Chik Him Wong

Outilli

васкдгои

Conformali

Simulation Setu

C---t----

Analysis

conformal hypothesis with

Fitting scaling function with physical model

Fitting general scalin function using B-form spline functions

Conclusion

Conformal Finite Size Scaling of Twelve Fermion Flavors

Chik Him Wong

Lattice Higgs Collaboration (LHC):

Zoltán Fodor ^{\$}, Kieran Holland *,

Julius Kuti [†], Dániel Nógrádi [–],

Chik Him Wong [†]

†: University of California, San Diego *: University of the Pacific \$: University of Wuppertal -: Eötvös University

LATTICE 2012

Chik Him Wong

Outline

Backgroun

Controversy

Simulation Set

Spectroscop

Fitting under

conformal hypothesis with FSS

with physical model
Fitting general scaling

spline functions

Conclusion

Outline

- Background
 - Conformality Controversy of $N_f = 12 SU(3)$ Fundamental
 - Simulation Setup
- Spectroscopy Analysis
- Fitting under conformal hypothesis with Finite Size Scaling study
 - Fitting scaling function with physical model
 - Fitting general scaling function using B-form spline functions
- Conclusion
 - Outstanding Problems
 - Future Plans

Chik Him Wong

Outlin

Backgrou

Conformality Controversy

Spectroscor

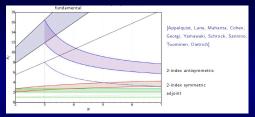
Analysis Analysis

Fitting under conformal hypothesis wit FSS

Fitting scaling function with physical model Fitting general scalin function using B-form spline functions

Conclusion

Conformality Controversy of $N_f = 12 SU(3)$ Fundamental



- Previously...
 - Likely: T. Appelquist et al, A. Deuzeman et al, A Hasenfratz et al, Y. Aoki et al
 - Not Likely: X.-Y. Jin et al, Z. Fodor et al
- Latest findings of our group:
 Finite Size Scaling Conformal scenario is Inconsistent and Suspect

Chik Him Wong

Outlin

Backgrour

Conformality Controversy

Simulation Setu

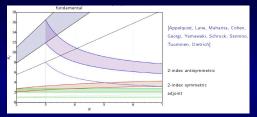
Spectrosco Analysis

Fitting under conformal hypothesis wit FSS

Fitting scaling function with physical model Fitting general scalin function using B-form

Conclusion

Conformality Controversy of $N_f = 12 SU(3)$ Fundamental



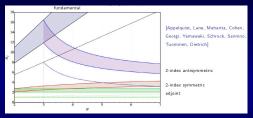
- Previously...
 - Likely: T. Appelquist et al, A. Deuzeman et al, A Hasenfratz et al, Y. Aoki et al
 - Not Likely: X.-Y. Jin et al, Z. Fodor et al
- Latest findings of our group:
 Finite Size Scaling Conformal scenario is Inconsistent and Suspect

Chik Him Wong

Conformality

Controversy

Conformality Controversy of $N_f = 12 SU(3)$ Fundamental

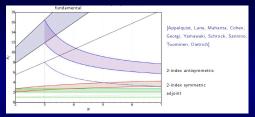


- Previously...
 - Likely: T. Appelquist et al, A. Deuzeman et al, A. Hasenfratz et al, Y. Aoki et al
- Latest findings of our group:

Chik Him Wong

Conformality Controversy

Conformality Controversy of $N_f = 12 SU(3)$ Fundamental



- Previously...
 - Likely: T. Appelquist et al, A. Deuzeman et al, A. Hasenfratz et al, Y. Aoki et al
 - Not Likely: X.-Y. Jin et al, Z. Fodor et al
- Latest findings of our group:

Chik Him Wong

Cime rinn 1101

Conformality

Controversy

Spectroscopy

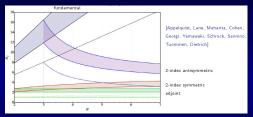
Fitting under conformal

FSS
Fitting scaling function with physical model

Fitting general scalin function using B-form spline functions

Conclusion

Conformality Controversy of $N_f = 12 SU(3)$ Fundamental



- Previously...
 - Likely: T. Appelquist et al, A. Deuzeman et al, A Hasenfratz et al, Y. Aoki et al
 - Not Likely: X.-Y. Jin et al, Z. Fodor et al
- Latest findings of our group:
 Finite Size Scaling Conformal scenario is Inconsistent and Suspect

Chik Him Wong

Outlin

Garage

Simulation Setup

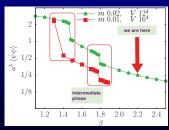
Fitting under

conformal hypothesis with FSS

with physical model Fitting general scalir function using B-for

Conclusion

- Action: Tree-level Symanzik-Improved gauge action with Staggered $N_f = 12$ Fundamental fermions
- HMC algorithm with multiple time scales and Omelyan integrator
- Autocorrelations monitored by time histories of Fermion condensate, plaquette and correlators
- $\beta \equiv 6/g^2 = 2.20$, which is in the Weak Coupling regime



C. Schroeder et al



A. Hasenfratz et al

Chik Him Wong

Outline

Backgrou

Controversy Simulation Setup

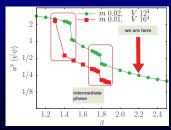
Fitting under

conformal hypothesis with FSS

with physical model Fitting general scalir function using B-for

Conclusion

- Action: Tree-level Symanzik-Improved gauge action with Staggered $N_f = 12$ Fundamental fermions
- HMC algorithm with multiple time scales and Omelyan integrator
- Autocorrelations monitored by time histories of Fermion condensate, plaquette and correlators
- $\beta \equiv 6/g^2 = 2.20$, which is in the Weak Coupling regime



C. Schroeder et al



A. Hasenfratz et al

Conformal Finite Size Scaling of Twelve Fermion Flavors Chik Him Wong

Outilile

Conforma

Simulation Setup

Spectroscopy

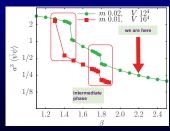
Fitting under conformal hypothesis with

FSS
Fitting scaling func

Fitting general scalin function using B-form

Conclusion

- Action: Tree-level Symanzik-Improved gauge action with Staggered $N_f = 12$ Fundamental fermions
- HMC algorithm with multiple time scales and Omelyan integrator
- Autocorrelations monitored by time histories of Fermion condensate, plaquette and correlators
- $\beta \equiv 6/g^2 = 2.20$, which is in the Weak Coupling regime



C. Schroeder et al

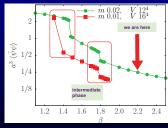


A. Hasenfratz et al

Chik Him Wong

Simulation Setup

- Action: Tree-level Symanzik-Improved gauge action with Staggered $N_f = 12$ Fundamental fermions
- HMC algorithm with multiple time scales and Omelyan integrator
- Autocorrelations monitored by time histories of Fermion condensate, plaquette and correlators
- $\beta \equiv 6/g^2 = 2.20$, which is in the Weak Coupling regime



C. Schroeder et al



A. Hasenfratz et al

Outlin

Backgrou

Conformal

Simulation Setup

Spectroscop

Fitting under conformal hypothesis with

FSS
Fitting scaling fun

Fitting general scal

function using B-fo spline functions

Conclusion

Simulation Setup

• Lattices used:($\sim 1000 - 2000$ Trajectories each)

	· · · · · · · · · · · · · · · · ·				
L	T	m_q			
48	96	0.0100, 0.0150			
40	80	0.0100, 0.0150, 0.0200, 0.0250			
32	64	0.0020, 0.0040, 0.0060, 0.0080,			
		$0.0100,\ 0.0150,\ 0.0200,\ 0.0250$			
28	56	0.0150			
24	48	$0.0020,\ 0.0040,\ 0.0060,\ 0.0080,\ 0.0100,\ 0.0150,$			
		$0.0200,\ 0.0250,\ 0.0300,\ 0.0325,\ 0.0350$			
20	40	0.0020, 0.0040, 0.0060, 0.0080,			
		$0.0100,\ 0.0150,\ 0.0200,\ 0.0250$			

Analysis Fitting under

conformal hypothesis with FSS

Fitting scaling functi with physical model Fitting general scalin function using B-form

Conclusion

Spectroscopy Analysis

- Double Jackknife to obtain good estimate on Covariance Matrix
 - Generate Jackknife ensembles of Correlators $\{C(t)\}_i$
 - Fit individual ensemble to obtain m_0^l or F_{π}^l using Covariance Matrix

$$C_{x_{4}x'_{4}}^{i} = \sum_{j=1}^{N-1} \{m_{eff}(x_{4})_{j}^{i} - \langle m_{eff}(x_{4}) \rangle_{i}\} \{m_{eff}(x'_{4})_{j}^{i} - \langle m_{eff}(x'_{4}) \rangle_{i}\}$$

With χ^2 defined as:

$$(\chi^2)^i = \sum_{x_4 = t_0}^{t_1} \sum_{x_4' = t_0}^{t_1} \{ m_0^i - \langle m_{eff}(x_4) \rangle_i \} [(C^i)^{-1}]_{x_4 x_4'} \{ m_0^i - \langle m_{eff}(x_4') \rangle_i \}$$

(above expressions also apply to F_{π}^{i})

Outlin

Backgroui

Conformali

Simulation Satu

Simulation Setu

Spectroscopy Analysis

Fitting under conformal hypothesis with FSS

Fitting scaling functi with physical model Fitting general scalin function using B-form

spline functions

Spectroscopy Analysis

- Double Jackknife to obtain good estimate on Covariance Matrix
 - Generate Jackknife ensembles of Correlators $\{C(t)\}_i$
 - Fit individual ensemble to obtain m_0^l or F_{π}^l using Covariance Matrix

$$C_{\mathbf{x}_{4}\mathbf{x}_{4}^{\prime}}^{i} = \sum_{j=1}^{N-1} \{m_{\textit{eff}}(\mathbf{x}_{4})_{j}^{i} - \langle m_{\textit{eff}}(\mathbf{x}_{4}) \rangle_{i} \} \{m_{\textit{eff}}(\mathbf{x}_{4}^{\prime})_{j}^{i} - \langle m_{\textit{eff}}(\mathbf{x}_{4}^{\prime}) \rangle_{i} \}$$

With χ^2 defined as:

$$(\chi^2)^i = \sum_{x_4 = t_0}^{t_1} \sum_{x_4' = t_0}^{t_1} \{ m_0^i - \langle m_{eff}(x_4) \rangle_i \} [(C^i)^{-1}]_{x_4 x_4'} \{ m_0^i - \langle m_{eff}(x_4') \rangle_i \}$$

(above expressions also apply to F_{π}^{i})

Outlin

Backgrou

Conformal

Simulation Satu

Simulation Setu

Spectroscopy Analysis

Fitting under conformal hypothesis with FSS

Fitting scaling funct with physical model

Fitting general scali function using B-for

Conclusion

Spectroscopy Analysis

- Double Jackknife to obtain good estimate on Covariance Matrix
 - Generate Jackknife ensembles of Correlators $\{C(t)\}_i$
 - Fit individual ensemble to obtain m_0^i or F_π^i using Covariance Matrix

$$C_{x_4,x_4'}^i = \sum_{j=1}^{N-1} \{ m_{eff}(x_4)_j^i - \langle m_{eff}(x_4) \rangle_i \} \{ m_{eff}(x_4')_j^i - \langle m_{eff}(x_4') \rangle_i \}$$

With χ^2 defined as:

$$(\chi^2)^i = \sum_{x_4 = t_0}^{t_1} \sum_{x_4' = t_0}^{t_1} \{ m_0^i - \langle m_{eff}(x_4) \rangle_i \} [(C^i)^{-1}]_{x_4 x_4'} \{ m_0^i - \langle m_{eff}(x_4') \rangle_i \}$$

(above expressions also apply to F_{π}^{i})

Chik Him Wong

Outlin

Backgrou

Conformal

Simulation Set

Spectroscop

Fitting under

hypothesis with
FSS
Fitting scaling function

with physical model Fitting general scaling

Fitting general scaling function using B-form spline functions

Conclusion

Fitting under conformal hypothesis with Finite Size Scaling study

$$LM = c_1 x + c_{\text{exp}} (c_{\pi} x)^{-1/2} e^{-c_{\pi} x}, \qquad x > x_{\text{cut}}$$

$$LM = c_0 + c_{\alpha} x^{\alpha}, \qquad x < x_{\text{cut}}$$

where
$$x \equiv Lm^{1/1+\gamma}$$
 and $M = M_{\pi}, M_{\rho}, M_N$ or F_{π}

- Conformal behavior:
 - $M \sim m^{1/1+\gamma}$ as $L \to \infty$ at fixed m
 - $M \sim L^{-1}$ as $m \to 0$
 - Other terms are finite size corrections
 - $c_{\text{exp}}(c_{\pi}x)^{-1/2}e^{-c_{\pi}x}$: leading exponential correction from wrap-around effect of the lightest Goldstone pion state ($c_{\pi} = c_{1}$ for pions and fitted value becomes c_{π} of other channels)
 - $c_{\alpha}x^{\alpha}$: simplest ansatz, could be polynomials
 - Continuity and first derivative continuity imposed at x_{cut}
 - 5 fit parameters: γ , c_1 , $c_{\rm exp}$, α , $x_{\rm cu}$

Chik Him Wong

Outline

Backgrou

Conforms

Controversy

E---t----

Analysis

conformal hypothesis with

Fitting scaling function with physical model Fitting general scaling

function using B-forn spline functions

Conclusion

Fitting under conformal hypothesis with Finite Size Scaling study

$$LM = c_1 x + c_{\exp}(c_{\pi} x)^{-1/2} e^{-c_{\pi} x}, \qquad x > x_{\text{cut}}$$

$$LM = c_0 + c_{\alpha} x^{\alpha}, \qquad x < x_{\text{cut}}$$

where
$$x \equiv Lm^{1/1+\gamma}$$
 and $M = M_{\pi}, M_{\rho}, M_N$ or F_{π}

- Conformal behavior:
 - $M \sim m^{1/1+\gamma}$ as $L \to \infty$ at fixed m
 - $M \sim L^{-1}$ as $m \to 0$
 - Other terms are finite size corrections
 - $c_{\exp}(c_{\pi}x)^{-1/2}e^{-c_{\pi}x}$: leading exponential correction from wrap-around effect of the lightest Goldstone pion state $(c_{\pi} = c_{1})$ for pions and fitted value becomes c_{π} of other channels)
 - $c_{\alpha}x^{\alpha}$: simplest ansatz, could be polynomials
 - Continuity and first derivative continuity imposed at x_{cut}
 - 5 fit parameters: γ , c_1 , $c_{\rm exp}$, α , $x_{\rm cu}$

Chik Him Wong

Outline

Backgrou

Conforma

Simulation Set

Spectroscop

Fitting under

hypothesis with FSS

Fitting scaling function with physical model Fitting general scaling

function using B-forr spline functions

Conclusion

Fitting under conformal hypothesis with Finite Size Scaling study

$$LM = c_1 x + c_{\exp}(c_{\pi}x)^{-1/2} e^{-c_{\pi}x}, \qquad x > x_{\text{cut}}$$

$$LM = c_0 + c_{\alpha}x^{\alpha}, \qquad x < x_{\text{cut}}$$

where
$$x \equiv Lm^{1/1+\gamma}$$
 and $M = M_{\pi}, M_{\rho}, M_N$ or F_{π}

- Conformal behavior:
 - $M \sim m^{1/1+\gamma}$ as $L \to \infty$ at fixed m
 - $M \sim L^{-1}$ as $m \to 0$
 - Other terms are finite size corrections
 - $c_{\exp}(c_{\pi}x)^{-1/2}e^{-c_{\pi}x}$: leading exponential correction from wrap-around effect of the lightest Goldstone pion state $(c_{\pi} = c_{1})$ for pions and fitted value becomes c_{π} of other channels)
 - $c_{\alpha}x^{\alpha}$: simplest ansatz, could be polynomials
 - Continuity and first derivative continuity imposed at x_{cut}
 - 5 fit parameters: γ , c_1 , c_{exp} , α , x_{cut}

Chik Him Wong

Outline

Backgrou

Conformal

Simulation Set

Spectroscop

Fitting under

hypothesis with FSS Fitting scaling function

with physical model Fitting general scalin

Fitting general scalin function using B-forr spline functions

Conclusion

Fitting under conformal hypothesis with Finite Size Scaling study

$$LM = c_1 x + c_{\exp}(c_{\pi} x)^{-1/2} e^{-c_{\pi} x}, \qquad x > x_{\text{cut}}$$

$$LM = c_0 + c_{\alpha} x^{\alpha}, \qquad x < x_{\text{cut}}$$

where
$$x \equiv Lm^{1/1+\gamma}$$
 and $M = M_{\pi}, M_{\rho}, M_N$ or F_{π}

- Conformal behavior:
 - $M \sim m^{1/1+\gamma}$ as $L \to \infty$ at fixed m
 - $M \sim L^{-1}$ as $m \to 0$
 - Other terms are finite size corrections
 - $c_{\text{exp}}(c_{\pi}x)^{-1/2}e^{-c_{\pi}x}$: leading exponential correction from wrap-around effect of the lightest Goldstone pion state ($c_{\pi} = c_1$ for pions and fitted value becomes c_{π} of other channels)
 - $c_{\alpha}x^{\alpha}$: simplest ansatz, could be polynomials
 - Continuity and first derivative continuity imposed at x_{cut}
 - 5 fit parameters: γ , c_1 , $c_{\rm exp}$, α , $x_{\rm cu}$

Conformal Finite Size Scaling of Twelve Fermion Flavors Chik Him Wong

Outline

васкдго

Controversy

Simulation Set

Spectroscop

Fitting under

hypothesis with FSS

Fitting scaling function with physical model Fitting general scaling

Fitting general scalin function using B-forr spline functions

Conclusion

Fitting under conformal hypothesis with Finite Size Scaling study

Approach 1: Fitting scaling function with physical model

$$LM = c_1 x + c_{\exp}(c_{\pi} x)^{-1/2} e^{-c_{\pi} x}, \qquad x > x_{\text{cut}}$$

$$LM = c_0 + c_{\alpha} x^{\alpha}, \qquad x < x_{\text{cut}}$$

where $x \equiv Lm^{1/1+\gamma}$ and $M = M_{\pi}, M_{\rho}, M_N$ or F_{π}

- Conformal behavior:
 - $M \sim m^{1/1+\gamma}$ as $L \to \infty$ at fixed m
 - $M \sim L^{-1}$ as $m \to 0$
 - Other terms are finite size corrections
 - $c_{\text{exp}}(c_{\pi}x)^{-1/2}e^{-c_{\pi}x}$: leading exponential correction from wrap-around effect of the lightest Goldstone pion state ($c_{\pi} = c_1$ for pions and fitted value becomes c_{π} of other channels)
 - $c_{\alpha}x^{\alpha}$: simplest ansatz, could be polynomials
 - Continuity and first derivative continuity imposed at x_{cut}
 - 5 fit parameters: γ , c_1 , $c_{\rm exp}$, α , $x_{\rm cu}$

Chik Him Wong

Dookaro

Conformality

Simulation Set

Spectrosco

Fitting under

hypothesis with FSS Fitting scaling function

with physical model Fitting general scalin

Fitting general scalin function using B-forr spline functions

Conclusion

Fitting under conformal hypothesis with Finite Size Scaling study

$$LM = c_1 x + c_{\text{exp}} (c_{\pi} x)^{-1/2} e^{-c_{\pi} x}, \qquad x > x_{\text{cut}}$$

$$LM = c_0 + c_{\alpha} x^{\alpha}, \qquad x < x_{\text{cut}}$$

where
$$x \equiv Lm^{1/1+\gamma}$$
 and $M = M_{\pi}, M_{\rho}, M_N$ or F_{π}

- Conformal behavior:
 - $M \sim m^{1/1+\gamma}$ as $L \to \infty$ at fixed m
 - $M \sim L^{-1}$ as $m \to 0$
 - Other terms are finite size corrections
 - $c_{\rm exp}(c_{\pi}x)^{-1/2}e^{-c_{\pi}x}$: leading exponential correction from wrap-around effect of the lightest Goldstone pion state $(c_{\pi}=c_1)$ for pions and fitted value becomes c_{π} of other channels)
 - $c_{\alpha}x^{\alpha}$: simplest ansatz, could be polynomials
 - Continuity and first derivative continuity imposed at x_{cut}
 - 5 fit parameters: γ , c_1 , $c_{\rm exp}$, α , $x_{\rm cu}$

Chik Him Wong

CHIK THIII WOI

D 1

Conformality

Simulation Se

Spectrosco Analysis

Fitting under

hypothesis with
FSS
Fitting scaling function

with physical model Fitting general scalin

function using B-form spline functions

Conclusion

Fitting under conformal hypothesis with Finite Size Scaling study

$$LM = c_1 x + c_{\text{exp}} (c_{\pi} x)^{-1/2} e^{-c_{\pi} x}, \qquad x > x_{\text{cut}}$$

$$LM = c_0 + c_{\alpha} x^{\alpha}, \qquad x < x_{\text{cut}}$$

where
$$x \equiv Lm^{1/1+\gamma}$$
 and $M = M_{\pi}, M_{\rho}, M_N$ or F_{π}

- Conformal behavior:
 - $M \sim m^{1/1+\gamma}$ as $L \to \infty$ at fixed m
 - $M \sim L^{-1}$ as $m \to 0$
 - Other terms are finite size corrections
 - $c_{\rm exp}(c_{\pi}x)^{-1/2}e^{-c_{\pi}x}$: leading exponential correction from wrap-around effect of the lightest Goldstone pion state $(c_{\pi} = c_1)$ for pions and fitted value becomes c_{π} of other channels)
 - $c_{\alpha}x^{\alpha}$: simplest ansatz, could be polynomials
 - Continuity and first derivative continuity imposed at x_{cut}
 - 5 fit parameters: γ , c_1 , $c_{\rm exp}$, α , $x_{\rm cu}$

Chik Him Wong

CHIK THIII WOI

D. 1

Conformali

Controversy Simulation Se

Spectroscop

Fitting unde

conformal hypothesis with FSS

Fitting scaling function with physical model Fitting general scaling

function using B-form spline functions

Conclusion

Fitting under conformal hypothesis with Finite Size Scaling study

Approach 1: Fitting scaling function with physical model

$$LM = c_1 x + c_{\exp}(c_{\pi} x)^{-1/2} e^{-c_{\pi} x}, \qquad x > x_{\text{cut}}$$

$$LM = c_0 + c_{\alpha} x^{\alpha}, \qquad x < x_{\text{cut}}$$

where $x \equiv Lm^{1/1+\gamma}$ and $M = M_{\pi}, M_{\rho}, M_N$ or F_{π}

- Conformal behavior:
 - $M \sim m^{1/1+\gamma}$ as $L \to \infty$ at fixed m
 - $M \sim L^{-1}$ as $m \to 0$
 - Other terms are finite size corrections
 - $c_{\rm exp}(c_{\pi}x)^{-1/2}e^{-c_{\pi}x}$: leading exponential correction from wrap-around effect of the lightest Goldstone pion state $(c_{\pi} = c_1)$ for pions and fitted value becomes c_{π} of other channels)
 - $c_{\alpha}x^{\alpha}$: simplest ansatz, could be polynomials
 - Continuity and first derivative continuity imposed at x_{cut}
 - 5 fit parameters: γ , c_1 , c_{exp} , α , x_{cut}

Chik Him Wong

Fitting scaling function with physical model

Fitting under conformal hypothesis with Finite Size Scaling study

Approach 1: Fitting scaling function with physical model

$$LM = c_1 x + c_{\exp}(c_{\pi} x)^{-1/2} e^{-c_{\pi} x}, \qquad x > x_{\text{cut}}$$

$$LM = c_0 + c_{\alpha} x^{\alpha}, \qquad x < x_{\text{cut}}$$

where $x \equiv Lm^{1/1+\gamma}$ and $M = M_{\pi}, M_{\Omega}, M_{N}$ or F_{π}

- Conformal behavior:
 - $M \sim m^{1/1+\gamma}$ as $L \to \infty$ at fixed m
 - $M \sim L^{-1}$ as $m \to 0$
 - Other terms are finite size corrections
 - $c_{\rm exp}(c_{\pi}x)^{-1/2}e^{-c_{\pi}x}$: leading exponential correction from wrap-around effect of the lightest Goldstone pion state ($c_{\pi} = c_1$ for pions and fitted value becomes c_{π} of other channels)
 - $c_{\alpha}x^{\alpha}$: simplest ansatz, could be polynomials
 - Continuity and first derivative continuity imposed at x_{cut}
 - 5 fit parameters: γ , c_1 , c_{exp} , α , x_{cut}

Chik Him Wong

Rackgrou

Garagrou

Conformali

Simulation Set

Spectroscoj Analysis

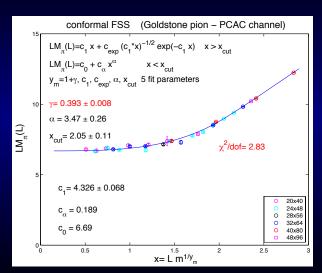
Fitting under conformal hypothesis with

Fitting scaling function with physical model

Fitting general scaling function using B-form

Fitting scaling function with physical model

Mπ



Outline

Backgrou

Conformali

Simulation Se

Spectroscop

Fitting under

hypothesis with FSS Fitting scaling function

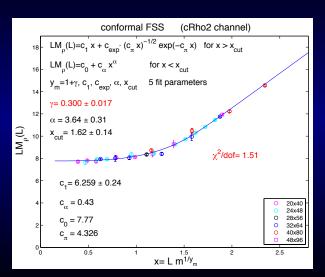
with physical model

Fitting general scaling function using B-form

Complemien

Fitting scaling function with physical model

M_O



Cliik Hilli Woll

Backgrou

Conformal

Controversy Simulation Sa

Spectroscor

Analysis
Fitting under

hypothesis with FSS

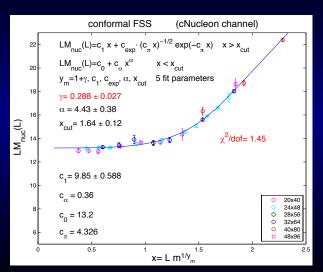
Fitting scaling function with physical model

Fitting general scaling function using B-form

Conclusion

Fitting scaling function with physical model

M_N



Chik Him Wong

Outline

васкдго

Conformal

m 12 m

Spectrosco

Analysis

Fitting under conformal hypothesis wit

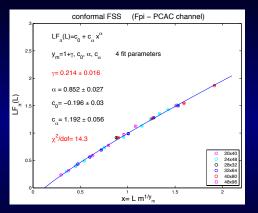
Fitting scaling function with physical model

Fitting general scalin function using B-form

Conclusion

Fitting scaling function with physical model

 \bullet F_{π}



- Only 4 parameters are kept because 5 parameter fit is not stable
- The unexpectedly curious behavior of the data set against conformal FSS remains unresolved.
- Question: What to be expected if conformal, e.g. SU(2) Adjoint?

Conformal Finite Size Scaling of Twelve Fermion Flavors Chik Him Wong

Outline

Backgrou

Conformali

Simulation Set

Spectrosco

Fitting under conformal

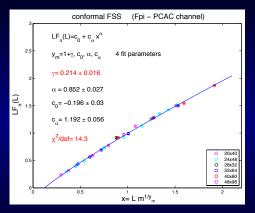
Fitting scaling function with physical model

Fitting general scaling function using B-form

Conclusion

Fitting scaling function with physical model

 \bullet F_{π}

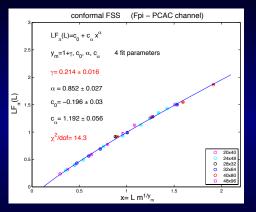


- Only 4 parameters are kept because 5 parameter fit is not stable
- The unexpectedly curious behavior of the data set against conformal FSS remains unresolved.
- Question: What to be expected if conformal, e.g. SU(2) Adjoint?

Chik Him Wong

Fitting scaling function with physical model

Fitting scaling function with physical model



- Only 4 parameters are kept because 5 parameter fit is not stable
- The unexpectedly curious behavior of the data set against conformal FSS remains unresolved.
- Question: What to be expected if conformal, e.g. SU(2) Adjoint?

Chik Him Wong

Chik Him Wol

Rackgrou

Dackgrou

Controversy

Simulation Set

Spectrosco

Fitting under conformal

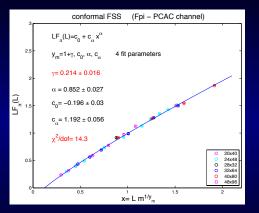
Fitting scaling function with physical model

Fitting general scalir function using B-for

Conclusion

Fitting scaling function with physical model

 \bullet F_{π}



- Only 4 parameters are kept because 5 parameter fit is not stable
- The unexpectedly curious behavior of the data set against conformal FSS remains unresolved.
- Question: What to be expected if conformal, e.g. SU(2) Adjoint?

Outlin

Backgroui

Conformali

Simulation Sat

Spectrosco Analysis

Fitting under conformal hypothesis with

Fitting scaling function with physical model

Fitting general scaling function using B-form

Conclusio

Fitting scaling function with physical model

Quantity	γ	χ^2/dof
$\overline{_{\pi}}$	0.393(8)	2.83
$M_{ ho}$	0.300(17)	1.51
M_N	0.288(27)	1.45
F_{π}	0.214(16)	14.3

- The composite particle masses in several quantum number channels can be reasonably fitted with conformal scaling functions
- BUT γ's are incompatible across different channels.
 ⇒ Global conformal FSS fit with identical γ will fa
- Conformal fit of F_{π} unexpectedly failed

Outlin

Backgroun

Conformal

Controversy

Spectroscop Analysis

Fitting under conformal

Fitting scaling function with physical model

Fitting general scaling function using B-form

Conclusion

Fitting scaling function with physical model

Quantity	γ	χ^2/dof
$\overline{_{\pi}}$	0.393(8)	2.83
$M_{ ho}$	0.300(17)	1.51
M_N	0.288(27)	1.45
F_{π}	0.214(16)	14.3

- The composite particle masses in several quantum number channels can be reasonably fitted with conformal scaling functions
- BUT γ's are incompatible across different channels.
 ⇒ Global conformal FSS fit with identical γ will fai
- Conformal fit of F_{π} unexpectedly failed

Outlin

Backgrou

Conformali

Simulation Se

C----

Analysis

Fitting under conformal hypothesis with

Fitting scaling function with physical model

Fitting general scaling function using B-form

Conclusion

Fitting scaling function with physical model

Quantity	γ	χ^2/dof
$\overline{_{\pi}}$	0.393(8)	2.83
$M_{ ho}$	0.300(17)	1.51
M_N	0.288(27)	1.45
F_{π}	0.214(16)	14.3

- The composite particle masses in several quantum number channels can be reasonably fitted with conformal scaling functions
- BUT γ's are incompatible across different channels.
 ⇒ Global conformal FSS fit with identical γ will fail
- Conformal fit of F_{π} unexpectedly failed

Outlin

Backgrou

Conformal

Simulation Se

Spectroscor

Analysis

Fitting under conformal hypothesis with

Fitting scaling function with physical model

Fitting general scaling function using B-forn

Conclusion

Fitting scaling function with physical model

Quantity	γ	χ^2/dof
$\overline{M_{\pi}}$	0.393(8)	2.83
$M_{ ho}$	0.300(17)	1.51
M_N	0.288(27)	1.45
${F}_{\pi}$	0.214(16)	14.3

- The composite particle masses in several quantum number channels can be reasonably fitted with conformal scaling functions
- BUT γ's are incompatible across different channels.
 ⇒ Global conformal FSS fit with identical γ will fail
- Conformal fit of F_{π} unexpectedly failed

Fitting scaling funwith physical mod

Fitting general scaling function using B-form spline functions

Conclusion

Fitting under conformal hypothesis with Finite Size Scaling study

- Approach 2: Fitting general scaling function using B-form spline functions
- Vary γ and perform Spline Fits at fixed γ 's:
 - Piecewise Polynomial fitting
 - Non-uniform B-form used
 - 3 knots used
 - 6 cubic spline functions
- Obtain γ_{\min} that minimizes $\chi^2(\gamma)/\text{dof}$
- The range of γ that reduce/increase χ^2/dof by 1 is regarded as the error estimate of γ_{\min}

Chik Him Wong

Outlin

Backgrou

Conformali

Simulation Set

Spectrosco

Fitting under

conformal hypothesis with FSS

with physical model
Fitting general scaling

Fitting general scaling function using B-form spline functions

Conclusion

- Approach 2: Fitting general scaling function using B-form spline functions
- Vary γ and perform Spline Fits at fixed γ 's:
 - Piecewise Polynomial fitting
 - Non-uniform B-form used
 - 3 knots used
 - 6 cubic spline functions
- Obtain γ_{\min} that minimizes $\chi^2(\gamma)/\text{dof}$
- The range of γ that reduce/increase χ^2/dof by 1 is regarded as the error estimate of γ_{\min}

Chik Him Wong

Outlin

Backgrou

Conformal

Cimulation Cat

Simulation Sc

Analysis

Fitting under conformal hypothesis wit

hypothesis with

with physical model Fitting general scaling

Fitting general scaling function using B-form spline functions

Conclusion

- Approach 2: Fitting general scaling function using B-form spline functions
- Vary γ and perform Spline Fits at fixed γ 's:
 - Piecewise Polynomial fitting
 - Non-uniform B-form used
 - 3 knots used
 - 6 cubic spline functions
- Obtain γ_{\min} that minimizes $\chi^2(\gamma)/\text{dof}$
- The range of γ that reduce/increase χ^2/dof by 1 is regarded as the error estimate of γ_{\min}

Chik Him Wong

Outlin

Backgrou

Conformali

Simulation Sets

Simulation Sc

Analysis

Fitting under

hypothesis with

with physical mode

Fitting general scaling function using B-form spline functions

Conclusion

- Approach 2: Fitting general scaling function using B-form spline functions
- Vary γ and perform Spline Fits at fixed γ 's:
 - Piecewise Polynomial fitting
 - Non-uniform B-form used
 - 3 knots used
 - 6 cubic spline functions
- Obtain γ_{\min} that minimizes $\chi^2(\gamma)/\text{dof}$
- The range of γ that reduce/increase χ^2/dof by 1 is regarded as the error estimate of γ_{\min}

Chik Him Wong

Outlin

Backgroun

Conformali

Simulation Sets

Simulation Se

Spectrosco

Fitting under

conformal hypothesis with FSS

FSS Fitting scaling fur

Fitting general scaling function using B-form spline functions

Conclusion

- Approach 2: Fitting general scaling function using B-form spline functions
- Vary γ and perform Spline Fits at fixed γ 's:
 - Piecewise Polynomial fitting
 - Non-uniform B-form used
 - 3 knots used
 - 6 cubic spline functions
- Obtain γ_{\min} that minimizes $\chi^2(\gamma)/\text{dof}$
- The range of γ that reduce/increase χ^2/dof by 1 is regarded as the error estimate of γ_{\min}

Chik Him Wong

Outline

Backgrou

Conformal

Simulation Set

Spectrosco

Fitting under

conformal hypothesis with FSS

Fitting scaling func with physical mode

Fitting general scaling function using B-form spline functions

Conclusion

- Approach 2: Fitting general scaling function using B-form spline functions
- Vary γ and perform Spline Fits at fixed γ 's:
 - Piecewise Polynomial fitting
 - Non-uniform B-form used
 - 3 knots used
 - 6 cubic spline functions
- Obtain γ_{\min} that minimizes $\chi^2(\gamma)/\text{dof}$
- The range of γ that reduce/increase χ^2/dof by 1 is regarded as the error estimate of γ_{\min}

Chik Him Wong

Outlin

Backgrou

Conformal

Simulation Set

C---t----

Anaiysis

conformal

FSS

Eitting cooling fun

with physical model Fitting general scaling function using B-form

spline functions

- Approach 2: Fitting general scaling function using B-form spline functions
- Vary γ and perform Spline Fits at fixed γ 's:
 - Piecewise Polynomial fitting
 - Non-uniform B-form used
 - 3 knots used
 - 6 cubic spline functions
- Obtain γ_{\min} that minimizes $\chi^2(\gamma)/\text{dof}$
- The range of γ that reduce/increase χ^2/dof by 1 is regarded as the error estimate of γ_{\min}

Chik Him Wong

Outline

Backgrou

Conformal

Simulation Set

C---t----

Analysis

Fitting under

conformal hypothesis with FSS

FSS Fitting scaling fund

Fitting general scaling function using B-form spline functions

Conclusion

- Approach 2: Fitting general scaling function using B-form spline functions
- Vary γ and perform Spline Fits at fixed γ 's:
 - Piecewise Polynomial fitting
 - Non-uniform B-form used
 - 3 knots used
 - 6 cubic spline functions
- Obtain γ_{\min} that minimizes $\chi^2(\gamma)/\text{dof}$
- The range of γ that reduce/increase χ^2 /dof by 1 is regarded as the error estimate of γ_{min}

Chik Him Wong

Outillic

Backgrou

Controversy Simulation Set

Spectrosco

Fitting under conformal

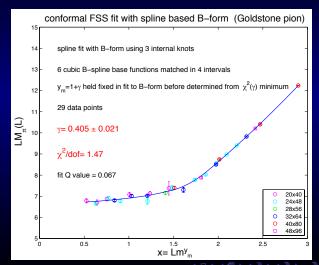
Fitting scaling functi

Fitting general scaling function using B-form spline functions

Conclusion

Fitting general scaling function using B-form spline functions

Mπ



Chik Him Wong

Backgro

Backgrou Conforma

Controversy Simulation Se

Spectrosco

Fitting under

conformal hypothesis wit FSS

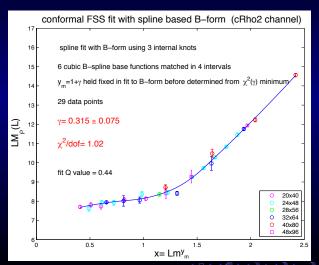
Fitting scaling funct with physical mode

Fitting general scaling function using B-form spline functions

Conclusion

Fitting general scaling function using B-form spline functions

*M*_ρ



Conformal Finite Size Scaling of Twelve Fermion Flavors Chik Him Wong

Backgro

Conformal

Simulation Set

Spectrosco

Fitting under conformal hypothesis wit

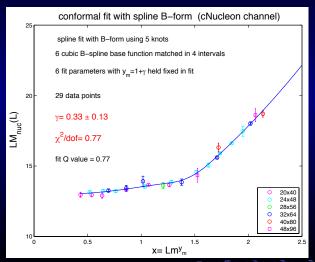
Fitting scaling function

Fitting general scaling function using B-form spline functions

Conclusion

Fitting general scaling function using B-form spline functions

M_N



Conformal Finite Size Scaling of Twelve Fermion Flavors Chik Him Wong

_ ...

Backgro

Conformal

Controversy Simulation Set

Spectroscop

Fitting under conformal

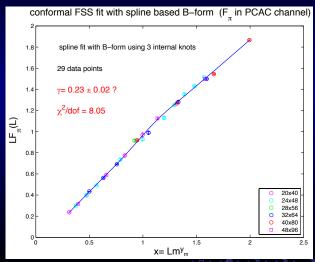
Fitting scaling funct with physical model

Fitting general scaling function using B-form spline functions

Conclusion

Fitting general scaling function using B-form spline functions

Fπ



Chik Him Wong

Outlin

Backgrou

Conformali

Cimulation Cat

omination oc

Analysis

Fitting under

conformal hypothesis wit FSS

Fitting scaling funct with physical model

Fitting general scaling function using B-form spline functions

Conclusion

Fitting general scaling function using B-form spline functions

Quantity	γ	χ^2/dof
$\overline{_{\pi}}$	0.405(21)	1.47
$M_{ ho}$	0.315(75)	1.02
$\dot{M_N}$	0.33(13)	0.77
${F}_{\pi}$	0.23(2)	8.05

- M_{π} improved as expected
- Tension of γ across channels decreased, but still problematic
- Fit to F_{π} remains unacceptable

Chik Him Wong

Outlin

Backgrou

Conformal

Simulation Set

Spectros Analysis

Fitting under conformal

conformal hypothesis with FSS

Fitting scaling functi with physical model

Fitting general scaling function using B-form spline functions

Conclusion

Fitting general scaling function using B-form spline functions

Quantity	γ	χ^2/dof
$\overline{}_{\pi}$	0.405(21)	1.47
$M_{ ho}$	0.315(75)	1.02
$\dot{M_N}$	0.33(13)	0.77
${F}_{\pi}$	0.23(2)	8.05

- M_{π} improved as expected
- Tension of γ across channels decreased, but still problematic
- Fit to F_{π} remains unacceptable

Chik Him Wong

Outline

Backgrou

Conformal

.

Analysis

Fitting under conformal hypothesis wit

Fitting scaling funct with physical model

Fitting general scaling function using B-form spline functions

Conclusion

Fitting general scaling function using B-form spline functions

Quantity	γ	χ^2/dof
M_{π}	0.405(21)	1.47
$M_{ ho}$	0.315(75)	1.02
$\dot{M_N}$	0.33(13)	0.77
${F}_{\pi}$	0.23(2)	8.05

- M_{π} improved as expected
- Tension of γ across channels decreased, but still problematic
- Fit to F_{π} remains unacceptable

Chik Him Wong

Fitting general scaling function using B-form spline functions

Fitting general scaling function using B-form spline functions

Quantity	γ	χ^2/dof
M_{π}	0.405(21)	1.47
$M_{ ho}$	0.315(75)	1.02
$\dot{M_N}$	0.33(13)	0.77
F_{π}	0.23(2)	8.05

- M_{π} improved as expected
- Tension of γ across channels decreased, but still problematic
- Fit to F_{π} remains unacceptable

Chik Him Wong

Backgro

ваского

Controversy

Simulation Set

Spectroscopy

Fitting under

conformal hypothesis with FSS

with physical model
Fitting general scaling
function using B-form

Conclusion

- The extended study of the spectroscopy of $N_f = 12$ Fundamental shows problems in the conformal scenario, consistent with our previous findings
- Outstanding Problem:
 - Scaling violation effect may fake scaling with inconsistent gamma values, but unlikely to be the only effect — Leading scaling violation effects has to be analyzed
 - Can the strongly squeezed wave function effects in chirally broken scenario explain the good scaling form in separate quantum number channels?
- Bottom line:
 - Conformal scenario remains inconsistent and suspect in our analysis
 - The issues are not settled yet. More definitive analyses are needed and ongoing

Chik Him Wong

Backgrou

Conformal

Simulation Sets

Spectroscopy

Fitting under

conformal hypothesis with FSS

with physical model Fitting general scalin function using B-form spline functions

Conclusion

- The extended study of the spectroscopy of $N_f = 12$ Fundamental shows problems in the conformal scenario, consistent with our previous findings
- Outstanding Problem:
 - Scaling violation effect may fake scaling with inconsistent gamma values, but unlikely to be the only effect \Rightarrow Leading scaling violation effects has to be analyzed
 - Can the strongly squeezed wave function effects in chirally broken scenario explain the good scaling form in separate quantum number channels?
- Bottom line:
 - Conformal scenario remains inconsistent and suspect in our analysis
 - The issues are not settled yet. More definitive analyses are needed and ongoing

Chik Him Wong

Conclusion

- The extended study of the spectroscopy of $N_f = 12$ Fundamental shows problems in the conformal scenario, consistent with our previous findings
- **Outstanding Problem:**
 - Scaling violation effect may fake scaling with inconsistent gamma values, but unlikely to be the only effect ⇒ Leading scaling violation effects has to be analyzed
 - scenario explain the good scaling form in separate quantum number

Chik Him Wong

Backgro

Conformalit

Simulation Sets

Spectroscopy

Fitting under conformal

conformal hypothesis with FSS

with physical model Fitting general scalin function using B-form spline functions

Conclusion

- The extended study of the spectroscopy of $N_f = 12$ Fundamental shows problems in the conformal scenario, consistent with our previous findings
- Outstanding Problem:
 - Scaling violation effect may fake scaling with inconsistent gamma values, but unlikely to be the only effect ⇒ Leading scaling violation effects has to be analyzed
 - Can the strongly squeezed wave function effects in chirally broken scenario explain the good scaling form in separate quantum number channels?
- Bottom line:
 - Conformal scenario remains inconsistent and suspect in our analysis
 - The issues are not settled yet. More definitive analyses are needed and ongoing

Chik Him Wong

Conclusion

- The extended study of the spectroscopy of $N_f = 12$ Fundamental shows problems in the conformal scenario, consistent with our previous findings
- Outstanding Problem:
 - Scaling violation effect may fake scaling with inconsistent gamma values, but unlikely to be the only effect \Rightarrow Leading scaling violation effects has to be analyzed
 - Can the strongly squeezed wave function effects in chirally broken scenario explain the good scaling form in separate quantum number channels?
- Bottom line:
 - Conformal scenario remains inconsistent and suspect in our analysis
 - The issues are not settled yet. More definitive analyses are needed

Chik Him Wong

Background

Conformality Controversy

Simulation Sets

Analysis

conformal hypothesis with FSS

with physical model Fitting general scalin function using B-form spline functions

Conclusion

- The extended study of the spectroscopy of $N_f = 12$ Fundamental shows problems in the conformal scenario, consistent with our previous findings
- Outstanding Problem:
 - Scaling violation effect may fake scaling with inconsistent gamma values, but unlikely to be the only effect ⇒ Leading scaling violation effects has to be analyzed
 - Can the strongly squeezed wave function effects in chirally broken scenario explain the good scaling form in separate quantum number channels?
- Bottom line:
 - Conformal scenario remains inconsistent and suspect in our analysis
 - The issues are not settled yet. More definitive analyses are needed and ongoing

Chik Him Wong

Cilik IIIII Wol

Backgro

Васкдго

Controversy

Simulation Set

Analysis

conformal hypothesis with

with physical model Fitting general scalin function using B-for spline functions

Conclusion

- The extended study of the spectroscopy of $N_f = 12$ Fundamental shows problems in the conformal scenario, consistent with our previous findings
- Outstanding Problem:
 - Scaling violation effect may fake scaling with inconsistent gamma values, but unlikely to be the only effect ⇒ Leading scaling violation effects has to be analyzed
 - Can the strongly squeezed wave function effects in chirally broken scenario explain the good scaling form in separate quantum number channels?
- Bottom line:
 - Conformal scenario remains inconsistent and suspect in our analysis
 - The issues are not settled yet. More definitive analyses are needed and ongoing