YITP workshop

Electroweak Symmetry Breaking

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Two of the most important questions in particle physics:

Who broke SU(2)xU(1)?

Who gave masses to fermions?

Higgs boson? Techinicolor? Something else?

LHC is running...

As theorists, we should know at least

* What kind of models are there?

* Are they viable models?

* What's good about each model?

* What's the predictions? Predictability?

Not just for our knowledge, I hope serious considerations of those will be helpful to get a new ideas on EWSB.

This will tell us what we should really look for or measure at the LHC.

Rule #1:

In this workshop, we concentrate on electroweak symmetry breaking and fermion masses.

Of course, there are related topics which is essential for EWSB. There will be a session of those topics on the last day of the workshop.

Now Let's go to physics.

The minimal model of EWSB [Glashow '61]

Just explicitly break SU(2)xU(1) and add fermion masses by hand.

The SU(2)xU(1) structure is confirmed experimentally.
All the particle predicted are found.

Question: What's wrong?

What's wrong?

This model can be thought of as a $m_h \longrightarrow \infty$ limit of the Standard Model.

→ Predictability is limited with the precision of $O(E/\Lambda)$ with $\Lambda \sim 4\pi v \sim 2\ \mathrm{TeV},$ and we naively expect $O(v^2/\Lambda^2)$ contributions to S,T parameters (times α), and also to the SU(2)xU(1) structure.

This is too big.

If you don't think this is a problem. There is nothing to discuss.

↓

Rule #2:

All the models we discuss *must be* better than the Glashow's model.

The Next to Minimal Models

1. Add a scalar field (the Higgs field) -- The Standard Model

[Weinberg '67][Salam '68]

This makes the theory be calculable. And the predicted values of S,T parameters are in good agreement with data for a relatively light Higgs boson.

Also, fermions can obtain masses through Yukawa interactions.

But, the existence of the Higgs field needs some explanation. Especially, we need to consider the consistency of the large Yukawa interaction of the top quark. (the Hierarchy problem)

The naive estimation of the cut-off scale is again a few TeV.

2. add massive vector fields – the Higgsless model
[Casalbuoni, De Curtis, Dominici, Feruglio, Gatto '89]
[Csaki, Grojean, Murayama, Pilo, Terning '03]

One can make the cut-off scale to a higher value, and S,T parameter can be tuned to be small.
[Cacciapaglia, Csaki, Grojean, Terning '04]

3. add interacting fermions -- Technicolor models [Weinberg '76 '79, Suskind '79]

Make $\langle \bar{\psi} \psi \rangle$ be responsible for the electroweak symmetry breaking as in QCD.

S,T parameter is calculable (in principle) ,
but it seems that the naive estimation (O(1)) is correct in many cases,
and moreover, the sign of S seems problematic.

Also, one needs some mechanism for fermion masses, especially,
for the top quark.

4. add a new interaction -- the top condensation

[Miransky, Tanabashi, Yamawaki '89]
[Bardeen, Hill, Linder '90]

Adding a four-top quark interaction. $q_L t_R q_L t_R / M^2$

This is the Nambu-Jona-Lasino model. The top-quark pair condenses, and break electroweak symmetry breaking. Top quark obtains a mass by themselves.

Need a full description of the theory to discuss the viability and predictions.

5. Yet unknown scenarios. [....]

....

The option 1. (the Standard Model) is data friendly but need more stuff to be a whole story. (maybe)

Examples are the supersymmetric standard model, and the little Higgs model [Arkani-hamed, Cohen, Georgi '01].

Probably 2 and 4 are low energy descriptions of 3 (+ mechanism for fermion masses) and all share the problems of S,T parameters and flavor changing processes, i.e., data unfriendly.

We should list the viable models of this kind.

Viable? What do we mean by viable?

Rule #3:

In any discussion, we should check the predictability.

We should ignore meaningless calculations.

Review talks:

Review 1: EWSB in strongly coupled theories (Tanabashi)

Review 2: EWSB in SUSY models (Ibe)

Review 3: EWSB in RS model and gauge-Higgs unification (Oda)

Review 4: Little Higgs models (Kurachi)

Let's learn what's good about each model!

Discussion sessions:

Session 1: Technicolor (leader: Asano)

Session 2: SUSY (leader: Hamaguchi)

Session 3: Composite Higgs models (leader: Matsumoto)
(RS, LH, GH models etc)

Session 4: Related topics (leader: Kanemura)

We will reconsider those models/topics carefully and make a brief presentation at the discussion sessions. All the participants should help leaders before the discussion session.

For this purpose, please pick up a group you'd like to join. After lunch, we form groups and each group should separately work on making presentations.

Approach (example)

* I think in each category, there are different or common problems.

e.g., flavor problem, etc..

* I think it's important to

We need a reason.

1, identify the problems.

2, discuss the seriousness of the problems.
(in regards to the LHC physics. Possible to postpone?)

3, discuss or summarize possible solutions to the problems.

4, discuss (LHC) predictions associated to each solutions.

5, discuss future situations (1.5 years later).