$K^{\pm}$

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

CHARGED KAON MASS

Revised 1994 by T.G. Trippe (LBNL).

The average of the six charged kaon mass measurements which we use in the Particle Listings is

$$m_{K^{\pm}} = 493.677 \pm 0.013 \ \text{MeV (S} = 2.4) \ , \qquad (1)$$

where the error has been increased by the scale factor S. The large scale factor indicates a serious disagreement between different input data. The average before scaling the error is

$$m_{K^{\pm}} = 493.677 \pm 0.005 \ \text{MeV} \ ,$$
$$\chi^2 = 22.9 \ \text{for 5 D.F., Prob.} \ = 0.04\% \ , \qquad (2)$$

where the high χ^2 and correspondingly low χ^2 probability further quantify the disagreement.

The main disagreement is between the two most recent and precise results,

$$m_{K^{\pm}} = 493.696 \pm 0.007 \ \text{MeV} \qquad \text{DENISOV 91}$$
$$m_{K^{\pm}} = 493.636 \pm 0.011 \ \text{MeV (S} = 1.5) \quad \text{GALL 88}$$
$$\text{Average} = 493.679 \pm 0.006 \ \text{MeV}$$
$$\chi^2 = 21.2 \ \text{for 1 D.F., Prob.} \ = 0.0004\% \ , \qquad (3)$$

both of which are measurements of x-ray energies from kaonic atoms. Comparing the average in Eq. (3) with the overall average in Eq. (2), it is clear that DENISOV 91 [1] and GALL 88 [2] dominate the overall average, and that their disagreement is responsible for most of the high χ^2.

The GALL 88 measurement was made using four different kaonic atom transitions, K^- Pb ($9 \to 8$), K^- Pb ($11 \to 10$), K^- W ($9 \to 8$), and K^- W ($11 \to 10$). The $m_{K^\pm}$ values they obtain from each of these transitions is shown in the Particle Listings and in Fig. 1. Their K^- Pb ($9 \to 8$) $m_{K^\pm}$is below and somewhat inconsistent with their other three transitions. The average of their four measurements is

$$m_{K^\pm} = 493.636 \pm 0.007 \ ,$$
$$\chi^2 = 7.0 \ \text{for 3 D.F., Prob.} \ = 7.2\% \ . \tag{4}$$

This is a low but acceptable χ^2 probability so, to be conservative, GALL 88 scaled up the error on their average by S=1.5 to obtain their published error ± 0.011 shown in Eq. (3) above and used in the Particle Listings average.

The ideogram in Fig. 1 shows that the DENISOV 91 measurement and the GALL 88 K^- Pb ($9 \to 8$) measurement yield two well-separated peaks. One might suspect the GALL 88 K^- Pb ($9 \to 8$) measurement since it is responsible both for the internal inconsistency in the GALL 88 measurements and the disagreement with DENISOV 91.

To see if the disagreement could result from a systematic problem with the K^- Pb ($9 \to 8$) transition, we have separated the CHENG 75 [3] data, which also used K^- Pb, into its separate transitions. Figure 1 shows that the CHENG 75 and GALL 88 K^- Pb ($9 \to 8$) values are consistent, suggesting the possibility of a common effect such as contaminant nuclear γ rays near the K^- Pb ($9 \to 8$) transition energy, although the CHENG 75 errors are too large to make a strong conclusion. The average of all 13 measurements has a χ^2 of 52.6 as shown in Fig. 1 and the first line of Table 1, yielding an unacceptable χ^2 probability of 0.00005%. The second line of Table 1 excludes

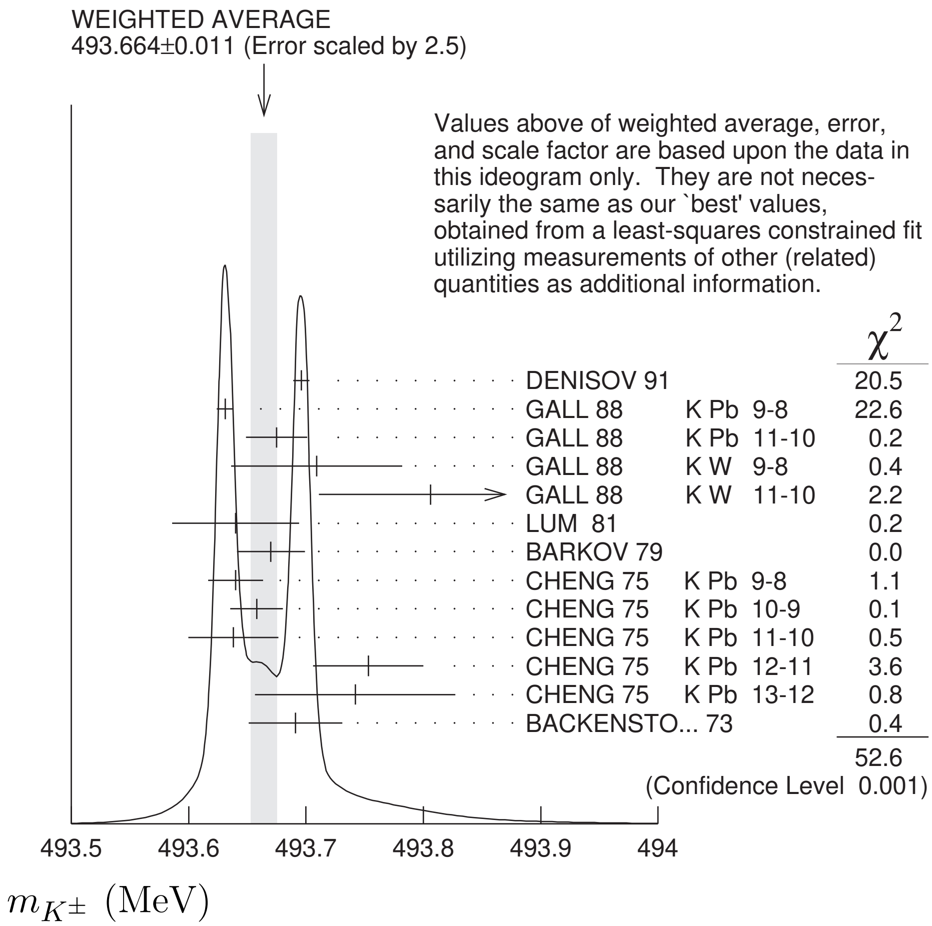


Figure 1: Ideogram of $m_{K^\pm}$ mass measurements. GALL 88 and CHENG 75 measurements are shown separately for each transition they measured.

both the GALL 88 and CHENG 75 measurements of the K^- Pb ($9 \rightarrow 8$) transition and yields a χ^2 probability of 43%. The third [fourth] line of Table 1 excludes only the GALL 88 K^- Pb ($9 \rightarrow 8$) [DENISOV 91] measurement and yields a χ^2 probability of 20% [8.6%]. Table 1 shows that removing both measurements of the K^- Pb ($9 \rightarrow 8$) transition produces the most consistent set of data, but that excluding only the GALL 88 K^- Pb ($9 \rightarrow 8$) transition or DENISOV 91 also produces acceptable probabilities.

Table 1: $m_{K^\pm}$ averages for some combinations of Fig. 1 data.

$m_{K^\pm}$ (MeV)	χ^2	D.F.	Prob. (%)	Measurements used
493.664 ± 0.004	52.6	12	0.00005	all 13 measurements
493.690 ± 0.006	10.1	10	43	no K^- Pb(9→8)
493.687 ± 0.006	14.6	11	20	no GALL 88 K^- Pb(9→8)
493.642 ± 0.006	17.8	11	8.6	no DENISOV 91

Yu.M. Ivanov, representing DENISOV 91, has estimated corrections needed for the older experiments because of improved ^{192}Ir and ^{198}Au calibration γ-ray energies. He estimates that CHENG 75 and BACKENSTOSS 73 [4] $m_{K^\pm}$ values could be raised by about 15 keV and 22 keV, respectively. With these estimated corrections, Table 1 becomes Table 2. The last line of Table 2 shows that if such corrections are assumed, then GALL 88 K^- Pb ($9 \to 8$) is inconsistent with the rest of the data even when DENISOV 91 is excluded. Yu.M. Ivanov warns that these are rough estimates. Accordingly, we do not use Table 2 to reject the GALL 88 K^- Pb ($9 \to 8$) transition, but we note that a future reanalysis of the CHENG 75 data could be useful because it might provide supporting evidence for such a rejection.

The GALL 88 measurement uses a Ge semiconductor spectrometer which has a resolution of about 1 keV, so they run the risk of some contaminant nuclear γ rays. Studies of γ rays following stopped π^- and Σ^- absorption in nuclei (unpublished) do not show any evidence for contaminants according to GALL 88 spokesperson, B.L. Roberts. The DENISOV 91 measurement uses a crystal diffraction spectrometer with a resolution of 6.3 eV for radiation at 22.1 keV to measure the 4f-3d transition in K^- ^{12}C. The high resolution and the light nucleus reduce the probability for overlap by contaminant γ rays, compared with the measurement of GALL 88. The DENISOV 91 measurement is supported by their high-precision measurement of the 4d-2p transition energy in π^{-} ^{12}C, which is good agreement with the calculated energy.

Table 2: $m_{K^\pm}$ averages for some combinations of Fig. 1 data after raising CHENG 75 and BACKENSTOSS 73 values by 0.015 and 0.022 MeV respectively.

$m_{K^\pm}$ (MeV)	χ^2	D.F.	Prob. (%)	Measurements used
493.666 ± 0.004	53.9	12	0.00003	all 13 measurements
493.693 ± 0.006	9.0	10	53	no K^- Pb(9→8)
493.690 ± 0.006	11.5	11	40	no GALL 88 K^- Pb(9→8)
493.645 ± 0.006	23.0	11	1.8	no DENISOV 91

While we suspect that the GALL 88 K^- Pb $(9 \rightarrow 8)$ measurements could be the problem, we are unable to find clear grounds for rejecting it. Therefore, we retain their measurement in the average and accept the large scale factor until further information can be obtained from new measurements and/or from reanalysis of GALL 88 and CHENG 75 data.

We thank B.L. Roberts (Boston Univ.) and Yu.M. Ivanov (Petersburg Nuclear Physics Inst.) for their extensive help in understanding this problem.

References

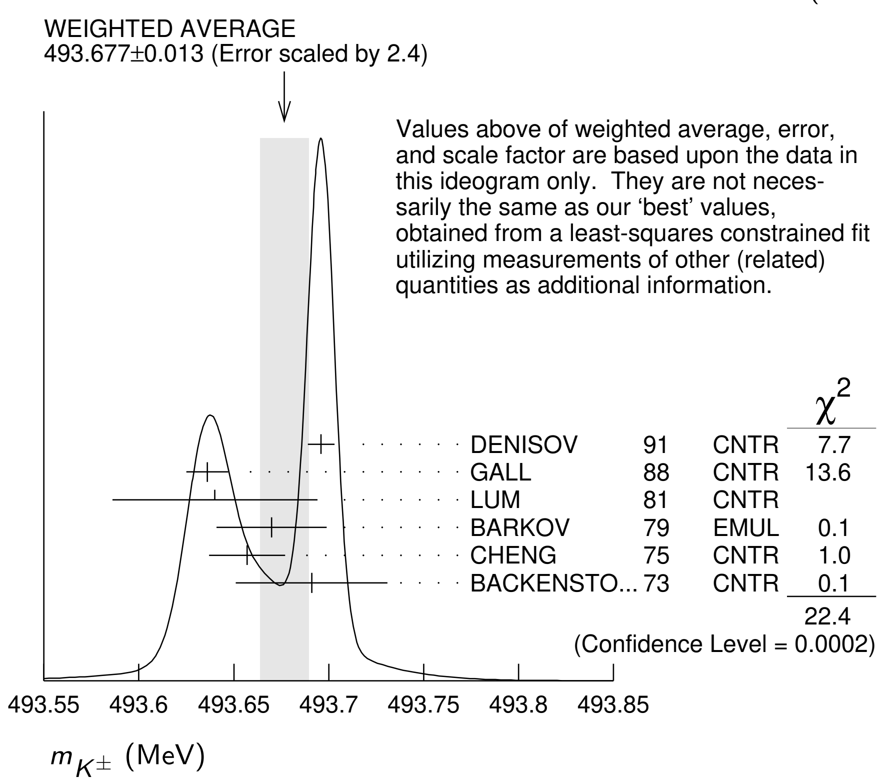
1. A.S. Denisov, *et al.* [DENISOV 91], Sov. Phys. JETP Lett. **54**, 558 (1991).
2. K.P. Gall, *et al.* [GALL 88], Phys. Rev. Lett. **60**, 186 (1988).

3. S.C. Cheng, *et al.* [CHENG 75], Nucl. Phys. **A254**, 381 (1975).
4. G. Backenstoss, *et al.* [BACKENSTOSS 73], Phys. Lett. **43B**, 431 (1973).

$K^{\pm}$ MASS

493.677±0.015 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.

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*CHG*	*COMMENT*
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)



[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.

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

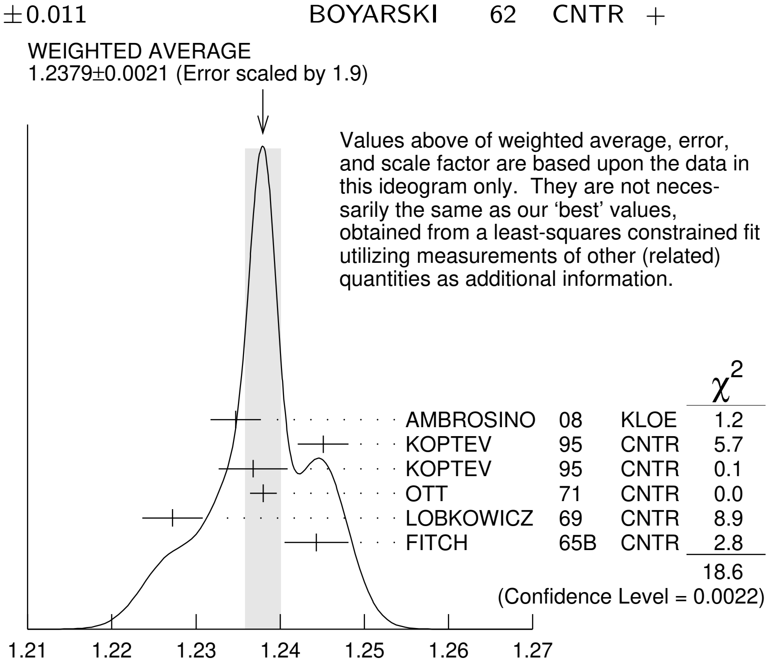
Test of *CPT*.

VALUE (MeV)	*EVTS*	*DOCUMENT ID*		*TECN*	*CHG*
$\mathbf{-0.032 \pm 0.090}$	1.5M	[1] FORD	72	ASPK	$\pm$

[1] 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*
1.2380±0.0020 OUR FIT Error includes scale factor of 1.8.						
1.2379±0.0021 OUR AVERAGE Error includes scale factor of 1.9. See the ideogram below.						
1.2347 ± 0.0030	15M	[1] AMBROSINO	08	KLOE	$\pm$	$\phi \to K^+ K^-$
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	[2] KOPTEV	95	CNTR		K at rest
1.221 ± 0.011		FORD	67	CNTR	$\pm$	
1.231 ± 0.011		BOYARSKI	62	CNTR	$+$	



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

[1] Result obtained by averaging the decay length and decay time analyses taking correlations into account.
[2] KOPTEV 95 report this weighted average of their U-target and Cu-target results, where they have weighted by $1/\sigma$ rather than $1/\sigma^2$.

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

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

VALUE (%)	DOCUMENT ID		TECN
0.10 ±0.09 OUR AVERAGE	Error includes scale factor of 1.2.		
−0.4 ±0.4	AMBROSINO	08	KLOE
0.090±0.078	LOBKOWICZ	69	CNTR
0.47 ±0.30	FORD	67	CNTR

See the related review(s):

Rare Kaon Decays

K^+ DECAY MODES

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

	Mode		Fraction (Γ_i/Γ)	Scale factor/ Confidence level
	Leptonic and semileptonic modes			
Γ_1	$e^+ \nu_e$		(1.582±0.007) × 10^{-5}	
Γ_2	$\mu^+ \nu_\mu$		(63.56 ±0.11) %	S=1.2
Γ_3	$\pi^0 e^+ \nu_e$		(5.07 ±0.04) %	S=2.1
	Called K^+_{e3}.			
Γ_4	$\pi^0 \mu^+ \nu_\mu$		(3.352±0.034) %	S=1.9
	Called $K^+_{\mu 3}$.			
Γ_5	$\pi^0 \pi^0 e^+ \nu_e$		(2.55 ±0.04) × 10^{-5}	S=1.1
Γ_6	$\pi^0 \pi^0 \mu^+ \nu_\mu$		(3.45 ±0.16) × 10^{-6}	
Γ_7	$\pi^+ \pi^- e^+ \nu_e$		(4.247±0.024) × 10^{-5}	
Γ_8	$\pi^+ \pi^- \mu^+ \nu_\mu$		(1.4 ±0.9) × 10^{-5}	
Γ_9	$\pi^0 \pi^0 \pi^0 e^+ \nu_e$		< 5.4 × 10^{-8}	CL=90%
	Hadronic modes			
Γ_{10}	$\pi^+ \pi^0$		(20.67 ±0.08) %	S=1.2
Γ_{11}	$\pi^+ \pi^0 \pi^0$		(1.760±0.023) %	S=1.1
Γ_{12}	$\pi^+ \pi^+ \pi^-$		(5.583±0.024) %	
	Leptonic and semileptonic modes with photons			
Γ_{13}	$\mu^+ \nu_\mu \gamma$	[a,b]	(6.2 ±0.8) × 10^{-3}	
Γ_{14}	$\mu^+ \nu_\mu \gamma (\text{SD}^+)$	[c,d]	(1.33 ±0.22) × 10^{-5}	

Γ_{15}	$\mu^+ \nu_\mu \gamma$(SD$^+$INT)	[c,d]	<	2.7×10^{-5}	CL=90%
Γ_{16}	$\mu^+ \nu_\mu \gamma$(SD$^-$ + SD$^-$INT)	[c,d]	<	2.6×10^{-4}	CL=90%
Γ_{17}	$e^+ \nu_e \gamma$			$(1.03 \pm 0.14) \times 10^{-5}$	
Γ_{18}	$\pi^0 e^+ \nu_e \gamma$	[a,b]		$(2.698 \pm 0.033) \times 10^{-4}$	
Γ_{19}	$\pi^0 e^+ \nu_e \gamma$(SD)	[c,d]	<	5.3×10^{-5}	CL=90%
Γ_{20}	$\pi^0 \mu^+ \nu_\mu \gamma$	[a,b]		$(1.25 \pm 0.25) \times 10^{-5}$	
Γ_{21}	$\pi^0 \pi^0 e^+ \nu_e \gamma$		<	5×10^{-6}	CL=90%

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

Γ_{22}	$\pi^+ \pi^0 \gamma$(INT)			$(-4.2 \pm 0.9) \times 10^{-6}$	
Γ_{23}	$\pi^+ \pi^0 \gamma$(DE)	[a,e]		$(6.0 \pm 0.4) \times 10^{-6}$	
Γ_{24}	$\pi^+ \pi^0 e^+ e^-$			$(4.24 \pm 0.14) \times 10^{-6}$	
Γ_{25}	$\pi^+ \pi^0 \pi^0 \gamma$	[a,b]		$(4.0 \pm 1.1) \times 10^{-6}$	
Γ_{26}	$\pi^+ \pi^+ \pi^- \gamma$	[a,b]		$(7.1 \pm 0.5) \times 10^{-6}$	
Γ_{27}	$\pi^+ \gamma \gamma$	[a]		$(9.65 \pm 0.16) \times 10^{-7}$	
Γ_{28}	$\pi^+ 3\gamma$	[a]	<	1.0×10^{-4}	CL=90%
Γ_{29}	$\pi^+ e^+ e^- \gamma$			$(1.19 \pm 0.13) \times 10^{-8}$	

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

Γ_{30}	$e^+ \nu_e \nu \overline{\nu}$		<	6×10^{-5}	CL=90%
Γ_{31}	$\mu^+ \nu_\mu \nu \overline{\nu}$		<	1.0×10^{-6}	CL=90%
Γ_{32}	$e^+ \nu_e e^+ e^-$			$(2.48 \pm 0.20) \times 10^{-8}$	
Γ_{33}	$\mu^+ \nu_\mu e^+ e^-$			$(7.06 \pm 0.31) \times 10^{-8}$	
Γ_{34}	$e^+ \nu_e \mu^+ \mu^-$			$(1.7 \pm 0.5) \times 10^{-8}$	
Γ_{35}	$\mu^+ \nu_\mu \mu^+ \mu^-$		<	4.1×10^{-7}	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_{36}	$\pi^+ \pi^+ e^- \overline{\nu}_e$	*SQ*		<	1.3×10^{-8}	CL=90%
Γ_{37}	$\pi^+ \pi^+ \mu^- \overline{\nu}_\mu$	*SQ*		<	3.0×10^{-6}	CL=95%
Γ_{38}	$\pi^+ e^+ e^-$	*S1*			$(3.00 \pm 0.09) \times 10^{-7}$	
Γ_{39}	$\pi^+ \mu^+ \mu^-$	*S1*			$(9.17 \pm 0.14) \times 10^{-8}$	S=1.8
Γ_{40}	$\pi^+ e^+ e^- e^+ e^-$	*S1*		<	1.4×10^{-8}	CL=90%
Γ_{41}	$\pi^+ \nu \overline{\nu}$	*S1*			$(1.14 {}^{+0.40}_{-0.33}) \times 10^{-10}$	
Γ_{42}	$\pi^+ \pi^0 \nu \overline{\nu}$	*S1*		<	4.3×10^{-5}	CL=90%
Γ_{43}	$\mu^- \nu e^+ e^+$	*LF*		<	8.1×10^{-11}	CL=90%
Γ_{44}	$\mu^+ \nu_e$	*LF*	[f]	<	4×10^{-3}	CL=90%
Γ_{45}	$\pi^+ \mu^+ e^-$	*LF*		<	1.3×10^{-11}	CL=90%
Γ_{46}	$\pi^0 \pi^+ \mu^+ e^-$	*LF*		<	5.0×10^{-10}	CL=90%
Γ_{47}	$\pi^+ \mu^- e^+$	*LF*		<	6.6×10^{-11}	CL=90%
Γ_{48}	$\pi^0 \pi^+ \mu^- e^+$	*LF*		<	3.1×10^{-10}	CL=90%
Γ_{49}	$\pi^- \mu^+ e^+$	*L*		<	4.2×10^{-11}	CL=90%
Γ_{50}	$\pi^0 \pi^- \mu^+ e^+$	*L*		<	2.9×10^{-10}	CL=90%
Γ_{51}	$\pi^- e^+ e^+$	*L*		<	5.3×10^{-11}	CL=90%

Γ_{52}	$\pi^- \mu^+ \mu^+$	L	$<$	4.2	$\times 10^{-11}$	CL=90%
Γ_{53}	$\pi^- \pi^0 e^+ e^+$	L	$<$	8.5	$\times 10^{-10}$	CL=90%
Γ_{54}	$\mu^+ \overline{\nu}_e$	L	[f] $<$	3.3	$\times 10^{-3}$	CL=90%
Γ_{55}	$\pi^0 e^+ \overline{\nu}_e$	L	$<$	3	$\times 10^{-3}$	CL=90%
Γ_{56}	$\pi^+ \gamma$		[g] $<$	2.3	$\times 10^{-9}$	CL=90%

[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] Structure-dependent part.

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

[e] Direct-emission branching fraction.

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

[g] Violates angular-momentum conservation.

CONSTRAINED FIT INFORMATION

An overall fit to the mean life, a decay rate, and 15 branching ratios uses 35 measurements and one constraint to determine 8 parameters. The overall fit has a $\chi^2 = 53.4$ for 28 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_2	x_3	x_4	x_5	x_{10}	x_{11}	x_{12}
x_3	−66						
x_4	−64	89					
x_5	−12	−5	−5				
x_{10}	−67	0	−1	−6			
x_{11}	−13	−6	−5	91	−6		
x_{12}	−14	−6	−6	2	−7	2	
Γ	3	1	1	0	2	0	−24

	Mode	Rate (10^8 s^{-1})	Scale factor
Γ_2	$\mu^+ \nu_\mu$	0.5134 $\pm$0.0012	1.5
Γ_3	$\pi^0 e^+ \nu_e$ Called K^+_{e3}.	0.0410 $\pm$0.0004	2.1
Γ_4	$\pi^0 \mu^+ \nu_\mu$ Called $K^+_{\mu 3}$.	0.02707$\pm$0.00028	1.9

Γ_5	$\pi^0\pi^0 e^+\nu_e$	$(2.059\ \pm 0.029\ ) \times 10^{-5}$	1.1
Γ_{10}	$\pi^+\pi^0$	$0.1670\ \pm 0.0007$	1.3
Γ_{11}	$\pi^+\pi^0\pi^0$	0.01421 ± 0.00018	1.1
Γ_{12}	$\pi^+\pi^+\pi^-$	0.04510 ± 0.00019	

$K^\pm$ DECAY RATES

$\Gamma(\mu^+\nu_\mu)$ — Γ_2

VALUE (10^6 s^{-1})	DOCUMENT ID		TECN	CHG
51.34±0.12 OUR FIT Error includes scale factor of 1.5.				
• • • We do not use the following data for averages, fits, limits, etc. • • •				
51.2 ±0.8	FORD	67	CNTR	±

$\Gamma(\pi^+\pi^+\pi^-)$ — Γ_{12}

VALUE (10^6 s^{-1})	EVTS	DOCUMENT ID		TECN	CHG
4.510±0.019 OUR FIT					
4.511±0.024		[1] FORD	70	ASPK	
• • • We do not use the following data for averages, fits, limits, etc. • • •					
4.529±0.032	3.2M	[1] FORD	70	ASPK	
4.496±0.030		[1] FORD	67	CNTR	±

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

K^+ BRANCHING RATIOS

Leptonic and semileptonic modes

$\Gamma(e^+\nu_e)/\Gamma(\mu^+\nu_\mu)$ — Γ_1/Γ_2

See the note on "Decay Constants of Charged Pseudoscalar Mesons" in the D_s^+ Listings.

VALUE (units 10^{-5})	EVTS	DOCUMENT ID		TECN	CHG
2.488±0.009 OUR AVERAGE					
2.488±0.007±0.007	150k	[1] LAZZERONI	13	NA62	±
2.493±0.025±0.019	13.8k	[2] AMBROSINO	09E	KLOE	±
• • • We do not use the following data for averages, fits, limits, etc. • • •					
2.487±0.011±0.007	60k	[3] LAZZERONI	11	NA62	+
2.51 ±0.15	404	HEINTZE	76	SPEC	+
2.37 ±0.17	534	HEARD	75B	SPEC	+
2.42 ±0.42	112	CLARK	72	OSPK	+

[1] LAZZERONI 13 uses full data sample collected from 2007 to 2008. This ratio is defined to be fully inclusive, including internal-bremsstrahlung.

[2] The ratio is defined to include internal-bremsstrahlung, ignoring direct-emission contributions. AMBROSINO 09E determined the ratio from the measurement of $\Gamma(K \to e\nu(\gamma)$, $E_\gamma < 10$ MeV) / $\Gamma(K \to \mu\nu(\gamma))$. 89.8% of $K \to e\nu(\gamma)$ events had $E_\gamma <$10 MeV.

[3] This ratio is defined to be fully inclusive, including internal-bremsstrahlung.

$\Gamma(\mu^+\nu_\mu)/\Gamma_{total}$ — Γ_2/Γ

See the note on "Decay Constants of Charged Pseudoscalar Mesons" in the D_s^+ Listings.

VALUE (units 10^{-2})	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
63.56±0.11 OUR FIT Error includes scale factor of 1.2.						
63.60±0.16 OUR AVERAGE						
63.66±0.09±0.15	865k	[1] AMBROSINO	06A	KLOE	+	
63.24±0.44	62k	CHIANG	72	OSPK	+	1.84 GeV/c K^+

[1] Fully inclusive. Used tagged kaons from ϕ decays.

$\Gamma(\pi^0 e^+\nu_e)/\Gamma_{total}$ — Γ_3/Γ

VALUE (units 10^{-2})	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
5.07 ±0.04 OUR FIT Error includes scale factor of 2.1.						
4.94 ±0.05 OUR AVERAGE						
4.965±0.038±0.037		[1] AMBROSINO	08A	KLOE	±	
4.86 ±0.10	3516	CHIANG	72	OSPK	+	1.84 GeV/c K^+
• • • We do not use the following data for averages, fits, limits, etc. • • •						
4.7 ±0.3	429	SHAKLEE	64	HLBC	+	
5.0 ±0.5		ROE	61	HLBC	+	

[1] Depends on K^+ lifetime τ. AMBROSINO 08A uses PDG 06 value of $\tau = (1.2385 \pm 0.0024) \times 10^{-8}$ sec. The correlation between K_{e3}^+ and $K_{\mu 3}^+$ branching fraction measurements is 62.7%.

$\Gamma(\pi^0 e^+\nu_e)/\Gamma(\mu^+\nu_\mu)$ — Γ_3/Γ_2

VALUE	EVTS	DOCUMENT ID		TECN	CHG
0.0798±0.0008 OUR FIT Error includes scale factor of 1.9.					
• • • We do not use the following data for averages, fits, limits, etc. • • •					
0.069 ±0.006	350	ZELLER	69	ASPK	+
0.0775±0.0033	960	BOTTERILL	68C	ASPK	+
0.069 ±0.006	561	GARLAND	68	OSPK	+
0.0791±0.0054	295	[1] AUERBACH	67	OSPK	+

[1] AUERBACH 67 changed from 0.0797 ± 0.0054. See comment with ratio $\Gamma(\pi^0\mu^+\nu_\mu)/\Gamma(\mu^+\nu_\mu)$. The value 0.0785 ± 0.0025 given in AUERBACH 67 is an average of AUERBACH 67 $\Gamma(\pi^0 e^+\nu_e)/\Gamma(\mu^+\nu_\mu)$ and CESTER 66 $\Gamma(\pi^0 e^+\nu_e)/\left[\Gamma(\mu^+\nu_\mu) + \Gamma(\pi^+\pi^0)\right]$.

$\Gamma(\pi^0 e^+\nu_e)/\left[\Gamma(\mu^+\nu_\mu)+\Gamma(\pi^+\pi^0)\right]$ — $\Gamma_3/(\Gamma_2+\Gamma_{10})$

VALUE (units 10^{-2})	EVTS	DOCUMENT ID		TECN	CHG
6.02±0.06 OUR FIT Error includes scale factor of 2.1.					
6.02±0.15 OUR AVERAGE					
6.16±0.22	5110	ESCHSTRUTH	68	OSPK	+
5.89±0.21	1679	CESTER	66	OSPK	+
• • • We do not use the following data for averages, fits, limits, etc. • • •					
5.92±0.65		[1] WEISSENBE...	76	SPEC	+

[1] Value calculated from WEISSENBERG 76 ($\pi^0 e\nu$), ($\mu\nu$), and ($\pi\pi^0$) values to eliminate dependence on our 1974 ($\pi 2\pi^0$) and ($\pi\pi^+\pi^-$) fractions.

$\Gamma(\pi^0 e^+ \nu_e)/[\Gamma(\pi^0 \mu^+ \nu_\mu)+\Gamma(\pi^+ \pi^0)+\Gamma(\pi^+ \pi^0 \pi^0)]$ $\Gamma_3/(\Gamma_4+\Gamma_{10}+\Gamma_{11})$

VALUE	EVTS	DOCUMENT ID		TECN	CHG
0.1967±0.0016 OUR FIT Error includes scale factor of 2.5.					
0.1962±0.0008±0.0035	71k	SHER	03	B865	+

$\Gamma(\pi^0 e^+ \nu_e)/\Gamma(\pi^+ \pi^0)$ Γ_3/Γ_{10}

VALUE	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
0.2454±0.0023 OUR FIT Error includes scale factor of 2.6.						
0.2467±0.0011 OUR AVERAGE Error includes scale factor of 1.1.						
0.2423±0.0015±0.0037	31k	UVAROV	14	ISTR	−	ISTRA+
0.2470±0.0009±0.0004	87k	BATLEY	07A	NA48	±	
• • • We do not use the following data for averages, fits, limits, etc. • • •						
0.221 ±0.012	786	[1] LUCAS	73B	HBC	−	Dalitz pairs only

[1] LUCAS 73B gives N(K_{e3}) = 786 ± 3.1%, N(2π) = 3564 ± 3.1%. We use these values to obtain quoted result.

$\Gamma(\pi^0 e^+ \nu_e)/\Gamma(\pi^+ \pi^+ \pi^-)$ Γ_3/Γ_{12}

VALUE	EVTS	DOCUMENT ID		TECN	CHG
0.908±0.009 OUR FIT Error includes scale factor of 1.6.					
• • • We do not use the following data for averages, fits, limits, etc. • • •					
0.867±0.027	2768	BARMIN	87	XEBC	+
0.856±0.040	2827	BRAUN	75	HLBC	+
0.850±0.019	4385	[1] HAIDT	71	HLBC	+
0.846±0.021	4385	[1] EICHTEN	68	HLBC	+
0.94 ±0.09	854	BELLOTTI	67B	HLBC	
0.90 ±0.06	230	BORREANI	64	HBC	+

[1] HAIDT 71 is a reanalysis of EICHTEN 68. Not included in average because of large discrepancy in $\Gamma(\pi^0 \mu^+ \nu)/\Gamma(\pi^0 e^+ \nu)$ with more precise results.

$\Gamma(\pi^0 \mu^+ \nu_\mu)/\Gamma_{total}$ Γ_4/Γ

VALUE (units 10^{-2})	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
3.352±0.034 OUR FIT Error includes scale factor of 1.9.						
3.24 ±0.04 OUR AVERAGE						
3.233±0.029±0.026		[1] AMBROSINO	08A	KLOE	±	
3.33 ±0.16	2345	CHIANG	72	OSPK	+	1.84 GeV/c K^+
• • • We do not use the following data for averages, fits, limits, etc. • • •						
2.8 ±0.4		[2] TAYLOR	59	EMUL	+	

[1] Depends on K^+ lifetime τ. AMBROSINO 08A uses PDG 06 value of $\tau = (1.2385 \pm 0.0024) \times 10^{-8}$ sec. The correlation between K^+_{e3} and $K^+_{\mu 3}$ branching fraction measurements is 62.7%.
[2] Earlier experiments not averaged.

$\Gamma(\pi^0 \mu^+ \nu_\mu)/\Gamma(\mu^+ \nu_\mu)$ Γ_4/Γ_2

VALUE	EVTS	DOCUMENT ID		TECN	CHG
0.0527±0.0006 OUR FIT Error includes scale factor of 1.8.					
• • • We do not use the following data for averages, fits, limits, etc. • • •					
0.054 ±0.009	240	ZELLER	69	ASPK	+
0.0480±0.0037	424	[1] GARLAND	68	OSPK	+
0.0486±0.0040	307	[2] AUERBACH	67	OSPK	+

[1] GARLAND 68 changed from 0.055 ± 0.004 in agreement with μ-spectrum calculation of GAILLARD 70 appendix B. L.G.Pondrom, (private communication 73).
[2] AUERBACH 67 changed from 0.0602 ± 0.0046 by erratum which brings the μ-spectrum calculation into agreement with GAILLARD 70 appendix B.

$\Gamma(\pi^0 \mu^+ \nu_\mu)/\Gamma(\pi^0 e^+ \nu_e)$ — Γ_4/Γ_3

VALUE	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
0.6608±0.0031 OUR FIT Error includes scale factor of 1.2.						
0.6618±0.0027 OUR AVERAGE						
0.663 ±0.003 ±0.001	77k	BATLEY	07A	NA48	±	
0.671 ±0.007 ±0.008	24k	HORIE	01	SPEC		
0.670 ±0.014		[1] HEINTZE	77	SPEC	+	
0.667 ±0.017	5601	BOTTERILL	68B	ASPK	+	
• • • We use the following data for averages but not for fits. • • •						
0.6511±0.0064		[2] AMBROSINO	08A	KLOE	±	
• • • We do not use the following data for averages, fits, limits, etc. • • •						
0.608 ±0.014	1585	[3] BRAUN	75	HLBC	+	
0.705 ±0.063	554	[4] LUCAS	73B	HBC	−	Dalitz pairs only
0.698 ±0.025	3480	[5] CHIANG	72	OSPK	+	1.84 GeV/c K^+
0.596 ±0.025		[6] HAIDT	71	HLBC	+	
0.604 ±0.022	1398	[6] EICHTEN	68	HLBC		
0.703 ±0.056	1509	CALLAHAN	66B	HLBC		

[1] HEINTZE 77 value from fit to λ_0. Assumes μ-e universality.
[2] Not used in the fit. This result enters the fit via correlation of K^+_{e3} and $K^+_{\mu 3}$ branching fraction measurements of AMBROSINO 08A.
[3] BRAUN 75 value is from form factor fit. Assumes μ-e universality.
[4] LUCAS 73B gives N($K_{\mu 3}$) = 554 ± 7.6%, N(K_{e3}) = 786 ± 3.1%. We divide.
[5] CHIANG 72 $\Gamma(\pi^0 \mu^+ \nu_\mu)/\Gamma(\pi^0 e^+ \nu_e)$ is statistically independent of CHIANG 72 $\Gamma(\pi^0 \mu^+ \nu_\mu)/\Gamma_{\rm total}$ and $\Gamma(\pi^0 e^+ \nu_e)/\Gamma_{\rm total}$.
[6] HAIDT 71 is a reanalysis of EICHTEN 68. Not included in average because of large discrepancy with more precise results.

$\left[\Gamma(\pi^0 \mu^+ \nu_\mu) + \Gamma(\pi^+ \pi^0)\right]/\Gamma_{\rm total}$ — $(\Gamma_4+\Gamma_{10})/\Gamma$

We combine these two modes for experiments measuring them in xenon bubble chamber because of difficulties of separating them there.

VALUE (units 10^{-2})	EVTS	DOCUMENT ID		TECN	CHG
24.02±0.08 OUR FIT Error includes scale factor of 1.2.					
• • • We do not use the following data for averages, fits, limits, etc. • • •					
25.4 ±0.9	886	SHAKLEE	64	HLBC	+
23.4 ±1.1		ROE	61	HLBC	+

$\Gamma(\pi^0 \mu^+ \nu_\mu)/\Gamma(\pi^+ \pi^0)$ — Γ_4/Γ_{10}

VALUE	EVTS	DOCUMENT ID		TECN	CHG
0.1637±0.0006±0.0003	77k	BATLEY	07A	NA48	±

$\Gamma(\pi^0 \mu^+ \nu_\mu)/\Gamma(\pi^+ \pi^+ \pi^-)$ — Γ_4/Γ_{12}

VALUE	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
0.600±0.007 OUR FIT Error includes scale factor of 1.6.						
• • • We do not use the following data for averages, fits, limits, etc. • • •						
0.503±0.019	1505	[1] HAIDT	71	HLBC	+	
0.510±0.017	1505	[1] EICHTEN	68	HLBC	+	
0.63 ±0.07	2845	[2] BISI	65B	BC	+	HBC+HLBC

[1] HAIDT 71 is a reanalysis of EICHTEN 68. Not included in average because of large discrepancy in $\Gamma(\pi^0 \mu^+ \nu)/\Gamma(\pi^0 e^+ \nu)$ with more precise results.
[2] Error enlarged for background problems. See GAILLARD 70.

$\Gamma(\pi^0 \pi^0 e^+ \nu_e)/\Gamma_{total}$ — Γ_5/Γ

VALUE (units 10^{-5})	EVTS	DOCUMENT ID		TECN	CHG
2.55±0.04 OUR FIT	Error includes scale factor of 1.1.				
2.54±0.89	10	BARMIN	88B	HLBC	+

$\Gamma(\pi^0 \pi^0 \mu^+ \nu_\mu)/\Gamma_{total}$ — Γ_6/Γ

VALUE (units 10^{-6})	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
3.45±0.16	2437	[1] BATLEY	24	NA48	±	model extrapolation

[1] BATLEY 24 reported the result extrapolated to the full kinematic space, based on the measurement $B(K^\pm \rightarrow \pi^0 \pi^0 \mu^\pm \nu) = (0.65 \pm 0.03) \times 10^{-6}$, in the kinematic region where the squared dilepton mass is above 0.03 GeV^2/c^4.

$\Gamma(\pi^0 \pi^0 e^+ \nu_e)/\Gamma(\pi^+ \pi^0 \pi^0)$ — Γ_5/Γ_{11}

VALUE (units 10^{-3})	EVTS	DOCUMENT ID		TECN	CHG
1.449±0.008 OUR FIT					
1.449±0.006±0.006	65.2k	[1] BATLEY	14A	NA48	±

[1] Data collected in 2003–2004. This leads to the scalar form factor $(1+ \delta_{EM})\ f_s = 6.079 \pm 0.012 \pm 0.027 \pm 0.046$ where the last error is due to the normalizing decay mode uncertainty.

$\Gamma(\pi^0 \pi^0 e^+ \nu_e)/\Gamma(\pi^0 e^+ \nu_e)$ — Γ_5/Γ_3

VALUE (units 10^{-4})	EVTS	DOCUMENT ID		TECN	CHG
5.03±0.09 OUR FIT	Error includes scale factor of 1.2.				
4.1 $^{+1.0}_{-0.7}$ OUR AVERAGE					
4.2 $^{+1.0}_{-0.9}$	25	BOLOTOV	86B	CALO	−
3.8 $^{+5.0}_{-1.2}$	2	LJUNG	73	HLBC	+

$\Gamma(\pi^+ \pi^- e^+ \nu_e)/\Gamma(\pi^+ \pi^+ \pi^-)$ — Γ_7/Γ_{12}

VALUE (units 10^{-4})	EVTS	DOCUMENT ID		TECN	CHG
7.606±0.029 OUR AVERAGE					
7.615±0.008±0.028	1.1M	[1] BATLEY	12	NA48	±
7.35 ±0.01 ±0.19	388k	[2] PISLAK	01	B865	
7.21 ±0.32	30k	ROSSELET	77	SPEC	+
• • • We do not use the following data for averages, fits, limits, etc. • • •					
7.36 ±0.68	500	BOURQUIN	71	ASPK	
7.0 ±0.9	106	SCHWEINB...	71	HLBC	+
5.83 ±0.63	269	ELY	69	HLBC	+

[1] BATLEY 12 uses data collected in 2003–2004. The result is inclusive of $K^\pm \rightarrow \pi^+ \pi^- e^\pm \nu \gamma$ decays. Using PDG 12 value for $\Gamma(\pi^+ \pi^- \pi^+)/\Gamma = (5.59 \pm 0.04) \times 10^{-2}$. BATLEY 12 obtains $B(\pi^+ \pi^- e \nu) = (4.257 \pm 0.004 \pm 0.035) \times 10^{-5}$ where the syst. error is dominated by the error on the normalization mode.
[2] PISLAK 01 reports $\Gamma(\pi^+ \pi^- e^+ \nu_e)/\Gamma_{total} = (4.109 \pm 0.008 \pm 0.110) \times 10^{-5}$ using the PDG 00 value $\Gamma(\pi^+ \pi^+ \pi^-)/\Gamma_{total} = (5.59 \pm 0.05) \times 10^{-2}$. We divide by the PDG

value and unfold its error from the systematic error. PISLAK 03 and PISLAK 10A give additional details on the branching ratio measurement and give improved errors on the S-wave π-π scattering length: $a_0^0 = 0.235 \pm 0.013$ and $a_0^2 = -0.0410 \pm 0.0027$.

$\Gamma(\pi^+\pi^-\mu^+\nu_\mu)/\Gamma_{total}$ — Γ_8/Γ

VALUE (units 10^{-5})	EVTS	DOCUMENT ID		TECN	CHG
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$0.77^{+0.54}_{-0.50}$	1	CLINE	65	FBC	+

$\Gamma(\pi^+\pi^-\mu^+\nu_\mu)/\Gamma(\pi^+\pi^+\pi^-)$ — Γ_8/Γ_{12}

VALUE (units 10^{-4})	EVTS	DOCUMENT ID		TECN	CHG
2.57±1.55	7	BISI	67	DBC	+
• • • We do not use the following data for averages, fits, limits, etc. • • •					
~ 2.5	1	GREINER	64	EMUL	+

$\Gamma(\pi^0\pi^0\pi^0 e^+\nu_e)/\Gamma_{total}$ — Γ_9/Γ

VALUE	CL%	DOCUMENT ID		TECN	CHG
$<5.4 \times 10^{-8}$	90	ARTAMONOV	24A	OKA	+
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$<9 \times 10^{-6}$	90	BARMIN	92	XEBC	+
$<3.5 \times 10^{-6}$	90	BOLOTOV	88	SPEC	−

Hadronic modes

$\Gamma(\pi^+\pi^0)/\Gamma_{total}$ — Γ_{10}/Γ

VALUE (units 10^{-2})	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
20.67±0.08 OUR FIT Error includes scale factor of 1.2.						
20.70±0.16 OUR AVERAGE Error includes scale factor of 1.8.						
20.65±0.05±0.08	1.4M	[1] AMBROSINO	08E	KLOE	+	$\phi \to K^+K^-$
21.18±0.28	16k	CHIANG	72	OSPK	+	1.84 GeV/c K^+
• • • We do not use the following data for averages, fits, limits, etc. • • •						
21.0 ±0.6		CALLAHAN	65	HLBC		See Γ_{10}/Γ_{12}

[1] Fully inclusive of final-state radiation. The branching ratio is evaluated using K^+ lifetime, τ= 12.385 ns.

$\Gamma(\pi^+\pi^0)/\Gamma(\mu^+\nu_\mu)$ — Γ_{10}/Γ_2

VALUE	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
0.3252±0.0016 OUR FIT Error includes scale factor of 1.2.						
0.3325±0.0032 OUR AVERAGE						
0.3329±0.0047±0.0010	45k	USHER	92	SPEC	+	$p\overline{p}$ at rest
0.3355±0.0057		[1] WEISSENBE...	76	SPEC	+	
0.3277±0.0065	4517	[2] AUERBACH	67	OSPK	+	
• • • We do not use the following data for averages, fits, limits, etc. • • •						
0.328 ±0.005	25k	[1] WEISSENBE...	74	STRC	+	
0.305 ±0.018	1600	ZELLER	69	ASPK	+	

[1] WEISSENBERG 76 revises WEISSENBERG 74.
[2] AUERBACH 67 changed from 0.3253 ± 0.0065. See comment with ratio $\Gamma(\pi^0\mu^+\nu_\mu)/\Gamma(\mu^+\nu_\mu)$.

$\Gamma(\pi^+\pi^0)/\Gamma(\pi^+\pi^+\pi^-)$ Γ_{10}/Γ_{12}

VALUE	EVTS	DOCUMENT ID		TECN	CHG
3.702±0.022 OUR FIT Error includes scale factor of 1.1.					
• • • We do not use the following data for averages, fits, limits, etc. • • •					
3.96 ±0.15	1045	CALLAHAN	66	FBC	+

$\Gamma(\pi^+\pi^0\pi^0)/\Gamma_{\text{total}}$ Γ_{11}/Γ

VALUE (units 10^{-2})	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
1.760±0.023 OUR FIT Error includes scale factor of 1.1.						
1.775±0.028 OUR AVERAGE Error includes scale factor of 1.2.						
1.763±0.013±0.022		ALOISIO	04A	KLOE	±	
1.84 ±0.06	1307	CHIANG	72	OSPK	+	1.84 GeV/c K^+
• • • We do not use the following data for averages, fits, limits, etc. • • •						
1.53 ±0.11	198	[1] PANDOULAS	70	EMUL	+	
1.8 ±0.2	108	SHAKLEE	64	HLBC	+	
1.7 ±0.2		ROE	61	HLBC	+	
1.5 ±0.2		[2] TAYLOR	59	EMUL	+	

[1] Includes events of TAYLOR 59.
[2] Earlier experiments not averaged.

$\Gamma(\pi^+\pi^0\pi^0)/\Gamma(\pi^+\pi^0)$ Γ_{11}/Γ_{10}

VALUE	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
0.0851±0.0012 OUR FIT Error includes scale factor of 1.1.						
• • • We do not use the following data for averages, fits, limits, etc. • • •						
0.081 ±0.005	574	[1] LUCAS	73B	HBC	−	Dalitz pairs only

[1] LUCAS 73B gives N($\pi 2\pi^0$) = 574 ± 5.9%, N(2π) = 3564 ± 3.1%. We quote 0.5N($\pi 2\pi^0$)/N(2π) where 0.5 is because only Dalitz pair π^0's were used.

$\Gamma(\pi^+\pi^0\pi^0)/\Gamma(\pi^+\pi^+\pi^-)$ Γ_{11}/Γ_{12}

VALUE	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
0.315±0.004 OUR FIT Error includes scale factor of 1.1.						
0.303±0.009	2027	BISI	65	BC	+	HBC+HLBC
• • • We do not use the following data for averages, fits, limits, etc. • • •						
0.393±0.099	17	YOUNG	65	EMUL	+	

$\Gamma(\pi^+\pi^+\pi^-)/\Gamma_{\text{total}}$ Γ_{12}/Γ

VALUE (units 10^{-2})	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
5.583±0.024 OUR FIT						
5.565±0.031±0.025	68k	[1] BABUSCI	14B	KLOE	+	
• • • We do not use the following data for averages, fits, limits, etc. • • •						
5.56 ±0.20	2330	[2] CHIANG	72	OSPK	+	1.84 GeV/c K^+
5.34 ±0.21	693	[3] PANDOULAS	70	EMUL	+	
5.71 ±0.15		DEMARCO	65	HBC		
6.0 ±0.4	44	YOUNG	65	EMUL	+	
5.54 ±0.12	2332	CALLAHAN	64	HLBC	+	
5.1 ±0.2	540	SHAKLEE	64	HLBC	+	
5.7 ±0.3		ROE	61	HLBC	+	

[1] Inclusive of final-state radiation. Result obtained from averaging two branching ratios: one from a sample with $K^- \to \mu\nu(\gamma)$ tagging and another with $K^- \to \pi^-\pi^0(\gamma)$ tagging.

[2] Value is not independent of CHIANG 72 $\Gamma(\mu^+\nu_\mu)/\Gamma_{\text{total}}$, $\Gamma(\pi^+\pi^0)/\Gamma_{\text{total}}$, $\Gamma(\pi^+\pi^0\pi^0)/\Gamma_{\text{total}}$, $\Gamma(\pi^0\mu^+\nu_\mu)/\Gamma_{\text{total}}$, and $\Gamma(\pi^0 e^+\nu_e)/\Gamma_{\text{total}}$.
[3] Includes events of TAYLOR 59.

Leptonic and semileptonic modes with photons

$\Gamma(\mu^+\nu_\mu\gamma)/\Gamma_{\text{total}}$ — Γ_{13}/Γ

VALUE (units 10^{-3})	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
6.2±0.8 OUR AVERAGE						
6.6±1.5		[1,2] DEMIDOV	90	XEBC		$P(\mu) <231.5$ MeV/c
6.0±0.9		BARMIN	88	HLBC	+	$P(\mu) <231.5$ MeV/c
• • • We do not use the following data for averages, fits, limits, etc. • • •						
3.5±0.8		[2,3] DEMIDOV	90	XEBC		$E(\gamma) > 20$ MeV
3.2±0.5	57	[4] BARMIN	88	HLBC	+	$E(\gamma) >20$ MeV
5.4±0.3		[5] AKIBA	85	SPEC		$P(\mu) <231.5$ MeV/c

[1] $P(\mu)$ cut given in DEMIDOV 90 paper, 235.1 MeV/c, is a misprint according to authors (private communication).
[2] DEMIDOV 90 quotes only inner bremsstrahlung (IB) part.
[3] Not independent of above DEMIDOV 90 value. Cuts differ.
[4] Not independent of above BARMIN 88 value. Cuts differ.
[5] Assumes μ-e universality and uses constraints from $K \to e\nu\gamma$.

$\Gamma(\mu^+\nu_\mu\gamma(\text{SD}^+))/\Gamma_{\text{total}}$ — Γ_{14}/Γ

Structure-dependent part with $+\gamma$ helicity (SD$^+$ term). See the "Note on $\pi^\pm \to \ell^\pm\nu\gamma$ and $K^\pm \to \ell^\pm\nu\gamma$ Form Factors" in the $\pi^\pm$ section of the Particle Data Listings above.

VALUE (units 10^{-5})	CL%	EVTS	DOCUMENT ID		TECN
1.33±0.12±0.18		2588	[1] ADLER	00B	B787
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<3.0	90		AKIBA	85	SPEC

[1] ADLER 00B obtains the branching ratio by extrapolating the measurement in the kinematic region $E_\mu > 137$ MeV, $E_\gamma > 90$ MeV to the full SD$^+$ phase-space. Also reports $|F_V + F_A| = 0.165 \pm 0.007 \pm 0.011$ and $-0.04 < F_V - F_A < 0.24$ at 90% CL.

$\Gamma(\mu^+\nu_\mu\gamma(\text{SD}^+\text{INT}))/\Gamma_{\text{total}}$ — Γ_{15}/Γ

Interference term between internal Bremsstrahlung and SD$^+$ term. See the "Note on $\pi^\pm \to \ell^\pm\nu\gamma$ and $K^\pm \to \ell^\pm\nu\gamma$ Form Factors" in the $\pi^\pm$ section of the Particle Data Listings above.

VALUE (units 10^{-5})	CL%	DOCUMENT ID		TECN
<2.7	90	AKIBA	85	SPEC

$\Gamma(\mu^+\nu_\mu\gamma(\text{SD}^- + \text{SD}^-\text{INT}))/\Gamma_{\text{total}}$ — Γ_{16}/Γ

Sum of structure-dependent part with $-\gamma$ helicity (SD$^-$ term) and interference term between internal Bremsstrahlung and SD$^-$ term. See the "Note on $\pi^\pm \to \ell^\pm\nu\gamma$ and $K^\pm \to \ell^\pm\nu\gamma$ Form Factors" in the $\pi^\pm$ section of the Particle Data Listings above.

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN
<2.6	90	[1] AKIBA	85	SPEC

[1] Assumes μ-e universality and uses constraints from $K \to e\nu\gamma$.

$\Gamma(e^+\nu_e\gamma)/\Gamma(\mu^+\nu_\mu)$ — Γ_{17}/Γ_2

VALUE (units 10^{-5})	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
1.62 ±0.22 OUR AVERAGE		Error includes scale factor of 3.9.				
1.98 ±0.11	95	[1] KOBAYASHI	23	E36		E_γ in 10–250 MeV, $p_e > 200$ MeV/c
1.483±0.066±0.013	1.4k	[2] AMBROSINO	09E	KLOE	±	E_γ in 10–250 MeV, $p_e > 200$ MeV/c
• • • We do not use the following data for averages, fits, limits, etc. • • •						
1.85 ±0.11 ±0.07	574	[3,4] ITO	22	E36	+	E_γ in 10–250 MeV, $p_e > 200$ MeV/c

[1] KOBAYASHI 23 observed 95 ± 10 $K^{SD+}_{e2\gamma(\gamma)}$ events and derived B($K^{SD+}_{e2\gamma(\gamma)}$)/B($K_{e2(\gamma)}$) $= 1.25 \pm 0.14 \pm 0.08$. The authors obtained the R_γ value $(1.98 \pm 0.11) \times 10^{-5}$ by averaging KOBAYASHI 23 with ITO 22 after updating the ITO 22 result to include internal bremsstrahlung process in the acceptance calculation.

[2] AMBROSINO 09E measured the differential width $dR_\gamma/dE_\gamma = (1/\Gamma(K \to \mu\nu))$ $(d\Gamma(K \to e\nu\gamma)/dE_\gamma)$. Result obtained by integrating the differential width over E_γ from 10 to 250 MeV.

[3] ITO 22 result derived from B($K^{SD+}_{e2\gamma}$)/B($K_{e2(\gamma)}$) $= 1.12 \pm 0.07 \pm 0.04$.

[4] superseded by KOBAYASHI 2023

$\Gamma(\pi^0 e^+\nu_e\gamma)/\Gamma(\pi^0 e^+\nu_e)$ — Γ_{18}/Γ_3

VALUE (units 10^{-3})	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
5.32±0.05 OUR AVERAGE						
5.33±0.03±0.04	130k	[1] CORTINA-GIL	23D	NA62	+	$E_\gamma > 10$ MeV, $0.6 < \cos(\theta_{e\gamma}) < 0.9$
5.32±0.10±0.12	7248	[2] POLYARUSH	21	OKA	+	$E_\gamma > 10$ MeV, $0.6 < \cos(\theta_{e\gamma}) < 0.9$
4.7 ±0.2 ±0.3	1456	[3] AKIMENKO	07	ISTR	−	$E_\gamma > 10$ MeV, $0.6 < \cos(\theta_{e\gamma}) < 0.9$
4.6 ±0.8	82	[4] BARMIN	91	XEBC		$E_\gamma > 10$ MeV, $0.6 < \cos(\theta_{e\gamma}) < 0.9$
5.6 ±0.4	192	[5] BOLOTOV	86B	CALO	−	$E_\gamma > 10$ MeV
• • • We do not use the following data for averages, fits, limits, etc. • • •						
18.1 ±0.3 ±0.7	4476	[3] AKIMENKO	07	ISTR	−	E_γ>10 MeV, $\theta_{e\gamma} > 10°$
6.3 ±0.2 ±0.3		[3] AKIMENKO	07	ISTR	−	E_γ>30 MeV, $\theta_{e\gamma} > 20°$
15.1 ±2.5	82	[4] BARMIN	91	XEBC		$E_\gamma > 10$ MeV, $\cos(\theta_{e\gamma}) < 0.98$
4.8 ±2.0	16	[6] LJUNG	73	HLBC	+	$E_\gamma > 30$ MeV
2.2 $^{+1.5}_{-1.0}$		[6] LJUNG	73	HLBC	+	$E_\gamma > 30$ MeV
7.6 ±2.8	13	[7] ROMANO	71	HLBC		$E_\gamma > 10$ MeV
5.3 ±2.2		[7] ROMANO	71	HLBC	+	$E_\gamma > 30$ MeV
12 ±8		BELLOTTI	67	HLBC		$E_\gamma > 30$ MeV

[1] CORTINA-GIL 23D provides values for three kinematic regions. For averaging, we use value with $E_\gamma > 10$ MeV and $0.6 < \cos(\theta_{e\gamma}) < 0.9$.

[2] POLYARUSH 21 provides values for three kinematic regions. For averaging, we use value with $E_\gamma > 10$ MeV and $0.6 < \cos(\theta_{e\gamma}) < 0.9$.

[3] AKIMENKO 07 provides values for three kinematic regions. For averaging, we use value with $E_\gamma > 10$ MeV and $0.6 < \cos(\theta_{e\gamma}) < 0.9$.

[4] BARMIN 91 quotes branching ratio $\Gamma(K \to e\pi^0\nu\gamma)/\Gamma_{\text{all}}$. The measured normalization is $[\Gamma(K \to e\pi^0\nu) + \Gamma(K \to \pi^+\pi^+\pi^-)]$. For comparison with other experiments we used $\Gamma(K \to e\pi^0\nu)/\Gamma_{\text{all}} = 0.0482$ to calculate the values quoted here.

[5] $\cos(\theta_{e\gamma})$ between 0.6 and 0.9.

[6] First LJUNG 73 value is for $\cos(\theta_{e\gamma}) < 0.9$, second value is for $\cos(\theta_{e\gamma})$ between 0.6 and 0.9 for comparison with ROMANO 71.

[7] Both ROMANO 71 values are for $\cos(\theta_{e\gamma})$ between 0.6 and 0.9. Second value is for comparison with second LJUNG 73 value. We use lowest E_γ cut for Summary Table value. See ROMANO 71 for E_γ dependence.

$\Gamma(\pi^0 e^+ \nu_e \gamma(\text{SD}))/\Gamma_{\text{total}}$ — Γ_{19}/Γ

Structure-dependent part.

VALUE (units 10^{-5})	CL%	DOCUMENT ID		TECN	CHG
<5.3	90	BOLOTOV	86B	CALO	−

$\Gamma(\pi^0 \mu^+ \nu_\mu \gamma)/\Gamma_{\text{total}}$ — Γ_{20}/Γ

VALUE (units 10^{-5})	CL%	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
1.25±0.25 OUR AVERAGE							
1.10±0.32±0.05		23	[1] ADLER	10	B787		$30 < E_\gamma < 60$ MeV
1.46±0.22±0.32		153	[2] TCHIKILEV	07	ISTR	−	$30 < E_\gamma < 60$ MeV
• • • We do not use the following data for averages, fits, limits, etc. • • •							
2.4 ±0.5 ±0.6		125	SHIMIZU	06	K470	+	$E_\gamma > 30$ MeV; $\Theta_{\mu\gamma} > 20°$
<6.1	90	0	LJUNG	73	HLBC	+	$E(\gamma) > 30$ MeV

[1] Value obtained from $B(K^+ \to \pi^0\mu^+\nu_\mu\gamma) = (2.51 \pm 0.74 \pm 0.12) \times 10^{-5}$ obtained in the kinematic region $E_\gamma > 20$ MeV, and then theoretical $K_{\mu3\gamma}$ spectrum has been used. Also $B(K^+ \to \pi^0\mu^+\nu_\mu\gamma) = (1.58 \pm 0.46 \pm 0.08) \times 10^{-5}$, for $E_\gamma > 30$ MeV and $\theta_{\mu\gamma} > 20°$, was determined.

[2] Obtained from measuring $B(K_{\mu3\gamma})$ / $B(K_{\mu3})$ and using PDG 02 value $B(K_{\mu3}) = 3.27\%$. $B(K_{\mu3\gamma}) = (8.82 \pm 0.94 \pm 0.86) \times 10^{-5}$ is obtained for 5 MeV < E_γ < 30 MeV.

$\Gamma(\pi^0\pi^0 e^+ \nu_e \gamma)/\Gamma_{\text{total}}$ — Γ_{21}/Γ

VALUE (units 10^{-6})	CL%	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
<5	90	0	BARMIN	92	XEBC	+	$E_\gamma > 10$ MeV

Hadronic modes with photons

$\Gamma(\pi^+\pi^0\gamma(\text{INT}))/\Gamma_{\text{total}}$ — Γ_{22}/Γ

The $K^+ \to \pi^+\pi^0\gamma$ differential decay rate can be described in terms of T_{π^+}, the charged pion kinetic energy, and $W^2 = (P_K \cdot P_\gamma)(P_{\pi^+} \cdot P_\gamma) / (m_K m_{\pi^+})^2$; then we can write $d^2\Gamma(K^+ \to \pi^+\pi^0\gamma) / (dT_{\pi^+} dW^2) = d^2\Gamma(K^+ \to \pi^+\pi^0\gamma)_{IB} / (dT_{\pi^+} dW^2) [1 + 2\cos(\pm\phi + \delta^1_1 - \delta^2_0)\, m^2_\pi m^2_K W^2 X_E + m^4_\pi m^4_K (X^2_E + X^2_M) W^4]$. The IB differential and total branching ratios are expressed in terms of the non-radiative experimental width $\Gamma(K^+ \to \pi^+\pi^0)$ by Low's theorem. Using

PDG 10 B($K^+ \to \pi^+\pi^0$) = 0.2066 ± 0.0008, one obtains respectively B($K^+ \to \pi^+\pi^0\gamma)_{IB}$ (55 < T_{π^+} < 90 MeV)= 2.55×10^{-4} and B($K^+ \to \pi^+\pi^0\gamma)_{IB}$ (0 < T_{π^+} < 80 MeV)= 1.80×10^{-4}. Fitting respectively the piece proportional to W^2 and the piece proportional to W^4, the interference contribution (INT), proportional to X_E, and the direct contribution (DE) proportional to $X_E^2 + X_M^2$ are extracted.

VALUE (units 10^{-6})	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
−4.24±0.63±0.70	600k	[1] BATLEY	10A	NA48	±	T_{π^+} 0–80 MeV

[1] The cut on the photon energy implies $W^2 > 0.2$. BATLEY 10A obtains the INT and DE fractional branchings with respect to IB from a simultaneous kinematical fit of INT and DE and then we use the PDG 10 value for B($K^+ \to \pi^+\pi^0$) = 20.66 ± 0.08 to determine the IB. The INT and DE correlation coefficients −0.83. Assuming a constant electric amplitude, X_E, this INT value implies $X_E = -24 \pm 6$ GeV^{-4}.

$\Gamma(\pi^+\pi^0\gamma(\text{DE}))/\Gamma_{\text{total}}$ Γ_{23}/Γ

Direct emission (DE) part of $\Gamma(\pi^+\pi^0\gamma)/\Gamma_{\text{total}}$, assuming that interference (INT) component is zero.

VALUE (units 10^{-6})	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
5.99±0.27±0.25	600k	[1] BATLEY	10A	NA48	±	T_{π^+} 0–80 MeV
• • • We do not use the following data for averages, fits, limits, etc. • • •						
3.8 ±0.8 ±0.7	10k	ALIEV	06	K470	+	T_{π^+} 55–90 MeV
3.7 ±3.9 ±1.0	930	UVAROV	06	ISTR	−	T_{π^-} 55–90 MeV
3.2 ±1.3 ±1.0	4k	ALIEV	03	K470	+	T_{π^+} 55–90 MeV
6.1 ±2.5 ±1.9	4k	ALIEV	03	K470	+	T_{π^+} full range
4.7 ±0.8 ±0.3	20k	[2] ADLER	00C	B787	+	T_{π^+} 55–90 MeV
20.5 ±4.6 $^{+3.9}_{-2.3}$		BOLOTOV	87	WIRE	−	T_{π^-} 55–90 MeV
15.6 ±3.5 ±5.0		ABRAMS	72	ASPK	±	$T_{\pi^\pm}$ 55–90 MeV

[1] The cut on the photon energy implies $W^2 > 0.2$. BATLEY 10A obtains the INT and DE fractional branchings with respect to IB from a simultaneous kinematical fit of INT and DE and then we use the PDG 10 value for B($K^+ \to \pi^+\pi^0$) = 20.66 ± 0.08 to determine the IB. The INT and DE correlation coefficients −0.93. Assuming constant electric and magnetic amplitudes, X_E and X_M, these INTand DE values imply $X_E = -24 \pm 6$ GeV^{-4} and $X_M = -254 \pm 9$ GeV^{-4}.

[2] ADLER 00C measures the INT component to be (−0.4 ± 1.6)% of the inner bremsstrahlung (IB) component.

$\Gamma(\pi^+\pi^0 e^+ e^-)/\Gamma_{\text{total}}$ Γ_{24}/Γ

VALUE (units 10^{-6})	EVTS	DOCUMENT ID		TECN
4.24±0.14	4.9k	[1] BATLEY	19	NA48

[1] BATLEY 19 result is obtained from an exposure of 1.7×10^{11} charged kaon decays recorded in 2003–2004. The study of the kinematic space shows evidence for a structure dependent contribution consistent with predictions from chiral perturbation theory.

$\Gamma(\pi^+\pi^0\pi^0\gamma)/\Gamma(\pi^+\pi^0\pi^0)$ Γ_{25}/Γ_{11}

VALUE (units 10^{-4})	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
2.3±0.6 OUR AVERAGE	Error includes scale factor of 1.2.					
2.1±0.5	60	[1] ARTAMONOV	24	OKA	+	$E(\gamma) > 10$ MeV
4.3$^{+3.2}_{-1.7}$		BOLOTOV	85	SPEC	−	$E(\gamma) > 10$ MeV

[1] ARTAMONOV 24 obtains the branching ratio B($K^+ \to \pi^+ \pi^0 \pi^0 \gamma$) = (3.7 ± 0.9 ± 0.3) × 10^{-6} by normalizing to B($K^+ \to \pi^+ \pi^0 \pi^0$) = (1.760 ± 0.023) × 10^{-2}.

$\Gamma(\pi^+\pi^+\pi^-\gamma)/\Gamma_{total}$ — Γ_{26}/Γ

VALUE (units 10^{-4})	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
0.071±0.005 OUR AVERAGE						
0.071±0.005	450	SHAPKIN	19	OKA	+	$E(\gamma)$ >30 MeV
1.10 ±0.48	7	BARMIN	89	XEBC		$E(\gamma)$ > 5 MeV
1.0 ±0.4		STAMER	65	EMUL	+	$E(\gamma)$ >11 MeV

$\Gamma(\pi^+\gamma\gamma)/\Gamma_{total}$ — Γ_{27}/Γ

VALUE (units 10^{-7})	CL%	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
9.65±0.16 OUR AVERAGE							
9.61±0.15±0.07		3693	[1] CORTINA-GIL	24	NA62	+	ChPT extrapolatioin
10.03±0.51±0.24		215	[2] LAZZERONI	14	NA62	±	
11 ±3 ±1		31	[3] KITCHING	97	B787	+	
• • • We do not use the following data for averages, fits, limits, etc. • • •							
9.10±0.72±0.22		149	[4] BATLEY	14	NA48	±	
< 0.083	90		[5] ARTAMONOV	05	B949	+	P_π > 213 MeV/c
< 10	90	0	ATIYA	90B	B787	+	T_π117–127 MeV
< 84	90	0	ASANO	82	CNTR	+	T_π 117–127 MeV
−420 ± 520		0	ABRAMS	77	SPEC	+	T_π < 92 MeV
< 350	90	0	LJUNG	73	HLBC	+	6–102, 114–127 MeV
< 500	90	0	KLEMS	71	OSPK	+	T_π < 117 MeV
−100 ± 600			CHEN	68	OSPK	+	T_π 60–90 MeV

[1] CORTINA-GIL 24 uses data collected by NA62 at CERN in 2017 to 2018. This result, for the full kinematic range, is extrapolated using O(p^6) ChPT theoretical calculation from the model-independent branching fraction, B($K^+ \to \pi^+\gamma\gamma$)=(9.46 ± 0.19 ± 0.07) × 10^{-7}, obtained for $0.2<(m_{\gamma\gamma}/m_K)^2 < 0.51$. The ChPT parameter $\hat{c}$ = 1.144 ± 0.069 ± 0.034 is measured.

[2] LAZZERONI 14 combines NA62 and NA48/2 results. The result for the full kinematic range is extrapolated from the model-independent branching fraction (9.65 ± 0.61 ± 0.14) × 10^{-7} for $(m_{\gamma\gamma}/m_K)^2 > 0.2$. The measured ChPT parameter $\hat{c} = 1.86 \pm 0.25$.

[3] KITCHING 97 is extrapolated from their model-independent branching fraction (6.0 ± 1.5 ± 0.7) × 10^{-7} for 100 MeV/c<P_{π^+} < 180 MeV/c using Chiral Perturbation Theory.

[4] BATLEY 14 uses data collected in 2003 and 2004. Branching ratio is obtained by determining the parameter $\hat{c}$ = 1.41 ± 0.38 ± 0.11 and integrating the $\mathcal{O}(p^6)$ chiral spectrum. A model independent value for the branching ratio is also obtained (8.77 ± 0.87 ± 0.17) × 10^{-7} for kinematic range $(m_{\gamma\gamma}/m_K)^2 > 0.2$.

[5] ARTAMONOV 05 limit assumes ChPT with $\hat{c}$= 1.8 with unitarity corrections. With $\hat{c}$= 1.6 and no unitarity corrections they obtain < 2.3 × 10^{-8} at 90% CL. This partial branching ratio is predicted to be 6.10 × 10^{-9} and 0.49 × 10^{-9} for the cases with and without unitarity correction.

$\Gamma(\pi^+ 3\gamma)/\Gamma_{total}$ — Γ_{28}/Γ

Values given here assume a phase space pion energy spectrum.

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN	CHG	COMMENT
<1.0	90	ASANO	82	CNTR	+	$T(\pi)$ 117–127 MeV
• • • We do not use the following data for averages, fits, limits, etc. • • •						
<3.0	90	KLEMS	71	OSPK	+	$T(\pi)$ >117 MeV

$\Gamma(\pi^+ e^+ e^- \gamma)/\Gamma_{total}$ — Γ_{29}/Γ

VALUE (units 10^{-8})	EVTS	DOCUMENT ID		TECN	COMMENT
1.19±0.12±0.04	113	[1] BATLEY	08	NA48	$m_{ee\gamma} > 260$ MeV

[1] BATLEY 08 also reports the Chiral Perturbation Theory parameter $\hat{c} = 0.9 \pm 0.45$ obtained using the shape of the $e^+ e^- \gamma$ invariant mass spectrum. By extrapolating the theoretical amplitude to $m_{ee\gamma} < 260$ MeV, it obtains the inclusive B($K^+ \to \pi^+ e^+ e^- \gamma$) = $(1.29 \pm 0.13 \pm 0.03) \times 10^{-8}$, where the first error is the combined statistical and systematic errors and the second error is from the uncertainty in $\hat{c}$.

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

$\Gamma(e^+ \nu_e \nu \overline{\nu})/\Gamma(e^+ \nu_e)$ — Γ_{30}/Γ_1

VALUE	CL%	EVTS	DOCUMENT ID		TECN	CHG
<3.8	90	0	HEINTZE	79	SPEC	+

$\Gamma(\mu^+ \nu_\mu \nu \overline{\nu})/\Gamma_{total}$ — Γ_{31}/Γ

VALUE	CL%	DOCUMENT ID		TECN	CHG
<1.0 × 10⁻⁶	90	[1] CORTINA-GIL	21	NA62	+
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$<2.4 \times 10^{-6}$	90	[2] ARTAMONOV	16	B949	+
$<6.0 \times 10^{-6}$	90	[3] PANG	73	CNTR	+

[1] CORTINA-GIL 21 assumes Standard Model μ spectrum. The search is performed in the reconstructed missing mass interval $m_{miss} > 316$ MeV/c^2.

[2] ARTAMONOV 16 assumes Standard model μ spectrum. The search is performed in the muon momentum region between 130 and 175 MeV/c.

[3] PANG 73 assumes μ spectrum from ν-ν interaction of BARDIN 70.

$\Gamma(e^+ \nu_e e^+ e^-)/\Gamma_{total}$ — Γ_{32}/Γ

VALUE (units 10^{-8})	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
2.48± 0.14±0.14	410	POBLAGUEV	02	B865	+	$m_{ee} > 150$ MeV
• • • We do not use the following data for averages, fits, limits, etc. • • •						
20 ±20	4	DIAMANT-...	76	SPEC	+	$m_{e^+e^-} > 140$ MeV

$\Gamma(\mu^+ \nu_\mu e^+ e^-)/\Gamma_{total}$ — Γ_{33}/Γ

VALUE (units 10^{-8})	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
7.06± 0.16±0.26	2.7k	POBLAGUEV	02	B865	+	$m_{ee} > 145$ MeV
• • • We do not use the following data for averages, fits, limits, etc. • • •						
100 ±30	14	DIAMANT-...	76	SPEC	+	$m_{e^+e^-} > 140$ MeV

$\Gamma(e^+ \nu_e \mu^+ \mu^-)/\Gamma_{total}$ — Γ_{34}/Γ

VALUE (units 10^{-8})	CL%	DOCUMENT ID		TECN
1.72±0.45		MA	06	B865
• • • We do not use the following data for averages, fits, limits, etc. • • •				
<50	90	ADLER	98	B787

$\Gamma(\mu^+ \nu_\mu \mu^+ \mu^-)/\Gamma_{total}$ — Γ_{35}/Γ

VALUE (units 10^{-7})	CL%	DOCUMENT ID		TECN	CHG
<4.1	90	ATIYA	89	B787	+

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

$\Gamma(\pi^+\pi^+e^-\overline{\nu}_e)/\Gamma_{\text{total}}$ — Γ_{36}/Γ

Test of $\Delta S = \Delta Q$ rule.

VALUE (units 10^{-7})	CL%	EVTS	DOCUMENT ID		TECN	CHG
• • • We do not use the following data for averages, fits, limits, etc. • • •						
$<$ 9.0	95	0	SCHWEINB...	71	HLBC	+
$<$ 6.9	95	0	ELY	69	HLBC	+
$<$20.	95		BIRGE	65	FBC	+

$\Gamma(\pi^+\pi^+e^-\overline{\nu}_e)/\Gamma(\pi^+\pi^-e^+\nu_e)$ — Γ_{36}/Γ_7

Test of $\Delta S = \Delta Q$ rule.

VALUE (units 10^{-4})	CL%	EVTS	DOCUMENT ID		TECN
$<$ 3	90	3	[1] BLOCH	76	SPEC
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$<$130.	95	0	BOURQUIN	71	ASPK

[1] BLOCH 76 quotes 3.6×10^{-4} at CL = 95%, we convert.

$\Gamma(\pi^+\pi^+\mu^-\overline{\nu}_\mu)/\Gamma_{\text{total}}$ — Γ_{37}/Γ

Test of $\Delta S = \Delta Q$ rule.

VALUE (units 10^{-6})	CL%	EVTS	DOCUMENT ID		TECN	CHG
$<$3.0	95	0	BIRGE	65	FBC	+

$\Gamma(\pi^+e^+e^-)/\Gamma_{\text{total}}$ — Γ_{38}/Γ

Test for $\Delta S = 1$ weak neutral current. Allowed by combined first-order weak and electromagnetic interactions.

VALUE (units 10^{-7})	EVTS	DOCUMENT ID		TECN	CHG
3.00±0.09 OUR AVERAGE					
3.11±0.04±0.12	7253	[1] BATLEY	09	NA48	±
2.94±0.05±0.14	10300	[2] APPEL	99	SPEC	+
2.75±0.23±0.13	500	[3] ALLIEGRO	92	SPEC	+
2.7 ±0.5	41	[4] BLOCH	75	SPEC	+

[1] Value extrapolated from a measurement in the region z = $(m_{ee}/m_K)^2$ >0.08. BATLEY 09 also evaluated the shape of the form factor using four different theoretical models.

[2] APPEL 99 establishes vector nature of this decay and determines form factor $f(Z) = f_0 (1 + \delta Z)$, $Z = M^2_{ee}/m^2_K$, $\delta = 2.14 \pm 0.13 \pm 0.15$. Also reports constraints on scalar and tensor interactions: $|f_S| < 6.6 \times 10^{-5}$, $|f_T| < 3.7 \times 10^{-4}$ at 90% C.L.

[3] ALLIEGRO 92 assumes a vector interaction with a form factor given by $\lambda = 0.105 \pm 0.035 \pm 0.015$ and a correlation coefficient of -0.82.

[4] BLOCH 75 assumes a vector interaction.

$\Gamma(\pi^+\mu^+\mu^-)/\Gamma_{\text{total}}$ — Γ_{39}/Γ

Test for $\Delta S = 1$ weak neutral current. Allowed by higher-order electroweak interactions.

VALUE (units 10^{-8})	CL%	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
9.17±0.14 OUR AVERAGE Error includes scale factor of 1.8.							
9.15±0.06±0.05		28k	[1] CORTINA-GIL	22A	NA62		2017–18 data
9.62±0.21±0.13		3120	[2] BATLEY	11A	NA48	±	2003–04 data
9.8 ±1.0 ±0.5		110	[3] PARK	02	HYCP	±	
9.22±0.60±0.49		402	[4] MA	00	B865	+	
5.0 ±0.4 ±0.9		207	[5] ADLER	97C	B787	+	

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

9.7 ±1.2 ±0.4		65	PARK	02	HYCP	+
10.0 ±1.9 ±0.7		35	PARK	02	HYCP	−
<23	90		ATIYA	89	B787	+

[1] CORTINA-GIL 22A also studies the form factor $f(z)$ dependence of the decay, described via single photon exchange: assuming a linear form factor including π-π rescattering, $W_{\pi\pi}$, as in DAMBROSIO 98A, finding $f(z) = G_F\ m_K^2\ (a_+ + b_+\ z) + W_{\pi\pi}(z)$, $a_+ = -0.575 \pm 0.013$, $b_+ = -0.722 \pm 0.043$.

[2] BATLEY 11A also studies the form factor $f(z)$ dependence of the decay, described via single photon exchange: i) assuming a linear form factor, $f(z) = f_0\ (1+\ \delta\ z\ )$, $z = (M_{\mu\mu}/m_K)^2$, finding $f_0 = 0.470 \pm 0.040$ and $\delta = 3.11 \pm 0.57$ and ii) assuming a linear form factor including π-π rescattering , $W_{\pi\pi}$, as in DAMBROSIO 98A, finding $f(z) = G_F\ m_K^2\ (a_+ + b_+\ z) + W_{\pi\pi}(z)$, $a_+ = -0.575 \pm 0.039$, $b_+ = -0.813 \pm 0.145$.

[3] PARK 02 "±" result comes from combining $K^+ \rightarrow \pi^+ \mu^+ \mu^-$ and $K^- \rightarrow \pi^- \mu^+ \mu^-$, assuming CP is conserved.

[4] MA 00 establishes vector nature of this decay and determines form factor $f(z) = f_0\ (1 + \delta\ z)$, $z = (M_{\mu\mu}/m_K)^2$, $\delta = 2.45^{+1.30}_{-0.95}$.

[5] ADLER 97C gives systematic error 0.7×10^{-8} and theoretical uncertainty 0.6×10^{-8}, which we combine in quadrature to obtain our second error.

$\Gamma(\pi^+ e^+ e^- e^+ e^-)/\Gamma_{\text{total}}$ — Γ_{40}/Γ

VALUE	CL%	DOCUMENT ID		TECN	CHG
$<1.4 \times 10^{-8}$	90	[1] CORTINA-GIL	23B	NA62	+

[1] Quoted limit is obtained using data collected from 2017 to 2018. CORTINA-GIL 23B also reports upper limits at 90% C.L. at the level of 10^{-9} for the branching ratios of two prompt decay chains involving pair-production of hidden-sector mediators: $K^+ \rightarrow \pi^+ a a$, $a \rightarrow e^+ e^-$ and $K^+ \rightarrow \pi^+ S$, $S \rightarrow XX$, $X \rightarrow e^+ e^-$.

$\Gamma(\pi^+ \nu\overline{\nu})/\Gamma_{\text{total}}$ — Γ_{41}/Γ

Test for $\Delta S = 1$ weak neutral current. Allowed by higher-order electroweak interactions. Branching ratio values are extrapolated from the momentum or energy regions shown in the comments assuming Standard Model phase space except for those labeled "Scalar" or "Tensor" to indicate the assumed non-Standard-Model interaction.

VALUE (units 10^{-10})	CL%	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
$1.14^{+0.40}_{-0.33}$ OUR AVERAGE							
$1.06^{+0.41}_{-0.35}$		20	[1] CORTINA-GIL	21B	NA62	+	
$1.73^{+1.15}_{-1.05}$		7	[2] ARTAMONOV	08	B949	+	$140<P_\pi<199$ MeV, $211<P_\pi<229$MeV
• • • We do not use the following data for averages, fits, limits, etc. • • •							
$0.48^{+0.72}_{-0.48}$			[3] CORTINA-GIL	20C	NA62	+	
< 11	90	1	[4] CORTINA-GIL	19B	NA62	+	decay-in-flight
$7.89^{+9.26}_{-5.10}$		3	[5] ARTAMONOV	08	B949	+	$140<P_\pi<199$ MeV
< 22	90	1	[6] ADLER	04	B787	+	$211<P_\pi<229$ MeV
< 27	90		ADLER	04	B787	+	Scalar
< 18	90		ADLER	04	B787	+	Tensor

$1.47^{+1.30}_{-0.89}$		3	[7] ANISIMOVSK...	04	B949	+	$211<P_\pi<229$ MeV
$1.57^{+1.75}_{-0.82}$		2	ADLER	02	B787	+	$P_\pi>211$ MeV/c
$<$ 42	90	1	ADLER	02C	B787	+	$140<P_\pi<195$ MeV
$<$ 47	90		[8] ADLER	02C	B787	+	Scalar
$<$ 25	90		[8] ADLER	02C	B787	+	Tensor
$1.5^{+3.4}_{-1.2}$		1	ADLER	00	B787		In ADLER 02
$4.2^{+9.7}_{-3.5}$		1	ADLER	97	B787		
$<$ 24	90		ADLER	96	B787		
$<$ 75	90		ATIYA	93	B787	+	$T(\pi)$ 115–127 MeV
$<$ 52	90		[9] ATIYA	93	B787	+	
$<$ 170	90	0	ATIYA	93B	B787	+	$T(\pi)$ 60–100 MeV
$<$ 340	90		ATIYA	90	B787	+	
$<$1400	90		ASANO	81B	CNTR	+	$T(\pi)$ 116–127 MeV

[1] CORTINA-GIL 21B analysis of the NA62 data taken in 2016–2018 observed 20 candidate events with an expected background of 7 events. The achieved single event sensitivity is $(0.839 \pm 0.054) \times 10^{-11}$. The quoted branching ratio includes result from CORTINA-GIL 20C which observed two candidate events. This provides evidence for the very rare $K^+ \to \pi^+ \nu\overline{\nu}$ decay, observed with a significance of 3.4 σ. Search for a feebly interacting scalar or pseudo-scalar particle X in the decay $K^+ \to \pi^+ X$ was performed and an upper limit from $< 3\times10^{-11}$ to $< 6\times10^{-11}$ at the 90% C.L. was set for an invisible particle with a mass of 0–110 MeV/c^2 and $< 1\times10^{-11}$ for mass of 160–260 MeV/c^2.

[2] Value obtained combining ANISIMOVSKY 04, ADLER 04, and the present ARTAMONOV 08 results.

[3] CORTINA-GIL 20C analysis of the NA62 data taken in 2017 observed two candidate events with an expected background of 1.5 events. The achieved single event sensitivity is $(0.389 \pm 0.024)\times10^{-10}$. The quoted branching ratio includes result from CORTINA-GIL 19B which observed one candidate event. The corresponding upper limit B($K^+ \to \pi^+ \nu\overline{\nu}$) $< 1.78\times10^{-10}$ at 90% C.L. Superseded by CORTINA-GIL 21B.

[4] Based on a sample of 1.21×10^{11} K^+ decays collected in 2016. One signal candidate is observed while the expected background is 0.152 events. The single-event-sensitivity is estimated to be 3.15×10^{-10}.

[5] Observed 3 events with an estimated background of $0.93 \pm 0.17^{+0.32}_{-0.24}$. Signal-to-background ratio for each of these 3 events is 0.20, 0.42, and 0.47.

[6] Value obtained combining the previous result ADLER 02C with 1 event and the present result with 0 events to obtain an expected background 1.22 ± 0.24 events and 1 event observed.

[7] Value obtained combining the previous E787 result ADLER 02 with 2 events and the present E949 with 1 event. The additional event has a signal-to-background ratio 0.9. Superseded by ARTAMONOV 08.

[8] Superseded by ADLER 04.

[9] Combining ATIYA 93 and ATIYA 93B results. Superseded by ADLER 96.

$\Gamma(\pi^+\pi^0\nu\overline{\nu})/\Gamma_{\text{total}}$ Γ_{42}/Γ

Test for $\Delta S = 1$ weak neutral current. Allowed by higher-order electroweak interactions.

VALUE (units 10^{-5})	CL%	DOCUMENT ID		TECN
<4.3	90	[1] ADLER	01	SPEC

[1] Search region defined by 90 MeV/$c<P_{\pi^+}<$188 MeV/c and 135 MeV$<E_{\pi^0}<$180 MeV.

$\Gamma(\mu^- \nu e^+ e^+)/\Gamma_{\text{total}}$ — Γ_{43}/Γ

VALUE	CL%	DOCUMENT ID		TECN
$<8.1 \times 10^{-11}$	90	[1] CORTINA-GIL	23	NA62

[1] Performed using the dataset collected by the NA62 experiment at CERN from 2016 to 2018.

$\Gamma(\mu^- \nu e^+ e^+)/\Gamma(\pi^+ \pi^- e^+ \nu_e)$ — Γ_{43}/Γ_7

Test of lepton family number conservation.

VALUE (units 10^{-3})	CL%	EVTS	DOCUMENT ID		TECN	CHG
<0.5	90	0	[1] DIAMANT-...	76	SPEC	+

[1] DIAMANT-BERGER 76 quotes this result times our 1975 $\pi^+ \pi^- e \nu$ BR ratio.

$\Gamma(\mu^+ \nu_e)/\Gamma_{\text{total}}$ — Γ_{44}/Γ

Forbidden by lepton family number conservation.

VALUE	CL%	EVTS	DOCUMENT ID		TECN	COMMENT
<0.004	90	0	[1] LYONS	81	HLBC	200 GeV K^+ narrow band ν beam
• • • We do not use the following data for averages, fits, limits, etc. • • •						
<0.012	90		[1] COOPER	82	HLBC	Wideband ν beam

[1] COOPER 82 and LYONS 81 limits on ν_e observation are here interpreted as limits on lepton family number violation in the absence of mixing.

$\Gamma(\pi^+ \mu^+ e^-)/\Gamma_{\text{total}}$ — Γ_{45}/Γ

Test of lepton family number conservation.

VALUE (units 10^{-10})	CL%	DOCUMENT ID		TECN	CHG
<0.13	90	[1] SHER	05	RVUE	+
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<0.21	90	SHER	05	B865	+
<0.39	90	APPEL	00	B865	+
<2.1	90	LEE	90	SPEC	+

[1] This result combines SHER 05 1998 data, APPEL 00 1996 data, and data from BERGMAN 97 and PISLAK 97 theses, all from BNL-E865, with LEE 90 BNL-E777 data.

$\Gamma(\pi^0 \pi^+ \mu^+ e^-)/\Gamma_{\text{total}}$ — Γ_{46}/Γ

VALUE	CL%	DOCUMENT ID		TECN	CHG
$<5.0 \times 10^{-10}$	90	[1] ASHRAF	24	NA62	+

[1] ASHRAF 24 performed the search using a dataset collected by the NA62 experiment from 2016 to 2018.

$\Gamma(\pi^+ \mu^- e^+)/\Gamma_{\text{total}}$ — Γ_{47}/Γ

Test of lepton family number conservation.

VALUE	CL%	DOCUMENT ID		TECN	CHG
$< 6.6 \times 10^{-11}$	90	ALIBERTI	21	NA62	+
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$< 5.2 \times 10^{-10}$	90	APPEL	00B	B865	+
$<70 \times 10^{-10}$	90	[1] DIAMANT-...	76	SPEC	+

[1] Measurement actually applies to the sum of the $\pi^+ \mu^- e^+$ and $\pi^- \mu^+ e^+$ modes.

$\Gamma(\pi^0\pi^+\mu^-e^+)/\Gamma_{total}$ Γ_{48}/Γ

VALUE	CL%	DOCUMENT ID		TECN	CHG
$<3.1 \times 10^{-10}$	90	[1] ASHRAF	24	NA62	$+$

[1] ASHRAF 24 performed the search using a dataset collected by the NA62 experiment from 2016 to 2018.

$\Gamma(\pi^-\mu^+e^+)/\Gamma_{total}$ Γ_{49}/Γ

Test of total lepton number conservation.

VALUE	CL%	DOCUMENT ID		TECN	CHG
$< 4.2 \times 10^{-11}$	90	ALIBERTI	21	NA62	$+$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$< 5.0 \times 10^{-10}$	90	APPEL	00B	B865	$+$
$<70 \times 10^{-10}$	90	[1] DIAMANT-...	76	SPEC	$+$

[1] Measurement actually applies to the sum of the $\pi^+\mu^-e^+$ and $\pi^-\mu^+e^+$ modes.

$\Gamma(\pi^0\pi^-\mu^+e^+)/\Gamma_{total}$ Γ_{50}/Γ

VALUE	CL%	DOCUMENT ID		TECN	CHG
$<2.9 \times 10^{-10}$	90	[1] ASHRAF	24	NA62	$+$

[1] ASHRAF 24 performed the search using a dataset collected by the NA62 experiment from 2016 to 2018.

$\Gamma(\pi^-e^+e^+)/\Gamma_{total}$ Γ_{51}/Γ

Test of total lepton number conservation.

VALUE	CL%	DOCUMENT ID		TECN	CHG	COMMENT
$<5.3 \times 10^{-11}$	90	[1] CORTINA-GIL	22	NA62	$+$	decay-in-flight
• • • We do not use the following data for averages, fits, limits, etc. • • •						
$<2.2 \times 10^{-10}$	90	[2] CORTINA-GIL	19A	NA62	$+$	decay-in-flight
$<6.4 \times 10^{-10}$	90	APPEL	00B	B865	$+$	
$<9.2 \times 10^{-9}$	90	DIAMANT-...	76	SPEC	$+$	
$<1.5 \times 10^{-5}$		CHANG	68	HBC	$-$	

[1] CORTINA-GIL 22 uses the complete dataset collected by the NA62 experiment at CERN from 2016 to 2018. Supersedes CORTINA-GIL 19A.
[2] CORTINA-GIL 19A results are obtained with 2017 data. Superseded by CORTINA-GIL 22

$\Gamma(\pi^-\mu^+\mu^+)/\Gamma_{total}$ Γ_{52}/Γ

Forbidden by total lepton number conservation.

VALUE	CL%	DOCUMENT ID		TECN	CHG	COMMENT
$<4.2 \times 10^{-11}$	90	[1] CORTINA-GIL	19A	NA62	$+$	decay-in-flight
• • • We do not use the following data for averages, fits, limits, etc. • • •						
$<8.6 \times 10^{-11}$	90	[2] BATLEY	17	NA48	$\pm$	
$<1.1 \times 10^{-9}$	90	BATLEY	11A	NA48	$\pm$	
$<3.0 \times 10^{-9}$	90	APPEL	00B	B865	$+$	
$<1.5 \times 10^{-4}$	90	[3] LITTENBERG	92	HBC		

[1] CORTINA-GIL 19A results are obtained with 2017 data.
[2] BATLEY 17 result is based on data taken in 2003 to 2004. Limits for two-body resonance X in $K^{\pm} \rightarrow \pi\mu\mu$ decays are also reported.
[3] LITTENBERG 92 is from retroactive data analysis of CHANG 68 bubble chamber data.

$\Gamma(\pi^- \pi^0 e^+ e^+)/\Gamma_{total}$ Γ_{53}/Γ

Test of total lepton number conservation.

VALUE	CL%	DOCUMENT ID		TECN	CHG	COMMENT
$<8.5 \times 10^{-10}$	90	[1] CORTINA-GIL	22	NA62	+	decay-in-flight

[1] CORTINA-GIL 22 uses the complete dataset collected by the NA62 experiment at CERN from 2016 to 2018.

$\Gamma(\mu^+ \overline{\nu}_e)/\Gamma_{total}$ Γ_{54}/Γ

Forbidden by total lepton number conservation.

VALUE (units 10^{-3})	CL%	DOCUMENT ID		TECN	COMMENT
<3.3	90	[1] COOPER	82	HLBC	Wideband ν beam

[1] COOPER 82 limit on $\overline{\nu}_e$ observation is here interpreted as a limit on lepton number violation in the absence of mixing.

$\Gamma(\pi^0 e^+ \overline{\nu}_e)/\Gamma_{total}$ Γ_{55}/Γ

Forbidden by total lepton number conservation.

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<0.003	90	[1] COOPER	82	HLBC	Wideband ν beam

[1] COOPER 82 limit on $\overline{\nu}_e$ observation is here interpreted as a limit on lepton number violation in the absence of mixing.

$\Gamma(\pi^+ \gamma)/\Gamma_{total}$ Γ_{56}/Γ

Violates angular momentum conservation and gauge invariance. Current interest in this decay is as a search for non-commutative space-time effects as discussed in ARTAMONOV 05 and for exotic physics such as a vacuum expectation value of a new vector field, non-local Superstring effects, or departures from Lorentz invariance, as discussed in ADLER 02B.

VALUE	CL%	DOCUMENT ID		TECN	CHG
< 2.3×10^{-9}	90	ARTAMONOV	05	B949	+
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$< 360 \times 10^{-9}$	90	ADLER	02B	B787	+
$<1400 \times 10^{-9}$	90	ASANO	82	CNTR	+
$<4000 \times 10^{-9}$	90	[1] KLEMS	71	OSPK	+

[1] Test of model of Selleri, Nuovo Cimento **60A** 291 (1969).

CPT VIOLATION TESTS IN $K^{\pm}$ DECAYS

$$\Delta = (\Gamma(K^+) - \Gamma(K^-)) \,/\, (\Gamma(K^+) + \Gamma(K^-))$$

$\Delta(K^{\pm} \to \mu^{\pm} \nu_{\mu})$ RATE DIFFERENCE/SUM

VALUE (%)	DOCUMENT ID		TECN
-0.27 ± 0.21	FORD	67	CNTR

$\Delta(K^{\pm} \to \pi^{\pm} \pi^0)$ RATE DIFFERENCE/SUM

VALUE (%)	DOCUMENT ID		TECN
0.4 ± 0.6	HERZO	69	OSPK

CP VIOLATION TESTS IN $K^{\pm}$ DECAYS

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

$\Delta(K^{\pm} \to \pi^{\pm} e^+ e^-)$ RATE DIFFERENCE/SUM

VALUE (units 10^{-2})	DOCUMENT ID		TECN
−2.2±1.5±0.6	[1] BATLEY	09	NA48

[1] This implies an upper limit of 2.1×10^{-2} at 90% CL.

$\Delta(K^{\pm} \to \pi^{\pm} \mu^+ \mu^-)$ RATE DIFFERENCE/SUM

VALUE	DOCUMENT ID		TECN
0.010±0.023 OUR AVERAGE			
0.011±0.023	[1] BATLEY	11A	NA48
−0.02 ±0.11 ±0.04	PARK	02	HYCP

[1] This corresponds to the asymmetry upper limit of $< 2.9 \times 10^{-2}$ at 90% CL.

$\Delta(K^{\pm} \to \pi^{\pm} \pi^0 \gamma)$ RATE DIFFERENCE/SUM

VALUE (units 10^{-3})	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
0.0± 1.2 OUR AVERAGE						
0.0± 1.0±0.6	1M	[1] BATLEY	10A	NA48		
4 ±29	2461	SMITH	76	WIRE	±	E_{π} 55–90 MeV
5 ±20	4000	ABRAMS	73B	ASPK	±	E_{π} 51–100 MeV

[1] This value implies the upper bound for this asymmetry 1.5×10^{-3} at 90% CL.

$\Delta(K^{\pm} \to \pi^{\pm} \pi^+ \pi^-)$ RATE DIFFERENCE/SUM

VALUE (%)	EVTS	DOCUMENT ID		TECN	CHG
0.04±0.06		[1] FORD	70	ASPK	
• • • We do not use the following data for averages, fits, limits, etc. • • •					
−0.01±0.08		[2] SMITH	73	ASPK	±
0.05±0.07	3.2M	[1] FORD	70	ASPK	
−0.25±0.45		FLETCHER	67	OSPK	
−0.02±0.11		[1] FORD	67	CNTR	

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

$\Delta(K^{\pm} \to \pi^{\pm} \pi^0 \pi^0)$ RATE DIFFERENCE/SUM

VALUE (%)	EVTS	DOCUMENT ID		TECN	CHG
−0.02±0.28 OUR AVERAGE					
0.04±0.29		SMITH	73	ASPK	±
−0.6 ±0.9	1802	HERZO	69	OSPK	

T VIOLATION TESTS IN K^+ AND K^- DECAYS

P_T in $K^+ \to \pi^0 \mu^+ \nu_{\mu}$

T-violating muon polarization. Sensitive to new sources of CP violation beyond the Standard Model.

VALUE (units 10^{-3})	EVTS	DOCUMENT ID		TECN	CHG
−1.7±2.3±1.1		[1] ABE	04F	K246	+
• • • We do not use the following data for averages, fits, limits, etc. • • •					
−4.2±4.9±0.9	3.9M	ABE	99S	K246	+

[1] Includes three sets of data: 96-97 (ABE 99S), 98, and 99-00 totaling about three times the ABE 99S data sample. Corresponds to $P_T < 5.0 \times 10^{-3}$ at 90% CL.

P_T in $K^+ \to \mu^+ \nu_\mu \gamma$

T-violating muon polarization. Sensitive to new sources of *CP* violation beyond the Standard Model.

VALUE (units 10^{-2})	EVTS	DOCUMENT ID	TECN	CHG
$-0.64 \pm 1.85 \pm 0.10$	114k	[1] ANISIMOVSK...03	K246	+

[1] Muons stopped and polarization measured from decay to positrons.

Im(ξ) in $K^+ \to \pi^0 \mu^+ \nu_\mu$ DECAY (from transverse μ pol.)

Test of *T* reversal invariance.

VALUE	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
-0.006 ± 0.008 OUR AVERAGE						
$-0.0053 \pm 0.0071 \pm 0.0036$		[1] ABE	04F	K246	+	
-0.016 ± 0.025	20M	CAMPBELL	81	CNTR	+	Pol.
• • • We do not use the following data for averages, fits, limits, etc. • • •						
$-0.013 \pm 0.016 \pm 0.003$	3.9M	ABE	99S	CNTR	+	p_T K^+ at rest

[1] Includes three sets of data: 96-97 (ABE 99S), 98, and 99-00 totaling about three times the ABE 99S data sample. Corresponds to Im(ξ) < 0.016 at 90% CL.

DALITZ PLOT PARAMETERS FOR $K \to 3\pi$ DECAYS

Revised 1999 by T.G. Trippe (LBNL).

The Dalitz plot distribution for $K^\pm \to \pi^\pm\pi^\pm\pi^\mp$, $K^\pm \to \pi^0\pi^0\pi^\pm$, and $K_L^0 \to \pi^+\pi^-\pi^0$ can be parameterized by a series expansion such as that introduced by Weinberg [1]. We use the form

$$\left|M\right|^2 \propto 1 + g\frac{(s_3 - s_0)}{m_{\pi^+}^2} + h\left[\frac{s_3 - s_0}{m_{\pi^+}^2}\right]^2 + j\ \frac{(s_2 - s_1)}{m_{\pi^+}^2} + k\left[\frac{s_2 - s_1}{m_{\pi^+}^2}\right]^2 + f\ \frac{(s_2 - s_1)}{m_{\pi^+}^2}\frac{(s_3 - s_0)}{m_{\pi^+}^2} + \cdots\ , \quad (1)$$

where $m_{\pi^+}^2$ has been introduced to make the coefficients g, h, j, and k dimensionless, and

$$s_i = (P_K - P_i)^2 = (m_K - m_i)^2 - 2m_K T_i \ , \ i = 1,2,3,$$
$$s_0 = \frac{1}{3}\sum_i s_i = \frac{1}{3}(m_K^2 + m_1^2 + m_2^2 + m_3^2) \quad .$$

Here the P_i are four-vectors, m_i and T_i are the mass and kinetic energy of the i^{th} pion, and the index 3 is used for the odd pion.

The coefficient g is a measure of the slope in the variable s_3 (or T_3) of the Dalitz plot, while h and k measure the quadratic dependence on s_3 and $(s_2 - s_1)$, respectively. The coefficient j is related to the asymmetry of the plot and must be zero if CP invariance holds. Note also that if CP is good, g, h, and k must be the same for $K^+ \to \pi^+\pi^+\pi^-$ as for $K^- \to \pi^-\pi^-\pi^+$.

Since different experiments use different forms for $\left|M\right|^2$, in order to compare the experiments we have converted to g, h, j, and k whatever coefficients have been measured. Where such conversions have been done, the measured coefficient a_y, a_t, a_u, or a_v is given in the comment at the right. For definitions of these coefficients, details of this conversion, and discussion of the data, see the April 1982 version of this note [2].

References

1. S. Weinberg, Phys. Rev. Lett. **4**, 87 (1960).
2. Particle Data Group, Phys. Lett. **111B**, 69 (1982).

ENERGY DEPENDENCE OF $K^{\pm}$ DALITZ PLOT

$|\text{matrix element}|^2 = 1 + gu + hu^2 + kv^2$
where $u = (s_3 - s_0) / m_\pi^2$ and $v = (s_2 - s_1) / m_\pi^2$

LINEAR COEFFICIENT g FOR $K^{\pm} \to \pi^{\pm}\pi^{+}\pi^{-}$

Some experiments use Dalitz variables x and y. In the comments we give a_y = coefficient of y term. See note above on "Dalitz Plot Parameters for $K \to 3\pi$ Decays." For discussion of the conversion of a_y to g, see the earlier version of the same note in the *Review* published in Physics Letters **111B** 70 (1982).

VALUE	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
−0.21134±0.00017	471M	[1] BATLEY	07B	NA48	±	

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

−0.2221	±0.0065	225k	DEVAUX	77	SPEC	+	a_y=.2814±.0082
−0.199	±0.008	81k	[2] LUCAS	73	HBC	−	a_y=0.252±0.011
−0.2157	±0.0028	750k	FORD	72	ASPK	+	a_y=.2734±.0035
−0.2186	±0.0028	750k	FORD	72	ASPK	−	a_y=.2770±.0035
−0.200	±0.009	39819	[3] HOFFMASTER	72	HLBC	+	
−0.196	±0.012	17898	[4] GRAUMAN	70	HLBC	+	a_y=0.228±0.030
−0.193	±0.010	50919	MAST	69	HBC	−	a_y=0.244±0.013
−0.218	±0.016	9994	[5] BUTLER	68	HBC	+	a_y=0.277±0.020
−0.190	±0.023	5778	[5,6] MOSCOSO	68	HBC	−	a_y=0.242±0.029
−0.22	±0.024	5428	[5,6] ZINCHENKO	67	HBC	+	a_y=0.28 ± 0.03
−0.220	±0.035	1347	[7] FERRO-LUZZI	61	HBC	−	a_y=0.28 ± 0.045

[1] Final state strong interaction and radiative corrections not included in the fit.
[2] Quadratic dependence is required by K^0_L experiments.
[3] HOFFMASTER 72 includes GRAUMAN 70 data.
[4] Emulsion data added — all events included by HOFFMASTER 72.
[5] Experiments with large errors not included in average.
[6] Also includes DBC events.
[7] No radiative corrections included.

QUADRATIC COEFFICIENT *h* FOR $K^\pm \to \pi^\pm\pi^+\pi^-$

VALUE (units 10^{-2})	EVTS	DOCUMENT ID		TECN	CHG
1.848±0.040	471M	[1] BATLEY	07B	NA48	±
• • • We do not use the following data for averages, fits, limits, etc. • • •					
−0.06 ±1.43	225k	DEVAUX	77	SPEC	+
1.87 ±0.62	750k	FORD	72	ASPK	+
1.25 ±0.62	750k	FORD	72	ASPK	−
−0.9 ±1.4	39819	HOFFMASTER	72	HLBC	+
−0.1 ±1.2	50919	MAST	69	HBC	−

[1] Final state strong interaction and radiative corrections not included in the fit.

QUADRATIC COEFFICIENT *k* FOR $K^\pm \to \pi^\pm\pi^+\pi^-$

VALUE (units 10^{-3})	EVTS	DOCUMENT ID		TECN	CHG
− 4.63± 0.14	471M	[1] BATLEY	07B	NA48	±
• • • We do not use the following data for averages, fits, limits, etc. • • •					
−20.5 ± 3.9	225k	DEVAUX	77	SPEC	+
− 7.5 ± 1.9	750k	FORD	72	ASPK	+
− 8.3 ± 1.9	750k	FORD	72	ASPK	−
−10.5 ± 4.5	39819	HOFFMASTER	72	HLBC	+
−14 ±12	50919	MAST	69	HBC	−

[1] Final state strong interaction and radiative corrections not included in the fit.

$(g_+ - g_-)$ / $(g_+ + g_-)$ FOR $K^\pm \to \pi^\pm\pi^+\pi^-$

This is a *CP* violating asymmetry between linear coefficients g_+ for $K^+ \to \pi^+\pi^+\pi^-$ decay and g_- for $K^- \to \pi^-\pi^+\pi^-$ decay.

VALUE (units 10^{-4})	EVTS	DOCUMENT ID		TECN
− 1.5± 1.5±1.6	3.1G	[1] BATLEY	07E	NA48

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

1.7± 2.1±2.0	1.7G	[2] BATLEY	06	NA48
−70.0±53	3.2M	FORD	70	ASPK

[1] BATLEY 07E includes data from BATLEY 06. Uses quadratic parametrization and value $g_+ + g_- = 2g$ from BATLEY 07B. This measurement neglects any possible charge asymmetries in higher order slope parameters h or k.

[2] This measurement neglects any possible charge asymmetries in higher order slope parameters h or k.

LINEAR COEFFICIENT g FOR $K^\pm \to \pi^\pm \pi^0 \pi^0$

Unless otherwise stated, all experiments include terms quadratic in $(s_3 - s_0) / m^2_{\pi^+}$. See note above on "Dalitz Plot Parameters for $K \to 3\pi$ Decays."

See BATUSOV 98 for a discussion of the discrepancy between their result and others, especially BOLOTOV 86. At this time we have no way to resolve the discrepancy so we depend on the large scale factor as a warning.

VALUE	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
0.626 ±0.007 OUR AVERAGE						
0.6259±0.0043±0.0093	493k	AKOPDZHAN..	05B	TNF	±	
0.627 ±0.004 ±0.010	252k	[1,2] AJINENKO	03B	ISTR	−	
• • • We do not use the following data for averages, fits, limits, etc. • • •						
0.736 ±0.014 ±0.012	33k	BATUSOV	98	SPEC	+	
0.582 ±0.021	43k	BOLOTOV	86	CALO	−	
0.670 ±0.054	3263	BRAUN	76B	HLBC	+	
0.630 ±0.038	5635	SHEAFF	75	HLBC	+	
0.510 ±0.060	27k	SMITH	75	WIRE	+	
0.67 ±0.06	1365	AUBERT	72	HLBC	+	
0.544 ±0.048	4048	DAVISON	69	HLBC	+	Also emulsion

[1] Measured using in-flight decays of the 25 GeV negative secondary beam.

[2] They form new world averages $g_- = (0.617 \pm 0.018)$ and $g_+ = (0.684 \pm 0.033)$ which give $\Delta g_{\tau'} = 0.051 \pm 0.028$.

QUADRATIC COEFFICIENT h FOR $K^\pm \to \pi^\pm \pi^0 \pi^0$

VALUE	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
0.052 ±0.008 OUR AVERAGE						
0.0551±0.0044±0.0086	493k	AKOPDZHAN..	05B	TNF	±	
0.046 ±0.004 ±0.012	252k	[1] AJINENKO	03B	ISTR	−	
• • • We do not use the following data for averages, fits, limits, etc. • • •						
0.128 ±0.015 ±0.024	33k	BATUSOV	98	SPEC	+	
0.037 ±0.024	43k	BOLOTOV	86	CALO	−	
0.152 ±0.082	3263	BRAUN	76B	HLBC	+	
0.041 ±0.030	5635	SHEAFF	75	HLBC	+	
0.009 ±0.040	27k	SMITH	75	WIRE	+	
−0.01 ±0.08	1365	AUBERT	72	HLBC	+	
0.026 ±0.050	4048	DAVISON	69	HLBC	+	Also emulsion

[1] Measured using in-flight decays of the 25 GeV negative secondary beam.

QUADRATIC COEFFICIENT k FOR $K^\pm \to \pi^\pm \pi^0 \pi^0$

VALUE	EVTS	DOCUMENT ID		TECN	CHG
0.0054±0.0035 OUR AVERAGE Error includes scale factor of 2.5.					
0.0082±0.0011±0.0014	493k	AKOPDZHAN..	05B	TNF	±
0.001 ±0.001 ±0.002	252k	[1] AJINENKO	03B	ISTR	−
• • • We do not use the following data for averages, fits, limits, etc. • • •					
0.0197±0.0045±0.0029	33k	BATUSOV	98	SPEC	+

[1] Measured using in-flight decays of the 25 GeV negative secondary beam.

$(g_+ - g_-)$ / $(g_+ + g_-)$ FOR $K^\pm \rightarrow \pi^\pm \pi^0 \pi^0$

A nonzero value for this quantity indicates *CP* violation.

VALUE (units 10^{-4})	EVTS	DOCUMENT ID		TECN
1.8± 1.8 OUR AVERAGE				
1.8± 1.7±0.6	91.3M	[1] BATLEY	07E	NA48
2 ±18 ±5	619k	[2] AKOPDZHAN..	05	TNF
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1.8± 2.2±1.3	47M	[3] BATLEY	06A	NA48

[1] BATLEY 07E includes data from BATLEY 06A. Uses quadratic parametrization and PDG 06 value $g = 0.626 \pm 0.007$ to obtain $g_+ - g_- = (2.2 \pm 2.1 \pm 0.7) \times 10^{-4}$. Neglects any possible charge asymmetries in higher order slope parameters h or k.

[2] Asymmetry obtained assuming that $g_+ + g_- = 2\times 0.652$ (PDG 02) and that asymmetries in h and k are zero.

[3] Linear and quadratic slopes from PDG 04 are used. Any possible charge asymmetries in higher order slope parameters h or k are neglected.

ALTERNATIVE PARAMETRIZATIONS OF $K^\pm \rightarrow \pi^\pm \pi^0 \pi^0$ DALITZ PLOT

The following functional form for the matrix element suggested by $\pi\pi$ rescattering in $K^+ \rightarrow \pi^+$“$\pi^+\pi^-$”$\rightarrow \pi^+\pi^0\pi^0$ is used for this fit (CABIBBO 04A, CABIBBO 05): Matrix element = $M_0 + M_1$ where $M_0 = 1 + (1/2)g_0\, u + (1/2)\, h'\, u^2 + (1/2)k_0\, v^2$ with $u = (s_3 - s_0)/(m_{\pi^+})^2$, $v = (s_2 - s_1)/(m_{\pi^+})^2$ and where M_1 takes into account the non-analytic piece due to pi pi rescattering amplitudes a_0 and a_2; The parameters g_0 and h' are related to the parameters g and h of the matrix element squared given in the previous section by the approximations $g_0 \sim g^{PDG}$ and $h' \sim h^{PDG} - (g/2)^2$ and $k_0 \sim k^{PDG}$.

In addition, we also consider the effective field theory framework of COLANGELO 06A and BISSEGGER 09 to extract g_{BB} and h'_{BB}.

LINEAR COEFFICIENT g_0 FOR $K^\pm \rightarrow \pi^\pm \pi^0 \pi^0$

VALUE	EVTS	DOCUMENT ID		TECN	CHG
0.6525±0.0009±0.0033	60M	[1] BATLEY	09A	NA48	±
• • • We do not use the following data for averages, fits, limits, etc. • • •					
0.645 ±0.004 ±0.009	23M	[2] BATLEY	06B	NA48	±

[1] This fit is obtained with the CABIBBO 05 matrix element in the $2\pi^0$ invariant mass squared range $0.074094 < m^2_{2\pi^0} < 0.104244$ GeV^2. Electromagnetic corrections and CHPT constraints for $\pi\pi$ phase shifts (a_0 and a_2) have been used. Also measured $(a_0 - a_2)\, m_{\pi^+} = 0.2646 \pm 0.0021 \pm 0.0023$, where k_0 was kept fixed in the fit at -0.0099.

[2] Superseded by BATLEY 09A. This fit is obtained with the CABIBBO 05 matrix element in the $2\pi^0$ invariant mass squared range 0.074 GeV^2 $< m^2_{2\pi^0} <$ 0.097 GeV^2, assuming $k = 0$ (no term proportional to $(s_2 - s_1)^2$) and excluding the kinematic region around the cusp ($m^2_{2\pi^0} = (2m_{\pi^+})^2 \pm 0.000525$ GeV^2). Also π-π phase shifts a_0 and a_2 are measured: $(a_0 - a_2)m_{\pi^+} = 0.268 \pm 0.010 \pm 0.004 \pm 0.013$(external) and $a_2\, m_{\pi^+} = -0.041 \pm 0.022 \pm 0.014$.

QUADRATIC COEFFICIENT h' FOR $K^{\pm} \to \pi^{\pm}\pi^0\pi^0$

VALUE	EVTS	DOCUMENT ID		TECN	CHG
−0.0433±0.0008±0.0026	60M	[1] BATLEY	09A	NA48	±
• • • We do not use the following data for averages, fits, limits, etc. • • •					
−0.047 ±0.012 ±0.011	23M	[2] BATLEY	06B	NA48	±

[1] This fit is obtained with the CABIBBO 05 matrix element in the $2\pi^0$ invariant mass squared range $0.074094 < m^2_{2\pi^0} < 0.104244$ GeV^2. Electromagnetic corrections and CHPT constraints for $\pi\pi$ phase shifts (a_0 and a_2) have been used. Also measured $(a_0 - a_2)\ m_{\pi^+} = 0.2646 \pm 0.0021 \pm 0.0023$, where k_0 was kept fixed in the fit at -0.0099.

[2] Superseded by BATLEY 09A. This fit is obtained with the CABIBBO 05 matrix element in the $2\pi^0$ invariant mass squared range 0.074 GeV^2 $< m^2_{2\pi^0} <$ 0.097 GeV^2, assuming $k = 0$ (no term proportional to $(s_2 - s_1)^2$) and excluding the kinematic region around the cusp ($m^2_{2\pi^0} = (2m_{\pi^+})^2 \pm 0.000525$ GeV^2). Also π-π phase shifts a_0 and a_2 are measured: $(a_0 - a_2)m_{\pi^+} = 0.268 \pm 0.010 \pm 0.004 \pm 0.013$(external) and $a_2\ m_{\pi^+} = -0.041 \pm 0.022 \pm 0.014$.

QUADRATIC COEFFICIENT k_0 FOR $K^{\pm} \to \pi^{\pm}\pi^0\pi^0$

VALUE	EVTS	DOCUMENT ID		TECN	CHG
0.0095±0.00017±0.00048	60M	[1] BATLEY	09A	NA48	±

[1] Assumed $a_2\ m_{\pi^+} = -0.0044$ in the fit.

LINEAR COEFFICIENT g_{BB} FOR $K^{\pm} \to \pi^{\pm}\pi^0\pi^0$

VALUE	EVTS	DOCUMENT ID		TECN	CHG
0.6219±0.0009±0.0033	60M	[1] BATLEY	09A	NA48	±

[1] This fit is obtained using parametrizations of COLANGELO 06A and BISSEGGER 09 in the $2\pi^0$ invariant mass squared range $0.074094 < m^2_{2\pi^0} < 0.104244$ GeV^2. Electromagnetic corrections and CHPT constraints for $\pi\pi$ phase shifts (a_0 and a_2) have been used. Also measured $(a_0 - a_2)\ m_{\pi^+} = 0.2633 \pm 0.0024 \pm 0.0024$, where k_0 was kept fixed in the fit at 0.0085.

QUADRATIC COEFFICIENT h'_{BB} FOR $K^{\pm} \to \pi^{\pm}\pi^0\pi^0$

VALUE	EVTS	DOCUMENT ID		TECN	CHG
−0.0520±0.0009±0.0026	60M	[1] BATLEY	09A	NA48	±

[1] This fit is obtained using parametrizations of COLANGELO 06A and BISSEGGER 09 in the $2\pi^0$ invariant mass squared range $0.074094 < m^2_{2\pi^0} < 0.104244$ GeV^2. Electromagnetic corrections and CHPT constraints for $\pi\pi$ phase shifts (a_0 and a_2) have been used. Also measured $(a_0 - a_2)\ m_{\pi^+} = 0.2633 \pm 0.0024 \pm 0.0024$, where k_0 was kept fixed in the fit at 0.0085.

$K^{\pm}_{\ell 3}$ FORM FACTORS

In the form factor comments, the following symbols are used.

f_+ and f_- are form factors for the vector matrix element.

f_S and f_T refer to the scalar and tensor term.

$f_0 = f_+ + f_-\ t/(m^2_{K^+} - m^2_{\pi^0})$.

t = momentum transfer to the π.

λ_+ and λ_0 are the linear expansion coefficients of f_+ and f_0:

$f_+(t) = f_+(0)\ (1 + \lambda_+ t\ /m^2_{\pi^+})$

For quadratic expansion

$f_+(t) = f_+(0)\ (1 + \lambda'_+ t\ /m^2_{\pi^+} + \frac{\lambda''_+}{2}\ t^2/m^4_{\pi^+}\ )$

as used by KTeV. If there is a non-vanishing quadratic term, then λ_+ represents an average slope, which is then different from λ'_+.

NA48/2 and OKA quadratic expansion coefficients are converted with

$\lambda'_+{}^{PDG} = \lambda'_+{}^{NA48/2}$ and $\lambda''_+{}^{PDG} = 2\ \lambda''_+{}^{NA48/2}$

$\lambda'_+{}^{PDG} = (\frac{m_{\pi^+}}{m_{\pi^0}})^2\ \lambda'_+{}^{OKA}$ and

$\lambda''_+{}^{PDG} = 2\ (\frac{m_{\pi^+}}{m_{\pi^0}})^4\ \lambda''_+{}^{OKA}$

OKA linear expansion coefficients are converted with

$\lambda_+{}^{PDG} = (\frac{m_{\pi^+}}{m_{\pi^0}})^2\ \lambda_+{}^{OKA}$ and $\lambda_0{}^{PDG} = (\frac{m_{\pi^+}}{m_{\pi^0}})^2\ \lambda_0{}^{OKA}$

The pole parametrization is

$$f_+(t) = f_+(0)\ (\frac{M_V^2}{M_V^2 - t}\ )$$

$$f_0(t) = f_0(0)\ (\frac{M_S^2}{M_S^2 - t}\ )$$

where M_V and M_S are the vector and scalar pole masses.

The following abbreviations are used:

DP = Dalitz plot analysis.

PI = π spectrum analysis.

MU = μ spectrum analysis.

POL= μ polarization analysis.

BR = $K^{\pm}_{\mu 3}/K^{\pm}_{e3}$ branching ratio analysis.

E = positron or electron spectrum analysis.

RC = radiative corrections.

For previous λ'_+ and λ''_+ parametrizations used by NA48 (e.g. LAI 07A) and ISTRA (e.g. YUSHCHENKO 04B) see PDG 18.

λ_+ (LINEAR ENERGY DEPENDENCE OF f_+ IN $K^{\pm}_{e3}$ DECAY)

These results are for a linear expansion only. See the next section for fits including a quadratic term. For radiative correction of the $K^{\pm}_{e3}$ Dalitz plot, see GINSBERG 67, BECHERRAWY 70, CIRIGLIANO 02, CIRIGLIANO 04, and ANDRE 07. Results labeled OUR FIT are discussed in the review "$K^{\pm}_{\ell 3}$ and $K^0_{\ell 3}$ Form Factors" above. For earlier, lower statistics results, see the 2004 edition of this review, Physics Letters **B592** 1 (2004).

VALUE (units 10^{-2})	EVTS	DOCUMENT ID	TECN	CHG	COMMENT
2.959±0.025 OUR FIT	Assuming μ-e universality				
2.956±0.025 OUR AVERAGE					
2.95 ±0.022±0.018	5.25M	YUSHCHENKO 18	OKA	+	
3.044±0.083±0.074	1.1M	AKOPDZANOV 09	TNF	±	
2.966±0.050±0.034	919k	[1] YUSHCHENKO 04B	ISTR	−	DP

2.78 $\pm$0.26 $\pm$0.30	41k		SHIMIZU	00	SPEC	+	DP
2.84 $\pm$0.27 $\pm$0.20	32k	[2]	AKIMENKO	91	SPEC		PI, no RC
2.9 $\pm$0.4	62k	[3]	BOLOTOV	88	SPEC		PI, no RC
• • • We do not use the following data for averages, fits, limits, etc. • • •							
3.06 $\pm$0.09 $\pm$0.06	550k	[1,4]	AJINENKO	03C	ISTR	−	DP
2.93 $\pm$0.15 $\pm$0.2	130k	[4]	AJINENKO	02	SPEC		DP

[1] Rescaled to agree with our conventions as noted above.

[2] AKIMENKO 91 state that radiative corrections would raise λ_+ by 0.0013.

[3] BOLOTOV 88 state radiative corrections of GINSBERG 67 would raise λ_+ by 0.002.

[4] Superseded by YUSHCHENKO 04B.

λ_+ (LINEAR ENERGY DEPENDENCE OF f_+ IN $K^\pm_{\mu 3}$ DECAY)

Results labeled OUR FIT are discussed in the review "$K^\pm_{\ell 3}$ and $K^0_{\ell 3}$ Form Factors" above. For earlier, lower statistics results, see the 2004 edition of this review, Physics Letters **B592** 1 (2004).

VALUE (units 10^{-2})	EVTS		DOCUMENT ID		TECN	CHG	COMMENT
2.959$\pm$0.025 OUR FIT	Assuming μ-e universality						
3.09 $\pm$0.25 OUR FIT	Error includes scale factor of 1.5. Not assuming μ-e universality						
2.96 $\pm$0.14 $\pm$0.10	540k	[1]	YUSHCHENKO	04	ISTR	−	DP
• • • We do not use the following data for averages, fits, limits, etc. • • •							
3.21 $\pm$0.45	112k	[2]	AJINENKO	03	ISTR	−	DP

[1] Rescaled to agree with our conventions as noted above.

[2] Superseded by YUSHCHENKO 04.

λ_0 (LINEAR ENERGY DEPENDENCE OF f_0 IN $K^\pm_{\mu 3}$ DECAY)

Results labeled OUR FIT are discussed in the review "$K^\pm_{\ell 3}$ and $K^0_{\ell 3}$ Form Factors" above. For earlier, lower statistics results, see the 2004 edition of this review, Physics Letters **B592** 1 (2004).

VALUE (units 10^{-2})	$d\lambda_0/d\lambda_+$	EVTS		DOCUMENT ID		TECN	CHG	COMMENT
1.76 $\pm$0.25 OUR FIT	Error includes scale factor of 2.7. Assuming μ-e universality							
1.73 $\pm$0.27 OUR FIT	Error includes scale factor of 2.6. Not assuming μ-e universality							
1.420$\pm$0.114$\pm$0.107		2.3M	[1]	BATLEY	18	NA48	$\pm$	
1.96 $\pm$0.12 $\pm$0.06	−0.348	540k	[2]	YUSHCHENKO	04	ISTR	−	DP
• • • We do not use the following data for averages, fits, limits, etc. • • •								
2.09 $\pm$0.45	−0.46	112k	[3]	AJINENKO	03	ISTR	−	DP
1.9 $\pm$0.64		24k	[4]	HORIE	01	SPEC	+	BR
1.9 $\pm$1.0	+0.03	55k	[5]	HEINTZE	77	SPEC	+	BR

[1] Data collected in 2004 by NA48/2. Obtained from a fit with a quadratic vector form factor. Correlation coefficient with linear slope is 0.511, with quadratic slope is −0.513. χ^2/NDF = 409.9/381. BATLEY 18 also performed a combined $K^\pm_{e3}$ and $K^\pm_{\mu 3}$ fit assuming $\mu - e$ universality and obtained $(14.47 \pm 0.63 \pm 1.17) \times 10^{-3}$.

[2] Rescaled to agree with our conventions as noted above.

[3] Superseded by YUSHCHENKO 04.

[4] HORIE 01 assumes μ-e universality in $K^+_{\ell 3}$ decay and uses SHIMIZU 00 value λ=0.0278$\pm$0.0040 from $K^\pm_{e3}$ decay.

[5] HEINTZE 77 uses $\lambda_+ = 0.029 \pm 0.003$. $d\lambda_0/d\lambda_+$ estimated by us.

λ'_+ (LINEAR $K^\pm_{e3}$ FORM FACTOR FROM QUADRATIC FIT)

VALUE (units 10^{-2})	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
2.59 ±0.04 OUR AVERAGE						
2.426±0.078±0.130	4.4M	[1] BATLEY	18	NA48	±	
2.611±0.035±0.028	5.25M	YUSHCHENKO	18	OKA	+	
2.485±0.163±0.034	919k	[2,3] YUSHCHENKO	04B	ISTR	−	DP
• • • We do not use the following data for averages, fits, limits, etc. • • •						
3.07 ±0.21	550k	[2,4] AJINENKO	03C	ISTR	−	DP

[1] Data collected in 2004 by NA48/2. Correlation coefficient with quadratic slope is −0.929. χ^2/NDF = 569.1/687. BATLEY 18 also performed a combined $K^\pm_{e3}$ and $K^\pm_{\mu3}$ fit assuming $\mu - e$ universality and obtained $(24.24 \pm 0.75 \pm 1.3) \times 10^{-3}$.
[2] Rescaled to agree with our conventions as noted above.
[3] YUSHCHENKO 04B λ'_+ and λ''_+ are strongly correlated with coefficient $\rho(\lambda'_+, \lambda''_+) = -0.95$.
[4] Superseded by YUSHCHENKO 04B.

λ''_+(QUADRATIC $K^\pm_{e3}$ FORM FACTOR)

VALUE (units 10^{-2})	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
0.186±0.021 OUR AVERAGE						
0.164±0.030±0.039	4.4M	[1] BATLEY	18	NA48	±	
0.191±0.019±0.014	5.25M	YUSHCHENKO	18	OKA	+	
0.192±0.062±0.071	919k	[2,3] YUSHCHENKO	04B	ISTR	−	DP
• • • We do not use the following data for averages, fits, limits, etc. • • •						
−0.5 ±0.7 ±1.5	550k	[2,4] AJINENKO	03C	ISTR	−	DP

[1] Data collected in 2004 by NA48/2. Correlation coefficient with quadratic slope is −0.929. χ^2/NDF = 569.1/687. BATLEY 18 also performed a combined $K^\pm_{e3}$ and $K^\pm_{\mu3}$ fit assuming $\mu - e$ universality and obtained $(1.67 \pm 0.29 \pm 0.41) \times 10^{-3}$.
[2] Rescaled to agree with our conventions as noted above.
[3] YUSHCHENKO 04B λ'_+ and λ''_+ are strongly correlated with coefficient $\rho(\lambda'_+, \lambda''_+) = -0.95$.
[4] Superseded by YUSHCHENKO 04B.

λ'_+ (LINEAR $K^\pm_{\mu3}$ FORM FACTOR FROM QUADRATIC FIT)

VALUE (units 10^{-3})	EVTS	DOCUMENT ID		TECN	CHG
24.27±2.88±2.89	2.3M	[1] BATLEY	18	NA48	±

[1] Data collected in 2004 by NA48/2. Correlation coefficient with quadratic slope is −0.974, with scalar slope is 0.511. χ^2/NDF = 409.9/381. BATLEY 18 also performed a combined $K^\pm_{e3}$ and $K^\pm_{\mu3}$ fit assuming $\mu - e$ universality and obtained $(24.24 \pm 0.75 \pm 1.3) \times 10^{-3}$.

λ''_+ (QUADRATIC $K^\pm_{\mu3}$ FORM FACTOR)

VALUE (units 10^{-3})	EVTS	DOCUMENT ID		TECN	CHG
1.83±1.05±1.09	2.3M	[1] BATLEY	18	NA48	±

[1] Data collected in 2004 by NA48/2. Correlation coefficient with linear slope is −0.974, with scalar slope is 0.513. χ^2/NDF = 409.9/381. BATLEY 18 also performed a combined $K^\pm_{e3}$ and $K^\pm_{\mu3}$ fit assuming $\mu - e$ universality and obtained $(1.67 \pm 0.29 \pm 0.41) \times 10^{-3}$.

M_V (VECTOR POLE MASS FOR $K^{\pm}_{e3}$ DECAY)

See the review on $K^{\pm}_{l3}$ and K^{0}_{l3} Form Factors for details.

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG
890.3±2.8 OUR AVERAGE					
885.2±3.3±7.2	4.4M	[1] BATLEY	18	NA48	±
891 ±3	5.25M	[2] YUSHCHENKO	18	OKA	+

[1] Data collected in 2004 by NA48/2. $\chi^2/NDF = 568.9/688$. BATLEY 18 also performed a combined $K^{\pm}_{e3}$ and $K^{\pm}_{\mu3}$ fit assuming $\mu - e$ universality and obtained $884.4 \pm 3.1 \pm 6.7$ MeV.

[2] Assumed no scalar or tensor contributions to the form factor.

M_V (VECTOR POLE MASS FOR $K^{\pm}_{\mu3}$ DECAY)

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG
878.4±8.8±8.3	2.3M	[1] BATLEY	18	NA48	±

[1] Data collected in 2004 by NA48/2. $\chi^2/NDF = 409.9/382$. BATLEY 18 also performed a combined $K^{\pm}_{e3}$ and $K^{\pm}_{\mu3}$ fit assuming $\mu - e$ universality and obtained $884.4 \pm 3.1 \pm 6.7$ MeV.

M_S (SCALAR POLE MASS FOR $K^{\pm}_{\mu3}$ DECAY)

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG
1214.8±23.5±49.2	2.3M	[1] BATLEY	18	NA48	±

[1] Data collected in 2004 by NA48/2. $\chi^2/NDF = 409.9/382$. BATLEY 18 also performed a combined $K^{\pm}_{e3}$ and $K^{\pm}_{\mu3}$ fit assuming $\mu - e$ universality and obtained $1208.3 \pm 21.2 \pm 47.5$ MeV.

Λ_+ (DISPERSIVE VECTOR FORM FACTOR IN $K^{\pm}_{e3}$ DECAY)

See the review on $K^{\pm}_{l3}$ and K^{0}_{l3} Form Factors for details.

VALUE (units 10^{-2})	EVTS	DOCUMENT ID		TECN	CHG
2.460±0.017 OUR AVERAGE					
2.494±0.021±0.064	4.4M	[1] BATLEY	18	NA48	±
2.458±0.018	5.25M	[2] YUSHCHENKO	18	OKA	+

[1] Data collected in 2004 by NA48/2. $\chi^2/NDF = 569.0/688$. BATLEY 18 also performed a combined $K^{\pm}_{e3}$ and $K^{\pm}_{\mu3}$ fit assuming $\mu - e$ universality and obtained $(24.99 \pm 0.20 \pm 0.62) \times 10^{-3}$.

[2] Assumed no scalar or tensor contributions to the form factor.

Λ_+ (DISPERSIVE VECTOR FORM FACTOR IN $K^{\pm}_{\mu3}$ DECAY)

VALUE (units 10^{-3})	EVTS	DOCUMENT ID		TECN	CHG
25.36±0.58±0.72	2.3M	[1] BATLEY	18	NA48	±

[1] Data collected in 2004 by NA48/2. $\chi^2/NDF = 410.3/382$. BATLEY 18 also performed a combined $K^{\pm}_{e3}$ and $K^{\pm}_{\mu3}$ fit assuming $\mu - e$ universality and obtained $(24.99 \pm 0.20 \pm 0.62) \times 10^{-3}$.

ln(C) (DISPERSIVE SCALAR FORM FACTOR in $K^{\pm}_{\mu3}$ decays)

VALUE (units 10^{-3})	EVTS	DOCUMENT ID		TECN	CHG
182.17±6.31±14.45	2.3M	[1] BATLEY	18	NA48	±

[1] Data collected in 2004 by NA48/2. Combined fit with dispersive vector form factor $\Lambda_+ = 25.36 \pm 0.58 \pm 0.72$. Correlation coefficient is 0.104. $\chi^2/NDF = 410.3/382$. BATLEY 18 also performed a combined $K^\pm_{e3}$ and $K^\pm_{\mu 3}$ fit assuming $\mu - e$ universality and obtained $(183.65 \pm 5.92 \pm 14.25) \times 10^{-3}$.

$|f_S/f_+|$ FOR $K^\pm_{e3}$ DECAY

Ratio of scalar to f_+ couplings.

VALUE (units 10^{-2})	CL%	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
$-0.08^{+0.34}_{-0.40}$ OUR AVERAGE							
$0.01^{+0.38}_{-0.46}$		5.25M	YUSHCHENKO	18	OKA	+	λ'_+, λ''_+, f_S fit
$-0.37^{+0.66}_{-0.56} \pm 0.41$		919k	YUSHCHENKO	04B	ISTR	−	λ'_+, λ''_+, f_S fit
$0.2 \pm 2.6 \pm 1.4$		41k	SHIMIZU	00	SPEC	+	λ_+, f_S, f_T fit
• • • We do not use the following data for averages, fits, limits, etc. • • •							
$0.2\ ^{+2.0}_{-2.2} \pm 0.3$		550k	[1] AJINENKO	03C	ISTR	−	λ_+, f_S, f_T fit
$-1.9\ ^{+2.5}_{-1.6}$		130k	[1] AJINENKO	02	SPEC		λ_+, f_S fit
$7.0 \pm 1.6 \pm 1.6$		32k	AKIMENKO	91	SPEC		λ_+, f_S, f_T, ϕ fit
0 ± 10		2827	[2] BRAUN	75	HLBC	+	
< 13	90	4017	CHIANG	72	OSPK	+	
14^{+3}_{-4}		2707	[2] STEINER	71	HLBC	+	λ_+, f_S, f_T, ϕ fit
< 23	90		BOTTERILL	68C	ASPK		
< 18	90		BELLOTTI	67B	HLBC		
< 30	95		KALMUS	67	HLBC	+	

[1] Superseded by YUSHCHENKO 04B.
[2] Statistical errors only.

$|f_T/f_+|$ FOR $K^\pm_{e3}$ DECAY

Ratio of tensor to f_+ couplings.

VALUE (units 10^{-2})	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
$-1.2^{+1.3}_{-1.1}$ OUR AVERAGE						
$-1.24^{+1.6}_{-1.3}$	5.25M	YUSHCHENKO	18	OKA	+	λ'_+,λ''_+,f_T fit
$-1.2 \pm 2.1 \pm 1.1$	919k	YUSHCHENKO	04B	ISTR	−	λ'_+,λ''_+,f_T fit
$1 \pm 14 \pm 9$	41k	SHIMIZU	00	SPEC	+	λ_+, f_S, f_T fit
• • • We do not use the following data for averages, fits, limits, etc. • • •						
$2.1^{+6.4}_{-7.5} \pm 2.6$	550k	[1] AJINENKO	03C	ISTR	−	λ_+, f_S, f_T fit
$-4.5^{+6.0}_{-5.7}$	130k	[1] AJINENKO	02	SPEC		λ_+, f_T fit
$53\ ^{+9}_{-10} \pm 10$	32k	AKIMENKO	91	SPEC		λ_+, f_S, f_T, ϕ fit

[1] Superseded by YUSHCHENKO 04B.

f_S/f_+ FOR $K^\pm_{\mu 3}$ DECAY

Ratio of scalar to f_+ couplings.

VALUE (units 10^{-2})	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
$0.17 \pm 0.14 \pm 0.54$	540k	[1] YUSHCHENKO	04	ISTR	−	DP

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

0.4 ±0.5 ±0.5	112k	[2] AJINENKO	03	ISTR	−	DP

[1] The second error is the theoretical error from the uncertainty in the chiral perturbation theory prediction for λ_0, ±0.0053, combined in quadrature with the systematic error ±0.0009.

[2] The second error is the theoretical error from the uncertainty in the chiral perturbation theory prediction for λ_0. Superseded by YUSHCHENKO 04.

f_T/f_+ FOR $K^\pm_{\mu3}$ DECAY

Ratio of tensor to f_+ couplings.

VALUE (units 10^{-2})	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
−0.07± 0.71±0.20	540k	YUSHCHENKO	04	ISTR	−	DP
• • • We do not use the following data for averages, fits, limits, etc. • • •						
−2.1 ± 2.8 ±1.4	112k	[1] AJINENKO	03	ISTR	−	DP
2 ±12	1585	BRAUN	75	HLBC		

[1] The second error is the theoretical error from the uncertainty in the chiral perturbation theory prediction for λ_0. Superseded by YUSHCHENKO 04.

$K^\pm_{\ell4}$ FORM FACTORS

Based on the parametrizations of AMOROS 99, the $K^\pm_{\ell4}$ form factors can be expressed as

$$F_s = f_s + f'_s\, q^2 + f''_s\, q^4 + f'_e\, S_e \,/\, 4m^2_\pi$$
$$F_p = f_p$$
$$G_p = g_p + g'_p\, q^2$$
$$H_p = h_p$$

where $q^2 = (S_\pi \,/\, 4m^2_\pi) - 1$, S_π is the invariant mass squared of the dipion, and S_e is the invariant mass squared of the dilepton.

f_s FOR $K^\pm \to \pi^+\pi^- e^\pm \nu$ DECAY

VALUE	EVTS	DOCUMENT ID		TECN	CHG
5.712±0.032 OUR AVERAGE					
5.705±0.003±0.035	1.1M	[1] BATLEY	12	NA48	±
5.75 ±0.02 ±0.08	400k	[2] PISLAK	03	B865	+

[1] BATLEY 12 uses data collected in 2003–2004. The result is obtained from a measurement of $\Gamma(\pi^+\pi^- e\nu)/\Gamma(\pi^+\pi^-\pi^+)$ and assumed PDG 12 value of $\Gamma(\pi^+\pi^-\pi^+)/\Gamma = (5.59 \pm 0.04) \times 10^{-2}$.

[2] Radiative corrections included. Using Roy equations and not including isospin breaking, PISLAK 03 obtains the following $\pi\pi$ scattering lengths $a^0_0 = 0.228 \pm 0.012 \pm 0.004^{+0.012}_{-0.016}$(theor.) and $a^2_0 = -0.0365 \pm 0.0023 \pm 0.0008^{+0.0031}_{-0.0026}$(theor.).

f'_s/f_s FOR $K^\pm \to \pi^+\pi^- e^\pm \nu$ DECAY

VALUE (units 10^{-2})	EVTS	DOCUMENT ID		TECN	CHG
15.2±0.7±0.5	1.13M	[1] BATLEY	10C	NA48	±
• • • We do not use the following data for averages, fits, limits, etc. • • •					
17.2±0.9±0.6	670k	[2] BATLEY	08A	NA48	±

[1] Radiative corrections included. Using Roy equations and including isospin breaking, BATLEY 10C obtains the following scattering lengths $a_0^0 = 0.2220 \pm 0.0128 \pm 0.0050 \pm 0.0037$ (theor.), $a_0^2 = -0.0432 \pm 0.0086 \pm 0.0034 \pm 0.0028$ (theor.). The correlation with $f''_s/f_s = -0.954$ and with $f'_e/f_s = 0.080$. Supersedes BATLEY 08A.

[2] Radiative corrections included. Using Roy equations and not including isospin breaking, BATLEY 08A obtains the following $\pi\pi$ scattering length $a_0^0 = 0.233 \pm 0.016 \pm 0.007$ $a_0^2 = -0.0471 \pm 0.011 \pm 0.004$.

f''_s/f_s FOR $K^\pm \to \pi^+\pi^- e^\pm \nu$ DECAY

VALUE (units 10^{-2})	*EVTS*	*DOCUMENT ID*		*TECN*	*CHG*
−7.3±0.7±0.6	1.13M	[1] BATLEY	10C	NA48	±
• • • We do not use the following data for averages, fits, limits, etc. • • •					
−9.0±0.9±0.7	670k	[2] BATLEY	08A	NA48	±

[1] Radiative corrections included. Using Roy equations and including isospin breaking, BATLEY 10C obtains the following scattering lengths $a_0^0 = 0.2220 \pm 0.0128 \pm 0.0050 \pm 0.0037$ (theor.), $a_0^2 = -0.0432 \pm 0.0086 \pm 0.0034 \pm 0.0028$ (theor.). The correlation with $f'_s/f_s = -0.954$ and with $f'_e/f_s = 0.019$. Supersedes BATLEY 08A.

[2] Radiative corrections included. Using Roy equations and not including isospin breaking, BATLEY 08A obtains the following $\pi\pi$ scattering length $a_0^0 = 0.233 \pm 0.016 \pm 0.007$ $a_0^2 = -0.0471 \pm 0.011 \pm 0.004$.

f'_e/f_s FOR $K^\pm \to \pi^+\pi^- e^\pm \nu$ DECAY

VALUE (units 10^{-2})	*EVTS*	*DOCUMENT ID*		*TECN*	*CHG*
6.8±0.6±0.7	1.13M	[1] BATLEY	10C	NA48	±
• • • We do not use the following data for averages, fits, limits, etc. • • •					
8.1±0.8±0.9	670k	[2] BATLEY	08A	NA48	±

[1] Radiative corrections included. Using Roy equations and including isospin breaking, BATLEY 10C obtains the following scattering lengths $a_0^0 = 0.2220 \pm 0.0128 \pm 0.0050 \pm 0.0037$ (theor.), $a_0^2 = -0.0432 \pm 0.0086 \pm 0.0034 \pm 0.0028$ (theor.). The correlation with $f'_s/f_s = 0.080$ and with $f''_s/f_s = 0.019$. Supersedes BATLEY 08A.

[2] Radiative corrections included. Using Roy equations and not including isospin breaking, BATLEY 08A obtains the following $\pi\pi$ scattering length $a_0^0 = 0.233 \pm 0.016 \pm 0.007$ $a_0^2 = -0.0471 \pm 0.011 \pm 0.004$.

f_p/f_s FOR $K^\pm \to \pi^+\pi^- e^\pm \nu$ DECAY

VALUE (units 10^{-2})	*EVTS*	*DOCUMENT ID*		*TECN*	*CHG*
−4.8±0.3±0.4	1.13M	[1] BATLEY	10C	NA48	±
• • • We do not use the following data for averages, fits, limits, etc. • • •					
−4.8±0.4±0.4	670k	[2] BATLEY	08A	NA48	±

[1] Radiative corrections included. Using Roy equations and including isospin breaking, BATLEY 10C obtains the following scattering lengths $a_0^0 = 0.2220 \pm 0.0128 \pm 0.0050 \pm 0.0037$ (theor.), $a_0^2 = -0.0432 \pm 0.0086 \pm 0.0034 \pm 0.0028$ (theor.). Supersedes BATLEY 08A.

[2] Radiative corrections included. Using Roy equations and not including isospin breaking, BATLEY 08A obtains the following $\pi\pi$ scattering length $a_0^0 = 0.233 \pm 0.016 \pm 0.007$ $a_0^2 = -0.0471 \pm 0.011 \pm 0.004$.

g_p/f_s FOR $K^{\pm} \rightarrow \pi^+\pi^- e^{\pm}\nu$ DECAY

VALUE (units 10^{-2})	EVTS	DOCUMENT ID		TECN	CHG
86.8±1.0±1.0	1.13M	[1] BATLEY	10C	NA48	±
• • • We do not use the following data for averages, fits, limits, etc. • • •					
87.3±1.3±1.2	670k	[2] BATLEY	08A	NA48	±
80.9±0.9±1.2	400k	[3] PISLAK	03	B865	±

[1] Radiative corrections included. Using Roy equations and including isospin breaking, BATLEY 10C obtains the following scattering lengths $a_0^0 = 0.2220 \pm 0.0128 \pm 0.0050 \pm 0.0037$ (theor.), $a_0^2 = -0.0432 \pm 0.0086 \pm 0.0034 \pm 0.0028$ (theor.). Supersedes BATLEY 08A. The correlation with $g'_p/f_s = -0.914$. Supersedes BATLEY 08A.

[2] Radiative corrections included. Using Roy equations and not including isospin breaking, BATLEY 08A obtains the following $\pi\pi$ scattering length $a_0^0 = 0.233 \pm 0.016 \pm 0.007$ $a_0^2 = -0.0471 \pm 0.011 \pm 0.004$.

[3] Radiative corrections included. Using Roy equations PISLAK 03 obtains the following scattering lengths $a_0^0 = 0.203 \pm 0.033 \pm 0.004$, $a_0^2 = -0.055 \pm 0.023 \pm 0.003$.

g'_p/f_s FOR $K^{\pm} \rightarrow \pi^+\pi^- e^{\pm}\nu$ DECAY

VALUE (units 10^{-2})	EVTS	DOCUMENT ID		TECN	CHG
8.9±1.7±1.3	1.13M	[1] BATLEY	10C	NA48	±
• • • We do not use the following data for averages, fits, limits, etc. • • •					
8.1±2.2±1.5	670k	[2] BATLEY	08A	NA48	±
12.0±1.9±0.7	400k	[3] PISLAK	03	B865	±

[1] Radiative corrections included. Using Roy equations and including isospin breaking, BATLEY 10C obtains the following scattering lengths $a_0^0 = 0.2220 \pm 0.0128 \pm 0.0050 \pm 0.0037$ (theor.), $a_0^2 = -0.0432 \pm 0.0086 \pm 0.0034 \pm 0.0028$ (theor.). The correlation with $g_p/f_s = -0.914$. Supersedes BATLEY 08A.

[2] Radiative corrections included. Using Roy equations and not including isospin breaking, BATLEY 08A obtains the following $\pi\pi$ scattering length $a_0^0 = 0.233 \pm 0.016 \pm 0.007$ $a_0^2 = -0.0471 \pm 0.011 \pm 0.004$.

[3] Radiative corrections included. Using Roy equations PISLAK 03 obtains the following scattering lengths $a_0^0 = 0.203 \pm 0.033 \pm 0.004$, $a_0^2 = -0.055 \pm 0.023 \pm 0.003$.

h_p/f_s FOR $K^{\pm} \rightarrow \pi^+\pi^- e^{\pm}\nu$ DECAY

VALUE (units 10^{-2})	EVTS	DOCUMENT ID		TECN	CHG
−39.8±1.5±0.8	1.13M	[1] BATLEY	10C	NA48	±
• • • We do not use the following data for averages, fits, limits, etc. • • •					
−41.1±1.9±0.8	670k	[2] BATLEY	08A	NA48	±
−51.3±3.3±3.5	400k	[3] PISLAK	03	B865	±

[1] Radiative corrections included. Using Roy equations and including isospin breaking, BATLEY 10C obtains the following scattering lengths $a_0^0 = 0.2220 \pm 0.0128 \pm 0.0050 \pm 0.0037$ (theor.), $a_0^2 = -0.0432 \pm 0.0086 \pm 0.0034 \pm 0.0028$ (theor.). Supersedes BATLEY 08A.

[2] Radiative corrections included. Using Roy equations and not including isospin breaking, BATLEY 08A obtains the following $\pi\pi$ scattering length $a_0^0 = 0.233 \pm 0.016 \pm 0.007$ $a_0^2 = -0.0471 \pm 0.011 \pm 0.004$.

[3] Radiative corrections included. Using Roy equations PISLAK 03 obtains the following scattering lengths $a_0^0 = 0.203 \pm 0.033 \pm 0.004$, $a_0^2 = -0.055 \pm 0.023 \pm 0.003$.

DECAY FORM FACTOR FOR $K^\pm \to \pi^0\pi^0 e^\pm \nu$

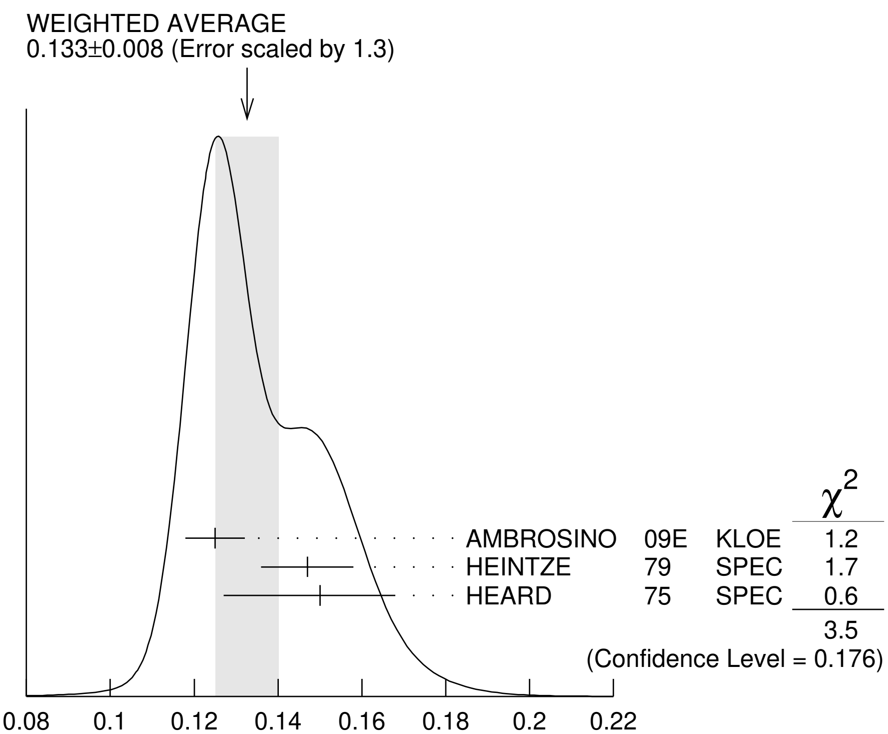
Given in BOLOTOV 86B, BARMIN 88B, and SHIMIZU 04.

$K^\pm \to \ell^\pm \nu\gamma$ FORM FACTORS

For definitions of the axial-vector F_A and vector F_V form factor, see the "Note on $\pi^\pm \to \ell^\pm \nu\gamma$ and $K^\pm \to \ell^\pm \nu\gamma$ Form Factors" in the $\pi^\pm$ section. In the kaon literature, often different definitions $a_K = F_A/m_K$ and $v_K = F_V/m_K$ are used.

$F_A + F_V$, SUM OF AXIAL-VECTOR AND VECTOR FORM FACTOR FOR $K \to e\nu_e\gamma$

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.133±0.008 OUR AVERAGE		Error includes scale factor of 1.3.			See the ideogram below.
$0.125 \pm 0.007 \pm 0.001$	1.4k	[1] AMBROSINO	09E	KLOE	E_γ in 10–250 MeV, $p_e > 200$ MeV/c
0.147 ± 0.011	51	[2] HEINTZE	79	SPEC	
$0.150^{+0.018}_{-0.023}$	56	[3] HEARD	75	SPEC	



$F_A + F_V$, SUM OF AXIAL-VECTOR AND VECTOR FORM FACTOR FOR $K \to e\nu_e\gamma$

[1] AMBROSINO 09E measures the absolute value $|F_A + F_V|$ which is parametrized as $|F_A + F_V| = F_V\,(1 + \lambda(1-x)) + F_A$, $x = 2E_\gamma/m_K$. $(F_A + F_V)$ and λ are fit

parameters. The fitted value of $\lambda = 0.38 \pm 0.20 \pm 0.02$ with a correlation of -0.93 between ($F_A + F_V$) and λ.

[2] HEINTZE 79 quotes absolute value of $|F_A + F_V| \sin\theta_c$. We use $\sin\theta_c = V_{us} = 0.2205$.

[3] HEARD 75 quotes absolute value of $|F_A + F_V| \sin\theta_c$. We use $\sin\theta_c = V_{us} = 0.2205$.

$F_A + F_V$, SUM OF AXIAL-VECTOR AND VECTOR FORM FACTOR FOR $K \to \mu\nu_\mu\gamma$

VALUE	CL%	EVTS	DOCUMENT ID		TECN	CHG
0.165±0.007±0.011		2588	[1] ADLER	00B	B787	+
• • • We do not use the following data for averages, fits, limits, etc. • • •						
−1.2 to 1.1	90		DEMIDOV	90	XEBC	
< 0.23	90		[1] AKIBA	85	SPEC	

[1] Quotes absolute value. Sign not determined.

$F_A - F_V$, DIFFERENCE OF AXIAL-VECTOR AND VECTOR FORM FACTOR FOR $K \to e\nu_e\gamma$

VALUE	CL%	DOCUMENT ID		TECN
<0.49	90	[1] HEINTZE	79	SPEC

[1] HEINTZE 79 quotes $|F_A - F_V| < \sqrt{11}\,|F_A + F_V|$.

$F_A - F_V$, DIFFERENCE OF AXIAL-VECTOR AND VECTOR FORM FACTOR FOR $K \to \mu\nu_\mu\gamma$

VALUE	CL%	EVTS	DOCUMENT ID		TECN	CHG
−0.153±0.033 OUR AVERAGE Error includes scale factor of 1.1.						
−0.134±0.021±0.027		95k	KRAVTSOV	19	OKA	+
−0.21 ±0.06		22k	DUK	11	ISTR	−
• • • We do not use the following data for averages, fits, limits, etc. • • •						
−0.24 to 0.04	90	2588	ADLER	00B	B787	+
−2.2 to 0.6	90		DEMIDOV	90	XEBC	
−2.5 to 0.3	90		AKIBA	85	SPEC	

$K^\pm$ CHARGE RADIUS

VALUE (fm)	DOCUMENT ID		COMMENT
0.560±0.031 OUR AVERAGE			
0.580±0.040	AMENDOLIA	86B	$K e \to K e$
0.530±0.050	DALLY	80	$K e \to K e$
• • • We do not use the following data for averages, fits, limits, etc. • • •			
0.620±0.037	BLATNIK	79	VMD + dispersion relations

K^+ LONGITUDINAL POLARIZATION OF EMITTED μ^+

VALUE	CL%	DOCUMENT ID		TECN	CHG	COMMENT
<−0.990	90	[1] AOKI	94	SPEC	+	
• • • We do not use the following data for averages, fits, limits, etc. • • •						
<−0.990	90	IMAZATO	92	SPEC	+	Repl. by AOKI 94

-0.970 ± 0.047	[2] YAMANAKA	86	SPEC	+
$-1.0 \quad \pm 0.1$	[2] CUTTS	69	SPRK	+
$-0.96 \quad \pm 0.12$	[2] COOMBES	57	CNTR	+

[1] AOKI 94 measures $\xi P_{\mu} = -0.9996 \pm 0.0030 \pm 0.0048$. The above limit is obtained by summing the statistical and systematic errors in quadrature, normalizing to the physically significant region ($|\xi P_{\mu}| < 1$) and assuming that ξ=1, its maximum value.

[2] Assumes ξ=1.

FORWARD-BACKWARD ASYMMETRY IN $K^{\pm}$ DECAYS

$$A_{FB}(K^{\pm}_{\pi\mu\mu}) = \frac{\Gamma(cos(\theta_{K\mu})>0)-\Gamma(cos(\theta_{K\mu})<0)}{\Gamma(cos(\theta_{K\mu})>0)+\Gamma(cos(\theta_{K\mu})<0)}$$

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<0.9 × 10^{-2}	90	[1] CORTINA-GIL	22A	NA62	2017–18 data
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$<2.3 \times 10^{-2}$	90	[2] BATLEY	11A	NA48	

[1] CORTINA-GIL 22A measured the asymmetry $A_{FB} = (0.0 \pm 0.7) \times 10^{-2}$. The quoted 90% C.L. was obtained via private communication and also presented at the Moriond 2023 conference. The authors will publish this limit in an addendum to the publication.

[2] BATLEY 11A gives a corresponding value of the asymmetry $A_{FB} = (-2.4 \pm 1.8) \times 10^{-2}$.

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ARTAMONOV	24A	JETPL 120 554	A.V. Artamonov et al.	(OKA Collab.)
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BATLEY	19	PL B788 552	J.R. Batley et al.	(NA48/2 Collab.)
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ADLER	10	PR D81 092001	S. Adler *et al.*	(BNL E787 Collab.)
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Also		EPJ C65 703 (errat.)	F. Ambrosino *et al.*	(KLOE Collab.)
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LAI	07A	PL B647 341	A. Lai *et al.*	(CERN NA48 Collab.)
TCHIKILEV	07	PAN 70 29	O.G. Tchikilev *et al.*	(ISTRA+ Collab.)
ALIEV	06	EPJ C46 61	M.A. Aliev *et al.*	(KEK E470 Collab.)
AMBROSINO	06A	PL B632 76	F. Ambrosino *et al.*	(KLOE Collab.)
BATLEY	06	PL B634 474	J.R. Batley *et al.*	(CERN NA48/2 Collab.)
BATLEY	06A	PL B638 22	J.R. Batley *et al.*	(CERN NA48/2 Collab.)
Also		PL B640 297 (errat.)	J.R. Batley *et al.*	(CERN NA48/2 Collab.)
BATLEY	06B	PL B633 173	J.R. Batley *et al.*	(CERN NA48/2 Collab.)
COLANGELO	06A	PL B638 187	G. Colangelo *et al.*	
MA	06	PR D73 037101	H. Ma *et al.*	(BNL E865 Collab.)
PDG	06	JP G33 1	W.-M. Yao *et al.*	(PDG Collab.)
SHIMIZU	06	PL B633 190	S. Shimizu *et al.*	(KEK E470 Collab.)
UVAROV	06	PAN 69 26	V.A. Uvarov *et al.*	(ISTRA+ Collab.)
AKOPDZHAN...	05	EPJ C40 343	G.A. Akopdzhanov *et al.*	(IHEP)
Also		PAN 68 948	G.A. Akopdzhanov *et al.*	(IHEP)
		Translated from YAF 68 986.		
AKOPDZHAN...	05B	JETPL 82 675	G.A. Akopdzhanov *et al.*	(IHEP)
		Translated from ZETFP 82 771.		
ARTAMONOV	05	PL B623 192	A.V. Artamonov *et al.*	(BNL E949 Collab.)
CABIBBO	05	JHEP 0503 021	N. Cabibbo, G. Isidori	(CERN, ROMAI, FRAS)
SHER	05	PR D72 012005	A. Sher *et al.*	(BNL E865 Collab.)
ABE	04F	PRL 93 131601	M. Abe *et al.*	(KEK E246 Collab.)
Also		PR D73 072005	M. Abe *et al.*	(KEK E246 Collab.)
ADLER	04	PR D70 037102	S. Adler *et al.*	(BNL E787 Collab.)
ALOISIO	04A	PL B597 139	A. Aloisio *et al.*	(KLOE Collab.)
ANISIMOVSK...	04	PRL 93 031801	V.V. Anisimovsky *et al.*	(BNL E949 Collab.)
Also		PR D77 052003	S. Adler *et al.*	(BNL E949 Collab.)
CABIBBO	04A	PRL 93 121801	N. Cabibbo	(CERN, ROMAI)
CIRIGLIANO	04	EPJ C35 53	V. Cirigliano, H. Neufeld, H. Pichl	(CIT, VALE+)
PDG	04	PL B592 1	S. Eidelman *et al.*	(PDG Collab.)
SHIMIZU	04	PR D70 037101	S. Shimizu *et al.*	(KEK E470 Collab.)
YUSHCHENKO	04	PL B581 31	O.P. Yushchenko *et al.*	(INRM, INRM)
YUSHCHENKO	04B	PL B589 111	O.P. Yushchenko *et al.*	(INRM)
AJINENKO	03	PAN 66 105	I.V. Ajinenko *et al.*	(IHEP, INRM)
		Translated from YAF 66 107.		
AJINENKO	03B	PL B567 159	I.V. Ajinenko *et al.*	(IHEP, INRM)
AJINENKO	03C	PL B574 14	I.V. Ajinenko *et al.*	(IHEP, INRM)
ALIEV	03	PL B554 7	M.A. Aliev *et al.*	(KEK E470 Collab.)
ANISIMOVSK...	03	PL B562 166	V.V. Anisimovsky *et al.*	
PISLAK	03	PR D67 072004	S. Pislak *et al.*	(BNL E865 Collab.)
Also		PR D81 119903E	S. Pislak *et al.*	(BNL E865 Collab.)
SHER	03	PRL 91 261802	A. Sher *et al.*	(BNL E865 Collab.)
ADLER	02	PRL 88 041803	S. Adler *et al.*	(BNL E787 Collab.)
ADLER	02B	PR D65 052009	S. Adler *et al.*	(BNL E787 Collab.)
ADLER	02C	PL B537 211	S. Adler *et al.*	(BNL E787 Collab.)

AJINENKO 02 PAN 65 2064 I.V. Ajinenko et al. (IHEP, INRM)
Translated from YAF 65 2125.
CIRIGLIANO 02 EPJ C23 121 V. Cirigliano et al. (VIEN, VALE, MARS)
PARK 02 PRL 88 111801 H.K. Park et al. (FNAL HyperCP Collab.)
PDG 02 PR D66 010001 K. Hagiwara et al. (PDG Collab.)
POBLAGUEV 02 PRL 89 061803 A.A. Poblaguev et al. (BNL 865 Collab.)
ADLER 01 PR D63 032004 S. Adler et al. (BNL E787 Collab.)
HORIE 01 PL B513 311 K. Horie et al. (KEK E426 Collab.)
PISLAK 01 PRL 87 221801 S. Pislak et al. (BNL E865 Collab.)
Also PR D67 072004 S. Pislak et al. (BNL E865 Collab.)
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ADLER 00 PRL 84 3768 S. Adler et al. (BNL E787 Collab.)
ADLER 00B PRL 85 2256 S. Adler et al. (BNL E787 Collab.)
ADLER 00C PRL 85 4856 S. Adler et al. (BNL E787 Collab.)
APPEL 00 PRL 85 2450 R. Appel et al. (BNL 865 Collab.)
Also Thesis, Yale Univ. D.R. Bergman
Also Thesis, Univ. Zurich S. Pislak
APPEL 00B PRL 85 2877 R. Appel et al. (BNL 865 Collab.)
MA 00 PRL 84 2580 H. Ma et al. (BNL 865 Collab.)
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SHIMIZU 00 PL B495 33 S. Shimizu et al. (KEK E246 Collab.)
ABE 99S PRL 83 4253 M. Abe et al. (KEK E246 Collab.)
AMOROS 99 JP G25 1607 G. Amoros, J. Bijnens (LUND, HELS)
APPEL 99 PRL 83 4482 R. Appel et al. (BNL 865 Collab.)
ADLER 98 PR D58 012003 S. Adler et al. (BNL E787 Collab.)
BATUSOV 98 NP B516 3 V.Y. Batusov et al.
DAMBROSIO 98A JHEP 9808 004 G. D'Ambrosio et al.
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ADLER 96 PRL 76 1421 S. Adler et al. (BNL E787 Collab.)
KOPTEV 95 JETPL 61 877 V.P. Koptev et al. (PNPI)
Translated from ZETFP 61 865.
AOKI 94 PR D50 69 M. Aoki et al. (INUS, KEK, TOKMS)
ATIYA 93 PRL 70 2521 M.S. Atiya et al. (BNL E787 Collab.)
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ATIYA 90 PRL 64 21 M.S. Atiya et al. (BNL E787 Collab.)
ATIYA 90B PRL 65 1188 M.S. Atiya et al. (BNL E787 Collab.)
DEMIDOV 90 SJNP 52 1006 V.S. Demidov et al. (ITEP)
Translated from YAF 52 1595.
LEE 90 PRL 64 165 A.M. Lee et al. (BNL, FNAL, VILL, WASH+)
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Translated from YAF 47 1011.
BARMIN 88B SJNP 48 1032 V.V. Barmin et al. (ITEP)
Translated from YAF 48 1719.
BOLOTOV 88 JETPL 47 7 V.N. Bolotov et al. (ASCI)
Translated from ZETFP 47 8.
GALL 88 PRL 60 186 K.P. Gall et al. (BOST, MIT, WILL, CIT+)
BARMIN 87 SJNP 45 62 V.V. Barmin et al. (ITEP)
Translated from YAF 45 97.
BOLOTOV 87 SJNP 45 1023 V.N. Bolotov et al. (INRM)
Translated from YAF 45 1652.
AMENDOLIA 86B PL B178 435 S.R. Amendolia et al. (CERN NA7 Collab.)
BOLOTOV 86 SJNP 44 73 V.N. Bolotov et al. (INRM)
Translated from YAF 44 117.

BOLOTOV	86B	SJNP 44 68	V.N. Bolotov *et al.*	(INRM)
		Translated from YAF 44 108.		
YAMANAKA	86	PR D34 85	T. Yamanaka *et al.*	(KEK, TOKY)
Also		PRL 52 329	R.S. Hayano *et al.*	(TOKY, KEK)
AKIBA	85	PR D32 2911	Y. Akiba *et al.*	(TOKY, TINT, TSUK, KEK)
BOLOTOV	85	JETPL 42 481	V.N. Bolotov *et al.*	(INRM)
		Translated from ZETFP 42 390.		
ASANO	82	PL 113B 195	Y. Asano *et al.*	(KEK, TOKY, INUS, OSAK)
COOPER	82	PL 112B 97	A.M. Cooper *et al.*	(RL)
PDG	82B	PL 111B 70	M. Roos *et al.*	(HELS, CIT, CERN)
ASANO	81B	PL 107B 159	Y. Asano *et al.*	(KEK, TOKY, INUS, OSAK)
CAMPBELL	81	PRL 47 1032	M.K. Campbell *et al.*	(YALE, BNL)
Also		PR D27 1056	S.R. Blatt *et al.*	(YALE, BNL)
LUM	81	PR D23 2522	G.K. Lum *et al.*	(LBL, NBS+)
LYONS	81	ZPHY C10 215	L. Lyons, C. Albajar, G. Myatt	(OXF)
DALLY	80	PRL 45 232	E.B. Dally *et al.*	(UCLA+)
BARKOV	79	NP B148 53	L.M. Barkov *et al.*	(NOVO, KIAE)
BLATNIK	79	LNC 24 39	S. Blatnik, J. Stahov, C.B. Lang	(TUZL, GRAZ)
HEINTZE	79	NP B149 365	J. Heintze *et al.*	(HEIDP, CERN)
ABRAMS	77	PR D15 22	R.J. Abrams *et al.*	(BNL)
DEVAUX	77	NP B126 11	B. Devaux *et al.*	(SACL, GEVA)
HEINTZE	77	PL 70B 482	J. Heintze *et al.*	(HEIDP, CERN)
ROSSELET	77	PR D15 574	L. Rosselet *et al.*	(GEVA, SACL)
BLOCH	76	PL 60B 393	P. Bloch *et al.*	(GEVA, SACL)
BRAUN	76B	LNC 17 521	H.M. Braun *et al.*	(AACH3, BARI, BELG+)
DIAMANT-...	76	PL 62B 485	A.M. Diamant-Berger *et al.*	(SACL, GEVA)
HEINTZE	76	PL 60B 302	J. Heintze *et al.*	(HEIDP)
SMITH	76	NP B109 173	K.M. Smith *et al.*	(GLAS, LIVP, OXF+)
WEISSENBE...	76	NP B115 55	A.O. Weissenberg *et al.*	(ITEP, LEBD)
BLOCH	75	PL 56B 201	P. Bloch *et al.*	(SACL, GEVA)
BRAUN	75	NP B89 210	H.M. Braun *et al.*	(AACH3, BARI, BRUX+)
CHENG	75	NP A254 381	S.C. Cheng *et al.*	(COLU, YALE)
HEARD	75	PL 55B 324	K.S. Heard *et al.*	(CERN, HEIDH)
HEARD	75B	PL 55B 327	K.S. Heard *et al.*	(CERN, HEIDH)
SHEAFF	75	PR D12 2570	M. Sheaff	(WISC)
SMITH	75	NP B91 45	K.M. Smith *et al.*	(GLAS, LIVP, OXF+)
WEISSENBE...	74	PL 48B 474	A.O. Weissenberg *et al.*	(ITEP, LEBD)
ABRAMS	73B	PRL 30 500	R.J. Abrams *et al.*	(BNL)
BACKENSTO...	73	PL 43B 431	G. Backenstoss *et al.*	(CERN, KARLK, KARLE+)
LJUNG	73	PR D8 1307	D. Ljung, D. Cline	(WISC)
Also		PRL 28 523	D. Ljung	(WISC)
Also		PRL 28 1287	D. Cline, D. Ljung	(WISC)
Also		PRL 23 326	U. Camerini *et al.*	(WISC)
LUCAS	73	PR D8 719	P.W. Lucas, H.D. Taft, W.J. Willis	(YALE)
LUCAS	73B	PR D8 727	P.W. Lucas, H.D. Taft, W.J. Willis	(YALE)
PANG	73	PR D8 1989	C.Y. Pang *et al.*	(EFI, ARIZ, LBL)
Also		PL 40B 699	G.D. Cable *et al.*	(EFI, LBL)
SMITH	73	NP B60 411	K.M. Smith *et al.*	(GLAS, LIVP, OXF+)
ABRAMS	72	PRL 29 1118	R.J. Abrams *et al.*	(BNL)
AUBERT	72	NC 12A 509	B. Aubert *et al.*	(ORSAY, BRUX, EPOL)
CHIANG	72	PR D6 1254	I.H. Chiang *et al.*	(ROCH, WISC)
CLARK	72	PRL 29 1274	A.R. Clark *et al.*	(LBL)
FORD	72	PL 38B 335	W.T. Ford *et al.*	(PRIN)
HOFFMASTER	72	NP B36 1	S. Hoffmaster *et al.*	(STEV, SETO, LEHI)
BOURQUIN	71	PL 36B 615	M.H. Bourquin *et al.*	(GEVA, SACL)
HAIDT	71	PR D3 10	D. Haidt	(AACH, BARI, CERN, EPOL, NIJM+)
Also		PL 29B 691	D. Haidt *et al.*	(AACH, BARI, CERN, EPOL+)
KLEMS	71	PR D4 66	J.H. Klems, R.H. Hildebrand, R. Stiening	(CHIC+)
Also		PRL 24 1086	J.H. Klems, R.H. Hildebrand, R. Stiening	(LRL+)
Also		PRL 25 473	J.H. Klems, R.H. Hildebrand, R. Stiening	(LRL+)
OTT	71	PR D3 52	R.J. Ott, T.W. Pritchard	(LOQM)
ROMANO	71	PL 36B 525	F. Romano *et al.*	(BARI, CERN, ORSAY)
SCHWEINB...	71	PL 36B 246	W. Schweinberger	(AACH, BELG, CERN, NIJM+)
STEINER	71	PL 36B 521	H.J. Steiner	(AACH, BARI, CERN, EPOL, ORSAY+)
BARDIN	70	PL 32B 121	D.Y. Bardin, S.N. Bilenky, B.M. Pontecorvo	(JINR)
BECHERRAWY	70	PR D1 1452	T. Becherrawy	(ROCH)
FORD	70	PRL 25 1370	W.T. Ford *et al.*	(PRIN)
GAILLARD	70	CERN 70-14	J.M. Gaillard, L.M. Chounet	(CERN, ORSAY)
GRAUMAN	70	PR D1 1277	J. Grauman *et al.*	(STEV, SETO, LEHI)
Also		PRL 23 737	J.U. Grauman *et al.*	(STEV, SETO, LEHI)
PANDOULAS	70	PR D2 1205	D. Pandoulas *et al.*	(STEV, SETO)

CUTTS	69	PR 184 1380	D. Cutts *et al.*	(LRL, MIT)
Also		PRL 20 955	D. Cutts *et al.*	(LRL, MIT)
DAVISON	69	PR 180 1333	D.C. Davison *et al.*	(UCR)
ELY	69	PR 180 1319	R.P.J. Ely *et al.*	(LOUC, WISC, LRL)
HERZO	69	PR 186 1403	D. Herzo *et al.*	(ILL)
LOBKOWICZ	69	PR 185 1676	F. Lobkowicz *et al.*	(ROCH, BNL)
Also		PRL 17 548	F. Lobkowicz *et al.*	(ROCH, BNL)
MAST	69	PR 183 1200	T.S. Mast *et al.*	(LRL)
SELLERI	69	NC 60A 291	F. Selleri	
ZELLER	69	PR 182 1420	M.E. Zeller *et al.*	(UCLA, LRL)
BOTTERILL	68B	PRL 21 766	D.R. Botterill *et al.*	(OXF)
BOTTERILL	68C	PR 174 1661	D.R. Botterill *et al.*	(OXF)
BUTLER	68	UCRL 18420	W.D. Butler *et al.*	(LRL)
CHANG	68	PRL 20 510	C.Y. Chang *et al.*	(UMD, RUTG)
CHEN	68	PRL 20 73	M. Chen *et al.*	(LRL, MIT)
EICHTEN	68	PL 27B 586	T. Eichten	(AACH, BARI, CERN, EPOL, ORSAY+)
ESCHSTRUTH	68	PR 165 1487	P.T. Eschstruth *et al.*	(PRIN, PENN)
GARLAND	68	PR 167 1225	R. Garland *et al.*	(COLU, RUTG, WISC)
MOSCOSO	68	Thesis	L. Moscoso	(ORSAY)
AUERBACH	67	PR 155 1505	L.B. Auerbach *et al.*	(PENN, PRIN)
Also		PR D9 3216	L.B. Auerbach	
Erratum.				
BELLOTTI	67	Heidelberg Conf.	E. Bellotti, A. Pullia	(MILA)
BELLOTTI	67B	NC 52A 1287	E. Bellotti, E. Fiorini, A. Pullia	(MILA)
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BISI	67	PL 25B 572	V. Bisi *et al.*	(TORI)
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KALMUS	67	PR 159 1187	G.E. Kalmus, A. Kernan	(LRL)
ZINCHENKO	67	Thesis Rutgers	A.I. Zinchenko	(RUTG)
CALLAHAN	66	NC 44A 90	A.C. Callahan	(WISC)
CALLAHAN	66B	PR 150 1153	A.C. Callahan *et al.*	(WISC, LRL, UCR+)
CESTER	66	PL 21 343	R. Cester *et al.*	(PPA)
See footnote 1 in AUERBACH 67.				
Also		PR 155 1505	L.B. Auerbach *et al.*	(PENN, PRIN)
BIRGE	65	PR 139 B1600	R.W. Birge *et al.*	(LRL, WISC)
BISI	65	NC 35 768	V. Bisi *et al.*	(TORI)
BISI	65B	PR 139 B1068	V. Bisi *et al.*	(TORI)
CALLAHAN	65	PRL 15 129	A. Callahan, D. Cline	(WISC)
CLINE	65	PL 15 293	D. Cline, W.F. Fry	(WISC)
DEMARCO	65	PR 140 B1430	A. de Marco, C. Grosso, G. Rinaudo	(TORI, CERN)
FITCH	65B	PR 140 B1088	V.L. Fitch, C.A. Quarles, H.C. Wilkins	(PRIN+)
STAMER	65	PR 138 B440	P. Stamer *et al.*	(STEV)
YOUNG	65	Thesis UCRL 16362	P.S. Young	(LRL)
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FERRO-LUZZI	61	NC 22 1087	M. Ferro-Luzzi *et al.*	(LRL)
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HAIDT	69B	PL 29B 696	D. Haidt *et al.*	(AACH, BARI, CERN, EPOL+)
CRONIN	68B	Vienna Conf. 241	J.W. Cronin	(PRIN)
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WILLIS	67	Heidelberg Conf. 273	W.J. Willis	(YALE)
Rapporteur talk.				
CABIBBO	66	Berkeley Conf. 33	N. Cabibbo	(CERN)
ADAIR	64	PL 12 67	R.K. Adair, L.B. Leipuner	(YALE, BNL)
CABIBBO	64	PL 9 352	N. Cabibbo, A. Maksymowicz	(CERN)
Also		PL 11 360	N. Cabibbo, A. Maksymowicz	(CERN)
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BIRGE	63	PRL 11 35	R.W. Birge *et al.*	(LRL, WISC, BARI)
BLOCK	62B	CERN Conf. 371	M.M. Block, L. Lendinara, L. Monari	(NWES, BGNA)
BRENE	61	NP 22 553	N. Brene, L. Egardt, B. Qvist	(NORD)