Impact of Asqtad Lattices

As noted in the proposal, a significant number of physicists outside our collaboration are using the Asqtad lattices we are generating in their own research. These include colleagues at Boston U., Brookhaven National Laboratory, CalTech, U. of Connecticut, Cornell U., DePaul U., U. of Edinburgh, Fermi National Accelerator Laboratory, U. of Glasgow, U. Illinois, Thomas Jefferson National Accelerator Facility, MIT, Ohio State U., Oxford U., Simon Fraser U and U. of Washington. Their research covers a very broad range of topics including determinations of the strong coupling constant, the masses of the strange, charm and \( b \) quarks, quarkonium spectroscopy and decay widths, the weak decays of mesons containing heavy quarks, the quark and gluon structure of hadrons, and hadronic contributions to the muon anomalous magnetic moment. We believe that the outstanding research they are doing with our lattices is an additional justification for the resources we request. In preparing our last two NRAC proposals we asked some of the physicists making use of our lattices to comment on the impact they are having. Since these comments were quite uniform, this year we have simply repeat the responses of those who wrote last year. We also include a list of publications that arose from use of our lattices by physicists outside our collaboration. We are co-authors of some of these publications, but not of others. Finally, at the end of this attachment we provide a table of the lattices as of July, 2004.

Tom Blum is an RBRC Fellow at the Riken/BNL Research Center at Brookhaven National Laboratory. He wrote:

Dear Bob,

I strongly support the MILC collaboration’s proposal to the NSF for computing resources. The generation of QCD gauge configurations with the fermion determinant, i.e. including the effect of light-quark vacuum polarization, is the single most important aspect of the field at present. Your current-state-of-the-art lattices are uniquely suited for my theoretical calculation of the hadronic contributions to the muon anomalous magnetic moment which themselves arise from the hadronic vacuum polarization. These contributions represent the largest theoretical uncertainty in this important Standard Model prediction. The recent experiment at BNL has measured the muon anomaly to less than 1 ppm. Extremely accurate lattice calculations may therefore provide a stringent test of the Standard Model, and leverage these beautiful but expensive experiments. I am happy to say that there is widespread interest in this calculation.

With their light quark masses and large volumes, the current MILC lattices should help me to attain a combined systematic and statistical precision of less than 10 percent—in fact this error estimate is dominated by the systematic uncertainties. These calculations are on-going. Such a result would be very exciting, and would demonstrate the feasibility of such calculations. Your proposed small lattice spacing runs with the light quark masses equal to 0.1 times the strange quark mass may reduce this uncertainty to the five percent level. This would be an extremely positive advance for lattice QCD and subsequent Standard Model predictions.

Finally, let me say that the MILC collaboration is to be commended for its long-time, pioneering, efforts to generate dynamical gauge configurations, and for making them available to the field in a timely manner.

Sincerely,
Tom Blum
Christine Davies is Professor of Physics at the University of Glasgow, and head of the Glasgow Particle Physics Theory Group. She wrote:

Dear Bob,

I am writing to give my strongest support for your application for supercomputer time to generate some more gauge field configurations including up, down and strange dynamical quarks with light up and down quark masses. It will be great if you are able to reduce the up, down quark masses further on both your coarse and fine lattice spacing ensembles. As you know, we have been calculating the Upsilon spectrum on these configurations and contributed results for the spin-independent splittings to the joint paper we wrote recently giving an overall picture of results from your ensembles, showing how a range of well-defined quantities give answers in agreement with experiment at last. I’ve shown this result at a number of meetings in the UK and Europe over the last year (most recently at Flavor physics and CP violation 2003 in Paris last week) and it has had a big impact, especially among experimentalists. They see it as very positive, indicating that we will be able to do the calculations they need and get reliable results in the near future. We are in the process of writing up a long paper on the Upsilon results that we have and another paper on the $\alpha_s$ determination that this leads to. This is in collaboration with researchers at Cornell University, Simon Fraser University, Vancouver and the Ohio State University. The $\alpha_s$ determination will be significantly better than any previous one, because it is a genuine determination for the real world with 3 dynamical quark flavours and does not have to be extrapolated to that point as other calculations have had to be. We are also starting some new calculations of the psi spectrum using charm quarks in NRQCD. Both these and the Upsilon calculations are designed to test the action for charm and bottom quarks so that they can be combined with light quarks for results for the $B$ and $D$ that experimentalists are so keen to get. The preliminary calculations that we have for the $B$ meson decay constant look very good and seem set to solve the current problem of how large a difference the extrapolation to physical light quark masses makes for the ratio of decay constants for the $B_s$ meson and the $B_d$. I also showed these results in Paris since this is of key importance to the experimentalists and theorists who were there who are working on pinning down the CKM triangle. In conclusion, we certainly plan to continue this work on the further ensembles that we hope you can make. This is currently the only way to get dynamical up and down quarks with light enough masses to do meaningful chiral extrapolations to connect to the real world. We wish you every success with your application.

Best wishes,
Christine
Peter Lepage is Professor of Physics and Dean of Science at Cornell University. He wrote:

Dear Bob,

Once again, I enthusiastically support MILC’s request for additional NSF computer time. The gluon configurations being produced by MILC are critically important to the research of several collaborations, including my own.

During the past year, we have used MILC configurations in series of studies. Working with MILC, for example, we completed a first detailed demonstration that the MILC configurations can deliver 2-3% precision for a wide variety of light and heavy quark masses and amplitudes. We will shortly be publishing the most accurate determinations to date of the QCD coupling (from any method, lattice or otherwise) using MILC configurations; and a study of the strange and heavy-quark masses is only a few months off. In the coming year we will be focusing heavily on leptonic widths and semileptonic form factors of Bs and Ds. We have already completed first passes on many of these, but want far greater precision.

MILC’s configurations are uniquely valuable, and MILC has been unusually generous in sharing them with other collaborations. The continued production of MILC configurations is of the utmost importance to my collaboration’s research, and to the entire field of lattice QCD.

Sincerely,
Peter

Paul Mackenzie is a senior staff scientist at the Fermi National Accelerator Center. He wrote:

Dear Bob,

I would like to express my strong support for the lattice QCD NSF proposal of the MILC collaboration. This proposal benefits not only the members of the MILC collaboration, but a large number of other lattice theorists throughout the United States and the world, including us at Fermilab. We have used these in recently completed calculations of the charmonium system. We are currently working with the MILC collaboration to produce B and D meson leptonic and semileptonic decays using improved staggered light quarks and Fermilab heavy quarks.

The MILC collaboration have made available the gauge configurations, whose creation consumes the bulk of the computer time granted under this proposal, to researchers around the world. These gauge configurations have played an essential role in the recent lattice calculations of our group here at Fermilab. By my count, 35 or 40% of US lattice gauge theorists make use of them in one way or another. The MILC library of configurations constitutes the most important such resource available today, and I strongly endorse its continued development.

Yours truly,
Paul Mackenzie
John Negele is the William A. Coolidge Professor of Physics at the Massachusetts Institute for Technology. He wrote:

Dear Bob,

I am writing to express my strong support for your proposal for NSF computer resources to produce lattice QCD gluon configurations that will play an unprecedented role in exploring QCD in the physical regime of light quark masses. The gluon configurations that the MILC collaboration produces and shares with the entire particle and nuclear physics community represent a highly leveraged investment of computational resources that is having decisive impact on many areas of physics including my own field of investigating the quark and gluon structure of hadrons.

A dominant feature of the nucleon is the pion cloud surrounding it at large distances. In a world in which quarks are much heavier than those occurring in nature, this cloud is strongly suppressed and the properties of the nucleon are thereby drastically changed. Due to limitations in computational resources, past lattice calculations of the structure of the nucleon have been relegated to small spatial volumes in which the quarks must necessarily be too heavy, the physics of the pion cloud is strongly suppressed, and observable structure of hadrons is far different from that measured in major experimental initiatives supported by the NSF and DOE. Discrepancies between observables in this unphysical regime and experiment can be as large as 50%.

Hence, this spring, our Lattice Hadron Physics Collaboration has begin a major new project to use the current MILC lattices to calculate the properties of hadrons in the physical regime of light quark masses, and we hope to report this summer the first full QCD calculations ever carried out in this regime. However, the present MILC configurations are only a first step, and bringing this project to fruition will require the new set of large $40^3 \times 96$ lattices that MILC is proposing. Our physics, as well as that of colleagues studying many different aspects of QCD, will benefit greatly by using these gluon configurations.

Best Regards,
John

Junko Shigemitsu is Professor of Physics at Ohio State University. She wrote:

Dear Bob,

I am writing in support of the MILC collaboration’s proposal to the NSF for supercomputer time. I am happy to do so, especially since my own research program, together with that of many other lattice groups, has benefit enormously from MILC’s program to create state-of-the-art dynamical gauge configurations and make them generally available to the lattice community. I cannot think of another development in recent years that has had more impact or contributed more to progress in lattice gauge theory than these efforts by the MILC collaboration.

The MILC dynamical configurations are currently the most realistic configurations in the world. For the first time, the light dynamical quark masses are starting to be small enough so that meaningful, controlled chiral extrapolations can be undertaken. Impressive results have been achieved already by the MILC collaboration on light
spectroscopy, pion and kaon decay constants and QCD thermodynamics. The MILC configurations are also being used by several other lattice collaborations to investigate topics ranging from quarkonium spectroscopy and decay widths, to $B$- and $D$-meson leptonic and semileptonic decays and to $B_0 - \bar{B}_0$ and $K_0 - \bar{K}_0$ mixings. For instance, during the past year, we at Ohio State have been calculating $B$ and $D$ meson decay constants using the MILC dynamical configurations, and we will be reporting shortly on our results at the annual Lattice conference in July. Simulations of semileptonic decay form factors have also been initiated. Our goal is to provide experimentalists and phenomenologists with the most realistic and precise QCD theory inputs needed for Heavy Quark programs such as those at BaBar and CLEO-c. Our efforts would not have been possible without the work of the MILC collaboration.

The MILC collaboration is continuing to expand the sets of dynamical gauge configurations to include more (and lighter) dynamical quark masses, different lattice spacings and lattice volumes. The new configurations will be very important in helping us understand and reduce systematic errors in physical quantities. Providing MILC with the necessary computing resources to carry out its program should, in my opinion, be given the highest priority by funding agencies. This will impact the research programs and productivity of many more lattice collaborations than of just the MILC collaboration. Hence your proposal to the NSF has my strongest support.

Best Regards,
Junko Shigemitsu
Publications Based on the Asqtad Lattices

Several research groups in the US and UK have begun using our recently generated lattice gauge configuration to address a wide variety of physics problems. Some of them are collaborating with us, while others are using the lattices for separate projects. Here we list work done entirely by other groups or by other groups who worked with us. Since the research is very new, the citations are necessarily mostly to recent Lattice conference presentations. The topics covered in this work are as follows:

- Spectroscopy of mesons with a heavy quark and heavy antiquark [1, 2, 3].
- Spectroscopy of mesons with a heavy quark and a light antiquark [2].
- Light meson decay constants [3].
- Heavy-light meson decay constants [2, 4]
- Heavy-light meson decay form factors [5].
- $B - \bar{B}$ mixing [6].
- Strong interaction coupling $\alpha_s$ [7].
- Heavy-light meson semileptonic form factors [5].
- Light quark masses [8]
- Nucleon parton distributions [9].
- Meson form factors [10].
- Hadron contribution to the muon $g - 2$ [11]
- Meson spectral functions [12]
- Free energy of quark-antiquark pairs at high temperature [13].

The following is the list of authors of the papers cited above:

M. Alford (Washington U) T. Blum (Connecticut U) F.D.R. Bonnet (Regina U)
R.C. Brower (Boston U) C. Davies (Glasgow U) M. Di Pierro (DePaul U)
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W. Schreers (MIT) J. Shigemitsu (Ohio State U) J. Simone (Fermilab)
H. Trottier (Simon Fraser U) M. Wingate (Washington U)
References


MILC Library of Asqtad Lattices as of July 2004

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Parameters of the simulations with the improved Asqtad action. The first column gives the light and strange quark masses in lattice units, and the second column, the gauge coupling. L is the spatial size of the lattice. The time size is 64 for the coarse lattices and 96 for the fine lattices. \(u_0\) is obtained from the average plaquette. The conjugate gradient residual tabulated here is the residual used in generating configurations; a smaller residual was used in computing hadron propagators. \(\varepsilon\) is the time step size in configuration generation. The second to the last column is the lattice spacing in units of \(r_1\), determined from the static potential in this run. \(r_1 \approx 0.317\) fm. The last column is the number of stored lattices. Those marked with an \(R\) are still running, and those marked with an \(N\) are publically available from the NERSC Data Connection. The top fifteen lines are the coarse lattices with \(a \approx 0.12\) fm and the last four lines are the fine lattices with \(a \approx 0.09\) fm.