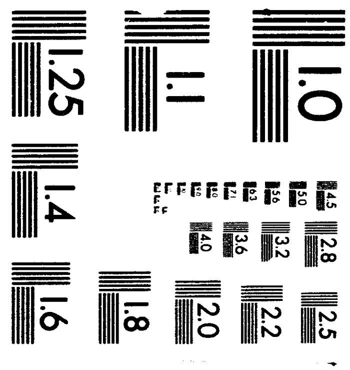
1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
4.5
5.0
5.6

ANL-HEP-CP-93-98
November 1993

Quenched QCD spectrum on a $32^3 \times 64$ lattice*

Seyong Kim† and D. K. Sinclair
High Energy Physics Division
Argonne National Laboratory
9700 S. Cass Avenue
Argonne, Il 60439

We present light hadron masses calculated from quenched QCD on a $32^3 \times 64$ lattice, using staggered quark sources of masses, $m_q a = 0.01, 0.005$ and 0.0025. Results from $\beta = 6.0$(preliminary) and those from $\beta = 6.5$ are compared. Using $m_\rho(m_q = 0)$ and f_π, we suggest that $\beta = 6.5$ is in the asymptotic scaling region and $\beta = 6.0$ result shows $\sim 20\%$ (bare coupling) or $\sim 10\%$ (improved coupling) scaling violation. Flavor symmetry appears to be restored at $\beta = 6.5$. The estimated pion decay constant, f_π, is 93(4) MeV at $\beta = 6.5$, where the experimental value is 93 MeV.

Continuing our efforts[1] on the light hadron spectrum calculation of quenched QCD on a $32^3 \times 64$ lattice, we have collected 100 propagators at $\beta = 6.5$ and 66 at $\beta = 6.0$ so far. Two different wall sources for staggered quarks with masses, 0.01, 0.005 and 0.0025 are used and a point sink is used. We use a multihit-Metropolis method and an overrelaxation method for the gauge field updating and use the conjugate gradient method for the matrix inversion. The gauge field configurations are separated by 1000 sweeps. Further computational details and information on the Intel Touchstone Delta computer can be found in[1,2].

Preliminary results at $\beta = 6.0$ are summarized in the table 1 (for full results at $\beta = 6.5$, refer to [2]). As an illustration we show the effective mass plot for π(fig 1). The figure suggests that π effective mass behaves rather well at $\beta = 6.0$ within the current statistics. However, we noticed that for the other particles, the signals are a lot noisier at $\beta = 6.0$ than those at $\beta = 6.5$ and it is more difficult to find a plateau in each effective mass plot. Probably this is due to the larger physical size of wall sources and the smaller physical quark masses at $\beta = 6.0$. Also, the $\beta = 6.0$ data shows flavor symmetry violations in contrast to $\beta = 6.5$ data. The mass difference in, e.g., π and π_2 (parity partner of the σ) is $\sim 20\%$ of the π mass, as reported by other groups. Such mass difference may be understandable because the flavor symmetry violation is a lattice artifact and the lattice is coarser at $\beta = 6.0$. In the similar sense, fig 2 shows roughly what we expected. Since the lattice spacing at $\beta = 6.0$ is about as twice large as that at $\beta = 6.5$, the physical quark masses get smaller and pion masses get lighter at 6.0 following PCAC for a given quark mass in lattice unit. Since the physical volume is larger at $\beta = 6.0$, we see less finite physical volume effect on the nucleon mass, which makes the simulation data points lie below the curve.

Fig 3 shows ρ meson mass which is extrapolated to zero quark mass, and Fig 4 shows f_π as a function of $\beta = 6/g^2$ and $\beta_{\overline{MS}} = 6/g^2_{\overline{MS}}$. $\beta_{\overline{MS}}$ is calculated from β and the average plaquette as[3,4]

$$\beta_{\overline{MS}}(\pi) = \beta\langle \frac{1}{3}\,\mathrm{Tr}\, U_\Box \rangle + 0.14766(3). \quad (1)$$

The guiding line is the two loop scaling function which has the form,

$$m_\rho = C(\beta_0 g^2)^{-\beta_1/2\beta_0^2} exp(-1/2\beta_0 g^2), \quad (2)$$

or

$$f_\pi = C'(\beta_0 g^2)^{-\beta_1/2\beta_0^2} exp(-1/2\beta_0 g^2). \quad (3)$$

Here, the constants, C, C', are fixed by constraining the curve to pass through our $\beta = 6.5$ data. In

*Work supported by the U.S. Department of Energy, Division of High Energy Physics, Contract W-31-109-ENG-38.
†The talk was presented by Seyong Kim.

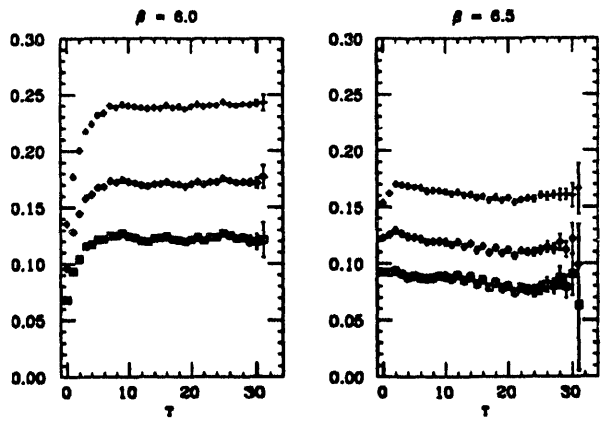

Figure 1. π effective mass plot for $\beta = 6.0$ and $\beta = 6.5$

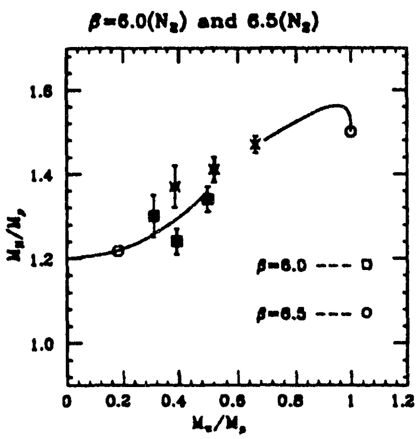

Figure 2. Edinburgh plot.

the figures, ◯ are our points, ◇ is the APE collaboration result, × is the LANL collaboration result, and □ is the HEMCGC result[5]. These figures clearly suggest that the asymptotic scaling is achieved for $\beta \gtrsim 6.2$. At $\beta = 6.0$, our f_π is 0.0511(1). The two-loop prediction is 0.0431(bare coupling) and 0.0470(improved coupling) respectively. Thus at $\beta = 6.0$, there may be $\sim$ 20% scaling violation if the bare coupling is used and may be $\sim$ 10% scaling violation if the improved couping is used, for the light hadron masses from the staggered formulation of quenched QCD. We used f_π instead of $m_\rho(m_q = 0)$ for the comparison because our extrapolated $m_\rho(m_q = 0)$ has large error bars at the moment. This supports our remark in [2] that light hadron mass calculation may need to go beyond $\beta = 6.0$ if the staggered formulation of quenched QCD is used, since not all the aspects of the continuum limit are achieved at this lower β.

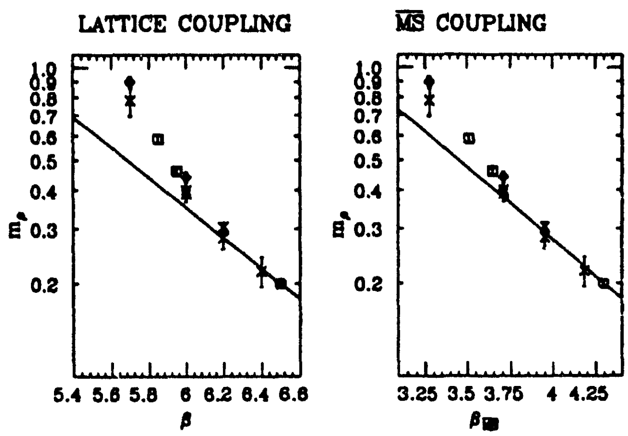

Figure 3. $m_\rho(m_q = 0)$ vs. β and $\beta_{\overline{MS}}$. Symbols are explained in the text.

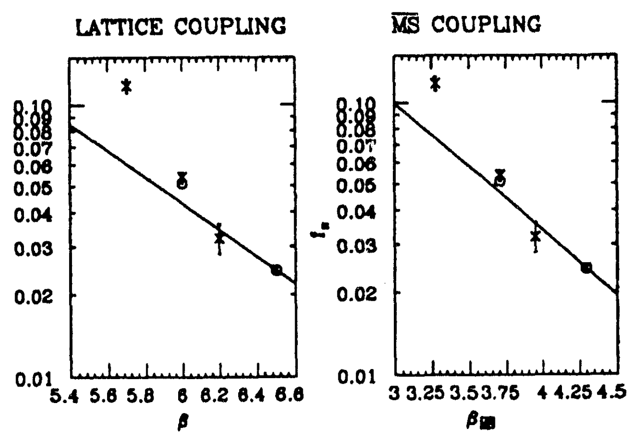

Figure 4. f_π vs.β and $\beta_{\overline{MS}}$. The meaning of symbols are the same as fig 3.

In conclusion, preliminary results at $\beta = 6.0$ indicate scaling violation and flavor symmetry violation and we are accumulating more data on $\beta = 6.0$ in order to reduce statistical fluctuations. Recently, we initiated a spectrum calculation on a $16^3 \times 64$ lattice at $\beta = 6.0$ with the same quark masses in the lattice unit, using Intel A4 Paragon in order to augment our understanding of systematic errors involved in hadron mass extraction. At $\beta = 6.5$, we believe the hadron masses follow the asymptotic scaling. Flavor symmetry is restored due to small lattice spacing. However, the Edinburgh plot shows finite volume effects on nucleon mass. Therefore, increasing lattice volume at $\beta = 6.5$ is desirable.

This research was performed in part using the Intel Touchstone Delta System operated by Caltech on behalf of the Concurrent Supercomputing Consortium. We would like to thank R. Stevens and W. Gropp of MCS division and F. Fradin, the Associate Laboratory Director for Physical Research at Argonne National Laboratory, T. Anderson of Intel corporation, and CCSF staff at Caltech.

REFERENCES

1. S. Kim, Nucl. Phys. **B** (Proc. Suppl.) 30 (1993), 381.
2. S. Kim and D. K. Sinclair, ANL-HEP-PR-93-29 (to be appeared in Phys. Rev. **D**).
3. A. Hasenfratz and P. Hasenfratz, Phys. Lett. **93B**, 165, (1980), R. Dashen and D. J. Gross, Phys. Rev. **D23**, 2340, (1981), and A. X. El-Khadra, G. Hockney, A. S. Kronfeld and P. B. Mackenzie, Phys. Rev. Lett. **69**, 729, (1992).
4. G. P. Lepage and P. B. Mackenzie, Phys. Rev. **D48**, 2250 (1993).
5. R. Gupta et al., unpublished. See also A. Ukawa, Nucl. Phys. **B**(Proc. Suppl.) **30**, 3, (1993). R. Gupta et al., Phys. Rev. **D43**, 2003, (1991). S. Cabasino et al., Phys. Lett. **B258**, 202, (1991) and Nucl. Phys. **B343**, 228, (1990). K. M. Bitar et al., Nucl. Phys. **B** (Proc. Suppl.) **26**, 259, (1992) and ANL-HEP-PR-93-38(1993).

Table 1
hadron masses for $m_q a = 0.01, 0.005$ and 0.0025 at $\beta = 6.0$

$m_q a$	particle	t_{min}	mass
	π	14	0.2402(3)
	π_2	5	0.2934(10)
	ρ	9	0.4806(65)
	ρ_2	7	0.4766(54)
	a_1	7	0.6274(394)
	b_1	9	0.4518(615)
0.01	σ	5	0.5215(130)
	N_1	7	0.6766(82)
	N_1p.p.	7	0.7366(721)
	N_2	8	0.6448(87)
	N_2p.p.	8	0.8828(970)
	Δ	6	0.7355(91)
	Δp.p.	6	0.8145(307)
	π	9	0.1716(3)
	π_2	4	0.2342(20)
	ρ	8	0.4371(110)
	ρ_2	6	0.4420(91)
	a_1	6	0.7857(551)
	b_1	8	0.3971(919)
0.005	σ	4	0.5029(203)
	N_1	4	0.5904(80)
	N_1p.p.	4	0.8509(341)
	N_2	4	0.5430(54)
	N_2p.p.	4	0.8357(349)
	Δ	5	0.7433(70)
	Δp.p.	8	0.7870(507)
	π	10	0.1225(4)
	π_2	-	-
	ρ	7	0.3936(114)
	ρ_2	6	0.4388(177)
	a_1	4	0.6622(270)
	b_1	7	0.2925(432)
0.0025	σ	-	-
	N_1	4	0.5458(149)
	N_1p.p.	4	0.8088(715)
	N_2	5	0.5118(138)
	N_2p.p.	5	0.5275(921)
	Δ	4	0.7238(239)
	Δp.p.	4	0.9096(648)

DATE FILMED

2/7/94

END