Targeting the Conformal Window: Determining the Running Coupling

Can the Higgs be a composite resonance?

- A composite resonance is a natural mechanism, as e.g. in superconductivity
- Likely avoids a “walking” theory near a conformal infrared fixed point (IRFP)
- Light Higgs could be the dilution of broken conformal symmetry
- Walking coupling leads to enhanced chiral condensate needed for precision EW constraints
- Strongly coupled model requires non-perturbative studies
- Exploratory lattice results [1]

The conformal window

- Seek a model with “walking” behavior
- IRFP of 12-flavor system (Nf = 0)
- System is chirally broken for m⊙ = 0
- Infrared: system is chirally broken for m⊙ = 0
- The anomalous dimension is large across a wide energy range
- The coupling shows signs of “walking” as β→∞
- Controls the energy dependence of the gauge coupling
- Tuning mass m⊙ controls the energy dependence of the gauge coupling

Alternative model: 4+8 flavors

- Study SU(3) with Nc = 4; Nf = 8 flavors
- Renormalized trajectory (RT) emerges from the IRFP of 12-flavor system (m⊙ = 0)
- For small m⊙ ≪ 1 the RG flow lines approach this IRFP
- If original gauge coupling is close to RT, IR behavior of the system is characterized by m⊙
- Investigate the system as a function of m⊙ with fixed β
- At finite temperature the chiral condensate ⟨ψiψi⟩ serves as order parameter

Numerical setup

- Fit the Wilson flow scale to a given value of m⊙
- Dash lines indicate δ(0) as cut-off effects
- Statistical errors are smaller or comparable to the line width
- Compute average ⟨ψiψi⟩ with m⊙ = 0, 0.060, 0.080, and 0.100
- m⊙ = 0.060 shows very little “walking” (almost QCD-like)
- m⊙ = 0.080 shows some “walking”
- m⊙ = 0.100 shows the “walking” range
- Timings m⊙ controls the energy dependence of the gauge coupling

The phase diagram

- Study SU(3) with Nc = 4; Nf = 8 flavors
- Determine Wilson flow scale by shifting to the IRFP
- Compute average ⟨ψiψi⟩ with m⊙ = 0, 0.060, 0.080, and 0.100
- m⊙ = 0.060 shows very little “walking” (almost QCD-like)
- m⊙ = 0.080 shows some “walking”
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Anomalous Dimension from the Mode number

- Large anomalous dimension with walking coupling leads to enhancement of the condensate, important for phenomenological applications
- The scale dependent anomalous dimension can be determined from the mode number [2]
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Determination of the running coupling using Wilson flow

- Extrapolate Wilson flow data to the chiral limit
- Define an improved renormalized coupling using the gradient flow [6, 3]
- The lattice in (K(t) + m⊙) reduces the O(a 2) cut-off errors of 2g2φ2
- Determine Wilson flow scale for shifted data: K(t) = 0.3
- Optimize m⊙ by requiring consistency of 2g2φ2(t) near t = 8 between different m⊙
- Control finite volume effects by restricting 2g2φ2 ≤ 0.2L; L = 32
- Control cut-off effects by restricting 2g2φ2(t) > 2 (indicated by solid lines)
- Data at β = 4.0 on 323 × 64 lattices

Running coupling for different masses m⊙

- Plot 2g2φ2 vs. µ/βm⊙ and normalize on-axis by τ1/2 = 1/√2m⊙ (0.090)
- Dashed lines indicate 2g2φ2 > 2 (cut-off effects)
- Statistical errors are smaller or comparable to the line width
- Check validity of results with m⊙ = 0.060, 0.080, and 0.100
- τ1/2 = 1/√2m⊙ (0.090) shows very little “walking” (almost QCD-like)
- τ1/2 = 0.080 shows the “walking” range
- τ1/2 = 0.100 and below has extended “walking” range

Summary and outlook

- The Nc = 4 + 8 flavor system allows controlled study of the emergence of the conformal window
- First results are promising and follow expectations
- The coupling shows signs of “walking” as m⊙ → 0
- The anomalous dimension is large across a wide energy range
- The O(a 2) scale M⊙ decreases as m⊙ → 0 (talk by E. Weinberg, Monday, 5:30pm)
- The 4 + 8 flavor system presents new challenges
- The phase diagram is complicated and the continuum limit requires m⊙ → 0 in addition to β→∞
- Heavy and light flavors mix, complicating spectrum studies
- Future plans:
  - Numerical exploration of the finite-temperature phase diagram
  - Study of the fermion condensate and the ratio Lτ/EF
  - Spectral studies, including the disconnected scalar, with smaller m⊙, larger volumes

References


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