格子シミュレーションによる 非自明固定点の探索

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Numerical simulation was carried out on the vector supercomputer NEC SX-8 in YITP, Kyoto University and RCNP, Osaka University

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Large flavor QCD理論に
非自明赤外固定点が存在する
か？

格子シミュレーションで非摂動論
的なrunning coupling constantを
みてみよう

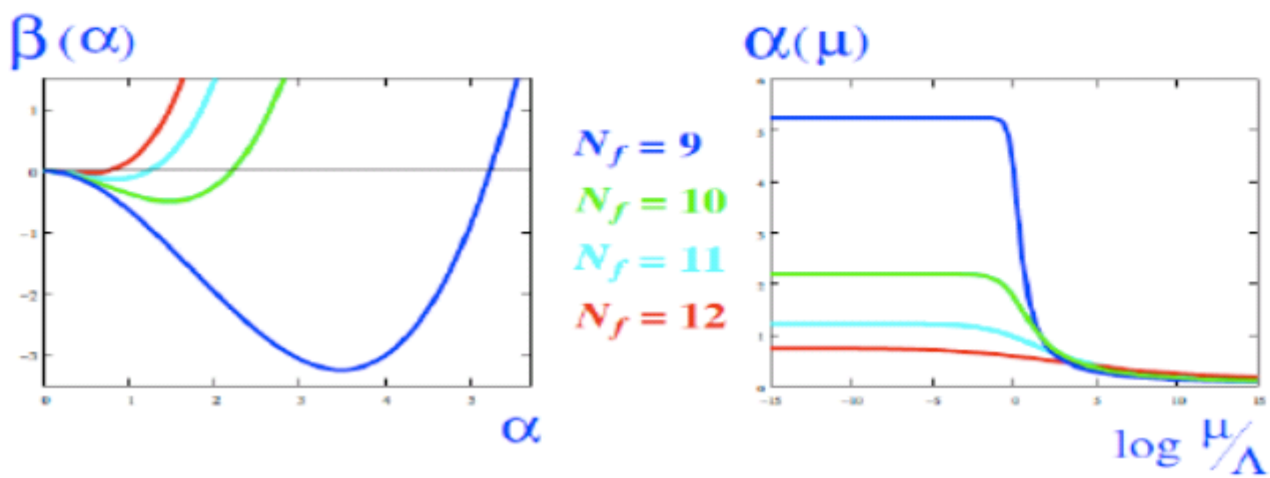
動機と関連した研究

Large flavor QCD

— a promising candidate for a theory with IR fixed point

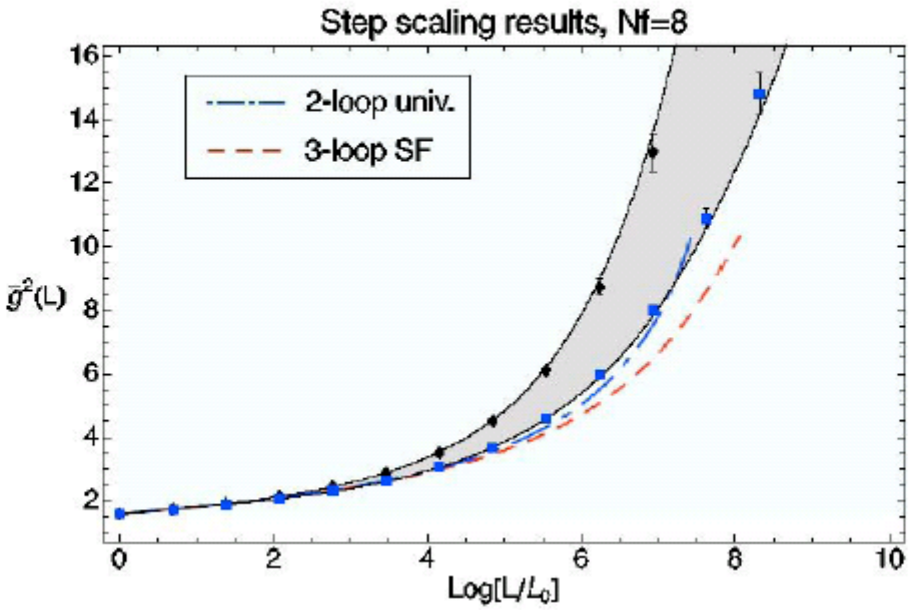
- Two-loop running coupling : $\mu\frac{d}{d\mu}\alpha(\mu) = \beta(\alpha) = -b\,\alpha^2(\mu) - c\,\alpha^3(\mu)$

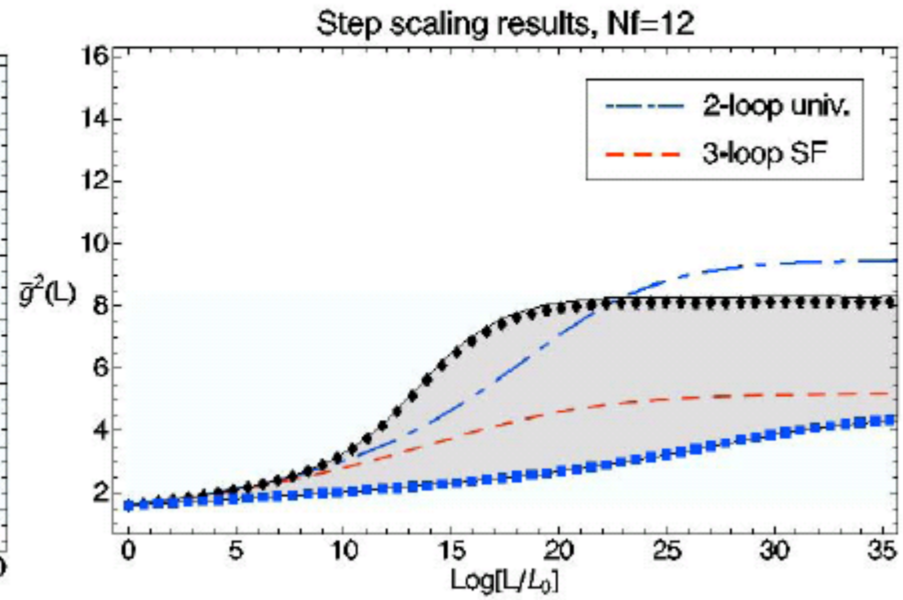
$(N_c = 3)$	$N_f < 8.05$	$8.05 < N_f < 16.5$	$16.5 < N_f$
$b = \frac{1}{6\pi}(33 - 2N_f)$	+	+	−
$c = \frac{1}{12\pi^2}(153 - 19N_f)$	+	−	−



Is this true beyond perturbation?

Appelquist, Fleming and Neil, PRL 100, 171607 (2008)





No evidence of IR fixed point
Nonperturbative results are
Similar to pertubation at 2-,3-loop

Flat region in small erengy scale
Large systematic error
From continuum extraploation

nonperturbative beta function with Schrodinger functional coupling scheme

There is a large O(a) discretization efffects in SF scheme

今日の発表の流れ(10分用)

- 動機と関連した研究

  先行する研究では、大きいsystematic errorが問題

  （連続極限を取るときのfit関数によるエラー）

- 新しい繰り込みスキームの定義

  O(a/L) エラーを持たないrenormalized couplingを定義

- running coupling constantをみるには？

  step scalingの方法

- シミュレーションのパラメータと結果
- Technical steps
- N_f=12 のシミュレーションの状況

Wilson loop scheme
Polyakov loop scheme

新しい繰り込みスキームの定義

The Wilson loop

L_0 : box size (spatial)

T_0 : box size (temporal)

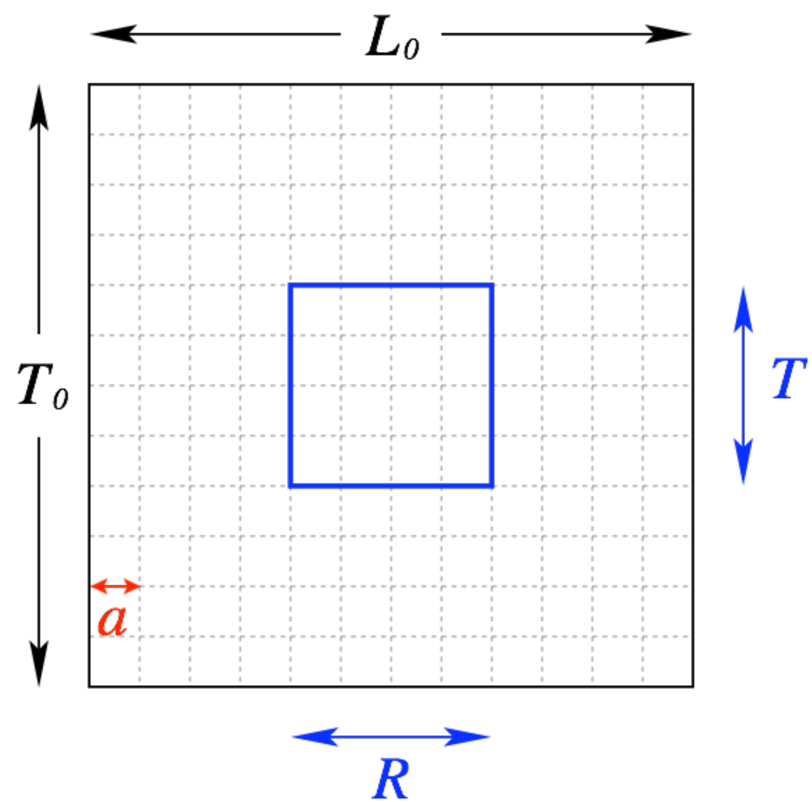
R : size of the Wilson loop (spatial)

T : size of the Wilson loop (temporal)

a : lattice spacing

g_0 : bare coupling

$$W(L_0, R, T_0, T, a, g_0)$$

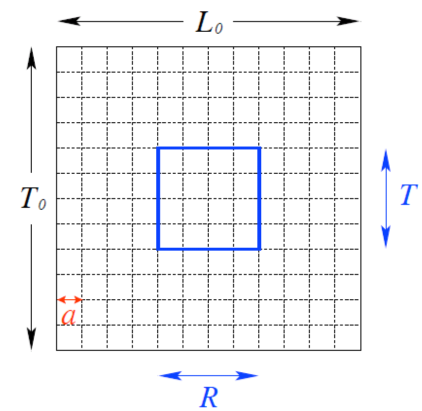


We choose the renormalization scheme:

$$g^2 = -R^2 \frac{\partial^2}{\partial R \partial T} \ln\langle W(R,T)\rangle^{\mathrm{NP}}|_{T=R} \Big/ k$$

$-\frac{\partial^2}{\partial R \partial T} \ln\langle W(R,T)\rangle$ is estimated by calculating the Creutz ratio.

$$CR(\hat{R},\hat{T}) = -\ln\left(\frac{W(\hat{R},\hat{T})W(\hat{R}-1,\hat{T}-1)}{W(\hat{R},\hat{T}-1)W(\hat{R}-1,\hat{T})}\right)$$



No O(a/L) contribution!!

Renormalized coupling in "Wilson loop scheme"

$$g_W^2 = \hat{R}^2 * CR(\hat{R},\hat{T}) \Big/ k$$

renormalized coupling $g^2\left(L_0, \frac{R}{L_0}, \frac{a}{L_0}\right)$

- fix the free parameter in the renormalization condition $r \equiv \frac{R+1/2}{L_0} (= 0.25, 0.30, 0.35)$
- take the continuum limit $\frac{a}{L_0} \to 0$
- L_0 is the scale which defines the running coupling constant of step scaling

How to take the continuum limit

$$g_R^2\left(\frac{1}{L_0}\right) \equiv \lim_{a \to 0} Z_R\left(\frac{a}{L_0}, g_0^2\right)\Big|_{L_0} g_0^2$$

To take the continuum limit, we have to set the scale " a ".
It corresponds to tuning g_0^2 to keep a certain input physical parameter constant.

input $g_W^2(1/L_0)$ → output $g_W^2(s/L_0)$

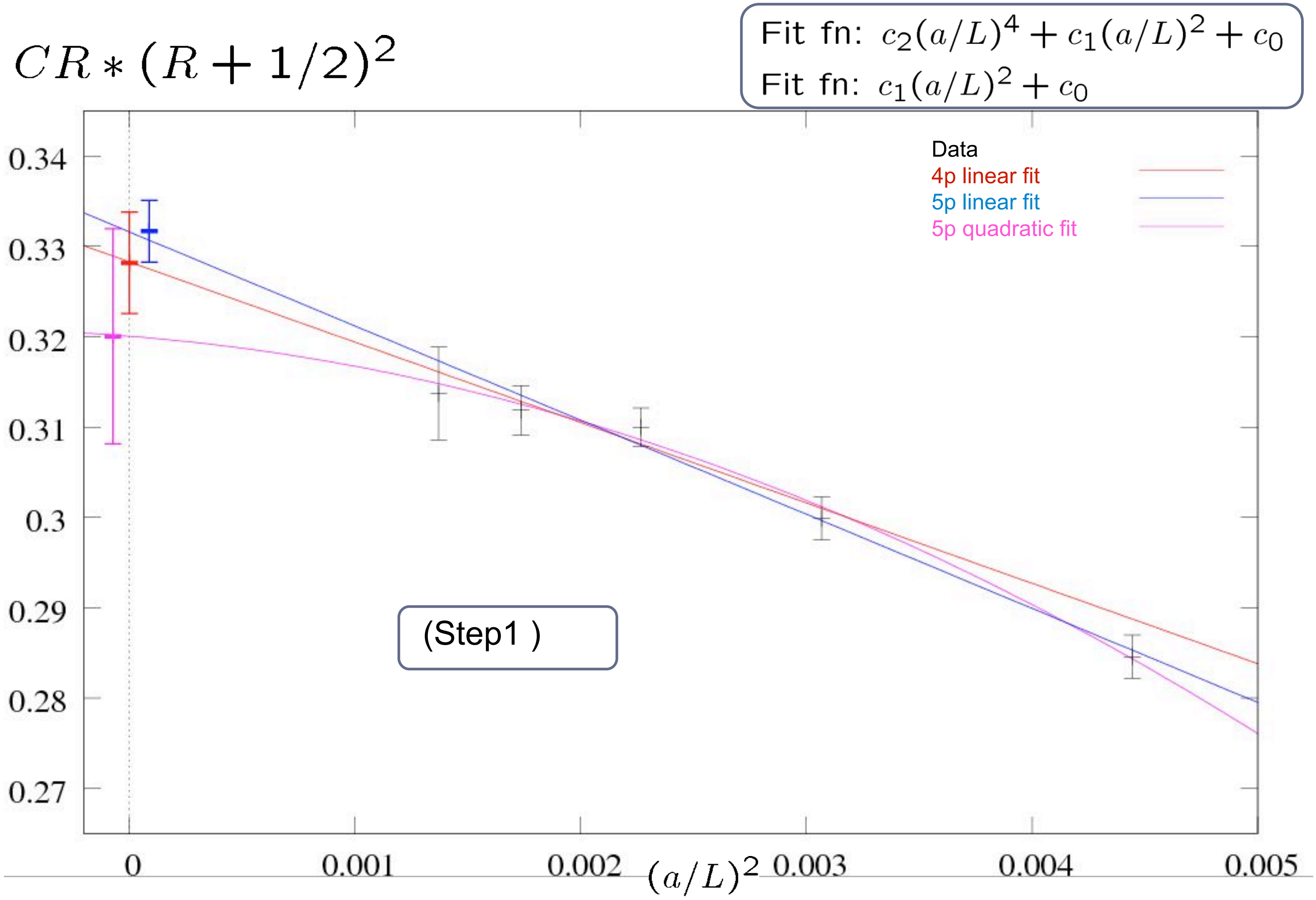
s : scaling parameter

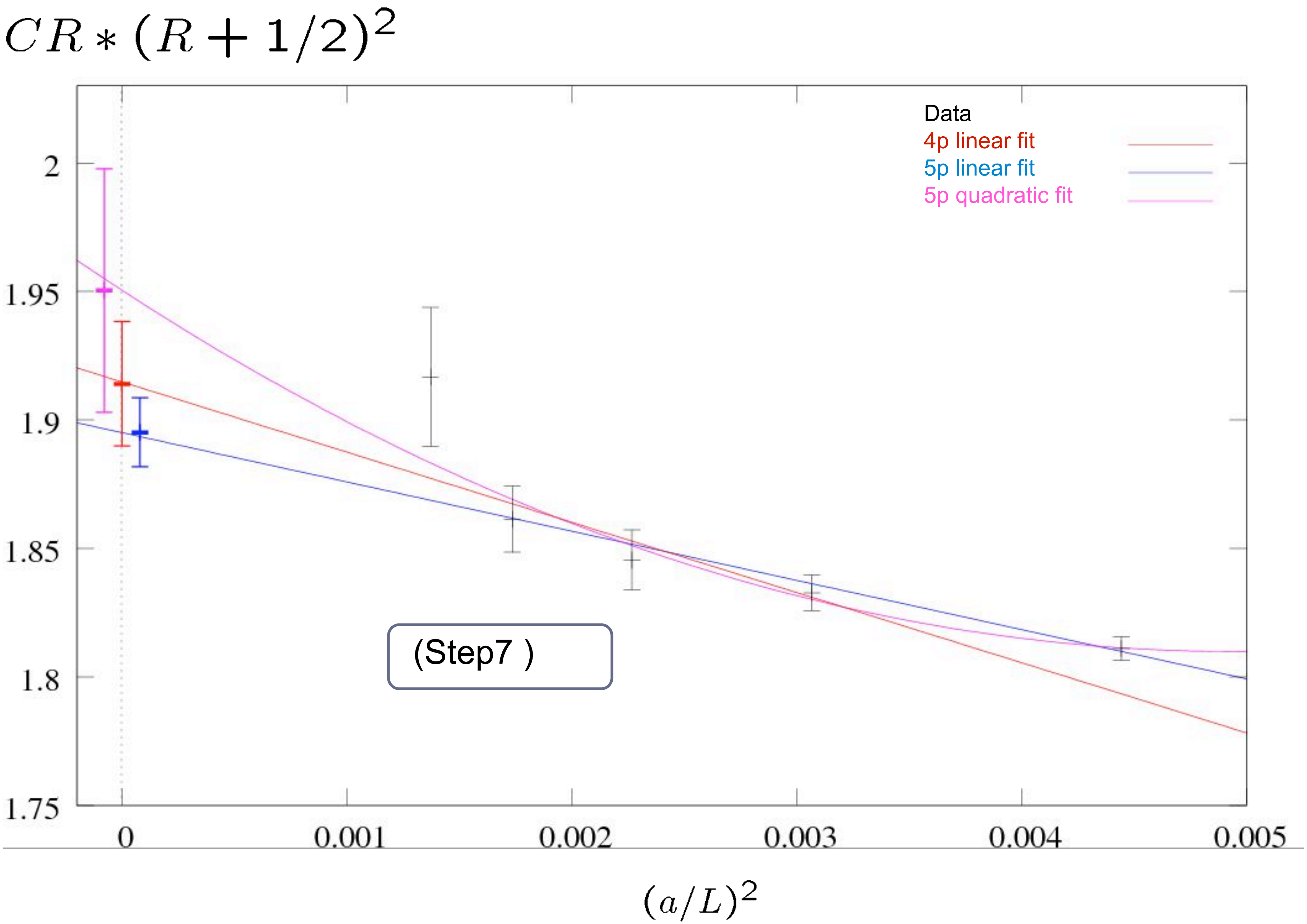
シミュレーションの結果

明日の1時間トークで！

quenched QCDの場合
(fermionのloopはない)

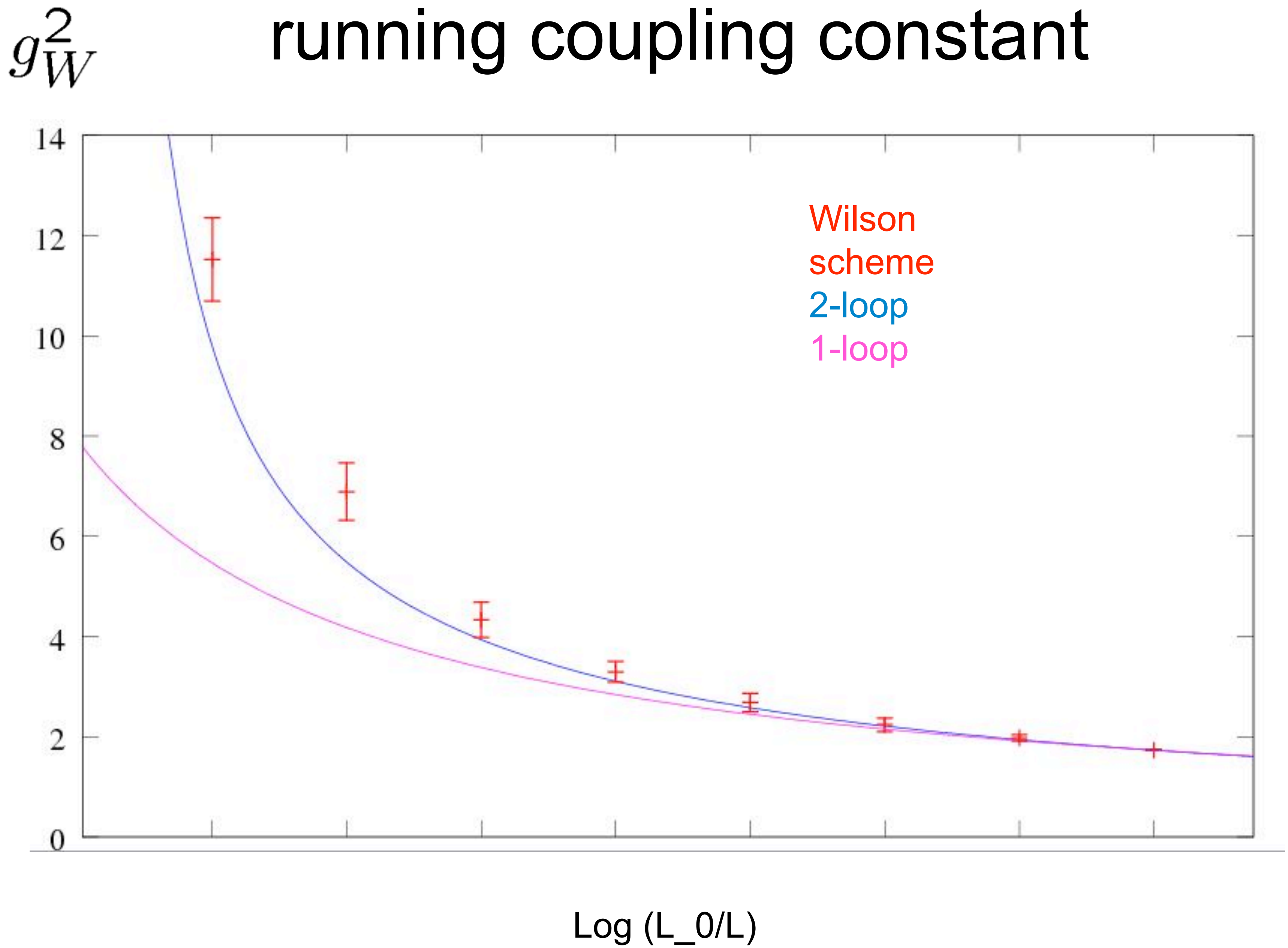
Extrapolation to the continuum limit



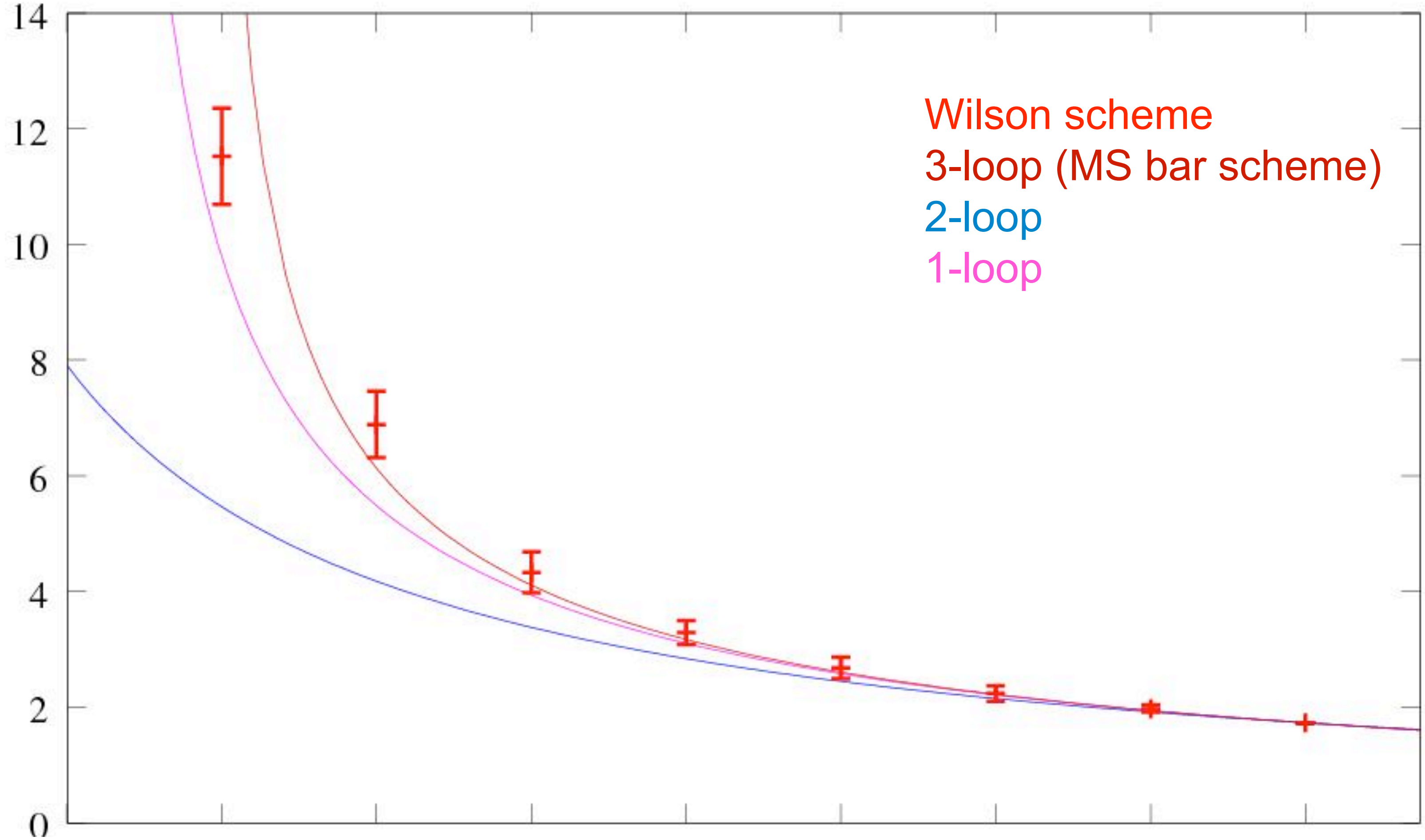


$CR*(R+1/2)^2$
Data
4p linear fit
5p linear fit
5p quadratic fit
(Step7)
2
1.95
1.9
1.85
1.8
1.75
0
0.001
0.002
0.003
0.004
0.005
$(a/L)^2$

running coupling constant



g_W^2 running coupling constant



Log (L_0/L)

quenched QCD testのまとめ

- “Wilson loop scheme”を定義した。
- smearingによって統計誤差が劇的に小さくなった。
- smearing levelとR/Lの比の取り方を調べた。

発表の流れ(1時間用)

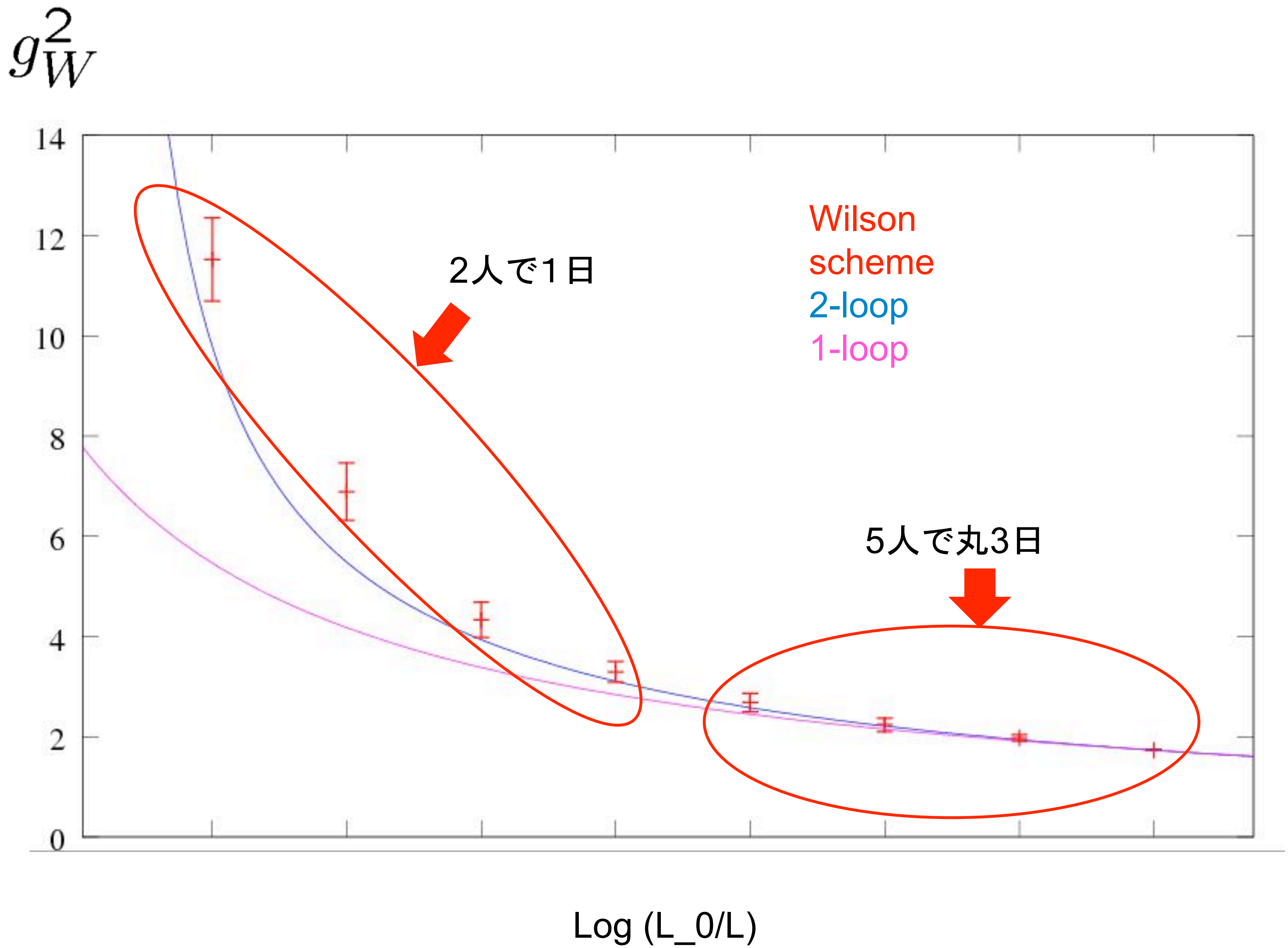
- 動機と関連した研究
- 新しい繰り込みスキームの定義
- running coupling constantをみるには？

  ⇨ step scaling

- シミュレーションのパラメータと結果
- Technical steps

  Smearing　小さい統計誤差
  Extrapolation to the continuum limit　小さい系統誤差
  Binning　シミュレーション時間の短縮

- N_f=12 のシミュレーションの状況



g_W^2
14
12
10
8
6
4
2
0
Wilson
scheme
2-loop
1-loop
2人で1日
5人で丸3日
Log (L_0/L)