μ

$J = \frac{1}{2}$

μ MASS

The mass is known more precisely in u (atomic mass units) than in MeV (see the footnote to COHEN 87). The conversion from u to MeV, 1 u = 931.49432 ± 0.00028 MeV, involves the relatively poorly known electronic charge.

Where m_μ/m_e was measured, we have used the 1986 CODATA value for m_e = 0.51099906 ± 0.00000015 MeV.

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*CHG*	*COMMENT*
105.658389±0.000034	[1] COHEN	87	RVUE		1986 CODATA value
• • • We do not use the following data for averages, fits, limits, etc. • • •					
105.65841 ±0.00033	[2] BELTRAMI	86	SPEC	−	Muonic atoms
105.658432±0.000064	[3] KLEMPT	82	CNTR	+	Incl. in MARIAM 82
105.658386±0.000044	[4] MARIAM	82	CNTR	+	
105.65856 ±0.00015	[5] CASPERSON	77	CNTR	+	
105.65836 ±0.00026	[6] CROWE	72	CNTR		
105.65865 ±0.00044	[7] CRANE	71	CNTR		

[1] The mass is known more precisely in u: m = 0.113428913 ± 0.000000017 u. COHEN 87 makes use of the other entries below.

[2] BELTRAMI 86 gives m_μ/m_e = 206.76830(64).

[3] KLEMPT 82 gives m_μ/m_e = 206.76835(11).

[4] MARIAM 82 gives m_μ/m_e = 206.768259(62).

[5] CASPERSON 77 gives m_μ/m_e = 206.76859(29).

[6] CROWE 72 gives m_μ/m_e = 206.7682(5).

[7] CRANE 71 gives m_μ/m_e = 206.76878(85).

μ MEAN LIFE τ

Measurements with an error > 0.001 × 10^{-6} s have been omitted.

VALUE (10^{-6} s)	*DOCUMENT ID*		*TECN*	*CHG*
2.19703 ±0.00004 OUR AVERAGE				
2.197078±0.000073	BARDIN	84	CNTR	+
2.197025±0.000155	BARDIN	84	CNTR	−
2.19695 ±0.00006	GIOVANETTI	84	CNTR	+
2.19711 ±0.00008	BALANDIN	74	CNTR	+
2.1973 ±0.0003	DUCLOS	73	CNTR	+

$\tau_{\mu^+}/\tau_{\mu^-}$ MEAN LIFE RATIO

A test of *CPT* invariance.

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
1.000024±0.000078	BARDIN	84	CNTR	
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1.0008 ±0.0010	BAILEY	79	CNTR	Storage ring
1.000 ±0.001	MEYER	63	CNTR	Mean life μ^+/ μ^-

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

A test of *CPT* invariance. Calculated from the mean-life ratio, above.

VALUE	*DOCUMENT ID*
$(2\pm8)\times10^{-5}$ OUR EVALUATION	

μ MAGNETIC MOMENT ANOMALY

$\mu_\mu/(e\hbar/2m_\mu)-1 = (g_\mu-2)/2$

For reviews of theory and experiments, see HUGHES 85, KINOSHITA 84, COMBLEY 81, FARLEY 79, and CALMET 77.

VALUE (units 10^{-6})	*DOCUMENT ID*		*TECN*	*CHG*	*COMMENT*
1165.9230±0.0084	COHEN	87	RVUE		1986 CODATA value
• • • We do not use the following data for averages, fits, limits, etc. • • •					
1165.910 ±0.011	[8] BAILEY	79	CNTR	+	Storage ring
1165.937 ±0.012	[8] BAILEY	79	CNTR	−	Storage ring
1165.923 ±0.0085	[8] BAILEY	79	CNTR	±	Storage ring
1165.922 ±0.009	[8] BAILEY	77	CNTR	±	Storage ring
1166.16 ±0.31	BAILEY	68	CNTR	±	Storage rings
1162.0 ±5.0	CHARPAK	62	CNTR	+	

[8] BAILEY 79 is final result. Includes BAILEY 77 data. We use μ/p magnetic moment ratio = 3.1833452 and recalculate the BAILEY 79 values. Third BAILEY 79 result is first two combined.

$(g_{\mu^+} - g_{\mu^-}) / g_{\text{average}}$

A test of *CPT* invariance.

VALUE (units 10^{-8})	*DOCUMENT ID*	
−2.6±1.6	BAILEY	79

μ ELECTRIC DIPOLE MOMENT

A nonzero value is forbidden by both T invariance and P invariance.

VALUE (10^{-19} e cm)	DOCUMENT ID		TECN	CHG	COMMENT
3.7±3.4	[9] BAILEY	78	CNTR	±	Storage ring
• • • We do not use the following data for averages, fits, limits, etc. • • •					
8.6±4.5	BAILEY	78	CNTR	+	Storage rings
0.8±4.3	BAILEY	78	CNTR	−	Storage rings

[9] This is the combination of the two BAILEY 78 results given below.

μ/p MAGNETIC MOMENT RATIO

This ratio is used to obtain a precise value of the muon mass. Measurements with an error > 0.00001 have been omitted.

VALUE	DOCUMENT ID		TECN	CHG	COMMENT
3.18334547±0.00000047	[10] COHEN	87	RVUE		1986 CODATA value
• • • We do not use the following data for averages, fits, limits, etc. • • •					
3.1833441 ±0.0000017	KLEMPT	82	CNTR	+	Precession strob
3.1833461 ±0.0000011	MARIAM	82	CNTR	+	HFS splitting
3.1833448 ±0.0000029	CAMANI	78	CNTR	+	See KLEMPT 82
3.1833403 ±0.0000044	CASPERSON	77	CNTR	+	HFS splitting
3.1833402 ±0.0000072	COHEN	73	RVUE		1973 CODATA value
3.1833467 ±0.0000082	CROWE	72	CNTR	+	Precession phase

[10] COHEN 87 (1986 CODATA) value was fitted using their own selection of the following data. Because their value is from a multiparameter fit, correlations with other quantities may be important and one cannot arrive at this result by any average of these data alone.

μ^- DECAY MODES

μ^+ modes are charge conjugates of the modes below.

	Mode			Fraction (Γ_i/Γ)		Confidence level
Γ_1	$e^-\overline{\nu}_e\nu_\mu$			$\approx$ 100%		
Γ_2	$e^-\overline{\nu}_e\nu_\mu\gamma$		[a]	(1.4±0.4) %		
Γ_3	$e^-\overline{\nu}_e\nu_\mu e^+e^-$		[b]	(3.4±0.4) $\times 10^{-5}$		
	Lepton Family number (*LF*) violating modes					
Γ_4	$e^-\nu_e\overline{\nu}_\mu$	*LF*	[c]	< 1.2	%	90%
Γ_5	$e^-\gamma$	*LF*		< 4.9	$\times 10^{-11}$	90%
Γ_6	$e^-e^+e^-$	*LF*		< 1.0	$\times 10^{-12}$	90%
Γ_7	$e^-2\gamma$	*LF*		< 7.2	$\times 10^{-11}$	90%

[a] This only includes events with the γ energy > 10 MeV. Since the $e^-\overline{\nu}_e\nu_\mu$ and $e^-\overline{\nu}_e\nu_\mu\gamma$ modes cannot be clearly separated, we regard the latter mode as a subset of the former.

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

[c] A test of additive vs. multiplicative lepton family number conservation.

μ^- BRANCHING RATIOS

$\Gamma(e^- \overline{\nu}_e \nu_\mu \gamma)/\Gamma_{\text{total}}$ — Γ_2/Γ

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.014 ±0.004		CRITTENDEN	61	CNTR	γ KE > 10 MeV
• • • We do not use the following data for averages, fits, limits, etc. • • •					
	862	BOGART	67	CNTR	γ KE > 14.5 MeV
0.0033±0.0013		CRITTENDEN	61	CNTR	γ KE > 20 MeV
	27	ASHKIN	59	CNTR	

$\Gamma(e^- \overline{\nu}_e \nu_\mu e^+ e^-)/\Gamma_{\text{total}}$ — Γ_3/Γ

VALUE (units 10^{-5})	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
3.4±0.2±0.3	7443	[11] BERTL	85	SPEC	+	SINDRUM
• • • We do not use the following data for averages, fits, limits, etc. • • •						
2.2±1.5	7	[12] CRITTENDEN	61	HLBC	+	$E(e^+ e^-)$>10 MeV
2	1	[13] GUREVICH	60	EMUL	+	
1.5±1.0	3	[14] LEE	59	HBC	+	

[11] BERTL 85 has transverse momentum cut p_T > 17 MeV/c. Systematic error was increased by us.

[12] CRITTENDEN 61 count only those decays where total energy of either (e^+, e^-) combination is >10 MeV.

[13] GUREVICH 60 interpret their event as either virtual or real photon conversion. e^+ and e^- energies not measured.

[14] In the three LEE 59 events, the sum of energies E(e^+) + E(e^-) + E(e^+) was 51 MeV, 55 MeV, and 33 MeV.

$\Gamma(e^- \nu_e \overline{\nu}_\mu)/\Gamma_{\text{total}}$ — Γ_4/Γ

Forbidden by the additive conservation law for lepton family number. A multiplicative law predicts this branching ratio to be 1/2. For a review see NEMETHY 81.

VALUE	CL%	DOCUMENT ID		TECN	CHG	COMMENT
< 0.012	90	[15] FREEDMAN	93	CNTR	+	ν oscillation search
• • • We do not use the following data for averages, fits, limits, etc. • • •						
< 0.018	90	KRAKAUER	91B	CALO	+	
< 0.05	90	[16] BERGSMA	83	CALO		$\overline{\nu}_\mu e \to \mu^- \overline{\nu}_e$
< 0.09	90	JONKER	80	CALO		See BERGSMA 83
−0.001±0.061		WILLIS	80	CNTR	+	
0.13 ±0.15		BLIETSCHAU	78	HLBC	±	Avg. of 4 values
< 0.25	90	EICHTEN	73	HLBC	+	

[15] FREEDMAN 93 limit on $\overline{\nu}_e$ observation is here interpreted as a limit on lepton family number violation.

[16] BERGSMA 83 gives a limit on the inverse muon decay cross-section ratio $\sigma(\overline{\nu}_\mu e^- \to \mu^- \overline{\nu}_e)/\sigma(\nu_\mu e^- \to \mu^- \nu_e)$, which is essentially equivalent to $\Gamma(e^- \nu_e \overline{\nu}_\mu)/\Gamma_{\text{total}}$ for small values like that quoted.

$\Gamma(e^-\gamma)/\Gamma_{total}$ — Γ_5/Γ

Forbidden by lepton family number conservation.

VALUE (units 10^{-11})	CL%	DOCUMENT ID		TECN	CHG	COMMENT
< 4.9	90	BOLTON	88	CBOX	+	LAMPF
• • • We do not use the following data for averages, fits, limits, etc. • • •						
<100	90	AZUELOS	83	CNTR	+	TRIUMF
< 17	90	KINNISON	82	SPEC	+	LAMPF
<100	90	SCHAAF	80	ELEC	+	SIN

$\Gamma(e^-e^+e^-)/\Gamma_{total}$ — Γ_6/Γ

Forbidden by lepton family number conservation.

VALUE (units 10^{-12})	CL%	DOCUMENT ID		TECN	CHG	COMMENT
< 1.0	90	[17] BELLGARDT	88	SPEC	+	SINDRUM
• • • We do not use the following data for averages, fits, limits, etc. • • •						
< 36	90	BARANOV	91	SPEC	+	ARES
< 35	90	BOLTON	88	CBOX	+	LAMPF
< 2.4	90	[17] BERTL	85	SPEC	+	SINDRUM
<160	90	[17] BERTL	84	SPEC	+	SINDRUM
<130	90	[17] BOLTON	84	CNTR		LAMPF

[17] These experiments assume a constant matrix element.

$\Gamma(e^-2\gamma)/\Gamma_{total}$ — Γ_7/Γ

Forbidden by lepton family number conservation.

VALUE (units 10^{-11})	CL%	DOCUMENT ID		TECN	CHG	COMMENT
< 7.2	90	BOLTON	88	CBOX	+	LAMPF
• • • We do not use the following data for averages, fits, limits, etc. • • •						
< 840	90	[18] AZUELOS	83	CNTR	+	TRIUMF
<5000	90	[19] BOWMAN	78	CNTR		DEPOMMIER 77 data

[18] AZUELOS 83 uses the phase space distribution of BOWMAN 78.

[19] BOWMAN 78 assumes an interaction Lagrangian local on the scale of the inverse μ mass.

LIMIT ON $\mu^- \rightarrow e^-$ CONVERSION

Forbidden by lepton family number conservation.

$\sigma(\mu^-\,{}^{32}\mathrm{S} \rightarrow e^-\,{}^{32}\mathrm{S})\,/\,\sigma(\mu^-\,{}^{32}\mathrm{S} \rightarrow \nu_\mu\,{}^{32}\mathrm{P}^*)$

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
$<7 \times 10^{-11}$	90	BADERT...	80	STRC	SIN
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$<4 \times 10^{-10}$	90	BADERT...	77	STRC	SIN

$\sigma(\mu^-\,\mathrm{Cu} \rightarrow e^-\,\mathrm{Cu})\,/\,\sigma(\mu^-\,\mathrm{Cu} \rightarrow \text{capture})$

VALUE	CL%	DOCUMENT ID		TECN
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$<1.6 \times 10^{-8}$	90	BRYMAN	72	SPEC

$\sigma(\mu^- \mathrm{Ti} \to e^- \mathrm{Ti}) / \sigma(\mu^- \mathrm{Ti} \to \text{capture})$

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<4.3 × 10⁻¹²	90	[20] DOHMEN	93	SPEC	SINDRUM II
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$<4.6 \times 10^{-12}$	90	AHMAD	88	TPC	TRIUMF
$<1.6 \times 10^{-11}$	90	BRYMAN	85	TPC	TRIUMF

[20] DOHMEN 93 assumes $\mu^- \to e^-$ conversion leaves the nucleus in its ground state, a process enhanced by coherence and expected to dominate.

$\sigma(\mu^- \mathrm{Pb} \to e^- \mathrm{Pb}) / \sigma(\mu^- \mathrm{Pb} \to \text{capture})$

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<4.6 × 10⁻¹¹	90	HONECKER	96	SPEC	SINDRUM II
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$<4.9 \times 10^{-10}$	90	AHMAD	88	TPC	TRIUMF

LIMIT ON $\mu^- \to e^+$ CONVERSION

Forbidden by total lepton number conservation.

$\sigma(\mu^- \, ^{32}\mathrm{S} \to e^+ \, ^{32}\mathrm{Si}^*) / \sigma(\mu^- \, ^{32}\mathrm{S} \to \nu_\mu \, ^{32}\mathrm{P}^*)$

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<9 × 10⁻¹⁰	90	BADERT...	80	STRC	SIN
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$<1.5 \times 10^{-9}$	90	BADERT...	78	STRC	SIN

$\sigma(\mu^- \, ^{127}\mathrm{I} \to e^+ \, ^{127}\mathrm{Sb}^*) / \sigma(\mu^- \, ^{127}\mathrm{I} \to \text{anything})$

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<3 × 10⁻¹⁰	90	[21] ABELA	80	CNTR	Radiochemical tech.

[21] ABELA 80 is upper limit for $\mu^- e^+$ conversion leading to particle-stable states of ^{127}Sb. Limit for total conversion rate is higher by a factor less than 4 (G. Backenstoss, private communication).

$\sigma(\mu^- \mathrm{Cu} \to e^+ \mathrm{Co}) / \sigma(\mu^- \mathrm{Cu} \to \nu_\mu \mathrm{Ni})$

VALUE	CL%	DOCUMENT ID		TECN
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$<2.6 \times 10^{-8}$	90	BRYMAN	72	SPEC
$<2.2 \times 10^{-7}$	90	CONFORTO	62	OSPK

$\sigma(\mu^- \mathrm{Ti} \to e^+ \mathrm{Ca}) / \sigma(\mu^- \mathrm{Ti} \to \text{capture})$

VALUE	CL%	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
<3.6 × 10⁻¹¹	90	1	[22,23] KAULARD	98	SPEC	−	SINDRUM II
• • • We do not use the following data for averages, fits, limits, etc. • • •							
$<1.7 \times 10^{-12}$	90	1	[23,24] KAULARD	98	SPEC	−	SINDRUM II
$<4.3 \times 10^{-12}$	90		[24] DOHMEN	93	SPEC		SINDRUM II
$<8.9 \times 10^{-11}$	90		[22] DOHMEN	93	SPEC		SINDRUM II
$<1.7 \times 10^{-10}$	90		[25] AHMAD	88	TPC		TRIUMF

[22] This limit assumes a giant resonance excitation of the daughter Ca nucleus (mean energy and width both 20 MeV).

[23] KAULARD 98 obtained these same limits using the unified classical analysis of FELDMAN 98.
[24] This limit assumes the daughter Ca nucleus is left in the ground state. However, the probability of this is unknown.
[25] Assuming a giant-resonance-excitation model.

LIMIT ON MUONIUM → ANTIMUONIUM CONVERSION

Forbidden by lepton family number conservation.

$R_g = G_C / G_F$

The effective Lagrangian for the $\mu^+ e^- \rightarrow \mu^- e^+$ conversion is assumed to be

$$\mathcal{L} = 2^{-1/2}\ G_C\ [\overline{\psi}_\mu \gamma_\lambda\ (1-\gamma_5)\ \psi_e]\ [\overline{\psi}_\mu \gamma_\lambda\ (1-\gamma_5)\ \psi_e] + \text{h.c.}$$

The experimental result is then an upper limit on G_C/G_F, where G_F is the Fermi coupling constant.

VALUE	CL%	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
< 0.0030	90	1	[26] WILLMANN	99	SPEC	+	μ^+ at 26 GeV/c
• • • We do not use the following data for averages, fits, limits, etc. • • •							
< 0.14	90	1	[27] GORDEEV	97	SPEC	+	JINR phasotron
< 0.018	90	0	[28] ABELA	96	SPEC	+	μ^+ at 24 MeV
< 6.9	90		NI	93	CBOX		LAMPF
< 0.16	90		MATTHIAS	91	SPEC		LAMPF
< 0.29	90		HUBER	90B	CNTR		TRIUMF
<20	95		BEER	86	CNTR		TRIUMF
<42	95		MARSHALL	82	CNTR		

[26] WILLMANN 99 quote both probability $P_{M\overline{M}} < 8.3 \times 10^{-11}$ at 90%CL in a 0.1 T field and $R_g = G_C/G_F$.
[27] GORDEEV 97 quote limits on both $f = G_{MM}/GF$ and the probability $W_{MM} < 4.7 \times 10^{-7}$ (90%CL).
[28] ABELA 96 quote both probability $P_{M\overline{M}} < 8 \times 10^{-9}$ at 90% CL and $R_g = G_C/G_F$.

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μ DECAY PARAMETERS

ρ PARAMETER

($V-A$) theory predicts $\rho = 0.75$.

VALUE	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
0.7518±0.0026		DERENZO	69	RVUE		
• • • We do not use the following data for averages, fits, limits, etc. • • •						
0.762 ±0.008	170k	[29] FRYBERGER	68	ASPK	+	25–53 MeV e^+
0.760 ±0.009	280k	[29] SHERWOOD	67	ASPK	+	25–53 MeV e^+
0.7503±0.0026	800k	[29] PEOPLES	66	ASPK	+	20–53 MeV e^+

[29] η constrained = 0. These values incorporated into a two parameter fit to ρ and η by DERENZO 69.

η PARAMETER

$(V-A)$ theory predicts $\eta = 0$.

VALUE	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
-0.007 ± 0.013 OUR AVERAGE						
-0.007 ± 0.013	5.3M	[30] BURKARD	85B	FIT	+	9–53 MeV e^+
-0.12 ± 0.21	6346	DERENZO	69	HBC	+	1.6–6.8 MeV e^+
• • • We do not use the following data for averages, fits, limits, etc. • • •						
$-0.012 \pm 0.015 \pm 0.003$	5.3M	[31] BURKARD	85B	CNTR	+	9–53 MeV e^+
$0.011 \pm 0.081 \pm 0.026$	5.3M	BURKARD	85B	CNTR	+	9–53 MeV e^+
-0.7 ± 0.5	170k	[32] FRYBERGER	68	ASPK	+	25–53 MeV e^+
-0.7 ± 0.6	280k	[32] SHERWOOD	67	ASPK	+	25–53 MeV e^+
0.05 ± 0.5	800k	[32] PEOPLES	66	ASPK	+	20–53 MeV e^+
-2.0 ± 0.9	9213	[33] PLANO	60	HBC	+	Whole spectrum

[30] Global fit to all measured parameters. Correlation coefficients are given in BURKARD 85B.
[31] $\alpha = \alpha' = 0$ assumed.
[32] ρ constrained $= 0.75$.
[33] Two parameter fit to ρ and η; PLANO 60 discounts value for η.

δ PARAMETER

$(V-A)$ theory predicts $\delta = 0.75$.

VALUE	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
$0.7486 \pm 0.0026 \pm 0.0028$		[34] BALKE	88	SPEC	+	Surface μ^+'s
• • • We do not use the following data for averages, fits, limits, etc. • • •						
		[35] VOSSLER	69			
0.752 ± 0.009	490k	FRYBERGER	68	ASPK	+	25–53 MeV e^+
0.782 ± 0.031		KRUGER	61			
0.78 ± 0.05	8354	PLANO	60	HBC	+	Whole spectrum

[34] BALKE 88 uses $\rho = 0.752 \pm 0.003$.
[35] VOSSLER 69 has measured the asymmetry below 10 MeV. See comments about radiative corrections in VOSSLER 69.

$|(\xi$ PARAMETER$)\times(\mu$ LONGITUDINAL POLARIZATION$)|$

$(V-A)$ theory predicts $\xi = 1$, longitudinal polarization $= 1$.

VALUE	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
$1.0027 \pm 0.0079 \pm 0.0030$		BELTRAMI	87	CNTR		SIN, π decay in flight
• • • We do not use the following data for averages, fits, limits, etc. • • •						
$1.0013 \pm 0.0030 \pm 0.0053$		[36] IMAZATO	92	SPEC	+	$K^+ \to \mu^+ \nu_\mu$
0.975 ± 0.015		AKHMANOV	68	EMUL		140 kG
0.975 ± 0.030	66k	GUREVICH	64	EMUL		See AKHMANOV 68
0.903 ± 0.027		[37] ALI-ZADE	61	EMUL	+	27 kG
0.93 ± 0.06	8354	PLANO	60	HBC	+	8.8 kG
0.97 ± 0.05	9k	BARDON	59	CNTR		Bromoform target

[36] The corresponding 90% confidence limit from IMAZATO 92 is $|\xi P_\mu| > 0.990$. This measurement is of K^+ decay, not π^+ decay, so we do not include it in an average, nor do we yet set up a separate data block for K results.
[37] Depolarization by medium not known sufficiently well.

ξ × (μ LONGITUDINAL POLARIZATION) × δ / ρ

VALUE	CL%		DOCUMENT ID		TECN	CHG	COMMENT
>0.99682	90	[38]	JODIDIO	86	SPEC	+	TRIUMF
• • • We do not use the following data for averages, fits, limits, etc. • • •							
>0.9966	90	[39]	STOKER	85	SPEC	+	μ-spin rotation
>0.9959	90		CARR	83	SPEC	+	11 kG

[38] JODIDIO 86 includes data from CARR 83 and STOKER 85. The value here is from the erratum.

[39] STOKER 85 find ($\xi P_{\mu}\delta/\rho$) >0.9955 and >0.9966, where the first limit is from new μ spin-rotation data and the second is from combination with CARR 83 data. In $V-A$ theory, $(\delta/\rho) = 1.0$.

ξ' = LONGITUDINAL POLARIZATION OF e^+

($V-A$) theory predicts the longitudinal polarization = ±1 for $e^{\pm}$, respectively. We have flipped the sign for e^- so our programs can average.

VALUE	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
1.00 ±0.04 OUR AVERAGE						
0.998±0.045	1M	BURKARD	85	CNTR	+	Bhabha + annihil
0.89 ±0.28	29k	SCHWARTZ	67	OSPK	−	Moller scattering
0.94 ±0.38		BLOOM	64	CNTR	+	Brems. transmiss.
1.04 ±0.18		DUCLOS	64	CNTR	+	Bhabha scattering
1.05 ±0.30		BUHLER	63	CNTR	+	Annihilation

ξ'' PARAMETER

VALUE	EVTS		DOCUMENT ID		TECN	CHG	COMMENT
0.65±0.36	326k	[40]	BURKARD	85	CNTR	+	Bhabha + annihil

[40] BURKARD 85 measure $(\xi''-\xi\xi')/\xi$ and ξ' and set $\xi = 1$.

TRANSVERSE e^+ POLARIZATION IN PLANE OF μ SPIN, e^+ MOMENTUM

VALUE	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •						
0.016±0.021±0.01	5.3M	BURKARD	85B	CNTR	+	Annihil 9–53 MeV

TRANSVERSE e^+ POLARIZATION NORMAL TO PLANE OF μ SPIN, e^+ MOMENTUM

Zero if T invariance holds.

VALUE	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
0.007±0.022±0.007	5.3M	BURKARD	85B	CNTR	+	Annihil 9–53 MeV

α/A

VALUE (units 10^{-3})	EVTS		DOCUMENT ID		TECN	CHG	COMMENT
0.4± 4.3		[41]	BURKARD	85B	FIT		
• • • We do not use the following data for averages, fits, limits, etc. • • •							
15 ±50 ±14	5.3M		BURKARD	85B	CNTR	+	9–53 MeV e^+

[41] Global fit to all measured parameters. Correlation coefficients are given in BURKARD 85B.

α'/A

Zero if T invariance holds.

VALUE (units 10^{-3})	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
− 0.2± 4.3		[42] BURKARD	85B	FIT		
• • • We do not use the following data for averages, fits, limits, etc. • • •						
−47 ±50 ±14	5.3M	[43] BURKARD	85B	CNTR	+	9–53 MeV e^+

[42] Global fit to all measured parameters. Correlation coefficients are given in BURKARD 85B.
[43] BURKARD 85B measure e^+ polarizations P_{T_1} and P_{T_2} versus e^+ energy.

β/A

VALUE (units 10^{-3})	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
3.9± 6.2		[44] BURKARD	85B	FIT		
• • • We do not use the following data for averages, fits, limits, etc. • • •						
2 ±17 ±6	5.3M	BURKARD	85B	CNTR	+	9–53 MeV e^+

[44] Global fit to all measured parameters. Correlation coefficients are given in BURKARD 85B.

β'/A

Zero if T invariance holds.

VALUE (units 10^{-3})	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
1.5± 6.3		[45] BURKARD	85B	FIT		
• • • We do not use the following data for averages, fits, limits, etc. • • •						
17 ±17 ±6	5.3M	[46] BURKARD	85B	CNTR	+	9–53 MeV e^+

[45] Global fit to all measured parameters. Correlation coefficients are given in BURKARD 85B.
[46] BURKARD 85B measure e^+ polarizations P_{T_1} and P_{T_2} versus e^+ energy.

a/A

This comes from an alternative parameterization to that used in the Summary Table (see the "Note on Muon Decay Parameters" above).

VALUE (units 10^{-3})	CL%	DOCUMENT ID		TECN
• • • We do not use the following data for averages, fits, limits, etc. • • •				
<15.9	90	[47] BURKARD	85B	FIT

[47] Global fit to all measured parameters. Correlation coefficients are given in BURKARD 85B.

a'/A

This comes from an alternative parameterization to that used in the Summary Table (see the "Note on Muon Decay Parameters" above).

VALUE (units 10^{-3})	DOCUMENT ID		TECN
• • • We do not use the following data for averages, fits, limits, etc. • • •			
5.3±4.1	[48] BURKARD	85B	FIT

[48] Global fit to all measured parameters. Correlation coefficients are given in BURKARD 85B.

$(b'+b)/A$

This comes from an alternative parameterization to that used in the Summary Table (see the "Note on Muon Decay Parameters" above).

VALUE (units 10^{-3})	*CL%*	*DOCUMENT ID*		*TECN*
• • • We do not use the following data for averages, fits, limits, etc. • • •				
<1.04	90	[49] BURKARD	85B	FIT

[49] Global fit to all measured parameters. Correlation coefficients are given in BURKARD 85B.

c/A

This comes from an alternative parameterization to that used in the Summary Table (see the "Note on Muon Decay Parameters" above).

VALUE (units 10^{-3})	*CL%*	*DOCUMENT ID*		*TECN*
• • • We do not use the following data for averages, fits, limits, etc. • • •				
<6.4	90	[50] BURKARD	85B	FIT

[50] Global fit to all measured parameters. Correlation coefficients are given in BURKARD 85B.

c'/A

This comes from an alternative parameterization to that used in the Summary Table (see the "Note on Muon Decay Parameters" above).

VALUE (units 10^{-3})	*DOCUMENT ID*		*TECN*
• • • We do not use the following data for averages, fits, limits, etc. • • •			
3.5±2.0	[51] BURKARD	85B	FIT

[51] Global fit to all measured parameters. Correlation coefficients are given in BURKARD 85B.

$\overline{\eta}$ PARAMETER

($V-A$) theory predicts $\overline{\eta} = 0$. $\overline{\eta}$ affects spectrum of radiative muon decay.

VALUE	*DOCUMENT ID*		*TECN*	*CHG*	*COMMENT*
0.02 ±0.08 OUR AVERAGE					
−0.014±0.090	EICHENBER...	84	ELEC	+	ρ free
+0.09 ±0.14	BOGART	67	CNTR	+	
• • • We do not use the following data for averages, fits, limits, etc. • • •					
−0.035±0.098	EICHENBER...	84	ELEC	+	ρ=0.75 assumed

μ REFERENCES

WILLMANN	99	PRL 82 49	L. Willmann+	
FELDMAN	98	PR D57 3873	G.J. Feldman, R.D. Cousins	
KAULARD	98	PL B422 334	J. Kaulard+	(SINDRUM-II Collab.)
GORDEEV	97	PAN 60 1164	V.A. Gordeev+	(PNPI)
		Translated from YAF 60 1291.		
ABELA	96	PRL 77 1950	+Bagaturia+	(PSI, ZURI, HEIDH, TBIL, YALE+)
HONECKER	96	PRL 76 200	+Dohmen, Haan, Junker+	(SINDRUM II Collab.)
DOHMEN	93	PL B317 631	+Groth, Heer+	(PSI SINDRUM-II Collab.)
FREEDMAN	93	PR D47 811	+Fujikawa, Napolitano, Nelson+	(LAMPF E645 Collab.)
NI	93	PR D48 1976	+Arnold, Chmely+	(LAMPF Crystal-Box Collab.)
IMAZATO	92	PRL 69 877	+Kawashima, Tanaka+	(KEK, INUS, TOKY, TOKMS)
BARANOV	91	SJNP 53 802	+Vanko, Glazov, Evtukhovich+	(JINR)
		Translated from YAF 53 1302.		

KRAKAUER 91B PL B263 534 +Talaga, Allen, Chen, Doe+ (UMD, UCI, LANL)
MATTHIAS 91 PRL 66 2716 +Ahn+ (YALE, HEIDP, WILL, GSI, VILL, BNL)
Also 91B PRL 67 932 erratum Matthias, Ahn+ (YALE, HEIDP, WILL, GSI, VILL, BNL)
HUBER 90B PR D41 2709 + (WYOM, VICT, ARIZ, ROCH, TRIU, SFRA, BRCO)
AHMAD 88 PR D38 2102 +Azuelos+ (TRIU, VICT, VPI, BRCO, MONT, CNRC)
Also 87 PRL 59 970 Ahmad+ (TRIU, VPI, VICT, BRCO, MONT, CNRC)
BALKE 88 PR D37 587 +Gidal, Jodidio+ (LBL, UCB, COLO, NWES, TRIU)
BELLGARDT 88 NP B299 1 +Otter, Eichler+ (SINDRUM Collab.)
BOLTON 88 PR D38 2077 +Cooper, Frank, Hallin+ (LANL, STAN, CHIC, TEMP)
Also 86 PRL 56 2461 Bolton, Bowman, Cooper+ (LANL, STAN, CHIC, TEMP)
Also 86 PRL 57 3241 Grosnick, Wright, Bolton+ (CHIC, LANL, STAN, TEMP)
BELTRAMI 87 PL B194 326 +Burkard, Von Dincklage+ (ETH, SIN, MANZ)
COHEN 87 RMP 59 1121 +Taylor (RISC, NBS)
BEER 86 PRL 57 671 +Marshall, Mason+ (VICT, TRIU, WYOM)
BELTRAMI 86 NP A451 679 +Aas, Beer, Dechambrier, Goudsmit+ (ETH, FRIB)
JODIDIO 86 PR D34 1967 +Balke, Carr, Gidal, Shinsky+ (LBL, NWES, TRIU)
Also 88 PR D37 237 erratum Jodidio, Balke, Carr+ (LBL, NWES, TRIU)
BERTL 85 NP B260 1 +Egli, Eichler+ (SINDRUM Collab.)
BRYMAN 85 PRL 55 465 + (TRIU, CNRC, BRCO, LANL, CHIC, CARL+)
BURKARD 85 PL 150B 242 +Corriveau, Egger+ (ETH, SIN, MANZ)
BURKARD 85B PL 160B 343 +Corriveau, Egger+ (ETH, SIN, MANZ)
Also 81B PR D24 2004 Corriveau, Egger, Fetscher+ (ETH, SIN, MANZ)
Also 83B PL 129B 260 Corriveau, Egger, Fetscher+ (ETH, SIN, MANZ)
HUGHES 85 CNPP 14 341 +Kinoshita (YALE, CORN)
STOKER 85 PRL 54 1887 +Balke, Carr, Gidal+ (LBL, NWES, TRIU)
BARDIN 84 PL 137B 135 +Duclos, Magnon+ (SACL, CERN, BGNA, FIRZ)
BERTL 84 PL 140B 299 +Eichler, Felawka+ (SINDRUM Collab.)
BOLTON 84 PRL 53 1415 +Bowman, Carlini+ (LANL, CHIC, STAN, TEMP)
EICHENBER... 84 NP A412 523 Eichenberger, Engfer, VanderSchaff (ZURI)
GIOVANETTI 84 PR D29 343 +Dey, Eckhause, Hart+ (WILL)
KINOSHITA 84 PRL 52 717 +Nizic, Okamoto (CORN)
AZUELOS 83 PRL 51 164 +Depommier, Leroy, Martin+ (MONT, TRIU, BRCO)
Also 77 PRL 39 1113 Depommier+ (MONT, BRCO, TRIU, VICT, MELB)
BERGSMA 83 PL 122B 465 +Dorenbosch, Jonker+ (CHARM Collab.)
CARR 83 PRL 51 627 +Gidal, Gobbi, Jodidio, Oram+ (LBL, NWES, TRIU)
KINNISON 82 PR D25 2846 +Anderson, Matis, Wright+ (EFI, STAN, LANL)
Also 79 PRL 42 556 Bowman, Cooper, Hamm+ (LASL, EFI, STAN)
KLEMPT 82 PR D25 652 +Schulze, Wolf, Camani, Gygax+ (MANZ, ETH)
MARIAM 82 PRL 49 993 +Beer, Bolton, Egan, Gardner+ (YALE, HEIDH, BERN)
MARSHALL 82 PR D25 1174 +Warren, Oram, Kiefl (BRCO)
COMBLEY 81 PRPL 68 93 +Farley, Picasso (SHEF, RMCS, CERN)
NEMETHY 81 CNPP 10 147 +Hughes (LBL, YALE)
ABELA 80 PL 95B 318 +Backenstoss, Simons, Wuest+ (BASL, KARLK, KARLE)
BADERT... 80 LNC 28 401 Badertscher, Borer, Czapek, Flueckiger+ (BERN)
Also 82 NP A377 406 Badertscher, Borer, Czapek, Flueckiger+ (BERN)
JONKER 80 PL 93B 203 +Panman, Udo, Allaby+ (CHARM Collab.)
SCHAAF 80 NP A340 249 +Engfer, Povel, Dey+ (ZURI, ETH, SIN)
Also 77 PL 72B 183 Povel, Dey, Walter, Pfeiffer+ (ZURI, ETH, SIN)
WILLIS 80 PRL 44 522 +Hughes+ (YALE, LBL, LASL, SACL, SIN, CNRC+)
Also 80B PRL 45 1370 Willis+ (YALE, LBL, LASL, SACL, SIN, CNRC+)
BAILEY 79 NP B150 1 (CERN, DARE, MANZ)
FARLEY 79 ARNPS 29 243 +Picasso (RMCS, CERN)
BADERT... 78 PL 79B 371 Badertscher, Borer, Czapek, Flueckiger+ (BERN)
BAILEY 78 JPG 4 345 (DARE, BERN, SHEF, MANZ, RMCS, CERN, BIRM)
Also 79 NP B150 1 Bailey (CERN, DARE, MANZ)
BLIETSCHAU 78 NP B133 205 +Deden, Hasert, Krenz+ (Gargamelle Collab.)
BOWMAN 78 PRL 41 442 +Cheng, Li, Matis (LASL, IAS, CMU, EFI)
CAMANI 78 PL 77B 326 +Gygax, Klempt, Schenck, Schulze+ (ETH, MANZ)
BADERT... 77 PRL 39 1385 Badertscher, Borer, Czapek, Flueckiger+ (BERN)
BAILEY 77 PL 67B 225 + (CERN Muon Storage Ring Collab.)
Also 77C PL 68B 191 Bailey+ (CERN, DARE, BERN, SHEF, MANZ+)
Also 75 PL 55B 420 Bailey+ (CERN Muon Storage Ring Collab., BIRM)
CALMET 77 RMP 49 21 +Narison, Perrottet+ (CPPM)
CASPERSON 77 PRL 38 956 +Crane+ (BERN, HEIDH, LASL, WYOM, YALE)
DEPOMMIER 77 PRL 39 1113 + (MONT, BRCO, TRIU, VICT, MELB)
BALANDIN 74 JETP 40 811 +Grebenyuk, Zinov, Konin, Ponomarev (JINR)
Translated from ZETF 67 1631.

COHEN	73	JPCRD 2 663	+Taylor	(RISC, NBS)
DUCLOS	73	PL 47B 491	+Magnon, Picard	(SACL)
EICHTEN	73	PL 46B 281	+Deden, Hasert, Krenz+	(Gargamelle Collab.)
BRYMAN	72	PRL 28 1469	+Blecher, Gotow, Powers	(VPI)
CROWE	72	PR D5 2145	+Hague, Rothberg, Schenck+	(LBL, WASH)
CRANE	71	PRL 27 474	+Casperson, Crane, Egan, Hughes+	(YALE)
DERENZO	69	PR 181 1854		(EFI)
VOSSLER	69	NC 63A 423		(EFI)
AKHMANOV	68	SJNP 6 230	+Gurevich, Dobretsov, Makarina+	(KIAE)
		Translated from YAF 6 316.		
BAILEY	68	PL 28B 287	+Bartl, VonBochmann, Brown, Farley+	(CERN)
Also	72	NC 9A 369	Bailey, Bartl, VonBochmann, Brown+	(CERN)
FRYBERGER	68	PR 166 1379		(EFI)
BOGART	67	PR 156 1405	+Dicapua, Nemethy, Strelzoff	(COLU)
SCHWARTZ	67	PR 162 1306		(EFI)
SHERWOOD	67	PR 156 1475		(EFI)
PEOPLES	66	Nevis 147 unpub.		(COLU)
BLOOM	64	PL 8 87	+Dick, Feuvrais, Henry, Macq, Spighel	(CERN)
DUCLOS	64	PL 9 62	+Heintze, DeRujula, Soergel	(CERN)
GUREVICH	64	PL 11 185	+Makarina+	(KIAE)
BUHLER	63	PL 7 368	+Cabibbo, Fidecaro, Massam, Muller+	(CERN)
MEYER	63	PR 132 2693	+Anderson, Bleser, Lederman+	(COLU)
CHARPAK	62	PL 1 16	+Farley, Garwin+	(CERN)
CONFORTO	62	NC 26 261	+Conversi, Dilella+	(INFN, ROMA, CERN)
ALI-ZADE	61	JETP 13 313	+Gurevich, Nikolski	
		Translated from ZETF 40 452.		
CRITTENDEN	61	PR 121 1823	+Walker, Ballam	(WISC, MSU)
KRUGER	61	UCRL 9322 unpub.		(LRL)
GUREVICH	60	JETP 10 225	+Nikolski, Surkova	(ITEP)
		Translated from ZETF 37 318.		
PLANO	60	PR 119 1400		(COLU)
ASHKIN	59	NC 14 1266	+Fazzini, Fidecaro, Lipman, Merrison+	(CERN)
BARDON	59	PRL 2 56	+Berley, Lederman	(COLU)
LEE	59	PRL 3 55	+Samios	(COLU)