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Final Report on DOE Grant DE-FG03-93ER25186

Title: Lattice Gauge Theory on a Massively Parallel Computing Facility

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This grant provided access to the massively parallel computing facilities at Oak Ridge National Laboratory for the study of lattice gauge theory. The major project was a calculation of the weak decay constants of pseudoscalar mesons with one light and one heavy quark. A number of these constants have not yet been measured, so our calculations constituted a set of predictions which will be tested by future experiments. More importantly, f_B and f_{B_s}, the decay constants of the B and B_s mesons, are crucial inputs for extracting information regarding the CKM matrix element V_{td} from experimental measurements of B-$\bar{B}$ mixing, and future measurements of B_s-$\bar{B}_s$ mixing planned for the B-factory currently under construction at the Stanford Linear Accelerator Center. V_{td} is one of the least well determined parameters of the Standard Model of High Energy Physics. It does not appear likely that f_B and f_{B_s} will be measured experimentally in the near future, so lattice calculations such as ours will play a crucial role in extracting information about the Standard Model from the B-factory experiments. We have carried out the most accurate calculations of the heavy-light decay constants to date within the quenched approximation, that is ignoring the effects of sea quarks. Furthermore, we are the only group to have estimated the errors in the decay constants associated with the quenched approximation. Our results are:

$$f_B = 159 \pm 11 \,^{+22}_{-9}\,^{+21}_{-0} \text{ MeV}$$
$$f_{B_s} = 175 \pm 10 \,^{+28}_{-10}\,^{+25}_{-1} \text{ MeV}$$
$$f_D = 195 \pm 11 \,^{+15}_{-8}\,^{+15}_{-0} \text{ MeV}$$
$$f_{D_s} = 213 \pm 9 \,^{+23}_{-9}\,^{+17}_{-0} \text{ MeV}$$
$$f_{B_s}/f_B = 1.11 \pm 0.02 \,^{+0.04}_{-0.03} \pm 0.03$$
$$f_{D_s}/f_D = 1.10 \pm 0.02 \,^{+0.04}_{-0.02}\,^{+0.02}_{-0.03}$$
$$f_B/f_{D_s} = 0.75 \pm 0.03 \,^{+0.04}_{-0.02}\,^{+0.07}_{-0.00}$$
$$f_{B_s}/f_{D_s} = 0.85 \pm 0.03 \,^{+0.04}_{-0.03}\,^{+0.05}_{-0.00}$$

where the errors are statistical, systematic (within the quenched approximation), and systematic (of quenching), respectively. Our result for f_{D_s}, the only one of these decay constants to have been measured to date, is consistent with the experimental value of $241 \pm 21 \pm 30$.

The gauge configurations generated for the calculation of the decay constants were used in several other projects. The first of these was the most extensive study of the light hadron mass spectrum in full quantum chromodynamics yet undertaken. This is a very large project which is still in progress, and resources provided from this grant allowed us to make major progress on it. Our data will allow us to make extrapolations to the chiral and continuum limit, and to make detailed comparisons with our recent quenched approximation calculations. Another important set of calculations carried out under this

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grant were the first lattice gauge theory estimates of the masses of exotic mesons. Like glueballs, exotic mesons are striking predictions of quantum chromodynamics which go beyond the quark model. Theoretical predictions for the masses and branching ratios of these mesons would be valuable for experimentalists searching for them. Although no such mesons are firmly established, there is currently excitement in the experimental community over the possibility of identifying them. Finally, we are using the gauge configurations generated under this grant to carry out more detailed studies of the decay properties of heavy-light mesons. This work too is directly related to the experimental program planned for the SLAC B-factory. Thus, we expect the resources provided by this grant to continue to contribute to our research in lattice gauge theory for several years to come.

Below we list the publications that have resulted from resources provided by this grant.

1. Preliminary heavy-light decay constants from the MILC collaboration, C. Bernard, T. Blum, A. De, T. DeGrand, C. DeTar, S. Gottlieb, U.M. Heller, N. Ishizuka, L. Kärkkäinen, J. Labrenz, A. Soni, R.L. Sugar and D. Toussaint, *Nucl. Phys. B (Proc. Suppl.)* **42**, 388, (1995).
2. Status and prospect for determining f_B, f_{B_s}, f_{B_s}/f_B on the lattice, C. Bernard, T. Blum, T. DeGrand, C. DeTar, S. Gottlieb, U.M. Heller, N. Ishizuka, L. Kärkkäinen, J. Labrenz, K. Rummukainen, A. Soni, R.L. Sugar and D. Toussaint, Proceedings of the LISHEP'95 Session C: Heavy Flavor Physics, page 399-407, Edited by F. Caruso, M.E. Pol, A. Santoro and R. Shellard, Editions Frontieres.
3. The Continuum Limit in the Quenched Approximation, C. Bernard, T. Blum, C. DeTar, S. Gottlieb, U.M. Heller, J. Hetrick, K. Rummukainen, R.L. Sugar, D. Toussaint, and M. Wingate, *Nucl. Phys. B* **(Proc. Suppl.)**, 47, 345, (1996).
4. f_B Quenched and Unquenched C. Bernard, T. Blum, A. De, T. DeGrand, C. DeTar, S. Gottlieb, U.M. Heller, J. Hetrick, N. Ishizuka, J. Labrenz, K. Rummukainen, A. Soni, R.L. Sugar, D. Toussaint, and M. Wingate, *Nucl. Phys. B* **(Proc. Suppl.)**, 47, 459, (1996).
5. Assorted weak matrix elements involving the bottom quark, C. Bernard, T. Blum, T. DeGrand, C. DeTar, S. Gottlieb, U.M. Heller, J. Hetrick, C. McNeile, K. Rummukainen, R.L. Sugar, D. Toussaint, and M. Wingate, hep-lat/9608088, *Nucl. Phys. B, (Proc. Suppl.)* **53**, 374, (1997).
6. Update on f_B, C. Bernard, T. Blum, T. DeGrand, C. DeTar, Steven Gottlieb, U.M. Heller, J. Hetrick, C. McNeile, K. Rummukainen, A. Soni, R.L. Sugar, D. Toussaint, and M. Wingate, hep-lat/9608026, *Nucl. Phys. B* **(Proc. Suppl.)**, 53, 358, (1997).
7. Recent MILC spectrum results, C. Bernard, T. Blum, T. DeGrand, C. DeTar, Steven Gottlieb, U.M. Heller, J. Hetrick, C. McNeile, K. Rummukainen, R.L. Sugar, D. Toussaint, and M. Wingate, hep-lat/9608102, *Nucl. Phys. B* **(Proc. Suppl.)**, 53, 212, (1997).
8. Exotic Mesons in quenched lattice QCD, C. Bernard, T. DeGrand, C. DeTar, S. Gottlieb, U. Heller, J. Hetrick, C. McNeile, K. Rummukainen, R.L. Sugar, D. Toussaint, and M. Wingate, hep-lat/9707008, *Phys. Rev. D* **56**, 7038, (1997).