where the coefficients c_S and c_U depend on the renormalization scheme. Various authors use different reference values for m_t and M_H when determining S, T, and U from the data. In the following $M_H^{\rm ref} = 300$ GeV and the global best fit value $m_t^{\rm ref} = 169$ GeV will be used when the CDF constraint is not imposed. The allowed ranges of the parameters will then represent both the effects of new physics and of values of m_t and M_H different from the reference values, *i.e.*, $S = S_{\rm new} + \Delta S$, $T = T_{\rm new} + \Delta T$, $U = U_{\rm new} + \Delta U$. For later use, note that $\Delta S = \Delta S_t + \Delta S_{\rm Higgs}$ and similarly for ΔT.

The $Z \to b\bar{b}$ vertex is sensitive to certain types of new physics which primarily couple to heavy families [18,19]. It is useful to introduce an additional parameter γ_b by [20]

$$\Gamma(Z \to b\bar{b}) = \Gamma^0(Z \to b\bar{b})(1+\gamma_b) \ , \tag{27.19}$$

where Γ^0 is the Standard Model expression (or the expression modified by S, T, U, and ρ_0). Experimentally, $R_b \equiv \Gamma(Z \to b\bar{b})/\Gamma(\text{had})$ is about 1.8σ above the Standard Model expectations, favoring a positive γ_b. Extended technicolor models generally yield negative values of γ_b of a few percent [18], while supersymmetry can yield (typically small) contributions of either sign [19].

The indirect data allow a simultaneous determination of $\widehat{s}^2_Z$ (*e.g.*, from the Z-pole asymmetries), S (from M_Z), U (from M_W), T (*e.g.*, from the Z-decay widths), α_s (from $\Gamma(Z \to \text{had})/\Gamma(\ell\bar{\ell})$, and γ_b (from R_b) with little correlation. Combining with the CDF direct value of m_t, one can determine $S_{\rm new}$, $T_{\rm new}$, $U_{\rm new}$, and γ_b directly, in a simultaneous fit with $\widehat{s}^2_Z$, $\alpha_s(M_Z)$, and m_t. One obtains

$$\begin{aligned} S_{\rm new} &= -0.42 \pm 0.36^{-0.08}_{+0.17} \\ T_{\rm new} &= -0.35 \pm 0.44^{+0.18}_{-0.11} \\ U_{\rm new} &= -1.3 \ \ \pm 1.3 \\ \gamma_b &= \ \ \ 0.032 \pm 0.017 \ , \end{aligned} \tag{27.20b}$$

and the allowed region in $S'_{\rm new}-T'_{\rm new}$ is shown in Fig. 27.1. ($S'_{\rm new}$ includes the M_H dependence explicitly, $S'_{\rm new} \equiv S_{\rm new} + \Delta S_{\rm Higgs}$, and similarly for $T'_{\rm new}$, see Eq. (27.16).) The second error bars represent the uncertainty due to M_H ranging from the reference value of 300 GeV to 1000 (upper) or 60 (lower) GeV. The values in Eq. (27.20*b*) are almost identical to those without using m_t from CDF except for a small increase in the errors due to the variation of m_t around the best fit value 175 ± 16. From Eq. (27.20*b*) one obtains $S_{\rm new} < 0.09\,(+0.23)$, and $T < 0.27\,(0.43)$ at $90\,(95)\%$ CL. Only one heavy generation of ordinary fermions is allowed at 95% CL. The favored value of $S_{\rm new}$ is problematic for technicolor models with many techni-doublets and