EUROPEAN LABORATORY FOR PARTICLE PHYSICS

LEPEWWG/TGC/97-01
ALEPH 97-088 PHYSIC 97-078
DELPHI 97-151 PHYS 730
L3 Note 2159
OPAL Technical Note TN-506
September 8, 1997

A Combination of Preliminary Measurements of Triple Gauge Boson Coupling Parameters Measured by the LEP Experiments.

The LEP Collaborations [1] ALEPH, DELPHI, L3, OPAL
The LEP TGC combination group [2]

Abstract

This note presents a combination of published and preliminary measurements of anomalous triple-gauge-boson coupling parameters from the four LEP experiments. The measurements result from the analysis of the data recorded by LEP2 during 1996 yielding approximately 10pb^{-1} at 161GeV and 10pb^{-1} at 172GeV centre of mass energies, per experiment. These results have been prepared for the EPS conference, Jerusalem 1997.

[1] The LEP Collaborations each take responsibility for the data of their own experiment. The combination procedure is the responsibility of the TGC combination group.

[2] TGC contacts from each experiment are J.Beck-Hansen (ALEPH / Beck@nbi.dk), C.Matteuzzi (DELPHI / Clara.Matteuzzi@cern.ch), M.Grunewald (L3 / Martin.Grunewald@cern.ch), P.Clarke (OPAL / Peter.Clarke@cern.ch).

1 Introduction

During the initial year of operation of LEP2 (1996), centre-of-mass energies have been attained which allow the production of W^+W^- boson pairs for the first time in e^+e^- collisions. A total integrated luminosity of approximately 10 pb^{-1} was recorded at a centre-of-mass energy of 161 GeV and 10pb^{-1} at 172 GeV, per experiment.

The W^+W^- production process involves the triple gauge boson vertices between the W^+W^- and the Z^0 or photon. The measurement of these triple gauge boson couplings (TGCs) and the search for possible anomalous values is one of the principal physics goals at LEP2.

The four LEP experiments have recently presented measurements of anomalous coupling parameters [1, 2, 3, 4] using this 1996 data set. In this note we present the results of a combination to obtain LEP averages of those parameters which have been measured by all four experiments.

Other experiments also measure TGCs and at present the most precise results come from the Tevatron experiments CDF [5] and D0 [6] based upon an analysis of nearly 100pb^{-1} per experiment.

Anomalous coupling parameters

The parameterisation of anomalous TGCs is described in references [7, 8, 9, 10, 11, 12]. The most general Lorentz invariant Lagrangian which describes the triple gauge boson interaction has fourteen independent terms, seven describing the WWγ vertex and seven describing the WWZ vertex. Assuming electromagnetic gauge invariance and C and P conservation the number of parameters reduces to five. One 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. Another such set is $\{\delta_z, \Delta\kappa_z, \Delta\kappa_\gamma, y_z, y_\gamma\}$ which are all zero in the Standard Model.

Different sets of parameters have also been proposed which are motivated by SU(2)$\times$U(1) gauge invariance and constraints arising from precise measurements at LEP1. One such set [12] is:

$$\alpha_{W\phi} \equiv \Delta g_1^z \cos^2\theta_w \tag{1}$$

$$\alpha_W \equiv \lambda_\gamma \tag{2}$$
$$\alpha_{B\phi} \equiv \Delta\kappa_\gamma - \Delta g_1^{z} \cos^2\theta_w \tag{3}$$

with the constraints that $\Delta\kappa_z = -\Delta\kappa_\gamma \tan^2\theta_w + \Delta g_1^z$ and $\lambda_z = \lambda_\gamma$. The Δ indicates the deviation of the respective quantity from its Standard Model value and θ_w is the weak mixing angle. Each of the α parameters has the value zero in the Standard Model.

Each of the experiments has measured several of the many possible TGCparameters and the references should be consulted for the complete set of measurements in each case. At the present time the common overlap of all experiments are the measurements of $\alpha_{W\phi}$, α_W and $\alpha_{B\phi}$ and in this note we present combinations of these parameters.

2 Input measurements

Each of the experiments has independently analysed the 1996 data set [1, 2, 3, 4]. These measurements result from approximately 25 and 100 events per experiment at 161 GeV and 172 GeV respectively. The results from each experiment are shown in table 1, where the errors include both statistical and systematic effects.

Anomalous TGCs can affect both the total production cross-section and the shape of the differential cross-section as a function of the 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, and of different decay modes of the WW system. The reader should consult the references for details. In general, however, all analyses use at least the expected variations of the total production cross-section and the W^- production angle.

Parameter	ALEPH [1]	DELPHI [2]	L3 [3]	OPAL [4]
$\alpha_{W\phi}$	$-0.14^{+0.29}_{-0.28}$	$0.24^{+0.26}_{-0.27}$	$0.04^{+0.43}_{-0.35}$	$-0.08^{+0.30}_{-0.27}$
α_{W}	$0.06^{+0.59}_{-0.55}$	$0.14^{+0.46}_{-0.47}$	$0.22^{+0.59}_{-0.61}$	$0.18^{+0.54}_{-0.52}$
$\alpha_{B\phi}$	$1.01^{+0.91}_{-2.17}$	$0.40^{+0.71}_{-0.92}$	$0.07^{+1.77}_{-1.16}$	$0.35^{+1.34}_{-1.14}$

Table 1: The measured central values and one standard deviation errors obtained by the four LEP experiments for the anomalous TGC parameters mentioned in section 1. Both statistical and systematic errors are included.

3 Combination of measurements

Each of the experiments have provided the full negative log likelihood curve, $\log \mathcal{L}$, as a function of each of the measured TGC parameters. The $\log \mathcal{L}$ curves from each experiment include both statistical and systematic effects. It is necessary to use the $\log \mathcal{L}$ curves directly for the combination as they are not parabolic, and it is therefore not possible to combine the results correctly by taking simple averages of one standard deviation measurements.

In principle there are some common systematic effects which should be included in a correlated way. These include the uncertainties of the LEP beam energy and the W mass, and some effects estimated by varying Monte Carlo generators. However, in this first combination we neglect this correlation as it has a negligible effect compared to the uncorrelated systematic and statistical errors.

The individual $\log \mathcal{L}$ curves for each parameter are added together. The results of this procedure are shown in figures 1 to 3 where each is plotted relative to its minimum value.

We obtain the one standard deviation limits (S.D.) directly from the curves [3] by taking the values of each TGC parameter where $\Delta \log \mathcal{L} = +0.5$ from the

[3] Given the non-parabolic nature of some of the $\log \mathcal{L}$ curves a more complicated pro-

minimum. We obtain the 95% confidence level (C.L.) limit given by the values of each TGC parameter where $\Delta \log \mathcal{L} = +1.92$. The results obtained are given in table 2. The value of each TGC parameter given in the table is consistent with the expectation of the Standard Model.

Parameter	1 S.D.	95% C.L. interval
$\alpha_{W\phi}$	$0.02^{+0.16}_{-0.15}$	$[-0.28, \quad 0.33]$
α_{W}	$0.15^{+0.27}_{-0.27}$	$[-0.37, \quad 0.68]$
$\alpha_{B\phi}$	$0.45^{+0.56}_{-0.67}$	$[-0.81, \quad 1.50]$

Table 2: The combined one standard deviation and 95% confidence intervals obtained after combination of the results from the four LEP experiments. The anomalous TGC parameters are those listed in section 1. Both statistical and systematic errors are included.

Acknowledgements

We would like to thank the SL Division of CERN for the efficient operation of the LEP accelerator and their close cooperation with the four experiments.

cedure to determine the error limits can be envisaged. We are currently investigating this possibility. In the meantime we proceed with the prescription given in the text.

References

[1] The ALEPH Collaboration, Contrib. paper to LP97 Hamburg, LP-257. The ALEPH Collaboration, Contrib. paper to EPS-HEP97 Jerusalem, EPS/97-601.

[2] DELPHI Collaboration, P. Abreu *et al.*, Phys. Lett. **B397** (1997) 158, DELPHI Collaboration, Contrib. paper to EPS-HEP97 Jerusalem, EPS/97-295, and DELPHI 97-113 CONF 95.

[3] L3 Collaboration, M. Acciarri *et al.*, Phys. Lett. **B398** (1997) 223,
L3 Collaboration, M. Acciarri *et al.*, CERN-PPE/97-98, submitted to Phys.Lett.B.

[4] OPAL Collaboration, K. Ackerstaff *et al.*, Phys. Lett. **B397** (1997) 147, OPAL Collaboration, Paper in preparation, to be submitted to Z.Phys.C.

[5] CDF Collaboration, F. Abe *et al.*, Phys. Rev. Lett. **75** (1995) 1017,
CDF Collaboration, F. Abe *et al.*, Phys. Rev. Lett. **78** (1997) 4536.

[6] D0 Collaboration, S. Abachi *et al.*, Phys. Rev. Lett. **75** (1995) 1023,
S. Abachi *et al.*, Phys. Rev. Lett. **75** (1995) 1034,
S. Abachi *et al.*, Phys. Rev. Lett. **77** (1996) 3303,
S. Abachi *et al.*, Phys. Rev. Lett. **78** (1997) 3634,
S. Abachi *et al.*, Fermilab-Pub-97/088-E, submitted to Phys. Rev.D ,
B. Abbott *et al.*, Fermilab-Pub-97/136-E, submitted to Phys. Rev. Lett.

[7] K. Gaemers and G. Gounaris, Zeit. Phys. **C1** (1979) 259.

[8] K. Hagiwara, R.D. Peccei, D. Zeppenfeld, K. Hikasa, Nucl. Phys. **B282** (1987) 253.

[9] M. Bilenky, J.L. Kneur, F.M. Renard and D. Schildknecht, Nucl. Phys. **B409** (1993) 22.
M. Bilenky, J.L. Kneur, F.M. Renard and D. Schildknecht, Nucl. Phys. **B419** (1994) 240.

[10] I. Kuss and D. Schildknecht, Phys. Lett. **B383** (1996) 470.

[11] G. Gounaris and C.G. Papadopoulos, hep-ph/9612378.

[12] Physics at LEP2, Edited by G. Altarelli, T. Sjostrand and F. Zwirner, Report on the LEP2 workshop 1995, CERN 96-01 (1996) Vol 1 p525.

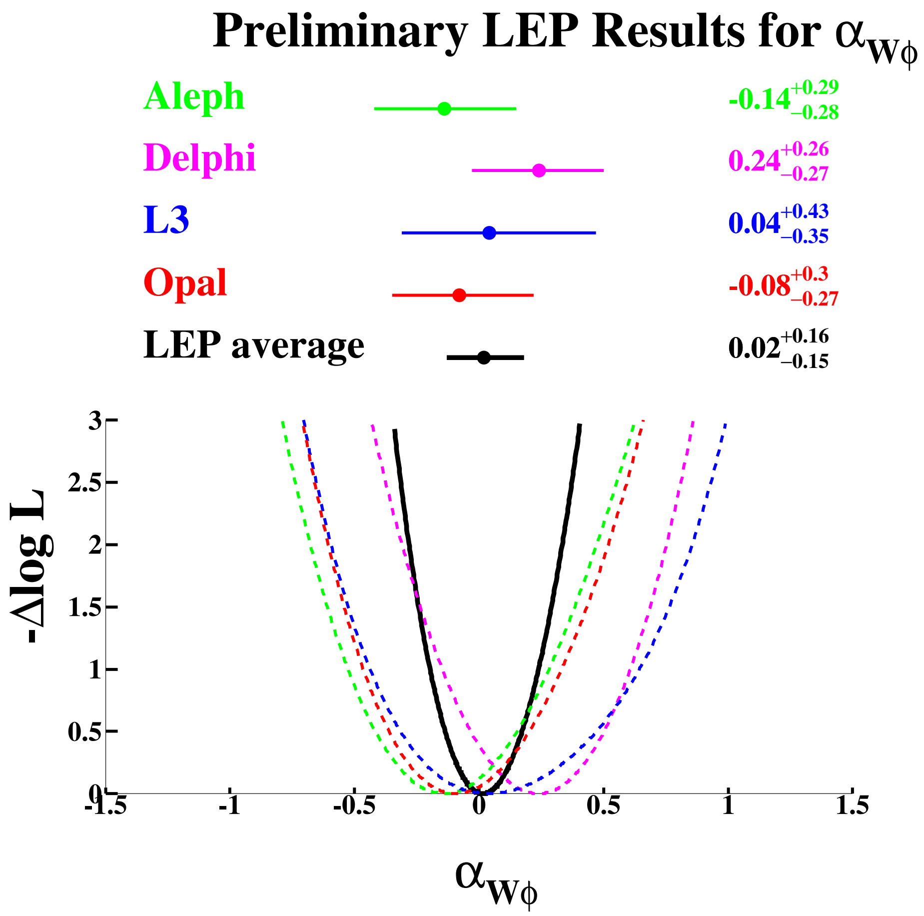

Figure 1: The LEP combined $\log \mathcal{L}$ curve as a function of the parameter $\alpha_{W\phi}$. This is obtained from the combination of the curves from the individual LEP experiments which are shown as dotted lines. The minimum value has been subtracted in all cases. The measurements and 1 standard deviation errors are also listed.

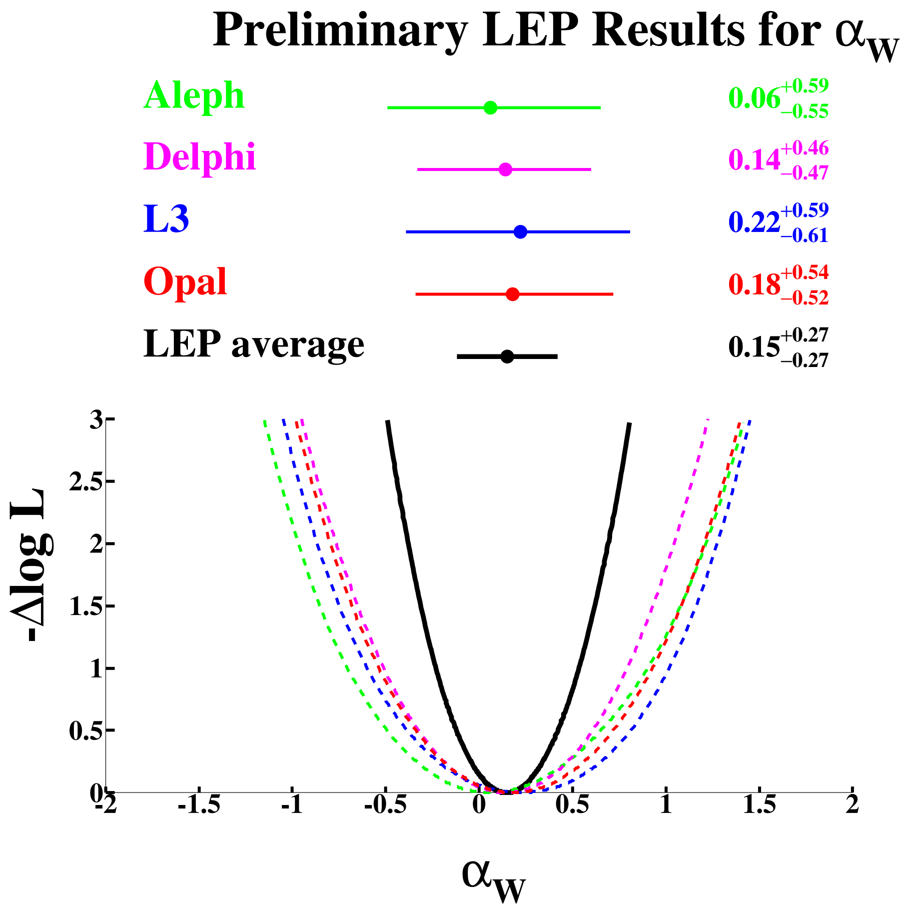

Figure 2: Results for α_W (same key as figure 1)

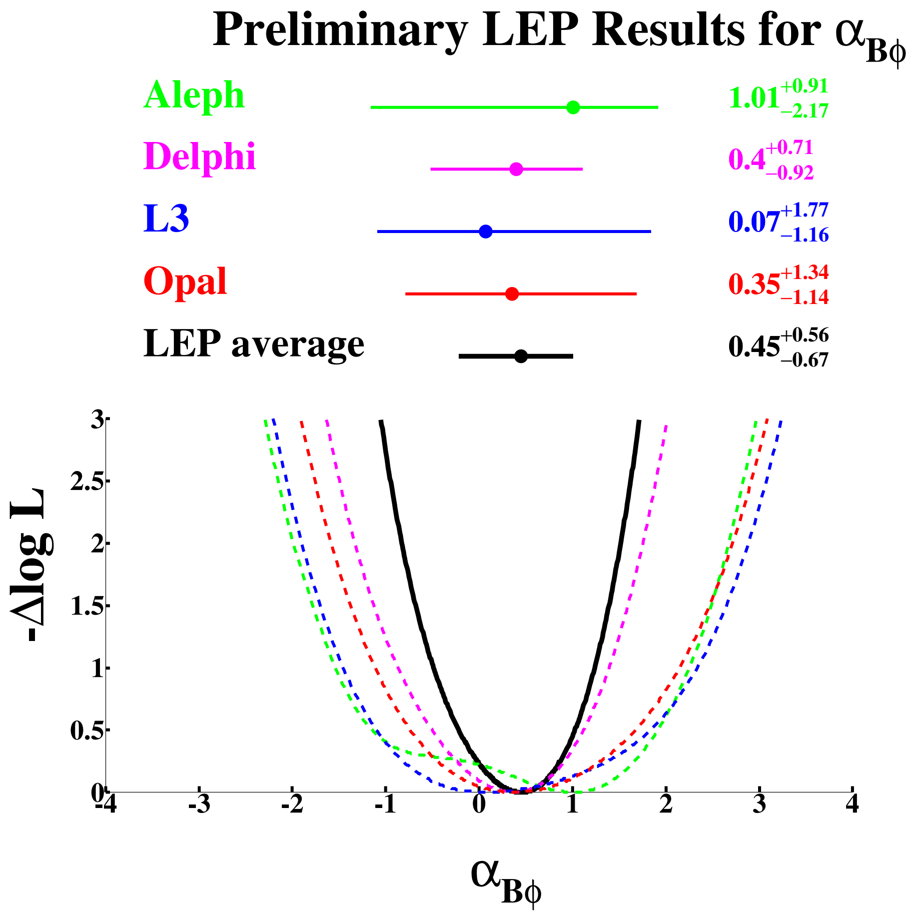

Figure 3: Results for $\alpha_{B\phi}$ (same key as figure 1)