LCH
@
LHC
IMPLICATIONS OF LHC DATA FOR A LIGHT COMPOSITE HIGGS

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★ Focus on Higgs searches


In collab. with Christophe Grojean (CERN) and Maggie Mühlleitner (Karlsruhe)
The SM Higgs sector is the less tested and more problematic.

Affected by hierarchy problem

It's very likely that the Higgs will depart from its SM properties.

Calls for new physics at the TeV scale.
IMPORTANCE OF THE HIGGS

Not as the keystone of the SM

but as the portal to reveal the cracks in the SM
We look forward to:

★ Lower limits and then Excesses

that make these kind of plots not applicable!
Two main avenues for BSM Higgs

★ Elementary Higgs (SUSY, …)
★ Composite Higgs ← This talk

More precisely Light Composite Higgs

Bound state of fields from a strongly interacting sector
the PseudoGoldstone remnant of a global symmetry brkng.

In this talk \( m_h \in [80 \text{ GeV}, 200 \text{ GeV}] \)
EFFECTIVE LAGRANGIAN DESCRIPTION

\[ \mathcal{L}_{\text{silh}} = \frac{c_H}{2f^2} (\partial^\mu H^\dagger H)^2 + \frac{c_I}{2f^2} (H^\dagger D^\mu H)^2 + \left( \frac{c_{yy} f}{f^2} HH^\dagger f_L H f_R + \text{h.c.} \right) + \frac{ic_w g^2}{2m_p^2} (H^\dagger D^\mu H) (D^\nu W^\nu)^* + \frac{ic_{BG}}{2m_p^2} (H^\dagger D^\mu H) (\partial^\nu B^\mu)^* \ldots \]

\text{H of Goldstone origin:}

\[ \mathcal{L}_{\text{silh}} \text{ Non generic!} \Rightarrow \text{More predictive} \]

Relic effects from heavy strong sector, controlled by

\[ \xi = \frac{\alpha^2}{f^2} \]

\[ \xi = 0 \Rightarrow \text{SM} \]

\[ \xi = 1 \Rightarrow \text{Technicolor Limit} \]

Electroweak precision tests prefer smaller \( \xi \)
ANOMALOUS HIGGS PROPERTIES

SM connection between masses and Higgs couplings:

\[ m_{h} \sim g_{2} \]

\[ m_{\gamma} \sim y_{\gamma} \]

is lost in the presence of nonrenormalizable h interactions:

\[ \sum_{n} c_{n} h \rightarrow \sum_{n} n(n-1)c_{n} h \]

\[ \sum_{n} n c_{n} h \rightarrow \text{...} \]
Two ConcretE Models

Based on holographic 5D AdS models with $SO(5)/SO(4)$ coset space.

Minimal $\Rightarrow$ just 4 Goldstones: $\{C^0, G^\pm, h, Z^0, W^\pm\}$

Gauge interactions of $h$ fixed by coset structure:

\[
\begin{align*}
&h \xrightarrow{w_1^2} \sqrt{1-\xi} \times (SM) \\
&h \xrightarrow{w_2^2} (1-2\xi) \times (SM)
\end{align*}
\]

Interaction with fermions depend on the fermionic reps. under $SO(5)$

\[
\begin{align*}
\text{Spinorials} : & \quad \sqrt{1-\xi} \times (SM) & \quad \text{MCHM4} \\
\text{Fundamentals} : & \quad \frac{1-2\xi}{\sqrt{1-\xi}} \times (SM) & \quad \text{MCHM5}
\end{align*}
\]
SEARCH OF LIGHT COMPOSITE HIGGS

* Only \( h \) couplings modified w.r.t. SM (only composite state)

\[
\begin{array}{c}
\text{Signal process} \\
\text{modified}
\end{array}
\]

but same kinematics.

* Background processes unaffected.

Can use SM analyses!
Universal reduction: \( h \rightarrow \text{[diagram]} \sqrt{1-\xi} \times (\text{SM}) \)

Production Xsections

BRs unaffected

Higgs width

\[ \sigma_{LCH} = (1-\xi) \sigma_{SM} \]

\[ \Gamma_h = (1-\xi) \Gamma_{SM} \]
\[(Rescaling\ factors)^2\]

\[MCHM5\]

\[f \frac{1-2\xi}{1-\xi} \times (SM)\]

\[\frac{(1-2\xi)^2}{1-\xi}\]

\[\xi \quad 1-\xi\]

\[SM\]

\[\sqrt{1-\xi} \times (SM)\]
(Rescaling factors)^2

\[ \text{MCHM5} \]

\[ h \sim f \frac{1-2\xi}{1-\xi} \times \text{(SM)} \]

\[ \frac{(1-2\xi)^2}{1-\xi} \]

\[ 1-\xi \]

\[ \xi \]

\[ \text{SM} \]

\[ \text{Reduction for small } \xi \]

\[ \sqrt{1-\xi} \times \text{(SM)} \]


\[(\text{Rescaling factors})^2\]

\[\frac{1-2\xi}{1-\xi} \times \text{(SM)}\]

\[\frac{(1-2\xi)^2}{1-\xi}\]

SM

Reduction for small $\xi$

Fermiophobic
$\frac{(1-2\xi)^2}{1-\xi} \times (\text{SM})$

$\frac{1-2\xi}{1-\xi} \times (\text{SM})$

Reduction for small $\xi$

Fermiophobic

Gaugeophobic
Production Xsections:

\[ h \rightarrow V V \quad \sqrt{1 - \frac{4}{5}} \times (SM) \quad \sigma \left[ \begin{array}{c} \ \end{array} \right] = (1 - \frac{4}{5}) \sigma_{SM} \]

\[ h \rightarrow f f \quad \frac{1 - 2\xi}{\sqrt{1 - \xi}} \times (SM) \quad \sigma \left[ \begin{array}{c} \ \end{array} \right] = \frac{1 - 2\xi}{\sqrt{1 - \xi}} \times (SM) \]

\[ \sigma \left[ \begin{array}{c} \ \end{array} \right] = \frac{(1 - 2\xi)^2}{1 - \xi} \times (SM) \]
BRs (MCHM5)

\[ h \xrightarrow{\gamma} \gamma = \frac{1-2\xi}{\sqrt{1-\xi}} \times (\text{SM})_\gamma + \sqrt{1-\xi} \times (\text{SM})_W \]

![Graphs showing BRs for different processes and higgs masses.](Image)
COMBINED LIMITS FOR LIGHT $m_H$

**ATLAS** Preliminary

- **CLs Limits**
  - **Observed**
  - **Expected**
  - $\int L dt = 1.0 - 2.3 \text{ fb}^{-1}$
  - $\sqrt{s} = 7 \text{ TeV}$

**CMS** Preliminary, $\sqrt{s} = 7 \text{ TeV}$

- **Combined**, $L_{\text{int}} = 1.1 - 1.7 \text{ fb}^{-1}$
  - **Observed**
  - **Expected $\pm 1\sigma$**
  - **Expected $\pm 2\sigma$**

The plots illustrate the 95% CL limit on $\sigma/\sigma_{\text{SM}}$ as a function of $m_H$ [GeV] and Higgs boson mass (GeV/c$^2$).
BACK TO INDIVIDUAL CHANNELS

Re-scale individual channels separately
Combine them back
YE SHALL NOT COMBINE!
EXPECTATIONS  (30fb⁻¹)

SM

MCHM4  
(ζ = 0.8)
EXPECTATIONS (30fb⁻¹)

SM

MCHM5 (κ=0.5)
EXPECTATIONS (30 fb⁻¹)

SM

MCHM

(ξ = 0.8)
EXPECTATIONS (30 fb⁻¹)

**MCHM4**

![Graph showing MCHM4 model](image)

**MCHM5**

![Graph showing MCHM5 model](image)
EXCLUSIONS

MCHM4

MCHM5
**CONCLUSIONS**

* Very likely Higgs is not SM-like

* Besides a SUSY Higgs we should seriously consider
  - Light
  - Composite Higgses

* Combined TH-EXP effort to improve the analysis is worth undertaking.

* Discussed expectations and exclusion from LHC Higgs searches on 2 benchmark models
TH-EXP DIALOGUE

What we say to dogs
Okay, Ginger! I've had it! You stay out of the garbage! Understand, Ginger? Stay out of the garbage, or else!

What they hear
Blah blah GINGER blah blah blah blah blah GINGER blah blah blah blah GINGER...
What we say to cats...

Well, Fluffy, you've clawed the furniture for the last time! I'll not tolerate that behavior any longer!

What they hear

Gary Larson
WHAT EXPERIMENTALISTS TELL THEORISTS:

Beware of correlations and uncertainties!
Don't do these combinations at home!
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Beware of correlations and uncertainties!
Don't do these combinations at home!

WHAT THEORISTS HEAR/THINK:

Let's see how well we can do it!
COMBINED 95% C.L. LIMIT ON $\sigma/\sigma_{SM}$

$\sigma/\sigma_{SM}$

ATLAS-LP

$M_{h}/$GeV

SM Xcheck
MODEL SPACE

\[ \mathcal{L}_{\text{EWBS}} = \frac{\rho^2}{4} \text{Tr} \left[ D_{\mu} \Sigma^T D^\mu \Sigma \right] \left( 1 + 2a \frac{h}{\alpha} + b \frac{h^2}{\alpha^2} \right) \left( 1 + c \frac{h}{\alpha} \right) - y_f \bar{f}_L \Sigma f_R \left( 1 + c \frac{h}{\alpha} \right) \]

Unknown parameters \( a, b, c \).

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