The QCD transition with 2+1 dynamical flavors

Y. Aoki, Z. Fodor, S. D. Katz, S. Krieg, K. Szabo

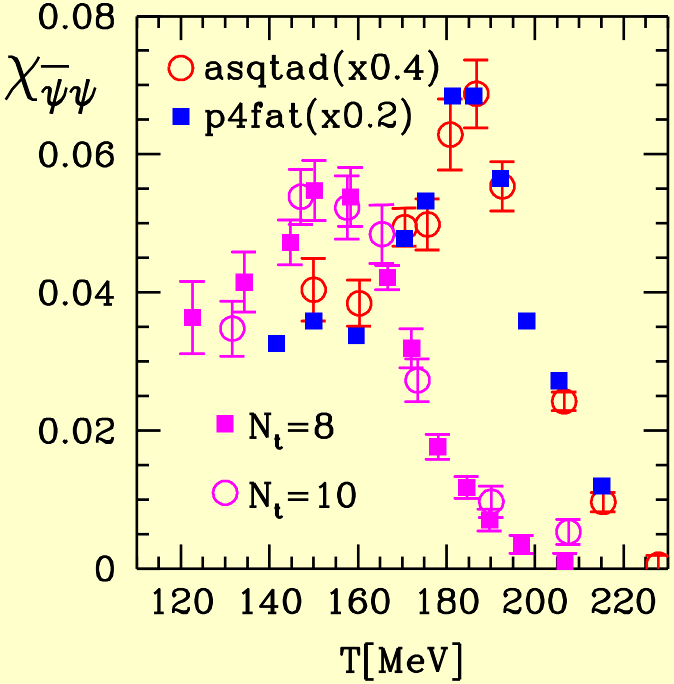
1. Discrepancy in the transition temperature
2. $T = 0$ simulations at the physical point
3. $N_t = 12$ simulations at finite temperature

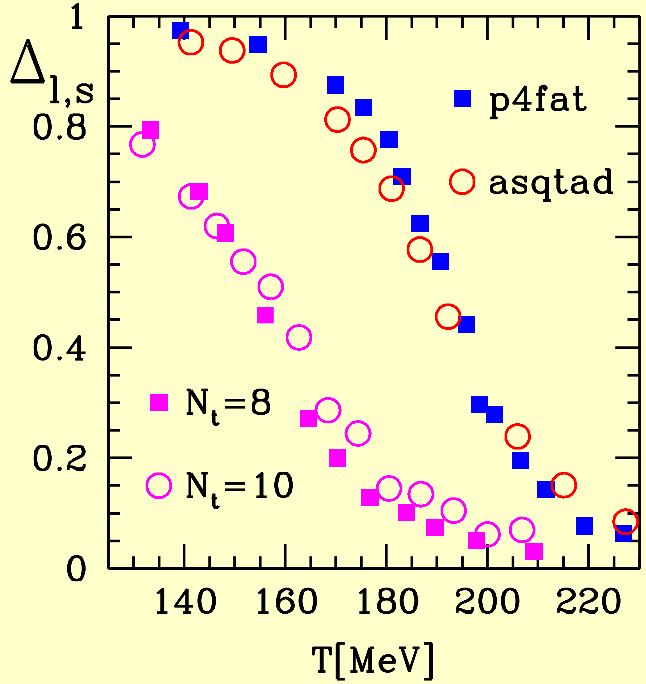
Problem

hotQCD finite T results are very different from ours

(hotQCD data points: 0710.1655, 0711.0661, 0804.4148, RBRC workshop 04.08)

(our old data points: hep-lat/0609068)





chiral susceptibility, rescaled (quark masses are different)

$$\chi_{\bar{\psi}\psi} = m_l^2 \frac{\partial^2}{\partial m_l^2}(f(T) - f(T=0))$$

chiral condensate

$$\Delta_{l,s} = \left(\langle \bar{l}l \rangle - m_l/m_s \langle \bar{s}s \rangle\right) / \left(\langle \bar{l}l \rangle_{T=0} - m_l/m_s \langle \bar{s}s \rangle_{T=0}\right)$$

Possible resolutions

hep-lat/0609068: $N_t = 4, 6$ of 'p4fat3' are too coarse, no controlled continuum limit, status 2008: fine $N_t = 8$ somewhat better but still large discrepancy

our simulations:

• scale set by f_K, non-Goldstone pions distort chiral extrapolation or continuum limit

• naive staggered dispersion relation has large artefacts

hotQCD:

• nonphysical quark masses $\rightarrow \sim 5$ MeV Soeldner's talk

• scale set by $r_0^{\text{HPQCD,UKQCD}}$=0.469(7) fm

r_0^{ETM}=0.444(4) fm, r_0^{QCDSF}=0.467(6) fm, $r_0^{\text{PACS-CS}}$= 0.492(6)(+7) fm

both:

• universality problem of staggered discretization

• bug in computer code

• ...

maybe a bit of all

systematic errors are simply underestimated

Improving our previous results

1. improving $T = 0$ simulations

previously: $m_\pi \geq 240\text{MeV}$ + chiral extrapolations

now: $\boxed{m = m^{\text{phys}}}$, no need for chiral extrapolations

$\Rightarrow$ more precise scale/renormalization

2. improving $T > 0$ simulations

previously: $N_t = 4, 6, 8, 10$ at the physical point

now: $\boxed{N_t = 12}$ at the physical point

$\Rightarrow$ more control over lattice artefacts

Simulation setup: finite T

nVidia GeForce 8800 Ultra
768 MB video memory
103.7 GB/sec bandwidth
two cards per machine

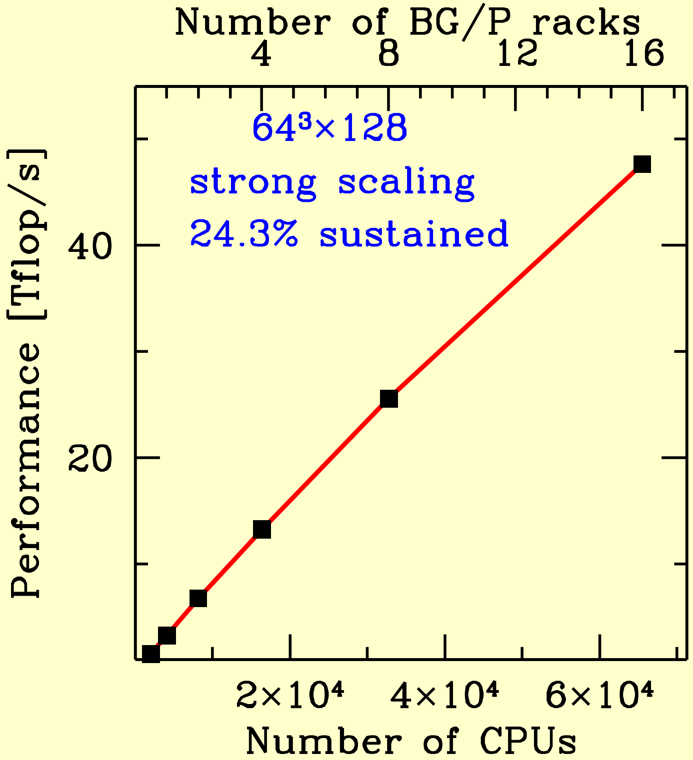
multishift inverter on $12 \cdot 36^3$ fits to the video memory and runs with 32 Gflop
gauge force on the video card: 15 Gflop

only single precision arithmetics, HMC-force is not needed more precisely, for HMC-energy mixed precision inverters ($\epsilon = 10^{-8}$)

50 dual GPU PC's in Wuppertal $\rightarrow$ 3 Tflops $\sim$ 1 BGP rack
cluster computing: ideal for finite T with many parameter sets

Simulation setup: zero T

zero T lattices are too large for a single video card → BG/P supercomputer in Juelich



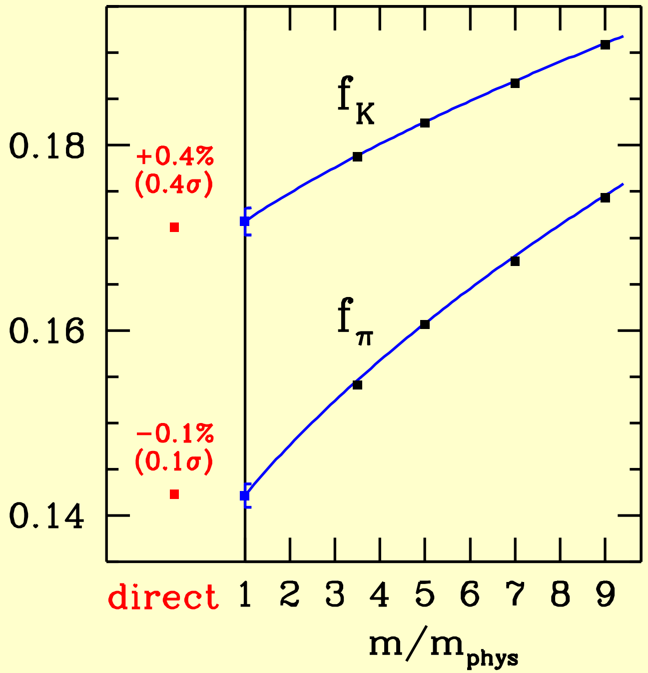
Simulation setup: zero T

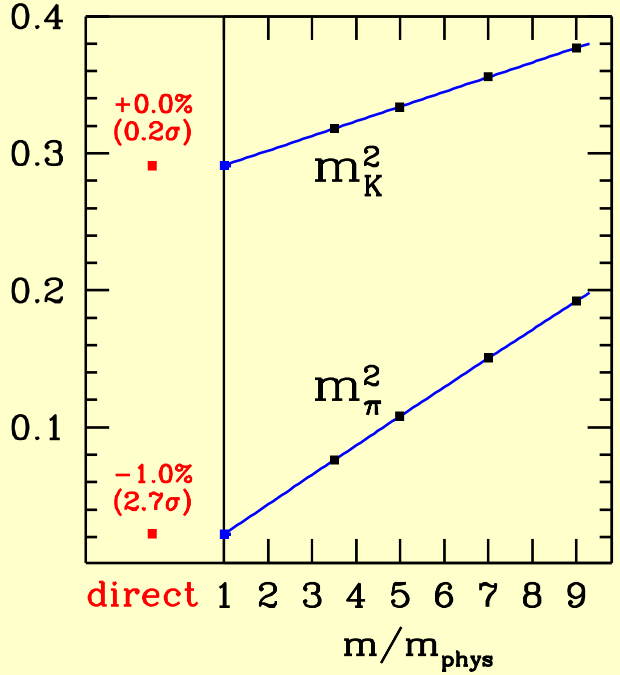
simulations directly at the physical point

choose lattice sizes, so that finite volume corrections are below 0.5% for f_π, m_π, f_K, m_K (cont. formula of Colangelo, Durr, Haefeli '05)

β	N_t^{crit}	lattice	#traj
3.45	~ 4	$24^3 \times 32$	1500
3.55	~ 6	$24^3 \times 32$	3000
3.67	~ 8	$32^3 \times 48$	1500
3.75	~ 10	$40^3 \times 48$	1500
3.85	~ 13	$48^3 \times 64$	1500

Zero T results at the physical point



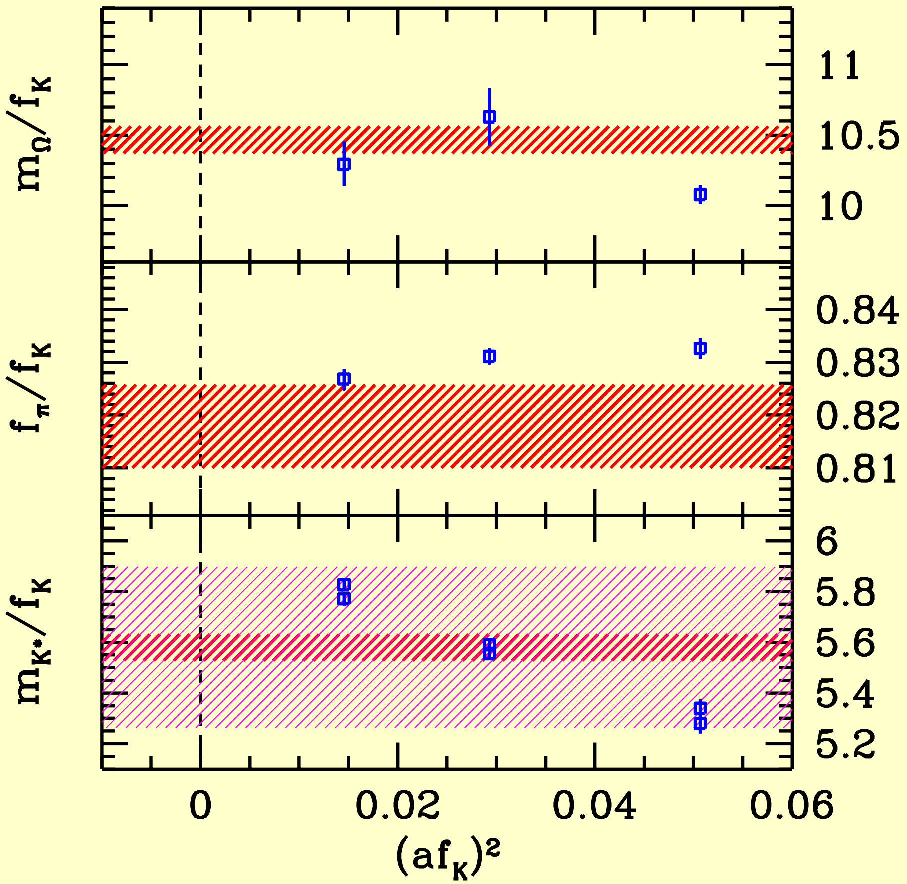


chiral extrapolations (not staggered χPT !) work amazingly well

for all analyzed spacings the extrapolation error for f_π, m_π, f_K, m_K is $\leq$ 1%

hep-lat/0609068: "2% is the accuracy of our LCP."

Zero T results at the physical point



extend spectrum analysis to Ω

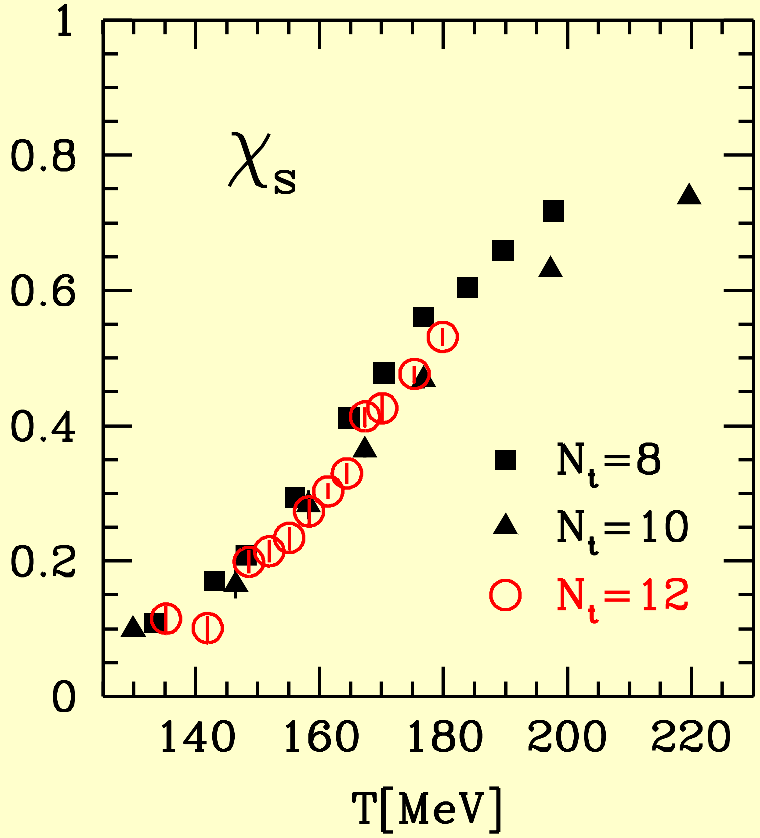
red bands are the experimental values with uncertanities

K^* decays in the physical point, width is also given (pink)

smaller spacings and r_0 are currently under analysis

Finite T results

strange quark number susceptiblity



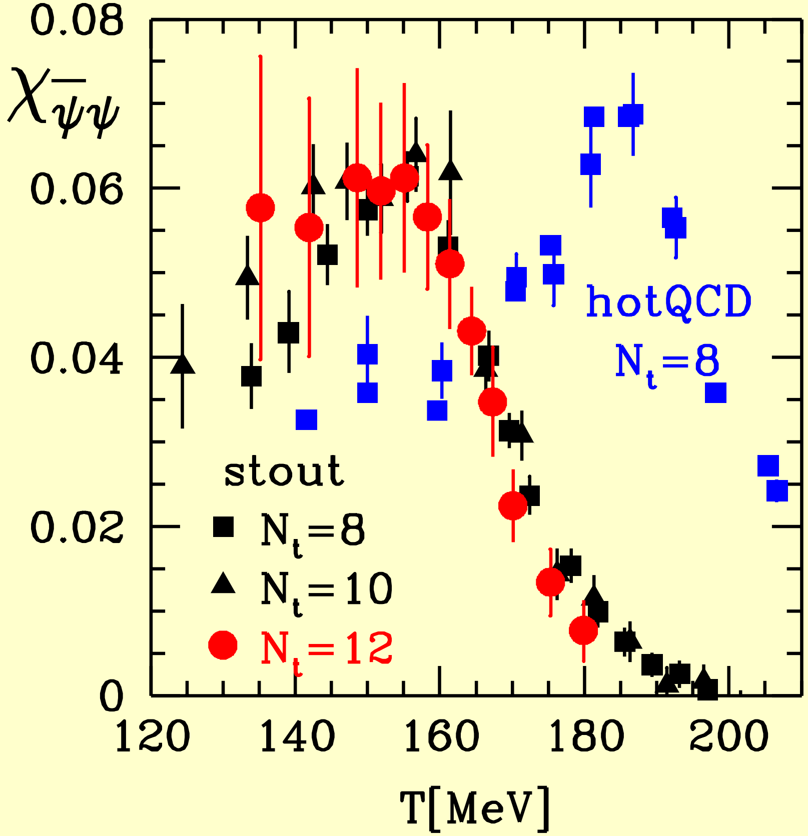
preliminary results, 300-500 trajectories in each point

good agreement with old $N_t = 10$ data

hep-lat/0609068: "For the transition temperature in the continuum limit one gets: $T_c(\chi_s) = 175(2)(4)$ MeV"

Finite T results

renormalized chiral susceptibility



nice agreement with old $N_t = 8, 10$ data

hep-lat/0609068: "the transition temperature based on the chiral susceptibilty reads $T_c(\chi_{\bar\psi\psi}) = 151(3)(3)$ MeV"

Summary

• improving determination of thermodynamical observables by

1. zero T simulations with physical quark masses
2. finite T simulations with $N_t = 12$

• chiral extrapolations were correct on the 1% level

• preliminary results for chiral susceptibility and strange susceptibility on $N_t = 12$ are in good agreement with our old data