Confining force and running coupling with twelve fundamental and two sextet fermions

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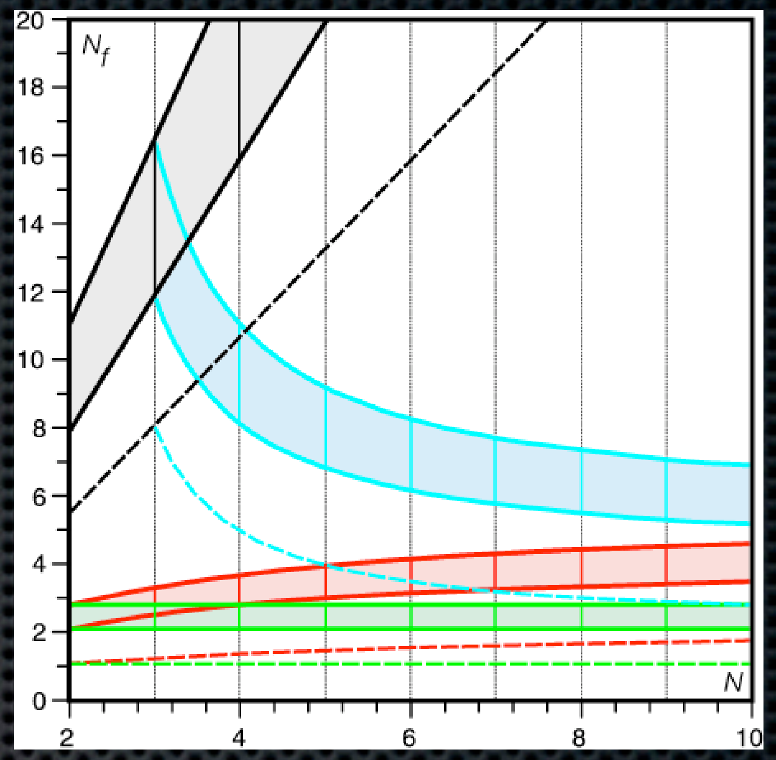
motivation



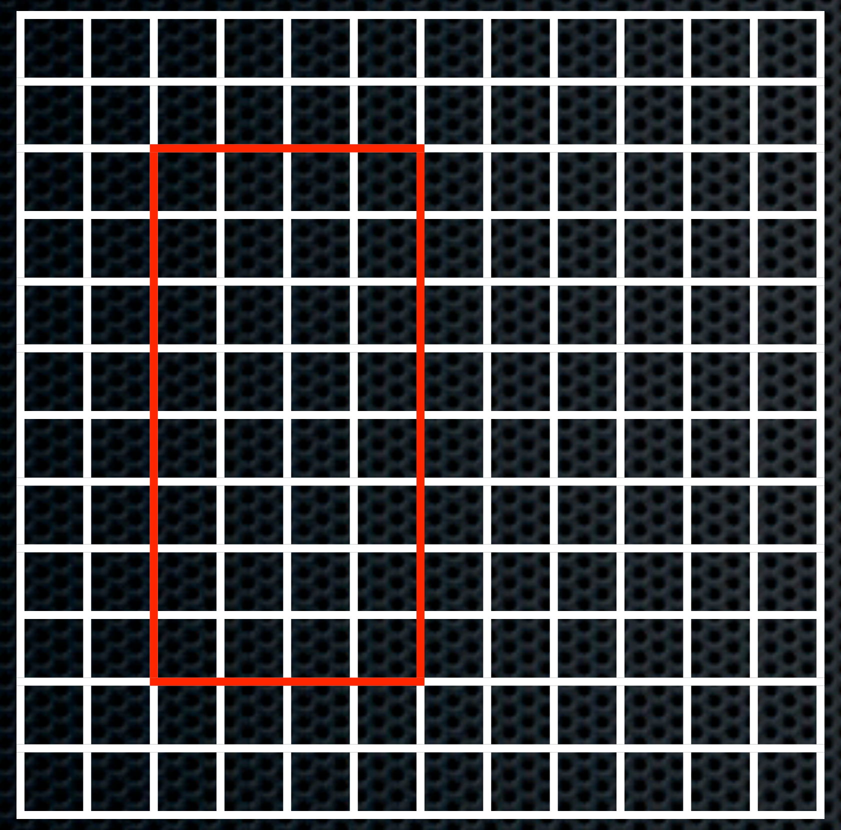
* Beyond SM: replace Higgs sector with new gauge theory - technicolor
* non-abelian gauge theories can be conformal, non-conformal or trivial
* our recent work: test conformal/non-conformal behavior via spectroscopy
* quark potential can be measured on same ensembles - economic
* potential connected to running coupling - QQ scheme

* 12-flavor fundamental rep: ongoing inconsistencies among studies
* 2-flavor sextet rep: maybe more realistic BSM candidate

simulation details

* tree-level Symanzik-improved gauge action, stout-smeared staggered fermion
* relatively long runs: 1-2 thousand trajectories
* quark potential measurements: $48^3 \times 96, 40^3 \times 80, 32^3 \times 64$
* lightest pion mass $1/(m_\pi a) \approx 6 - 7$

4dim HYP-smeared time links



3dim APE-smeared space links

improve quark potential signal:

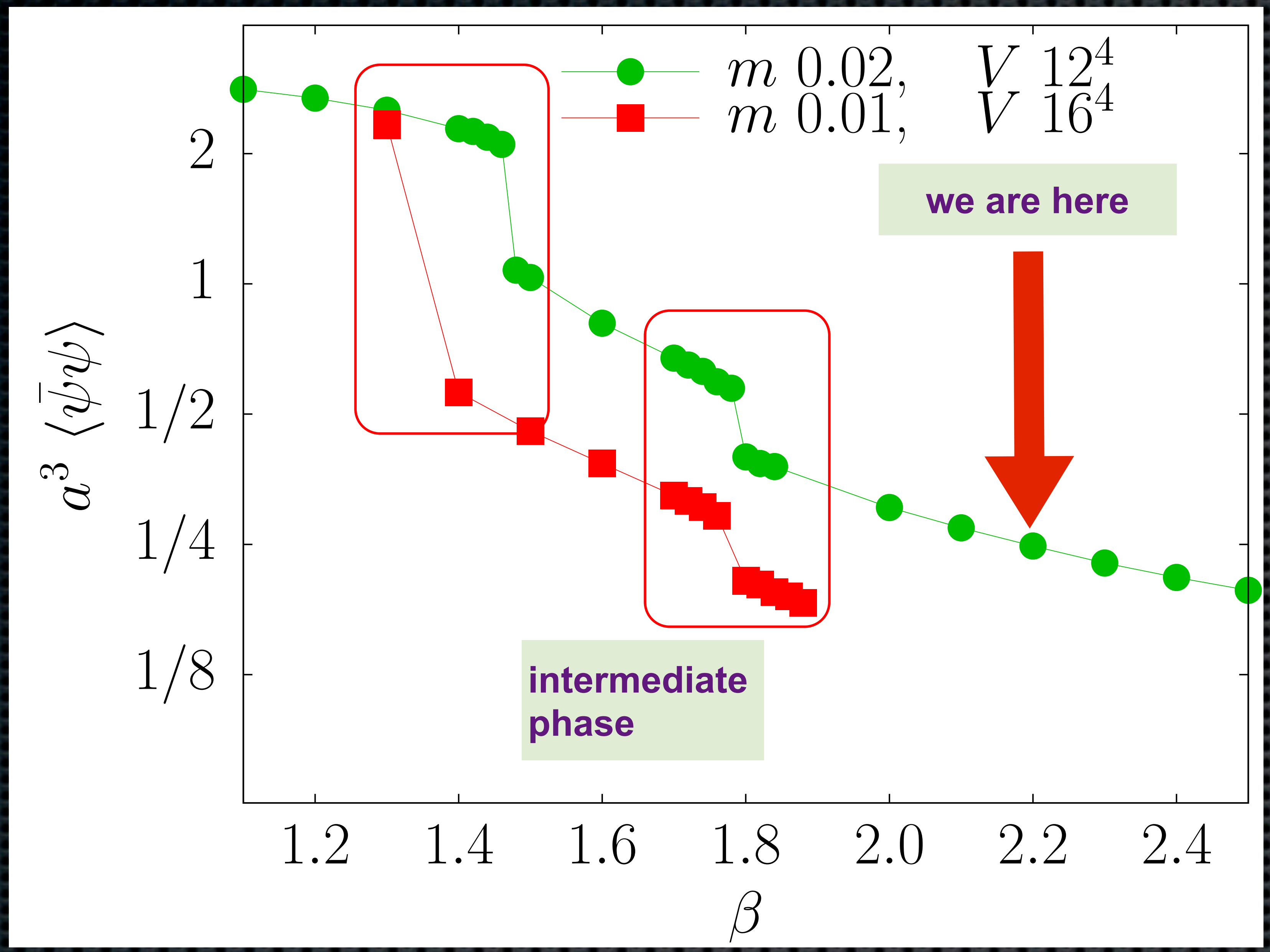
* HYP smear time-like links: reduce quark pair self-energy
* APE smear space-like links: build correlation matrix for Generalized Eigenvalue method

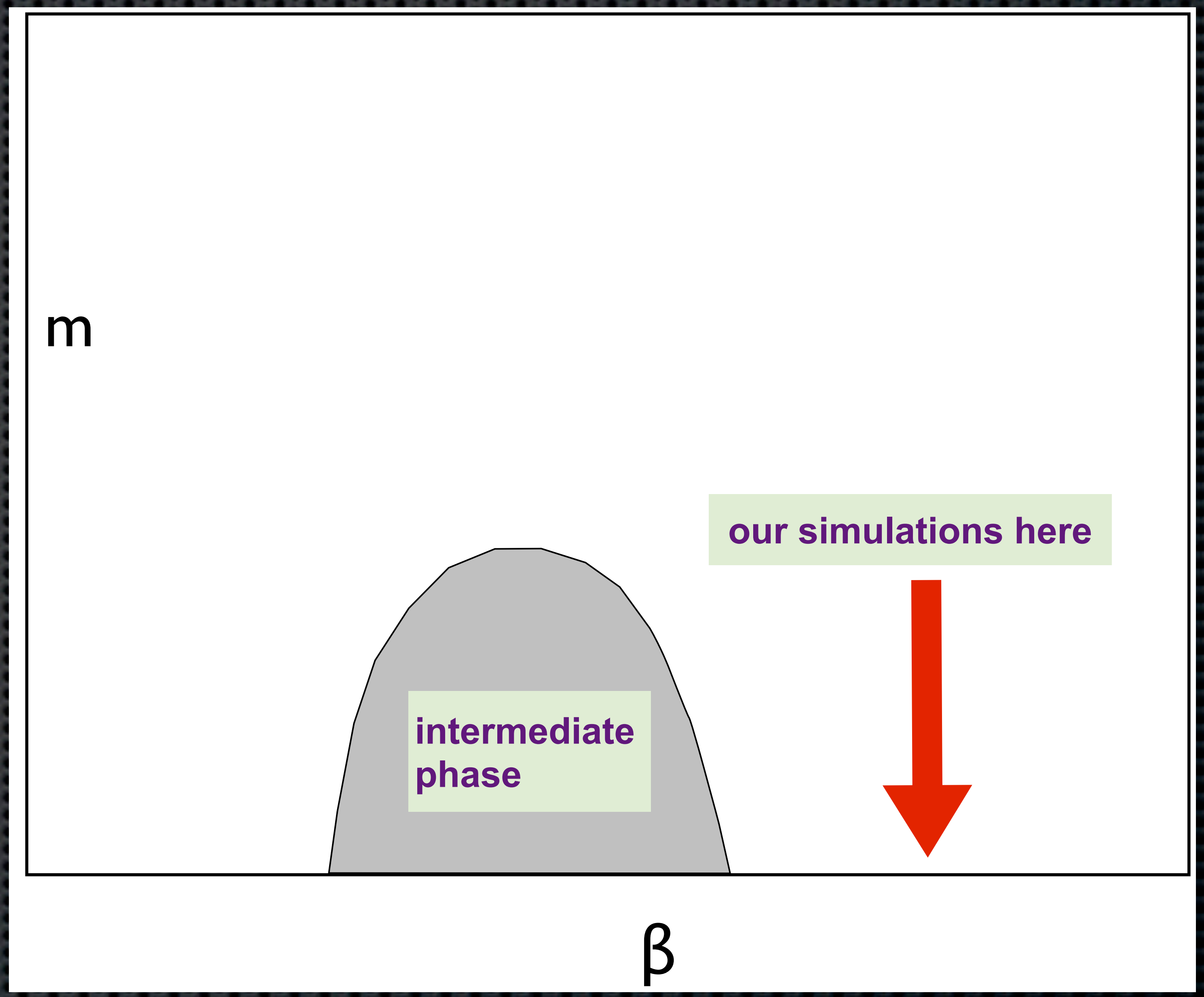
this talk: one diagonal of correlation matrix

use Double Jackknife to estimate Covariance Matrix for chi-squared fitting of effective “mass”

phase diagram

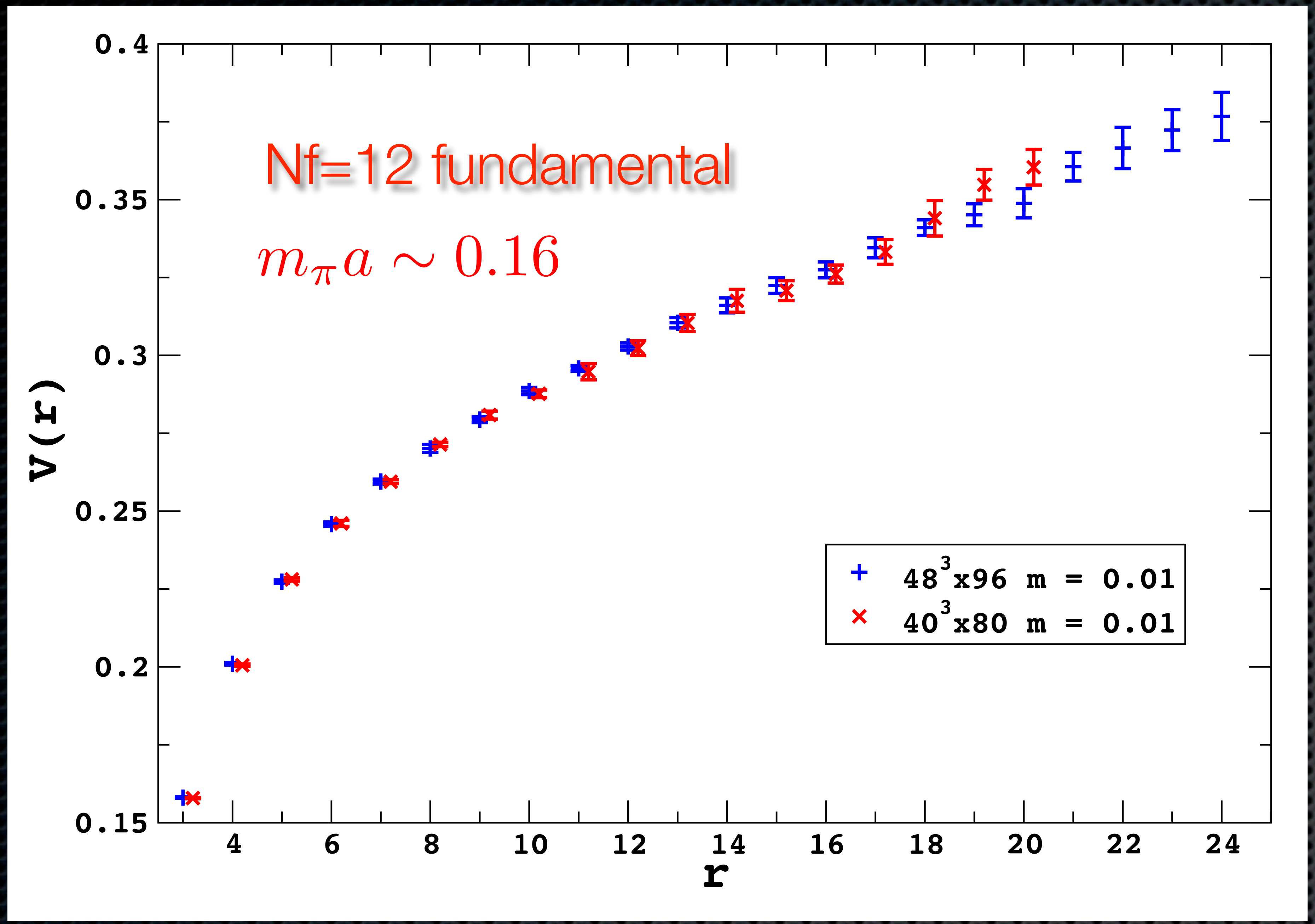
Nf=12 fundamental

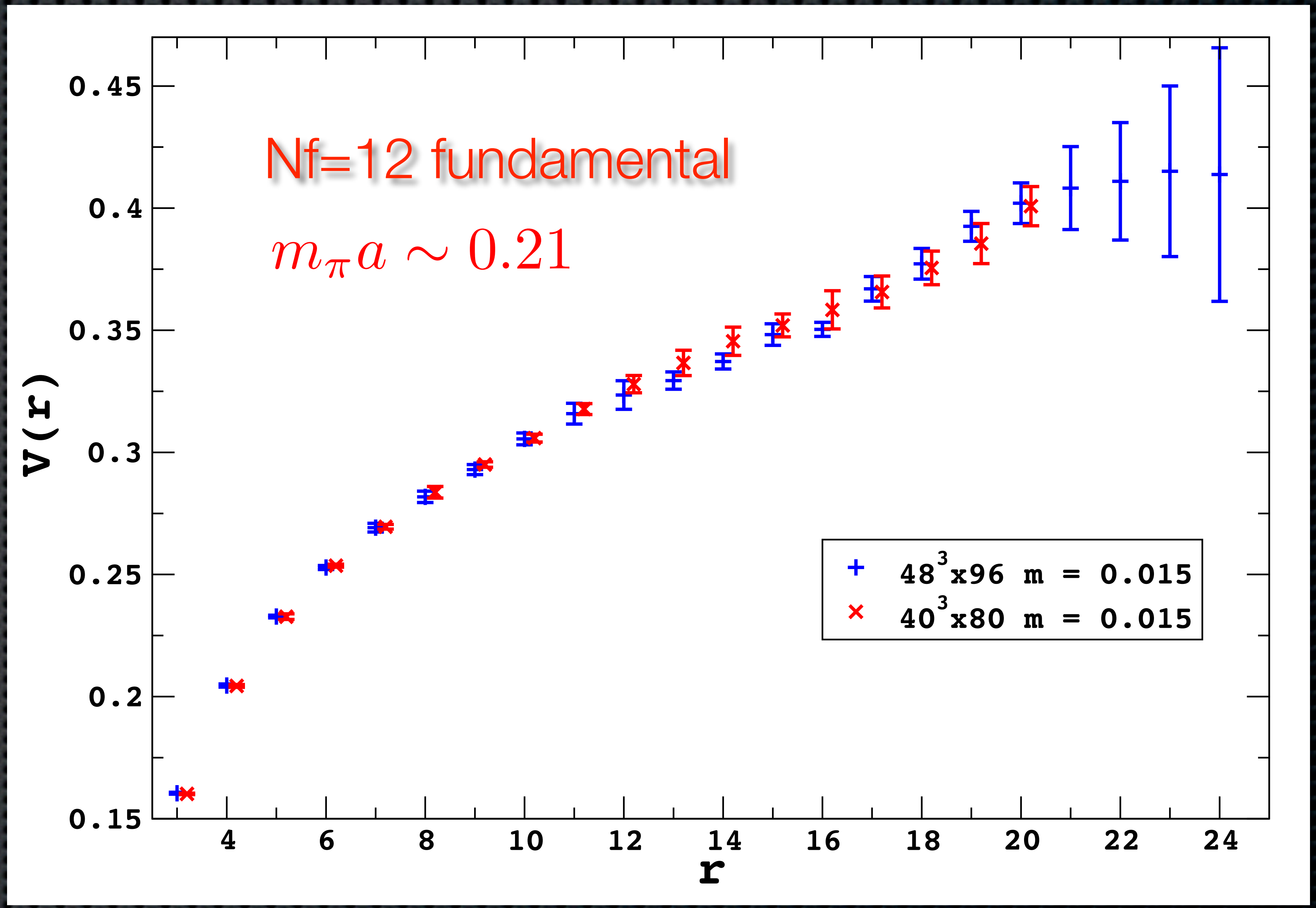




simulate at 1 bare coupling far away from bulk phase transitions, unusual phases

12-flavor fundamental

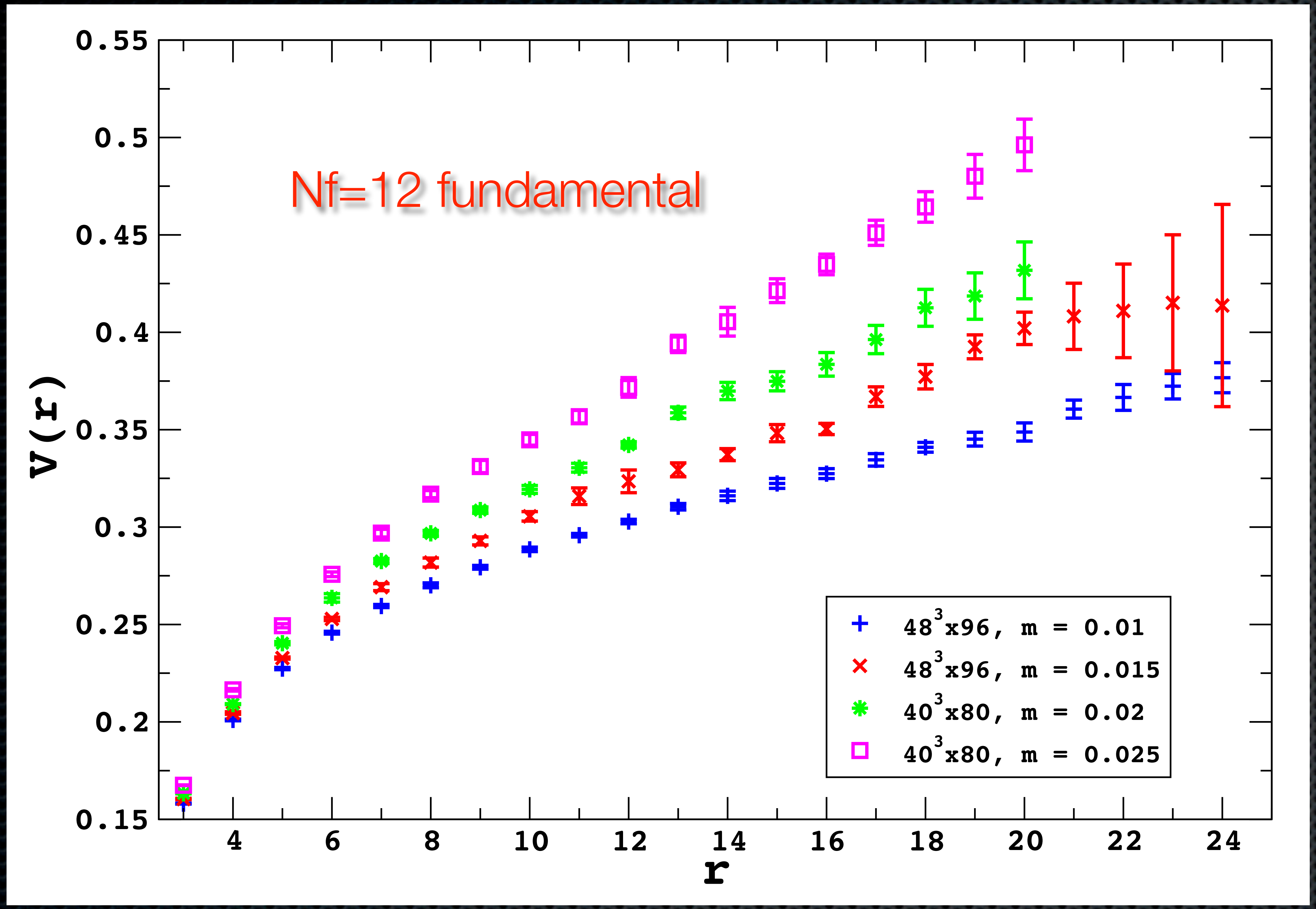




little volume dependence seen for 2 lightest pion masses m=0.01,0.015

for larger masses, sufficient to extract potential from volumes $40^3 \times 80$

mass dependence



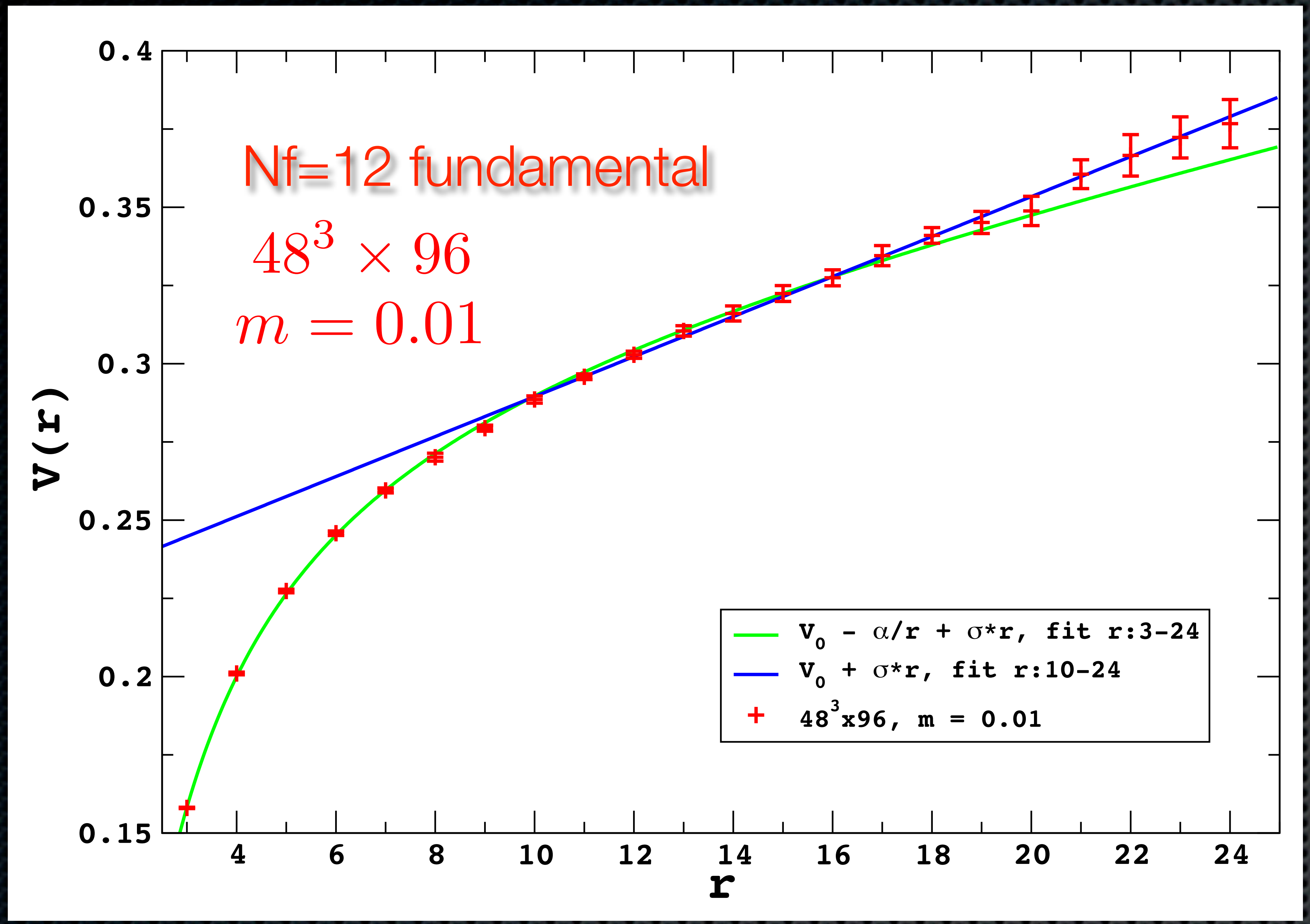
significant mass dependence in potential

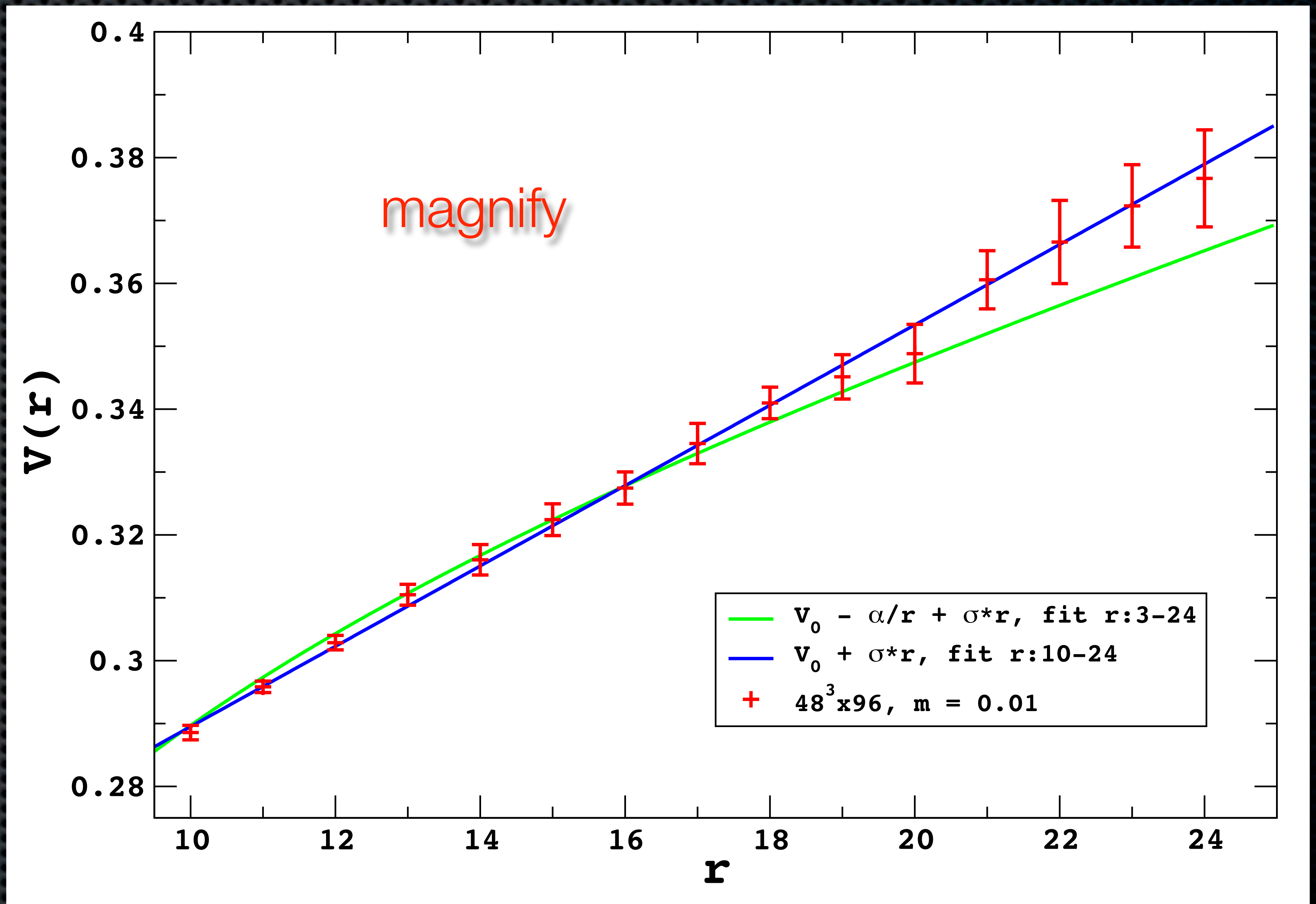
m=0.01,0.015,0.02,0.025 $m_\pi a \sim 0.16 - 0.30$

these 4 runs close to infinite volume

fit V(r) separately for each, then study chiral limit of fit parameters

fit potential



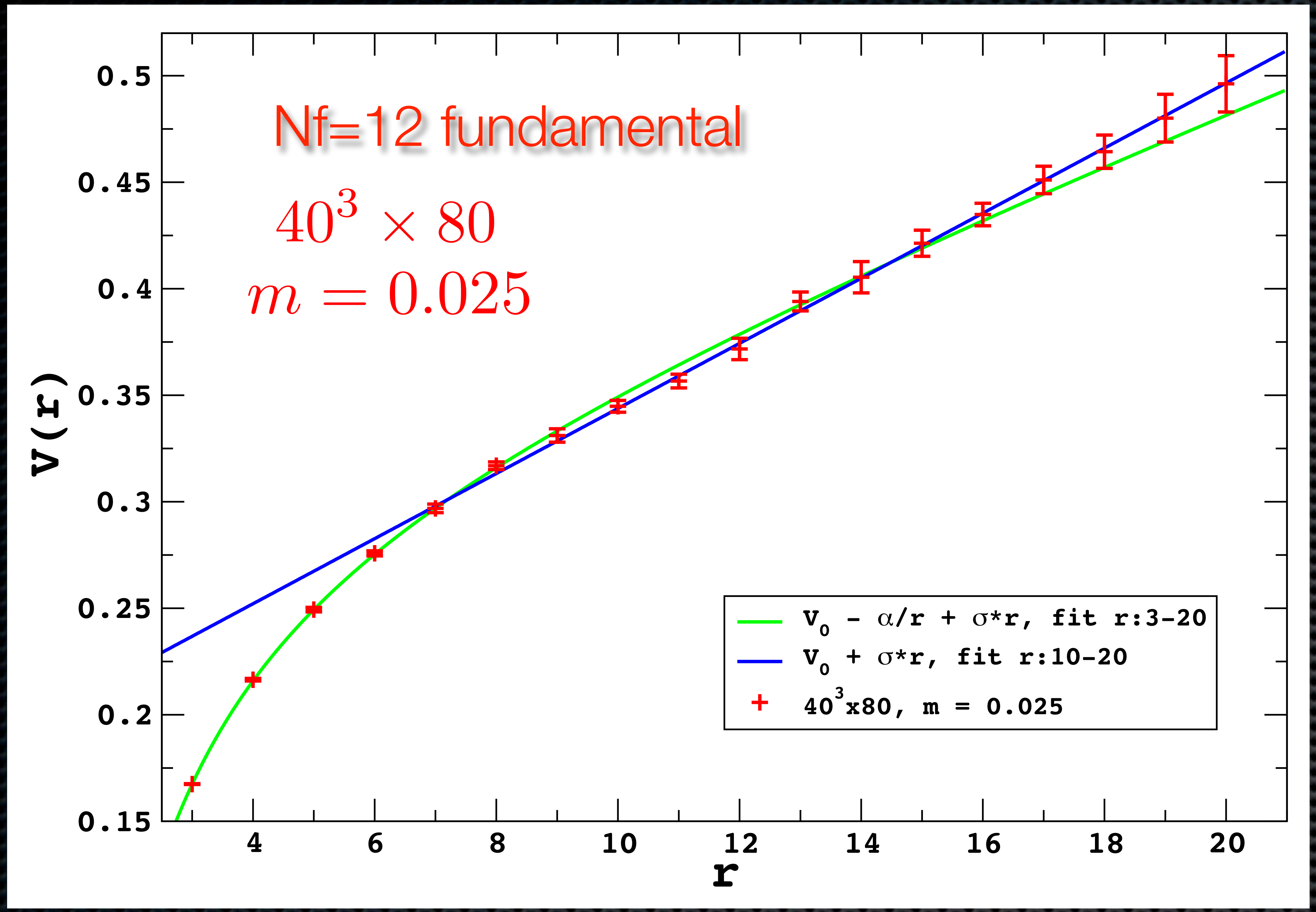


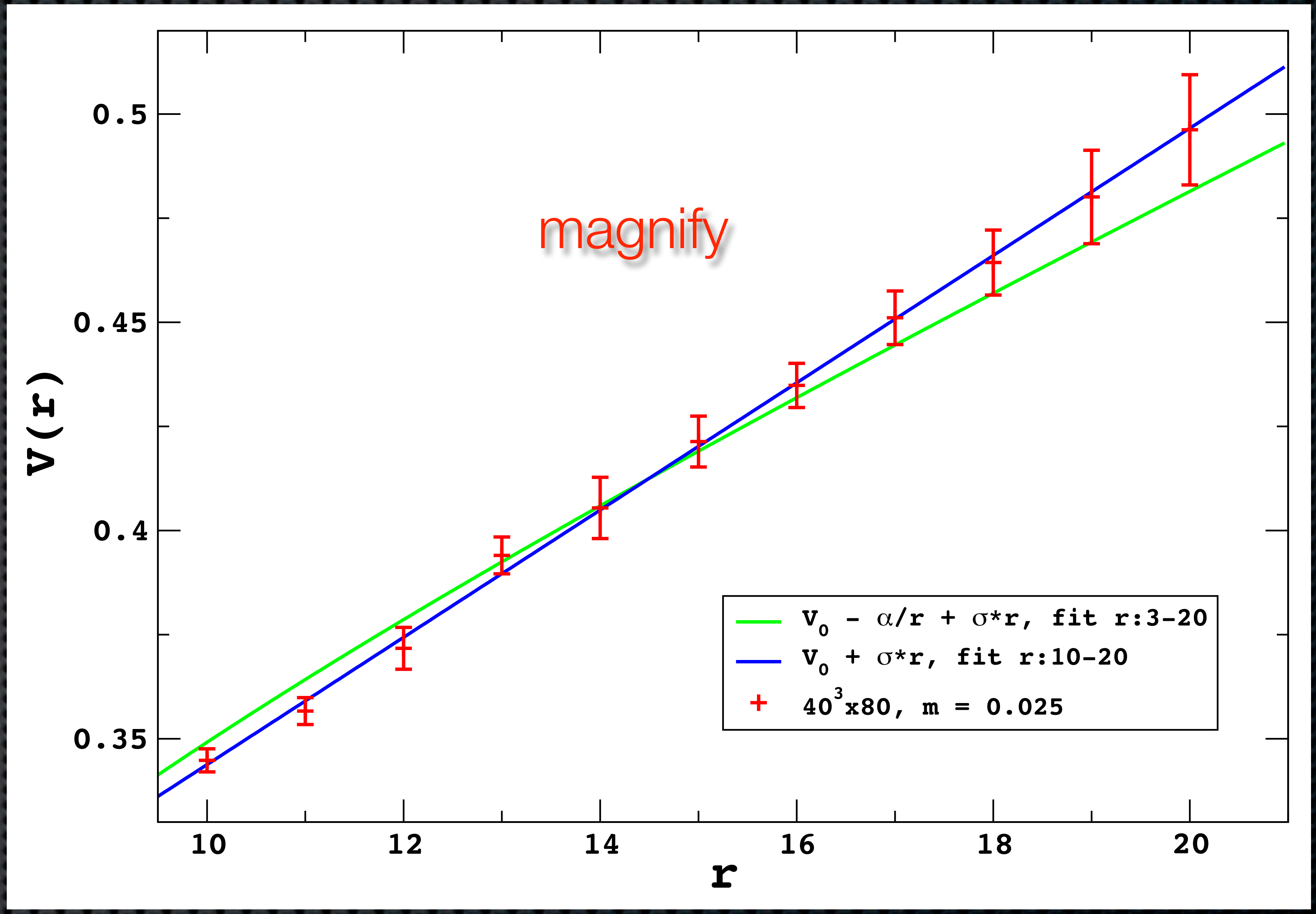
Two V(r) parametrizations

1. small and large r $\quad V(r) = V_0 - \dfrac{\alpha}{r} + \sigma r \quad \chi^2/N = 32.8/19$
2. larger r only $\quad V(r) = V_0 + \sigma r \quad \chi^2/N = 3.8/13$

data at larger r do not show much curvature - linear fit better?

fit potential





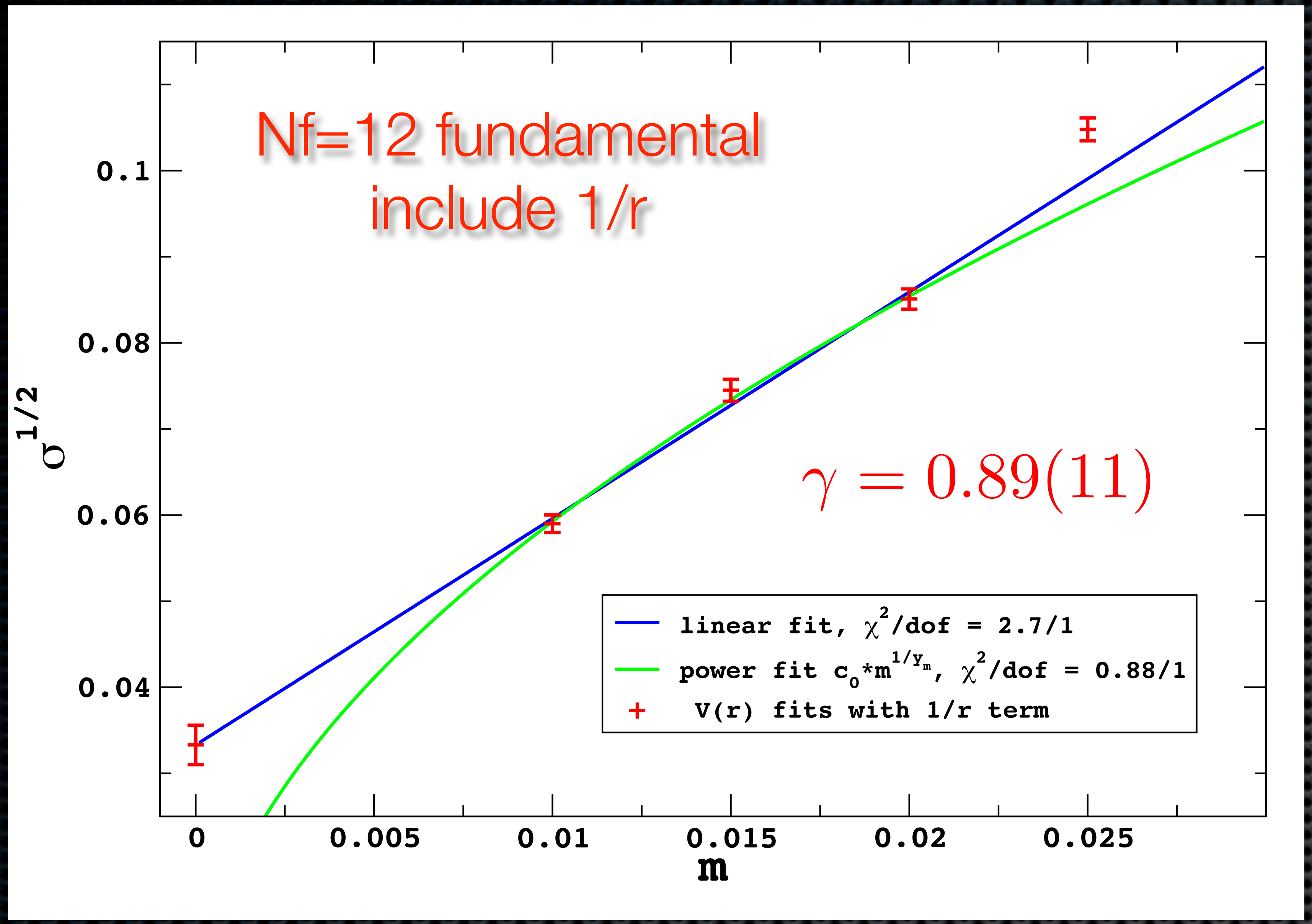
similar behavior at heavier mass - little curvature in data at larger r

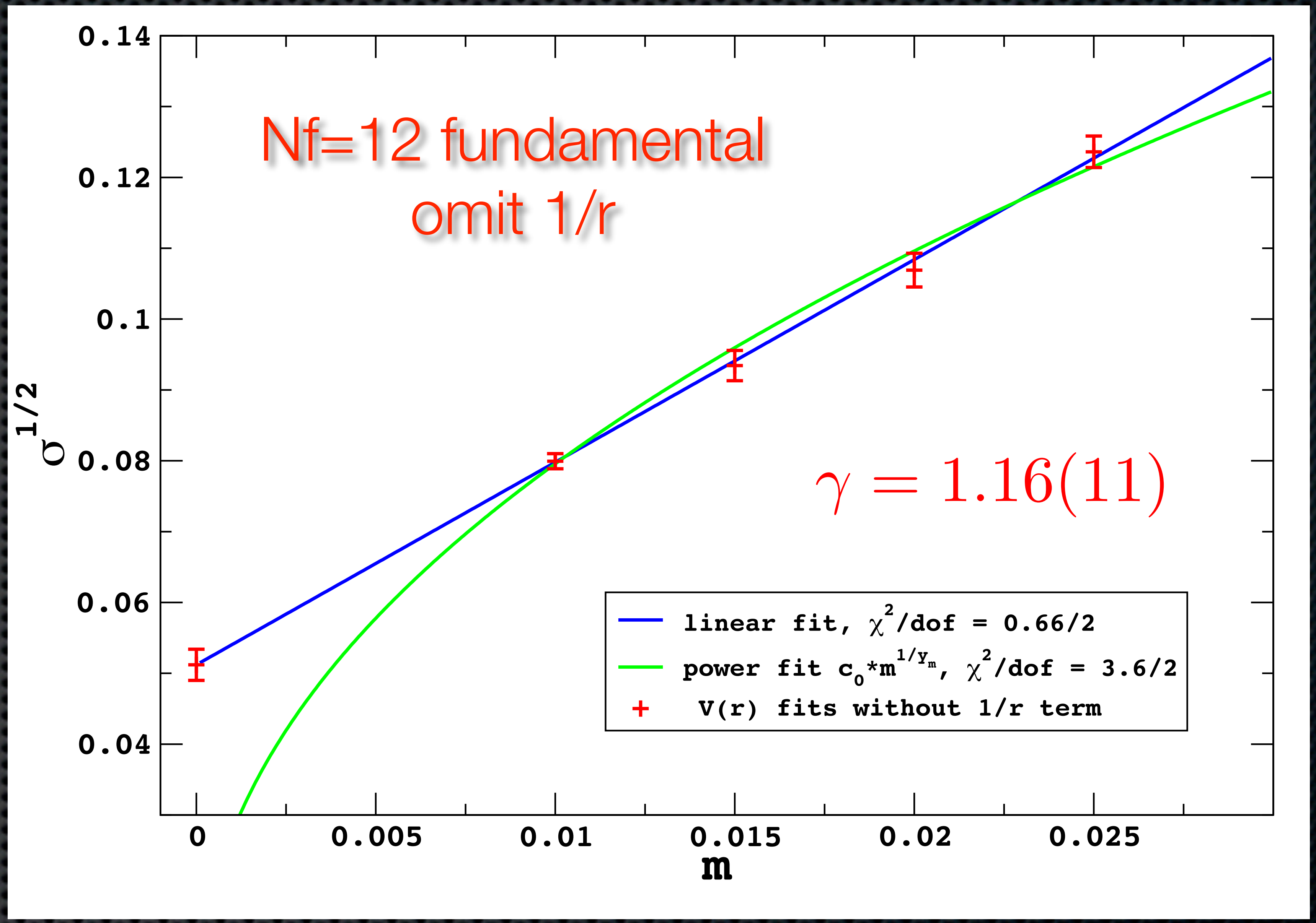
two parametrizations

$$V(r) = V_0 - \frac{\alpha}{r} + \sigma r \qquad \chi^2/N = 16.2/15$$

$$V(r) = V_0 + \sigma r \qquad \chi^2/N = 2.1/9$$

fit string tension





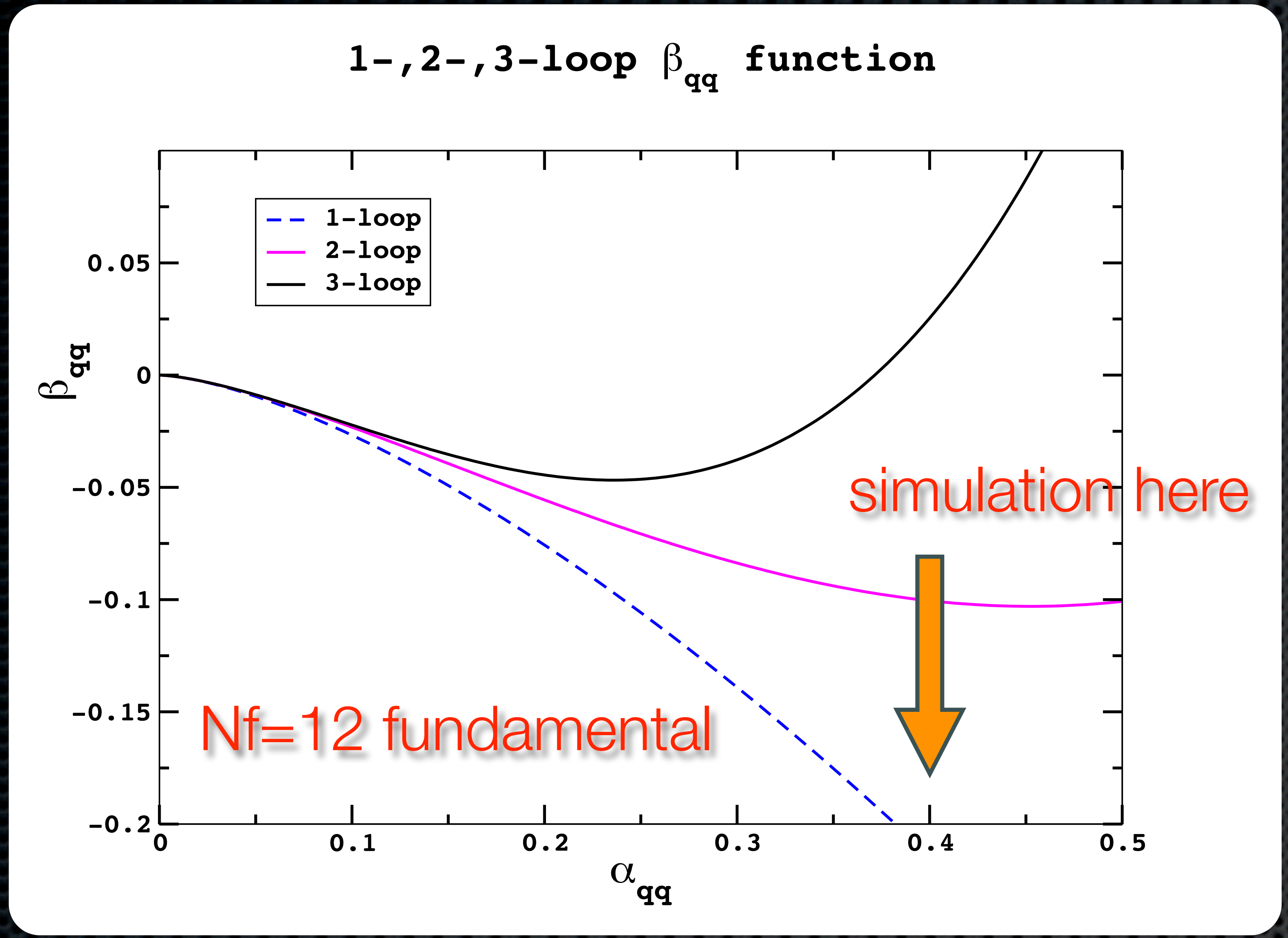
non-conformal $\sigma^{1/2} = \sigma_0^{1/2} + a_1 m$ conformal $\sigma^{1/2} = c_0 m^{1/y_m}, \quad y_m = 1 + \gamma$

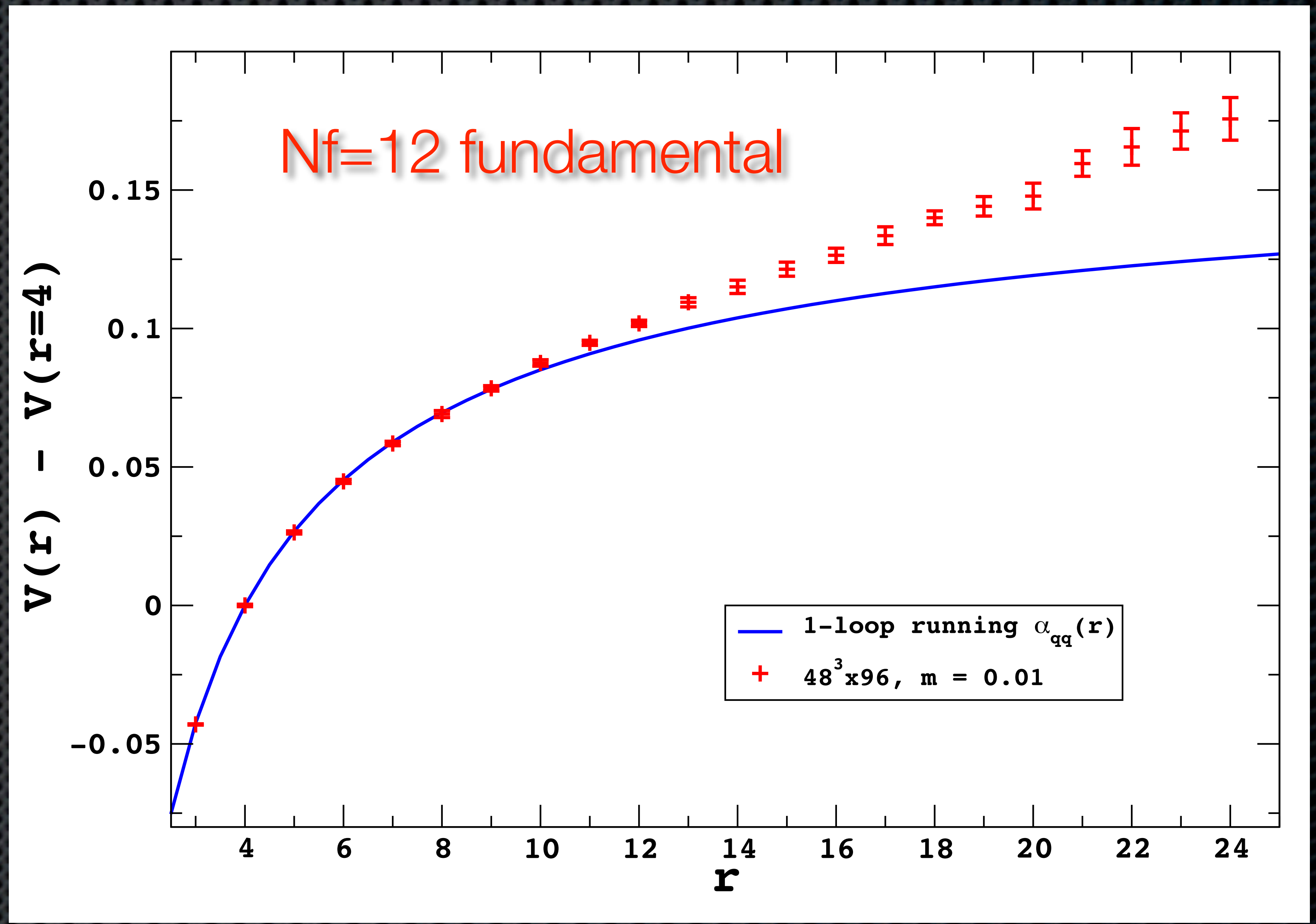
- * fit V(r) with 1/r : neither form describes m=0.025 data
- * fit V(r) without 1/r : both forms can fit all 4 mass data

exponent values inconsistent with spectroscopy $\gamma \sim 0.3 - 0.4$

linear fits: clear non-zero chiral limit

running coupling





3-loop QQ scheme, fundamental rep

IR fixed point $\alpha^*_{qq} = 0.371$

$$F(r) = \frac{dV}{dr} = C_F \frac{\alpha_{qq}(r)}{r^2}$$

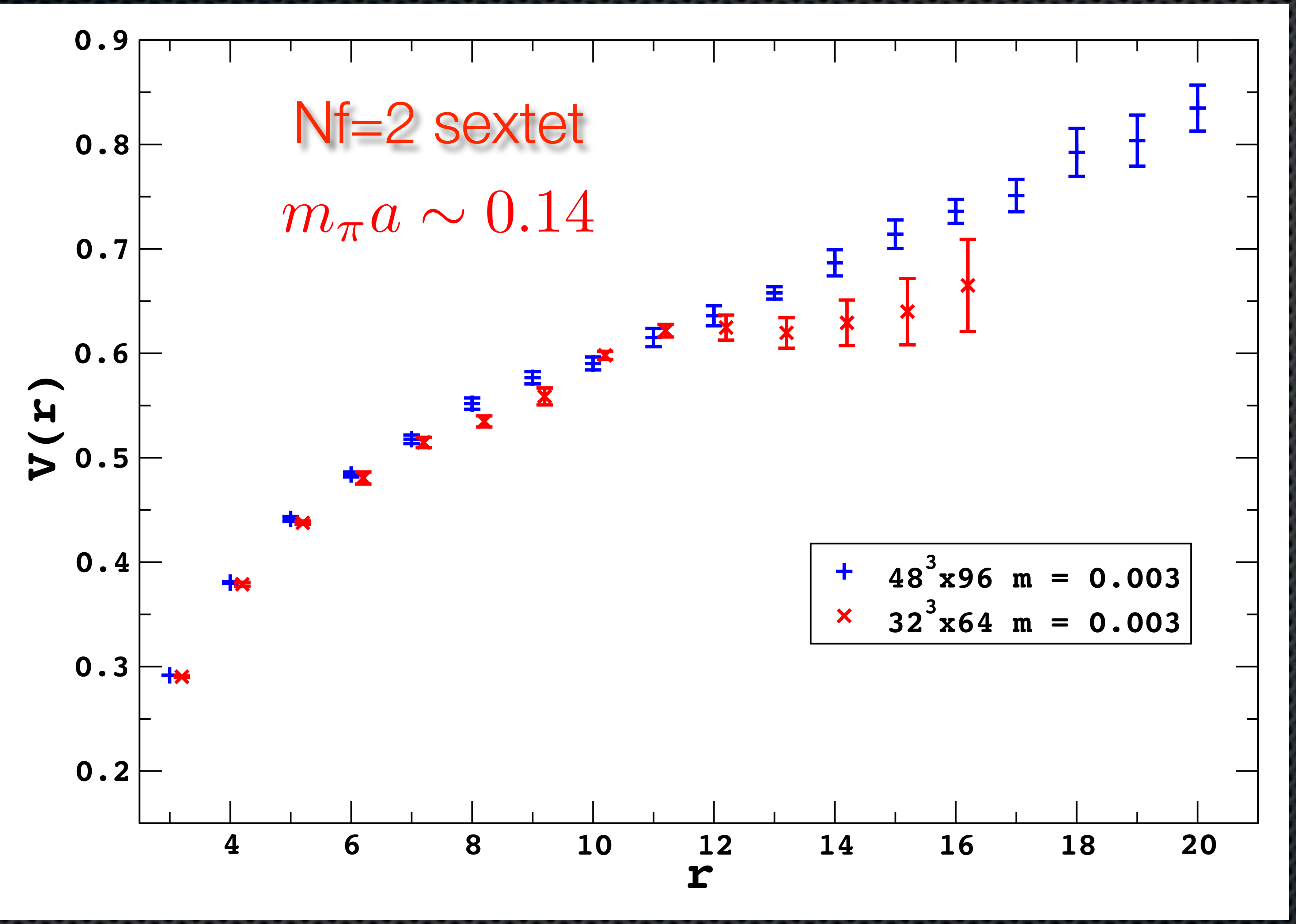
direct measurement from V(r):

$$\alpha_{qq}(r = 4.457...) = 0.393(11)$$

pert thy prediction: $V(r) - V(r_0) = C_F \int_{r_0}^{r} \frac{\alpha_{qq}(r')}{r'^2} dr'$

V(r) data increase fast with r - no sign of IRFP

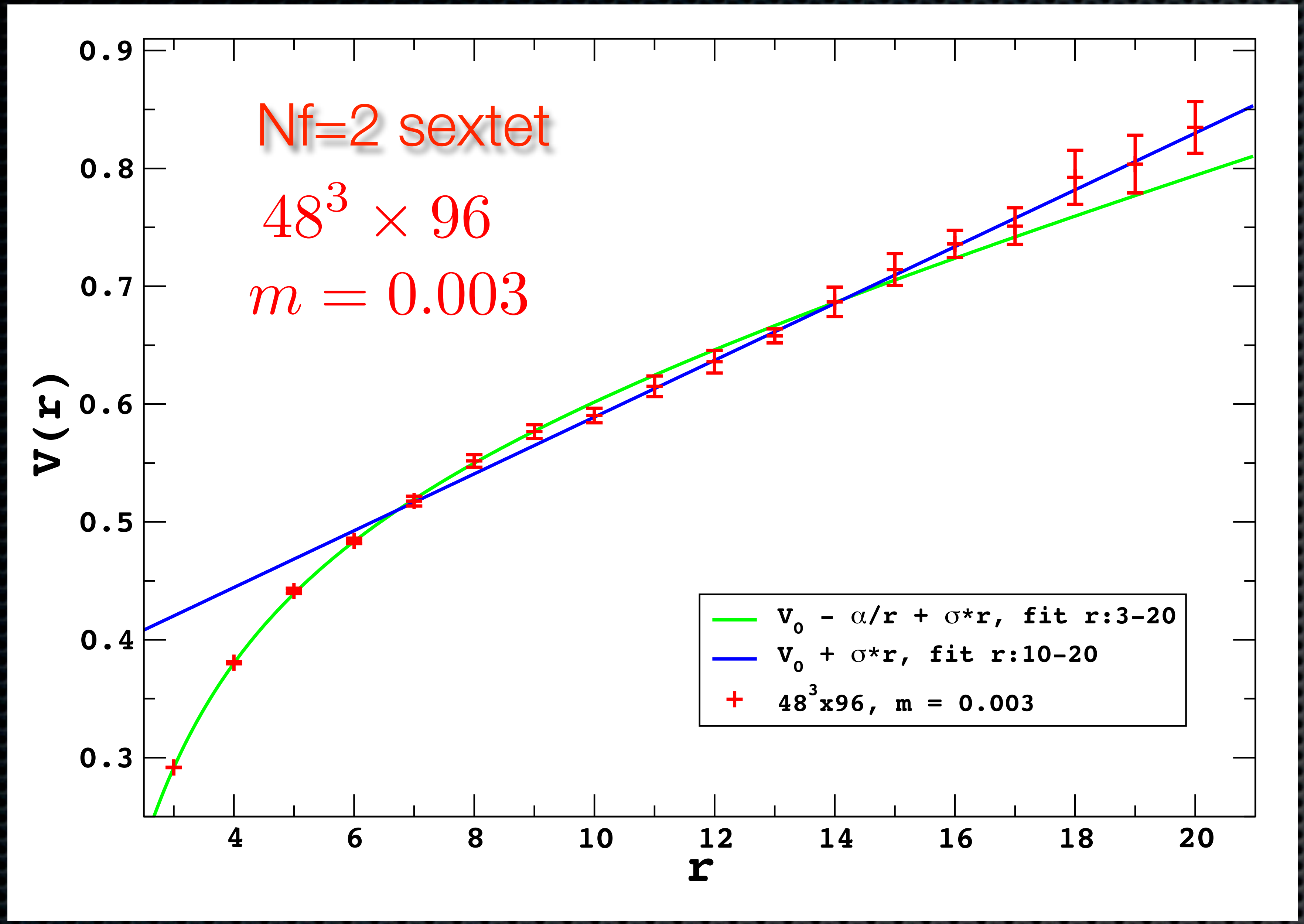
2-flavor sextet

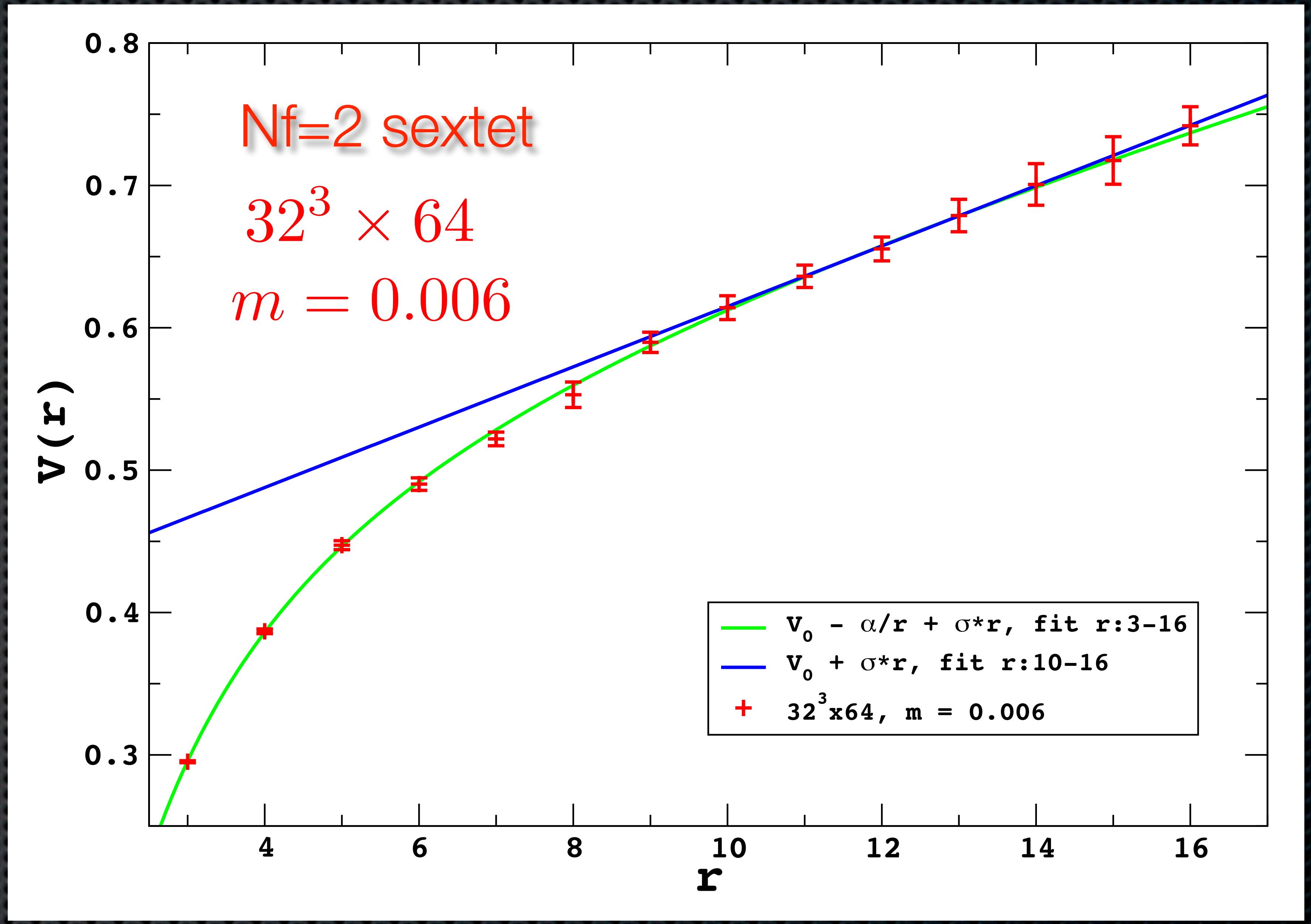


only 1 very large volume run $48^3 \times 96$ remainder of runs $32^3 \times 64$

do not have clear evidence that L=32 sufficient for heavier masses

fit potential

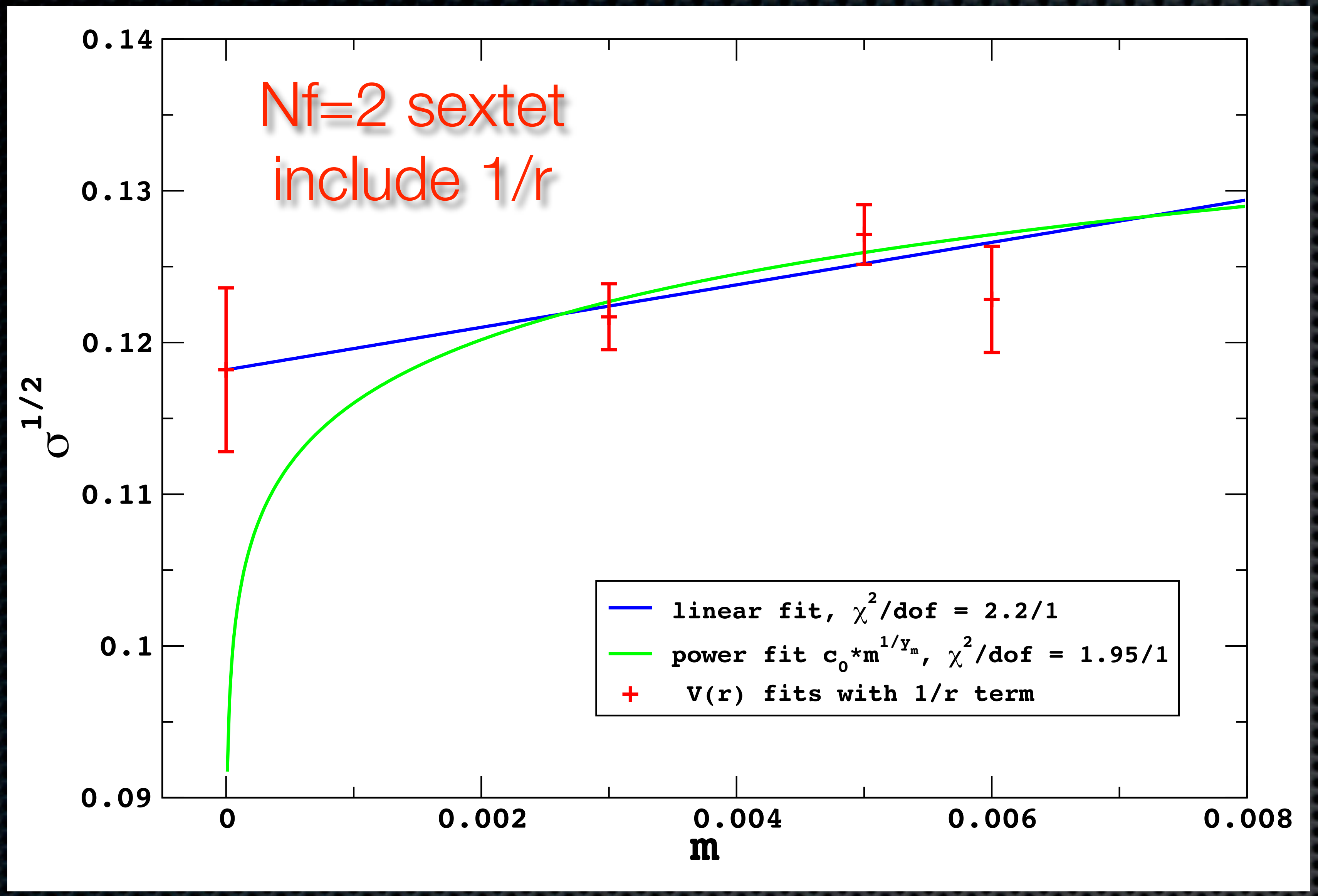


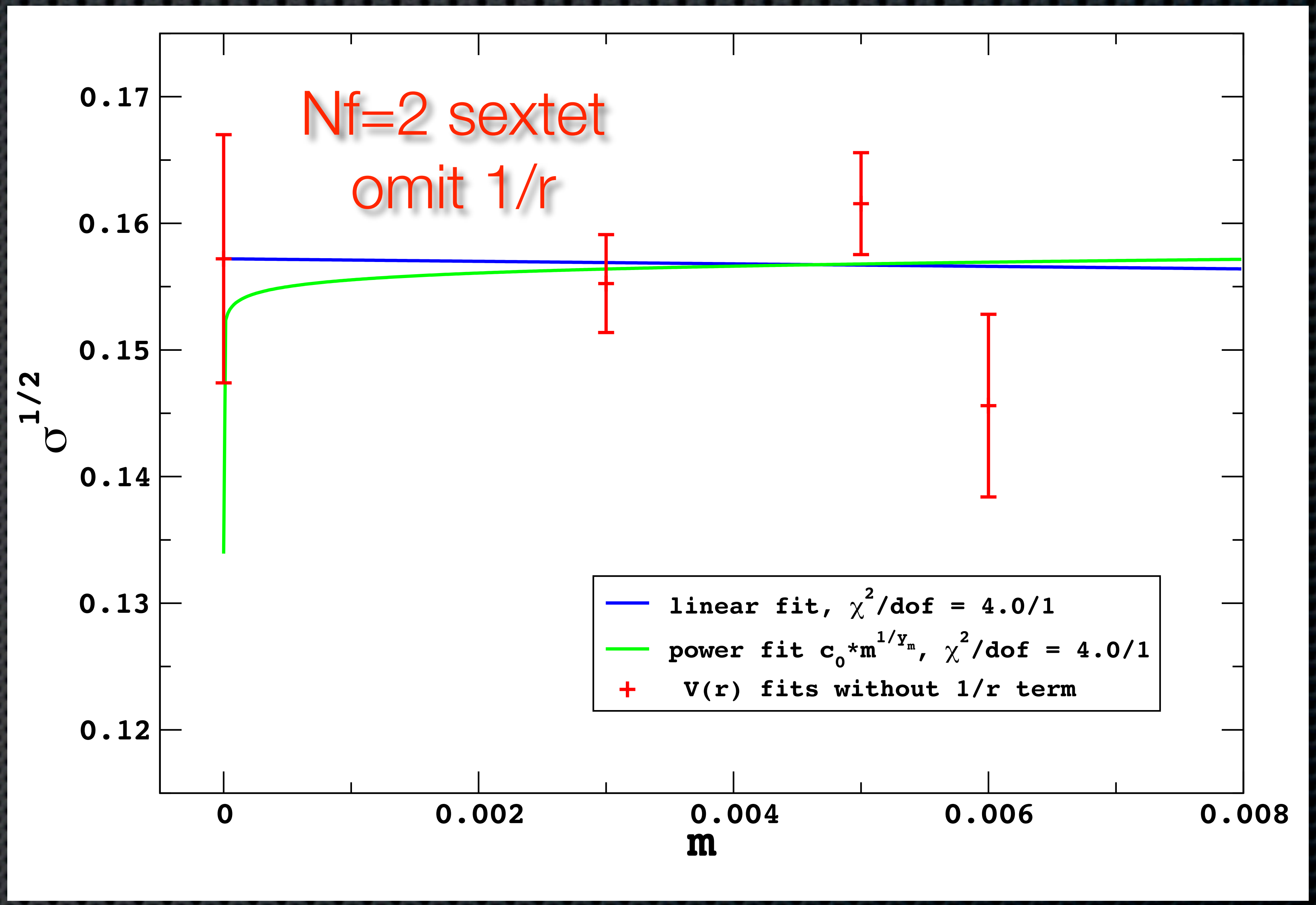


like fundamental: fit V(r) with & without 1/r term - 2 parametrizations

again, V(r) data at larger r show little curvature

fit string tension





both parametrizations: string tension has little mass dependence

conformal fit: $\sigma^{1/2} = c_0 m^{1/y_m}, \quad y_m = 1 + \gamma$

include 1/r: $1/y_m = 0.051(39)$ omit 1/r: $1/y_m = 0.005(59)$ unacceptable

linear fits almost constant, looks like clear non-zero chiral limit

summary

* 12-flavor fundamental
  - 2 methods to parametrize V(r)
  - for both, conformal fit exponent inconsistent with spectroscopy
  - for both, linear extrapolation to chiral limit gives non-zero string tension
  - potential runs faster that pert theory, do not see IR fixed point
  - consistent with spectroscopy: theory looks more like non-conformal
* 2-flavor sextet
  - again, 2 methods to parametrize V(r)
  - for both, little mass dependence in string tension
  - conformal fits give unacceptable exponent values
  - string tension non-zero chiral limit; looks non-conformal; spectrum agrees
  - are volumes large enough?

hotel down under?

dryer upside down
on ceiling

washing machine