27. CONSTRAINTS ON NEW PHYSICS FROM ELECTROWEAK ANALYSES

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As discussed in the Standard Model review (Sec. 26), the combination of indirect data with the CDF value for m_t allows stringent limits on new physics. In particular, many extensions of the Standard Model are described by the ρ_0 parameter:

$$\rho_0 \equiv M_W^2/(M_Z^2\,\widehat{c}_Z^{\,2}\,\widehat{\rho}) \;, \tag{27.7}$$

which describes new sources of SU(2) breaking that cannot be accounted for by Higgs doublets or m_t effects. It has previously been difficult (experimentally) to distinguish ρ_0 from the Standard Model value, $\widehat{\rho} \simeq 1 + \rho_t$ (where $\rho_t \equiv 3m_t^2 G_F/8\pi^2\sqrt{2}$), though some separation could be done utilizing R_b [8]. Using the CDF m_t value as an independent constraint, however, one can calculate $\widehat{\rho}$ and thus obtain the precise value [2] $\rho_0 = 1.0004 \pm 0.0022 \pm 0.002$, where the second error is from M_H. In the Standard Model review (Sec. 26), this result was used to constrain the vacuum expectation values of higher-dimensional Higgs representations. It can also be used to constrain Δm^2 from nondegenerate SU(2) multiplets, as defined in Eq. (27.5). That is, in the presence of such multiplets, one has

$$\frac{3G_F}{8\sqrt{2}\pi^2}\sum_i \frac{C_i}{3}\,\Delta m_i^2 = \rho_0 - 1 \;, \tag{27.8}$$

implying

$$\sum_i \frac{C_i}{3}\,\Delta m_i^2 < (95\ \text{GeV})^2\;,\;\; (111\ \text{GeV})^2\;,\;\; (128\ \text{GeV})^2 \tag{27.9}$$

for $M_H = 60$, 300, or 1000 GeV at 90% CL.

It is also possible to parametrize the effects of large $m_t \gg M_Z$ (except for the $b\overline{b}$ vertex) or $M_H \gg M_Z$ in terms of S, T, and U. If one takes $m_t = m_t^{\text{ref}}, M_H = M_H^{\text{ref}}$ as a reference point, then other values of m_t and M_H can be expressed for large m_t, M_H as [11]

$$\begin{aligned}
\Delta T &= \frac{\rho_t(m_t) - \rho_t(m_t^{\text{ref}})}{\alpha} \\
&\quad - \frac{3G_F}{4\sqrt{2}\alpha\pi^2}(M_Z^2 - M_W^2)\ln(M_H/M_H^{\text{ref}}) \\
\Delta S &= c_S \ln(m_t/m_t^{\text{ref}}) + \frac{1}{6\pi}\ln(M_H/M_H^{\text{ref}}) \\
\Delta U &= c_U \ln(m_t/m_t^{\text{ref}}) \;,
\end{aligned} \tag{27.16}$$