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Sara Collins, Robert G. Edwards,
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Differences Between Clover and Wilson Spectroscopy on a 2 GeV Lattice

Sara Collins^a, Robert G. Edwards^b, Urs M. Heller^b, and John Sloan^{b,*}

^aDept. of Physics, Glasgow University, Glasgow, Scotland

^bSCRI, Florida State University, Tallahassee, FL 32306-4052, USA

We compare the hadronic spectrum obtained using the Wilson and Clover fermionic discretizations at an inverse lattice spacing of 2 GeV. We find the largest effect to be an additive shift in the vector mass.

1. INTRODUCTION

This talk is part of a program at SCRI of attempting to understand, in detail, the difference in scaling violations between Wilson and Clover fermions. It is an extension of last year's contribution [1], and complements Edwards' talk [2].

The focus of this work is a comparison of Wilson and Clover light spectroscopy at a lattice cutoff of roughly 2 GeV. Our main advances since last year are: 1) results for both decuplet and octet baryons, 2) both shell and wall source smearings in all channels, allowing simultaneous 2 state fits to 2 correlators. We parameterize our light spectroscopy results by fitting to a chiral expansion of M_{hadron} vs. M_{PS} ; the parameters from lowest order chiral perturbation theory are a slope (with respect to M_{PS}^2) and an intercept each for the vector(V), octet(N) and decuplet(Δ) multiplets. Our main result is that, of these six chiral parameters, we can resolve a difference between the Wilson and Clover discretizations at this lattice spacing only for the intercept of the vector (and possibly of the decuplet). The other four parameters have consistent values, within errors, for the Wilson and Clover formulations.

2. THE SIMULATION AND FITTING

The $16^3 \times 32$ gauge configurations were generated by the HEMCGC collaboration [3], with $\beta = 5.6$ and 2 flavors of staggered fermions at a mass of $am = 0.01$, and have an inverse lat-

tice spacing of roughly 2GeV. Technical details of our calculation and fitting procedures are discussed in [1]. One advance over last year is that we now have both shell and wall smearings for all states. This has allowed us to perform 2c2s (2 Cosh, 2 Smearing) fits to all states (last year's results mostly used 1c2s fits, where a γ_0 was included in the interpolating field to provide the second smearing).

3. MESONS

In Fig. 1 we present our results for M_V vs. M_{PS}^2 for the Wilson and Clover actions; both degenerate and non-degenerate κ combinations are included. The vertical dotted and dot-dash lines represent the ρ , K^* and ϕ masses for the Wilson and Clover actions, respectively. The ρ and K^* were chosen by requiring that the ratio M_V/M_{PS} match experiment. The pseudoscalar mass corresponding to the ϕ was chosen using the lowest order χPT formula $M_{s3}^2 = 2m_K^2 - m_\pi^2$.

As in [1], chiral fits were performed using the ansätze

$$\begin{aligned} 2-1 &: C_0 + C_2 M_{PS}^2 \\ 3-1 &: C_0 + C_2 M_{PS}^2 + C_3 M_{PS}^3 \\ 4-2 &: C_0 + C_2 M_{PS}^2 + C_4 M_{PS}^4 \\ 4-1 &: C_0 + C_2 M_{PS}^2 + C_3 M_{PS}^3 + C_4 M_{PS}^4, \end{aligned}$$

where the first number indicates the order of the polynomial and the second is the number of coefficients set to zero. The C_0 , C_2 , and C_4 terms are all analytic in m_q ; the (non-analytic) C_3 term is motivated by [4]. The 3-1 fit is shown in Fig. 1; all of the points shown are included in the fit.

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Figure 1. Cubic chiral fits to M_V for Clover and Wilson actions.

As in [1], the 3-1 and 4-2 ansätze fit roughly the same range of points with similar confidence; the 3-1 curve, however, did a much better job of describing the data at even higher masses. The 2-1, 3-1, and 4-2 fits to the (Clover) vector mass have C_0 's of .403(7), .385(7), and .397(5), respectively; this indicates the size of chiral extrapolation errors. We have doubled all statistical uncertainties to account for this systematic error.

4. BARYONS

In our simulations we have studied baryons both with fully and doubly degenerate κ combinations (i.e. AAA and ABB, respectively in the notation of [5]). We have not investigated totally non-degenerate (ABC) combinations. For each combination of kappas studied, we formed an “average degenerate” pseudo-scalar mass $\bar{M}$ by using the lowest order χPT formula to average the masses of the quarks in the baryon:

$$\bar{M}_{ABC}^2 = (M_{AA}^2 + M_{BB}^2 + M_{CC}^2)/3. \quad (1)$$

This weighted $\bar{M}$ was used in all our baryon fits.

Another complication in studying baryons containing non-degenerate quarks arises in the octet sector, where there are two slope parameters, F and D [5]. The D parameter controls the size of the Σ - Λ splitting (which we have not yet examined), while the combination $(12F - D)$ is proportional to the chiral slope parameter of the (de-

generate) nucleon. It is easy to show that, for ABB quark combinations, $M_\Sigma - M_\Lambda$ and $M_{\bar{N}} = (M_\Sigma + M_\Lambda)/2$ (where Σ and Λ denote $A\{BB\}$ and $A[BB]$, respectively) isolate these combinations and that, for degenerate quark masses, $M_{\bar{N}} = M_{nucleon}$ (cf. (7.9) in [5]). The decuplet sector has only one slope parameter; at lowest order in χPT M_Δ depends only upon $\bar{M}$, even for ABB baryons.

We performed two sets of chiral fits each of $M_{\bar{N}}$ and M_Δ vs. M_{PS} for both Wilson and Clover fermions; using all of our data and keeping only degenerate κ combinations. For the nucleon, the situation is very similar to the vector meson fits; both the 3-1 and 4-2 ansätze were favored over 2-1, with the 3-1 fit better describing the data at higher (unfit) masses. For the decuplet, we were unable to resolve a cubic term; we quote results using the 2-1 ansatz.

Figure 2. Chiral fit to $M_{\bar{N}}$ for Wilson fermions with both mixed (unlabeled) and degenerate (diamond label) κ combinations included.

In Fig. 2, we show the results of a 3-1 fit to $M_{\bar{N}}$ as a function of $\bar{M}_{PS}$. Degenerate κ combinations are labeled by diamonds; only the first 12 points are included in the fit (indicated by the solid portion of the curve). Note that, as expected, the degenerate and non-degenerate points tend to fall on the same curve, which is close to the fit curve well after the fit has broken down.

The three (rightmost) outlying points correspond to singly charmed baryons. It is well known that, for large quark mass, the static (M_1) and kinetic (M_2) masses become inconsistent; the use of M_2 to prepare Fig. 2 rather than M_1 (as we have done) would probably improve the agreement between the heavier points and the fitted curve.

Table 1

Wilson and Clover chiral fit parameters. Statistical error bars have been doubled to include systematic errors due to fit procedures and chiral extrapolations.

State	Wilson		Clover	
	C_0	C_2	C_0	C_2
V	.336(14)	1.24(10)	.385(14)	1.19(10)
$\bar{N}$	.505(24)	2.20(24)	.51 (4)	2.3 (6)
Δ	.619(24)	1.34(10)	.658(28)	1.29(14)

In Tab. 1, we present the results of our chiral fits. Most of the parameters are consistent between Wilson and Clover; the only significant difference is $\delta C_0(V) = 0.048(15)$, where the error in the difference was calculated using a jackknife procedure and then doubled to include systematic effects. The similarity between Wilson and Clover baryons is emphasized in Fig. 3; the two curves lie almost on top of one another! From Fig. 3 one can also see how the shift in the ρ mass can feed back into other observables; the right-most dotted and dot-dash lines represent the pseudo-scalar mass corresponding to singly strange baryons for Wilson and Clover, respectively (obtained from Fig. 1). Even though the two curves agree, the Wilson prediction of $M_\Sigma + M_\Lambda$ will differ from that of Clover, since the Wilson scaling violations in M_V feed through into the choice of κ_{strange} .

5. CONCLUSIONS

We saw surprisingly little difference between the Wilson and Clover calculations. The biggest effect was an additive shift to the vector mass, independent of pseudo-scalar mass, leading to a 13(3)% correction to the ρ mass. (This can be understood as an enhancement of the hyperfine splitting by the clover term.) If we express this as a scale μ , such that $\mu * a = .13(3)$, we obtain

Figure 3. Superposition of M_{nucleon} vs. M_{PS}^2 for Wilson and Clover actions.

250(60) MeV; this agrees with the typical QCD scale of 300-500 MeV and with our quenched result of 280 MeV [2], obtained by directly calculating the slope (with respect to a) of the Wilson scaling violations. The baryonic results are also consistent with our quenched results; we have calculated the (quenched) Wilson scaling violation slopes for the nucleon and Δ to be 100 MeV and 160 MeV, respectively, leading to corrections of 5% and 8%. For the nucleon, our uncertainties in δC_0 are about 12%, so we shouldn't be (and aren't) able to resolve a difference. For the Δ , we have $\delta C_0 = 0.06(5)\%$, again consistent with the quenched results. Assuming the coefficient of the $O(a^2)$ Clover scaling violations is also of order $(200 \text{ MeV})^2$, we expect discretization errors of only 1% - 2% at a cutoff of 2 GeV.

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