Lattice 2004
Fermilab
June 21-26, 2004

# Light

- Hadron Spectrum
- Renormalization Constants
- Quark Masses

# with 2 Dynamical Fermions

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SPQcdR Collaboration

# SPQcdR Collaboration's

## $1^{st}$ partially quenched simulation

**(APEmille)**

**Let's start with a "simple" analysis**

**SPECTROSCOPY**

**Later on:**

$K^0 - \overline{K^0}$ MIXING

$K$ semileptonic decays

$K \to \pi\pi$ ...

**Near future (Autumn 2004)**

**ape*NEXT***
**[INFN+DESY+Paris Sud]** → **(1÷10 TFlops)**

# PARTIALLY QUENCHED SIMULATION
## (2 dynamical fermions)

- Plaquette Gauge Action($\beta$=5.8) + Wilson Quark Action
- 2 Volumes: $16^3$x48, $24^3$x48 (in progress)
- 4 sea quark mass values: $M_{PS}/M_V$=0.66÷0.80

**4 values of $k_s$, $k_{v1}$, $k_{v2}$ combined in all possible ways**

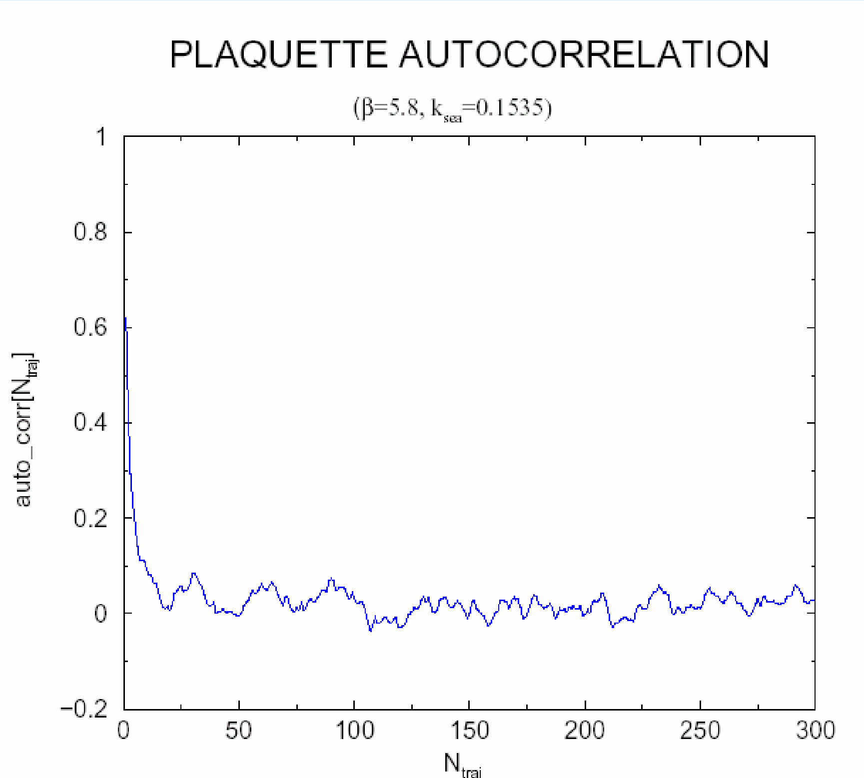
- Preconditioned (LL-SSOR) Hybrid Monte Carlo ($L_{traj}$=1)
- Leap-frog Integration Scheme ($\delta t = 4 \cdot 10^{-3}$)
- BiCGStab Inversion Algorithm ($r=10^{-15}$, $N_{max}$=600)

**ACCEPTANCE >80%**
**REVERSIBILITY at level $10^{-11}$**
**INVERSION ROUNDING ERROR~$10^{-8}$**

## $V=16^3x48$ : 4500 traj. at each sea quark mass
## 45 trajectories ⇒ 1 independent configuration

# AUTOCORRELATION

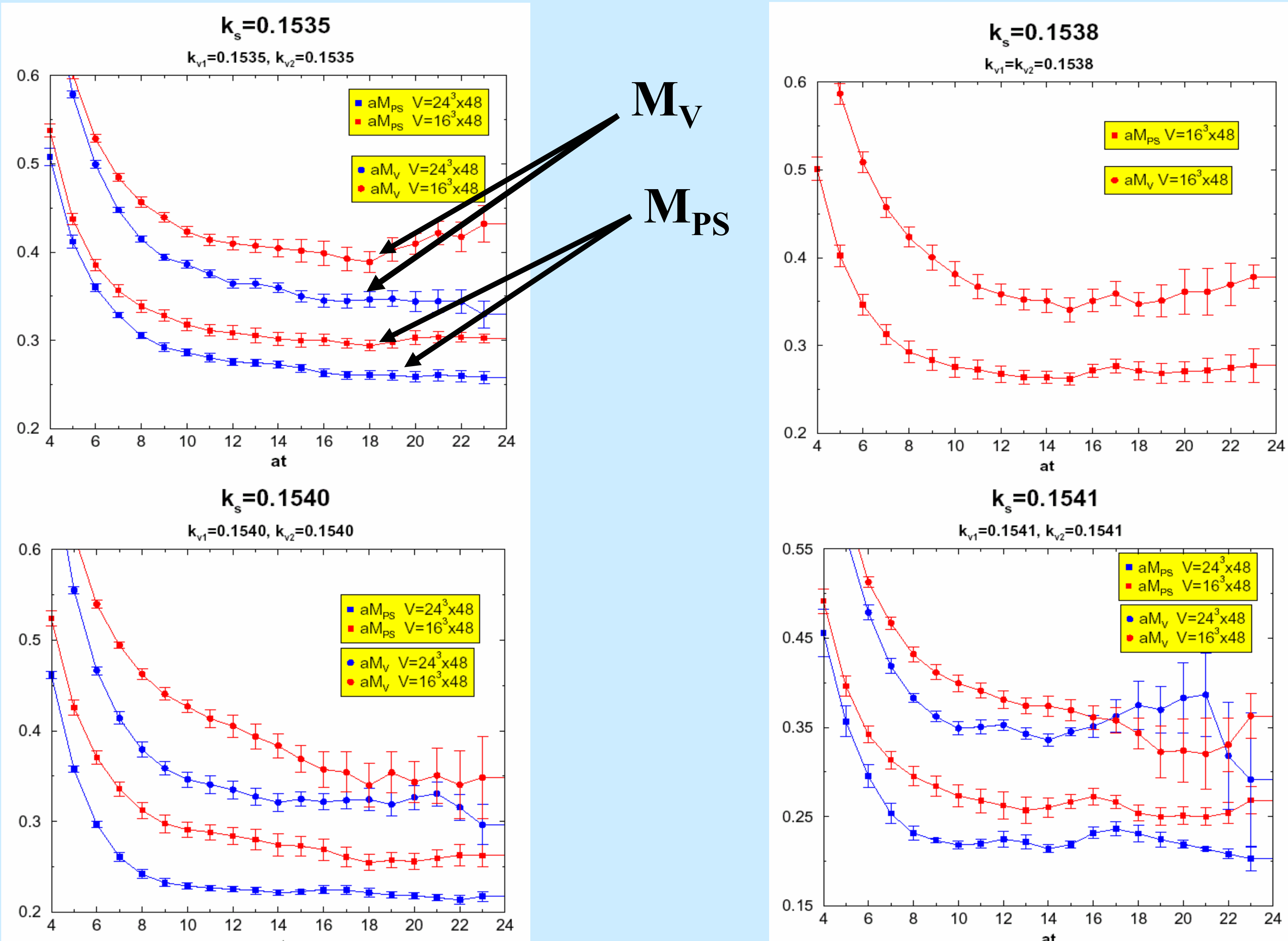
$$\rho_f(t) = \frac{< f_s f_{s+t} > - < f_s >^2}{< f_s f_s > - < f_s >^2}$$



Decreasing sea quark mass

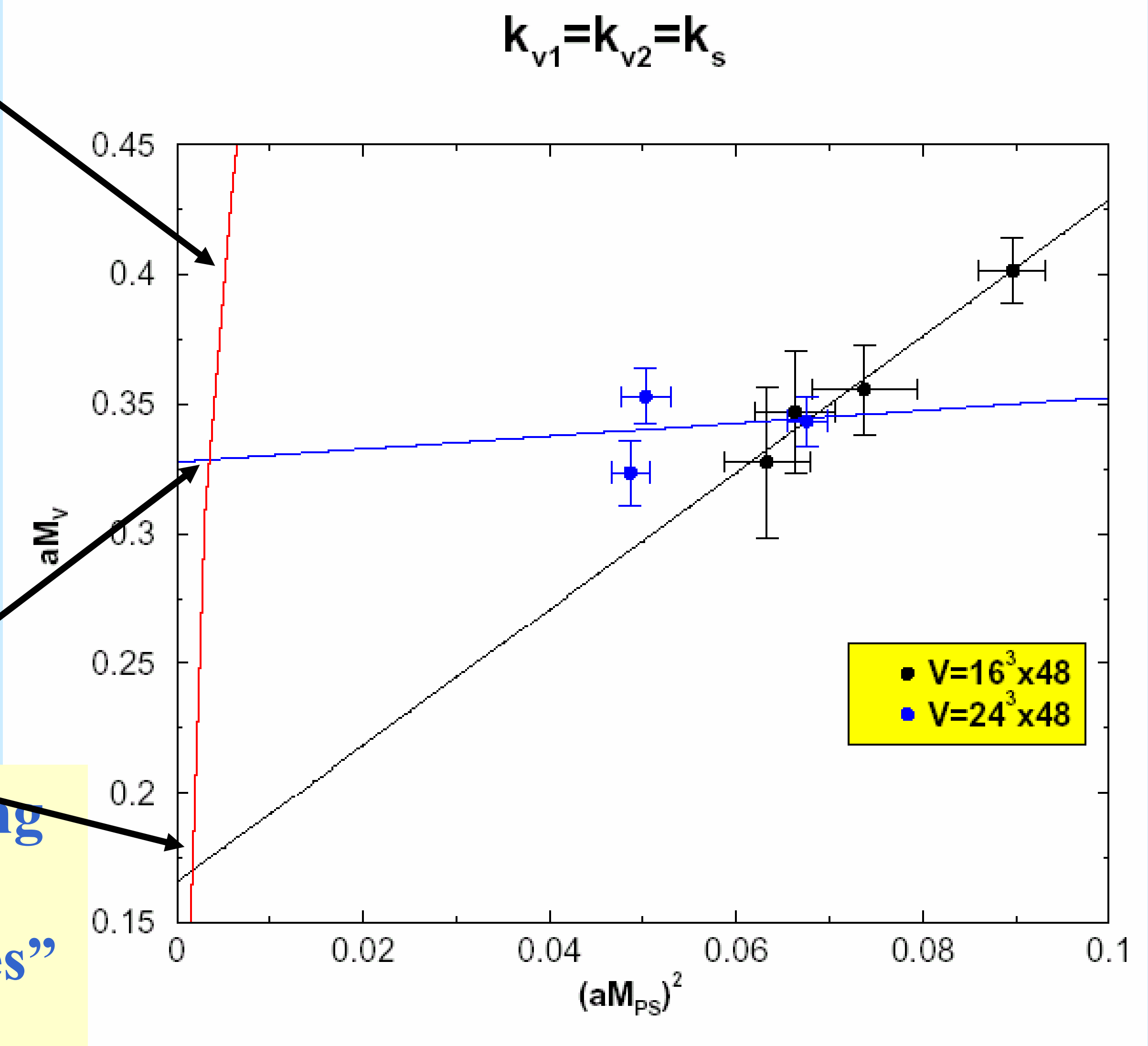
# LIGHT HADRON SPECTRUM

## Plateaux and Finite Volume Effects



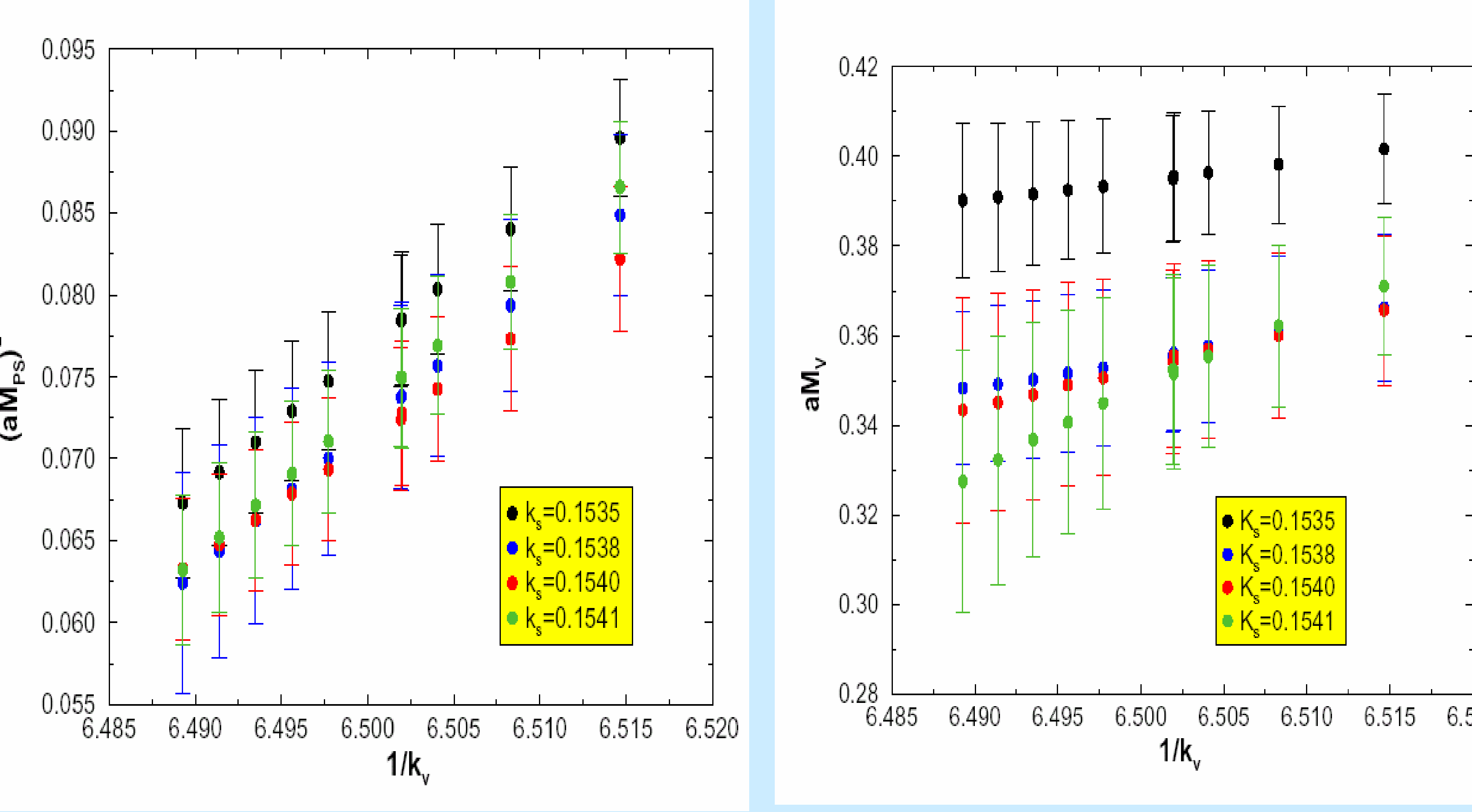
# LARGE FINITE VOLUME EFFECTS

$(M_\rho/M_\pi)^{phys}$

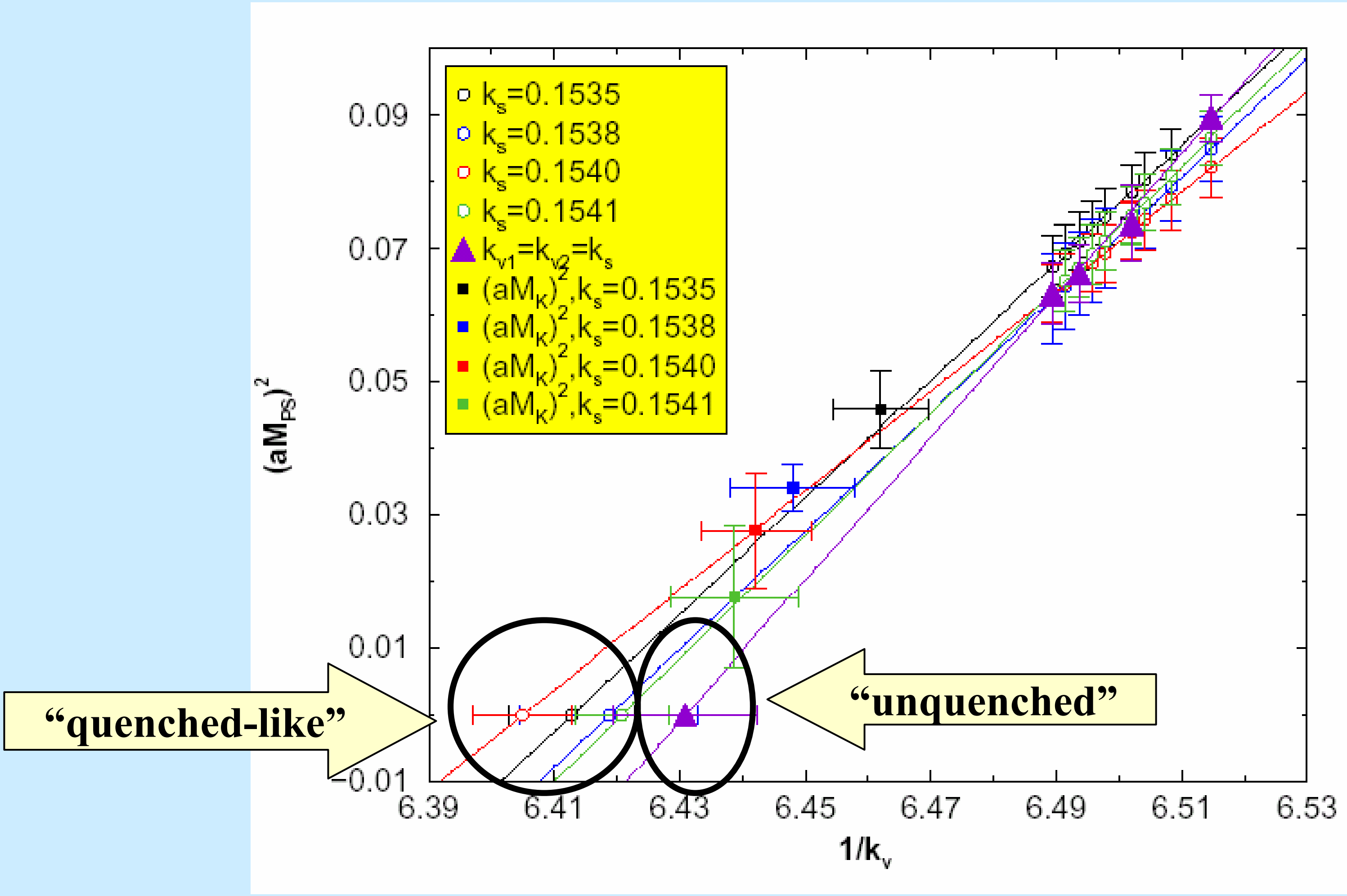



Lattice spacing from the "lattice-planes" method

# Irregular dependence on the sea quark mass



# "UNQUENCHED" VS "QUENCHED-like" ANALYSIS



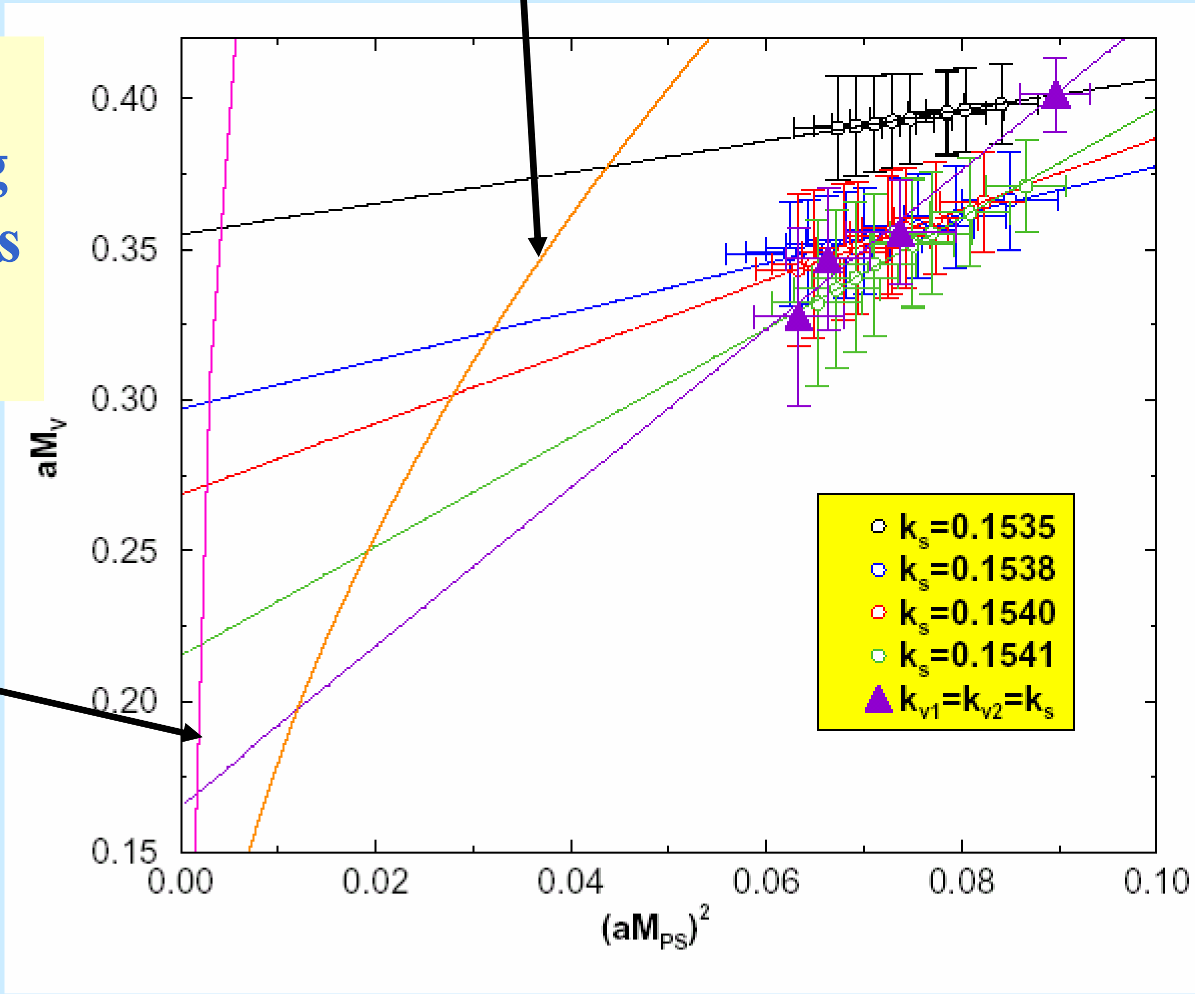
# Uncertainty on the lattice spacing

$$g^2_{lat} = g^2_0[1-2g^2_0\beta_0\ln(a\mu)+\ldots]$$

**Independence of the lattice spacing on the quark mass**

**[ALPHA,CP-PACS and JLQCD, 2003]**

$(M_{K*}/M_K)^{phys}$




$(M_\rho/M_\pi)^{phys}$

# RENORMALIZATION CONSTANTS

## (non-perturbative RI-MOM method)

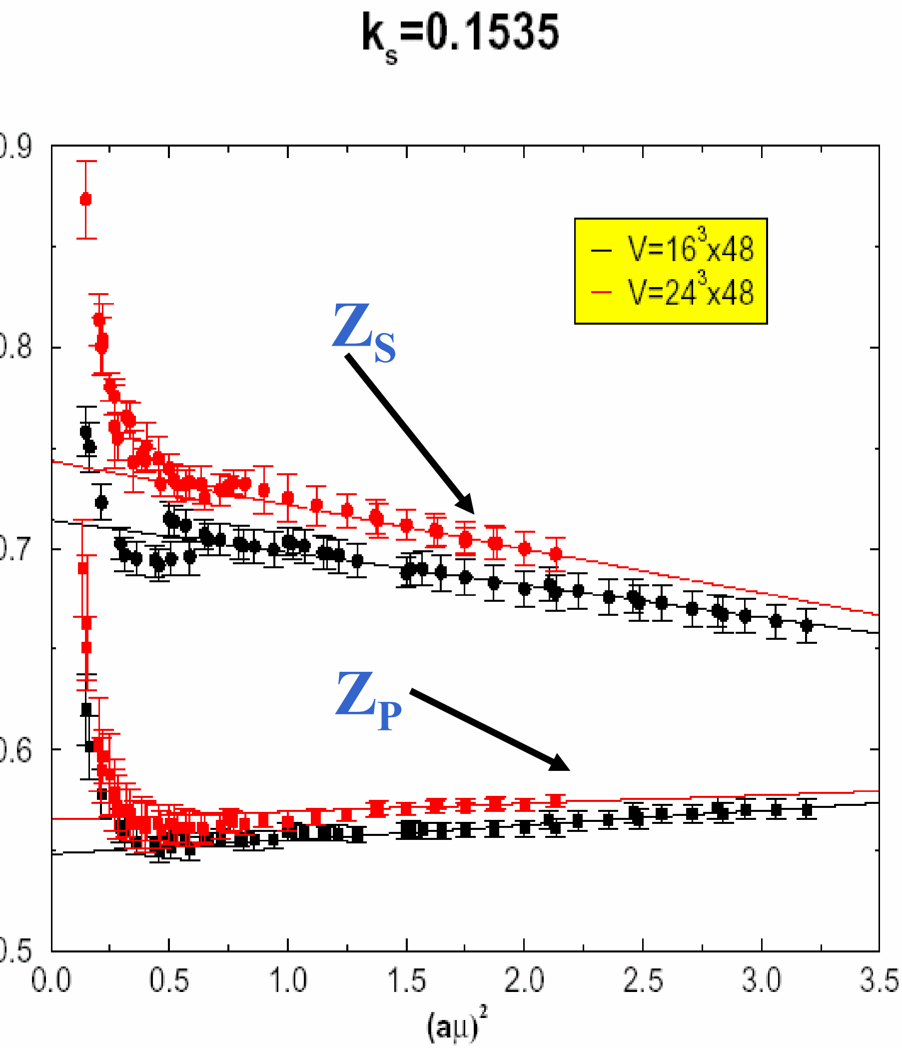
$$Z_\Gamma \Gamma_\Gamma(p)\big|_{p^2=\mu^2} = 1, \qquad \Lambda_{\mathrm{QCD}} << \mu << \frac{\pi}{a}$$

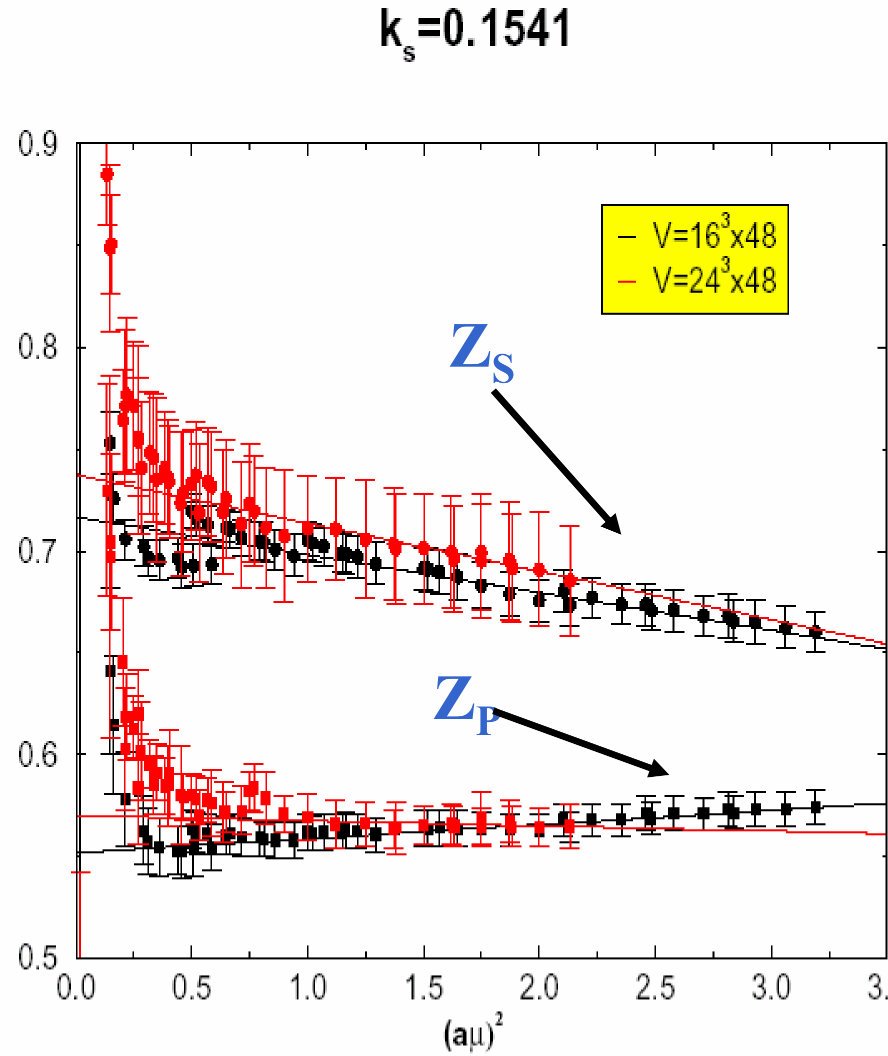
$$Z_A, Z_V, Z_S(\mu), Z_P(\mu), Z_T(\mu)$$

## From the renormalization group equation:

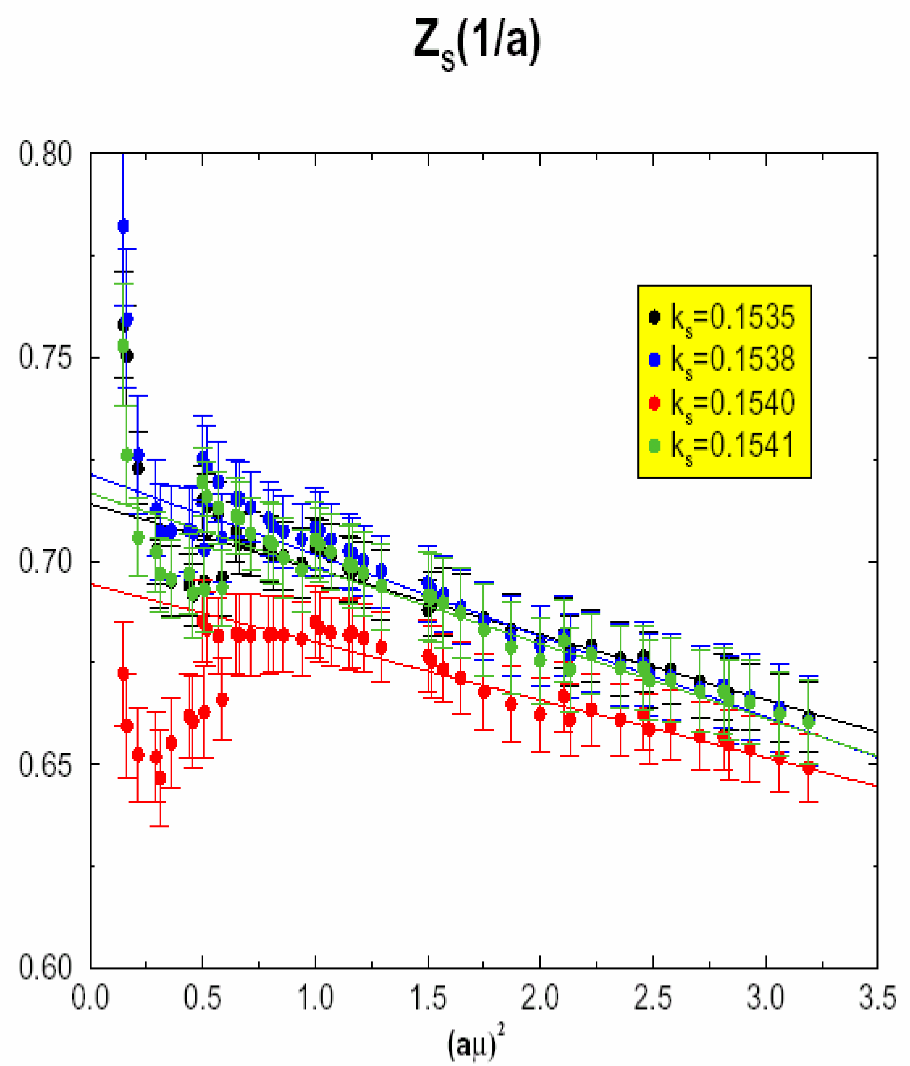
$$Z_\Gamma(\mu) = Z_\Gamma(\mu_0)\left(\frac{\alpha_s(\mu)}{\alpha_s(\mu_0)}\right)^{\gamma_0/(2\beta_0)}\left(1 + \frac{\alpha_s(\mu)-\alpha_s(\mu_0)}{4\pi} J\right)$$

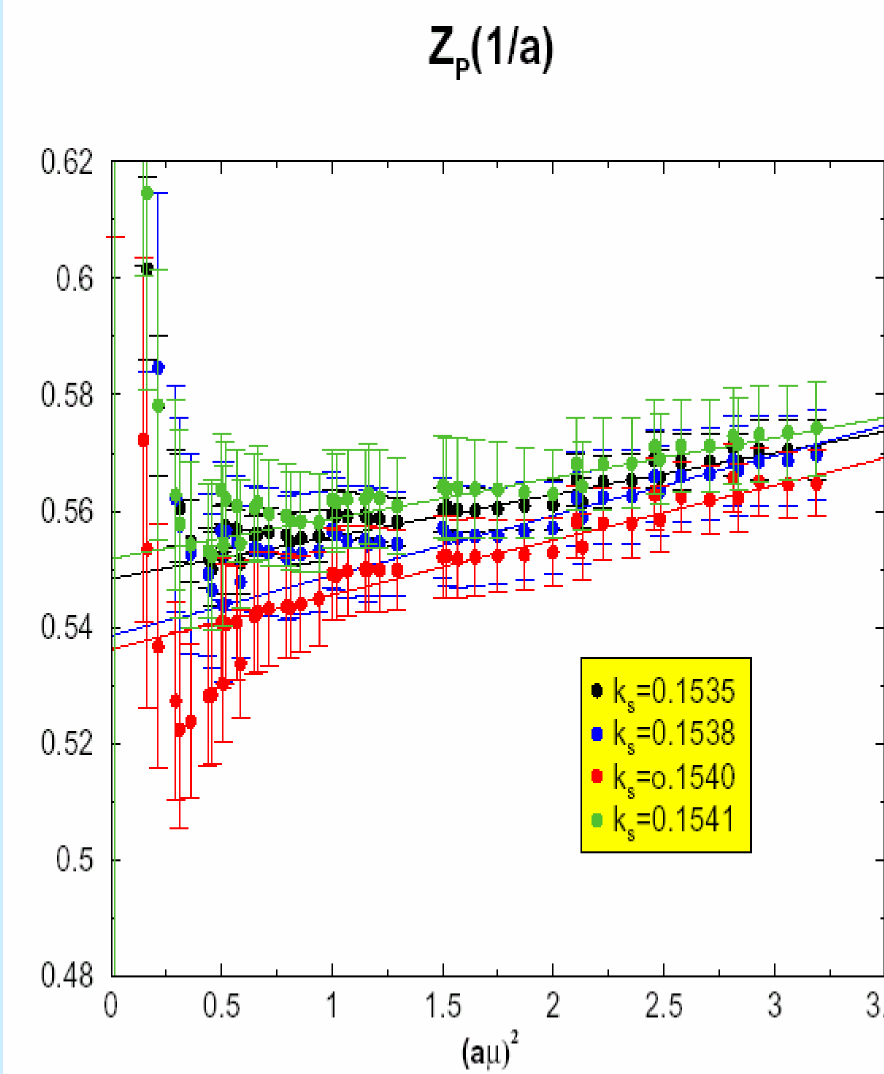
# Finite Volume Effects



# Small dependence on the sea quark mass



# LIGHT QUARK MASSES

Ward Identities + ChPT guided Fits:

$$M_{PS}^2 = A \cdot (am)^{VWI}$$
$$M_{PS}^2 = B \cdot (am)^{AWI} + C$$

**O(a)**

## VWI

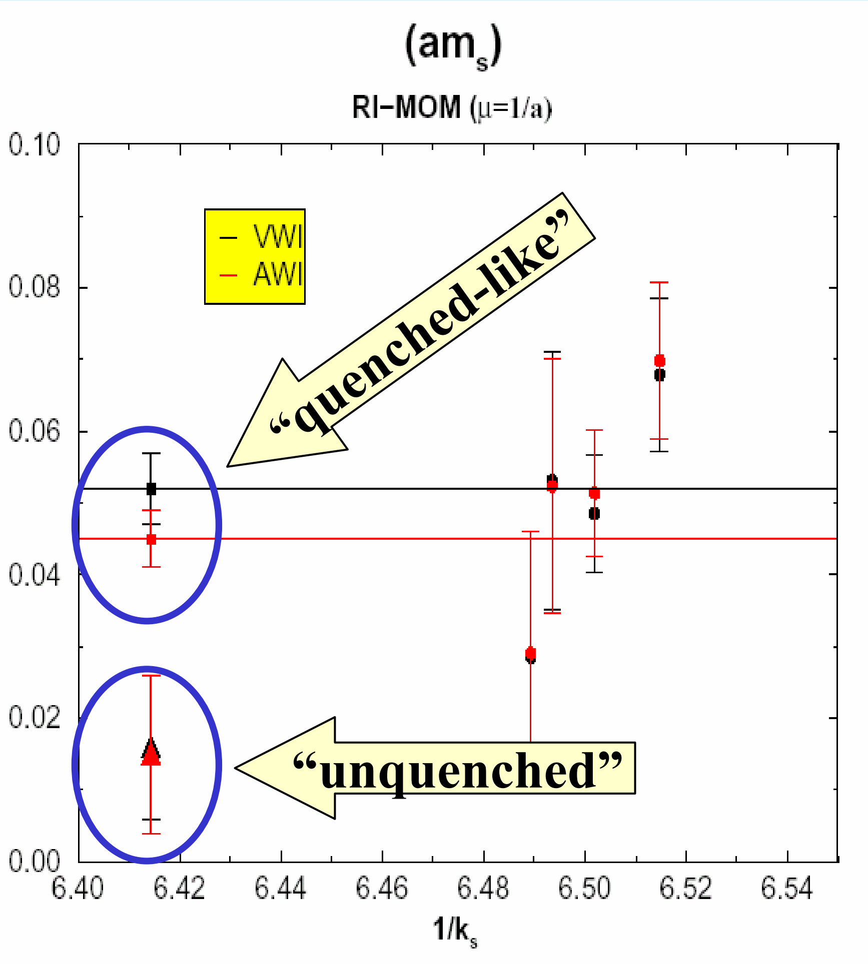
$$\nabla_\mu < \alpha | \hat{V}_\mu | \beta > = (\hat{m}_1(\mu) - \hat{m}_2(\mu)) < \alpha | \hat{S}(\mu) | \beta >$$

$$a\hat{m}(\mu) = Z_S^{-1}(\mu) \frac{1}{2} \left( \frac{1}{k} - \frac{1}{k_c} \right)$$

## AWI

$$\nabla_\mu < \alpha | \hat{A}_\mu | \beta > = (\hat{m}_1(\mu) + \hat{m}_2(\mu)) < \alpha | \hat{P}(\mu) | \beta >$$

$$a\hat{m}(\mu) = \frac{Z_A}{Z_P(\mu)} a\tilde{\rho} = \frac{Z_A}{Z_P(\mu)} \frac{1}{2} \frac{< \alpha | \nabla_0 A_0 | \beta >}{< \alpha | P | \beta >}$$




# PRELIMINARY!!!

## "unquenched" results

$$\overline{MS}(\mu = 2GeV)$$

| VWI | AWI |
| --- | --- |
| $m_l = (3.6 \pm 1.1)MeV$ | $m_l = (3.3 \pm 1.4)Me$ |
| $m_s = (74 \pm 26)MeV$ | $m_s = (69 \pm 31)Me$ |

## "quenched-like" results

$$\overline{MS}(\mu = 2GeV)$$

| VWI | AWI |
| --- | --- |
| $m_l = (6.4 \pm 0.4)MeV$ | $m_l = (5.5 \pm 0.4)Me$ |
| $m_s = (145 \pm 9)MeV$ | $m_s = (125 \pm 7)Me$ |

- Good agreement between VWI and AWI
- Discrepancy between "unquenched" and "quenched-like" analysis

# CONCLUSIONS

## HADRON SPECTRUM

- large finite volume effects (~10%)
- irregular dependence on the sea quark mass

## RI-MOM RENORMALIZATION CONSTANTS

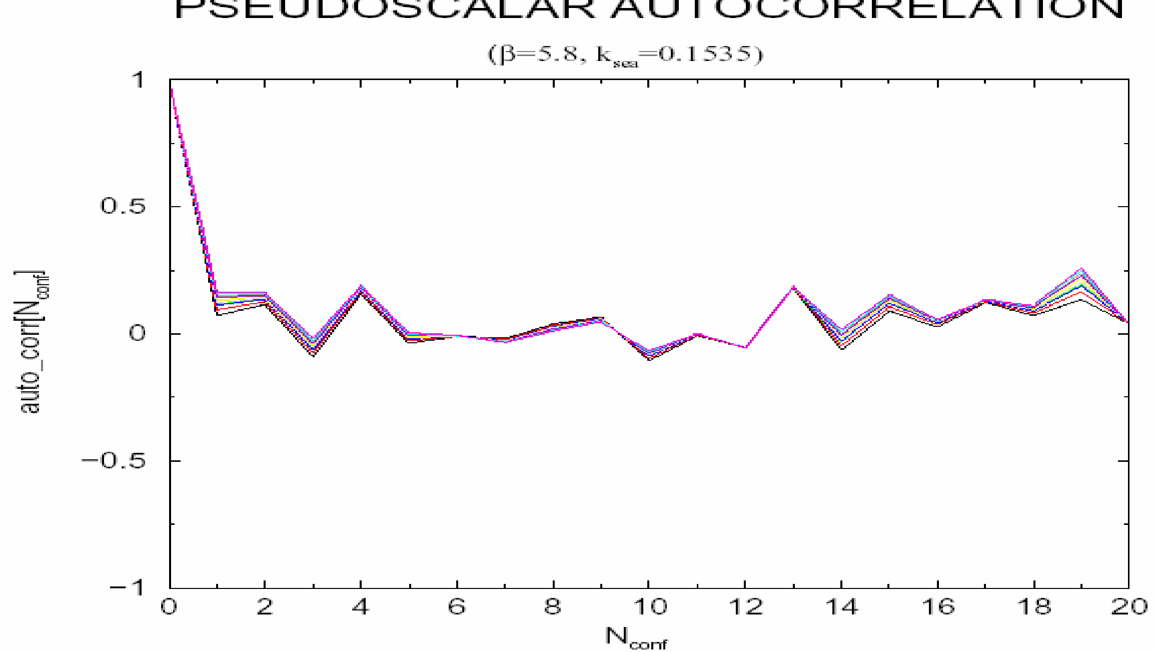
- finite volume effects (<5%)
- small dependence on the sea quark mass

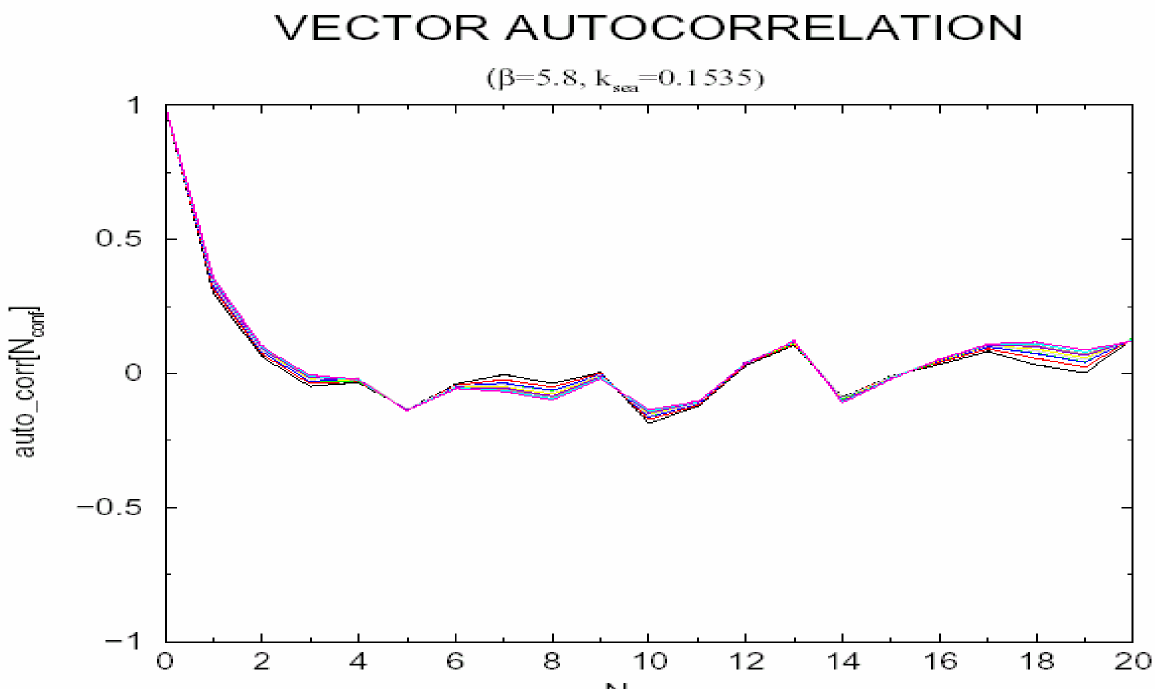
## QUARK MASSES

- discrepancy between "unquenched" and "quenched-like" analysis
- preliminary results

## TO DO:

- more configurations at $V=24^3x48$
- smearing
- other sea quark mass values
- other $\beta$ values
- twisted mass QCD


PSEUDOSCALAR AUTOCORRELATION
(β=5.8, k_sea=0.1535)
auto_corr[N_conf]
N_conf
1
0.5
0
−0.5
−1
0
2
4
6
8
10
12
14
16
18
20


VECTOR AUTOCORRELATION
(β=5.8, k_sea=0.1535)
auto_corr[N_conf]
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0
−0.5
−1
0
2
4
6
8
10
12
14
16
18
20