Mesonic Correlators at Finite Temperature on Anisotropic Lattice

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for *QCD-TARO Collaboration*

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CONTENTS

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Physical goals:

- Finite Temperature QCD
  → *I.-O. Stamatescu and H. M.*
- Finite Chemical Potential
  → *T. Takaishi (poster)*
- MCRG and Improved Actions
  → *T. Umeda (talk)*

Introduction

Finite temperature hadron properties:

Change of masses and width below T_c
Excitation of hadronic modes above T_c

Observe

- Pole and screening masses
- Wave function
- Spectral function

Need detailed information in t- (temperature) direction

$\Rightarrow$ *Anisotropic lattice*

[Karsch (1982),
Burgers, Karsch, Nakamura and Stamatescu (1988)]

This work:

- coarse lattice ($a_s^{-1} = 0.85$ GeV)
- unimproved actions

$\longrightarrow$ only qualitative result, yet

Simulation Parameters

Lattice:

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

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

- #conf. = 60 (30 for quark at present)
- On Intel Paragon XP/S (56 nodes) in INSAM, Hiroshima Univ.
- Anisotropy: $\xi \equiv a_s/a_t = 5.3(1)$
  [Engels, Karsch and Scheideler (1997), Klassen (1998)]
- Cutoff: $a_s^{-1} = 0.85$ GeV, $a_t^{-1} = 4.5(2)$ GeV
  (from heavy quark potential)

Quark:

Anisotropic Wilson action

- Hopping parameter and bare anisotropy:

κ_s	γ_F	m_{PS}	m_V (GeV)
0.0810	4.05	0.81	0.90
0.0840	3.89	0.68	0.80
0.0860	3.78	0.61	0.75

γ_F determined by calibration

- Periodic b. c. for spatial direction

Another set of lattices (Lattice-A):

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

$N_t = 72, 20, 18, 16, 12$, #conf.=20

with different manner of calbration

$\Rightarrow \xi = 5.9$, different (κ, γ_F)

Quark action calibration

Anisotropic Wilson action

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

$$K[U](x,y) = \delta_{x,y} - \sum_\mu \kappa_\mu \left[\ (1-\gamma_\mu)\ U_\mu(x)\, \delta_{x+\hat{\mu},y} \right. \\ \left. + \ (1+\gamma_\mu)\ U_\mu^\dagger(x-\hat{\mu})\, \delta_{x-\hat{\mu},y} \right]$$

$$\kappa_i = \kappa_s, \qquad \kappa_4 = \kappa_t = \gamma_F \kappa_s$$

Mesonic correlators

$$C^{(t)}(t) \ = \ \sum_{\vec{x}} \langle O_\Gamma(x) O_\Gamma(0) \rangle \propto \exp(-m^{(t)} t)$$

$$C^{(s)}(z) \ = \ \sum_{x,y,t} \langle O_\Gamma(x) O_\Gamma(0) \rangle \propto \exp(-m^{(s)} z)$$

$$\xi_F \equiv m^{(s)}/m^{(t)}$$

Adjust γ_F so that $\xi_F = \xi$

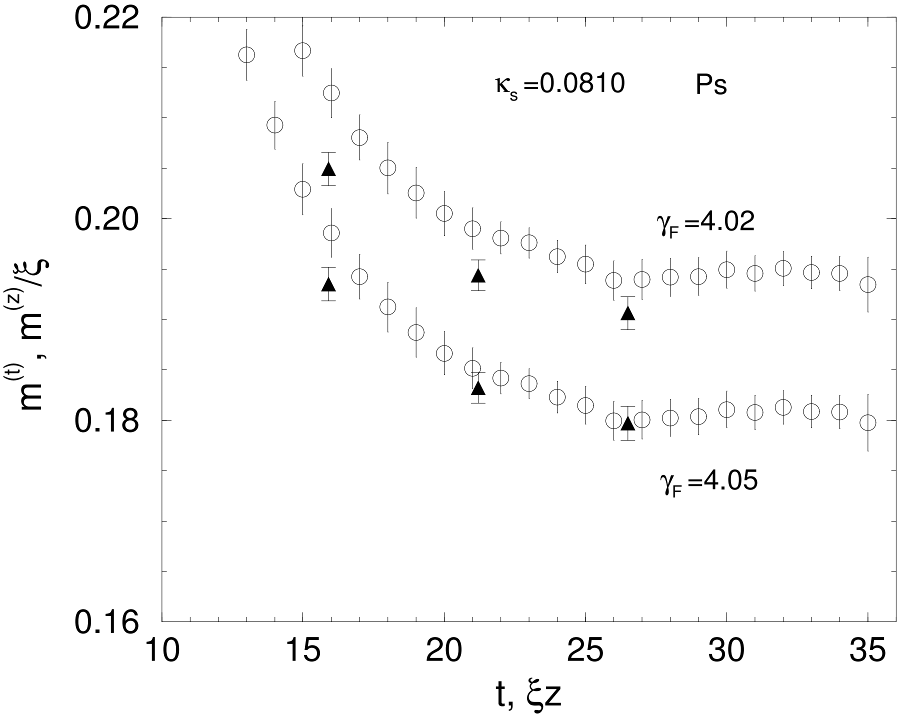
In the calibration, anti-periodic boundary condition is used for all four directions.

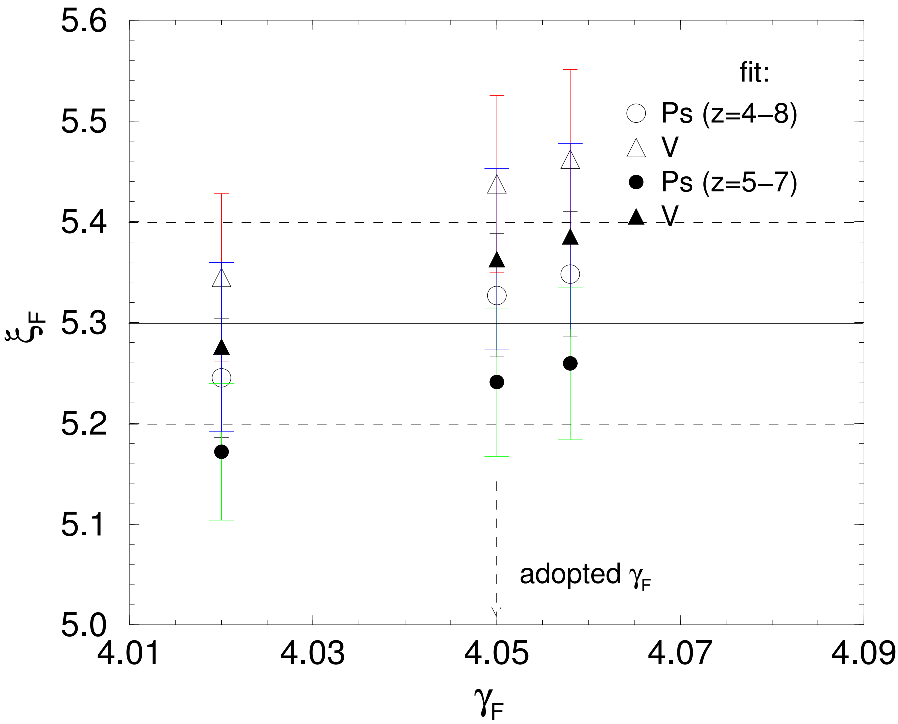
Discrepancy of ξ_F for Ps and V meson masses

$\Rightarrow O(a)$ error

Quark action calibration (Figures)

Effective plot





Pole mass

The pole mass is extracted from hadronic correlators in "temperature" direction

[Hashimoto, Nakamura and Stamatescu (1993)]

Smearing (source)
– Observed wave function at $T = 0$ (fit to $\exp(-ar^p)$)
$\rightarrow$ "exp" source
–No sink smearing

$\Rightarrow$ three sets of source smearing:
"point-point", "point-exp", "exp-exp"

— Figures —

"point-exp" and "exp-exp" correlators seem to reach plateau, but their values are different.

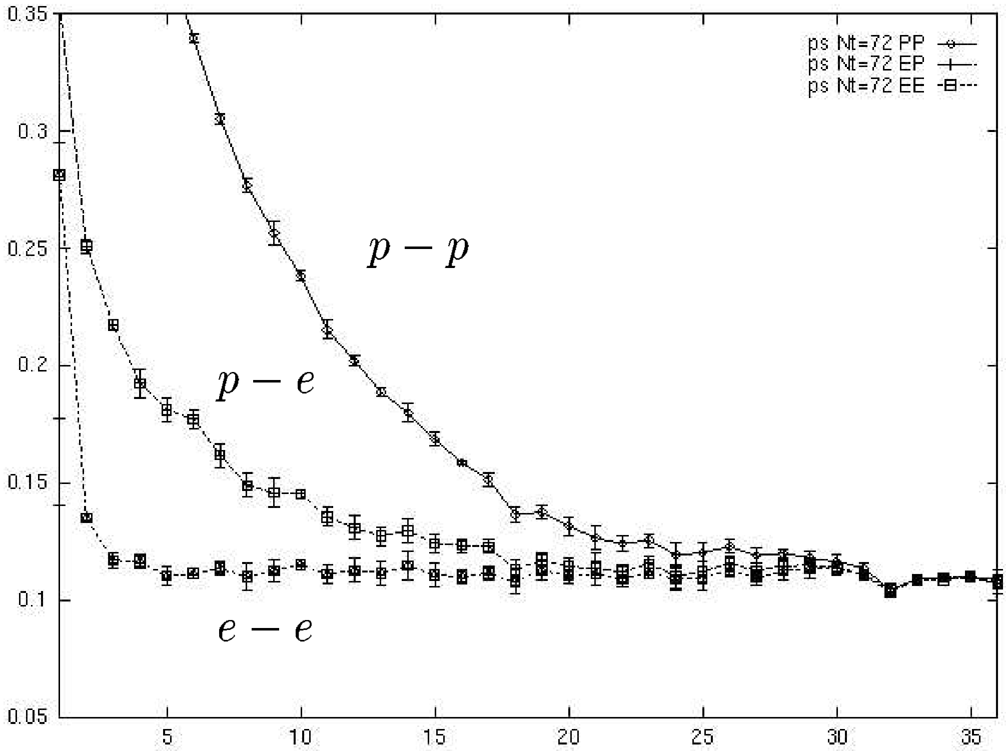
Differences: 20 % at $N_t = 20$ and 30 % at $N_t = 12$

At present, we regard that as a systematic uncertainty, and use "exp-exp" result in the following.

Effective plot $(T = 0)$

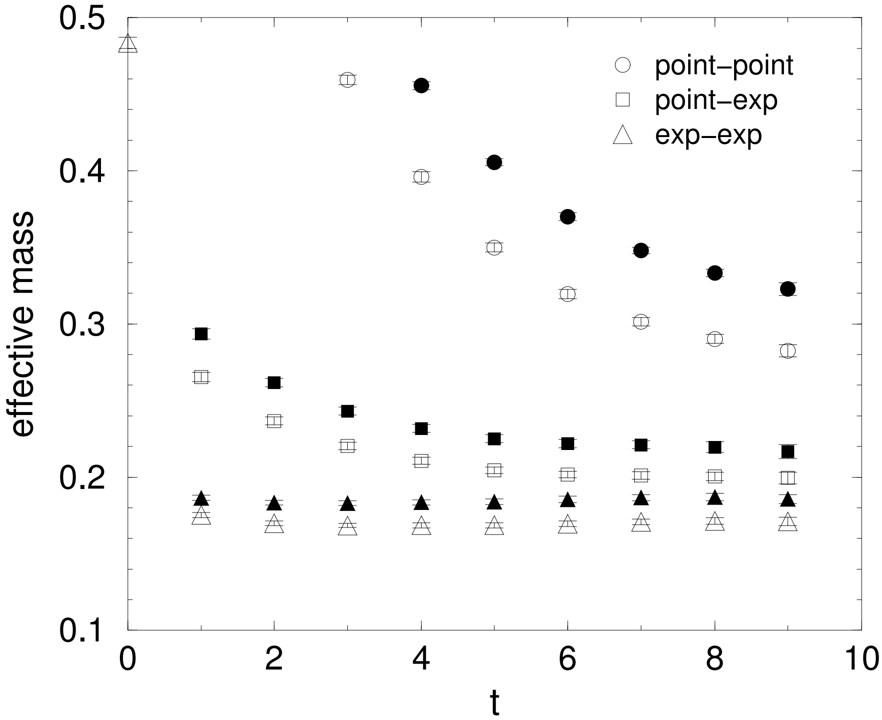
Lattice-A, $N_t = 72$

Ps meson

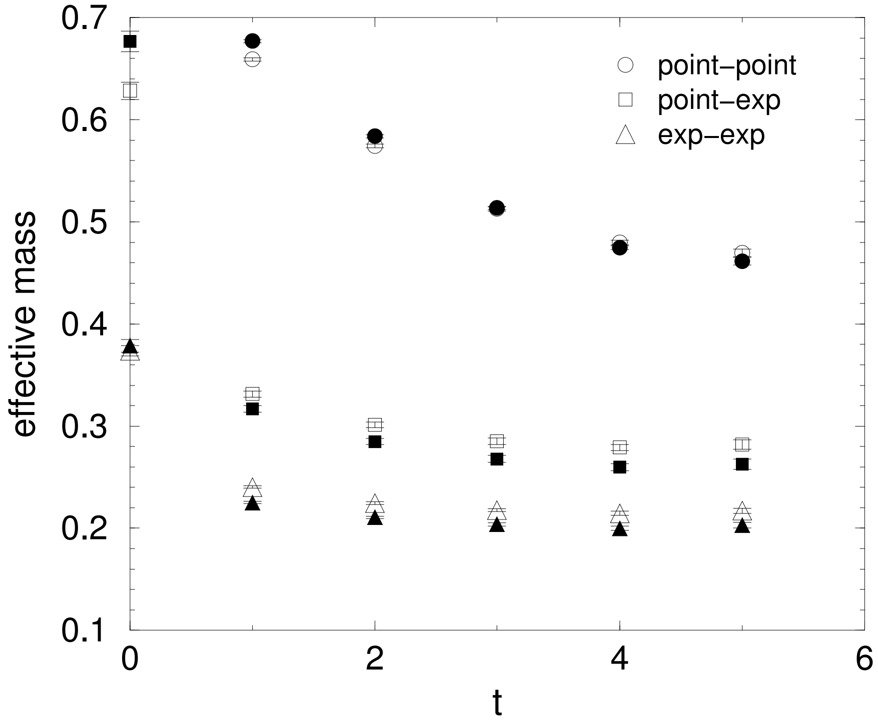


Effective mass plots in t-direction

$N_t = 20$ (open: Ps, filled: V)



$N_t = 12$



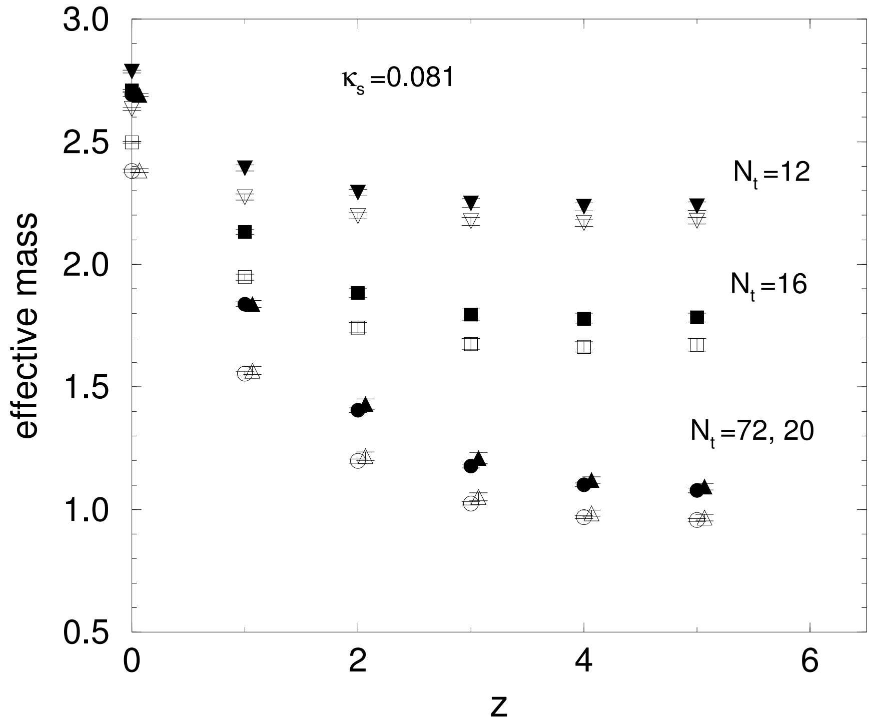
Screeniing mass

Extracted from hadronic correlators in z-direction with "point-point" source

In all cases, the range $z = [5, 7]$ is used

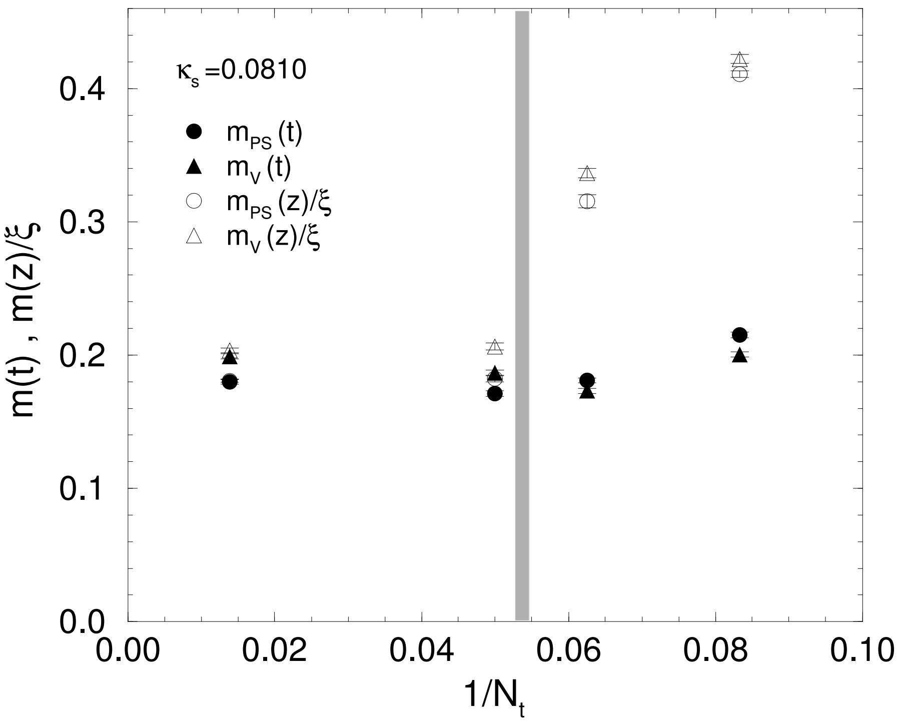
Effective mass plots in z-direction

(open: Ps, filled: V)

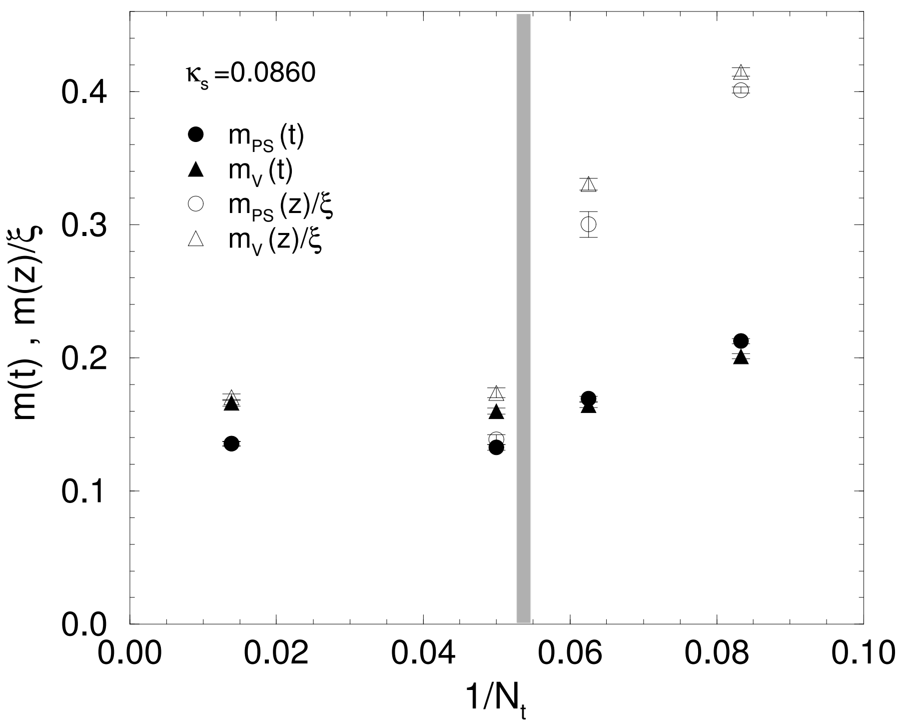


T-dependence of masses

$\kappa_s = 0.0810$



$\kappa_s = 0.0860$



Chiral extrapolation

Naive relation

$$\frac{1}{\kappa} \equiv \frac{1}{\kappa_s} - 2(\gamma_F - 1) = 2(m_0 + 4)$$

$\Downarrow$

Extrapolation in $1/\kappa$

Ps meson:

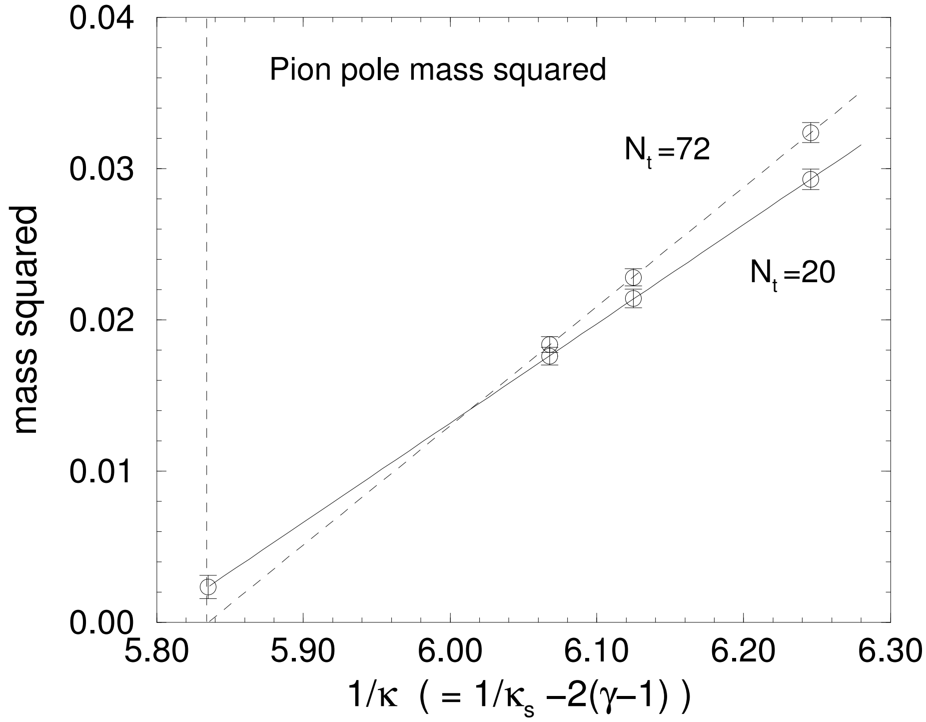
$T = 0$ — m_{PS}^2 linear in $1/\kappa \Rightarrow \kappa_c$
$T < T_c$ — m_{PS}^2 linear in $1/\kappa$
$T > T_c$ — m_{PS} linear in $1/\kappa$

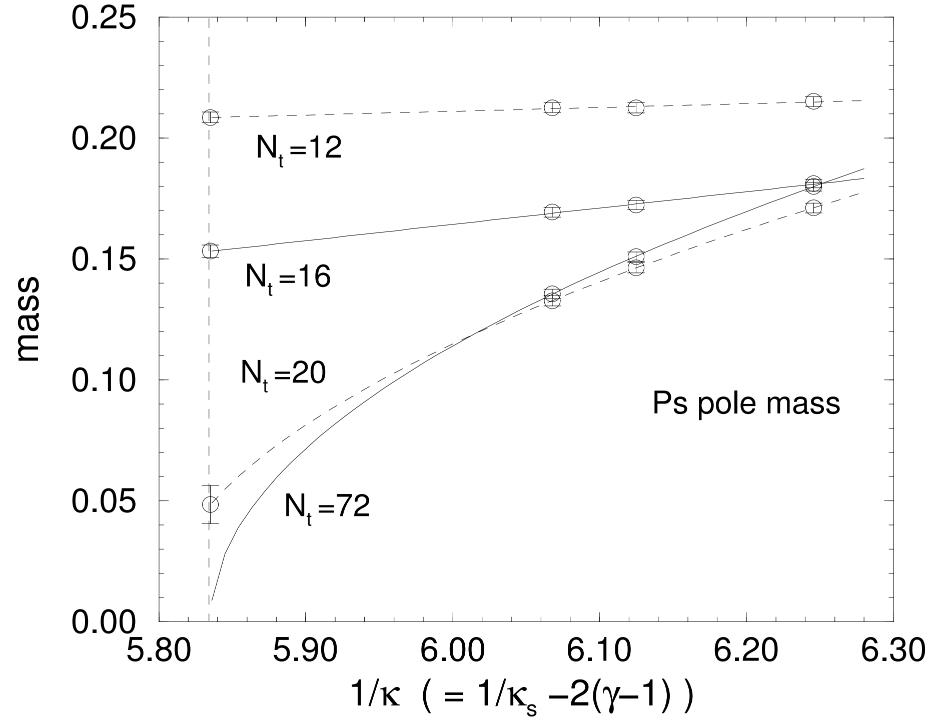
V meson: linear in $1/\kappa$

At $T = 0$ ($N_t = 72$), from pole masses:

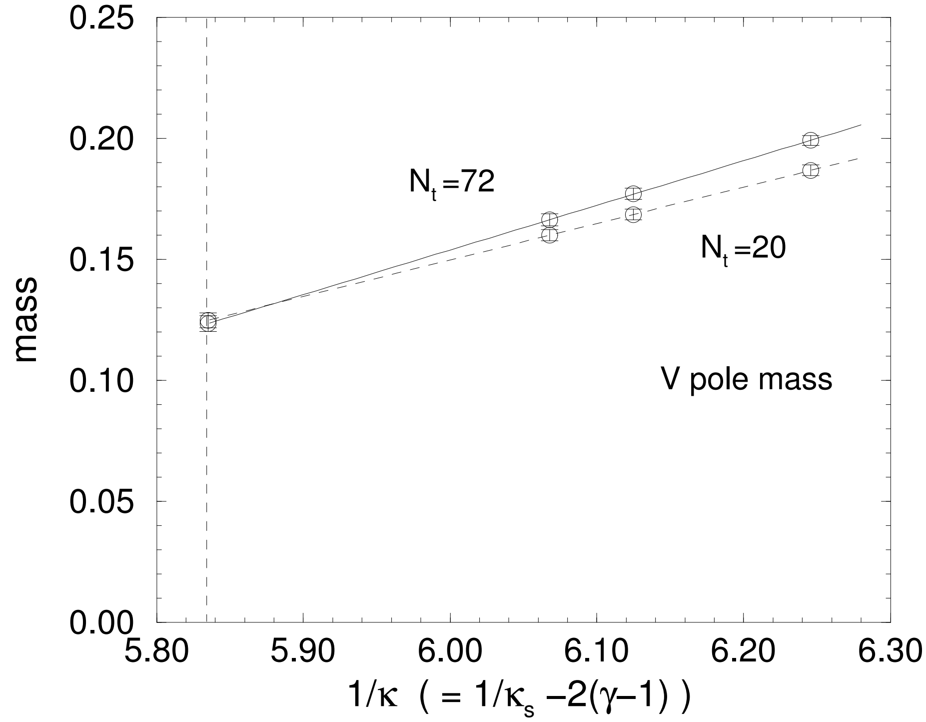
$\kappa_c = 0.17138(20)$
$a_t^{-1}(\rho) = 6.23(16)$ GeV

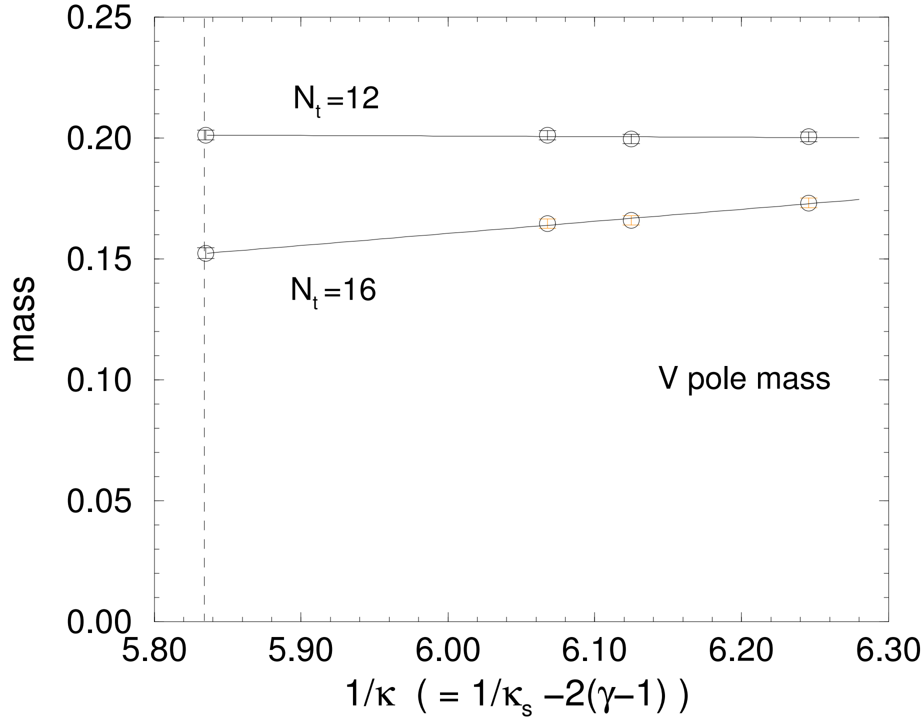
Chiral extrapolation (pole masses: Ps)





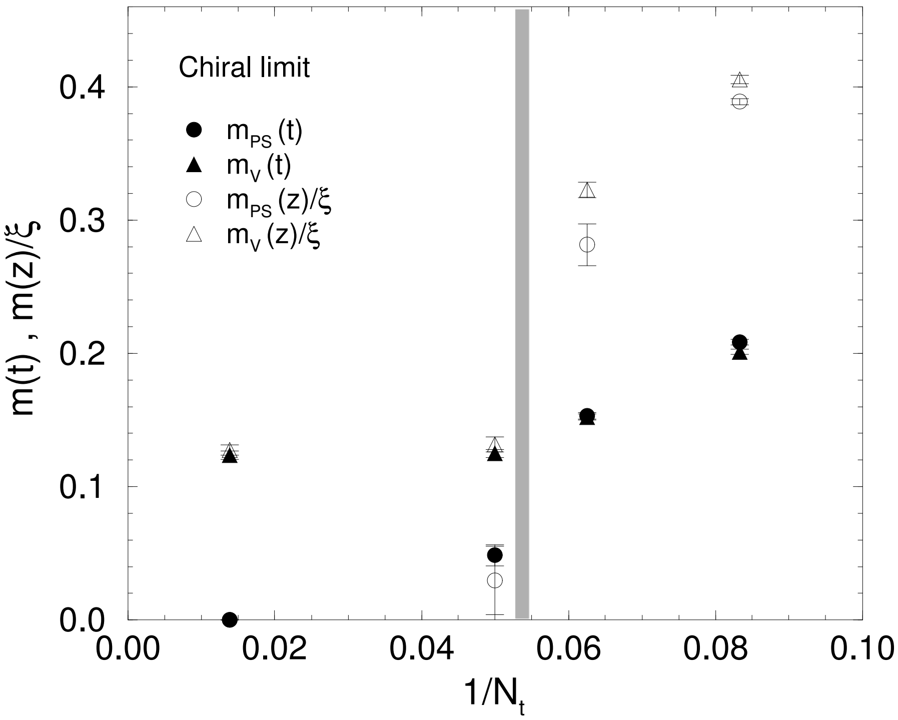
Chiral extrapolation (pole masses: V)





T-dependence of masses (chiral limit)

$\kappa = \kappa_c$

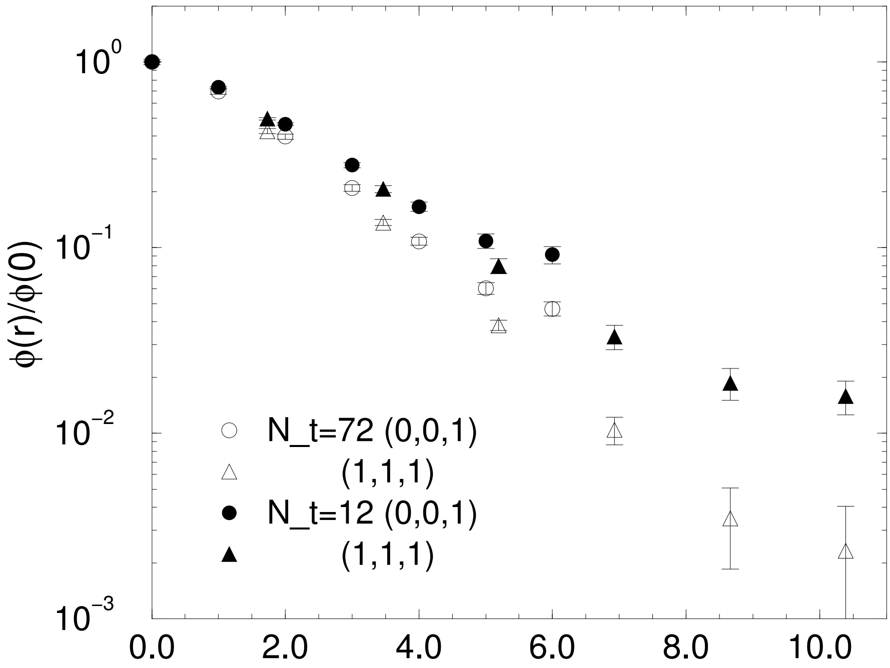


NJL model results

Please see Figure 6.10 in
T. Hatsuda and T. Kunihiro, Phys. Rep. 247 (1994) 221.
In talk, this figure was shown.

Wave function

$\kappa_s = 0.0810,\ N_t = 72,\ 12$



Summary

We calculated pole and screening masses at finite temperature and studied their T-dependence.

- ∘ Difference between pole and screening masses above T_c
- ∘ Ambiguity remains in the extraction of pole masses

Outlook

Other channels: S, A, N
Relation with topological quantities
Precise determination of mass shift
Spectral function

$\Rightarrow$ Larger, improved lattice