

STRANGE MESONS

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

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

 K^\pm

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

$$\text{Mass } m = 493.677 \pm 0.016 \text{ MeV } [a] \quad (S = 2.8)$$

$$\text{Mean life } \tau = (1.2385 \pm 0.0024) \times 10^{-8} \text{ s} \quad (S = 2.0)$$

$$c\tau = 3.713 \text{ m}$$

Slope parameter g [b]

(See Particle Listings for quadratic coefficients an alternative parameterization related to $\pi\pi$ scattering)

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

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

$$K^\pm \rightarrow \pi^\pm \pi^+ \pi^- (g_+ - g_-) / (g_+ + g_-) = (1.5 \pm 2.9) \times 10^{-4}$$

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

$$K^\pm \rightarrow \pi^\pm \pi^0 \pi^0 (g_+ - g_-) / (g_+ + g_-) = (0.02 \pm 0.19)\%$$

 K^\pm decay form factors [c,d]

Assuming μ -e universality

$$\lambda_+(K_{\mu 3}^+) = \lambda_+(K_{e 3}^+) = (2.96 \pm 0.05) \times 10^{-2}$$

$$\lambda_0(K_{\mu 3}^+) = (1.96 \pm 0.12) \times 10^{-2}$$

Not assuming μ -e universality

$$\lambda_+(K_{e 3}^+) = (2.96 \pm 0.06) \times 10^{-2}$$

$$\lambda_+(K_{\mu 3}^+) = (2.96 \pm 0.17) \times 10^{-2}$$

$$\lambda_0(K_{\mu 3}^+) = (1.96 \pm 0.13) \times 10^{-2}$$

$K_{e 3}$ form factor quadratic fit

$$\lambda'_+(K_{e 3}^\pm) \text{ linear coeff.} = (2.48 \pm 0.17) \times 10^{-2}$$

$$\lambda''_+(K_{e 3}^\pm) \text{ quadratic coeff.} = (0.19 \pm 0.09) \times 10^{-2}$$

$$K_{e 3}^+ \quad |f_S/f_+| = (-0.3^{+0.8}_{-0.7}) \times 10^{-2}$$

$$K_{e 3}^+ \quad |f_T/f_+| = (-1.2 \pm 2.3) \times 10^{-2}$$

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

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

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

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

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

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

Charge Radius

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

CP violation parameters

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

T violation parameters

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

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

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

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			
$e^+ \nu_e$	$(1.55 \pm 0.07) \times 10^{-5}$		247
$\mu^+ \nu_{\mu}$	$(63.44 \pm 0.14) \%$	S=1.2	236
$\pi^0 e^+ \nu_e$	$(4.98 \pm 0.07) \%$	S=1.3	228
Called K_{e3}^+ .			
$\pi^0 \mu^+ \nu_{\mu}$	$(3.32 \pm 0.06) \%$	S=1.2	215
Called $K_{\mu 3}^+$.			
$\pi^0 \pi^0 e^+ \nu_e$	$(2.2 \pm 0.4) \times 10^{-5}$		206
$\pi^+ \pi^- e^+ \nu_e$	$(4.09 \pm 0.09) \times 10^{-5}$		203
$\pi^+ \pi^- \mu^+ \nu_{\mu}$	$(1.4 \pm 0.9) \times 10^{-5}$		151
$\pi^0 \pi^0 \pi^0 e^+ \nu_e$	$< 3.5 \times 10^{-6}$	CL=90%	135
Hadronic modes			
$\pi^+ \pi^0$	$(20.92 \pm 0.12) \%$	S=1.1	205
$\pi^+ \pi^0 \pi^0$	$(1.757 \pm 0.024) \%$	S=1.1	133
$\pi^+ \pi^+ \pi^-$	$(5.590 \pm 0.031) \%$	S=1.1	125
Leptonic and semileptonic modes with photons			
$\mu^+ \nu_{\mu} \gamma$	[e,f] $(6.2 \pm 0.8) \times 10^{-3}$		236
$\mu^+ \nu_{\mu} \gamma(\text{SD}^+)$	[g] $< 3.0 \times 10^{-5}$	CL=90%	—
$\mu^+ \nu_{\mu} \gamma(\text{SD}^+\text{INT})$	[g] $< 2.7 \times 10^{-5}$	CL=90%	—
$\mu^+ \nu_{\mu} \gamma(\text{SD}^- + \text{SD}^-\text{INT})$	[g] $< 2.6 \times 10^{-4}$	CL=90%	—
$e^+ \nu_e \gamma(\text{SD}^+)$	[g] $(1.52 \pm 0.23) \times 10^{-5}$		—
$e^+ \nu_e \gamma(\text{SD}^-)$	[g] $< 1.6 \times 10^{-4}$	CL=90%	—
$\pi^0 e^+ \nu_e \gamma$	[e,f] $(2.69 \pm 0.20) \times 10^{-4}$		228
$\pi^0 e^+ \nu_e \gamma(\text{SD})$	[g] $< 5.3 \times 10^{-5}$	CL=90%	228
$\pi^0 \mu^+ \nu_{\mu} \gamma$	[e,f] $(2.4 \pm 0.8) \times 10^{-5}$		215
$\pi^0 \pi^0 e^+ \nu_e \gamma$	$< 5 \times 10^{-6}$	CL=90%	206

Hadronic modes with photons

$\pi^+ \pi^0 \gamma$	[e,f]	$(2.75 \pm 0.15) \times 10^{-4}$	205
$\pi^+ \pi^0 \gamma$ (DE)	[f,h]	$(4.4 \pm 0.7) \times 10^{-6}$	205
$\pi^+ \pi^0 \pi^0 \gamma$	[e,f]	$(7.6 \begin{smallmatrix} +5.6 \\ -3.0 \end{smallmatrix}) \times 10^{-6}$	133
$\pi^+ \pi^+ \pi^- \gamma$	[e,f]	$(1.04 \pm 0.31) \times 10^{-4}$	125
$\pi^+ \gamma \gamma$	[f]	$(1.10 \pm 0.32) \times 10^{-6}$	227
$\pi^+ 3\gamma$	[f]	$< 1.0 \times 10^{-4}$ CL=90%	227

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

$e^+ \nu_e \nu \bar{\nu}$		$< 6 \times 10^{-5}$ CL=90%	247
$\mu^+ \nu_\mu \nu \bar{\nu}$		$< 6.0 \times 10^{-6}$ CL=90%	236
$e^+ \nu_e e^+ e^-$		$(2.48 \pm 0.20) \times 10^{-8}$	247
$\mu^+ \nu_\mu e^+ e^-$		$(7.06 \pm 0.31) \times 10^{-8}$	236
$e^+ \nu_e \mu^+ \mu^-$		$(1.7 \pm 0.5) \times 10^{-8}$	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	$< 1.2 \times 10^{-8}$ CL=90%	203
$\pi^+ \pi^+ \mu^- \bar{\nu}_\mu$	SQ	$< 3.0 \times 10^{-6}$ CL=95%	151
$\pi^+ e^+ e^-$	S1	$(2.88 \pm 0.13) \times 10^{-7}$	227
$\pi^+ \mu^+ \mu^-$	S1	$(8.1 \pm 1.4) \times 10^{-8}$ S=2.7	172
$\pi^+ \nu \bar{\nu}$	S1	$(1.5 \begin{smallmatrix} +1.3 \\ -0.9 \end{smallmatrix}) \times 10^{-10}$	227
$\pi^+ \pi^0 \nu \bar{\nu}$	S1	$< 4.3 \times 10^{-5}$ CL=90%	205
$\mu^- \nu e^+ e^+$	LF	$< 2.0 \times 10^{-8}$ CL=90%	236
$\mu^+ \nu_e$	LF	[i] $< 4 \times 10^{-3}$ CL=90%	236
$\pi^+ \mu^+ e^-$	LF	$< 1.3 \times 10^{-11}$ CL=90%	214
$\pi^+ \mu^- e^+$	LF	$< 5.2 \times 10^{-10}$ CL=90%	214
$\pi^- \mu^+ e^+$	L	$< 5.0 \times 10^{-10}$ CL=90%	214
$\pi^- e^+ e^+$	L	$< 6.4 \times 10^{-10}$ CL=90%	227
$\pi^- \mu^+ \mu^+$	L	[i] $< 3.0 \times 10^{-9}$ CL=90%	172
$\mu^+ \bar{\nu}_e$	L	[i] $< 3.3 \times 10^{-3}$ CL=90%	236
$\pi^0 e^+ \bar{\nu}_e$	L	$< 3 \times 10^{-3}$ CL=90%	228
$\pi^+ \gamma$	[j]	$< 2.3 \times 10^{-9}$ CL=90%	227

K^0

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

50% K_S , 50% K_L

Mass $m = 497.648 \pm 0.022$ MeV

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

Mean Square Charge Radius

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

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

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

CPT-violation parameters [c]

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

$$\text{Im } \delta = (-0.2 \pm 2.0) \times 10^{-5}$$

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

$$\text{Re}(x_-), K_{e3} \text{ parameter} = (-0.8 \pm 2.5) \times 10^{-3}$$

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

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

Tests of $\Delta S = \Delta Q$

$$\text{Re}(x_+), K_{e3} \text{ parameter} = (-0.8 \pm 3.1) \times 10^{-3}$$



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

Mean life $\tau = (0.8953 \pm 0.0005) \times 10^{-10}$ s (S = 1.1) Assuming CPT

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

$$c\tau = 2.6842 \text{ cm} \quad \text{Assuming CPT}$$

CP-violation parameters [l]

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

$$\text{Im}(\eta_{000}) = (-0.1 \pm 1.6) \times 10^{-2}$$

$$|\eta_{000}| = |A(K_S^0 \rightarrow 3\pi^0)/A(K_L^0 \rightarrow 3\pi^0)| < 0.018, \text{ CL} = 90\%$$

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

K_S^0 DECAY MODES	Fraction (Γ_i/Γ)	Confidence level ($\frac{P}{\text{MeV}/c}$)
Hadronic modes		
$\pi^0\pi^0$	$(30.69 \pm 0.05)\%$	209
$\pi^+\pi^-$	$(69.20 \pm 0.05)\%$	206
$\pi^+\pi^-\pi^0$	$(3.5 \pm 1.1 \text{ } ^{+1.1}_{-0.9}) \times 10^{-7}$	133
Modes with photons or $l\bar{l}$ pairs		
$\pi^+\pi^-\gamma$	[e,m] $(1.79 \pm 0.05) \times 10^{-3}$	206
$\pi^+\pi^-\text{e}^+\text{e}^-$	$(4.69 \pm 0.30) \times 10^{-5}$	206
$\pi^0\gamma\gamma$	[m] $(4.9 \pm 1.8) \times 10^{-8}$	231
$\gamma\gamma$	$(2.84 \pm 0.07) \times 10^{-6}$	249

Semileptonic modes

$$\pi^\pm e^\mp \nu_e \quad [n] \quad (7.04 \pm 0.09) \times 10^{-4} \quad 229$$

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

$3\pi^0$	CP	< 1.2	$\times 10^{-7}$	90%	139
$\mu^+ \mu^-$	S1	< 3.2	$\times 10^{-7}$	90%	225
$e^+ e^-$	S1	< 1.4	$\times 10^{-7}$	90%	249
$\pi^0 e^+ e^-$	S1	[m]	$(3.0 \begin{smallmatrix} +1.5 \\ -1.2 \end{smallmatrix}) \times 10^{-9}$		231
$\pi^0 \mu^+ \mu^-$	S1		$(2.9 \begin{smallmatrix} +1.5 \\ -1.2 \end{smallmatrix}) \times 10^{-9}$		177



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

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

$$= (0.5292 \pm 0.0009) \times 10^{10} \hbar s^{-1} \quad (S = 1.2) \quad \text{Assuming } CPT$$

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

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

$$\text{Mean life } \tau = (5.114 \pm 0.021) \times 10^{-8} \text{ s}$$

$$c\tau = 15.33 \text{ m}$$

Slope parameter g ^[b]

(See Particle Listings for quadratic coefficients)

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

K_L decay form factors ^[c]

Linear parametrization assuming μ -e universality

$$\lambda_+(K_{\mu 3}^0) = \lambda_+(K_{e 3}^0) = (2.84 \pm 0.04) \times 10^{-2}$$

$$\lambda_0(K_{\mu 3}^0) = (1.64 \pm 0.11) \times 10^{-2}$$

Quadratic parametrization assuming μ -e universality

$$\lambda'_+(K_{\mu 3}^0) = \lambda'_+(K_{e 3}^0) = (2.42 \pm 0.14) \times 10^{-2} \quad (S = 1.3)$$

$$\lambda''_+(K_{\mu 3}^0) = \lambda''_+(K_{e 3}^0) = (0.18 \pm 0.05) \times 10^{-2} \quad (S = 1.1)$$

$$\lambda_0(K_{\mu 3}^0) = (1.46 \pm 0.13) \times 10^{-2}$$

Pole parametrization assuming μ - e universality

$$M_V^\mu (K_{\mu 3}^0) = M_V^e (K_{e 3}^0) = 877 \pm 5 \text{ MeV} \quad (S = 1.1)$$

$$M_S^\mu (K_{\mu 3}^0) = 1187 \pm 50$$

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

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

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

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

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

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

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

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

CP-violation parameters [1]

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

$$|\eta_{00}| = (2.225 \pm 0.007) \times 10^{-3}$$

$$|\eta_{+-}| = (2.236 \pm 0.007) \times 10^{-3}$$

$$|\epsilon| = (2.232 \pm 0.007) \times 10^{-3}$$

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

$$\text{Re}(\epsilon'/\epsilon) = (1.66 \pm 0.26) \times 10^{-3} \text{ [o]} \quad (S = 1.6)$$

Assuming *CPT*

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

$$\phi_{00} = (43.50 \pm 0.06)^\circ \quad (S = 1.2)$$

$$\phi_\epsilon = \phi_{\text{SW}} = (43.51 \pm 0.05)^\circ \quad (S = 1.1)$$

Not assuming *CPT*

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

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

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

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

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

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

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

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

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

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

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

T-violation parameters

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

CPT invariance tests

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

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

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

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

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

K_L^0 DECAY MODES	Fraction (Γ_i/Γ)	Scale factor/ Confidence level	ρ (MeV/c)
Semileptonic modes			
$\pi^\pm e^\mp \nu_e$ Called K_{e3}^0 .	[n] (40.53 \pm 0.15) %	S=2.1	229
$\pi^\pm \mu^\mp \nu_\mu$ Called $K_{\mu 3}^0$.	[n] (27.02 \pm 0.07) %		216
$(\pi \mu \text{atom})\nu$	(1.05 \pm 0.11) $\times 10^{-7}$		188
$\pi^0 \pi^\pm e^\mp \nu$	[n] (5.20 \pm 0.11) $\times 10^{-5}$		207
Hadronic modes, including Charge conjugation \times Parity Violating (CPV) modes			
$3\pi^0$	(19.56 \pm 0.14) %	S=1.9	139
$\pi^+ \pi^- \pi^0$	(12.56 \pm 0.05) %		133
$\pi^+ \pi^-$	CPV (1.976 \pm 0.008) $\times 10^{-3}$		206
$\pi^0 \pi^0$	CPV (8.69 \pm 0.04) $\times 10^{-4}$	S=1.1	209
Semileptonic modes with photons			
$\pi^\pm e^\mp \nu_e \gamma$	[e, n, p] (3.79 \pm 0.08) $\times 10^{-3}$		229
$\pi^\pm \mu^\mp \nu_\mu \gamma$	(5.64 \pm 0.23) $\times 10^{-4}$		216
Hadronic modes with photons or $\ell\bar{\ell}$ pairs			
$\pi^0 \pi^0 \gamma$	< 5.6 $\times 10^{-6}$		209
$\pi^+ \pi^- \gamma$	[e, p] (4.17 \pm 0.15) $\times 10^{-5}$		206
$\pi^0 2\gamma$	[p] (1.49 \pm 0.08) $\times 10^{-6}$	S=2.0	231
$\pi^0 \gamma e^+ e^-$	(2.3 \pm 0.4) $\times 10^{-8}$		231
Other modes with photons or $\ell\bar{\ell}$ pairs			
2γ	(5.48 \pm 0.05) $\times 10^{-4}$	S=1.2	249
3γ	< 2.4 $\times 10^{-7}$	CL=90%	249
$e^+ e^- \gamma$	(10.0 \pm 0.5) $\times 10^{-6}$	S=1.5	249
$\mu^+ \mu^- \gamma$	(3.59 \pm 0.11) $\times 10^{-7}$	S=1.3	225
$e^+ e^- \gamma \gamma$	[p] (5.95 \pm 0.33) $\times 10^{-7}$		249
$\mu^+ \mu^- \gamma \gamma$	[p] (1.0 $^{+0.8}_{-0.6}$) $\times 10^{-8}$		225

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

$\mu^+ \mu^-$	$S1$	$(6.87 \pm 0.11) \times 10^{-9}$	225
$e^+ e^-$	$S1$	$(9 \begin{smallmatrix} +6 \\ -4 \end{smallmatrix}) \times 10^{-12}$	249
$\pi^+ \pi^- e^+ e^-$	$S1$ [p]	$(3.11 \pm 0.19) \times 10^{-7}$	206
$\pi^0 \pi^0 e^+ e^-$	$S1$	$< 6.6 \times 10^{-9}$ CL=90%	209
$\mu^+ \mu^- e^+ e^-$	$S1$	$(2.69 \pm 0.27) \times 10^{-9}$	225
$e^+ e^- e^+ e^-$	$S1$	$(3.56 \pm 0.21) \times 10^{-8}$	249
$\pi^0 \mu^+ \mu^-$	$CP, S1$ [q]	$< 3.8 \times 10^{-10}$ CL=90%	177
$\pi^0 e^+ e^-$	$CP, S1$ [q]	$< 2.8 \times 10^{-10}$ CL=90%	231
$\pi^0 \nu \bar{\nu}$	$CP, S1$ [r]	$< 5.9 \times 10^{-7}$ CL=90%	231
$e^\pm \mu^\mp$	LF [n]	$< 4.7 \times 10^{-12}$ CL=90%	238
$e^\pm e^\pm \mu^\mp \mu^\mp$	LF [n]	$< 4.12 \times 10^{-11}$ CL=90%	225
$\pi^0 \mu^\pm e^\mp$	LF [n]	$< 6.2 \times 10^{-9}$ CL=90%	217

$K^*(892)$

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

$K^*(892)^\pm$ mass $m = 891.66 \pm 0.26$ MeV
 $K^*(892)^0$ mass $m = 896.00 \pm 0.25$ MeV (S = 1.4)
 $K^*(892)^\pm$ full width $\Gamma = 50.8 \pm 0.9$ MeV
 $K^*(892)^0$ full width $\Gamma = 50.3 \pm 0.6$ MeV (S = 1.1)

$K^*(892)$ DECAY MODES	Fraction (Γ_i/Γ)	Confidence level	p (MeV/c)
$K \pi$	~ 100 %		289
$K^0 \gamma$	$(2.31 \pm 0.20) \times 10^{-3}$		307
$K^\pm \gamma$	$(9.9 \pm 0.9) \times 10^{-4}$		309
$K \pi \pi$	$< 7 \times 10^{-4}$	95%	223

$K_1(1270)$

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

Mass $m = 1272 \pm 7$ MeV [s]
 Full width $\Gamma = 90 \pm 20$ MeV [s]

$K_1(1270)$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$K \rho$	$(42 \pm 6) \%$	45
$K_0^*(1430) \pi$	$(28 \pm 4) \%$	†
$K^*(892) \pi$	$(16 \pm 5) \%$	302
$K \omega$	$(11.0 \pm 2.0) \%$	†
$K f_0(1370)$	$(3.0 \pm 2.0) \%$	†
γK^0	seen	539

$K_1(1400)$

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

Mass $m = 1402 \pm 7$ MeV

Full width $\Gamma = 174 \pm 13$ MeV ($S = 1.6$)

$K_1(1400)$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$K^*(892)\pi$	(94 \pm 6) %	402
$K\rho$	(3.0 \pm 3.0) %	292
$Kf_0(1370)$	(2.0 \pm 2.0) %	†
$K\omega$	(1.0 \pm 1.0) %	284
$K_0^*(1430)\pi$	not seen	†
γK^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 ($S = 1.1$)

$K^*(1410)$ DECAY MODES	Fraction (Γ_i/Γ)	Confidence level	p (MeV/c)
$K^*(892)\pi$	> 40 %	95%	410
$K\pi$	(6.6 \pm 1.3) %		612
$K\rho$	< 7 %	95%	305
γK^0	seen		619

$K_0^*(1430) [t]$

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

Mass $m = 1414 \pm 6$ MeV

Full width $\Gamma = 290 \pm 21$ MeV

$K_0^*(1430)$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$K\pi$	(93 \pm 10) %	613

$K_2^*(1430)$

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

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

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

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

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

$K_2^*(1430)$ DECAY MODES	Fraction (Γ_i/Γ)	Scale factor/ Confidence level	p (MeV/c)
$K\pi$	$(49.9 \pm 1.2) \%$		619
$K^*(892)\pi$	$(24.7 \pm 1.5) \%$		419
$K^*(892)\pi\pi$	$(13.4 \pm 2.2) \%$		372
$K\rho$	$(8.7 \pm 0.8) \%$	S=1.2	318
$K\omega$	$(2.9 \pm 0.8) \%$		311
$K^+\gamma$	$(2.4 \pm 0.5) \times 10^{-3}$	S=1.1	627
$K\eta$	$(1.5^{+3.4}_{-1.0}) \times 10^{-3}$	S=1.3	487
$K\omega\pi$	$< 7.2 \times 10^{-4}$	CL=95%	100
$K^0\gamma$	$< 9 \times 10^{-4}$	CL=90%	626

$K^*(1680)$

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

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

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

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

$K_2(1770)$ ^[u]

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

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
$K_2^*(1430)\pi$	dominant	288
$K^*(892)\pi$	seen	654
$Kf_2(1270)$	seen	53
$K\phi$	seen	441
$K\omega$	seen	607

$K_3^*(1780)$

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

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

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

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

 $K_2(1820)$ [v]

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

Mass $m = 1816 \pm 13$ MeVFull width $\Gamma = 276 \pm 35$ MeV

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

 $K_4^*(2045)$

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

Mass $m = 2045 \pm 9$ MeV ($S = 1.1$)Full width $\Gamma = 198 \pm 30$ MeV

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

NOTES

- [a] See the note in the K^\pm Particle Listings.
- [b] The definition of the slope parameter g of the $K \rightarrow 3\pi$ Dalitz plot is as follows (see also “Note on Dalitz Plot Parameters for $K \rightarrow 3\pi$ Decays” in the K^\pm Particle Listings):
- $$|M|^2 = 1 + g(s_3 - s_0)/m_{\pi^+}^2 + \dots$$
- [c] For more details and definitions of parameters see the Particle Listings.
- [d] See the “Note on $\pi^\pm \rightarrow \ell^\pm \nu \gamma$ and $K^\pm \rightarrow \ell^\pm \nu \gamma$ Form Factors” in the π^\pm Particle Listings for definitions and details.
- [e] Most of this radiative mode, the low-momentum γ part, is also included in the parent mode listed without γ 's.
- [f] See the K^\pm Particle Listings for the energy limits used in this measurement.
- [g] Structure-dependent part.
- [h] Direct-emission branching fraction.
- [i] Derived from an analysis of neutrino-oscillation experiments.
- [j] Violates angular-momentum conservation.
- [k] Derived from measured values of ϕ_{+-} , ϕ_{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.”
- [l] 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 $\text{Re}(\eta_{000}) \simeq 0$.

- [*m*] See the K_S^0 Particle Listings for the energy limits used in this measurement.
- [*n*] The value is for the sum of the charge states or particle/antiparticle states indicated.
- [*o*] $\text{Re}(\epsilon'/\epsilon) = \epsilon'/\epsilon$ to a very good approximation provided the phases satisfy *CPT* invariance.
- [*p*] See the K_L^0 Particle Listings for the energy limits used in this measurement.
- [*q*] Allowed by higher-order electroweak interactions.
- [*r*] Violates *CP* in leading order. Test of direct *CP* violation since the indirect *CP*-violating and *CP*-conserving contributions are expected to be suppressed.
- [*s*] This is only an educated guess; the error given is larger than the error on the average of the published values. See the Particle Listings for details.
- [*t*] See the "Note on $f_0(1370)$ " in the $f_0(1370)$ Particle Listings and in the 1994 edition.
- [*u*] See the note in the $L(1770)$ Particle Listings in Reviews of Modern Physics **56** No. 2 Pt. II (1984), p. S200. See also the "Note on $K_2(1770)$ and the $K_2(1820)$ " in the $K_2(1770)$ Particle Listings .
- [*v*] See the "Note on $K_2(1770)$ and the $K_2(1820)$ " in the $K_2(1770)$ Particle Listings .