



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

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### $K^\pm$ MASS

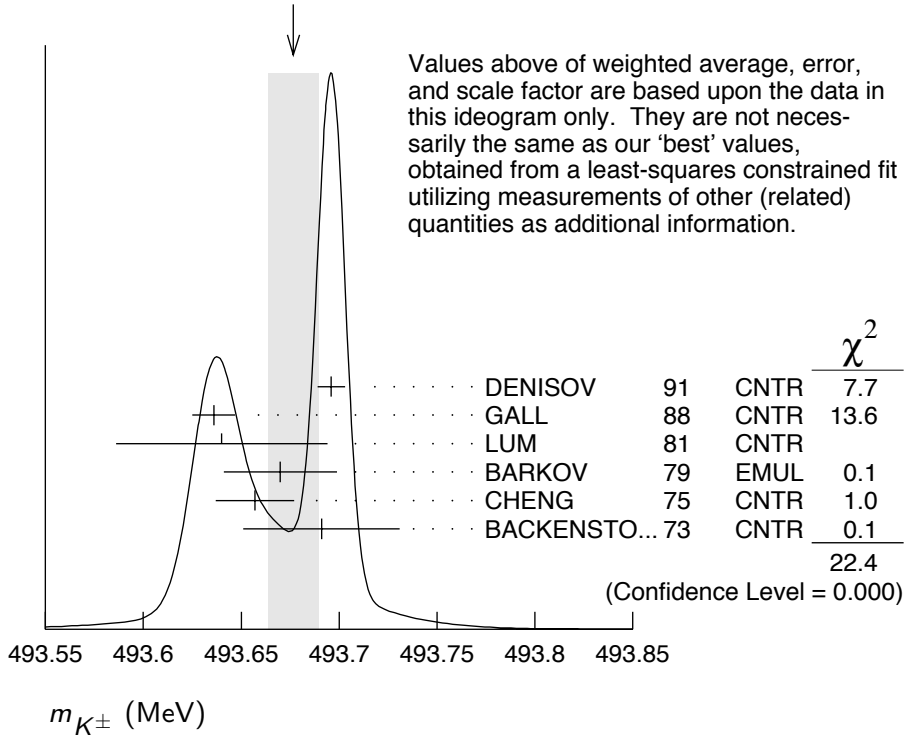
<u>VALUE (MeV)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>	<u>COMMENT</u>
<b>493.677±0.016 OUR FIT</b>	Error includes scale factor of 2.8.			
<b>493.677±0.013 OUR AVERAGE</b>	Error includes scale factor of 2.4. See the ideogram below.			
493.696±0.007	<sup>1</sup> DENISOV	91	CNTR –	Kaonic atoms
493.636±0.011	<sup>2</sup> 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	<sup>2</sup> CHENG	75	CNTR –	Kaonic atoms
493.691±0.040	BACKENSTO...73	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	<sup>3</sup> CHENG	75	CNTR –	$K^-$ Pb (9→ 8)
493.658±0.019±0.012	<sup>3</sup> CHENG	75	CNTR –	$K^-$ Pb (10→ 9)
493.638±0.035±0.016	<sup>3</sup> CHENG	75	CNTR –	$K^-$ Pb (11→ 10)
493.753±0.042±0.021	<sup>3</sup> CHENG	75	CNTR –	$K^-$ Pb (12→ 11)
493.742±0.081±0.027	<sup>3</sup> CHENG	75	CNTR –	$K^-$ Pb (13→ 12)

<sup>1</sup> Error increased from 0.0059 based on the error analysis in IVANOV 92.

<sup>2</sup> This value is the authors' combination of all of the separate transitions listed for this paper.

<sup>3</sup> 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  $\pm 5$  eV uncertainty in the theoretical transition energies.

WEIGHTED AVERAGE  
 $493.677 \pm 0.013$  (Error scaled by 2.4)



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

Test of *CPT*.

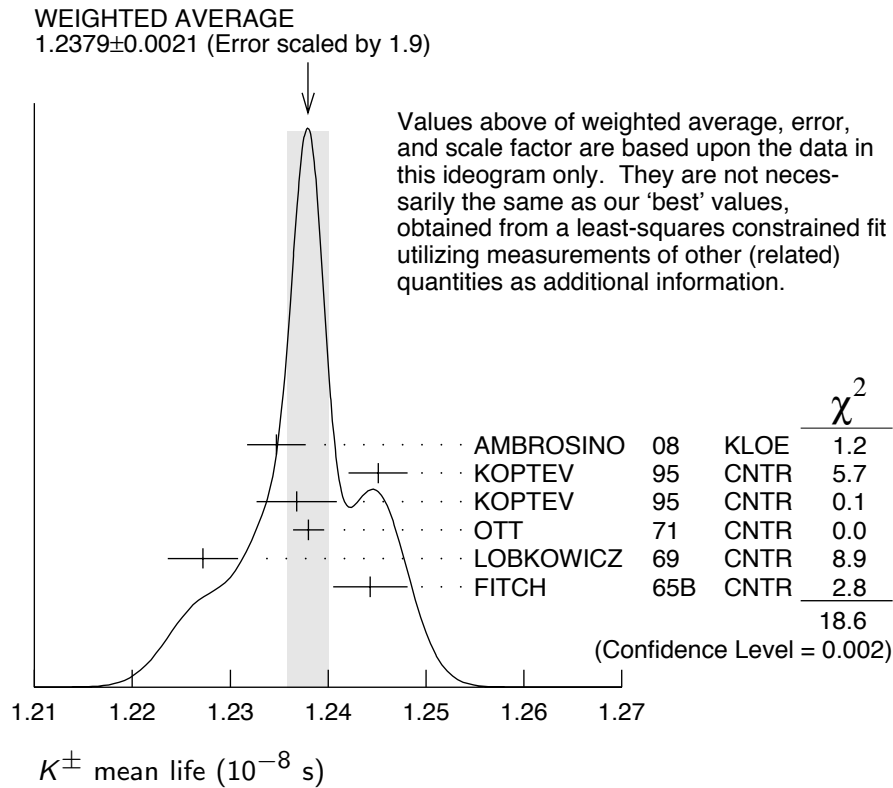
VALUE (MeV)	EVTS	DOCUMENT ID	TECN	CHG
$-0.032 \pm 0.090$	1.5M	<sup>4</sup> FORD	72	ASPK ±

<sup>4</sup> 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
<b><math>1.2380 \pm 0.0021</math> OUR FIT</b>		Error includes scale factor of 1.9.			
<b><math>1.2379 \pm 0.0021</math> OUR AVERAGE</b>		Error includes scale factor of 1.9. See the ideogram below.			
1.2347 ± 0.0030	15M	<sup>5</sup> AMBROSINO	08	KLOE ±	$\phi \rightarrow K^+ K^-$
1.2451 ± 0.0030	250k	KOPTEV	95	CNTR	<i>K</i> at rest, U target
1.2368 ± 0.0041	150k	KOPTEV	95	CNTR	<i>K</i> at rest, Cu target
1.2380 ± 0.0016	3M	OTT	71	CNTR +	<i>K</i> at rest
1.2272 ± 0.0036		LOBKOWICZ	69	CNTR +	<i>K</i> in flight
1.2443 ± 0.0038		FITCH	65B	CNTR +	<i>K</i> at rest
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●					
1.2415 ± 0.0024	400k	<sup>6</sup> KOPTEV	95	CNTR	<i>K</i> at rest
1.221 ± 0.011		FORD	67	CNTR ±	
1.231 ± 0.011		BOYARSKI	62	CNTR +	

- <sup>5</sup> Result obtained by averaging the decay length and decay time analyses taking correlations into account.
- <sup>6</sup> 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.

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

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### **$K^+$ DECAY MODES**

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

Mode	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor/ Confidence level
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### Leptonic and semileptonic modes

$\Gamma_1$	$K^+ \rightarrow e^+ \nu_e$	$( 1.55 \pm 0.07 ) \times 10^{-5}$	
$\Gamma_2$	$K^+ \rightarrow \mu^+ \nu_\mu$	$(63.54 \pm 0.14 ) \%$	S=1.3
$\Gamma_3$	$K^+ \rightarrow \pi^0 e^+ \nu_e$	$( 5.08 \pm 0.05 ) \%$	S=2.1
	Called $K_{e3}^+$ .		
$\Gamma_4$	$K^+ \rightarrow \pi^0 \mu^+ \nu_\mu$	$( 3.35 \pm 0.04 ) \%$	S=1.9
	Called $K_{\mu 3}^+$ .		
$\Gamma_5$	$K^+ \rightarrow \pi^0 \pi^0 e^+ \nu_e$	$( 2.2 \pm 0.4 ) \times 10^{-5}$	
$\Gamma_6$	$K^+ \rightarrow \pi^+ \pi^- e^+ \nu_e$	$( 4.09 \pm 0.10 ) \times 10^{-5}$	
$\Gamma_7$	$K^+ \rightarrow \pi^+ \pi^- \mu^+ \nu_\mu$	$( 1.4 \pm 0.9 ) \times 10^{-5}$	
$\Gamma_8$	$K^+ \rightarrow \pi^0 \pi^0 \pi^0 e^+ \nu_e$	$< 3.5 \times 10^{-6}$	CL=90%

### Hadronic modes

$\Gamma_9$	$K^+ \rightarrow \pi^+ \pi^0$	$(20.68 \pm 0.13 ) \%$	S=1.6
$\Gamma_{10}$	$K^+ \rightarrow \pi^+ \pi^0 \pi^0$	$( 1.761 \pm 0.022 ) \%$	S=1.1
$\Gamma_{11}$	$K^+ \rightarrow \pi^+ \pi^+ \pi^-$	$( 5.59 \pm 0.04 ) \%$	S=1.5

### Leptonic and semileptonic modes with photons

$\Gamma_{12}$	$K^+ \rightarrow \mu^+ \nu_\mu \gamma$	$[a,b] ( 6.2 \pm 0.8 ) \times 10^{-3}$	
$\Gamma_{13}$	$K^+ \rightarrow \mu^+ \nu_\mu \gamma (SD^+)$	$[c,d] < 3.0 \times 10^{-5}$	CL=90%
$\Gamma_{14}$	$K^+ \rightarrow \mu^+ \nu_\mu \gamma (SD^+INT)$	$[c,d] < 2.7 \times 10^{-5}$	CL=90%
$\Gamma_{15}$	$K^+ \rightarrow \mu^+ \nu_\mu \gamma (SD^- + SD^-INT)$	$[c,d] < 2.6 \times 10^{-4}$	CL=90%
$\Gamma_{16}$	$K^+ \rightarrow e^+ \nu_e \gamma (SD^+)$	$[c,d] ( 1.52 \pm 0.23 ) \times 10^{-5}$	
$\Gamma_{17}$	$K^+ \rightarrow e^+ \nu_e \gamma (SD^-)$	$[c,d] < 1.6 \times 10^{-4}$	CL=90%
$\Gamma_{18}$	$K^+ \rightarrow \pi^0 e^+ \nu_e \gamma$	$[a,b] ( 2.56 \pm 0.16 ) \times 10^{-4}$	
$\Gamma_{19}$	$K^+ \rightarrow \pi^0 e^+ \nu_e \gamma (SD)$	$[c,d] < 5.3 \times 10^{-5}$	CL=90%
$\Gamma_{20}$	$K^+ \rightarrow \pi^0 \mu^+ \nu_\mu \gamma$	$[a,b] ( 1.5 \pm 0.4 ) \times 10^{-5}$	
$\Gamma_{21}$	$K^+ \rightarrow \pi^0 \pi^0 e^+ \nu_e \gamma$	$< 5 \times 10^{-6}$	CL=90%

### Hadronic modes with photons or $l\bar{l}$ pairs

$\Gamma_{22}$	$K^+ \rightarrow \pi^+ \pi^0 \gamma$	$[a,b] ( 2.75 \pm 0.15 ) \times 10^{-4}$	
$\Gamma_{23}$	$K^+ \rightarrow \pi^+ \pi^0 \gamma (DE)$	$[b,e] ( 4.3 \pm 0.7 ) \times 10^{-6}$	
$\Gamma_{24}$	$K^+ \rightarrow \pi^+ \pi^0 \pi^0 \gamma$	$[a,b] ( 7.6 \begin{smallmatrix} +5.6 \\ -3.0 \end{smallmatrix} ) \times 10^{-6}$	
$\Gamma_{25}$	$K^+ \rightarrow \pi^+ \pi^+ \pi^- \gamma$	$[a,b] ( 1.04 \pm 0.31 ) \times 10^{-4}$	
$\Gamma_{26}$	$K^+ \rightarrow \pi^+ \gamma \gamma$	$[b] ( 1.10 \pm 0.32 ) \times 10^{-6}$	
$\Gamma_{27}$	$K^+ \rightarrow \pi^+ 3\gamma$	$[b] < 1.0 \times 10^{-4}$	CL=90%
$\Gamma_{28}$	$K^\pm \rightarrow \pi^+ e^+ e^- \gamma$	$( 1.19 \pm 0.13 ) \times 10^{-8}$	

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

$\Gamma_{29}$	$K^+ \rightarrow e^+ \nu_e \nu \bar{\nu}$	$< 6$	$\times 10^{-5}$	CL=90%
$\Gamma_{30}$	$K^+ \rightarrow \mu^+ \nu_\mu \nu \bar{\nu}$	$< 6.0$	$\times 10^{-6}$	CL=90%
$\Gamma_{31}$	$K^+ \rightarrow e^+ \nu_e e^+ e^-$	$( 2.48 \pm 0.20 ) \times 10^{-8}$		
$\Gamma_{32}$	$K^+ \rightarrow \mu^+ \nu_\mu e^+ e^-$	$( 7.06 \pm 0.31 ) \times 10^{-8}$		
$\Gamma_{33}$	$K^+ \rightarrow e^+ \nu_e \mu^+ \mu^-$	$( 1.7 \pm 0.5 ) \times 10^{-8}$		
$\Gamma_{34}$	$K^+ \rightarrow \mu^+ \nu_\mu \mu^+ \mu^-$	$< 4.1$	$\times 10^{-7}$	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**

$\Gamma_{35}$	$K^+ \rightarrow \pi^+ \pi^+ e^- \bar{\nu}_e$	$SQ$	$< 1.2$	$\times 10^{-8}$	CL=90%
$\Gamma_{36}$	$K^+ \rightarrow \pi^+ \pi^+ \mu^- \bar{\nu}_\mu$	$SQ$	$< 3.0$	$\times 10^{-6}$	CL=95%
$\Gamma_{37}$	$K^+ \rightarrow \pi^+ e^+ e^-$	$S1$	$( 2.88 \pm 0.13 ) \times 10^{-7}$		
$\Gamma_{38}$	$K^+ \rightarrow \pi^+ \mu^+ \mu^-$	$S1$	$( 8.1 \pm 1.4 ) \times 10^{-8}$ S=2.7		
$\Gamma_{39}$	$K^+ \rightarrow \pi^+ \nu \bar{\nu}$	$S1$	$( 1.5 \begin{smallmatrix} +1.3 \\ -0.9 \end{smallmatrix} ) \times 10^{-10}$		
$\Gamma_{40}$	$K^+ \rightarrow \pi^+ \pi^0 \nu \bar{\nu}$	$S1$	$< 4.3$	$\times 10^{-5}$	CL=90%
$\Gamma_{41}$	$K^+ \rightarrow \mu^- \nu e^+ e^+$	$LF$	$< 2.0$	$\times 10^{-8}$	CL=90%
$\Gamma_{42}$	$K^+ \rightarrow \mu^+ \nu_e$	$LF$ [f]	$< 4$	$\times 10^{-3}$	CL=90%
$\Gamma_{43}$	$K^+ \rightarrow \pi^+ \mu^+ e^-$	$LF$	$< 1.3$	$\times 10^{-11}$	CL=90%
$\Gamma_{44}$	$K^+ \rightarrow \pi^+ \mu^- e^+$	$LF$	$< 5.2$	$\times 10^{-10}$	CL=90%
$\Gamma_{45}$	$K^+ \rightarrow \pi^- \mu^+ e^+$	$L$	$< 5.0$	$\times 10^{-10}$	CL=90%
$\Gamma_{46}$	$K^+ \rightarrow \pi^- e^+ e^+$	$L$	$< 6.4$	$\times 10^{-10}$	CL=90%
$\Gamma_{47}$	$K^+ \rightarrow \pi^- \mu^+ \mu^+$	$L$ [f]	$< 3.0$	$\times 10^{-9}$	CL=90%
$\Gamma_{48}$	$K^+ \rightarrow \mu^+ \bar{\nu}_e$	$L$ [f]	$< 3.3$	$\times 10^{-3}$	CL=90%
$\Gamma_{49}$	$K^+ \rightarrow \pi^0 e^+ \bar{\nu}_e$	$L$	$< 3$	$\times 10^{-3}$	CL=90%
$\Gamma_{50}$	$K^+ \rightarrow \pi^+ \gamma$	[g]	$< 2.3$	$\times 10^{-9}$	CL=90%

[a] Most of this radiative mode, the low-momentum  $\gamma$  part, is also included in the parent mode listed without  $\gamma$ 's.

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

[c] See the "Note on  $\pi^\pm \rightarrow \ell^\pm \nu \gamma$  and  $K^\pm \rightarrow \ell^\pm \nu \gamma$  Form Factors" in the  $\pi^\pm$  Particle Listings for definitions and details.

[d] Structure-dependent part.

[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 13 branching ratios uses 31 measurements and one constraint to determine 8 parameters. The overall fit has a  $\chi^2 = 51.7$  for 24 degrees of freedom.

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

$x_3$	-42						
$x_4$	-40	91					
$x_5$	-2	4	4				
$x_9$	-77	-13	-15	-1			
$x_{10}$	-4	-5	-5	0	-11		
$x_{11}$	-8	-10	-10	0	-21	5	
$\Gamma$	2	2	2	0	4	-1	-20
	$x_2$	$x_3$	$x_4$	$x_5$	$x_9$	$x_{10}$	$x_{11}$

	Mode	Rate ( $10^8 \text{ s}^{-1}$ )	Scale factor
$\Gamma_2$	$K^+ \rightarrow \mu^+ \nu_\mu$	$0.5132 \pm 0.0014$	1.4
$\Gamma_3$	$K^+ \rightarrow \pi^0 e^+ \nu_e$	$0.0410 \pm 0.0004$	2.1
	Called $K_{e3}^+$ .		
$\Gamma_4$	$K^+ \rightarrow \pi^0 \mu^+ \nu_\mu$	$0.02709 \pm 0.00030$	1.9
	Called $K_{\mu 3}^+$ .		
$\Gamma_5$	$K^+ \rightarrow \pi^0 \pi^0 e^+ \nu_e$	$(1.77 \begin{smallmatrix} +0.35 \\ -0.30 \end{smallmatrix}) \times 10^{-5}$	
$\Gamma_9$	$K^+ \rightarrow \pi^+ \pi^0$	$0.1670 \pm 0.0011$	1.6
$\Gamma_{10}$	$K^+ \rightarrow \pi^+ \pi^0 \pi^0$	$0.01423 \pm 0.00018$	1.1
$\Gamma_{11}$	$K^+ \rightarrow \pi^+ \pi^+ \pi^-$	$0.04518 \pm 0.00035$	1.5

## $K^\pm$ DECAY RATES

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

$\Gamma_2$

VALUE ( $10^6 \text{ s}^{-1}$ )      DOCUMENT ID    TECN    CHG

**51.32 ± 0.14 OUR FIT** Error includes scale factor of 1.4.

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

51.2 ± 0.8      FORD      67    CNTR ±

$\Gamma(\pi^+\pi^+\pi^-)$  $\Gamma_{11}$ 

VALUE ( $10^6 \text{ s}^{-1}$ )	EVTS	DOCUMENT ID	TECN	CHG
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**4.518±0.035 OUR FIT** Error includes scale factor of 1.5.**4.511±0.024** <sup>7</sup>FORD 70 ASPK

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

4.529±0.032 3.2M <sup>7</sup>FORD 70 ASPK4.496±0.030 <sup>7</sup>FORD 67 CNTR ±<sup>7</sup>First FORD 70 value is second FORD 70 combined with FORD 67. $(\Gamma(K^+) - \Gamma(K^-)) / \Gamma(K)$  $K^\pm \rightarrow \mu^\pm \nu_\mu$  RATE DIFFERENCE/AVERAGETest of *CPT* conservation.

VALUE (%)	DOCUMENT ID	TECN
<b>-0.54±0.41</b>	FORD	67 CNTR

 $K^\pm \rightarrow \pi^\pm \pi^+ \pi^-$  RATE DIFFERENCE/AVERAGETest of *CP* conservation.

VALUE (%)	EVTS	DOCUMENT ID	TECN	CHG
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**0.08±0.12** <sup>8</sup>FORD 70 ASPK

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

-0.02±0.16 <sup>9</sup>SMITH 73 ASPK ±0.10±0.14 3.2M <sup>8</sup>FORD 70 ASPK

-0.50±0.90 FLETCHER 67 OSPK

-0.04±0.21 <sup>8</sup>FORD 67 CNTR<sup>8</sup>First FORD 70 value is second FORD 70 combined with FORD 67.<sup>9</sup>SMITH 73 value of  $K^\pm \rightarrow \pi^\pm \pi^+ \pi^-$  rate difference is derived from SMITH 73 value of  $K^\pm \rightarrow \pi^\pm 2\pi^0$  rate difference. $K^\pm \rightarrow \pi^\pm \pi^0 \pi^0$  RATE DIFFERENCE/AVERAGETest of *CP* conservation.

VALUE (%)	EVTS	DOCUMENT ID	TECN	CHG
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**0.0 ±0.6 OUR AVERAGE**

0.08±0.58 SMITH 73 ASPK ±

-1.1 ±1.8 1802 HERZO 69 OSPK

 $K^\pm \rightarrow \pi^\pm \pi^0$  RATE DIFFERENCE/AVERAGETest of *CPT* conservation.

VALUE (%)	DOCUMENT ID	TECN
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**0.8±1.2** HERZO 69 OSPK $K^\pm \rightarrow \pi^\pm \pi^0 \gamma$  RATE DIFFERENCE/AVERAGETest of *CP* conservation.

VALUE (%)	EVTS	DOCUMENT ID	TECN	CHG	COMMENT
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**0.9±3.3 OUR AVERAGE**0.8±5.8 2461 SMITH 76 WIRE ±  $E_\pi$  55–90 MeV1.0±4.0 4000 ABRAMS 73B ASPK ±  $E_\pi$  51–100 MeV $K^+$  BRANCHING RATIOS

———— Leptonic and semileptonic modes ————

### $\Gamma(e^+ \nu_e)/\Gamma(\mu^+ \nu_\mu)$

$\Gamma_1/\Gamma_2$

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

<u>VALUE (units <math>10^{-5}</math>)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>
<b>2.45±0.11 OUR AVERAGE</b>				
2.51±0.15	404	HEINTZE	76	SPEC +
2.37±0.17	534	HEARD	75B	SPEC +
2.42±0.42	112	CLARK	72	OSPK +

### $\Gamma(\mu^+ \nu_\mu)/\Gamma_{\text{total}}$

$\Gamma_2/\Gamma$

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

<u>VALUE (units <math>10^{-2}</math>)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>	<u>COMMENT</u>
<b>63.54±0.14 OUR FIT</b>					Error includes scale factor of 1.3.
<b>63.60±0.16 OUR AVERAGE</b>					
63.66±0.09±0.15	865k	<sup>10</sup> AMBROSINO 06A	KLOE	+	
63.24±0.44	62k	CHIANG 72	OSPK	+	1.84 GeV/c $K^+$

<sup>10</sup> Fully inclusive. Used tagged kaons from  $\phi$  decays.

### $\Gamma(\pi^0 e^+ \nu_e)/\Gamma_{\text{total}}$

$\Gamma_3/\Gamma$

<u>VALUE (units <math>10^{-2}</math>)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>	<u>COMMENT</u>
<b>5.08 ±0.05 OUR FIT</b>					Error includes scale factor of 2.1.
<b>4.94 ±0.05 OUR AVERAGE</b>					

4.965±0.038±0.037		<sup>11</sup> 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	+	

<sup>11</sup> Depends on  $K^+$  lifetime  $\tau$ . 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%.

### $\Gamma(\pi^0 e^+ \nu_e)/\Gamma(\mu^+ \nu_\mu)$

$\Gamma_3/\Gamma_2$

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>
<b>0.0799±0.0008 OUR FIT</b>				

• • • 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	<sup>12</sup> AUERBACH 67	OSPK	+

<sup>12</sup> AUERBACH 67 changed from  $0.0797 \pm 0.0054$ . See comment with ratio  $\Gamma(\pi^0 \mu^+ \nu_\mu)/\Gamma(\mu^+ \nu_\mu)$ . The value  $0.0785 \pm 0.0025$  given in AUERBACH 67 is an average of AUERBACH 67  $\Gamma(\pi^0 e^+ \nu_e)/\Gamma(\mu^+ \nu_\mu)$  and CESTER 66  $\Gamma(\pi^0 e^+ \nu_e)/[\Gamma(\mu^+ \nu_\mu) + \Gamma(\pi^+ \pi^0)]$ .



$$\Gamma(\pi^0 e^+ \nu_e) / [\Gamma(\mu^+ \nu_\mu) + \Gamma(\pi^+ \pi^0)] \quad \Gamma_3 / (\Gamma_2 + \Gamma_9)$$

VALUE (units $10^{-2}$ )	EVTS	DOCUMENT ID	TECN	CHG
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**6.03 ± 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	+
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5.89 ± 0.21	1679	CESTER 66	OSPK	+
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• • • We do not use the following data for averages, fits, limits, etc. • • •

5.92 ± 0.65	<sup>13</sup>	WEISSENBE... 76	SPEC	+
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<sup>13</sup> 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.

$$\Gamma(\pi^0 e^+ \nu_e) / [\Gamma(\pi^0 \mu^+ \nu_\mu) + \Gamma(\pi^+ \pi^0) + \Gamma(\pi^+ \pi^0 \pi^0)] \quad \Gamma_3 / (\Gamma_4 + \Gamma_9 + \Gamma_{10})$$

VALUE	EVTS	DOCUMENT ID	TECN	CHG
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**0.1968 ± 0.0020 OUR FIT** Error includes scale factor of 3.0.

<b>0.1962 ± 0.0008 ± 0.0035</b>	71k	SHER	03 B865	+
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$$\Gamma(\pi^0 e^+ \nu_e) / \Gamma(\pi^+ \pi^0) \quad \Gamma_3 / \Gamma_9$$

VALUE	EVTS	DOCUMENT ID	TECN	CHG	COMMENT
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**0.2455 ± 0.0029 OUR FIT** Error includes scale factor of 3.2.

<b>0.2470 ± 0.0009 ± 0.0004</b>	87k	BATLEY 07A	NA48	±	
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• • • We do not use the following data for averages, fits, limits, etc. • • •

0.221 ± 0.012	786	<sup>14</sup> LUCAS 73B	HBC	-	Dalitz pairs only
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<sup>14</sup> LUCAS 73B gives  $N(K_{e3}) = 786 \pm 3.1\%$ ,  $N(2\pi) = 3564 \pm 3.1\%$ . We use these values to obtain quoted result.

$$\Gamma(\pi^0 e^+ \nu_e) / \Gamma(\pi^+ \pi^+ \pi^-) \quad \Gamma_3 / \Gamma_{11}$$

VALUE	EVTS	DOCUMENT ID	TECN	CHG
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**0.907 ± 0.012 OUR FIT** Error includes scale factor of 1.8.

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

0.867 ± 0.027	2768	BARMIN 87	XEBC	+
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0.856 ± 0.040	2827	BRAUN 75	HLBC	+
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0.850 ± 0.019	4385	<sup>15</sup> HAIDT 71	HLBC	+
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0.846 ± 0.021	4385	<sup>15</sup> EICHTEN 68	HLBC	+
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0.94 ± 0.09	854	BELLOTTI 67B	HLBC	
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0.90 ± 0.06	230	BORREANI 64	HBC	+
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<sup>15</sup> 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.

$$\Gamma(\pi^0 \mu^+ \nu_\mu) / \Gamma_{\text{total}} \quad \Gamma_4 / \Gamma$$

VALUE (units $10^{-2}$ )	EVTS	DOCUMENT ID	TECN	CHG	COMMENT
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**3.35 ± 0.04 OUR FIT** Error includes scale factor of 1.9.

**3.24 ± 0.04 OUR AVERAGE**

3.233 ± 0.029 ± 0.026	<sup>16</sup>	AMBROSINO 08A	KLOE	±	
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3.33 ± 0.16	2345	CHIANG 72	OSPK	+	1.84 GeV/c $K^+$
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• • • We do not use the following data for averages, fits, limits, etc. • • •

2.8 ± 0.4	<sup>17</sup>	TAYLOR 59	EMUL	+	
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<sup>16</sup> Depends on  $K^+$  lifetime  $\tau$ . 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%.

<sup>17</sup> Earlier experiments not averaged.

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

$\Gamma_4 / \Gamma_2$

VALUE                      EVTS                      DOCUMENT ID                      TECN                      CHG

**0.0528 ± 0.0006 OUR FIT** Error includes scale factor of 1.7.

• • • 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	<sup>18</sup> GARLAND	68	OSPK	+
0.0486 ± 0.0040	307	<sup>19</sup> AUERBACH	67	OSPK	+

<sup>18</sup> GARLAND 68 changed from 0.055 ± 0.004 in agreement with  $\mu$ -spectrum calculation of GAILLARD 70 appendix B. L.G.Pondrom, (private communication 73).

<sup>19</sup> AUERBACH 67 changed from 0.0602 ± 0.0046 by erratum which brings the  $\mu$ -spectrum calculation into agreement with GAILLARD 70 appendix B.

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

$\Gamma_4 / \Gamma_3$

VALUE                      EVTS                      DOCUMENT ID                      TECN                      CHG                      COMMENT

**0.6608 ± 0.0030 OUR FIT** Error includes scale factor of 1.1.

**0.6618 ± 0.0027 OUR AVERAGE**

0.6511 ± 0.0064		<sup>20</sup> AMBROSINO	08A	KLOE	±
0.663 ± 0.003 ± 0.001	77k	BATLEY	07A	NA48	±
0.671 ± 0.007 ± 0.008	24k	HORIE	01	SPEC	
0.670 ± 0.014		<sup>21</sup> HEINTZE	77	SPEC	+
0.667 ± 0.017	5601	BOTTERILL	68B	ASPK	+

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

0.608 ± 0.014	1585	<sup>22</sup> BRAUN	75	HLBC	+
0.705 ± 0.063	554	<sup>23</sup> LUCAS	73B	HBC	– Dalitz pairs only
0.698 ± 0.025	3480	<sup>24</sup> CHIANG	72	OSPK	+ 1.84 GeV/c $K^+$
0.596 ± 0.025		<sup>25</sup> HAIDT	71	HLBC	+
0.604 ± 0.022	1398	<sup>25</sup> EICHTEN	68	HLBC	
0.703 ± 0.056	1509	CALLAHAN	66B	HLBC	

<sup>20</sup> 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.

<sup>21</sup> HEINTZE 77 value from fit to  $\lambda_0$ . Assumes  $\mu$ -e universality.

<sup>22</sup> BRAUN 75 value is from form factor fit. Assumes  $\mu$ -e universality.

<sup>23</sup> LUCAS 73B gives  $N(K_{\mu 3}) = 554 \pm 7.6\%$ ,  $N(K_{e3}) = 786 \pm 3.1\%$ . We divide.

<sup>24</sup> CHIANG 72  $\Gamma(\pi^0 \mu^+ \nu_\mu) / \Gamma(\pi^0 e^+ \nu_e)$  is statistically independent of CHIANG 72  $\Gamma(\pi^0 \mu^+ \nu_\mu) / \Gamma_{\text{total}}$  and  $\Gamma(\pi^0 e^+ \nu_e) / \Gamma_{\text{total}}$ .

<sup>25</sup> HAIDT 71 is a reanalysis of EICHTEN 68. Not included in average because of large discrepancy with more precise results.

$[\Gamma(\pi^0 \mu^+ \nu_\mu) + \Gamma(\pi^+ \pi^0)] / \Gamma_{\text{total}}$

$(\Gamma_4 + \Gamma_9) / \Gamma$

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

**24.03 ± 0.13 OUR FIT** Error includes scale factor of 1.4.

• • • 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	+

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

$\Gamma_4 / \Gamma_9$

VALUE                      EVTS                      DOCUMENT ID                      TECN                      CHG

**0.1637 ± 0.0006 ± 0.0003** 77k BATLEY 07A NA48 ±

$\Gamma(\pi^0 \mu^+ \nu_\mu) / \Gamma(\pi^+ \pi^+ \pi^-)$   $\Gamma_4 / \Gamma_{11}$

VALUE (units  $10^{-5}$ )      EVTS      DOCUMENT ID      TECN      CHG      COMMENT

**0.600 ± 0.008 OUR FIT**      Error includes scale factor of 1.7.

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

0.503 ± 0.019	1505	<sup>26</sup> HAIDT	71	HLBC	+	
0.510 ± 0.017	1505	<sup>26</sup> EICHTEN	68	HLBC	+	
0.63 ± 0.07	2845	<sup>27</sup> BISI	65B	BC	+	HBC+HLBC

<sup>26</sup> 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.

<sup>27</sup> Error enlarged for background problems. See GAILLARD 70.

$\Gamma(\pi^0 \pi^0 e^+ \nu_e) / \Gamma_{\text{total}}$   $\Gamma_5 / \Gamma$

VALUE (units  $10^{-5}$ )      EVTS      DOCUMENT ID      TECN      CHG

**2.2 ± 0.4 OUR FIT**

**2.54 ± 0.89**      10      BARMIN      88B      HLBC      +

$\Gamma(\pi^0 \pi^0 e^+ \nu_e) / \Gamma(\pi^0 e^+ \nu_e)$   $\Gamma_5 / \Gamma_3$

VALUE (units  $10^{-4}$ )      EVTS      DOCUMENT ID      TECN      CHG

**4.3<sup>+0.9</sup><sub>-0.7</sub> OUR FIT**

**4.1<sup>+1.0</sup><sub>-0.7</sub> OUR AVERAGE**

4.2 <sup>+1.0</sup> <sub>-0.9</sub>	25	BOLOTOV	86B	CALO	-	
3.8 <sup>+5.0</sup> <sub>-1.2</sub>	2	LJUNG	73	HLBC	+	

$\Gamma(\pi^+ \pi^- e^+ \nu_e) / \Gamma(\pi^+ \pi^+ \pi^-)$   $\Gamma_6 / \Gamma_{11}$

VALUE (units  $10^{-4}$ )      EVTS      DOCUMENT ID      TECN      CHG

**7.31 ± 0.16 OUR AVERAGE**

7.35 ± 0.01 ± 0.19	388k	<sup>28</sup> 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	+	

<sup>28</sup> PISLAK 01 reports  $\Gamma(\pi^+ \pi^- e^+ \nu_e) / \Gamma_{\text{total}} = (4.109 \pm 0.008 \pm 0.110) \times 10^{-5}$  using the PDG 00 value  $\Gamma(\pi^+ \pi^+ \pi^-) / \Gamma_{\text{total}} = (5.59 \pm 0.05) \times 10^{-2}$ . We divide by the PDG value and unfold its error from the systematic error. PISLAK 03 gives additional details on the branching ratio measurement and gives improved errors on the S-wave  $\pi-\pi$  scattering length:  $a_0^0 = 0.216 \pm 0.013(\text{stat.}) \pm 0.002(\text{sys.}) \pm 0.002(\text{theor.})$ .

$\Gamma(\pi^+ \pi^- \mu^+ \nu_\mu) / \Gamma_{\text{total}}$   $\Gamma_7 / \Gamma$

VALUE (units  $10^{-5}$ )      EVTS      DOCUMENT ID      TECN      CHG

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

0.77 <sup>+0.54</sup> <sub>-0.50</sub>	1	CLINE	65	FBC	+	
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$\Gamma(\pi^+\pi^-\mu^+\nu_\mu)/\Gamma(\pi^+\pi^+\pi^-)$   $\Gamma_7/\Gamma_{11}$

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

$\Gamma(\pi^0\pi^0\pi^0e^+\nu_e)/\Gamma_{\text{total}}$   $\Gamma_8/\Gamma$

<u>VALUE (units <math>10^{-6}</math>)</u>	<u>CL%</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>
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<b>&lt;3.5</b>	90	0	BOLOTOV	88	SPEC -
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<9	90	0	BARMIN	92	XEBC +

————— **Hadronic modes** —————

$\Gamma(\pi^+\pi^0)/\Gamma_{\text{total}}$   $\Gamma_9/\Gamma$

<u>VALUE (units <math>10^{-2}</math>)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>	<u>COMMENT</u>
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<b>20.68±0.13 OUR FIT</b>	Error includes scale factor of 1.6.				
<b>21.18±0.28</b>	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 $\Gamma(\pi^+\pi^0)/\Gamma(\pi^+\pi^+\pi^-)$

$\Gamma(\pi^+\pi^0)/\Gamma(\pi^+\pi^+\pi^-)$   $\Gamma_9/\Gamma_{11}$

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>
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<b>3.70±0.04 OUR FIT</b>	Error includes scale factor of 1.6.			
• • • We do not use the following data for averages, fits, limits, etc. • • •				
3.96±0.15	1045	CALLAHAN	66	FBC +

$\Gamma(\pi^+\pi^0)/\Gamma(\mu^+\nu_\mu)$   $\Gamma_9/\Gamma_2$

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>	<u>COMMENT</u>
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<b>0.3254±0.0026 OUR FIT</b>	Error includes scale factor of 1.4.				
<b>0.3325±0.0032 OUR AVERAGE</b>					
0.3329±0.0047±0.0010	45k	USHER	92	SPEC +	$p\bar{p}$ at rest
0.3355±0.0057		<sup>29</sup> WEISSENBE...	76	SPEC +	
0.3277±0.0065	4517	<sup>30</sup> AUERBACH	67	OSPK +	
• • • We do not use the following data for averages, fits, limits, etc. • • •					
0.328 ±0.005	25k	<sup>29</sup> WEISSENBE...	74	STRC +	
0.305 ±0.018	1600	ZELLER	69	ASPK +	
<sup>29</sup> WEISSENBERG 76 revises WEISSENBERG 74.					
<sup>30</sup> AUERBACH 67 changed from 0.3253 ± 0.0065. See comment with ratio $\Gamma(\pi^0\mu^+\nu_\mu)/\Gamma(\mu^+\nu_\mu)$ .					

$\Gamma(\pi^+\pi^0\pi^0)/\Gamma_{\text{total}}$   $\Gamma_{10}/\Gamma$

<u>VALUE (units <math>10^{-2}</math>)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>	<u>COMMENT</u>
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**1.761±0.022 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	<sup>31</sup> PANDOULAS	70	EMUL	+
1.8 ±0.2	108	SHAKLEE	64	HLBC	+
1.7 ±0.2		ROE	61	HLBC	+
1.5 ±0.2		<sup>32</sup> TAYLOR	59	EMUL	+

<sup>31</sup>Includes events of TAYLOR 59.

<sup>32</sup>Earlier experiments not averaged.

$\Gamma(\pi^+\pi^0\pi^0)/\Gamma(\pi^+\pi^0)$   $\Gamma_{10}/\Gamma_9$

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>	<u>COMMENT</u>
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**0.0852±0.0013 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	<sup>33</sup> LUCAS	73B	HBC	- Dalitz pairs only
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<sup>33</sup>LUCAS 73B gives  $N(\pi^2\pi^0) = 574 \pm 5.9\%$ ,  $N(2\pi) = 3564 \pm 3.1\%$ . We quote  $0.5N(\pi^2\pi^0)/N(2\pi)$  where 0.5 is because only Dalitz pair  $\pi^0$ 's were used.

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

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>	<u>COMMENT</u>
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**0.315±0.005 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	+
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$\Gamma(\pi^+\pi^+\pi^-)/\Gamma_{\text{total}}$   $\Gamma_{11}/\Gamma$

<u>VALUE (units <math>10^{-2}</math>)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>	<u>COMMENT</u>
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**5.59±0.04 OUR FIT** Error includes scale factor of 1.5.

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

5.56±0.20	2330	<sup>34</sup> CHIANG	72	OSPK	+ 1.84 GeV/c $K^+$
5.34±0.21	693	<sup>35</sup> 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	+

<sup>34</sup>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  $\Gamma(\pi^0e^+\nu_e)/\Gamma_{\text{total}}$ .

<sup>35</sup>Includes events of TAYLOR 59.

————— **Leptonic and semileptonic modes with photons** —————

**$\Gamma(\mu^+ \nu_\mu \gamma)/\Gamma_{\text{total}}$**   **$\Gamma_{12}/\Gamma$**

<u>VALUE (units <math>10^{-3}</math>)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>	<u>COMMENT</u>
<b>6.2±0.8 OUR AVERAGE</b>					
6.6±1.5	36,37	DEMIDOV	90	XEBC	$P(\mu) < 231.5 \text{ MeV}/c$
6.0±0.9		BARMIN	88	HLBC +	$P(\mu) < 231.5 \text{ MeV}/c$
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●					
3.5±0.8	37,38	DEMIDOV	90	XEBC	$E(\gamma) > 20 \text{ MeV}$
3.2±0.5	57 39	BARMIN	88	HLBC +	$E(\gamma) > 20 \text{ MeV}$
5.4±0.3	40	AKIBA	85	SPEC	$P(\mu) < 231.5 \text{ MeV}/c$

<sup>36</sup>  $P(\mu)$  cut given in DEMIDOV 90 paper, 235.1 MeV/c, is a misprint according to authors (private communication).

<sup>37</sup> DEMIDOV 90 quotes only inner bremsstrahlung (IB) part.

<sup>38</sup> Not independent of above DEMIDOV 90 value. Cuts differ.

<sup>39</sup> Not independent of above BARMIN 88 value. Cuts differ.

<sup>40</sup> Assumes  $\mu$ -e universality and uses constraints from  $K \rightarrow e\nu\gamma$ .

**$\Gamma(\mu^+ \nu_\mu \gamma(\text{SD}^+))/\Gamma_{\text{total}}$**   **$\Gamma_{13}/\Gamma$**

Structure-dependent part with  $+\gamma$  helicity (SD<sup>+</sup> term). See the “Note on  $\pi^\pm \rightarrow \ell^\pm \nu \gamma$  and  $K^\pm \rightarrow \ell^\pm \nu \gamma$  Form Factors” in the  $\pi^\pm$  section of the Particle Data Listings above.

<u>VALUE (units <math>10^{-5}</math>)</u>	<u>CL%</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
<b>&lt;3.0</b>	90	AKIBA	85 SPEC

**$\Gamma(\mu^+ \nu_\mu \gamma(\text{SD}^+\text{INT}))/\Gamma_{\text{total}}$**   **$\Gamma_{14}/\Gamma$**

Interference term between internal Bremsstrahlung and SD<sup>+</sup> term. See the “Note on  $\pi^\pm \rightarrow \ell^\pm \nu \gamma$  and  $K^\pm \rightarrow \ell^\pm \nu \gamma$  Form Factors” in the  $\pi^\pm$  section of the Particle Data Listings above.

<u>VALUE (units <math>10^{-5}</math>)</u>	<u>CL%</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
<b>&lt;2.7</b>	90	AKIBA	85 SPEC

**$\Gamma(\mu^+ \nu_\mu \gamma(\text{SD}^- + \text{SD}^-\text{INT}))/\Gamma_{\text{total}}$**   **$\Gamma_{15}/\Gamma$**

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

<u>VALUE (units <math>10^{-4}</math>)</u>	<u>CL%</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
<b>&lt;2.6</b>	90	<sup>41</sup> AKIBA	85 SPEC

<sup>41</sup> Assumes  $\mu$ -e universality and uses constraints from  $K \rightarrow e\nu\gamma$ .

**$\Gamma(e^+ \nu_e \gamma(\text{SD}^+))/\Gamma_{\text{total}}$**   **$\Gamma_{16}/\Gamma$**

Structure-dependent part with  $+\gamma$  helicity (SD<sup>+</sup> term). See the “Note on  $\pi^\pm \rightarrow \ell^\pm \nu \gamma$  and  $K^\pm \rightarrow \ell^\pm \nu \gamma$  Form Factors” in the  $\pi^\pm$  section of the Particle Data Listings above.

<u>VALUE (units <math>10^{-5}</math>)</u>	<u>CL%</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>	<u>COMMENT</u>
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●					
<7.1	90	MACEK	70	OSPK +	$P(e) 234\text{--}247$

$\Gamma(e^+ \nu_e \gamma(SD^+))/\Gamma(e^+ \nu_e)$   $\Gamma_{16}/\Gamma_1$

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

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>	<u>COMMENT</u>
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• • • We do not use the following data for averages, fits, limits, etc. • • •

1.05 <sup>+0.25</sup> <sub>-0.30</sub>	56	42 HEARD	75	SPEC	+	P(e) 236–247
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<sup>42</sup> This value is included in the first HEINTZE 79 value in the section on  $\Gamma(e^+ \nu_e \gamma(SD^+))/\Gamma(\mu^+ \nu_\mu)$  above.

$\Gamma(e^+ \nu_e \gamma(SD^+))/\Gamma(\mu^+ \nu_\mu)$   $\Gamma_{16}/\Gamma_2$

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

<u>VALUE (units 10<sup>-5</sup>)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>
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<b>2.40±0.36</b>	107	43 HEINTZE	79	SPEC	+
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• • • We do not use the following data for averages, fits, limits, etc. • • •

2.33±0.42	51	43 HEINTZE	79	SPEC	+
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<sup>43</sup> First HEINTZE 79 result is second combined with HEARD 75 result from section  $\Gamma(e^+ \nu_e \gamma(SD^+))/\Gamma(e^+ \nu_e)$  below.

$\Gamma(e^+ \nu_e \gamma(SD^-))/\Gamma_{total}$   $\Gamma_{17}/\Gamma$

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

<u>VALUE (units 10<sup>-4</sup>)</u>	<u>CL%</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>
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<b>&lt;1.6</b>	90	44 HEINTZE	79	SPEC	+
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<sup>44</sup> Implies (axial vector/vector) amplitude ratio outside range from  $-1.8$  to  $-0.54$ .

$\Gamma(\pi^0 e^+ \nu_e \gamma)/\Gamma(\pi^0 e^+ \nu_e)$   $\Gamma_{18}/\Gamma_3$

<u>VALUE (units 10<sup>-2</sup>)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>	<u>COMMENT</u>
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<b>0.505±0.032 OUR AVERAGE</b>		Error includes scale factor of 1.3. See the ideogram below.			
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0.47 ±0.02 ±0.03	4476	<sup>45</sup> AKIMENKO	07	ISTR	-	$E_\gamma > 10$ MeV, $0.6 < \cos(\theta_{e\gamma}) < 0.9$
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0.46 ±0.08	82	<sup>46</sup> BARMIN	91	XEBC	-	$E_\gamma > 10$ MeV, $0.6 < \cos(\theta_{e\gamma}) < 0.9$
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0.56 ±0.04	192	<sup>47</sup> BOLOTOV	86B	CALO	-	$E_\gamma > 10$ MeV
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• • • We do not use the following data for averages, fits, limits, etc. • • •

1.81 ±0.03 ±0.07	4476	<sup>45</sup> AKIMENKO	07	ISTR	-	$E_\gamma > 10$ MeV, $\theta_{e\gamma} > 10^\circ$
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0.63 ±0.02 ±0.03	4476	<sup>45</sup> AKIMENKO	07	ISTR	-	$E_\gamma > 30$ MeV, $\theta_{e\gamma} > 20^\circ$
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1.51 ±0.25	82	<sup>46</sup> BARMIN	91	XEBC	-	$E_\gamma > 10$ MeV, $\cos(\theta_{e\gamma}) < 0.98$
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0.48 ±0.20	16	<sup>48</sup> LJUNG	73	HLBC	+	$E_\gamma > 30$ MeV
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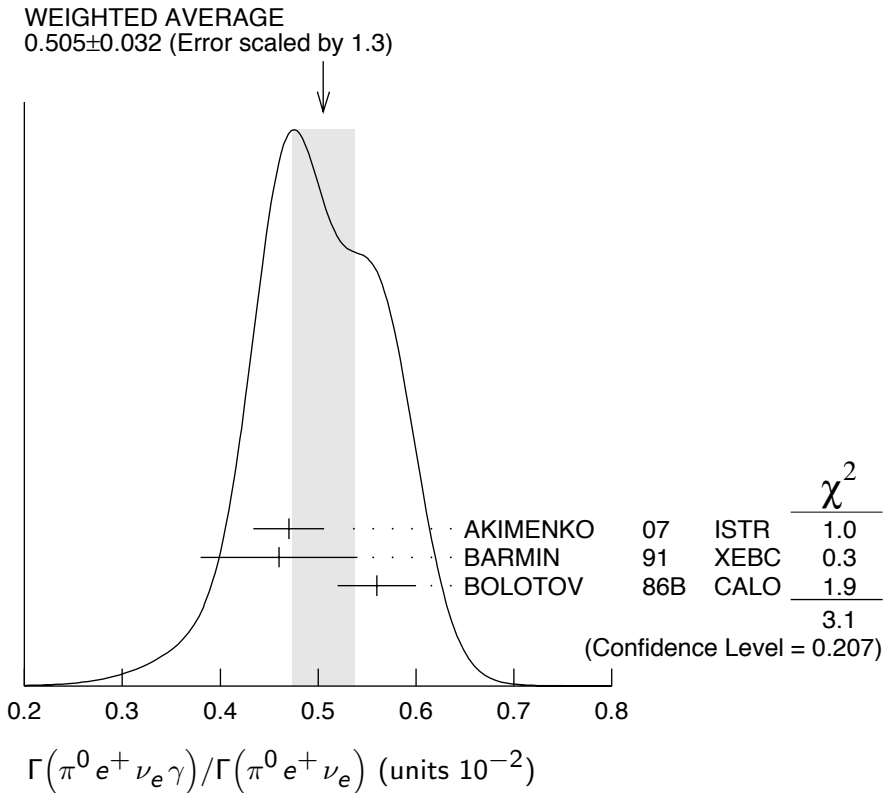
0.22 <sup>+0.15</sup> <sub>-0.10</sub>		<sup>48</sup> LJUNG	73	HLBC	+	$E_\gamma > 30$ MeV
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0.76 ±0.28	13	<sup>49</sup> ROMANO	71	HLBC	-	$E_\gamma > 10$ MeV
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0.53 ±0.22		<sup>49</sup> ROMANO	71	HLBC	+	$E_\gamma > 30$ MeV
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1.2 ±0.8		BELLOTTI	67	HLBC	-	$E_\gamma > 30$ MeV
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- 45 AKIMENKO 07 provides values for three kinematic regions. For averaging, we use value with  $E_\gamma > 10$  MeV and  $0.6 < \cos(\theta_{e\gamma}) < 0.9$ .
- 46 BARMIN 91 quotes branching ratio  $\Gamma(K \rightarrow e\pi^0\nu\gamma)/\Gamma_{\text{all}}$ . The measured normalization is  $[\Gamma(K \rightarrow e\pi^0\nu) + \Gamma(K \rightarrow \pi^+\pi^+\pi^-)]$ . For comparison with other experiments we used  $\Gamma(K \rightarrow e\pi^0\nu)/\Gamma_{\text{all}} = 0.0482$  to calculate the values quoted here.
- 47  $\cos(\theta_{e\gamma})$  between 0.6 and 0.9.
- 48 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.
- 49 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  $E_\gamma$  cut for Summary Table value. See ROMANO 71 for  $E_\gamma$  dependence.



**$\Gamma(\pi^0 e^+ \nu_e \gamma) / \Gamma_{\text{total}}$**   
Structure-dependent part.

**$\Gamma_{19}/\Gamma$**

VALUE (units $10^{-5}$ )	CL%	DOCUMENT ID	TECN	CHG
<b>&lt;5.3</b>	90	BOLOTOV 86B	CALO	-

**$\Gamma(\pi^0 \mu^+ \nu_\mu \gamma) / \Gamma_{\text{total}}$**

**$\Gamma_{20}/\Gamma$**

VALUE (units $10^{-5}$ )	CL%	EVTS	DOCUMENT ID	TECN	CHG	COMMENT
<b>1.46 ± 0.22 ± 0.32</b>		153	50 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; $\Theta_{\mu\gamma} > 20^\circ$	
<6.1	90	0	LJUNG	73	HLBC	+	$E(\gamma) > 30$ MeV



<sup>50</sup> Obtained from measuring  $B(K_{\mu 3\gamma}) / B(K_{\mu 3})$  and using PDG 02 value  $B(K_{\mu 3}) = 3.27\%$ .

$B(K_{\mu 3\gamma}) = (8.82 \pm 0.94 \pm 0.86) \times 10^{-5}$  is obtained for  $5 \text{ MeV} < E_{\gamma} < 30 \text{ MeV}$ .

$\Gamma(\pi^0 \pi^0 e^+ \nu_e \gamma) / \Gamma_{\text{total}}$						$\Gamma_{21} / \Gamma$
VALUE (units $10^{-6}$ )	CL%	EVTS	DOCUMENT ID	TECN	CHG	COMMENT
<5	90	0	BARMIN	92	XEBC	+ $E_{\gamma} > 10 \text{ MeV}$

————— **Hadronic modes with photons** —————

$\Gamma(\pi^+ \pi^0 \gamma) / \Gamma_{\text{total}}$						$\Gamma_{22} / \Gamma$
VALUE (units $10^{-4}$ )	CL%	EVTS	DOCUMENT ID	TECN	CHG	COMMENT
<b>2.75 ± 0.15 OUR AVERAGE</b>						
2.71 ± 0.45		140	BOLOTOV	87	WIRE	– $T_{\pi^-}$ 55–90 MeV
2.87 ± 0.32		2461	SMITH	76	WIRE	± $T_{\pi^{\pm}}$ 55–90 MeV
2.71 ± 0.19		2100	ABRAMS	72	ASPK	± $T_{\pi^+}$ 55–90 MeV

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

1.5 $^{+1.1}_{-0.6}$			<sup>51</sup> LJUNG	73	HLBC	+ $T_{\pi^+}$ 55–80 MeV
2.6 $^{+1.5}_{-1.1}$			<sup>51</sup> LJUNG	73	HLBC	+ $T_{\pi^+}$ 55–90 MeV
6.8 $^{+3.7}_{-2.1}$		17	<sup>51</sup> LJUNG	73	HLBC	+ $T_{\pi^+}$ 55–102 MeV
2.4 ± 0.8		24	EDWARDS	72	OSPK	$T_{\pi^+}$ 58–90 MeV
<1.0		0	<sup>52</sup> MALTSEV	70	HLBC	+ $T_{\pi^+}$ <55 MeV
<1.9	90	0	EMMERSON	69	OSPK	$T_{\pi^+}$ 55–80 MeV
2.2 ± 0.7		18	CLINE	64	FBC	+ $T_{\pi^+}$ 55–80 MeV

<sup>51</sup> The LJUNG 73 values are not independent.

<sup>52</sup> MALTSEV 70 selects low  $\pi^+$  energy to enhance direct emission contribution.

$\Gamma(\pi^+ \pi^0 \gamma(\text{DE})) / \Gamma_{\text{total}}$						$\Gamma_{23} / \Gamma$
Direct emission (DE) part of $\Gamma(\pi^+ \pi^0 \gamma) / \Gamma_{\text{total}}$ , assuming that interference (INT) component is zero.						
VALUE (units $10^{-6}$ )	CL%	EVTS	DOCUMENT ID	TECN	CHG	COMMENT

**4.3 ± 0.7 OUR AVERAGE**

3.8 ± 0.8 ± 0.7		10k	ALIEV	06	K470	+ $T_{\pi^+}$ 55–90 MeV
3.7 ± 3.9 ± 1.0		930	UVAROV	06	ISTR	– $T_{\pi^-}$ 55–90 MeV
4.7 ± 0.8 ± 0.3		20k	<sup>53</sup> ADLER	00C	B787	+ $T_{\pi^+}$ 55–90 MeV

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

3.2 ± 1.3 ± 1.0		4k	ALIEV	03	K470	+ $T_{\pi^+}$ 55–90 MeV
6.1 ± 2.5 ± 1.9		4k	ALIEV	03	K470	+ $T_{\pi^+}$ full range
20.5 ± 4.6 $^{+3.9}_{-2.3}$			BOLOTOV	87	WIRE	– $T_{\pi^-}$ 55–90 MeV
15.6 ± 3.5 ± 5.0			ABRAMS	72	ASPK	± $T_{\pi^{\pm}}$ 55–90 MeV

<sup>53</sup> ADLER 00C measures the INT component to be  $(-0.4 \pm 1.6)\%$  of the inner bremsstrahlung (IB) component.

$\Gamma(\pi^+ \pi^0 \pi^0 \gamma) / \Gamma(\pi^+ \pi^0 \pi^0)$						$\Gamma_{24} / \Gamma_{10}$
VALUE (units $10^{-4}$ )	CL%	EVTS	DOCUMENT ID	TECN	CHG	COMMENT
<b>4.3 <math>^{+3.2}_{-1.7}</math></b>			BOLOTOV	85	SPEC	– $E(\gamma) > 10 \text{ MeV}$

$\Gamma(\pi^+\pi^+\pi^-\gamma)/\Gamma_{\text{total}}$   $\Gamma_{25}/\Gamma$

VALUE (units $10^{-4}$ )	EVTS	DOCUMENT ID	TECN	CHG	COMMENT
<b>1.04±0.31 OUR AVERAGE</b>					
1.10±0.48	7	BARMIN	89	XEBC	$E(\gamma) > 5$ MeV
1.0 ±0.4		STAMER	65	EMUL +	$E(\gamma) > 11$ MeV

$\Gamma(\pi^+\gamma\gamma)/\Gamma_{\text{total}}$   $\Gamma_{26}/\Gamma$

VALUE (units $10^{-7}$ )	CL%	EVTS	DOCUMENT ID	TECN	CHG	COMMENT
<b>11±3 ±1</b>		31	<sup>54</sup> KITCHING	97	B787	
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●						
< 0.083	90		<sup>55</sup> ARTAMONOV	05	B949 +	$P_\pi > 213$ MeV/c
< 10	90	0	ATIYA	90B	B787	$T_\pi$ 117–127 MeV
< 84	90	0	ASANO	82	CNTR +	$T_\pi$ 117–127 MeV
−420 ± 520		0	ABRAMS	77	SPEC +	$T_\pi < 92$ MeV
< 350	90	0	LJUNG	73	HLBC +	6–102, 114–127 MeV
< 500	90	0	KLEMS	71	OSPK +	$T_\pi < 117$ MeV
−100 ± 600			CHEN	68	OSPK +	$T_\pi$ 60–90 MeV

<sup>54</sup>KITCHING 97 is extrapolated from their model-independent branching fraction ( $6.0 \pm 1.5 \pm 0.7$ )  $\times 10^{-7}$  for  $100 \text{ MeV}/c < P_{\pi^+} < 180 \text{ MeV}/c$  using Chiral Perturbation Theory.

<sup>55</sup>ARTAMONOV 05 limit assumes ChPT with  $\hat{c} = 1.8$  with unitarity corrections. With  $\hat{c} = 1.6$  and no unitarity corrections they obtain  $< 2.3 \times 10^{-8}$  at 90% CL. This partial branching ratio is predicted to be  $6.10 \times 10^{-9}$  and  $0.49 \times 10^{-9}$  for the cases with and without unitarity correction.

$\Gamma(\pi^+3\gamma)/\Gamma_{\text{total}}$   $\Gamma_{27}/\Gamma$

Values given here assume a phase space pion energy spectrum.

VALUE (units $10^{-4}$ )	CL%	DOCUMENT ID	TECN	CHG	COMMENT
<b>&lt;1.0</b>	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
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$\Gamma(\pi^+e^+e^-\gamma)/\Gamma_{\text{total}}$   $\Gamma_{28}/\Gamma$

VALUE (units $10^{-8}$ )	EVTS	DOCUMENT ID	TECN	COMMENT
<b>1.19±0.12±0.04</b>	113	<sup>56</sup> BATLEY	08	NA48 $m_{ee\gamma} > 260$ MeV

<sup>56</sup>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  $B(K^+ \rightarrow \pi^+e^+e^-\gamma) = (1.29 \pm 0.13 \pm 0.03) \times 10^{-8}$ , 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  $\ell\bar{\ell}$  pairs ————

$\Gamma(e^+\nu_e\nu\bar{\nu})/\Gamma(e^+\nu_e)$   $\Gamma_{29}/\Gamma_1$

VALUE	CL%	EVTS	DOCUMENT ID	TECN	CHG
<b>&lt;3.8</b>	90	0	HEINTZE	79	SPEC +

$\Gamma(\mu^+ \nu_\mu \nu \bar{\nu})/\Gamma_{\text{total}}$   $\Gamma_{30}/\Gamma$

VALUE (units $10^{-6}$ )	CL%	EVTS	DOCUMENT ID	TECN	CHG
<b>&lt;6.0</b>	90	0	<sup>57</sup> PANG	73	CNTR +

<sup>57</sup> PANG 73 assumes  $\mu$  spectrum from  $\nu$ - $\nu$  interaction of BARDIN 70.

$\Gamma(e^+ \nu_e e^+ e^-)/\Gamma_{\text{total}}$   $\Gamma_{31}/\Gamma$

VALUE (units $10^{-8}$ )	CL%	EVTS	DOCUMENT ID	TECN	CHG	COMMENT
<b>2.48 ± 0.14 ± 0.14</b>		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
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$\Gamma(\mu^+ \nu_\mu e^+ e^-)/\Gamma_{\text{total}}$   $\Gamma_{32}/\Gamma$

VALUE (units $10^{-8}$ )	CL%	EVTS	DOCUMENT ID	TECN	CHG	COMMENT
<b>7.06 ± 0.16 ± 0.26</b>		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
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$\Gamma(e^+ \nu_e \mu^+ \mu^-)/\Gamma_{\text{total}}$   $\Gamma_{33}/\Gamma$

VALUE (units $10^{-8}$ )	CL%	DOCUMENT ID	TECN	CHG
<b>1.72 ± 0.45</b>		MA	06	B865

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

<50	90	ADLER	98	B787
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$\Gamma(\mu^+ \nu_\mu \mu^+ \mu^-)/\Gamma_{\text{total}}$   $\Gamma_{34}/\Gamma$

VALUE (units $10^{-7}$ )	CL%	DOCUMENT ID	TECN	CHG
<b>&lt;4.1</b>	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 —————

$\Gamma(\pi^+ \pi^+ e^- \bar{\nu}_e)/\Gamma_{\text{total}}$   $\Gamma_{35}/\Gamma$

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

VALUE (units $10^{-7}$ )	CL%	EVTS	DOCUMENT ID	TECN	CHG
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• • • 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 +

$\Gamma(\pi^+ \pi^+ e^- \bar{\nu}_e)/\Gamma(\pi^+ \pi^- e^+ \nu_e)$   $\Gamma_{35}/\Gamma_6$

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

VALUE (units $10^{-4}$ )	CL%	EVTS	DOCUMENT ID	TECN	CHG
<b>&lt; 3</b>	90	3	<sup>58</sup> BLOCH	76	SPEC

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

< 130.	95	0	BOURQUIN	71	ASPK
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<sup>58</sup> BLOCH 76 quotes  $3.6 \times 10^{-4}$  at CL = 95%, we convert.

$\Gamma(\pi^+ \pi^+ \mu^- \bar{\nu}_\mu) / \Gamma_{\text{total}}$   $\Gamma_{36} / \Gamma$   
 Test of  $\Delta S = \Delta Q$  rule.

<u>VALUE (units <math>10^{-6}</math>)</u>	<u>CL%</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>
<b>&lt;3.0</b>	95	0	BIRGE	65	FBC +

$\Gamma(\pi^+ e^+ e^-) / \Gamma_{\text{total}}$   $\Gamma_{37} / \Gamma$   
 Test for  $\Delta S = 1$  weak neutral current. Allowed by combined first-order weak and electromagnetic interactions.

<u>VALUE (units <math>10^{-7}</math>)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>
<b>2.88 ± 0.13 OUR AVERAGE</b>				
2.94 ± 0.05 ± 0.14	10300	<sup>59</sup> APPEL	99	SPEC +
2.75 ± 0.23 ± 0.13	500	<sup>60</sup> ALLIEGRO	92	SPEC +
2.7 ± 0.5	41	<sup>61</sup> BLOCH	75	SPEC +

<sup>59</sup> APPEL 99 establishes vector nature of this decay and determines form factor  $f(Z) = f_0(1 + \delta Z)$ ,  $Z = M_{ee}^2 / m_K^2$ ,  $\delta = 2.14 \pm 0.13 \pm 0.15$ .

<sup>60</sup> 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  $-0.82$ .

<sup>61</sup> BLOCH 75 assumes a vector interaction.

$\Gamma(\pi^+ \mu^+ \mu^-) / \Gamma_{\text{total}}$   $\Gamma_{38} / \Gamma$   
 Test for  $\Delta S = 1$  weak neutral current. Allowed by higher-order electroweak interactions.

<u>VALUE (units <math>10^{-8}</math>)</u>	<u>CL%</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>
<b>8.1 ± 1.4 OUR AVERAGE</b> Error includes scale factor of 2.7. See the ideogram below.					

9.8 ± 1.0 ± 0.5	110	<sup>62</sup> PARK	02	HYCP ±
9.22 ± 0.60 ± 0.49	402	<sup>63</sup> MA	00	B865 +
5.0 ± 0.4 ± 0.9	207	<sup>64</sup> ADLER	97C	B787 +

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

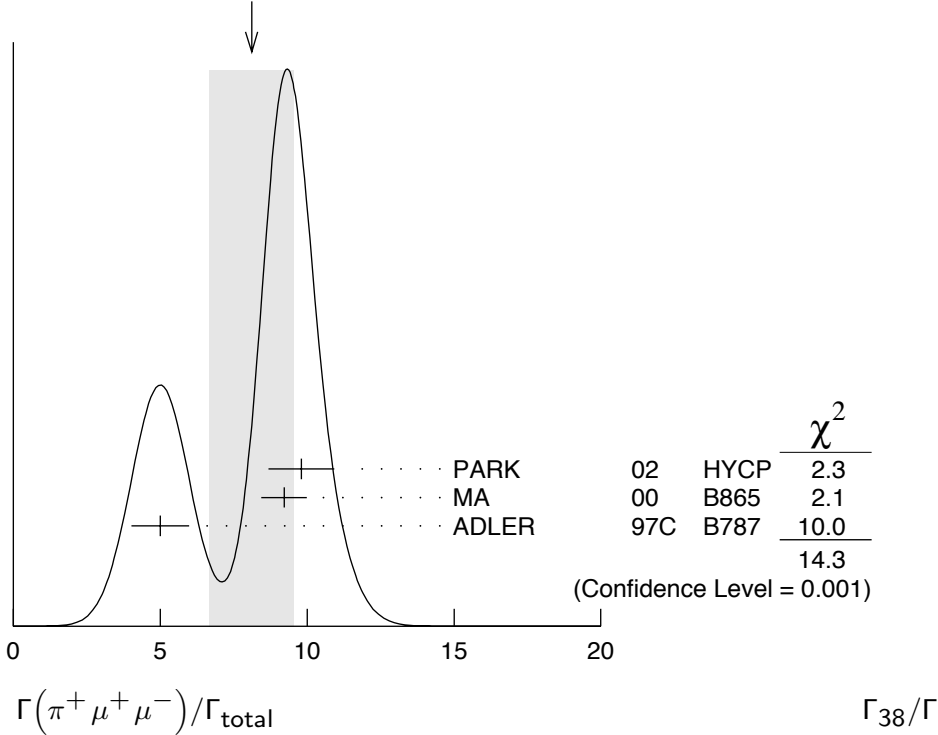
9.7 ± 1.2 ± 0.4	65	PARK	02	HYCP +
10.0 ± 1.9 ± 0.7	35	PARK	02	HYCP -
<23	90	ATIYA	89	B787 +

<sup>62</sup> PARK 02 “±” result comes from combining  $K^+ \rightarrow \pi^+ \mu^+ \mu^-$  and  $K^- \rightarrow \pi^- \mu^+ \mu^-$ , assuming  $CP$  is conserved.

<sup>63</sup> MA 00 establishes vector nature of this decay and determines form factor  $f(Z) = f_0(1 + \delta Z)$ ,  $Z = M_{\mu\mu}^2 / m_K^2$ ,  $\delta = 2.45^{+1.30}_{-0.95}$ .

<sup>64</sup> ADLER 97C gives systematic error  $0.7 \times 10^{-8}$  and theoretical uncertainty  $0.6 \times 10^{-8}$ , which we combine in quadrature to obtain our second error.

WEIGHTED AVERAGE  
 $8.1 \pm 1.4$  (Error scaled by 2.7)



**$\Gamma(\pi^+ \nu \bar{\nu}) / \Gamma_{\text{total}}$**

**$\Gamma_{39} / \Gamma$**

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.

<u>VALUE (units <math>10^{-9}</math>)</u>	<u>CL%</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>	<u>COMMENT</u>
<b><math>0.147^{+0.130}_{-0.089}</math></b>		3	<sup>65</sup> ANISIMOVSK...04	B949	+	$211 < P_\pi < 229$ MeV
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●						
< 2.2	90		<sup>66</sup> ADLER	04	B787	+ $140 < P_\pi < 195$ MeV
$0.157^{+0.175}_{-0.082}$		2	ADLER	02	B787	$P_\pi > 211$ MeV/c
< 4.2	90	1	ADLER	02C	B787	$140 < P_\pi < 195$ MeV
< 4.7	90		ADLER	02C	B787	Scalar
< 2.5	90		ADLER	02C	B787	Tensor
$0.15^{+0.34}_{-0.12}$		1	ADLER	00	B787	In ADLER 02
$0.42^{+0.97}_{-0.35}$		1	ADLER	97	B787	
< 2.4	90		ADLER	96	B787	
< 7.5	90		ATIYA	93	B787	+ $T(\pi)$ 115–127 MeV
< 5.2	90		<sup>67</sup> ATIYA	93	B787	+
< 17	90	0	ATIYA	93B	B787	+ $T(\pi)$ 60–100 MeV
< 34	90		ATIYA	90	B787	+
< 140	90		ASANO	81B	CNTR	+ $T(\pi)$ 116–127 MeV

<sup>65</sup> Value obtained combining the previous E787 result ADLER 02 with 2 evts and the present E949 with 1 evt. The additional event has a signal-to-background ratio 0.9.

<sup>66</sup> Value obtained combining the previous result ADLER 02C with 1 event and the present result with 0 events to obtain an expected background  $1.22 \pm 0.24$  evts and 1 evt observed.

<sup>67</sup> Combining ATIYA 93 and ATIYA 93B results. Superseded by ADLER 96.

$\Gamma(\pi^+ \pi^0 \nu \bar{\nu})/\Gamma_{\text{total}}$   $\Gamma_{40}/\Gamma$

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

<u>VALUE (units <math>10^{-5}</math>)</u>	<u>CL%</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
<b>&lt;4.3</b>	90	<sup>68</sup> ADLER 01	SPEC

<sup>68</sup> Search region defined by  $90 \text{ MeV}/c < P_{\pi^+} < 188 \text{ MeV}/c$  and  $135 \text{ MeV} < E_{\pi^0} < 180 \text{ MeV}$ .

$\Gamma(\mu^- \nu e^+ e^+)/\Gamma(\pi^+ \pi^- e^+ \nu_e)$   $\Gamma_{41}/\Gamma_6$

Test of lepton family number conservation.

<u>VALUE (units <math>10^{-3}</math>)</u>	<u>CL%</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>
<b>&lt;0.5</b>	90	0	<sup>69</sup> DIAMANT-...	76	SPEC +

<sup>69</sup> DIAMANT-BERGER 76 quotes this result times our 1975  $\pi^+ \pi^- e \nu$  BR ratio.

$\Gamma(\mu^+ \nu_e)/\Gamma_{\text{total}}$   $\Gamma_{42}/\Gamma$

Forbidden by lepton family number conservation.

<u>VALUE</u>	<u>CL%</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>&lt;0.004</b>	90	0	<sup>70</sup> LYONS 81	HLBC	200 GeV $K^+$ narrow band $\nu$ beam

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

<0.012	90	<sup>70</sup> COOPER 82	HLBC	Wideband $\nu$ beam
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<sup>70</sup> COOPER 82 and LYONS 81 limits on  $\nu_e$  observation are here interpreted as limits on lepton family number violation in the absence of mixing.

$\Gamma(\pi^+ \mu^+ e^-)/\Gamma_{\text{total}}$   $\Gamma_{43}/\Gamma$

Test of lepton family number conservation.

<u>VALUE (units <math>10^{-10}</math>)</u>	<u>CL%</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>
<b>&lt;0.13</b>	90	<sup>71</sup> 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	+

<sup>71</sup> 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.

$\Gamma(\pi^+ \mu^- e^+)/\Gamma_{\text{total}}$   $\Gamma_{44}/\Gamma$

Test of lepton family number conservation.

<u>VALUE (units <math>10^{-10}</math>)</u>	<u>CL%</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>
<b>&lt; 5.2</b>	90	0	APPEL 00B	B865	+

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

<70	90	0	<sup>72</sup> DIAMANT-...	76	SPEC +
-----	----	---	---------------------------	----	--------

<sup>72</sup> Measurement actually applies to the sum of the  $\pi^+ \mu^- e^+$  and  $\pi^- \mu^+ e^+$  modes.

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

Test of total lepton number conservation.

VALUE (units $10^{-10}$ )	CL%	EVTS	DOCUMENT ID	TECN	CHG
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< 5.0	90	0	APPEL	00B B865	+
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• • • We do not use the following data for averages, fits, limits, etc. • • •

<70	90	0	<sup>73</sup> DIAMANT-...	76 SPEC	+
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<sup>73</sup> Measurement actually applies to the sum of the  $\pi^+ \mu^- e^+$  and  $\pi^- \mu^+ e^+$  modes.

$\Gamma(\pi^- e^+ e^+)/\Gamma_{\text{total}}$   $\Gamma_{46}/\Gamma$

Test of total lepton number conservation.

VALUE	CL%	EVTS	DOCUMENT ID	TECN	CHG
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< $6.4 \times 10^{-10}$	90	0	APPEL	00B B865	+
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• • • We do not use the following data for averages, fits, limits, etc. • • •

< $9.2 \times 10^{-9}$	90	0	DIAMANT-...	76 SPEC	+
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< $1.5 \times 10^{-5}$			CHANG	68 HBC	-
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$\Gamma(\pi^- \mu^+ \mu^+)/\Gamma_{\text{total}}$   $\Gamma_{47}/\Gamma$

Forbidden by total lepton number conservation.

VALUE	CL%	EVTS	DOCUMENT ID	TECN	CHG
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< $3.0 \times 10^{-9}$	90	0	APPEL	00B B865	+
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• • • We do not use the following data for averages, fits, limits, etc. • • •

< $1.5 \times 10^{-4}$	90		<sup>74</sup> LITTENBERG	92 HBC	
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<sup>74</sup> LITTENBERG 92 is from retroactive data analysis of CHANG 68 bubble chamber data.

$\Gamma(\mu^+ \bar{\nu}_e)/\Gamma_{\text{total}}$   $\Gamma_{48}/\Gamma$

Forbidden by total lepton number conservation.

VALUE (units $10^{-3}$ )	CL%	DOCUMENT ID	TECN	COMMENT
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< 3.3	90	<sup>75</sup> COOPER	82 HLBC	Wideband $\nu$ beam
-------	----	----------------------	---------	---------------------

<sup>75</sup> COOPER 82 limit on  $\bar{\nu}_e$  observation is here interpreted as a limit on lepton number violation in the absence of mixing.

$\Gamma(\pi^0 e^+ \bar{\nu}_e)/\Gamma_{\text{total}}$   $\Gamma_{49}/\Gamma$

Forbidden by total lepton number conservation.

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
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< 0.003	90	<sup>76</sup> COOPER	82 HLBC	Wideband $\nu$ beam
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<sup>76</sup> COOPER 82 limit on  $\bar{\nu}_e$  observation is here interpreted as a limit on lepton number violation in the absence of mixing.

$\Gamma(\pi^+ \gamma)/\Gamma_{\text{total}}$   $\Gamma_{50}/\Gamma$

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 (units $10^{-9}$ )	CL%	DOCUMENT ID	TECN	CHG
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< 2.3	90	ARTAMONOV 05	B949	+
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• • • We do not use the following data for averages, fits, limits, etc. • • •

< 360	90	ADLER	02B B787	+
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< 1400	90	ASANO	82 CNTR	+
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< 4000	90	<sup>77</sup> KLEMS	71 OSPK	+
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<sup>77</sup> Test of model of Selleri, Nuovo Cimento **60A** 291 (1969).

**$K^+$  LONGITUDINAL POLARIZATION OF EMITTED  $\mu^+$** 

VALUE	CL%	DOCUMENT ID	TECN	CHG	COMMENT
<b>&lt; -0.990</b>	90	<sup>78</sup> AOKI	94	SPEC	+
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●					
< -0.990	90	IMAZATO	92	SPEC	+
-0.970 ± 0.047		<sup>79</sup> YAMANAKA	86	SPEC	+
-1.0 ± 0.1		<sup>79</sup> CUTTS	69	SPRK	+
-0.96 ± 0.12		<sup>79</sup> COOMBES	57	CNTR	+

<sup>78</sup>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  $\xi=1$ , its maximum value.

<sup>79</sup>Assumes  $\xi=1$ .

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**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  $K^\pm \rightarrow \pi^\pm \pi^+ \pi^-$** 

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  $K \rightarrow 3\pi$  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
<b>-0.21134 ± 0.00017</b>	471M	<sup>80</sup> BATLEY	07B	NA48	±
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●					
-0.2221 ± 0.0065	225k	DEVAUX	77	SPEC	+
-0.199 ± 0.008	81k	<sup>81</sup> LUCAS	73	HBC	-
-0.2157 ± 0.0028	750k	FORD	72	ASPK	+
-0.2186 ± 0.0028	750k	FORD	72	ASPK	-
-0.200 ± 0.009	39819	<sup>82</sup> HOFFMASTER	72	HLBC	+
-0.196 ± 0.012	17898	<sup>83</sup> GRAUMAN	70	HLBC	+
-0.193 ± 0.010	50919	MAST	69	HBC	-
-0.218 ± 0.016	9994	<sup>84</sup> BUTLER	68	HBC	+
-0.190 ± 0.023	5778	<sup>84,85</sup> MOSCOSO	68	HBC	-
-0.22 ± 0.024	5428	<sup>84,85</sup> ZINCHENKO	67	HBC	+
-0.220 ± 0.035	1347	<sup>86</sup> FERRO-LUZZI	61	HBC	-

<sup>80</sup>Final state strong interaction and radiative corrections not included in the fit.

<sup>81</sup>Quadratic dependence is required by  $K_L^0$  experiments.

<sup>82</sup>HOFFMASTER 72 includes GRAUMAN 70 data.

<sup>83</sup>Emulsion data added — all events included by HOFFMASTER 72.

<sup>84</sup>Experiments with large errors not included in average.

<sup>85</sup>Also includes DBC events.

<sup>86</sup>No radiative corrections included.



### QUADRATIC COEFFICIENT $h$ FOR $K^\pm \rightarrow \pi^\pm \pi^+ \pi^-$

<u>VALUE (units <math>10^{-2}</math>)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>
<b>1.848 ± 0.040</b>	471M	<sup>87</sup> 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	HOFFMASTER72	HLBC	+
−0.1 ± 1.2	50919	MAST	69 HBC	−

<sup>87</sup> Final state strong interaction and radiative corrections not included in the fit.

### QUADRATIC COEFFICIENT $k$ FOR $K^\pm \rightarrow \pi^\pm \pi^+ \pi^-$

<u>VALUE (units <math>10^{-3}</math>)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>
− <b>4.63 ± 0.14</b>	471M	<sup>88</sup> 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	HOFFMASTER72	HLBC	+
−14 ± 12	50919	MAST	69 HBC	−

<sup>88</sup> Final state strong interaction and radiative corrections not included in the fit.

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

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

<u>VALUE (units <math>10^{-4}</math>)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
− <b>1.5 ± 1.5 ± 1.6</b>	3.1G	<sup>89</sup> BATLEY	07E NA48
• • • We do not use the following data for averages, fits, limits, etc. • • •			
1.7 ± 2.1 ± 2.0	1.7G	<sup>90</sup> BATLEY	06 NA48
−70.0 ± 53	3.2M	FORD	70 ASPK

<sup>89</sup> 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  $k$ .

<sup>90</sup> This measurement neglects any possible charge asymmetries in higher order slope parameters  $h$  or  $k$ .

### LINEAR COEFFICIENT $g$ FOR $K^\pm \rightarrow \pi^\pm \pi^0 \pi^0$

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

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>	<u>COMMENT</u>
<b>0.626 ± 0.007 OUR AVERAGE</b>					
0.6259 ± 0.0043 ± 0.0093	493k	AKOPDZHAN..05B	TNF	±	
0.627 ± 0.004 ± 0.010	252k	<sup>91,92</sup> 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

<sup>91</sup> Measured using in-flight decays of the 25 GeV negative secondary beam.

<sup>92</sup> They form new world averages  $g_- = (0.617 \pm 0.018)$  and  $g_+ = (0.684 \pm 0.033)$  which give  $\Delta g_{\pi^0} = 0.051 \pm 0.028$ .

### QUADRATIC COEFFICIENT $h$ FOR $K^\pm \rightarrow \pi^\pm \pi^0 \pi^0$

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>	<u>COMMENT</u>
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**0.052 ±0.008 OUR AVERAGE**

0.0551 ±0.0044 ±0.0086 493k AKOPDZHAN..05B TNF ±

0.046 ±0.004 ±0.012 252k <sup>93</sup> 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

<sup>93</sup> Measured using in-flight decays of the 25 GeV negative secondary beam.

### QUADRATIC COEFFICIENT $k$ FOR $K^\pm \rightarrow \pi^\pm \pi^0 \pi^0$

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>
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**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 <sup>94</sup> 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 +

<sup>94</sup> 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.

<u>VALUE (units <math>10^{-4}</math>)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
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**1.8 ± 1.8 OUR AVERAGE**

1.8 ± 1.7 ± 0.6 91.3M <sup>95</sup> BATLEY 07E NA48

2 ± 18 ± 5 619k <sup>96</sup> AKOPDZHAN..05 TNF

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

1.8 ± 2.2 ± 1.3 47M <sup>97</sup> BATLEY 06A NA48

<sup>95</sup> 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  $k$ .

<sup>96</sup> Asymmetry obtained assuming that  $g_+ + g_- = 2 \times 0.652$  (PDG 02) and that asymmetries in  $h$  and  $k$  are zero.

<sup>97</sup> Linear and quadratic slopes from PDG 04 are used. Any possible charge asymmetries in higher order slope parameters  $h$  or  $k$  are neglected.

## ALTERNATIVE PARAMETERIZATION 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  $M_0 = 1 + (1/2)g_0 u + (1/2)h' u^2$  with  $u = (s_3 - s_0)/(m_{\pi^+})^2$  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  $h' \sim h^{PDG} - (g/2)^2$ .

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

VALUE	EVTS	DOCUMENT ID	TECN	CHG
<b>0.645 ± 0.004 ± 0.009</b>	23M	<sup>98</sup> BATLEY	06B NA48	±

<sup>98</sup>This fit is obtained with the CABIBBO 05 matrix element in the  $2\pi^0$  invariant mass squared range  $0.074 \text{ GeV}^2 < m_{2\pi^0}^2 < 0.097 \text{ GeV}^2$ , assuming  $k = 0$  (no term proportional to  $(s_2 - s_1)^2$ ) and excluding the kinematic region around the cusp ( $m_{2\pi^0}^2 = (2m_{\pi^+})^2 \pm 0.000525 \text{ GeV}^2$ ). Also  $\pi$ - $\pi$  phase shifts  $a_0$  and  $a_2$  are measured:  $(a_0 - a_2)m_{\pi^+} = 0.268 \pm 0.010 \pm 0.004 \pm 0.013(\text{external})$  and  $a_2 m_{\pi^+} = -0.041 \pm 0.022 \pm 0.014$ .

### QUADRATIC COEFFICIENT $h'$ FOR $K^\pm \rightarrow \pi^\pm \pi^0 \pi^0$

VALUE	EVTS	DOCUMENT ID	TECN	CHG
<b>-0.047 ± 0.012 ± 0.011</b>	23M	<sup>99</sup> BATLEY	06B NA48	±

<sup>99</sup>This fit is obtained with the CABIBBO 05 matrix element in the  $2\pi^0$  invariant mass squared range  $0.074 \text{ GeV}^2 < m_{2\pi^0}^2 < 0.097 \text{ GeV}^2$ , assuming  $k = 0$  (no term proportional to  $(s_2 - s_1)^2$ ) and excluding the kinematic region around the cusp ( $m_{2\pi^0}^2 = (2m_{\pi^+})^2 \pm 0.000525 \text{ GeV}^2$ ). Also  $\pi$ - $\pi$  phase shifts  $a_0$  and  $a_2$  are measured:  $(a_0 - a_2)m_{\pi^+} = 0.268 \pm 0.010 \pm 0.004 \pm 0.013(\text{external})$  and  $a_2 m_{\pi^+} = -0.041 \pm 0.022 \pm 0.014$ .

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## $K_{\ell 3}^\pm$ 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.

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

$t$  = momentum transfer to the  $\pi$ .

$\lambda_+$  and  $\lambda_0$  are the linear expansion coefficients of  $f_+$  and  $f_0$ :

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

For quadratic expansion

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

as used by KTeV. If there is a non-vanishing quadratic term, then  $\lambda_+$

represents an average slope, which is then different from  $\lambda'_+$ .

NA48 and ISTRA quadratic expansion coefficients are converted with  $\lambda'_{+PDG} = \lambda_{+NA48}$  and  $\lambda''_{+PDG} = 2 \lambda'_{+NA48}$

$$\lambda'_{+PDG} = \left(\frac{m_{\pi^+}}{m_{\pi^0}}\right)^2 \lambda_{+ISTRA} \text{ and}$$

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

ISTRA linear expansion coefficients are converted with

$$\lambda_{+PDG} = \left(\frac{m_{\pi^+}}{m_{\pi^0}}\right)^2 \lambda_{+ISTRA} \text{ and } \lambda_{0PDG} = \left(\frac{m_{\pi^+}}{m_{\pi^0}}\right)^2 \lambda_{0ISTRA}$$

The pole parametrization is

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

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

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

The following abbreviations are used:

DP = Dalitz plot analysis.

PI =  $\pi$  spectrum analysis.

MU =  $\mu$  spectrum analysis.

POL =  $\mu$  polarization analysis.

BR =  $K_{\mu 3}^{\pm}/K_{e 3}^{\pm}$  branching ratio analysis.

E = positron or electron spectrum analysis.

RC = radiative corrections.

## $\lambda_+$ (LINEAR ENERGY DEPENDENCE OF $f_+$ IN $K_{e 3}^{\pm}$ DECAY)

These results are for a linear expansion only. See the next section for fits including a quadratic term. For radiative correction of the  $K_{e 3}^{\pm}$  Dalitz plot, see GINSBERG 67, BECHERRAWY 70, CIRIGLIANO 02, CIRIGLIANO 04, and ANDRE 04. Results labeled OUR FIT are discussed in the review " $K_{\ell 3}^{\pm}$  and  $K_{\ell 3}^0$  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
<b>2.96 ± 0.06 OUR FIT</b>	Assuming $\mu$ -e universality				
<b>2.96 ± 0.06 OUR AVERAGE</b>					
2.966 ± 0.050 ± 0.034	919k	<sup>100</sup> YUSHCHENKO04B	ISTR	—	DP
2.78 ± 0.26 ± 0.30	41k	SHIMIZU	00	SPEC	+
2.84 ± 0.27 ± 0.20	32k	<sup>101</sup> AKIMENKO	91	SPEC	PI, no RC
2.9 ± 0.4	62k	<sup>102</sup> BOLOTOV	88	SPEC	PI, no RC
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●					
3.06 ± 0.09 ± 0.06	550k	<sup>100,103</sup> AJINENKO	03C	ISTR	—
2.93 ± 0.15 ± 0.2	130k	<sup>103</sup> AJINENKO	02	SPEC	DP

<sup>100</sup> Rescaled to agree with our conventions as noted above.

<sup>101</sup> AKIMENKO 91 state that radiative corrections would raise  $\lambda_+$  by 0.0013.

<sup>102</sup> BOLOTOV 88 state radiative corrections of GINSBERG 67 would raise  $\lambda_+$  by 0.002.

<sup>103</sup> Superseded by YUSHCHENKO 04B.

**$\lambda_+$  (LINEAR ENERGY DEPENDENCE OF  $f_+$  IN  $K_{\mu 3}^{\pm}$  DECAY)**

Results labeled OUR FIT are discussed in the review “ $K_{\ell 3}^{\pm}$  and  $K_{\ell 3}^0$  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
<b>2.96±0.06 OUR FIT</b>	Assuming $\mu$ -e universality				
<b>2.96±0.17 OUR FIT</b>	Not assuming $\mu$ -e universality				
2.96±0.14±0.10	540k	<sup>104</sup> YUSHCHENKO04	ISTR	–	DP
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●					
3.21±0.45	112k	<sup>105</sup> AJINENKO	03	ISTR	– DP
<sup>104</sup> Rescaled to agree with our conventions as noted above.					
<sup>105</sup> Superseded by YUSHCHENKO 04.					

 **$\lambda_0$  (LINEAR ENERGY DEPENDENCE OF  $f_0$  IN  $K_{\mu 3}^{\pm}$  DECAY)**

Results labeled OUR FIT are discussed in the review “ $K_{\ell 3}^{\pm}$  and  $K_{\ell 3}^0$  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
<b>1.96±0.12 OUR FIT</b>	Assuming $\mu$ -e universality					
<b>1.96±0.13 OUR FIT</b>	Not assuming $\mu$ -e universality					
+1.96±0.12±0.06	–0.348	540k	<sup>106</sup> YUSHCHENKO04	ISTR	–	DP
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●						
+2.09±0.45	–0.46	112k	<sup>107</sup> AJINENKO	03	ISTR	– DP
+1.9 ±0.64		24k	<sup>108</sup> HORIE	01	SPEC	+ BR
+1.9 ±1.0	+0.03	55k	<sup>109</sup> HEINTZE	77	SPEC	+ BR
<sup>106</sup> Rescaled to agree with our conventions as noted above.						
<sup>107</sup> Superseded by YUSHCHENKO 04.						
<sup>108</sup> HORIE 01 assumes $\mu$ -e universality in $K_{\ell 3}^+$ decay and uses SHIMIZU 00 value $\lambda=0.0278 \pm 0.0040$ from $K_{e 3}^{\pm}$ decay.						
<sup>109</sup> HEINTZE 77 uses $\lambda_+ = 0.029 \pm 0.003$ . $d\lambda_0/d\lambda_+$ estimated by us.						

 **$\lambda'_+$  (LINEAR  $K_{e 3}^{\pm}$  FORM FACTOR FROM QUADRATIC FIT)**

VALUE (units $10^{-2}$ )	EVTS	DOCUMENT ID	TECN	CHG	COMMENT
<b>2.485±0.163±0.034</b>	919k	<sup>110,111</sup> YUSHCHENKO04B	ISTR	–	DP
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●					
3.07 ±0.21	550k	<sup>110,112</sup> AJINENKO	03C	ISTR	– DP
<sup>110</sup> Rescaled to agree with our conventions as noted above.					
<sup>111</sup> YUSHCHENKO 04B $\lambda'_+$ and $\lambda''_+$ are strongly correlated with coefficient $\rho(\lambda'_+, \lambda''_+) = -0.95$ .					
<sup>112</sup> Superseded by YUSHCHENKO 04B.					

 **$\lambda''_+$  (QUADRATIC  $K_{e 3}^{\pm}$  FORM FACTOR)**

VALUE (units $10^{-2}$ )	EVTS	DOCUMENT ID	TECN	CHG	COMMENT
<b>0.192±0.062±0.071</b>	919k	<sup>113,114</sup> YUSHCHENKO04B	ISTR	–	DP
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●					
–0.5 ±0.7 ±1.5	550k	<sup>113,115</sup> AJINENKO	03C	ISTR	– DP
<sup>113</sup> Rescaled to agree with our conventions as noted above.					
<sup>114</sup> YUSHCHENKO 04B $\lambda'_+$ and $\lambda''_+$ are strongly correlated with coefficient $\rho(\lambda'_+, \lambda''_+) = -0.95$ .					
<sup>115</sup> Superseded by YUSHCHENKO 04B.					

**$|f_S/f_+|$  FOR  $K_{e3}^\pm$  DECAY**Ratio of scalar to  $f_+$  couplings.

<u>VALUE (units <math>10^{-2}</math>)</u>	<u>CL%</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>	<u>COMMENT</u>
<b>-0.3 <math>^{+0.8}_{-0.7}</math> OUR AVERAGE</b>						
-0.37 $^{+0.66}_{-0.56} \pm 0.41$		919k	YUSHCHENKO04B	ISTR	-	$\lambda'_+, \lambda''_+, f_S$ fit
0.2 $\pm 2.6 \pm 1.4$		41k	SHIMIZU	00	SPEC	+ $\lambda_+, f_S, f_T$ fit
• • • We do not use the following data for averages, fits, limits, etc. • • •						
0.2 $^{+2.0}_{-2.2} \pm 0.3$		550k	<sup>116</sup> AJINENKO	03C	ISTR	- $\lambda_+, f_S, f_T$ fit
-1.9 $^{+2.5}_{-1.6}$		130k	<sup>116</sup> AJINENKO	02	SPEC	$\lambda_+, f_S$ fit
7.0 $\pm 1.6 \pm 1.6$		32k	AKIMENKO	91	SPEC	$\lambda_+, f_S, f_T, \phi$ fit
0 $\pm 10$		2827	<sup>117</sup> BRAUN	75	HLBC	+
< 13	90	4017	CHIANG	72	OSPK	+
14 $^{+3}_{-4}$		2707	<sup>117</sup> STEINER	71	HLBC	+ $\lambda_+, f_S, f_T, \phi$ fit
< 23	90		BOTTERILL	68C	ASPK	
< 18	90		BELLOTTI	67B	HLBC	
< 30	95		KALMUS	67	HLBC	+

<sup>116</sup>Superseded by YUSHCHENKO 04B.<sup>117</sup>Statistical errors only. **$|f_T/f_+|$  FOR  $K_{e3}^\pm$  DECAY**Ratio of tensor to  $f_+$  couplings.

<u>VALUE (units <math>10^{-2}</math>)</u>	<u>CL%</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>	<u>COMMENT</u>
<b>= 1.2 <math>\pm 2.3</math> OUR AVERAGE</b>						
- 1.2 $\pm 2.1 \pm 1.1$		919k	YUSHCHENKO04B	ISTR	-	$\lambda'_+, \lambda''_+, f_T$ fit
1 $\pm 14 \pm 9$		41k	SHIMIZU	00	SPEC	+ $\lambda_+, f_S, f_T$ fit
• • • We do not use the following data for averages, fits, limits, etc. • • •						
2.1 $^{+6.4}_{-7.5} \pm 2.6$		550k	<sup>118</sup> AJINENKO	03C	ISTR	- $\lambda_+, f_S, f_T$ fit
- 4.5 $^{+6.0}_{-5.7}$		130k	<sup>118</sup> AJINENKO	02	SPEC	$\lambda_+, f_T$ fit
53 $^{+9}_{-10} \pm 10$		32k	AKIMENKO	91	SPEC	$\lambda_+, f_S, f_T, \phi$ fit
7 $\pm 37$		2827	<sup>119</sup> BRAUN	75	HLBC	+
< 75	90	4017	CHIANG	72	OSPK	+
24 $^{+16}_{-14}$		2707	<sup>119</sup> STEINER	71	HLBC	+ $\lambda_+, f_S, f_T, \phi$ fit
< 58	90		BOTTERILL	68C	ASPK	
< 58	90		BELLOTTI	67B	HLBC	
< 110	95		KALMUS	67	HLBC	+

<sup>118</sup>Superseded by YUSHCHENKO 04B.<sup>119</sup>Statistical errors only.

### $f_S/f_+$ FOR $K_{\mu 3}^{\pm}$ DECAY

Ratio of scalar to  $f_+$  couplings.

VALUE (units $10^{-2}$ )	EVTS	DOCUMENT ID	TECN	CHG	COMMENT
<b>0.17±0.14±0.54</b>	540k	<sup>120</sup> YUSHCHENKO04	ISTR	–	DP

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

0.4 ±0.5 ±0.5	112k	<sup>121</sup> AJINENKO	03	ISTR	–	DP
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<sup>120</sup> The second error is the theoretical error from the uncertainty in the chiral perturbation theory prediction for  $\lambda_0$ ,  $\pm 0.0053$ , combined in quadrature with the systematic error  $\pm 0.0009$ .

<sup>121</sup> The second error is the theoretical error from the uncertainty in the chiral perturbation theory prediction for  $\lambda_0$ . Superseded by YUSHCHENKO 04.

### $f_T/f_+$ FOR $K_{\mu 3}^{\pm}$ DECAY

Ratio of tensor to  $f_+$  couplings.

VALUE (units $10^{-2}$ )	EVTS	DOCUMENT ID	TECN	CHG	COMMENT
<b>–0.07± 0.71±0.20</b>	540k	YUSHCHENKO04	ISTR	–	DP

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

–2.1 ± 2.8 ±1.4	112k	<sup>122</sup> AJINENKO	03	ISTR	–	DP
2 ±12	1585	BRAUN	75	HLBC		

<sup>122</sup> The second error is the theoretical error from the uncertainty in the chiral perturbation theory prediction for  $\lambda_0$ . Superseded by YUSHCHENKO 04.

### DECAY FORM FACTORS FOR $K^{\pm} \rightarrow \pi^+ \pi^- e^{\pm} \nu_e$

Given in PISLAK 01, ROSSELET 77, BEIER 73, and BASILE 71C.

### DECAY FORM FACTOR FOR $K^{\pm} \rightarrow \pi^0 \pi^0 e^{\pm} \nu$

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

### $K^{\pm} \rightarrow \ell^{\pm} \nu \gamma$ FORM FACTORS

For definitions of the axial-vector  $F_A$  and vector  $F_V$  form factor, see the “Note on  $\pi^{\pm} \rightarrow \ell^{\pm} \nu \gamma$  and  $K^{\pm} \rightarrow \ell^{\pm} \nu \gamma$  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 $K \rightarrow e \nu_e \gamma$

VALUE	EVTS	DOCUMENT ID	TECN	
<b>0.148±0.010 OUR AVERAGE</b>				
0.147±0.011	51	<sup>123</sup> HEINTZE	79	SPEC
0.150 <sup>+0.018</sup> <sub>–0.023</sub>	56	<sup>124</sup> HEARD	75	SPEC

<sup>123</sup> HEINTZE 79 quotes absolute value of  $|F_A + F_V| \sin\theta_c$ . We use  $\sin\theta_c = V_{us} = 0.2205$ .

<sup>124</sup> 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 $K \rightarrow \mu\nu_\mu\gamma$

VALUE	CL%	EVTS	DOCUMENT ID	TECN	CHG
<b>0.165±0.007±0.011</b>		2588	125 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	125	AKIBA	85 SPEC	

<sup>125</sup> Quotes absolute value. Sign not determined.

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

VALUE	EVTS	DOCUMENT ID	TECN
<b>&lt;0.49</b>	90	126 HEINTZE	79 SPEC

<sup>126</sup> 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 $K \rightarrow \mu\nu_\mu\gamma$

VALUE	CL%	EVTS	DOCUMENT ID	TECN	CHG
<b>-0.24 to 0.04</b>	90	2588	ADLER	00B B787	+

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

-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
<b>0.560±0.031 OUR AVERAGE</b>		
0.580±0.040	AMENDOLIA 86B	$K e \rightarrow K e$
0.530±0.050	DALLY 80	$K e \rightarrow K e$
• • • We do not use the following data for averages, fits, limits, etc. • • •		
0.620±0.037	BLATNIK 79	VMD + dispersion relations

### CP VIOLATION TESTS IN $K^+$ AND $K^-$ DECAYS

$$\Delta(K^\pm_{\pi\mu\mu}) = \frac{\Gamma(K^+_{\pi\mu\mu}) - \Gamma(K^-_{\pi\mu\mu})}{\Gamma(K^+_{\pi\mu\mu}) + \Gamma(K^-_{\pi\mu\mu})}$$

VALUE	DOCUMENT ID	TECN
<b>-0.02±0.11±0.04</b>	PARK	02 HYCP

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

#### $P_T$ in $K^+ \rightarrow \pi^0 \mu^+ \nu_\mu$

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

VALUE (units $10^{-3}$ )	EVTS	DOCUMENT ID	TECN	CHG
<b>-1.7±2.3±1.1</b>	127	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	+
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<sup>127</sup> 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  $K^+ \rightarrow \mu^+ \nu_\mu \gamma$** 

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

VALUE (units $10^{-2}$ )	EVTS	DOCUMENT ID	TECN	CHG
<b><math>-0.64 \pm 1.85 \pm 0.10</math></b>	114k	<sup>128</sup> ANISIMOVSK..03	K246	+

<sup>128</sup> Muons stopped and polarization measured from decay to positrons.

 **$\text{Im}(\xi)$  in  $K^+ \rightarrow \pi^0 \mu^+ \nu_\mu$  DECAY (from transverse  $\mu$  pol.)**

Test of  $T$  reversal invariance.

VALUE	EVTS	DOCUMENT ID	TECN	CHG	COMMENT
<b><math>-0.006 \pm 0.008</math></b>					<b>OUR AVERAGE</b>

$-0.0053 \pm 0.0071 \pm 0.0036$		<sup>129</sup> ABE	04F K246	+	
$-0.016 \pm 0.025$	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
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<sup>129</sup> Includes three sets of data: 96-97 (ABE 99S), 98, and 99-00 totaling about three times the ABE 99S data sample. Corresponds to  $\text{Im}(\xi) < 0.016$  at 90% CL.

 **$K^\pm$  REFERENCES**

AMBROSINO 08	JHEP 0801 073	F. Ambrosino <i>et al.</i>	(KLOE Collab.)
AMBROSINO 08A	JHEP 0802 098	F. Ambrosino <i>et al.</i>	(KLOE Collab.)
BATLEY 08	PL B659 493	J.R. Batley <i>et al.</i>	(CERN NA48/2 Collab.)
AKIMENKO 07	PAN 70 702	S.A. Akimenko <i>et al.</i>	(ISTRA+ Collab.)
Translated from YAF 70 734.			
BATLEY 07A	EPJ C50 329	J.R. Batley <i>et al.</i>	(CERN NA48/2 Collab.)
Also	EPJ C52 1021 (erratum)	J.R. Batley <i>et al.</i>	(CERN NA48/2 Collab.)
BATLEY 07B	PL B649 349	J.R. Batley <i>et al.</i>	(CERN NA48/2 Collab.)
BATLEY 07E	EPJ C52 875	J.R. Batley <i>et al.</i>	(CERN NA48/2 Collab.)
TCHIKILEV 07	PAN 70 29	O.G. Tchikilev <i>et al.</i>	(ISTRA+ Collab.)
ALIEV 06	EPJ C46 61	M.A. Aliev <i>et al.</i>	(KEK E470 Collab.)
AMBROSINO 06A	PL B632 76	F. Ambrosino <i>et al.</i>	(KLOE Collab.)
BATLEY 06	PL B634 474	J.R. Batley <i>et al.</i>	(CERN NA48/2 Collab.)
BATLEY 06A	PL B638 22	J.R. Batley <i>et al.</i>	(CERN NA48/2 Collab.)
Also	PL B640 297 (erratum)	J.R. Batley <i>et al.</i>	(CERN NA48/2 Collab.)
BATLEY 06B	PL B633 173	J.R. Batley <i>et al.</i>	(CERN NA48/2 Collab.)
MA 06	PR D73 037101	H. Ma <i>et al.</i>	(BNL E865 Collab.)
PDG 06	JPG 33 1	W.-M. Yao <i>et al.</i>	(PDG Collab.)
SHIMIZU 06	PL B633 190	S. Shimizu <i>et al.</i>	(KEK E470 Collab.)
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AKOPDZHAN...05	EPJ C40 343	G.A. Akopdzhanov <i>et al.</i>	(IHEP)
Also	PAN 68 948	G.A. Akopdzhanov <i>et al.</i>	(IHEP)
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AKOPDZHAN...05B	JETPL 82 675	G.A. Akopdzhanov <i>et al.</i>	(IHEP)
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CABIBBO 05	JHEP 0503 021	N. Cabibbo, G. Isidori	(CERN, ROMA1, FRAS)
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ABE 04F	PRL 93 131601	M. Abe <i>et al.</i>	(KEK E246 Collab.)
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ADLER 04	PR D70 037102	S. Adler <i>et al.</i>	(BNL E787 Collab.)
ALOISIO 04A	PL B597 139	A. Aloisio <i>et al.</i>	(KLOE Collab.)
ANDRE 04	hep-ph/0406006	T. Andre	(EFI)
ANISIMOVSK...04	PRL 93 031801	V.V. Anisimovsky <i>et al.</i>	(BNL E949 Collab.)
CABIBBO 04A	PRL 93 121801	N. Cabibbo	(CERN, ROMA1)
CIRIGLIANO 04	EPJ C35 53	V. Cirigliano, H. Neufeld, H. Pichl	(CIT, VALE+)
PDG 04	PL B592 1	S. Eidelman <i>et al.</i>	
SHIMIZU 04	PR D70 037101	S. Shimizu <i>et al.</i>	(KEK E470 Collab.)
YUSHCHENKO 04	PL B581 31	O.P. Yushchenko <i>et al.</i>	(INRM, INRM)
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AJINENKO	03B	PL B567 159	I.V. Ajinenko <i>et al.</i>	(IHEP, INRM)
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ALIEV	03	PL B554 7	M.A. Aliev <i>et al.</i>	(KEK E470 Collab.)
ANISIMOVSK...	03	PL B562 166	V.V. Anisimovsky <i>et al.</i>	
PISLAK	03	PR D67 072004	S. Pislak <i>et al.</i>	(BNL E865 Collab.)
SHER	03	PRL 91 261802	A. Sher <i>et al.</i>	(BNL E865 Collab.)
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PISLAK	01	PRL 87 221801	S. Pislak <i>et al.</i>	(BNL E865 Collab.)
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APPEL	00	PRL 85 2450	R. Appel <i>et al.</i>	(BNL 865 Collab.)
Also		Thesis, Yale Univ.	D.R. Bergman	
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PDG	00	EPJ C15 1	D.E. Groom <i>et al.</i>	
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BATUSOV	98	NP B516 3	V.Y. Batusov <i>et al.</i>	
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BERGMAN	97	Thesis, Yale Univ.	D.R. Bergman	
KITCHING	97	PRL 79 4079	P. Kitching <i>et al.</i>	(BNL E787 Collab.)
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ADLER	96	PRL 76 1421	S. Adler <i>et al.</i>	(BNL E787 Collab.)
KOPTEV	95	JETPL 61 877	V.P. Koptev <i>et al.</i>	(PNPI)
		Translated from ZETFP 61 865.		
AOKI	94	PR D50 69	M. Aoki <i>et al.</i>	(INUS, KEK, TOKMS)
ATIYA	93	PRL 70 2521	M.S. Atiya <i>et al.</i>	(BNL E787 Collab.)
Also		PRL 71 305 (erratum)	M.S. Atiya <i>et al.</i>	(BNL E787 Collab.)
ATIYA	93B	PR D48 R1	M.S. Atiya <i>et al.</i>	(BNL E787 Collab.)
ALLIEGRO	92	PRL 68 278	C. Alliegro <i>et al.</i>	(BNL, FNAL, PSI+)
BARMIN	92	SJNP 55 547	V.V. Barmin <i>et al.</i>	(ITEP)
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IMAZATO	92	PRL 69 877	J. Imazato <i>et al.</i>	(KEK, INUS, TOKY+)
IVANOV	92	THESIS	Yu.M. Ivanov	(PNPI)
LITTENBERG	92	PRL 68 443	L.S. Littenberg, R.E. Shrock	(BNL, STON)
USHER	92	PR D45 3961	T. Usher <i>et al.</i>	(UCI)
AKIMENKO	91	PL B259 225	S.A. Akimenko <i>et al.</i>	(SERP, JINR, TBIL+)
BARMIN	91	SJNP 53 606	V.V. Barmin <i>et al.</i>	(ITEP)
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DENISOV	91	JETPL 54 558	A.S. Denisov <i>et al.</i>	(PNPI)
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ATIYA	90	PRL 64 21	M.S. Atiya <i>et al.</i>	(BNL E787 Collab.)
ATIYA	90B	PRL 65 1188	M.S. Atiya <i>et al.</i>	(BNL E787 Collab.)
DEMIDOV	90	SJNP 52 1006	V.S. Demidov <i>et al.</i>	(ITEP)
		Translated from YAF 52 1595.		
LEE	90	PRL 64 165	A.M. Lee <i>et al.</i>	(BNL, FNAL, VILL, WASH+)
ATIYA	89	PRL 63 2177	M.S. Atiya <i>et al.</i>	(BNL E787 Collab.)
BARMIN	89	SJNP 50 421	V.V. Barmin <i>et al.</i>	(ITEP)
		Translated from YAF 50 679.		
BARMIN	88	SJNP 47 643	V.V. Barmin <i>et al.</i>	(ITEP)
		Translated from YAF 47 1011.		
BARMIN	88B	SJNP 48 1032	V.V. Barmin <i>et al.</i>	(ITEP)
		Translated from YAF 48 1719.		
BOLOTOV	88	JETPL 47 7	V.N. Bolotov <i>et al.</i>	(ASCI)
		Translated from ZETFP 47 8.		

GALL	88	PRL 60 186	K.P. Gall <i>et al.</i>	(BOST, MIT, WILL, CIT+)
BARMIN	87	SJNP 45 62	V.V. Barmin <i>et al.</i>	(ITEP)
		Translated from YAF 45 97.		
BOLOTOV	87	SJNP 45 1023	V.N. Bolotov <i>et al.</i>	(INRM)
		Translated from YAF 45 1652.		
AMENDOLIA	86B	PL B178 435	S.R. Amendolia <i>et al.</i>	(CERN NA7 Collab.)
BOLOTOV	86	SJNP 44 73	V.N. Bolotov <i>et al.</i>	(INRM)
		Translated from YAF 44 117.		
BOLOTOV	86B	SJNP 44 68	V.N. Bolotov <i>et al.</i>	(INRM)
		Translated from YAF 44 108.		
YAMANAKA	86	PR D34 85	T. Yamanaka <i>et al.</i>	(KEK, TOKY)
Also		PRL 52 329	R.S. Hayano <i>et al.</i>	(TOKY, KEK)
AKIBA	85	PR D32 2911	Y. Akiba <i>et al.</i>	(TOKY, TINT, TSUK, KEK)
BOLOTOV	85	JETPL 42 481	V.N. Bolotov <i>et al.</i>	(INRM)
		Translated from ZETFP 42 390.		
ASANO	82	PL 113B 195	Y. Asano <i>et al.</i>	(KEK, TOKY, INUS, OSAK)
COOPER	82	PL 112B 97	A.M. Cooper <i>et al.</i>	(RL)
PDG	82B	PL 111B 70	M. Roos <i>et al.</i>	(HELS, CIT, CERN)
ASANO	81B	PL 107B 159	Y. Asano <i>et al.</i>	(KEK, TOKY, INUS, OSAK)
CAMPBELL	81	PRL 47 1032	M.K. Campbell <i>et al.</i>	(YALE, BNL)
Also		PR D27 1056	S.R. Blatt <i>et al.</i>	(YALE, BNL)
LUM	81	PR D23 2522	G.K. Lum <i>et al.</i>	(LBL, NBS+)
LYONS	81	ZPHY C10 215	L. Lyons, C. Albajar, G. Myatt	(OXF)
DALLY	80	PRL 45 232	E.B. Dally <i>et al.</i>	(UCLA+)
BARKOV	79	NP B148 53	L.M. Barkov <i>et al.</i>	(NOVO, KIAE)
BLATNIK	79	LNC 24 39	S. Blatnik, J. Stahov, C.B. Lang	(TUZL, GRAZ)
HEINTZE	79	NP B149 365	J. Heintze <i>et al.</i>	(HEIDP, CERN)
ABRAMS	77	PR D15 22	R.J. Abrams <i>et al.</i>	(BNL)
DEVAUX	77	NP B126 11	B. Devaux <i>et al.</i>	(SACL, GEVA)
HEINTZE	77	PL 70B 482	J. Heintze <i>et al.</i>	(HEIDP, CERN)
ROSSELET	77	PR D15 574	L. Rosselet <i>et al.</i>	(GEVA, SACL)
BLOCH	76	PL 60B 393	P. Bloch <i>et al.</i>	(GEVA, SACL)
BRAUN	76B	LNC 17 521	H.M. Braun <i>et al.</i>	(AACH3, BARI, BELG+)
DIAMANT-...	76	PL 62B 485	A.M. Diamant-Berger <i>et al.</i>	(SACL, GEVA)
HEINTZE	76	PL 60B 302	J. Heintze <i>et al.</i>	(HEIDP)
SMITH	76	NP B109 173	K.M. Smith <i>et al.</i>	(GLAS, LIVP, OXF+)
WEISSENBE...	76	NP B115 55	A.O. Weissenberg <i>et al.</i>	(ITEP, LEBD)
BLOCH	75	PL 56B 201	P. Bloch <i>et al.</i>	(SACL, GEVA)
BRAUN	75	NP B89 210	H.M. Braun <i>et al.</i>	(AACH3, BARI, BRUX+)
CHENG	75	NP A254 381	S.C. Cheng <i>et al.</i>	(COLU, YALE)
HEARD	75	PL 55B 324	K.S. Heard <i>et al.</i>	(CERN, HEIDH)
HEARD	75B	PL 55B 327	K.S. Heard <i>et al.</i>	(CERN, HEIDH)
SHEAFF	75	PR D12 2570	M. Sheaff	(WISC)
SMITH	75	NP B91 45	K.M. Smith <i>et al.</i>	(GLAS, LIVP, OXF+)
WEISSENBE...	74	PL 48B 474	A.O. Weissenberg <i>et al.</i>	(ITEP, LEBD)
ABRAMS	73B	PRL 30 500	R.J. Abrams <i>et al.</i>	(BNL)
BACKENSTO...	73	PL 43B 431	G. Backenstoss <i>et al.</i>	(CERN, KARLK, KARLE+)
BEIER	73	PRL 30 399	E.W. Beier <i>et al.</i>	(PENN)
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 <i>et al.</i>	(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 <i>et al.</i>	(EFI, ARIZ, LBL)
Also		PL 40B 699	G.D. Cable <i>et al.</i>	(EFI, LBL)
SMITH	73	NP B60 411	K.M. Smith <i>et al.</i>	(GLAS, LIVP, OXF+)
ABRAMS	72	PRL 29 1118	R.J. Abrams <i>et al.</i>	(BNL)
AUBERT	72	NC 12A 509	B. Aubert <i>et al.</i>	(ORSAY, BRUX, EPOL)
CHIANG	72	PR D6 1254	I.H. Chiang <i>et al.</i>	(ROCH, WISC)
CLARK	72	PRL 29 1274	A.R. Clark <i>et al.</i>	(LBL)
EDWARDS	72	PR D5 2720	R.T. Edwards <i>et al.</i>	(ILL)
FORD	72	PL 38B 335	W.T. Ford <i>et al.</i>	(PRIN)
HOFFMASTER	72	NP B36 1	S. Hoffmaster <i>et al.</i>	(STEV, SETO, LEHI)
BASILE	71C	PL 36B 619	P. Basile <i>et al.</i>	(SACL, GEVA)
BOURQUIN	71	PL 36B 615	M.H. Bourquin <i>et al.</i>	(GEVA, SACL)
HAIDT	71	PR D3 10	D. Haidt	(AACH, BARI, CERN, EPOL, NIJM+)
Also		PL 29B 691	D. Haidt <i>et al.</i>	(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 <i>et al.</i>	(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 <i>et al.</i>	(PRIN)
GAILLARD	70	CERN 70-14	J.M. Gaillard, L.M. Chounet	(CERN, ORSAY)
GRAUMAN	70	PR D1 1277	J. Grauman <i>et al.</i>	(STEV, SETO, LEHI)
Also		PRL 23 737	J.U. Grauman <i>et al.</i>	(STEV, SETO, LEHI)
MACEK	70	PR D1 1249	R.J. Macek <i>et al.</i>	(PENN)
MALTSEV	70	SJNP 10 678	E.I. Maltsev <i>et al.</i>	(JINR)
PANDOULAS	70	PR D2 1205	D. Pandoulas <i>et al.</i>	(STEV, SETO)
CUTTS	69	PR 184 1380	D. Cutts <i>et al.</i>	(LRL, MIT)
Also		PRL 20 955	D. Cutts <i>et al.</i>	(LRL, MIT)
DAVISON	69	PR 180 1333	D.C. Davison <i>et al.</i>	(UCR)
ELY	69	PR 180 1319	R.P.J. Ely <i>et al.</i>	(LOUC, WISC, LRL)
EMMERSON	69	PRL 23 393	J.M.L. Emmerson, T.W. Quirk	(OXF)
HERZO	69	PR 186 1403	D. Herzo <i>et al.</i>	(ILL)
LOBKOWICZ	69	PR 185 1676	F. Lobkowicz <i>et al.</i>	(ROCH, BNL)
Also		PRL 17 548	F. Lobkowicz <i>et al.</i>	(ROCH, BNL)
MAST	69	PR 183 1200	T.S. Mast <i>et al.</i>	(LRL)
SELLERI	69	NC 60A 291	F. Selleri	
ZELLER	69	PR 182 1420	M.E. Zeller <i>et al.</i>	(UCLA, LRL)
BOTTERILL	68B	PRL 21 766	D.R. Botterill <i>et al.</i>	(OXF)
BOTTERILL	68C	PR 174 1661	D.R. Botterill <i>et al.</i>	(OXF)
BUTLER	68	UCRL 18420	W.D. Butler <i>et al.</i>	(LRL)
CHANG	68	PRL 20 510	C.Y. Chang <i>et al.</i>	(UMD, RUTG)
CHEN	68	PRL 20 73	M. Chen <i>et al.</i>	(LRL, MIT)
EICHTEN	68	PL 27B 586	T. Eichten	(AACH, BARI, CERN, EPOL, ORSAY+)
ESCHSTRUTH	68	PR 165 1487	P.T. Eschstruth <i>et al.</i>	(PRIN, PENN)
GARLAND	68	PR 167 1225	R. Garland <i>et al.</i>	(COLU, RUTG, WISC)
MOSCOSO	68	Thesis	L. Moscoso	(ORSAY)
AUERBACH	67	PR 155 1505	L.B. Auerbach <i>et al.</i>	(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)
Also		PL 20 690	E. Bellotti <i>et al.</i>	(MILA)
BISI	67	PL 25B 572	V. Bisi <i>et al.</i>	(TORI)
FLETCHER	67	PRL 19 98	C.R. Fletcher <i>et al.</i>	(ILL)
FORD	67	PRL 18 1214	W.T. Ford <i>et al.</i>	(PRIN)
GINSBERG	67	PR 162 1570	E.S. Ginsberg	(MASB)
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 <i>et al.</i>	(WISC, LRL, UCR+)
CESTER	66	PL 21 343	R. Cester <i>et al.</i>	(PPA)
See footnote 1 in		AUERBACH 67.		
Also		PR 155 1505	L.B. Auerbach <i>et al.</i>	(PENN, PRIN)
BIRGE	65	PR 139 B1600	R.W. Birge <i>et al.</i>	(LRL, WISC)
BISI	65	NC 35 768	V. Bisi <i>et al.</i>	(TORI)
BISI	65B	PR 139 B1068	V. Bisi <i>et al.</i>	(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 140B 1430	A. de Marco, C. Grosso, G. Rinaudo	(TORI, CERN)
FITCH	65B	PR 140B 1088	V.L. Fitch, C.A. Quarles, H.C. Wilkins	(PRIN+)
STAMER	65	PR 138 B440	P. Stamer <i>et al.</i>	(STEV)
YOUNG	65	Thesis UCRL 16362	P.S. Young	(LRL)
Also		PR 156 1464	P.S. Young, W.Z. Osborne, W.H. Barkas	(LRL)
BORREANI	64	PL 12 123	G. Borreani, G. Rinaudo, A.E. Werbroeck	(TORI)
CALLAHAN	64	PR 136 B1463	A. Callahan, R. March, R. Stark	(WISC)
CLINE	64	PRL 13 101	D. Cline, W.F. Fry	(WISC)
GREINER	64	PRL 13 284	D.E. Greiner, W.Z. Osborne, W.H. Barkas	(LRL)
SHAKLEE	64	PR 136 B1423	F.S. Shaklee <i>et al.</i>	(MICH)
BOYARSKI	62	PR 128 2398	A.M. Boyarski <i>et al.</i>	(MIT)
FERRO-LUZZI	61	NC 22 1087	M. Ferro-Luzzi <i>et al.</i>	(LRL)
ROE	61	PRL 7 346	B.P. Roe <i>et al.</i>	(MICH, LRL)

TAYLOR	59	PR 114 359	S. Taylor <i>et al.</i>	(COLU)
COOMBES	57	PR 108 1348	C.A. Coombes <i>et al.</i>	(LBL)

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		"Rare K Decays"		
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		Status and Perspectives of K Decay Physics		
BRYMAN	89	IJMP A4 79	D.A. Bryman	(TRIU)
		"Rare Kaon Decays"		
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FEARING	70	PR D2 542	H.W. Fearing, E. Fischbach, J. Smith	(STON, BOHR)
HAIDT	69B	PL 29B 696	D. Haidt <i>et al.</i>	(AACH, BARI, CERN, EPOL+)
CRONIN	68B	Vienna Conf. 241	J.W. Cronin	(PRIN)
		Rapporteur talk.		
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)
		Also PL 14 72	N. Cabibbo, A. Maksymowicz	(CERN)
BIRGE	63	PRL 11 35	R.W. Birge <i>et al.</i>	(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)