CITATION: R.M. Barnett *et al.* Physical Review D54, 1 (1996) and 1997 off-year partial update for the 1998 edition (URL: http://pdg.lbl.gov)

$K^{\pm}$ – THIS IS PART 1 OF 3

To reduce the size of this section's PostScript file, we have divided it into three PostScript files. We present the following index:

PART 1

PART 2

PART 3

$K^{\pm}$

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

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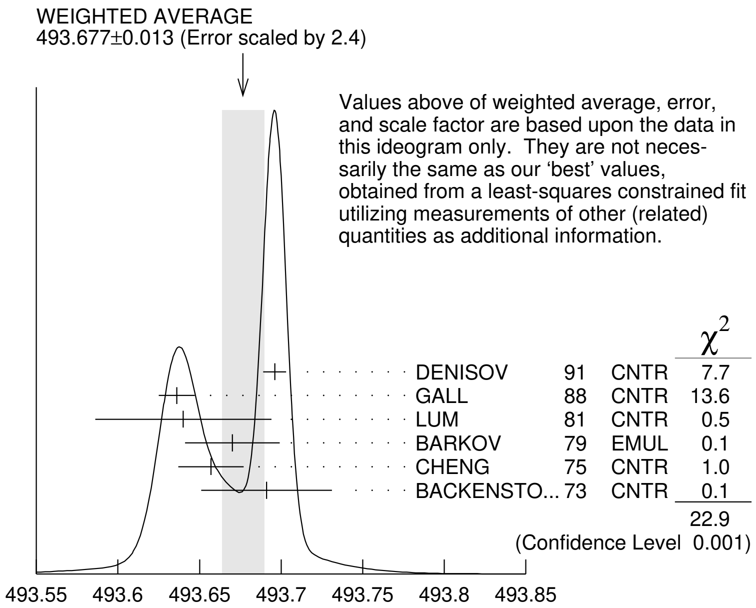
$K^{\pm}$ MASS

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*CHG*	*COMMENT*
493.677±0.016 OUR FIT	Error includes scale factor of 2.8.				
493.677±0.013 OUR AVERAGE	Error includes scale factor of 2.4. See the ideogram below.				
493.696±0.007	[1] DENISOV	91	CNTR	−	Kaonic atoms
493.636±0.011	[2] GALL	88	CNTR	−	Kaonic atoms
493.640±0.054	LUM	81	CNTR	−	Kaonic atoms
493.670±0.029	BARKOV	79	EMUL	±	$e^+ e^- \rightarrow K^+ K^-$
493.657±0.020	[2] CHENG	75	CNTR	−	Kaonic atoms
493.691±0.040	BACKENSTO...	73	CNTR	−	Kaonic atoms
• • • We do not use the following data for averages, fits, limits, etc. • • •					
493.631±0.007	GALL	88	CNTR	−	K^- Pb (9→ 8)
493.675±0.026	GALL	88	CNTR	−	K^- Pb (11→ 10)
493.709±0.073	GALL	88	CNTR	−	K^- W (9→ 8)
493.806±0.095	GALL	88	CNTR	−	K^- W (11→ 10)
493.640±0.022±0.008	[3] CHENG	75	CNTR	−	K^- Pb (9→ 8)
493.658±0.019±0.012	[3] CHENG	75	CNTR	−	K^- Pb (10→ 9)
493.638±0.035±0.016	[3] CHENG	75	CNTR	−	K^- Pb (11→ 10)
493.753±0.042±0.021	[3] CHENG	75	CNTR	−	K^- Pb (12→ 11)
493.742±0.081±0.027	[3] CHENG	75	CNTR	−	K^- Pb (13→ 12)
493.662±0.19	KUNSELMAN	74	CNTR	−	Kaonic atoms
493.78 ±0.17	GREINER	65	EMUL	+	
493.7 ±0.3	BARKAS	63	EMUL	−	
493.9 ±0.2	COHEN	57	RVUE	+	

[1] Error increased from 0.0059 based on the error analysis in IVANOV 92.

[2] This value is the authors' combination of all of the separate transitions listed for this paper.

[3] The CHENG 75 values for separate transitions were calculated from their Table 7 transition energies. The first error includes a 20% systematic error in the noncircular contaminant shift. The second error is due to a ±5 eV uncertainty in the theoretical transition energies.



$m_{K^\pm}$ (MeV)

$m_{K^+} - m_{K^-}$

Test of *CPT*.

VALUE (MeV)	*EVTS*	*DOCUMENT ID*		*TECN*	*CHG*
-0.032 ± 0.090	1.5M	[4] FORD	72	ASPK	$\pm$

[4] FORD 72 uses $m_{\pi^+} - m_{\pi^-} = +28 \pm 70$ keV.

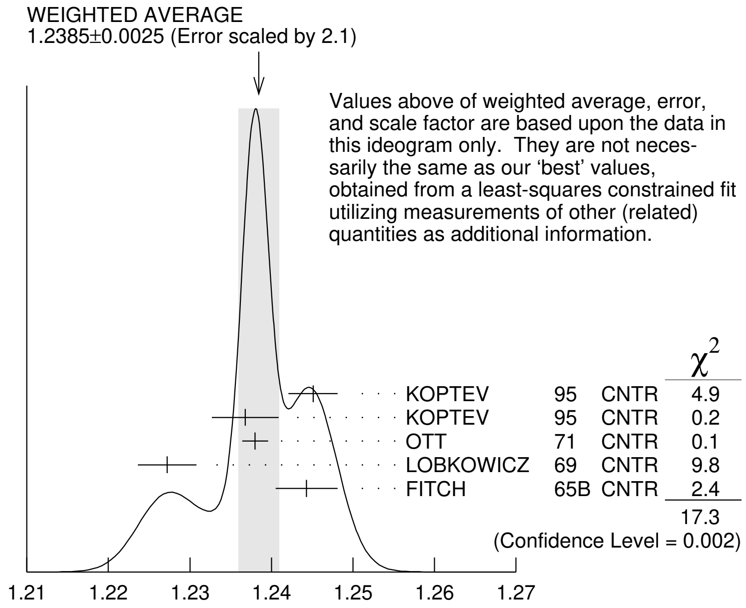
$K^\pm$ MEAN LIFE

VALUE (10^{-8} s)	*EVTS*	*DOCUMENT ID*		*TECN*	*CHG*	*COMMENT*
1.2386 ± 0.0024 OUR FIT	Error includes scale factor of 2.0.					
1.2385 ± 0.0025 OUR AVERAGE	Error includes scale factor of 2.1. See the ideogram below.					
1.2451 ± 0.0030	250k	KOPTEV	95	CNTR		K at rest, U target
1.2368 ± 0.0041	150k	KOPTEV	95	CNTR		K at rest, Cu target
1.2380 ± 0.0016	3M	OTT	71	CNTR	+	K at rest
1.2272 ± 0.0036		LOBKOWICZ	69	CNTR	+	K in flight
1.2443 ± 0.0038		FITCH	65B	CNTR	+	K at rest

• • • We do not use the following data for averages, fits, limits, etc. • • •

1.2415 ± 0.0024	400k	[5] KOPTEV	95	CNTR		K at rest
1.221 ± 0.011		FORD	67	CNTR	$\pm$	
1.231 ± 0.011		BOYARSKI	62	CNTR	$+$	
$1.25^{+0.22}_{-0.17}$		BARKAS	61	EMUL		
$1.27^{+0.36}_{-0.23}$	51	BHOWMIK	61	EMUL		
1.31 ± 0.08	293	NORDIN	61	HBC	$-$	
1.24 ± 0.07		NORDIN	61	RVUE	$-$	
1.38 ± 0.24	33	FREDEN	60B	EMUL		
1.21 ± 0.06		BURROWES	59	CNTR		
1.60 ± 0.3	52	EISENBERG	58	EMUL		
$0.95^{+0.36}_{-0.25}$		ILOFF	56	EMUL		

[5] KOPTEV 95 report this weighted average of their U-target and Cu-target results, where they have weighted by $1/\sigma$ rather than $1/\sigma^2$.



$K^{\pm}$ mean life (10^{-8} s)

$(\tau_{K^+} - \tau_{K^-}) / \tau_{\text{average}}$

This quantity is a measure of *CPT* invariance in weak interactions.

VALUE (%)	*DOCUMENT ID*		*TECN*
0.11 ±0.09 OUR AVERAGE	Error includes scale factor of 1.2.		
0.090 ± 0.078	LOBKOWICZ	69	CNTR
0.47 ± 0.30	FORD	67	CNTR

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K^+ DECAY MODES

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

	Mode		Fraction (Γ_i/Γ)	Scale factor/ Confidence level
Γ_1	$\mu^+\nu_\mu$		(63.51 ± 0.18) %	S=1.3
Γ_2	$e^+\nu_e$		$(1.55\pm0.07)\times10^{-5}$	
Γ_3	$\pi^+\pi^0$		(21.16 ± 0.14) %	S=1.1
Γ_4	$\pi^+\pi^+\pi^-$		(5.59 ± 0.05) %	S=1.8
Γ_5	$\pi^+\pi^0\pi^0$		(1.73 ± 0.04) %	S=1.2
Γ_6	$\pi^0\mu^+\nu_\mu$		(3.18 ± 0.08) %	S=1.5
	Called $K^+_{\mu3}$.			
Γ_7	$\pi^0 e^+\nu_e$		(4.82 ± 0.06) %	S=1.3
	Called K^+_{e3}.			
Γ_8	$\pi^0\pi^0 e^+\nu_e$		$(2.1\pm0.4)\times10^{-5}$	
Γ_9	$\pi^+\pi^- e^+\nu_e$		$(3.91\pm0.17)\times10^{-5}$	
Γ_{10}	$\pi^+\pi^-\mu^+\nu_\mu$		$(1.4\pm0.9)\times10^{-5}$	
Γ_{11}	$\pi^0\pi^0\pi^0 e^+\nu_e$		$< 3.5\times10^{-6}$	CL=90%
Γ_{12}	$\pi^+\gamma\gamma$	[a]	$< 1\times10^{-6}$	CL=90%
Γ_{13}	$\pi^+ 3\gamma$	[a]	$< 1.0\times10^{-4}$	CL=90%
Γ_{14}	$\mu^+\nu_\mu\nu\overline{\nu}$		$< 6.0\times10^{-6}$	CL=90%
Γ_{15}	$e^+\nu_e\nu\overline{\nu}$		$< 6\times10^{-5}$	CL=90%
Γ_{16}	$\mu^+\nu_\mu e^+e^-$		$(1.3\pm0.4)\times10^{-7}$	
Γ_{17}	$e^+\nu_e e^+e^-$		$(3.0\ ^{+3.0}_{-1.5})\times10^{-8}$	
Γ_{18}	$\mu^+\nu_\mu\mu^+\mu^-$		$< 4.1\times10^{-7}$	CL=90%
Γ_{19}	$\mu^+\nu_\mu\gamma$	[a,b]	$(5.50\pm0.28)\times10^{-3}$	
Γ_{20}	$\pi^+\pi^0\gamma$	[a,b]	$(2.75\pm0.15)\times10^{-4}$	
Γ_{21}	$\pi^+\pi^0\gamma$(DE)	[a,c]	$(1.8\pm0.4)\times10^{-5}$	
Γ_{22}	$\pi^+\pi^+\pi^-\gamma$	[a,b]	$(1.04\pm0.31)\times10^{-4}$	
Γ_{23}	$\pi^+\pi^0\pi^0\gamma$	[a,b]	$(7.5\ ^{+5.5}_{-3.0})\times10^{-6}$	
Γ_{24}	$\pi^0\mu^+\nu_\mu\gamma$	[a,b]	$< 6.1\times10^{-5}$	CL=90%
Γ_{25}	$\pi^0 e^+\nu_e\gamma$	[a,b]	$(2.62\pm0.20)\times10^{-4}$	
Γ_{26}	$\pi^0 e^+\nu_e\gamma$(SD)	[d]	$< 5.3\times10^{-5}$	CL=90%
Γ_{27}	$\pi^0\pi^0 e^+\nu_e\gamma$		$< 5\times10^{-6}$	CL=90%

Lepton Family number (*LF*), Lepton number (*L*), $\Delta S = \Delta Q$ (*SQ*) violating modes, or $\Delta S = 1$ weak neutral current (*S1*) modes

Γ_{28}	$\pi^+ \pi^+ e^- \overline{\nu}_e$	*SQ*		$<$	1.2	$\times 10^{-8}$	CL=90%
Γ_{29}	$\pi^+ \pi^+ \mu^- \overline{\nu}_\mu$	*SQ*		$<$	3.0	$\times 10^{-6}$	CL=95%
Γ_{30}	$\pi^+ e^+ e^-$	*S1*			(2.74$\pm$0.23)	$\times 10^{-7}$	
Γ_{31}	$\pi^+ \mu^+ \mu^-$	*S1*		$<$	2.3	$\times 10^{-7}$	CL=90%
Γ_{32}	$\pi^+ \nu \overline{\nu}$	*S1*		$<$	2.4	$\times 10^{-9}$	CL=90%
Γ_{33}	$\mu^- \nu e^+ e^+$	*LF*		$<$	2.0	$\times 10^{-8}$	CL=90%
Γ_{34}	$\mu^+ \nu_e$	*LF*	[e]	$<$	4	$\times 10^{-3}$	CL=90%
Γ_{35}	$\pi^+ \mu^+ e^-$	*LF*		$<$	2.1	$\times 10^{-10}$	CL=90%
Γ_{36}	$\pi^+ \mu^- e^+$	*LF*		$<$	7	$\times 10^{-9}$	CL=90%
Γ_{37}	$\pi^- \mu^+ e^+$	*L*		$<$	7	$\times 10^{-9}$	CL=90%
Γ_{38}	$\pi^- e^+ e^+$	*L*		$<$	1.0	$\times 10^{-8}$	CL=90%
Γ_{39}	$\pi^- \mu^+ \mu^+$	*L*	[e]	$<$	1.5	$\times 10^{-4}$	CL=90%
Γ_{40}	$\mu^+ \overline{\nu}_e$	*L*	[e]	$<$	3.3	$\times 10^{-3}$	CL=90%
Γ_{41}	$\pi^0 e^+ \overline{\nu}_e$	*L*		$<$	3	$\times 10^{-3}$	CL=90%
Γ_{42}	$\pi^+ \gamma$						

[*a*] See the Particle Listings below for the energy limits used in this measurement.

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

[*c*] Direct-emission branching fraction.

[*d*] Structure-dependent part.

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

CONSTRAINED FIT INFORMATION

An overall fit to the mean life, 2 decay rate, and 20 branching ratios uses 60 measurements and one constraint to determine 8 parameters. The overall fit has a χ^2 = 78.1 for 53 degrees of freedom.

The following *off-diagonal* array elements are the correlation coefficients $\left\langle\delta p_i \delta p_j\right\rangle/(\delta p_i \cdot \delta p_j)$, in percent, from the fit to parameters p_i, including the branching fractions, $x_i \equiv \Gamma_i/\Gamma_{\text{total}}$. The fit constrains the x_i whose labels appear in this array to sum to one.

x_3	−58						
x_4	−41	−12					
x_5	−27	−4	21				
x_6	−48	−17	14	2			
x_7	−50	−16	34	6	39		
x_8	−3	−1	2	0	2	6	
Γ	7	2	−18	−4	−2	−6	0
	x_1	x_3	x_4	x_5	x_6	x_7	x_8

	Mode	Rate (10^8 s^{-1})	Scale factor
Γ_1	$\mu^+\nu_\mu$	0.5128 ±0.0018	1.5
Γ_3	$\pi^+\pi^0$	0.1708 ±0.0012	1.1
Γ_4	$\pi^+\pi^+\pi^-$	0.0452 ±0.0004	1.8
Γ_5	$\pi^+\pi^0\pi^0$	0.01399±0.00032	1.2
Γ_6	$\pi^0\mu^+\nu_\mu$ Called $K^+_{\mu 3}$.	0.0257 ±0.0006	1.5
Γ_7	$\pi^0 e^+\nu_e$ Called K^+_{e3}.	0.0389 ±0.0005	1.3
Γ_8	$\pi^0\pi^0 e^+\nu_e$	$(1.69\ {}^{+0.34}_{-0.29}) \times 10^{-5}$	

$K^\pm$ DECAY RATES

$\Gamma(\mu^+\nu_\mu)$ $\qquad\qquad$ Γ_1

VALUE (10^6 s^{-1})	*DOCUMENT ID*		*TECN*	*CHG*
51.28±0.18 OUR FIT Error includes scale factor of 1.5.				
51.2 ±0.8	FORD	67	CNTR	±

$\Gamma(\pi^+\pi^+\pi^-)$ — Γ_4

VALUE (10^6 s^{-1})	*EVTS*	*DOCUMENT ID*		*TECN*	*CHG*
4.52 ±0.04 OUR FIT Error includes scale factor of 1.8.					
4.511±0.024		[6] FORD	70	ASPK	
• • • We do not use the following data for averages, fits, limits, etc. • • •					
4.529±0.032	3.2M	[6] FORD	70	ASPK	
4.496±0.030		[6] FORD	67	CNTR	±

[6] First FORD 70 value is second FORD 70 combined with FORD 67.

$(\Gamma(K^+) - \Gamma(K^-)) / \Gamma(K)$

$K^\pm \rightarrow \mu^\pm \nu_\mu$ RATE DIFFERENCE/AVERAGE

Test of *CPT* conservation.

VALUE (%)	*DOCUMENT ID*		*TECN*
−0.54±0.41	FORD	67	CNTR

$K^\pm \rightarrow \pi^\pm \pi^+ \pi^-$ RATE DIFFERENCE/AVERAGE

Test of *CP* conservation.

VALUE (%)	*EVTS*	*DOCUMENT ID*		*TECN*	*CHG*
0.07±0.12 OUR AVERAGE					
0.08±0.12		[7] FORD	70	ASPK	
−0.50±0.90		FLETCHER	67	OSPK	
• • • We do not use the following data for averages, fits, limits, etc. • • •					
−0.02±0.16		[8] SMITH	73	ASPK	±
0.10±0.14	3.2M	[7] FORD	70	ASPK	
−0.04±0.21		[7] FORD	67	CNTR	

[7] First FORD 70 value is second FORD 70 combined with FORD 67.
[8] SMITH 73 value of $K^\pm \rightarrow \pi^\pm \pi^+ \pi^-$ rate difference is derived from SMITH 73 value of $K^\pm \rightarrow \pi^\pm 2\pi^0$ rate difference.

$K^\pm \rightarrow \pi^\pm \pi^0 \pi^0$ RATE DIFFERENCE/AVERAGE

Test of *CP* conservation.

VALUE (%)	*EVTS*	*DOCUMENT ID*		*TECN*	*CHG*
0.0 ±0.6 OUR AVERAGE					
0.08±0.58		SMITH	73	ASPK	±
−1.1 ±1.8	1802	HERZO	69	OSPK	

$K^\pm \rightarrow \pi^\pm \pi^0$ RATE DIFFERENCE/AVERAGE

Test of *CPT* conservation.

VALUE (%)	*DOCUMENT ID*		*TECN*
0.8±1.2	HERZO	69	OSPK

$K^\pm \rightarrow \pi^\pm \pi^0 \gamma$ RATE DIFFERENCE/AVERAGE

Test of *CP* conservation.

VALUE (%)	*EVTS*	*DOCUMENT ID*		*TECN*	*CHG*	*COMMENT*
0.9± 3.3 OUR AVERAGE						
0.8± 5.8	2461	SMITH	76	WIRE	±	E_π 55–90 MeV
1.0± 4.0	4000	ABRAMS	73B	ASPK	±	E_π 51–100 MeV
0.0±24.0	24	EDWARDS	72	OSPK		E_π 58–90 MeV