Baryon spectrum of an SU(4) composite Higgs theory†

E. T. Neil[*1,*2] [for the Tel Aviv-Colorado Collaboration]

The possibility that the Higgs boson is not a fundamental scalar, but rather a composite bound state of some new strongly-coupled sector, provides an intriguing scenario for new physics beyond the Standard Model. Current measurements of the properties of the Higgs boson provide only weak constraints on the possible scale of compositeness for the Higgs. If the Higgs is indeed a composite bound state, then there will be an associated spectrum of other new composite particles which may be within discovery reach of the Large Hadron Collider (LHC) or other future colliders. The overall pattern of the spectrum is directly related to the underlying fundamental structure, just as the spectrum of QCD is predicted by the quark masses and the gauge symmetry group SU(3).

The full spectrum of a strongly-coupled gauge theory cannot be predicted by traditional perturbative methods. Instead, lattice simulations can be used to obtain numerical but systematically controlled results for the spectrum of a particular theory. In this work, we chose to study an SU(4) gauge theory proposed as a composite Higgs model by Ferretti.[1)] This model includes two types of fermions, charged under the fundamental **4** and "sextet" two-index antisymmetric **6** representations of SU(4). We have developed a lattice code capable of dealing with fermions in multiple representations, with previous results on the "meson" spectrum[2)] and thermodynamic properties of this theory.[3)]

Composite bound states can be enumerated by classifying all SU(4)-singlet combinations of fermions. Writing the **4** fermions as q and the **6** fermions as Q, we can identify bound states such as $qqqq$ which are direct analogues of the familiar QCD baryons. However, there is an additional baryon-like bound state composed of qqQ fermions. This "chimera baryon" is especially interesting in the context of the composite Higgs model, in which it has the same quantum numbers as the fundamental top quark. Mixing between the top quark and this top-partner chimera is responsible for the generation of the observed top mass.

Using standard lattice spectroscopy techniques, we compute the mass of the chimera and the other baryon-like states for a range of input fermion masses. The physical limit for the composite Higgs model requires taking the massless limit for the sextet fermions $m_6 \to 0$, but the other fermion mass m_4 remains a free parameter of the model. Figure 1 shows our results for the spectrum versus m_4 with 1σ error bands. The units are set in terms of F_6, the sextet NGB decay constant, which is related to the Higgs vacuum expectation value; experimental constraints require $F_6 \gtrsim 1$ TeV, so the plot units are equivalent to TeV scale.

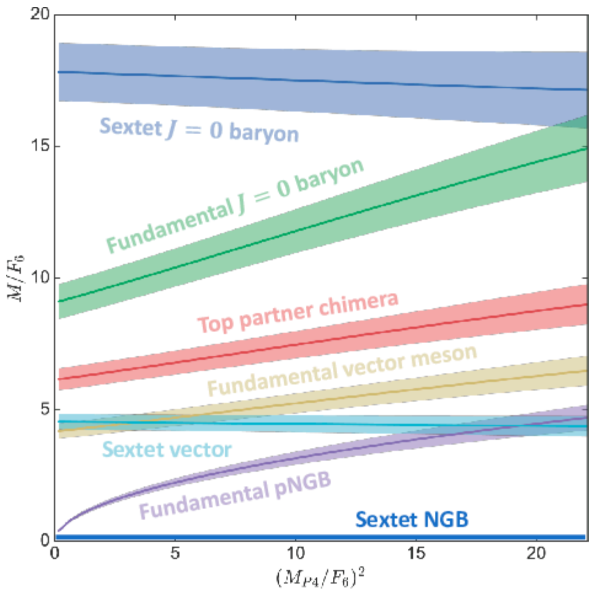

Fig. 1. Spectrum of bound states computed from lattice simulation for SU(4) gauge theory with two Dirac fermions in the **4** and **6** ("sextet") gauge representations. Bound-state masses (vertical axis) are shown versus the squared fundamental Nambu-Goldstone boson (NGB) mass $M^2_{P,4}$, which is proportional to the input fermion mass m_4, treated as a free parameter. In the context of the composite Higgs model, F_6 is bounded by experiment to be $F_6 \gtrsim 1$ TeV, so the plot can be read in TeV units. Most bound states are seen to be heavier than 5 TeV for the entire parameter space.

We see that for the full parameter space, all bound states are found to be quite heavy, with masses of order 5 TeV or larger, and thus likely out of the reach of the LHC. However, the fundamental pseudo-Nambu-Goldstone boson (NGB, purple curve) may be within reach for at least part of the parameter space. Future lattice studies will focus on non-perturbative contributions to the Higgs potential in this model, which should greatly constrain the allowed parameters of the model.

References

1) G. Ferretti, JHEP **1406**, 142 (2014).
2) V. Ayyar, T. DeGrand, D. C. Hackett, W. I. Jay, E. T. Neil, Y. Shamir, B. Svetitsky, Phy. Rev. D **97**, no. 7, 074505 (2018).
3) V. Ayyar, T. DeGrand, D. C. Hackett, W. I. Jay, E. T. Neil, Y. Shamir, B. Svetitsky, Phy. Rev. D **97**, no. 11, 114502 (2018).

† Condensed from the article in Phy. Rev. D **97**, no. 11, 114505 (2018)

*1 RIKEN Nishina Center
*2 Department of Physics, University of Colorado, Boulder