | 665  |
| $\psi(2S)\pi^+$   | $(2.44 \pm 0.30) \times 10^{-5}$            |        | 1347 |
| $\psi(2S)K^+$   | $(6.24 \pm 0.20) \times 10^{-4}$            |        | 1284 |
| $\psi(2S)K^*(892)^+$  | $(6.7 \pm 1.4) \times 10^{-4}$              | S=1.3  | 1116 |
| $\psi(2S)K^+\pi^+\pi^-$   | $(4.3 \pm 0.5) \times 10^{-4}$              |        | 1179 |
| $\psi(2S)\phi(1020)K^+$   | $(4.0 \pm 0.7) \times 10^{-6}$              |        | 417  |
| $\psi(3770)K^+$   | $(4.3 \pm 1.1) \times 10^{-4}$              |        | 1218 |
| $\psi(3770)K^+, \psi \rightarrow D^0\bar{D}^0$                        | $(1.5 \pm 0.5) \times 10^{-4}$              | S=1.4  | 1218 |
| $\psi(3770)K^+, \psi \rightarrow D^+D^-$                              | $(9.4 \pm 3.5) \times 10^{-5}$              |        | 1218 |
| $\psi(3770)K^+, \psi \rightarrow p\bar{p}$                            | $< 2 \times 10^{-7}$                        | CL=95% | —    |
| $\psi(4040)K^+$   | $< 1.3 \times 10^{-4}$                      | CL=90% | 1003 |
| $\psi(4040)K^+, \psi \rightarrow D^+D^-$                              | $(1.1 \pm 0.5) \times 10^{-5}$              |        | —    |
| $\psi(4160)K^+$   | $(5.1 \pm 2.7) \times 10^{-4}$              |        | 868  |
| $\psi(4160)K^+, \psi \rightarrow \bar{D}^0D^0$                        | $(8 \pm 5) \times 10^{-5}$                  |        | —    |
| $\psi(4160)K^+, \psi \rightarrow D^+D^-$                              | $(1.5 \pm 0.6) \times 10^{-5}$              |        | —    |
| $\psi(4415)K^+, \psi \rightarrow D^+D^-$                              | $(2.0 \pm 0.8) \times 10^{-5}$              |        | —    |
| $\chi_{c0}\pi^+, \chi_{c0} \rightarrow \pi^+\pi^-$                    | $< 1 \times 10^{-7}$                        | CL=90% | 1531 |
| $\chi_{c0}K^+$  | $(1.51 \pm_{-0.13}^{+0.15}) \times 10^{-4}$ |        | 1478 |
| $\chi_{c0}K^*(892)^+$   | $< 2.1 \times 10^{-4}$                      | CL=90% | 1341 |
| $\chi_{c1}(1P)\pi^+$  | $(2.2 \pm 0.5) \times 10^{-5}$              |        | 1468 |
| $\chi_{c1}(1P)K^+$  | $(4.74 \pm 0.22) \times 10^{-4}$            |        | 1412 |
| $\chi_{c1}(1P)K^*(892)^+$   | $(3.0 \pm 0.6) \times 10^{-4}$              | S=1.1  | 1265 |
| $\chi_{c1}(1P)K^0\pi^+$   | $(5.8 \pm 0.4) \times 10^{-4}$              |        | 1370 |
| $\chi_{c1}(1P)K^+\pi^0$   | $(3.29 \pm 0.35) \times 10^{-4}$            |        | 1373 |
| $\chi_{c1}(1P)K^+\pi^+\pi^-$  | $(3.74 \pm 0.30) \times 10^{-4}$            |        | 1319 |
| $\chi_{c1}(2P)K^+, \chi_{c1}(2P) \rightarrow \pi^+\pi^-\chi_{c1}(1P)$ | $< 1.1 \times 10^{-5}$                      | CL=90% | —    |
| $\chi_{c2}K^+$  | $(1.1 \pm 0.4) \times 10^{-5}$              |        | 1379 |
| $\chi_{c2}K^+, \chi_{c2} \rightarrow p\bar{p}\pi^+\pi^-$              | $< 1.9 \times 10^{-7}$                      |        | —    |
| $\chi_{c2}K^*(892)^+$   | $< 1.2 \times 10^{-4}$                      | CL=90% | 1228 |
| $\chi_{c2}K^0\pi^+$   | $(1.16 \pm 0.25) \times 10^{-4}$            |        | 1336 |
| $\chi_{c2}K^+\pi^0$   | $< 6.2 \times 10^{-5}$                      | CL=90% | 1339 |
| $\chi_{c2}K^+\pi^+\pi^-$  | $(1.34 \pm 0.19) \times 10^{-4}$            |        | 1284 |
| $\chi_{c2}(3930)K^+, \chi_{c2} \rightarrow D^+D^-$                    | $(1.6 \pm 0.6) \times 10^{-5}$              |        | —    |
| $\chi_{c2}(3930)\pi^+, \chi_{c2} \rightarrow \pi^+\pi^-$              | $< 1 \times 10^{-7}$                        | CL=90% | 1437 |
| $h_c(1P)K^+$  | $(3.7 \pm 1.2) \times 10^{-5}$              |        | 1401 |

|   |   |                  |        |      |
|---|---|------------------|--------|------|
| $h_c(1P)K^+, h_c \rightarrow p\bar{p}$                      | < 6.4   | $\times 10^{-8}$ | CL=95% | —    |
| <b>K or K* modes</b>  |   |                  |        |      |
| $K^0\pi^+$  | ( 2.37 ± 0.08 )   | $\times 10^{-5}$ |        | 2614 |
| $K^+\pi^0$  | ( 1.29 ± 0.05 )   | $\times 10^{-5}$ |        | 2615 |
| $\eta'K^+$  | ( 7.04 ± 0.25 )   | $\times 10^{-5}$ |        | 2528 |
| $\eta'K^*(892)^+$   | ( 4.8 $\begin{smallmatrix} + \\ - \end{smallmatrix}$ 1.8 / 1.6 )    | $\times 10^{-6}$ |        | 2472 |
| $\eta'K_0^*(1430)^+$  | ( 5.2 ± 2.1 )   | $\times 10^{-6}$ |        | —    |
| $\eta'K_2^*(1430)^+$  | ( 2.8 ± 0.5 )   | $\times 10^{-5}$ |        | 2346 |
| $\eta K^+$  | ( 2.4 ± 0.4 )   | $\times 10^{-6}$ | S=1.7  | 2588 |
| $\eta K^*(892)^+$   | ( 1.93 ± 0.16 )   | $\times 10^{-5}$ |        | 2534 |
| $\eta K_0^*(1430)^+$  | ( 1.8 ± 0.4 )   | $\times 10^{-5}$ |        | —    |
| $\eta K_2^*(1430)^+$  | ( 9.1 ± 3.0 )   | $\times 10^{-6}$ |        | 2414 |
| $\eta(1295)K^+ \times B(\eta(1295) \rightarrow \eta\pi\pi)$ | ( 2.9 $\begin{smallmatrix} + \\ - \end{smallmatrix}$ 0.8 / 0.7 )    | $\times 10^{-6}$ |        | 2455 |
| $\eta(1405)K^+ \times B(\eta(1405) \rightarrow \eta\pi\pi)$ | < 1.3   | $\times 10^{-6}$ | CL=90% | 2425 |
| $\eta(1405)K^+ \times B(\eta(1405) \rightarrow K^*K)$       | < 1.2   | $\times 10^{-6}$ | CL=90% | 2425 |
| $\eta(1475)K^+ \times B(\eta(1475) \rightarrow K^*K)$       | ( 1.38 $\begin{smallmatrix} + \\ - \end{smallmatrix}$ 0.21 / 0.18 ) | $\times 10^{-5}$ |        | 2407 |
| $f_1(1285)K^+$  | < 2.0   | $\times 10^{-6}$ | CL=90% | 2458 |
| $f_1(1420)K^+ \times B(f_1(1420) \rightarrow \eta\pi\pi)$   | < 2.9   | $\times 10^{-6}$ | CL=90% | 2420 |
| $f_1(1420)K^+ \times B(f_1(1420) \rightarrow K^*K)$         | < 4.1   | $\times 10^{-6}$ | CL=90% | 2420 |
| $\phi(1680)K^+ \times B(\phi(1680) \rightarrow K^*K)$       | < 3.4   | $\times 10^{-6}$ | CL=90% | 2344 |
| $f_0(1500)K^+$  | ( 3.7 ± 2.2 )   | $\times 10^{-6}$ |        | 2398 |
| $\omega K^+$  | ( 6.5 ± 0.4 )   | $\times 10^{-6}$ |        | 2558 |
| $\omega K^*(892)^+$   | < 7.4   | $\times 10^{-6}$ | CL=90% | 2503 |
| $\omega(K\pi)_0^{*+}$                                       | ( 2.8 ± 0.4 )   | $\times 10^{-5}$ |        | —    |
| $\omega K_0^*(1430)^+$                                      | ( 2.4 ± 0.5 )   | $\times 10^{-5}$ |        | —    |
| $\omega K_2^*(1430)^+$                                      | ( 2.1 ± 0.4 )   | $\times 10^{-5}$ |        | 2379 |
| $a_0(980)^+K^0 \times B(a_0(980)^+ \rightarrow \eta\pi^+)$  | < 3.9   | $\times 10^{-6}$ | CL=90% | —    |
| $a_0(980)^0K^+ \times B(a_0(980)^0 \rightarrow \eta\pi^0)$  | < 2.5   | $\times 10^{-6}$ | CL=90% | —    |
| $K^*(892)^0\pi^+$   | ( 1.01 ± 0.08 )   | $\times 10^{-5}$ |        | 2562 |
| $K^*(892)^+\pi^0$   | ( 6.8 ± 0.9 )   | $\times 10^{-6}$ |        | 2563 |
| $K^+\pi^-\pi^+$   | ( 5.10 ± 0.29 )   | $\times 10^{-5}$ |        | 2609 |
| $K^+\pi^-\pi^+$ nonresonant                                 | ( 1.63 $\begin{smallmatrix} + \\ - \end{smallmatrix}$ 0.21 / 0.15 ) | $\times 10^{-5}$ |        | 2609 |

|  |   |        |      |
|--|---|--------|------|
| $\omega(782)K^+$   | $( 6 \pm 9 ) \times 10^{-6}$                  |        | 2558 |
| $K^+ f_0(980) \times B(f_0(980) \rightarrow \pi^+ \pi^-)$        | $( 9.4 \pm_{-1.2}^{+1.0} ) \times 10^{-6}$    |        | 2522 |
| $f_2(1270)^0 K^+$  | $( 1.07 \pm 0.27 ) \times 10^{-6}$            |        | —    |
| $f_0(1370)^0 K^+ \times B(f_0(1370)^0 \rightarrow \pi^+ \pi^-)$  | $< 1.07 \times 10^{-5}$                       | CL=90% | —    |
| $\rho^0(1450)K^+ \times B(\rho^0(1450) \rightarrow \pi^+ \pi^-)$ | $< 1.17 \times 10^{-5}$                       | CL=90% | —    |
| $f'_2(1525)K^+ \times B(f'_2(1525) \rightarrow \pi^+ \pi^-)$     | $< 3.4 \times 10^{-6}$                        | CL=90% | 2394 |
| $K^+ \rho^0$   | $( 3.7 \pm 0.5 ) \times 10^{-6}$              |        | 2559 |
| $K_0^*(1430)^0 \pi^+$  | $( 3.9 \pm_{-0.5}^{+0.6} ) \times 10^{-5}$    | S=1.4  | 2445 |
| $K_2^*(1430)^0 \pi^+$  | $( 5.6 \pm_{-1.5}^{+2.2} ) \times 10^{-6}$    |        | 2445 |
| $K^*(1410)^0 \pi^+$  | $< 4.5 \times 10^{-5}$                        | CL=90% | 2448 |
| $K^*(1680)^0 \pi^+$  | $< 1.2 \times 10^{-5}$                        | CL=90% | 2358 |
| $K^+ \pi^0 \pi^0$  | $( 1.62 \pm 0.19 ) \times 10^{-5}$            |        | 2610 |
| $f_0(980)K^+ \times B(f_0 \rightarrow \pi^0 \pi^0)$              | $( 2.8 \pm 0.8 ) \times 10^{-6}$              |        | 2522 |
| $K^- \pi^+ \pi^+$  | $< 4.6 \times 10^{-8}$                        | CL=90% | 2609 |
| $K^- \pi^+ \pi^+$ nonresonant                                    | $< 5.6 \times 10^{-5}$                        | CL=90% | 2609 |
| $K_1(1270)^0 \pi^+$  | $< 4.0 \times 10^{-5}$                        | CL=90% | 2489 |
| $K_1(1400)^0 \pi^+$  | $< 3.9 \times 10^{-5}$                        | CL=90% | 2451 |
| $K^0 \pi^+ \pi^0$  | $< 6.6 \times 10^{-5}$                        | CL=90% | 2609 |
| $K_0^*(1430)^+ \pi^0$  | $( 1.19 \pm_{-0.23}^{+0.20} ) \times 10^{-5}$ |        | —    |
| $K^0 \rho^+$   | $( 7.3 \pm_{-1.2}^{+1.0} ) \times 10^{-6}$    |        | 2558 |
| $K^*(892)^+ \pi^+ \pi^-$   | $( 7.5 \pm 1.0 ) \times 10^{-5}$              |        | 2557 |
| $K^*(892)^+ \rho^0$  | $( 4.6 \pm 1.1 ) \times 10^{-6}$              |        | 2504 |
| $K^*(892)^+ f_0(980)$  | $( 4.2 \pm 0.7 ) \times 10^{-6}$              |        | 2466 |
| $a_1^+ K^0$  | $( 3.5 \pm 0.7 ) \times 10^{-5}$              |        | —    |
| $b_1^+ K^0 \times B(b_1^+ \rightarrow \omega \pi^+)$             | $( 9.6 \pm 1.9 ) \times 10^{-6}$              |        | —    |
| $K^*(892)^0 \rho^+$  | $( 9.2 \pm 1.5 ) \times 10^{-6}$              |        | 2504 |
| $K_1(1400)^+ \rho^0$   | $< 7.8 \times 10^{-4}$                        | CL=90% | 2388 |
| $K_2^*(1430)^+ \rho^0$   | $< 1.5 \times 10^{-3}$                        | CL=90% | 2381 |
| $b_1^0 K^+ \times B(b_1^0 \rightarrow \omega \pi^0)$             | $( 9.1 \pm 2.0 ) \times 10^{-6}$              |        | —    |
| $b_1^+ K^{*0} \times B(b_1^+ \rightarrow \omega \pi^+)$          | $< 5.9 \times 10^{-6}$                        | CL=90% | —    |
| $b_1^0 K^{*+} \times B(b_1^0 \rightarrow \omega \pi^0)$          | $< 6.7 \times 10^{-6}$                        | CL=90% | —    |
| $K^+ \bar{K}^0$  | $( 1.31 \pm 0.17 ) \times 10^{-6}$            | S=1.2  | 2593 |
| $\bar{K}^0 K^+ \pi^0$  | $< 2.4 \times 10^{-5}$                        | CL=90% | 2578 |
| $K^+ K_S^0 K_S^0$  | $( 1.05 \pm 0.04 ) \times 10^{-5}$            |        | 2521 |
| $f_0(980)K^+, f_0 \rightarrow K_S^0 K_S^0$                       | $( 1.47 \pm 0.33 ) \times 10^{-5}$            |        | —    |
| $f_0(1710)K^+, f_0 \rightarrow K_S^0 K_S^0$                      | $( 4.8 \pm_{-2.6}^{+4.0} ) \times 10^{-7}$    |        | —    |

|   |   |        |      |
|---|---|--------|------|
| $K^+ K_S^0 K_S^0$ nonresonant                             | $( 2.0 \pm 0.4 ) \times 10^{-5}$              |        | 2521 |
| $K_S^0 K_S^0 \pi^+$                                       | $< 5.1 \times 10^{-7}$                        | CL=90% | 2577 |
| $K^+ K^- \pi^+$   | $( 5.2 \pm 0.4 ) \times 10^{-6}$              |        | 2578 |
| $K^+ K^- \pi^+$ nonresonant                               | $( 1.68 \pm 0.26 ) \times 10^{-6}$            |        | 2578 |
| $K^+ \bar{K}^*(892)^0$                                    | $( 5.9 \pm 0.8 ) \times 10^{-7}$              |        | 2540 |
| $K^+ \bar{K}_0^*(1430)^0$                                 | $( 3.8 \pm 1.3 ) \times 10^{-7}$              |        | 2421 |
| $\pi^+ (K^+ K^-)_{S\text{-wave}}$                         | $( 8.5 \pm 0.9 ) \times 10^{-7}$              |        | 2578 |
| $K^+ K^+ \pi^-$   | $< 1.1 \times 10^{-8}$                        | CL=90% | 2578 |
| $K^+ K^+ \pi^-$ nonresonant                               | $< 8.79 \times 10^{-5}$                       | CL=90% | 2578 |
| $f_2'(1525) K^+$  | $( 1.8 \pm 0.5 ) \times 10^{-6}$              | S=1.1  | 2394 |
| $K^{*+} \pi^+ K^-$  | $< 1.18 \times 10^{-5}$                       | CL=90% | 2524 |
| $K^*(892)^+ K^*(892)^0$                                   | $( 9.1 \pm 2.9 ) \times 10^{-7}$              |        | 2485 |
| $K^{*+} K^+ \pi^-$  | $< 6.1 \times 10^{-6}$                        | CL=90% | 2524 |
| $K^+ K^- K^+$   | $( 3.40 \pm 0.14 ) \times 10^{-5}$            | S=1.4  | 2523 |
| $K^+ \phi$  | $( 8.8 \pm_{-0.6}^{+0.7} ) \times 10^{-6}$    | S=1.1  | 2516 |
| $f_0(980) K^+ \times B(f_0(980) \rightarrow K^+ K^-)$     | $( 9.4 \pm 3.2 ) \times 10^{-6}$              |        | 2522 |
| $a_2(1320) K^+ \times B(a_2(1320) \rightarrow K^+ K^-)$   | $< 1.1 \times 10^{-6}$                        | CL=90% | 2449 |
| $X_0(1550) K^+ \times B(X_0(1550) \rightarrow K^+ K^-)$   | $( 4.3 \pm 0.7 ) \times 10^{-6}$              |        | —    |
| $\phi(1680) K^+ \times B(\phi(1680) \rightarrow K^+ K^-)$ | $< 8 \times 10^{-7}$                          | CL=90% | 2344 |
| $f_0(1710) K^+ \times B(f_0(1710) \rightarrow K^+ K^-)$   | $( 1.1 \pm 0.6 ) \times 10^{-6}$              |        | 2336 |
| $K^+ K^- K^+$ nonresonant                                 | $( 2.38 \pm_{-0.50}^{+0.28} ) \times 10^{-5}$ |        | 2523 |
| $K^*(892)^+ K^+ K^-$                                      | $( 3.6 \pm 0.5 ) \times 10^{-5}$              |        | 2466 |
| $K^*(892)^+ \phi$   | $( 10.0 \pm 2.0 ) \times 10^{-6}$             | S=1.7  | 2460 |
| $\phi(K\pi)_0^{*+}$                                       | $( 8.3 \pm 1.6 ) \times 10^{-6}$              |        | —    |
| $\phi K_1(1270)^+$  | $( 6.1 \pm 1.9 ) \times 10^{-6}$              |        | 2380 |
| $\phi K_1(1400)^+$  | $< 3.2 \times 10^{-6}$                        | CL=90% | 2339 |
| $\phi K^*(1410)^+$  | $< 4.3 \times 10^{-6}$                        | CL=90% | —    |
| $\phi K_0^*(1430)^+$                                      | $( 7.0 \pm 1.6 ) \times 10^{-6}$              |        | —    |
| $\phi K_2^*(1430)^+$                                      | $( 8.4 \pm 2.1 ) \times 10^{-6}$              |        | 2332 |
| $\phi K_2^*(1770)^+$                                      | $< 1.50 \times 10^{-5}$                       | CL=90% | —    |
| $\phi K_2^*(1820)^+$                                      | $< 1.63 \times 10^{-5}$                       | CL=90% | —    |
| $a_1^+ K^{*0}$  | $< 3.6 \times 10^{-6}$                        | CL=90% | —    |
| $K^+ \phi \phi$   | $( 5.0 \pm 1.2 ) \times 10^{-6}$              | S=2.3  | 2306 |
| $\eta' \eta' K^+$   | $< 2.5 \times 10^{-5}$                        | CL=90% | 2338 |
| $\omega \phi K^+$   | $< 1.9 \times 10^{-6}$                        | CL=90% | 2374 |
| $X(1812) K^+ \times B(X \rightarrow \omega \phi)$         | $< 3.2 \times 10^{-7}$                        | CL=90% | —    |
| $K^*(892)^+ \gamma$                                       | $( 3.92 \pm 0.22 ) \times 10^{-5}$            | S=1.7  | 2564 |

|                                 |  |                         |      |
|---------------------------------|--|-------------------------|------|
| $K_1(1270)^+ \gamma$            | $( 4.4 \begin{smallmatrix} + 0.7 \\ - 0.6 \end{smallmatrix} ) \times 10^{-5}$    |                         | 2491 |
| $\eta K^+ \gamma$               | $( 7.9 \pm 0.9 ) \times 10^{-6}$   |                         | 2588 |
| $\eta' K^+ \gamma$              | $( 2.9 \begin{smallmatrix} + 1.0 \\ - 0.9 \end{smallmatrix} ) \times 10^{-6}$    |                         | 2528 |
| $\phi K^+ \gamma$               | $( 2.7 \pm 0.4 ) \times 10^{-6}$   | S=1.2                   | 2516 |
| $K^+ \pi^- \pi^+ \gamma$        | $( 2.58 \pm 0.15 ) \times 10^{-5}$   | S=1.3                   | 2609 |
| $K^*(892)^0 \pi^+ \gamma$       | $( 2.33 \pm 0.12 ) \times 10^{-5}$   |                         | 2562 |
| $K^+ \rho^0 \gamma$             | $( 8.2 \pm 0.9 ) \times 10^{-6}$   |                         | 2559 |
| $(K^+ \pi^-)_{NR} \pi^+ \gamma$ | $( 9.9 \begin{smallmatrix} + 1.7 \\ - 2.0 \end{smallmatrix} ) \times 10^{-6}$    |                         | 2609 |
| $K^0 \pi^+ \pi^0 \gamma$        | $( 4.6 \pm 0.5 ) \times 10^{-5}$   |                         | 2609 |
| $K_1(1400)^+ \gamma$            | $( 10 \begin{smallmatrix} + 5 \\ - 4 \end{smallmatrix} ) \times 10^{-6}$         |                         | 2453 |
| $K^*(1410)^+ \gamma$            | $( 2.7 \begin{smallmatrix} + 0.8 \\ - 0.6 \end{smallmatrix} ) \times 10^{-5}$    |                         | —    |
| $K_0^*(1430)^0 \pi^+ \gamma$    | $( 1.32 \begin{smallmatrix} + 0.26 \\ - 0.32 \end{smallmatrix} ) \times 10^{-6}$ |                         | 2445 |
| $K_2^*(1430)^+ \gamma$          | $( 1.4 \pm 0.4 ) \times 10^{-5}$   |                         | 2447 |
| $K^*(1680)^+ \gamma$            | $( 6.7 \begin{smallmatrix} + 1.7 \\ - 1.4 \end{smallmatrix} ) \times 10^{-5}$    |                         | 2360 |
| $K_3^*(1780)^+ \gamma$          | $< 3.9$  | $\times 10^{-5}$ CL=90% | 2340 |
| $K_4^*(2045)^+ \gamma$          | $< 9.9$  | $\times 10^{-3}$ CL=90% | 2242 |

### Light unflavored meson modes

|  |   |                         |      |
|--|---|-------------------------|------|
| $\rho^+ \gamma$                                      | $( 9.8 \pm 2.5 ) \times 10^{-7}$  |                         | 2583 |
| $\pi^+ \pi^0$  | $( 5.5 \pm 0.4 ) \times 10^{-6}$  | S=1.2                   | 2636 |
| $\pi^+ \pi^+ \pi^-$                                  | $( 1.52 \pm 0.14 ) \times 10^{-5}$  |                         | 2630 |
| $\rho^0 \pi^+$                                       | $( 8.3 \pm 1.2 ) \times 10^{-6}$  |                         | 2581 |
| $\pi^+ f_0(980), f_0 \rightarrow \pi^+ \pi^-$        | $< 1.5$   | $\times 10^{-6}$ CL=90% | 2545 |
| $\pi^+ f_2(1270)$                                    | $( 2.2 \begin{smallmatrix} + 0.7 \\ - 0.4 \end{smallmatrix} ) \times 10^{-6}$ |                         | 2484 |
| $\rho(1450)^0 \pi^+, \rho^0 \rightarrow \pi^+ \pi^-$ | $( 1.4 \begin{smallmatrix} + 0.6 \\ - 0.9 \end{smallmatrix} ) \times 10^{-6}$ |                         | 2434 |
| $\rho(1450)^0 \pi^+, \rho^0 \rightarrow K^+ K^-$     | $( 1.60 \pm 0.14 ) \times 10^{-6}$  |                         | —    |
| $f_0(1370) \pi^+, f_0 \rightarrow \pi^+ \pi^-$       | $< 4.0$   | $\times 10^{-6}$ CL=90% | 2460 |
| $f_0(500) \pi^+, f_0 \rightarrow \pi^+ \pi^-$        | $< 4.1$   | $\times 10^{-6}$ CL=90% | —    |
| $\pi^+ \pi^- \pi^+$ nonresonant                      | $( 5.3 \begin{smallmatrix} + 1.5 \\ - 1.1 \end{smallmatrix} ) \times 10^{-6}$ |                         | 2630 |
| $\pi^+ \pi^0 \pi^0$                                  | $< 8.9$   | $\times 10^{-4}$ CL=90% | 2631 |
| $\rho^+ \pi^0$                                       | $( 1.09 \pm 0.14 ) \times 10^{-5}$  |                         | 2581 |
| $\pi^+ \pi^- \pi^+ \pi^0$                            | $< 4.0$   | $\times 10^{-3}$ CL=90% | 2622 |
| $\rho^+ \rho^0$                                      | $( 2.40 \pm 0.19 ) \times 10^{-5}$  |                         | 2523 |
| $\rho^+ f_0(980), f_0 \rightarrow \pi^+ \pi^-$       | $< 2.0$   | $\times 10^{-6}$ CL=90% | 2486 |
| $a_1(1260)^+ \pi^0$                                  | $( 2.6 \pm 0.7 ) \times 10^{-5}$  |                         | 2494 |
| $a_1(1260)^0 \pi^+$                                  | $( 2.0 \pm 0.6 ) \times 10^{-5}$  |                         | 2494 |
| $\omega \pi^+$                                       | $( 6.9 \pm 0.5 ) \times 10^{-6}$  |                         | 2580 |
| $\omega \rho^+$                                      | $( 1.59 \pm 0.21 ) \times 10^{-5}$  |                         | 2522 |

|  |                                    |                         |      |
|--|------------------------------------|-------------------------|------|
| $\eta\pi^+$                                    | $( 4.02 \pm 0.27 ) \times 10^{-6}$ |                         | 2609 |
| $\eta\rho^+$                                   | $( 7.0 \pm 2.9 ) \times 10^{-6}$   | S=2.8                   | 2553 |
| $\eta'\pi^+$                                   | $( 2.7 \pm 0.9 ) \times 10^{-6}$   | S=1.9                   | 2551 |
| $\eta'\rho^+$                                  | $( 9.7 \pm 2.2 ) \times 10^{-6}$   |                         | 2492 |
| $\phi\pi^+$                                    | $( 3.2 \pm 1.5 ) \times 10^{-8}$   |                         | 2539 |
| $\phi\rho^+$                                   | $< 3.0$                            | $\times 10^{-6}$ CL=90% | 2480 |
| $a_0(980)^0\pi^+, a_0^0 \rightarrow \eta\pi^0$ | $< 5.8$                            | $\times 10^{-6}$ CL=90% | —    |
| $a_0(980)^+\pi^0, a_0^+ \rightarrow \eta\pi^+$ | $< 1.4$                            | $\times 10^{-6}$ CL=90% | —    |
| $\pi^+\pi^+\pi^+\pi^-\pi^-$                    | $< 8.6$                            | $\times 10^{-4}$ 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 |
| $b_1^0\pi^+, b_1^0 \rightarrow \omega\pi^0$    | $( 6.7 \pm 2.0 ) \times 10^{-6}$   |                         | —    |
| $b_1^+\pi^0, b_1^+ \rightarrow \omega\pi^+$    | $< 3.3$                            | $\times 10^{-6}$ CL=90% | —    |
| $\pi^+\pi^+\pi^+\pi^-\pi^-\pi^0$               | $< 6.3$                            | $\times 10^{-3}$ CL=90% | 2592 |
| $b_1^+\rho^0, b_1^+ \rightarrow \omega\pi^+$   | $< 5.2$                            | $\times 10^{-6}$ CL=90% | —    |
| $a_1(1260)^+ a_1(1260)^0$                      | $< 1.3$                            | % CL=90%                | 2336 |
| $b_1^0\rho^+, b_1^0 \rightarrow \omega\pi^0$   | $< 3.3$                            | $\times 10^{-6}$ CL=90% | —    |

### 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% | —    |
| $K^+ X^0, X^0 \rightarrow \mu^+ \mu^-$ | $< 1$  | $\times 10^{-7}$ CL=95% | —    |

### Baryon modes

|  |   |                         |      |
|--|---|-------------------------|------|
| $p\bar{p}\pi^+$  | $( 1.62 \pm 0.20 ) \times 10^{-6}$  |                         | 2439 |
| $p\bar{p}\pi^+$ nonresonant                              | $< 5.3$   | $\times 10^{-5}$ CL=90% | 2439 |
| $p\bar{p}\pi^+\pi^0$                                     | $( 4.6 \pm 1.3 ) \times 10^{-6}$  |                         | 2407 |
| $p\bar{p}K^+$  | $( 5.9 \pm 0.5 ) \times 10^{-6}$  | S=1.5                   | 2348 |
| $\Theta(1710)^{++}\bar{p}, \Theta^{++} \rightarrow pK^+$ | [ppp] $< 9.1$   | $\times 10^{-8}$ CL=90% | —    |
| $f_J(2220)K^+, f_J \rightarrow p\bar{p}$                 | [ppp] $< 4.1$   | $\times 10^{-7}$ CL=90% | 2135 |
| $p\bar{\Lambda}(1520)$                                   | $( 3.1 \pm 0.6 ) \times 10^{-7}$  |                         | 2322 |
| $p\bar{p}K^+$ nonresonant                                | $< 8.9$   | $\times 10^{-5}$ CL=90% | 2348 |
| $p\bar{p}K^*(892)^+$                                     | $( 3.6 \begin{smallmatrix} + 0.8 \\ - 0.7 \end{smallmatrix} ) \times 10^{-6}$ |                         | 2215 |
| $f_J(2220)K^{*+}, f_J \rightarrow p\bar{p}$              | $< 7.7$   | $\times 10^{-7}$ CL=90% | 2059 |
| $p\bar{\Lambda}$   | $( 2.4 \begin{smallmatrix} + 1.0 \\ - 0.9 \end{smallmatrix} ) \times 10^{-7}$ |                         | 2430 |
| $p\bar{\Lambda}\gamma$                                   | $( 2.4 \begin{smallmatrix} + 0.5 \\ - 0.4 \end{smallmatrix} ) \times 10^{-6}$ |                         | 2430 |
| $p\bar{\Lambda}\pi^0$                                    | $( 3.0 \begin{smallmatrix} + 0.7 \\ - 0.6 \end{smallmatrix} ) \times 10^{-6}$ |                         | 2402 |



|  |                          |                  |        |      |
|--|--------------------------|------------------|--------|------|
| $\rho\bar{\Sigma}(1385)^0$                                 | < 4.7                    | $\times 10^{-7}$ | CL=90% | 2362 |
| $\Delta^+\bar{\Lambda}$                                    | < 8.2                    | $\times 10^{-7}$ | CL=90% | —    |
| $\rho\bar{\Sigma}\gamma$                                   | < 4.6                    | $\times 10^{-6}$ | CL=90% | 2413 |
| $\rho\bar{\Lambda}\pi^+\pi^-$                              | ( 1.13 $\pm$ 0.13 )      | $\times 10^{-5}$ |        | 2367 |
| $\rho\bar{\Lambda}\pi^+\pi^-$ nonresonant                  | ( 5.9 $\pm$ 1.1 )        | $\times 10^{-6}$ |        | 2367 |
| $\rho\bar{\Lambda}\rho^0, \rho^0 \rightarrow \pi^+\pi^-$   | ( 4.8 $\pm$ 0.9 )        | $\times 10^{-6}$ |        | 2214 |
| $\rho\bar{\Lambda}f_2(1270), f_2 \rightarrow \pi^+\pi^-$   | ( 2.0 $\pm$ 0.8 )        | $\times 10^{-6}$ |        | 2026 |
| $\rho\bar{\Lambda}K^+K^-$                                  | ( 4.1 $\pm$ 0.7 )        | $\times 10^{-6}$ |        | 2132 |
| $\rho\bar{\Lambda}\phi$                                    | ( 8.0 $\pm$ 2.2 )        | $\times 10^{-7}$ |        | 2119 |
| $\bar{p}\Lambda K^+K^-$                                    | ( 3.7 $\pm$ 0.6 )        | $\times 10^{-6}$ |        | 2132 |
| $\Lambda\bar{\Lambda}\pi^+$                                | < 9.4                    | $\times 10^{-7}$ | CL=90% | 2358 |
| $\Lambda\bar{\Lambda}K^+$                                  | ( 3.4 $\pm$ 0.6 )        | $\times 10^{-6}$ |        | 2251 |
| $\Lambda\bar{\Lambda}K^{*+}$                               | ( 2.2 $\pm$ 1.2 / -0.9 ) | $\times 10^{-6}$ |        | 2098 |
| $\Lambda(1520)\bar{\Lambda}K^+$                            | ( 2.2 $\pm$ 0.7 )        | $\times 10^{-6}$ |        | 2126 |
| $\Lambda\bar{\Lambda}(1520)K^+$                            | < 2.08                   | $\times 10^{-6}$ |        | 2126 |
| $\bar{\Delta}^0\rho$                                       | < 1.38                   | $\times 10^{-6}$ | CL=90% | 2403 |
| $\Delta^{++}\bar{p}$                                       | < 1.4                    | $\times 10^{-7}$ | CL=90% | 2403 |
| $D^+\rho\bar{p}$   | < 1.5                    | $\times 10^{-5}$ | CL=90% | 1860 |
| $D^*(2010)^+\rho\bar{p}$                                   | < 1.5                    | $\times 10^{-5}$ | CL=90% | 1786 |
| $\bar{D}^0\rho\bar{p}\pi^+$                                | ( 3.72 $\pm$ 0.27 )      | $\times 10^{-4}$ |        | 1789 |
| $\bar{D}^{*0}\rho\bar{p}\pi^+$                             | ( 3.73 $\pm$ 0.32 )      | $\times 10^{-4}$ |        | 1709 |
| $D^-\rho\bar{p}\pi^+\pi^-$                                 | ( 1.66 $\pm$ 0.30 )      | $\times 10^{-4}$ |        | 1705 |
| $D^{*-}\rho\bar{p}\pi^+\pi^-$                              | ( 1.86 $\pm$ 0.25 )      | $\times 10^{-4}$ |        | 1621 |
| $\rho\bar{\Lambda}^0\bar{D}^0$                             | ( 1.43 $\pm$ 0.32 )      | $\times 10^{-5}$ |        | —    |
| $\rho\bar{\Lambda}^0\bar{D}^*(2007)^0$                     | < 5                      | $\times 10^{-5}$ | CL=90% | —    |
| $\bar{\Lambda}_c^-\rho\pi^+$                               | ( 2.3 $\pm$ 0.4 )        | $\times 10^{-4}$ | S=2.2  | 1980 |
| $\bar{\Lambda}_c^-\Delta(1232)^{++}$                       | < 1.9                    | $\times 10^{-5}$ | CL=90% | 1928 |
| $\bar{\Lambda}_c^-\Delta_X(1600)^{++}$                     | ( 4.7 $\pm$ 1.0 )        | $\times 10^{-5}$ |        | —    |
| $\bar{\Lambda}_c^-\Delta_X(2420)^{++}$                     | ( 3.7 $\pm$ 0.8 )        | $\times 10^{-5}$ |        | —    |
| $(\bar{\Lambda}_c^-\rho)_s\pi^+$                           | [qqq] ( 3.1 $\pm$ 0.7 )  | $\times 10^{-5}$ |        | —    |
| $\bar{\Sigma}_c(2520)^0\rho$                               | < 3                      | $\times 10^{-6}$ | CL=90% | 1904 |
| $\bar{\Sigma}_c(2800)^0\rho$                               | ( 2.6 $\pm$ 0.9 )        | $\times 10^{-5}$ |        | —    |
| $\bar{\Lambda}_c^-\rho\pi^+\pi^0$                          | ( 1.8 $\pm$ 0.6 )        | $\times 10^{-3}$ |        | 1935 |
| $\bar{\Lambda}_c^-\rho\pi^+\pi^+\pi^-$                     | ( 2.2 $\pm$ 0.7 )        | $\times 10^{-3}$ |        | 1880 |
| $\bar{\Lambda}_c^-\rho\pi^+\pi^+\pi^-\pi^0$                | < 1.34                   | %                | CL=90% | 1823 |
| $\Lambda_c^+\Lambda_c^-K^+$                                | ( 4.9 $\pm$ 0.7 )        | $\times 10^{-4}$ |        | 739  |
| $\Xi_c(2930)\Lambda_c^+, \Xi_c \rightarrow K^+\Lambda_c^-$ | ( 1.7 $\pm$ 0.5 )        | $\times 10^{-4}$ |        | —    |
| $\bar{\Sigma}_c(2455)^0\rho$                               | ( 2.9 $\pm$ 0.7 )        | $\times 10^{-5}$ |        | 1938 |
| $\bar{\Sigma}_c(2455)^0\rho\pi^0$                          | ( 3.5 $\pm$ 1.1 )        | $\times 10^{-4}$ |        | 1896 |
| $\bar{\Sigma}_c(2455)^0\rho\pi^-\pi^+$                     | ( 3.5 $\pm$ 1.1 )        | $\times 10^{-4}$ |        | 1845 |
| $\bar{\Sigma}_c(2455)^{--}\rho\pi^+\pi^+$                  | ( 2.37 $\pm$ 0.20 )      | $\times 10^{-4}$ |        | 1845 |
| $\bar{\Lambda}_c(2593)^-/\bar{\Lambda}_c(2625)^-\rho\pi^+$ | < 1.9                    | $\times 10^{-4}$ | CL=90% | —    |

|  |  |                                    |             |
|--|--|------------------------------------|-------------|
| $\Xi_c^0 \Lambda_c^+$  |  | $( 9.5 \pm 2.3 ) \times 10^{-4}$   | 1144        |
| $\Xi_c^0 \Lambda_c^+, \Xi_c^0 \rightarrow \Xi^+ \pi^-$       |  | $( 1.76 \pm 0.29 ) \times 10^{-5}$ | 1144        |
| $\Xi_c^0 \Lambda_c^+, \Xi_c^0 \rightarrow \Lambda K^+ \pi^-$ |  | $( 1.14 \pm 0.26 ) \times 10^{-5}$ | 1144        |
| $\Xi_c^0 \Lambda_c^+, \Xi_c^0 \rightarrow p K^- K^- \pi^+$   |  | $( 5.5 \pm 1.9 ) \times 10^{-6}$   | —           |
| $\Lambda_c^+ \Xi_c^0$  |  | $< 6.5 \times 10^{-4}$             | CL=90% 1023 |
| $\Lambda_c^+ \Xi_c(2645)^0$                                  |  | $< 7.9 \times 10^{-4}$             | CL=90% —    |
| $\Lambda_c^+ \Xi_c(2790)^0$                                  |  | $( 1.1 \pm 0.4 ) \times 10^{-3}$   | —           |

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

|                                 |    |   |        |      |
|---------------------------------|----|---|--------|------|
| $\pi^+ \ell^+ \ell^-$           | B1 | $< 4.9 \times 10^{-8}$                        | CL=90% | 2638 |
| $\pi^+ e^+ e^-$                 | B1 | $< 8.0 \times 10^{-8}$                        | CL=90% | 2638 |
| $\pi^+ \mu^+ \mu^-$             | B1 | $( 1.78 \pm 0.23 ) \times 10^{-8}$            |        | 2634 |
| $\pi^+ \nu \bar{\nu}$           | B1 | $< 1.4 \times 10^{-5}$                        | CL=90% | 2638 |
| $K^+ \ell^+ \ell^-$             | B1 | [iii] $( 4.7 \pm 0.5 ) \times 10^{-7}$        | S=2.3  | 2617 |
| $K^+ e^+ e^-$                   | B1 | $( 5.6 \pm 0.6 ) \times 10^{-7}$              |        | 2617 |
| $K^+ \mu^+ \mu^-$               | B1 | $( 4.53 \pm 0.35 ) \times 10^{-7}$            | S=1.8  | 2612 |
| $K^+ \mu^+ \mu^-$ nonresonant   | B1 | $( 4.37 \pm 0.27 ) \times 10^{-7}$            |        | 2612 |
| $K^+ \tau^+ \tau^-$             | B1 | $< 2.25 \times 10^{-3}$                       | CL=90% | 1687 |
| $K^+ \bar{\nu} \nu$             | B1 | $< 1.6 \times 10^{-5}$                        | CL=90% | 2617 |
| $\rho^+ \nu \bar{\nu}$          | B1 | $< 3.0 \times 10^{-5}$                        | CL=90% | 2583 |
| $K^*(892)^+ \ell^+ \ell^-$      | B1 | [iii] $( 1.01 \pm 0.11 ) \times 10^{-6}$      | S=1.1  | 2564 |
| $K^*(892)^+ e^+ e^-$            | B1 | $( 1.55 \pm_{-0.31}^{+0.40} ) \times 10^{-6}$ |        | 2564 |
| $K^*(892)^+ \mu^+ \mu^-$        | B1 | $( 9.6 \pm 1.0 ) \times 10^{-7}$              |        | 2560 |
| $K^*(892)^+ \nu \bar{\nu}$      | B1 | $< 4.0 \times 10^{-5}$                        | CL=90% | 2564 |
| $K^+ \pi^+ \pi^- \mu^+ \mu^-$   | B1 | $( 4.3 \pm 0.4 ) \times 10^{-7}$              |        | 2593 |
| $\phi K^+ \mu^+ \mu^-$          | B1 | $( 7.9 \pm_{-1.7}^{+2.1} ) \times 10^{-8}$    |        | 2490 |
| $\bar{\Lambda} p \nu \bar{\nu}$ |    | $< 3.0 \times 10^{-5}$                        | CL=90% | 2430 |
| $\pi^+ e^+ \mu^-$               | LF | $< 6.4 \times 10^{-3}$                        | CL=90% | 2637 |
| $\pi^+ e^- \mu^+$               | LF | $< 6.4 \times 10^{-3}$                        | CL=90% | 2637 |
| $\pi^+ e^\pm \mu^\mp$           | LF | $< 1.7 \times 10^{-7}$                        | CL=90% | 2637 |
| $\pi^+ e^+ \tau^-$              | LF | $< 7.4 \times 10^{-5}$                        | CL=90% | 2338 |
| $\pi^+ e^- \tau^+$              | LF | $< 2.0 \times 10^{-5}$                        | CL=90% | 2338 |
| $\pi^+ e^\pm \tau^\mp$          | LF | $< 7.5 \times 10^{-5}$                        | CL=90% | 2338 |
| $\pi^+ \mu^+ \tau^-$            | LF | $< 6.2 \times 10^{-5}$                        | CL=90% | 2333 |
| $\pi^+ \mu^- \tau^+$            | LF | $< 4.5 \times 10^{-5}$                        | CL=90% | 2333 |
| $\pi^+ \mu^\pm \tau^\mp$        | LF | $< 7.2 \times 10^{-5}$                        | CL=90% | 2333 |
| $K^+ e^+ \mu^-$                 | LF | $< 7.0 \times 10^{-9}$                        | CL=90% | 2615 |
| $K^+ e^- \mu^+$                 | LF | $< 6.4 \times 10^{-9}$                        | CL=90% | 2615 |
| $K^+ e^\pm \mu^\mp$             | LF | $< 9.1 \times 10^{-8}$                        | CL=90% | 2615 |
| $K^+ e^+ \tau^-$                | LF | $< 4.3 \times 10^{-5}$                        | CL=90% | 2312 |
| $K^+ e^- \tau^+$                | LF | $< 1.5 \times 10^{-5}$                        | CL=90% | 2312 |

|                                    |     |       |                  |        |      |
|------------------------------------|-----|-------|------------------|--------|------|
| $K^+ e^\pm \tau^\mp$               | LF  | < 3.0 | $\times 10^{-5}$ | CL=90% | 2312 |
| $K^+ \mu^+ \tau^-$                 | LF  | < 4.5 | $\times 10^{-5}$ | CL=90% | 2298 |
| $K^+ \mu^- \tau^+$                 | LF  | < 2.8 | $\times 10^{-5}$ | CL=90% | 2298 |
| $K^+ \mu^\pm \tau^\mp$             | LF  | < 4.8 | $\times 10^{-5}$ | CL=90% | 2298 |
| $K^*(892)^+ e^+ \mu^-$             | LF  | < 1.3 | $\times 10^{-6}$ | CL=90% | 2563 |
| $K^*(892)^+ e^- \mu^+$             | LF  | < 9.9 | $\times 10^{-7}$ | CL=90% | 2563 |
| $K^*(892)^+ e^\pm \mu^\mp$         | LF  | < 1.4 | $\times 10^{-6}$ | CL=90% | 2563 |
| $\pi^- e^+ e^+$                    | L   | < 2.3 | $\times 10^{-8}$ | CL=90% | 2638 |
| $\pi^- \mu^+ \mu^+$                | L   | < 4.0 | $\times 10^{-9}$ | CL=95% | 2634 |
| $\pi^- e^+ \mu^+$                  | L   | < 1.5 | $\times 10^{-7}$ | CL=90% | 2637 |
| $\rho^- e^+ e^+$                   | L   | < 1.7 | $\times 10^{-7}$ | CL=90% | 2583 |
| $\rho^- \mu^+ \mu^+$               | L   | < 4.2 | $\times 10^{-7}$ | CL=90% | 2578 |
| $\rho^- e^+ \mu^+$                 | L   | < 4.7 | $\times 10^{-7}$ | CL=90% | 2582 |
| $K^- e^+ e^+$                      | L   | < 3.0 | $\times 10^{-8}$ | CL=90% | 2617 |
| $K^- \mu^+ \mu^+$                  | L   | < 4.1 | $\times 10^{-8}$ | CL=90% | 2612 |
| $K^- e^+ \mu^+$                    | L   | < 1.6 | $\times 10^{-7}$ | CL=90% | 2615 |
| $K^*(892)^- e^+ e^+$               | L   | < 4.0 | $\times 10^{-7}$ | CL=90% | 2564 |
| $K^*(892)^- \mu^+ \mu^+$           | L   | < 5.9 | $\times 10^{-7}$ | CL=90% | 2560 |
| $K^*(892)^- e^+ \mu^+$             | L   | < 3.0 | $\times 10^{-7}$ | CL=90% | 2563 |
| $D^- e^+ e^+$                      | L   | < 2.6 | $\times 10^{-6}$ | CL=90% | 2309 |
| $D^- e^+ \mu^+$                    | L   | < 1.8 | $\times 10^{-6}$ | CL=90% | 2307 |
| $D^- \mu^+ \mu^+$                  | L   | < 6.9 | $\times 10^{-7}$ | CL=95% | 2303 |
| $D^{*-} \mu^+ \mu^+$               | L   | < 2.4 | $\times 10^{-6}$ | CL=95% | 2251 |
| $D_s^- \mu^+ \mu^+$                | L   | < 5.8 | $\times 10^{-7}$ | CL=95% | 2267 |
| $\overline{D}^0 \pi^- \mu^+ \mu^+$ | L   | < 1.5 | $\times 10^{-6}$ | CL=95% | 2295 |
| $\Lambda^0 \mu^+$                  | L,B | < 6   | $\times 10^{-8}$ | CL=90% | —    |
| $\Lambda^0 e^+$                    | L,B | < 3.2 | $\times 10^{-8}$ | CL=90% | —    |
| $\overline{\Lambda}^0 \mu^+$       | L,B | < 6   | $\times 10^{-8}$ | CL=90% | —    |
| $\overline{\Lambda}^0 e^+$         | L,B | < 8   | $\times 10^{-8}$ | CL=90% | —    |



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

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

$$\text{Mass } m_{B^0} = 5279.65 \pm 0.12 \text{ MeV}$$

$$m_{B^0} - m_{B^\pm} = 0.31 \pm 0.05 \text{ MeV}$$

$$\text{Mean life } \tau_{B^0} = (1.519 \pm 0.004) \times 10^{-12} \text{ s}$$

$$c\tau = 455.4 \text{ } \mu\text{m}$$

$$\tau_{B^+}/\tau_{B^0} = 1.076 \pm 0.004 \quad (\text{direct measurements})$$

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

$$\chi_d (B^0\text{-}\overline{B}^0 \text{ mixing probability}) = 0.1858 \pm 0.0011$$

$$\begin{aligned}\Delta m_{B^0} &= m_{B_H^0} - m_{B_L^0} = (0.5065 \pm 0.0019) \times 10^{12} \hbar \text{ s}^{-1} \\ &= (3.334 \pm 0.013) \times 10^{-10} \text{ MeV} \\ x_d &= \Delta m_{B^0} / \Gamma_{B^0} = 0.769 \pm 0.004 \\ \text{Re}(\lambda_{CP} / |\lambda_{CP}|) \text{ Re}(z) &= 0.047 \pm 0.022 \\ \Delta \Gamma \text{ Re}(z) &= -0.007 \pm 0.004 \\ \text{Re}(z) &= (-4 \pm 4) \times 10^{-2} \quad (S = 1.4) \\ \text{Im}(z) &= (-0.8 \pm 0.4) \times 10^{-2}\end{aligned}$$

### CP violation parameters

$$\begin{aligned}\text{Re}(\epsilon_{B^0}) / (1 + |\epsilon_{B^0}|^2) &= (-0.5 \pm 0.4) \times 10^{-3} \\ A_{T/CP}(B^0 \leftrightarrow \bar{B}^0) &= 0.005 \pm 0.018 \\ A_{CP}(B^0 \rightarrow D^*(2010)^+ D^-) &= 0.013 \pm 0.014 \\ A_{CP}(B^0 \rightarrow [K^+ K^-]_D K^*(892)^0) &= -0.05 \pm 0.10 \\ A_{CP}(B^0 \rightarrow [K^+ \pi^-]_D K^*(892)^0) &= 0.047 \pm 0.029 \\ A_{CP}(B^0 \rightarrow [K^+ \pi^- \pi^+ \pi^-]_D K^*(892)^0) &= 0.037 \pm 0.034 \\ A_{CP}(B^0 \rightarrow [K^- \pi^+]_D K^*(892)^0) &= 0.19 \pm 0.19 \\ A_{CP}(B^0 \rightarrow [K^- \pi^+ \pi^+ \pi^-]_D K^*(892)^0) &= -0.01 \pm 0.24 \\ R_d^+ = \Gamma(B^0 \rightarrow [\pi^+ K^-]_D K^{*0}) / \Gamma(B^0 \rightarrow [\pi^- K^+]_D K^{*0}) &= \\ &= 0.064 \pm 0.021 \\ R_d^- = \Gamma(\bar{B}^0 \rightarrow [\pi^- K^+]_D K^{*0}) / \Gamma(\bar{B}^0 \rightarrow [\pi^+ K^-]_D K^{*0}) &= \\ &= 0.095 \pm 0.021 \\ A_{CP}(B^0 \rightarrow [\pi^+ \pi^-]_D K^*(892)^0) &= -0.18 \pm 0.14 \\ A_{CP}(B^0 \rightarrow [\pi^+ \pi^- \pi^+ \pi^-]_D K^*(892)^0) &= -0.03 \pm 0.15 \\ R_d^+ = \Gamma(B^0 \rightarrow [\pi^+ K^- \pi^+ \pi^-]_D K^{*0}) / \Gamma(B^0 \rightarrow \\ &[\pi^- K^+ \pi^+ \pi^-]_D K^{*0}) = 0.074 \pm 0.026 \\ R_d^- = \Gamma(\bar{B}^0 \rightarrow [\pi^- K^+ \pi^+ \pi^-]_D K^{*0}) / \Gamma(\bar{B}^0 \rightarrow \\ &[\pi^+ K^- \pi^+ \pi^-]_D K^{*0}) = 0.072 \pm 0.025 \\ \mathbf{A_{CP}(B^0 \rightarrow K^+ \pi^-)} &= -0.083 \pm 0.004 \\ A_{CP}(B^0 \rightarrow \eta' K^*(892)^0) &= -0.07 \pm 0.18 \\ A_{CP}(B^0 \rightarrow \eta' K_0^*(1430)^0) &= -0.19 \pm 0.17 \\ A_{CP}(B^0 \rightarrow \eta' K_2^*(1430)^0) &= 0.14 \pm 0.18 \\ \mathbf{A_{CP}(B^0 \rightarrow \eta K^*(892)^0)} &= 0.19 \pm 0.05 \\ A_{CP}(B^0 \rightarrow \eta K_0^*(1430)^0) &= 0.06 \pm 0.13 \\ A_{CP}(B^0 \rightarrow \eta K_2^*(1430)^0) &= -0.07 \pm 0.19 \\ A_{CP}(B^0 \rightarrow b_1 K^+) &= -0.07 \pm 0.12 \\ A_{CP}(B^0 \rightarrow \omega K^{*0}) &= 0.45 \pm 0.25 \\ A_{CP}(B^0 \rightarrow \omega(K\pi)_0^{*0}) &= -0.07 \pm 0.09 \\ A_{CP}(B^0 \rightarrow \omega K_2^*(1430)^0) &= -0.37 \pm 0.17 \\ A_{CP}(B^0 \rightarrow K^+ \pi^- \pi^0) &= (0 \pm 6) \times 10^{-2} \\ A_{CP}(B^0 \rightarrow \rho^- K^+) &= 0.20 \pm 0.11 \\ A_{CP}(B^0 \rightarrow \rho(1450)^- K^+) &= -0.10 \pm 0.33 \\ A_{CP}(B^0 \rightarrow \rho(1700)^- K^+) &= -0.4 \pm 0.6\end{aligned}$$

$$\begin{aligned}
 A_{CP}(B^0 \rightarrow K^+ \pi^- \pi^0 \text{ nonresonant}) &= 0.10 \pm 0.18 \\
 A_{CP}(B^0 \rightarrow K^0 \pi^+ \pi^-) &= -0.01 \pm 0.05 \\
 \mathbf{A_{CP}(B^0 \rightarrow K^*(892)^+ \pi^-)} &= -0.27 \pm 0.04 \\
 A_{CP}(B^0 \rightarrow (K\pi)_0^{*+} \pi^-) &= 0.02 \pm 0.04 \\
 A_{CP}(B^0 \rightarrow K_2^*(1430)^+ \pi^-) &= -0.29 \pm 0.24 \\
 A_{CP}(B^0 \rightarrow K^*(1680)^+ \pi^-) &= -0.07 \pm 0.14 \\
 A_{CP}(B^0 \rightarrow f_0(980) K_S^0) &= 0.28 \pm 0.31 \\
 A_{CP}(B^0 \rightarrow (K\pi)_0^{*0} \pi^0) &= -0.15 \pm 0.11 \\
 A_{CP}(B^0 \rightarrow K^{*0} \pi^0) &= -0.15 \pm 0.13 \\
 A_{CP}(B^0 \rightarrow K^*(892)^0 \pi^+ \pi^-) &= 0.07 \pm 0.05 \\
 A_{CP}(B^0 \rightarrow K^*(892)^0 \rho^0) &= -0.06 \pm 0.09 \\
 A_{CP}(B^0 \rightarrow K^{*0} f_0(980)) &= 0.07 \pm 0.10 \\
 A_{CP}(B^0 \rightarrow K^{*+} \rho^-) &= 0.21 \pm 0.15 \\
 A_{CP}(B^0 \rightarrow K^*(892)^0 K^+ K^-) &= 0.01 \pm 0.05 \\
 A_{CP}(B^0 \rightarrow a_1^- K^+) &= -0.16 \pm 0.12 \\
 A_{CP}(B^0 \rightarrow K^0 K^0) &= -0.6 \pm 0.7 \\
 A_{CP}(B^0 \rightarrow K^*(892)^0 \phi) &= 0.00 \pm 0.04 \\
 A_{CP}(B^0 \rightarrow K^*(892)^0 K^- \pi^+) &= 0.2 \pm 0.4 \\
 A_{CP}(B^0 \rightarrow \phi (K\pi)_0^{*0}) &= 0.12 \pm 0.08 \\
 A_{CP}(B^0 \rightarrow \phi K_2^*(1430)^0) &= -0.11 \pm 0.10 \\
 A_{CP}(B^0 \rightarrow K^*(892)^0 \gamma) &= -0.006 \pm 0.011 \\
 A_{CP}(B^0 \rightarrow K_2^*(1430)^0 \gamma) &= -0.08 \pm 0.15 \\
 A_{CP}(B^0 \rightarrow X_S \gamma) &= -0.009 \pm 0.018 \\
 A_{CP}(B^0 \rightarrow \rho^+ \pi^-) &= 0.13 \pm 0.06 \quad (S = 1.1) \\
 A_{CP}(B^0 \rightarrow \rho^- \pi^+) &= -0.08 \pm 0.08 \\
 A_{CP}(B^0 \rightarrow a_1(1260)^\pm \pi^\mp) &= -0.07 \pm 0.06 \\
 A_{CP}(B^0 \rightarrow b_1^- \pi^+) &= -0.05 \pm 0.10 \\
 A_{CP}(B^0 \rightarrow \rho \bar{\rho} K^*(892)^0) &= 0.05 \pm 0.12 \\
 A_{CP}(B^0 \rightarrow \rho \bar{\Lambda} \pi^-) &= 0.04 \pm 0.07 \\
 A_{CP}(B^0 \rightarrow K^{*0} \ell^+ \ell^-) &= -0.05 \pm 0.10 \\
 A_{CP}(B^0 \rightarrow K^{*0} e^+ e^-) &= -0.21 \pm 0.19 \\
 A_{CP}(B^0 \rightarrow K^{*0} \mu^+ \mu^-) &= -0.034 \pm 0.024 \\
 C_{D^*-D^+} (B^0 \rightarrow D^*(2010)^- D^+) &= -0.02 \pm 0.08 \\
 \mathbf{S_{D^*-D^+} (B^0 \rightarrow D^*(2010)^- D^+)} &= -0.83 \pm 0.09 \\
 C_{D^{*+}D^-} (B^0 \rightarrow D^*(2010)^+ D^-) &= -0.03 \pm 0.09 \quad (S = 1.1) \\
 \mathbf{S_{D^{*+}D^-} (B^0 \rightarrow D^*(2010)^+ D^-)} &= -0.80 \pm 0.09 \\
 C_{D^{*+}D^{*-}} (B^0 \rightarrow D^{*+} D^{*-}) &= 0.01 \pm 0.09 \quad (S = 1.6) \\
 \mathbf{S_{D^{*+}D^{*-}} (B^0 \rightarrow D^{*+} D^{*-})} &= -0.59 \pm 0.14 \quad (S = 1.8) \\
 C_+ (B^0 \rightarrow D^{*+} D^{*-}) &= 0.00 \pm 0.10 \quad (S = 1.6) \\
 \mathbf{S_+ (B^0 \rightarrow D^{*+} D^{*-})} &= -0.73 \pm 0.09 \\
 C_- (B^0 \rightarrow D^{*+} D^{*-}) &= 0.19 \pm 0.31
 \end{aligned}$$

$$\begin{aligned}
S_{-} (B^0 \rightarrow D^{*+} D^{*-}) &= 0.1 \pm 1.6 \quad (S = 3.5) \\
C (B^0 \rightarrow D^{*(2010)+} D^{*(2010)-} K_S^0) &= 0.01 \pm 0.29 \\
S (B^0 \rightarrow D^{*(2010)+} D^{*(2010)-} K_S^0) &= 0.1 \pm 0.4 \\
C_{D^+ D^-} (B^0 \rightarrow D^+ D^-) &= -0.22 \pm 0.24 \quad (S = 2.5) \\
\mathbf{S_{D^+ D^-} (B^0 \rightarrow D^+ D^-)} &= -0.76_{-0.13}^{+0.15} \quad (S = 1.2) \\
C_{J/\psi(1S)\pi^0} (B^0 \rightarrow J/\psi(1S)\pi^0) &= 0.03 \pm 0.17 \quad (S = 1.5) \\
\mathbf{S_{J/\psi(1S)\pi^0} (B^0 \rightarrow J/\psi(1S)\pi^0)} &= -0.88 \pm 0.32 \quad (S = 2.2) \\
C (B^0 \rightarrow J/\psi(1S)\rho^0) &= -0.06 \pm 0.06 \\
\mathbf{S(B^0 \rightarrow J/\psi(1S)\rho^0)} &= -0.66_{-0.12}^{+0.16} \\
C_{D_{CP}^{(*)} h^0} (B^0 \rightarrow D_{CP}^{(*)} h^0) &= -0.02 \pm 0.08 \\
\mathbf{S_{D_{CP}^{(*)} h^0} (B^0 \rightarrow D_{CP}^{(*)} h^0)} &= -0.66 \pm 0.12 \\
C_{K^0 \pi^0} (B^0 \rightarrow K^0 \pi^0) &= 0.00 \pm 0.13 \quad (S = 1.4) \\
\mathbf{S_{K^0 \pi^0} (B^0 \rightarrow K^0 \pi^0)} &= 0.58 \pm 0.17 \\
C_{\eta'(958) K_S^0} (B^0 \rightarrow \eta'(958) K_S^0) &= -0.04 \pm 0.20 \quad (S = 2.5) \\
S_{\eta'(958) K_S^0} (B^0 \rightarrow \eta'(958) K_S^0) &= 0.43 \pm 0.17 \quad (S = 1.5) \\
C_{\eta' K^0} (B^0 \rightarrow \eta' K^0) &= -0.06 \pm 0.04 \\
\mathbf{S_{\eta' K^0} (B^0 \rightarrow \eta' K^0)} &= 0.63 \pm 0.06 \\
C_{\omega K_S^0} (B^0 \rightarrow \omega K_S^0) &= 0.0 \pm 0.4 \quad (S = 3.0) \\
S_{\omega K_S^0} (B^0 \rightarrow \omega K_S^0) &= 0.70 \pm 0.21 \\
C (B^0 \rightarrow K_S^0 \pi^0 \pi^0) &= -0.21 \pm 0.20 \\
S (B^0 \rightarrow K_S^0 \pi^0 \pi^0) &= 0.89_{-0.30}^{+0.27} \\
C_{\rho^0 K_S^0} (B^0 \rightarrow \rho^0 K_S^0) &= -0.04 \pm 0.20 \\
S_{\rho^0 K_S^0} (B^0 \rightarrow \rho^0 K_S^0) &= 0.50_{-0.21}^{+0.17} \\
C_{f_0 K_S^0} (B^0 \rightarrow f_0(980) K_S^0) &= 0.29 \pm 0.20 \\
\mathbf{S_{f_0 K_S^0} (B^0 \rightarrow f_0(980) K_S^0)} &= -0.50 \pm 0.16 \\
S_{f_2 K_S^0} (B^0 \rightarrow f_2(1270) K_S^0) &= -0.5 \pm 0.5 \\
C_{f_2 K_S^0} (B^0 \rightarrow f_2(1270) K_S^0) &= 0.3 \pm 0.4 \\
S_{f_x K_S^0} (B^0 \rightarrow f_x(1300) K_S^0) &= -0.2 \pm 0.5 \\
C_{f_x K_S^0} (B^0 \rightarrow f_x(1300) K_S^0) &= 0.13 \pm 0.35 \\
S_{K^0 \pi^+ \pi^-} (B^0 \rightarrow K^0 \pi^+ \pi^- \text{ nonresonant}) &= -0.01 \pm 0.33 \\
C_{K^0 \pi^+ \pi^-} (B^0 \rightarrow K^0 \pi^+ \pi^- \text{ nonresonant}) &= 0.01 \pm 0.26 \\
C_{K_S^0 K_S^0} (B^0 \rightarrow K_S^0 K_S^0) &= 0.0 \pm 0.4 \quad (S = 1.4) \\
S_{K_S^0 K_S^0} (B^0 \rightarrow K_S^0 K_S^0) &= -0.8 \pm 0.5
\end{aligned}$$

$$\begin{aligned}
 C_{K^+K^-K_S^0} (B^0 \rightarrow K^+K^-K_S^0 \text{ nonresonant}) &= 0.06 \pm 0.08 \\
 S_{K^+K^-K_S^0} (B^0 \rightarrow K^+K^-K_S^0 \text{ nonresonant}) &= -0.66 \pm 0.11 \\
 C_{K^+K^-K_S^0} (B^0 \rightarrow K^+K^-K_S^0 \text{ inclusive}) &= 0.01 \pm 0.09 \\
 S_{K^+K^-K_S^0} (B^0 \rightarrow K^+K^-K_S^0 \text{ inclusive}) &= -0.65 \pm 0.12 \\
 C_{\phi K_S^0} (B^0 \rightarrow \phi K_S^0) &= 0.01 \pm 0.14 \\
 S_{\phi K_S^0} (B^0 \rightarrow \phi K_S^0) &= 0.59 \pm 0.14 \\
 C_{K_S K_S K_S} (B^0 \rightarrow K_S K_S K_S) &= -0.23 \pm 0.14 \\
 S_{K_S K_S K_S} (B^0 \rightarrow K_S K_S K_S) &= -0.5 \pm 0.6 \quad (S = 3.0) \\
 C_{K_S^0 \pi^0 \gamma} (B^0 \rightarrow K_S^0 \pi^0 \gamma) &= 0.36 \pm 0.33 \\
 S_{K_S^0 \pi^0 \gamma} (B^0 \rightarrow K_S^0 \pi^0 \gamma) &= -0.8 \pm 0.6 \\
 C_{K_S^0 \pi^+ \pi^- \gamma} (B^0 \rightarrow K_S^0 \pi^+ \pi^- \gamma) &= -0.39 \pm 0.20 \\
 S_{K_S^0 \pi^+ \pi^- \gamma} (B^0 \rightarrow K_S^0 \pi^+ \pi^- \gamma) &= 0.14 \pm 0.25 \\
 C_{K^{*0} \gamma} (B^0 \rightarrow K^{*0} \gamma) &= -0.04 \pm 0.16 \quad (S = 1.2) \\
 S_{K^{*0} \gamma} (B^0 \rightarrow K^{*0} \gamma) &= -0.15 \pm 0.22 \\
 C_{\eta K^0 \gamma} (B^0 \rightarrow \eta K^0 \gamma) &= 0.1 \pm 0.4 \quad (S = 1.4) \\
 S_{\eta K^0 \gamma} (B^0 \rightarrow \eta K^0 \gamma) &= -0.5 \pm 0.5 \quad (S = 1.2) \\
 C_{K^0 \phi \gamma} (B^0 \rightarrow K^0 \phi \gamma) &= -0.3 \pm 0.6 \\
 S_{K^0 \phi \gamma} (B^0 \rightarrow K^0 \phi \gamma) &= 0.7_{-1.1}^{+0.7} \\
 C(B^0 \rightarrow K_S^0 \rho^0 \gamma) &= -0.05 \pm 0.19 \\
 S(B^0 \rightarrow K_S^0 \rho^0 \gamma) &= -0.04 \pm 0.23 \\
 C(B^0 \rightarrow \rho^0 \gamma) &= 0.4 \pm 0.5 \\
 S(B^0 \rightarrow \rho^0 \gamma) &= -0.8 \pm 0.7 \\
 C_{\pi^+ \pi^-} (B^0 \rightarrow \pi^+ \pi^-) &= -0.32 \pm 0.04 \\
 S_{\pi^+ \pi^-} (B^0 \rightarrow \pi^+ \pi^-) &= -0.65 \pm 0.04 \\
 C_{\pi^0 \pi^0} (B^0 \rightarrow \pi^0 \pi^0) &= -0.33 \pm 0.22 \\
 C_{\rho^+ \pi^-} (B^0 \rightarrow \rho^+ \pi^-) &= -0.03 \pm 0.07 \quad (S = 1.2) \\
 S_{\rho^+ \pi^-} (B^0 \rightarrow \rho^+ \pi^-) &= 0.05 \pm 0.07 \\
 \Delta C_{\rho^+ \pi^-} (B^0 \rightarrow \rho^+ \pi^-) &= 0.27 \pm 0.06 \\
 \Delta S_{\rho^+ \pi^-} (B^0 \rightarrow \rho^+ \pi^-) &= 0.01 \pm 0.08 \\
 C_{\rho^0 \pi^0} (B^0 \rightarrow \rho^0 \pi^0) &= 0.27 \pm 0.24 \\
 S_{\rho^0 \pi^0} (B^0 \rightarrow \rho^0 \pi^0) &= -0.23 \pm 0.34 \\
 C_{a_1 \pi} (B^0 \rightarrow a_1(1260)^+ \pi^-) &= -0.05 \pm 0.11 \\
 S_{a_1 \pi} (B^0 \rightarrow a_1(1260)^+ \pi^-) &= -0.2 \pm 0.4 \quad (S = 3.2) \\
 \Delta C_{a_1 \pi} (B^0 \rightarrow a_1(1260)^+ \pi^-) &= 0.43 \pm 0.14 \quad (S = 1.3) \\
 \Delta S_{a_1 \pi} (B^0 \rightarrow a_1(1260)^+ \pi^-) &= -0.11 \pm 0.12 \\
 C(B^0 \rightarrow b_1^- K^+) &= -0.22 \pm 0.24
 \end{aligned}$$

$$\begin{aligned}
\Delta C(B^0 \rightarrow b_1^- \pi^+) &= -1.04 \pm 0.24 \\
C_{\rho^0 \rho^0}(B^0 \rightarrow \rho^0 \rho^0) &= 0.2 \pm 0.9 \\
S_{\rho^0 \rho^0}(B^0 \rightarrow \rho^0 \rho^0) &= 0.3 \pm 0.7 \\
C_{\rho \rho}(B^0 \rightarrow \rho^+ \rho^-) &= 0.00 \pm 0.09 \\
S_{\rho \rho}(B^0 \rightarrow \rho^+ \rho^-) &= -0.14 \pm 0.13 \\
|\lambda|(B^0 \rightarrow J/\psi K^*(892)^0) &< 0.25, \text{ CL} = 95\% \\
\cos 2\beta(B^0 \rightarrow J/\psi K^*(892)^0) &= 1.7_{-0.9}^{+0.7} \quad (S = 1.6) \\
\cos 2\beta(B^0 \rightarrow [K_S^0 \pi^+ \pi^-]_{D^{(*)}} h^0) &= 0.91 \pm 0.25 \\
(S_+ + S_-)/2(B^0 \rightarrow D^{*-} \pi^+) &= -0.039 \pm 0.011 \\
(S_- - S_+)/2(B^0 \rightarrow D^{*-} \pi^+) &= -0.009 \pm 0.015 \\
(S_+ + S_-)/2(B^0 \rightarrow D^- \pi^+) &= -0.046 \pm 0.023 \\
(S_- - S_+)/2(B^0 \rightarrow D^- \pi^+) &= -0.022 \pm 0.021 \\
S_+(B^0 \rightarrow D^- \pi^+) &= 0.058 \pm 0.023 \\
S_-(B^0 \rightarrow D^+ \pi^-) &= 0.038 \pm 0.021 \\
(S_+ + S_-)/2(B^0 \rightarrow D^- \rho^+) &= -0.024 \pm 0.032 \\
(S_- - S_+)/2(B^0 \rightarrow D^- \rho^+) &= -0.10 \pm 0.06 \\
C_{\eta_c K_S^0}(B^0 \rightarrow \eta_c K_S^0) &= 0.08 \pm 0.13 \\
S_{\eta_c K_S^0}(B^0 \rightarrow \eta_c K_S^0) &= 0.93 \pm 0.17 \\
C_{c\bar{c}K^{(*)0}}(B^0 \rightarrow c\bar{c}K^{(*)0}) &= (0.5 \pm 1.7) \times 10^{-2} \\
\sin(2\beta) &= 0.695 \pm 0.019 \\
C_{J/\psi(nS)K^0}(B^0 \rightarrow J/\psi(nS)K^0) &= (0.5 \pm 2.0) \times 10^{-2} \\
S_{J/\psi(nS)K^0}(B^0 \rightarrow J/\psi(nS)K^0) &= 0.701 \pm 0.017 \\
C_{J/\psi K^{*0}}(B^0 \rightarrow J/\psi K^{*0}) &= 0.03 \pm 0.10 \\
S_{J/\psi K^{*0}}(B^0 \rightarrow J/\psi K^{*0}) &= 0.60 \pm 0.25 \\
C_{\chi_{c0} K_S^0}(B^0 \rightarrow \chi_{c0} K_S^0) &= -0.3_{-0.4}^{+0.5} \\
S_{\chi_{c0} K_S^0}(B^0 \rightarrow \chi_{c0} K_S^0) &= -0.7 \pm 0.5 \\
C_{\chi_{c1} K_S^0}(B^0 \rightarrow \chi_{c1} K_S^0) &= 0.06 \pm 0.07 \\
S_{\chi_{c1} K_S^0}(B^0 \rightarrow \chi_{c1} K_S^0) &= 0.63 \pm 0.10 \\
\sin(2\beta_{\text{eff}})(B^0 \rightarrow \phi K^0) &= 0.22 \pm 0.30 \\
\sin(2\beta_{\text{eff}})(B^0 \rightarrow \phi K_0^*(1430)^0) &= 0.97_{-0.52}^{+0.03} \\
\sin(2\beta_{\text{eff}})(B^0 \rightarrow K^+ K^- K_S^0) &= 0.77_{-0.12}^{+0.13} \\
\sin(2\beta_{\text{eff}})(B^0 \rightarrow [K_S^0 \pi^+ \pi^-]_{D^{(*)}} h^0) &= 0.80 \pm 0.16 \\
\beta_{\text{eff}}(B^0 \rightarrow [K_S^0 \pi^+ \pi^-]_{D^{(*)}} h^0) &= (22 \pm 5)^\circ \\
2\beta_{\text{eff}}(B^0 \rightarrow J/\psi \rho^0) &= (42_{-11}^{+10})^\circ \\
|\lambda|(B^0 \rightarrow [K_S^0 \pi^+ \pi^-]_{D^{(*)}} h^0) &= 1.01 \pm 0.08 \\
|\sin(2\beta + \gamma)| &> 0.40, \text{ CL} = 90\% \\
2\beta + \gamma &= (83 \pm 60)^\circ
\end{aligned}$$



$$\begin{aligned}
 \alpha &= (84.9^{+5.1}_{-4.5})^\circ \\
 x_+(B^0 \rightarrow DK^{*0}) &= 0.04 \pm 0.17 \\
 x_-(B^0 \rightarrow DK^{*0}) &= -0.16 \pm 0.14 \\
 y_+(B^0 \rightarrow DK^{*0}) &= -0.68 \pm 0.22 \\
 y_-(B^0 \rightarrow DK^{*0}) &= 0.20 \pm 0.25 \quad (S = 1.2) \\
 r_{B^0}(B^0 \rightarrow DK^{*0}) &= 0.220^{+0.041}_{-0.047} \\
 \delta_{B^0}(B^0 \rightarrow DK^{*0}) &= (194^{+30}_{-22})^\circ
 \end{aligned}$$

$\bar{B}^0$  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.,  $B \rightarrow D^\pm X$ , 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/<br>Confidence level | $\rho$<br>(MeV/c) |
|---|------------------------------------|-----------------------------------|-------------------|
| $\ell^+ \nu_\ell X$   | [iii] ( 10.33 ± 0.28 ) %           |                                   | —                 |
| $e^+ \nu_e X_c$   | ( 10.1 ± 0.4 ) %                   |                                   | —                 |
| $D \ell^+ \nu_\ell X$   | ( 9.4 ± 0.9 ) %                    |                                   | —                 |
| $D^- \ell^+ \nu_\ell$   | [iii] ( 2.31 ± 0.10 ) %            |                                   | 2309              |
| $D^- \tau^+ \nu_\tau$   | ( 1.08 ± 0.23 ) %                  |                                   | 1909              |
| $D^*(2010)^- \ell^+ \nu_\ell$   | [iii] ( 5.06 ± 0.12 ) %            |                                   | 2257              |
| $D^*(2010)^- \tau^+ \nu_\tau$   | ( 1.57 ± 0.09 ) %                  | S=1.1                             | 1838              |
| $\bar{D}^0 \pi^- \ell^+ \nu_\ell$                                     | ( 4.1 ± 0.5 ) × 10 <sup>-3</sup>   |                                   | 2308              |
| $D_0^*(2300)^- \ell^+ \nu_\ell, D_0^{*-} \rightarrow \bar{D}^0 \pi^-$ | ( 3.0 ± 1.2 ) × 10 <sup>-3</sup>   | S=1.8                             | —                 |
| $D_2^*(2460)^- \ell^+ \nu_\ell, D_2^{*-} \rightarrow \bar{D}^0 \pi^-$ | ( 1.21 ± 0.33 ) × 10 <sup>-3</sup> | S=1.8                             | 2065              |
| $\bar{D}^{(*)} n \pi \ell^+ \nu_\ell (n \geq 1)$                      | ( 2.3 ± 0.5 ) %                    |                                   | —                 |
| $\bar{D}^{*0} \pi^- \ell^+ \nu_\ell$                                  | ( 5.8 ± 0.8 ) × 10 <sup>-3</sup>   | S=1.4                             | 2256              |
| $D_1(2420)^- \ell^+ \nu_\ell, D_1^- \rightarrow \bar{D}^{*0} \pi^-$   | ( 2.80 ± 0.28 ) × 10 <sup>-3</sup> |                                   | —                 |

|  |  |      |
|--|--|------|
| $D_1'(2430)^- \ell^+ \nu_\ell, D_1'^- \rightarrow \bar{D}^{*0} \pi^-$    | $( 3.1 \pm 0.9 ) \times 10^{-3}$         | —    |
| $D_2^*(2460)^- \ell^+ \nu_\ell, D_2^{*-} \rightarrow \bar{D}^{*0} \pi^-$ | $( 6.8 \pm 1.2 ) \times 10^{-4}$         | 2065 |
| $D^- \pi^+ \pi^- \ell^+ \nu_\ell$  | $( 1.3 \pm 0.5 ) \times 10^{-3}$         | 2299 |
| $D^{*-} \pi^+ \pi^- \ell^+ \nu_\ell$                                     | $( 1.4 \pm 0.5 ) \times 10^{-3}$         | 2247 |
| $\rho^- \ell^+ \nu_\ell$   | [iii] $( 2.94 \pm 0.21 ) \times 10^{-4}$ | 2583 |
| $\pi^- \ell^+ \nu_\ell$  | [iii] $( 1.50 \pm 0.06 ) \times 10^{-4}$ | 2638 |
| $\pi^- \tau^+ \nu_\tau$  | $< 2.5 \times 10^{-4}$ CL=90%            | 2339 |

**Inclusive modes**

|                       |  |   |
|-----------------------|--|---|
| $K^\pm X$             | $( 78 \pm 8 ) \%$  | — |
| $D^0 X$               | $( 8.1 \pm 1.5 ) \%$   | — |
| $\bar{D}^0 X$         | $( 47.4 \pm 2.8 ) \%$  | — |
| $D^+ X$               | $< 3.9 \%$ CL=90%  | — |
| $D^- X$               | $( 36.9 \pm 3.3 ) \%$  | — |
| $D_s^+ X$             | $( 10.3 \begin{smallmatrix} + 2.1 \\ - 1.8 \end{smallmatrix} ) \%$ | — |
| $D_s^- X$             | $< 2.6 \%$ CL=90%  | — |
| $\Lambda_c^+ X$       | $< 3.1 \%$ CL=90%  | — |
| $\bar{\Lambda}_c^- X$ | $( 5.0 \begin{smallmatrix} + 2.1 \\ - 1.5 \end{smallmatrix} ) \%$  | — |
| $\bar{c} X$           | $( 95 \pm 5 ) \%$  | — |
| $c X$                 | $( 24.6 \pm 3.1 ) \%$  | — |
| $\bar{c}/c X$         | $( 119 \pm 6 ) \%$   | — |

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

|                                       |                                    |       |      |
|---------------------------------------|------------------------------------|-------|------|
| $D^- \pi^+$                           | $( 2.52 \pm 0.13 ) \times 10^{-3}$ | S=1.1 | 2306 |
| $D^- \rho^+$                          | $( 7.6 \pm 1.2 ) \times 10^{-3}$   |       | 2235 |
| $D^- K^0 \pi^+$                       | $( 4.9 \pm 0.9 ) \times 10^{-4}$   |       | 2259 |
| $D^- K^*(892)^+$                      | $( 4.5 \pm 0.7 ) \times 10^{-4}$   |       | 2211 |
| $D^- \omega \pi^+$                    | $( 2.8 \pm 0.6 ) \times 10^{-3}$   |       | 2204 |
| $D^- K^+$                             | $( 1.86 \pm 0.20 ) \times 10^{-4}$ |       | 2279 |
| $D^- K^+ \pi^+ \pi^-$                 | $( 3.5 \pm 0.8 ) \times 10^{-4}$   |       | 2236 |
| $D^- K^+ \bar{K}^0$                   | $< 3.1 \times 10^{-4}$ CL=90%      |       | 2188 |
| $D^- K^+ \bar{K}^*(892)^0$            | $( 8.8 \pm 1.9 ) \times 10^{-4}$   |       | 2070 |
| $\bar{D}^0 \pi^+ \pi^-$               | $( 8.8 \pm 0.5 ) \times 10^{-4}$   |       | 2301 |
| $D^*(2010)^- \pi^+$                   | $( 2.74 \pm 0.13 ) \times 10^{-3}$ |       | 2255 |
| $\bar{D}^0 K^+ K^-$                   | $( 5.9 \pm 0.5 ) \times 10^{-5}$   |       | 2191 |
| $D^- \pi^+ \pi^+ \pi^-$               | $( 6.0 \pm 0.7 ) \times 10^{-3}$   | S=1.1 | 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 |
| $D^*(2010)^- \pi^+ \pi^0$             | $( 1.5 \pm 0.5 ) \%$               |       | 2248 |
| $D^*(2010)^- \rho^+$                  | $( 6.8 \pm 0.9 ) \times 10^{-3}$   |       | 2180 |
| $D^*(2010)^- K^+$                     | $( 2.12 \pm 0.15 ) \times 10^{-4}$ |       | 2226 |

|  |  |             |
|--|--|-------------|
| $D^*(2010)^- K^0 \pi^+$                                  | $( 3.0 \pm 0.8 ) \times 10^{-4}$   | 2205        |
| $D^*(2010)^- K^*(892)^+$                                 | $( 3.3 \pm 0.6 ) \times 10^{-4}$   | 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        |
| $D^*(2010)^- \pi^+ \pi^+ \pi^-$                          | $( 7.21 \pm 0.29 ) \times 10^{-3}$   | 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        |
| $D^*(2010)^- a_1(1260)^+$                                | $( 1.30 \pm 0.27 ) \%$   | 2061        |
| $\bar{D}_1(2420)^0 \pi^- \pi^+, \bar{D}_1^0 \rightarrow$ | $( 1.47 \pm 0.35 ) \times 10^{-4}$   | —           |
| $D^{*-} \pi^+$   |  |             |
| $D^*(2010)^- K^+ \pi^- \pi^+$                            | $( 4.7 \pm 0.4 ) \times 10^{-4}$   | 2181        |
| $D^*(2010)^- \pi^+ \pi^+ \pi^- \pi^0$                    | $( 1.76 \pm 0.27 ) \%$   | 2218        |
| $D^{*-} 3\pi^+ 2\pi^-$                                   | $( 4.7 \pm 0.9 ) \times 10^{-3}$   | 2195        |
| $D^*(2010)^- \omega \pi^+$                               | $( 2.46 \pm 0.18 ) \times 10^{-3}$   | S=1.2 2148  |
| $\bar{D}_1(2430)^0 \omega, \bar{D}_1^0 \rightarrow$      | $( 2.7 \begin{smallmatrix} +0.8 \\ -0.4 \end{smallmatrix} ) \times 10^{-4}$    | 1992        |
| $D^{*-} \pi^+$   |  |             |
| $D^{*-} \rho(1450)^+, \rho^+ \rightarrow \omega \pi^+$   | $( 1.07 \begin{smallmatrix} +0.40 \\ -0.34 \end{smallmatrix} ) \times 10^{-3}$ | —           |
| $\bar{D}_1(2420)^0 \omega, \bar{D}_1^0 \rightarrow$      | $( 7.0 \pm 2.2 ) \times 10^{-5}$   | 1995        |
| $D^{*-} \pi^+$   |  |             |
| $\bar{D}_2^*(2460)^0 \omega, \bar{D}_2^0 \rightarrow$    | $( 4.0 \pm 1.4 ) \times 10^{-5}$   | 1975        |
| $D^{*-} \pi^+$   |  |             |
| $D^{*-} b_1(1235)^+, b_1^+ \rightarrow$                  | $< 7 \times 10^{-5}$   | CL=90% —    |
| $\bar{D}^{*-} \pi^+$                                     |  |             |
| $\bar{D}^{*-} \omega \pi^+$                              | [ <i>nnn</i> ] $( 1.9 \pm 0.9 ) \times 10^{-3}$                                | —           |
| $D_1(2420)^- \pi^+, D_1^- \rightarrow$                   | $( 9.9 \begin{smallmatrix} +2.0 \\ -2.5 \end{smallmatrix} ) \times 10^{-5}$    | —           |
| $D^- \pi^+ \pi^-$  |  |             |
| $D_1(2420)^- \pi^+, D_1^- \rightarrow$                   | $< 3.3 \times 10^{-5}$   | CL=90% —    |
| $D^{*-} \pi^+ \pi^-$                                     |  |             |
| $\bar{D}_2^*(2460)^- \pi^+, (D_2^*)^- \rightarrow$       | $( 2.38 \pm 0.16 ) \times 10^{-4}$   | 2062        |
| $D^0 \pi^-$  |  |             |
| $\bar{D}_0^*(2400)^- \pi^+, (D_0^*)^- \rightarrow$       | $( 7.6 \pm 0.8 ) \times 10^{-5}$   | 2090        |
| $D^0 \pi^-$  |  |             |
| $D_2^*(2460)^- \pi^+, (D_2^*)^- \rightarrow$             | $< 2.4 \times 10^{-5}$   | CL=90% —    |
| $D^{*-} \pi^+ \pi^-$                                     |  |             |
| $\bar{D}_2^*(2460)^- \rho^+$                             | $< 4.9 \times 10^{-3}$   | CL=90% 1974 |
| $D^0 \bar{D}^0$  | $( 1.4 \pm 0.7 ) \times 10^{-5}$   | 1868        |
| $D^{*0} \bar{D}^0$                                       | $< 2.9 \times 10^{-4}$   | CL=90% 1794 |
| $D^- D^+$  | $( 2.11 \pm 0.18 ) \times 10^{-4}$   | 1864        |
| $D^\pm D^{*\mp}$ (CP-averaged)                           | $( 6.1 \pm 0.6 ) \times 10^{-4}$   | —           |
| $D^- D_s^+$  | $( 7.2 \pm 0.8 ) \times 10^{-3}$   | 1812        |
| $D^*(2010)^- D_s^+$                                      | $( 8.0 \pm 1.1 ) \times 10^{-3}$   | 1735        |
| $D^- D_s^{*+}$   | $( 7.4 \pm 1.6 ) \times 10^{-3}$   | 1732        |

|  |   |      |
|--|---|------|
| $D^*(2010)^- D_s^{*+}$   | ( 1.77 ± 0.14 ) %   | 1649 |
| $D_{s0}(2317)^- K^+, D_{s0}^- \rightarrow D_s^- \pi^0$                     | ( 4.2 ± 1.4 ) × 10 <sup>-5</sup>  | 2097 |
| $D_{s0}(2317)^- \pi^+, D_{s0}^- \rightarrow D_s^- \pi^0$                   | < 2.5 × 10 <sup>-5</sup> CL=90%   | 2128 |
| $D_{sJ}(2457)^- K^+, D_{sJ}^- \rightarrow D_s^- \pi^0$                     | < 9.4 × 10 <sup>-6</sup> CL=90%   | —    |
| $D_{sJ}(2457)^- \pi^+, D_{sJ}^- \rightarrow D_s^- \pi^0$                   | < 4.0 × 10 <sup>-6</sup> CL=90%   | —    |
| $D_s^- D_s^+$  | < 3.6 × 10 <sup>-5</sup> CL=90%   | 1759 |
| $D_s^{*-} D_s^+$   | < 1.3 × 10 <sup>-4</sup> CL=90%   | 1674 |
| $D_s^{*0} D_s^+$   | < 2.4 × 10 <sup>-4</sup> CL=90%   | 1583 |
| $D_{s0}^*(2317)^+ D^-, D_{s0}^{*+} \rightarrow D_s^+ \pi^0$                | ( 1.06 ± 0.16 ) × 10 <sup>-3</sup> S=1.1  | 1602 |
| $D_{s0}(2317)^+ D^-, D_{s0}^+ \rightarrow D_s^{*+} \gamma$                 | < 9.5 × 10 <sup>-4</sup> CL=90%   | —    |
| $D_{s0}(2317)^+ D^*(2010)^-, D_{s0}^+ \rightarrow D_s^+ \pi^0$             | ( 1.5 ± 0.6 ) × 10 <sup>-3</sup>  | 1509 |
| $D_{sJ}(2457)^+ D^-$   | ( 3.5 ± 1.1 ) × 10 <sup>-3</sup>  | —    |
| $D_{sJ}(2457)^+ D^-, D_{sJ}^+ \rightarrow D_s^+ \gamma$                    | ( 6.5 $\begin{smallmatrix} + 1.7 \\ - 1.4 \end{smallmatrix}$ ) × 10 <sup>-4</sup> | —    |
| $D_{sJ}(2457)^+ D^-, D_{sJ}^+ \rightarrow D_s^{*+} \gamma$                 | < 6.0 × 10 <sup>-4</sup> CL=90%   | —    |
| $D_{sJ}(2457)^+ D^-, D_{sJ}^+ \rightarrow D_s^+ \pi^+ \pi^-$               | < 2.0 × 10 <sup>-4</sup> CL=90%   | —    |
| $D_{sJ}(2457)^+ D^-, D_{sJ}^+ \rightarrow D_s^+ \pi^0$                     | < 3.6 × 10 <sup>-4</sup> CL=90%   | —    |
| $D^*(2010)^- D_{sJ}(2457)^+$   | ( 9.3 ± 2.2 ) × 10 <sup>-3</sup>  | —    |
| $D_{sJ}(2457)^+ D^*(2010), D_{sJ}^+ \rightarrow D_s^+ \gamma$              | ( 2.3 $\begin{smallmatrix} + 0.9 \\ - 0.7 \end{smallmatrix}$ ) × 10 <sup>-3</sup> | —    |
| $D^- D_{s1}(2536)^+, D_{s1}^+ \rightarrow D^{*0} K^+ + D^{*+} K^0$         | ( 2.8 ± 0.7 ) × 10 <sup>-4</sup>  | 1444 |
| $D^- D_{s1}(2536)^+, D_{s1}^+ \rightarrow D^{*0} K^+$                      | ( 1.7 ± 0.6 ) × 10 <sup>-4</sup>  | 1444 |
| $D^- D_{s1}(2536)^+, D_{s1}^+ \rightarrow D^{*+} K^0$                      | ( 2.6 ± 1.1 ) × 10 <sup>-4</sup>  | 1444 |
| $D^*(2010)^- D_{s1}(2536)^+, D_{s1}^+ \rightarrow D^{*0} K^+ + D^{*+} K^0$ | ( 5.0 ± 1.4 ) × 10 <sup>-4</sup>  | 1336 |

|   |   |      |
|---|---|------|
| $D^*(2010)^- D_{s1}(2536)^+,$<br>$D_{s1}^+ \rightarrow D^{*0} K^+$  | $( 3.3 \pm 1.1 ) \times 10^{-4}$  | 1336 |
| $D^{*-} D_{s1}(2536)^+, D_{s1}^+ \rightarrow$<br>$D^{*+} K^0$       | $( 5.0 \pm 1.7 ) \times 10^{-4}$  | 1336 |
| $D^- D_{sJ}(2573)^+, D_{sJ}^+ \rightarrow$<br>$D^0 K^+$             | $( 3.4 \pm 1.8 ) \times 10^{-5}$  | 1414 |
| $D^*(2010)^- D_{sJ}(2573)^+,$<br>$D_{sJ}^+ \rightarrow D^0 K^+$     | $< 2 \times 10^{-4}$ CL=90%   | 1304 |
| $D^- D_{sJ}(2700)^+, D_{sJ}^+ \rightarrow$<br>$D^0 K^+$             | $( 7.1 \pm 1.2 ) \times 10^{-4}$  | —    |
| $D^+ \pi^-$   | $( 7.4 \pm 1.3 ) \times 10^{-7}$  | 2306 |
| $D_s^+ \pi^-$   | $( 2.16 \pm 0.26 ) \times 10^{-5}$  | 2270 |
| $D_s^{*+} \pi^-$  | $( 2.1 \pm 0.4 ) \times 10^{-5}$ S=1.4  | 2215 |
| $D_s^+ \rho^-$  | $< 2.4 \times 10^{-5}$ CL=90%   | 2197 |
| $D_s^{*+} \rho^-$   | $( 4.1 \pm 1.3 ) \times 10^{-5}$  | 2138 |
| $D_s^+ a_0^-$   | $< 1.9 \times 10^{-5}$ CL=90%   | —    |
| $D_s^{*+} a_0^-$  | $< 3.6 \times 10^{-5}$ CL=90%   | —    |
| $D_s^+ a_1(1260)^-$   | $< 2.1 \times 10^{-3}$ CL=90%   | 2080 |
| $D_s^{*+} a_1(1260)^-$  | $< 1.7 \times 10^{-3}$ CL=90%   | 2015 |
| $D_s^+ a_2^-$   | $< 1.9 \times 10^{-4}$ CL=90%   | —    |
| $D_s^{*+} a_2^-$  | $< 2.0 \times 10^{-4}$ CL=90%   | —    |
| $D_s^- K^+$   | $( 2.7 \pm 0.5 ) \times 10^{-5}$ S=2.7  | 2242 |
| $D_s^{*-} K^+$  | $( 2.19 \pm 0.30 ) \times 10^{-5}$  | 2185 |
| $D_s^- K^*(892)^+$  | $( 3.5 \pm 1.0 ) \times 10^{-5}$  | 2172 |
| $D_s^{*-} K^*(892)^+$   | $( 3.2 \begin{smallmatrix} + 1.5 \\ - 1.3 \end{smallmatrix} ) \times 10^{-5}$ | 2112 |
| $D_s^- \pi^+ K^0$   | $( 9.7 \pm 1.4 ) \times 10^{-5}$  | 2222 |
| $D_s^{*-} \pi^+ K^0$  | $< 1.10 \times 10^{-4}$ CL=90%  | 2164 |
| $D_s^- K^+ \pi^+ \pi^-$   | $( 1.7 \pm 0.5 ) \times 10^{-4}$  | 2198 |
| $D_s^- \pi^+ K^*(892)^0$  | $< 3.0 \times 10^{-3}$ CL=90%   | 2138 |
| $D_s^{*-} \pi^+ K^*(892)^0$   | $< 1.6 \times 10^{-3}$ CL=90%   | 2076 |
| $\overline{D}^0 K^0$  | $( 5.2 \pm 0.7 ) \times 10^{-5}$  | 2280 |
| $\overline{D}^0 K^+ \pi^-$  | $( 8.8 \pm 1.7 ) \times 10^{-5}$  | 2261 |
| $\overline{D}^0 K^*(892)^0$   | $( 4.5 \pm 0.6 ) \times 10^{-5}$  | 2213 |
| $\overline{D}^0 K^*(1410)^0$  | $< 6.7 \times 10^{-5}$ CL=90%   | 2062 |
| $\overline{D}^0 K_0^*(1430)^0$                                      | $( 7 \pm 7 ) \times 10^{-6}$  | 2058 |
| $\overline{D}^0 K_2^*(1430)^0$                                      | $( 2.1 \pm 0.9 ) \times 10^{-5}$  | 2057 |
| $D_0^*(2300)^- K^+, D_0^{*-} \rightarrow$<br>$\overline{D}^0 \pi^-$ | $( 1.9 \pm 0.9 ) \times 10^{-5}$  | —    |
| $D_2^*(2460)^- K^+, D_2^{*-} \rightarrow$<br>$\overline{D}^0 \pi^-$ | $( 2.03 \pm 0.35 ) \times 10^{-5}$  | 2029 |

|   |  |                  |        |      |
|---|--|------------------|--------|------|
| $D_3^*(2760)^- K^+, D_3^{*-} \rightarrow \bar{D}^0 \pi^-$ | < 1.0  | $\times 10^{-6}$ | CL=90% | -    |
| $\bar{D}^0 K^+ \pi^-$ nonresonant                         | < 3.7  | $\times 10^{-5}$ | CL=90% | 2261 |
| $[K^+ K^-]_D K^*(892)^0$                                  | ( 4.2 ± 0.7 )  | $\times 10^{-5}$ |        | -    |
| $[\pi^+ \pi^-]_D K^*(892)^0$                              | ( 6.0 ± 1.1 )  | $\times 10^{-5}$ |        | -    |
| $[\pi^+ \pi^- \pi^+ \pi^-]_D K^{*0}$                      | ( 4.6 ± 0.9 )  | $\times 10^{-5}$ |        | -    |
| $\bar{D}^0 \pi^0$   | ( 2.63 ± 0.14 )  | $\times 10^{-4}$ |        | 2308 |
| $\bar{D}^0 \rho^0$  | ( 3.21 ± 0.21 )  | $\times 10^{-4}$ |        | 2237 |
| $\bar{D}^0 f_2$   | ( 1.56 ± 0.21 )  | $\times 10^{-4}$ |        | -    |
| $\bar{D}^0 \eta$  | ( 2.36 ± 0.32 )  | $\times 10^{-4}$ | S=2.5  | 2274 |
| $\bar{D}^0 \eta'$   | ( 1.38 ± 0.16 )  | $\times 10^{-4}$ | S=1.3  | 2198 |
| $\bar{D}^0 \omega$  | ( 2.54 ± 0.16 )  | $\times 10^{-4}$ |        | 2235 |
| $D^0 \phi$  | < 2.3  | $\times 10^{-6}$ | CL=95% | 2183 |
| $D^0 K^+ \pi^-$   | ( 5.3 ± 3.2 )  | $\times 10^{-6}$ |        | 2261 |
| $D^0 K^*(892)^0$  | ( 2.2 $\begin{smallmatrix} +0.9 \\ -1.0 \end{smallmatrix}$ ) | $\times 10^{-6}$ |        | 2213 |
| $\bar{D}^{*0} \gamma$                                     | < 2.5  | $\times 10^{-5}$ | CL=90% | 2258 |
| $\bar{D}^*(2007)^0 \pi^0$                                 | ( 2.2 ± 0.6 )  | $\times 10^{-4}$ | S=2.6  | 2256 |
| $\bar{D}^*(2007)^0 \rho^0$                                | < 5.1  | $\times 10^{-4}$ | CL=90% | 2182 |
| $\bar{D}^*(2007)^0 \eta$                                  | ( 2.3 ± 0.6 )  | $\times 10^{-4}$ | S=2.8  | 2220 |
| $\bar{D}^*(2007)^0 \eta'$                                 | ( 1.40 ± 0.22 )  | $\times 10^{-4}$ |        | 2141 |
| $\bar{D}^*(2007)^0 \pi^+ \pi^-$                           | ( 6.2 ± 2.2 )  | $\times 10^{-4}$ |        | 2249 |
| $\bar{D}^*(2007)^0 K^0$                                   | ( 3.6 ± 1.2 )  | $\times 10^{-5}$ |        | 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 |
| $D^*(2007)^0 \pi^+ \pi^+ \pi^- \pi^-$                     | ( 2.7 ± 0.5 )  | $\times 10^{-3}$ |        | 2219 |
| $D^*(2010)^+ D^*(2010)^-$                                 | ( 8.0 ± 0.6 )  | $\times 10^{-4}$ |        | 1711 |
| $\bar{D}^*(2007)^0 \omega$                                | ( 3.6 ± 1.1 )  | $\times 10^{-4}$ | S=3.1  | 2180 |
| $D^*(2010)^+ D^-$   | ( 6.1 ± 1.5 )  | $\times 10^{-4}$ | S=1.6  | 1790 |
| $D^*(2007)^0 \bar{D}^*(2007)^0$                           | < 9  | $\times 10^{-5}$ | CL=90% | 1715 |
| $D^- D^0 K^+$   | ( 1.07 ± 0.11 )  | $\times 10^{-3}$ |        | 1574 |
| $D^- D^*(2007)^0 K^+$                                     | ( 3.5 ± 0.4 )  | $\times 10^{-3}$ |        | 1478 |
| $D^*(2010)^- D^0 K^+$                                     | ( 2.47 ± 0.21 )  | $\times 10^{-3}$ |        | 1479 |
| $D^*(2010)^- D^*(2007)^0 K^+$                             | ( 1.06 ± 0.09 )  | %                |        | 1366 |
| $D^- D^+ K^0$   | ( 7.5 ± 1.7 )  | $\times 10^{-4}$ |        | 1568 |
| $D^*(2010)^- D^+ K^0 + D^- D^*(2010)^+ K^0$               | ( 6.4 ± 0.5 )  | $\times 10^{-3}$ |        | 1473 |
| $D^*(2010)^- D^*(2010)^+ K^0$                             | ( 8.1 ± 0.7 )  | $\times 10^{-3}$ |        | 1360 |
| $D^{*-} D_{s1}(2536)^+, D_{s1}^+ \rightarrow D^{*+} K^0$  | ( 8.0 ± 2.4 )  | $\times 10^{-4}$ |        | 1336 |
| $\bar{D}^0 D^0 K^0$                                       | ( 2.7 ± 1.1 )  | $\times 10^{-4}$ |        | 1574 |
| $D^0 \bar{D}^0 K^+ \pi^-$                                 | ( 3.5 ± 0.5 )  | $\times 10^{-4}$ |        | 1476 |
| $\bar{D}^0 D^*(2007)^0 K^0 + \bar{D}^*(2007)^0 D^0 K^0$   | ( 1.1 ± 0.5 )  | $\times 10^{-3}$ |        | 1478 |
| $\bar{D}^*(2007)^0 D^*(2007)^0 K^0$                       | ( 2.4 ± 0.9 )  | $\times 10^{-3}$ |        | 1365 |

|  |   |             |
|--|---|-------------|
| $(\bar{D} + \bar{D}^*)(D + D^*)K$                        | $(3.68 \pm 0.26) \%$                        | —           |
| <b>Charmonium modes</b>                                  |   |             |
| $\eta_c K^0$   | $(8.0 \pm 1.1) \times 10^{-4}$              | 1751        |
| $\eta_c(1S)K^+\pi^-$                                     | $(6.0 \pm 0.7) \times 10^{-4}$              | 1722        |
| $\eta_c(1S)K^+\pi^-$ (NR)                                | $(6.2 \pm 1.3) \times 10^{-5}$              | —           |
| $X(4100)^- K^+, X^- \rightarrow$                         | $(2.0 \pm 1.0) \times 10^{-5}$              | —           |
| $\eta_c \pi^-$   |   |             |
| $\eta_c(1S)K^*(1410)^0$                                  | $(1.9 \pm 1.5) \times 10^{-4}$              | 1395        |
| $\eta_c(1S)K_0^*(1430)^0$                                | $(1.6 \pm 0.4) \times 10^{-4}$              | 1387        |
| $\eta_c(1S)K_2^*(1430)^0$                                | $(5.0 \pm_{-2.7}^{+2.3}) \times 10^{-5}$    | 1386        |
| $\eta_c(1S)K^*(1680)^0$                                  | $(3 \pm 4) \times 10^{-5}$                  | 1166        |
| $\eta_c(1S)K_0^*(1950)^0$                                | $(4.4 \pm_{-4.0}^{+3.0}) \times 10^{-5}$    | —           |
| $\eta_c K^*(892)^0$                                      | $(5.2 \pm_{-0.9}^{+0.8}) \times 10^{-4}$    | S=1.6 1646  |
| $\eta_c(2S)K_S^0, \eta_c \rightarrow p\bar{p}\pi^+\pi^-$ | $(4.2 \pm_{-1.2}^{+1.4}) \times 10^{-7}$    | —           |
| $\eta_c(2S)K^{*0}$                                       | $< 3.9 \times 10^{-4}$                      | CL=90% 1159 |
| $h_c(1P)K_S^0$   | $< 1.4 \times 10^{-5}$                      | 1401        |
| $h_c(1P)K^{*0}$  | $< 4 \times 10^{-4}$                        | CL=90% 1253 |
| $J/\psi(1S)K^0$  | $(8.91 \pm 0.21) \times 10^{-4}$            | 1683        |
| $J/\psi(1S)K^+\pi^-$                                     | $(1.15 \pm 0.05) \times 10^{-3}$            | 1652        |
| $J/\psi(1S)K^*(892)^0$                                   | $(1.27 \pm 0.05) \times 10^{-3}$            | 1571        |
| $J/\psi(1S)\eta K_S^0$                                   | $(5.4 \pm 0.9) \times 10^{-5}$              | 1508        |
| $J/\psi(1S)\eta' K_S^0$                                  | $< 2.5 \times 10^{-5}$                      | CL=90% 1271 |
| $J/\psi(1S)\phi K^0$                                     | $(4.9 \pm 1.0) \times 10^{-5}$              | S=1.3 1224  |
| $J/\psi(1S)\omega K^0$                                   | $(2.3 \pm 0.4) \times 10^{-4}$              | 1386        |
| $X(3915), X \rightarrow J/\psi\omega$                    | $(2.1 \pm 0.9) \times 10^{-5}$              | 1102        |
| $J/\psi(1S)K(1270)^0$                                    | $(1.3 \pm 0.5) \times 10^{-3}$              | 1402        |
| $J/\psi(1S)\pi^0$  | $(1.66 \pm 0.10) \times 10^{-5}$            | 1728        |
| $J/\psi(1S)\eta$   | $(1.08 \pm 0.23) \times 10^{-5}$            | S=1.5 1673  |
| $J/\psi(1S)\pi^+\pi^-$                                   | $(4.00 \pm 0.15) \times 10^{-5}$            | 1716        |
| $J/\psi(1S)\pi^+\pi^-$ nonresonant                       | $< 1.2 \times 10^{-5}$                      | CL=90% 1716 |
| $J/\psi(1S)f_0(500), f_0 \rightarrow \pi\pi$             | $(8.8 \pm_{-1.6}^{+1.2}) \times 10^{-6}$    | —           |
| $J/\psi(1S)f_2$  | $(3.3 \pm_{-0.6}^{+0.5}) \times 10^{-6}$    | S=1.5 —     |
| $J/\psi(1S)\rho^0$                                       | $(2.55 \pm_{-0.16}^{+0.18}) \times 10^{-5}$ | 1612        |
| $J/\psi(1S)f_0(980), f_0 \rightarrow$<br>$\pi^+\pi^-$    | $< 1.1 \times 10^{-6}$                      | CL=90% —    |
| $J/\psi(1S)\rho(1450)^0, \rho^0 \rightarrow$<br>$\pi\pi$ | $(2.9 \pm_{-0.7}^{+1.6}) \times 10^{-6}$    | —           |
| $J/\psi\rho(1700)^0, \rho^0 \rightarrow \pi^+\pi^-$      | $(2.0 \pm 1.3) \times 10^{-6}$              | —           |
| $J/\psi(1S)\omega$                                       | $(1.8 \pm_{-0.5}^{+0.7}) \times 10^{-5}$    | 1609        |

|  |  |      |
|--|--|------|
| $J/\psi(1S)K^+K^-$   | $(2.54 \pm 0.35) \times 10^{-6}$             | 1534 |
| $J/\psi(1S)a_0(980), a_0 \rightarrow K^+K^-$               | $(4.7 \pm 3.4) \times 10^{-7}$               | —    |
| $J/\psi(1S)\phi$   | $< 1.9 \times 10^{-7}$ CL=90%                | 1520 |
| $J/\psi(1S)\eta'(958)$                                     | $(7.6 \pm 2.4) \times 10^{-6}$               | 1546 |
| $J/\psi(1S)K^0\pi^+\pi^-$                                  | $(4.5 \pm 0.4) \times 10^{-4}$               | 1611 |
| $J/\psi(1S)K^0K^-\pi^+ + \text{c.c.}$                      | $< 2.1 \times 10^{-5}$ CL=90%                | 1467 |
| $J/\psi(1S)K^0K^+K^-$                                      | $(2.5 \pm 0.7) \times 10^{-5}$ S=1.8         | 1249 |
| $J/\psi(1S)K^0\rho^0$                                      | $(5.4 \pm 3.0) \times 10^{-4}$               | 1390 |
| $J/\psi(1S)K^*(892)^+\pi^-$                                | $(8 \pm 4) \times 10^{-4}$                   | 1514 |
| $J/\psi(1S)\pi^+\pi^-\pi^+\pi^-$                           | $(1.44 \pm 0.12) \times 10^{-5}$             | 1670 |
| $J/\psi(1S)f_1(1285)$                                      | $(8.4 \pm 2.1) \times 10^{-6}$               | 1385 |
| $J/\psi(1S)K^*(892)^0\pi^+\pi^-$                           | $(6.6 \pm 2.2) \times 10^{-4}$               | 1447 |
| $\eta_{c2}(1D)K_S^0, \eta_{c2} \rightarrow h_c\gamma$      | $< 3.5 \times 10^{-5}$ CL=90%                | —    |
| $\eta_{c2}(1D)\pi^-K^+, \eta_{c2} \rightarrow h_c\gamma$   | $< 1.0 \times 10^{-4}$ CL=90%                | —    |
| $\chi_{c1}(3872)^-K^+$                                     | $< 5 \times 10^{-4}$ CL=90%                  | —    |
| $\chi_{c1}(3872)^-K^+, [000]$                              | $< 4.2 \times 10^{-6}$ CL=90%                | —    |
| $\chi_{c1}(3872)^- \rightarrow J/\psi(1S)\pi^-\pi^0$       |  |      |
| $\chi_{c1}(3872)K^0$                                       | $(1.1 \pm 0.4) \times 10^{-4}$               | 1140 |
| $\chi_{c1}(3872)K^*(892)^0$                                | $(1.0 \pm 0.5) \times 10^{-4}$               | 940  |
| $\chi_{c1}(3872)K^+\pi^-$                                  | $(2.1 \pm 0.8) \times 10^{-4}$               | 1087 |
| $\chi_{c1}(3872)\gamma$                                    | $< 1.3 \times 10^{-5}$ CL=90%                | 1220 |
| $Z_c(4430)^\pm K^\mp, Z_c^\pm \rightarrow \psi(2S)\pi^\pm$ | $(6.0 \pm 3.0 \text{ } -2.4) \times 10^{-5}$ | 583  |
| $Z_c(4430)^\pm K^\mp, Z_c^\pm \rightarrow J/\psi\pi^\pm$   | $(5.4 \pm 4.0 \text{ } -1.2) \times 10^{-6}$ | 583  |
| $Z_c(3900)^\pm K^\mp, Z_c^\pm \rightarrow J/\psi\pi^\pm$   | $< 9 \times 10^{-7}$                         | —    |
| $Z_c(4200)^\pm K^\mp, X^\pm \rightarrow J/\psi\pi^\pm$     | $(2.2 \pm 1.3 \text{ } -0.8) \times 10^{-5}$ | —    |
| $J/\psi(1S)p\bar{p}$                                       | $(4.5 \pm 0.6) \times 10^{-7}$               | 862  |
| $J/\psi(1S)\gamma$   | $< 1.5 \times 10^{-6}$ CL=90%                | 1732 |
| $J/\psi(1S)\bar{D}^0$                                      | $< 1.3 \times 10^{-5}$ CL=90%                | 877  |
| $\psi(2S)\pi^0$  | $(1.17 \pm 0.19) \times 10^{-5}$             | 1348 |
| $\psi(2S)K^0$  | $(5.8 \pm 0.5) \times 10^{-4}$               | 1283 |
| $\psi(3770)K^0, \psi \rightarrow \bar{D}^0D^0$             | $< 1.23 \times 10^{-4}$ CL=90%               | 1217 |
| $\psi(3770)K^0, \psi \rightarrow D^-D^+$                   | $< 1.88 \times 10^{-4}$ CL=90%               | 1217 |
| $\psi(2S)\pi^+\pi^-$                                       | $(2.24 \pm 0.35) \times 10^{-5}$             | 1331 |
| $\psi(2S)K^+\pi^-$   | $(5.8 \pm 0.4) \times 10^{-4}$               | 1239 |
| $\psi(2S)K^*(892)^0$                                       | $(5.9 \pm 0.4) \times 10^{-4}$               | 1116 |
| $\chi_{c0}K^0$   | $(1.9 \pm 0.4) \times 10^{-4}$               | 1477 |
| $\chi_{c0}K^*(892)^0$                                      | $(1.7 \pm 0.4) \times 10^{-4}$               | 1342 |



|   |   |      |
|---|---|------|
| $\chi_{c1}\pi^0$  | $( 1.12 \pm 0.28 ) \times 10^{-5}$  | 1468 |
| $\chi_{c1}K^0$  | $( 3.95 \pm 0.27 ) \times 10^{-4}$  | 1411 |
| $\chi_{c1}\pi^-K^+$                                       | $( 4.97 \pm 0.30 ) \times 10^{-4}$  | 1371 |
| $\chi_{c1}K^*(892)^0$                                     | $( 2.38 \pm 0.19 ) \times 10^{-4}$ S=1.2  | 1265 |
| $X(4051)^-K^+, X^- \rightarrow \chi_{c1}\pi^-$            | $( 3.0 \begin{smallmatrix} + \\ - \end{smallmatrix} \begin{smallmatrix} 4.0 \\ 1.8 \end{smallmatrix} ) \times 10^{-5}$  | —    |
| $X(4248)^-K^+, X^- \rightarrow \chi_{c1}\pi^-$            | $( 4.0 \begin{smallmatrix} + \\ - \end{smallmatrix} \begin{smallmatrix} 20.0 \\ 1.0 \end{smallmatrix} ) \times 10^{-5}$ | —    |
| $\chi_{c1}\pi^+\pi^-K^0$                                  | $( 3.2 \pm 0.5 ) \times 10^{-4}$  | 1318 |
| $\chi_{c1}\pi^-\pi^0K^+$                                  | $( 3.5 \pm 0.6 ) \times 10^{-4}$  | 1321 |
| $\chi_{c2}K^0$  | $< 1.5 \times 10^{-5}$ CL=90%   | 1379 |
| $\chi_{c2}K^*(892)^0$                                     | $( 4.9 \pm 1.2 ) \times 10^{-5}$ S=1.1  | 1228 |
| $\chi_{c2}\pi^-K^+$                                       | $( 7.2 \pm 1.0 ) \times 10^{-5}$  | 1338 |
| $\chi_{c2}\pi^+\pi^-K^0$                                  | $< 1.70 \times 10^{-4}$ CL=90%  | 1282 |
| $\chi_{c2}\pi^-\pi^0K^+$                                  | $< 7.4 \times 10^{-5}$ CL=90%   | 1286 |
| $\psi(4660)K^0, \psi \rightarrow \Lambda_c^+ \Lambda_c^-$ | $< 2.3 \times 10^{-4}$ CL=90%   | —    |
| $\psi(4260)^0K^0, \psi^0 \rightarrow J/\psi\pi^+\pi^-$    | $< 1.7 \times 10^{-5}$ CL=90%   | —    |

### K or K\* modes

|  |   |      |
|--|---|------|
| $K^+\pi^-$   | $( 1.96 \pm 0.05 ) \times 10^{-5}$  | 2615 |
| $K^0\pi^0$   | $( 9.9 \pm 0.5 ) \times 10^{-6}$  | 2615 |
| $\eta'K^0$   | $( 6.6 \pm 0.4 ) \times 10^{-5}$ S=1.4  | 2528 |
| $\eta'K^*(892)^0$                                      | $( 2.8 \pm 0.6 ) \times 10^{-6}$  | 2472 |
| $\eta'K_0^*(1430)^0$                                   | $( 6.3 \pm 1.6 ) \times 10^{-6}$  | 2346 |
| $\eta'K_2^*(1430)^0$                                   | $( 1.37 \pm 0.32 ) \times 10^{-5}$  | 2346 |
| $\eta K^0$   | $( 1.23 \begin{smallmatrix} + \\ - \end{smallmatrix} \begin{smallmatrix} 0.27 \\ 0.24 \end{smallmatrix} ) \times 10^{-6}$ | 2587 |
| $\eta K^*(892)^0$                                      | $( 1.59 \pm 0.10 ) \times 10^{-5}$  | 2534 |
| $\eta K_0^*(1430)^0$                                   | $( 1.10 \pm 0.22 ) \times 10^{-5}$  | 2415 |
| $\eta K_2^*(1430)^0$                                   | $( 9.6 \pm 2.1 ) \times 10^{-6}$  | 2414 |
| $\omega K^0$   | $( 4.8 \pm 0.4 ) \times 10^{-6}$  | 2557 |
| $a_0(980)^0K^0, a_0^0 \rightarrow \eta\pi^0$           | $< 7.8 \times 10^{-6}$ CL=90%   | —    |
| $b_1^0K^0, b_1^0 \rightarrow \omega\pi^0$              | $< 7.8 \times 10^{-6}$ CL=90%   | —    |
| $a_0(980)^\pm K^\mp, a_0^\pm \rightarrow \eta\pi^\pm$  | $< 1.9 \times 10^{-6}$ CL=90%   | —    |
| $b_1^-K^+, b_1^- \rightarrow \omega\pi^-$              | $( 7.4 \pm 1.4 ) \times 10^{-6}$  | —    |
| $b_1^0K^{*0}, b_1^0 \rightarrow \omega\pi^0$           | $< 8.0 \times 10^{-6}$ CL=90%   | —    |
| $b_1^-K^{*+}, b_1^- \rightarrow \omega\pi^-$           | $< 5.0 \times 10^{-6}$ CL=90%   | —    |
| $a_0(1450)^\pm K^\mp, a_0^\pm \rightarrow \eta\pi^\pm$ | $< 3.1 \times 10^{-6}$ CL=90%   | —    |
| $K_S^0 X^0$ (Familon)                                  | $< 5.3 \times 10^{-5}$ CL=90%   | —    |
| $\omega K^*(892)^0$                                    | $( 2.0 \pm 0.5 ) \times 10^{-6}$  | 2503 |
| $\omega(K\pi)_0^{*0}$                                  | $( 1.84 \pm 0.25 ) \times 10^{-5}$  | —    |
| $\omega K_0^*(1430)^0$                                 | $( 1.60 \pm 0.34 ) \times 10^{-5}$  | 2380 |

|   |   |        |      |
|---|---|--------|------|
| $\omega K_2^*(1430)^0$  | $( 1.01 \pm 0.23 ) \times 10^{-5}$            |        | 2380 |
| $\omega K^+ \pi^-$ nonresonant                                  | $( 5.1 \pm 1.0 ) \times 10^{-6}$              |        | 2542 |
| $K^+ \pi^- \pi^0$   | $( 3.78 \pm 0.32 ) \times 10^{-5}$            |        | 2609 |
| $K^+ \rho^-$  | $( 7.0 \pm 0.9 ) \times 10^{-6}$              |        | 2559 |
| $K^+ \rho(1450)^-$  | $( 2.4 \pm 1.2 ) \times 10^{-6}$              |        | —    |
| $K^+ \rho(1700)^-$  | $( 6 \pm 7 ) \times 10^{-7}$                  |        | —    |
| $(K^+ \pi^- \pi^0)$ nonresonant                                 | $( 2.8 \pm 0.6 ) \times 10^{-6}$              |        | 2609 |
| $(K\pi)_0^{*+} \pi^-, (K\pi)_0^{*+} \rightarrow$<br>$K^+ \pi^0$ | $( 3.4 \pm 0.5 ) \times 10^{-5}$              |        | —    |
| $(K\pi)_0^{*0} \pi^0, (K\pi)_0^{*0} \rightarrow$<br>$K^+ \pi^-$ | $( 8.6 \pm 1.7 ) \times 10^{-6}$              |        | —    |
| $K_2^*(1430)^0 \pi^0$   | $< 4.0 \times 10^{-6}$                        | CL=90% | 2445 |
| $K^*(1680)^0 \pi^0$   | $< 7.5 \times 10^{-6}$                        | CL=90% | 2358 |
| $K_x^{*0} \pi^0$  | [rrr] $( 6.1 \pm 1.6 ) \times 10^{-6}$        |        | —    |
| $K^0 \pi^+ \pi^-$   | $( 4.97 \pm 0.18 ) \times 10^{-5}$            |        | 2609 |
| $K^0 \pi^+ \pi^-$ nonresonant                                   | $( 1.39 \pm_{-0.18}^{+0.26} ) \times 10^{-5}$ | S=1.6  | 2609 |
| $K^0 \rho^0$  | $( 3.4 \pm 1.1 ) \times 10^{-6}$              | S=2.3  | 2558 |
| $K^*(892)^+ \pi^-$  | $( 7.5 \pm 0.4 ) \times 10^{-6}$              |        | 2563 |
| $K_0^*(1430)^+ \pi^-$   | $( 3.3 \pm 0.7 ) \times 10^{-5}$              | S=2.0  | —    |
| $K_x^{*+} \pi^-$  | [rrr] $( 5.1 \pm 1.6 ) \times 10^{-6}$        |        | —    |
| $K^*(1410)^+ \pi^-, K^{*+} \rightarrow$<br>$K^0 \pi^+$          | $< 3.8 \times 10^{-6}$                        | CL=90% | —    |
| $(K\pi)_0^{*+} \pi^-, (K\pi)_0^{*+} \rightarrow$<br>$K^0 \pi^+$ | $( 1.62 \pm 0.13 ) \times 10^{-5}$            |        | —    |
| $f_0(980) K^0, f_0 \rightarrow \pi^+ \pi^-$                     | $( 8.1 \pm 0.8 ) \times 10^{-6}$              | S=1.3  | 2522 |
| $K^0 f_0(500)$  | $( 1.6 \pm_{-1.6}^{+2.5} ) \times 10^{-7}$    |        | —    |
| $K^0 f_0(1500)$   | $( 1.3 \pm 0.8 ) \times 10^{-6}$              |        | 2397 |
| $f_2(1270) K^0$   | $( 2.7 \pm_{-1.2}^{+1.3} ) \times 10^{-6}$    |        | 2459 |
| $f_x(1300) K^0, f_x \rightarrow \pi^+ \pi^-$                    | $( 1.8 \pm 0.7 ) \times 10^{-6}$              |        | —    |
| $K^*(892)^0 \pi^0$  | $( 3.3 \pm 0.6 ) \times 10^{-6}$              |        | 2563 |
| $K_2^*(1430)^+ \pi^-$   | $( 3.65 \pm 0.34 ) \times 10^{-6}$            |        | 2445 |
| $K^*(1680)^+ \pi^-$   | $( 1.41 \pm 0.10 ) \times 10^{-5}$            |        | 2358 |
| $K^+ \pi^- \pi^+ \pi^-$   | [sss] $< 2.3 \times 10^{-4}$                  | CL=90% | 2600 |
| $\rho^0 K^+ \pi^-$  | $( 2.8 \pm 0.7 ) \times 10^{-6}$              |        | 2543 |
| $f_0(980) K^+ \pi^-, f_0 \rightarrow \pi \pi$                   | $( 1.4 \pm_{-0.6}^{+0.5} ) \times 10^{-6}$    |        | 2506 |
| $K^+ \pi^- \pi^+ \pi^-$ nonresonant                             | $< 2.1 \times 10^{-6}$                        | CL=90% | 2600 |
| $K^*(892)^0 \pi^+ \pi^-$  | $( 5.5 \pm 0.5 ) \times 10^{-5}$              |        | 2557 |
| $K^*(892)^0 \rho^0$   | $( 3.9 \pm 1.3 ) \times 10^{-6}$              | S=1.9  | 2504 |
| $K^*(892)^0 f_0(980), f_0 \rightarrow \pi \pi$                  | $( 3.9 \pm_{-1.8}^{+2.1} ) \times 10^{-6}$    | S=3.9  | 2466 |
| $K_1(1270)^+ \pi^-$   | $< 3.0 \times 10^{-5}$                        | CL=90% | 2489 |
| $K_1(1400)^+ \pi^-$   | $< 2.7 \times 10^{-5}$                        | CL=90% | 2451 |

|  |       |   |             |
|--|-------|---|-------------|
| $a_1(1260)^- K^+$                                  | [sss] | $(1.6 \pm 0.4) \times 10^{-5}$  | 2471        |
| $K^*(892)^+ \rho^-$                                |       | $(1.03 \pm 0.26) \times 10^{-5}$  | 2504        |
| $K_0^*(1430)^+ \rho^-$                             |       | $(2.8 \pm 1.2) \times 10^{-5}$  | —           |
| $K_1(1400)^0 \rho^0$                               |       | $< 3.0 \times 10^{-3}$  | CL=90% 2388 |
| $K_0^*(1430)^0 \rho^0$                             |       | $(2.7 \pm 0.6) \times 10^{-5}$  | 2381        |
| $K_0^*(1430)^0 f_0(980), f_0 \rightarrow \pi\pi$   |       | $(2.7 \pm 0.9) \times 10^{-6}$  | —           |
| $K_2^*(1430)^0 f_0(980), f_0 \rightarrow \pi\pi$   |       | $(8.6 \pm 2.0) \times 10^{-6}$  | —           |
| $K^+ K^-$  |       | $(7.8 \pm 1.5) \times 10^{-8}$  | 2593        |
| $K^0 \bar{K}^0$                                    |       | $(1.21 \pm 0.16) \times 10^{-6}$  | 2593        |
| $K^0 K^- \pi^+$                                    |       | $(6.7 \pm 0.5) \times 10^{-6}$  | 2578        |
| $K^*(892)^\pm K^\mp$                               |       | $< 4 \times 10^{-7}$  | CL=90% 2540 |
| $\bar{K}^{*0} K^0 + K^{*0} \bar{K}^0$              |       | $< 9.6 \times 10^{-7}$  | CL=90% —    |
| $K^+ K^- \pi^0$                                    |       | $(2.2 \pm 0.6) \times 10^{-6}$  | 2579        |
| $K_S^0 K_S^0 \pi^0$                                |       | $< 9 \times 10^{-7}$  | CL=90% 2578 |
| $K_S^0 K_S^0 \eta$                                 |       | $< 1.0 \times 10^{-6}$  | CL=90% 2515 |
| $K_S^0 K_S^0 \eta'$                                |       | $< 2.0 \times 10^{-6}$  | CL=90% 2453 |
| $K^0 K^+ K^-$                                      |       | $(2.68 \pm 0.11) \times 10^{-5}$  | 2522        |
| $K^0 \phi$   |       | $(7.3 \pm 0.7) \times 10^{-6}$  | 2516        |
| $f_0(980) K^0, f_0 \rightarrow K^+ K^-$            |       | $(7.0 \begin{smallmatrix} + 3.5 \\ - 3.0 \end{smallmatrix}) \times 10^{-6}$ | —           |
| $f_0(1500) K^0$                                    |       | $(1.3 \begin{smallmatrix} + 0.7 \\ - 0.5 \end{smallmatrix}) \times 10^{-5}$ | 2397        |
| $f_2'(1525)^0 K^0$                                 |       | $(3 \begin{smallmatrix} + 5 \\ - 4 \end{smallmatrix}) \times 10^{-7}$       | —           |
| $f_0(1710) K^0, f_0 \rightarrow K^+ K^-$           |       | $(4.4 \pm 0.9) \times 10^{-6}$  | —           |
| $K^0 K^+ K^-$ nonresonant                          |       | $(3.3 \pm 1.0) \times 10^{-5}$  | 2522        |
| $K_S^0 K_S^0 K_S^0$                                |       | $(6.0 \pm 0.5) \times 10^{-6}$  | S=1.1 2521  |
| $f_0(980) K^0, f_0 \rightarrow K_S^0 K_S^0$        |       | $(2.7 \pm 1.8) \times 10^{-6}$  | —           |
| $f_0(1710) K^0, f_0 \rightarrow K_S^0 K_S^0$       |       | $(5.0 \begin{smallmatrix} + 5.0 \\ - 2.6 \end{smallmatrix}) \times 10^{-7}$ | —           |
| $f_2(2010) K^0, f_2 \rightarrow K_S^0 K_S^0$       |       | $(5 \pm 6) \times 10^{-7}$  | —           |
| $K_S^0 K_S^0 K_S^0$ nonresonant                    |       | $(1.33 \pm 0.31) \times 10^{-5}$  | 2521        |
| $K_S^0 K_S^0 K_L^0$                                |       | $< 1.6 \times 10^{-5}$  | CL=90% 2521 |
| $K^*(892)^0 K^+ K^-$                               |       | $(2.75 \pm 0.26) \times 10^{-5}$  | 2467        |
| $K^*(892)^0 \phi$                                  |       | $(1.00 \pm 0.05) \times 10^{-5}$  | 2460        |
| $K^+ K^- \pi^+ \pi^-$ nonresonant                  |       | $< 7.17 \times 10^{-5}$   | CL=90% 2559 |
| $K^*(892)^0 K^- \pi^+$                             |       | $(4.5 \pm 1.3) \times 10^{-6}$  | 2524        |
| $K^*(892)^0 \bar{K}^*(892)^0$                      |       | $(8.3 \pm 2.4) \times 10^{-7}$  | S=1.5 2485  |
| $K^+ K^+ \pi^- \pi^-$ nonresonant                  |       | $< 6.0 \times 10^{-6}$  | CL=90% 2559 |
| $K^*(892)^0 K^+ \pi^-$                             |       | $< 2.2 \times 10^{-6}$  | CL=90% 2524 |
| $K^*(892)^0 K^*(892)^0$                            |       | $< 2 \times 10^{-7}$  | CL=90% 2485 |
| $K^*(892)^+ K^*(892)^-$                            |       | $< 2.0 \times 10^{-6}$  | CL=90% 2485 |
| $K_1(1400)^0 \phi$                                 |       | $< 5.0 \times 10^{-3}$  | CL=90% 2339 |
| $\phi(K\pi)_0^{*0}$                                |       | $(4.3 \pm 0.4) \times 10^{-6}$  | —           |
| $\phi(K\pi)_0^{*0} (1.60 < m_{K\pi} < 2.15)$ [ttt] |       | $< 1.7 \times 10^{-6}$  | CL=90% —    |

|  |                 |                  |        |      |
|--|-----------------|------------------|--------|------|
| $K_0^*(1430)^0 K^- \pi^+$                      | < 3.18          | $\times 10^{-5}$ | CL=90% | 2403 |
| $K_0^*(1430)^0 \bar{K}^*(892)^0$               | < 3.3           | $\times 10^{-6}$ | CL=90% | 2360 |
| $K_0^*(1430)^0 \bar{K}_0^*(1430)^0$            | < 8.4           | $\times 10^{-6}$ | CL=90% | 2222 |
| $K_0^*(1430)^0 \phi$                           | ( 3.9 ± 0.8 )   | $\times 10^{-6}$ |        | 2333 |
| $K_0^*(1430)^0 K^*(892)^0$                     | < 1.7           | $\times 10^{-6}$ | CL=90% | 2360 |
| $K_0^*(1430)^0 K_0^*(1430)^0$                  | < 4.7           | $\times 10^{-6}$ | CL=90% | 2222 |
| $K^*(1680)^0 \phi$                             | < 3.5           | $\times 10^{-6}$ | CL=90% | 2238 |
| $K^*(1780)^0 \phi$                             | < 2.7           | $\times 10^{-6}$ | CL=90% | —    |
| $K^*(2045)^0 \phi$                             | < 1.53          | $\times 10^{-5}$ | CL=90% | —    |
| $K_2^*(1430)^0 \rho^0$                         | < 1.1           | $\times 10^{-3}$ | CL=90% | 2381 |
| $K_2^*(1430)^0 \phi$                           | ( 6.8 ± 0.9 )   | $\times 10^{-6}$ | S=1.2  | 2332 |
| $K_0^0 \phi \phi$                              | ( 4.5 ± 0.9 )   | $\times 10^{-6}$ |        | 2305 |
| $\eta' \eta' K^0$                              | < 3.1           | $\times 10^{-5}$ | CL=90% | 2337 |
| $\eta K^0 \gamma$                              | ( 7.6 ± 1.8 )   | $\times 10^{-6}$ |        | 2587 |
| $\eta' K^0 \gamma$                             | < 6.4           | $\times 10^{-6}$ | CL=90% | 2528 |
| $K^0 \phi \gamma$                              | ( 2.7 ± 0.7 )   | $\times 10^{-6}$ |        | 2516 |
| $K^+ \pi^- \gamma$                             | ( 4.6 ± 1.4 )   | $\times 10^{-6}$ |        | 2615 |
| $K^*(892)^0 \gamma$                            | ( 4.18 ± 0.25 ) | $\times 10^{-5}$ | S=2.1  | 2565 |
| $K^*(1410) \gamma$                             | < 1.3           | $\times 10^{-4}$ | CL=90% | 2451 |
| $K^+ \pi^- \gamma$ nonresonant                 | < 2.6           | $\times 10^{-6}$ | CL=90% | 2615 |
| $K^*(892)^0 X(214), X \rightarrow \mu^+ \mu^-$ | [uuu] < 2.26    | $\times 10^{-8}$ | CL=90% | —    |
| $K^0 \pi^+ \pi^- \gamma$                       | ( 1.99 ± 0.18 ) | $\times 10^{-5}$ |        | 2609 |
| $K^+ \pi^- \pi^0 \gamma$                       | ( 4.1 ± 0.4 )   | $\times 10^{-5}$ |        | 2609 |
| $K_1(1270)^0 \gamma$                           | < 5.8           | $\times 10^{-5}$ | CL=90% | 2491 |
| $K_1(1400)^0 \gamma$                           | < 1.2           | $\times 10^{-5}$ | CL=90% | 2454 |
| $K_2^*(1430)^0 \gamma$                         | ( 1.24 ± 0.24 ) | $\times 10^{-5}$ |        | 2447 |
| $K^*(1680)^0 \gamma$                           | < 2.0           | $\times 10^{-3}$ | CL=90% | 2360 |
| $K_3^*(1780)^0 \gamma$                         | < 8.3           | $\times 10^{-5}$ | CL=90% | 2340 |
| $K_4^*(2045)^0 \gamma$                         | < 4.3           | $\times 10^{-3}$ | CL=90% | 2243 |

### Light unflavored meson modes

|  |  |                  |        |      |
|--|--|------------------|--------|------|
| $\rho^0 \gamma$                            | ( 8.6 ± 1.5 )  | $\times 10^{-7}$ |        | 2583 |
| $\rho^0 X(214), X \rightarrow \mu^+ \mu^-$ | [uuu] < 1.73   | $\times 10^{-8}$ | CL=90% | —    |
| $\omega \gamma$                            | ( 4.4 $\begin{smallmatrix} + \\ - \end{smallmatrix}$ 1.8 / 1.6 ) | $\times 10^{-7}$ |        | 2582 |
| $\phi \gamma$                              | < 1.0  | $\times 10^{-7}$ | CL=90% | 2541 |
| $\pi^+ \pi^-$                              | ( 5.12 ± 0.19 )  | $\times 10^{-6}$ |        | 2636 |
| $\pi^0 \pi^0$                              | ( 1.59 ± 0.26 )  | $\times 10^{-6}$ | S=1.4  | 2636 |
| $\eta \pi^0$                               | ( 4.1 ± 1.7 )  | $\times 10^{-7}$ |        | 2610 |
| $\eta \eta$                                | < 1.0  | $\times 10^{-6}$ | CL=90% | 2582 |
| $\eta' \pi^0$                              | ( 1.2 ± 0.6 )  | $\times 10^{-6}$ | S=1.7  | 2551 |
| $\eta' \eta'$                              | < 1.7  | $\times 10^{-6}$ | CL=90% | 2460 |
| $\eta' \eta$                               | < 1.2  | $\times 10^{-6}$ | CL=90% | 2523 |

|   |                          |                    |        |      |
|---|--------------------------|--------------------|--------|------|
| $\eta' \rho^0$  | $< 1.3$                  | $\times 10^{-6}$   | CL=90% | 2492 |
| $\eta' f_0(980), f_0 \rightarrow \pi^+ \pi^-$                                 | $< 9$                    | $\times 10^{-7}$   | CL=90% | 2454 |
| $\eta \rho^0$   | $< 1.5$                  | $\times 10^{-6}$   | CL=90% | 2553 |
| $\eta f_0(980), f_0 \rightarrow \pi^+ \pi^-$                                  | $< 4$                    | $\times 10^{-7}$   | CL=90% | 2516 |
| $\omega \eta$   | $( 9.4 \pm 4.0$          | $) \times 10^{-7}$ |        | 2552 |
| $\omega \eta'$  | $( 1.0 \pm 0.5$          | $) \times 10^{-6}$ |        | 2491 |
| $\omega \rho^0$   | $< 1.6$                  | $\times 10^{-6}$   | CL=90% | 2522 |
| $\omega f_0(980), f_0 \rightarrow \pi^+ \pi^-$                                | $< 1.5$                  | $\times 10^{-6}$   | CL=90% | 2485 |
| $\omega \omega$   | $( 1.2 \pm 0.4 )$        | $\times 10^{-6}$   |        | 2521 |
| $\phi \pi^0$  | $< 1.5$                  | $\times 10^{-7}$   | CL=90% | 2540 |
| $\phi \eta$   | $< 5$                    | $\times 10^{-7}$   | CL=90% | 2511 |
| $\phi \eta'$  | $< 5$                    | $\times 10^{-7}$   | CL=90% | 2448 |
| $\phi \pi^+ \pi^-$  | $( 1.8 \pm 0.5 )$        | $\times 10^{-7}$   |        | 2533 |
| $\phi \rho^0$   | $< 3.3$                  | $\times 10^{-7}$   | CL=90% | 2480 |
| $\phi f_0(980), f_0 \rightarrow \pi^+ \pi^-$                                  | $< 3.8$                  | $\times 10^{-7}$   | CL=90% | 2441 |
| $\phi \omega$   | $< 7$                    | $\times 10^{-7}$   | CL=90% | 2479 |
| $\phi \phi$   | $< 2.7$                  | $\times 10^{-8}$   | CL=90% | 2435 |
| $a_0(980)^\pm \pi^\mp, a_0^\pm \rightarrow \eta \pi^\pm$                      | $< 3.1$                  | $\times 10^{-6}$   | CL=90% | —    |
| $a_0(1450)^\pm \pi^\mp, a_0^\pm \rightarrow \eta \pi^\pm$                     | $< 2.3$                  | $\times 10^{-6}$   | CL=90% | —    |
| $\pi^+ \pi^- \pi^0$   | $< 7.2$                  | $\times 10^{-4}$   | CL=90% | 2631 |
| $\rho^0 \pi^0$  | $( 2.0 \pm 0.5 )$        | $\times 10^{-6}$   |        | 2581 |
| $\rho^\mp \pi^\pm$  | [aa] $( 2.30 \pm 0.23 )$ | $\times 10^{-5}$   |        | 2581 |
| $\pi^+ \pi^- \pi^+ \pi^-$   | $< 1.12$                 | $\times 10^{-5}$   | CL=90% | 2621 |
| $\rho^0 \pi^+ \pi^-$  | $< 8.8$                  | $\times 10^{-6}$   | CL=90% | 2575 |
| $\rho^0 \rho^0$   | $( 9.6 \pm 1.5 )$        | $\times 10^{-7}$   |        | 2523 |
| $f_0(980) \pi^+ \pi^-, f_0 \rightarrow \pi^+ \pi^-$                           | $< 3.0$                  | $\times 10^{-6}$   | CL=90% | —    |
| $\rho^0 f_0(980), f_0 \rightarrow \pi^+ \pi^-$                                | $( 7.8 \pm 2.5 )$        | $\times 10^{-7}$   |        | 2486 |
| $f_0(980) f_0(980), f_0 \rightarrow \pi^+ \pi^-, f_0 \rightarrow \pi^+ \pi^-$ | $< 1.9$                  | $\times 10^{-7}$   | CL=90% | 2447 |
| $f_0(980) f_0(980), f_0 \rightarrow \pi^+ \pi^-, f_0 \rightarrow K^+ K^-$     | $< 2.3$                  | $\times 10^{-7}$   | CL=90% | 2447 |
| $a_1(1260)^\mp \pi^\pm$   | [aa] $( 2.6 \pm 0.5 )$   | $\times 10^{-5}$   | S=1.9  | 2494 |
| $a_2(1320)^\mp \pi^\pm$   | [aa] $< 6.3$             | $\times 10^{-6}$   | CL=90% | 2473 |
| $\pi^+ \pi^- \pi^0 \pi^0$   | $< 3.1$                  | $\times 10^{-3}$   | CL=90% | 2622 |
| $\rho^+ \rho^-$   | $( 2.77 \pm 0.19 )$      | $\times 10^{-5}$   |        | 2523 |
| $a_1(1260)^0 \pi^0$   | $< 1.1$                  | $\times 10^{-3}$   | CL=90% | 2495 |
| $\omega \pi^0$  | $< 5$                    | $\times 10^{-7}$   | CL=90% | 2580 |
| $\pi^+ \pi^+ \pi^- \pi^- \pi^0$   | $< 9.0$                  | $\times 10^{-3}$   | CL=90% | 2609 |
| $a_1(1260)^+ \rho^-$  | $< 6.1$                  | $\times 10^{-5}$   | CL=90% | 2433 |
| $a_1(1260)^0 \rho^0$  | $< 2.4$                  | $\times 10^{-3}$   | CL=90% | 2433 |
| $b_1^\mp \pi^\pm, b_1^\mp \rightarrow \omega \pi^\mp$                         | $( 1.09 \pm 0.15 )$      | $\times 10^{-5}$   |        | —    |
| $b_1^0 \pi^0, b_1^0 \rightarrow \omega \pi^0$                                 | $< 1.9$                  | $\times 10^{-6}$   | CL=90% | —    |

|  |                 |                  |        |      |
|--|-----------------|------------------|--------|------|
| $b_1^- \rho^+, b_1^- \rightarrow \omega \pi^-$   | < 1.4           | $\times 10^{-6}$ | CL=90% | —    |
| $b_1^0 \rho^0, b_1^0 \rightarrow \omega \pi^0$   | < 3.4           | $\times 10^{-6}$ | CL=90% | —    |
| $\pi^+ \pi^+ \pi^+ \pi^- \pi^- \pi^-$  | < 3.0           | $\times 10^{-3}$ | CL=90% | 2592 |
| $a_1(1260)^+ a_1(1260)^-, a_1^+ \rightarrow$<br>$2\pi^+ \pi^-, a_1^- \rightarrow 2\pi^- \pi^+$ | ( 1.18 ± 0.31 ) | $\times 10^{-5}$ |        | 2336 |
| $\pi^+ \pi^+ \pi^+ \pi^- \pi^- \pi^- \pi^0$  | < 1.1           | %                | CL=90% | 2572 |

### Baryon modes

|   |  |                  |        |      |
|---|--|------------------|--------|------|
| $p\bar{p}$  | ( 1.25 ± 0.32 )                                | $\times 10^{-8}$ |        | 2467 |
| $p\bar{p}\pi^+\pi^-$  | ( 2.87 ± 0.19 )                                | $\times 10^{-6}$ |        | 2406 |
| $p\bar{p}K^+\pi^-$  | ( 6.3 ± 0.5 )                                  | $\times 10^{-6}$ |        | 2306 |
| $p\bar{p}K^0$   | ( 2.66 ± 0.32 )                                | $\times 10^{-6}$ |        | 2347 |
| $\Theta(1540)^+ \bar{p}, \Theta^+ \rightarrow pK_S^0$ [vvv] | < 5  | $\times 10^{-8}$ | CL=90% | 2318 |
| $f_J(2220)K^0, f_J \rightarrow p\bar{p}$                    | < 4.5  | $\times 10^{-7}$ | CL=90% | 2135 |
| $p\bar{p}K^*(892)^0$  | ( 1.24 <sup>+</sup> <sub>-</sub> 0.28 / 0.25 ) | $\times 10^{-6}$ |        | 2216 |
| $f_J(2220)K_0^*, f_J \rightarrow p\bar{p}$                  | < 1.5  | $\times 10^{-7}$ | CL=90% | —    |
| $p\bar{p}K^+K^-$  | ( 1.21 ± 0.32 )                                | $\times 10^{-7}$ |        | 2179 |
| $p\bar{p}\pi^0$   | ( 5.0 ± 1.9 )                                  | $\times 10^{-7}$ |        | 2440 |
| $p\rho\bar{p}\bar{p}$                                       | < 2.0  | $\times 10^{-7}$ | CL=90% | 1735 |
| $p\bar{\Lambda}\pi^-$                                       | ( 3.14 ± 0.29 )                                | $\times 10^{-6}$ |        | 2401 |
| $p\bar{\Lambda}\pi^-\gamma$                                 | < 6.5  | $\times 10^{-7}$ | CL=90% | 2401 |
| $p\bar{\Sigma}^-(1385)^-$                                   | < 2.6  | $\times 10^{-7}$ | CL=90% | 2363 |
| $\Delta(1232)^+ \bar{p} + \Delta(1232)^- p$                 | < 1.6  | $\times 10^{-6}$ |        | —    |
| $\Delta^0 \bar{\Lambda}$                                    | < 9.3  | $\times 10^{-7}$ | CL=90% | 2364 |
| $p\bar{\Lambda}K^-$   | < 8.2  | $\times 10^{-7}$ | CL=90% | 2308 |
| $p\bar{\Lambda}D^-$   | ( 2.5 ± 0.4 )                                  | $\times 10^{-5}$ |        | 1765 |
| $p\bar{\Lambda}D^{*-}$                                      | ( 3.4 ± 0.8 )                                  | $\times 10^{-5}$ |        | 1685 |
| $p\bar{\Sigma}^0 \pi^-$                                     | < 3.8  | $\times 10^{-6}$ | CL=90% | 2383 |
| $\bar{\Lambda}\Lambda$                                      | < 3.2  | $\times 10^{-7}$ | CL=90% | 2392 |
| $\bar{\Lambda}\Lambda K^0$                                  | ( 4.8 <sup>+</sup> <sub>-</sub> 1.0 / 0.9 )    | $\times 10^{-6}$ |        | 2250 |
| $\bar{\Lambda}\Lambda K^{*0}$                               | ( 2.5 <sup>+</sup> <sub>-</sub> 0.9 / 0.8 )    | $\times 10^{-6}$ |        | 2098 |
| $\bar{\Lambda}\Lambda D^0$                                  | ( 1.00 <sup>+</sup> <sub>-</sub> 0.30 / 0.26 ) | $\times 10^{-5}$ |        | 1662 |
| $D^0 \Sigma^0 \bar{\Lambda} + c.c.$                         | < 3.1  | $\times 10^{-5}$ | CL=90% | 1611 |
| $\Delta^0 \bar{\Delta}^0$                                   | < 1.5  | $\times 10^{-3}$ | CL=90% | 2335 |
| $\Delta^{++} \bar{\Delta}^{--}$                             | < 1.1  | $\times 10^{-4}$ | CL=90% | 2335 |
| $\bar{D}^0 p\bar{p}$  | ( 1.04 ± 0.07 )                                | $\times 10^{-4}$ |        | 1863 |
| $D_s^- \bar{\Lambda} p$                                     | ( 2.8 ± 0.9 )                                  | $\times 10^{-5}$ |        | 1710 |
| $\bar{D}^*(2007)^0 p\bar{p}$                                | ( 9.9 ± 1.1 )                                  | $\times 10^{-5}$ |        | 1788 |
| $D^*(2010)^- p\bar{n}$                                      | ( 1.4 ± 0.4 )                                  | $\times 10^{-3}$ |        | 1785 |
| $D^- p\bar{p}\pi^+$   | ( 3.32 ± 0.31 )                                | $\times 10^{-4}$ |        | 1786 |
| $D^*(2010)^- p\bar{p}\pi^+$                                 | ( 4.7 ± 0.5 )                                  | $\times 10^{-4}$ | S=1.2  | 1708 |

|  |  |      |
|--|--|------|
| $\bar{D}^0 p \bar{p} \pi^+ \pi^-$  | $( 3.0 \pm 0.5 ) \times 10^{-4}$         | 1708 |
| $\bar{D}^{*0} p \bar{p} \pi^+ \pi^-$   | $( 1.9 \pm 0.5 ) \times 10^{-4}$         | 1623 |
| $\Theta_c \bar{p} \pi^+, \Theta_c \rightarrow D^- p$                                       | $< 9 \times 10^{-6}$ CL=90%              | –    |
| $\Theta_c \bar{p} \pi^+, \Theta_c \rightarrow D^{*-} p$                                    | $< 1.4 \times 10^{-5}$ CL=90%            | –    |
| $\bar{\Sigma}_c^{--} \Delta^{++}$  | $< 8 \times 10^{-4}$ CL=90%              | 1839 |
| $\bar{\Lambda}_c^- p \pi^+ \pi^-$  | $( 1.02 \pm 0.14 ) \times 10^{-3}$ S=1.3 | 1934 |
| $\bar{\Lambda}_c^- p$  | $( 1.54 \pm 0.18 ) \times 10^{-5}$       | 2021 |
| $\bar{\Lambda}_c^- p \pi^0$  | $( 1.55 \pm 0.19 ) \times 10^{-4}$       | 1982 |
| $\Sigma_c(2455)^- p$   | $< 2.4 \times 10^{-5}$                   | –    |
| $\bar{\Lambda}_c^- p \pi^+ \pi^- \pi^0$  | $< 5.07 \times 10^{-3}$ CL=90%           | 1883 |
| $\bar{\Lambda}_c^- p \pi^+ \pi^- \pi^+ \pi^-$  | $< 2.74 \times 10^{-3}$ CL=90%           | 1821 |
| $\bar{\Lambda}_c^- p \pi^+ \pi^-$ (nonresonant)  | $( 5.5 \pm 1.0 ) \times 10^{-4}$ S=1.3   | 1934 |
| $\bar{\Sigma}_c(2520)^{--} p \pi^+$  | $( 1.02 \pm 0.18 ) \times 10^{-4}$       | 1860 |
| $\bar{\Sigma}_c(2520)^0 p \pi^-$   | $< 3.1 \times 10^{-5}$ CL=90%            | 1860 |
| $\bar{\Sigma}_c(2455)^0 p \pi^-$   | $( 1.08 \pm 0.16 ) \times 10^{-4}$       | 1895 |
| $\bar{\Sigma}_c(2455)^0 N^0, N^0 \rightarrow p \pi^-$                                      | $( 6.4 \pm 1.7 ) \times 10^{-5}$         | –    |
| $\bar{\Sigma}_c(2455)^{--} p \pi^+$  | $( 1.83 \pm 0.24 ) \times 10^{-4}$       | 1895 |
| $\Lambda_c^- p K^+ \pi^-$  | $( 3.4 \pm 0.7 ) \times 10^{-5}$         | 1786 |
| $\bar{\Sigma}_c(2455)^{--} p K^+, \bar{\Sigma}_c^{--} \rightarrow \bar{\Lambda}_c^- \pi^-$ | $( 8.8 \pm 2.5 ) \times 10^{-6}$         | 1754 |
| $\Lambda_c^- p K^*(892)^0$   | $< 2.42 \times 10^{-5}$ CL=90%           | 1647 |
| $\Lambda_c^- p K^+ K^-$  | $( 2.0 \pm 0.4 ) \times 10^{-5}$         | 1588 |
| $\Lambda_c^- p \phi$   | $< 1.0 \times 10^{-5}$ CL=90%            | 1567 |
| $\Lambda_c^- p \bar{p} p$  | $< 2.8 \times 10^{-6}$                   | 677  |
| $\bar{\Lambda}_c^- \Lambda K^+$  | $( 4.8 \pm 1.1 ) \times 10^{-5}$         | 1767 |
| $\bar{\Lambda}_c^- \Lambda_c^+$  | $< 1.6 \times 10^{-5}$ CL=95%            | 1319 |
| $\bar{\Lambda}_c(2593)^- / \bar{\Lambda}_c(2625)^- p$                                      | $< 1.1 \times 10^{-4}$ CL=90%            | –    |
| $\bar{\Xi}_c^- \Lambda_c^+$  | $( 1.2 \pm 0.8 ) \times 10^{-3}$         | 1147 |
| $\bar{\Xi}_c^- \Lambda_c^+, \bar{\Xi}_c^- \rightarrow \bar{\Xi}^+ \pi^- \pi^-$             | $( 2.4 \pm 1.1 ) \times 10^{-5}$ S=1.8   | 1147 |
| $\bar{\Xi}_c^- \Lambda_c^+, \bar{\Xi}_c^- \rightarrow \bar{p} K^+ \pi^-$                   | $( 5.3 \pm 1.7 ) \times 10^{-6}$         | –    |
| $\Lambda_c^+ \Lambda_c^- K^0$  | $( 4.0 \pm 0.9 ) \times 10^{-4}$         | 732  |
| $\bar{\Xi}_c(2930)^- \Lambda_c^+, \bar{\Xi}_c^- \rightarrow \Lambda_c^- K^0$               | $( 2.4 \pm 0.6 ) \times 10^{-4}$         | –    |

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

|                      |    |  |      |
|----------------------|----|--|------|
| $\gamma \gamma$      | B1 | $< 3.2 \times 10^{-7}$ CL=90%  | 2640 |
| $e^+ e^-$            | B1 | $< 2.5 \times 10^{-9}$ CL=90%  | 2640 |
| $e^+ e^- \gamma$     | B1 | $< 1.2 \times 10^{-7}$ CL=90%  | 2640 |
| $\mu^+ \mu^-$        | B1 | $( 5 \begin{smallmatrix} +17 \\ -15 \end{smallmatrix} ) \times 10^{-11}$ S=1.8 | 2638 |
| $\mu^+ \mu^- \gamma$ | B1 | $< 1.6 \times 10^{-7}$ CL=90%  | 2638 |

|   |            |  |                   |        |      |
|---|------------|--|-------------------|--------|------|
| $\mu^+ \mu^- \mu^+ \mu^-$                                       | <i>B1</i>  | < 6.9  | $\times 10^{-10}$ | CL=95% | 2629 |
| $SP, S \rightarrow \mu^+ \mu^-,$<br>$P \rightarrow \mu^+ \mu^-$ | <i>B1</i>  | [xxx] < 6.0  | $\times 10^{-10}$ | CL=95% | —    |
| $\tau^+ \tau^-$   | <i>B1</i>  | < 2.1  | $\times 10^{-3}$  | CL=95% | 1952 |
| $\pi^0 \ell^+ \ell^-$   | <i>B1</i>  | < 5.3  | $\times 10^{-8}$  | CL=90% | 2638 |
| $\pi^0 e^+ e^-$   | <i>B1</i>  | < 8.4  | $\times 10^{-8}$  | CL=90% | 2638 |
| $\pi^0 \mu^+ \mu^-$   | <i>B1</i>  | < 6.9  | $\times 10^{-8}$  | CL=90% | 2634 |
| $\eta \ell^+ \ell^-$  | <i>B1</i>  | < 6.4  | $\times 10^{-8}$  | CL=90% | 2611 |
| $\eta e^+ e^-$  | <i>B1</i>  | < 1.08   | $\times 10^{-7}$  | CL=90% | 2611 |
| $\eta \mu^+ \mu^-$  | <i>B1</i>  | < 1.12   | $\times 10^{-7}$  | CL=90% | 2607 |
| $\pi^0 \nu \bar{\nu}$   | <i>B1</i>  | < 9  | $\times 10^{-6}$  | CL=90% | 2638 |
| $K^0 \ell^+ \ell^-$   | <i>B1</i>  | [iii] ( 3.3 ± 0.6 )  | $\times 10^{-7}$  |        | 2616 |
| $K^0 e^+ e^-$   | <i>B1</i>  | ( 2.5 $\begin{smallmatrix} + \\ - \end{smallmatrix}$ 1.1 / 0.9 )       | $\times 10^{-7}$  | S=1.3  | 2616 |
| $K^0 \mu^+ \mu^-$   | <i>B1</i>  | ( 3.39 ± 0.35 )  | $\times 10^{-7}$  | S=1.1  | 2612 |
| $K^0 \nu \bar{\nu}$   | <i>B1</i>  | < 2.6  | $\times 10^{-5}$  | CL=90% | 2616 |
| $\rho^0 \nu \bar{\nu}$  | <i>B1</i>  | < 4.0  | $\times 10^{-5}$  | CL=90% | 2583 |
| $K^*(892)^0 \ell^+ \ell^-$                                      | <i>B1</i>  | [iii] ( 9.9 $\begin{smallmatrix} + \\ - \end{smallmatrix}$ 1.2 / 1.1 ) | $\times 10^{-7}$  |        | 2565 |
| $K^*(892)^0 e^+ e^-$  | <i>B1</i>  | ( 1.03 $\begin{smallmatrix} + \\ - \end{smallmatrix}$ 0.19 / 0.17 )    | $\times 10^{-6}$  |        | 2565 |
| $K^*(892)^0 \mu^+ \mu^-$  | <i>B1</i>  | ( 9.4 ± 0.5 )  | $\times 10^{-7}$  |        | 2560 |
| $\pi^+ \pi^- \mu^+ \mu^-$                                       | <i>B1</i>  | ( 2.1 ± 0.5 )  | $\times 10^{-8}$  |        | 2626 |
| $K^*(892)^0 \nu \bar{\nu}$                                      | <i>B1</i>  | < 1.8  | $\times 10^{-5}$  | CL=90% | 2565 |
| invisible   | <i>B1</i>  | < 2.4  | $\times 10^{-5}$  | CL=90% | —    |
| $\nu \bar{\nu} \gamma$  | <i>B1</i>  | < 1.6  | $\times 10^{-5}$  | CL=90% | 2640 |
| $\phi \nu \bar{\nu}$  | <i>B1</i>  | < 1.27   | $\times 10^{-4}$  | CL=90% | 2541 |
| $e^\pm \mu^\mp$   | <i>LF</i>  | [aa] < 1.0   | $\times 10^{-9}$  | CL=90% | 2639 |
| $\pi^0 e^\pm \mu^\mp$   | <i>LF</i>  | < 1.4  | $\times 10^{-7}$  | CL=90% | 2637 |
| $K^0 e^\pm \mu^\mp$   | <i>LF</i>  | < 3.8  | $\times 10^{-8}$  | CL=90% | 2615 |
| $K^*(892)^0 e^+ \mu^-$  | <i>LF</i>  | < 1.6  | $\times 10^{-7}$  | CL=90% | 2563 |
| $K^*(892)^0 e^- \mu^+$  | <i>LF</i>  | < 1.2  | $\times 10^{-7}$  | CL=90% | 2563 |
| $K^*(892)^0 e^\pm \mu^\mp$                                      | <i>LF</i>  | < 1.8  | $\times 10^{-7}$  | CL=90% | 2563 |
| $e^\pm \tau^\mp$  | <i>LF</i>  | [aa] < 2.8   | $\times 10^{-5}$  | CL=90% | 2341 |
| $\mu^\pm \tau^\mp$  | <i>LF</i>  | [aa] < 1.4   | $\times 10^{-5}$  | CL=95% | 2339 |
| $\Lambda_c^+ \mu^-$   | <i>L,B</i> | < 1.4  | $\times 10^{-6}$  | CL=90% | 2143 |
| $\Lambda_c^+ e^-$   | <i>L,B</i> | < 4  | $\times 10^{-6}$  | CL=90% | 2145 |

## B<sup>±</sup>/B<sup>0</sup> ADMIXTURE

### CP violation

$$A_{CP}(B \rightarrow K^*(892)\gamma) = -0.003 \pm 0.011$$

$$A_{CP}(B \rightarrow s\gamma) = 0.015 \pm 0.011$$

$$A_{CP}(B \rightarrow (s+d)\gamma) = 0.010 \pm 0.031$$



$$\begin{aligned}
 A_{CP}(B \rightarrow X_s \ell^+ \ell^-) &= 0.04 \pm 0.11 \\
 A_{CP}(B \rightarrow X_s \ell^+ \ell^-) (1.0 < q^2 < 6.0 \text{ GeV}^2/c^4) &= -0.06 \pm 0.22 \\
 A_{CP}(B \rightarrow X_s \ell^+ \ell^-) (10.1 < q^2 < 12.9 \text{ or } q^2 > 14.2 \text{ GeV}^2/c^4) \\
 &= 0.19 \pm 0.18 \\
 A_{CP}(B \rightarrow K^* e^+ e^-) &= -0.18 \pm 0.15 \\
 A_{CP}(B \rightarrow K^* \mu^+ \mu^-) &= -0.03 \pm 0.13 \\
 A_{CP}(B \rightarrow K^* \ell^+ \ell^-) &= -0.04 \pm 0.07 \\
 A_{CP}(B \rightarrow \eta \text{ anything}) &= -0.13^{+0.04}_{-0.05} \\
 \Delta A_{CP}(X_s \gamma) &= A_{CP}(B^\pm \rightarrow X_s \gamma) - A_{CP}(B^0 \rightarrow X_s \gamma) = \\
 &0.041 \pm 0.023 \\
 \bar{A}_{CP}(B \rightarrow X_s \gamma) &= (A_{CP}(B^+ \rightarrow X_s \gamma) + A_{CP}(B^0 \rightarrow \\
 &X_s \gamma))/2 = 0.009 \pm 0.012 \\
 \Delta A_{CP}(B \rightarrow K^* \gamma) &= A_{CP}(B^+ \rightarrow K^{*+} \gamma) - A_{CP}(B^0 \rightarrow \\
 &K^{*0} \gamma) = 0.024 \pm 0.028 \\
 \bar{A}_{CP}(B \rightarrow K^* \gamma) &= (A_{CP}(B^+ \rightarrow K^{*+} \gamma) + A_{CP}(B^0 \rightarrow \\
 &K^{*0} \gamma))/2 = -0.001 \pm 0.014
 \end{aligned}$$

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.,  $B \rightarrow D^\pm \text{ anything}$ , the treatment of multiple  $D$ 's in the final state must be defined. One possibility would be to count the number of events with one-or-more  $D$ 's and divide by the total number of  $B$ 's. Another possibility would be to count the total number of  $D$ 's and divide by the total number of  $B$ 's, which is the definition of average multiplicity. The two definitions are identical if only one  $D$  is allowed in the final state. Even though the "one-or-more" definition seems sensible, for practical reasons inclusive branching fractions are almost always measured using the multiplicity definition. For heavy final state particles, authors call their results inclusive branching fractions while for light particles some authors call their results multiplicities. In the  $B$  sections, we list all results as inclusive branching fractions, adopting a multiplicity definition. This means that inclusive branching fractions can exceed 100% and that inclusive partial widths can exceed total widths, just as inclusive cross sections can exceed total cross section.

$\bar{B}$  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/<br>Confidence level (MeV/c) | $p$  |
|--|--|---|------|
| <b>Semileptonic and leptonic modes</b>       |  |   |      |
| $\ell^+ \nu_\ell \text{ anything}$           | $[iii,yyy]$ ( 10.86 $\pm$ 0.16 ) %         |   | —    |
| $D^- \ell^+ \nu_\ell \text{ anything}$       | $[iii]$ ( 2.6 $\pm$ 0.5 ) %                |   | —    |
| $\bar{D}^0 \ell^+ \nu_\ell \text{ anything}$ | $[iii]$ ( 7.3 $\pm$ 1.5 ) %                |   | —    |
| $\bar{D} \ell^+ \nu_\ell$                    | ( 2.42 $\pm$ 0.12 ) %                      |   | 2310 |
| $D^{*-} \ell^+ \nu_\ell \text{ anything}$    | $[zzz]$ ( 6.7 $\pm$ 1.3 ) $\times 10^{-3}$ |   | —    |
| $\bar{D}^* \ell^+ \nu_\ell$                  | $[aaaa]$ ( 4.95 $\pm$ 0.11 ) %             |   | 2257 |

|  |             |                                    |        |      |
|--|-------------|------------------------------------|--------|------|
| $\overline{D}^{*\ast} \ell^+ \nu_\ell$   | [iii, bbaa] | ( 2.7 ± 0.7 ) %                    |        | —    |
| $\overline{D}_1(2420) \ell^+ \nu_\ell$ anything  |             | ( 3.8 ± 1.3 ) × 10 <sup>-3</sup>   | S=2.4  | —    |
| $\overline{D} \pi \ell^+ \nu_\ell$ anything +<br>$\overline{D}^* \pi \ell^+ \nu_\ell$ anything |             | ( 2.6 ± 0.5 ) %                    | S=1.5  | —    |
| $\overline{D} \pi \ell^+ \nu_\ell$ anything  |             | ( 1.5 ± 0.6 ) %                    |        | —    |
| $\overline{D}^* \pi \ell^+ \nu_\ell$ anything  |             | ( 1.9 ± 0.4 ) %                    |        | —    |
| $\overline{D}_2^*(2460) \ell^+ \nu_\ell$ anything  |             | ( 4.4 ± 1.6 ) × 10 <sup>-3</sup>   |        | —    |
| $D^{*-} \pi^+ \ell^+ \nu_\ell$ anything  |             | ( 1.00 ± 0.34 ) %                  |        | —    |
| $\overline{D} \pi^+ \pi^- \ell^+ \nu_\ell$   |             | ( 1.62 ± 0.32 ) × 10 <sup>-3</sup> |        | 2301 |
| $\overline{D}^* \pi^+ \pi^- \ell^+ \nu_\ell$   |             | ( 9.4 ± 3.2 ) × 10 <sup>-4</sup>   |        | 2247 |
| $D_s^- \ell^+ \nu_\ell$ anything   | [iii]       | < 7 × 10 <sup>-3</sup>             | CL=90% | —    |
| $D_s^- \ell^+ \nu_\ell K^+$ anything   | [iii]       | < 5 × 10 <sup>-3</sup>             | CL=90% | —    |
| $D_s^- \ell^+ \nu_\ell K^0$ anything   | [iii]       | < 7 × 10 <sup>-3</sup>             | CL=90% | —    |
| $X_c \ell^+ \nu_\ell$  |             | ( 10.65 ± 0.16 ) %                 |        | —    |
| $X_u \ell^+ \nu_\ell$  |             | ( 2.13 ± 0.30 ) × 10 <sup>-3</sup> |        | —    |
| $K^+ \ell^+ \nu_\ell$ anything   | [iii]       | ( 6.3 ± 0.6 ) %                    |        | —    |
| $K^- \ell^+ \nu_\ell$ anything   | [iii]       | ( 10 ± 4 ) × 10 <sup>-3</sup>      |        | —    |
| $K^0 / \overline{K}^0 \ell^+ \nu_\ell$ anything  | [iii]       | ( 4.6 ± 0.5 ) %                    |        | —    |
| $\overline{D} \tau^+ \nu_\tau$   |             | ( 8.2 ± 0.8 ) × 10 <sup>-3</sup>   |        | 1911 |
| $\overline{D}^* \tau^+ \nu_\tau$   |             | ( 1.46 ± 0.08 ) %                  |        | 1838 |

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

|  |            |                          |        |      |
|--|------------|--------------------------|--------|------|
| $D^\pm$ anything   |            | ( 23.1 ± 1.2 ) %         |        | —    |
| $D^0 / \overline{D}^0$ anything  |            | ( 61.6 ± 2.9 ) %         | S=1.3  | —    |
| $D^*(2010)^\pm$ anything   |            | ( 22.5 ± 1.5 ) %         |        | —    |
| $\overline{D}^*(2007)^0$ anything  |            | ( 26.0 ± 2.7 ) %         |        | —    |
| $D_s^\pm$ anything   | [aa]       | ( 8.3 ± 0.8 ) %          |        | —    |
| $D_s^{*\pm}$ anything  |            | ( 6.3 ± 1.0 ) %          |        | —    |
| $D_s^{*\pm} \overline{D}^{(*)}$  |            | ( 3.4 ± 0.6 ) %          |        | —    |
| $\overline{D} D_{s0}(2317)$  |            | seen                     |        | 1605 |
| $\overline{D} D_{sJ}(2457)$  |            | seen                     |        | —    |
| $D^{(*)} \overline{D}^{(*)} K^0 +$<br>$D^{(*)} \overline{D}^{(*)} K^\pm$ | [aa, ccaa] | ( 7.1 ± 2.7 / - 1.7 ) %  |        | —    |
| $b \rightarrow c \overline{c} s$   |            | ( 22 ± 4 ) %             |        | —    |
| $D_s^{(*)} \overline{D}^{(*)}$   | [aa, ccaa] | ( 3.9 ± 0.4 ) %          |        | —    |
| $D^* D^*(2010)^\pm$  | [aa]       | < 5.9 × 10 <sup>-3</sup> | CL=90% | 1711 |
| $D D^*(2010)^\pm + D^* D^\pm$  | [aa]       | < 5.5 × 10 <sup>-3</sup> | CL=90% | —    |
| $D D^\pm$  | [aa]       | < 3.1 × 10 <sup>-3</sup> | CL=90% | 1866 |
| $D_s^{(*)\pm} \overline{D}^{(*)} X(n\pi^\pm)$                            | [aa, ccaa] | ( 9 ± 5 / - 4 ) %        |        | —    |
| $\overline{D}^*(2010)\gamma$   |            | < 1.1 × 10 <sup>-3</sup> | CL=90% | 2257 |

|  |      |       |                  |        |   |
|--|------|-------|------------------|--------|---|
| $D_s^+ \pi^-, D_s^{*+} \pi^-, D_s^+ \rho^-,$     | [aa] | < 4   | $\times 10^{-4}$ | CL=90% | — |
| $D_s^{*+} \rho^-, D_s^+ \pi^0, D_s^{*+} \pi^0,$  |      |       |                  |        |   |
| $D_s^+ \eta, D_s^{*+} \eta, D_s^+ \rho^0,$       |      |       |                  |        |   |
| $D_s^{*+} \rho^0, D_s^+ \omega, D_s^{*+} \omega$ |      |       |                  |        |   |
| $D_{s1}(2536)^+$ anything                        |      | < 9.5 | $\times 10^{-3}$ | CL=90% | — |

### Charmonium modes

|  |                  |                   |                    |                    |      |
|--|------------------|-------------------|--------------------|--------------------|------|
| $J/\psi(1S)$ anything                    | (                | $1.094 \pm 0.032$ | ) %                | S=1.1              | —    |
| $J/\psi(1S)$ (direct) anything           | (                | $7.8 \pm 0.4$     | ) $\times 10^{-3}$ | S=1.1              | —    |
| $\psi(2S)$ anything                      | (                | $3.07 \pm 0.21$   | ) $\times 10^{-3}$ |                    | —    |
| $\chi_{c1}(1P)$ anything                 | (                | $3.55 \pm 0.27$   | ) $\times 10^{-3}$ | S=1.3              | —    |
| $\chi_{c1}(1P)$ (direct) anything        | (                | $3.08 \pm 0.19$   | ) $\times 10^{-3}$ |                    | —    |
| $\chi_{c2}(1P)$ anything                 | (                | $10.0 \pm 1.7$    | ) $\times 10^{-4}$ | S=1.6              | —    |
| $\chi_{c2}(1P)$ (direct) anything        | (                | $7.5 \pm 1.1$     | ) $\times 10^{-4}$ |                    | —    |
| $\eta_c(1S)$ anything                    | <                | 9                 | $\times 10^{-3}$   | CL=90%             | —    |
| $K \chi_{c1}(3872)$                      | (                | $2.3 \pm 0.7$     | ) $\times 10^{-4}$ |                    | 1141 |
| $K X(3940), X \rightarrow D^{*0} D^0$    | <                | 6.7               | $\times 10^{-5}$   | CL=90%             | 1084 |
| $K X(3915), X \rightarrow \omega J/\psi$ | [d $\bar{d}$ aa] | (                 | $7.1 \pm 3.4$      | ) $\times 10^{-5}$ | 1103 |

### K or K\* modes

|  |      |      |  |                    |      |
|--|------|------|--|--------------------|------|
| $K^\pm$ anything                         | [aa] | (    | $78.9 \pm 2.5$   | ) %                | —    |
| $K^+$ anything                           |      | (    | $66 \pm 5$   | ) %                | —    |
| $K^-$ anything                           |      | (    | $13 \pm 4$   | ) %                | —    |
| $K^0 / \bar{K}^0$ anything               | [aa] | (    | $64 \pm 4$   | ) %                | —    |
| $K^*(892)^\pm$ anything                  |      | (    | $18 \pm 6$   | ) %                | —    |
| $K^*(892)^0 / \bar{K}^*(892)^0$ anything | [aa] | (    | $14.6 \pm 2.6$   | ) %                | —    |
| $K^*(892)\gamma$                         |      | (    | $4.2 \pm 0.6$  | ) $\times 10^{-5}$ | 2565 |
| $\eta K \gamma$                          |      | (    | $8.5 \begin{smallmatrix} + 1.8 \\ - 1.6 \end{smallmatrix}$ | ) $\times 10^{-6}$ | 2588 |
| $K_1(1400)\gamma$                        | <    | 1.27 | $\times 10^{-4}$   | CL=90%             | 2454 |
| $K_2^*(1430)\gamma$                      |      | (    | $1.7 \begin{smallmatrix} + 0.6 \\ - 0.5 \end{smallmatrix}$ | ) $\times 10^{-5}$ | 2447 |
| $K_2(1770)\gamma$                        | <    | 1.2  | $\times 10^{-3}$   | CL=90%             | 2342 |
| $K_3^*(1780)\gamma$                      | <    | 3.7  | $\times 10^{-5}$   | CL=90%             | 2340 |
| $K_4^*(2045)\gamma$                      | <    | 1.0  | $\times 10^{-3}$   | CL=90%             | 2243 |
| $K \eta'(958)$                           |      | (    | $8.3 \pm 1.1$  | ) $\times 10^{-5}$ | 2528 |
| $K^*(892)\eta'(958)$                     |      | (    | $4.1 \pm 1.1$  | ) $\times 10^{-6}$ | 2472 |
| $K \eta$                                 | <    | 5.2  | $\times 10^{-6}$   | CL=90%             | 2588 |
| $K^*(892)\eta$                           |      | (    | $1.8 \pm 0.5$  | ) $\times 10^{-5}$ | 2534 |
| $K \phi \phi$                            |      | (    | $2.3 \pm 0.9$  | ) $\times 10^{-6}$ | 2306 |
| $\bar{b} \rightarrow \bar{s} \gamma$     |      | (    | $3.49 \pm 0.19$  | ) $\times 10^{-4}$ | —    |
| $\bar{b} \rightarrow \bar{d} \gamma$     |      | (    | $9.2 \pm 3.0$  | ) $\times 10^{-6}$ | —    |
| $\bar{b} \rightarrow \bar{s}$ gluon      | <    | 6.8  | %  | CL=90%             | —    |
| $\eta$ anything                          |      | (    | $2.6 \begin{smallmatrix} + 0.5 \\ - 0.8 \end{smallmatrix}$ | ) $\times 10^{-4}$ | —    |

|                         |                                  |          |
|-------------------------|----------------------------------|----------|
| $\eta'$ anything        | ( 4.2 ± 0.9 ) × 10 <sup>-4</sup> | —        |
| $K^+$ gluon (charmless) | < 1.87 × 10 <sup>-4</sup>        | CL=90% — |
| $K^0$ gluon (charmless) | ( 1.9 ± 0.7 ) × 10 <sup>-4</sup> | —        |

### Light unflavored meson modes

|                           |                                    |        |      |
|---------------------------|------------------------------------|--------|------|
| $\rho\gamma$              | ( 1.39 ± 0.25 ) × 10 <sup>-6</sup> | S=1.2  | 2583 |
| $\rho/\omega\gamma$       | ( 1.30 ± 0.23 ) × 10 <sup>-6</sup> | S=1.2  | —    |
| $\pi^\pm$ anything        | [aa, eaaa] ( 358 ± 7 ) %           |        | —    |
| $\pi^0$ anything          | ( 235 ± 11 ) %                     |        | —    |
| $\eta$ anything           | ( 17.6 ± 1.6 ) %                   |        | —    |
| $\rho^0$ anything         | ( 21 ± 5 ) %                       |        | —    |
| $\omega$ anything         | < 81 %                             | CL=90% | —    |
| $\phi$ anything           | ( 3.43 ± 0.12 ) %                  |        | —    |
| $\phi K^*(892)$           | < 2.2 × 10 <sup>-5</sup>           | CL=90% | 2460 |
| $\pi^+$ gluon (charmless) | ( 3.7 ± 0.8 ) × 10 <sup>-4</sup>   |        | —    |

### Baryon modes

|   |  |        |      |
|---|--|--------|------|
| $\Lambda_c^+ / \bar{\Lambda}_c^-$ anything            | ( 3.6 ± 0.4 ) %                          |        | —    |
| $\Lambda_c^+$ anything                                | < 1.3 %                                  | CL=90% | —    |
| $\bar{\Lambda}_c^-$ anything                          | < 7 %                                    | CL=90% | —    |
| $\bar{\Lambda}_c^- \ell^+$ anything                   | < 9 × 10 <sup>-4</sup>                   | CL=90% | —    |
| $\bar{\Lambda}_c^- e^+$ anything                      | < 1.8 × 10 <sup>-3</sup>                 | CL=90% | —    |
| $\bar{\Lambda}_c^- \mu^+$ anything                    | < — 1.4 × 10 <sup>-3</sup>               | CL=90% | —    |
| $\bar{\Lambda}_c^- p$ anything                        | ( 2.04 ± 0.33 ) %                        |        | —    |
| $\bar{\Lambda}_c^- p e^+ \nu_e$                       | < 8 × 10 <sup>-4</sup>                   | CL=90% | 2021 |
| $\bar{\Sigma}_c^-$ anything                           | ( 3.3 ± 1.7 ) × 10 <sup>-3</sup>         |        | —    |
| $\bar{\Sigma}_c^-$ anything                           | < 8 × 10 <sup>-3</sup>                   | CL=90% | —    |
| $\bar{\Sigma}_c^0$ anything                           | ( 3.7 ± 1.7 ) × 10 <sup>-3</sup>         |        | —    |
| $\bar{\Sigma}_c^0 N (N = p \text{ or } n)$            | < 1.2 × 10 <sup>-3</sup>                 | CL=90% | 1938 |
| $\Xi_c^0$ anything, $\Xi_c^0 \rightarrow \Xi^- \pi^+$ | ( 1.93 ± 0.30 ) × 10 <sup>-4</sup>       | S=1.1  | —    |
| $\Xi_c^+, \Xi_c^+ \rightarrow \Xi^- \pi^+ \pi^+$      | ( 4.5 ± 1.3 / - 1.2 ) × 10 <sup>-4</sup> |        | —    |
| $p/\bar{p}$ anything                                  | [aa] ( 8.0 ± 0.4 ) %                     |        | —    |
| $p/\bar{p}$ (direct) anything                         | [aa] ( 5.5 ± 0.5 ) %                     |        | —    |
| $\bar{p} e^+ \nu_e$ anything                          | < 5.9 × 10 <sup>-4</sup>                 | CL=90% | —    |
| $\Lambda/\bar{\Lambda}$ anything                      | [aa] ( 4.0 ± 0.5 ) %                     |        | —    |
| $\Lambda$ anything                                    | seen                                     |        | —    |
| $\bar{\Lambda}$ anything                              | seen                                     |        | —    |
| $\Xi^- / \bar{\Xi}^+$ anything                        | [aa] ( 2.7 ± 0.6 ) × 10 <sup>-3</sup>    |        | —    |
| baryons anything                                      | ( 6.8 ± 0.6 ) %                          |        | —    |
| $p\bar{p}$ anything                                   | ( 2.47 ± 0.23 ) %                        |        | —    |
| $\Lambda\bar{\Lambda}/\bar{\Lambda}p$ anything        | [aa] ( 2.5 ± 0.4 ) %                     |        | —    |
| $\Lambda\bar{\Lambda}$ anything                       | < 5 × 10 <sup>-3</sup>                   | CL=90% | —    |

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

|                        |      |         |                 |                    |           |      |
|------------------------|------|---------|-----------------|--------------------|-----------|------|
| $se^+e^-$              | $B1$ | (       | $6.7 \pm 1.7$   | ) $\times 10^{-6}$ | $S=2.0$   | –    |
| $s\mu^+\mu^-$          | $B1$ | (       | $4.3 \pm 1.0$   | ) $\times 10^{-6}$ |           | –    |
| $sl^+\ell^-$           | $B1$ | [iii] ( | $5.8 \pm 1.3$   | ) $\times 10^{-6}$ | $S=1.8$   | –    |
| $\pi\ell^+\ell^-$      | $B1$ | <       | 5.9             | $\times 10^{-8}$   | $CL=90\%$ | 2638 |
| $\pi e^+e^-$           | $B1$ | <       | 1.10            | $\times 10^{-7}$   | $CL=90\%$ | 2638 |
| $\pi\mu^+\mu^-$        | $B1$ | <       | 5.0             | $\times 10^{-8}$   | $CL=90\%$ | 2634 |
| $Ke^+e^-$              | $B1$ | (       | $4.4 \pm 0.6$   | ) $\times 10^{-7}$ |           | 2617 |
| $K^*(892)e^+e^-$       | $B1$ | (       | $1.19 \pm 0.20$ | ) $\times 10^{-6}$ | $S=1.2$   | 2565 |
| $K\mu^+\mu^-$          | $B1$ | (       | $4.4 \pm 0.4$   | ) $\times 10^{-7}$ |           | 2612 |
| $K^*(892)\mu^+\mu^-$   | $B1$ | (       | $1.06 \pm 0.09$ | ) $\times 10^{-6}$ |           | 2560 |
| $K\ell^+\ell^-$        | $B1$ | (       | $4.8 \pm 0.4$   | ) $\times 10^{-7}$ |           | 2617 |
| $K^*(892)\ell^+\ell^-$ | $B1$ | (       | $1.05 \pm 0.10$ | ) $\times 10^{-6}$ |           | 2565 |
| $K\nu\bar{\nu}$        | $B1$ | <       | 1.6             | $\times 10^{-5}$   | $CL=90\%$ | 2617 |
| $K^*\nu\bar{\nu}$      | $B1$ | <       | 2.7             | $\times 10^{-5}$   | $CL=90\%$ | –    |
| $\pi\nu\bar{\nu}$      | $B1$ | <       | 8               | $\times 10^{-6}$   | $CL=90\%$ | 2638 |
| $\rho\nu\bar{\nu}$     | $B1$ | <       | 2.8             | $\times 10^{-5}$   | $CL=90\%$ | 2583 |
| $se^\pm\mu^\mp$        | $LF$ | [aa] <  | 2.2             | $\times 10^{-5}$   | $CL=90\%$ | –    |
| $\pi e^\pm\mu^\mp$     | $LF$ | <       | 9.2             | $\times 10^{-8}$   | $CL=90\%$ | 2637 |
| $\rho e^\pm\mu^\mp$    | $LF$ | <       | 3.2             | $\times 10^{-6}$   | $CL=90\%$ | 2582 |
| $Ke^\pm\mu^\mp$        | $LF$ | <       | 3.8             | $\times 10^{-8}$   | $CL=90\%$ | 2616 |
| $K^*(892)e^\pm\mu^\mp$ | $LF$ | <       | 5.1             | $\times 10^{-7}$   | $CL=90\%$ | 2563 |

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

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

$$\text{Mean life } \tau = (1.5667 \pm 0.0029) \times 10^{-12} \text{ s}$$

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

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

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

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

The branching fraction measurements are for an admixture of  $B$  mesons and baryons at energies above the  $\Upsilon(4S)$ . Only the highest energy results (LHC, LEP, Tevatron,  $Spp\bar{S}$ ) are used in the branching fraction averages. In the following, we assume that the production fractions are the same at the LHC, 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/<br>Confidence level | $p$<br>(MeV/c) |
|-----------------------|--------------------------------|-----------------------------------|----------------|
|-----------------------|--------------------------------|-----------------------------------|----------------|

### 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 (HFLAV) as described in the note “ $B^0$ - $\bar{B}^0$  Mixing” in the  $B^0$  Particle Listings. We no longer provide world averages of the  $b$ -hadron production fractions, where results from LEP, Tevatron and LHC are averaged together; indeed the available data (from CDF and LHCb) shows that the fractions depend on the kinematics (in particular the  $p_T$ ) of the produced  $b$  hadron. Hence we would like to list the fractions in  $Z$  decays instead, which are well-defined physics observables. The production fractions in  $p\bar{p}$  collisions at the Tevatron are also listed at the end of the section. 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 correlation coefficients between production fractions are also reported:

$$\text{cor}(B_s^0, b\text{-baryon}) = 0.064$$

$$\text{cor}(B_s^0, B^\pm=B^0) = -0.633$$

$$\text{cor}(b\text{-baryon}, B^\pm=B^0) = -0.813.$$

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,  $B(\bar{b} \rightarrow B^0)$ .

Note these production fractions are  $b$ -hadronization fractions, not the conventional branching fractions of  $b$ -quark to a  $B$ -hadron, which may have considerable dependence on the initial and final state kinematic and production environment.

|             |                  |   |
|-------------|------------------|---|
| $B^+$       | ( 40.8 ± 0.7 ) % | — |
| $B^0$       | ( 40.8 ± 0.7 ) % | — |
| $B_s^0$     | ( 10.0 ± 0.8 ) % | — |
| $b$ -baryon | ( 8.4 ± 1.1 ) %  | — |

### DECAY MODES

#### Semileptonic and leptonic modes

|                            |   |   |
|----------------------------|---|---|
| $\nu$ anything             | ( 23.1 ± 1.5 ) %                                | — |
| $\ell^+ \nu_\ell$ anything | [iii] ( 10.69 ± 0.22 ) %                        | — |
| $e^+ \nu_e$ anything       | ( 10.86 ± 0.35 ) %                              | — |
| $\mu^+ \nu_\mu$ anything   | ( 10.95 <sup>+</sup> <sub>-</sub> 0.29/0.25 ) % | — |

|  |            |  |        |   |
|--|------------|--|--------|---|
| $D^- \ell^+ \nu_\ell$ anything   | [iii]      | ( 2.2 ± 0.4 ) %  | S=1.9  | — |
| $D^- \pi^+ \ell^+ \nu_\ell$ anything   |            | ( 4.9 ± 1.9 ) × 10 <sup>-3</sup>   |        | — |
| $D^- \pi^- \ell^+ \nu_\ell$ anything   |            | ( 2.6 ± 1.6 ) × 10 <sup>-3</sup>   |        | — |
| $\overline{D}^0 \ell^+ \nu_\ell$ anything  | [iii]      | ( 6.79 ± 0.34 ) %  |        | — |
| $\overline{D}^0 \pi^- \ell^+ \nu_\ell$ anything  |            | ( 1.07 ± 0.27 ) %  |        | — |
| $\overline{D}^0 \pi^+ \ell^+ \nu_\ell$ anything  |            | ( 2.3 ± 1.6 ) × 10 <sup>-3</sup>   |        | — |
| $D^{*-} \ell^+ \nu_\ell$ anything  | [iii]      | ( 2.75 ± 0.19 ) %  |        | — |
| $D^{*-} \pi^- \ell^+ \nu_\ell$ anything  |            | ( 6 ± 7 ) × 10 <sup>-4</sup>   |        | — |
| $D^{*-} \pi^+ \ell^+ \nu_\ell$ anything  |            | ( 4.8 ± 1.0 ) × 10 <sup>-3</sup>   |        | — |
| $\overline{D}_j^0 \ell^+ \nu_\ell$ anything ×<br>B( $\overline{D}_j^0 \rightarrow D^{*+} \pi^-$ )                      | [iii,ffaa] | ( 2.6 ± 0.9 ) × 10 <sup>-3</sup>   |        | — |
| $D_j^- \ell^+ \nu_\ell$ anything ×<br>B( $D_j^- \rightarrow D^0 \pi^-$ )   | [iii,ffaa] | ( 7.0 ± 2.3 ) × 10 <sup>-3</sup>   |        | — |
| $\overline{D}_2^*(2460)^0 \ell^+ \nu_\ell$ anything<br>× B( $\overline{D}_2^*(2460)^0 \rightarrow$<br>$D^{*-} \pi^+$ ) | <          | 1.4 × 10 <sup>-3</sup>   | CL=90% | — |
| $D_2^*(2460)^- \ell^+ \nu_\ell$ anything<br>× B( $D_2^*(2460)^- \rightarrow$<br>$D^0 \pi^-$ )                          |            | ( 4.2 $\begin{smallmatrix} + \\ - \end{smallmatrix}$ $\begin{smallmatrix} 1.5 \\ 1.8 \end{smallmatrix}$ ) × 10 <sup>-3</sup> |        | — |
| $\overline{D}_2^*(2460)^0 \ell^+ \nu_\ell$ anything<br>× B( $\overline{D}_2^*(2460)^0 \rightarrow$<br>$D^- \pi^+$ )    |            | ( 1.6 ± 0.8 ) × 10 <sup>-3</sup>   |        | — |
| charmless $\ell \bar{\nu}_\ell$  | [iii]      | ( 1.7 ± 0.5 ) × 10 <sup>-3</sup>   |        | — |
| $\tau^+ \nu_\tau$ anything   |            | ( 2.41 ± 0.23 ) %  |        | — |
| $D^{*-} \tau \nu_\tau$ anything  |            | ( 9 ± 4 ) × 10 <sup>-3</sup>   |        | — |
| $\bar{c} \rightarrow \ell^- \bar{\nu}_\ell$ anything   | [iii]      | ( 8.02 ± 0.19 ) %  |        | — |
| $c \rightarrow \ell^+ \nu$ anything  |            | ( 1.6 $\begin{smallmatrix} + \\ - \end{smallmatrix}$ $\begin{smallmatrix} 0.4 \\ 0.5 \end{smallmatrix}$ ) %                  |        | — |

### Charmed meson and baryon modes

|                                  |      |   |        |   |
|----------------------------------|------|---|--------|---|
| $\overline{D}^0$ anything        |      | ( 58.7 ± 2.8 ) %  |        | — |
| $D^0 D_s^\pm$ anything           | [aa] | ( 9.1 $\begin{smallmatrix} + \\ - \end{smallmatrix}$ $\begin{smallmatrix} 4.0 \\ 2.8 \end{smallmatrix}$ ) % |        | — |
| $D^\mp D_s^\pm$ anything         | [aa] | ( 4.0 $\begin{smallmatrix} + \\ - \end{smallmatrix}$ $\begin{smallmatrix} 2.3 \\ 1.8 \end{smallmatrix}$ ) % |        | — |
| $\overline{D}^0 D^0$ anything    | [aa] | ( 5.1 $\begin{smallmatrix} + \\ - \end{smallmatrix}$ $\begin{smallmatrix} 2.0 \\ 1.8 \end{smallmatrix}$ ) % |        | — |
| $D^0 D^\pm$ anything             | [aa] | ( 2.7 $\begin{smallmatrix} + \\ - \end{smallmatrix}$ $\begin{smallmatrix} 1.8 \\ 1.6 \end{smallmatrix}$ ) % |        | — |
| $D^\pm D^\mp$ anything           | [aa] | < 9 × 10 <sup>-3</sup>  | CL=90% | — |
| $D^-$ anything                   |      | ( 22.7 ± 1.6 ) %  |        | — |
| $D^*(2010)^+$ anything           |      | ( 17.3 ± 2.0 ) %  |        | — |
| $D_1(2420)^0$ anything           |      | ( 5.0 ± 1.5 ) %   |        | — |
| $D^*(2010)^\mp D_s^\pm$ anything | [aa] | ( 3.3 $\begin{smallmatrix} + \\ - \end{smallmatrix}$ $\begin{smallmatrix} 1.6 \\ 1.3 \end{smallmatrix}$ ) % |        | — |

|  |        |   |   |
|--|--------|---|---|
| $D^0 D^{*}(2010)^{\pm}$ anything               | [aa]   | $( 3.0 \begin{smallmatrix} + \\ - \end{smallmatrix} \frac{1.1}{0.9} ) \%$ | — |
| $D^{*}(2010)^{\pm} D^{\mp}$ anything           | [aa]   | $( 2.5 \begin{smallmatrix} + \\ - \end{smallmatrix} \frac{1.2}{1.0} ) \%$ | — |
| $D^{*}(2010)^{\pm} D^{*}(2010)^{\mp}$ anything | [aa]   | $( 1.2 \pm 0.4 ) \%$  | — |
| $\bar{D} D$ anything                           |        | $( 10 \begin{smallmatrix} + \\ - \end{smallmatrix} \frac{11}{10} ) \%$    | — |
| $D_2^{*}(2460)^0$ anything                     |        | $( 4.7 \pm 2.7 ) \%$  | — |
| $D_s^-$ anything                               |        | $( 14.7 \pm 2.1 ) \%$   | — |
| $D_s^+$ anything                               |        | $( 10.1 \pm 3.1 ) \%$   | — |
| $\Lambda_c^+$ anything                         |        | $( 7.7 \pm 1.1 ) \%$  | — |
| $\bar{c}/c$ anything                           | [eeaa] | $(116.2 \pm 3.2) \%$  | — |

### Charmonium modes

|  |  |                                    |   |
|--|--|------------------------------------|---|
| $J/\psi(1S)$ anything  |  | $( 1.16 \pm 0.10 ) \%$             | — |
| $\psi(2S)$ anything  |  | $( 3.06 \pm 0.30 ) \times 10^{-3}$ | — |
| $\chi_{c0}(1P)$ anything                                     |  | $( 1.5 \pm 0.6 ) \%$               | — |
| $\chi_{c1}(1P)$ anything                                     |  | $( 1.4 \pm 0.4 ) \%$               | — |
| $\chi_{c2}(1P)$ anything                                     |  | $( 6.2 \pm 2.9 ) \times 10^{-3}$   | — |
| $\chi_c(2P)$ anything, $\chi_c \rightarrow \phi\phi$         |  | $< 2.8 \times 10^{-7}$ CL=95%      | — |
| $\eta_c(1S)$ anything  |  | $( 5.6 \pm 0.9 ) \times 10^{-3}$   | — |
| $\eta_c(2S)$ anything, $\eta_c \rightarrow \phi\phi$         |  | $( 3.9 \pm 1.4 ) \times 10^{-7}$   | — |
| $\chi_{c1}(3872)$ anything, $\chi_{c1} \rightarrow \phi\phi$ |  | $< 4.5 \times 10^{-7}$ CL=95%      | — |
| $X(3915)$ anything, $X \rightarrow \phi\phi$                 |  | $< 3.1 \times 10^{-7}$ CL=95%      | — |

### K or K\* modes

|                       |    |                                  |   |
|-----------------------|----|----------------------------------|---|
| $\bar{S}\gamma$       |    | $( 3.1 \pm 1.1 ) \times 10^{-4}$ | — |
| $\bar{S}\bar{\nu}\nu$ | B1 | $< 6.4 \times 10^{-4}$ CL=90%    | — |
| $K^{\pm}$ anything    |    | $( 74 \pm 6 ) \%$                | — |
| $K_S^0$ anything      |    | $( 29.0 \pm 2.9 ) \%$            | — |

### Pion modes

|                      |        |                        |   |
|----------------------|--------|------------------------|---|
| $\pi^{\pm}$ anything |        | $(397 \pm 21) \%$      | — |
| $\pi^0$ anything     | [eeaa] | $(278 \pm 60) \%$      | — |
| $\phi$ anything      |        | $( 2.82 \pm 0.23 ) \%$ | — |

### Baryon modes

|                                  |  |                       |   |
|----------------------------------|--|-----------------------|---|
| $p/\bar{p}$ anything             |  | $( 13.1 \pm 1.1 ) \%$ | — |
| $\Lambda/\bar{\Lambda}$ anything |  | $( 5.9 \pm 0.6 ) \%$  | — |
| $b$ -baryon anything             |  | $( 10.2 \pm 2.8 ) \%$ | — |

### Other modes

|   |        |   |   |
|---|--------|---|---|
| charged anything                        | [eeaa] | $(497 \pm 7) \%$  | — |
| hadron <sup>+</sup> hadron <sup>-</sup> |        | $( 1.7 \begin{smallmatrix} + \\ - \end{smallmatrix} \frac{1.0}{0.7} ) \times 10^{-5}$ | — |
| charmless                               |        | $( 7 \pm 21 ) \times 10^{-3}$   | — |



**$\Delta B = 1$  weak neutral current ( $B1$ ) modes** $\mu^+ \mu^-$  anything  $B1$  < 3.2  $\times 10^{-4}$  CL=90% — **$B^*$** 

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

$I, J, P$  need confirmation.

Quantum numbers shown are quark-model predictions.

$$\text{Mass } m_{B^*} = 5324.70 \pm 0.21 \text{ MeV}$$

$$m_{B^*} - m_B = 45.21 \pm 0.21 \text{ MeV}$$

$$m_{B^{*+}} - m_{B^+} = 45.37 \pm 0.21 \text{ MeV}$$

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

 **$B_1(5721)$** 

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

$I, J, P$  need confirmation.

$$B_1(5721)^+ \text{ mass} = 5725.9^{+2.5}_{-2.7} \text{ MeV}$$

$$m_{B_1^+} - m_{B^{*0}} = 401.2^{+2.4}_{-2.7} \text{ MeV}$$

$$B_1(5721)^0 \text{ mass} = 5726.1 \pm 1.3 \text{ MeV} \quad (S = 1.2)$$

$$m_{B_1^0} - m_{B^+} = 446.7 \pm 1.3 \text{ MeV} \quad (S = 1.2)$$

$$m_{B_1^0} - m_{B^{*+}} = 401.4 \pm 1.2 \text{ MeV} \quad (S = 1.2)$$

$$\text{Full width } \Gamma(B_1(5721)^+) = 31 \pm 6 \text{ MeV} \quad (S = 1.1)$$

$$\text{Full width } \Gamma(B_1(5721)^0) = 27.5 \pm 3.4 \text{ MeV} \quad (S = 1.1)$$

| <b><math>B_1(5721)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|---|--------------------------------|-------------|
| $B^* \pi$                                 | seen                           | 365         |

 **$B_2^*(5747)$** 

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

$I, J, P$  need confirmation.

$$B_2^*(5747)^+ \text{ mass} = 5737.2 \pm 0.7 \text{ MeV}$$

$$m_{B_2^{*+}} - m_{B^0} = 457.5 \pm 0.7 \text{ MeV}$$

$$B_2^*(5747)^0 \text{ mass} = 5739.5 \pm 0.7 \text{ MeV} \quad (S = 1.4)$$

$$m_{B_2^{*0}} - m_{B_1^0} = 13.4 \pm 1.4 \text{ MeV} \quad (S = 1.3)$$

$$m_{B_2^{*0}} - m_{B^+} = 460.2 \pm 0.6 \text{ MeV} \quad (S = 1.4)$$

$$\text{Full width } \Gamma(B_2^*(5747)^+) = 20 \pm 5 \text{ MeV} \quad (S = 2.2)$$

$$\text{Full width } \Gamma(B_2^*(5747)^0) = 24.2 \pm 1.7 \text{ MeV}$$

| <b><math>B_2^*(5747)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ ) | $\rho$ (MeV/c) |
|---|--------------------------------|----------------|
| $B\pi$                                      | seen                           | 420            |
| $B^*\pi$                                    | seen                           | 376            |

### $B_J(5970)$

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

$I, J, P$  need confirmation.

$$B_J(5970)^+ \text{ mass } m = 5964 \pm 5 \text{ MeV}$$

$$m_{B_J(5970)^+} - m_{B^0} = 685 \pm 5 \text{ MeV}$$

$$B_J(5970)^0 \text{ mass } m = 5971 \pm 5 \text{ MeV}$$

$$m_{B_J(5970)^0} - m_{B^+} = 691 \pm 5 \text{ MeV}$$

$$B_J(5970)^+ \text{ full width } \Gamma = 62 \pm 20 \text{ MeV}$$

$$B_J(5970)^0 \text{ full width } \Gamma = 81 \pm 12 \text{ MeV}$$

| <b><math>B_J(5970)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ ) | $\rho$ (MeV/c) |
|---|--------------------------------|----------------|
| $B\pi$                                    | possibly seen                  | 633            |
| $B^*\pi$                                  | seen                           | 592            |

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

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

### $B_s^0$

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

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

$$\text{Mass } m_{B_s^0} = 5366.88 \pm 0.14 \text{ MeV}$$

$$m_{B_s^0} - m_B = 87.38 \pm 0.16 \text{ MeV}$$

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

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

$$\Delta\Gamma_{B_s^0} = \Gamma_{B_{sL}^0} - \Gamma_{B_{sH}^0} = (0.082 \pm 0.005) \times 10^{12} \text{ s}^{-1} \quad (S = 1.8)$$

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

$$\Delta m_{B_s^0} = m_{B_{sH}^0} - m_{B_{sL}^0} = (17.741 \pm 0.020) \times 10^{12} \text{ } \hbar \text{ s}^{-1}$$

$$= (1.1677 \pm 0.0013) \times 10^{-8} \text{ MeV}$$

$$x_s = \Delta m_{B_s^0} / \Gamma_{B_s^0} = 26.89 \pm 0.11$$

$$\chi_s (B_s^0-\bar{B}_s^0 \text{ mixing parameter}) = 0.499312 \pm 0.000006$$

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

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

$$C_{KK}(B_s^0 \rightarrow K^+ K^-) = 0.14 \pm 0.11$$

$$S_{KK}(B_s^0 \rightarrow K^+ K^-) = 0.30 \pm 0.13$$

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

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

$$\text{CP Violation phase } \beta_s = (2.5 \pm 1.0) \times 10^{-2} \text{ rad}$$

$$|\lambda| (B_s^0 \rightarrow J/\psi(1S)\phi) = 1.001 \pm 0.018 \quad (S = 1.2)$$

$$|\lambda| = 0.999 \pm 0.017$$

$$A, \text{ CP violation parameter} = -0.75 \pm 0.12$$

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

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

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

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

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

$$\mathbf{ACP}(B_s \rightarrow \pi^+ K^-) = 0.221 \pm 0.015$$

$$A_{CP}(B_s^0 \rightarrow [K^+ K^-]_D \bar{K}^*(892)^0) = -0.04 \pm 0.07$$

$$A_{CP}(B_s^0 \rightarrow [\pi^+ K^-]_D K^*(892)^0) = -0.01 \pm 0.04$$

$$A_{CP}(B_s^0 \rightarrow [\pi^+ \pi^-]_D K^*(892)^0) = 0.06 \pm 0.13$$

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

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

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

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

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

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

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

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

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

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

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

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

| $B_s^0$ DECAY MODES   | Fraction ( $\Gamma_i/\Gamma$ )       | Scale factor/<br>Confidence level | $\rho$<br>(MeV/c) |
|---|--------------------------------------|-----------------------------------|-------------------|
| $D_s^-$ anything  | (93 $\pm$ 25 ) %                     |                                   | –                 |
| $l\nu_l X$  | ( 9.6 $\pm$ 0.8 ) %                  |                                   | –                 |
| $e^+ \nu X^-$   | ( 9.1 $\pm$ 0.8 ) %                  |                                   | –                 |
| $\mu^+ \nu X^-$   | (10.2 $\pm$ 1.0 ) %                  |                                   | –                 |
| $D_s^- l^+ \nu_l$ anything  | [ <i>ggaa</i> ] ( 8.1 $\pm$ 1.3 ) %  |                                   | –                 |
| $D_s^{*-} l^+ \nu_l$ anything                                       | ( 5.4 $\pm$ 1.1 ) %                  |                                   | –                 |
| $D_s^- \mu^+ \nu_\mu$   | ( 2.52 $\pm$ 0.24 ) %                |                                   | 2321              |
| $D_s^{*-} \mu^+ \nu_\mu$  | ( 5.4 $\pm$ 0.5 ) %                  |                                   | 2266              |
| $D_{s1}(2536)^- \mu^+ \nu_\mu, D_{s1}^- \rightarrow D_s^{*-} K_S^0$ | ( 2.7 $\pm$ 0.7 ) $\times 10^{-3}$   |                                   | –                 |
| $D_{s1}(2536)^- X \mu^+ \nu, D_{s1}^- \rightarrow \bar{D}^0 K^+$    | ( 4.4 $\pm$ 1.3 ) $\times 10^{-3}$   |                                   | –                 |
| $D_{s2}(2573)^- X \mu^+ \nu, D_{s2}^- \rightarrow \bar{D}^0 K^+$    | ( 2.7 $\pm$ 1.0 ) $\times 10^{-3}$   |                                   | –                 |
| $D_s^- \pi^+$   | ( 3.00 $\pm$ 0.23 ) $\times 10^{-3}$ |                                   | 2320              |
| $D_s^- \rho^+$  | ( 6.9 $\pm$ 1.4 ) $\times 10^{-3}$   |                                   | 2249              |
| $D_s^- \pi^+ \pi^+ \pi^-$   | ( 6.1 $\pm$ 1.0 ) $\times 10^{-3}$   |                                   | 2301              |
| $D_{s1}(2536)^- \pi^+, D_{s1}^- \rightarrow D_s^- \pi^+ \pi^-$      | ( 2.5 $\pm$ 0.8 ) $\times 10^{-5}$   |                                   | –                 |
| $D_s^\mp K^\pm$   | ( 2.27 $\pm$ 0.19 ) $\times 10^{-4}$ |                                   | 2293              |
| $D_s^- K^+ \pi^+ \pi^-$   | ( 3.2 $\pm$ 0.6 ) $\times 10^{-4}$   |                                   | 2249              |
| $D_s^+ D_s^-$   | ( 4.4 $\pm$ 0.5 ) $\times 10^{-3}$   |                                   | 1824              |
| $D_s^- D^+$   | ( 2.8 $\pm$ 0.5 ) $\times 10^{-4}$   |                                   | 1875              |
| $D^+ D^-$   | ( 2.2 $\pm$ 0.6 ) $\times 10^{-4}$   |                                   | 1925              |
| $D^0 \bar{D}^0$   | ( 1.9 $\pm$ 0.5 ) $\times 10^{-4}$   |                                   | 1930              |
| $D_s^{*-} \pi^+$  | ( 2.0 $\pm$ 0.5 ) $\times 10^{-3}$   |                                   | 2265              |
| $D_s^{*\mp} K^\pm$  | ( 1.33 $\pm$ 0.35 ) $\times 10^{-4}$ |                                   | –                 |
| $D_s^{*-} \rho^+$   | ( 9.6 $\pm$ 2.1 ) $\times 10^{-3}$   |                                   | 2191              |
| $D_s^{*+} D_s^- + D_s^{*-} D_s^+$                                   | ( 1.39 $\pm$ 0.17 ) %                |                                   | 1742              |
| $D_s^{*+} D_s^{*-}$   | ( 1.44 $\pm$ 0.21 ) %                | S=1.1                             | 1655              |
| $D_s^{(*)+} D_s^{(*)-}$   | ( 4.5 $\pm$ 1.4 ) %                  |                                   | –                 |
| $\bar{D}^{*0} \bar{K}^0$  | ( 2.8 $\pm$ 1.1 ) $\times 10^{-4}$   |                                   | 2278              |
| $\bar{D}^0 \bar{K}^0$   | ( 4.3 $\pm$ 0.9 ) $\times 10^{-4}$   |                                   | 2330              |
| $\bar{D}^0 K^- \pi^+$   | ( 1.04 $\pm$ 0.13 ) $\times 10^{-3}$ |                                   | 2312              |
| $\bar{D}^0 \bar{K}^*(892)^0$  | ( 4.4 $\pm$ 0.6 ) $\times 10^{-4}$   |                                   | 2264              |
| $\bar{D}^0 \bar{K}^*(1410)$   | ( 3.9 $\pm$ 3.5 ) $\times 10^{-4}$   |                                   | 2117              |
| $\bar{D}^0 \bar{K}_0^*(1430)$                                       | ( 3.0 $\pm$ 0.7 ) $\times 10^{-4}$   |                                   | 2113              |
| $\bar{D}^0 \bar{K}_2^*(1430)$                                       | ( 1.1 $\pm$ 0.4 ) $\times 10^{-4}$   |                                   | 2112              |

|   |                                    |                  |        |      |
|---|------------------------------------|------------------|--------|------|
| $\overline{D}^0 \overline{K}^*(1680)$                                     | $< 7.8$                            | $\times 10^{-5}$ | CL=90% | 1997 |
| $\overline{D}^0 \overline{K}_0^*(1950)$                                   | $< 1.1$                            | $\times 10^{-4}$ | CL=90% | 1890 |
| $\overline{D}^0 \overline{K}_3^*(1780)$                                   | $< 2.6$                            | $\times 10^{-5}$ | CL=90% | 1970 |
| $\overline{D}^0 \overline{K}_4^*(2045)$                                   | $< 3.1$                            | $\times 10^{-5}$ | CL=90% | 1835 |
| $\overline{D}^0 K^- \pi^+$ (non-resonant)                                 | $( 2.1 \pm 0.8 )$                  | $\times 10^{-4}$ |        | 2312 |
| $D_{s2}^*(2573)^- \pi^+$ , $D_{s2}^* \rightarrow$<br>$\overline{D}^0 K^-$ | $( 2.6 \pm 0.4 )$                  | $\times 10^{-4}$ |        | —    |
| $D_{s1}^*(2700)^- \pi^+$ , $D_{s1}^* \rightarrow$<br>$\overline{D}^0 K^-$ | $( 1.6 \pm 0.8 )$                  | $\times 10^{-5}$ |        | —    |
| $D_{s1}^*(2860)^- \pi^+$ , $D_{s1}^* \rightarrow$<br>$\overline{D}^0 K^-$ | $( 5 \pm 4 )$                      | $\times 10^{-5}$ |        | —    |
| $D_{s3}^*(2860)^- \pi^+$ , $D_{s3}^* \rightarrow$<br>$\overline{D}^0 K^-$ | $( 2.2 \pm 0.6 )$                  | $\times 10^{-5}$ |        | —    |
| $\overline{D}^0 K^+ K^-$  | $( 5.5 \pm 0.8 )$                  | $\times 10^{-5}$ |        | 2243 |
| $\overline{D}^0 f_0(980)$   | $< 3.1$                            | $\times 10^{-6}$ | CL=90% | 2242 |
| $\overline{D}^0 \phi$   | $( 3.0 \pm 0.5 )$                  | $\times 10^{-5}$ |        | 2235 |
| $\overline{D}^{*0} \phi$  | $( 3.7 \pm 0.6 )$                  | $\times 10^{-5}$ |        | 2178 |
| $D^{*\mp} \pi^\pm$  | $< 6.1$                            | $\times 10^{-6}$ | CL=90% | —    |
| $\eta_c \phi$   | $( 5.0 \pm 0.9 )$                  | $\times 10^{-4}$ |        | 1663 |
| $\eta_c \pi^+ \pi^-$  | $( 1.8 \pm 0.7 )$                  | $\times 10^{-4}$ |        | 1840 |
| $J/\psi(1S) \phi$   | $( 1.08 \pm 0.08 )$                | $\times 10^{-3}$ |        | 1588 |
| $J/\psi(1S) \phi \phi$  | $( 1.24^+_{-0.17} \text{ } 0.19 )$ | $\times 10^{-5}$ |        | 764  |
| $J/\psi(1S) \pi^0$  | $< 1.2$                            | $\times 10^{-3}$ | CL=90% | 1787 |
| $J/\psi(1S) \eta$   | $( 4.0 \pm 0.7 )$                  | $\times 10^{-4}$ | S=1.4  | 1733 |
| $J/\psi(1S) K_S^0$  | $( 1.92 \pm 0.14 )$                | $\times 10^{-5}$ |        | 1743 |
| $J/\psi(1S) \overline{K}^*(892)^0$  | $( 4.1 \pm 0.4 )$                  | $\times 10^{-5}$ |        | 1637 |
| $J/\psi(1S) \eta'$  | $( 3.3 \pm 0.4 )$                  | $\times 10^{-4}$ |        | 1612 |
| $J/\psi(1S) \pi^+ \pi^-$  | $( 2.09 \pm 0.23 )$                | $\times 10^{-4}$ | S=1.3  | 1775 |
| $J/\psi(1S) f_0(500)$ , $f_0 \rightarrow$<br>$\pi^+ \pi^-$                | $< 4$                              | $\times 10^{-6}$ | CL=90% | —    |
| $J/\psi(1S) \rho$ , $\rho \rightarrow \pi^+ \pi^-$                        | $< 4$                              | $\times 10^{-6}$ | CL=90% | —    |
| $J/\psi(1S) f_0(980)$ , $f_0 \rightarrow$<br>$\pi^+ \pi^-$                | $( 1.28 \pm 0.18 )$                | $\times 10^{-4}$ | S=1.7  | —    |
| $J/\psi(1S) f_2(1270)$ , $f_2 \rightarrow$<br>$\pi^+ \pi^-$               | $( 1.1 \pm 0.4 )$                  | $\times 10^{-6}$ |        | —    |
| $J/\psi(1S) f_2(1270)_0$ , $f_2 \rightarrow$<br>$\pi^+ \pi^-$             | $( 7.5 \pm 1.8 )$                  | $\times 10^{-7}$ |        | —    |
| $J/\psi(1S) f_2(1270)_\parallel$ , $f_2 \rightarrow$<br>$\pi^+ \pi^-$     | $( 1.09 \pm 0.34 )$                | $\times 10^{-6}$ |        | —    |
| $J/\psi(1S) f_2(1270)_\perp$ , $f_2 \rightarrow$<br>$\pi^+ \pi^-$         | $( 1.3 \pm 0.8 )$                  | $\times 10^{-6}$ |        | —    |
| $J/\psi(1S) f_0(1370)$ , $f_0 \rightarrow$<br>$\pi^+ \pi^-$               | $( 4.5^+_{-4.0} )$                 | $\times 10^{-5}$ |        | —    |

|   |   |             |
|---|---|-------------|
| $J/\psi(1S) f_0(1500), f_0 \rightarrow \pi^+ \pi^-$           | $( 2.11 \pm_{-0.29}^{+0.40} ) \times 10^{-5}$ | —           |
| $J/\psi(1S) f_2'(1525)_0, f_2' \rightarrow \pi^+ \pi^-$       | $( 1.07 \pm 0.24 ) \times 10^{-6}$            | —           |
| $J/\psi(1S) f_2'(1525)_{  }, f_2' \rightarrow \pi^+ \pi^-$    | $( 1.3 \pm_{-0.9}^{+2.7} ) \times 10^{-7}$    | —           |
| $J/\psi(1S) f_2'(1525)_{\perp}, f_2' \rightarrow \pi^+ \pi^-$ | $( 5 \pm 4 ) \times 10^{-7}$                  | —           |
| $J/\psi(1S) f_0(1790), f_0 \rightarrow \pi^+ \pi^-$           | $( 5.0 \pm_{-1.1}^{+11.0} ) \times 10^{-6}$   | —           |
| $J/\psi(1S) \pi^+ \pi^-$ (nonresonant)                        | $( 1.8 \pm_{-0.4}^{+1.1} ) \times 10^{-5}$    | 1775        |
| $J/\psi(1S) \bar{K}^0 \pi^+ \pi^-$                            | $< 4.4 \times 10^{-5}$                        | CL=90% 1675 |
| $J/\psi(1S) K^+ K^-$  | $( 7.9 \pm 0.7 ) \times 10^{-4}$              | 1601        |
| $J/\psi(1S) K^0 K^- \pi^+ + \text{c.c.}$                      | $( 9.5 \pm 1.3 ) \times 10^{-4}$              | 1538        |
| $J/\psi(1S) \bar{K}^0 K^+ K^-$                                | $< 1.2 \times 10^{-5}$                        | CL=90% 1333 |
| $J/\psi(1S) f_2'(1525)$                                       | $( 2.6 \pm 0.6 ) \times 10^{-4}$              | 1310        |
| $J/\psi(1S) \rho \bar{\rho}$                                  | $( 3.6 \pm 0.4 ) \times 10^{-6}$              | 982         |
| $J/\psi(1S) \gamma$   | $< 7.3 \times 10^{-6}$                        | CL=90% 1790 |
| $J/\psi(1S) \pi^+ \pi^- \pi^+ \pi^-$                          | $( 7.8 \pm 1.0 ) \times 10^{-5}$              | 1731        |
| $J/\psi(1S) f_1(1285)$  | $( 7.2 \pm 1.4 ) \times 10^{-5}$              | 1460        |
| $\psi(2S) \eta$   | $( 3.3 \pm 0.9 ) \times 10^{-4}$              | 1338        |
| $\psi(2S) \eta'$  | $( 1.29 \pm 0.35 ) \times 10^{-4}$            | 1158        |
| $\psi(2S) \pi^+ \pi^-$  | $( 7.1 \pm 1.3 ) \times 10^{-5}$              | 1397        |
| $\psi(2S) \phi$   | $( 5.4 \pm 0.6 ) \times 10^{-4}$              | 1120        |
| $\psi(2S) K^- \pi^+$  | $( 3.1 \pm 0.4 ) \times 10^{-5}$              | 1310        |
| $\psi(2S) \bar{K}^*(892)^0$                                   | $( 3.3 \pm 0.5 ) \times 10^{-5}$              | 1196        |
| $\chi_{c1} \phi$  | $( 2.04 \pm 0.30 ) \times 10^{-4}$            | 1274        |
| $\chi_{c1}(3872) \phi$  | $( 1.1 \pm 0.4 ) \times 10^{-4}$              | 936         |
| $\pi^+ \pi^-$   | $( 7.0 \pm 1.0 ) \times 10^{-7}$              | 2680        |
| $\pi^0 \pi^0$   | $< 2.1 \times 10^{-4}$                        | CL=90% 2680 |
| $\eta \pi^0$  | $< 1.0 \times 10^{-3}$                        | CL=90% 2654 |
| $\eta \eta$   | $< 1.5 \times 10^{-3}$                        | CL=90% 2627 |
| $\rho^0 \rho^0$   | $< 3.20 \times 10^{-4}$                       | CL=90% 2569 |
| $\eta' \eta'$   | $( 3.3 \pm 0.7 ) \times 10^{-5}$              | 2507        |
| $\eta' \phi$  | $< 8.2 \times 10^{-7}$                        | CL=90% 2495 |
| $\phi f_0(980), f_0(980) \rightarrow \pi^+ \pi^-$             | $( 1.12 \pm 0.21 ) \times 10^{-6}$            | —           |
| $\phi f_2(1270), f_2(1270) \rightarrow \pi^+ \pi^-$           | $( 6.1 \pm_{-1.5}^{+1.8} ) \times 10^{-7}$    | —           |
| $\phi \rho^0$   | $( 2.7 \pm 0.8 ) \times 10^{-7}$              | 2526        |
| $\phi \pi^+ \pi^-$  | $( 3.5 \pm 0.5 ) \times 10^{-6}$              | 2579        |
| $\phi \phi$   | $( 1.87 \pm 0.15 ) \times 10^{-5}$            | 2482        |
| $\phi \phi \phi$  | $( 2.2 \pm 0.7 ) \times 10^{-6}$              | 2165        |
| $\pi^+ K^-$   | $( 5.8 \pm 0.7 ) \times 10^{-6}$              | 2659        |

|   |  |                                    |        |      |
|---|--|------------------------------------|--------|------|
| $K^+ K^-$                               |  | $( 2.66 \pm 0.22 ) \times 10^{-5}$ |        | 2638 |
| $K^0 \bar{K}^0$                         |  | $( 1.76 \pm 0.31 ) \times 10^{-5}$ |        | 2637 |
| $K^0 \pi^+ \pi^-$                       |  | $( 9.5 \pm 2.1 ) \times 10^{-6}$   |        | 2653 |
| $K^0 K^\pm \pi^\mp$                     |  | $( 8.4 \pm 0.9 ) \times 10^{-5}$   |        | 2622 |
| $K^*(892)^- \pi^+$                      |  | $( 2.9 \pm 1.1 ) \times 10^{-6}$   |        | 2607 |
| $K^*(892)^\pm K^\mp$                    |  | $( 1.9 \pm 0.5 ) \times 10^{-5}$   |        | 2585 |
| $K_0^*(1430)^\pm K^\mp$                 |  | $( 3.1 \pm 2.5 ) \times 10^{-5}$   |        | —    |
| $K_2^*(1430)^\pm K^\mp$                 |  | $( 1.0 \pm 1.7 ) \times 10^{-5}$   |        | —    |
| $K^*(892)^0 \bar{K}^0 + \text{c.c.}$    |  | $( 2.0 \pm 0.6 ) \times 10^{-5}$   |        | 2585 |
| $K_0^*(1430) \bar{K}^0 + \text{c.c.}$   |  | $( 3.3 \pm 1.0 ) \times 10^{-5}$   |        | 2468 |
| $K_2^*(1430)^0 \bar{K}^0 + \text{c.c.}$ |  | $( 1.7 \pm 2.2 ) \times 10^{-5}$   |        | 2467 |
| $K_S^0 \bar{K}^*(892)^0 + \text{c.c.}$  |  | $( 1.6 \pm 0.4 ) \times 10^{-5}$   |        | 2585 |
| $K^0 K^+ K^-$                           |  | $( 1.3 \pm 0.6 ) \times 10^{-6}$   |        | 2568 |
| $\bar{K}^*(892)^0 \rho^0$               |  | $< 7.67 \times 10^{-4}$            | CL=90% | 2550 |
| $\bar{K}^*(892)^0 K^*(892)^0$           |  | $( 1.11 \pm 0.27 ) \times 10^{-5}$ |        | 2531 |
| $\phi K^*(892)^0$                       |  | $( 1.14 \pm 0.30 ) \times 10^{-6}$ |        | 2507 |
| $p \bar{p}$                             |  | $< 1.5 \times 10^{-8}$             | CL=90% | 2514 |
| $p \bar{p} K^+ K^-$                     |  | $( 4.5 \pm 0.5 ) \times 10^{-6}$   |        | 2231 |
| $p \bar{p} K^+ \pi^-$                   |  | $( 1.39 \pm 0.26 ) \times 10^{-6}$ |        | 2355 |
| $p \bar{p} \pi^+ \pi^-$                 |  | $( 4.3 \pm 2.0 ) \times 10^{-7}$   |        | 2454 |
| $p \bar{\Lambda} K^- + \text{c.c.}$     |  | $( 5.5 \pm 1.0 ) \times 10^{-6}$   |        | 2358 |
| $\Lambda_c^- \Lambda \pi^+$             |  | $( 3.6 \pm 1.6 ) \times 10^{-4}$   |        | 1979 |
| $\Lambda_c^- \Lambda_c^+$               |  | $< 8.0 \times 10^{-5}$             | CL=95% | 1405 |

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

|   |          |                                  |        |      |
|---|----------|----------------------------------|--------|------|
| $\gamma \gamma$   | B1       | $< 3.1 \times 10^{-6}$           | CL=90% | 2683 |
| $\phi \gamma$   | B1       | $( 3.4 \pm 0.4 ) \times 10^{-5}$ |        | 2587 |
| $\mu^+ \mu^-$   | B1       | $( 2.9 \pm 0.4 ) \times 10^{-9}$ |        | 2681 |
| $e^+ e^-$   | B1       | $< 9.4 \times 10^{-9}$           | CL=90% | 2683 |
| $\tau^+ \tau^-$   | B1       | $< 6.8 \times 10^{-3}$           | CL=95% | 2011 |
| $\mu^+ \mu^- \mu^+ \mu^-$                                       | B1       | $< 2.5 \times 10^{-9}$           | CL=95% | 2673 |
| $SP, S \rightarrow \mu^+ \mu^-,$<br>$P \rightarrow \mu^+ \mu^-$ | B1 [xxx] | $< 2.2 \times 10^{-9}$           | CL=95% | —    |
| $\phi(1020) \mu^+ \mu^-$  | B1       | $( 8.2 \pm 1.2 ) \times 10^{-7}$ |        | 2582 |
| $\bar{K}^*(892)^0 \mu^+ \mu^-$                                  | B1       | $( 2.9 \pm 1.1 ) \times 10^{-8}$ |        | 2605 |
| $\pi^+ \pi^- \mu^+ \mu^-$                                       | B1       | $( 8.4 \pm 1.7 ) \times 10^{-8}$ |        | 2670 |
| $\phi \nu \bar{\nu}$  | B1       | $< 5.4 \times 10^{-3}$           | CL=90% | 2587 |
| $e^\pm \mu^\mp$   | LF [aa]  | $< 5.4 \times 10^{-9}$           | CL=90% | 2682 |
| $\mu^\pm \tau^\mp$  | LF       | $< 4.2 \times 10^{-5}$           | CL=95% | 2388 |

**$B_s^*$** 

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

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

$$\text{Mass } m = 5415.4^{+1.8}_{-1.5} \text{ MeV} \quad (S = 2.9)$$

$$m_{B_s^*} - m_{B_s} = 48.6^{+1.8}_{-1.5} \text{ MeV} \quad (S = 2.9)$$

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

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

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

$I, J, P$  need confirmation.

$$\text{Mass } m = 5828.70 \pm 0.20 \text{ MeV}$$

$$m_{B_{s1}^0} - m_{B^{*+}} = 504.00 \pm 0.17 \text{ MeV}$$

$$\text{Full width } \Gamma = 0.5 \pm 0.4 \text{ MeV}$$

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

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

$$I(J^P) = 0(2^+)$$

$I, J, P$  need confirmation.

$$\text{Mass } m = 5839.86 \pm 0.12 \text{ MeV}$$

$$m_{B_{s2}^{*0}} - m_{B^+} = 560.52 \pm 0.14 \text{ MeV}$$

$$\text{Full width } \Gamma = 1.49 \pm 0.27 \text{ MeV}$$

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



# BOTTOM, CHARMED MESONS

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

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

### $B_c^+$

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

Quantum numbers shown are quark-model predictions.

Mass  $m = 6274.47 \pm 0.32$  MeV

Mean life  $\tau = (0.510 \pm 0.009) \times 10^{-12}$  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 | $P$<br>(MeV/c) |
|---|--------------------------------|------------------|----------------|
|---|--------------------------------|------------------|----------------|

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      | $(8.2 \pm 1.3) \times 10^{-5}$       |     | —    |
| $J/\psi(1S) \pi^+$                         | seen                                 |     | 2370 |
| $J/\psi(1S) K^+$                           | seen                                 |     | 2341 |
| $J/\psi(1S) \pi^+ \pi^+ \pi^-$             | seen                                 |     | 2350 |
| $J/\psi(1S) a_1(1260)$                     | $< 1.2 \times 10^{-3}$               | 90% | 2169 |
| $J/\psi(1S) K^+ K^- \pi^+$                 | seen                                 |     | 2203 |
| $J/\psi(1S) \pi^+ \pi^+ \pi^+ \pi^- \pi^-$ | seen                                 |     | 2309 |
| $\psi(2S) \pi^+$                           | seen                                 |     | 2051 |
| $J/\psi(1S) D^0 K^+$                       | seen                                 |     | 1539 |
| $J/\psi(1S) D^*(2007)^0 K^+$               | seen                                 |     | 1411 |
| $J/\psi(1S) D^*(2010)^+ K^{*0}$            | seen                                 |     | 919  |
| $J/\psi(1S) D^+ K^{*0}$                    | seen                                 |     | 1122 |
| $J/\psi(1S) D_s^+$                         | seen                                 |     | 1821 |
| $J/\psi(1S) D_s^{*+}$                      | seen                                 |     | 1727 |
| $J/\psi(1S) \rho \bar{p} \pi^+$            | seen                                 |     | 1791 |
| $\chi_c^0 \pi^+$                           | $(2.4^{+0.9}_{-0.8}) \times 10^{-5}$ |     | 2205 |
| $\rho \bar{p} \pi^+$                       | not seen                             |     | 2970 |
| $D^0 K^+$                                  | $(3.8^{+1.2}_{-1.1}) \times 10^{-7}$ |     | 2837 |
| $D^0 \pi^+$                                | $< 1.6 \times 10^{-7}$               | 95% | 2858 |
| $D^{*0} \pi^+$                             | $< 4 \times 10^{-7}$                 | 95% | 2814 |
| $D^{*0} K^+$                               | $< 4 \times 10^{-7}$                 | 95% | 2792 |

|  |   |                  |     |      |
|--|---|------------------|-----|------|
| $D_s^+ \bar{D}^0$                          | $< 1.4$                                 | $\times 10^{-7}$ | 90% | 2483 |
| $D_s^+ D^0$                                | $< 6$                                   | $\times 10^{-8}$ | 90% | 2483 |
| $D^+ \bar{D}^0$                            | $< 3.0$                                 | $\times 10^{-6}$ | 90% | 2521 |
| $D^+ D^0$                                  | $< 1.9$                                 | $\times 10^{-6}$ | 90% | 2521 |
| $D^*(2010)^+ \bar{D}^0$                    | $< 6.2$                                 | $\times 10^{-3}$ | 90% | 2467 |
| $D_s^{*+} \bar{D}^*(2007)^0$               | $< 1.7$                                 | $\times 10^{-6}$ | 90% | 2366 |
| $D_s^{*+} D^*(2007)^0$                     | $< 3.1$                                 | $\times 10^{-6}$ | 90% | 2366 |
| $D^*(2010)^+ \bar{D}^*(2007)^0$            | $< 1.0$                                 | $\times 10^{-4}$ | 90% | 2410 |
| $D^*(2010)^+ D^*(2007)^0$                  | $< 2.0$                                 | $\times 10^{-5}$ | 90% | 2410 |
| $D^+ K^{*0}$                               | $< 0.20$                                | $\times 10^{-6}$ | 90% | 2783 |
| $D^+ \bar{K}^{*0}$                         | $< 0.16$                                | $\times 10^{-6}$ | 90% | 2783 |
| $D_s^+ K^{*0}$                             | $< 0.28$                                | $\times 10^{-6}$ | 90% | 2751 |
| $D_s^+ \bar{K}^{*0}$                       | $< 0.4$                                 | $\times 10^{-6}$ | 90% | 2751 |
| $D_s^+ \phi$                               | $< 0.32$                                | $\times 10^{-6}$ | 90% | 2727 |
| $K^+ K^0$                                  | $< 4.6$                                 | $\times 10^{-7}$ | 90% | 3098 |
| $B_s^0 \pi^+ / B(\bar{b} \rightarrow B_s)$ | $(2.37^{+0.37}_{-0.35}) \times 10^{-3}$ |                  |     | –    |

**$B_c(2S)^\pm$**

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

Mass  $m = 6871.2 \pm 1.0$  MeV

| <b><math>B_c(2S)^\pm</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|---|--------------------------------|-------------|
| $B_c^+ \pi^+ \pi^-$                         | seen                           | 504         |

## $c\bar{c}$ MESONS (including possibly non- $q\bar{q}$ states)

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

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

Mass  $m = 2983.9 \pm 0.4$  MeV ( $S = 1.2$ )

Full width  $\Gamma = 32.0 \pm 0.7$  MeV

| <b><math>\eta_c(1S)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ ) | Confidence level ( $\frac{p}{\text{MeV/c}}$ ) |
|--|--------------------------------|---|
|--|--------------------------------|---|

### Decays involving hadronic resonances

|                                      |                     |      |
|--------------------------------------|---------------------|------|
| $\eta'(958) \pi \pi$                 | ( 4.1 $\pm$ 1.7 ) % | 1323 |
| $\rho \rho$                          | ( 1.8 $\pm$ 0.5 ) % | 1275 |
| $K^*(892)^0 K^- \pi^+ + \text{c.c.}$ | ( 2.0 $\pm$ 0.7 ) % | 1278 |

|  |                                    |     |      |
|--|------------------------------------|-----|------|
| $K^*(892)\bar{K}^*(892)$               | $( 6.9 \pm 1.3 ) \times 10^{-3}$   |     | 1196 |
| $K^*(892)^0\bar{K}^*(892)^0\pi^+\pi^-$ | $( 1.1 \pm 0.5 ) \%$               |     | 1073 |
| $\phi K^+ K^-$                         | $( 2.9 \pm 1.4 ) \times 10^{-3}$   |     | 1104 |
| $\phi\phi$                             | $( 1.74 \pm 0.19 ) \times 10^{-3}$ |     | 1089 |
| $\phi 2(\pi^+\pi^-)$                   | $< 4 \times 10^{-3}$               | 90% | 1251 |
| $a_0(980)\pi$                          | $< 2 \%$                           | 90% | 1327 |
| $a_2(1320)\pi$                         | $< 2 \%$                           | 90% | 1196 |
| $K^*(892)\bar{K} + \text{c.c.}$        | $< 1.28 \%$                        | 90% | 1310 |
| $f_2(1270)\eta$                        | $< 1.1 \%$                         | 90% | 1145 |
| $\omega\omega$                         | $( 2.9 \pm 0.8 ) \times 10^{-3}$   |     | 1270 |
| $\omega\phi$                           | $< 2.5 \times 10^{-4}$             | 90% | 1185 |
| $f_2(1270)f_2(1270)$                   | $( 9.8 \pm 2.5 ) \times 10^{-3}$   |     | 774  |
| $f_2(1270)f_2'(1525)$                  | $( 9.5 \pm 3.2 ) \times 10^{-3}$   |     | 524  |
| $f_0(980)\eta$                         | seen                               |     | 1264 |
| $f_0(1500)\eta$                        | seen                               |     | 1025 |
| $f_0(2200)\eta$                        | seen                               |     | 498  |
| $a_0(980)\pi$                          | seen                               |     | 1327 |
| $a_0(1320)\pi$                         | seen                               |     | —    |
| $a_0(1450)\pi$                         | seen                               |     | 1123 |
| $a_0(1950)\pi$                         | seen                               |     | 860  |
| $K_0^*(1430)\bar{K}$                   | seen                               |     | —    |
| $K_2^*(1430)\bar{K}$                   | seen                               |     | —    |
| $K_0^*(1950)\bar{K}$                   | seen                               |     | —    |

### Decays into stable hadrons

|  |                                    |     |      |
|--|------------------------------------|-----|------|
| $K\bar{K}\pi$                              | $( 7.3 \pm 0.4 ) \%$               |     | 1381 |
| $K\bar{K}\eta$                             | $( 1.36 \pm 0.15 ) \%$             |     | 1265 |
| $\eta\pi^+\pi^-$                           | $( 1.7 \pm 0.6 ) \%$               |     | 1428 |
| $\eta 2(\pi^+\pi^-)$                       | $( 4.4 \pm 1.6 ) \%$               |     | 1386 |
| $K^+K^-\pi^+\pi^-$                         | $( 6.6 \pm 1.1 ) \times 10^{-3}$   |     | 1345 |
| $K^+K^-\pi^+\pi^-\pi^0$                    | $( 3.5 \pm 0.6 ) \%$               |     | 1304 |
| $K^0K^-\pi^+\pi^-\pi^+ + \text{c.c.}$      | $( 5.6 \pm 1.9 ) \%$               |     | —    |
| $K^+K^- 2(\pi^+\pi^-)$                     | $( 7.5 \pm 2.4 ) \times 10^{-3}$   |     | 1254 |
| $2(K^+K^-)$                                | $( 1.43 \pm 0.30 ) \times 10^{-3}$ |     | 1056 |
| $\pi^+\pi^-\pi^0$                          | $< 5 \times 10^{-4}$               | 90% | 1476 |
| $\pi^+\pi^-\pi^0\pi^0$                     | $( 4.7 \pm 1.4 ) \%$               |     | 1460 |
| $2(\pi^+\pi^-)$                            | $( 9.1 \pm 1.2 ) \times 10^{-3}$   |     | 1459 |
| $2(\pi^+\pi^-\pi^0)$                       | $( 15.8 \pm 2.3 ) \%$              |     | 1409 |
| $3(\pi^+\pi^-)$                            | $( 1.7 \pm 0.4 ) \%$               |     | 1407 |
| $p\bar{p}$                                 | $( 1.44 \pm 0.14 ) \times 10^{-3}$ |     | 1160 |
| $p\bar{p}\pi^0$                            | $( 3.6 \pm 1.5 ) \times 10^{-3}$   |     | 1101 |
| $\Lambda\bar{\Lambda}$                     | $( 1.06 \pm 0.23 ) \times 10^{-3}$ |     | 991  |
| $K^+\bar{p}\Lambda + \text{c.c.}$          | $( 2.5 \pm 0.4 ) \times 10^{-3}$   |     | 772  |
| $\bar{\Lambda}(1520)\Lambda + \text{c.c.}$ | $( 3.1 \pm 1.3 ) \times 10^{-3}$   |     | 694  |

|                           |                                  |      |
|---------------------------|----------------------------------|------|
| $\Sigma^+ \bar{\Sigma}^-$ | $( 2.1 \pm 0.6 ) \times 10^{-3}$ | 901  |
| $\Xi^- \bar{\Xi}^+$       | $( 9.0 \pm 2.6 ) \times 10^{-4}$ | 692  |
| $\pi^+ \pi^- p \bar{p}$   | $( 5.3 \pm 2.1 ) \times 10^{-3}$ | 1027 |

**Radiative decays**

|                |                                    |      |
|----------------|------------------------------------|------|
| $\gamma\gamma$ | $( 1.61 \pm 0.12 ) \times 10^{-4}$ | 1492 |
|----------------|------------------------------------|------|

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

|               |               |                  |     |      |
|---------------|---------------|------------------|-----|------|
| $\pi^+ \pi^-$ | $P, CP < 1.1$ | $\times 10^{-4}$ | 90% | 1485 |
| $\pi^0 \pi^0$ | $P, CP < 4$   | $\times 10^{-5}$ | 90% | 1486 |
| $K^+ K^-$     | $P, CP < 6$   | $\times 10^{-4}$ | 90% | 1408 |
| $K_S^0 K_S^0$ | $P, CP < 3.1$ | $\times 10^{-4}$ | 90% | 1407 |

**J/ψ(1S)**

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

Mass  $m = 3096.900 \pm 0.006$  MeV

Full width  $\Gamma = 92.6 \pm 1.7$  keV (S = 1.1)

| <b>J/ψ(1S) DECAY MODES</b>           | Fraction ( $\Gamma_i/\Gamma$ )          | Scale factor/<br>Confidence level (MeV/c) | $p$  |
|--------------------------------------|---|---|------|
| hadrons                              | $(87.7 \pm 0.5) \%$                     |   | —    |
| virtual $\gamma \rightarrow$ hadrons | $(13.50 \pm 0.30) \%$                   |   | —    |
| $g g g$                              | $(64.1 \pm 1.0) \%$                     |   | —    |
| $\gamma g g$                         | $( 8.8 \pm 1.1 ) \%$                    |   | —    |
| $e^+ e^-$                            | $( 5.971 \pm 0.032 ) \%$                |   | 1548 |
| $e^+ e^- \gamma$                     | [hhaa] $( 8.8 \pm 1.4 ) \times 10^{-3}$ |   | 1548 |
| $\mu^+ \mu^-$                        | $( 5.961 \pm 0.033 ) \%$                |   | 1545 |

**Decays involving hadronic resonances**

|  |                                  |       |      |
|--|----------------------------------|-------|------|
| $\rho\pi$  | $( 1.69 \pm 0.15 ) \%$           | S=2.4 | 1448 |
| $\rho^0 \pi^0$   | $( 5.6 \pm 0.7 ) \times 10^{-3}$ |       | 1448 |
| $\rho(770)^\mp K^\pm K_S^0$                                    | $( 1.9 \pm 0.4 ) \times 10^{-3}$ |       | —    |
| $\rho(1450)\pi \rightarrow \pi^+ \pi^- \pi^0$                  | $( 2.3 \pm 0.7 ) \times 10^{-3}$ |       | —    |
| $\rho(1450)^\pm \pi^\mp \rightarrow K_S^0 K^\pm \pi^\mp$       | $( 3.5 \pm 0.6 ) \times 10^{-4}$ |       | —    |
| $\rho(1450)^0 \pi^0 \rightarrow K^+ K^- \pi^0$                 | $( 2.7 \pm 0.6 ) \times 10^{-4}$ |       | —    |
| $\rho(1450)\eta'(958) \rightarrow$<br>$\pi^+ \pi^- \eta'(958)$ | $( 3.3 \pm 0.7 ) \times 10^{-6}$ |       | —    |
| $\rho(1700)\pi \rightarrow \pi^+ \pi^- \pi^0$                  | $( 1.7 \pm 1.1 ) \times 10^{-4}$ |       | —    |
| $\rho(2150)\pi \rightarrow \pi^+ \pi^- \pi^0$                  | $( 8 \pm 40 ) \times 10^{-6}$    |       | —    |
| $a_2(1320)\rho$  | $( 1.09 \pm 0.22 ) \%$           |       | 1123 |
| $\omega \pi^+ \pi^+ \pi^- \pi^-$                               | $( 8.5 \pm 3.4 ) \times 10^{-3}$ |       | 1392 |
| $\omega \pi^+ \pi^- \pi^0$                                     | $( 4.0 \pm 0.7 ) \times 10^{-3}$ |       | 1418 |
| $\omega \pi^+ \pi^-$   | $( 7.2 \pm 1.0 ) \times 10^{-3}$ |       | 1435 |
| $\omega f_2(1270)$   | $( 4.3 \pm 0.6 ) \times 10^{-3}$ |       | 1142 |

|  |  |            |
|--|--|------------|
| $K^*(892)^0 \bar{K}^*(892)^0$  | $( 2.3 \pm 0.6 ) \times 10^{-4}$             | 1266       |
| $K^*(892)^\pm K^*(892)^\mp$  | $( 1.00 \pm_{-0.40}^{0.22} ) \times 10^{-3}$ | 1266       |
| $K^*(892)^\pm K^*(700)^\mp$  | $( 1.1 \pm_{-0.6}^{1.0} ) \times 10^{-3}$    | —          |
| $K_S^0 \pi^- K^*(892)^+ + \text{c.c.}$   | $( 2.0 \pm 0.5 ) \times 10^{-3}$             | 1342       |
| $K_S^0 \pi^- K^*(892)^+ + \text{c.c.} \rightarrow$<br>$K_S^0 K_S^0 \pi^+ \pi^-$                    | $( 6.7 \pm 2.2 ) \times 10^{-4}$             | —          |
| $K_S^0 K^*(892)^0 \rightarrow \gamma K_S^0 K_S^0$  | $( 6.3 \pm_{-0.5}^{0.6} ) \times 10^{-6}$    | —          |
| $K_2^*(1430)^+ K^- + \text{c.c.} \rightarrow$<br>$K^+ K^- \pi^0$                                   | $( 2.69 \pm_{-0.19}^{0.25} ) \times 10^{-4}$ | —          |
| $K_2^*(1980)^+ K^- + \text{c.c.} \rightarrow$<br>$K^+ K^- \pi^0$                                   | $( 1.10 \pm_{-0.14}^{0.60} ) \times 10^{-5}$ | —          |
| $K_4^*(2045)^+ K^- + \text{c.c.} \rightarrow$<br>$K^+ K^- \pi^0$                                   | $( 6.2 \pm_{-1.6}^{2.9} ) \times 10^{-6}$    | —          |
| $\eta K^*(892)^0 \bar{K}^*(892)^0$   | $( 1.15 \pm 0.26 ) \times 10^{-3}$           | 1003       |
| $\eta' K^{*\pm} K^\mp$   | $( 1.48 \pm 0.13 ) \times 10^{-3}$           | —          |
| $\eta' K^{*0} \bar{K}^0 + \text{c.c.}$   | $( 1.66 \pm 0.21 ) \times 10^{-3}$           | 1000       |
| $\eta' h_1(1415) \rightarrow \eta' K^* \bar{K} + \text{c.c.}$                                      | $( 2.16 \pm 0.31 ) \times 10^{-4}$           | —          |
| $\eta' h_1(1415) \rightarrow \eta' K^{*\pm} K^\mp$   | $( 1.51 \pm 0.23 ) \times 10^{-4}$           | —          |
| $K^*(1410) \bar{K} + \text{c.c.} \rightarrow$<br>$K^\pm K^\mp \pi^0$                               | $( 7 \pm 4 ) \times 10^{-5}$                 | —          |
| $K^*(1410) \bar{K} + \text{c.c.} \rightarrow$<br>$K_S^0 K^\pm \pi^\mp$                             | $( 8 \pm 6 ) \times 10^{-5}$                 | —          |
| $K_2^*(1430) \bar{K} + \text{c.c.} \rightarrow$<br>$K^\pm K^\mp \pi^0$                             | $( 1.0 \pm 0.5 ) \times 10^{-4}$             | —          |
| $K_2^*(1430) \bar{K} + \text{c.c.} \rightarrow$<br>$K_S^0 K^\pm \pi^\mp$                           | $( 4.0 \pm 1.0 ) \times 10^{-4}$             | —          |
| $K^*(892)^0 \bar{K}_2^*(1430)^0 + \text{c.c.}$   | $( 4.67 \pm 0.29 ) \times 10^{-3}$           | 1011       |
| $K^*(892)^+ K_2^*(1430)^- + \text{c.c.}$   | $( 3.4 \pm 2.9 ) \times 10^{-3}$             | 1011       |
| $K^*(892)^+ K_2^*(1430)^- + \text{c.c.} \rightarrow$<br>$K^*(892)^+ K_S^0 \pi^- + \text{c.c.}$     | $( 4 \pm 4 ) \times 10^{-4}$                 | —          |
| $K^*(892)^0 \bar{K}_2^*(1770)^0 + \text{c.c.} \rightarrow$<br>$K^*(892)^0 K^- \pi^+ + \text{c.c.}$ | $( 6.9 \pm 0.9 ) \times 10^{-4}$             | —          |
| $\omega K^*(892) \bar{K} + \text{c.c.}$  | $( 6.1 \pm 0.9 ) \times 10^{-3}$             | 1097       |
| $\bar{K} K^*(892) + \text{c.c.} \rightarrow$<br>$K_S^0 K^\pm \pi^\mp$                              | $( 5.0 \pm 0.5 ) \times 10^{-3}$             | —          |
| $K^+ K^*(892)^- + \text{c.c.}$   | $( 6.0 \pm_{-1.0}^{0.8} ) \times 10^{-3}$    | S=2.9 1373 |
| $K^+ K^*(892)^- + \text{c.c.} \rightarrow$<br>$K^+ K^- \pi^0$                                      | $( 2.69 \pm_{-0.20}^{0.13} ) \times 10^{-3}$ | —          |
| $K^+ K^*(892)^- + \text{c.c.} \rightarrow$<br>$K^0 K^\pm \pi^\mp + \text{c.c.}$                    | $( 3.0 \pm 0.4 ) \times 10^{-3}$             | —          |

|  |      |                                  |            |
|--|------|----------------------------------|------------|
| $K^0 \bar{K}^*(892)^0 + \text{c.c.}$                   |      | $(4.2 \pm 0.4) \times 10^{-3}$   | 1373       |
| $K^0 \bar{K}^*(892)^0 + \text{c.c.} \rightarrow$       |      | $(3.2 \pm 0.4) \times 10^{-3}$   | –          |
| $K^0 K^\pm \pi^\mp + \text{c.c.}$                      |      |                                  |            |
| $K_1(1400)^\pm K^\mp$                                  |      | $(3.8 \pm 1.4) \times 10^{-3}$   | 1170       |
| $\bar{K}^*(892)^0 K^+ \pi^- + \text{c.c.}$             |      | $(7.7 \pm 1.6) \times 10^{-3}$   | 1343       |
| $K^*(892)^\pm K^\mp \pi^0$                             |      | $(4.1 \pm 1.3) \times 10^{-3}$   | 1344       |
| $K^*(892)^0 K_S^0 \pi^0$                               |      | $(7 \pm 4) \times 10^{-4}$       | 1343       |
| $\omega \pi^0 \pi^0$                                   |      | $(3.4 \pm 0.8) \times 10^{-3}$   | 1436       |
| $\omega \pi^0 \eta$                                    |      | $(3.4 \pm 1.7) \times 10^{-4}$   | 1363       |
| $b_1(1235)^\pm \pi^\mp$                                | [aa] | $(3.0 \pm 0.5) \times 10^{-3}$   | 1300       |
| $\omega K^\pm K_S^0 \pi^\mp$                           | [aa] | $(3.4 \pm 0.5) \times 10^{-3}$   | 1210       |
| $b_1(1235)^0 \pi^0$                                    |      | $(2.3 \pm 0.6) \times 10^{-3}$   | 1300       |
| $\eta K^\pm K_S^0 \pi^\mp$                             | [aa] | $(2.2 \pm 0.4) \times 10^{-3}$   | 1278       |
| $\phi K^*(892) \bar{K} + \text{c.c.}$                  |      | $(2.18 \pm 0.23) \times 10^{-3}$ | 969        |
| $\omega K \bar{K}$                                     |      | $(1.9 \pm 0.4) \times 10^{-3}$   | 1268       |
| $\omega f_0(1710) \rightarrow \omega K \bar{K}$        |      | $(4.8 \pm 1.1) \times 10^{-4}$   | 878        |
| $\phi 2(\pi^+ \pi^-)$                                  |      | $(1.60 \pm 0.32) \times 10^{-3}$ | 1318       |
| $\Delta(1232)^{++} \bar{p} \pi^-$                      |      | $(1.6 \pm 0.5) \times 10^{-3}$   | 1030       |
| $\omega \eta$  |      | $(1.74 \pm 0.20) \times 10^{-3}$ | S=1.6 1394 |
| $\omega \eta' \pi^+ \pi^-$                             |      | $(1.12 \pm 0.13) \times 10^{-3}$ | 1173       |
| $\phi K \bar{K}$                                       |      | $(1.77 \pm 0.16) \times 10^{-3}$ | S=1.3 1179 |
| $\phi K_S^0 K_S^0$                                     |      | $(5.9 \pm 1.5) \times 10^{-4}$   | 1176       |
| $\phi f_0(1710) \rightarrow \phi K \bar{K}$            |      | $(3.6 \pm 0.6) \times 10^{-4}$   | 875        |
| $\phi K^+ K^-$   |      | $(8.3 \pm 1.1) \times 10^{-4}$   | 1179       |
| $\phi f_2(1270)$                                       |      | $(3.2 \pm 0.6) \times 10^{-4}$   | 1036       |
| $\Delta(1232)^{++} \bar{\Delta}(1232)^{--}$            |      | $(1.10 \pm 0.29) \times 10^{-3}$ | 938        |
| $\Sigma(1385)^- \bar{\Sigma}(1385)^+ (\text{or c.c.})$ | [aa] | $(1.16 \pm 0.05) \times 10^{-3}$ | 697        |
| $\Sigma(1385)^0 \bar{\Sigma}(1385)^0$                  |      | $(1.07 \pm 0.08) \times 10^{-3}$ | 697        |
| $K^+ K^- f_2'(1525)$                                   |      | $(1.06 \pm 0.35) \times 10^{-3}$ | 897        |
| $\phi f_2'(1525)$                                      |      | $(8 \pm 4) \times 10^{-4}$       | S=2.7 877  |
| $\phi \pi^+ \pi^-$                                     |      | $(9.4 \pm 1.5) \times 10^{-4}$   | S=1.7 1365 |
| $\phi \pi^0 \pi^0$                                     |      | $(5.0 \pm 1.0) \times 10^{-4}$   | 1366       |
| $\phi K^\pm K_S^0 \pi^\mp$                             | [aa] | $(7.2 \pm 0.8) \times 10^{-4}$   | 1114       |
| $\omega f_1(1420)$                                     |      | $(6.8 \pm 2.4) \times 10^{-4}$   | 1062       |
| $\phi \eta$  |      | $(7.4 \pm 0.8) \times 10^{-4}$   | S=1.5 1320 |
| $\Xi^0 \Xi^0$  |      | $(1.17 \pm 0.04) \times 10^{-3}$ | 818        |
| $\Xi(1530)^- \bar{\Xi}^+ + \text{c.c.}$                |      | $(3.18 \pm 0.08) \times 10^{-4}$ | 600        |
| $p K^- \bar{\Sigma}(1385)^0$                           |      | $(5.1 \pm 3.2) \times 10^{-4}$   | 646        |
| $\omega \pi^0$   |      | $(4.5 \pm 0.5) \times 10^{-4}$   | S=1.4 1446 |
| $\omega \pi^0 \rightarrow \pi^+ \pi^- \pi^0$           |      | $(1.7 \pm 0.8) \times 10^{-5}$   | –          |
| $\phi \eta'(958)$                                      |      | $(4.6 \pm 0.5) \times 10^{-4}$   | S=2.2 1192 |
| $\phi f_0(980)$  |      | $(3.2 \pm 0.9) \times 10^{-4}$   | S=1.9 1178 |
| $\phi f_0(980) \rightarrow \phi \pi^+ \pi^-$           |      | $(2.60 \pm 0.34) \times 10^{-4}$ | –          |
| $\phi f_0(980) \rightarrow \phi \pi^0 \pi^0$           |      | $(1.8 \pm 0.5) \times 10^{-4}$   | –          |

|   |      |  |        |      |
|---|------|--|--------|------|
| $\phi\eta\eta'$   |      | $(2.32 \pm 0.17) \times 10^{-4}$         |        | 885  |
| $\phi\pi^0 f_0(980) \rightarrow \phi\pi^0\pi^+\pi^-$                            |      | $(4.5 \pm 1.0) \times 10^{-6}$           |        | —    |
| $\phi\pi^0 f_0(980) \rightarrow \phi\pi^0\rho^0\pi^0$                           |      | $(1.7 \pm 0.6) \times 10^{-6}$           |        | 1045 |
| $\eta\phi f_0(980) \rightarrow \eta\phi\pi^+\pi^-$                              |      | $(3.2 \pm 1.0) \times 10^{-4}$           |        | —    |
| $\phi a_0(980)^0 \rightarrow \phi\eta\pi^0$                                     |      | $(4.4 \pm 1.4) \times 10^{-6}$           |        | —    |
| $\Xi(1530)^0 \Xi^0$   |      | $(3.2 \pm 1.4) \times 10^{-4}$           |        | 608  |
| $\Sigma(1385)^- \bar{\Sigma}^+$ (or c.c.)                                       | [aa] | $(3.1 \pm 0.5) \times 10^{-4}$           |        | 855  |
| $\phi f_1(1285)$  |      | $(2.6 \pm 0.5) \times 10^{-4}$           |        | 1032 |
| $\phi f_1(1285) \rightarrow$  |      | $(9.4 \pm 2.8) \times 10^{-7}$           |        | 952  |
| $\phi\pi^0 f_0(980) \rightarrow$  |      |  |        |      |
| $\phi\pi^0\pi^+\pi^-$   |      |  |        |      |
| $\phi f_1(1285) \rightarrow$  |      | $(2.1 \pm 2.2) \times 10^{-7}$           |        | 955  |
| $\phi\pi^0 f_0(980) \rightarrow$  |      |  |        |      |
| $\phi\pi^0\pi^0\pi^0$   |      |  |        |      |
| $\eta\pi^+\pi^-$  |      | $(3.8 \pm 0.7) \times 10^{-4}$           |        | 1487 |
| $\eta\rho$  |      | $(1.93 \pm 0.23) \times 10^{-4}$         |        | 1396 |
| $\omega\eta'(958)$  |      | $(1.89 \pm 0.18) \times 10^{-4}$         |        | 1279 |
| $\omega f_0(980)$   |      | $(1.4 \pm 0.5) \times 10^{-4}$           |        | 1267 |
| $\rho\eta'(958)$  |      | $(8.1 \pm 0.8) \times 10^{-5}$           | S=1.6  | 1281 |
| $a_2(1320)^\pm\pi^\mp$  | [aa] | $< 4.3 \times 10^{-3}$                   | CL=90% | 1263 |
| $K\bar{K}_2^*(1430)^+$ c.c.   |      | $< 4.0 \times 10^{-3}$                   | CL=90% | 1158 |
| $K_1(1270)^\pm K^\mp$   |      | $< 3.0 \times 10^{-3}$                   | CL=90% | 1240 |
| $K_1(1270)K_S^0 \rightarrow \gamma K_S^0 K_S^0$                                 |      | $(8.5 \pm 2.5) \times 10^{-7}$           |        | —    |
| $K_S^0\pi^- K_2^*(1430)^+ +$ c.c.   |      | $(3.6 \pm 1.8) \times 10^{-3}$           |        | 1116 |
| $K_2^*(1430)^0 \bar{K}_2^*(1430)^0$   |      | $< 2.9 \times 10^{-3}$                   | CL=90% | 601  |
| $\phi\pi^0$   |      | $3 \times 10^{-6}$ or $1 \times 10^{-7}$ |        | 1377 |
| $\phi\eta(1405) \rightarrow \phi\eta\pi^+\pi^-$                                 |      | $(2.0 \pm 1.0) \times 10^{-5}$           |        | 946  |
| $\omega f_2'(1525)$   |      | $< 2.2 \times 10^{-4}$                   | CL=90% | 1007 |
| $\omega X(1835) \rightarrow \omega p\bar{p}$                                    |      | $< 3.9 \times 10^{-6}$                   | CL=95% | —    |
| $\omega X(1835), X \rightarrow \eta'\pi^+\pi^-$                                 |      | $< 6.2 \times 10^{-5}$                   |        | —    |
| $\phi X(1835) \rightarrow \phi p\bar{p}$  |      | $< 2.1 \times 10^{-7}$                   | CL=90% | —    |
| $\phi X(1835) \rightarrow \phi\eta\pi^+\pi^-$                                   |      | $< 2.8 \times 10^{-4}$                   | CL=90% | 578  |
| $\phi X(1870) \rightarrow \phi\eta\pi^+\pi^-$                                   |      | $< 6.13 \times 10^{-5}$                  | CL=90% | —    |
| $\eta\phi(2170) \rightarrow \eta\phi f_0(980) \rightarrow$                      |      | $(1.2 \pm 0.4) \times 10^{-4}$           |        | 628  |
| $\eta\phi\pi^+\pi^-$  |      |  |        |      |
| $\eta\phi(2170) \rightarrow$  |      | $< 2.52 \times 10^{-4}$                  | CL=90% | —    |
| $\eta K^*(892)^0 \bar{K}^*(892)^0$  |      |  |        |      |
| $\Sigma(1385)^0 \bar{\Lambda} +$ c.c.   |      | $< 8.2 \times 10^{-6}$                   | CL=90% | 912  |
| $\Delta(1232)^+ \bar{p}$  |      | $< 1 \times 10^{-4}$                     | CL=90% | 1100 |
| $\Lambda(1520) \bar{\Lambda} +$ c.c. $\rightarrow \gamma \Lambda \bar{\Lambda}$ |      | $< 4.1 \times 10^{-6}$                   | CL=90% | —    |
| $\bar{\Lambda}(1520) \Lambda +$ c.c.  |      | $< 1.80 \times 10^{-3}$                  | CL=90% | 807  |
| $\Theta(1540) \bar{\Theta}(1540) \rightarrow$                                   |      | $< 1.1 \times 10^{-5}$                   | CL=90% | —    |
| $K_S^0 p K^- \bar{n} +$ c.c.  |      |  |        |      |
| $\Theta(1540) K^- \bar{n} \rightarrow K_S^0 p K^- \bar{n}$                      |      | $< 2.1 \times 10^{-5}$                   | CL=90% | —    |

|  |         |                  |        |   |
|--|---------|------------------|--------|---|
| $\Theta(1540) K_S^0 \bar{p} \rightarrow K_S^0 \bar{p} K^+ n$ | $< 1.6$ | $\times 10^{-5}$ | CL=90% | — |
| $\bar{\Theta}(1540) K^+ n \rightarrow K_S^0 \bar{p} K^+ n$   | $< 5.6$ | $\times 10^{-5}$ | CL=90% | — |
| $\bar{\Theta}(1540) K_S^0 p \rightarrow K_S^0 p K^- \bar{n}$ | $< 1.1$ | $\times 10^{-5}$ | CL=90% | — |

### Decays into stable hadrons

|   |                                      |                  |        |      |
|---|--------------------------------------|------------------|--------|------|
| $2(\pi^+ \pi^-) \pi^0$  | $( 3.73 \pm 0.32 ) \%$               |                  | S=1.4  | 1496 |
| $3(\pi^+ \pi^-) \pi^0$  | $( 2.9 \pm 0.6 ) \%$                 |                  |        | 1433 |
| $\pi^+ \pi^- \pi^0$   | $( 2.10 \pm 0.08 ) \%$               |                  | S=1.6  | 1533 |
| $\pi^+ \pi^- \pi^0 \pi^0 \pi^0$                                       | $( 2.71 \pm 0.29 ) \%$               |                  |        | 1497 |
| $\rho^\pm \pi^\mp \pi^0 \pi^0$  | $( 1.41 \pm 0.22 ) \%$               |                  |        | 1421 |
| $\rho^+ \rho^- \pi^0$   | $( 6.0 \pm 1.1 ) \times 10^{-3}$     |                  |        | 1298 |
| $\pi^+ \pi^- \pi^0 K^+ K^-$   | $( 1.20 \pm 0.30 ) \%$               |                  |        | 1368 |
| $4(\pi^+ \pi^-) \pi^0$  | $( 9.0 \pm 3.0 ) \times 10^{-3}$     |                  |        | 1345 |
| $\pi^+ \pi^- K^+ K^-$   | $( 6.86 \pm 0.28 ) \times 10^{-3}$   |                  |        | 1407 |
| $\pi^+ \pi^- K_S^0 K_L^0$   | $( 3.8 \pm 0.6 ) \times 10^{-3}$     |                  |        | 1406 |
| $\pi^+ \pi^- K_S^0 K_S^0$   | $( 1.68 \pm 0.19 ) \times 10^{-3}$   |                  |        | 1406 |
| $\pi^\pm \pi^0 K^\mp K_S^0$   | $( 5.7 \pm 0.5 ) \times 10^{-3}$     |                  |        | 1408 |
| $K^+ K^- K_S^0 K_S^0$   | $( 4.2 \pm 0.7 ) \times 10^{-4}$     |                  |        | 1127 |
| $\pi^+ \pi^- K^+ K^- \eta$  | $( 4.7 \pm 0.7 ) \times 10^{-3}$     |                  |        | 1221 |
| $\pi^0 \pi^0 K^+ K^-$   | $( 2.13 \pm 0.22 ) \times 10^{-3}$   |                  |        | 1410 |
| $\pi^0 \pi^0 K_S^0 K_L^0$   | $( 1.9 \pm 0.4 ) \times 10^{-3}$     |                  |        | 1408 |
| $K \bar{K} \pi$   | $( 6.1 \pm 1.0 ) \times 10^{-3}$     |                  |        | 1442 |
| $K^+ K^- \pi^0$   | $( 2.88 \pm 0.12 ) \times 10^{-3}$   |                  |        | 1442 |
| $K_S^0 K^\pm \pi^\mp$   | $( 5.6 \pm 0.5 ) \times 10^{-3}$     |                  |        | 1440 |
| $K_S^0 K_L^0 \pi^0$   | $( 2.06 \pm 0.26 ) \times 10^{-3}$   |                  |        | 1440 |
| $K^*(892)^0 \bar{K}^0 + \text{c.c.} \rightarrow K_S^0 K_L^0 \pi^0$    | $( 1.21 \pm 0.18 ) \times 10^{-3}$   |                  |        | —    |
| $K_2^*(1430)^0 \bar{K}^0 + \text{c.c.} \rightarrow K_S^0 K_L^0 \pi^0$ | $( 4.3 \pm 1.3 ) \times 10^{-4}$     |                  |        | —    |
| $K_S^0 K_L^0 \eta$  | $( 1.45 \pm 0.33 ) \times 10^{-3}$   |                  |        | 1328 |
| $2(\pi^+ \pi^-)$  | $( 3.57 \pm 0.30 ) \times 10^{-3}$   |                  |        | 1517 |
| $3(\pi^+ \pi^-)$  | $( 4.3 \pm 0.4 ) \times 10^{-3}$     |                  |        | 1466 |
| $2(\pi^+ \pi^- \pi^0)$  | $( 1.61 \pm 0.20 ) \%$               |                  |        | 1468 |
| $2(\pi^+ \pi^-) \eta$   | $( 2.26 \pm 0.28 ) \times 10^{-3}$   |                  |        | 1446 |
| $3(\pi^+ \pi^-) \eta$   | $( 7.2 \pm 1.5 ) \times 10^{-4}$     |                  |        | 1379 |
| $\pi^+ \pi^- \pi^0 \pi^0 \eta$  | $( 2.3 \pm 0.5 ) \times 10^{-3}$     |                  |        | 1448 |
| $\rho^\pm \pi^\mp \pi^0 \eta$   | $( 1.9 \pm 0.8 ) \times 10^{-3}$     |                  |        | 1326 |
| $p \bar{p}$   | $( 2.120 \pm 0.029 ) \times 10^{-3}$ |                  |        | 1232 |
| $p \bar{p} \pi^0$   | $( 1.19 \pm 0.08 ) \times 10^{-3}$   |                  | S=1.1  | 1176 |
| $p \bar{p} \pi^+ \pi^-$   | $( 6.0 \pm 0.5 ) \times 10^{-3}$     |                  | S=1.3  | 1107 |
| $p \bar{p} \pi^+ \pi^- \pi^0$   | $( 2.3 \pm 0.9 ) \times 10^{-3}$     | [iiaa]           | S=1.9  | 1033 |
| $p \bar{p} \eta$  | $( 2.00 \pm 0.12 ) \times 10^{-3}$   |                  |        | 948  |
| $p \bar{p} \rho$  | $< 3.1$                              | $\times 10^{-4}$ | CL=90% | 774  |



|  |      |                                      |        |      |
|--|------|--------------------------------------|--------|------|
| $p\bar{p}\omega$                                 |      | $( 9.8 \pm 1.0 ) \times 10^{-4}$     | S=1.3  | 768  |
| $p\bar{p}\eta'(958)$                             |      | $( 1.29 \pm 0.14 ) \times 10^{-4}$   | S=2.0  | 596  |
| $p\bar{p}a_0(980) \rightarrow p\bar{p}\pi^0\eta$ |      | $( 6.8 \pm 1.8 ) \times 10^{-5}$     |        | –    |
| $p\bar{p}\phi$                                   |      | $( 5.19 \pm 0.33 ) \times 10^{-5}$   |        | 527  |
| $n\bar{n}$                                       |      | $( 2.09 \pm 0.16 ) \times 10^{-3}$   |        | 1231 |
| $n\bar{n}\pi^+\pi^-$                             |      | $( 4 \pm 4 ) \times 10^{-3}$         |        | 1106 |
| $\Sigma^+\bar{\Sigma}^-$                         |      | $( 1.50 \pm 0.24 ) \times 10^{-3}$   |        | 992  |
| $\Sigma^0\bar{\Sigma}^0$                         |      | $( 1.172 \pm 0.032 ) \times 10^{-3}$ | S=1.4  | 988  |
| $2(\pi^+\pi^-)K^+K^-$                            |      | $( 3.1 \pm 1.3 ) \times 10^{-3}$     |        | 1320 |
| $p\bar{n}\pi^-$                                  |      | $( 2.12 \pm 0.09 ) \times 10^{-3}$   |        | 1174 |
| $nN(1440)$                                       |      | seen                                 |        | 978  |
| $nN(1520)$                                       |      | seen                                 |        | 928  |
| $nN(1535)$                                       |      | seen                                 |        | 917  |
| $\Xi^-\bar{\Xi}^+$                               |      | $( 9.7 \pm 0.8 ) \times 10^{-4}$     | S=1.4  | 807  |
| $\Lambda\bar{\Lambda}$                           |      | $( 1.89 \pm 0.09 ) \times 10^{-3}$   | S=2.8  | 1074 |
| $\Lambda\bar{\Sigma}^-\pi^+$ (or c.c.)           | [aa] | $( 8.3 \pm 0.7 ) \times 10^{-4}$     | S=1.2  | 950  |
| $pK^-\bar{\Lambda} + \text{c.c.}$                |      | $( 8.6 \pm 1.1 ) \times 10^{-4}$     |        | 876  |
| $2(K^+K^-)$                                      |      | $( 7.2 \pm 0.8 ) \times 10^{-4}$     |        | 1131 |
| $pK^-\bar{\Sigma}^0$                             |      | $( 2.9 \pm 0.8 ) \times 10^{-4}$     |        | 819  |
| $K^+K^-$   |      | $( 2.86 \pm 0.21 ) \times 10^{-4}$   |        | 1468 |
| $K_S^0 K_L^0$                                    |      | $( 1.95 \pm 0.11 ) \times 10^{-4}$   | S=2.4  | 1466 |
| $\Lambda\bar{\Lambda}\pi^+\pi^-$                 |      | $( 4.3 \pm 1.0 ) \times 10^{-3}$     |        | 903  |
| $\Lambda\bar{\Lambda}\eta$                       |      | $( 1.62 \pm 0.17 ) \times 10^{-4}$   |        | 672  |
| $\Lambda\bar{\Lambda}\pi^0$                      |      | $( 3.8 \pm 0.4 ) \times 10^{-5}$     |        | 998  |
| $\bar{\Lambda}nK_S^0 + \text{c.c.}$              |      | $( 6.5 \pm 1.1 ) \times 10^{-4}$     |        | 872  |
| $\pi^+\pi^-$                                     |      | $( 1.47 \pm 0.14 ) \times 10^{-4}$   |        | 1542 |
| $\Lambda\bar{\Sigma} + \text{c.c.}$              |      | $( 2.83 \pm 0.23 ) \times 10^{-5}$   |        | 1034 |
| $K_S^0 K_S^0$                                    |      | $< 1.4 \times 10^{-8}$               | CL=95% | 1466 |

### Radiative decays

|   |  |  |        |      |
|---|--|--|--------|------|
| $3\gamma$   |  | $( 1.16 \pm 0.22 ) \times 10^{-5}$   |        | 1548 |
| $4\gamma$   |  | $< 9 \times 10^{-6}$   | CL=90% | 1548 |
| $5\gamma$   |  | $< 1.5 \times 10^{-5}$   | CL=90% | 1548 |
| $\gamma\pi^0\pi^0$                                    |  | $( 1.15 \pm 0.05 ) \times 10^{-3}$   |        | 1543 |
| $\gamma\eta\pi^0$                                     |  | $( 2.14 \pm 0.31 ) \times 10^{-5}$   |        | 1497 |
| $\gamma a_0(980)^0 \rightarrow \gamma\eta\pi^0$       |  | $< 2.5 \times 10^{-6}$   | CL=95% | –    |
| $\gamma a_2(1320)^0 \rightarrow \gamma\eta\pi^0$      |  | $< 6.6 \times 10^{-6}$   | CL=95% | –    |
| $\gamma K_S^0 K_S^0$                                  |  | $( 8.1 \pm 0.4 ) \times 10^{-4}$   |        | 1466 |
| $\gamma\eta_c(1S)$                                    |  | $( 1.7 \pm 0.4 ) \%$   | S=1.5  | 111  |
| $\gamma\eta_c(1S) \rightarrow 3\gamma$                |  | $( 3.8 \begin{smallmatrix} + \\ - \end{smallmatrix} \begin{smallmatrix} 1.3 \\ 1.0 \end{smallmatrix} ) \times 10^{-6}$ | S=1.1  | –    |
| $\gamma\eta_c(1S) \rightarrow \gamma\eta\eta\eta'$    |  | $( 4.9 \pm 0.8 ) \times 10^{-5}$   |        | –    |
| $\gamma\pi^+\pi^-2\pi^0$                              |  | $( 8.3 \pm 3.1 ) \times 10^{-3}$   |        | 1518 |
| $\gamma\eta\pi\pi$                                    |  | $( 6.1 \pm 1.0 ) \times 10^{-3}$   |        | 1487 |
| $\gamma\eta_2(1870) \rightarrow \gamma\eta\pi^+\pi^-$ |  | $( 6.2 \pm 2.4 ) \times 10^{-4}$   |        | –    |

|  |   |        |      |
|--|---|--------|------|
| $\gamma\eta(1405/1475) \rightarrow \gamma K \bar{K} \pi$ | $( 2.8 \pm 0.6 ) \times 10^{-3}$              | S=1.6  | 1223 |
| $\gamma\eta(1405/1475) \rightarrow \gamma\gamma\rho^0$   | $( 7.8 \pm 2.0 ) \times 10^{-5}$              | S=1.8  | 1223 |
| $\gamma\eta(1405/1475) \rightarrow \gamma\eta\pi^+\pi^-$ | $( 3.0 \pm 0.5 ) \times 10^{-4}$              |        | —    |
| $\gamma\eta(1405/1475) \rightarrow \gamma\gamma\phi$     | $< 8.2 \times 10^{-5}$                        | CL=95% | —    |
| $\gamma\eta(1405) \rightarrow \gamma\gamma\gamma$        | $< 2.63 \times 10^{-6}$                       | CL=90% | —    |
| $\gamma\eta(1475) \rightarrow \gamma\gamma\gamma$        | $< 1.86 \times 10^{-6}$                       | CL=90% | —    |
| $\gamma\rho\rho$   | $( 4.5 \pm 0.8 ) \times 10^{-3}$              |        | 1340 |
| $\gamma\rho\omega$                                       | $< 5.4 \times 10^{-4}$                        | CL=90% | 1338 |
| $\gamma\rho\phi$   | $< 8.8 \times 10^{-5}$                        | CL=90% | 1258 |
| $\gamma\eta'(958)$                                       | $( 5.25 \pm 0.07 ) \times 10^{-3}$            | S=1.3  | 1400 |
| $\gamma 2\pi^+ 2\pi^-$                                   | $( 2.8 \pm 0.5 ) \times 10^{-3}$              | S=1.9  | 1517 |
| $\gamma f_2(1270) f_2(1270)$                             | $( 9.5 \pm 1.7 ) \times 10^{-4}$              |        | 878  |
| $\gamma f_2(1270) f_2(1270)$ (non resonant)              | $( 8.2 \pm 1.9 ) \times 10^{-4}$              |        | —    |
| $\gamma K^+ K^- \pi^+ \pi^-$                             | $( 2.1 \pm 0.6 ) \times 10^{-3}$              |        | 1407 |
| $\gamma f_4(2050)$                                       | $( 2.7 \pm 0.7 ) \times 10^{-3}$              |        | 891  |
| $\gamma\omega\omega$                                     | $( 1.61 \pm 0.33 ) \times 10^{-3}$            |        | 1336 |
| $\gamma\eta(1405/1475) \rightarrow \gamma\rho^0\rho^0$   | $( 1.7 \pm 0.4 ) \times 10^{-3}$              | S=1.3  | 1223 |
| $\gamma f_2(1270)$                                       | $( 1.64 \pm 0.12 ) \times 10^{-3}$            | S=1.3  | 1286 |
| $\gamma f_2(1270) \rightarrow \gamma K_S^0 K_S^0$        | $( 2.58 \pm_{-0.22}^{+0.60} ) \times 10^{-5}$ |        | —    |
| $\gamma f_0(1370) \rightarrow \gamma K \bar{K}$          | $( 4.2 \pm 1.5 ) \times 10^{-4}$              |        | —    |
| $\gamma f_0(1370) \rightarrow \gamma K_S^0 K_S^0$        | $( 1.1 \pm 0.4 ) \times 10^{-5}$              |        | —    |
| $\gamma f_0(1500) \rightarrow \gamma K_S^0 K_S^0$        | $( 1.59 \pm_{-0.60}^{+0.24} ) \times 10^{-5}$ |        | —    |
| $\gamma f_0(1710) \rightarrow \gamma K \bar{K}$          | $( 9.5 \pm_{-0.5}^{+1.0} ) \times 10^{-4}$    | S=1.5  | 1075 |
| $\gamma f_0(1710) \rightarrow \gamma\pi\pi$              | $( 3.8 \pm 0.5 ) \times 10^{-4}$              |        | —    |
| $\gamma f_0(1710) \rightarrow \gamma\omega\omega$        | $( 3.1 \pm 1.0 ) \times 10^{-4}$              |        | —    |
| $\gamma f_0(1710) \rightarrow \gamma\eta\eta$            | $( 2.4 \pm_{-0.7}^{+1.2} ) \times 10^{-4}$    |        | —    |
| $\gamma\eta$   | $( 1.108 \pm 0.027 ) \times 10^{-3}$          |        | 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 |
| $\gamma f_1(1510) \rightarrow \gamma\eta\pi^+\pi^-$      | $( 4.5 \pm 1.2 ) \times 10^{-4}$              |        | —    |
| $\gamma f_2'(1525)$                                      | $( 5.7 \pm_{-0.5}^{+0.8} ) \times 10^{-4}$    | S=1.5  | 1177 |
| $\gamma f_2'(1525) \rightarrow \gamma K_S^0 K_S^0$       | $( 8.0 \pm_{-0.5}^{+0.7} ) \times 10^{-5}$    |        | —    |
| $\gamma f_2'(1525) \rightarrow \gamma\eta\eta$           | $( 3.4 \pm 1.4 ) \times 10^{-5}$              |        | —    |
| $\gamma f_2(1640) \rightarrow \gamma\omega\omega$        | $( 2.8 \pm 1.8 ) \times 10^{-4}$              |        | —    |
| $\gamma f_2(1910) \rightarrow \gamma\omega\omega$        | $( 2.0 \pm 1.4 ) \times 10^{-4}$              |        | —    |
| $\gamma f_0(1750) \rightarrow \gamma K_S^0 K_S^0$        | $( 1.11 \pm_{-0.33}^{+0.20} ) \times 10^{-5}$ |        | —    |
| $\gamma f_0(1710) \rightarrow \gamma\omega\phi$          | $( 2.5 \pm 0.6 ) \times 10^{-4}$              |        | —    |
| $\gamma f_2(1810) \rightarrow \gamma\eta\eta$            | $( 5.4 \pm_{-2.4}^{+3.5} ) \times 10^{-5}$    |        | —    |

|   |  |        |      |
|---|--|--------|------|
| $\gamma f_2(1950) \rightarrow$                        | $( 7.0 \pm 2.2 ) \times 10^{-4}$   |        | —    |
| $\gamma K^*(892) \bar{K}^*(892)$                      |  |        |      |
| $\gamma K^*(892) \bar{K}^*(892)$                      | $( 4.0 \pm 1.3 ) \times 10^{-3}$   |        | 1266 |
| $\gamma \phi \phi$                                    | $( 4.0 \pm 1.2 ) \times 10^{-4}$   | S=2.1  | 1166 |
| $\gamma p \bar{p}$                                    | $( 3.8 \pm 1.0 ) \times 10^{-4}$   |        | 1232 |
| $\gamma \eta(2225)$                                   | $( 3.14 \begin{smallmatrix} + 0.50 \\ - 0.19 \end{smallmatrix} ) \times 10^{-4}$ |        | 752  |
| $\gamma \eta(1760) \rightarrow \gamma \rho^0 \rho^0$  | $( 1.3 \pm 0.9 ) \times 10^{-4}$   |        | 1048 |
| $\gamma \eta(1760) \rightarrow \gamma \omega \omega$  | $( 1.98 \pm 0.33 ) \times 10^{-3}$   |        | —    |
| $\gamma \eta(1760) \rightarrow \gamma \gamma \gamma$  | $< 4.80 \times 10^{-6}$  | CL=90% | —    |
| $\gamma X(1835) \rightarrow \gamma \pi^+ \pi^- \eta'$ | $( 2.7 \begin{smallmatrix} + 0.6 \\ - 0.8 \end{smallmatrix} ) \times 10^{-4}$    | S=1.6  | 1006 |
| $\gamma X(1835) \rightarrow \gamma p \bar{p}$         | $( 7.7 \begin{smallmatrix} + 1.5 \\ - 0.9 \end{smallmatrix} ) \times 10^{-5}$    |        | —    |
| $\gamma X(1835) \rightarrow \gamma K_S^0 K_S^0 \eta$  | $( 3.3 \begin{smallmatrix} + 2.0 \\ - 1.3 \end{smallmatrix} ) \times 10^{-5}$    |        | —    |
| $\gamma X(1835) \rightarrow \gamma \gamma \gamma$     | $< 3.56 \times 10^{-6}$  | CL=90% | —    |
| $\gamma X(2370) \rightarrow \gamma K^+ K^- \eta'$     | $( 1.8 \pm 0.7 ) \times 10^{-5}$   |        | —    |
| $\gamma X(2370) \rightarrow \gamma K_S^0 K_S^0 \eta'$ | $( 1.2 \pm 0.5 ) \times 10^{-5}$   |        | —    |
| $\gamma X(2370) \rightarrow \gamma \eta \eta \eta'$   | $< 9.2 \times 10^{-6}$   | CL=90% | —    |
| $\gamma X(1840) \rightarrow \gamma 3(\pi^+ \pi^-)$    | $( 2.4 \begin{smallmatrix} + 0.7 \\ - 0.8 \end{smallmatrix} ) \times 10^{-5}$    |        | —    |
| $\gamma (K \bar{K} \pi) [J^{PC} = 0^{-+}]$            | $( 7 \pm 4 ) \times 10^{-4}$   | S=2.1  | 1442 |
| $\gamma \pi^0$  | $( 3.56 \pm 0.17 ) \times 10^{-5}$   |        | 1546 |
| $\gamma p \bar{p} \pi^+ \pi^-$                        | $< 7.9 \times 10^{-4}$   | CL=90% | 1107 |
| $\gamma \Lambda \bar{\Lambda}$                        | $< 1.3 \times 10^{-4}$   | CL=90% | 1074 |
| $\gamma f_0(2100) \rightarrow \gamma \eta \eta$       | $( 1.13 \begin{smallmatrix} + 0.60 \\ - 0.30 \end{smallmatrix} ) \times 10^{-4}$ |        | —    |
| $\gamma f_0(2100) \rightarrow \gamma \pi \pi$         | $( 6.2 \pm 1.0 ) \times 10^{-4}$   |        | —    |
| $\gamma f_0(2200) \rightarrow \gamma K \bar{K}$       | $( 5.9 \pm 1.3 ) \times 10^{-4}$   |        | —    |
| $\gamma f_0(2200) \rightarrow \gamma K_S^0 K_S^0$     | $( 2.72 \begin{smallmatrix} + 0.19 \\ - 0.50 \end{smallmatrix} ) \times 10^{-4}$ |        | —    |
| $\gamma f_J(2220) \rightarrow \gamma \pi \pi$         | $< 3.9 \times 10^{-5}$   | CL=90% | —    |
| $\gamma f_J(2220) \rightarrow \gamma K \bar{K}$       | $< 4.1 \times 10^{-5}$   | CL=90% | —    |
| $\gamma f_J(2220) \rightarrow \gamma p \bar{p}$       | $( 1.5 \pm 0.8 ) \times 10^{-5}$   |        | —    |
| $\gamma f_0(2330) \rightarrow \gamma K_S^0 K_S^0$     | $( 4.9 \pm 0.7 ) \times 10^{-5}$   |        | —    |
| $\gamma f_2(2340) \rightarrow \gamma \eta \eta$       | $( 5.6 \begin{smallmatrix} + 2.4 \\ - 2.2 \end{smallmatrix} ) \times 10^{-5}$    |        | —    |
| $\gamma f_2(2340) \rightarrow \gamma K_S^0 K_S^0$     | $( 5.5 \begin{smallmatrix} + 4.0 \\ - 1.5 \end{smallmatrix} ) \times 10^{-5}$    |        | —    |
| $\gamma f_0(1500) \rightarrow \gamma \pi \pi$         | $( 1.09 \pm 0.24 ) \times 10^{-4}$   |        | 1183 |
| $\gamma f_0(1500) \rightarrow \gamma \eta \eta$       | $( 1.7 \begin{smallmatrix} + 0.6 \\ - 1.4 \end{smallmatrix} ) \times 10^{-5}$    |        | —    |
| $\gamma A \rightarrow \gamma \text{invisible}$        | $[jjaa] < 1.7 \times 10^{-6}$  | CL=90% | —    |
| $\gamma A^0 \rightarrow \gamma \mu^+ \mu^-$           | $[kkaa] < 5 \times 10^{-6}$  | CL=90% | —    |
| <b>Dalitz decays</b>                                  |  |        |      |
| $\pi^0 e^+ e^-$                                       | $( 7.6 \pm 1.4 ) \times 10^{-7}$   |        | 1546 |

|   |                                  |             |
|---|----------------------------------|-------------|
| $\eta e^+ e^-$                                | $(1.43 \pm 0.07) \times 10^{-5}$ | 1500        |
| $\eta'(958) e^+ e^-$                          | $(6.59 \pm 0.18) \times 10^{-5}$ | 1400        |
| $\eta U \rightarrow \eta e^+ e^-$             | $< 9.11 \times 10^{-7}$          | CL=90% -    |
| $\eta'(958) U \rightarrow \eta'(958) e^+ e^-$ | $< 2.0 \times 10^{-7}$           | CL=90% -    |
| $\phi e^+ e^-$                                | $< 1.2 \times 10^{-7}$           | CL=90% 1381 |

### Weak decays

|  |                        |            |
|--|------------------------|------------|
| $D^- e^+ \nu_e + \text{c.c.}$          | $< 1.2 \times 10^{-5}$ | CL=90% 984 |
| $\bar{D}^0 e^+ e^- + \text{c.c.}$      | $< 8.5 \times 10^{-8}$ | CL=90% 987 |
| $D_s^- e^+ \nu_e + \text{c.c.}$        | $< 1.3 \times 10^{-6}$ | CL=90% 923 |
| $D_s^{*-} e^+ \nu_e + \text{c.c.}$     | $< 1.8 \times 10^{-6}$ | CL=90% 828 |
| $D^- \pi^+ + \text{c.c.}$              | $< 7.5 \times 10^{-5}$ | CL=90% 977 |
| $\bar{D}^0 \bar{K}^0 + \text{c.c.}$    | $< 1.7 \times 10^{-4}$ | CL=90% 898 |
| $\bar{D}^0 \bar{K}^{*0} + \text{c.c.}$ | $< 2.5 \times 10^{-6}$ | CL=90% 670 |
| $D_s^- \pi^+ + \text{c.c.}$            | $< 1.3 \times 10^{-4}$ | CL=90% 915 |
| $D_s^- \rho^+ + \text{c.c.}$           | $< 1.3 \times 10^{-5}$ | CL=90% 663 |

### Charge conjugation (C), Parity (P), Lepton Family number (LF) violating modes

|                                 |    |                        |        |      |
|---------------------------------|----|------------------------|--------|------|
| $\gamma\gamma$                  | C  | $< 2.7 \times 10^{-7}$ | CL=90% | 1548 |
| $\gamma\phi$                    | C  | $< 1.4 \times 10^{-6}$ | CL=90% | 1381 |
| $e^\pm \mu^\mp$                 | LF | $< 1.6 \times 10^{-7}$ | CL=90% | 1547 |
| $e^\pm \tau^\mp$                | LF | $< 8.3 \times 10^{-6}$ | CL=90% | 1039 |
| $\mu^\pm \tau^\mp$              | LF | $< 2.0 \times 10^{-6}$ | CL=90% | 1035 |
| $\Lambda_c^+ e^- + \text{c.c.}$ |    | $< 6.9 \times 10^{-8}$ | CL=90% | -    |

### Other decays

|           |                      |        |   |
|-----------|----------------------|--------|---|
| invisible | $< 7 \times 10^{-4}$ | CL=90% | - |
|-----------|----------------------|--------|---|

**$\chi_{c0}(1P)$**

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

Mass  $m = 3414.71 \pm 0.30$  MeV

Full width  $\Gamma = 10.8 \pm 0.6$  MeV

| <b><math>\chi_{c0}(1P)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ ) | Scale factor/<br>Confidence level | $p$<br>(MeV/c) |
|---|--------------------------------|-----------------------------------|----------------|
|---|--------------------------------|-----------------------------------|----------------|

### Hadronic decays

|                                    |                                |      |
|------------------------------------|--------------------------------|------|
| $2(\pi^+ \pi^-)$                   | $(2.34 \pm 0.18) \%$           | 1679 |
| $\rho^0 \pi^+ \pi^-$               | $(9.1 \pm 2.9) \times 10^{-3}$ | 1607 |
| $f_0(980) f_0(980)$                | $(6.6 \pm 2.1) \times 10^{-4}$ | 1391 |
| $\pi^+ \pi^- \pi^0 \pi^0$          | $(3.3 \pm 0.4) \%$             | 1680 |
| $\rho^+ \pi^- \pi^0 + \text{c.c.}$ | $(2.9 \pm 0.4) \%$             | 1607 |
| $4\pi^0$                           | $(3.3 \pm 0.4) \times 10^{-3}$ | 1681 |
| $\pi^+ \pi^- K^+ K^-$              | $(1.81 \pm 0.14) \%$           | 1580 |

|   |                                      |             |
|---|--------------------------------------|-------------|
| $K_0^*(1430)^0 \bar{K}_0^*(1430)^0 \rightarrow \pi^+ \pi^- K^+ K^-$               | $(9.8^{+4.0}_{-2.8}) \times 10^{-4}$ | —           |
| $K_0^*(1430)^0 \bar{K}_2^*(1430)^0 + \text{c.c.} \rightarrow \pi^+ \pi^- K^+ K^-$ | $(8.0^{+2.0}_{-2.4}) \times 10^{-4}$ | —           |
| $K_1(1270)^+ K^- + \text{c.c.} \rightarrow \pi^+ \pi^- K^+ K^-$                   | $(6.3 \pm 1.9) \times 10^{-3}$       | —           |
| $K_1(1400)^+ K^- + \text{c.c.} \rightarrow \pi^+ \pi^- K^+ K^-$                   | $< 2.7 \times 10^{-3}$               | CL=90% —    |
| $f_0(980) f_0(980)$   | $(1.6^{+1.0}_{-0.9}) \times 10^{-4}$ | 1391        |
| $f_0(980) f_0(2200)$  | $(7.9^{+2.0}_{-2.5}) \times 10^{-4}$ | 586         |
| $f_0(1370) f_0(1370)$   | $< 2.7 \times 10^{-4}$               | CL=90% 1019 |
| $f_0(1370) f_0(1500)$   | $< 1.7 \times 10^{-4}$               | CL=90% 920  |
| $f_0(1370) f_0(1710)$   | $(6.7^{+3.5}_{-2.3}) \times 10^{-4}$ | 740         |
| $f_0(1500) f_0(1370)$   | $< 1.3 \times 10^{-4}$               | CL=90% 920  |
| $f_0(1500) f_0(1500)$   | $< 5 \times 10^{-5}$                 | CL=90% 804  |
| $f_0(1500) f_0(1710)$   | $< 7 \times 10^{-5}$                 | CL=90% 581  |
| $K^+ K^- \pi^+ \pi^- \pi^0$   | $(8.6 \pm 0.9) \times 10^{-3}$       | 1545        |
| $K_S^0 K^\pm \pi^\mp \pi^+ \pi^-$   | $(4.2 \pm 0.4) \times 10^{-3}$       | 1543        |
| $K^+ K^- \pi^0 \pi^0$   | $(5.6 \pm 0.9) \times 10^{-3}$       | 1582        |
| $K^+ \pi^- \bar{K}^0 \pi^0 + \text{c.c.}$   | $(2.49 \pm 0.33) \%$                 | 1581        |
| $\rho^+ K^- K^0 + \text{c.c.}$  | $(1.21 \pm 0.21) \%$                 | 1458        |
| $K^*(892)^- K^+ \pi^0 \rightarrow K^+ \pi^- \bar{K}^0 \pi^0 + \text{c.c.}$        | $(4.6 \pm 1.2) \times 10^{-3}$       | —           |
| $K_S^0 K_S^0 \pi^+ \pi^-$   | $(5.7 \pm 1.1) \times 10^{-3}$       | 1579        |
| $K^+ K^- \eta \pi^0$  | $(3.0 \pm 0.7) \times 10^{-3}$       | 1468        |
| $3(\pi^+ \pi^-)$  | $(1.20 \pm 0.18) \%$                 | 1633        |
| $K^+ \bar{K}^*(892)^0 \pi^- + \text{c.c.}$  | $(7.5 \pm 1.6) \times 10^{-3}$       | 1523        |
| $K^*(892)^0 \bar{K}^*(892)^0$   | $(1.7 \pm 0.6) \times 10^{-3}$       | 1456        |
| $\pi \pi$   | $(8.51 \pm 0.33) \times 10^{-3}$     | 1702        |
| $\pi^0 \eta$  | $< 1.8 \times 10^{-4}$               | 1661        |
| $\pi^0 \eta'$   | $< 1.1 \times 10^{-3}$               | 1570        |
| $\pi^0 \eta_c$  | $< 1.6 \times 10^{-3}$               | CL=90% 383  |
| $\eta \eta$   | $(3.01 \pm 0.19) \times 10^{-3}$     | 1617        |
| $\eta \eta'$  | $(9.1 \pm 1.1) \times 10^{-5}$       | 1521        |
| $\eta' \eta'$   | $(2.17 \pm 0.12) \times 10^{-3}$     | 1413        |
| $\omega \omega$   | $(9.7 \pm 1.1) \times 10^{-4}$       | 1517        |
| $\omega \phi$   | $(1.41 \pm 0.13) \times 10^{-4}$     | 1447        |
| $\omega K^+ K^-$  | $(1.94 \pm 0.21) \times 10^{-3}$     | 1457        |
| $K^+ K^-$   | $(6.05 \pm 0.31) \times 10^{-3}$     | 1634        |
| $K_S^0 K_S^0$   | $(3.16 \pm 0.17) \times 10^{-3}$     | 1633        |
| $\pi^+ \pi^- \eta$  | $< 2.0 \times 10^{-4}$               | CL=90% 1651 |
| $\pi^+ \pi^- \eta'$   | $< 4 \times 10^{-4}$                 | CL=90% 1560 |

|   |                                  |        |      |
|---|----------------------------------|--------|------|
| $\bar{K}^0 K^+ \pi^- + \text{c.c.}$                       | $< 9 \times 10^{-5}$             | CL=90% | 1610 |
| $K^+ K^- \pi^0$   | $< 6 \times 10^{-5}$             | CL=90% | 1611 |
| $K^+ K^- \eta$  | $< 2.3 \times 10^{-4}$           | CL=90% | 1512 |
| $K^+ K^- K_S^0 K_S^0$                                     | $(1.4 \pm 0.5) \times 10^{-3}$   |        | 1331 |
| $K_S^0 K_S^0 K_S^0 K_S^0$                                 | $(5.8 \pm 0.5) \times 10^{-4}$   |        | 1327 |
| $K^+ K^- K^+ K^-$   | $(2.82 \pm 0.29) \times 10^{-3}$ |        | 1333 |
| $K^+ K^- \phi$  | $(9.7 \pm 2.5) \times 10^{-4}$   |        | 1381 |
| $\bar{K}^0 K^+ \pi^- \phi + \text{c.c.}$                  | $(3.7 \pm 0.6) \times 10^{-3}$   |        | 1326 |
| $K^+ K^- \pi^0 \phi$                                      | $(1.90 \pm 0.35) \times 10^{-3}$ |        | 1329 |
| $\phi \pi^+ \pi^- \pi^0$                                  | $(1.18 \pm 0.15) \times 10^{-3}$ |        | 1525 |
| $\phi \phi$   | $(8.0 \pm 0.7) \times 10^{-4}$   |        | 1370 |
| $\phi \phi \eta$  | $(8.4 \pm 1.0) \times 10^{-4}$   |        | 1100 |
| $p \bar{p}$   | $(2.21 \pm 0.08) \times 10^{-4}$ |        | 1426 |
| $p \bar{p} \pi^0$   | $(7.0 \pm 0.7) \times 10^{-4}$   | S=1.3  | 1379 |
| $p \bar{p} \eta$  | $(3.5 \pm 0.4) \times 10^{-4}$   |        | 1187 |
| $p \bar{p} \omega$  | $(5.2 \pm 0.6) \times 10^{-4}$   |        | 1043 |
| $p \bar{p} \phi$  | $(6.0 \pm 1.4) \times 10^{-5}$   |        | 876  |
| $p \bar{p} \pi^+ \pi^-$                                   | $(2.1 \pm 0.7) \times 10^{-3}$   | S=1.4  | 1320 |
| $p \bar{p} \pi^0 \pi^0$                                   | $(1.04 \pm 0.28) \times 10^{-3}$ |        | 1324 |
| $p \bar{p} K^+ K^- (\text{non-resonant})$                 | $(1.22 \pm 0.26) \times 10^{-4}$ |        | 890  |
| $p \bar{p} K_S^0 K_S^0$                                   | $< 8.8 \times 10^{-4}$           | CL=90% | 884  |
| $p \bar{n} \pi^-$   | $(1.27 \pm 0.11) \times 10^{-3}$ |        | 1376 |
| $\bar{p} n \pi^+$   | $(1.37 \pm 0.12) \times 10^{-3}$ |        | 1376 |
| $p \bar{n} \pi^- \pi^0$                                   | $(2.34 \pm 0.21) \times 10^{-3}$ |        | 1321 |
| $\bar{p} n \pi^+ \pi^0$                                   | $(2.21 \pm 0.18) \times 10^{-3}$ |        | 1321 |
| $\Lambda \bar{\Lambda}$                                   | $(3.27 \pm 0.24) \times 10^{-4}$ |        | 1292 |
| $\Lambda \bar{\Lambda} \pi^+ \pi^-$                       | $(1.18 \pm 0.13) \times 10^{-3}$ |        | 1153 |
| $\Lambda \bar{\Lambda} \pi^+ \pi^- (\text{non-resonant})$ | $< 5 \times 10^{-4}$             | CL=90% | 1153 |
| $\Sigma(1385)^+ \bar{\Lambda} \pi^- + \text{c.c.}$        | $< 5 \times 10^{-4}$             | CL=90% | 1083 |
| $\Sigma(1385)^- \bar{\Lambda} \pi^+ + \text{c.c.}$        | $< 5 \times 10^{-4}$             | CL=90% | 1083 |
| $K^+ \bar{p} \Lambda + \text{c.c.}$                       | $(1.25 \pm 0.12) \times 10^{-3}$ | S=1.3  | 1132 |
| $K^*(892)^+ \bar{p} \Lambda + \text{c.c.}$                | $(4.8 \pm 0.9) \times 10^{-4}$   |        | 845  |
| $K^+ \bar{p} \Lambda(1520) + \text{c.c.}$                 | $(2.9 \pm 0.7) \times 10^{-4}$   |        | 859  |
| $\Lambda(1520) \bar{\Lambda}(1520)$                       | $(3.1 \pm 1.2) \times 10^{-4}$   |        | 780  |
| $\Sigma^0 \bar{\Sigma}^0$                                 | $(4.68 \pm 0.32) \times 10^{-4}$ |        | 1222 |
| $\Sigma^+ \bar{p} K_S^0 + \text{c.c.}$                    | $(3.52 \pm 0.27) \times 10^{-4}$ |        | 1089 |
| $\Sigma^0 \bar{p} K^+ + \text{c.c.}$                      | $(3.03 \pm 0.20) \times 10^{-4}$ |        | 1090 |
| $\Sigma^+ \bar{\Sigma}^-$                                 | $(4.6 \pm 0.8) \times 10^{-4}$   | S=2.6  | 1225 |
| $\Sigma^- \bar{\Sigma}^+$                                 | $(5.1 \pm 0.5) \times 10^{-4}$   |        | 1217 |
| $\Sigma(1385)^+ \bar{\Sigma}(1385)^-$                     | $(1.6 \pm 0.6) \times 10^{-4}$   |        | 1001 |
| $\Sigma(1385)^- \bar{\Sigma}(1385)^+$                     | $(2.3 \pm 0.7) \times 10^{-4}$   |        | 1001 |
| $K^- \Lambda \bar{\Xi}^+ + \text{c.c.}$                   | $(1.94 \pm 0.35) \times 10^{-4}$ |        | 873  |
| $\Xi^0 \bar{\Xi}^0$                                       | $(3.1 \pm 0.8) \times 10^{-4}$   |        | 1089 |
| $\Xi^- \bar{\Xi}^+$                                       | $(4.8 \pm 0.7) \times 10^{-4}$   |        | 1081 |

$\eta_c \pi^+ \pi^-$   $< 7 \times 10^{-4}$  CL=90% 307

### Radiative decays

|                          |                                  |        |      |
|--------------------------|----------------------------------|--------|------|
| $\gamma J/\psi(1S)$      | $(1.40 \pm 0.05) \%$             |        | 303  |
| $\gamma \rho^0$          | $< 9 \times 10^{-6}$             | CL=90% | 1619 |
| $\gamma \omega$          | $< 8 \times 10^{-6}$             | CL=90% | 1618 |
| $\gamma \phi$            | $< 6 \times 10^{-6}$             | CL=90% | 1555 |
| $\gamma \gamma$          | $(2.04 \pm 0.09) \times 10^{-4}$ |        | 1707 |
| $e^+ e^- J/\psi(1S)$     | $(1.33 \pm 0.29) \times 10^{-4}$ |        | 303  |
| $\mu^+ \mu^- J/\psi(1S)$ | $< 1.9 \times 10^{-5}$           | CL=90% | 226  |

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

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

Mass  $m = 3510.67 \pm 0.05$  MeV ( $S = 1.2$ )

Full width  $\Gamma = 0.84 \pm 0.04$  MeV

| <b><math>\chi_{c1}(1P)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ ) | Scale factor/<br>Confidence level | $p$<br>(MeV/c) |
|---|--------------------------------|-----------------------------------|----------------|
|---|--------------------------------|-----------------------------------|----------------|

### Hadronic decays

|  |                                  |        |      |
|--|----------------------------------|--------|------|
| $3(\pi^+ \pi^-)$   | $(5.8 \pm 1.4) \times 10^{-3}$   | S=1.2  | 1683 |
| $2(\pi^+ \pi^-)$   | $(7.6 \pm 2.6) \times 10^{-3}$   |        | 1728 |
| $\pi^+ \pi^- \pi^0 \pi^0$  | $(1.19 \pm 0.15) \%$             |        | 1729 |
| $\rho^+ \pi^- \pi^0 + \text{c.c.}$   | $(1.45 \pm 0.24) \%$             |        | 1658 |
| $\rho^0 \pi^+ \pi^-$   | $(3.9 \pm 3.5) \times 10^{-3}$   |        | 1657 |
| $4\pi^0$   | $(5.4 \pm 0.8) \times 10^{-4}$   |        | 1729 |
| $\pi^+ \pi^- K^+ K^-$  | $(4.5 \pm 1.0) \times 10^{-3}$   |        | 1632 |
| $K^+ K^- \pi^0 \pi^0$  | $(1.12 \pm 0.27) \times 10^{-3}$ |        | 1634 |
| $K^+ K^- \pi^+ \pi^- \pi^0$  | $(1.15 \pm 0.13) \%$             |        | 1598 |
| $K_S^0 K^\pm \pi^\mp \pi^+ \pi^-$  | $(7.5 \pm 0.8) \times 10^{-3}$   |        | 1596 |
| $K^+ \pi^- \bar{K}^0 \pi^0 + \text{c.c.}$  | $(8.6 \pm 1.4) \times 10^{-3}$   |        | 1632 |
| $\rho^- K^+ \bar{K}^0 + \text{c.c.}$   | $(5.0 \pm 1.2) \times 10^{-3}$   |        | 1514 |
| $K^*(892)^0 \bar{K}^0 \pi^0 \rightarrow$<br>$K^+ \pi^- \bar{K}^0 \pi^0 + \text{c.c.}$  | $(2.3 \pm 0.6) \times 10^{-3}$   |        | —    |
| $K^+ K^- \eta \pi^0$   | $(1.12 \pm 0.34) \times 10^{-3}$ |        | 1523 |
| $\pi^+ \pi^- K_S^0 K_S^0$  | $(6.9 \pm 2.9) \times 10^{-4}$   |        | 1630 |
| $K^+ K^- \eta$   | $(3.2 \pm 1.0) \times 10^{-4}$   |        | 1566 |
| $\bar{K}^0 K^+ \pi^- + \text{c.c.}$  | $(7.0 \pm 0.6) \times 10^{-3}$   |        | 1661 |
| $K^*(892)^0 \bar{K}^0 + \text{c.c.}$   | $(10 \pm 4) \times 10^{-4}$      |        | 1602 |
| $K^*(892)^+ K^- + \text{c.c.}$   | $(1.4 \pm 0.6) \times 10^{-3}$   |        | 1602 |
| $K_J^*(1430)^0 \bar{K}^0 + \text{c.c.} \rightarrow$<br>$K_S^0 K^+ \pi^- + \text{c.c.}$ | $< 8 \times 10^{-4}$             | CL=90% | —    |
| $K_J^*(1430)^+ K^- + \text{c.c.} \rightarrow$<br>$K_S^0 K^+ \pi^- + \text{c.c.}$       | $< 2.1 \times 10^{-3}$           | CL=90% | —    |

|  |  |        |      |
|--|--|--------|------|
| $K^+ K^- \pi^0$  | $( 1.81 \pm 0.24 ) \times 10^{-3}$         |        | 1662 |
| $\eta \pi^+ \pi^-$   | $( 4.62 \pm 0.23 ) \times 10^{-3}$         |        | 1701 |
| $a_0(980)^+ \pi^- + \text{c.c.} \rightarrow \eta \pi^+ \pi^-$    | $( 3.2 \pm 0.4 ) \times 10^{-3}$           | S=2.2  | —    |
| $a_2(1320)^+ \pi^- + \text{c.c.} \rightarrow \eta \pi^+ \pi^-$   | $( 1.76 \pm 0.24 ) \times 10^{-4}$         |        | —    |
| $a_2(1700)^+ \pi^- + \text{c.c.} \rightarrow \eta \pi^+ \pi^-$   | $( 4.6 \pm 0.7 ) \times 10^{-5}$           |        | —    |
| $f_2(1270) \eta \rightarrow \eta \pi^+ \pi^-$                    | $( 3.5 \pm 0.6 ) \times 10^{-4}$           |        | —    |
| $f_4(2050) \eta \rightarrow \eta \pi^+ \pi^-$                    | $( 2.5 \pm 0.9 ) \times 10^{-5}$           |        | —    |
| $\pi_1(1400)^+ \pi^- + \text{c.c.} \rightarrow \eta \pi^+ \pi^-$ | $< 5 \times 10^{-5}$                       | CL=90% | —    |
| $\pi_1(1600)^+ \pi^- + \text{c.c.} \rightarrow \eta \pi^+ \pi^-$ | $< 1.5 \times 10^{-5}$                     | CL=90% | —    |
| $\pi_1(2015)^+ \pi^- + \text{c.c.} \rightarrow \eta \pi^+ \pi^-$ | $< 8 \times 10^{-6}$                       | CL=90% | —    |
| $f_2(1270) \eta$   | $( 6.7 \pm 1.1 ) \times 10^{-4}$           |        | 1467 |
| $\pi^+ \pi^- \eta'$  | $( 2.2 \pm 0.4 ) \times 10^{-3}$           |        | 1612 |
| $K^+ K^- \eta'(958)$   | $( 8.8 \pm 0.9 ) \times 10^{-4}$           |        | 1461 |
| $K_0^*(1430)^+ K^- + \text{c.c.}$                                | $( 6.4 \pm_{-2.8}^{+2.2} ) \times 10^{-4}$ |        | —    |
| $f_0(980) \eta'(958)$  | $( 1.6 \pm_{-0.7}^{+1.4} ) \times 10^{-4}$ |        | 1460 |
| $f_0(1710) \eta'(958)$   | $( 7 \pm_5^+ ) \times 10^{-5}$             |        | 1118 |
| $f_2'(1525) \eta'(958)$  | $( 9 \pm 6 ) \times 10^{-5}$               |        | 1229 |
| $\pi^0 f_0(980) \rightarrow \pi^0 \pi^+ \pi^-$                   | $( 3.5 \pm 0.9 ) \times 10^{-7}$           |        | —    |
| $K^+ \bar{K}^*(892)^0 \pi^- + \text{c.c.}$                       | $( 3.2 \pm 2.1 ) \times 10^{-3}$           |        | 1577 |
| $K^*(892)^0 \bar{K}^*(892)^0$                                    | $( 1.4 \pm 0.4 ) \times 10^{-3}$           |        | 1512 |
| $K^+ K^- K_S^0 K_S^0$  | $< 4 \times 10^{-4}$                       | CL=90% | 1390 |
| $K_S^0 K_S^0 K_S^0 K_S^0$  | $( 3.5 \pm 1.0 ) \times 10^{-5}$           |        | 1387 |
| $K^+ K^- K^+ K^-$  | $( 5.4 \pm 1.1 ) \times 10^{-4}$           |        | 1393 |
| $K^+ K^- \phi$   | $( 4.1 \pm 1.5 ) \times 10^{-4}$           |        | 1440 |
| $\bar{K}^0 K^+ \pi^- \phi + \text{c.c.}$                         | $( 3.3 \pm 0.5 ) \times 10^{-3}$           |        | 1387 |
| $K^+ K^- \pi^0 \phi$   | $( 1.62 \pm 0.30 ) \times 10^{-3}$         |        | 1390 |
| $\phi \pi^+ \pi^- \pi^0$   | $( 7.5 \pm 1.0 ) \times 10^{-4}$           |        | 1578 |
| $\omega \omega$  | $( 5.7 \pm 0.7 ) \times 10^{-4}$           |        | 1571 |
| $\omega K^+ K^-$   | $( 7.8 \pm 0.9 ) \times 10^{-4}$           |        | 1513 |
| $\omega \phi$  | $( 2.7 \pm 0.4 ) \times 10^{-5}$           |        | 1503 |
| $\phi \phi$  | $( 4.2 \pm 0.5 ) \times 10^{-4}$           |        | 1429 |
| $\phi \phi \eta$   | $( 3.0 \pm 0.5 ) \times 10^{-4}$           |        | 1172 |
| $\rho \bar{\rho}$  | $( 7.60 \pm 0.34 ) \times 10^{-5}$         |        | 1484 |
| $\rho \bar{\rho} \pi^0$  | $( 1.55 \pm 0.18 ) \times 10^{-4}$         |        | 1438 |
| $\rho \bar{\rho} \eta$   | $( 1.45 \pm 0.25 ) \times 10^{-4}$         |        | 1254 |
| $\rho \bar{\rho} \omega$   | $( 2.12 \pm 0.31 ) \times 10^{-4}$         |        | 1117 |
| $\rho \bar{\rho} \phi$   | $< 1.7 \times 10^{-5}$                     | CL=90% | 962  |
| $\rho \bar{\rho} \pi^+ \pi^-$                                    | $( 5.0 \pm 1.9 ) \times 10^{-4}$           |        | 1381 |
| $\rho \bar{\rho} \pi^0 \pi^0$                                    | $< 5 \times 10^{-4}$                       | CL=90% | 1385 |



|  |                                  |        |      |
|--|----------------------------------|--------|------|
| $p\bar{p}K^+K^-$ (non-resonant)                  | $(1.27 \pm 0.22) \times 10^{-4}$ |        | 974  |
| $p\bar{p}K_S^0K_S^0$                             | $< 4.5 \times 10^{-4}$           | CL=90% | 968  |
| $p\bar{n}\pi^-$                                  | $(3.8 \pm 0.5) \times 10^{-4}$   |        | 1435 |
| $\bar{p}n\pi^+$                                  | $(3.9 \pm 0.5) \times 10^{-4}$   |        | 1435 |
| $p\bar{n}\pi^-\pi^0$                             | $(1.03 \pm 0.12) \times 10^{-3}$ |        | 1383 |
| $\bar{p}n\pi^+\pi^0$                             | $(1.01 \pm 0.12) \times 10^{-3}$ |        | 1383 |
| $\Lambda\bar{\Lambda}$                           | $(1.14 \pm 0.11) \times 10^{-4}$ |        | 1355 |
| $\Lambda\bar{\Lambda}\pi^+\pi^-$                 | $(2.9 \pm 0.5) \times 10^{-4}$   |        | 1223 |
| $\Lambda\bar{\Lambda}\pi^+\pi^-$ (non-resonant)  | $(2.5 \pm 0.6) \times 10^{-4}$   |        | 1223 |
| $\Sigma(1385)^+\bar{\Lambda}\pi^- + \text{c.c.}$ | $< 1.3 \times 10^{-4}$           | CL=90% | 1157 |
| $\Sigma(1385)^-\bar{\Lambda}\pi^+ + \text{c.c.}$ | $< 1.3 \times 10^{-4}$           | CL=90% | 1157 |
| $K^+\bar{p}\Lambda + \text{c.c.}$                | $(4.2 \pm 0.4) \times 10^{-4}$   | S=1.2  | 1203 |
| $K^*(892)^+\bar{p}\Lambda + \text{c.c.}$         | $(4.9 \pm 0.7) \times 10^{-4}$   |        | 935  |
| $K^+\bar{p}\Lambda(1520) + \text{c.c.}$          | $(1.7 \pm 0.4) \times 10^{-4}$   |        | 951  |
| $\Lambda(1520)\bar{\Lambda}(1520)$               | $< 9 \times 10^{-5}$             | CL=90% | 880  |
| $\Sigma^0\bar{\Sigma}^0$                         | $(4.2 \pm 0.6) \times 10^{-5}$   |        | 1288 |
| $\Sigma^+\bar{p}K_S^0 + \text{c.c.}$             | $(1.53 \pm 0.12) \times 10^{-4}$ |        | 1163 |
| $\Sigma^0\bar{p}K^+ + \text{c.c.}$               | $(1.46 \pm 0.10) \times 10^{-4}$ |        | 1163 |
| $\Sigma^+\bar{\Sigma}^-$                         | $(3.6 \pm 0.7) \times 10^{-5}$   |        | 1291 |
| $\Sigma^-\bar{\Sigma}^+$                         | $(5.7 \pm 1.5) \times 10^{-5}$   |        | 1283 |
| $\Sigma(1385)^+\bar{\Sigma}(1385)^-$             | $< 9 \times 10^{-5}$             | CL=90% | 1081 |
| $\Sigma(1385)^-\bar{\Sigma}(1385)^+$             | $< 5 \times 10^{-5}$             | CL=90% | 1081 |
| $K^-\Lambda\bar{\Xi}^+ + \text{c.c.}$            | $(1.35 \pm 0.24) \times 10^{-4}$ |        | 963  |
| $\Xi^0\bar{\Xi}^0$                               | $< 6 \times 10^{-5}$             | CL=90% | 1163 |
| $\Xi^-\bar{\Xi}^+$                               | $(8.0 \pm 2.1) \times 10^{-5}$   |        | 1155 |
| $\pi^+\pi^- + K^+K^-$                            | $< 2.1 \times 10^{-3}$           |        | —    |
| $K_S^0K_S^0$                                     | $< 6 \times 10^{-5}$             | CL=90% | 1683 |
| $\eta_c\pi^+\pi^-$                               | $< 3.2 \times 10^{-3}$           | CL=90% | 413  |

### Radiative decays

|                         |                                  |        |      |
|-------------------------|----------------------------------|--------|------|
| $\gamma J/\psi(1S)$     | $(34.3 \pm 1.0) \%$              |        | 389  |
| $\gamma\rho^0$          | $(2.16 \pm 0.17) \times 10^{-4}$ |        | 1670 |
| $\gamma\omega$          | $(6.8 \pm 0.8) \times 10^{-5}$   |        | 1668 |
| $\gamma\phi$            | $(2.4 \pm 0.5) \times 10^{-5}$   |        | 1607 |
| $\gamma\gamma$          | $< 6.3 \times 10^{-6}$           | CL=90% | 1755 |
| $e^+e^- J/\psi(1S)$     | $(3.46 \pm 0.22) \times 10^{-3}$ |        | 389  |
| $\mu^+\mu^- J/\psi(1S)$ | $(2.33 \pm 0.29) \times 10^{-4}$ |        | 335  |

**$h_c(1P)$**

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

Mass  $m = 3525.38 \pm 0.11$  MeV

Full width  $\Gamma = 0.7 \pm 0.4$  MeV

| <b><math>h_c(1P)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ ) | Confidence level | $P$<br>(MeV/c) |
|---|--------------------------------|------------------|----------------|
| $J/\psi(1S)\pi\pi$                      | not seen                       |                  | 312            |
| $J/\psi(1S)\pi^+\pi^-$                  | $< 2.3 \times 10^{-3}$         | 90%              | 305            |
| $p\bar{p}$                              | $< 1.5 \times 10^{-4}$         | 90%              | 1492           |
| $p\bar{p}\pi^+\pi^-$                    | $(2.9 \pm 0.6) \times 10^{-3}$ |                  | 1390           |
| $p\bar{p}\pi^0\pi^0$                    | $< 5 \times 10^{-4}$           | 90%              | 1394           |
| $\pi^+\pi^-\pi^0$                       | $(1.6 \pm 0.5) \times 10^{-3}$ |                  | 1749           |
| $\pi^+\pi^-\pi^0\eta$                   | $(7.2 \pm 2.3) \times 10^{-3}$ |                  | 1695           |
| $2\pi^+2\pi^-\pi^0$                     | $(8.1 \pm 1.8) \times 10^{-3}$ |                  | 1716           |
| $3\pi^+3\pi^-\pi^0$                     | $< 9 \times 10^{-3}$           | 90%              | 1661           |
| $K^+K^-\pi^+\pi^-$                      | $< 6 \times 10^{-4}$           | 90%              | 1640           |
| $K^+K^-\pi^+\pi^-\pi^0$                 | $(3.2 \pm 0.8) \times 10^{-3}$ |                  | 1606           |
| $K^+K^-\pi^+\pi^-\eta$                  | $< 2.3 \times 10^{-3}$         | 90%              | 1480           |
| $K^+K^-\pi^0$                           | $< 6 \times 10^{-4}$           | 90%              | 1670           |
| $K^+K^-\pi^0\eta$                       | $< 2.1 \times 10^{-3}$         | 90%              | 1532           |
| $K^+K^-\eta$                            | $< 9 \times 10^{-4}$           | 90%              | 1574           |
| $2K^+2K^-\pi^0$                         | $< 2.4 \times 10^{-4}$         | 90%              | 1339           |
| $K_S^0 K^\pm \pi^\mp$                   | $< 6 \times 10^{-4}$           | 90%              | 1668           |
| $K_S^0 K^\pm \pi^\mp \pi^+ \pi^-$       | $(2.8 \pm 1.0) \times 10^{-3}$ |                  | 1604           |
| <b>Radiative decays</b>                 |                                |                  |                |
| $\gamma\eta$                            | $(4.7 \pm 2.1) \times 10^{-4}$ |                  | 1720           |
| $\gamma\eta'(958)$                      | $(1.5 \pm 0.4) \times 10^{-3}$ |                  | 1633           |
| $\gamma\eta_c(1S)$                      | $(50 \pm 9) \%$                |                  | 500            |

**$\chi_{c2}(1P)$**

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

Mass  $m = 3556.17 \pm 0.07$  MeV

Full width  $\Gamma = 1.97 \pm 0.09$  MeV

| <b><math>\chi_{c2}(1P)</math> DECAY MODES</b>                         | Fraction ( $\Gamma_i/\Gamma$ )   | Confidence level | $P$<br>(MeV/c) |
|---|----------------------------------|------------------|----------------|
| <b>Hadronic decays</b>  |                                  |                  |                |
| $2(\pi^+\pi^-)$   | $(1.02 \pm 0.09) \%$             |                  | 1751           |
| $\pi^+\pi^-\pi^0\pi^0$  | $(1.83 \pm 0.23) \%$             |                  | 1752           |
| $\rho^+\pi^-\pi^0 + \text{c.c.}$                                      | $(2.19 \pm 0.34) \%$             |                  | 1682           |
| $4\pi^0$  | $(1.11 \pm 0.15) \times 10^{-3}$ |                  | 1752           |
| $K^+K^-\pi^0\pi^0$  | $(2.1 \pm 0.4) \times 10^{-3}$   |                  | 1658           |
| $K^+\pi^-\bar{K}^0\pi^0 + \text{c.c.}$                                | $(1.38 \pm 0.20) \%$             |                  | 1657           |
| $\rho^-K^+\bar{K}^0 + \text{c.c.}$                                    | $(4.1 \pm 1.2) \times 10^{-3}$   |                  | 1540           |
| $K^*(892)^0 K^-\pi^+ \rightarrow$<br>$K^-\pi^+K^0\pi^0 + \text{c.c.}$ | $(2.9 \pm 0.8) \times 10^{-3}$   |                  | —              |

|  |                                  |     |      |
|--|----------------------------------|-----|------|
| $K^*(892)^0 \bar{K}^0 \pi^0 \rightarrow$   | $(3.8 \pm 0.9) \times 10^{-3}$   | —   |      |
| $K^+ \pi^- \bar{K}^0 \pi^0 + \text{c.c.}$  |                                  |     |      |
| $K^*(892)^- K^+ \pi^0 \rightarrow$         | $(3.7 \pm 0.8) \times 10^{-3}$   | —   |      |
| $K^+ \pi^- \bar{K}^0 \pi^0 + \text{c.c.}$  |                                  |     |      |
| $K^*(892)^+ \bar{K}^0 \pi^- \rightarrow$   | $(2.9 \pm 0.8) \times 10^{-3}$   | —   |      |
| $K^+ \pi^- \bar{K}^0 \pi^0 + \text{c.c.}$  |                                  |     |      |
| $K^+ K^- \eta \pi^0$                       | $(1.3 \pm 0.4) \times 10^{-3}$   |     | 1549 |
| $K^+ K^- \pi^+ \pi^-$                      | $(8.4 \pm 0.9) \times 10^{-3}$   |     | 1656 |
| $K^+ K^- \pi^+ \pi^- \pi^0$                | $(1.17 \pm 0.13) \%$             |     | 1623 |
| $K_S^0 K^\pm \pi^\mp \pi^+ \pi^-$          | $(7.3 \pm 0.8) \times 10^{-3}$   |     | 1621 |
| $K^+ \bar{K}^*(892)^0 \pi^- + \text{c.c.}$ | $(2.1 \pm 1.1) \times 10^{-3}$   |     | 1602 |
| $K^*(892)^0 \bar{K}^*(892)^0$              | $(2.3 \pm 0.4) \times 10^{-3}$   |     | 1538 |
| $3(\pi^+ \pi^-)$                           | $(8.6 \pm 1.8) \times 10^{-3}$   |     | 1707 |
| $\phi \phi$                                | $(1.06 \pm 0.09) \times 10^{-3}$ |     | 1457 |
| $\phi \phi \eta$                           | $(5.3 \pm 0.6) \times 10^{-4}$   |     | 1206 |
| $\omega \omega$                            | $(8.4 \pm 1.0) \times 10^{-4}$   |     | 1597 |
| $\omega K^+ K^-$                           | $(7.3 \pm 0.9) \times 10^{-4}$   |     | 1540 |
| $\omega \phi$                              | $(9.6 \pm 2.7) \times 10^{-6}$   |     | 1529 |
| $\pi \pi$                                  | $(2.23 \pm 0.09) \times 10^{-3}$ |     | 1773 |
| $\rho^0 \pi^+ \pi^-$                       | $(3.7 \pm 1.6) \times 10^{-3}$   |     | 1682 |
| $\pi^+ \pi^- \pi^0$ (non-resonant)         | $(2.0 \pm 0.4) \times 10^{-5}$   |     | 1765 |
| $\rho(770)^\pm \pi^\mp$                    | $(6 \pm 4) \times 10^{-6}$       |     | —    |
| $\pi^+ \pi^- \eta$                         | $(4.8 \pm 1.3) \times 10^{-4}$   |     | 1724 |
| $\pi^+ \pi^- \eta'$                        | $(5.0 \pm 1.8) \times 10^{-4}$   |     | 1636 |
| $\eta \eta$                                | $(5.4 \pm 0.4) \times 10^{-4}$   |     | 1692 |
| $K^+ K^-$                                  | $(1.01 \pm 0.06) \times 10^{-3}$ |     | 1708 |
| $K_S^0 K_S^0$                              | $(5.2 \pm 0.4) \times 10^{-4}$   |     | 1707 |
| $K^*(892)^\pm K^\mp$                       | $(1.44 \pm 0.21) \times 10^{-4}$ |     | 1627 |
| $K^*(892)^0 \bar{K}^0 + \text{c.c.}$       | $(1.24 \pm 0.27) \times 10^{-4}$ |     | 1627 |
| $K_2^*(1430)^\pm K^\mp$                    | $(1.48 \pm 0.12) \times 10^{-3}$ |     | —    |
| $K_2^*(1430)^0 \bar{K}^0 + \text{c.c.}$    | $(1.24 \pm 0.17) \times 10^{-3}$ |     | 1443 |
| $K_3^*(1780)^\pm K^\mp$                    | $(5.2 \pm 0.8) \times 10^{-4}$   |     | —    |
| $K_3^*(1780)^0 \bar{K}^0 + \text{c.c.}$    | $(5.6 \pm 2.1) \times 10^{-4}$   |     | 1274 |
| $a_2(1320)^0 \pi^0$                        | $(1.29 \pm 0.34) \times 10^{-3}$ |     | —    |
| $a_2(1320)^\pm \pi^\mp$                    | $(1.8 \pm 0.6) \times 10^{-3}$   |     | 1530 |
| $\bar{K}^0 K^+ \pi^- + \text{c.c.}$        | $(1.28 \pm 0.18) \times 10^{-3}$ |     | 1685 |
| $K^+ K^- \pi^0$                            | $(3.0 \pm 0.8) \times 10^{-4}$   |     | 1686 |
| $K^+ K^- \eta$                             | $< 3.2 \times 10^{-4}$           | 90% | 1592 |
| $K^+ K^- \eta'(958)$                       | $(1.94 \pm 0.34) \times 10^{-4}$ |     | 1488 |
| $\eta \eta'$                               | $(2.2 \pm 0.5) \times 10^{-5}$   |     | 1600 |
| $\eta' \eta'$                              | $(4.6 \pm 0.6) \times 10^{-5}$   |     | 1498 |
| $\pi^+ \pi^- K_S^0 K_S^0$                  | $(2.2 \pm 0.5) \times 10^{-3}$   |     | 1655 |
| $K^+ K^- K_S^0 K_S^0$                      | $< 4 \times 10^{-4}$             | 90% | 1418 |
| $K_S^0 K_S^0 K_S^0 K_S^0$                  | $(1.13 \pm 0.18) \times 10^{-4}$ |     | 1415 |

|  |                                    |     |      |
|--|------------------------------------|-----|------|
| $K^+ K^- K^+ K^-$                                  | $( 1.65 \pm 0.20 ) \times 10^{-3}$ |     | 1421 |
| $K^+ K^- \phi$                                     | $( 1.42 \pm 0.29 ) \times 10^{-3}$ |     | 1468 |
| $\bar{K}^0 K^+ \pi^- \phi + \text{c.c.}$           | $( 4.8 \pm 0.7 ) \times 10^{-3}$   |     | 1416 |
| $K^+ K^- \pi^0 \phi$                               | $( 2.7 \pm 0.5 ) \times 10^{-3}$   |     | 1419 |
| $\phi \pi^+ \pi^- \pi^0$                           | $( 9.3 \pm 1.2 ) \times 10^{-4}$   |     | 1603 |
| $\rho \bar{\rho}$                                  | $( 7.33 \pm 0.33 ) \times 10^{-5}$ |     | 1510 |
| $\rho \bar{\rho} \pi^0$                            | $( 4.7 \pm 0.4 ) \times 10^{-4}$   |     | 1465 |
| $\rho \bar{\rho} \eta$                             | $( 1.74 \pm 0.25 ) \times 10^{-4}$ |     | 1285 |
| $\rho \bar{\rho} \omega$                           | $( 3.6 \pm 0.4 ) \times 10^{-4}$   |     | 1152 |
| $\rho \bar{\rho} \phi$                             | $( 2.8 \pm 0.9 ) \times 10^{-5}$   |     | 1002 |
| $\rho \bar{\rho} \pi^+ \pi^-$                      | $( 1.32 \pm 0.34 ) \times 10^{-3}$ |     | 1410 |
| $\rho \bar{\rho} \pi^0 \pi^0$                      | $( 7.8 \pm 2.3 ) \times 10^{-4}$   |     | 1414 |
| $\rho \bar{\rho} K^+ K^-$ (non-resonant)           | $( 1.91 \pm 0.32 ) \times 10^{-4}$ |     | 1013 |
| $\rho \bar{\rho} K_S^0 K_S^0$                      | $< 7.9 \times 10^{-4}$             | 90% | 1007 |
| $\rho \bar{n} \pi^-$                               | $( 8.5 \pm 0.9 ) \times 10^{-4}$   |     | 1463 |
| $\bar{\rho} n \pi^+$                               | $( 8.9 \pm 0.8 ) \times 10^{-4}$   |     | 1463 |
| $\rho \bar{n} \pi^- \pi^0$                         | $( 2.17 \pm 0.18 ) \times 10^{-3}$ |     | 1411 |
| $\bar{\rho} n \pi^+ \pi^0$                         | $( 2.11 \pm 0.18 ) \times 10^{-3}$ |     | 1411 |
| $\Lambda \bar{\Lambda}$                            | $( 1.84 \pm 0.15 ) \times 10^{-4}$ |     | 1384 |
| $\Lambda \bar{\Lambda} \pi^+ \pi^-$                | $( 1.25 \pm 0.15 ) \times 10^{-3}$ |     | 1255 |
| $\Lambda \bar{\Lambda} \pi^+ \pi^-$ (non-resonant) | $( 6.6 \pm 1.5 ) \times 10^{-4}$   |     | 1255 |
| $\Sigma(1385)^+ \bar{\Lambda} \pi^- + \text{c.c.}$ | $< 4 \times 10^{-4}$               | 90% | 1192 |
| $\Sigma(1385)^- \bar{\Lambda} \pi^+ + \text{c.c.}$ | $< 6 \times 10^{-4}$               | 90% | 1192 |
| $K^+ \bar{\rho} \Lambda + \text{c.c.}$             | $( 7.8 \pm 0.5 ) \times 10^{-4}$   |     | 1236 |
| $K^*(892)^+ \bar{\rho} \Lambda + \text{c.c.}$      | $( 8.2 \pm 1.1 ) \times 10^{-4}$   |     | 976  |
| $K^+ \bar{\rho} \Lambda(1520) + \text{c.c.}$       | $( 2.8 \pm 0.7 ) \times 10^{-4}$   |     | 992  |
| $\Lambda(1520) \bar{\Lambda}(1520)$                | $( 4.6 \pm 1.5 ) \times 10^{-4}$   |     | 924  |
| $\Sigma^0 \bar{\Sigma}^0$                          | $( 3.7 \pm 0.6 ) \times 10^{-5}$   |     | 1319 |
| $\Sigma^+ \bar{\rho} K_S^0 + \text{c.c.}$          | $( 8.2 \pm 0.9 ) \times 10^{-5}$   |     | 1197 |
| $\Sigma^0 \bar{\rho} K^+ + \text{c.c.}$            | $( 9.1 \pm 0.8 ) \times 10^{-5}$   |     | 1197 |
| $\Sigma^+ \bar{\Sigma}^-$                          | $( 3.4 \pm 0.7 ) \times 10^{-5}$   |     | 1322 |
| $\Sigma^- \bar{\Sigma}^+$                          | $( 4.4 \pm 1.8 ) \times 10^{-5}$   |     | 1314 |
| $\Sigma(1385)^+ \bar{\Sigma}(1385)^-$              | $< 1.6 \times 10^{-4}$             | 90% | 1118 |
| $\Sigma(1385)^- \bar{\Sigma}(1385)^+$              | $< 8 \times 10^{-5}$               | 90% | 1118 |
| $K^- \Lambda \bar{\Xi}^+ + \text{c.c.}$            | $( 1.76 \pm 0.32 ) \times 10^{-4}$ |     | 1004 |
| $\Xi^0 \bar{\Xi}^0$                                | $< 1.0 \times 10^{-4}$             | 90% | 1197 |
| $\Xi^- \bar{\Xi}^+$                                | $( 1.42 \pm 0.32 ) \times 10^{-4}$ |     | 1189 |
| $J/\psi(1S) \pi^+ \pi^- \pi^0$                     | $< 1.5 \%$                         | 90% | 185  |
| $\pi^0 \eta_c$                                     | $< 3.2 \times 10^{-3}$             | 90% | 511  |
| $\eta_c(1S) \pi^+ \pi^-$                           | $< 5.4 \times 10^{-3}$             | 90% | 459  |

### Radiative decays

|                     |                        |     |      |
|---------------------|------------------------|-----|------|
| $\gamma J/\psi(1S)$ | $( 19.0 \pm 0.5 ) \%$  |     | 430  |
| $\gamma \rho^0$     | $< 1.9 \times 10^{-5}$ | 90% | 1694 |
| $\gamma \omega$     | $< 6 \times 10^{-6}$   | 90% | 1692 |

|                         |                                  |     |      |
|-------------------------|----------------------------------|-----|------|
| $\gamma\phi$            | $< 7 \times 10^{-6}$             | 90% | 1632 |
| $\gamma\gamma$          | $(2.85 \pm 0.10) \times 10^{-4}$ |     | 1778 |
| $e^+e^- J/\psi(1S)$     | $(2.15 \pm 0.14) \times 10^{-3}$ |     | 430  |
| $\mu^+\mu^- J/\psi(1S)$ | $(2.02 \pm 0.33) \times 10^{-4}$ |     | 381  |

## $\eta_c(2S)$

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

Quantum numbers are quark model predictions.

$$\text{Mass } m = 3637.5 \pm 1.1 \text{ MeV} \quad (S = 1.2)$$

$$\text{Full width } \Gamma = 11.3^{+3.2}_{-2.9} \text{ MeV}$$

| $\eta_c(2S)$ DECAY MODES              | Fraction ( $\Gamma_i/\Gamma$ ) | Confidence level | $p$<br>(MeV/c) |
|---------------------------------------|--------------------------------|------------------|----------------|
| hadrons                               | not seen                       |                  | —              |
| $K\bar{K}\pi$                         | $(1.9 \pm 1.2) \%$             |                  | 1729           |
| $K\bar{K}\eta$                        | $(5 \pm 4) \times 10^{-3}$     |                  | 1637           |
| $2\pi^+2\pi^-$                        | not seen                       |                  | 1792           |
| $\rho^0\rho^0$                        | not seen                       |                  | 1645           |
| $3\pi^+3\pi^-$                        | not seen                       |                  | 1749           |
| $K^+K^-\pi^+\pi^-$                    | not seen                       |                  | 1700           |
| $K^{*0}\bar{K}^{*0}$                  | not seen                       |                  | 1585           |
| $K^+K^-\pi^+\pi^-\pi^0$               | $(1.4 \pm 1.0) \%$             |                  | 1667           |
| $K^+K^-\pi^+\pi^-$                    | not seen                       |                  | 1627           |
| $K_S^0 K^- 2\pi^+\pi^- + \text{c.c.}$ | seen                           |                  | 1666           |
| $2K^+2K^-$                            | not seen                       |                  | 1470           |
| $\phi\phi$                            | not seen                       |                  | 1506           |
| $p\bar{p}$                            | seen                           |                  | 1558           |
| $p\bar{p}\pi^+\pi^-$                  | seen                           |                  | 1461           |
| $\gamma\gamma$                        | $(1.9 \pm 1.3) \times 10^{-4}$ |                  | 1819           |
| $\gamma J/\psi(1S)$                   | $< 1.4 \%$                     | 90%              | 500            |
| $\pi^+\pi^-\eta$                      | not seen                       |                  | 1766           |
| $\pi^+\pi^-\eta'$                     | not seen                       |                  | 1680           |
| $\pi^+\pi^-\eta_c(1S)$                | $< 25 \%$                      | 90%              | 537            |

## $\psi(2S)$

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

$$\text{Mass } m = 3686.10 \pm 0.06 \text{ MeV} \quad (S = 5.9)$$

$$\text{Full width } \Gamma = 294 \pm 8 \text{ keV}$$

| $\psi(2S)$ DECAY MODES               | Fraction ( $\Gamma_i/\Gamma$ ) | Scale factor/<br>Confidence level | $p$<br>(MeV/c) |
|--------------------------------------|--------------------------------|-----------------------------------|----------------|
| hadrons                              | $(97.85 \pm 0.13) \%$          |                                   | —              |
| virtual $\gamma \rightarrow$ hadrons | $(1.73 \pm 0.14) \%$           | S=1.5                             | —              |

|                 |                                    |      |
|-----------------|------------------------------------|------|
| $ggg$           | ( 10.6 ± 1.6 ) %                   | —    |
| $\gamma g g$    | ( 1.03 ± 0.29 ) %                  | —    |
| light hadrons   | ( 15.4 ± 1.5 ) %                   | —    |
| $e^+ e^-$       | ( 7.93 ± 0.17 ) × 10 <sup>-3</sup> | 1843 |
| $\mu^+ \mu^-$   | ( 8.0 ± 0.6 ) × 10 <sup>-3</sup>   | 1840 |
| $\tau^+ \tau^-$ | ( 3.1 ± 0.4 ) × 10 <sup>-3</sup>   | 489  |

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

|                        |                                      |     |
|------------------------|--------------------------------------|-----|
| $J/\psi(1S)$ anything  | ( 61.4 ± 0.6 ) %                     | —   |
| $J/\psi(1S)$ neutrals  | ( 25.38 ± 0.32 ) %                   | —   |
| $J/\psi(1S)\pi^+\pi^-$ | ( 34.68 ± 0.30 ) %                   | 477 |
| $J/\psi(1S)\pi^0\pi^0$ | ( 18.24 ± 0.31 ) %                   | 481 |
| $J/\psi(1S)\eta$       | ( 3.37 ± 0.05 ) %                    | 199 |
| $J/\psi(1S)\pi^0$      | ( 1.268 ± 0.032 ) × 10 <sup>-3</sup> | 528 |

### Hadronic decays

|                                      |  |             |
|--------------------------------------|--|-------------|
| $\pi^0 h_c(1P)$                      | ( 8.6 ± 1.3 ) × 10 <sup>-4</sup>                           | 85          |
| $3(\pi^+\pi^-)\pi^0$                 | ( 3.5 ± 1.6 ) × 10 <sup>-3</sup>                           | 1746        |
| $2(\pi^+\pi^-)\pi^0$                 | ( 2.9 ± 1.0 ) × 10 <sup>-3</sup>                           | S=4.7 1799  |
| $\rho a_2(1320)$                     | ( 2.6 ± 0.9 ) × 10 <sup>-4</sup>                           | 1500        |
| $\pi^+\pi^-\pi^0\pi^0\pi^0$          | ( 5.3 ± 0.9 ) × 10 <sup>-3</sup>                           | 1800        |
| $\rho^\pm\pi^\mp\pi^0\pi^0$          | < 2.7 × 10 <sup>-3</sup>                                   | CL=90% 1737 |
| $p\bar{p}$                           | ( 2.94 ± 0.08 ) × 10 <sup>-4</sup>                         | 1586        |
| $n\bar{n}$                           | ( 3.06 ± 0.15 ) × 10 <sup>-4</sup>                         | 1586        |
| $\Delta^{++}\bar{\Delta}^{--}$       | ( 1.28 ± 0.35 ) × 10 <sup>-4</sup>                         | 1371        |
| $\Lambda\bar{\Lambda}\pi^0$          | < 2.9 × 10 <sup>-6</sup>                                   | CL=90% 1412 |
| $\Lambda\bar{\Lambda}\eta$           | ( 2.5 ± 0.4 ) × 10 <sup>-5</sup>                           | 1197        |
| $\Lambda\bar{p}K^+$                  | ( 1.00 ± 0.14 ) × 10 <sup>-4</sup>                         | 1327        |
| $K^*(892)^+\bar{p}\Lambda + c.c.$    | ( 6.3 ± 0.7 ) × 10 <sup>-5</sup>                           | 1087        |
| $\Lambda\bar{p}K^+\pi^+\pi^-$        | ( 1.8 ± 0.4 ) × 10 <sup>-4</sup>                           | 1167        |
| $\Lambda\bar{\Lambda}\pi^+\pi^-$     | ( 2.8 ± 0.6 ) × 10 <sup>-4</sup>                           | 1346        |
| $\Lambda\bar{\Lambda}$               | ( 3.81 ± 0.13 ) × 10 <sup>-4</sup>                         | S=1.4 1467  |
| $\Lambda\bar{\Sigma}^+\pi^- + c.c.$  | ( 1.40 ± 0.13 ) × 10 <sup>-4</sup>                         | 1376        |
| $\Lambda\bar{\Sigma}^-\pi^+ + c.c.$  | ( 1.54 ± 0.14 ) × 10 <sup>-4</sup>                         | 1379        |
| $\Lambda\bar{\Sigma}^0$              | ( 1.23 ± 0.24 ) × 10 <sup>-5</sup>                         | 1437        |
| $\Sigma^0\bar{p}K^+ + c.c.$          | ( 1.67 ± 0.18 ) × 10 <sup>-5</sup>                         | 1291        |
| $\Sigma^+\bar{\Sigma}^-$             | ( 2.32 ± 0.12 ) × 10 <sup>-4</sup>                         | 1408        |
| $\Sigma^0\bar{\Sigma}^0$             | ( 2.35 ± 0.09 ) × 10 <sup>-4</sup>                         | S=1.1 1405  |
| $\Sigma(1385)^+\bar{\Sigma}(1385)^-$ | ( 8.5 ± 0.7 ) × 10 <sup>-5</sup>                           | 1218        |
| $\Sigma(1385)^-\bar{\Sigma}(1385)^+$ | ( 8.5 ± 0.8 ) × 10 <sup>-5</sup>                           | 1218        |
| $\Sigma(1385)^0\bar{\Sigma}(1385)^0$ | ( 6.9 ± 0.7 ) × 10 <sup>-5</sup>                           | 1218        |
| $\Xi^-\bar{\Xi}^+$                   | ( 2.87 ± 0.11 ) × 10 <sup>-4</sup>                         | S=1.1 1284  |
| $\Xi^0\bar{\Xi}^0$                   | ( 2.3 ± 0.4 ) × 10 <sup>-4</sup>                           | S=4.2 1291  |
| $\Xi(1530)^0\bar{\Xi}(1530)^0$       | ( 5.2 <sup>+3.2</sup> <sub>-1.2</sub> ) × 10 <sup>-5</sup> | 1025        |

|   |  |        |      |
|---|--|--------|------|
| $K^- \Lambda \Xi^+ + \text{c.c.}$                           | $( 3.9 \pm 0.4 ) \times 10^{-5}$   |        | 1114 |
| $\Xi(1530)^- \Xi(1530)^+$                                   | $( 1.15 \pm 0.07 ) \times 10^{-4}$   |        | 1025 |
| $\Xi(1530)^- \Xi^+$   | $( 7.0 \pm 1.2 ) \times 10^{-6}$   |        | 1165 |
| $\Xi(1690)^- \Xi^+ \rightarrow K^- \Lambda \Xi^+ +$         | $( 5.2 \pm 1.6 ) \times 10^{-6}$   |        | —    |
| $\Xi(1820)^- \Xi^+ \rightarrow K^- \Lambda \Xi^+ +$         | $( 1.20 \pm 0.32 ) \times 10^{-5}$   |        | —    |
| $K^- \Sigma^0 \Xi^+ + \text{c.c.}$                          | $( 3.7 \pm 0.4 ) \times 10^{-5}$   |        | 1060 |
| $\Omega^- \bar{\Omega}^+$                                   | $( 5.66 \pm 0.30 ) \times 10^{-5}$   | S=1.3  | 774  |
| $\pi^0 p \bar{p}$   | $( 1.53 \pm 0.07 ) \times 10^{-4}$   |        | 1543 |
| $N(940) \bar{p} + \text{c.c.} \rightarrow \pi^0 p \bar{p}$  | $( 6.4 \begin{smallmatrix} +1.8 \\ -1.3 \end{smallmatrix} ) \times 10^{-5}$    |        | —    |
| $N(1440) \bar{p} + \text{c.c.} \rightarrow \pi^0 p \bar{p}$ | $( 7.3 \begin{smallmatrix} +1.7 \\ -1.5 \end{smallmatrix} ) \times 10^{-5}$    | S=2.5  | —    |
| $N(1520) \bar{p} + \text{c.c.} \rightarrow \pi^0 p \bar{p}$ | $( 6.4 \begin{smallmatrix} +2.3 \\ -1.8 \end{smallmatrix} ) \times 10^{-6}$    |        | —    |
| $N(1535) \bar{p} + \text{c.c.} \rightarrow \pi^0 p \bar{p}$ | $( 2.5 \pm 1.0 ) \times 10^{-5}$   |        | —    |
| $N(1650) \bar{p} + \text{c.c.} \rightarrow \pi^0 p \bar{p}$ | $( 3.8 \begin{smallmatrix} +1.4 \\ -1.7 \end{smallmatrix} ) \times 10^{-5}$    |        | —    |
| $N(1720) \bar{p} + \text{c.c.} \rightarrow \pi^0 p \bar{p}$ | $( 1.79 \begin{smallmatrix} +0.26 \\ -0.70 \end{smallmatrix} ) \times 10^{-5}$ |        | —    |
| $N(2300) \bar{p} + \text{c.c.} \rightarrow \pi^0 p \bar{p}$ | $( 2.6 \begin{smallmatrix} +1.2 \\ -0.7 \end{smallmatrix} ) \times 10^{-5}$    |        | —    |
| $N(2570) \bar{p} + \text{c.c.} \rightarrow \pi^0 p \bar{p}$ | $( 2.13 \begin{smallmatrix} +0.40 \\ -0.31 \end{smallmatrix} ) \times 10^{-5}$ |        | —    |
| $\eta p \bar{p}$  | $( 6.0 \pm 0.4 ) \times 10^{-5}$   |        | 1373 |
| $N(1535) \bar{p} + \text{c.c.} \rightarrow \eta p \bar{p}$  | $( 4.4 \pm 0.7 ) \times 10^{-5}$   |        | —    |
| $\omega p \bar{p}$  | $( 6.9 \pm 2.1 ) \times 10^{-5}$   |        | 1247 |
| $\eta' p \bar{p}$   | $( 1.10 \pm 0.13 ) \times 10^{-5}$   |        | 1141 |
| $\phi p \bar{p}$  | $( 6.1 \pm 0.6 ) \times 10^{-6}$   |        | 1109 |
| $\phi X(1835) \rightarrow \phi p \bar{p}$                   | $< 1.82 \times 10^{-7}$  | CL=90% | —    |
| $\pi^+ \pi^- p \bar{p}$                                     | $( 6.0 \pm 0.4 ) \times 10^{-4}$   |        | 1491 |
| $p \bar{n} \pi^- \text{ or c.c.}$                           | $( 2.48 \pm 0.17 ) \times 10^{-4}$   |        | —    |
| $p \bar{n} \pi^- \pi^0$                                     | $( 3.2 \pm 0.7 ) \times 10^{-4}$   |        | 1492 |
| $2(\pi^+ \pi^- \pi^0)$                                      | $( 4.8 \pm 1.5 ) \times 10^{-3}$   |        | 1776 |
| $\eta \pi^+ \pi^-$  | $< 1.6 \times 10^{-4}$   | CL=90% | 1791 |
| $\eta \pi^+ \pi^- \pi^0$                                    | $( 9.5 \pm 1.7 ) \times 10^{-4}$   |        | 1778 |
| $2(\pi^+ \pi^-) \eta$                                       | $( 1.2 \pm 0.6 ) \times 10^{-3}$   |        | 1758 |
| $\pi^+ \pi^- \pi^0 \pi^0 \eta$                              | $< 4 \times 10^{-4}$   | CL=90% | 1760 |
| $\eta' \pi^+ \pi^- \pi^0$                                   | $( 4.5 \pm 2.1 ) \times 10^{-4}$   |        | 1692 |
| $\omega \pi^+ \pi^-$  | $( 7.3 \pm 1.2 ) \times 10^{-4}$   | S=2.1  | 1748 |
| $b_1^\pm \pi^\mp$   | $( 4.0 \pm 0.6 ) \times 10^{-4}$   | S=1.1  | 1635 |
| $b_1^0 \pi^0$   | $( 2.4 \pm 0.6 ) \times 10^{-4}$   |        | —    |
| $\omega f_2(1270)$  | $( 2.2 \pm 0.4 ) \times 10^{-4}$   |        | 1515 |
| $\omega \pi^0 \pi^0$  | $( 1.11 \pm 0.35 ) \times 10^{-3}$   |        | 1749 |
| $\pi^0 \pi^0 K^+ K^-$                                       | $( 2.6 \pm 1.3 ) \times 10^{-4}$   |        | 1728 |
| $\pi^+ \pi^- K^+ K^-$                                       | $( 7.3 \pm 0.5 ) \times 10^{-4}$   |        | 1726 |

|   |   |        |      |
|---|---|--------|------|
| $\pi^0 \pi^0 K_S^0 K_L^0$   | $( 1.3 \pm 0.6 ) \times 10^{-3}$  |        | 1726 |
| $\rho^0 K^+ K^-$  | $( 2.2 \pm 0.4 ) \times 10^{-4}$  |        | 1616 |
| $K^*(892)^0 \bar{K}_2^*(1430)^0$                                    | $( 1.9 \pm 0.5 ) \times 10^{-4}$  |        | 1417 |
| $K^+ K^- \pi^+ \pi^- \eta$  | $( 1.3 \pm 0.7 ) \times 10^{-3}$  |        | 1574 |
| $K^+ K^- 2(\pi^+ \pi^-) \pi^0$                                      | $( 1.00 \pm 0.31 ) \times 10^{-3}$  |        | 1611 |
| $K^+ K^- 2(\pi^+ \pi^-)$  | $( 1.9 \pm 0.9 ) \times 10^{-3}$  |        | 1654 |
| $K_1(1270)^\pm K^\mp$   | $( 1.00 \pm 0.28 ) \times 10^{-3}$  |        | 1588 |
| $K_S^0 K_L^0 \pi^+ \pi^-$   | $( 2.2 \pm 0.4 ) \times 10^{-4}$  |        | 1724 |
| $\rho^0 \rho \bar{\rho}$  | $( 5.0 \pm 2.2 ) \times 10^{-5}$  |        | 1252 |
| $K^+ \bar{K}^*(892)^0 \pi^- + \text{c.c.}$                          | $( 6.7 \pm 2.5 ) \times 10^{-4}$  |        | 1674 |
| $2(\pi^+ \pi^-)$  | $( 2.4 \pm 0.6 ) \times 10^{-4}$  | S=2.2  | 1817 |
| $\rho^0 \pi^+ \pi^-$  | $( 2.2 \pm 0.6 ) \times 10^{-4}$  | S=1.4  | 1750 |
| $K^+ K^- \pi^+ \pi^- \pi^0$   | $( 1.26 \pm 0.09 ) \times 10^{-3}$  |        | 1694 |
| $\omega f_0(1710) \rightarrow \omega K^+ K^-$                       | $( 5.9 \pm 2.2 ) \times 10^{-5}$  |        | —    |
| $K^*(892)^0 K^- \pi^+ \pi^0 + \text{c.c.}$                          | $( 8.6 \pm 2.2 ) \times 10^{-4}$  |        | —    |
| $K^*(892)^+ K^- \pi^+ \pi^- + \text{c.c.}$                          | $( 9.6 \pm 2.8 ) \times 10^{-4}$  |        | —    |
| $K^*(892)^+ K^- \rho^0 + \text{c.c.}$                               | $( 7.3 \pm 2.6 ) \times 10^{-4}$  |        | —    |
| $K^*(892)^0 K^- \rho^+ + \text{c.c.}$                               | $( 6.1 \pm 1.8 ) \times 10^{-4}$  |        | —    |
| $\eta K^+ K^-$ , no $\eta \phi$                                     | $( 3.49 \pm 0.17 ) \times 10^{-5}$  |        | 1664 |
| $\omega K^+ K^-$  | $( 1.62 \pm 0.11 ) \times 10^{-4}$  | S=1.1  | 1614 |
| $\omega K^*(892)^+ K^- + \text{c.c.}$                               | $( 2.07 \pm 0.26 ) \times 10^{-4}$  |        | 1482 |
| $\omega K_2^*(1430)^+ K^- + \text{c.c.}$                            | $( 6.1 \pm 1.2 ) \times 10^{-5}$  |        | 1252 |
| $\omega \bar{K}^*(892)^0 K^0$                                       | $( 1.68 \pm 0.30 ) \times 10^{-4}$  |        | 1481 |
| $\omega \bar{K}_2^*(1430)^0 K^0$                                    | $( 5.8 \pm 2.2 ) \times 10^{-5}$  |        | 1250 |
| $\omega X(1440) \rightarrow \omega K_S^0 K^- \pi^+ + \text{c.c.}$   | $( 1.6 \pm 0.4 ) \times 10^{-5}$  |        | —    |
| $\omega X(1440) \rightarrow \omega K^+ K^- \pi^0$                   | $( 1.09 \pm 0.26 ) \times 10^{-5}$  |        | —    |
| $\omega f_1(1285) \rightarrow \omega K_S^0 K^- \pi^+ + \text{c.c.}$ | $( 3.0 \pm 1.0 ) \times 10^{-6}$  |        | —    |
| $\omega f_1(1285) \rightarrow \omega K^+ K^- \pi^0$                 | $( 1.2 \pm 0.7 ) \times 10^{-6}$  |        | —    |
| $3(\pi^+ \pi^-)$  | $( 3.5 \pm 2.0 ) \times 10^{-4}$  | S=2.8  | 1774 |
| $\rho \bar{\rho} \pi^+ \pi^- \pi^0$                                 | $( 7.3 \pm 0.7 ) \times 10^{-4}$  |        | 1435 |
| $K^+ K^-$   | $( 7.5 \pm 0.5 ) \times 10^{-5}$  |        | 1776 |
| $K_S^0 K_L^0$   | $( 5.34 \pm 0.33 ) \times 10^{-5}$  |        | 1775 |
| $\pi^+ \pi^- \pi^0$   | $( 2.01 \pm 0.17 ) \times 10^{-4}$  | S=1.7  | 1830 |
| $\rho(2150) \pi \rightarrow \pi^+ \pi^- \pi^0$                      | $( 1.9 \begin{smallmatrix} +1.2 \\ -0.4 \end{smallmatrix} ) \times 10^{-4}$ |        | —    |
| $\rho(770) \pi \rightarrow \pi^+ \pi^- \pi^0$                       | $( 3.2 \pm 1.2 ) \times 10^{-5}$  | S=1.8  | —    |
| $\pi^+ \pi^-$   | $( 7.8 \pm 2.6 ) \times 10^{-6}$  |        | 1838 |
| $K_1(1400)^\pm K^\mp$   | $< 3.1 \times 10^{-4}$  | CL=90% | 1532 |
| $K_2^*(1430)^\pm K^\mp$   | $( 7.1 \begin{smallmatrix} +1.3 \\ -0.9 \end{smallmatrix} ) \times 10^{-5}$ |        | —    |
| $K^+ K^- \pi^0$   | $( 4.07 \pm 0.31 ) \times 10^{-5}$  |        | 1754 |
| $K_S^0 K_L^0 \pi^0$   | $< 3.0 \times 10^{-4}$  | CL=90% | 1753 |
| $K_S^0 K_L^0 \eta$  | $( 1.3 \pm 0.5 ) \times 10^{-3}$  |        | 1661 |



|   |   |        |      |
|---|---|--------|------|
| $K^+ K^*(892)^- + \text{c.c.}$  | $( 2.9 \pm 0.4 ) \times 10^{-5}$  | S=1.2  | 1698 |
| $K^*(892)^0 \bar{K}^0 + \text{c.c.}$  | $( 1.09 \pm 0.20 ) \times 10^{-4}$  |        | 1697 |
| $\phi \pi^+ \pi^-$  | $( 1.18 \pm 0.26 ) \times 10^{-4}$  | S=1.5  | 1690 |
| $\phi f_0(980) \rightarrow \pi^+ \pi^-$   | $( 7.5 \pm 3.3 ) \times 10^{-5}$  | S=1.6  | —    |
| $2(K^+ K^-)$  | $( 6.3 \pm 1.3 ) \times 10^{-5}$  |        | 1499 |
| $\phi K^+ K^-$  | $( 7.0 \pm 1.6 ) \times 10^{-5}$  |        | 1546 |
| $2(K^+ K^-) \pi^0$  | $( 1.10 \pm 0.28 ) \times 10^{-4}$  |        | 1440 |
| $\phi \eta$   | $( 3.10 \pm 0.31 ) \times 10^{-5}$  |        | 1654 |
| $\eta \phi(2170), \phi(2170) \rightarrow$<br>$\phi f_0(980), f_0 \rightarrow \pi^+ \pi^-$ | $< 2.2 \times 10^{-6}$  | CL=90% | —    |
| $\phi \eta'$  | $( 1.54 \pm 0.20 ) \times 10^{-5}$  |        | 1555 |
| $\phi f_1(1285)$  | $( 3.0 \pm 1.3 ) \times 10^{-5}$  |        | 1436 |
| $\phi \eta(1405) \rightarrow \phi \pi^+ \pi^- \eta$                                       | $( 8.5 \pm 1.7 ) \times 10^{-6}$  |        | —    |
| $\omega \eta'$  | $( 3.2 \begin{smallmatrix} +2.5 \\ -2.1 \end{smallmatrix} ) \times 10^{-5}$ |        | 1623 |
| $\omega \pi^0$  | $( 2.1 \pm 0.6 ) \times 10^{-5}$  |        | 1757 |
| $\rho \eta'$  | $( 1.9 \begin{smallmatrix} +1.7 \\ -1.2 \end{smallmatrix} ) \times 10^{-5}$ |        | 1625 |
| $\rho \eta$   | $( 2.2 \pm 0.6 ) \times 10^{-5}$  | S=1.1  | 1717 |
| $\omega \eta$   | $< 1.1 \times 10^{-5}$  | CL=90% | 1715 |
| $\phi \pi^0$  | $< 4 \times 10^{-7}$  | CL=90% | 1699 |
| $\eta_c \pi^+ \pi^- \pi^0$  | $< 1.0 \times 10^{-3}$  | CL=90% | 512  |
| $\bar{p} \bar{p} K^+ K^-$   | $( 2.7 \pm 0.7 ) \times 10^{-5}$  |        | 1118 |
| $\bar{\Lambda} n K_S^0 + \text{c.c.}$   | $( 8.1 \pm 1.8 ) \times 10^{-5}$  |        | 1324 |
| $\phi f_2'(1525)$   | $( 4.4 \pm 1.6 ) \times 10^{-5}$  |        | 1325 |
| $\Theta(1540) \bar{\Theta}(1540) \rightarrow$<br>$K_S^0 p K^- \bar{n} + \text{c.c.}$      | $< 8.8 \times 10^{-6}$  | CL=90% | —    |
| $\Theta(1540) K^- \bar{n} \rightarrow K_S^0 p K^- \bar{n}$                                | $< 1.0 \times 10^{-5}$  | CL=90% | —    |
| $\Theta(1540) K_S^0 \bar{p} \rightarrow K_S^0 \bar{p} K^+ n$                              | $< 7.0 \times 10^{-6}$  | CL=90% | —    |
| $\bar{\Theta}(1540) K^+ n \rightarrow K_S^0 \bar{p} K^+ n$                                | $< 2.6 \times 10^{-5}$  | CL=90% | —    |
| $\bar{\Theta}(1540) K_S^0 p \rightarrow K_S^0 p K^- \bar{n}$                              | $< 6.0 \times 10^{-6}$  | CL=90% | —    |
| $K_S^0 K_S^0$   | $< 4.6 \times 10^{-6}$  |        | 1775 |
| $\Lambda_c^+ \bar{p} e^+ e^- + \text{c.c.}$   | $< 1.7 \times 10^{-6}$  | CL=90% | 830  |

### Radiative decays

|   |  |       |      |
|---|--|-------|------|
| $\gamma \chi_{c0}(1P)$                          | $( 9.79 \pm 0.20 ) \%$   |       | 261  |
| $\gamma \chi_{c1}(1P)$                          | $( 9.75 \pm 0.24 ) \%$   |       | 171  |
| $\gamma \chi_{c2}(1P)$                          | $( 9.52 \pm 0.20 ) \%$   |       | 128  |
| $\gamma \eta_c(1S)$                             | $( 3.4 \pm 0.5 ) \times 10^{-3}$   | S=1.3 | 635  |
| $\gamma \eta_c(2S)$                             | $( 7 \pm 5 ) \times 10^{-4}$   |       | 48   |
| $\gamma \pi^0$                                  | $( 1.04 \pm 0.22 ) \times 10^{-6}$   | S=1.4 | 1841 |
| $\gamma \eta'(958)$                             | $( 1.24 \pm 0.04 ) \times 10^{-4}$   |       | 1719 |
| $\gamma f_2(1270)$                              | $( 2.73 \begin{smallmatrix} +0.29 \\ -0.25 \end{smallmatrix} ) \times 10^{-4}$ | S=1.8 | 1622 |
| $\gamma f_0(1370) \rightarrow \gamma K \bar{K}$ | $( 3.1 \pm 1.7 ) \times 10^{-5}$   |       | 1588 |

|   |   |                         |      |
|---|---|-------------------------|------|
| $\gamma f_0(1500)$  | $( 9.3 \pm 1.9 ) \times 10^{-5}$  |                         | 1535 |
| $\gamma f'_2(1525)$   | $( 3.3 \pm 0.8 ) \times 10^{-5}$  |                         | 1531 |
| $\gamma f_0(1710) \rightarrow \gamma \pi \pi$   | $( 3.5 \pm 0.6 ) \times 10^{-5}$  |                         | —    |
| $\gamma f_0(1710) \rightarrow \gamma K \bar{K}$   | $( 6.6 \pm 0.7 ) \times 10^{-5}$  |                         | —    |
| $\gamma f_0(2100) \rightarrow \gamma \pi \pi$   | $( 4.8 \pm 1.0 ) \times 10^{-6}$  |                         | 1244 |
| $\gamma f_0(2200) \rightarrow \gamma K \bar{K}$   | $( 3.2 \pm 1.0 ) \times 10^{-6}$  |                         | 1193 |
| $\gamma f_J(2220) \rightarrow \gamma \pi \pi$   | $< 5.8$   | $\times 10^{-6}$ CL=90% | 1168 |
| $\gamma f_J(2220) \rightarrow \gamma K \bar{K}$   | $< 9.5$   | $\times 10^{-6}$ CL=90% | 1168 |
| $\gamma \gamma$   | $< 1.5$   | $\times 10^{-4}$ CL=90% | 1843 |
| $\gamma \eta$   | $( 9.2 \pm 1.8 ) \times 10^{-7}$  |                         | 1802 |
| $\gamma \eta \pi^+ \pi^-$   | $( 8.7 \pm 2.1 ) \times 10^{-4}$  |                         | 1791 |
| $\gamma \eta(1405) \rightarrow \gamma K \bar{K} \pi$  | $< 9$   | $\times 10^{-5}$ CL=90% | 1569 |
| $\gamma \eta(1405) \rightarrow \eta \pi^+ \pi^-$  | $( 3.6 \pm 2.5 ) \times 10^{-5}$  |                         | —    |
| $\gamma \eta(1405) \rightarrow \gamma f_0(980) \pi^0 \rightarrow$<br>$\gamma \pi^+ \pi^- \pi^0$ | $< 5.0$   | $\times 10^{-7}$ CL=90% | —    |
| $\gamma \eta(1475) \rightarrow K \bar{K} \pi$   | $< 1.4$   | $\times 10^{-4}$ CL=90% | —    |
| $\gamma \eta(1475) \rightarrow \eta \pi^+ \pi^-$  | $< 8.8$   | $\times 10^{-5}$ CL=90% | —    |
| $\gamma 2(\pi^+ \pi^-)$   | $( 4.0 \pm 0.6 ) \times 10^{-4}$  |                         | 1817 |
| $\gamma K^{*0} K^+ \pi^- + \text{c.c.}$   | $( 3.7 \pm 0.9 ) \times 10^{-4}$  |                         | 1674 |
| $\gamma K^{*0} \bar{K}^{*0}$  | $( 2.4 \pm 0.7 ) \times 10^{-4}$  |                         | 1613 |
| $\gamma K_S^0 K^+ \pi^- + \text{c.c.}$  | $( 2.6 \pm 0.5 ) \times 10^{-4}$  |                         | 1753 |
| $\gamma K^+ K^- \pi^+ \pi^-$  | $( 1.9 \pm 0.5 ) \times 10^{-4}$  |                         | 1726 |
| $\gamma \rho \bar{\rho}$  | $( 3.9 \pm 0.5 ) \times 10^{-5}$  | S=2.0                   | 1586 |
| $\gamma f_2(1950) \rightarrow \gamma \rho \bar{\rho}$   | $( 1.20 \pm 0.22 ) \times 10^{-5}$  |                         | —    |
| $\gamma f_2(2150) \rightarrow \gamma \rho \bar{\rho}$   | $( 7.2 \pm 1.8 ) \times 10^{-6}$  |                         | —    |
| $\gamma X(1835) \rightarrow \gamma \rho \bar{\rho}$   | $( 4.6 \begin{smallmatrix} +1.8 \\ -4.0 \end{smallmatrix} ) \times 10^{-6}$ |                         | —    |
| $\gamma X \rightarrow \gamma \rho \bar{\rho}$   | [ <i>l</i> aa] $< 2$  | $\times 10^{-6}$ CL=90% | —    |
| $\gamma \pi^+ \pi^- \rho \bar{\rho}$  | $( 2.8 \pm 1.4 ) \times 10^{-5}$  |                         | 1491 |
| $\gamma 2(\pi^+ \pi^-) K^+ K^-$   | $< 2.2$   | $\times 10^{-4}$ CL=90% | 1654 |
| $\gamma 3(\pi^+ \pi^-)$   | $< 1.7$   | $\times 10^{-4}$ CL=90% | 1774 |
| $\gamma K^+ K^- K^+ K^-$  | $< 4$   | $\times 10^{-5}$ CL=90% | 1499 |
| $\gamma \gamma J/\psi$  | $( 3.1 \begin{smallmatrix} +1.0 \\ -1.2 \end{smallmatrix} ) \times 10^{-4}$ |                         | 542  |
| $e^+ e^- \eta'$   | $( 1.90 \pm 0.26 ) \times 10^{-6}$  |                         | 1719 |
| $e^+ e^- \chi_{c0}(1P)$   | $( 1.06 \pm 0.24 ) \times 10^{-3}$  |                         | 261  |
| $e^+ e^- \chi_{c1}(1P)$   | $( 8.5 \pm 0.6 ) \times 10^{-4}$  |                         | 171  |
| $e^+ e^- \chi_{c2}(1P)$   | $( 7.0 \pm 0.8 ) \times 10^{-4}$  |                         | 128  |
| <b>Weak decays</b>  |   |                         |      |
| $D^0 e^+ e^- + \text{c.c.}$   | $< 1.4$   | $\times 10^{-7}$ CL=90% | 1371 |
| <b>Other decays</b>   |   |                         |      |
| invisible   | $< 1.6$   | % CL=90%                | —    |

**$\psi(3770)$** 

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

Mass  $m = 3773.7 \pm 0.4$  MeV (S = 1.4)Full width  $\Gamma = 27.2 \pm 1.0$  MeV

| <b><math>\psi(3770)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ )      | Scale factor/<br>Confidence level | $p$<br>(MeV/c) |
|--|-------------------------------------|-----------------------------------|----------------|
| $D\bar{D}$                                 | (93 $^{+8}_{-9}$ ) %                | S=2.0                             | 287            |
| $D^0\bar{D}^0$                             | (52 $^{+4}_{-5}$ ) %                | S=2.0                             | 287            |
| $D^+D^-$                                   | (41 $\pm 4$ ) %                     | S=2.0                             | 254            |
| $J/\psi\pi^+\pi^-$                         | (1.93 $\pm 0.28$ ) $\times 10^{-3}$ |                                   | 561            |
| $J/\psi\pi^0\pi^0$                         | (8.0 $\pm 3.0$ ) $\times 10^{-4}$   |                                   | 565            |
| $J/\psi\eta$                               | (9 $\pm 4$ ) $\times 10^{-4}$       |                                   | 361            |
| $J/\psi\pi^0$                              | < 2.8 $\times 10^{-4}$              | CL=90%                            | 604            |
| $e^+e^-$                                   | (9.6 $\pm 0.7$ ) $\times 10^{-6}$   | S=1.3                             | 1887           |

**Decays to light hadrons**

|                                     |                                   |        |      |
|-------------------------------------|-----------------------------------|--------|------|
| $b_1(1235)\pi$                      | < 1.4 $\times 10^{-5}$            | CL=90% | 1684 |
| $\phi\eta'$                         | < 7 $\times 10^{-4}$              | CL=90% | 1607 |
| $\omega\eta'$                       | < 4 $\times 10^{-4}$              | CL=90% | 1672 |
| $\rho^0\eta'$                       | < 6 $\times 10^{-4}$              | CL=90% | 1674 |
| $\phi\eta$                          | (3.1 $\pm 0.7$ ) $\times 10^{-4}$ |        | 1703 |
| $\omega\eta$                        | < 1.4 $\times 10^{-5}$            | CL=90% | 1762 |
| $\rho^0\eta$                        | < 5 $\times 10^{-4}$              | CL=90% | 1764 |
| $\phi\pi^0$                         | < 3 $\times 10^{-5}$              | CL=90% | 1746 |
| $\omega\pi^0$                       | < 6 $\times 10^{-4}$              | CL=90% | 1803 |
| $\pi^+\pi^-\pi^0$                   | < 5 $\times 10^{-6}$              | CL=90% | 1874 |
| $\rho\pi$                           | < 5 $\times 10^{-6}$              | CL=90% | 1805 |
| $K^*(892)^+K^- + \text{c.c.}$       | < 1.4 $\times 10^{-5}$            | CL=90% | 1745 |
| $K^*(892)^0\bar{K}^0 + \text{c.c.}$ | < 1.2 $\times 10^{-3}$            | CL=90% | 1745 |
| $K_S^0K_L^0$                        | < 1.2 $\times 10^{-5}$            | CL=90% | 1820 |
| $2(\pi^+\pi^-)$                     | < 1.12 $\times 10^{-3}$           | CL=90% | 1861 |
| $2(\pi^+\pi^-)\pi^0$                | < 1.06 $\times 10^{-3}$           | CL=90% | 1844 |
| $2(\pi^+\pi^-\pi^0)$                | < 5.85 %                          | CL=90% | 1821 |
| $\omega\pi^+\pi^-$                  | < 6.0 $\times 10^{-4}$            | CL=90% | 1794 |
| $3(\pi^+\pi^-)$                     | < 9.1 $\times 10^{-3}$            | CL=90% | 1820 |
| $3(\pi^+\pi^-)\pi^0$                | < 1.37 %                          | CL=90% | 1792 |
| $3(\pi^+\pi^-)2\pi^0$               | < 11.74 %                         | CL=90% | 1760 |
| $\eta\pi^+\pi^-$                    | < 1.24 $\times 10^{-3}$           | CL=90% | 1836 |
| $\pi^+\pi^-2\pi^0$                  | < 8.9 $\times 10^{-3}$            | CL=90% | 1862 |
| $\rho^0\pi^+\pi^-$                  | < 6.9 $\times 10^{-3}$            | CL=90% | 1796 |
| $\eta3\pi$                          | < 1.34 $\times 10^{-3}$           | CL=90% | 1824 |
| $\eta2(\pi^+\pi^-)$                 | < 2.43 %                          | CL=90% | 1804 |
| $\eta\rho^0\pi^+\pi^-$              | < 1.45 %                          | CL=90% | 1708 |

|  |        |                  |        |      |
|--|--------|------------------|--------|------|
| $\eta' 3\pi$                           | < 2.44 | $\times 10^{-3}$ | CL=90% | 1741 |
| $K^+ K^- \pi^+ \pi^-$                  | < 9.0  | $\times 10^{-4}$ | CL=90% | 1773 |
| $\phi \pi^+ \pi^-$                     | < 4.1  | $\times 10^{-4}$ | CL=90% | 1737 |
| $K^+ K^- 2\pi^0$                       | < 4.2  | $\times 10^{-3}$ | CL=90% | 1774 |
| $4(\pi^+ \pi^-)$                       | < 1.67 | %                | CL=90% | 1757 |
| $4(\pi^+ \pi^-)\pi^0$                  | < 3.06 | %                | CL=90% | 1720 |
| $\phi f_0(980)$                        | < 4.5  | $\times 10^{-4}$ | CL=90% | 1597 |
| $K^+ K^- \pi^+ \pi^- \pi^0$            | < 2.36 | $\times 10^{-3}$ | CL=90% | 1741 |
| $K^+ K^- \rho^0 \pi^0$                 | < 8    | $\times 10^{-4}$ | CL=90% | 1624 |
| $K^+ K^- \rho^+ \pi^-$                 | < 1.46 | %                | CL=90% | 1623 |
| $\omega K^+ K^-$                       | < 3.4  | $\times 10^{-4}$ | CL=90% | 1664 |
| $\phi \pi^+ \pi^- \pi^0$               | < 3.8  | $\times 10^{-3}$ | CL=90% | 1723 |
| $K^{*0} K^- \pi^+ \pi^0 + \text{c.c.}$ | < 1.62 | %                | CL=90% | 1694 |
| $K^{*+} K^- \pi^+ \pi^- + \text{c.c.}$ | < 3.23 | %                | CL=90% | 1693 |
| $K^+ K^- \pi^+ \pi^- 2\pi^0$           | < 2.67 | %                | CL=90% | 1705 |
| $K^+ K^- 2(\pi^+ \pi^-)$               | < 1.03 | %                | CL=90% | 1702 |
| $K^+ K^- 2(\pi^+ \pi^-)\pi^0$          | < 3.60 | %                | CL=90% | 1661 |
| $\eta K^+ K^-$                         | < 4.1  | $\times 10^{-4}$ | CL=90% | 1712 |
| $\eta K^+ K^- \pi^+ \pi^-$             | < 1.24 | %                | CL=90% | 1624 |
| $\rho^0 K^+ K^-$                       | < 5.0  | $\times 10^{-3}$ | CL=90% | 1666 |
| $2(K^+ K^-)$                           | < 6.0  | $\times 10^{-4}$ | CL=90% | 1552 |
| $\phi K^+ K^-$                         | < 7.5  | $\times 10^{-4}$ | CL=90% | 1598 |
| $2(K^+ K^-)\pi^0$                      | < 2.9  | $\times 10^{-4}$ | CL=90% | 1494 |
| $2(K^+ K^-)\pi^+ \pi^-$                | < 3.2  | $\times 10^{-3}$ | CL=90% | 1426 |
| $K_S^0 K^- \pi^+$                      | < 3.2  | $\times 10^{-3}$ | CL=90% | 1799 |
| $K_S^0 K^- \pi^+ \pi^0$                | < 1.33 | %                | CL=90% | 1773 |
| $K_S^0 K^- \rho^+$                     | < 6.6  | $\times 10^{-3}$ | CL=90% | 1665 |
| $K_S^0 K^- 2\pi^+ \pi^-$               | < 8.7  | $\times 10^{-3}$ | CL=90% | 1740 |
| $K_S^0 K^- \pi^+ \rho^0$               | < 1.6  | %                | CL=90% | 1621 |
| $K_S^0 K^- \pi^+ \eta$                 | < 1.3  | %                | CL=90% | 1670 |
| $K_S^0 K^- 2\pi^+ \pi^- \pi^0$         | < 4.18 | %                | CL=90% | 1703 |
| $K_S^0 K^- 2\pi^+ \pi^- \eta$          | < 4.8  | %                | CL=90% | 1570 |
| $K_S^0 K^- \pi^+ 2(\pi^+ \pi^-)$       | < 1.22 | %                | CL=90% | 1658 |
| $K_S^0 K^- \pi^+ 2\pi^0$               | < 2.65 | %                | CL=90% | 1742 |
| $K_S^0 K^- K^+ K^- \pi^+$              | < 4.9  | $\times 10^{-3}$ | CL=90% | 1491 |
| $K_S^0 K^- K^+ K^- \pi^+ \pi^0$        | < 3.0  | %                | CL=90% | 1427 |
| $K_S^0 K^- K^+ K^- \pi^+ \eta$         | < 2.2  | %                | CL=90% | 1214 |
| $K^{*0} K^- \pi^+ + \text{c.c.}$       | < 9.7  | $\times 10^{-3}$ | CL=90% | 1722 |
| $p\bar{p}\pi^0$                        | < 4    | $\times 10^{-5}$ | CL=90% | 1595 |
| $p\bar{p}\pi^+ \pi^-$                  | < 5.8  | $\times 10^{-4}$ | CL=90% | 1544 |
| $\Lambda\bar{\Lambda}$                 | < 1.2  | $\times 10^{-4}$ | CL=90% | 1522 |
| $p\bar{p}\pi^+ \pi^- \pi^0$            | < 1.85 | $\times 10^{-3}$ | CL=90% | 1490 |
| $\omega p\bar{p}$                      | < 2.9  | $\times 10^{-4}$ | CL=90% | 1310 |

|                                  |       |                  |        |      |
|----------------------------------|-------|------------------|--------|------|
| $\Lambda\bar{\Lambda}\pi^0$      | < 7   | $\times 10^{-5}$ | CL=90% | 1469 |
| $p\bar{p}2(\pi^+\pi^-)$          | < 2.6 | $\times 10^{-3}$ | CL=90% | 1426 |
| $\eta p\bar{p}$                  | < 5.4 | $\times 10^{-4}$ | CL=90% | 1431 |
| $\eta p\bar{p}\pi^+\pi^-$        | < 3.3 | $\times 10^{-3}$ | CL=90% | 1284 |
| $\rho^0 p\bar{p}$                | < 1.7 | $\times 10^{-3}$ | CL=90% | 1314 |
| $p\bar{p}K^+K^-$                 | < 3.2 | $\times 10^{-4}$ | CL=90% | 1186 |
| $\eta p\bar{p}K^+K^-$            | < 6.9 | $\times 10^{-3}$ | CL=90% | 737  |
| $\pi^0 p\bar{p}K^+K^-$           | < 1.2 | $\times 10^{-3}$ | CL=90% | 1094 |
| $\phi p\bar{p}$                  | < 1.3 | $\times 10^{-4}$ | CL=90% | 1178 |
| $\Lambda\bar{\Lambda}\pi^+\pi^-$ | < 2.5 | $\times 10^{-4}$ | CL=90% | 1405 |
| $\Lambda\bar{p}K^+$              | < 2.8 | $\times 10^{-4}$ | CL=90% | 1387 |
| $\Lambda\bar{p}K^+\pi^+\pi^-$    | < 6.3 | $\times 10^{-4}$ | CL=90% | 1234 |
| $\Lambda\bar{\Lambda}\eta$       | < 1.9 | $\times 10^{-4}$ | CL=90% | 1263 |
| $\Sigma^+\bar{\Sigma}^-$         | < 1.0 | $\times 10^{-4}$ | CL=90% | 1465 |
| $\Sigma^0\bar{\Sigma}^0$         | < 4   | $\times 10^{-5}$ | CL=90% | 1462 |
| $\Xi^+\bar{\Xi}^-$               | < 1.5 | $\times 10^{-4}$ | CL=90% | 1347 |
| $\Xi^0\bar{\Xi}^0$               | < 1.4 | $\times 10^{-4}$ | CL=90% | 1353 |

### Radiative decays

|                    |                                  |                  |        |      |
|--------------------|----------------------------------|------------------|--------|------|
| $\gamma\chi_{c2}$  | < 6.4                            | $\times 10^{-4}$ | CL=90% | 211  |
| $\gamma\chi_{c1}$  | $(2.49 \pm 0.23) \times 10^{-3}$ |                  |        | 254  |
| $\gamma\chi_{c0}$  | $(6.9 \pm 0.6) \times 10^{-3}$   |                  |        | 342  |
| $\gamma\eta_c$     | < 7                              | $\times 10^{-4}$ | CL=90% | 707  |
| $\gamma\eta_c(2S)$ | < 9                              | $\times 10^{-4}$ | CL=90% | 134  |
| $\gamma\eta'$      | < 1.8                            | $\times 10^{-4}$ | CL=90% | 1765 |
| $\gamma\eta$       | < 1.5                            | $\times 10^{-4}$ | CL=90% | 1847 |
| $\gamma\pi^0$      | < 2                              | $\times 10^{-4}$ | CL=90% | 1884 |

## $\psi_2(3823)$

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

$I, J, P$  need confirmation.

was  $\psi(3823), X(3823)$

$$\text{Mass } m = 3823.7 \pm 0.5 \text{ MeV} \quad (S = 1.1)$$

$$\text{Full width } \Gamma < 5.2 \text{ MeV, CL} = 90\%$$

| $\psi_2(3823)$ DECAY MODES | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|----------------------------|--------------------------------|-------------|
| $J/\psi(1S)\pi^+\pi^-$     | seen                           | 607         |
| $\chi_{c1}\gamma$          | seen                           | 300         |
| $\chi_{c2}\gamma$          | not seen                       | 258         |

**$\psi_3(3842)$** 

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

$J, P$  need confirmation.

Seen by a single experiment only.

Mass  $m = 3842.71 \pm 0.20$  MeV

Full width  $\Gamma = 2.8 \pm 0.6$  MeV

| <b><math>\psi_3(3842)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|--|--------------------------------|-------------|
| $D^+ D^-$                                    | seen                           | 443         |
| $D^0 \bar{D}^0$                              | seen                           | 463         |

 **$\chi_{c1}(3872)$** 

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

also known as  $X(3872)$ 

Mass  $m = 3871.65 \pm 0.06$  MeV

$m_{\chi_{c1}(3872)} - m_{J/\psi} = 775 \pm 4$  MeV

Full width  $\Gamma = 1.19 \pm 0.21$  MeV ( $S = 1.1$ )

| <b><math>\chi_{c1}(3872)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ ) | Confidence level | $p$ (MeV/c) |
|---|--------------------------------|------------------|-------------|
| $e^+ e^-$                                       | $< 2.8 \times 10^{-6}$         | 90%              | 1936        |
| $\pi^+ \pi^- J/\psi(1S)$                        | $(3.8 \pm 1.2) \%$             |                  | 650         |
| $\pi^+ \pi^- \pi^0 J/\psi(1S)$                  | not seen                       |                  | 588         |
| $\omega \eta_c(1S)$                             | $< 33 \%$                      | 90%              | 368         |
| $\omega J/\psi(1S)$                             | $(4.3 \pm 2.1) \%$             |                  | †           |
| $\phi \phi$                                     | not seen                       |                  | 1646        |
| $D^0 \bar{D}^0 \pi^0$                           | $(49^{+18}_{-20}) \%$          |                  | 116         |
| $\bar{D}^{*0} D^0$                              | $(37 \pm 9) \%$                |                  | †           |
| $\gamma \gamma$                                 | $< 11 \%$                      | 90%              | 1936        |
| $D^0 \bar{D}^0$                                 | $< 29 \%$                      | 90%              | 519         |
| $D^+ D^-$                                       | $< 19 \%$                      | 90%              | 502         |
| $\pi^0 \chi_{c2}$                               | $< 4 \%$                       | 90%              | 273         |
| $\pi^0 \chi_{c1}$                               | $(3.4 \pm 1.6) \%$             |                  | 319         |
| $\pi^0 \chi_{c0}$                               | $< 70 \%$                      | 90%              | —           |
| $\pi^+ \pi^- \eta_c(1S)$                        | $< 14 \%$                      | 90%              | 745         |
| $\pi^+ \pi^- \chi_{c1}$                         | $< 7 \times 10^{-3}$           | 90%              | 218         |
| $p \bar{p}$                                     | $< 2.4 \times 10^{-5}$         | 95%              | 1693        |

**Radiative decays**

|                        |                            |     |     |
|------------------------|----------------------------|-----|-----|
| $\gamma D^+ D^-$       | $< 4 \%$                   | 90% | 502 |
| $\gamma \bar{D}^0 D^0$ | $< 6 \%$                   | 90% | 519 |
| $\gamma J/\psi$        | $(8 \pm 4) \times 10^{-3}$ |     | 697 |

|                   |                 |                  |     |     |
|-------------------|-----------------|------------------|-----|-----|
| $\gamma\chi_{c1}$ | $< 9$           | $\times 10^{-3}$ | 90% | 344 |
| $\gamma\chi_{c2}$ | $< 3.2$         | %                | 90% | 303 |
| $\gamma\psi(2S)$  | $(4.5 \pm 2.0)$ | %                |     | 181 |

### C-violating decays

|               |         |   |     |     |
|---------------|---------|---|-----|-----|
| $\eta J/\psi$ | $< 1.8$ | % | 90% | 491 |
|---------------|---------|---|-----|-----|

## Z<sub>c</sub>(3900)

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

was X(3900)

$$\text{Mass } m = 3887.1 \pm 2.6 \text{ MeV} \quad (S = 1.7)$$

$$\text{Full width } \Gamma = 28.4 \pm 2.6 \text{ MeV}$$

| Z <sub>c</sub> (3900) DECAY MODES | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|-----------------------------------|--------------------------------|-------------|
| $J/\psi \pi$                      | seen                           | 699         |
| $h_c \pi^\pm$                     | not seen                       | 318         |
| $\eta_c \pi^+ \pi^-$              | not seen                       | 759         |
| $(D\bar{D}^*)^\pm$                | seen                           | —           |
| $D^0 D^{*-} + \text{c.c.}$        | seen                           | 152         |
| $D^- D^{*0} + \text{c.c.}$        | seen                           | 143         |
| $\omega \pi^\pm$                  | not seen                       | 1862        |
| $J/\psi \eta$                     | not seen                       | 510         |
| $D^+ D^{*-} + \text{c.c.}$        | seen                           | —           |
| $D^0 \bar{D}^{*0} + \text{c.c.}$  | seen                           | —           |

## X(3915)

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

was  $\chi_{c0}(3915)$

$$\text{Mass } m = 3921.7 \pm 1.8 \text{ MeV} \quad (S = 1.5)$$

$$\text{Full width } \Gamma = 18.8 \pm 3.5 \text{ MeV}$$

| X(3915) DECAY MODES      | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|--------------------------|--------------------------------|-------------|
| $\omega J/\psi$          | seen                           | 231         |
| $\pi^+ \pi^- \eta_c(1S)$ | not seen                       | 788         |
| $\eta_c \eta$            | not seen                       | 668         |
| $\eta_c \pi^0$           | not seen                       | 817         |
| $K \bar{K}$              | not seen                       | 1898        |
| $\gamma\gamma$           | seen                           | 1961        |

**$\chi_{c2}(3930)$** 

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

Mass  $m = 3922.5 \pm 1.0$  MeV (S = 1.7)Full width  $\Gamma = 35.2 \pm 2.2$  MeV (S = 1.2)

| $\chi_{c2}(3930)$ DECAY MODES | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|-------------------------------|--------------------------------|-------------|
| $\gamma\gamma$                | seen                           | 1961        |
| $D\bar{D}$                    | seen                           | 607         |
| $D^+D^-$                      | seen                           | 592         |
| $D^0\bar{D}^0$                | seen                           | 607         |
| $\pi^+\pi^-\eta_c(1S)$        | not seen                       | 788         |
| $K\bar{K}$                    | not seen                       | 1898        |

 **$X(4020)^\pm$** 

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

Mass  $m = 4024.1 \pm 1.9$  MeVFull width  $\Gamma = 13 \pm 5$  MeV (S = 1.7)

| $X(4020)^\pm$ DECAY MODES  | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|----------------------------|--------------------------------|-------------|
| $h_c(1P)\pi$               | seen                           | 450         |
| $D^*\bar{D}^*$             | seen                           | 85          |
| $D\bar{D}^* + \text{c.c.}$ | not seen                       | 542         |
| $\eta_c\pi^+\pi^-$         | not seen                       | 872         |
| $J/\psi(1S)\pi^\pm$        | not seen                       | 811         |

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

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

Mass  $m = 4039 \pm 1$  MeVFull width  $\Gamma = 80 \pm 10$  MeV

Due to the complexity of the  $c\bar{c}$  threshold region, in this listing, “seen” (“not seen”) means that a cross section for the mode in question has been measured at effective  $\sqrt{s}$  near this particle’s central mass value, more (less) than  $2\sigma$  above zero, without regard to any peaking behavior in  $\sqrt{s}$  or absence thereof. See mode listing(s) for details and references.

| $\psi(4040)$ DECAY MODES   | Fraction ( $\Gamma_i/\Gamma$ )   | Confidence level | $p$ (MeV/c) |
|----------------------------|----------------------------------|------------------|-------------|
| $e^+e^-$                   | $(1.07 \pm 0.16) \times 10^{-5}$ |                  | 2019        |
| $D\bar{D}$                 | seen                             |                  | 775         |
| $D^0\bar{D}^0$             | seen                             |                  | 775         |
| $D^+D^-$                   | seen                             |                  | 763         |
| $D^*\bar{D} + \text{c.c.}$ | seen                             |                  | 569         |



|  |                 |                  |     |      |
|--|-----------------|------------------|-----|------|
| $D^*(2007)^0 \bar{D}^0 + \text{c.c.}$  | seen            |                  |     | 575  |
| $D^*(2010)^+ D^- + \text{c.c.}$  | seen            |                  |     | 561  |
| $D^* \bar{D}^*$  | seen            |                  |     | 193  |
| $D^*(2007)^0 \bar{D}^*(2007)^0$  | seen            |                  |     | 226  |
| $D^*(2010)^+ D^*(2010)^-$  | seen            |                  |     | 193  |
| $D^0 D^- \pi^+ + \text{c.c. (excl. } D^*(2007)^0 \bar{D}^0 + \text{c.c., } D^*(2010)^+ D^- + \text{c.c.)}$ | not seen        |                  |     | —    |
| $D \bar{D}^* \pi$ (excl. $D^* \bar{D}^*$ )   | not seen        |                  |     | —    |
| $D^0 \bar{D}^{*-} \pi^+ + \text{c.c. (excl. } D^*(2010)^+ D^*(2010)^-)$                                    | seen            |                  |     | —    |
| $D_s^+ D_s^-$  | seen            |                  |     | 452  |
| $J/\psi \pi^+ \pi^-$   | $< 4$           | $\times 10^{-3}$ | 90% | 794  |
| $J/\psi \pi^0 \pi^0$   | $< 2$           | $\times 10^{-3}$ | 90% | 797  |
| $J/\psi \eta$  | $(5.2 \pm 0.7)$ | $\times 10^{-3}$ |     | 675  |
| $J/\psi \pi^0$   | $< 2.8$         | $\times 10^{-4}$ | 90% | 823  |
| $J/\psi \pi^+ \pi^- \pi^0$   | $< 2$           | $\times 10^{-3}$ | 90% | 746  |
| $\chi_{c1} \gamma$   | $< 3.4$         | $\times 10^{-3}$ | 90% | 494  |
| $\chi_{c2} \gamma$   | $< 5$           | $\times 10^{-3}$ | 90% | 454  |
| $\chi_{c1} \pi^+ \pi^- \pi^0$  | $< 1.1$         | %                | 90% | 306  |
| $\chi_{c2} \pi^+ \pi^- \pi^0$  | $< 3.2$         | %                | 90% | 233  |
| $h_c(1P) \pi^+ \pi^-$  | $< 3$           | $\times 10^{-3}$ | 90% | 403  |
| $\phi \pi^+ \pi^-$   | $< 3$           | $\times 10^{-3}$ | 90% | 1880 |
| $\Lambda \bar{\Lambda} \pi^+ \pi^-$  | $< 2.9$         | $\times 10^{-4}$ | 90% | 1578 |
| $\Lambda \bar{\Lambda} \pi^0$  | $< 9$           | $\times 10^{-5}$ | 90% | 1636 |
| $\Lambda \bar{\Lambda} \eta$   | $< 3.0$         | $\times 10^{-4}$ | 90% | 1452 |
| $\Sigma^+ \bar{\Sigma}^-$  | $< 1.3$         | $\times 10^{-4}$ | 90% | 1632 |
| $\Sigma^0 \bar{\Sigma}^0$  | $< 7$           | $\times 10^{-5}$ | 90% | 1630 |
| $\Xi^+ \bar{\Xi}^-$  | $< 1.6$         | $\times 10^{-4}$ | 90% | 1527 |
| $\Xi^0 \bar{\Xi}^0$  | $< 1.8$         | $\times 10^{-4}$ | 90% | 1533 |
| $\mu^+ \mu^-$  | $(9 \pm 6)$     | $\times 10^{-6}$ |     | 2017 |

### $\chi_{c1}(4140)$

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

was  $X(4140)$

$$\text{Mass } m = 4146.8 \pm 2.4 \text{ MeV} \quad (S = 1.1)$$

$$\text{Full width } \Gamma = 22^{+8}_{-7} \text{ MeV} \quad (S = 1.3)$$

| $\chi_{c1}(4140)$ DECAY MODES | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|-------------------------------|--------------------------------|-------------|
| $J/\psi \phi$                 | seen                           | 217         |
| $\gamma\gamma$                | not seen                       | 2073        |

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

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

Mass  $m = 4191 \pm 5$  MeVFull width  $\Gamma = 70 \pm 10$  MeV

Due to the complexity of the  $c\bar{c}$  threshold region, in this listing, “seen” (“not seen”) means that a cross section for the mode in question has been measured at effective  $\sqrt{s}$  near this particle’s central mass value, more (less) than  $2\sigma$  above zero, without regard to any peaking behavior in  $\sqrt{s}$  or absence thereof. See mode listing(s) for details and references.

| <b><math>\psi(4160)</math> DECAY MODES</b>  | Fraction ( $\Gamma_i/\Gamma$ ) | Confidence level | $P$<br>(MeV/c) |
|---|--------------------------------|------------------|----------------|
| $e^+e^-$  | $(6.9 \pm 3.3) \times 10^{-6}$ |                  | 2096           |
| $\mu^+\mu^-$  | seen                           |                  | 2093           |
| $D\bar{D}$  | seen                           |                  | 956            |
| $D^0\bar{D}^0$  | seen                           |                  | 956            |
| $D^+D^-$  | seen                           |                  | 947            |
| $D^*\bar{D} + \text{c.c.}$  | seen                           |                  | 798            |
| $D^*(2007)^0\bar{D}^0 + \text{c.c.}$  | seen                           |                  | 802            |
| $D^*(2010)^+D^- + \text{c.c.}$  | seen                           |                  | 792            |
| $D^*\bar{D}^*$  | seen                           |                  | 592            |
| $D^*(2007)^0\bar{D}^*(2007)^0$  | seen                           |                  | 604            |
| $D^*(2010)^+D^*(2010)^-$  | seen                           |                  | 592            |
| $D^0D^-\pi^+ + \text{c.c.}$ (excl.<br>$D^*(2007)^0\bar{D}^0 + \text{c.c.},$<br>$D^*(2010)^+D^- + \text{c.c.}$ ) | not seen                       |                  | —              |
| $D\bar{D}^*\pi + \text{c.c.}$ (excl. $D^*\bar{D}^*$ )   | seen                           |                  | —              |
| $D^0D^{*-}\pi^+ + \text{c.c.}$ (excl.<br>$D^*(2010)^+D^*(2010)^-$ )   | not seen                       |                  | —              |
| $D_s^+D_s^-$  | not seen                       |                  | 719            |
| $D_s^{*+}D_s^- + \text{c.c.}$   | seen                           |                  | 385            |
| $J/\psi\pi^+\pi^-$  | $< 3$                          | $\times 10^{-3}$ | 90% 919        |
| $J/\psi\pi^0\pi^0$  | $< 3$                          | $\times 10^{-3}$ | 90% 922        |
| $J/\psi K^+K^-$   | $< 2$                          | $\times 10^{-3}$ | 90% 407        |
| $J/\psi\eta$  | $< 8$                          | $\times 10^{-3}$ | 90% 822        |
| $J/\psi\pi^0$   | $< 1$                          | $\times 10^{-3}$ | 90% 944        |
| $J/\psi\eta'$   | $< 5$                          | $\times 10^{-3}$ | 90% 457        |
| $J/\psi\pi^+\pi^-\pi^0$   | $< 1$                          | $\times 10^{-3}$ | 90% 879        |
| $\psi(2S)\pi^+\pi^-$  | $< 4$                          | $\times 10^{-3}$ | 90% 396        |
| $\chi_{c1}\gamma$   | $< 5$                          | $\times 10^{-3}$ | 90% 625        |
| $\chi_{c2}\gamma$   | $< 1.3$                        | %                | 90% 587        |
| $\chi_{c1}\pi^+\pi^-\pi^0$  | $< 2$                          | $\times 10^{-3}$ | 90% 496        |
| $\chi_{c2}\pi^+\pi^-\pi^0$  | $< 8$                          | $\times 10^{-3}$ | 90% 445        |
| $h_c(1P)\pi^+\pi^-$   | $< 5$                          | $\times 10^{-3}$ | 90% 556        |

|  |          |                  |     |      |
|--|----------|------------------|-----|------|
| $h_c(1P)\pi^0\pi^0$                                  | $< 2$    | $\times 10^{-3}$ | 90% | 560  |
| $h_c(1P)\eta$  | $< 2$    | $\times 10^{-3}$ | 90% | 348  |
| $h_c(1P)\pi^0$                                       | $< 4$    | $\times 10^{-4}$ | 90% | 600  |
| $\phi\pi^+\pi^-$                                     | $< 2$    | $\times 10^{-3}$ | 90% | 1961 |
| $\gamma\chi_{c1}(3872)$                              | $< 1.8$  | $\times 10^{-3}$ | 90% | 308  |
| $\gamma X(3915) \rightarrow \gamma J/\psi\pi^+\pi^-$ | $< 1.36$ | $\times 10^{-4}$ | 90% | —    |
| $\gamma X(3930) \rightarrow \gamma J/\psi\pi^+\pi^-$ | $< 1.18$ | $\times 10^{-4}$ | 90% | —    |
| $\gamma X(3940) \rightarrow \gamma J/\psi\pi^+\pi^-$ | $< 1.47$ | $\times 10^{-4}$ | 90% | —    |
| $\gamma X(3915) \rightarrow \gamma\gamma J/\psi$     | $< 1.26$ | $\times 10^{-4}$ | 90% | —    |
| $\gamma X(3930) \rightarrow \gamma\gamma J/\psi$     | $< 8.8$  | $\times 10^{-5}$ | 90% | —    |
| $\gamma X(3940) \rightarrow \gamma\gamma J/\psi$     | $< 1.79$ | $\times 10^{-4}$ | 90% | —    |
| $p\bar{p}p\bar{p}$                                   | not seen |                  |     | 834  |

**$\psi(4230)$**

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

also known as  $Y(4230)$ ; was  $X(4230)$

See also  $\psi(4260)$  entry in Particle Listings.

Mass  $m = 4220 \pm 15$  MeV

Full width  $\Gamma = 20$  to 100 MeV

| <b><math>\psi(4230)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|--|--------------------------------|-------------|
| $\omega\chi_{c0}$                          | seen                           | 171         |
| $\pi^+\pi^-h_c$                            | seen                           | 583         |
| $\pi^0\pi^0 J/\psi$                        | seen                           | 944         |
| $\pi^+\pi^- J/\psi$                        | seen                           | 942         |
| $\eta J/\psi$                              | seen                           | 848         |
| $\pi^+\pi^-\psi(2S)$                       | seen                           | 426         |
| $\pi^+D^0D^{*-} + \text{c.c.}$             | seen                           | 650         |
| $\gamma\chi_{c1}(3872)$                    | seen                           | 334         |
| $\pi^+\pi^-\pi^0\eta_c$                    | seen                           | 992         |
| $\pi^+\pi^-\eta_c$                         | not seen                       | 1027        |
| $\gamma\pi^0\eta_c$                        | not seen                       | 1049        |
| $p\bar{p}p\bar{p}$                         | not seen                       | 864         |

**$\chi_{c1}(4274)$**

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

was  $X(4274)$

Mass  $m = 4274^{+8}_{-6}$  MeV

Full width  $\Gamma = 49 \pm 12$  MeV

| $\chi_{c1}(4274)$ DECAY MODES | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|-------------------------------|--------------------------------|-------------|
| $J/\psi \phi$                 | seen                           | 503         |

**$\psi(4360)$**

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

also known as  $Y(4360)$ ; was  $X(4360)$

$$\psi(4360) \text{ MASS} = 4368 \pm 13 \text{ MeV} \quad (S = 3.7)$$

$$\psi(4360) \text{ WIDTH} = 96 \pm 7 \text{ MeV}$$

| $\psi(4360)$ DECAY MODES         | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|----------------------------------|--------------------------------|-------------|
| $\psi(2S)\pi^+\pi^-$             | seen                           | 573         |
| $\psi_2(3823)\pi^+\pi^-$         | possibly seen                  | 438         |
| $D_1(2420)\bar{D} + \text{c.c.}$ | possibly seen                  | 416         |

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

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

$$\text{Mass } m = 4421 \pm 4 \text{ MeV}$$

$$\text{Full width } \Gamma = 62 \pm 20 \text{ MeV}$$

Due to the complexity of the  $c\bar{c}$  threshold region, in this listing, “seen” (“not seen”) means that a cross section for the mode in question has been measured at effective  $\sqrt{s}$  near this particle’s central mass value, more (less) than  $2\sigma$  above zero, without regard to any peaking behavior in  $\sqrt{s}$  or absence thereof. See mode listing(s) for details and references.

| $\psi(4415)$ DECAY MODES   | Fraction ( $\Gamma_i/\Gamma$ ) | Confidence level | $p$ (MeV/c) |
|--|--------------------------------|------------------|-------------|
| $D\bar{D}$   | seen                           |                  | 1187        |
| $D^0\bar{D}^0$   | seen                           |                  | 1187        |
| $D^+D^-$   | seen                           |                  | 1179        |
| $D^*\bar{D} + \text{c.c.}$   | seen                           |                  | 1063        |
| $D^*(2007)^0\bar{D}^0 + \text{c.c.}$   | seen                           |                  | 1067        |
| $D^*(2010)^+D^- + \text{c.c.}$   | seen                           |                  | 1059        |
| $D^*\bar{D}^*$   | seen                           |                  | 919         |
| $D^*(2007)^0\bar{D}^*(2007)^0 + \text{c.c.}$   | seen                           |                  | 927         |
| $D^*(2010)^+D^*(2010)^- + \text{c.c.}$   | seen                           |                  | 919         |
| $D^0D^-\pi^+$ (excl. $D^*(2007)^0\bar{D}^0$<br>+c.c., $D^*(2010)^+D^- + \text{c.c.}$ ) | < 2.3 %                        | 90%              | –           |
| $D\bar{D}_2^*(2460) \rightarrow D^0D^-\pi^+ + \text{c.c.}$                             | (10 ± 4) %                     |                  | –           |
| $D^0D^{*-}\pi^+ + \text{c.c.}$   | < 11 %                         | 90%              | 926         |

|                                  |                                |          |
|----------------------------------|--------------------------------|----------|
| $D_1(2420)\bar{D} + \text{c.c.}$ | possibly seen                  | 537      |
| $D_s^+ D_s^-$                    | not seen                       | 1006     |
| $\omega \chi_{c2}$               | possibly seen                  | 330      |
| $D_s^{*+} D_s^- + \text{c.c.}$   | seen                           | —        |
| $D_s^{*+} D_s^{*-}$              | not seen                       | 652      |
| $\psi_2(3823)\pi^+\pi^-$         | possibly seen                  | 492      |
| $\psi(3770)\pi^+\pi^-$           | possibly seen                  | 541      |
| $J/\psi\eta$                     | $< 6 \times 10^{-3}$           | 90% 1022 |
| $\chi_{c1}\gamma$                | $< 8 \times 10^{-4}$           | 90% 817  |
| $\chi_{c2}\gamma$                | $< 4 \times 10^{-3}$           | 90% 780  |
| $e^+e^-$                         | $(9.4 \pm 3.2) \times 10^{-6}$ | 2210     |
| $\mu^+\mu^-$                     | $(2.0 \pm 1.0) \times 10^{-5}$ | 2208     |

### **Z<sub>c</sub>(4430)**

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

G, C need confirmation.

was  $X(4430)^\pm$

Quantum numbers not established.

$$\text{Mass } m = 4478_{-18}^{+15} \text{ MeV}$$

$$\text{Full width } \Gamma = 181 \pm 31 \text{ MeV}$$

| <b>Z<sub>c</sub>(4430) DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|--|--------------------------------|-------------|
| $\pi^+\psi(2S)$                        | seen                           | 711         |
| $\pi^+J/\psi$                          | seen                           | 1162        |

### **$\psi(4660)$**

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

also known as  $Y(4660)$ ; was  $X(4660)$

$$\psi(4660) \text{ MASS} = 4630 \pm 6 \text{ MeV} \quad (S = 1.4)$$

$$\psi(4660) \text{ WIDTH} = 62_{-7}^{+9} \text{ MeV}$$

| <b><math>\psi(4660)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|--|--------------------------------|-------------|
| $e^+e^-$                                   | not seen                       | 2315        |
| $\psi(2S)\pi^+\pi^-$                       | seen                           | 809         |
| $J/\psi\eta$                               | not seen                       | 1192        |
| $D^0 D^{*-}\pi^+$                          | not seen                       | 1153        |
| $\chi_{c1}\gamma$                          | not seen                       | 984         |
| $\chi_{c2}\gamma$                          | not seen                       | 949         |
| $\Lambda_c^+ \Lambda_c^-$                  | seen                           | 362         |
| $D_s^+ D_{s1}(2536)^-$                     | seen                           | 533         |

# $b\bar{b}$ MESONS

## (including possibly non- $q\bar{q}$ states)

### $\eta_b(1S)$

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

Mass  $m = 9398.7 \pm 2.0$  MeV (S = 1.5)

Full width  $\Gamma = 10^{+5}_{-4}$  MeV

| $\eta_b(1S)$ DECAY MODES | Fraction ( $\Gamma_i/\Gamma$ ) | Confidence level | $p$<br>(MeV/c) |
|--------------------------|--------------------------------|------------------|----------------|
| hadrons                  | seen                           |                  | —              |
| $3h^+3h^-$               | not seen                       |                  | 4672           |
| $2h^+2h^-$               | not seen                       |                  | 4689           |
| $4h^+4h^-$               | not seen                       |                  | 4648           |
| $\gamma\gamma$           | not seen                       |                  | 4699           |
| $\mu^+\mu^-$             | $<9 \times 10^{-3}$            | 90%              | 4698           |
| $\tau^+\tau^-$           | $<8\%$                         | 90%              | 4350           |

### $\Upsilon(1S)$

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

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

Full width  $\Gamma = 54.02 \pm 1.25$  keV

| $\Upsilon(1S)$ DECAY MODES | Fraction ( $\Gamma_i/\Gamma$ ) | Scale factor/<br>Confidence level | $p$<br>(MeV/c) |
|----------------------------|--------------------------------|-----------------------------------|----------------|
| $\tau^+\tau^-$             | ( 2.60 $\pm$ 0.10 ) %          |                                   | 4384           |
| $e^+e^-$                   | ( 2.38 $\pm$ 0.11 ) %          |                                   | 4730           |
| $\mu^+\mu^-$               | ( 2.48 $\pm$ 0.05 ) %          |                                   | 4729           |

#### Hadronic decays

|                        |                                    |                         |      |
|------------------------|------------------------------------|-------------------------|------|
| $ggg$                  | (81.7 $\pm$ 0.7 ) %                |                         | —    |
| $\gamma gg$            | ( 2.2 $\pm$ 0.6 ) %                |                         | —    |
| $\eta'(958)$ anything  | ( 2.94 $\pm$ 0.24 ) %              |                         | —    |
| $J/\psi(1S)$ anything  | ( 5.4 $\pm$ 0.4 ) $\times 10^{-4}$ | S=1.4                   | 4223 |
| $J/\psi(1S)\eta_c$     | $< 2.2$                            | $\times 10^{-6}$ CL=90% | 3623 |
| $J/\psi(1S)\chi_{c0}$  | $< 3.4$                            | $\times 10^{-6}$ CL=90% | 3429 |
| $J/\psi(1S)\chi_{c1}$  | ( 3.9 $\pm$ 1.2 ) $\times 10^{-6}$ |                         | 3382 |
| $J/\psi(1S)\chi_{c2}$  | $< 1.4$                            | $\times 10^{-6}$ CL=90% | 3359 |
| $J/\psi(1S)\eta_c(2S)$ | $< 2.2$                            | $\times 10^{-6}$ CL=90% | 3317 |
| $J/\psi(1S)X(3940)$    | $< 5.4$                            | $\times 10^{-6}$ CL=90% | 3148 |
| $J/\psi(1S)X(4160)$    | $< 5.4$                            | $\times 10^{-6}$ CL=90% | 3018 |

|  |                                  |                  |        |      |
|--|----------------------------------|------------------|--------|------|
| $X(4350)$ anything, $X \rightarrow J/\psi(1S)\phi$                 | $< 8.1$                          | $\times 10^{-6}$ | CL=90% | —    |
| $Z_c(3900)^\pm$ anything, $Z_c \rightarrow J/\psi(1S)\pi^\pm$      | $< 1.3$                          | $\times 10^{-5}$ | CL=90% | —    |
| $Z_c(4200)^\pm$ anything, $Z_c \rightarrow J/\psi(1S)\pi^\pm$      | $< 6.0$                          | $\times 10^{-5}$ | CL=90% | —    |
| $Z_c(4430)^\pm$ anything, $Z_c \rightarrow J/\psi(1S)\pi^\pm$      | $< 4.9$                          | $\times 10^{-5}$ | CL=90% | —    |
| $X_{cs}^\pm$ anything, $X \rightarrow J/\psi K^\pm$                | $< 5.7$                          | $\times 10^{-6}$ | CL=90% | —    |
| $\psi(4260)$ anything, $\psi \rightarrow J/\psi(1S)\pi^+\pi^-$     | $< 3.8$                          | $\times 10^{-5}$ | CL=90% | —    |
| $\psi(4260)$ anything, $\psi \rightarrow J/\psi(1S)K^+K^-$         | $< 7.5$                          | $\times 10^{-6}$ | CL=90% | —    |
| $\chi_{c1}(4140)$ anything, $\chi_{c1} \rightarrow J/\psi(1S)\phi$ | $< 5.2$                          | $\times 10^{-6}$ | CL=90% | —    |
| $\chi_{c0}$ anything   | $< 4$                            | $\times 10^{-3}$ | CL=90% | —    |
| $\chi_{c1}$ anything   | $(1.90 \pm 0.35) \times 10^{-4}$ |                  |        | —    |
| $\chi_{c1}(1P)X_{tetra}$   | $< 3.78$                         | $\times 10^{-5}$ | CL=90% | —    |
| $\chi_{c2}$ anything   | $(2.8 \pm 0.8) \times 10^{-4}$   |                  |        | —    |
| $\psi(2S)$ anything  | $(1.23 \pm 0.20) \times 10^{-4}$ |                  |        | —    |
| $\psi(2S)\eta_c$   | $< 3.6$                          | $\times 10^{-6}$ | CL=90% | 3345 |
| $\psi(2S)\chi_{c0}$  | $< 6.5$                          | $\times 10^{-6}$ | CL=90% | 3124 |
| $\psi(2S)\chi_{c1}$  | $< 4.5$                          | $\times 10^{-6}$ | CL=90% | 3070 |
| $\psi(2S)\chi_{c2}$  | $< 2.1$                          | $\times 10^{-6}$ | CL=90% | 3043 |
| $\psi(2S)\eta_c(2S)$   | $< 3.2$                          | $\times 10^{-6}$ | CL=90% | 2994 |
| $\psi(2S)X(3940)$  | $< 2.9$                          | $\times 10^{-6}$ | CL=90% | 2797 |
| $\psi(2S)X(4160)$  | $< 2.9$                          | $\times 10^{-6}$ | CL=90% | 2642 |
| $\psi(4260)$ anything, $\psi \rightarrow \psi(2S)\pi^+\pi^-$       | $< 7.9$                          | $\times 10^{-5}$ | CL=90% | —    |
| $\psi(4360)$ anything, $\psi \rightarrow \psi(2S)\pi^+\pi^-$       | $< 5.2$                          | $\times 10^{-5}$ | CL=90% | —    |
| $\psi(4660)$ anything, $\psi \rightarrow \psi(2S)\pi^+\pi^-$       | $< 2.2$                          | $\times 10^{-5}$ | CL=90% | —    |
| $X(4050)^\pm$ anything, $X \rightarrow \psi(2S)\pi^\pm$            | $< 8.8$                          | $\times 10^{-5}$ | CL=90% | —    |
| $Z_c(4430)^\pm$ anything, $Z_c \rightarrow \psi(2S)\pi^\pm$        | $< 6.7$                          | $\times 10^{-5}$ | CL=90% | —    |
| $\chi_{c1}(3872)$ anything   | $< 2.5$                          | $\times 10^{-4}$ | CL=90% | —    |
| $Z_c(4200)^+ Z_c(4200)^-$  | $< 2.23$                         | $\times 10^{-5}$ | CL=90% | —    |
| $Z_c(3900)^\pm Z_c(4200)^\mp$                                      | $< 8.1$                          | $\times 10^{-6}$ | CL=90% | —    |
| $Z_c(3900)^+ Z_c(3900)^-$  | $< 1.8$                          | $\times 10^{-6}$ | CL=90% | —    |
| $X(4050)^+ X(4050)^-$  | $< 1.58$                         | $\times 10^{-5}$ | CL=90% | —    |
| $X(4250)^+ X(4250)^-$  | $< 2.66$                         | $\times 10^{-5}$ | CL=90% | —    |

|  |                       |                  |        |      |
|--|-----------------------|------------------|--------|------|
| $X(4050)^\pm X(4250)^\mp$                      | < 4.42                | $\times 10^{-5}$ | CL=90% | —    |
| $Z_c(4430)^+ Z_c(4430)^-$                      | < 2.03                | $\times 10^{-5}$ | CL=90% | —    |
| $X(4055)^\pm X(4055)^\mp$                      | < 2.33                | $\times 10^{-5}$ | CL=90% | —    |
| $X(4055)^\pm Z_c(4430)^\mp$                    | < 4.55                | $\times 10^{-5}$ | CL=90% | —    |
| $\rho\pi$                                      | < 3.68                | $\times 10^{-6}$ | CL=90% | 4697 |
| $\omega\pi^0$                                  | < 3.90                | $\times 10^{-6}$ | CL=90% | 4697 |
| $\pi^+\pi^-$                                   | < 5                   | $\times 10^{-4}$ | CL=90% | 4728 |
| $K^+K^-$                                       | < 5                   | $\times 10^{-4}$ | CL=90% | 4704 |
| $p\bar{p}$                                     | < 5                   | $\times 10^{-4}$ | CL=90% | 4636 |
| $\pi^+\pi^-\pi^0$                              | ( 2.1 $\pm$ 0.8 )     | $\times 10^{-6}$ |        | 4725 |
| $\phi K^+K^-$                                  | ( 2.4 $\pm$ 0.5 )     | $\times 10^{-6}$ |        | 4622 |
| $\omega\pi^+\pi^-$                             | ( 4.5 $\pm$ 1.0 )     | $\times 10^{-6}$ |        | 4694 |
| $K^*(892)^0 K^-\pi^+ + \text{c.c.}$            | ( 4.4 $\pm$ 0.8 )     | $\times 10^{-6}$ |        | 4667 |
| $\phi f'_2(1525)$                              | < 1.63                | $\times 10^{-6}$ | CL=90% | 4551 |
| $\omega f_2(1270)$                             | < 1.79                | $\times 10^{-6}$ | CL=90% | 4611 |
| $\rho(770)a_2(1320)$                           | < 2.24                | $\times 10^{-6}$ | CL=90% | 4605 |
| $K^*(892)^0 \bar{K}_2^*(1430)^0 + \text{c.c.}$ | ( 3.0 $\pm$ 0.8 )     | $\times 10^{-6}$ |        | 4578 |
| $K_1(1270)^\pm K^\mp$                          | < 2.41                | $\times 10^{-6}$ | CL=90% | 4634 |
| $K_1(1400)^\pm K^\mp$                          | ( 1.0 $\pm$ 0.4 )     | $\times 10^{-6}$ |        | 4613 |
| $b_1(1235)^\pm \pi^\mp$                        | < 1.25                | $\times 10^{-6}$ | CL=90% | 4649 |
| $\pi^+\pi^-\pi^0\pi^0$                         | ( 1.28 $\pm$ 0.30 )   | $\times 10^{-5}$ |        | 4720 |
| $K_S^0 K^+\pi^- + \text{c.c.}$                 | ( 1.6 $\pm$ 0.4 )     | $\times 10^{-6}$ |        | 4696 |
| $K^*(892)^0 \bar{K}^0 + \text{c.c.}$           | ( 2.9 $\pm$ 0.9 )     | $\times 10^{-6}$ |        | 4675 |
| $K^*(892)^- K^+ + \text{c.c.}$                 | < 1.11                | $\times 10^{-6}$ | CL=90% | 4675 |
| $f_1(1285)$ anything                           | ( 4.6 $\pm$ 3.1 )     | $\times 10^{-3}$ |        | —    |
| $D^*(2010)^\pm$ anything                       | ( 2.52 $\pm$ 0.20 )   | %                |        | —    |
| $f_1(1285) X_{tetra}$                          | < 6.24                | $\times 10^{-5}$ | CL=90% | —    |
| ${}^2H$ anything                               | ( 2.85 $\pm$ 0.25 )   | $\times 10^{-5}$ |        | —    |
| Sum of 100 exclusive modes                     | ( 1.200 $\pm$ 0.017 ) | %                |        | —    |

### 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 |
| $\gamma\pi\pi$ (S-wave)      | ( 4.6 $\pm$ 0.7 )          | $\times 10^{-5}$ |        | 4728 |
| $\gamma\pi^0\eta$            | < 2.4                      | $\times 10^{-6}$ | CL=90% | 4713 |
| $\gamma K^+K^-$              | [ooaa] ( 1.14 $\pm$ 0.13 ) | $\times 10^{-5}$ |        | 4704 |
| $\gamma p\bar{p}$            | [ppaa] < 6                 | $\times 10^{-6}$ | CL=90% | 4636 |
| $\gamma 2h^+2h^-$            | ( 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 ±0.6 ) × 10 <sup>-4</sup>                            | 4604 |
| $\gamma 2\pi^+2\pi^-p\bar{p}$   | ( 4 ±6 ) × 10 <sup>-5</sup>                                | 4563 |
| $\gamma 2K^+2K^-$   | ( 2.0 ±2.0 ) × 10 <sup>-5</sup>                            | 4601 |
| $\gamma\eta'(958)$  | < 1.9 × 10 <sup>-6</sup> CL=90%                            | 4682 |
| $\gamma\eta$  | < 1.0 × 10 <sup>-6</sup> CL=90%                            | 4714 |
| $\gamma f_0(980)$   | < 3 × 10 <sup>-5</sup> CL=90%                              | 4678 |
| $\gamma f_2'(1525)$   | ( 2.9 ±0.6 ) × 10 <sup>-5</sup>                            | 4608 |
| $\gamma f_2(1270)$  | ( 1.01 ±0.06 ) × 10 <sup>-4</sup>                          | 4644 |
| $\gamma\eta(1405)$  | < 8.2 × 10 <sup>-5</sup> CL=90%                            | 4625 |
| $\gamma f_0(1500)$  | < 1.5 × 10 <sup>-5</sup> CL=90%                            | 4610 |
| $\gamma f_0(1500) \rightarrow \gamma K^+K^-$                          | ( 1.0 ±0.4 ) × 10 <sup>-5</sup>                            | —    |
| $\gamma f_0(1710)$  | < 2.6 × 10 <sup>-4</sup> CL=90%                            | 4577 |
| $\gamma f_0(1710) \rightarrow \gamma K^+K^-$                          | ( 1.01 ±0.32 ) × 10 <sup>-5</sup>                          | —    |
| $\gamma f_0(1710) \rightarrow \gamma\pi^+\pi^-$                       | ( 5.3 ±2.0 ) × 10 <sup>-6</sup>                            | —    |
| $\gamma f_0(1710) \rightarrow \gamma\pi^0\pi^0$                       | < 1.4 × 10 <sup>-6</sup> CL=90%                            | —    |
| $\gamma f_0(1710) \rightarrow \gamma\eta\eta$                         | < 1.8 × 10 <sup>-6</sup> CL=90%                            | —    |
| $\gamma f_4(2050)$  | < 5.3 × 10 <sup>-5</sup> CL=90%                            | 4515 |
| $\gamma f_0(2200) \rightarrow \gamma K^+K^-$                          | < 2 × 10 <sup>-4</sup> CL=90%                              | 4475 |
| $\gamma f_J(2220) \rightarrow \gamma K^+K^-$                          | < 8 × 10 <sup>-7</sup> CL=90%                              | 4469 |
| $\gamma f_J(2220) \rightarrow \gamma\pi^+\pi^-$                       | < 6 × 10 <sup>-7</sup> CL=90%                              | —    |
| $\gamma f_J(2220) \rightarrow \gamma p\bar{p}$                        | < 1.1 × 10 <sup>-6</sup> CL=90%                            | —    |
| $\gamma\eta(2225) \rightarrow \gamma\phi\phi$                         | < 3 × 10 <sup>-3</sup> CL=90%                              | 4469 |
| $\gamma\eta_c(1S)$  | < 2.9 × 10 <sup>-5</sup> CL=90%                            | 4260 |
| $\gamma\eta_c(2S)$  | < 4 × 10 <sup>-4</sup> CL=90%                              | 4031 |
| $\gamma\chi_{c0}$   | < 6.6 × 10 <sup>-5</sup> CL=90%                            | 4114 |
| $\gamma\chi_{c1}$   | ( 4.7 <sup>+2.4</sup> <sub>-1.9</sub> ) × 10 <sup>-5</sup> | 4079 |
| $\gamma\chi_{c2}$   | < 7.6 × 10 <sup>-6</sup> CL=90%                            | 4062 |
| $\gamma\chi_{c1}(3872)$   | < 4 × 10 <sup>-5</sup> CL=90%                              | 3938 |
| $\gamma\chi_{c1}(3872), \chi_{c1} \rightarrow \pi^+\pi^-\pi^0 J/\psi$ | < 2.8 × 10 <sup>-6</sup> CL=90%                            | —    |
| $\gamma X(3915) \rightarrow \omega J/\psi$                            | < 3.0 × 10 <sup>-6</sup> CL=90%                            | —    |
| $\gamma\chi_{c1}(4140) \rightarrow \phi J/\psi$                       | < 2.2 × 10 <sup>-6</sup> CL=90%                            | —    |
| $\gamma X$  | [qqaa] < 4.5 × 10 <sup>-6</sup> CL=90%                     | —    |
| $\gamma X\bar{X}(m_X < 3.1 \text{ GeV})$                              | [rraa] < 1 × 10 <sup>-3</sup> CL=90%                       | —    |
| $\gamma X\bar{X}(m_X < 4.5 \text{ GeV})$                              | [ssaa] < 2.4 × 10 <sup>-4</sup> CL=90%                     | —    |
| $\gamma X \rightarrow \gamma + \geq 4 \text{ prongs}$                 | [ttaa] < 1.78 × 10 <sup>-4</sup> CL=95%                    | —    |
| $\gamma a_1^0 \rightarrow \gamma\mu^+\mu^-$                           | [uuaa] < 9 × 10 <sup>-6</sup> CL=90%                       | —    |
| $\gamma a_1^0 \rightarrow \gamma\tau^+\tau^-$                         | [ooaa] < 1.30 × 10 <sup>-4</sup> CL=90%                    | —    |
| $\gamma a_1^0 \rightarrow \gamma g g$                                 | [vvaa] < 1 % CL=90%  | —    |
| $\gamma a_1^0 \rightarrow \gamma s\bar{s}$                            | [vvaa] < 1 × 10 <sup>-3</sup> CL=90%                       | —    |

### Lepton Family number (LF) violating modes

|                   |    |                                 |      |
|-------------------|----|---------------------------------|------|
| $\mu^\pm\tau^\mp$ | LF | < 6.0 × 10 <sup>-6</sup> CL=95% | 4563 |
|-------------------|----|---------------------------------|------|

**Other decays**invisible < 3.0  $\times 10^{-4}$  CL=90% – **$\chi_{b0}(1P)$**  [xxaa]

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

 $J$  needs confirmation.

Mass  $m = 9859.44 \pm 0.42 \pm 0.31$  MeV

| <b><math>\chi_{b0}(1P)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ ) | Confidence level | $P$<br>(MeV/c) |
|---|--------------------------------|------------------|----------------|
| $\gamma \Upsilon(1S)$                         | ( 1.94 ± 0.27 ) %              |                  | 391            |
| $D^0 X$                                       | < 10.4 %                       | 90%              | –              |
| $\pi^+ \pi^- K^+ K^- \pi^0$                   | < 1.6 $\times 10^{-4}$         | 90%              | 4875           |
| $2\pi^+ \pi^- K^- K_S^0$                      | < 5 $\times 10^{-5}$           | 90%              | 4875           |
| $2\pi^+ \pi^- K^- K_S^0 2\pi^0$               | < 5 $\times 10^{-4}$           | 90%              | 4846           |
| $2\pi^+ 2\pi^- 2\pi^0$                        | < 2.1 $\times 10^{-4}$         | 90%              | 4905           |
| $2\pi^+ 2\pi^- K^+ K^-$                       | ( 1.1 ± 0.6 ) $\times 10^{-4}$ |                  | 4861           |
| $2\pi^+ 2\pi^- K^+ K^- \pi^0$                 | < 2.7 $\times 10^{-4}$         | 90%              | 4846           |
| $2\pi^+ 2\pi^- K^+ K^- 2\pi^0$                | < 5 $\times 10^{-4}$           | 90%              | 4828           |
| $3\pi^+ 2\pi^- K^- K_S^0 \pi^0$               | < 1.6 $\times 10^{-4}$         | 90%              | 4827           |
| $3\pi^+ 3\pi^-$                               | < 8 $\times 10^{-5}$           | 90%              | 4904           |
| $3\pi^+ 3\pi^- 2\pi^0$                        | < 6 $\times 10^{-4}$           | 90%              | 4881           |
| $3\pi^+ 3\pi^- K^+ K^-$                       | ( 2.4 ± 1.2 ) $\times 10^{-4}$ |                  | 4827           |
| $3\pi^+ 3\pi^- K^+ K^- \pi^0$                 | < 1.0 $\times 10^{-3}$         | 90%              | 4808           |
| $4\pi^+ 4\pi^-$                               | < 8 $\times 10^{-5}$           | 90%              | 4880           |
| $4\pi^+ 4\pi^- 2\pi^0$                        | < 2.1 $\times 10^{-3}$         | 90%              | 4850           |
| $J/\psi J/\psi$                               | < 7 $\times 10^{-5}$           | 90%              | 3836           |
| $J/\psi \psi(2S)$                             | < 1.2 $\times 10^{-4}$         | 90%              | 3571           |
| $\psi(2S) \psi(2S)$                           | < 3.1 $\times 10^{-5}$         | 90%              | 3273           |
| $J/\psi(1S)$ anything                         | < 2.3 $\times 10^{-3}$         | 90%              | –              |

 **$\chi_{b1}(1P)$**  [xxaa]

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

 $J$  needs confirmation.

Mass  $m = 9892.78 \pm 0.26 \pm 0.31$  MeV

| <b><math>\chi_{b1}(1P)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ ) | Confidence level | $P$<br>(MeV/c) |
|---|--------------------------------|------------------|----------------|
| $\gamma \Upsilon(1S)$                         | (35.2 ± 2.0) %                 |                  | 423            |
| $D^0 X$                                       | (12.6 ± 2.2) %                 |                  | –              |
| $\pi^+ \pi^- K^+ K^- \pi^0$                   | ( 2.0 ± 0.6 ) $\times 10^{-4}$ |                  | 4892           |
| $2\pi^+ \pi^- K^- K_S^0$                      | ( 1.3 ± 0.5 ) $\times 10^{-4}$ |                  | 4892           |
| $2\pi^+ \pi^- K^- K_S^0 2\pi^0$               | < 6 $\times 10^{-4}$           | 90%              | 4863           |
| $2\pi^+ 2\pi^- 2\pi^0$                        | ( 8.0 ± 2.5 ) $\times 10^{-4}$ |                  | 4921           |
| $2\pi^+ 2\pi^- K^+ K^-$                       | ( 1.5 ± 0.5 ) $\times 10^{-4}$ |                  | 4878           |

|                                 |                                  |     |      |
|---------------------------------|----------------------------------|-----|------|
| $2\pi^+ 2\pi^- K^+ K^- \pi^0$   | $( 3.5 \pm 1.2 ) \times 10^{-4}$ |     | 4863 |
| $2\pi^+ 2\pi^- K^+ K^- 2\pi^0$  | $( 8.6 \pm 3.2 ) \times 10^{-4}$ |     | 4845 |
| $3\pi^+ 2\pi^- K^- K_S^0 \pi^0$ | $( 9.3 \pm 3.3 ) \times 10^{-4}$ |     | 4844 |
| $3\pi^+ 3\pi^-$                 | $( 1.9 \pm 0.6 ) \times 10^{-4}$ |     | 4921 |
| $3\pi^+ 3\pi^- 2\pi^0$          | $( 1.7 \pm 0.5 ) \times 10^{-3}$ |     | 4898 |
| $3\pi^+ 3\pi^- K^+ K^-$         | $( 2.6 \pm 0.8 ) \times 10^{-4}$ |     | 4844 |
| $3\pi^+ 3\pi^- K^+ K^- \pi^0$   | $( 7.5 \pm 2.6 ) \times 10^{-4}$ |     | 4825 |
| $4\pi^+ 4\pi^-$                 | $( 2.6 \pm 0.9 ) \times 10^{-4}$ |     | 4897 |
| $4\pi^+ 4\pi^- 2\pi^0$          | $( 1.4 \pm 0.6 ) \times 10^{-3}$ |     | 4867 |
| $\omega$ anything               | $( 4.9 \pm 1.4 ) \%$             |     | —    |
| $\omega X_{tetra}$              | $< 4.44 \times 10^{-4}$          | 90% | —    |
| $J/\psi J/\psi$                 | $< 2.7 \times 10^{-5}$           | 90% | 3857 |
| $J/\psi \psi(2S)$               | $< 1.7 \times 10^{-5}$           | 90% | 3594 |
| $\psi(2S) \psi(2S)$             | $< 6 \times 10^{-5}$             | 90% | 3298 |
| $J/\psi(1S)$ anything           | $< 1.1 \times 10^{-3}$           | 90% | —    |
| $J/\psi(1S) X_{tetra}$          | $< 2.27 \times 10^{-4}$          | 90% | —    |

### $h_b(1P)$

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

Mass  $m = 9899.3 \pm 0.8$  MeV

| $h_b(1P)$ DECAY MODES | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|-----------------------|--------------------------------|-------------|
| $\eta_b(1S)\gamma$    | $(52_{-5}^{+6}) \%$            | 488         |

### $\chi_{b2}(1P)$ [xxaa]

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

$J$  needs confirmation.

Mass  $m = 9912.21 \pm 0.26 \pm 0.31$  MeV

| $\chi_{b2}(1P)$ DECAY MODES     | Fraction ( $\Gamma_i/\Gamma$ )   | Confidence level | $p$ (MeV/c) |
|---------------------------------|----------------------------------|------------------|-------------|
| $\gamma \Upsilon(1S)$           | $(18.0 \pm 1.0) \%$              |                  | 442         |
| $D^0 X$                         | $< 7.9 \%$                       | 90%              | —           |
| $\pi^+ \pi^- K^+ K^- \pi^0$     | $( 8 \pm 5 ) \times 10^{-5}$     |                  | 4902        |
| $2\pi^+ \pi^- K^- K_S^0$        | $< 1.0 \times 10^{-4}$           | 90%              | 4901        |
| $2\pi^+ \pi^- K^- K_S^0 2\pi^0$ | $( 5.3 \pm 2.4 ) \times 10^{-4}$ |                  | 4873        |
| $2\pi^+ 2\pi^- 2\pi^0$          | $( 3.5 \pm 1.4 ) \times 10^{-4}$ |                  | 4931        |
| $2\pi^+ 2\pi^- K^+ K^-$         | $( 1.1 \pm 0.4 ) \times 10^{-4}$ |                  | 4888        |
| $2\pi^+ 2\pi^- K^+ K^- \pi^0$   | $( 2.1 \pm 0.9 ) \times 10^{-4}$ |                  | 4872        |
| $2\pi^+ 2\pi^- K^+ K^- 2\pi^0$  | $( 3.9 \pm 1.8 ) \times 10^{-4}$ |                  | 4855        |
| $3\pi^+ 2\pi^- K^- K_S^0 \pi^0$ | $< 5 \times 10^{-4}$             | 90%              | 4854        |

|                               |                                |     |      |
|-------------------------------|--------------------------------|-----|------|
| $3\pi^+ 3\pi^-$               | $(7.0 \pm 3.1) \times 10^{-5}$ |     | 4931 |
| $3\pi^+ 3\pi^- 2\pi^0$        | $(1.0 \pm 0.4) \times 10^{-3}$ |     | 4908 |
| $3\pi^+ 3\pi^- K^+ K^-$       | $< 8 \times 10^{-5}$           | 90% | 4854 |
| $3\pi^+ 3\pi^- K^+ K^- \pi^0$ | $(3.6 \pm 1.5) \times 10^{-4}$ |     | 4835 |
| $4\pi^+ 4\pi^-$               | $(8 \pm 4) \times 10^{-5}$     |     | 4907 |
| $4\pi^+ 4\pi^- 2\pi^0$        | $(1.8 \pm 0.7) \times 10^{-3}$ |     | 4877 |
| $J/\psi J/\psi$               | $< 4 \times 10^{-5}$           | 90% | 3869 |
| $J/\psi \psi(2S)$             | $< 5 \times 10^{-5}$           | 90% | 3608 |
| $\psi(2S) \psi(2S)$           | $< 1.6 \times 10^{-5}$         | 90% | 3313 |
| $J/\psi(1S)$ anything         | $(1.5 \pm 0.4) \times 10^{-3}$ |     | —    |

## $\Upsilon(2S)$

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

Mass  $m = 10023.26 \pm 0.31$  MeV

$m_{\Upsilon(3S)} - m_{\Upsilon(2S)} = 331.50 \pm 0.13$  MeV

Full width  $\Gamma = 31.98 \pm 2.63$  keV

| <b><math>\Upsilon(2S)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ ) | Scale factor/<br>Confidence level | $p$<br>(MeV/c) |
|--|--------------------------------|-----------------------------------|----------------|
| $\Upsilon(1S) \pi^+ \pi^-$                   | $(17.85 \pm 0.26) \%$          |                                   | 475            |
| $\Upsilon(1S) \pi^0 \pi^0$                   | $(8.6 \pm 0.4) \%$             |                                   | 480            |
| $\tau^+ \tau^-$                              | $(2.00 \pm 0.21) \%$           |                                   | 4686           |
| $\mu^+ \mu^-$                                | $(1.93 \pm 0.17) \%$           | S=2.2                             | 5011           |
| $e^+ e^-$                                    | $(1.91 \pm 0.16) \%$           |                                   | 5012           |
| $\Upsilon(1S) \pi^0$                         | $< 4 \times 10^{-5}$           | CL=90%                            | 531            |
| $\Upsilon(1S) \eta$                          | $(2.9 \pm 0.4) \times 10^{-4}$ | S=2.0                             | 126            |
| $J/\psi(1S)$ anything                        | $< 6 \times 10^{-3}$           | CL=90%                            | 4533           |
| $J/\psi(1S) \eta_c$                          | $< 5.4 \times 10^{-6}$         | CL=90%                            | 3984           |
| $J/\psi(1S) \chi_{c0}$                       | $< 3.4 \times 10^{-6}$         | CL=90%                            | 3808           |
| $J/\psi(1S) \chi_{c1}$                       | $< 1.2 \times 10^{-6}$         | CL=90%                            | 3765           |
| $J/\psi(1S) \chi_{c2}$                       | $< 2.0 \times 10^{-6}$         | CL=90%                            | 3744           |
| $J/\psi(1S) \eta_c(2S)$                      | $< 2.5 \times 10^{-6}$         | CL=90%                            | 3707           |
| $J/\psi(1S) X(3940)$                         | $< 2.0 \times 10^{-6}$         | CL=90%                            | 3555           |
| $J/\psi(1S) X(4160)$                         | $< 2.0 \times 10^{-6}$         | CL=90%                            | 3440           |
| $\chi_{c1}$ anything                         | $(2.2 \pm 0.5) \times 10^{-4}$ |                                   | —              |
| $\chi_{c1}(1P)^0 X_{tetra}$                  | $< 3.67 \times 10^{-5}$        | CL=90%                            | —              |
| $\chi_{c2}$ anything                         | $(2.3 \pm 0.8) \times 10^{-4}$ |                                   | —              |
| $\psi(2S) \eta_c$                            | $< 5.1 \times 10^{-6}$         | CL=90%                            | 3732           |
| $\psi(2S) \chi_{c0}$                         | $< 4.7 \times 10^{-6}$         | CL=90%                            | 3536           |
| $\psi(2S) \chi_{c1}$                         | $< 2.5 \times 10^{-6}$         | CL=90%                            | 3488           |
| $\psi(2S) \chi_{c2}$                         | $< 1.9 \times 10^{-6}$         | CL=90%                            | 3464           |
| $\psi(2S) \eta_c(2S)$                        | $< 3.3 \times 10^{-6}$         | CL=90%                            | 3422           |
| $\psi(2S) X(3940)$                           | $< 3.9 \times 10^{-6}$         | CL=90%                            | 3250           |
| $\psi(2S) X(4160)$                           | $< 3.9 \times 10^{-6}$         | CL=90%                            | 3118           |

|   |   |                  |        |      |
|---|---|------------------|--------|------|
| $Z_c(3900)^+ Z_c(3900)^-$                           | < 1.0   | $\times 10^{-6}$ | CL=90% | —    |
| $Z_c(4200)^+ Z_c(4200)^-$                           | < 1.67  | $\times 10^{-5}$ | CL=90% | —    |
| $Z_c(3900)^\pm Z_c(4200)^\mp$                       | < 7.3   | $\times 10^{-6}$ | CL=90% | —    |
| $X(4050)^+ X(4050)^-$                               | < 1.35  | $\times 10^{-5}$ | CL=90% | —    |
| $X(4250)^+ X(4250)^-$                               | < 2.67  | $\times 10^{-5}$ | CL=90% | —    |
| $X(4050)^\pm X(4250)^\mp$                           | < 2.72  | $\times 10^{-5}$ | CL=90% | —    |
| $Z_c(4430)^+ Z_c(4430)^-$                           | < 2.03  | $\times 10^{-5}$ | CL=90% | —    |
| $X(4055)^\pm X(4055)^\mp$                           | < 1.11  | $\times 10^{-5}$ | CL=90% | —    |
| $X(4055)^\pm Z_c(4430)^\mp$                         | < 2.11  | $\times 10^{-5}$ | CL=90% | —    |
| $\overline{^2H}$ anything                           | $( 2.78 \pm_{-0.26}^{+0.30} ) \times 10^{-5}$ |                  | S=1.2  | —    |
| hadrons   | $( 94 \pm 11 ) \%$                            |                  |        | —    |
| $g g g$   | $( 58.8 \pm 1.2 ) \%$                         |                  |        | —    |
| $\gamma g g$  | $( 1.87 \pm 0.28 ) \%$                        |                  |        | —    |
| $\phi K^+ K^-$                                      | $( 1.6 \pm 0.4 ) \times 10^{-6}$              |                  |        | 4910 |
| $\omega \pi^+ \pi^-$                                | < 2.58  | $\times 10^{-6}$ | CL=90% | 4977 |
| $K^*(892)^0 K^- \pi^+ + \text{c.c.}$                | $( 2.3 \pm 0.7 ) \times 10^{-6}$              |                  |        | 4952 |
| $\phi f'_2(1525)$                                   | < 1.33  | $\times 10^{-6}$ | CL=90% | 4842 |
| $\omega f_2(1270)$                                  | < 5.7   | $\times 10^{-7}$ | CL=90% | 4899 |
| $\rho(770) a_2(1320)$                               | < 8.8   | $\times 10^{-7}$ | CL=90% | 4894 |
| $K^*(892)^0 \overline{K}_2^*(1430)^0 + \text{c.c.}$ | $( 1.5 \pm 0.6 ) \times 10^{-6}$              |                  |        | 4869 |
| $K_1(1270)^\pm K^\mp$                               | < 3.22  | $\times 10^{-6}$ | CL=90% | 4921 |
| $K_1(1400)^\pm K^\mp$                               | < 8.3   | $\times 10^{-7}$ | CL=90% | 4901 |
| $b_1(1235)^\pm \pi^\mp$                             | < 4.0   | $\times 10^{-7}$ | CL=90% | 4935 |
| $\rho \pi$  | < 1.16  | $\times 10^{-6}$ | CL=90% | 4981 |
| $\pi^+ \pi^- \pi^0$                                 | < 8.0   | $\times 10^{-7}$ | CL=90% | 5007 |
| $\omega \pi^0$                                      | < 1.63  | $\times 10^{-6}$ | CL=90% | 4980 |
| $\pi^+ \pi^- \pi^0 \pi^0$                           | $( 1.30 \pm 0.28 ) \times 10^{-5}$            |                  |        | 5002 |
| $K_S^0 K^+ \pi^- + \text{c.c.}$                     | $( 1.14 \pm 0.33 ) \times 10^{-6}$            |                  |        | 4979 |
| $K^*(892)^0 \overline{K}^0 + \text{c.c.}$           | < 4.22  | $\times 10^{-6}$ | CL=90% | 4959 |
| $K^*(892)^- K^+ + \text{c.c.}$                      | < 1.45  | $\times 10^{-6}$ | CL=90% | 4960 |
| $f_1(1285)$ anything                                | $( 2.2 \pm 1.6 ) \times 10^{-3}$              |                  |        | —    |
| $f_1(1285) X_{tetra}$                               | < 6.47  | $\times 10^{-5}$ | CL=90% | —    |
| Sum of 100 exclusive modes                          | $( 2.90 \pm 0.30 ) \times 10^{-3}$            |                  |        | —    |

### Radiative decays

|                     |                        |                  |        |      |
|---------------------|------------------------|------------------|--------|------|
| $\gamma X_{b1}(1P)$ | $( 6.9 \pm 0.4 ) \%$   |                  |        | 130  |
| $\gamma X_{b2}(1P)$ | $( 7.15 \pm 0.35 ) \%$ |                  |        | 110  |
| $\gamma X_{b0}(1P)$ | $( 3.8 \pm 0.4 ) \%$   |                  |        | 162  |
| $\gamma f_0(1710)$  | < 5.9                  | $\times 10^{-4}$ | CL=90% | 4867 |
| $\gamma f'_2(1525)$ | < 5.3                  | $\times 10^{-4}$ | CL=90% | 4897 |
| $\gamma f_2(1270)$  | < 2.41                 | $\times 10^{-4}$ | CL=90% | 4930 |
| $\gamma \eta_c(1S)$ | < 2.7                  | $\times 10^{-5}$ | CL=90% | 4567 |
| $\gamma X_{c0}$     | < 1.0                  | $\times 10^{-4}$ | CL=90% | 4430 |
| $\gamma X_{c1}$     | < 3.6                  | $\times 10^{-6}$ | CL=90% | 4397 |

|   |  |                  |        |      |
|---|--|------------------|--------|------|
| $\gamma\chi_{c2}$   | $< 1.5$                                  | $\times 10^{-5}$ | CL=90% | 4381 |
| $\gamma\chi_{c1}(3872)$   | $< 2.1$                                  | $\times 10^{-5}$ | CL=90% | 4264 |
| $\gamma\chi_{c1}(3872), \chi_{c1} \rightarrow \pi^+\pi^-\pi^0 J/\psi$ | $< 2.4$                                  | $\times 10^{-6}$ | CL=90% | —    |
| $\gamma X(3915) \rightarrow \omega J/\psi$                            | $< 2.8$                                  | $\times 10^{-6}$ | CL=90% | —    |
| $\gamma\chi_{c1}(4140) \rightarrow \phi J/\psi$                       | $< 1.2$                                  | $\times 10^{-6}$ | CL=90% | —    |
| $\gamma X(4350) \rightarrow \phi J/\psi$                              | $< 1.3$                                  | $\times 10^{-6}$ | CL=90% | —    |
| $\gamma\eta_b(1S)$  | $(5.5 \pm_{-0.9}^{+1.1}) \times 10^{-4}$ |                  | S=1.2  | 605  |
| $\gamma\eta_b(1S) \rightarrow \gamma$ Sum of 26 exclusive modes       | $< 3.7$                                  | $\times 10^{-6}$ | CL=90% | —    |
| $\gamma X_{b\bar{b}} \rightarrow \gamma$ Sum of 26 exclusive modes    | $< 4.9$                                  | $\times 10^{-6}$ | CL=90% | —    |
| $\gamma X \rightarrow \gamma + \geq 4$ prongs [yyaa]                  | $< 1.95$                                 | $\times 10^{-4}$ | CL=95% | —    |
| $\gamma A^0 \rightarrow \gamma$ hadrons                               | $< 8$                                    | $\times 10^{-5}$ | CL=90% | —    |
| $\gamma a_1^0 \rightarrow \gamma\mu^+\mu^-$                           | $< 8.3$                                  | $\times 10^{-6}$ | CL=90% | —    |

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

|                    |    |         |                  |        |      |
|--------------------|----|---------|------------------|--------|------|
| $e^\pm \tau^\mp$   | LF | $< 3.2$ | $\times 10^{-6}$ | CL=90% | 4854 |
| $\mu^\pm \tau^\mp$ | LF | $< 3.3$ | $\times 10^{-6}$ | CL=90% | 4854 |

**$\Upsilon_2(1D)$**

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

was  $\Upsilon(1D)$

$$\text{Mass } m = 10163.7 \pm 1.4 \text{ MeV} \quad (S = 1.7)$$

| <b><math>\Upsilon_2(1D)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|--|--------------------------------|-------------|
| $\gamma\gamma \Upsilon(1S)$                    | seen                           | 679         |
| $\gamma\chi_{bJ}(1P)$                          | seen                           | 300         |
| $\eta \Upsilon(1S)$                            | not seen                       | 426         |
| $\pi^+\pi^- \Upsilon(1S)$                      | $(6.6 \pm 1.6) \times 10^{-3}$ | 623         |

**$\chi_{b0}(2P)$  [xxaa]**

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

$J$  needs confirmation.

$$\text{Mass } m = 10232.5 \pm 0.4 \pm 0.5 \text{ MeV}$$

| <b><math>\chi_{b0}(2P)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ ) | Confidence level     | $p$ (MeV/c) |
|---|--------------------------------|----------------------|-------------|
| $\gamma \Upsilon(2S)$                         | $(1.38 \pm 0.30) \%$           |                      | 207         |
| $\gamma \Upsilon(1S)$                         | $(3.8 \pm 1.7) \times 10^{-3}$ |                      | 743         |
| $D^0 X$                                       | $< 8.2$                        | % 90%                | —           |
| $\pi^+\pi^- K^+ K^- \pi^0$                    | $< 3.4$                        | $\times 10^{-5}$ 90% | 5064        |
| $2\pi^+\pi^- K^- K_S^0$                       | $< 5$                          | $\times 10^{-5}$ 90% | 5063        |

|                             |       |                  |     |      |
|-----------------------------|-------|------------------|-----|------|
| $2\pi^+\pi^-K^-K_S^02\pi^0$ | < 2.2 | $\times 10^{-4}$ | 90% | 5036 |
| $2\pi^+2\pi^-2\pi^0$        | < 2.4 | $\times 10^{-4}$ | 90% | 5092 |
| $2\pi^+2\pi^-K^+K^-$        | < 1.5 | $\times 10^{-4}$ | 90% | 5050 |
| $2\pi^+2\pi^-K^+K^-\pi^0$   | < 2.2 | $\times 10^{-4}$ | 90% | 5035 |
| $2\pi^+2\pi^-K^+K^-2\pi^0$  | < 1.1 | $\times 10^{-3}$ | 90% | 5019 |
| $3\pi^+2\pi^-K^-K_S^0\pi^0$ | < 7   | $\times 10^{-4}$ | 90% | 5018 |
| $3\pi^+3\pi^-$              | < 7   | $\times 10^{-5}$ | 90% | 5091 |
| $3\pi^+3\pi^-2\pi^0$        | < 1.2 | $\times 10^{-3}$ | 90% | 5070 |
| $3\pi^+3\pi^-K^+K^-$        | < 1.5 | $\times 10^{-4}$ | 90% | 5017 |
| $3\pi^+3\pi^-K^+K^-\pi^0$   | < 7   | $\times 10^{-4}$ | 90% | 4999 |
| $4\pi^+4\pi^-$              | < 1.7 | $\times 10^{-4}$ | 90% | 5069 |
| $4\pi^+4\pi^-2\pi^0$        | < 6   | $\times 10^{-4}$ | 90% | 5039 |

$\chi_{b1}(2P)$  [xxaa]

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

Mass  $m = 10255.46 \pm 0.22 \pm 0.50$  MeV

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

| $\chi_{b1}(2P)$ DECAY MODES | Fraction ( $\Gamma_i/\Gamma$ )               | $p$ (MeV/c) |
|-----------------------------|--|-------------|
| $\omega \Upsilon(1S)$       | ( 1.63 <sup>+0.40</sup> <sub>-0.34</sub> ) % | 135         |
| $\gamma \Upsilon(2S)$       | (18.1 $\pm$ 1.9 ) %                          | 230         |
| $\gamma \Upsilon(1S)$       | ( 9.9 $\pm$ 1.0 ) %                          | 764         |
| $\pi\pi\chi_{b1}(1P)$       | ( 9.1 $\pm$ 1.3 ) $\times 10^{-3}$           | 238         |
| $D^0 X$                     | ( 8.8 $\pm$ 1.7 ) %                          | —           |
| $\pi^+\pi^-K^+K^-\pi^0$     | ( 3.1 $\pm$ 1.0 ) $\times 10^{-4}$           | 5075        |
| $2\pi^+\pi^-K^-K_S^0$       | ( 1.1 $\pm$ 0.5 ) $\times 10^{-4}$           | 5075        |
| $2\pi^+\pi^-K^-K_S^02\pi^0$ | ( 7.7 $\pm$ 3.2 ) $\times 10^{-4}$           | 5047        |
| $2\pi^+2\pi^-2\pi^0$        | ( 5.9 $\pm$ 2.0 ) $\times 10^{-4}$           | 5104        |
| $2\pi^+2\pi^-K^+K^-$        | (10 $\pm$ 4 ) $\times 10^{-5}$               | 5062        |
| $2\pi^+2\pi^-K^+K^-\pi^0$   | ( 5.5 $\pm$ 1.8 ) $\times 10^{-4}$           | 5047        |
| $2\pi^+2\pi^-K^+K^-2\pi^0$  | (10 $\pm$ 4 ) $\times 10^{-4}$               | 5030        |
| $3\pi^+2\pi^-K^-K_S^0\pi^0$ | ( 6.7 $\pm$ 2.6 ) $\times 10^{-4}$           | 5029        |
| $3\pi^+3\pi^-$              | ( 1.2 $\pm$ 0.4 ) $\times 10^{-4}$           | 5103        |
| $3\pi^+3\pi^-2\pi^0$        | ( 1.2 $\pm$ 0.4 ) $\times 10^{-3}$           | 5081        |
| $3\pi^+3\pi^-K^+K^-$        | ( 2.0 $\pm$ 0.8 ) $\times 10^{-4}$           | 5029        |
| $3\pi^+3\pi^-K^+K^-\pi^0$   | ( 6.1 $\pm$ 2.2 ) $\times 10^{-4}$           | 5011        |
| $4\pi^+4\pi^-$              | ( 1.7 $\pm$ 0.6 ) $\times 10^{-4}$           | 5080        |
| $4\pi^+4\pi^-2\pi^0$        | ( 1.9 $\pm$ 0.7 ) $\times 10^{-3}$           | 5051        |

**$h_b(2P)$**

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

Mass  $m = 10259.8 \pm 1.2$  MeV

| <b><math>h_b(2P)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|---|--------------------------------|-------------|
| hadrons                                 | not seen                       | —           |
| $\eta_b(1S)\gamma$                      | $(22 \pm 5) \%$                | 825         |
| $\eta_b(2S)\gamma$                      | $(48 \pm 13) \%$               | 257         |

**$\chi_{b2}(2P)$  <sup>[xxaa]</sup>**

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

$J$  needs confirmation.

Mass  $m = 10268.65 \pm 0.22 \pm 0.50$  MeV

$$m_{\chi_{b2}(2P)} - m_{\chi_{b1}(2P)} = 13.10 \pm 0.24$$
 MeV

| <b><math>\chi_{b2}(2P)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ ) | Confidence level | $p$ (MeV/c) |
|---|--------------------------------|------------------|-------------|
| $\omega \Upsilon(1S)$                         | $(1.10^{+0.34}_{-0.30}) \%$    |                  | 194         |
| $\gamma \Upsilon(2S)$                         | $(8.9 \pm 1.2) \%$             |                  | 242         |
| $\gamma \Upsilon(1S)$                         | $(6.6 \pm 0.8) \%$             |                  | 777         |
| $\pi\pi \chi_{b2}(1P)$                        | $(5.1 \pm 0.9) \times 10^{-3}$ |                  | 229         |
| $D^0 X$                                       | $< 2.4 \%$                     | 90%              | —           |
| $\pi^+ \pi^- K^+ K^- \pi^0$                   | $< 1.1 \times 10^{-4}$         | 90%              | 5082        |
| $2\pi^+ \pi^- K^- K_S^0$                      | $< 9 \times 10^{-5}$           | 90%              | 5082        |
| $2\pi^+ \pi^- K^- K_S^0 2\pi^0$               | $< 7 \times 10^{-4}$           | 90%              | 5054        |
| $2\pi^+ 2\pi^- 2\pi^0$                        | $(3.9 \pm 1.6) \times 10^{-4}$ |                  | 5110        |
| $2\pi^+ 2\pi^- K^+ K^-$                       | $(9 \pm 4) \times 10^{-5}$     |                  | 5068        |
| $2\pi^+ 2\pi^- K^+ K^- \pi^0$                 | $(2.4 \pm 1.1) \times 10^{-4}$ |                  | 5054        |
| $2\pi^+ 2\pi^- K^+ K^- 2\pi^0$                | $(4.7 \pm 2.3) \times 10^{-4}$ |                  | 5037        |
| $3\pi^+ 2\pi^- K^- K_S^0 \pi^0$               | $< 4 \times 10^{-4}$           | 90%              | 5036        |
| $3\pi^+ 3\pi^-$                               | $(9 \pm 4) \times 10^{-5}$     |                  | 5110        |
| $3\pi^+ 3\pi^- 2\pi^0$                        | $(1.2 \pm 0.4) \times 10^{-3}$ |                  | 5088        |
| $3\pi^+ 3\pi^- K^+ K^-$                       | $(1.4 \pm 0.7) \times 10^{-4}$ |                  | 5036        |
| $3\pi^+ 3\pi^- K^+ K^- \pi^0$                 | $(4.2 \pm 1.7) \times 10^{-4}$ |                  | 5017        |
| $4\pi^+ 4\pi^-$                               | $(9 \pm 5) \times 10^{-5}$     |                  | 5087        |
| $4\pi^+ 4\pi^- 2\pi^0$                        | $(1.3 \pm 0.5) \times 10^{-3}$ |                  | 5058        |

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

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

Mass  $m = 10355.2 \pm 0.5$  MeV

$$m_{\Upsilon(3S)} - m_{\Upsilon(2S)} = 331.50 \pm 0.13$$
 MeV



Full width  $\Gamma = 20.32 \pm 1.85$  keV

| <b><math>\Upsilon(3S)</math> DECAY MODES</b>     | Fraction ( $\Gamma_i/\Gamma$ )      | Scale factor/<br>Confidence level | $p$<br>(MeV/c) |
|--|-------------------------------------|-----------------------------------|----------------|
| $\Upsilon(2S)$ anything                          | (10.6 $\pm$ 0.8 ) %                 |                                   | 296            |
| $\Upsilon(2S)\pi^+\pi^-$                         | ( 2.82 $\pm$ 0.18) %                | S=1.6                             | 177            |
| $\Upsilon(2S)\pi^0\pi^0$                         | ( 1.85 $\pm$ 0.14) %                |                                   | 190            |
| $\Upsilon(2S)\gamma\gamma$                       | ( 5.0 $\pm$ 0.7 ) %                 |                                   | 327            |
| $\Upsilon(2S)\pi^0$                              | < 5.1                               | $\times 10^{-4}$ CL=90%           | 298            |
| $\Upsilon(1S)\pi^+\pi^-$                         | ( 4.37 $\pm$ 0.08) %                |                                   | 813            |
| $\Upsilon(1S)\pi^0\pi^0$                         | ( 2.20 $\pm$ 0.13) %                |                                   | 816            |
| $\Upsilon(1S)\eta$                               | < 1                                 | $\times 10^{-4}$ CL=90%           | 677            |
| $\Upsilon(1S)\pi^0$                              | < 7                                 | $\times 10^{-5}$ CL=90%           | 846            |
| $h_b(1P)\pi^0$                                   | < 1.2                               | $\times 10^{-3}$ CL=90%           | 426            |
| $h_b(1P)\pi^0 \rightarrow \gamma\eta_b(1S)\pi^0$ | ( 4.3 $\pm$ 1.4 ) $\times 10^{-4}$  |                                   | –              |
| $h_b(1P)\pi^+\pi^-$                              | < 1.2                               | $\times 10^{-4}$ CL=90%           | 353            |
| $\tau^+\tau^-$                                   | ( 2.29 $\pm$ 0.30) %                |                                   | 4863           |
| $\mu^+\mu^-$                                     | ( 2.18 $\pm$ 0.21) %                | S=2.1                             | 5177           |
| $e^+e^-$   | ( 2.18 $\pm$ 0.20) %                |                                   | 5178           |
| hadrons  | (93 $\pm$ 12 ) %                    |                                   | –              |
| $ggg$  | (35.7 $\pm$ 2.6 ) %                 |                                   | –              |
| $\gamma gg$                                      | ( 9.7 $\pm$ 1.8 ) $\times 10^{-3}$  |                                   | –              |
| ${}^2H$ anything                                 | ( 2.33 $\pm$ 0.33) $\times 10^{-5}$ |                                   | –              |

### Radiative decays

|   |                                    |                         |     |
|---|------------------------------------|-------------------------|-----|
| $\gamma\chi_{b2}(2P)$                         | (13.1 $\pm$ 1.6 ) %                | S=3.4                   | 86  |
| $\gamma\chi_{b1}(2P)$                         | (12.6 $\pm$ 1.2 ) %                | S=2.4                   | 99  |
| $\gamma\chi_{b0}(2P)$                         | ( 5.9 $\pm$ 0.6 ) %                | S=1.4                   | 122 |
| $\gamma\chi_{b2}(1P)$                         | (10.0 $\pm$ 1.0 ) $\times 10^{-3}$ | S=1.7                   | 434 |
| $\gamma\chi_{b1}(1P)$                         | ( 9 $\pm$ 5 ) $\times 10^{-4}$     | S=1.8                   | 452 |
| $\gamma\chi_{b0}(1P)$                         | ( 2.7 $\pm$ 0.4 ) $\times 10^{-3}$ |                         | 484 |
| $\gamma\eta_b(2S)$                            | < 6.2                              | $\times 10^{-4}$ CL=90% | 350 |
| $\gamma\eta_b(1S)$                            | ( 5.1 $\pm$ 0.7 ) $\times 10^{-4}$ |                         | 912 |
| $\gamma A^0 \rightarrow \gamma$ hadrons       | < 8                                | $\times 10^{-5}$ CL=90% | –   |
| $\gamma X \rightarrow \gamma + \geq 4$ prongs | [zzaa] < 2.2                       | $\times 10^{-4}$ CL=95% | –   |
| $\gamma a_1^0 \rightarrow \gamma\mu^+\mu^-$   | < 5.5                              | $\times 10^{-6}$ CL=90% | –   |
| $\gamma a_1^0 \rightarrow \gamma\tau^+\tau^-$ | [aabb] < 1.6                       | $\times 10^{-4}$ CL=90% | –   |

### Lepton Family number (LF) violating modes

|                   |    |       |                         |      |
|-------------------|----|-------|-------------------------|------|
| $e^\pm\tau^\mp$   | LF | < 4.2 | $\times 10^{-6}$ CL=90% | 5025 |
| $\mu^\pm\tau^\mp$ | LF | < 3.1 | $\times 10^{-6}$ CL=90% | 5025 |

**$\chi_{b1}(3P)$**

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

Mass  $m = 10513.4 \pm 0.7$  MeV

| $\chi_{b1}(3P)$ DECAY MODES | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|-----------------------------|--------------------------------|-------------|
| $\Upsilon(1S)\gamma$        | seen                           | 1000        |
| $\Upsilon(2S)\gamma$        | seen                           | 479         |
| $\Upsilon(3S)\gamma$        | seen                           | 157         |

**$\chi_{b2}(3P)$**

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

Mass  $m = 10524.0 \pm 0.8$  MeV

| $\chi_{b2}(3P)$ DECAY MODES | Fraction ( $\Gamma_i/\Gamma$ ) | $p$ (MeV/c) |
|-----------------------------|--------------------------------|-------------|
| $\Upsilon(3S)\gamma$        | seen                           | 167         |

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

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

also known as  $\Upsilon(10580)$

Mass  $m = 10579.4 \pm 1.2$  MeV

Full width  $\Gamma = 20.5 \pm 2.5$  MeV

| $\Upsilon(4S)$ DECAY MODES             | Fraction ( $\Gamma_i/\Gamma$ )   | Confidence level | $p$ (MeV/c) |
|--|----------------------------------|------------------|-------------|
| $B\bar{B}$                             | > 96 %                           | 95%              | 326         |
| $B^+B^-$                               | (51.4 ± 0.6) %                   |                  | 331         |
| $D_S^+$ anything + c.c.                | (17.8 ± 2.6) %                   |                  | –           |
| $B^0\bar{B}^0$                         | (48.6 ± 0.6) %                   |                  | 326         |
| $J/\psi K_S^0 + (J/\psi, \eta_c)K_S^0$ | < 4 × 10 <sup>-7</sup>           | 90%              | –           |
| non- $B\bar{B}$                        | < 4 %                            | 95%              | –           |
| $e^+e^-$                               | (1.57 ± 0.08) × 10 <sup>-5</sup> |                  | 5290        |
| $\rho^+\rho^-$                         | < 5.7 × 10 <sup>-6</sup>         | 90%              | 5233        |
| $K^*(892)^0\bar{K}^0$                  | < 2.0 × 10 <sup>-6</sup>         | 90%              | 5240        |
| $J/\psi(1S)$ anything                  | < 1.9 × 10 <sup>-4</sup>         | 95%              | –           |
| $D^{*+}$ anything + c.c.               | < 7.4 %                          | 90%              | 5099        |
| $\phi$ anything                        | (7.1 ± 0.6) %                    |                  | 5240        |
| $\phi\eta$                             | < 1.8 × 10 <sup>-6</sup>         | 90%              | 5226        |
| $\phi\eta'$                            | < 4.3 × 10 <sup>-6</sup>         | 90%              | 5196        |
| $\rho\eta$                             | < 1.3 × 10 <sup>-6</sup>         | 90%              | 5247        |
| $\rho\eta'$                            | < 2.5 × 10 <sup>-6</sup>         | 90%              | 5217        |

|                          |                                  |     |      |
|--------------------------|----------------------------------|-----|------|
| $\Upsilon(1S)$ anything  | $< 4 \times 10^{-3}$             | 90% | 1053 |
| $\Upsilon(1S)\pi^+\pi^-$ | $(8.2 \pm 0.4) \times 10^{-5}$   |     | 1026 |
| $\Upsilon(1S)\eta$       | $(1.81 \pm 0.18) \times 10^{-4}$ |     | 924  |
| $\Upsilon(1S)\eta'$      | $(3.4 \pm 0.9) \times 10^{-5}$   |     | –    |
| $\Upsilon(2S)\pi^+\pi^-$ | $(8.2 \pm 0.8) \times 10^{-5}$   |     | 468  |
| $h_b(1P)\pi^+\pi^-$      | not seen                         |     | 600  |
| $h_b(1P)\eta$            | $(2.18 \pm 0.21) \times 10^{-3}$ |     | 390  |
| $\eta_b(1S)\omega$       | $< 1.8 \times 10^{-4}$           | 90% | –    |
| ${}^2H$ anything         | $< 1.3 \times 10^{-5}$           | 90% | –    |

### Double Radiative Decays

|  |                        |     |   |
|--|------------------------|-----|---|
| $\gamma\gamma \Upsilon(D) \rightarrow \gamma\gamma\eta \Upsilon(1S)$ | $< 2.3 \times 10^{-5}$ | 90% | – |
|--|------------------------|-----|---|

**Z<sub>b</sub>(10610)**

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

was X(10610)

Mass  $m = 10607.2 \pm 2.0$  MeV

Full width  $\Gamma = 18.4 \pm 2.4$  MeV

| <b>Z<sub>b</sub>(10610) DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ )       | $p$ (MeV/c) |
|---|--------------------------------------|-------------|
| $\Upsilon(1S)\pi^+$                     | $(5.4^{+1.9}_{-1.5}) \times 10^{-3}$ | 1077        |
| $\Upsilon(1S)\pi^0$                     | not seen                             | 1077        |
| $\Upsilon(2S)\pi^+$                     | $(3.6^{+1.1}_{-0.8}) \%$             | 551         |
| $\Upsilon(2S)\pi^0$                     | seen                                 | 552         |
| $\Upsilon(3S)\pi^+$                     | $(2.1^{+0.8}_{-0.6}) \%$             | 207         |
| $\Upsilon(3S)\pi^0$                     | seen                                 | 210         |
| $h_b(1P)\pi^+$                          | $(3.5^{+1.2}_{-0.9}) \%$             | 671         |
| $h_b(2P)\pi^+$                          | $(4.7^{+1.7}_{-1.3}) \%$             | 313         |
| $B^+\bar{B}^0$                          | not seen                             | 505         |
| $B^+\bar{B}^{*0} + B^{*+}\bar{B}^0$     | $(85.6^{+2.1}_{-2.9}) \%$            | –           |

**Z<sub>b</sub>(10650)**

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

$I, G, C$  need confirmation.

was X(10650)<sup>±</sup>

Mass  $m = 10652.2 \pm 1.5$  MeV

Full width  $\Gamma = 11.5 \pm 2.2$  MeV

$Z_b(10650)^-$  decay modes are charge conjugates of the modes below.

| <b><math>Z_b(10650)^+</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ )       | $p$ (MeV/c) |
|--|--------------------------------------|-------------|
| $\Upsilon(1S)\pi^+$                          | $(1.7^{+0.8}_{-0.6}) \times 10^{-3}$ | 1117        |
| $\Upsilon(2S)\pi^+$                          | $(1.4^{+0.6}_{-0.4}) \%$             | 595         |
| $\Upsilon(3S)\pi^+$                          | $(1.6^{+0.7}_{-0.5}) \%$             | 259         |
| $h_b(1P)\pi^+$                               | $(8.4^{+2.9}_{-2.4}) \%$             | 714         |
| $h_b(2P)\pi^+$                               | $(15 \pm 4) \%$                      | 360         |
| $B^+\bar{B}^0$                               | not seen                             | 703         |
| $B^+\bar{B}^{*0} + B^{*+}\bar{B}^0$          | not seen                             | —           |
| $B^{*+}\bar{B}^{*0}$                         | $(74^{+4}_{-6}) \%$                  | 122         |

**$\Upsilon(10860)$**

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

Mass  $m = 10885.2^{+2.6}_{-1.6}$  MeV

Full width  $\Gamma = 37 \pm 4$  MeV

| <b><math>\Upsilon(10860)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ )       | Confidence level | $p$ (MeV/c) |
|---|--------------------------------------|------------------|-------------|
| $B\bar{B}X$                                     | $(76.2^{+2.7}_{-4.0}) \%$            | —                | —           |
| $B\bar{B}$                                      | $(5.5 \pm 1.0) \%$                   | —                | 1322        |
| $B\bar{B}^* + \text{c.c.}$                      | $(13.7 \pm 1.6) \%$                  | —                | —           |
| $B^*\bar{B}^*$                                  | $(38.1 \pm 3.4) \%$                  | —                | 1127        |
| $B\bar{B}^{(*)}\pi$                             | $< 19.7 \%$                          | 90%              | 1015        |
| $B\bar{B}\pi$                                   | $(0.0 \pm 1.2) \%$                   | —                | 1015        |
| $B^*\bar{B}\pi + B\bar{B}^*\pi$                 | $(7.3 \pm 2.3) \%$                   | —                | —           |
| $B^*\bar{B}^*\pi$                               | $(1.0 \pm 1.4) \%$                   | —                | 739         |
| $B\bar{B}\pi\pi$                                | $< 8.9 \%$                           | 90%              | 551         |
| $B_s^{(*)}\bar{B}_s^{(*)}$                      | $(20.1 \pm 3.1) \%$                  | —                | 905         |
| $B_s\bar{B}_s$                                  | $(5 \pm 5) \times 10^{-3}$           | —                | 905         |
| $B_s\bar{B}_s^* + \text{c.c.}$                  | $(1.35 \pm 0.32) \%$                 | —                | —           |
| $B_s^*\bar{B}_s^*$                              | $(17.6 \pm 2.7) \%$                  | —                | 543         |
| no open-bottom                                  | $(3.8^{+5.0}_{-0.5}) \%$             | —                | —           |
| $e^+e^-$  | $(8.3 \pm 2.1) \times 10^{-6}$       | —                | 5443        |
| $K^*(892)^0\bar{K}^0$                           | $< 1.0 \times 10^{-5}$               | 90%              | 5395        |
| $\Upsilon(1S)\pi^+\pi^-$                        | $(5.3 \pm 0.6) \times 10^{-3}$       | —                | 1306        |
| $\Upsilon(2S)\pi^+\pi^-$                        | $(7.8 \pm 1.3) \times 10^{-3}$       | —                | 783         |
| $\Upsilon(3S)\pi^+\pi^-$                        | $(4.8^{+1.9}_{-1.7}) \times 10^{-3}$ | —                | 440         |

|  |                                      |     |      |
|--|--------------------------------------|-----|------|
| $\Upsilon(1S)K^+K^-$                                 | $(6.1 \pm 1.8) \times 10^{-4}$       |     | 959  |
| $\eta \Upsilon_J(1D)$                                | $(4.8 \pm 1.1) \times 10^{-3}$       |     | —    |
| $h_b(1P)\pi^+\pi^-$                                  | $(3.5^{+1.0}_{-1.3}) \times 10^{-3}$ |     | 903  |
| $h_b(2P)\pi^+\pi^-$                                  | $(5.7^{+1.7}_{-2.1}) \times 10^{-3}$ |     | 544  |
| $\chi_{bJ}(1P)\pi^+\pi^-\pi^0$                       | $(2.5 \pm 2.3) \times 10^{-3}$       |     | 894  |
| $\chi_{b0}(1P)\pi^+\pi^-\pi^0$                       | $< 6.3 \times 10^{-3}$               | 90% | 894  |
| $\chi_{b0}(1P)\omega$                                | $< 3.9 \times 10^{-3}$               | 90% | 631  |
| $\chi_{b0}(1P)(\pi^+\pi^-\pi^0)_{\text{non-}\omega}$ | $< 4.8 \times 10^{-3}$               | 90% | —    |
| $\chi_{b1}(1P)\pi^+\pi^-\pi^0$                       | $(1.85 \pm 0.33) \times 10^{-3}$     |     | 861  |
| $\chi_{b1}(1P)\omega$                                | $(1.57 \pm 0.30) \times 10^{-3}$     |     | 582  |
| $\chi_{b1}(1P)(\pi^+\pi^-\pi^0)_{\text{non-}\omega}$ | $(5.2 \pm 1.9) \times 10^{-4}$       |     | —    |
| $\chi_{b2}(1P)\pi^+\pi^-\pi^0$                       | $(1.17 \pm 0.30) \times 10^{-3}$     |     | 841  |
| $\chi_{b2}(1P)\omega$                                | $(6.0 \pm 2.7) \times 10^{-4}$       |     | 552  |
| $\chi_{b2}(1P)(\pi^+\pi^-\pi^0)_{\text{non-}\omega}$ | $(6 \pm 4) \times 10^{-4}$           |     | —    |
| $\gamma X_b \rightarrow \gamma \Upsilon(1S)\omega$   | $< 3.8 \times 10^{-5}$               | 90% | —    |
| $\eta_b(1S)\omega$                                   | $< 1.3 \times 10^{-3}$               | 90% | 1177 |
| $\eta_b(2S)\omega$                                   | $< 5.6 \times 10^{-3}$               | 90% | 399  |

### Inclusive Decays.

These decay modes are submodes of one or more of the decay modes above.

|                       |                          |   |
|-----------------------|--------------------------|---|
| $\phi$ anything       | $(13.8^{+2.4}_{-1.7})\%$ | — |
| $D^0$ anything + c.c. | $(108 \pm 8)\%$          | — |
| $D_s$ anything + c.c. | $(46 \pm 6)\%$           | — |
| $J/\psi$ anything     | $(2.06 \pm 0.21)\%$      | — |
| $B^0$ anything + c.c. | $(77 \pm 8)\%$           | — |
| $B^+$ anything + c.c. | $(72 \pm 6)\%$           | — |

**$\Upsilon(11020)$**

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

Mass  $m = 11000 \pm 4$  MeV

Full width  $\Gamma = 24^{+8}_{-6}$  MeV

| <b><math>\Upsilon(11020)</math> DECAY MODES</b> | Fraction ( $\Gamma_i/\Gamma$ )       | $p$ (MeV/c) |
|---|--------------------------------------|-------------|
| $e^+e^-$  | $(5.4^{+1.9}_{-2.1}) \times 10^{-6}$ | 5500        |
| $\chi_{bJ}(1P)\pi^+\pi^-\pi^0$                  | $(9^{+9}_{-8}) \times 10^{-3}$       | 1007        |
| $\chi_{b1}(1P)\pi^+\pi^-\pi^0$                  | seen                                 | 975         |
| $\chi_{b2}(1P)\pi^+\pi^-\pi^0$                  | seen                                 | 956         |

## NOTES

- [a] See the review on “Form Factors for Radiative Pion and Kaon Decays” 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  $10^{-13}$ .
- [f] Forbidden by angular momentum conservation.
- [g] C parity forbids this to occur as a single-photon process.
- [h] The  $\omega \rho$  interference is then due to  $\omega \rho$  mixing only, and is expected to be small. If  $e\mu$  universality holds,  $\Gamma(\rho^0 \rightarrow \mu^+ \mu^-) = \Gamma(\rho^0 \rightarrow e^+ e^-) \times 0.99785$ .
- [i] See the “Note on  $a_1(1260)$ ” in the  $a_1(1260)$  Particle Listings in PDG 06, Journal of Physics **G33** 1 (2006).
- [j] Our estimate. See the Particle Listings for details.
- [k] See also the  $\omega(1650)$ .
- [l] See also the  $\omega(1420)$ .
- [n] See the note in the  $K^\pm$  Particle Listings.
- [o] Neglecting photon channels. See, *e.g.*, A. Pais and S.B. Treiman, Phys. Rev. **D12**, 2744 (1975).
- [p] The definition of the slope parameters 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):
- $$|M|^2 = 1 + g(s_3 - s_0)/m_{\pi^+}^2 + \dots$$
- [q] For more details and definitions of parameters see the Particle Listings.
- [r] See the  $K^\pm$  Particle Listings for the energy limits used in this measurement.
- [s] Most of this radiative mode, the low-momentum  $\gamma$  part, is also included in the parent mode listed without  $\gamma$ 's.
- [t] Structure-dependent part.
- [u] Direct-emission branching fraction.
- [v] Violates angular-momentum conservation.

[x] 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.”

[y] 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  $\text{Re}(\eta_{000}) \simeq 0$ .

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

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

[bb]  $\text{Re}(\epsilon'/\epsilon) = \epsilon'/\epsilon$  to a very good approximation provided the phases satisfy  $CPT$  invariance.

[cc] This mode includes gammas from inner bremsstrahlung but not the direct emission mode  $K_L^0 \rightarrow \pi^+\pi^-\gamma(\text{DE})$ .

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

[ee] Allowed by higher-order electroweak interactions.

[ff] Violates  $CP$  in leading order. Test of direct  $CP$  violation since the indirect  $CP$ -violating and  $CP$ -conserving contributions are expected to be suppressed.

[gg] See our minireview under the  $K_2(1770)$  in the 2004 edition of this Review.

[hh] 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.

- [ii] See the Particle Listings for the (complicated) definition of this quantity.
- [jj] 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.
- [kk] These subfractions of the  $K^- 2\pi^+$  mode are uncertain: see the Particle Listings.
- [ll] Submodes of the  $D^+ \rightarrow K^- 2\pi^+ \pi^0$  and  $K_S^0 2\pi^+ \pi^-$  modes were studied by ANJOS 92C and COFFMAN 92B, but with at most 142 events for the first mode and 229 for the second – not enough for precise results. With nothing new for 18 years, we refer to our 2008 edition, Physics Letters **B667** 1 (2008), for those results.
- [nn] The unseen decay modes of the resonances are included.
- [oo] This is *not* a test for the  $\Delta C=1$  weak neutral current, but leads to the  $\pi^+ \ell^+ \ell^-$  final state.
- [pp] This mode is not a useful test for a  $\Delta C=1$  weak neutral current because both quarks must change flavor in this decay.
- [qq] In the 2010 *Review*, the values for these quantities were given using a measure of the asymmetry that was inconsistent with the usual definition.
- [rr] This value is obtained by subtracting the branching fractions for 2-, 4- and 6-prongs from unity.
- [ss] This is the sum of our  $K^- 2\pi^+ \pi^-$ ,  $K^- 2\pi^+ \pi^- \pi^0$ ,  $\bar{K}^0 2\pi^+ 2\pi^-$ ,  $K^+ 2K^- \pi^+$ ,  $2\pi^+ 2\pi^-$ ,  $2\pi^+ 2\pi^- \pi^0$ ,  $K^+ K^- \pi^+ \pi^-$ , and  $K^+ K^- \pi^+ \pi^- \pi^0$ , branching fractions.
- [tt] This is the sum of our  $K^- 3\pi^+ 2\pi^-$  and  $3\pi^+ 3\pi^-$  branching fractions.
- [uu] The branching fractions for the  $K^- e^+ \nu_e$ ,  $K^*(892)^- e^+ \nu_e$ ,  $\pi^- e^+ \nu_e$ , and  $\rho^- e^+ \nu_e$  modes add up to  $6.17 \pm 0.17$  %.
- [vv] This is a doubly Cabibbo-suppressed mode.
- [xx] Submodes of the  $D^0 \rightarrow K_S^0 \pi^+ \pi^- \pi^0$  mode with a  $K^*$  and/or  $\rho$  were studied by COFFMAN 92B, but with only 140 events. With nothing new for 18 years, we refer to our 2008 edition, Physics Letters **B667** 1 (2008), for those results.
- [yy] This branching fraction includes all the decay modes of the resonance in the final state.
- [zz] This limit is for either  $D^0$  or  $\bar{D}^0$  to  $p e^-$ .
- [aaa] This limit is for either  $D^0$  or  $\bar{D}^0$  to  $\bar{p} e^+$ .
- [bbb] This is the purely  $e^+$  semileptonic branching fraction: the  $e^+$  fraction from  $\tau^+$  decays has been subtracted off. The sum of our (non- $\tau$ )  $e^+$  exclusive fractions — an  $e^+ \nu_e$  with an  $\eta$ ,  $\eta'$ ,  $\phi$ ,  $K^0$ , or  $K^{*0}$  — is  $5.99 \pm 0.31$  %.



- [ccc] This fraction includes  $\eta$  from  $\eta'$  decays.
- [ddd] The sum of our exclusive  $\eta'$  fractions —  $\eta' e^+ \nu_e$ ,  $\eta' \mu^+ \nu_\mu$ ,  $\eta' \pi^+$ ,  $\eta' \rho^+$ , and  $\eta' K^+$  — is  $11.8 \pm 1.6\%$ .
- [eee] This branching fraction includes all the decay modes of the final-state resonance.
- [fff] A test for  $u\bar{u}$  or  $d\bar{d}$  content in the  $D_s^+$ . Neither Cabibbo-favored nor Cabibbo-suppressed decays can contribute, and  $\omega - \phi$  mixing is an unlikely explanation for any fraction above about  $2 \times 10^{-4}$ .
- [ggg] We decouple the  $D_s^+ \rightarrow \phi \pi^+$  branching fraction obtained from mass projections (and used to get some of the other branching fractions) from the  $D_s^+ \rightarrow \phi \pi^+$ ,  $\phi \rightarrow K^+ K^-$  branching fraction obtained from the Dalitz-plot analysis of  $D_s^+ \rightarrow K^+ K^- \pi^+$ . That is, the ratio of these two branching fractions is not exactly the  $\phi \rightarrow K^+ K^-$  branching fraction 0.491.
- [hhh] This is the average of a model-independent and a  $K$ -matrix parametrization of the  $\pi^+ \pi^-$   $S$ -wave and is a sum over several  $f_0$  mesons.
  - [iii] An  $\ell$  indicates an  $e$  or a  $\mu$  mode, not a sum over these modes.
  - [jjj] An  $CP(\pm 1)$  indicates the  $CP=+1$  and  $CP=-1$  eigenstates of the  $D^0$ - $\bar{D}^0$  system.
  - [kkk]  $D$  denotes  $D^0$  or  $\bar{D}^0$ .
    - [lll]  $D_{CP+}^{*0}$  decays into  $D^0 \pi^0$  with the  $D^0$  reconstructed in  $CP$ -even eigenstates  $K^+ K^-$  and  $\pi^+ \pi^-$ .
- [nnn]  $\bar{D}^{**}$  represents an excited state with mass  $2.2 < M < 2.8$  GeV/ $c^2$ .
- [ooo]  $\chi_{c1}(3872)^+$  is a hypothetical charged partner of the  $\chi_{c1}(3872)$ .
- [ppp]  $\Theta(1710)^{++}$  is a possible narrow pentaquark state and  $G(2220)$  is a possible glueball resonance.
- [qqq]  $(\bar{A}_c^- p)_s$  denotes a low-mass enhancement near 3.35 GeV/ $c^2$ .
  - [rrr] Stands for the possible candidates of  $K^*(1410)$ ,  $K_0^*(1430)$  and  $K_2^*(1430)$ .
- [sss]  $B^0$  and  $B_s^0$  contributions not separated. Limit is on weighted average of the two decay rates.
- [ttt] This decay refers to the coherent sum of resonant and nonresonant  $J^P = 0^+ K \pi$  components with  $1.60 < m_{K\pi} < 2.15$  GeV/ $c^2$ .
- [uuu]  $X(214)$  is a hypothetical particle of mass 214 MeV/ $c^2$  reported by the HyperCP experiment, Physical Review Letters **94** 021801 (2005)
- [vvv]  $\Theta(1540)^+$  denotes a possible narrow pentaquark state.
- [xxx] Here  $S$  and  $P$  are the hypothetical scalar and pseudoscalar particles with masses of 2.5 GeV/ $c^2$  and 214.3 MeV/ $c^2$ , respectively.

- [yyy] These values are model dependent.
- [zzz] Here “anything” means at least one particle observed.
- [aaaa] This is a  $B(B^0 \rightarrow D^{*-} \ell^+ \nu_\ell)$  value.
- [bbaa]  $D^{**}$  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.
- [ccaa]  $D^{(*)}\bar{D}^{(*)}$  stands for the sum of  $D^*\bar{D}^*$ ,  $D^*\bar{D}$ ,  $D\bar{D}^*$ , and  $D\bar{D}$ .
- [ddaa]  $X(3915)$  denotes a near-threshold enhancement in the  $\omega J/\psi$  mass spectrum.
- [eeaa] Inclusive branching fractions have a multiplicity definition and can be greater than 100%.
- [ffaa]  $D_j$  represents an unresolved mixture of pseudoscalar and tensor  $D^{**}$  ( $P$ -wave) states.
- [ggaa] Not a pure measurement. See note at head of  $B_S^0$  Decay Modes.
- [hhaa] For  $E_\gamma > 100$  MeV.
  - [jiaa] Includes  $p\bar{p}\pi^+\pi^-\gamma$  and excludes  $p\bar{p}\eta$ ,  $p\bar{p}\omega$ ,  $p\bar{p}\eta'$ .
  - [jjaa] For a narrow state  $A$  with mass less than 960 MeV.
  - [kkaa] For a narrow scalar or pseudoscalar  $A^0$  with mass 0.21–3.0 GeV.
  - [llaa] For a narrow resonance in the range  $2.2 < M(X) < 2.8$  GeV.
- [nnaa]  $J^{PC}$  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.
- [ooaa]  $2m_\tau < M(\tau^+\tau^-) < 9.2$  GeV
- [ppaa]  $2$  GeV  $< m_{K^+K^-} < 3$  GeV
- [qqaa]  $X =$  scalar with  $m < 8.0$  GeV
- [rraa]  $X\bar{X} =$  vectors with  $m < 3.1$  GeV
- [ssaa]  $X$  and  $\bar{X} =$  zero spin with  $m < 4.5$  GeV
- [ttaa]  $1.5$  GeV  $< m_X < 5.0$  GeV
- [uuaa]  $201$  MeV  $< M(\mu^+\mu^-) < 3565$  MeV
- [vva]  $0.5$  GeV  $< m_X < 9.0$  GeV, where  $m_X$  is the invariant mass of the hadronic final state.
- [xxaa] Spectroscopic labeling for these states is theoretical, pending experimental information.
- [yyaa]  $1.5$  GeV  $< m_X < 5.0$  GeV
- [zzaa]  $1.5$  GeV  $< m_X < 5.0$  GeV
- [aabb] For  $m_{\tau^+\tau^-}$  in the ranges 4.03–9.52 and 9.61–10.10 GeV.