The low mass scalar impostor and the composite Higgs

Chik Him (Ricky) Wong

Lattice Higgs Collaboration (LHC):
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Julius Kuti $†, Santanu Mondal $−,
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Outline

- Review: Sextet model as Composite Higgs candidate
- Hadron Spectroscopy on Extended Dataset
  - Simulation Details
  - Scale-setting: $M_{\pi}$ and $F_{\pi}$
  - Taste-breaking check: $M_{\pi_{sc}}$, $M_{\pi_{ij}}$, and $M_{\pi_{i5}}$
  - Light $0^{++}$ ground state $M_{f_{0}}$ as Higgs Impostor
  - Other phenomenologically interesting channels:
    - LHC reachable: $M_{a_{0}}$, $M_{\rho}$, $M_{a_{1}}$
    - Dark Matter candidate: $M_{N}$
- Study on topological effects
- Conclusion
Review:
Sextet model as Composite Higgs candidate

- Goal: Look for a Composite Higgs model:
  An infrared fixed point almost exists + Confining below
  Electroweak scale ⇒ models at the edge of conformal window
- After Higgs boson discovery: Light $0^{++}$ Higgs + reproduce
detected phenomenology
- Parameter Space: $N_C, N_f$, Representations of $SU(N_C)$

- Focus of this talk: $SU(3) N_f = 2$ Sextet(Two-index symmetric)
  Model
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**Sextet model as Composite Higgs candidate**

- **SU(3) \( N_f = 2 \) Sextet (Two-index symmetric) Model**
- Intrinsically very close to Conformal Window
- Seems to be still \( \chi \text{SB} \)
  - Chiral Condensate: non-zero (Fodor et al, PoS (LATTICE 2013) 089)
  - Effective Potential: confining (Fodor et al, PoS (Lattice 2012) 025)
  - Hadron Spectrum: more consistent with \( \chi \text{SB} \) than Conformal hypothesis (Fodor et al, Phys.Lett B 718, p. 657-666)
- \( \beta \) function is being studied (details in Julius Kuti’s talk)
- Can a Higgs Impostor be hidden in this model? \( \Rightarrow \) Investigate \( 0^{++} \) spectroscopy
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- $M_{f_0}$ can be as light as $1F - 3F = 250 - 750$ GeV
- Radiative corrections due to top quarks can turn it into a Higgs Impostor (Foadi et al, Phys. Rev. D 87, 095001)

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Triplet and singlet masses from $0^{++}$ correlators

$M_{t/s} = a_{t/s} + b_{t/s} m$ (fitting functions) $\beta = 3.2 \times 64$

$F = 0.0279 (4)$ setting the EWSB scale

$M_{H}/F \sim 1-3$ range

$F^+ = \frac{M_{H}}{F} \approx 1-3$ range

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- Action: Tree-level Symanzik-Improved gauge action with Staggered $N_f = 2$ Sextet SU(3) fermions
- RHMC algorithm with multiple time scales and Omelyan integrator
- $\beta \equiv \frac{6}{g^2} = 3.20$ and 3.25, which is in the weak coupling regime
- Lattices available: (~2000 – 4000 Trajectories each)

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$M_{\pi}$ determination

\[M_{\pi}^2 = 2B m + p_{M} m^2\]
\[2B = 6.280(60)\]
\[p_{M} = 30.8(8.8)\]
\[\chi^2/\text{dof} = 3.04\]

\[M_{\pi}^2 = 2B m\]
\[2B = 5.363(21)\]
\[\chi^2/\text{dof} = 3.05\]
Hadron Spectroscopy on Extended Dataset - Scale-setting

- $F_\pi$ determination

\[ F_\pi = F + p_m \]
\[ F = 0.02422(45) \]
\[ p_m = 4.07(10) \]
\[ \chi^2/dof = 1.28 \]

\[ \beta = 3.20 \]

\[ F_\pi = F + p_m \]
\[ F = 0.02214(42) \]
\[ p_m = 3.22(11) \]
\[ \chi^2/dof = 3.71 \]

\[ \beta = 3.25 \]
**Hadron Spectroscopy on Extended Dataset - Finite Size Scaling**

- Finite Size Scaling is under control

- Largest volume data available \((48^3 \times 96 \text{ or } 32^3 \times 64)\) are taken as infinite volume values
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**Hadron Spectroscopy on Extended Dataset - Finite Size Scaling**

- **Finite Size Scaling is under control**

![Graph showing Finite Size Scaling](image)

- **Largest volume data available $(48^3 \times 96$ or $32^3 \times 64)$ are taken as infinite volume values**

\[
M_q(L) = M_q + c_q g_q(M_q L)
\]

\[
c_q(1\text{-loop}) = M_q^2/64\pi^2 F_q^2\]

\[
M_q = 0.13564(51)
\]

\[
c_q = 0.066(17)
\]

\[
X^2/dof = 1.77
\]

\[
F_q(L) = F_q + c_q g_q(M_q L)
\]

\[
c_q(1\text{-loop}) = -M_q^2/16\pi^2 F_q^2\]

\[
F_q = 0.03658(23)
\]

\[
c_q = -0.021(43)
\]

\[
X^2/dof = 1.39
\]
Hadron Spectroscopy on Extended Dataset - Taste-breaking checks

- $M_{\pi_{sc}}$, $M_{\pi_{i5}}$, $M_{\pi_{ij}}$

Taste-breaking is reduced at larger $\beta$
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Hadron Spectroscopy on Extended Dataset - Light $0^{++}$ ground state as Higgs Impostor

- $M_{a_0}$ and $M_{f_0}$

- $M_{f_0}$ remains low and difficult to determine
- Mixing with glueball operators may help
- Most-sensitive to topological effects that may not be under full control (more in later slides)
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- Most-sensitive to topological effects that may not be under full control (more in later slides)
Hadron Spectroscopy on Extended Dataset - Other channels

- $M_\rho$ and $M_{\alpha_1}$

- Lowest states within reach of LHC
The low mass scalar impostor and the composite Higgs

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**Hadron Spectroscopy on Extended Dataset - Other channels**

- $M_\rho$ and $M_{a_1}$

![Graphs showing $M_\rho$ and $M_{a_1}$](image)

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Hadron Spectroscopy on Extended Dataset - Other channels

- Dark Matter candidate: $M_N$
- Tricky to construct due to symmetric color structure (details in Santanu Mondal’s talk)

Clean signals are observed for the first time.
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![Graph showing $M_N = c_0 + c_1 m$ with $c_0 = 0.332(13)$, $c_1 = 38.8(2.1)$, and $\chi^2$/dof = 0.506]

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Hadron Spectroscopy on Extended Dataset

Summary:

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- $M_{a_0}$ changes by a lot, probably due to under-estimated errors or topological effects (more on this in coming slides)
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- Previous study on $M_{f_0}$ (Fodor et al, PoS (LATTICE 2013) 062)

- No $Q$-dependence detected… But is it actually there? How about other channels?

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![Graph showing topological charge Q vs trajectory numbers]

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![Graph showing topological tunneling](image-url)
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![Graph](image)

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