STANDARD MODEL OF ELECTROWEAK INTERACTIONS

To reduce the size of this section's PostScript file, we have divided it into three PostScript files. We present the following index:

PART 1

PART 2

PART 3

10.5. Deviations from the Standard Model

The Z pole, W mass, and neutral-current data can be used to search for and set limits on deviations from the Standard Model.

For example, the relation between M_W and M_Z is modified if there are Higgs multiplets with weak isospin $> 1/2$ with significant vacuum expectation values. In order to calculate to higher orders in such theories one must define a set of four fundamental renormalized parameters. It is convenient to take these as α, G_F, M_Z, and M_W, since M_W and M_Z are directly measurable. Then $\widehat{s}^2_Z$ and ρ_0 can be considered dependent parameters defined by

$$\widehat{s}^2_Z \equiv A_0^2/M_W^2(1-\Delta\widehat{r}_W) \tag{10.40}$$

and

$$\rho_0 \equiv M_W^2/(M_Z^2\,\widehat{c}^2_Z\,\widehat{\rho}) \ . \tag{10.41}$$

Provided that the new physics which yields $\rho_0 \neq 1$ is a small perturbation which does not significantly affect the radiative corrections, ρ_0 can be regarded as a phenomenological parameter which multiplies G_F in Eqs. (10.12)–(10.14), (10.28), and Γ_Z in Eq. (10.36). (Also, the expression for M_Z is divided by $\sqrt{\rho_0}$; the M_W formula is unchanged.) There is now enough data to determine ρ_0, $\sin^2\theta_W$, m_t, and α_s simultaneously. In particular, R_b and the direct CDF and DØ events yield m_t independent of ρ_0, the asymmetries yield $\widehat{s}^2_Z$, R gives α_s, and M_Z and the widths constrain ρ_0. From the global fit (including CDF and DØ),

$$\rho_0 = 1.0012 \pm 0.0013 \pm 0.0018 \tag{10.42}$$

$$\widehat{s}^2_Z = 0.2314 \pm 0.0002 \pm 0.0002 \tag{10.43}$$

$$\alpha_s = 0.121 \pm 0.004 \pm 0.001 \tag{10.44}$$

$$m_t = 171 \pm 12 \ , \tag{10.45}$$

where the second error is from M_H. This is in remarkable agreement with the Standard Model expectation $\rho_0 = 1$, and constrains any higher-dimensional Higgs representation to have vacuum expectation values of less than a few percent of those of the doublets. The allowed regions in the $\rho_0 - \widehat{s}^2_Z$ plane are shown in Fig. 10.2. Allowing for new physics in R_b, one obtains $\rho_0 = 1.0002(14)(18)$ and $\alpha_s = 0.101(8)(1)$. The effects of other types of new physics are described in Sec. 14 on "Constraints on New Physics from Electroweak Analyses" in this *Review*.

Most of the parameters relevant to ν-hadron, νe, e-hadron, and e^+e^- processes are determined uniquely and precisely from the data in "model independent" fits (*i.e.*, fits which allow for an arbitrary electroweak gauge theory). The values for the parameters defined in Eqs. (10.12)–(10.14) are given in Table 10.6 along with the predictions

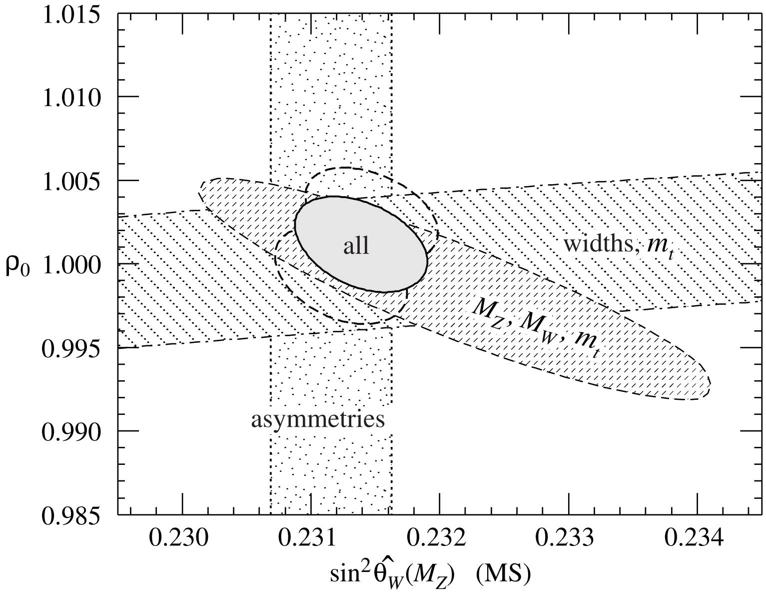

Figure 10.2: The allowed regions in $\sin^2\widehat{\theta}_W - \rho_0$ at 90% CL. m_t is a free parameter and $M_H = 300$ GeV is assumed. (The upper (lower) dashed contours are for $M_H = 1000$ (60) GeV.) The horizontal (width) band uses the experimental value of M_Z in Eq. (10.36).

of the Standard Model. The agreement is excellent. The low-energy e^+e^- results are difficult to present in a model-independent way because Z-propagator effects are non-negligible at TRISTAN, PETRA, and PEP energies. However, assuming e-μ-τ universality, the lepton asymmetries imply [45] $4(g_A^e)^2 = 0.99 \pm 0.05$, in good agreement with the Standard Model prediction $\simeq 1$. The much more precisely measured Z-pole parameters in Table 10.3 are in excellent agreement with the Standard Model.

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Table 10.6: Values of the model-independent neutral-current parameters, compared with the Standard Model prediction using $M_Z = 91.1884$ GeV for $m_t = 180 \pm 7$ GeV and $M_H = 300$ GeV. There is a second $g_{V,A}^{\nu e}$ solution, given approximately by $g_V^{\nu e} \leftrightarrow g_A^{\nu e}$, which is eliminated by e^+e^- data under the assumption that the neutral current is dominated by the exchange of a single Z. θ_i, $i = L$ or R, is defined as $\tan^{-1}[\epsilon_i(u)/\epsilon_i(d)]$.

Quantity	Experimental Value	Standard Model Prediction	Correlation	
$\epsilon_L(u)$	0.332 ± 0.016	0.345 ± 0.0003		
$\epsilon_L(d)$	-0.438 ± 0.012	-0.429 ± 0.0004		non-
$\epsilon_R(u)$	-0.178 ± 0.013	-0.156		Gaussian
$\epsilon_R(d)$	$-0.026\ ^{+0.075}_{-0.048}$	0.078		
g_L^2	0.3017 ± 0.0033	0.303 ± 0.0005		
g_R^2	0.0326 ± 0.0033	0.030		small
θ_L	2.50 ± 0.035	2.46		
θ_R	$4.58\ ^{+0.46}_{-0.28}$	5.18		
$g_A^{\nu e}$	-0.507 ± 0.014	-0.507 ± 0.0004		-0.04
$g_V^{\nu e}$	-0.041 ± 0.015	-0.037 ± 0.0003		
C_{1u}	-0.214 ± 0.046	-0.190 ± 0.0005	-0.995	-0.79
C_{1d}	0.359 ± 0.041	0.342 ± 0.0004		0.79
$C_{2u} - \frac{1}{2}C_{2d}$	-0.04 ± 0.13	-0.052 ± 0.0009		

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