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

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Abstract

This note presents a combination of published and preliminary measurements of anomalous triple-gauge-boson coupling parameters from the four LEP experiments and the DØ experiment. The measurements result from the combination of published DØ data, published data recorded at LEP2 during 1996 and preliminary analysis of 1997 LEP2 data corresponding to approximately 55 pb^{-1} at 183 GeV centre of mass energy per experiment.

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The Collaborations each take responsibility for the preliminary data of their own experiment.

1 Introduction

During 1997 operation, LEP2 reached a centre-of-mass energy of 183 GeV at which a total integrated luminosity of approximately 55 pb^{-1} was recorded per experiment. Each experiment selected about 800 $\mathrm{W}^+\mathrm{W}^-$ pairs.

The $\mathrm{W}^+\mathrm{W}^-$ production process involves the triple gauge boson vertices between the $\mathrm{W}^+\mathrm{W}^-$ and the Z 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 and DØ have recently published measurements of anomalous coupling parameters [1–5]. In those analyses the LEP experiments used the 1996 data set. In this note we present the results of a combination of those measurements combined with preliminary analysis based on the 1997 data from the four LEP experiments [6–9] and DØ [10].

The most recent results from DØ are based upon an analysis of approximately 100 pb^{-1} of data collected during the 1992–1995 Tevatron collider runs at Fermilab.

Anomalous coupling parameters

The parameterisation of anomalous TGCs is described in references [11–16]. The most general Lorentz invariant Lagrangian which describes the triple gauge boson interaction has fourteen independent terms, seven describing the $\mathrm{WW}\gamma$ 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.

The set of parameters proposed in [16] and used here are:

$$\alpha_{W\phi} \equiv \Delta g_1^z \cos^2\theta_{\mathrm{W}} \tag{1}$$
$$\alpha_W \equiv \lambda_\gamma \tag{2}$$
$$\alpha_{B\phi} \equiv \Delta\kappa_\gamma - \Delta g_1^z \cos^2\theta_{\mathrm{W}} \tag{3}$$

with the constraints that $\Delta\kappa_z = -\Delta\kappa_\gamma \tan^2\theta_w + \Delta g_1^z$ and $\lambda_z = \lambda_\gamma$, where Δ indicates the deviation of the respective quantity from its Standard Model value (and therefore are all zero in this context), and θ_W is the weak mixing angle. Each of the α parameters has the value zero in the Standard Model. These couplings neither generate anomalous Higgs couplings nor affect the gauge-boson propagators at tree level, thus are not constrained by LEP-I results.

Each of the experiments has measured several of the many possible TGC parameters 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

LEP results from 161 and 172 GeV data have already been published [1–4]. Each of the experiments has now analysed the 1997 data set using different channels, typically the semileptonic, fully hadronic and fully leptonic W decays [6–9]. 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; 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. At 183 GeV, ALEPH data [6] entering in this combination come at present only from the analysis of the $WW\gamma$ coupling in the single photon final state.

In the DØ analyses, the anomalous couplings are modified by dipole form factors with a scale Λ (*e.g.* $\lambda_\gamma(\hat{s}) = \lambda_\gamma/(1+\hat{s}/\Lambda^2)^2$, where $\hat{s}$ is the square of the invariant mass of the WW or WZ system). DØ uses $\Lambda = 2.0$ TeV, which corresponds to a few % correction to the anomalous couplings at $\hat{s} = 0$ or $\Lambda = \infty$. In the case of LEP results, this would imply a correction of 1.7%. Since this is a negligible effect, the correction has not been perfomed for the combination. The limits from DØ are obtained by performing a simultaneous fit to the data samples of three gauge boson pair final states: $W\gamma$ production with the W decaying to $e\nu$ and $\mu\nu$, W pair production with both of the W's decaying to $e\nu$ or $\mu\nu$, and WW or WZ production with one W decaying to $e\nu$ and the other W or the Z decaying to two jets.

The results from each experiment are shown in table 1, where the errors include both statistical and systematic effects. For the determination of each coupling, all others are set to their Standard Model value.

Parameter	ALEPH [1,6]	DELPHI [7]	L3 [3,8]	OPAL [4,9]	DØ [5,10]
$\alpha_{W\phi}$	$-0.14^{+0.27}_{-0.25}$	$0.01^{+0.11}_{-0.08}$	$-0.12^{+0.11}_{-0.10}$	$-0.03^{+0.13}_{-0.13}$	$0.11^{+0.16}_{-0.16}$
α_W	$0.04^{+0.52}_{-0.47}$	$-0.11^{+0.16}_{-0.16}$	$-0.25^{+0.23}_{-0.16}$	$0.05^{+0.23}_{-0.21}$	$-0.00^{+0.10}_{-0.10}$
$\alpha_{B\phi}$	$0.28^{+0.80}_{-0.94}$	$0.31^{+0.76}_{-0.51}$	$-0.43^{+0.33}_{-0.27}$	$0.25^{+0.61}_{-0.51}$	$-0.08^{+0.34}_{-0.34}$

Table 1: The measured central values and one standard deviation errors obtained by the four LEP and DØ experiments for the anomalous TGC parameters mentioned in section 1. Both statistical and systematic errors are included. For the fits to each coupling, the values of the other two are set to zero.

3 Combination of measurements

The method followed is the same already used in the previous combination [17]. Each of the experiments has 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 the combination this correlation is neglected, as it has a negligible effect. The uncorrelated systematic errors are typically 1/5 of the statistical errors. The main contributions come from Monte Carlo limited statistics, background to the selected W^+W^- sample, detector resolutions, fitting methods. Their importance varies for each experiments and the individual experiment publications should be consulted for details.

The individual $\log \mathcal{L}$ curves for each parameter are added together. The results of this procedure are shown in figures 1 to 3 for the 4 LEP experiments (where each is plotted relative to its minimum value). Figure 4 shows the combination with the D0 values.

The one standard deviation limits (S.D.) are obtained directly from the curves [1] by taking the values of each TGC parameter where $\Delta \log \mathcal{L} = +0.5$ from the minimum, as already done in the previous combination [17]. The 95% confidence level (C.L.) limit is 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
$\alpha_{W\phi}$	$-0.03^{+0.06}_{-0.06}$	$[-0.14, \ 0.10]$
α_{W}	$-0.03^{+0.08}_{-0.08}$	$[-0.18, \ 0.13]$
$\alpha_{B\phi}$	$-0.05^{+0.22}_{-0.20}$	$[-0.42, \ 0.43]$

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

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

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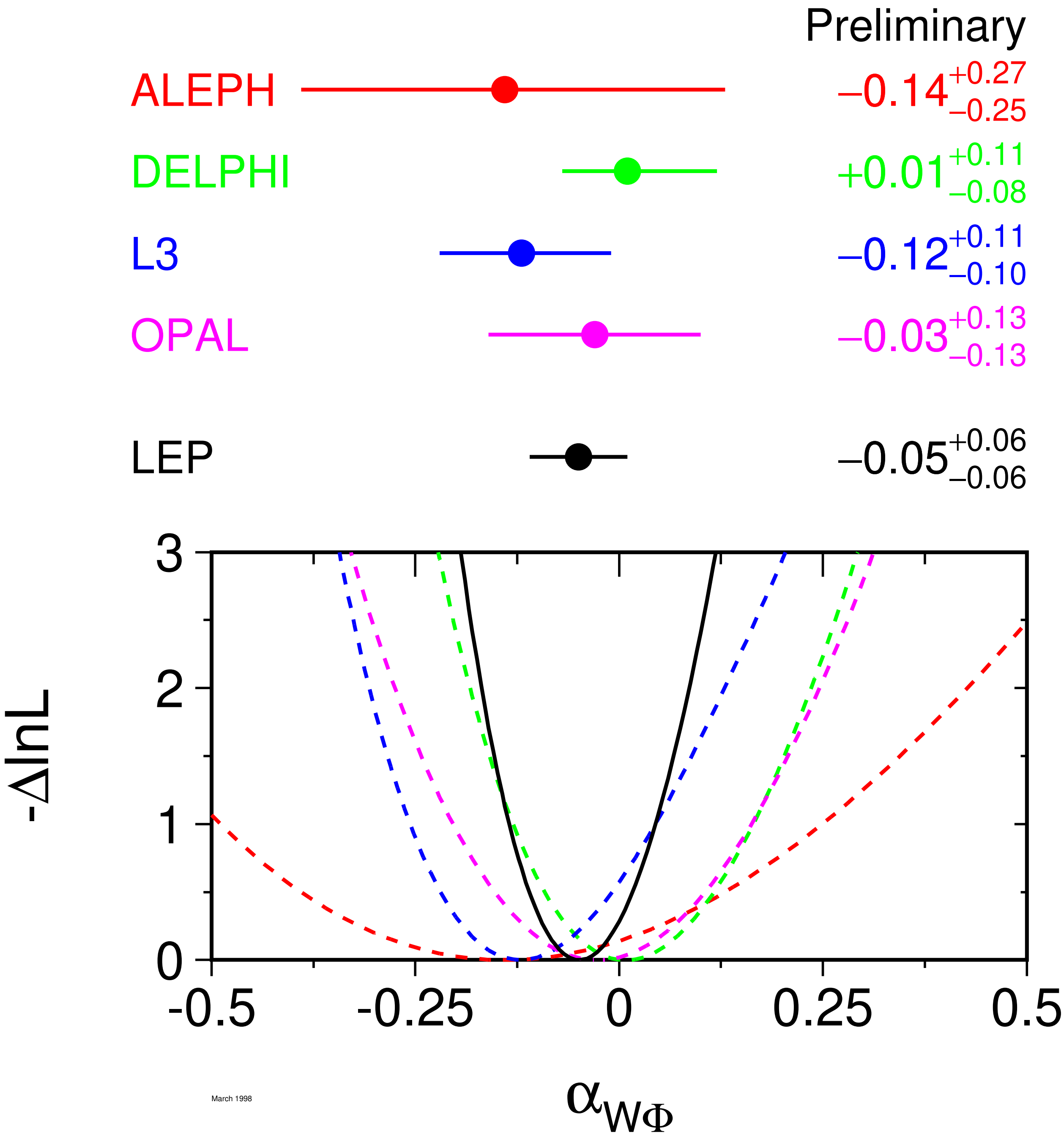

Figure 1: The LEP combined log $\mathcal{L}$ curve as a function of the parameter $\alpha_{W\phi}$. This is obtained from the combination of the curves from the individual LEP experiments which are shown as dotted lines. The minimum value has been subtracted in all cases. The measurements and 1 standard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

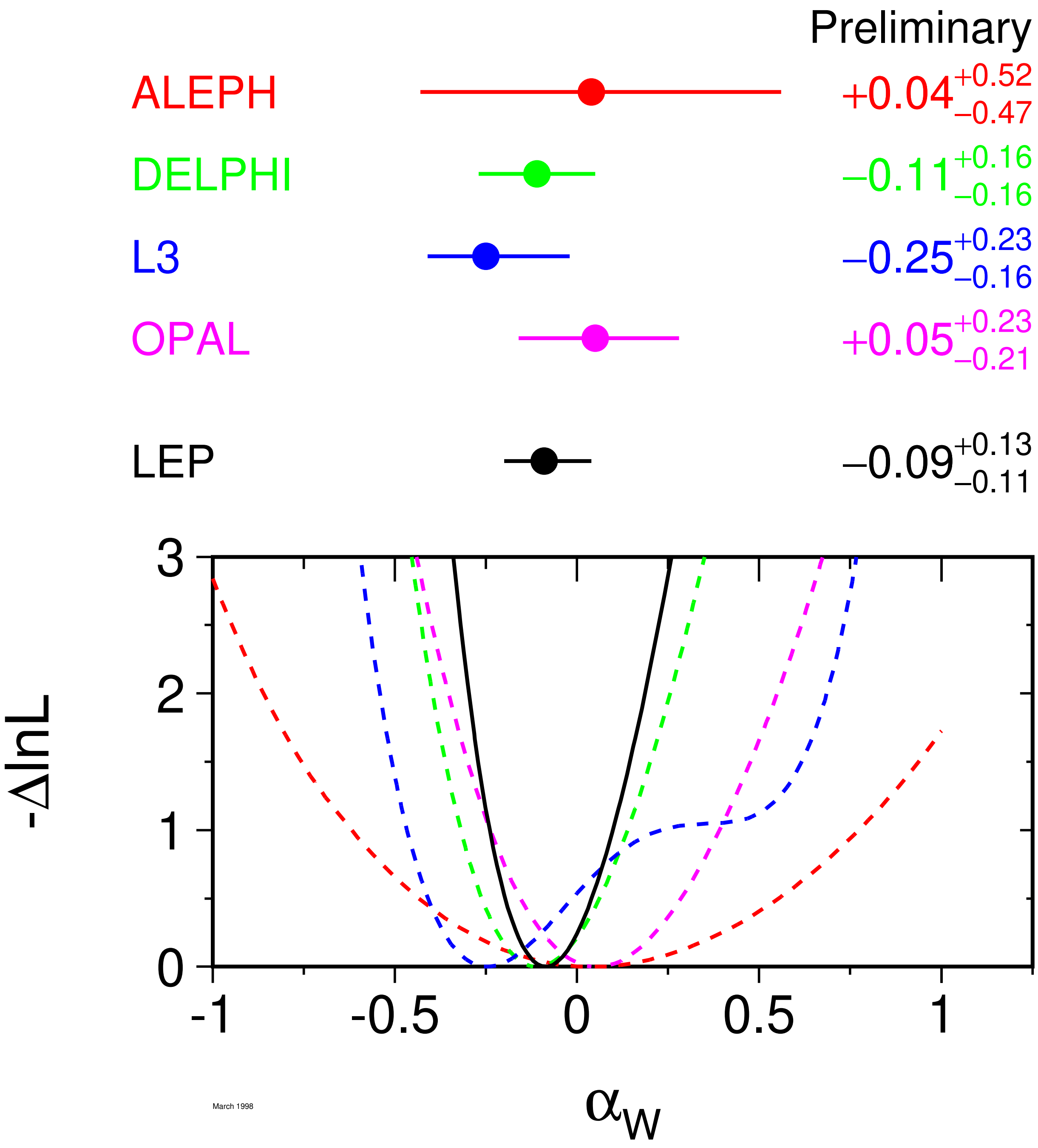

Figure 2: Results for α_W (same key as figure 1)

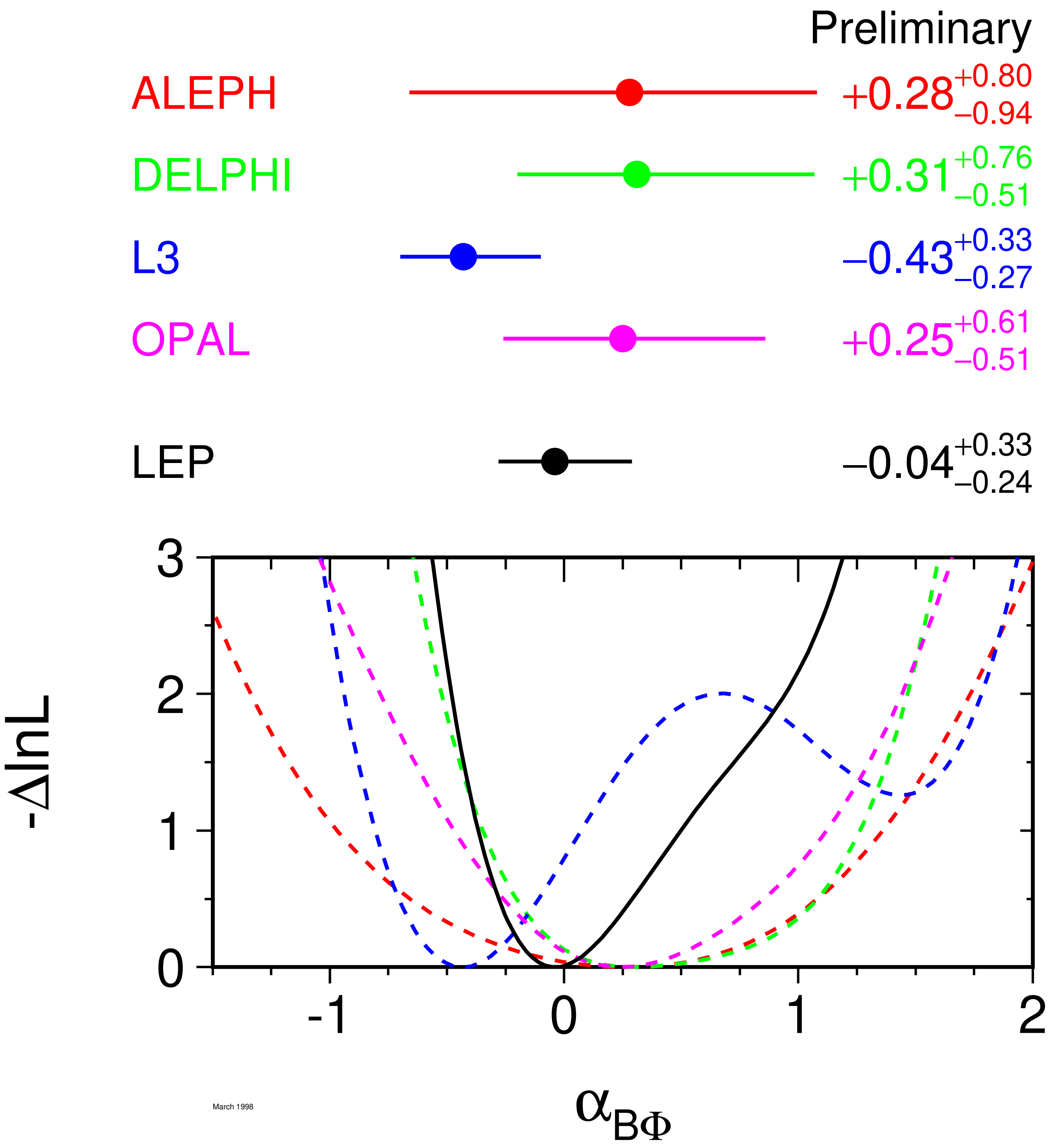

Figure 3: Results for $\alpha_{B\phi}$ (same key as figure 1)

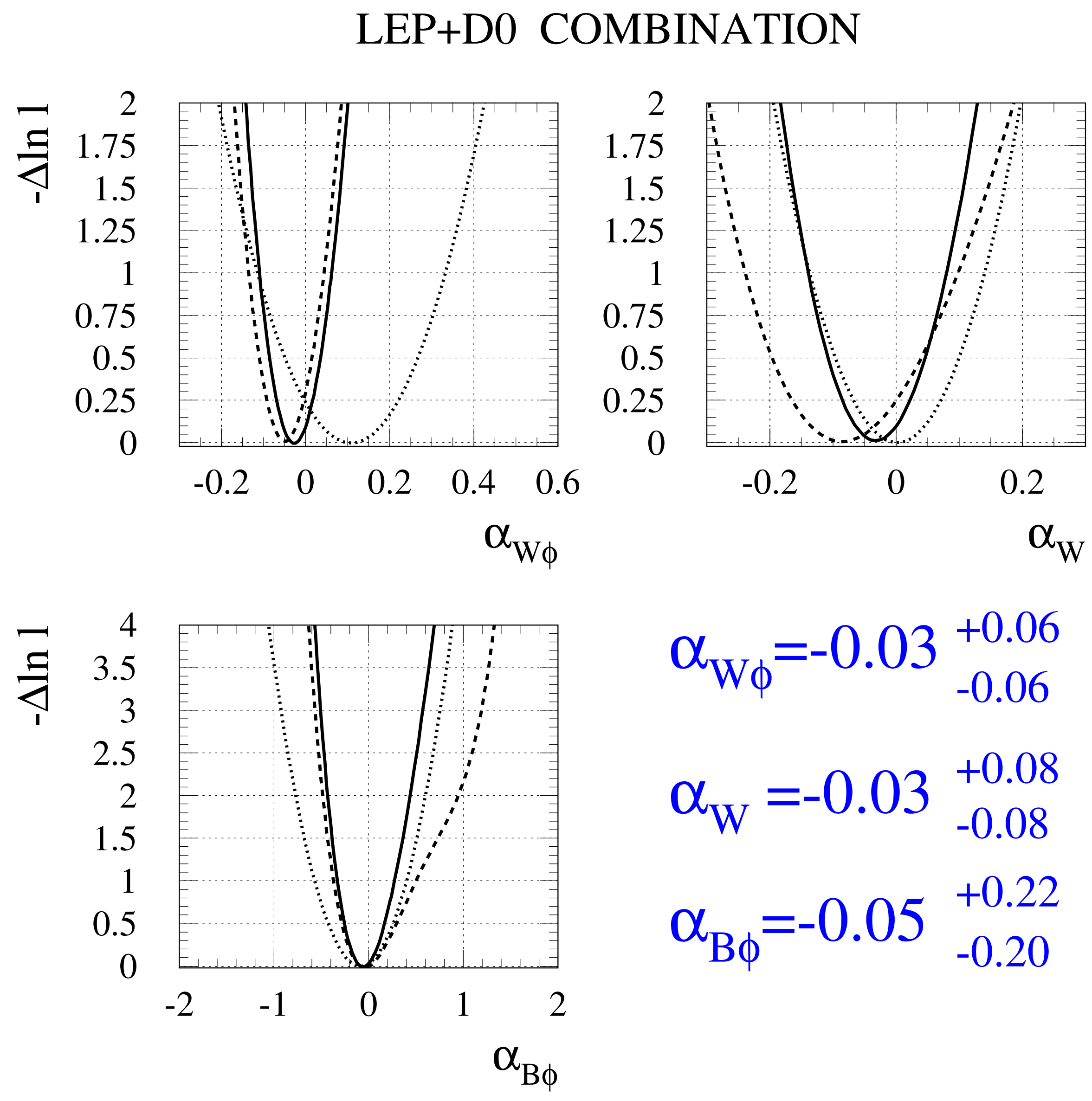

Figure 4: Results (continuous line) for the three α couplings combining LEP (dashed line) and DØ (dotted line) results.