DYNAMICAL ELECTROWEAK SYMMETRY BREAKING

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We provide a brief description of the material covered during the lectures on dynamical electroweak symmetry breaking and a guide to further reading.

1. Lecture Themes and Overview

These lectures explored the idea that the physics of electroweak symmetry breaking arises from novel strong dynamics. We started from the familiar strong-interaction dynamics of QCD, introduced simple dynamical electroweak symmetry breaking models whose strong dynamics imitate those of QCD, analyzed the limitations of these models, and finally moved on to theories whose dynamics differ from those of QCD in intriguing and useful ways. Because strong-dynamics models predict new states at accessible energies, experimental constraints have played a large role in the development of these theories. Accordingly, we discussed a number of specific classes of models that have been created to meet specific experimental challenges and examine their phenomenology.

Some may ask why it is necessary to keep creating and studying new kinds of models, why the Standard Model and its supersymmetric extension(s) do not suffice. The answer, quite simply, is that we lack experimental evidence as to the mechanism of electroweak symmetry breaking. Theoretical arguments about which general kinds of mechanisms are plausible leave us with too many open possibilities, each with its own strengths and weaknesses. It is often pointed out that we need experimental data to winnow the options.

At the same time, we must think carefully about what conclusions one will be able to draw from the data. For example, if a collider experiment produces a new scalar state decaying to $b\bar{b}$, how will we know whether it is a standard model Higgs if we have not understood the characteristics of other candidates such as a supersymmetric Higgs, a technipion, or a top-pion? Likewise, if we find a color-octet of new heavy gauge bosons, how will we distinguish whether these are colorons, Kaluza-Klein modes of gluons, or colored extended-technicolor bosons, unless we understand the phenomenology of the models that contain such states?

Studying specific models helps us to understand the strengths and limitations of general theoretical ideas. It gives us a vantage from which to suggest promising directions for experiments. And it enables us to construct frameworks that can help us decipher the implications of experimental data. But a good model-builder should always recall Aristotle's words: "It is the mark of an educated mind to be able to entertain a thought without accepting it."

2. A Guide to Further Reading

The TASI-2004 lectures on dynamical symmetry breaking drew heavily on reviews that we have previously published. The first is the most recent and comprehensive, and focuses exclusively on dynamical electroweak symmetry breaking – this is the place to start for a pedagogical introduction to the subject, and also contains a complete set of references to the original literature. The second and third reviews, based on lectures we gave at TASI-2000, place the material on dynamical electroweak symmetry breaking in slightly different contexts – in the context of compositeness and top-quark physics, respectively. The last review provides a survey of current experimental constraints on these models.

(1) C. T. Hill and E. H. Simmons, "Strong Dynamics and Electroweak Symmetry Breaking," Phys. Rept. **381**, 235 (2003) [Erratum-ibid. **390**, 553 (2004)] [arXiv:hep-ph/0203079].
(2) R. S. Chivukula, "Technicolor and Compositeness," TASI-2000 [arXiv:hep-ph/0011264].
(3) E. H. Simmons, "Top Physics," TASI-2000 [arXiv:hep-ph/0011244].
(4) R. S. Chivukula, M. Narain and J. Womersley, "Dynamical Electroweak Symmetry Breaking," in S. Eidelman *et al.* [Particle Data Group], "Review of Particle Physics," Phys. Lett. B **592**, 1 (2004).

The last lecture included a brief introduction to the most complete attempt to construct a model of extended technicolor, and incorporate ordinary fermions with a quasi-realistic mass matrix. This work is not extensively described in the references above: the model(s) are built on the ideas introduced in the first reference given below, and are thoroughly analyzed in the second and third.

(1) T. Appelquist and J. Terning, "An Extended Technicolor Model," Phys. Rev. D **50**, 2116 (1994) [arXiv:hep-ph/9311320].
(2) T. Appelquist, M. Piai and R. Shrock, "Fermion Masses and Mixing in Extended Technicolor Models," Phys. Rev. D **69**, 015002 (2004) [arXiv:hep-ph/0308061].
(3) T. Appelquist, N. Christensen, M. Piai and R. Shrock, "Flavor-Changing Processes in Extended Technicolor," Phys. Rev. D **70**, 093010 (2004) [arXiv:hep-ph/0409035].