IMPLICATIONS OF PHYSICS AT LEP, SLC AND TEVATRON

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Abstract

We discuss the consequences of results from CDF, SLC, LEP and elsewhere for the Standard Model and for new physics. A global fit to all data yields $m_t = 175 \pm 11^{+17}_{-19}$ GeV, $\sin^2 \hat{\theta}_{\overline{MS}} = 0.2317(3)(2)$ and $\alpha_s = 0.127(5)(2)$. The m_t value is in remarkable agreement with direct determinations at the Tevatron. There is a slight preference for a light Higgs with $M_H < 730$ (880) GeV at 95% c.l. if the CDF m_t value is (not) included. The value of α_s (mainly from $R_{\rm had}$) is clean theoretically assuming the Standard Model, but is sensitive to the presence of new physics. We will also present results from more general fits to parameters describing new physics effects.

The outstanding experimental developments in 1994, on which the results of this contribution are primarily based, were

CDF – the candidate events of the top quark and the determination of its mass [1], $m_t = 174 \pm 16$ GeV;

SLD – the precise measurement of the left-right asymmetry [2], $A^0_{LR} = 0.1656 \pm 0.0076$;

LEP – a high statistics run at the Z resonance including a very precise measurement of its width [3], $\Gamma_Z = 2.4974 \pm 0.0038$ GeV.

Other inputs include the W mass, $M_W = 80.21 \pm 0.16$ GeV, as determined in $p\bar{p}$ collision by the UA2, CDF and D0 collaborations; the effective weak charge, Q_W, in atomic parity violation; results from neutrino electron and deep inelastic neutrino nucleon scattering; as well as older low energy data.

The agreement between theory and experiment is generally excellent, but the following remarks are called for:

- $R_b = \Gamma_{b\bar{b}}/\Gamma_{\rm had} = 0.2202 \pm 0.0020$ is 2.3 σ higher than the Standard Model (SM) prediction 0.2156 ± 0.0004. This branching ratio is by accident virtually independent of α_s and almost independent of the Higgs mass, M_H, but it is sensitive to m_t. In contrast, most of the other observables possess a leading M_H dependence, which is strongly correlated with the dominant m_t^2 term. This results in an overall preference for a light Higgs. Except for its unique m_t dependence, R_b is also particularly interesting as it is expected to be sensitive to new kinds of physics and the symmetry breaking sector.

- $A^0_{LR} \equiv A_e$ corresponds (in the SM) to a direct measurement of the effective weak mixing angle defined for electrons, $\sin^2\theta^e_{\rm eff} \equiv \bar{s}^2_e$, since it is based on initial state polarization. Dependences on final state couplings cancel. There is a 2.2 σ discrepancy to A_e determinations at LEP through the angular distributions of electron and polarized τ final states. The discrepancy to LEP under the assumption of lepton universality is 2.0 σ and the deviation w.r.t. the SM amounts to 2.5 σ. We have shown that neither non-standard $Zf\bar{f}$ couplings [4] nor extra non-Z related events mediated by effective four-Fermi interactions [5] can account for the discrepancy[1]. Non-Z related fermion production near the Z peak are particularly suited to possibly explain the observed discrepancy, since in this situation the above mentioned cancellation of final state couplings ceases to hold. However, data from e^+e^- annihilation experiments at lower center of mass energies (rather than Z pole data by themselves) exclude this scenario.

- The measured angular distribution of τ final states, $A^{0\tau}_{FB} = 0.0228 \pm 0.0028$, deviates by 2.8 σ from SM expectations.

[1]See, however, the possibility of an almost mass degenerate Z' [6], which escapes the description by four-Fermi operators due to the different s dependence of its cross section.

- $\alpha_s(M_Z) = 0.127 \pm 0.005 \pm 0.002$, as determined by our analysis of precision data, is in conflict with low energy determinations such as from deep inelastic neutrino and μ scattering, quarkonium decays and spectra, and the CLEO determinations using e^+e^- jet rates and R_τ, which all give central values in the range $0.110 \leq \alpha_s \leq 0.115$ [7]. It is, however, in agreement with LEP determinations from violation of scaling in jet fragmentation, event shapes and their R_τ analysis [7]. It is also in perfect agreement with grand desert SUSY-GUT expectations. We included QCD corrections to the hadronic decay width, $\Gamma_{\rm had}$, up to three loop order with their full bottom mass dependence. The fourth order term is estimated [8] to contribute about -0.4 MeV to the hadronic decay width, raising the extracted α_s by somewhat less than 0.001.

We regard these deviations as consistent with statistical fluctuations and have therefore refrained from using scale factors as suggested by the Particle Data Group.

Table 1 summarizes the results of various fits to $\sin^2\hat{\theta}_{\overline{MS}} = \hat{s}_Z^2$, $\alpha_s(M_Z)$ and m_t. The first line is from a fit to all indirect data, while the second line includes the CDF m_t constraint. The central values assume $M_H = 300$ GeV, while the second errors are for $M_H \rightarrow 1000$ GeV (+) and 60 GeV (−). The third line is from a supersymmetry inspired fit with 60 GeV $< M_H <$ 150 GeV, and the central value is for $M_H = M_Z$. The increase in the overall χ^2 when increasing

Table 1: Results for electroweak parameters.

Set	$\hat{s}_Z^2$	$\alpha_s(M_Z)$	m_t [GeV]
Indirect	$0.2317(3)(^1_2)$	0.127(5)(2)	$175 \pm 11^{+17}_{-19}$
Indirect + CDF (174 ± 16)	$0.2317(3)(^2_3)$	0.127(5)(2)	$175 \pm 9^{+12}_{-13}$
Indirect	0.2316(3)(1)	0.126(5)(1)	$160^{+11}_{-12}{}^{+6}_{-5}$

M_H from 60 to 1000 GeV is 4.4. We find upper limits (95% c.l.) on M_H of 880 (730) GeV for the first (second) data set. More details and results of fits to various subsets of the precision data can be found in [9].

With the new CDF result for m_t, it is now possible to clearly separate new physics effects from the data. A simultaneous fit to the "oblique" parameters[2], S, T, and U [10], describing propagator corrections to the intermediate vector bosons yields

$$\begin{aligned} S_{\rm new} &= S - S_{m_t} - S_{M_H} &&= -0.21 \pm 0.24^{-0.08}_{+0.17}, \\ T_{\rm new} &= T - T_{m_t} - T_{M_H} &&= +0.03 \pm 0.30^{+0.17}_{-0.10}, \\ U_{\rm new} &= U - U_{m_t} &&= -0.50 \pm 0.61, \end{aligned} \tag{1}$$

where we have subtracted standard top quark and Higgs boson contributions. Allowing the parameter ρ_0, which describes sources of $SU(2)$ breaking beyond the SM and is related to the T parameter, to be free, one finds

$$\rho_0 = 1.0012 \pm 0.0017 \pm 0.0017, \tag{2}$$

[2]They are defined with a factor α factored out so that they are expected to be of order unity if non-zero.

remarkably close to unity. In view of the above mentioned conflicting α_s determinations, it is interesting to note that one obtains the significantly lower value $\alpha_s = 0.111 \pm 0.009$, if one allows for a non-standard vertex correction

$$\delta_{b\bar{b}}^{\rm new} = \frac{\Gamma_{b\bar{b}}}{\Gamma_{b\bar{b}}^{\rm SM}} - 1 = 0.023 \pm 0.011. \quad (3)$$

The extraction of a much lower value for α_s in the presence of new physics is a general feature: any non-standard positive contribution to $\Gamma_{\rm had}$ or a lowering or $\Gamma_{l^+l^-}$ decreases the α_s value.

Acknowledgements

It is a pleasure to thank Paul Langacker for very fruitful collaboration. I am very grateful to the Moriond organizers for inviting me and for a very pleasant and stimulating week on and off the slopes.

References

[1] The CDF Collaboration (F. Abe et al.), Phys. Rev. Lett. 73 (1994) 225.

[2] The SLD Collaboration (K. Abe et al.), Phys. Rev. Lett. 73 (1994) 25.

[3] D. Schaile, *Precision Tests of the Electroweak Interaction*, plenary talk (Pl-2) presented at the 27th International Conference on High Energy Physics, Glasgow, Scotland, July 1994; The LEP Collaborations, CERN/PPE/94-187.

[4] J. Erler, Nucl. Phys. B (Proc. Suppl.) 37B (1994) 44.

[5] J. Erler, *Four-Fermi Operators in $e^+ e^-$ Annihilation Experiments and Uncertainties in Z Boson Properties*, Univ. of Pennsylvania preprint UPR-0633T (1994), to appear in Phys. Rev. D.

[6] F. Caravaglios and G. G. Ross, Phys. Lett. B346 (1995) 159.

[7] B. R. Webber, *QCD and Jet Physics*, preprint Cavendish-HEP-94/15, plenary talk (Pl-13) presented at the 27th International Conference on High Energy Physics, Glasgow, Scotland, July 1994.

[8] A. L. Kataev and V. V. Starshenko, Mod. Phys. Lett. A10 (1995) 235.

[9] J. Erler and P. Langacker, *Implications of High Precision Experiments and the CDF Top Quark Candidates*, Univ. of Pennsylvania preprint UPR-0632T (1994); to appear in Phys. Rev. D.

[10] M. E. Peskin and T. Takeuchi, Phys. Rev. Lett. 65 (1990) 964 and Phys. Rev. D46 (1992) 381;
M. Golden and L. Randall, Nucl. Phys. B361 (1991) 3.