COLOR CONFINEMENT AND DUAL SUPER-CONDUCTIVITY IN UNQUENCHED QCD

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ICHEP 2002 AMSTERDAM

ABSTRACT: WE REPORT ON EVIDENCE FROM LATTICE SIMULATIONS THAT CONFINEMENT IS PRODUCED BY DUAL SUPERCONDUCTIVITY IN FULL QCD, AS IN QUENCHED QCD. VACUUM IS A DUAL SUPERCONDUCTOR IN THE CONFINING PHASE, WHILST THE U(1) MAGNETIC SYMMETRY IS REALIZED À LA WIGNER IN THE DECONFINED PHASE.

INTRODUCTION

- SOLID EVIDENCE $\exists$ THAT CONFINEMENT IN QUENCHED QCD [PURE GAUGE] IS PRODUCED BY CONDENSATION OF MAGNETIC MONOPOLES.
[A.dG et al Phys Rev D61 034503, 034504]

- DISORDER PARAMETER $\langle\mu\rangle$, μ A MAGNETICALLY CHARGED OPERATOR, COLOR SINGLET, GAUGE INVARIANT, MAGNETIC $U(1)$ GAUGE INVARIANT. (DIRAC OPERATOR).
$\langle\mu\rangle$ INDEPENDENT OF THE ABELIAN PROJECTION: NUMERICAL EVIDENCE & A THEOREM [A.d.G 0206010]

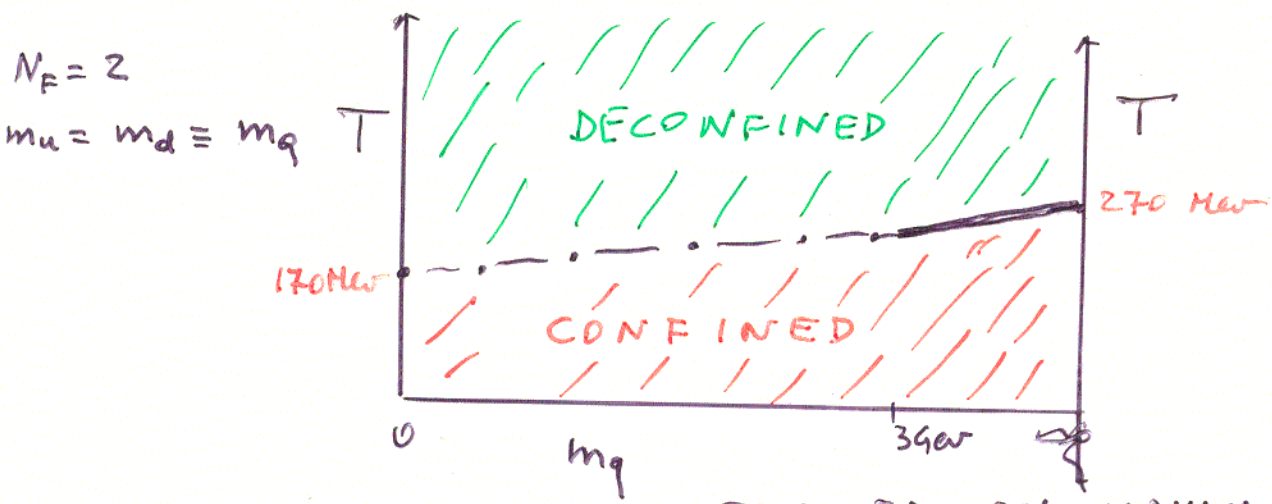
$\langle\mu\rangle \neq 0$ CONFINED PHASE [HIGGS BROKEN MAGN. $U(1)$]

$\langle\mu\rangle = 0$ DECONFINED PHASE [MAGN. CHARGE SUPERSELECTED]

$E \simeq \sigma R$ ABRIKOSOV FLUXTUBES

- PURE GAUGE: TRADITIONAL ORDER PARAMETER $\langle L\rangle$ (DISORDER PARAMETER $\langle\tilde{L}\rangle$) TO COMPARE WITH:
$\langle\mu\rangle = \langle\tilde{L}\rangle$ [L. Del Debbio et al Nucl Phys B 594, 287 (2001)
Phys Lett B 500, 326, (2001)]

- FULL QCD: TRADITIONAL DESCRIPTION CONFUSING



TRANSITION LINE DEFINED BY MAXIMA OF χ'S
[Karsch et al]

$$\chi_{LL}^{(T,m_q)} = \int d^3x \langle L^+(\vec{x})\, L(\vec{0})\rangle$$

$$\chi^{(T,m_q)} = \int d^3x \langle \bar\Psi\Psi(\vec{x})\, \bar\Psi\Psi(\vec{0})\rangle$$

ALL $\chi_S(T, m_q)$'s HAVE A MAXIMUM AT THE SAME VALUE $T_c(m$

HOWEVER THIS MAXIMUM DOES NOT DIVERGE AS $N_S^3 = V \Rightarrow \infty$

IN THE RANGE $0 < m_q < \sim 3\,\text{GeV}$ $\Longrightarrow$ CROSSOVER. $(N_S^{1/\nu}$

- SUSCEPTIBILITIES THAT KEEP MEMORY OF THE ORDER OF THE TRANSITION ARE THOSE OF THE ORDER PARAMETERS.

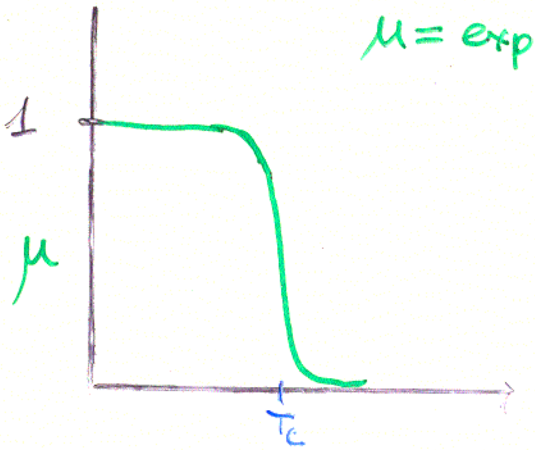
$\langle L \rangle$ ORDER PARAMETER AT $m_q \simeq \infty$ (QUENCHED)

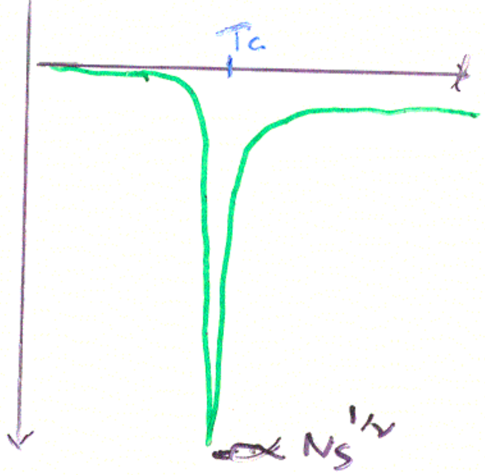
$\langle \bar\psi \psi \rangle$ ORDER PARAMETER AT $m_q \simeq 0$ (CHIRAL LIMIT)

- DISORDER PARAMETER $\langle \mu \rangle \neq 0$ SIGNALS DUAL SUPERCONDUCTIVITY OF VACUUM. CAN BE A BETTER PARAMETER.

- RESULTS LATTICES 4×12^3; 4×16^3; 4×20^3; 4×32^3

$\mu = \exp\left[\int_0^\beta \rho(\beta')\, d\beta'\right]$ $\qquad$ $\rho \equiv \frac{d}{d\beta} \ln \langle \mu \rangle$





$V \to \infty$ $\qquad$ $V = N_S^3$

$T < T_c$ $\qquad$ $\mu \neq 0$ $\qquad$ $\rho \underset{V\to\infty}{\to} \bar\rho$ FINITE

$T > T_c$ $\qquad$ $\mu = 0$ $\qquad$ $\rho = -K N_S + \rho_0$ $\qquad$ $K > 0$

$T \simeq T_c$ $\qquad$ $\langle \mu \rangle \simeq \tau^\delta \, \Phi\left(\frac{a}{\xi}, \frac{\xi}{L_S}, m_q L_S^\gamma\right)$

γ = anom. dim. m_q ; $\qquad$ $\xi \sim \tau^{-\nu}$; $\qquad$ $\tau \equiv \left(1 - \frac{T}{}\right)$

SCALING $\frac{a}{\xi} \simeq 0$ $\frac{\xi}{L_s} \Leftrightarrow L_s^{1/\nu}\tau$

$$\langle \mu \rangle = \tau^{\delta}\, \Phi(0, L_s^{1/\nu}\tau, m_q L_s^{\gamma})$$

- QUENCHED : NO m_q.

$$\langle \mu \rangle = \tau^{\delta}\, \Phi(0, L_s^{1/\nu}\tau) \Rightarrow \rho / L_s^{1/\nu} = f(\tau L_s^{1/\nu})$$

$\Downarrow$ ν, T_c, δ

SU(2) $\nu = .62(1)$ $\delta = .20(2)$ 2nd order

SU(3) $\nu = .33(1)$ $\delta = .50(2)$ 1st order

[A.D.G. et al 2000]

. UNQUENCHED (new)

2 scales : keep $m_q L_s^{\gamma}$ fixed $\gamma = .83$ [Karsch et al]

AGAIN $\rho / L_s^{1/\nu} = f(\tau L_s^{1/\nu})$

$\Rightarrow$ ν, $T_c(m)$, δ

PRELIMINARY RESULT : $\nu = 1/3$ 1st ORDER.

FIGS

CONCLUSIONS & OUTLOOK.

- IN FULL QCD CONFINEMENT IS PRODUCED BY MONOPOLE CONDENSATION LIKE IN QUENCHED QCD

A UNIFYING ORDER PARAMETER EXISTS

- (PRELIMINARY) THE DECONFINING TRANSITION AT $m_q \neq 0$ IS 1st ORDER. TO BE CHECKED IN MORE DETAIL BY USE OF (BIELEFELD) IMPROVED ACTION.

= IMPORTANT ISSUE FOR QGP DETECTION IN HEAVY IONS COLLISIONS

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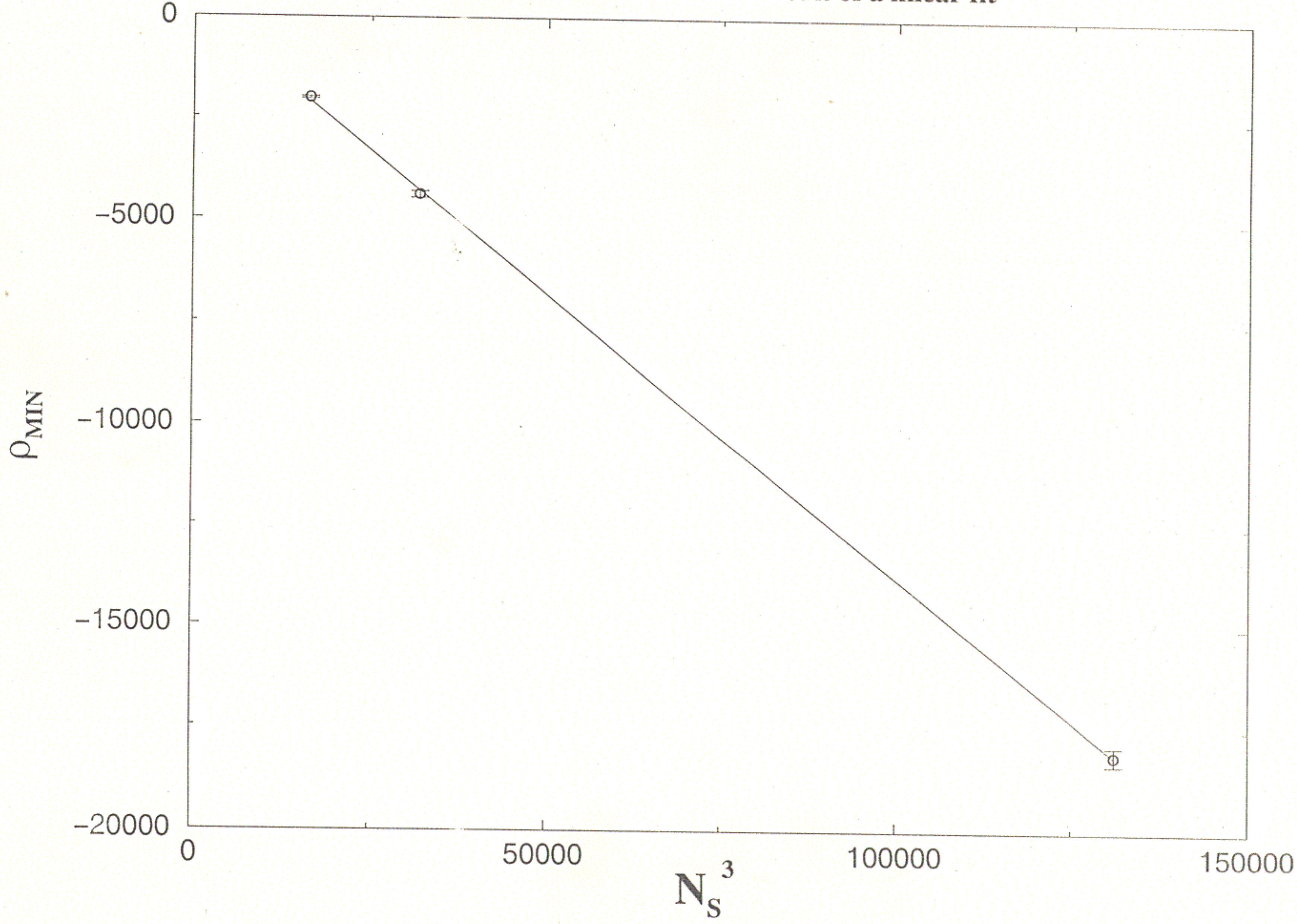
Scaling of the ρ peak

The continuous line is the result of a linear fit



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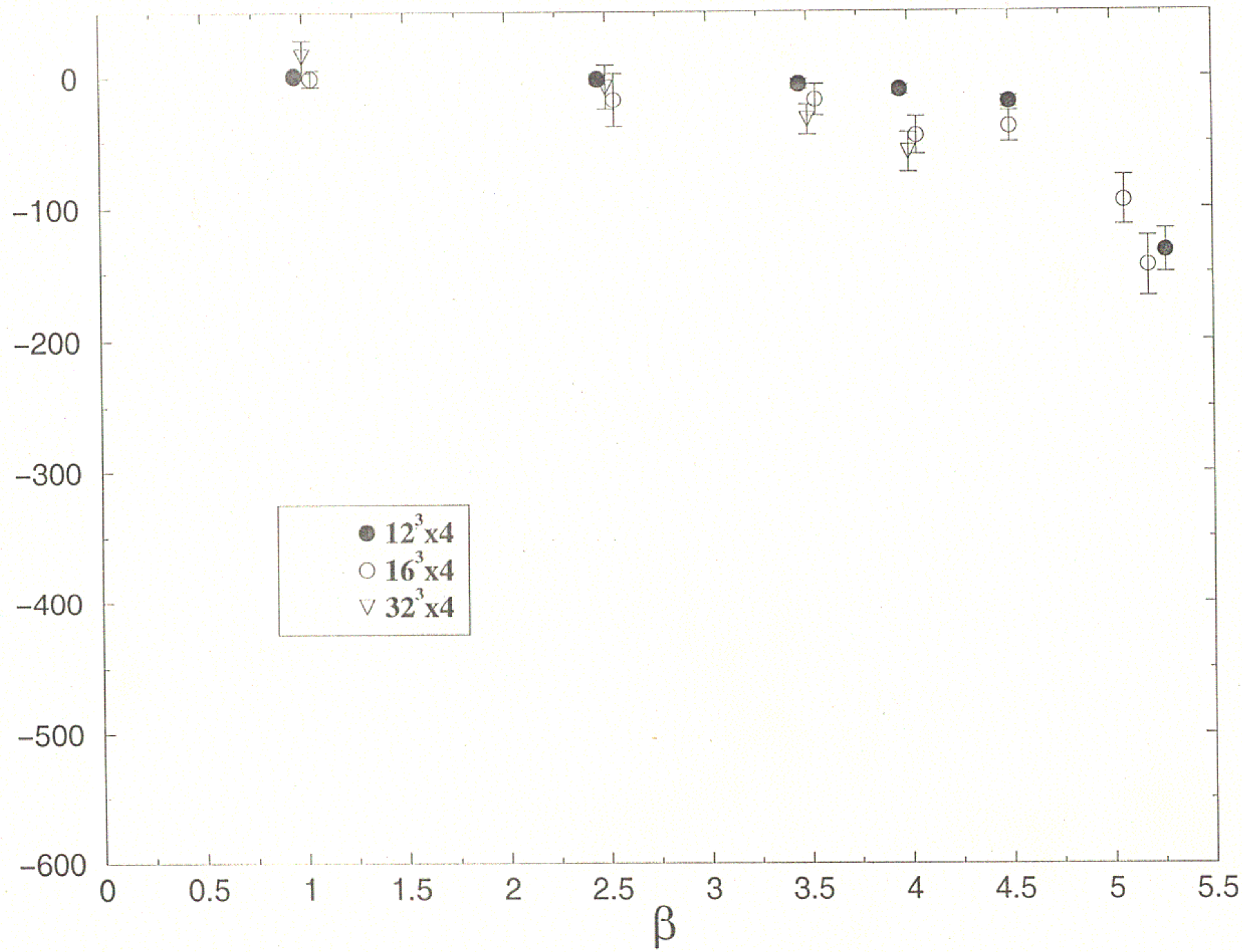
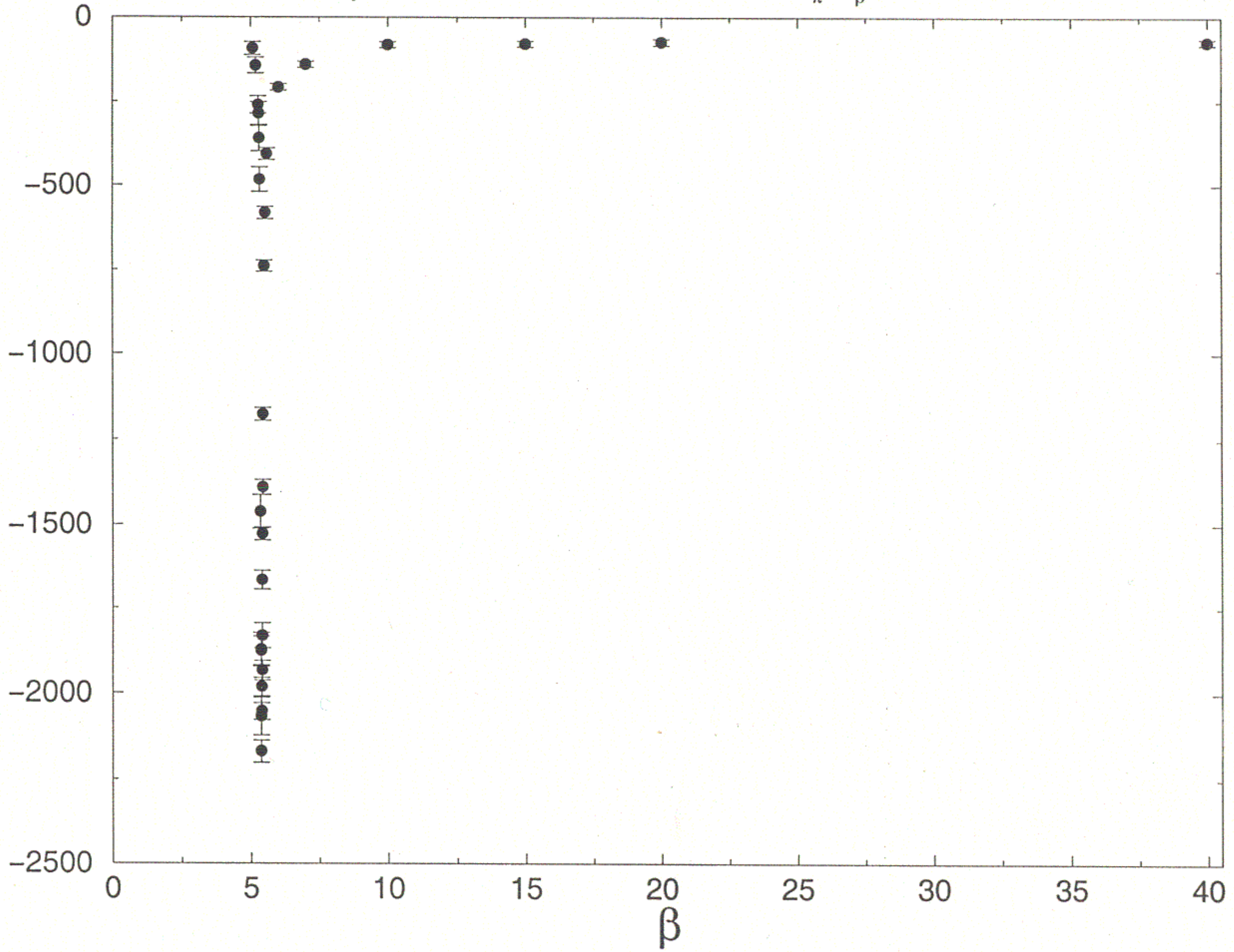
Strong coupling behaviour of rho

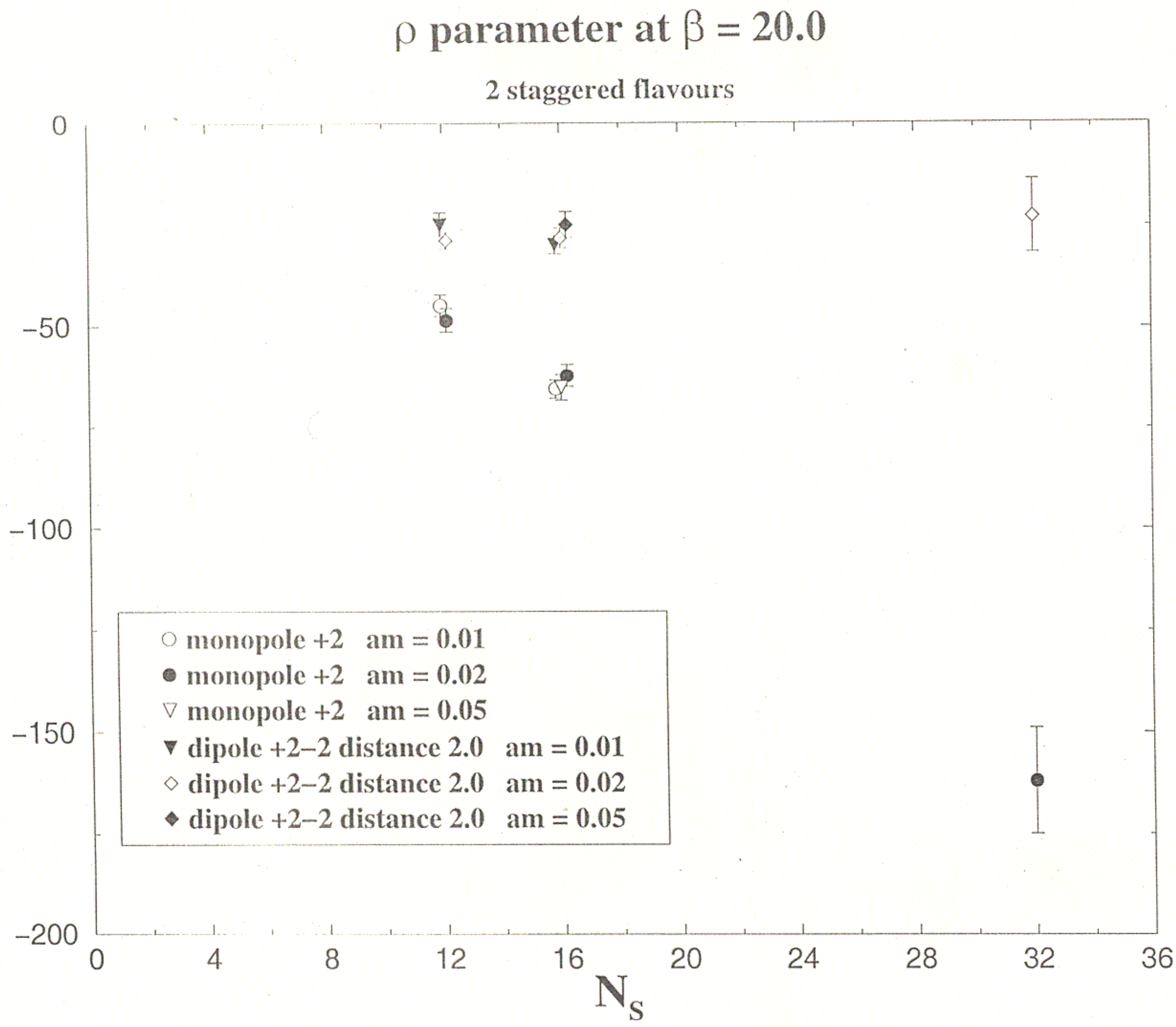
2 flavours QCD



Rho parameter in two flavours QCD

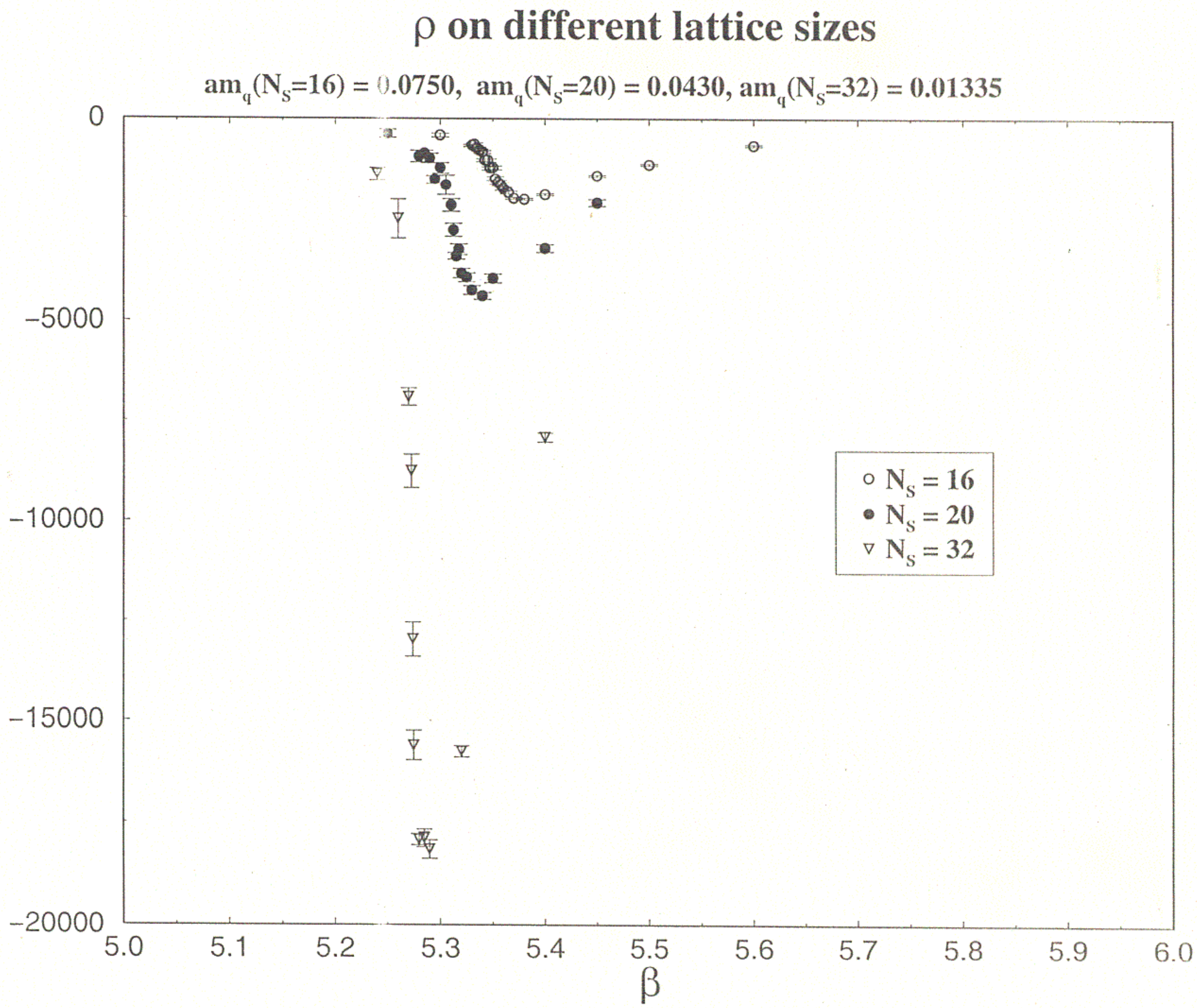
$N_t = 4$, KS fermions, 16^3x4 lattice, $m_\pi/m_\rho = 0.505$





ρ parameter at β = 20.0
2 staggered flavours
0
−50
−100
−150
−200
0
4
8
12
16
20
24
28
32
36
N_S
monopole +2 am = 0.01
monopole +2 am = 0.02
monopole +2 am = 0.05
dipole +2−2 distance 2.0 am = 0.01
dipole +2−2 distance 2.0 am = 0.02
dipole +2−2 distance 2.0 am = 0.05

L02 45



ρ on different lattice sizes
am_q(N_S=16) = 0.0750, am_q(N_S=20) = 0.0430, am_q(N_S=32) = 0.01335
0
−5000
−10000
−15000
−20000
5.0
5.1
5.2
5.3
5.4
5.5
5.6
5.7
5.8
5.9
6.0
β
N_S = 16
N_S = 20
N_S = 32

Finite size scaling analysis with $\nu = 1/3$