Report of the RBRC Scientific Review Committee

Brookhaven National Laboratory

November 16-17, 2004

I. Overview

The RBRC SRC met at BNL for the purpose of reviewing the scientific progress made in the last year. The membership of the Committee and the agenda of the meeting are attached at the end of this report.

Overall, the Committee found the scientific program to be in excellent shape and very productive, the spirit and enthusiasm to be high, and the optimism about the future to be strong. It has been a pleasure for this Committee to review this program and to make this report.

The success and good spirit of the RBRC stems from the initial inspiration that Professor T. D. Lee provided. He endowed the RBRC with a successful management style, a spirited academic atmosphere, and a scientific program devoted to excellence. The RBRC is now in the capable hands of Nick Samios, Director, and Hideto En'yo, Associate Director. Professor Lee is now Director Emeritus.

The Committee was presented with a set of talks covering RBRC's experimental activities at RHIC, theoretical activities relating to QCD and heavy ion physics, and lattice gauge theory and status of the QCDSP and QCDOC facilities. Most of the morning of the second day was devoted to interviews with the students, postdocs, researchers, and staff of the RBRC.

The RBRC is a very successful enterprise. Among its accomplishments are:

(i) The success in bringing together Theory, Experiment, and Accelerator disciplines.

These disciplines interact under the RBRC umbrella in a positive and coherent way. The interplay between theorists and experimenters is natural in the research environment in RBRC, adding quality and relevance to both aspects of the science. The same interplay can be seen in the cooperation

between experimental and accelerator disciplines. The Committee could see this cooperative spirit at work during the Review and during the interviews with the students, postdocs, staff, and management of RBRC. The RBRC has managed to create an exceptional intellectual and creative environment where the young people can broaden their skills and make an impact on the current issues in the science.

(ii) An outstanding physics program.

The discoveries coming from the Au-Au and d-Au collider runs lead the list. However outstanding results in p-p running promise to lead soon to new and important results in nucleon structure. (RHIC is scheduled to start the p-p collider run in the very near future.) The warm helical snake recently added to the AGS raised the beam polarization to $\sim$ 50%. PHENIX showed evidence of direct photon production in the collisions, in excellent agreement with the NLO QCD calculations. Evidence for direct photon production signals important progress toward the $\Delta G(x)$ (the spin content of the proton due to gluon) measurement. Future plans at RHIC are rich in topics to be pursued in heavy ions and p-p running.

(iii) A healthy growth to maturity.

The RBRC staffing has reached a stable level. The student headcount continues to show some growth at a modest rate. There has been a normal turnover of researchers whose appointments have ended and who have been replaced by new researchers. The RBRC proudly shows a list of graduates who have successfully found positions in academic institutions. A number of these have received tenured positions in excellent research universities.

(iv) Training of the young scientists.

The Committee interviewed many students, postdocs, and young staff scientists in RBRC. A number of talks listed in the Agenda were given by these young researchers. Overall, we found the spirits and enthusiasm of these people to be very high.

In the following sections, we discuss in some detail the contributions being made by individuals in the RBRC program.

II. The Experimental Program

The RBRC experimental activities focus on two general areas:

(i) The RHIC p-p collider program emphasizing polarization phenomena.

The RBRC contributions have been profound and unique. The warm helical snake provided by RIKEN has allowed for enhanced polarization ($\sim 50\%$) in the AGS, and subsequently in RHIC. The gas jet target has become operational, and has provided new physics results through absolute calibration of the pC-CNI polarimeters. Recent publications have come from these accomplishments, with promises of more and better results to come in 2005 from the extended p-p running that is scheduled. The p-p spin physics program in RHIC is a unique contribution from the RBRC, leading to new data such as the direct photon distributions, and through those, to a better understanding of the gluon contribution to the spin structure of the nucleon.

(ii) The PHENIX Collaboration, where members in RBRC play a leadership role.

The experimental group of the RBRC continues to be guided well by the Group Leader Hideto En'yo and the Deputy Group Leader Gerry Bunce. The experimental activities have matured considerably, particularly in the high energy spin physics program, but also in aspects of the PHENIX program. The p-p run achieved ≈ 3000 nb^{-1} of luminosity delivered to PHENIX, and polarization of $\sim 50\%$. This polarization was significantly higher than for earlier runs. The high polarization resulted from the successful operation of the warm helical snake in the AGS. The high resulting value of the polarization showed up as soon as the beams were established through the snake. Injection into RHIC did not degrade this higher polarization, and the resulting physics run at 200 GeV/c cms energy used this improved polarization to considerable advantage. Preliminary measurements of the longitudinal asymmetry in π° production, $A_{LL}(\pi^\circ)$, were reported.

The p-p running also allowed for the first measurements of direct photon production. Agreement with a next-to-leading order (NLO) QCD calculations were shown to be excellent. Direct photon production in polarized p-p running is the best direct means to measure the gluon contribution to the spin of the proton ($\Delta G(x)$). Another significant development in the past year of

experimental activities was the successful operation of the polarized gas jet target. The gas jet target, based on atomic beam source (ABS) technology, is an important and significant component of the spin physics program. The target was built, installed and commissioned by a collaboration of RBRC, the BNL Collider Accelerator Department, and other personnel (Wisconsin University, for example). The high source polarization allowed for measurement of the transverse spin asymmetry in p-p elastic scattering ($A_N(pp)$) and for an absolute calibration of the pC-CNI polarimeters. These tools have now become available for the general use in the spin physics program.

Hideto En'yo discussed the personnel status for the experimental program. The total headcount involved in experimental activities continued to grow in 2004 at a modest rate. The growth was largely due to an increase in the number of students and visitors. This growth is a clear indication of RBRC's ability to attract young researchers and of the success of the RBRC research. Demand for access to the program is strong.

The RBRC Fellows positions have been an important career step for several RBRC graduates. Abhay Deshpande has moved to a tenure track position at Stony Brook (SUNY) and is doing exceptionally well, successfully splitting his time and talents between teaching and research. Mattheus Gross-Perdekamp has a similar position with Illinois (UIUC) and is doing quite well in it. Doug Fields is actively teaching at New Mexico (UNM) this year and travels a longer distance than the other two to carry out RBRC research. We comment later in this report on issues raised in the interviews, including factors affecting the degrees of success for the Fellows in the RBRC.

The Fellows program has been exceptionally good at placing graduates into university positions, and bringing to the RBRC new groups and new students. Two recent additions to the Fellows list are David Kawall, soon to move to Massachusetts (UMass), and Wei Xie.

Presentations by individual RBRC researchers went well. A brief summary of each follows.

Masashi Kaneta (an RBRC postdoc) presented jet flow and high p_t supression results in Au-Au collisions in PHENIX. He described the PHENIX apparatus and displayed the K, π, and p azimuthal anisotropies (versus p_t), characterized by the parameter $v_2 =< \cos 2(\phi - \Psi_r) >$ where $\phi - \Psi_r$ is the azimuthal

angle relative to the reaction plane. The azimuthal asymmetries are large. v_2 rises with p_t to a value of ~ 0.25 for $p_t \geq 3$ GeV/c.

Doug Fields (UNM Assistant Professor) presented an update on the status of muons at PHENIX and showed the J/Ψ signal seen in the $\mu\mu$ channel from p-p, Au-Au, and d-Au running.

Werner Vogelsang (RBRC and BNL Theory groups) stepped into the experimental presentations to discuss the theoretical and phenomenological status of π° and γ (direct photons) in p-p collisions. The QCD next-to-leading order (NLO) calculations give excellent agreement with the data. These results give significant hope that the gluon contribution to the proton spin ($\Delta G(x)$) will be measured from the upcoming polarized p-p runs in 2005.

Kensuke Okada (an RBRC postdoc) continued the discussion of direct photons in p-p data. His emphasis was on the experimental details in PHENIX. PHENIX has studied procedures for enhancing the signal through isolation cuts on the photon, which suppress the π° background.

Tsuguchika Tabaru (an RBRC postdoc) has been studying the production of single electrons in Au-Au collisions, in the 62.4 GeV runs. The background from converted γs is discussed and subtracted in the analysis. The remaining signal is then compared to known sources of electrons (ρ, ω, and $\phi \rightarrow e^+e^-$).

Abhay Deshpande(Stony Brook Assistant Professor) presented a view of a broad p-p program for Run 4 and beyond.

Masahiro Okamura (RIKEN researcher) presented the status of the warm helical snake and the plans for a second snake built on the superconducting magnet technology. The warm snake was enormously successful in its first run, in which the proton beam polarization in the AGS reached $\sim 50\%$. The plans for the cold snake show a calculated rise in the AGS polarization to $\sim 70\%$. Since the figure of merit for polarization asymmetries scale as P^4, these investments in the snakes carry significant benefit to the future spin physics program.

Osamu Jinnouchi (an RBRC postdoc) described the polarimetry techniques and results from pC and pp elastic scattering using the pC CNI polarimeter and the gas jet target in RHIC. The transverse asymmetry A_N in pp elastic scattering confirmed earlier E704 Fermilab measurements and established

with high precision the trends of the data. Precision calibration of the pC CNI polarimeter was accomplished. Excellent fits to the precision elastic pC data at the higher t values could be achieved, but required inclusion of hadronic spin flip amplitudes.

Yasushi Watanabe discussed the status of the computer facility at RIKEN (CCJ). The data from the p-p spin physics program will be processed by the CCJ. The plans for growth of the capacity of the system were described.

Wei Xie (an RBRC Fellow) discussed the PHENIX muon trigger upgrade plans. The upgrade activities are underway in anticipation of higher rates expected from future 500 GeV p-p running. Resistive plate chambers (RPCs) are under study at Illinois and fast readout electronics are under study at Kyoto.

Junkichi Asai (an RBRC postdoc) described the silicon vertex tracker development activities at RIKEN and BNL.

David Kawall (an RBRC Fellow) discussed the systematic effects associated with p-p spin physics asymmetries due to various beam effects. Accuracies of 1% in the physics asymmetries require $\leq$ few $\times 10^{-4}$ control of certain systematic errors. This study raises important experimental issues to be dealt with in the upcoming p-p running..

III. The Theoretical Program

In his presentation Professor Samios gave a short summary of the activities of the RBRC theory group since the last visit of this Committee. The group is very strong, with 6 research associates, 5 RSP (RIKEN Spin Program) research associates, 2 RSP young researchers (graduate students), 4 fellows and 11 tenure track/RHIC physics fellows. These scientists are engaged in research of the highest quality and have been very productive, as evidenced by the 84 papers published during the past year, plus the proceedings of 13 workshops. They profit from the guidance of the theory group leader and deputy leader, Professors Larry McLerran and Anthony Baltz, two nuclear/particle theorists of international renown, and take great advantage from the collocation of the RBRC with the Brookhaven National Laboratory,

which facilitates scientific exchanges and collaborative research with the scientists in the Laboratory's staff. The scientists engaged in computationally based research, moreover, benefit enormously from the availability of some of the most powerful supercomputers in the world, namely the QCDSP and QCDOC special purpose computers, which have been designed to support in a most efficient manner simulations of quantum field theories and other particle systems.

The theory group leader, Professor McLerran, gave the visiting Committee a broad overview of the research activities of the group, which range from lattice gauge theory calculations to studies of the quark gluon plasma, the color glass condensate and perturbative QCD. The Committee then heard presentations from 18 theorists summarizing their recent research.

In the area of lattice gauge theory much effort was dedicated to simulating QCD with the "domain wall" regularization of the quark field. This method of regularization has the advantage of preserving the all important chiral symmetry of QCD, but comes at a heavy computational cost, as it requires extending space-time into an additional fifth dimension. RBRC scientists have pioneered the application of this technique and, this year, they illustrated novel results on heavy quark spectroscopy and nuclear structure functions (Shigemi Ohta, Norikazu Yamada), the electric dipole moment of the neutron (Thom Blum), the hadron spectrum (Taku Izubuchi) and kaon mixing parameter B_K (Christopher Dawson). Because of the computational complexity of the domain wall regularization, most domain wall simulations are done neglecting dynamical effects from quark-antiquark pair creation (the so-called "quenched" approximation). However, in some of the above investigations the RBRC researchers went beyond the quenched approximation and, with yet another pioneering accomplishment, managed to incorporate effects from dynamical quarks. Simulations with dynamical quarks, but with the more traditional Wilson regularization of the Dirac operator, were used to tackle two problems of great current importance, namely the determination of the pion scattering phase shift and the existence of pentaquark particle (Takeshi Yamazaki, Takumi Doi). A novel technique for lattice gauge theory, based on variational principles, was also the subject of investigations (Takanori Sugihara). Finally, lattice techniques were used to investigate meson spectral functions at zero and finite temperature (Peter Petreczky).

Further presentations involved topics in astrophysics, hadron physics and the phenomenology of heavy ion reactions, of direct relevance to the RHIC experimental program. Instanton techniques formed the basis for a study of the spin of the nucleon and the possible violation of the OZI rule (Thomas Schaefer). The color glass model of initial conditions was combined with the hydrodynamical evolution for the late phase of heavy ion collisions, with the goal of obtaining a unified dynamical approach to relativistic heavy ion collisions (Tetsufumi Hirano, in collaboration with Y. Nara). Photon interferometry was studied in the context of the parton cascade model (Steffen Bass). The properties of the odderon were calculated in the framework of the color glass condensate (Yoshitaka Hatta). The application of classical and semiclassical concepts in many body field theories was investigated (Sangyong Jeon). The melting of the diquark condensates was studied on the basis of a Landau Ginsburg formulation, which allows a treatment of the effects of the strange quark mass. It was shown that weak coupling calculations of the pairing gap are possible in the presence of a finite strange quark mass and that the thermal fluctuations of color magnetic fields can change the nature of the phase transition (Kei Iida). The role of fluctuations near the conjectured QCD critical point was studied in detail (Mikhail Stephanov). QCD effects relevant for the analysis of the NuTeV anomaly were calculated (Stefan Kretzer). An analysis was presented of the impact parameter dependence in the Baltitsky-Kovchegov equation (Takashi Ikeda in collaboration with L. McLerran). The physics of ultrahigh-energy cosmic rays was also investigated (Alexander Kusenko).

Professors Christ and Mawhinney gave presentations on the status of QCDOC hardware and software and on the computational investigations planned for the new supercomputer. The development of QCDOC is on schedule. The supercomputer is being built and will be fully operational within a few months. The operating system and other needed software are also in good shape. The Committee finds it very gratifying that this major enterprise is reaching a successful conclusion and sees in QCDOC a very valuable tool which will be of great help to RBRC theorists in their investigations of nonperturbative properties of QCD.

The theory activities focus on various aspects of QCD. With the advent of the QCDOC facility, scheduled for operation in early 2005, lattice gauge theory calculations will have a major impact on high energy hadron physics on

a broad front. The QCDOC will have 10 teraflops peak computation power. RBRC plans to devote $\sim 90\%$ of the cycles to lattice gauge calculations, and the remaining $\sim 10\%$ to other projects. A duplicate QCDOC facility has been tested at Brookhaven and shipped to the UK. Plans to coordinate theoretical work with the Columbia and Edinborough groups exist; optimizing the impact of these machines on lattice gauge calculations is the goal.

IV. Comments and Summary

The Committee held closed door interviews with most of the RBRC researchers, in order to listen to and address any concerns they may have. These interviews were in two groups. The experimenters met with Akira Masaike, Charles Prescott and Jack Sandweiss; the theorists met with Jean-Paul Blaizot, Claudio Rebbi, and Makoto Kobayashi.

As was the case in previous years, 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. Some postdocs pointed out however a growing imbalance of populations. After several non-Japanese postdocs have left, some have the feeling that there are now relatively too many Japanese postdocs. Also, the Committee was left with the impression that more communication between Japanese students and other experimental group members would be desireable.

The tenure-track/RIKEN fellow program continues to be remarkably successful. The tenure-track/RIKEN fellows acknowledged the remarkable opportunity that has been offered them, but pointed out again the need for a mechanism to allow them to keep contact with the RBRC and the laboratory after they have graduated and 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 Committee was pleased to learn that four new positions are becoming available at several universities.

The factors that influence the successful transition of a RBRC Fellow to academia should be monitored closely. The Committee took special note of the differing degrees of success of three cases. Both Prof. Deshpande (Stony Brook) and Prof. Grosse-Perdekamp (UIUC) continue to play strong leadership roles in PHENIX, while Prof. Fields (UNM) has found it difficult to maintain his teaching responsibilities at his home institution while keeping his research activities at the level he wants. The Committee concluded that for a RBRC Fellow to fully succeed, strong support by the home institution for outside research was essential, good students were essential, and that the travel time and distance were factors. A Professor depends on graduate level students who participate in the research program and on academic colleagues who can help with the teaching load while the Professor is away on research. Strong support by an institution would be indicated by having a strong research program and the ability to attract good students interested in and dedicated to science careers.

The Committee deems excellent the quality of the work done by the subgroup working on spin physics, and quite remarkable the integration of this activity with the experimental RHIC spin program. Werner Vogelsang plays here an essential role. He is an expert in perturbative QCD and has done very successful NLO calculation of immediate relevance for the experiments.

Plans for the spin physics running have been moving forward quite satisfactorily. The experimenters are anxious to enter the data taking phase and are committed to making this phase of the RHIC program as successful as the heavy ion program has been. In this regard they expressed concerns about the schedule for the cold snake for the AGS and expressed a desire to have early feasibility tests to support the upgrade to 500 GeV. The Committee agrees with the importance of the high energy spin physics program and urges the laboratory to maintain a timely schedule for upgrading the energy and polarization capabilities of RHIC.

For these and other activities, the Committee felt it would be desireable to hear more about the present issues and the future prospects in the presentations.

The Committee also found excellent the program of research in lattice gauge theory. With the deployment of the QCDOC supercomputer RBRC will have a twenty-fold increase in its effective computational power. The center will then be a 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.

The Committee was pleased to hear that the efforts by the Nuclear Theory group at BNL to hire a senior lattice theorist with interests in finite temperature and density QCD will concretize with the arrival of Frithjof Karsch early next year. Petreczky expressed the need to balance the subfields of study at QCDOC by getting new RBRC postdocs in the field of QCD thermodynamics.

The Committee commends the inclusion of graduate students into the program. The Committee met with H. Yokoya, who is working under the supervision of W. Vogelsang, and with K. Hashimoto, who is working with Izubuchi. The Committee views very positively the participation of young students to RBRC programs, and encourages the management in its efforts to continue attracting them. The students feel that there should be more of them.

In conclusion, the Committee was highly impressed by the productivity and research quality of the scientists at RBRC. All the fellows 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 directions, and will certainly continue to do so in the future. The Administration should be commended for engendering an environment conducive to scientific collaborations and to investigations of the highest level. The RBRC program should be continued vigorously.

Appendices:

Committee Members

Review Agenda