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A Combination of Results on Charged Triple Gauge Boson Couplings Measured by the LEP Experiments

The LEP Collaborations ALEPH, DELPHI, L3, OPAL, and the LEP TGC Working Group*

Prepared from published results of the LEP experiments.

Abstract

This note is a short reference for combination of published charged Triple Gauge Boson Couplings (cTGCs) measurements as performed for the 2005 edition of the Particle Data Book by the LEP TGC Working Group. We give an updated combination of the charged TGCs g_1^Z, κ_γ and λ_γ in single parameter fits.

*Contact: Ulrich Parzefall, email: Ulrich.Parzefall@physik.uni-freiburg.de
WWW access at http://www.cern.ch/LEPEWWG/lepww/tgc/

1 Introduction

During its second phase of operation, from 1996 until November 2000, the e^+e^- collider LEP at CERN steadily increased its centre-of-mass energy from 161 GeV reaching up to 209 GeV in the final year. Until the end of LEP-II operation, a total integrated luminosity of approximately 700 pb^{-1} per experiment has been recorded.

The measurement of gauge boson couplings and the search for possible anomalous contributions due to the effects of new physics beyond the Standard Model are among the principal physics aims at LEP-II [1]. Combined measurements of charged triple gauge boson couplings are presented here. Results from W-pair production are combined in single parameter fits, including final results from ALEPH [2], L3 [3] and OPAL [4].

The combination performed and described in this concise reference note for the PDG publication is simply a rerun of the standard LEP cTGC combination mechanism, using all available published LEP results on the subject. Therefore, we refer to the previous LEP GC note [5] for a description of the combination procedure. In particular, the sources of systematic errors considered correlated between the experiments, and their treatment in the combination is explained there.

The W-pair production process, $e^+e^- \to W^+W^-$, involves charged triple gauge boson vertices between the W^+W^- and the Z or photon. During LEP-II operation, about 10,000 W-pair events were collected by each experiment. Single W ($e\nu W$) and single photon ($\nu\bar{\nu}\gamma$) production at LEP are also sensitive to the $WW\gamma$ vertex. Results from these channels are also included in the combination for some experiments; the individual references should be consulted for details.

For the charged TGCs, Monte Carlo calculations (RacoonWW [6] and YFSWW [7]) incorporating an improved treatment of $O(\alpha_{em})$ corrections to the WW production have become our standard by now. The corrections affect the measurements of the charged TGCs in W-pair production. Final results including these $O(\alpha_{em})$ corrections have been submitted from ALEPH, L3 and OPAL. DELPHI [8] results are still given as preliminary and are not included in this combination.

1.1 Charged Triple Gauge Boson Couplings

The parametrisation of the charged triple gauge boson vertices is described in References [1, 9–14]. The most general Lorentz invariant Lagrangian which describes the triple gauge boson interaction has fourteen independent complex couplings, seven describing the $WW\gamma$ vertex and seven describing the WWZ vertex. Assuming electromagnetic gauge invariance as well as C and P conservation, the number of independent TGCs reduces to five. A common set is $\{g_1^Z, \kappa_Z, \kappa_\gamma, \lambda_Z, \lambda_\gamma\}$ where $g_1^Z = \kappa_Z = \kappa_\gamma = 1$ and $\lambda_Z = \lambda_\gamma = 0$ in the Standard Model. The parameters proposed in [1] and used by the LEP experiments are g_1^Z, λ_γ and κ_γ with the gauge constraints:

$$\kappa_Z = g_1^Z - (\kappa_\gamma - 1)\tan^2\theta_W\,, \qquad (1)$$

$$\lambda_Z = \lambda_\gamma\,, \qquad (2)$$

where θ_W is the weak mixing angle. The couplings are considered as real, with the imaginary parts fixed to zero. Note that the cTGC parameters can be quoted in different notations. In this combination, the LEP experiments and the LEP GC group quote the measured coupling values themselves. In older LEP combinations [15, 16] and the Particle Data Book, the deviations of the couplings from the Standard Model are quoted.

2 Measurements

The combined results presented here are obtained from charged electroweak gauge boson coupling measurements as discussed above. The individual references should be consulted for details about the data samples used.

TGCs affect both the total production cross-section and the shape of the differential cross-section as a function of the polar W^- production angle. The relative contributions of each helicity state of the W bosons are also changed, which in turn affects the distributions of their decay products. The analyses presented by each experiment make use of different combinations of each of these quantities. In general, however, all analyses use at least the expected variations of the total production cross-section and the W^- production angle. Results from $e\nu W$ and $\nu\bar{\nu}\gamma$ production are included by some experiments. Single W production is particularly sensitive to κ_γ, thus providing information complementary to that from W-pair production.

3 Results

The results of single-parameter fits from each experiment are shown in Table 1. As the methods of including systematic errors for extraction of TGC parameters differ among experiments, the LEP GC group re-computes these parameters for each experiment using a uniform method [5]. The individual $\log \mathcal{L}$ curve and their sum are shown in Figure 1. The results of the combination are given in Table 2.

Parameter	ALEPH	L3	OPAL
g_1^Z	$1.001 \pm 0.027 \pm 0.013$	$0.966^{+0.034}_{-0.032} \pm 0.015$	$0.987^{+0.034}_{-0.033}$
	$(0.996^{+0.030}_{-0.028})$	$(0.965^{+0.038}_{-0.037})$	$(0.984^{+0.035}_{-0.034})$
κ_γ	$0.971 \pm 0.055 \pm 0.030$	$1.013^{+0.067}_{-0.064} \pm 0.026$	$0.88^{+0.09}_{-0.08}$
	$(0.963^{+0.066}_{-0.063})$	$(1.020^{+0.075}_{-0.069})$	$(0.90^{+0.09}_{-0.08})$
λ_γ	$-0.012 \pm 0.027 \pm 0.011$	$-0.021^{+0.035}_{-0.034} \pm 0.017$	$-0.060^{+0.034}_{-0.033}$
	$(-0.016^{+0.030}_{-0.027})$	$(-0.023^{+0.042}_{-0.039})$	$(-0.061^{+0.037}_{-0.036})$

Table 1: The central values and one standard deviation errors as published by the experiments and, in parenthesis, those obtained with our combination method when applied to a single experiment. If two errors are quoted for an experiment, the first one is statistic while the second one is systematic. For results in parenthesis, the errors include statistical and systematic errors. The two results for a given parameter differ slightly, as explained in the text, thus when quoting results from a single experiment their respective published values [2–4] should be used.

4 Conclusions

Combinations of charged triple gauge boson couplings were made, based on published results from ALEPH, L3 and OPAL. No significant deviation from the Standard Model prediction is seen for any of the couplings studied. With the LEP-combined charged TGC results, the existence of triple gauge boson couplings among the electroweak gauge bosons is experimentally verified.

Parameter	68% C.L.
g_1^Z	$0.984^{+0.022}_{-0.019}$
κ_γ	$0.973^{+0.044}_{-0.045}$
λ_γ	$-0.028^{+0.020}_{-0.021}$

Table 2: The combined 68% C.L. errors obtained combining the results from ALEPH, L3 and OPAL. In each case the parameter listed is varied while the other two are fixed to their Standard Model values. Both statistical and systematic errors are included.

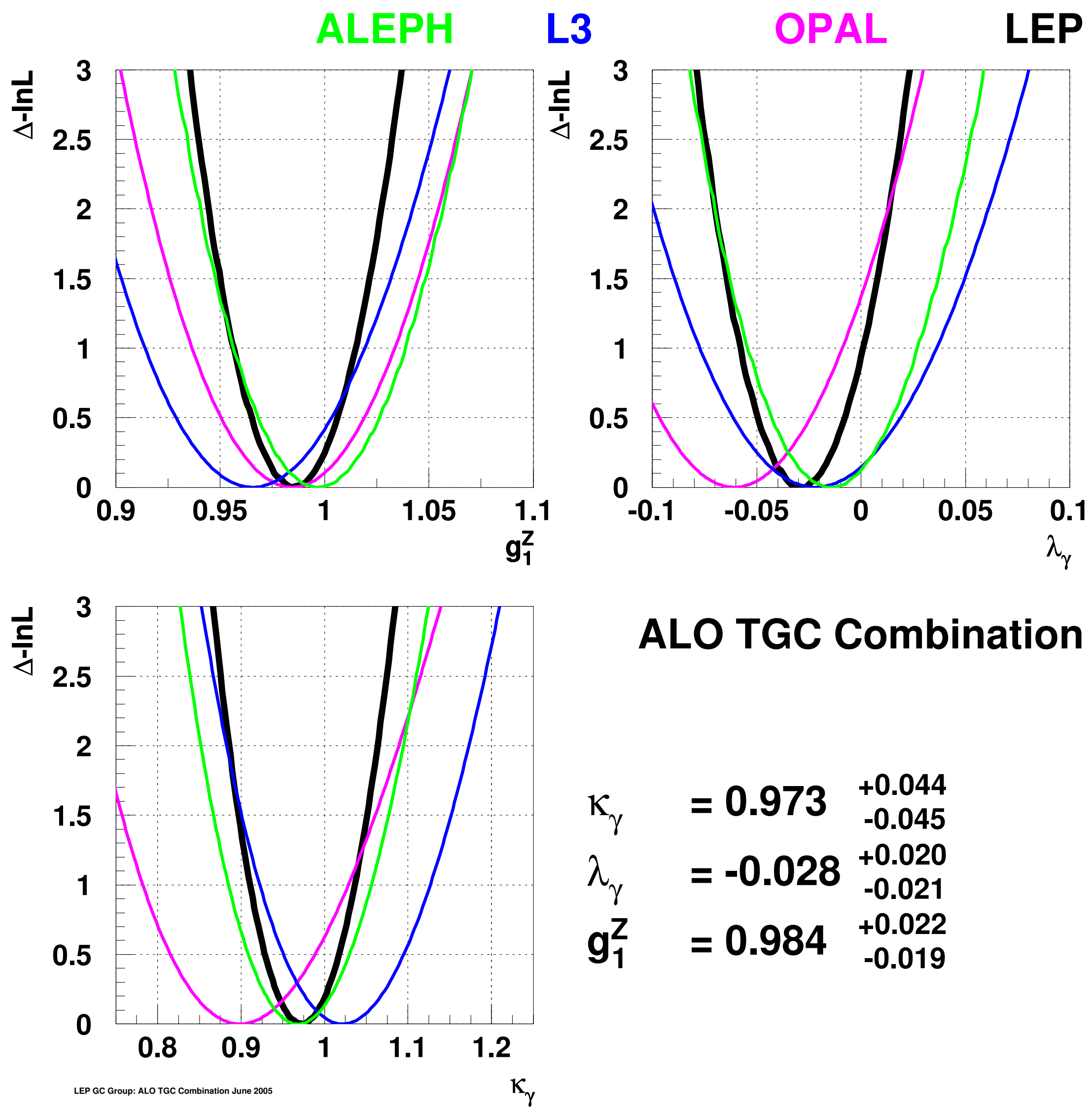

Figure 1: The $\log\mathcal{L}$ curves of the individual experiments (thin lines) and the combined curve (thick line) for the three charged TGCs g_1^Z, κ_γ and λ_γ. In each case, the minimal value is subtracted.

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