Report of the RBRC Scientific Review Committee

November 20-21, 2003

1 Overview

The Scientific Review Committee met at Brookhaven on November 20-21, 2003. The membership of the Committee and the agenda of the meeting are attached.

The committee was once again impressed by the success of RBRC. It is a superb institute, supporting research at the forefront of modern nuclear science. The scientific focus of RBRC is the strong interaction which is responsible for all nuclear phenomenon and which encompasses new states of nuclear matter in all its aspects.These aspects range from the state of deconfined quarks and gluons (the Quark Gluon Plasma, QGP) currently the goal of the Relativistic Heavy Ion Collider (RHIC), to the early universe, neutron (or strange) stars which are the compact remnants of supernova explosions, to the study of the violation of CP symmetry in the electroweak interaction and possibly in the strong interaction.

The primary actions of RBRC, to provide a venue and an environment for the scientific research and interaction among young scientists, is one of the most efficient and productive means of developing both the physics and the physicists in this important area. As we have noted in past reports, RBRC with its emphasis on youth and quality is also a most successful mechanism for promoting international collaboration.

Of course the success of the Center has, and does, depend on the quality of the management. The most promising candidates must be selected for the Fellowships, the spirit and style must foster the best work and the most productive interactions. In this regard we note the crucial role of Professor T.D. Lee in the creation of RBRC and in its operation up through this past year.

The success and great spirit of RBRC owe a great deal to the wisdom, the scientific knowledge and the dedication of Professor Lee. In this work he has been assisted

by the efforts of Dr. N.P. Samios as Associate Director. In the coming year Dr. Samios will be Director and Dr. H. Enyo will be the Associate Director. Professor Lee will be available as Director Emeritus.

The demonstrated skill, knowledge and dedication of Dr. Samios and Dr. Enyo insure that RBRC will continue in the style and success it has so richly enjoyed in the past.

As has been noted in last years report, RBRC is now a mature organization as regards size. Since the operation of RBRC involves Fellows and research associates with definite terms, the success of the institute depends on the quality of the new scientific staff which join RBRC. In turn this is affected by the success of the previous graduates. Abundant evidence of the high quality exists in the research accomplishments which the committee heard in the presentations. These are discussed in greater detail in the following sections.

Some demonstrations of the high quality are the fact that since the inception of the DOE Outstanding Junior Investigator Awards five years ago,, five have been awarded to tenure-track/RBRC Felows. The most recent in 2003, to Assistant Professor Stefan Bass of Duke University. RBRC scientists in the past year have produced 95 theoretical and 33 experimental publications. RBRC has held 8 workshops on relevant topics and has operated a vital seminar program at BNL, averaging about 6 per week.

Finally we note that all of the graduates of the RBRC Fellows program have gone on to tenured professorships or to major research positions.

The detail of the theoretical and experimental activities are given in the following sections. We note here only a few selected topics among the many covered.

The RHIC run in 2003 provided both d-Au collisions at the top energy, 200 GeV, and polarized p-p collisions also at 200 GeV. RBRC scientists were active participants in all aspects of the research.

The d-Au run established the result that the disappearance of the away side jet in central Au-Au collisions was a final state effect, not an initial state effect. This strongly supports the conclusion that a high energy density, essentially gluonic, state is produced in the Au-Au collisions.

We note also the measurement of the decay of the J/Ψ, produced in p-p collisions, into muon pairs, accomplished with the muon arms which were a major focus of RBRC physicists; the successful rotation of the proton spin from the transverse to the longitudinal with the subsequent measurement of the π^0 A_{LL}; the measurement of direct electrons and photons in the d-Au collisions.

The proton polarization used was about 34% due to the use of a normal magnet siberian snake in the AGS. In next year's run a fully superconducting snake will be available which should lead to significant improvement. Also, a polarized gas jet target has been completed and installed. It will be used in the 2004 polarized proton studies. This polarized gas jet will permit the important measurement of the absolute polarization.

Finally we note that the RIKEN-QCDSP supercomputer was used at a level close to 100% during the past year. The many interesting results obtained are described in the following section on the theoretical research. The committee was also pleased to learn of the excellent progress in the construction of the next RIKEN-BNL supercomputer, the QCDOC which will operate at 10 Teraflops. This is a tremendous opportunity for the RBRC and we look forward to many interesting and important results to come.

2 Experimental Program at the RBRC

The RBRC experimental group headed by Hideto Enyo and Deputy Group Leader Gerry Bunce has continued, and evolved, in a most successful fashion from the pioneering results of last year. The program advanced in both the spin physics and the heavy ion physics aspects.

In the spin physics program the AGS source continued to produce high polarization, more than 70%. However, during acceleration in the AGS, the polarization decreased to about 35%. This loss was due to the use of a partial (warm) Siberian snake in the AGS. The full, superconducting snake will be completed in time to be installed for next years run. This should result in substantially improved polarization.

The acceleration in the RHIC rings largely preserved this polarization, achieving some 34% at the final energy. This is somewhat better than the peformance of last year but the major improvement will come with the full superconducting snake in the AGS. It should be noted that the polarization, spin studies were made possible by the superb performance of the CNI (Coulomb-Nuclear Interference) polarimeters which were produced and operated largely by the RBRC group.

These polarimeters measure an assymmettry which is extremely useful for relative measurements but an absolute measurement is crucial for the final physics goals of the spin program. A polarized gas jet polarimeter has been constructed and installed for the current run (run IV) and will be commisioned and used when the polarized proton phase of run IV begins.

Another significant result from the run of last year was the observation of the sin-

gle transverse asmmetry, A_n, in the forward neutron production at RHIC. This asymmetry allows the rotation of the proton spin to the longitudinal direction and insures that the experiments are carried out with longitudinally polarized protons. It is hard to overemphasize the importance of this result in allowing the spin program to proceed along its most interesting lines, e.g. the measurement of the gluon spin structure function, which require longitudinal polarization.

The above results on the spin rotator studies were carried out by RBRC physicists, as part of the PHENIX collaboration, as were a number of other important observations during the run. We list some of these below.

The names of the RBRC scientists making the presentations on these results are listed in the attached agenda. Of course in almost all cases, the work is collaborative and a number of RBRC physicists and students made significant contributions.

1. Work was done by the RBRC group in implmenting the central arm trigger system in PHENIX. This allowed a number of measurements including a first measurement of J/Ψ production in p-p collisions at 200 GeV.

2. The measurement of the important spin variables requires a careful understanding of the accelerator luminosity. Beautiful, careful studies were made of the individual bunch crossing luminosities which permitted the measurements to proceed.

3. Using the above and other measurements a first measurement of the quantity A_{LL} in p-p collisions at 200 GeV was made. Interestingly, this measurement disagrees with the theoretical expectations.

4. The north and south muon arms, now completed thanks to the efforts of RBRC physicists, performed well. This allowed the observation of J/Ψ via its decay into muon pairs.

5. In the study of the heavy ion collisions (Au-Au at 200 GeV), The anisotropy of the π^0 meson production was measured. This measured the parameter known as V_2 which had previously been measured for charged particles and which showed striking evidence for a large degree of thermalization in the early stages of the heavy ion collision. This result is one of the key measuements pointing to the production of the Quark Gluon Plasma. Therefore the π^0 results are very important to verify that this observation is a general one for π mesons and not fortuitous. The result is highly consistent with the charged particle results.

6. Also in the heavy ion program, a first measurement has been carried out on the single electron and direct photon production. Leptons and photons are special in the study of high energy heavy ion reactions since they do not interact with the medium after they are produced. Therefore, can they provide information on the early stage of the collision. This is an important result which begins an important approach to the study of the new forms of matter which are produced in these collisions.

In addition to the detector and physics results noted above RBRC physicists have been active, together with RIKEN, in the development of a new vertex detector to be used in the PHENIX experiment. This silicon detector, both pixel and strip, will allow PHENIX to identify heavy meson decays (charm and beauty) by their (short) decay topologies. This will make a very substantial improvement in the detection and measurement of these mesons. Their study opens many important new windows on the physics of the new states of matter and the dynamics of the collisons.

In summary, the experimental group continues to excel. The Fellows who have left have gone to significant research jobs, new very promising Fellows enter the program. The research is building. The spin program is adding crucial instrumentation and expertise and one can anticipate most important new results as it matures in the next few years. The program also has breadth, with important new results being produced in the high energy heavy ion phase as well as the spin phase. The spirit of the group is excellent.

The two tenure-track/RIKEN Fellows, Douglas Fields at the University of New Mexico and Mathias Grosse Perdekamp at the Universty of Illinois Urbana Champaign have continued to prosper. Perdekamp has received tenure and a tenure decision is underway for Fields. Fields has been a leader in the J/Ψ analysis using the muon arms and Perdekamp has recently spent time with the Belle collaboration to extract fragmentation functions which will be important in the future spin program.

The tenure-track/RIKEN fellow program in experimental physics naturally involves fewer Fellows than the theoretical one for reasons related to the nature of experimental work. However, it is very important in providing new students and postdoctoral scientists to the program. The tenure-track RIKEN Fellows program in experimental physics also strengthens the collaboration between RBRC and the Universities, both in Asia and the United States.

The experimental part of the review committee met individually with each RBRC experimentalist and was most impressed with the ability, interest, and dedication of this group of young researchers.

3 Theoretical Physics at the RIKEN-BNL Center

The size of the theory group has reached a steady state, with 10 research associates (including three Riken Spin Physics [RSP] research associates), 4 RIKEN fellows (full time at Brookhaven), and 11 tenure-track/RIKEN fellows (half time at Brookhaven). The committee welcomes the strengthening of the subgroup working on spin physics. The committee was pleased to note that the overall quality of the scientific work of the theory group continues to be excellent.

The tenure-track/RIKEN fellow program continues to be remarkably successful. In particular, four of the fellows received early tenure this year from their home institutions (A. Kusenko, T. Schaefer, M. Stephanov and U. van Kolck), and one fellow received the Department of Energy "Outstanding Junior Investigator Award in Nuclear Theory" (Stefan Bass). This OJI program has been in place for four years, and in each year at least one of the two recipients has been a RIKEN fellow. The committee feels that the attempt by the RBRC to rejuvenate theoretical work on hadronic and nuclear physics has been extraordinarily successful.

All fellows and research associates are very positive about the scientific activities at RBRC, and the breadth and quality of the scientific programs. They unanimously acknowledge the truly exceptional atmosphere at the laboratory and feel well integrated into it; most of them interact significantly with BNL physicists in the nuclear theory and high energy groups. In particular, the integration of Japanese research associates and students was felt to be satisfactory. The Committee encourages Dr. Larry Mc Lerran in his intention to actively mentor the younger researchers.

The tenure-track/RIKEN fellows acknowledge the remarkable opportunity that has been offered them. As some are graduating, they feel the need for a mechanism to allow them to keep contact with the RBRC and the laboratory after they have taken up full-time positions at their universities. The committee feels that the program has created an impressive and highly active community of young researchers, and supports any efforts by the RBRC directorate to continue the integration of these researchers into the RBRC's program.

The fellows greatly appreciated the possibility of organizing workshops at RBRC, and the committee strongly endorses the continuation of the workshop program.

The committee heard presentations by almost all the RBRC theorists and had discussions with most of them. The scientific activities are very diverse and of high quality. The RBRC fellows constitute a team of outstanding young theorists working in various aspects of strong interaction physics (ranging from astrophysics, to effective theories at high density or for nuclear systems, to the phenomenology of heavy ion reactions, and not forgetting spin physics). All are very active, and the

Committee was pleased to note that they are coming back each year to describe new topics of research. Together they have energized the field, and pushed it in new direactions, and will certainly continue to do so in the future. This program should be continued vigorously.

Tilo Wettig explained how one could incorporate the effects of non-zero chemical potential into random matrix models, and presented results for a number of properties of the eigenvalue distributions. This gives a window onto the properties of QCD at finite density, which, to date, cannot be simulated directly except at high temperature and low density. It provides a window because random matrix models have been shown to correctly describe the distribution of small eigenvalues of the QCD Dirac operator for zero and small chemical potential, and it is speculated that this carries over to large chemical potentials.

Chris Dawson has led the effort to use the QCDSP computer to study lattice QCD with dynamical domain wall fermions (DWF). These fermions have much better chiral and flavor properties than other discretizations, but are considerably more difficult to simulate. By using a significant fraction of the QCDSP for the last year, Dawson and the RBC (RIKEN/BNL/Columbia) collaboration have succeeded in producing a large ensemble of lattices with dynamical quarks down to half the strange quark mass. This has required a considerable effort at optimization, increasing the speed of the code by a factor of three. It allows the RBC group to understand what simulations will be possible with the upcoming QCDOC machine, and has produced several very interesting physics results, including an indication that the kaon B parameter may be 10

Yukio Nemoto described the first calculation of the pion vector form factor using DWF in the quenched approximation. It is hoped that the good chiral properties of these fermions will improve the small mass behavior of the form factor.

Norikazu Yamada explained the application of the Symanzik improvement program to DWF. This will be necessary to obtain results with an accuracy better than 5fermions, but the values they take at tree level differ from those for Wilson fermions. He has determined these using quark-quark scattering.

Takanori Sugihara proposed a new fermion discretization which, at tree level, allows the discretization of chiral gauge theories. Possible problems with non-perturbative anomalies have not yet been addressed.

Jun-Ichi Noaki described the status of the RBC collaboration's calculations of weak matrix elements using DWF. A new quenched ensemble at smaller lattice spacing and using the DBW2 gauge action (which improves the chiral properties) has been generated, as well as the dynamical ensemble described by Dawson above. This will

allow a determination of some of the systematic errors in earlier DWF calculations.

Tom Blum gave an update on his calculation of the hadronic vacuum polarization. This is needed to have a first principles computation of the hadronic contribution to the muon g-2. Blum has done the calculation on lattices generated by the MILC collaboration using three flavors of light improved staggered fermions, and compared his results to his earlier work using quenched DWF. He emphasized that the vacuum polarization provides a very useful diagnostic of the size of discretization errors.

Thomas Schaefer presented a systematic approach to the physics of low lying excitations near the Fermi system in very dense systems. He emphasized the role of hard dense loops in constructing effective theories. He showed that effective theories provide a consistent framework to discuss various infrared effects, in particular those associated with color super-conductivity.

Steffen Bass reported on a new phenomenological approach to the hadronization at RHIC, based on a combination of parton recombination and fragmentation. This approach leads to simple scaling laws for various observables, such as the elliptic flow, which appear to be well satisfied by the data.

Tetsufumi Hirano discussed the interplay between soft and hard hadronic interactions at RHIC. He has developed an approach in which soft interactions are described by hydrodynamics while hard interactions lead to mini-jet production. He emphasized the role of radial flow in interpreting jet quenching phenomena.

Werner Vogelsang is undertaking perturbative QCD (pQCD) calculations of asymmetry observables which can be measured in polarized pp collisions. Recent data from PHENIX suggest that the spin asymmetry could be negative (although the statistical errors are large enough to allow positive values as well). Vogelsang made the point that while the negative sign is not excluded by pQCD, the magnitude of the effect, if confirmed by improved measurements, is too large to be understood by pQCD at next-to-leading-order.

Alexander Kusenko offered an interpretation for the origin of the observed pulsar motions based on the existence of sterile neutrinos: these could leave the neutron star essentially without interacting, producing in reaction a kick in the star motion. He argued that there are values of parameters for which such neutrinos, with mass in the 1-20 KeV range could also constitute the dark matter. He suggested that such a mechanism could be confirmed through gravitational wave measurements.

Bira van Kolck came up with a new application of effective theories to the determination of charge symmetry breaking in few nucleon systems. He presented arguments suggesting that experiments could help disentangle effects due to quark mass differences from those of electromagnetic interactions. He also argued that

some important parameters of charge symmetry breaking could be calculated on the lattice.

Mikhail Stephanov presented a fresh look at conventional hadronic physics. He constructed a theory involving an infinite number of local symmetries, with which he can recover various features of the hadron spectrum. This new theory can be reformulated in a five dimensional space, where the calculation of the correlators takes the same form as that obtained from the AdS/CFT correspondence. For simple choices of the background metric, low energy properties of hadrons are well reproduced.

Takashi Ikeda presented a generalized Kadanoff-Baym ansatz to solve kinetic equations in scalar field theory. He showed that when memory effects are properly taken into account, non exponential damping occurs, with, so far non-understood, oscillations in the damping of quasi-particle excitations.

The Committee received reports from Taku Izubuchi and Sangyong Jeon, neither of whom could attend the meeting. Izubuchi described the calculation of the kaon B-parameter with dynamical DWF in detail. Jeon's recent work concerns the energy loss of leading partons in the quark-gluon plasma.

The Committee also held a discussion with RBRC young researchers Y. Hatta, and H. Yokoya. Y. Hatta has already spent one year at BNL, working in particular with R. Pisarski. He is a very promising young physicist who is developing well, and is becoming an independent scientist. H. Yokoya is a newcomer, working under the supervision of W. Vogelsang. The Committee views very positively the participation of such young students to RBRC programs, and encourages the management in its efforts to continue attracting them.

Concerning the effort in lattice QCD, the committee was pleased to hear that Tom Blum is taking up a tenure-track job at the University of Connecticut and will continue his association with RBRC as a University fellow. Blum and Dawson are the backbone of the lattice effort, and are concerned that recent departure of two lattice postdocs, Y. Aoki and K. Orginos, has reduced the breadth of the lattice program. In this regard, the committee was pleased to hear of efforts by the Nuclear Theory group at BNL to hire a senior lattice theorist with interests in finite temperature and density QCD, as well as the hiring of Peter Petrezky as a half-time fellow (joint with the BNL Nuclear Theory Group). Petrezy is a promising young lattice theorist with interests in its applications to RHIC physics. We strongly support the broadening of the lattice research program to include such applications, and we encourage active efforts to integrate Petrezky and the possible future BNL hire into the RIKEN and RBC program.

In the next year, the RIKEN center will have a twenty-fold increase in its effective computational power, with the arrival of the 10 Teraflops QCDOC. The center will then be the world's leader in computational power for lattice QCD. This is a tremendous opportunity for the RBRC, and we encourage the center to develop careful, efficient and transparent mechanisms for deciding on the allocation of computer time.