Lattice QCD with Eight Degenerate Quark Flavors

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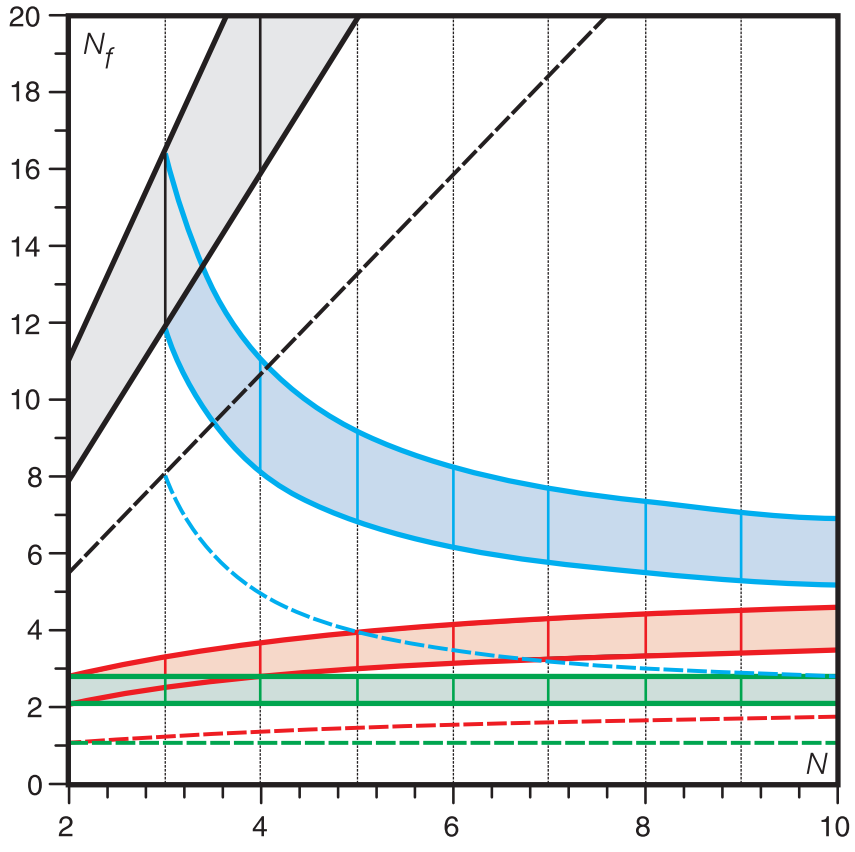
Lattice 2008

Outline

Phase diagram



[Dennis D. Dietrich, Francesco Sannino, arXiv:hep-ph/0611341v1]

Recent works on the lattice

- SU(2), 2 flavors in symmetric representation
  Simon Catterall, Francesco Sannino, arXiv:0705.1664v1 [hep-lat]
- SU(2), 2 flavors in adjoint representation.
  Luigi Del Debbio, Agostino Patella, Claudio Pica, arXiv:0805.2058v1 [hep-lat]
- Running of coupling using Schrodinger functional.
  Thomas Appelquist, George T. Fleming, Ethan T. Neil, Phys. Rev. Lett. 100, 171607 (2008), (arXiv:0712.0609v2 [hep-ph])
- Finite temperature phase transition of 8 flavors using Asqtad.
  Albert Deuzeman, Maria Paola Lombardo, Elesabetta Pallante, arXiv:0804.2905v2 [hep-lat]
- And much more in this conference.

Outline

Algorithm test in 4 flavors

Comparison between RHMC and Φ algorithm using naive staggered fermion, Wilson gauge, $N_f = 4$, $m_q = 0.015$, $\beta = 5.4$

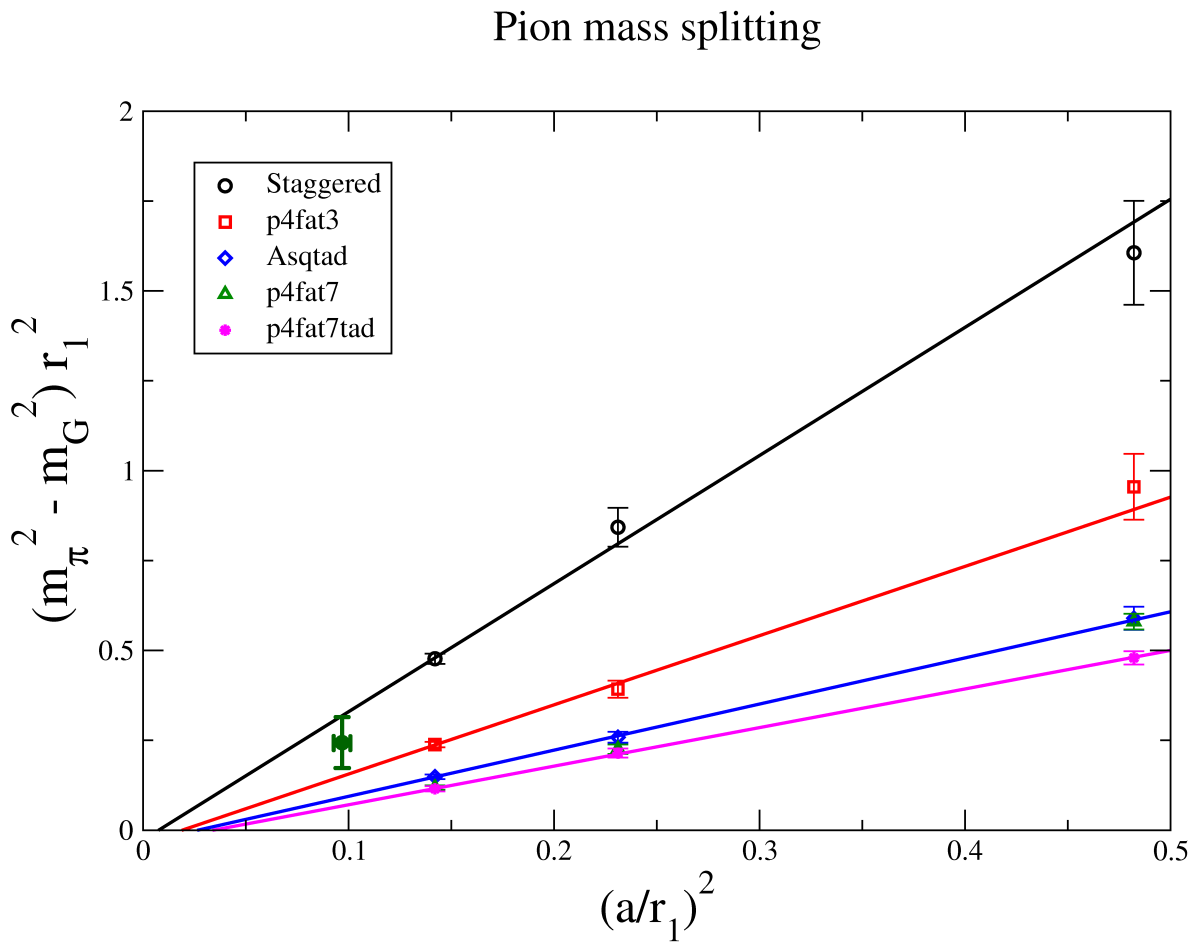
Algorithm	Φ	RHMC
Plaquette	0.560130(14)	0.560072(30)
$\langle\bar{\psi}\psi\rangle$	0.0404(1)	0.04105(19)
m_π	0.3210(40)	0.3191(36)
m_{π_2}	0.3543(35)	0.361(20)
m_ρ	0.4763(59)	0.481(10)
m_{ρ_2}	0.4777(84)	0.459(40)

Results of Φ algorithm are from ChengZhong Sui, Ph. D. thesis, Columbia University, 2000.

DBW2 improved gauge action

- More dynamic flavors on the lattice make the gauge field rougher.
- DBW2 smooths out the gauge field.
- DBW2 with naive staggered fermion runs fast.

Effect on taste symmetry breaking



- Quenched results from M. Cheng, *et. al.*, arXiv:hep-lat/0612030v1.
- Dark blue symbol is dynamic result from staggered DBW2 action with 2 flavors.

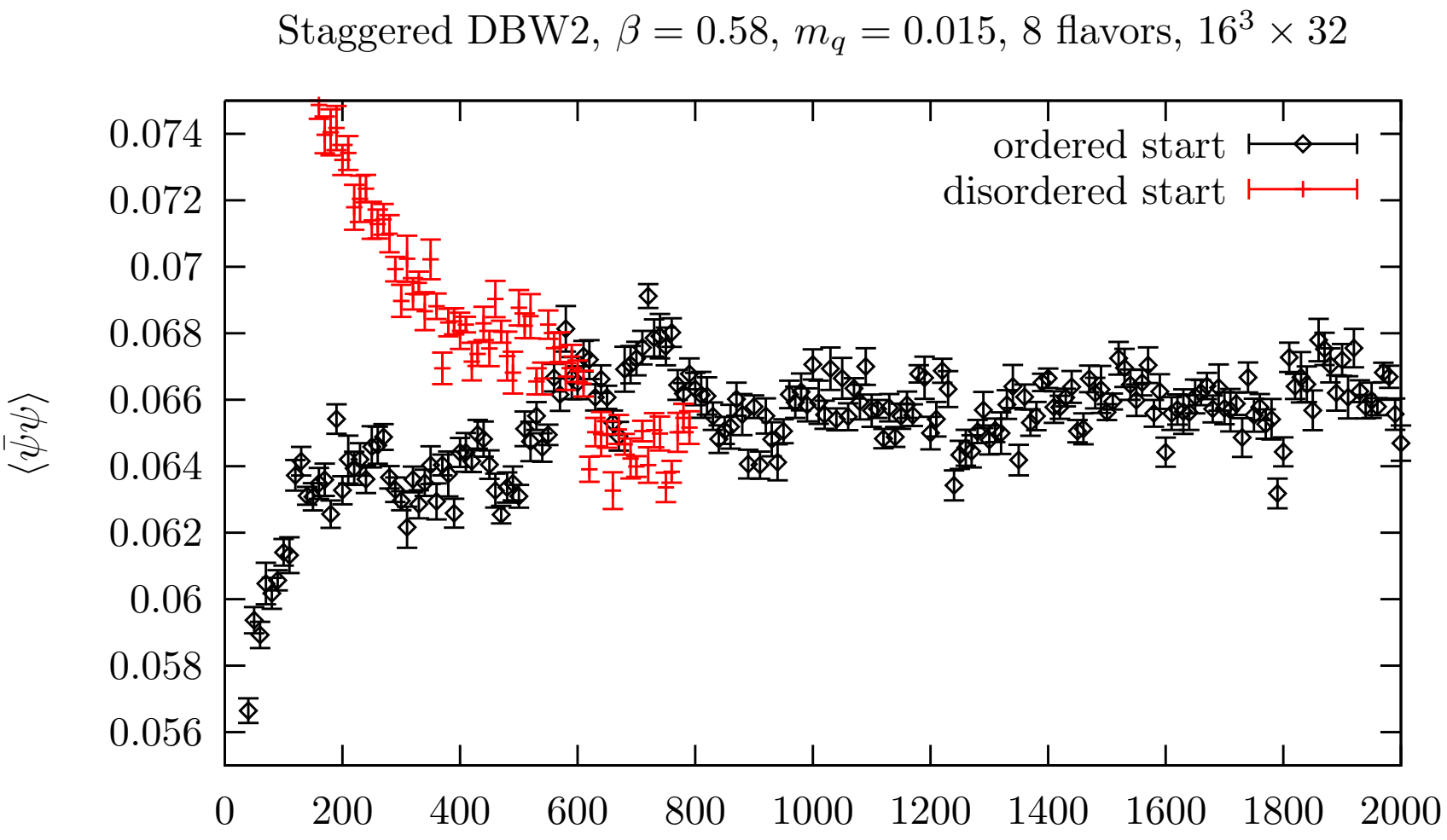
Outline

Simulation Details

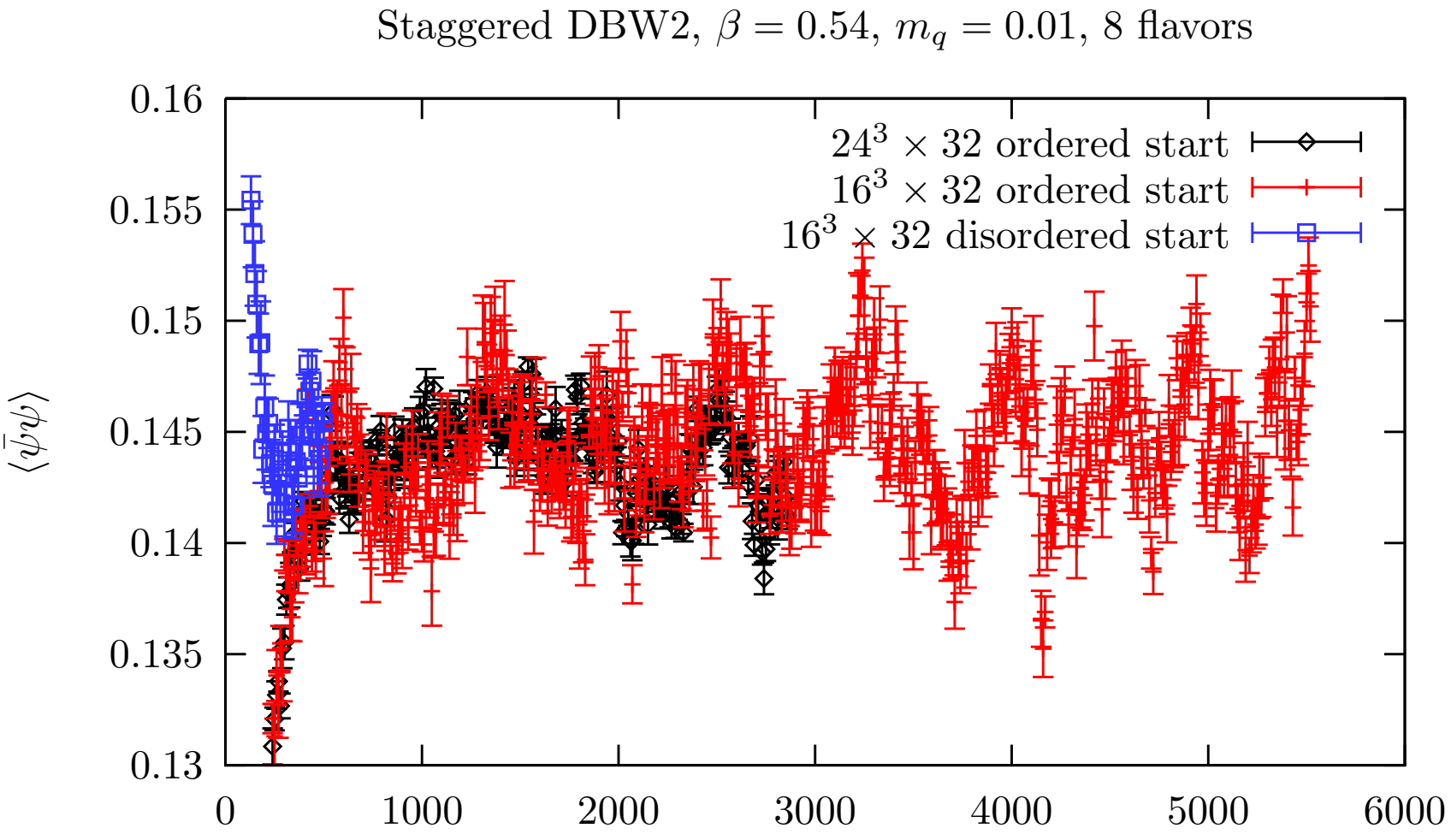
β	Size	m_q	Trajectories	$\langle\bar{\psi}\psi\rangle$	m_ρ	r_0
0.58	$16^3 \times 32$	0.025	1330 ~ 2760	0.09973(27)	0.812(11)	4.39(56)
		0.015	880 ~ 1950	0.06582(13)	0.619(13)	5.05(78)
	$24^3 \times 32$	0.025	1060 ~ 3390	0.100381(67)	0.7832(30)	4.126(96)
		0.015	960 ~ 2930	0.06652(11)	0.6126(28)	5.10(11)
0.56	$16^3 \times 32$	0.024	970 ~ 4920	0.13643(20)	0.9431(38)	3.19(18)
		0.016	1040 ~ 3730	0.10147(26)	0.803(12)	3.68(15)
	$24^3 \times 32$	0.024	1010 ~ 3340	0.13668(14)	0.9693(69)	3.120(48)
		0.016	1040 ~ 3190	0.10208(12)	0.8085(93)	3.793(97)
		0.008	1000 ~ 2970	0.06148(16)	0.6022(73)	4.716(92)
0.54	$16^3 \times 32$	0.03	1010 ~ 6220	0.23100(20)	1.258(17)	2.197(52)
		0.02	990 ~ 5300	0.19646(28)	1.176(19)	2.350(47)
		0.01	1030 ~ 5520	0.14464(37)	0.993(14)	2.849(51)
	$24^3 \times 32$	0.01	1070 ~ 2860	0.14393(39)	1.022(17)	2.830(48)

- Trajectory length is 0.5 in MD unit.
- Measurements are done every 10 trajectories.
- All simulation of lattice size $24^3 \times 32$ and some of $16^3 \times 32$ are done on NYBlue(BlueGene/L).

Evolution of $\langle\bar{\psi}\psi\rangle$, $\beta = 0.58$, $m_q = 0.015$

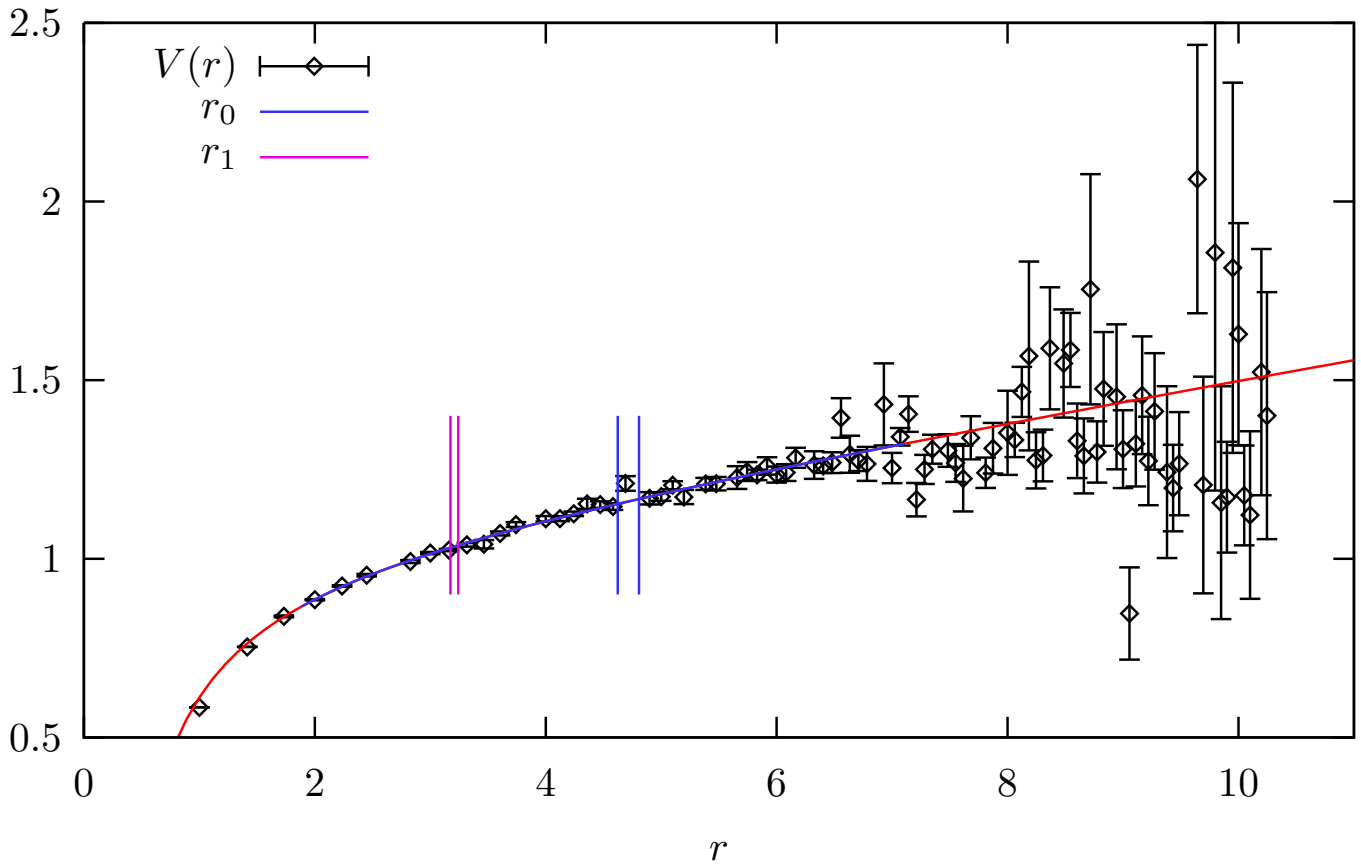


Evolution of $\langle\bar{\psi}\psi\rangle$, $\beta = 0.54$, $m_q = 0.01$

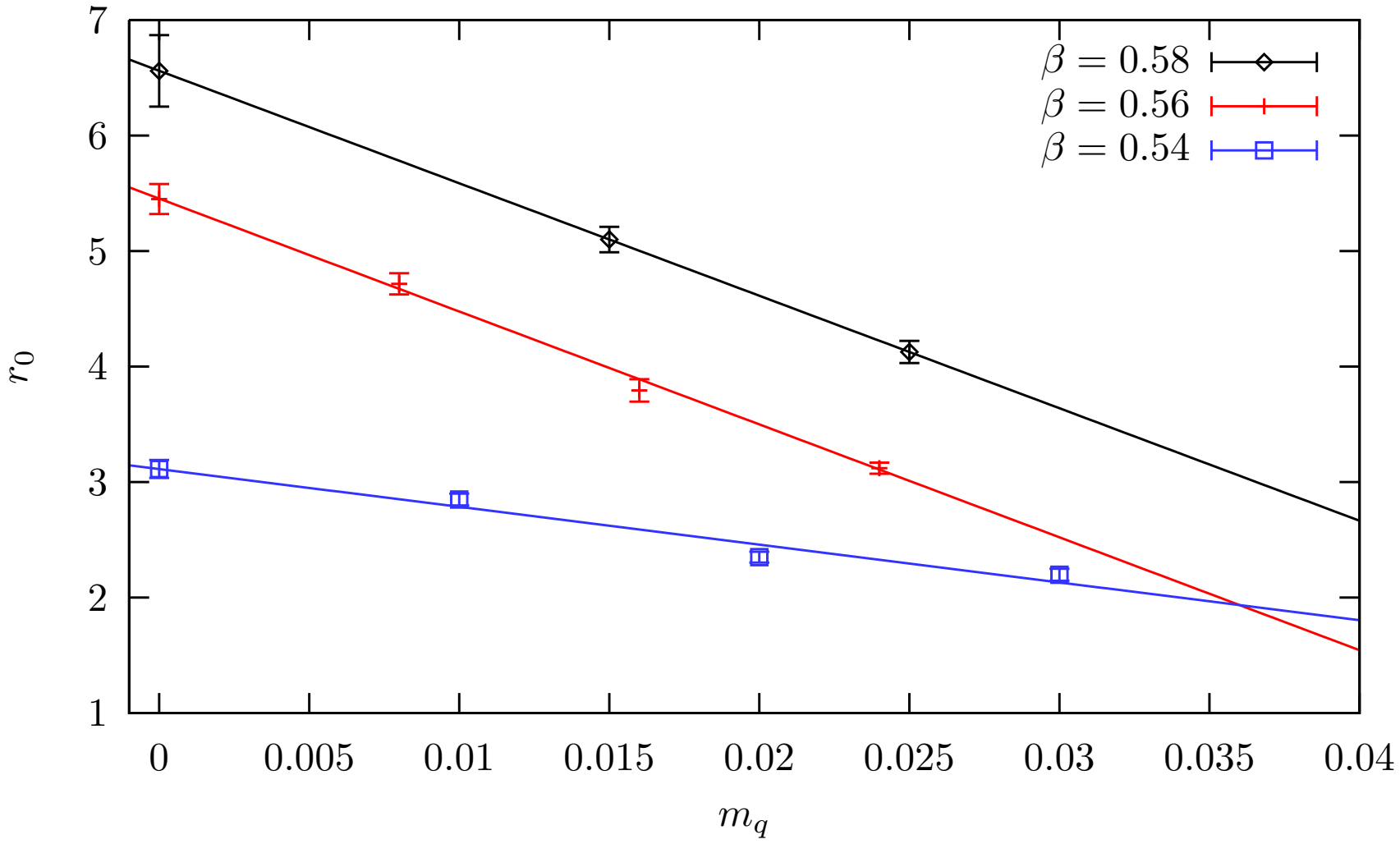


Heavy quark potential

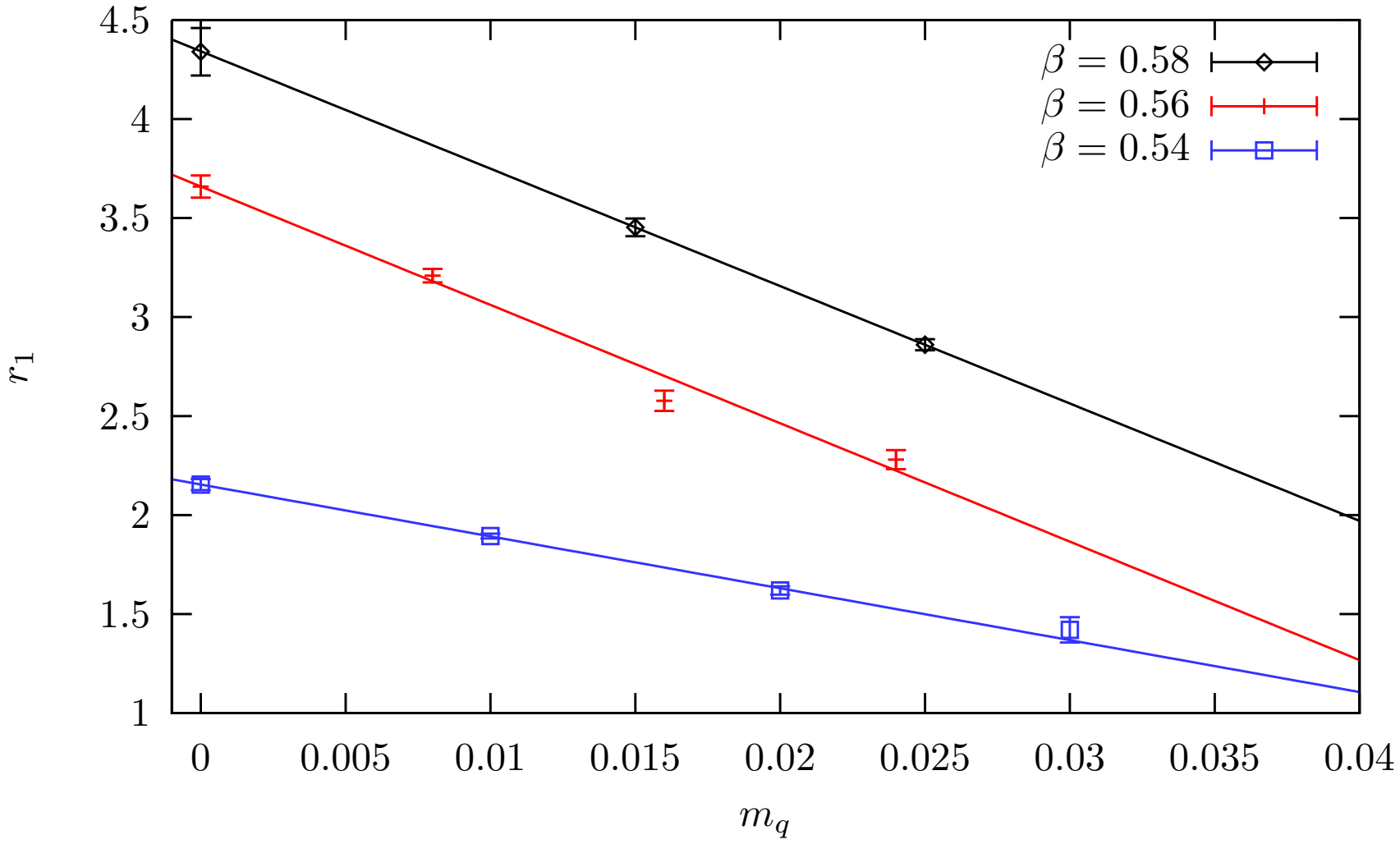
Heavy quark potential measured on ensemble of $\beta = 0.56$, $m_q = 0.008$, with lattice size of $24^3 \times 32$



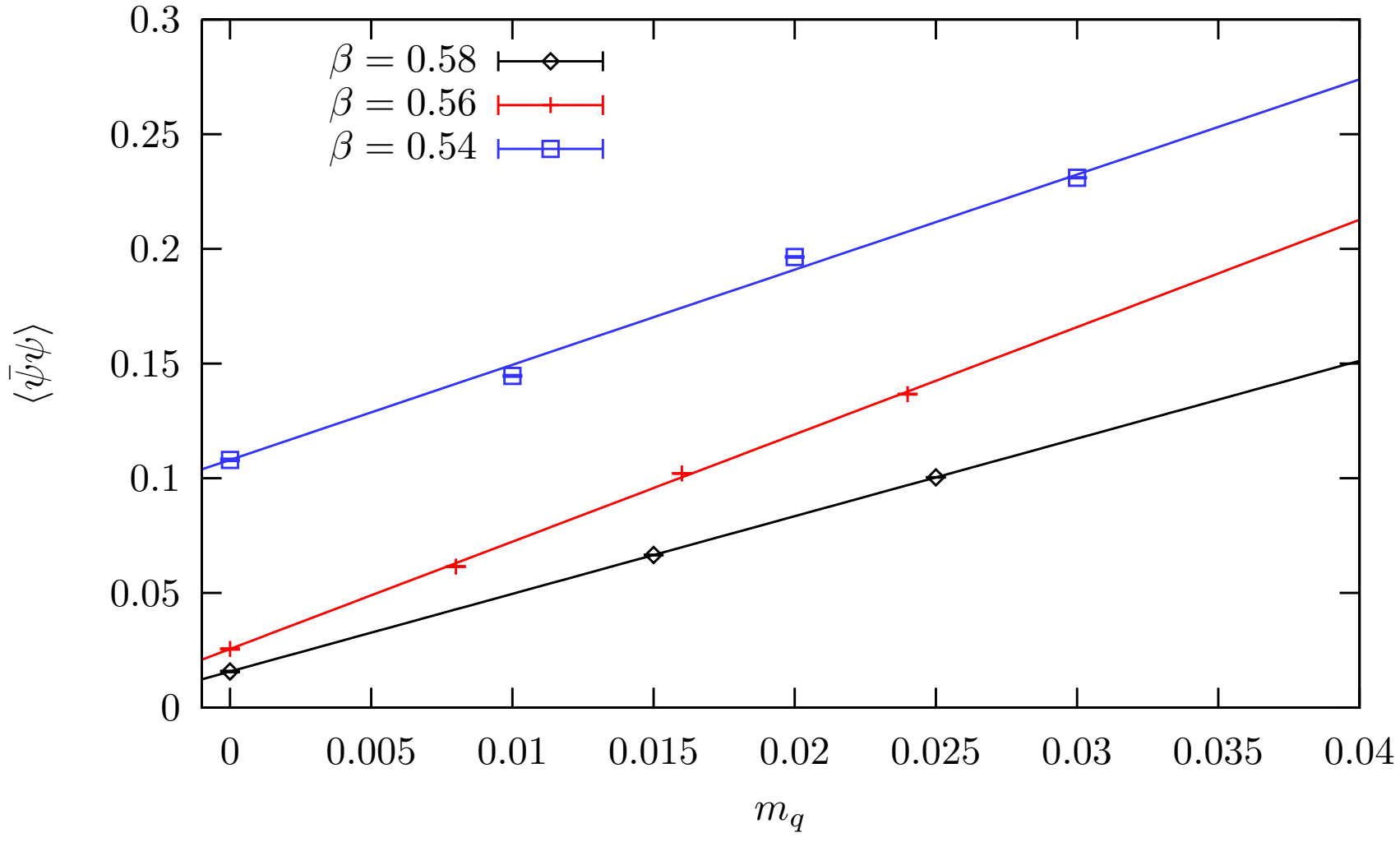
r_0 from heavy quark potential



r_1 from heavy quark potential

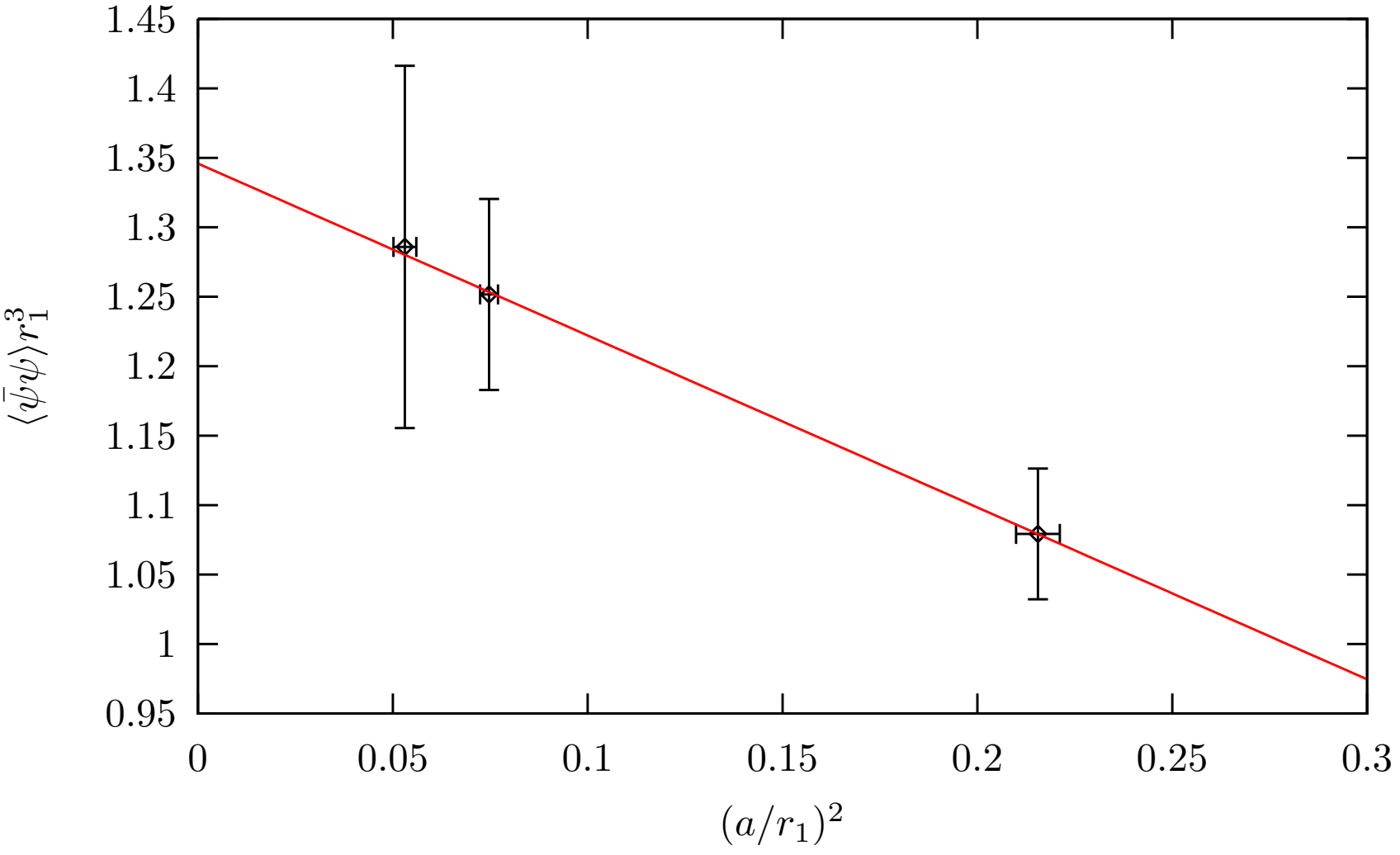


Chiral condensate — Chiral extrapolation

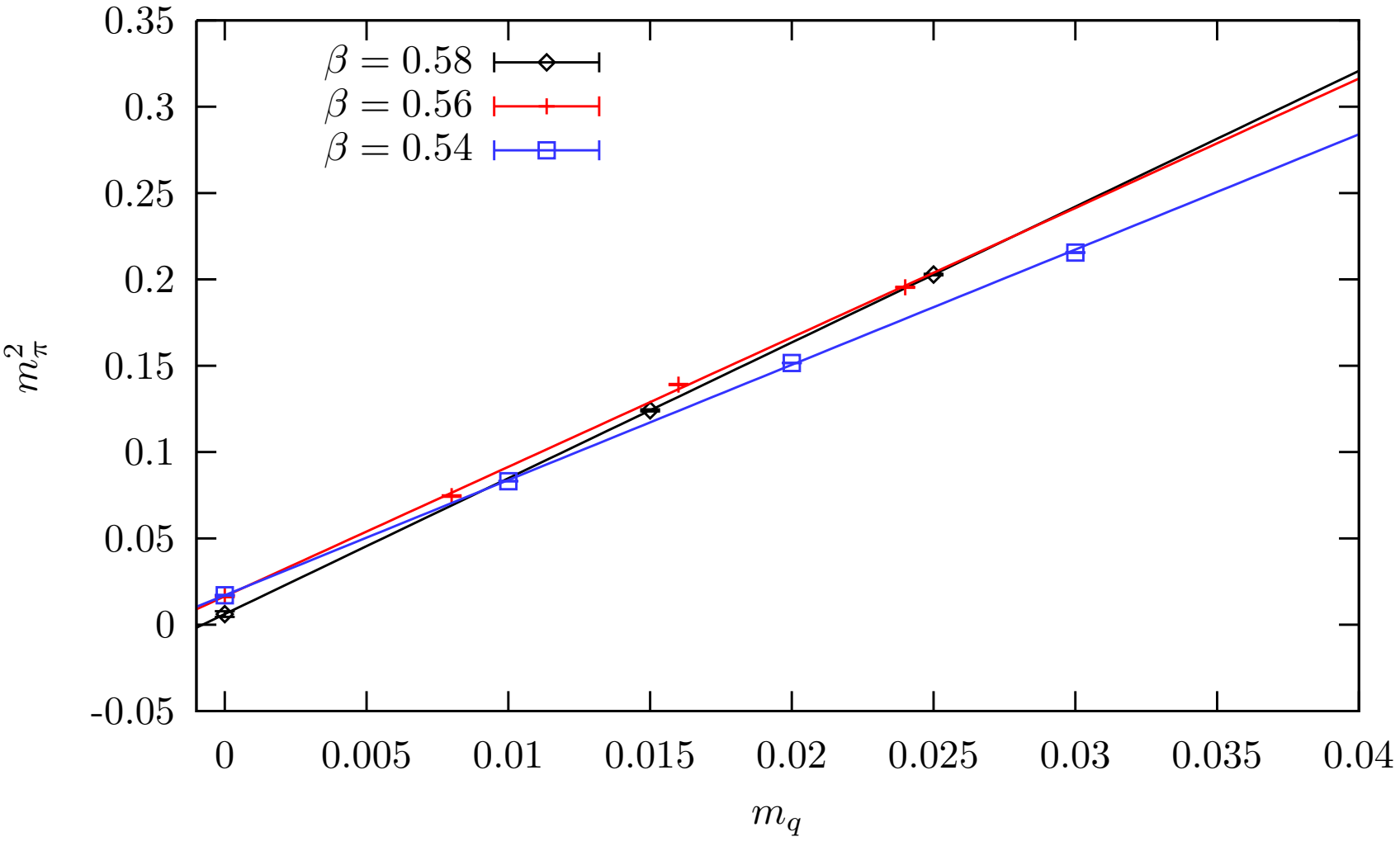


Chiral condensate — a^2 dependence

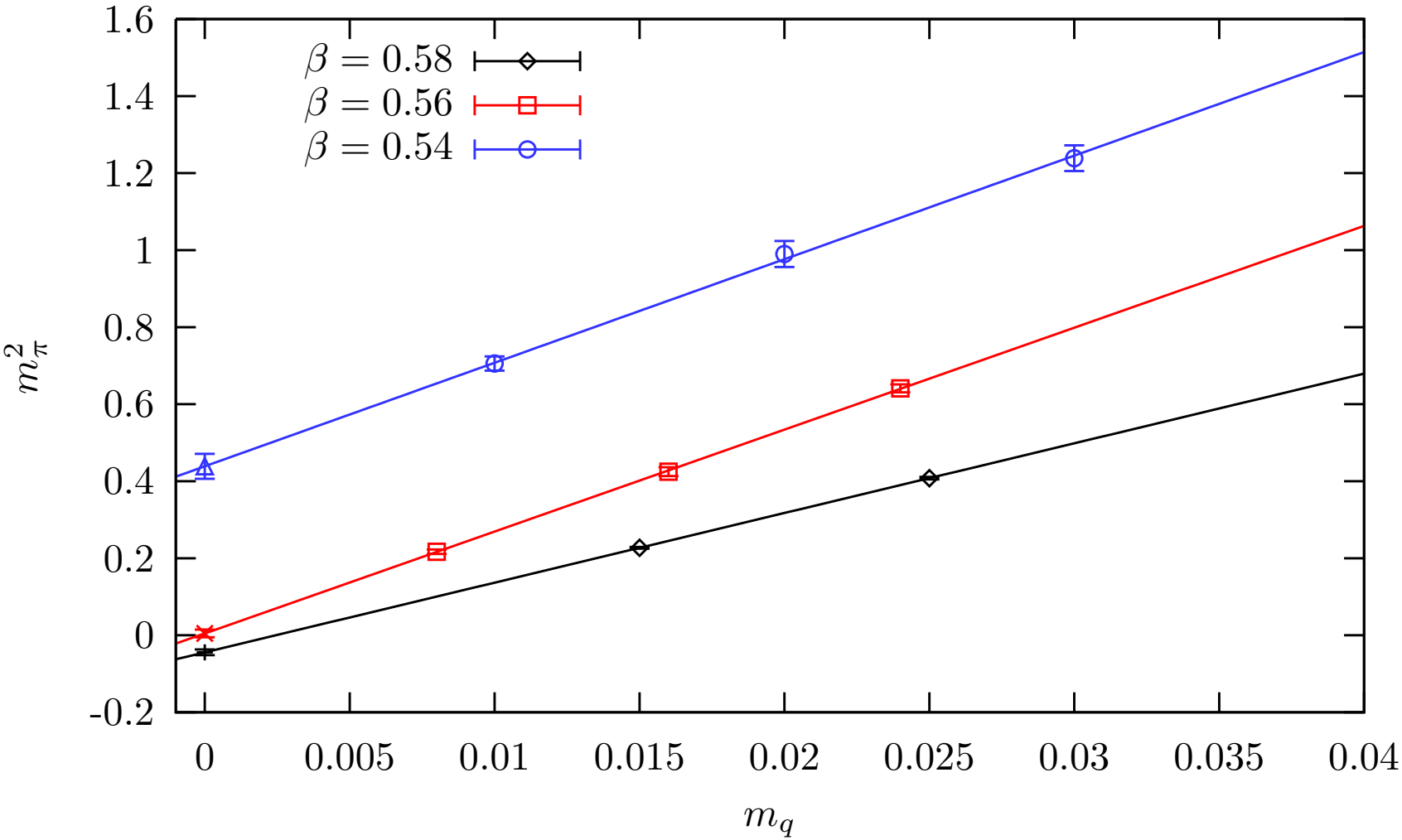
Unrenormalized chiral condensate in naive linear extrapolation.



Goldstone Pion mass — Chiral extrapolation

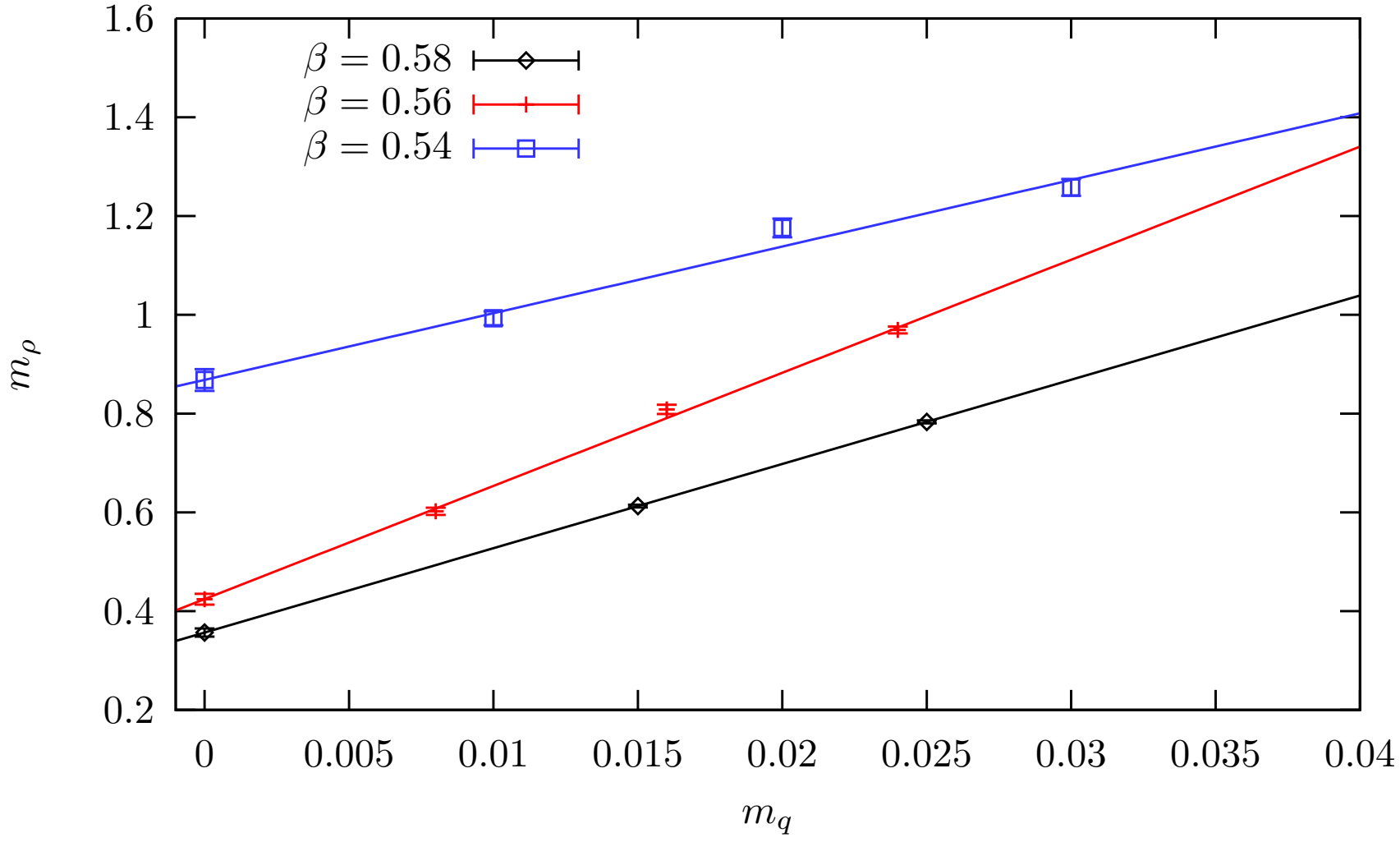


Non-Goldstone Pion mass — Chiral extrapolation

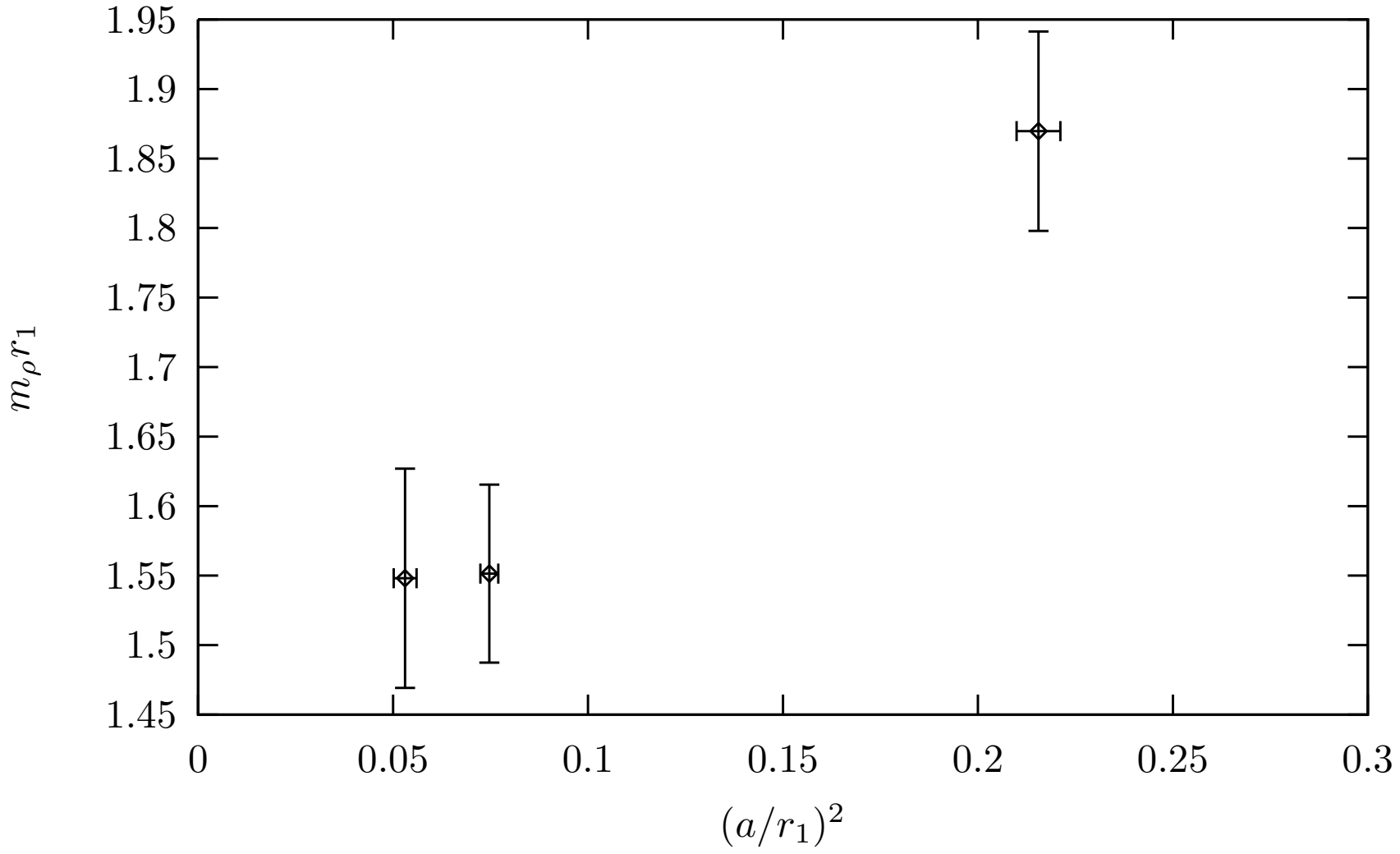


- Scalar channel of the meson propagators.
- Corresponds to $r^{\sigma_s \sigma_{123}} = 1++$

Rho mass — Chiral extrapolation



Rho mass — a^2 dependence



Conclusion and outlook

- Conclusion
  - System behaves as in normal chiral symmetry breaking phase.
  - $\langle\bar{\psi}\psi\rangle$ obtains non zero value in the chiral limit and continuum limit.
  - Goldstone Pion mass vanishes in the chiral limit.
- Outlook
  - Deal with chiral logarithms, if high quality results are needed.
  - Investigate rapid transition from $\beta = 0.56$ to $\beta = 0.54$.
  - Explore into the proposed conformal window (More flavors!).