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Abstract

We summarize the latest results from performing Lattice QCD calculations with two different discretization schemes, asqtad and p4fat3, on the LLNL BG/L supercomputer, and present a plan for continued running to complete the calculation of the QCD transition temperature and equation of state.

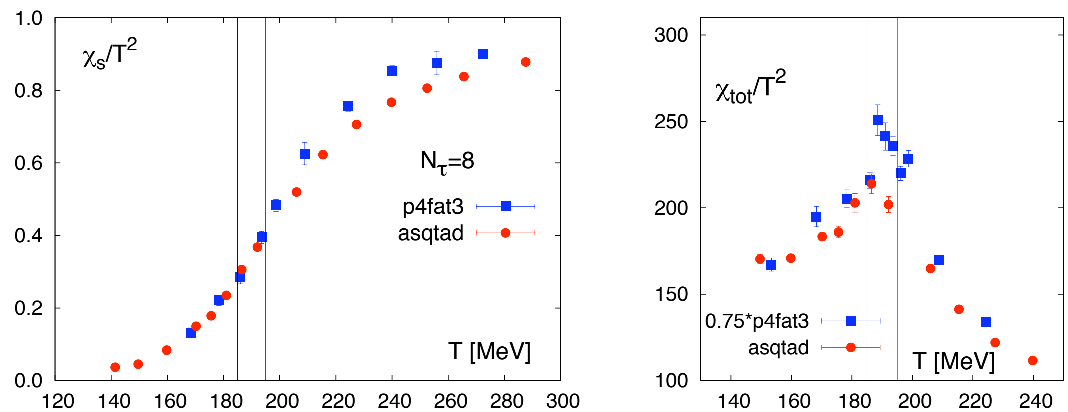

Figure 1: Strange quark number susceptibility for N_τ=8 and asqtad and p4fat3 actions vs. temperature in MeV is shown on the left. The inflection point for this quantity is indicative of the deconfinement temperature, at which the quarks can exist outside of the confines of hadronic bound states (i.e., protons and neutrons). The right panel shows the total chiral susceptibility for p4fat3 and asqtad actions with $N_\tau = 8$ *vs.* temperature in MeV. The peak of this distribution marks the transition in the reduction of the quark masses to their current mass values. All results are preliminary and were calculated by the HotQCD Collaboration running on the LLNL BG/L supercomputer [4, 5].

In May 2006, we proposed performing calculations of the properties of the quantum chromodynamics (QCD) phase transition by running Lattice QCD calculations on the LLNL BG/L supercomputing [1]. The proposed goals were to calculate on a $32^3 \times 8$ lattice the equation of state, the order, and the critical temperature of the QCD phase transition that is realized in heavy ion collisions using a 10% allocation of the LLNL BlueGene/L supercomputer for ∼1 year. Following an initial test of the MILC asqtad and RBC p4fat3 collaboration codes shown at Quark Matter 2006, calculations began in February 2007 by the newly formed HotQCD Collaboration, ending in a four-week run on 12 racks in the summer.

The physics of the transition region has received increased attention recently after another collaboration claimed to find two temperatures, differing by 25 MeV, locating the phenomena of chiral symmetry restoration (the temperature above which the chiral susceptibility vanishes as the quark mass vanishes) and quark deconfinement (the temperature at which the quarks form a plasma) [2, 3]. This result, if true, has important consequences for our fundamental understanding of the strong nuclear force, as well is for the ongoing experimental programs in heavy ion collisions at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory, the Large Hadron Collider (LHC) at CERN, and also the planned Facility for Antiproton and Ion Research (FAIR) at GSI.

The HotQCD preliminary results, presented in a series of talks at the International Symposium on Lattice Field Theory in Regensburg in August, 2007 [4, 5] provide conclusive evidence that these two transition temperatures are much closer and an indication of why the BG/L calculations are more reliable. These preliminary results are summarized in Fig. 1. The inflection point of the strange quark number susceptibility in the left panel is a measure of the deconfinement transition temperature, and the peak in the total chiral susceptibility on the right panel indicates the temperature of the chiral transition. Our results show not only that both transitions lie in the vicinity of 185–195 MeV at these quark masses, but that the results from both lattice formulations are extraordinarily consistent. A calculation performed with two actions in such close agreement and with this level of precision does not exist in the published literature. The highest priority for the HotQCD collaboration is to complete the proposed calculations and to publish our final results for the transition temperature and equation of state. This requires a doubling of the current statistics for these lattice parameters, an additional calculation at a different quark mass at only the temperature values near the transition, and a zero temperature run (on a larger lattice) required to calculate the pressure and energy density (equation of state).

Action	**N_tau**	**mq/ms**	**rck/b**	**N_b**	**Rcks**	**min/traj**	**wks**	**traj (k)**	**Rack*weeks**
p4	8	0.1	1	8	8	6	3	5	24
p4	8	0.2	1	10	10	6	3	5	30
p4	32	0.1	2	10	20	12	3	2.5	60
p4 total					**38**				**114**
asqtad	6	0.1	0.5	8	4	1.5	3	12	12
asqtad	6	0.2	0.5	8	4	1.5	3	12	12
asqtad	8	0.1	0.5	10	5	2.5	3	12	15
asqtad	8	0.2	0.5	10	5	2.5	3	12	15
asqtad	32	0.1	1	16	16	5	3	6	48
asq total					**34**				**102**
dwf	8	0.15	2	6	**12**	30	4.5	1.5	**54**
Grand Total					**84**				**270**

Figure 2: Proposed follow-on run for HotQCD collaboration to complete QCD transition temperature and equation of state calculations on BG/L

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The plan to complete these measurements is given in Table 2. Distinct calculations are divided by code and input parameter values and placed in order to optimize the overall efficiency and time to complete the calculations. The proposed calculation would finish in three-weeks on the current 104 rack cluster, divided into a combination of double, single, and half-rack partitions. However, the calculation can run in any number of ways on smaller allocations, but for a longer period of time. Parts of the calculation could also be performed on an open BG/L cluster, however, in most cases the results would be moved to a secure filesystem to perform a combined analysis with previously generated results.

This proposal also includes our first attempt to calculate a transition temperature with the domain wall fermion (DWF) action. This calculation, also part of the original proposal [1], has the advantage that it preserves chiral symmetry on the lattice, but at significant computational expense. These results will need to run 50% longer, and will be published separately. We also plan to use an additional ∼10 racks to begin calculations of the nucleon-nucleon scattering length working with the NPLQCD collaboration. This calculation is described more fully in the LDRD entitled, "Linking QCD to Experimental Data", which supports our work.

References

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