Clover Action on Anisotropic Lattice
-Charmonium at Finite Temperature-

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<u>Introduction</u>

Motivation

Hadron physics of QCD phase transition

$\Downarrow$

use finite temperature lattice QCD

◇Charmomium

- ∘ mass shift near T_c
- ∘ J/ψ suppression above T_c

◇Light Hadrons

- ∘mass shift near T_c
- ∘existence of bound state above T_c
- ∘chiral restoration

Difficulties

∘T $\rightarrow$ large, N_t(d.o.f. in t-direction)$\rightarrow$ small

$\Rightarrow$ Anisotropic lattice(more info. about t-direction)

∘Remove O(a) effect

$\Rightarrow$ Clover quark action

Anisotropic Lattice

Detailed information in t-(temperature) direction

$\Rightarrow$ Anisotropic lattice

Iso-Latt Fig.

Aniso-Latt Fig.

Lattice Actions

Gauge field action:

$$S_G(\beta,\gamma) = \sum_{x,i,j}[\frac{\beta}{\gamma}U_{i,j}(x) + \beta\gamma U_{i,4}(x)]$$

input(β,γ)$\longrightarrow$(a_s,ξ)

Heavy quark action:

$\Rightarrow$Fermilab (Clover) action on Anisotropic lattice

Clover action : Sheikholeslami,Wohlert('85)

Fermilab action : El-Khadra,Kronfeld,Mackenzie('97)

$$S_F(\kappa_s,\gamma_F) = \sum_x \bar{q}(y)K[U](x,y)q(x)$$

$$K[U](x,y) = 1 - \kappa_s\sum_i[(\xi^{-1} - \gamma_i)T_{+i} + (\xi^{-1} + \gamma_i)T_{-i}]$$

$$-\kappa_t[(1-\gamma_4)T_{+4} + (1+\gamma_4)T_{-4}]$$

$$-\kappa_s\frac{1}{2\xi}c_B\vec{\Sigma}\cdot\vec{B} + \kappa_t\frac{1}{2\xi}c_E\vec{\alpha}\cdot\vec{E}$$

$\kappa_t = \gamma_F\kappa_s$

input(κ_s,γ_F)$\longrightarrow$(m_q,ξ_F)

c_B, c_E :Clover coefficients

$T_{+\mu}(x,y) = U_\mu(x)\delta_{x+\hat{\mu},y}$

$T_{-\mu}(x,y) = U_\mu(x-\hat{\mu})\delta_{x-\hat{\mu},y}$

Calibration

Find γ_F $(and\ \kappa_s)$ which gives $\xi_F = \xi$

○Anisotropy of gauge field : ξ

$$\xi = a_s/a_t$$

determined from Wilson loops

○Anisotropy of quark field : ξ_F

use Dispersion Relation of meson

◇Dispersion Relation

$$\xi_F^2 = \frac{1}{2}\frac{\hat{\vec{P}}^2}{\cosh E(\vec{p}) - \cosh E(0)}$$

$$\hat{P}_i = 2\sin\frac{P_i}{2}$$

◇Meson correlator

- $C(\vec{P},t) = \sum_{\vec{x}} e^{-i\vec{P}\cdot\vec{x}} \cdot \langle O_\Gamma(x) \cdot O_\Gamma^\dagger(0) \rangle$
- $P_i = (\frac{2\pi}{N_i} \cdot k_i) \qquad k_i \in Z$
- $C(\vec{P},t) \underset{t \gg 1}{\longrightarrow} Z(p) \cdot exp\{-E(\vec{p}) \cdot t\}$

Simulation Parameters

Gauge field:

∘Quenched lattice

∘ $12^3 \times N_t$, $\beta = 5.68$, $\gamma = 4.0$

N_t=72(T $\simeq$ 0), 20(T$<T_c$), 16,12(T$>T_c$)

∘ ♯Conf=60 ∘ Anisotropy:$\xi = a_s/a_t = 5.3(1)$

∘ Cut-off: a_s^{-1}=0.85(3)GeV, a_t^{-1}=4.5(2)GeV

from heavy quark potential

Heavy quark field:

∘Hopping parameter and bare Anisotropy

•Calibration($N_t = 72$, ♯conf.=20)

$\kappa_s = 0.10, \gamma_F = 3.8, 3.9$

•$T \neq 0$(♯conf.=20)

$\kappa_s = 0.10, \gamma_F = 3.8$

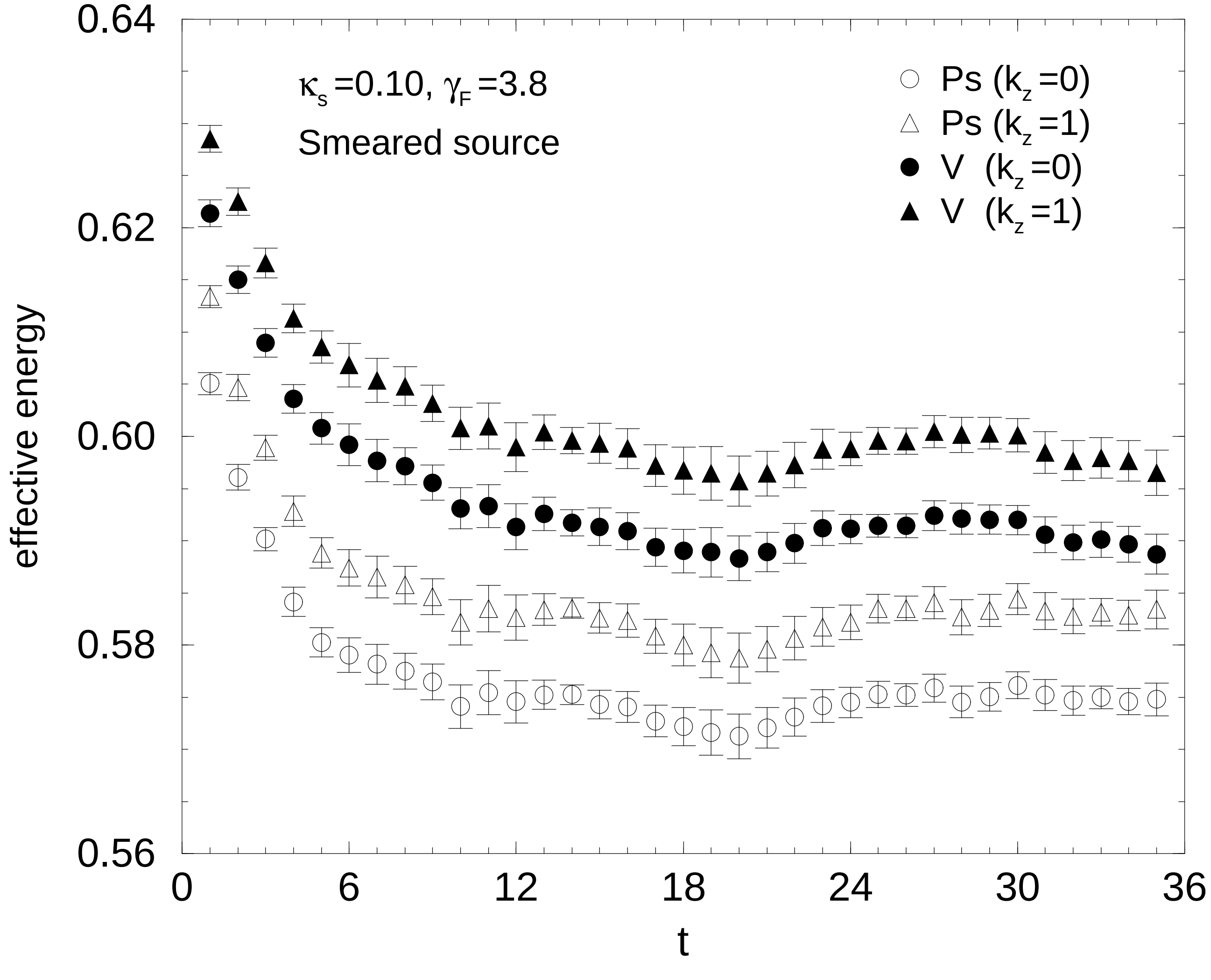
∘Mean-field(Tadpole) improvement

$U_\mu \to U_\mu / u_{0\mu}$

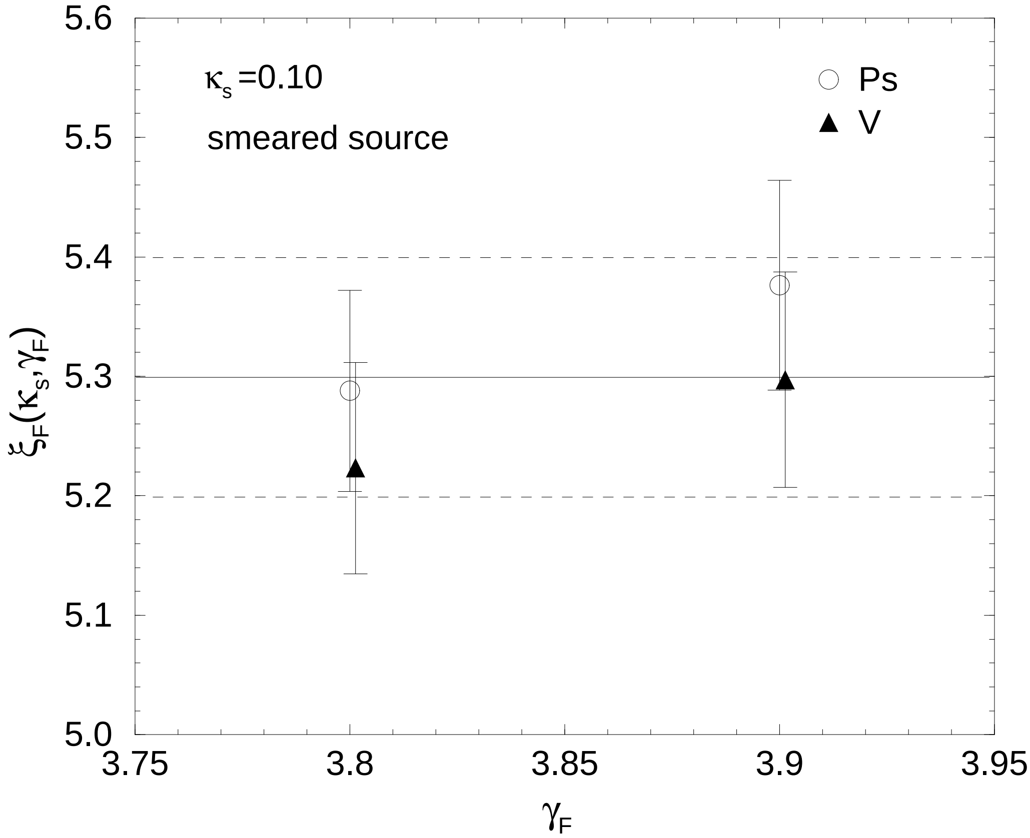
u_{0s}, u_{0t} : determined with plaquette

$\gamma_F \simeq 3.6$ in MF improvement

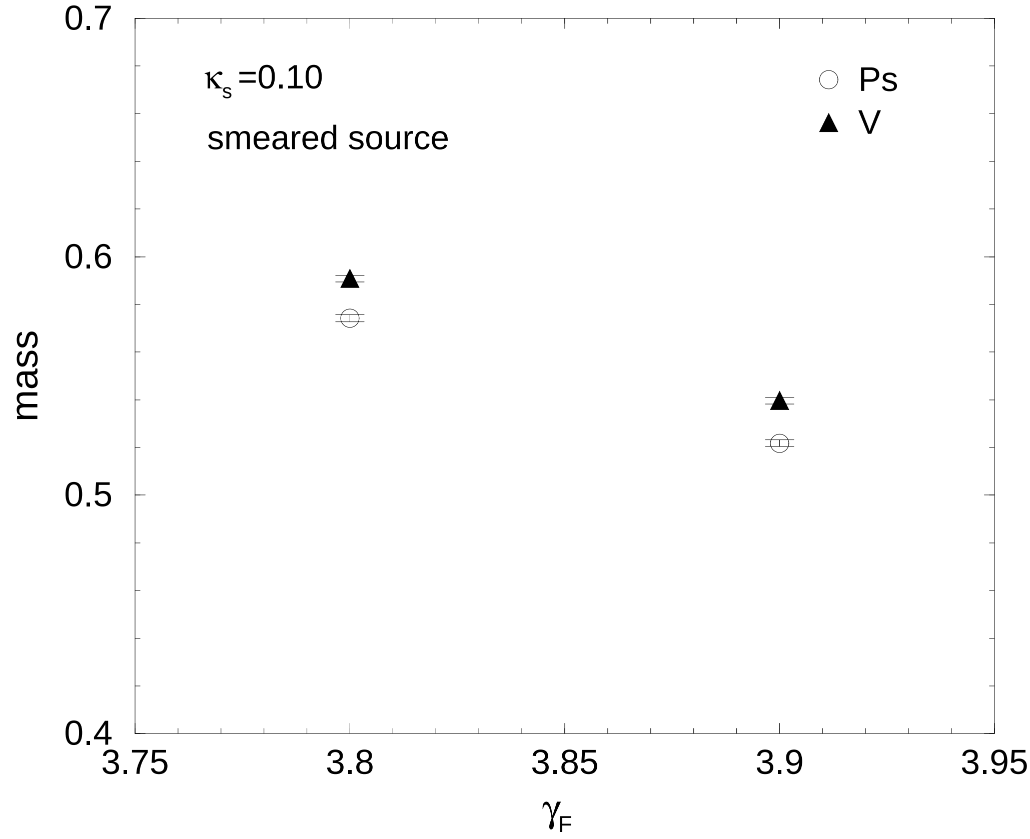
$c_E = 1/u_{0t}^2 u_{0s}$, $c_B = 1/u_{0s}^3$



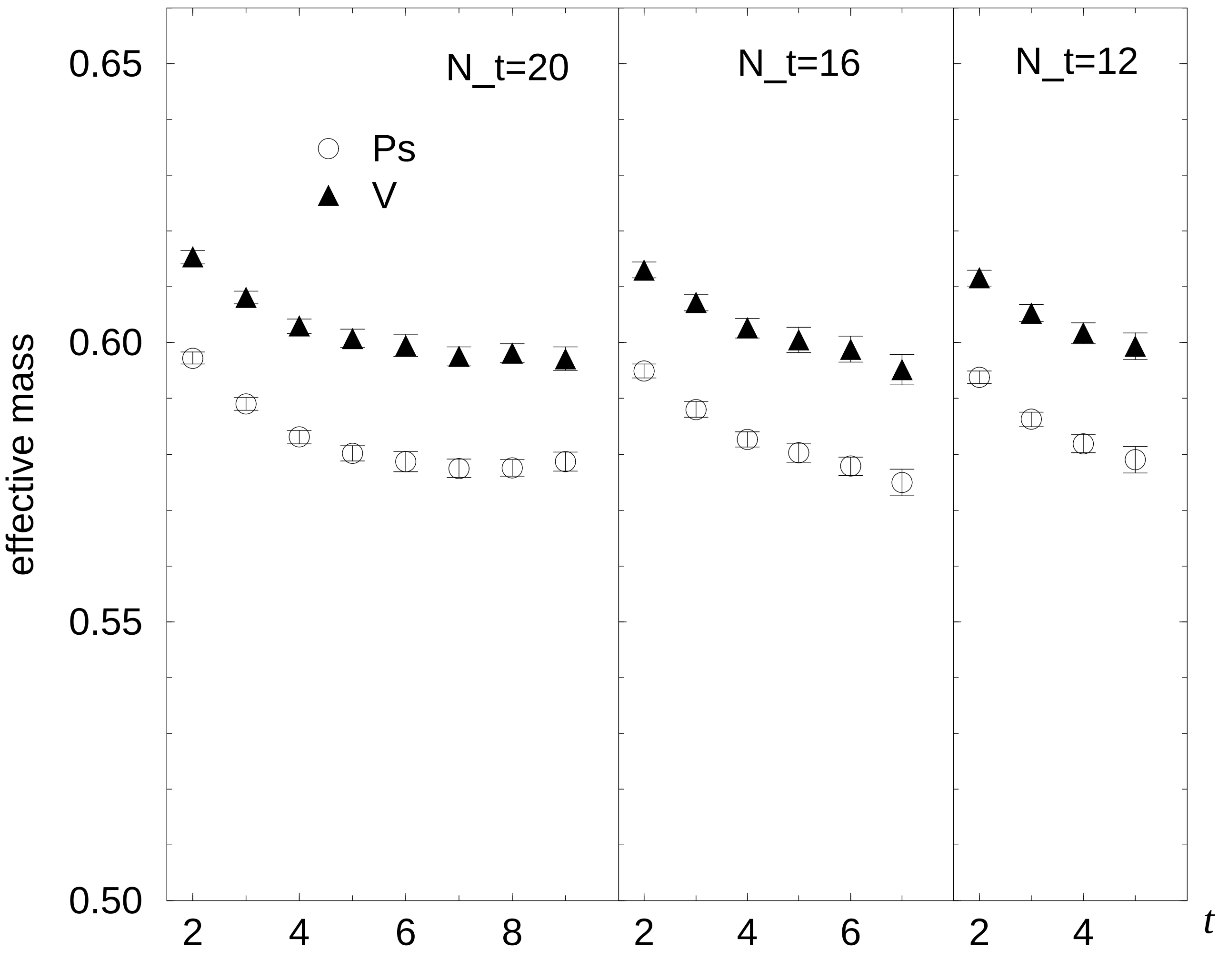
0.64
0.62
0.60
0.58
0.56
effective energy
0
6
12
18
24
30
36
t
κ_s =0.10, γ_F =3.8
Smeared source
Ps (k_z =0)
Ps (k_z =1)
V (k_z =0)
V (k_z =1)



5.6
5.5
5.4
5.3
5.2
5.1
5.0
3.75
3.8
3.85
3.9
3.95
κ_s =0.10
smeared source
Ps
V
$\xi_F(\kappa_s,\gamma_F)$
γ_F



0.7
0.6
0.5
0.4
3.75
3.8
3.85
3.9
3.95
κ_s =0.10
smeared source
Ps
V
mass
γ_F



effective mass
0.65
0.60
0.55
0.50
N_t=20
N_t=16
N_t=12
Ps
V
2
4
6
8
2
4
6
2
4
t

Summary

◦Anisotropic Fermilab action

◦Calibration with Dispersion Relation

◦Measure charmonium mass

◦γ_F is consistent with that in MF improvement

◦mass : very sensitive to γ_F

◦Unclear result for $N_t = 20, 16, 12$

→variational analysis

Future Plan

◦More detailed analysis of $m_{J/\psi}$,etc..

◦Light quark with clover action
(mass shift,chiral restoraion,etc..)

◦Fine Lattice

◦Dynamical Quark