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Will Higgs Particles Ever Be Found?*

David J.E. Callaway
Department of Physics
The Rockefeller University
1230 York Avenue
New York, New York 10021-6399

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Abstract

Strong evidence supports the idea that pure $(\phi^4)_4$ field theory is "trivial" or non-interacting. Should such a situation persist when gauge fields are present, it is fair to question the idea of symmetry breaking (and gauge boson mass generation) by elementary scalars. An alternative possibility, suggested by the consideration of toy models, is that a consistent non-trivial theory may exist for only a select range of parameters, implying for example that the standard model Higgs mass may be bounded or calculable. In principle the Monte Carlo renormalization group can be used to examine this possibility. Various aspects of the problem are considered and the results of the first calculation for the standard model are discussed.

"I would like to offer a theoretical prediction at the 5% confidence level: within five years there will be a rigorous construction of the solutions of $\lambda(\phi^4)_4$ and of spin-½ quantum electrodynamics in four-dimensional space-time."

-- Arthur S. Wightman (1977) [1,2]

"When we try to pick out anything by itself, we find it hitched to everything else in the universe."

-- John Muir

Expectations often remain unfulfilled. Much of the early excitement over the standard model of the weak interaction was caused by the discovery that it was renormalizable, and hence could be considered a viable candidate for a fundamental theory of elementary particles. The standard model was a remarkable achievement, for it included the <u>lucus a non lucendo</u> of massive gauge bosons in a consistent fashion and so afforded a place for the mediators of the weak force, the $W^\pm$ and Z°. The standard model also posits the existence of an unobserved new elementary scalar particle, the Higgs boson. The <u>interactions</u> of this Higgs particle are a necessary ingredient in the standard model.

As discussed in Ref. 3, strong evidence suggests that a theory which only includes Higgs particles is "trivial" or noninteracting. Should the triviality persist when the Higgs is "hitched to everything else" in the standard model, then the standard model scenario is in trouble. It would then be fair to ask if a real "Higgs particle" should exist, or whether this putative elementary scalar is instead just an invisible metaphor for a more complicated mechanism. The obvious question to ask -- what this new mechanism may be -- is not as obviously answerable.

A more informative set of possibilities does however exist if the Higgs sector of the standard model (or indeed of any realistic Higgs model) is nontrivial. In this case it is likely possible to calculate upper bounds upon the Higgs mass or even to predict its value. The requirement that the theory be nontrivial thus can imply phenomenological constraints on the theory (see Refs. 4). By contrast, a naive semiclassical analysis of the scalar sector of the standard model does <u>not</u> yield any information on the Higgs mass.

One simple argument which suggests that the Higgs mass is predictable [4,5] is based upon the precepts of the renormalization group. If a nontrivial continuum limit of a Higgs lattice gauge theory exists, it must correspond to a fixed point of the renormalization group transformation. The number of relevant directions at this fixed point equals the number of independent renormalized parameters in the theory [6]. Yet universality suggests that the quartic coupling is irrelevant at this fixed point. Thus at least one parameter of the theory (e.g., the Higgs mass) might be predictable from the others.

Partially in order to explore this possibility, we have performed a Monte Carlo renormalization group analysis of the fixed-length SU(2) x U(1) standard model [5]. This calculation is made using a specific "maximal truncation" approximation. Several fixed points do, in fact, appear in this scheme. Some of these fixed points possess "marginal" directions, suggesting that (in addition to the possibility of a calculable quartic coupling, as implied by universality) *a priori* bounds on other renormalized couplings can be set.

Several important studies must be done however before any firm conclusions can be drawn. For example, little is known about the variable-magnitude SU(2) x U(1) lattice standard model. Moreover, no comprehensive analysis of the effects of variant or higher-representation lattice actions in this model has been made. Further computations by the Monte Carlo renormalization group or other methods like finite-size scaling are needed before the critical exponents of the theory can be obtained. These exponents would yield the anomalous dimensions of various operators (like Φ^2) in the theory, and could be used to learn whether a non-trivial continuum limit for the standard model is possible.

It is however evident that the question of the triviality of Higgs models is of more than philosophical interest. The inquiry as to whether an elementary scalar particle exists (and if its mass is predictable) is also given immediacy by the contemporary agenda for the construction of new accelerators. The intended purpose of these machines typically includes a search for the Higgs particle. Fortunately for these experimental efforts, progress is being made in the understanding of triviality and its implications for elementary particle phenomenology. Much remains to be done, however. Although techniques such as the analysis of lattice gauge theories by the Monte Carlo renormalization group may well hold the key to the middle of triviality, the final answers are not yet known. This talk therefore concludes with the same question as it started with: Will Higgs particles ever be found? The future holds the answer.

References

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