Improved Lattice Spectroscopy of Minimal Walking Technicolor

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Outline

Motivation

- Electroweak symmetry breaking in nature about to be probed
- Dynamical EWSB remains a possible mechanism
- Requires new gauge sector with low N_c and N_f which is near-conformal $\rightarrow$ Chivukula, Sat
- Non-perturbative question, requires lattice input $\rightarrow$ Del Debbio, Thurs

Outline

Minimal Walking Technicolor

- $SU(2)$ theory with two (Dirac) flavours of adjoint fermion
- Attracted significant phenomenological and lattice attention
- Candidate model for new gauge sector of near-conformal technicolor theory
- Previous simulations have provided some evidence for existence of IR fixed point
  - Renormalisation flow analysis [HRT09, BDDK$^+$09, BDDK$^+$10]
  - Spectroscopic evidence [CS07, DDPP08, HRRT09]
- Systematics largely unexplored

Simulation

- Simulation details found in [DDLP+10b, DDLP+10a], → Pica & Patella, Tues
- Wilson fermions ⇒ $am \neq 0$
- Configs from *HiRep* code for arbitrary N_c, N_f and fermion representation
- Fixed lattice spacing $\beta = 2.25$, (2.10), range of bare masses and volumes

Spectroscopy

- Original analysis involved local correlators

$$C_{\Gamma}^{l}(t) = a^6 \sum_{\vec{x}} \langle \bar{\psi}(\vec{x}, t)\Gamma\psi(\vec{x}, t)\bar{\psi}(\vec{0}, 0)\Gamma\psi(\vec{0}, 0)\rangle$$

- Generalised *chroma* package to general N_c, N_f, fermion representation
- Made use of *chroma* quark smearing routines
  - Gaussian Shell Smearing
  - Wall Smearing
  - Stochastic $\mathbb{Z}_2$ Smearing

Improved Plateaux

- Wall smearing expected to have lower overlap with excited states

$$C^s_\Gamma(t) = a^6 \sum_{\vec{x}} \langle \bar{\psi}(\vec{x}, t) \Gamma \psi(\vec{x}, t) \sum_{\vec{y}, \vec{z}} \bar{\psi}(\vec{y}, 0) \Gamma \psi(\vec{z}, 0) \rangle$$

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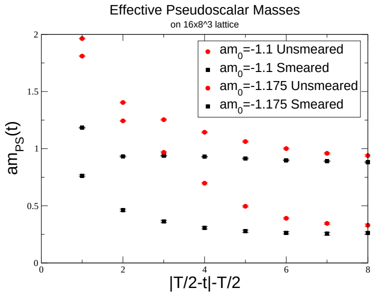

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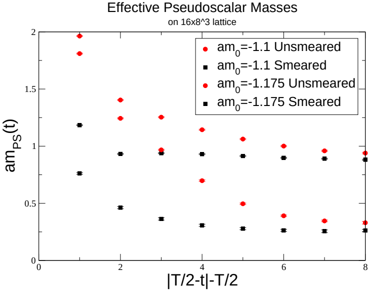
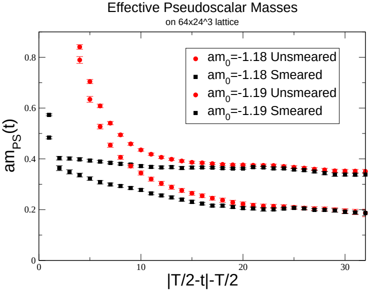




Dealing with systematics

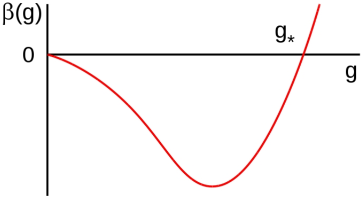
- Results show lower uncertainties due to smaller contribution from excited states
- Discrepancies are apparent at small volume
- Systematically combine two data sets (c.f. Addendum)

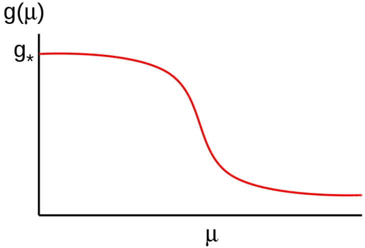
- Also explored effective mass definitions
  - Settle on one mass *Prony* method [FCLP09]
- And varying definition of effective observables
  - Limited impact

Outline

IR Conformal

- We are interested in IR conformal theories





$$\beta(g_*) = 0 \qquad \gamma_{\langle\bar{\psi}\psi\rangle}(g_*) = \gamma_*$$

$$\rho = \frac{1}{1+\gamma_*}$$

Conformal Comparison

QCD

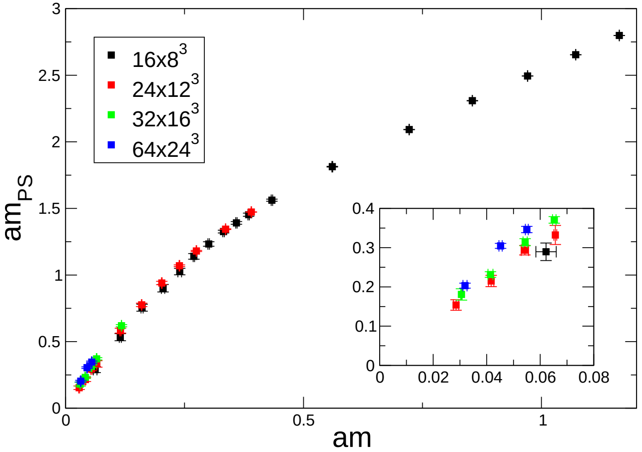
- $m_{\mathrm{PS}} \sim m^{\frac{1}{2}}$
- $\frac{m_{\mathrm{PS}}}{m_{\mathrm{V}}} \xrightarrow{m \to 0} 0$
- Volume effects $\sim e^{-m_{\mathrm{PS}} L_s}$

IR Conformal

- $m_{\mathrm{PS}} \sim M \sim m^{\rho}$
- $\frac{m_{\mathrm{PS}}}{m_{\mathrm{V}}} \sim 1$
- $LM = f(x) \quad x = (Lm)^{\rho}$

Outline

Pseudoscalar Meson



Pseudoscalar Mass Scaling

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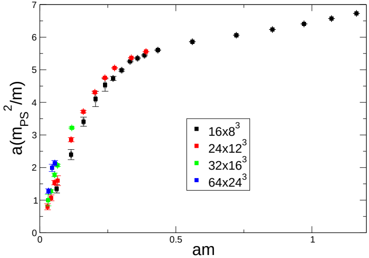

$$\frac{m_{PS}^2}{m} \overset{m \to 0}{\longrightarrow} 0?$$

Pseudoscalar Mass Scaling

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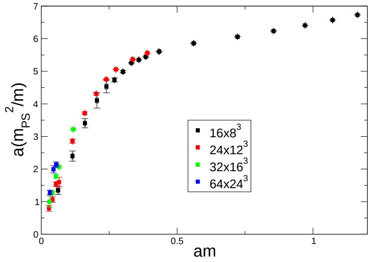
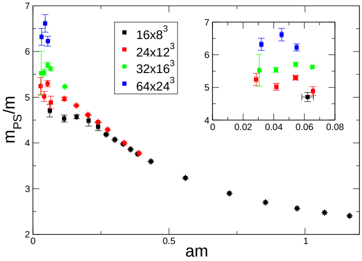


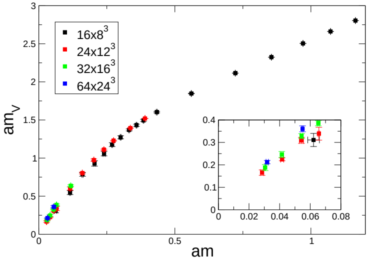


$$\frac{m_{PS}^2}{m} \xrightarrow{m \to 0} 0?$$

$$0 < \gamma < 1?$$

Vector Meson

$$\text{QCD: } \frac{m_V}{m_{PS}} \xrightarrow{m \to 0} \infty$$



$$m_V \xrightarrow{m \to 0} 0?$$

Vector Meson

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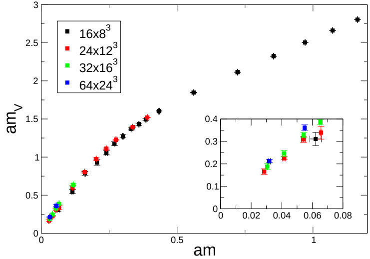

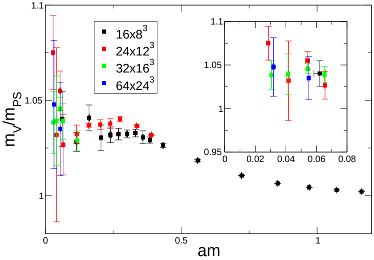

$$m_V \xrightarrow{m \to 0} 0?$$

$$\frac{m_V}{m_{PS}} \overset{m \to 0}{\sim} 1$$

Pseudoscalar Decay Constant

- Smearing requires combination of two correlators to extract amplitude
- Leads to large fluctuations at large times, on small volumes

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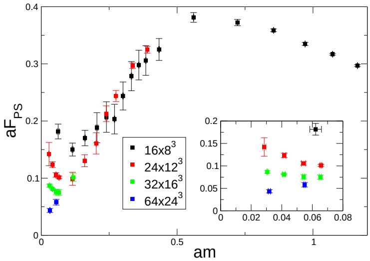

V effects large

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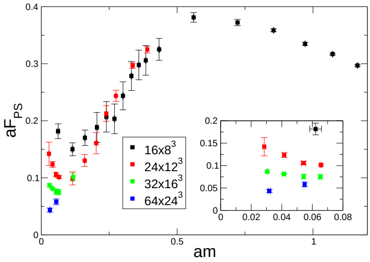

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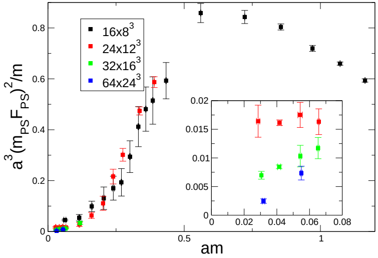
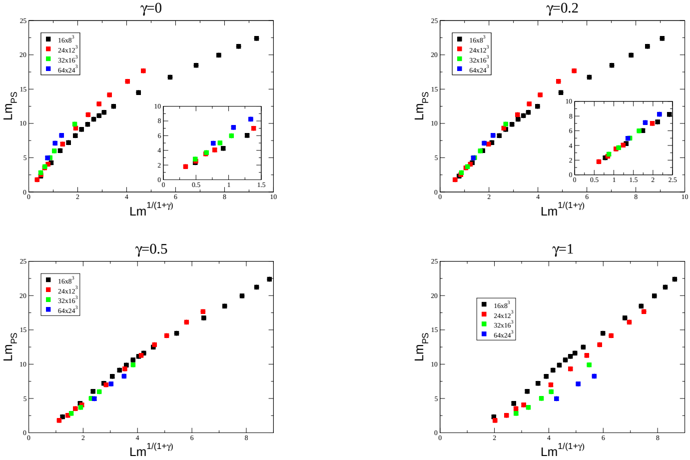


$$\frac{(m_{PS}F_{PS})^2}{m} \xrightarrow{m\to 0} 0?$$

Finite Volume Scaling

$$LM = f(x) \quad x = (Lm)^{\rho}$$



Outline

Summary

- Supported the results in [DDLP+10a, DDLP+10b]
- Clarified reliability of fits
- Accounted for systematics where present
- Further indications of near-conformal dynamics

Plateaux

- Define effective observable $M(t) \xrightarrow{t \to \frac{T}{2}} M$
- Examine behaviour at large times
- Fit over range of t over which $M(t)$ roughly constant

Effective Observables

$$M = \lim_{t \to \frac{L_t}{2}} M(t)$$

- We use *Prony* method [FCLP09] (1 mass) to compute effective masses
- Fits using 2 masses disfavoured because of inflated uncertainties on ground state mass

$$a^2 |G_{\mathrm{PS}}|(t) = \sqrt{V_s \frac{2am_{\mathrm{PS}}(t) C_{\gamma_5}(t)}{h_+(m_{\mathrm{PS}}(t), T, t)}}$$

- Also trialled different effective observable definitions.
  - Impact limited
  - Where possible, chosen definition giving best fit

Combining Data Sets

$$M_1 \pm \sigma_1 \qquad\qquad M_2 \pm \sigma_2$$

$$M' = \frac{\frac{M_1}{\sigma_1^2} + \frac{M_2}{\sigma_2^2}}{\frac{1}{\sigma_1^2} + \frac{1}{\sigma_2^2}}$$

$$= \frac{\sigma_2^2 M_1 + \sigma_1^2 M_2}{\sigma_1^2 + \sigma_2^2}$$

$$\sigma' = \frac{1}{\sqrt{\frac{1}{\sigma_1^2} + \frac{1}{\sigma_2^2}}} \times \left(1 + \frac{(M_1 - M_2)^2}{\sigma_1^2 + \sigma_2^2}\right)$$

$$= \frac{\sigma_1 \sigma_2}{\sqrt{\sigma_1^2 + \sigma_2^2}} \times \left(1 + \frac{(M_1 - M_2)^2}{\sigma_1^2 + \sigma_2^2}\right)$$

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