$\pi^{\pm}$ MASS

Measurements with an error > 0.005 MeV have been omitted from this Listing. The fit uses $m_{\pi^{\pm}}$ and $(m_{\pi^{\pm}} - m_{\pi^0})$.

VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT
139.56995±0.00035 OUR FIT					
139.56995±0.00035	[1] JECKELMANN	94	CNTR	−	π^- atom, Soln. B
• • • We do not use the following data for averages, fits, limits, etc. • • •					
139.56782±0.00037	[1] JECKELMANN	94	CNTR	−	π^- atom, Soln. A
139.56996±0.00067	[2] DAUM	91	SPEC	+	$\pi^+ \to \mu^+ \nu$
139.56752±0.00037	[3] JECKELMANN	86B	CNTR	−	Mesonic atoms
139.5704 ±0.0011	[2] ABELA	84	SPEC	+	See DAUM 91
139.5664 ±0.0009	[4] LU	80	CNTR	−	Mesonic atoms
139.5686 ±0.0020	CARTER	76	CNTR	−	Mesonic atoms
139.5660 ±0.0024	[4,5] MARUSHEN...	76	CNTR	−	Mesonic atoms

[1] See the above "Note on the Charged Pion Mass" for a discussion of the two JECKELMANN 94 values.
[2] The DAUM 91 value includes the ABELA 84 result. The value is based on a measurement of the μ^+ momentum for π^+ decay at rest, $p_\mu = 29.79179 \pm 0.00053$ MeV, uses $m_\mu = 105.658389 \pm 0.000034$ MeV, and assumes that $m_{\nu_\mu} = 0$. The last assumption means that in fact the value is a lower limit.
[3] JECKELMANN 86B gives $m_\pi/m_e = 273.12677(71)$. We use $m_e = 0.51099906(15)$ MeV from COHEN 87. The authors note that two solutions for the probability distribution of K-shell occupancy fit equally well, and use other data to choose the lower of the two possible $\pi^\pm$ masses.
[4] These values are scaled with a new wavelength-energy conversion factor $V\lambda = 1.23984244(37) \times 10^{-6}$ eV m from COHEN 87. The LU 80 screening correction relies upon a theoretical calculation of inner-shell refilling rates.
[5] This MARUSHENKO 76 value used at the authors' request to use the accepted set of calibration γ energies. Error increased from 0.0017 MeV to include QED calculation error of 0.0017 MeV (12 ppm).

$m_{\pi^+} - m_{\mu^+}$

Measurements with an error > 0.05 MeV have been omitted from this Listing.

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •						
33.91157±0.00067		[6] DAUM	91	SPEC	+	$\pi^+ \to \mu^+ \nu$
33.9111 ±0.0011		ABELA	84	SPEC		See DAUM 91
33.925 ±0.025		BOOTH	70	CNTR	+	Magnetic spect.
33.881 ±0.035	145	HYMAN	67	HEBC	+	K^- He

[6] The DAUM 91 value assumes that $m_{\nu_\mu} = 0$ and uses our $m_\mu = 105.658389 \pm 0.000034$ MeV.

$(m_{\pi^+} - m_{\pi^-}) / m_{\text{average}}$

A test of *CPT* invariance.

VALUE (units 10^{-4})	DOCUMENT ID		TECN
2±5	AYRES	71	CNTR

$\pi^{\pm}$ MEAN LIFE

Measurements with an error > 0.02×10^{-8} s have been omitted.

VALUE (10^{-8} s)	DOCUMENT ID		TECN	CHG
2.6030±0.0024 OUR AVERAGE				
2.609 ±0.008	DUNAITSEV	73	CNTR	+
2.602 ±0.004	AYRES	71	CNTR	±
2.604 ±0.005	NORDBERG	67	CNTR	+
2.602 ±0.004	ECKHAUSE	65	CNTR	+
• • • We do not use the following data for averages, fits, limits, etc. • • •				
2.640 ±0.008	[7] KINSEY	66	CNTR	+

[7] Systematic errors in the calibration of this experiment are discussed by NORDBERG 67.

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

A test of *CPT* invariance.

VALUE (units 10^{-4})	DOCUMENT ID		TECN
5.5± 7.1	AYRES	71	CNTR
• • • We do not use the following data for averages, fits, limits, etc. • • •			
−14 ±29	PETRUKHIN	68	CNTR
40 ±70	BARDON	66	CNTR
23 ±40	[8] LOBKOWICZ	66	CNTR

[8] This is the most conservative value given by LOBKOWICZ 66.

π^+ DECAY MODES

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

	Mode		Fraction (Γ_i/Γ)	Confidence level
Γ_1	$\mu^+ \nu_\mu$	[a]	(99.98770±0.00004) %	
Γ_2	$\mu^+ \nu_\mu \gamma$	[b]	(1.24 ±0.25) $\times 10^{-4}$	
Γ_3	$e^+ \nu_e$	[a]	(1.230 ±0.004) $\times 10^{-4}$	
Γ_4	$e^+ \nu_e \gamma$	[b]	(1.61 ±0.23) $\times 10^{-7}$	
Γ_5	$e^+ \nu_e \pi^0$		(1.025 ±0.034) $\times 10^{-8}$	
Γ_6	$e^+ \nu_e e^+ e^-$		(3.2 ±0.5) $\times 10^{-9}$	
Γ_7	$e^+ \nu_e \nu \overline{\nu}$		< 5 $\times 10^{-6}$	90%
	Lepton Family number (*LF*) or Lepton number (*L*) violating modes			
Γ_8	$\mu^+ \overline{\nu}_e$	*L* [c]	< 1.5 $\times 10^{-3}$	90%
Γ_9	$\mu^+ \nu_e$	*LF* [c]	< 8.0 $\times 10^{-3}$	90%
Γ_{10}	$\mu^- e^+ e^+ \nu$	*LF*	< 1.6 $\times 10^{-6}$	90%

[a] Measurements of $\Gamma(e^+\nu_e)/\Gamma(\mu^+\nu_\mu)$ always include decays with γ's, and measurements of $\Gamma(e^+\nu_e\gamma)$ and $\Gamma(\mu^+\nu_\mu\gamma)$ never include low-energy γ's. Therefore, since no clean separation is possible, we consider the modes with γ's to be subreactions of the modes without them, and let $[\Gamma(e^+\nu_e) + \Gamma(\mu^+\nu_\mu)]/\Gamma_{\text{total}} = 100\%$.

[b] See the Full Listings below for the energy limits used in this measurement; low-energy γ's are not included.

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

π^+ BRANCHING RATIOS

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

See note [a] in the list of π^+ decay modes just above, and see also the next block of data.

VALUE (units 10^{-4})	DOCUMENT ID
1.230±0.004 OUR EVALUATION	

$[\Gamma(e^+\nu_e) + \Gamma(e^+\nu_e\gamma)]/[\Gamma(\mu^+\nu_\mu) + \Gamma(\mu^+\nu_\mu\gamma)]$ — $(\Gamma_3+\Gamma_4)/(\Gamma_1+\Gamma_2)$

See note [a] in the list of π^+ decay modes above. See NUMAO 92 for a discussion of e-μ universality.

VALUE (units 10^{-4})	EVTS	DOCUMENT ID		TECN	COMMENT
1.230 ±0.004 OUR AVERAGE					
1.2346±0.0035±0.0036	120k	CZAPEK	93	CALO	Stopping π^+
1.2265±0.0034±0.0044	190k	BRITTON	92	CNTR	Stopping π^+
1.218 ±0.014	32k	BRYMAN	86	CNTR	Stopping π^+
• • • We do not use the following data for averages, fits, limits, etc. • • •					
1.273 ±0.028	11k	[9] DICAPUA	64	CNTR	
1.21 ±0.07		ANDERSON	60	SPEC	

[9] DICAPUA 64 has been updated using the current mean life.

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

Note that measurements here do not cover the full kinematic range.

VALUE (units 10^{-4})	EVTS	DOCUMENT ID		TECN	COMMENT
1.24±0.25	26	CASTAGNOLI	58	EMUL	KE_μ < 3.38 MeV