with $A = 16$. In the pure V–A theory, $Q_{LL} = 1$ and the others are zero.

Since the upper bounds on Q_{RR}, Q_{LR}, and Q_{RL} are found to be small, and since the helicity of the ν_μ in pion decay is known from experiment [9,10] to very high precision to be -1 [11], the cross section S of *inverse* muon decay, normalized to the V–A value, yields [2]

$$|g^S_{LL}|^2 \leq 4(1-S) \tag{3}$$

and

$$|g^V_{LL}|^2 = S \ . \tag{4}$$

Thus the Standard Model assumption of a pure V–A leptonic charged weak interaction for e and μ is confirmed (within errors) by experiments at energies far below the mass of the $W^\pm$: Eq. (4) gives a lower limit for V–A, and Eqs. (2) and (3) give upper limits for the other four-fermion interactions. The existence of such upper limits may also be seen from $Q_{RR}+Q_{RL} = (1-\xi')/2$ and $Q_{RR}+Q_{LR} = \frac{1}{2}(1+\xi/3-16\xi\delta/9)$. Table 1 gives the current experimental limits on the magnitudes of the $g^\gamma_{\varepsilon\mu}$'s.

Table 1. Ninety-percent confidence level experimental limits for the coupling constants $g^\gamma_{\varepsilon\mu}$. The limits on $|g^S_{LL}|$ and $|g^V_{LL}|$ are from Ref. 12, and the others are from Ref. 13. The experimental uncertainty on the muon polarization in pion decay is included.

$\vert g^S_{RR}\vert < 0.066$	$\vert g^V_{RR}\vert < 0.033$	$\vert g^T_{RR}\vert \equiv 0$
$\vert g^S_{LR}\vert < 0.125$	$\vert g^V_{LR}\vert < 0.060$	$\vert g^T_{LR}\vert < 0.036$
$\vert g^S_{RL}\vert < 0.424$	$\vert g^V_{RL}\vert < 0.110$	$\vert g^T_{RL}\vert < 0.122$
$\vert g^S_{LL}\vert < 0.55$	$\vert g^V_{LL}\vert > 0.96$	$\vert g^T_{LL}\vert \equiv 0$

Limits on the "charge retention" coordinates, as used in the older literature (*e.g.*, Ref. 14), are given by Burkard *et al.* [15].

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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	[24] FRYBERGER	68	ASPK	+	25–53 MeV e^+
0.760 ±0.009	280k	[24] SHERWOOD	67	ASPK	+	25–53 MeV e^+
0.7503±0.0026	800k	[24] PEOPLES	66	ASPK	+	20–53 MeV e^+

[24] 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	[25] 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±0.015±0.003	5.3M	[26] BURKARD	85B	CNTR	+	9–53 MeV e^+
0.011±0.081±0.026	5.3M	BURKARD	85B	CNTR	+	9–53 MeV e^+
−0.7 ±0.5	170k	[27] FRYBERGER	68	ASPK	+	25–53 MeV e^+
−0.7 ±0.6	280k	[27] SHERWOOD	67	ASPK	+	25–53 MeV e^+
0.05 ±0.5	800k	[27] PEOPLES	66	ASPK	+	20–53 MeV e^+
−2.0 ±0.9	9213	[28] PLANO	60	HBC	+	Whole spectrum

[25] Global fit to all measured parameters. Correlation coefficients are given in BURKARD 85B.
[26] $\alpha = \alpha' = 0$ assumed.
[27] ρ constrained = 0.75.
[28] 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±0.0026±0.0028		[29] BALKE	88	SPEC	+	Surface μ^+'s
• • • We do not use the following data for averages, fits, limits, etc. • • •						
		[30] 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

[29] BALKE 88 uses $\rho = 0.752 \pm 0.003$.
[30] 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±0.0079±0.0030		BELTRAMI	87	CNTR		SIN, π decay in flight
• • • We do not use the following data for averages, fits, limits, etc. • • •						
1.0013±0.0030±0.0053		[31] IMAZATO	92	SPEC	+	$K^+ \rightarrow \mu^+ \nu_\mu$
0.975 ±0.015		AKHMANOV	68	EMUL		140 kG
0.975 ±0.030	66k	GUREVICH	64	EMUL		See AKHMANOV 68
0.903 ±0.027		[32] 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

[31] 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.
[32] Depolarization by medium not known sufficiently well.

$\xi \times (\mu$ LONGITUDINAL POLARIZATION$) \times \delta / \rho$

VALUE	CL%	DOCUMENT ID		TECN	CHG	COMMENT
>0.99682	90	[33] JODIDIO	86	SPEC	+	TRIUMF
• • • We do not use the following data for averages, fits, limits, etc. • • •						
>0.9966	90	[34] STOKER	85	SPEC	+	μ-spin rotation
>0.9959	90	CARR	83	SPEC	+	11 kG

[33] JODIDIO 86 includes data from CARR 83 and STOKER 85. The value here is from the erratum.
[34] 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 $= \pm1$ 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