BRIEF REPORTS

Brief Reports are accounts of completed research which do not warrant regular articles or the priority handling given to Rapid Communications; however, the same standards of scientific quality apply. (Addenda are included in Brief Reports.) A Brief Report may be no longer than four printed pages and must be accompanied by an abstract.

Precision electroweak experiments and heavy physics: An update

D. C. Kennedy and Paul Langacker
University of Pennsylvania, Philadelphia, Pennsylvania 19104
(Received 15 March 1991)

We update our previous global analysis of weak neutral current and Z and W data in which the parameters h_V and h_A associated with new heavy physics were constrained, by incorporating recent results on Z properties and M_W. We obtain $-0.93<h_V<0.33$, $-1.9<h_{AZ}<0.27$, and $-2.5<h_{AW}<1.5$ at 90% C.L., considerably better than the previous limits.

Recently a number of authors have discussed the implications of types of new heavy physics which only affect the Z, W, and weak current observables [1–7] through gauge-boson self-energy diagrams. In particular, we performed a global analysis [5] of all available data as of August, 1990 to obtain the experimental constraints on the three relevant parameters h_V, h_{AZ}, and h_{AW}. Since then, a number of new results have become available. The Z mass, width, and partial widths from experiments at the CERN e^+e^- collider LEP are now more precise. We use here an average of the ALEPH, DELPHI, L3, and OPAL results that incorporates all 1989–1990 data and properly deals with common systematic errors [8], which yields $M_Z=91.174\pm0.021$ GeV, $\Gamma_Z=2.487\pm0.009$ GeV, $\Gamma_{l\bar{l}}=83.3\pm0.4$ GeV, and $R\equiv\Gamma_{\rm had}/\Gamma_{l\bar{l}}=20.94\pm0.12$. There are also measurements of the Z-pole forward-backward asymmetry in $e^+e^-\to\mu^+\mu^-$, $A_{\rm FB}(\mu)=0.0154\pm0.0048$ [9], and a new absolute determination $M_W=79.91\pm0.39$ GeV from the Collider Detector at Fermilab [10]. In this work, we update our previous analysis to incorporate these new results.

From a fit to all data one obtains

$$h_V=-0.30\pm0.49\ ,$$

$$h_{AZ}=-0.90\pm0.86\ ,$$

$$h_{AW}=-0.6\pm1.6\ ,$$

$$\sin^2\hat{\theta}_W(M_Z^2)_{\overline{\rm MS}}=0.231\pm0.002\ ,$$

$$s_*^2(M_Z^2)=0.231\pm0.002\ ,$$

which are much better constrained than in [5]. ($\overline{\rm MS}$ denotes the modified minimal-subtraction scheme.) The upper limits are $h_V<0.33$ (0.50), $h_{AZ}<0.27$ (0.59), $h_{AW}<1.5$ (2.1) at 90 (95)% C.L. If one assumes $h_{AZ}=h_{AW}\equiv h_A$, then $h_A<0.14$ (0.44). The 90% C.L. lower limits are $h_V>-0.93$, $h_{AZ}>-1.9$, $h_{AW}>-2.5$. All of these results assume $m_t=M_H=M_Z$. As described in [5], h_V and $h_{AZ,W}$ describe the effects of different values for m_t and M_H and also of non-standard-model heavy physics. The 90% C.L. regions in (h_A,h_V) from various inputs are shown in Fig. 1. The allowed region is considerably smaller than in [5] both because of the inclusion of $A_{\rm FB}(\mu)$ and also because of the smaller experimental errors in M_Z, Γ_Z, and $\Gamma_{l\bar{l}}$.

The upper limit on h_V can be interpreted as an upper limit on the top-quark mass m_t, most easily using the simplified quadratic form for the m_t dependence of h_V (Eq. (8a) of [5]). For $m_t<200$ GeV, however, the

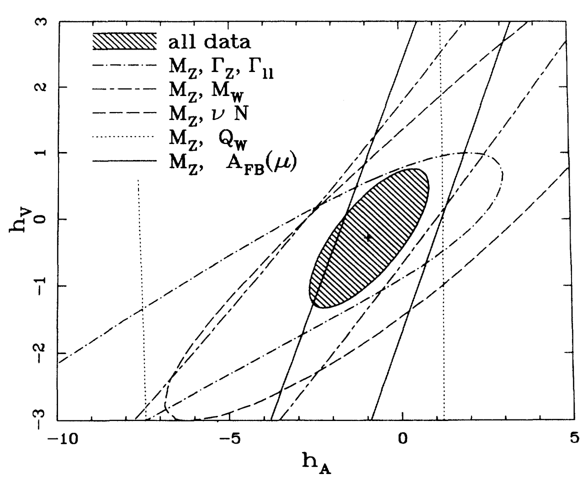

FIG. 1. 90% C.L. regions in (h_A,h_V) from simultaneous fits of M_Z with various other observables, as well as *all data*. The fit to *all data* assumes $h_{AZ}=h_{AW}$. The fit to (M_Z,M_W) involves h_{AW}, while the others use h_{AZ} alone.

simplified form is not correct, and it is better to fit the standard model directly to data with the top-quark and Higgs-boson masses as the only unknowns and to include the complete m_t dependence in the radiative corrections (i.e., including the subquadratic terms). This yields [11] the central value $m_t = 124 \pm 34$ GeV, with upper limits $m_t < 174$ (182) GeV at 90 (95)% C.L., no useful limits on the Higgs-boson mass, and $\sin^2\hat{\theta}_W(M_Z^2)_{\overline{\rm MS}} = 0.2334 \pm 0.0008$. Allowing the tree-level $\rho_0 \neq 1$ (nonminimal Higgs bosons), one obtains [11] $m_t < 294$ (310) GeV at 90 (95)% C.L., $\rho_0 = 0.992 \pm 0.011$, and $\sin^2\hat{\theta}_W(M_Z^2)_{\overline{\rm MS}} = 0.2333 \pm 0.0008$.

This work was supported by the Institute for Theoretical Physics of the University of California at Santa Barbara and by the Department of Energy, Contract No. DE-AC02-76-ERO-3071.

[1] B. W. Lynn, M. E. Peskin, and R. G. Stuart, in *Physics at LEP,* LEP Jamboree, Geneva, Switzerland, 1985, edited by J. Ellis and R. Peccei (CERN Yellow Report No. 86-02, Geneva, 1986), p. 90.

[2] M. Peskin and T. Takeuchi, Phys. Rev. Lett. **65**, 964 (1990).

[3] M. Golden and L. Randall, Report No. FNAL-PUB-90/83-T (unpublished).

[4] W. Marciano and J. Rosner, Phys. Rev. Lett. **65**, 2963 (1990).

[5] D. C. Kennedy and P. Langacker, Phys. Rev. Lett. **65**, 2967 (1990).

[6] G. Altarelli and R. Barbieri, Phys. Lett. B **253**, 161 (1991).

[7] B. Holdom and J. Terning, Phys. Lett. B **247**, 88 (1990).

[8] S. Lloyd, presented at the 1991 Aspen Winter Conference in Elementary Particle Physics, 1991 (unpublished).

[9] This value is derived from the average $\bar{g}_V^2$ and $\bar{g}_A^2$ presented in [8].

[10] F. Abe *et al.,* Phys. Rev. Lett. **65**, 2243 (1990); Phys. Rev. D **43**, 2070 (1991).

[11] P. Langacker and M. X. Luo, Phys. Rev. D **44**, 817 (1991).