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

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

$K^\pm$

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

Mass $m = 493.677 \pm 0.015$ MeV [a] (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 (Δ = rate difference/sum)

$\Delta(K^\pm \to \mu^\pm \nu_\mu) = (-0.27 \pm 0.21)\%$
$\Delta(K^\pm \to \pi^\pm \pi^0) = (0.4 \pm 0.6)\%$ [b]

CP violation parameters (Δ = rate difference/sum)

$\Delta(K^\pm \to \pi^\pm e^+ e^-) = (-2.2 \pm 1.6) \times 10^{-2}$
$\Delta(K^\pm \to \pi^\pm \mu^+ \mu^-) = 0.010 \pm 0.023$
$\Delta(K^\pm \to \pi^\pm \pi^0 \gamma) = (0.0 \pm 1.2) \times 10^{-3}$
$\Delta(K^\pm \to \pi^\pm \pi^+ \pi^-) = (0.04 \pm 0.06)\%$
$\Delta(K^\pm \to \pi^\pm \pi^0 \pi^0) = (-0.02 \pm 0.28)\%$

T violation parameters

$K^+ \to \pi^0 \mu^+ \nu_\mu \quad P_T = (-1.7 \pm 2.5) \times 10^{-3}$
$K^+ \to \mu^+ \nu_\mu \gamma \quad P_T = (-0.6 \pm 1.9) \times 10^{-2}$
$K^+ \to \pi^0 \mu^+ \nu_\mu \quad \mathrm{Im}(\xi) = -0.006 \pm 0.008$

Slope parameter *g* [c]

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

$K^\pm \to \pi^\pm \pi^+ \pi^- \; g = -0.21134 \pm 0.00017$
$(g_+ - g_-) \,/\, (g_+ + g_-) = (-1.5 \pm 2.2) \times 10^{-4}$
$K^\pm \to \pi^\pm \pi^0 \pi^0 \; g = 0.626 \pm 0.007$
$(g_+ - g_-) \,/\, (g_+ + g_-) = (1.8 \pm 1.8) \times 10^{-4}$

$K^\pm$ decay form factors [d,e]

Assuming μ-e universality

$\lambda_+(K^+_{\mu 3}) = \lambda_+(K^+_{e3}) = (2.959 \pm 0.025) \times 10^{-2}$
$\lambda_0(K^+_{\mu 3}) = (1.76 \pm 0.25) \times 10^{-2}$ (S = 2.7)

Not assuming μ-e universality

$\lambda_+(K^+_{e3}) = (2.956 \pm 0.025) \times 10^{-2}$

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

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

K_{e3} form factor quadratic fit

λ'_+ ($K^\pm_{e3}$) linear coeff. $= (2.59 \pm 0.04) \times 10^{-2}$

λ''_+($K^\pm_{e3}$) quadratic coeff. $= (0.186 \pm 0.021) \times 10^{-2}$

λ'_+ (LINEAR $K^\pm_{\mu 3}$ FORM FACTOR FROM QUADRATIC FIT) $= (24 \pm 4) \times 10^{-3}$

λ''_+ (QUADRATIC $K^\pm_{\mu 3}$ FORM FACTOR) $= (1.8 \pm 1.5) \times 10^{-3}$

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

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

M_S (SCALAR POLE MASS FOR $K^\pm_{\mu 3}$ DECAY) $= 1210 \pm 50$ MeV

Λ_+ (DISPERSIVE VECTOR FORM FACTOR IN $K^\pm_{e3}$ DECAY) $= (2.460 \pm 0.017) \times 10^{-2}$

Λ_+ (DISPERSIVE VECTOR FORM FACTOR IN $K^\pm_{\mu 3}$ DECAY) $= (25.4 \pm 0.9) \times 10^{-3}$

ln(C) (DISPERSIVE SCALAR FORM FACTOR in $K^\pm_{\mu 3}$ decays) $= (182 \pm 16) \times 10^{-3}$

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

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

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

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

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

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

$K^+ \to e^+\nu_e\gamma$ $|F_A - F_V| < 0.49$, CL = 90%

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

Charge radius

$\langle r \rangle = 0.560 \pm 0.031$ fm

Forward-backward asymmetry

$A_{FB}(K^\pm_{\pi\mu\mu}) = \frac{\Gamma(cos(\theta_{K\mu})>0) - \Gamma(cos(\theta_{K\mu})<0)}{\Gamma(cos(\theta_{K\mu})>0) + \Gamma(cos(\theta_{K\mu})<0)} < 0.9 \times 10^{-2}$, CL = 90%

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

K^+ DECAY MODES	Fraction (Γ_i/Γ)	Scale factor/ Confidence level	p (MeV/c)
Leptonic and semileptonic modes			
$e^+\nu_e$	$(1.582\pm0.007)\times10^{-5}$		247
$\mu^+\nu_\mu$	(63.56 ± 0.11) %	S=1.2	236
$\pi^0 e^+\nu_e$	(5.07 ± 0.04) %	S=2.1	228
Called K^+_{e3}.			
$\pi^0\mu^+\nu_\mu$	(3.352 ± 0.034) %	S=1.9	215
Called $K^+_{\mu3}$.			
$\pi^0\pi^0 e^+\nu_e$	$(2.55\pm0.04)\times10^{-5}$	S=1.1	206
$\pi^+\pi^- e^+\nu_e$	$(4.247\pm0.024)\times10^{-5}$		203
$\pi^+\pi^-\mu^+\nu_\mu$	$(1.4\pm0.9)\times10^{-5}$		151
$\pi^0\pi^0\pi^0 e^+\nu_e$	$< 3.5\times10^{-6}$	CL=90%	135
Hadronic modes			
$\pi^+\pi^0$	(20.67 ± 0.08) %	S=1.2	205
$\pi^+\pi^0\pi^0$	(1.760 ± 0.023) %	S=1.1	133
$\pi^+\pi^+\pi^-$	(5.583 ± 0.024) %		125
Leptonic and semileptonic modes with photons			
$\mu^+\nu_\mu\gamma$	[f,g] $(6.2\pm0.8)\times10^{-3}$		236
$\mu^+\nu_\mu\gamma(\mathrm{SD}^+)$	[d,h] $(1.33\pm0.22)\times10^{-5}$		–
$\mu^+\nu_\mu\gamma(\mathrm{SD}^+\mathrm{INT})$	[d,h] $< 2.7\times10^{-5}$	CL=90%	–
$\mu^+\nu_\mu\gamma(\mathrm{SD}^- + \mathrm{SD}^-\mathrm{INT})$	[d,h] $< 2.6\times10^{-4}$	CL=90%	–
$e^+\nu_e\gamma$	$(1.03\pm0.14)\times10^{-5}$		247
$\pi^0 e^+\nu_e\gamma$	[f,g] $(2.698\pm0.033)\times10^{-4}$		228
$\pi^0 e^+\nu_e\gamma(\mathrm{SD})$	[d,h] $< 5.3\times10^{-5}$	CL=90%	228
$\pi^0\mu^+\nu_\mu\gamma$	[f,g] $(1.25\pm0.25)\times10^{-5}$		215
$\pi^0\pi^0 e^+\nu_e\gamma$	$< 5\times10^{-6}$	CL=90%	206
Hadronic modes with photons or $\ell\bar{\ell}$ pairs			
$\pi^+\pi^0\gamma(\mathrm{INT})$	$(-4.2\pm0.9)\times10^{-6}$		–
$\pi^+\pi^0\gamma(\mathrm{DE})$	[f,i] $(6.0\pm0.4)\times10^{-6}$		205
$\pi^+\pi^0 e^+ e^-$	$(4.24\pm0.14)\times10^{-6}$		205
$\pi^+\pi^0\pi^0\gamma$	[f,g] $(7.6\,^{+6.0}_{-3.0})\times10^{-6}$		133
$\pi^+\pi^+\pi^-\gamma$	[f,g] $(7.1\pm0.5)\times10^{-6}$		125
$\pi^+\gamma\gamma$	[f] $(1.01\pm0.06)\times10^{-6}$		227
$\pi^+ 3\gamma$	[f] $< 1.0\times10^{-4}$	CL=90%	227
$\pi^+ e^+ e^-\gamma$	$(1.19\pm0.13)\times10^{-8}$		227

Leptonic modes with $\ell\overline{\ell}$ pairs

$e^+\nu_e\nu\overline{\nu}$		$<$	6	$\times 10^{-5}$	CL=90%	247
$\mu^+\nu_\mu\nu\overline{\nu}$		$<$	1.0	$\times 10^{-6}$	CL=90%	236
$e^+\nu_e e^+ e^-$		(	2.48 $\pm$0.20)	$\times 10^{-8}$		247
$\mu^+\nu_\mu e^+ e^-$		(	7.06 $\pm$0.31)	$\times 10^{-8}$		236
$e^+\nu_e\mu^+\mu^-$		(	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

$\pi^+\pi^+ e^-\overline{\nu}_e$	SQ		$<$	1.3	$\times 10^{-8}$	CL=90%	203
$\pi^+\pi^+\mu^-\overline{\nu}_\mu$	SQ		$<$	3.0	$\times 10^{-6}$	CL=95%	151
$\pi^+ e^+ e^-$	$S1$		(	3.00 $\pm$0.09)	$\times 10^{-7}$		227
$\pi^+\mu^+\mu^-$	$S1$		(	9.17 $\pm$0.14)	$\times 10^{-8}$	S=1.8	172
$\pi^+ e^+ e^- e^+ e^-$			$<$	1.4	$\times 10^{-8}$	CL=90%	227
$\pi^+\nu\overline{\nu}$	$S1$		(	1.14 $^{+0.40}_{-0.33}$)	$\times 10^{-10}$		227
$\pi^+\pi^0\nu\overline{\nu}$	$S1$		$<$	4.3	$\times 10^{-5}$	CL=90%	205
$\mu^-\nu e^+ e^+$	LF		$<$	8.1	$\times 10^{-11}$	CL=90%	236
$\mu^+\nu_e$	LF	[j]	$<$	4	$\times 10^{-3}$	CL=90%	236
$\pi^+\mu^+ e^-$	LF		$<$	1.3	$\times 10^{-11}$	CL=90%	214
$\pi^+\mu^- e^+$	LF		$<$	6.6	$\times 10^{-11}$	CL=90%	214
$\pi^-\mu^+ e^+$	L		$<$	4.2	$\times 10^{-11}$	CL=90%	214
$\pi^- e^+ e^+$	L		$<$	5.3	$\times 10^{-11}$	CL=90%	227
$\pi^-\mu^+\mu^+$	L		$<$	4.2	$\times 10^{-11}$	CL=90%	172
$\pi^-\pi^0 e^+ e^+$	L		$<$	8.5	$\times 10^{-10}$	CL=90%	205
$\mu^+\overline{\nu}_e$	L	[j]	$<$	3.3	$\times 10^{-3}$	CL=90%	236
$\pi^0 e^+\overline{\nu}_e$	L		$<$	3	$\times 10^{-3}$	CL=90%	228
$\pi^+\gamma$		[k]	$<$	2.3	$\times 10^{-9}$	CL=90%	227

K^0

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

50% K_S, 50% K_L

Mass $m = 497.611 \pm 0.013$ MeV (S = 1.2)

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

Mean square charge radius

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

T-violation parameters in K^0-$\overline{K}^0$ mixing [e]

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

CP-violation parameters

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

CPT-violation parameters [e]

Re $\delta = (2.5 \pm 2.3) \times 10^{-4}$
Im $\delta = (-1.5 \pm 1.6) \times 10^{-5}$
Re(y), K_{e3} parameter $= (0.4 \pm 2.5) \times 10^{-3}$
Re(x_-), K_{e3} parameter $= (-2.9 \pm 2.0) \times 10^{-3}$
$\left|m_{K^0} - m_{\overline{K}^0}\right| / m_{\text{average}} < 6 \times 10^{-19}$, CL = 90% [l]
$(\Gamma_{K^0} - \Gamma_{\overline{K}^0})/m_{\text{average}} = (8 \pm 8) \times 10^{-18}$

Tests of $\Delta S = \Delta Q$

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

K^0_S

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

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 [n]

Im(η_{+-0}) $= -0.002 \pm 0.009$
Im(η_{000}) $= -0.001 \pm 0.016$
$|\eta_{000}| = |A(K^0_S \to 3\pi^0)/A(K^0_L \to 3\pi^0)| < 0.0088$, CL = 90%
CP asymmetry *A* in $\pi^+\pi^- e^+ e^-$ $= (-0.4 \pm 0.8)\%$

K^0_S DECAY MODES		Fraction (Γ_i/Γ)	Scale factor/ Confidence level	*p* (MeV/*c*)
Hadronic modes				
$\pi^0\pi^0$		(30.69±0.05) %		209
$\pi^+\pi^-$		(69.20±0.05) %		206
$\pi^+\pi^-\pi^0$		$(3.5\ ^{+1.1}_{-0.9}) \times 10^{-7}$		133
Modes with photons or $\ell\bar{\ell}$ pairs				
$\pi^+\pi^-\gamma$	[g,o]	$(1.79 \pm 0.05) \times 10^{-3}$		206
$\pi^+\pi^- e^+ e^-$		$(4.79 \pm 0.15) \times 10^{-5}$		206
$\pi^0\gamma\gamma$	[o]	$(4.9 \pm 1.8) \times 10^{-8}$		230
$\gamma\gamma$		$(2.63 \pm 0.17) \times 10^{-6}$	S=3.1	249
$\mu^+\mu^-\mu^+\mu^-$		$< 5.1 \times 10^{-12}$	CL=90%	119

Semileptonic modes

$\pi^\pm e^\mp \nu_e$	[p]	$(\ 7.14 \pm 0.06) \times 10^{-4}$		229

***CP* violating (*CP*) and $\Delta S = 1$ weak neutral current (*S1*) modes**

$3\pi^0$	*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*	[o] $(\ 3.0\ ^{+1.5}_{-1.2}\ ) \times 10^{-9}$			230
$\pi^0 \mu^+ \mu^-$	*S1*	$(\ 2.9\ ^{+1.5}_{-1.2}\ ) \times 10^{-9}$			177

K_L^0

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

$m_{K_L} - m_{K_S}$
$= (0.5293 \pm 0.0009) \times 10^{10}\ \hbar\ \mathrm{s}^{-1}$ (S = 1.3) Assuming *CPT*
$= (3.484 \pm 0.006) \times 10^{-12}$ MeV Assuming *CPT*
$= (0.5289 \pm 0.0010) \times 10^{10}\ \hbar\ \mathrm{s}^{-1}$ Not assuming *CPT*

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

$c\tau = 15.34$ m

Slope parameters [c]

(See Particle Listings for other linear and quadratic coefficients)

$K_L^0 \to \pi^+\pi^-\pi^0$: $g = 0.678 \pm 0.008$ (S = 1.5)
$K_L^0 \to \pi^+\pi^-\pi^0$: $h = 0.076 \pm 0.006$
$K_L^0 \to \pi^+\pi^-\pi^0$: $k = 0.0099 \pm 0.0015$
$K_L^0 \to \pi^0\pi^0\pi^0$: $h = (0.6 \pm 1.2) \times 10^{-3}$

K_L decay form factors [e]

Linear parametrization assuming μ-e universality

$\lambda_+(K^0_{\mu 3}) = \lambda_+(K^0_{e3}) = (2.82 \pm 0.04) \times 10^{-2}$ (S = 1.1)
$\lambda_0(K^0_{\mu 3}) = (1.38 \pm 0.18) \times 10^{-2}$ (S = 2.2)

Quadratic parametrization assuming μ-e universality

$\lambda'_+(K^0_{\mu 3}) = \lambda'_+(K^0_{e3}) = (2.40 \pm 0.12) \times 10^{-2}$ (S = 1.2)
$\lambda''_+(K^0_{\mu 3}) = \lambda''_+(K^0_{e3}) = (0.20 \pm 0.05) \times 10^{-2}$ (S = 1.2)
$\lambda_0(K^0_{\mu 3}) = (1.16 \pm 0.09) \times 10^{-2}$ (S = 1.2)

Pole parametrization assuming μ-e universality

$M_V^\mu\ (K^0_{\mu 3}) = M_V^e\ (K^0_{e3}) = 878 \pm 6$ MeV (S = 1.1)
$M_S^\mu\ (K^0_{\mu 3}) = 1252 \pm 90$ MeV (S = 2.6)

Dispersive parametrization assuming μ-e universality

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

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

K^0_{e3} $|f_S/f_+| = (1.5^{+1.4}_{-1.6}) \times 10^{-2}$

K^0_{e3} $|f_T/f_+| = (5^{+4}_{-5}) \times 10^{-2}$

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

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

$K^0_L \to \ell^+\ell^-\gamma$, $K^0_L \to \ell^+\ell^-\ell'^+\ell'^-$: $\alpha_{DIP} = -1.69 \pm 0.08$ (S = 1.7)

$K_L \to \pi^+\pi^- e^+ e^-$: $a_1/a_2 = -0.737 \pm 0.014$ GeV^2

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

CP-violation parameters [n]

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

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

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

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

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

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

Assuming *CPT*

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

$\phi_{00} = (43.52 \pm 0.05)^\circ$ (S = 1.2)

$\phi_\epsilon = \phi_{SW} = (43.52 \pm 0.04)^\circ$ (S = 1.2)

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

Not assuming *CPT*

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

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

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

CP asymmetry A in $K^0_L \to \pi^+\pi^- e^+ e^- = (13.7 \pm 1.5)\%$

β_{CP} from $K^0_L \to e^+ e^- e^+ e^- = -0.19 \pm 0.07$

γ_{CP} from $K^0_L \to e^+ e^- e^+ e^- = 0.01 \pm 0.11$ (S = 1.6)

j for $K^0_L \to \pi^+\pi^-\pi^0 = 0.0012 \pm 0.0008$

f for $K^0_L \to \pi^+\pi^-\pi^0 = 0.004 \pm 0.006$

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

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

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

$|g_{E1}|$ for $K^0_L \to \pi^+\pi^-\gamma < 0.21$, CL = 90%

T-violation parameters

Im(ξ) in $K^0_{\mu 3} = -0.007 \pm 0.026$

CPT invariance tests

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

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

$\Delta S = -\Delta Q$ in $K^0_{\ell 3}$ decay

Re $x = -0.002 \pm 0.006$

Im $x = 0.0012 \pm 0.0021$

K^0_L DECAY MODES			Fraction (Γ_i/Γ)	Scale factor/ Confidence level	p (MeV/c)
Semileptonic modes					
$\pi^\pm e^\mp \nu_e$ Called K^0_{e3}.		[p]	(40.55 ±0.11) %	S=1.7	229
$\pi^\pm \mu^\mp \nu_\mu$ Called $K^0_{\mu 3}$.		[p]	(27.04 ±0.07) %	S=1.1	216
$(\pi\mu\text{atom})\nu$			(1.05 ±0.11) $\times 10^{-7}$		188
$\pi^0\pi^\pm e^\mp \nu$		[p]	(5.20 ±0.11) $\times 10^{-5}$		207
$\pi^\pm e^\mp \nu e^+ e^-$		[p]	(1.26 ±0.04) $\times 10^{-5}$		229
Hadronic modes, including Charge conjugation×Parity Violating (*CPV*) modes					
$3\pi^0$			(19.52 ±0.12) %	S=1.6	139
$\pi^+\pi^-\pi^0$			(12.54 ±0.05) %		133
$\pi^+\pi^-$	*CPV*	[r]	(1.967±0.010) $\times 10^{-3}$	S=1.5	206
$\pi^0\pi^0$	*CPV*		(8.64 ±0.06) $\times 10^{-4}$	S=1.8	209
Semileptonic modes with photons					
$\pi^\pm e^\mp \nu_e \gamma$		[g,p,s]	(3.79 ±0.06) $\times 10^{-3}$		229
$\pi^\pm \mu^\mp \nu_\mu \gamma$			(5.65 ±0.23) $\times 10^{-4}$		216
Hadronic modes with photons or $\ell\bar{\ell}$ pairs					
$\pi^0\pi^0\gamma$			< 2.43 $\times 10^{-7}$	CL=90%	209
$\pi^+\pi^-\gamma$		[g,s]	(4.15 ±0.15) $\times 10^{-5}$	S=2.8	206
$\pi^+\pi^-\gamma$(DE)			(2.84 ±0.11) $\times 10^{-5}$	S=2.0	206
$\pi^0 2\gamma$		[s]	(1.273±0.033) $\times 10^{-6}$		230
$\pi^0\gamma e^+ e^-$			(1.62 ±0.17) $\times 10^{-8}$		230

Other modes with photons or $\ell\overline{\ell}$ pairs

2γ		$(\ 5.47 \pm 0.04\ ) \times 10^{-4}$	S=1.1		249
3γ		$< 7.4 \times 10^{-8}$	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
$\mu^+ \mu^- \mu^+ \mu^-$		$< 2.3 \times 10^{-9}$	CL=90%		119
$e^+ e^- \gamma\gamma$	[s]	$(\ 5.95 \pm 0.33\ ) \times 10^{-7}$			249
$\mu^+ \mu^- \gamma\gamma$	[s]	$(\ 1.0\ ^{+0.8}_{-0.6}\ ) \times 10^{-8}$			225

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

$\mu^+ \mu^-$	*S1*		$(\ 6.84 \pm 0.11\ ) \times 10^{-9}$			225
$e^+ e^-$	*S1*		$(\ 9\ ^{+6}_{-4}\ ) \times 10^{-12}$			249
$\pi^+ \pi^- e^+ e^-$	*S1*	[s]	$(\ 3.11 \pm 0.19\ ) \times 10^{-7}$			206
$\pi^0 \pi^0 e^+ e^-$	*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*	[t]	$< 3.8 \times 10^{-10}$	CL=90%		177
$\pi^0 e^+ e^-$	*CP,S1*	[t]	$< 2.8 \times 10^{-10}$	CL=90%		230
$\pi^0 \nu\overline{\nu}$	*CP,S1*	[u]	$< 3.0 \times 10^{-9}$	CL=90%		230
$\pi^0 \pi^0 \nu\overline{\nu}$	*S1*		$< 8.1 \times 10^{-7}$	CL=90%		209
$e^\pm \mu^\mp$	*LF*	[p]	$< 4.7 \times 10^{-12}$	CL=90%		238
$e^\pm e^\pm \mu^\mp \mu^\mp$	*LF*	[p]	$< 4.12 \times 10^{-11}$	CL=90%		225
$\pi^0 \mu^\pm e^\mp$	*LF*	[p]	$< 7.6 \times 10^{-11}$	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 κ; was $K_0^*(800)$

See the review on "Scalar Mesons below 1 GeV."

Mass (T-Matrix Pole $\sqrt{s}$) = (630–730) − i (260–340) MeV
Mass (Breit-Wigner) = 845 ± 17 MeV
Full width (Breit-Wigner) = 468 ± 30 MeV

$K_0^*(700)$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$K\pi$	100 %	256

$K^*(892)$

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

Mass (T-Matrix Pole $\sqrt{s}$) = (890 ± 14) − i (26 ± 6) MeV
$K^*(892)^\pm$ hadroproduced mass $m = 891.67 \pm 0.26$ MeV
$K^*(892)^\pm$ in τ 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 τ decays full width $\Gamma = 46.2 \pm 1.3$ MeV
$K^*(892)^0$ full width $\Gamma = 47.3 \pm 0.5$ MeV (S = 2.0)

$K^*(892)$ DECAY MODES	Fraction (Γ_i/Γ)	Confidence level	p (MeV/c)
$K\pi$	∼ 100 %		289
$K^0\gamma$	(2.46±0.21) × 10^{-3}		307
$K^\pm\gamma$	(9.8 ±0.9) × 10^{-4}		309
$K\pi\pi$	< 7 × 10^{-4}	95%	223

$K_1(1270)$

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

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

$K_1(1270)$ DECAY MODES	Fraction (Γ_i/Γ)	Scale factor	p (MeV/c)
$K\rho$	(38 ±13) %	2.2	†
$K_0^*(1430)\pi$	(28 ± 4) %		†
$K^*(892)\pi$	(21 ±10) %	2.2	286
$K\omega$	(11.0± 2.0) %		†
$Kf_0(1370)$	(3.0± 2.0) %		†
γK^0	seen		528

$K_1(1400)$

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

Mass $m = 1403 \pm 7$ MeV
Full width $\Gamma = 174 \pm 13$ MeV (S = 1.6)

$K_1(1400)$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$K^*(892)\pi$	(94 ±6) %	402
$K\rho$	(3.0±3.0) %	293
$Kf_0(1370)$	(2.0±2.0) %	†
$K\omega$	(1.0±1.0) %	284
$K_0^*(1430)\pi$	not seen	†

γK^0	seen	613
$K\phi$	seen	†

$K^*(1410)$ $I(J^P) = \frac{1}{2}(1^-)$

T-matrix pole $\sqrt{s} = (1368 \pm 38) - i\,(106^{+48}_{-59})$ MeV
Mass $m = 1414 \pm 15$ MeV (S = 1.3)
Full width $\Gamma = 232 \pm 21$ MeV (S = 1.1)

$K^*(1410)$ DECAY MODES	Fraction (Γ_i/Γ)	Confidence level	p (MeV/c)
$K^*(892)\pi$	> 40 %	95%	410
$K\pi$	(6.6±1.3) %		612
$K\rho$	< 7 %	95%	305
γK^0	< 2.3 $\times 10^{-4}$	90%	619
$K\phi$	seen		†

$K_0^*(1430)$ $I(J^P) = \frac{1}{2}(0^+)$

T-matrix pole $\sqrt{s} = (1431 \pm 6) - i\,(110 \pm 19)$ MeV
Mass $m = 1425 \pm 50$ MeV [v]
Full width $\Gamma = 270 \pm 80$ MeV [v]

$K_0^*(1430)$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$K\pi$	(93 ±10) %	619
$K\eta$	($8.6^{+\ 2.7}_{-\ 3.4}$) %	486
$K\eta'(958)$	seen	†

$K_2^*(1430)$ $I(J^P) = \frac{1}{2}(2^+)$

T-matrix pole $\sqrt{s} = (1424 \pm 4) - i\,(66 \pm 2)$ MeV
$K_2^*(1430)^\pm$ 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 $\Gamma = 100.0 \pm 2.2$ MeV (S = 1.1)
$K_2^*(1430)^0$ full width $\Gamma = 109 \pm 5$ MeV (S = 1.9)

$K_2^*(1430)$ DECAY MODES	Fraction (Γ_i/Γ)	Scale factor/ Confidence level	p (MeV/c)
$K\pi$	(49.9±1.2) %		620
$K^*(892)\pi$	(24.7±1.5) %		420
$K^*(892)\pi\pi$	(13.4±2.2) %		373

$K\rho$	(8.7±0.8) %	S=1.2	320
$K\omega$	(2.9±0.8) %		313
$K^+\gamma$	(2.4±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

$K(1460)$

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

$K(1460)$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$K^*(892)\pi$	seen	–
$K\rho$	seen	–
$K_0^*(1430)\pi$	seen	–
$K\phi$	seen	–

$K_1(1650)$

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

Mass $m = 1650 \pm 50$ MeV
Full width $\Gamma = 150 \pm 50$ MeV

$K^*(1680)$

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

Mass $m = 1718 \pm 18$ MeV
Full width $\Gamma = 320 \pm 110$ MeV (S = 4.2)

$K^*(1680)$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$K\pi$	(38.7±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

$K_2(1770)$ [x]

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

Mass $m = 1773 \pm 8$ MeV
Full width $\Gamma = 186 \pm 14$ MeV

$K_2(1770)$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$K\pi\pi$		794
$K_2^*(1430)\pi$	seen	287
$K^*(892)\pi$	seen	654
$Kf_2(1270)$	seen	53
$Kf_0(980)$	possibly seen	466
$K\phi$	seen	441
$K\omega$	seen	607

$K_3^*(1780)$

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

T-matrix pole $\sqrt{s} = (1754 \pm 13) - i\,(119 \pm 14)$ MeV
Mass $m = 1779 \pm 8$ MeV (S = 1.2)
Full width $\Gamma = 161 \pm 17$ MeV (S = 1.1)

$K_3^*(1780)$ DECAY MODES	Fraction (Γ_i/Γ)	Confidence level	p (MeV/c)
$K\rho$	(31 ± 9) %		616
$K^*(892)\pi$	(20 ± 5) %		657
$K\pi$	(18.8± 1.0) %		815
$K\eta$	(30 ±13) %		721
$K_2^*(1430)\pi$	< 16 %	95%	292

$K_2(1820)$ [x]

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

Mass $m = 1819 \pm 12$ MeV
Full width $\Gamma = 264 \pm 34$ MeV

$K_2(1820)$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$K\pi\pi$	seen	819
$K_2^*(1430)\pi$	seen	328
$K^*(892)\pi$	seen	683
$Kf_2(1270)$	seen	191
$K\omega$	seen	640
$K\phi$	seen	483

$K_0^*(1950)$

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

Mass $m = 1957 \pm 14$ MeV
Full width $\Gamma = 170 \pm 50$ MeV (S = 2.2)

$K_0^*(1950)$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$K^-\pi^+$	(52±14) %	911

$K_2^*(1980)$

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

Mass $m = 1990^{+60}_{-50}$ MeV (S = 2.8)
Full width $\Gamma = 348^{+50}_{-30}$ MeV (S = 1.3)

$K_2^*(1980)$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$K^*(892)\pi$	possibly seen	791
$K\rho$	possibly seen	762
$Kf_2(1270)$	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

$K_4^*(2045)$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$K\pi$	(9.9±1.2) %	960
$K^*(892)\pi\pi$	(9 ±5) %	804
$K^*(892)\pi\pi\pi$	(7 ±5) %	770
$\rho K\pi$	(5.7±3.2) %	744
$\omega K\pi$	(5.0±3.0) %	740
$\phi K\pi$	(2.8±1.4) %	597
$\phi K^*(892)$	(1.4±0.7) %	368

NOTES

[*a*] See the note in the $K^{\pm}$ Particle Listings.

[*b*] Neglecting photon channels. See, *e.g.*, A. Pais and S.B. Treiman, Phys. Rev. **D12**, 2744 (1975).

[*c*] The definition of the slope parameters of the $K \to\ 3\pi$ Dalitz plot is as follows (see also "Note on Dalitz Plot Parameters for $K \to\ 3\pi$ Decays" in the $K^{\pm}$ Particle Listings):

$$|M|^2 = 1 + g(s_3 - s_0)/m^2_{\pi^+} + \cdots .$$

[*d*] See the review on "Form Factors for Radiative Pion and Kaon Decays" for definitions and details.

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

[*f*] See the $K^{\pm}$ Particle Listings for the energy limits used in this measurement.

[*g*] Most of this radiative mode, the low-momentum γ part, is also included in the parent mode listed without γ's.

[*h*] Structure-dependent part.

[*i*] Direct-emission branching fraction.

[*j*] Derived from an analysis of neutrino-oscillation experiments.

[*k*] Violates angular-momentum conservation.

[*l*] Derived from measured values of ϕ_{+-}, ϕ_{00}, $|\eta|$, $|m_{K^0_L} - m_{K^0_S}|$, and $\tau_{K^0_S}$, as described in the introduction to "Tests of Conservation Laws."

[*n*] The *CP*-violation parameters are defined as follows (see also "Note on *CP* Violation in $K_S \to\ 3\pi$" and "Note on *CP* Violation in K^0_L Decay" in the Particle Listings):

$$\eta_{+-} = |\eta_{+-}|e^{i\phi_{+-}} = \frac{A(K^0_L \to\ \pi^+\pi^-)}{A(K^0_S \to\ \pi^+\pi^-)} = \epsilon\ +\ \epsilon'$$

$$\eta_{00} = |\eta_{00}|e^{i\phi_{00}} = \frac{A(K^0_L \to\ \pi^0\pi^0)}{A(K^0_S \to\ \pi^0\pi^0)} = \epsilon - 2\epsilon'$$

$$\delta = \frac{\Gamma(K^0_L \to\ \pi^-\ell^+\nu) - \Gamma(K^0_L \to\ \pi^+\ell^-\nu)}{\Gamma(K^0_L \to\ \pi^-\ell^+\nu) + \Gamma(K^0_L \to\ \pi^+\ell^-\nu)} ,$$

$$\mathrm{Im}(\eta_{+-0})^2 = \frac{\Gamma(K^0_S \to\ \pi^+\pi^-\pi^0)^{CP\ \text{viol.}}}{\Gamma(K^0_L \to\ \pi^+\pi^-\pi^0)} ,$$

$$\mathrm{Im}(\eta_{000})^2 = \frac{\Gamma(K^0_S \to\ \pi^0\pi^0\pi^0)}{\Gamma(K^0_L \to\ \pi^0\pi^0\pi^0)} .$$

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

[*o*] See the K^0_S Particle Listings for the energy limits used in this measurement.

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

[*q*] $\mathrm{Re}(\epsilon'/\epsilon) = \epsilon'/\epsilon$ to a very good approximation provided the phases satisfy CPT invariance.

[*r*] This mode includes gammas from inner bremsstrahlung but not the direct emission mode $K^0_L \to \pi^+\pi^-\gamma$(DE).

[*s*] See the K^0_L Particle Listings for the energy limits used in this measurement.

[*t*] Allowed by higher-order electroweak interactions.

[*u*] Violates CP in leading order. Test of direct CP violation since the indirect CP-violating and CP-conserving contributions are expected to be suppressed.

[*v*] Our estimate. See the Particle Listings for details.

[*x*] See our minireview under the $K_2(1770)$ in the 2004 edition of this *Review*.