QCD HADRON SPECTROSCOPY WITH STAGGERED DYNAMICAL QUARKS AT 
$\beta = 5.6$ 

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We present preliminary results from the 1991 HEMCGC simulations with staggered dynamical fermions on a $16^3 \times 32$ lattice at $\beta = 5.6$ with sea quark masses $m_s = 0.025$ and 0.01. The spectroscopy was done both for staggered valence quarks with mass equal to the sea quark masses and for Wilson valence quarks at six different values for $\kappa$, 0.1320, 0.1410, 0.1525, 0.1565, 0.1585, and 0.1600. In addition to the measurements performed in our earlier work, we also measured the $\Delta$ and other ‘extended’ hadrons for staggered valence quarks and pseudo-scalar decay constants and vector meson matrix elements, the wave function at the origin, for Wilson valence quarks.

The HEMCGC (“High Energy Monte Carlo Grand Challenge”) collaboration continued its program of spectrum calculations with two flavors of staggered dynamical quarks in 1991, with the simulations being carried out on the CM2 at SCRI. The spectroscopy simulation, though in principal straightforward, has to be under control before one can trust lattice computations of more complicated and interesting matrix elements. As before, we used $\beta = 6/g^2 = 5.6$ and dynamical quark masses $ma = 0.025$ and 0.01. But this time, the simulations were done on a $16^3 \times 32$ lattice and the time direction was not doubled for the mass measurements, as we have done previously [1]. We have also used different wall sources for the staggered spectroscopy which allowed us to measure in addition to the nucleon, $p$, also the $\Delta$ as well as some extended $\pi$’s and $\rho$’s. Here we present some preliminary results [2].

We did the simulations for $ma = 0.01$ because with the lattice doubling we observed strange “wiggles” in the pion effective mass [1], which we suspected were due to the lattice doubling in the time direction. For mass $ma = 0.025$, we previously used a spatial lattice of $12^3$ sites and wanted to check for finite size effects.

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For both quark masses we ran, after equilibration, 2000 trajectories of unit length with the hybrid molecular dynamics algorithm. Staggered spectroscopy measurements were done every 5th trajectory. We used a conjugate gradient residue of $4 \times 10^{-5}$ and $dt = 0.02$ and 0.01 for $m = 0.025$ and 0.01, respectively.

The first thing to notice is that the “wiggles” in the pion effective mass disappeared, as shown in Fig. 1, now that we generate the configurations already on an elongated lattice.

For the new spectroscopy, we used two sources, one with 1’s on all even sites in a time slice and the other with 1’s on the odd sites (even-odd source). This allows the construction of propagators for the $\Delta$ and some extended mesons. The meson masses agree well with our previous results (see Table 1). The nucleon comes out systematically lighter. Its effective mass reaches a plateau only at larger distances. Unfortunately, we first had a bug in the baryon propagators. We started reanalyzing the lattices, doing also

measurements with the old (corner) source, with 1’s in one corner of each $2^3$ cube of a time slice, and have processed about half the $m = 0.01$ lattices so far. The effective nucleon masses with new and old source are shown in Fig. 2. It suggests that we might not have reached the asymptotic limit on our lattices with the new (even-odd) source, and that the old (corner) source has better overlap with the nucleon. The new source also couples much less to the opposite parity nucleon state. We obtain $m_p = 0.725(21)$ with the new source versus $0.742(17)$ with the old source, which agrees reasonably with our earlier calculation ($0.77(1)$). Because of the slow approach to the asymptotic limit of the new source nu-

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**Table 1**

| $am$ | run | $\pi$ | $\pi_2$ | $\rho$ |
|------|-----|------|------|------|
| 0.01 | new | 0.270(2) | 0.350(3) | 0.516(3) |
| 0.01 | old | 0.266(1) | 0.339(6) | 0.52(1) |
| 0.025 | new | 0.419(1) | 0.511(2) | 0.640(3) |
| 0.025 | old | 0.415(2) | 0.499(5) | 0.63(1) |

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Fig. 1. Pion effective masses for $ma = 0.01$ on the old, doubled (⋄) and the new undoubled lattices with ‘even-odd’ source (×) and ‘corner’ source (◦).

Fig. 2. Nucleon effective masses with new and old source and from the old run, all with $ma = 0.01$. 

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cleon, we regard the old source to be more trustworthy. However the new source allows measurement also of the $\Delta$ with the preliminary result $m_\Delta = 0.835(12)$ for $ma = 0.01$. The effective mass plot of the $\Delta$ shows a quite nice plateau.

As in our previous run, we also did propagator measurements from a wall source, every $20^{th}$ trajectory, with Wilson valence quarks at six different values for $\kappa$, 0.1320, 0.1410, 0.1525, 0.1565, 0.1585, and 0.1600. The hadron masses, for those parameter values that we had measured in the previous set of runs, came out in satisfactory agreement (see Table 2), except for the lightest $\Delta$. While we measured baryons only for equal mass quarks, we measured the meson propagators for all pairs of $\kappa$'s. An Edinburgh plot summarizing all our results is shown in Fig. 3.

We used both point and wall sinks and also measured vector and axial-vector current operators at the sink. This allows the extraction of certain matrix elements, the pseudo-scalar decay constant $f_\pi$ from the axial-vector and $1/f_\rho$, related to the wave function at the origin, from the vector current $\bar{q}q$, up to $Z$ factors (except for the conserved vector current). The determination of the $Z$ factors would require measurements of appropriate 3-point functions, which we did not attempt (we judged our lattices to be too small for a meaningful measurement). Using $Z$ factors from quenched calculations, we obtain $f_\pi = 105 \rightarrow 120$ MeV from a local and a nonlocal axial current, and $1/f_\rho = 0.21(1)$ from the conserved vector current. These results have been extrapolated to $\kappa_c$ from the 3 largest $\kappa$'s and come out somewhat too small. For $f_\pi$ this might be due to the use of $Z_A$ from quenched simulations, but for $1/f_\rho$ this argument does not hold. Possibly we are still at too strong a coupling, that is too far away from continuum physics.

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