BROOKHAVEN
NATIONAL LABORATORY

BNL-74823-2005-CP

Perspectives on the Standard Model

Sally Dawson

Presented at the 15th Topical Conference on Hadron Collider Physics
(HCP 2004), July 14-18, 2004

July 2005

Physics Department

Brookhaven National Laboratory
P.O. Box 5000
Upton, NY 11973-5000
www.bnl.gov

Managed by
Brookhaven Science Associates, LLC
for the United States Department of Energy under
Contract No. DE-AC02-98CH10886

This is a preprint of a paper intended for publication in a journal or proceedings. Since changes may be made before publication, this preprint is made available with the understanding that it will not be cited or reproduced without the permission of the author.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or any third party's use or the results of such use of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Printed on recycled paper

arXiv:hep-ph/0411276 v1 20 Nov 2004

Perspectives on the Standard Model*

Sally Dawson
Physics Department, Brookhaven National Laboratory, Upton, N.Y. 11973

Summary. We discuss recent results from global electroweak fits and from the Tevatron and review the motivation for physics at the TeV energy scale.

1 Introduction

We live in exciting times for particle physics. The Tevatron Run II program is producing new physics results, which will be followed by the startup of the LHC in three years. These machines have a rich physics menu of new physics searches, precision measurements, QCD studies, t, b, and c quark physics, and much more.

We are in an enviable position. We have an electroweak theory which is consistent with all data, but which predicts new physics waiting to be discovered at the Tevatron and the LHC. When the LHC begins accumulating data, the physics landscape will change dramatically: the number of observed top quark pairs will jump from 10^4 at the Tevatron to 10^7 in the first 10 fb^{-1} at the LHC. Similarly, the number of $b\bar{b}$ pairs in our world data set will increase from 10^9 from the B factories at SLAC and KEK to $10^{12} - 10^{13}$ at the LHC. We are confident in our predictions that the wealth of new data at the LHC will guarantee new discoveries.

In this note, we begin by reviewing new measurements of the top quark and W boson masses and their implications for electroweak physics. We continue by discussing the emergence of the Tevatron as a machine for precsion studies. Finally, we conclude by emphasizing our certainty that new physics discoveries are just around the corner.

2 Top and W Masses from the Tevatron

Two of the most interesting results of the last year were the new values for the top quark and the W boson masses. A review of other electroweak measurements at the Tevatron can be found in Ref. [1].

* To appear in the *Proceedings of the 15th Topical Conference on Hadron Collider Physics (HCP 2004)*, 14 - 18 July, 2004, Michigan State University, East Lansing, Michigan.

In 2003, we had for the world average for the top quark mass[2,3],

$$M_t = 174 \pm 5.1\ GeV \qquad \textbf{2003 Result}\ . \tag{1}$$

The D0 collaboration improved their Run I analysis to include matrix element calculations, and this analysis dominates the new world average. In 2004, we have the new combination of Run I results[3],

$$M_t = 178.0 \pm 4.3\ GeV \qquad \textbf{2004 Result} \tag{2}$$

This value for M_t is most sensitive to the D0 lepton plus jets result. As the Tevatron Run II program continues, we expect ever more accurate measurements of the top quark mass[4].

The top quark mass plays a special role in the Standard Model. In QED, the running of α_{EM} at a scale μ is not affected by heavy quarks with $M >> \mu$. The decoupling theorem tells us that diagrams with heavy virtual particles don't contribute to experimental observables at scales $\mu << M$ if two conditions are met:

- Coupling constants don't grow with M, and
- The gauge theory with the heavy quark removed is still renormalizable.

The spontaneously broken $SU(2) \times U(1)$ gauge theory violates both conditions and we expect large effects from virtual diagrams involving the top quark, with effects from virtual top quarks growing quadratically with M_t^2. A small change in the top quark mass therefore has large effects in the inferred predictions of the Standard Model.

The W boson is produced at the Tevatron through the partonic subprocess, $u\bar{d} \to W^+$, and the leptonic decays of the W can be used to determine the W mass and width to good precision through a measurement of the transverse W mass or the p_T of the lepton. The Run I value for the W mass from a combination of CDF and D0 data is $M_W = 80.452 \pm 0.59\ GeV$[5]. At LEP2, the W boson was pair produced through the process, $e^+e^- \to W^+W^-$, (see Fig. 4), and a value for the W mass was found of $M_W = 80.412 \pm 0.042\ GeV$. The Run I and LEP2 values have been combined to give a new world average for the W mass of[2]

$$M_W = 80.425 \pm 0.034\ GeV \qquad \textbf{2004 Result}\ . \tag{3}$$

This is slightly lower than the previous value,

$$M_W = 80.426 \pm .034\ GeV \qquad \textbf{2003 Result}\ . \tag{4}$$

3 Electroweak Precision Measurements

3.1 Global fits

The result of the new top quark mass is to shift the best fit value for the Higgs boson mass as can be seen in Fig. 1[2,6],

$$M_h < 219\ GeV \qquad \textbf{2003 Result}$$

$$M_h < 251\ GeV \qquad \textbf{2004 Result} \tag{5}$$

The small shift in the top quark mass, $\delta M_t \sim 3\ GeV$ shifted the 95% confidence level limit on the Higgs mass by roughly 30 GeV. The best fit for the Higgs mass is now[1] [2]

$$M_h = 114^{+69}_{-45}\ GeV \qquad \textbf{2004 Result}\ . \tag{6}$$

It is reassuring to see that the best fit value is not in the region excluded by the direct search experiments at LEP. (The best fit value of 2003 was $M_h = 96^{+60}_{-38}\ GeV$, a value which is excluded by the direct search experiments.)

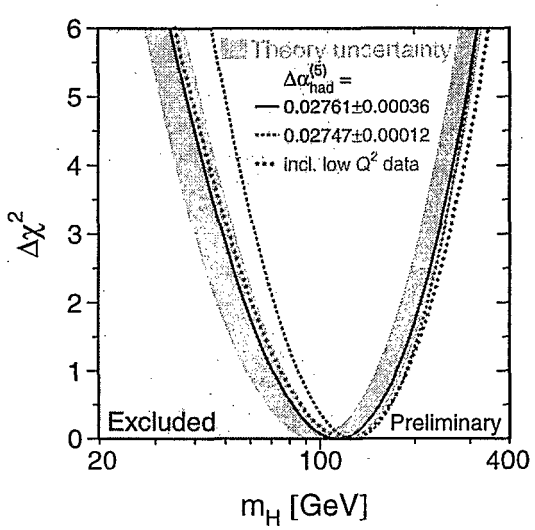

Fig. 1. Limit on the Higgs boson mass from the summer, 2004 LEPEWWG fit, using the updated value for the top quark mass, Eq. 2[2].

The global fit of the experimental data to the parameters of the Standard Model is shown in Fig. 2 and is in spectacular agreement with the predictions of the Standard Model. The fits have been redone using the new value of M_t and only the high Q^2 data is included in the 2004 fits. The results of the low energy experiments such as atomic parity violation in Cesium, neutrino-nucleon scattering (NuTeV), and Moller scattering (e^-e^-) are now predicted results.

[1] As emphasized in Ref.[6], the best fit value for the Higgs mass depends on whether the measurements of M_W and M_t from the Tevatron are included in the fit. A fit to the Higgs mass without the W mass measurement gives a best fit value of $M_h = 129^{+76}_{-50}\ GeV$, while a fit which does not include M_t or M_W as measured at the Tevtraon gives $M_h = 117^{+162}_{-62}\ GeV$.

The prediction of the global fit for $M_t(fit) = 178.2\ GeV$ is in good agreement with the value of Eq. 2, while the best fit value for M_W (with the experimental value of M_t included in the fit) is slightly lower than the experimental value[6],

$$M_W = 80.386 \pm .023\ GeV \qquad \textbf{Fit} \quad . \tag{7}$$

The puzzles of the global fit from previous years remain. The extracted value of $\sin^2\theta^{lept}_{W\ eff}$ still has the problem that measurements from experiments with leptons and from experiments with hadrons disagree by 2.9σ[2]. Using the value of $\sin^2\theta^{lept}_{W\ eff}$ found from leptons at SLD (A_l),

$$\sin^2\theta^{lept}_{W\ eff} = 0.23098 \pm 0.00026 \qquad \textbf{SLD}, \tag{8}$$

a value of the Higgs boson mass in conflict with the direct search experiments is predicted. On the other hand, using $\sin^2\theta^{lept}_{W\ eff}$ from the forward backward b asymmetry at LEP ($A^{0,b}_{fb}$),

$$\sin^2\theta^{lept}_{W\ eff} = 0.23212 \pm 0.00029 \qquad \textbf{LEP}, \tag{9}$$

one obtains a prediction in disagreement with the measured value of M_W. This can be seen in Fig. 3. It is extremely difficult to construct models which explain this feature.

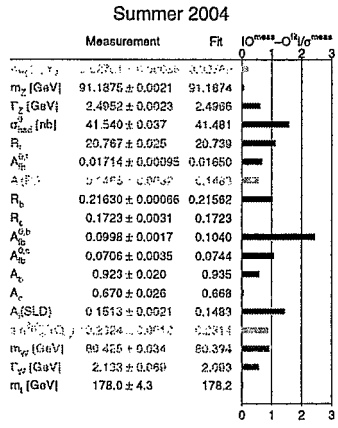

Fig. 2. Global fit to electroweak data from the summer, 2004 LEPEWWG fit. Low Q^2 data is not included in the fit[2].

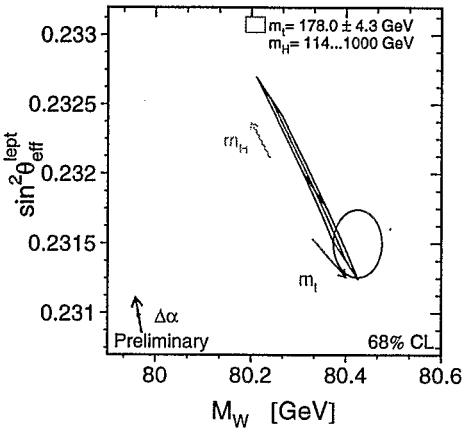

Fig. 3. Relation between the extracted value of $sin^2\theta^{lept}_{W\,eff}$ and the W mass and its dependence on the Higgs boson mass[2].

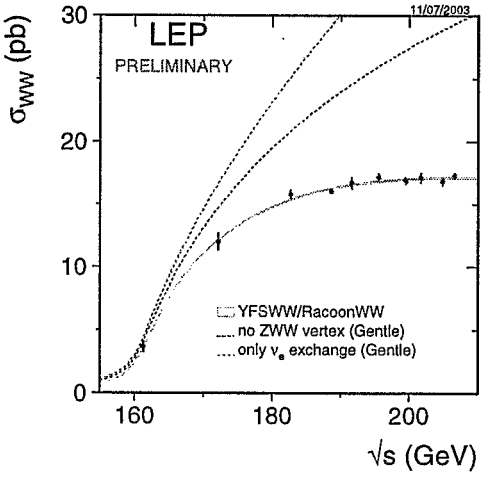

Fig. 4. The total cross section for the process $e^+e^- \rightarrow W^+W^-$ measured at LEP2 and the Standard Model prediction[7]. If the three gauge boson (ZW^+W^-) vertex is removed from the theory, the prediction deviates wildly from the data.

3.2 Low Energy Measurements

Measurements at low energy test our understanding of the energy scaling of the theory. The best fit values for the parameters of the Standard Model which are given in Fig. 2 can be used to make predictions for Moller scattering, for the value of $\sin^2\theta_W$ which is extracted from NuTeV experiment, and for atomic parity violation in Cesium, and then compared with the experimental values. The energy dependence of the weak mixing angle $\sin^2\theta_W$ is predicted in the Standard Model and is shown as the solid line in Fig. 5 and we see that the results of the low energy experiments are in reasonable, although not perfect,agreement with the predictions of the Standard Model except for the NuTev result[10].

The NuTeV collaboration has published its result for the ratio of neutral currents to charged currents in neutrino-nucleon scattering. When the measurement is interpreted in terms of $\sin^2\theta_W$, it is 3σ away from the global fit[2]:

$$\begin{aligned}\sin^2\theta_W &= 0.2277 \pm 0.0013(stat) \pm 0.0009(syst) - 0.00022\frac{M_t^2 - (175\ GeV)^2}{(50\ GeV)^2} \\ &\quad +0.00032\ln\left(\frac{M_h}{150\ GeV}\right) \qquad \textbf{Experiment} \\ \sin^2\theta_W &= 0.2227 \pm 0.0004 \qquad \textbf{Fit} \quad . \end{aligned} \tag{10}$$

The NuTev experiment is under intense theoretical scrutiny since connecting the experimental observables with theoretical predictions requires a detailed understanding of theory. A number of possible solutions to the discrepancy between theory and experiment have been proposed, including an asymmetry in the strange/anti-strange parton distributions[8], and the effects of higher order $\mathcal{O}(\alpha)$ corrections[9]

The situation with atomic parity violation has improved since the 2002 global fit showed a 1.5σ deviation of the experiment from the global fit. There is a new calculation of QED corrections which is now in good agreement with the best fit value[11]

$$\begin{aligned} Q_W &= -72.84 \pm 0.29(exp) \pm 0.36(theory) \qquad \textbf{Experiment} \\ Q_W &= -72.880 \pm 0.003 \qquad \textbf{Fit} \quad . \end{aligned} \tag{11}$$

Moller scattering ($e^-e^- \to e^-e^-$) provides a clean measurement of the weak mixing angle since it is a purely leptonic process. A cominbination of the E158 Experiment at SLAC Run I,II and III data gives the result[12],

$$\begin{aligned} &\sin^2\theta_W(Q^2 = .026\ GeV^2) = \\ &\quad 0.2403 \pm 0.0010(stat) \pm 0.0009(stat) \qquad \textbf{Experiment} \end{aligned} \tag{12}$$

In good agreement with the theoretical prediction,

$$\sin^2\theta_W(Q^2 = .026\ GeV^2) = 0.2385 \pm 0.006 \qquad \textbf{Theory} \quad . \tag{13}$$

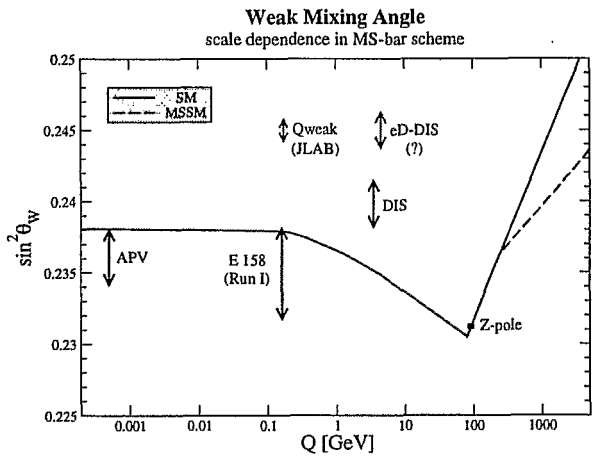

Fig. 5. Comparison of low Q^2 data from NuTeV, Moller Scattering, and atomic parity violation with the energy scaling predicted by the $SU(2) \times U(1)$ Standard Model[10]. The red points are proposed future experiments.

The inclusion of the low Q^2 results into the fit has very little effect on the Higgs mass limits. The conclusion from the electroweak fits is that electroweak physics is in even better shape this year than last year!

4 The Standard Model at the Tevatron

The Standard Model continues to be tested at the Tevatron. In the coming few years, we can expect that the properties of Standard Model particles will be measured with high precision. W and Z gauge bosons have large cross sections at the Tevatron, so high statistics and precision measurements will dominate: W and Z masses and width measurements, production cross sections, and gauge boson pair production cross sections. Measurements of the top quark mass and top quark properties will continue to unfold, along with Higgs searches, new physics searches, b physics, and QCD studies, to name just a few areas. This conference saw a large number of new results in these areas from the D0 and CDF collaborations.

The top quark plays a leading role in many models with physics beyond the Standard Model, so measurements of top quark properties play an especially important role in constraining these models. One particularly important measurement which we look forward to in the future is single top production. Single top production at the Tevatron has a total rate of roughly $\sigma \sim 3\ pb$[13], approximately half that of top pair production, and can serve

to measure the CKM mixing parameter, V_{tb}. D0 has looked for single top production in 156 pb^{-1} and 169 pb^{-1} of Run II data and finds the 95% *c.l.* limits[14],

$$\begin{aligned} &\sigma(\text{s-channel production}) && < 19\ pb \\ &\sigma(\text{t-channel production}) && < 25\ pb \\ &\sigma(\text{s+t- channel production}) && < 23\ pb \quad \mathbf{D0}\ , \end{aligned} \tag{14}$$

while CDF finds the corresponding 95% *c.l.* limits[15],

$$\begin{aligned} &\sigma(\text{s-channel production}) && < 13.6\ pb \\ &\sigma(\text{t-channel production}) && < 10.1\ pb \\ &\sigma(\text{s+t- channel production}) && < 17.8\ pb \quad \mathbf{CDF}\ . \end{aligned} \tag{15}$$

The production of W and Z bosons tests the QCD production mechanism, while the ratio of the production cross section times the leptonic branching ratios can be used to extract the W boson total width. Figs. 6 and 7 show the results of 177.3 pb^{-1} of data from D0, and 72 pb^{-1} from CDF, for W production with the decay $W \to l\nu$ and for Z production followed by the leptonic decay, $Z \to l^+l^-$, along with a comparison to the Standard Model prediction. There is good agreement with the Standard Model predictions.

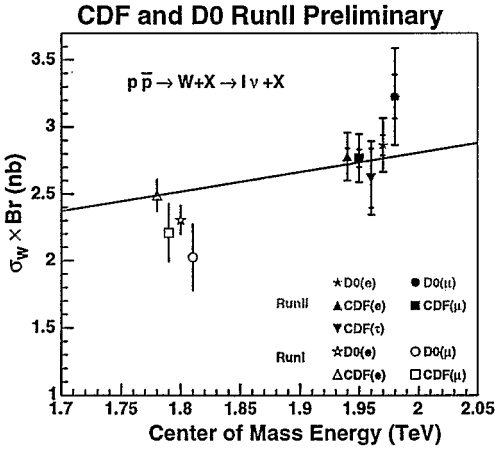

Fig. 6. Comparison of CDF and D0 results for W production, followed by the decay $W \to l\nu$[17].

A particularly interesting set of results concerns two gauge boson production, which is sensitive to the three gauge boson vertices, and hence to the

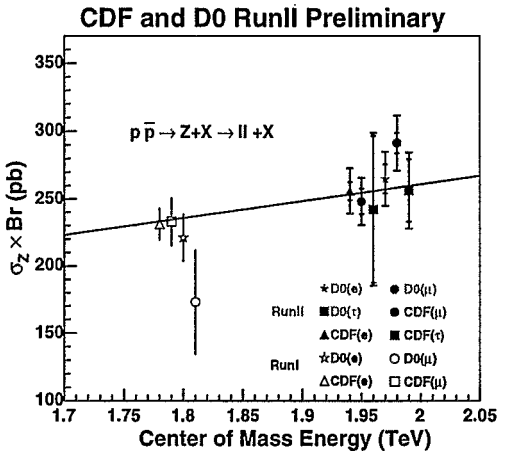

Fig. 7. Comparison of CDF and D0 results for Z production, followed by the decay $Z \to l^+l^-$[17].

non-Abelian nature of the theory. The results from LEP2 for $e^+e^- \to W^+W^-$ (Fig. 4) show that the three gauge boson couplings are very close to their Standard Model values. In an effective theory where there is new physics at a higher energy scale, the non-Standard Model contributions to the three gauge boson couplings would grow like $\frac{s}{\Lambda^2}$[16] and we can expect enhanced couplings at the Tevatron and LHC. Preliminary measurements[18] of the W^+W^- pair production cross section at the Tevatron show good agreement with next-to-leading order (NLO) QCD predictions and no indication of non-Standard Model gauge couplings[19],

$$\begin{aligned} \sigma_{WW} &= 13.8^{+4.3}_{-3.8}(stat)^{+1.2}_{-0.9}(syst) \pm 0.9\ pb && \text{D0} \\ \sigma_{WW} &= 14.3^{+5.6}_{-4.9}(stat) \pm 1.6(syst) \pm 0.9\ pb && \text{CDF} \\ \sigma_{WW} &= 12 - 13.5\ pb && \text{NLO theory} \quad . \end{aligned} \tag{16}$$

4.1 Advances in theory

Advances in theory go hand in hand with higher statistics measurements at the Tevatron. The strong coupling constant is not small:

$$\alpha_s(M_Z) \sim .12 >> 15\alpha_{EM} \ . \tag{17}$$

Emission of soft gluons and multi-particle states are important, along with large effects from higher order perturbative QCD corrections. Understanding precision measurements at the Tevatron and the LHC requires new tools and the systematic inclusion of higher order QCD effects. This in turn requires new techniques for computing the higher order corrections.

Many processes are now calculated at next-to-next-to leading order (NNLO). Not only total cross sections[21], but also kinematic distributions for a few processes are becoming available at NNLO. For example, predictions for the Drell-Yan rapidity computed to NNLO in perturbative QCD at the LHC are shown in Fig. 8[22], We see the very small error bar due to the scale de-

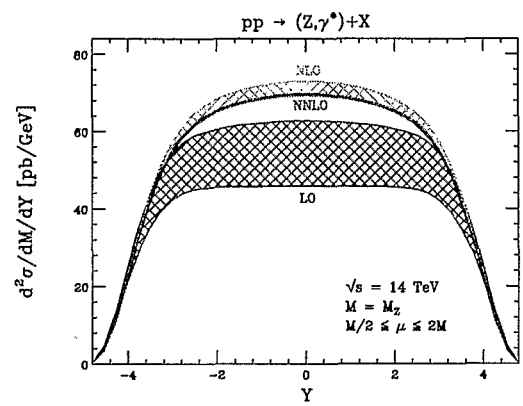

Fig. 8. Rapidity distribution of on-shell Z bosons at the LHC. The band indicates the renormalization/factorization scale dependence[22].

pendence at NNLO. This suggests that it may be possible to use Drell Yan production to measure parton distribution functions at NNLO.

Understanding the precise data from the Tevatron and future data from the LHC will require Monte Carlo programs which incorporate physics at next-to-leading order (NLO) in perturbative QCD. There are several programs on the market. The MC@NLO program matches parton showering calculations at low p_T with exact NLO matrix element calculations at high p_T[23]. An example of the importance of properly incorportating higher order effects is the b production cross section at the Tevatron, which has been a long standing puzzle. By including the higher order QCD corrections in both the production and the fragmentation functions, the theoretical prediction now agrees quite well with the data, as can be seen in Fig. 9[24].

Another approach to including higher order QCD corrections is the MCFM Monte Carlo program[26]. This program includes exact matrix element calculations for both the signal and background processes for a number of processes at hadron colliders. For most processes, the matrix elements are included to next-to-leading order and the full set of spin correlations is included for the decays.

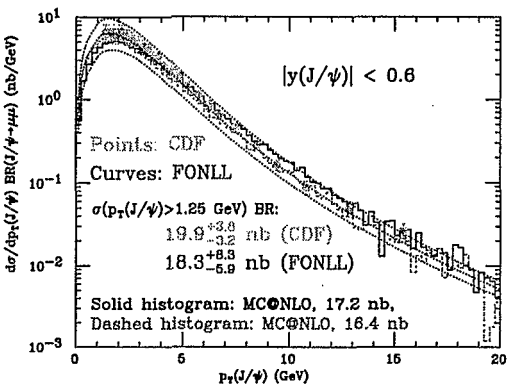

Fig. 9. b pair production cross section at the Tevatron. The theoretical predictions include higher order effects in both the production and the decay and use the Monte Carlo program MC@NLO[25].

5 Outlook

Despite the successes of the Standard Model, the arguments for new physics at the TeV scale have never been stronger. Many of the questions particle physicists seek to answer become even more pressing as accelerators approach the TeV energy scale:

- The question of naturalness: Why is M_W so much smaller than M_{pl}?
- Dark matter: What is it? Why is there so much of it?
- Neutrino masses: Where do they come from? Why are they so small?
- What mechanism restores unitarity to the WW scattering amplitude: Is there a light Higgs? Is there some other mechanism?

Extensions of the Standard Model which have been proposed in various attempts to answer these questions almost uniformly predict physics beyond that of the Standard Model at the TeV energy scale[27]. So even though current results from LEP and the Tevatron support the experimental validity of the Standard Model, we are confident that there is new physics just around the corner.

Furthermore, the Higgs sector of the Standard Model is unsatisfactory to theorists. Light scalar particles, such as the Higgs boson, are unnatural in the sense that the scalar Higgs mass depends quadratically on new physics which may exist at a higher energy scale. In order to have a Higgs boson mass below 200 GeV (as suggested by the precision electroweak measurements), large cancellations between various contributions to the Higgs boson mass are required. Attempts to avoid this problem have led to an explosion of model building in recent years[27,28].

Models of new physics are highly constrained by precision measurements. New physics effects can be parameterized in a model independent fashion by adding a tower of dimension six operators to the Standard Model:

$$\mathcal{L} \sim \Sigma \frac{c_i}{\Lambda^2} \mathcal{O}_i \quad . \tag{18}$$

Precision measurements place significant limits on many possible operators. For example,current data requires[20],

$$\begin{aligned} \mathcal{O}_i &= \bar{e}\gamma_\mu e \bar{l}\gamma^\mu l \qquad & \Lambda > 4.5 - 6\ TeV \\ \mathcal{O}_i &= \bar{e}\gamma_\mu\gamma_5 e \bar{b}\gamma^\mu\gamma_5 b \qquad & \Lambda > 3 - 4\ TeV\ . \end{aligned} \tag{19}$$

A more complete list of constraints on dimension 6 operators is given in Ref. [16,20]. Operators which violate flavor conservation are even more tightly constrained, often requiring scales $\Lambda > 100\ TeV$. The fact that physics at the 1 TeV scale may already be excluded experimentally is termed the "little hierarchy" problem.

Attempts to evade the little hierarchy probem have recently stimulated much activity in electroweak scale model building. These attempts fall into three general categories:

- Remove the Higgs boson completely: Models of this type include models with dynamical symmetry breaking[29] and Higgsless models in extra dimensions[30].
- Lower the cut-off scale Λ of Eq. 19: Examples of this class of models are models with large extra dimensions[31].
- Force cancellations between contributions to the Higgs boson mass: Supersymmetric models are the favorite of this type, while little Higgs models are a new entrant into the theory game (although they have difficulty being consistent with precision measurements[32].)

Each of these models makes different predictions for physics at the TeV scale. Only the data can tell for sure what lies ahead!

References

1. For a review of recent electroweak results from the Tevatron, see E. Thomson, talk given at the DPF2004 meeting, http://dpf2004.ucr.edu/plenary/thomson.pdf.
2. LEP Collaborations and EWWG: hep-ex/0312023 (2003); http://lepewwg.web.cern.ch/LEPEWWG.
3. The CDF, D0, and LEP electroweak working groups, hep-ex/0404010.
4. CDF Collaboration, http://www-cdf.fnal.gov/physics/new/top/top.html#MASS; D0 Collaboration, hep-ex/0404040.
5. The CDF, D0, and LEP electroweak working group, hep-ex/0311039.
6. G. Altarelli and M. Grunewald, hep-ph/0404165.

7. A. Denner, S. Dittmaier, M. Roth, and D. Wackeroth, *Nucl. Phys.* **B587** (2000) 67.
8. S. Kretzer, hep-ph/0405221, S. Kretzer, F. Olness, J. Pumplin, D. Stump, W.-K. Tung, and M. Reno, *Phys. Rev. Lett.* **93** (2004) 041802, hep-ph/0312322.
9. B. Dobrescu and R. Ellis, *Phys. Rev.* **D69** (2004) 114014, hep-ph/0310154; K. Diener, S. Dittmaier, and W. Hollik, hep-ph/0310364.
10. Erler and Ramsey-Musolf, hep-ph/0404291.
11. M. Kuckiev and V. Flambaum, hep-ph/0305053.
12. E158 Collaboration, *Phys. Rev. Lett* **92** (2004) 181602, hep-ex/0312035; http://www.slac.stanford.edu/exp/e158/plots/results/html.
13. Z. Sullivan, hep-ph/0408049; B. Harris, E. Laenen, L. Phaf, Z. Sullivan, and S. Weinzierl, *Phys. Rev.* **D66** (2002) 054024, hep-ph/0207055; T. Stelzer, Z. Sullivan, and S.Willenbrock, *Phys. Rev.* **D58** (1998) 094021, hep-ph/9807340.
14. D0 Collaboration, D0Note 4510-CONF.
15. CDF Collaboration, hep-ex/0410058.
16. S. Alam, S. Dawson, and R. Szalapski, *Phys. Rev.* **D57** (1998) 1577, hep-ph/9706542; J. Bagger, S. Dawson, and G. Valencia, *Nucl. Phys* **B399** (1993) 364, hep-ph/9204211.
17. D0 Experiment, D0Note-4403-CONF, CDF experiment, hep-ph/0406078.
18. D0 Experiment, Fermilab-Pub-04/293-E.
19. J. Ohnemus, *Phys. Rev* **D44** (1991) 1403, *Phys. Rev* **D44** (1994) 1931; J. Campbell and R. K. Ellis, *Phys. Rev* **D60** (1999) 113006
20. G. Guidice, **Int. J. Mod. Phys. A19** (2004) 835, hep-ph/0311344.
21. R. Harlander and W. Kilgore, *Phys. Rev. Lett.* **88** (2002, 201801, hep-ph/0201206; C. Anastasiou and K. Melnikov, *Nucl. Phys.* B646 (2002), 220, hep-ph/0207004; C. Catani, D. de Florian, and M. Grazzini, **JHEP05** (2001), 025, hep-ph/0102227; O. Brein , A. Djouadi, and R. Harlander, *Phys. Lett.* **B579** (2004) 149, hep-ph/0307206; R. Harlander and M. Steinhauser, *Phys. Rev.* **D68** (2003) 111701, hep-ph/0308210.
22. C. Anastasiou, L. Dixon, K. Melnikov, and F. Petriello, hep-ph/0312266.
23. S. Frixioni, P. Nason, and B. Webber, **JHEP0308** (2003), 007, hep-ph/0305252; S. Frixione and B. Webber,hep-ph/0309186; hep-ph/0307146; hep-ph/0402116.
24. M. Cacciari, S. Frixione, M. Mangano, P. Nason, and G. Ridolfi, **JHEP0407** (2003) 033, hep-ph/0312132.
25. S. Frixione, hep-ph/0408317.
26. J. Campbell and R. K. Ellis, *Phys. Rev.* **D62** (2000) 114012, hep-ph/0006304; http://mcfm.fnal.gov.
27. See B. C. Allanach *et. al.*, hep-ph/0402295 and references therein.
28. For a review, see D. Rainwater, talk given at the DPF2004 meeting, http://dpf2004.ucr.edu/plenary/rainwater.pdf.
29. For a review, see C. Hill and E. Simmons, *Phys. Rept.* **381** (2003) 235, hep-ph/0203079.
30. C. Csaki, C. Grojean,H. Murayama, L. Pilo, and J. Terning, *Phys. Rev.* **D69** (2004) 055006, hep-ph/0305237; H. Davoudiasl, J. Hewett, B. Lillie, and T. Rizzo, *Phys. Rev.* **D70** (2004) 015006.
31. For a review, see R. Hewett and J. March-Russell, Particle Data Group, *Phys. Lett* **B592** (2004) 1.

32. G. Kribs, hep-ph/0305157 and references therein;J. Hewett, F. Petriello, T. Rizzo, **JHEP0310** (2003) 062, hep-ph/0211218; T. Han, H. Logan, B. McElrath, and L.Wang, *Phy. Rev.* **D67** (2003) 095004, hep-ph/0301040; M. Chen and S. Dawson, *Phys. Rev.* **D70** (2004) 015003, hep-ph/0311032.