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QUENCHED HADRON SPECTRUM OF QCD[1]

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Seyong Kim
HEP Division, Argonne National Laboratory
9700 S.Cass Avenue, Argonne, Il 60439, USA

ABSTRACT

We calculate hadron spectrum of quantum chromodynamics without dynamical fermions on a $32^3 \times 64$ lattice volume at $\beta = 6.5$. Using two different wall sources of staggered fermion whose mass is 0.01, 0.005 and 0.0025 under the background gauge configurations, we extract local light hadron masses and the Δ masses and compare these hadron masses with those from experiments. The numerical simulation is executed on the Intel Touchstone Delta computer. We employ multihit metropolis algorithm with over-relaxation method steps to update gauge field configuration and gauge field configuration are collected at every 1000 sweeps. After the gauge field configuration is fixed to Coulomb gauge, the conjugate gradient method is used for Dirac matrix inversion.

1. Motivation

Many interesting physical quantities related to the strong interaction can be calculated using numerical simulation method from the first principles of quantum field theory. We try to calculate the light hadron mass spectrum of QCD. Although there have been intense efforts[1, 2] to get the hadron mass spectrum right within a few % numerical accuracy, the nucleon to rho mass ratio always comes out too large compared to the experimental value so far. Among several possible causes for this, the effects due to finite box size and too large a quark mass seem to be the main reason[3, 4]. Therefore D. K. Sinclair and my effort is concentrated on lattice QCD simulation on a large lattice volume ($32^3 \times 64$) and light valence quark masses (0.01, 0.005 and 0.0025)[5]. Also, our choice of coupling, $\beta = 6/g^2 = 6.5$, is large enough to ensure the applicability of asymptotic scaling.

2. Method

We use a 10 hit Metropolis algorithm and over-relaxation method in updating the gauge field configuration and conjugate gradient method for the Dirac Matrix inversion. Separation between the stored gauge configurations is 1000 sweeps. Two kinds of wall sources are used : one is the corner source and the other is all the even points source. The mass of the $\pi, \pi_2, \rho, a_1, b_1, \rho_2, \sigma$, N and its parity partner are measured with the former source. The N, the N parity partner, the Δ, and the Δ parity partner masses are measured using the latter source following[6, 7]. A point

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sink is used. The total number of hadron propagators sets used for analysis is 76 at the moment. 2 parameter fit for the π and 4 parameter fit for the other particles are used. The minimum of the correlated χ^2 in parameter space is found by the CERN library minimization routine MINUIT. The correlations between average propagators at different time separations are included. Auto-correlation of measurements has not been taken into cosideration. The error bar quoted in all the data reflects the necessary parameter changes to increase $\chi^2 \rightarrow \chi^2 + 1$.

The numerical simulation is done using the Intel Touchstone Delta computer. The Delta has 16×33 mesh structure and we use a 16×32 mesh configuration for our simulation. Since the computing node is based on Intel i860 microprocessor, the peak speed for 16×32 configuration is 41 Gflops for 32 bit arithmetics. The machine has 16 Mbyte DRAM per node and 64 1.5 Gbyte hard disks. The communication bandwidth is 135 μsec + 6.5 Mbytes/node/sec [8]. The sustained speed of our code is 9.5 Gflops for gauge field updating and the link update time is 0.48 μsec. To take advantage of pipelining and the dual instruction mode of i860 as well as to manage its data cache, most of our code is written in i860 assembly language.

3. Results and Discussion

Figure 1 shows $\pi, \pi_2, \rho, \rho_2, N_1, N_2$, and Δ as a function of quark mass. Here, π_2 is the parity partner of σ channel and ρ_2 is the parity partner of a_1 channel. Note that π and π_2, ρ and ρ_2 lie almost on top of each other. Thus flavor symmetry appears to be restored with current $32^3 \times 64$ lattice volume. Nucleon masses from two different sources do not agree with each other. It needs further investigation. On the other hand, we may simply conclude that the second source is better since in the effective mass plot N_2 shows broad plateau and N_1 does not.

Figure 2 is the Edinburgh plot which shows the nucleon to ρ mass ratio as a function of π to ρ mass ratio for three different quark masses. The points appear to be grouped in two because the ratio using N_1 mass is systematically higher. If we fix the m_ρ scale by using the experimental value 770 MeV, we get : $m_\pi = 504(8), m_{N_2} = 1128(18), m_\Delta = 1320(23)$ for $m_q a = 0.01$. $m_\pi = 398(12), m_{N_2} = 1123(37), m_\Delta = 1352(40)$ for $m_q a = 0.005$. $m_\pi = 297(10), m_{N_2} = 989(41), m_\Delta = 1330(85)$ for $m_q a = 0.0025$, where the experimental values are 138, 938, and 1232 MeV respectively.

Therefore, large lattice volume and light quark mass seem to be the right direction to pursue in the case of light hadron mass spectrum calculation. Although the hadrons masses from $m_q a = 0.0025$ is still large compared with experimental values and our simulation does not take the effect of dynamical quarks into consideration, our results are improved compared to those by others[1]. Also, restoration of flavor symmetry is noticeable in $32^3 \times 64$ lattice volume.

4. Acknowledgements

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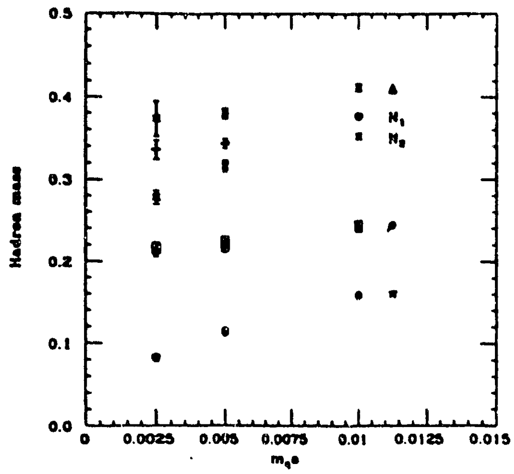

Figure 1: hadron masses vs. $m_q a$.

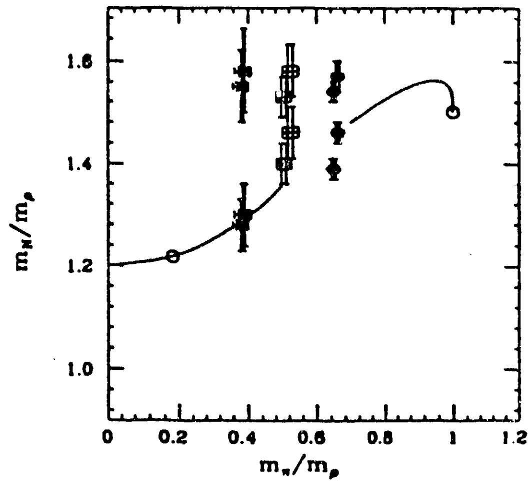

Figure 2: Edinburgh plot.

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