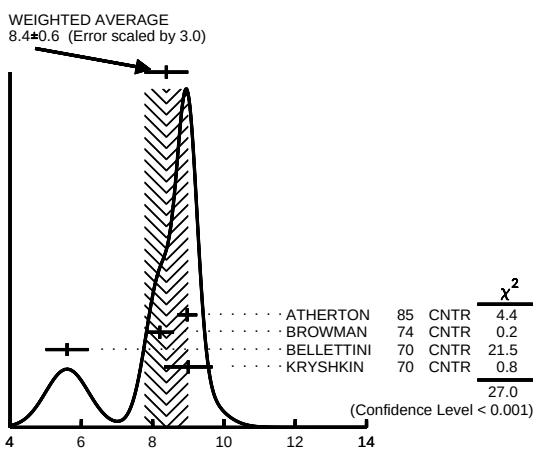
π^0 MEAN LIFE

Measurements with an error $> 1 \times 10^{-17}$ s have been omitted.

VALUE (10^{-17} s)	EVTS	DOCUMENT ID		TECN	COMMENT
8.4 ±0.6 OUR AVERAGE		Error includes scale factor of 3.0. See the ideogram below.			
8.97±0.22±0.17		ATHERTON	85	CNTR	
8.2 ±0.4		[1] BROWMAN	74	CNTR	Primakoff effect
5.6 ±0.6		BELLETTINI	70	CNTR	Primakoff effect
9 ±0.68		KRYSHKIN	70	CNTR	Primakoff effect
• • • We do not use the following data for averages, fits, limits, etc. • • •					
8.4 ±0.5 ±0.5	1182	[2] WILLIAMS	88	CBAL	$e^+e^- \to e^+e^-\pi^0$

[1] BROWMAN 74 gives a π^0 width $\Gamma = 8.02 \pm 0.42$ eV. The mean life is $\hbar/\Gamma$.
[2] WILLIAMS 88 gives $\Gamma(\gamma\gamma) = 7.7 \pm 0.5 \pm 0.5$ eV. We give here $\tau = \hbar/\Gamma$(total).



π^0 DECAY MODES

	Mode	Fraction (Γ_i/Γ)	Scale factor/ Confidence level
Γ_1	2γ	(98.798±0.032) %	S=1.1
Γ_2	$e^+e^-\gamma$	(1.198±0.032) %	S=1.1
Γ_3	γ positronium	(1.82 ±0.29) $\times 10^{-9}$	
Γ_4	$e^+e^+e^-e^-$	(3.14 ±0.30) $\times 10^{-5}$	
Γ_5	e^+e^-	(7.5 ±2.0) $\times 10^{-8}$	
Γ_6	4γ	< 2 $\times 10^{-8}$	CL=90%
Γ_7	$\nu\overline{\nu}$	[a] < 8.3 $\times 10^{-7}$	CL=90%
Γ_8	$\nu_e\overline{\nu}_e$	< 1.7 $\times 10^{-6}$	CL=90%
Γ_9	$\nu_\mu\overline{\nu}_\mu$	< 3.1 $\times 10^{-6}$	CL=90%
Γ_{10}	$\nu_\tau\overline{\nu}_\tau$	< 2.1 $\times 10^{-6}$	CL=90%

Charge conjugation (C) or Lepton Family number (LF) violating modes

Γ_{11}	3γ	C	< 3.1 $\times 10^{-8}$		CL=90%
Γ_{12}	μ^+e^-	LF			
Γ_{13}	$\mu^+e^- + e^-\mu^+$	LF	< 1.72 $\times 10^{-8}$		CL=90%

[a] Astrophysical and cosmological arguments give limits of order 10^{-13}; see the Full Listings below.

CONSTRAINED FIT INFORMATION

An overall fit to 2 branching ratios uses 4 measurements and one constraint to determine 3 parameters. The overall fit has a $\chi^2 = 1.9$ for 2 degrees of freedom.

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

x_2	−100	
x_4	−1	0
	x_1	x_2

π^0 BRANCHING RATIOS

$\Gamma(e^+e^-\gamma)/\Gamma(2\gamma)$ Γ_2/Γ_1

VALUE (%)	EVTS	DOCUMENT ID		TECN	COMMENT
1.213±0.033 OUR FIT		Error includes scale factor of 1.1.			
1.213±0.030 OUR AVERAGE					
1.25 ±0.04		SCHARDT	81	SPEC	$\pi^- p \to n\pi^0$
1.166±0.047	3071	[3] SAMIOS	61	HBC	$\pi^- p \to n\pi^0$
1.17 ±0.15	27	BUDAGOV	60	HBC	
• • • We do not use the following data for averages, fits, limits, etc. • • •					
1.196		JOSEPH	60	THEO	QED calculation

[3] SAMIOS 61 value uses a Panofsky ratio = 1.62.

$\Gamma(\gamma\,\text{positronium})/\Gamma(2\gamma)$ Γ_3/Γ_1

VALUE (units 10^{-9})	EVTS	DOCUMENT ID		TECN	COMMENT
1.84±0.29	277	AFANASYEV	90	CNTR	pC 70 GeV

$\Gamma(e^+e^+e^-e^-)/\Gamma(2\gamma)$ Γ_4/Γ_1

VALUE (units 10^{-5})	EVTS	DOCUMENT ID		TECN
3.18±0.30 OUR FIT				
3.18±0.30	146	[4] SAMIOS	62B	HBC

[4] SAMIOS 62B value uses a Panofsky ratio = 1.62.

$\Gamma(e^+e^-)/\Gamma_{\rm total}$ Γ_5/Γ

VALUE (units 10^{-8})	EVTS	DOCUMENT ID		TECN	COMMENT
7.5±2.0 OUR AVERAGE					
6.9±2.3±0.6	21	[5] DESHPANDE	93	SPEC	$K^+ \to \pi^+\pi^0$
$8.8^{+4.5}_{-3.2}\pm0.6$	8	[6] MCFARLAND	93	SPEC	$K_L^0 \to 3\pi^0$ in flight

[5] The DESHPANDE 93 result with bremsstrahlung radiative corrections is $(8.0 \pm 2.6 \pm 0.6) \times 10^{-8}$.
[6] The MCFARLAND 93 result with radiative corrections and excluding $[m_{ee}/m_{\pi^0}]^2 < 0.95$ is $(7.6^{+3.9}_{-2.8} \pm 0.5) \times 10^{-8}$.

$\Gamma(e^+e^-)/\Gamma(2\gamma)$ Γ_5/Γ_1

VALUE (units 10^{-7})	CL%	EVTS	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •						
<1.3	90		NIEBUHR	89	SPEC	$\pi^- p \to \pi^0 n$ at rest
<5.3	90		ZEPHAT	87	SPEC	$\pi^- p \to \pi^0 n$ 0.3 GeV/c
1.7 ±0.6 ±0.3		59	FRANK	83	SPEC	$\pi^- p \to n\pi^0$
1.8 ±0.6		58	MISCHKE	82	SPEC	See FRANK 83
$2.23^{+2.40}_{-1.10}$	90	8	FISCHER	78B	SPRK	$K^+ \to \pi^+\pi^0$

$\Gamma(4\gamma)/\Gamma_{\rm total}$ Γ_6/Γ

VALUE (units 10^{-8})	CL%	EVTS	DOCUMENT ID		TECN	COMMENT
< 2	90		MCDONOUGH	88	CBOX	$\pi^- p$ at rest
• • • We do not use the following data for averages, fits, limits, etc. • • •						
<160	90		BOLOTOV	86C	CALO	
<440	90	0	AUERBACH	80	CNTR	

$\Gamma(\nu\overline{\nu})/\Gamma_{\rm total}$ Γ_7/Γ

The astrophysical and cosmological limits are many orders of magnitude lower, but we use the best laboratory limit for the Summary Tables.

VALUE (units 10^{-6})	CL%	EVTS	DOCUMENT ID		TECN	COMMENT
< 0.83	90		[7] ATIYA	91	CNTR	$K^+ \to \pi^+ \nu\nu'$
• • • We do not use the following data for averages, fits, limits, etc. • • •						
< 2.9 × 10^{-7}			[8] LAM	91		Cosmological limit
< 3.2 × 10^{-7}			[9] NATALE	91		SN 1987A
< 6.5	90		DORENBOS...	88	CHRM	Beam dump, prompt ν
<24	90	0	[7] HERCZEG	81	RVUE	$K^+ \to \pi^+ \nu\nu'$

[7] This limit applies to all possible $\nu\nu'$ states as well as to other massless, weakly interacting states.
[8] LAM 91 considers the production of right-handed neutrinos produced from the cosmic thermal background at the temperature of about the pion mass through the reaction $\gamma\gamma \to \pi^0 \to \nu\overline{\nu}$.
[9] NATALE 91 considers the excess energy-loss rate from SN1987A if the process $\gamma\gamma \to \pi^0 \to \nu\overline{\nu}$ occurs, permitted if the neutrinos have a right-handed component. As pointed out in LAM 91 (and confirmed by Natale), there is a factor 4 error in the NATALE 91 published result (0.8×10^{-7}).

$\Gamma(\nu_e\overline{\nu}_e)/\Gamma_{\rm total}$ Γ_8/Γ

VALUE (units 10^{-6})	CL%	DOCUMENT ID		TECN	COMMENT
<1.7	90	DORENBOS...	88	CHRM	Beam dump, prompt ν
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<3.1	90	[10] HOFFMAN	88	RVUE	Beam dump, prompt ν

[10] HOFFMAN 88 analyzes data from a 400-GeV BEBC beam-dump experiment.