



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

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### $K^\pm$ MASS

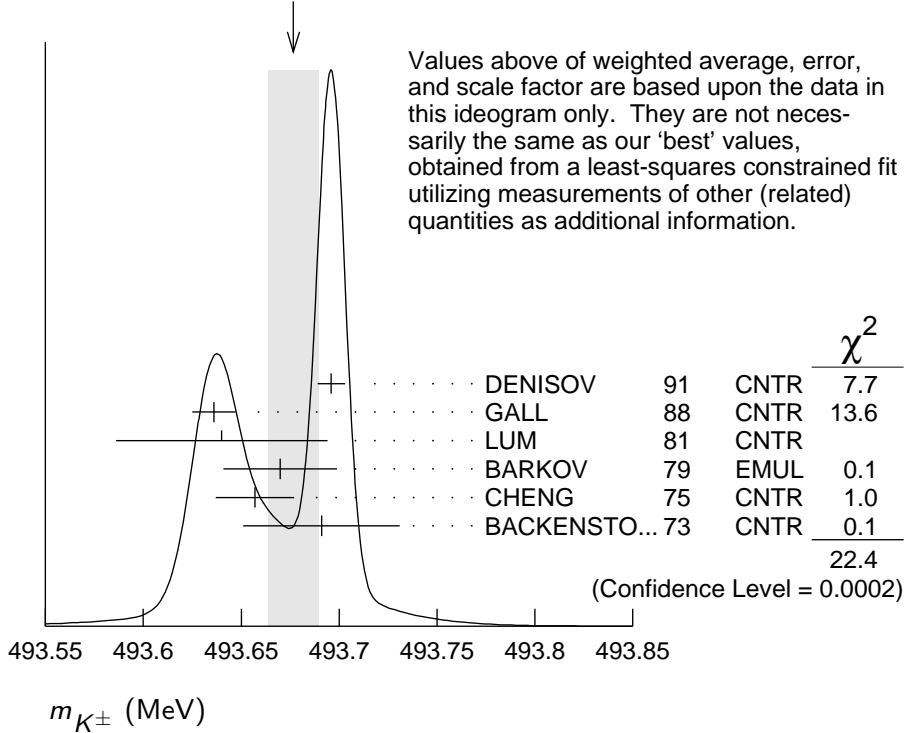
<u>VALUE (MeV)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>	<u>COMMENT</u>
<b>493.677±0.016 OUR FIT</b>	Error includes scale factor of 2.8.			
<b>493.677±0.013 OUR AVERAGE</b>	Error includes scale factor of 2.4. See the ideogram below.			
493.696±0.007	<sup>1</sup> DENISOV	91	CNTR –	Kaonic atoms
493.636±0.011	<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	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*.

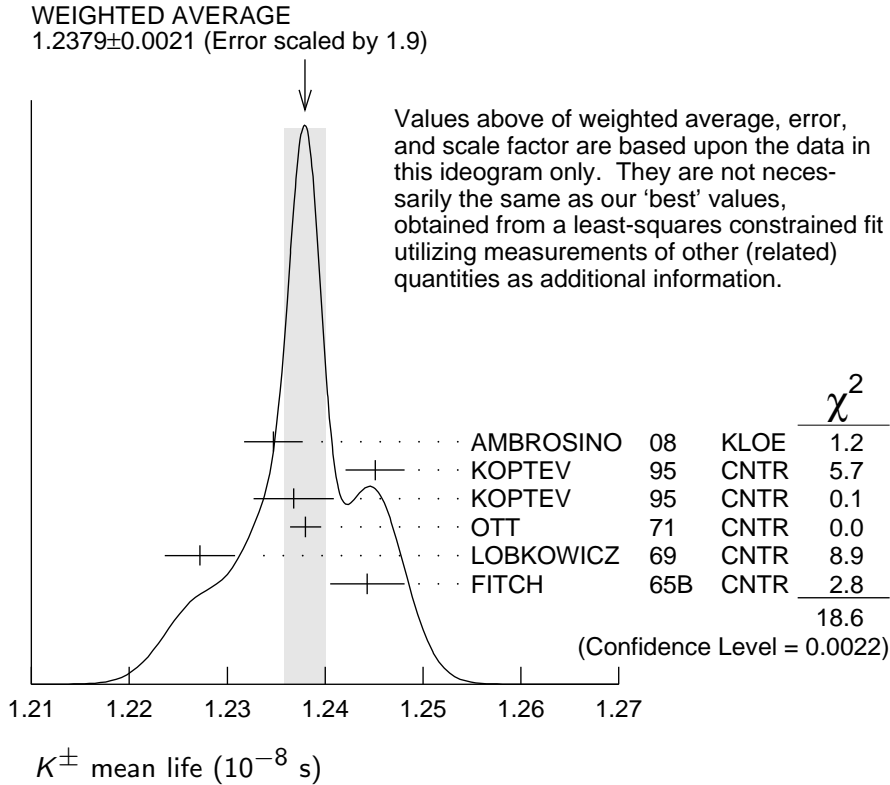
VALUE (MeV)	EVTS	DOCUMENT ID	TECN	CHG
<b><math>-0.032 \pm 0.090</math></b>	1.5M	<sup>4</sup> FORD	72	ASPK ±

<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 0.0020</math></b>	<b>OUR FIT</b>	Error includes scale factor of 1.8.			
<b><math>1.2379 \pm 0.0021</math></b>	<b>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.

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

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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
<b>Leptonic and semileptonic modes</b>		
$\Gamma_1$ $e^+ \nu_e$	( $1.582 \pm 0.007$ ) $\times 10^{-5}$	
$\Gamma_2$ $\mu^+ \nu_\mu$	( $63.56 \pm 0.11$ ) %	S=1.2
$\Gamma_3$ $\pi^0 e^+ \nu_e$	( $5.07 \pm 0.04$ ) %	S=2.1
Called $K_{e3}^+$ .		
$\Gamma_4$ $\pi^0 \mu^+ \nu_\mu$	( $3.352 \pm 0.033$ ) %	S=1.9
Called $K_{\mu 3}^+$ .		
$\Gamma_5$ $\pi^0 \pi^0 e^+ \nu_e$	( $2.55 \pm 0.04$ ) $\times 10^{-5}$	S=1.1
$\Gamma_6$ $\pi^+ \pi^- e^+ \nu_e$	( $4.247 \pm 0.024$ ) $\times 10^{-5}$	
$\Gamma_7$ $\pi^+ \pi^- \mu^+ \nu_\mu$	( $1.4 \pm 0.9$ ) $\times 10^{-5}$	
$\Gamma_8$ $\pi^0 \pi^0 \pi^0 e^+ \nu_e$	$< 3.5 \times 10^{-6}$	CL=90%
<b>Hadronic modes</b>		
$\Gamma_9$ $\pi^+ \pi^0$	( $20.67 \pm 0.08$ ) %	S=1.2
$\Gamma_{10}$ $\pi^+ \pi^0 \pi^0$	( $1.760 \pm 0.023$ ) %	S=1.1
$\Gamma_{11}$ $\pi^+ \pi^+ \pi^-$	( $5.583 \pm 0.024$ ) %	
<b>Leptonic and semileptonic modes with photons</b>		
$\Gamma_{12}$ $\mu^+ \nu_\mu \gamma$	[a,b] ( $6.2 \pm 0.8$ ) $\times 10^{-3}$	
$\Gamma_{13}$ $\mu^+ \nu_\mu \gamma(\text{SD}^+)$	[c,d] ( $1.33 \pm 0.22$ ) $\times 10^{-5}$	
$\Gamma_{14}$ $\mu^+ \nu_\mu \gamma(\text{SD}^+\text{INT})$	[c,d] $< 2.7 \times 10^{-5}$	CL=90%
$\Gamma_{15}$ $\mu^+ \nu_\mu \gamma(\text{SD}^- + \text{SD}^-\text{INT})$	[c,d] $< 2.6 \times 10^{-4}$	CL=90%
$\Gamma_{16}$ $e^+ \nu_e \gamma$	( $9.4 \pm 0.4$ ) $\times 10^{-6}$	
$\Gamma_{17}$ $\pi^0 e^+ \nu_e \gamma$	[a,b] ( $2.56 \pm 0.16$ ) $\times 10^{-4}$	
$\Gamma_{18}$ $\pi^0 e^+ \nu_e \gamma(\text{SD})$	[c,d] $< 5.3 \times 10^{-5}$	CL=90%
$\Gamma_{19}$ $\pi^0 \mu^+ \nu_\mu \gamma$	[a,b] ( $1.25 \pm 0.25$ ) $\times 10^{-5}$	
$\Gamma_{20}$ $\pi^0 \pi^0 e^+ \nu_e \gamma$	$< 5 \times 10^{-6}$	CL=90%
<b>Hadronic modes with photons or <math>\ell\bar{\ell}</math> pairs</b>		
$\Gamma_{21}$ $\pi^+ \pi^0 \gamma(\text{INT})$	( $-4.2 \pm 0.9$ ) $\times 10^{-6}$	
$\Gamma_{22}$ $\pi^+ \pi^0 \gamma(\text{DE})$	[a,e] ( $6.0 \pm 0.4$ ) $\times 10^{-6}$	
$\Gamma_{23}$ $\pi^+ \pi^0 \pi^0 \gamma$	[a,b] ( $7.6 \begin{smallmatrix} +6.0 \\ -3.0 \end{smallmatrix}$ ) $\times 10^{-6}$	
$\Gamma_{24}$ $\pi^+ \pi^+ \pi^- \gamma$	[a,b] ( $1.04 \pm 0.31$ ) $\times 10^{-4}$	
$\Gamma_{25}$ $\pi^+ \gamma \gamma$	[a] ( $1.01 \pm 0.06$ ) $\times 10^{-6}$	
$\Gamma_{26}$ $\pi^+ 3\gamma$	[a] $< 1.0 \times 10^{-4}$	CL=90%
$\Gamma_{27}$ $\pi^+ e^+ e^- \gamma$	( $1.19 \pm 0.13$ ) $\times 10^{-8}$	

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

$\Gamma_{28}$	$e^+ \nu_e \nu \bar{\nu}$		< 6	$\times 10^{-5}$	CL=90%
$\Gamma_{29}$	$\mu^+ \nu_\mu \nu \bar{\nu}$		< 6.0	$\times 10^{-6}$	CL=90%
$\Gamma_{30}$	$e^+ \nu_e e^+ e^-$		( 2.48 $\pm$ 0.20 )	$\times 10^{-8}$	
$\Gamma_{31}$	$\mu^+ \nu_\mu e^+ e^-$		( 7.06 $\pm$ 0.31 )	$\times 10^{-8}$	
$\Gamma_{32}$	$e^+ \nu_e \mu^+ \mu^-$		( 1.7 $\pm$ 0.5 )	$\times 10^{-8}$	
$\Gamma_{33}$	$\mu^+ \nu_\mu \mu^+ \mu^-$		< 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**

$\Gamma_{34}$	$\pi^+ \pi^+ e^- \bar{\nu}_e$	$SQ$	< 1.3	$\times 10^{-8}$	CL=90%
$\Gamma_{35}$	$\pi^+ \pi^+ \mu^- \bar{\nu}_\mu$	$SQ$	< 3.0	$\times 10^{-6}$	CL=95%
$\Gamma_{36}$	$\pi^+ e^+ e^-$	$S1$	( 3.00 $\pm$ 0.09 )	$\times 10^{-7}$	
$\Gamma_{37}$	$\pi^+ \mu^+ \mu^-$	$S1$	( 9.4 $\pm$ 0.6 )	$\times 10^{-8}$	S=2.6
$\Gamma_{38}$	$\pi^+ \nu \bar{\nu}$	$S1$	( 1.7 $\pm$ 1.1 )	$\times 10^{-10}$	
$\Gamma_{39}$	$\pi^+ \pi^0 \nu \bar{\nu}$	$S1$	< 4.3	$\times 10^{-5}$	CL=90%
$\Gamma_{40}$	$\mu^- \nu e^+ e^+$	$LF$	< 2.1	$\times 10^{-8}$	CL=90%
$\Gamma_{41}$	$\mu^+ \nu_e$	$LF$ [f]	< 4	$\times 10^{-3}$	CL=90%
$\Gamma_{42}$	$\pi^+ \mu^+ e^-$	$LF$	< 1.3	$\times 10^{-11}$	CL=90%
$\Gamma_{43}$	$\pi^+ \mu^- e^+$	$LF$	< 5.2	$\times 10^{-10}$	CL=90%
$\Gamma_{44}$	$\pi^- \mu^+ e^+$	$L$	< 5.0	$\times 10^{-10}$	CL=90%
$\Gamma_{45}$	$\pi^- e^+ e^+$	$L$	< 6.4	$\times 10^{-10}$	CL=90%
$\Gamma_{46}$	$\pi^- \mu^+ \mu^+$	$L$ [f]	< 1.1	$\times 10^{-9}$	CL=90%
$\Gamma_{47}$	$\mu^+ \bar{\nu}_e$	$L$ [f]	< 3.3	$\times 10^{-3}$	CL=90%
$\Gamma_{48}$	$\pi^0 e^+ \bar{\nu}_e$	$L$	< 3	$\times 10^{-3}$	CL=90%
$\Gamma_{49}$	$\pi^+ \gamma$	[g]	< 2.3	$\times 10^{-9}$	CL=90%

- [a] See the Particle Listings below for the energy limits used in this measurement.
- [b] Most of this radiative mode, the low-momentum  $\gamma$  part, is also included in the parent mode listed without  $\gamma$ 's.
- [c] Structure-dependent part.
- [d] 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.
- [e] Direct-emission branching fraction.
- [f] Derived from an analysis of neutrino-oscillation experiments.
- [g] Violates angular-momentum conservation.

### CONSTRAINED FIT INFORMATION

An overall fit to the mean life, a decay rate, and 15 branching ratios uses 35 measurements and one constraint to determine 8 parameters. The overall fit has a  $\chi^2 = 53.4$  for 28 degrees of freedom.

The following *off-diagonal* array elements are the correlation coefficients  $\langle \delta p_i \delta p_j \rangle / (\delta p_i \cdot \delta p_j)$ , 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.

$x_3$	-66						
$x_4$	-64	90					
$x_5$	-12	-5	-5				
$x_9$	-67	0	-1	-6			
$x_{10}$	-13	-6	-5	91	-6		
$x_{11}$	-14	-6	-6	2	-7	2	
$\Gamma$	3	1	1	0	2	0	-24
	$x_2$	$x_3$	$x_4$	$x_5$	$x_9$	$x_{10}$	$x_{11}$

	Mode	Rate ( $10^8 \text{ s}^{-1}$ )	Scale factor
$\Gamma_2$	$\mu^+ \nu_\mu$	$0.5134 \pm 0.0012$	1.5
$\Gamma_3$	$\pi^0 e^+ \nu_e$ Called $K_{e3}^+$	$0.0410 \pm 0.0004$	2.1
$\Gamma_4$	$\pi^0 \mu^+ \nu_\mu$ Called $K_{\mu 3}^+$	$0.02707 \pm 0.00027$	1.9
$\Gamma_5$	$\pi^0 \pi^0 e^+ \nu_e$	$(2.059 \pm 0.029) \times 10^{-5}$	1.1
$\Gamma_9$	$\pi^+ \pi^0$	$0.1670 \pm 0.0007$	1.3
$\Gamma_{10}$	$\pi^+ \pi^0 \pi^0$	$0.01421 \pm 0.00018$	1.1
$\Gamma_{11}$	$\pi^+ \pi^+ \pi^-$	$0.04510 \pm 0.00019$	

### $K^\pm$ DECAY RATES

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

$\Gamma_2$

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

**51.34 ± 0.12 OUR FIT** Error includes scale factor of 1.5.

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

51.2 ± 0.8                      FORD            67    CNTR    ±

$\Gamma(\pi^+\pi^+\pi^-)$

$\Gamma_{11}$

<u>VALUE</u> ( $10^6 \text{ s}^{-1}$ )	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>
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**4.510 ± 0.019 OUR FIT**

**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    ASPK

4.496 ± 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/AVERAGE

Test of *CPT* conservation.

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

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

Test of *CP* conservation.

<u>VALUE</u> (%)	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>
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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/AVERAGE

Test of *CP* conservation.

<u>VALUE</u> (%)	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>
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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/AVERAGE

Test of *CPT* conservation.

<u>VALUE</u> (%)	<u>DOCUMENT ID</u>	<u>TECN</u>
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**0.8 ± 1.2**                      HERZO                      69    OSPK

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

Test of *CP* conservation.

<u>VALUE</u> (%)	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>	<u>COMMENT</u>
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**0.9 ± 3.3 OUR AVERAGE**

0.8 ± 5.8                      2461                      SMITH                      76    WIRE ±                       $E_\pi$  55–90 MeV

1.0 ± 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>2.488 ± 0.009 OUR AVERAGE</b>				
2.488 ± 0.007 ± 0.007	150k	<sup>10</sup> LAZZERONI	13 NA62	±
2.493 ± 0.025 ± 0.019	13.8K	<sup>11</sup> AMBROSINO	09E KLOE	±
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●				
2.487 ± 0.011 ± 0.007	60k	<sup>12</sup> LAZZERONI	11 NA62	+
2.51 ± 0.15	404	HEINTZE	76 SPEC	+
2.37 ± 0.17	534	HEARD	75B SPEC	+
2.42 ± 0.42	112	CLARK	72 OSPK	+

<sup>10</sup> LAZZERONI 13 uses full data sample collected from 2007 to 2008. This ratio is defined to be fully inclusive, including internal-bremsstrahlung.

<sup>11</sup> The ratio is defined to include internal-bremsstrahlung, ignoring direct-emission contributions. AMBROSINO 09E determined the ratio from the measurement of  $\Gamma(K \rightarrow e\nu(\gamma), E_\gamma < 10 \text{ MeV}) / \Gamma(K \rightarrow \mu\nu(\gamma))$ . 89.8% of  $K \rightarrow e\nu(\gamma)$  events had  $E_\gamma < 10 \text{ MeV}$ .

<sup>12</sup> This ratio is defined to be fully inclusive, including internal-bremsstrahlung.

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

$$\Gamma_2 / \Gamma$$

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>63.56 ± 0.11 OUR FIT</b>					Error includes scale factor of 1.2.
<b>63.60 ± 0.16 OUR AVERAGE</b>					
63.66 ± 0.09 ± 0.15	865k	<sup>13</sup> AMBROSINO	06A KLOE	+	
63.24 ± 0.44	62k	CHIANG	72 OSPK	+	1.84 GeV/c $K^+$

<sup>13</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>5.07 ± 0.04 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>14</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>14</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>0.0798±0.0008 OUR FIT</b>				

Error includes scale factor of 1.9.

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

0.069 ±0.006	350	ZELLER	69	ASPK	+
0.0775±0.0033	960	BOTTERILL	68C	ASPK	+
0.069 ±0.006	561	GARLAND	68	OSPK	+
0.0791±0.0054	295	<sup>15</sup> AUERBACH	67	OSPK	+

<sup>15</sup>AUERBACH 67 changed from 0.0797 ± 0.0054. See comment with ratio  $\Gamma(\pi^0 \mu^+ \nu_\mu)/\Gamma(\mu^+ \nu_\mu)$ . The value 0.0785 ± 0.0025 given in AUERBACH 67 is an average of AUERBACH 67  $\Gamma(\pi^0 e^+ \nu_e)/\Gamma(\mu^+ \nu_\mu)$  and CESTER 66  $\Gamma(\pi^0 e^+ \nu_e)/[\Gamma(\mu^+ \nu_\mu) + \Gamma(\pi^+ \pi^0)]$ .

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

<u>VALUE (units 10<sup>-2</sup>)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>
<b>6.02±0.06 OUR FIT</b>				

Error includes scale factor of 2.1.

**6.02±0.15 OUR AVERAGE**

6.16±0.22	5110	ESCHSTRUTH	68	OSPK	+
5.89±0.21	1679	CESTER	66	OSPK	+

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

5.92±0.65		<sup>16</sup> WEISSENBE...	76	SPEC	+
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<sup>16</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.

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

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>
<b>0.1967±0.0016 OUR FIT</b>				

Error includes scale factor of 2.5.

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

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>	<u>COMMENT</u>
<b>0.2454±0.0023 OUR FIT</b>					

Error includes scale factor of 2.6.

**0.2467±0.0011 OUR AVERAGE** Error includes scale factor of 1.1.

0.2423±0.0015±0.0037	31k	UVAROV	14	ISTR	-	ISTRA+
0.2470±0.0009±0.0004	87k	BATLEY	07A	NA48	±	

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

0.221 ±0.012	786	<sup>17</sup> LUCAS	73B	HBC	-	Dalitz pairs only
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<sup>17</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.

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

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>
<b>0.908±0.009 OUR FIT</b>				

Error includes scale factor of 1.6.

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

0.867±0.027	2768	BARMIN	87	XEBC	+
0.856±0.040	2827	BRAUN	75	HLBC	+
0.850±0.019	4385	<sup>18</sup> HAIDT	71	HLBC	+
0.846±0.021	4385	<sup>18</sup> EICHTEN	68	HLBC	+
0.94 ±0.09	854	BELLOTTI	67B	HLBC	
0.90 ±0.06	230	BORREANI	64	HBC	+

<sup>18</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.

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

VALUE (units  $10^{-2}$ )    EVTS    DOCUMENT ID    TECN    CHG    COMMENT

**3.352 ± 0.033 OUR FIT** Error includes scale factor of 1.9.

**3.24 ± 0.04 OUR AVERAGE**

3.233 ± 0.029 ± 0.026    <sup>19</sup> AMBROSINO 08A KLOE ±  
 3.33 ± 0.16    2345    CHIANG 72 OSPK +    1.84 GeV/c  $K^+$

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

2.8 ± 0.4    <sup>20</sup> TAYLOR 59 EMUL +

<sup>19</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>20</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

**0.0527 ± 0.0006 OUR FIT** Error includes scale factor of 1.8.

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

0.054 ± 0.009    240    ZELLER 69 ASPK +

0.0480 ± 0.0037    424    <sup>21</sup> GARLAND 68 OSPK +

0.0486 ± 0.0040    307    <sup>22</sup> AUERBACH 67 OSPK +

<sup>21</sup> GARLAND 68 changed from  $0.055 \pm 0.004$  in agreement with  $\mu$ -spectrum calculation of GAILLARD 70 appendix B. L.G.Pondrom, (private communication 73).

<sup>22</sup> AUERBACH 67 changed from  $0.0602 \pm 0.0046$  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 ± 0.0029 OUR FIT** Error includes scale factor of 1.1.

**0.6618 ± 0.0027 OUR AVERAGE**

0.663 ± 0.003 ± 0.001    77k    BATLEY 07A NA48 ±

0.671 ± 0.007 ± 0.008    24k    HORIE 01 SPEC

0.670 ± 0.014    <sup>23</sup> HEINTZE 77 SPEC +

0.667 ± 0.017    5601    BOTTERILL 68B ASPK +

• • • We use the following data for averages but not for fits. • • •

0.6511 ± 0.0064    <sup>24</sup> AMBROSINO 08A KLOE ±

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

0.608 ± 0.014    1585    <sup>25</sup> BRAUN 75 HLBC +

0.705 ± 0.063    554    <sup>26</sup> LUCAS 73B HBC -    Dalitz pairs only

0.698 ± 0.025    3480    <sup>27</sup> CHIANG 72 OSPK +    1.84 GeV/c  $K^+$

0.596 ± 0.025    <sup>28</sup> HAIDT 71 HLBC +

0.604 ± 0.022    1398    <sup>28</sup> EICHTEN 68 HLBC

0.703 ± 0.056    1509    CALLAHAN 66B HLBC

<sup>23</sup> HEINTZE 77 value from fit to  $\lambda_0$ . Assumes  $\mu$ -e universality.

<sup>24</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>25</sup> BRAUN 75 value is from form factor fit. Assumes  $\mu$ -e universality.

<sup>26</sup> LUCAS 73B gives  $N(K_{\mu 3}) = 554 \pm 7.6\%$ ,  $N(K_{e3}) = 786 \pm 3.1\%$ . We divide.

<sup>27</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>28</sup> HAIDT 71 is a reanalysis of EICHTEN 68. Not included in average because of large discrepancy with more precise results.

$$\left[ \Gamma(\pi^0 \mu^+ \nu_\mu) + \Gamma(\pi^+ \pi^0) \right] / \Gamma_{\text{total}} \qquad (\Gamma_4 + \Gamma_9) / \Gamma$$

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

<u>VALUE (units <math>10^{-2}</math>)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>
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**24.02 ± 0.08 OUR FIT** Error includes scale factor of 1.2.

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

25.4 ± 0.9	886	SHAKLEE	64	HLBC	+
23.4 ± 1.1		ROE	61	HLBC	+

$$\Gamma(\pi^0 \mu^+ \nu_\mu) / \Gamma(\pi^+ \pi^0) \qquad \Gamma_4 / \Gamma_9$$

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>
<b>0.1637 ± 0.0006 ± 0.0003</b>	77k	BATLEY	07A NA48	±

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

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>	<u>COMMENT</u>
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**0.600 ± 0.007 OUR FIT** Error includes scale factor of 1.6.

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

0.503 ± 0.019	1505	<sup>29</sup> HAIDT	71	HLBC	+
0.510 ± 0.017	1505	<sup>29</sup> EICHTEN	68	HLBC	+
0.63 ± 0.07	2845	<sup>30</sup> BISI	65B BC	+	HBC+HLBC

<sup>29</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>30</sup> Error enlarged for background problems. See GAILLARD 70.

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

<u>VALUE (units <math>10^{-5}</math>)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>
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**2.55 ± 0.04 OUR FIT** Error includes scale factor of 1.1.

<b>2.54 ± 0.89</b>	10	BARMIN	88B HLBC	+
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$$\Gamma(\pi^0 \pi^0 e^+ \nu_e) / \Gamma(\pi^+ \pi^0 \pi^0) \qquad \Gamma_5 / \Gamma_{10}$$

<u>VALUE (units <math>10^{-3}</math>)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>
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**1.449 ± 0.008 OUR FIT**

<b>1.449 ± 0.006 ± 0.006</b>	65.2k	<sup>31</sup> BATLEY	14A NA48	±
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<sup>31</sup> Data collected in 2003–2004. This leads to the scalar form factor  $(1 + \delta_{EM}) f_S = 6.079 \pm 0.012 \pm 0.027 \pm 0.046$  where the last error is due to the normalizing decay mode uncertainty.

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

$\Gamma_5/\Gamma_3$

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

**5.03±0.09 OUR FIT** Error includes scale factor of 1.2.

**4.1  $^{+1.0}_{-0.7}$  OUR AVERAGE**

4.2 $^{+1.0}_{-0.9}$	25	BOLOTOV	86B	CALO	–
3.8 $^{+5.0}_{-1.2}$	2	LJUNG	73	HLBC	+

$\Gamma(\pi^+\pi^-e^+\nu_e)/\Gamma(\pi^+\pi^+\pi^-)$

$\Gamma_6/\Gamma_{11}$

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

**7.606±0.029 OUR AVERAGE**

7.615±0.008±0.028	1.1M	<sup>32</sup> BATLEY	12	NA48	±
7.35 ±0.01 ±0.19	388k	<sup>33</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>32</sup>BATLEY 12 uses data collected in 2003–2004. The result is inclusive of  $K^\pm \rightarrow \pi^+\pi^-e^\pm\nu\gamma$  decays. Using PDG 12 value for  $\Gamma(\pi^+\pi^-\pi^+)/\Gamma = (5.59 \pm 0.04) \times 10^{-2}$ .  
 BATLEY 12 obtains  $B(\pi^+\pi^-e\nu) = (4.257 \pm 0.004 \pm 0.035) \times 10^{-5}$  where the syst. error is dominated by the error on the normalization mode.

<sup>33</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 and PISLAK 10A give additional details on the branching ratio measurement and give improved errors on the S-wave  $\pi$ - $\pi$  scattering length:  $a_0^0 = 0.235 \pm 0.013$  and  $a_2^0 = -0.0410 \pm 0.0027$ .

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

$\Gamma_7/\Gamma$

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

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

0.77 $^{+0.54}_{-0.50}$	1	CLINE	65	FBC	+
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$\Gamma(\pi^+\pi^-\mu^+\nu_\mu)/\Gamma(\pi^+\pi^+\pi^-)$

$\Gamma_7/\Gamma_{11}$

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

**2.57±1.55**    7    BISI    67    DBC    +

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

~ 2.5	1	GREINER	64	EMUL	+
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$\Gamma(\pi^0\pi^0\pi^0e^+\nu_e)/\Gamma_{\text{total}}$

$\Gamma_8/\Gamma$

VALUE (units  $10^{-6}$ )    CL%    EVTS    DOCUMENT ID    TECN    CHG

**<3.5**    90    0    BOLOTOV    88    SPEC    –

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

<9	90	0	BARMIN	92	XEBC	+
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**Hadronic modes**


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

<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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**20.67±0.08 OUR FIT** Error includes scale factor of 1.2.

**20.70±0.16 OUR AVERAGE** Error includes scale factor of 1.8.

20.65±0.05±0.08	1.4M	<sup>34</sup> AMBROSINO	08E	KLOE	+	$\phi \rightarrow K^+K^-$
21.18±0.28	16k	CHIANG	72	OSPK	+	1.84 GeV/c $K^+$

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

21.0 ±0.6		CALLAHAN	65	HLBC		See $\Gamma_9/\Gamma_{11}$
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<sup>34</sup> Fully inclusive of final-state radiation. The branching ratio is evaluated using  $K^+$  lifetime,  $\tau = 12.385$  ns.

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

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>
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**3.702±0.022 OUR FIT** Error includes scale factor of 1.1.

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

3.96 ±0.15	1045	CALLAHAN	66	FBC	+
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 **$\Gamma(\pi^+\pi^0)/\Gamma(\mu^+\nu_\mu)$   $\Gamma_9/\Gamma_2$** 

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>	<u>COMMENT</u>
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**0.3252±0.0016 OUR FIT** Error includes scale factor of 1.2.

**0.3325±0.0032 OUR AVERAGE**

0.3329±0.0047±0.0010	45k	USHER	92	SPEC	+	$\rho\bar{p}$ at rest
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0.3355±0.0057		<sup>35</sup> WEISSENBE...	76	SPEC	+
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0.3277±0.0065	4517	<sup>36</sup> AUERBACH	67	OSPK	+
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• • • We do not use the following data for averages, fits, limits, etc. • • •

0.328 ±0.005	25k	<sup>35</sup> WEISSENBE...	74	STRC	+
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0.305 ±0.018	1600	ZELLER	69	ASPK	+
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<sup>35</sup> WEISSENBERG 76 revises WEISSENBERG 74.

<sup>36</sup> AUERBACH 67 changed from  $0.3253 \pm 0.0065$ . 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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**1.760±0.023 OUR FIT** Error includes scale factor of 1.1.

**1.775±0.028 OUR AVERAGE** Error includes scale factor of 1.2.

1.763±0.013±0.022		ALOISIO	04A	KLOE	±
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1.84 ±0.06	1307	CHIANG	72	OSPK	+	1.84 GeV/c $K^+$
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• • • We do not use the following data for averages, fits, limits, etc. • • •

1.53 ±0.11	198	<sup>37</sup> PANDOULAS	70	EMUL	+
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1.8 ±0.2	108	SHAKLEE	64	HLBC	+
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1.7 ±0.2		ROE	61	HLBC	+
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1.5 ±0.2		<sup>38</sup> TAYLOR	59	EMUL	+
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<sup>37</sup> Includes events of TAYLOR 59.

<sup>38</sup> Earlier experiments not averaged.

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

VALUE	EVTS	DOCUMENT ID	TECN	CHG	COMMENT
<b>0.0851±0.0012 OUR FIT</b>					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>39</sup> LUCAS	73B	HBC	–	Dalitz pairs only
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<sup>39</sup> LUCAS 73B gives  $N(\pi^+\pi^0) = 574 \pm 5.9\%$ ,  $N(2\pi) = 3564 \pm 3.1\%$ . We quote  $0.5N(\pi^+\pi^0)/N(2\pi)$  where 0.5 is because only Dalitz pair  $\pi^0$ 's were used.

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

VALUE	EVTS	DOCUMENT ID	TECN	CHG	COMMENT
<b>0.315±0.004 OUR FIT</b>					Error includes scale factor of 1.1.

<b>0.303±0.009</b>	2027	BISI	65	BC	+	HBC+HLBC
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• • • We do not use the following data for averages, fits, limits, etc. • • •

0.393±0.099	17	YOUNG	65	EMUL	+	
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$\Gamma(\pi^+\pi^+\pi^-)/\Gamma_{total}$   $\Gamma_{11}/\Gamma$

VALUE (units $10^{-2}$ )	EVTS	DOCUMENT ID	TECN	CHG	COMMENT
<b>5.583±0.024 OUR FIT</b>					

<b>5.565±0.031±0.025</b>	68K	<sup>40</sup> BABUSCI	14B	KLOE	+	
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• • • We do not use the following data for averages, fits, limits, etc. • • •

5.56 ±0.20	2330	<sup>41</sup> CHIANG	72	OSPK	+	1.84 GeV/c $K^+$
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5.34 ±0.21	693	<sup>42</sup> PANDOULAS	70	EMUL	+	
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5.71 ±0.15		DEMARCO	65	HBC		
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6.0 ±0.4	44	YOUNG	65	EMUL	+	
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5.54 ±0.12	2332	CALLAHAN	64	HLBC	+	
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5.1 ±0.2	540	SHAKLEE	64	HLBC	+	
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5.7 ±0.3		ROE	61	HLBC	+	
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<sup>40</sup> Inclusive of final-state radiation. Result obtained from averaging two branching ratios: one from a sample with  $K^- \rightarrow \mu\nu(\gamma)$  tagging and another with  $K^- \rightarrow \pi^-\pi^0(\gamma)$  tagging.

<sup>41</sup> Value is not independent of CHIANG 72  $\Gamma(\mu^+\nu_\mu)/\Gamma_{total}$ ,  $\Gamma(\pi^+\pi^0)/\Gamma_{total}$ ,  $\Gamma(\pi^+\pi^0\pi^0)/\Gamma_{total}$ ,  $\Gamma(\pi^0\mu^+\nu_\mu)/\Gamma_{total}$ , and  $\Gamma(\pi^0e^+\nu_e)/\Gamma_{total}$ .

<sup>42</sup> Includes events of TAYLOR 59.

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

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

VALUE (units $10^{-3}$ )	EVTS	DOCUMENT ID	TECN	CHG	COMMENT
<b>6.2±0.8 OUR AVERAGE</b>					

6.6±1.5	43,44	DEMIDOV	90	XEBC	$P(\mu) < 231.5 \text{ MeV}/c$
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6.0±0.9		BARMIN	88	HLBC	+	$P(\mu) < 231.5 \text{ MeV}/c$
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• • • We do not use the following data for averages, fits, limits, etc. • • •

3.5±0.8	44,45	DEMIDOV	90	XEBC	$E(\gamma) > 20 \text{ MeV}$
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3.2±0.5	57	<sup>46</sup> BARMIN	88	HLBC	+	$E(\gamma) > 20 \text{ MeV}$
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5.4±0.3	47	AKIBA	85	SPEC	$P(\mu) < 231.5 \text{ MeV}/c$
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<sup>43</sup>  $P(\mu)$  cut given in DEMIDOV 90 paper, 235.1 MeV/c, is a misprint according to authors (private communication).

<sup>44</sup> DEMIDOV 90 quotes only inner bremsstrahlung (IB) part.

<sup>45</sup> Not independent of above DEMIDOV 90 value. Cuts differ.

<sup>46</sup> Not independent of above BARMIN 88 value. Cuts differ.

<sup>47</sup> Assumes  $\mu$ -e universality and uses constraints from  $K \rightarrow e\nu\gamma$ .

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

Structure-dependent part with  $+\gamma$  helicity ( $SD^+$  term). See the “Note on  $\pi^\pm \rightarrow \ell^\pm \nu_\ell \gamma$  and  $K^\pm \rightarrow \ell^\pm \nu_\ell \gamma$  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>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
<b>1.33±0.12±0.18</b>		2588	<sup>48</sup> ADLER	00B B787

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

<3.0	90	AKIBA	85	SPEC
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<sup>48</sup> ADLER 00B obtains the branching ratio by extrapolating the measurement in the kinematic region  $E_\mu > 137$  MeV,  $E_\gamma > 90$  MeV to the full  $SD^+$  phase-space. Also reports  $|F_V + F_A| = 0.165 \pm 0.007 \pm 0.011$  and  $-0.04 < F_V - F_A < 0.24$  at 90% CL.

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

Interference term between internal Bremsstrahlung and  $SD^+$  term. See the “Note on  $\pi^\pm \rightarrow \ell^\pm \nu_\ell \gamma$  and  $K^\pm \rightarrow \ell^\pm \nu_\ell \gamma$  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

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

Sum of structure-dependent part with  $-\gamma$  helicity ( $SD^-$  term) and interference term between internal Bremsstrahlung and  $SD^-$  term. See the “Note on  $\pi^\pm \rightarrow \ell^\pm \nu_\ell \gamma$  and  $K^\pm \rightarrow \ell^\pm \nu_\ell \gamma$  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>49</sup> AKIBA	85 SPEC

<sup>49</sup> Assumes  $\mu$ - $e$  universality and uses constraints from  $K \rightarrow e \nu \gamma$ .

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

<u>VALUE (units <math>10^{-5}</math>)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>	<u>COMMENT</u>
<b>1.483±0.066±0.013</b>	1.4K	<sup>50</sup> AMBROSINO	09E KLOE	±	$E_\gamma$ in 10–250 MeV, $p_e > 200$ MeV/c

<sup>50</sup> AMBROSINO 09E measured the differential width  $dR_\gamma/dE_\gamma = (1/\Gamma(K \rightarrow \mu\nu)) (d\Gamma(K \rightarrow e\nu\gamma)/dE_\gamma)$ . Result obtained by integrating the differential width over  $E_\gamma$  from 10 to 250 MeV.

$\Gamma(\pi^0 e^+ \nu_e \gamma)/\Gamma(\pi^0 e^+ \nu_e)$   $\Gamma_{17}/\Gamma_3$

<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>0.505±0.032 OUR AVERAGE</b>		Error includes scale factor of 1.3. See the ideogram below.			
0.47 ±0.02 ±0.03	4476	<sup>51</sup> AKIMENKO	07 ISTR	–	$E_\gamma > 10$ MeV, $0.6 < \cos(\theta_{e\gamma}) < 0.9$
0.46 ±0.08	82	<sup>52</sup> BARMIN	91 XEBC		$E_\gamma > 10$ MeV, $0.6 < \cos(\theta_{e\gamma}) < 0.9$
0.56 ±0.04	192	<sup>53</sup> BOLOTOV	86B CALO	–	$E_\gamma > 10$ MeV

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

1.81 ± 0.03 ± 0.07	4476	51	AKIMENKO	07	ISTR	–	$E_\gamma > 10$ MeV, $\theta_{e\gamma} > 10^\circ$
0.63 ± 0.02 ± 0.03	4476	51	AKIMENKO	07	ISTR	–	$E_\gamma > 30$ MeV, $\theta_{e\gamma} > 20^\circ$
1.51 ± 0.25	82	52	BARMIN	91	XEBC		$E_\gamma > 10$ MeV, $\cos(\theta_{e\gamma}) < 0.98$
0.48 ± 0.20	16	54	LJUNG	73	HLBC	+	$E_\gamma > 30$ MeV
0.22 <sup>+0.15</sup> <sub>–0.10</sub>		54	LJUNG	73	HLBC	+	$E_\gamma > 30$ MeV
0.76 ± 0.28	13	55	ROMANO	71	HLBC		$E_\gamma > 10$ MeV
0.53 ± 0.22		55	ROMANO	71	HLBC	+	$E_\gamma > 30$ MeV
1.2 ± 0.8			BELLOTTI	67	HLBC		$E_\gamma > 30$ MeV

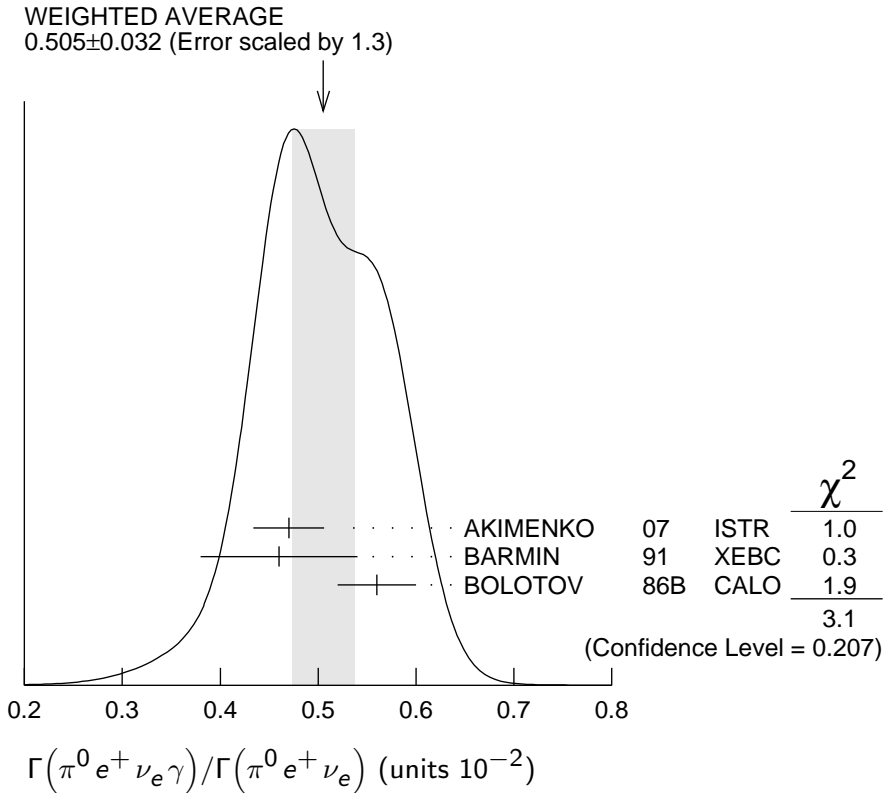
<sup>51</sup> AKIMENKO 07 provides values for three kinematic regions. For averaging, we use value with  $E_\gamma > 10$  MeV and  $0.6 < \cos(\theta_{e\gamma}) < 0.9$ .

<sup>52</sup> 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.

<sup>53</sup>  $\cos(\theta_{e\gamma})$  between 0.6 and 0.9.

<sup>54</sup> 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.

<sup>55</sup> 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.





$\Gamma(\pi^0 e^+ \nu_e \gamma(\text{SD}))/\Gamma_{\text{total}}$   $\Gamma_{18}/\Gamma$   
 Structure-dependent part.

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

$\Gamma(\pi^0 \mu^+ \nu_\mu \gamma)/\Gamma_{\text{total}}$   $\Gamma_{19}/\Gamma$

VALUE (units $10^{-5}$ )	CL%	EVTS	DOCUMENT ID	TECN	CHG	COMMENT
<b>1.25 ± 0.25 OUR AVERAGE</b>						
1.10 ± 0.32 ± 0.05		23	<sup>56</sup> ADLER	10	B787	30 < $E_\gamma$ < 60 MeV
1.46 ± 0.22 ± 0.32		153	<sup>57</sup> 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	LJUNG	73	HLBC +	$E(\gamma) > 30$ MeV

<sup>56</sup> Value obtained from  $B(K^+ \rightarrow \pi^0 \mu^+ \nu_\mu \gamma) = (2.51 \pm 0.74 \pm 0.12) \times 10^{-5}$  obtained in the kinematic region  $E_\gamma > 20$  MeV, and then theoretical  $K_{\mu 3\gamma}$  spectrum has been used. Also  $B(K^+ \rightarrow \pi^0 \mu^+ \nu_\mu \gamma) = (1.58 \pm 0.46 \pm 0.08) \times 10^{-5}$ , for  $E_\gamma > 30$  MeV and  $\theta_{\mu\gamma} > 20^\circ$ , was determined.

<sup>57</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  $5 \text{ MeV} < E_\gamma < 30 \text{ MeV}$ .

$\Gamma(\pi^0 \pi^0 e^+ \nu_e \gamma)/\Gamma_{\text{total}}$   $\Gamma_{20}/\Gamma$

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

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

$\Gamma(\pi^+ \pi^0 \gamma(\text{INT}))/\Gamma_{\text{total}}$   $\Gamma_{21}/\Gamma$

The  $K^+ \rightarrow \pi^+ \pi^0 \gamma$  differential decay rate can be described in terms of  $T_{\pi^+}$ , the charged pion kinetic energy, and  $W^2 = (P_K \cdot P_\gamma)(P_{\pi^+} \cdot P_\gamma) / (m_K m_{\pi^+})^2$ ; then we can write  $d^2\Gamma(K^+ \rightarrow \pi^+ \pi^0 \gamma) / (dT_{\pi^+} dW^2) = d^2\Gamma(K^+ \rightarrow \pi^+ \pi^0 \gamma)_{IB} / (dT_{\pi^+} dW^2) [1 + 2 \cos(\pm\phi + \delta_1^1 - \delta_0^2) m_\pi^2 m_K^2 W^2 X_E + m_\pi^4 m_K^4 (X_E^2 + X_M^2) W^4]$ . The IB differential and total branching ratios are expressed in terms of the non-radiative experimental width  $\Gamma(K^+ \rightarrow \pi^+ \pi^0)$  by Low's theorem. Using PDG 10  $B(K^+ \rightarrow \pi^+ \pi^0) = 0.2066 \pm 0.0008$ , one obtains respectively  $B(K^+ \rightarrow \pi^+ \pi^0 \gamma)_{IB} (55 < T_{\pi^+} < 90 \text{ MeV}) = 2.55 \times 10^{-4}$  and  $B(K^+ \rightarrow \pi^+ \pi^0 \gamma)_{IB} (0 < T_{\pi^+} < 80 \text{ MeV}) = 1.80 \times 10^{-4}$ . Fitting respectively the piece proportional to  $W^2$  and the piece proportional to  $W^4$ , the interference contribution (INT), proportional to  $X_E$ , and the direct contribution (DE) proportional to  $X_E^2 + X_M^2$  are extracted.

VALUE (units $10^{-6}$ )	EVTS	DOCUMENT ID	TECN	CHG	COMMENT
<b>-4.24 ± 0.63 ± 0.70</b>	600k	<sup>58</sup> BATLEY	10A	NA48 ±	$T_{\pi^+}$ 0-80 MeV

<sup>58</sup> The cut on the photon energy implies  $W^2 > 0.2$ . BATLEY 10A obtains the INT and DE fractional branchings with respect to IB from a simultaneous kinematical fit of INT and DE and then we use the PDG 10 value for  $B(K^+ \rightarrow \pi^+ \pi^0) = 20.66 \pm 0.08$  to determine the IB. The INT and DE correlation coefficients -0.83. Assuming a constant electric amplitude,  $X_E$ , this INT value implies  $X_E = -24 \pm 6 \text{ GeV}^{-4}$ .

$\Gamma(\pi^+\pi^0\gamma(\text{DE}))/\Gamma_{\text{total}}$   $\Gamma_{22}/\Gamma$

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

<u>VALUE (units <math>10^{-6}</math>)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>	<u>COMMENT</u>
<b>5.99±0.27±0.25</b>	600k	<sup>59</sup> BATLEY 10A	NA48	±	$T_{\pi^+}$ 0–80 MeV
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●					
3.8 ±0.8 ±0.7	10k	ALIEV	06 K470	+	$T_{\pi^+}$ 55–90 MeV
3.7 ±3.9 ±1.0	930	UVAROV	06 ISTR	–	$T_{\pi^-}$ 55–90 MeV
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
4.7 ±0.8 ±0.3	20k	<sup>60</sup> ADLER	00C B787	+	$T_{\pi^+}$ 55–90 MeV
20.5 ±4.6 <sup>+3.9</sup> / <sub>–2.3</sub>		BOLOTOV	87 WIRE	–	$T_{\pi^-}$ 55–90 MeV
15.6 ±3.5 ±5.0		ABRAMS	72 ASPK	±	$T_{\pi^\pm}$ 55–90 MeV

<sup>59</sup> The cut on the photon energy implies  $W^2 > 0.2$ . BATLEY 10A obtains the INT and DE fractional branchings with respect to IB from a simultaneous kinematical fit of INT and DE and then we use the PDG 10 value for  $B(K^+ \rightarrow \pi^+\pi^0) = 20.66 \pm 0.08$  to determine the IB. The INT and DE correlation coefficients  $-0.93$ . Assuming constant electric and magnetic amplitudes,  $X_E$  and  $X_M$ , these INT and DE values imply  $X_E = -24 \pm 6 \text{ GeV}^{-4}$  and  $X_M = -254 \pm 9 \text{ GeV}^{-4}$ .

<sup>60</sup> ADLER 00C measures the INT component to be  $(-0.4 \pm 1.6)\%$  of the inner bremsstrahlung (IB) component.

$\Gamma(\pi^+\pi^0\pi^0\gamma)/\Gamma(\pi^+\pi^0\pi^0)$   $\Gamma_{23}/\Gamma_{10}$

<u>VALUE (units <math>10^{-4}</math>)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>	<u>COMMENT</u>
<b>4.3<sup>+3.2</sup>/<sub>–1.7</sub></b>	BOLOTOV	85 SPEC	–	$E(\gamma) > 10 \text{ MeV}$

$\Gamma(\pi^+\pi^+\pi^-\gamma)/\Gamma_{\text{total}}$   $\Gamma_{24}/\Gamma$

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

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

<u>VALUE (units <math>10^{-7}</math>)</u>	<u>CL%</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>	<u>COMMENT</u>
<b>10.1 ±0.6 OUR AVERAGE</b>						
10.03±0.51±0.24		215	<sup>61</sup> LAZZERONI 14	NA62	±	
11 ±3 ±1		31	<sup>62</sup> KITCHING 97	B787	+	
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●						
9.10±0.72±0.22		149	<sup>63</sup> BATLEY 14	NA48	±	
< 0.083	90		<sup>64</sup> ARTAMONOV 05	B949	+	$P_\pi > 213 \text{ MeV}/c$
< 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	+	$T_\pi < 92 \text{ MeV}$
< 350	90	0	LJUNG 73	HLBC	+	6–102, 114–127 MeV
< 500	90	0	KLEMS 71	OSPK	+	$T_\pi < 117 \text{ MeV}$
–100 ± 600			CHEN 68	OSPK	+	$T_\pi$ 60–90 MeV

- <sup>61</sup> LAZZERONI 14 combines NA62 and NA48/2 results. The result for the full kinematic range is extrapolated from the model-independent branching fraction  $(9.65 \pm 0.61 \pm 0.14) \times 10^{-7}$  for  $(m_{\gamma\gamma}/m_K)^2 > 0.2$ . The measured ChPT parameter  $\hat{c} = 1.86 \pm 0.25$ .
- <sup>62</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>63</sup> BATLEY 14 uses data collected in 2003 and 2004. Branching ratio is obtained by determining the parameter  $\hat{c} = 1.41 \pm 0.38 \pm 0.11$  and integrating the  $\mathcal{O}(p^6)$  chiral spectrum. A model independent value for the branching ratio is also obtained  $(8.77 \pm 0.87 \pm 0.17) \times 10^{-7}$  for kinematic range  $(m_{\gamma\gamma}/m_K)^2 > 0.2$ .
- <sup>64</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.

**$\Gamma(\pi^+ 3\gamma)/\Gamma_{\text{total}}$   $\Gamma_{26}/\Gamma$**

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	+	$T(\pi) 117\text{--}127 \text{ MeV}$

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

<3.0	90	KLEMS	71	OSPK	+	$T(\pi) > 117 \text{ MeV}$
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**$\Gamma(\pi^+ e^+ e^- \gamma)/\Gamma_{\text{total}}$   $\Gamma_{27}/\Gamma$**

VALUE (units $10^{-8}$ )	EVTS	DOCUMENT ID	TECN	CHG	COMMENT	
<b>1.19 ± 0.12 ± 0.04</b>	113	<sup>65</sup> BATLEY	08	NA48	+	$m_{e e \gamma} > 260 \text{ MeV}$

- <sup>65</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  $m_{e e \gamma} < 260 \text{ MeV}$ , 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  $l\bar{l}$  pairs** —————

**$\Gamma(e^+ \nu_e \nu \bar{\nu})/\Gamma(e^+ \nu_e)$   $\Gamma_{28}/\Gamma_1$**

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

**$\Gamma(\mu^+ \nu_\mu \nu \bar{\nu})/\Gamma_{\text{total}}$   $\Gamma_{29}/\Gamma$**

VALUE (units $10^{-6}$ )	CL%	EVTS	DOCUMENT ID	TECN	CHG	
<b>&lt;6.0</b>	90	0	<sup>66</sup> PANG	73	CNTR	+

- <sup>66</sup> PANG 73 assumes  $\mu$  spectrum from  $\nu$ - $\nu$  interaction of BARDIN 70.

**$\Gamma(e^+ \nu_e e^+ e^-)/\Gamma_{\text{total}}$   $\Gamma_{30}/\Gamma$**

VALUE (units $10^{-8}$ )	EVTS	DOCUMENT ID	TECN	CHG	COMMENT	
<b>2.48 ± 0.14 ± 0.14</b>	410	POBLAGUEV	02	B865	+	$m_{e e} > 150 \text{ MeV}$

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

20 ± 20	4	DIAMANT-...	76	SPEC	+	$m_{e^+ e^-} > 140 \text{ MeV}$
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$\Gamma(\mu^+ \nu_\mu e^+ e^-)/\Gamma_{\text{total}}$   $\Gamma_{31}/\Gamma$

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

$\Gamma(e^+ \nu_e \mu^+ \mu^-)/\Gamma_{\text{total}}$   $\Gamma_{32}/\Gamma$

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

$\Gamma(\mu^+ \nu_\mu \mu^+ \mu^-)/\Gamma_{\text{total}}$   $\Gamma_{33}/\Gamma$

<u>VALUE (units <math>10^{-7}</math>)</u>	<u>CL%</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>
<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 ————

$\Gamma(\pi^+ \pi^+ e^- \bar{\nu}_e)/\Gamma_{\text{total}}$   $\Gamma_{34}/\Gamma$   
 Test of  $\Delta S = \Delta Q$  rule.

<u>VALUE (units <math>10^{-7}</math>)</u>	<u>CL%</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>
• • • 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	+

$\Gamma(\pi^+ \pi^+ e^- \bar{\nu}_e)/\Gamma(\pi^+ \pi^- e^+ \nu_e)$   $\Gamma_{34}/\Gamma_6$   
 Test of  $\Delta S = \Delta Q$  rule.

<u>VALUE (units <math>10^{-4}</math>)</u>	<u>CL%</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
<b>&lt; 3</b>	90	3	<sup>67</sup> BLOCH	76 SPEC
• • • We do not use the following data for averages, fits, limits, etc. • • •				
<130.	95	0	BOURQUIN	71 ASPK
<sup>67</sup> BLOCH 76 quotes $3.6 \times 10^{-4}$ at CL = 95%, we convert.				

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

$\Gamma(\pi^+ e^+ e^-)/\Gamma_{\text{total}}$   $\Gamma_{36}/\Gamma$   
 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><math>3.00 \pm 0.09</math> OUR AVERAGE</b>				
$3.11 \pm 0.04 \pm 0.12$	7253	<sup>68</sup> BATLEY	09 NA48	$\pm$
$2.94 \pm 0.05 \pm 0.14$	10300	<sup>69</sup> APPEL	99 SPEC	+
$2.75 \pm 0.23 \pm 0.13$	500	<sup>70</sup> ALLIEGRO	92 SPEC	+
$2.7 \pm 0.5$	41	<sup>71</sup> BLOCH	75 SPEC	+

- <sup>68</sup> Value extrapolated from a measurement in the region  $z = (m_{ee}/m_K)^2 > 0.08$ . BATLEY 09 also evaluated the shape of the form factor using four different theoretical models.
- <sup>69</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>70</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>71</sup> BLOCH 75 assumes a vector interaction.

$\Gamma(\pi^+ \mu^+ \mu^-) / \Gamma_{\text{total}}$   $\Gamma_{37} / \Gamma$   
 Test for  $\Delta S = 1$  weak neutral current. Allowed by higher-order electroweak interactions.

VALUE (units  $10^{-8}$ )    CL%    EVTS    DOCUMENT ID    TECN    CHG    COMMENT

**9.4 ± 0.6 OUR AVERAGE**    Error includes scale factor of 2.6. See the ideogram below.

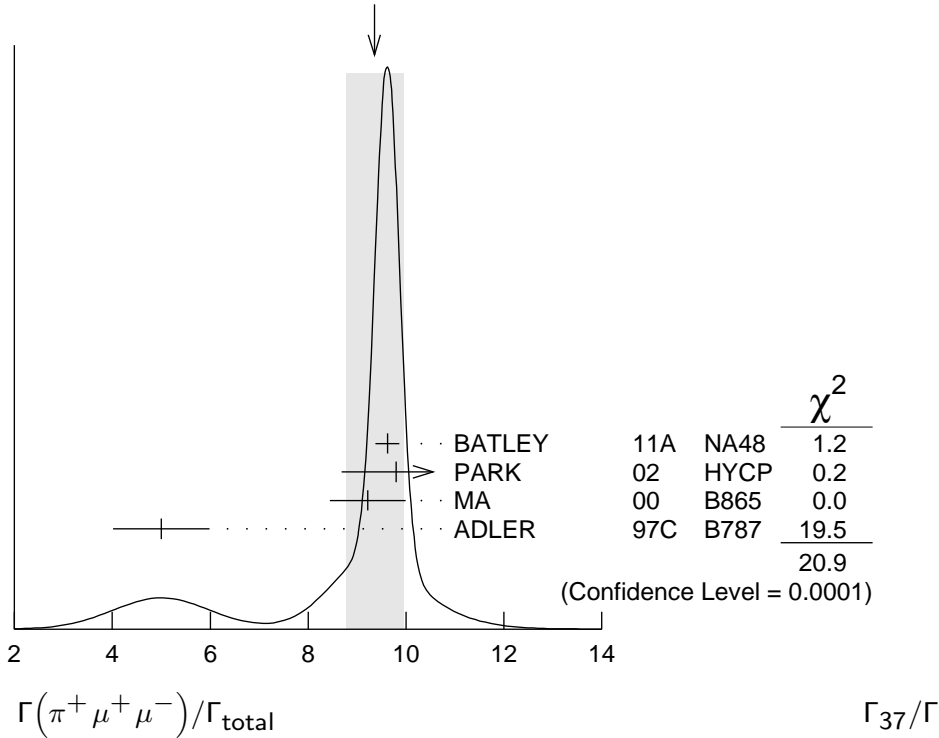
9.62 ± 0.21 ± 0.13	3120	72	BATLEY	11A	NA48	±	2003-04 data
9.8 ± 1.0 ± 0.5	110	73	PARK	02	HYCP	±	
9.22 ± 0.60 ± 0.49	402	74	MA	00	B865	+	
5.0 ± 0.4 ± 0.9	207	75	ADLER	97C	B787	+	

• • • 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>72</sup> BATLEY 11A also studies the form factor  $f(z)$  dependence of the decay, described via single photon exchange: i) assuming a linear form factor,  $f(z) = f_0(1 + \delta z)$ ,  $z = (M_{\mu\mu}/m_K)^2$ , finding  $f_0 = 0.470 \pm 0.040$  and  $\delta = 3.11 \pm 0.57$  and ii) assuming a linear form factor including  $\pi$ - $\pi$  rescattering,  $W_{\pi\pi}$ , as in DAMBROSIO 98A, finding  $f(z) = G_F m_K^2 (a_+ + b_+ z) + W_{\pi\pi}(z)$ ,  $a_+ = -0.575 \pm 0.039$ ,  $b_+ = -0.813 \pm 0.145$ .
- <sup>73</sup> PARK 02 "±" result comes from combining  $K^+ \rightarrow \pi^+ \mu^+ \mu^-$  and  $K^- \rightarrow \pi^- \mu^+ \mu^-$ , assuming  $CP$  is conserved.
- <sup>74</sup> MA 00 establishes vector nature of this decay and determines form factor  $f(z) = f_0(1 + \delta z)$ ,  $z = (M_{\mu\mu}/m_K)^2$ ,  $\delta = 2.45^{+1.30}_{-0.95}$ .
- <sup>75</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  
 $9.4 \pm 0.6$  (Error scaled by 2.6)



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

$\Gamma_{38} / \Gamma$

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.

VALUE (units $10^{-9}$ )	CL%	EVTS	DOCUMENT ID	TECN	CHG	COMMENT
$0.173^{+0.115}_{-0.105}$		7	76 ARTAMONOV 08	B949	+	$140 < P_\pi < 199$ MeV, $211 < P_\pi < 229$ MeV

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

$0.789^{+0.926}_{-0.510}$		3	77 ARTAMONOV 08	B949	+	$140 < P_\pi < 199$ MeV
< 2.2	90	1	78 ADLER	04 B787	+	$211 < P_\pi < 229$ MeV
< 2.7	90		ADLER	04 B787	+	Scalar
< 1.8	90		ADLER	04 B787	+	Tensor
$0.147^{+0.130}_{-0.089}$		3	79 ANISIMOVSK...04	B949	+	$211 < P_\pi < 229$ 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		80 ADLER	02C B787	+	Scalar
< 2.5	90		80 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>81</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>76</sup> Value obtained combining ANISIMOVSKY 04, ADLER 04, and the present ARTAMONOV 08 results.

<sup>77</sup> Observed 3 events with an estimated background of  $0.93 \pm 0.17^{+0.32}_{-0.24}$ . Signal-to-background ratio for each of these 3 events is 0.20, 0.42, and 0.47.

<sup>78</sup> Value obtained combining the previous result ADLER 02C with 1 event and the present result with 0 events to obtain an expected background  $1.22 \pm 0.24$  events and 1 event observed.

<sup>79</sup> Value obtained combining the previous E787 result ADLER 02 with 2 events and the present E949 with 1 event. The additional event has a signal-to-background ratio 0.9. Superseded by ARTAMONOV 08.

<sup>80</sup> Superseded by ADLER 04.

<sup>81</sup> Combining ATIYA 93 and ATIYA 93B results. Superseded by ADLER 96.

### $\Gamma(\pi^+ \pi^0 \nu \bar{\nu})/\Gamma_{\text{total}}$ $\Gamma_{39}/\Gamma$

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

VALUE (units $10^{-5}$ )	CL%		DOCUMENT ID	TECN
<b>&lt;4.3</b>	90	<sup>82</sup>	ADLER	01 SPEC

<sup>82</sup> Search region defined by  $90 \text{ MeV}/c < P_{\pi^+} < 188 \text{ MeV}/c$  and  $135 \text{ MeV} < E_{\pi^0} < 180 \text{ MeV}$ .

### $\Gamma(\mu^- \nu e^+ e^+)/\Gamma(\pi^+ \pi^- e^+ \nu_e)$ $\Gamma_{40}/\Gamma_6$

Test of lepton family number conservation.

VALUE (units $10^{-3}$ )	CL%	EVTS	DOCUMENT ID	TECN	CHG
<b>&lt;0.5</b>	90	0	<sup>83</sup> DIAMANT-...	76 SPEC	+

<sup>83</sup> DIAMANT-BERGER 76 quotes this result times our 1975  $\pi^+ \pi^- e \nu$  BR ratio.

### $\Gamma(\mu^+ \nu_e)/\Gamma_{\text{total}}$ $\Gamma_{41}/\Gamma$

Forbidden by lepton family number conservation.

VALUE	CL%	EVTS	DOCUMENT ID	TECN	COMMENT
<b>&lt;0.004</b>	90	0	<sup>84</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>84</sup>COOPER      82      HLBC      Wideband  $\nu$  beam

<sup>84</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.

### $\Gamma(\pi^+ \mu^+ e^-)/\Gamma_{\text{total}}$ $\Gamma_{42}/\Gamma$

Test of lepton family number conservation.

VALUE (units $10^{-10}$ )	CL%		DOCUMENT ID	TECN	CHG
<b>&lt;0.13</b>	90	<sup>85</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>85</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.

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

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>86</sup> DIAMANT-...	76 SPEC	+
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<sup>86</sup> Measurement actually applies to the sum of the  $\pi^+ \mu^- e^+$  and  $\pi^- \mu^+ e^+$  modes.

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

Test of total lepton 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; 5.0</b>	90	0	APPEL	00B B865	+

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

<70	90	0	<sup>87</sup> DIAMANT-...	76 SPEC	+
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<sup>87</sup> Measurement actually applies to the sum of the  $\pi^+ \mu^- e^+$  and  $\pi^- \mu^+ e^+$  modes.

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

Test of total lepton number conservation.

<u>VALUE</u>	<u>CL%</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>
<b>&lt; <math>6.4 \times 10^{-10}</math></b>	90	0	APPEL	00B B865	+

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

< $9.2 \times 10^{-9}$	90	0	DIAMANT-...	76 SPEC	+
< $1.5 \times 10^{-5}$			CHANG	68 HBC	-

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

Forbidden by total lepton number conservation.

<u>VALUE</u>	<u>CL%</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>
<b>&lt; <math>1.1 \times 10^{-9}</math></b>	90	BATLEY	11A NA48	±

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

< $3.0 \times 10^{-9}$	90	APPEL	00B B865	+
< $1.5 \times 10^{-4}$	90	<sup>88</sup> LITTENBERG	92 HBC	

<sup>88</sup> LITTENBERG 92 is from retroactive data analysis of CHANG 68 bubble chamber data.

$\Gamma(\mu^+ \bar{\nu}_e)/\Gamma_{\text{total}}$   $\Gamma_{47}/\Gamma$

Forbidden by total lepton number conservation.

<u>VALUE (units <math>10^{-3}</math>)</u>	<u>CL%</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>&lt; 3.3</b>	90	<sup>89</sup> COOPER	82 HLBC	Wideband $\nu$ beam

<sup>89</sup> COOPER 82 limit on  $\bar{\nu}_e$  observation is here interpreted as a limit on lepton number violation in the absence of mixing.

$\Gamma(\pi^0 e^+ \bar{\nu}_e)/\Gamma_{\text{total}}$   $\Gamma_{48}/\Gamma$

Forbidden by total lepton number conservation.

<u>VALUE</u>	<u>CL%</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>&lt; 0.003</b>	90	<sup>90</sup> COOPER	82 HLBC	Wideband $\nu$ beam

<sup>90</sup> COOPER 82 limit on  $\bar{\nu}_e$  observation is here interpreted as a limit on lepton number violation in the absence of mixing.



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

$\Gamma_{49}/\Gamma$

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
< <b>2.3</b>	90	ARTAMONOV 05	B949	+
< 360	90	ADLER 02B	B787	+
<1400	90	ASANO 82	CNTR	+
<4000	90	<sup>91</sup> KLEMS 71	OSPK	+

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

<sup>91</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>-0.990</b>	90	<sup>92</sup> AOKI 94	SPEC	+	
< -0.990	90	IMAZATO 92	SPEC	+	Repl. by AOKI 94
-0.970 $\pm$ 0.047		<sup>93</sup> YAMANAKA 86	SPEC	+	
-1.0 $\pm$ 0.1		<sup>93</sup> CUTTS 69	SPRK	+	
-0.96 $\pm$ 0.12		<sup>93</sup> COOMBES 57	CNTR	+	

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

<sup>92</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>93</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 <math>\pm</math> 0.00017</b>	471M	<sup>94</sup> BATLEY 07B	NA48	$\pm$	

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

-0.2221 ±0.0065	225k	DEVAUX	77	SPEC	+	$a_y = .2814 \pm .0082$
-0.199 ±0.008	81k	<sup>95</sup> LUCAS	73	HBC	-	$a_y = 0.252 \pm 0.011$
-0.2157 ±0.0028	750k	FORD	72	ASPK	+	$a_y = .2734 \pm .0035$
-0.2186 ±0.0028	750k	FORD	72	ASPK	-	$a_y = .2770 \pm .0035$
-0.200 ±0.009	39819	<sup>96</sup> HOFFMASTER	72	HLBC	+	
-0.196 ±0.012	17898	<sup>97</sup> GRAUMAN	70	HLBC	+	$a_y = 0.228 \pm 0.030$
-0.193 ±0.010	50919	MAST	69	HBC	-	$a_y = 0.244 \pm 0.013$
-0.218 ±0.016	9994	<sup>98</sup> BUTLER	68	HBC	+	$a_y = 0.277 \pm 0.020$
-0.190 ±0.023	5778	<sup>98,99</sup> MOSCOSO	68	HBC	-	$a_y = 0.242 \pm 0.029$
-0.22 ±0.024	5428	<sup>98,99</sup> ZINCHENKO	67	HBC	+	$a_y = 0.28 \pm 0.03$
-0.220 ±0.035	1347	<sup>100</sup> FERRO-LUZZI	61	HBC	-	$a_y = 0.28 \pm 0.045$

<sup>94</sup> Final state strong interaction and radiative corrections not included in the fit.

<sup>95</sup> Quadratic dependence is required by  $K_L^0$  experiments.

<sup>96</sup> HOFFMASTER 72 includes GRAUMAN 70 data.

<sup>97</sup> Emulsion data added — all events included by HOFFMASTER 72.

<sup>98</sup> Experiments with large errors not included in average.

<sup>99</sup> Also includes DBC events.

<sup>100</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>101</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	HOFFMASTER	72	HLBC	+
-0.1 ±1.2	50919	MAST	69	HBC	-

<sup>101</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>102</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	HOFFMASTER	72	HLBC	+
-14 ±12	50919	MAST	69	HBC	-

<sup>102</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.

VALUE (units $10^{-4}$ )	EVTS	DOCUMENT ID	TECN
$-1.5 \pm 1.5 \pm 1.6$	3.1G	<sup>103</sup> BATLEY	07E NA48

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

$1.7 \pm 2.1 \pm 2.0$	1.7G	<sup>104</sup> BATLEY	06 NA48
$-70.0 \pm 53$	3.2M	FORD	70 ASPK

<sup>103</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>104</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.

VALUE	EVTS	DOCUMENT ID	TECN	CHG	COMMENT
<b><math>0.626 \pm 0.007</math></b>					<b>OUR AVERAGE</b>

$0.6259 \pm 0.0043 \pm 0.0093$  493k AKOPDZHAN..05B TNF  $\pm$

$0.627 \pm 0.004 \pm 0.010$  252k<sup>105,106</sup> AJINENKO 03B ISTR  $-$

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

$0.736 \pm 0.014 \pm 0.012$  33k BATUSOV 98 SPEC  $+$

$0.582 \pm 0.021$  43k BOLOTOV 86 CALO  $-$

$0.670 \pm 0.054$  3263 BRAUN 76B HLBC  $+$

$0.630 \pm 0.038$  5635 SHEAFF 75 HLBC  $+$

$0.510 \pm 0.060$  27k SMITH 75 WIRE  $+$

$0.67 \pm 0.06$  1365 AUBERT 72 HLBC  $+$

$0.544 \pm 0.048$  4048 DAVISON 69 HLBC  $+$  Also emulsion

<sup>105</sup> Measured using in-flight decays of the 25 GeV negative secondary beam.

<sup>106</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 $K^\pm \rightarrow \pi^\pm \pi^0 \pi^0$

VALUE	EVTS	DOCUMENT ID	TECN	CHG	COMMENT
<b><math>0.052 \pm 0.008</math></b>					<b>OUR AVERAGE</b>

$0.0551 \pm 0.0044 \pm 0.0086$  493k AKOPDZHAN..05B TNF  $\pm$

$0.046 \pm 0.004 \pm 0.012$  252k<sup>107</sup> AJINENKO 03B ISTR  $-$

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

$0.128 \pm 0.015 \pm 0.024$  33k BATUSOV 98 SPEC  $+$

$0.037 \pm 0.024$  43k BOLOTOV 86 CALO  $-$

$0.152 \pm 0.082$  3263 BRAUN 76B HLBC  $+$

$0.041 \pm 0.030$  5635 SHEAFF 75 HLBC  $+$

$0.009 \pm 0.040$  27k SMITH 75 WIRE  $+$

$-0.01 \pm 0.08$  1365 AUBERT 72 HLBC  $+$

$0.026 \pm 0.050$  4048 DAVISON 69 HLBC  $+$  Also emulsion

<sup>107</sup> Measured using in-flight decays of the 25 GeV negative secondary beam.

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

VALUE	EVTS	DOCUMENT ID	TECN	CHG
<b>0.0054 ± 0.0035 OUR AVERAGE</b>				
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>108</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	+
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<sup>108</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.

VALUE (units $10^{-4}$ )	EVTS	DOCUMENT ID	TECN
<b>1.8 ± 1.8 OUR AVERAGE</b>			
1.8 ± 1.7 ± 0.6	91.3M	<sup>109</sup> BATLEY	07E NA48
2 ± 18 ± 5	619k	<sup>110</sup> AKOPDZHAN..05	TNF

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

1.8 ± 2.2 ± 1.3	47M	<sup>111</sup> BATLEY	06A NA48
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<sup>109</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>110</sup> Asymmetry obtained assuming that  $g_+ + g_- = 2 \times 0.652$  (PDG 02) and that asymmetries in  $h$  and  $k$  are zero.

<sup>111</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 PARAMETRIZATIONS OF $K^\pm \rightarrow \pi^\pm \pi^0 \pi^0$ DALITZ PLOT

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

In addition, we also consider the effective field theory framework of COLANGELO 06A and BISSEGGER 09 to extract  $g_{BB}$  and  $h_{BB}^l$ .

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

VALUE	EVTS	DOCUMENT ID	TECN	CHG
<b>0.6525 ± 0.0009 ± 0.0033</b>	60M	<sup>112</sup> BATLEY	09A NA48	±
0.645 ± 0.004 ± 0.009	23M	<sup>113</sup> BATLEY	06B NA48	±

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

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

113 Superseded by BATLEY 09A. This fit is obtained with the CABIBBO 05 matrix element in the  $2\pi^0$  invariant mass squared range  $0.074 \text{ GeV}^2 < m_{2\pi^0}^2 < 0.097 \text{ GeV}^2$ , 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 $K^\pm \rightarrow \pi^\pm \pi^0 \pi^0$

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>
<b><math>-0.0433 \pm 0.0008 \pm 0.0026</math></b>	60M	114 BATLEY	09A NA48	$\pm$

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

$-0.047 \pm 0.012 \pm 0.011$	23M	115 BATLEY	06B NA48	$\pm$
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114 This fit is obtained with the CABIBBO 05 matrix element in the  $2\pi^0$  invariant mass squared range  $0.074094 < m_{2\pi^0}^2 < 0.104244 \text{ GeV}^2$ . Electromagnetic corrections and CHPT constraints for  $\pi\pi$  phase shifts ( $a_0$  and  $a_2$ ) have been used. Also measured  $(a_0 - a_2) m_{\pi^+} = 0.2646 \pm 0.0021 \pm 0.0023$ , where  $k_0$  was kept fixed in the fit at  $-0.0099$ .

115 Superseded by BATLEY 09A. This fit is obtained with the CABIBBO 05 matrix element in the  $2\pi^0$  invariant mass squared range  $0.074 \text{ GeV}^2 < m_{2\pi^0}^2 < 0.097 \text{ GeV}^2$ , 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 $k_0$ 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>
<b><math>0.0095 \pm 0.00017 \pm 0.00048</math></b>	60M	116 BATLEY	09A NA48	$\pm$

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

### LINEAR COEFFICIENT $g_{BB}$ 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>
<b><math>0.6219 \pm 0.0009 \pm 0.0033</math></b>	60M	117 BATLEY	09A NA48	$\pm$

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

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

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>
<b><math>-0.0520 \pm 0.0009 \pm 0.0026</math></b>	60M	118 BATLEY	09A NA48	$\pm$

<sup>118</sup>This fit is obtained using parametrizations of COLANGELO 06A and BISSEGGER 09 in the  $2\pi^0$  invariant mass squared range  $0.074094 < m_{2\pi^0}^2 < 0.104244 \text{ GeV}^2$ . Electromagnetic corrections and CHPT constraints for  $\pi\pi$  phase shifts ( $a_0$  and  $a_2$ ) have been used. Also measured  $(a_0 - a_2) m_{\pi^+} = 0.2633 \pm 0.0024 \pm 0.0024$ , where  $k_0$  was kept fixed in the fit at 0.0085.

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### $K_{e3}^{\pm}$ 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

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

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

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

ISTRA linear expansion coefficients are converted with

$$\lambda_+{}^{PDG} = \left(\frac{m_{\pi^+}}{m_{\pi^0}}\right)^2 \lambda_+{}^{ISTRA} \text{ and } \lambda_0{}^{PDG} = \left(\frac{m_{\pi^+}}{m_{\pi^0}}\right)^2 \lambda_0{}^{ISTRA}$$

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  $K_{e3}^\pm$  DECAY)**

These results are for a linear expansion only. See the next section for fits including a quadratic term. For radiative correction of the  $K_{e3}^\pm$  Dalitz plot, see GINSBERG 67, BECHERRAWY 70, CIRIGLIANO 02, CIRIGLIANO 04, and ANDRE 07. 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 B* **592** 1 (2004).

<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>2.97 ± 0.05 OUR FIT</b>	Assuming $\mu$ -e universality				
<b>2.98 ± 0.05 OUR AVERAGE</b>					
3.044 ± 0.083 ± 0.074	1.1M	AKOPDZANOV 09	TNF	±	
2.966 ± 0.050 ± 0.034	919k	<sup>119</sup> YUSHCHENKO 04B	ISTR	–	DP
2.78 ± 0.26 ± 0.30	41k	SHIMIZU 00	SPEC	+	DP
2.84 ± 0.27 ± 0.20	32k	<sup>120</sup> AKIMENKO 91	SPEC		PI, no RC
2.9 ± 0.4	62k	<sup>121</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>119,122</sup> AJINENKO 03C	ISTR	–	DP
2.93 ± 0.15 ± 0.2	130k	<sup>122</sup> AJINENKO 02	SPEC		DP

<sup>119</sup> Rescaled to agree with our conventions as noted above.

<sup>120</sup> AKIMENKO 91 state that radiative corrections would raise  $\lambda_+$  by 0.0013.

<sup>121</sup> BOLOTOV 88 state radiative corrections of GINSBERG 67 would raise  $\lambda_+$  by 0.002.

<sup>122</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 B* **592** 1 (2004).

<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>2.97 ± 0.05 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>123</sup> YUSHCHENKO04	ISTR	–	DP
• • • We do not use the following data for averages, fits, limits, etc. • • •					
3.21 ± 0.45	112k	<sup>124</sup> AJINENKO 03	ISTR	–	DP
<sup>123</sup> Rescaled to agree with our conventions as noted above.					
<sup>124</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 B* **592** 1 (2004).

<u>VALUE (units <math>10^{-2}</math>)</u>	<u><math>d\lambda_0/d\lambda_+</math></u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>	<u>COMMENT</u>
<b>1.95 ± 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>125</sup> YUSHCHENKO04	ISTR	–	DP

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

+2.09±0.45	-0.46	112k	<sup>126</sup> AJINENKO	03	ISTR	-	DP
+1.9 ±0.64		24k	<sup>127</sup> HORIE	01	SPEC	+	BR
+1.9 ±1.0	+0.03	55k	<sup>128</sup> HEINTZE	77	SPEC	+	BR

<sup>125</sup> Rescaled to agree with our conventions as noted above.

<sup>126</sup> Superseded by YUSHCHENKO 04.

<sup>127</sup> HORIE 01 assumes  $\mu$ - $e$  universality in  $K_{\ell 3}^+$  decay and uses SHIMIZU 00 value  $\lambda=0.0278 \pm 0.0040$  from  $K_{e3}^{\pm}$  decay.

<sup>128</sup> HEINTZE 77 uses  $\lambda_+ = 0.029 \pm 0.003$ .  $d\lambda_0/d\lambda_+$  estimated by us.

### $\lambda'_+$ (LINEAR $K_{e3}^{\pm}$ FORM FACTOR FROM QUADRATIC FIT)

VALUE (units $10^{-2}$ )	EVTS	DOCUMENT ID	TECN	CHG	COMMENT
<b>2.485±0.163±0.034</b>	919k	129,130 YUSHCHENKO04B	ISTR	-	DP

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

3.07 ±0.21	550k	<sup>129,131</sup> AJINENKO	03C	ISTR	-	DP
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<sup>129</sup> Rescaled to agree with our conventions as noted above.

<sup>130</sup> YUSHCHENKO 04B  $\lambda'_+$  and  $\lambda''_+$  are strongly correlated with coefficient  $\rho(\lambda'_+, \lambda''_+) = -0.95$ .

<sup>131</sup> Superseded by YUSHCHENKO 04B.

### $\lambda''_+$ (QUADRATIC $K_{e3}^{\pm}$ FORM FACTOR)

VALUE (units $10^{-2}$ )	EVTS	DOCUMENT ID	TECN	CHG	COMMENT
<b>0.192±0.062±0.071</b>	919k	132,133 YUSHCHENKO04B	ISTR	-	DP

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

-0.5 ±0.7 ±1.5	550k	<sup>132,134</sup> AJINENKO	03C	ISTR	-	DP
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<sup>132</sup> Rescaled to agree with our conventions as noted above.

<sup>133</sup> YUSHCHENKO 04B  $\lambda'_+$  and  $\lambda''_+$  are strongly correlated with coefficient  $\rho(\lambda'_+, \lambda''_+) = -0.95$ .

<sup>134</sup> Superseded by YUSHCHENKO 04B.

### $|f_S/f_+|$ FOR $K_{e3}^{\pm}$ DECAY

Ratio of scalar to  $f_+$  couplings.

VALUE (units $10^{-2}$ )	CL%	EVTS	DOCUMENT ID	TECN	CHG	COMMENT
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**-0.3 <sup>+0.8</sup>/<sub>-0.7</sub> OUR AVERAGE**

-0.37 <sup>+0.66</sup> / <sub>-0.56</sub> ±0.41	919k	YUSHCHENKO04B	ISTR	-	$\lambda'_+, \lambda''_+, f_S$ fit
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0.2 ±2.6 ±1.4	41k	SHIMIZU	00	SPEC	+	$\lambda_+, f_S, f_T$ fit
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• • • We do not use the following data for averages, fits, limits, etc. • • •

0.2 <sup>+2.0</sup> / <sub>-2.2</sub> ±0.3	550k	<sup>135</sup> AJINENKO	03C	ISTR	-	$\lambda_+, f_S, f_T$ fit
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-1.9 <sup>+2.5</sup> / <sub>-1.6</sub>	130k	<sup>135</sup> AJINENKO	02	SPEC		$\lambda_+, f_S$ fit
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7.0 ±1.6 ±1.6	32k	AKIMENKO	91	SPEC		$\lambda_+, f_S, f_T, \phi$ fit
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0 ± 10	2827	<sup>136</sup> BRAUN	75	HLBC	+	
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< 13	90	4017 CHIANG	72	OSPK	+	
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14 <sup>+3</sup> / <sub>-4</sub>	2707	<sup>136</sup> STEINER	71	HLBC	+	$\lambda_+, f_S, f_T, \phi$ fit
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< 23	90	BOTTERILL	68C	ASPK		
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< 18	90	BELLOTTI	67B	HLBC		
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< 30	95	KALMUS	67	HLBC	+	
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<sup>135</sup> Superseded by YUSHCHENKO 04B.

<sup>136</sup> Statistical errors only.

### $|f_T/f_+|$ FOR $K_{e3}^\pm$ DECAY

Ratio of tensor to  $f_+$  couplings.

VALUE (units $10^{-2}$ )	CL%	EVTS	DOCUMENT ID	TECN	CHG	COMMENT
<b>– 1.2 ± 2.3 OUR AVERAGE</b>						
– 1.2 ± 2.1 ± 1.1		919k	YUSHCHENKO04B	ISTR	–	$\lambda'_+, \lambda''_+, f_T$ fit
1 ± 14 ± 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 <sup>+</sup> <sub>–</sub> 6.4 <sup>±</sup> <sub>7.5</sub> ± 2.6		550k	<sup>137</sup> AJINENKO	03C	ISTR	– $\lambda_+, f_S, f_T$ fit
– 4.5 <sup>+</sup> <sub>–</sub> 6.0 <sub>5.7</sub>		130k	<sup>137</sup> AJINENKO	02	SPEC	$\lambda_+, f_T$ fit
53 <sup>+</sup> <sub>–10</sub> ± 10		32k	AKIMENKO	91	SPEC	$\lambda_+, f_S, f_T, \phi$ fit
7 ± 37		2827	<sup>138</sup> BRAUN	75	HLBC	+
< 75	90	4017	CHIANG	72	OSPK	+
24 <sup>+</sup> <sub>–14</sub> ± 16		2707	<sup>138</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>137</sup> Superseded by YUSHCHENKO 04B.

<sup>138</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>139</sup> YUSHCHENKO04	ISTR	–	DP
• • • We do not use the following data for averages, fits, limits, etc. • • •					
0.4 ± 0.5 ± 0.5	112k	<sup>140</sup> AJINENKO	03	ISTR	– DP

<sup>139</sup> The second error is the theoretical error from the uncertainty in the chiral perturbation theory prediction for  $\lambda_0$ , ±0.0053, combined in quadrature with the systematic error ±0.0009.

<sup>140</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>141</sup> AJINENKO	03	ISTR	– DP
2 ± 12	1585	BRAUN	75	HLBC	

<sup>141</sup> The second error is the theoretical error from the uncertainty in the chiral perturbation theory prediction for  $\lambda_0$ . Superseded by YUSHCHENKO 04.

## $K_{\ell 4}^{\pm}$ FORM FACTORS

Based on the parametrizations of AMOROS 99, the  $K_{\ell 4}^{\pm}$  form factors can be expressed as

$$F_s = f_s + f'_s q^2 + f''_s q^4 + f'_e S_e / 4m_\pi^2$$

$$F_p = f_p$$

$$G_p = g_p + g'_p q^2$$

$$H_p = h_p$$

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

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

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>
<b>5.712±0.032 OUR AVERAGE</b>				
5.705±0.003±0.035	1.1M	142 BATLEY	12 NA48	±
5.75 ±0.02 ±0.08	400k	143 PISLAK	03 B865	+

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

143 Radiative corrections included. Using Roy equations and not including isospin breaking, PISLAK 03 obtains the following  $\pi\pi$  scattering lengths  $a_0^0 = 0.228 \pm 0.012 \pm 0.004^{+0.012}_{-0.016}$ (theor.) and  $a_0^2 = -0.0365 \pm 0.0023 \pm 0.0008^{+0.0031}_{-0.0026}$ (theor.).

### $f'_s/f_s$ FOR $K^{\pm} \rightarrow \pi^+ \pi^- e^{\pm} \nu$ DECAY

<u>VALUE (units <math>10^{-2}</math>)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>
<b>15.2±0.7±0.5</b>	1.13M	144 BATLEY	10C NA48	±
• • • We do not use the following data for averages, fits, limits, etc. • • •				
17.2±0.9±0.6	670k	145 BATLEY	08A NA48	±

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

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

### $f''_s/f_s$ FOR $K^{\pm} \rightarrow \pi^+ \pi^- e^{\pm} \nu$ DECAY

<u>VALUE (units <math>10^{-2}</math>)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>
<b>-7.3±0.7±0.6</b>	1.13M	146 BATLEY	10C NA48	±
• • • We do not use the following data for averages, fits, limits, etc. • • •				
-9.0±0.9±0.7	670k	147 BATLEY	08A NA48	±

<sup>146</sup> Radiative corrections included. Using Roy equations and including isospin breaking, BATLEY 10C obtains the following scattering lengths  $a_0^0 = 0.2220 \pm 0.0128 \pm 0.0050 \pm 0.0037$  (theor.),  $a_0^2 = -0.0432 \pm 0.0086 \pm 0.0034 \pm 0.0028$  (theor.). The correlation with  $f'_s/f_s = -0.954$  and with  $f'_e/f_s = 0.019$ . Supersedes BATLEY 08A.

<sup>147</sup> Radiative corrections included. Using Roy equations and not including isospin breaking, BATLEY 08A obtains the following  $\pi\pi$  scattering length  $a_0^0 = 0.233 \pm 0.016 \pm 0.007$   
 $a_0^2 = -0.0471 \pm 0.011 \pm 0.004$ .

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

<u>VALUE (units <math>10^{-2}</math>)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>
<b>6.8±0.6±0.7</b>	1.13M	<sup>148</sup> BATLEY	10C NA48	±

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

8.1±0.8±0.9	670k	<sup>149</sup> BATLEY	08A NA48	±
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<sup>148</sup> Radiative corrections included. Using Roy equations and including isospin breaking, BATLEY 10C obtains the following scattering lengths  $a_0^0 = 0.2220 \pm 0.0128 \pm 0.0050 \pm 0.0037$  (theor.),  $a_0^2 = -0.0432 \pm 0.0086 \pm 0.0034 \pm 0.0028$  (theor.). The correlation with  $f'_s/f_s = 0.080$  and with  $f''_s/f_s = 0.019$ . Supersedes BATLEY 08A.

<sup>149</sup> Radiative corrections included. Using Roy equations and not including isospin breaking, BATLEY 08A obtains the following  $\pi\pi$  scattering length  $a_0^0 = 0.233 \pm 0.016 \pm 0.007$   
 $a_0^2 = -0.0471 \pm 0.011 \pm 0.004$ .

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

<u>VALUE (units <math>10^{-2}</math>)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>
<b>-4.8±0.3±0.4</b>	1.13M	<sup>150</sup> BATLEY	10C NA48	±

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

-4.8±0.4±0.4	670k	<sup>151</sup> BATLEY	08A NA48	±
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<sup>150</sup> Radiative corrections included. Using Roy equations and including isospin breaking, BATLEY 10C obtains the following scattering lengths  $a_0^0 = 0.2220 \pm 0.0128 \pm 0.0050 \pm 0.0037$  (theor.),  $a_0^2 = -0.0432 \pm 0.0086 \pm 0.0034 \pm 0.0028$  (theor.). Supersedes BATLEY 08A.

<sup>151</sup> Radiative corrections included. Using Roy equations and not including isospin breaking, BATLEY 08A obtains the following  $\pi\pi$  scattering length  $a_0^0 = 0.233 \pm 0.016 \pm 0.007$   
 $a_0^2 = -0.0471 \pm 0.011 \pm 0.004$ .

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

<u>VALUE (units <math>10^{-2}</math>)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>
<b>86.8±1.0±1.0</b>	1.13M	<sup>152</sup> BATLEY	10C NA48	±

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

87.3±1.3±1.2	670k	<sup>153</sup> BATLEY	08A NA48	±
80.9±0.9±1.2	400k	<sup>154</sup> PISLAK	03 B865	±

- 152 Radiative corrections included. Using Roy equations and including isospin breaking, BATLEY 10C obtains the following scattering lengths  $a_0^0 = 0.2220 \pm 0.0128 \pm 0.0050 \pm 0.0037$  (theor.),  $a_0^2 = -0.0432 \pm 0.0086 \pm 0.0034 \pm 0.0028$  (theor.). Supersedes BATLEY 08A. The correlation with  $g'_p/f_s = -0.914$ . Supersedes BATLEY 08A.
- 153 Radiative corrections included. Using Roy equations and not including isospin breaking, BATLEY 08A obtains the following  $\pi\pi$  scattering length  $a_0^0 = 0.233 \pm 0.016 \pm 0.007$ ,  $a_0^2 = -0.0471 \pm 0.011 \pm 0.004$ .
- 154 Radiative corrections included. Using Roy equations PISLAK 03 obtains the following scattering lengths  $a_0^0 = 0.203 \pm 0.033 \pm 0.004$ ,  $a_0^2 = -0.055 \pm 0.023 \pm 0.003$ .

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

<u>VALUE (units <math>10^{-2}</math>)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>
<b><math>8.9 \pm 1.7 \pm 1.3</math></b>	1.13M	155 BATLEY	10C NA48	$\pm$

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

$8.1 \pm 2.2 \pm 1.5$	670k	156 BATLEY	08A NA48	$\pm$
$12.0 \pm 1.9 \pm 0.7$	400k	157 PISLAK	03 B865	$\pm$

- 155 Radiative corrections included. Using Roy equations and including isospin breaking, BATLEY 10C obtains the following scattering lengths  $a_0^0 = 0.2220 \pm 0.0128 \pm 0.0050 \pm 0.0037$  (theor.),  $a_0^2 = -0.0432 \pm 0.0086 \pm 0.0034 \pm 0.0028$  (theor.). The correlation with  $g_p/f_s = -0.914$ . Supersedes BATLEY 08A.
- 156 Radiative corrections included. Using Roy equations and not including isospin breaking, BATLEY 08A obtains the following  $\pi\pi$  scattering length  $a_0^0 = 0.233 \pm 0.016 \pm 0.007$ ,  $a_0^2 = -0.0471 \pm 0.011 \pm 0.004$ .
- 157 Radiative corrections included. Using Roy equations PISLAK 03 obtains the following scattering lengths  $a_0^0 = 0.203 \pm 0.033 \pm 0.004$ ,  $a_0^2 = -0.055 \pm 0.023 \pm 0.003$ .

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

<u>VALUE (units <math>10^{-2}</math>)</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>
<b><math>-39.8 \pm 1.5 \pm 0.8</math></b>	1.13M	158 BATLEY	10C NA48	$\pm$

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

$-41.1 \pm 1.9 \pm 0.8$	670k	159 BATLEY	08A NA48	$\pm$
$-51.3 \pm 3.3 \pm 3.5$	400k	160 PISLAK	03 B865	$\pm$

- 158 Radiative corrections included. Using Roy equations and including isospin breaking, BATLEY 10C obtains the following scattering lengths  $a_0^0 = 0.2220 \pm 0.0128 \pm 0.0050 \pm 0.0037$  (theor.),  $a_0^2 = -0.0432 \pm 0.0086 \pm 0.0034 \pm 0.0028$  (theor.). Supersedes BATLEY 08A.
- 159 Radiative corrections included. Using Roy equations and not including isospin breaking, BATLEY 08A obtains the following  $\pi\pi$  scattering length  $a_0^0 = 0.233 \pm 0.016 \pm 0.007$ ,  $a_0^2 = -0.0471 \pm 0.011 \pm 0.004$ .
- 160 Radiative corrections included. Using Roy equations PISLAK 03 obtains the following scattering lengths  $a_0^0 = 0.203 \pm 0.033 \pm 0.004$ ,  $a_0^2 = -0.055 \pm 0.023 \pm 0.003$ .

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

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.

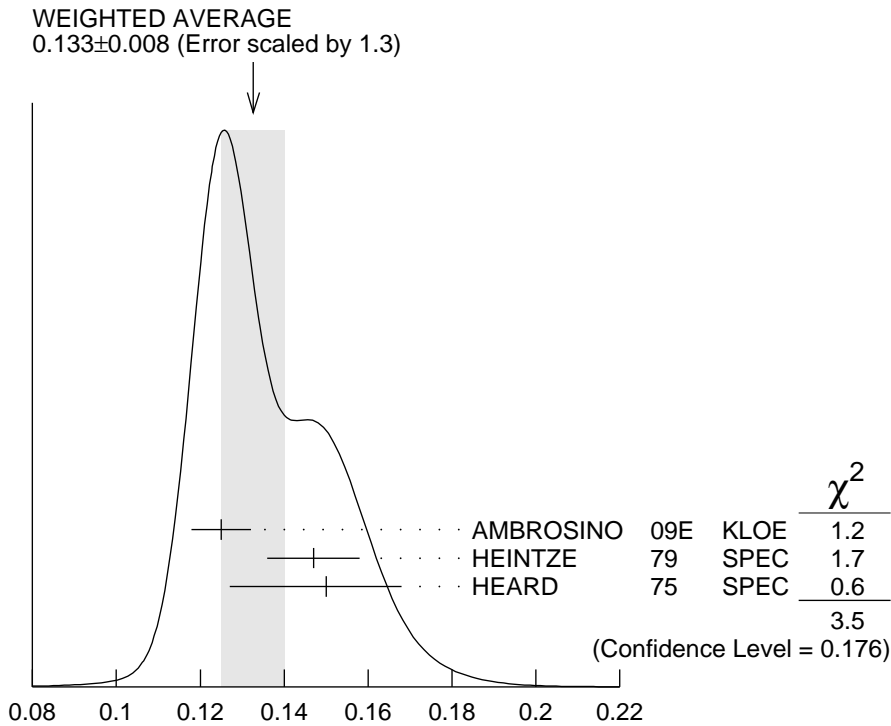
### $F_A + F_V$ , SUM OF AXIAL-VECTOR AND VECTOR FORM FACTOR FOR $K \rightarrow e \nu_e \gamma$

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
<b>0.133±0.008 OUR AVERAGE</b>		Error includes scale factor of 1.3. See the ideogram below.		
0.125±0.007±0.001	1.4K	<sup>161</sup> AMBROSINO 09E	KLOE	$E_\gamma$ in 10–250 MeV, $p_e > 200$ MeV/c
0.147±0.011	51	<sup>162</sup> HEINTZE 79	SPEC	
0.150 <sup>+0.018</sup> <sub>-0.023</sub>	56	<sup>163</sup> HEARD 75	SPEC	

<sup>161</sup> Vector form factor fitted with a linear function,  $V(x) = F_V (1 + \lambda(1-x))$ ,  $x = 2E_\gamma/m_K$ .  
The fitted value of  $\lambda = 0.38 \pm 0.20 \pm 0.02$  with a correlation of  $-0.93$  between  $(F_V + F_A)$  and  $\lambda$ .

<sup>162</sup> HEINTZE 79 quotes absolute value of  $|F_A + F_V| \sin\theta_c$ . We use  $\sin\theta_c = V_{us} = 0.2205$ .

<sup>163</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 $K \rightarrow e \nu_e \gamma$

### $F_A + F_V$ , SUM OF AXIAL-VECTOR AND VECTOR FORM FACTOR FOR $K \rightarrow \mu\nu\mu\gamma$

<u>VALUE</u>	<u>CL%</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>
<b>0.165±0.007±0.011</b>		2588	<sup>164</sup> 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		<sup>164</sup> AKIBA	85	SPEC

<sup>164</sup> Quotes absolute value. Sign not determined.

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

<u>VALUE</u>	<u>CL%</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
<b>&lt;0.49</b>	90	<sup>165</sup> HEINTZE	79 SPEC

<sup>165</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 $K \rightarrow \mu\nu\mu\gamma$

<u>VALUE</u>	<u>CL%</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>CHG</u>
<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

<u>VALUE (fm)</u>	<u>DOCUMENT ID</u>	<u>COMMENT</u>
<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

$$\Delta(K_{\pi ee}^\pm) = \frac{\Gamma(K_{\pi ee}^+) - \Gamma(K_{\pi ee}^-)}{\Gamma(K_{\pi ee}^+) + \Gamma(K_{\pi ee}^-)}$$

<u>VALUE (units <math>10^{-2}</math>)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
<b>-2.2±1.5±0.6</b>	<sup>166</sup> BATLEY	09 NA48

<sup>166</sup> This implies an upper limit of  $2.1 \times 10^{-2}$  at 90% CL.

$$\Delta(K_{\pi\mu\mu}^\pm) = \frac{\Gamma(K_{\pi\mu\mu}^+) - \Gamma(K_{\pi\mu\mu}^-)}{\Gamma(K_{\pi\mu\mu}^+) + \Gamma(K_{\pi\mu\mu}^-)}$$

<u>VALUE</u>	<u>DOCUMENT ID</u>	<u>TECN</u>
<b>0.010±0.023 OUR AVERAGE</b>		
0.011±0.023	<sup>167</sup> BATLEY	11A NA48
-0.02 ±0.11 ±0.04	PARK	02 HYCP

<sup>167</sup> This corresponds to the asymmetry upper limit of  $< 2.9 \times 10^{-2}$  at 90% CL.

$$\Delta(K_{\pi\pi\gamma}^{\pm}) = \frac{\Gamma(K_{\pi\pi\gamma}^{+}) - \Gamma(K_{\pi\pi\gamma}^{-})}{\Gamma(K_{\pi\pi\gamma}^{+}) + \Gamma(K_{\pi\pi\gamma}^{-})}$$

VALUE (units $10^{-3}$ )	EVTs	DOCUMENT ID	TECN
<b><math>0.0 \pm 1.0 \pm 0.6</math></b>	1M	168 BATLEY	10A NA48

<sup>168</sup> This value implies the upper bound for this asymmetry  $1.5 \times 10^{-3}$  at 90% CL.

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

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

VALUE	CL%	DOCUMENT ID	TECN
<b><math>&lt; 2.3 \times 10^{-2}</math></b>	90	169 BATLEY	11A NA48

<sup>169</sup> BATLEY 11A gives a corresponding value of the asymmetry  $A_{FB} = (-2.4 \pm 1.8) \times 10^{-2}$ .

### 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><math>-1.7 \pm 2.3 \pm 1.1</math></b>		170 ABE	04F K246	+

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

$-4.2 \pm 4.9 \pm 0.9$	3.9M	ABE	99S K246	+
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<sup>170</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	171 ANISIMOVSK..03	K246	+

<sup>171</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> OUR AVERAGE</b>					

$-0.0053 \pm 0.0071 \pm 0.0036$		172 ABE	04F K246	+	
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$-0.016 \pm 0.025$	20M	CAMPBELL	81 CNTR	+	Pol.
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• • • 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>172</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**

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BATLEY	14	PL B730 141	J.R. Batley <i>et al.</i>	(CERN NA48/2 Collab.)
BATLEY	14A	JHEP 1408 159	J.R. Batley <i>et al.</i>	(CERN NA48/2 Collab.)
LAZZERONI	14	PL B732 65	C. Lazzeroni <i>et al.</i>	(CERN NA62 Collab.)
UVAROV	14	PAN 77 725	V. A. Uvarov <i>et al.</i>	(ISTRA+ Collab.)
		Translated from YAF 77 765.		
LAZZERONI	13	PL B719 326	C. Lazzeroni <i>et al.</i>	(CERN NA62 Collab.)
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PDG	12	PR D86 010001	J. Beringer <i>et al.</i>	(PDG Collab.)
BATLEY	11A	PL B697 107	J.R. Batley <i>et al.</i>	(CERN NA48/2 Collab.)
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ADLER	10	PR D81 092001	S. Adler <i>et al.</i>	(BNL E787 Collab.)
BATLEY	10A	EPJ C68 75	J.R. Batley <i>et al.</i>	(CERN NA48/2 Collab.)
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AMBROSINO	09E	EPJ C64 627	F. Ambrosino <i>et al.</i>	(KLOE Collab.)
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BATLEY	09	PL B677 246	J.R. Batley <i>et al.</i>	(CERN NA48/2 Collab.)
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ARTAMONOV	08	PRL 101 191802	A.V. Artamonov <i>et al.</i>	(BNL E949 Collab.)
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Also		EPJ C52 1021 (errata)	J.R. Batley <i>et al.</i>	(CERN NA48/2 Collab.)
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CIRIGLIANO	02	EPJ C23 121	V. Cirigliano <i>et al.</i>	(VIEN, VALE, MARS)
PARK	02	PRL 88 111801	H.K. Park <i>et al.</i>	(FNAL HyperCP Collab.)
PDG	02	PR D66 010001	K. Hagiwara <i>et al.</i>	
POBLAGUEV	02	PRL 89 061803	A.A. Poblaguev <i>et al.</i>	(BNL 865 Collab.)
ADLER	01	PR D63 032004	S. Adler <i>et al.</i>	(BNL E787 Collab.)
HORIE	01	PL B513 311	K. Horie <i>et al.</i>	(KEK E426 Collab.)
PISLAK	01	PRL 87 221801	S. Pislak <i>et al.</i>	(BNL E865 Collab.)
Also		PR D67 072004	S. Pislak <i>et al.</i>	(BNL E865 Collab.)
Also		PRL 105 019901E	S. Pislak <i>et al.</i>	(BNL E865 Collab.)
ADLER	00	PRL 84 3768	S. Adler <i>et al.</i>	(BNL E787 Collab.)
ADLER	00B	PRL 85 2256	S. Adler <i>et al.</i>	(BNL E787 Collab.)
ADLER	00C	PRL 85 4856	S. Adler <i>et al.</i>	(BNL E787 Collab.)
APPEL	00	PRL 85 2450	R. Appel <i>et al.</i>	(BNL 865 Collab.)
Also		Thesis, Yale Univ.	D.R. Bergman	
Also		Thesis, Univ. Zurich	S. Pislak	
APPEL	00B	PRL 85 2877	R. Appel <i>et al.</i>	(BNL 865 Collab.)
MA	00	PRL 84 2580	H. Ma <i>et al.</i>	(BNL 865 Collab.)
PDG	00	EPJ C15 1	D.E. Groom <i>et al.</i>	(PDG Collab.)
SHIMIZU	00	PL B495 33	S. Shimizu <i>et al.</i>	(KEK E246 Collab.)
ABE	99S	PRL 83 4253	M. Abe <i>et al.</i>	(KEK E246 Collab.)
AMOROS	99	JP G25 1607	G. Amoros, J. Bijnens	(LUND, HELS)
APPEL	99	PRL 83 4482	R. Appel <i>et al.</i>	(BNL 865 Collab.)
ADLER	98	PR D58 012003	S. Adler <i>et al.</i>	(BNL E787 Collab.)
BATUSOV	98	NP B516 3	V.Y. Batusov <i>et al.</i>	
DAMBROSIO	98A	JHEP 9808 004	G. D'Ambrosio <i>et al.</i>	
ADLER	97	PRL 79 2204	S. Adler <i>et al.</i>	(BNL E787 Collab.)
ADLER	97C	PRL 79 4756	S. Adler <i>et al.</i>	(BNL E787 Collab.)
BERGMAN	97	Thesis, Yale Univ.	D.R. Bergman	
KITCHING	97	PRL 79 4079	P. Kitching <i>et al.</i>	(BNL E787 Collab.)
PISLAK	97	Thesis, Univ. Zurich	S. Pislak	
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)
		Translated from YAF 55 976.		
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)
		Translated from YAF 53 981.		
DENISOV	91	JETPL 54 558	A.S. Denisov <i>et al.</i>	(PNPI)
		Translated from ZETFP 54 557.		
Also		THESIS	Yu.M. Ivanov	(PNPI)
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+)
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)
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)
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)
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)
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. Werbrouck	(TORI)
CALLAHAN	64	PR 136 B1463	A. Callahan, R. March, R. Stark	(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 *et al.* (COLU)  
 COOMBES 57 PR 108 1348 C.A. Coombes *et al.* (LBL)

———— **OTHER RELATED PAPERS** ————

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 "Rare *K* Decays"  
 BATTISTON 92 PRPL 214 293 R. Battiston *et al.* (PGIA, CERN, TRSTT)  
 Status and Perspectives of *K* Decay Physics  
 BRYMAN 89 IJMP A4 79 D.A. Bryman (TRIU)  
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 CHOUNET 72 PRPL 4C 199 L.M. Chounet, J.M. Gaillard, M.K. Gaillard (ORSAY+)  
 FEARING 70 PR D2 542 H.W. Fearing, E. Fischbach, J. Smith (STON, BOHR)  
 HAIDT 69B PL 29B 696 D. Haidt *et al.* (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)  
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 Also PL 14 72 N. Cabibbo, A. Maksymowicz (CERN)  
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