Chirality conservation requires

$$\eta_L \eta_R = 0 \; . \tag{4}$$

These couplings can arise from SU(2)×U(1)-invariant higher-dimensional interactions. A well-studied model is the interaction of homodoublet type ℓ^* with the Lagrangian [2,3]

$$\mathcal{L} = \frac{1}{2\Lambda} \overline{L}^* (g f \tfrac{\tau^a}{2} W^a_{\mu\nu} + g' f' Y B_{\mu\nu}) \tfrac{1-\gamma_5}{2} L + \text{h.c.} \; , \tag{5}$$

where L denotes the lepton doublet (ν, ℓ), Λ is the compositeness scale, g, g' are SU(2) and U(1)$_Y$ gauge couplings, and $W^a_{\mu\nu}$ and $B_{\mu\nu}$ are the field strengths for SU(2) and U(1)$_Y$ gauge fields. The same interaction occurs for mirror-type excited leptons. For sequential-type excited leptons, the ℓ^* and ν^* couplings become unrelated, and the couplings receive the extra suppression of $(250\,\text{GeV})/\Lambda$ or m_{L^*}/Λ. In any case, these couplings satisfy the relation

$$\lambda_W = -\sqrt{2} \sin^2\theta_W (\lambda_Z \cot\theta_W + \lambda_\gamma) \; . \tag{6}$$

Additional coupling with gluons is possible for excited quarks:

$$\mathcal{L} = \frac{1}{2\Lambda} \overline{Q}^* \sigma^{\mu\nu} \left(g_s f_s \tfrac{\lambda^a}{2} G^a_{\mu\nu} + g\, f \tfrac{\tau^a}{2} W^a_{\mu\nu} + g'\, f' Y B_{\mu\nu} \right) \times \tfrac{1-\gamma_5}{2} Q + \text{h.c.} \; , \tag{7}$$

where Q denotes a quark doublet, g_s is the QCD gauge coupling, and $G^a_{\mu\nu}$ the gluon field strength.

Some experimental analyses assume the relation $\eta_L = \eta_R = 1$, which violates chiral symmetry. We encode the results of such analyses if the crucial part of the cross section is proportional to the factor $\eta_L^2 + \eta_R^2$ and the limits can be reinterpreted as those for chirality conserving cases $(\eta_L, \eta_R) = (1, 0)$ or $(0, 1)$ after rescaling λ.

Several different conventions are used by LEP experiments to express the transition magnetic couplings. To facilitate comparison, we reexpress these in terms of λ_Z and λ_γ using the following relations and taking $\sin^2\theta_W = 0.23$. We assume chiral couplings, *i.e.*, $|c| = |d|$ in the notation of Ref. 2.

1. ALEPH (charged lepton and neutrino)

$$\lambda_Z^{\text{ALEPH}} = \frac{1}{2} \lambda_Z \quad \text{(1990 papers)} \tag{8a}$$

$$\frac{2c}{\Lambda} = \frac{\lambda_Z}{m_{\ell^*} [\text{or } m_{\nu^*}]} \quad (\text{for } |c| = |d|) \tag{8b}$$

2. ALEPH (quark)

$$\lambda_u^{\text{ALEPH}} = \frac{\sin\theta_W \cos\theta_W}{\sqrt{\frac{1}{4} - \frac{2}{3}\sin^2\theta_W + \frac{8}{9}\sin^4\theta_W}} \lambda_Z = 1.11 \lambda_Z \tag{9}$$

3. L3 and DELPHI (charged lepton)

$$\lambda^{\text{L3}} = \lambda_Z^{\text{DELPHI}} = -\frac{\sqrt{2}}{\cot\theta_W - \tan\theta_W} \lambda_Z = -1.10 \lambda_Z \tag{10}$$

4. L3 (neutrino)

$$f_Z^{\text{L3}} = \sqrt{2} \lambda_Z \tag{11}$$

5. OPAL (charged lepton)

$$\frac{f^{\text{OPAL}}}{\Lambda} = -\frac{2}{\cot\theta_W - \tan\theta_W} \frac{\lambda_Z}{m_{\ell^*}} = -1.56 \frac{\lambda_Z}{m_{\ell^*}} \tag{12}$$

6. OPAL (quark)

$$\frac{f^{\text{OPAL}} c}{\Lambda} = \frac{\lambda_Z}{2 m_{q^*}} \quad (\text{for } |c| = |d|) \tag{13}$$

7. DELPHI (charged lepton)

$$\lambda_\gamma^{\text{DELPHI}} = -\frac{1}{\sqrt{2}} \lambda_\gamma \tag{14}$$

If leptons are made of color triplet and antitriplet constituents, we may expect their color-octet partners. Transitions between the octet leptons (ℓ_8) and the ordinary lepton (ℓ) may take place via the dimension-five interactions

$$\mathcal{L} = \frac{1}{2\Lambda} \sum_\ell \left\{ \overline{\ell}_8^\alpha \, g_S \, F^\alpha_{\mu\nu} \sigma^{\mu\nu} \left(\eta_L \, \ell_L + \eta_R \, \ell_R \right) + h.c. \right\} \tag{15}$$

where the summation is over charged leptons and neutrinos. The leptonic chiral invariance implies $\eta_L \, \eta_R = 0$ as before.

References

1. E.J. Eichten, K.D. Lane, and M.E. Peskin, Phys. Rev. Lett. **50**, 811 (1983).
2. K. Hagiwara, S. Komamiya, and D. Zeppenfeld, Z. Phys. **C29**, 115 (1985).
3. N. Cabibbo, L. Maiani, and Y. Srivastava, Phys. Lett. **139B**, 459 (1984).

SCALE LIMITS for Contact Interactions: $\Lambda(eeee)$

Limits are for $\Lambda^{\pm}_{LL}$ only. For other cases, see each reference.

Λ^+_{LL} (TeV)	Λ^-_{LL} (TeV)	CL%	DOCUMENT ID		TECN	COMMENT
>1.6		95	[1,2] BUSKULIC	93Q	RVUE	
	>3.6	95	[3] KROHA	92	RVUE	
• • • We do not use the following data for averages, fits, limits, etc. • • •						
>1.6	>2.0	95	[2] BUSKULIC	93Q	ALEP	E_{cm}=88.25–94.25 GeV
	>2.2	95	BUSKULIC	93Q	RVUE	
>1.3		95	[3] KROHA	92	RVUE	
>0.7	>2.8	95	BEHREND	91C	CELL	E_{cm}=35 GeV
>1.3	>1.3	95	KIM	89	AMY	E_{cm}=50–57 GeV
>1.4	>3.3	95	[4] BRAUNSCH...	88	TASS	E_{cm}=12–46.8 GeV
>1.0	>0.7	95	[5] FERNANDEZ	87B	MAC	E_{cm}=29 GeV
>1.1	>1.4	95	[6] BARTEL	86C	JADE	E_{cm}=12–46.8 GeV
>1.17	>0.87	95	[7] DERRICK	86	HRS	E_{cm}=29 GeV
>1.1	>0.76	95	[8] BERGER	85B	PLUT	E_{cm}=34.7 GeV

[1] This BUSKULIC 93Q value is from ALEPH data plus PEP/PETRA/TRISTAN data reanalyzed by KROHA 92.

[2] BUSKULIC 93Q uses the following prescription to obtain the limit: when the naive 95%CL limit is better than the statistically expected sensitivity for the limit, the latter is adopted for the limit.

[3] KROHA 92 limit is from fit to BERGER 85B, BARTEL 86C, DERRICK 86B, FERNANDEZ 87B, BRAUNSCHWEIG 88, BEHREND 91B, and BEHREND 91C. The fit gives $\eta/\Lambda^2_{LL} = +0.230 \pm 0.206$ TeV^{-2}.

[4] BRAUNSCHWEIG 88 assumed $m_Z = 92$ GeV and $\sin^2\theta_W = 0.23$.

[5] FERNANDEZ 87B assumed $\sin^2\theta_W = 0.22$.

[6] BARTEL 86C assumed $m_Z = 93$ GeV and $\sin^2\theta_W = 0.217$.

[7] DERRICK 86 assumed $m_Z = 93$ GeV and $g_V^2 = (-1/2+2\sin^2\theta_W)^2 = 0.004$.

[8] BERGER 85B assumed $m_Z = 93$ GeV and $\sin^2\theta_W = 0.217$.