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

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

## $D^\pm$

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

Mass $m = 1869.3 \pm 0.4$ MeV (S = 1.1)
Mean life $\tau = (1040 \pm 7) \times 10^{-15}$ s
$c\tau = 311.8$ $\mu$m

### *c*-quark decays

$\Gamma(c \to \ell^+ \text{anything})/\Gamma(c \to \text{anything}) = 0.096 \pm 0.004$ [a]
$\Gamma(c \to D^*(2010)^+ \text{anything})/\Gamma(c \to \text{anything}) = 0.255 \pm 0.017$

### *CP*-violation decay-rate asymmetries

$A_{CP}(K^0_S\pi^\pm) = -0.016 \pm 0.017$
$A_{CP}(K^0_S K^\pm) = 0.07 \pm 0.06$
$A_{CP}(K^+K^-\pi^\pm) = 0.007 \pm 0.008$
$A_{CP}(K^\pm K^{*0}) = 0.005 \pm 0.017$
$A_{CP}(\phi\pi^\pm) = -0.001 \pm 0.015$
$A_{CP}(\pi^+\pi^-\pi^\pm) = -0.02 \pm 0.04$
$A_{CP}(K^0_S K^\pm\pi^+\pi^-) = -0.04 \pm 0.07$

### *T*-violation decay-rate asymmetry

$A_T(K^0_S K^\pm\pi^+\pi^-) = 0.02 \pm 0.07$

### $D^+ \to \overline{K}^*(892)^0\ell^+\nu_\ell$ form factors

$r_v = 1.62 \pm 0.08$ (S = 1.5)
$r_2 = 0.83 \pm 0.05$
$r_3 = 0.0 \pm 0.4$
$\Gamma_L/\Gamma_T = 1.13 \pm 0.08$
$\Gamma_+/\Gamma_- = 0.22 \pm 0.06$ (S = 1.6)

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

| $D^+$ DECAY MODES | Fraction ($\Gamma_i/\Gamma$) | Scale factor/ Confidence level | $p$ (MeV/$c$) |
|---|---|---|---|
| **Inclusive modes** | | | |
| $e^+$ anything | (17.2 $\pm$1.9 ) % | | – |
| $K^-$ anything | (27.5 $\pm$2.4 ) % | | – |
| $\overline{K}^0$ anything + $K^0$ anything | (61 $\pm$8 ) % | | – |
| $K^+$ anything | ( 5.5 $\pm$1.6 ) % | | – |
| $\overline{K}^*(892)^0$ anything | (23 $\pm$5 ) % | | – |
| $K^*(892)^0$ anything | < 6.6 % | CL=90% | – |
| $\eta$ anything | [*b*] < 13 % | CL=90% | – |
| $\phi$ anything | < 1.8 % | CL=90% | – |
| $\phi e^+$ anything | < 1.6 % | CL=90% | – |
| **Leptonic and semileptonic modes** | | | |
| $e^+\nu_e$ | < 2.4 $\times 10^{-5}$ | CL=90% | 935 |
| $\mu^+\nu_\mu$ | ( 4.4 $\pm$0.7 ) $\times 10^{-4}$ | | 932 |
| $\overline{K}^0 e^+\nu_e$ | ( 8.6 $\pm$0.5 ) % | | 868 |
| $\overline{K}^0 \mu^+\nu_\mu$ | ( 9.5 $\pm$0.8 ) % | | 865 |
| $K^-\pi^+ e^+\nu_e$ | ( 4.5 $^{+1.0}_{-0.8}$ ) % | S=1.1 | 863 |
| $\overline{K}^*(892)^0 e^+\nu_e$, $\overline{K}^*(892)^0 \to K^-\pi^+$ | ( 3.74$\pm$0.21) % | | 722 |
| $K^-\pi^+ e^+\nu_e$ nonresonant | < 7 $\times 10^{-3}$ | CL=90% | 863 |
| $K^-\pi^+\mu^+\nu_\mu$ | ( 4.0 $\pm$0.5 ) % | | 851 |
| $\overline{K}^*(892)^0\mu^+\nu_\mu$, $\overline{K}^*(892)^0 \to K^-\pi^+$ | ( 3.7 $\pm$0.3 ) % | | 717 |
| $K^-\pi^+\mu^+\nu_\mu$ nonresonant | ( 2.1 $\pm$0.6 ) $\times 10^{-3}$ | | 851 |
| $(\overline{K}^*(892)\pi)^0 e^+\nu_e$ | < 1.2 % | CL=90% | 712 |
| $(\overline{K}\pi\pi)^0 e^+\nu_e$ non-$\overline{K}^*(892)$ | < 9 $\times 10^{-3}$ | CL=90% | 846 |
| $K^-\pi^+\pi^0\mu^+\nu_\mu$ | < 1.7 $\times 10^{-3}$ | CL=90% | 825 |
| $\pi^0 e^+\nu_e$ | ( 4.4 $\pm$0.7 ) $\times 10^{-3}$ | | 930 |

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

| | | | |
|---|---|---|---|
| $\overline{K}^*(892)^0 e^+\nu_e$ | ( 5.61$\pm$0.31) % | S=1.1 | 722 |
| $\overline{K}^*(892)^0\mu^+\nu_\mu$ | ( 5.5 $\pm$0.5 ) % | S=1.1 | 717 |
| $\overline{K}_1(1270)^0\mu^+\nu_\mu$ | < 4 % | CL=95% | 493 |
| $\overline{K}_0^*(1430)^0\mu^+\nu_\mu$ | < 2.5 $\times 10^{-4}$ | | 388 |
| $\overline{K}_2^*(1430)^0\mu^+\nu_\mu$ | < 1.1 % | CL=95% | 380 |
| $\overline{K}^*(1680)^0\mu^+\nu_\mu$ | < 1.6 $\times 10^{-3}$ | | 105 |

| | | | | | |
|---|---|---|---|---|---|
| $\rho^0 e^+ \nu_e$ | | ( 2.2 $\pm$0.4 ) $\times 10^{-3}$ | | | 774 |
| $\rho^0 \mu^+ \nu_\mu$ | | ( 3.4 $\pm$0.8 ) $\times 10^{-3}$ | | | 770 |
| $\omega e^+ \nu_e$ | | ( 1.6 $^{+0.7}_{-0.6}$ ) $\times 10^{-3}$ | | | 771 |
| $\phi e^+ \nu_e$ | | $<$ 2.09 | % | CL=90% | 657 |
| $\phi \mu^+ \nu_\mu$ | | $<$ 3.72 | % | CL=90% | 651 |
| $\eta \ell^+ \nu_\ell$ | | $<$ 7 | $\times 10^{-3}$ | CL=90% | 854 |
| $\eta'(958) \mu^+ \nu_\mu$ | | $<$ 1.1 | % | CL=90% | 684 |

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

| | | | | | |
|---|---|---|---|---|---|
| $K^0_S \pi^+$ | | ( 1.47$\pm$0.06) % | | S=1.1 | 862 |
| $K^- \pi^+ \pi^+$ | [c] | ( 9.51$\pm$0.34) % | | S=1.1 | 845 |
| $\overline{K}^*(892)^0 \pi^+$, | [d] | ( 1.33$\pm$0.11) % | | | 714 |
| $\overline{K}^*(892)^0 \rightarrow K^- \pi^+$ | | | | | |
| $\overline{K}^*_0(1430)^0 \pi^+$, | [d] | ( 2.41$\pm$0.24) % | | | 382 |
| $\overline{K}^*_0(1430)^0 \rightarrow K^- \pi^+$ | | | | | |
| $\overline{K}^*(1680)^0 \pi^+$, | [d] | ( 4.0 $\pm$0.8 ) $\times 10^{-3}$ | | | 58 |
| $\overline{K}^*(1680)^0 \rightarrow K^- \pi^+$ | | | | | |
| $K^- \pi^+ \pi^+$ nonresonant | [d] | ( 9.0 $\pm$0.7 ) % | | | 845 |
| $K^0_S \pi^+ \pi^0$ | [c] | ( 7.0 $\pm$0.5 ) % | | S=1.2 | 845 |
| $K^0_S \rho^+$ | | ( 4.8 $\pm$1.1 ) % | | | 677 |
| $\overline{K}^*(892)^0 \pi^+$, | | ( 1.3 $\pm$0.6 ) % | | | 714 |
| $\overline{K}^*(892)^0 \rightarrow K^0_S \pi^0$ | | | | | |
| $K^0_S \pi^+ \pi^0$ nonresonant | | ( 9 $\pm$7 ) $\times 10^{-3}$ | | | 845 |
| $K^- \pi^+ \pi^+ \pi^0$ | [c] | ( 5.5 $\pm$2.7 ) % | | S=1.2 | 816 |
| $\overline{K}^*(892)^0 \rho^+$ total, | | ( 1.3 $\pm$0.8 ) % | | | 422 |
| $\overline{K}^*(892)^0 \rightarrow K^- \pi^+$ | | | | | |
| $\overline{K}_1(1400)^0 \pi^+$, | | ( 1.8 $\pm$0.7 ) % | | | 390 |
| $\overline{K}_1(1400)^0 \rightarrow K^- \pi^+ \pi^0$ | | | | | |
| $K^- \rho^+ \pi^+$ total | | ( 2.6 $\pm$1.6 ) % | | | 613 |
| $K^- \rho^+ \pi^+$ 3-body | | ( 9 $\pm$6 ) $\times 10^{-3}$ | | | 613 |
| $\overline{K}^*(892)^0 \pi^+ \pi^0$ total, | | ( 4.2 $\pm$0.6 ) % | | | 690 |
| $\overline{K}^*(892)^0 \rightarrow K^- \pi^+$ | | | | | |
| $\overline{K}^*(892)^0 \pi^+ \pi^0$ 3-body, | | ( 2.7 $\pm$0.8 ) % | | | 690 |
| $\overline{K}^*(892)^0 \rightarrow K^- \pi^+$ | | | | | |
| $K^*(892)^- \pi^+ \pi^+$ 3-body, | | ( 6 $\pm$3 ) $\times 10^{-3}$ | | | 688 |
| $K^*(892)^- \rightarrow K^- \pi^0$ | | | | | |
| $K^- \pi^+ \pi^+ \pi^0$ nonresonant | [e] | ( 1.0 $\pm$0.7 ) % | | | 816 |
| $K^0_S \pi^+ \pi^+ \pi^-$ | [c] | ( 3.11$\pm$0.21) % | | S=1.1 | 814 |
| $K^0_S a_1(1260)^+$, | | ( 1.8 $\pm$0.3 ) % | | | 328 |
| $a_1(1260)^+ \rightarrow \pi^+ \pi^+ \pi^-$ | | | | | |
| $\overline{K}_1(1400)^0 \pi^+$, | | ( 1.8 $\pm$0.7 ) % | | | 390 |
| $\overline{K}_1(1400)^0 \rightarrow K^0_S \pi^+ \pi^-$ | | | | | |

| | | | | |
|---|---|---|---|---|
| $K^*(892)^-\pi^+\pi^+$ 3-body, $K^*(892)^- \to K^0_S\pi^-$ | | ( 1.3 ±0.6 ) % | | 688 |
| $K^0_S\rho^0\pi^+$ total | | ( 1.86±0.34) % | CL=90% | 610 |
| $K^0_S\rho^0\pi^+$ 3-body | | ( 2.2 ±2.2 ) × $10^{-3}$ | | 610 |
| $K^0_S\pi^+\pi^+\pi^-$ nonresonant | | ( 3.7 ±1.9 ) × $10^{-3}$ | | 814 |
| $K^-3\pi^+\pi^-$ | [c] | ( 5.8 ±0.6 ) × $10^{-3}$ | S=1.1 | 772 |
| $\overline{K}^*(892)^0\pi^+\pi^+\pi^-$, $\overline{K}^*(892)^0 \to K^-\pi^+$ | | ( 1.2 ±0.4 ) × $10^{-3}$ | | 645 |
| $\overline{K}^*(892)^0\rho^0\pi^+$, $\overline{K}^*(892)^0 \to K^-\pi^+$ | | ( 2.3 ±0.4 ) × $10^{-3}$ | | 239 |
| $K^-\rho^0\pi^+\pi^+$ | | ( 1.75±0.29) × $10^{-3}$ | | 524 |
| $K^-3\pi^+\pi^-$ nonresonant | | ( 4.1 ±3.0 ) × $10^{-4}$ | | 772 |
| $K^+2K^0_S$ | | ( 4.7 ±2.1 ) × $10^{-3}$ | | 545 |
| $K^+K^-K^0_S\pi^+$ | | ( 2.4 ±0.6 ) × $10^{-4}$ | | 435 |

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

| | | | | |
|---|---|---|---|---|
| $K^0_S a_1(1260)^+$ | | ( 3.6 ±0.6 ) % | | 328 |
| $K^0_S a_2(1320)^+$ | | < 1.5 × $10^{-3}$ | CL=90% | 199 |
| $\overline{K}^*(892)^0\rho^+$ total | [e] | ( 1.8 ±1.4 ) % | | 422 |
| $\overline{K}^*(892)^0\rho^+$ $S$-wave | [e] | ( 1.4 ±1.5 ) % | | 422 |
| $\overline{K}^*(892)^0\rho^+$ $P$-wave | | < 1 × $10^{-3}$ | CL=90% | 422 |
| $\overline{K}^*(892)^0\rho^+$ $D$-wave | | ( 8 ±7 ) × $10^{-3}$ | | 422 |
| $\overline{K}^*(892)^0\rho^+$ $D$-wave longitudinal | | < 7 × $10^{-3}$ | CL=90% | 422 |
| $\overline{K}_1(1270)^0\pi^+$ | | < 7 × $10^{-3}$ | CL=90% | 487 |
| $\overline{K}_1(1400)^0\pi^+$ | | ( 4.3 ±1.5 ) % | S=1.2 | 390 |
| $\overline{K}^*(892)^0\pi^+\pi^0$ total | | ( 5.8 ±2.9 ) % | | 690 |
| $\overline{K}^*(892)^0\pi^+\pi^0$ 3-body | [e] | ( 3.6 ±2.1 ) % | | 690 |
| $K^*(892)^-\pi^+\pi^+$ total | | — | | 688 |
| $K^*(892)^-\pi^+\pi^+$ 3-body | | ( 1.8 $^{+1.1}_{-0.9}$ ) % | S=1.2 | 688 |
| $\overline{K}^*(892)^0 a_1(1260)^+$ | | ( 9.4 ±1.9 ) × $10^{-3}$ | | † |

## Pionic modes

| | | | | |
|---|---|---|---|---|
| $\pi^+\pi^0$ | | ( 1.28±0.09) × $10^{-3}$ | | 925 |
| $\pi^+\pi^+\pi^-$ | | ( 3.31±0.21) × $10^{-3}$ | | 908 |
| $\rho^0\pi^+$ | | ( 1.07±0.11) × $10^{-3}$ | | 766 |
| $\pi^+(\pi^+\pi^-)_{S-\text{wave}}$ | | ( 1.86±0.18) × $10^{-3}$ | | 908 |
| $\sigma\pi^+$, $\sigma \to \pi^+\pi^-$ | | ( 1.53±0.32) × $10^{-3}$ | | – |
| $f_0(980)\pi^+$, $f_0(980) \to \pi^+\pi^-$ | | ( 2.1 ±0.5 ) × $10^{-4}$ | | 669 |
| $f_0(1370)\pi^+$, $f_0(1370) \to \pi^+\pi^-$ | | ( 8 ±6 ) × $10^{-5}$ | | – |

| | | | | |
|---|---|---|---|---|
| $f_2(1270)\pi^+$, $f_2(1270) \to \pi^+\pi^-$ | | $(\ 4.8\ \pm 1.3\ ) \times 10^{-4}$ | | 485 |
| $\pi^+ 2\pi^0$ | | $(\ 4.8\ \pm 0.4\ ) \times 10^{-3}$ | | 910 |
| $\pi^+\pi^+\pi^-\pi^0$ | | $(\ 1.18 \pm 0.09)$ % | | 883 |
| $\eta\pi^+$, $\eta \to \pi^+\pi^-\pi^0$ | | $(\ 7.9\ \pm 0.7\ ) \times 10^{-4}$ | | 848 |
| $\omega\pi^+$, $\omega \to \pi^+\pi^-\pi^0$ | | $< 3 \times 10^{-4}$ | CL=90% | 763 |
| $3\pi^+ 2\pi^-$ | | $(\ 1.68 \pm 0.17) \times 10^{-3}$ | S=1.1 | 845 |

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

| | | | | |
|---|---|---|---|---|
| $\eta\pi^+$ | | $(\ 3.50 \pm 0.32) \times 10^{-3}$ | | 848 |
| $\omega\pi^+$ | | $< 3.4 \times 10^{-4}$ | CL=90% | 763 |
| $\eta\rho^+$ | | $< 7 \times 10^{-3}$ | CL=90% | 655 |
| $\eta'(958)\pi^+$ | | $(\ 5.3\ \pm 1.1\ ) \times 10^{-3}$ | | 680 |
| $\eta'(958)\rho^+$ | | $< 6 \times 10^{-3}$ | CL=90% | 348 |

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

| | | | | |
|---|---|---|---|---|
| $K^+ K^0_S$ | | $(\ 2.96 \pm 0.19) \times 10^{-3}$ | | 792 |
| $K^+ K^-\pi^+$ | [c] | $(\ 1.00 \pm 0.04)$ % | S=1.2 | 744 |
| $\phi\pi^+$, $\phi \to K^+ K^-$ | | $(\ 3.2\ \pm 0.4\ ) \times 10^{-3}$ | | 647 |
| $K^+ \overline{K}^*(892)^0$, $\overline{K}^*(892)^0 \to K^-\pi^+$ | | $(\ 3.02 \pm 0.35) \times 10^{-3}$ | | 613 |
| $K^+ \overline{K}^*_0(1430)^0$, $\overline{K}^*_0(1430)^0 \to K^-\pi^+$ | | $(\ 3.7\ \pm 0.4\ ) \times 10^{-3}$ | | – |
| $K^0_S K^0_S \pi^+$ | | — | | 741 |
| $K^*(892)^+ K^0_S$, $K^*(892)^+ \to K^0_S\pi^+$ | | $(\ 5.3\ \pm 2.3\ ) \times 10^{-3}$ | | 611 |
| $K^+ K^-\pi^+\pi^0$ | | — | | 682 |
| $\phi\pi^+\pi^0$, $\phi \to K^+ K^-$ | | $(\ 1.1\ \pm 0.5\ )$ % | | 619 |
| $\phi\rho^+$, $\phi \to K^+ K^-$ | | $< 7 \times 10^{-3}$ | CL=90% | 258 |
| $K^+ K^-\pi^+\pi^0$ non-$\phi$ | | $(\ 1.5\ ^{+0.7}_{-0.6}\ )$ % | | 682 |
| $K^+ K^0_S \pi^+\pi^-$ | | $(\ 1.75 \pm 0.21) \times 10^{-3}$ | | 678 |
| $K^0_S K^-\pi^+\pi^+$ | | $(\ 2.39 \pm 0.23) \times 10^{-3}$ | | 678 |
| $K^*(892)^+ \overline{K}^*(892)^0$, $K^{*+} \to K^0_S\pi^+$, $\overline{K}^{*0} \to K^-\pi^+$ | | $(\ 5.8\ \pm 2.4\ ) \times 10^{-3}$ | | 280 |
| $K^0_S K^-\pi^+\pi^+$ (non-$K^{*+}\overline{K}^{*0}$) | | $< 4 \times 10^{-3}$ | CL=90% | 678 |
| $K^+ K^-\pi^+\pi^+\pi^-$ | | $(\ 2.3\ \pm 1.2\ ) \times 10^{-4}$ | | 600 |

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

| | | | | |
|---|---|---|---|---|
| $\phi\pi^+$ | | $(\ 6.5\ \pm 0.7\ ) \times 10^{-3}$ | | 647 |
| $\phi\pi^+\pi^0$ | | $(\ 2.3\ \pm 1.0\ )$ % | | 619 |

| | | | | | |
|---|---|---|---|---|---|
| $\phi\rho^+$ | $<$ 1.5 | % | CL=90% | 259 |
| $K^*(892)^+ K_S^0$ | ( 1.6 $\pm$0.7 ) % | | | 611 |
| $K^*(892)^+ \overline{K}^*(892)^0$ | ( 2.6 $\pm$1.1 ) % | | | 280 |

**Doubly Cabibbo-suppressed modes**

| | | | | |
|---|---|---|---|---|
| $K^+\pi^0$ | $<$ 4.2 | $\times 10^{-4}$ | CL=90% | 864 |
| $K^+\pi^+\pi^-$ | ( 6.4 $\pm$0.8 ) $\times 10^{-4}$ | | | 845 |
| $K^+\rho^0$ | ( 2.5 $\pm$0.7 ) $\times 10^{-4}$ | | | 678 |
| $K^*(892)^0\pi^+$, $K^*(892)^0 \to K^+\pi^-$ | ( 3.0 $\pm$0.6 ) $\times 10^{-4}$ | | | 714 |
| $K^+ f_0(980)$, $f_0(980) \to \pi^+\pi^-$ | ( 5.7 $\pm$3.5 ) $\times 10^{-5}$ | | | – |
| $K_2^*(1430)^0\pi^+$, $K_2^*(1430)^0 \to K^+\pi^-$ | ( 5.2 $\pm$3.5 ) $\times 10^{-5}$ | | | – |
| $K^+K^+K^-$ | ( 9.0 $\pm$2.1 ) $\times 10^{-5}$ | | | 550 |

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

| | | | | | | |
|---|---|---|---|---|---|---|
| $\pi^+ e^+ e^-$ | *C1* | $<$ 7.4 | $\times 10^{-6}$ | CL=90% | 929 |
| $\pi^+\phi$, $\phi \to e^+e^-$ | [f] | ( 2.7 $^{+3.6}_{-1.8}$ ) $\times 10^{-6}$ | | | – |
| $\pi^+\mu^+\mu^-$ | *C1* | $<$ 8.8 | $\times 10^{-6}$ | CL=90% | 917 |
| $\rho^+\mu^+\mu^-$ | *C1* | $<$ 5.6 | $\times 10^{-4}$ | CL=90% | 757 |
| $K^+e^+e^-$ | [g] | $<$ 6.2 | $\times 10^{-6}$ | CL=90% | 869 |
| $K^+\mu^+\mu^-$ | [g] | $<$ 9.2 | $\times 10^{-6}$ | CL=90% | 856 |
| $\pi^+ e^\pm \mu^\mp$ | *LF* | [h] $<$ 3.4 | $\times 10^{-5}$ | CL=90% | 926 |
| $K^+ e^\pm \mu^\mp$ | *LF* | [h] $<$ 6.8 | $\times 10^{-5}$ | CL=90% | 866 |
| $\pi^- e^+ e^+$ | *L* | $<$ 3.6 | $\times 10^{-6}$ | CL=90% | 929 |
| $\pi^-\mu^+\mu^+$ | *L* | $<$ 4.8 | $\times 10^{-6}$ | CL=90% | 917 |
| $\pi^- e^+\mu^+$ | *L* | $<$ 5.0 | $\times 10^{-5}$ | CL=90% | 926 |
| $\rho^-\mu^+\mu^+$ | *L* | $<$ 5.6 | $\times 10^{-4}$ | CL=90% | 757 |
| $K^- e^+ e^+$ | *L* | $<$ 4.5 | $\times 10^{-6}$ | CL=90% | 869 |
| $K^-\mu^+\mu^+$ | *L* | $<$ 1.3 | $\times 10^{-5}$ | CL=90% | 856 |
| $K^- e^+\mu^+$ | *L* | $<$ 1.3 | $\times 10^{-4}$ | CL=90% | 866 |
| $K^*(892)^-\mu^+\mu^+$ | *L* | $<$ 8.5 | $\times 10^{-4}$ | CL=90% | 703 |

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## $D^0$

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

Mass $m = 1864.5 \pm 0.4$ MeV (S = 1.1)
$m_{D^\pm} - m_{D^0} = 4.78 \pm 0.10$ MeV (S = 1.1)
Mean life $\tau = (410.1 \pm 1.5) \times 10^{-15}$ s
$c\tau = 122.9$ $\mu$m
$\left|m_{D_1^0} - m_{D_2^0}\right| < 7 \times 10^{10}\ \hbar\ \mathrm{s}^{-1}$, CL = 95% [i]
$(\Gamma_{D_1^0} - \Gamma_{D_2^0})/\Gamma = 2y = (1.4 \pm 1.0) \times 10^{-2}$

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

$\Gamma\big(K^+\pi^-$ (via $\overline{D}^0$)$\big)/\Gamma\big(K^-\pi^+\big) < 4.0\times10^{-4}$, CL = 95%

$\Gamma\big(K^0_S\pi^+\pi^-$ (in $D^0\to\overline{D}^0$)$\big)/\Gamma\big(K^0_S\pi^+\pi^-\big)$ $\Gamma_0/\Gamma_0$ $< 0.0063$, CL = 95%

### *CP*-violation decay-rate asymmetries

$A_{CP}(K^+K^-) = 0.014 \pm 0.010$

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

$A_{CP}(\pi^+\pi^-) = 0.013 \pm 0.012$

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

$A_{CP}(\pi^+\pi^-\pi^0) = 0.01^{+0.10}_{-0.09}$

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

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

$A_{CP}(K^\pm\pi^\mp) = 0.05 \pm 0.04$

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

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

$A_{CP}(K^0_S\pi^+\pi^-) = -0.009^{+0.026}_{-0.061}$

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

$A_{CP}(K^+K^-\pi^+\pi^-) = -0.08 \pm 0.07$

### *T*-violation decay-rate asymmetry

$A_T(K^+K^-\pi^+\pi^-) = 0.01 \pm 0.07$

### *CPT*-violation decay-rate asymmetry

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

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

| **$D^0$ DECAY MODES** | | Fraction ($\Gamma_i/\Gamma$) | Scale factor/ Confidence level | $p$ (MeV/$c$) |
|---|---|---|---|---|
| | | **Topological modes** | | |
| 0-prongs | [$j$] | (19 ± 6 ) % | | – |
| 2-prongs | | (67 ± 6 ) % | | – |
| 4-prongs | [$k$] | (13.8 ± 0.5 ) % | | – |
| 6-prongs | | ( 1.2 $^{+\ 1.3}_{-\ 0.7}$ ) $\times 10^{-3}$ | | – |

## Inclusive modes

| | | | | |
|---|---|---|---|---|
| $e^+$ anything | [l] | ( 6.71 ± 0.29 ) % | | – |
| $\mu^+$ anything | | ( 6.5 ± 0.7 ) % | | – |
| $K^-$ anything | | (53 ± 4 ) % | S=1.3 | – |
| $\overline{K}^0$ anything + $K^0$ anything | | (42 ± 5 ) % | | – |
| $K^+$ anything | | ( 3.4 $^{+\ 0.6}_{-\ 0.4}$ ) % | | – |
| $\overline{K}^*(892)^0$ anything | | ( 9 ± 4 ) % | | – |
| $K^*(892)^0$ anything | | ( 2.8 ± 1.3 ) % | | – |
| $\eta$ anything | [b] | < 13 % | CL=90% | – |
| $\phi$ anything | | ( 1.7 ± 0.8 ) % | | – |

## Semileptonic modes

| | | | | |
|---|---|---|---|---|
| $K^- e^+ \nu_e$ | | ( 3.51 ± 0.11 ) % | | 867 |
| $K^- \mu^+ \nu_\mu$ | | ( 3.19 ± 0.16 ) % | | 863 |
| $K^*(892)^- e^+ \nu_e$ | | ( 2.17 ± 0.16 ) % | | 719 |
| $K^*(892)^- \mu^+ \nu_\mu$ | | ( 1.95 ± 0.25 ) % | | 714 |
| $K^- \pi^+ \pi^- \mu^+ \nu_\mu$ | | < 1.2 $\times 10^{-3}$ | CL=90% | 821 |
| $(\overline{K}^*(892)\pi)^- \mu^+ \nu_\mu$ | | < 1.4 $\times 10^{-3}$ | CL=90% | 692 |
| $\pi^- e^+ \nu_e$ | | ( 2.81 ± 0.19 ) $\times 10^{-3}$ | | 927 |
| $\pi^- \mu^+ \nu_\mu$ | | ( 2.4 ± 0.4 ) $\times 10^{-3}$ | | 924 |
| $\rho^- e^+ \nu_e$ | | ( 1.9 ± 0.4 ) $\times 10^{-3}$ | | 771 |

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

| | | | | |
|---|---|---|---|---|
| $K^- \pi^+$ | | ( 3.80 ± 0.07 ) % | S=1.1 | 861 |
| $K^0_S \pi^0$ | | ( 1.14 ± 0.12 ) % | | 860 |
| $K^0_S \pi^+ \pi^-$ | [c] | ( 2.90 ± 0.19 ) % | | 842 |
| $K^0_S \rho^0$ | | ( 7.5 $^{+\ 0.6}_{-\ 0.8}$ ) $\times 10^{-3}$ | | 674 |
| $K^0_S \omega$, $\omega \to \pi^+ \pi^-$ | | ( 2.1 ± 0.6 ) $\times 10^{-4}$ | | 670 |
| $K^0_S f_0(980)$, $f_0(980) \to \pi^+ \pi^-$ | | ( 1.36 $^{+\ 0.30}_{-\ 0.22}$ ) $\times 10^{-3}$ | | 549 |
| $K^0_S f_2(1270)$, $f_2(1270) \to \pi^+ \pi^-$ | | ( 1.3 $^{+\ 1.1}_{-\ 0.7}$ ) $\times 10^{-4}$ | | 262 |
| $K^0_S f_0(1370)$, $f_0(1370) \to \pi^+ \pi^-$ | | ( 2.5 ± 0.6 ) $\times 10^{-3}$ | | † |
| $K^*(892)^- \pi^+$, $K^*(892)^- \to K^0_S \pi^-$ | | ( 1.91 ± 0.14 ) % | | 711 |
| $K^*(892)^+ \pi^-$, $K^*(892)^+ \to K^0_S \pi^+$ | [m] | (10 $^{+12}_{-\ 4}$ ) $\times 10^{-5}$ | | 711 |
| $K^*_0(1430)^- \pi^+$, $K^*_0(1430)^- \to K^0_S \pi^-$ | | ( 2.8 $^{+\ 0.6}_{-\ 0.4}$ ) $\times 10^{-3}$ | | 378 |

| | | | | | |
|---|---|---|---|---|---|
| $K_2^*(1430)^-\pi^+$, | | ( 3.2 $^{+\ 2.1}_{-\ 1.1}$ ) $\times 10^{-4}$ | | | 367 |
| $K_2^*(1430)^- \to K_S^0\pi^-$ | | | | | |
| $K^*(1680)^-\pi^+$, | | ( 6 $\pm$ 5 ) $\times 10^{-4}$ | | | 46 |
| $K^*(1680)^- \to K_S^0\pi^-$ | | | | | |
| $K_S^0\pi^+\pi^-$ nonresonant | | ( 2.6 $^{+\ 5.9}_{-\ 1.6}$ ) $\times 10^{-4}$ | | | 842 |
| $K^-\pi^+\pi^0$ | [c] | (14.1 $\pm$ 0.5 ) % | | S=1.2 | 844 |
| $K^-\rho^+$ | | (11.0 $\pm$ 0.7 ) % | | | 675 |
| $K^-\rho(1700)^+$, | | ( 8.0 $\pm$ 1.7 ) $\times 10^{-3}$ | | | † |
| $\rho(1700)^+ \to \pi^+\pi^0$ | | | | | |
| $K^*(892)^-\pi^+$, | | ( 2.25 $^{+\ 0.36}_{-\ 0.20}$ ) % | | | 711 |
| $K^*(892)^- \to K^-\pi^0$ | | | | | |
| $\overline{K}^*(892)^0\pi^0$, | | ( 1.91 $\pm$ 0.24 ) % | | | 711 |
| $\overline{K}^*(892)^0 \to K^-\pi^+$ | | | | | |
| $K_0^*(1430)^-\pi^+$, | | ( 4.6 $\pm$ 2.2 ) $\times 10^{-3}$ | | | 378 |
| $K_0^*(1430)^- \to K^-\pi^0$ | | | | | |
| $\overline{K}_0^*(1430)^0\pi^0$, | | ( 5.8 $^{+\ 4.6}_{-\ 1.5}$ ) $\times 10^{-3}$ | | | 379 |
| $\overline{K}_0^*(1430)^0 \to K^-\pi^+$ | | | | | |
| $K^*(1680)^-\pi^+$, | | ( 1.8 $\pm$ 0.7 ) $\times 10^{-3}$ | | | 46 |
| $K^*(1680)^- \to K^-\pi^0$ | | | | | |
| $K^-\pi^+\pi^0$ nonresonant | | ( 1.13 $^{+\ 0.54}_{-\ 0.20}$ ) % | | | 844 |
| $K_S^0\pi^0\pi^0$ | | — | | | 843 |
| $\overline{K}^*(892)^0\pi^0$, | | ( 6.3 $^{+\ 1.8}_{-\ 1.5}$ ) $\times 10^{-3}$ | | | 711 |
| $\overline{K}^*(892)^0 \to K_S^0\pi^0$ | | | | | |
| $K_S^0\pi^0\pi^0$ nonresonant | | ( 4.2 $\pm$ 1.1 ) $\times 10^{-3}$ | | | 843 |
| $K^-\pi^+\pi^+\pi^-$ | [c] | ( 7.72 $\pm$ 0.28 ) % | | S=1.3 | 812 |
| $K^-\pi^+\rho^0$ total | | ( 6.4 $\pm$ 0.4 ) % | | | 609 |
| $K^-\pi^+\rho^0$ 3-body | | ( 4.9 $\pm$ 2.2 ) $\times 10^{-3}$ | | | 609 |
| $\overline{K}^*(892)^0\rho^0$, | | ( 1.00 $\pm$ 0.22 ) % | | | 416 |
| $\overline{K}^*(892)^0 \to K^-\pi^+$ | | | | | |
| $K^-a_1(1260)^+$, | | ( 3.6 $\pm$ 0.6 ) % | | | 327 |
| $a_1(1260)^+ \to \pi^+\pi^+\pi^-$ | | | | | |
| $\overline{K}^*(892)^0\pi^+\pi^-$ total, | | ( 1.5 $\pm$ 0.4 ) % | | | 685 |
| $\overline{K}^*(892)^0 \to K^-\pi^+$ | | | | | |
| $\overline{K}^*(892)^0\pi^+\pi^-$ 3-body, | | ( 9.7 $\pm$ 2.1 ) $\times 10^{-3}$ | | | 685 |
| $\overline{K}^*(892)^0 \to K^-\pi^+$ | | | | | |
| $K_1(1270)^-\pi^+$, | [e] | ( 2.9 $\pm$ 0.3 ) $\times 10^{-3}$ | | | 484 |
| $K_1(1270)^- \to K^-\pi^+\pi^-$ | | | | | |
| $K^-\pi^+\pi^+\pi^-$ nonresonant | | ( 1.80 $\pm$ 0.25 ) % | | | 812 |
| $K_S^0\pi^+\pi^-\pi^0$ | [c] | ( 5.3 $\pm$ 0.6 ) % | | | 812 |
| $K_S^0\eta$, $\eta \to \pi^+\pi^-\pi^0$ | | ( 8.6 $\pm$ 1.4 ) $\times 10^{-4}$ | | | 772 |
| $K_S^0\omega$, $\omega \to \pi^+\pi^-\pi^0$ | | ( 9.8 $\pm$ 1.8 ) $\times 10^{-3}$ | | | 670 |

| | | | | |
|---|---|---|---|---|
| $K^*(892)^-\rho^+$, | | ( 2.1 ± 0.8 ) % | | 416 |
| $K^*(892)^- \to K^0_S\pi^-$ | | | | |
| $K_1(1270)^-\pi^+$, | [e] | ( 2.2 ± 0.6 ) $\times 10^{-3}$ | | 484 |
| $K_1(1270)^- \to K^0_S\pi^-\pi^0$ | | | | |
| $\overline{K}^*(892)^0\pi^+\pi^-$ 3-body, | | ( 2.4 ± 0.5 ) $\times 10^{-3}$ | | 685 |
| $\overline{K}^*(892)^0 \to K^0_S\pi^0$ | | | | |
| $K^0_S\pi^+\pi^-\pi^0$ nonresonant | | ( 1.1 ± 1.1 ) % | | 812 |
| $K^-\pi^+\pi^+\pi^-\pi^0$ | | ( 4.1 ± 0.4 ) % | | 771 |
| $\overline{K}^*(892)^0\pi^+\pi^-\pi^0$, | | ( 1.2 ± 0.6 ) % | | 643 |
| $\overline{K}^*(892)^0 \to K^-\pi^+$ | | | | |
| $K^-\pi^+\omega$, $\omega \to \pi^+\pi^-\pi^0$ | | ( 2.7 ± 0.5 ) % | | 605 |
| $\overline{K}^*(892)^0\omega$, | | ( 6.5 ± 2.4 ) $\times 10^{-3}$ | | 410 |
| $\overline{K}^*(892)^0 \to K^-\pi^+$, | | | | |
| $\omega \to \pi^+\pi^-\pi^0$ | | | | |
| $K^0_S\eta\pi^0$ | | ( 5.2 ± 1.2 ) $\times 10^{-3}$ | | 721 |
| $K^0_S a_0(980)$, $a_0(980) \to \eta\pi^0$ | | ( 6.2 ± 2.0 ) $\times 10^{-3}$ | | – |
| $\overline{K}^*(892)^0\eta$, $\overline{K}^*(892)^0 \to$ | | ( 1.5 ± 0.5 ) $\times 10^{-3}$ | | – |
| $K^0_S\pi^0$ | | | | |
| $K^0_S 2\pi^+ 2\pi^-$ | | ( 2.75 ± 0.31 ) $\times 10^{-3}$ | | 768 |
| $K^0_S\rho^0\pi^+\pi^-$, no $K^*(892)^-$ | | ( 1.1 ± 0.7 ) $\times 10^{-3}$ | | – |
| $K^*(892)^-\pi^+\pi^+\pi^-$, | | ( 5 ± 8 ) $\times 10^{-4}$ | | 642 |
| $K^*(892)^- \to K^0_S\pi^-$, | | | | |
| no $\rho^0$ | | | | |
| $K^*(892)^-\rho^0\pi^+$, | | ( 1.7 ± 0.7 ) $\times 10^{-3}$ | | 230 |
| $K^*(892)^- \to K^0_S\pi^-$ | | | | |
| $K^0_S 2\pi^+ 2\pi^-$ nonresonant | | < 1.3 $\times 10^{-3}$ | CL=90% | 768 |
| $K^- 3\pi^+ 2\pi^-$ | | ( 2.1 ± 0.5 ) $\times 10^{-4}$ | | 713 |

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

| | | | | |
|---|---|---|---|---|
| $K^0_S\eta$ | | ( 3.8 ± 0.6 ) $\times 10^{-3}$ | | 772 |
| $K^0_S\omega$ | | ( 1.10 ± 0.20 ) % | | 670 |
| $K^0_S\eta'(958)$ | | ( 9.1 ± 1.4 ) $\times 10^{-3}$ | | 565 |
| $K^- a_1(1260)^+$ | | ( 7.5 ± 1.1 ) % | | 327 |
| $\overline{K}^0 a_1(1260)^0$ | | < 1.9 % | CL=90% | 322 |
| $K^- a_2(1320)^+$ | | < 2 $\times 10^{-3}$ | CL=90% | 197 |
| $\overline{K}^*(892)^0\pi^+\pi^-$ total | | ( 2.3 ± 0.5 ) % | | 685 |
| $\overline{K}^*(892)^0\pi^+\pi^-$ 3-body | | ( 1.46 ± 0.32 ) % | | 685 |
| $\overline{K}^*(892)^0\rho^0$ | | ( 1.50 ± 0.33 ) % | | 417 |
| $\overline{K}^*(892)^0\rho^0$ transverse | | ( 1.6 ± 0.5 ) % | | 417 |
| $\overline{K}^*(892)^0\rho^0$ $S$-wave | | ( 2.9 ± 0.6 ) % | | 417 |

| | | | | | |
|---|---|---|---|---|---|
| $\overline{K}^*(892)^0\rho^0$ $S$-wave long. | $<$ 3 | $\times 10^{-3}$ | CL=90% | | 417 |
| $\overline{K}^*(892)^0\rho^0$ $P$-wave | $<$ 3 | $\times 10^{-3}$ | CL=90% | | 417 |
| $\overline{K}^*(892)^0\rho^0$ $D$-wave | ( 2.0 ± 0.6 ) | % | | | 417 |
| $K^*(892)^-\rho^+$ | ( 6.4 ± 2.5 ) | % | | | 417 |
| $K^*(892)^-\rho^+$ longitudinal | ( 3.1 ± 1.2 ) | % | | | 417 |
| $K^*(892)^-\rho^+$ transverse | ( 3.4 ± 2.0 ) | % | | | 417 |
| $K^*(892)^-\rho^+$ $P$-wave | $<$ 1.5 | % | CL=90% | | 417 |
| $K_1(1270)^-\pi^+$ | [e] ( 1.12 ± 0.31 ) | % | | | 484 |
| $K_1(1400)^-\pi^+$ | $<$ 1.2 | % | CL=90% | | 386 |
| $\overline{K}_1(1400)^0\pi^0$ | $<$ 3.7 | % | CL=90% | | 387 |
| $\overline{K}^*(892)^0\pi^+\pi^-\pi^0$ | ( 1.8 ± 0.9 ) | % | | | 643 |
| $K^-\pi^+\omega$ | ( 3.0 ± 0.6 ) | % | | | 605 |
| $\overline{K}^*(892)^0\omega$ | ( 1.1 ± 0.4 ) | % | | | 410 |
| $K^-\pi^+\eta'(958)$ | ( 7.2 ± 1.8 ) | $\times 10^{-3}$ | | | 479 |
| $\overline{K}^*(892)^0\eta'(958)$ | $<$ 1.1 | $\times 10^{-3}$ | CL=90% | | 118 |

## Hadronic modes with three $K$'s

| | | | | | |
|---|---|---|---|---|---|
| $K^0_S K^+ K^-$ | ( 4.58 ± 0.34 ) | $\times 10^{-3}$ | | | 544 |
| $K^0_S a_0(980)^0$, $a^0_0 \to K^+K^-$ | ( 3.0 ± 0.4 ) | $\times 10^{-3}$ | | | – |
| $K^- a_0(980)^+$, $a^+_0 \to K^+K^0_S$ | ( 6.1 ± 1.8 ) | $\times 10^{-4}$ | | | – |
| $K^+ a_0(980)^-$, $a^-_0 \to K^-K^0_S$ | $<$ 1.1 | $\times 10^{-4}$ | CL=95% | | – |
| $K^0_S f_0(980)$, $f_0 \to K^+K^-$ | $<$ 1.0 | $\times 10^{-4}$ | CL=95% | | – |
| $K^0_S \phi$, $\phi \to K^+K^-$ | ( 2.10 ± 0.16 ) | $\times 10^{-3}$ | | | 520 |
| $K^0_S f_0(1400)$, $f_0 \to K^+K^-$ | ( 1.7 ± 1.1 ) | $\times 10^{-4}$ | | | – |
| $3K^0_S$ | ( 9.3 ± 1.3 ) | $\times 10^{-4}$ | | | 538 |
| $K^+K^-K^-\pi^+$ | ( 2.11 ± 0.31 ) | $\times 10^{-4}$ | | | 434 |
| $K^+K^-\overline{K}^*(892)^0$, $\overline{K}^*(892)^0 \to K^-\pi^+$ | ( 4.2 ± 1.7 ) | $\times 10^{-5}$ | | | † |
| $K^-\pi^+\phi$, $\phi \to K^+K^-$ | ( 3.8 ± 1.6 ) | $\times 10^{-5}$ | | | 422 |
| $\phi\overline{K}^*(892)^0$, $\phi \to K^+K^-$, $\overline{K}^*(892)^0 \to K^-\pi^+$ | ( 1.01 ± 0.20 ) | $\times 10^{-4}$ | | | † |
| $K^+K^-K^-\pi^+$ nonresonant | ( 3.2 ± 1.4 ) | $\times 10^{-5}$ | | | 434 |
| $K^0_S K^0_S K^\pm\pi^\mp$ | ( 6.1 ± 1.3 ) | $\times 10^{-4}$ | | | 427 |

## Pionic modes

| | | | | | |
|---|---|---|---|---|---|
| $\pi^+\pi^-$ | ( 1.364± 0.032) | $\times 10^{-3}$ | | | 922 |
| $\pi^0\pi^0$ | ( 7.9 ± 0.8 ) | $\times 10^{-4}$ | | | 922 |
| $\pi^+\pi^-\pi^0$ | ( 1.31 ± 0.06 ) | % | | | 907 |
| $\rho^+\pi^-$ | (10.0 ± 0.6 ) | $\times 10^{-3}$ | | | 764 |
| $\rho^0\pi^0$ | ( 3.2 ± 0.4 ) | $\times 10^{-3}$ | | | 764 |
| $\rho^-\pi^+$ | ( 4.5 ± 0.4 ) | $\times 10^{-3}$ | | | 764 |
| $f_0(980)\pi^0$, $f_0(980) \to \pi^+\pi^-$ | $<$ 3.4 | $\times 10^{-6}$ | CL=95% | | – |

| | | | | |
|---|---|---|---|---|
| $f_0(600)\pi^0$, $f_0(600) \to \pi^+\pi^-$ | | $< 2.7$ | $\times 10^{-5}$ CL=95% | – |
| $(\pi^+\pi^-)_{S-\text{wave}}\,\pi^0$ | | $< 2.5$ | $\times 10^{-4}$ CL=95% | 907 |
| $3\pi^0$ | | $< 3.5$ | $\times 10^{-4}$ CL=90% | 908 |
| $2\pi^+2\pi^-$ | | $(7.31 \pm 0.27) \times 10^{-3}$ | | 879 |
| $\pi^+\pi^-2\pi^0$ | | $(9.8 \pm 0.9) \times 10^{-3}$ | | 882 |
| $\eta\pi^0$ | [n] | $(5.6 \pm 1.4) \times 10^{-4}$ | | 846 |
| $\omega\pi^0$ | [n] | $< 2.6$ | $\times 10^{-4}$ CL=90% | 761 |
| $2\pi^+2\pi^-\pi^0$ | | $(4.1 \pm 0.5) \times 10^{-3}$ | | 844 |
| $\eta\pi^+\pi^-$ | [n] | $< 1.9$ | $\times 10^{-3}$ CL=90% | 827 |
| $\omega\pi^+\pi^-$ | [n] | $(1.6 \pm 0.5) \times 10^{-3}$ | | 738 |
| $3\pi^+3\pi^-$ | | $(4.0 \pm 1.1) \times 10^{-4}$ | | 795 |

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

| | | | | |
|---|---|---|---|---|
| $K^+K^-$ | | $(3.84 \pm 0.10) \times 10^{-3}$ | | 791 |
| $2K^0_S$ | | $(3.7 \pm 0.7) \times 10^{-4}$ | | 788 |
| $K^0_S K^-\pi^+$ | | $(3.4 \pm 0.5) \times 10^{-3}$ | S=1.1 | 739 |
| $\overline{K}^*(892)^0 K^0_S$, $\overline{K}^*(892)^0 \to K^-\pi^+$ | | $< 6$ | $\times 10^{-4}$ CL=90% | 608 |
| $K^*(892)^+K^-$, $K^*(892)^+ \to K^0_S\pi^+$ | | $(1.2 \pm 0.3) \times 10^{-3}$ | | 610 |
| $K^0_S K^-\pi^+$ nonresonant | | $(1.1 \pm 1.1) \times 10^{-3}$ | | 739 |
| $K^0_S K^+\pi^-$ | | $(2.6 \pm 0.5) \times 10^{-3}$ | | 739 |
| $K^*(892)^0 K^0_S$, $K^*(892)^0 \to K^+\pi^-$ | | $< 3$ | $\times 10^{-4}$ CL=90% | 608 |
| $K^*(892)^-K^+$, $K^*(892)^- \to K^0_S\pi^-$ | | $(7 \pm 4) \times 10^{-4}$ | | 610 |
| $K^0_S K^+\pi^-$ nonresonant | | $(1.9 \,^{+\,1.1}_{-\,0.8}) \times 10^{-3}$ | | 739 |
| $K^+K^-\pi^0$ | | $(1.3 \pm 0.4) \times 10^{-3}$ | | 743 |
| $K^0_S K^0_S\pi^0$ | | $< 5.9 \times 10^{-4}$ | | 740 |
| $K^+K^-\pi^+\pi^-$ | [o] | $(2.32 \pm 0.13) \times 10^{-3}$ | | 676 |
| $\phi\pi^+\pi^-$ 3-body, $\phi \to K^+K^-$ | | $(2.3 \pm 2.3) \times 10^{-5}$ | | 614 |
| $\phi\rho^0$, $\phi \to K^+K^-$ | | $(6.7 \pm 0.6) \times 10^{-4}$ | | 250 |
| $K^+K^-\rho^0$ 3-body | | $(5 \pm 7) \times 10^{-5}$ | | 302 |
| $f_0(980)\pi^+\pi^-$, $f_0 \to K^+K^-$ | | $(3.5 \pm 0.9) \times 10^{-4}$ | | – |
| $K^*(892)^0 K^\mp\pi^\pm$ 3-body, $K^{*0} \to K^\pm\pi^\mp$ | [p] | $(2.5 \pm 0.5) \times 10^{-4}$ | | 531 |
| $K^*(892)^0\overline{K}^*(892)^0$, $K^{*0} \to K^\pm\pi^\mp$ | | $(7 \pm 5) \times 10^{-5}$ | | 272 |
| $K_1(1270)^\pm K^\mp$, $K_1(1270)^\pm \to K^\pm\pi^+\pi^-$ | | $(7.6 \pm 1.7) \times 10^{-4}$ | | – |
| $K_1(1400)^\pm K^\mp$, $K_1(1400)^\pm \to K^\pm\pi^+\pi^-$ | | $(5.1 \pm 1.2) \times 10^{-4}$ | | – |

| | | | | |
|---|---|---|---|---|
| $K^0_S K^0_S \pi^+ \pi^-$ | | $( 1.26 \pm 0.24 ) \times 10^{-3}$ | | 673 |
| $K^0_S K^- \pi^+ \pi^+ \pi^-$ | | $< 1.5$ | $\times 10^{-4}$ CL=90% | 595 |
| $K^+ K^- \pi^+ \pi^- \pi^0$ | | $( 3.1 \pm 2.0 ) \times 10^{-3}$ | | 600 |

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

| | | | | |
|---|---|---|---|---|
| $\overline{K}^*(892)^0 K^0_S$ | | $< 8$ | $\times 10^{-4}$ CL=90% | 608 |
| $K^*(892)^+ K^-$ | | $( 3.7 \pm 0.8 ) \times 10^{-3}$ | | 610 |
| $K^*(892)^0 K^0_S$ | | $< 4$ | $\times 10^{-4}$ CL=90% | 608 |
| $K^*(892)^- K^+$ | | $( 2.0 \pm 1.1 ) \times 10^{-3}$ | | 610 |
| $\phi\pi^0$ | | $( 7.4 \pm 0.5 ) \times 10^{-4}$ | | 644 |
| $\phi\eta$ | | $( 1.4 \pm 0.4 ) \times 10^{-4}$ | | 489 |
| $\phi\omega$ | | $< 2.1$ | $\times 10^{-3}$ CL=90% | 237 |

## Radiative modes

| | | | | |
|---|---|---|---|---|
| $\rho^0\gamma$ | | $< 2.4$ | $\times 10^{-4}$ CL=90% | 771 |
| $\omega\gamma$ | | $< 2.4$ | $\times 10^{-4}$ CL=90% | 768 |
| $\phi\gamma$ | | $( 2.4 \, {}^{+\,0.7}_{-\,0.6} ) \times 10^{-5}$ | | 654 |
| $\overline{K}^*(892)^0\gamma$ | | $< 7.6$ | $\times 10^{-4}$ CL=90% | 719 |

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

| | | | | |
|---|---|---|---|---|
| $K^+ \ell^- \overline{\nu}_\ell$(via $\overline{D}^0$) | *C2M* | $< 1.8$ | $\times 10^{-4}$ CL=90% | – |
| $K^+$ or $K^*(892)^+ e^- \overline{\nu}_e$(via $\overline{D}^0$) | *C2M* | $< 6$ | $\times 10^{-5}$ CL=90% | – |
| $K^+\pi^-$ | *DC* | $( 1.43 \pm 0.04 ) \times 10^{-4}$ | | 861 |
| $K^+\pi^-$ (via $\overline{D}^0$) | *C2M* | $< 1.5$ | $\times 10^{-5}$ CL=95% | 861 |
| $K^0_S\pi^+\pi^-$ (in $D^0 \to \overline{D}^0$) | *C2M* | $< 1.8$ | $\times 10^{-4}$ CL=95% | – |
| $K^*(892)^+\pi^-$, $K^*(892)^+ \to K^0_S\pi^+$ | *DC* | $(10 \, {}^{+12}_{-\,4} ) \times 10^{-5}$ | | 711 |
| $K^+\pi^-\pi^0$ | *DC* | $( 3.29 \, {}^{+\,0.30}_{-\,0.27} ) \times 10^{-4}$ | | 844 |
| $K^+\pi^-\pi^+\pi^-$ | *DC* | $( 2.49 \, {}^{+\,0.21}_{-\,0.19} ) \times 10^{-4}$ | | 812 |
| $K^+\pi^-\pi^+\pi^-$ (via $\overline{D}^0$) | *C2M* | $< 4$ | $\times 10^{-4}$ CL=90% | 812 |
| $\mu^-$ anything (via $\overline{D}^0$) | *C2M* | $< 4$ | $\times 10^{-4}$ CL=90% | – |

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

| | | | | |
|---|---|---|---|---|
| $\gamma\gamma$ | *C1* | $< 2.6$ | $\times 10^{-5}$ CL=90% | 932 |
| $e^+e^-$ | *C1* | $< 1.2$ | $\times 10^{-6}$ CL=90% | 932 |
| $\mu^+\mu^-$ | *C1* | $< 1.3$ | $\times 10^{-6}$ CL=90% | 926 |
| $\pi^0 e^+ e^-$ | *C1* | $< 4.5$ | $\times 10^{-5}$ CL=90% | 927 |
| $\pi^0\mu^+\mu^-$ | *C1* | $< 1.8$ | $\times 10^{-4}$ CL=90% | 915 |

| | | | | | | |
|---|---|---|---|---|---|---|
| $\eta e^+ e^-$ | *C1* | | < | 1.1 | $\times 10^{-4}$ CL=90% | 852 |
| $\eta \mu^+ \mu^-$ | *C1* | | < | 5.3 | $\times 10^{-4}$ CL=90% | 838 |
| $\pi^+ \pi^- e^+ e^-$ | *C1* | | < | 3.73 | $\times 10^{-4}$ CL=90% | 922 |
| $\rho^0 e^+ e^-$ | *C1* | | < | 1.0 | $\times 10^{-4}$ CL=90% | 771 |
| $\pi^+ \pi^- \mu^+ \mu^-$ | *C1* | | < | 3.0 | $\times 10^{-5}$ CL=90% | 894 |
| $\rho^0 \mu^+ \mu^-$ | *C1* | | < | 2.2 | $\times 10^{-5}$ CL=90% | 754 |
| $\omega e^+ e^-$ | *C1* | | < | 1.8 | $\times 10^{-4}$ CL=90% | 768 |
| $\omega \mu^+ \mu^-$ | *C1* | | < | 8.3 | $\times 10^{-4}$ CL=90% | 751 |
| $K^- K^+ e^+ e^-$ | *C1* | | < | 3.15 | $\times 10^{-4}$ CL=90% | 791 |
| $\phi e^+ e^-$ | *C1* | | < | 5.2 | $\times 10^{-5}$ CL=90% | 654 |
| $K^- K^+ \mu^+ \mu^-$ | *C1* | | < | 3.3 | $\times 10^{-5}$ CL=90% | 709 |
| $\phi \mu^+ \mu^-$ | *C1* | | < | 3.1 | $\times 10^{-5}$ CL=90% | 631 |
| $\overline{K}^0 e^+ e^-$ | | [*g*] | < | 1.1 | $\times 10^{-4}$ CL=90% | 866 |
| $\overline{K}^0 \mu^+ \mu^-$ | | [*g*] | < | 2.6 | $\times 10^{-4}$ CL=90% | 852 |
| $K^- \pi^+ e^+ e^-$ | *C1* | | < | 3.85 | $\times 10^{-4}$ CL=90% | 861 |
| $\overline{K}^*(892)^0 e^+ e^-$ | | [*g*] | < | 4.7 | $\times 10^{-5}$ CL=90% | 719 |
| $K^- \pi^+ \mu^+ \mu^-$ | *C1* | | < | 3.59 | $\times 10^{-4}$ CL=90% | 829 |
| $\overline{K}^*(892)^0 \mu^+ \mu^-$ | | [*g*] | < | 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* | [*h*] | < | 8.1 | $\times 10^{-7}$ CL=90% | 929 |
| $\pi^0 e^\pm \mu^\mp$ | *LF* | [*h*] | < | 8.6 | $\times 10^{-5}$ CL=90% | 924 |
| $\eta e^\pm \mu^\mp$ | *LF* | [*h*] | < | 1.0 | $\times 10^{-4}$ CL=90% | 848 |
| $\pi^+ \pi^- e^\pm \mu^\mp$ | *LF* | [*h*] | < | 1.5 | $\times 10^{-5}$ CL=90% | 911 |
| $\rho^0 e^\pm \mu^\mp$ | *LF* | [*h*] | < | 4.9 | $\times 10^{-5}$ CL=90% | 767 |
| $\omega e^\pm \mu^\mp$ | *LF* | [*h*] | < | 1.2 | $\times 10^{-4}$ CL=90% | 764 |
| $K^- K^+ e^\pm \mu^\mp$ | *LF* | [*h*] | < | 1.8 | $\times 10^{-4}$ CL=90% | 754 |
| $\phi e^\pm \mu^\mp$ | *LF* | [*h*] | < | 3.4 | $\times 10^{-5}$ CL=90% | 648 |
| $\overline{K}^0 e^\pm \mu^\mp$ | *LF* | [*h*] | < | 1.0 | $\times 10^{-4}$ CL=90% | 862 |
| $K^- \pi^+ e^\pm \mu^\mp$ | *LF* | [*h*] | < | 5.53 | $\times 10^{-4}$ CL=90% | 848 |
| $\overline{K}^*(892)^0 e^\pm \mu^\mp$ | *LF* | [*h*] | < | 8.3 | $\times 10^{-5}$ CL=90% | 714 |
| $\pi^- \pi^- e^+ e^+ +$ c.c. | *L* | | < | 1.12 | $\times 10^{-4}$ CL=90% | 922 |
| $\pi^- \pi^- \mu^+ \mu^+ +$ c.c. | *L* | | < | 2.9 | $\times 10^{-5}$ CL=90% | 894 |
| $K^- \pi^- e^+ e^+ +$ c.c. | *L* | | < | 2.06 | $\times 10^{-4}$ CL=90% | 861 |
| $K^- \pi^- \mu^+ \mu^+ +$ c.c. | *L* | | < | 3.9 | $\times 10^{-4}$ CL=90% | 829 |
| $K^- K^- e^+ e^+ +$ c.c. | *L* | | < | 1.52 | $\times 10^{-4}$ CL=90% | 791 |
| $K^- K^- \mu^+ \mu^+ +$ c.c. | *L* | | < | 9.4 | $\times 10^{-5}$ CL=90% | 709 |
| $\pi^- \pi^- e^+ \mu^+ +$ c.c. | *L* | | < | 7.9 | $\times 10^{-5}$ CL=90% | 911 |
| $K^- \pi^- e^+ \mu^+ +$ c.c. | *L* | | < | 2.18 | $\times 10^{-4}$ CL=90% | 848 |
| $K^- K^- e^+ \mu^+ +$ c.c. | *L* | | < | 5.7 | $\times 10^{-5}$ CL=90% | 754 |

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

$I(J^P) = \frac{1}{2}(1^-)$
*I*, *J*, *P* need confirmation.

Mass $m = 2006.7 \pm 0.4$ MeV (S = 1.1)
$m_{D^{*0}} - m_{D^0} = 142.12 \pm 0.07$ MeV
Full width $\Gamma < 2.1$ MeV, CL = 90%

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

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

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

$I(J^P) = \frac{1}{2}(1^-)$
*I*, *J*, *P* need confirmation.

Mass $m = 2010.0 \pm 0.4$ MeV (S = 1.1)
$m_{D^*(2010)^+} - m_{D^+} = 140.64 \pm 0.10$ MeV (S = 1.1)
$m_{D^*(2010)^+} - m_{D^0} = 145.421 \pm 0.010$ MeV (S = 1.1)
Full width $\Gamma = 96 \pm 22$ keV

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

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

## $D_1(2420)^0$

$I(J^P) = \frac{1}{2}(1^+)$
*I*, *J*, *P* need confirmation.

Mass $m = 2422.3 \pm 1.3$ MeV (S = 1.2)
$m_{D_1^0} - m_{D^{*+}} = 411.7 \pm 0.8$
Full width $\Gamma = 20.4 \pm 1.7$ MeV

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

| $D_1(2420)^0$ DECAY MODES | Fraction ($\Gamma_i/\Gamma$) | *p* (MeV/*c*) |
|---|---|---|
| $D^*(2010)^+\pi^-$ | seen | 355 |
| $D^0\pi^+\pi^-$ | seen | 426 |
| $D^+\pi^-$ | not seen | 474 |
| $D^{*0}\pi^+\pi^-$ | not seen | 281 |

## $D_2^*(2460)^0$ $I(J^P) = \frac{1}{2}(2^+)$

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

Mass $m = 2461.1 \pm 1.6$ MeV (S = 1.3)
$m_{D_2^{*0}} - m_{D^+} = 593.9 \pm 0.8$
Full width $\Gamma = 43 \pm 4$ MeV (S = 1.8)

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

| $D_2^*(2460)^0$ DECAY MODES | Fraction ($\Gamma_i/\Gamma$) | $p$ (MeV/$c$) |
|---|---|---|
| $D^+\pi^-$ | seen | 506 |
| $D^*(2010)^+\pi^-$ | seen | 389 |
| $D^0\pi^+\pi^-$ | not seen | 462 |
| $D^{*0}\pi^+\pi^-$ | not seen | 325 |

## $D_2^*(2460)^\pm$ $I(J^P) = \frac{1}{2}(2^+)$

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

Mass $m = 2459 \pm 4$ MeV (S = 1.7)
$m_{D_2^*(2460)^\pm} - m_{D_2^*(2460)^0} = 2.4 \pm 1.7$ MeV
Full width $\Gamma = 29 \pm 5$ MeV

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

| $D_2^*(2460)^\pm$ DECAY MODES | Fraction ($\Gamma_i/\Gamma$) | $p$ (MeV/$c$) |
|---|---|---|
| $D^0\pi^+$ | seen | 507 |
| $D^{*0}\pi^+$ | seen | 390 |
| $D^+\pi^+\pi^-$ | not seen | 456 |
| $D^{*+}\pi^+\pi^-$ | not seen | 319 |

## NOTES

[*a*] This result applies to $Z^0 \to c\overline{c}$ decays only. Here $\ell^+$ is an average (not a sum) of $e^+$ and $\mu^+$ decays.

[*b*] This is a weighted average of $D^\pm$ (44%) and $D^0$ (56%) branching fractions. See "$D^+$ and $D^0 \to$ ($\eta$ anything) / (total $D^+$ and $D^0$)" under "$D^+$ Branching Ratios" in the Particle Listings.

[*c*] 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.

[*d*] These subfractions of the $K^-\pi^+\pi^+$ mode are uncertain: see the Particle Listings.

[*e*] The two experiments measuring this fraction are in serious disagreement. See the Particle Listings.

[*f*] This is *not* a test for the $\Delta C$=1 weak neutral current, but leads to the $\pi^+ e^+ e^-$ final state.

[*g*] This mode is not a useful test for a $\Delta C$=1 weak neutral current because both quarks must change flavor in this decay.

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

[*i*] This $D_1^0 - D_2^0$ limit is inferred from the $D^0$-$\overline{D}^0$ mixing ratio $\Gamma(K^+\pi^-$ (via $\overline{D}^0$)) / $\Gamma(K^-\pi^+)$ near the end of the $D^0$ Listings.

[*j*] This value is obtained by subtracting the branching fractions for 2-, 4- and 6-prongs from unity.

[*k*] This is the sum of our $K^-\pi^+\pi^+\pi^-$, $K^-\pi^+\pi^+\pi^-\pi^0$, $\overline{K}^0 2\pi^+ 2\pi^-$, $2\pi^+ 2\pi^-$, $2\pi^+ 2\pi^- \pi^0$, $K^+K^-\pi^+\pi^-$, and $K^+K^-\pi^+\pi^-\pi^0$, branching fractions.

[*l*] 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 6.14 $\pm$ 0.20 %.

[*m*] This is a doubly Cabibbo-suppressed mode.

[*n*] This branching fraction includes all the decay modes of the resonance in the final state.

[*o*] The experiments on the division of this charge mode amongst its submodes disagree, and the submode branching fractions here add up to considerably more than the charged-mode fraction.

[*p*] However, these upper limits are in serious disagreement with values obtained in another experiment.