Beyond the Minimal Composite Higgs Model

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CERN TH

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BMG, A. Pomarol, F. Riva, J. Serra, arXiv:0902.1483 [hep-ph]

Outline

Experimental facts about EWSB

- Gross features, Precision Tests

Theory Models

- The Standard Model
- Composite models from $SO(3)$ to $SO(6)$

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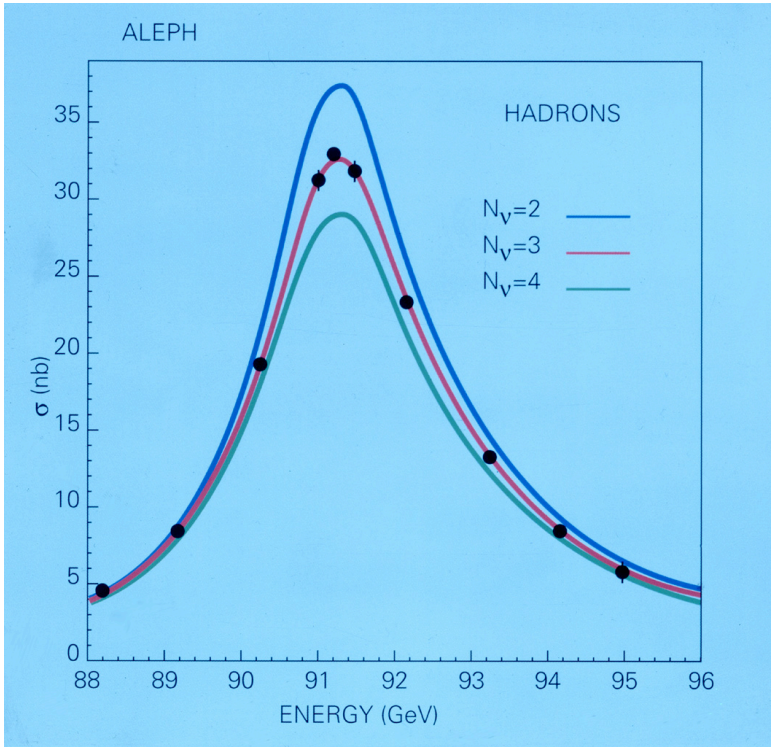
Experimental facts about EWSB

EWSB: Gross features

- Weak interactions are gauge interactions $\Longrightarrow$ symmetry
- Weak interactions are short range $\Longrightarrow$ symmetry is broken

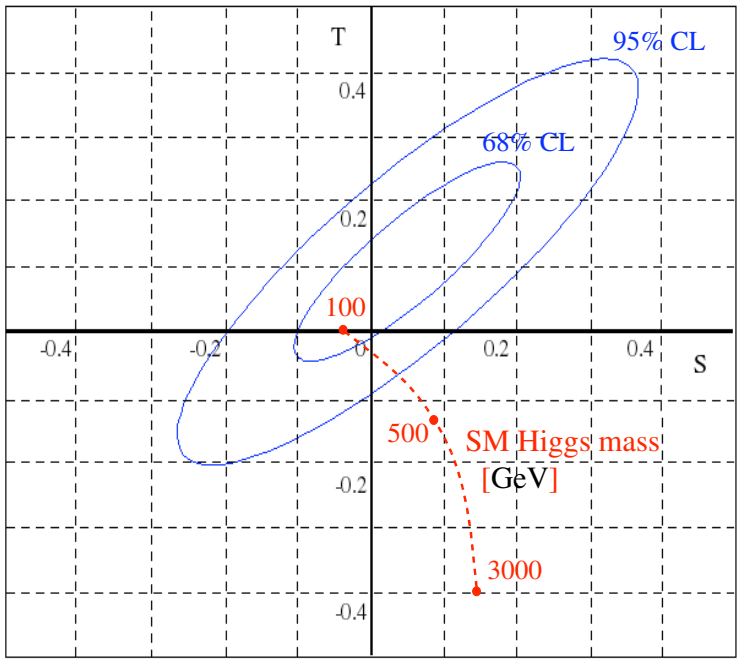


EWSB: Gross features

- So what is the symmetry and what is the symmetry breaking?
- At least $SU(2)_L \times U(1)_Y \longrightarrow U(1)_{em}$

EWSB: Precise features

- $\frac{m_Z}{m_W}\cos\theta_W \simeq 1 \implies T \sim 0$
- $\frac{v^2}{\Lambda^2} Z_{\mu\nu} F^{\mu\nu} \implies S \sim 0$



The Standard Model

The Standard Model

- Add a scalar field H, a $\mathbf{2}_{1/2}$ of $SU(2) \times U(1)_Y$
- Potential $V = \mu^2 H^\dagger H + \lambda (H^\dagger H)^2$

The Standard Model

Is it a good model . . . ?

- Renormalizable lagrangian
- Make predictions to arbitrarily high scales

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SM: Gross Features

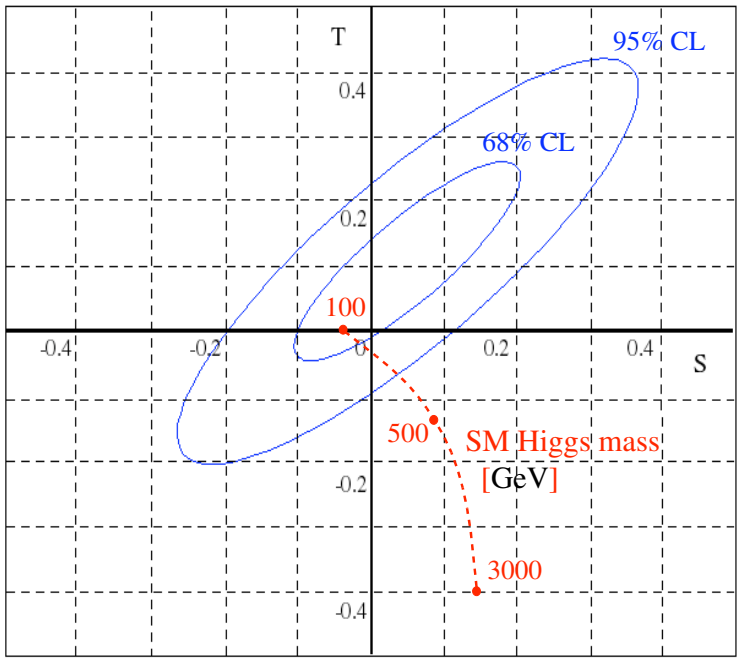
Is it a good model . . . ?

- $v = \langle H \rangle \sim 246 GeV \implies SU(2) \times U(1)_Y \to U(1)_q$

So gross features are reproduced.

SM: Precise Features

Is it a good model . . . ?



So precise features are reproduced.

SM: Precise Features

But is it such a good model? After all, we haven't yet seen the Higgs, despite a lot of searching.

- $m_h > 114$ GeV

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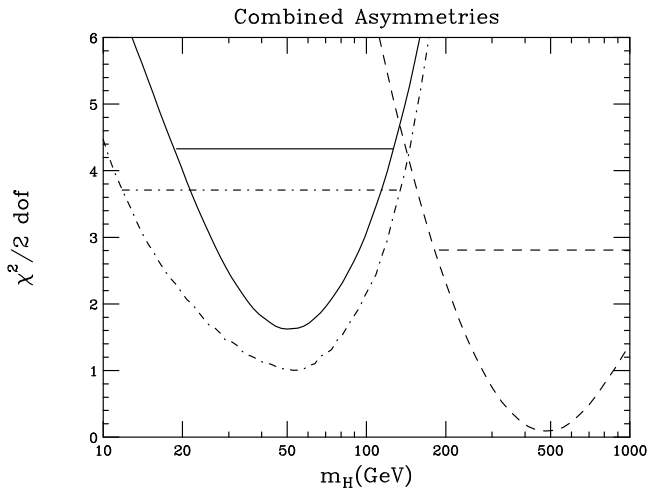


- solid: leptonic asymmetries, $m_h \sim 50\text{GeV}$
- dash: hadronic asymmetries, $m_h \sim 500\text{GeV}$
- dot-dash: non-asymmetry measurements, $m_h \sim 50\text{GeV}$
- combined, $m_h \sim 85\text{GeV}$, $CL(14.1, 7) = 0.05$

Chanowitz, 0806.0890

The Standard Model

But is it such a good model?

- Do we need renormalizability?
- What explains the hierarchy between $v \sim 246$ GeV and $M_P \sim 10^{19}$ GeV?

Composite models from $SO(3)$ to $SO(6)$

Composite models

Back to the beginning ... what do we really need?

Composites: Gross structure

$SU(2)_L \times U(1)_Y \to U(1)_{em}$

- Need 3 Goldstone bosons
- Do not need to live in a Higgs doublet
- Effective lagrangian
- Non-renormalizable; but good up to $4\pi v \sim 3$ TeV.

Composites: Gross structure

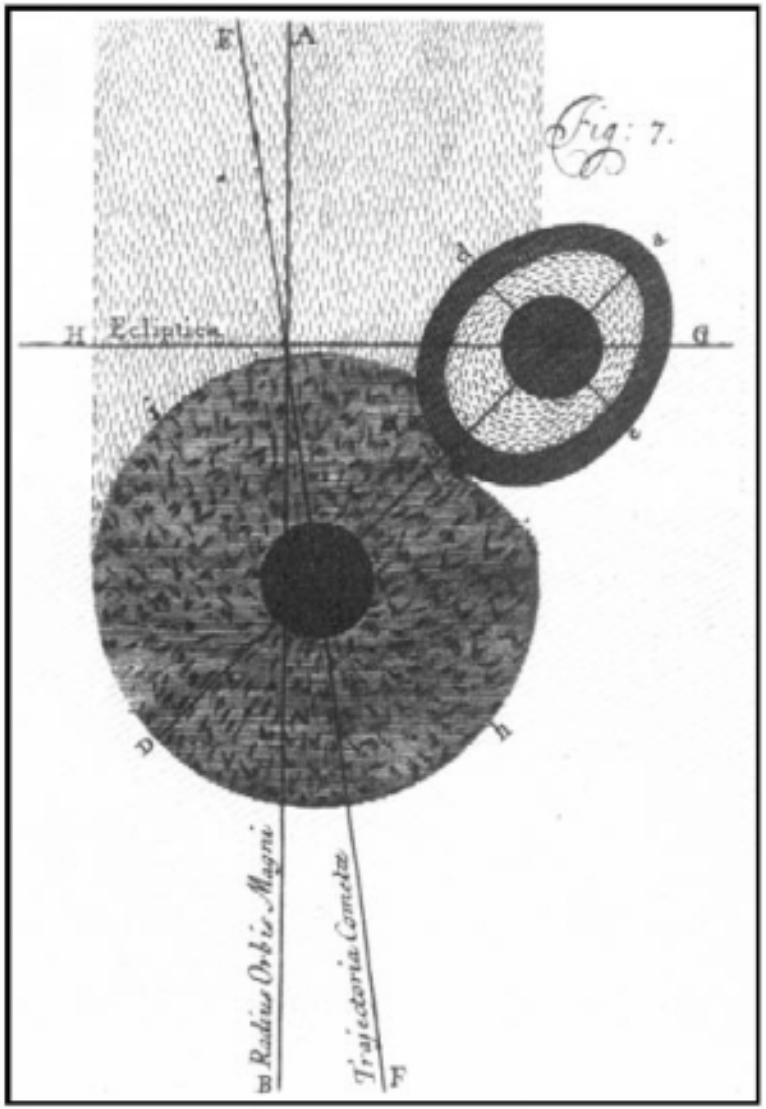
$SU(2)_L \times U(1)_Y \to U(1)_{em}$

- $SU(2) = SO(3)$
- $U(1) = SO(2)$

Like the Earth ...

Earth: $SO(3) \to SO(2)$

Like the Earth . . .



W. Whiston, Astronomical Principles of Religion

Composites: Precise structure

- $\frac{m_Z}{m_W}\cos\theta_W \simeq 1 \implies T \sim 0$

- Custodial symmetry
- Replace $U(1)_Y$ by $SU(2)_R$
- $SU(2)_L \times SU(2)_R \longrightarrow SU(2)_C$

Sikivie, Susskind, Voloshin, Zakharov

- $SU(2) = SO(3)$ but $SU(2) \times SU(2) = SO(4)$

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HyperEarth: $SO(4) \longrightarrow SO(3)$

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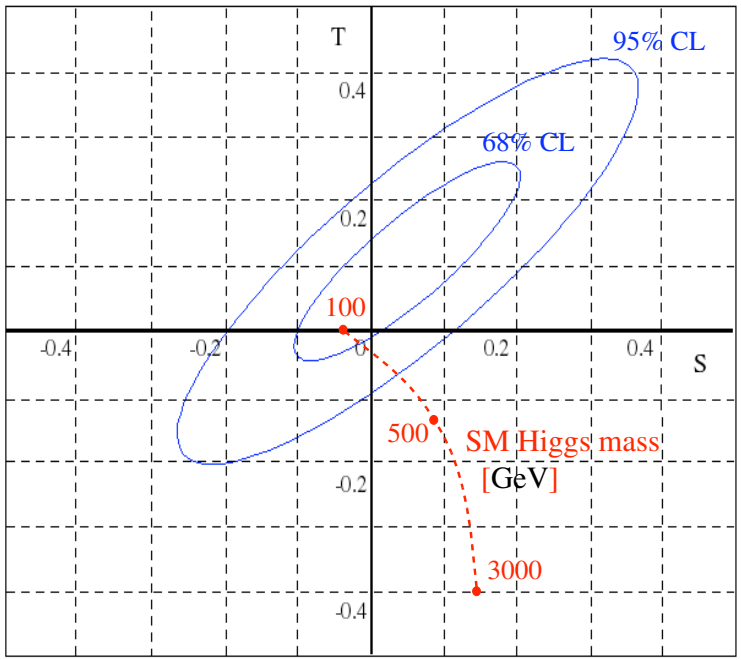
- $T \sim 0$
- GBs a **3** of $SO(3)$

Composites: Precise structure

- But $S \sim 0$ as well.



No symmetry

Favours light Higgs with infinite cut-off ...

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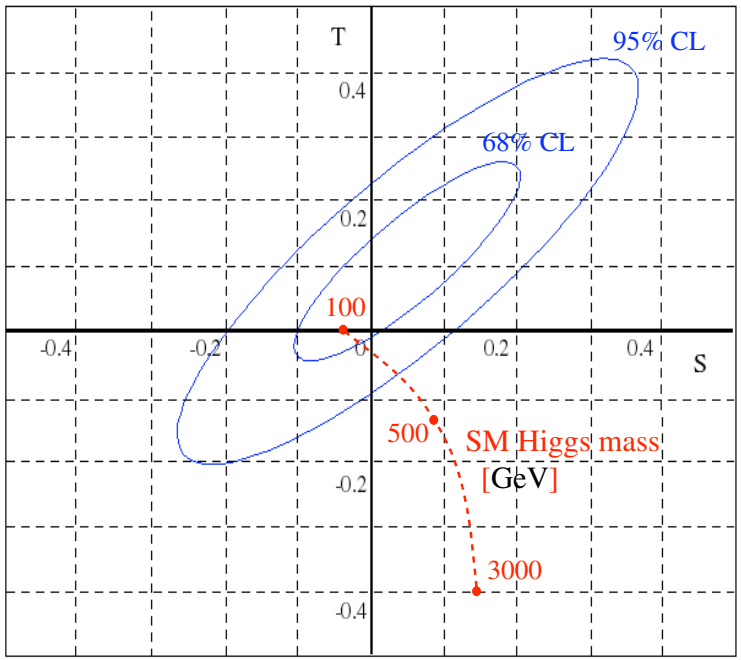

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SuperEarth: $SO(5) \to SO(4)$

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  Agashe, Contino, Pomarol, hep-ph/0412089

- GBs a **4** of $SO(4)$ or a $(2,2)$ of $SU(2)_L \times SU(2)_R$
- Like the Higgs!
- SM interactions break $SO(5)$
- Higgs gets a small mass from top loop

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Composites: Precise structure

Lastly, what about the global EW fit?

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- Can we hide Higgs from LEP?

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- Higgs mass from top loop
- Singlet mass from any loop
- Singlet can be very light
- Singlet can decay in any channel
- e.g. Dominant Higgs decay $h \to \eta\eta \to 4\tau, 4c$
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- CP-odd singlet: spontaneous CPV
- Singlet can mediate FCNC $\implies m_\eta > 40$ GeV
- Flavour-violating singlet decays, $\eta \to t\bar{c}, b\bar{s}$
- Stable singlet and DM
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