Light hadron physics

the MILC collaboration

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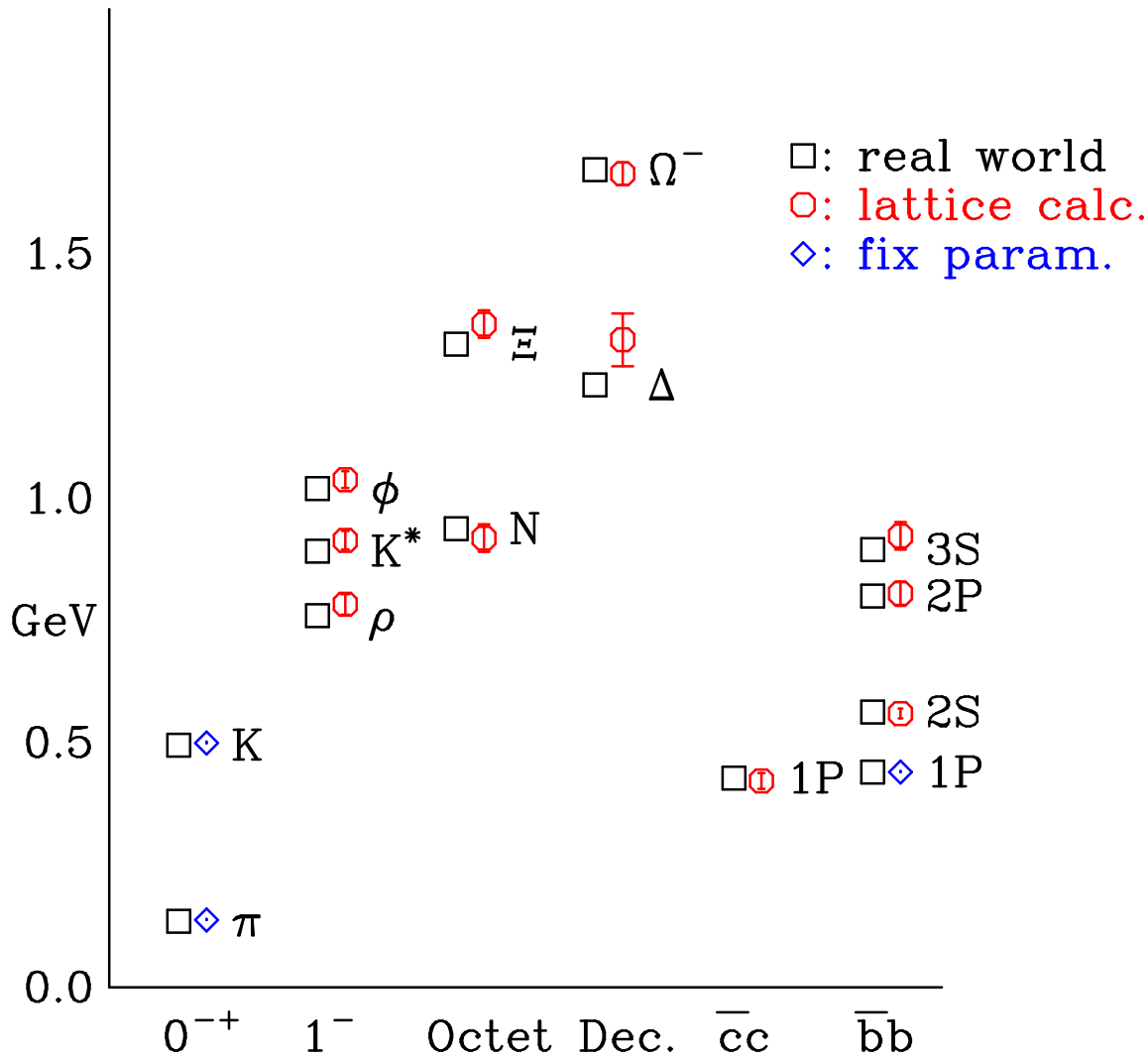


Coarse view of hadron spectroscopy.

Statistical errors only.

Three flavor lattice generation

Improved staggered quarks

Most errors $\approx \alpha a^2$

Taste violation $\approx \alpha^2 a^2$

Square (fourth) root of $det(M)$ for light (strange) quarks

Refreshed Molecular Dyanmics ("R") algorithm

step size $\approx \frac{2}{3} m_s$.

Use for variety of physics, by several groups

Extending the ensembles:

40^3, $a = 0.09$ fm., $m_{u,d} = 0.1 m_s$ ($\approx$1/2 done)

$48^3 \times 144$, $a = 0.06$ fm, $m_{u,d} = 0.4 m_s$ (starting)

$48^3 \times 144$, $a = 0.06$ fm, $m_{u,d} = 0.2 m_s$ (???)

$am_{u,d}/am_s$	m_π/m_ρ	$10/g^2$	lats.	a/r_1
quenched	na	8.00	408 N	0.3762(8)
quenched	na	8.40	415 N	0.2686(6)
0.02/na	0.50	7.20	547	0.3744(11)
0.40/0.40	0.94	7.35	332 N	0.3766(10)
0.20/0.20	0.89	7.15	341 N	0.3707(10)
0.10/0.10	0.79	6.96	339 N	0.3730(14)
0.05/0.05	0.68	6.85	425 N	0.3742(15)
0.04/0.05	0.63	6.83	351 N	0.3765(14)
0.03/0.05	0.58	6.81	564 N	0.3775(12)
0.02/0.05	0.51	6.79	484 N	0.3775(12)
0.01/0.05	0.39	6.76	658 N	0.3846(12)
0.01/0.05*	0.39	6.76	268	0.3801(17)
0.007/0.05	0.34	6.76	494 N	0.3782(14)
0.005/0.05	0.30	6.76	400	0.3778(13)
0.03/0.03	0.59	6.79	360	0.3748(16)
0.01/0.03	0.40	6.75	349	0.3778(20)
0.031/0.031	0.67	7.18	496 N	0.2613(8)
0.0124/0.031	0.50	7.11	527 N	0.2697(10)
0.0062/0.031	0.38	7.09	592 N	0.2712(8)
0.0031/0.031*	0.27	7.08	170 R	0.2709(10)

Parameters of the improved action simulations

$r_1 \approx 0.317(7)(5)$ fm

N = Posted at NERSC: `http://qcd.nersc.gov`

R = Currently running

Coarse lattices are $20^3 \times 64$ (* $28^3 \times 64$)

Fine lattices are $28^3 \times 96$ (* $40^3 \times 96$)

$\mathbf{a = 0.06}$ fm tuning:

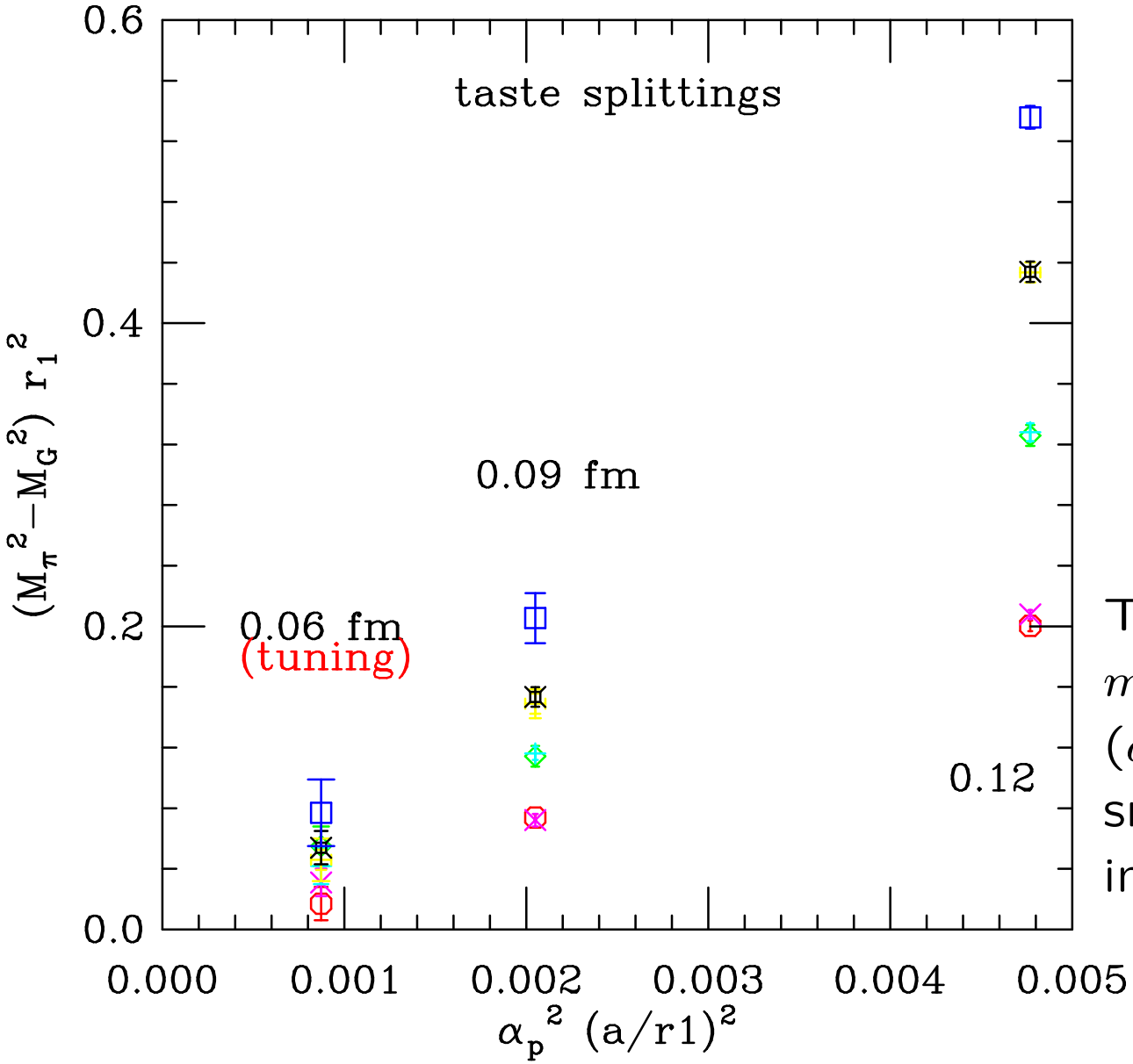
$10/g^2 = 7.48$, $am = 0.0072/0.018$

$28^3 \times 96$ lattice (1.7 fm)

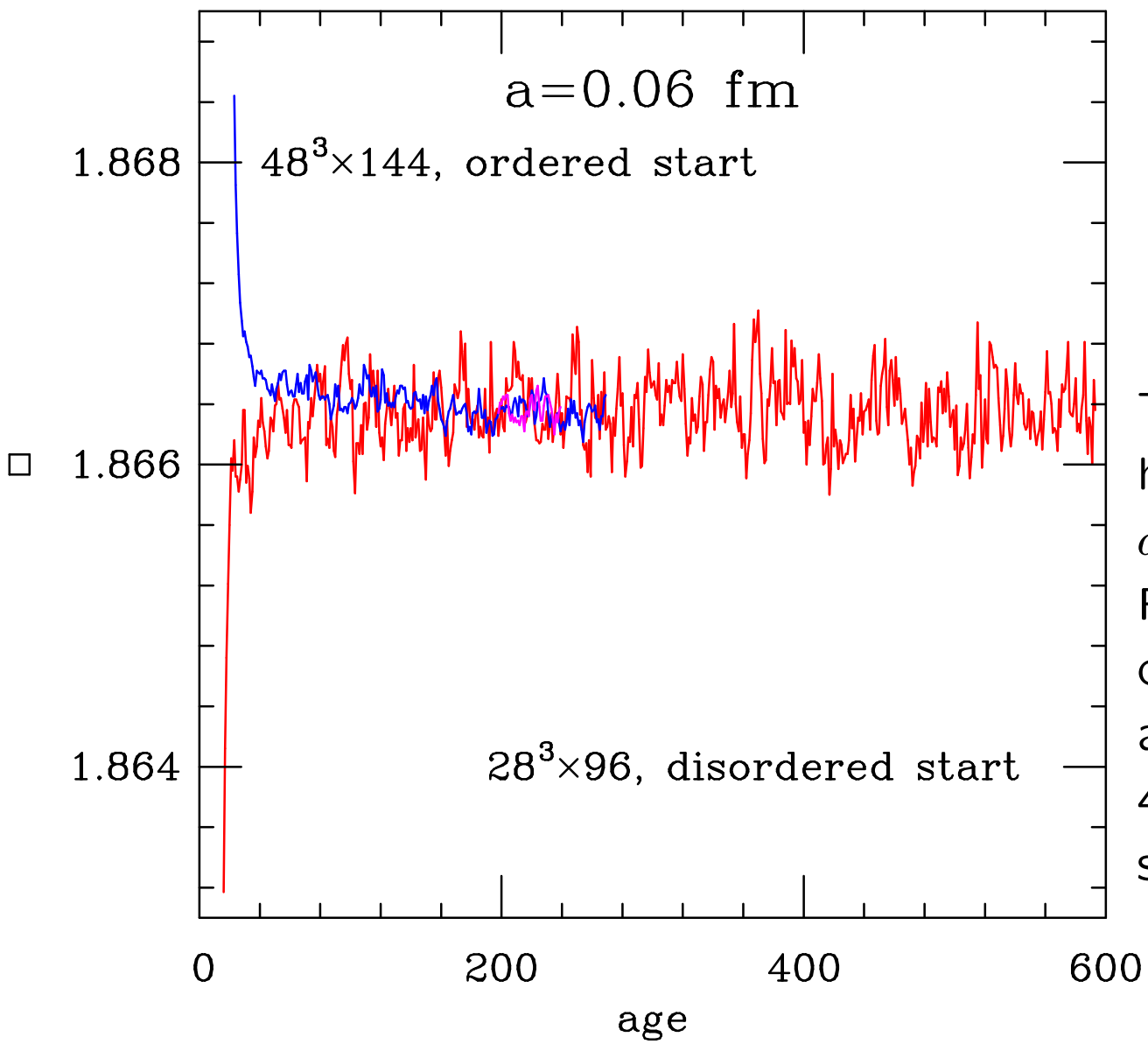
(real run uses $48^3 \times 144$)

Use previous pseudoscalar fits to find expected masses.

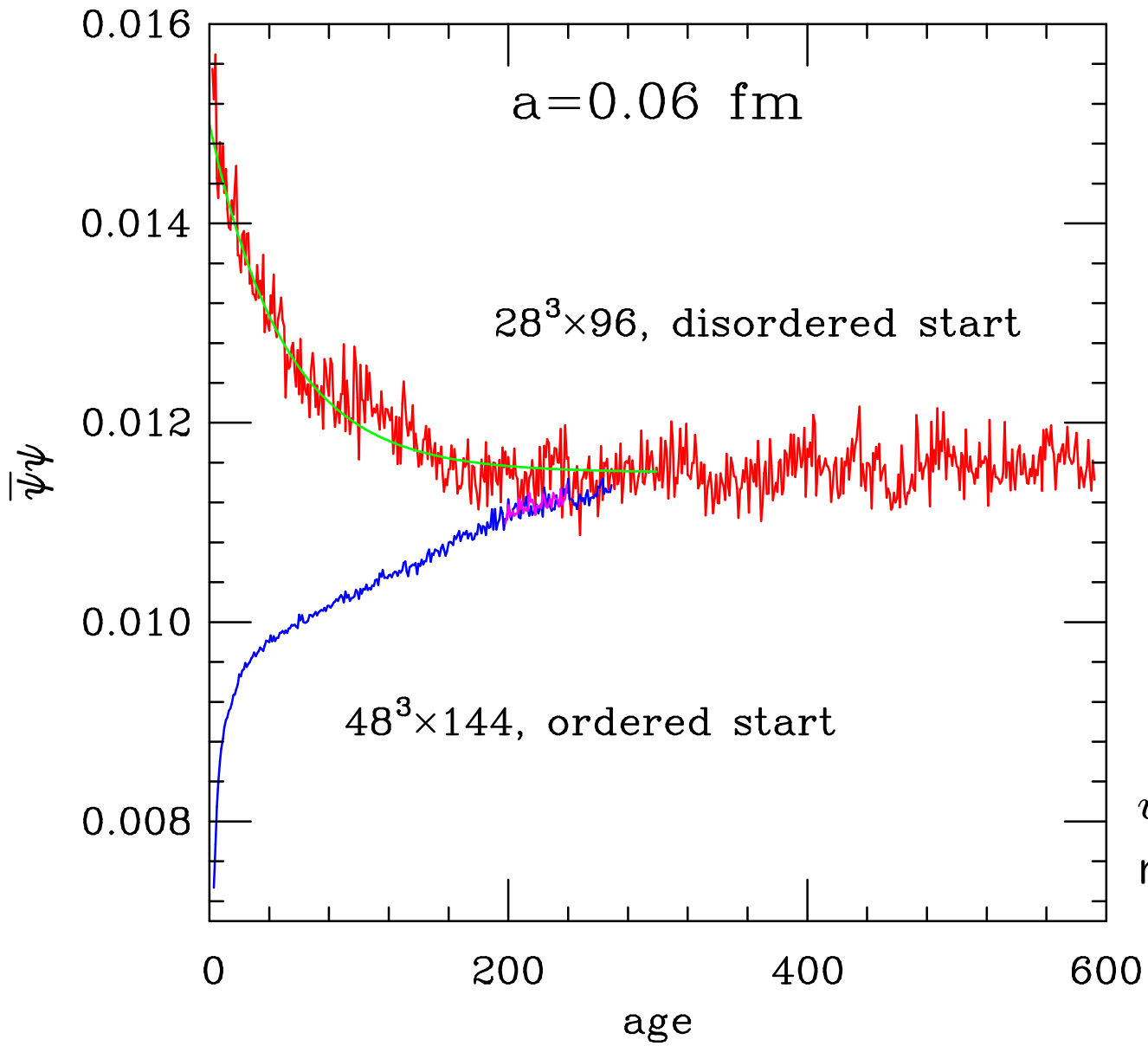
Quant.	Want:	Have (05/09/05)
r_1/a	5.28	5.25(5)
$m_\pi r_1$	0.710	0.721(13)
$m_K r_1$	0.933	0.956(18)
$m_{s\bar{s}} r_1$	1.108	1.097(20)
m_π/m_K	0.761	0.772(7)
$m_K/m_{s\bar{s}}$	0.843	0.843(6)



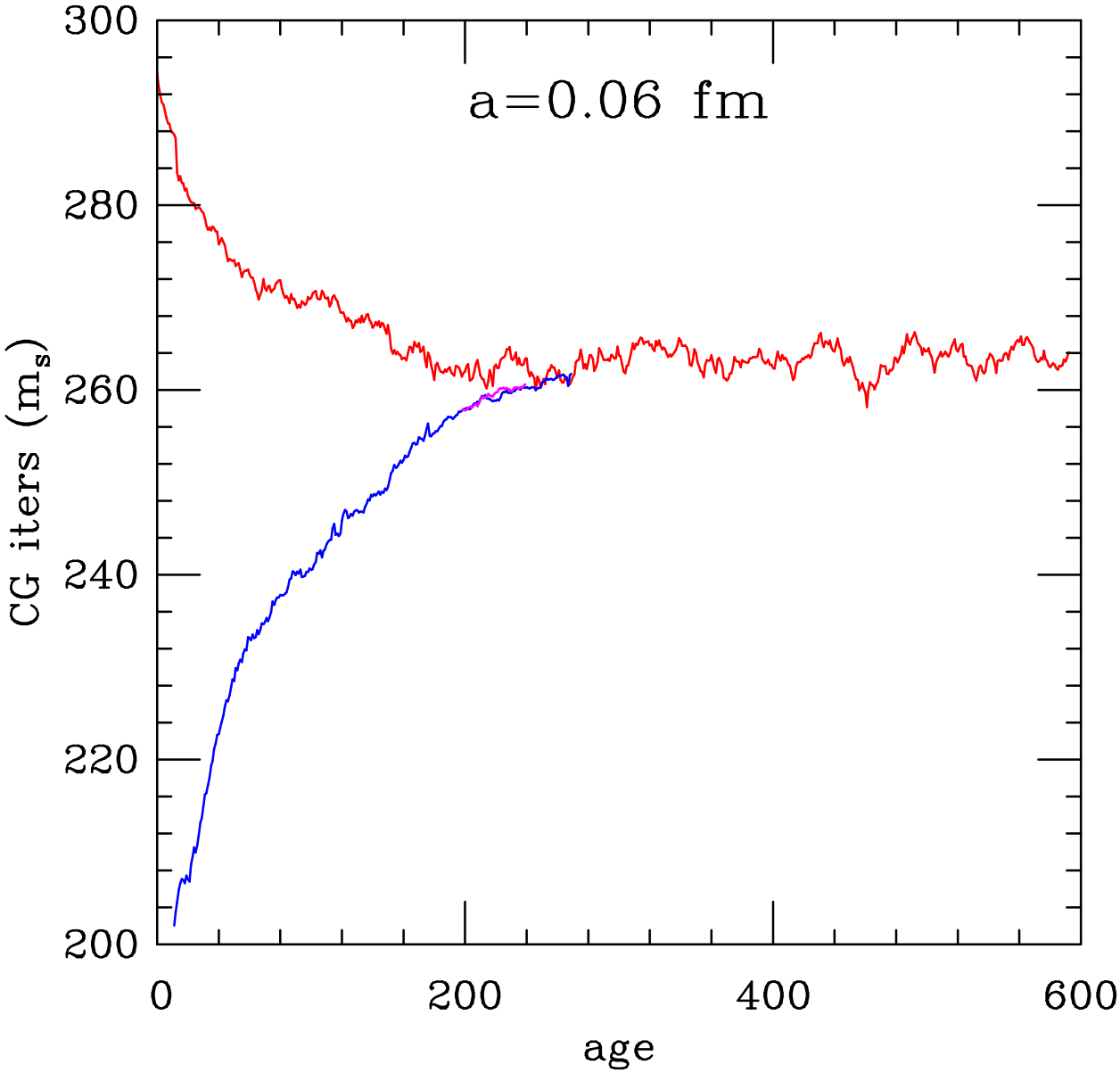
Taste splittings at $m_{u,d} \approx 0.4 m_s$ ($a = 0.06$ fm is small lattice tuning run.)



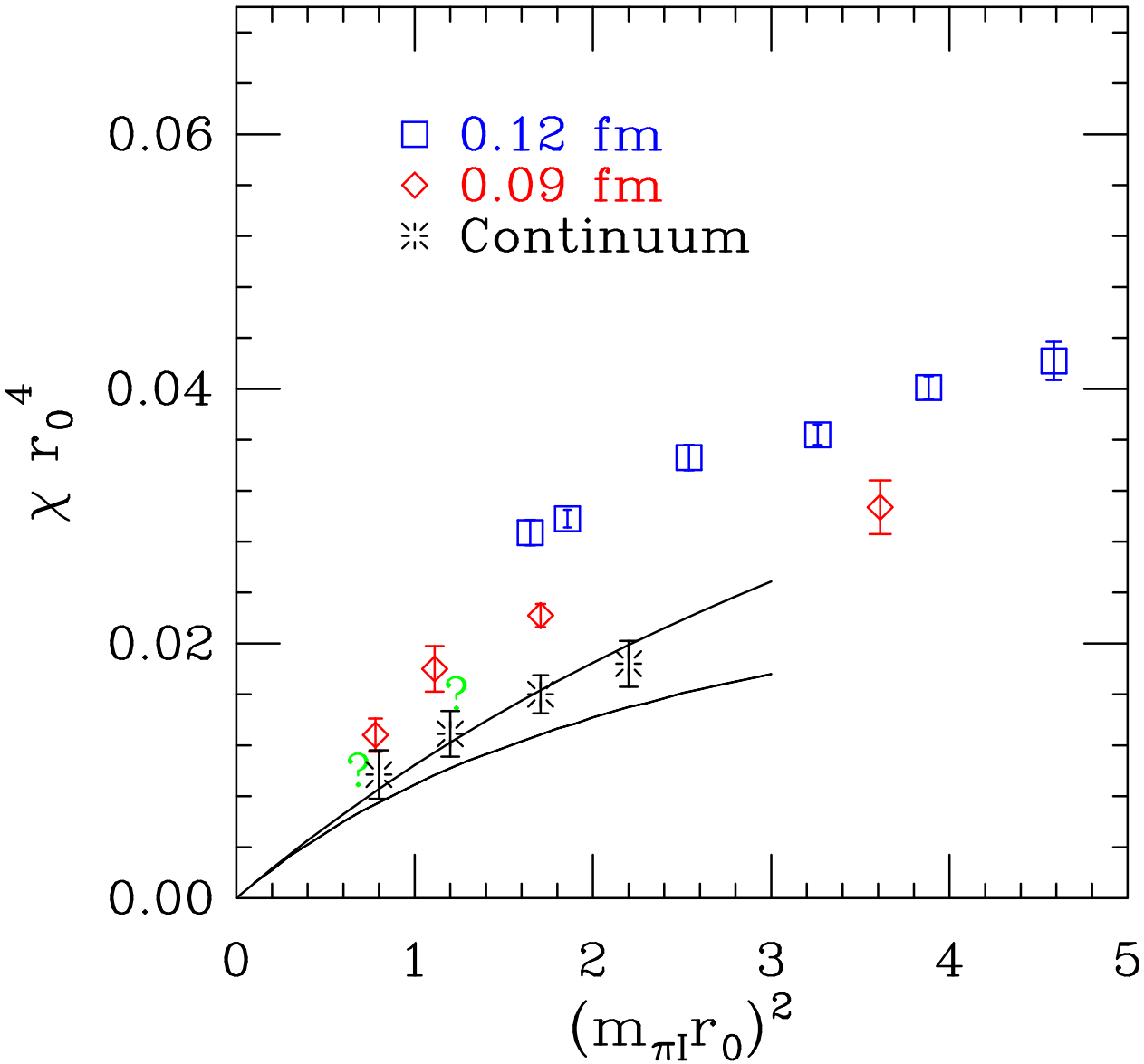
The plaquette from hot and cold starts. $a = 0.06$ fm. Red is $28^3 \times 96$ disordered start, Blue and magenta are $48^3 \times 144$ ordered start (run splits).



$\bar{\psi}\psi$ in the same runs.



Strange quark conjugate gradient iterations. Sensitive to low eigenmodes?



Topological susceptibility.
"?" is where $a = 0.06$ fm $m_{u,d} \approx 0.4 m_s$ and $0.2 m_s$ points might fall.

Pseudoscalar masses and decay constants

Partially quenched: 8-9 valence quark masses on each set.

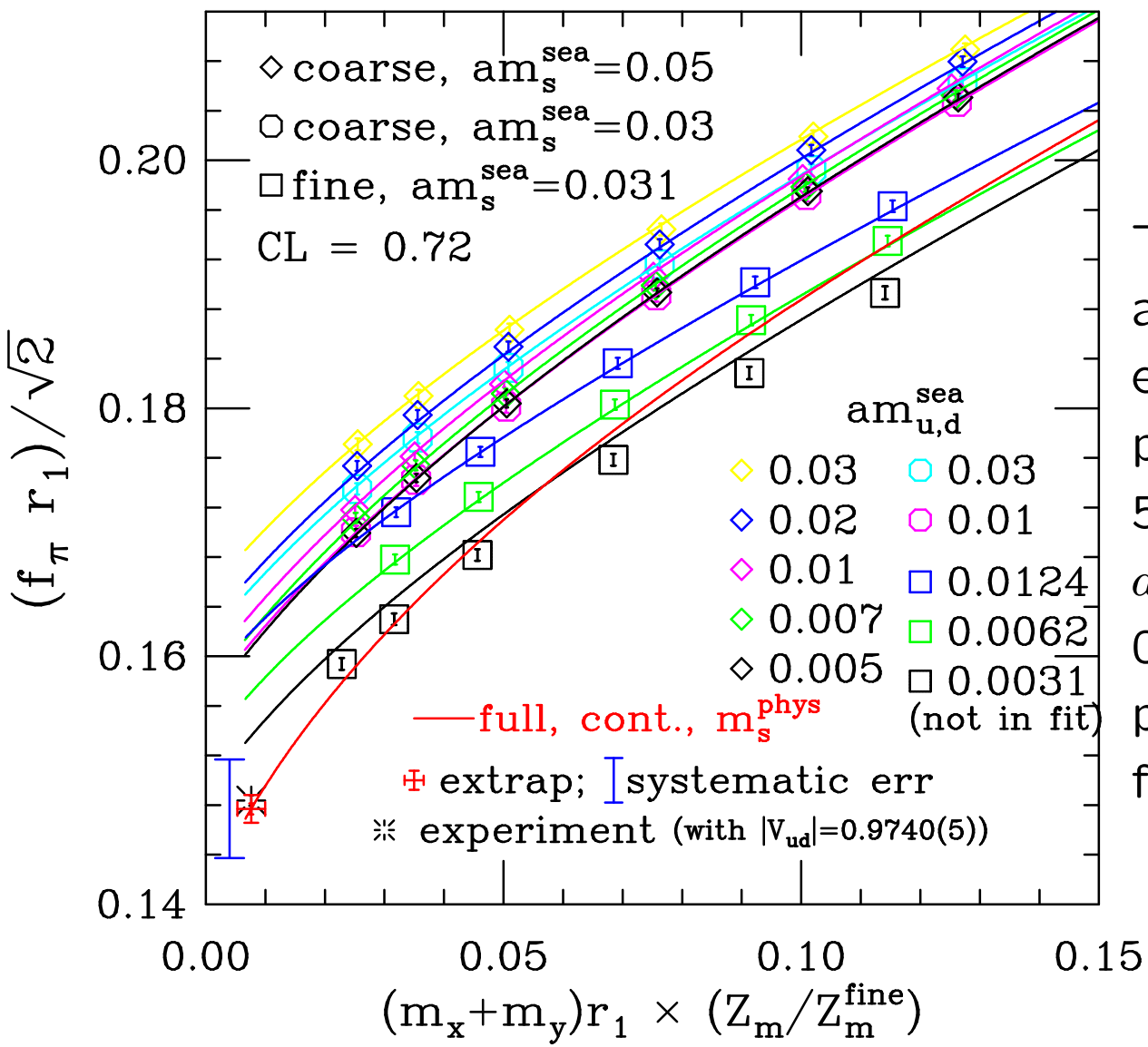
Chiral perturbation theory: partially quenched + staggered artifacts (Lee and Sharpe, Aubin and Bernard)

Up to NNNLO analytic terms $\rightarrow \approx$ 50 parameters.

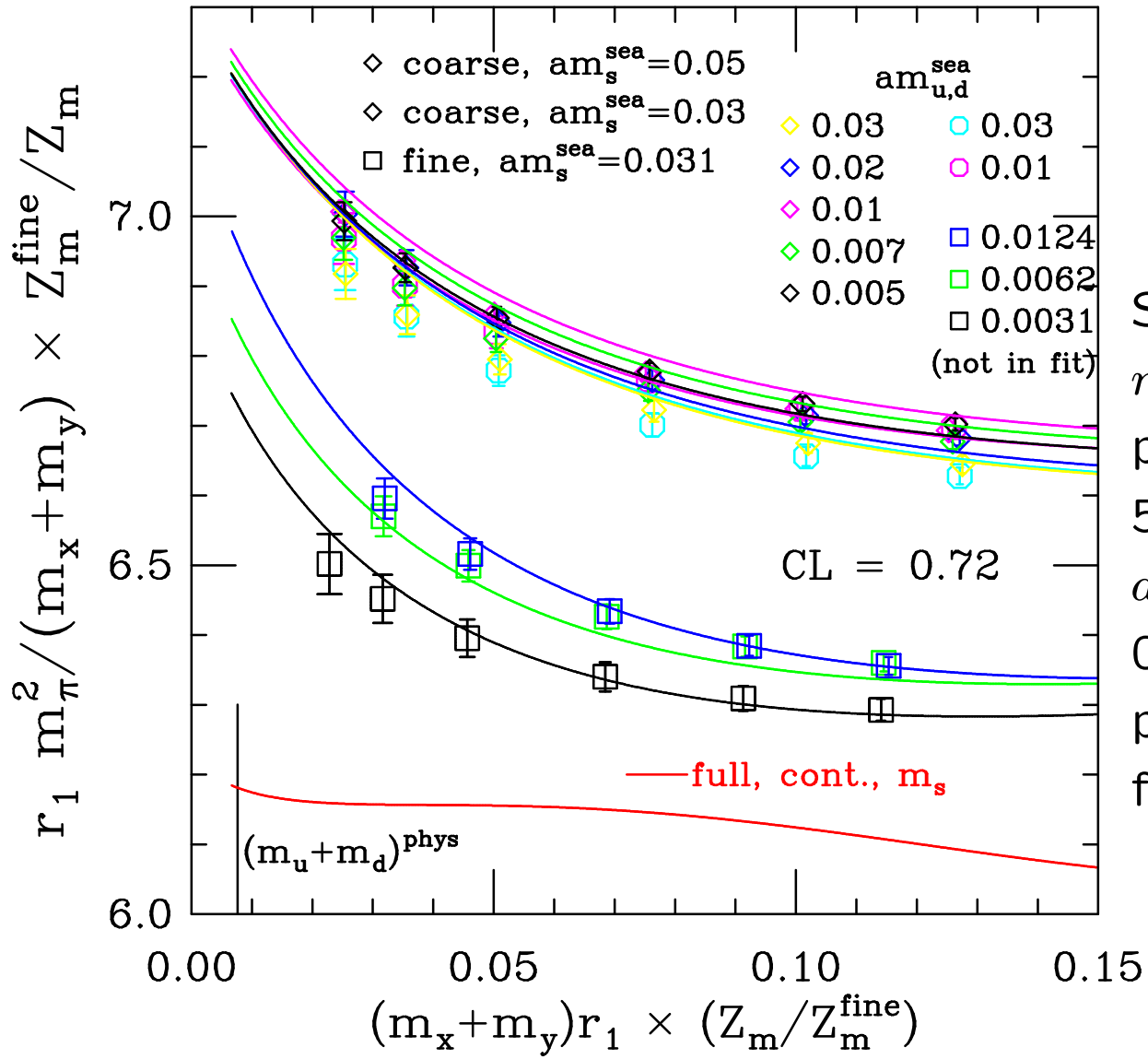
Extract f_π, f_K, m_s, m_u, m_d, L_i.

(and indirectly V_{ud} and V_{us}.

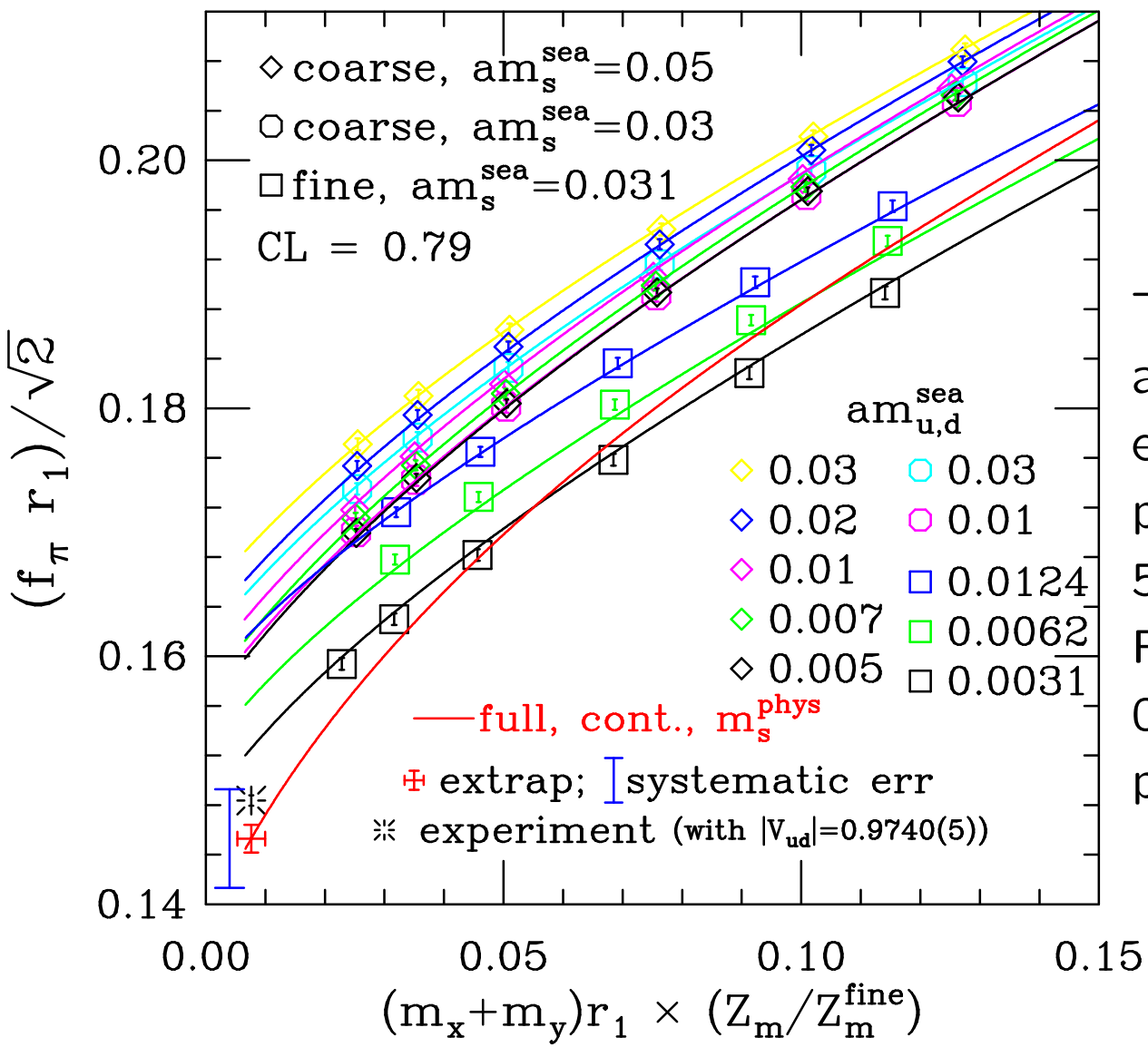
New: $am_s = 0.03$ runs, $am_{u,d} = 0.0031$ run in progress.



Three flavor f_π and continuum extrapolation, preliminary 5/26/05 am_q = 0.0031/0.031 points not used in fit.

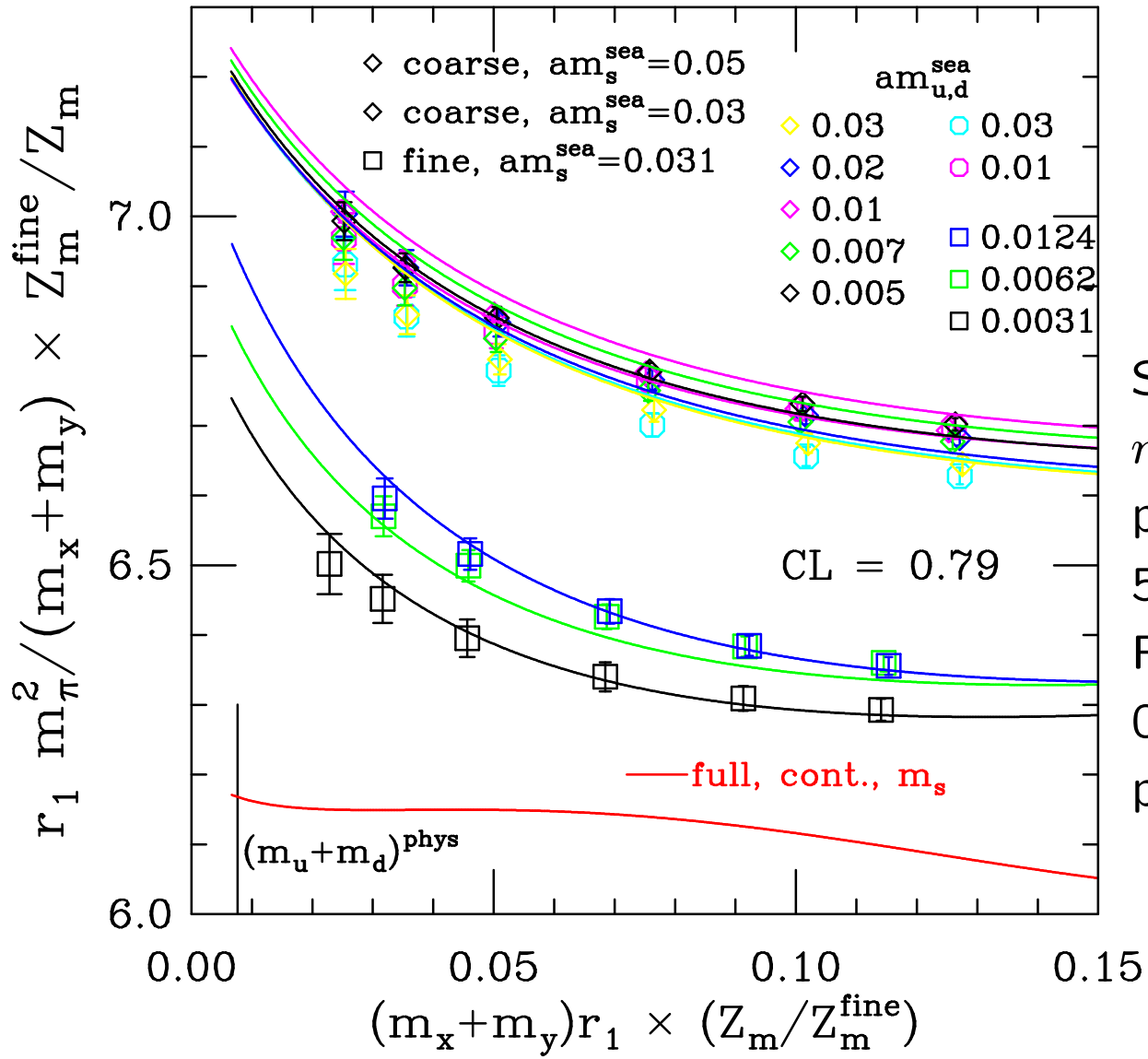


Same, for $m_\pi^2/(\approx 2m_{u,d})$ preliminary 5/26/05 am_q = 0.0031/0.031 points not used in fit.



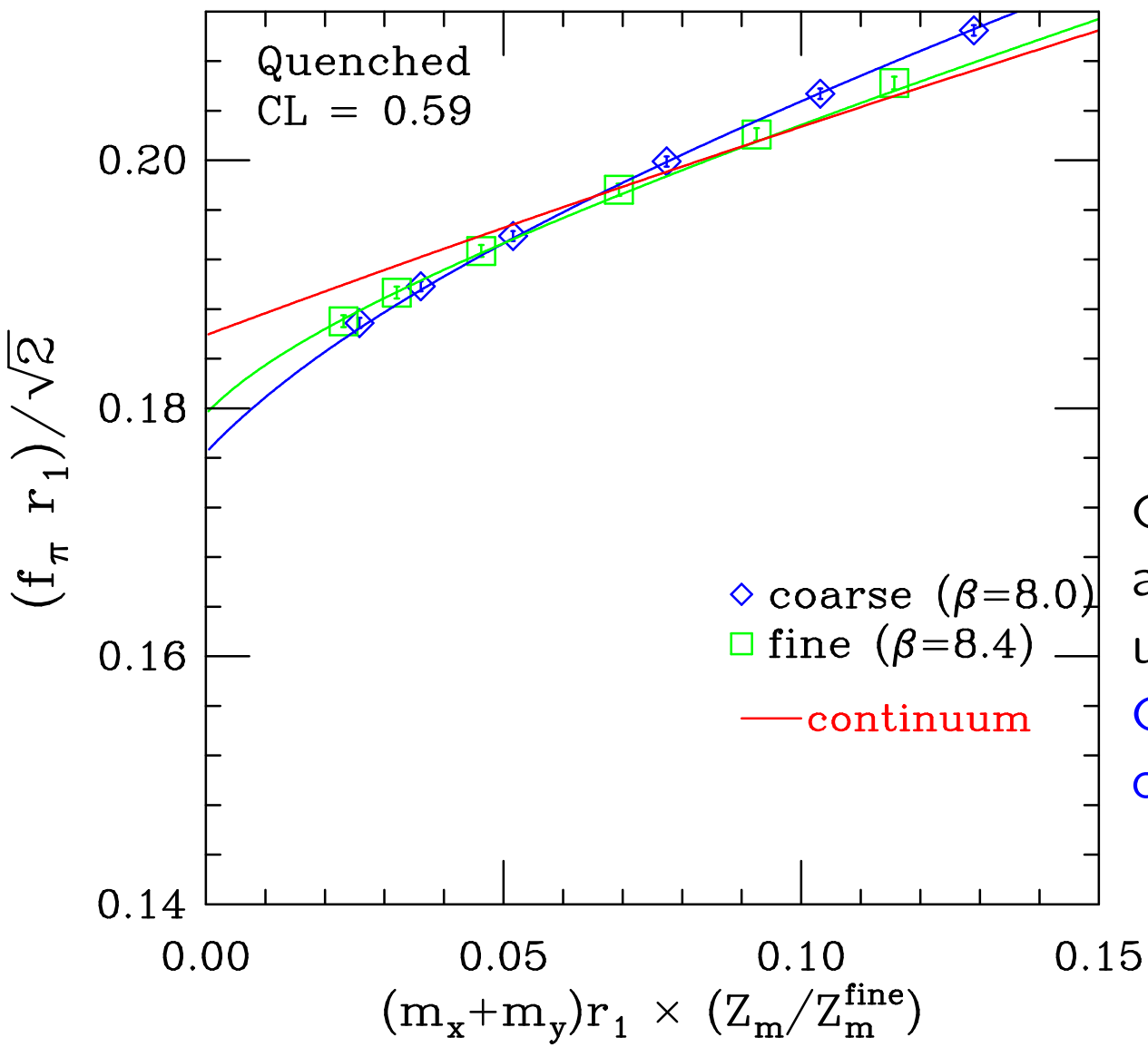
Three flavor f_π and continuum extrapolation, preliminary 5/26/05

Fit includes am_q = 0.0031/0.031 points.

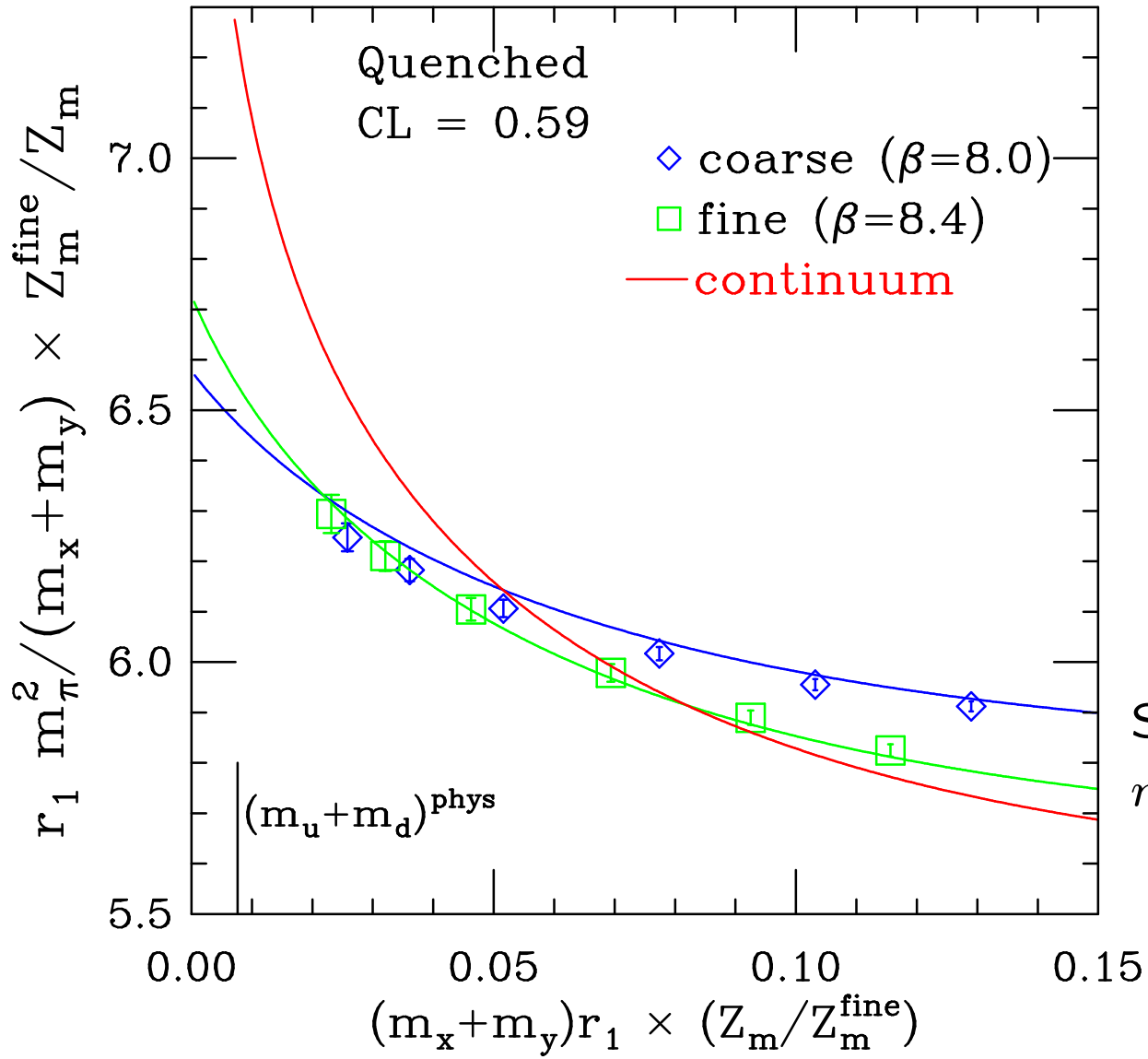


Same, for $m_\pi^2/(\approx 2m_{u,d})$ preliminary 5/26/05

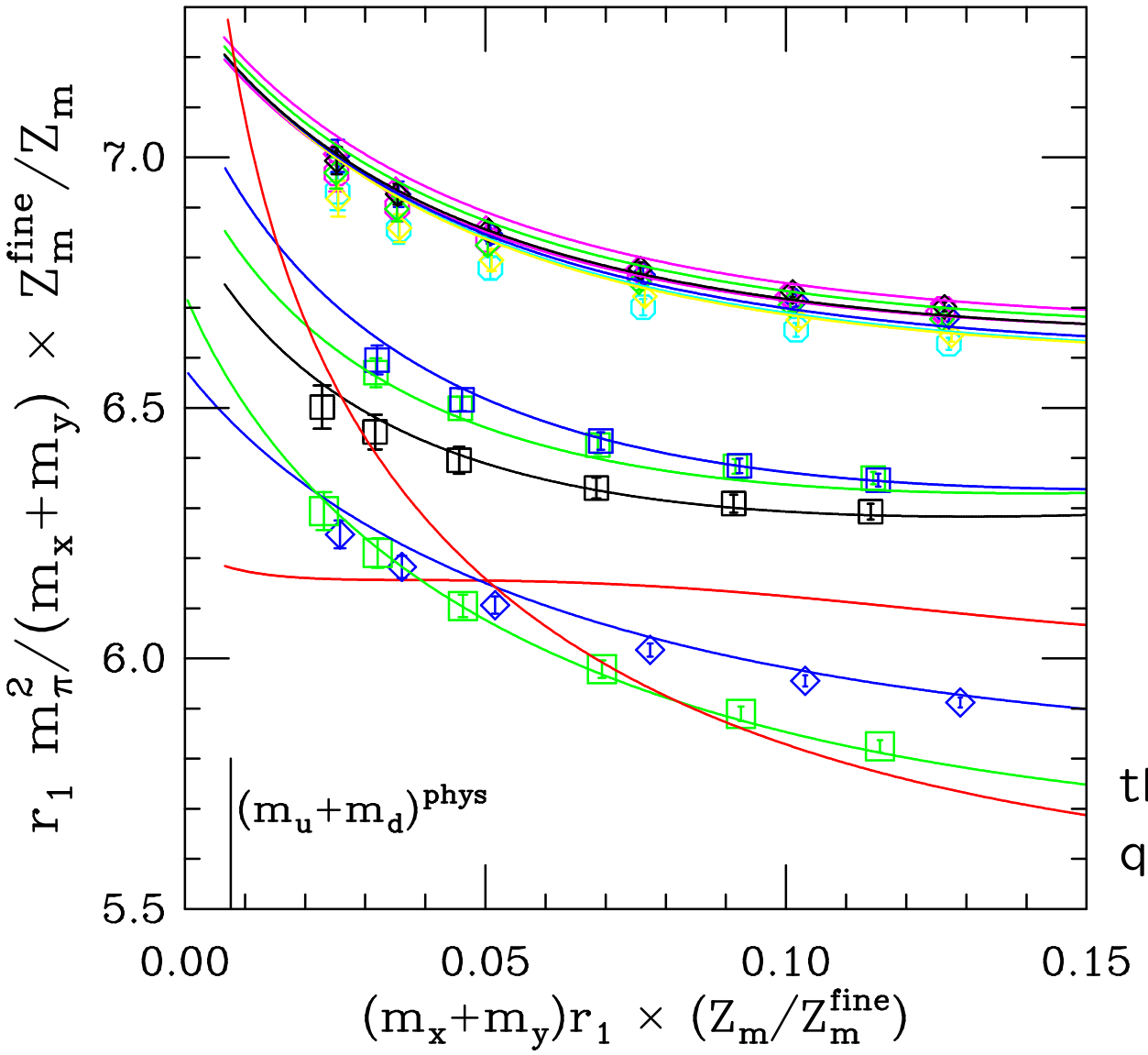
Fit includes am_q = 0.0031/0.031 points.



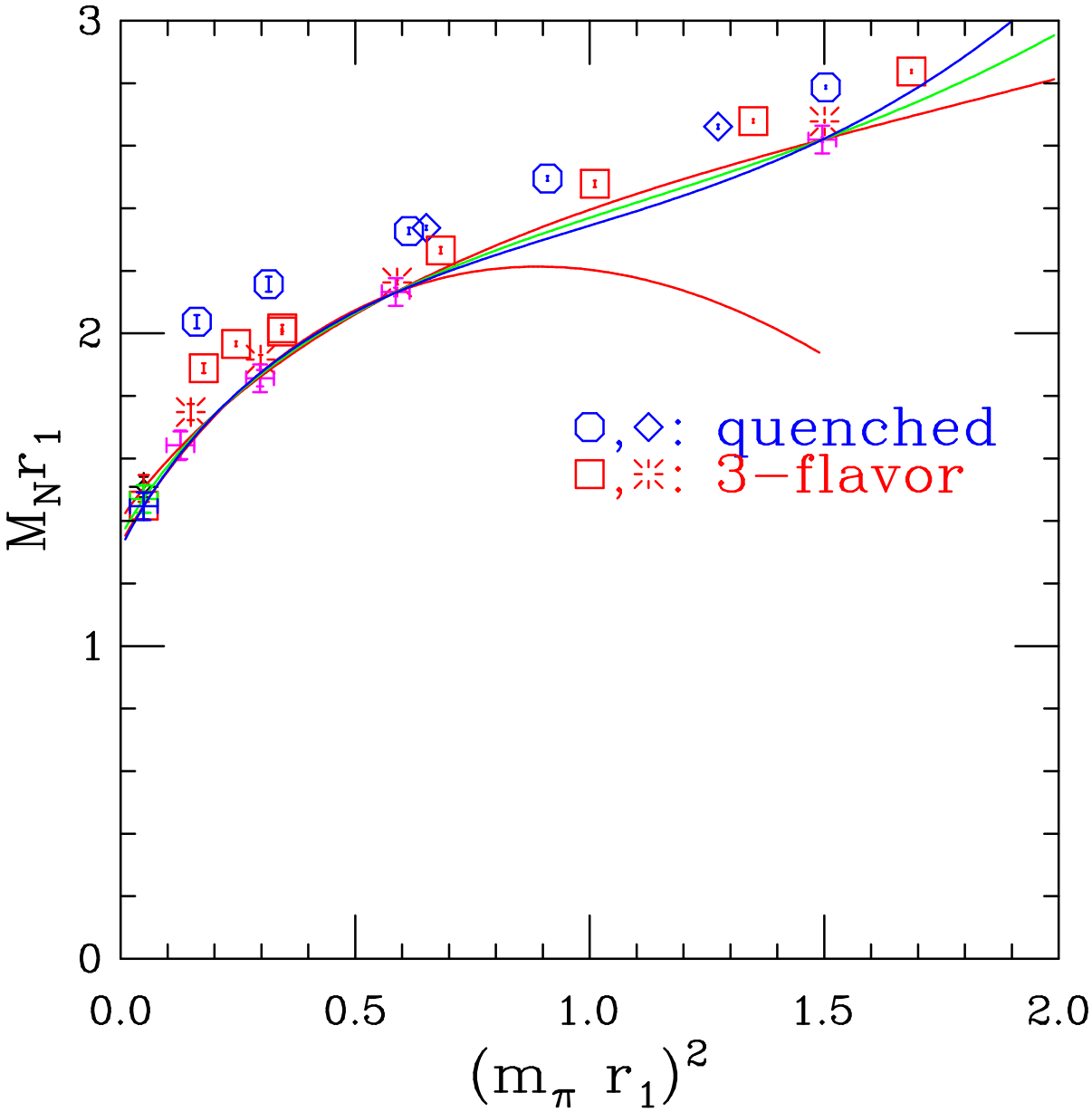
Quenched f_π and a quenched continuum extrapolation. Quenched f_π has no chiral log.



Same, for
$m_\pi^2/(\approx 2m_{u,d})$



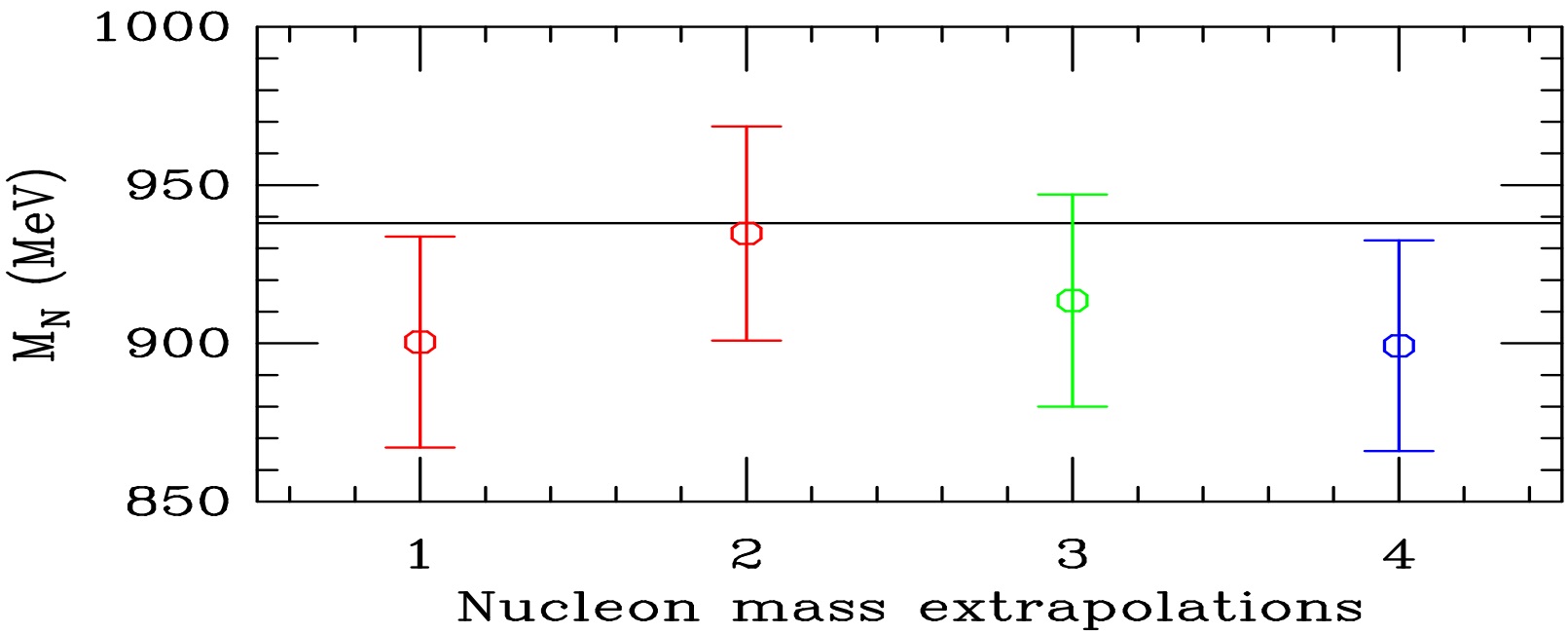
three flavor and quenched m_π^2.



Nucleon masses, continuum extrapolations, and chiral fits.

(or use staggered chiral pert. theory (Jon Bailey))

At the moment, requires Ch.P.T. up to m_s.



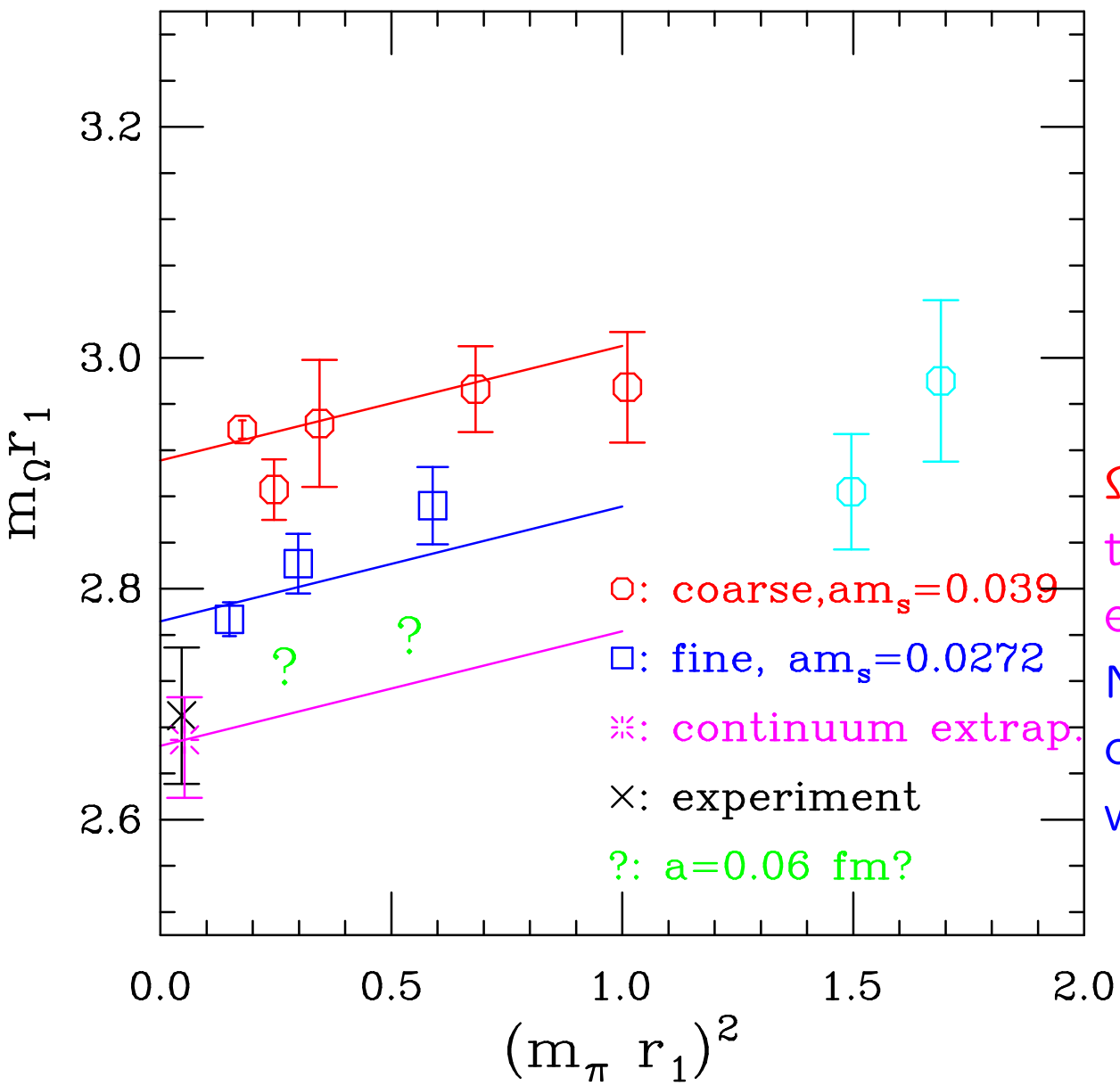
Chiral extrapolations compared to experimental value.

m_π^3 term only, fitting three points

m_π^3 term plus m_π^4, fitting four points

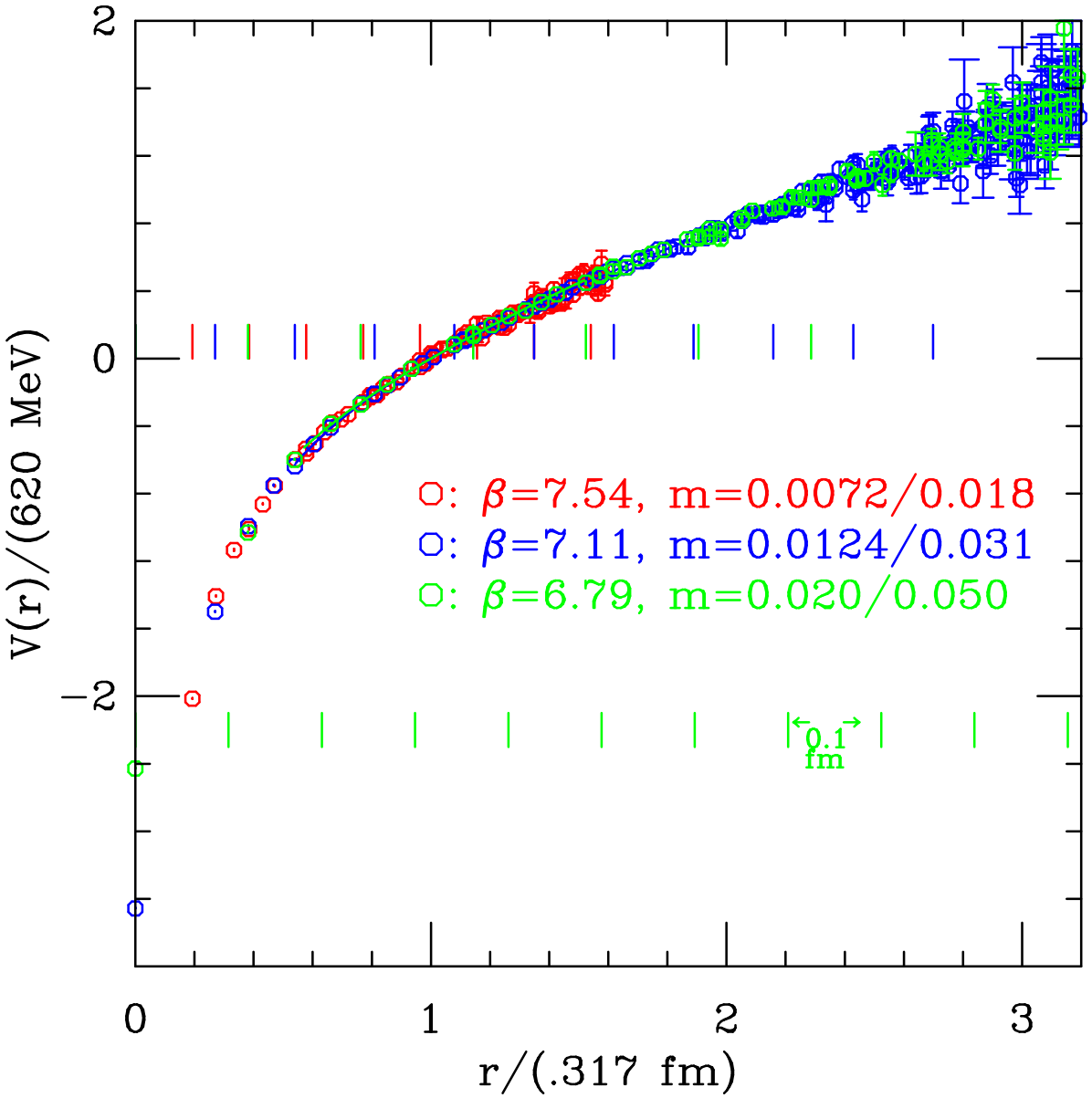
"Active Δ (V. Bernard *et al.*)

m_π^3, m_π^4 and $m_\pi^4 \log(m_\pi)$ terms



Ω^- masses, continuum and chiral extrapolation,

No one-loop chiral corrections with m_π.



Static quark potential at $m_{u,d} \approx 0.4 m_s$. $a = 0.06$, 0.09 , 0.13 fm ($a = 0.06$ fm is small lattice tuning run.)